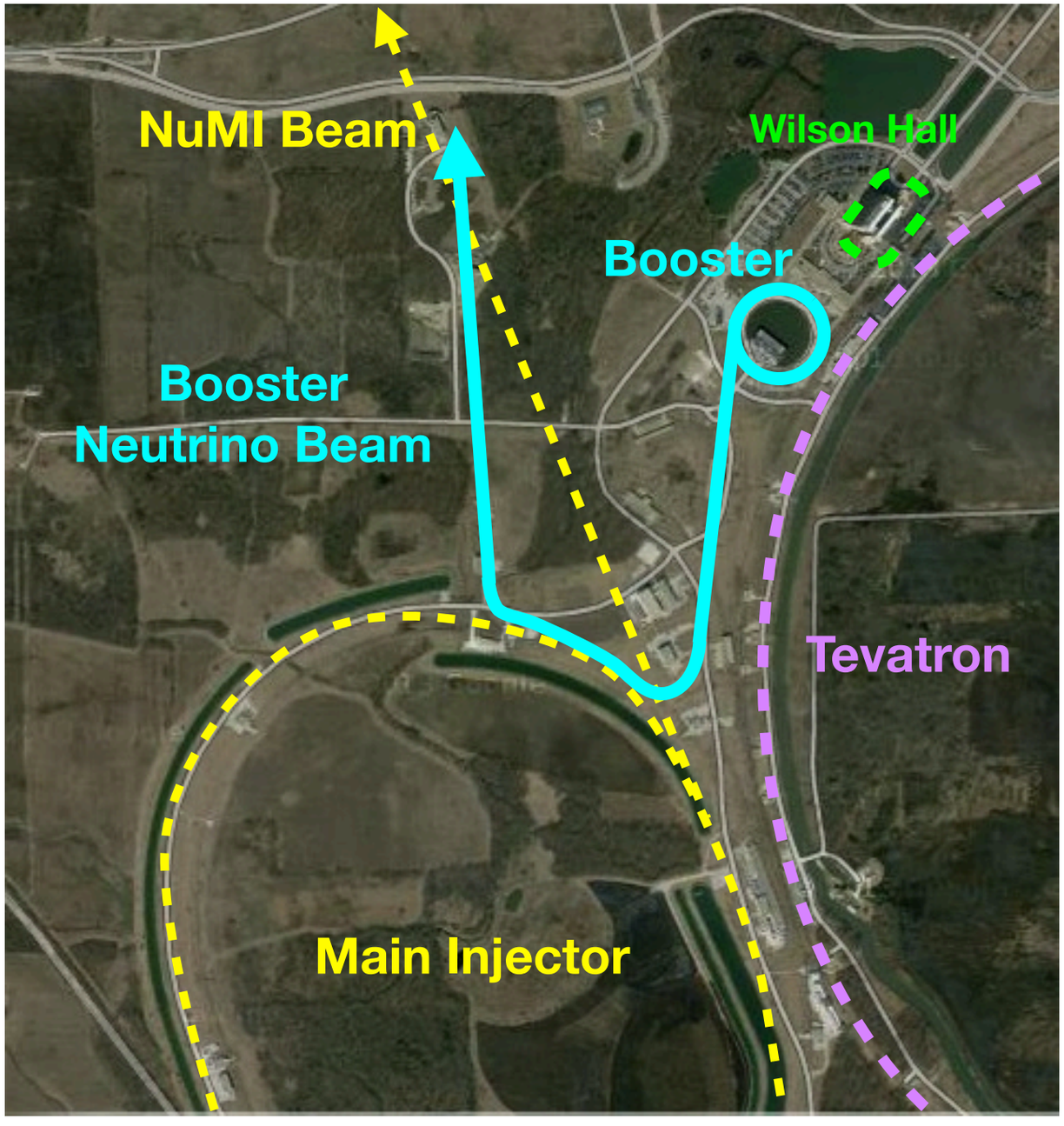
# The MicroBooNE LArTPC

Sarah Lockwitz, *FNAL*
2013 DPF

August 15, 2013

# MicroBooNE is a LAr TPC

- A liquid argon (LAr) time-projection chamber (TPC)
  - It will be placed in the **Boo**ster **Ne**utrino beam at **Fermilab**
- It has both physics and R&D goals:
  - Physics:  High-statistics measurements of ν's on Ar
    - Investigate MiniBooNE's low-energy excess
  - R&D:  Gain experience building & operating a LArTPC
    - Will put a ★ near featured efforts



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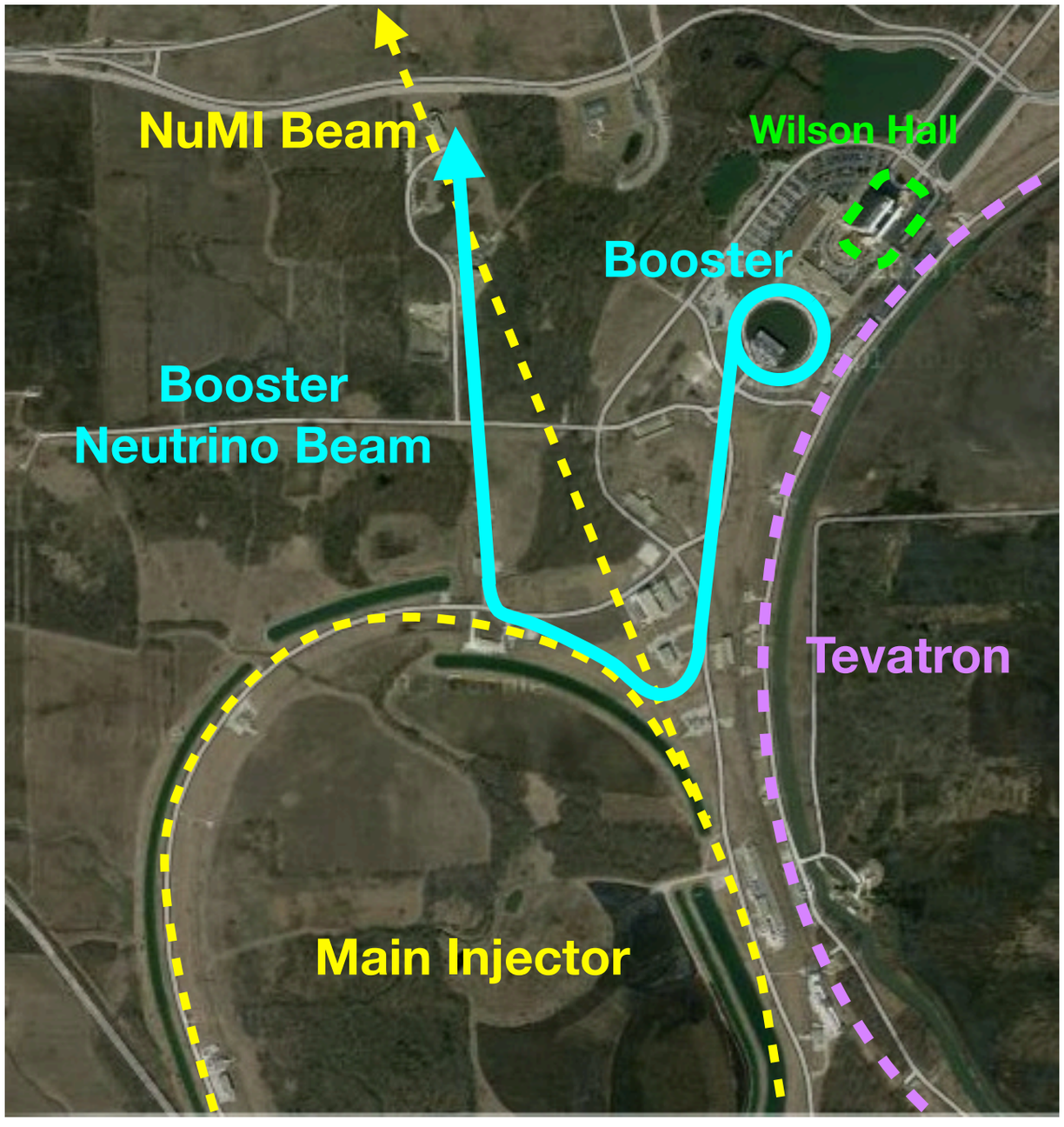
B. Carls talk will focus on this



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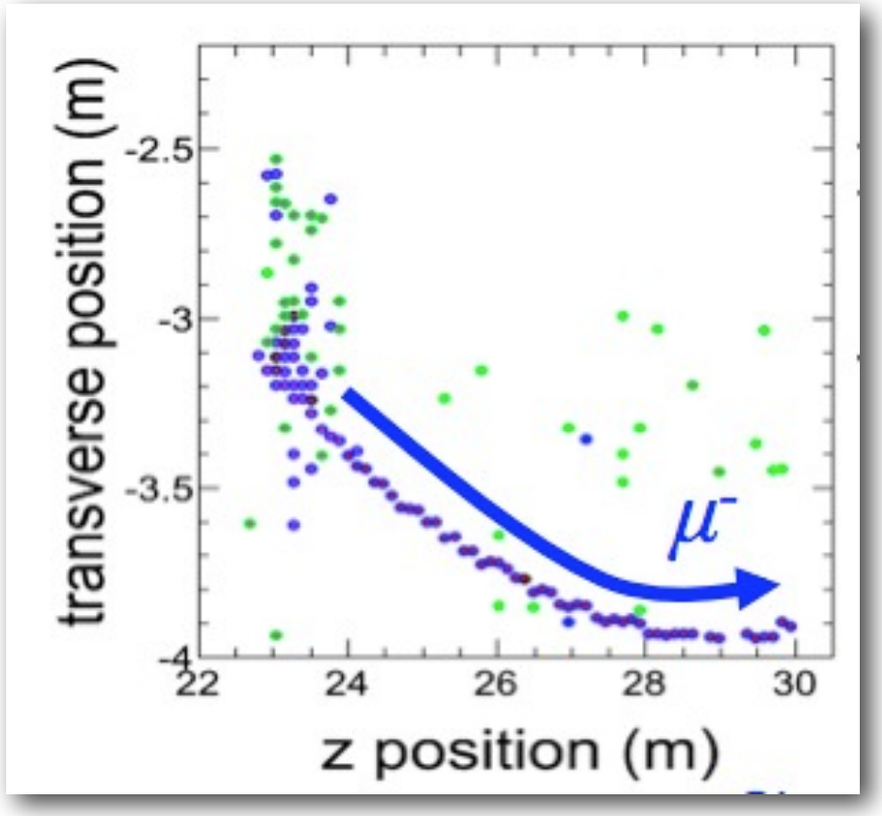

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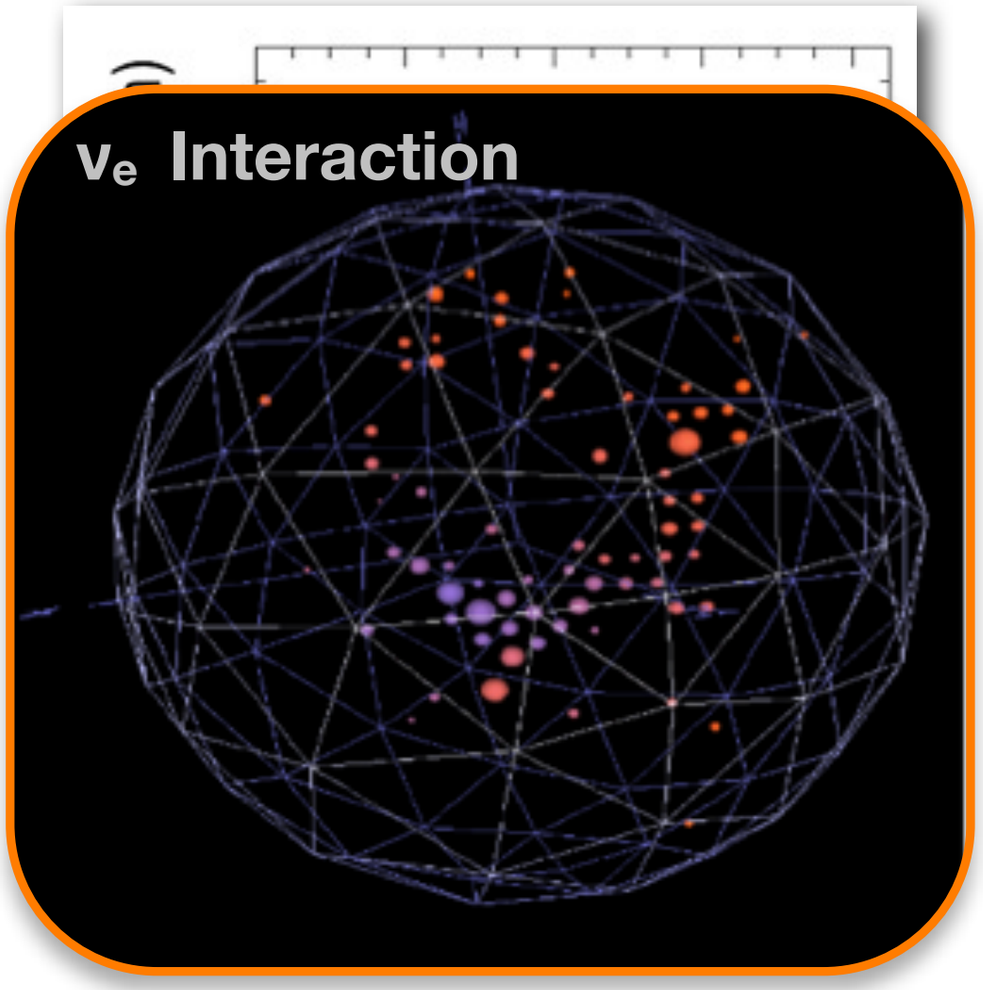

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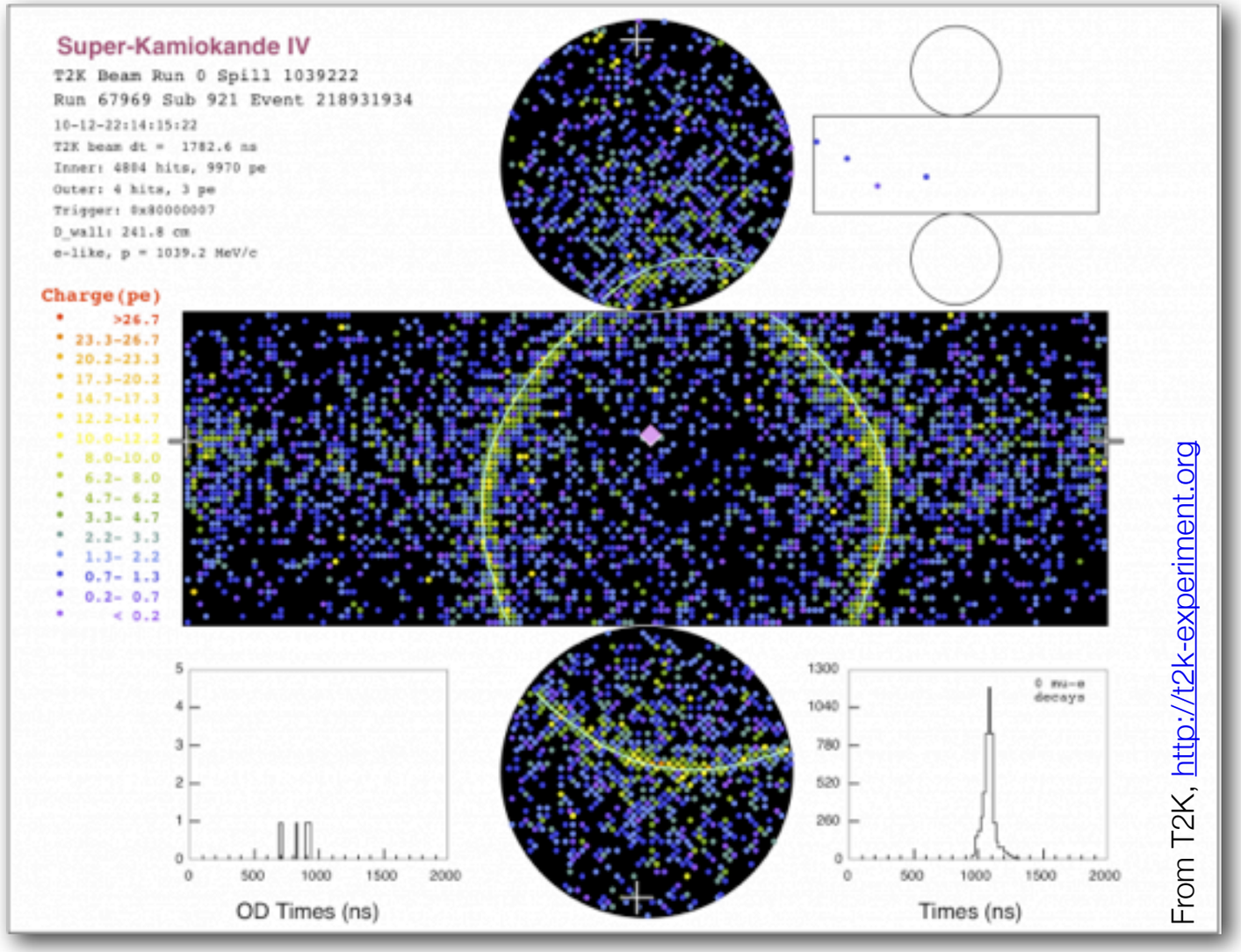


