

COLLABORATIVE PROJECT**Design Study**

FP7-INFRASTRUCTURES-2007-1

Proposal title (max 200 characters)	Design of a pan-European Infrastructure for Large Apparatus studying Grand Unification and Neutrino Astrophysics
Proposal acronym	LAGUNA
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Proposal abstract (Form A1)

Key questions in particle and astroparticle physics can be answered only by construction of new giant underground observatories to search for rare events and to study sources of terrestrial and extra-terrestrial neutrinos. In this context, the European Astroparticle Roadmap of 03/07, via ApPEC and ASPERA, states:

“We recommend a new large European infrastructure, an international multi-purpose facility of 10^5 - 10^6 ton scale for improved studies of proton decay and low-energy neutrinos. Water-Cherenkov, Liq. Scintillator & Liq. Argon should be evaluated as a common design study together with the underground infrastructure and eventual detection of accelerator neutrino beams. This study should take into account worldwide efforts and converge by 2010...”

Furthermore, the latest particle physics roadmap from CERN of 11/06 states:

“A range of very important non-accelerator experiments takes place at the overlap of particle and astroparticle physics exploring otherwise inaccessible phenomena; Council will seek with ApPEC a coordinated strategy in these areas of mutual interest.”

Reacting to this, uniting scientists across Europe, we propose here a design study, LAGUNA, to produce by 2010 a **full conceptual design** sufficient to provide policy makers and funding agencies with enough information for a construction decision.

Has Europe the technical and human capability to lead future underground science by hosting the next generation underground neutrino and rare event observatory? We aim to answer this question. Certainly construction will exceed the capacity of any single European nation - to compete with the US and Asia unification of our scattered efforts is essential. Failure to plan now risks not only that our picture of Nature's laws remain fundamentally incomplete but also that leadership in the field enjoyed by Europe for 20 years falls away. EU FP7 input now is timely and will have major strategic impact, guaranteeing coherence and stimulating national funding.

Table of contents:

1.	Scientific and/or technical quality, relevant to the topics addressed by the call.....	5
1.1.	Concept and objectives	5
1.2.	Progress beyond the state-of-the-art	6
1.2.1.	Prepare to answer fundamental questions.....	6
1.2.2.	The need to plan even larger and better instruments	6
1.2.3.	Towards a proposal around 2010.....	10
1.3.	S/T methodology and associated work plan.....	10
1.3.1.	WP1 – Management, coordination and assessment.....	11
1.3.2.	WP2 – Underground infrastructures and engineering.....	11
1.3.3.	WP3 – Tank infrastructure and liquid handling	15
1.3.4.	WP4 – Instrumentation of the tank and data handling.....	18
1.3.5.	WP5 – Safety and environmental issues	21
1.3.6.	WP6 – Science Impact and Outreach.....	23
2.	Implementation.....	38
2.1.	Management structure and procedures	38
2.2.	Individual participants	40
2.3.	Consortium as a whole.....	63
2.4.	Resources to be committed	66
3.	Impact	69
3.1.	Expected impacts listed in the work programme	69
3.1.1.	Direct impact of this DS on scientific performance of Europe	69
3.1.2.	Direct impact of the planned experiments on particle and astroparticle physics	69
3.1.3.	Impact to technological development capacity in Europe	70
3.1.4.	Impact on society	71
3.2.	Dissemination and/or exploitation of project results, and management of intellectual property	71
4.	Ethical Issues.....	73
5.	Consideration of gender aspects.....	74
6.	Glossary on Initiatives and Committees in the field of astroparticle physics and related fields	74

1. Scientific and/or technical quality, relevant to the topics addressed by the call

1.1. Concept and objectives

There are fundamental questions in particle and astroparticle physics that can only be answered with next-generation very large volume underground observatories searching for rare events and studying terrestrial and extra-terrestrial sources of neutrinos. The great physics potentials of the new research infrastructure envisioned in this DS have been internationally recognized. In particular, ApPEC has recently stated that: *"We recommend that a new large European infrastructure is put forward, as a future international multi-purpose facility on the 100'000-1'000'000 tons scale for improved studies of proton decay and of low-energy neutrinos from astrophysical origin. The three detection techniques being studied for such large detectors in Europe, Water-Cherenkov, Liquid Scintillator and Liquid Argon, should be evaluated in the context of a common design study, which should also address the underground infrastructure, and the possibility of an eventual detection of future accelerator neutrino beams. This design study should take into account worldwide efforts and converge, on a time scale of 2010, to a common proposal."*

The need for such experiments is also recognized by CERN, the largest laboratory for particle physics in the world: high-energy accelerators like the CERN Large Hadron Collider (LHC) or the planned International Linear Collider (ILC) will not be able to answer all fundamental questions about Nature. In 2005 the CERN Council initiated a Strategy Group to produce a Draft Strategy Document (DSD) addressing the main lines of Particle Physics in Europe, including R&D for novel accelerator and detector technologies. The DSD¹ was unanimously approved by CERN Council in July 2006. In this document, Council recognised that *"A range of very important non-accelerator experiments take place at the overlap between particle and astroparticle physics exploring otherwise inaccessible phenomena; Council will seek to work with ApPEC to develop a coordinated strategy in these areas of mutual interest."* Hence, this line of investigation represents a unique way to address these otherwise undiscovered fundamental questions of particle physics.

These fields of research are at the forefront of astroparticle and particle physics and are the subject of intense investigation worldwide. What will be the European contributions in these rapidly expanding fields? Europe is currently leading deep underground science with its four long running and two emerging deep underground laboratories. This leadership is endangered by the lack of plan for a new and bigger research infrastructure, capable of hosting next generation large volume experiments. The DUSEL (Deep Underground Science and Engineering Laboratory) initiative in the USA and the Japanese plans for a large upgrade at the Kamioka site represents real competition. In order to be credible in front of the American and Asian projects, Europe must act coherently and in a unified way in deep underground science.

Can Europe aim at becoming a world leader in deep underground science by hosting the next generation very large underground neutrino and rare event detection observatory? The present DS will represent a unique opportunity to answer this question and take a leading role in research fields of fundamental importance for particle and astroparticle physics. The DS will provide the scientific and objective information to make an optimized choice of the site(s) for a European Underground Infrastructure capable of hosting large mass, underground observatories.

Designing and constructing the next major underground laboratory and building the required large-scale instruments by far exceed the capacity of a single European nation and technically non-trivial. A common approach and a coordinated international effort are required to even conceive them. This DS is the most effective tool towards achieving this goal. A substantial EU contribution will inevitably raise national funding and redirect the otherwise scattered local efforts coherently towards this common European goal.

A coherent and coordinated study group aimed towards common physics goals was formed at the ApPEC "Munich meeting" in November 2005 with the aim of developing conceptual designs for European large underground detectors, investigating physics complementarities and common R&D needs, fostering work in synergy and problem-solving activities, as well as taking into account the unique technological expertise in Europe and other existing or planned programmes in the world. It was hoped that mature designs and credible proposals could emerge around 2010. This DS will formalize, organize and very effectively provide the means for a cohesive and integrated action towards these goals.

The LAGUNA consortium includes the highest-level expertise in Europe for the required tasks. All major European underground laboratories are partners or will be consulted, and emerging candidate sites are also represented. The countries proposing the site for the facility have assigned the best companies in underground engineering as partners. All universities and institutes participating in the collaborations of the suggested experiments are taking part in the project. Our human resources include more than 60 top-

¹ The CERN Council, in a special meeting held the 14th of July 2006 in Lisbon, agreed on the European strategy for particle physics. The strategy is defined by the 17 statements approved by Council, and contained in the Strategy Statement (available at <http://council-strategygroup.web.cern.ch/council-strategygroup/>).

level scientists, representing also the scientific community taking advantage of the results of the experiments to be performed in the laboratories. The main deliverable will be a conceptual design report (CDR), which should provide the policy makers and the funding agencies all the information for a construction decision. The deliverables include “decision factors” such as technical feasibility (underground halls and their access, safety issues, procurement of large quantity of liquid material for the detectors, related infrastructure, ...), cost optimization (digging, safety, detector design...), physics performance (e.g. hall depth, baseline from accelerator facilities, ...), in addition to spin-off and outreach issues.

The infrastructure, if built in Europe, will certainly attract scientists from many parts of the globe and will ensure that Europe can continue to play a leading role in the field. Europe must act coherently and in a unified way in deep underground science. The very successful history of CERN, the largest particle physics laboratory in the world, shows that this is in principle possible.

The failure to comply with the deadline set by ApPEC creates the danger that Europe falls behind other continents in underground science. Observation of Nature using very large underground experiments will be the most cost-effective way to look for physics beyond our current understanding and without them our picture of the fundamental laws of Nature will remain incomplete.

Has Europe the technical capabilities and the human and financial resources to become an international leader for future deep underground science, by hosting the next generation very large underground neutrino and rare event detection observatory? The aim of this DS is to answer to this question.

1.2. Progress beyond the state-of-the-art

1.2.1. Prepare to answer fundamental questions

The next-generation very large volume underground observatories searching for rare events and studying various terrestrial and extra-terrestrial sources of neutrinos will answer fundamental questions of particle and astroparticle physics.

Firstly, the proton, one of the main building blocks of matter, is known to be an extremely stable particle, yet many models predict that it might not live forever. A positive detection of proton decay would represent the most generic and directly verifiable consequence of the unification of the fundamental interaction (strong, electromagnetic and weak forces) of Nature. Thought by many to be as important as the search for the Higgs boson or the existence of supersymmetric particles (SUSY), the discovery of proton decay would have a tremendous impact on our understanding of Nature at the highest energies (in an energy domain in the range of 10^{16} GeV, to be compared with the energy domain up to 10^3 GeV explored by the highest energy Large Hadron Collider LHC at CERN), yielding otherwise inaccessible information on the structure of matter at extremely small scales. The new instruments envisioned in this DS will allow exploration of otherwise unreachable domains at the extreme high energies.

Secondly, the neutrino is unique among the fundamental particles in that it has no conserved quantum numbers except, perhaps, a global lepton number. The recent discovery that the neutrino changes type, or flavour, as it travels through space, a phenomenon referred to as neutrino oscillations, implies that neutrinos have a tiny, but non-zero mass, that lepton flavour is not conserved, and that the Standard Model of particle physics is incomplete. Neutrinos can travel very large distances in space and traverse dense zones of the Universe, since they only very weakly interact with matter, and provide therefore unique information on their sources. The new instruments envisioned in this DS will allow for unprecedented measurements of fundamental neutrino properties, providing us with new and deep insights into their sources, notably the Sun, the core-collapse supernovae and the Earth itself.

A very active international scientific community is discussing these scientific topics in the NNN workshop, where NNN stands for “Next generation Nucleon decay and Neutrino detectors”. This series of workshops has been devoted to discussion of experiments that go beyond the reach of current projects, as well as the related theoretical work. The first NNN Workshop was held in 1999 at Stony Brook, USA. Recently, NNN05 took place in Aussois, France, and NNN06 in Seattle, USA. The next meetings will be held in Hamamatsu, Japan in 2007 and in Paris in 2008.

1.2.2. The need to plan even larger and better instruments

The first successful detection of neutrinos from the supernova SN-1987A by the Kamiokande experiment (Japan), recognized with the Nobel Prize in 2002, has opened the field of neutrino astronomy, a by now 20-year long tradition of incredibly rich physics with large underground detectors, the largest one being the 22.5 kton Super-Kamiokande detector. These instruments, thanks to technical breakthroughs, have achieved fundamental results like the solution of the solar neutrino puzzle and the understanding of the physics of the Sun, the discovery of non-vanishing neutrino masses. Limits on the flux of supernovae relic neutrinos have been set. The lifetime of protons has been pushed towards limits in the range of a few 10^{33} years. KamLAND has announced first evidence of so-called geo-neutrinos, emitted by radioactive elements within the Earth, opening the way to new methods of investigation of the Earth’s interior. Soon the neutrino flavour oscillation mixing matrix is going to be further studied with an intense accelerator neutrino beam

from the newly built J-PARC accelerator complex in Japan (T2K experiment), complementing the efforts at Fermilab in USA and at the CERN-Gran Sasso in Europe.

Further advances in low energy neutrino astronomy and neutrino astroparticle physics, as well direct investigation of Grand Unification (GU) of fundamental interactions require the construction of next-generation very large volume underground observatories. With complementary techniques, facilities on the mass scale of 50 kton to 500 kton could dramatically increase the potential of past and present underground detectors, however as expected, represent rather large extrapolations compared to current worldwide state-of-the-art, requiring advances in several fields, like underground civil engineering, mechanical engineering, large scale detector instrumentation and integration, and last-but-not-least safety and environmental issues.



Figure 1 The existing or emerging six national underground science laboratories.

There is currently no infrastructure in the world able to host instruments of this size, although many European national underground laboratories with high-level technical expertise are currently operated with forefront smaller-scale underground experiments (see Figure 1). Very large underground laboratories are being considered in Japan in the context of the Hyper-Kamiokande² project and in the USA as part of the DUSEL process³. A pan-European research infrastructure able to host new generation underground instruments with total volumes in the range of 100'000 m³ up to 1'000'000 m³ would provide new and unique scientific opportunities and very likely lead to fundamental discoveries in the field of particle and astroparticle physics, attracting interest from scientists worldwide.

The present Design Study (DS) focuses on the study of feasibility and design of such a new infrastructure in Europe and on the scrutiny of the technical requirements necessary for the next generation large-scale underground observatories. This DS intends to explore different detector technologies currently being investigated by various European research institutes, and different potential underground sites in order to identify the scientifically and technical most appropriate and cost-effective strategy for future large-scale underground detectors in Europe. The main deliverable will be a CDR report which should contain all the relevant information for a construction decision around 2010.

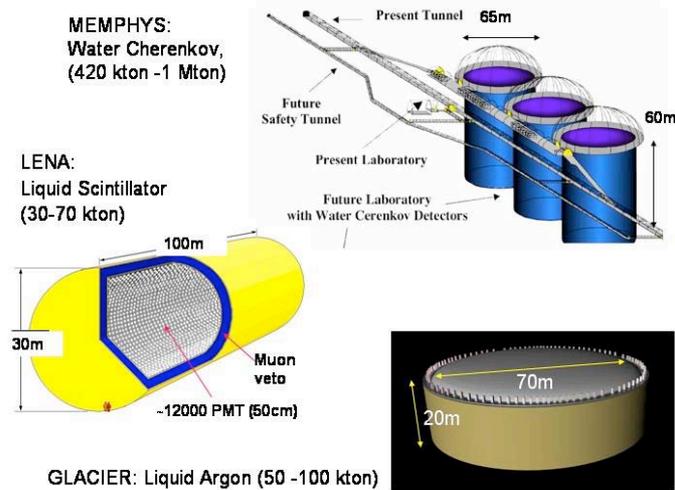
We have already mentioned that the above physics topics have historically produced very important results. It is reasonable to assume that the physics programme addressed by this DS will span over 30 years and more, with the involvement of several generations of worldwide researchers. Investigating the proton lifetime up to 10³⁵ years will provide a very stringent, perhaps ultimate test of the Grand Unification hypothesis. After the optical observation of supernovae (SN) by mankind during the last centuries and the SN1987A neutrino detection, the next observable event with neutrinos will occur with high probability in the next decade and with near certainty in the next 30 years. Meanwhile the background flux of neutrinos from relic supernovae can be observed. The study of neutrino properties has shown the first indication of physics beyond the Standard Model of Elementary Particles. New discoveries, like CP-violation in the leptonic sector, are expected in this field.

² K. Nakamura, "HYPER-KAMIOKANDE: A next generation water Cherenkov detector for a nucleon decay experiment," *Front. Phys.* 35, 359 (2000).

³ See <http://www.dusel.org>

Several conceptual ideas for next-generation very-massive, multi-purpose underground detectors have emerged worldwide and in Europe over the last years. All the designs consist of large volumes of liquid observed by detectors, which are arranged on the inner surfaces of the vessels. The liquid simultaneously acts as the target and as the detecting medium. The first one relies on the concept of Super-Kamiokande and uses water (MEMPHYS R&D project), the second builds on the initial experience with ICARUS and uses Liquid Argon (GLACIER R&D project), the third extrapolates experience gained in reactor experiments and BOREXINO and uses liquid scintillator (LENA R&D project). See Figure 2.

Figure 2 R&D projects being discussed in Europe as possible next generation very large volume underground detectors: MEMPHYS, LENA and GLACIER.

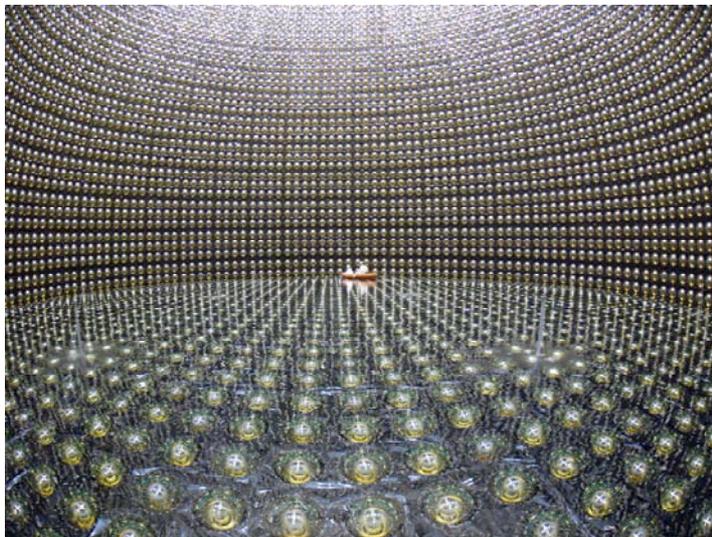


In this DS, we therefore evaluate these three technologies:

Water Cherenkov imaging: As the cheapest available (active) target material, water is the only liquid that is realistic for extremely large detectors, up to several hundreds or thousands of ktons. Water Cherenkov detectors have sufficiently good resolution in energy, position and angle. The technology is well proven, as previously used for the IMB, Kamiokande and Super-Kamiokande experiments (See Figure 3).

Liquid scintillator: Experiments using liquid scintillator as the active target provide high-energy resolution and offer low-energy threshold. They are particularly attractive for very low energy particle detection, as for example solar neutrinos and geo-neutrinos. Also liquid scintillator detectors feature a well-established technology, already successfully applied at relatively large scale in the Borexino and KamLAND experiments.

Liquid Argon Time Projection Chambers (LAr TPC): This detection technology has among the three the best performance in the identification of the topology of interactions and decays of particles, thanks to the bubble-chamber like imaging performance. Liquid Argon TPCs are very versatile and work well with a wide particle energy range. Experience with such detectors has been gained within the ICARUS project.



The three technologies have in common similar requirements for their design, installation and operation in the future underground facilities. They have similar (high) discovery potential and exhibit some interesting elements of complementarity. In addition, the three proposed solutions are backed by rather large and active European communities. This DS will create the opportunity for a concerted effort towards a global optimization of the projects, increasing the probability of success with the elaboration of shared strategies.

Figure 3 Inside view of the Superkamiokande detector in Japan. The large volume of water is seen by 11000 photo-detectors for a total sensitive mass of 22.5 ktons.

From a practical point of view, the most straightforward liquid is water, where the detection is based on the Cherenkov light emission by the final state particles. This faint light is detected by a very large number of photomultipliers positioned on the surface of the container. The technology has been pioneered by the IMB and Kamiokande projects (USA and Japan, respectively) and successfully extended to Super-Kamiokande during many years of operation. Super-Kamiokande has a fiducial mass of 22.5 kton observed by about 11,000 large-size photomultipliers. The possibility of building a water Cherenkov detector with a fiducial mass of about 500 kton observed by about 200,000 photomultipliers is currently being investigated by different groups around the world, and for different underground sites. While water is a cheap medium,

the size of such detectors is limited by the cost of excavation and of the photomultipliers. The MEMPHYS project is being discussed for deployment in an extended Frejus laboratory (France/Italy). In the US, the UNO detector is being proposed for a future underground facility in North America. In Japan Hyper-Kamiokande will provide an extension of Super-Kamiokande, using a new cavern to be excavated near Super-Kamiokande. Hyper-Kamiokande could serve as the far detector for the T2K experiment. Water-Cherenkov detectors are ideally matched for neutrino energies below 1 GeV. They have also a high sensitivity for proton decays with two isolated Cherenkov rings like for example the channel $p \rightarrow e^+ \pi^0$.

A second possibility is a very large liquid scintillator volume observed by photomultipliers. The scintillator technology is based on the developments within the BOREXINO and DoubleCHOOZ projects. The total light yield of a scintillator is much larger than that of water, resulting in a much better energy resolution and lower detection threshold. A high efficiency can be achieved in the search for the proton decay via $p \rightarrow \bar{\nu} K^+$, as the Kaon and its decay products can be observed directly. In addition to the detection of Supernova neutrinos and the diffuse Supernova neutrino background, the very low threshold allows measuring different contributions to the solar neutrino spectrum at high statistics. Moreover, due to the delayed coincidence signal of electron antineutrinos liquid scintillator is the only proposed technology able to detect geo-neutrinos. LENA is a European proposal for such a detector. Already with a mass of 50 kt, the detector would provide interesting physics. This mass could be enlarged as the main costs are due to the price of the scintillator and the photomultipliers. There is a growing interest in the technique in North America, with the SNO+ experiment and the proposed deep ocean geo-neutrino observatory HanoHano.

A third possibility is the liquid Argon Time Projection Chamber developed under European leadership over many years of ICARUS R&D programme. This technology is able to image rare events with the quality of bubble-chambers, which are famous for having led to important discoveries in particle physics. The liquid Argon TPC is fully electronic and can be extrapolated to very large masses, possibly beyond many tens of kilotons. The Liquefied Natural Gas (LNG) technology developed by the petrochemical industry has proven that the storage of very large volumes of cryogen is safe. The ionization charge produced by charged particles when they traverse the medium and the associated scintillation light can be independently readout to provide a tracking-calorimetry detector. Thanks to their imaging capability, these detectors provide improved sensitivity to the proton decay channels where backgrounds are the limiting factor in Water Cherenkov detectors, such as the channel $p \rightarrow \bar{\nu} K^+$. GLACIER is a European design for a new generation liquid Argon TPC, eventually scalable up to at least 100 kton, and dedicated R&D for the extrapolation of the liquid Argon TPC to very large scales is been pursued. Interest in the technology has recently also grown in the USA in the context of a second generation long-baseline experiment at Fermilab.

The three mentioned detector types represent a variety of complementary aspects (see Table 1): MEMPHYS would collect the largest statistics, GLACIER would have the best pattern recognition, LENA would have the lowest energy threshold. MEMPHYS and LENA are superior in anti-neutrino detection while GLACIER is best in neutrino detection. Neutrinos and anti-neutrinos together provide the full information to study supernovae. MEMPHYS has complementary sensitivity to LENA and GLACIER on proton decay flavour signatures.

Table 1 Overview of the physics potential of the three types of instruments considered

Topics	GLACIER (100 kt)	LENA (50 kt)	MEMPHYS (400 kt)
proton decay , sensitivity (years)			
decay mode $e^+ \pi^0$	$0.5 \cdot 10^{35}$	TBD	$1.0 \cdot 10^{35}$
decay mode anti- νK^+	$1.1 \cdot 10^{35}$	$0.4 \cdot 10^{35}$	$0.2 \cdot 10^{35}$
SN at 10 kpc , # events			
CC	$2.5 \cdot 10^4$ (ν_e)	$9.0 \cdot 10^3$ (anti- ν_e)	$2.0 \cdot 10^5$ (anti- ν_e)
NC	$3.0 \cdot 10^4$	$3.0 \cdot 10^3$	-
ES	$1.0 \cdot 10^3$ (e)	$5.0 \cdot 10^3$ (p) $6.0 \cdot 10^2$ (p)	$1.0 \cdot 10^3$ (e)
Diffuse SN			
# Signal/Background events (after 5 years)	60/30	(10-115)/4	(40-110)/50 (with Gadolinium)
Solar neutrinos			
# events, 1 year	$^8\text{B ES}: 4.5 \cdot 10^4$ Abs: $1.6 \cdot 10^5$	$^7\text{Be}: 2.0 \cdot 10^6$ pep: $7.7 \cdot 10^4$ CNO: $7.6 \cdot 10^4$ $^8\text{B(CC)}: 3.6 \cdot 10^2$ $^8\text{B(NC)}: 5 \cdot 10^3$	$^8\text{B ES}: 1.1 \cdot 10^5$
Atmospheric ν			
# events, 1 year	$1.1 \cdot 10^4$	TBD	$4.0 \cdot 10^4$
Geo-neutrinos # events, 1 year	Below threshold	$1.5 \cdot 10^3$	Below threshold

1.2.3. Towards a proposal around 2010

Without any doubt, a very large underground detector facility has an extremely rich physics programme. The construction and operation clearly represents a difficult technological challenge and a significant investment on the scale of several hundred millions of Euros. It is intimately connected to the question of large underground infrastructures. The choice of the most appropriate technology, of the site and of the designs of such super-massive detectors should be carefully optimized taking into account the technical feasibility and predicted costs, the multiple physics goals, and also the possible existence of accelerator neutrino beams. To set the scale, the Hall B at the LNGS underground laboratory (See Figure 4) is one of the largest volumes available today for underground experiments. It has an instrumentable volume of about 15'000 m³. In comparison, this DS foresees total instrumentable volumes ranging from 100'000 to 1'000'000 m³. The technical and economical feasibility of an underground observatory of this magnitude, perhaps ultimate in size, requires a strong coordinate and coherent European strategy and will be heavily reliant on the possibility to contain costs compared to today's state-of-the-art by a careful optimization of all elements involved in the project: (1) the excavation and preparation of the underground space, (2) the design and construction of the tank, (3) the instrumentation and (4) the safety aspects. This implies that cost is optimized at all level of the project, and must heavily rely on careful design and engineering.

At the ApPEC "Munich meeting" held in November 2005, a coordinated effort among the 3 "liquid" technologies was proposed and accepted. Large detectors like Water Cherenkov, Liquid Scintillator and Liquid Argon TPC present, in addition to the above mentioned physics complementarities, a lot of common needs for R&D studies that will be fostered by synergies and task sharing.



