Liquid Argon TPC R&D Update
(a Fermilab perspective)

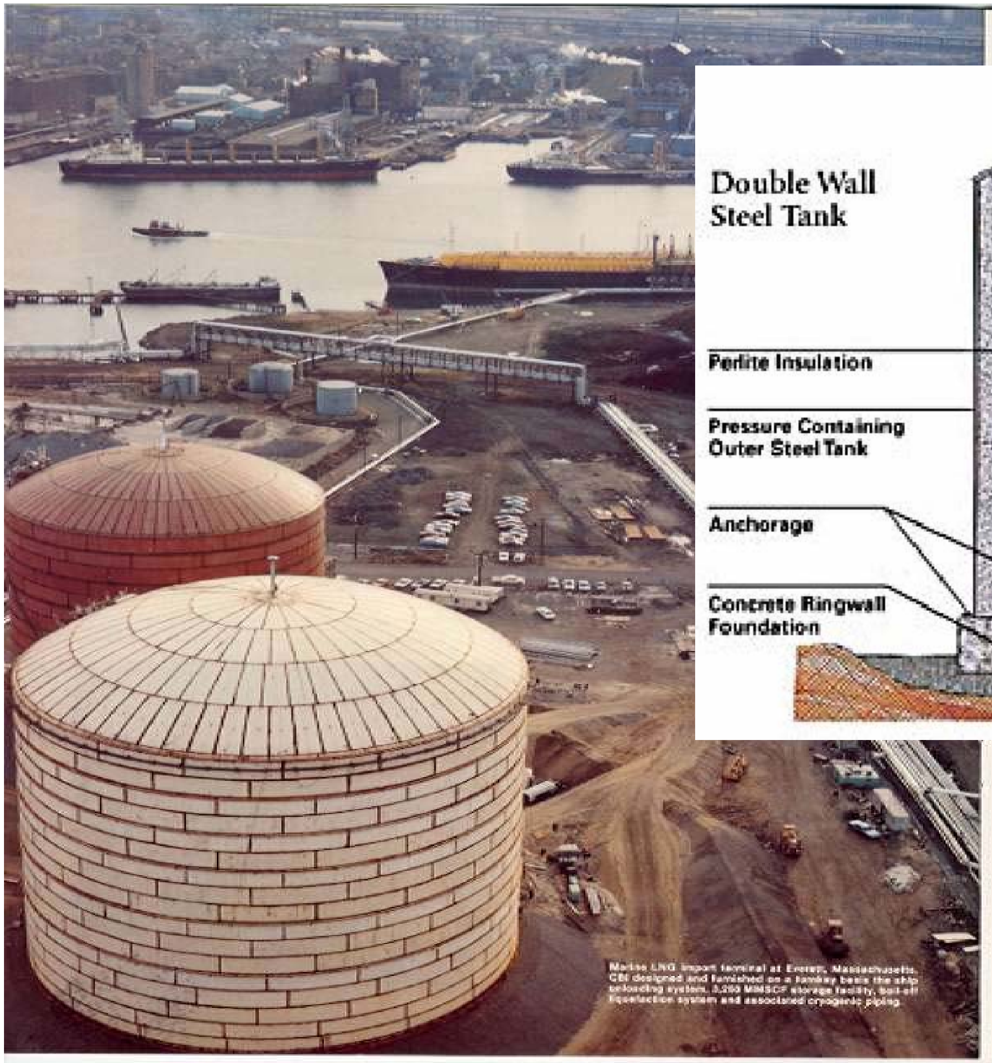
- Massive LAr Detector Paradigms

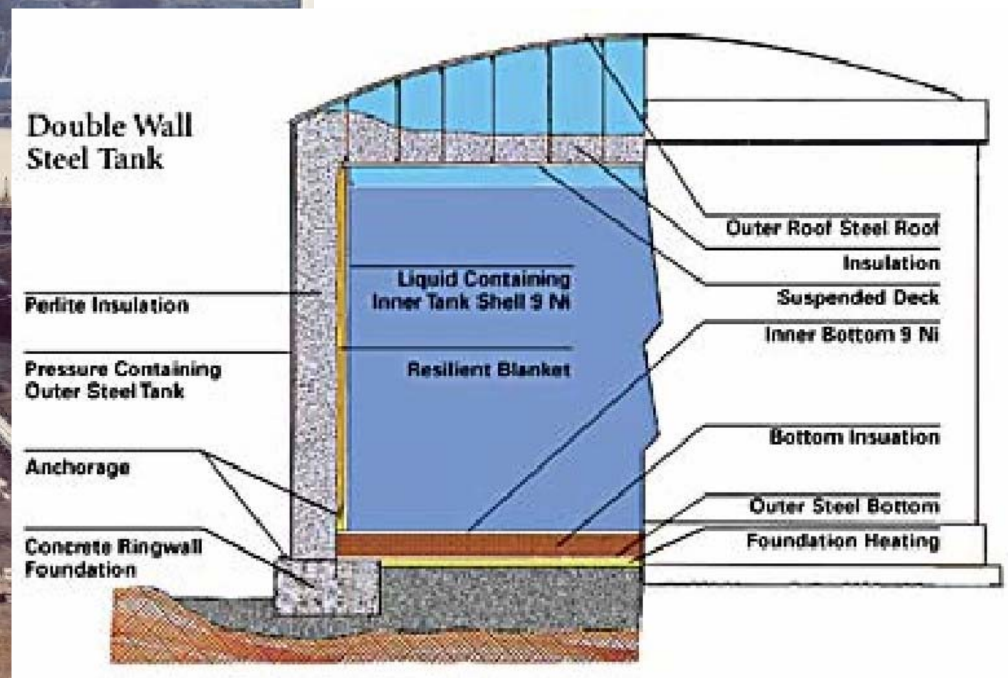
- Technical Efforts at Fermilab

Massive Detector Paradigms

- Liquefied Natural Gas tank (FLARE-like)
  - Single large volume with multiple horizontal drift regions
- Liquefied Natural Gas tank (GLACIER-like)
  - Single large volume with single vertical drift region followed by multiplication in the gas
- Modules (ICARUS-like)
  - Many (perhaps identical) detectors of the largest practical "modest" size with horizontal drift regions

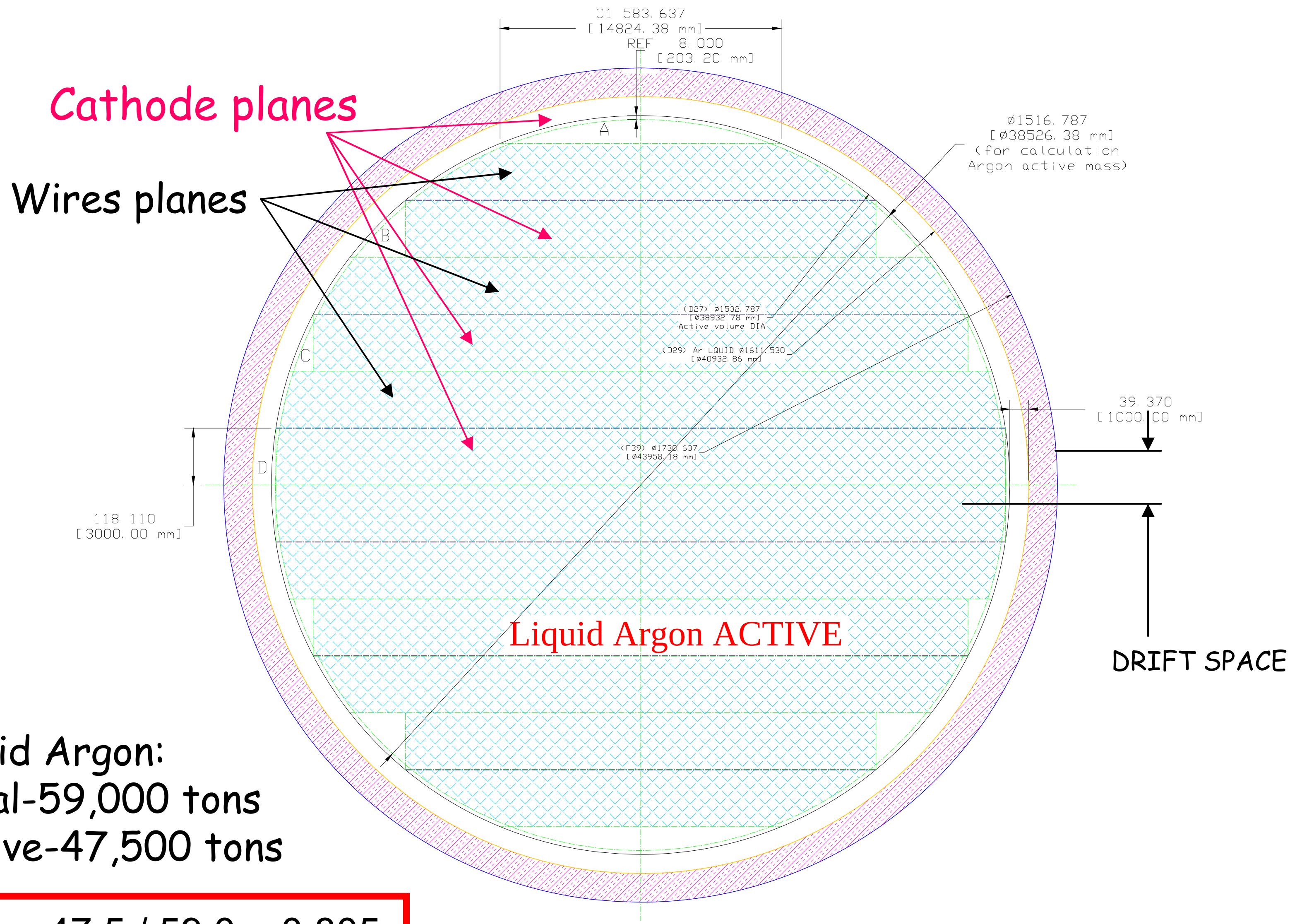
Detector Tank based on Industrial Liquefied Natural Gas (LNG) storage tanks





