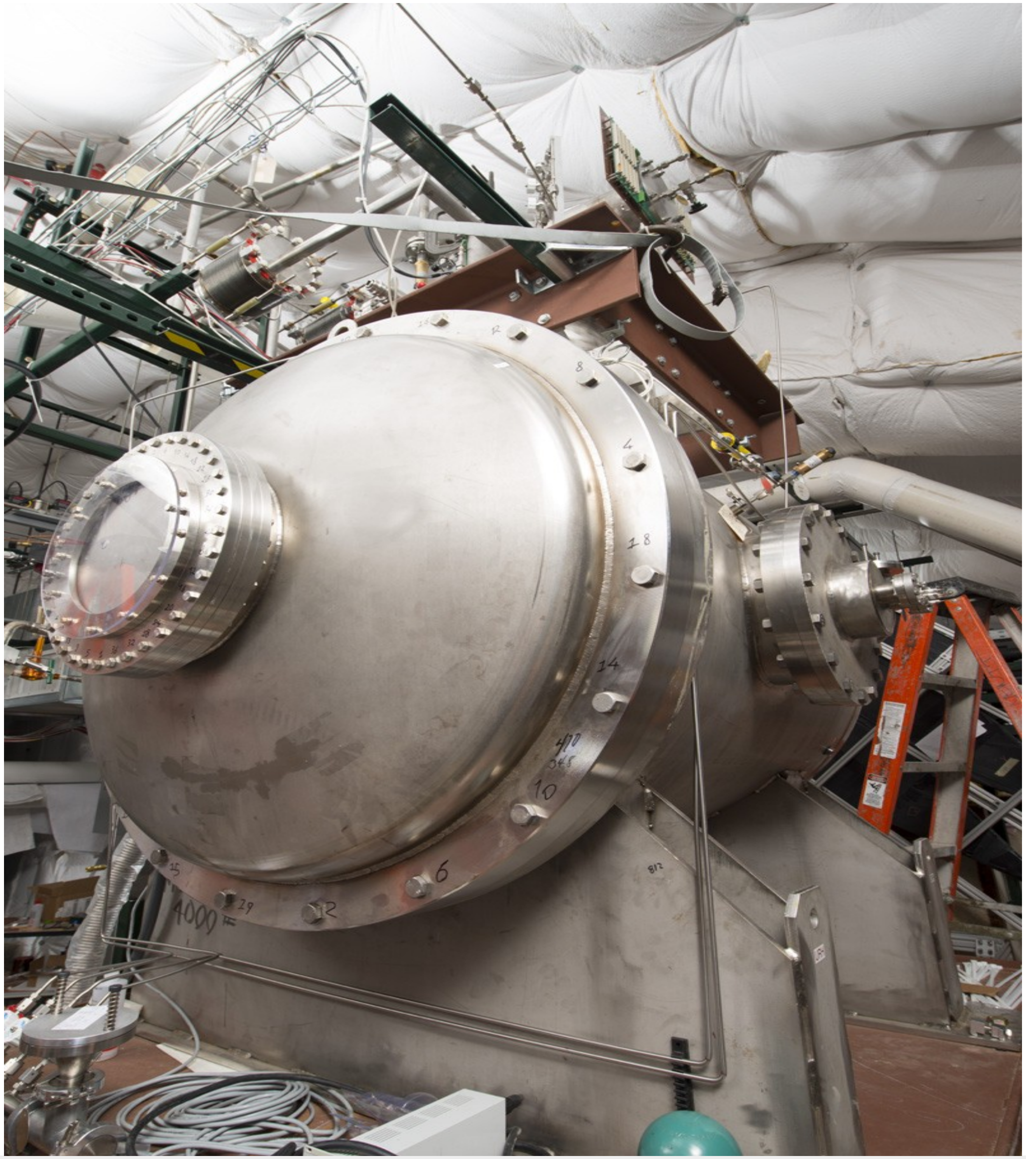
LArIAT
Liquid Argon TPC In A Testbeam
Charged Pion-Ar total interaction cross-section

Animesh Chatterjee
University of Texas Arlington
On behalf of the LArIAT Collaboration

ICHEP, August 3-10, 2016
Chicago

Office of Science
U.S. Department of Energy

What is LArIAT?

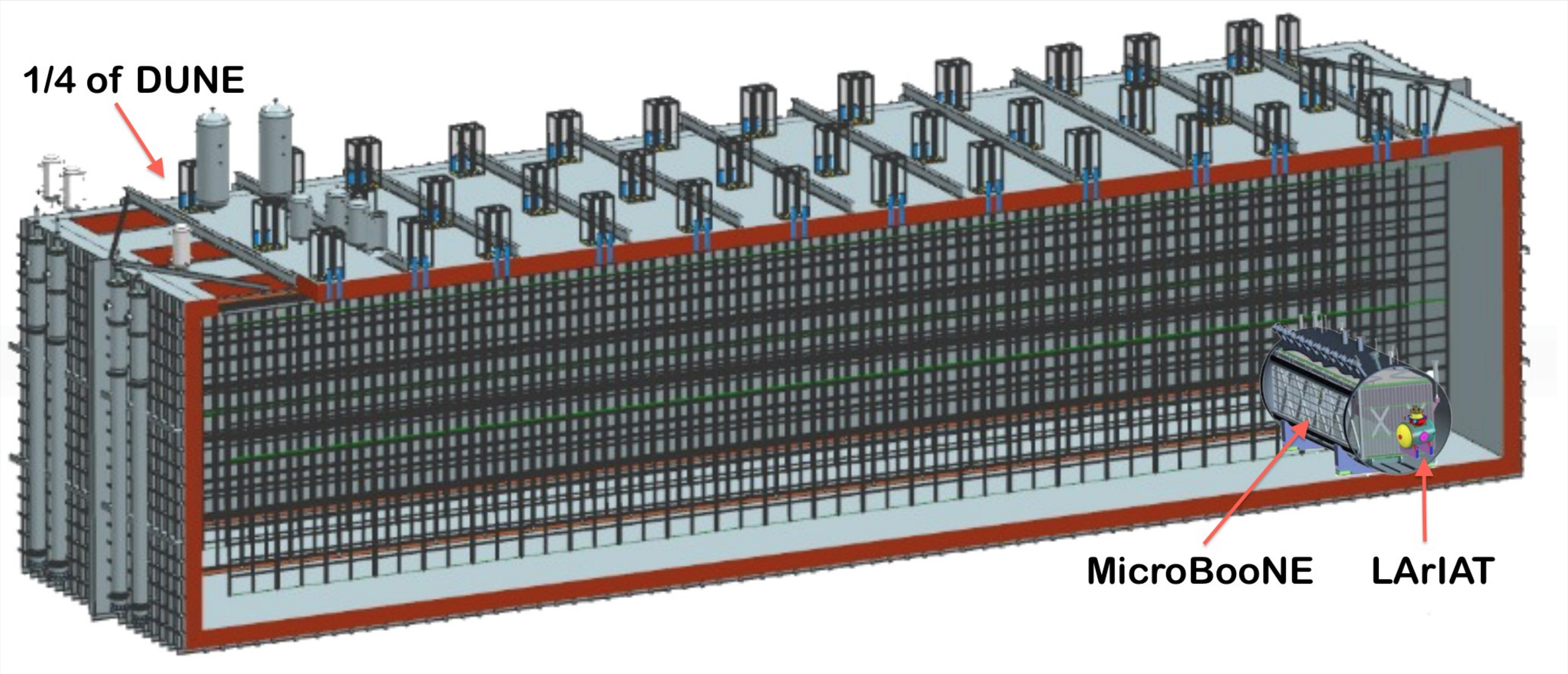


- LArIAT is a 170 liters of LArTPC designed for calibrating detector response in a charged particle beam.
- Main motivation is to execute a comprehensive program to characterize LArTPC performance in the energy range relevant to both the Short-Baseline (μBooNE, SBND, ICARUS) and Long-Baseline(DUNE) neutrino experiments.

LArIAT: Liquid Argon In A Testbeam

Scale of LArIAT

- One 10kT DUNE LArTPC Module(18m x 19m x 66m)



LArIAT TPC (0.25 tons)
(0.4 m x 0.47 m x 0.9 m)

Small detector but Rich Physics goal !

Why LArIAT?

- **Physics Goals :**

  - Hadron-Ar interaction cross sections

  - Study of nuclear effects in Ar

  - e/γ shower identification

  - Particle sign determination in the absence of a magnetic field utilizing topology(e.g. decay vs capture).

