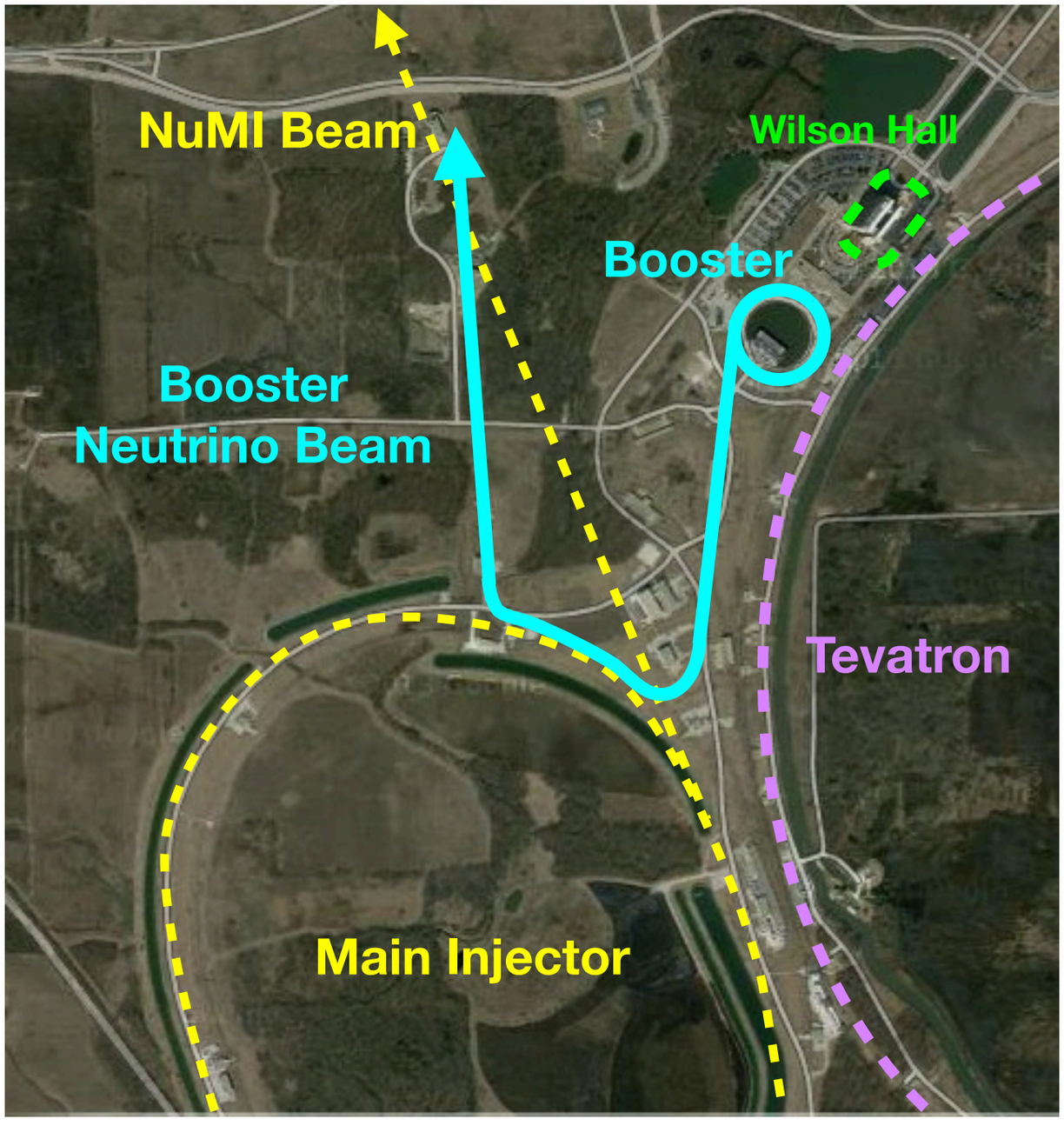
The MicroBooNE LArTPC

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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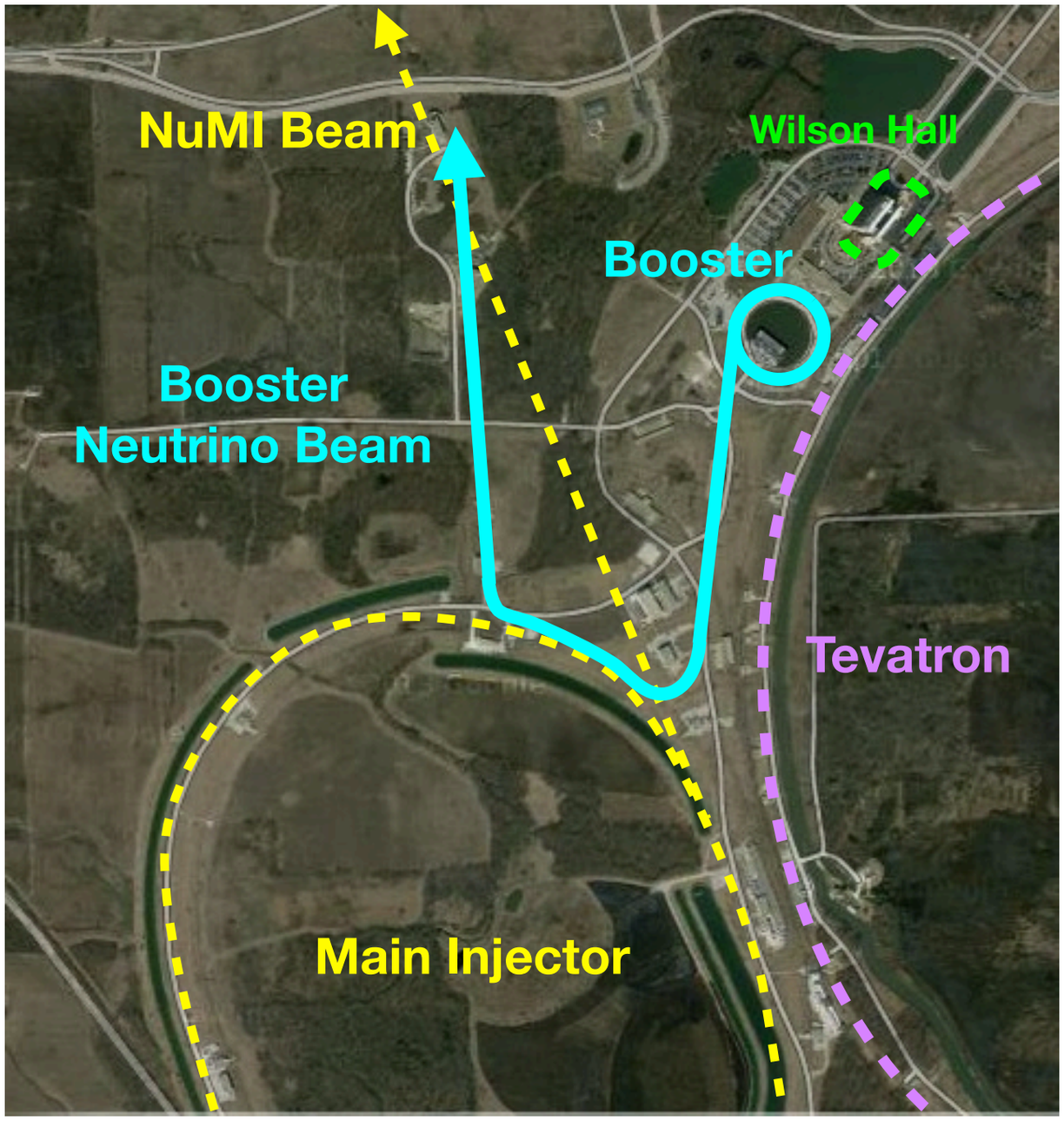
B. Carls talk will focus on this



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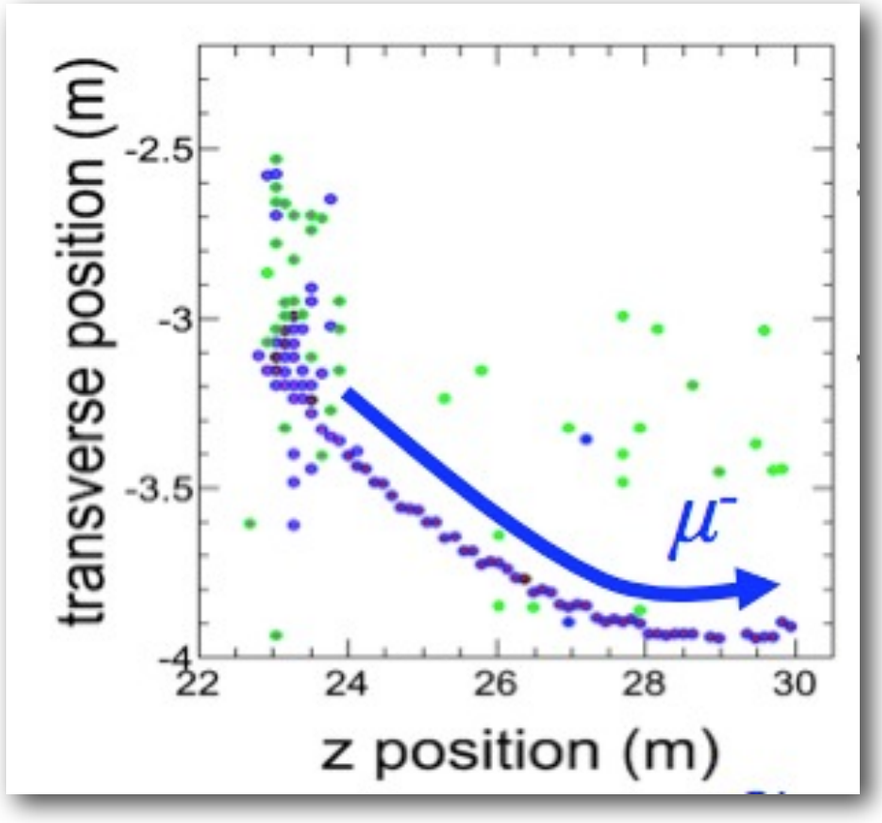

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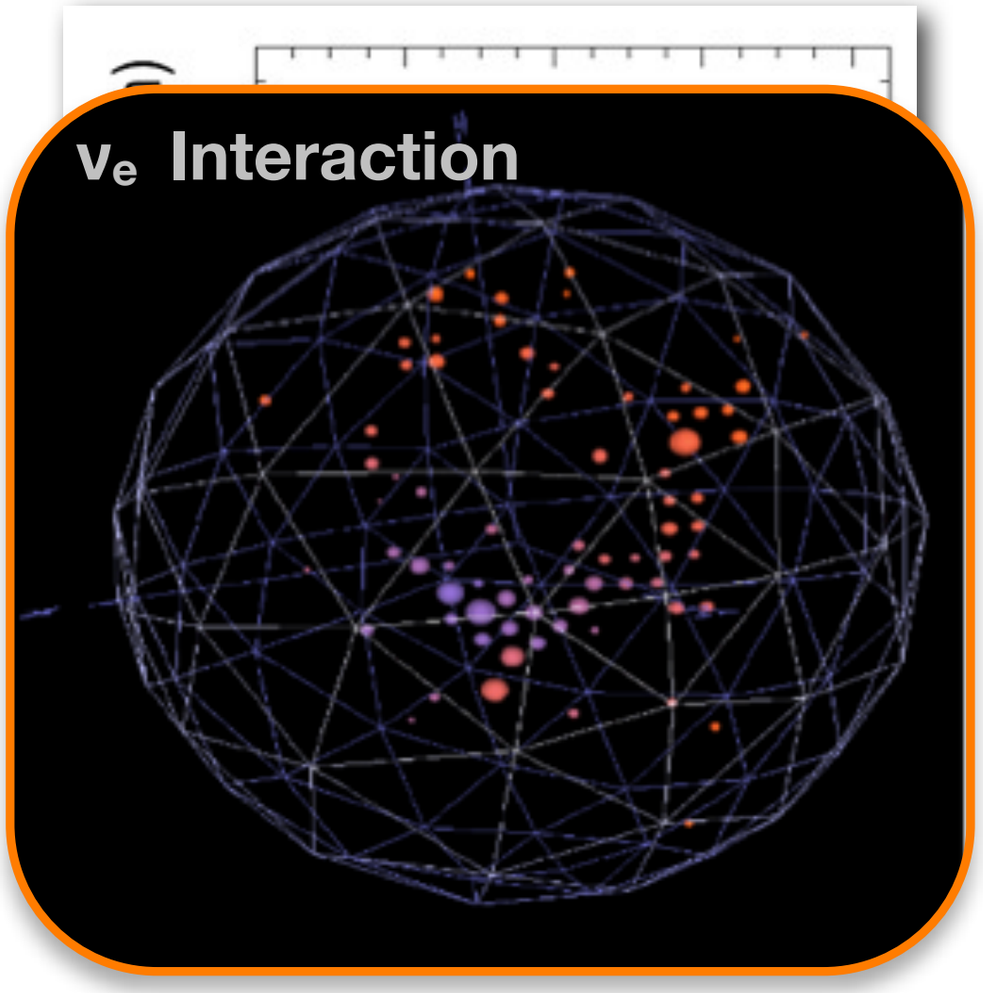

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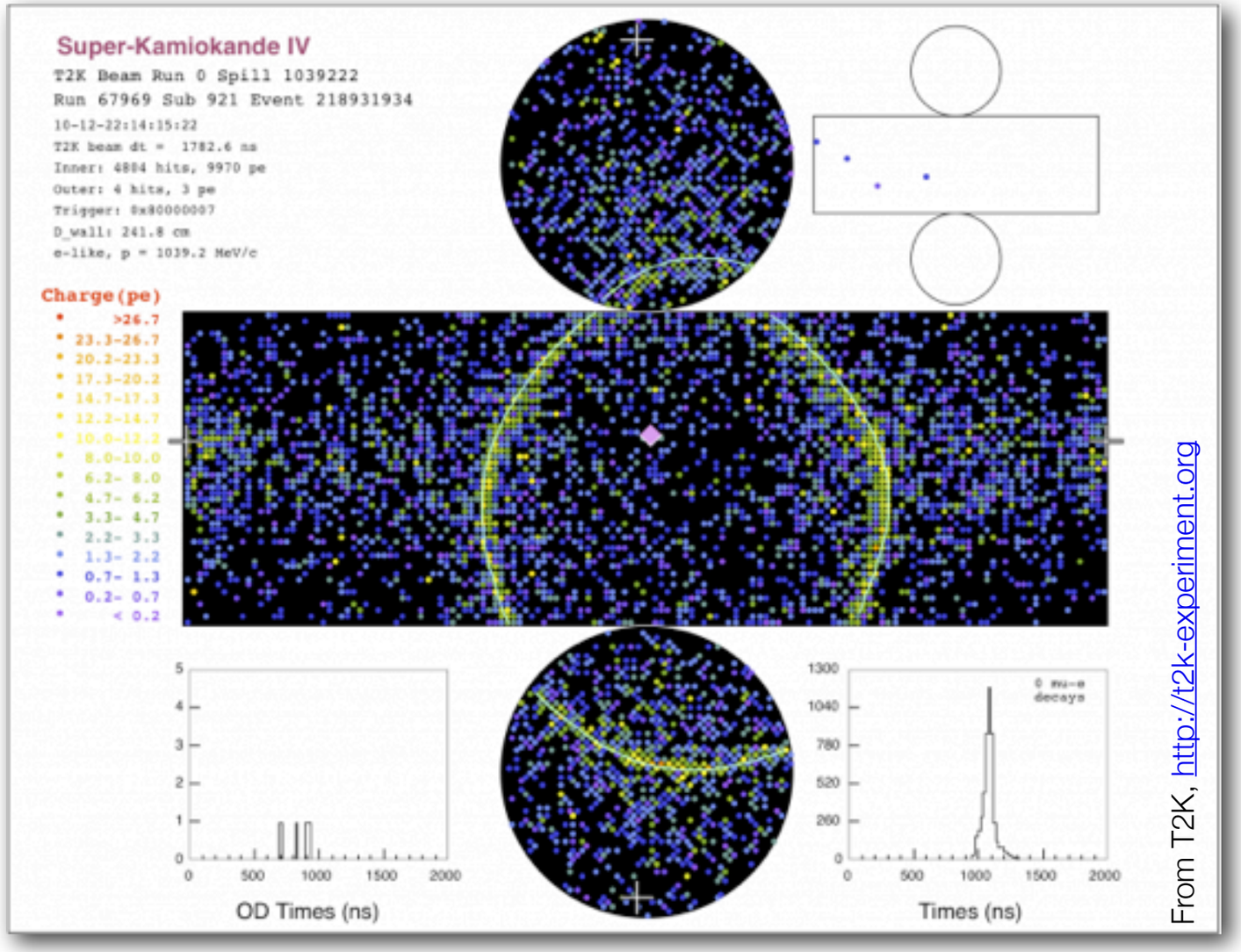

