

ProtoDUNE-HD Data Analysis Organization

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ProtoDUNE DRA PDS Sim/Reco Meeting

Feb 5th, 2024

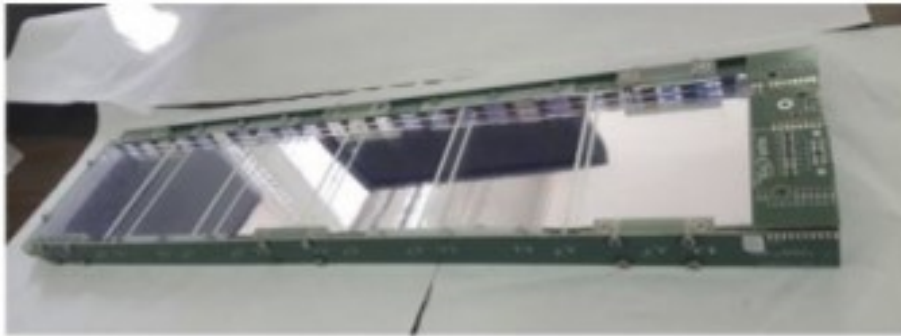


ProtoDUNEs

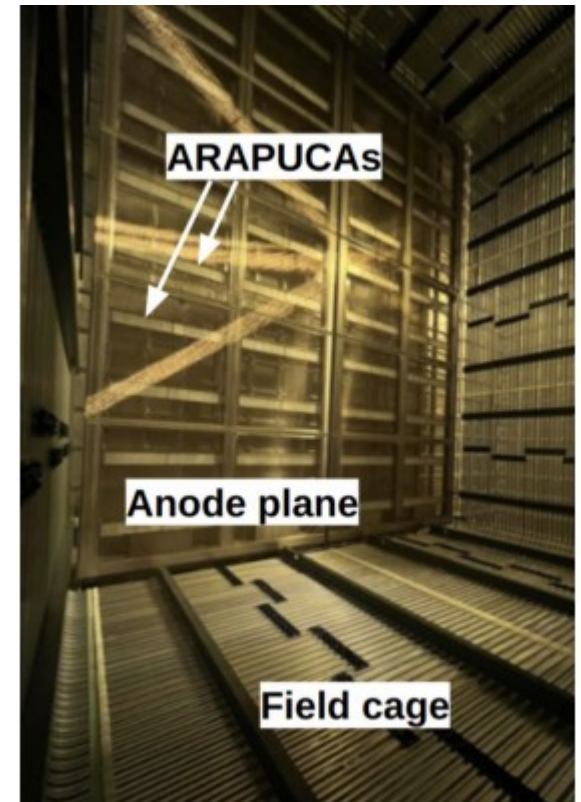
- The DUNE prototypes are the place for testing the technology that will be put in the far detectors
 - Unique opportunity to characterize the systems in DUNE-like conditions
- The DUNE PDS is new and has never been characterized in its proposed setup
- Goals (technical perspective)
 - Show that X-Arapucas work as expected
 - Show that the proposed PDS meets the requirements for a successful DUNE physics program
 - Feed our simulations with data-based information and make it as close as possible to the real system

PDHD PDS

- Supercells: 160 X-arapucas of 10 x 50 cm²



- Daphne v2 DAQ
- Different components (2 WLS bars and 2 SiPM models) will require dedicated effort to disentangle their individual impacts on parameters of interest