  - Geant4 validation

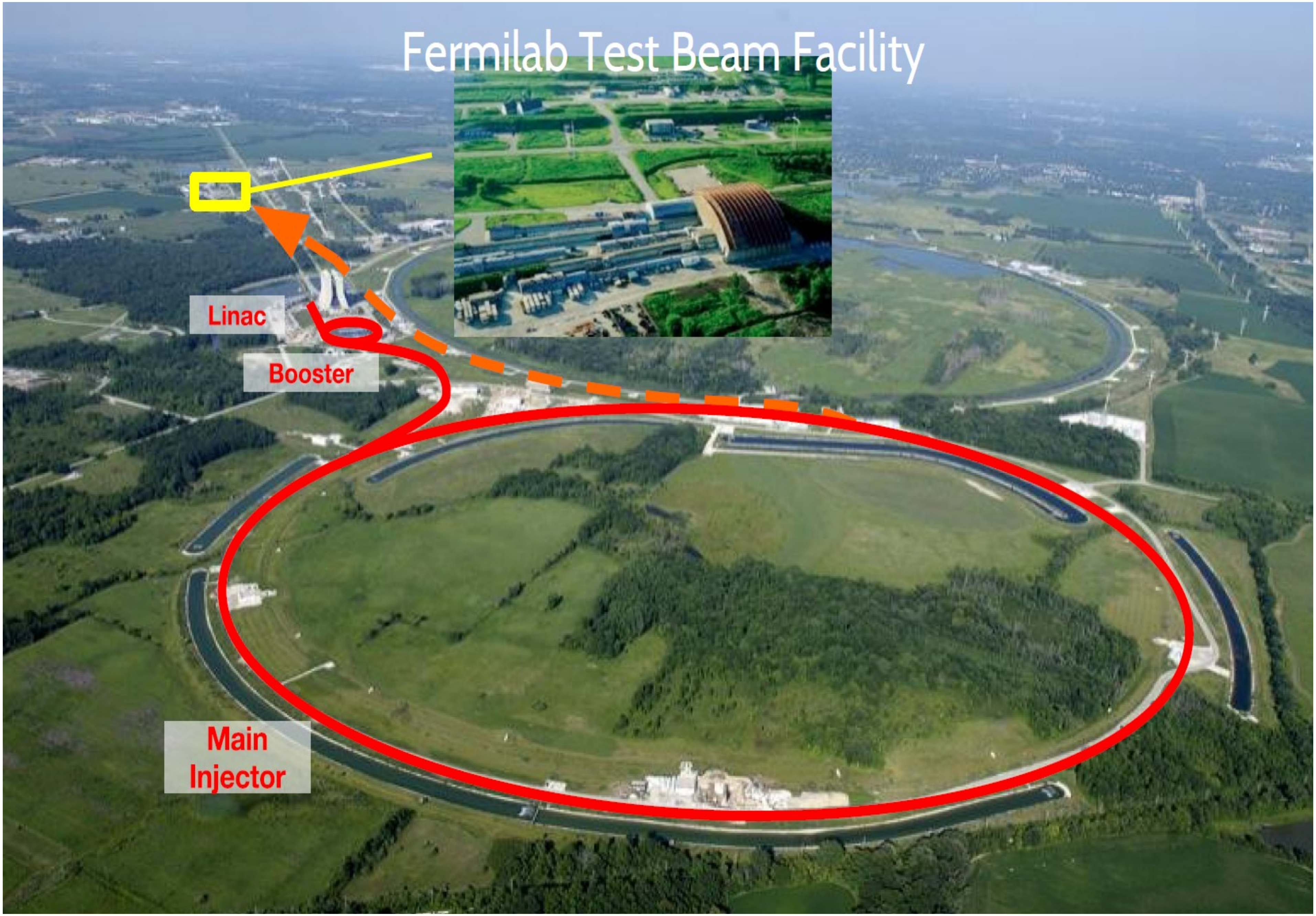
- **R&D Goals :**

  - Ionization and scintillation light studies

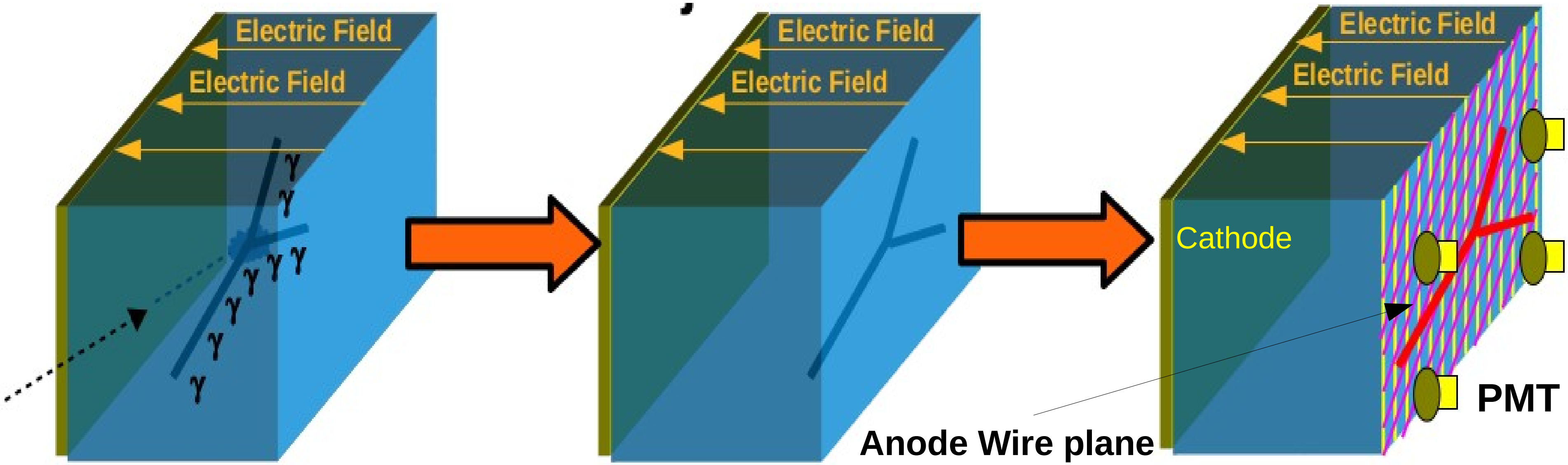
  - Optimization of particle ID techniques

  - LArTPC event reconstruction

Where is LArIAT?

