Photon Detection System of the Single Phase DUNE Far Detector

MU Wei for the DUNE Collaboration

ICHEP 2020 | PRAGUE

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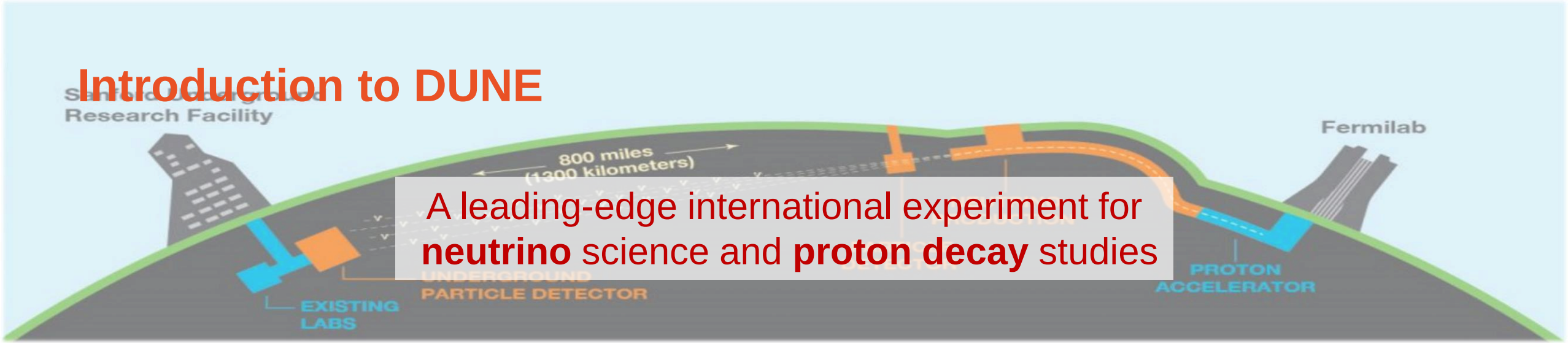
Fermilab

DUNE

Introduction to DUNE



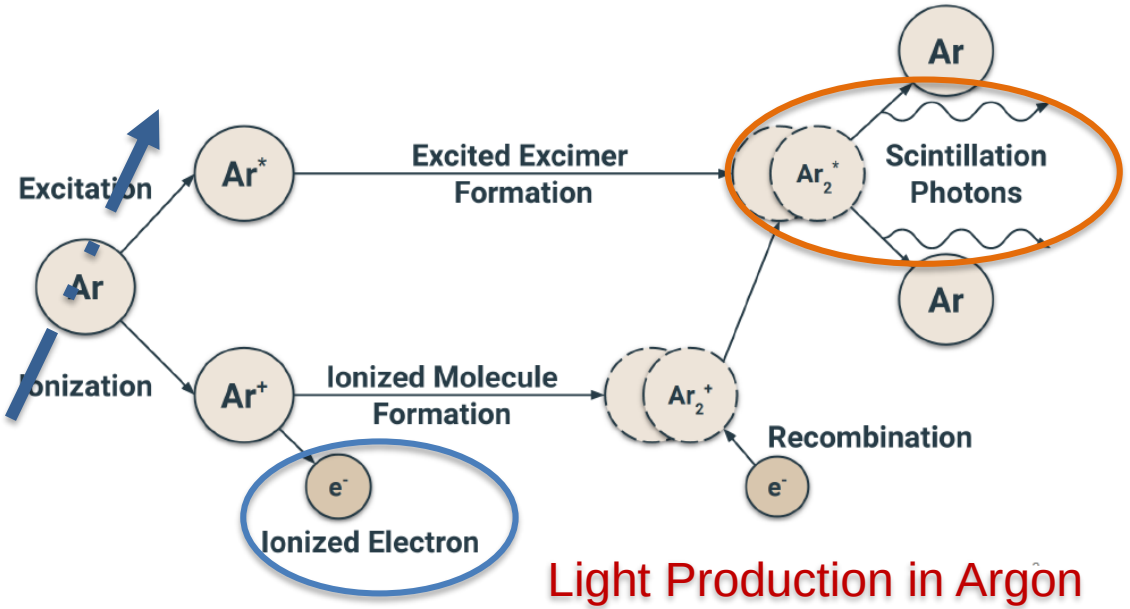
A leading-edge international experiment for **neutrino** science and **proton decay** studies

- One Near Detector
- Four Far Detectors
  - Single Phase
  - Dual Phase
  - …
- LBNF
  - Neutrino Beamline
  - Infrastructure

