Liquid Argon TPC Activities at Fermilab etc

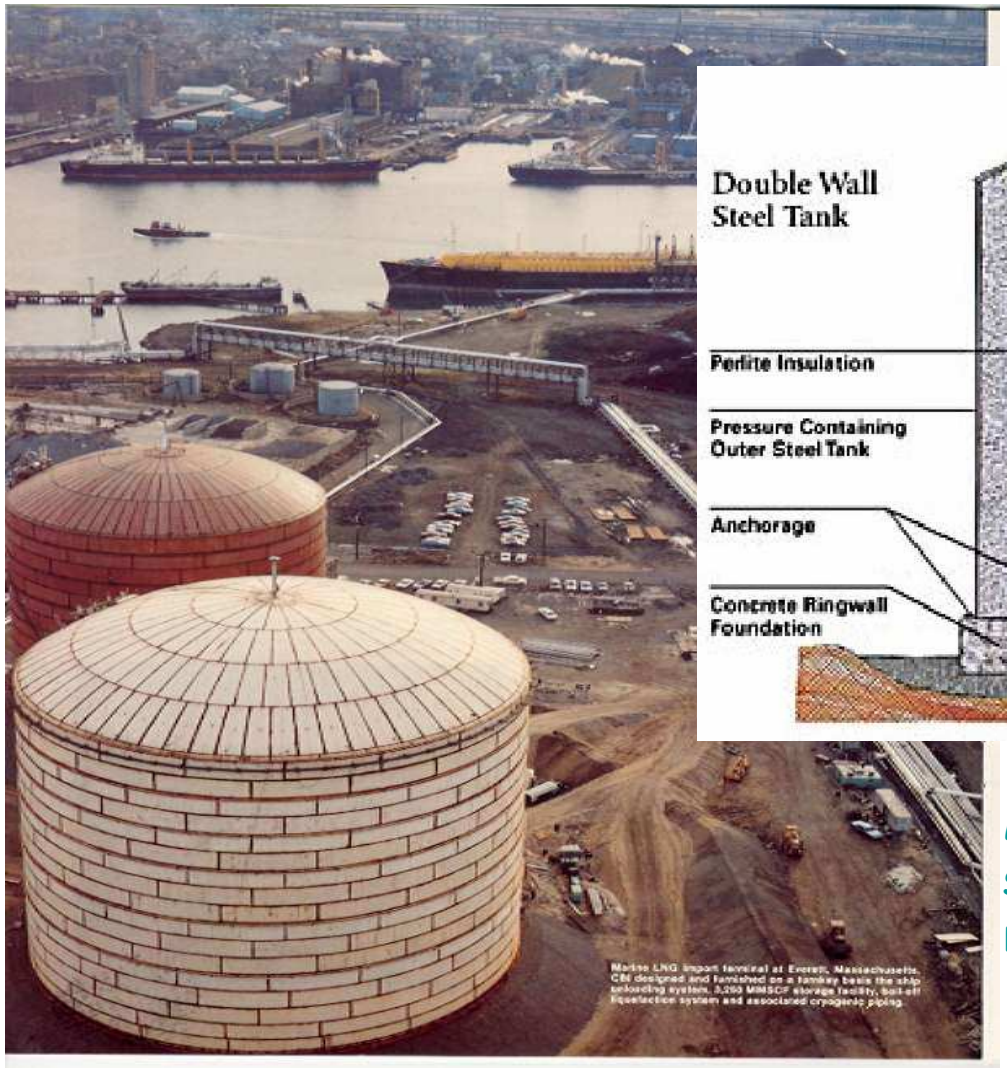
- Big Tank Paradigms
- Technical Progress at Fermilab etc
- The Future and the Bigger Picture

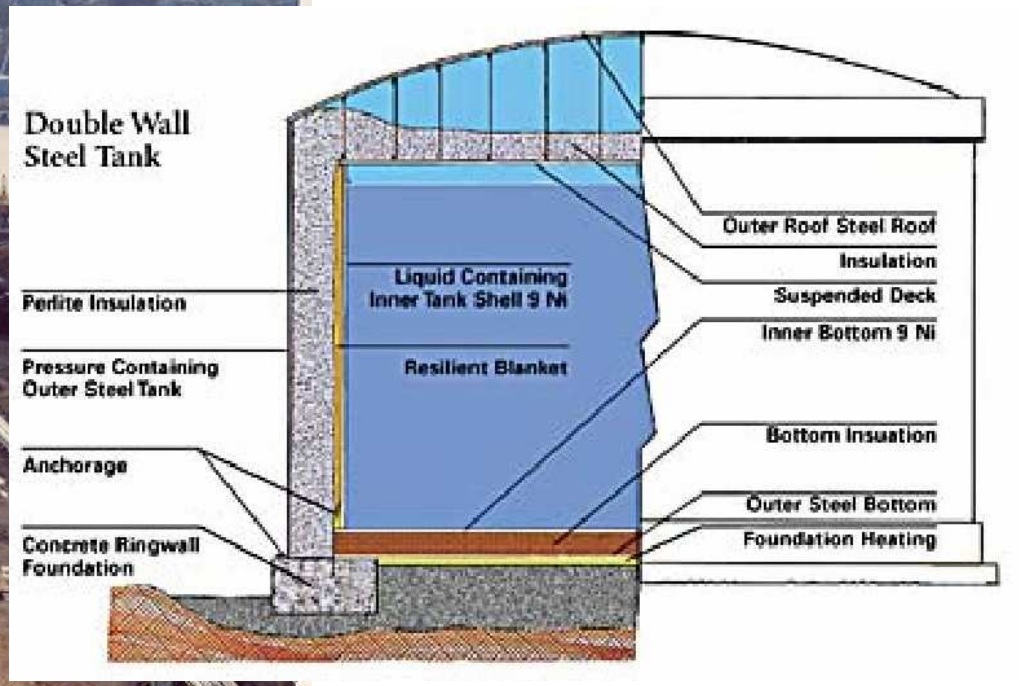
Big Tank Paradigms

- The present paradigm shared by Fermilab:
  - A detector in a neutrino beam on the surface
  - Although the neutrino beam itself may only be ~10 microseconds, the TPC will take ~2 milliseconds to read out

- Another paradigm (which could be shared by Fermilab):
  - A detector under (at least 50 meters of) dirt/rock cover, and the deeper the better
  - This also allows for a "dc" trigger for proton decay and supernovae neutrino watches

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



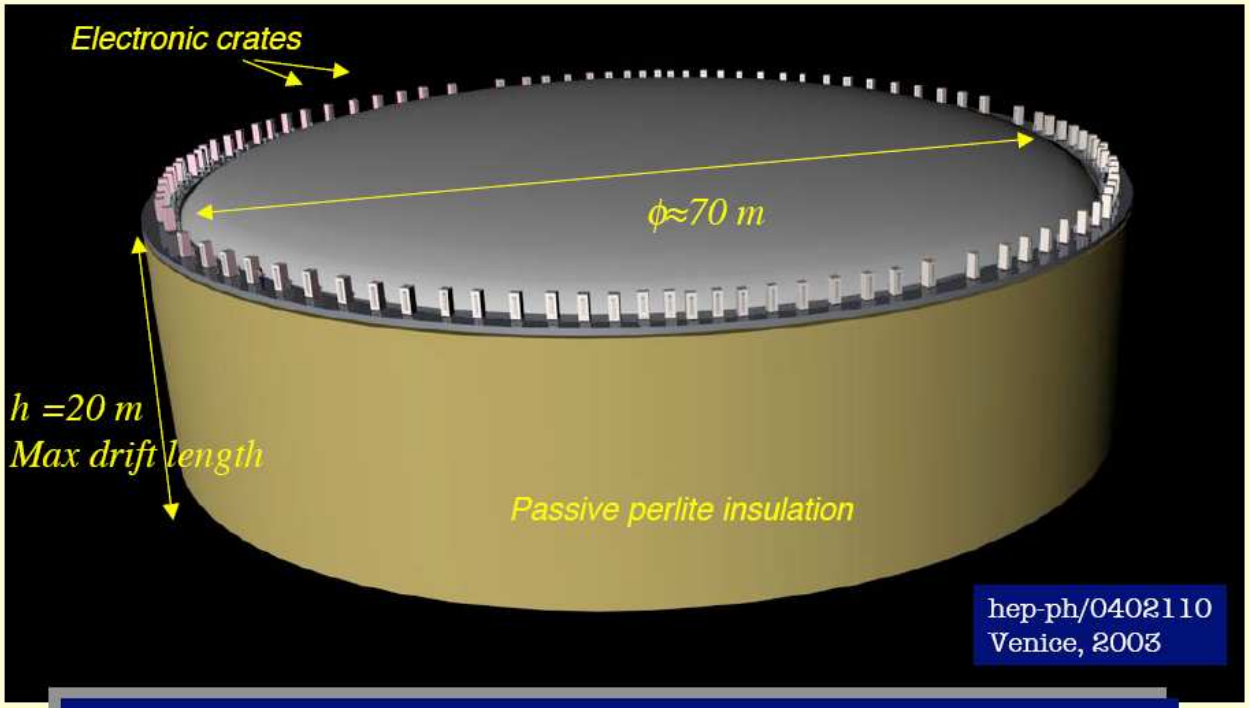


Many large LNG tanks in service. excellent safety record

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

Liquid Argon TPC Activities at Fermilab etc

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- The Future and the Bigger Picture

Focus of Fermilab efforts on LArTPC

- Focusing technical effort on issues related to the "Big Tank"

  - Build a purity monitor and show it can measure the purity required for the Big Tank

  -Build a Materials 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)

  - Iterate designs of the Big Tank (beyond FLARE) …

Liquid Argon TPC Overview for NuSAG

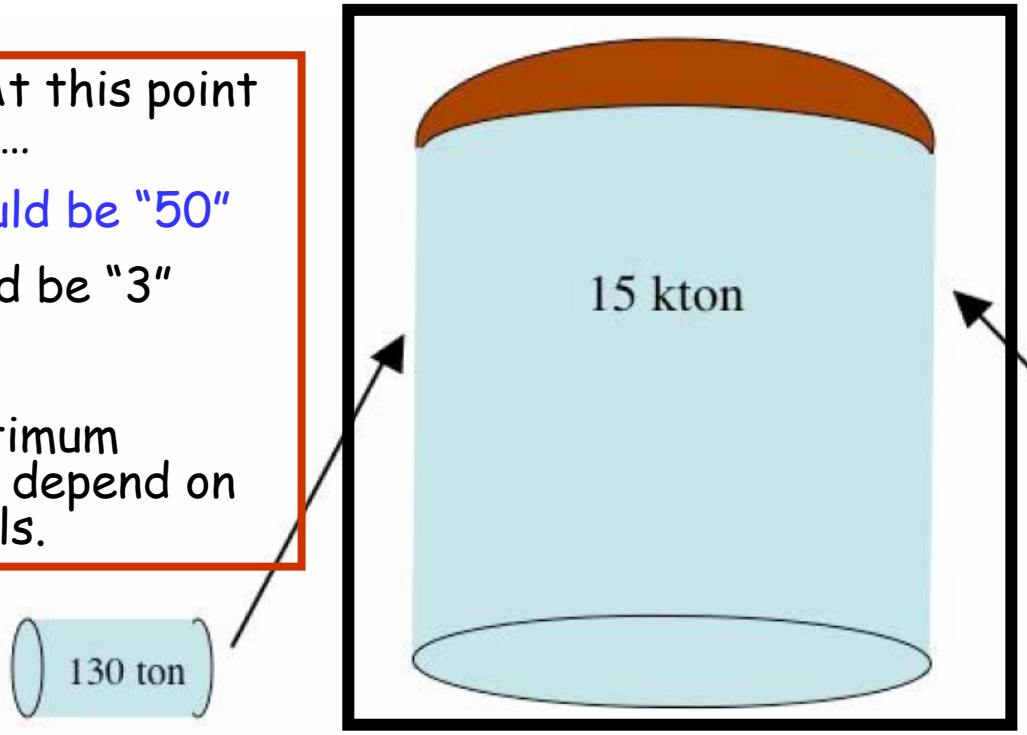
Note: At this point in time …

"15" could be "50"

"1" could be "3"

etc

The optimum choices depend on the goals.