From T2K, http://t2k-experiment.org

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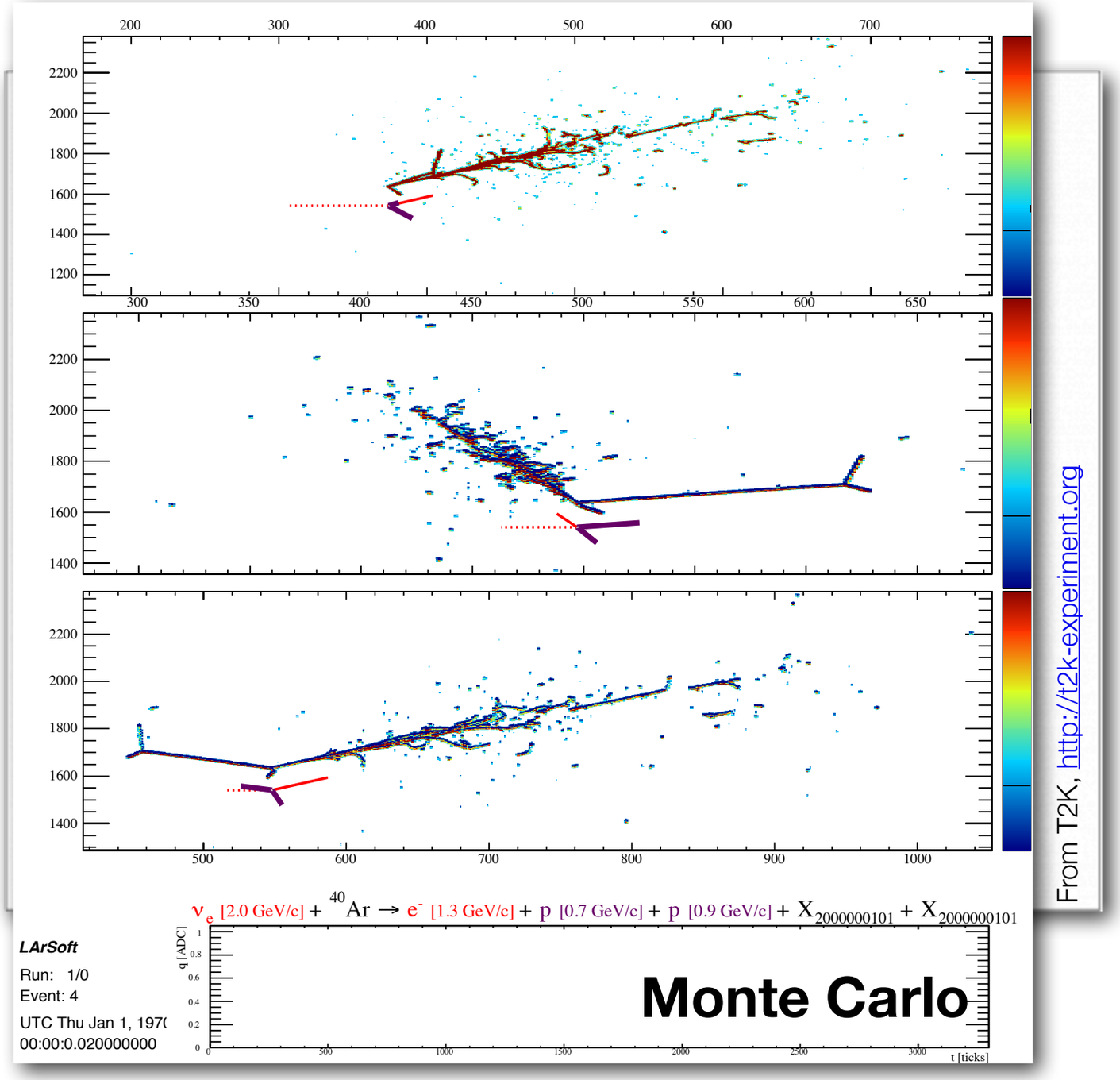

# Liquid Argon Work at Fermilab

Materials/
Electronics Test
Stand

2008

LAPD

**2014**

Multikiloton
LAr detector

LBNE

100% R&D

100%
Physics

2007

ArgoNeuT

2010

**MicroBooNE**
(also LArIAT & 35T)

?????

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**ICARUS**
Pioneering LAr in Europe
2001, 2010

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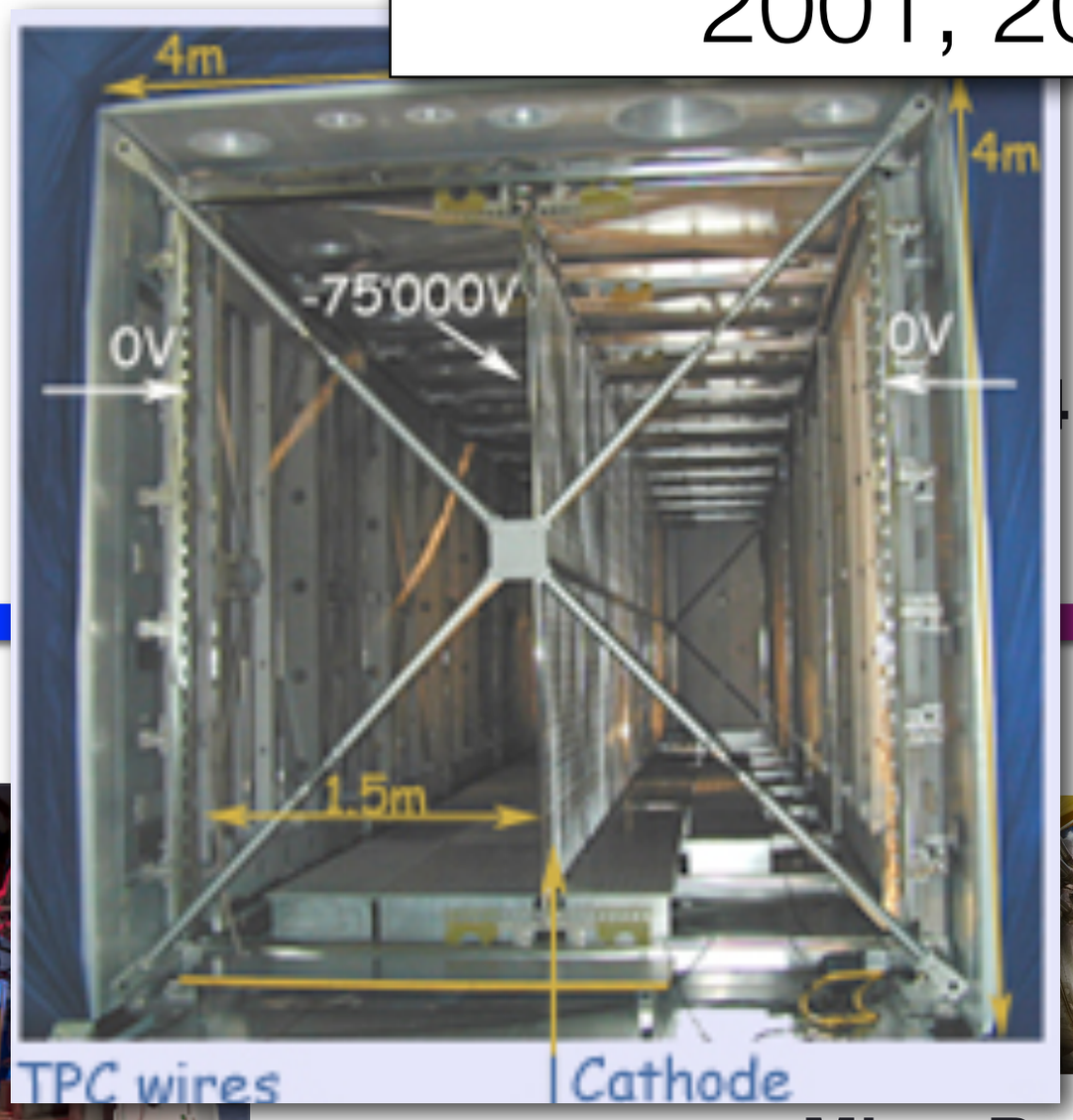



100%
Physics

?????

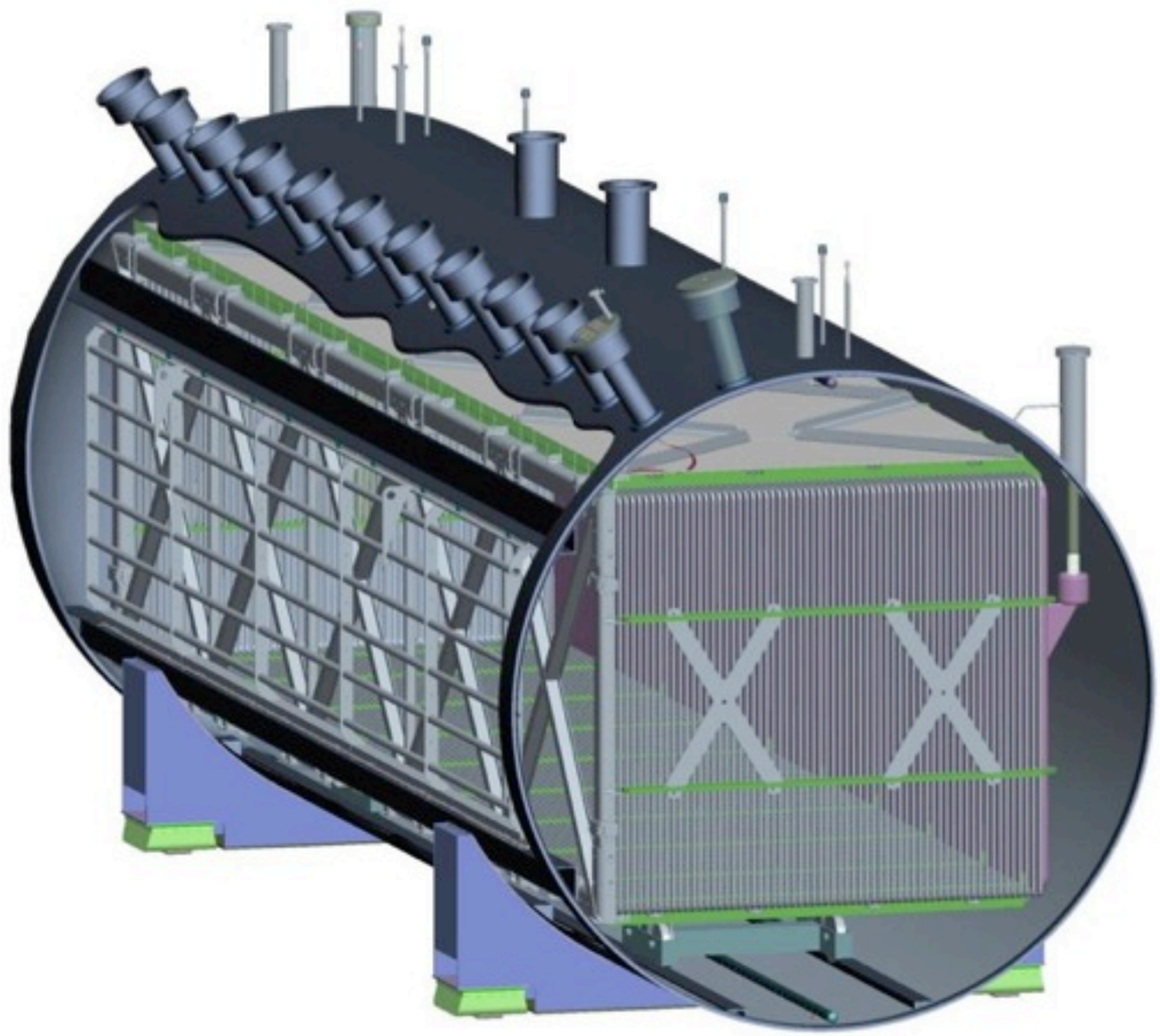


ArgoNeuT

**MicroBooNE**
(also LArIAT & 35T)

# Outline

- Reminder of how a TPC works
- Why argon?
- Design and construction efforts
  - Frame (+ Cathode & Anode readout)
  - PMTs
  - Cryostat & Cryosystem
- Status and outlook



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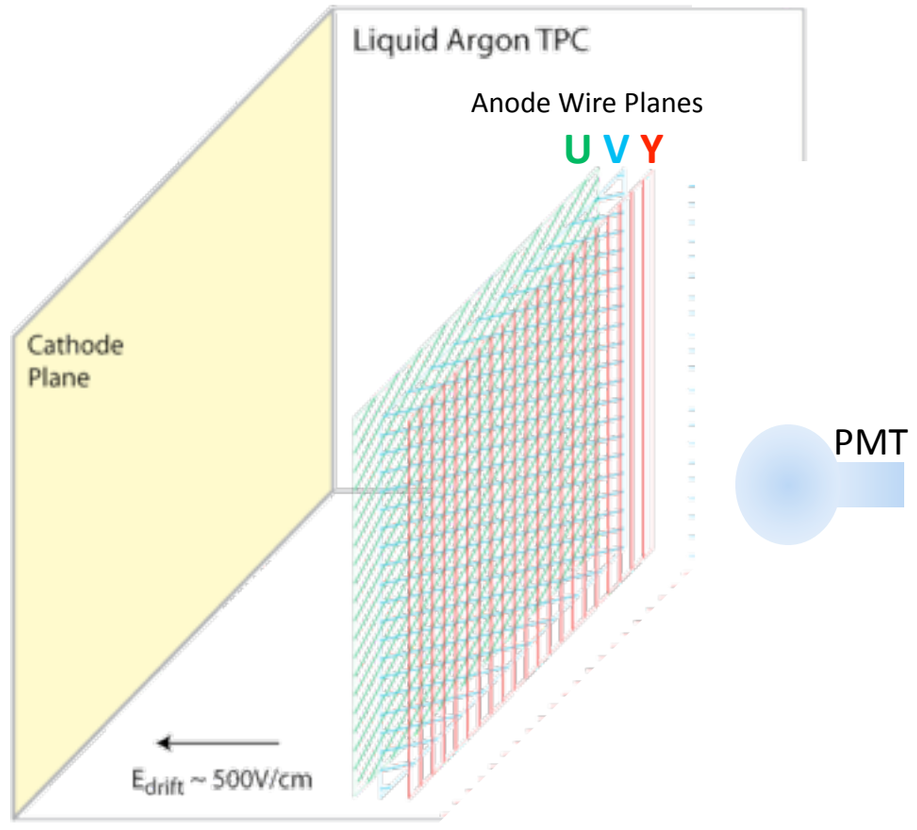

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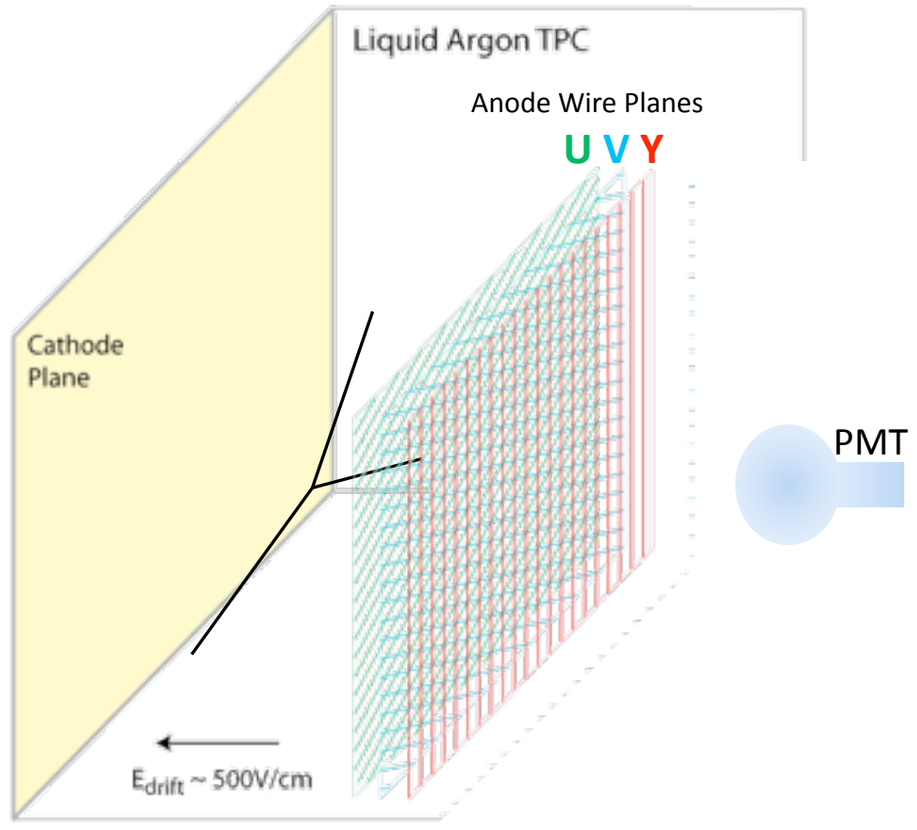

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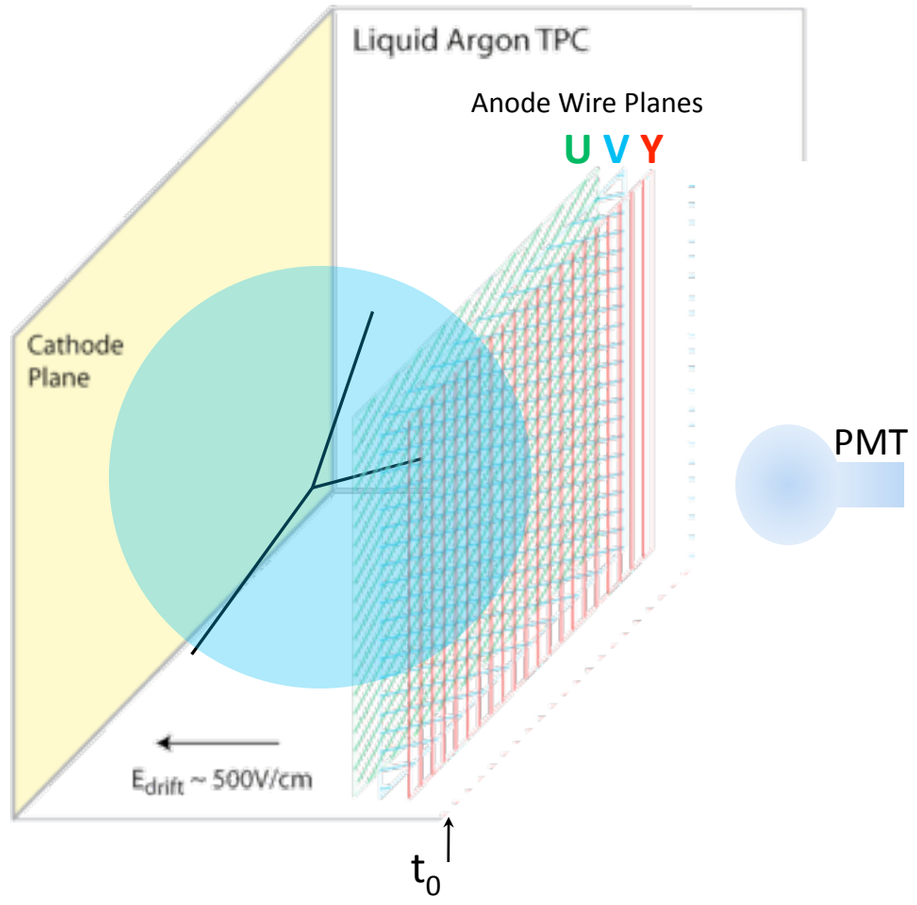