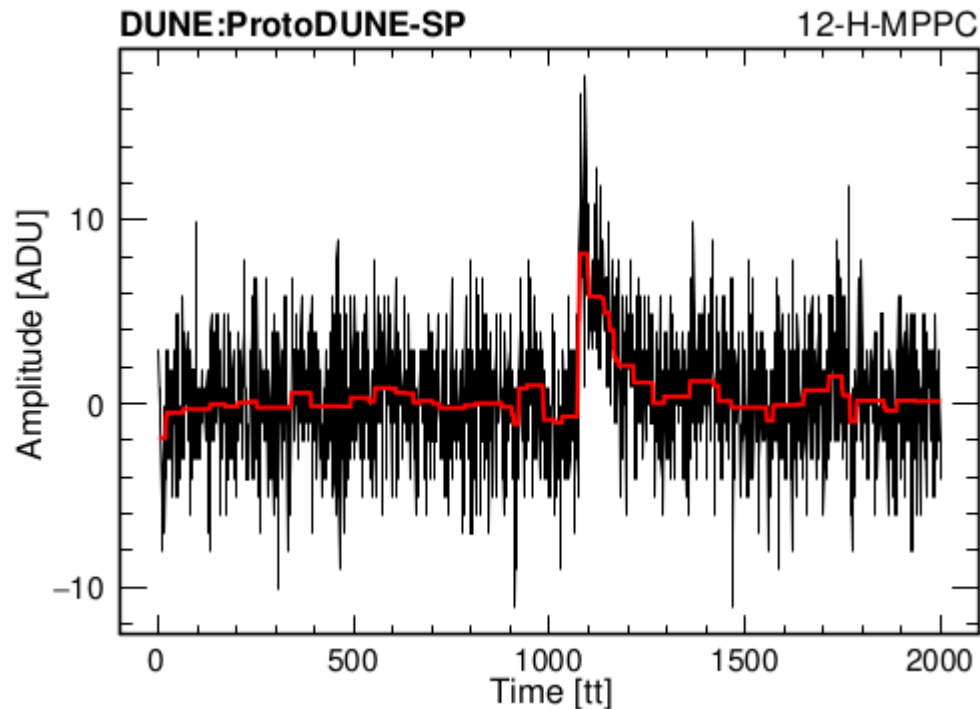


Plans for ProtoDUNE-HD

- Single PE characterization
- Gain vs voltage, SNR, calibration
- Cross-talk & afterpulses
- Stability overtime
- Time resolution
- Arapuca detection efficiency
- Comparison of components' performance

