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Many thanks to all poster presenters and judges!

- 30 posters
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3 poster winners

3 poster winners

Manoa Andriamirado

“Final Search for Short-Baseline Neutrino Oscillations with the PROSPECT-I Detector at HFIR”

3 poster winners

Manoa
Andriamirado

Miguel Angel
Hernandez Morquecho

"Measurements of Pion and Muon Nuclear Capture at Rest on Argon
in the LArIAT Test Beam Experiment"

3 poster winners

Manoa
Andriamirado

Miguel Angel
Hernandez Morquecho

Diana
Leon Silverio

"Particle identification for proton and pion event discrimination using the SuperFGD prototype detector"

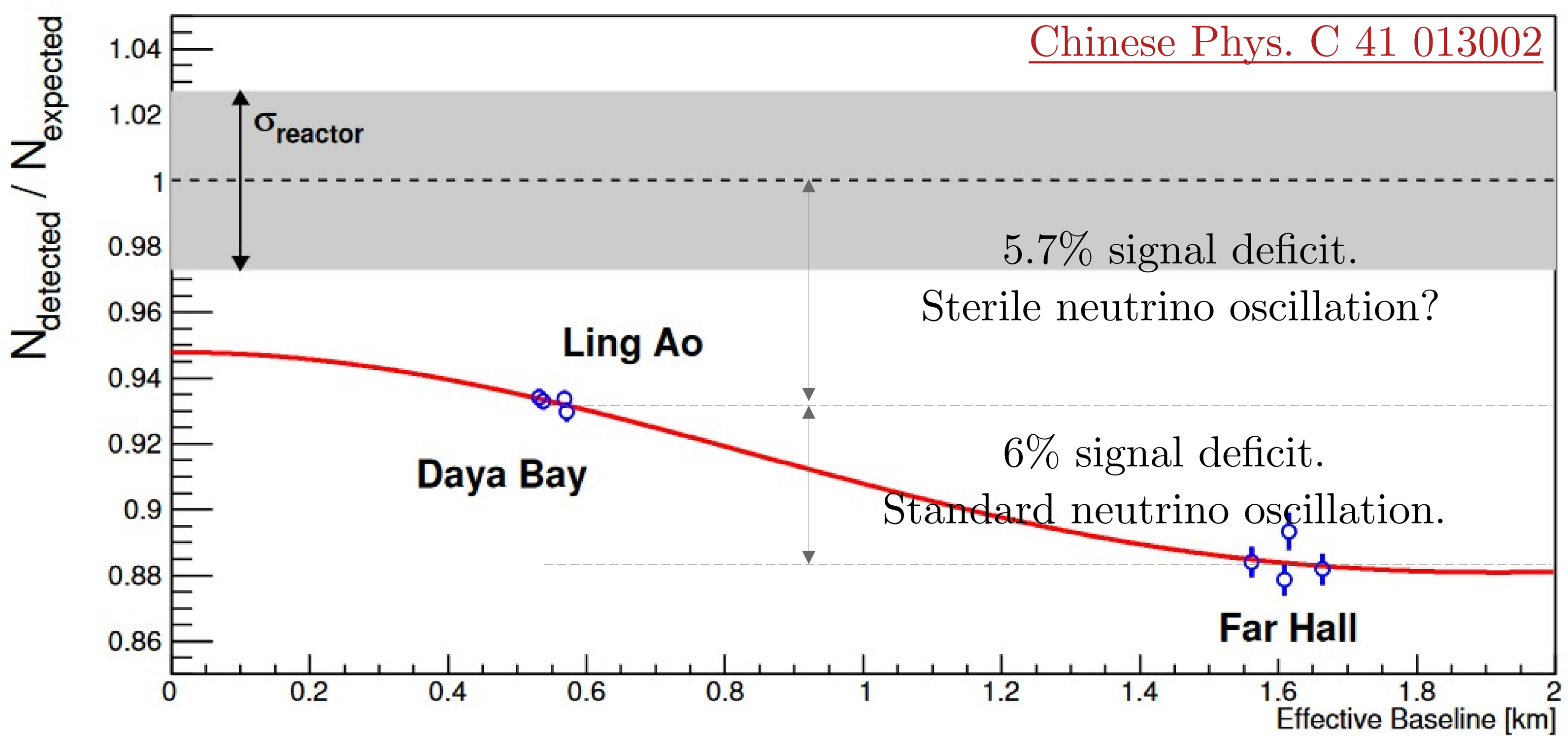
Final Search for Short-Baseline Neutrino Oscillations with the PROSPECT-I Detector at HFIR