- Origin of Matter
  - Neutrino Oscillation
- Unification of Force
  - Proton Decay
- Black Hole Formation
  - Supernova Neutrino Bursts

Photon Detection for DUNE

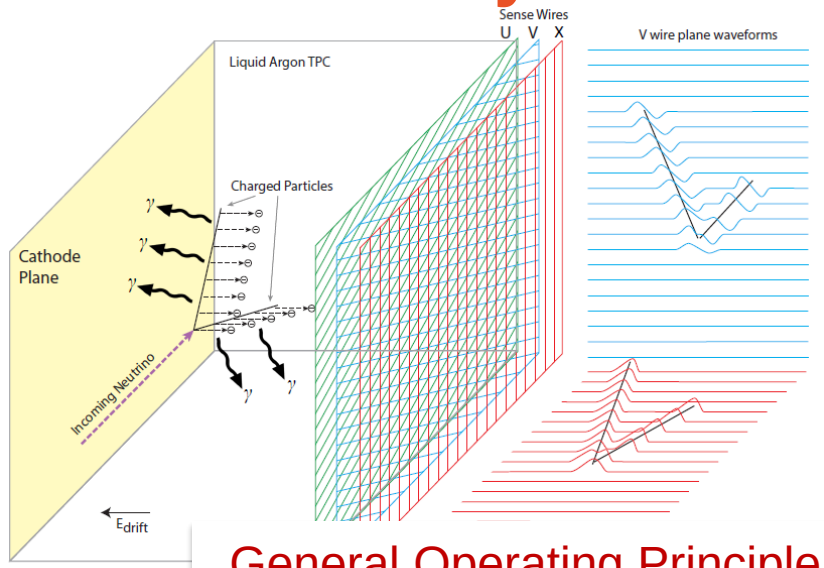
- Clock start time t_0
  - Essential for **proton decay** searches
  - Proper location of the **SNB** events vertex
  - Complement trigger scheme for the **SNB** events
- Calorimetric energy of **neutrino**
  - Crosscheck to the energy measured by the TPC
  - Improve the energy resolution
- New areas of investigation
  - Enhance DUNE's capability to observe few-MeV scale events, such as **solar neutrino**
  - Identify **Michel electrons** from decay of a stopped muon



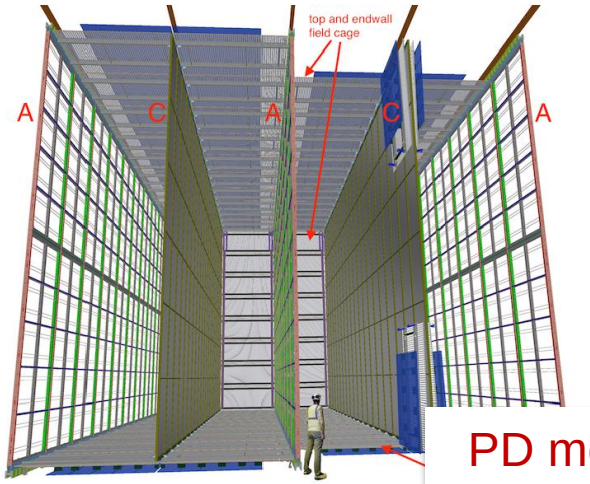
Light Production in Argon

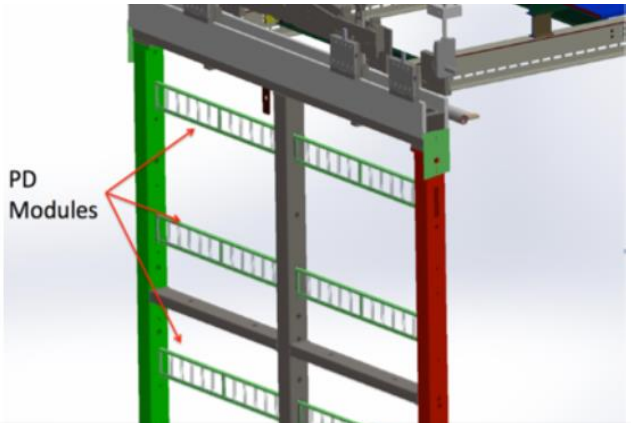
Single Phase DUNE Far Detector and Photon Detection System

- Single Phase DUNE Far Detector
  - A **10-kilo-tonne** Single Phase LArTPC
  - Read out the pattern of ionization with **sub-cm** granularity
  - Search from **MeV** to **GeV**-scale neutrino interactions
- Photon Detection Module Design
  - Goals
    - Maximize the **active volume**
    - Maximize the **light yield**
  - Considerations
    - Constraint of the **APA** structure
    - Cost-effective: large area **light collector**