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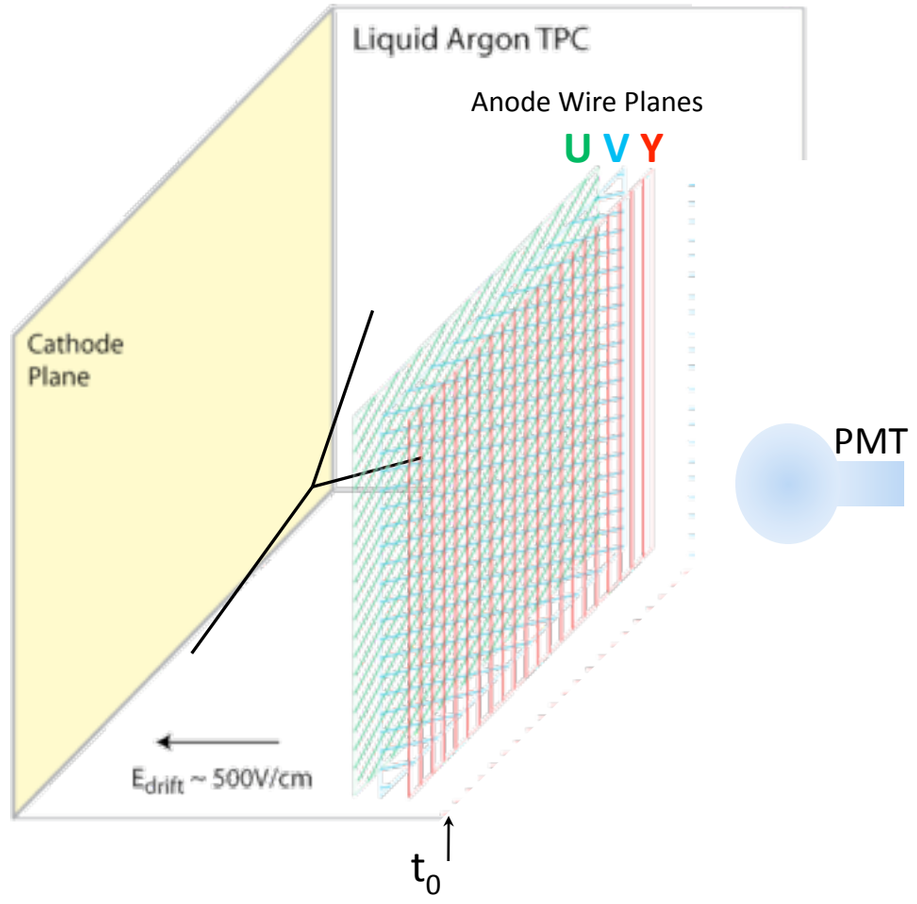

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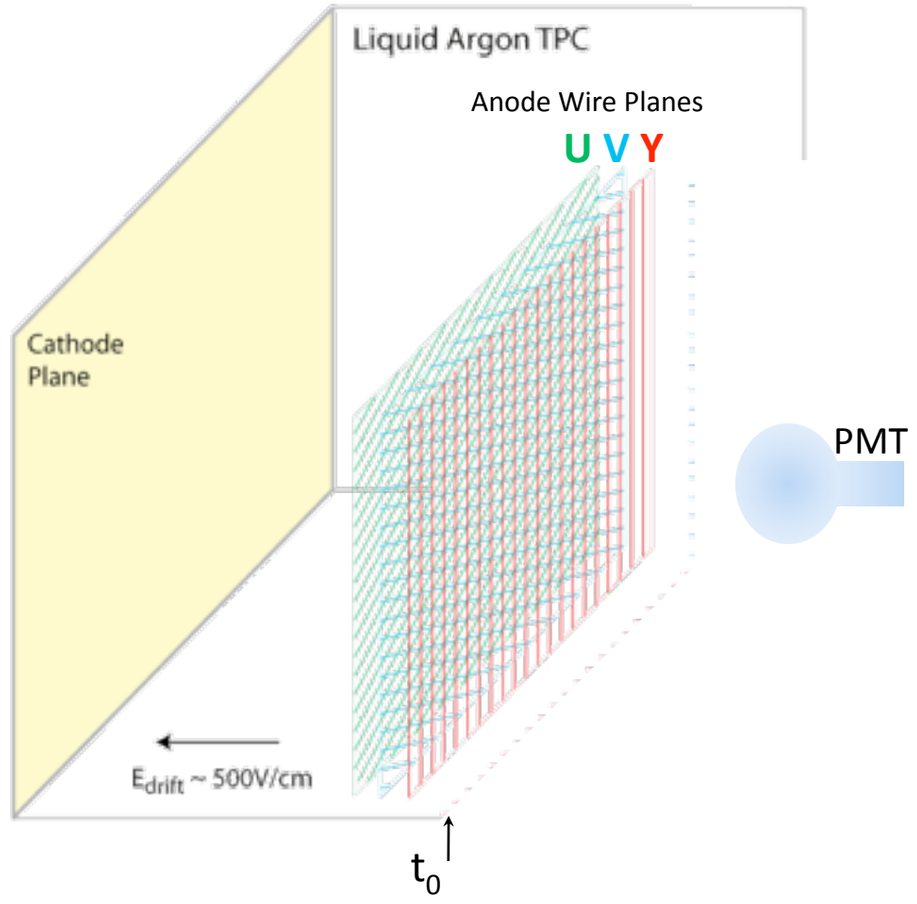

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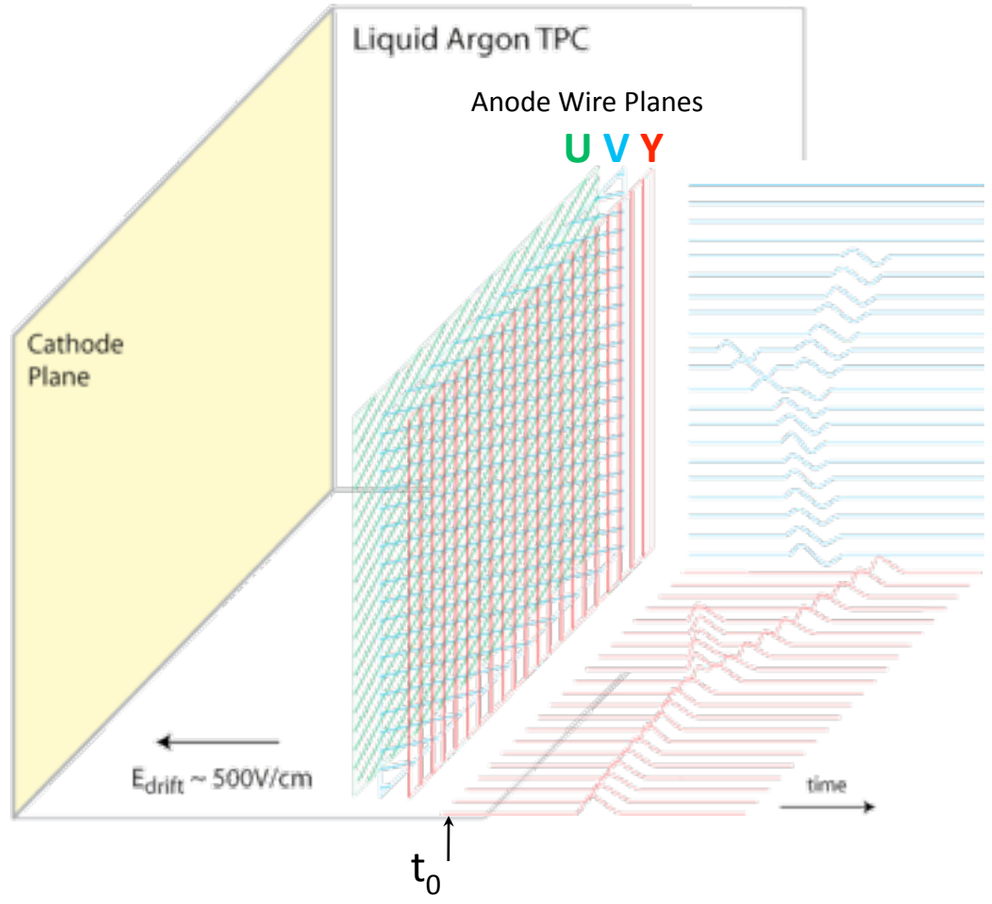

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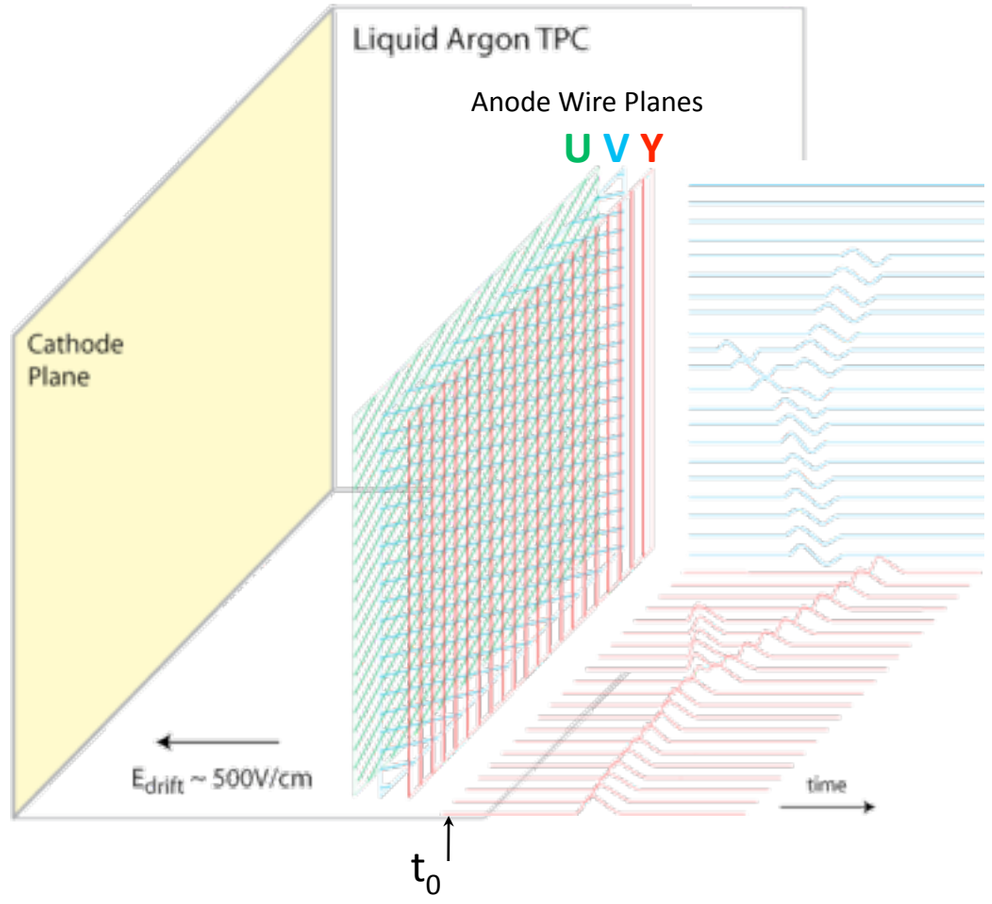

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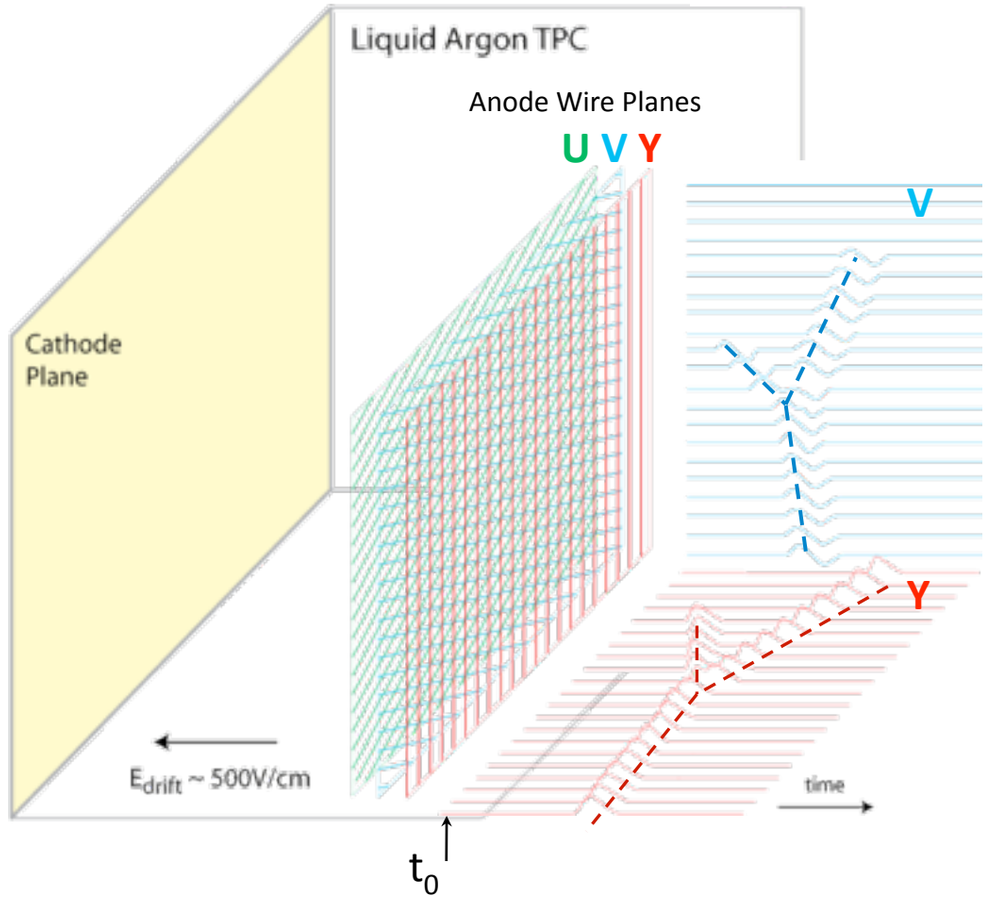
- Tracks are reconstructed from wire signals:
  - Two dimensions from wires
  - Drift distance is found from knowing $t_0$ & $v_d$ → Time projection!



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| Density [g/cm³] | 0.125 | 1.2 | 1.4 | 2.4 | 3.0 | 1 |
| Radiation Length [cm] | 755.2 | 24.0 | 14.0 | 4.9 | 2.8 | 36.1 |
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From M. Soderberg

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Can be cooled by $LN_2$

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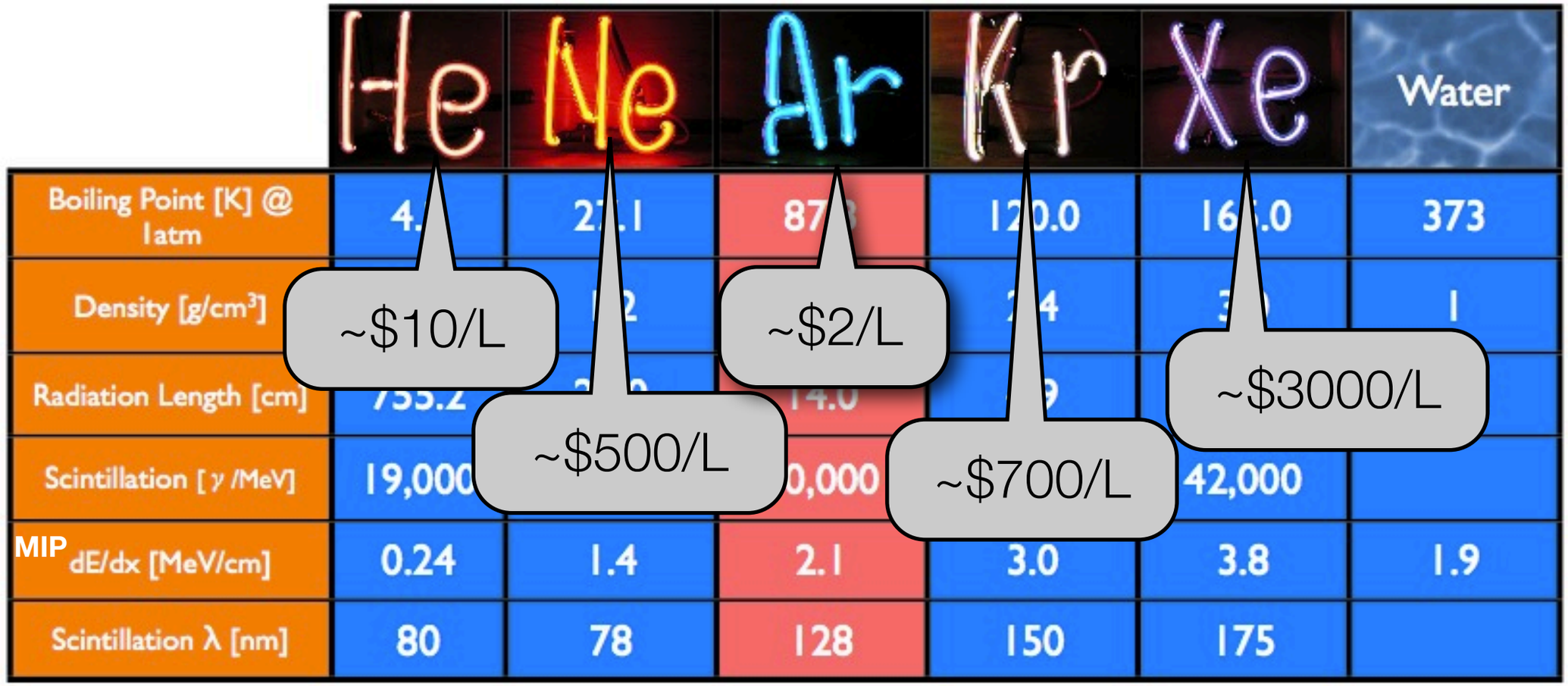


