R&D for an Ash River LAr Detector …and beyond

- One Slide Overview
- Concept for Mid-Term R&D path
- Cellular Design
- High Voltage Distribution

First: A One Slide Overview for Director Briefing David Finley April 24, 2007

Liquid Argon TPC R&D (Fermilab perspective)

See: http://lartpc-docdb.fnal.gov/cgi-bin/ShowDocument?docid=253

- Massive (5, 10, 50, 100 kton) LAr Detector for neutrino physics
- "Big Tank" Technical Efforts at Fermilab
  - Design of 150 ton Tank Purity Demonstration (without evacuation)
  - Argon Piston (first step from atmosphere for big tank purification)
  - Materials Test Station (to qualify / disqualify TPC materials)
  - Cellular Design of the TPC (to simplify TPC installation in big tanks)
  - Purity Monitors, Purification techniques (to few parts per trillion)
- "Small" Technical Efforts at Fermilab
  - Smallest TPC for electronics development (MSU, et al.)
  - Small (~0.5 ton) TPC in MINOS near neutrino beam (T962, Yale et al.)
- Discussions
  - Long Drifts (up to 5 meters), ICARUS, Collaboration, Workshops
  - 150 ton TPC Detector in neutrino beam to see "all that neutrinos do in LAr"
  - 5 to 10 kton TPC off-axis neutrino physics experiment

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Liquid Argon TPC Overview for NuSAG

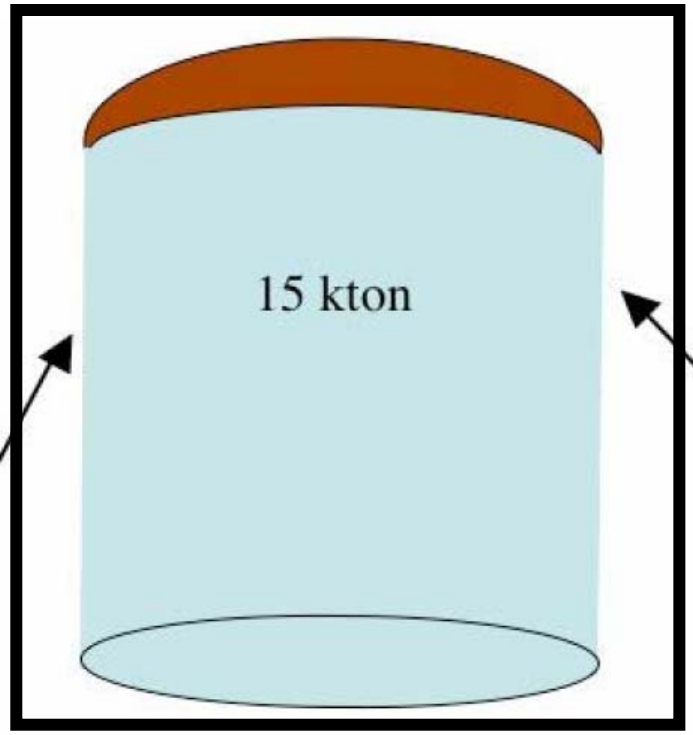
Note: At this point in time …

"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:

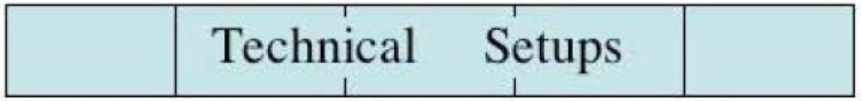
Construction of Tank

Argon Purity

Mechanical Integrity of TPC

Readout S/N

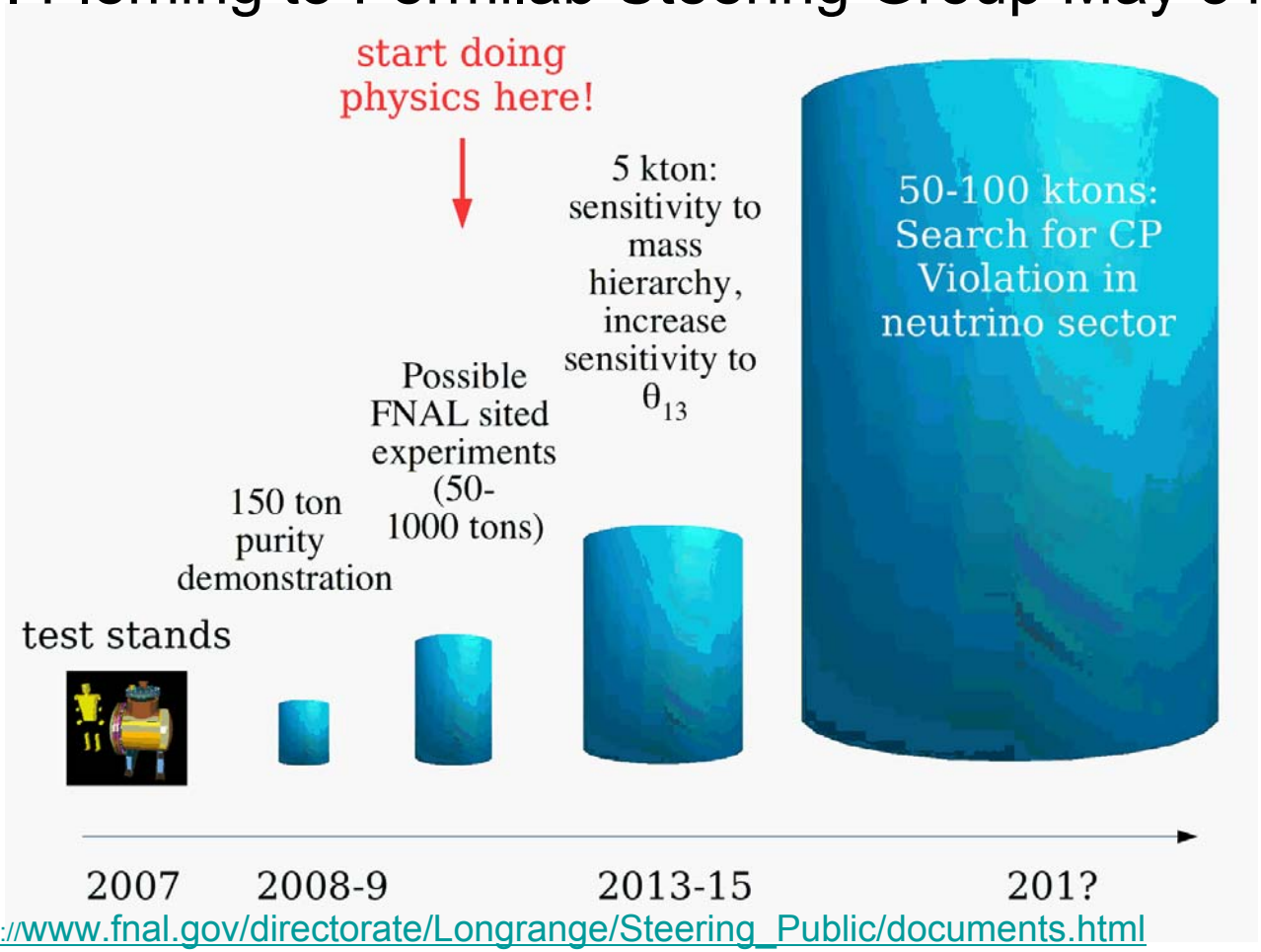
Microphonics due to Argon Flow



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

Concept for Mid-Term R&D Path

From B. Fleming to Fermilab Steering Group May 31, 2007



http://www.fnal.gov/directorate/Longrange/Steering_Public/documents.html

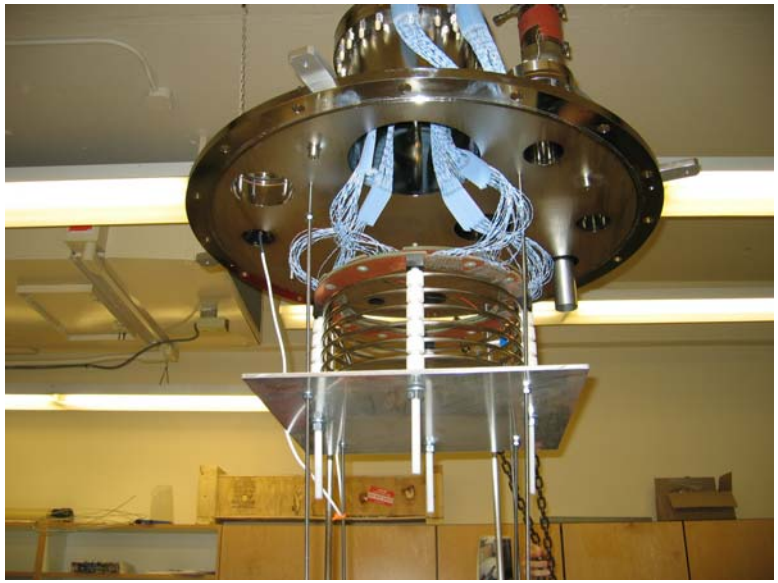
Test Stands in the US

- A TPC at Yale
  - First tracks in the US in an LArTPC
  - ICARUS electronics, FNAL filtering, Yale determination
- Materials Test Station at Fermilab
  - Qualify / disqualify materials with/without evacuation
  - Status: Fully assembled, awaiting safety improvements
- A TPC at Fermilab
  - ~0.036 ton (d=~25cm, h=~50cm)
  - Michigan State U electronics development for T962
  - Status: Fully assembled, awaiting safety approval
- T962 (Yale, MSU, Fermilab)
  - ~0.7/~0.35 ton TPC (total/active)
  - Proposed to be put in front of the MINOS near detector

A TPC at Yale

(from Bonnie Fleming to Steering Group May 31, 2007)

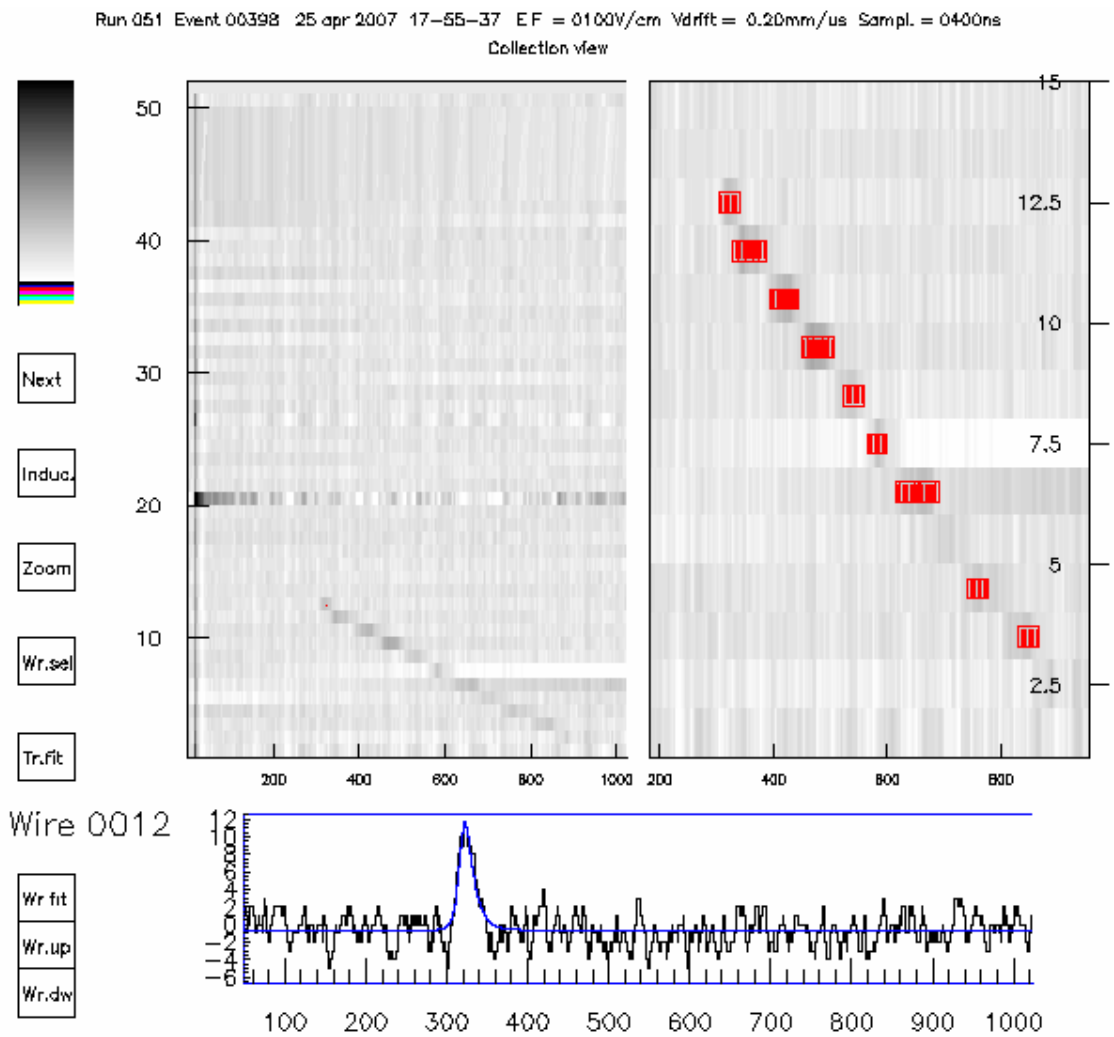
First tracks seen March 21, 2007
(first ever in the US)



