

MicroBooNE

Liquid Argon TPC at Fermilab

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@

Columbia University / Fermilab

MicroBooNE

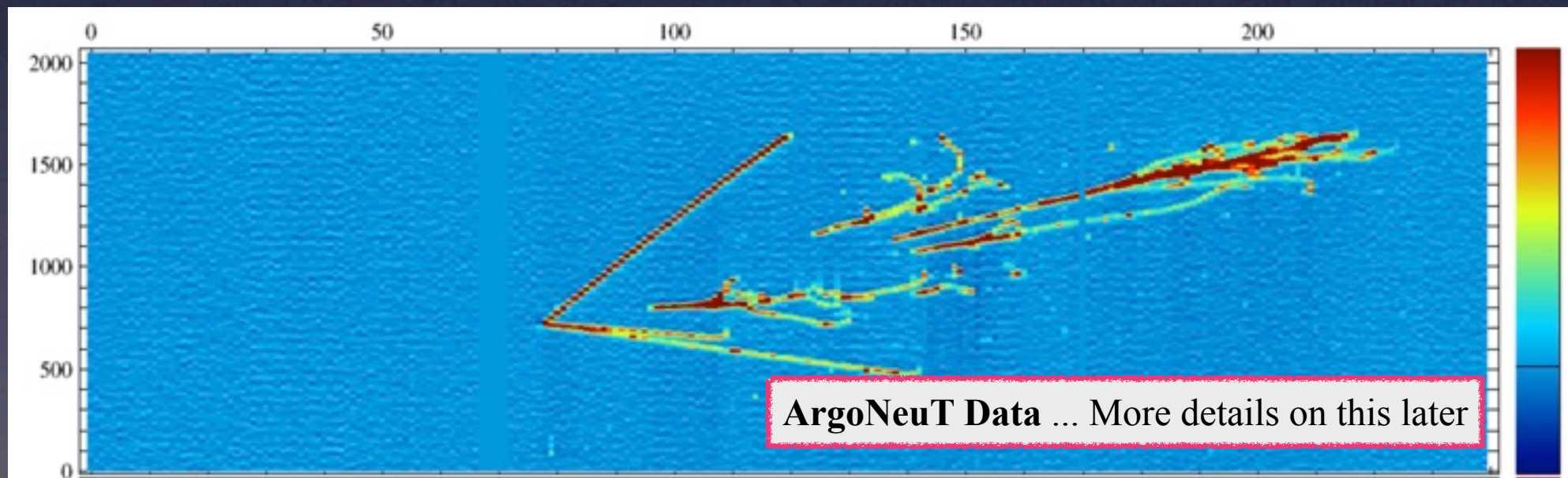
Liquid Argon TPC at Fermilab

Outline:

1. Introduction
2. MicroBooNE Experiment
3. Where We Are
4. Summary

What Is MicroBooNE?

- MicroBooNE is ...
 - a **short baseline neutrino oscillation experiment** @ Fermilab
 - ▶ Oscillation: $\nu_\mu \Rightarrow \nu_e$ @ $L/E \approx 0$ (1 m/MeV)
 - ▶ neutrino source = running Booster Neutrino Beam @ Fermilab
 - a **Liquid Argon Time Projection Chamber** (LArTPC)
 - ▶ mass = 170 ton (active = 90 ton)
 - ▶ provides excellent particle ID and calorimetry



LArTPC provides “photo quality image” of particle interaction!
Basically digitized “bubble chamber” image!

Why MicroBooNE?

- **MiniBooNE: Booster Neutrino Experiment @ Fermilab**

- Oscillation mode: $\nu_\mu \Rightarrow \nu_e$ & $\bar{\nu}_\mu \Rightarrow \bar{\nu}_e$... $L/E \simeq 0$ (1 m/MeV)
- Cherenkov detector w/ mineral oil
- Source: Booster Neutrino Beam (BNB)

PRL 110, 161801(2013)

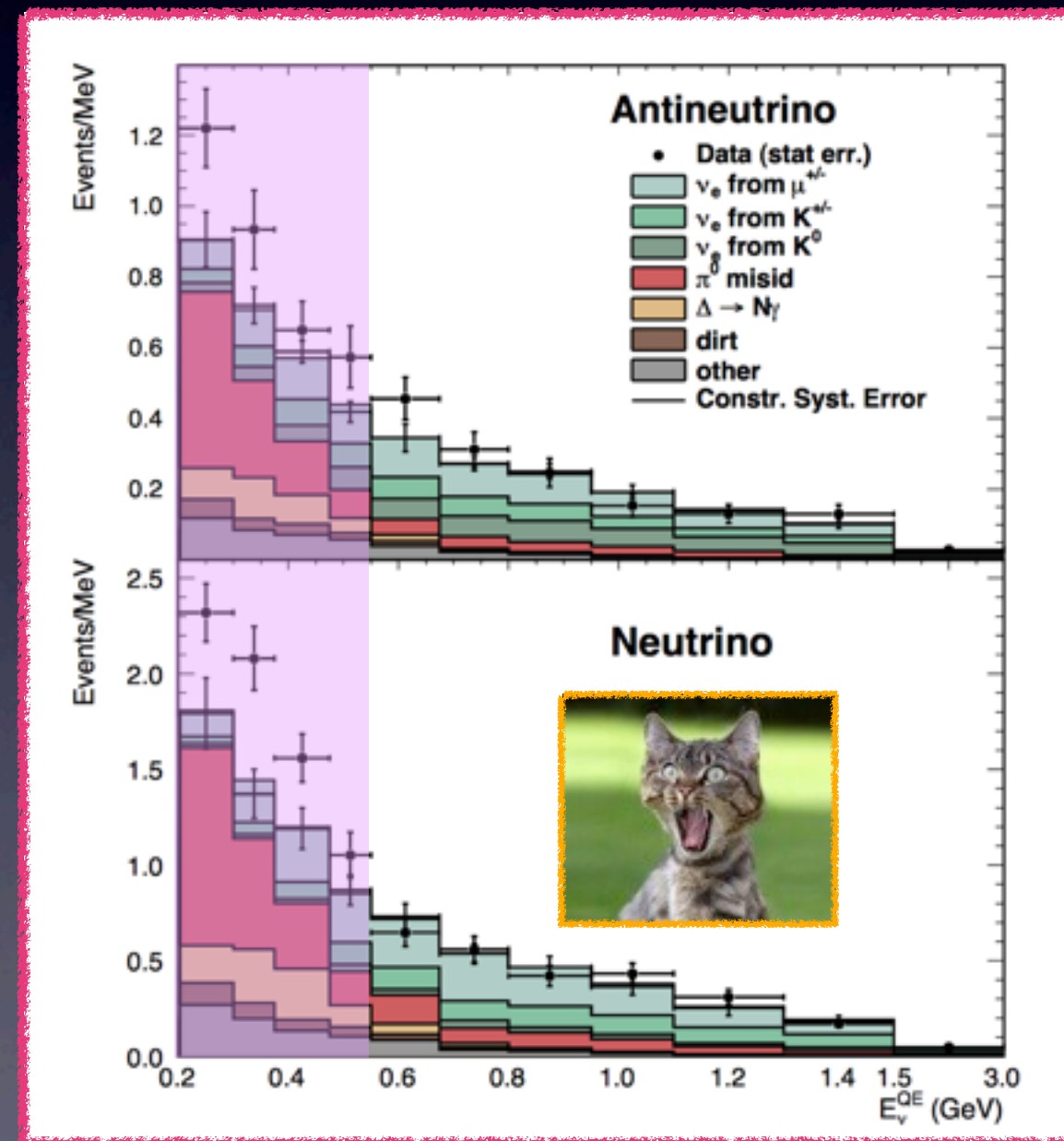
- **MiniBooNE saw an excess!**

- But with $\Delta m^2 \simeq 1 \text{ eV}^2$
 - ▶ Much larger than known Δm^2 values
 - ▶ “Sterile neutrino”
- Is this an oscillation signal?
 - ▶ “Low energy excess” ($< 600 \text{ MeV}$)
 - ▶ Region dominated by γ background
 - ▶ Is it single e^- or γ ?

Call for a definitive measurement!

MicroBooNE

LArTPC w/ Excellent Particle ID



MicroBooNE

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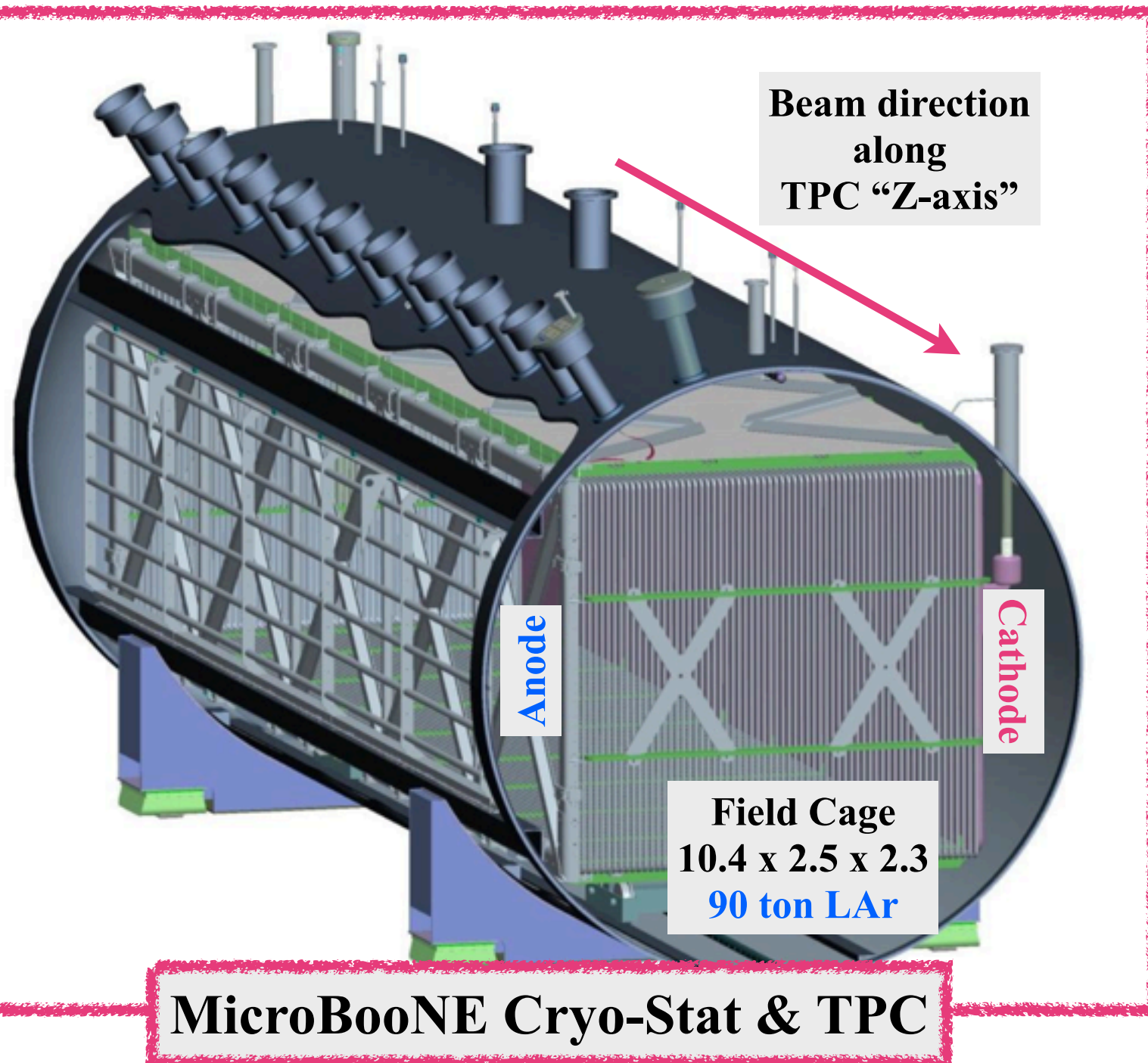


MicroBooNE!



