

The Photon Detection System (PDS) at ProtoDUNE Single Phase

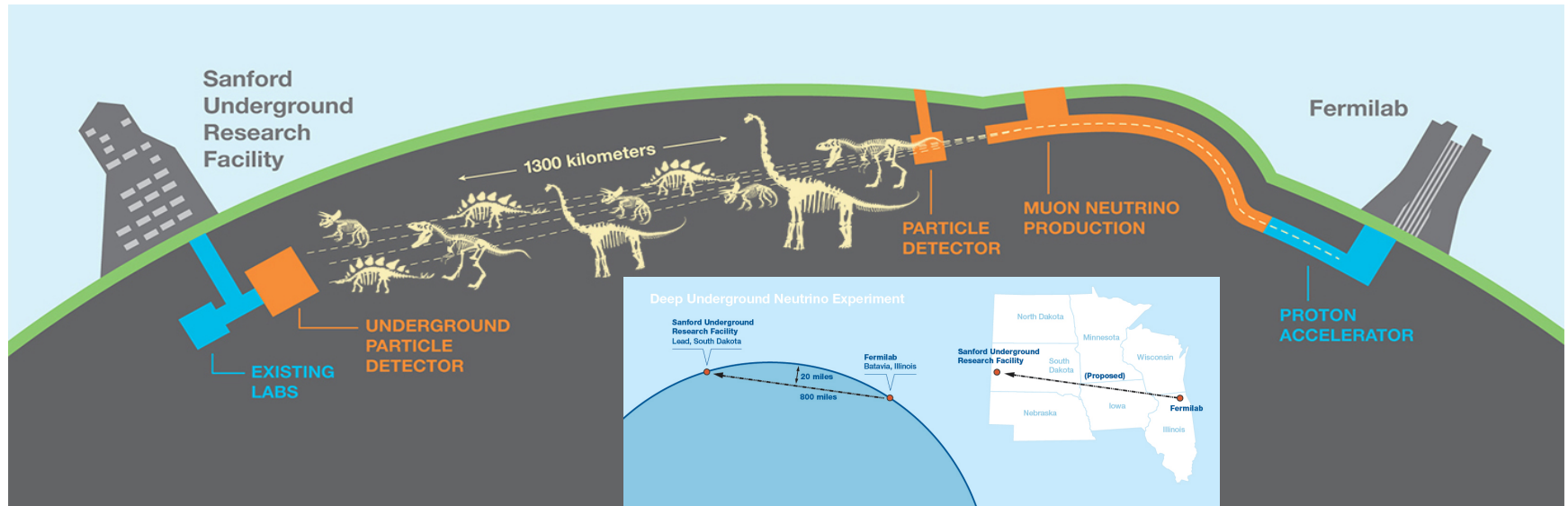
Bryan Ramson (on behalf of the DUNE collaboration)

APS April Meeting 2019

April 14, 2019

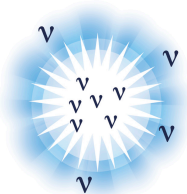
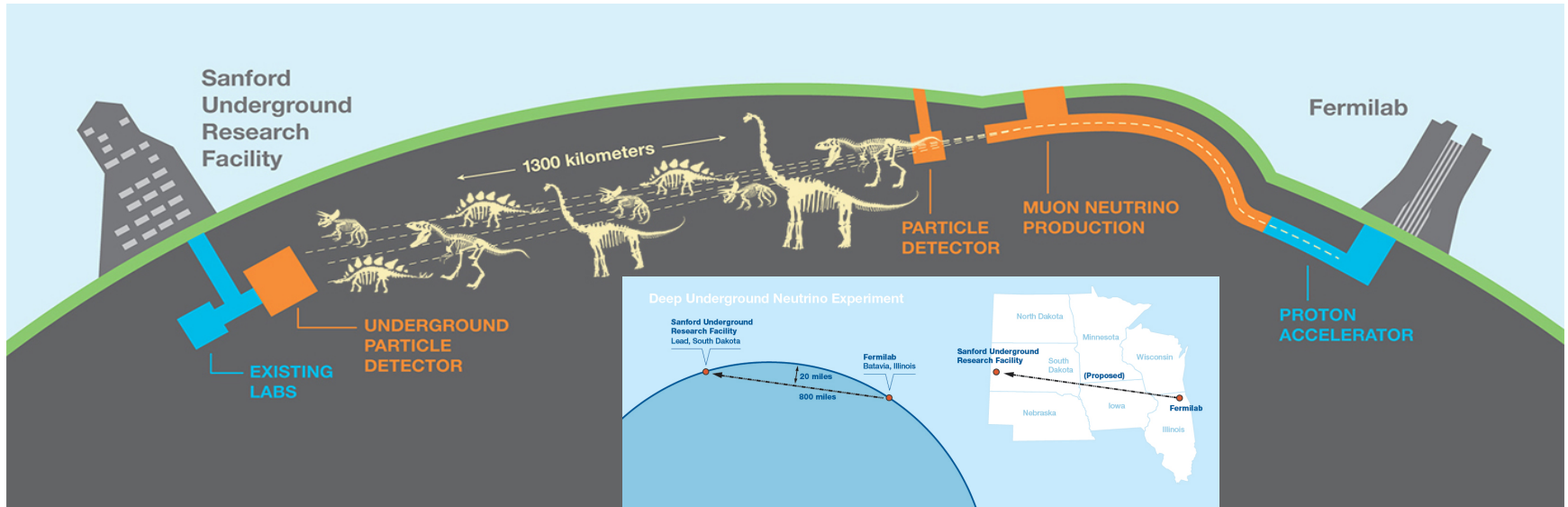
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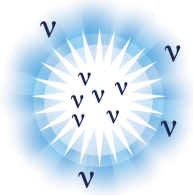
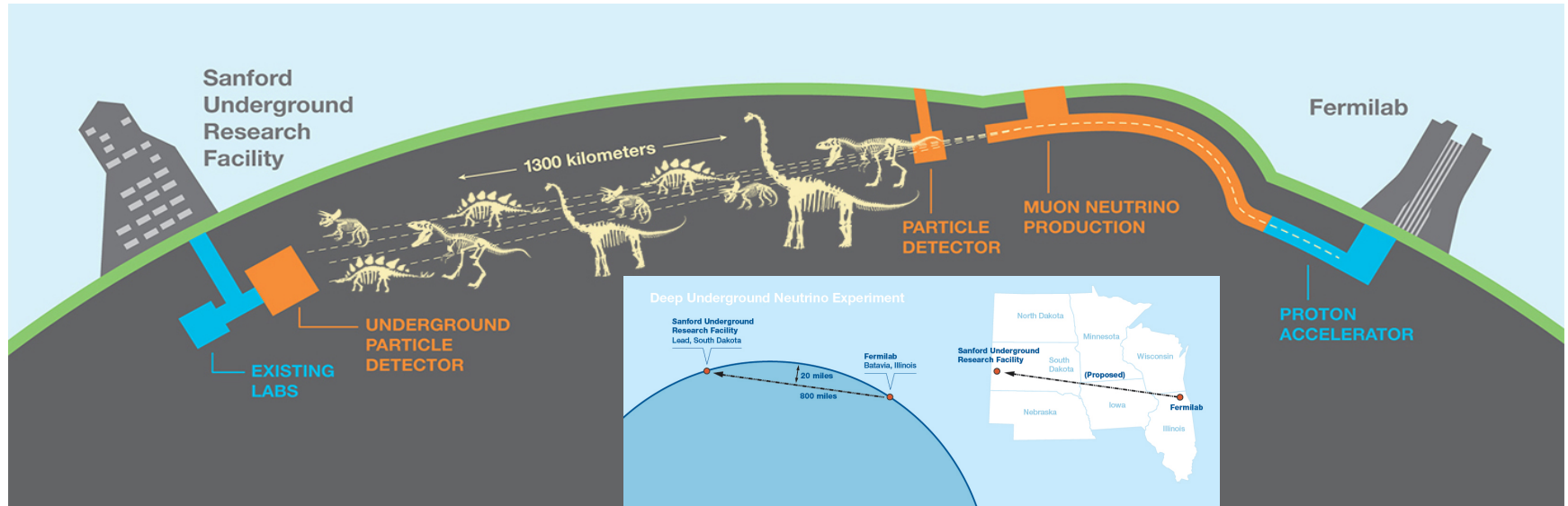