Manoa Andriamirado
Illinois Institute of Technology
On behalf of the PROSPECT Collaboration

ILLINOIS INSTITUTE OF TECHNOLOGY

PROSPECT

Sterile Neutrinos

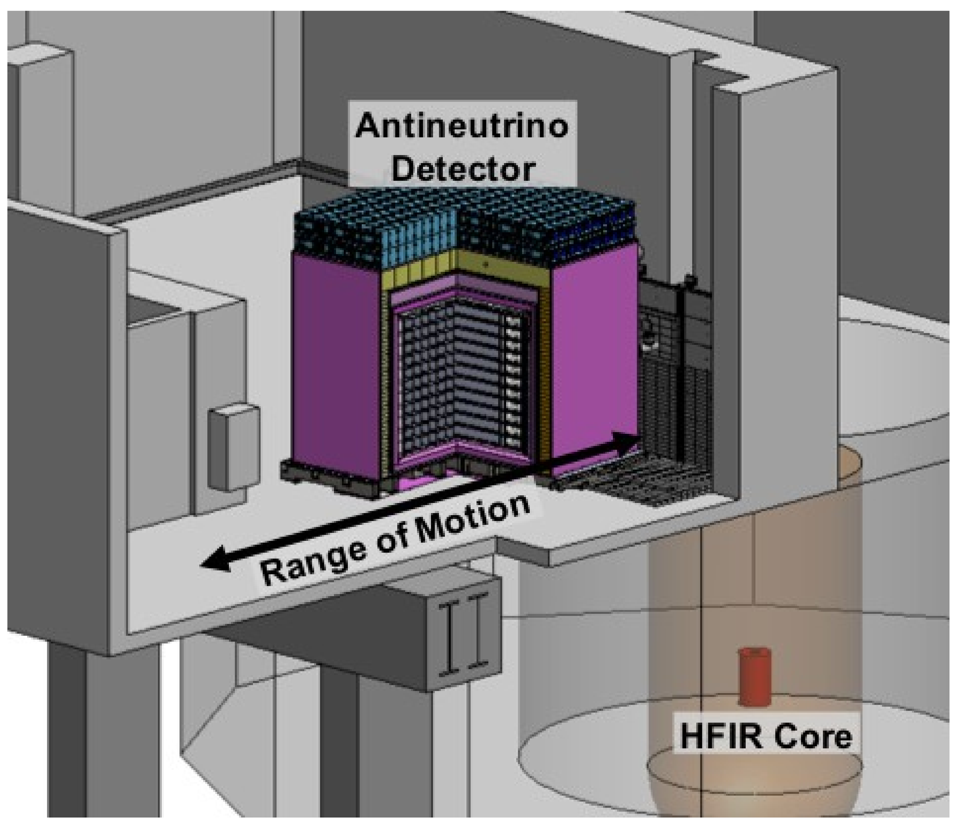


- Antineutrino flux deficit could be explained by the oscillation of active antineutrinos into sterile states.
  - Portal to Physics Beyond the Standard Model.
- Other anomalies point to the existence of sterile neutrino: LSND/MiniBoone, and the gallium anomaly.
- Recent result from the Neutrino-4 experiment claimed a non-zero oscillation. Phys. Rev. D 104, 032003 .