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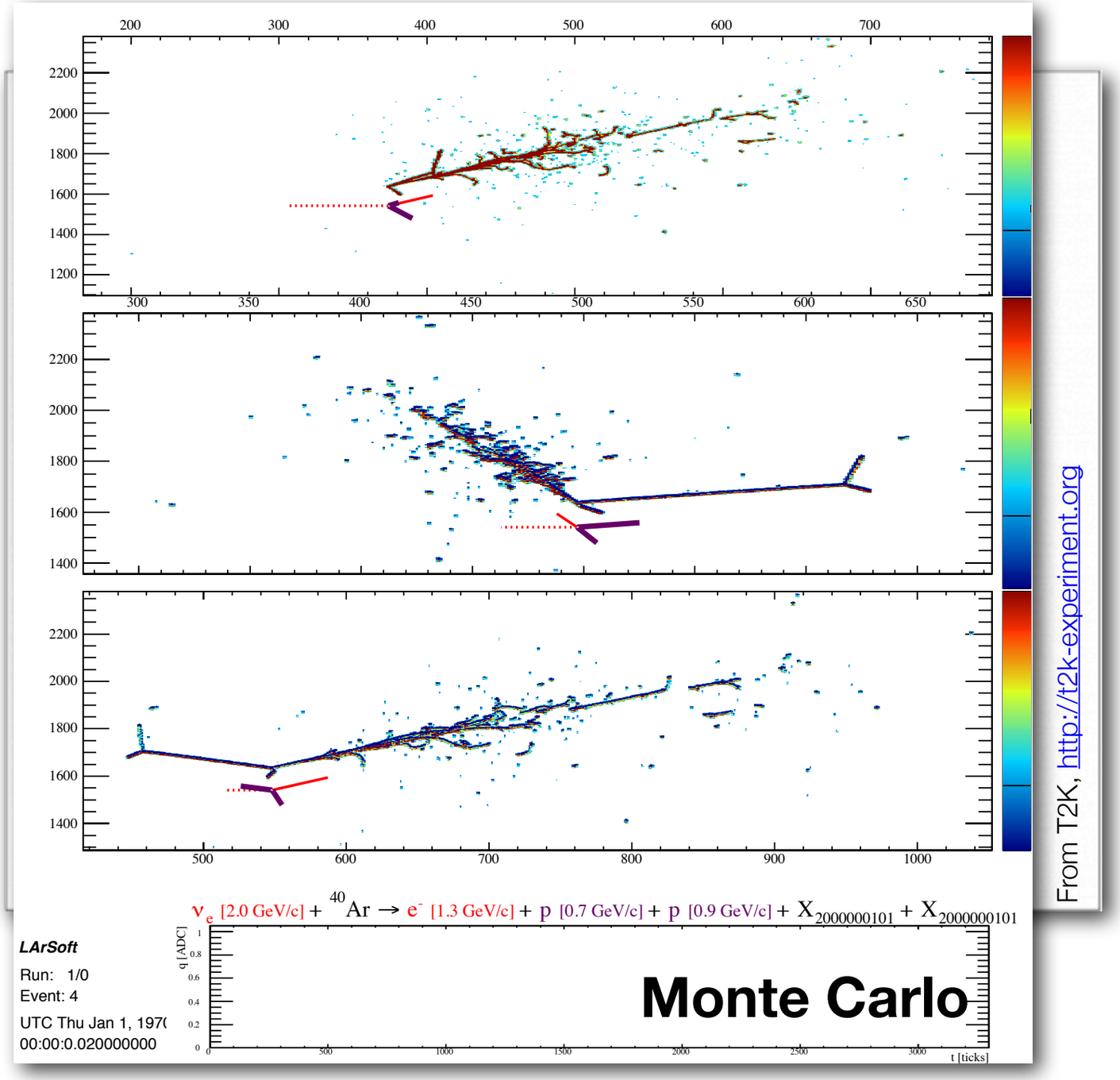

Liquid Argon Work at Fermilab

Materials/
Electronics Test
Stand

2008

LAPD

2014

Multikiloton
LAr detector

LBNE

100% R&D

100%
Physics

2007

ArgoNeuT

2010

MicroBooNE
(also LArIAT & 35T)

?????

Liquid Argon Work at

ICARUS
Pioneering LAr in Europe
2001, 2010

Materials/
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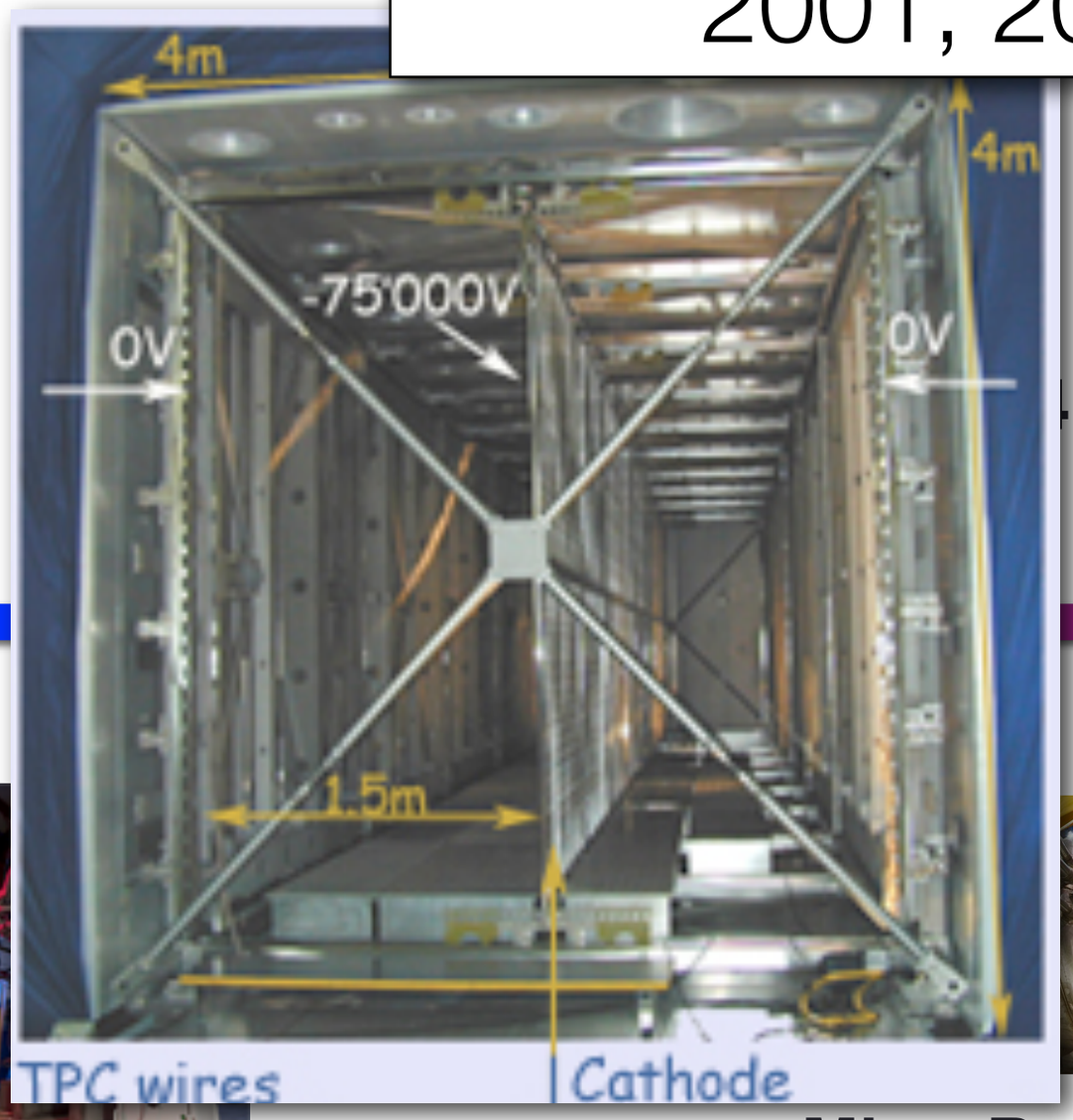
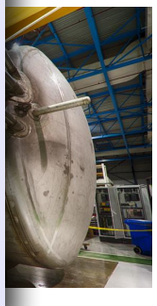
2007



100%
Physics

?????

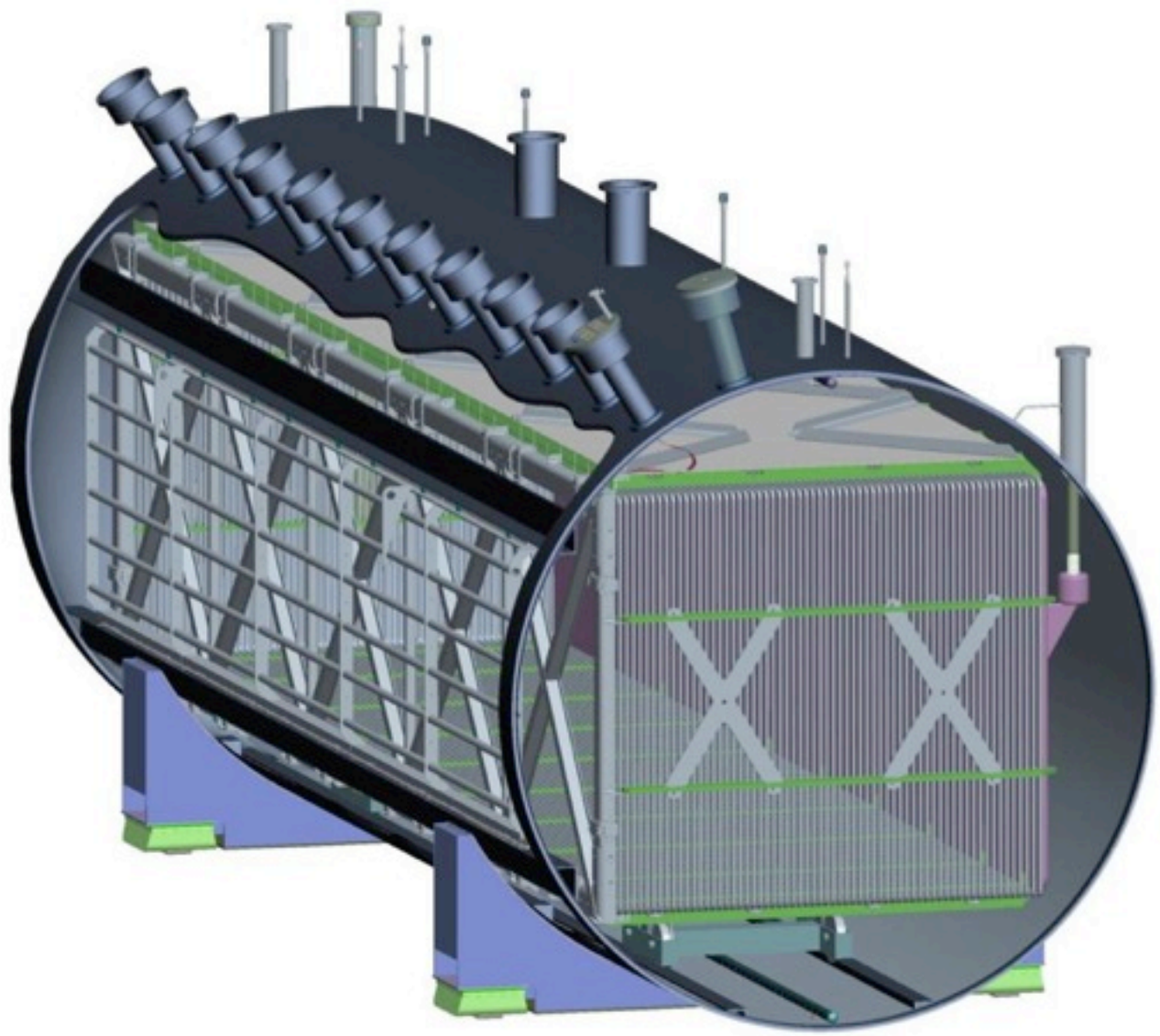
ArgoNeuT



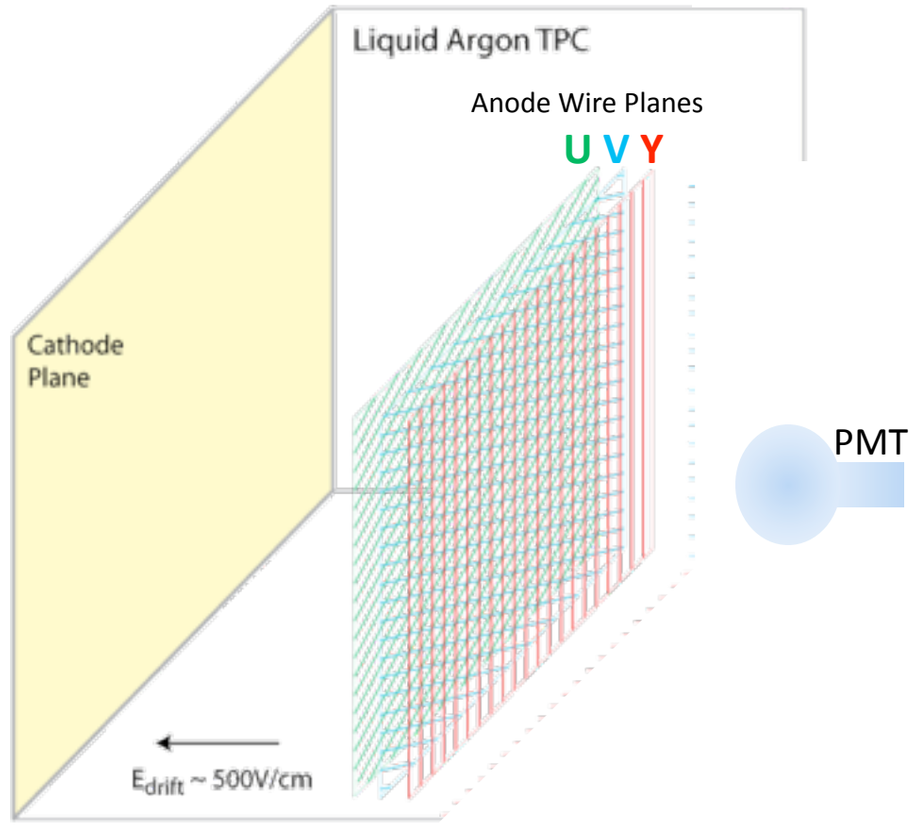
MicroBooNE
(also LArIAT & 35T)

Outline

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



A Time-Projection Chamber Works by...



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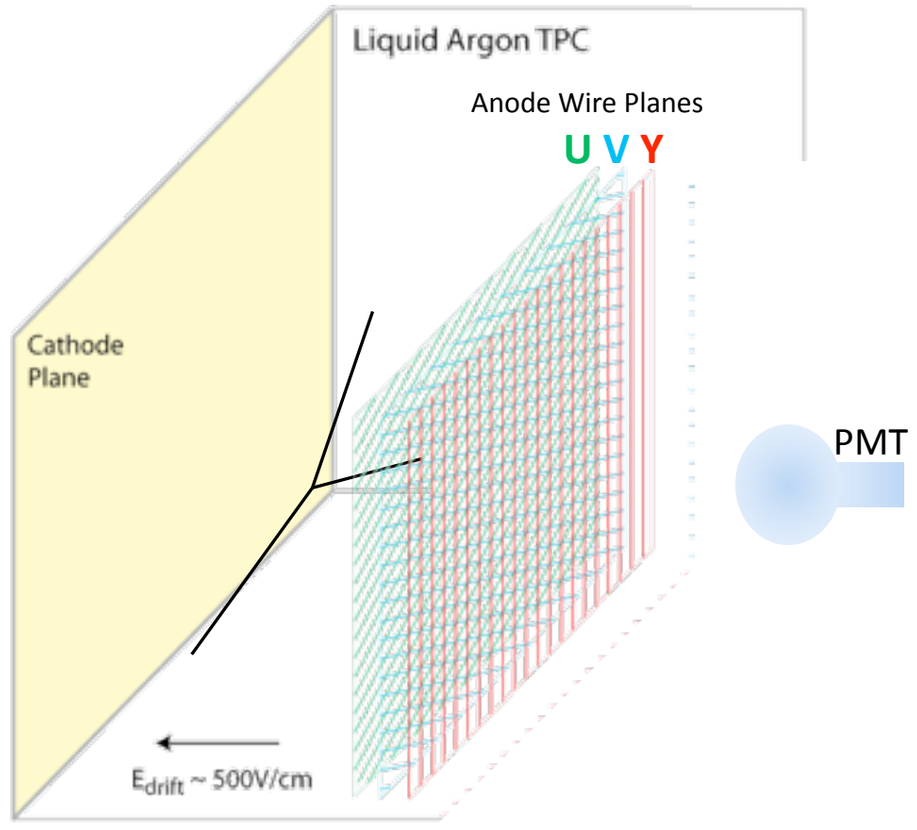

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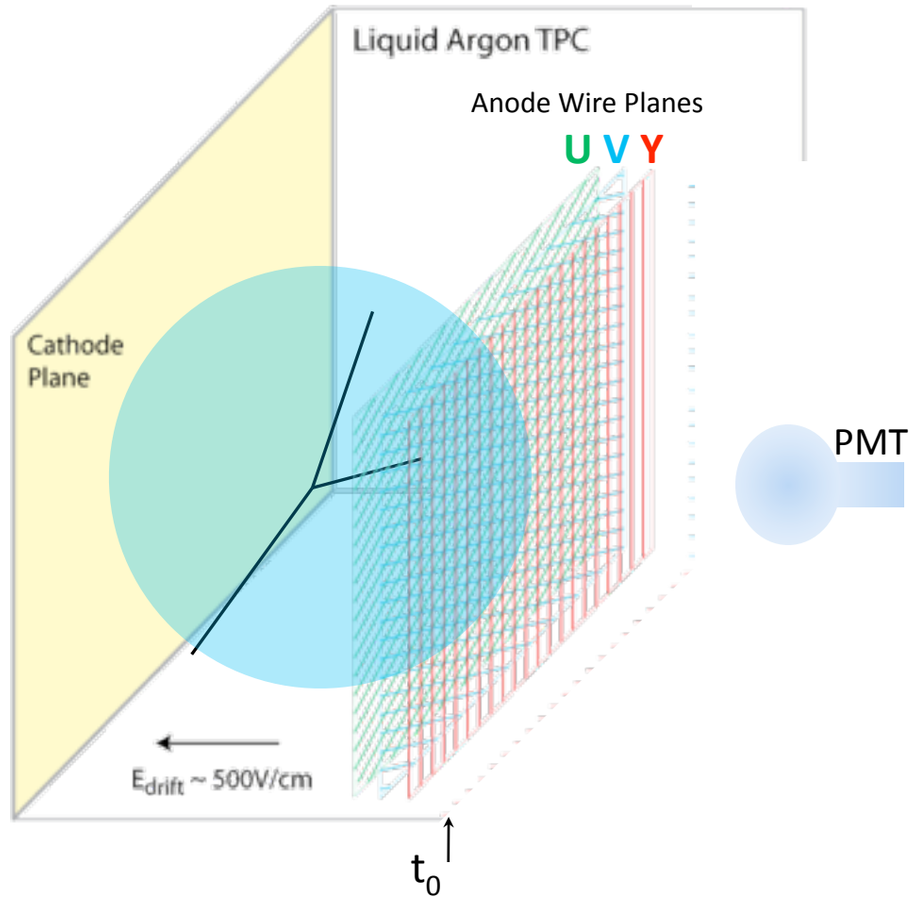

