Fermilab Work for Liquid Argon TPC:

*aimed at Large Detectors for Long Baseline Neutrino Physics*

**technical issues:**

- argon purity (without evacuation)
- electronics (large capacitance detector)
- TPC design (large area)
- light collection
- DAQ, reconstruction, analysis
- cosmic background (surface detector)
Thirty years of progress

Bubble diameter ≈ 3 mm (diffraction limited)

LAr is a cheap liquid (≈1CHF/litre), vastly produced by industry

Gargamelle bubble chamber   ICARUS   electronic chamber

<table>
<thead>
<tr>
<th>Medium</th>
<th>Heavy freon</th>
<th>Liquid Argon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitive mass</td>
<td>3.0 ton</td>
<td>Many ktons</td>
</tr>
<tr>
<td>Density</td>
<td>1.5 g/cm³</td>
<td>1.4 g/cm³</td>
</tr>
<tr>
<td>Radiation length</td>
<td>11.0 cm</td>
<td>14.0 cm</td>
</tr>
<tr>
<td>Collision length</td>
<td>49.5 cm</td>
<td>54.8 cm</td>
</tr>
<tr>
<td>dE/dx</td>
<td>2.3 MeV/cm</td>
<td>2.1 MeV/cm</td>
</tr>
</tbody>
</table>

Fermilab Oct. 2005

Slide# : 13
The Large Liquid Argon TPC: Sketch

A large size, low rate, fully active, high efficiency, fine spatial resolution, imaging detector of relatively low cost. (5mm wire spacing, 3 meter drift)

Perfect for neutrino work (esp. off axis), but also for other uses (proton decay, super nova neutrino detection, and double beta decay)

But note that it is not a fully proven technology, if it is to be based on an LNG tank design.
NuMI Liquid Argon TPC Overview

From the submission to NUSAG – waiting with baited breath (2005)
Immediate Synergies with Dark Matter Argon experiments:

argon purity (chemical)
(drift-lifetime (oxygen), light output (nitrogen))
cryogenics of argon handling
Argon Purity (chemical)

1) achieving purity (long electron drift times)
2) measuring purity (oxygen, nitrogen)
3) avoiding contamination by detector materials

Electron drift-velocity at 500V/cm is 1.5 m/ms. 1ppb Oxygen equivalent gives a drift-lifetime of 0.3 milliseconds.

For 3 m drift, want ~10 ms => 30 ppt

1) home-made, single-pass filtration system (buy supplies), copper on aluminum (oxygen), zeolite (water) - filters regenerated in place
2) Purity monitor (developed by ICARUS) for oxygen, photometric technique for Nitrogen based on Tevatron device.
3) Materials Test System for ... testing materials without evacuation
Motivation for Materials Test System (MTS):

- test all materials that will go into the cryostat to ensure they do not contaminate the argon long-term.

Challenge for MTS:

- Insert materials into clean argon without first putting the materials under vacuum. (Kiloton TPCs will not be evacuable)

Features of MTS:

- Single-pass fill system with oxygen (activated copper) and water (molecular sieve) regenerated in place.
- Argon-lock plus drive and platform system to insert without evacuation;
- Internal filter-pump, gas-insertion line, gas-monitoring line,
- Ability to put material in liquid, and in gas-phase at temperatures from 90K to 300K.
Overview of Materials Test System

Regeneration 95% Ar 5% H

Dewpoint Sensor

Liquid Argon dump

MN

LN2 Trap

Filter

Ar Space Vacuum

H2O Molecular Sieve

O2 Filter

绝缘真空

LN2

Airlock

Sample Cage

Cryostat

Purity Monitor

Scrubber Filter

Vacuum

C. Kendziora 03.03.07

He

N2

Ar
Setup at the Proton Assembly Building (PAB)

- molecular sieve
- copper on aluminum filter
- Argon test cryostat (Luke)
- TPC test cryostat (Bo)
- my brief case
The essentials of the MTS cryostat.

The main features are

the condenser
(to maintain a closed system)
the sample insertion mechanism
(allow insertion of materials without evacuation)
the lifetime monitor (PrM)
(to measure the electron drift-lifetime)
the filter pump (2 moving parts total)
(filled with zeolite and oxygen-filter material)
Drift lifetime Measurement (purity monitor)

\[ \frac{Q_A}{Q_C} = e^{-t_{\text{drift}}/\text{lifetime}} \]

(G. Carugno et al., NIM A292 (1990))
Plot from on-going run where we have tested a BNL pre-amplifier, a T-962 blocking capacitor board and a mass of cable-ties and cable.

