Optical Properties of Liquid Argon measured by the PDS in ProtoDUNE-SP

Bryan Ramson (on behalf of the DUNE collaboration)

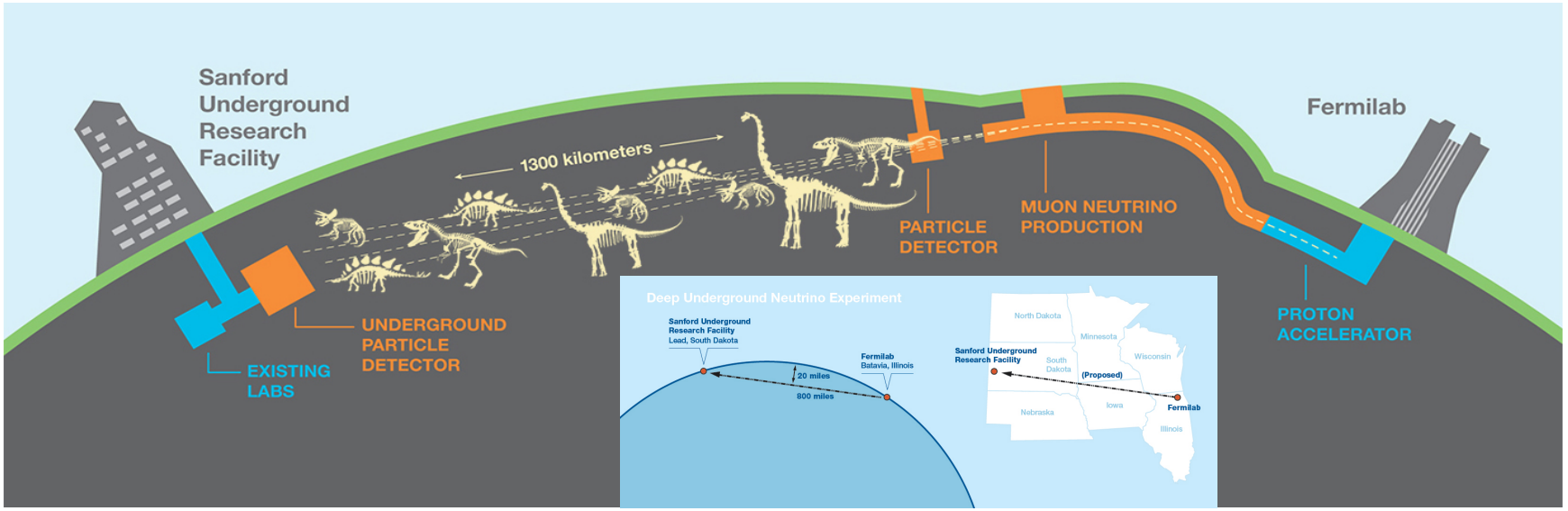
LIDINE 2019, Manchester, UK

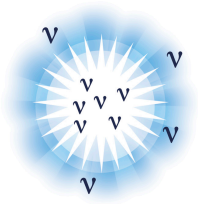
August 30, 2019

Fermilab DUNE

Introduction—(What is DUNE?)

The Fermilab Deep Underground Neutrino Experiment (DUNE) is a future accelerator based neutrino experiment hosted at Fermilab.





Will measure with greater precision:

- leptonic CP-violation (δ_{CP},Δ**L=0**?)
- Neutrino oscillation (θ_{12}, θ_{13}, and θ_{23})
- Neutrino mass hierarchy (**NH** or **IH**)

Will observe or further constrain:

- Proton Decay (Δ**B=0?,GUT)**

Will observe:

- Core-collapse/supernova burst neutrinos

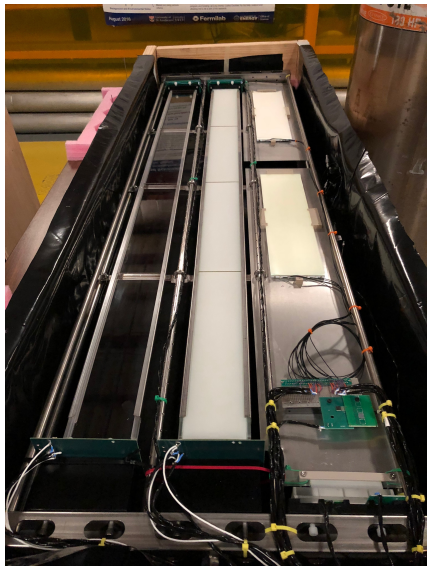
Alex Himmel, 8/28/2019, 2:45 PM
Neutrino Overview

Introduction—(What is ProtoDUNE?)

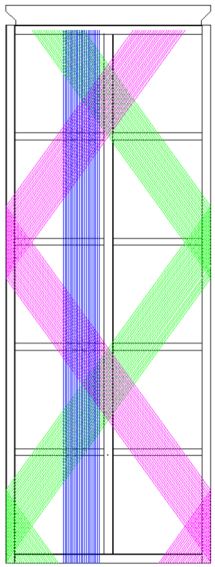
The ProtoDUNE project is two full scale prototypes of different DUNE Far Detector Modules with proton beam from the CERN SPS. One is based on a Single Phase (SP) Liquid-Argon (LAr) Time Projection Chamber (TPC) and the other a Dual Phase (DP) Liquid/Gaseous-Argon TPC.

ProtoDUNE-SP consists of:

- Single-Phase (SP) Liquid-Argon (LAr) based Time-Projection Chamber (TPC)
- Photon Detection System (PDS)
- Cosmic Ray Tagger (CRT)