Many large LNG tanks in service. excellent safety record

FLARE Design: View from the Top of 50kton LArTPC



Liquid Argon:
Total-59,000 tons
Active-47,500 tons

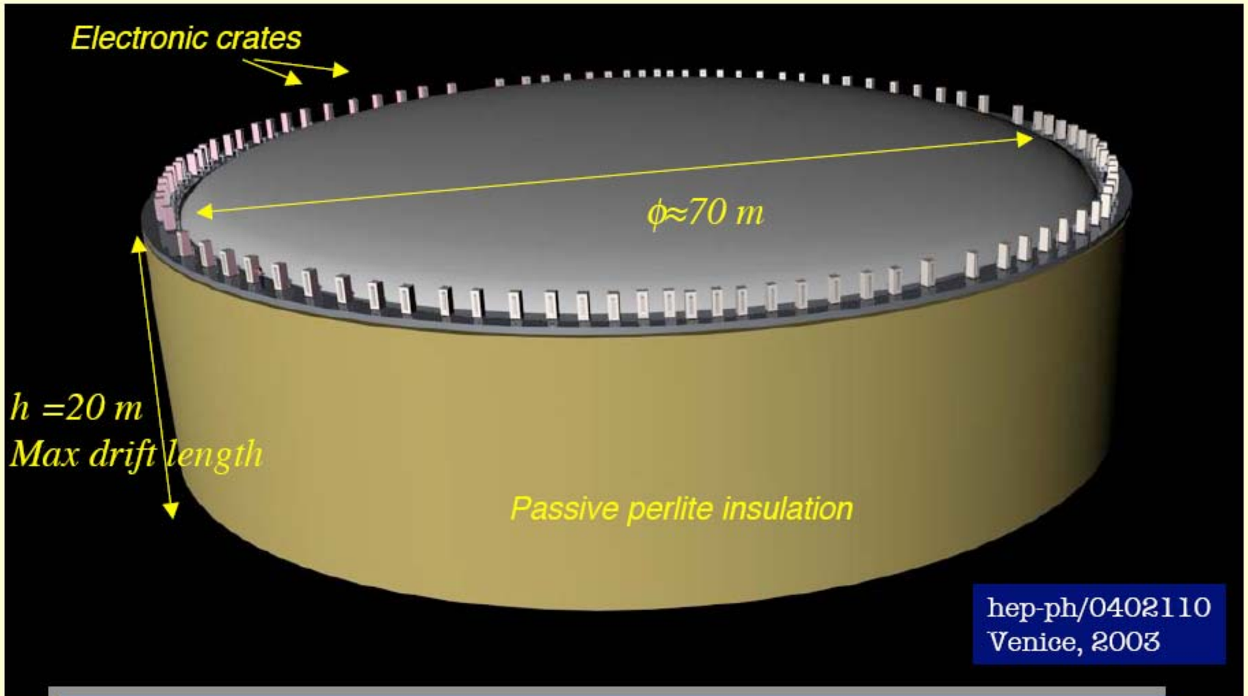
Note: 47.5 / 59.0 = 0.805

SECTION B-B

André Rubbia (ETH Zürich)

http://neutrino.ethz.ch/GLACIER/

A 100 kton liquid Argon TPC detector

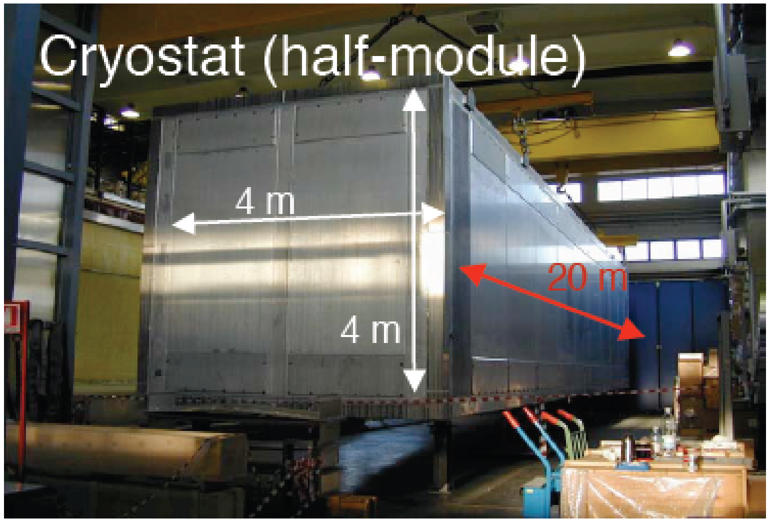


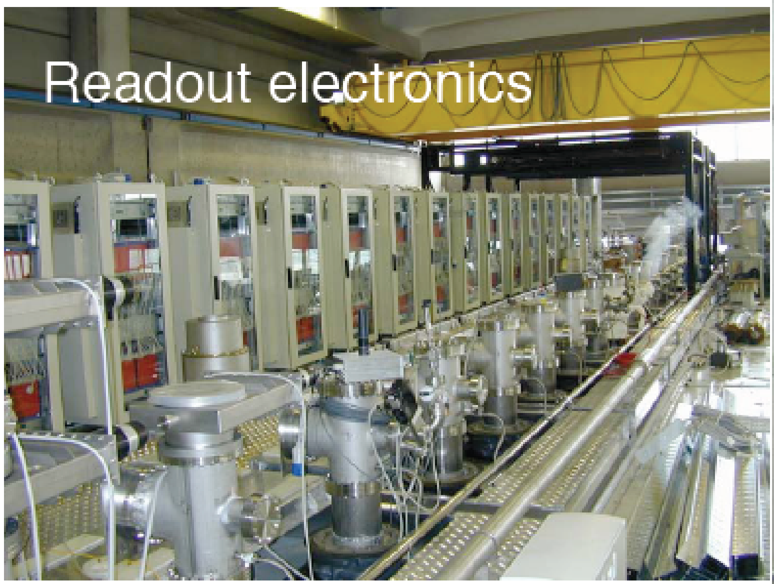
Single module cryo-tanker based on industrial LNG technology

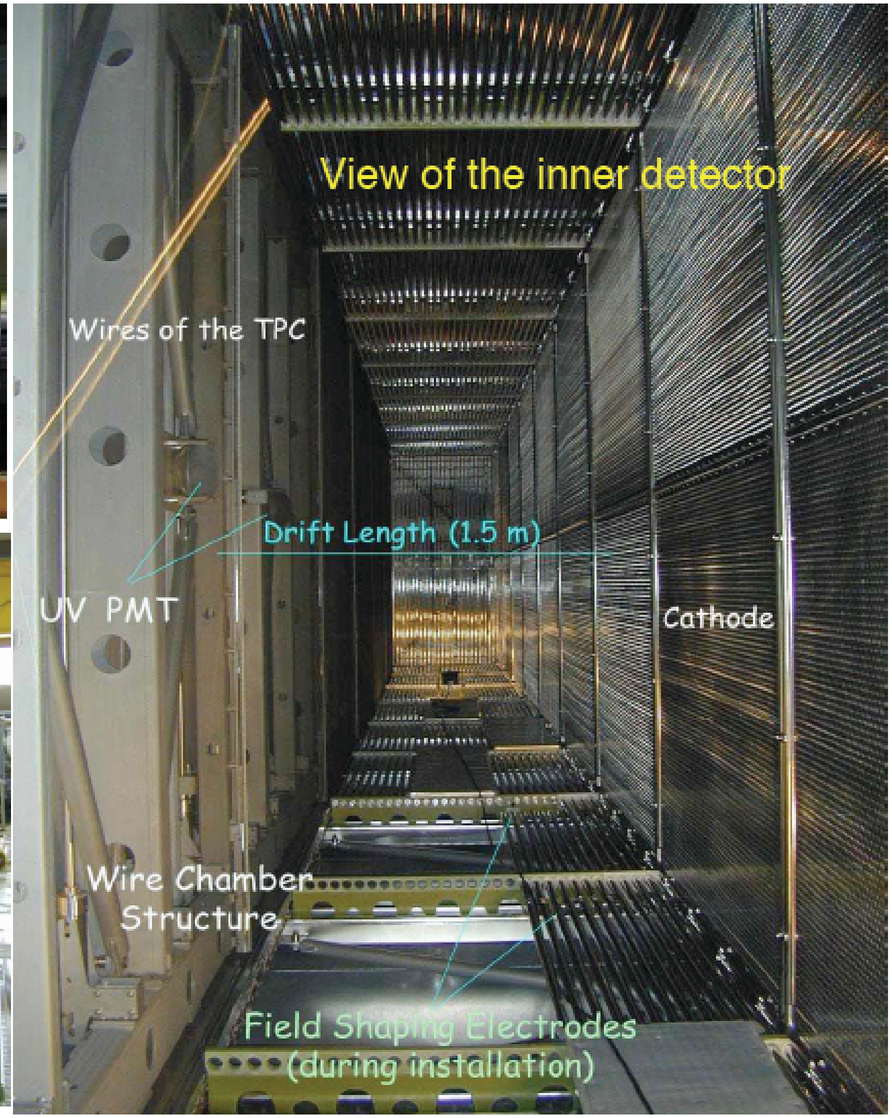
A "general-purpose" detector for superbeams, beta-beams and neutrino factories with broad non-accelerator physics program (SN ν, p-decay, atm ν, …)

International Neutrino Factory And Superbeam Scoping Study Meeting, CERN - 22-24 September 2005

ICARUS T300 prototype







C. Rubbia at Fermilab October 2005 “20 years of liquid Argon technology”

Some uses of Massive LAr Detectors

- One use (of particular interest at Fermilab):
  - An excellent electron neutrino detector in a neutrino beam
  - Although the neutrino beam itself may only be ~10 microseconds long, the electrons will take ~2 milliseconds to drift to the TPC sense wires
  - If it can be demonstrated that the cosmic ray background can be handled it may be sensible to locate the detector near the surface (under a few meters of overburden).

- Another use:
  - A detector under (at least ~50 meters of) dirt/rock cover to reduce cosmic ray background
  - This allows for nucleon decay, supernovae neutrino watches … and it can still be put in a neutrino beam.

Some Features of Massive LAr Detectors

- Features of modular approach:
  - It avoids various problems with large dimension objects
  - It does not "put all your eggs in one basket"
  - It allows for a staged turn on of data taking
- Light collection is another feature
  - Provides a trigger for natural processes such as nucleon decay and supernovae … and is very useful for sorting out background tracks in detectors in neutrino beams
- Feature of long drift: Purity
  - ICARUS has shown it can be done on 300ton scale
  - Now it must be done better to be useful for massive scale

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- Massive LAr Detector Paradigms
- Technical Efforts at Fermilab
  - Overview
  - Purity Monitors
  - Materials Test Station
  - Argon Piston
  - Purity Demonstration
  - Cellular Design of the TPC

Overview: 1

- Focus of technical effort Fermilab: "Big Tank" issues
  - This Talk

- Using Fermilab's neutrino beams:
  - Proposal to put a ~300liter TPC in front of the MINOS near detector (T962) by Yale, Michigan State University and Fermilab
  - Conceptual development of a 150ton neutrino detector on the surface almost directly above the MINOS near detector.

- Long Baseline study with Brookhaven
  - LArTPC physics case studies include using off-axis NuMI beam as well as on-axis beam to DUSEL (off-axis = narrow band, on-axis = broad band)

- Specific recent study
  - Understand the physics reach of a 5kton LArTPC detector near the location of NOvA.

- We continue to trade ideas with other groups around the world.

