LArIAT in 10 minutes

New Perspectives 2017

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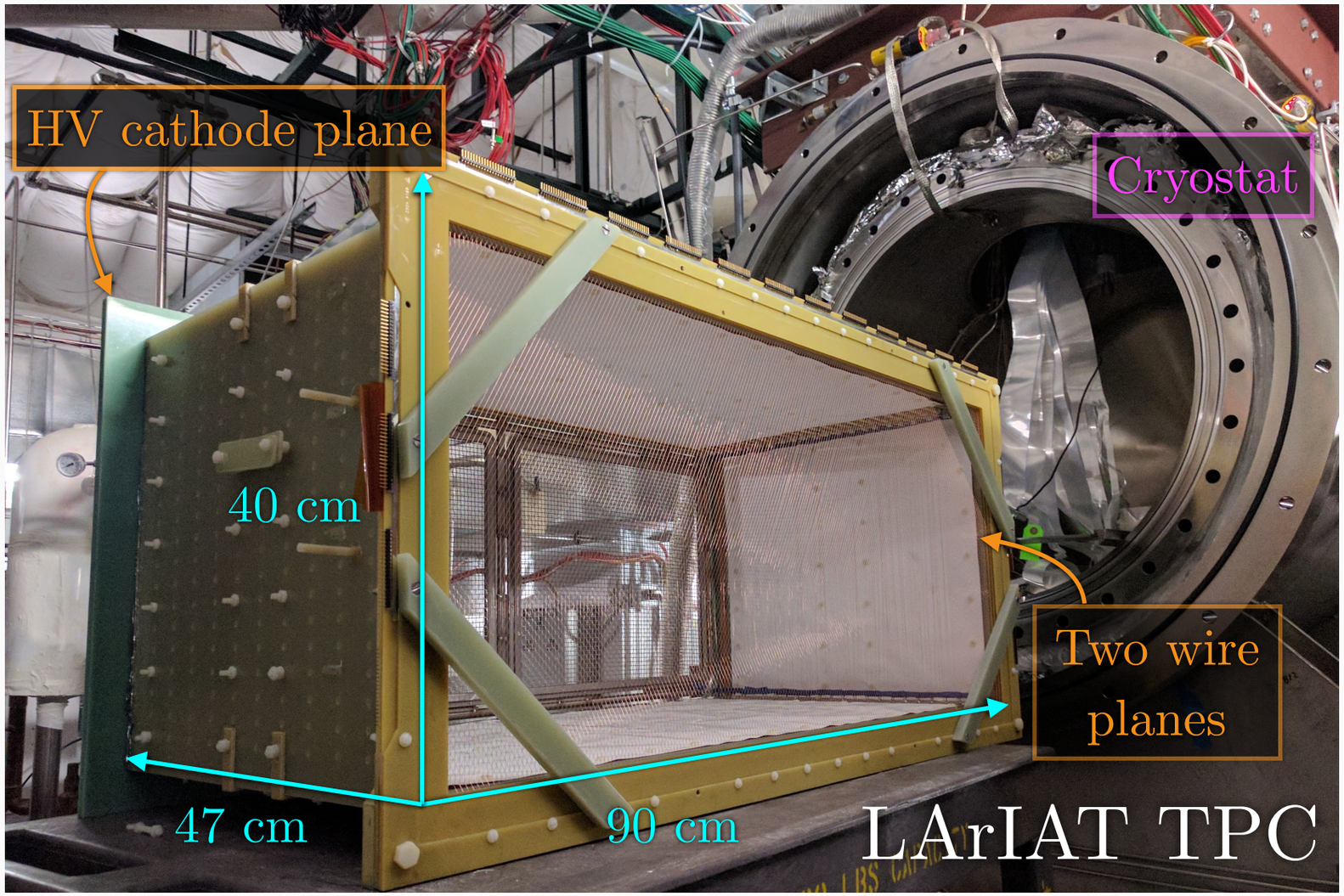
University of Chicago
On behalf of the LArIAT collaboration

What is LArIAT?

- LArIAT (Liquid Argon In A Test beam) is a 0.24-ton liquid argon TPC exposed to a beam of charged particles at the Fermilab Test Beam Facility (FTBF)
- LArIAT's program, including both physics and R&D goals, is ultimately devoted to the calibration and precise characterization of the calorimetric response of liquid argon TPCs for neutrino experiments (DUNE, Short-Baseline Neutrino program)