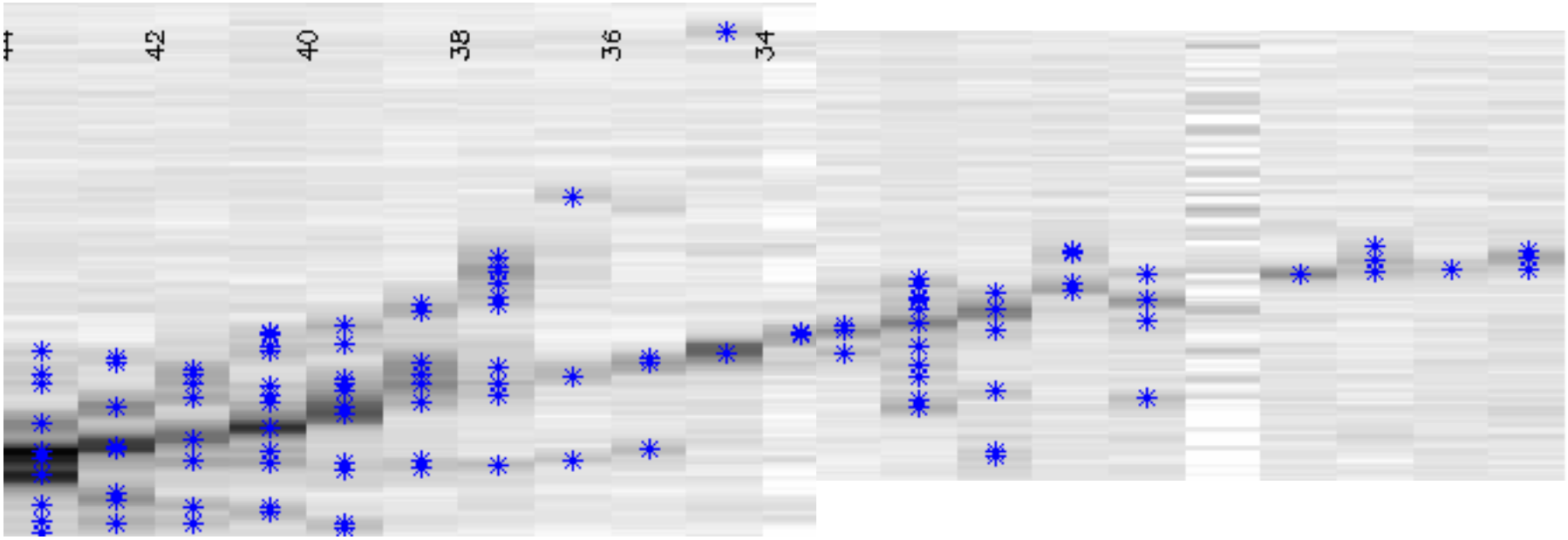
Alessandro and Mitch at Yale,
Spring 2007

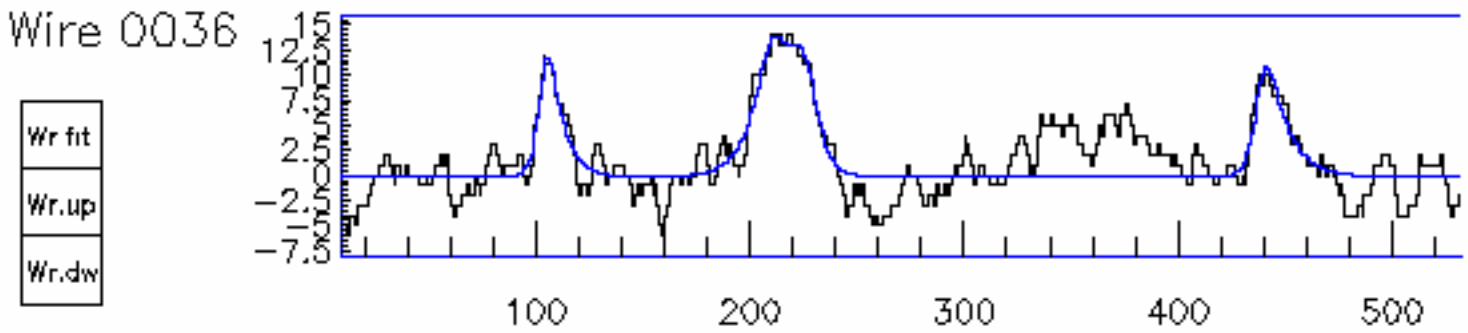
A TPC at Yale

(from Alessandro Curioni at NuInt07)



A TPC at Yale
(from Alessandro Curioni at NuInt07)





Materials Test Station a Fermilab

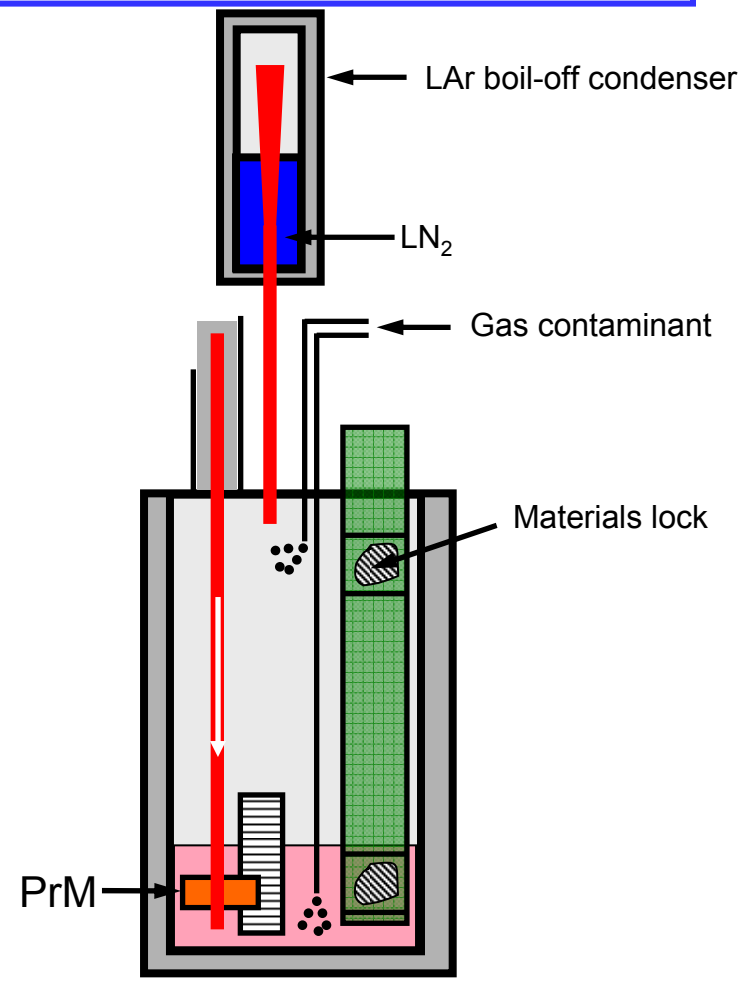
Implement the Materials Test Station..
- Closed system cryostat - sketch at right

It is fully assembled and awaiting implementation of Oxygen Deficiency Hazard mitigation. (New fans in the room and fully documented procedures.)

Note Materials lock which allows introduction of materials without evacuating.

Uses in-cryostat filtering (new development)

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

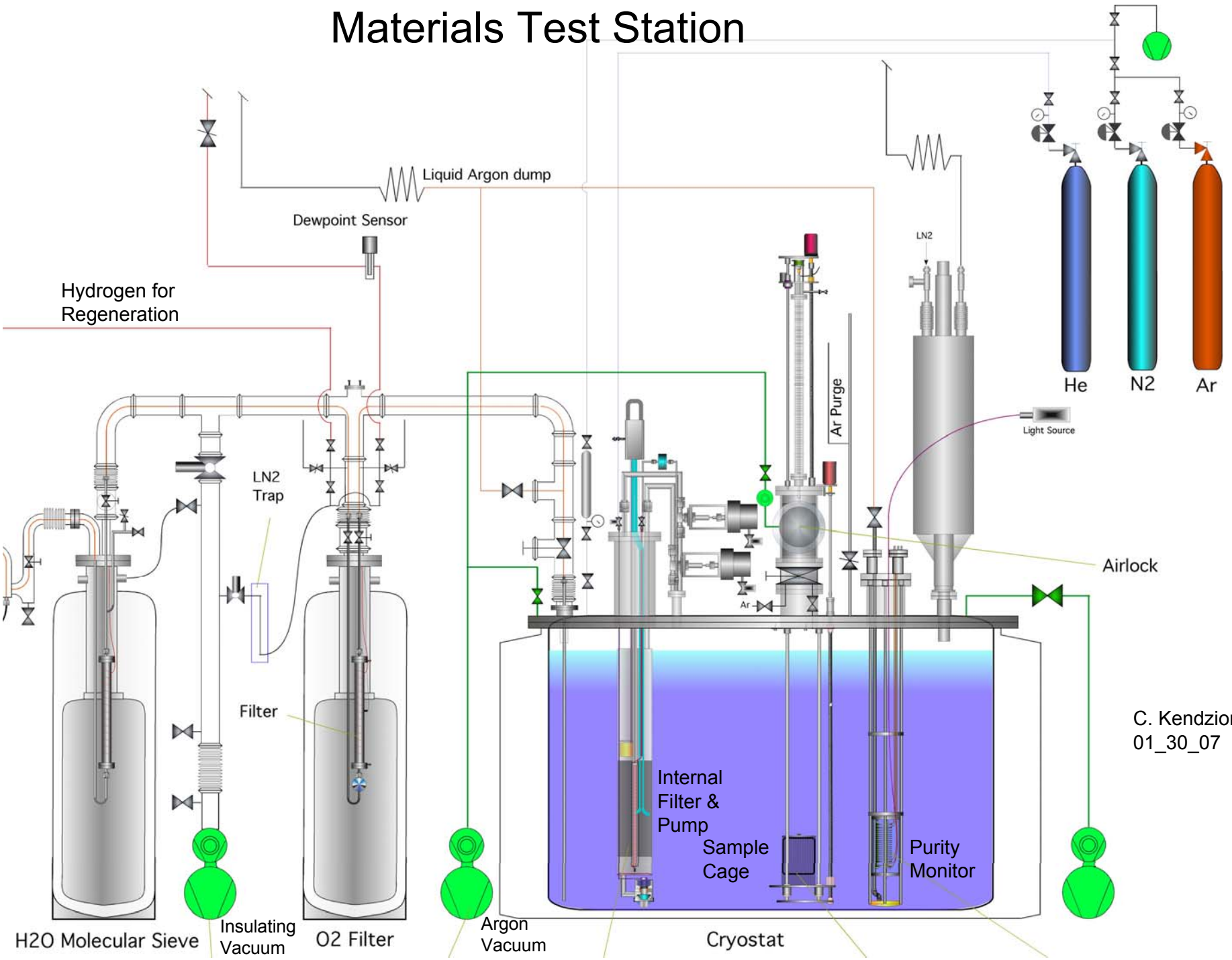


T. Tope

Materials Test Station at Fermilab

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

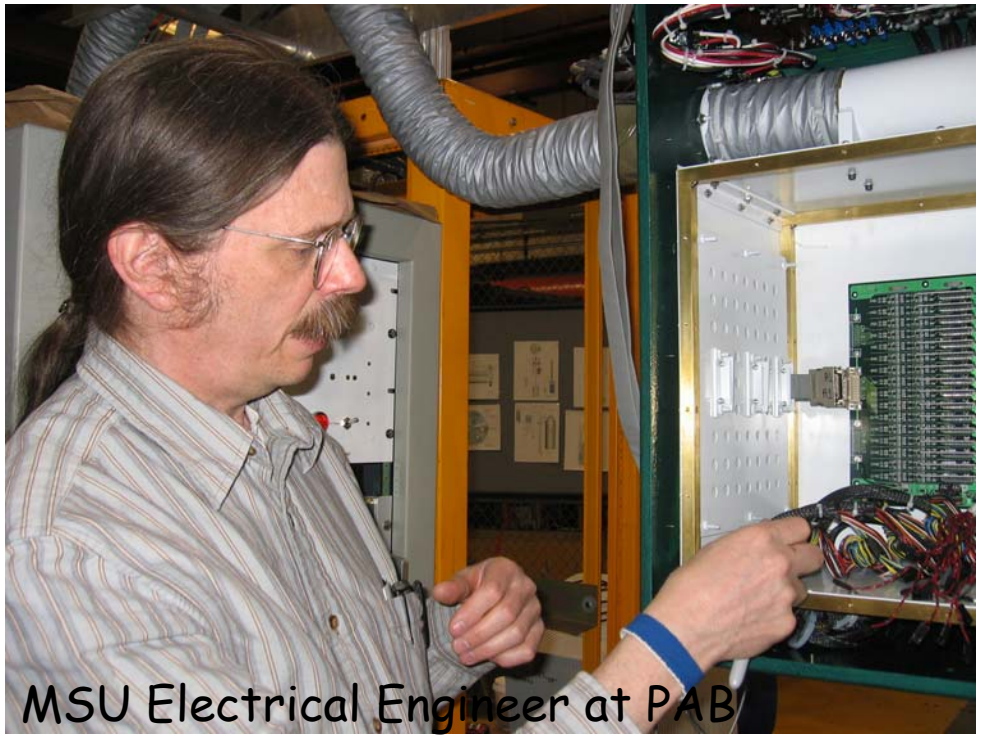
Materials Test Station



C. Kendziora
01_30_07

A 0.036 ton TPC at Fermilab

Physicist and Technician at PAB



MSU Electrical Engineer at PAB

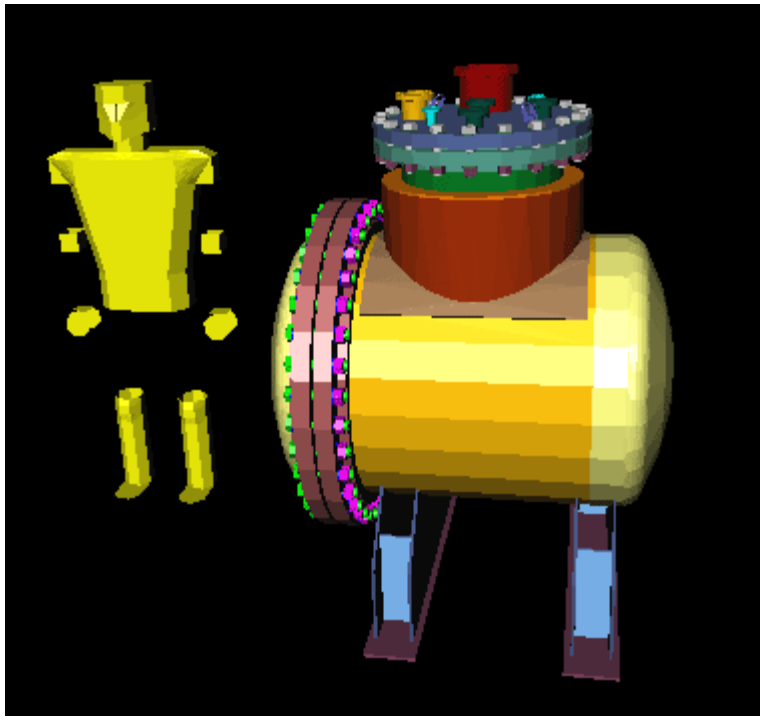
Electronics development led by MSU (for T962), under test at Fermilab, will see tracks some day.