Overview: 2

- Commissioning of the Materials Test Station
  - qualify / disqualify materials to be used in a detector

- Purity demonstration without evacuation
  - Demonstrate that the purity required by a large liquid argon TPC detector can be achieved without evacuation, and estimate the associated costs for a 5kton scale detector or larger
  - A key is to use argon as a "piston" to push out the air as an inexpensive first step (e.g., remove ~ton of oxygen in a 5kton tank)

- Cellular TPC design
  - The presently preferred TPC design at Fermilab for the 5kton detector is the Cellular Design.

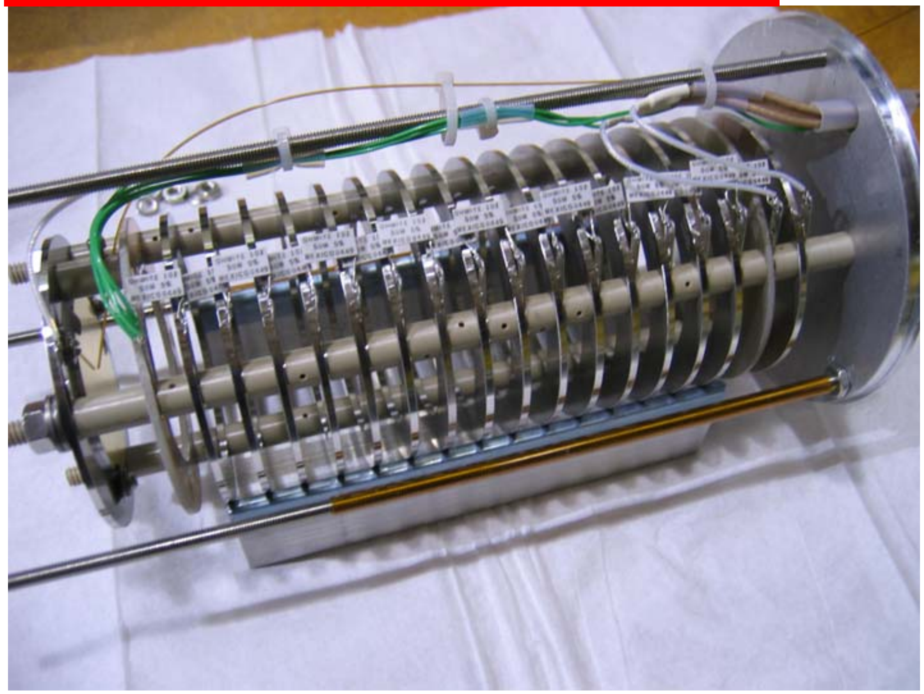
- Systems integration test in a ~30liter TPC (not in this talk)
  - Observe cosmic ray tracks
  - Develop electronics needed for T962 and other detectors (MSU)

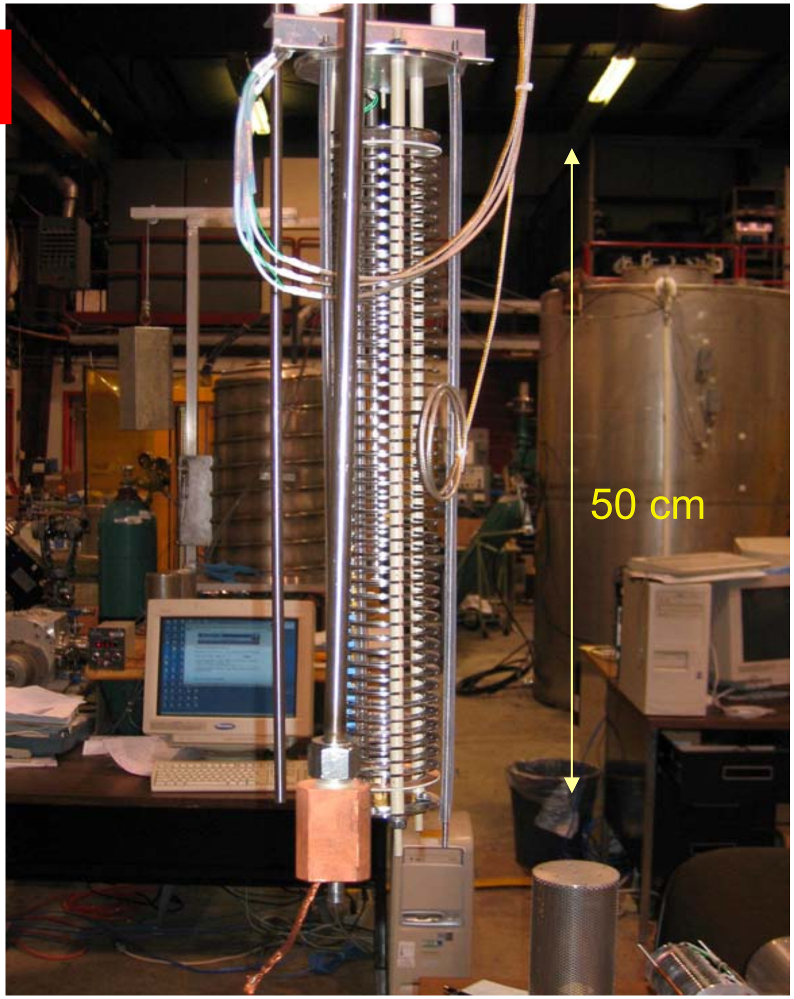
- Purity monitors
  - Will make more as needed for the purity demonstration without evacuation and other uses.

More Purity Monitors

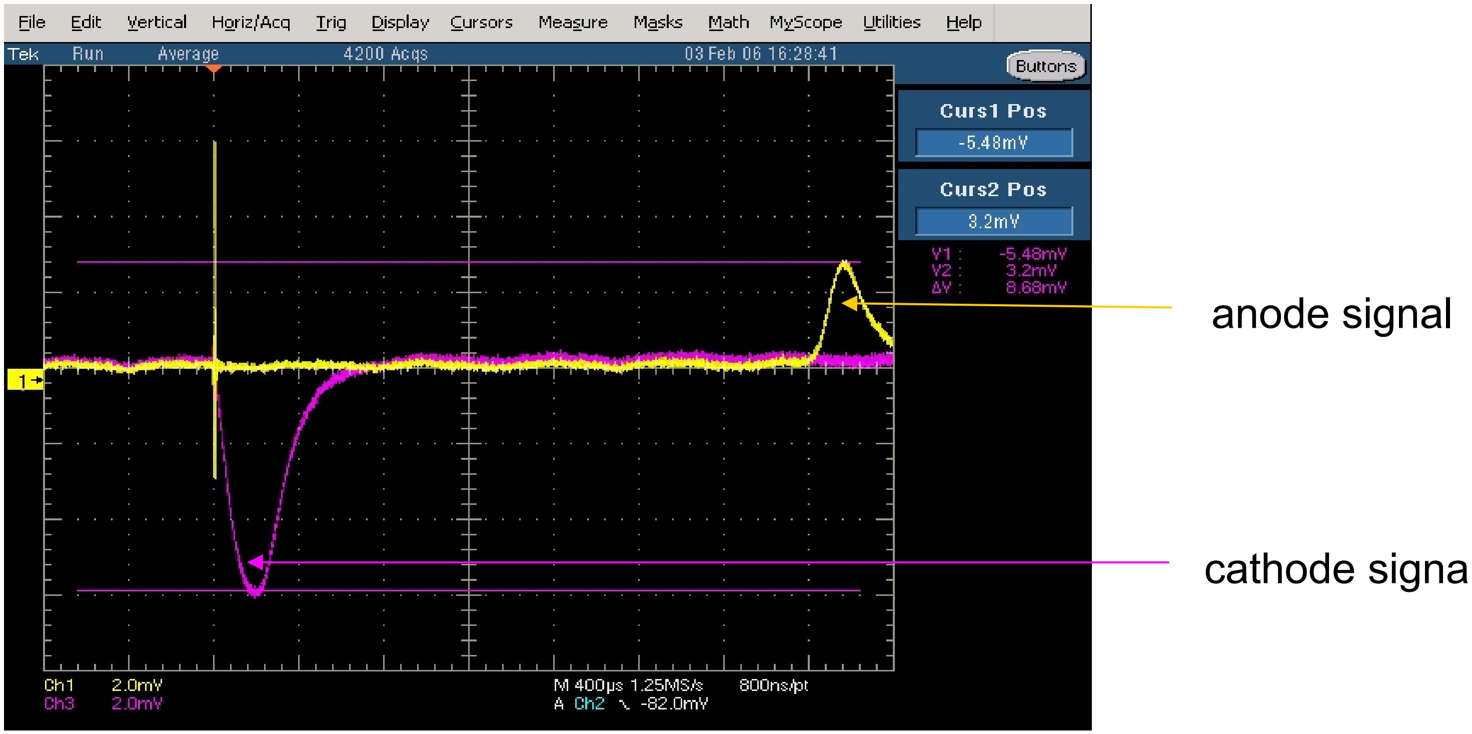
Long Purity Monitor - for long drift life times

ICARUS Clone made at Fermilab





Electron lifetime measurement in LAr



a 2.8 millisecond drift, $Q_{anode}/Q_{cathode} \sim 0.4^{(*)}$

(*) peaks need some correction for cathode signal rise-time

• Our **first measurement** May 4, 2006 surpassed the 10 msec lifetime required for a 3m drift with a 20% loss for a 500 V/cm field.

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Materials Test Station

Implement the Materials Test Station..
- Closed system cryostat - sketch at right

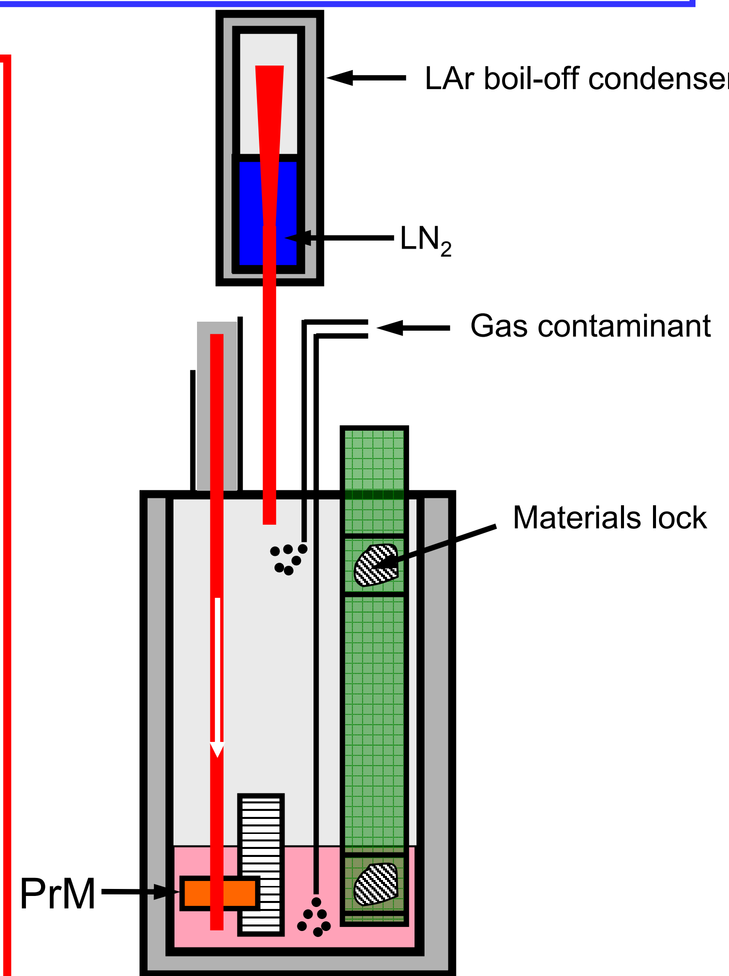
It is fully assembled and awaiting safety review.