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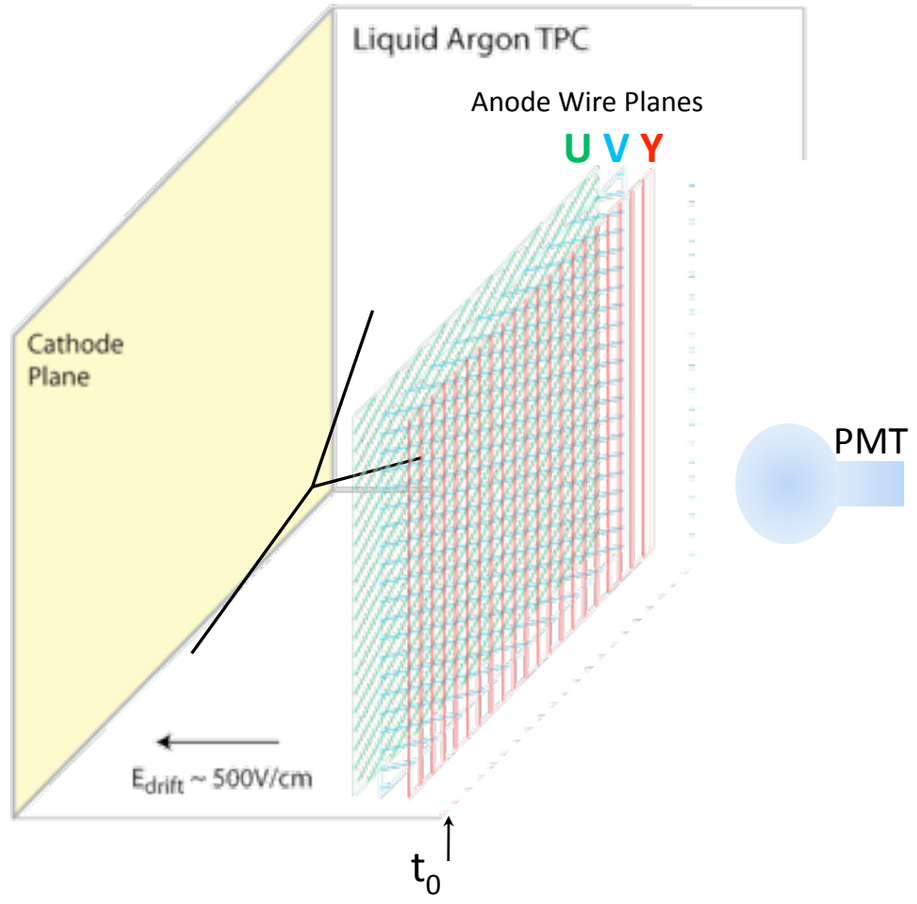

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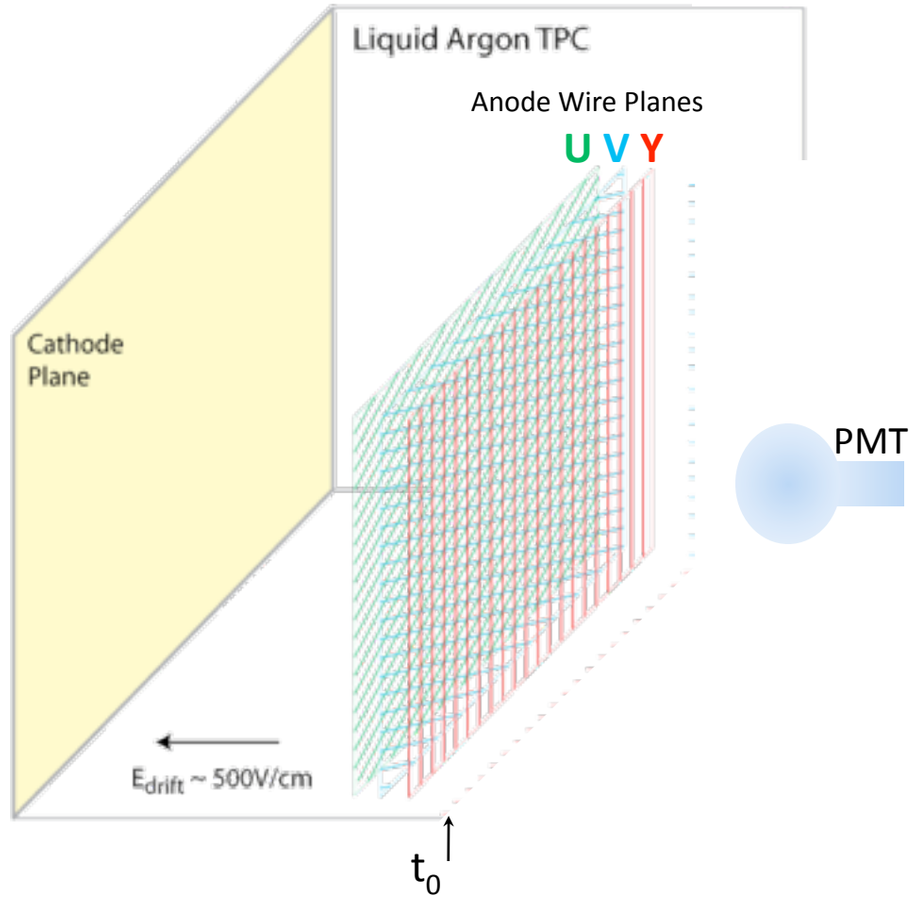

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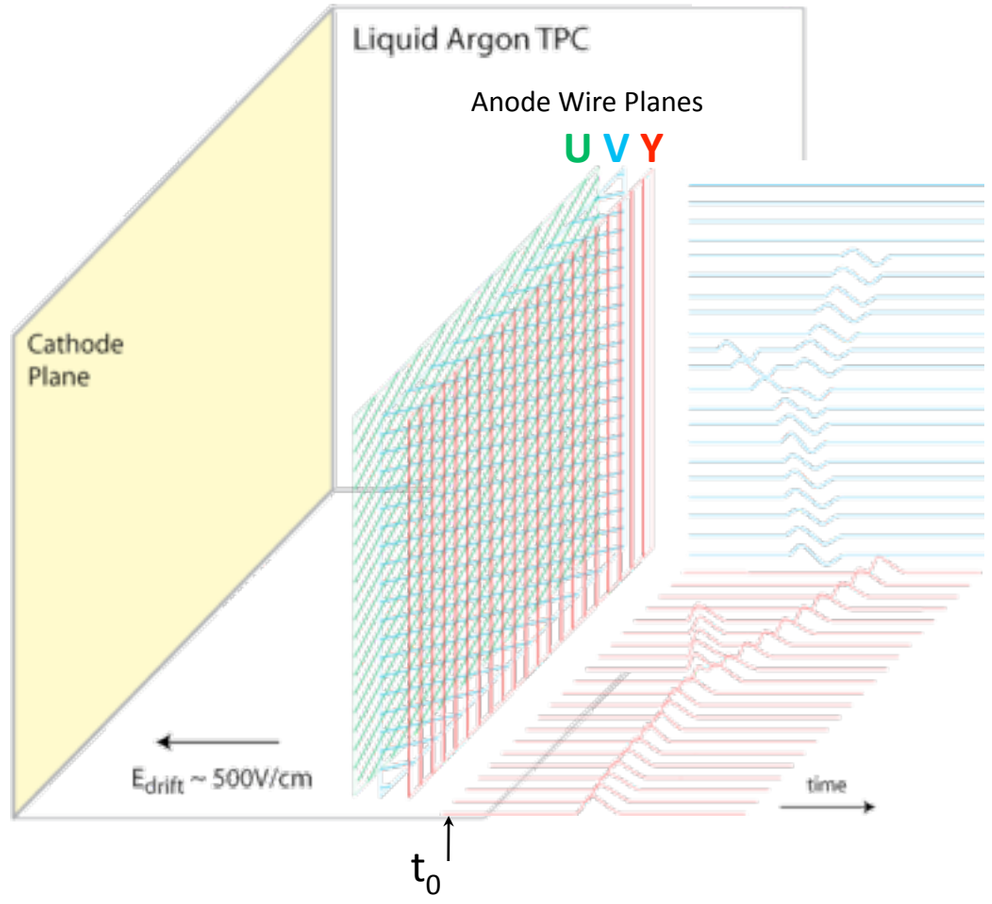

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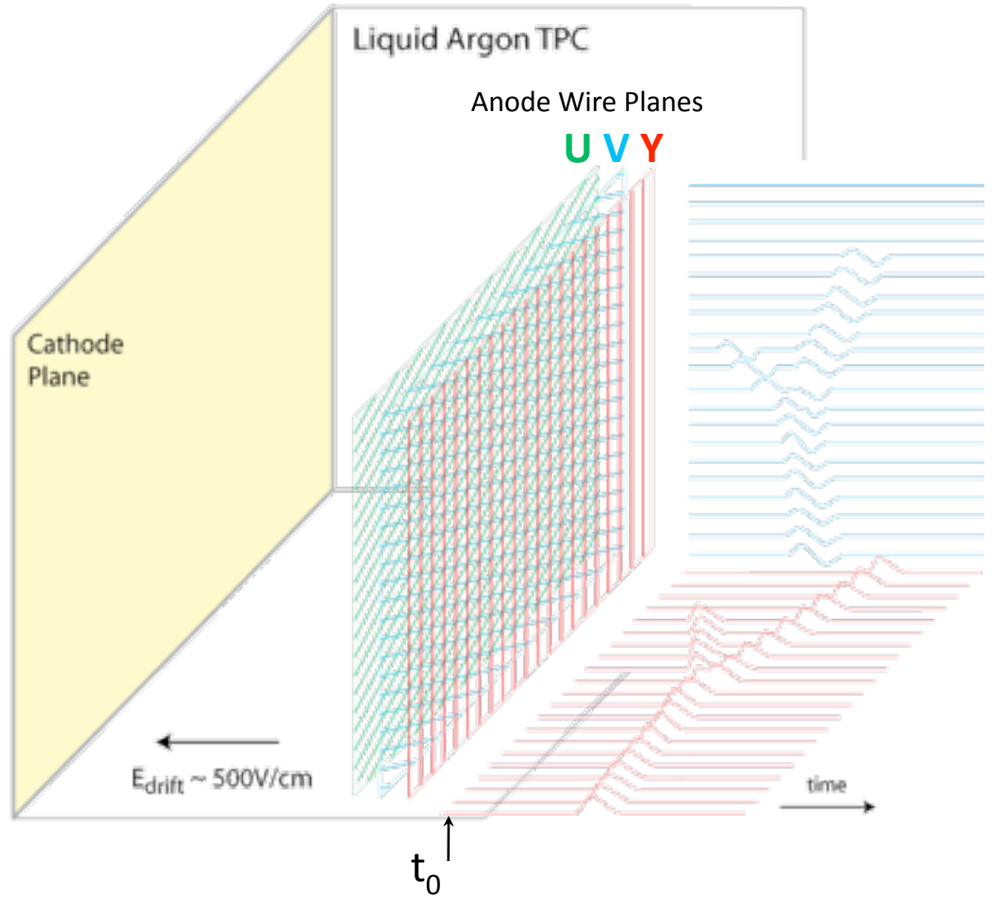

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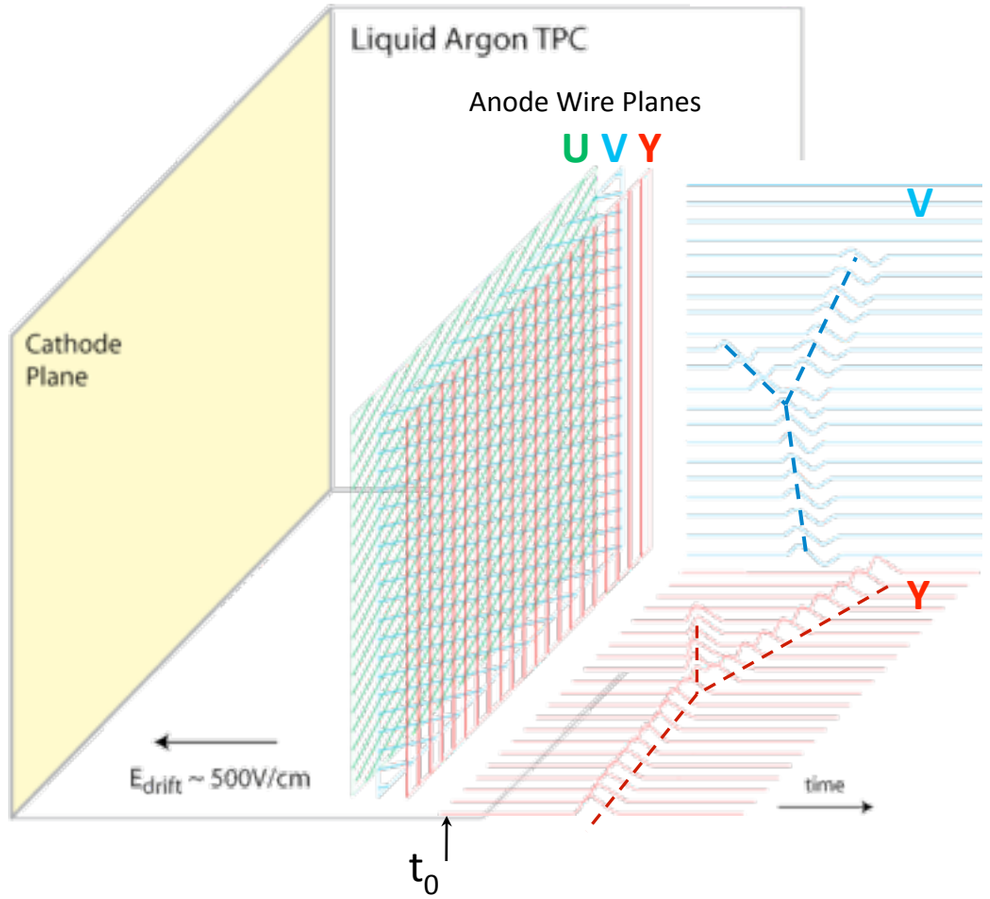
- Tracks are reconstructed from wire signals:
  - Two dimensions from wires
  - Drift distance is found from knowing t_0 & v_d → Time projection!



MicroBooNE is a LAr TPC — Why LAr?

- We need to drift electrons from ionization to sense wires → closed shell
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Radiation Length [cm]	755.2	24.0	14.0	4.9	2.8	36.1
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Can be cooled by LN_2

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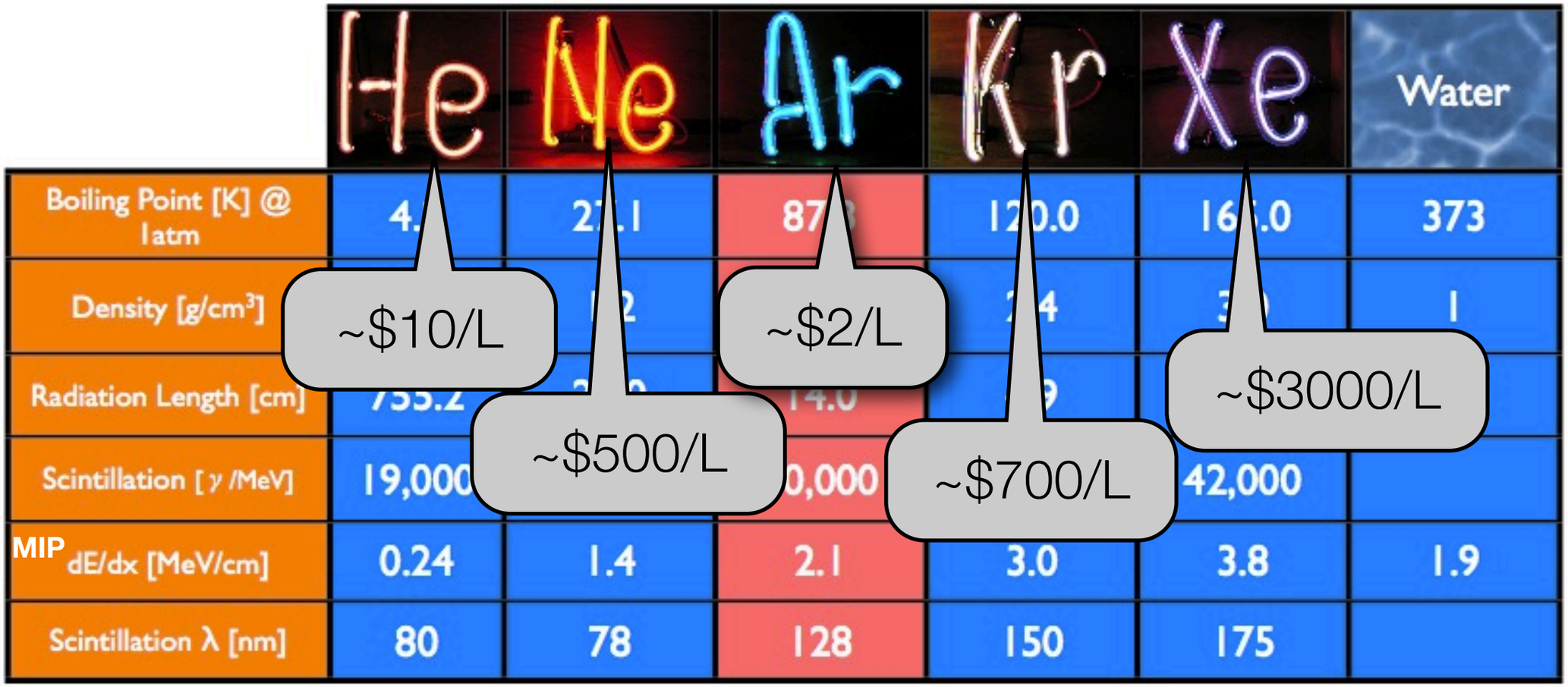