Single PE characterization

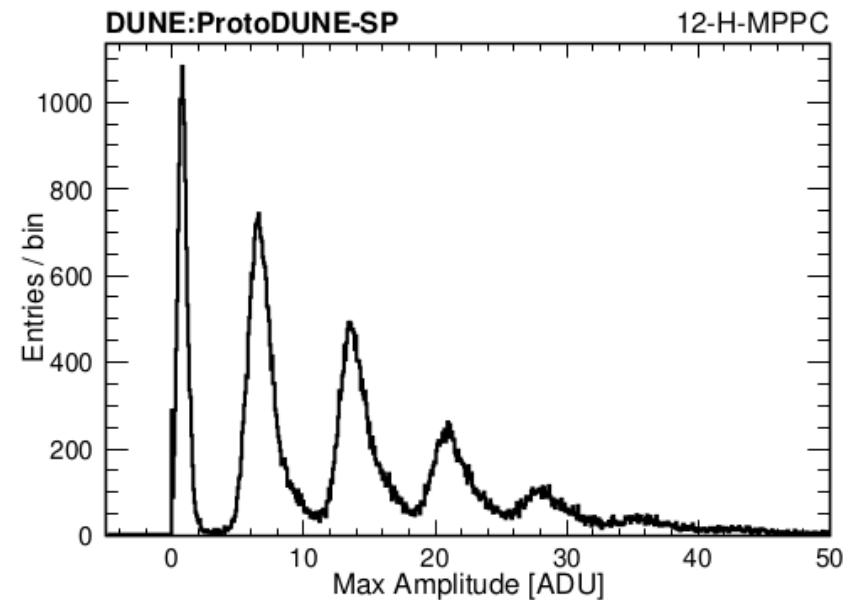
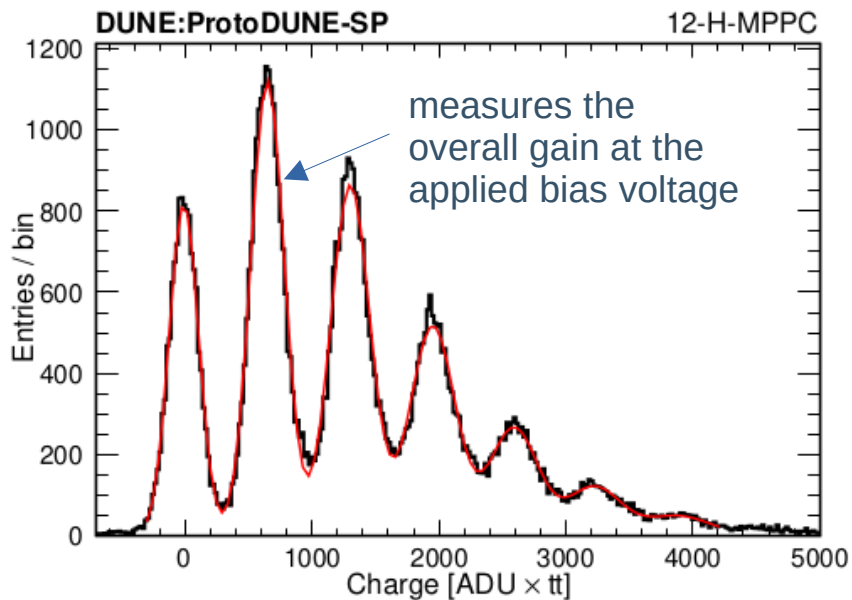
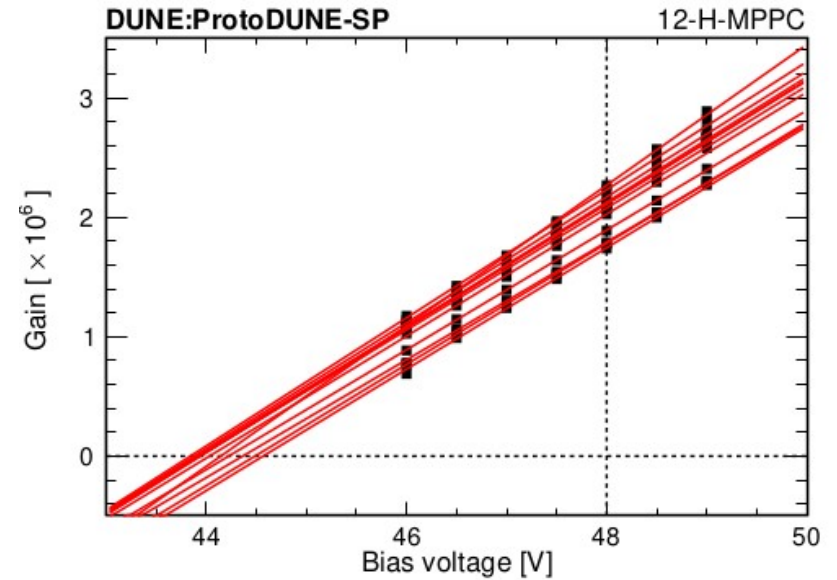
- Study done in ProtoDUNE-SP



- Use of de-noising algorithms that preserve the signal rise time and integral

Gain

- Study done in ProtoDUNE-SP



SNR and Calibration

*Needs correction for background photons

- Study done in ProtoDUNE-SP

$$\text{SNR} = \frac{\mu_1}{\sigma_0}$$

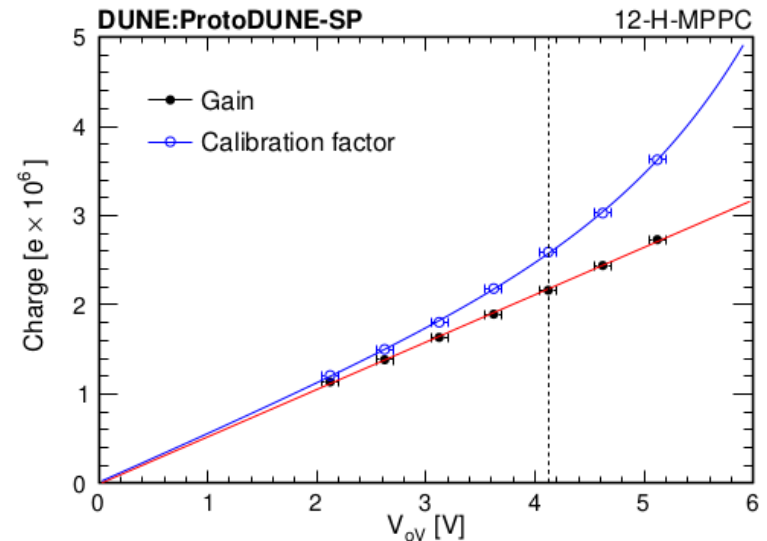
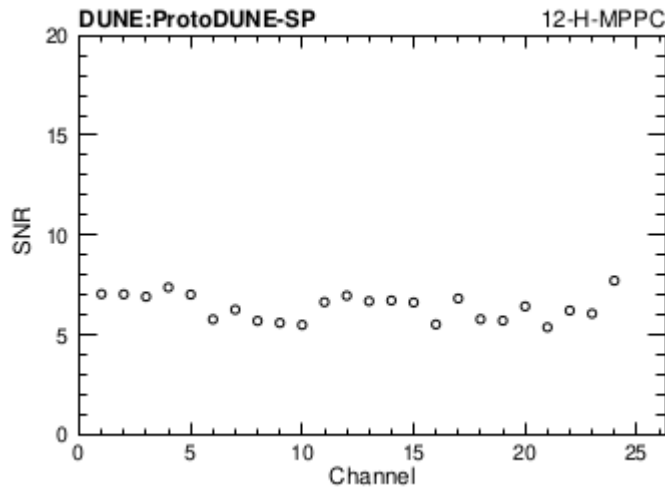
mean value from the Gaussian fit of the 1PE peak