Note Materials lock which allows introduction of materials without evacuating

Start debugging the system in March 2007

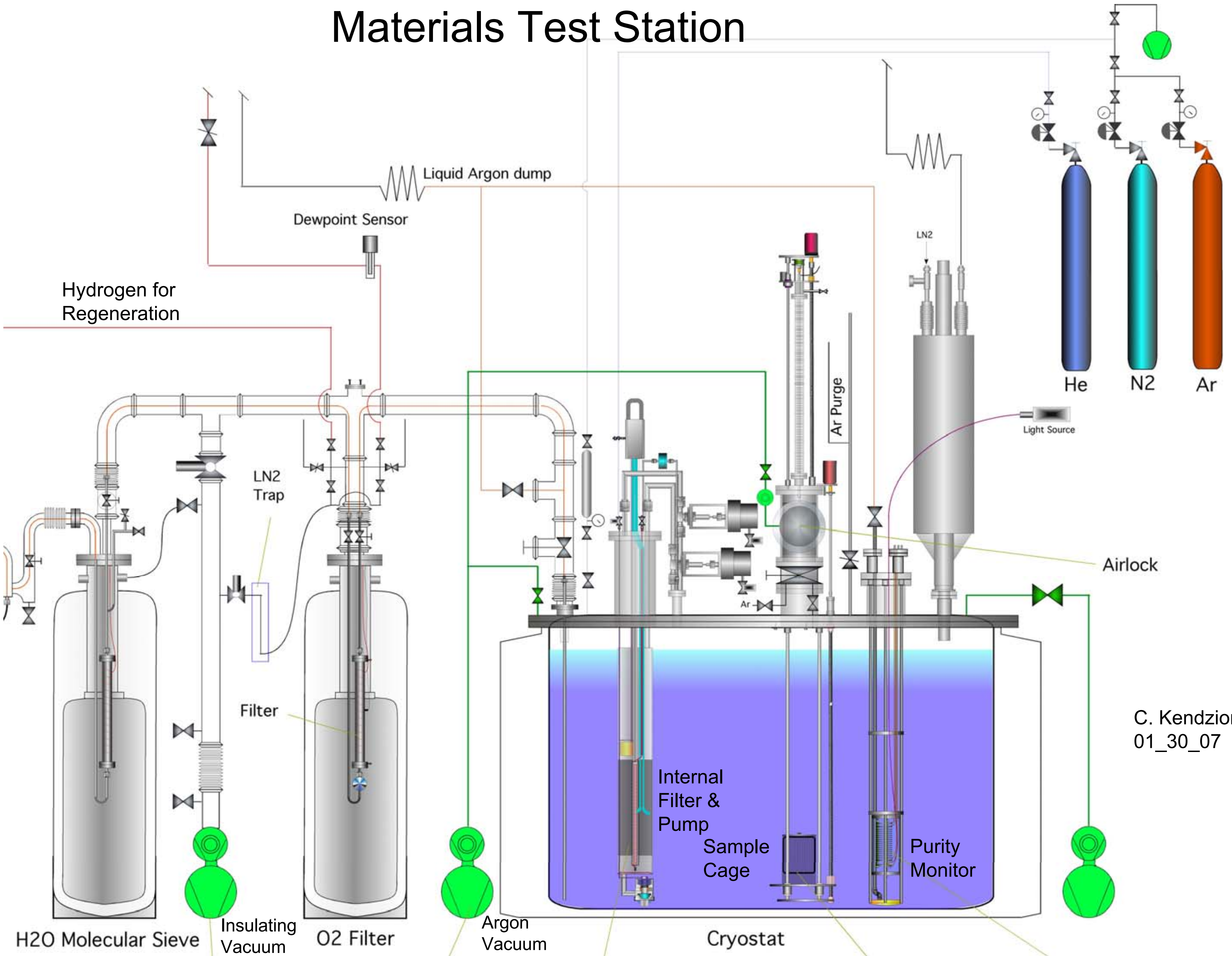
Developing in-cryostat filtering
(new development)

Start testing materials by the summer of 2007 … if all continues to go well.



T. Tope

Materials Test Station



C. Kendziora
01_30_07

Materials Test Station

Stay tuned … and feel free to suggest materials to be tested

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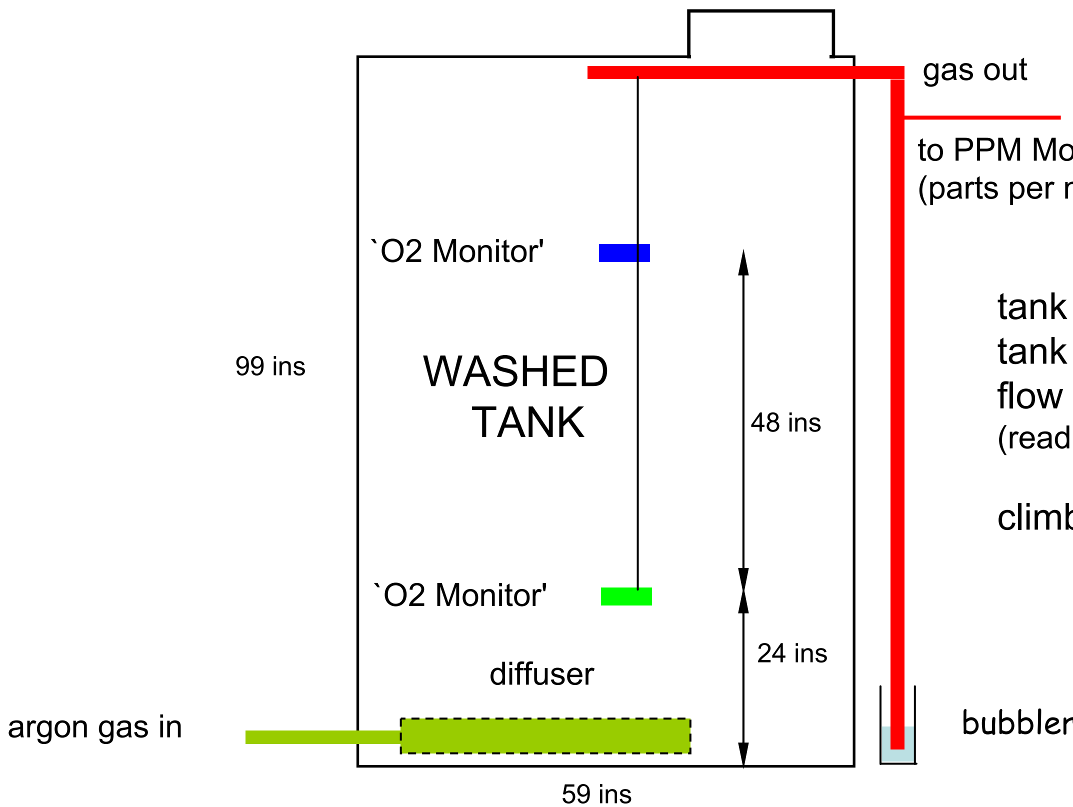
Using an “Argon Piston” to Purge oxygen (reported at Gran Sasso Cryodet Workshop March 2006)

Test of purging a volume from atmosphere (without evacuation):

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 requires 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

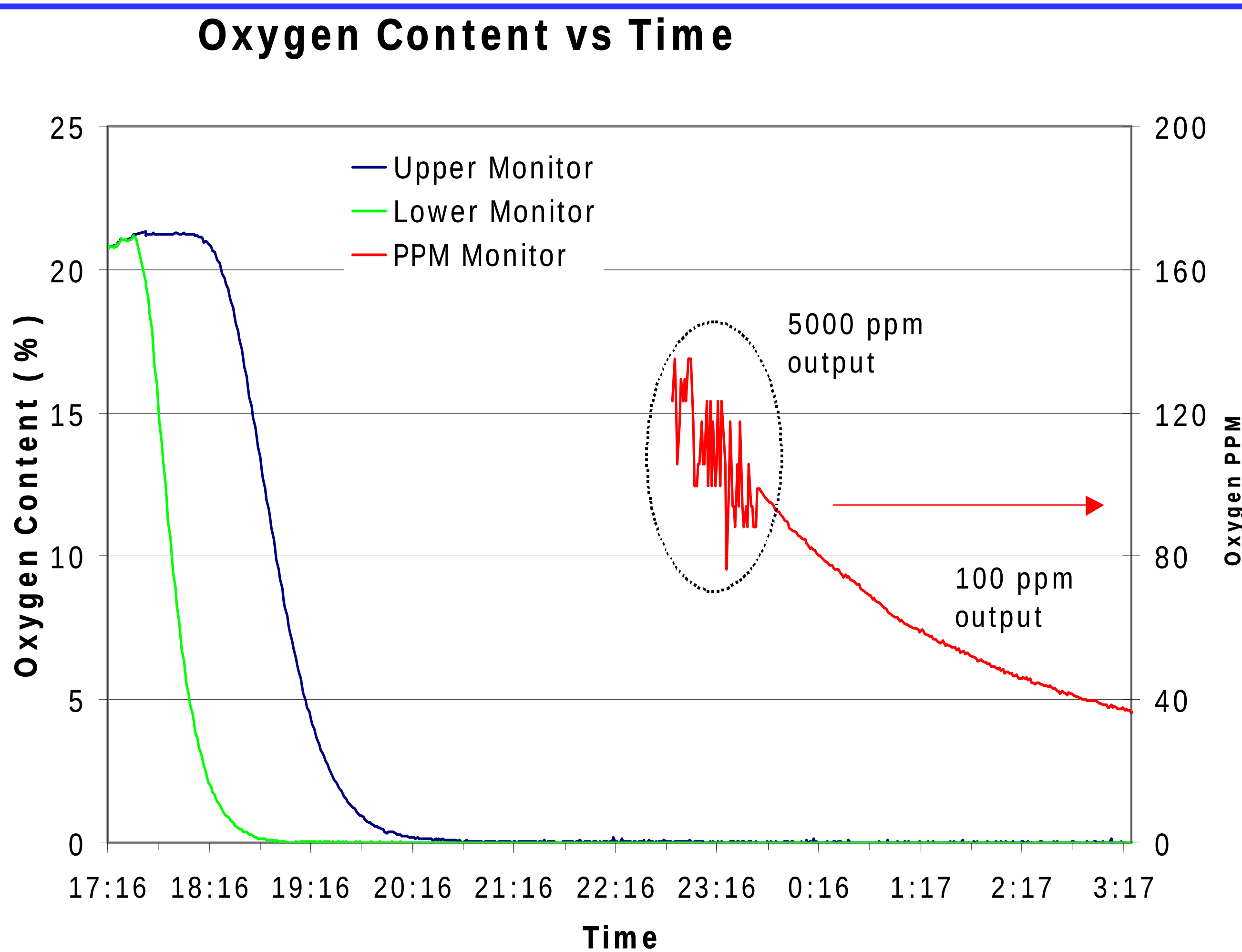
Using an "Argon Piston" to Purge oxygen

The Test Tank …

… behind an average sized Fermilab engineer.