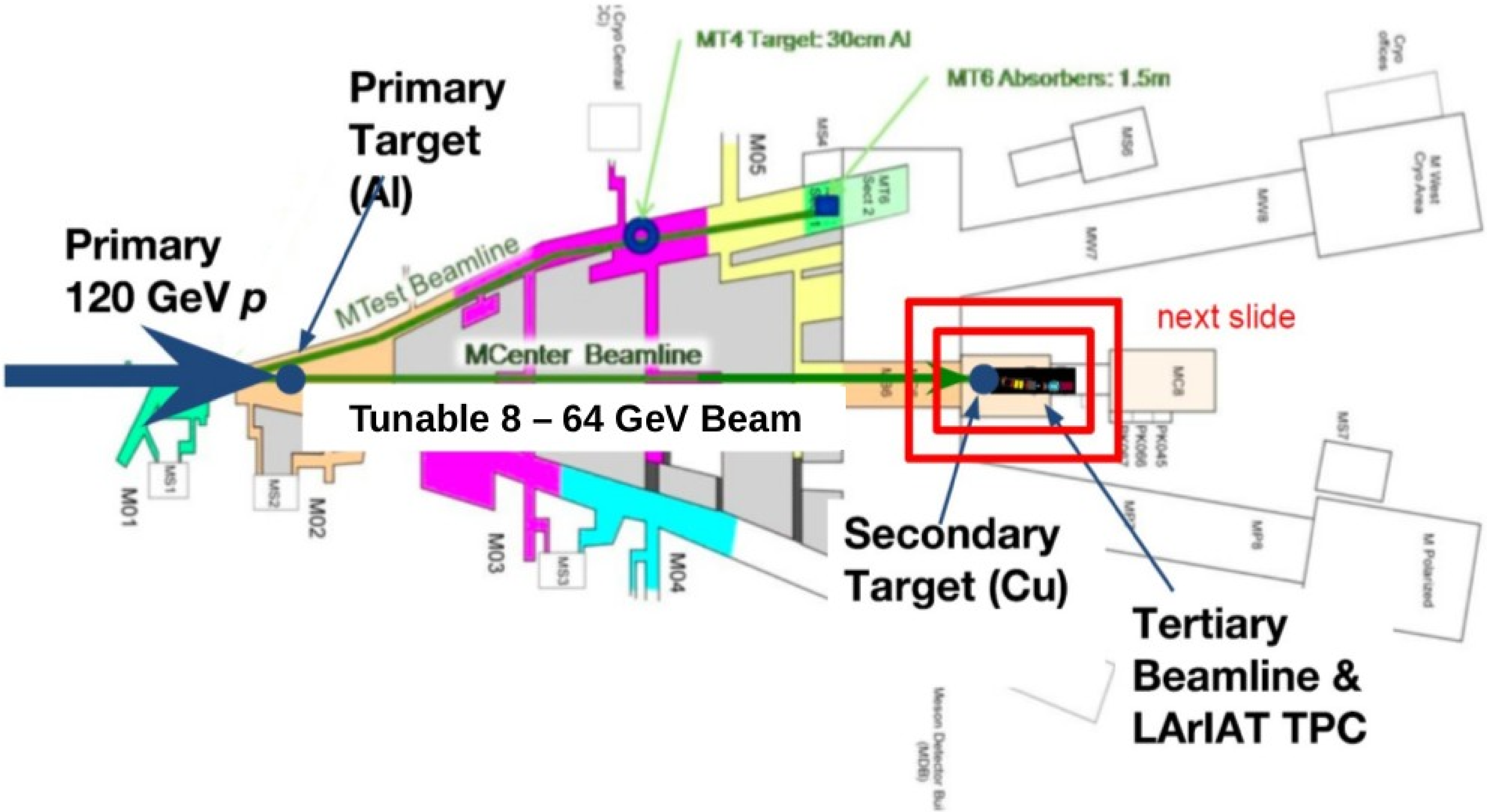


LArTPC working principles

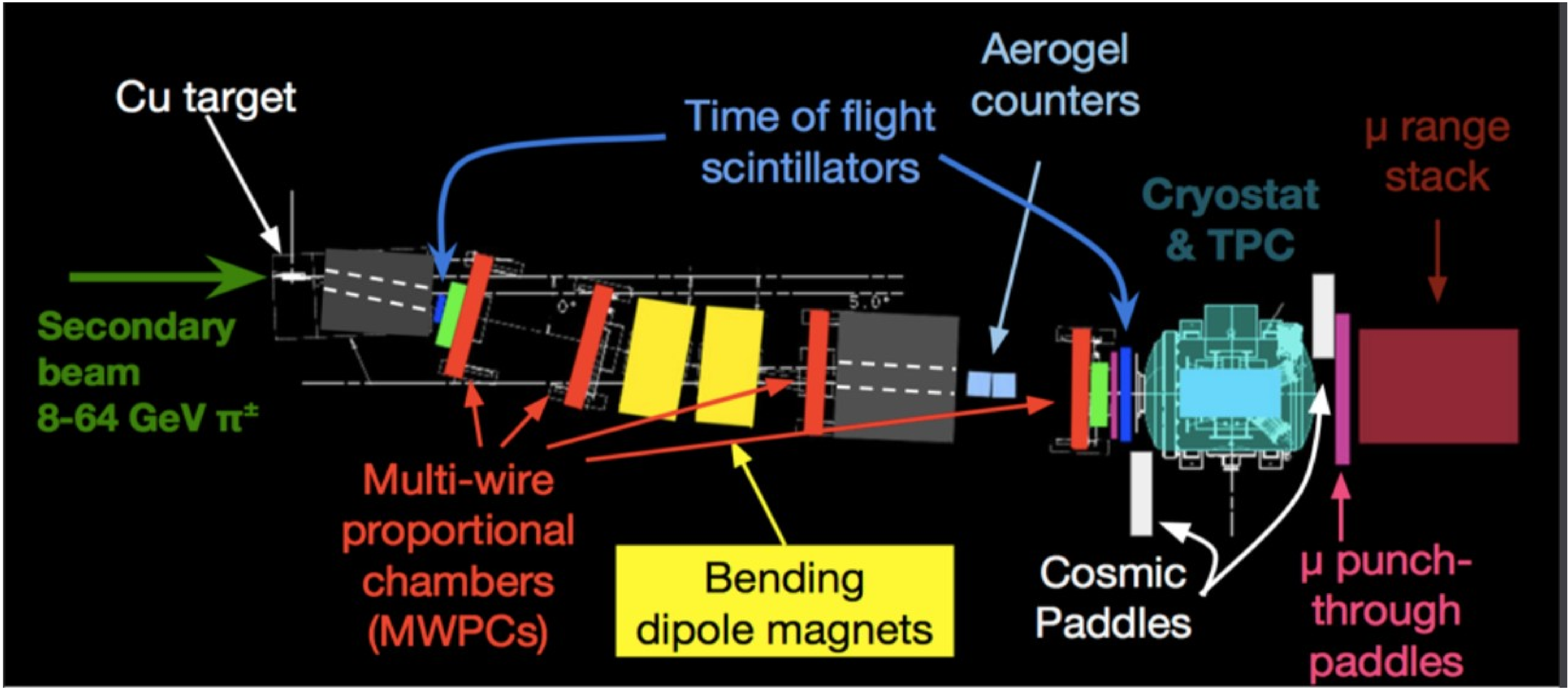


- Particle interaction in LAr produces ionization and scintillation light.
- Prompt light emission (read out by PMT's) starts the clock.
- Electrons drifts to the anode (Ar^+ ion drifts to the cathode).
- Electron induces charge on the wire.
- Tracks are reconstructed from the wire signals.

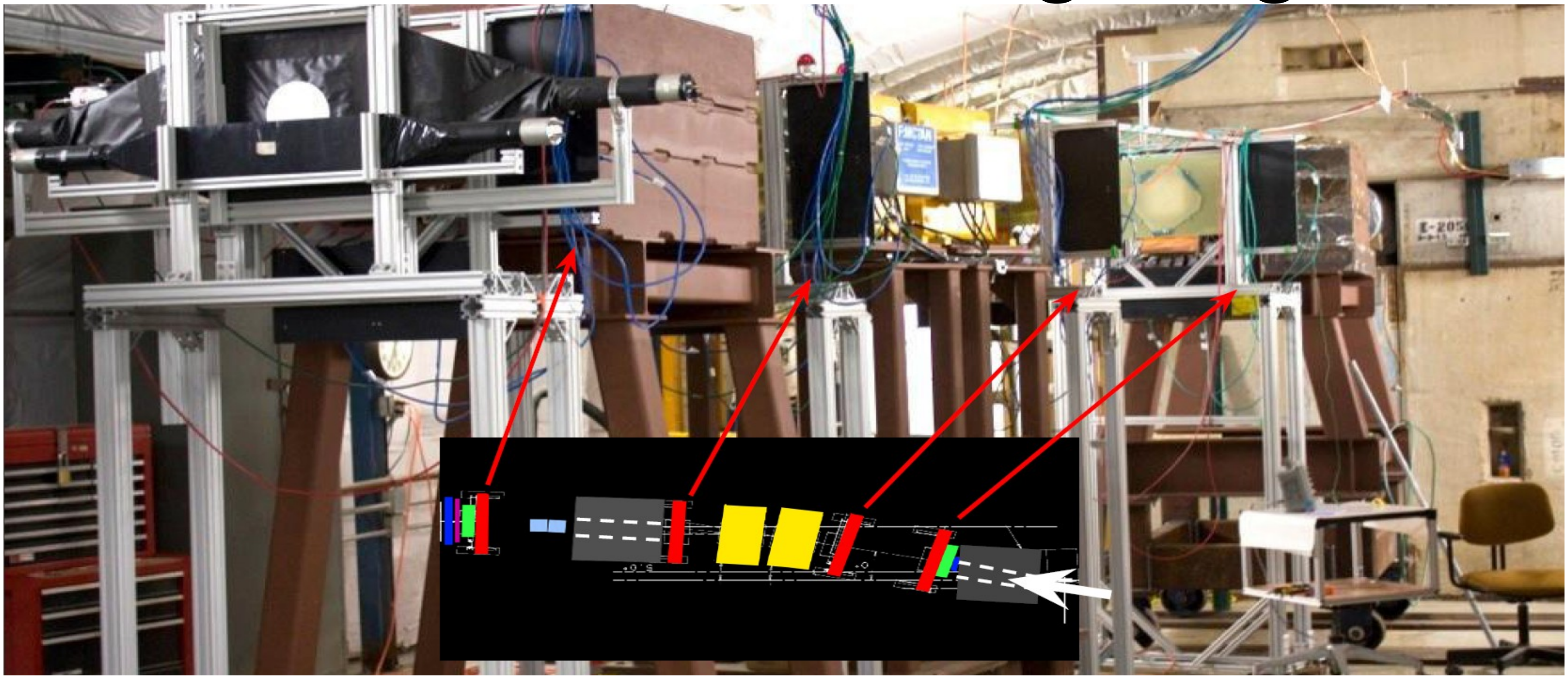
LArIAT Beamline



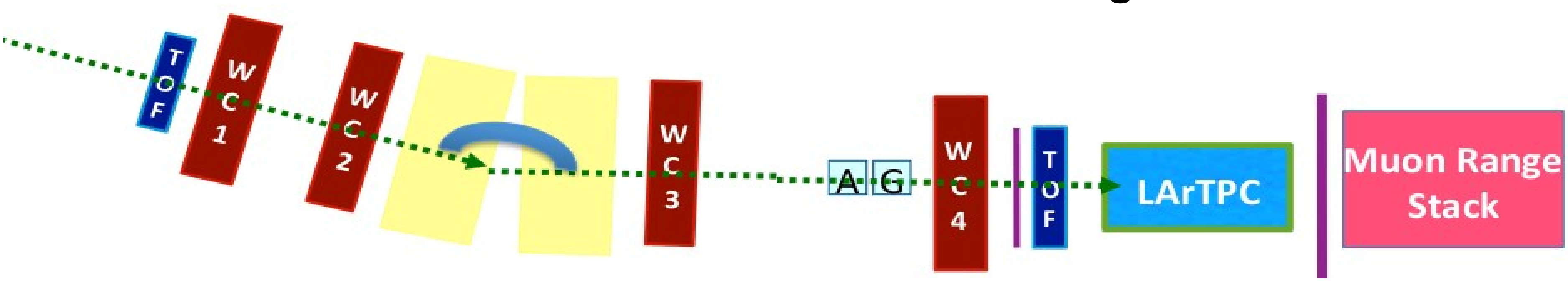
Tertiary Beamline



MWPC and Bending magnet



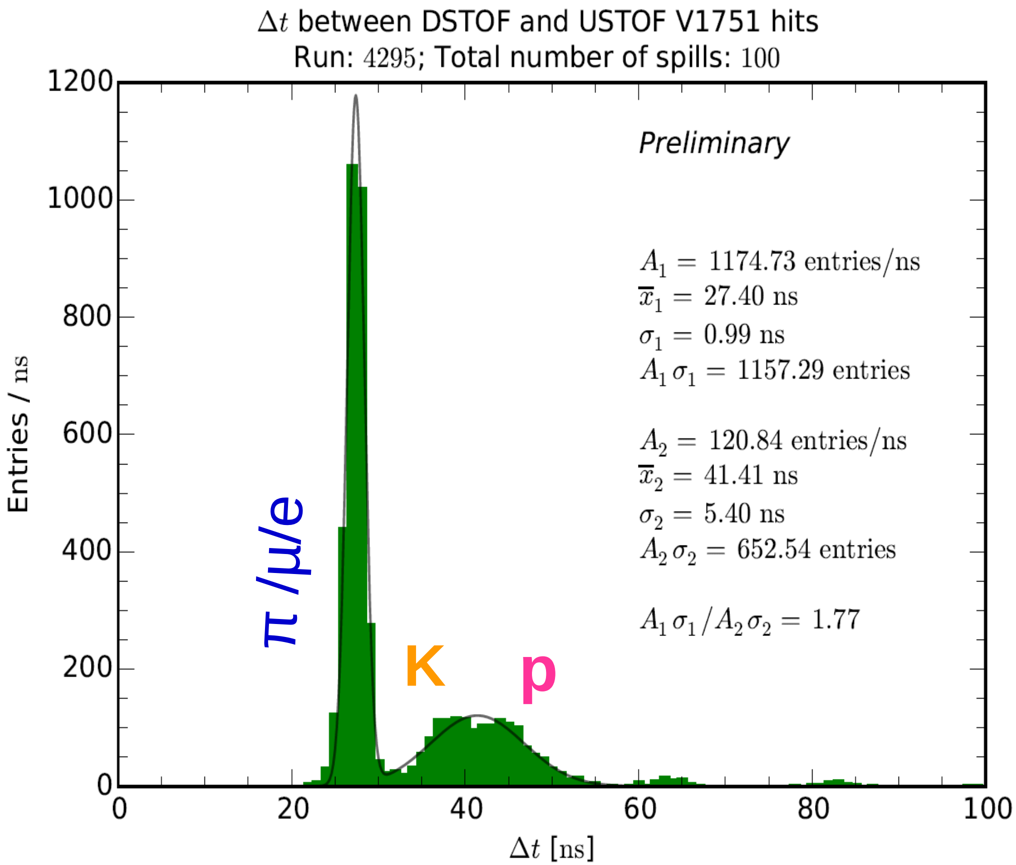
- **Goal: Momentum reconstruction before entering TPC.**