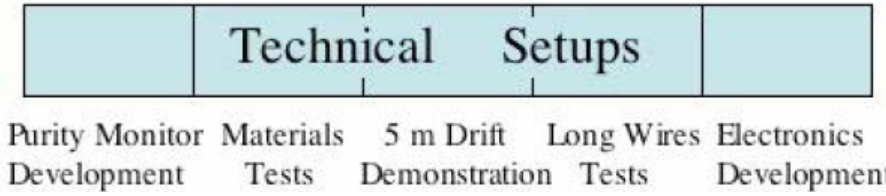
Submitted to NuSAG by the LArTPC group

Summer 2005

The "LArTPC group" is Fermilab plus 6 universities

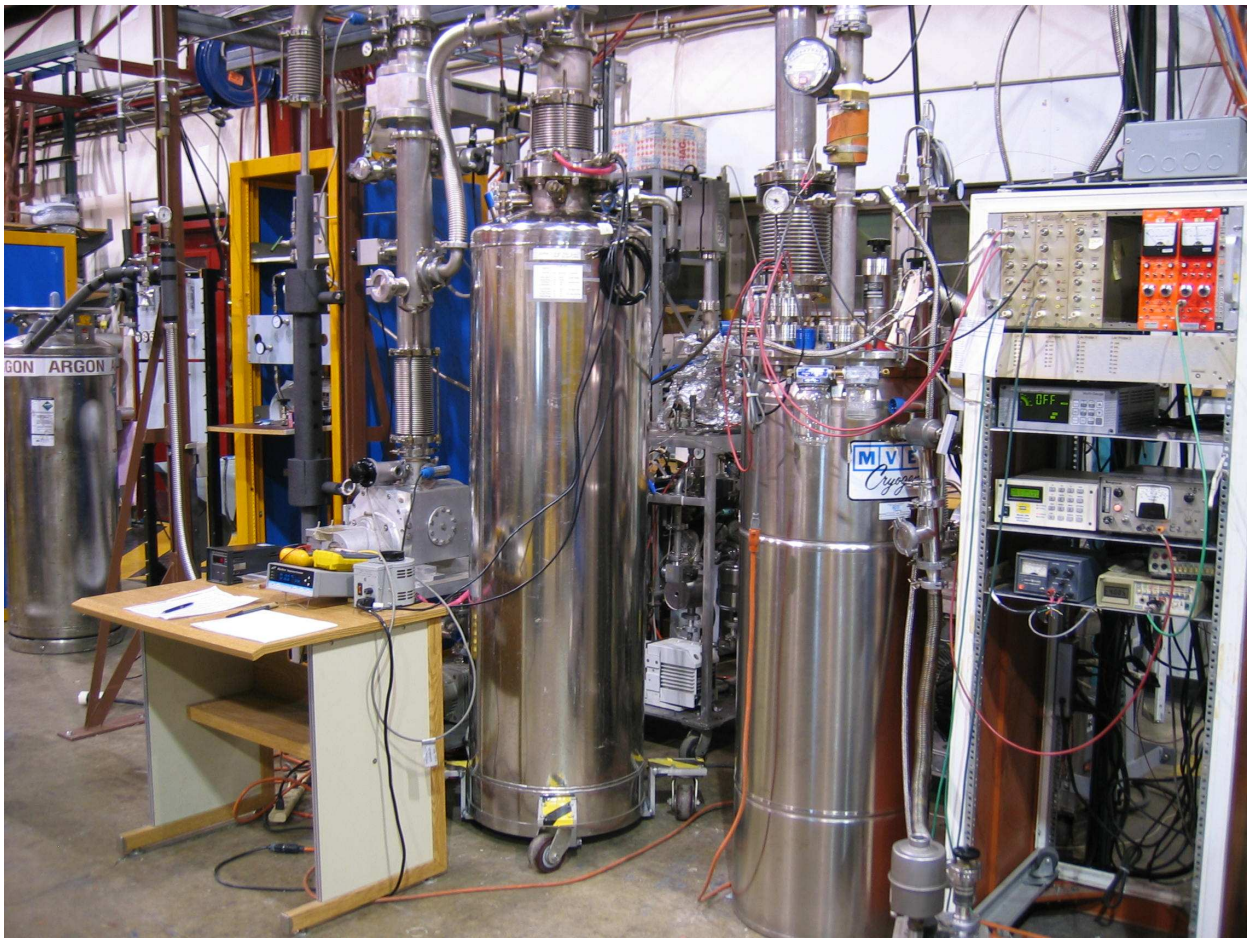
Physics Development *using* ***existing*** *technology*
Record **complete neutrino interactions**: (ν_e & ν_μ)
Establish **Physics Collaboration**
Develop **Event Identification**,
Develop **Reconstruction**,
Develop **Analysis**,
Establish successful **Technology transfer**

Engineering Development:
Construction of Tank
Argon Purity
Mechanical Integrity of TPC
Readout S/N
Microphonics due to Argon Flow



Setup at PAB (Proton Assembly Building)

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)

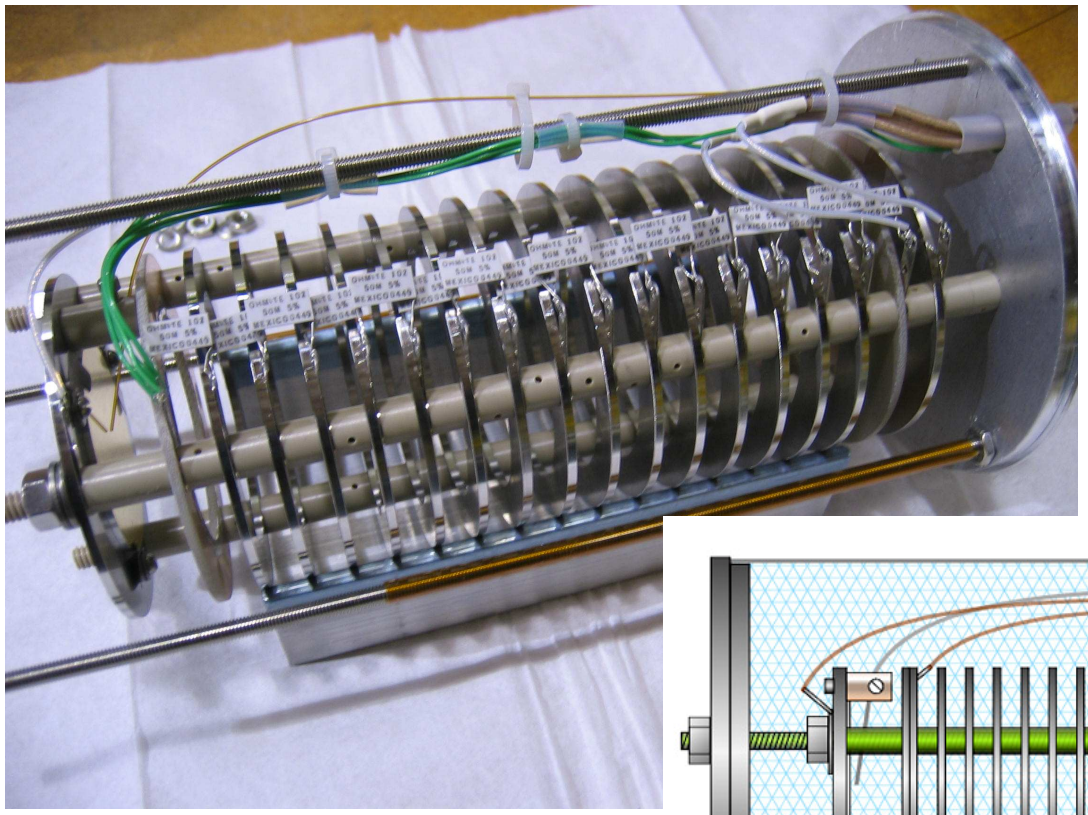


May 4, 2006 Milestone

With only a purity monitor immersed in LAr in the test dewar, we measured a purity better than that required for a ~15 kton Big Tank.

(Spec: 3 meter drift has less than a 20% loss of signal.)

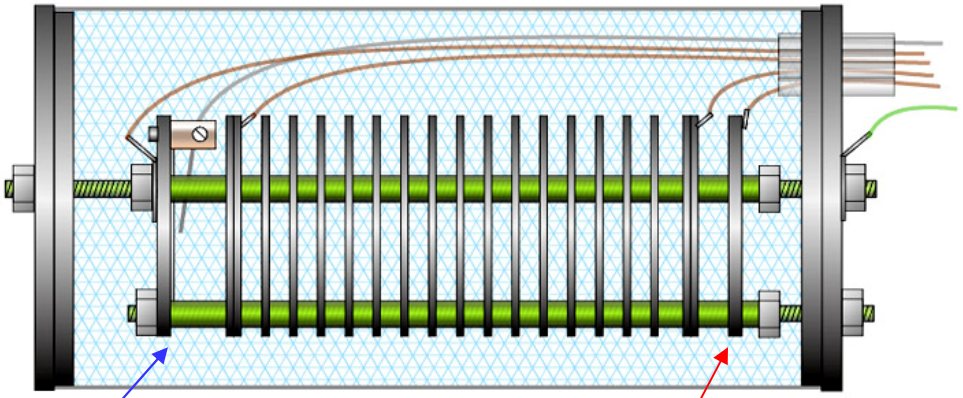
Liquid Argon Purity Monitor



~ 20 cm from anode to cathode.

Based on ICARUS design.

Used to measure electron "lifetime".