LArIAT at the Fermilab Test Beam Facility

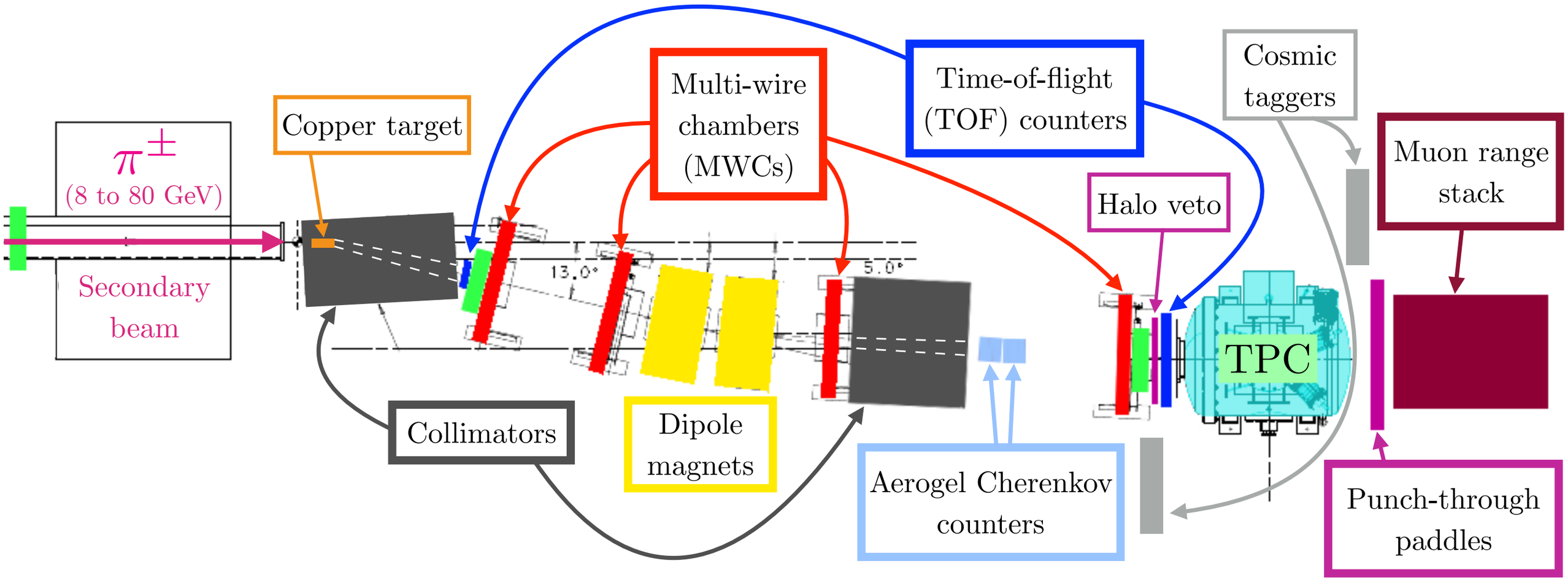
Test Beam Facility

Linac

Booster

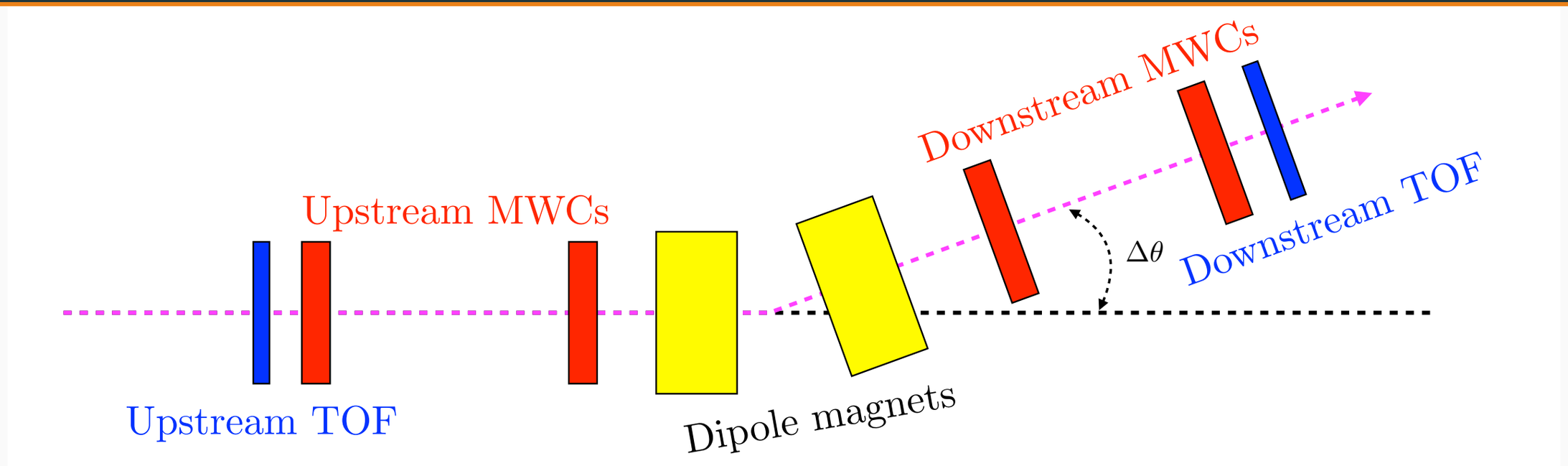
Main Injector

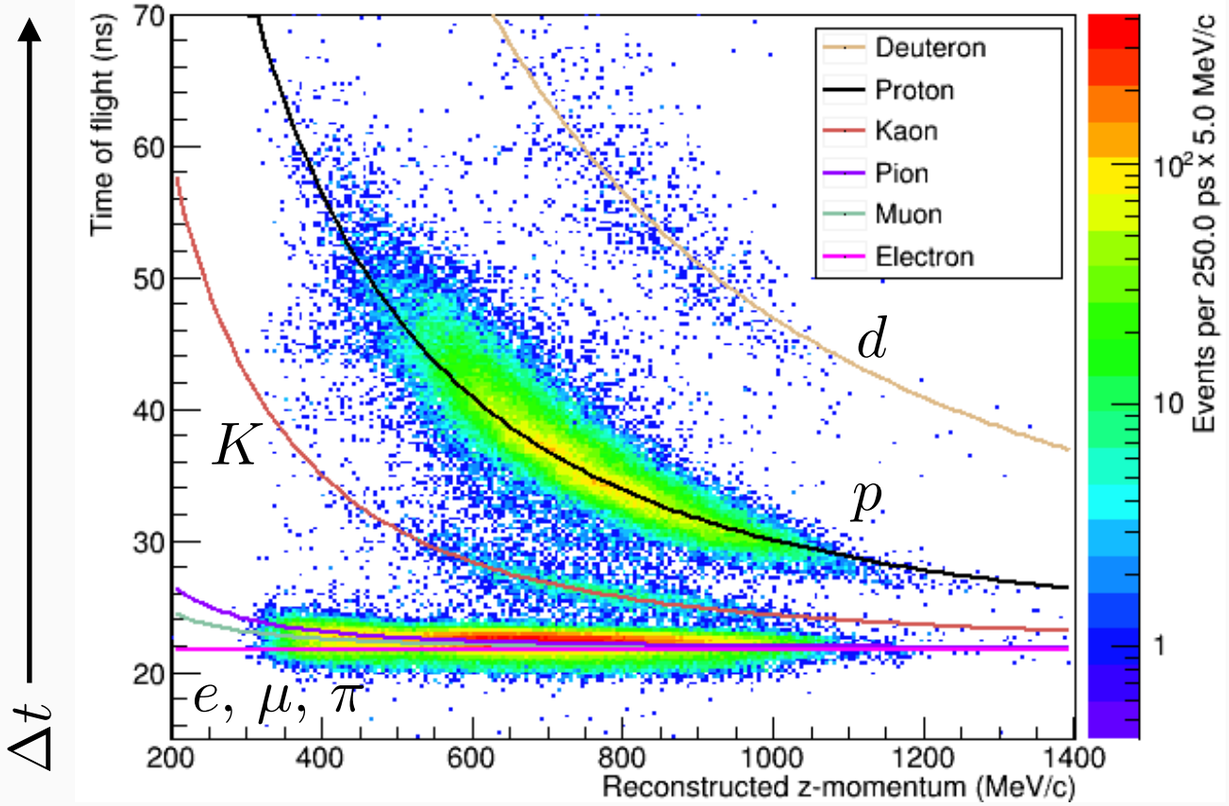
LArIAT beamline at FTBF

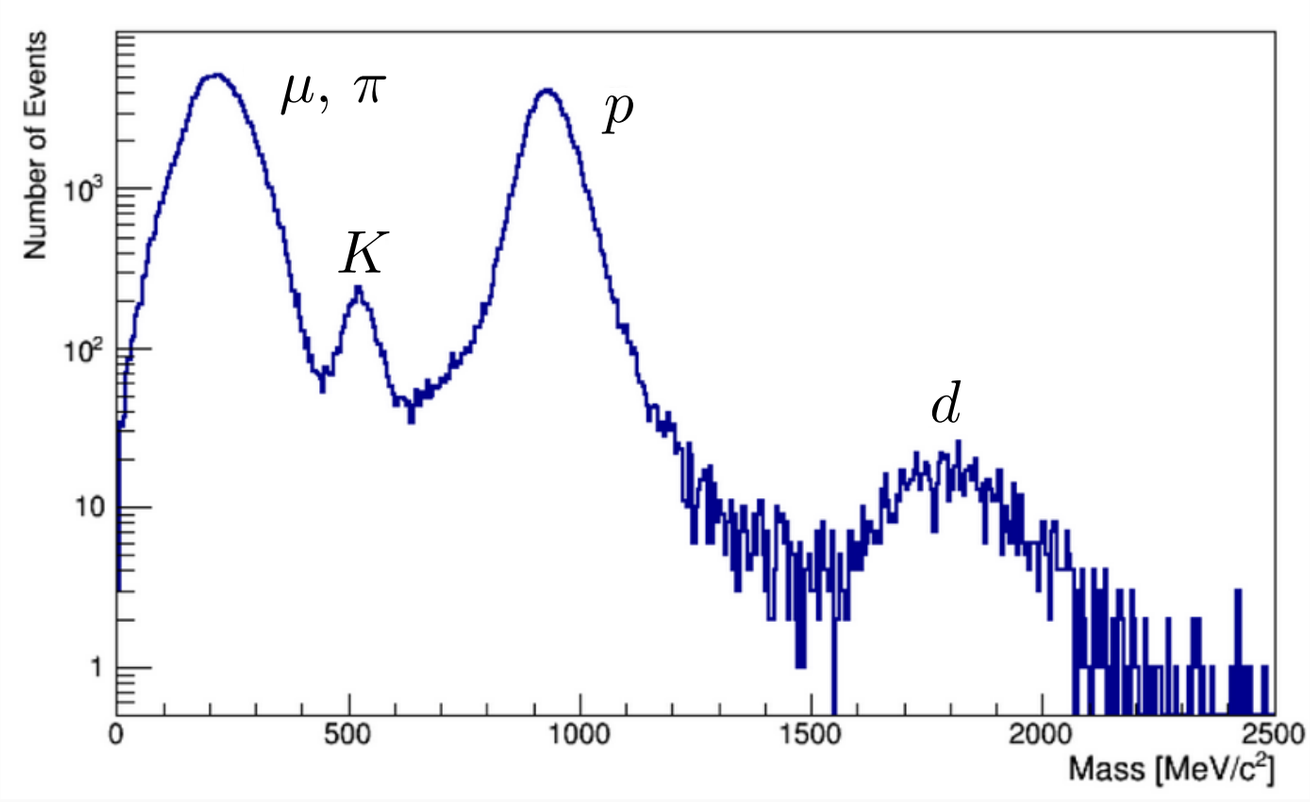


- Why put a LArTPC in a beam of charged particles?
- So that we know exactly what type of particle is going into our LArTPC!

LArIAT beamline: Particle ID with TOF and MWCs

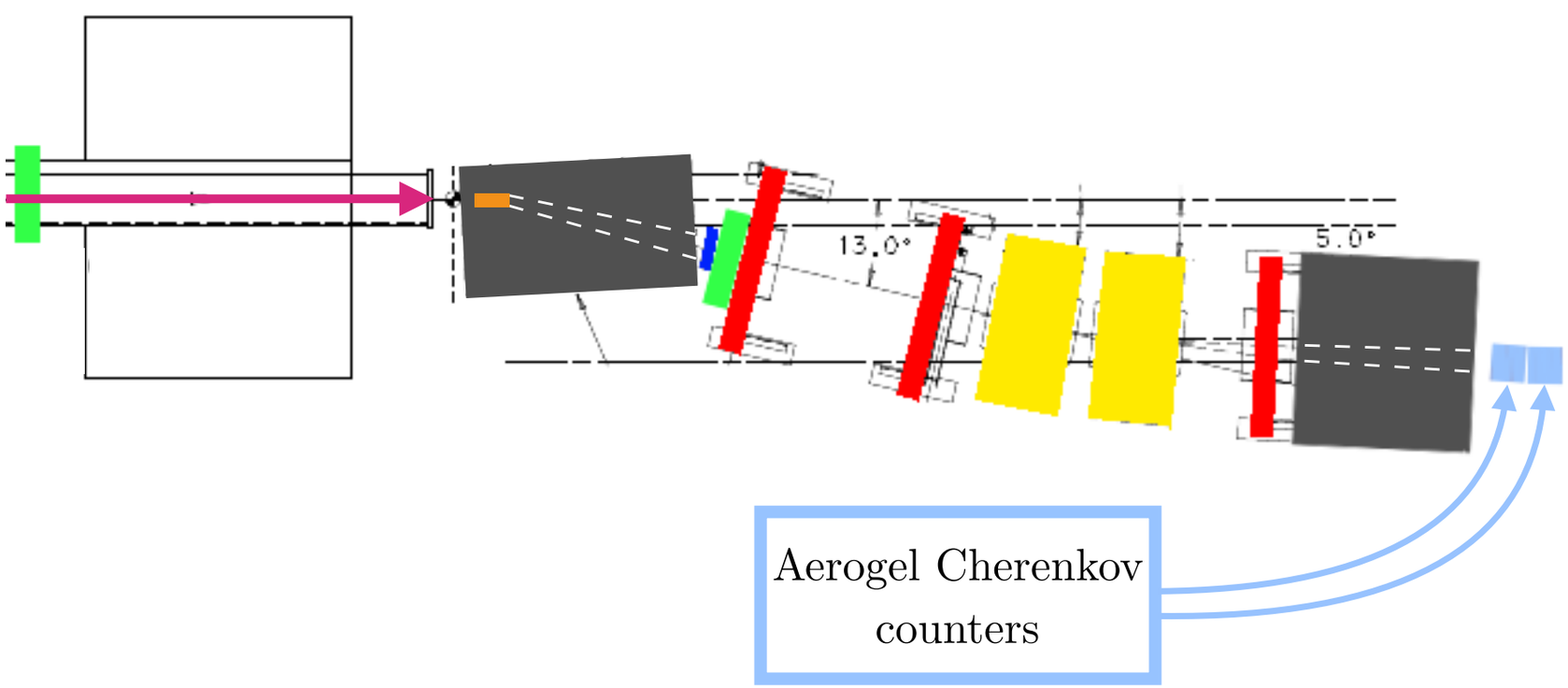


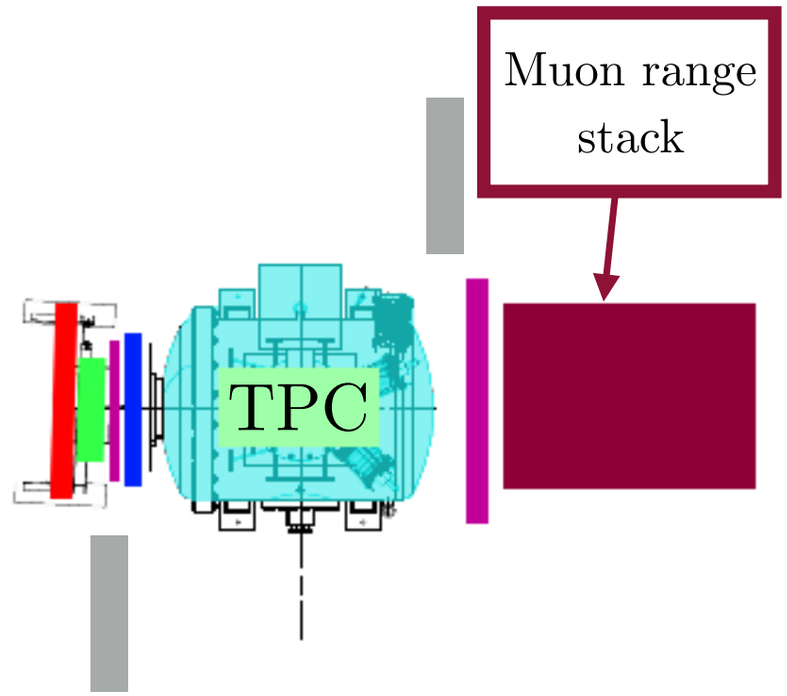




$$m = \frac{p_z}{c}\sqrt{\left(\frac{c\Delta t}{L}\right)^2 - 1}$$

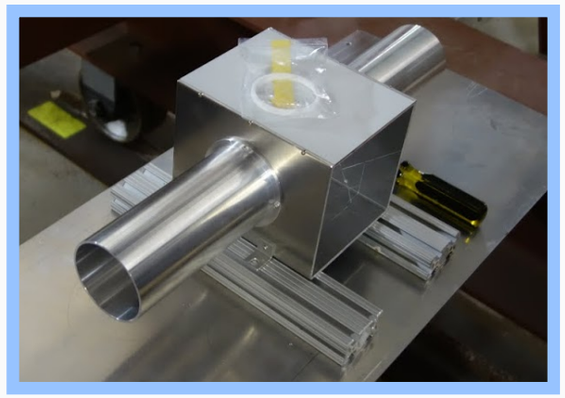
LArIAT beamline: $\pi^{\pm}/\mu^{\pm}$ discrimination

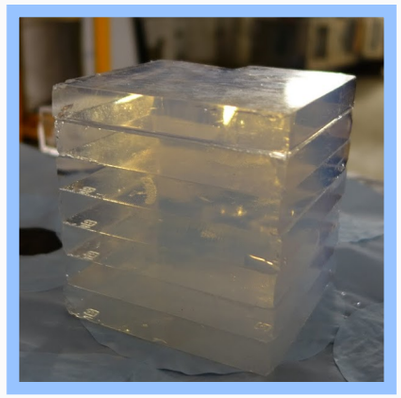




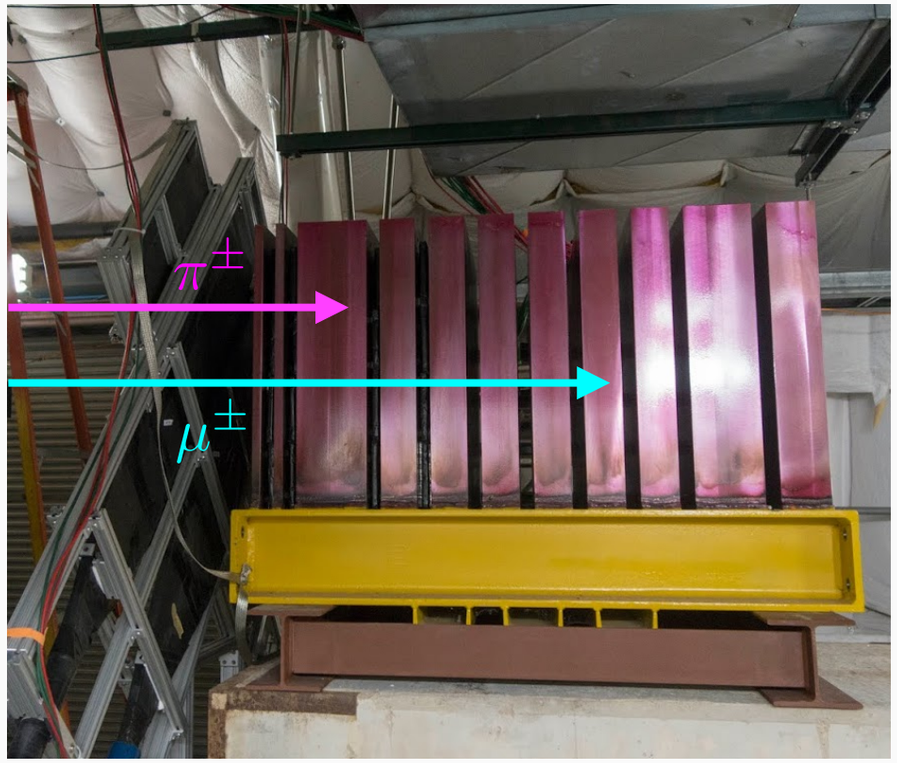
Aerogel Cherenkov counters

p_z (MeV/c)	$n = 1.11$	$n = 1.057$
200-300	$\mu^{\pm}$ $\pi^{\pm}$	$\mu^{\pm}$ $\pi^{\pm}$
300-400	$\mu^{\pm}$ $\pi^{\pm}$	$\mu^{\pm}$ $\pi^{\pm}$