Gaussian spread of the 0PE peak

charge signal → # photons detected

$$P(n) = \frac{\lambda^n e^{-\lambda}}{n!} \quad \text{with} \quad P(0) = e^{-\lambda}$$

mean number of photons per flash → $\lambda = -\ln\left(\frac{N_0}{N_{\text{Tot}}}\right)$



Crosstalk and afterpulses

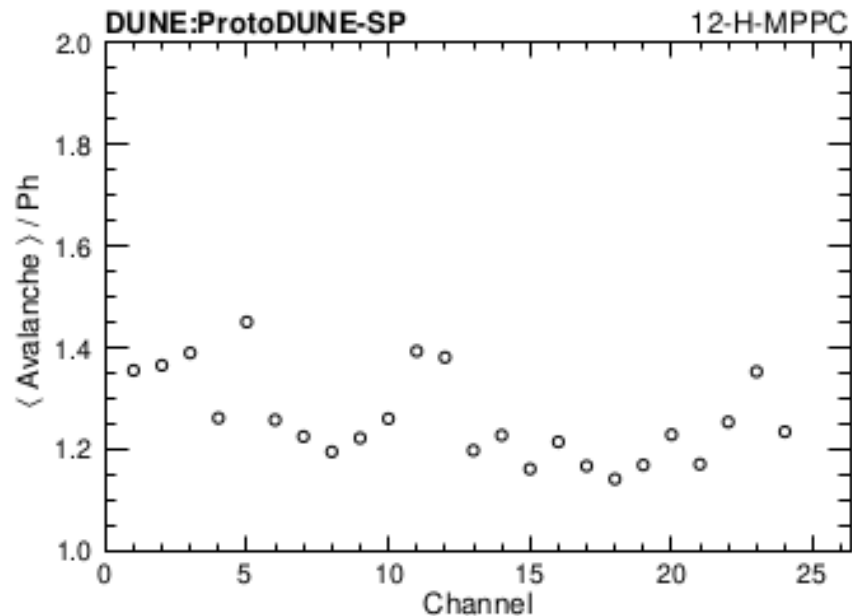
- Study done in ProtoDUNE-SP