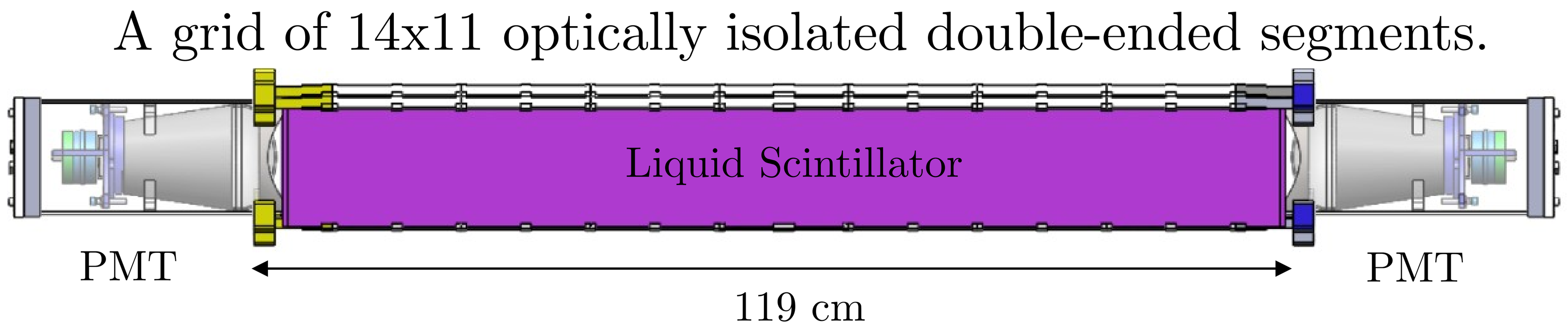
The PROSPECT Experiment

The Precision Reactor Oscillation and SPECTrum experiment is a reactor antineutrino experiment, designed to search for sterile neutrino oscillation and measure ^{235}U antineutrino spectrum.

- On-surface deployment with minimal overburden.
- 85 MW compact Higly Enriched Uranium reactor.
- Detector covers baseline of 7-9 m from the reactor core.
- Detector is filled with 4-ton of ^{6}Li-doped PSD-capable liquid scintillator.
- Antineutrino detection via Inverse Beta Decay (IBD).



A grid of 14x11 optically isolated double-ended segments.



The ingress of liquid scintillator into PMTs led to the failure of some PMTs, resulting previous results to be dominated by statistical uncertainty.