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

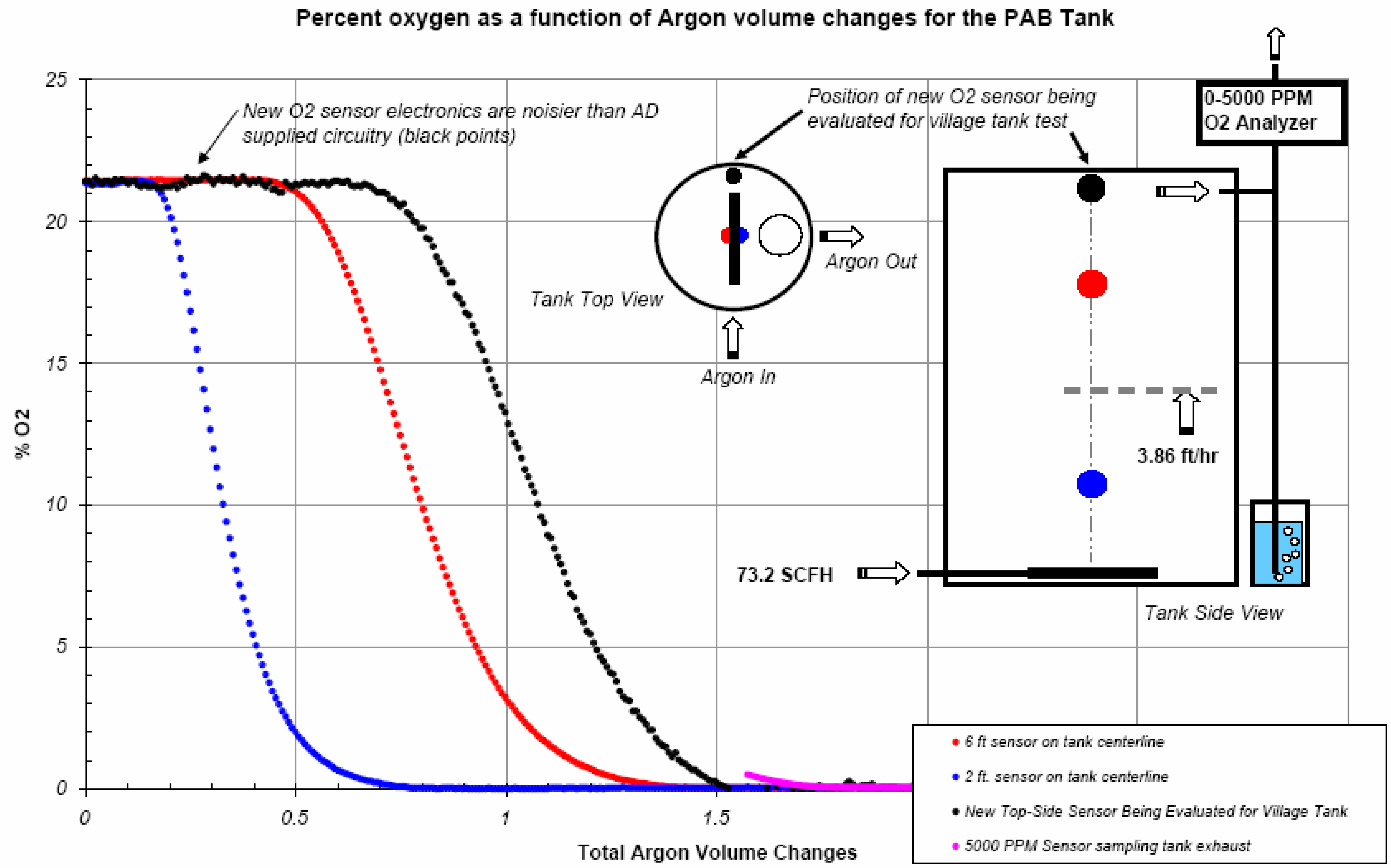
Measurements using an “Argon Piston” to Purge oxygen (reported at Gran Sasso Cryodet Workshop March 2006)



to 100 ppm (reduction of 2,000) takes 6 hrs = 2.6 volume changes
(cf simple mixing, which predicts ln(2000) = 7.6 volume changes)

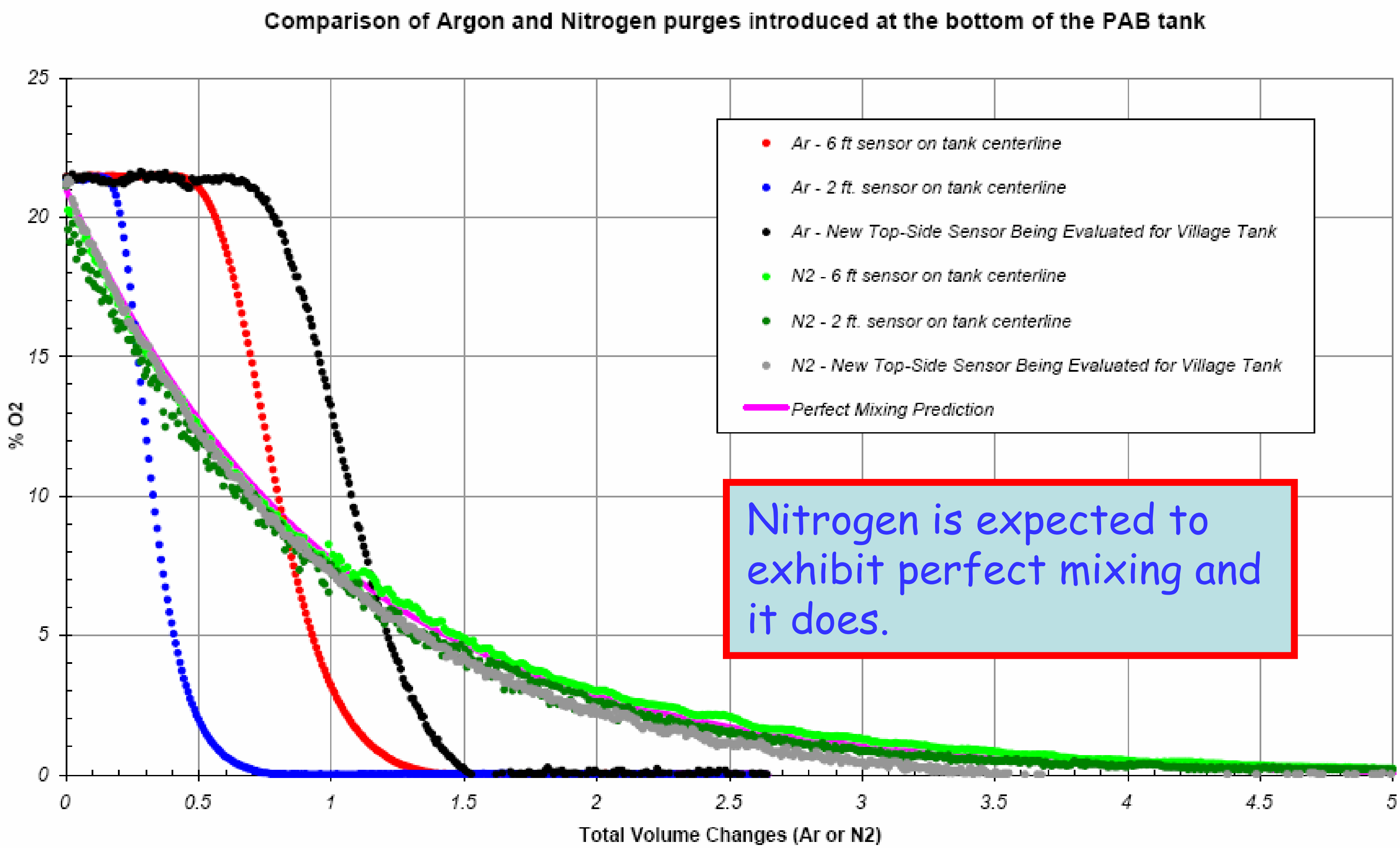
Argon Piston: Add Instrumentation

Terry Tope
6/5/06



Argon Piston compared with Nitrogen

Terry Tope
6/5/06



Purity Demonstration: 1

- Demonstrate that the purity required by a large liquid argon TPC detector can be achieved without evacuation, and estimate the associated costs.
- A credible demonstration must use, as much as possible, the same materials and techniques as expected to be used for a massive detector (e.g., 5kton). Thus, the design of the detector must be sufficiently understood.
- The purity demonstration itself does not need a functioning TPC, but it does need to include the TPC materials arranged as in an experiment, and prepared in the same manner as in an experiment.
- The present focus is to propose using a 150ton LNG tank constructed by an LNG contractor.
  - 150tons is scaled down from 5ktons by a factor of 30
  - appropriately modified to accommodate a TPC
  - appropriately cleaned
  - use appropriately clean techniques to insert the cellular design TPC

Purity Demonstration: 2

- Three steps starting from air in the tank:
  - Warm argon gas used as a piston
    - purge oxygen to 50ppm or less
    - vertical velocity chosen to control diffusion and to be the same as to be used in a 5kton detector
  - Recirculation of warm argon gas
    - recirculated through filter scaled down from 5kton
    - remove water and oxygen, goal is 500ppb
    - i. e., achieve purity similar to that achieved by ICARUS with evacuation
  - Liquid purification system similar to ICARUS
    - Final purity expected to be determined by contaminants from tank walls, TPC materials, flow restrictions due to presence of TPC, leaks, etc.