$$\text{crosstalk and afterpulse probability} = c_i / g_i$$

calibration factor \swarrow

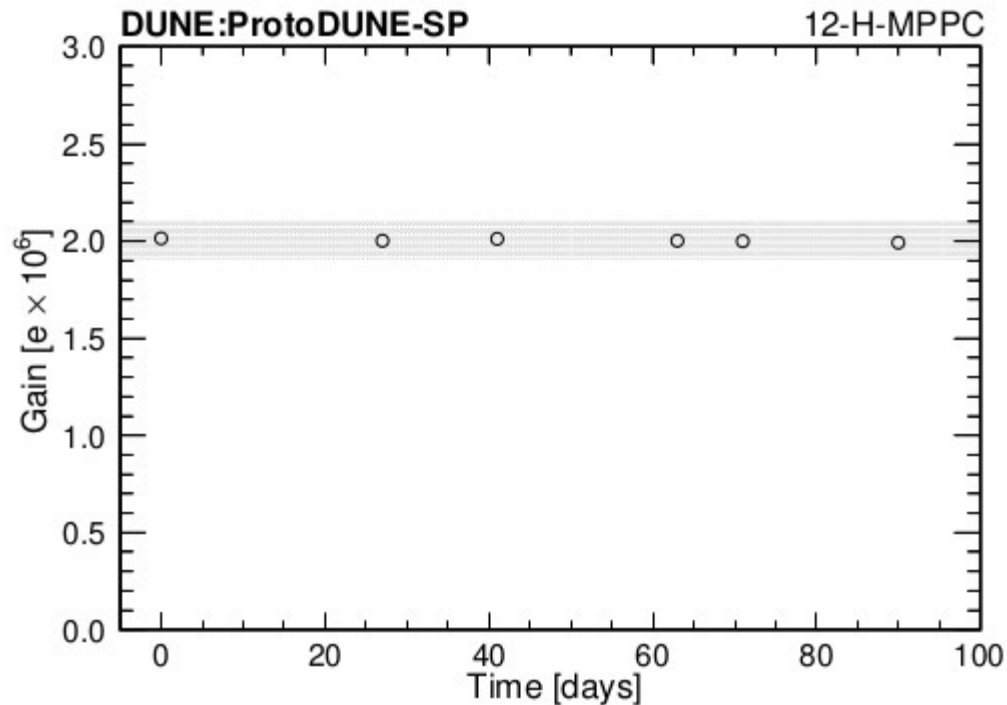
\nwarrow gain

- sensitive to the over-voltage on the PD



Stability over time

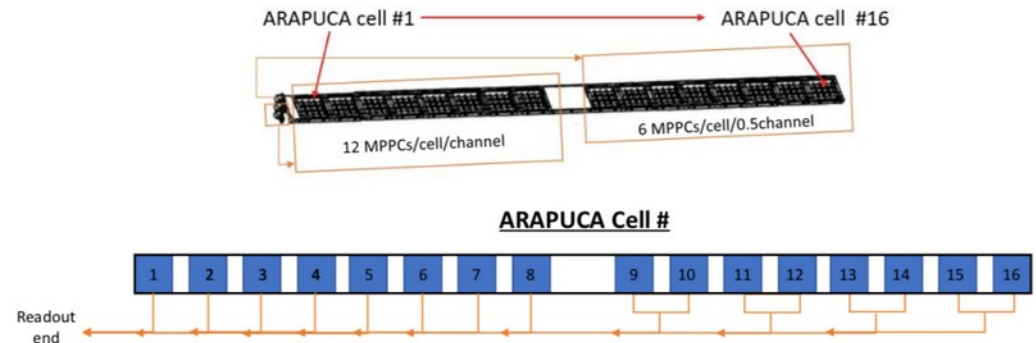
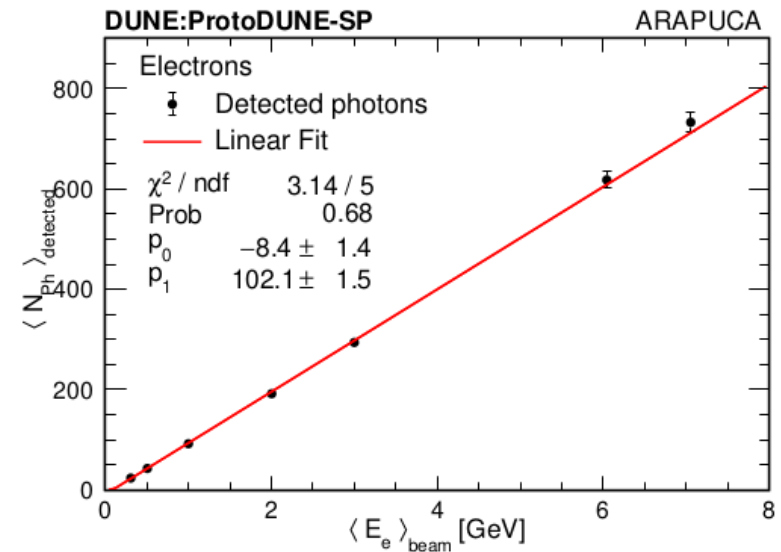
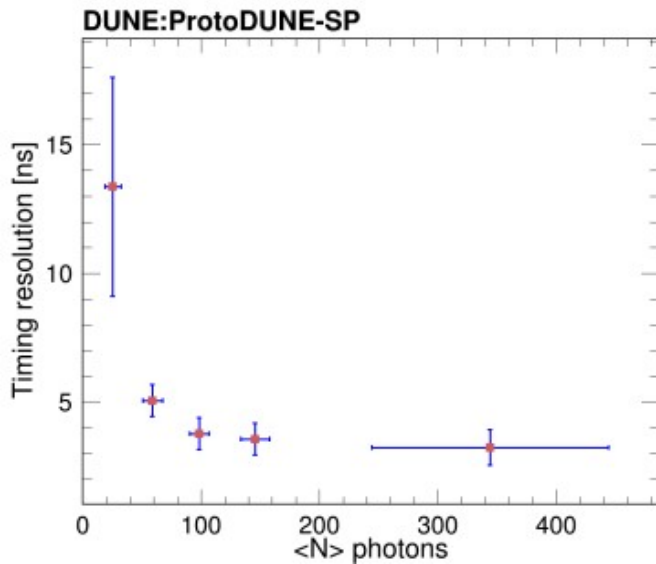
- Study done in ProtoDUNE-SP