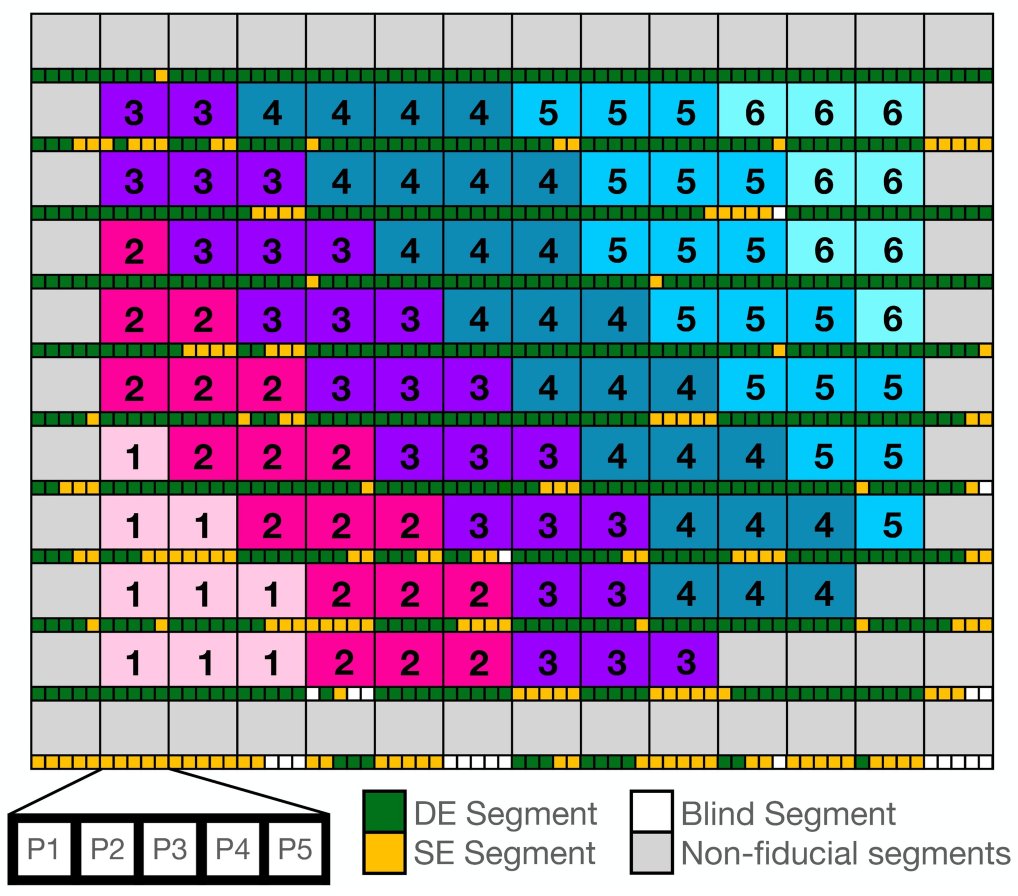
Multi-period analysis

- 96 days of data taking from March 5 to October 6, 2018.
- Split the data into 5 periods to recover IBD statistics:
  - Apply Single-Ended Event Reconstruction (SEER) to further reduce backgrounds.
- Total IBD count: 61,029 with 3.9 of S/B ratio.
- Used this optimized dataset for antineutrino spectrum measurement at PROSPECT, Phys. Rev. Lett. 131, 021802.