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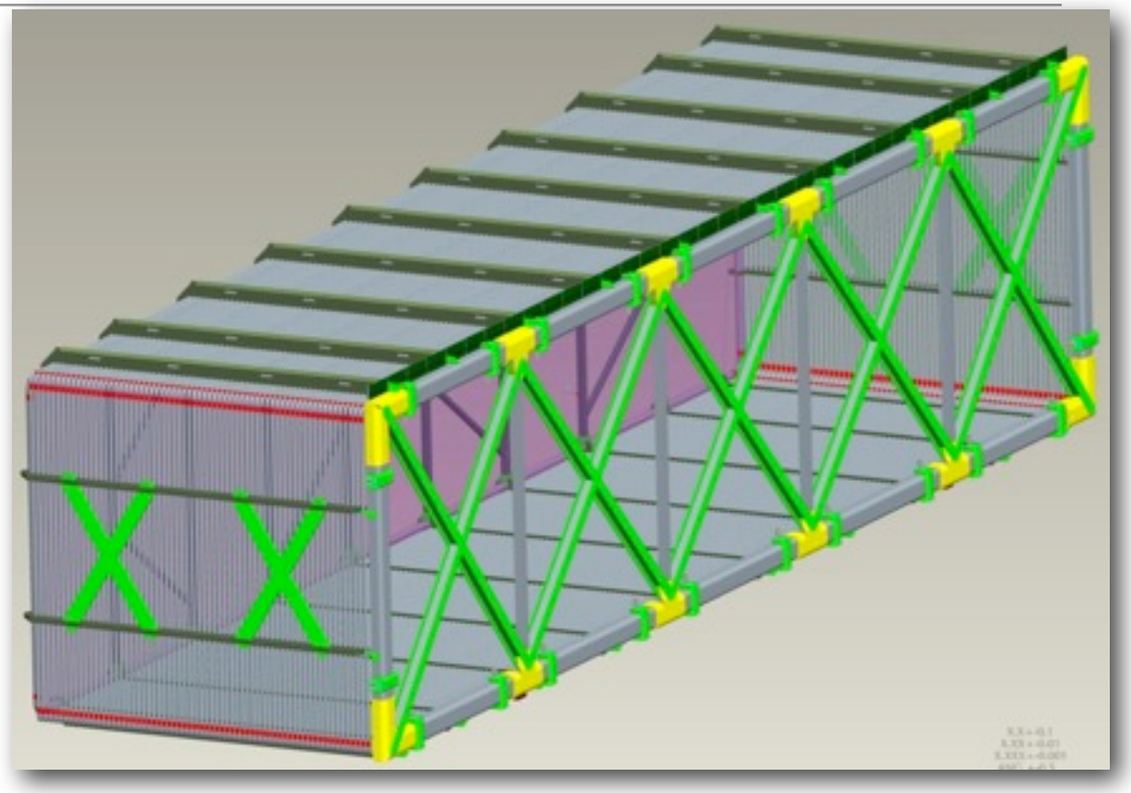

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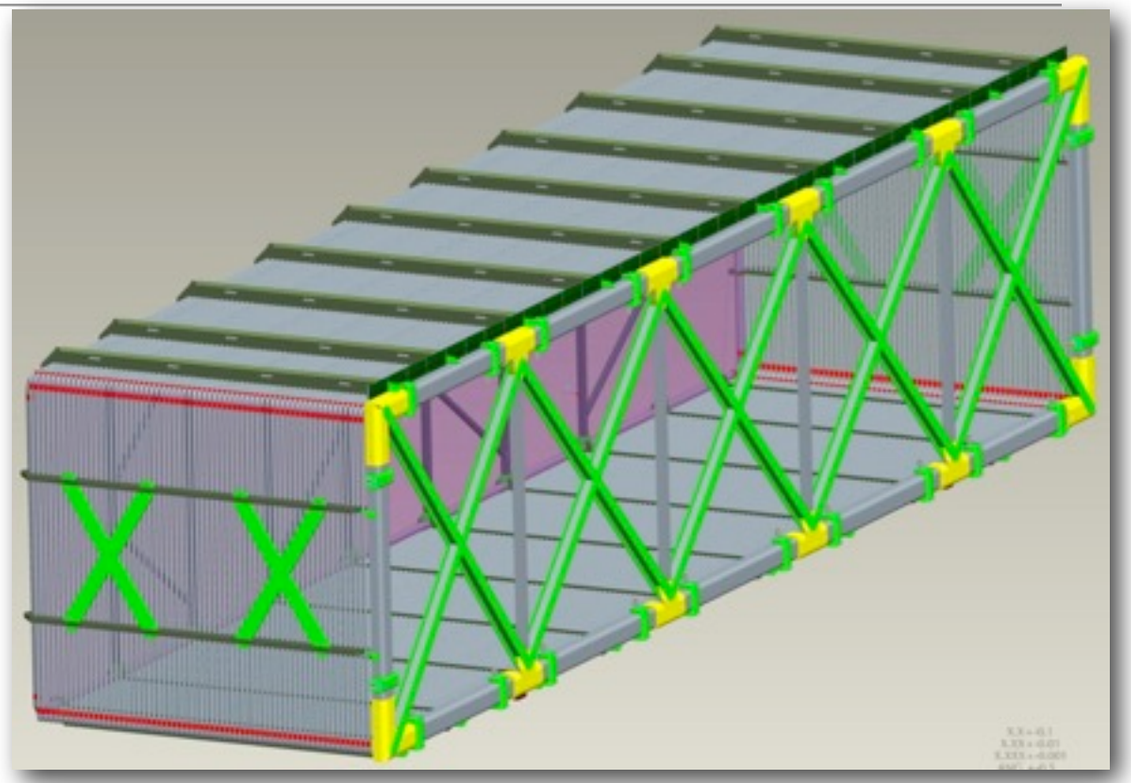

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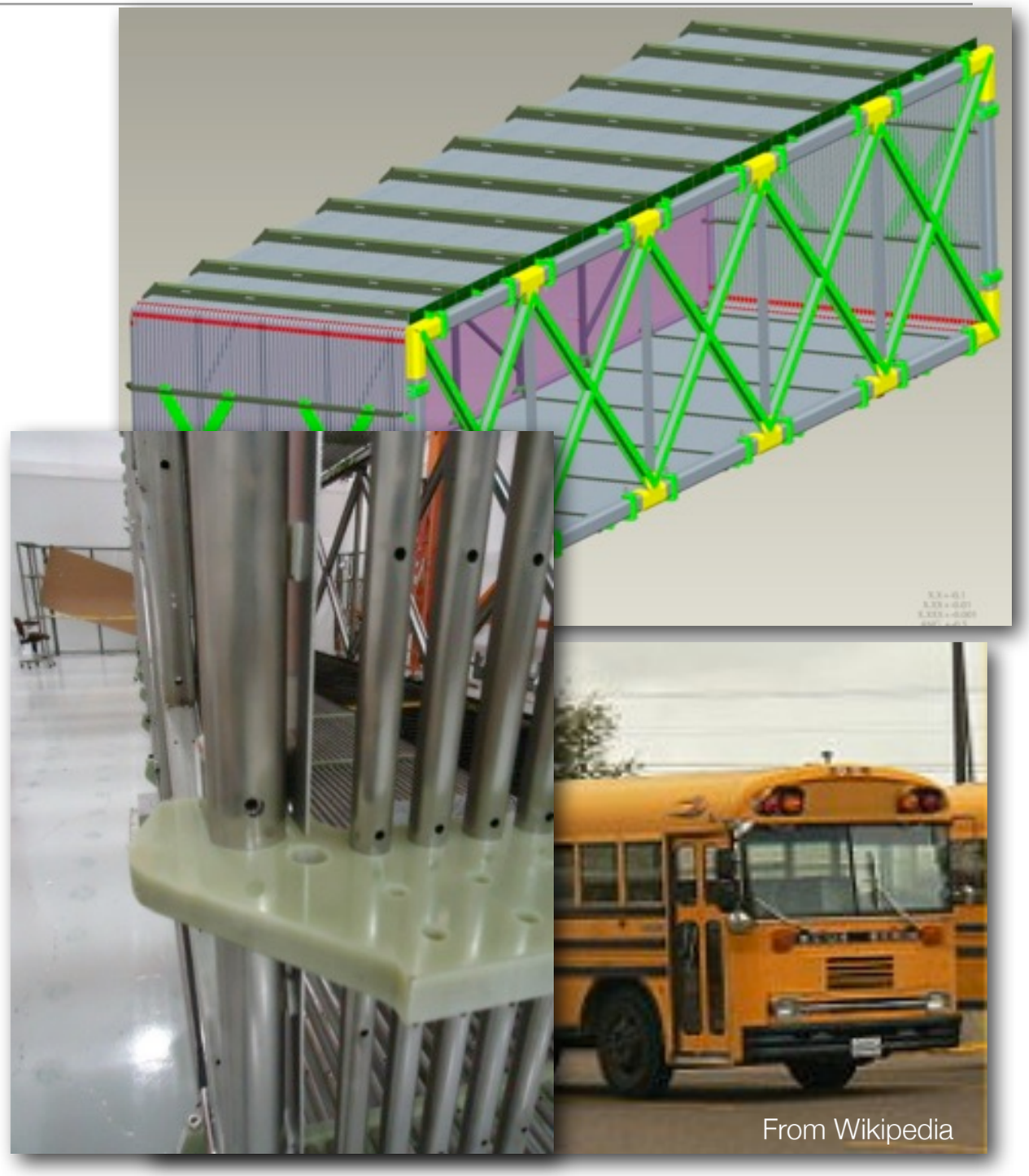
- The electric field cage is made from stainless steel tubes
    - Held parallel by G10 braces



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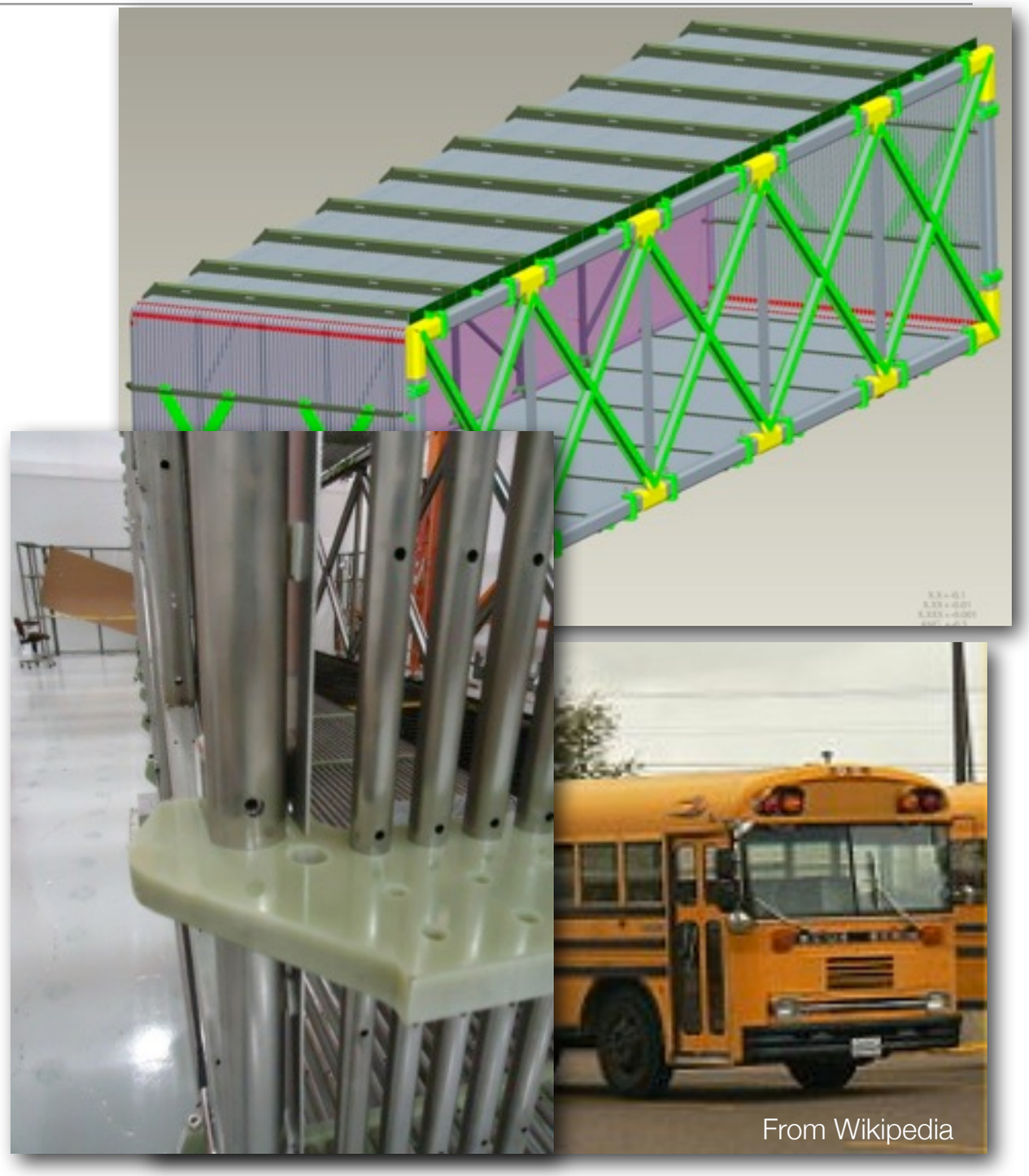
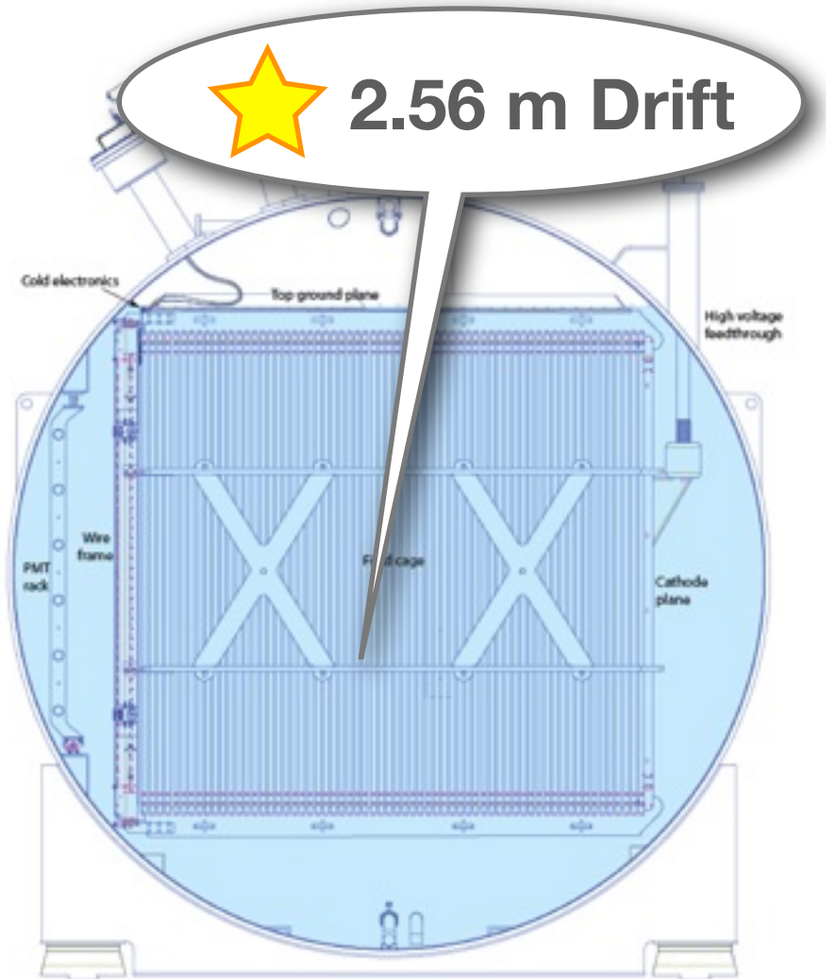
    - We then step down the voltage between each tube to create a uniform electric field



From Wikipedia

# Cathode Plane



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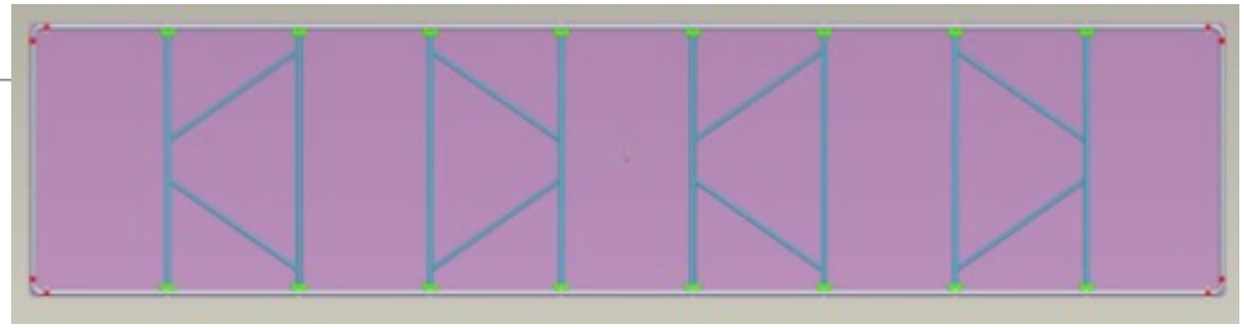

