LB report – Technical Issues section

October 26, 2006

While LArTPCs show great promise with excellent efficiencies and background rejection for a variety of physics goals, they have not yet been demonstrated on scales larger than ∼1 kton in size. An active R&D program culminating in the success of the T600 program [1] has illustrated the capabilities of the detector, however, further R&D is necessary to consider massive detectors, on the scale of tens of ktons.

There are several different design ideas for massive detectors including a modularized detector [2], a single detector but with modularized drift regions [**?**], and a single open volume, very long drift detector combining charge and light collection [**?**]. The technical issues described here are relevant primarily for single massive detectors with modularized drift regions, the design studied by the contributors to this study. For these, there are no clear showstoppers to scaling to detectors on the scale of 50-100 ktons, however, there is an R&D path that must be realized in order to consider massive detector construction, operation, and data analysis. Details on this path and major R&D goals can be found in [3]. The major challenges for scaling to a large detector include:

- Argon purity
- Signal to noise in a massive TPC
- Understanding Cost and Schedule

Progress and path for each of these is described below.

For ionization electrons to drift 3m in a LArTPC, a 10ms electron lifetime must be achieved and maintained. Studies from the T600 run suggest this is possible, however, for a massive detector, modifications in the purification system and ability to reach purity levels necessary in an industrial environment, beyond what has been learned with the T600, must be understood. Over the past year, Fermilab has embarked on purity testing towards this goal. They have developed a new, Trigon filter which is not proprietary (like those used in the T600) and can be regenerated inline. With this filter system, Fermilab has achieved 12ms lifetimes in a small test vessel. Over this next year, purity studies will continue with a Materials Test Stand [4] at Fermilab where argon will be re-purified after being exposed to contaminants expected in a massive LArTPC. An added challenge to purity is a consequence of inability to achieve vacuum before the initial argon fill in a massive detector. An idea to purge the vessel with clean Argon gas prior to liquid fill is being tested at Fermilab now with studies continuing in the upcoming year [5]. While purity is a major concern for feasibility of a massive detector, first tests using small vessels suggest it is a solvable problem.

A very massive detector will have signal wires as long as tens of meters. Long wires present challenges related to wire breakage, wire assembly and stringing, and electronics noise. Existing R&D work at Fermilab focuses on assembly techniques and noise pickup using a long wire test stand at Lab 6 [6]. Work on electronics design to minmize signal to noise specifically by employing cold electronics, is underway at Fermilab and Michigan State University. A new idea for internal wire configuration, a cellular design, avoids many of the stringing and assembly problems of long wires by stringing wires onto pre-assembled ladders before installation. These ideas, described here [7] are presently under study at Fermilab as well.

There are two cost drivers for a liquid argon TPC which have some certainty at this point. The first of these was given by the LArTPC group in its September 2005 report to NuSAG [reference Fermilab Note: FN-0776-E or better]. There, the cost of liquid argon alone (without a purification system) is reported as about $1,000,000 per kiloton. Subsequent to that report, a simple scaling relationship has been developed based on information from two vendors for tanks appropriate for containing liquid argon (but without modifications required to put a TPC inside it). This relationship, which is expected to be valid between 5 ktons and 50 ktons, is $2.72M + 0.306 $M/kton. Thus taking a 50 kton detector as an example, these two cost drivers (the liquid argon plus a containment tank) would cost about $50M plus $18M or $68M.

There are many other costs, both technically driven and project driven, but the design of the TPC itself needs to be specified in more detail before such a more complete costing exercise can sensibly converge. For example, the recently developing cellular design for the TPC itself significantly changes the requirements on the containment tank compared to the design in the September 2005 LArTPC report to NuSAG. Also, since this design allows for fabrication of the TPC wire planes themselves at the same time the containment tank is being constructed, and since the assembly of the cells inside the containment tank will take less time than the previous design, the schedule for construction of the detector is shorter. If electronics are used in the liquid argon itself, the cellular design will change and the requirements on pattern recognition will become easier. Finally, the idea of using several smaller tanks to achieve a large mass will impact the cost of the purification system as well as the cost of the containment tank(s). These are some of the design choices for the TPC that need to be made before a cost estimate of the technical components, other than the liquid argon itself and a cost for a single containment tank, can be made.

In addition to the major challenges for scaling to large detectors as described above, issues relating to detector siting have also been studied. Water Cerenkov detectors for these physics measurements must be located deep underground due to cosmic backgrounds. By contrast, Liquid Argon detectors can likely be located on the surface, or near surface, with some overburden. As part of this study, cosmic rates in a massive LArTPC detector were calculated and their impact on the physics program was considered [8] and is discussed in more detail in section **??**. If massive LArTPCs are sited with some overburden, such as at the 300ft drive in site at Homestake, cavern construction for these detectors must still be understood. As part of this study, cavern designs modeled after liquified natural gas vessels built within ships hulls were considered [9]. This design is promising and studies on this are ongoing.

The R&D path towards a massive detector includes small scale tests and studies as described above. Construction of a significantly larger prototype, ∼1kton, is also likely necessary before embarking on the massive detector project. The details of this R&D path at Fermilab will be addressed within the next year.

References

[1] S. Amerio *et al.* [ICARUS Collaboration], "Design, construction and tests of the ICARUS T600 detector," Nucl. Instrum. Meth. A **527**, 329 (2004).

[2] D. Cline, "LOI for a Study of a LANNDD of 100kTon at Homestake DUSEL", submitted to the Homestake PAC, 2006.

[3] See response to question from NuSAG on R&D path

[4] D. Finley *et al.*, "Work at FNAL to acheive long electron drift time in Argon". Writeup for the FNAL/BNL Long Baseline Study.

[5] S. Pordes, Argon Purging writeup for the FNAL/BNL Long Baseline Study.

[6] D. Jensen, Long Wires technical note for the FNAL/BNL Long Baseline Study

[7] H. Jostlein, Cellular design technical note for the FNAL/BNL Long Baseline study

[8] D. Gerstle and S. Pordes, "Cosmic Ray Rates on a Surface Liquid Argon TPC". Writeup for the FNAL/BNL Long Baseline Study.

[9] C. Bromberg, "Deep Underground Cryostat for a LArTPC". Writeup for the FNAL/BNL Long Baseline Study