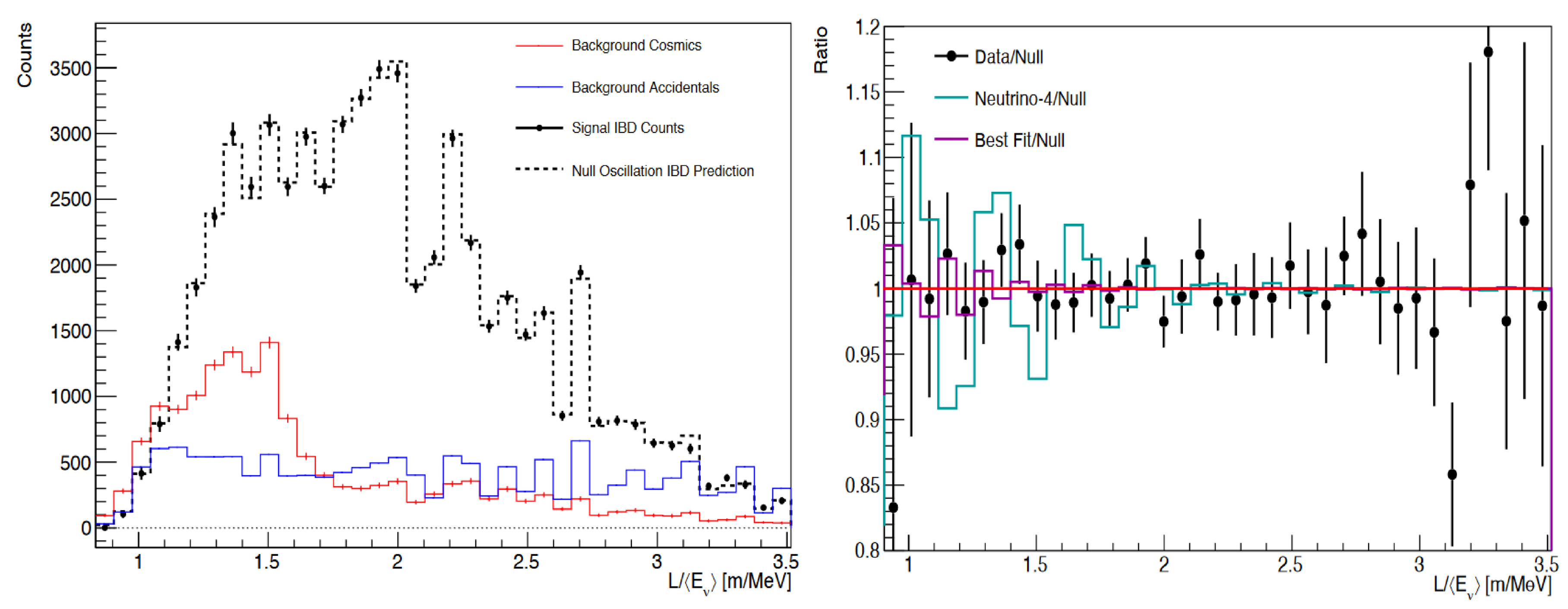
Data Set	Rx-On(Off) Days	N_{IBD}	N_{eff}	S:CB(AB)
Prev. Analysis	95.65(73.09)	50560 ± 406	18100	1.37(1.78)
This Analysis	95.62(72.69)	61029 ± 338	36204	3.90(4.31)
Period 1	9.54(14.58)	6357 ± 100	4328	4.03(6.21)
Period 2	22.83(15.71)	16546 ± 172	10259	4.35(4.64)
Period 3	23.20(16.40)	15094 ± 166	9050	4.04(4.44)
Period 4	22.29(16.79)	13486 ± 161	7742	3.72(3.39)
Period 5	17.76(9.21)	9546 ± 146	4825	3.38(2.88)