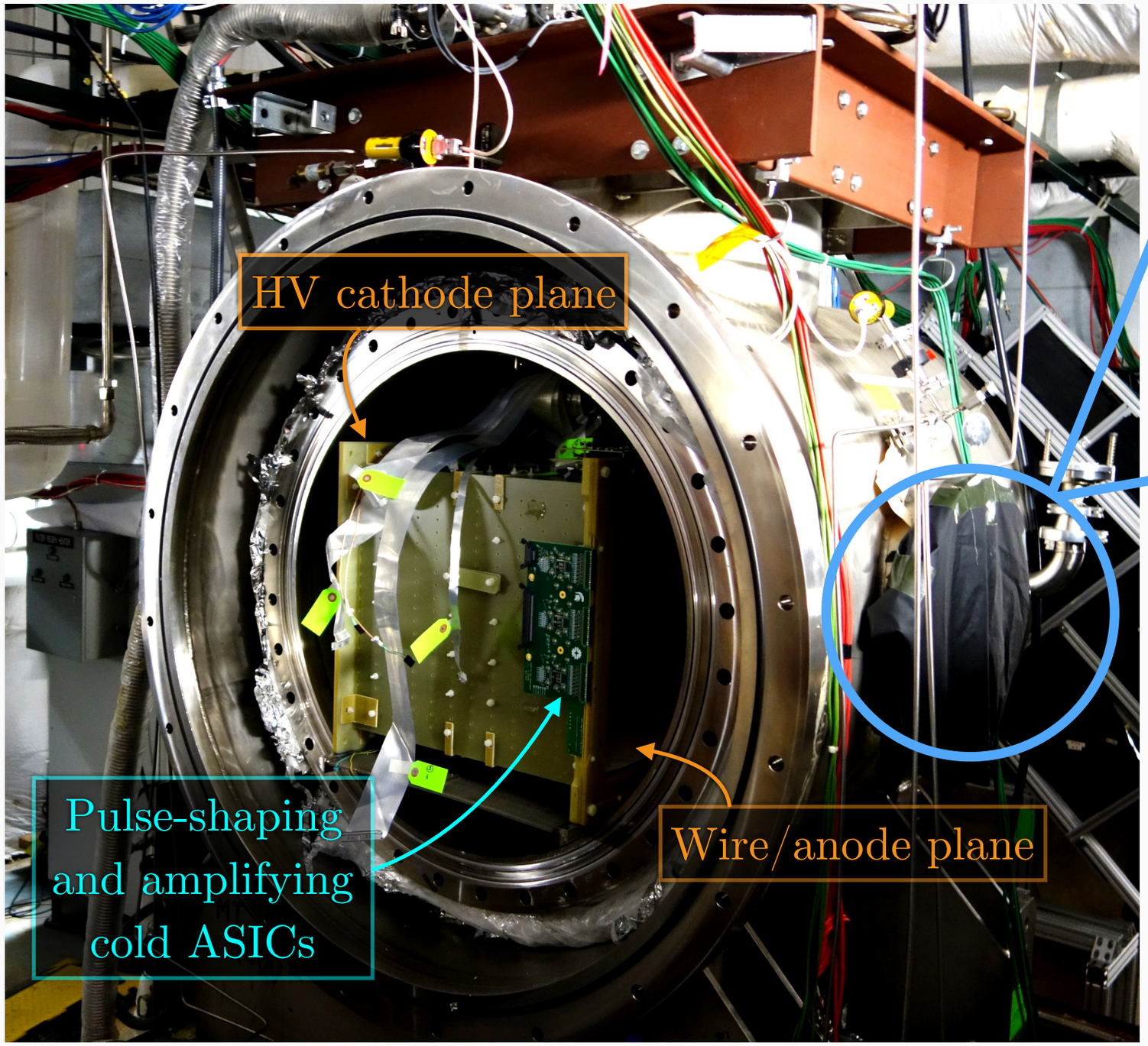


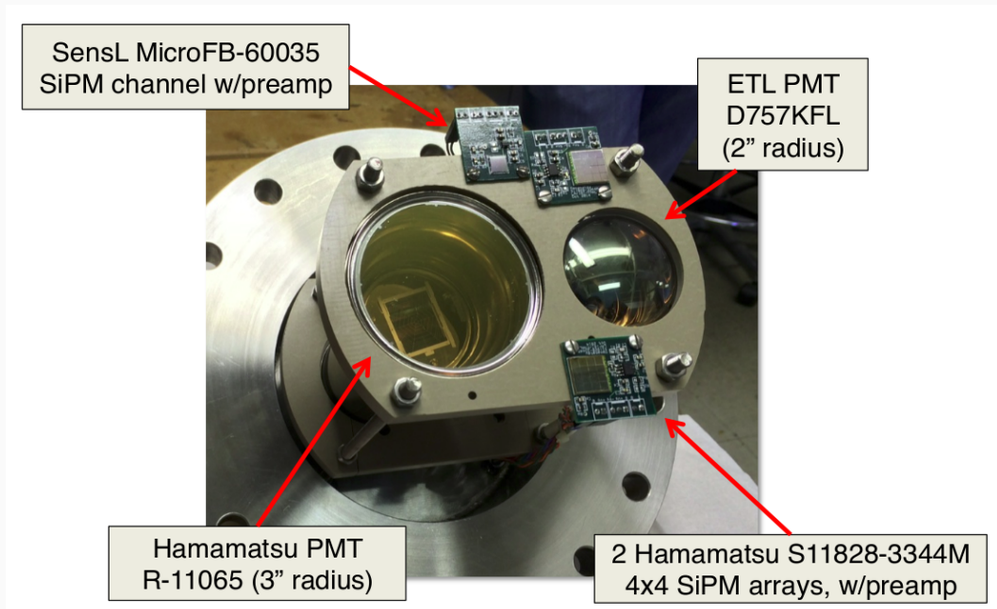


Muon range stack



Inside the LArIAT cryostat



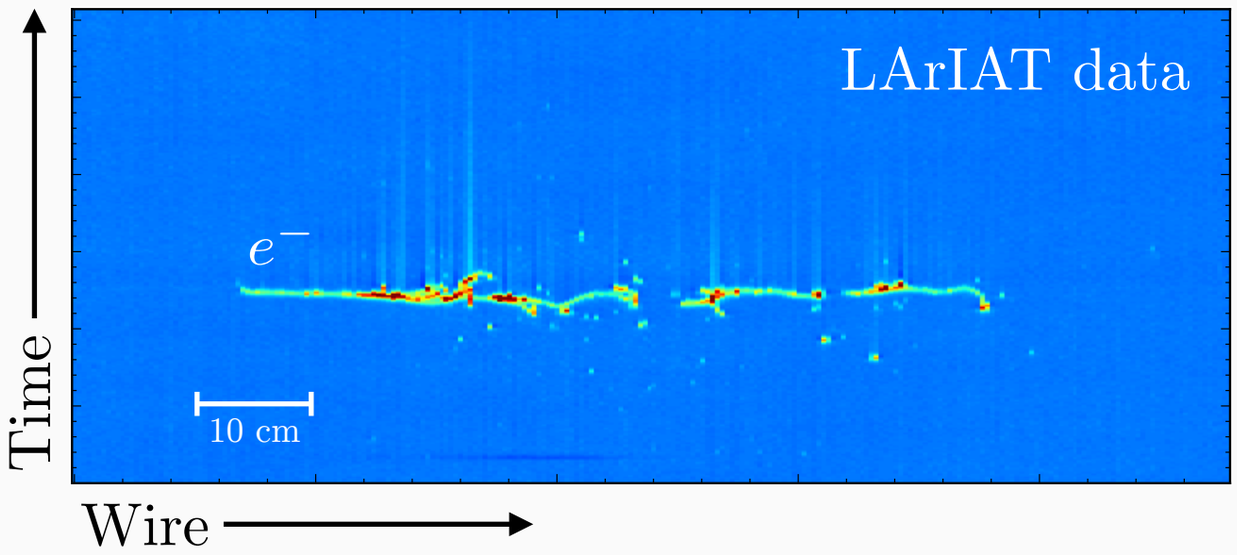


Cold readout electronics give a signal-to-noise ratio of ~50:1 for Run I (2015) and ~70:1 for Run II (2016)

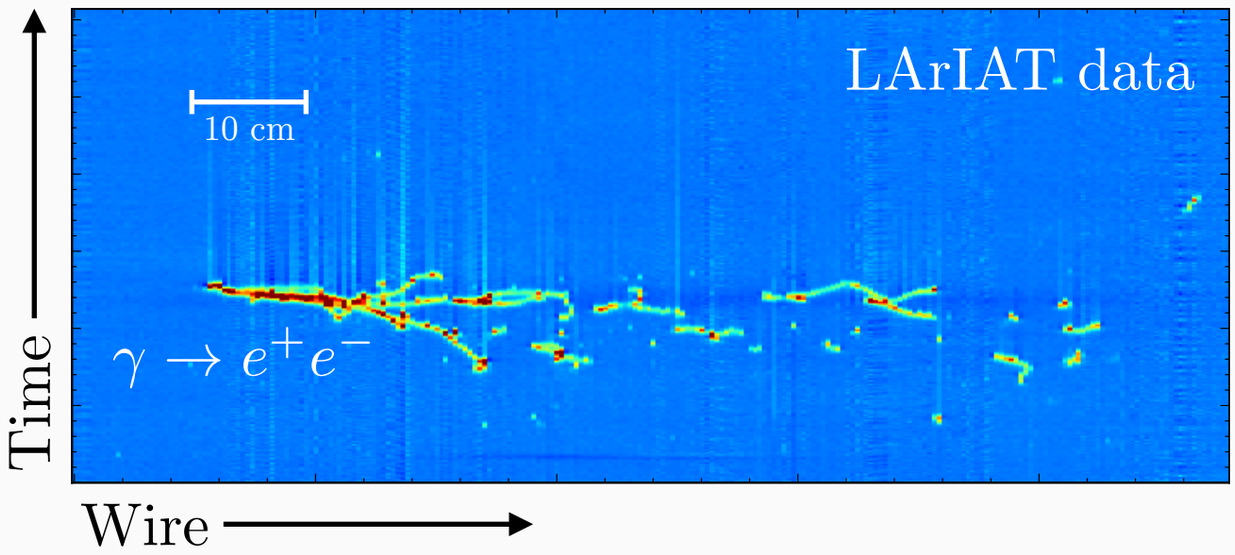
R&D in LArIAT

- Calorimetric calibration for particle identification of charged particles such as $\pi^{\pm}$, $\mu^{\pm}$, $p^{\pm}$, $K^{\pm}$, and $e^{\pm}$—particles that emerge from neutrino interactions
- Distinguish between e– and γ–initiated electromagnetic showers
- Event reconstruction in LArTPC
- Study relationship between scintillation light yield and ionization charge deposition