- **Short Baseline Neutrino Oscillation Experiment @ Fermilab**

- Oscillation mode: $\nu_\mu \Rightarrow \nu_e$... $L/E \approx 0$ (1 m/MeV)



- **Neutrino source**

- “Booster Neutrino Beam”
 - Accelerator @ Fermilab

- **Detector (nu-target)**

- 170 ton of liquid Argon (LAr)
 - Time Projection Chamber

Three Objectives

1. **MiniBooNE low E excess**
2. **Low E ν -Ar cross-section**
3. **LArTPC R&D**

U.S. based R&D Program for LArTPC

- Wide effort on LArTPC R&D in the U.S.
- MicroBooNE has an important role as the next large scale LArTPC



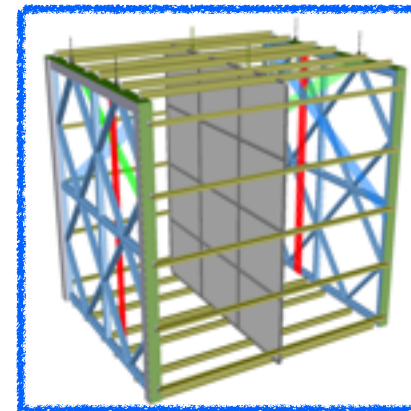
Bo TPC
0.02 ton



ArgoNeuT
0.3 ton



MicroBooNE
0.1 kilo-ton



SBN
0.05 + 0.6 kilo-ton



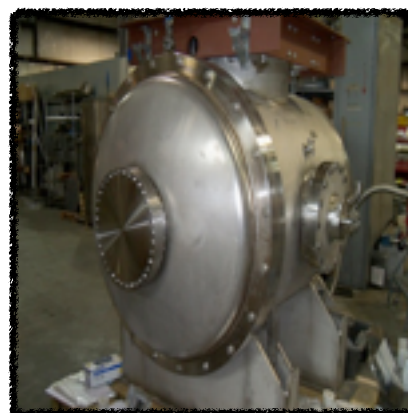
LBNE Far Detector
34 kilo-ton



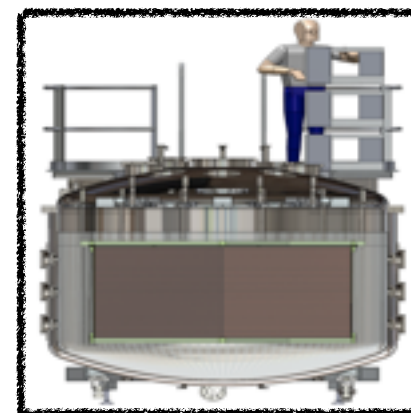
LUKE
(Material Test Stand)



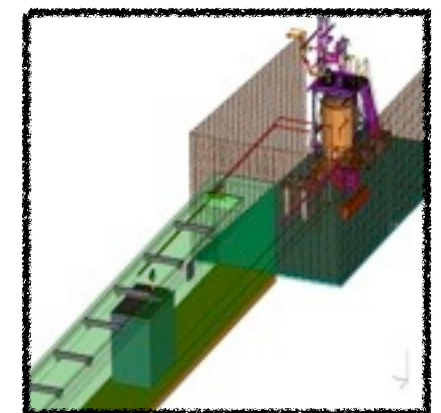
LAPD
Purity Demonstrator



LArIAT
TPC Calibration



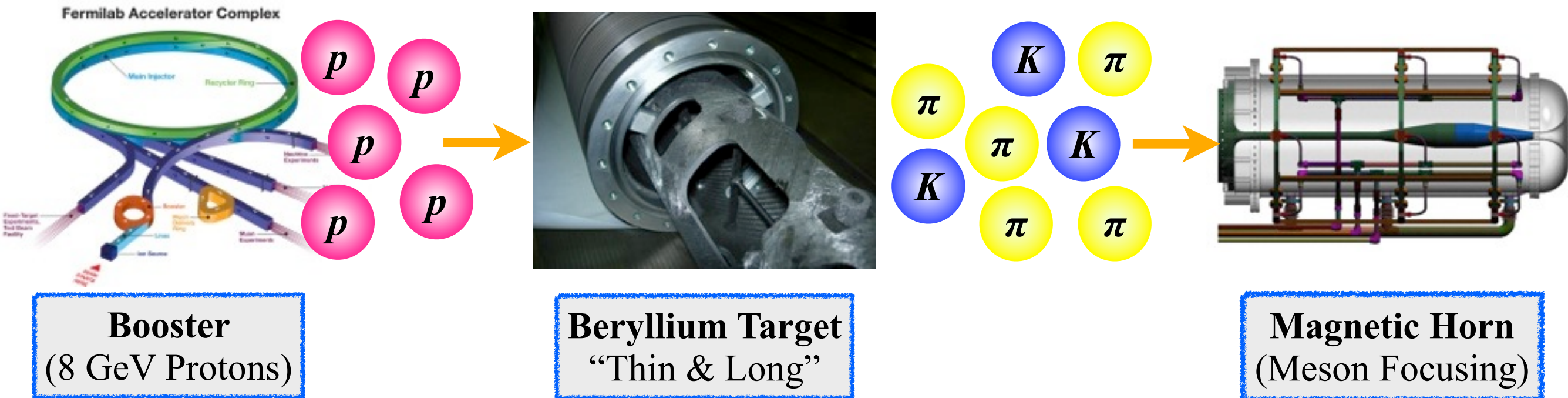
CAPTAIN
TPC Calibration



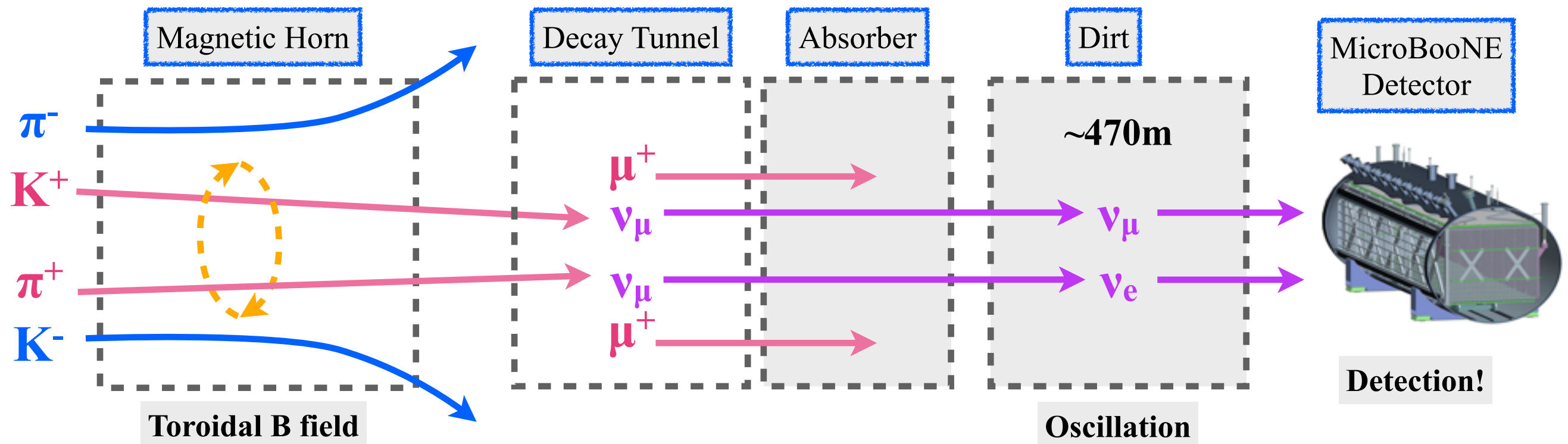
LBNE 35 ton
Purity Demonstrator

BNB: Neutrino Source

- 8 GeV protons from Booster hits Beryllium target to produce mesons



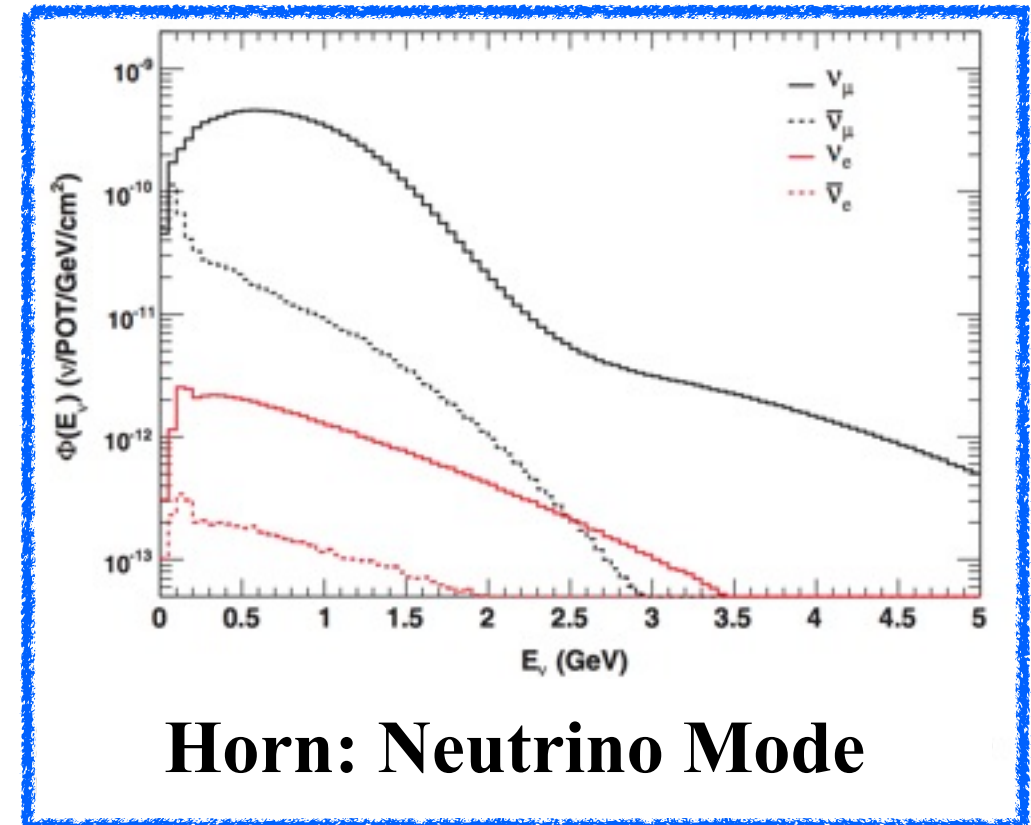
- Horn focuses positive (negative) mesons to produce neutrinos (anti-nu)



BNB: Providing Neutrinos Over a Decade



PRD 79, 072002 (2009)



Event Rate Break Down (flux & xs)

- $\nu_{\mu} \approx 98.6\%$
- $\bar{\nu}_{\mu} \approx 0.8 \%$
- $\nu_e \approx 0.6 \%$
- $\bar{\nu}_e \approx 0.02 \%$

... **high purity ν_{μ} beam** ...