The purpose of this proposal is to develop a conceptual design report for a pan-European infrastructure capable of hosting large-scale liquid detector(s). This study will allow a coherent and well-coordinated EU-wide design effort towards a large infrastructure, solving common problems together, taking into account the unique technological expertise in rare event detection technologies, underground excavation and construction, such that mature designs and credible scenarios can be proposed around 2010.

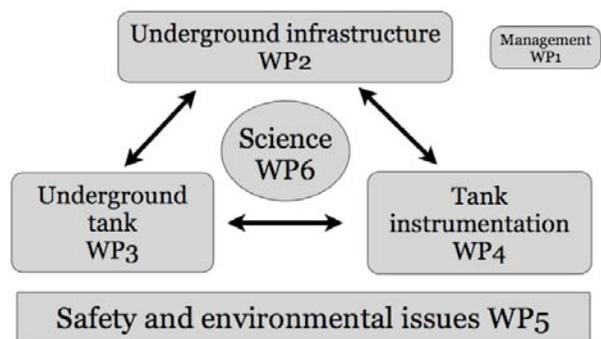
Figure 4 The Hall B at the LNGS underground laboratory. This hall is one of the largest volumes available today for underground experiments.

An important point is the possibility to eventually couple the research instruments that will be studied in this DS with existing or future neutrinos produced with accelerators. In Europe, the CERN Council at its December 1999 meeting has approved the CNGS project. Construction started in September 2000, and the first beam was obtained in the Fall 2006. This beam will serve the OPERA experiment at LNGS for the next five years. The further improvement of knowledge of neutrinos oscillation parameters requires precise measurements of parameters governing neutrino oscillations, which will require new high intensity neutrino oscillation facilities in which neutrino beams are generated using new and highly challenging concepts. Whatever the kind of beam that will be technically realisable, it will require a massive underground detector as a far detector. Therefore, our present DS addresses a fundamental point in the feasibility of future long baseline neutrinos programme, since it will assess where in Europe, very large underground detectors could be conceivable and at what cost.

1.3. S/T methodology and associated work plan

The main goal of the DS is to bring together on one hand the scientific community interested in this kind of research infrastructure and on the other the industrial and technical experts able to help assess its feasibility. The DS is subdivided into 6 workpackages (WP), interconnected with each other. The list of WP is the following:

- WP1 = Management, coordination and assessment
- WP2 = Underground infrastructures and engineering
- WP3 = Tank infrastructure and liquid handling
- WP4 = Tank instrumentation and data handling
- WP5 = Safety and environmental issues
- WP6 = Science impact and outreach

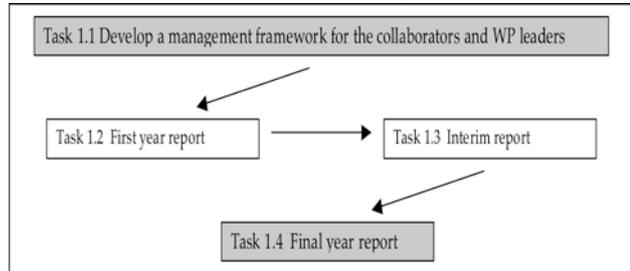


1.3.1. WP1 – Management, coordination and assessment

The management WP will coordinate the contractual, financial and administrative aspects of the Design Study and will oversee the technical and scientific work of the other WPs. It will be responsible for ensuring the project milestones are achieved and the deliverables produced on time. Furthermore, this WP will be responsible for knowledge management for the Design Study, coordinating the protection, use and dissemination of the knowledge generated during the project.

Task 1.1 Development of a management framework

The first task is to outline a management structure to allow efficient coordination of all contractual, financial and administrative aspects of the Design Study. This will be completed within the first 4 months of the project, although the management network created will continue, through the various WP leaders, to monitor milestones, ensuring that deliverables are produced on time.



Task 1.2 First year report

To be completed in the 12th month, this document will summarize the work done in all WP, and will compare progress against milestones and deliverables.

Task 1.3 Interim report

At the end of the 24th month an interim report will be submitted detailing the progress made in each WP, comparing these with the respective milestones, and outlining any conclusions which can be drawn.

Task 1.4 Final year report

To be completed in the 36th month of the project, this report will describe the achievements of the Design Study and will include a detailed comparison of all sites and experiments considered. Based on the findings, a recommendation will be made for the feasibility of the project with respect to scientific performance, underground construction, engineering infrastructure, and cost. This will include a CDR for the facilities and storage vessels selected.

1.3.2. WP2 – Underground infrastructures and engineering

The WP focuses on the technical issues of underground large-scale civil engineering needed to host large volume instruments considered in the DS. The purpose of this WP is

- to assess the feasibility of large underground cavern in six potential European sites to host large volume detectors of each target liquid,
- to select a subset of candidate sites (so called “promising” sites) and
- to perform more detailed feasibility studies of the excavation of large-scale cavities in those “promising” sites.

The main deliverable will be a feasibility document containing the scientific and technical information related to excavation of large caverns in those sites. Its PERT diagram is shown in Figure 5.

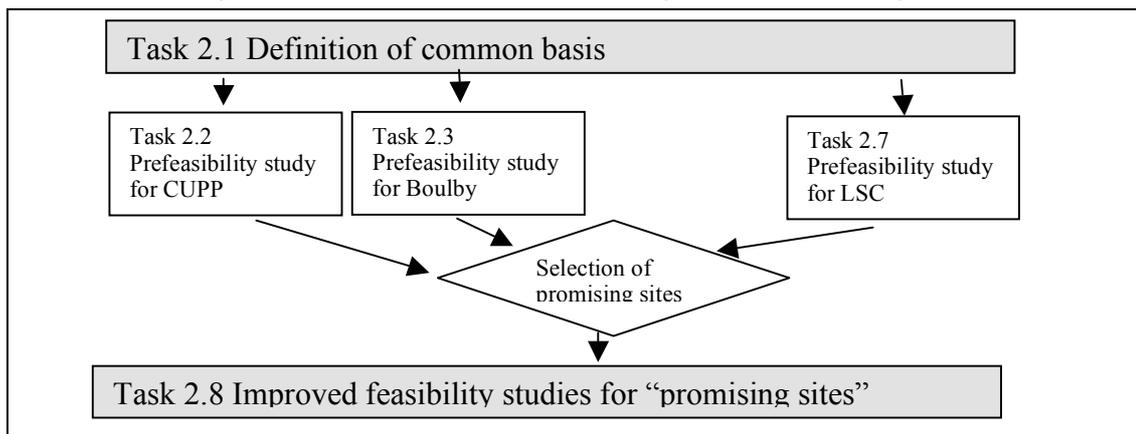


Figure 5 PERT diagram for WP2.

A report, subject to commercial confidentiality where appropriate, with conceptual designs of the underground cavities will be delivered, recommending the sites that are technically suitable for large excavations and if relevant which target liquids can be envisaged in a particle location. Estimates for costs of cavern and access excavations will be included. A critical comparison of these costs, pointing out potential relative and absolute cost differences, will be included in the report.

In each country involved there will be two participants: a scientific institute and a technical (engineering) partner. The role of the technical partner is to prepare the technical part of the design and to study the feasibility of the rock construction. The role of the scientific partner is to provide scientific expertise for the design, particularly outlining the requirements and preferences of the experiments and acting as a link between the technical partner and the scientific community. All countries need their own local participants for the site studies, because the local conditions are very specific and different in each participating country (See for example Figure 6 to illustrate difference in bedrock), considering both geology and default host and access.

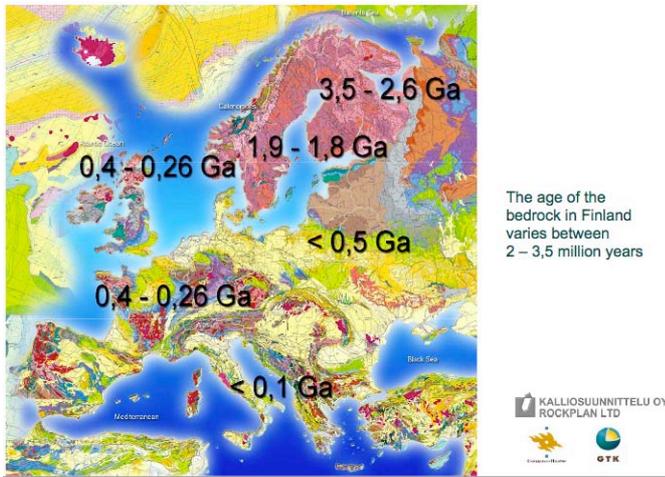


Figure 6 Bedrock conditions in Europe. Conditions vary substantially from one location to another.

All partners of DS will commit to work together and share data whenever possible, experience and expertise. The work is started with the underground sites shown in Table 2. The first goal of the DS is to guarantee that each of the six European sites has been investigated with the same level of detail. This is important in order to allow a coherent and fair comparison of the pros and cons of the potential sites. Hence, in a pre-feasibility study phase all sites will be investigated in order to reach the same level of understanding of their potential for very large excavations. This DS will include special requirements of the experiments, as well as plans for normal insulation, ventilation, power and other building technical tasks. The interface to the local host infrastructure (mine, tunnel) and the access from the surface will also be studied. The scientific preferences and requirements will be studied in parallel with the technical studies by scientists in the community in the other WPs. Detailed executive designs are out of scope of this DS, since it is a normal practice to include them in the construction budget.

Table 2 Sites to be explored during the DS.

Name	Country	Region	Host institute	Site type
1) Boulby mine	United Kingdom	Boulby	Sheffield Univ.	Mine/salt (potash) or rock
2) Fréjus	France	Fréjus	CEA / IN2P3	Road tunnel / hard rock
3) CERN CNGS off-axis location	Italy	Along CERN neutrino beam	Not yet defined	Soft rock/shallow depth
4) LSC	Spain	Pyrenees	MEC/Regional Governm./ Univ. Aragon Zaragoza	Soft rock
5) Pyhäsalmi	Finland	Pyhäjärvi	Oulu Univ.	Mine / hard rock
6) SUNLAB	Poland	Polkowice - Sieroszowice	Not yet defined	Mine / salt & rock

Engineering companies will perform the main part of this WP. There will be a separate local company for each laboratory, as specific knowledge of the local conditions is mandatory.

The pre-feasibility studies will include geological studies of the sites, analysis of available rock samples and simulations of rock mechanics. The main topics to be addressed in the prefeasibility studies of each six sites are:

- Determination of the best shape for very large cavities and of their maximum possible dimensions. Assessment of environment suitability for specific scientific applications with respect to the geo-mechanical structure and the limitations it imposes on cavern size and shape.
- Assessment of the implications of the rock characteristics on costs, operations, and site lifetime relevant to the science being undertaken.

- Definition and optimization of the strategy for the containment of each type of liquid (in connection with WP3).
- Determination of the technical requirements internal to the laboratory infrastructure including access arrangements, underground and surface facilities such as cryogenic, gas extraction, clean room facilities, LAr and/or LN₂ provision, dedicated ventilation, air filtering and conditioning, electrical power supply, water, access roadways, specific safety requirements, liquid transportation and local production factory for their continuous purification (in connection with WP3 & WP5); and to study the special services and requirements specific to each experiment; optimisation of the strategy for the near access to each cavity.
- Assessment of requirements for, or impact on the infrastructure of transportation and assembly of experimental equipment – roadway type and size, shaft access, craneage, and lifting equipment.
- Incorporation of the relevant safety conditions and equipments (for fire, liquid leaks and evaporation, etc.) in connection with WP5.
- Assessment of the needs for computing facilities, networking, and communications.
- Study of the prospect for flexible designs and provision for expansion and eventual decommissioning.
- Study of the operation of the laboratories from a legal, financial, and managerial perspective.
- Estimation of costs and time for execution of excavation. Identification of the factors that affect costs.
- Estimation of the maintenance costs of the underground infrastructures (ventilation, water pumping, controls and reparations etc) with different options.

Task 2.1 Start-up phase

The first task is to agree on a common framework to the different site studies. In order to compare the results at an equal basis, we define the standards to be used in all studies and set up the template for the interim reports. We also ensure that all partners have similar starting points, agree on intercommunication and introduce all technical partners to each other to share data and knowledge. This task is to be completed during the first six months of the project.

Task 2.2 Prefeasibility study for CUPP/Pyhäsalmi

For CUPP a pre-feasibility study for a deep laboratory was done in 2002, with two drill holes. The rock was found to be very good, though the rock pressure was high. Although the study did not consider as large cavities as in LAGUNA, it did not show any evident obstacle for such cavities (See Figure 7). The feasibility of large underground constructions in a new underground laboratory located by the Pyhäsalmi mine will be further studied in this DS. The integration into the infrastructures and operation of an active mine will be specifically studied.

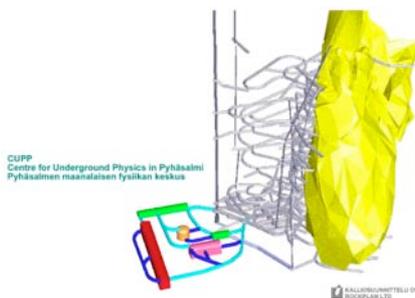


Figure 7 Pre-feasibility study at CUPP/Pyhäsalmi.

Task 2.3 Prefeasibility study for Fréjus

In Fréjus a pre-feasibility study for excavation of very large cavities in the context of the MEMPHYS project was done 2005⁴. It included rock mechanical analysis using the existing data of the rock in the road tunnel. No technical obstacles for caverns of the kind needed by the MEMPHYS project were discovered so far. Using the general rock properties the optimal shape of the cavity for MEMPHYS was found to be individual cylinders (3 to 5) of ca 250 000 m³ each. The cavity for GLACIER in its preferred form was found to be infeasible, but another form was suggested (e.g. 2 modules of 50 ktons each). The programme of this DS will consist of a more advanced and precise study including the basic equipments of the laboratory, as needed by each target liquid. The main task could be subcontracted to the SETEC⁵ and LOMBARDI⁶ companies. Fine-tuning of the shape of the cavities will be an important point of the study. In addition, a study of compatibility between the excavation operations for a megaton-scale laboratory at the Fréjus site and the running conditions of the future safety tunnel at the Fréjus (with a diameter = 8 m) will be assessed: need of ventilation, of excavated rock evacuation, etc.

Task 2.4 Prefeasibility study for Boulby mine

The Boulby mine, a working salt and potash mine in north east England, at 1100m deep, is the deepest mine in Britain with over 1000km of tunnels excavated over the last 40 years. The potential for expansion is a priori excellent and there is already interest from the mine operators Cleveland Potash Ltd (CPL) in

⁴ "Cavernes de 1 Million de metres cubes : Étude préliminaire de faisabilité" STONE (Juin 2005)

http://www.apc.univ-paris7.fr/APC_CS/Experiences/MEMPHYS/ and "Étude préliminaire de faisabilité de puits de grande dimension (au Fréjus) : Méthodes de réalisation Coûts et Délais SETEC-TPI (12 octobre 2005)"

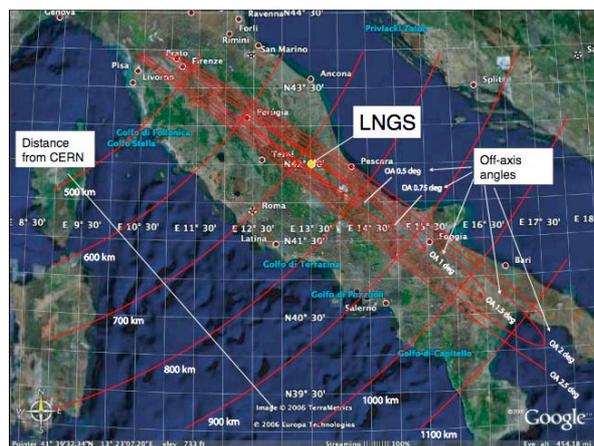
⁵ SETEC-TPI, Tour Gamma D 58, Quai de la Rapée, 75583 Paris (France)

⁶ LOMBARDI SA, Ingegneri Consulenti, Via R. Simen 19, CH-6648 Minusio Locarno, Switzerland.

excavating deeper to exploit polyhalite ore. Whereas excavations in the salt seam are limited to 8m wide by 5m high, polyhalite is thought to be a far more competent rock, which is expected to be self-supporting over large areas. Based on a core sample taken from the polyhalite seam 200m below the salt and potash layers, CPL predicts that labs as large as those seen in existing hard rock locations are possible, and that cavities 30m wide and high are potentially feasible. In its current form LENA appears to be viable, and based on the cavity geometry permitted by the surrounding rock, GLACIER and potentially MEMPHYS could also be adapted to fit. The concept of a new underground science facility in this seam is strongly supported by CPL. The study in this DS would involve strategic exploration to identify the economic viability of mining the deeper polyhalite resources, and a full appraisal of the feasibility of establishing a full laboratory with all associated services required for underground science including specific reports for each proposed experiment and their requirements both above and below ground. CPL would act as a professional engineering consultant and would liaise with Sheffield University, the scientific institute. The main aim for CPL would be to undertake a detailed scientific environmental study of the polyhalite deposit to assess suitability for a deep laboratory for the science intended, and hence to inform critical areas of the facility design. Boulby mine is a fully functioning salt and potash mine, and as such it is only correct that the mine operators CPL have the final decision on the making public of any and all facts concerning Boulby mine and CPL deemed to be of a private, proprietary, or sensitive nature for whatever reason by way of a confidentiality agreement. This will provide written assurance from the Principle Investigators, before any feasibility study is carried out, and is seen as an essential first step of the design study.

Task 2.5 Prefeasibility study of a shallow site along the CERN NGS neutrino beam

The CERN CNGS project, approved by the CERN Council in 1999, has been commissioned in the Fall 2006. This high-energy beam, using the CERN accelerator complex, is directed towards the Gran Sasso Underground Laboratory and will serve the underground OPERA experiment located in Hall C of LNGS



for a period of about five years. The current optimization of the CNGS beam is tuned to the particular physics programme of the OPERA project and exhibits limited interest for the physics addressed in the present DS. The physics potential of an intensity upgraded and energy re-optimized CNGS neutrino beam coupled to an “off-axis detector” of very large mass could offer interesting physics opportunities (See Figure 8). Within this DS, possible shallow depths sites will be investigated taking into account the expected profile of the CNGS beam and possible upgrades its intensity, in agreement with CERN long term plans.

Figure 8 The profile of the CERN CNGS beam. Several locations symbolized by the red ellipses are a priori candidate sites for an off-axis configuration.

Task 2.6 Prefeasibility study for SUNLAB

The Sieroszowice Underground LABORatory (SUNLAB) is planned to be located in the Sieroszowice mine, which belongs to the KGHM holding of the copper mines in the west-southern Poland. The site is placed 70 km from the airport in Wroclaw and 40 km from the motorway A4 crossing the southern Poland in the west-east direction. At a depth of 900-1000 meters below the surface there is a layer of salt about 70 meters thick. Over and under the salt deposit, layers of high stiffness and strength parameters (anhydrite, limestone and dolomite) are observed, often water saturated. So far, the cavities executed at such depths in the Polish rock salt formations were of a smaller scale. One of existing caverns, 100 m long, 15 m wide and 15 m high, is located in Sieroszowice at 950 m below the surface. It serves now for measurement purposes. The movements of the salt walls have been monitored since 1997 in order to better understand a viscous creep of salt at big depths. A very large underground infrastructure for the LAGUNA project would be an innovating enterprise. In Sieroszowice an initial study was done in 2004/2005, showing prospects to host a large detector for GLACIER Liquid Argon detector. The preliminary conclusion of finite elements analyses showed that very large caverns in the salt layers could be potentially considered. The full pre-feasibility study for SUNLAB will be performed by KGHM Cuprum in close collaboration with IGSMiE PAN and the Sieroszowice mine’s personnel. It will embrace all mining and geological aspects of large salt cavern design, from its location selection to water and energy supply. 3d stability analysis performed using the finite differences numerical tool (Flac3d) will permit determining the optimum cavern’s shape constituting the main objective of the overall study. This feasibility study will focus particularly on salt-rock creep behaviour as well as the appropriate strength hypothesis assessment based on mechanical tests performed in KGHM Cuprum laboratory site, validated later on by field measurements in the existing underground salt chambers. During the computation procedure, salt-rock and surrounding hard rock mass will be scanned out whether the values of stability measures expressed by so called safety margins are maintained

within a given safe bounds. This kind of numerical modelling will include the multi-phase and time-dependent excavation process and salt-rock creep behaviour in long-term horizon as well.

Task 2.7 Prefeasibility study for LSC

The Canfranc laboratory is located at 1080 m over the sea level and has a natural rock shielding amounting up to 2450 meters water equivalent. The lab originally consisted of two small halls (known as Lab1 and Lab3) located 780m and 2500m away from the Spanish entrance of the tunnel, respectively. A new lab was recently constructed. It consists of a main hall with an area of $45 \times 15 \text{ m}^2$ and has a height of 10 meters. In addition, there are storage corridors, workshops, clean rooms, etc. for a total surface exceeding 1000 m^2 .

So far no plans for possible extensions of this laboratory have been considered. Within this DS, possible extension of the laboratory either near the current site, which offers a dedicated entrance via the abandoned train tunnel, or in the neighbouring sites, will be investigated.

Task 2.8 Improved feasibility studies for "promising sites"

The selection process of the promising sites forms the major milestone of the work. On the subset of promising sites, more detailed studies will be performed. We expect to reduce the number of sites to three "promising" ones and to consider for each of them two or three liquids, hence, the number of cases should range between 6 and 9. In addition to a more detailed study of the works mentioned above, these studies include the extraction and preparation of rock samples across the site volume, and thorough analysis of their geological properties. The radio-purity of the rock and factors such as temperature, humidity, and rock stability will be assessed. The sizes and shapes of the cavities will be fine-tuned to fit the requirements of experiments. WP3 (tank), WP5 (safety) and WP6 (physics optimisation, background issues) will deliver the necessary input. The costs for the construction of the cavities will be estimated with 20% accuracy. Detailed designs are not included in this DS, as they belong to the construction phase, after approval.

1.3.3. WP3 – Tank infrastructure and liquid handling

This WP will establish the feasibility of underground tanks to handle and store large amounts of pure target liquids, while assessing their cost. The WP includes several tasks (a) to determine the optimum strategy for design and manufacture of underground tanks specific to each target liquid, (b) to assess methods of procurement of large quantities of liquid in the "promising" sites defined in WP2 and (c) to define liquid filling and large-scale purification strategies. In order to contain costs and avoid custom designs, whenever possible, readily available commercial solutions or extrapolations from these are to be considered. Fortunately, the technology for large storage tank is rather well developed and well documented in EUROCODES. The nature of the tasks in this WP necessitates significant liaison with specialised industries such as Technodyne Ltd and/or e.g. Kalliosuunnittelu Oy Rockplan Ltd in either a partnership or subcontracting capacity. In addition partnership with specialised civil and cryogenic engineering departments would prove beneficial as would discussion with companies exploiting mine or road tunnels for transportation of construction equipment and materials. Throughout the study constant communication will be maintained between senior physicists, industrial partners and specialised engineers to ensure engineering solutions do not compromise scientific performance. Milestones will identify key design stages and interim reports will outline progress. Regular meetings among senior physicists, industrial partners and contractors will identify problem areas and help ensure the engineering aspects of the design do not supersede the scientific requirements of the instruments.

Task 3.1 Definition and assessment of prior conditions

Two different shapes of liquid tanks will be considered for the liquid containment: vertical cylindrical and horizontal cylindrical tanks. One of the tasks of the WP is to assess the optimal shape of the tank in synergy with the feasibility and costs optimization of the cavern excavation (WP2), the detector instrumentation (WP4), the safety aspects (WP5) and the related physics performance issues (WP6).

As was already demonstrated in the context of the MEMPHYS R&D programme, a very large volume of $1'000'000 \text{ m}^3$ is not readily realizable as a single unitary cavern. A staged approach, contemplating five tanks of $250'000 \text{ m}^3$, has therefore been preferred in the MEMPHYS pre-feasibility study at the Fréjus site. Similarly, a staged approach, with say, two or three "modules" of increasing volume, e.g. $10'000$, $20'000$ and $40'000 \text{ m}^3$ to reach the required total volume, will be studied in this WP. Clearly, from the tank point of view, the largest single unit approach is the most cost-effective solution, however, this will be considered in relation to the requirements of excavation (WP1), instrumentation (WP4) and of safety (WP5). A "scalable" design should a priori be considered as the most optimal approach.

Regardless of the shape or the size of the container, each liquid target imposes specific requirements on the design of the tanks. In particular, large water tanks housed within underground areas are conventionally either single stainless steel walled, surrounded by large sumps to catch escaping fluid, or double skinned with an internal lattice construction within the wall cavity to isolate leaks flowing from areas of the inner surface. Chemical incompatibility of liquid scintillators with materials used in the construction of tanks imposes design restrictions. The implications of chemical spills necessitate the use either of double skinned walled tanks, or of multiple units of a modular design housed within a sealed sump of reduced size. Tanks

used to contain large quantities of cryogenics (a.k.a. liquid Argon), although more complex in design, have been demonstrated worldwide to be both reliable and safe in their application to LNG storage. For LNG storage, the largest above ground tank that has been built to date is the 180,000 m³ tank at Senboku Japan. The industry also perceives the requirement to increase the capacity to above 200,000 m³ in the near future. It is feasible to increase the tank capacities of Concrete / 9% Ni Steel storage tank designs to capacities above 200,000 m³.