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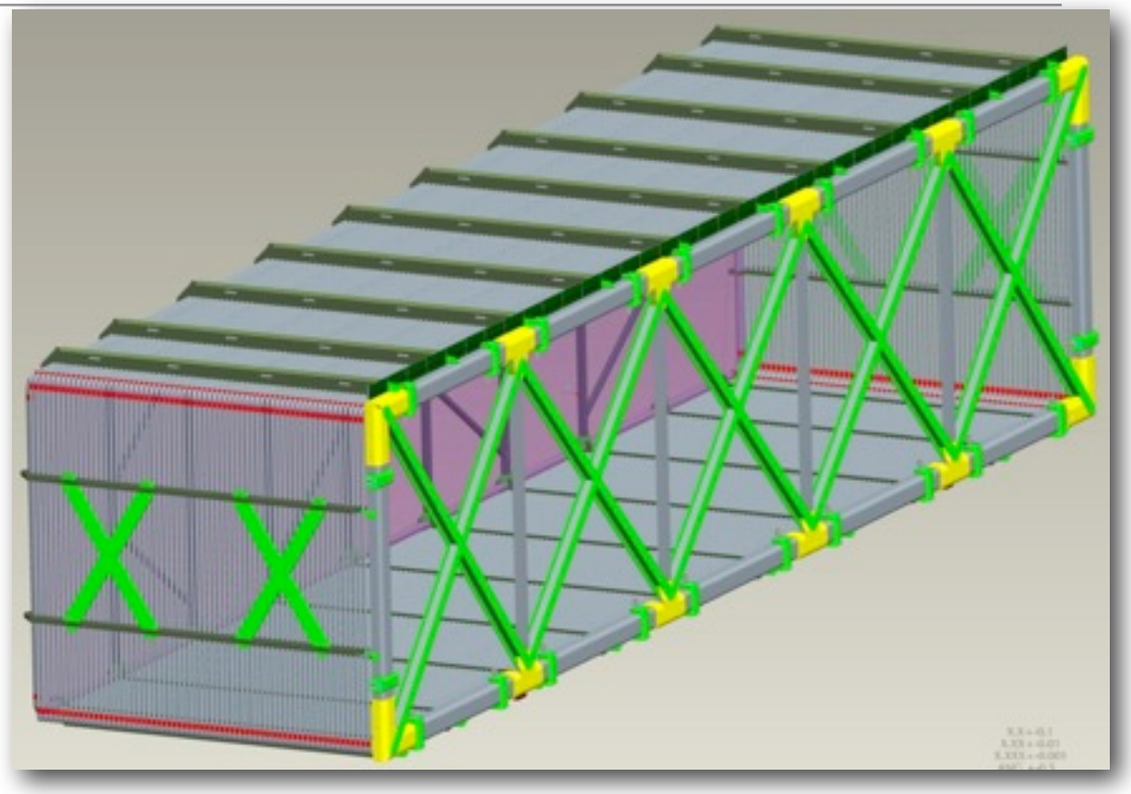

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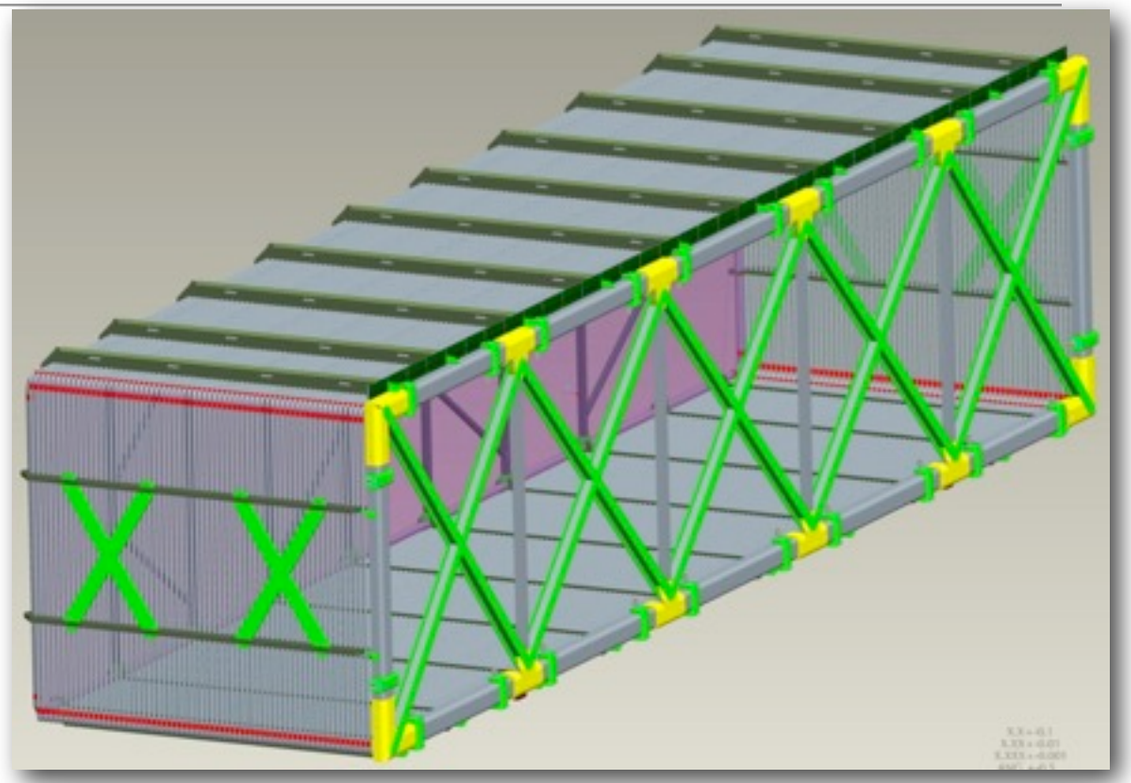

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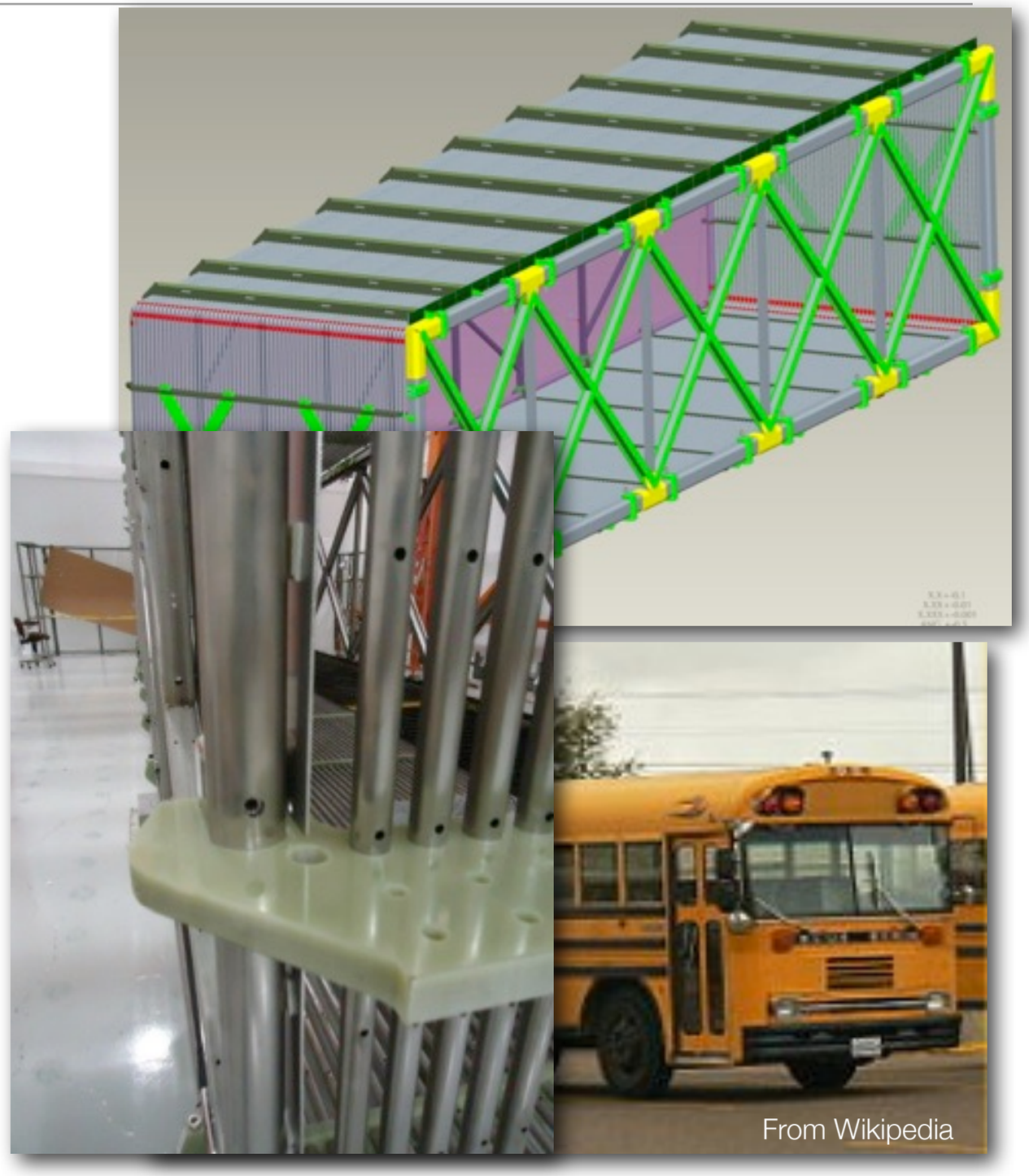
- The electric field cage is made from stainless steel tubes
    - Held parallel by G10 braces



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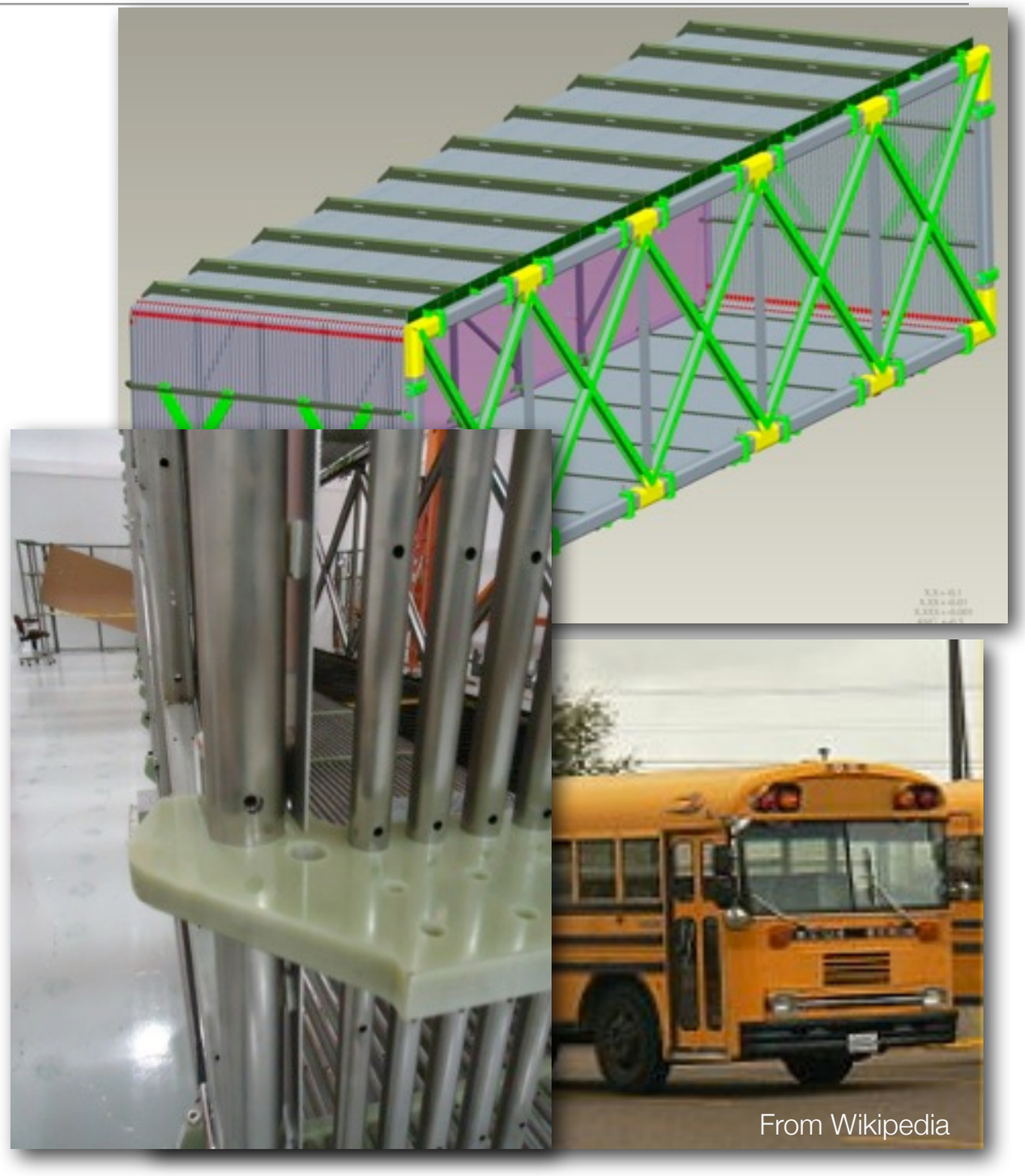
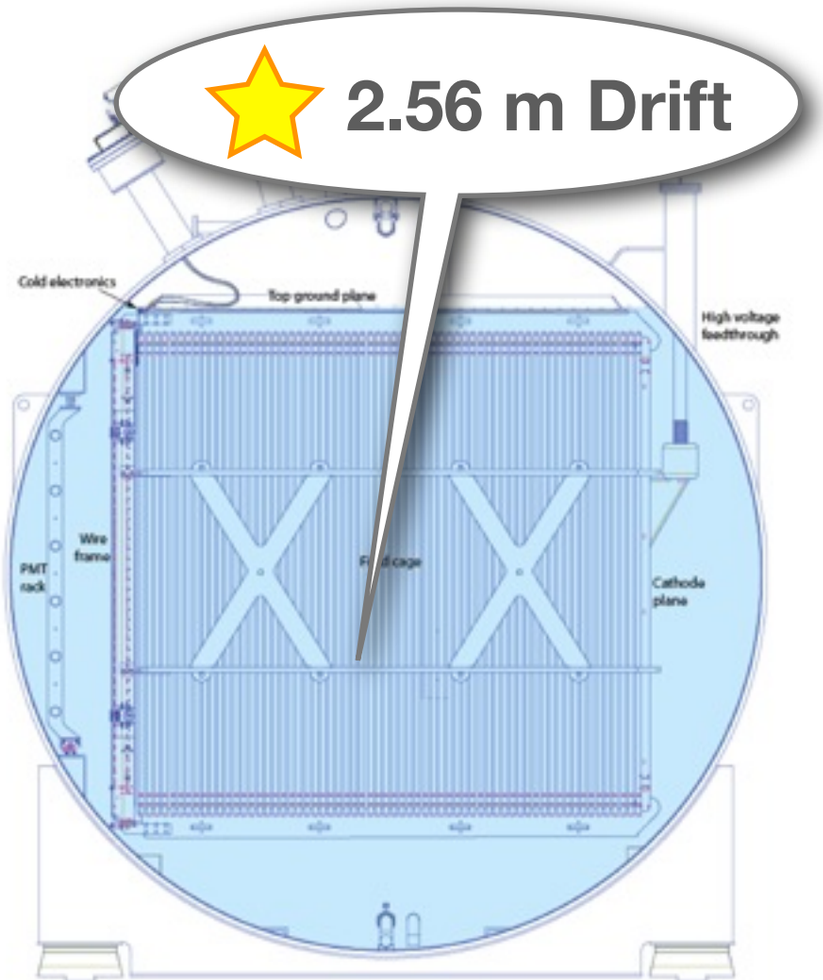
    - Held parallel by G10 braces
    - We then step down the voltage between each tube to create a uniform electric field



From Wikipedia

Cathode Plane



Cathode Plane

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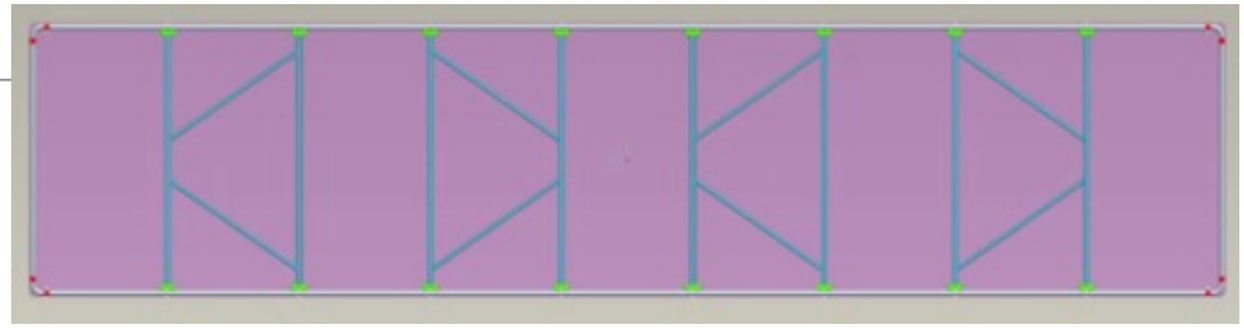