- Shaded area corresponds to 5% gain interval

Time resolution

- Study done in ProtoDUNE-SP



- High resolution: 14 ns for consecutive light signals

3 ns for [T0](#)

- ProtoDUNE-SP had an optical clock of 150 MHz (FD1-2 will use 62.5 MHz)

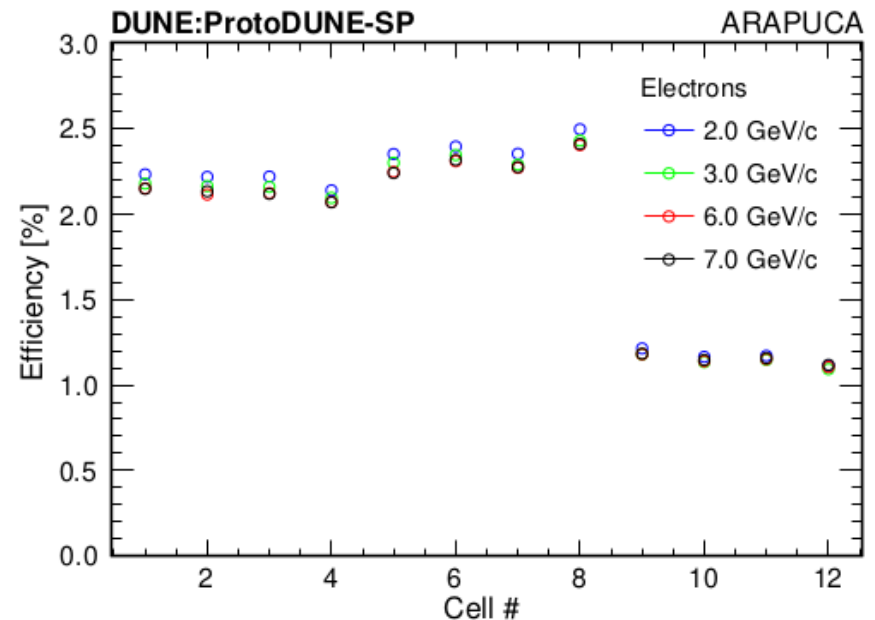
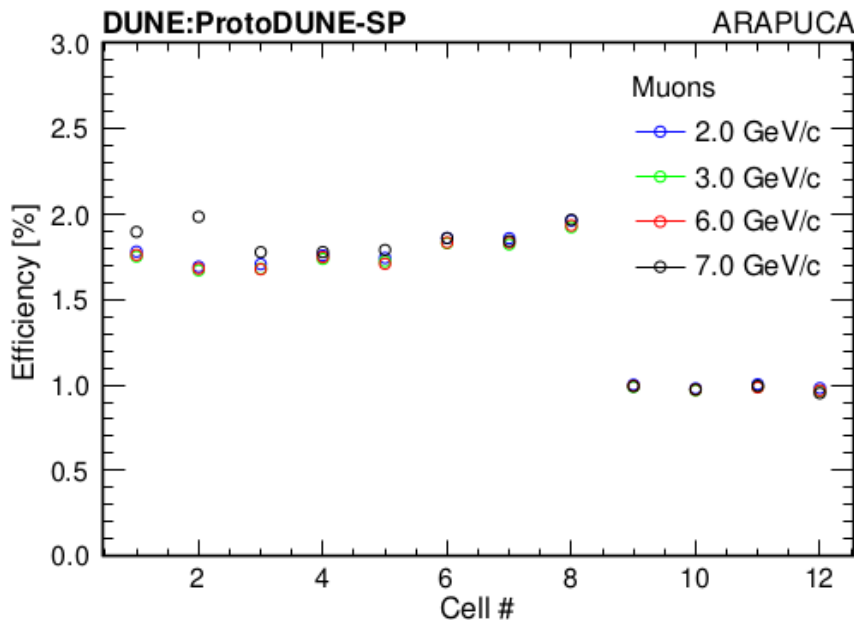
Arapuca detection efficiency