MicroBooNE Detector



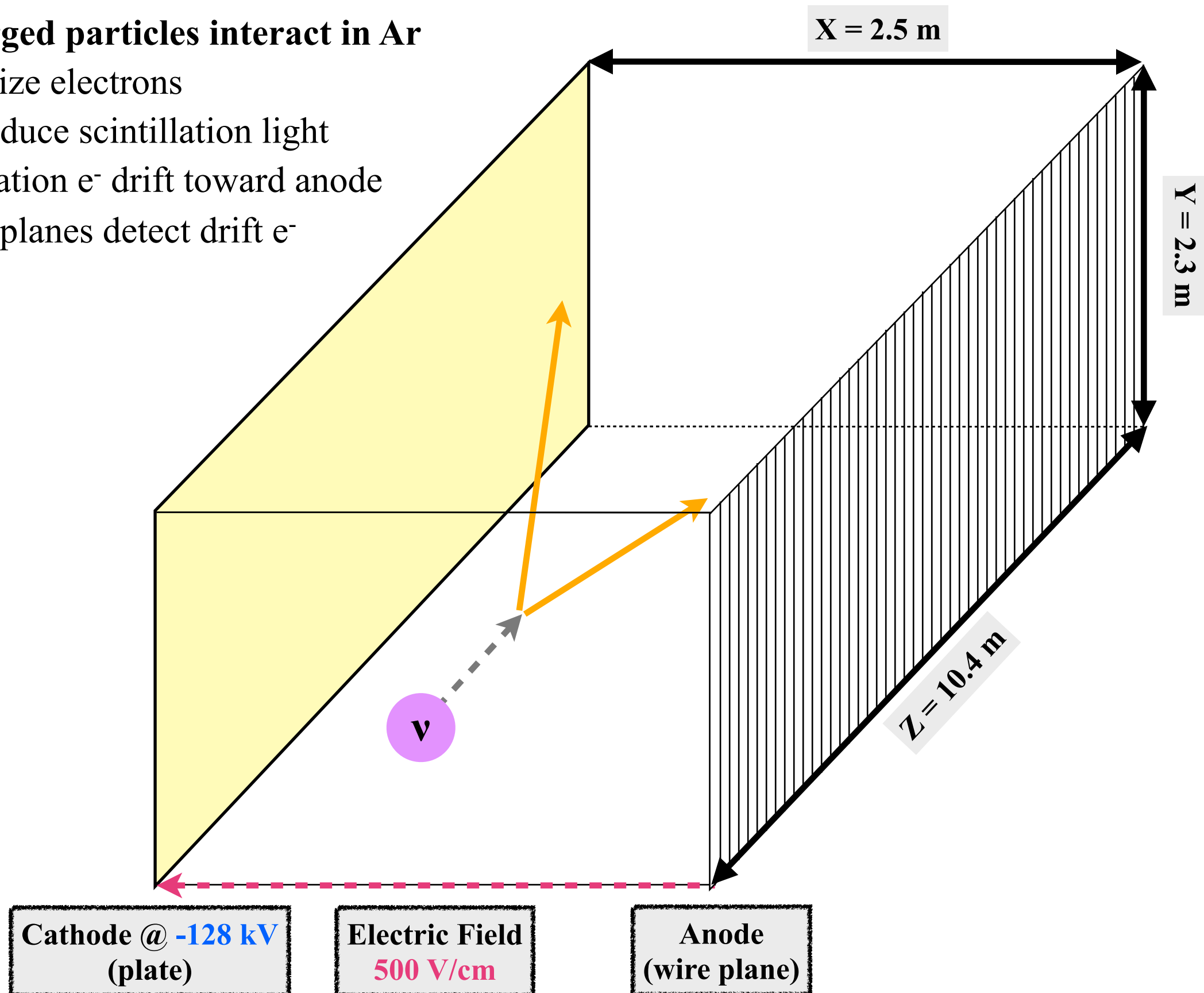
TPC Working Principle

1. Charged particles interact in Ar

- Ionize electrons
- Produce scintillation light

2. Ionization e^- drift toward anode

3. Wire planes detect drift e^-



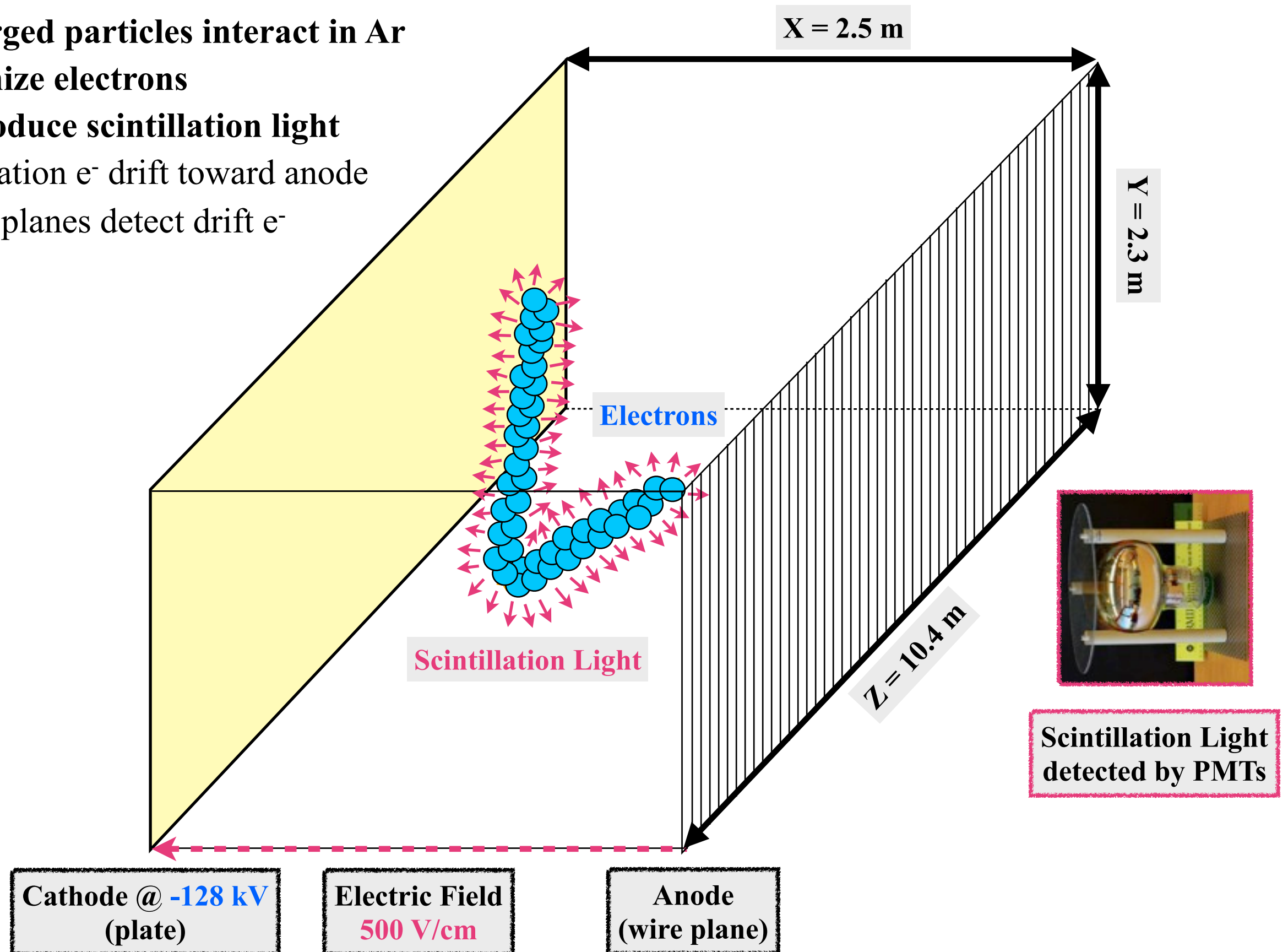
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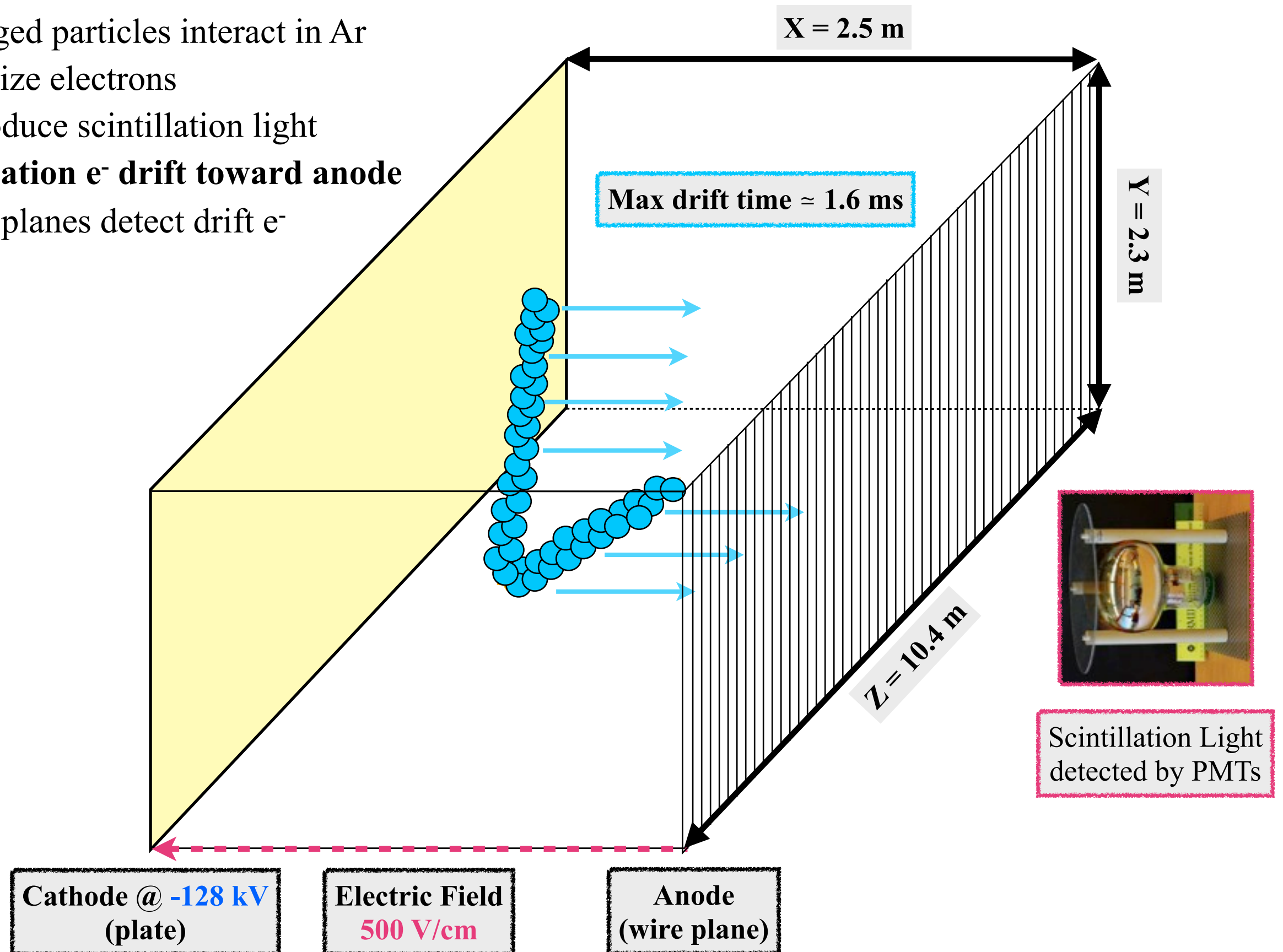
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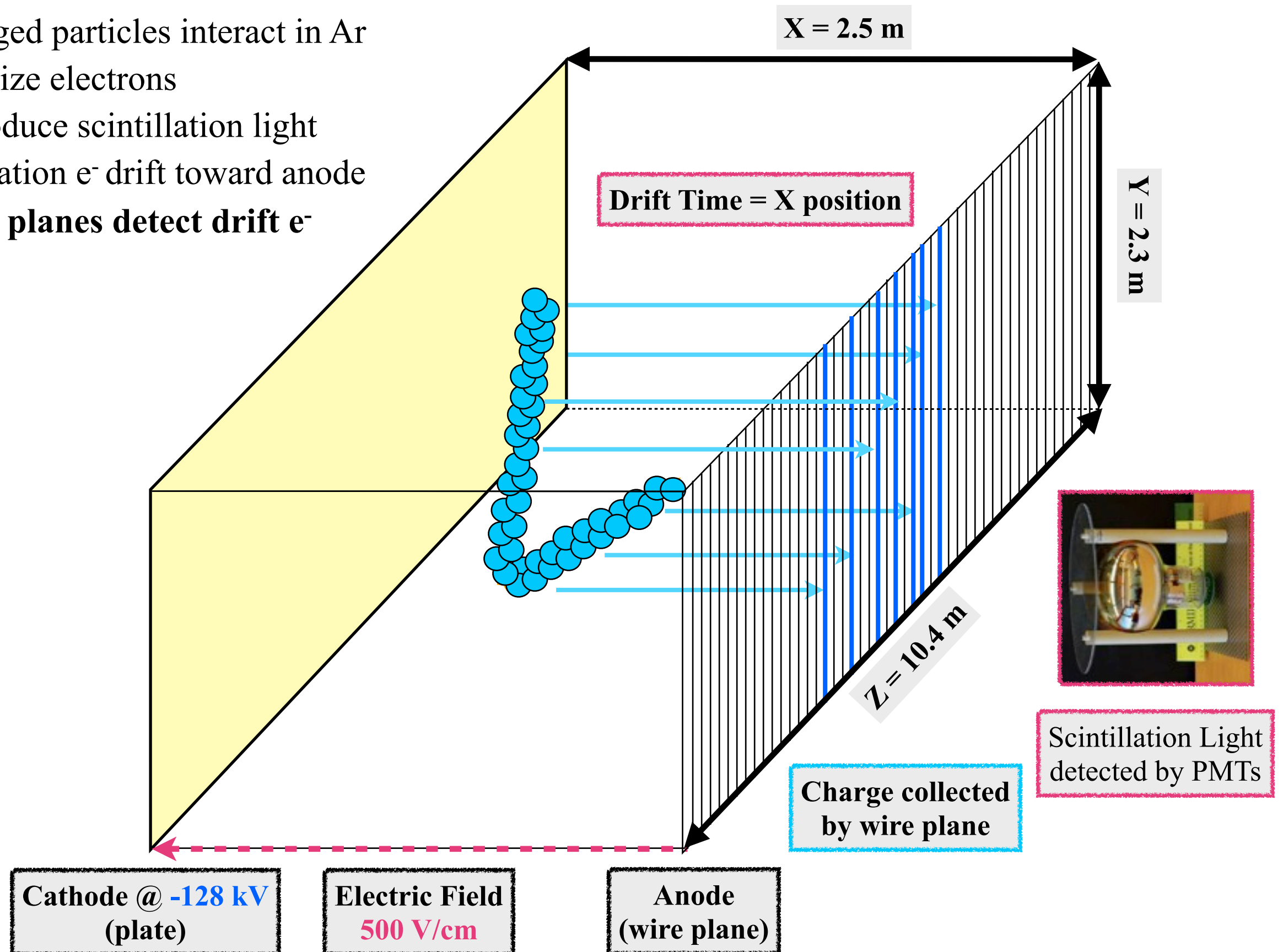
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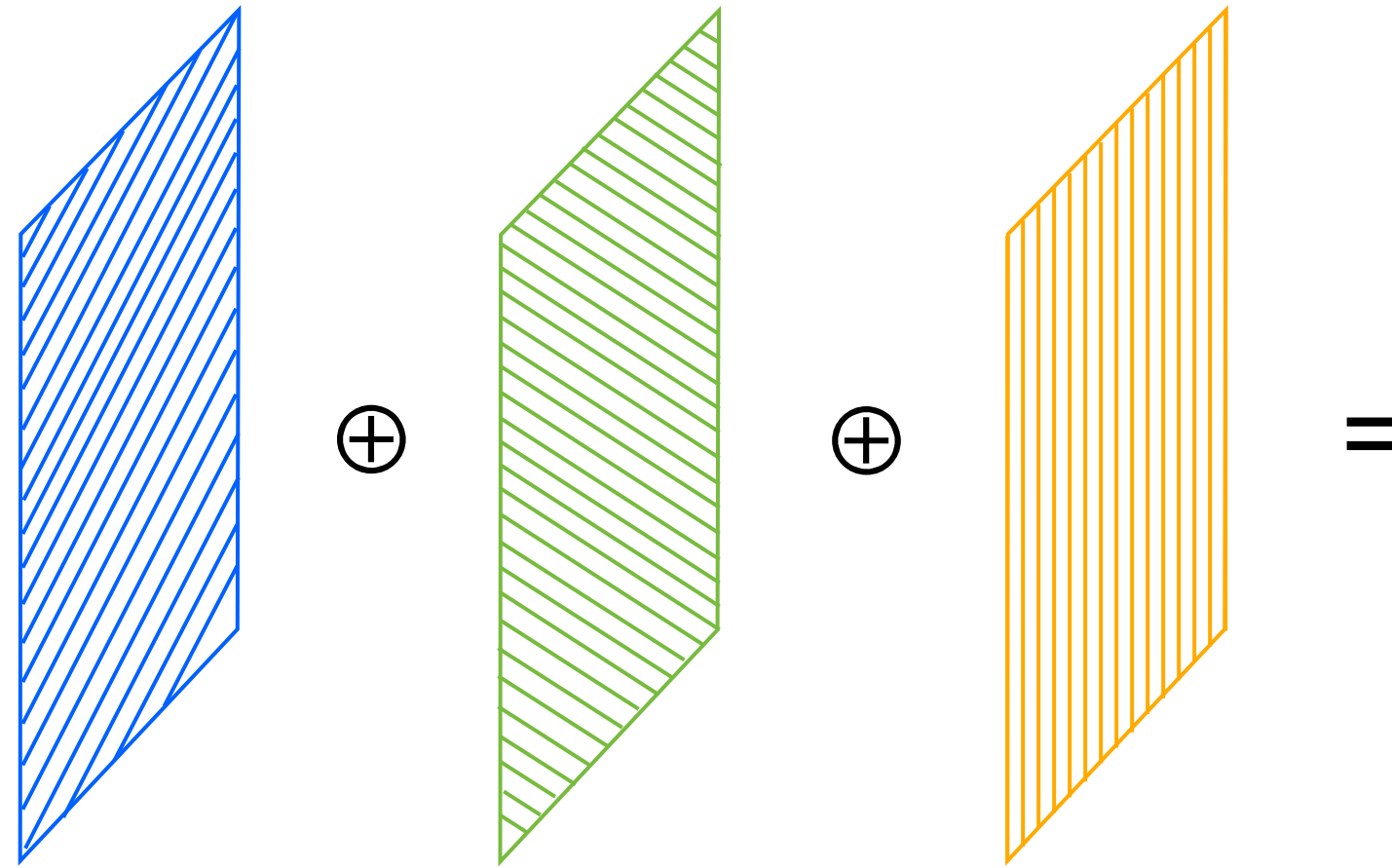