General Operating Principle

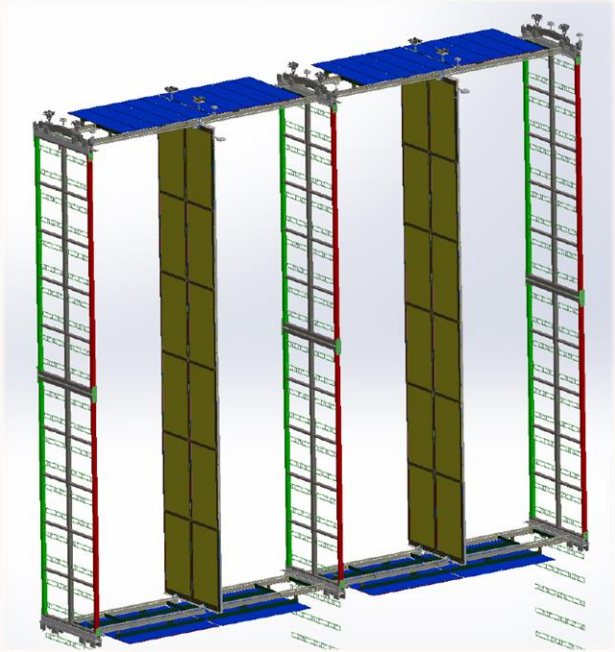


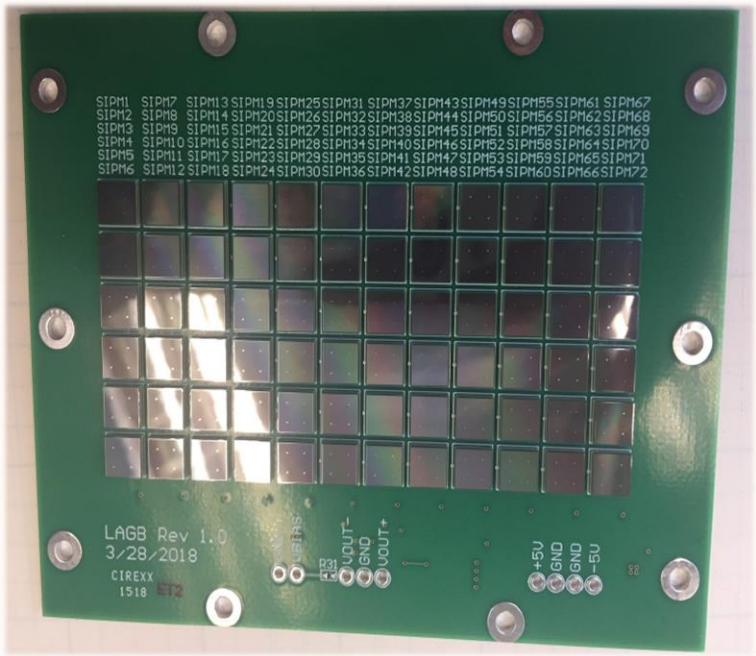


PD modules mounted inside an APA

Photon Detection System: Baseline Design

Light Collector	Photon Sensor	Cold and Warm Electronics



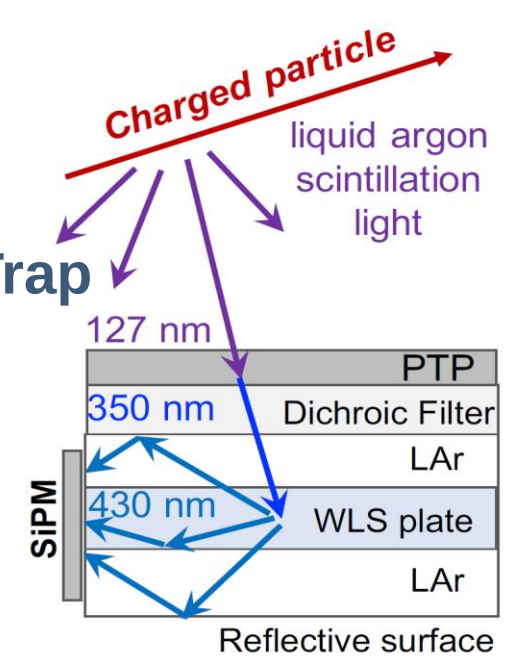


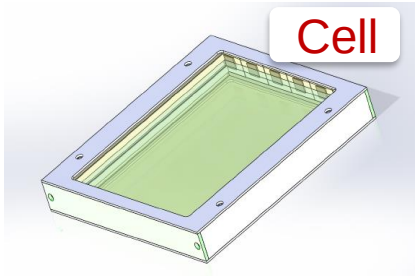
X-ARAPUCA	MPPC	Active Summing	Ultrasound ASICs