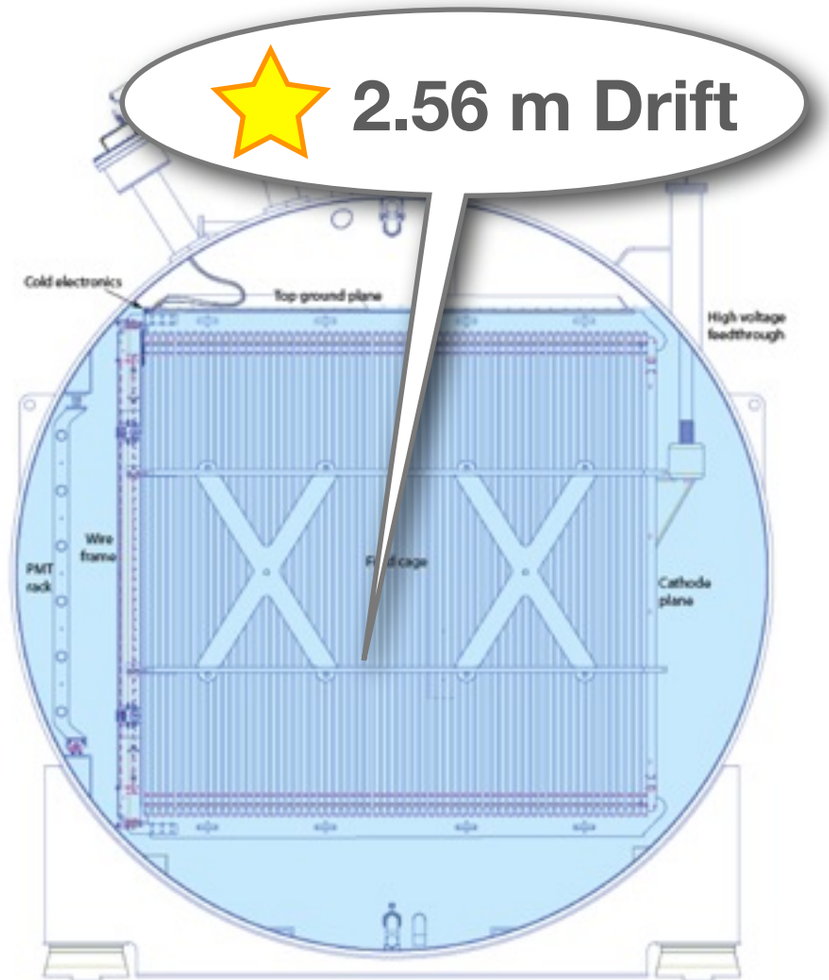

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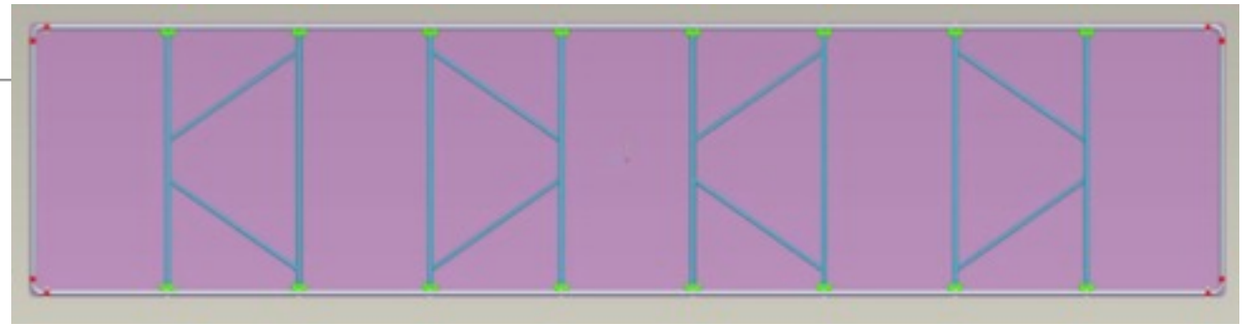
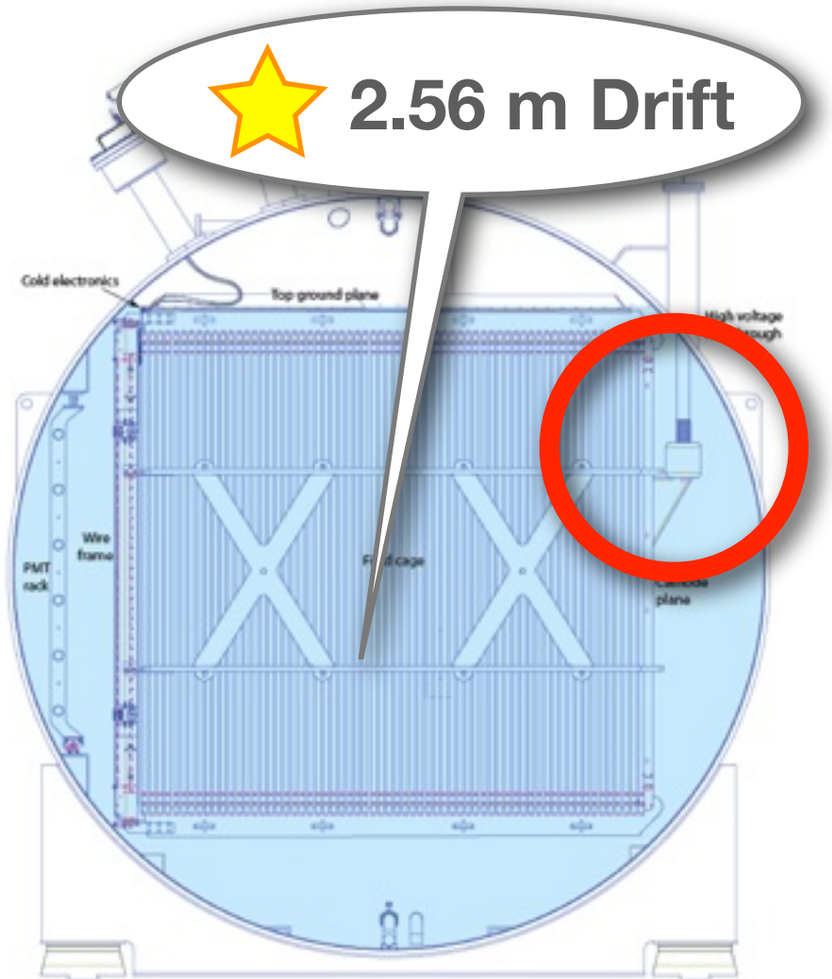


- The cathode plane is made of nine stainless steel sheets:
- The high voltage (HV) for the E field is generated outside of the TPC by a Glassman power supply
  - The HV is in contact with the cathode plane by a feed through that will be in contact with a cup on the back of the plane



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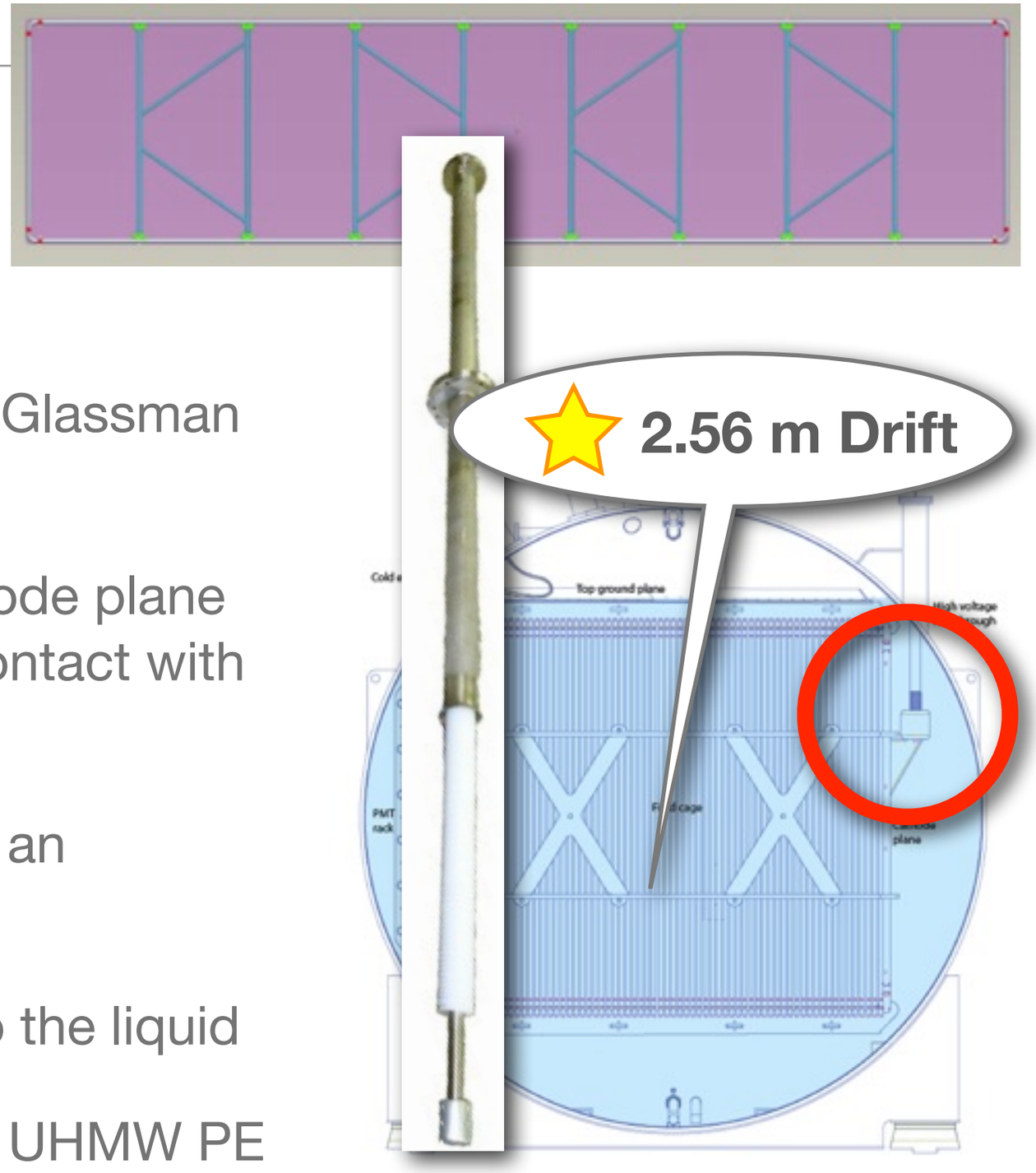
  - The feed through is modeled after an ICARUS design
    - Outer ground tube extends into the liquid
    - Inner conductor is insulated by UHMW PE

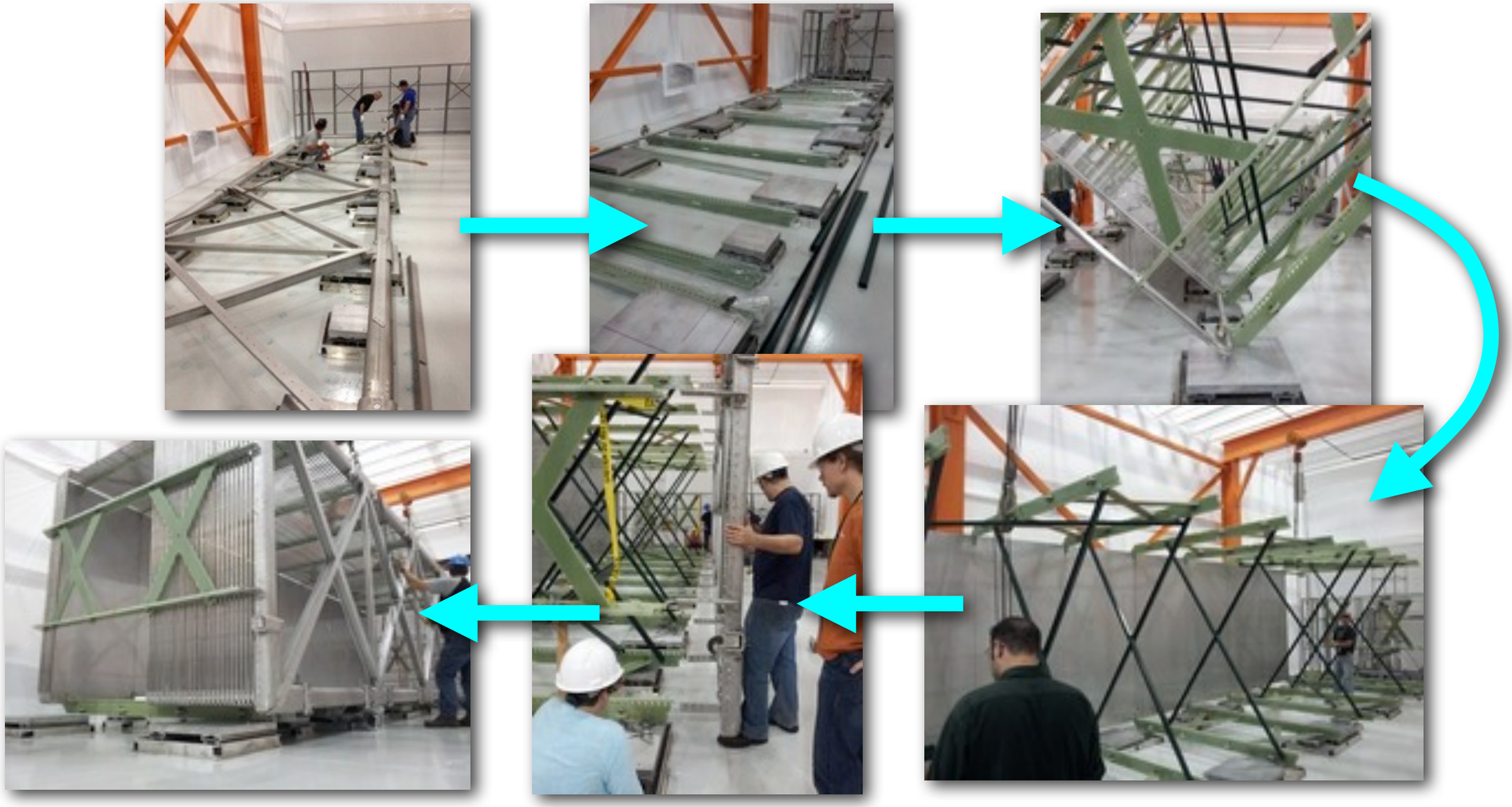


TPC Frame Construction

- 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

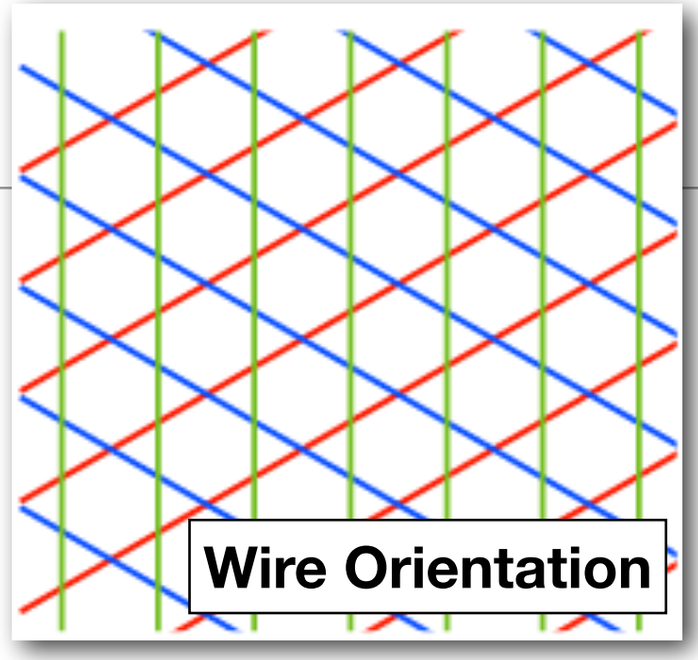
TPC Frame Construction

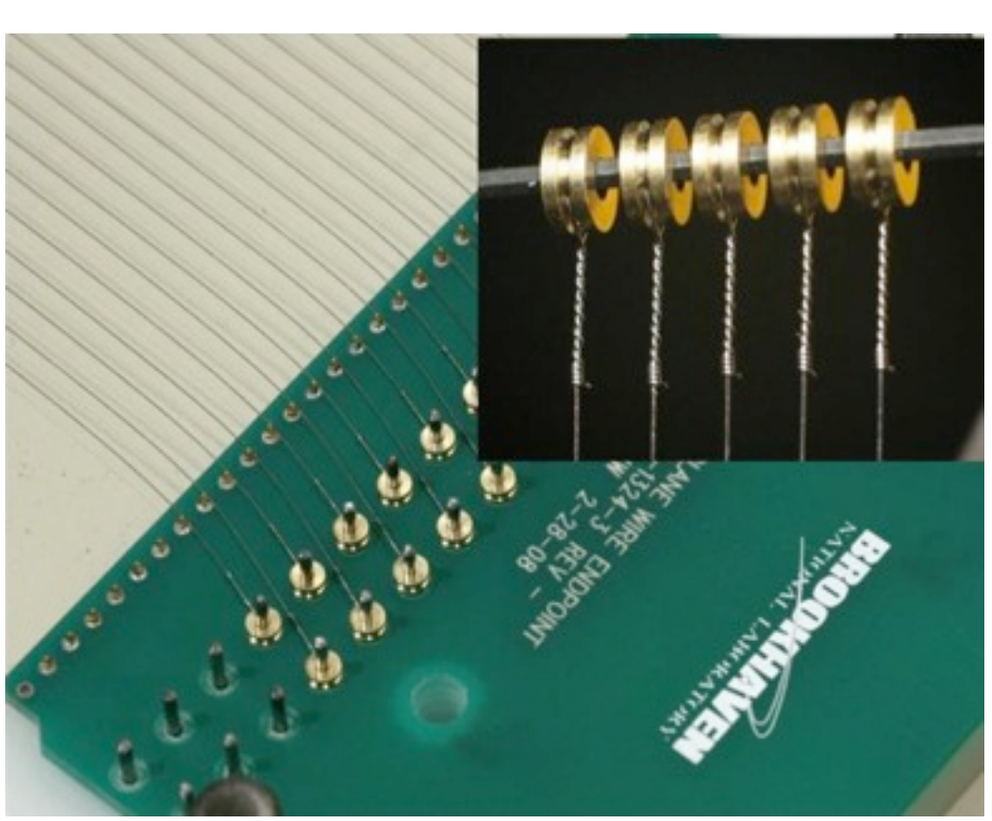
- It was constructed and surveyed within the last year in our clean room tent