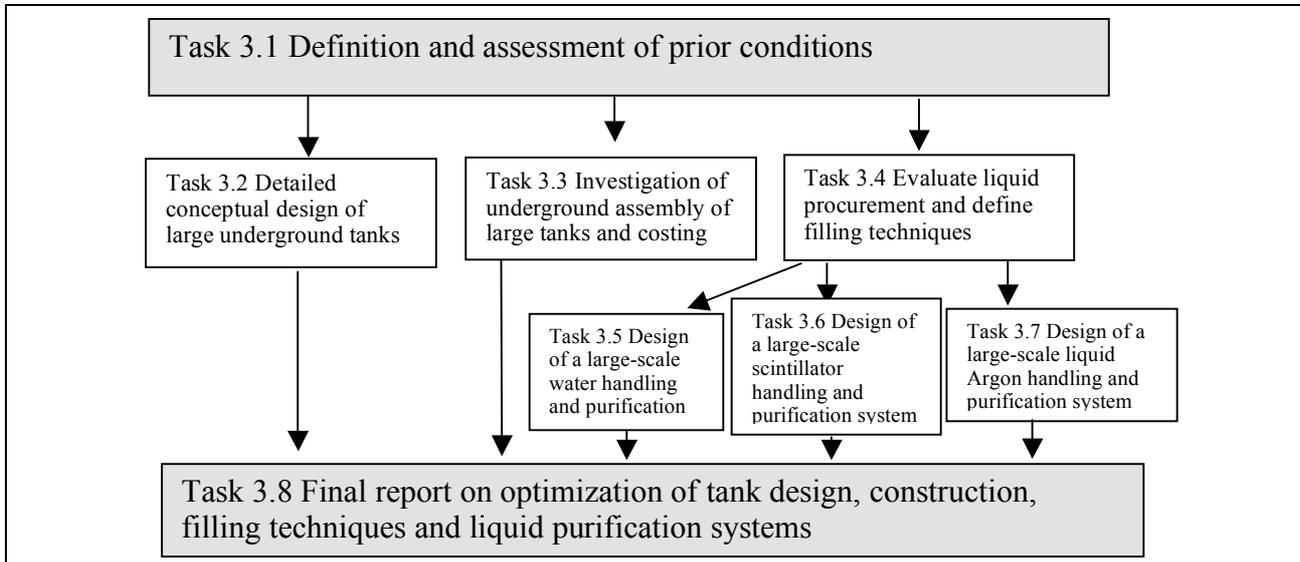


Figure 9 PERT diagram for WP3.

For above ground tanks, the rules defined in Part 4-2 of EUROCODE 3 provide principles and application rules for the structural design of vertical cylindrical above ground steel tanks for the storage of liquid products with the following characteristics: (a) internal pressures above the liquid level not less than -100mbar and not more than 500 mbar; (b) design metal temperature in the range of -50°C to +300°C. For tanks constructed using austenitic stainless steel, the design metal temperature may be in the range of -165°C to +300°C and (c) maximum design liquid level not higher than the top of the cylindrical shell. EN 1993-4-2 is concerned only with the requirements for resistance and stability of steel tanks. Other design requirements are covered by prEN 14015 for ambient temperature tanks, prEN 14620 for cryogenic tanks and prEN 1090 for fabrication and erection considerations. These other requirements include foundations and settlement, fabrication, erection and testing, functional performance, and details like man-holes, flanges, and filling devices. Provisions concerning the special requirements of seismic design are provided

	Title: Large Underground Argon Storage Tank Study report	Page: 11 of 33
		Rev: C Date: 15-Dec-04
		Author: JMH
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in EUROCODE 8, Part 4, which complements the provisions of EUROCODE 3 specifically for this purpose. The design of a supporting structure for a tank is dealt with in EN 1993-1-1. The design of an aluminium roof structure on a steel tank is dealt with in EN 1999-1-5.

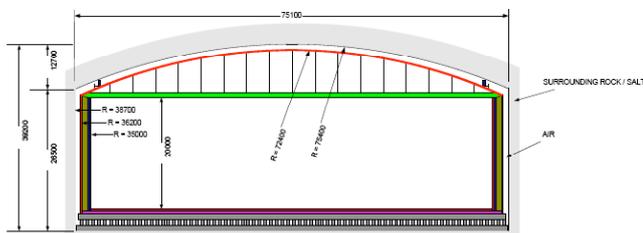


Figure 10 Conceptual design of a large underground Argon storage tank by Technodyne Ltd.

In comparison, the underground tanks contemplated in this DS are relatively small compared to those used by the petro-chemical industry for above ground storage of materials. Extra considerations will obviously have to be taken into account when underground, however, other design considerations such as wind loading and solar heating effects are eliminated from the above ground case. The main issues to be understood are therefore related to the underground operation and construction of these tanks. Significant industrial consultation will be required with companies possessing extensive experience in the design and construction of such large storage tanks. For this we will rely on the Technodyne Ltd SME acting as a participant in this DS.

In 2004 a pre-study on the feasibility of a large underground liquid Argon storage tank⁷ of 77'000 m³ was mandated to Technodyne Ltd and resulted in a conceptual design presented in

Figure 10. Studies carried out within this WP will include more detailed designs of the tanks, the support structure, the storage vessels and required ancillary safety structures required. Once "promising" sites have been identified in WP2, the suitability of the tanks will be studied in more details with regards to underground access and construction, cavern size and local infrastructure. Based on a successful appraisal, more detailed designs of suitable tanks and their interface to the cavern and host infrastructure will begin.

Task 3.2 Detailed conceptual design of large underground tanks

Most of the work in this subtask will be performed in tight collaboration between physicists and the engineering expertise from the Technodyne partner. In addition, consultation with other experts in the field like for example GEOSTOCK⁸ and UGS⁹, is foreseen. We have noted that Europe has significant expertise in the development of tools for the relevant engineering of this package. We mention for example LUSAS engineering software.¹⁰ A report will be produced containing detailed tank designs suitable for each target liquid, including construction time and predicted costs with assistance from companies specialising in the construction of storage tanks for the petrochemical and cryogenic industries. Mechanical considerations will in general compete with scientific requirements. For example the overall shape must be chosen to maximise the active instrumented volume to total liquid volume ratio to increase active target mass, whilst in the case of cryogenics minimising the external surface to volume ratio to limit thermal losses. For cryogenic tanks, the report will assess the best thermal insulation methods, for example using expanded Perlite cavity wall insulation. It will include a thermal load calculation in order to assess both the cooling requirements and the boil off rate, a parameter to be optimized taking into account the convective motions and the temperature uniformity of the liquid. Throughout the study, the implications to the science will be constantly addressed and benefits to engineering aspects of the design balanced against the impact they may have on the physics performance of the apparatus. Optimisation of tank shape, modularity, and geometry will be discussed in the contexts of detector operation, target sensitivity, construction optimisation, cost, and safety implications (in relation with WP5). The design specification for each target will also be influenced by the local infrastructure, the methods of access and any other limitations imposed by the site. In addition to the main target tanks, the report will include the design of the support structure, and the materials used in all aspects of the construction. Typically large room-temperature liquid tanks are supported by an array of H beams connecting a series of horizontal rings surrounding the tanks at various vertical positions on the outer surface. Double walled tanks are usually sufficiently strengthened by the honeycomb structures between the tank walls. For cryogenic tanks, the interface between the tank, its supportive structure and the cavern walls will be studied in details, considering for example a thermal buffer obtained with a circulation of hot air in the gap between the tank and the cavern. A final report will detail the viability of constructing underground tanks containing large liquid volumes for the proposed experiments. The report will include: (a) an underground site specific detailed design of detector and storage tanks including ancillary safety vessels and support structures, (b) materials used and thermal load calculations, and (c) site specific construction strategy and costs. This will allow the scientific community to select the most suitable tank and storage design for each target liquid for given sites.

Task 3.3 Investigation of underground assembly of large tanks and costing

For each design an assessment will be made of the feasibility of underground construction and assembly, and the strategies required based on the underground access route and local infrastructure. In an above-ground scenario the large storage tanks are usually constructed using common civil construction techniques. As there is no restriction on headroom the use of large cranes is normal. In the underground scenario it is less likely that there will be enough headroom to allow the use of large cranes. The domed roof is normally constructed on the bottom of the tank and then raised and welded in place using air pumped into the vessel. This technique is commonly used when manufacturing these types of tank and does not present a problem underground. The only requirement being a supply of electricity to power the air fans needed to raise the roof. An alternative technique could then be employed where the roof is built first together with the top ring of the shell. The assembly would then be jacked up about 3m and the next lower ring installed. Successive ring welding / jacking operations would be performed until the shell is completed without the use of a large crane. This is a common technique for large diameter oil storage tanks.

⁷ "Large underground liquid Argon storage tank", Technodyne Ltd, 2004.

⁸ GEOSTOCK underground storage facilities for liquid, liquefied and gaseous hydrocarbons : it is an international engineering group specialized in the design, construction and operation of underground storage facilities for liquid, liquefied and gaseous hydrocarbons. GEOSTOCK SAS, 7, rue E. et A. Peugeot 92563 RUEIL-MALMAISON Cedex, FRANCE Tel.: 33 (0) 1 47 08 73 00 Fax: 33 (0) 1 47 08 73 73

⁹ UGS (Untergrundspeicher und Geotechnologie - Systeme GmbH), Berliner Chaussee 2 15749 Mittenwalde, GERMANY, Tel.: 49 (0) 337 64820.

¹⁰ LUSAS engineering software, LUSAS Forge House, 66 High Street, Kingston upon Thames, Surrey KT1 1HN, United Kingdom.

The order of construction of the tank would be as follows: (a) base (b) roof and deck (c) outer shell (d) base insulation (e) inner shell base (f) inner shell (g) insulation.

Task 3.4 Evaluate liquid procurement and define filling techniques

In parallel to the design of the tanks, this task will evaluate the methods of procurement in large quantities of each target liquid in the “promising” sites selected in WP2. To set the scale, a single truck can typically transport $\approx 30 \text{ m}^3$ of liquid. In comparison, the total volumes are typically 3 to 4 orders of magnitude larger, requiring the use of many thousands of trucks. This is not without causing significant technical and safety issues and potentially creates interference with local activities of the site. Strategies to bring very large quantities of liquids into the underground tanks will be discussed and an optimization of the liquid procurement methods will be attempted. Availability nearby the “promising” sites will be investigated and costs for transport will be estimated taking into account purity at delivery. Methods of local production will be assessed. For cryogenics, local liquefaction of air will be considered. The liquids will not be produced *ab initio* with the required purity, so a trade-off between initial purity versus in-situ purification systems will be studied taking into account costs. The filling techniques of deep underground tanks avoiding recontamination will be defined. In addition, methods to further purify and maintain high purity levels of the liquids will be designed by extrapolation to large scale of existing methods employed in currently operating projects. The definition of the purification methods will be based on input from the senior physicists and industrial partners involved in the business. All methods of storage and liquid transfer will be considered in terms of the impact on laboratory space, cost, safety, speed of transfer, and implications on the science. In the case of liquid Argon this will include both the cryogenic cooling requirements within the detector tank, and the boil off rate induced by auto-refrigeration. Although unlikely to occur more than once in the lifetime of the experiment, the emptying of the tanks will be addressed.

Task 3.5 Design of a large scale water handling and purification system

Large water Cerenkov detectors require pure water. A water purification system for a megaton system, including chemical and radioactive purity of the water, will be defined. The stability and control of an admixture of Gd is part of the project.

Task 3.6 Design of a large scale scintillator handling and purification system

Large scintillator detectors require very pure liquid. The present task encompasses the piping and instrumentation design (PID) of the liquid as well as the gaseous system for filling the detector in the underground laboratory. Further purification methods for removing radioactive trace elements and improving the optical properties of the liquid will be explored. This work will be based on the experience gained in the solar neutrino experiment BOREXINO. In parallel, measurements of the optical properties of liquid scintillator (attenuation length, light collection) using spectrophotometer and PMT readout techniques used for SIREN and OMNIS collaborations are required. A high purity liquid scintillator pump will also be developed and measurements of the compatibility of potential detector components with the preferred scintillator base will be performed. Finally radiopurity testing is envisaged, and based on the ageing, design of the purification columns required for high liquid flow rates will be performed.

Task 3.7 Design of a large scale liquid Argon handling and purification system

Very large liquid Argon detectors require extremely high levels of liquid purities, which can be achieved with continuous purification techniques. Although mastered in the laboratory, the purification and recirculation technology and purity monitoring will be extrapolated to the scale required for the GLACIER project. The requirements for compression, purification and reintroduction of boil off Argon gas from an auto-refrigerated tank will be considered based on detailed heat load calculations, advice from the technical partner, and experimental evidence. A fluid thermal and dynamical calculation for liquid Argon storage will be performed. The design of the recirculation system will be done in collaboration with the ILK¹¹ and Technodyne Ltd. The system will require low power consumption pumps. All the pumps will have to be compatible with the purity standard required and should work continuously at cryogenic temperature and without maintenance for the whole running time of the experiments. This development has potential industrial applications, for example in the automotive industry (hydrogen).

Task 3.8 Final report on optimization of tank design, construction, filling and liquid purification

In a final report, the findings from the other tasks will be merged into a single report summarizing the result of the optimization of the tank shape, design and construction, the results of the assessment of the liquid filling and purification techniques. A list of compatibilities and eventual incompatibilities between the various targets will be investigated. In particular, the possibility or eventual impossibility to host several instruments based on different liquid targets in the same site will be investigated.

1.3.4. WP4 – Instrumentation of the tank and data handling

This work package will rely heavily on existing particle and astroparticle projects sponsored by national funding agencies, namely: BOREXINO, DOUBLE-CHOOZ, ICARUS T600, ZEPLIN, and MEMPHYS,

¹¹ Institut für Luft- und Kältetechnik GmbH (Dresden, Germany).

GLACIER, LENA R&D. The existing projects can be considered as prototypes for the new observatories contemplated in this DS. The main focus of this work package is hence geared towards understanding the extrapolation of these technologies to very large volume detectors which require distributed systems with large number of channels, while reducing the cost per channel in order to contain the cost. In particular, one important objective is driven by the wish to establish the cost effectiveness of large area photo-detection and modern electronic full custom integration to reduce the total cost of the facilities. Although WP4 contains several tasks specific to each target liquid, their execution within a common WP framework will foster communication and cross-fertilization of ideas among physicists involved in the development of different instruments. The results of each task will be presented at the LAGUNA general and WP4 meetings to the entire community. WP4 will improve the overall knowledge of each physicist involved in the DS, since he/she will be exposed to detailed reports and presentations on activities of all three target liquids. This common effort will further increase European cohesion and collaborative spirit among the participants and will be a relevant social factor for a realization of a common very large European infrastructure.

Task 4.1 Start-up and assessment of prior state-of-the-art of all techniques

Several conceptual ideas for next-generation very-massive, multi-purpose underground detectors have emerged worldwide and in Europe over the last years. All the designs consist of large volumes of liquid observed by detectors, which are arranged on the inner surfaces of the vessels. The first task is to agree on a common framework to the technology-dependent and independent studies. Common specifications will be defined. We will ensure that all partners have similar starting points, agree on intercommunication and constructive work. This task is to be completed during the first six months of the project.

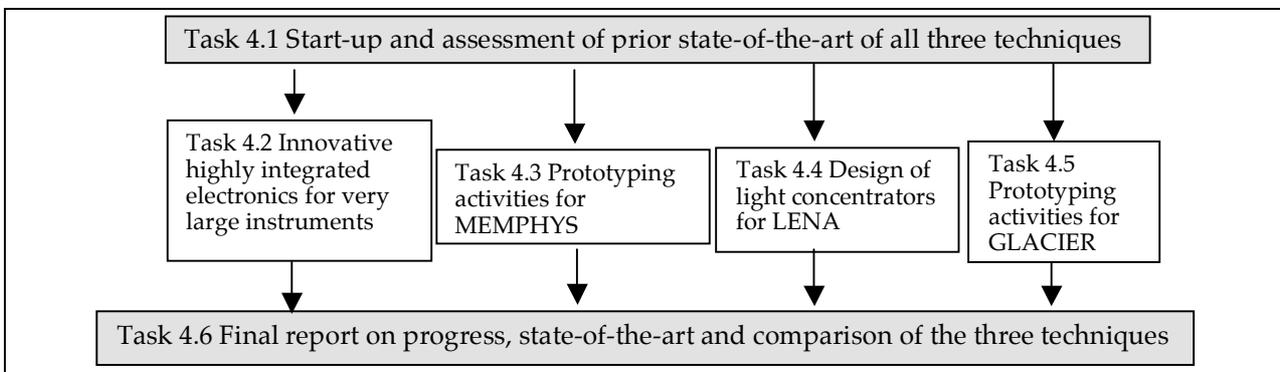


Figure 11 PERT diagram for WP4.

Task 4.2 Innovative highly integrated electronics for very large instruments

All three kinds of detection techniques considered in this DS will rely on sophisticated, large scale and distributed electronic readout systems. Extrapolation of existing prototypes to large systems can be made cost-effective by using advanced electronic technologies made available by the progress of microelectronics. These developments allow integration of all the components for amplification and signal processing for dozens of channels in a single chip (ASIC). Two main streams of developments will be considered in this DS: (a) ASIC for charge readout (b) ASIC for light (PMT) readout.

It is foreseen to establish the design for a low cost and large-scale readout solution for a LAr TPC characterized by low noise analog front-end and treatment of large data volumes (each readout channel is continuously sampled at 2.5 MHz and with at least 10 bit resolution). Design of the analog readout based on a low noise ASIC chip allowing for the low cost integration of a large number of channels and compatible with application at cryogenic temperatures, optimization and integration with the charge readout scheme. Design of the digital data acquisition system based on a distributed system of asynchronous smart sensors, reading large groups of channels, with local processors dealing with zero suppression and transmitting data through a Gigabit Ethernet network up to a cluster of PC used for the event building, reconstruction and storage. Design of a precise clock distribution system used for the time-stamp of the collected charges, integrated in the data network by exploiting the IEEE1588 standard. Many of these techniques for the data acquisition system and clock distribution are also applicable to the other detector options considered in the design study. Optimization and design of a large scale, low cost readout solution for the LAr detector will be performed, including: analog front-end, digital building blocks for data acquisition, transmission, zero suppression and events reconstruction and storage, clock distribution system. Some parts of these developments may be shared by the three techniques envisaged.

The development of the macro pixel sensors and the microelectronics is important also for the LENA project. The results of tests with this prototype can be transformed directly into the design of the electronic and photo-sensor system of the large liquid scintillator detector LENA while the optical properties of the scintillator will be studied separately.

Task 4.3 Prototyping activities for MEMPHYS

The goal of this task is to design, assemble and operate a 10t water Cherenkov test facility instrumented with a 16 photomultiplier units with integrated electronics. This task will segment very large surfaces in macro pixels connected to the innovative electronics autonomous then allowing to reduce considerably the surface cost of these detectors and facilitating their industrialization. The chain from the signals, the front-end electronics, the DAQ and triggering system will be tested. With this prototype we will also test the water purification system and the stability of an admixture of Gd salt. The prototype will be located at surface level in the APC laboratory to allow easy access for debugging the electronics and the DAQ system. Later it could be transferred to the Fréjus Underground laboratory (LSM).

Task 4.4 Design of light concentrators for LENA

The optimization of the light collection in LENA is one of the most important issues of its design study in order to lower the energy threshold in the sub-MeV region. Additionally energy resolution as well as the precision of position reconstruction depends on this parameter significantly. Within this task the optimal shape of the concentrators in front of the photomultipliers has to be calculated with Monte Carlo codes. The compatibility of reflecting materials with the organic scintillator has to be determined. This can be performed in laboratory works via accelerated aging tests. The radio-purity of the materials used has to be tested via neutron activation analysis by high-resolution gamma spectroscopy in the shallow underground laboratory at TUM in Garching, Germany.

Task 4.5 Prototyping activities for GLACIER

The R&D and prototyping for the GLACIER experiment described in this task correspond to ongoing activities financed with national agencies. Many technological solutions, to be extrapolated to the very large detectors, will be developed within these subtasks, subdivided as described below:

The ArDM subtask: The goal is to design, assemble and operate a ≈ 1 ton Argon detector with independent ionization and scintillation readout. The actual layout of the inner detector is shown in Figure 12. The detector is contained in a cylindrical vessel where the liquid and vapor of the Argon are in equilibrium (at ≈ 1 bar). The ionization electrons are drifted to the liquid-vapor interface and are extracted into the gas phase. In the vapour a Large Electron Multiplier (LEM) is installed to provide the electron amplification by means of a high field generated in small (cylindrically shaped) holes. Finally, photo-detectors are installed outside of the drift region below the cathode. The robustness and longevity of PMTs using test equipment, assisted by a long-standing relationship with ETL, will be tested. Through this association the potential for developing novel large area PMTs capable of operating at low temperature will be assessed. This research will include light collection simulations.

The ArgonTube subtask: One of the fundamental parameter in order to scale the size of a liquid Argon TPC is the maximal possible drift path. The realization of a 5 m long detector column will allow experimental proof of the feasibility of long drift paths. The basic technologies developed in the ArDM subtask will be extrapolated to operate this prototype with very long drift. Different methods of readout based on LEMs, GEMs, Micromegas, and bulk Micromegas will be tested. The latter has been shown to produce excellent gain and resolution, can be prepared by standard photolithographic industrial processes to cover large areas. New ways of measuring Argon purity will be developed. New purity monitors using charge quenching in order to measure the O_2 concentration will be addressed. New materials based on luminescence quenching will be developed. The design and optimization of new slow control systems will be performed. In particular, level-meters based on superconducting materials will be developed.

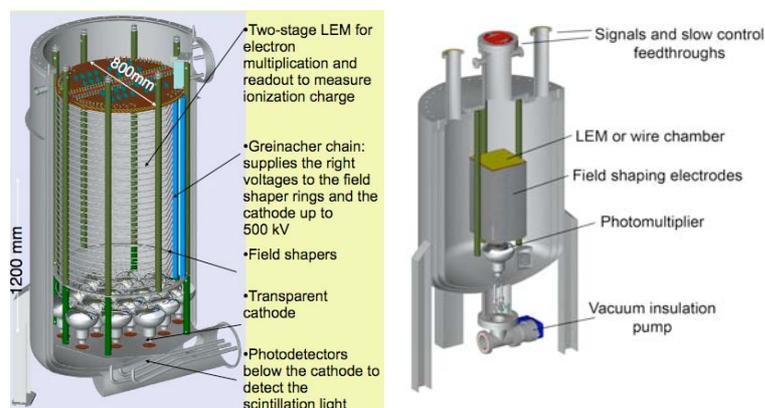


Figure 12 (left) Layout of the 1 ton ArDM prototype (right) Micro-EPiLAR: the prototype for the electron/ π^0 separation test.

The ePiLAR subtask: The liquid Argon TPC imaging should offer optimal conditions to detect electrons in the GeV range, while distinguishing them from misidentified π^0 's. A test-beam setup dedicated to the

reconstruction and separation of electrons from neutral pions will be designed (EPiLAR). The EPiLAR setup will be developed in stages, where the first step will be the prototype Micro-EPiLAR (see Figure 12). The Time Projection Chamber is immersed in liquid Argon inside a vacuum insulated dewar. A system of field shaping electrodes provides a uniform drift electric field between the cathode and the charge collection device on top. As charge collection several different methods will be tested, in order to understand the differences in performance between both readout methods in identifying, separating and reconstructing electrons and π^0 's. At the bottom a photomultiplier will be mounted to collect the scintillation light. The dewar consists of three parts: the inner vessel for the pure liquid Argon, a surrounding liquid Argon bath and a vacuum insulation.

Task 4.6 Final report on progress, state-of-the-art and comparison of the three techniques

At the end of the 36 months, several areas of progress and new results for the different detection techniques are expected. In this final report, the results of the common developments as well as those specific to each technique will be summarized. It will include an assessment of the state of advancement and maturity of each detection technique, asserting, where possible, that each technology has reached a sufficient level of maturity to go into an implementation phase were the decision of construction granted.

1.3.5. WP5 – Safety and environmental issues

The safety and environmental issues for large underground research infrastructures must be tackled from the beginning of the project and taken into account in the DS. This work package will identify both general and specific hazards for the underground sites and will establish associated safety protocols and additional infrastructure to mitigate the risks. The PERT diagram of this WP is shown in Figure 13.

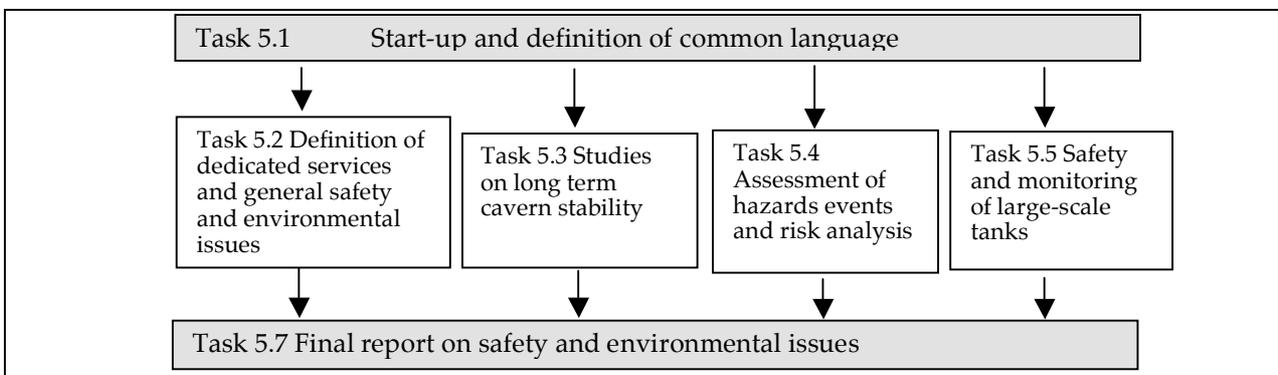


Figure 13 PERT diagram for WP5.

Task 5.1 Start-up and definition of common language

This WP will determine the relevant safety considerations for each experimental site and assess the potential impact on the local environment both due to normal operation of the facility, and as the result of an accident. Studies carried out within this WP will include a description of the underground safety systems, protocols, and training, and will identify site specific requirements from a legal and environmental viewpoint, in accordance with directives from the site hosts. Various safety aspects related to the handling of very large quantities of liquids, at room or at cryogenic temperature, with a particular focus on assessing the necessary legal authorization requirements at each promising site will be studied. In this context, it is important to define the interface and the sharing of responsibilities in terms of safety between the research infrastructure and the host. The host can be either the company owning or running the nearby road tunnel or the company exploiting the mine. In this case the access will have to be operated in “shared” mode and the coordination of the activities of research infrastructure will have to be tightly coordinated. In the case of a dedicated site (e.g. new site at shallow depth) the interface with the local political authorities and security community (fire brigades, ...) will be addressed. For each site and experiment a distinction will be made between internal risks i.e. hazards associated with the running of the experiment, and external risks i.e. hazards connected with the local area such as earthquake, fire, or rock collapse and will identify systems which must be employed to mitigate damage to the workforce, the equipment, the cavern, and the environment in accordance with local law. Definition of the interface between the installation safety and the overall safety strategy of the host including coordination with the host’s safety experts will also be made.