Analysis strategy

- Search for spectral distortion at each baseline of the detector.
- Perform a shape analysis which remove the reactor model dependency.
- Quantify the agreement between data and prediction with a χ^2 statistical test.
  - Combined Neyman-Pearson test to minimize bias from low statistics bins.

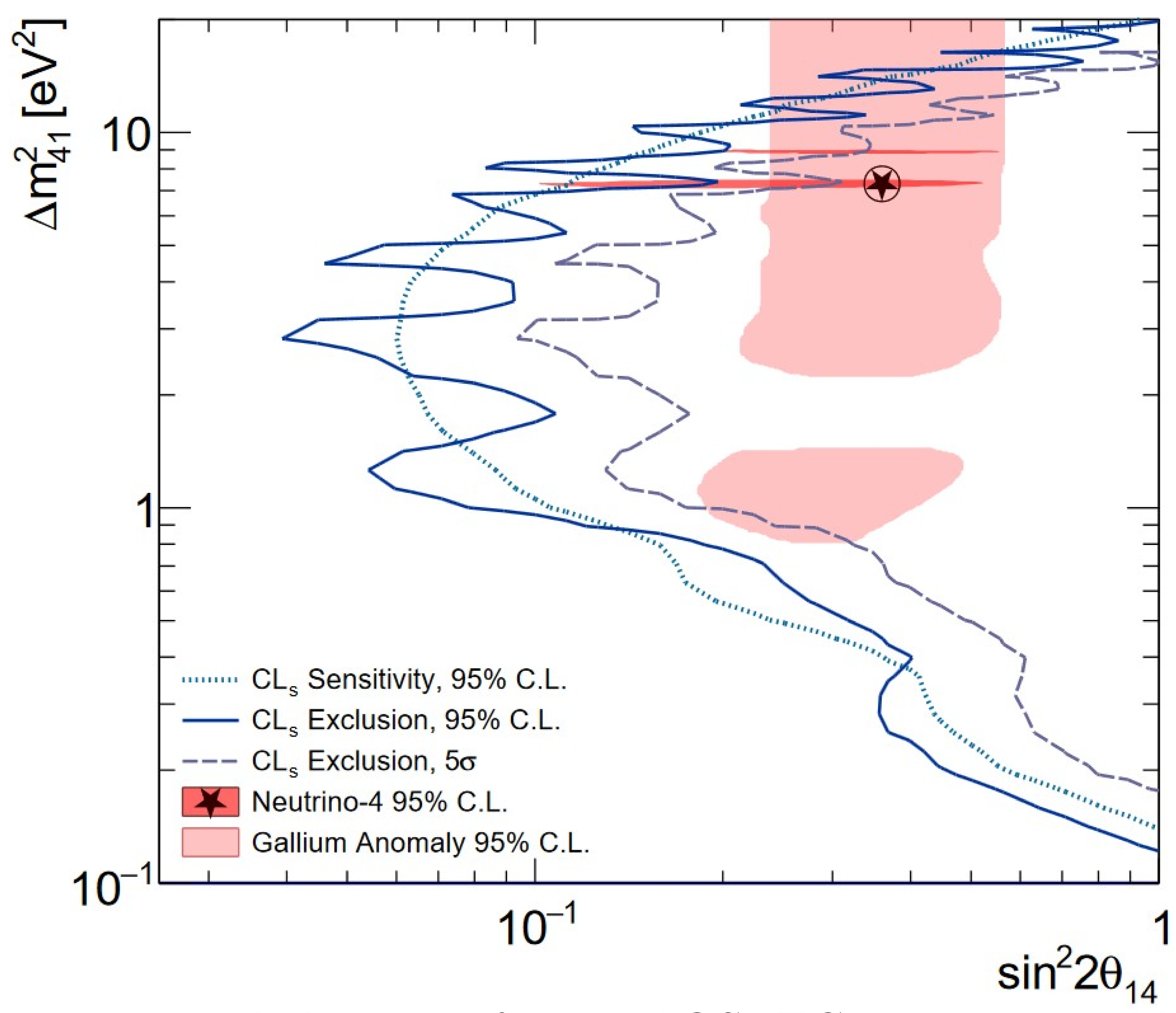


Data Visualization



- Short-baseline oscillation behavior in PROSECT can be visualized by grouping its IBD data into bins of common L/E_ν.
- Ratios expected due to oscillations at the PROSPECT data and Neutrino-4 best-fit points are also depicted.
- No obvious sign of short-baseline oscillation from PROSPECT IBD's dataset.

Result



- New optimized data set from PROSPECT is compatible with the absence of sterile neutrino oscillations.
- Claimed observation of short-baseline oscillation from the Neutrino-4 experiment is ruled out at more than 5σ.
- Exclude all phase-space for Δm^2 below 10 eV^2 suggested by the recently strengthened Gallium Anomaly.

This work is supported by the US DOE Office of High Energy Physics, the Heising-Simons Foundation, CFREF and NSERC of Canada, and internal investments at all institutions

Measurements of Pion and Muon Nuclear Capture at Rest on Argon in the LArIAT Test Beam Experiment

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[1]Department of Physics, Illinois Institute of Technology

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Motivation

- DUNE (Deep Underground Neutrino Experiment) will be the largest neutrino LArTPC in the world.
- Identification of mu/pi would improve the understanding of BSM events, like decay of heavy neutral leptons with unusual topologies as final state with $\mu^+\mu^-/\pi^+\pi^-$ [2]. This is *difficult* using standard track-based dE/dx methods due to the similar masses and energy deposition profiles in argon.