Will measure with greater precision:

- leptonic CP-violation ($\delta_{CP}, \Delta L=0?$)
- Neutrino oscillation ($\theta_{12}, \theta_{13},$ and θ_{23})
- Neutrino mass hierarchy (NH or IH)

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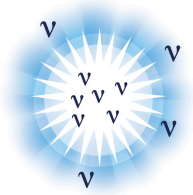
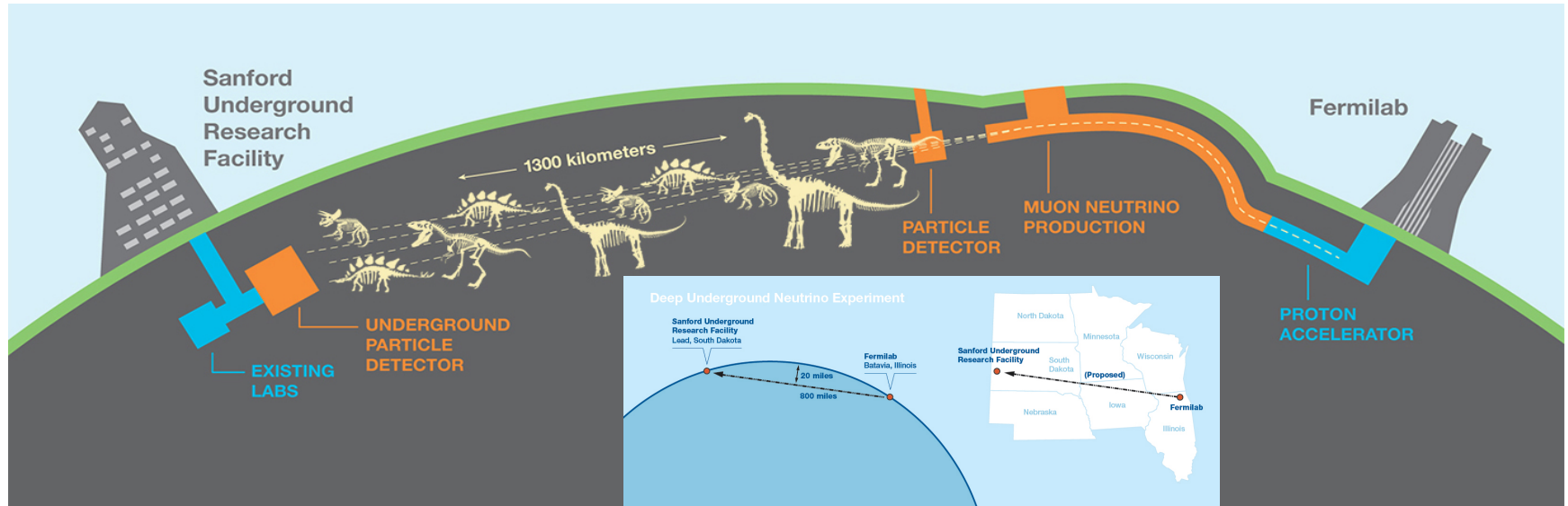
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Will observe:

- Core-collapse/supernova burst neutrinos

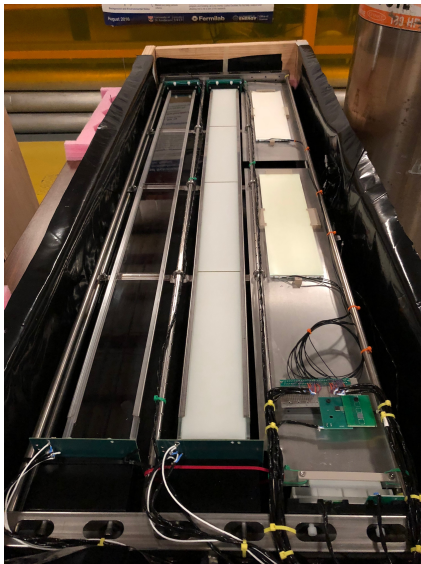
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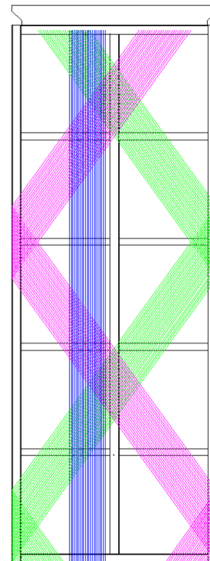
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T12.00005, Hannah Elizabeth Rogers, 4/15/2019, 4:18 PM
Overview of ProtoDUNE and Initial Study of Space Charge