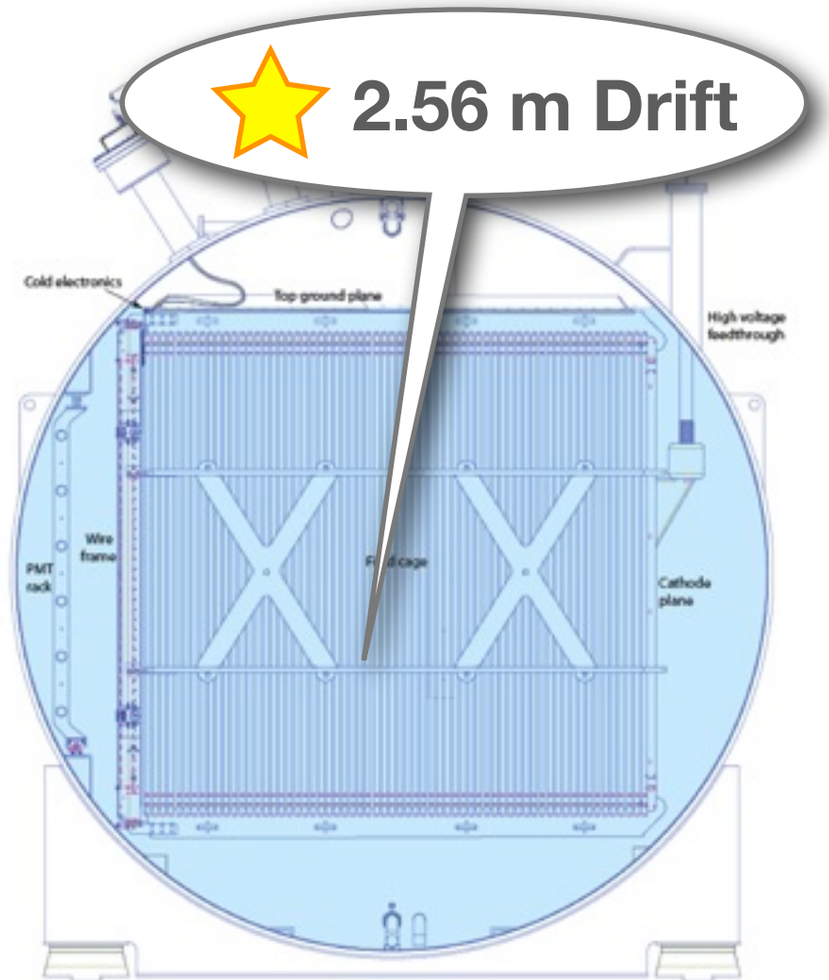

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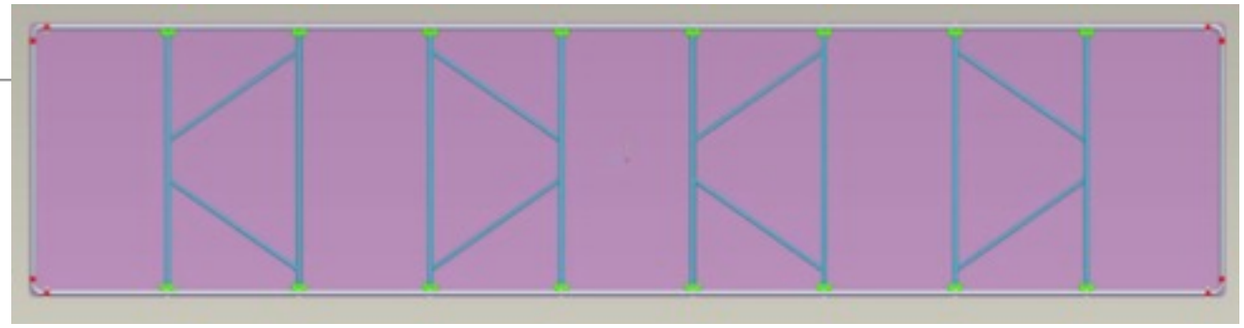

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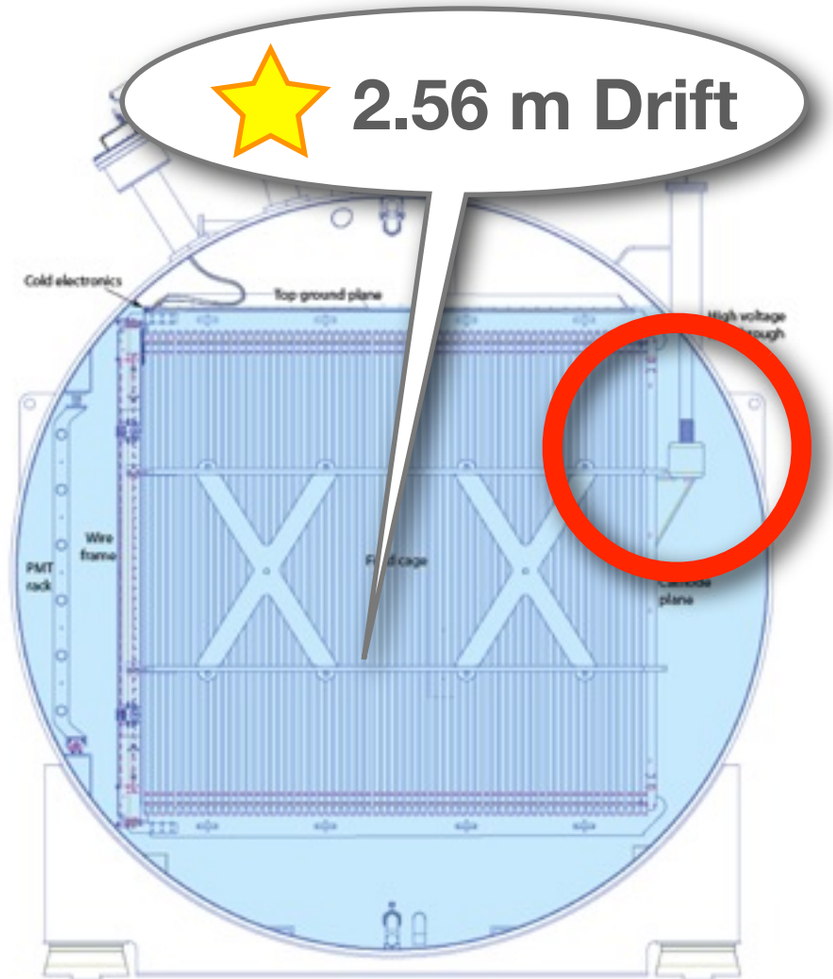
- The high voltage (HV) for the E field is generated outside of the TPC by a Glassman power supply
  - The HV is in contact with the cathode plane by a feed through that will be in contact with a cup on the back of the plane



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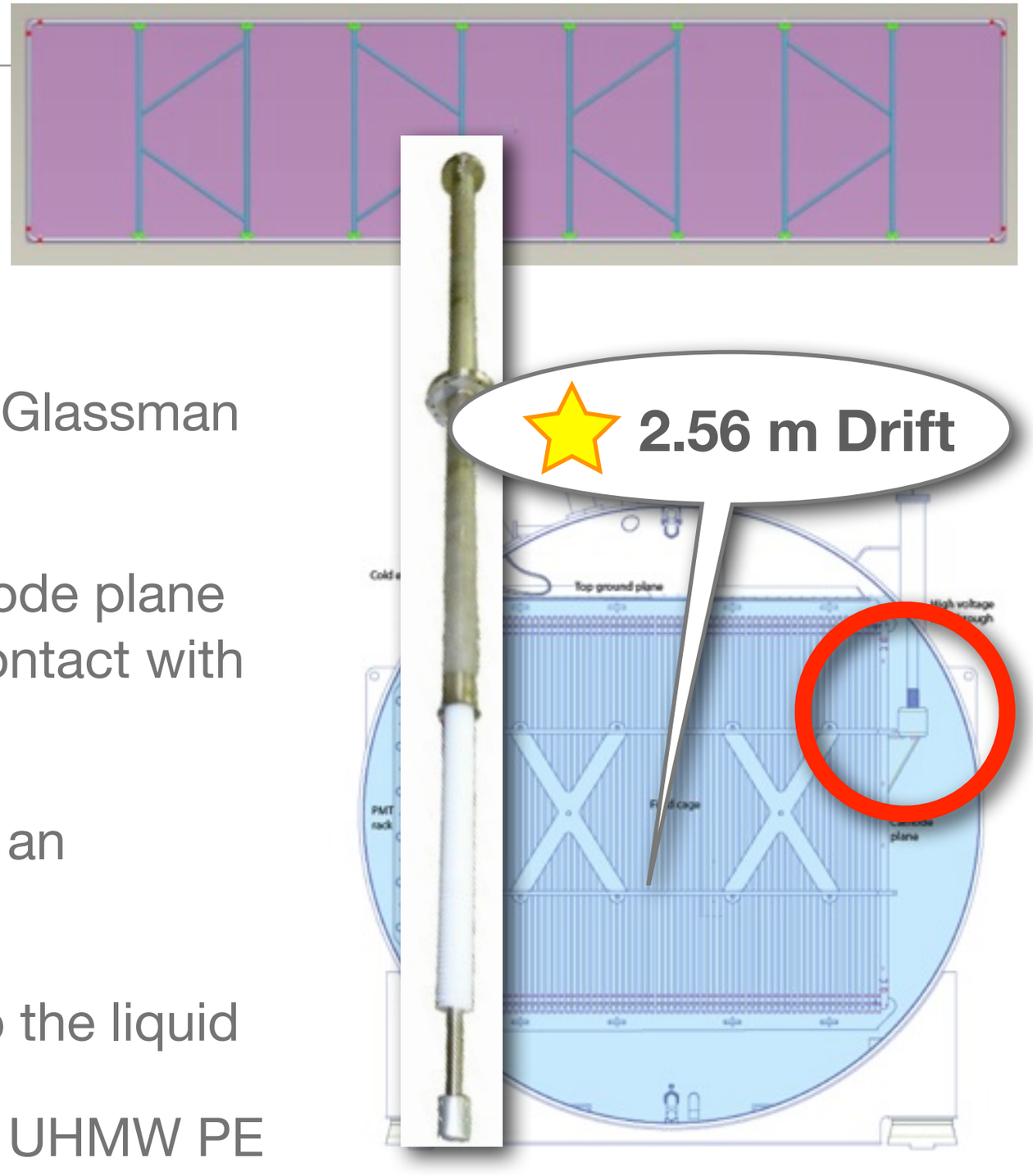
  - The feed through is modeled after an ICARUS design
    - Outer ground tube extends into the liquid
    - Inner conductor is insulated by UHMW PE

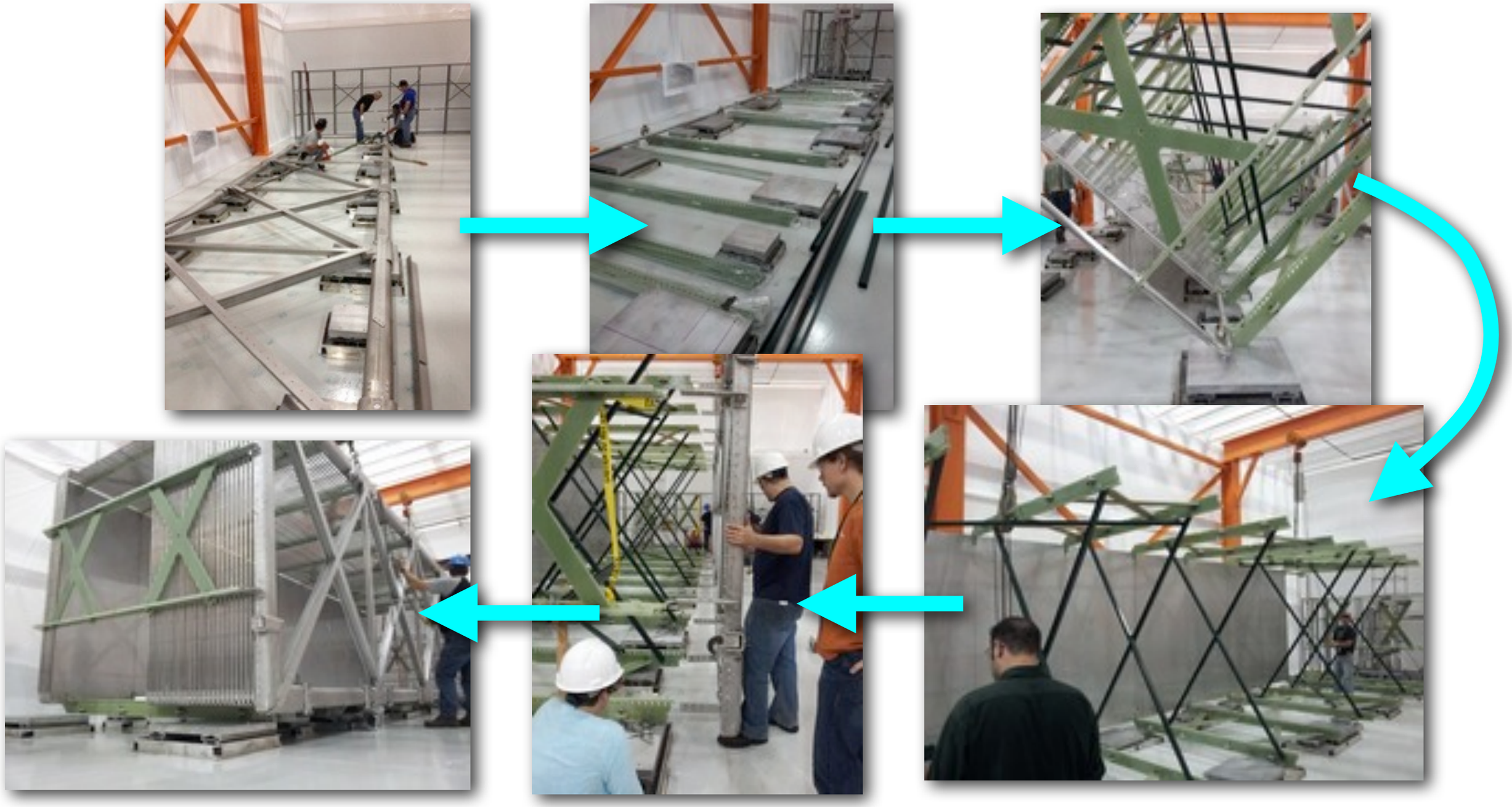


# TPC Frame Construction

- Parts were cleaned and deburred last summer
  - Pure argon & reduce high fields
- Everyone from undergrads to professors and scientists have been working on the assembly

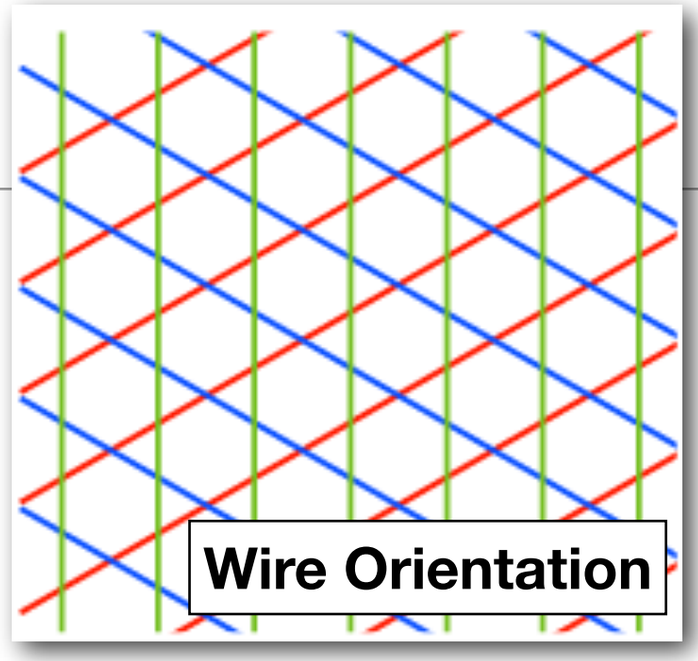
# TPC Frame Construction

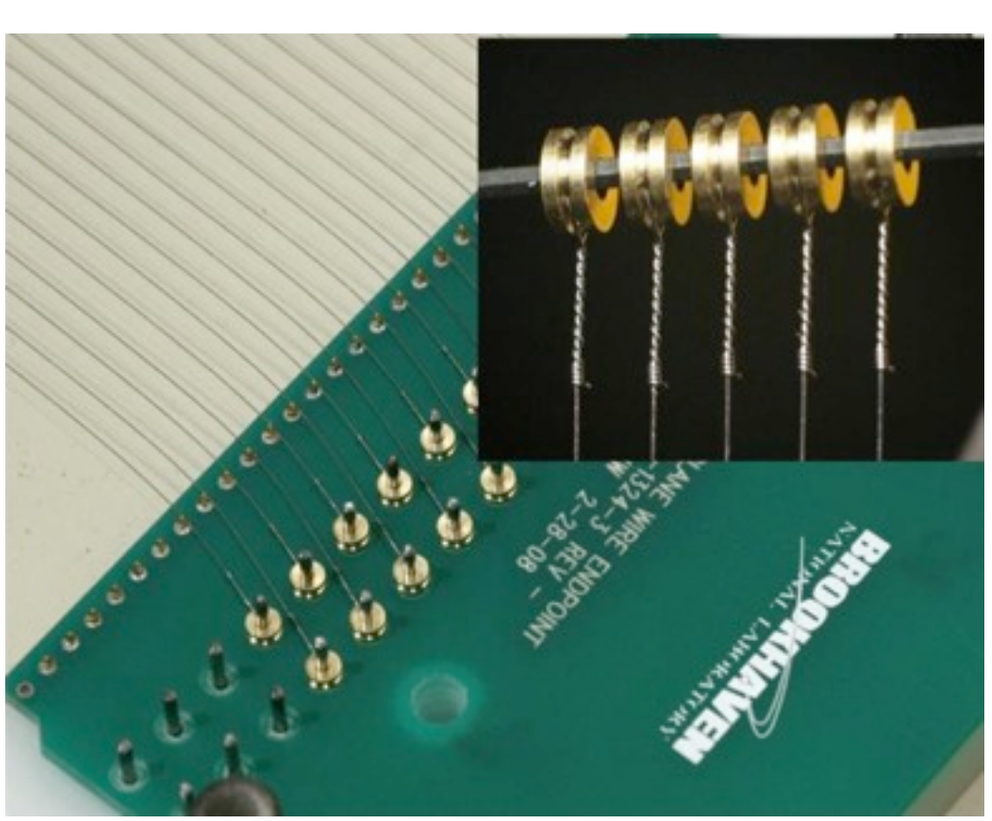
- It was constructed and surveyed within the last year in our clean room tent



