Liquid Argon Purity Demonstrator (LAPD) - Preliminary

Internship for Physics Majors and Science Undergraduate Laboratory Intenship

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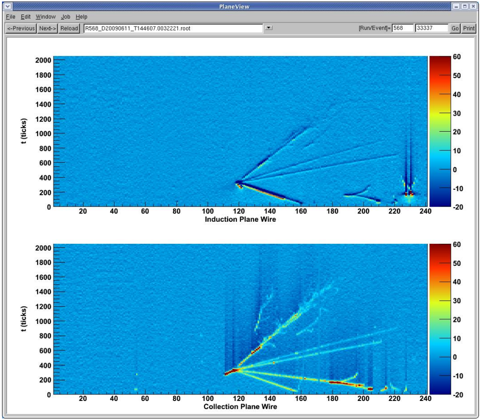
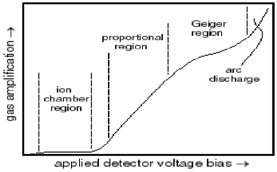
Introduction

Liquid Argon is used for neutrino detection. The following scheme shows an event that took place in a LArTPC (Liquid Argon Time Projection Chamber) at Fermilab.



Introduction

- LArTPC is an application of a drift chamber.
- DRIFT CHAMBERS use the fact that the liberated electrons take time to drift from their point of production to the sensing planes.
- We are working in the ion chamber mode, since we have a liquid rather than a gas.



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Introduction

- Why are we using Liquid Argon?
  1. It is not expensive.
  2. It is a inert element
  3. It is ionizable and gives off light in the process.
  4. Using Ar on its liquid form increases the rate of interaction because there is more mass in a finite volume.
- The atmosphere is composed of aproximately 20 percent of 0_2. If oxygen is in the cryostat it will eat up electrons.
- If the oxygen content exceeds 100ppt it will kill our measurements.
- In the past, taking a vessel down to vacuum has solved this problem; however, evacuation is very expensive for a massive tank size.

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Steps for the test

- The proposal is that the evacaution is not needed, instead we will use an argon piston.
- TEST
  1.In order to remove the oxygen and water, Argon gas will be introduced in the bottom of the chamber, pushing the lighter atomosphere to the top of the vessel. Gaseous argon will be circulating till the purity level is achieved (50 parts per million).
  2. Once we achieve this purity the LAr will be introduced and will be circulating till we have 100 parts per trillion, as the LAr circulates it will pass through some filters designed to remove water and oxygen.
  3. Then, all the structural components of a potential detector will be put in place in order to check that purity remains.

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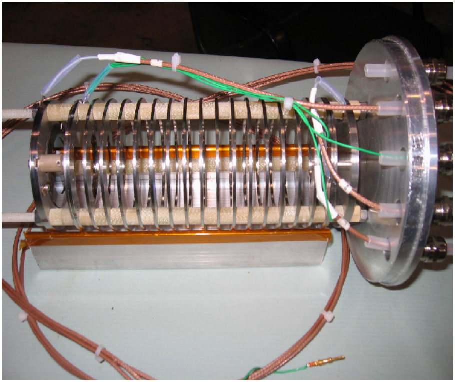
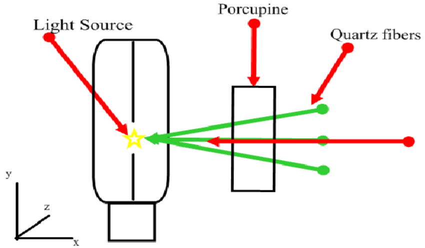
Purity Monitor

- HOW DO WE MEASURE HOW PURE OUR ARGON IS?
  Purity monitors measure purity by means of the electron life-time. A light pulse from a xenon lamp is fired at a photocathode, ejecting electrons. These are drifted to the anode with an electric field. The number of electrons surviving the transit from the cathode to the anode gives a measure of the argon purity.



- Since our cryostat is not evacuated, our phototubes have a low quantum efficiency. Therefore, in order to have strong readings we need more light.
- With such a large-scale argon purification system , we want to maximize the light capture from every single Xenon Flash Lamp.
- We used a device that holds and aims multiple fibers at a central focus.
- We constructed a test to measure the differences in the amount of light traveling through each fiber.