Task 5.2 Definition of dedicated services and general safety and environmental issues

Irrespective of the location of the site, it is vital that the underground environment is suitable for both the needs of the science and personnel. In addition to the main target area, control rooms and ancillary systems, the cavern will feature meeting rooms, kitchens, offices, communication studios, electrical and mechanical workshops, storage facilities, clean rooms and decontamination and wash areas. Surface facilities will include clean rooms, workshops and lab space required to pre-assemble and test equipment prior to transfer underground. The geothermal gradient at each site coupled with the requirements of the

individual experiments will determine the extent of ventilation, air conditioning, air humidity and purification required. The report will detail all site specific requirements and will include a detailed analysis of the local power distribution from the national power grid, through the substation and distribution network, to the local system transformers and switchgear, estimating the power requirements of the laboratory and the requirements this imposes on the cavern supply, the underground power supply system, and the national grid. Irrespective of the location of each experiment, compliance with all applicable environmental regulations is a legal requirement. Included in the proposal for each scientific site will be a detailed appraisal of the local environmental impact, including waste disposal procedures, environmental protection and potential risk due to accidental chemical release. Each report will document specific procedures, administrative controls and review processes required to mitigate each risk and the techniques employed to render any exhaust products released into the atmosphere benign in compliance with local law. The report will detail the consequences to the local transport infrastructure and surrounding communities due to increased commercial road traffic and personnel. It will also identify final decommissioning and decontamination procedures at the conclusion of research. Construction will use recycled materials where possible, all electrical equipment will be selected for the best energy efficiency, and all wood, paper, plastic, and electronic waste will be separated for recycling.

Task 5.3 Studies on long-term cavern stability and assessment of sources of instabilities

The fundamental concern of any underground excavation is the integrity of the cavity. Geologists, rock engineers, and mining experts over many years have created large caverns that have demonstrated excellent long-term stability. Geotechnical advances such as rock creep monitoring, and simulation studies coupled with improvements in machinery and mining techniques, have led to further improvements both in the size of cavern possible, and its longevity. However frequent evaluation must be made of the condition of the rock either by the mining corporation or professional rock engineering contractors.

Task 5.4 Assessment of hazards events and risk analysis

The implications of a serious incident in a LAGUNA site are profound and depending on the severity could result in the closure of all facilities. In many countries it is a legal requirement that all accidents resulting in injury or having the potential to cause harm be reported. In addition to the publication of a document detailing the safety policies and protocols required to ensure safety of LAGUNA staff, general underground personnel, and visitors, health and safety awareness of employees would be improved through continuous laboratory safety appraisals, equipment inspections, training, and courses. The minimum standards would be determined by the individual codes and rules set out by the specific site owners, the local law, and the governmental site inspectorate, and would include appropriate training, safety equipment, emergency procedures, and protocols. Mine sites have different issues compared to tunnel sites with regard to emergency egress, ventilation systems, fires, large volume liquid gas emergencies, production of liquid cryogenics and air quality monitoring. Appraisal of each site will reflect this. A risk management consultant or in some cases mining and safety experts employed on site by the facility owners, will identify potential failures or unexpected incidents and their effect on the project. In addition to leaks, fire, engineering delays and scientific underperformance, these should include discovery of unacceptable rock properties during cavern excavation, major underground rock collapse in either the cavern or the access routes, and closure of the host site should it become economically unviable. Although catastrophic rupture of a liquid or liquid noble gas tank in an underground site is by far the worst-case scenario, the technologies involved in large tank production coupled with many decades of incident free operation belie concern. Throughout the world cryogenic tanks of similar design are operated without problem and have been designed to withstand earthquakes and subsidence. Leaks are far more likely to occur due to thermal expansion of liquid scintillator or during transfer from the storage facility to the main experimental tanks. In this case total liquid containment is essential and the report will detail ancillary equipment, procedures, control systems, and environmental monitors required to achieve this. The report will also investigate commercial solutions for tank monitoring and environmental control such as pumps to circulate noble liquids to avoid stratification – liquid fractionation producing thermoclines within the volume possibly due to pockets of impurities – potentially leading to rapid evolution of gas on turnover. In the event of a total power failure, emergency power would be provided to vital scientific support systems such as liquid scintillator cooling, purification of both liquid scintillator and liquid noble gas, and noble gas boil off compression via diesel generators. These generators would also supply power to life support systems such as emergency lighting, ventilation of toxic gases or smoke and the underground communication network. The report will identify in detail the total power demands for each system and the requirements imposed by the site hosts due to integration of an additional power generating system within the overall local grid. Fibre optic cabling will enable communication and small-scale data transfer, although the report will also include potential upgrades for an improved transfer network, and will detail proposed environmental monitoring and control devices. Each LAGUNA experiment represents a significant investment and, in today's global climate, must be viewed as a potential terrorist target. The report will identify security measures both to limit site access to those approved and qualified and to safeguard the underground systems from attack.

Task 5.5 Safety and monitoring of large-scale tanks

Safety of large systems can benefit greatly if existing and proven solutions are identified and utilized whenever possible. We mention as an example the case for LNG tanks: for over 40 years, WHESOE S.A.¹² has developed instrumentation and safety shut-off valve systems for LNG / LPG storages, ensuring that all hazardous aspects are known and controllable. In close cooperation with leading gas companies, new technologies have been extensively tested for endurance, accuracy and reliability in harsh environments. WHESOE'S Total LNG Storage tank Instrumentation Solution® consists of one single, totally integrated tank instrumentation package and integrated SCADA platforms. All instrumentation such as process level gauges, LTD gauge, in-tank temperature sensing and transmission devices as well as leak detection and cool-down monitoring system are designed and built at their manufacturing facilities. All system components are to be interconnected in a fully redundant communications loop. Information obtained from all tank instrumentation is displayed, using clear and concise displays, at the control system. WHESOE is the only company worldwide, supplying a single source, total LNG storage tank instrumentation complete with LNG MASTER® Stratification and roll-over predictive software¹³.

Task 5.6 Final report on safety and environmental issues

The report, subject to commercial confidentiality where appropriate, will include an assessment of site specific power requirements such as the installation of additional transformers for air conditioning, ventilation, atmospheric purification, pumping and chiller systems, underground workshops, surface buildings, experimental areas, cranes and associated heavy duty equipment required during construction. It will identify alternative ventilation and cooling schemes for tailored cooling of sensitive components such as the heat exchange on compressors. It will assess the redundancy amongst vital components such as the cooling and purification systems of LENA and the boil off compressors for GLACIER. Although it is envisaged that the ventilation system for the majority of sites will allow air to pass directly from the experimental areas into the general underground site, the report will also outline options to redirect the air flow in the event of a toxic release or fire through a secondary ventilation pipe directly to the surface, thereby limiting contamination of the site and ensuring safe egress of personnel. The report will outline the requisite skills and qualifications for all personnel and will detail the mandatory safety requirements at each site including the local building fire protection codes for fire prevention and containment, noise control, and electrical safety. The report will identify safety considerations specific to each proposed site in addition to emergency response equipment, air monitoring, and egress procedures, such as hazardous material handling, dedicated ventilation piping for the removal of boil off noble gas, cryogenic coolants, and toxic scintillator vapour, and containment systems for scintillator and liquid noble gas spillages. It will detail an emergency management plan, fire containment procedures and evacuation route. It will identify training required for the underground rescue and emergency response teams relevant to the specific experimental target material, and will detail the steps required to contain and dispose of hazardous laboratory materials, and subsequent decontamination in accordance with local law. It will consider the possible failure modes for each experiment, making an assessment of the severity of each, the potential costs involved, and ways in which each can be mitigated.

1.3.6. WP6 – Science Impact and Outreach

This WP will explore different detector technologies and different underground laboratory sites in order to identify the best strategy for future large-scale detectors. Its PERT diagram is shown in Figure 14.

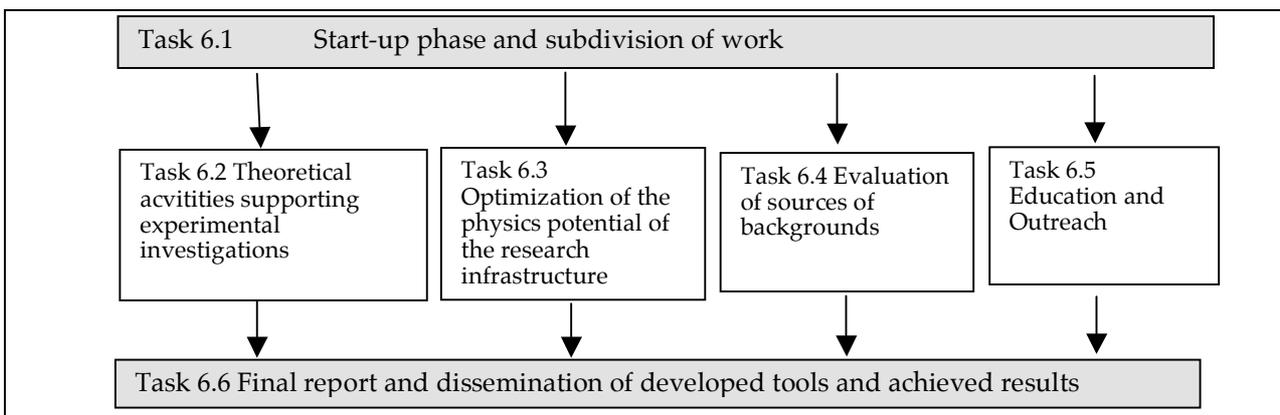


Figure 14 PERT diagram for WP6.

¹² Whessoe S.A. - 135, Rue de Bitche - 62100 Calais Tél.: +33 (0)3 21 96 49 93 - Fax : +33 (0)3 21 34 36 12 - contact@whessoe.fr

¹³ LNG MASTER® is developed and owned by Gaz de France.

Task 6.1 Start-up phase and subdivision of work

Groups working each on one type of detector have already done preliminary work. Therefore, it is important to collect all the existing programs and results of simulations. By comparing, analysing and extending them, a common strategy for the evaluation of the different sites and detectors will be reached. A common framework and common software will be agreed upon. Theorists and experimentalists will collaborate in order to find the best physics generators, detector geometry descriptions, analysis tools etc. Close collaboration between groups from various countries and groups working on different detectors will be established in order to avoid unnecessary duplication of work as well as leaving important problems uncovered. This collaboration will lead to the creation of common WEB pages and of an easily accessible software repository. Frequent contacts will be based on teleconferences.

Task 6.2 Theoretical activities supporting experimental investigations

The main focus of the LAGUNA proposal is to investigate the best strategy for a large underground detector, aiming at measuring proton decay and a rich neutrino physics program. Proton decay is a process of fundamental importance for an understanding of the basic laws of particle physics, which has so far eluded detection. The most promising channel for proton decay depends on expectations from a larger theoretical picture. These expectations evolve due to new theoretical insights as well as due to experiments, which will be carried out in future years. Theoretical expertise is therefore included in this task, in order to study the most promising decay channels, lifetimes and the corresponding search strategies. In the same way, theoretical expertise is needed in order to optimally connect the R&D being done towards a large underground detector with theoretical expectations and new insights from other experiments. Examples how theory may play an important role in this project is given by new results from lepton flavour violation (LFV) experiments and from LHC. New LFV experiments should see a signal in the years to come and the type of signal has profound consequences for the flavour structure of physics beyond the Standard Model. In the same way, LHC-experiments may or may not find supersymmetry, which has immediate consequences for the expected lifetimes, decay channels and search strategies for proton decay.

Task 6.3 Optimization of the physics potential of the LAGUNA research infrastructure based on detailed detector simulations

In order to optimise the performance of the experiments their behaviour must be simulated. It would be preferable to have one common toolbox that could be used to simulate all considered experiments and the physics to be studied with them. This would allow comparison on equal footing. The toolbox can be made applicable to other experiments studying similar phenomena. Moreover, these simulations allow for studies of combinations of different measurements and to develop an approach for the most synergistic use of the proposed large-scale facilities. The simulation tools will contain the essential physics:

- Modelling of the sources (solar and supernova neutrinos, supernova relic neutrinos, geo-neutrinos, neutrinos from beams or reactors).
- The propagation of neutrinos to the detector - This includes modelling of matter effects in the propagation of neutrinos through the Earth.
- Properties of the detector.

Incorporating other relevant experimental information is important for LAGUNA. Data from a wide variety of other probes will be included, ranging from accelerator data, data from dark matter and neutrinoless double beta decay experiments to absolute neutrino mass measurements from experiments such as KATRIN and cosmological probes. A common framework for detector simulations will be set-up. The detailed simulation of the response of the three types of detectors, including accurate description of geometry and materials, details on light propagation and detection will be developed. This simulation will be the basis for evaluating the impact of backgrounds, for optimising the detector design and for evaluating the reach of the project in the different physics channels. Another activity will concern developing the analysis tools for the extraction of (or the determination of the limit on) the measured parameters. As a result, we will decide which approaches are the most efficient for the suppression of backgrounds, thus enhancing the sensitivity of the three experiments. In these dedicated studies we aim at improving the discovery potential of all three experiments quoted in our reference document¹⁴.

Task 6.4 Evaluation of sources of backgrounds: cosmogenics and natural radioactivity

Knowing and reducing the background is fundamental for experiments studying rare phenomena. The purpose of this task is to evaluate more exactly the relevant backgrounds for the experiments in the considered sites, and also to define the minimum tolerable background rates. Methods to reduce the backgrounds will be studied and recommendations for the depth and site selection will be given. The cosmogenic background is due to secondary particles produced by cosmic rays deeply penetrating underground. It depends on the amount and chemical composition of the material above the cavern and on the location of the laboratory (under a mountain or under flat land). The natural radioactivity depends on the chemical and isotopic composition of the rocks around the cavern. The data for the existing laboratory

¹⁴ J. Aysto *et al.*, arXiv:0705.0116v1 [hep-ph].

caverns are available. For each projected LAGUNA cavern both backgrounds must be evaluated. The results will be used as input for the simulations of the physics performance of the detectors if located in this cavern. The cosmogenic background will be calculated. In the case of caverns inside mountains, the mountain shape must be simulated in order to correctly evaluate the directional dependence of the background. The evaluation of the local background due to natural radioactivity must be based on measurements. Two types of measurements are foreseen: α - and γ -spectrometric measurements of the rock probes performed in the specialized laboratories of the institutes involved in the LAGUNA project and in-situ measurements of the total radioactivity level as well as of the radon content in the cavern's air. In both cases the same methodology and software should be applied everywhere in order to make a fair comparison of all sites. There are some aspects specific to a given type of detector. For example, in the case of Liquid Argon a flow of warm air could be required to avoid the freezing of the surrounding rocks and that would mean a higher level of radon around the detector.

Task 6.5 Education and Outreach

In the LAGUNA project, all the European leading experts on underground laboratories are involved. The interdisciplinary character and non-standard problems of this research create unique opportunities for teaching and outreach. Students of physics, astrophysics, geology, civil engineering, geo-mechanics and hydrology can mix, make first class research in their field and learn much about the other fields. An important aspect is attracting good students to scientific careers. The goals for outreach are:

- A document for the general public explaining all the aspects of underground science and its achievements and prospects in Europe.
- A public web site popularising the research done in the framework of LAGUNA.
- Hands-on displays related to underground science.
- Advertising the LAGUNA project during the "open doors" days of the participating institutions.
- Popularising LAGUNA via the European newspapers, radio and TV.
- Contacts with local communities and, in the case of mines, with the mine personnel.

In addition, specific actions at particular sites will be considered: for example, at Boulby the idea to build on this foundation by carrying out a viability and funding study for a dedicated surface building featuring a visitors centre illustrating underground science and mining, a video conferencing studio, scientific workshops and conference rooms suitable for public lectures was proposed. One would investigate potential sources of funding from the local education authority, through local and national government grants, the tourist board, and CPL. In addition one would evaluate the use of internet education technologies such as interactive online study courses, and the value of recruiting summer students. Finally, meeting with senior scientists from earth sciences, engineering, and geological disciplines would be organized. The developments of links with, and the formulation of letters of intent from potential collaborators in the fields of bio-science, geo-physics, environmental sciences, geo-chemistry, and microbiology to study for example microbial evolution, population, and diversity could be considered. In addition one would foster links with geological and engineering groups to identify potential research topics such as the interaction of mechanical, thermal, chemical, and hydrological processes on the nature of underground rock, and would investigate the potential for long-term studies using novel geophysical imaging technologies to measure pressure and stress changes, and hence the long-term stability of large cavern excavations.

Task 6.6 Final report and dissemination of developed tools and achieved results

The main result contained in the final report will be the evaluation of the potential for doing physics at all the proposed European underground sites with the basic detector types. It is important that these results will be ready around year 2010, when in particular experiments at LHC are likely to have produced much interesting information, which will serve as input to our estimates. The dissemination of the tools developed in our work will be of great interest to particle physicists and astrophysicists. Our open access software will include: an extension of the GLOBES program for the simulation of the oscillations of non-accelerator neutrinos, an improved theoretical description of the secondary particle interactions in nuclei, and programs for global physics simulations in underground laboratories. This kind of contributions will be disseminated by publications and by reports at conferences. For the general public a popular paper will be prepared, where the many fascinating aspects of underground physics will be described. Owing to our results we will be able to give a unified, bird eye view on the subject.

GANTT chart of the LAGUNA DS

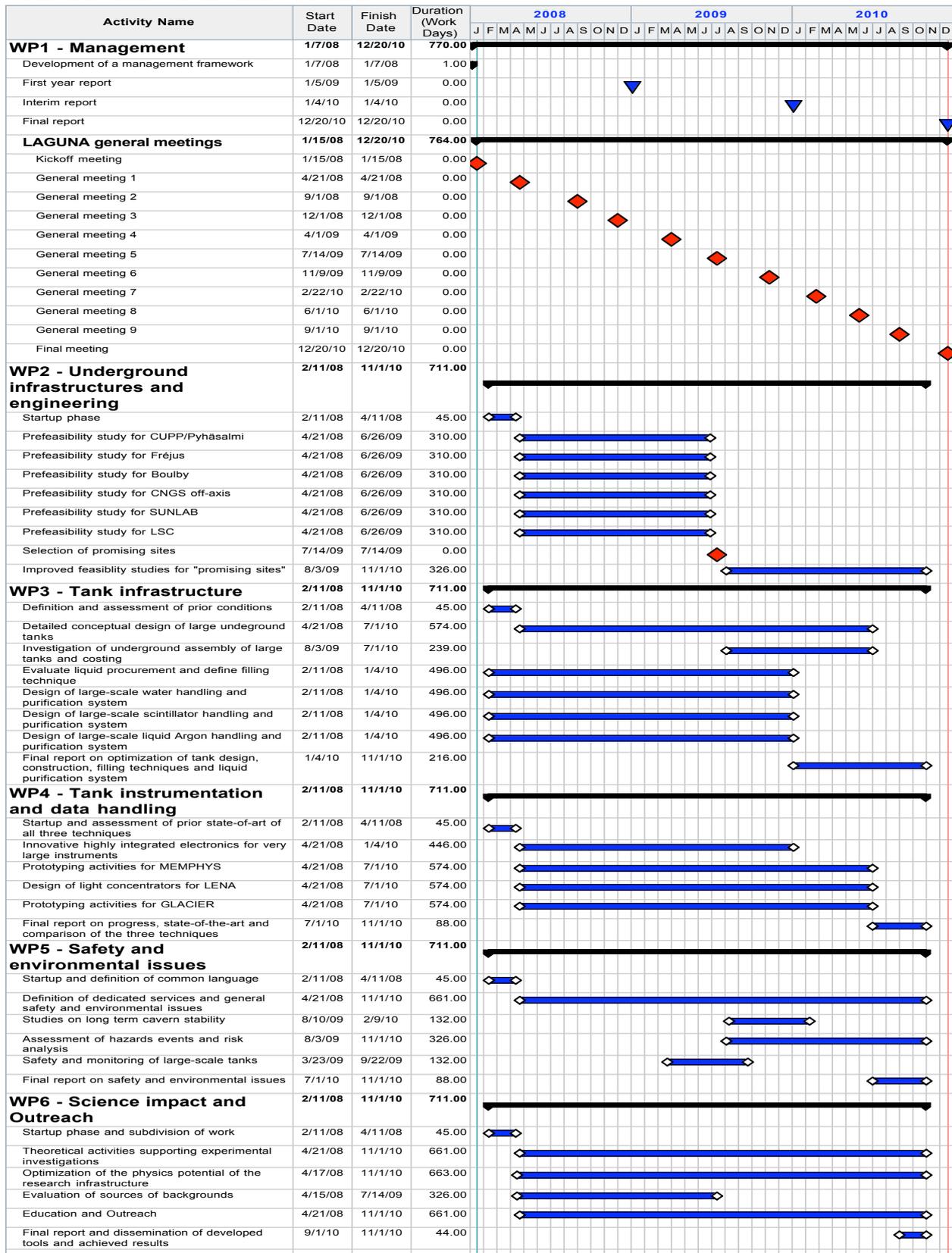


Table 1.3 a: Work package list

Work package no.	Work package title	Type of activity	Lead participant no.	Person-months	Start month	End month
WP1	Management, coordination and assessment	MGT	ETHZ	52	1	36
WP2	Underground Infrastructures and Engineering	RTD	U-Oulu	221	1	35
WP3	Tank Infrastructure and Liquid Handling	RTD	TUM	249	1	35
WP4	Tank Instrumentation and Data Handling	RTD	IN2P3	439	1	35
WP5	Safety and environmental issues	RTD	U-Sheffield	65	1	35
WP6	Science Impact and Outreach	RTD	IFJ PAN	454	1	35
	TOTAL			1480		

Table 1.3 b: Deliverables list

Del. No.	Deliverable Name	WP No	Nature (Report, Prototype, Demonstrator, Other)	Dissemination Level (Public, PP, RE, CO)	Delivery date (month)
1.1	First year report	1	Report	Public	12
1.2	Interim report	1	Report	Public	24
1.3	Final report	1	Report	Public	36
2.1	Interim reports for each site	2	Report	Public	18
2.2	Final report for "promising" sites	2	Report	Public	35
3.1	Optimal tank design report	3	Report	Public	18
3.2	Liquid report	3	Report	Public	24
3.3	Final report on site specific tank design	3	Report	Public	35
4.1	Target common specification agreement	4	Report	Public	6
4.2	Microelectronic technology report	4	Report	Public	24
4.3	Final report on tank instrumentation	4	Report	Public	35
5.1	Site specific safety overview report	5	Report	Public	18
5.2	Final report on safety for selected site/experiments	5	Report	Public	35
6.1	Optimal site simulation report	6	Report	Public	6-18
6.2	Background report	6	Report	Public	18
6.3	Simulation toolpack	6	Report	Public	35
6.4	Deep science paper	6	Report	Public	35

Table 1.3 c: Work package description**Description of Work package:**

Work package number	1	Starting date or starting event:	Contract start date
Work package title:	Management, coordination and assessment		
Activity type:	MGT		
Participants number:	1	All participants leading a WP will devote 2 person x months, while all other participants will devote 1 person x month.	
Person months per participant:	22		
Objectives: Coordinate the contractual, financial and administrative aspects of the Design Study and oversee the technical and scientific work of the other work packages. Ensure that the project milestones are achieved and the deliverables produced on time. Take care of the knowledge management for the Design Study, coordinating the protection, use and dissemination of the knowledge generated during the project.			
Description of work (possibly broken down in tasks), and role of participants: <ul style="list-style-type: none"> • Coordination task: coordination of the contractual, financial and administrative aspects of the Design Study, including delivery of annual reports and control of the funds. • Oversight task: oversight of the technical and scientific aspects of the Design Study, including the monitoring of milestones and ensuring that deliverables are produced on time. • Knowledge task: management of the knowledge generated by the Design Study, including its protection, use and dissemination. • Promote international contacts with North America and Asia. Develop outreach activities in Europe. 			
Deliverables (brief description and month of delivery): <ul style="list-style-type: none"> • Report of 1st year activities in month 12, summarizing the work done by all the WPs and comparing progress against milestones and deliverables. • Interim report in month 24. • Final report, submitted in month 36, describing the achievements of the Design Study, including CDR for the facility, checking that all deliverables have been delivered. The report includes: (a) comparison chart of all sites and experiments considered (b) recommendation of the feasibility of each experiment on the sites (c) cost predictions (d) preliminary plans for the cavities and supporting underground infrastructures (e) drawings. 			

Description of Work package:

Work package number	2	Starting date or starting event:												1	
Work package title:	Underground infrastructures and engineering														
Activity type:	RTD														
Participant number:	1	2	3	4	5	6	7	11	15	16	17	20	21	23	24
Person months per participant:	15	5	4	10	30	12	5	3	50	28	12	18	5	12	12
Objectives:															
<ul style="list-style-type: none"> • To assess the feasibility of large underground caverns in six potential European sites to host large volume detectors of each kind. • To find the optimal shape and size for the caverns. • To provide the technical information, including cost estimates, needed for potential construction decision and site selection. 															
Description of work:															
<p>The technical issues of the construction of large-scale underground cavities are studied. The studies include general geological studies of the sites, preliminary designs for the cavities, simulations of rock mechanics, analyses of local rocks, planning of the cavity construction and cost optimisation. This WP consists of the following tasks:</p> <ul style="list-style-type: none"> ○ Start up by defining the common basis so that all studies are comparable. ○ Prefeasibility studies made separately but coherently for each site, sharing data and experiences. ○ Selection of promising sites ○ More thorough feasibility studies for the promising sites, including rock sampling. <p>The selection processes narrowing the scope form the major milestones of the work. For each site there is a scientific partner and a technical partner. The technical partner (an engineering company) will do the technical studies and designs, while the scientific partner sets the goals and acts as a link between the technical partner and the scientific collaborators. All sites need their own partners that know well the local conditions.</p>															
Deliverables (brief description and month of delivery):															
<ul style="list-style-type: none"> • Interim reports for each site will be delivered within the first 18 months. They are to be used by the consortium to decide on which alternatives to concentrate further efforts. • The main deliverable is a final conceptual design report in month 35 on the feasibility of constructing large-scale underground cavities in the “promising” locations (CDR). The report includes: (a) comparison chart of all sites and experiments considered (b) recommendation of the feasibility of each experiment on the sites (c) cost predictions (at 20-25 % accuracy) for underground construction (d) preliminary plans for the cavities and supporting underground infrastructures (e) visual outline drawings. 															