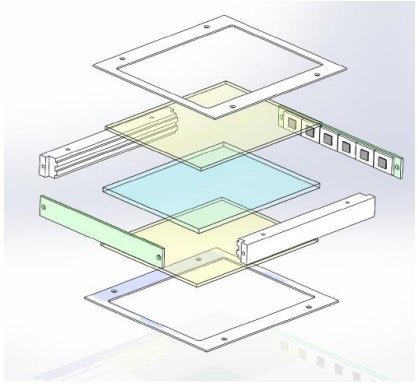
Photon Detection System: X-ARAPUCA

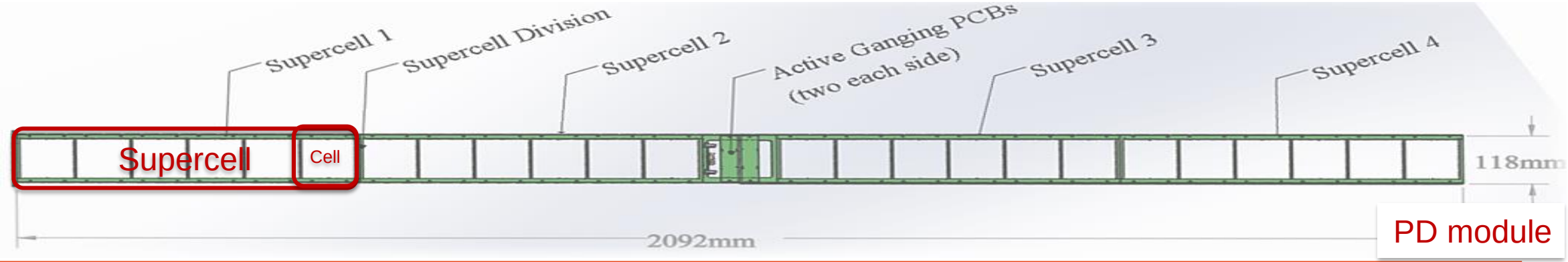
- Cell: basic unit
  - PTP (wavelength shifter)
  - Dichroic filters
  - WLS-plate
- Supercell: **6** cells - 488 × 100 × 8 mm^3
- PD Module: **4** supercells - 2092 × 118 × 23 mm^3
  - Bar-like configuration