# TPC Wires

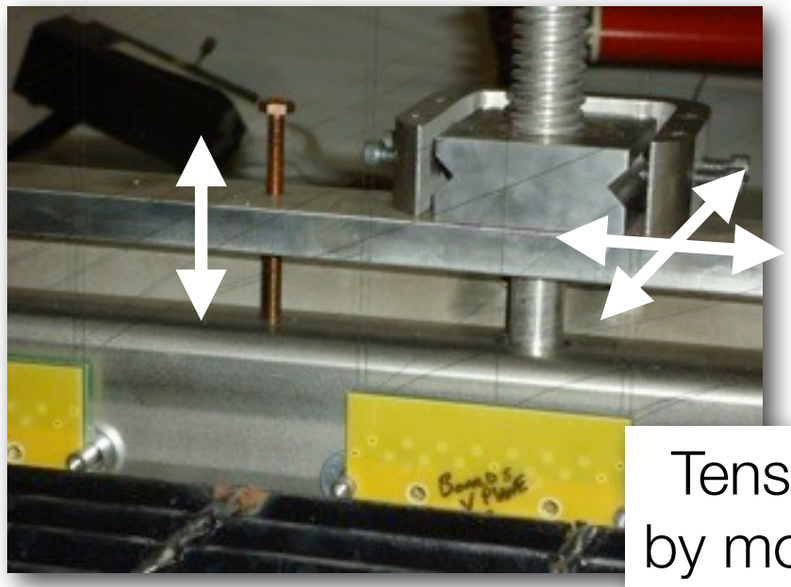
- The wires that read out the ionization signal are 150 μm stainless with 2 μm copper plating and a thin flash of gold
- We have three wire planes (3456 vertical, 2400 +60°, 2400 -60° ⇒ 8256 channels) separated by 3 mm
- All wires have a 3 mm pitch
- They attach to a wire carrier board for assembly onto the TPC frame
- Winding of the ferrules and attachment to the boards took place last year off site by students and post docs



# TPC Wires

- Installation of the boards to the TPC frame took place this spring
- Surveying the tensioning of the wires took place this summer
  - Tension goal was 0.7 kg — need to prevent sag, but also prevent breakage during cool down



Tension can be adjusted by moving the support bar

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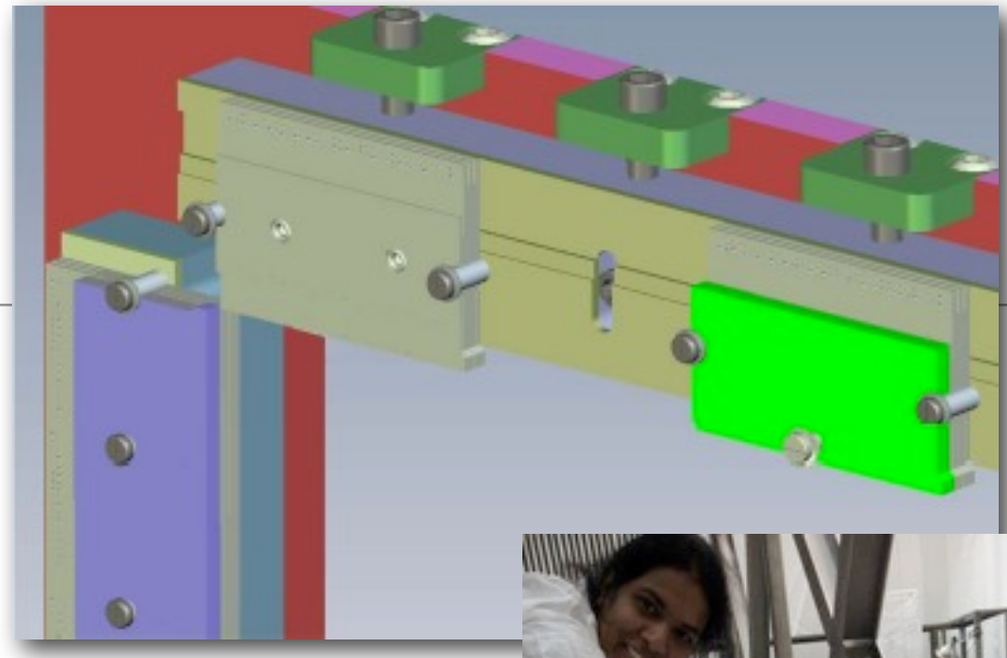

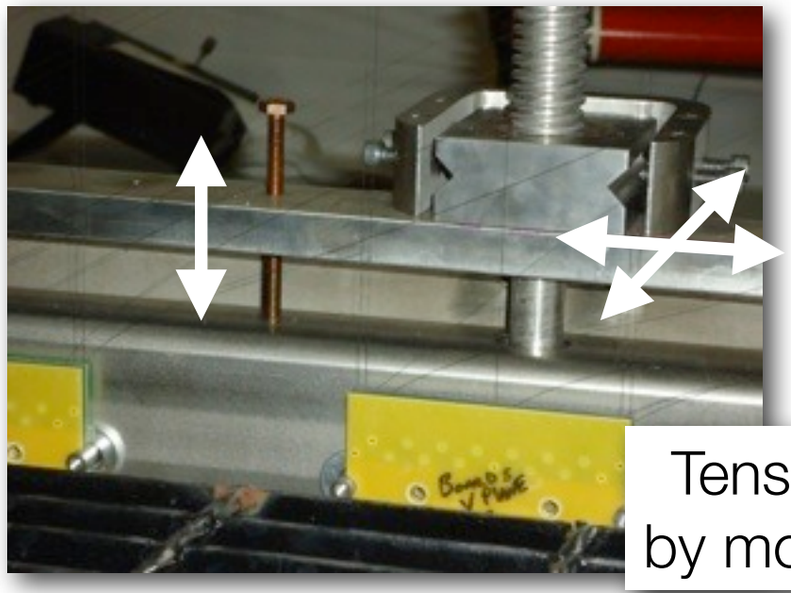

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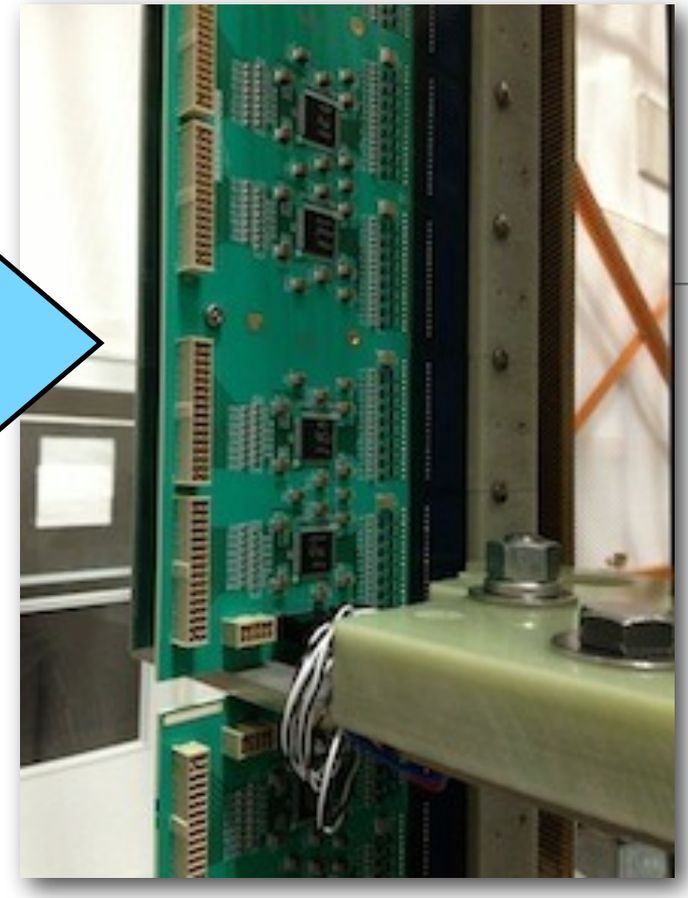
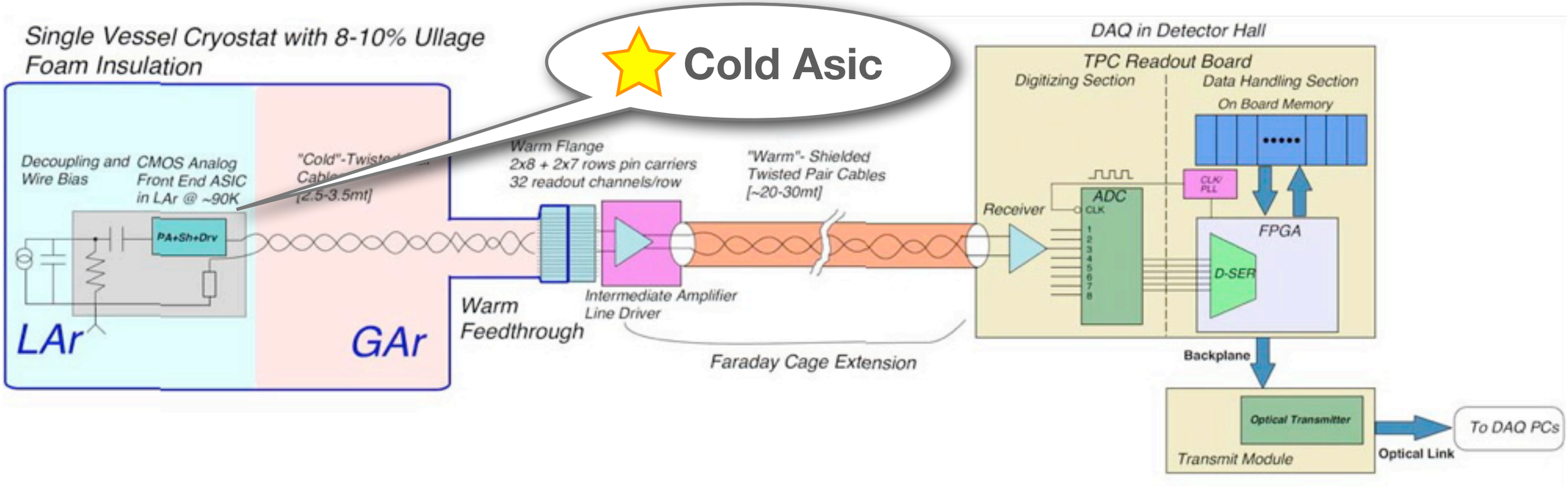
# Electronics

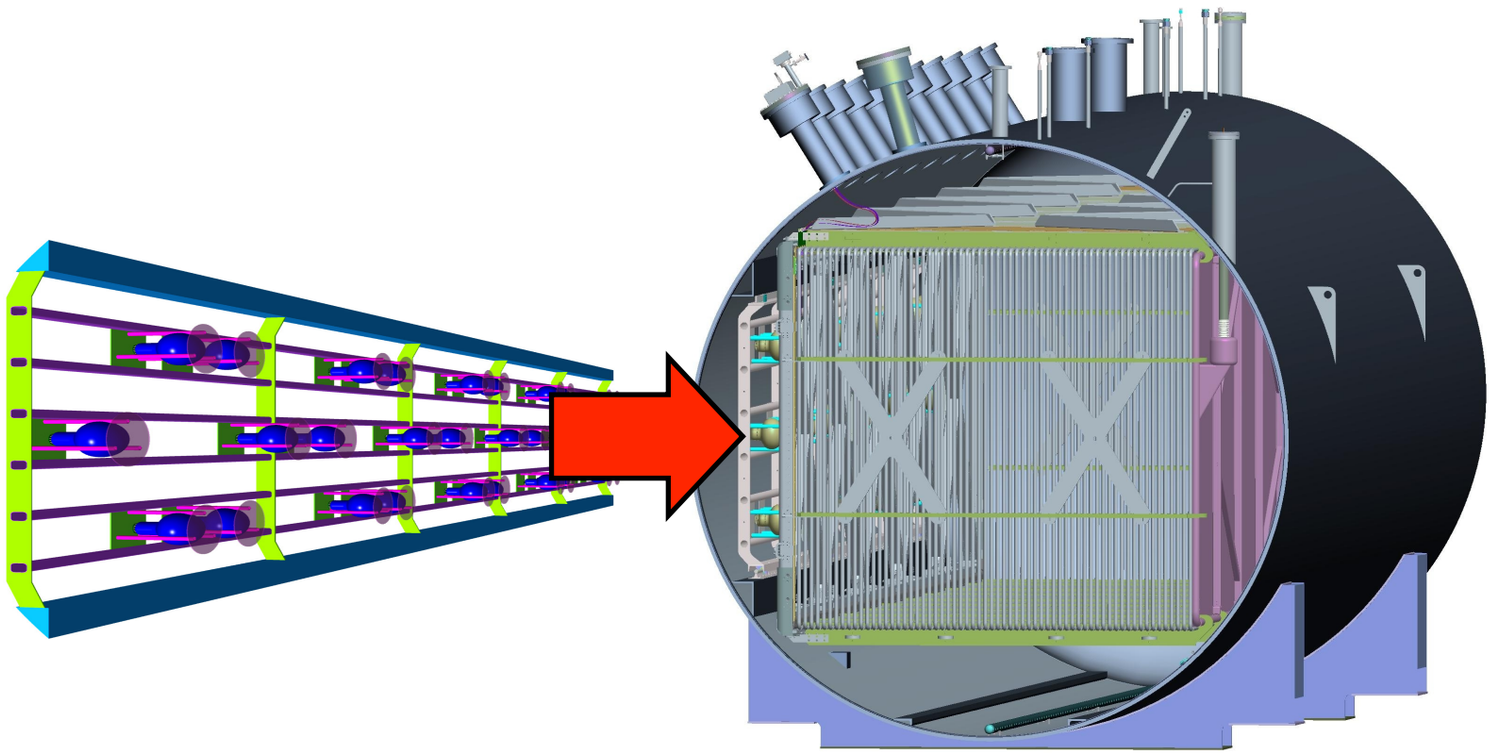
- Attachment of the cold electronics to the wire carrier boards happened this summer
- Once the TPC is inserted into the cryostat, the motherboards will be connected to the warm intermediate amplifiers
  - → Digitizers → DAQ





# PMTs — Timing Information!

- Timing information is especially important since we are on the surface → lots of cosmics

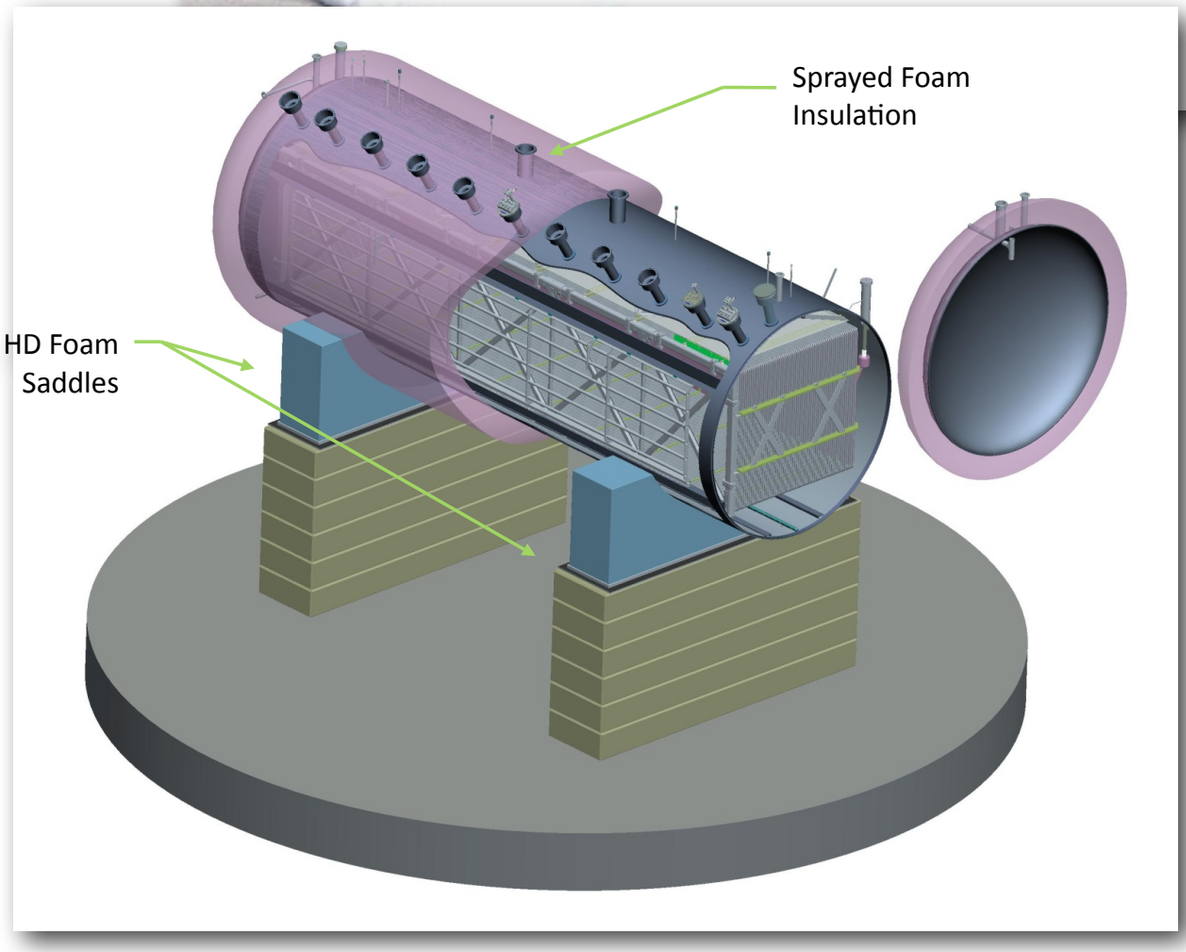


- Behind the anode frame, there will be a rack of 32 PMTs

- Ar scintillates at 128 nm so a plate with a wavelength shifting coating is put in front of the PMTs to make light collection possible