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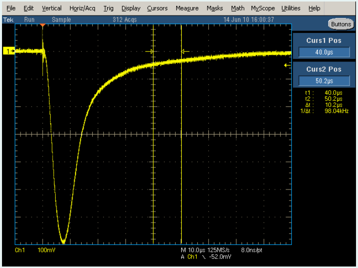
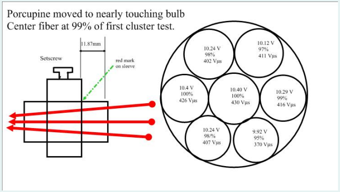
A graph and a scheme of our measurements. Using the scope we found the maximum peak in the middle fiber and then we measured the drop percentage in the other fibers

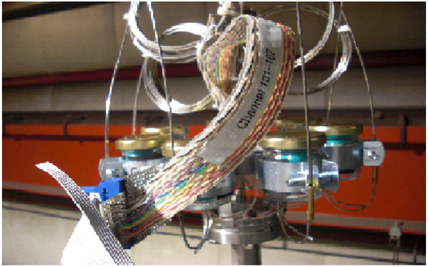




We can conclude that the outside fibers of the porcupine were within our target limit of 30 percent light difference .

Oxygen sensors and Capillary

In order to study in detail the Argon gas purging process in a non-evacuated $15m^3$ tank, 14 sampling tubes will be installed in two bundles, one at the center and one at the edge of the tank. Each bundle will sample the oxygen content at seven different elevations (about 90cm apart) as Argon replaces ambient air in the tank. Each sampling tube connects to a separate capsule containing an oxygen sensing cell, which is read out continuously by a scanning system.



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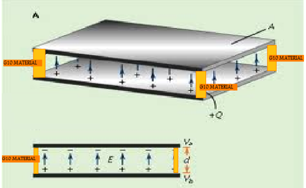
- We need a material suitable for structures inside the cryostat and which will allow the distance between our sensing planes to stay the same.



- These materials should not affect the electric field inside the plates.
- G10 materials have extremely high strength and high dimensional stability over temperature. We tested two different types of such G10 material.
- An important characteristic of these materials is high resistivity.

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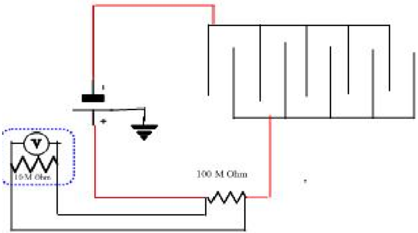
Discharge time

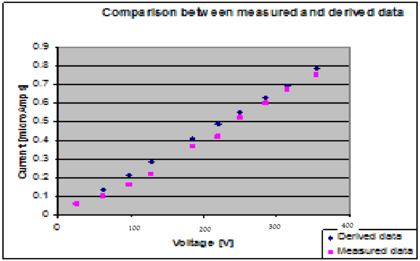
The structures need a resistance high enough to prevent current flow as the voltage we will have is about $50000 V/m$ but to still allow some discharge so as to prevent charge build up. An accumulation of charge might distort the electric field.

- If we recall the formula for the discharge of a capacitor : $V(t) = V_0 e^{\frac{-t}{RC}}$
  Where : $\tau = RC$ is the time constant.
- The discharging process needs to be slow, which is why the resistance needs to be big.
- In order to have a stable discharging process, the internal properties of the materials should be uniform. With the black G10 material we were looking for a uniform resistivity.

G10

As a regular ohmmeter can not measure high resistance, we used a HVPS (2500V) and followed the next circuit. Also we show a graph of our results.





The resistivity was found to be 1020$M\Omega * m$ under room conditions. On the other hand, under cryogenic conditions we could not measure any specific voltage across the resistor, as the voltmeter kept bouncing between 0 and 1.2mV.

In order to clarify the previous situation, we proceeded in a different manner. We used a G10 plate sandwiched between two thin cooper plates. The area of these plates was 378.56 cm^2 and the thickness of the plate was 0.63mm.

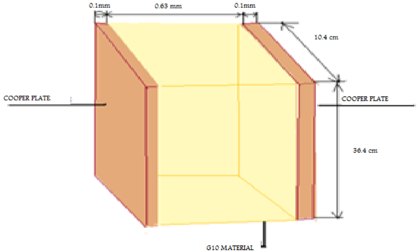


Table 1. Under room conditions.

Voltage(V)	Current(Amp)
0	0
50	103 E-9
75	142 E-9
100	188 E-9
125	170 E-9
150	220 E-9
175	260 E-9
200	320 E-9
100	98 E-9
50	37 E-9

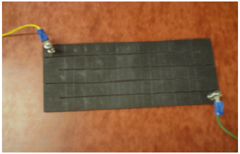
Table 2. Under cryogenic conditions

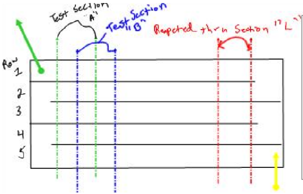
Voltage(V)	Current(Amp)
0	0 ±10 E-12
50	0 ± 30 E-12
75	0 ± 50 E-12
100	0 ± 100 E-12
125	0 ± 40 E-12
150	0± 100 E-12
175	0± 200 E-12
200	0 ± 100 E-12
250	0 ± 300 E-12
300	0 ± 100 E-12