TPC Working Principle

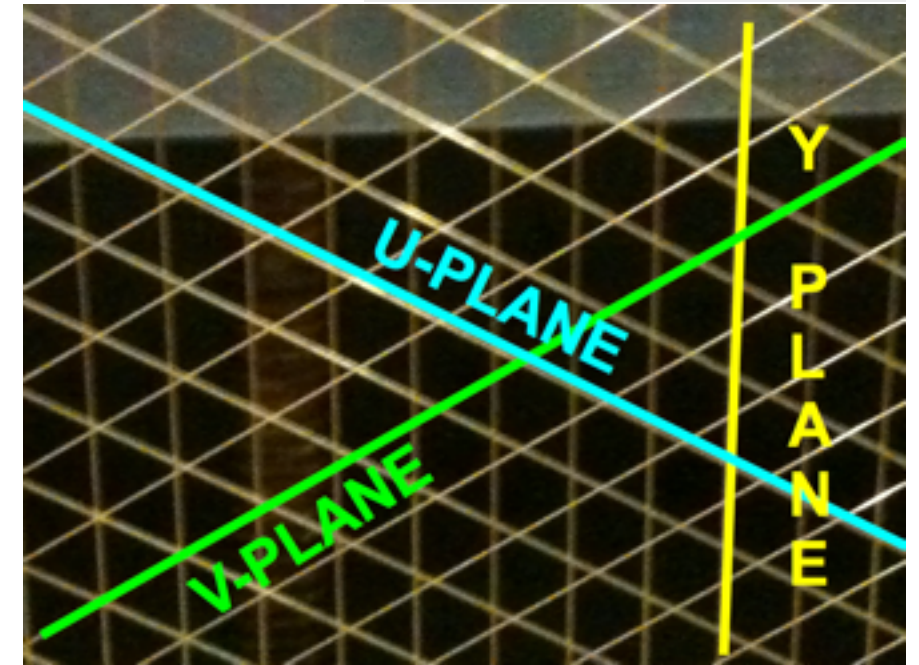
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Three Wire Planes



Picture courtesy of J. Asadi

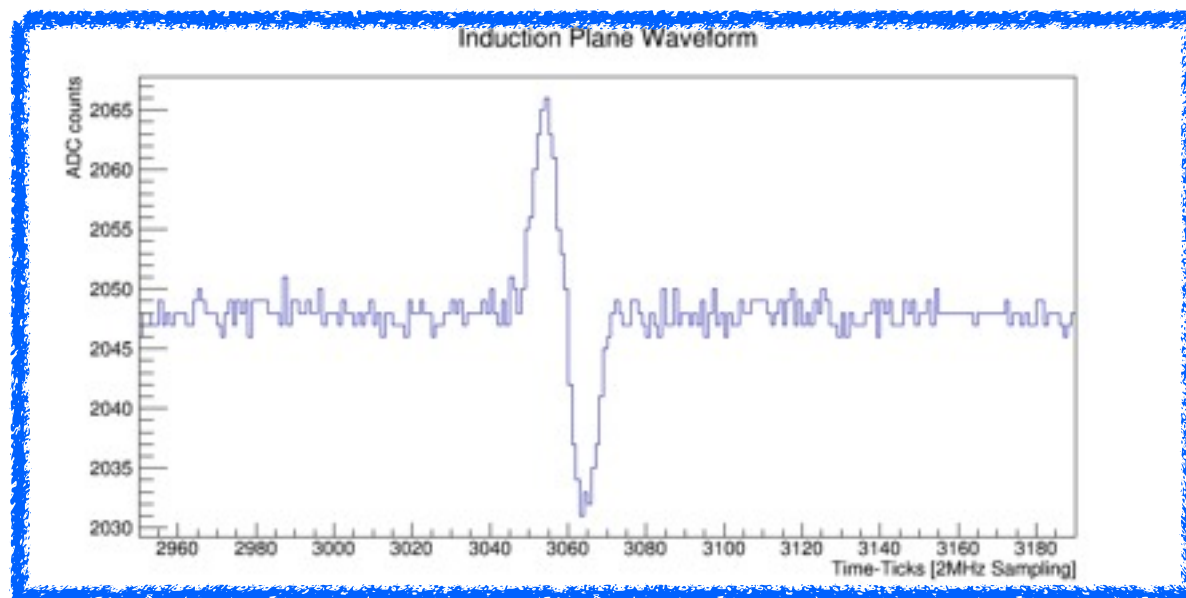


U plane
(induction)

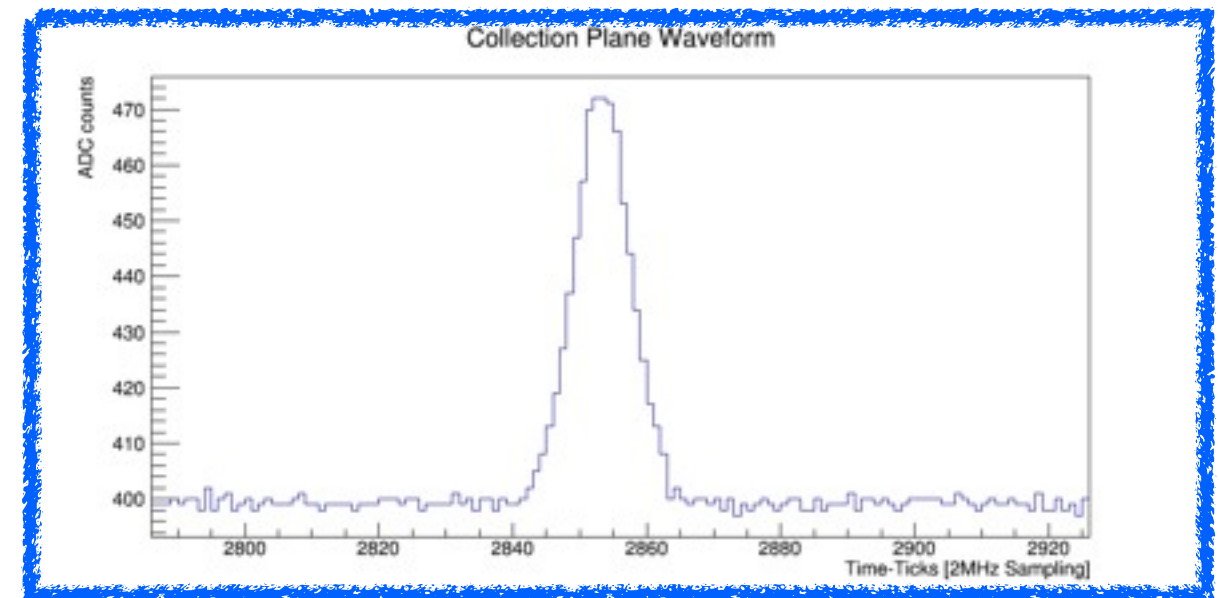
V plane
(induction)

Y plane
(collection)