~20 wires per plane

D=~25 cm, H=~50cm active volume

T962

- Cryostat: ~500 liters total volume inside cylinder
- TPC: ~0.5 x 0.5 x 1m = ~250 liters TPC (0.35 tons)



Will sit just upstream of the MINOS near detector which is used as a muon catcher (as PEANUT has done)

Expect ~300 nu_mu CC events / day (check this # with Bonnie)

150 ton Purity Demonstration

- 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 a true detector, and prepared in the same manner as in a true detector.

- The present focus is to propose using a 150ton LNG tank constructed by a contractor.
  - 150tons is scaled down from 5ktons by a factor of x30, and x~7 from 1kton
  - the tank must be appropriately modified to accommodate a TPC (include signal and HV feed-throughs, for example)
  - the tank will be appropriately cleaned, but not evacuated
  - use appropriately clean techniques to insert the cellular design TPC

3 Steps to Purity Without Evacuation

(the present proposal)

- Three steps starting from air in the tank:
  - Warm argon gas used as a piston (see cryodet1 talk by Finley)
    - 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 to purify warm argon gas
    - recirculated through filter system scaled down from 5kton
    - remove water and oxygen, goal is 500ppb oxygen
    - i. e., achieve purity similar to that achieved by ICARUS with evacuation
  - Liquid purification
    - Final purity expected to be determined by contaminants from tank walls, TPC materials, flow restrictions due to presence of TPC, leaks, etc.

Status: Demonstrate these 3 purification steps with a ~16ton tank

150 ton TPC

- This will be a true small scale prototype for kton or larger LArTPCs
  - To be constructed with same techniques as 5kton
    - No evacuation, cellular TPC design (see later)
  - To use same filtration techniques as planned for 5kton
  - Exposed to the "same" environment
    - Neutrino beam (but more intense than Ash River)
    - Cosmic ray environment and shielding
- Large enough to contain neutrino events
- Will see "all that neutrinos do in liquid argon"
- Too small to advance on path to CP violation physics
- Some see it can become a near detector for Ash River

R&D for an Ash River LAr Detector …and beyond

- One Slide Overview
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Cellular Design

- See: "Cellular Design for a Liquid Argon Time Projection Chamber" May 31, 2007
- David Gerstle (Yale) and Hans Jostlein (Fermilab) May 31, 2007
- http://lartpc-docdb.fnal.gov/0002/000263/003/CDNshort.pdf

Cellular Design: Gerstle and Jostlein

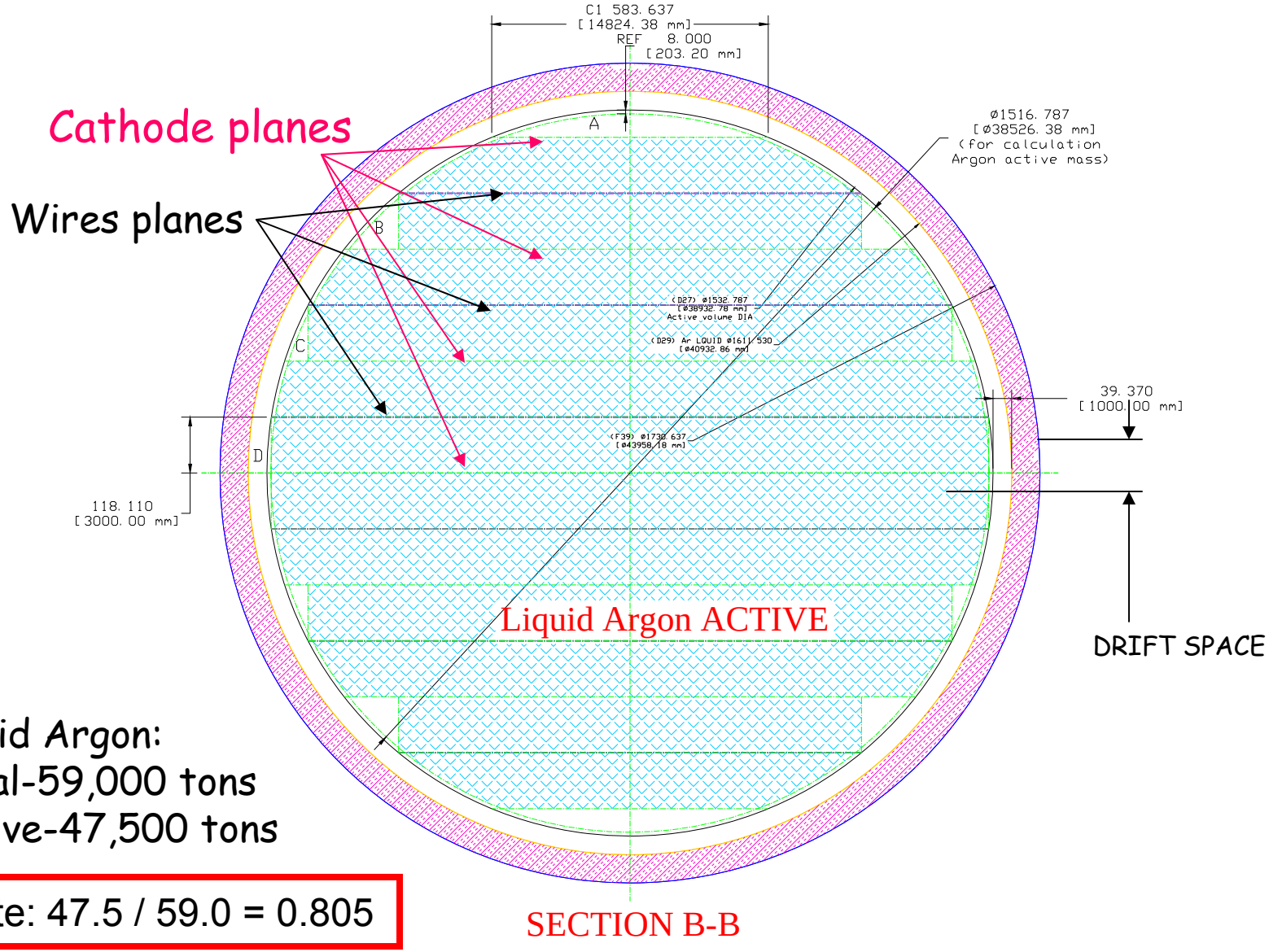
1 Introduction

One of the major challenges in the construction and operation of massive Liquid Argon Time Projection Chambers (LArTPCs) relates to the readout planes of the TPC. The readout uses three planes of wires: two angled planes and a vertical plane – all read out at the top. There are at least five issues surrounding these long wires:

1. Electronic noise due to the capacitance and resistance of the wires.
2. The incomplete coverage of the entire tank by all three wire planes.
3. The safety, time and logistical issues of installing the wires in the tank at the correct tension.
4. The danger and consequences of wire breakage, particularly on cool-down.
5. Reconstructing events and associating signals in the different planes

This note introduces a possible solution (called a Cellular Design) to some problems caused by the long wires needed for the readout planes of a massive LArTPC. The Cellular Design could, but does not necessarily, address the first issue and may complicate the fifth, but it virtually eliminates the other three.

Previous Design: View from the Top of 50kton LArTPC

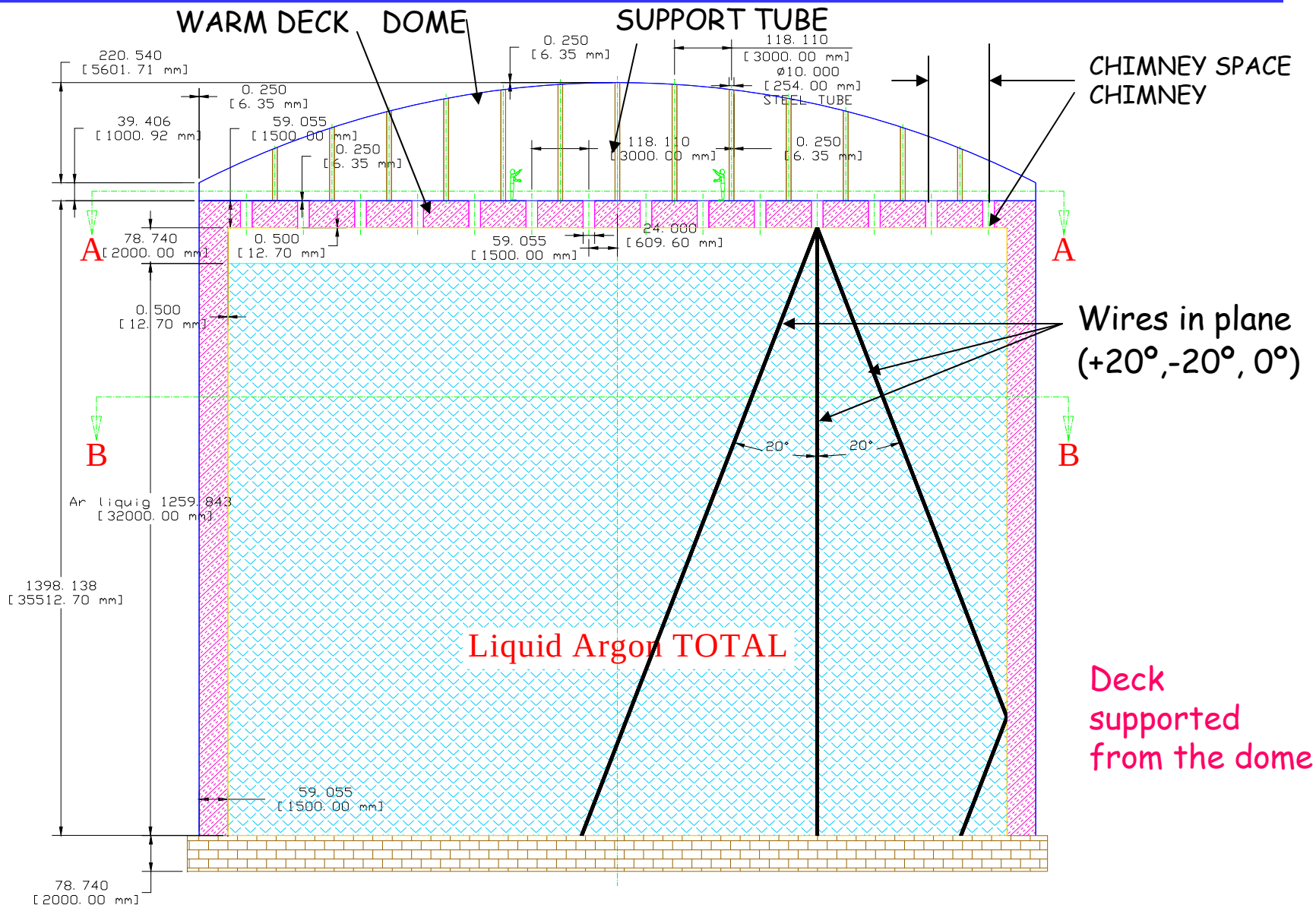


Liquid Argon:
Total-59,000 tons
Active-47,500 tons

Note: 47.5 / 59.0 = 0.805

SECTION B-B

Previous Design: LArTPC 50kton (wire plane section)



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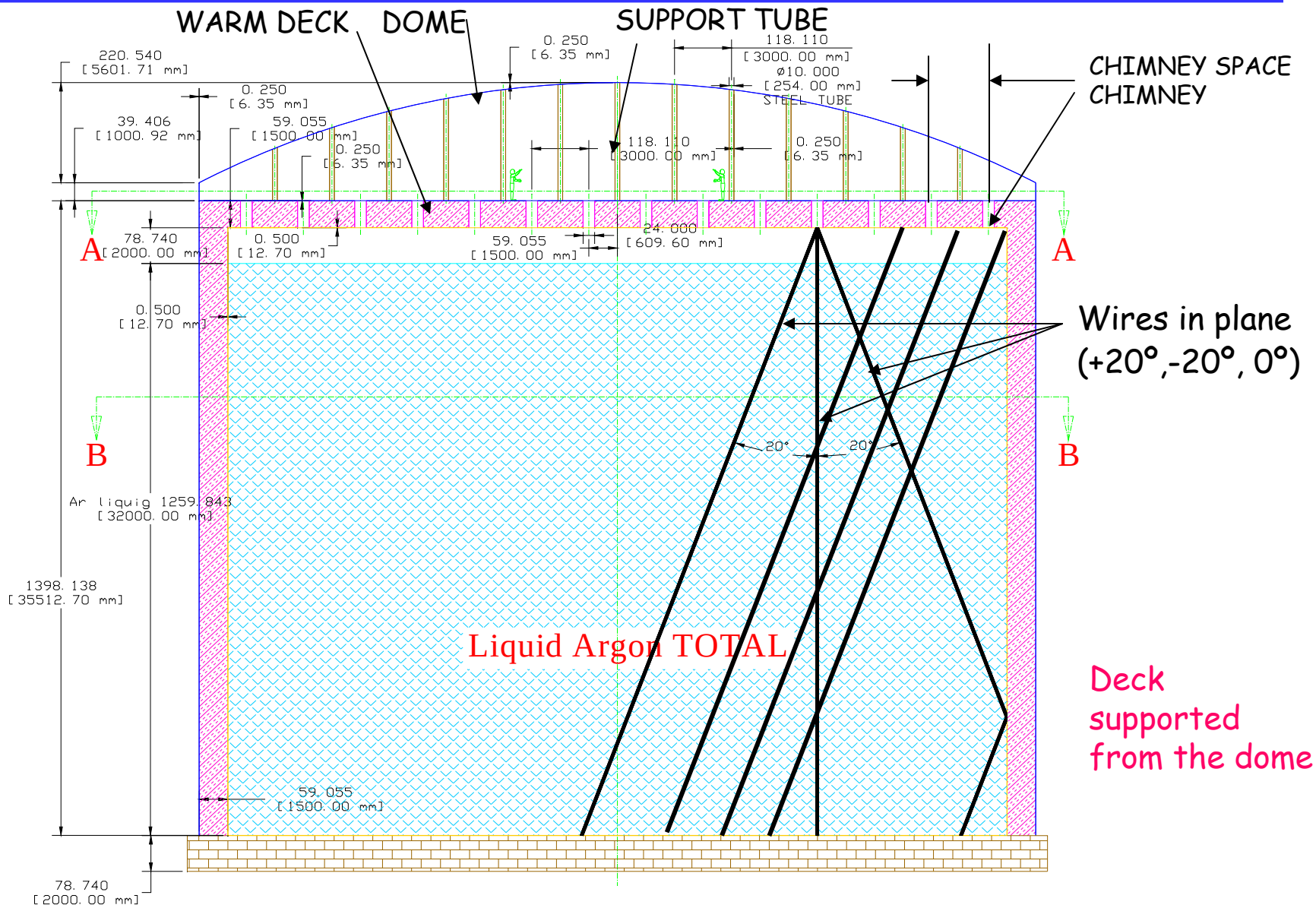