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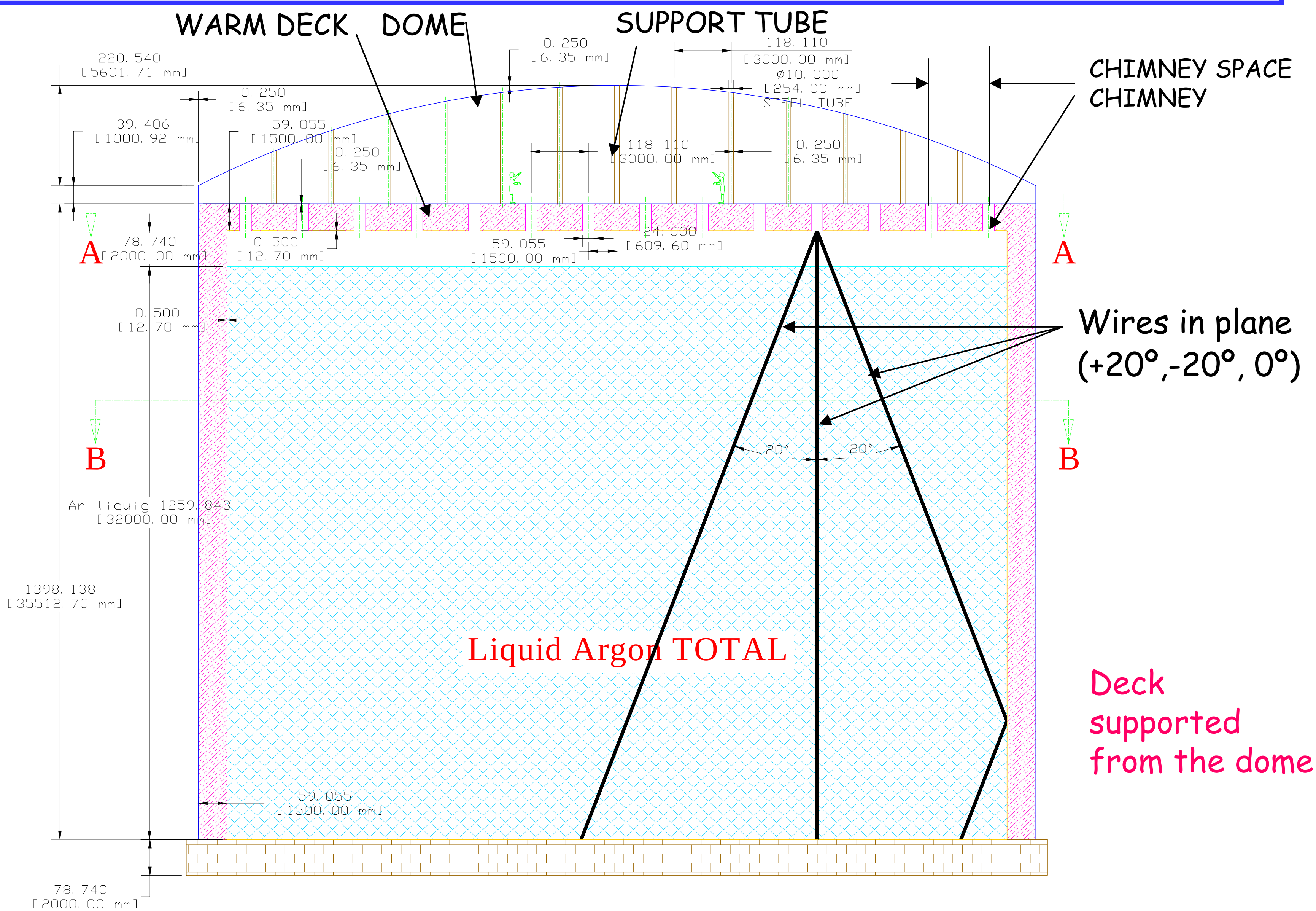
Previous Design: LArTPC 50kton (wire plane section)



Cellular Design: An Alternate Wire Layout (A Better Idea, perhaps)

In the previous design with angled wires, attached to the tank top, bottom, and sides, there will be some wires that do not reach all the way to the top. Hence they cannot easily be read out (without electronics immersed in the liquid, for example).

Each set of wire planes has 3 planes to detect electrons drifting in from the left, and 3 planes for electrons drifting in from the right.

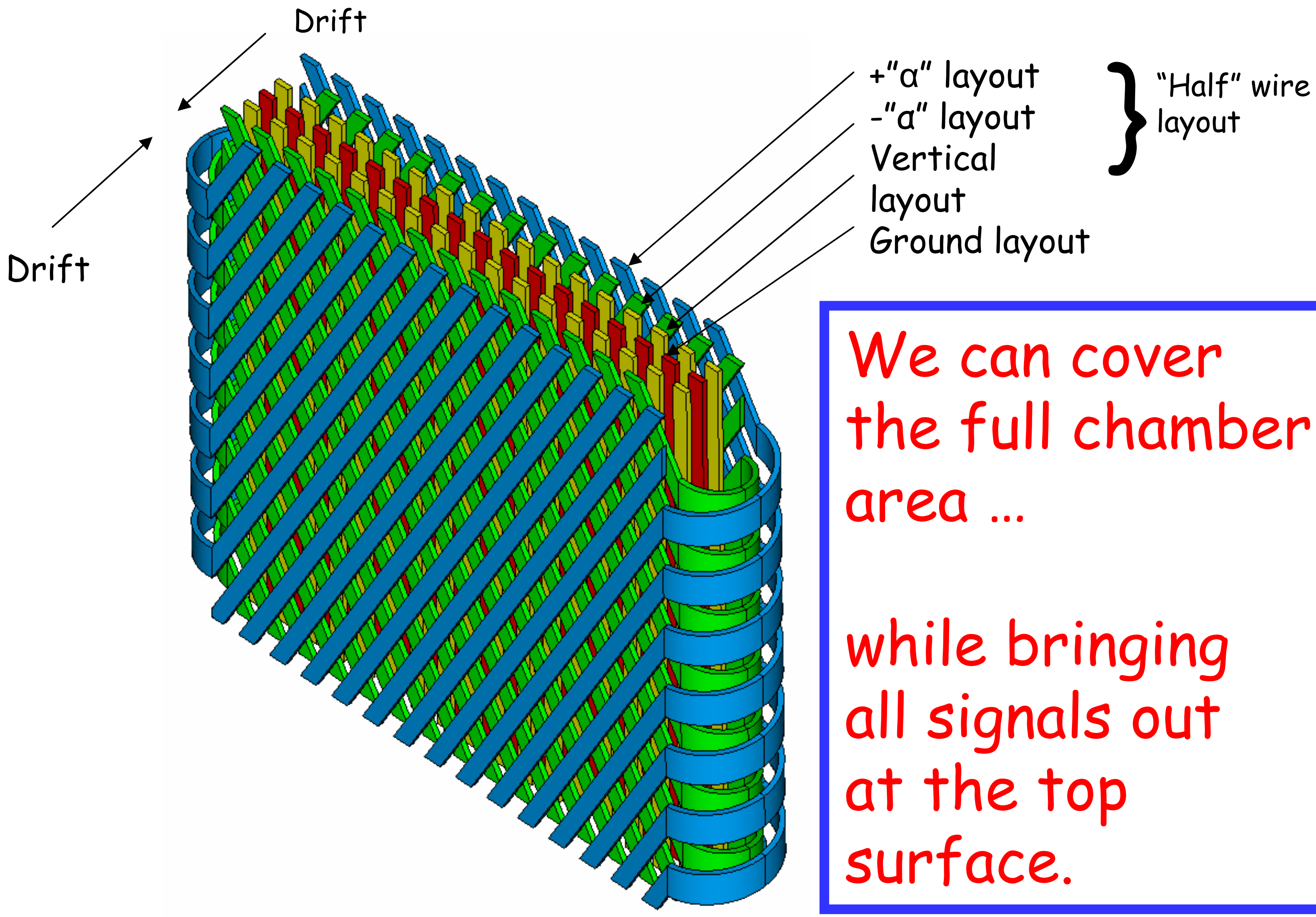
For each plane in the left triplet, there is a corresponding plane, with the same DC potential, in the right triplet.

Why not …

Connect the short wires on the left, that did not reach the top, to the set of short wires on the right that start not at the tank bottom, but higher up on the wall.

Voila: Complete coverage.

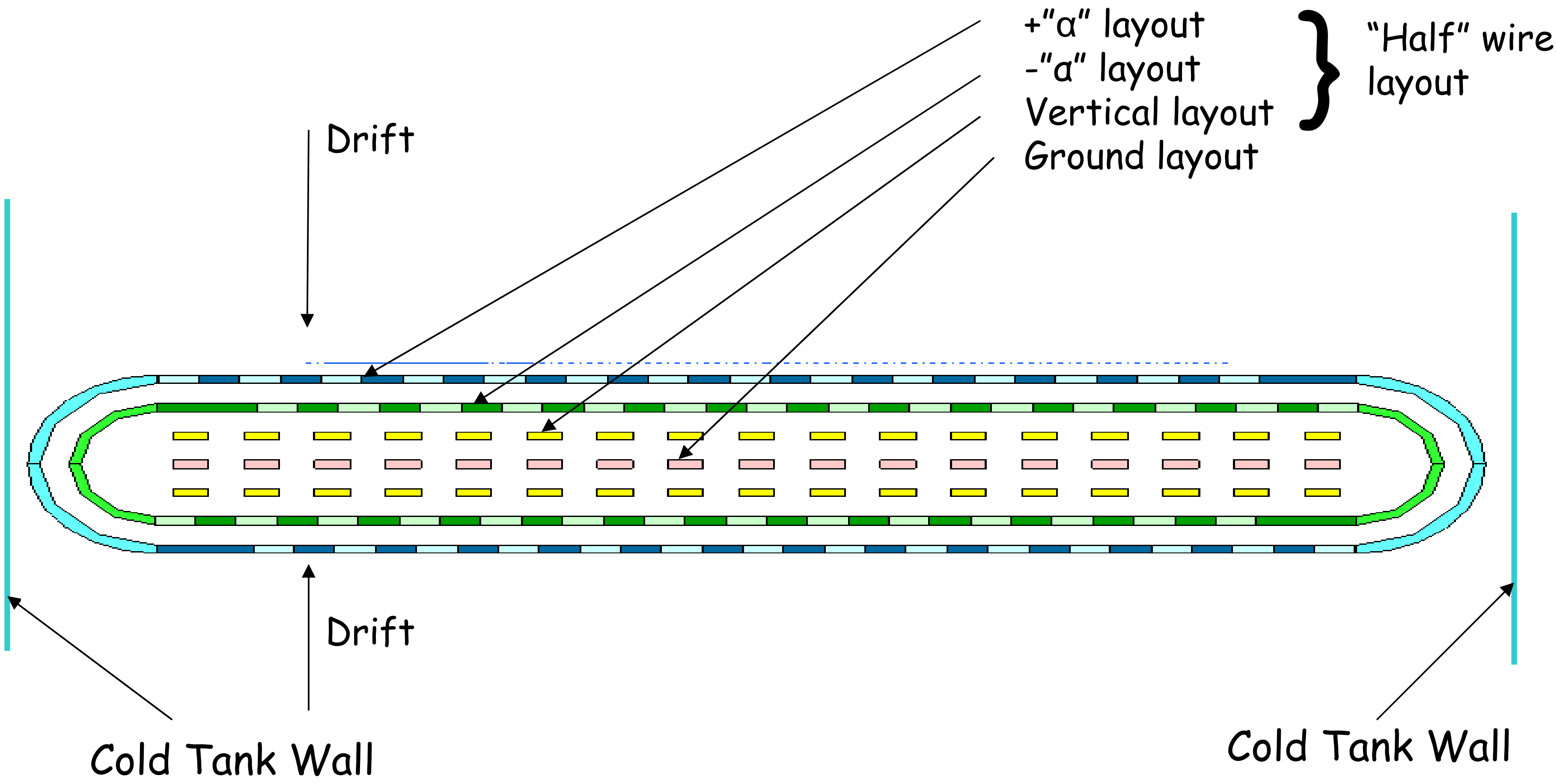
"Complete Coverage" Conceptual Layout



We can cover the full chamber area …

while bringing all signals out at the top surface.