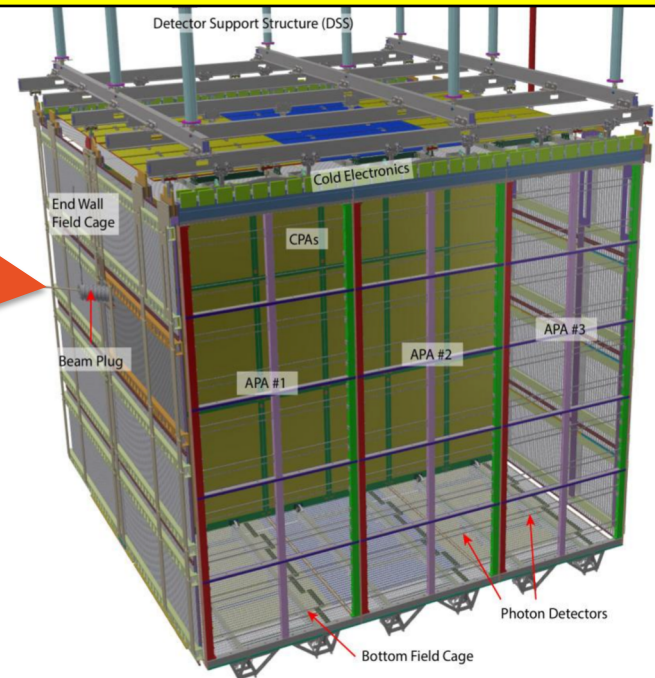


Individual Photon Detectors



APA Sketch

0.3-7 GeV
Beam from
CERN SPS



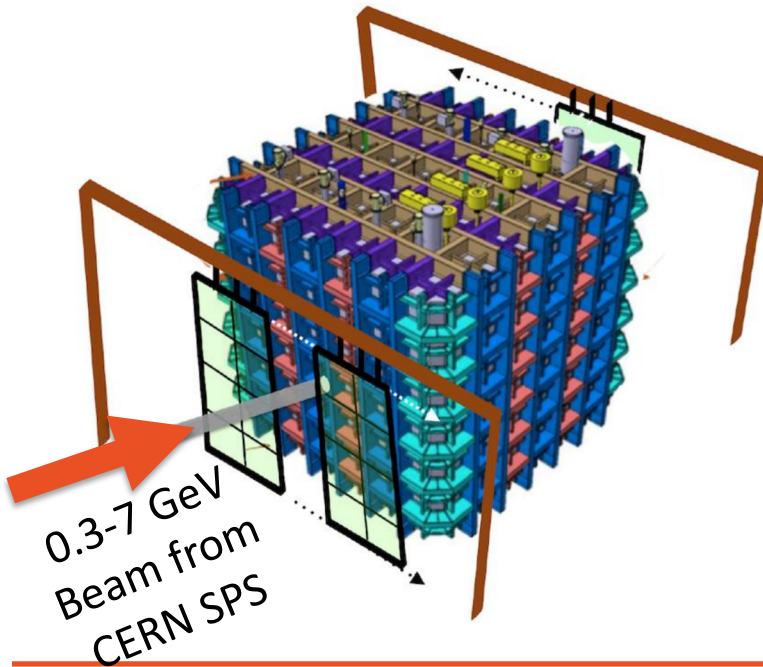
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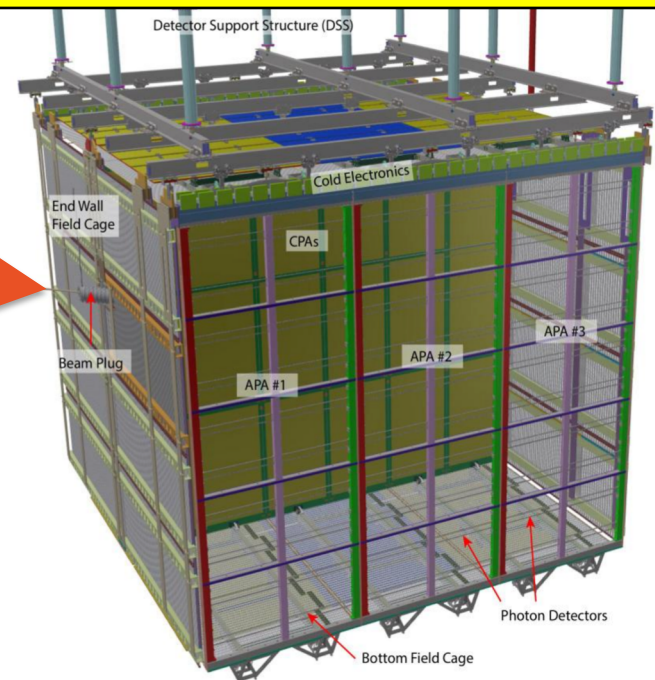
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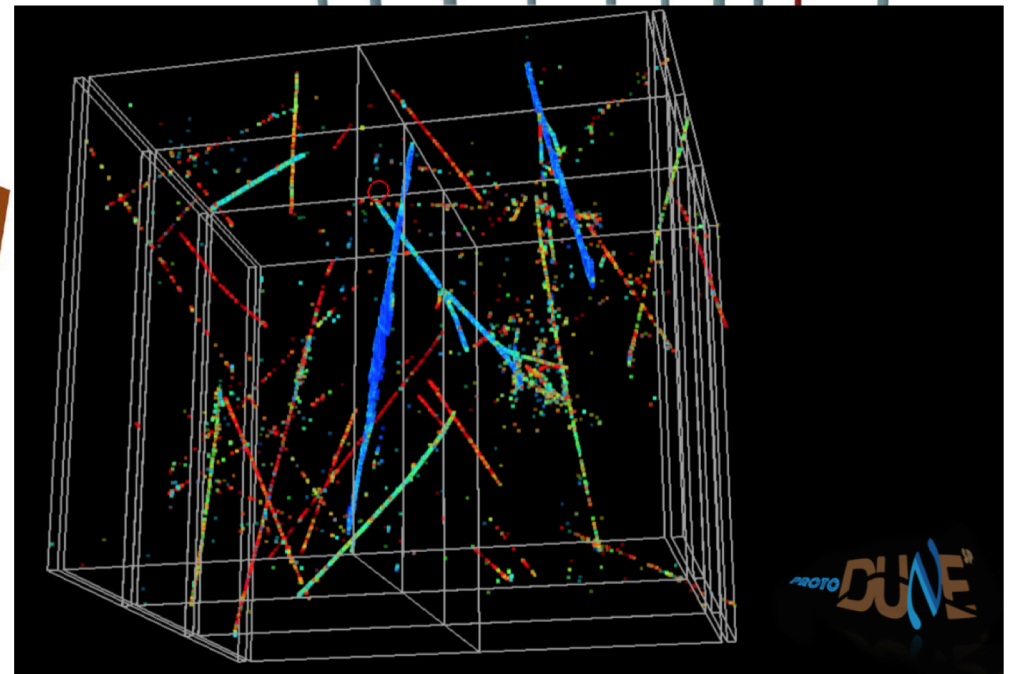