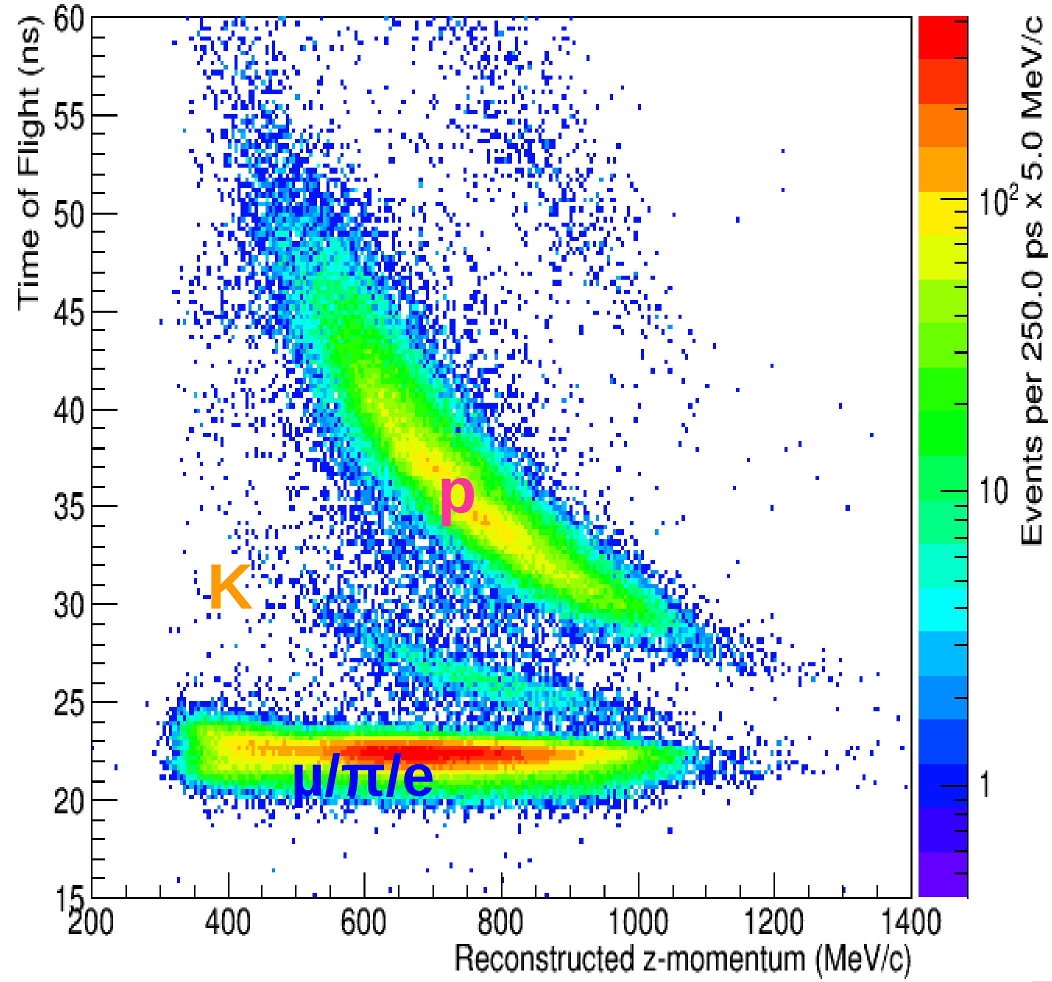


- Difference of the angle between the tracks determines the momentum.

Time of Flight

- **TOF separates μ/π/e from protons and kaons.**
- The timing readout of TOF and MWPC can separate particle ID(μ/π/e, p, K)





- We know the particle ID and momentum before it enters the TPC.

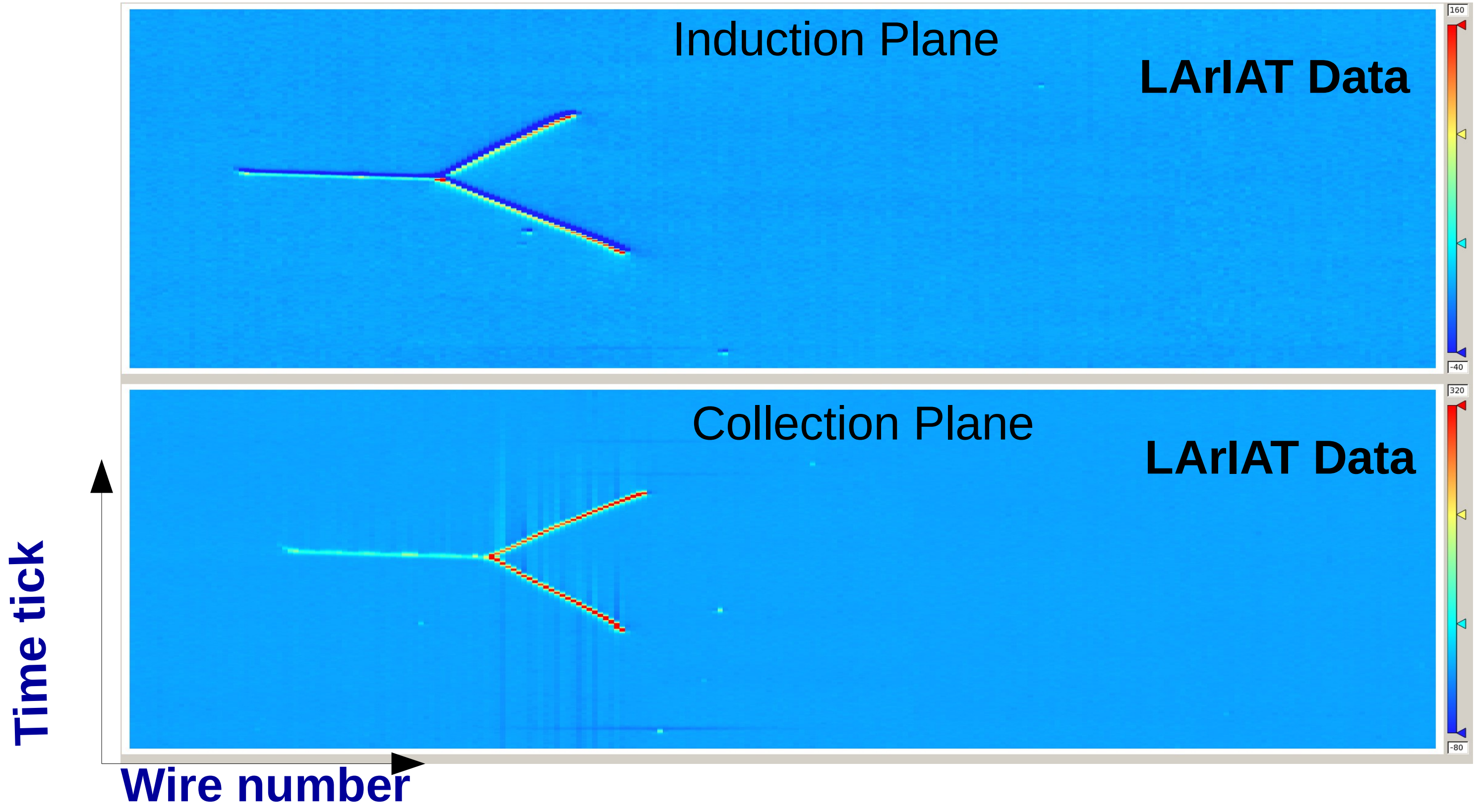
Cryostat and TPC

- **LArIAT uses refurbished ArgoNeuT TPC.**
  - 2 Readout Planes
  - 240 wires/plane +/- 60°, 4mm pitch
  - Drift field 500 V/cm

- **Light Collection system:**
  - Wavelength shifting reflector foils to shift the scintillation light into visible visible spectrum.(**William Foreman's talk**)

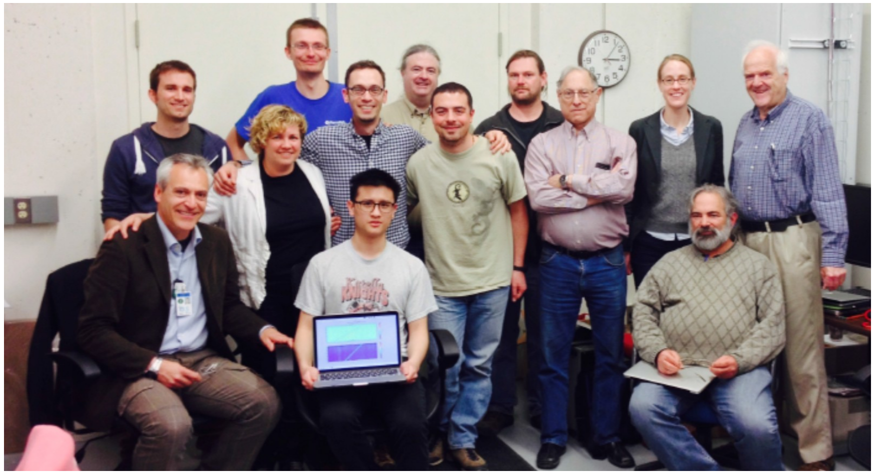
- **Signal to noise ratio:**
  - Run 1 : 50:1
  - Run 2 : 70:1

LArIAT Event !