TPC Wires

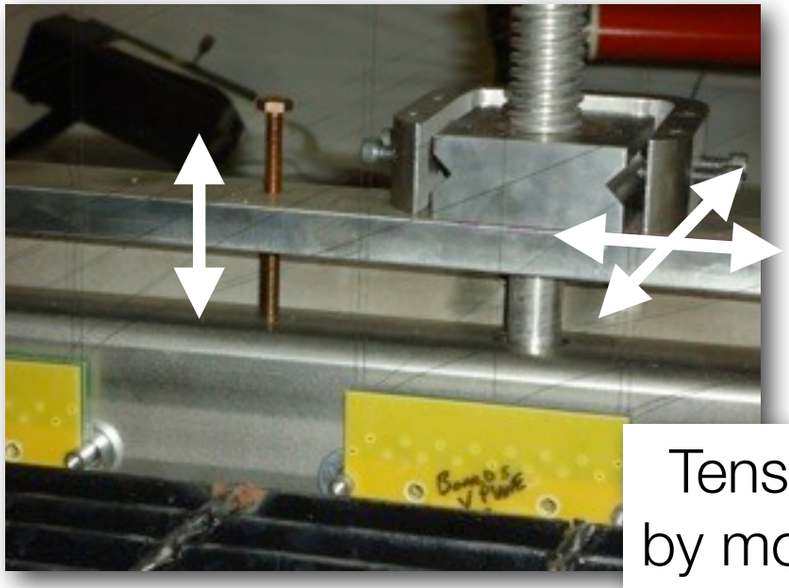
- The wires that read out the ionization signal are 150 μm stainless with 2 μm copper plating and a thin flash of gold
- We have three wire planes (3456 vertical, 2400 +60°, 2400 -60° ⇒ 8256 channels) separated by 3 mm
- All wires have a 3 mm pitch
- They attach to a wire carrier board for assembly onto 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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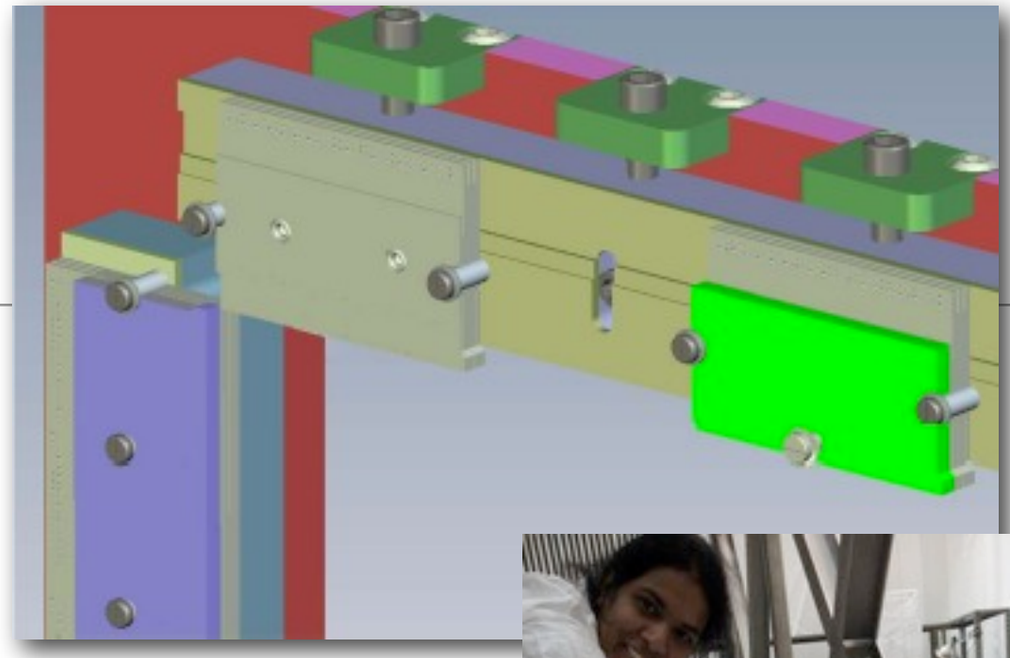

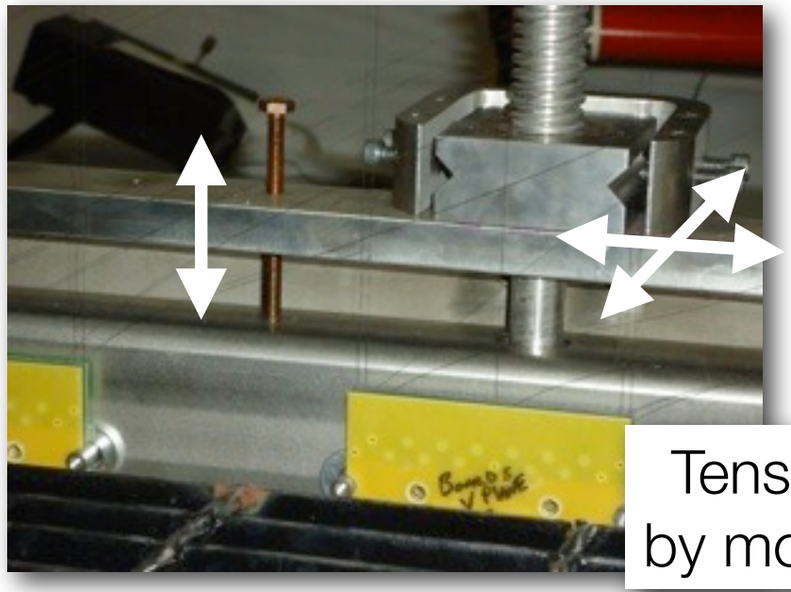

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  - BNL modified a digital camera to record the vibrational frequency of the wires

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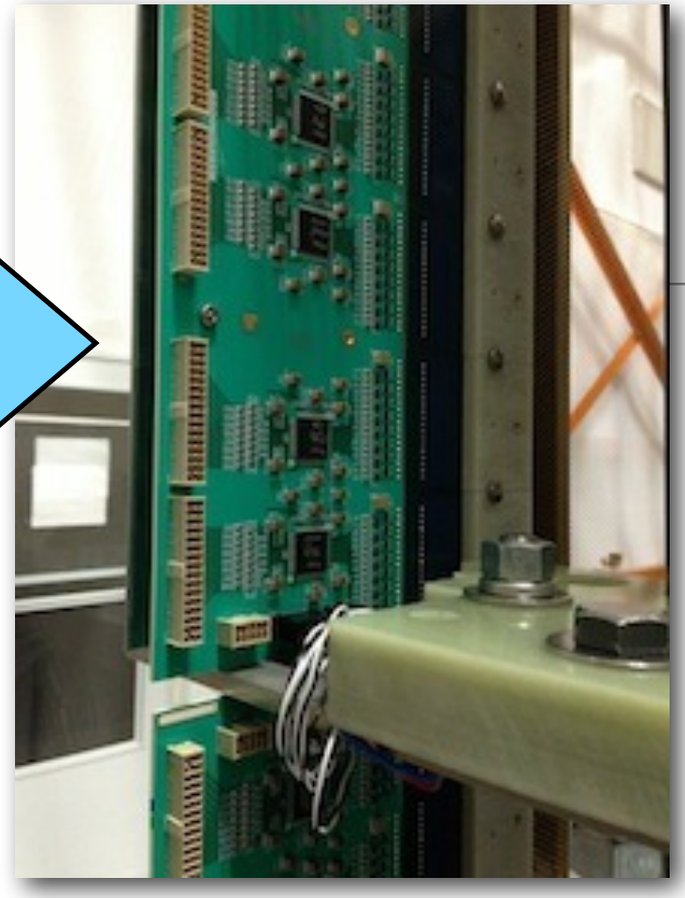
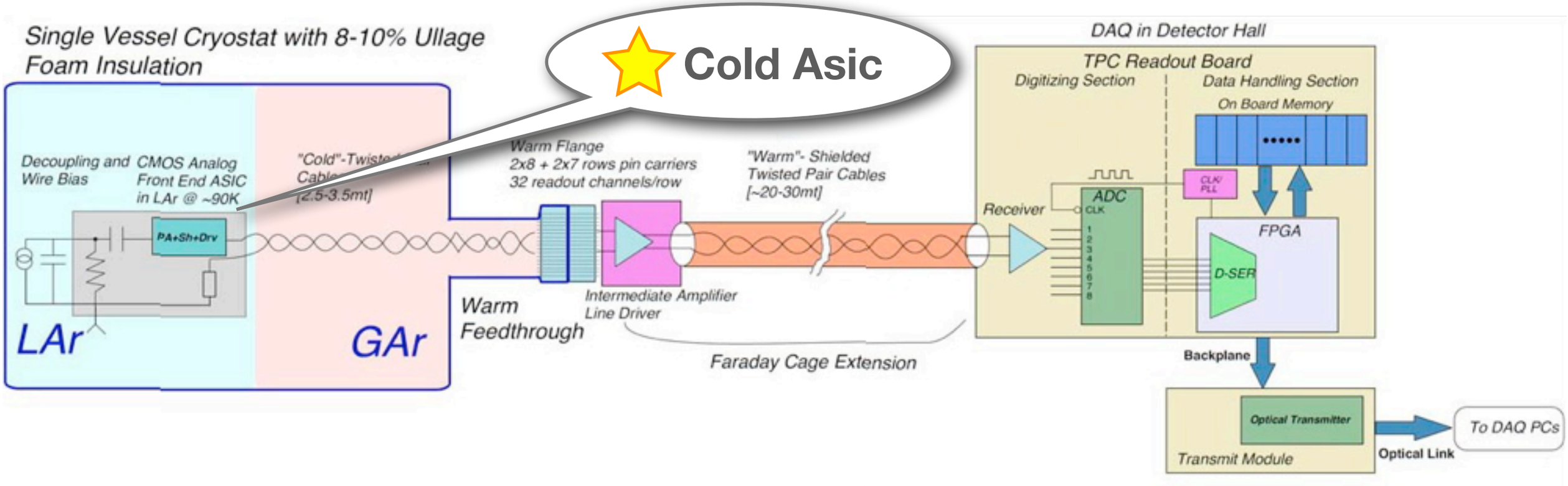
Electronics

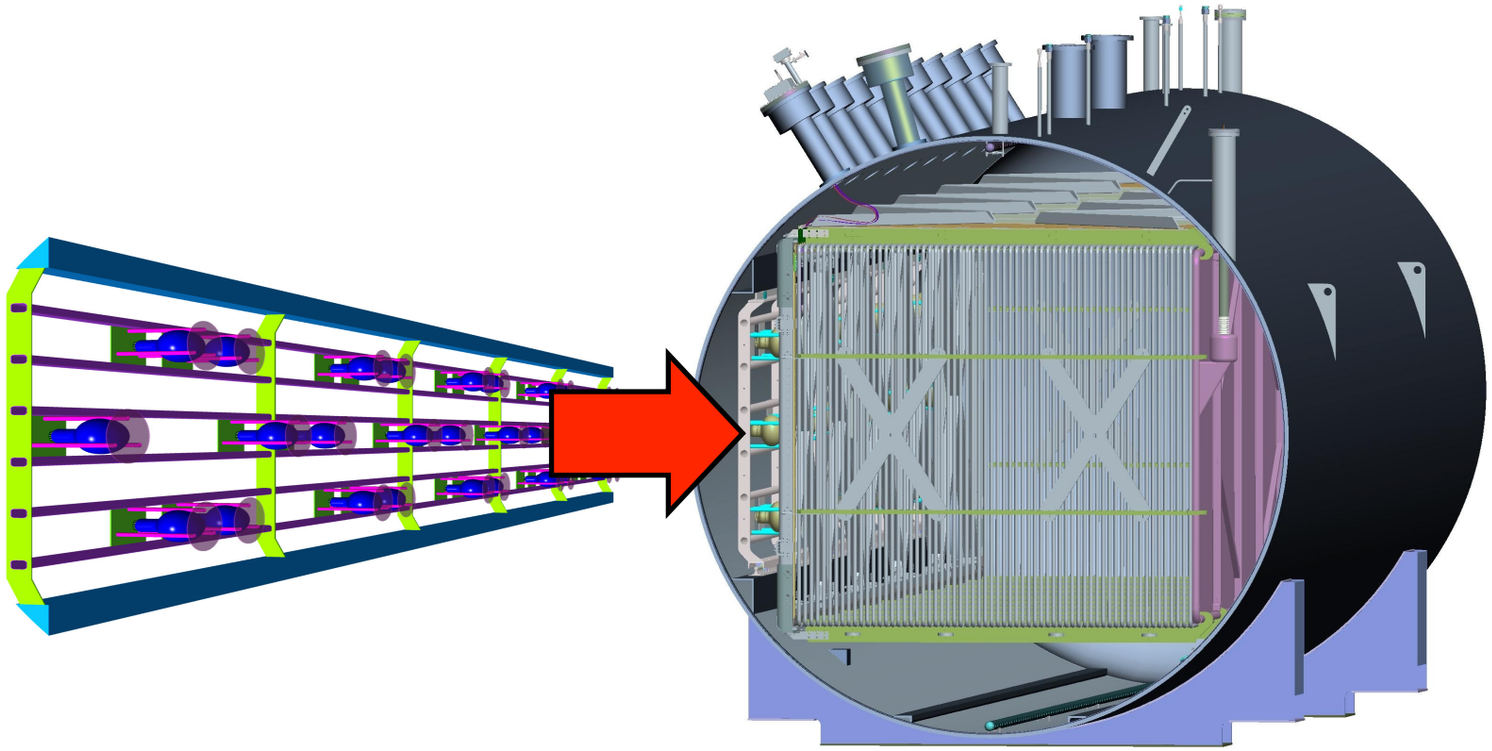
- Attachment of the cold electronics to the wire carrier boards happened this summer
- Once the TPC is inserted into the cryostat, the motherboards will be connected to the warm intermediate amplifiers
  - → Digitizers → DAQ





PMTs — Timing Information!