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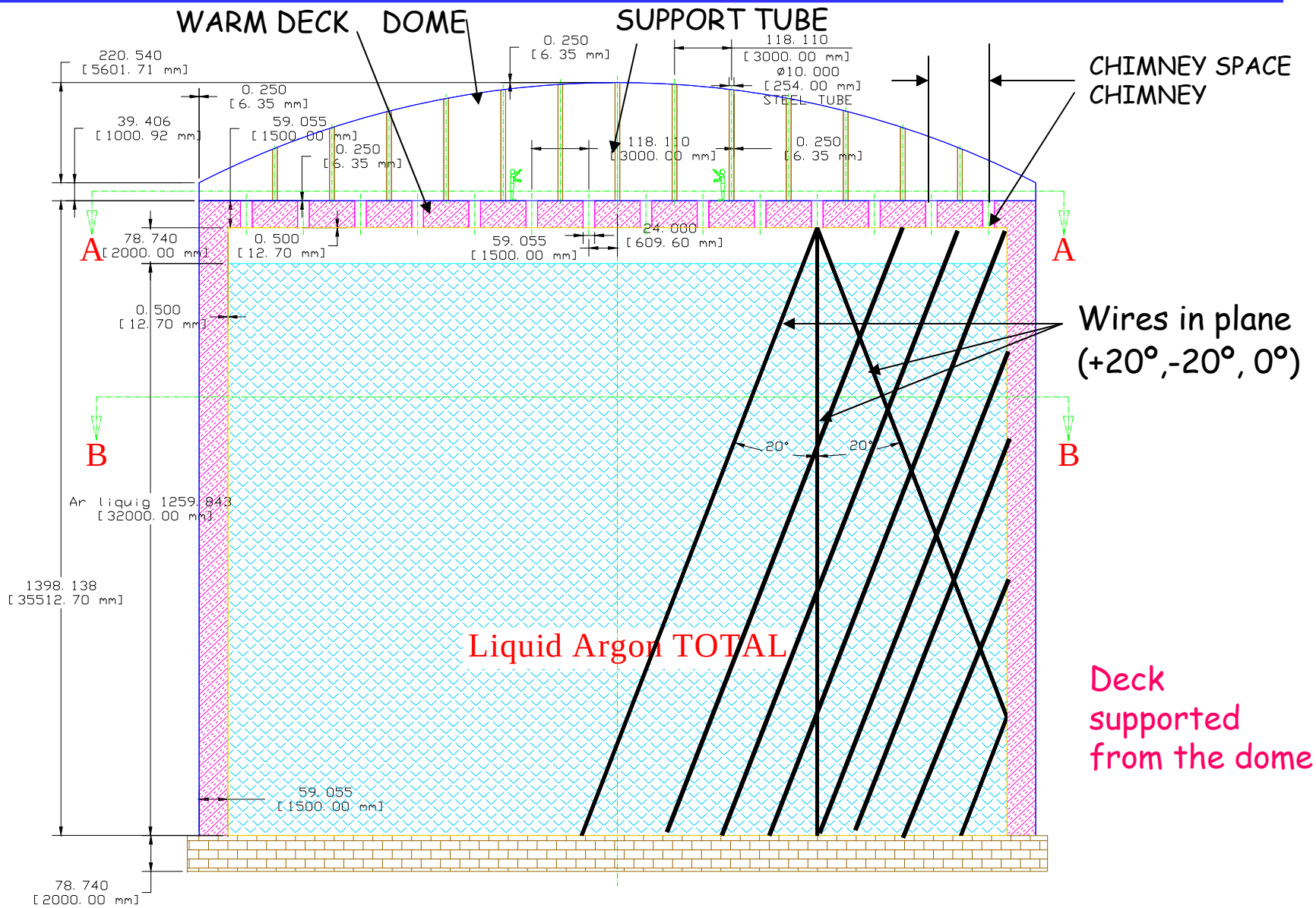

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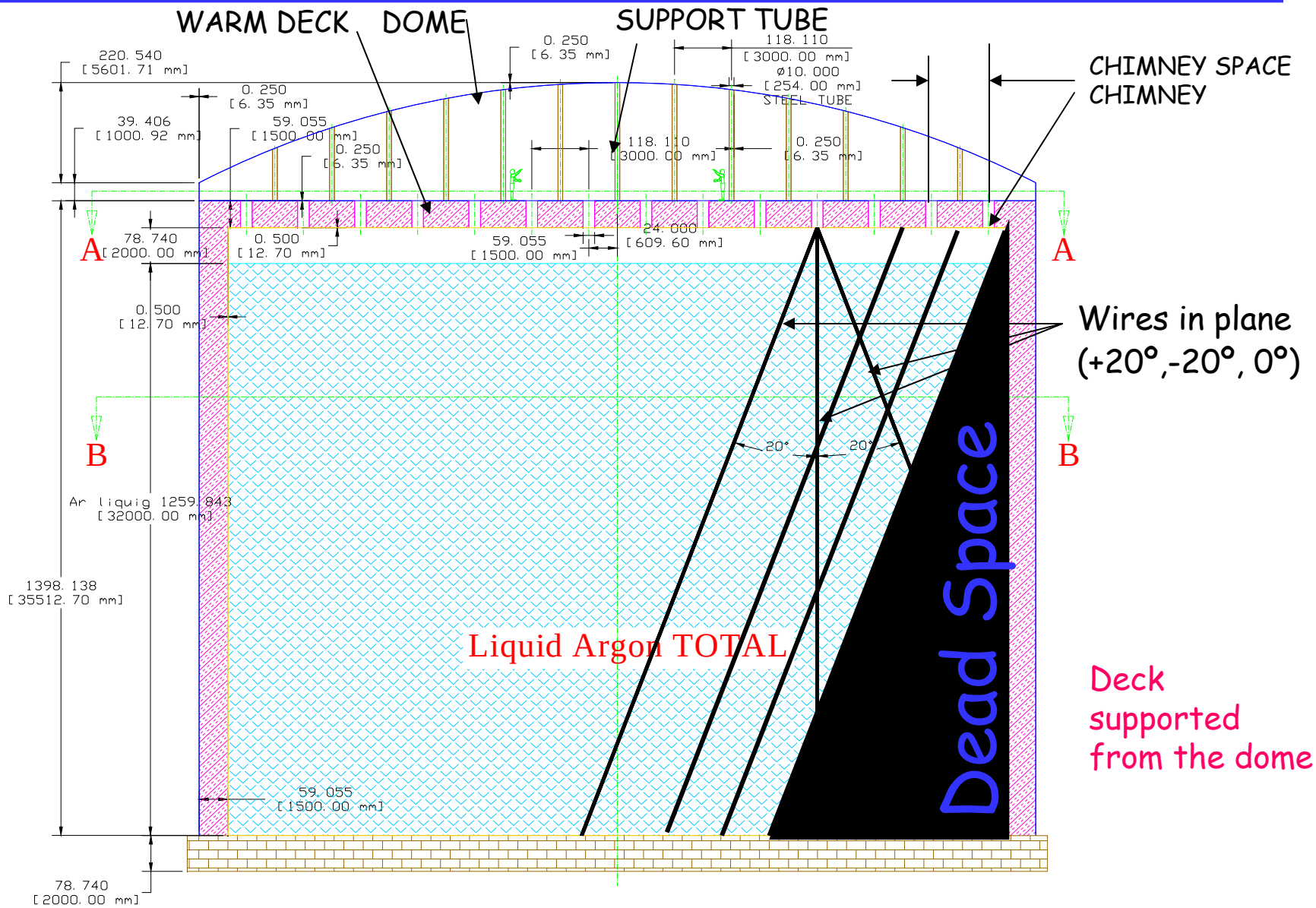


Cellular Design: Wire Planes

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). This leaves dead spaces which are not read out.

But … two notes …

Note 1: 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.

Note 2: For each plane in the left triplet, there is a corresponding plane, with the same DC potential, in the right triplet.

Why not … see next slide …

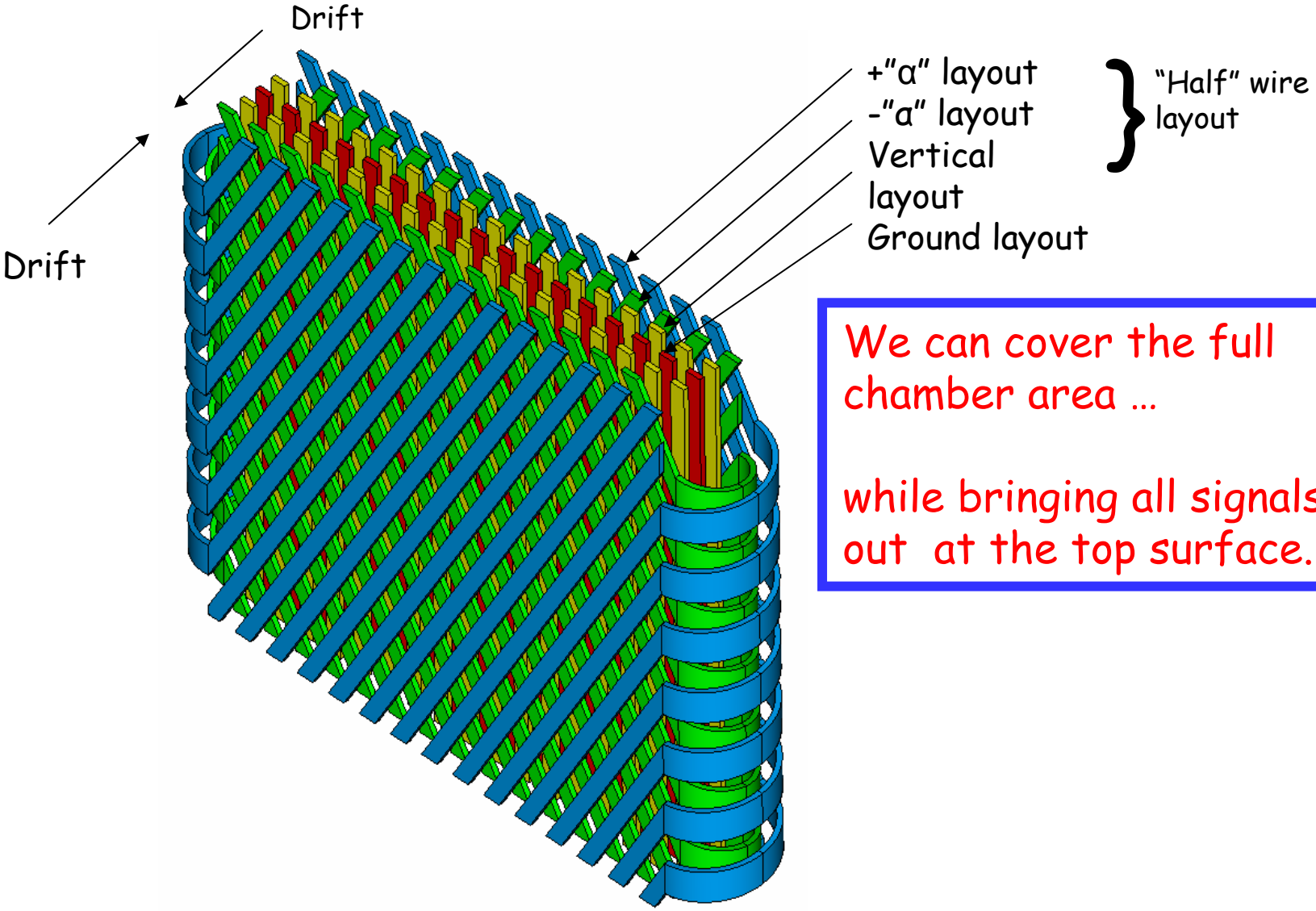
Cellular Design: Wire Planes

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. See next slide.

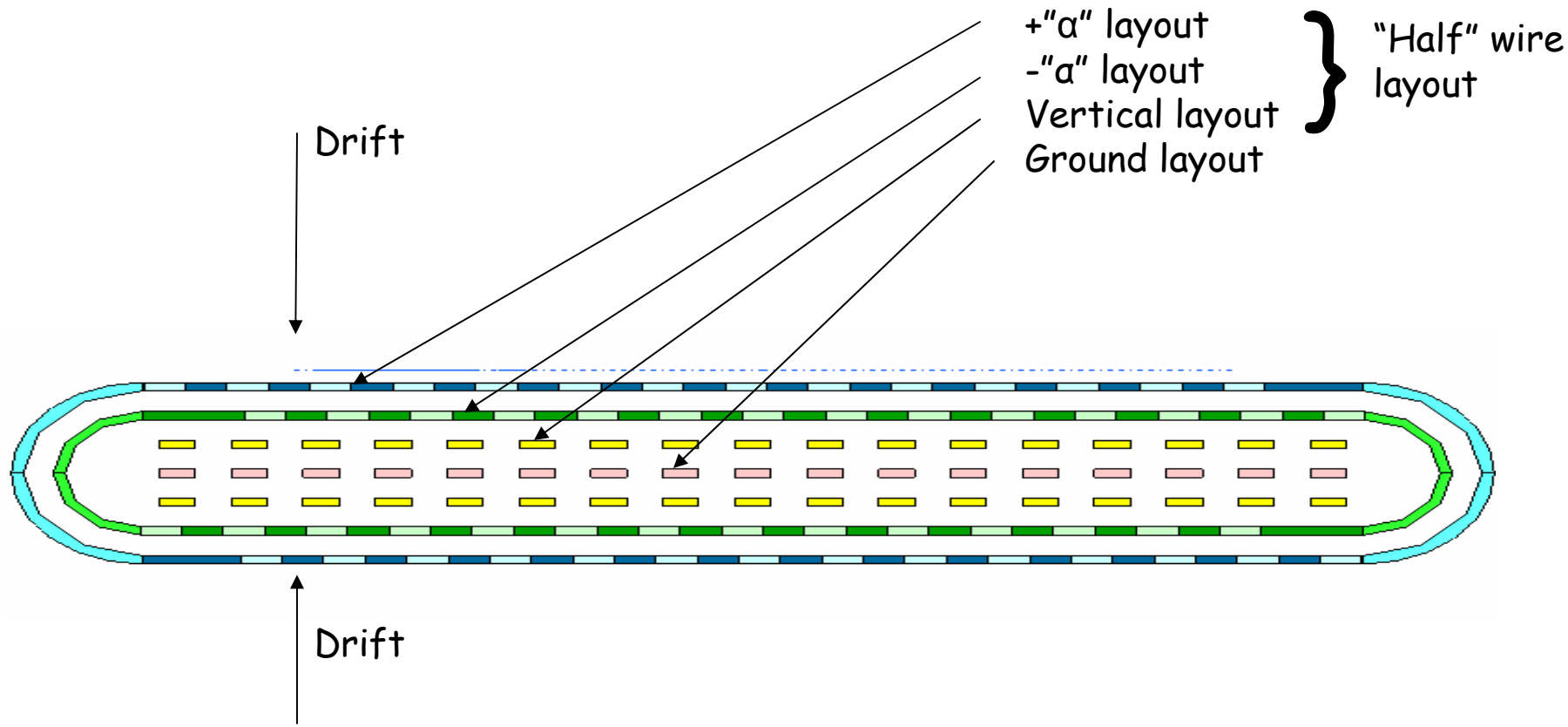
Cellular Design: "Complete Coverage" Conceptual Layout



We can cover the full chamber area …

while bringing all signals out at the top surface.