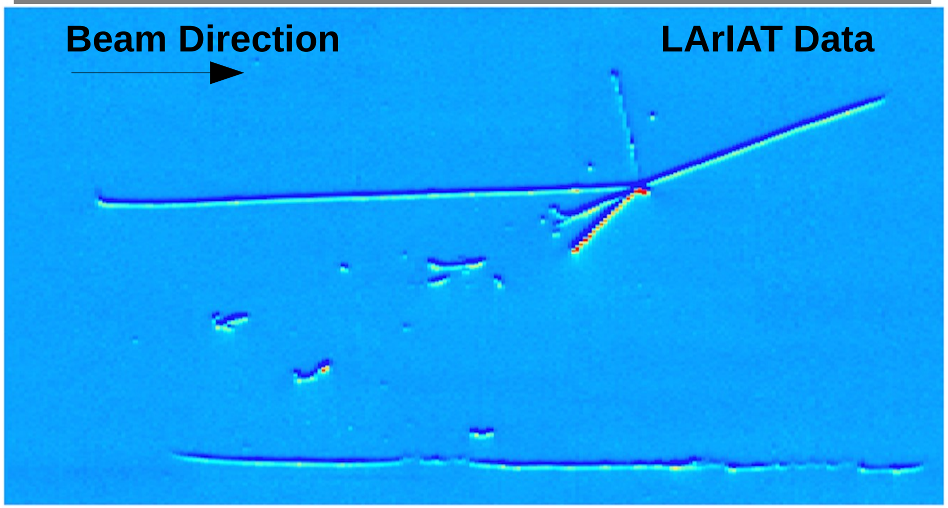
- 2D views from LArIAT on-line event display

- ✓ **LArIAT Run I : 9 weeks of data(May 1, 2015 – July 4, 2015)**
- ✓ **LArIAT Run II has just finished taking data(Feb 17 2016 to end of July 2016)**

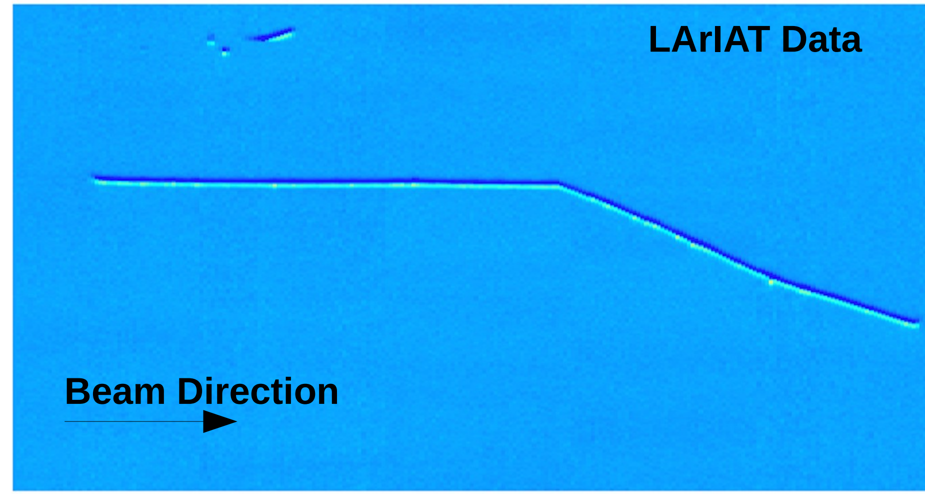


Interesting Events

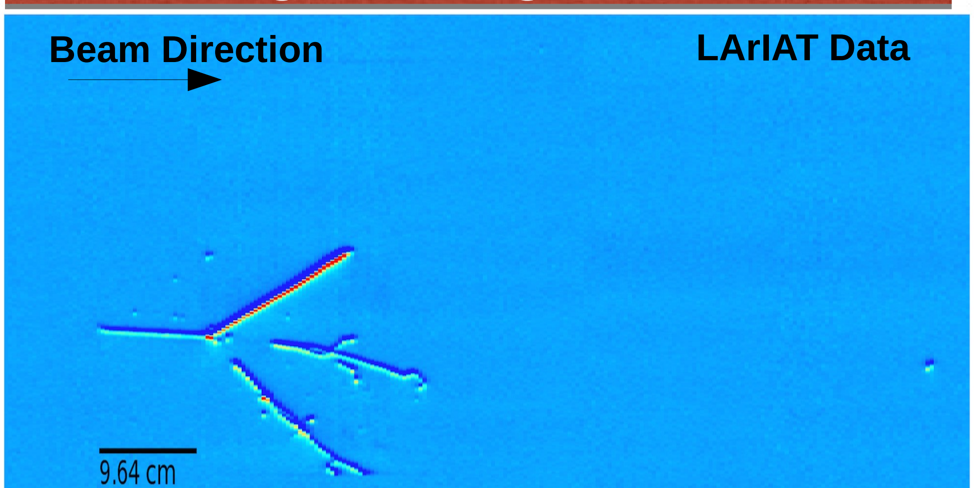
Pion Production Candidate



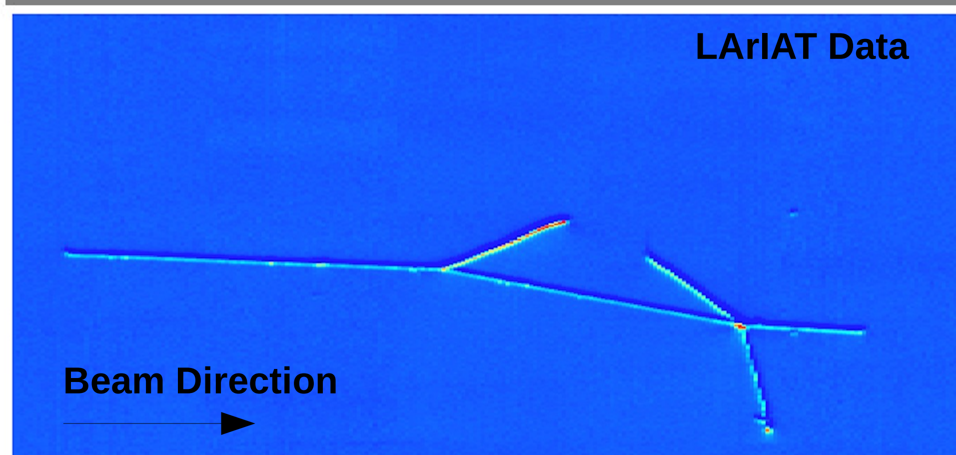
Pion - Elastic Scattering Candidate

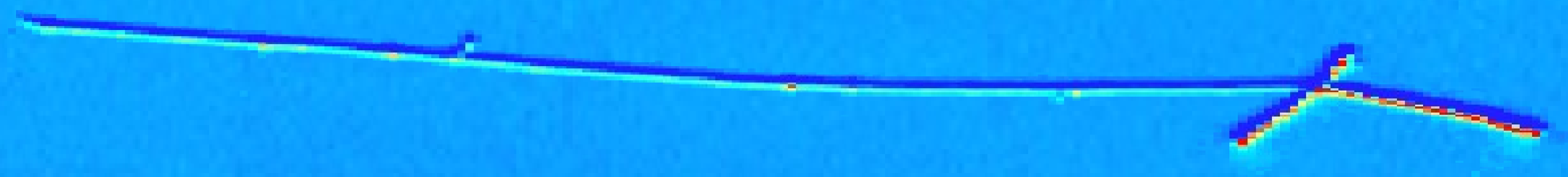


Pion - Charge Exchange Candidate



Pion - Inelastic Scattering Candidate



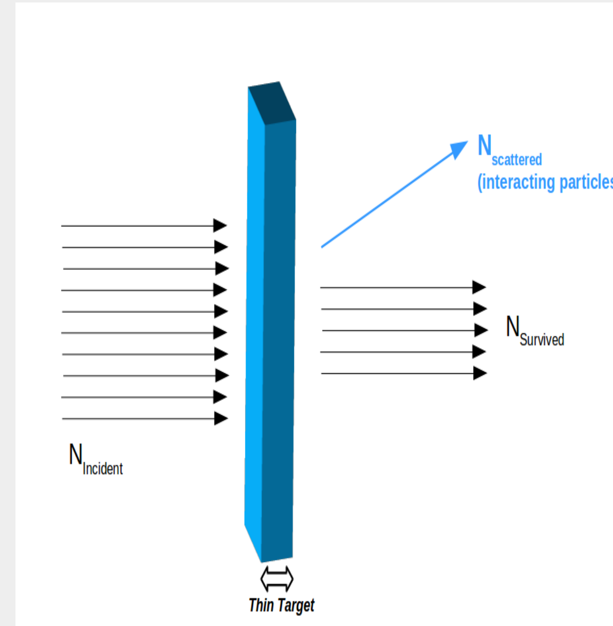


First Total π^--Ar Cross Section Result

Preliminary!