8256 wires w/ pitch = 3mm
(Y, Z) = coincidence on wire

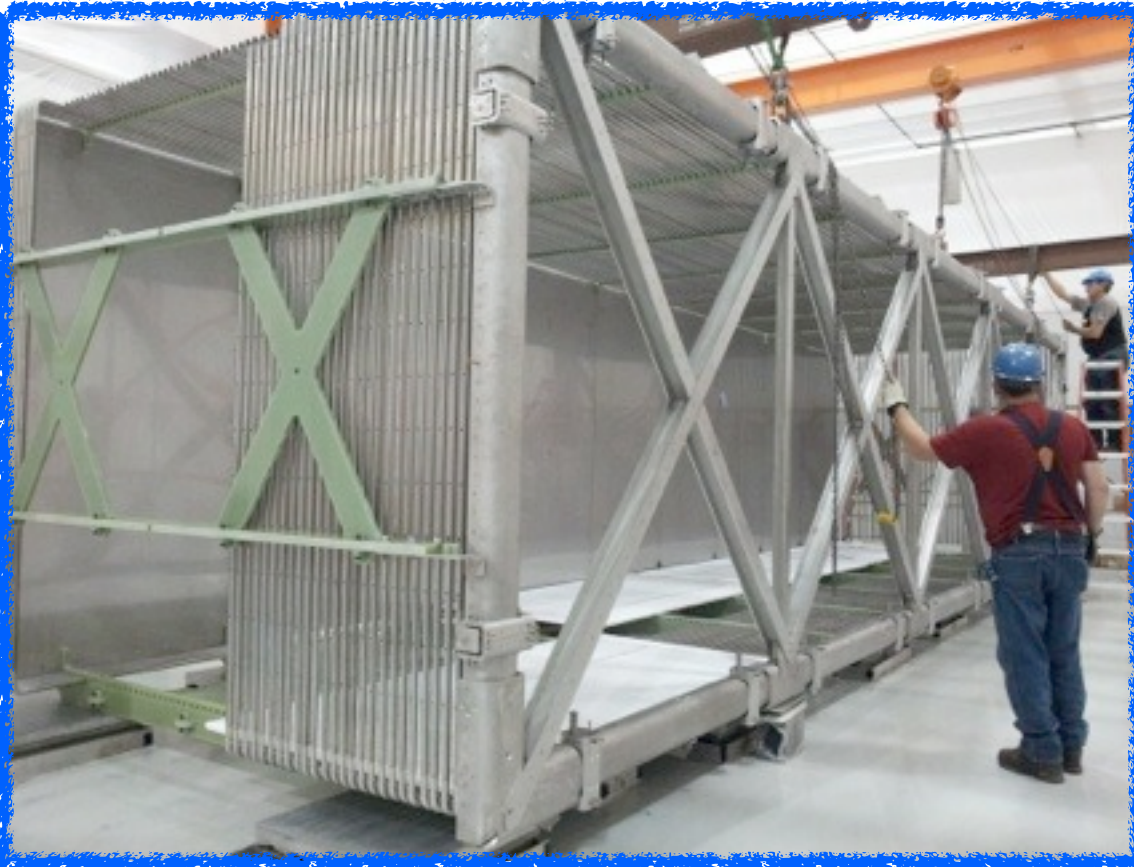
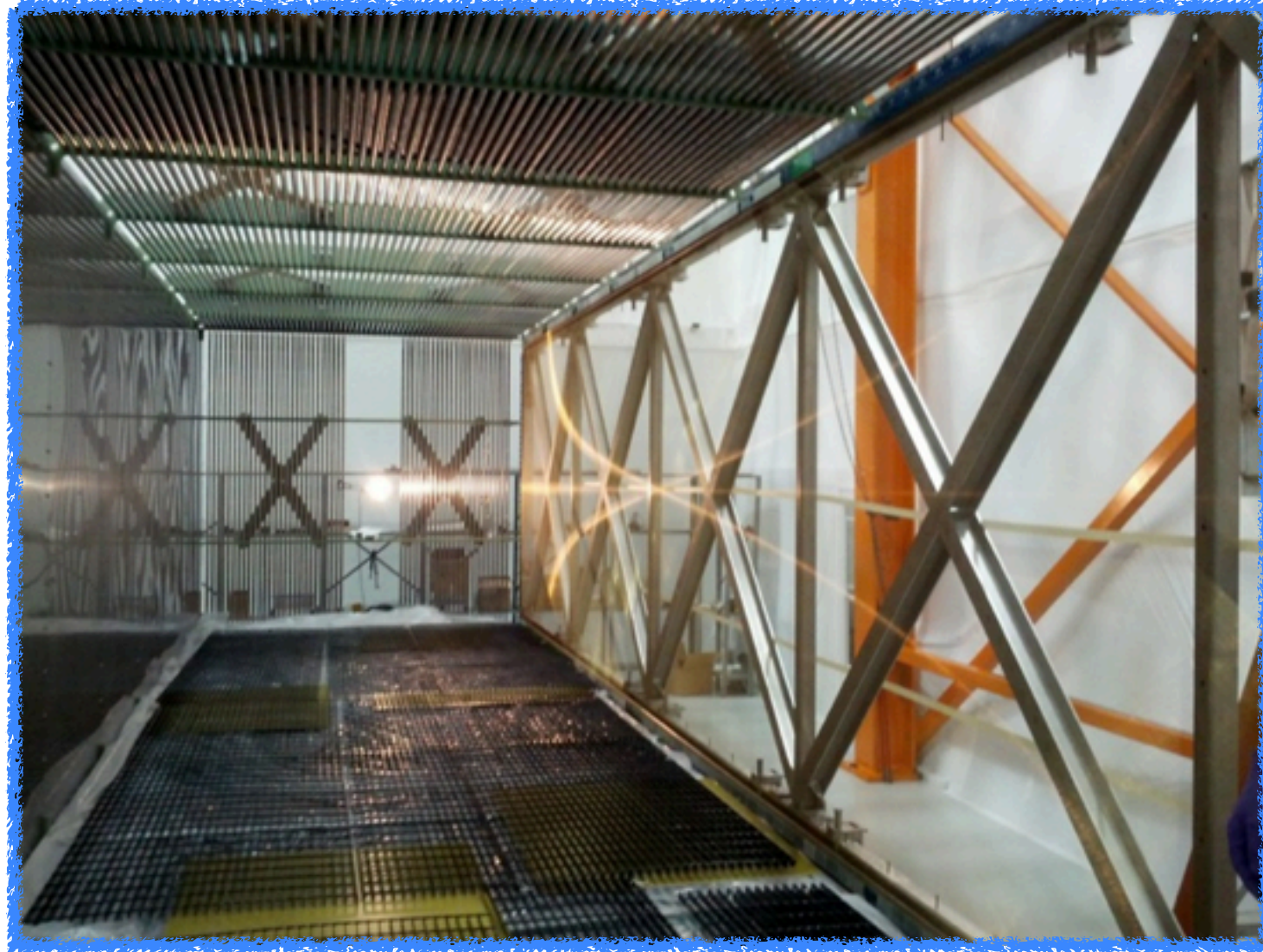


Induction Plane MC Waveform
(Bi-polar pulse as e^- pass through)



Collection Plane MC Waveform
(Uni-polar pulse as e^- pass through)

TPC Preparation



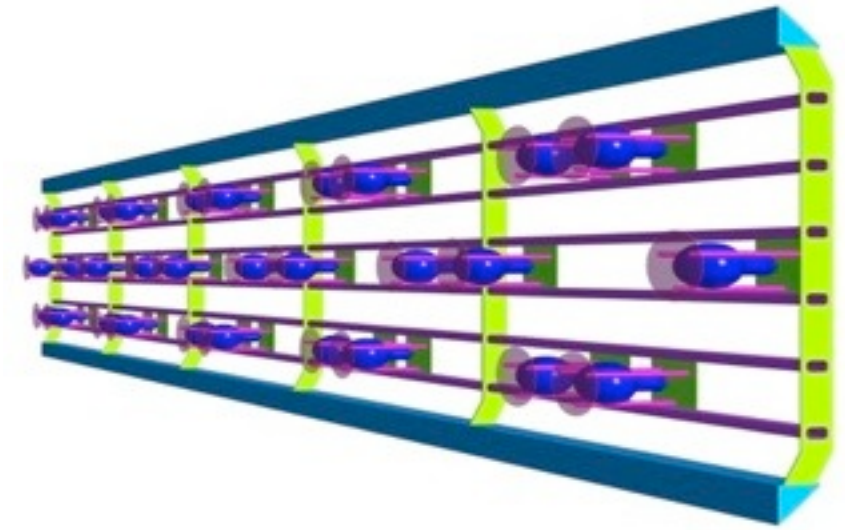
TPC built w/ 8256 wires!
w/ big effort on doing everything right :)

Optical Detector

- **What is it? What for?**
 - 32 of 8" PMTs
 - Crucial roles
 - ▶ **Getting trigger**
 - ▶ **Reconstructing YZ**
 - ✓ **Cosmic background rejection**



MicroBooNE PMT



Array of 32 PMTs

Optical Detector

- **What is it? What for?**

- 32 of 8" PMTs
- Crucial roles

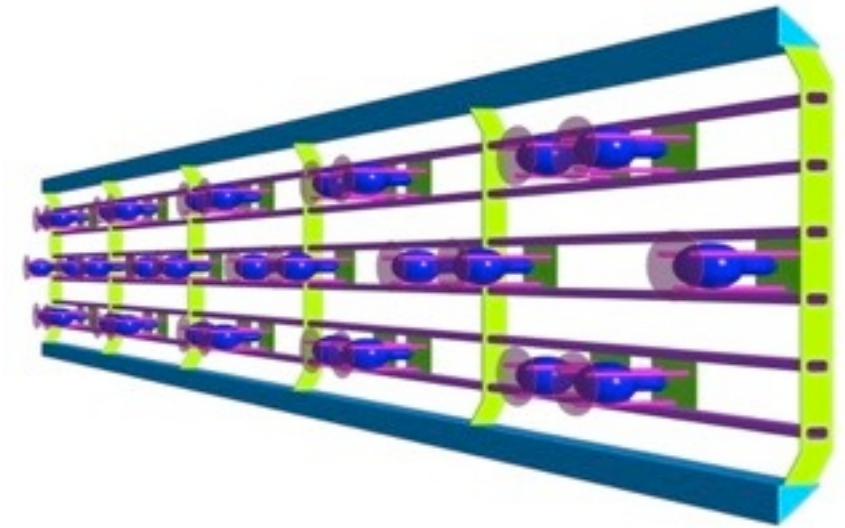
- ▶ **Getting trigger**

- ▶ **Reconstructing YZ**

- ✓ **Cosmic background rejection**



MicroBooNE PMT

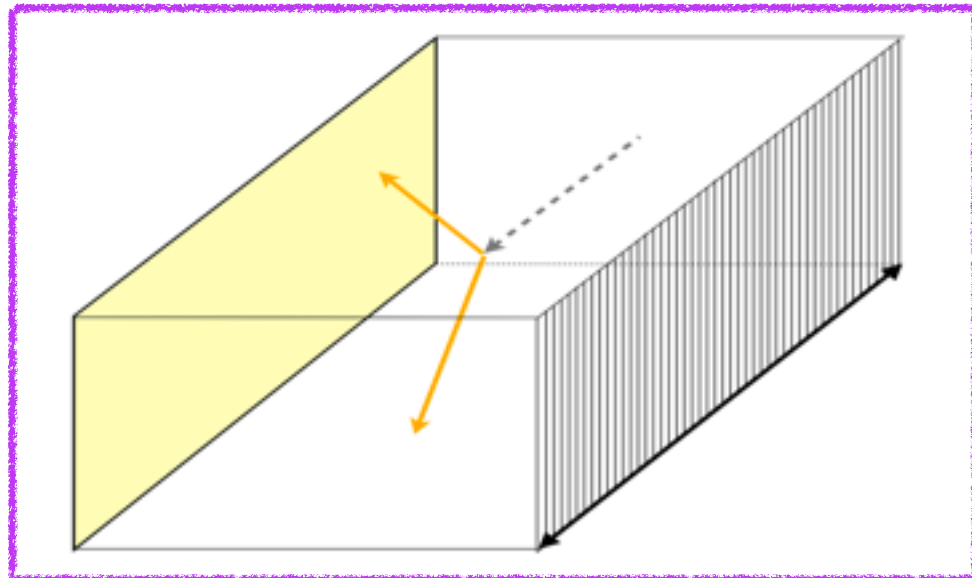


Array of 32 PMTs

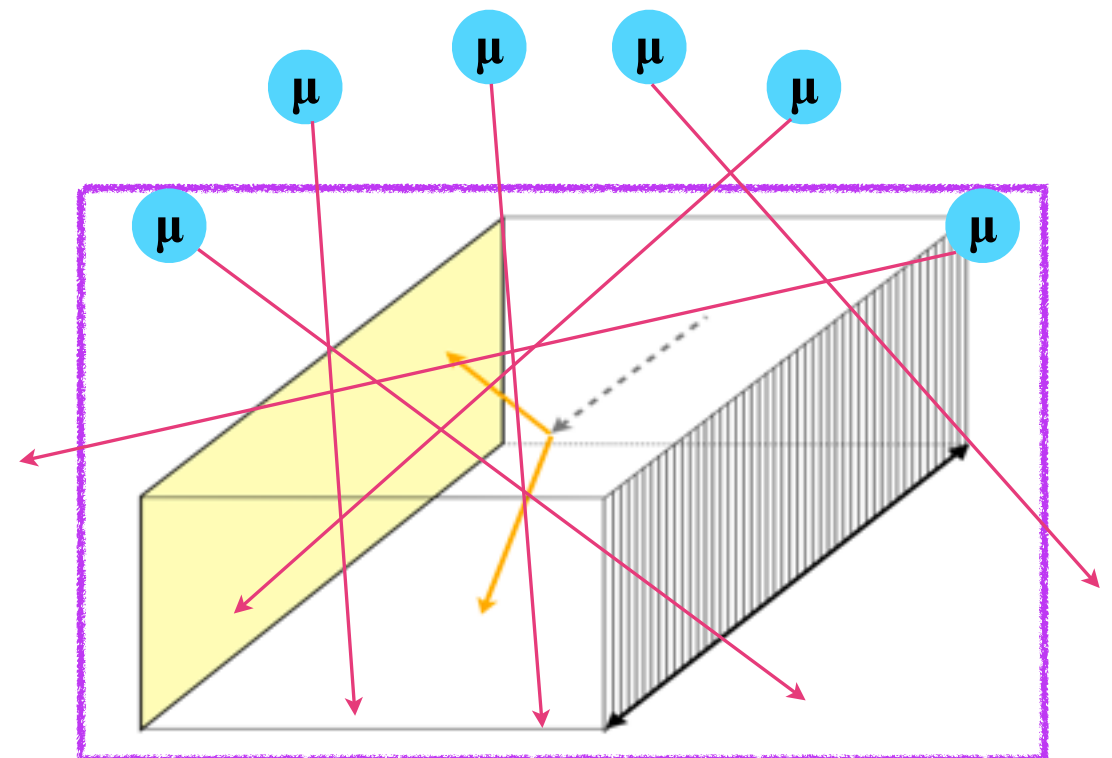
Crucial for MicroBooNE

because of

high cosmic ray rate ($\sim 5\text{kHz}$) @ surface!