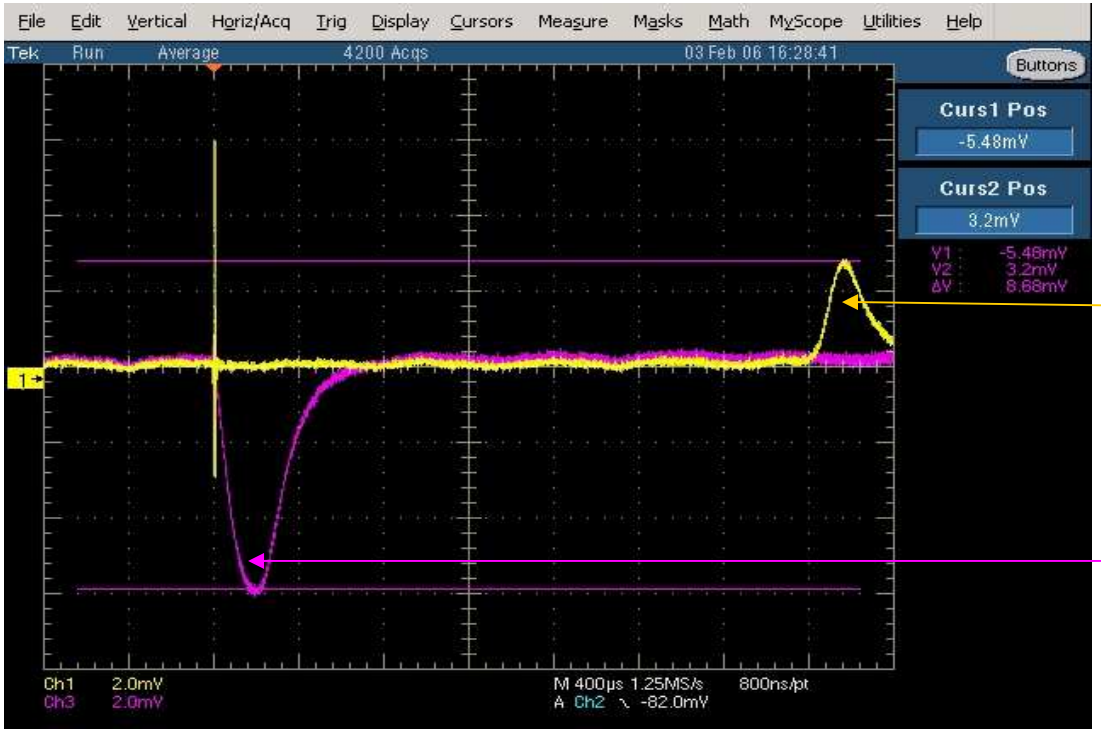


Flash of light strikes photocathode

Electrons arrive at anode

C.Kendziora2/3.05

Electron lifetime measurement in LAr



anode signal

cathode signal

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

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

- Our **first measurement** surpassed the 2 msec lifetime required for a 3 meter drift with a 20% loss.

Next Step: Materials Test Station

Implement the Materials test station.. (new closed system cryostat - sketch at right)

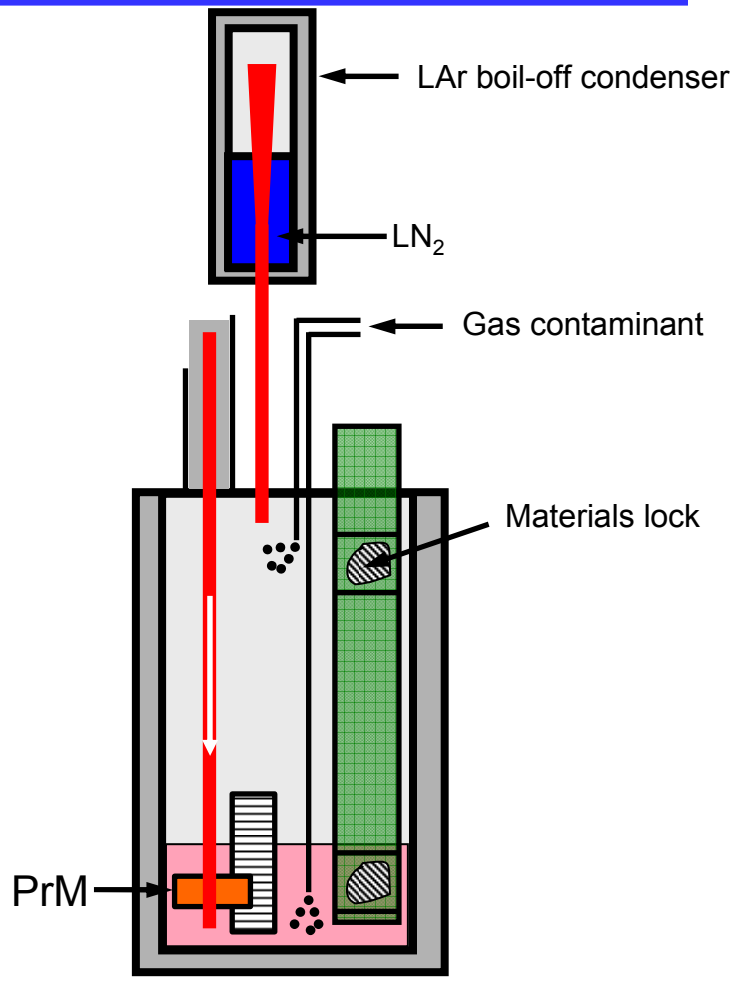
Develop in-cryostat thermal pump.

All of the parts for full system are on hand.

Note Materials lock.

Start debugging the system by October 2006

Start testing materials by November … if all continues to go well.



T. Tope

Materials Test Station Flange and People

Inserting Materials Test Station Flange

September 14, 2006

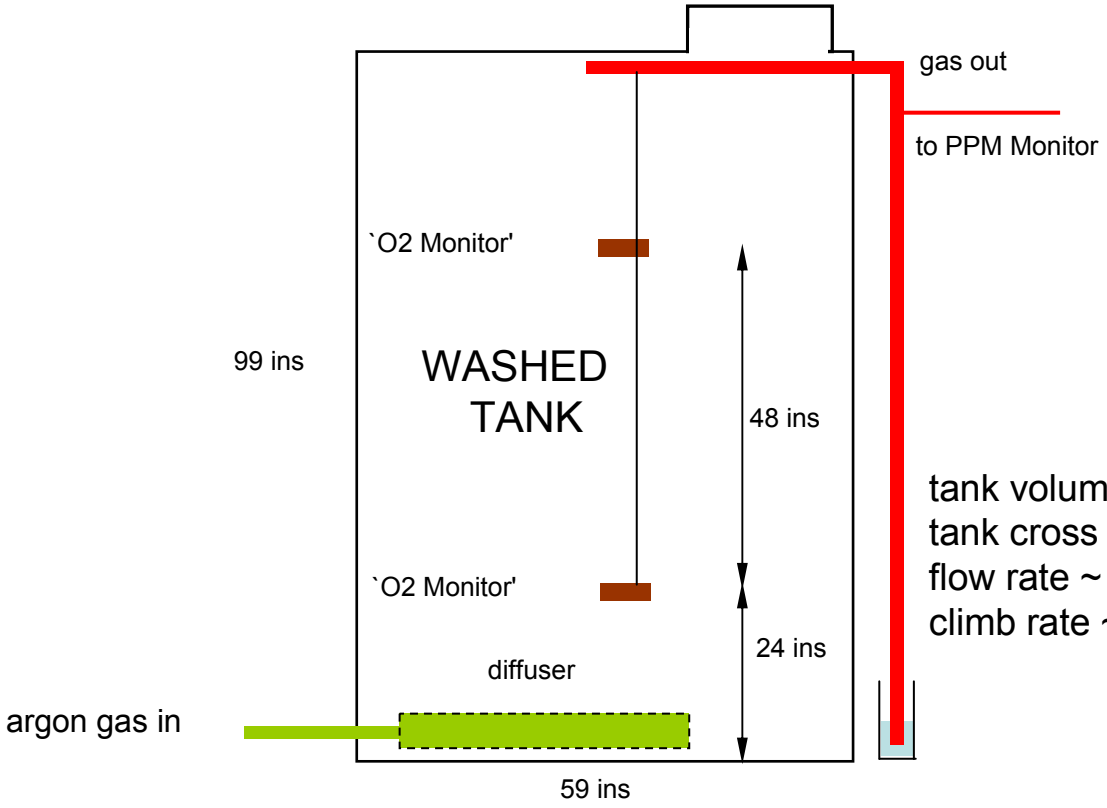
Stay tuned …

and feel free to suggest materials to be tested

Use an "Argon Piston" to Purge a "Tiny Tank"

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 model will achieve a given reduction in air concentration.



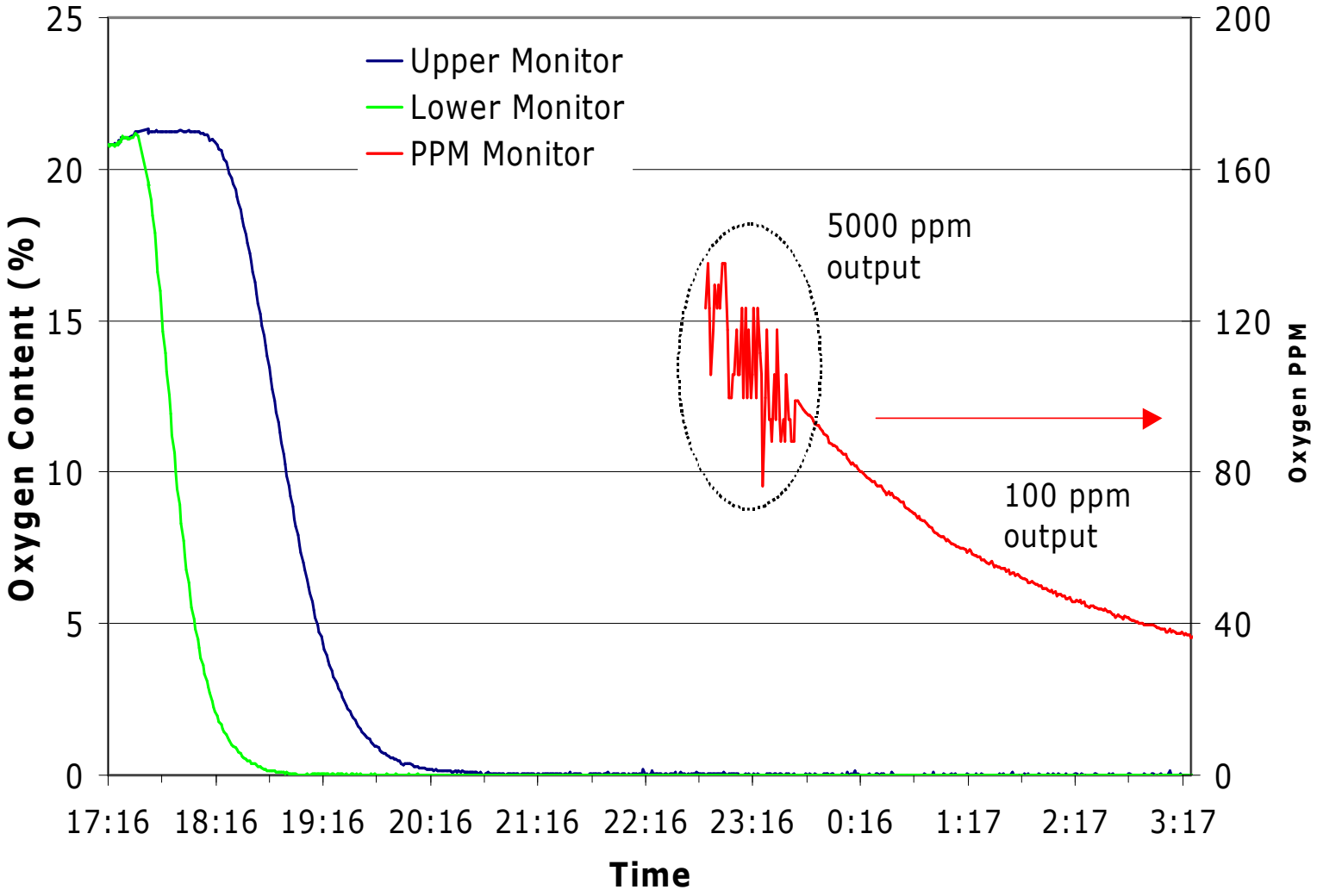
tank volume = 157 cf
tank cross section = 19 sf
flow rate ~ 73.2 cf/h (reading for air was 86 scfh)
climb rate ~ 3.8 f/h

The Tiny Tank …

… behind an average sized engineer.