Measuring the Cross-section Thin Sliced Method

- Using the granularity of the LArTPC, we have treated the wire-to-wire spacing as a series of "thin-slab" targets.



- The probability of pion interaction can be written as

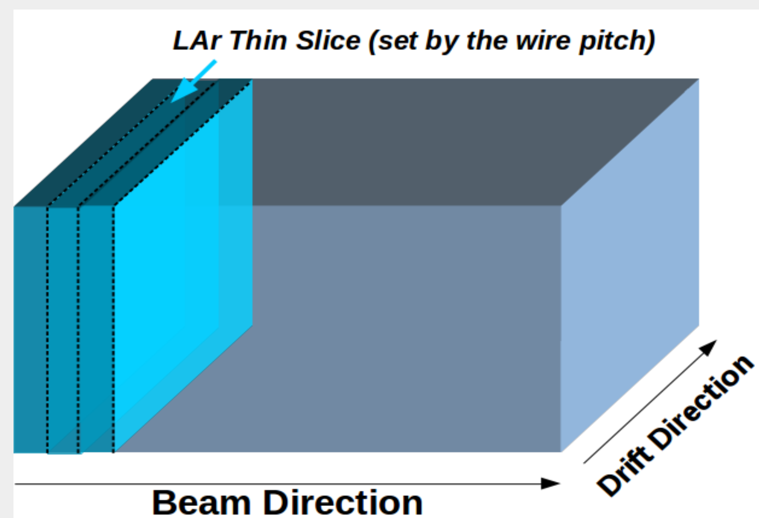
$$\frac{N_{\text{interacting}}}{N_{\text{Incident}}} = P_{\text{Interacting}} = 1 - e^{-\sigma n z}$$

Where σ is the cross-section per nucleon, z is the depth of the slab and n is the density of the slab.

- Thus we can write the pion cross-section as a function of energy as

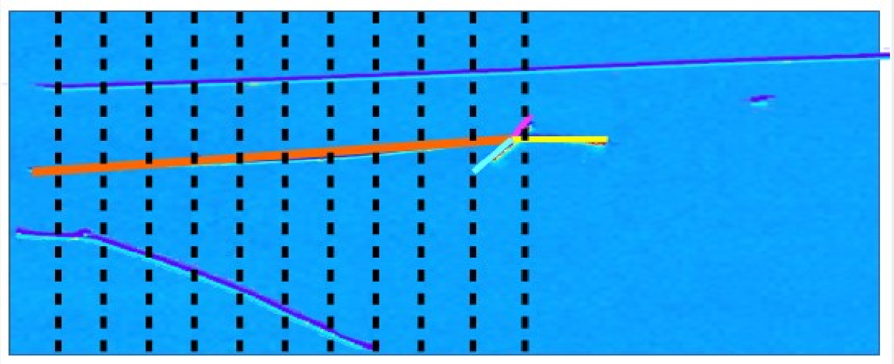
$$P_{\text{Interacting}} = 1 - (1 - \sigma n \delta z + \ldots)$$

$$\sigma(E) \approx \frac{1}{nz} P_{\text{Interacting}} = \frac{1}{nz} \frac{N_{\text{interacting}}}{N_{\text{Incident}}}$$



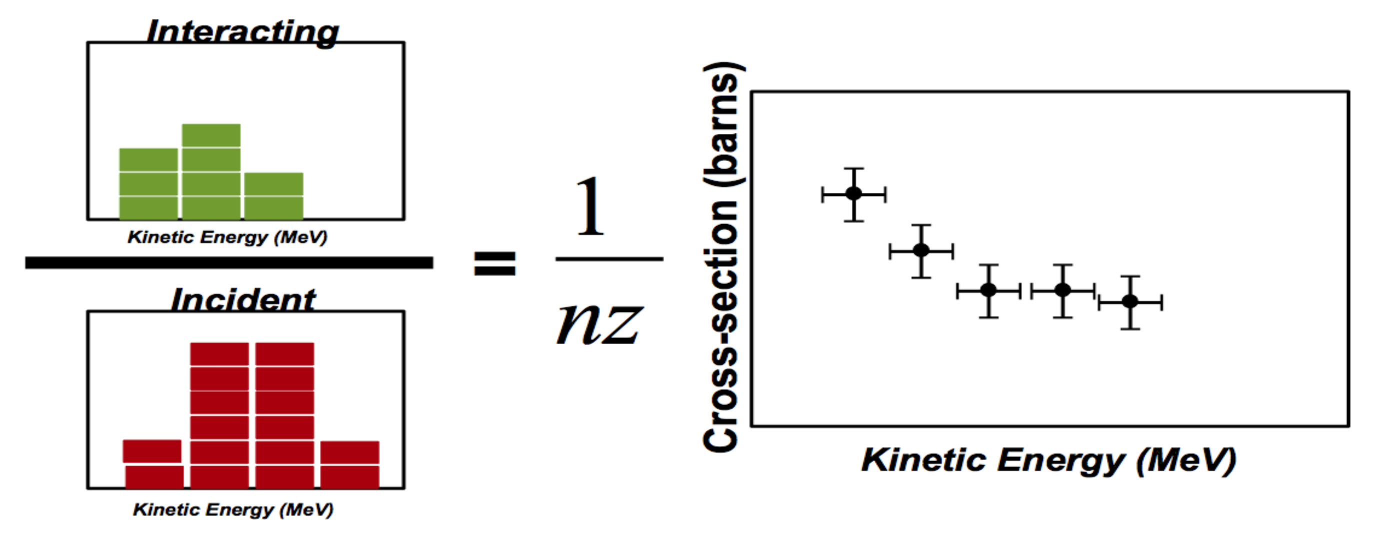
Event selection

- **We have a wire chamber track (with an initial kinetic energy) matched to a TPC track, we follow that TPC track in slices.**
  - For each slice we ask: **“Is this the end of the track?”**
  - NO: **Calculate the kinetic energy at this point and put that in our “incident” histogram.**



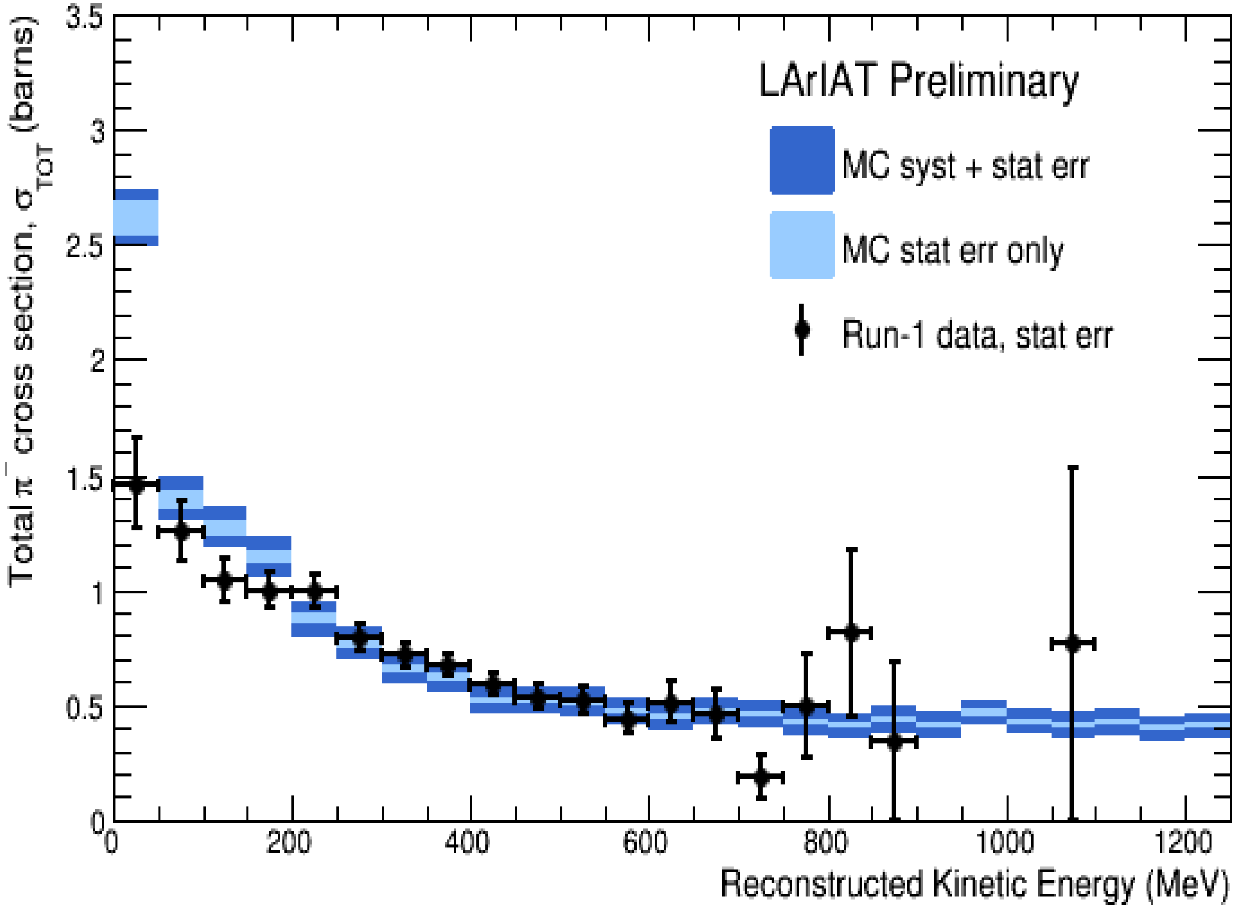
-Yes: **Calculate the kinetic energy at this point and put that in our both “interacting” and “incident” histogram.**

$$KE_{Interaction} = KE_i - \sum_{i=0}^{nSpts} dE/dX_i \times Pitch_i$$



First π^- Ar total Cross-Section

Run I (May 1, 2015-July 4, 2015)



<u>Systematics Considered</u>

- dE/dX Calibration: 5%
- Energy Loss Prior to entering the TPC: 3.5%
- Through Going Muon Contamination: 3%
- Wire Chamber Momentum Uncertainty: 3%

- **Reminder: Cross-section still contains capture and decay process, we are in a process of removing those from our sample.**

Conclusion

- **First analysis from LArIAT :**

  - Total Pion cross section on argon never before measured.