What we want

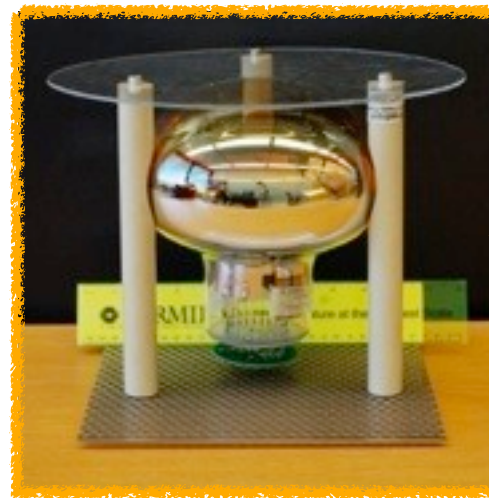


What we will have
several cosmes within
the **same drift time period (1.6 ms)**

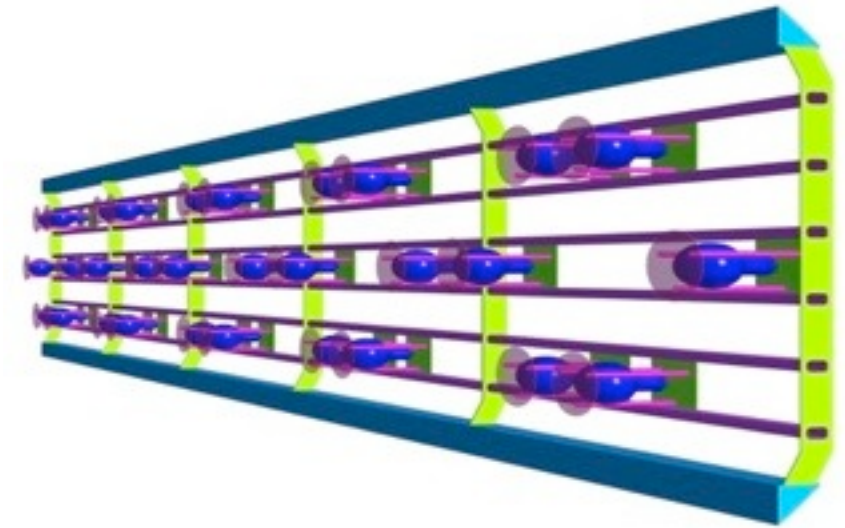
Optical Detector

- **What is it? What for?**

- 32 of 8" PMTs
- Crucial roles
 - ▶ Getting trigger
 - ▶ Reconstructing YZ
 - ✓ Cosmic background rejection



MicroBooNE PMT



Array of 32 PMTs

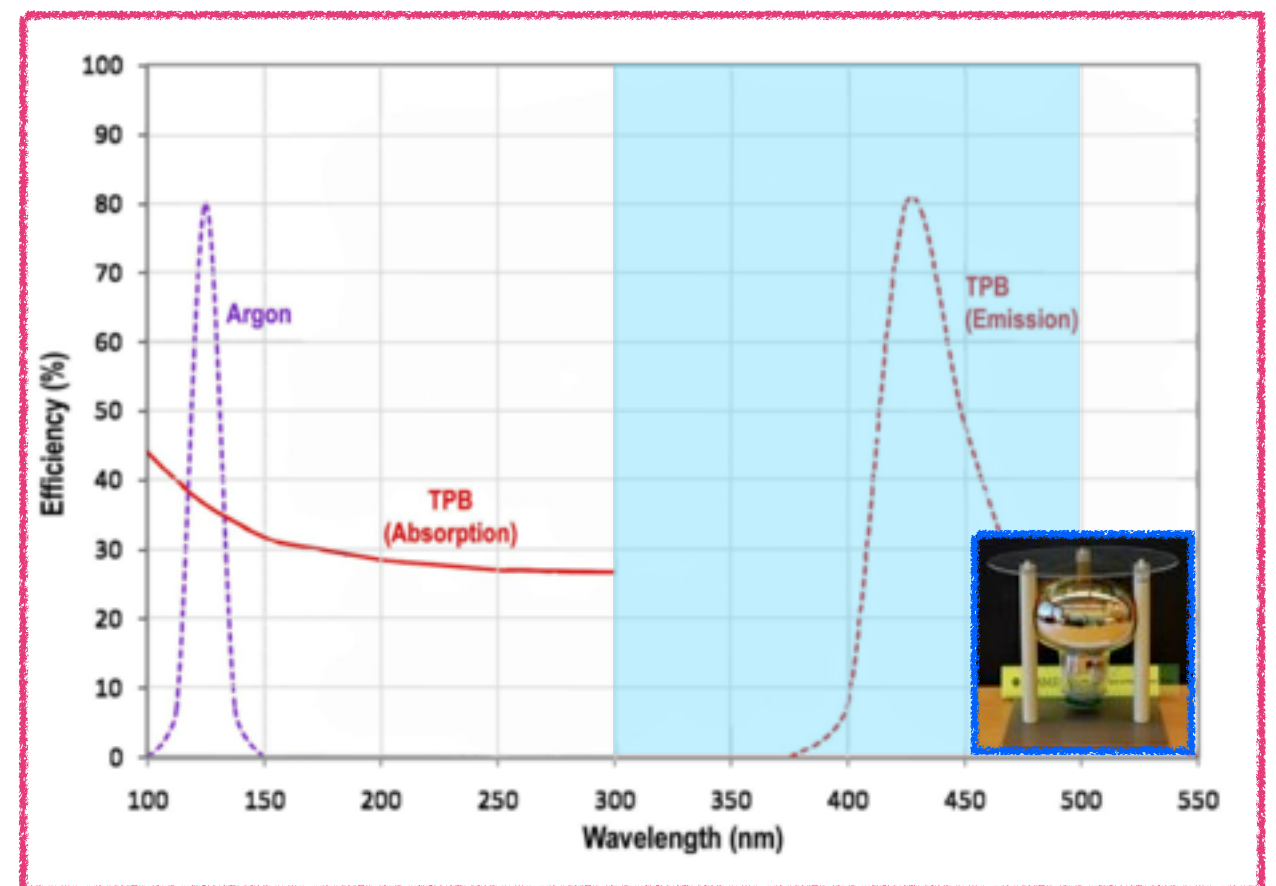
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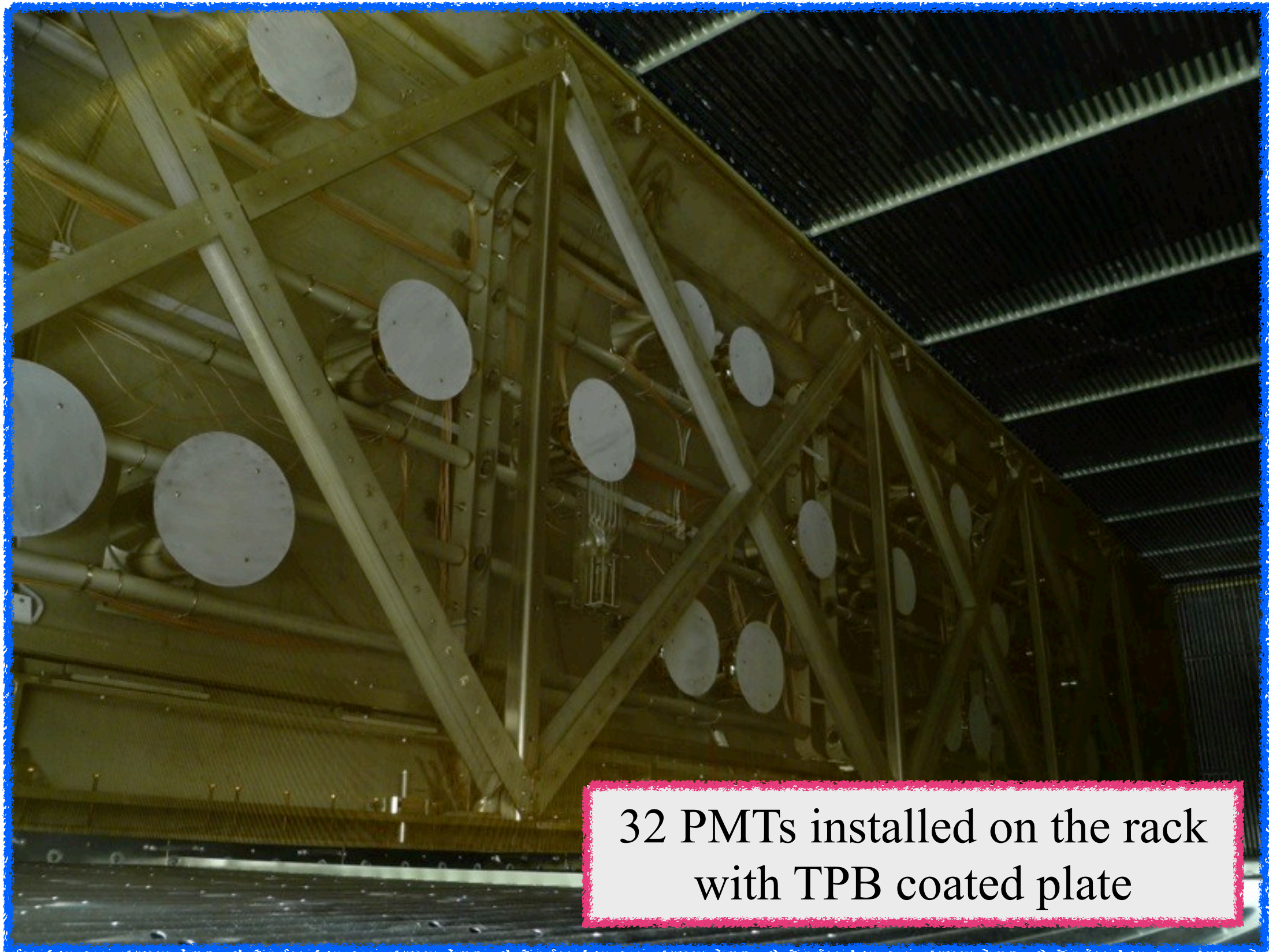
- **LAr optical properties**

- No detail here... but LOTS of physics!
 - ▶ Read arxiv 1306.4605 for instance
- Produced within **6 ns** of interaction
- High light yield ≈ 6000 photons / MeV
- **“Transparent” to its own light**
 - ▶ Light travels to PMT immediately
 - ▶ Wavelength shift by **TPB**



TPB shifts wavelength from 128 nm to 430 nm, appropriate for PMTs

Optical Detector



This picture is taken with 60 [s] exposure time in covered (dark) cryostat
Courtesy of Christoph Rudolf von Rohr

Getting Large LArTPC to Work

... is not trivial in case that is not clear!