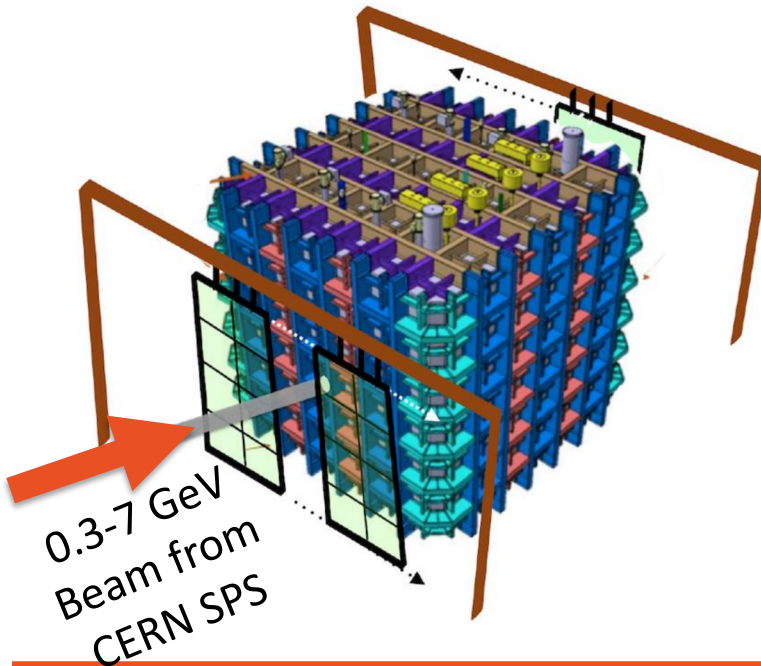
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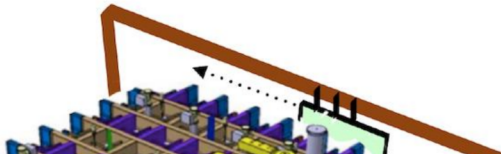
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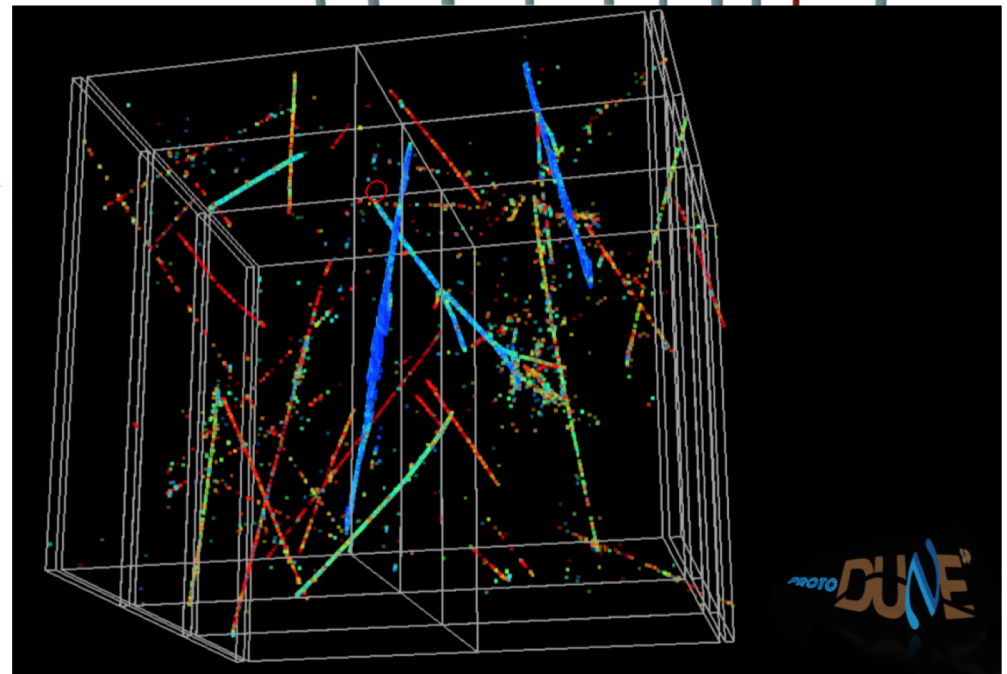
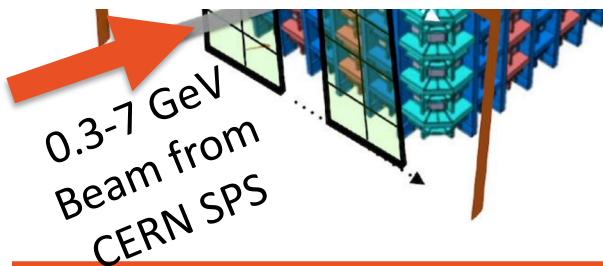
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Precise timing necessary for physics and track reconstruction!