View from the Top: Complete Coverage Layout



Cellular TPC

Interpret the previous cross section as that of a panel that forms a “cell” just 3 m wide.

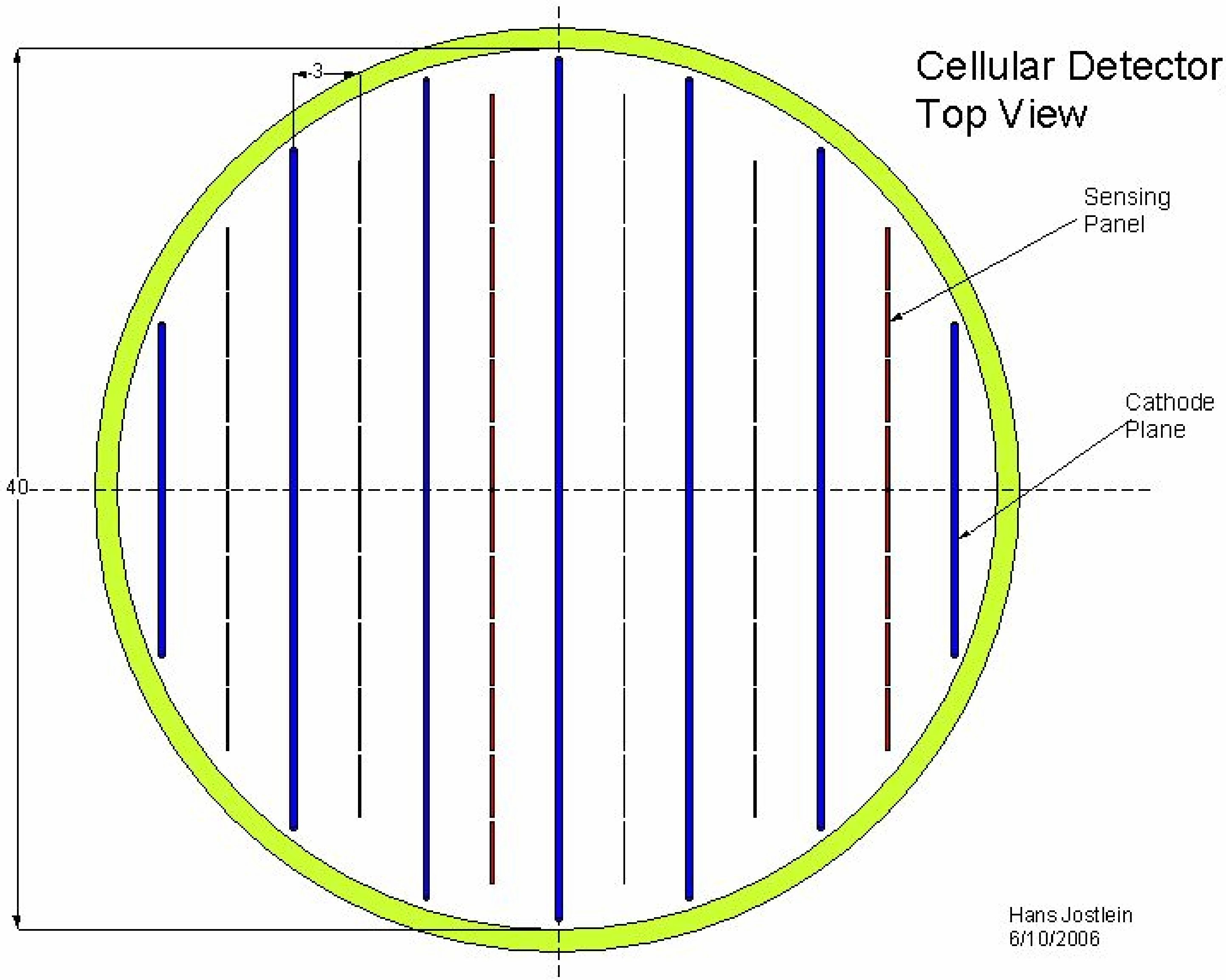
The panel is tall enough to reach the top of the Argon pool.

Since a single wire wraps around the cell from the left side to right side, this introduces pattern recognition complications.

What do we gain ?

1. Panels are made off-site and shipped (by truck or cargo plane) to the detector site
2. Panels are made while the tank is being built
3. Panels are fully tested and cold-shocked
4. Panel installation is fast and low-risk

Cellular TPC, Top View



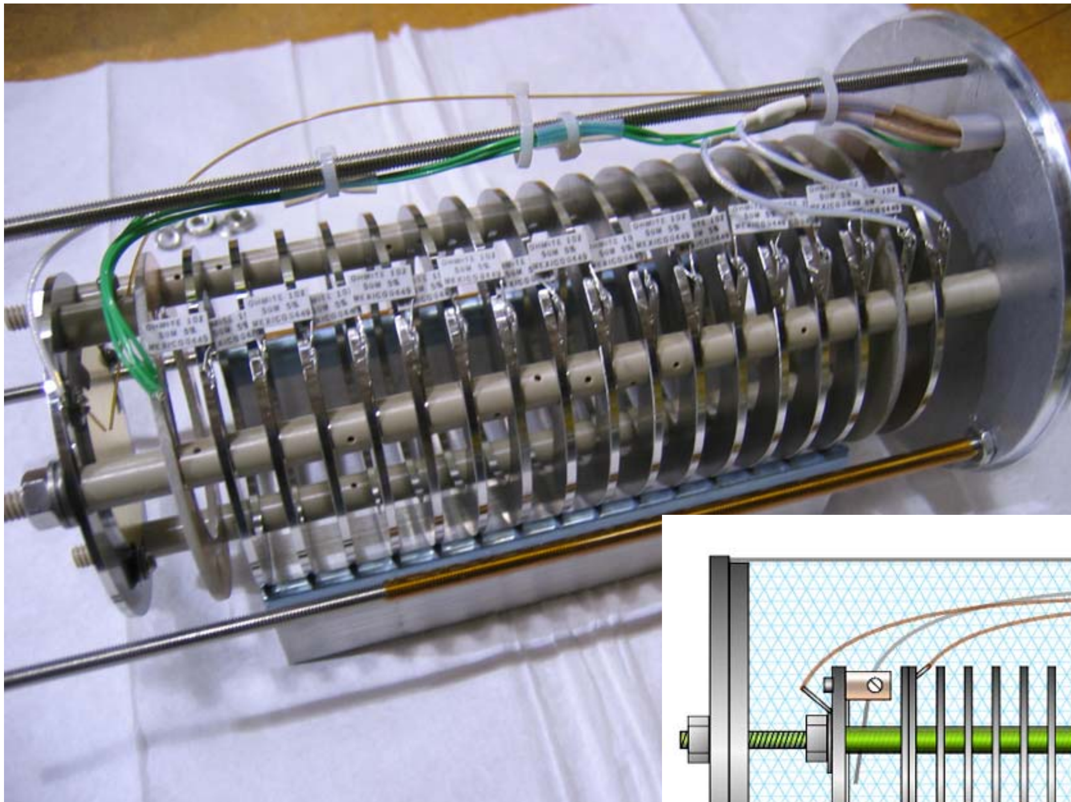
Some Web References for this talk

- Web site with many of the items in this talk
  - http://www-lartpc.fnal.gov/
  - http://lartpc-docdb.fnal.gov/cgi-bin/DocumentDatabase
- Cryodet workshop
  - http://cryodet.lngs.infn.it/agenda/agenda.htm
- Yale Workshop
  - http://www-lartpc.fnal.gov/atwork/workandconf/2006workshop/
- Draft Long Baseline report (not the final version)
  - http://nwg.phy.bnl.gov/fnal-bnl/

- Thank you!

Backup

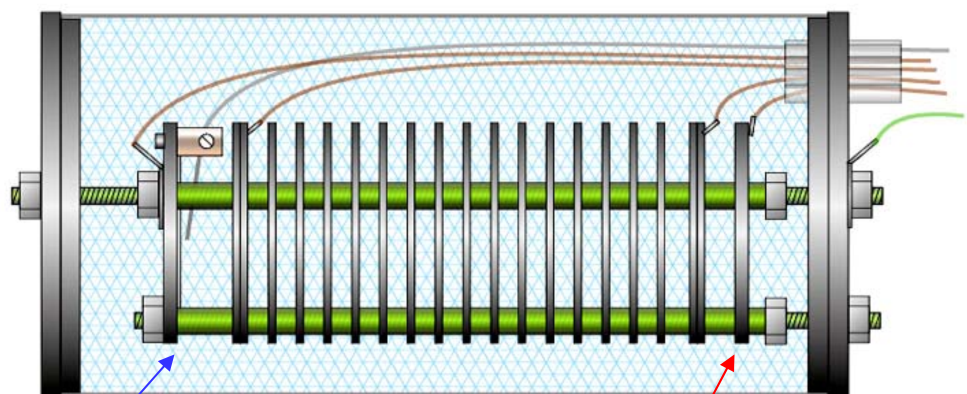
Liquid Argon Purity Monitor



~ 20 cm from anode to cathode.

Based on ICARUS design.

Used to measure electron "lifetime".