- **Design**

- Procedure to fill a large detector with high purity LAr + monitoring
- Prevention & protection of HV discharge in high purity LAr
- Cold electronics (first signal processing inside LAr)
- Optical properties of high purity LAr under HV

- **Operation**

- Good control for temperature, HV, purity, E-field ... “must” for high quality data
- High data rate handling

- **Calibration**

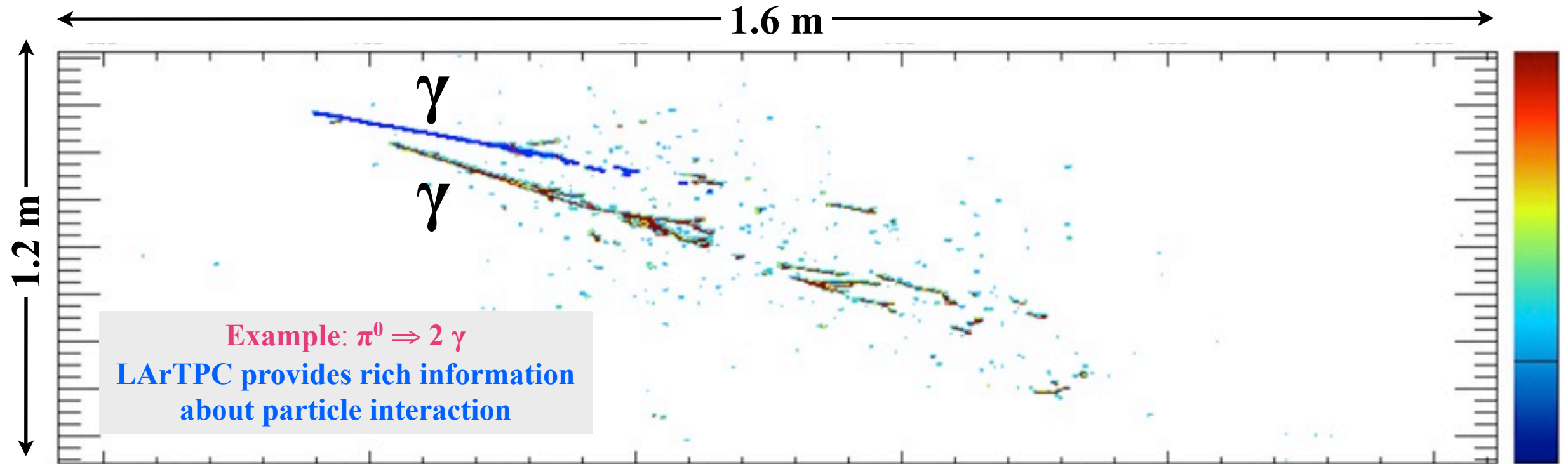
- UV laser calibration system for calibrating the non-uniform E field distortion

- **Reconstruction & Analysis**

- Development for an automated reconstruction software for generic LArTPC

MicroBooNE is a pioneer of LArTPC R&D!

... When All Work Out Well ...



Reconstructed “Hit” on the collection plane
Color = deposited charge

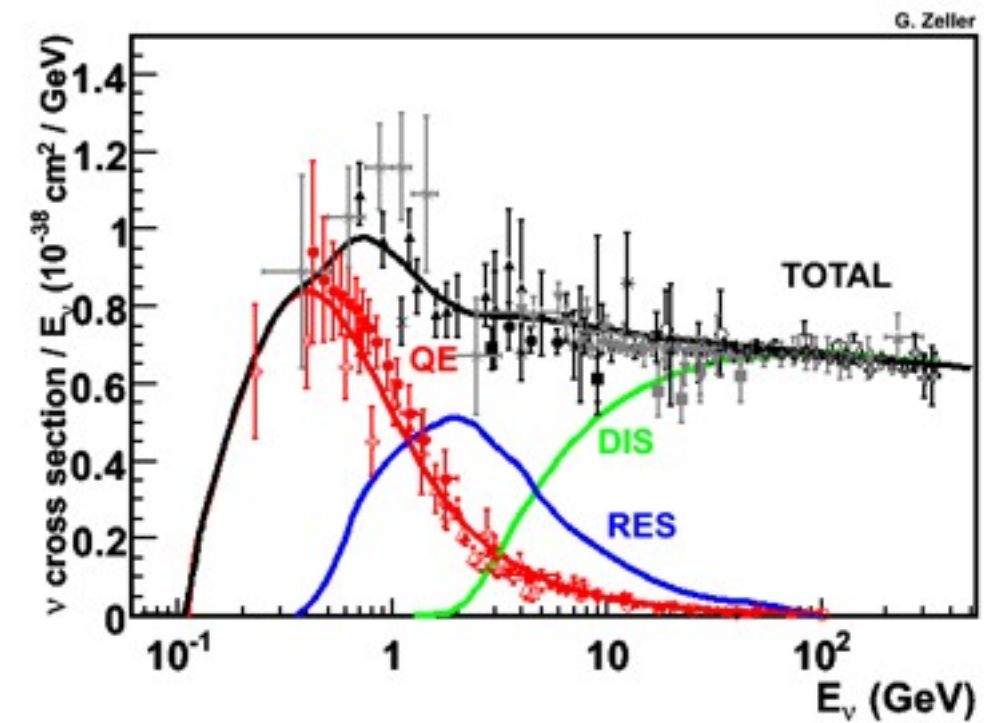
- We get:
 - Great detail of particle tracks
 - Calorimetry information from 3 planes
- Huge effort on automated reconstruction
 - Very active & exciting development frontier
 - Unfortunately I have to skip this time (a whole another talk!)

... So ...
what physics can we do?

MicroBooNE Physics: XS Measurement

- MicroBooNE adds **data points < 1 GeV**
 - The region that is not well explored
 - Crucial for future LAr experiments

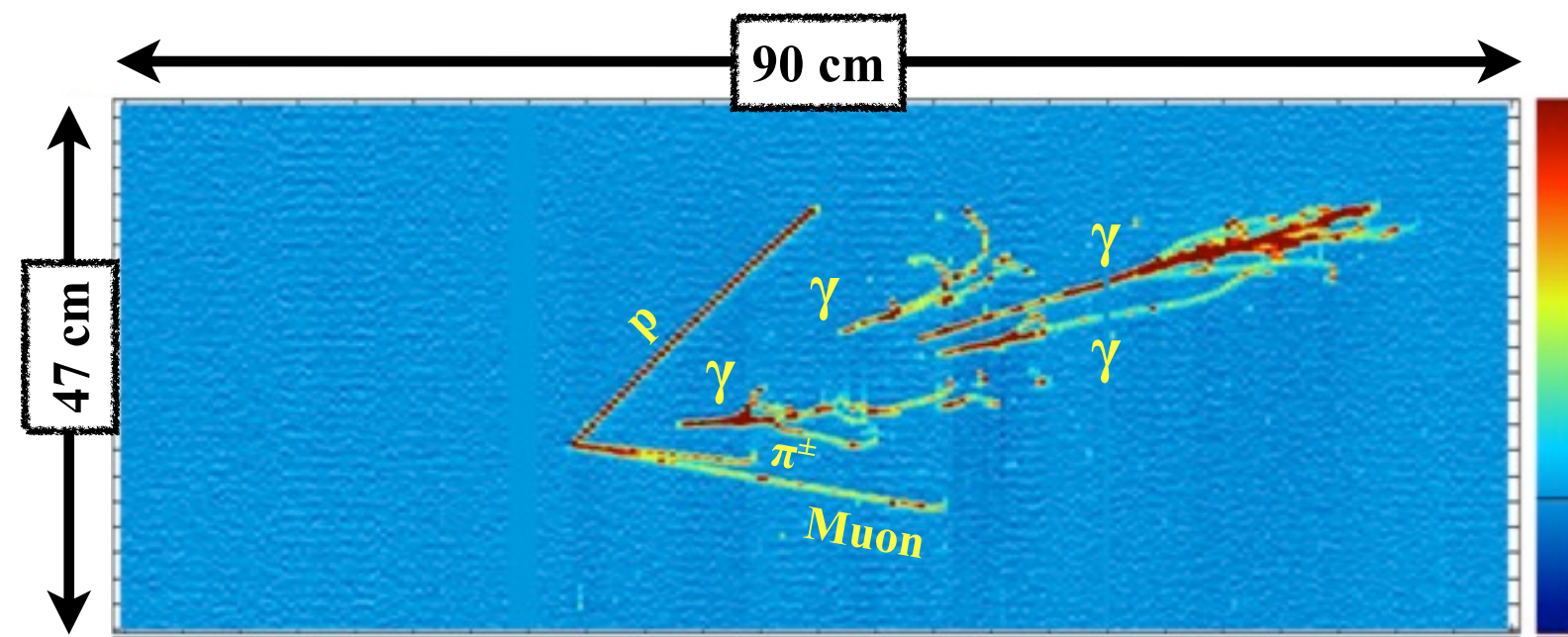
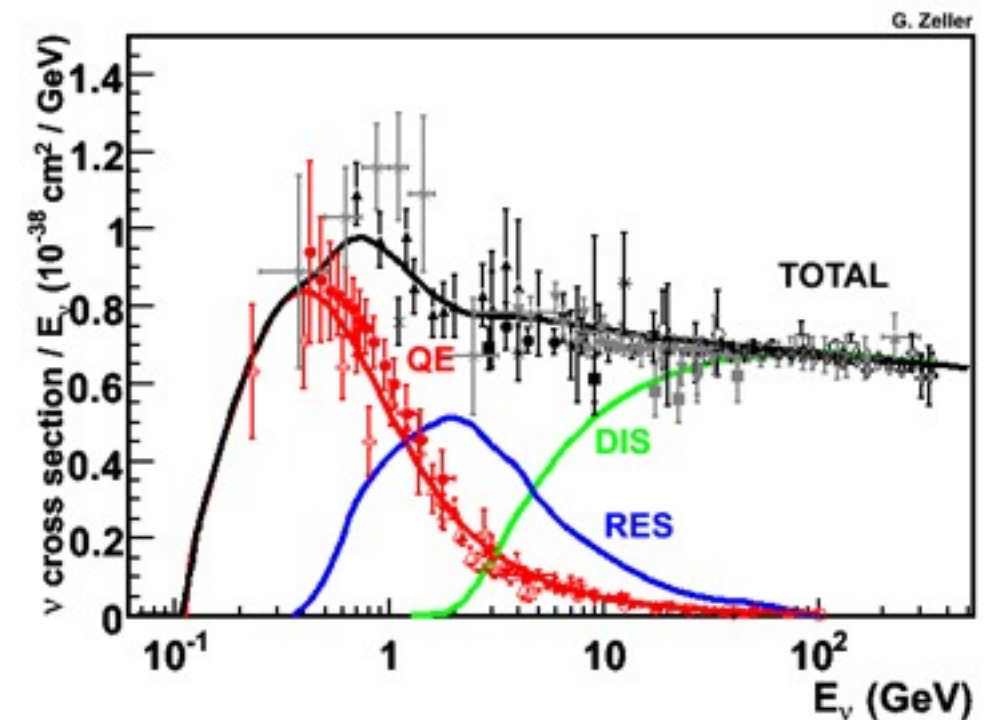
Neutrino per Nucleon XS
Rev. Mod. Phys. 84, 1307 (2012)



MicroBooNE Physics: XS Measurement

- MicroBooNE adds **data points < 1 GeV**
 - The region that is not well explored
 - Crucial for future LAr experiments
- **Probe various nuclear final state**
 - Huge effort on nuclear model on-going
 - Probe in this energy range is crucial

Neutrino per Nucleon XS
Rev. Mod. Phys. 84, 1307 (2012)