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

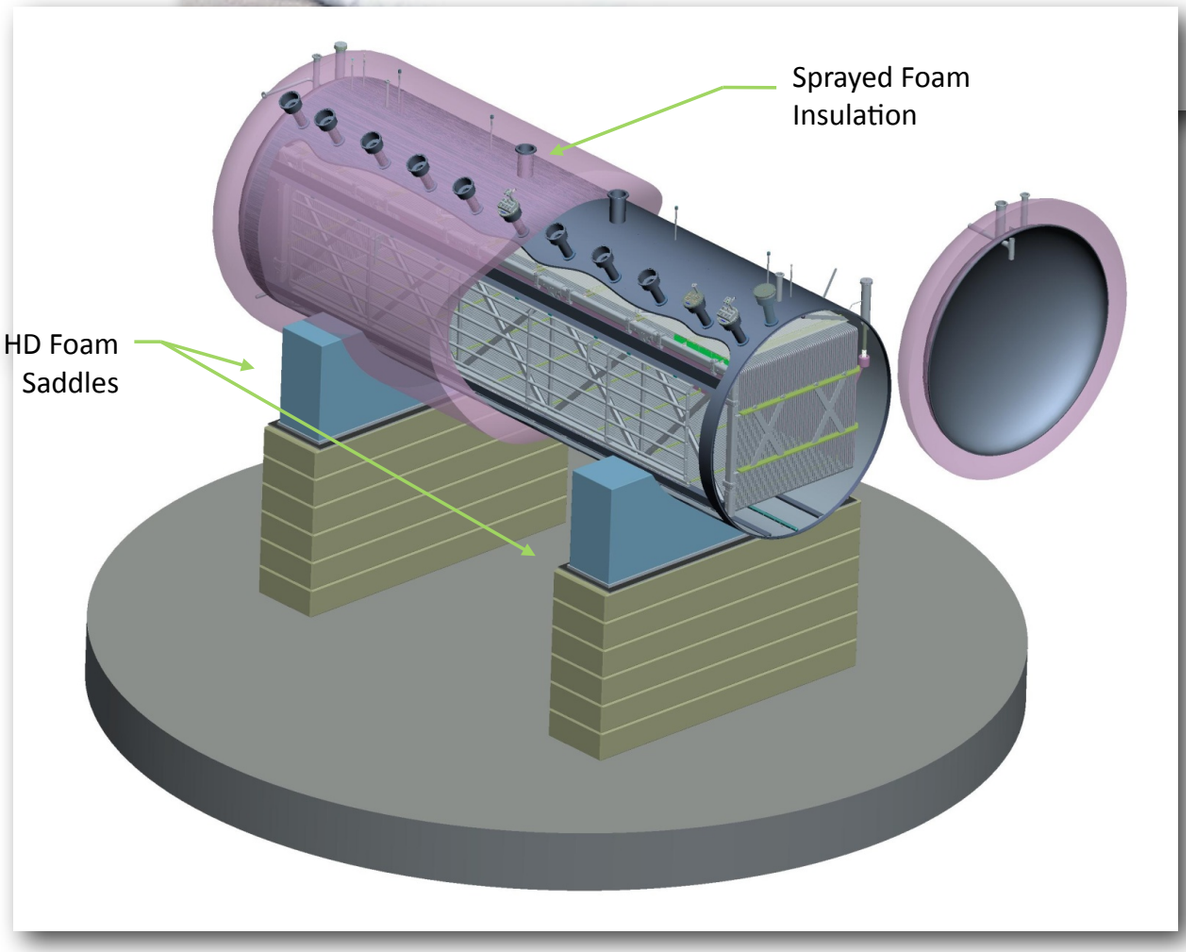


- Behind the anode frame, there will be a rack of 32 PMTs

- 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

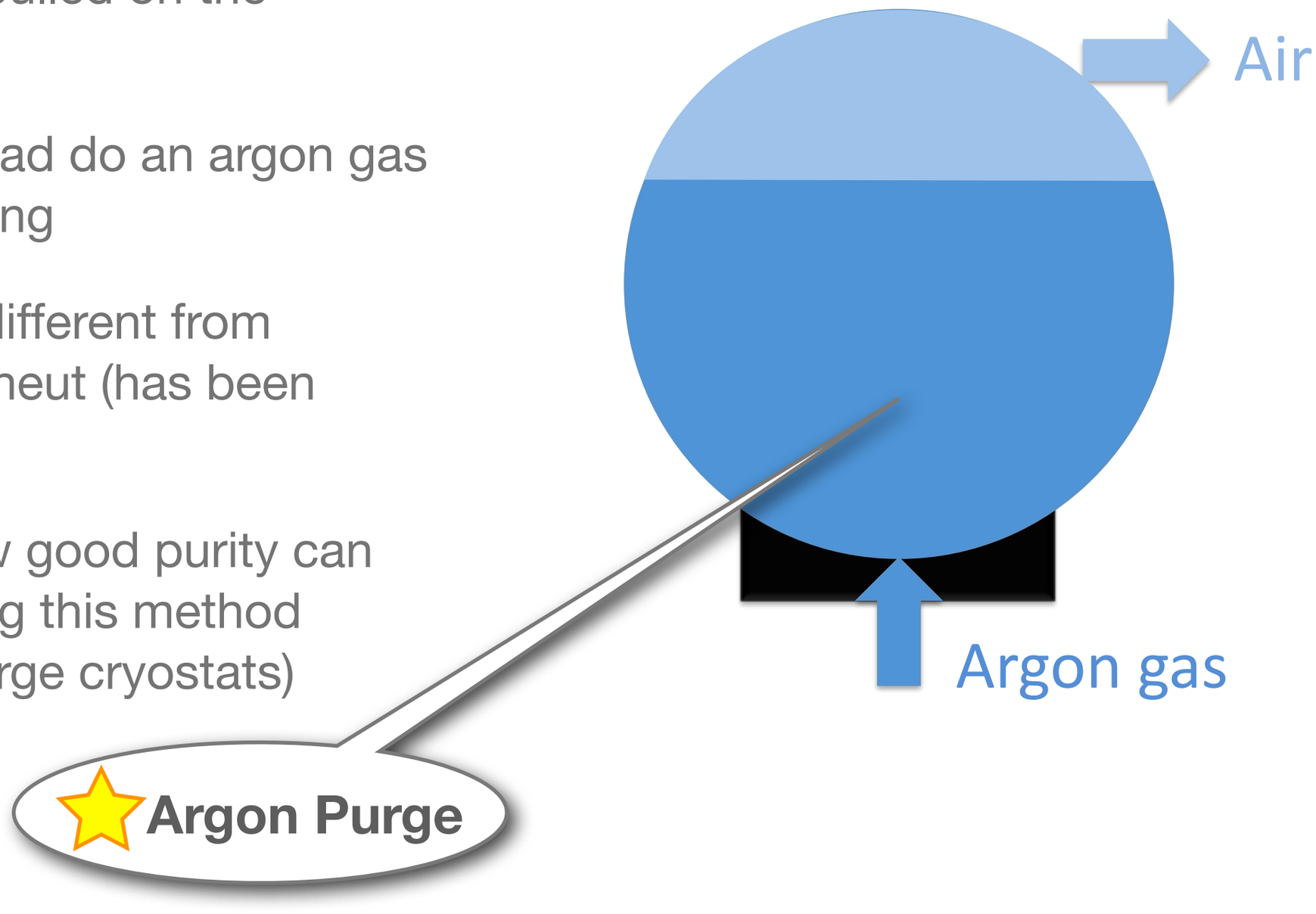
Cryostat

- 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



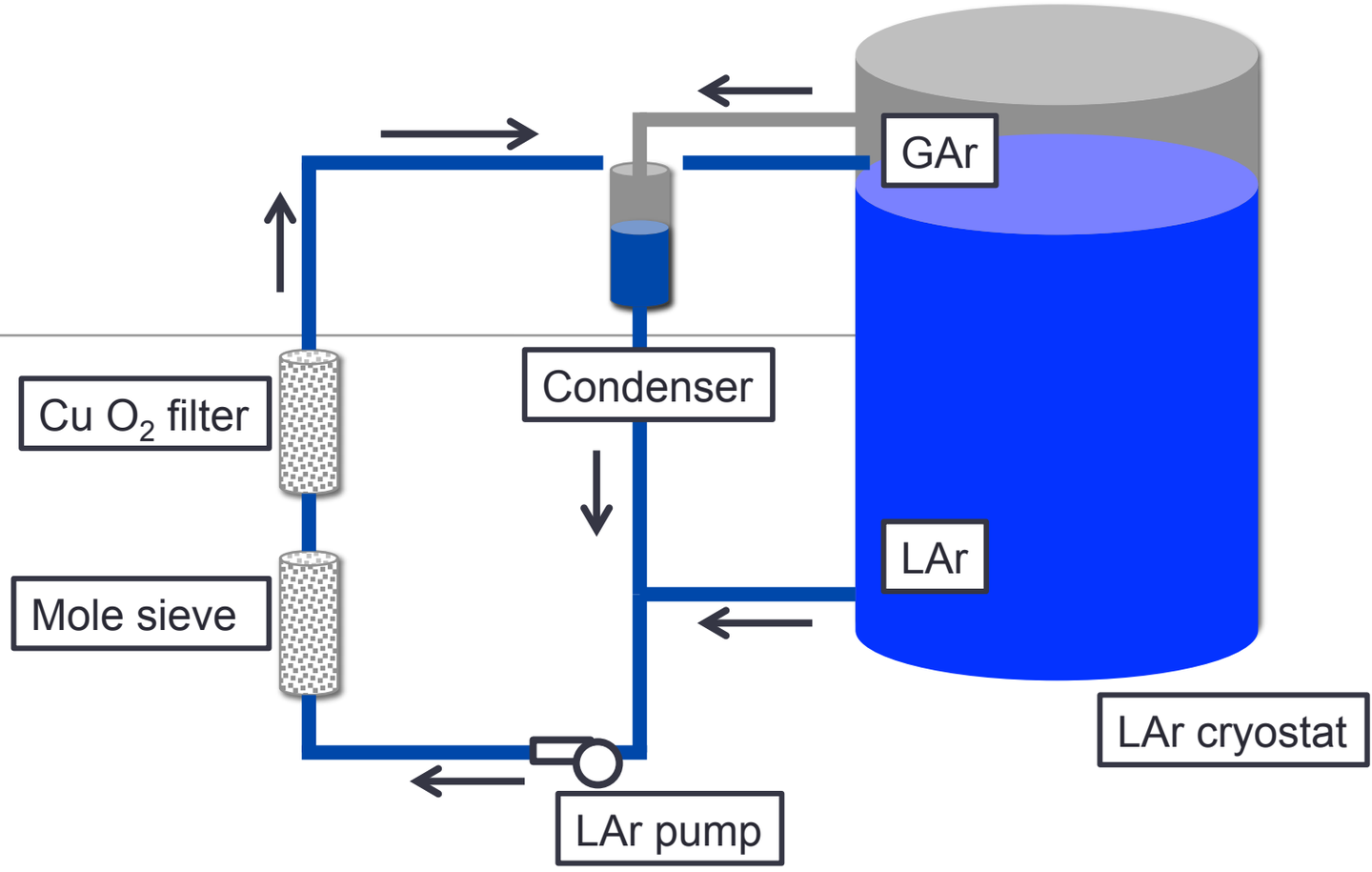
Cryostat

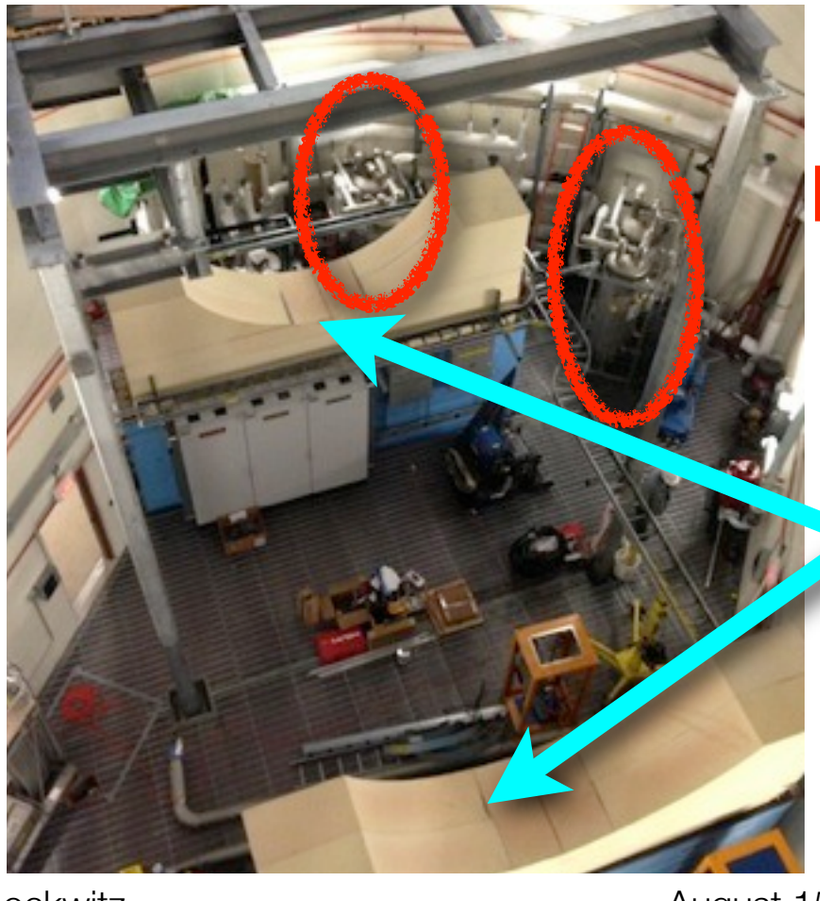
- In an effort to attain purity, typically a vacuum is initially pulled on the cryostat,
  - We plan to instead do an argon gas purge before filling
  - This is notably different from ICARUS & Argoneut (has been done at LAPD)
  - We plan to show good purity can be attained using this method (important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

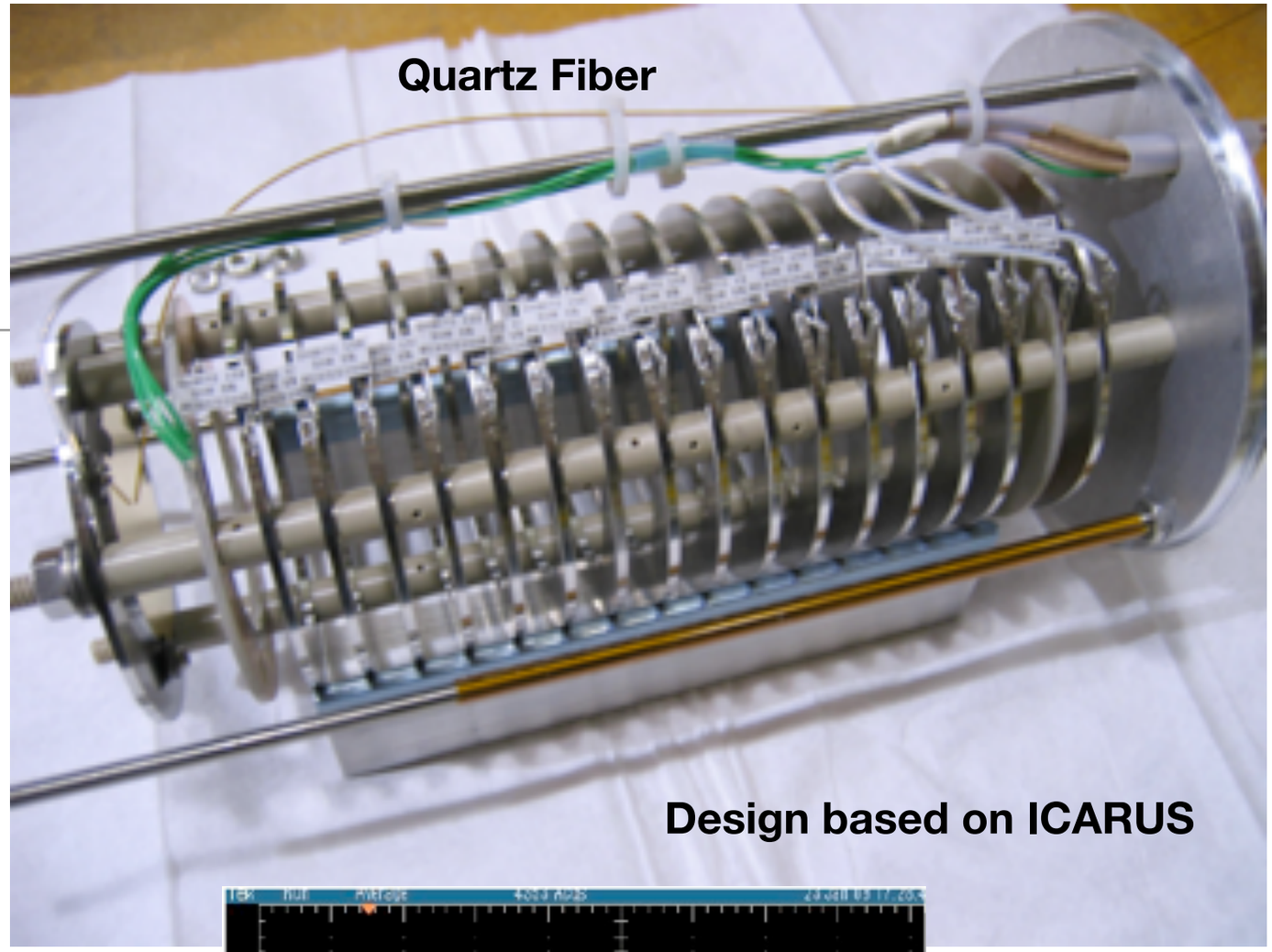


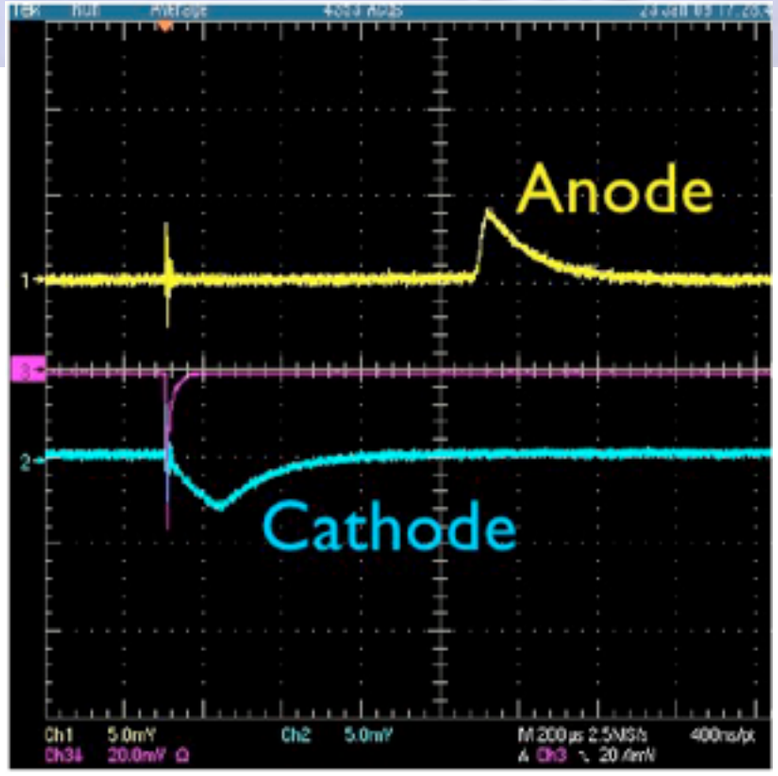


Cryosystem

- 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

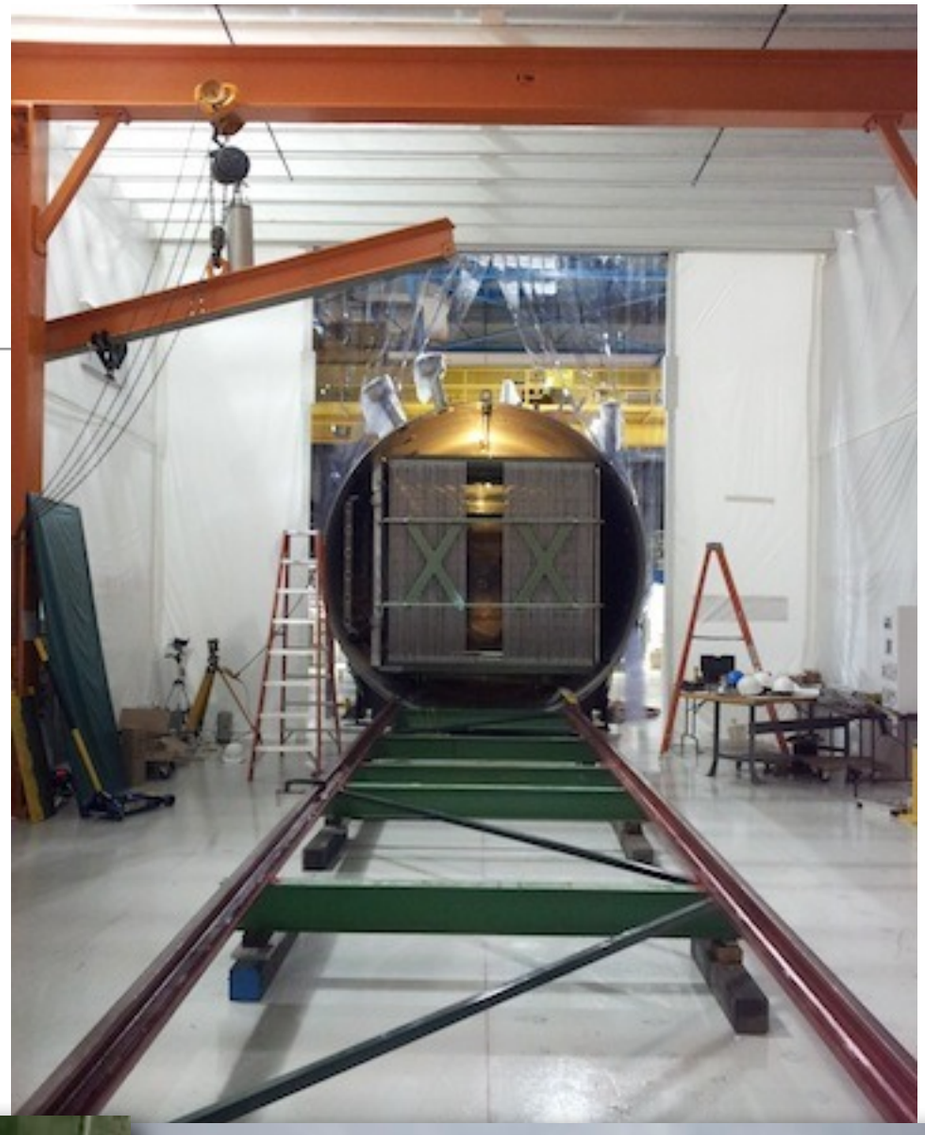
$$\frac{Q_0}{Q} = e^{t_d/\tau}$$





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
- Hucheng Chen
- Kai Chen (PD)
- Susan Duffin
- Jason Farell
- Francesco Lanni
- Yichen Li (PD)
- David Lissauer
- George Mahler
- Don Makowiecki
- Joseph Mead
- Veljko Radeka
- Sergio Rescia
- Andres Ruga
- Jack Sondericker
- Craig Thorn (IB)
- Bo Yu

