R&D Toward Large Liquid Argon Time Projection Chambers

- "Large" means up to 100 ktons
  - density of 1.4 g/cc means it is at least 35m diameter and 20m tall
- How does a TPC work?
  - Charged particles ionize argon atoms leaving a trail of electrons which are moved in a uniform electric field to planes of wires. The position of the electrons at the wires give x and y, and the time of arrival gives the distance from the wires where the electrons started.
  - The longest drift so far is 1.5m (ICARUS) and we now aim for 3m to 5m

R&D Toward Large Liquid Argon Time Projection Chambers

- What good is it?
  - Position resolution of millimeters
  - Energy deposition resolution can distinguish single particle from multiple particles
    - distinguishing single electron from electron positron pair from gamma conversion allows for pi_zero identification from neutral current single pion production … this is one of the major backgrounds in neutrino experiments looking for nu_e appearance, and another is photons from cosmic rays
  - Liquid argon transmits light (Cherenkov, scintillation)
  - Can be made really big with lots of mass … advantage for proton decay (lots of nucleons), neutrino experiments (supernovae, oscillation, maybe CP violation with leptons …)

R&D Toward Large Liquid Argon Time Projection Chambers

- Good and Bad
  - The good thing is it sees nearly everything.
  - The bad thing is it shows nearly everything and you have to handle it.
- Why is it not the chosen one?
  - Seen as riskier than other options at this time.

D. Finley to DOE Annual Review of Fermilab
May 17, 2006

Fermilab efforts on LArTPC

- Focusing technical effort on issues related to the "Big Tank"
  - Finish the assembly of a Purity Test Station to qualify materials for the Big Tank
  - Model and measure how well one can use argon gas, as a first step, to purge oxygen from large tanks similar to the Big Tank
  - Understand the issues for integrating a TPC with long wires into the Big Tank (mechanical issues, electrical issues, the TPC surviving in a big bath of LAr, achieving and maintaining LAr purity with a TPC in it, etc)
- Building on FLARE LoI of August 23, 2004
- Forming people connections which should lead to collaboration(s) including people from INFN, ICARUS, universities and elsewhere

Purity Test Station at Fermilab (under development)

A test station to study (a) the contamination of LAr by various materials and (b) the efficacy of various 'filters' for the removal of oxygen (and other electronegative species)

In May 2006, we achieved a purity which scales to a 3 meter drift with a 20% loss of electrons, meeting our goal for electron lifetime in the Big Detector.

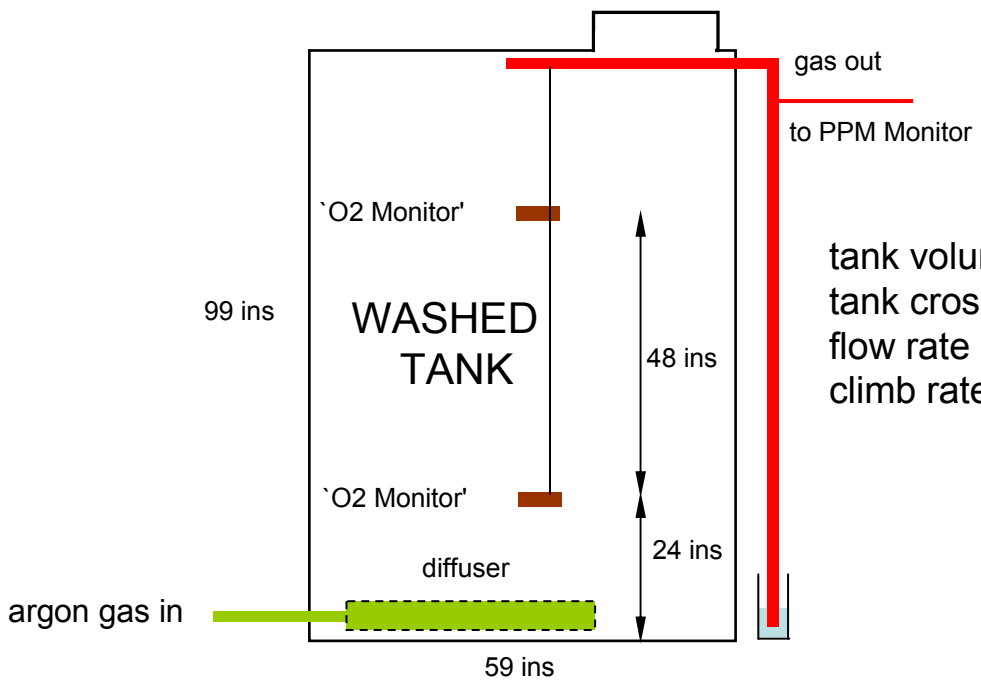
LArTPC: Purging a tiny tank

Test of purging a volume from atmosphere:

insert Argon gas at bottom of tank over large area at low velocity;

the Argon introduced being heavier than air will act as a piston and drive the air out of the tank at the top;

fewer volume changes than simple mixing model will achieve a given reduction in air concentration.



tank volume = 157 cf
tank cross section = 19 sf
flow rate ~ 73.2 cf/h (reading for air was 86 scfh)
climb rate ~ 3.8 f/h

The Tiny Tank …

… behind an average sized Engineer.

(The very small tank to his right is a “bubbler”.)

Purging a “Small Tank”

- The “Village water tank” has a volume the same as ~1,000 tons of liquid argon (1.40 g/cm^3).
- It was part of the village of Weston.
- The intention is to use it to challenge models of purging tanks with a “piston” of argon gas.
- Question: How does sunshine mess up the measurement?