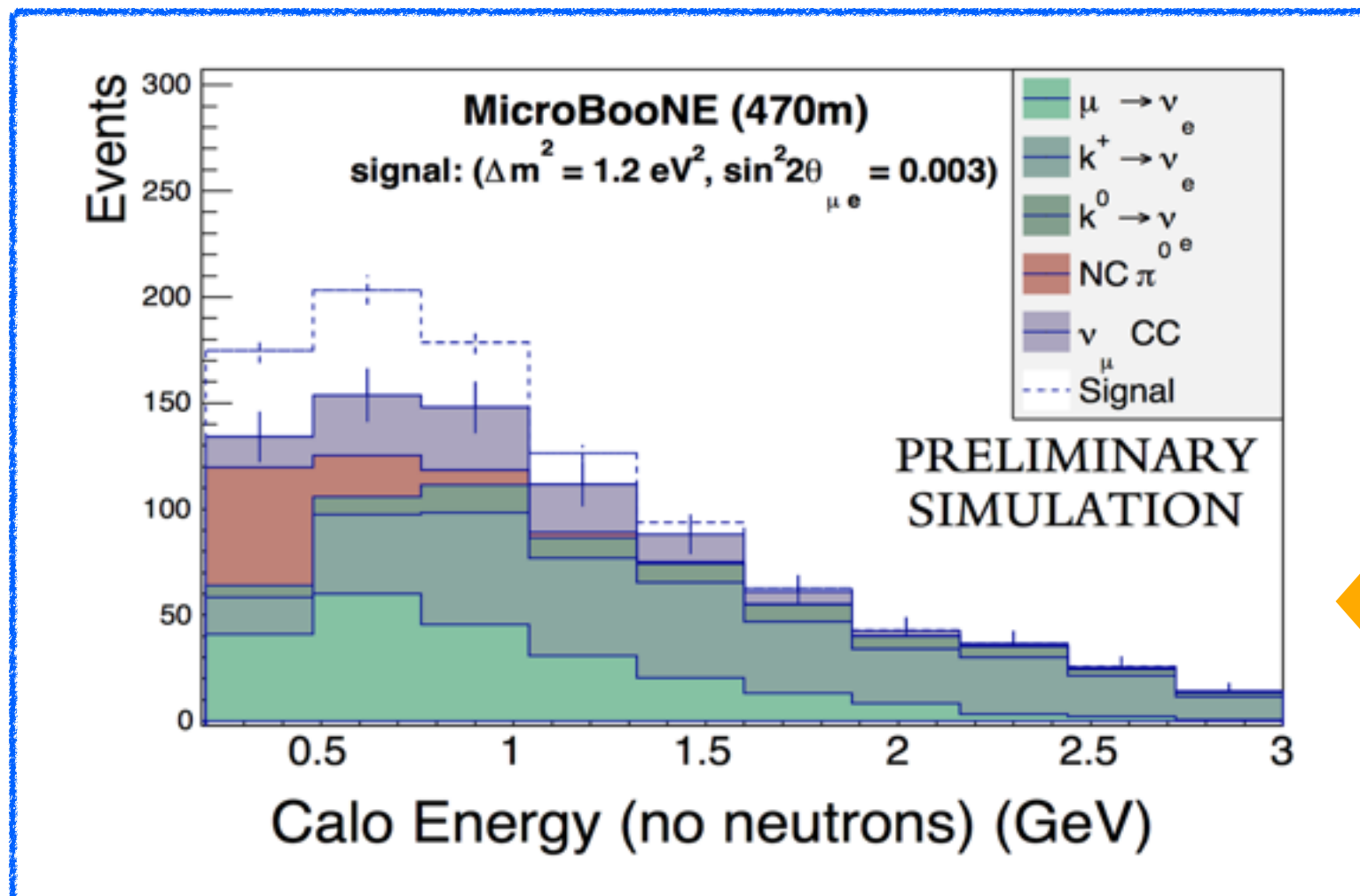


Example DIS event
(courtesy of ArgoNeuT collaboration)

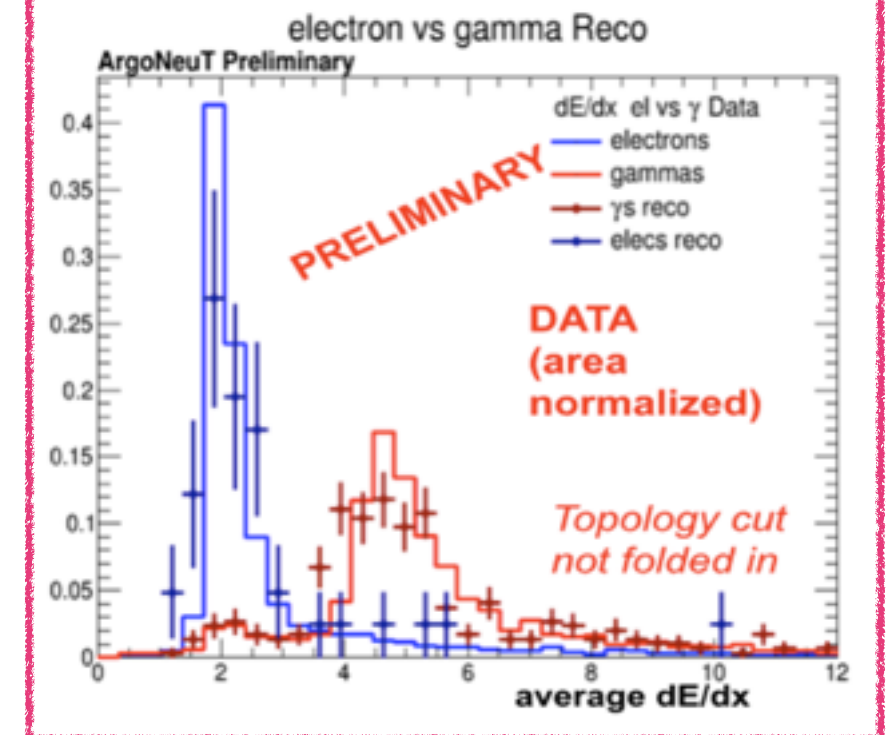
MicroBooNE provides
crucial knowledge
about **ν -Ar cross-section**
for future LArTPC

MicroBooNE Physics: Low E Excess

- Excellent particle ID using LArTPC
 - dE/dX distinguish single e^- from γ
 - ▶ 1 MIP for γ and 2 MIPs for e^- near shower vertex
- MicroBooNE can probe low E excess!
 - Identify the source is either e^- or γ like



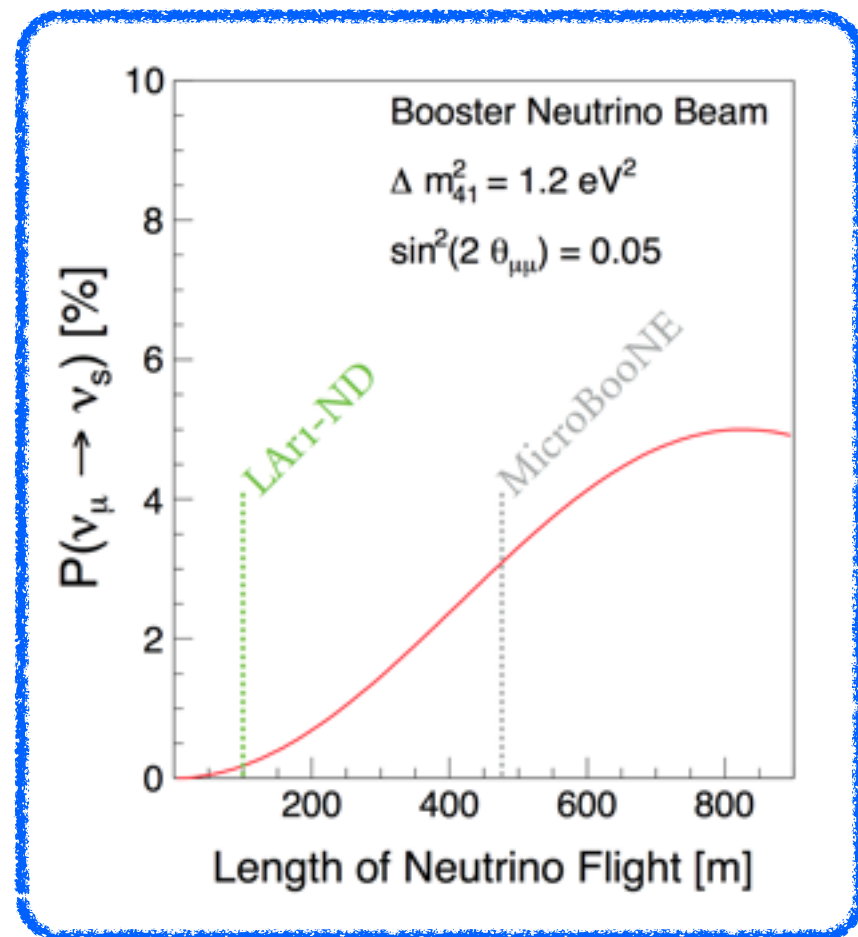
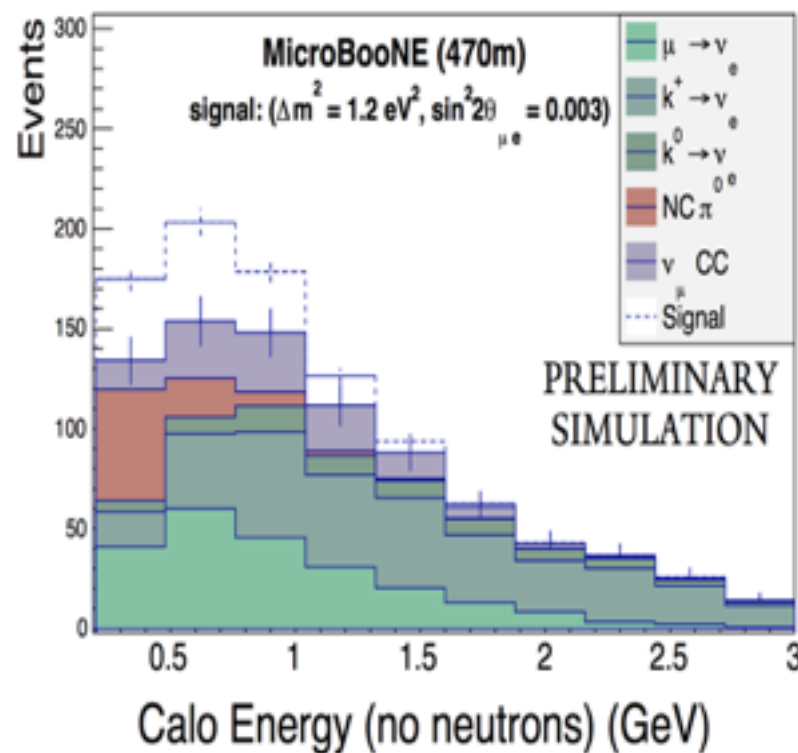
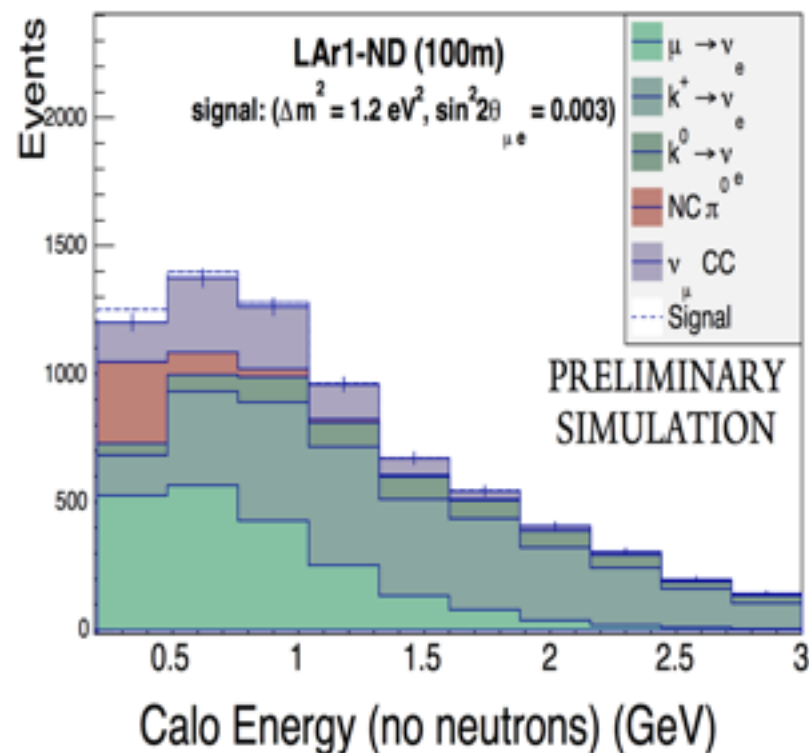
Data vs. MC comparison for
Single γ and e^- selection
 Andrzej S. from ArgoNeuT



Predicted low energy excess in MicroBooNE based on
 MiniBooNE excess and 3+1
 oscillation hypothesis
 Corey A. from MicroBooNE

MicroBooNE + Near Detector

- MicroBooNE definitively addresses the size & nature of low E excess
 - What about “definitive oscillation measurement”?
 - Modern approach: use a near detector to measure incoming flux
- Short Baseline Neutrino (SBN) experiment
 - Employs a near detector (ND)
 - Can be used as the ND for MicroBooNE!
- ND allows definitive oscillation measurement



Plots: courtesy of **Corey A.** from **Neutrino2014**
 Plots are based on MiniBooNE data with sterile neutrino assumption under (3+1 model)

MicroBooNE

Liquid Argon TPC at Fermilab

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Detector Construction Done!



Inserting TPC



Putting end cap on...

- TPC & TPC installed inside the cryostat
- End cap welded
- ... @ “DAB” ... assembly building!



Installation Begins!

- Detector moved to LArTF on 6/23
 - where we take data!
- Installation ... now!
 - platform, piping, etc.
- Detector commissioning in Fall
- Neutrino data taking in Winter!



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Summary

- **MicroBooNE**

- LArTPC (90 ton active) with BNB neutrino source at Fermilab
- Part of a big LArTPC R&D project in U.S.
- Physics goals
 - ▶ Probe MiniBooNE low energy excess
 - ▶ Neutrino-Argon cross-section measurement
 - ▶ Neutrino oscillation

- **Experiment Status**

- Detector construction finished
- Installation on-going
- Aiming for first neutrino in Winter 2014!

Back Up Slides