- **Next steps for the analysis :**

  - Treatment of pion capture and decay processes

  - Investigating the use of other beamline detectors to improve the sample purity.

- **More analyses to come from LArIAT :**

  . Exclusive π-Ar absorption and charge exchange channels as well as elastic, inelastic all are underway.

  - All of the above for π^+'s as well
  - Kaon (Total and possibly exclusive channels analysis)(**Elena Gramellini's Poster #708**)
  - proton, etc...

  - e/γ, muon sign determination, scintillation light studies.

Run II (Feb-Jul 2016) has produced 5 times more statistics! Stay tuned!

Thank you

Office of Science
U.S. Department of Energy

Backup Slides

LArTPC working principles

- **Why Ar ?**

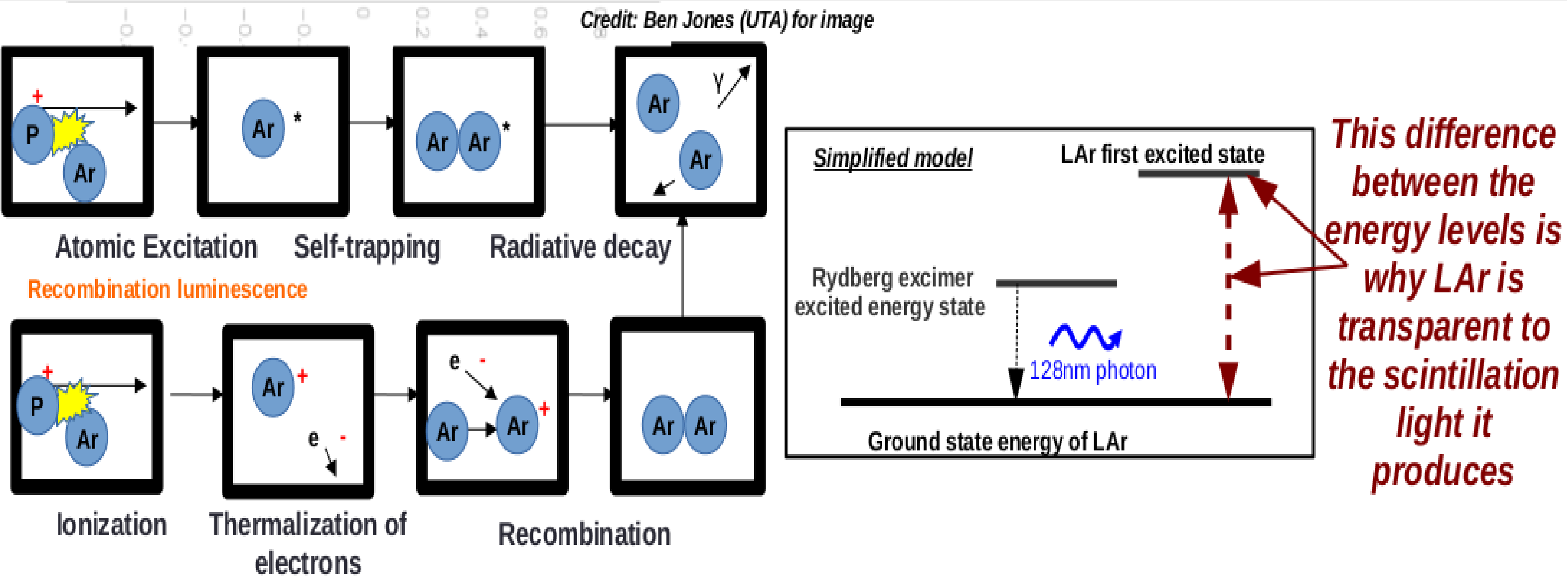
  -Dense(40% more dense than water)

  - **Abundant(**1% of the atmosphere**)**

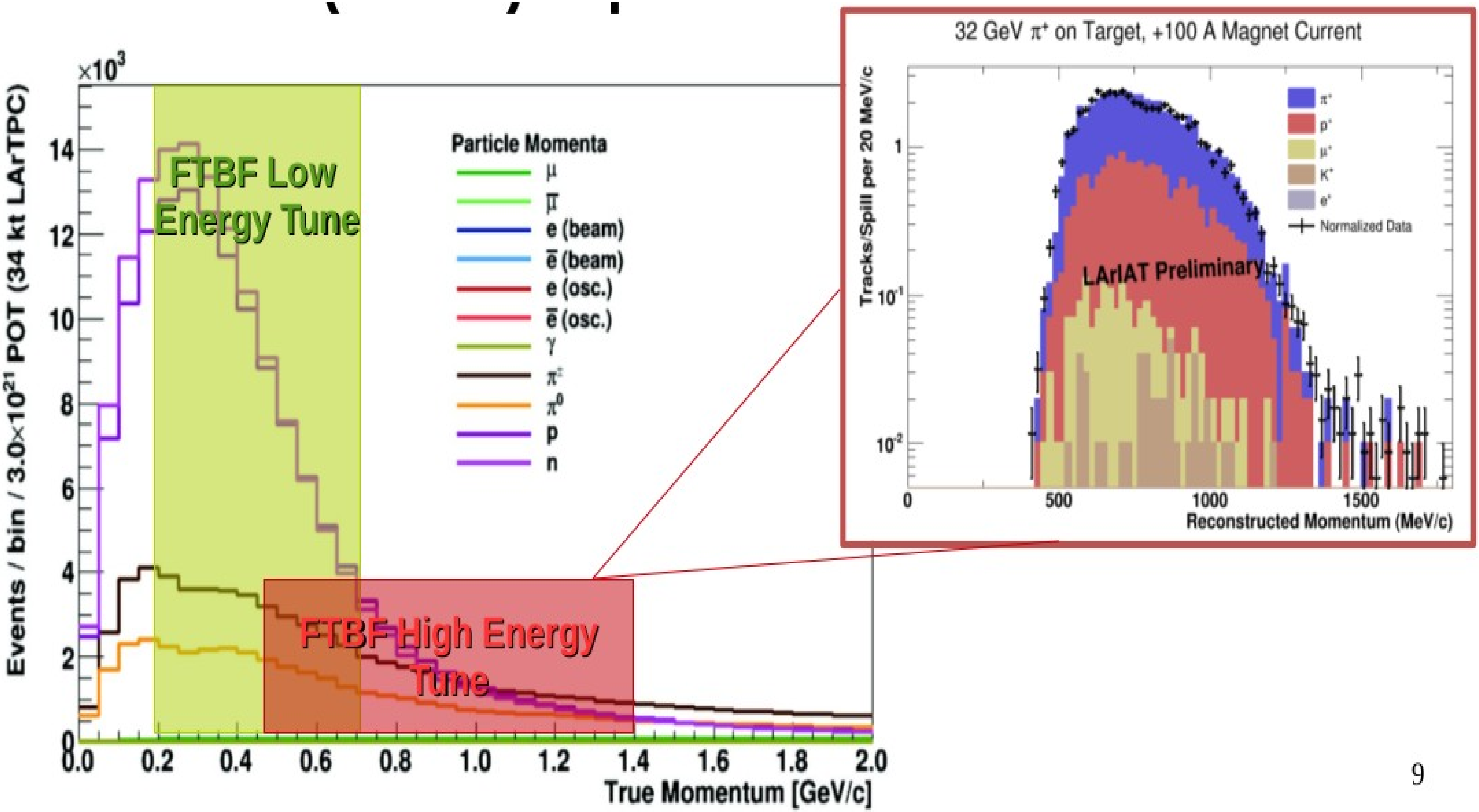
  - Ionizes easily(55,000 events/cm**)**