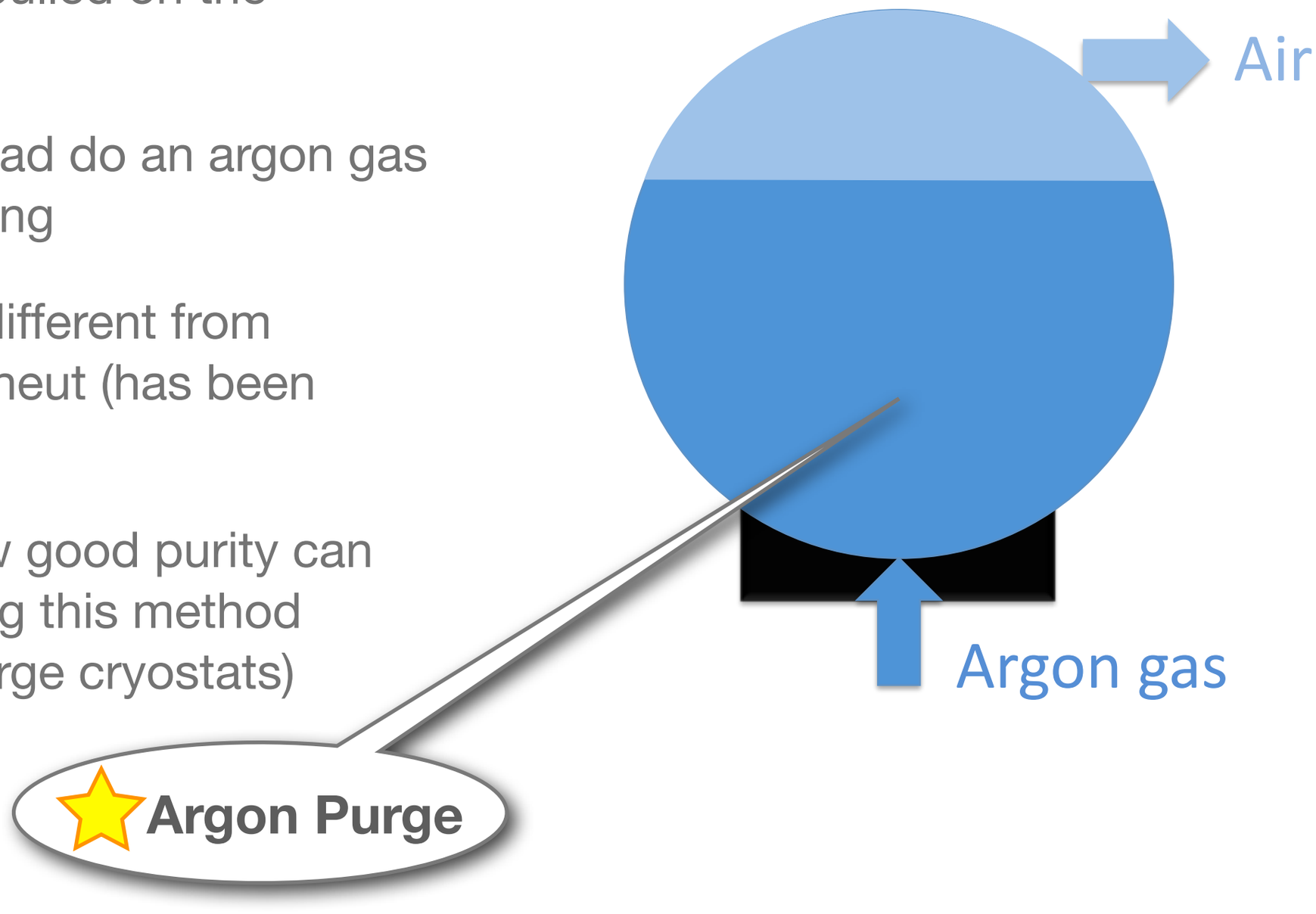
# Cryostat

- The entire TPC slides into our cryostat
  170 tons in LAr volume
    - This size was set by what could be delivered by truck!
- It's a single-walled vessel — foam will be used for insulation



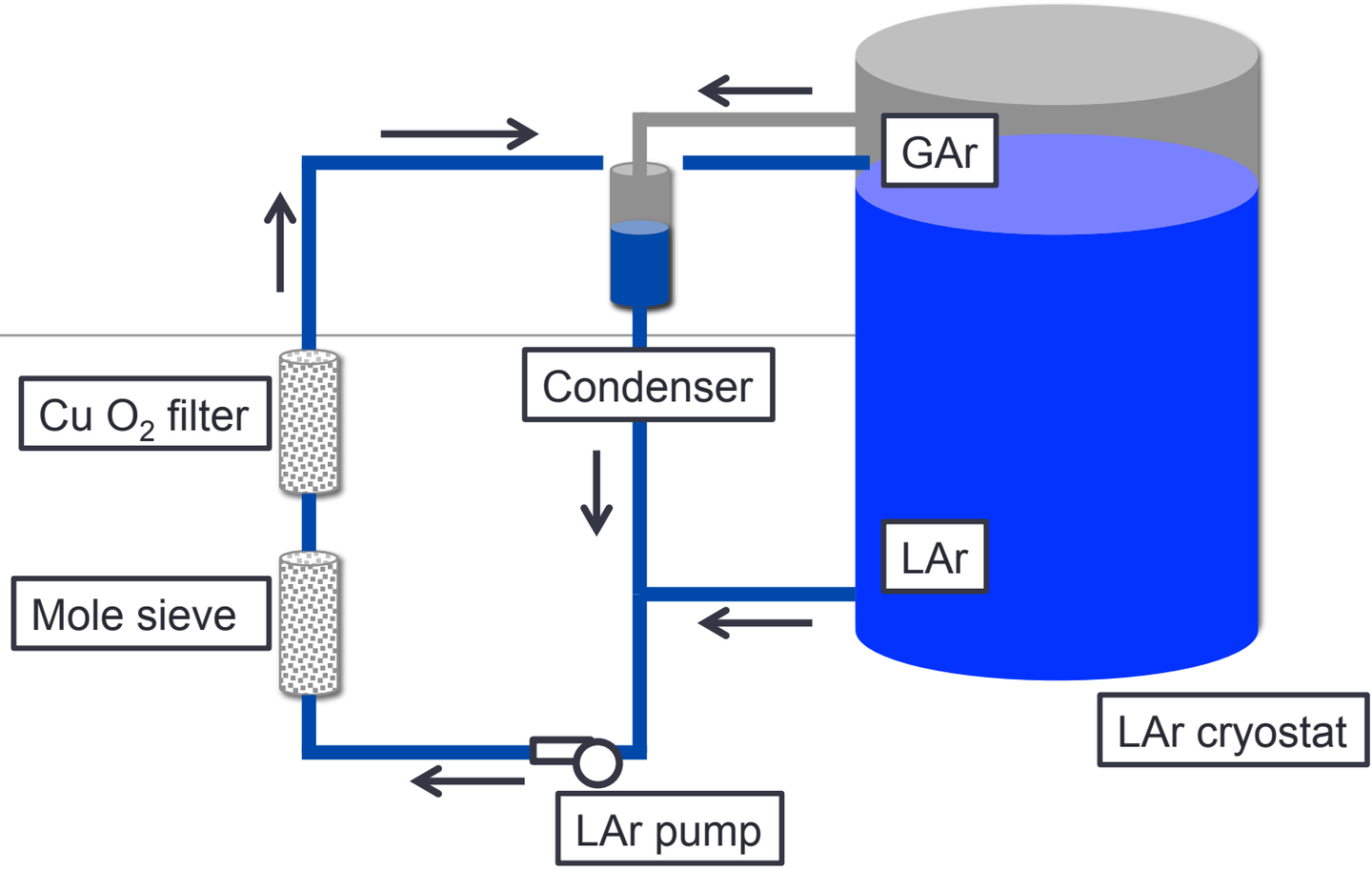
# Cryostat

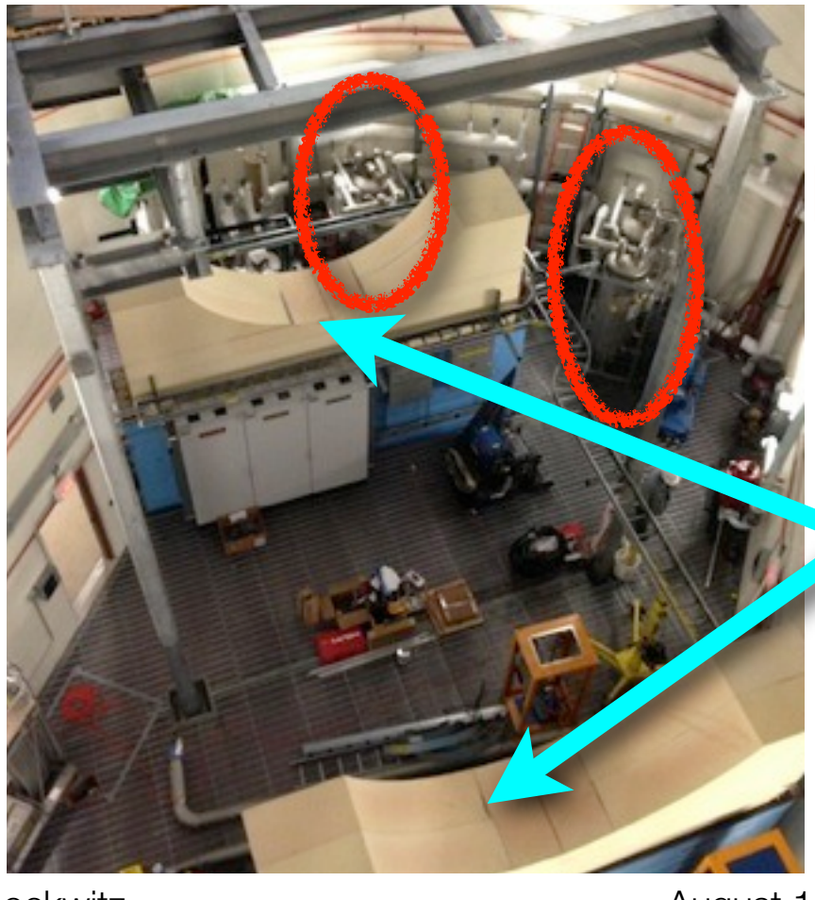
- In an effort to attain purity, typically a vacuum is initially pulled on the cryostat,
  - We plan to instead do an argon gas purge before filling
  - This is notably different from ICARUS & Argoneut (has been done at LAPD)
  - We plan to show good purity can be attained using this method (important for large cryostats)



# Cryosystem

- The cryosystem is nearly in place -- will be ready for testing this fall
- We will use $LN_2$ for cooling
- Electronegative impurities such as water and oxygen capture electrons, nitrogen is destructive for the scintillation light
  - The specs are < 100 ppt $O_2$ and < 1 ppm $N_2$
- We use a molecular sieve for the water removal followed by copper-based filter for oxygen removal

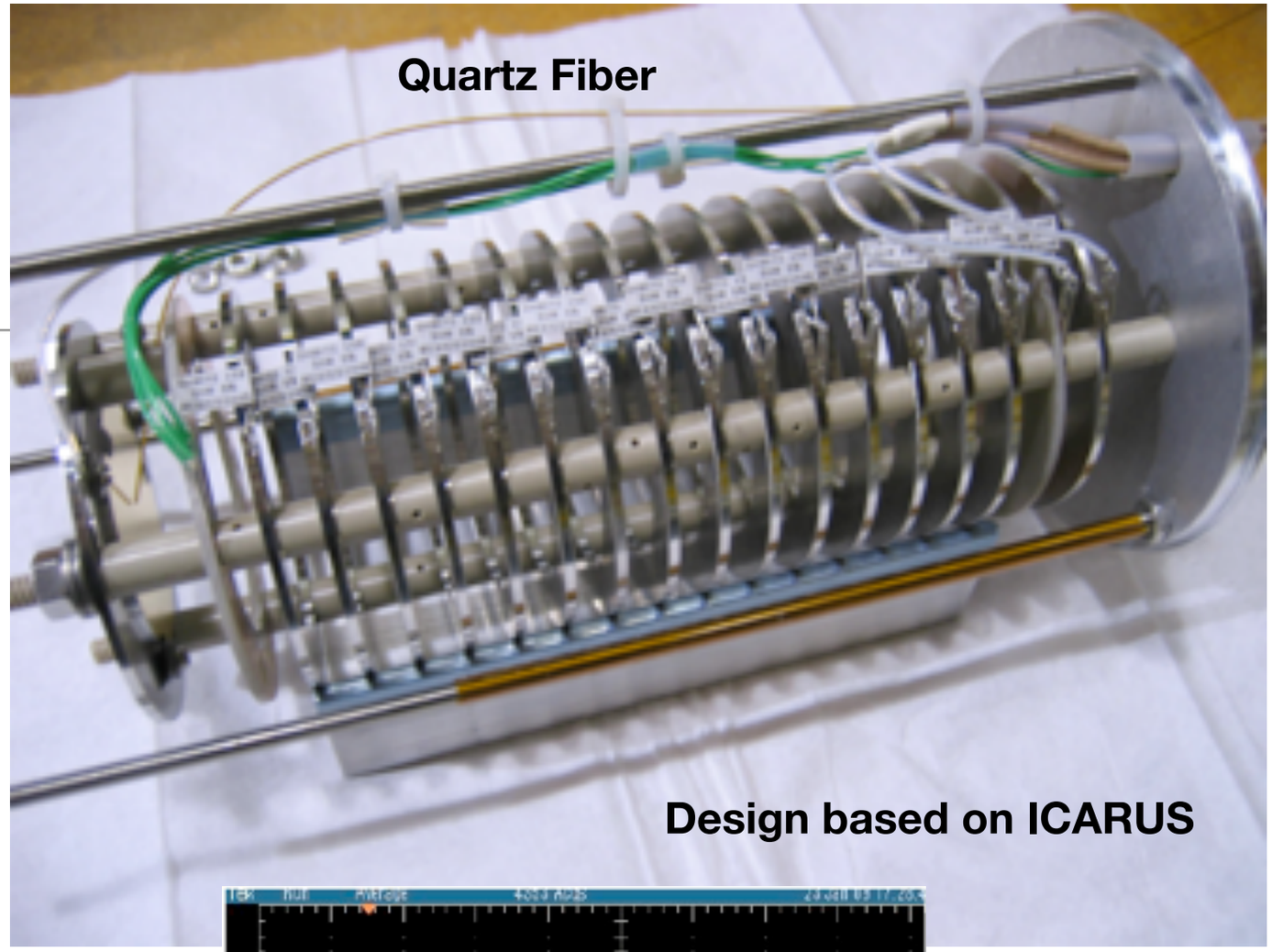


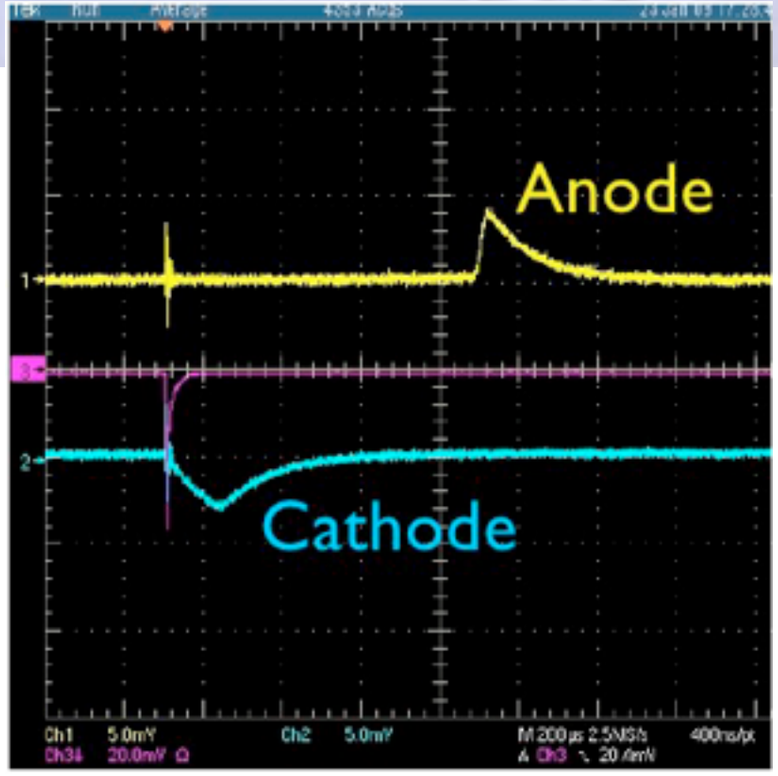



# Cryosystem

- Purity monitors placed in the tank and in the cryosystem will give attenuation measurements
  - Use a xenon flash lamp on a photocathode
  - Cathode signal is $Q_0$, anode is Q

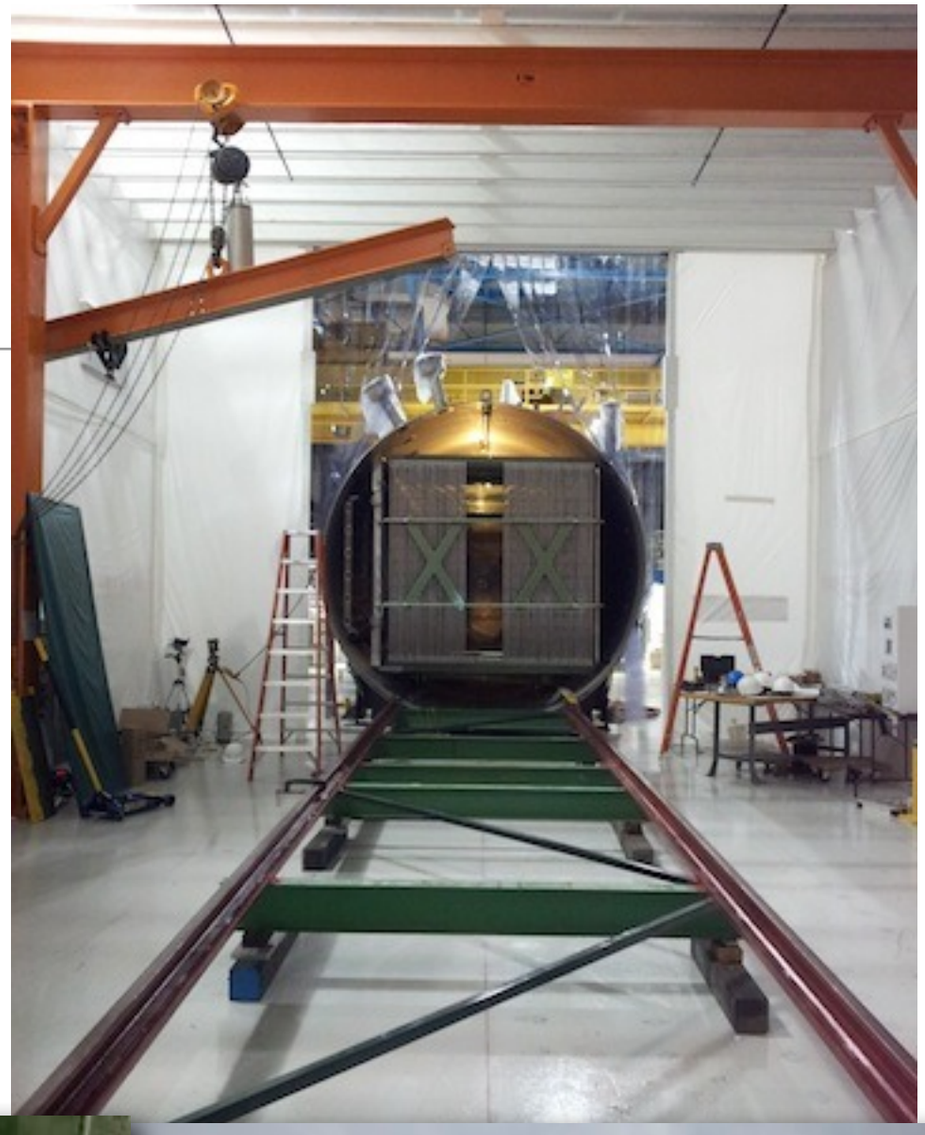
$$\frac{Q_0}{Q} = e^{t_d/\tau}$$



# Status and Plans

- We plan to push the TPC into the cryostat this fall
- The endcap will then be welded on
- The whole assembly will go by truck to our new home at LArTF
- After further commissioning, we expect data in mid-2014




# Summary

- MicroBooNE is being assembled now and will be collecting data next year!
- Its three main R&D goals are:
  - ⭐ 2.56 m drift — longest drift in a ν beam
  - ⭐ Cold electronics (ASIC in LAr) — Pioneering effort
  - ⭐ Achieving purity after a gas purge

- Thank you;
  - If you happen to be at Fermilab, we'd be happy to show you our TPC and Cryostat!