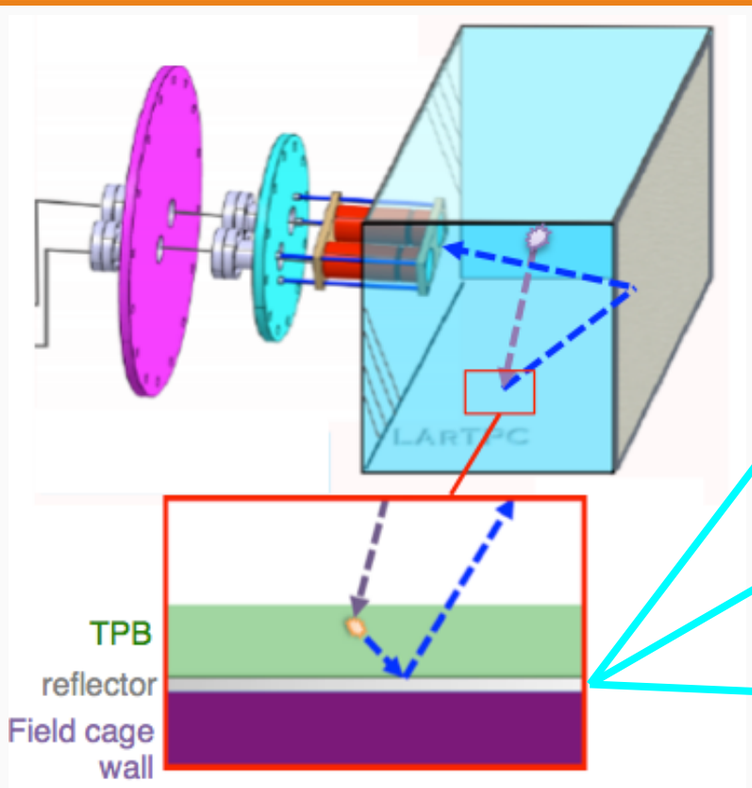
e–initiated shower candidate

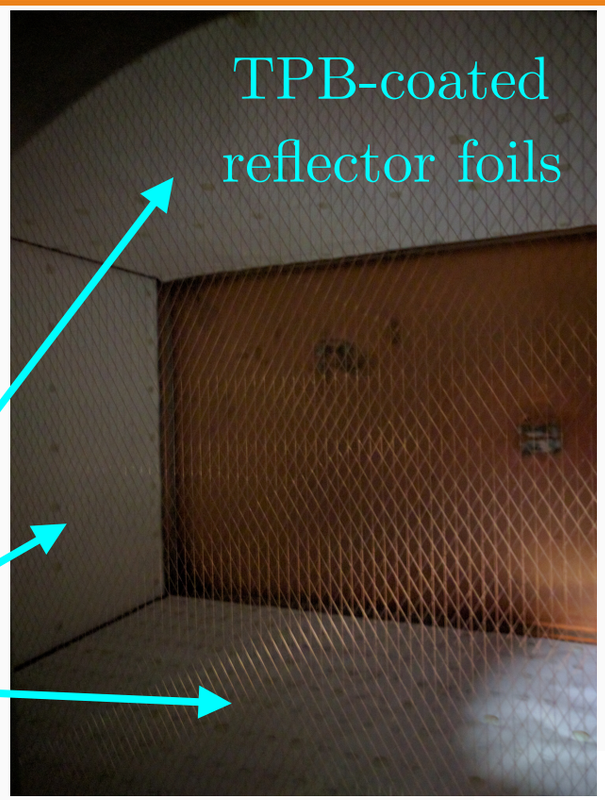


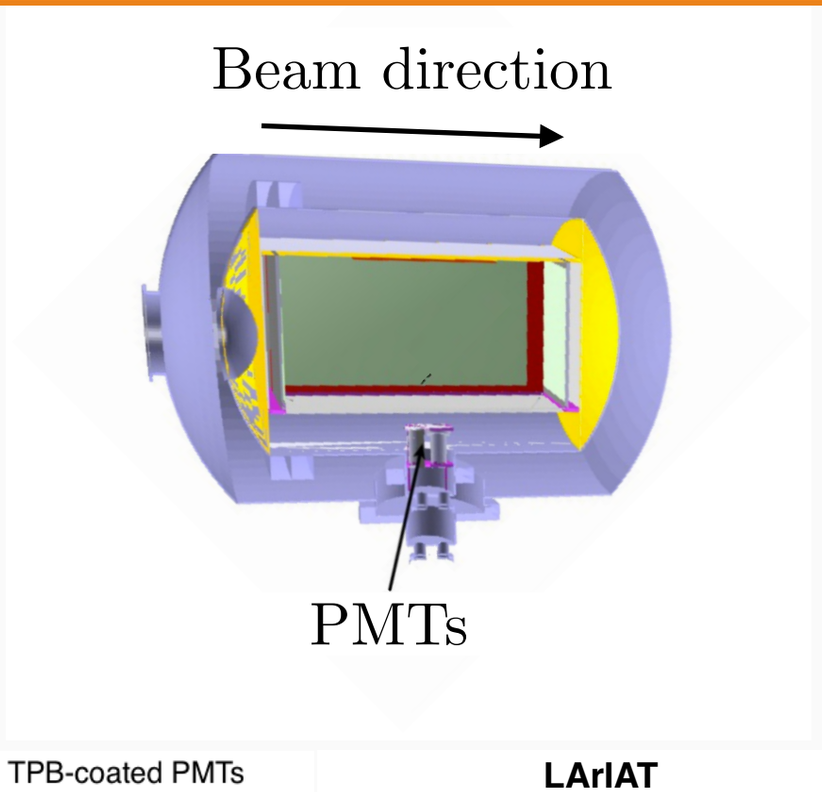
γ–initiated shower candidate



Light collection system

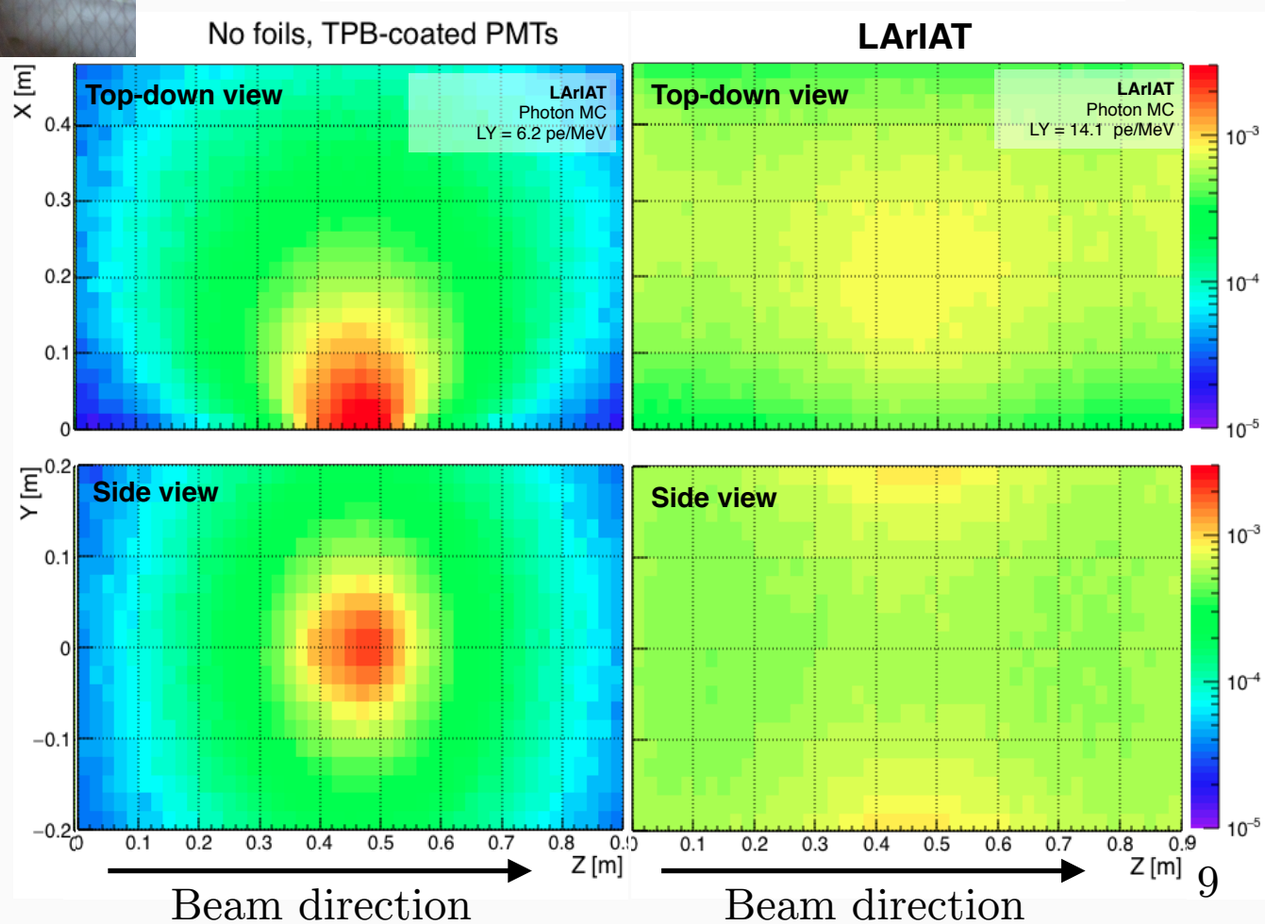






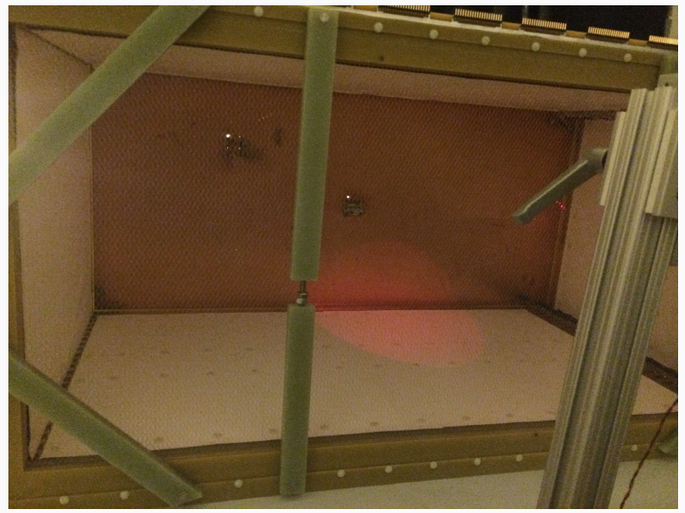
Credit: W. Foreman

- Wavelength-shifting (tetraphenyl butadiene, or TPB) reflector foils to shift the 128-nm scintillation light into the visible spectrum
- Provides greater and more uniform light yield compared to only coating the PMT photocathode with TPB
- R&D for future neutrino experiments as a way to improve calorimetry and triggering

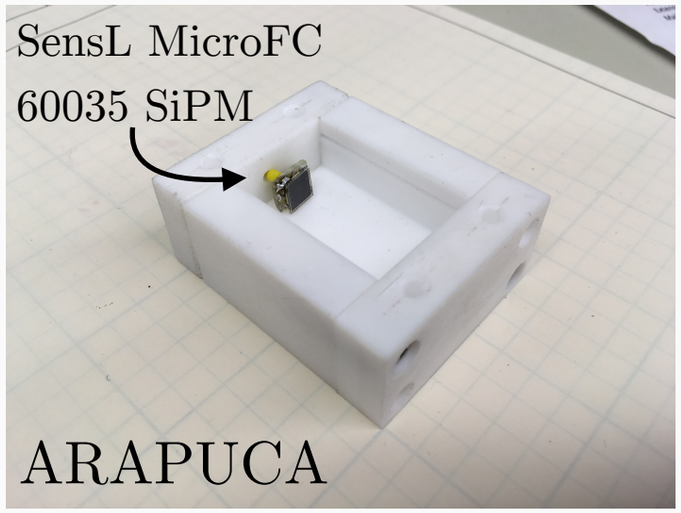


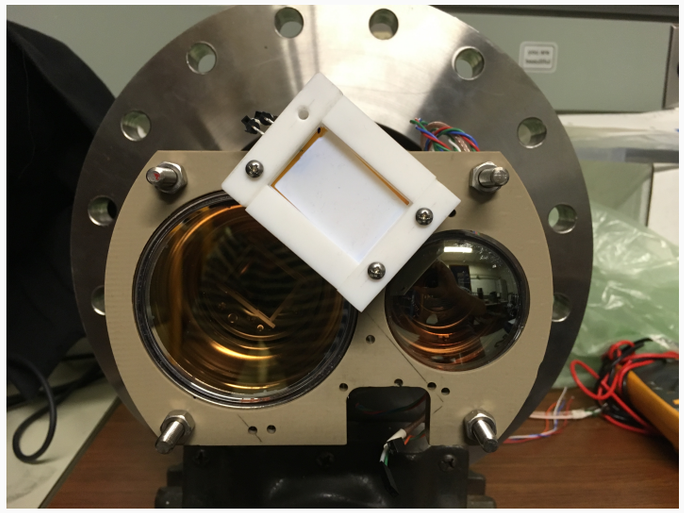
R&D in Run III

- Comparison of 5-mm wire spacing (DUNE) and 3-mm wire spacing (MicroBooNE, SBND)
  - 5-mm run completed 2.5 weeks ago
  - 3-mm run starting this week
- Testing of novel light collection device (ARAPUCA)
- Test of "transparent" mesh cathode for SBND

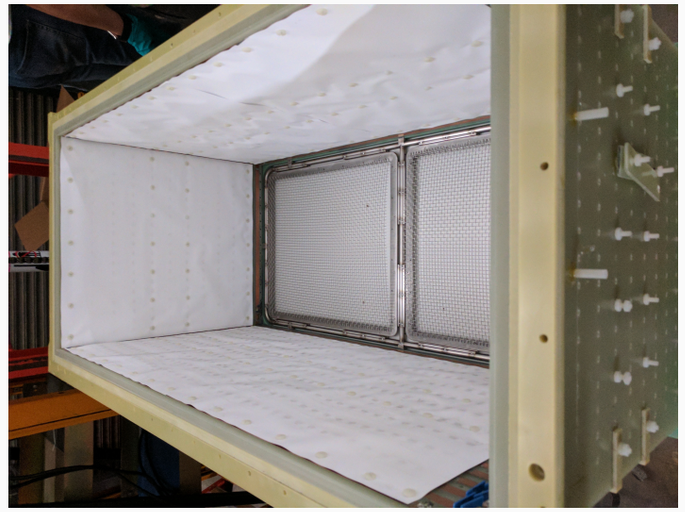


Cathode used in Run I/II





(Argon R&D Advanced Program @ UniCAmp)

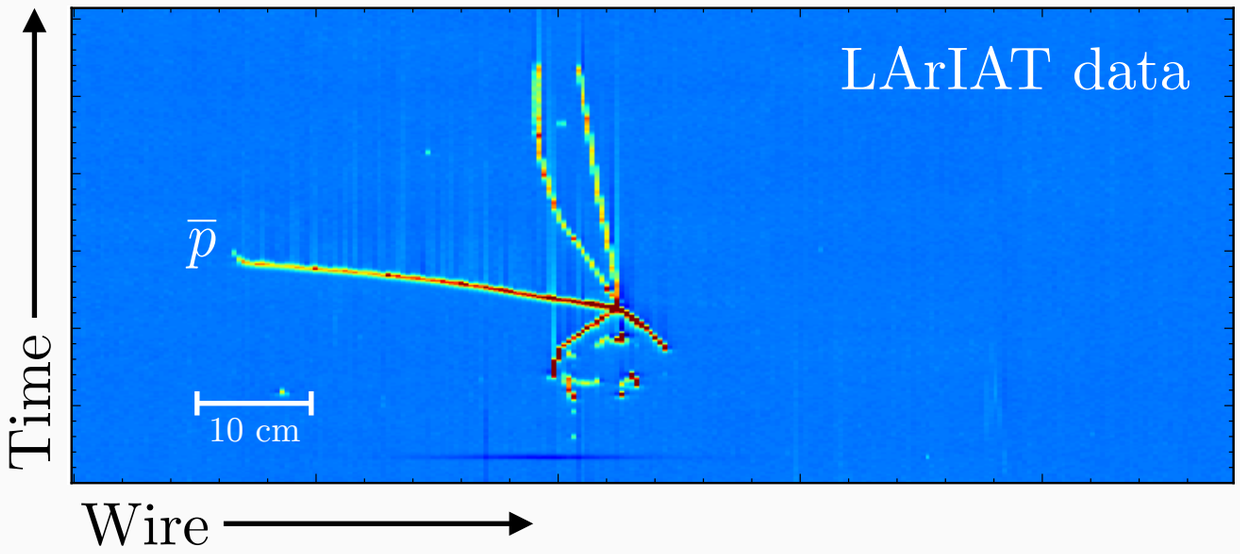


Mesh cathode in LArIAT

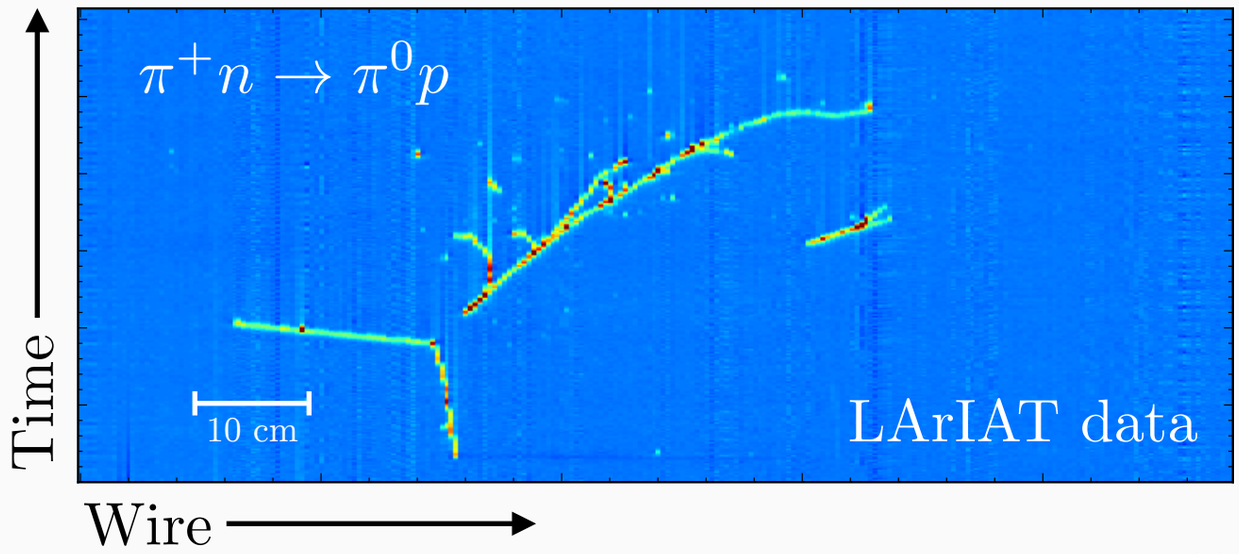
Physics in LArIAT

- Pion studies
  - Total inclusive pion–Ar cross section
  - Exclusive channels: pion absorption and pion charge exchange
  - Important for neutrino experiments because pions are often produced in neutrino interactions, and the pion–nucleus cross section is large
- Kaon studies for proton decay searches
- Anti-proton studies for n–$\overline{n}$ oscillation searches
- Geant4 validation