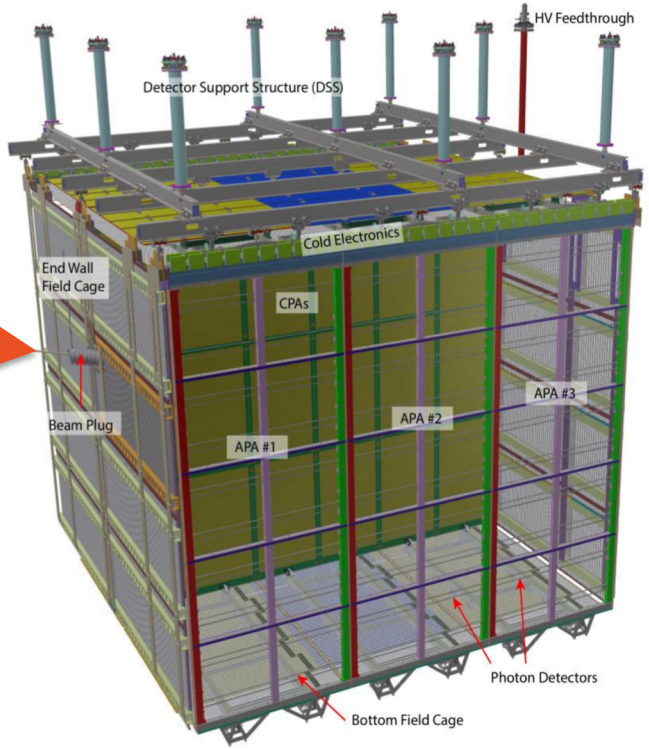


Individual Photon Detectors



APA Sketch

0.3-7 GeV Beam from CERN SPS



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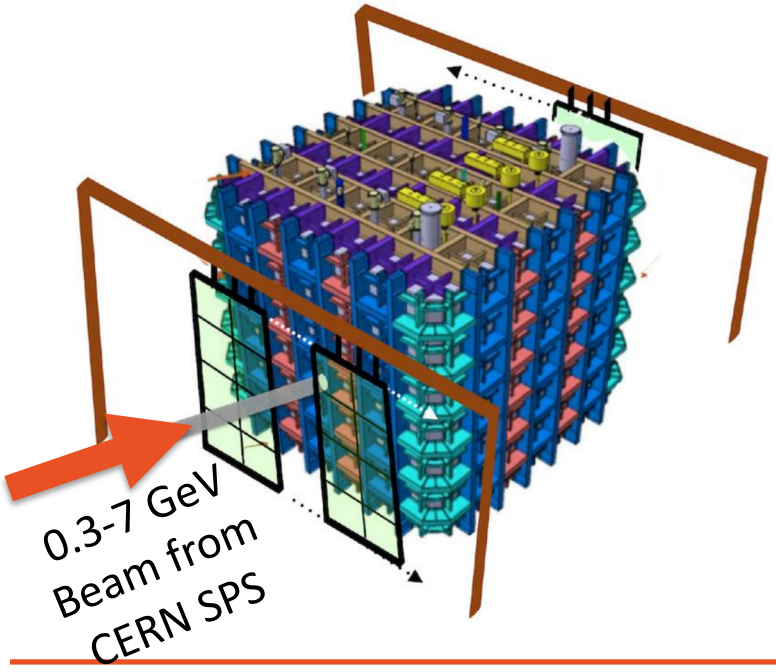

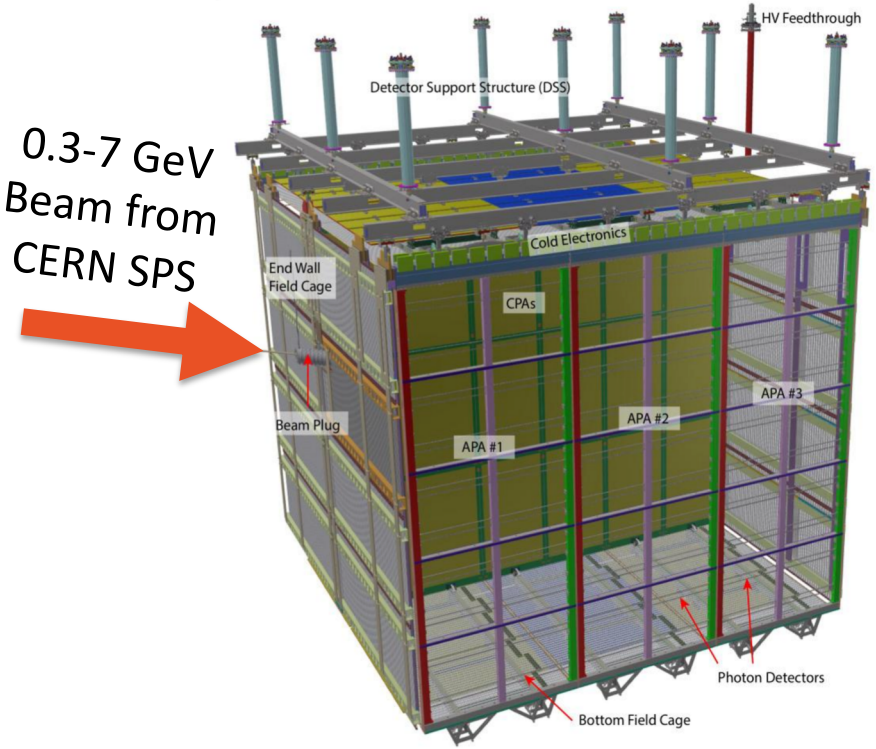

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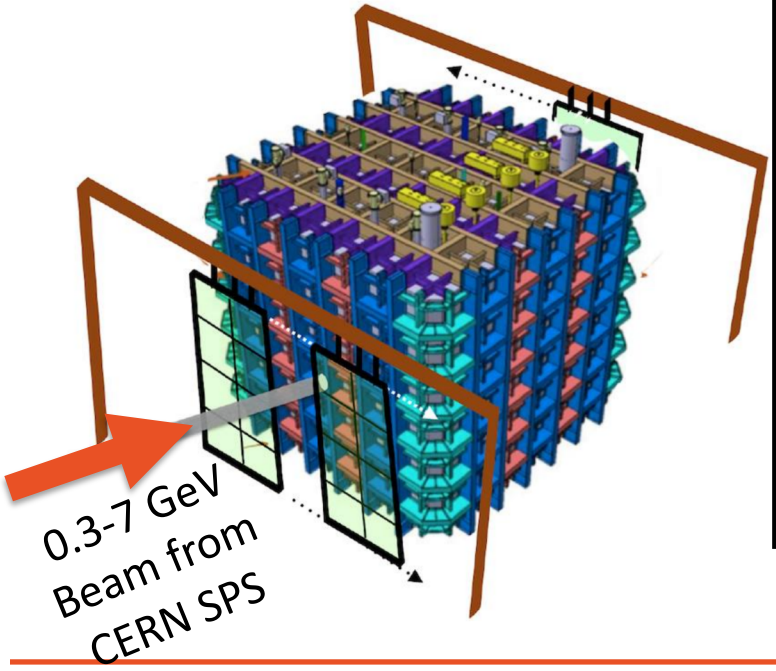
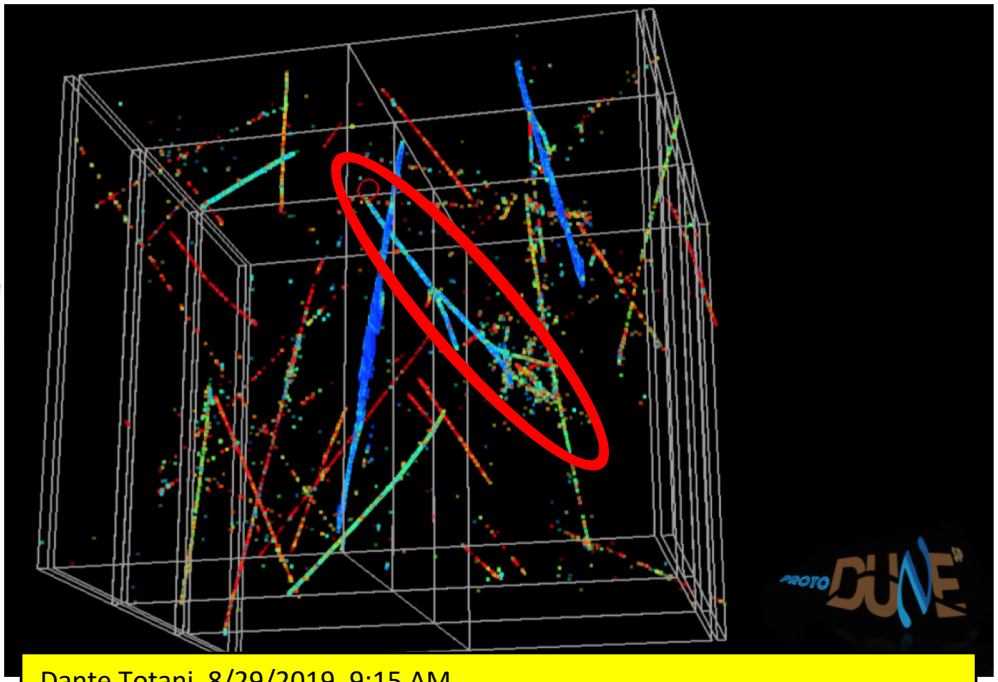
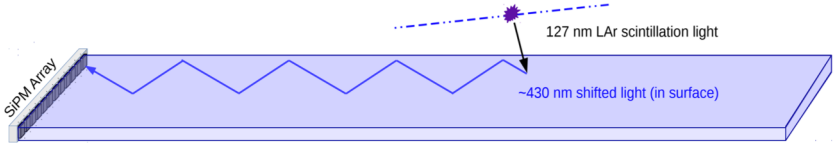