X-ARAPUCA: A Photon Trap



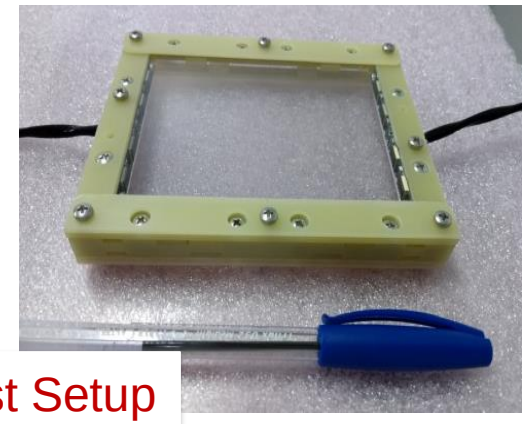


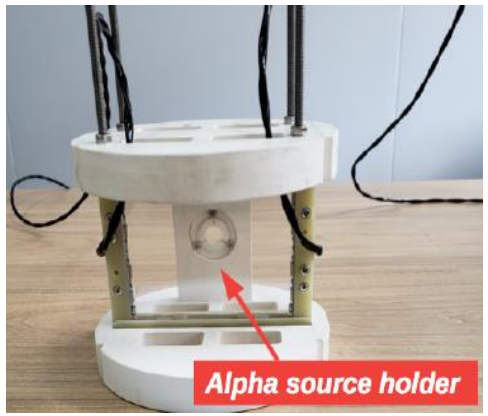




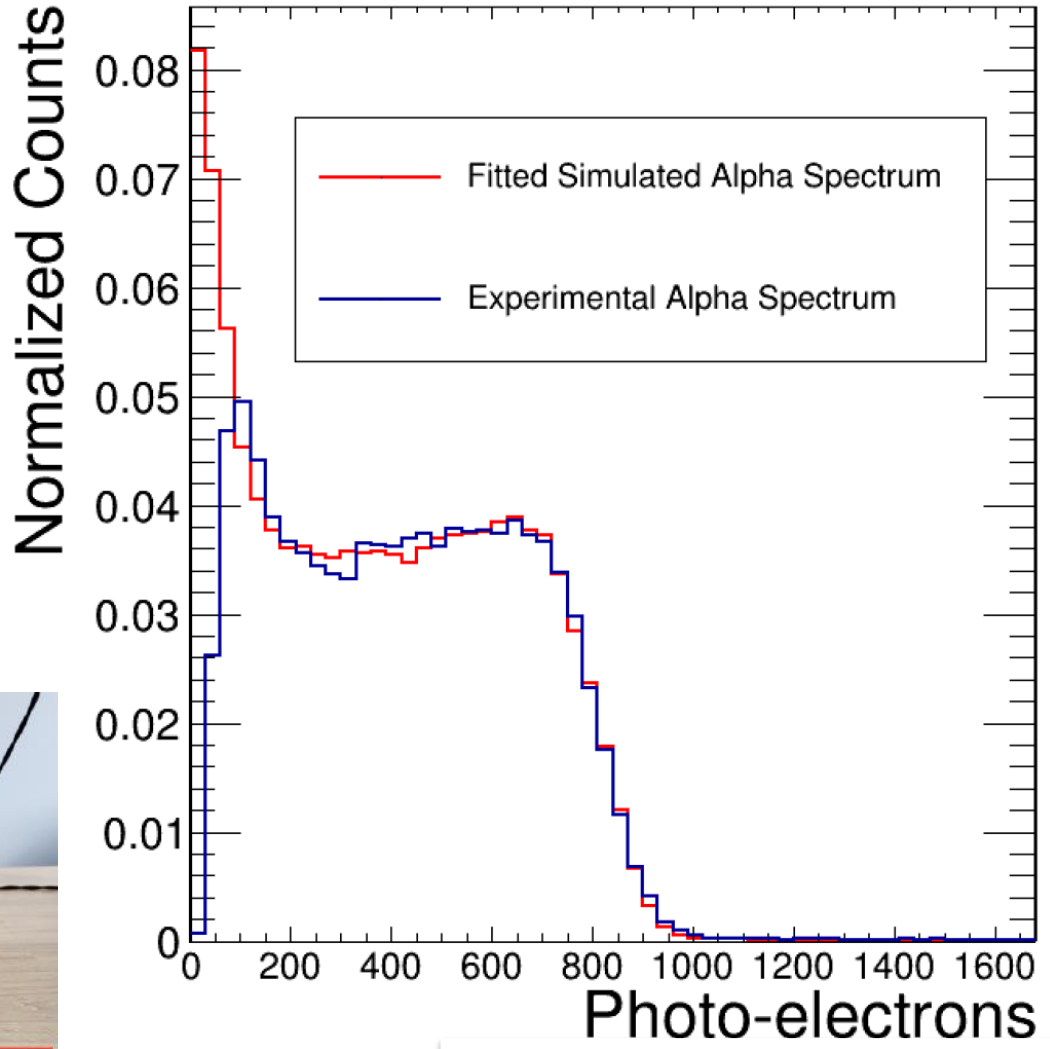
Photon Detection System: X-ARAPUCA

- Performance studied with alpha source
- Results compared to MC simulation
- Global photon collection efficiency
  - **>3%** (vs. 2.6% design requirement)