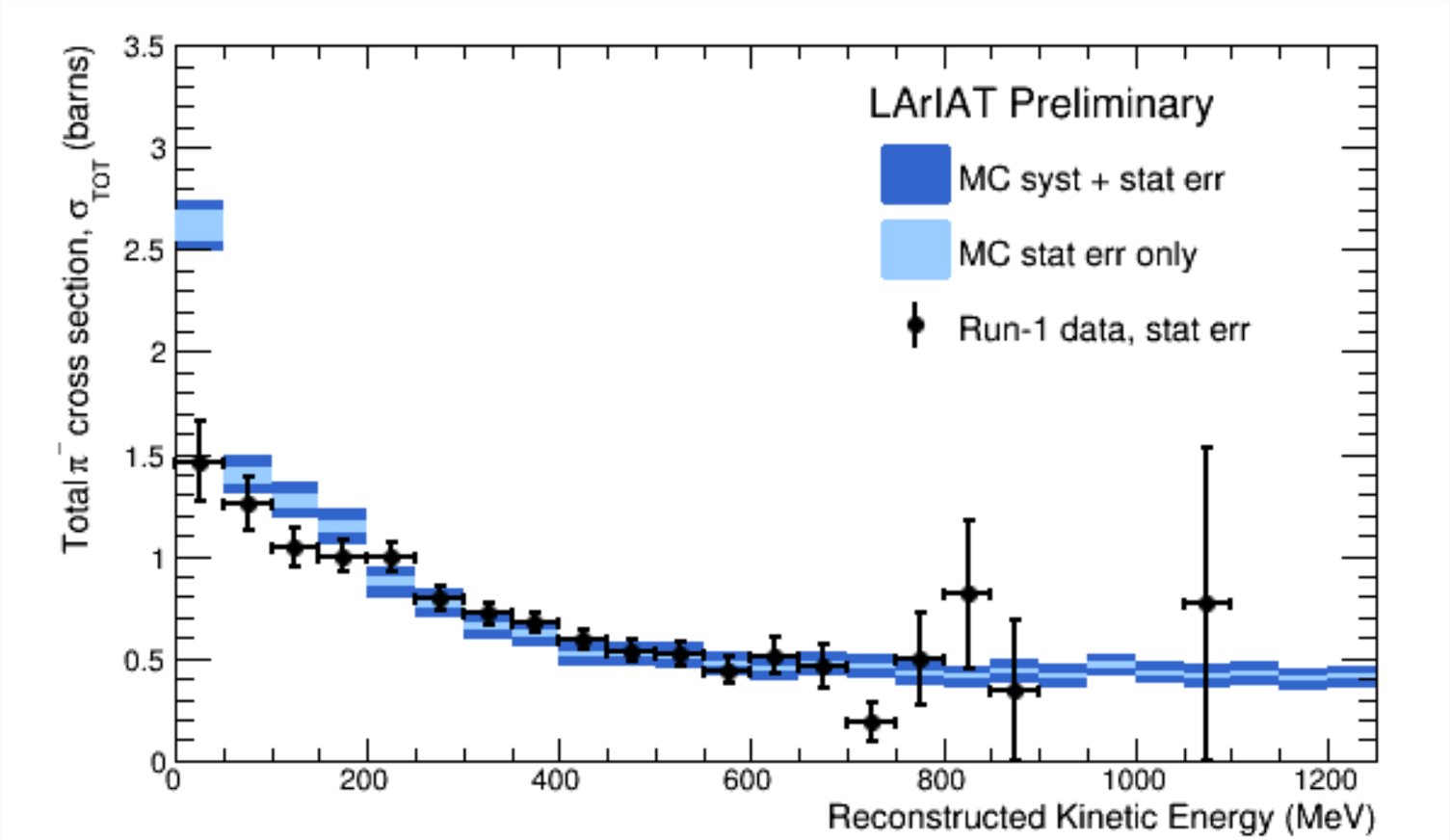
Anti-proton annihilation candidate



Pion single charge exchange candidate



π^-–Ar cross section measurement from Run I



World's first π^-–Ar cross-section measurement (presented at Fermilab's Wine & Cheese seminar on 8 April 2016).

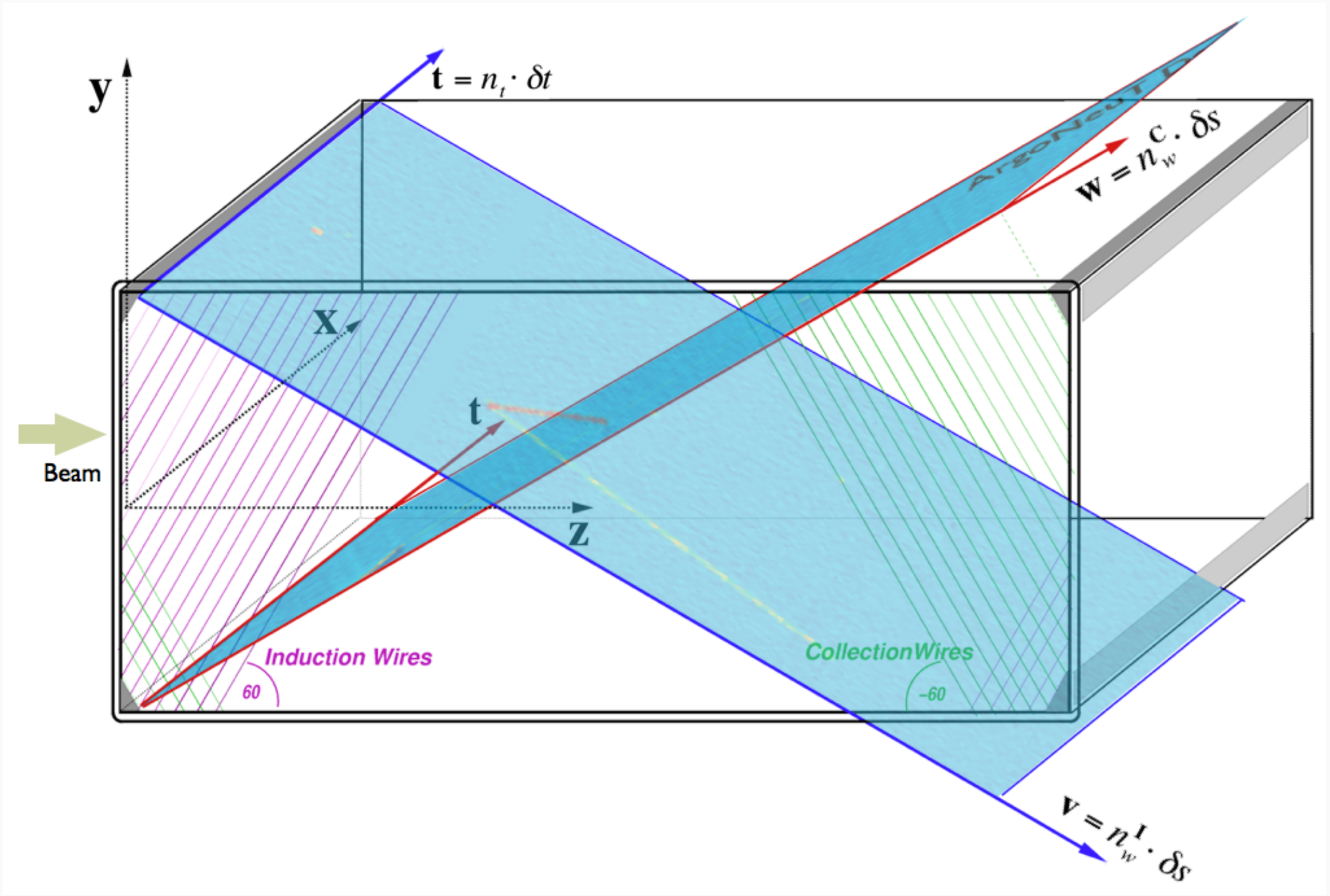
Conclusion

- LArIAT is a small detector capable of doing big physics and R&D
- Precise characterization and calibration of LArTPC response will inform larger neutrino experiments on measurements of final-state particles from neutrino interactions
- LArIAT has made the world's first pion–Ar cross section measurement
- More analyses to come from LArIAT, so stay tuned!

Thank you!