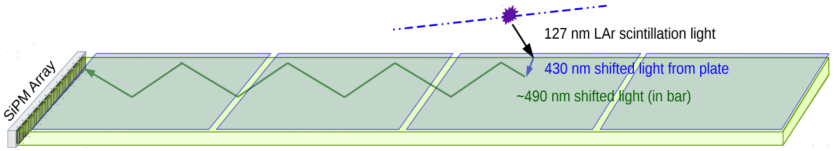
Dante Totani, 8/29/2019, 9:15 AM
Single photon rate observation and first calorimetric energy reconstruction of beam events from LAr scintillation light in protoDUNE-SP

The ProtoDUNE-SP PDS as a testbed

- (For DC & DS) 1 Collector + 12 Sensors = 1 Detector with 4 channels (1 Channel = 3 passively ganged sensors)
- (For ARAPUCA) 1 Collector + 144 Sensors = 1 Detector with 12 channels (1 Channel = 12 passively ganged sensors)
- Two types of sensors: SensL SiPMs and Hamamatsu MPPCs
- **Three types of Photon Collectors and two types of Photon Sensors across 60 Detectors**

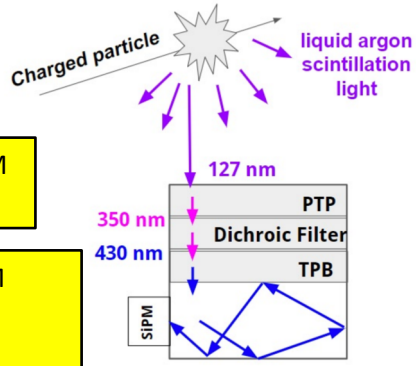


"Dip-Coated" (DC) Type Collector × 29



"Double-Shifted" (DS) Type Collector × 29

"ARAPUCA" Type Collector × 2



Ettore Segreto, 8/29/2019, 9:45 AM
X-ARAPUCA @ UNICAMP

Laura Paulucci, 8/30/2019, 9:00 AM
A complete simulation of the X-ARAPUCA device for detection of scintillation photons

Christopher Macias, 8/30/2019, 2:20 PM
Photon Detection System for ProtoDUNE Single Phase

- Detector wide timing resolution improves by a factor of 1000!
- ~60% of interaction energy produces scintillation light, enabling a beam particle calorimetry cross-check
- Necessary for proton decay and supernova physics.

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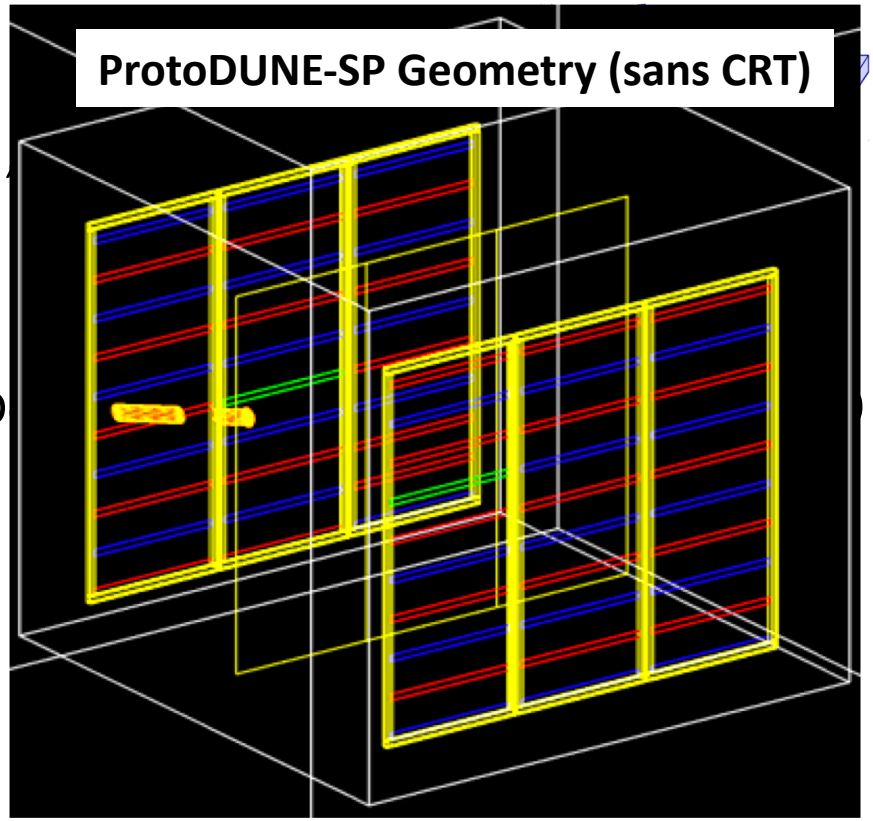