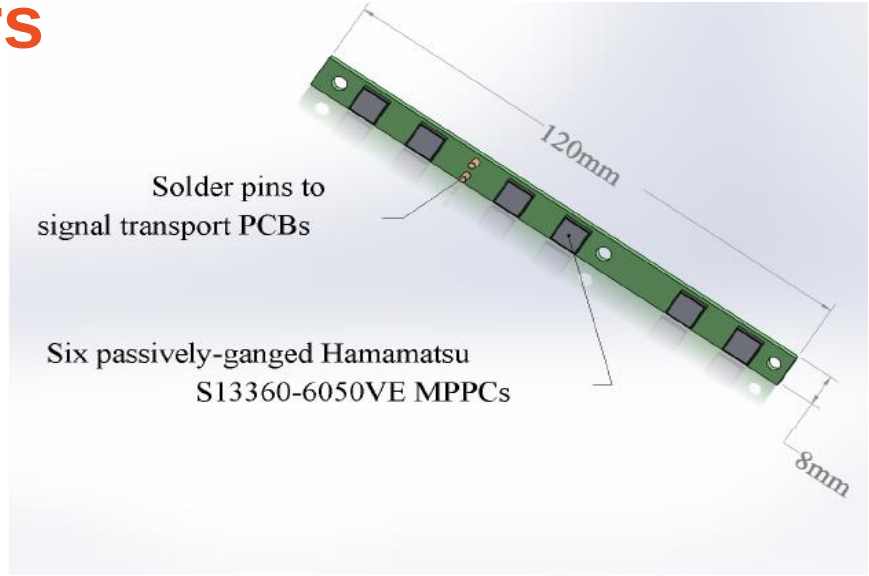
X-ARAPUCA Test Setup

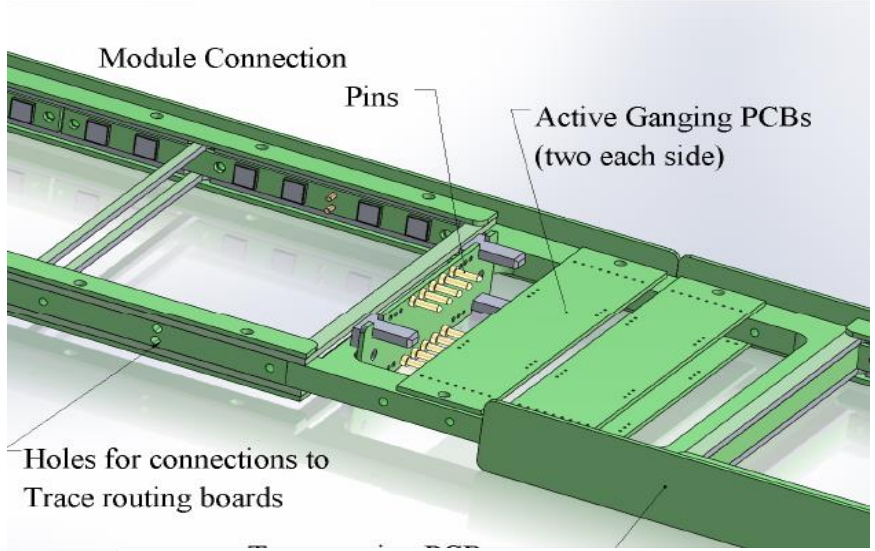


X-ARAPUCA Performance

Photon Detection System: Photon Sensors

- SiPM: MPPC
  - Hamamatsu Photonics K.K.: **S13360**/S14160
  - Fondazione Bruno Kessler (FBK): NUV-HD-LF
  - Characterized at cryogenic temperature (77K)
- 48 MMPCs per Supercell
  - 6 MMPCs per PMB passively ganged
  - 8 PMB actively ganged
- 192 MPPCs per PD module
  - 4 electronics readout channels
- 288,000 MPPCs in total