Description of Work package:

Work package number	3	Starting date or starting event:					1
Work package title:	Tank infrastructure and liquid handling						
Activity type:	RTD						
Participant number:	1	2	7	8	9	20	21
Person months per participant:	36	20	24	24	60	24	61
Objectives:							
<ul style="list-style-type: none"> To establish the feasibility of the underground tanks to store each target liquid To elaborate the detailed conceptual design of the tanks, including their inner structure, the support structures, the materials, the insulation, ... To investigate the underground assembly of the tanks, by assessing construction strategies as a function of underground access methods of the "promising" sites of WP2 To cost the underground construction of the tanks, and estimate the time of realization To evaluate the methods of the procurement of large quantities of each target liquid in the "promising" sites of WP2 and the cost associated to the in-situ procurement of a given quantity of each target liquid To define filling techniques maintaining the specifications during the process (purity, radiopurity, optical properties, ...) To design large scale purification systems for each target liquid to reach the required level of purity needed for the scientific operation, and to define methods of large-scale continuous purification (recirculation) to maintain purity in the liquids 							
Description of work (possibly broken down in tasks), and role of participants:							
<ul style="list-style-type: none"> The detailed design of the under-ground tanks will be developed for each target liquid, using as a starting point the specifications for large volume above-ground tank EUROCODES 3 (Part 4-2, BS EN 1993-4-2 Silos, tanks and pipelines – Tanks) The design engineering will include static and seismic analysis of the tanks for the "promising" sites in WP2 Regular meetings among senior physicists, industry and specialized engineers will be held in order to address the implications of the design choices to the science, and to balance the benefits to engineering aspects against the impact they may have on the physics The investigation of an underground assembly will be performed via partnership and/or subcontracting to specialized industries and with contact and/or partnership with companies exploiting mines or road tunnels The procurement of the cryogenic liquids will be performed via contacts with leading European companies in the market. The study will involve estimation of costs and transport methods. The designs of liquid purification systems will be defined by extrapolation to large volumes of existing methods developed by the 							

involved scientific institutes for each target liquid.

Deliverables (brief description and month of delivery):

- Identification of optimal geometry, technical specification, and construction method for each storage vessel, for each project, in each site to be delivered by month 18 and to form part of the selection procedure for most promising sites.
- Evaluation of liquid procurement, purification and handling. This report will be produced in month 24.
- A final report in month 35, detailing the viability of constructing underground tanks containing large liquid volumes for each liquid target, including: (a) an underground site specific detailed design of detector and storage tanks including ancillary safety vessels and support structures, (b) materials used and thermal load calculations, and (c) site specific construction strategy and costs.

Description of Work package:

Work package number	4	Starting date or starting event:											1	
Work package title:	Tank instrumentation and data handling													
Activity type:	RTD													
Participant number:	1	2	6	7	8	9	10	11	12	13	18	20	22	
Person months per participant:	108	20	24	78	36	60	12	16	23	8	30	14	10	
<p>Objectives: To establish design of large scale and low cost solutions for tank instrumentation, in particular:</p> <ul style="list-style-type: none"> • Design of light readout schemes for optimum light collection and cost in large volume liquid detectors for room and cryogenic temperatures • Design of charge readout schemes for optimum charge collection and cost in large volume for liquid Argon detectors • Large scale high voltage creation and distribution • Large number of channels readout electronics and interface to data acquisition and storage • Methods of calibration (amplitude and time), distribution of time synchronization for systems with large number of components distributed over large systems • Systems for distributed slow control; R&D on new slow control sensors • Mechanical supporting structures • Methods of accessing and if necessary replacing (part of) instrumentation • Find the parts where a common technical solution for all three liquids can be adopted 														
<p>Description of work (possibly broken down in tasks), and role of participants:</p> <ul style="list-style-type: none"> • Evaluation and optimization of best elements (best photo-detectors, best charge readout, ...) • Solutions for large area devices • Assess necessity and if applicable mass production of light concentrators • Reach of industrial solutions for mass production • Proposals for distributed data acquisition, slow control, calibration and time distribution • Assessment of failure rates and aging effects 														
<p>Deliverables (brief description and month of delivery):</p> <ul style="list-style-type: none"> • Based on effective management through communication and cross-fertilization of ideas, a report will be produced for each project in month 6, defining the common specifications of each target. • A report will detail, in month 24, the scope and performance of microelectronic technologies, specifically their amplification and signal processing capabilities both for charge and light readout applications in LAGUNA targets. • In month 35, as part of the final Design Study, based on the significant past experience of the collaborators, prototype vessels, and targeted experimental research, an assessment will be made of the maturity of each detection technique and its appropriateness for implementation. 														

Description of Work package:

Work package number	5	Starting date or starting event:								1
Work package title:	Safety and environmental issues									
Activity type:	RTD									
Participant number:	1	3	4	5	6	15	17	20	21	
Person months per participant:	15	2	4	5	5	14	5	10	5	
Objectives:										
<ul style="list-style-type: none"> Identify potential safety and environmental risks for each target liquid Assess legal authorization requirements for each target liquid at each “promising” site Define interface and the sharing of responsibilities in terms of safety between the research infrastructure and the host (road tunnel or mine) 										
Description of work (possibly broken down in tasks), and role of participants:										
<ul style="list-style-type: none"> Investigate commercial solution for monitoring of large scale tanks and assess their applicability to each target liquid Define and design needed services (ventilation system, electrical power requirements, liquid spill containment infrastructure, radon filter, etc...) Subcontract studies of risk analysis with safety experts 										
Deliverables (brief description and month of delivery):										
<ul style="list-style-type: none"> In month 18, and as part of the selection procedure for most promising sites, a report will be produced from each underground site in which the pertinent safety considerations are addressed. In addition to generic factors such as an appraisal of the underground safety protocols and the safety and support infrastructure, the document will detail regional environmental issues, transportation infrastructure and relevant local laws. Finally the report will identify key safety considerations specific to the type of detector which might be located at each site. The final Design Study in month 35 will define all safety and environmental issues of selected sites, and will include the additional infrastructure required for safe operation, in conjunction with the overall safety strategy of the host (road tunnel or mine). This will include the possible failure modes of each experiment, methods by which this risk can be mitigated, and a risk analysis for each site. 										

Description of Work package:

Work package number	6	Starting date or starting event:														1
Work package title:	Science Impact and Outreach															
Activity type:	RTD															
Participant number	1	2	3	4	6	7	8	9	11	12	13	14	18	19	20	23
Person months per participant:	36	36	12	4	10	36	45	58	47	26	28	30	30	36	8	12
<p>Objectives:</p> <ul style="list-style-type: none"> • Physics potential of the infrastructure including a mix of three technologies • Detector design optimization (modularity, coverage) via detailed simulations • Cosmogenic and local background studies • Multi-disciplinary and assessment of “other” sciences (biophysics, geophysics, geo-engineering) • External and subjective input for site selection 																
<p>Description of work (possibly broken down in tasks), and role of participants:</p> <ul style="list-style-type: none"> • Prepare the tools in order to have a common approach • Detailed detector response simulations (e.g. MC simulations of light propagation and detection) • Physics reach simulations and parameters fitting 																
<p>Deliverables (brief description and month of delivery):</p> <ul style="list-style-type: none"> • As part of the process for underground site selection, and where possible to provide guidance in the excavation of new cavities for WP2, a report will be produced between months 6 and 18 defining the minimal requirements and most favourable design parameters of each experiment, identifying the optimal depth, size and shape of caverns required. • As part of the selection procedure for the most promising sites, to be completed by month 18, an evaluation report will be produced detailing the relevant backgrounds in different sites. • Through effective communication, a common simulation toolpack for non-accelerator physics will be produced by month 35. • As part of the outreach programme, “Deep Science” a popular science paper will be produced in month 35. 																

Table 1.3 d: Summary of staff effort

Participant no./shortname	WP1	WP2	WP3	WP4	WP5	WP6	Total person months
1. ETHZ	22	15	36	108	15	36	232
2. U-Bern	2	5	20	20		36	83
3. U-Jyväskylä	1	4			2	12	19
4. U-Oulu	2	10			4	4	20
5. Rockplan	1	30			5		36
6. CEA	1	12		24	5	10	52
7. IN2P3	2	5	24	78		36	145
8. MPG	1		24	36		45	106
9. TUM	2	0	60	60	0	58	180
10. U-Hamburg	1			12			13
11. IFJ PAN	2	3	0	16	0	47	68
12. IPJ	1	0	0	23	0	26	50
13. US	1	0	0	8	0	28	37
14. UW _r	1	0	0	0	0	30	31
15. KGHM CUPRUM	1	50	0	0	14	0	65
16. IGSMiE PAN	1	28	0	0	0	0	29
17. LSC	1	12			5		18
18. UGR	1	0	0	30	0	30	61
19. UDUR	1					36	37
20. U-Sheffield	2	18	24	14	10	8	76
21. Technodyne	1	5	61		5		72
22. ETL	2			10			12
23. U-Aarhus	1	12				12	25
24. AGT	1	12				0	13
Total	52	221	249	439	65	454	1480

Table 1.3 e: List of milestones

Milestone Number	Milestone Name	WPs involved	Due date	Means of verification
1.1	Establish management	1	4	Collaboration meeting
1.2	First year report	1	12	First year report released
1.3	Interim report	1	24	Interim report is released
1.4	Final report	1	36	Final report is submitted
2.1 (a-f)	Feasibility study for all sites	2,3,4,5,6	18	An interim report on the feasibility of all cavities enabling selection of most promising sites
2.2	Selection of site/experiment combinations	2,3,4,5,6	35	Final report on most promising sites and their potential to house LAGUNA experiments
3.1	Optimal design of containment vessels for each experiment	3	18	An interim study on the technical specifications and requirements is released.
3.2 (a-c)	Liquid procurement and handling for each target	3	24	A report for each target on the procurement and filling of each target liquid
3.3 (a-c)	Liquid purification techniques for each target	3,4	24	A report for each target on the purification techniques required
3.4	Tank shape, design and construction	3,4,5	35	As part of the final report, the site and experiment specific tank and infrastructure is shown
4.1	Base-line concept document	4	6	Collaboration meeting to outline key design parameters in each experiment
4.2	Microelectronic technology report	4	24	A document outlining novel readout hardware for LAGUNA detectors
4.3	Detector technology report	4	35	As part of final report the maturity of each technique is outlined
5.1 (a-f)	Site specific safety protocols	2,5	18	An interim report on the underground safety and support infrastructure
5.2 (a-f)	Site specific environmental and legal factors	5	18	An interim report on the legal and regional considerations
5.3 (a-f)	Site specific risk assessment	5	18	A document defining possible failure modes
5.4 (a-c)	Detector specific safety and risk mitigation	3,4,5	18	A report detailing hazards associated with each experiment and associated monitoring infrastructure
6.1	Site simulations	2,6	6	Report identifying through simulations, optimal depth, size and shape of caverns
6.2	Background measurement	6	18	Report detailing background contributions at each site
6.3	Toolpack	6	35	Publish details of common simulations toolpack

2. Implementation

2.1. Management structure and procedures

The structure of the DS foresees in addition to the coordinator and the deputy coordinator, the existence of the governing board (GB) and a joint secretariat (JS). Their tasks are defined below:

The **coordinator** is responsible for the overall legal, contractual, ethical, financial and administrative management of the consortium, the co-ordination of knowledge management and other innovation-related activities, overseeing the promotion of gender equality in the project and overseeing science and society issues related to the research activities conducted within the project. He will ensure general liaison between the contractors and the Commission. He will submit financial statements, will receive in trust for the consortium all payments from the Commission and will distribute them among the contractors according to their decisions. He will represent the Design Study to the public and especially to partner councils inside and outside the EU not yet participating in the network. He will be accountable for keeping all contract commitments, for submitting all reports and financial records required from the Commission, for overlooking the joint secretariat, for supervising the implementation of the decisions of the Governing Board. The deputy coordinator whose main task is the scientific secretariat of the GB assists him.

The coordinator is Prof. André Rubbia. The deputy will be nominated during the first month of the DS.

The **governing board** (GB) comprises 1 representative from each LAGUNA participant. It is responsible for all management decisions of the network and for the approval of all documents results and approaches related to the LAGUNA activities. It has overall responsibility for monitoring the work performed, reviewing the objectives and progress achieved towards sustained co-operation and the specific objectives set and discussing corrective actions where necessary. The GB also has a general responsibility for the dissemination of information. Decisions are taken when more than 2/3 of the members are present or have proposed a proxy, by simple majority. It will meet at least once per year.

- The members of the Governing Board are: A. Rubbia (ETHZ), A. Ereditato (U-Bern), J. Maalampi (U-Jyväskylä), J. Peltoniemi (U-Oulu), J. Salmelainen (Rockplan), L. Mosca (CEA), T. Patzak (IN2P3), M. Lindner (MPG), F. von Feilitzsch (TUM), C. Hagner (U-Hamburg), A. Zalewska (IFJ PAN), E. Rondio (IPJ), J. Kisiel (US), J. Sobczyk (UWr), W. Pytel (KHGM CUPRUM), K. Slizowski (IGSMiE), tbd¹⁵ (LSC), A. Bueno (U-Granada), S. Pascoli (U-Durham), N. Spooner (U-Sheffield), J. Thompson (Technodyne), A. Cormack (ETL), H. Fynbo (U-Aarhus) and M. Temussi (AGT Ingegneria).

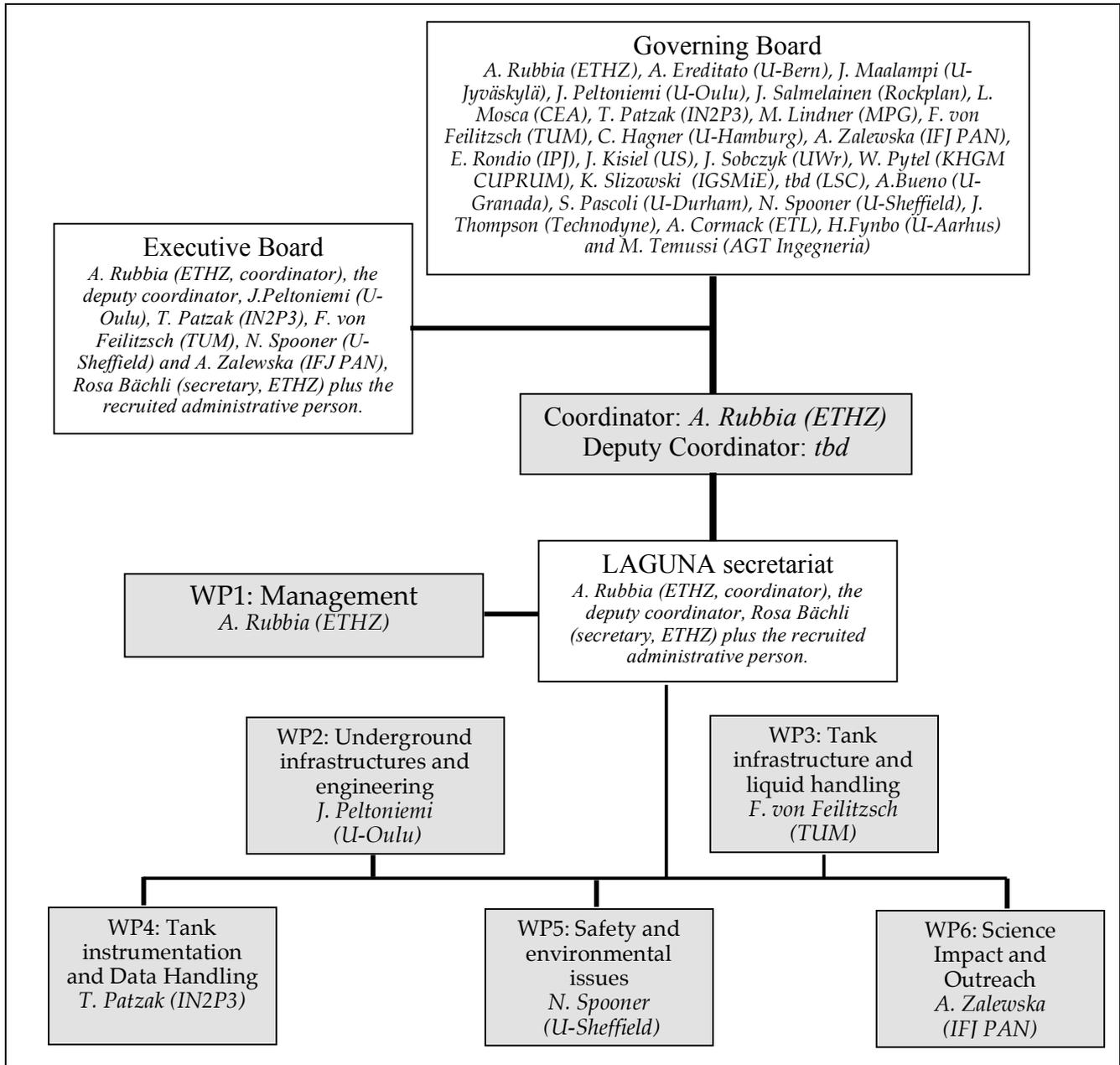
The **executive board** (EB) assures the day-to-day follow-up of the program and it is formed by the coordinators, the 6 workpackage leaders plus the administration responsible members. It will be responsible for the co-ordination and harmonization of all LAGUNA actions and particularly for the administrative and co-operative support of all transnational research activities. It will follow up all important horizontal issues and will prepare the GB meetings of the LAGUNA consortium. It will also be responsible for public relation issues and for the contents of the LAGUNA website. It will meet every two months, and decisions will be taken on a unanimity basis. On exceptional cases differences may be resolved by qualified majority rule (2/3 of the members) or can be directed to an exceptional GB meeting.

- The members of the Executive Board are: A. Rubbia (ETHZ, coordinator), the deputy coordinator, J. Peltoniemi (U-Oulu), T. Patzak (IN2P3), F. von Feilitzsch (TUM), N. Spooner (U-Sheffield) and A. Zalewska (IFJ PAN), Rosa Bächli (secretary, ETHZ) plus the recruited administrative person.

The **LAGUNA Secretariat** assures the day-to-day follow-up of the programme and it is formed by the coordinator and its deputy, the administration plus invited members of the LAGUNA consortium, like for example the leaders of the workpackage, depending on the session. The close interaction of the consortium partners in the joint secretariat belonging to different national institutes will improve coordination and internal quality control, but will most notably increase the acceptance and transparency within the LAGUNA consortium. All relevant quality control information within the six work packages will be collected within the project management. The division of labour between the partners is explained in the Workpackage description. The joint secretariat will be responsible for the coordination and harmonisation of all LAGUNA actions (electronic communication tools, ...), and particularly for the administrative and cooperative support of all transnational research activities. The joint secretariat will keep contact with all participants of the consortium. It will follow all important horizontal issues and will prepare the meetings of the LAGUNA consortium: the Governing Board, and the LAGUNA general meetings. It will also be responsible for public relation issues and for the contents of the LAGUNA website. The GB and LAGUNA meetings of the joint secretariat will be held at the different capitals of the countries participating in the network. Each major meeting will be accompanied by a joint secretariat meeting, while independent meetings will also be organized.

¹⁵ The LSC member of the GB will have been defined by the startup of the DS.

- The members of the LAGUNA Secretariat are: A. Rubbia (ETHZ, coordinator), the deputy coordinator, Rosa Bächli (secretary, ETHZ) plus the recruited administrative person. When necessary, WP coordinators will be asked to joint for particular meetings.



2.2. Individual participants**ETH Zürich – Swiss Federal Institute of Technology Zurich, Physics Department**

The ETH Zurich, often called Swiss Federal Institute of Technology, is a science and technology university in the city of Zurich, Switzerland. Its full name is Eidgenössische Technische Hochschule Zürich, with ETHZ also being a common unofficial abbreviation. The ETH is an internationally oriented university. It is a member of the IDEA League and the International Alliance of Research Universities IARU.

The Institute for Particle Physics (IPP) belongs to the Physics Department. The Institute's main research projects address fundamental questions in the following three research fields:

(1) experiments at the frontier of high-energy interactions between fundamental particles, (2) experiments in neutrino physics and 3) experiments in Astroparticle Physics.

The group has played or is playing significant roles in the following experiments: NOMAD experiment at CERN,

ETH-Transfer and Euresearch will help with the administrative tasks.

Profile of staff members who will be undertaking the work:

- Prof. Dr. A. Rubbia, head of the institute of particle physics, group leader, leading the ArDM and GLACIER R&D efforts. Chairman of CHIPP (Swiss Institute for Particle Physics. Elected member of the T2K executive board. Attended CERN course of management. Experimental high-energy particle and astro-particle physics, Search for neutrino flavor oscillations, Search for proton/neutron decay, Physics with positron/positronium, Detector R&D, Direct search for dark matter in the Universe, Phenomenology, Physics computing. Present and past international research projects: NA61, T2K, OPERA, ArDM, ICARUS, NOMAD, L3.
- Tit. Prof. Dr. W. Fetscher, faculty member, neutrino physics, precision measurements
- Tit. Prof. Dr. J. Ulbricht, faculty member, detector development, large systems, cryogenic and mechanical projects, liaison with industry and subcontractors
- Dr. A. Badertscher, senior researcher, detector construction, liquid Argon TPC detectors
- Dr. M. Laffranchi, PostDoc researcher, detector design and assembly, liquid Argon TPC detectors
- Dr. A. Marchionni, PostDoc researcher, neutrino beams and neutrino physics, expertise in detectors and accelerators, detector development, liquid Argon TPC detectors, electronic and readout systems
- Dr. A. Mereaglia, PostDoc researcher, computing, detector and physics simulation
- L. Kaufmann, PhD student, computing, numerical calculations, detector data analysis
- P. Otiougova, PhD student, detector development, liquid Argon TPC detectors
- T. Strauss, PhD student, neutrino physics, liquid Argon TPC detectors, high Tc superconductors, software
- L. Knecht, mechanical technician, elaboration of mechanical parts, contact with industry and local workshops
- G. Natterer, electrical engineer, analog design and assembly, simulation
- W. Bachmann, mechanical engineer, design, finite element analysis, elaboration of drawings, contact with mechanical technicians and workshop
- T. Viant, software engineer, computing, data acquisition systems, databases, cluster management
- R. Bächli, group secretary, elaboration of contracts, meeting organization, mail

[U-Bern] University of Bern, Laboratory for High Energy Physics (LHEP)

The University of Bern is one of the most important Swiss Universities. Already in 1528 it was structured as a "Hohe Schule". Today there are about 20000 students subdivided in 8 faculties: Theology, Law, Economics and Social Sciences, Medicine, Veterinary Medicine, Human Sciences and Science. The faculty of Science provides teaching and researches in the fields of Mathematics, Physics astronomy and philosophy, Chemistry and Biochemistry, Biology, Geology and Geography. Physics is subdivided into three institutes (Physics, Applied Physics and Theoretical Physics). The laboratory for High Energy Physics (LHEP) is one of the three departments of the

Physics Institute. More information can be found in: <http://www.unibe.ch/> and <http://www.philnat.unibe.ch/>

LHEP has also a long tradition in research and teaching. Elementary particle physics is one of the key specializations of the Institute of Physics at the University of Bern. It was introduced by H. Greinacher (lecturer 1924-1950) and F. Houtermans (lecturer 1952-1966), who was appointed to succeed H. Greinacher in 1952. F. Houtermans founded a working group in Bern which pursued experimental, fundamental research in the area of particle physics with a view to researching the fundamental building blocks of matter and their interactions. After the death of F. Houtermans (1966), J. Geiss was appointed as Head of the Institute of Physics. At the request of J. Geiss, the faculty and the government decided to set up an independent department of elementary particle physics at the Institute of Physics and to create a full professorship in this specialization. B. Hahn was appointed to this chair in 1968. K. Pretzl succeeded B. Hahn in 1988. He started a series of new projects in the field of particle physics. In particular he contributed to the search of strange-quark matter with the NA52 experiment in the heavy ion beam at the CERN Super Proton Synchrotron (SPS). Under his leadership the LHEP participated in the conceptual design of the ATLAS experiment for LHC. He also started a line of research on neutrino physics, joining the OPERA experiment for the search for neutrino oscillations. After retirement of K. Pretzl in 2006, A. Ereditato was appointed as his successor and is presently leading LHEP. The current activities of LHEP include the ATLAS, OPERA and T2K experiments in addition to an R&D study on novel particle detectors (as in particular LAr TPCs). As far as the latter subject is concerned we are realizing at LHEP, in collaboration with ETHZ and the University of Granada, a 5 m long LAr TPC detector (ARGONTUBE), in the framework of the GLACIER R&D program.

Profile of the staff members who will be undertaking the work:

- Prof. Dr. A. Ereditato, group leader, LAr detectors, management, physics. Experience in neutrino and astroparticle physics. Experience with large neutrino physics experiments at CERN and LNGS (CHARM II, CHORUS, OPERA, ICARUS) Experience with particle detectors: calorimeters, LAr TPC, emulsion detectors, imaging.
- Tit. Prof. Dr. U. Moser, Particle detectors, infrastructure, underground sites Experience with particle detectors and HEP experiments, also in neutrino physics (OPERA). Experience with organization of scientific activities.
- Dr. M. Messina, PostDoc senior researcher, Physics, LAr detectors, underground sites, outreach. Experience in particle physics and neutrino physics. Experience in LAr TPC detectors.
- Dr. I Kreslo, PostDoc researcher, Particle detectors, DAQ, experience with liquid scintillators, imaging. Experience in high space-resolution detectors (emulsions, capillaries, scintillator trackers, liquid scintillators, imaging).
- Dr. N. Savvinov, PostDoc researcher, Computing, data bases, Experience in particle physics, computing and advance software tools.
- Dr. C. Pistillo, PostDoc researcher, Computing, imaging, Experience in emulsion detectors, imaging, computing.
- J. Knuesel, PhD student, experience in data analysis and in emulsion detector.
- B. Rossi, PhD student, experience in computing and LAr detector constructions.
- M. Hess, electronic engineer
- Hans-Ulrich Schuetz, mechanical engineer

[Jyväskylä] University of Jyväskylä

The University of Jyväskylä is one of the best and most popular Universities in Finland. It mainly attracts the students from the central part of the country. Natural sciences and mathematics, human-centred sciences, sport and health sciences as well as teacher education form the core fields of the research and education. The University has the third highest number of Centres of Excellence in Finland and has been named a University of Excellence in Adult Education by the Finnish Ministry of Education.