L17.00002, Wenqiang Gu, 4/14/2019, 3:42 PM
Signal Processing in the ProtoDUNE-SP LArTPC

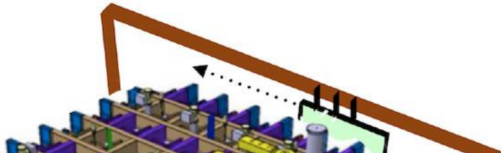


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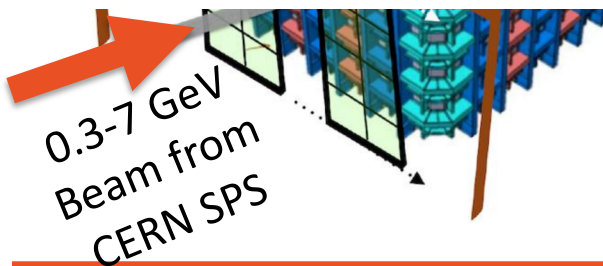
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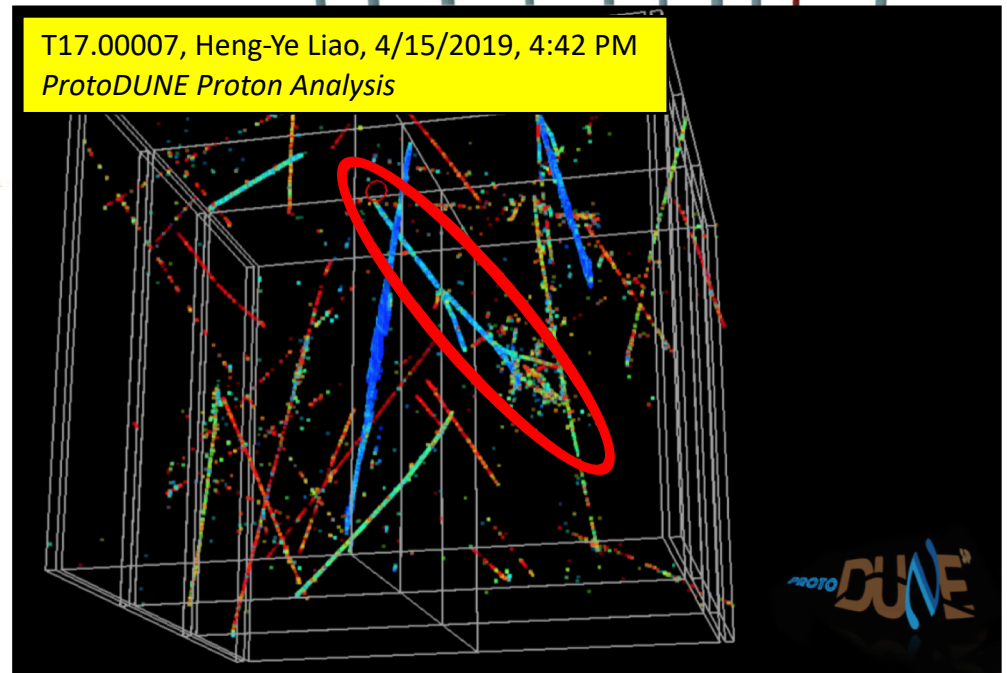
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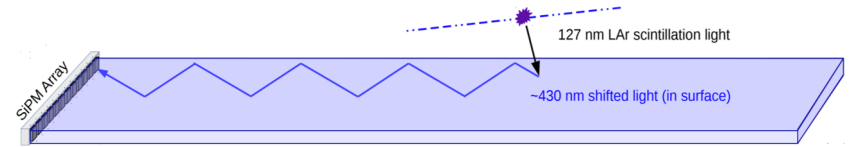
T12.00005, Hannah Elizabeth Rogers, 4/15/2019, 4:18 PM
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T17.00007, Heng-Ye Liao, 4/15/2019, 4:42 PM
ProtoDUNE Proton Analysis

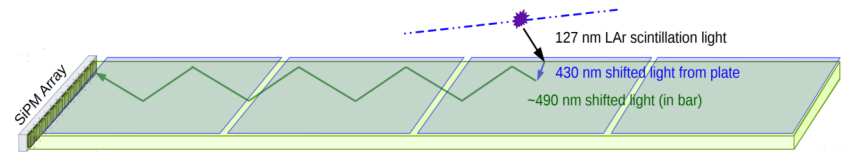


The ProtoDUNE-SP PDS as a testbed

- (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**

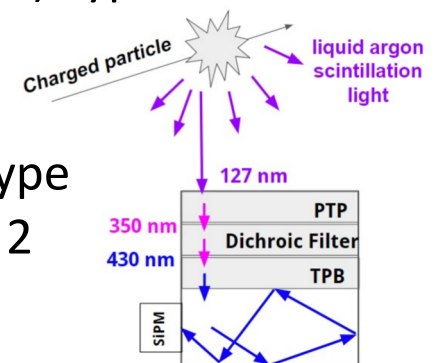


"Dip-Coated" (DC) Type Collector × 29



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

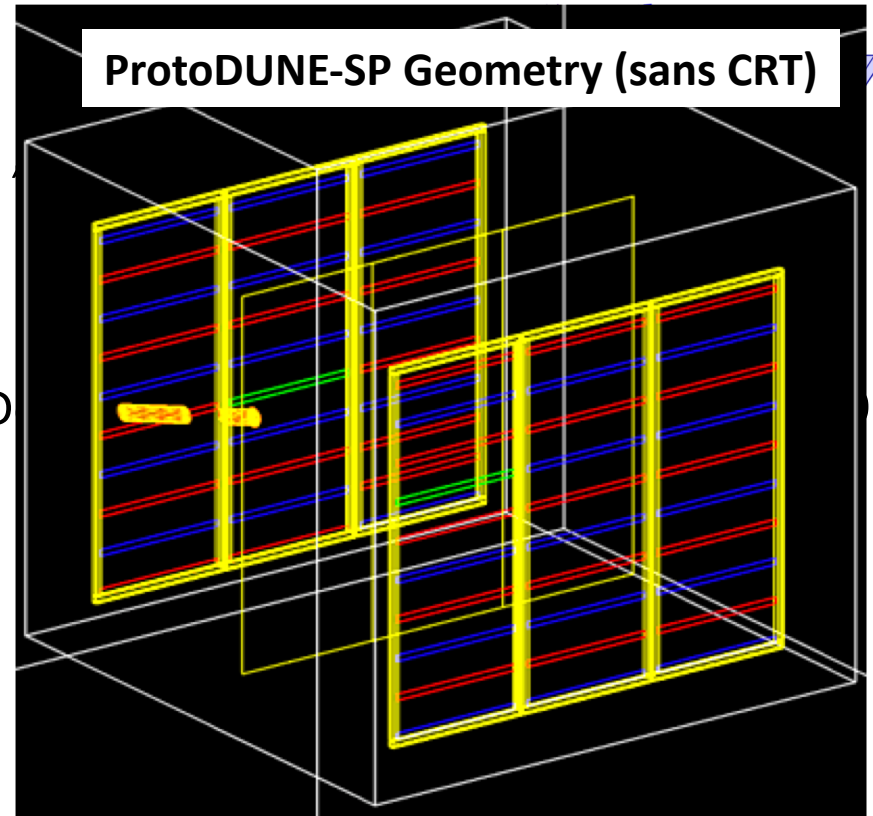
"ARAPUCA" Type Collector × 2



- 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 core-collapse/supernova physics.