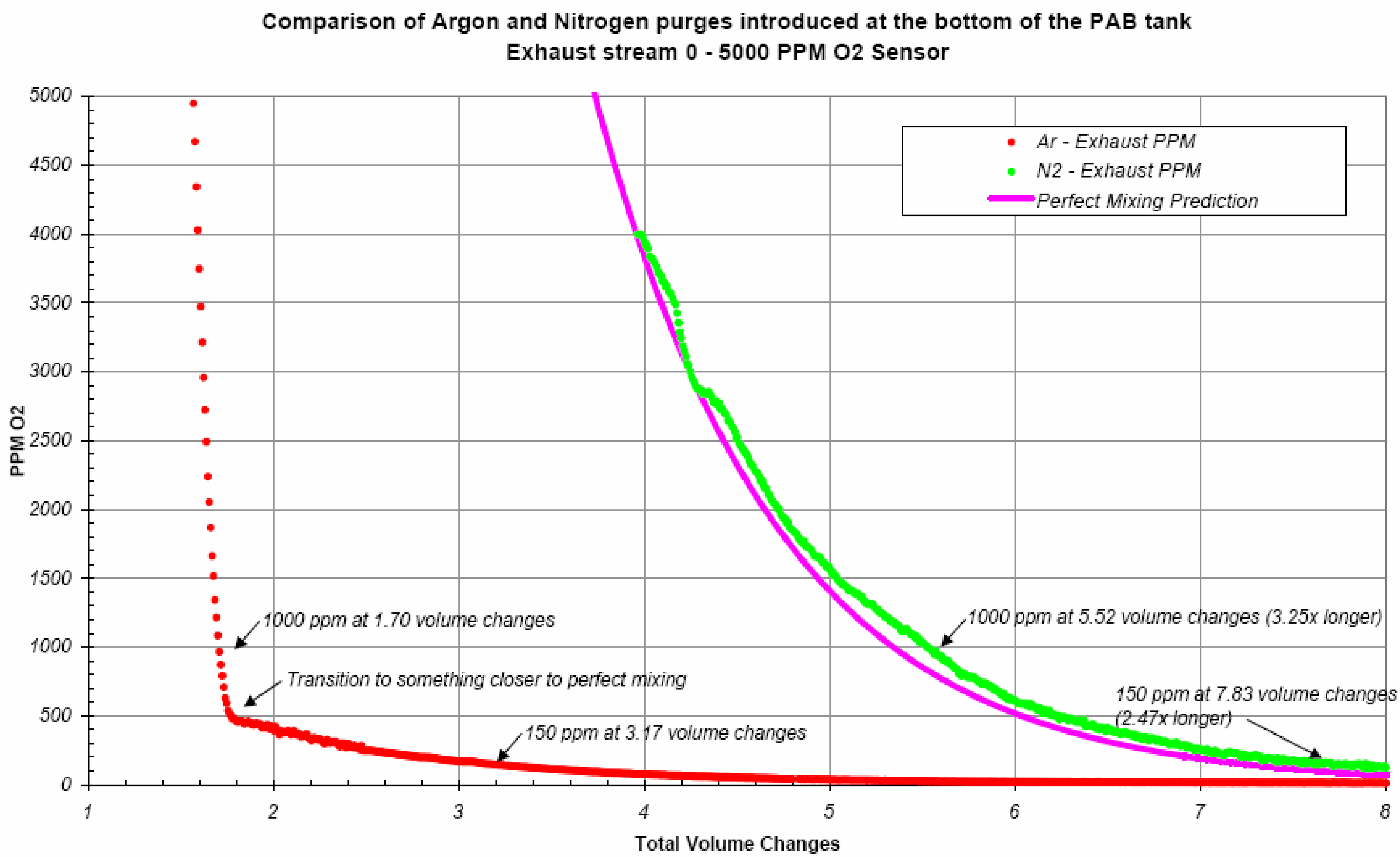
Flash of light strikes photocathode

Electrons arrive at anode

C.Kendziora2/3.05

Better View of Argon and Nitrogen purging

Terry Tope
6/5/06



Liquid Argon TPC Overview for NuSAG

Note: At this point in time …

"15" could be "50"

"1" could be "3"

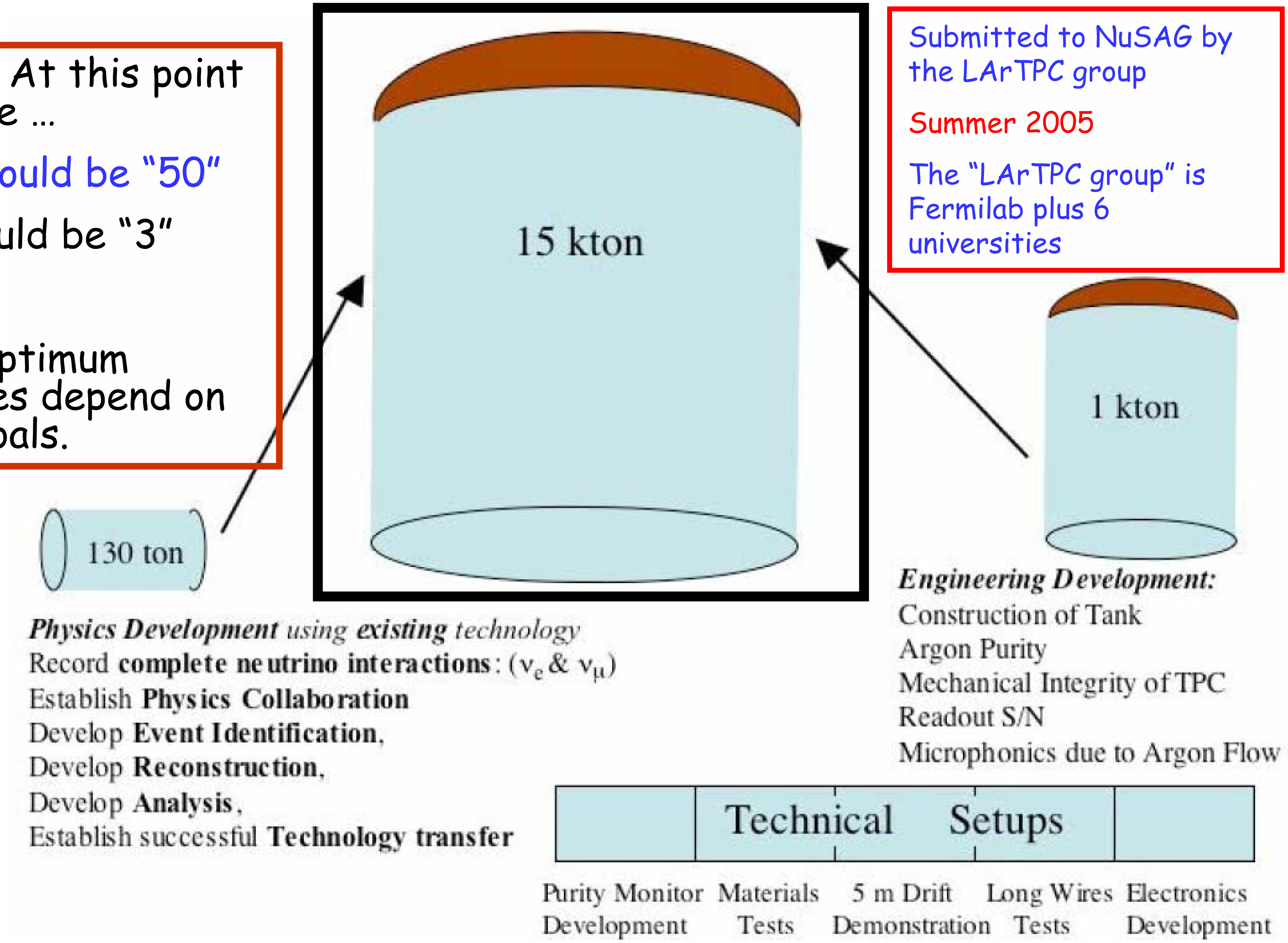
etc

The optimum choices depend on the goals.

Submitted to NuSAG by the LArTPC group

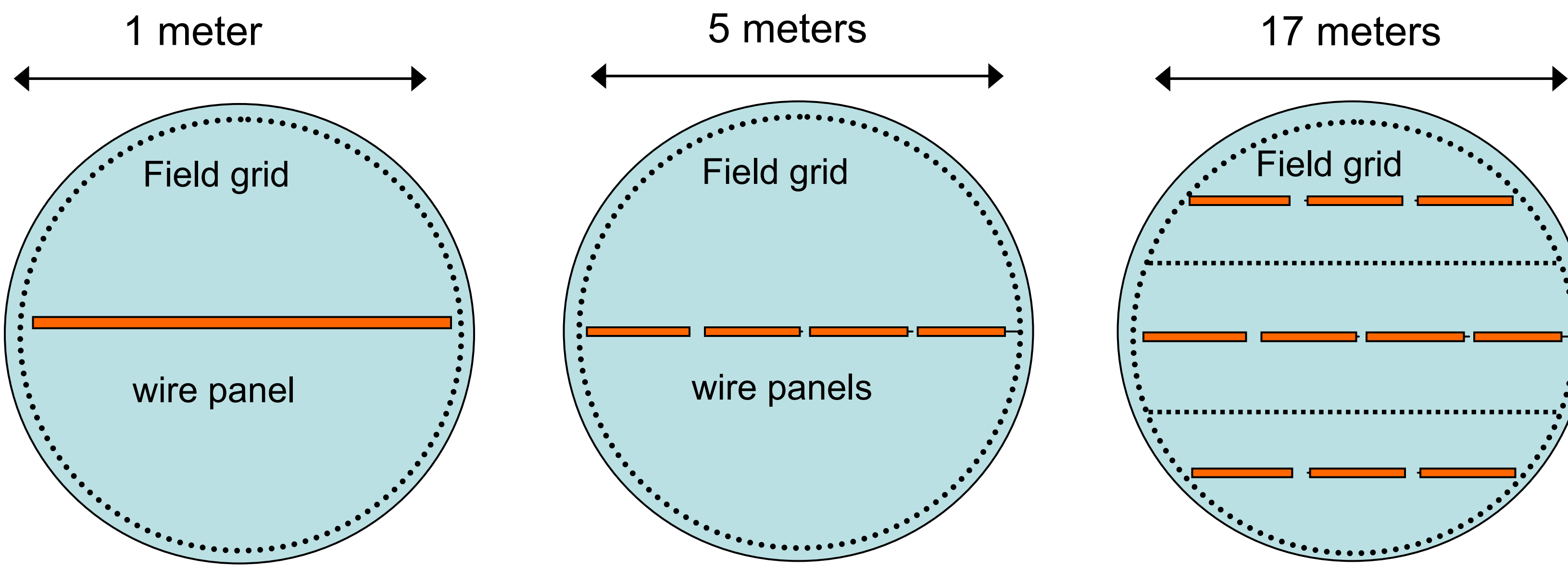
Summer 2005

The "LArTPC group" is Fermilab plus 6 universities



Liquid Argon Technical Agenda - Scaling up

A   5 ton detector is a cylinder 5 meters high with diameter 1 meter.
A 150 ton detector is a cylinder 5 meters high with diameter 5 meters.
A   5 kton detector is a cylinder 17 meters high with diameter 17 meters



The transverse dimension is partly modular - more panels, similar drift distances;

If the 150 ton detector works, the design of the 17 meter panel is probably the key technical challenge.