  - High electron lifetime

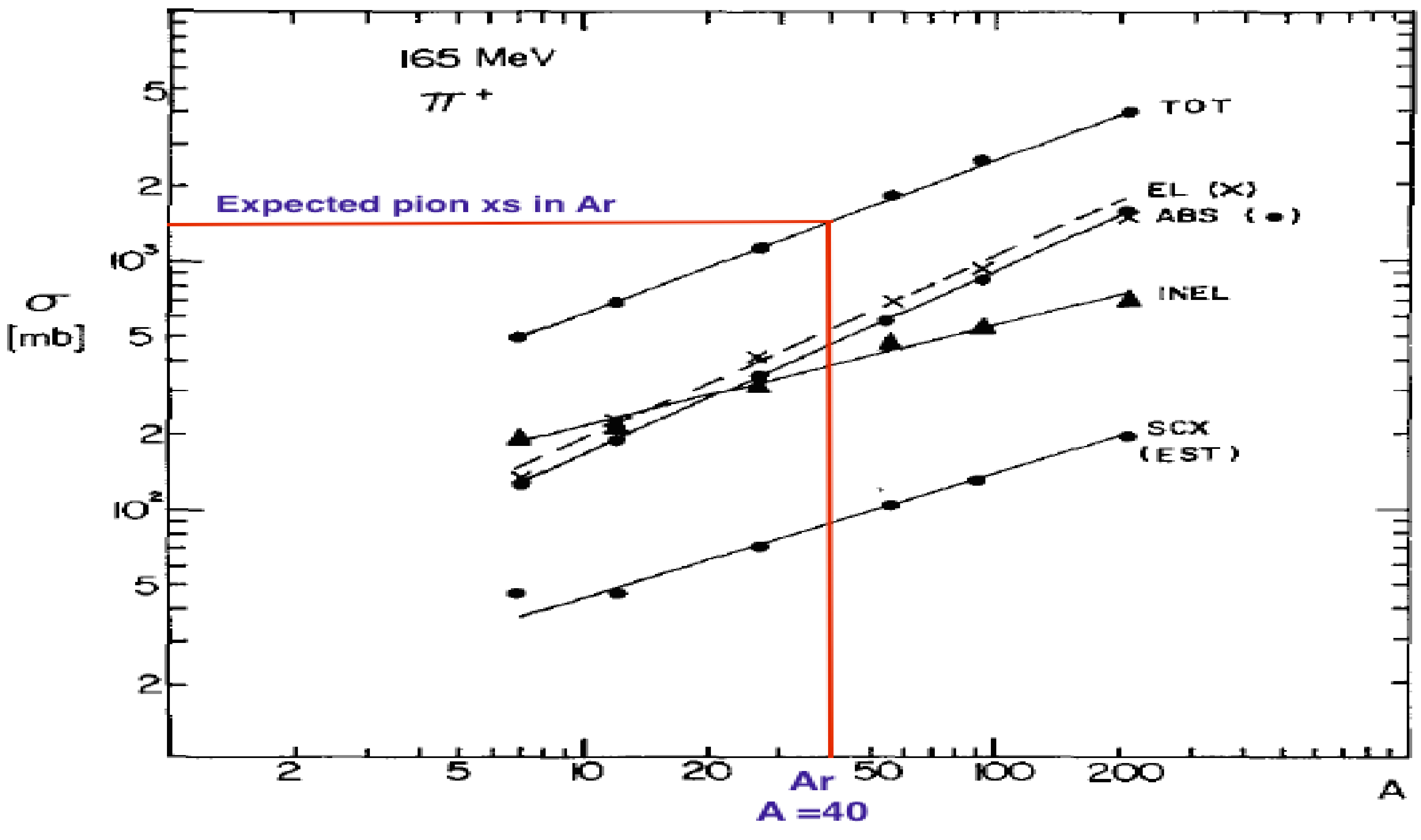
  - Lots of scintillation light



Energy window



Cross-section results from Geant4 so far



Event sample

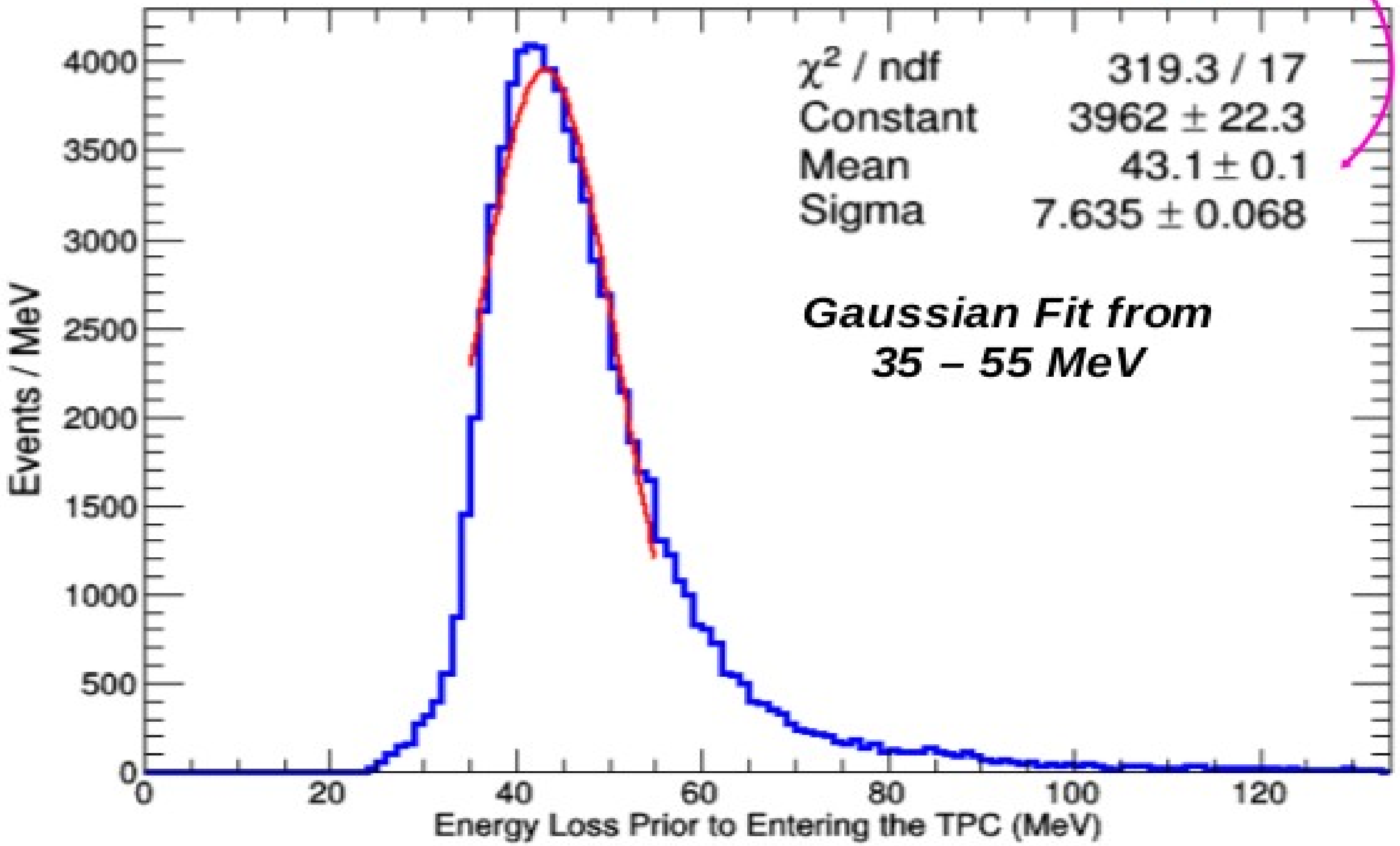
Event Sample	Number of Events
π^- Data Candidate Sample	32,064
$\pi/\mu/e$ ID	15,448
Requiring an upstream TPC Track within $z < 2$cm	14,330
< 4 tracks in the first $z < 14$cm	9,281
Wire Chamber / TPC Track Matching	2,864
Shower Rejection Filter	2,290

	π^-	e^-	γ	μ^-	K^-	$\bar{p}$
Beam Composition (%)	48.4	40.9	8.5	2.2	0.035	0.007

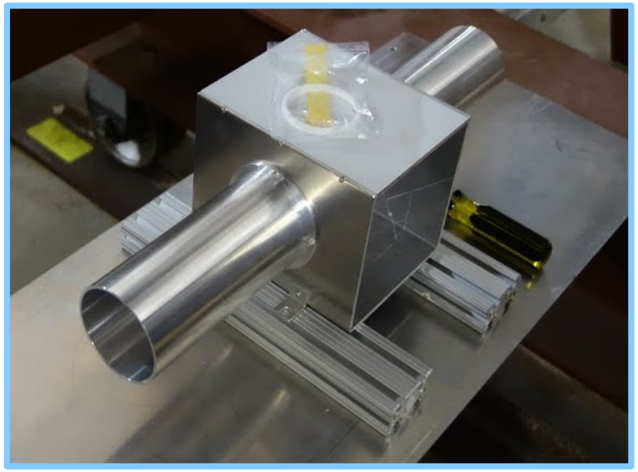
	π	e	μ	γ	K^-
Selection Efficiency	74.5%	3.6%	90.0%	0.9%	70.6 %

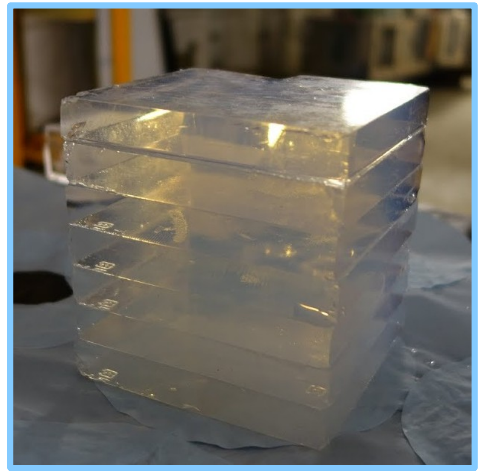
Energy Correction

$$KE_i = \sqrt{p^2 + m_\pi^2} - m_\pi - E_{\text{Flat}}$$



Aerogel Cherenkov detector





	n=1.11 Aerogel	n=1.057 Aerogel
200-300 MeV/c	μ π	μ π
300-400 MeV/c	μ π	μ π

- **Aerogel distinguishes pions from muons.**
- In a particular momentum range the aerogels will produce cherenkov light differently for pion and muon.
- Before reaching the TPC we could know the incident momentum, charge, particle ID.
- We have not used aerogel information in our cross-section analysis, but currently we are investigating.

Muon Range Stack

- **Muon range stack is for the improvement of Particle ID for through going pions and muons.**

  - A segmented block of steel with scintillator bars and PMTs.

  - Muons will penetrate further than pions

  - Match this activity to the rest of the beamline and the TPC.