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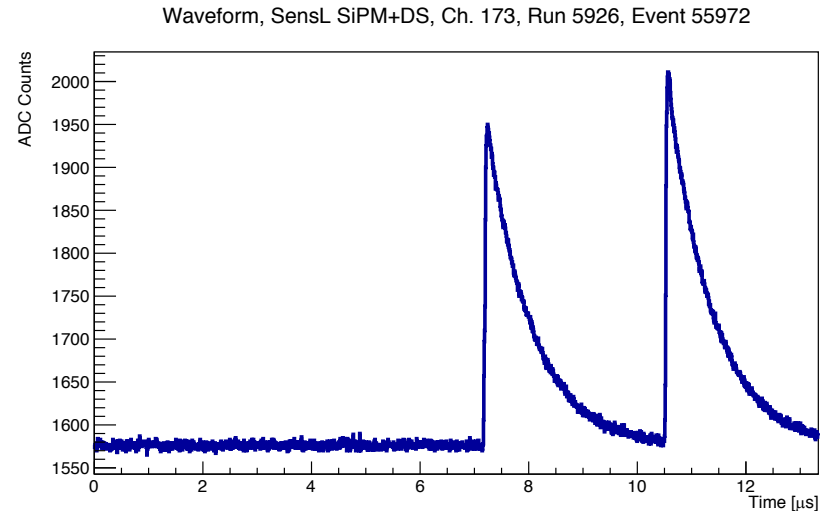
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Light Collection and Calibration

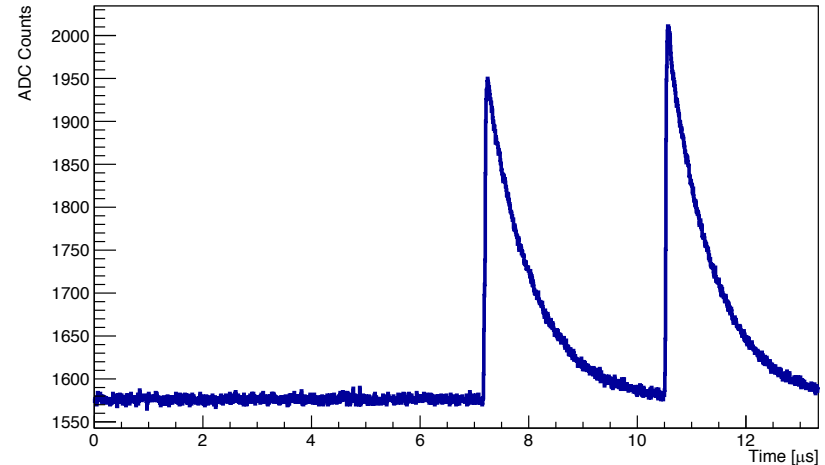
- Passively ganged photon sensors measure in Analog-to-Digital converter (ADC) units
- Calibration requires conversion to number of photons across different combinations of collector and sensor technology
- Twin pulses supplied by DUNE Calibration module
- Pedestal subtracted integration over waveform peak and relaxation to baseline yields integer photon peaks.
- Linear fit of integer photon peaks yields PE ratio to Integrated ADC.



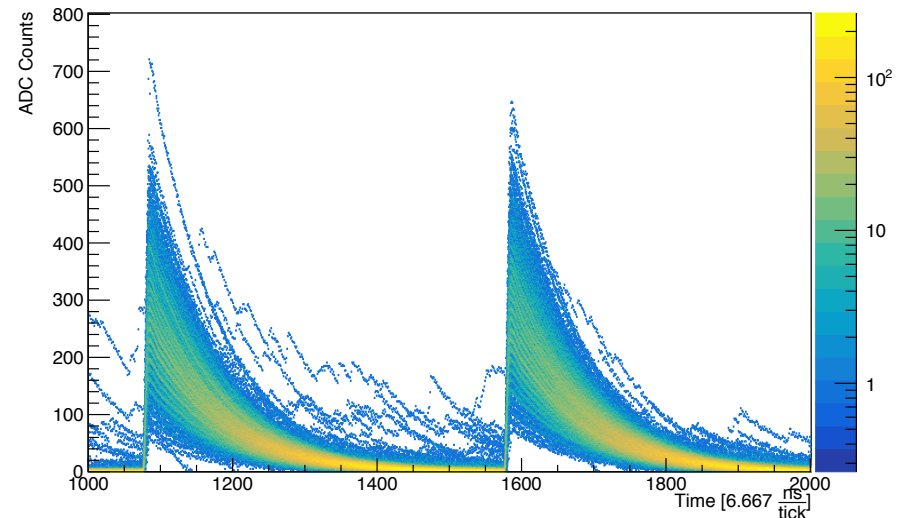
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Waveform, SensL SiPM+DS, Ch. 173, Run 5926, Event 55972



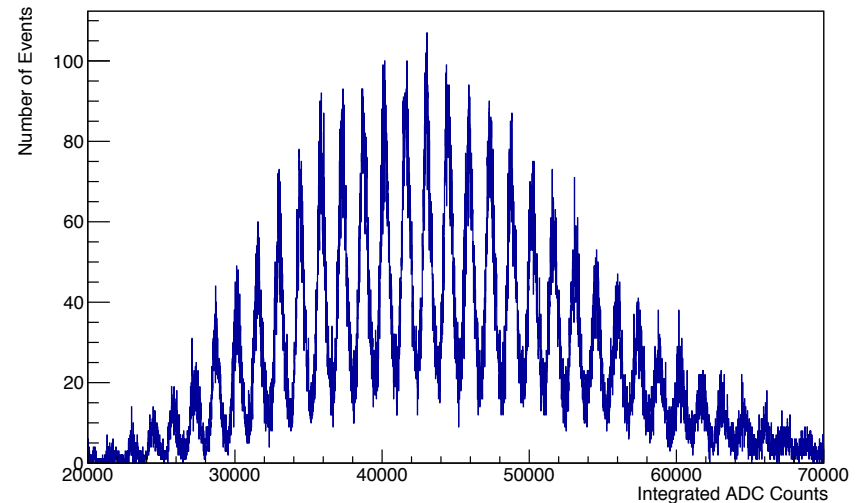
Persistence Trace, SensL SiPM+DS, Ch. 174, Run 5926