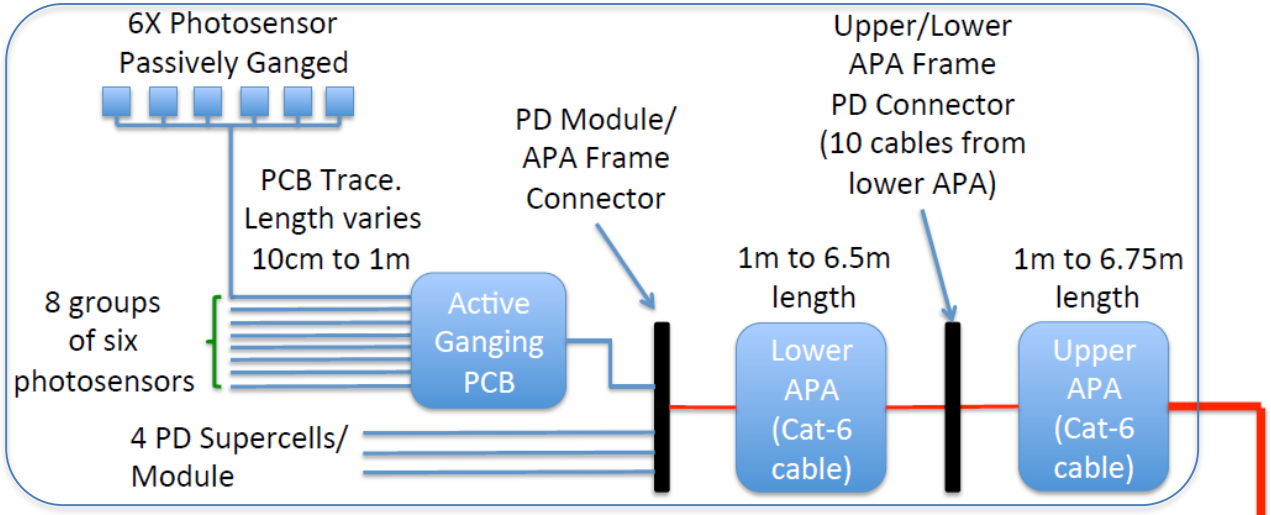


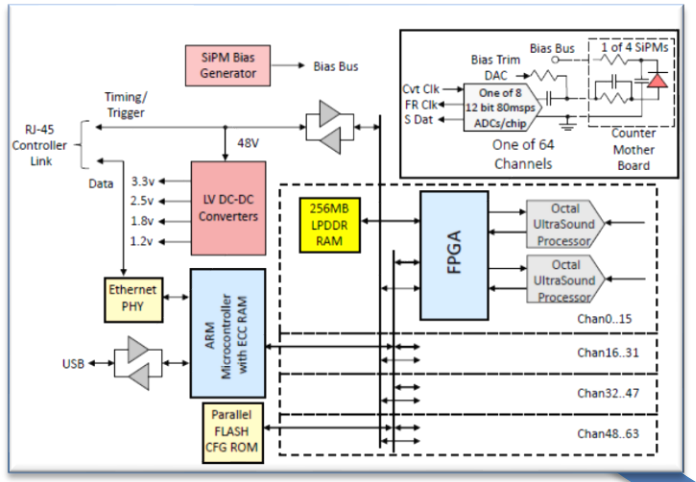


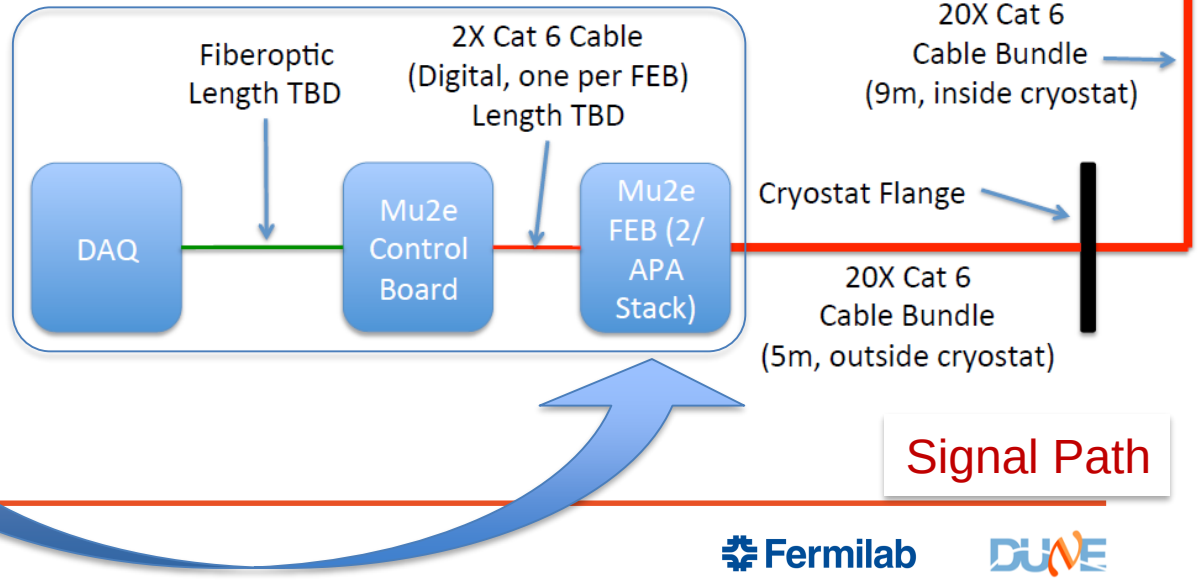
MPPC + PMB and Active Ganging

Photon Detection System: Electronics

- Cold Electronic: Passive/Active Ganging
  - Work at LAr temperature
  - Amplifier to adjust MPPC output
  - 6 MPPCs **passively** ganged
  - 8 groups **actively** ganged
- Warm (Front-End) Electronics
  - Mu2e FEB