Cellular Design: View from the Top



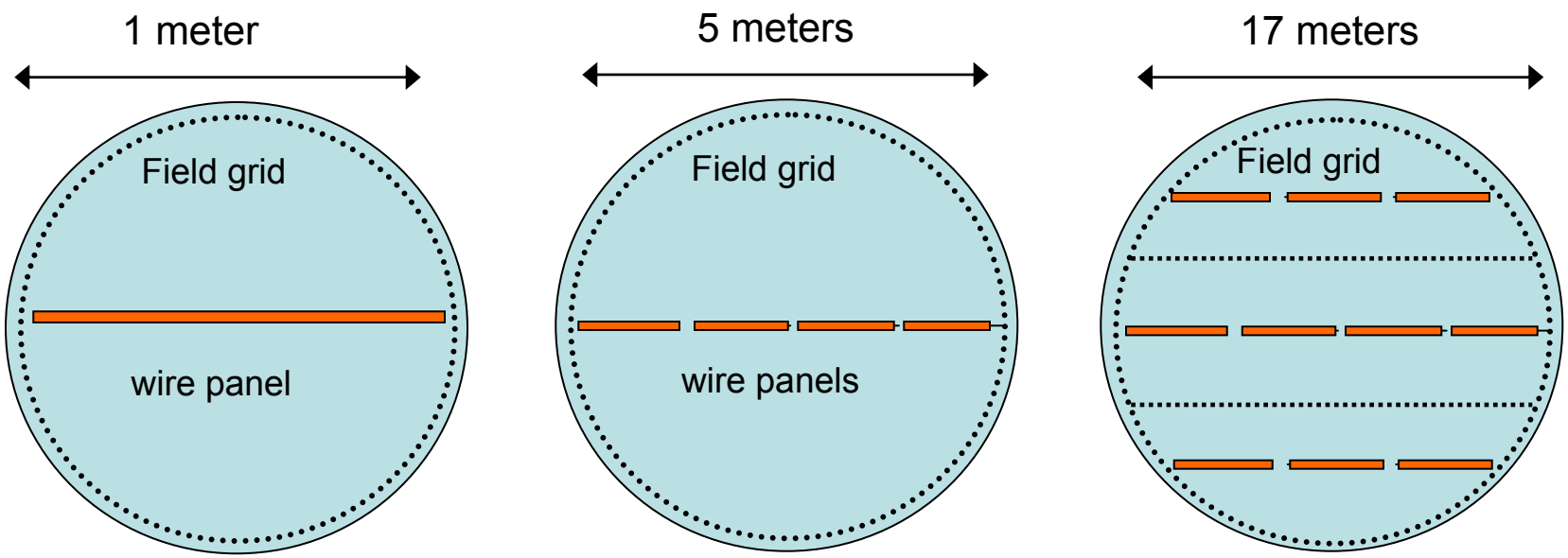
The width can be smaller than the distance between the tank walls.

Cellular Design: Scaling

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 (since purity without evacuation will have been demonstrated).

Cellular Design: Implications 1

- Original idea eliminated the dead spaces.
- Other positive implications of the panel concept were soon realized. The TPC panels can be:
  - built at the same time as the tank (and its site preparation), rather than having to construct the TPC inside the tank after it is completed.
  - fully tested and cold shocked before seeing liquid argon in the tank.
  - hung in the tank (simple and fast) and connected to the readouts.
  - built by collaborators at their home institutes, thus providing more opportunities for collaborators.

Cellular Design: Implications 2

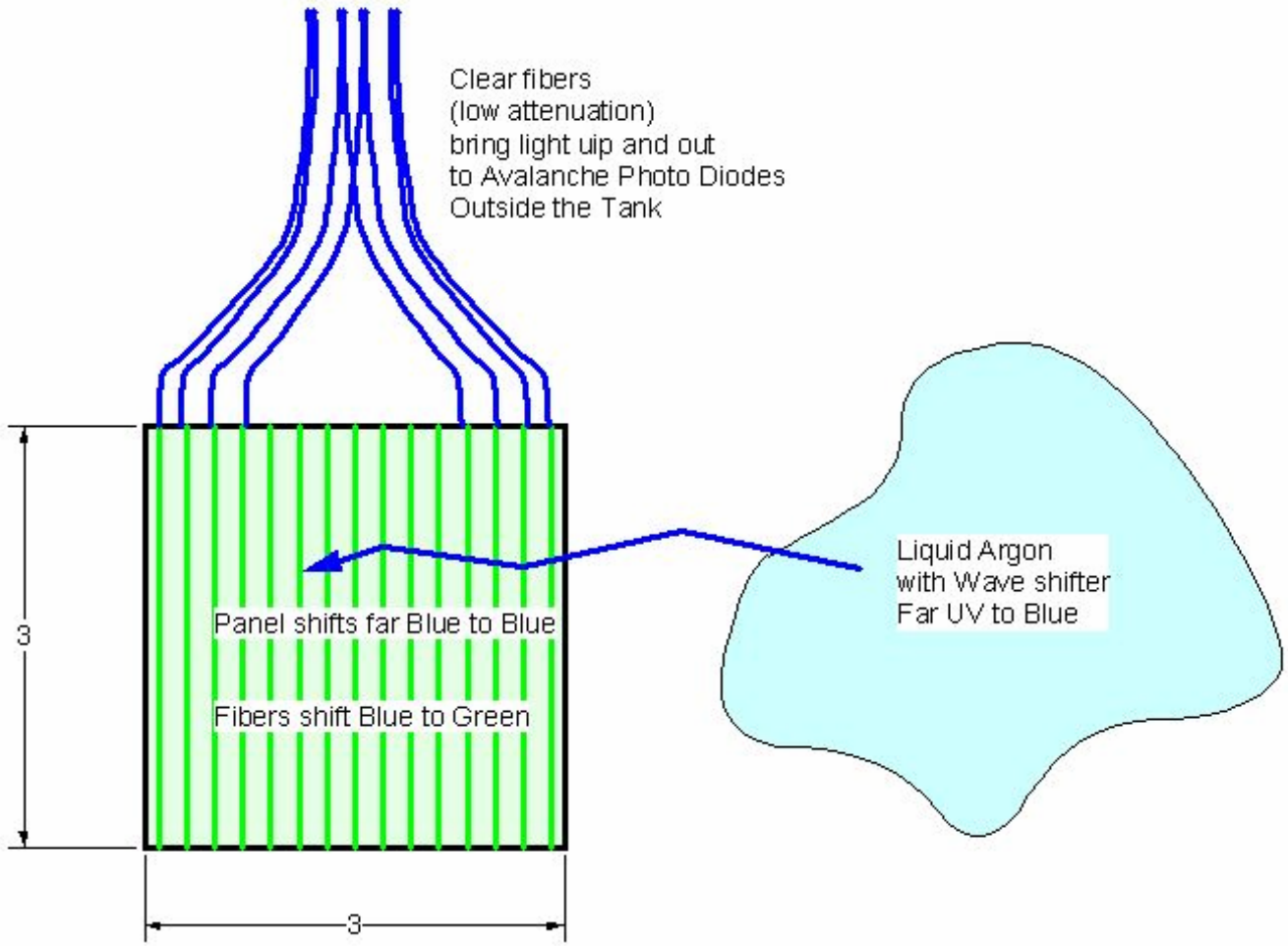
- One possible negative implication was initially suspected:
  - When the panel is tall compared to its width, a single wire can wind its way around the panel more than once …
  - Isn't the track reconstruction very hard to understand when the same track appears on the same wire more than once? The answer after a summer of study: No, but … it requires correlating track segments.

Cellular Design: Light Collection Sheets

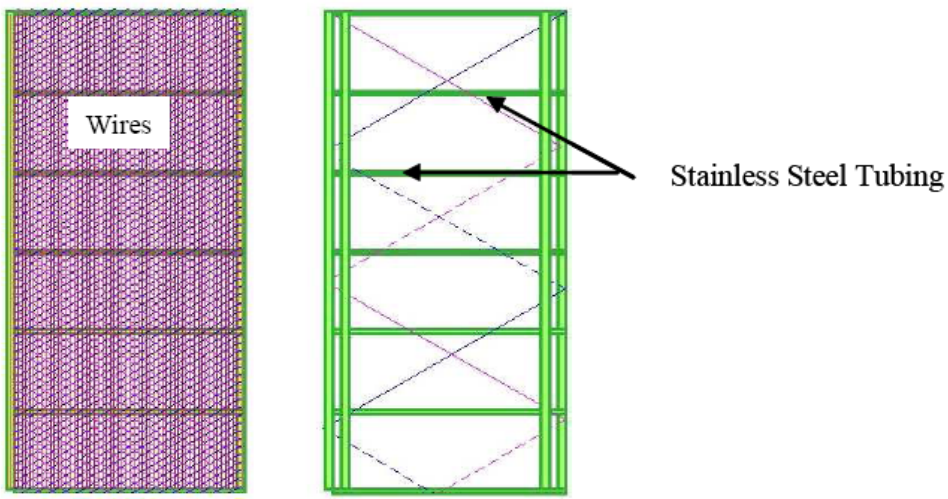
- Another idea under development is the use of plastic scintillator sheets placed between the two sets of the three wire planes.
- These sheets
  - provide a "tzero"
  - provide timing with respect to the neutrino beam
  - can help identify through going muons from cosmic rays
  - can help reduce the amount of data to collect

Cellular Design: Light Collection Using Sheets of Plastic Scintillator

Light Gathering and Sensing

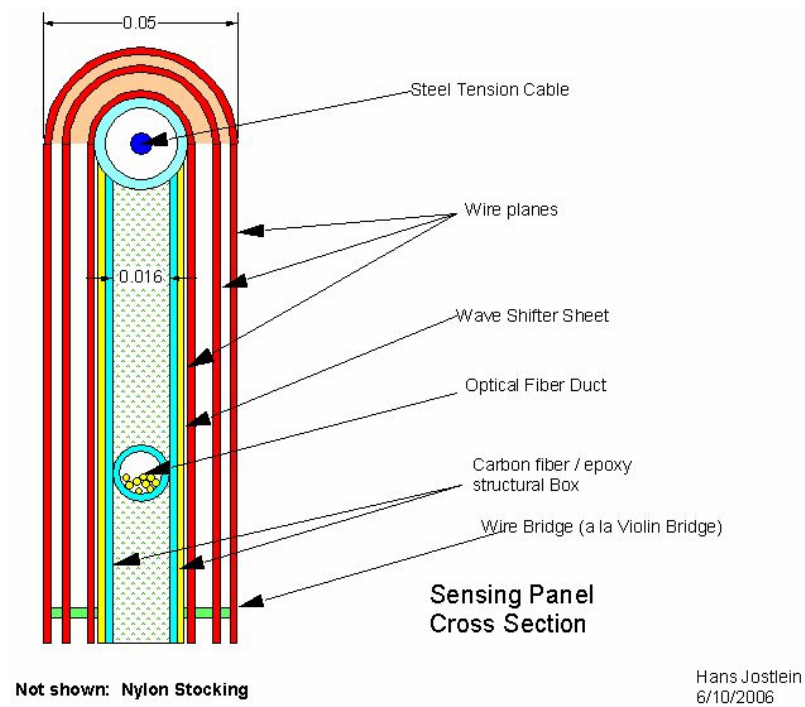


Finding space for the scintillator sheets

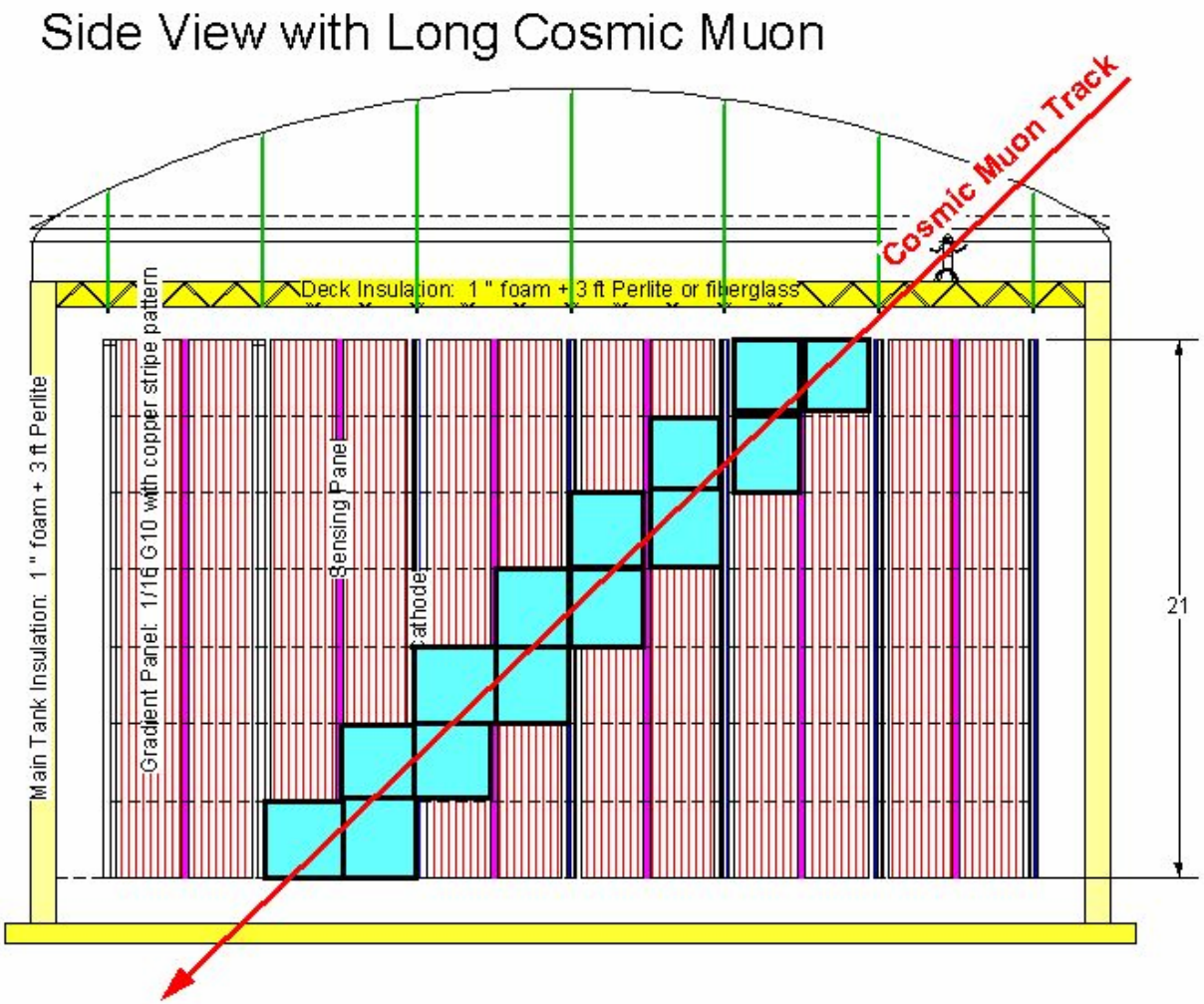


The spaces between adjacent stainless steel tubes are used for the scintillator panels ("wave shifter sheets") as shown below.