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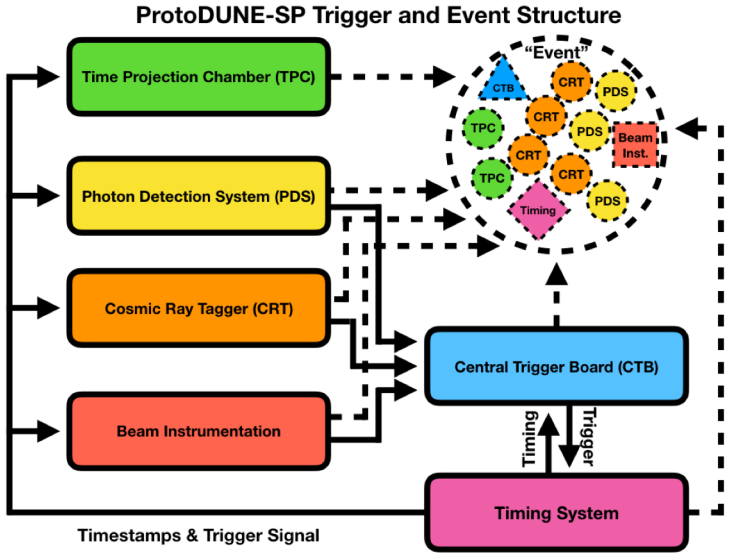
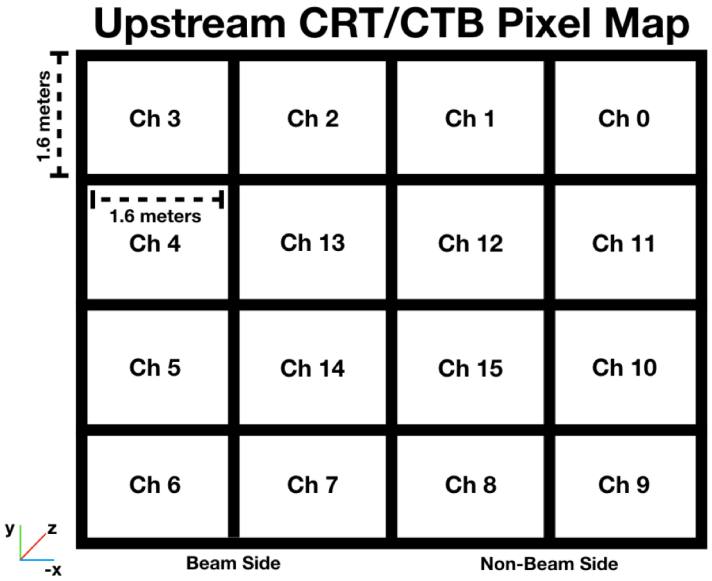
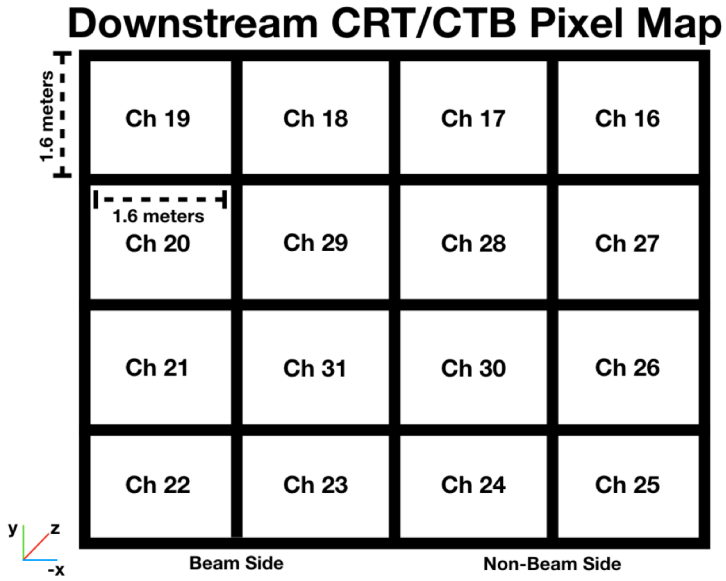
Cosmic Sample from CRT Triggering

- Can force all ProtoDUNE-SP subsystems to trigger on CRT pixel coincidence.







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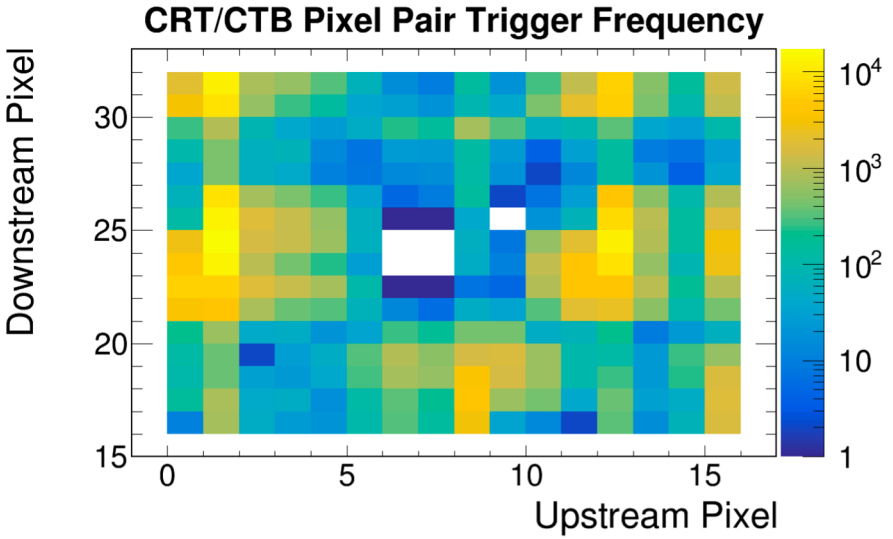
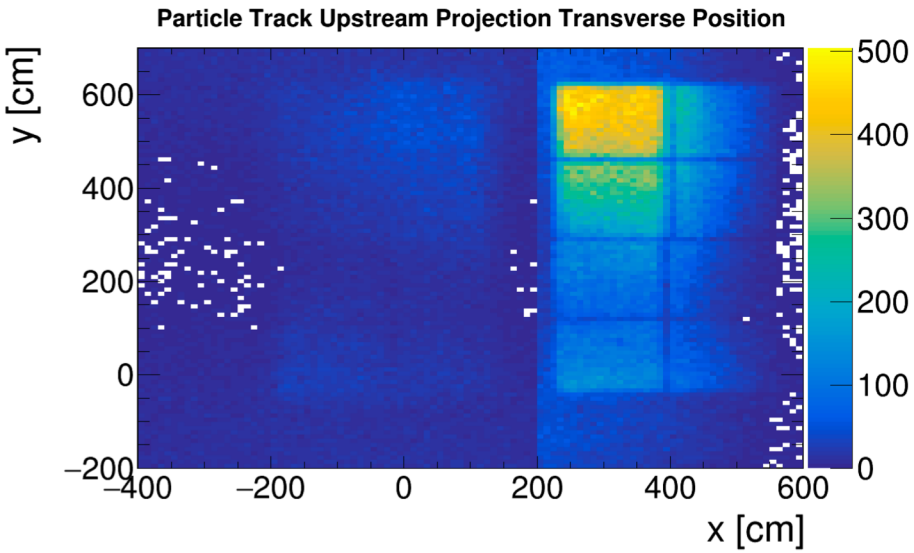
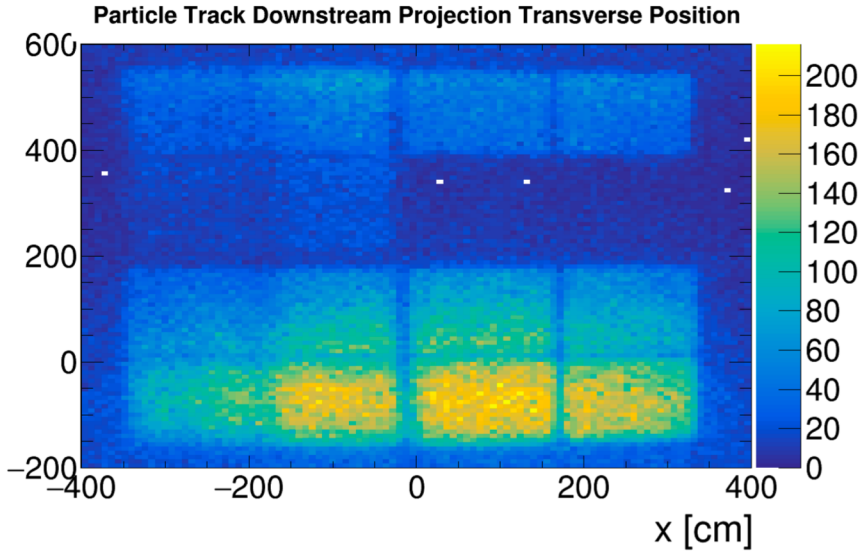
- Cosmic muons entering/exiting through upstream/downstream planes are reconstructed in TPC