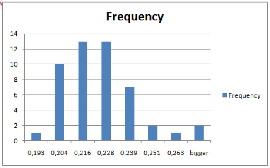
We found out that the resistance was aproximately 3$T\Omega$

ESD G10

- We had a plate where saw cuts were made.
- We applied $5V$ to it.
- We constructed a test for measuring the resistivity, a scheme of this is shown here:







We concluded that the resisitivity in this material is uniform. In this material the resistance doubled when we passed from room to cryogenic conditions.

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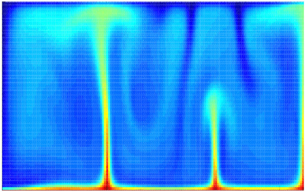
- When we have temperature gradients in a location of space,we expect to have heat transfer. One way of heat and mass transfer is convection.



- Convection currents inside the cryostat may change the electrons path and therefore our measurements.
- We need to make sure that these currents are not strong.
- In order to calculate the currents using a program we have to have the temperature distribution inside the cryostat.

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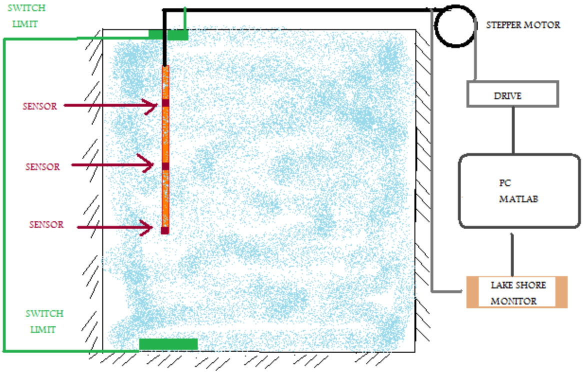
Objective

- In order to measure the temperature distribution inside the chamber we need a device such that we can automatize the process.
- We also require precise coordinates of the place where we are taking measurements.
- We need to take several measurements at the same time.
- We need a device able to get precise measurements of cryogenic temperatures.
- We need to be able to cross calibrate to insure accurate measurements.

Scheme of the scanning process



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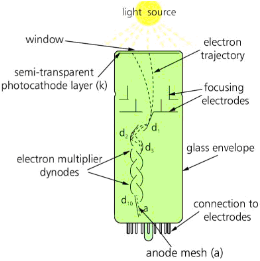
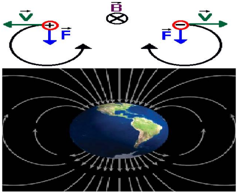
As the ionization is taking place, light will be produced, this is why a light detector will be needed. The detector we are using is a photomultiplier.



Introduction

- $\overline{F} = q\overline{v}x\overline{B}$



- The magnitude of the Earths magnetic field is aprox $30 - 60 microTeslas$.
- This field considerably affects the electrons path.

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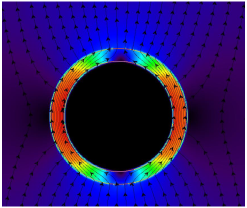
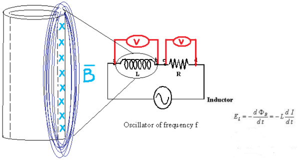
Magnetic shields

In order to stop this process we need a high permeable material such that it sucks in the Earths Magnetic Field.
The goal of this experiment was to study that the permeability of the material under cryogenic temperatures does not change.



We tried to calculate the permeability of the shield by using the following technique:



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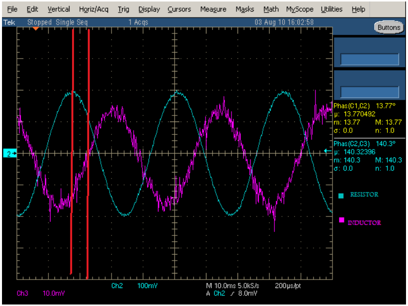
The following graph shows the voltage across the resistor and the inductor. We can see a phase difference between them which does not corresponds to what we should see.



We also tried to calculate the permeability using this shield as a transformer but we had the same phase difference problem. Therefore, we couldnt measure this property under different conditions.

Special Thanks

Special Thanks for making this a unique experience:

- Erik Ramberg, Roger Dixon, Eric Prebys.
- Carol Angarola, Amanda Petersen and Susan Q. Brown.
- Stephen Pordes, Hans Jostlein
- FUNDACION HERTEL
- To my little brother who told me about this.