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

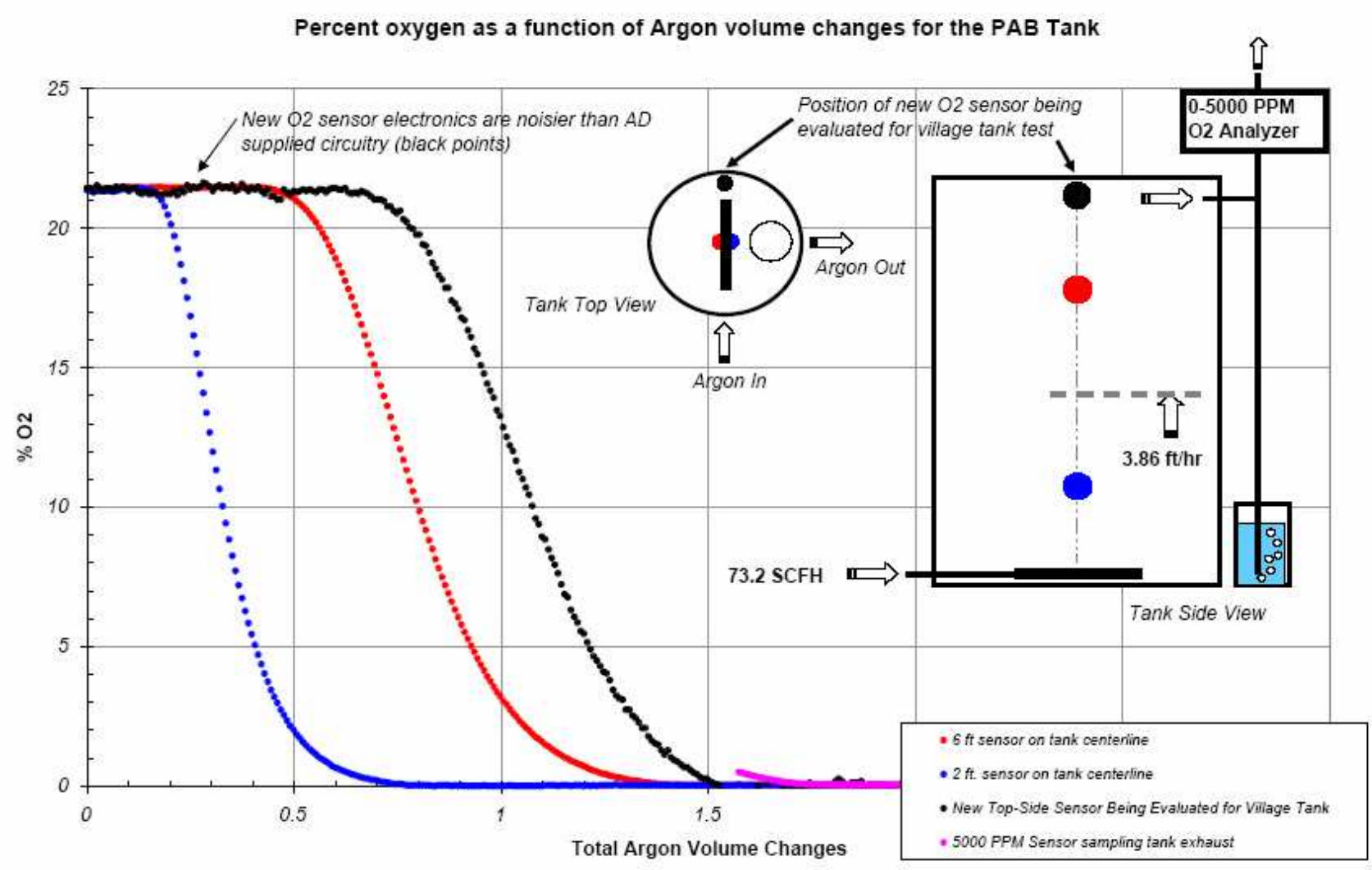
Oxygen Content vs Time



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)

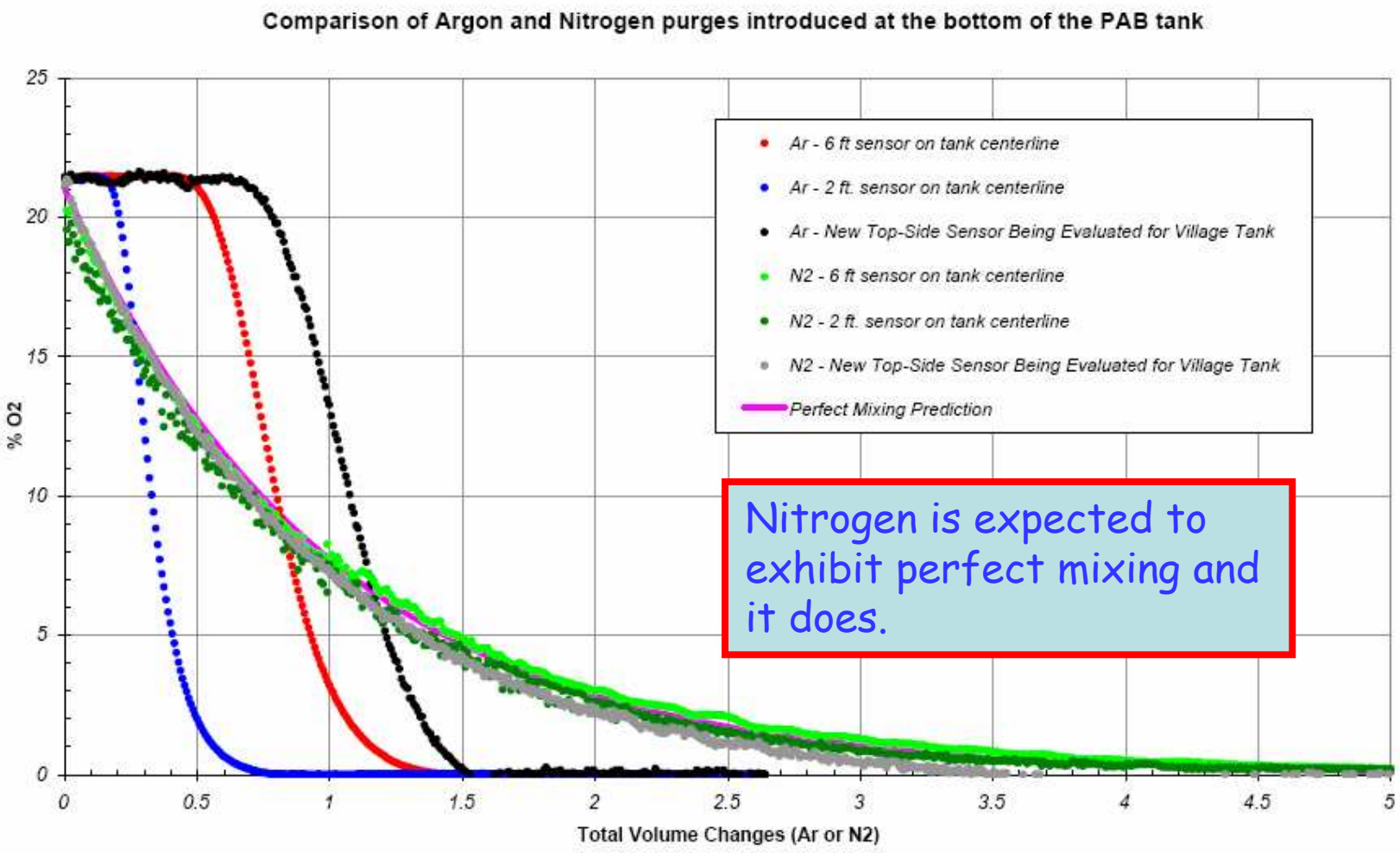
Next Step: More Instrumentation

Terry Tope
6/5/06



Final Step with "Tiny Tank"

Terry Tope
6/5/06



Purging a "small" tank

- The "Village water tank" was built for the village of Weston in the 1960's, and has a volume the same as ~1,000 tons of liquid argon (1.40 g/cm^3).

- We intend to explore its use to get data to challenge models and ideas for purging big tanks with argon gas.

- *starting from atmospheric conditions*
- *without evacuating the tank, or using clean room conditions to assemble the TPC (unlike what ICARUS has done)*

Only the first step towards a Big Tank with ~30 ppt with a LAr purification system (note: ppt)

Purging a "small" tank

• The "Village water tank" was

• Issue: It will take more than 24 hours to make the measurement since the argon piston must rise slowly.

• Question: How much will sunshine mess up the measurement?

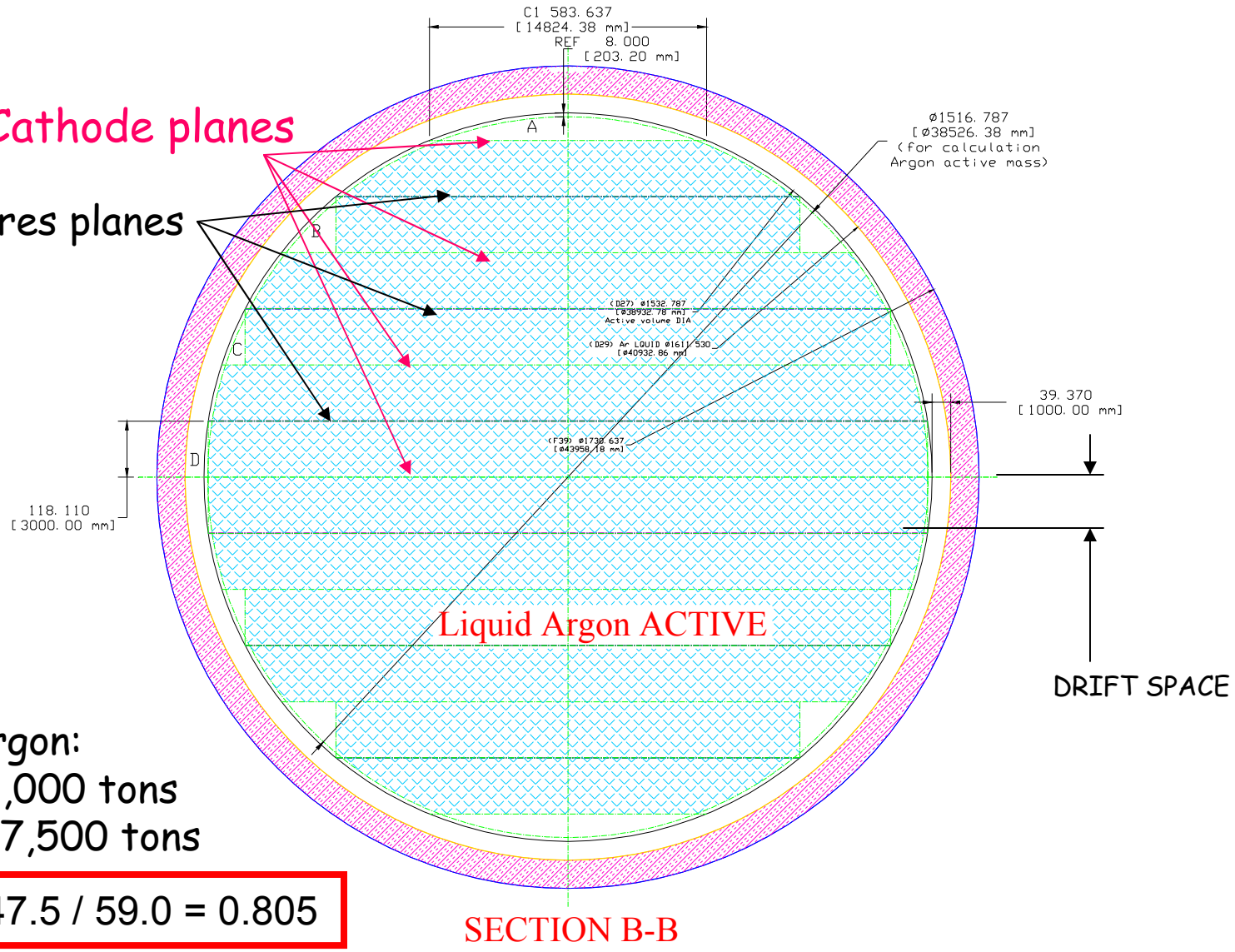
• Answer: Too much. When the sun shines on the tank one side is about 20 degrees C hotter than the other side.