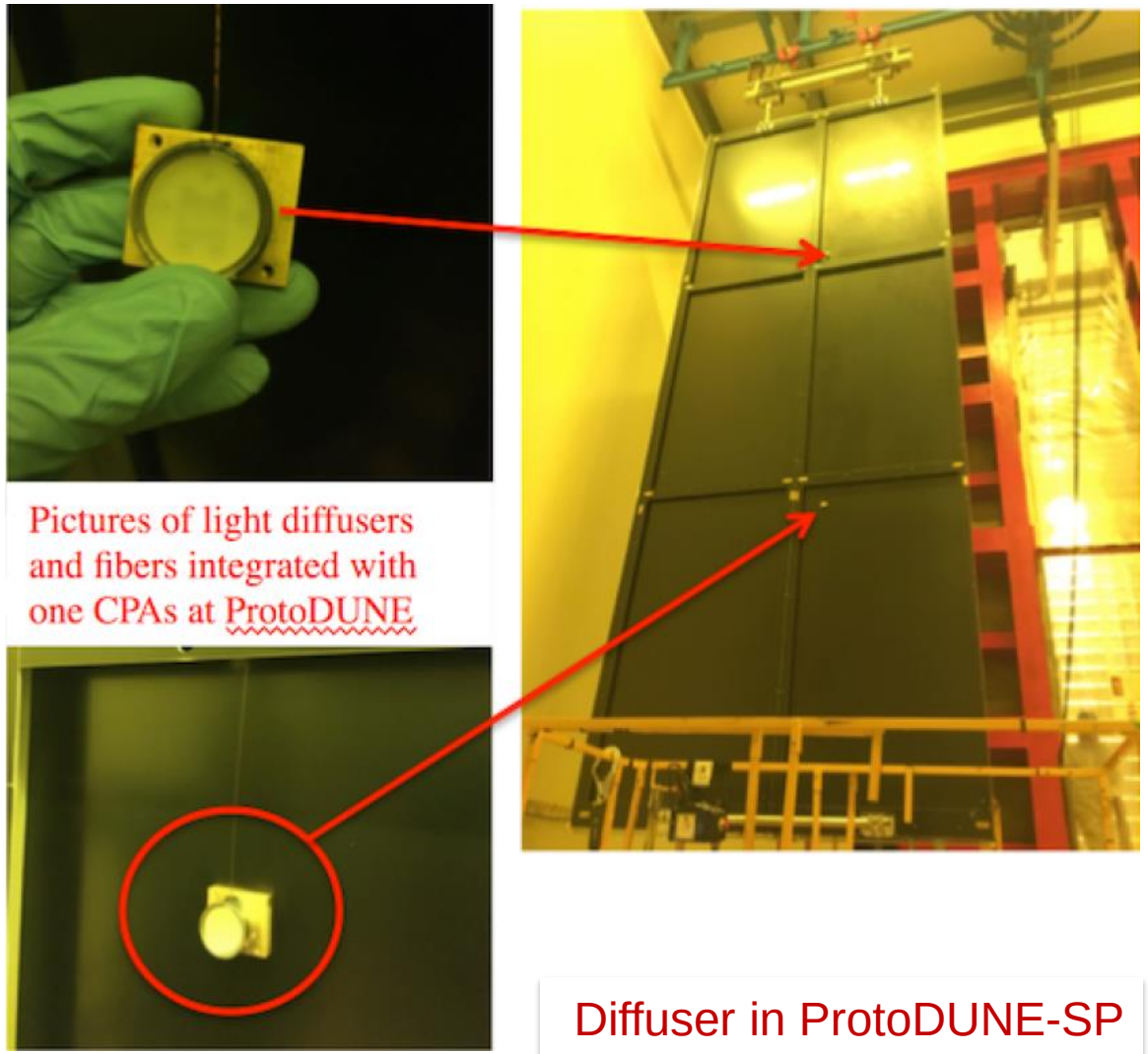




Photon Detection System: Calibration and Monitoring

Primary system: **Pulsed UV-light Source**

- Light Calibration Module
  - FPGA-based control logic unit
  - LED pulser module
  - Power supply
  - Outside the cryostat
- Quartz Fiber and Optical Feedthrough
- Light Diffusers
  - Mounted on cathode plane panels
  - Acting as light sources
  - In total: 45 diffusers



Diffuser in ProtoDUNE-SP

Photon Detection System: Testing

ProtoDUNE-SP (*see talk by D. Totani*)

- Equipped with three prototype light collectors
- Performance evaluation of the light collectors

ICEBERG Test Stand

- Equipped with ARAPUCA light collectors
- Comparison between difference warm electronics

SBND(2020/2021)

- *Operational test of X-ARAPUCAs light collector*

ProtoDUNE-SP-2 (2021/2022)

- *End-to-end test of finalized photon detection system*

ProtoDUNE-SP APA

ICEBERG APA

Summary

- The photon detection system directly enhances physics capabilities for all three DUNE physics drivers
  - Absolutely required by proton decay searches
  - Energy crosscheck and resolution improvement
  - Help to reject background
- The baseline design system meets the requirement
  - Excellent photon detection efficiency
  - Good performance of the electronics
- Extensive testing and validation of component designs is underway
  - Proved performance of the photon detection system