The Department of Physics performs research and offers education at highest international level on nuclear and accelerator-based physics, materials physics and high energy physics. In addition, it hosts a teacher education program. The accelerator laboratory is a Centre of Excellence under the national centre of excellence program. Part of the research is done at CERN. There is also a very strong theory group.

The main task of Jyväskylä is to work in close cooperation with CUPP on the design of the underground infrastructure for the new underground laboratory (WP2), address safety and environmental issues (WP5) and contribute to science impact and outreach (WP6). In addition, Jyväskylä team has started a research program to develop new techniques on the detection of geoneutrinos and is willing to contribute to theoretical studies relevant to LAGUNA.

Profile of the staff members who will be undertaking the work:

- Dr. Wladyslaw H. Trzaska. Scientific background in experimental nuclear and high energy physics, Project Leader of ALICE T0 detector, coordinator of the Nuclear Reaction Research at Jyväskylä, spokesman of the underground experiment EMMA. WP2, WP5.
- Prof. Jukka Maalampi, Head of the Department. Scientific background in theoretical physics, strong interest in sterile neutrinos. WP6.
- Prof. Jouni Suhonen. Scientific background in theoretical physics, strong interest in beta decay and matrix element calculations; author of a textbook for advanced students on nuclear concepts and microscopic theory. WP6.

[Oulu] University of Oulu

The University of Oulu is an active scientific learning and research community of 17 000 students and 3000 staff members. Its task is to promote well-being and education in Northern Finland by implementing high-quality international research. The University's six faculties and their departments form a multidisciplinary academic institution that enables diversified studies and multifaceted research.

The University aims to develop itself further as an internationally high-level scientific community by paying particular attention to the needs of science and society. The University's goal is to clarify and strengthen its competitiveness and know-how. Ability for renewal and multifaceted know-how form the recipe for success, and active participation in the international scientific community is the basis for such renewal and development. Strategic goals include the promotion of the University of Oulu as an attractive work place for international top-scientists, which means that teaching and research has to be of high quality. The University creates high-level research environments for international research groups.

The University of Oulu runs an underground laboratory in Pyhäsalmi mine, referred to as Centre for Underground Physics in Pyhäsalmi (CUPP). Oulu Southern Institute administers it, which is a regional organisation of the University of Oulu.

CUPP has been planning or running an underground laboratory since 1997. CUPP has hosted or realised some small-scale experiments in the lab, including neutron measurements. The current experimental activity focuses on a cosmic ray experiment EMMA (Experiment with MultiMuon Array) shallow underground, and the future plans concentrate on LAGUNA.

A prefeasibility study and preliminary plan for a new underground laboratory was made in 2002 with Rockplan. The University of Oulu has experience on participation on planning and developing of several major construction projects for its recent new premises.

The main task of Oulu in this Design Study is to work on WP2, the design of the underground infrastructure for the new underground laboratory that is the subject of this project. In more detail, Oulu is responsible for the scientific aspects for the Finnish candidate site and links with the participant #5 Rockplan, which is the respective technical partner. Oulu also contributes to WP5 (safety and environmental issues), particularly studying the site specific aspects and WP6 (Science impact and outreach), including physics optimisation and local background conditions.

Profile of the staff members who will be undertaking the work:

- Dr. Juha Peltoniemi, project director of CUPP, adjunct professor: leads the local group in this Design Study. Scientific background in neutrino physics, with recent contributions to cosmic ray experiments. Managing EU-funded (ERDF) projects since 2001. Coordinates WP2, participates in WP6.
- Dr. Timo Enqvist, senior researcher, manager of the Pyhäsalmi laboratory. Scientific background: experimental nuclear physics and astroparticle physics. WP2, WP5 (safety of site), WP6 (background)
- Dr. Pasi Kuusiniemi, PostDoc: experimental nuclear physics and astroparticle physics. WP2, WP5, WP6
- Prof. Kari Rummukainen, Department of Physical Sciences, University of Oulu: professor of theoretical particle physics, with the responsibility for the research program and teaching of particle physics at the University of Oulu. Scientific background in Cosmology and Finite temperature field theory. WP6

DAPNIA (CEA)

Dapnia (CEA) and IN2P3 (CNRS) are the two national French institutes concerned with particle, nuclear physics. They also fund major programs in astroparticle physics in collaboration with the Institute of the Sciences of the Universe INSU/CNRS, other departments of CNRS and other national organisms (CNES for space, IFREMER for the sea, etc.) .

At CEA, the particle physics groups have merged, since 1991, with nuclear physics and astrophysics groups in the department called DAPNIA, Laboratory of research into the fundamental laws of the Universe. Dapnia works in coordination with IN2P3, in particle astroparticle and nuclear physics.

In 2005 DAPNIA employed a total of 820 persons (420 engineers (including 200 researchers), 246 technicians and administrative staff, 19 CNRS or University staff and 135 non permanent staff (PHD, postdocs). DAPNIA is composed of 7 services.

The CEA & IN2P3 run the Fréjus-Modane Underground Laboratory (LSM) since 25 years and are involved in a wide spectrum of neutrino and astroparticle experiments. French laboratories have strong activities at CERN and all the other major particle physics facilities around the world (Fermilab, Stanford, Desy, Tsukuba, Jefferson laboratory, RHIC etc.). IN2P3 and DAPNIA have developed high competences in all technical fields related to particle physics: detectors, electronics, computing, accelerators conception and realization, superconducting magnets.

The CEA will work closely with the IN2P3 groups on WP2. The work in the WP2 would consist in making specification documents with the companies involved in the realisation of the new Fréjus safety tunnel to study the environment infrastructures needed for the building and the running of the large detectors proposed. This work would be concluded by a Technical Design Report.

Profile of staff members who will be undertaking the work:

- Dr. Luigi Mosca, former Director of LSM and at present Scientific Adviser for future projects at Fréjus site
- Dr. Marco Zito, PostDoc researcher at CEA/DAPNIA. Leader of the T2K team in Saclay.
- Dr. Christian Cavata, PostDoc researcher at CEA/DAPNIA. Scientific Deputy of the DAPNIA Chief of Department Scientific interest in neutrino physics and nucleon decay.

IN2P3 (CNRS)

IN2P3 has been created in 1971 as an institute of CNRS devoted to particle and nuclear physics, and more recently to astroparticle physics. It is tied by decree ties with the University research and has also strong connections with DAPNIA (CEA)(Dapnia) and CNES (Spatial program). IN2P3 is composed of 23 Laboratories most of which are contracting with universities and CNRS (so called UMR). One of these laboratories, the CCIN2P3, is a Computing Center supported and used by both DAPNIA (20%) and IN2P3 (80%). In 2005 the total IN2P3 permanent staff was 2488 persons (491 CNRS researchers, 304 University professors, 1460 CNRS staff, 233 University staff). For both DAPNIA and IN2P3 there are about 180 graduate students. The IN2P3 & CEA run the Fréjus-Modane Underground Laboratory (LSM) since 25 years and are involved in a wide spectrum of neutrino and astroparticle experiments.

The work in the WP2 would consist in making specification documents with the companies involved in the realisation of the new Fréjus safety tunnel to study the environment infrastructures needed for the building and the running of the large detectors proposed. For WP3, IN2P3 will work in the MEMPHYS tank technical design. It will consist of mechanical drawing documents those specifications are driven by the already existing state of the art Superkamiokande detector in Japan, and the new requirements given by the enlargement by a factor 4 the size of each tank module. IN2P3 will study for WP3 the whole water cycle from procurement to recycling passing through the purification, cooling and radio-decontamination phases. Also the case of adding and removing of gadolinium salt in pure water and the consequences on the material compatibility with the resulting acid solution will be studied. IN2P3 will lead the WP4, and will actively participate in the realisation of the two instrumentation prototypes (prototyping for MEMPHYS and GLACIER), it will specifically setup a small prototype ("MEMPHYNO") in the LSM. For WP6, IN2P3 will setup a physicists task force to be able to optimize the detector performances with respect to the physics subjects wished to be covered, the external infrastructure and the total cost limitation constraints.

Profile of staff members who will be undertaking the work:

- Pr. Thomas Patzak, project director at APC/IN2P3: leads the IN2P3 group of this project. Scientific activity in neutrino physics and particle physics detector development.
- Dr Alain de Bellefon, senior researcher at APC/IN2P3, Scientific in charge with outreach at CNRS, scientific interest in dark matter and neutrino physics, and Borexino member.
- Dr Jean-Eric Campagne, PostDoc researcher at LAL/IN2P3. Scientific interest in neutrino physics and nucleon decay search, co-coordinator of the MEMPHYS project, chairman of the Modane Underground Laboratory Scientific Committee.
- Dr. Alessandra Tonazzo, researcher and lecturer at APC/IN2P3, has contributed to different high-energy collider experiments, both with detector development and with data analysis
- Dr. Jacques Bouchez, senior researcher at APC/IN2P3. Scientific Adviser at CEA/DSM/DAPNIA. Scientific interest in neutrino physics and nucleon decay.
- Dr. Jacques Dumarchez, senior researcher at LPNHE/IN2P3. Scientific interest in neutrino physics and nucleon decay.
- Dr. José Busto, PostDoc researcher at CPPM/IN2P3. Scientific interest in neutrino physics.
- S Davidson, phenomenologist at IPNL/IN2P3, work in neutrino and charged lepton physics
- Dr. Nikolaos Vassilopoulos, foreign visitor at LAL/IN2P3. Scientific interest in detector design by simulation software
- Dr. Dario Autiero (IPNL/IN2P3), responsible of the neutrino group at IPN Lyon. Scientific background in neutrino physics with the NOMAD and OPERA experiments. Leads the local group of the LAGUNA project.
- Dr. Lionel Chaussard (UCBL/IPNL/IN2P3) responsible of the software working group in OPERA
- Dr. Yves Declais (IPNL/IN2P3), spokesman of the OPERA experiment and of the past CHOOZ experiment. Long standing scientific background in neutrino oscillation searches
- Dr. Jacques Marteau (UCBL/IPNL/IN2P3), project leader of the data acquisition system in OPERA
- Dr. Claude Girerd (IPNL/IN2P3), research engineer, main designer of the OPERA data acquisition system based on a Ethernet network of 1200 smart sensors with on-board linux processors.
- Dr. Hervez Mathez (IPNL/IN2P3), research engineer, head of the electronics service at IPN Lyon, with a long experience in low noise analog front-end
- Dr. Edouard Bechetoille (IPNL/IN2P3), research engineer, newly hired designer expert for the development of analog front-end ASICs.

[MPG] Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V.

The Max-Planck-Institut für Kernphysik (MPIK) in Heidelberg and the Max-Planck-Institut für Physik (MPP) in Munich are two well known institutions in particle and astroparticle physics. Both institutes are included via their head organisation, the Max-Planck-Gesellschaft (MPG). Coordination is done via the Max-Planck-Institute für Kernphysik in Heidelberg.

The experimental activities at MPIK are based on a strong research record in experimental neutrino physics and low-background techniques. Experiments which have been initiated at MPIK or to which MPIK provides major contributions are the GERDA double beta decay experiment, the Double Chooz reactor neutrino experiment and the Borexino solar neutrino experiment. MPIK played the leading role in the famous GALLEX/GNO solar neutrino experiment. The MPIK experimental know-how which is of relevance for the LAGUNA project, include:

- low-level counting techniques (HP-Ge, Rn gas counting, liquid scintillator, alpha counting, etc.)
- purification of liquid nitrogen and liquid noble gases
- noble gas mass spectrometry
- manipulation of radioactive noble gases and counting
- inorganic and organic chemistry (GC-MS, AAS, IR-spectrometry, etc.)
- scintillation counting
- organic liquid scintillator characterization (UV-VIS, fluorimetry, gamma-sources)
- metal loaded organic liquid scintillators
- liquid Argon scintillation light detection
- XUV-VIS wavelength shifter development
- modelling of energy transfer in organic scintillators and in Argon/Xenon scintillators

Special infrastructures available at MPIK includes an underground laboratory for low-level measurements, chemistry and radio chemistry laboratories, spectrometry laboratory for organic scintillator characterization, class 1000 clean room, multi-purpose laboratories, gas counting laboratory, liquid scintillator production hall, one ton low-level liquid Argon scintillation prototype detector.

The involved theoretical expertise at MPIK and MPP involves well known experts working on a broad set of topics which are directly and indirectly relevant for the LAGUNA proposal. The expertise includes on the formal side theoretical studies of neutrino mass models, extensions of the Standard Model which can accommodate neutrino properties and proton decay. The theoretical activities include various activities concerning the modelling of neutrino sources, including supernovae neutrinos, geo-neutrinos, neutrino beams, and reactor neutrinos. Another topics is the propagation of neutrinos in matter in the Earth and in supernovae and detection channels. Development and application of the GloBES software, a powerful simulation tool for long baseline and reactor neutrinos with three flavour oscillations in matter. There exists also a lot of expertise in the phenomenology of Dark Matter and axions and in theories beyond the Standard Model providing Dark Matter or axion candidates.

Profile of the staff members who will be undertaking the work:

- Prof. Dr. Manfred Lindner, director at MPI für Kernphysik, expertise in theoretical particle and astroparticle physics, phenomenological studies in neutrino physics.
- Dr. Stefan Schönert, MPI für Kernphysik, project leader, expertise in neutrino physics at low energies, underground and low background physics, detector technology.
- Prof. Dr. Georg Raffelt, MPI für Physik, senior research scientist at MPI für Physik, expertise in theoretical particle and astroparticle physics.
- Prof. Dr. Wolfgang Hampel, senior research scientist at MPIK, expertise in neutrino physics at low energies, underground and low background physics, detector technology.
- Prof. Evgeny Akhmedov, senior researcher at MPIK, expertise in theoretical particle physics
- Dr. Christian Buck, senior researcher at MPIK, expertise in neutrino physics and scintillator development.
- Dr. Hardy Simgen, senior researcher at MPIK, expertise in neutrino physics and low background techniques.
- Dr. Josefa Oehm, senior research scientists at MPIK, expertise in low background physics.
- Dr. Jochen Schreiner, senior research scientists at MPIK, expertise in low background physics.
- Dr. W. Rodejohann, senior researcher at MPIK, expertise in theoretical neutrino physics

[TUM] Technische Universität München, Physikdepartment E15

The institute E15 of the faculty of Physics at the Technische Universität München, Germany, is playing a leading role in Astroparticle Physics. Expertise has been achieved in the fields of solar neutrino measurements (GALLEX, GNO, and BOREXINO experiments), Dark Matter search (CRESST experiment), and experiments for investigating intrinsic neutrino properties (GÖSGEN, BUGEY, DOUBLE-CHOOZ). Technical expertise has been obtained in the development of scintillating detectors with extremely low levels in radioactivity. In addition large experience has been gained in cryogenic detector developments and in methods to characterise background levels with neutron activation and high sensitivity gamma spectroscopy. For this purpose a shallow site underground laboratory in Garching has been built. Experience in working in deep underground laboratories was obtained in the Italian Gran Sasso facility. Knowledge on electronics, data acquisition, single photon counting, data analysis, and Monte-Carlo calculations has been acquired. Connections to the High-Tech companies Fa. Vericold, Ketek, Infineon (Germany), Aquiris (CH) and ETL (UK) are fostered. The institute enforces public outreach with open doors days, information days for pupils, public seminars, by supporting the science-Lab of the Technical Museum in Munich. The group consists of 2 professors, 3 senior researchers and 7 PhD-students. A mechanical workshop including 2 engineers belongs to the institute. The group under Prof. F. von Feilitzsch is active in this field since 27 years.

Profile of the staff members who will be undertaking the work:

- Prof. Dr. Franz von Feilitzsch, chairman of the institute. Expertise in dark matter, neutrino and underground physics, and detector technology.
- Prof. Dr. Lothar Oberauer, Extraordinarius. Expertise in neutrino physics at low energies, rare event physics, detector technology and underground low background physics.
- Dr. Marianne Göger-Neff, senior researcher. Expertise in neutrino physics and scintillator development.
- Dr. Jean C. Lanfranchi, senior researcher. Expertise in low temperature detector developments, neutrino physics, and Dark Matter search.
- Dr. Walter Potzel, senior researcher. Expertise in Moessbauer-effect, low temperature detectors, neutrino physics, and Dark Matter.

Universität Hamburg, Physikdepartment

The University of Hamburg, with close to 40 000 students, is Germany's fifth largest university. There are about 850 professors engaged in teaching and research; in addition to that, the university's academic staff numbers 1800 and its technical and administrative staff, 6650. Students may choose from around 120 different subjects offered by six faculties.

The department of physics as member in the Faculty of Mathematics, Informatics and Natural Sciences has a long experience in high-energy detector and accelerator physics due to the vicinity of DESY Hamburg. Another focus has been nuclear, neutrino and astroparticle physics.

Profile of staff members who will be undertaking the work:

- Prof. Dr. C. Hagner, neutrino physics group leader, scientific background in neutrino physics (NOMAD, BOREXINO, DCHOOZ, OPERA) and in accelerator physics (BELLE)
- Dr. J. Ebert, researcher, experience in detector design and development (OPERA, H1)
- Dr. R. Zimmermann, researcher, project leader of the precision tracker drift tubes of the OPERA experiment, experience in electronics and detector development (OPERA, HERA-B)

IFJ PAN

The H. Niewodniczanski Institute of Nuclear Physics of the Polish Academy of Sciences (IFJ PAN) in Cracow is one of the leading and of the largest Polish research institutes. The Institute carries out basic and applied research in physics. At present the Institute is involved, as a contractor, in 18 projects of the Sixth Framework Programme.

The basic research, both theoretical and experimental, is aimed at explaining the structure of matter from microscopic to cosmic scales. It concerns particle physics and astrophysics, nuclear and strong interactions physics and condensed matter physics. Major topics in the field of theoretical particle physics are: application of QCD, electroweak physics and radiative corrections, meson scattering, quark models, nuclear matter, theoretical astrophysics and foundations of quantum mechanics. The experimental teams from IFJ PAN participate in the large international collaborations: ATLAS, LHCb and ALICE at LHC (CERN), ZEUS and H1 at HERA (DESY), Belle at KEKB (KEK), PHOBOS at RHIC (BNL), Auger in Argentina, ICARUS at Gran Sasso, T2K at J-PARC and ILC. Physicists in these teams are supplemented by an excellent technical staff whose mandate comprises the design and construction of detector mechanical structures, cooling systems, readout electronics, DAQ and trigger systems for experiments. This staff has also provided a significant contribution to the LHC Computing Grid and to the construction of the LHC accelerator.

The Institute, originally established as a nuclear physics research laboratory over 50 years ago, has by now expanded its research over a broad range of interdisciplinary applications of physics. It has for several years served as a leading regional centre in radiation and environmental biology, environmental physics, medical physics, dosimetry, nuclear geophysics, radiochemistry and material engineering. The IFJ PAN hosts three accredited laboratories, the centre of excellence ADREM and the Krakow Research Centre for Ion Engineering. This interdisciplinary research also stimulates technology transfer to the local industry.

In the LAGUNA project the group from IFJ PAN will coordinate the work package WP6 and will contribute to the work packages WP6, WP1 and WP4. In the framework of WP6 the following activities are foreseen: contributions to the general LAGUNA software, evaluation of physics potential of the Sieroszowice site with special emphasis on the Liquid Argon detector, measurements and simulations of the background due to the rock natural radioactivity, simulations of the cosmogenic background and dissemination of the LAGUNA results aimed at the general public as well as the promotion of the SUNLAB project within the local communities. In the framework of WP4 the group will participate in the R&D activities for Liquid Argon detectors.

Profile of the staff members who will be undertaking the work:

- Prof. Agnieszka Zalewska – head of the Department of Neutrino and Dark Matter Studies, experience in hadronic, e+e- and neutrino physics, expertise on detector techniques
- Assoc. Prof. Jerzy W. Mietelski – head of the Department of Nuclear Physical Chemistry, specialist on low level radioactivity measurement techniques
- Dr Monika Szarska – physicist, specialist in particle physics
- Dr Pawel Gaca – chemist, specialist in low level activity measurement techniques
- Sylwia Blazej, M.Sc. – physicist, PhD student in low level activity measurements
- Dorota Stefan, M.Sc. – physicist, PhD student, work on proton decay
- Tomasz Wachala, M.Sc. – physicist, PhD student, work on neutrino physics
- Dr Krzysztof Kozak – physicist specialized in environmental physics
- Dr Jadwiga Mazur – physicist specialized in environmental physics.

[IPJ] Soltan Institute for Nuclear Studies

The Soltan Institute for Nuclear Studies (SINS), with branches in Warsaw (Department of High Energy Physics), Swierk, near Warsaw (Department of Accelerator Physics and Technology) and Lodz (Department of Cosmic Ray Physics) is involved in a basic research in nuclear and particle physics, cosmic ray physics and plasma physics as well as in a development and implementation of new technologies in nuclear science and electronics.

SINS has a long term experience in ionisation radiation detectors, dosimetry, theory and technology of accelerators, nuclear electronics and the use of computer techniques in simulation of nuclear processes. The research performed at the intersection of pure and applied physics enables SINS to efficiently transmit the theoretical knowledge to practical applications and to industry. The Institute is also engaged in education through its special PhD studies programme. The Institute is entitled to award the PhD and habilitation degrees.

The SINS physicists and engineers are participating in preparation of modern experiments at (large) accelerators (CERN, FNAL, KEK, RHIC). The strong group interested in neutrino physics is active in the institute since 2000, consisting of 5 seniors, 4 PhD students (presently) and technical support in electronics and mechanics. The group is gaining experience in the liquid Argon TPC technology (participation in Icarus and in ArDM project and in planning of intermediate detector for T2K experiment). One of the members has experience in neutrino physics starting in IMB detector, through Super-Kamiokande from its beginning. The activity in dark matter searches includes in particular the simulation of backgrounds from radioactive materials and from cosmic muons.

Also significant experience exists in registration of neutrons generated in cosmic ray interactions. Observations were made on surface and in the underground laboratory 15 meters underneath using mostly helium counters. The thermal neutron background from energetic neutron background can be distinguish. This experience would allow the group in this Design Study to work on the development and instrumentation of extremely massive Liquid Argon detectors (WP4). The group also has broad experience in software for detector simulations and data analysis (WP6).

Profile of the staff members who will be undertaking the work:

- Prof. Ewa Rondio – leader of the group, experience in muon accelerator experiments at CERN (EMC, NMC, SMC, Compass)
- Dr hab. Danuta Kielczewska, long experience in neutrino physics (IMB, Super-Kamiokande, K2K)
- Dr Tadeusz Kozłowski, experience in nuclear physics and in precise measurements performed at PSI
- Prof. Joanna Stepaniak, experience in hadronic interactions at low energies (Lear, Wasa)
- Prof. Maria Szeptycka, experience in Delphi, detector construction
- Dr Jacek Szabelski, experience in cosmic ray physics and neutron measurements

First five on the list belong to the polish neutrino group, which is involved in Icarus and T2K experiments.

[US] University of Silesia

The University of Silesia was established in Katowice in 1968 as the ninth university in Poland and is an autonomous state university. The University has its origins in the Higher School of Education, which was founded in 1928 - at that time it was the only institution of higher education in the region. Later, the school became a branch of the Jagiellonian University in Kraków, the oldest Polish University. It now has campuses in four cities in the region: Katowice, Sosnowiec, Chorzów and Cieszyn. The majority of faculties are located in Katowice. The University consists of 12 faculties (divided into 23 institutes, 75 departments and 15 inner-faculty units). The total number of the teachers exceeds 1900 and includes 215 professors, 274 doctors with habilitation and 991 doctors. The total number of students (full-time, part-time, postgraduate and PhD) reaches 41000.

The A. Chełkowski Institute of Physics of the University of Silesia has been awarded „Category 1” scientific institution – the highest category in the Polish Ministry of Science and Higher Education ranking. It is divided into seven experimental and four theoretical departments and has two workshops (electrical and fine mechanics). The scientists publish more than 250 articles in the highest ranked international journals per year. More than 150BScs, 100MScs and 10PhDs graduate every year.

The Laboratory of Low Activities in the Institute of Physics of the University of Silesia carries environmental studies of radioactivity background from natural and anthropogenic radionuclides. Their activities will be measured *in situ* using a portable gamma-ray spectrometry workstation. The activities and radon surface emissions of rock samples will be determined in laboratory conditions and compared to the *in situ* measurements. Water samples for the ^{226}Ra and ^{228}Ra isotopes concentration measurements will be collected underground and analyzed in the laboratory, using the liquid scintillation method. The measurements of the radon (^{222}Rn) concentration in air are also planned. Some of the measurements mentioned above have already been performed in several European Underground Physics Laboratories (Gran Sasso, Modane and Boulby - within the ILIAS/TARI project in the 6th FP) and in Polkowice-Sieroszowice.

Profile of the staff members who will be undertaking the work:

- Dr hab. Jan Kisiel, prof. US: experience with large neutrino physics experiment (ICARUS), experience with particle detectors and radioactivity background measurements.
- Dr D.Malczewski: experience with different techniques of radioactivity background measurements, experience in geology.
- Mgr J.Dorda: experience with different techniques of radioactivity background measurements.

[UWr] - University of Wrocław

The University of Wrocław is the major university in southeastern part of Poland very close to the proposed site of SUNLAB (the distance is about 80 km).

The Wrocław University group is to contribute to WP6. It is involved in two neutrino experiments: ICARUS and T2K. The research activity is focused on the precise evaluation of neutrino interactions on nucleus targets. The group has been developing its own Monte Carlo generator describing the particle secondary interactions inside nuclei.

The group is composed from 3 doctors/professors, 1 PhD student and several undergraduate students who plan to undertake graduate studies.