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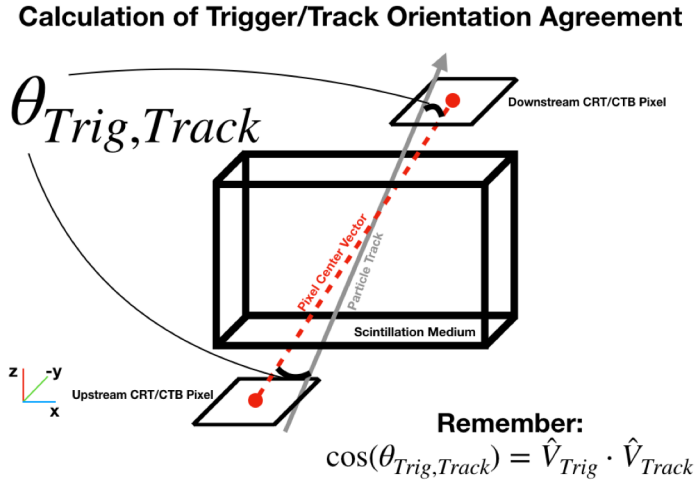
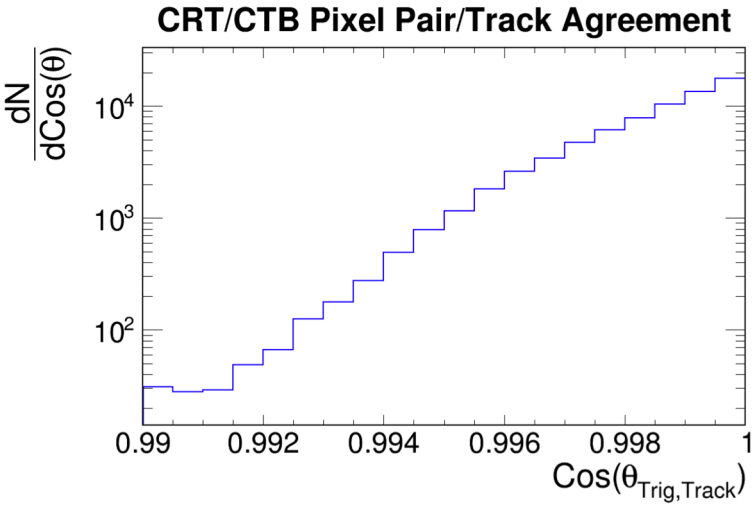
- Can refine CRT/TPC matching through comparison with orientation of CRT Pixels





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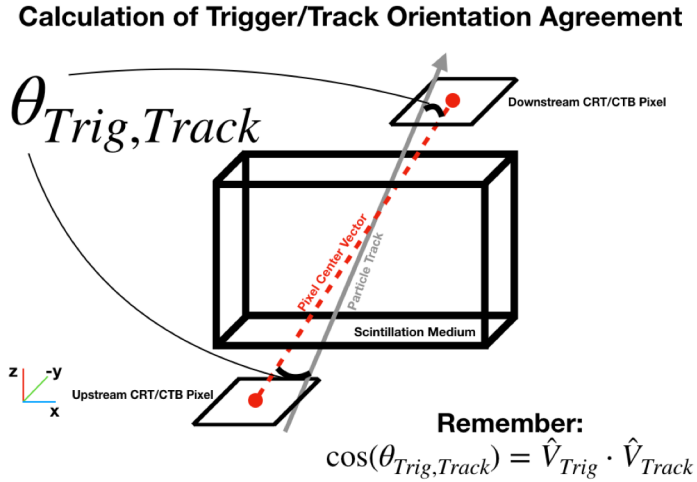