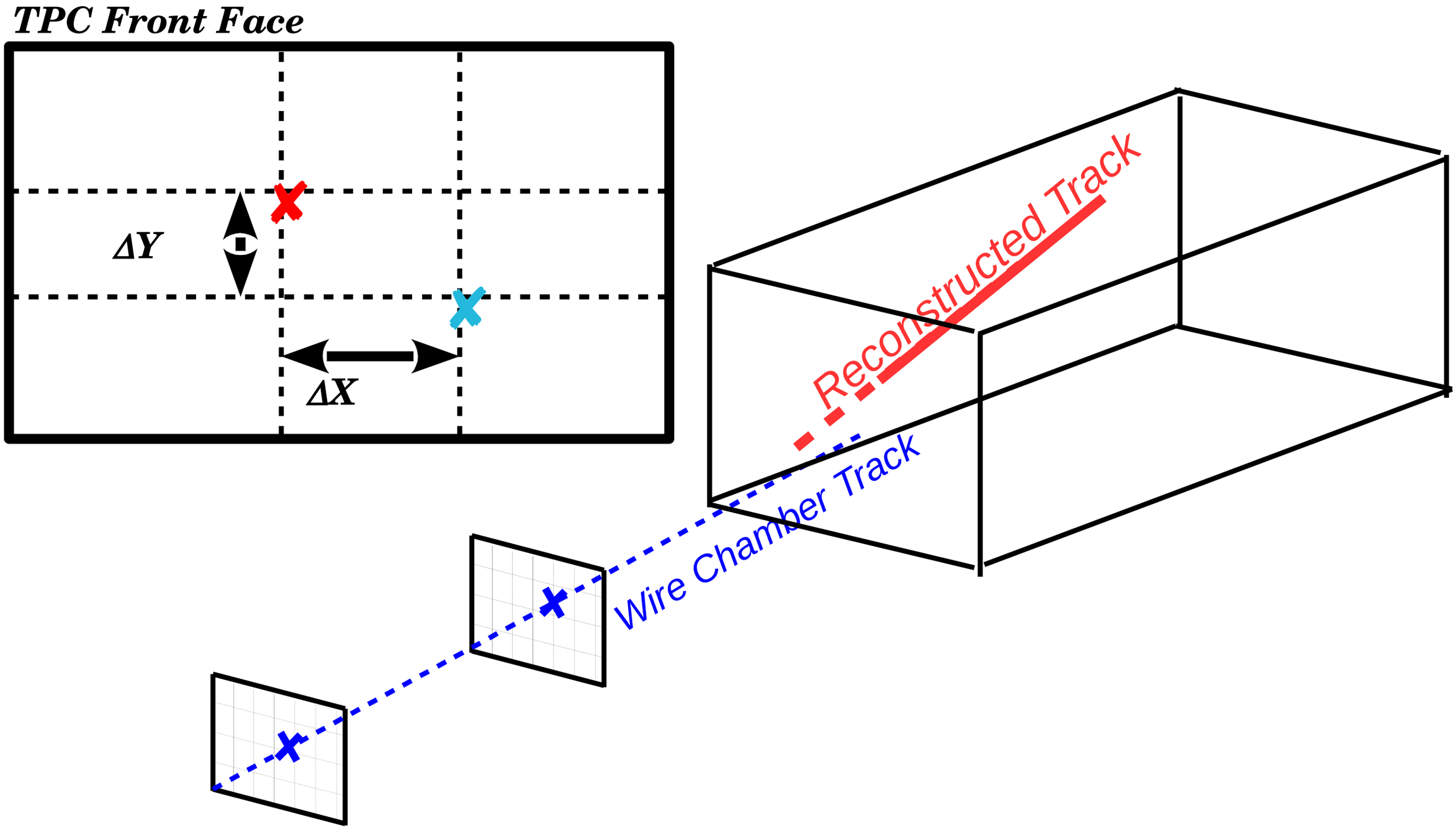
Backup

ArgoNeuT/LArIAT LArTPC

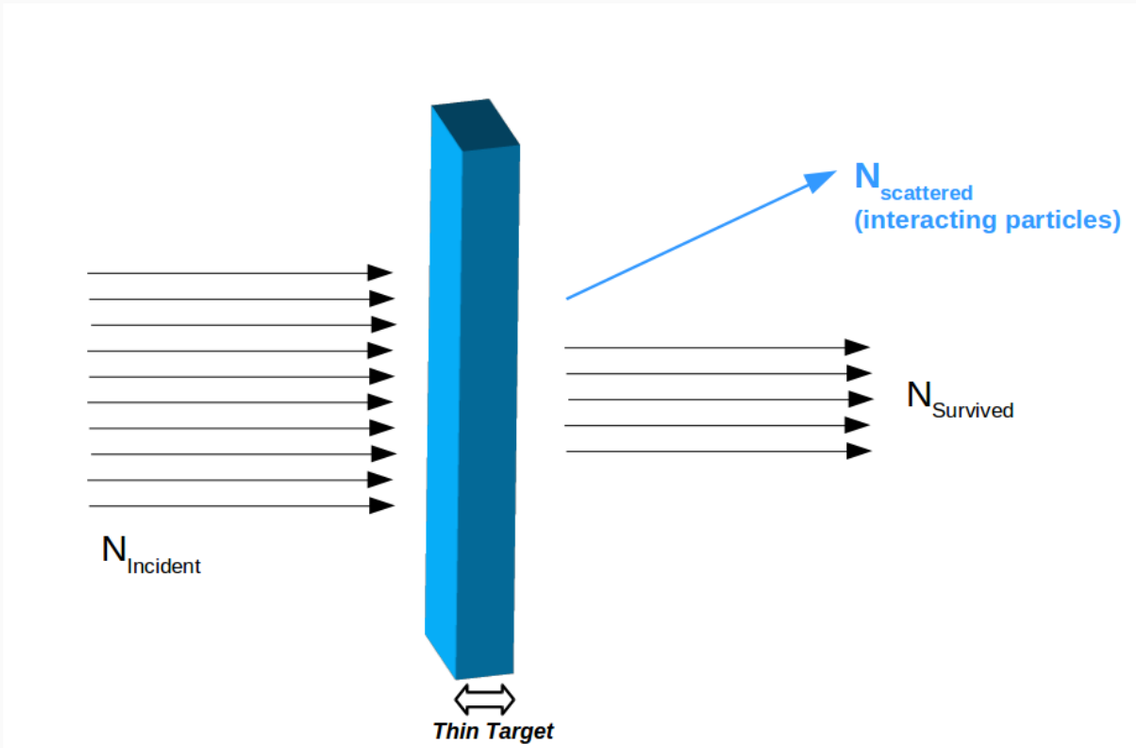


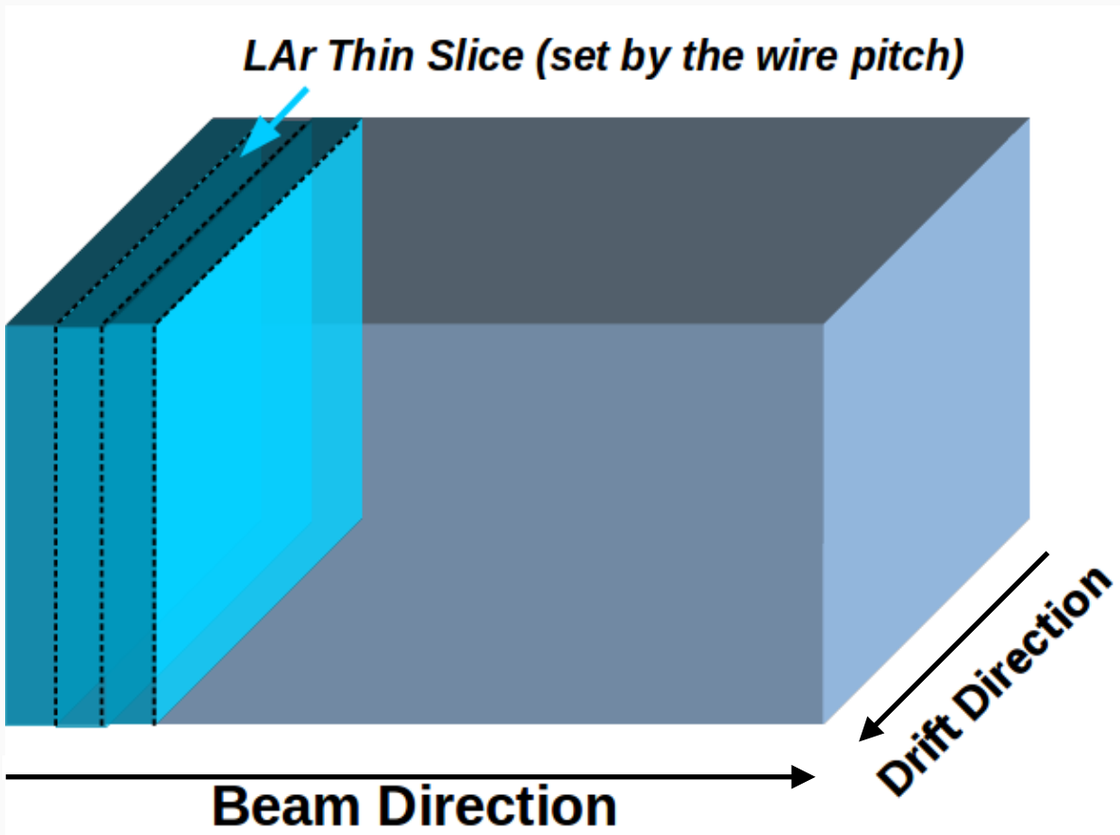
Courtesy of the ArgoNeuT collaboration

Matching MWC track with TPC track



Measuring cross sections with the “thin-slab” method





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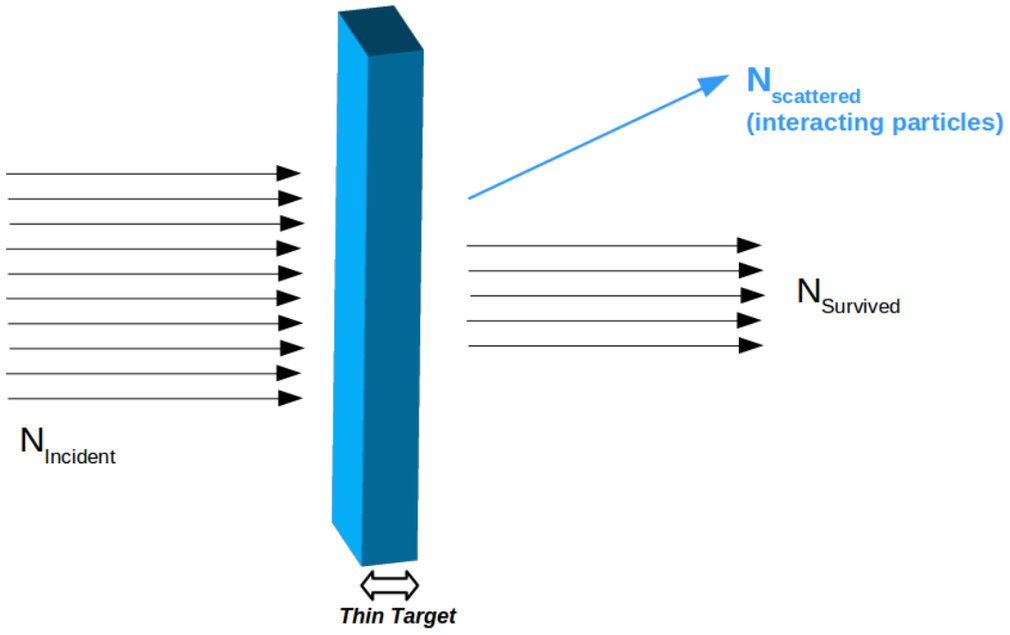
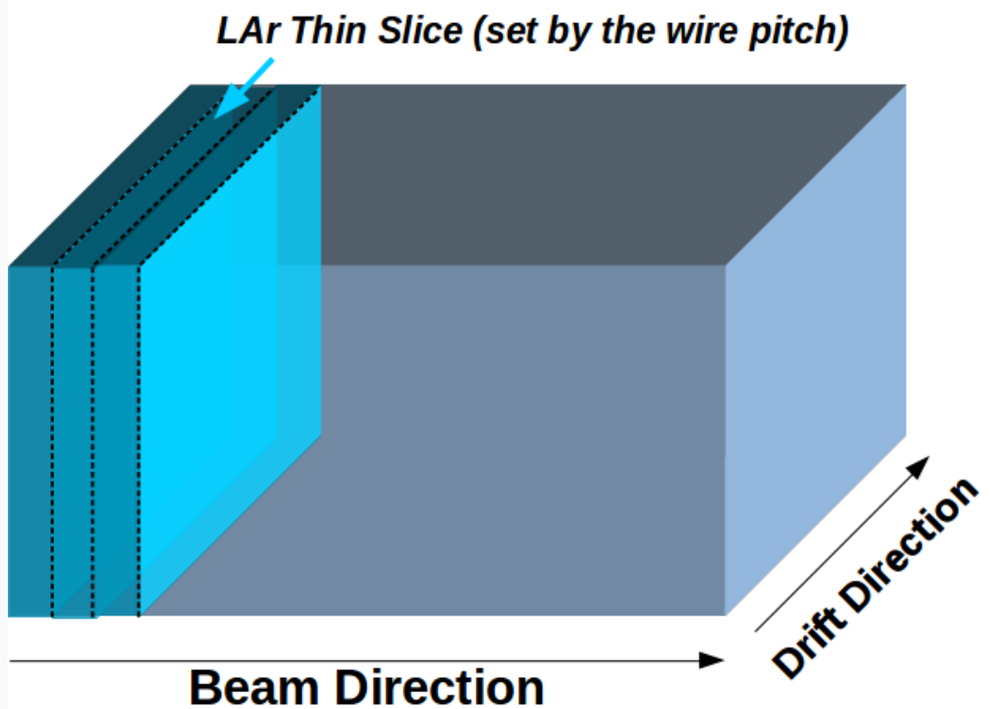
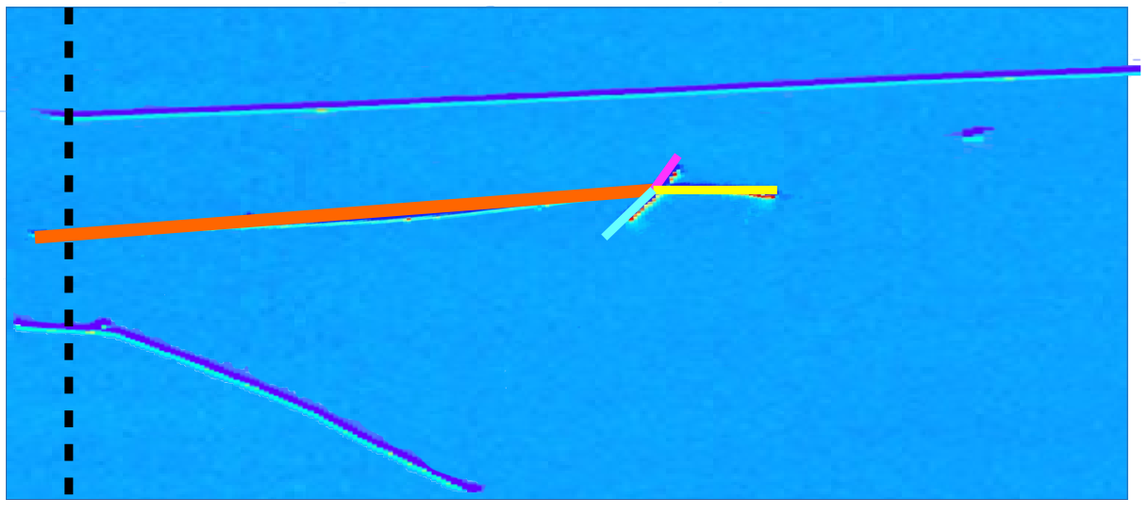
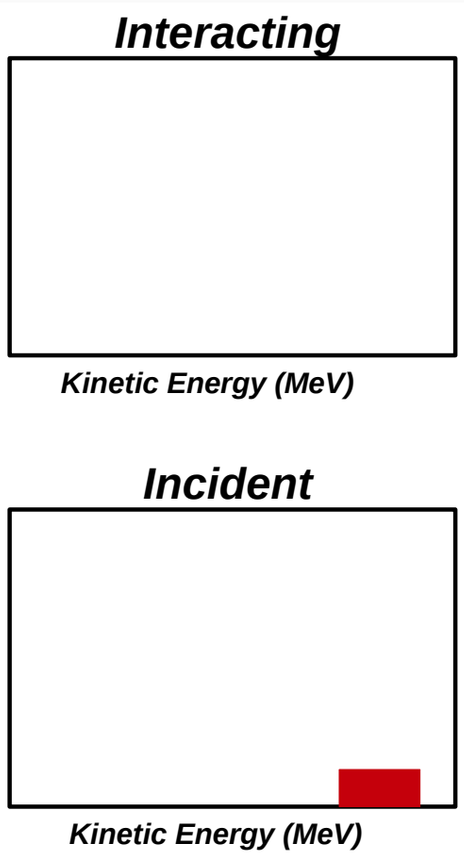




$$E_n^{\mathrm{KE}} = \left(\sqrt{p_{\mathrm{reco}}^2 - m_\pi^2} - m_\pi\right) - E_{\substack{\mathrm{flat} \\ \mathrm{corr.}}} - \sum_{i=0}^{n-1} \left(\frac{\mathrm{d}E}{\mathrm{d}s}\right)_i \Delta z_i$$