- Needs data + MC simulation

$$\epsilon_D = \frac{N_{Ph_{detected}}}{N_{Ph_{landing}}}$$

evaluated from offline data reconstruction
(baseline subtraction, waveform integration
and charge-to-photon conversion)

simulation within LArSoft



Interaction with other WGs

- Analysis held within the PD Consortium, by PD members
 - Important input for physics analysis → **DRA group**
 - Also the **Calibration WG**

Task list

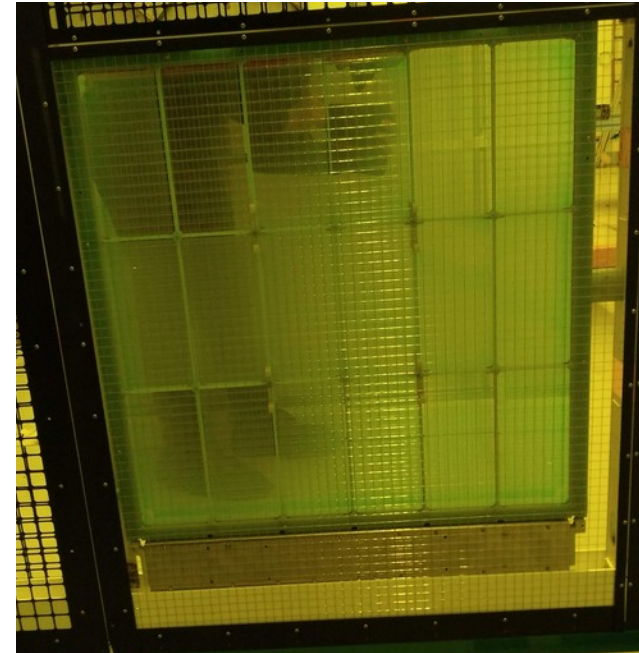
| Task Item | Person(s) Responsible – HD | Status – HD | Person(s) Responsible – VD | Status – VD |
|---|----------------------------|-------------|----------------------------|-------------|
| (...) | | | | |
| Develop PDS Timing Calibration | | | | |
| Develop PDS Gain Calibration | | | | |
| Develop PDS Single PE Response Shape Calibration/Tuning | | | | |
| Develop PDS Light Yield Calibration | | | | |
| (...) | | | | |

Rhiannon Jones & Mike Mooney | Physics calibration for ProtoDUNE II, January 2024



Looking forward: ProtoDUNE-VD

- We have to discuss what we want to do in PDVD
- X-Arapucas of 60 x 60 cm²
- Xe doping (?)
- Cosmics: only two small CRTs installed in NP02
- PD-DRA group plans on requesting beam with fixed lower possible energy (?)
- Will we be able to perform a full PDS characterization in this scenario?



Closing remarks

- We have developed a suite of requirements to ensure FD1 PDS does its part in meeting the high-level physics goals of DUNE
 - Now is the time to test the PDS and show this is indeed the case
 - We need to fully characterize FD1's PDS
- Proposal to discuss ongoing work on this meeting
 - Report progress at the PD consortium meeting
 - Report calibration progress at the calibration WG meeting

Please reach out to both José and myself if you are interested in analyzing PDHD data!