• Problem: Thermal currents will produce uncontrollable distortions of the "piston".

• Next step: Either abandon this test, or pay money to make it useful.

pt)

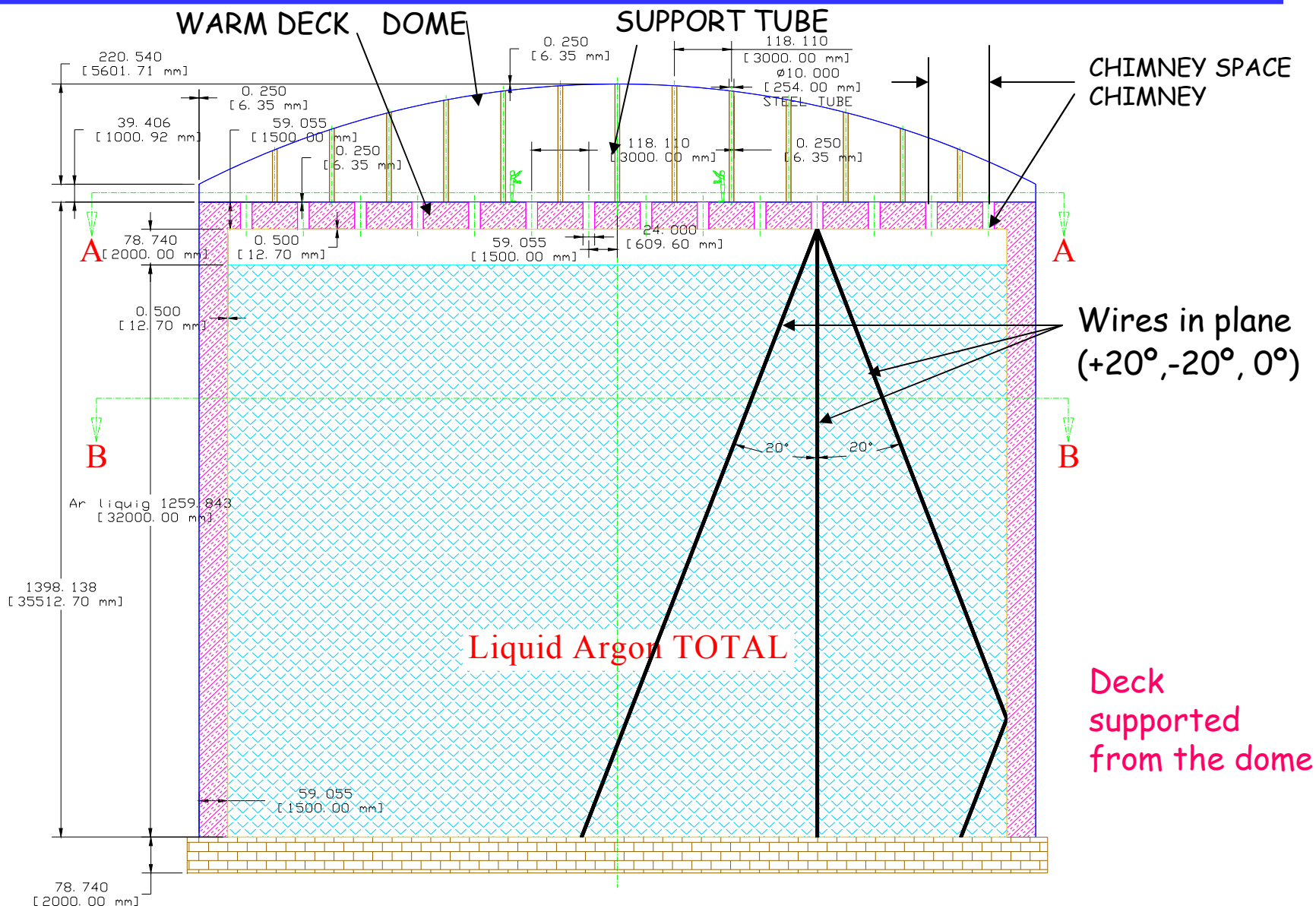
Example Design: View from the Top: LArTPC 50KT



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

Note: 47.5 / 59.0 = 0.805

Example Design: LArTPC 50KT (wire plane section)



An Alternate Wire Layout

In the example 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.

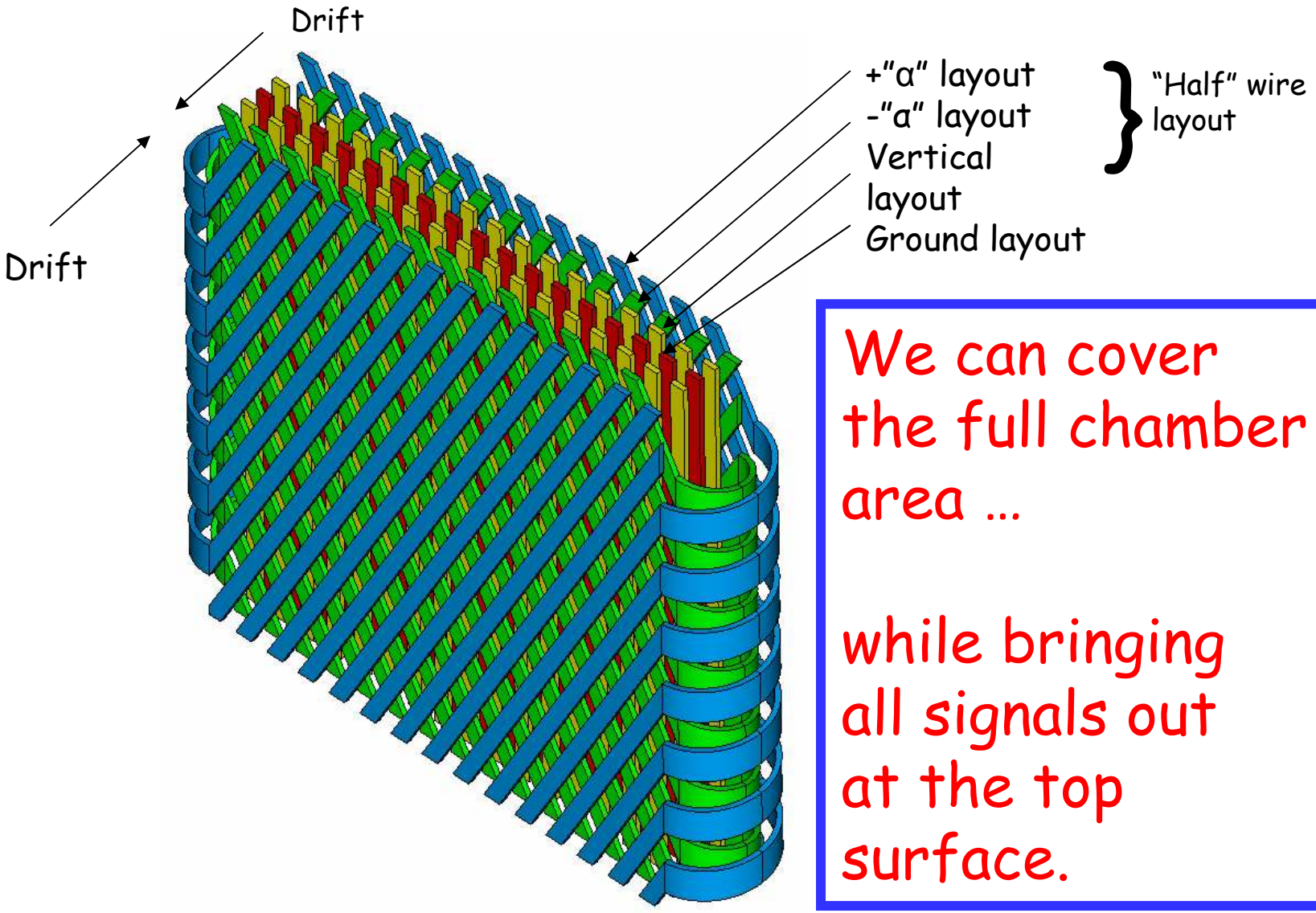
For each plane in the left triplet, there is a corresponding plane, with the same DC potential, in the right triplet.

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.

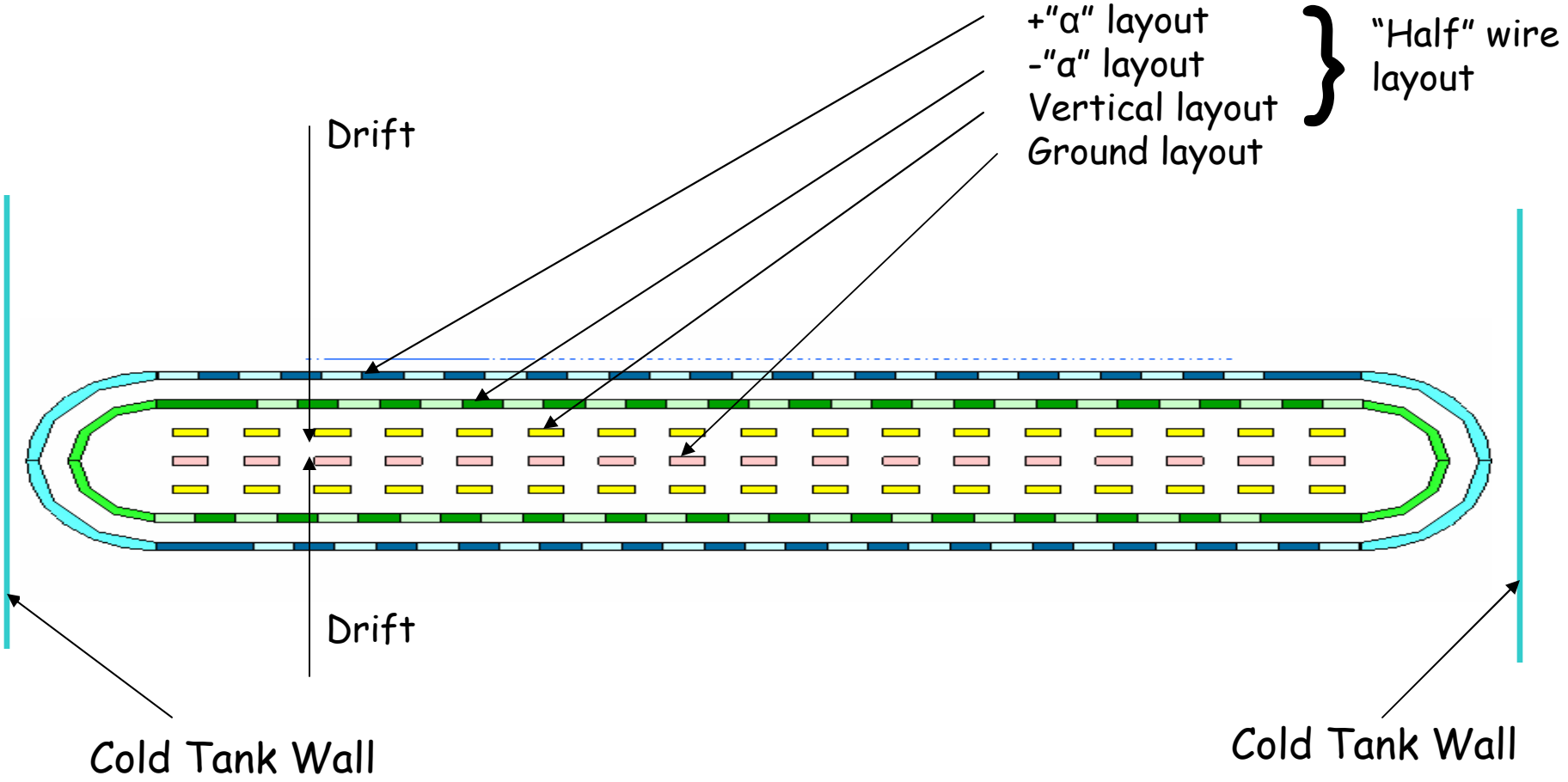
"Complete Coverage" Conceptual Layout



We can cover the full chamber area …

while bringing all signals out at the top surface.