Profile of the staff members involved in the project:

- Prof. Jan Sobczyk, the head of the group; experience in many aspects of particle physics.
- Dr Cezary Juszczak, experience in both theoretical physics and computer science.
- Dr Krzysztof Graczyk, post-doc, works on nuclear effects in neutrino interactions and on resonance excitation models used in Monte Carlo generators of events.
- Artur Ankowski, M.Sc., PhD student, work on nuclear effects in neutrino interactions

[UGR] University of Granada

The University of Granada is one of the largest universities in Spain from the point of view of the number of students assigned to it and from the amount of scientific production in international peer-reviewed journals. At European level, it has played a significant role both in innovation for education and research. In 1990, a theoretical group on Particle Physics was created. It is now a well-established research group that plays a relevant international role in the study of the phenomenology of the Standard Model and the Physics beyond it.

Recently, in 2002, this group was complemented by the creation of an experimental group on High Energy Physics. This is one of the youngest and more emergent groups for this field in Spain. In particular, it is the only one of these characteristics in the autonomous region of Andalusia (FEDER region type I). The group activities have been fully funded and supported since their onset by the Spanish Agency for Particle Physics. Nowadays the group is composed of three doctors, five Ph.D. students, an electronic engineer plus two technicians. It also operates a laboratory mainly devoted to R&D with cryogenic detectors. This infrastructure is key to carry out the tasks assigned to our group in this Design Study and having to do with the development and instrumentation of extremely massive Liquid Argon detectors (WP4). The group also has broad experience in software development both for detector simulations and data analysis (WP6).

Profile of the staff members who will be undertaking the work:

- Dr Antonio Bueno, Professor of Physics. Leads the local group of this project.
- Dr. Julio Lozano, senior PostDoc researcher.
- Dr Sergio Navas, senior PostDoc researcher.

All three members of the group have an ample scientific background in experimental neutrino physics with liquid Argon detectors. Since recently, they have made contributions as well to forefront Particle Physics research topics as cosmic ray (Pierre Auger Observatory) and dark matter (ArDM experiment).

University of Sheffield and Boulby

The University of Sheffield is a premier research University in the UK, participating here through the Department of Physics and Astronomy. Members of the department (led by Spooner) play a leading role in UK and European Astroparticle Physics through development of underground detector technology (for dark matter and neutrino physics) in Boulby Underground Laboratory at Boulby Mine, North Yorkshire. Our role at Boulby gives us unique experience to be a major contributor to LAGUNA - Boulby is the largest and longest running deep mine-based laboratory in Europe. Established in 1988 and expanded in 1999 with new facilities, it has been host to successful dark matter (NAIAD, ZEPLIN, DRIFT) and other experiments and has a strong record of R&D in connection with the ILIAS FP6 programme. The group (currently three academics and 10 students, technicians and PDRAs) has extensive experience gained over 15 years directly relevant to the workpackages in LAGUNA including: excavation and mine operations; development of large underground infrastructures and laboratories in mine environments; underground background and environment research; scintillator, liquid Argon, photon detection, electronics and data acquisition technology for underground detectors; engineering of unusual pressure vessels for underground use; interaction with non-physics applications, industrial cooperation and public outreach.

Profile of the staff members who will be undertaking the work:

- Prof. Neil Spooner, Director Boulby Laboratory, group leader. Expertise in dark matter, neutrino and underground physics, and detector technology
- Dr. Vitaly Kudryavtsev, senior academic researcher. Expertise in dark matter and rare event physics, detector technology and underground background simulations
- Dr. Sean Paling, senior researcher. Expertise in underground operations and engineering, rare event physics, analysis and detector development
- Dr. Phil Lightfoot, senior researcher. Expertise in cryogenic liquid, scintillator and gas technology underground, mine operations and engineering, rare event physics, novel readout techniques.
- Dr Matt Robinson, senior researcher. Expertise in data reduction, data analysis, simulations and data acquisition systems.

[UDUR] Durham University

Durham University is a world-class university in the city of Durham and at the Queen's Campus in Stockton, in the United Kingdom. It is engaged in high-quality teaching and learning and advanced research and partnership with business. Its academic teaching and research programmes are delivered through departments contained within three faculties: Arts and Humanities, Science, and Social Sciences and Health. The Department of Physics is part of the Science Faculty.

The Institute for Particle Physics Phenomenology (IPPP) was founded in 2000 as a joint venture of Durham University and the UK Particle Physics and Astronomy Research Council (PPARC). The IPPP is part of the Centre for Particle Theory (CPT) in Durham, based jointly in the Departments of Mathematical Sciences and Physics, with a number of academic staff having joint appointments in the two Departments. Its aim is to foster world-class research in particle physics phenomenology, and to provide a forum for interaction between experimentalists and theorists, coordinating common interests and future research through a series of discussion meetings, workshops and conferences. Within a short space of time, the IPPP has achieved international recognition and the recent Second International Review of UK Research in Physics and Astronomy stated "The IPPP has had major successes: creating a critical mass of particle theorists in Durham. There have been very healthy interactions reviving particle phenomenology throughout the UK." The IPPP currently comprises 14 permanent staff (Professors Glover (Director), Khoze, Pennington, Stirling and Drs Abel, Ball, Dedes, Krauss, Maxwell, Moortgat-Pick, Pascoli, Richardson, Signer and Weiglein) as well as 15 fixed term research staff and 22 postgraduate students. An extensive visitor programme brings world-class researchers to the IPPP for periods ranging from a few days to a year. Training for the next generation of particle physicists is provided through guidance in research, and dedicated graduate lecture programmes and summer schools.

Research activities cover all aspects of particle phenomenology and, in particular, topics directly related to the LAGUNA proposal, namely physics Beyond the Standard Model of Particle Physics, and neutrino physics. Known experts work on i) neutrino phenomenology, concerning the study of neutrino properties in present and future experiments, ii) theoretical aspects of neutrino physics with particular focus on the origin of neutrino masses, iii) the role of neutrinos in the Early Universe and in the evolution of astrophysical objects as supernovae. Expertise on extensions of the Standard Model, which predict proton decay, and on dark matter is also present.

The main task of Durham concerns the science impact and outreach (WP6), providing theoretical support to the experimental investigations and contributing to the detector simulations, in order to fully explore and optimise the physics potential of the LAGUNA research infrastructures.

Profile of the members who will be undertaking the work:

- Dr. S. Pascoli, faculty member. Research in neutrino physics, extensions of the Standard Model and cosmology.
- Dr. S. Palomares-Ruiz, postdoctoral researcher. Expertise in neutrino phenomenology, high energy cosmic rays, cosmology.
- C. Orme, PhD student. Studies on neutrino oscillation experiments.

[U-Aarhus] University of Aarhus

A high level of quality in both research and education is the aim of the University of Aarhus. Since its early beginnings in 1928, the university has provided both the Danish and international communities with more than 42,000 graduates, and has left its own special mark on the city of Aarhus, the Danish society and the international research community. The University of Aarhus has a reputation for education and training – a brand that extends well beyond Denmark's borders. It is a lively, modern university, which collaborates with the business community, cultural centers and other universities throughout the world.

The main task of U-Aarhus in this Design Study is to work on WP2, the design of the underground infrastructure for the new underground laboratory in collaboration with the CUPP center at Oulu, and to WP6 (Science impact and outreach).

Profile of the staff members who will be undertaking the work:

- Dr. Steen Hannestad, scientific background: Theoretical astroparticle and neutrino physics. Current or past board member of several European networks in these fields. Member of the governing council for ILIAS.
- Dr. Hans Fynbo, scientific background: experimental nuclear physics and nuclear-astrophysics. Spokesperson and project leader for numerous experiments at CERN-ISOLDE and other radioactive beam facilities in Europe.

[Rockplan] KALLIOSUUNNITTELU OY ROCKPLAN LTD

is a consulting company founded in 1986 and has over 20 years experience in every kind of underground facilities. For the most part acting as main designer, the company has gained experience through various projects in the field of rock engineering. The staff is mainly made up of architects, civil and rock engineers and geologists. The staff of 30 persons is mainly made up of architects, civil and rock engineers and geologists. The company is SME. The company has specialized in managing the design, general design, rock engineering design and structural design. Additional plans and designs are produced in co-operation with experienced subcontractors.

- Kalliosuunnittelu Oy Rockplan Ltd, (Rockplan), is able to act as **Design Manager**, coordinating and controlling the work or as a main designer.
- **General design** by Rockplan embraces both layout design and architectural design. In carrying out general design the company aims to create a suitable, safe, technically high quality underground facility meeting the client's requirements.
- The aim of Rockplan in **rock engineering design** is to use properties of the rock to the best advantage, and to prepare high quality plans excavation, reinforcing the rock surface, sealing and waterproofing. A fundamental consideration of the design is safety during construction.
- Rockplan aims to produce **structural designs** that take account of the special requirements of underground construction in cost effective manner. Structural design is required for among other things: entrance ramps and shafts, internal floors and structures and blast-resistant barriers.

Additional plans and designs are produced in co-operation with experienced subcontractors.

The **main task** of Rockplan in this Design Study is to make the preliminary design and technical feasibility study of the underground construction in the Finnish site, within WP2, working in close collaboration with Oulu. Rockplan is involved also in WP3 (tanks) and WP5 (safety).

Rockplan has been actively taken part in innovate new technology underground projects. One of the first steps was Hirvihaara deep storage of natural gas in Southern Finland. Rock lined covers of total volume of 1.6 M m³ were located in 850 meters depth. The detailed design of hoisting and service systems was carried out in years 1990-92 for Neste Oy Natural Gas. To the same client Rockplan designed also a concept of steel lined natural gas storage. The client discontinued these projects.

Rockplan has completed design of a 150.000 m³ steel lined petroleum storage in Finland. The storage consists of 5 tanks with diameter of 35 meters. This storage has been operated for 16 years. Client and details are confidential information.

Kamppi Centre (Kampin keskus), the largest single construction project that has been carried out in Finland, was the best construction site of the year 2003. The jury grounded the election on Kamppi's visionary rock engineering in difficult circumstances and innovative technical solutions. The blasting work has been remote sensed in realtime and the effects has been analysed for security purpose before the next coming blast.

Salmisaari, underground coal storage. The overall project involves 3,5 km of tunnel with 40 different cross sections. Total excavation of 550.000 m³ of granite/gneiss has being undertaken, all of which was crushed and screened for reuse by the local construction industry. The underground silos are each 65 m-high x 40 m-diameter with circular plan cross-section. The volumetric capacity of each silo is 81.000 m³. The Salmisaari coal transport tunnel will be re-equipped to charge the silos and a newly mined conveyor retrieval tunnel will be used to discharge the coal.

The staff members undertaking the work will include:

- Jarmo Roinisto, Chairman of the Board, Managing Director, M.Sc. (Civ.Eng.): Project management, design and supervision of rock engineering, tunnelling and underground spaces
- Juha Salmelainen, Development Director, M.Sc. (Eng.Geol.): management of rock engineering projects, site investigations and rock mechanical modelling
- Raimo Matikainen, emeritus professor of rock engineering, former Director General of the Finnish Geological Survey, Board member and vice chairman of The Finnish Academy of Technology: wide experience of engineering in mining industry and geological research
- Matti Hakala, Special Designer: rock modelling in 2D and 3D using the most advanced calculation programs

KGHM CUPRUM

The KGHM CUPRUM Ltd. Research and Development Centre (KGHM CUPRUM), which is a part of the KGHM Polska Miedź SA capital group, has existed for over 35 years. During the first few years of its activity the company developed the research and design studies for the Polish copper basin and then for many other home and foreign mine projects, which gave it a stable position in the non-ferrous metals, salt mining and mine construction industries. At present it widens its activity range participating in geological and mining projects of the European Union.

Being aware of the XXI-st century challenges the company widens its activity undertaking problems of environmental protection and companies restructuring. It is at the same time consultant, expert and authority in geology, extractive industry, minerals processing and environmental protection.

KGHM CUPRUM has a highly qualified and experienced team of specialists (over 140) who create the most modern technical solutions and guarantee services on a high quality level. It also has the ISO 9001 and 14001 certificates.

The company has its own, fully accredited laboratory of rock mechanics with excellent equipment for investigating rock behaviour under any kind of load. It has a special purpose software and unique test instruments like chromatographs for gas mixtures and volatile liquids analyses, an X-ray diffractometer, a spectrometer of infrared radiation, a modern noise level gauge, a portable system for gas emission measurements, a kit for measuring and analysing vibrations, thermovision equipment, instruments for non-destructive laboratory and field tests, and a set for water analyses.

The research activity of KGHM CUPRUM Ltd. RDC is presently focused on: geology, hydrogeology and mining projects feasibility studies, mining, including rock mechanics, mines electrification, automation, mechanisation and ventilation, minerals processing, environmental protection with its monitoring and wastes management, companies restructuring, economical studies, technical expertise and engineering concepts evaluation used mainly for copper mines (among them also the Sieroszowice mine) exploited by KGHM Polska Miedź S.A.

KGHM CUPRUM participated in geological and hydro geological, mining and environmental projects of the European Union within 5th and 6th FP including:

- Life Cycle Assessment of Mining Projects for Waste Minimization and Long Term Control of Rehabilitated Sites (LICYMIN) - G1RD - CT - 2000 – 00162
- Chemically Stabilized Layers (CLOTADAM) – G1RD-CT-2001-00480
- Lifetime Engineering of Buildings and Civil Infrastructures - (LIFETIME) - GTC1-2001-43046
- Network on European Extractive Mining Industries (NESMI) - G1RT-CT-2002-05078
- Search for a sustainable way of exploiting black ores using biotechnologies (BIOSHALE) – NMP2-CT-2004-50571

For many years CUPRUM has been organising domestic and international scientific conferences and seminars on roof bolting, minerals processing, metallurgy, environmental protection and mining in difficult rock-mass conditions. The company has an authorisation granted by the Minister of Environmental Protection, Natural Resources and Forestry to deal with: atmosphere protection, land surface protection, environmental impact assessments of investments and building structures.

The KGHM Cuprum contribution to the Laguna project will cover feasibility studies for large caverns, problems concerning the site accessibility, evaluating the geomechanical limitations excavation technology, ventilation requirements, costs evaluation (WP2), local geomechanical hazards assessment due to mine activity and environment protection analyses (WP5).

The staff members undertaking the work will include:

- Dr. hab. Witold Pytel – project leader, M.Sc. (Civ. Eng.), MBA: background in soil and rock mechanics, numerical modeling and rock mass stability analyses, risk assessment and management,
- Dr. Andrzej Grotowski, : expertise in environmental protection and mineral processing,
- Dr. Andrzej Markiewicz, Geologist: expertise in geological survey and tectonic structure research,
- Mirosław Raczynski, M.Sc. (Electr. Eng.): expertise in electric power supply and automation in mines,
- Zbigniew Sadecki, M.Sc. (Min. Eng.): expertise in mine planning and equipment selection,
- Dr. Sławomir Gajosinski, M.Sc. (Min. Eng.): expertise in mine ventilation and air-conditioning

IGSMiE PAN

The Mineral and Energy Economy Research Institute is part of the Polish Academy of Sciences (IGSMiE PAN), which has been leading research work on mining, geology, engineering geology, geotechnics, raw materials management and environment protection.

One of the main activities of the Institute is research on the physical and chemical properties, especially geological, geothermal, mineralogical, and hydrogeological of salt massifs. The results created a base for mathematical and physical models of rock salt formation which have been used for designing natural gas and liquid hydrocarbons storage caverns in rock salt deposits.

The Institute has been coordinating research work on the site selection and formation for the Polish deep radioactive waste storage project. The Institute is also participating in two European Union research framework FP6 projects related to geothermal energy and to carbon dioxide sequestration.

Staff members of the Institute have broad experience in design and in assessment of large-scale excavation long-term stability, including natural hazards (water, gas outburst) in Polish rock salt deposits. They have been participating in most of research projects, related with Polish salt mining in the last years.

In the case of the underground infrastructure for the SUNLAB project, the Institute is competent in the following tasks:

- Determining the optimum localization criteria for the laboratory,
- Study of the physical and chemical (including geological) properties of rock salt from the site of the potential localization,
- Formulating the constitutive law and effort criteria for rock salt formation,
- Cavern stability evaluation.

The staff members undertaking the work will include:

- Kazimierz Ślizowski – Head of the Underground Storage Department.
- Wiesław Bujakowski – Head of the Renewable Energy Department
- Zenon Pilecki – Head of the Department of Geodynamics and Environmental Engineering
- Kazimierz Urbańczyk – Specialist in the mathematical modelling of physical processes
- Jarosław Ślizowski – Specialist in the geomechanics of rheological media

ELECTRON TUBES

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Electron Tubes designs, develops, and manufactures photomultipliers and other light and radiation sensing devices and has done so since the 1950s, originally as a division of EMI and then as Thorn EMI. In 1994 we became Electron Tubes, an independent company, retaining and adding to they highly qualified staff of engineers and scientists.

They also manufacture products for use with photomultipliers, such as: voltage dividers, high voltage power supplies, housings, and electronics-hardware. They supply photomultipliers and all these products to customers in universities and research establishments. They also serve the large volume requirements of high energy physics and industry.

In the case of WP4, ETL is competent in the areas of longevity and robustness testing of PMTs, and in the development of large area room temperature and low temperature PMTs.

The staff members undertaking the work will include:

- Dr. Andy Cormack, Director. With a strong background in both physics and electrical engineering he has extensive experience in the development and testing of a wide range of light readout devices. As director of sensor development he is primarily responsible for the R&D required to maintain Electron Tubes at the forefront of technological advancement, and his expertise in pioneering photomultiplier design is unparalleled. With a strong background in effective and successful liaison with industry and higher education research institutions, his involvement in the project will be beneficial both within the context of specific photomultiplier development R&D, and for the global implications of equipping future full-scale LAGUNA targets.

Technodyne International Ltd

Technodyne International is a specialist Engineering Design consultancy, based in Eastleigh, on the UK South coast. Their main focus is on the design and engineering of Cryogenic Storage tanks but their broad scope of experience and flexible approach enables them to undertake a diverse range of projects, providing cost-effective and dependable solutions for their worldwide client base. Their in-house team of approximately 20 highly experienced and qualified engineers has accumulated over 300 man-years of valuable experience in the engineering industry, including Aviation, Automotive, Energy Supply, Marine, Nuclear, Oil & Gas, and Petrochemicals. During the last 10 years, they have worked on designs for over 40 large cryogenic storage tanks, including the current world's largest tanks for LNG storage, and they have been retained as engineering consultants on many others. No other company can combine this capability with their ability to harness the knowledge and experience gained from executing many very large and sophisticated projects for industrial applications, and defence projects: these are invariably "one-offs" (there are never any prototypes, or "trial runs", they must work first time). Their projects range from small consultancy roles, to involvement in those projects with a capital value in the hundreds of millions of Euros. As an ISO 9001 accredited company, their work is carried out to the highest quality standards, while their Health & Safety training complies with best industry practices.

The staff members undertaking the work will include:

- M. Haworth, director responsible for engineering, member of the institute of mechanical engineers, member of royal aeronautical society. Experience: 10 years as founder director, 4 years corporate management British Gas, 15 years in cryogenic tank and vessel engineering, and construction in the Petrochemical industry, 6 years experience in Defence and Aerospace special projects, total 35 years of experience in engineering design, engineering, project management and construction of multi-discipline teams in small and large companies. Consultant of Owner's Team for tanks specs 3 new LNG tanks for Isle of Grain (UK), Owner Engineer Team member for new LNG terminal in Europe, consultant on refurbishment Design of LNG tank for Isle of Grain, fitness for purpose assessment of LNG tank, India, Review seismic capability of existing LNG tank (UK), assessment of ability to meet current codes, calculations, establish failure rates, meeting with HSE. LNG piping stress analysis. Design of 4 LPG tanks for Agip (Italy). Design of LNG tank (China). Design of Propane tank (Spain). Design of 80'000 m³ LPG tanks (full design package of calc, detail drawings, MTO). Modifications to LNG tank Dynevor.
- D. Gurney, engineering manager, team leader. Professional and competent computer systems engineer. Experienced in leading teams of software and hardware engineers and in the use of a variety of computers, operating systems and programming languages. Has an in-depth knowledge of software quality control systems, cost/time estimation and the use of structured methods to ensure successful project completion. Lead Engineer for the design of 7500m³ Liquid Ethylene Tank for Vijay Tanks, India. Lead Engineer for the concept design of a 75000m³ Liquid Argon Tank for basic element physics research. Lead Engineer for the design of a 10000m³ LNG Tank for Chemtex, China. Design and specification of insulation systems for various Cryogenic Tanks including LNG, Liquid Ethylene, Propane, Butane and Argon.
- J. Thompson, administration, finance, electrical and C&I engineering. Experience: 40 years in electrical and project engineering; 10 years as Director of Technodyne International Limited, a company specialising in cryogenic storage facilities for LNG, LPG etc, and in the design and supply of aerospace and industrial test facilities; Extensive project management experience of major electrical equipment installations worldwide; Bid preparation, equipment marketing and sales of high value capital projects worldwide; Corporate Management of USA subsidiary company.
- R. Rogers, mechanical engineer. Engineering manager, over 35 years experience of mechanical engineering design and management on a wide range of capital plant and equipment. Work has included direct line management and direction of multi-disciplined engineering and design.
- B. Brockway, senior mechanical design-engineer. Design of Cryogenic Tank components, detail draughting. Responsible for design and supply contracts for 3x80'000 m³ LPG tanks, 15'000 m³ Ethylene tank (China), 25'000 m³ LPG tanks.
- Pool of three analysts and up to 8 drafters for engineering analysis

AGT Ingegneria Srl

AGT Ingegneria Srl (ISO 9001 accredited company), together with its partner (sub-contractor) Geoingegneria Srl, are both companies that work and collaborate in the field of road and geotechnical engineering.

The staff members who would be undertaking the work:

The two Technical Directors, Ing. Marco Temussi (AGT Ingegneria) and Ing. Giuseppe Ristaino (Geoingegneria) have more than 20 year experience in the above fields; their jobs in design have been committed by some of the most important Italian purchasers, in the public and in the private sectors (both building firms and engineering companies)

The most significant achievements in the recent years are:

- the preliminary design of all the road and railway connections in the General Contractor tender for the bridge over the "Stretto di Messina" (coordinator: Ing. M. Temussi), which includes several tunnels longer than 1 km;
- advise, as consultants, about geotechnical, geo mechanics and computing matters in many executive designs committed for the renovation of several parts of the Salerno-Reggio Calabria motorway, including natural tunnels with double pipe, for a total length of 5,744 Km, and all the needed connections;
- advise, as consultants, about geotechnical, geo mechanical and computing matters in the executive design and the construction of the closest part to Terni of the new highway Civitavecchia-Orte-Terni-Rieti, which includes three natural tunnels (the "Valnerina" Tunnel – about 4 Km long - the "Svincolo Valnerina" Tunnel and the intermediate access, called "Discenderia" Tunnel) for about a total length of 5,060 Km, together with all the artificial excavations needed to connect them;

The feasibility study proposed by AGT Ingegneria, in co-operation with Geoingegneria and other experienced subcontractors, will include:

- The determination of the optimal location for the underground laboratory, based on the geological, the geomorphological and the hydro geological characteristics of the site, and taking into account the scientific requirements as well;
- The geological, geotechnical and geo mechanical characterization of the formations found in the area under investigation and in the selected site; the prediction of the mechanical behaviour of the rocks and the preliminary design of the underground pits, including the assessment and the check of the stabilization work for the excavation, achieved through the use of specific computing programs based either on custom code, developed within the companies, or on standard technical codes (f.e.m.), internationally used, such as: PHASES (Plastic Hybrid Analysis of Stresses for Estimation of Support), developed by E. Hoek, J.L. Corvalho e B.T. Corkum at the Toronto University; FLAC (Fast Lagrangian Analysis of Continua), developed by M.J. Coetzee, R.D. Hart, P.M. Varona e P.A. Cundall for the Itasca Consulting Group, Inc. Minneapolis, Minnesota, USA;
- The preliminary design of the infrastructure equipments (ventilation, power supply, etc.);
- The analysis and the study of the safety requirements and infrastructures;
- The preliminary design of the road links within the site, at all phases of the project (building, assembling and installation of the scientific equipment, normal working of the laboratory);
- The study and the evaluation of the environmental impact of the project;
- The estimation of the costs for civil works (excavation, structures, external roads) and of the time for the execution of the excavation and of the subsequent works.

2.3. Consortium as a whole

The consortium includes very different participants from academic and industrial sectors. These combine the best European expertise in their technical and scientific fields. Due to the many stages involved in the transferral of concepts into functional technical plans, dissemination of knowledge is guaranteed between the scientific community and industry throughout the process. This guarantees the best possible potential for the exploitation of the results of this study and of the subsequent steps.

There is a clear complementarity of expertise among the scientific partners of the consortium. They are united by common physics goals and form a community speaking the same language. A list of most relevant scientific publications by members of the consortium can be found below. The study gathers some of the top specialists in the field, working at some of the leading institutes in European particle and astroparticle physics, as can be seen in the list of selected references below. This will assure that results will be delivered within the given time and cost framework. A long and well-structured preparation process has brought the members closer together and created a strong spirit of togetherness. A common scientific paper has already been prepared and submitted for publication¹⁶.

At the same time, a clear fraction of the consortium is composed of industries, selected uniquely because of their level of expertise. These companies represent the highest level of expertise that can be found in Europe to solve a particular problem. We are fortunate to have them as partners rather than subcontractors. In this way, they will be better integrated in the workflow and the exchange between scientists and engineers will be more efficient. In addition, the synergy between different companies in different countries working together, exchanging local expertise, to study multiple sites, with open access to information, will be an enriching experience. This is also one of the reasons why we proposed them as technical partners and not subcontractors.

Overall, we expect that all members from different communities will be integrated and united within the goal of the DS.

Additional scientific partners could be tempted to join the DS at later stages. We can mention the U-Helsinki who has already expressed an interest. Similarly, some other members from European universities and institutions have expressed desire to join the effort, possibly at a later stage.