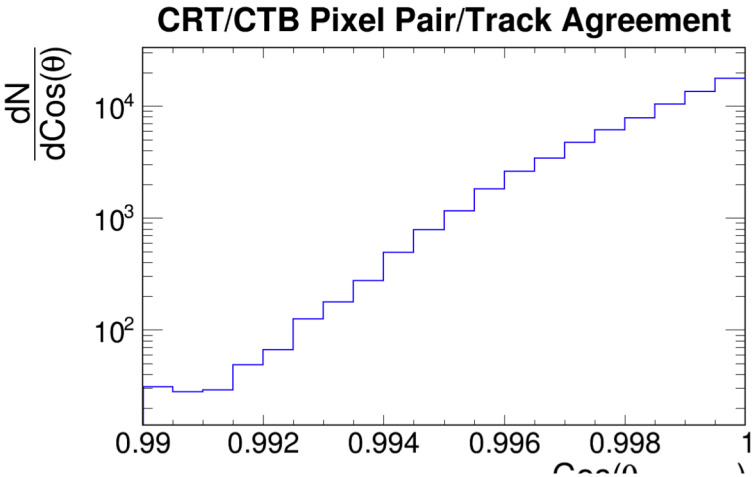

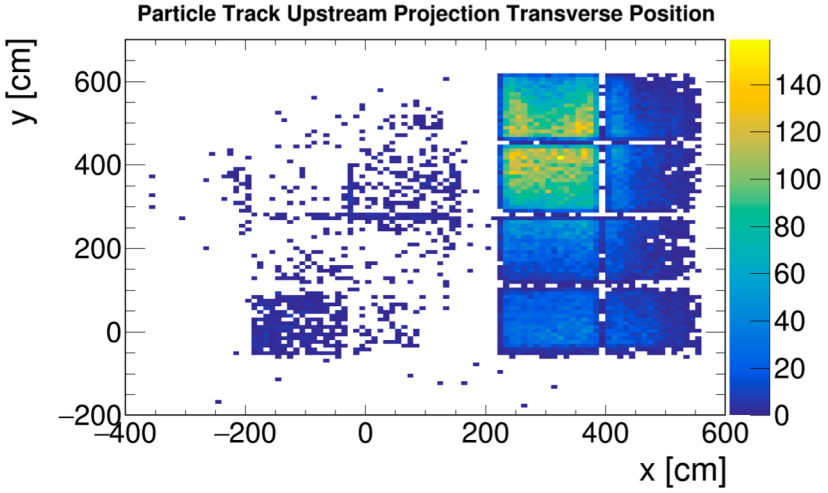

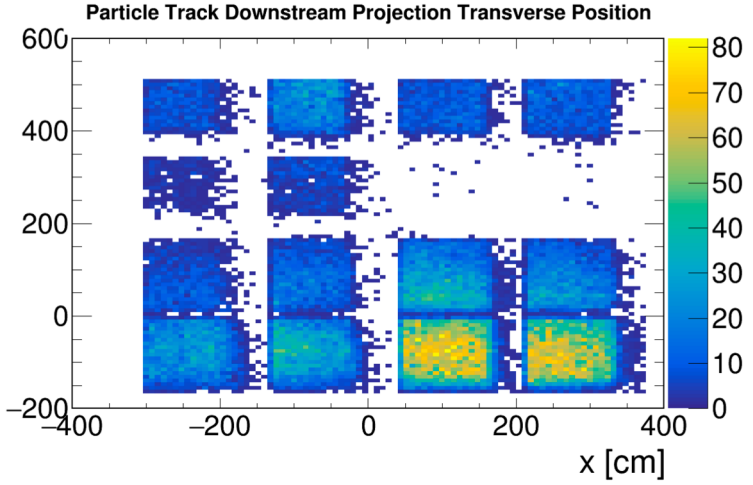

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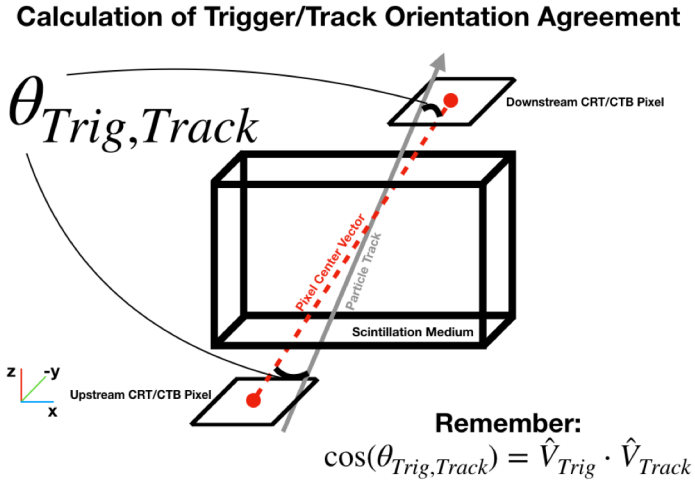
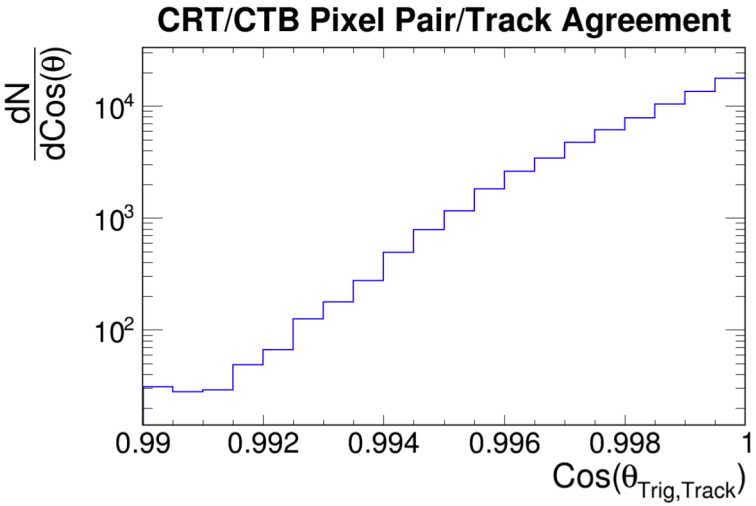
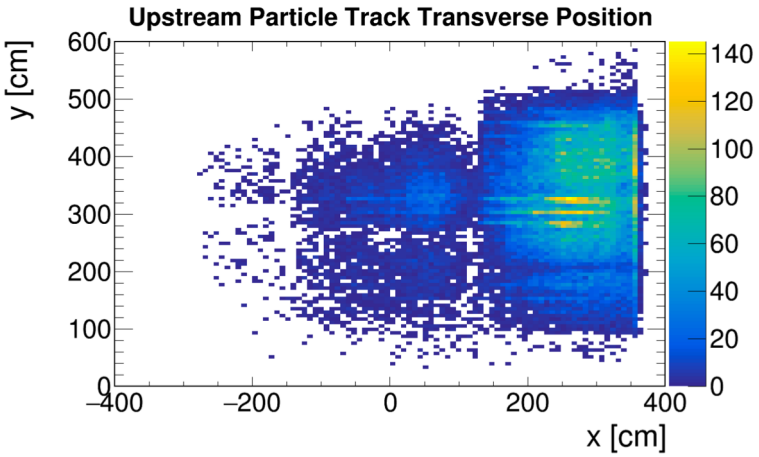
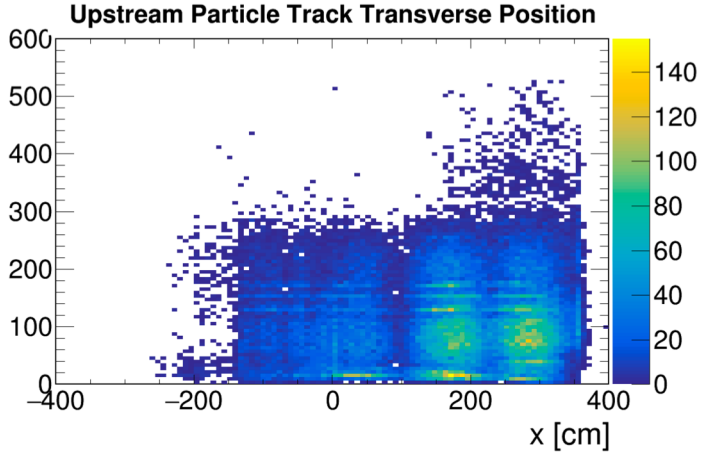