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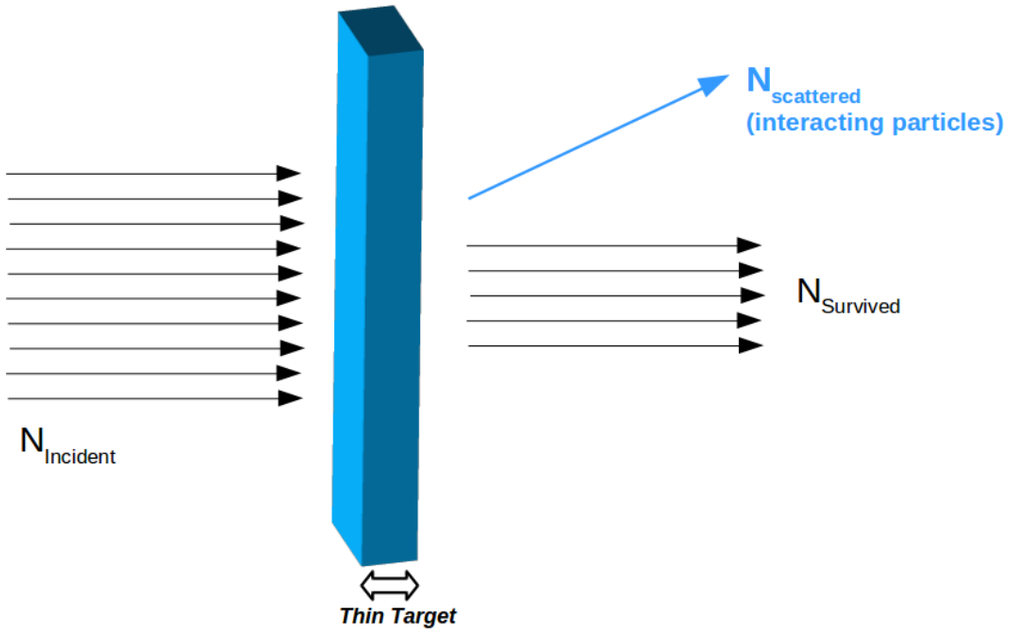

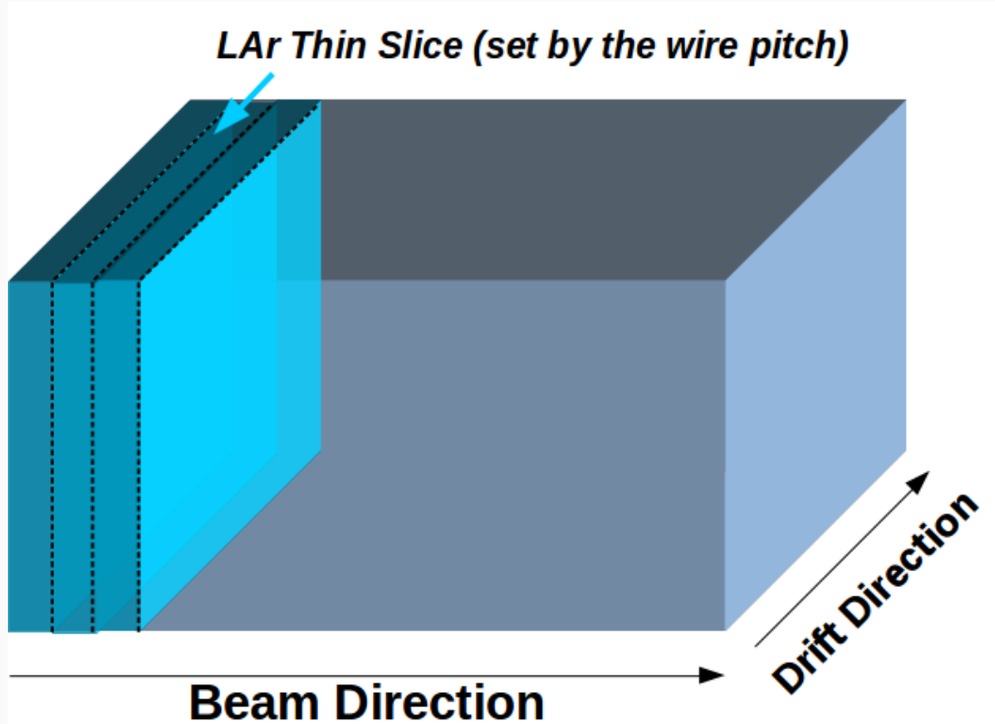

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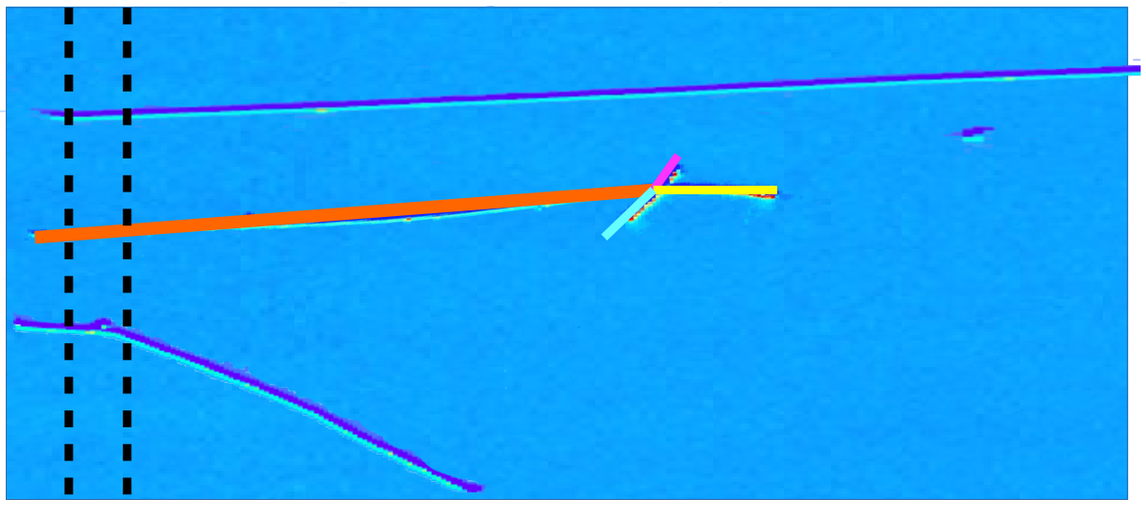

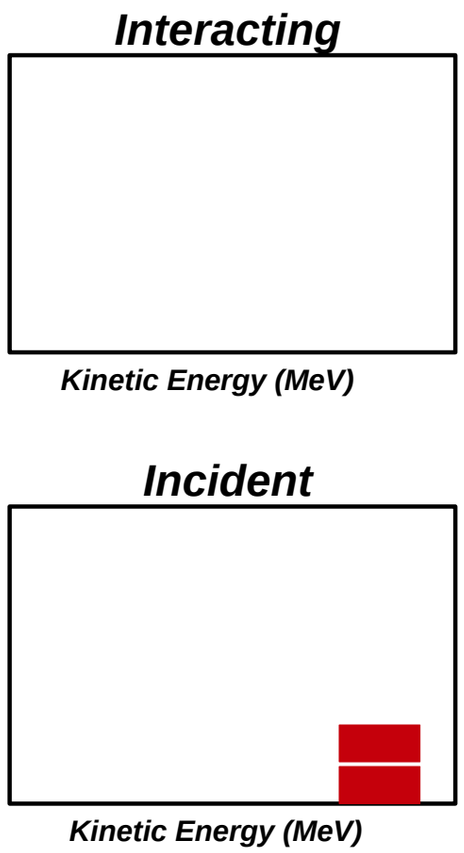

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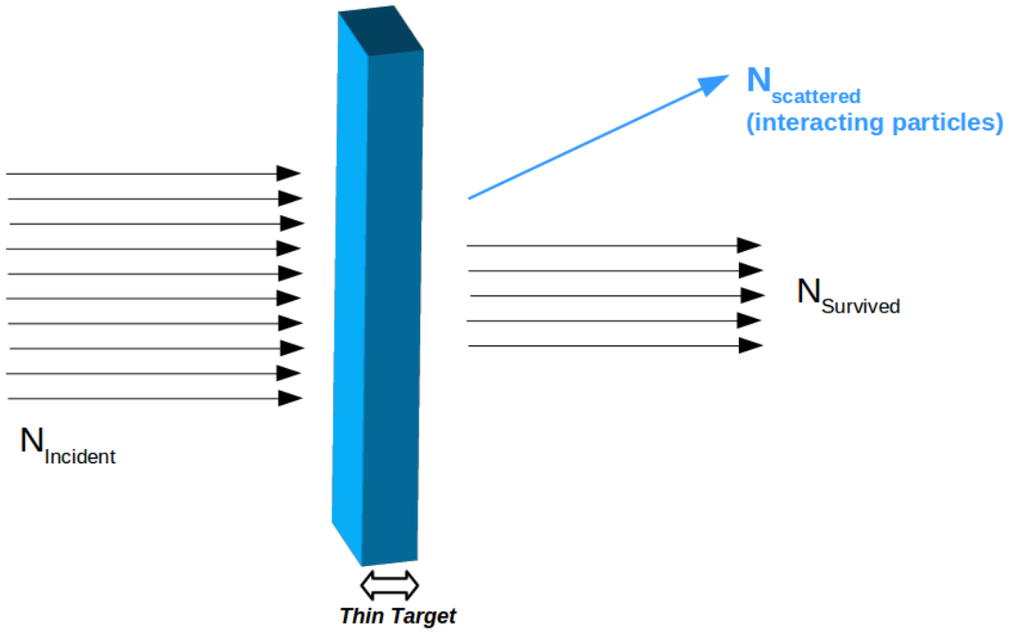

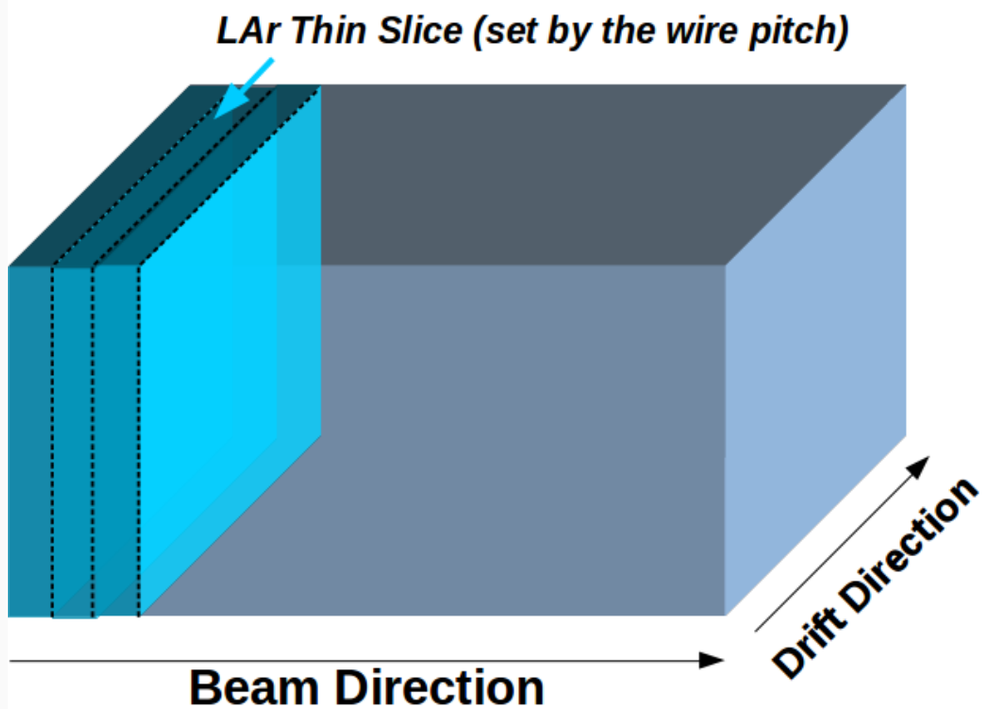

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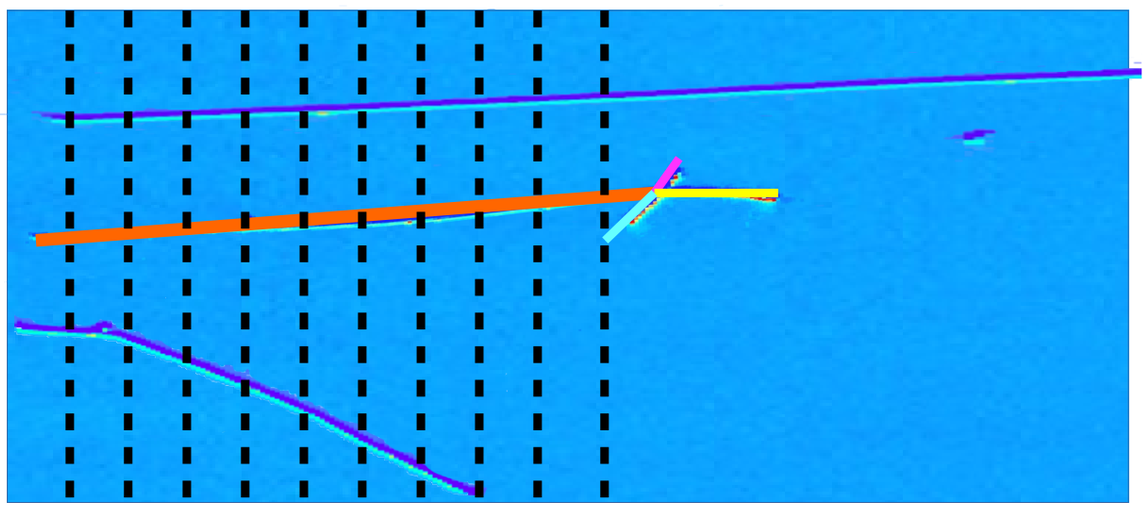