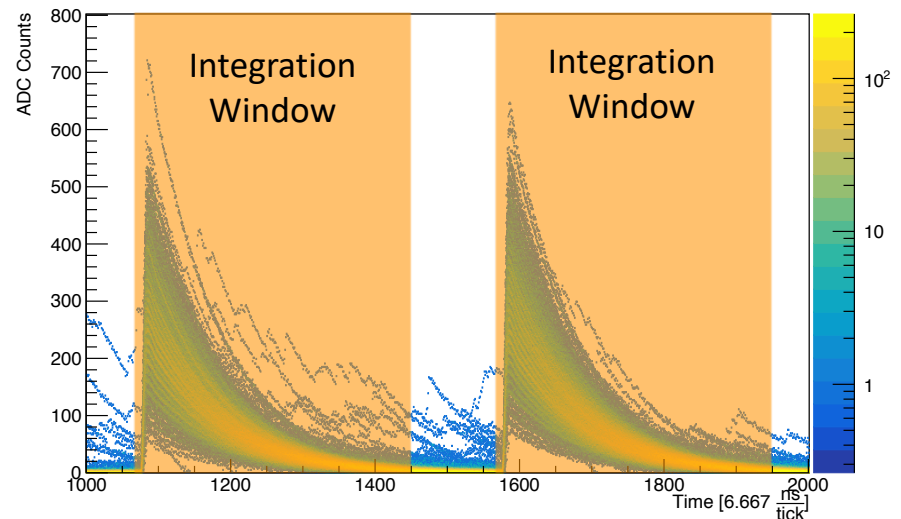
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Integrated ADC Counts, SensL SiPM+DS, Ch. 174, Run 5926



Persistence Trace, SensL SiPM+DS, Ch. 174, Run 5926



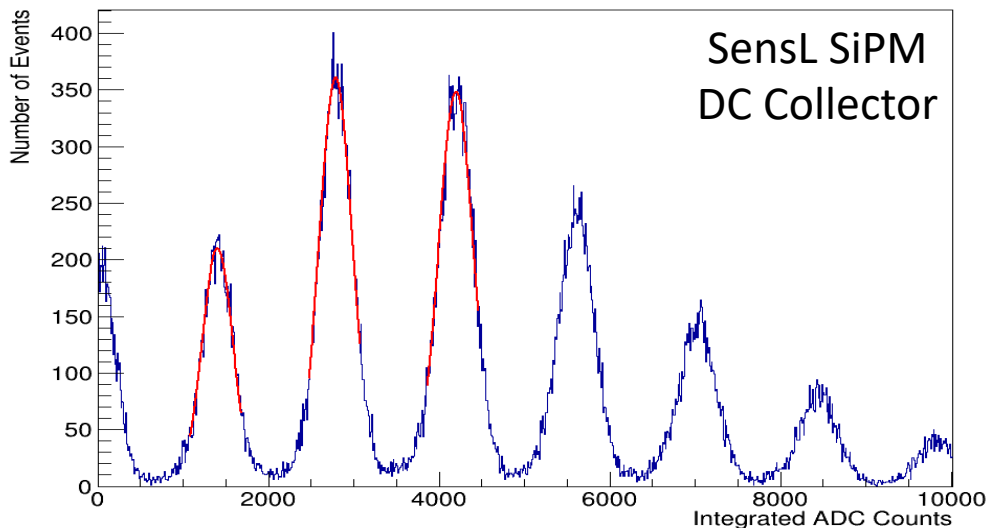
Calibration

Different combinations of Photon Collector and Sensor technology behave differently given the same light!

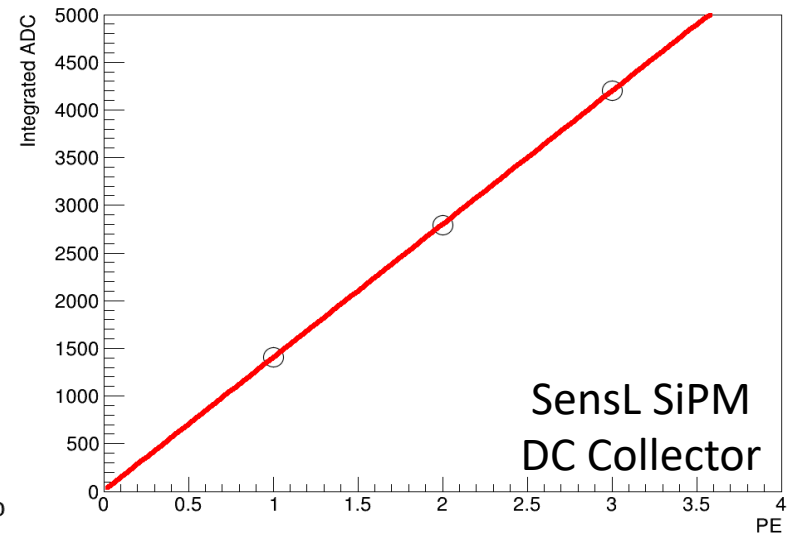
Divided Detectors into three groups:

- SensL SiPM type sensors with DS and DC Collectors
- Hamamatsu MPPC type sensors with DS and DC Collectors
- Hamamatsu MPPC type sensors with ARAPUCA Collectors