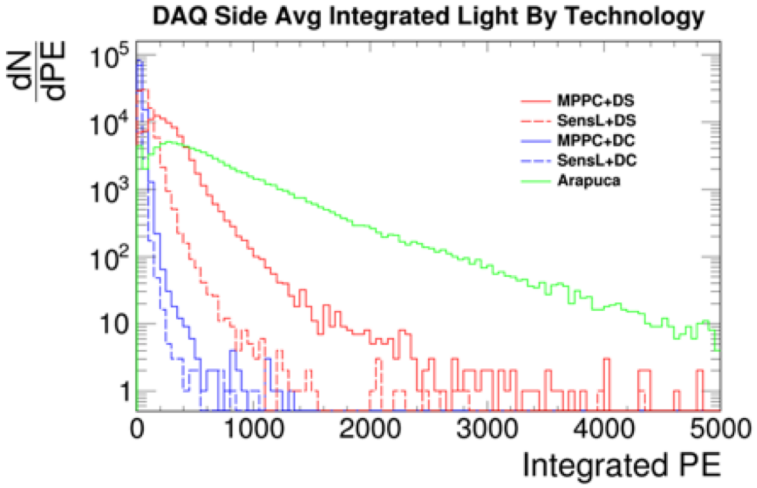






Light from Cosmics

- Sample is about 4 months of CRT-triggered cosmic data!



Light Stats		
Tech	**Average**	**StdDev**
SensL+DC	**20.24**	**17.19**
MPPC+DC	**37.61**	**27.49**
SENSL+DS	**84.22**	**79.39**
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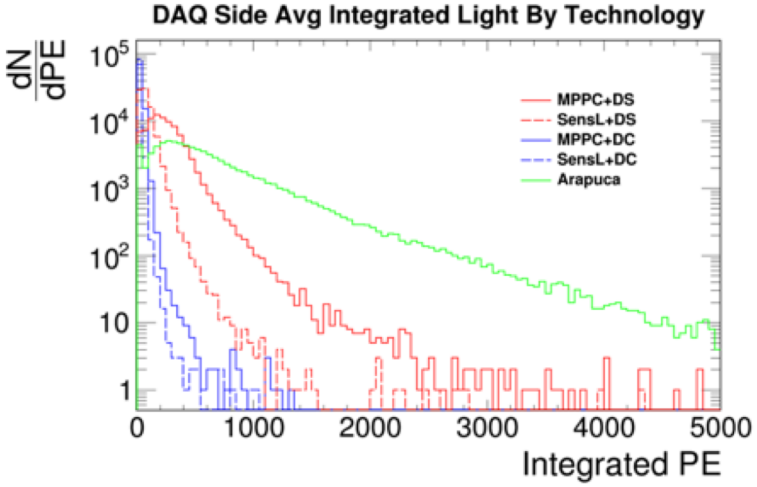

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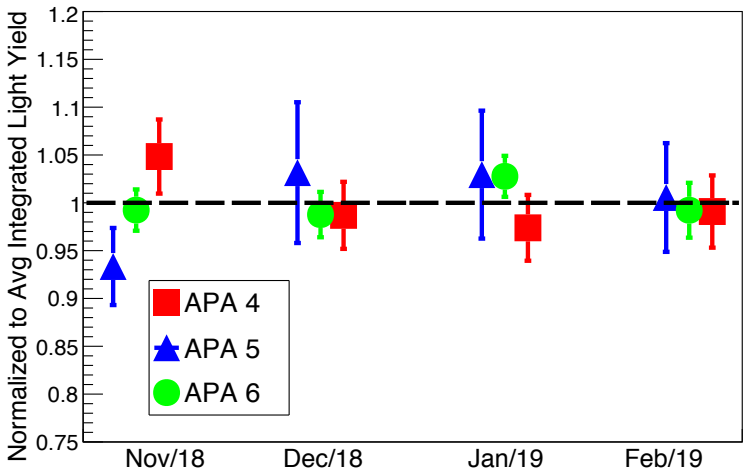
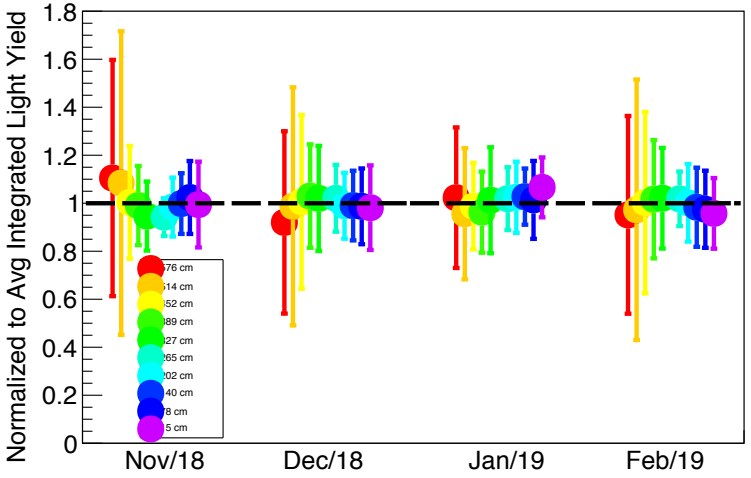
- Sample stability varies slightly by depth and height of photon detector (<10%).





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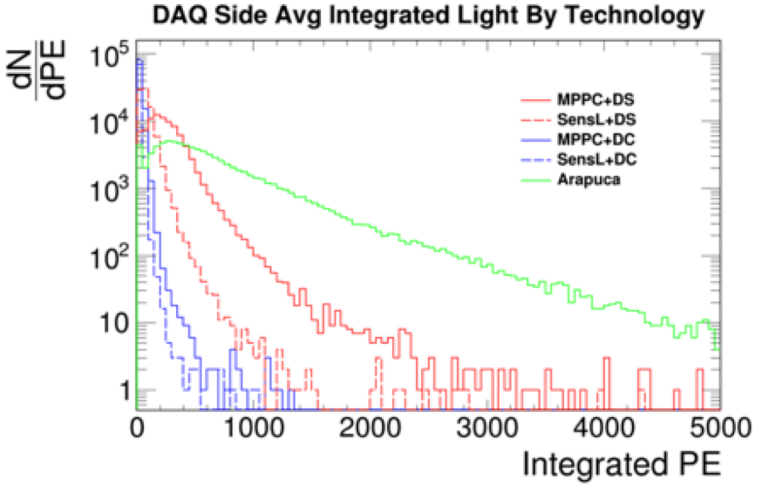