The stainless steel tubing as shown above provides structural support for the wires.



Light Collection Concept in 50kton tank



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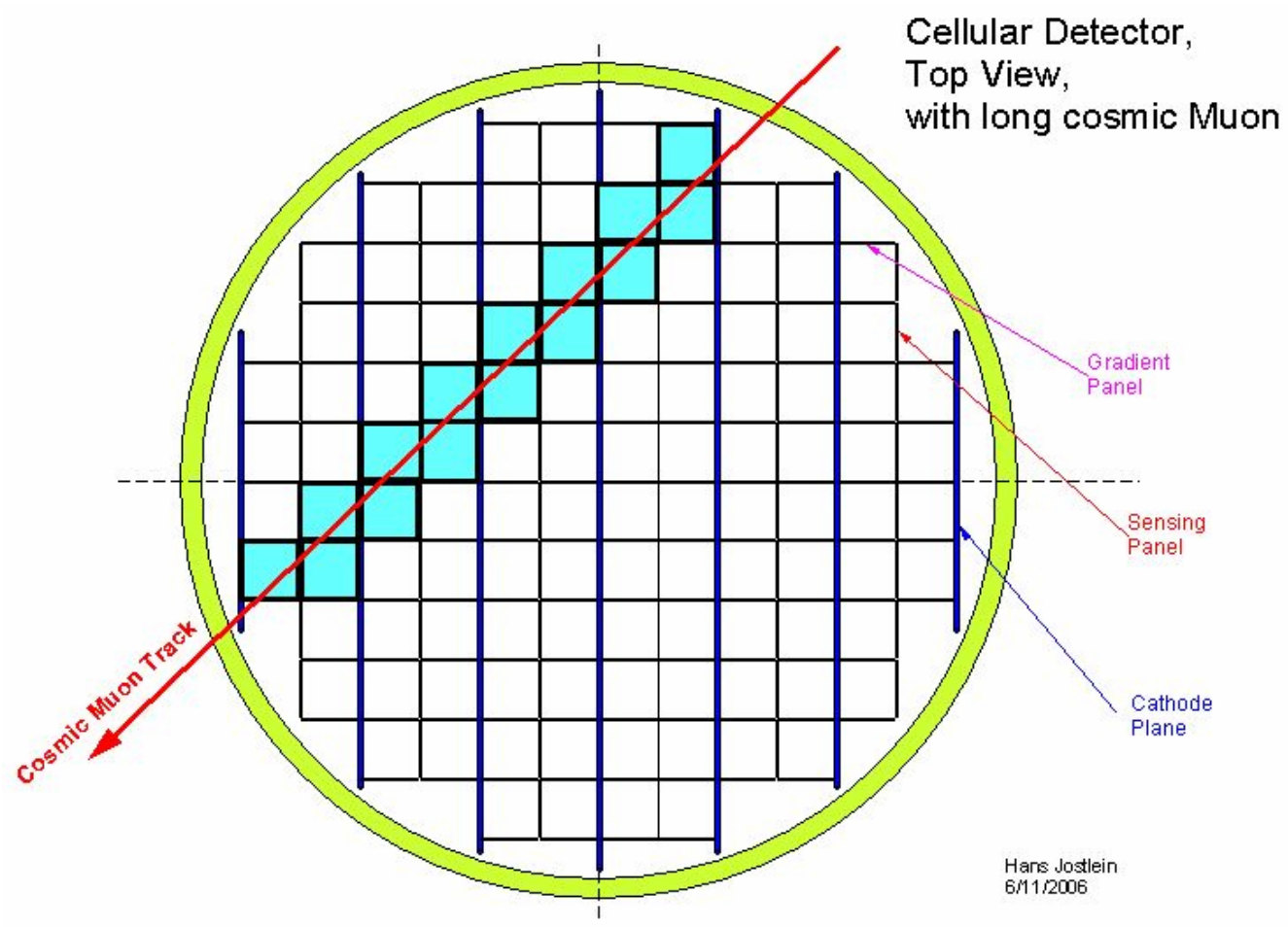

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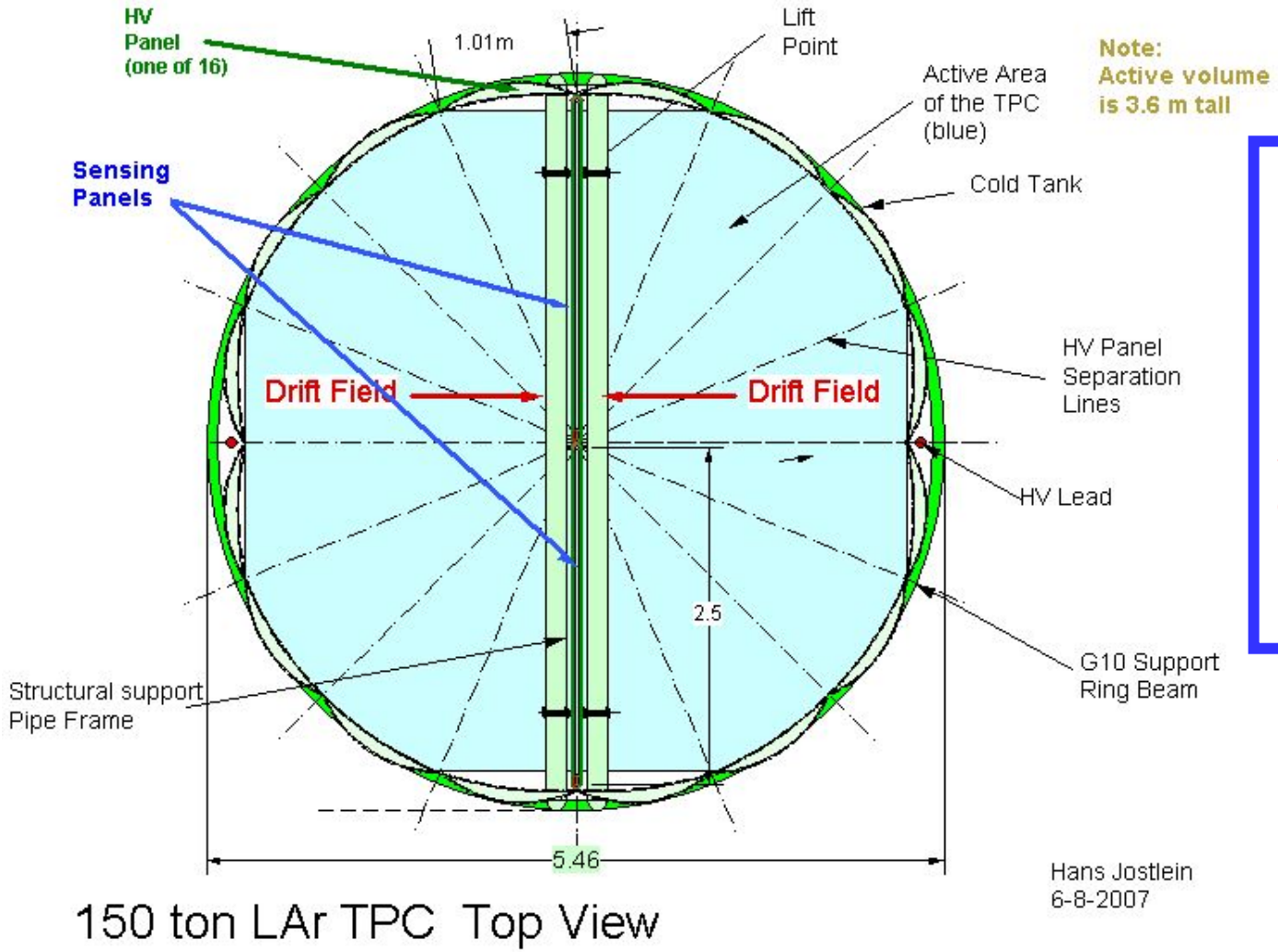
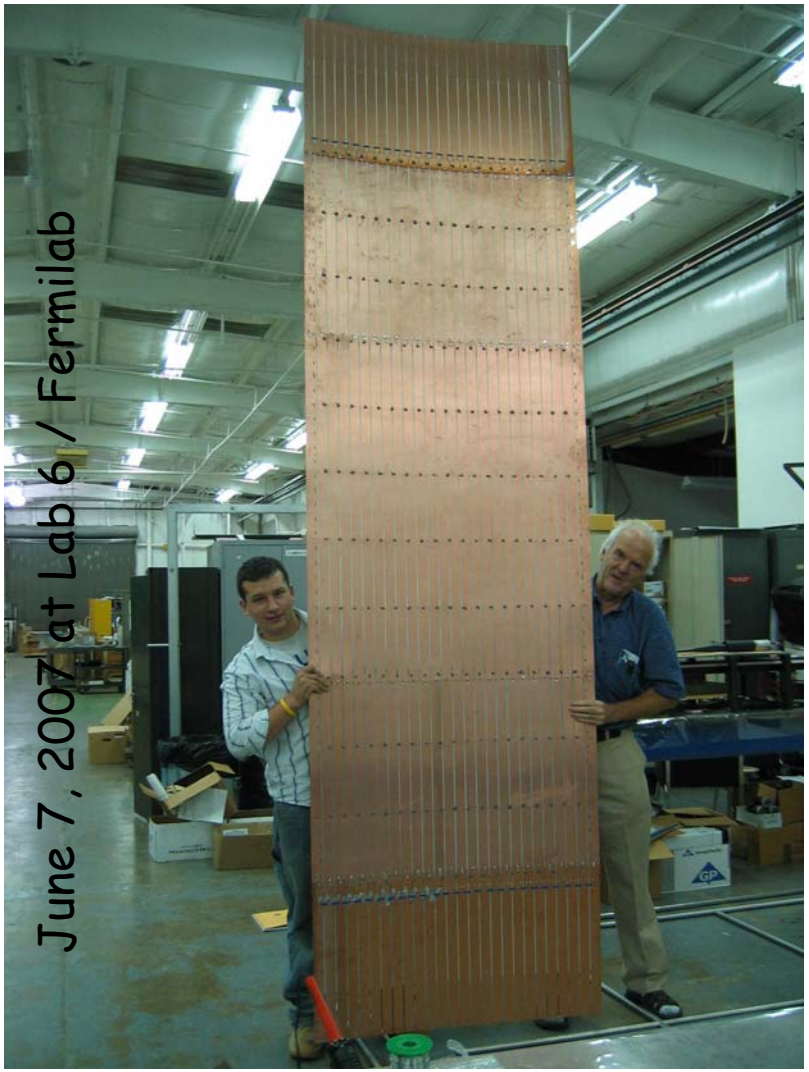
High Voltage distribution for 150 ton



The drift field will be uniform if the voltage is distributed as cos(theta) on a surface located at a constant distance from the center.

High Voltage "stave"



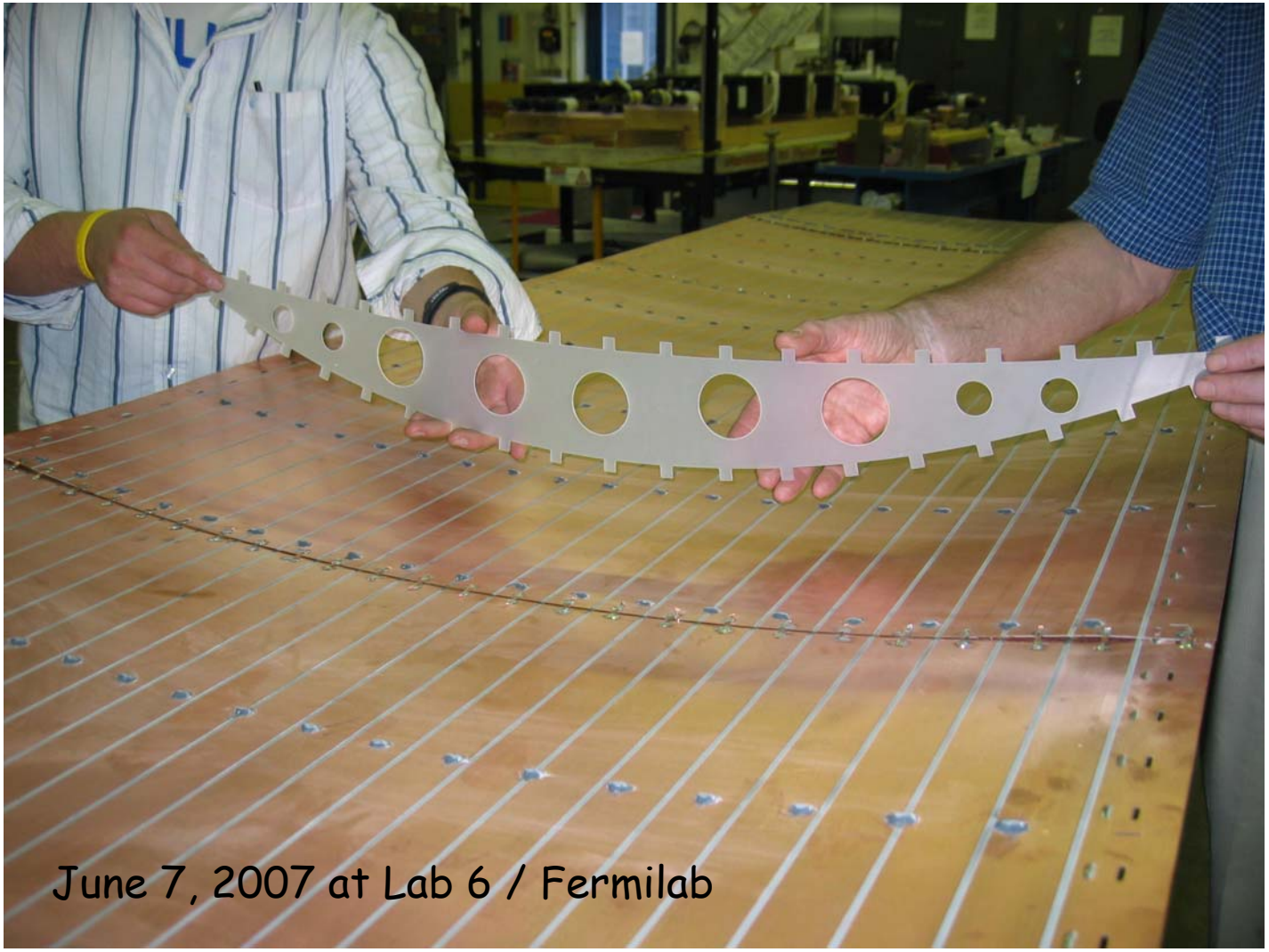
- This HV stave is for a tank with 150 tons of total LAr mass
- 16 HV staves, each 3.6 m tall and 1.04 m wide are made of G10, copper, resistors, etc
- The copper strips face the inside of the tank and provide a cos (theta) distribution of voltage