View from the Top: Complete Coverage Layout



Next Step: Cellular TPC Layout

Interpret the previous cross section as that of a panel or "ladder" that forms a "cell" just 3 m wide.

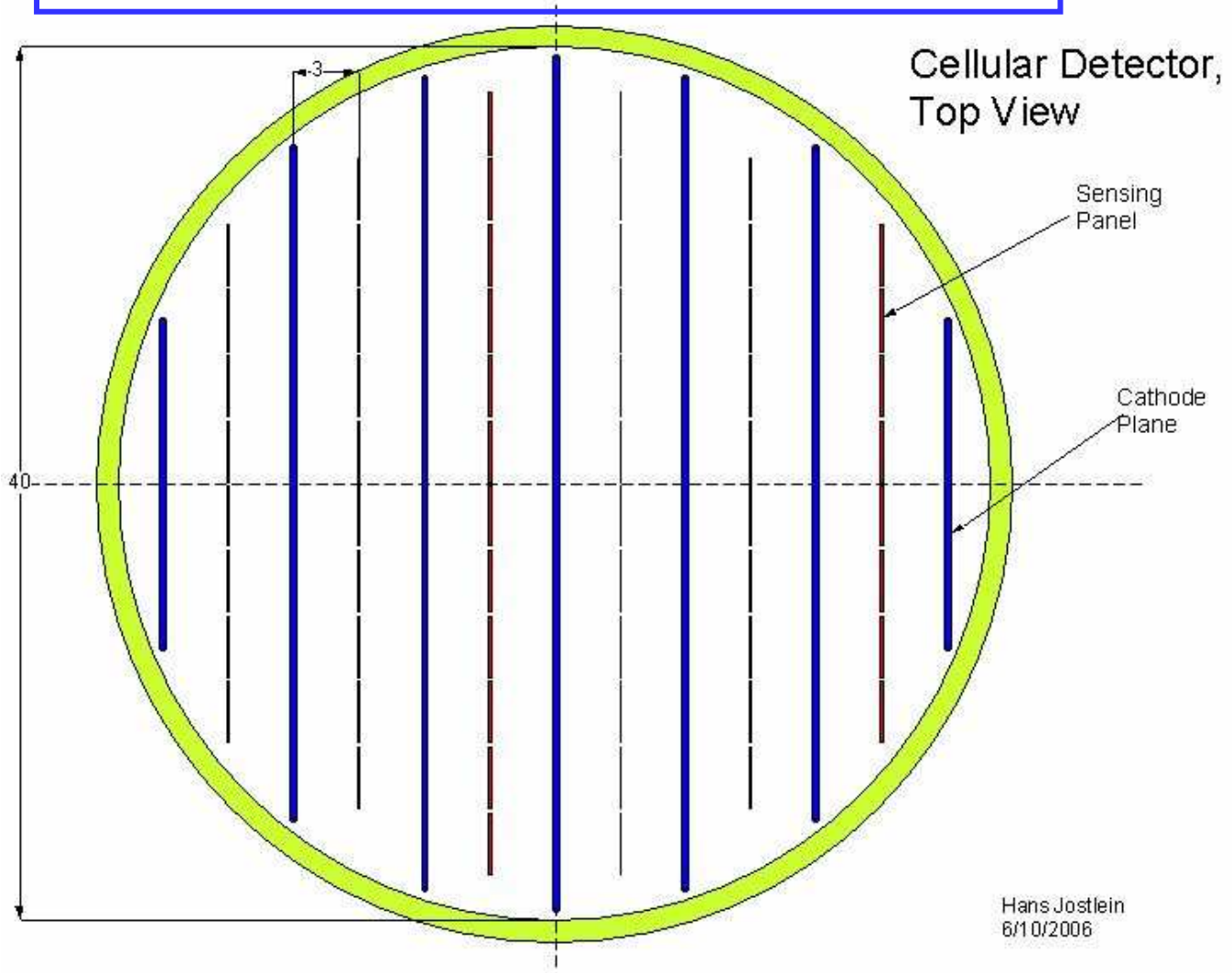
If you choose to do so (but it is not recommended), the wires may wrap several times around the ladder, depending on their angle … making pattern recognition becomes harder.

Make the ladder tall enough to reach the top of the Argon pool

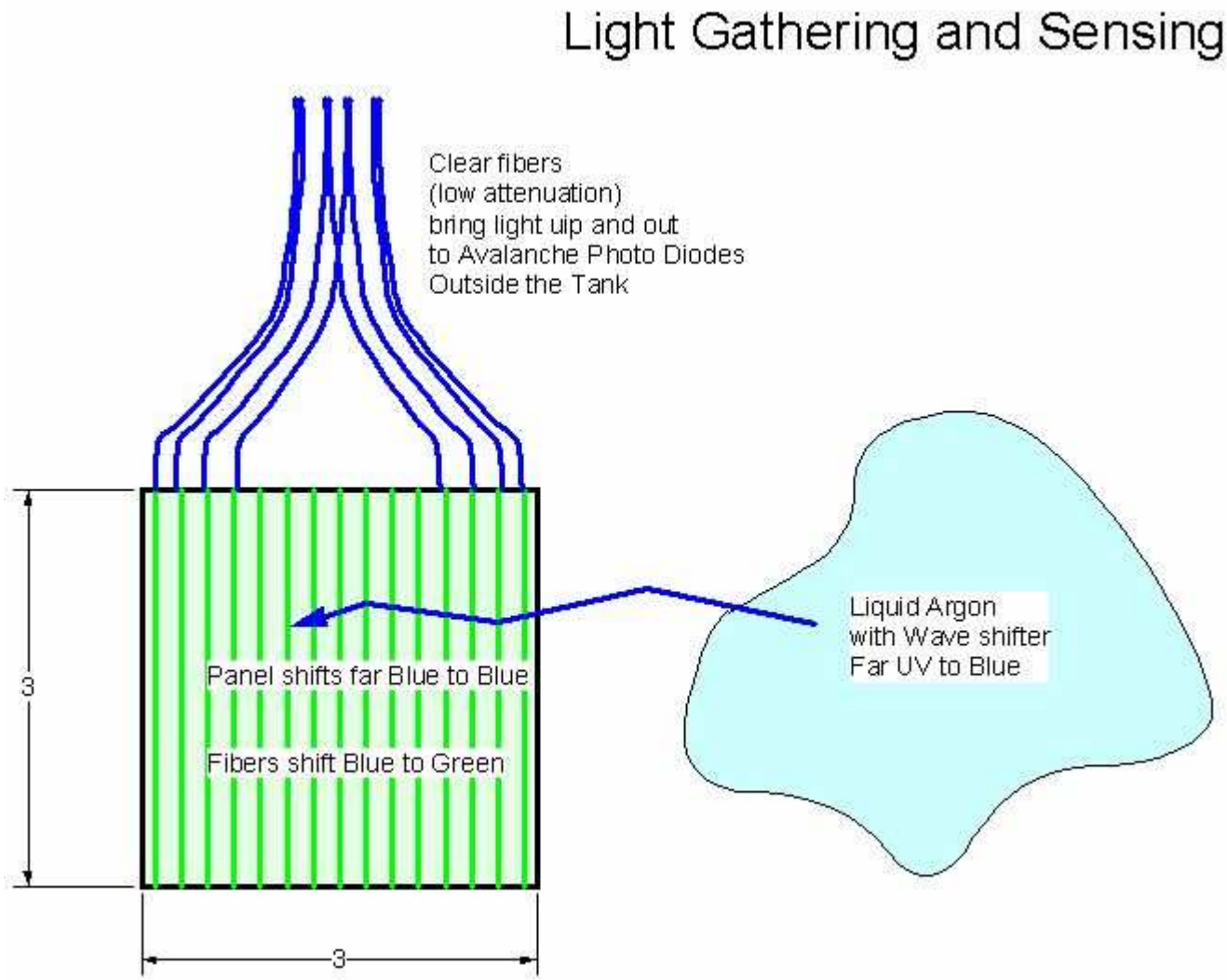
What do we gain ?