University of Chicago
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- Johnny Ho (GS)
- David Schmitz (IB)

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- Jason St. John (PD)
- Randy Johnson (IB)
- Bryce Littlejohn (PD)

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- Ben Carls (PD)
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- Herb Greenlee
- Cat James
- Eric James
- Hans Jostlein
- Mike Kirby
- Sarah Lockwitz (PD)
- Byron Lundberg
- Alberto Marchionni
- Stephen Pordes
- Jennifer Raaf
- Gina Rameika (IB)
- Brian Rebel
- Rich Schmitt
- Steve Wolbers
- Tingjun Yang (PD)
- Sam Zeller (*)

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- David McKee (PD)

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- Geoff Mills
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- Richard Van de Water (IB)

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- Gabriel Collin (GS)
- Janet Conrad (IB)
- Christina Ignarra (GS)
- Ben Jones (GS)
- Teppei Katori (PD)
- Matt Toups (PD)

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- Carl Bromberg (IB)
- Dan Edmunds

New Mexico State University
- Alistair McLean (U)
- Tia Miceli (PD)
- Vassili Papavassiliou (IB)
- Stephen Pate
- Katherine Woodruff (GS)

Otterbein University
- Nathaniel Tagg (IB)

Princeton University
- Kirk McDonald (IB)
- Bill Sands

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

SLAC
- Mark Convery (IB)
- Matt Graham
- David Muller

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- Jonathan Asaadi (PD)
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- Thomas Strauss (PD)

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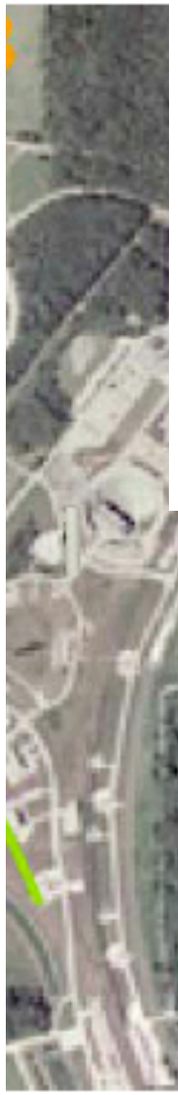
- Leonidas Kalousis (PD)
- Camillo Mariani (IB)

Yale University
- Corey Adams (GS)
- Christina Brasco (U)
- 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

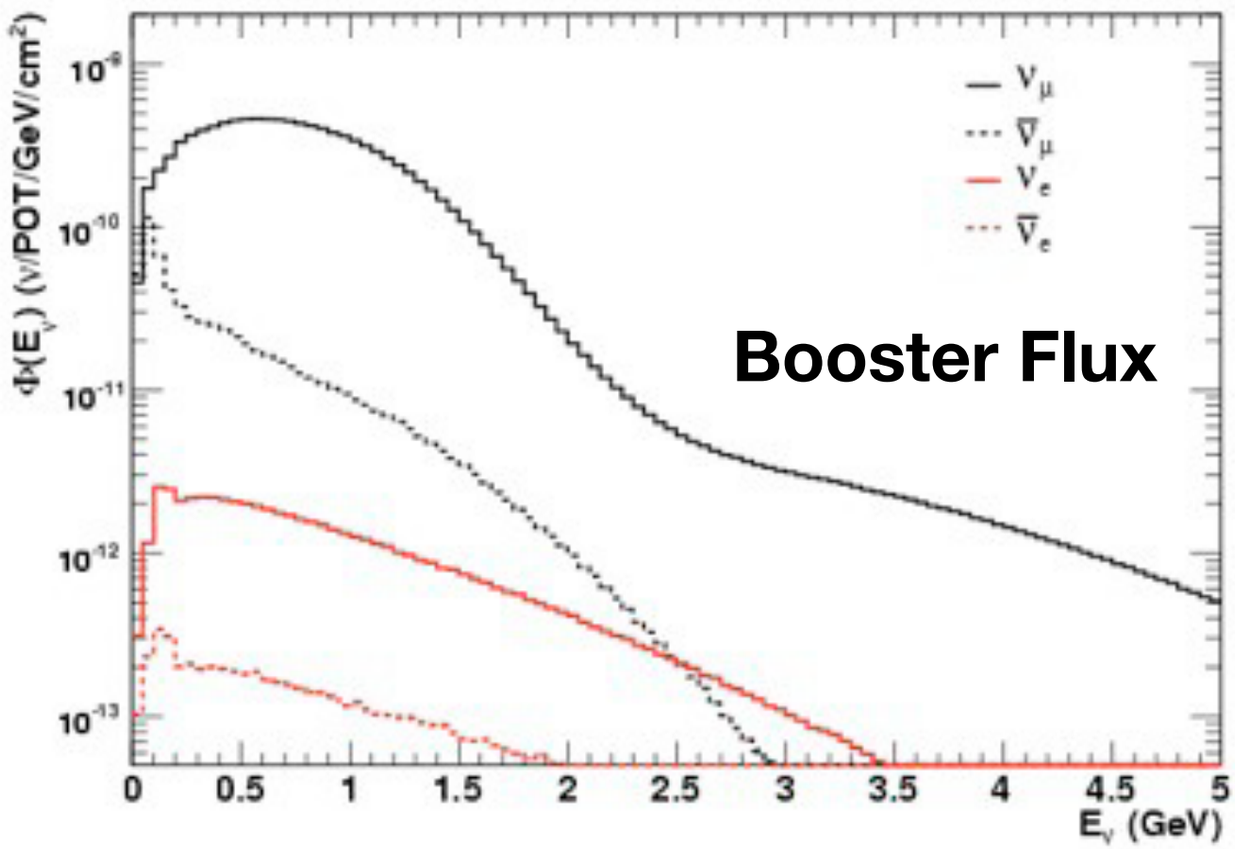
production mode	# events
CC QE ($\nu_\mu n \to \mu^- p$)	60,161
NC elastic ($\nu_\mu N \to \nu_\mu N$)	19,409
CC resonant π^+ ($\nu_\mu N \to \mu^- N \pi^+$)	25,149
CC resonant π^0 ($\nu_\mu n \to \mu^- p \pi^0$)	6,994
NC resonant π^0 ($\nu_\mu N \to \nu_\mu N \pi^0$)	7,388
NC resonant $\pi^\pm$ ($\nu_\mu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

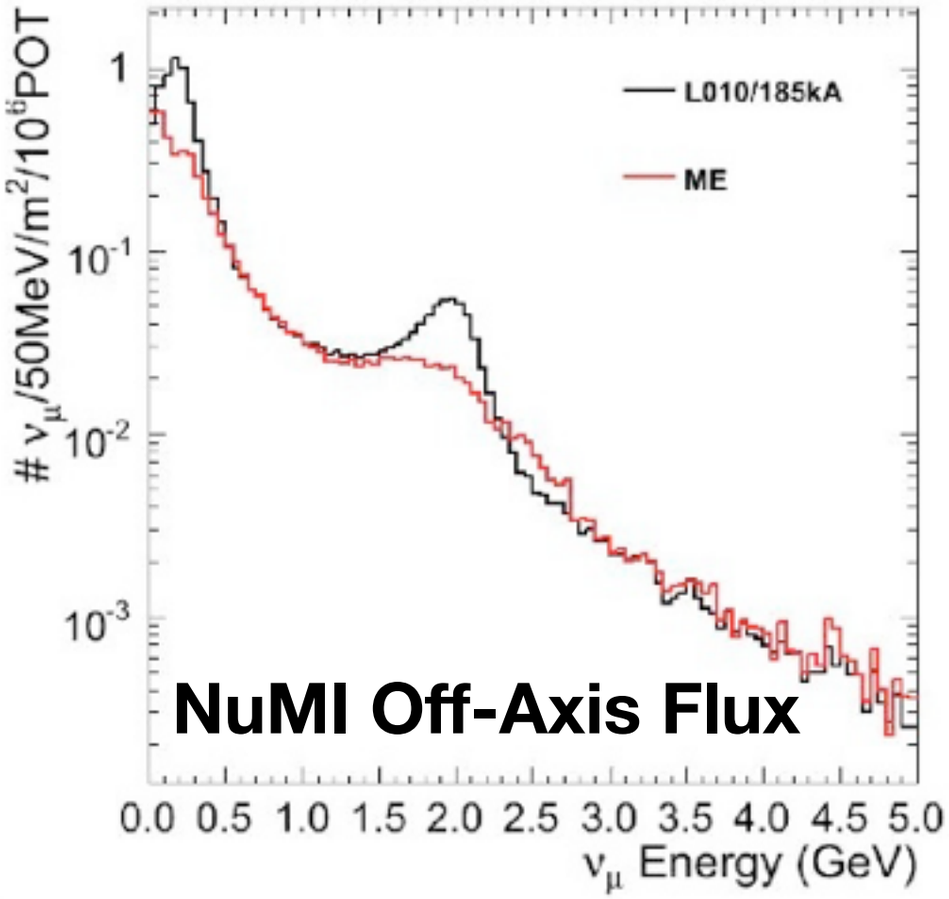


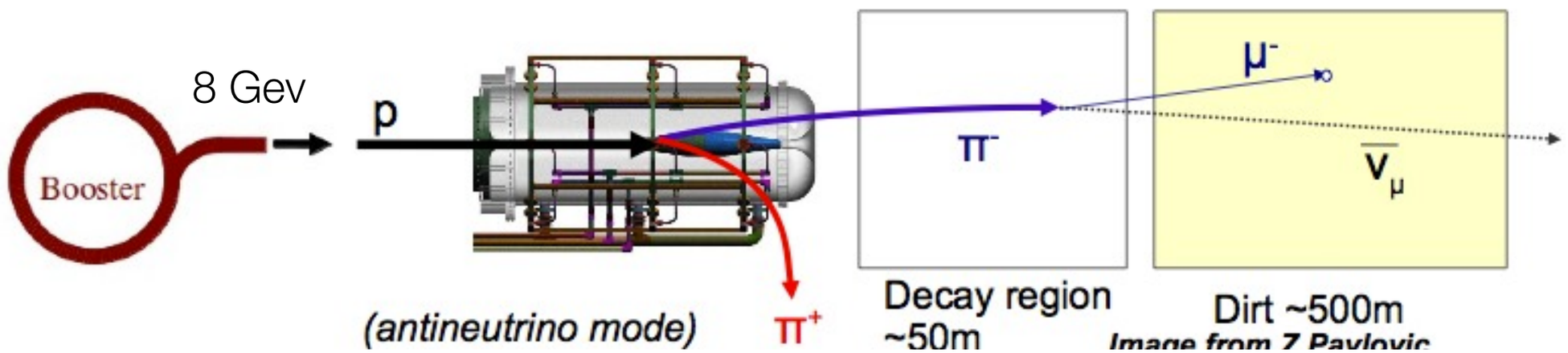
	BNB	NuMI
Total Events	**145k**	**60k**
ν_μ CCQE	68k	25k
NC π^o	8k	3k
ν_e CCQE	0.4k	1.2k
POT	$6x10^{20}$	$8x10^{20}$

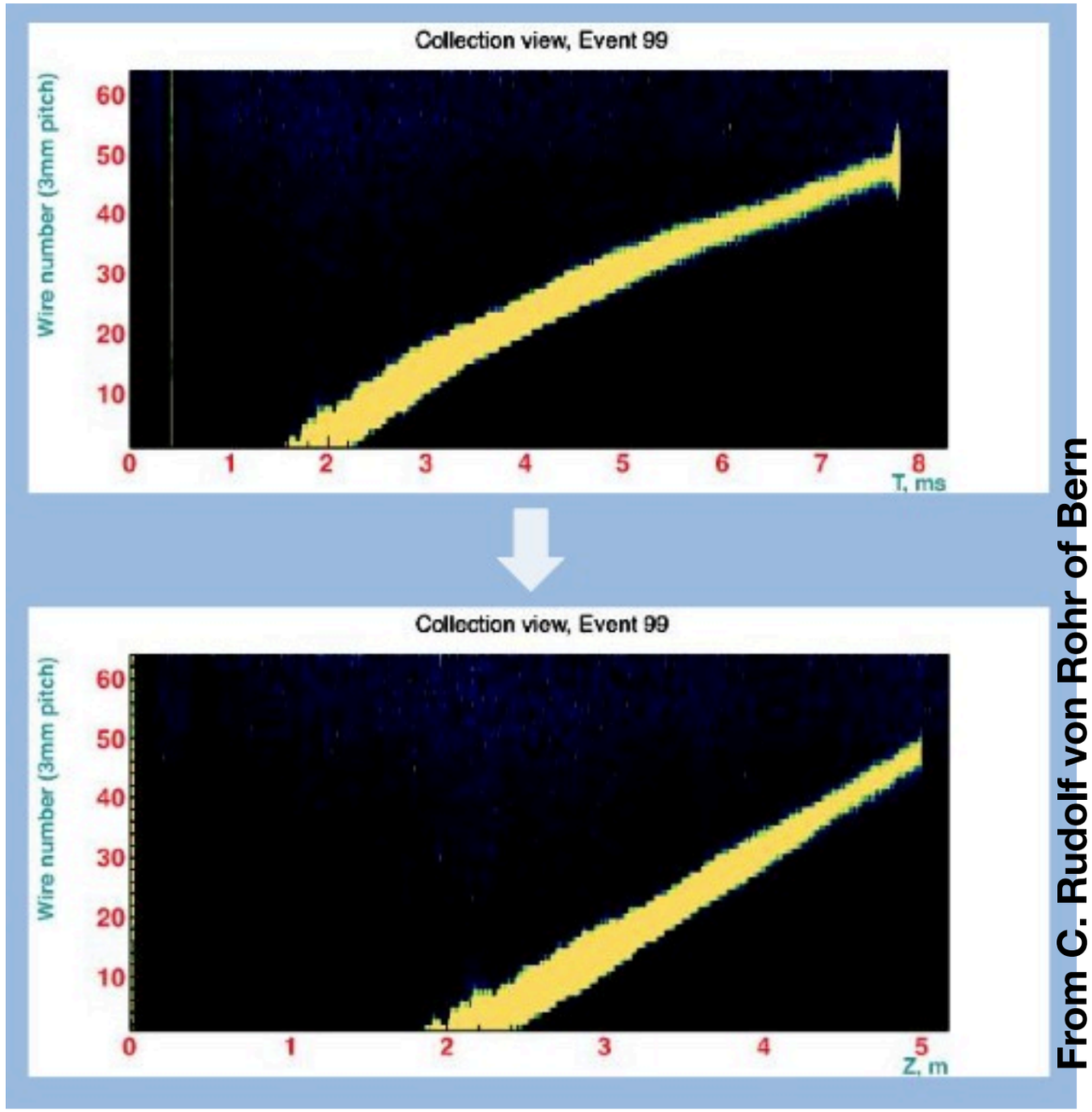
Projected Event Rates for MicroBooNE in 2-3 years.

Beam


Booster Flux
$\Phi(E_\nu)$ (ν/POT/GeV/cm^2)
ν_μ
$\bar{\nu}_\mu$
ν_e
$\bar{\nu}_e$
E_ν (GeV)


NuMI Off-Axis Flux
ν_μ/50MeV/m^2/10^{6}POT
L010/185kA
ME
ν_μ Energy (GeV)


8 Gev
Booster
p
(antineutrino mode)
π^+
π^-
μ^-
$\bar{\nu}_\mu$
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