Charge Integration, SensL SiPM, Ch. 147, Run 5926



Calibration Fit, SensL SiPM, Ch. 147, Run 5926



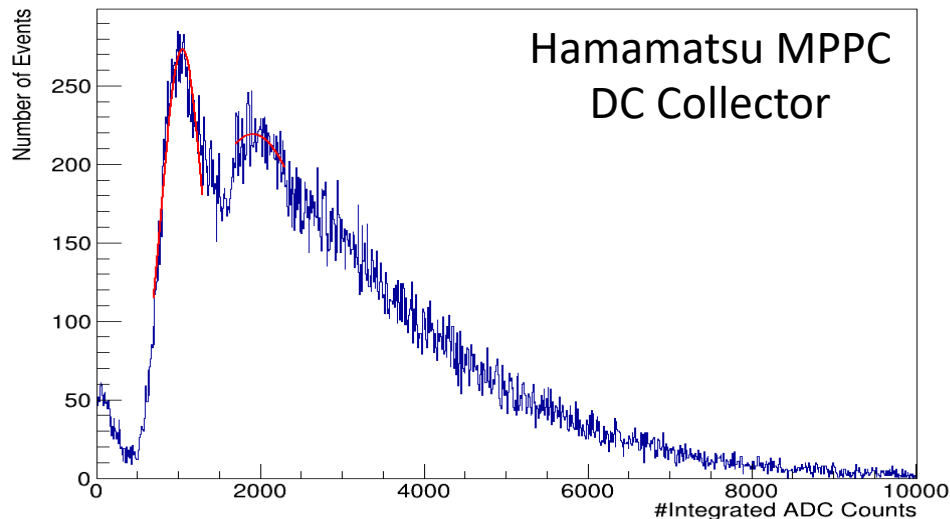
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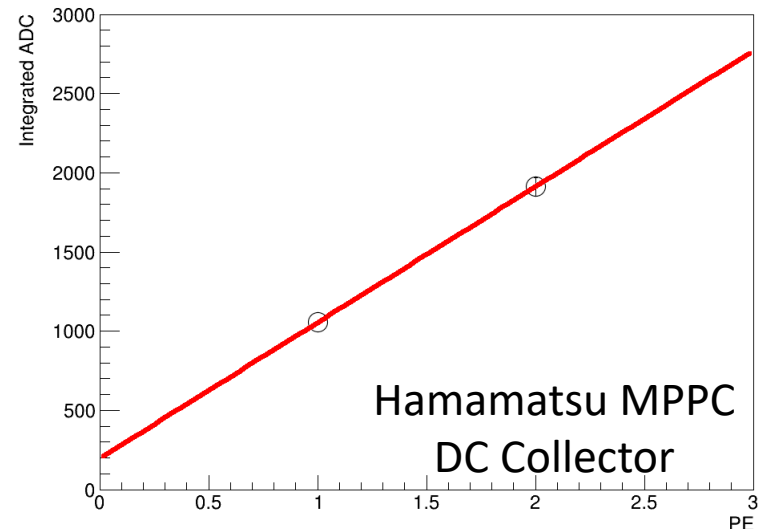
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Charge Integration, Hamamatsu MPPC, Ch. 218, Run 5926



Calibration Fit, Hamamatsu MPPC, Ch. 218, Run 5926



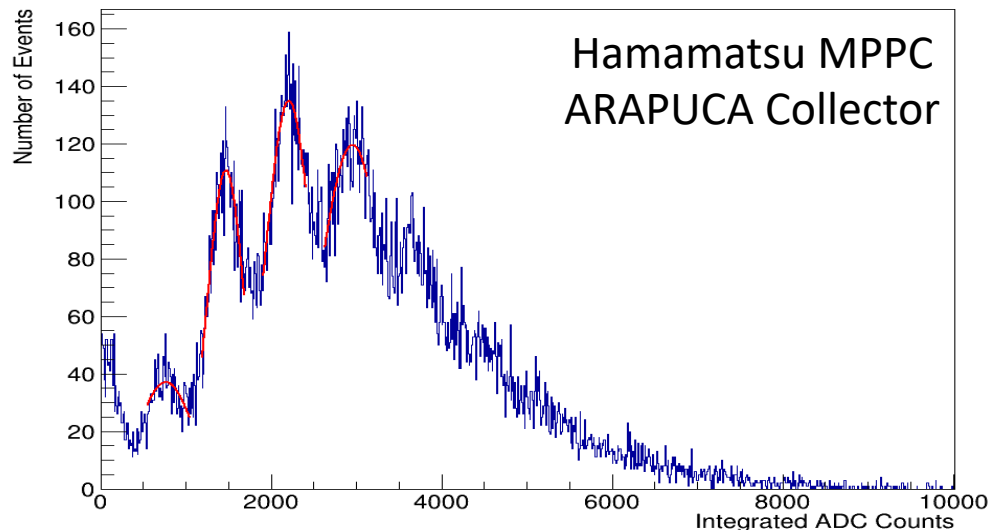
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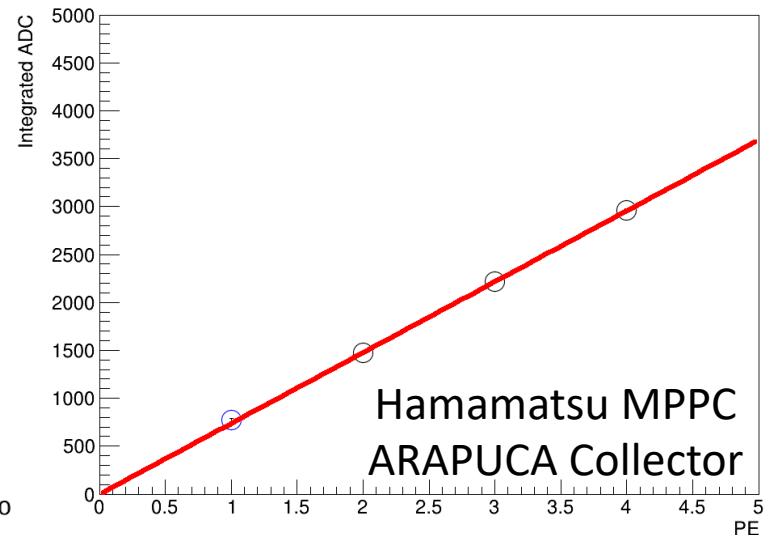
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Charge Integration, ARAPUCA+MPPC, Ch. 264, Run 5926



Calibration Fit, ARAPUCA+MPPC, Ch. 264, Run 5926



Next Steps & Conclusion

- Initial calibration in place for beam physics runs!
- Benchmark relative efficiency of different photon detector technologies
- Recalibrate with more precise techniques and additional calibration runs
 - Coordinate with different ProtoDUNE subsystems for beam independent track sample
- Pursue calculation of initial cosmic track time and other physics observables