# Back-Up Slides

# Collaboration

**Brookhaven Lab**
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- Kai Chen (PD)
- Susan Duffin
- Jason Farell
- Francesco Lanni
- Yichen Li (PD)
- David Lissauer
- George Mahler
- Don Makowiecki
- Joseph Mead
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- Sergio Rescia
- Andres Ruga
- Jack Sondericker
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- Mike Kirby
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- Alberto Marchionni
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- Sam Zeller (*)

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- David McKee (PD)

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- Ben Jones (GS)
- Teppei Katori (PD)
- Matt Toups (PD)

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**Princeton University**
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- Bill Sands

**Saint Mary's University of Minnesota**
- Paul Nienaber (IB)

**SLAC**
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- Eric Church
- Bonnie T. Fleming (*)
- Ellen Klein (U)
- Ornella Palamara
- Flavio Cavanna
- Roxanne Guenette (PD)
- Kinga Partyka (GS)
- Andrzej Szelc (PD)

# Event Rates

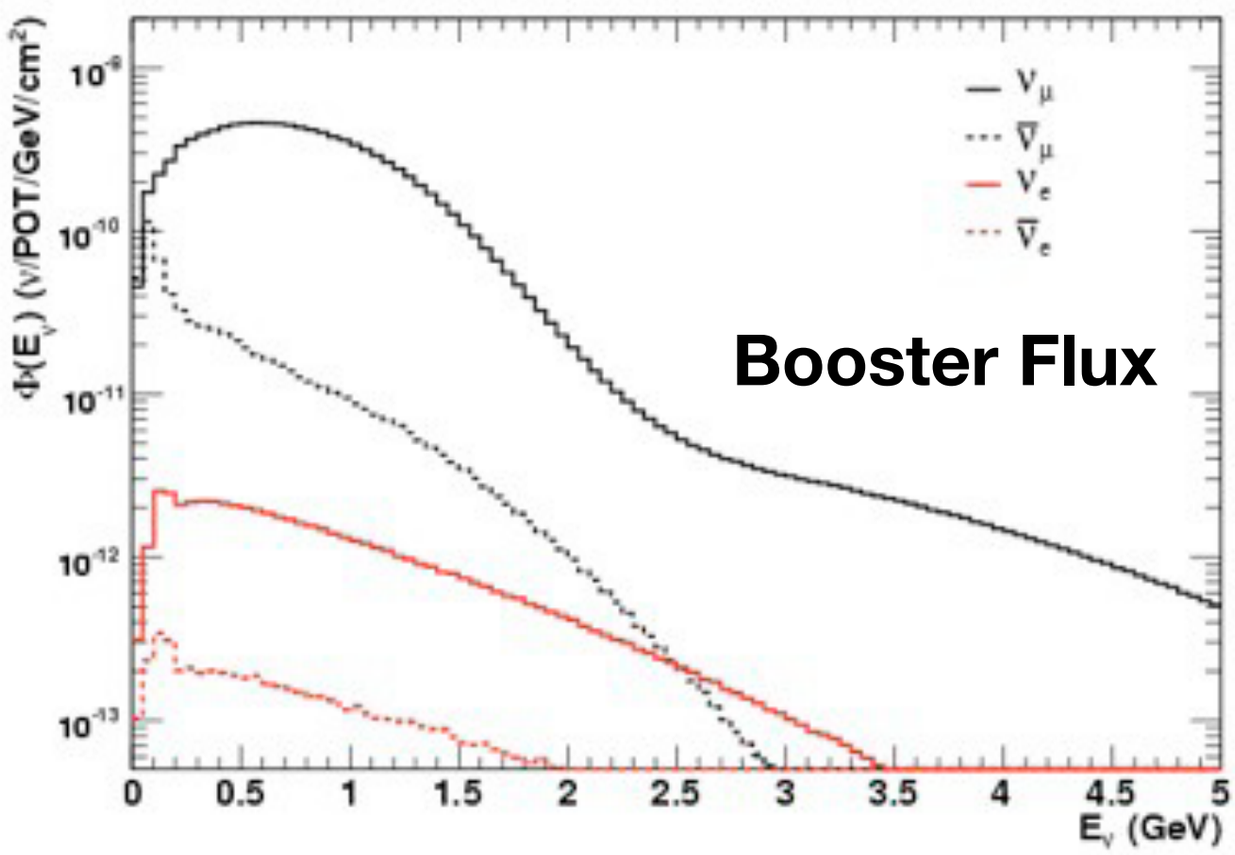
**Expected event rates for 6.6 x $10^{20}$ POT**

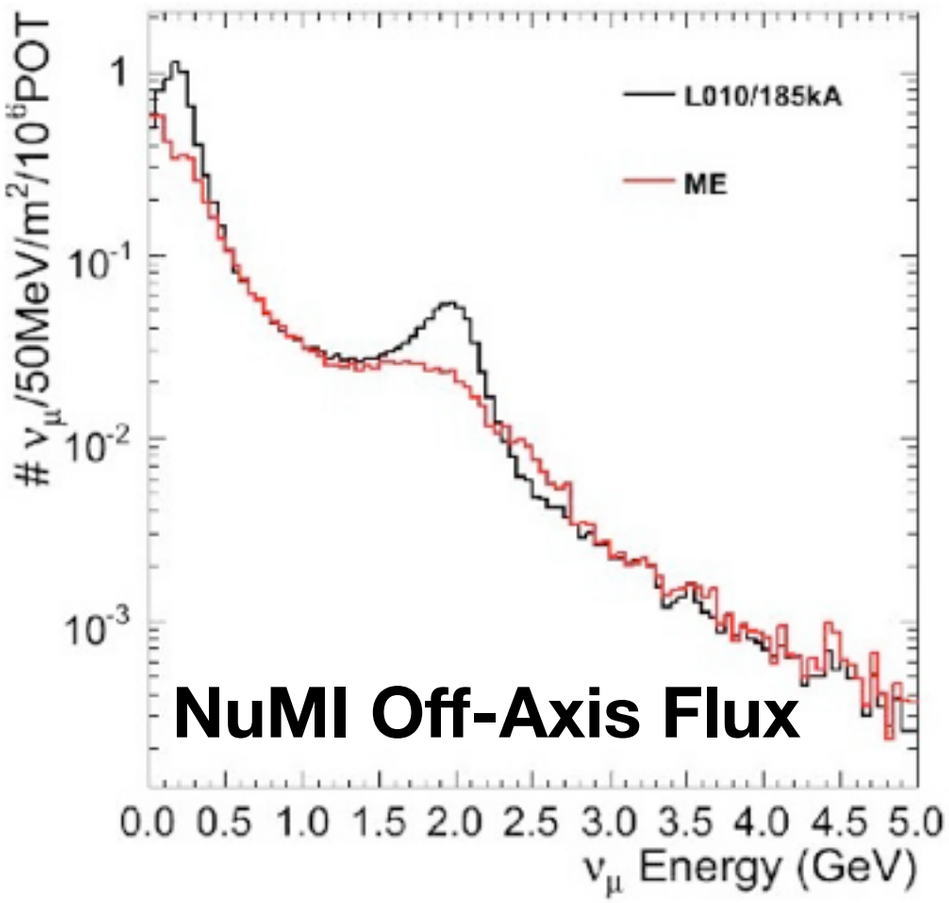
| production mode | # events |
|---|---|
| CC QE ($\nu_\mu n \to \mu^- p$) | 60,161 |
| NC elastic ($\nu_\mu N \to \nu_\mu N$) | 19,409 |
| CC resonant $\pi^+$ ($\nu_\mu N \to \mu^- N \pi^+$) | 25,149 |
| CC resonant $\pi^0$ ($\nu_\mu n \to \mu^- p \pi^0$) | 6,994 |
| NC resonant $\pi^0$ ($\nu_\mu N \to \nu_\mu N \pi^0$) | 7,388 |
| NC resonant $\pi^\pm$ ($\nu_\mu N \to \nu_\mu N' \pi^\pm$) | 4,796 |
| CC DIS ($\nu_\mu N \to \mu^- X$, $W > 2$ GeV) | 1,229 |
| NC DIS ($\nu_\mu N \to \nu_\mu X$, $W > 2$ GeV) | 456 |
| NC coherent $\pi^0$ ($\nu_\mu A \to \nu_\mu A \pi^0$) | 1,694 |
| CC coherent $\pi^+$ ($\nu_\mu A \to \mu^- A \pi^+$) | 2,626 |
| NC kaon ($\nu_\mu N \to \nu_\mu K X$) | 39 |
| CC kaon ($\nu_\mu N \to \mu^- K X$) | 117 |
| other $\nu_\mu$ | 3,678 |
| total $\nu_\mu$ CC | 98,849 |
| total $\nu_\mu$ NC+CC | 133,580 |
| $\nu_e$ QE | 326 |
| $\nu_e$ CC | 657 |

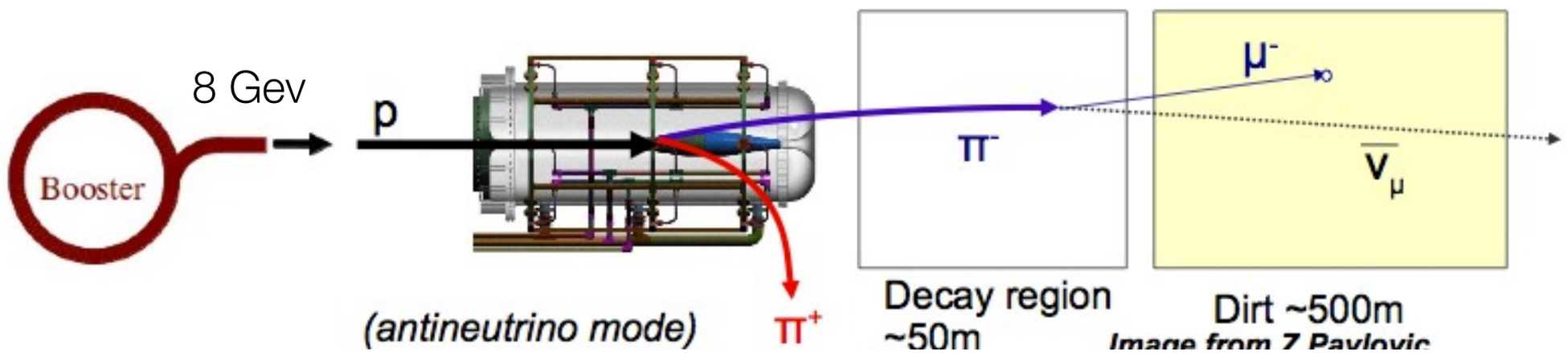
| | BNB | NuMI |
|---|---|---|
| Total Events | **145k** | **60k** |
| $\nu_\mu$ CCQE | 68k | 25k |
| NC $\pi^o$ | 8k | 3k |
| $\nu_e$ CCQE | 0.4k | 1.2k |
| POT | $6x10^{20}$ | $8x10^{20}$ |

Projected Event Rates for MicroBooNE in 2-3 years.

# Beam

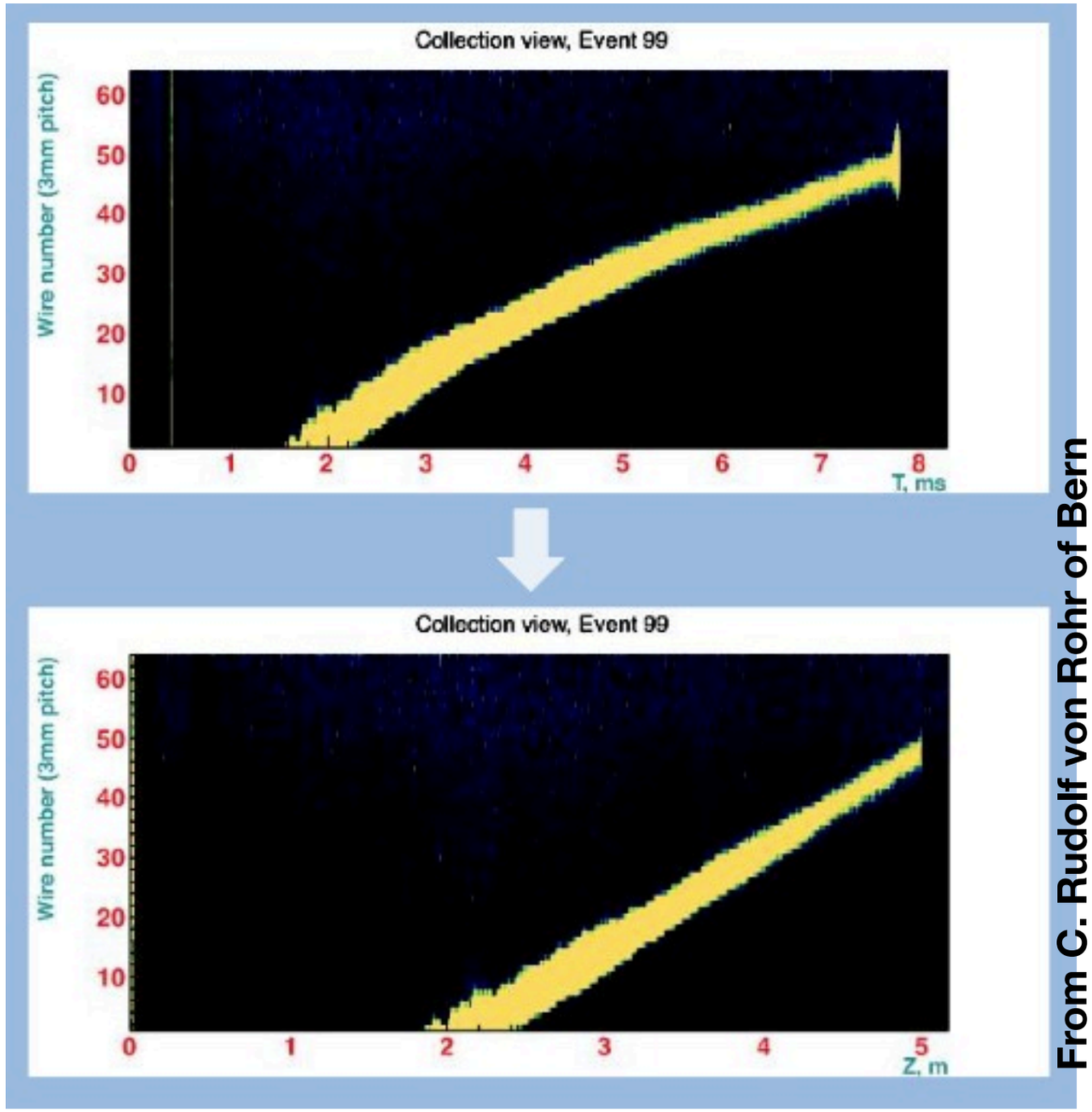

Booster Flux
$\nu_\mu$
$\bar{\nu}_\mu$
$\nu_e$
$\bar{\nu}_e$
$\Phi(E_\nu)$ ($\nu$/POT/GeV/cm$^2$)
$E_\nu$ (GeV)


NuMI Off-Axis Flux
L010/185kA
ME
# $\nu_\mu$/50MeV/m$^2$/10$^6$POT
$\nu_\mu$ Energy (GeV)


8 Gev
Booster
p
(antineutrino mode)
$\pi^+$
$\pi^-$
$\mu^-$
$\bar{\nu}_\mu$
Decay region
~50m
Dirt ~500m

# Laser

- The positive ions drift to the cathode plane much more slowly than the electrons (8 mm/s vs 1.6mm/μs)
- This distortion in field plus the flow of argon will distort the reconstructed objects
- We plan to characterize this distortion with a laser!
  - Nd YAG laser --> 266 nm output




From C. Rudolf von Rohr of Bern