**Anode Signal, Cathode Signal, Lifetime & Imps vs Time**

- Filter
- Cathode
- Anode
- Lifetime
- Imps

1.0 x 10^-2 Imps = 3/lifetime (ms)

**BNL pre-amp**

**T962 Capacitor Board**

**Cables & Cable-ties**

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6/04/08

S. Pordes, Fermilab R&D
Motivation for Bo:
Provide a system with signals from an actual TPC in LAr to test performance of front-end electronics (as developed at MSU and BNL).

Features of Bo:
Cylindrical TPC, 96 channels in 3 planes, with 50 cm drift and 24 cm diameter; separate purity monitor (PrM); there is space for electronics in the cryostat when we come to test `cold’ electronics. (TPC also has gold photocathode on cathode so it can act as its own PrM)

Present front-end electronics designed and built at Michigan State; MSU has provided DAQ, using DZero ADC and memory boards, and trigger.

Present Challenge for Bo:
Resources to complete the cryogenics system while developing Luke. (Electronics from MSU have been ready for > 1 year).
Development of local reconstruction and display software (may hear relevant stuff in ArgoNeut talk)
TPC being inserted into Bo:

Electronics Installation (Michigan State)

Response to Test Inputs and Noise Check
**Nitrogen in Helium Measurement - R. Walker (1977)**

**Fig 1: Overall Plan for Spectrographic Nitrogen Detector System**

- 1. Quartz gas cell
- 2. Tungsten electrodes
- 3. 30000 pF high voltage capacitor
- 4. 35 mm focal length condensing lens
- 5. Light seal
- 6. Scan McPherson 618/700 scanning monochromator, 1180 lines/mm grating, slits are set at 100 μm
- 7. Scan McPherson photomultiplier module model BU-701-50
- 8. Aluminum light box, image of light source is formed on monochromator entrance slit by lens 4.
Nitrogen in Argon Measurement
*(based on Nitrogen in Helium for Tevatron)*

Relative Emission Line Intensity for Nitrogen in Argon Balance

- Intensity for 50 ppm Scan
- Intensity for 1.2 ppm Scan

Sensitive to ~0.2 ppm Nitrogen
Liquid Argon Purity Demonstration - LAPD
(D. Finley & R. Schmitt)

Industrial vessel, trucked in to site, foam insulation, TPC materials (no assembly), 20 tons Lar, lifetime monitors, flow meters, RTDs

M & S (only) cost $300,000 - requested funding from DOE R&D funds.

Designed to test/demonstrate ability to achieve good lifetime within a year of receipt of go-ahead. Can also check flow and temperature distributions

Speed is of the essence:
- if successful, provides encouragement for MicroBooNE test (with real detector and real events) and larger devices;
- if initial failure, provides some time to investigate and implement changes for MicroBooNE
DUSEL R&D Proposal, Liquid Argon Purity Demonstration

Program announcement title: DUSEL R&D Proposals in FY2008
http://www.science.doe.gov/hep/DUSELRT&D.shtml
Name of laboratory: Fermi National Accelerator Laboratory
Name of principal investigator (PI): David Finley
Position title of PI: Scientist II, Fermilab
Mailing address of PI: M.S. 122, PO Box 500, Fermilab, Batavia, IL 60510
   Telephone of PI: 630-840-4620
   Fax number of PI: 630-840-3614
Electronic mail address of PI: finley@fnal.gov
Name of official signing for laboratory*: Pier Oddone
   Title of official: Director of Fermilab
   Fax number of official: 630-840-2900
   Telephone of official: 630-840-3211
Electronic mail address of official: pioddone@fnal.gov
Requested funding: One year of funds are requested totaling $334,950
   Use of human subjects in proposed project: No
   Use of vertebrate animals in proposed project: No
Some context:

*FNAL and Yale people are in contact with people in Europe (in and out of ICARUS) on purity and other issues.*

*Yale, MSU, FNAL and people from Italy are working on the 250 liter test TPC (ArgoNeut) to be placed in the NuMI beam at FNAL.*

*A proposal (MicroBooNE) for a 200 ton TPC to go into the Booster Neutrino beam has been submitted by BNL, FNAL, MSU, UTA & Yale.*

*A LOI for a 5 kiloton detector LAr5 has been submitted. LAr5 is comparable in physics reach to NOvA and could complement it at Ash River or at Soudan, or go to DUSEL.*