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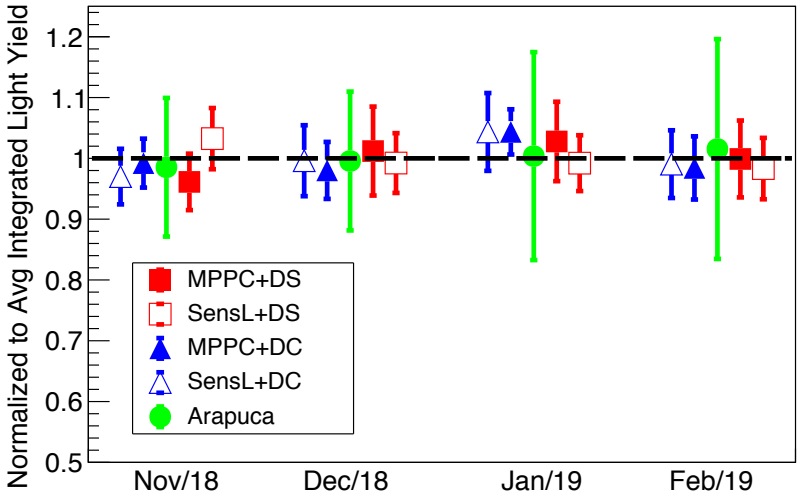
- Sample variation by technology is small (<4%).



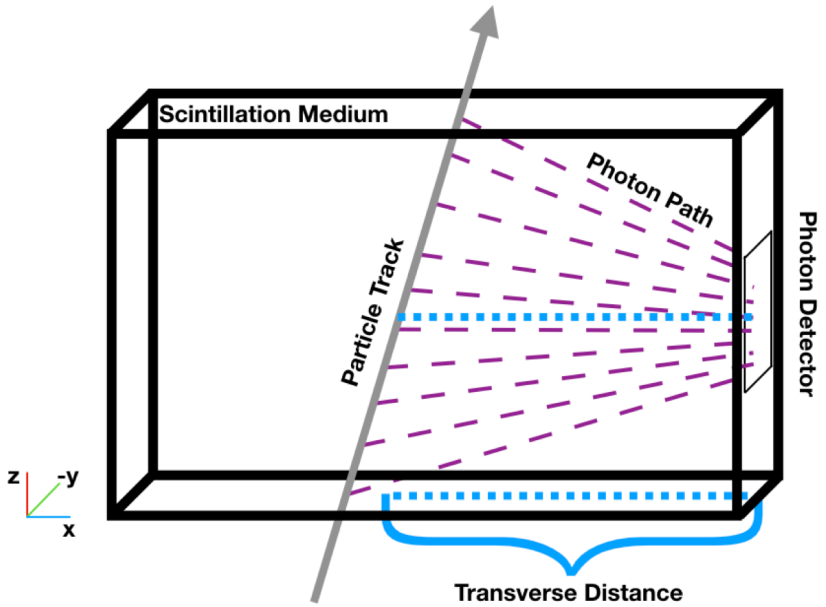
Towards an Estimate of Attenuation

- Measurement of true attenuation currently untenable in ProtoDUNE-SP, however "pseudo-attenuation" is measurable with cosmics!

$$T \propto e^{-\lambda x},$$

$$\lambda = \lambda_{Absorp.} + \lambda_{Rayleigh} + \lambda_{Cont.}$$

Track-Integrated Pseudo-Attenuation Event



- Light from many sources (i.e. many "slices" of the track) complicates the concept of a single isotropic light source, track-integrated pseudo-attenuation approximates true attenuation!

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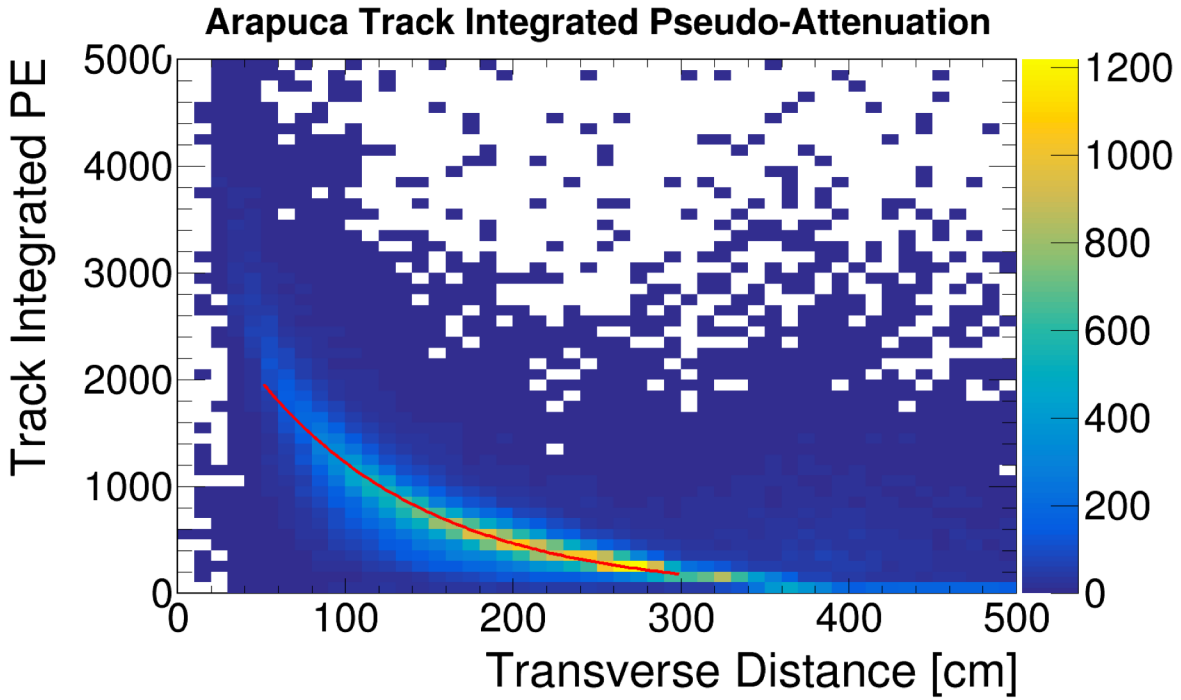

$$T_{Pseudo} \propto e^{C-\lambda_{Pseudo}x}$$

$$C = 8.07 \pm 0.04 \rightarrow$$
$$e^{C} = 3{,}197 \pm 1\ PE$$

$$\lambda_{Pseudo} = 0.009 \pm 0.003$$
$$= 111 \pm 37\ m$$

Summary and Next Steps

- An estimate of the optical properties was performed using cosmic tracks collected over four months in ProtoDUNE-SP.
- The light collected over the four months after the beam period was relatively stable in rate as were the collection efficiency of the different technologies.
- Pseudo-attenuation was used to estimate attenuation, but is by construction less precise than a true single source attenuation measurement.
- Possible effects from reflections and contaminants exist.
- Some effects can be disentangled with Monte Carlo.