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2.4. Resources to be committed

The "added-value" of the DS revolves around the need for an integrated and coherent European effort towards next generation large-scale underground science. The site and tank engineering corresponds to two regions of focus (explicitly WP2, WP3, and WP5), where the FP7 funding is expected to make the largest impact. In addition, the DS includes coherent activities in detector instrumentation (WP4) and phenomenological and theoretical activities (WP6). In these latter, the involved institutes will commit their experienced manpower as shown in Table 1.3d, corresponding to roughly a dedication to LAGUNA of about 35% FTE per each participating physicist. This experienced staff will obviously bring along and make available their existing local infrastructure and available equipment to the DS project, in particular for what concern experimental activities. Below we list in more details resources from each participant:

- The ETH Zurich group will contribute with personnel and staff, available equipment, local and national funds and large infrastructure to the implementation of the project. In particular, the ETH Zurich group has 8 offices, 3 laboratories in Zurich, access to the mechanical workshop of the physics department and to that of the Paul Scherrer Institute (PSI) in Villigen (CH). In addition, it has 6 offices at CERN and has been assigned an area of 250 m² of equipped laboratory (crane, power, cooling, cryogenic facility) at CERN¹⁷. Available investments correspond to fully equipped mechanical and electrical laboratories, cryogenic equipment, UHV vacuum equipment, pumps, small dewars, detectors, chambers. In addition, central and local computing with large disk storage space and high-speed networking facilities are available. The overall local available budget is approximately of the order of 1.4MCHF/yr in personnel and several hundred kCHF/yr in investment.
- The group of LHEP Bern will contribute to the DS with personnel, funds, local infrastructure and equipment. LHEP has several offices and laboratories at CERN and in Bern. In particular in Bern we own a fully operational cryogenic laboratory where particle detectors and prototype liquid Argon TPCs can be built and operated, and a large laboratory that is being equipped to host the large size LAr TPC ARGONTUBE. For this purpose, we have set up a LAr supply tank with cold lines, a crane and a series of ancillary systems for vacuum and for the purification of the liquid. We have large computing infrastructure linked to the GRID, electronics and mechanical workshops. As far funding is concerned we account on university and national funds to be devoted to the project. Our historical connection with CERN and PSI will be beneficial to set up measurement campaigns also exploiting particle beams.
- The University of Oulu receives and expects to receive substantial additional funding from the European Regional Development Fund for projects whose goals integrate with this DS, but because

¹⁷ The use of this space is negotiated at regular intervals with the CERN management.

of EU regulations they cannot be counted as the local funding. The level of this funding is currently about 300 k€/year, and both the total amount and the share devoted to support LAGUNA may be significantly increased when LAGUNA is accepted.

- The DAPNIA (CEA) Department will contribute to Working Packages WP1, WP2, WP4 and WP6 with personnel (52 person x months) and with relevant equipment from its infrastructure: namely the detector and electronic laboratories (access to mechanical workshop, facilities for micro-pattern and large PMT detectors, for design and test of state-of-the-art front end electronics, etc.), the computing infrastructures, and the LSM (Laboratoire Souterrain de Modane of CEA/IN2P3) as host laboratory for the MEMPHYNO prototype.
- The IN2P3/CNRS is funding research on MEMPHYS, through the GIS (Groupement d'Interet Scientifique) PHOTONIS, an association of the order of 30 researchers (half from the photodetector company PHOTONIS and half from Photonis) for the development of novel and low cost photodetection elements. The researchers of LAL and IPNO are also leading a half a million euro project funded by the ANR (Agence Nationale de la Recherche) called PMM2, to develop advanced data acquisition systems including many photodetector elements. There are 5 laboratories of IN2P3 participating in LAGUNA (APC, LAL, LPNHE, CPPM and UCBL). They have on average 150 researchers and engineers each, developed mechanics laboratories (very large testing rooms in APC, CPPM and LAL), large expertise in electronics development. High level electronics experts participate in the project (C. Girerd from Lyon, C. De la Taille from LAL and also indirectly J. Pouthas from IPNO). The infrastructure of the Laboratoire Souterrain de Modane LSM will be available for the Design Study with a reasonable percentage of use of resources (10%). The Tier-1 level computing platform of IN2P3 in Lyon (CC-IN2P3) will be available for computing. Finally the legal, valorisation and financial services of IN2P3 will be used for the development of the contractual and financial aspects. The overall local available budget will be of the order of half a million euros in personnel and a quarter of a million in investment.
- The MPG(MPIK) will make available, in addition to its very highly qualified staff in experimental and theoretical physics, the following infrastructure for the DS: organic and inorganic chemistry laboratories including gas-chromatography mass spectrometer (GC-MS), UV/Vis spectrometer, Fluorimeter, IR-spectrometer, Atomicabsorbtion spectrometer, Karl-Fischer (and more); radio-chemistry laboratory, liquid scintillator production hall, low-level laboratory with 4 HP-Ge detectors, noble gas mass spectrometer, 2 HP-Ge detectors at LNGS, 1 ton low-background liquid argon detector at LNGS, Faraday room for PMT and electronic testing, clean room facility, mechanical workshops, glas technical workshop, construction office, computing (cluster with ~100 cpu)
- The Technische Universität München will contribute to the DS with the already existing infrastructure and personnel, local and national funding. The LENA project has received national funding for the years 2007 – 2010 through the SFB/TR 27 'Neutrinos and beyond', through the cluster of excellence 'Origin and Structure of the Universe' and from the Munich accelerator laboratory (MLL). The group at TUM has five offices, four fully equipped laboratories for scintillator handling and measurement of optical properties as well as for photosensor and electronics testing. The institute has its own mechanical workshop with 3 technicians, and access to the mechanical workshop and the electronics laboratory of the physics department. In addition, an underground laboratory at a shallow depth (15 m.w.e.) equipped with 3 Germanium spectrometers is available for background studies and high precision radiopurity measurements. Through the university's computing center (LRZ), the group has access to large computing power and storage space.
- The Polish groups will contribute with personnel and infrastructure. The infrastructure comprises several fully equipped laboratories for analysis of natural radioactivity using different techniques, including in situ measurements. The mechanical workshop for the production of wires for wire chambers is fully equipped and available.
- The Sheffield group will contribute experienced local academic staff and technical effort (Table 1.3d) supported by infrastructure built from past and current local and national grants. The group has 5 offices, 5 laboratories in the department of Physics and Astronomy and access to the central physics laboratory machinery and technicians. The laboratories include, vacuum, cryogenic and scintillator facilities with dedicated spectrophotometer, electronics, PMT robustness apparatus, liquid gas handling equipment all available to the project. The group can contribute also dedicated chemistry and optics laboratories equipped with liquid scintillator chemical apparatus, analysis and evaporators and reflection apparatus. The group also owns a dedicated ground floor fabrication building of 200 m² equipped with crane and construction facilities, faraday room, UHV apparatus, cryogenic facilities and a dedicated neutron beam cell with control room. The group's

responsibility at Boulby provides direct access to the full existing underground laboratory facilities there (1500 m² of space) including specifically a dedicated low background facility with Ge detector and radon detector systems.

Finally, one can expect specific local or global sources of funding, to be synergistically employed with the EU funds. In addition, some of the underground sites included in this DS already have substantial infrastructures that can be exploited for this DS. The hosts (mine, tunnel) will also provide their infrastructures like access to existing and planned laboratory sites, typically at true-cost basis, and they will be involved in and informed on relevant steps of this DS. Most of the numerical computation involved in the civil and mechanical engineering will rely on the available infrastructure at the technical participants' home base.

It is also to be expected that several scientists from universities or institutes other than those listed as beneficiaries, will directly or indirectly complement the EC contribution by giving their time to work on the topics pertaining to this DS. In particular, we expect the physics work package (WP6) to foster an environment for general discussions within the scientific community, in dedicated seminar, workshops or international conferences.

Last but not least, specific entities, like for example the University of Helsinki, will also contribute to the DS although there are not direct beneficiaries. Helsinki Institute of Physics is considering a major proposal to establish a neutrino physics group to study neutrino phenomenology related to LAGUNA and neutrino beams.

3. Impact

3.1. Expected impacts listed in the work programme

3.1.1. Direct impact of this DS on scientific performance of Europe

The Conceptual Design Report resulting from this DS will be delivered to the appropriate funding agencies and policy makers (ApPEC, ASPERA, national agencies) for their evaluation. After appropriate reviews and consultancy, the respective organisations are expected to make decisions to realise the considered infrastructures. This Design Report should contain all necessary technical information required for the decisions, to be combined with the scientific priorities of the decision time.

The physics studies related to or motivated by this Design Study may widen our understanding of the universe and the properties of elementary particles. Particularly these studies may have major impact on many other experiments using similar kind of infrastructures, techniques or equipment.

3.1.2. Direct impact of the planned experiments on particle and astroparticle physics

Astroparticle physics has evolved as a new interdisciplinary field at the intersection of particle physics, astronomy and cosmology. It combines the experimental techniques and theoretical methods from both astronomy and particle physics. Particle physics is devoted to the intimate structure of matter and the laws that govern it. Cosmology addresses the large-scale structure of the Universe and its evolution since the Big Bang. Astrophysics studies the physical processes at work in celestial objects. Most discoveries in particle physics have immediate consequences on the understanding of the Universe and, vice versa, discoveries in cosmology have fundamental impact on theories of the infinitely small.

In 2005 the CERN Council initiated a Strategy Group to produce a Draft Strategy Document (DSD) addressing the main lines of Particle Physics in Europe, including R&D for novel accelerator and detector technologies. The DSD¹⁸ was delivered to Council in July 2006 and unanimously approved. This document formed the basis of Particle Physics input to the European Roadmap on future, large-scale research infrastructures produced by European Strategy Forum on Research Infrastructures.

In this document, Council recognised that "A range of very important non-accelerator experiments take place at the overlap between particle and astroparticle physics exploring otherwise inaccessible phenomena; Council will seek to work with ApPEC to develop a coordinated strategy in these areas of mutual interest."

This DS will explore different detector technologies and different underground laboratory sites in order to identify the best strategy for future large-scale instruments in the domain of low energy neutrino astronomy as well as direct investigation of Grand Unification of the known elementary forces. Such detectors are needed for experiments where a small counting rate or weak interaction cross sections play a key role, notably the search for proton decay and for numerous applications in the area of neutrino physics and neutrino astronomy.

One major objective of such detectors is the search for proton decay, a fundamental process that has eluded detection, yet is a natural consequence of virtually all unified particle-physics theories. They are strongly supported by indirect evidence besides their compelling theoretical appeal. The detection of proton decay and the identification of the decay channels would be a major discovery, providing us with new and deep insights into the structure of matter at extremely small scales.

The second major motivation obtains from the unique capabilities of the proposed large-scale detectors in the area of neutrino physics. These detectors allow for unprecedented measurements of fundamental neutrino properties, providing crucial input for the understanding of the elementary structure of matter. In addition, one can probe the properties of the neutrino sources, notably the Sun, core-collapse supernovae, and the Earth itself.

The solar neutrino flux would be measured with unprecedented accuracy, allowing for real-time observations of the Sun in the "light of neutrinos." Such precision observations would both improve our understanding of the Sun as a typical main-sequence star and lead to a much improved measurement of the neutrino mixing parameters that are responsible for solar neutrino oscillations.

Atmospheric neutrinos will be observed with high statistics and superior angular resolution, allowing for improved measurements of atmospheric neutrino oscillation parameters. Turning the argument around, this would also lead to a better understanding of the primaries and the neutrino production in the atmosphere.

¹⁸ The CERN Council, in a special meeting held the 14th of July 2006 in Lisbon, agreed on the European strategy for particle physics. The strategy is defined by the 17 statements approved by Council, and contained in the Strategy Statement (available at <http://council-strategygroup.web.cern.ch/council-strategygroup/>).

The large-scale detectors that we study would have outstanding capabilities to observe in detail the spectral and temporal features of the “neutrino light curve” from a core-collapse supernova in our galaxy. Such an observation would provide crucial tests of the core-collapse paradigm and the delayed explosion mechanism. In combination with electromagnetic and perhaps gravitational-wave observations, a true multi-messenger understanding of this spectacular phenomenon would be obtained. Moreover, the neutrino signal carries information about neutrino mixing parameters that conceivably can be extracted with a large-scale detector.

Galactic supernovae are rare, perhaps a few per century. Still, one can detect the cosmic diffuse supernova neutrino background (DSNB) that originates from all past core-collapse events in the universe. Observing this flux would push the frontiers of neutrino astronomy to the edge of the visible universe, providing information, for example, about the cosmic star formation history.

Recently the Earth itself has been added to the list of measured natural neutrino sources. Studying these “geo neutrinos,” i.e. anti-neutrinos from the decays of natural radioactive elements in the Earth's mantle and crust, may eventually lead to serious geological investigations with neutrinos. The large detectors studied here could play a pioneering role in this field.

Reactor anti-neutrinos are a background for many of the delicate measurements envisaged with the large-scale detectors so that locations far away from nuclear reactors are desirable. On the other hand, reactor anti-neutrinos allow for very interesting measurements so that we will study scenarios where a reactor would be visible only for some time because of a movable or switch-on situation.

In combination with a neutrino beam, large-scale detectors allow for very precise measurements of oscillation parameters. These measurements aim - amongst others - at determining leptonic CP violation, which likely is connected to the creation of the matter-antimatter asymmetry of the Universe.

The origin and evolution of earth's geomagnetic dynamo is tied to its energy sources, and this in turn depends on the composition of the core. Does earth's core contain a natural “geo-reactor”? By observing the number of neutrinos emanating from the core large underground detectors will measure radioactive decays in the earth's core to determine whether a geo-reactor sustains the earth's magnetic field.

The physics behind some of these observable effects has also interesting consequences for up-coming experiments at the Large Hadron Collider (LHC) and in Lepton Flavour Violation experiments (LFV). The LHC, for example, will test if the Minimal Supersymmetric Standard Model or some other new physics is realized in the TeV energy range. This will be a direct test of the extension of the particle spectrum, which is required for the unification of the known couplings of the electromagnetic, weak and strong forces. The type of extension has a sizable effect on the scale where proton decay is mediated, significantly affecting the expected proton lifetime. In addition the expectations for the dominant proton decay modes depend on the physics results to be found by the LHC.

3.1.3. Impact to technological development capacity in Europe

In addition to a boost to all the physics and engineering technologies associated with the tank and detector aspects of the project, we highlight here the anticipated major impact on the technological expertise of Europe in all aspects of underground engineering, safety and environmental fields across a range of disciplines. There is an ever-increasing demand for underground space worldwide and Europe holds leading positions in the field. However, there remain major engineering challenges to solve. An underground laboratory would provide both the academic and industrial communities with low-cost, long-term access to underground research sites to address these issues. For instance, progressive and sustained underground research is needed to develop new technologies for accurate prediction of rock behaviour, to understand the stability of deep underground constructions, the consequences of engineering activity there, the strength dependencies and mechanical properties of rock and the wider environmental impacts.

A deep massive volume underground laboratory as proposed provides a unique opportunity to address these challenges by making available a dedicated volume of rock directly accessible for long-term scientific and engineering research. A wide collection of rock engineering studies can then address fundamental questions in rock geophysics, expanding our technological capacity in areas such as fluid flow in rocks, excavation stability vs. rock fracture, and the relationship between high rock stress and increases in hazardous ground behaviours. A large, dedicated facility would also allow trials of new underground equipment to take place under controlled conditions free from constraints imposed by mining or tunnel operations.

All these aspects are core impacts available from the LAGUNA DS, which requires an engineering program to include rock characterization, design and construction, rock engineering, underground technology and safety. The engineering research envisaged will stimulate advances in underground construction techniques, improving cost-effectiveness and reducing risk. It will benefit European capacity and efficiency in the field by uniting expertise from different sub-fields, notably mining engineering with road tunnel engineering, and uniting activities across many countries. This process can build also on the

demonstrated success of the FP6 ILIAS underground laboratory programme, which has, for instance, developed new approaches to the technology of safety underground.

A particular aspect anticipated will be technological impact on the development of better sensing techniques to characterise rock at depth - the development of emerging remote imaging technologies. This would be a core component of the underground engineering program providing an excellent opportunity for geoscientists and engineers to cooperate on new technologies. Studies of rock variables include hydrodynamics, plastic flow, gases, impact strength and fracture mechanisms. The ability to recognize and characterize rock complexity is important for design and construction of large underground caverns. Meanwhile, the combination of depth and large span plus the need for stability for over 50 years stretches current knowledge. The construction period itself provides a unique opportunity for development of excavation technologies and designs.

Of the highest importance, for what will be a civil facility possibly in a working mine or transport tunnel, is safety and environmental impact. These must be fully integrated throughout the planning, design and construction stages. The design study and subsequent laboratory thus provide an ideal route for developing advances in safety systems and technology. Particular attention would go to advances in areas such as underground communication, fire prevention, ventilation, access, emergency egress and refuge design. Advances in environmental science and engineering are also possible. For instance, rock temperatures increase typically at 1-3 °C per 100 m of depth. This provides a means to undertake mechanical-systems research into environmental life support such as air conditioning and filtration at depth.

3.1.4. Impact on society

Environmental pressures, global warming, increasing population densities, increasing energy requirements, water shortages and protection of water supplies, growing transport systems, waste storage and disposal issues, increasing demand for scarce minerals and raw materials and concern for Earthquakes are all contributing to an accelerating demand worldwide for underground activity and the technology to support it. The LAGUNA programme, can provide clear impact on this demand from society.

For instance, new and deep underground laboratory space can provide vital access for research into geothermal energy and water flow behaviour in relation to fissures and rock mechanics. The latter can provide input to reservoir design and development to allow improved protection of drinking supplies. Bioengineering has a role to play here in understanding water purity aspects but also the possibility of improving waste disposal underground and carbon sequestration as a route to reduction of CO₂ in the atmosphere.

Radon emanation and fluid flow underground is now known to be related to rock seismic activity at depth. This opens the possibility of a route to prediction of Earthquakes. New underground laboratory space would offer the opportunity to measure directly the relationships and confirm the seismic properties of rock in this respect. In particular, this would allow researchers to understand the time-development of fault processes and hence produce improved computer simulations to allow predictions to be made of possible future earthquake activity that could have severe impact on local populations.

Life is now known to exist underground, in fact accounting for around 50% of the Earth's biomass. It is even possible that life originated deep underground. A new discipline in biology, geomicrobiology, has emerged to study this deep subsurface microbe population ("dark life"). The studies could have extreme implications for society, including progress towards an understanding of the origins of life, the impact of the biomass on the environment and evolution of the Earth. Development of pristine underground areas is now vital to the research and would stimulate further merger of fields as diverse as geochemistry, geology and hydrology with biology and genetics. The interaction of this life with the environment past and present is not understood and there are likely new practical applications that will emerge. The future large underground facility will offer an exceptional opportunity to carry out the studies needed.

3.2. Dissemination and/or exploitation of project results, and management of intellectual property

This DS has a clear "user chain" flow for dissemination and exploitation, as illustrated in Figure 15. As was mentioned in the ApPEC/ASPERA roadmap, this DS emerges from a need of the scientific community. During the DS, the many reports to be compiled (see deliverables list) will serve as database of open documents. Any publication will be opened to the public and be disseminated in various ways:

- The intermediate results and the status of the project will be reported to the scientific community by regular presentations in conferences, workshops and seminars.
- A web page showing the goals, results and status of the project will be set up and maintained by the LAGUNA executive board and secretariat.
- Technical reports resulting from this DS will be made available for all interested parties by electronic distribution.

- Scientific results will be published according to good scientific traditions in journals, reports and conferences.
- The final technical report (CDR) will be announced on month 36 and distributed to the community, to the funding agencies, and where appropriate to the press.
- The “deep science” document will be printed and distributed to funding agencies, universities and schools worldwide.
- The LAGUNA web site will remain active even after month 36, although updates will be less likely to occur.

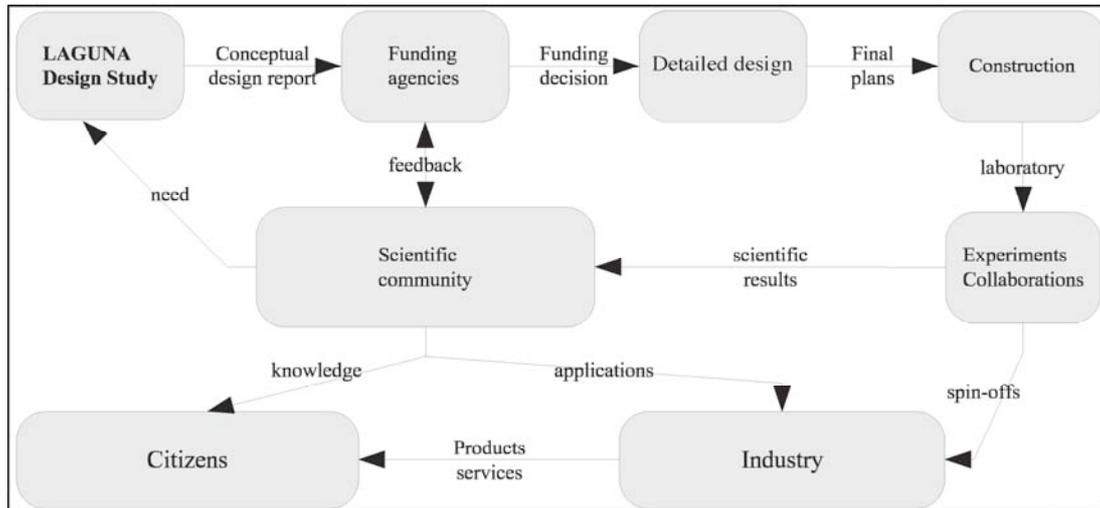


Figure 15 User chain flow.

The results of the studies will be published in a series a document, culminating with the final CDR document. The CDR will contain the objective and scientific information needed to reach the funding and construction phase. Assuming a positive feed-back from the funding agencies, the final CDR technical report will be a starting point for a subsequent detailed design work. This would lead to final plans for construction and approval of the new research infrastructure. The experimental results to be obtained in the research infrastructure will provide top-class, forefront scientific results, which will feedback to the scientific community. Of course, citizens will be part of the process and will acquire knowledge from the scientific community. Similarly, direct spin-offs and applications will feed into the industrial component, which itself via products and services will provide improved quality of life to the citizens.

No serious issues related to intellectual properties management are expected, as the design study will produce information to the public, except otherwise governed by specific intellectual property rights or a confidentiality agreement, like e.g. in a few explicit internal items related to the exploitation of particular sites. In particular, some information about the mines will not be made public.

4. Ethical Issues

No ethical issues are expected to arise during the course of the Design Study.

	YES	PAGE
Informed Consent		
• Does the proposal involve children?		
• Does the proposal involve patients or persons not able to give consent?		
• Does the proposal involve adult healthy volunteers?		
• Does the proposal involve Human Genetic Material?		
• Does the proposal involve Human biological samples?		
• Does the proposal involve Human data collection?		
Research on Human embryo/foetus		
• Does the proposal involve Human Embryos?		
• Does the proposal involve Human Foetal Tissue / Cells?		
• Does the proposal involve Human Embryonic Stem Cells?		
Privacy		
• Does the proposal involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)		
• Does the proposal involve tracking the location or observation of people?		
Research on Animals		
• Does the proposal involve research on animals?		
• Are those animals transgenic small laboratory animals?		
• Are those animals transgenic farm animals?		
• Are those animals cloning farm animals?		
• Are those animals non-human primates?		
Research Involving Developing Countries		
• Use of local resources (genetic, animal, plant etc)		
• Benefit to local community (capacity building ie access to healthcare, education etc)		
Dual Use		
• Research having potential military / terrorist application		
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	Yes	

5. Consideration of gender aspects

Both genders are naturally represented in the DS. Out of the 24 participants, women lead the following four: Prof. Caren Hagner (U-Hamburg), Prof. Agnieszka Zalewska (IFJ PAN), Prof. Ewa Rondio (IPJ), Prof. Silvia Pascoli (U-Durham).

During the duration of the DS, all efforts will be made to promote gender equality in an appropriate way, and to treat minorities on an equal basis.

6. Glossary on Initiatives and Committees in the field of astroparticle physics and related fields

ApPEC

ApPEC stands for Astroparticle Physics European Coordination. This is a group of national funding agencies which came into being in 2001 when six European scientific agencies (later growing to thirteen) took the initiative to coordinate and encourage Astroparticle Physics in Europe. ApPEC's main activities are:

- developing long-term strategies,
- expressing the view of European Astroparticle Physics in international forums,
- assessing astroparticle physics projects with the help of a Peer Review Committee,
- preparing a roadmap for astroparticle physics in Europe (the present document) which will serve as stage I of a process to be continued under the coordination of ASPERA.

ApPEC's work rests on two bodies: the Steering Committee (SC) and the Peer Review Committee (PRC, at present functioning as "Roadmap Committee").

<https://ptweb.desy.de/appec/>

ASPERA

ASPERA is a network proposed by ApPEC. It has been established as a four-year ERA-NET project under the European Commission's Sixth Framework Programme (FP6), by funding agencies and ministries from 17 national agencies in Europe responsible for funding astroparticle physics. It also comprises two transnational agencies: CERN as full participant and ESA as associated partner.

ASPERA has the following main goals:

- study funding and evaluation of astroparticle physics in Europe and identify formal and legal barriers to international coordination,
- define a roadmap on infrastructures and R&D (the phases II and III of the present roadmap),
- test the implementation of new European-wide procedures of common funding of large infrastructures and the corresponding R&D,
- explore the further linking of existing astroparticle physics infrastructures,
- install a common information system (a database and a website).

<http://www.aspera-eu.org>

CERN Strategy Group on European Particle Physics

This panel was established in June 2005 by the president of the CERN Council in order to produce a draft European roadmap for particle physics. A one-year procedure included several meetings of the Strategy Group as well as open meetings. It resulted in a three-volume Briefing Book and eventually in a two page strategy paper (CERN Courier, Sept 2006) which was adopted by the Council in July 2006. Representatives from ApPEC (both Steering Committee and Physics Review Committee) have been participating in the meeting of the strategy group. The two-page strategy document focuses on accelerator physics activities but also highlights astroparticle physics by summarizing "A range of very important non-accelerator experiments take place at the overlap between particle physics exploring otherwise inaccessible phenomena; Council will seek to work with ApPEC to develop a coordinated strategy in these areas of mutual interest".

<http://www.cern.ch/council-strategygroup>