Hans and the summer student who built this first stave are shown

HV distribution

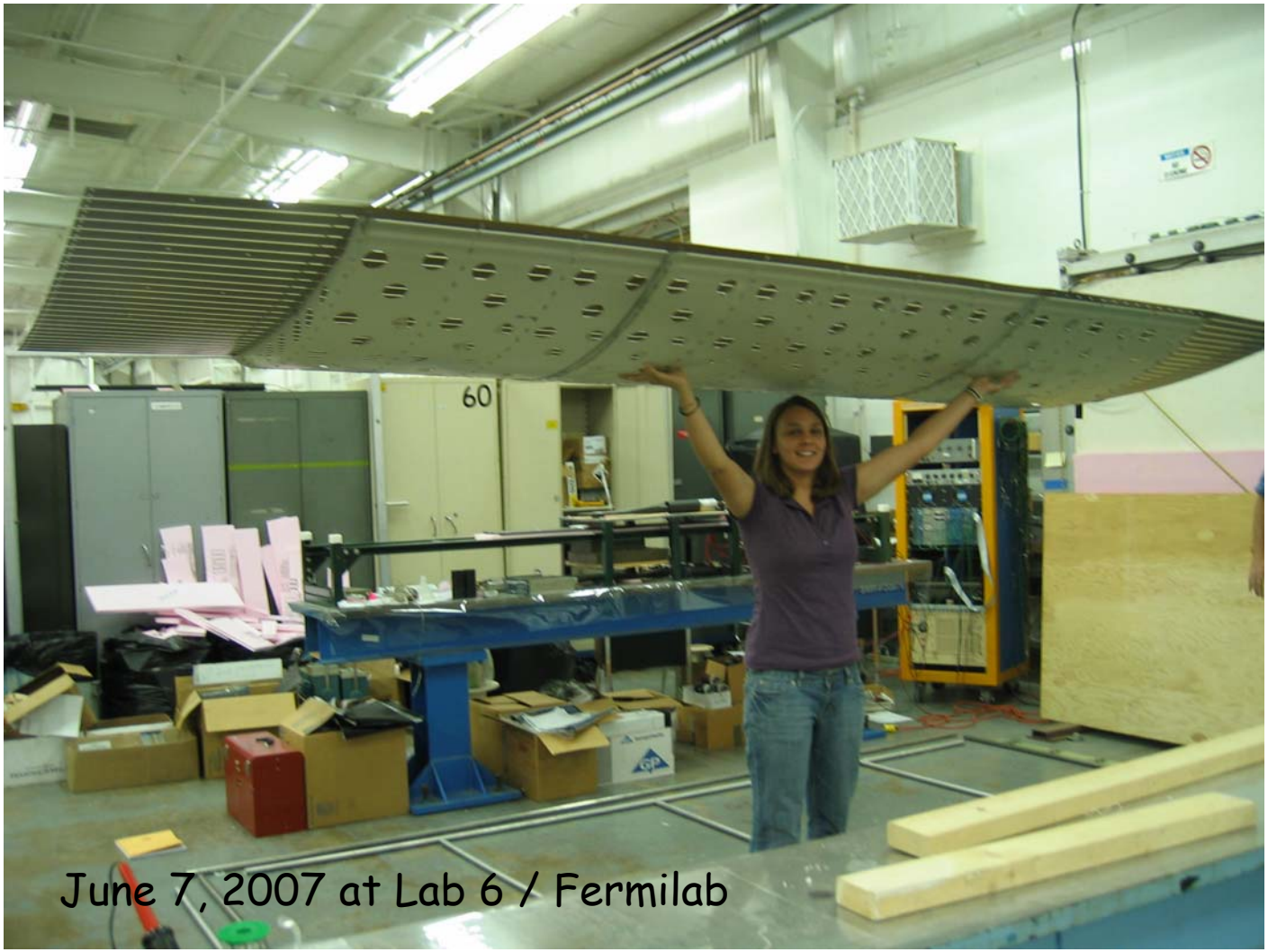
The resistor chain gives an ~cos(theta) voltage distribution which in turn provides a (very nearly) uniform electric field throughout the TPC volume, thus allowing full use of (nearly) all the liquid argon.

A set of ribs provides the appropriate radius of curvature



Hans and a student are holding a rib. The top of the rib shown in the picture has the curvature needed for the copper strips on the inside of the HV stave. A set of these ribs is installed underneath the stave and are hidden in this photo.

High Voltage "stave"



The support structure which provides the curvature shows one rib at the left end. The structure has holes in it to allow the argon to flow freely.

One complete stave is lightweight.

Summer student from Minnesota with the first HV stave

- Thank you!

Backup

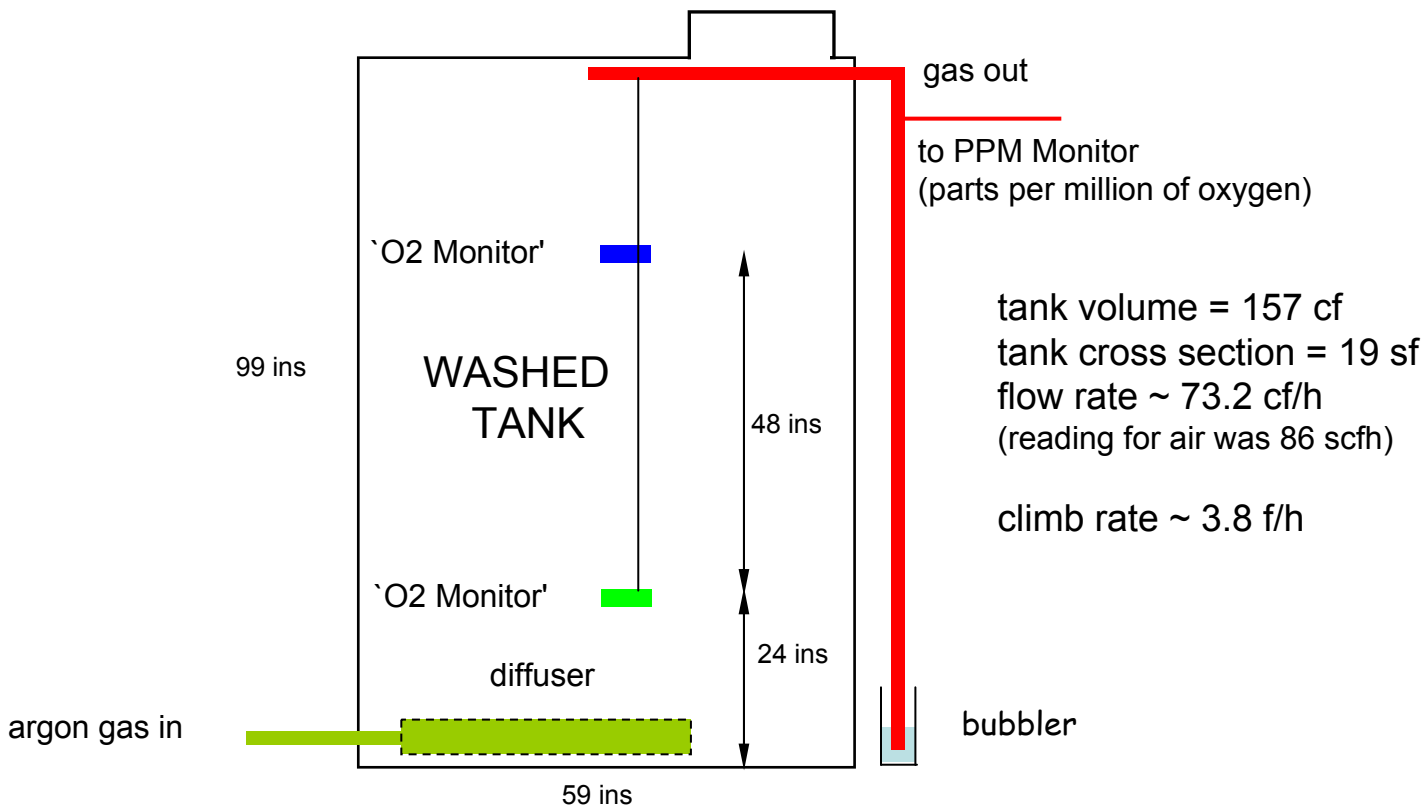
Using an "Argon Piston" to Purge oxygen (reported at Gran Sasso Cryodet1 Workshop March 2006)

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

Yale TPC
(from Alessandro Curioni at NuInt07)

TPC parameters:

- volume 15 l inside the field cage (within ~250 l ultra-pure liquid Ar)
- 50 wires collection
- 50 wires induction
- 5 mm wire pitch
- 17 cm drift region
- drift field ~100V/cm

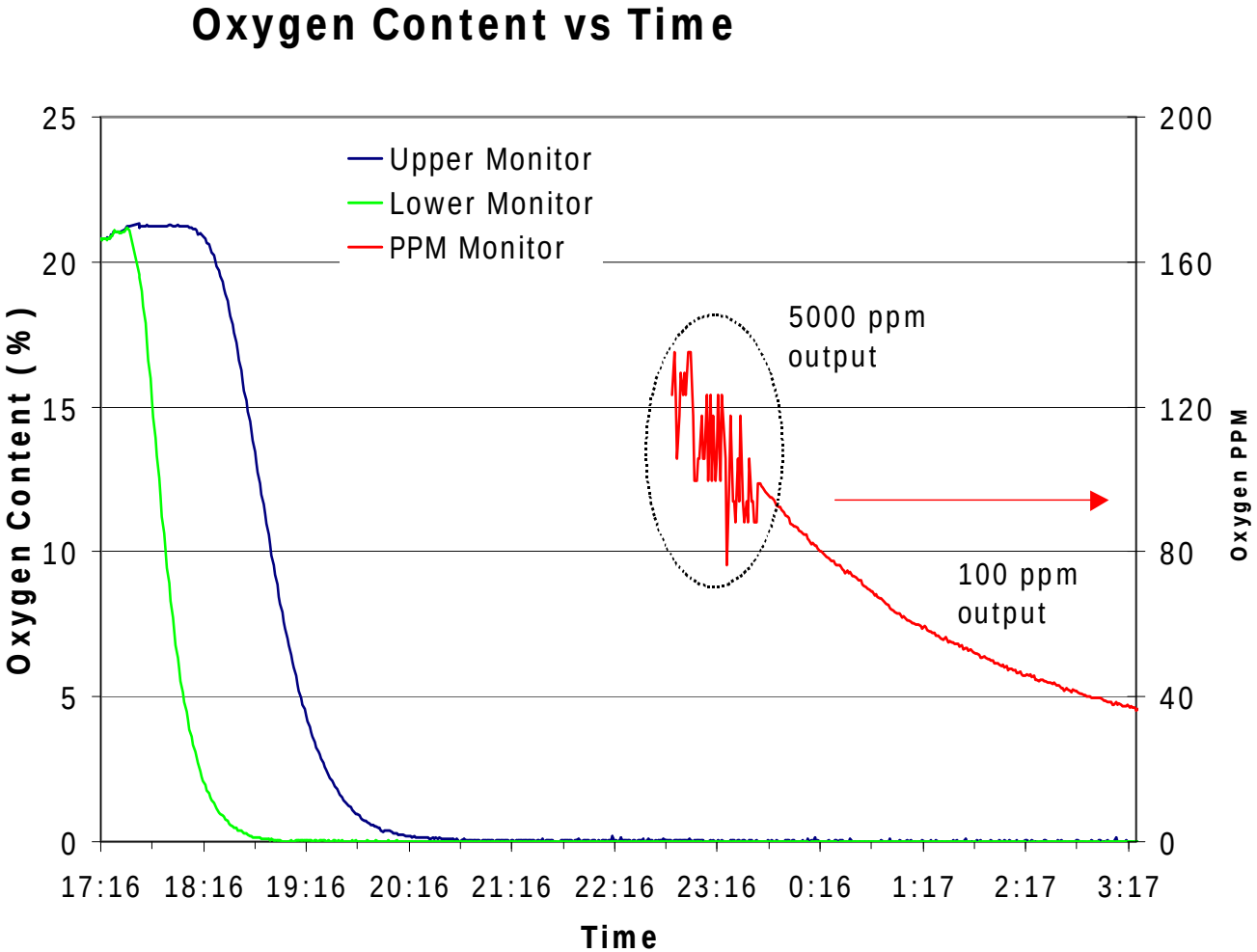
Using an “Argon Piston” to Purge oxygen

The Test Tank …

… behind an average sized Fermilab engineer.