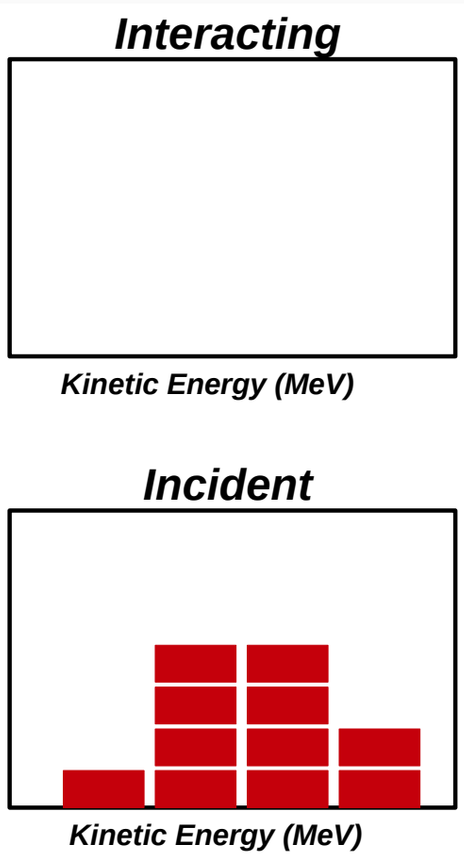

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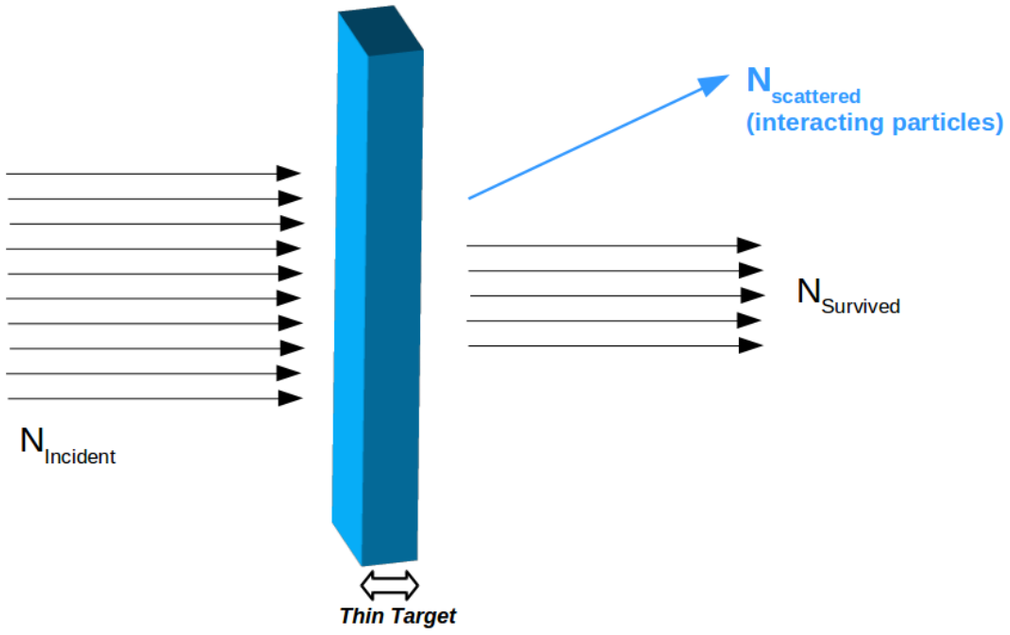

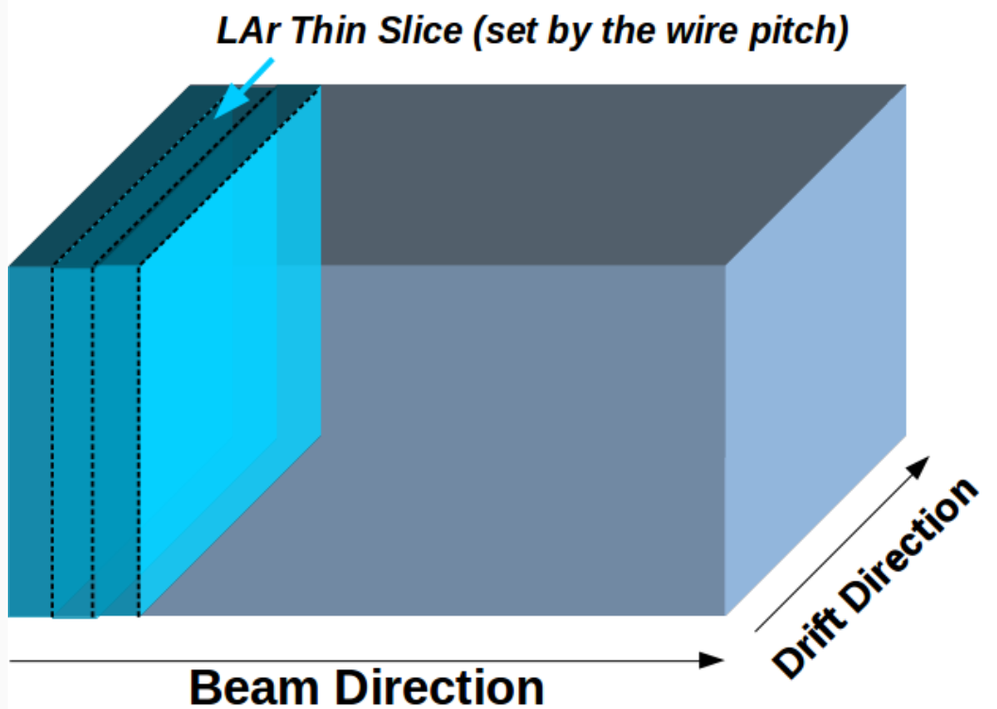

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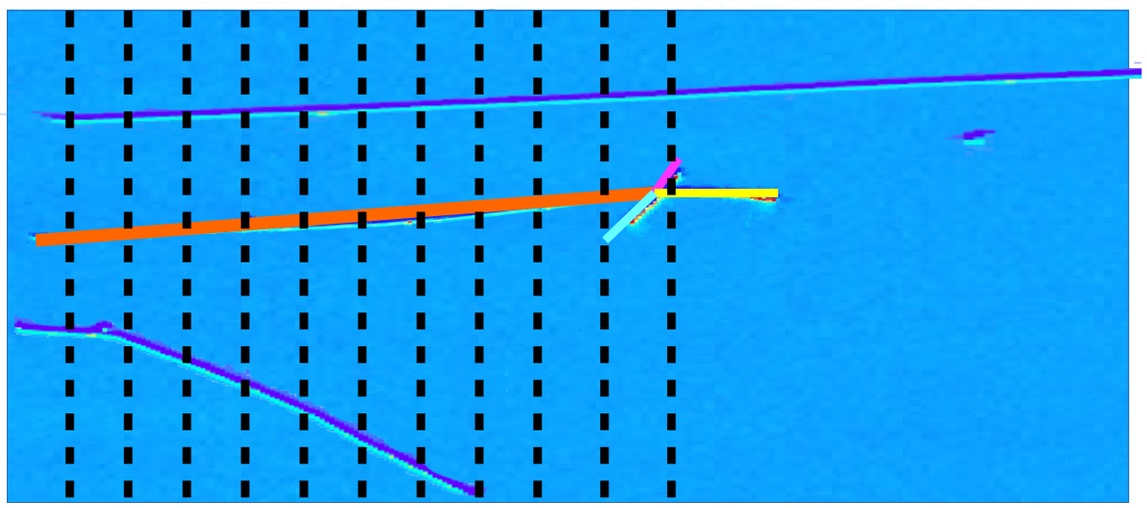

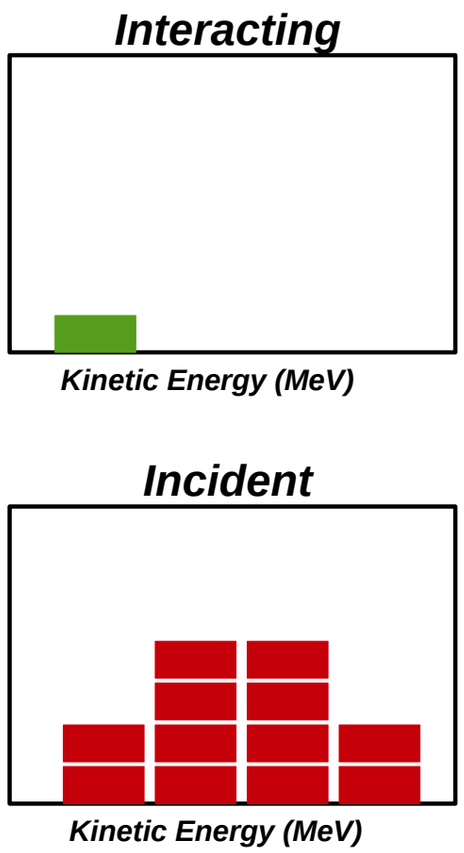

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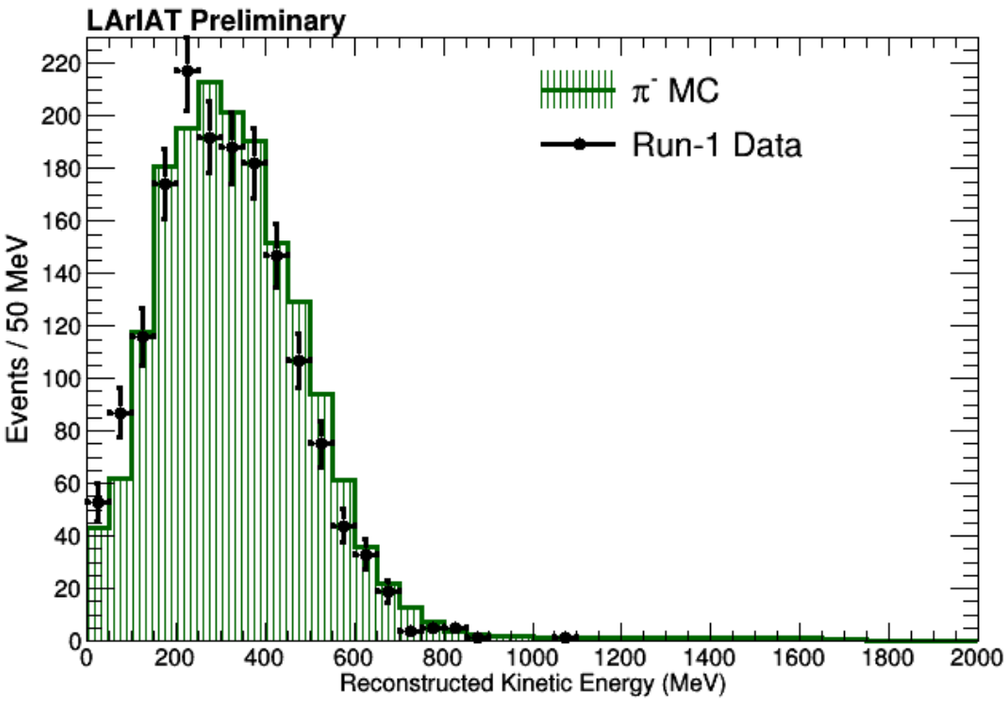

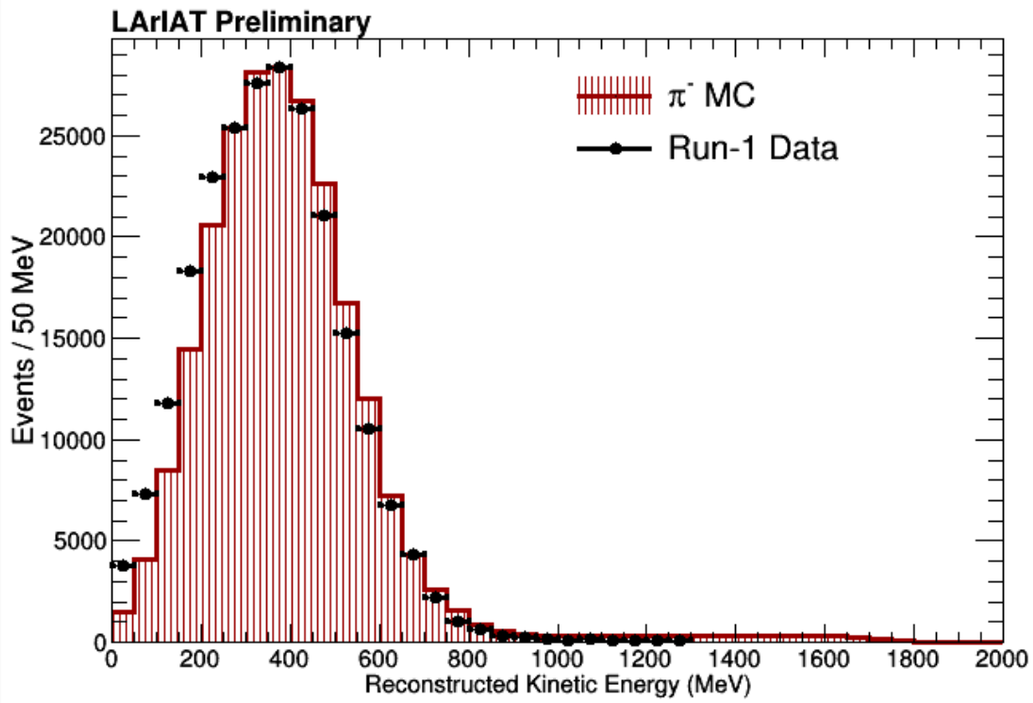

$$\sigma(E) \approx \frac{1}{nz} P_{\text{interacting}} = \frac{1}{nz} \frac{N_{\text{interacting}}}{N_{\text{incident}}}$$

where $n = \frac{\rho N_A}{A}$ and z is the slab depth.