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

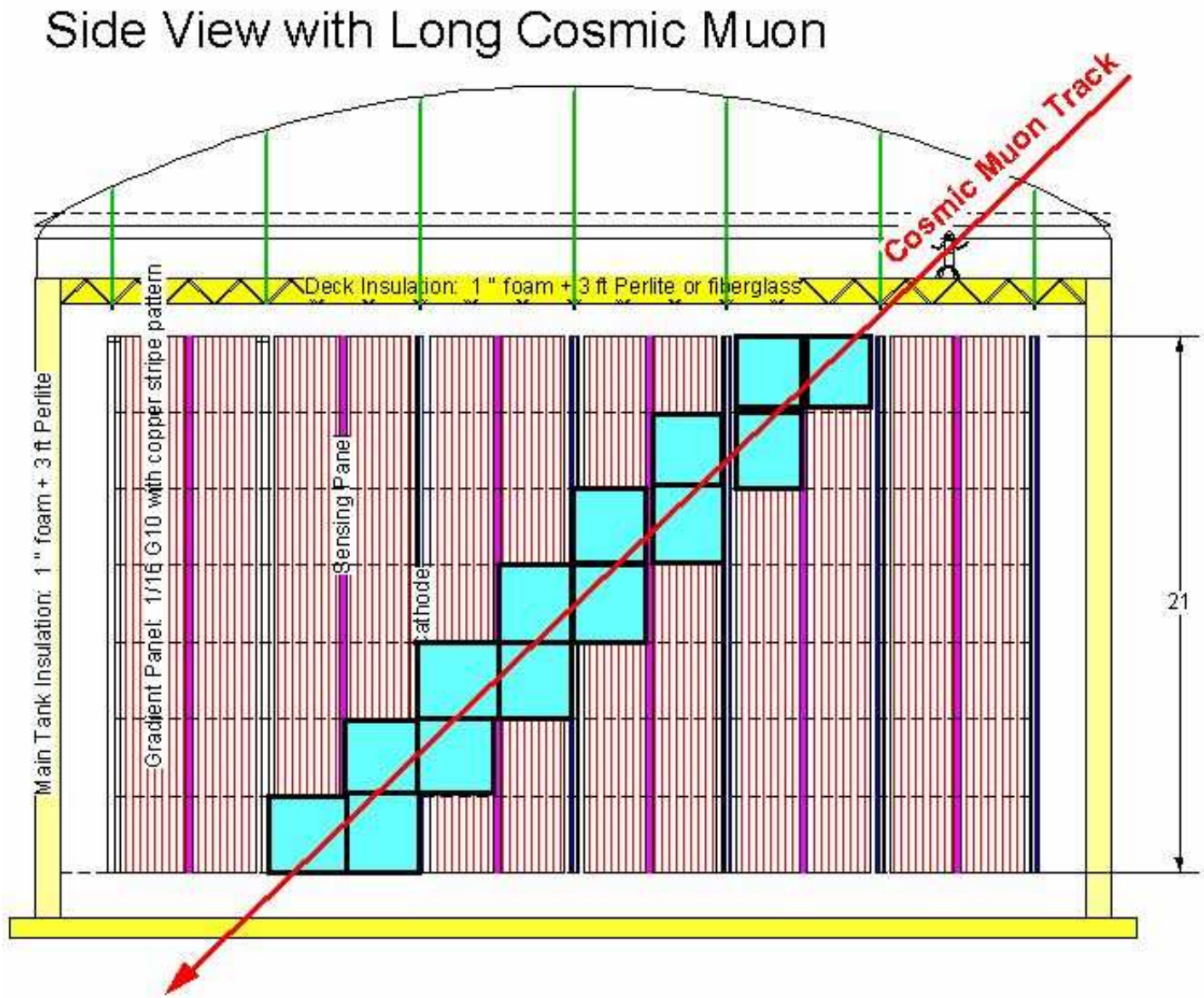
Cellular Detector, Top View



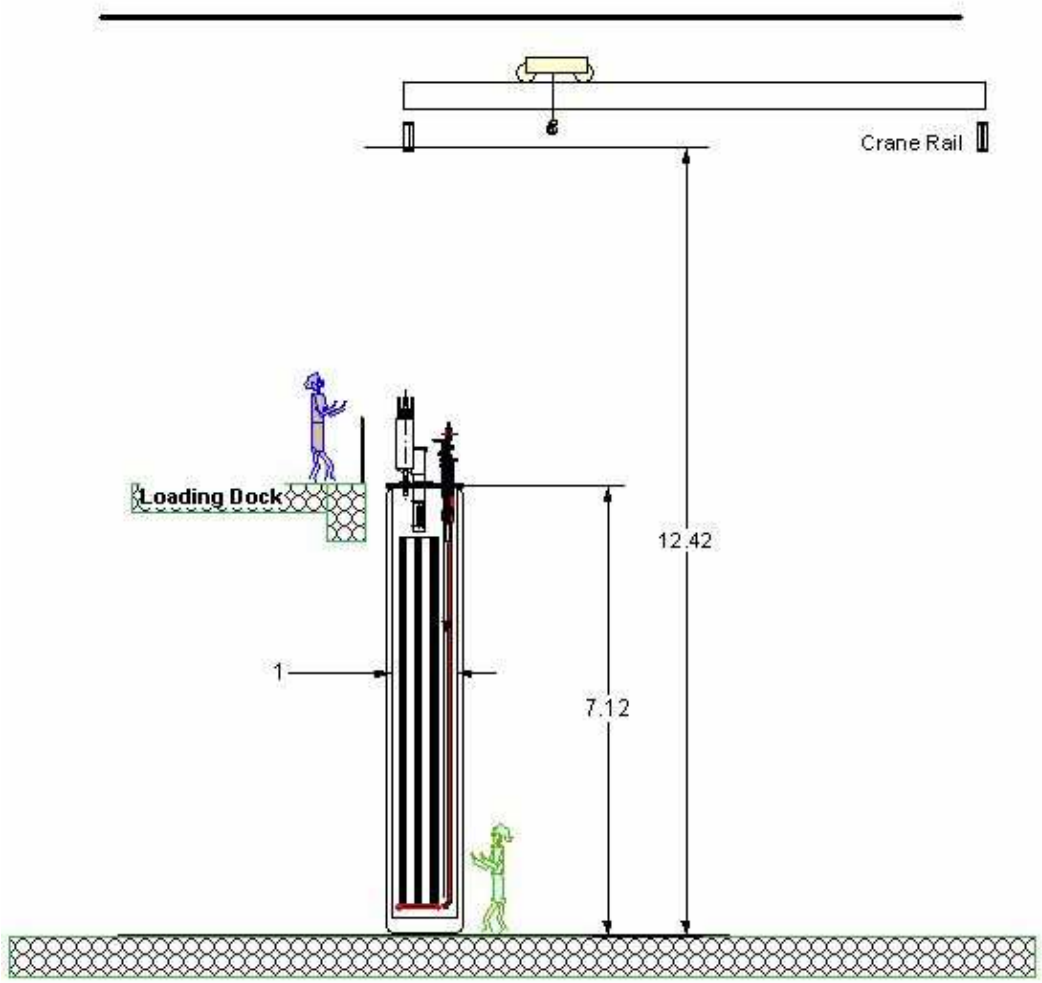
Possible Additional Capability: Light Collection



Light Pattern of a Long Muon



Concept for 5 meter vertical TPC (~5 tons)



5 m Cryostat in Wideband Lab

Hans Jostlein
7/26/2006

Drawn for the Wide Band Hall at Fermilab.

A concept, not yet a plan, much less a funded activity.

Purposes:
- Demonstrate drift of 3 or more (up to 5) meters
- Demonstrate level of purity achievable without evacuation and with a TPC
-Demonstrate cellular design for the Big Tank

What it does not do, but a horizontal TPC can do better:
- Measure pi_0's in test beam
- Measure neutrino interactions

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Selected Steps on the Liquid Argon TPC Path

- Workshops
  - –Cryogenic Detectors held at Gran Sasso March 2006
    - http://cryodet.lngs.infn.it/
    - focus on cryogenic detectors of all types probing neutrino physics, dark matter searches etc
    - Three speakers from the LArTPC group
  - – Workshop at Yale July, 2006
    - focus on the next credible steps towards a large liquid argon TPC based on more global collaboration ("large" means "much larger" than ICARUS' 600 Tons)

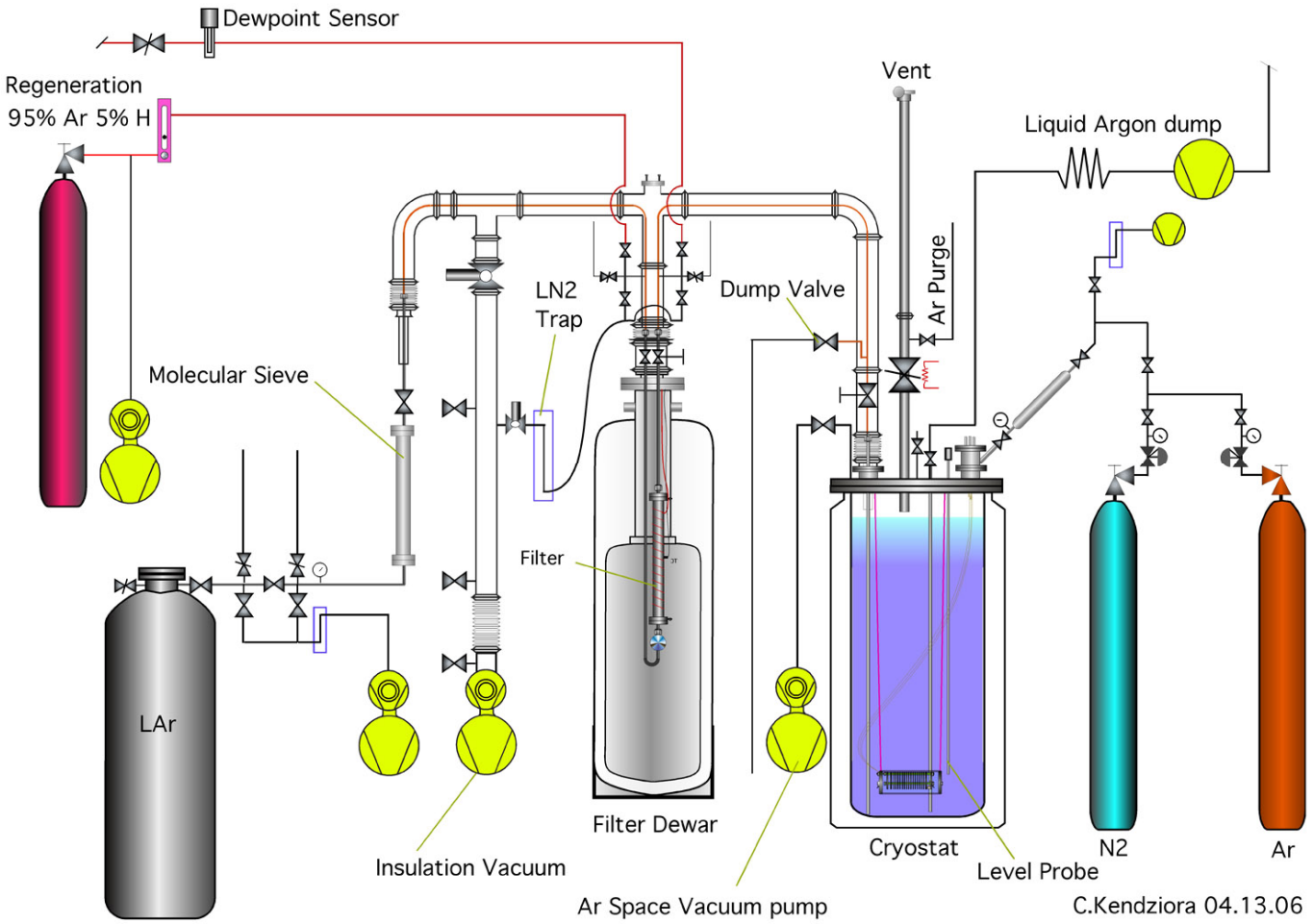
- Studies
  - – ISS (just now finishing a yearlong study)
  - – Long Baseline Study by Fermilab/Brookhaven
    - To be used by NuSAG
    - Design Against Cosmic Rays … Go underground! … or …
      - –Is this really an issue for neutrino beams, or just a worry?

- One of the next steps could use one of the Fermilab high intensity neutrino beams.