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

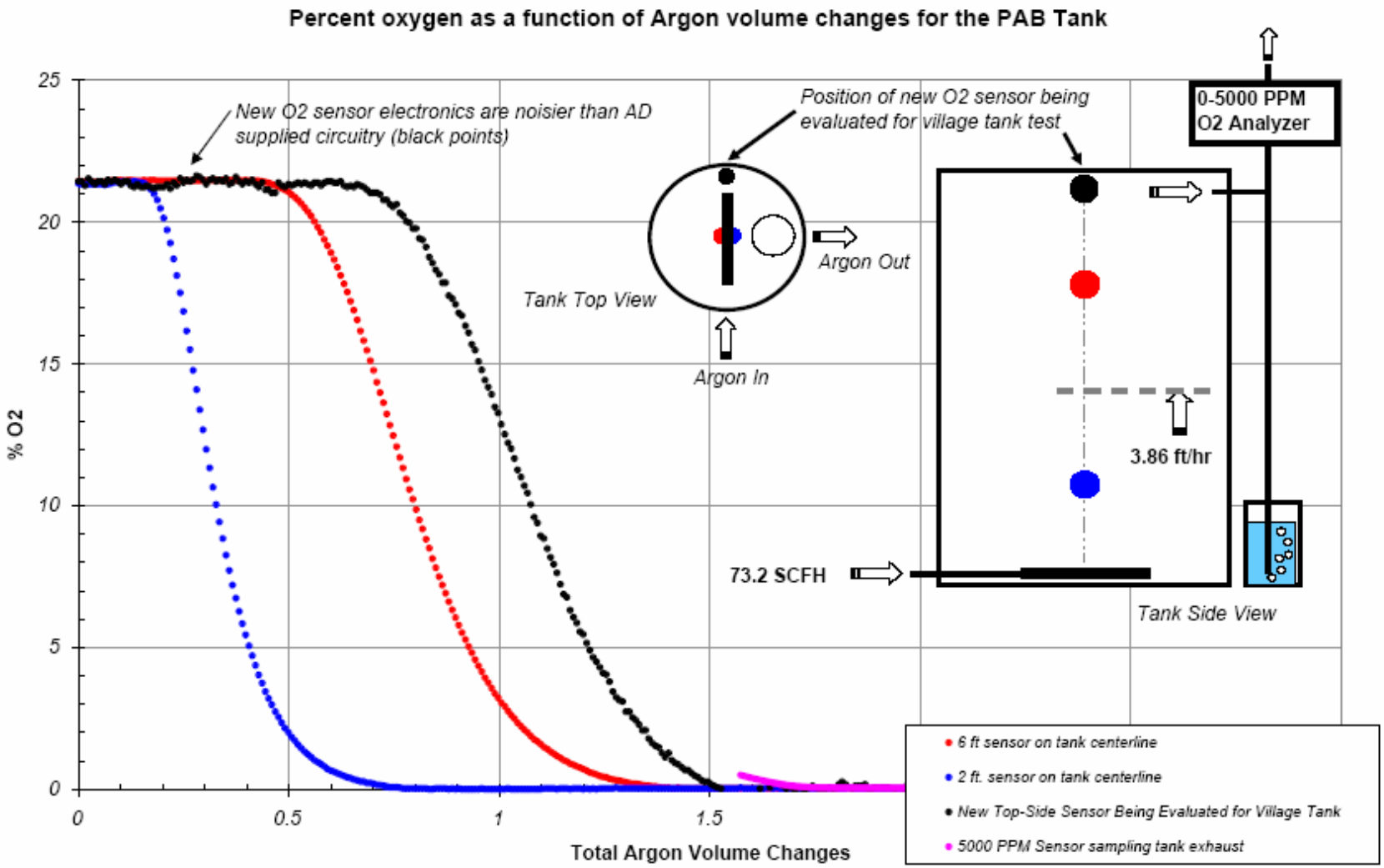
Measurements using an "Argon Piston" to Purge oxygen (reported at Gran Sasso Cryodet1 Workshop March 2006)



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

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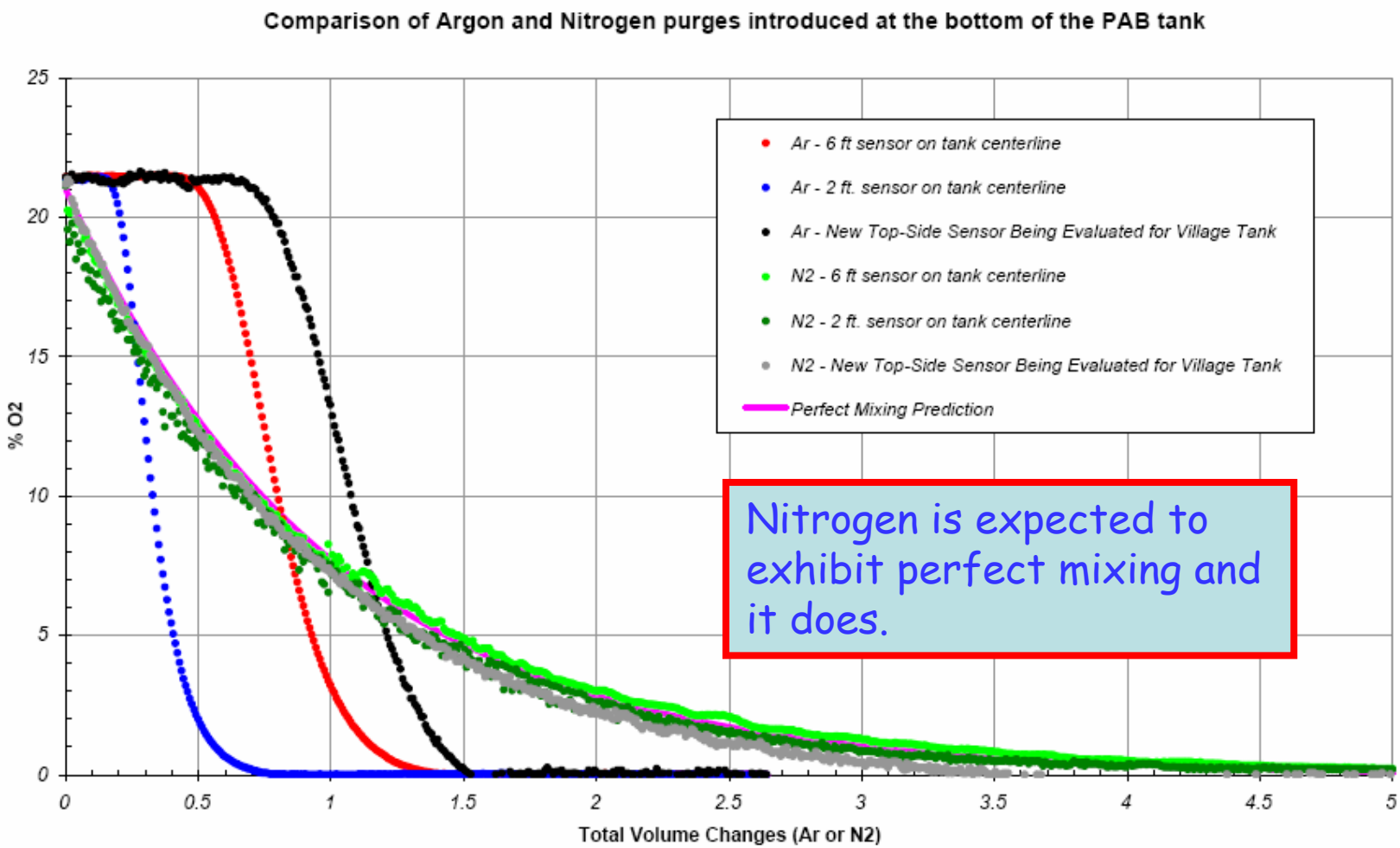

Nitrogen is expected to exhibit perfect mixing and it does.

Better View of Argon and Nitrogen purging

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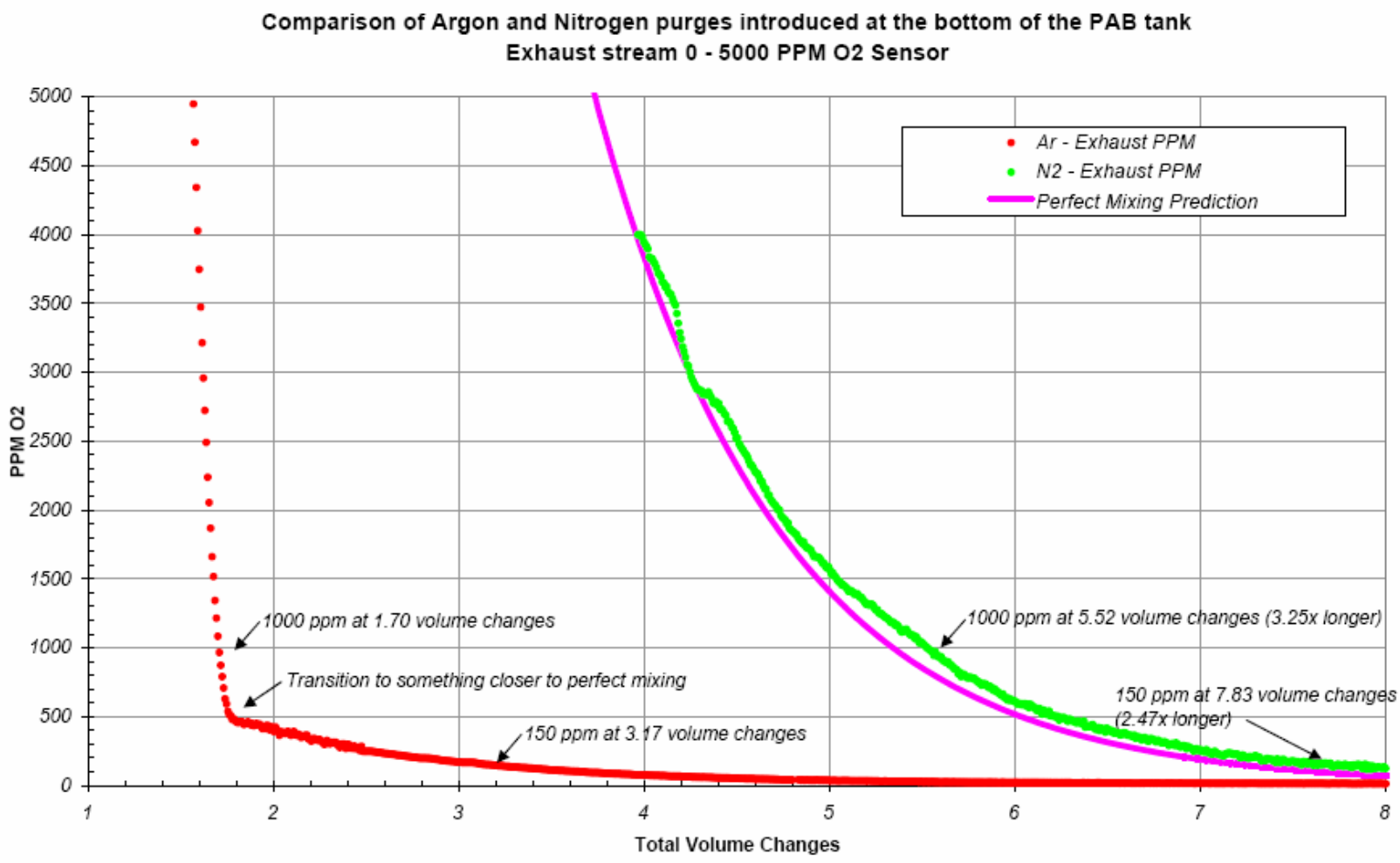

Cellular Design: Is this a problem?

A two dimensional view of the 'front' side of a panel is shown in Fig. 6.

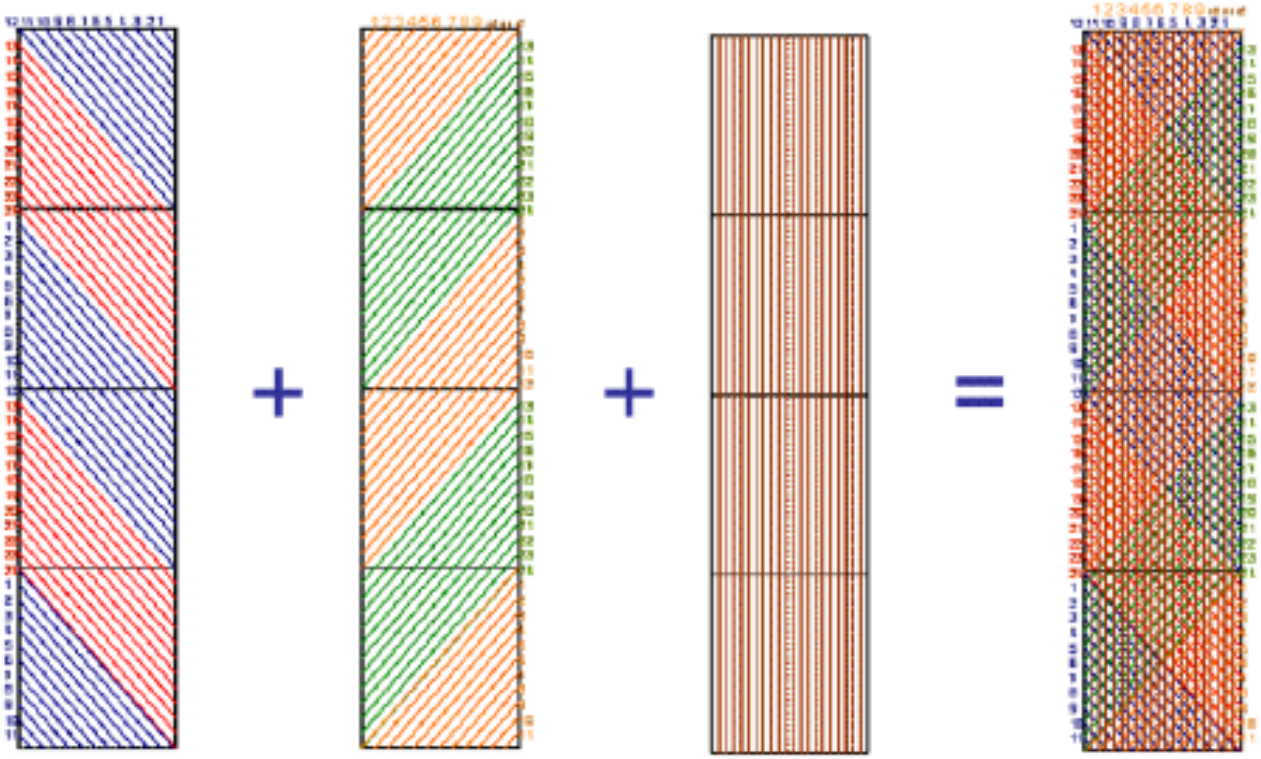

Figure 6: Graphically constructing one 'front' side of a panel – not to scale