1 kton represents the smallest “quantum”

Liquid Argon TPC Overview for NuSAG

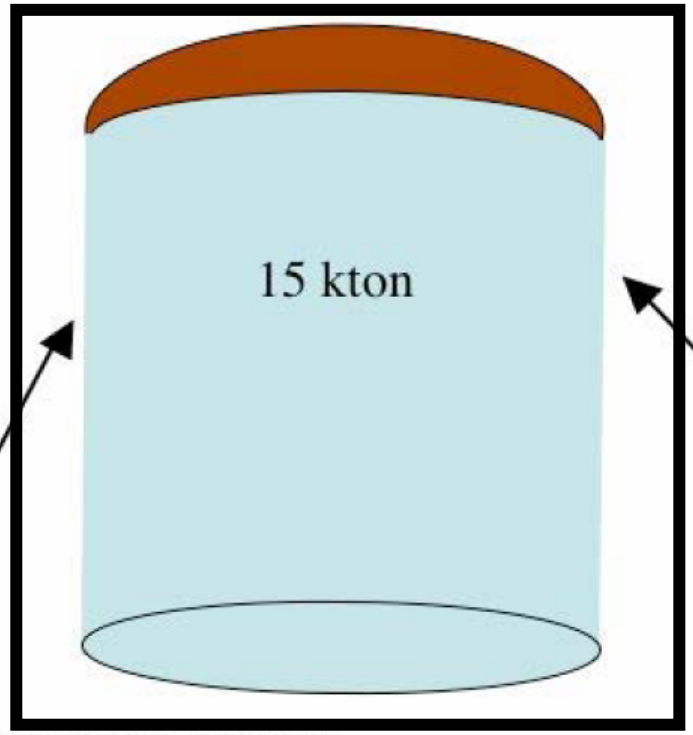
Note: At this point in time …

"15" could be "50"

"1" could be "3"

etc

The optimum choices depend on the goals.



Submitted to NuSAG

Summer 2005

Fermilab plus 6 universities

Physics Development *using* ***existing*** *technology*

Record **complete neutrino interactions**: (ν_e & ν_μ)

Establish **Physics Collaboration**

Develop **Event Identification**,

Develop **Reconstruction**,

Develop **Analysis**,

Establish successful **Technology transfer**

Engineering Development:

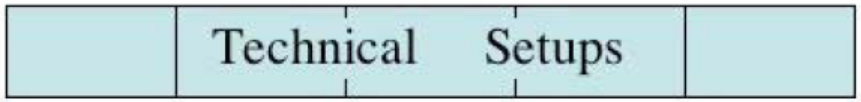
Construction of Tank

Argon Purity

Mechanical Integrity of TPC

Readout S/N

Microphonics due to Argon Flow



Purity Monitor Development | Materials Tests | 5 m Drift Demonstration | Long Wires Tests | Electronics Development

NuSAG February 28, 2006

6.2.3 The U.S. R&D program in Liquid Argon TPC's should be supported at a level that can establish if the technology is scalable to the 10-30 kiloton range. If workable, this technology will come into its own in the later phases of the long-baseline program.

NuSAG's charge suggested that we consider this technology as an alternative to NOvA. This was not the case presented to NuSAG by the proponents or by Fermilab. Instead, use of a liquid argon neutrino detector in later phases of the program is contemplated, possibly for a second detector in the NOvA program.

Besides dealing with longer wires, higher voltage, and longer drift times than the existing Icarus modules, cost reduction by about an order of magnitude will be required to make a 10-30 kiloton detector feasible.

NuSAG June 27, 2006

NuSAG Suggestions/Questions for the Long-baseline Working Group June 27, 2006

For Liquid Argon:

13. NuSAG recommends that the Liquid Argon group reweight its emphasis from sensitivity/reconstruction/pattern recognition to hardware issues and cost estimates. We realize that a full switch cannot occur if the LAr group is a big part of the more generic off-axis calculations in the Working Group, but, for example, LAr-specific reconstruction and particle ID algorithms seem less pressing than technical feasibility.

14. What has actually been measured on purity of the Ar in a tank made with industrial technology? If not yet tried, when will the first tests be?

15. When do you expect to have tried 3-m drifts and long wires in the US? What effect will the capacitance of very long wires have on electronic noise?

16. What are the R&D milestones, with an estimated schedule, that would lead to a first realistic cost estimate for a detector of the 2nd-off-axis or wide-band class?

Liquid Argon TPC Overview for NuSAG

Note: At this point in time …

"15

"1"

etc

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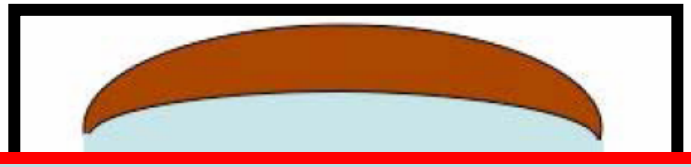

Submitted to NuSAG

Summer 2005

Need a new slide to show evolution from Summer of 2005 to Summer 2006

- **Joining up with Europeans, and we hope:**
- **Helping to finish T600 / ICARUS**
- **Mounting a significant (150t to 1000t) detector in the NuMI "parking lot" to demonstrate technology and cost scaling to the large detector**
- **Forming a joint design and development effort for large detectors (at least 50kton)**
- **Aside on physics: CP violation with leptons may require not only a LArTPC but a beta beam as well … but that is another talk.**