- Formation of collaboration(s) with global character to define technical goals, plans, schedules, costs and to get funding etc to enable the physics we want to do

Backup

PAB Setup for Purity Monitor



Our 1st Purity Monitor Signal in LAr

anode signal

photodiode

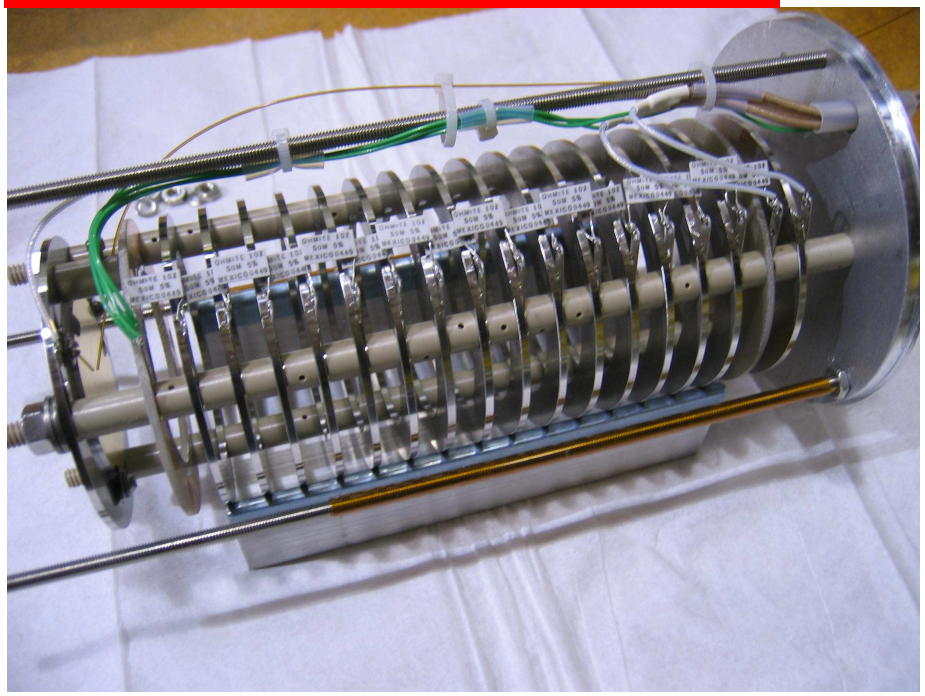
cathode signal

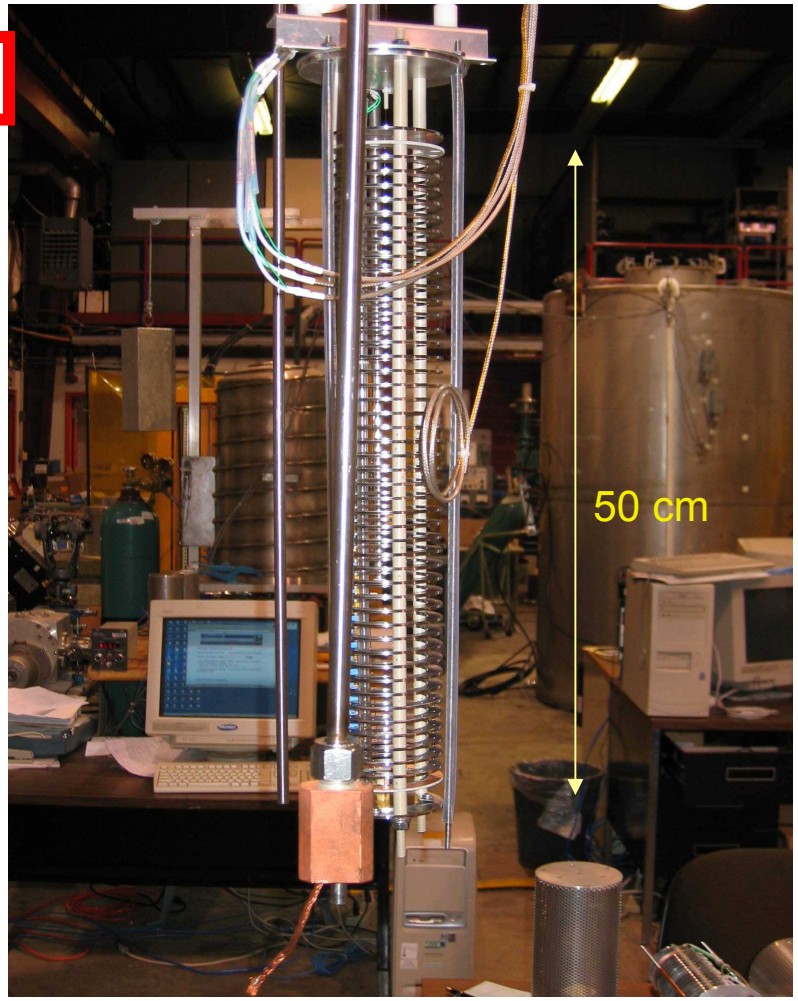
t_{drift}= 150 µs, $Q_{anode}/Q_{cathode}$= ~1

More Purity Monitors

Long Purity Monitor - for long drift life times

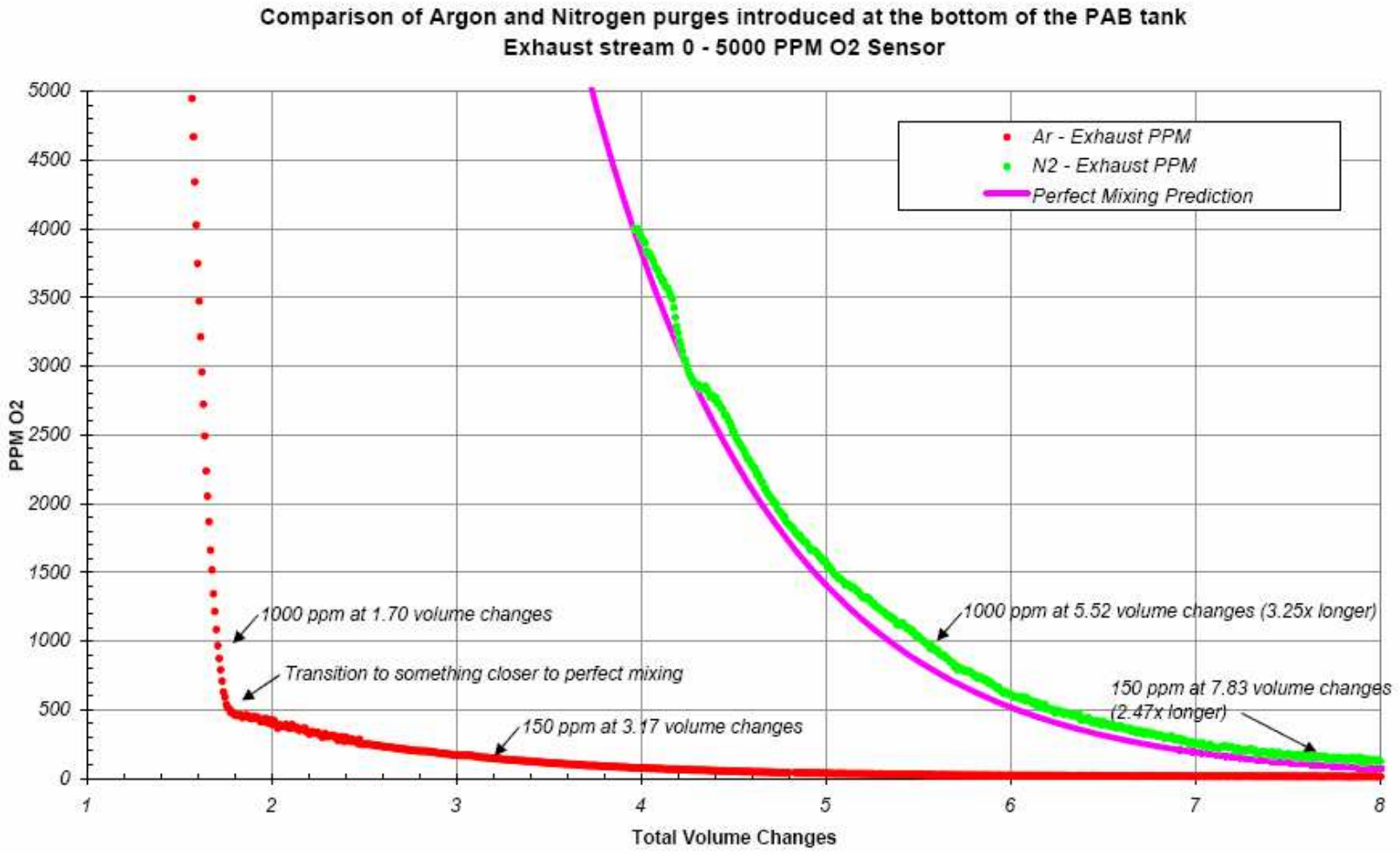
ICARUS Clone made at Fermilab



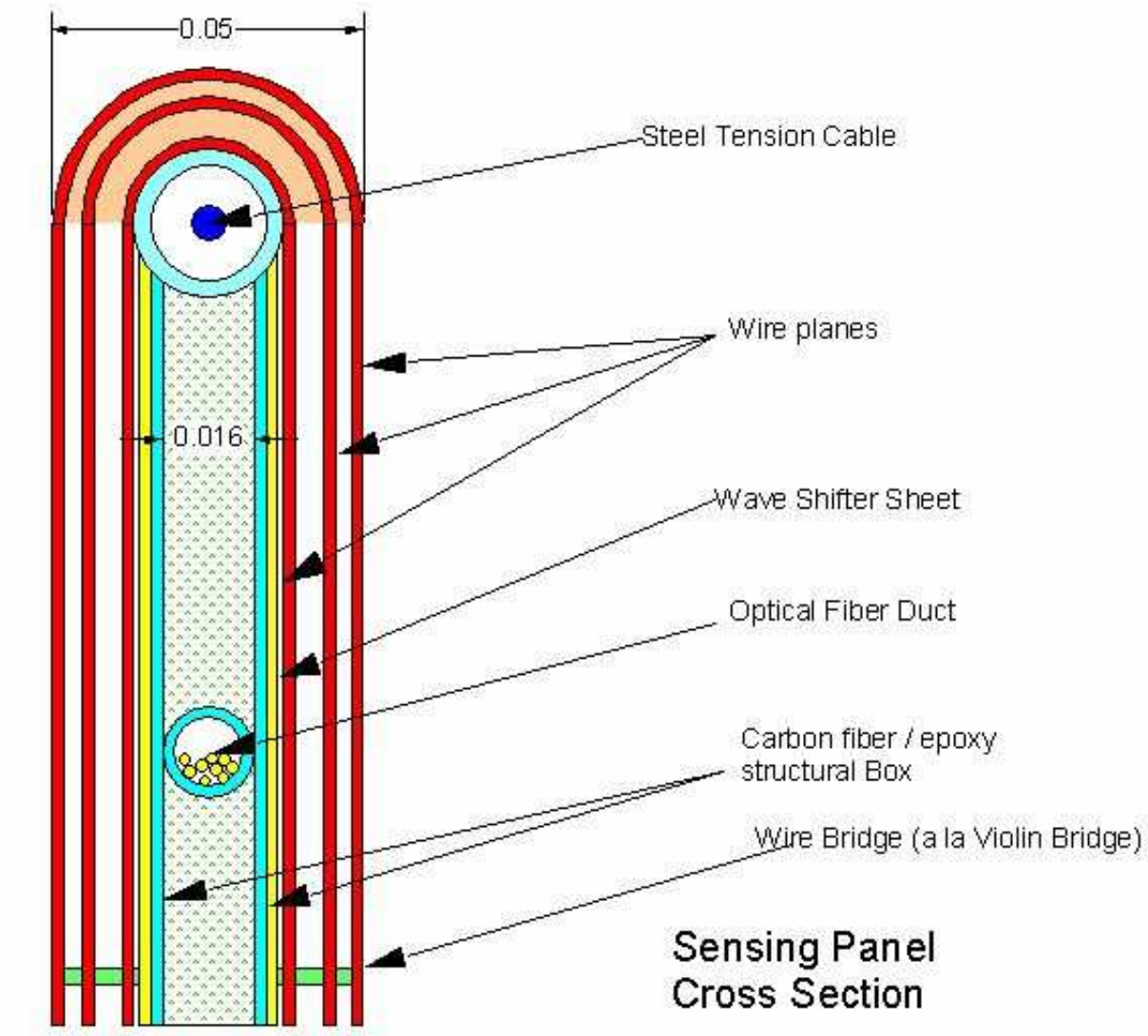


Better View of Final Step with "Tiny Tank"

Terry Tope
6/5/06



Sensing Ladder Cross Section



Not shown: Nylon Stocking

Hans Jostlein
6/10/2006