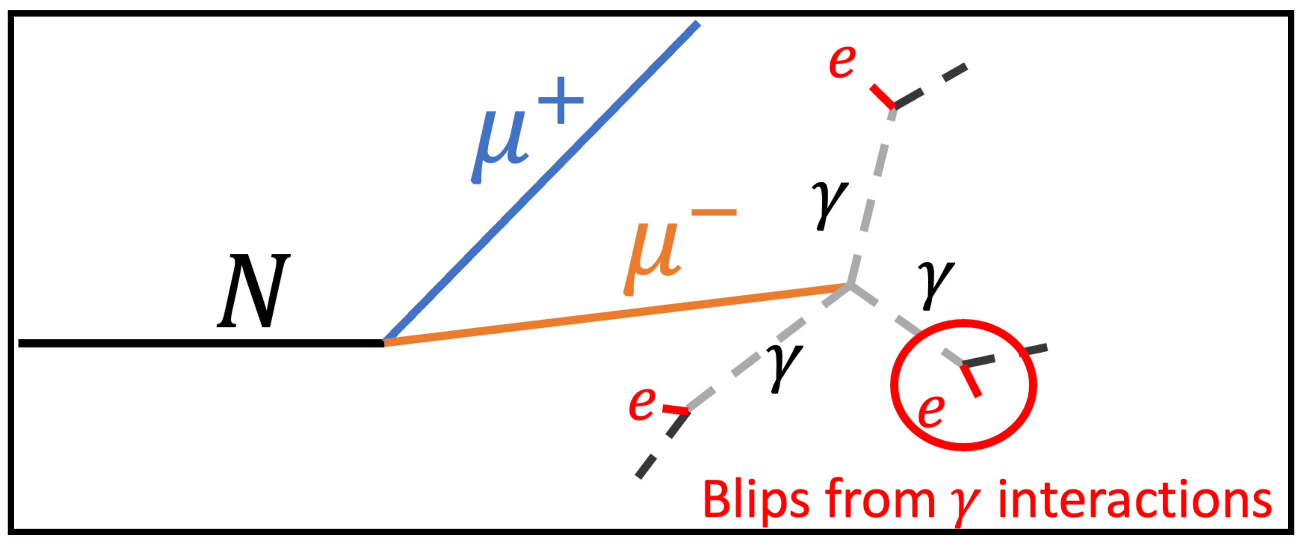
Missing energy !!!

$\mu^- + p \rightarrow n + \nu_\mu$ $\qquad$ $\pi^- + p \rightarrow n$

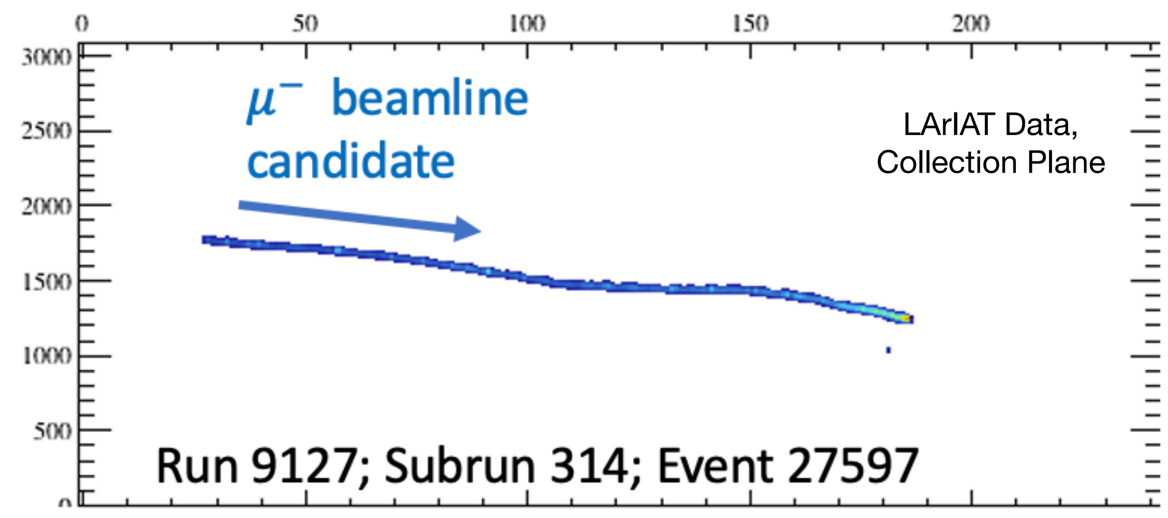
All energy to the nucleus !!!

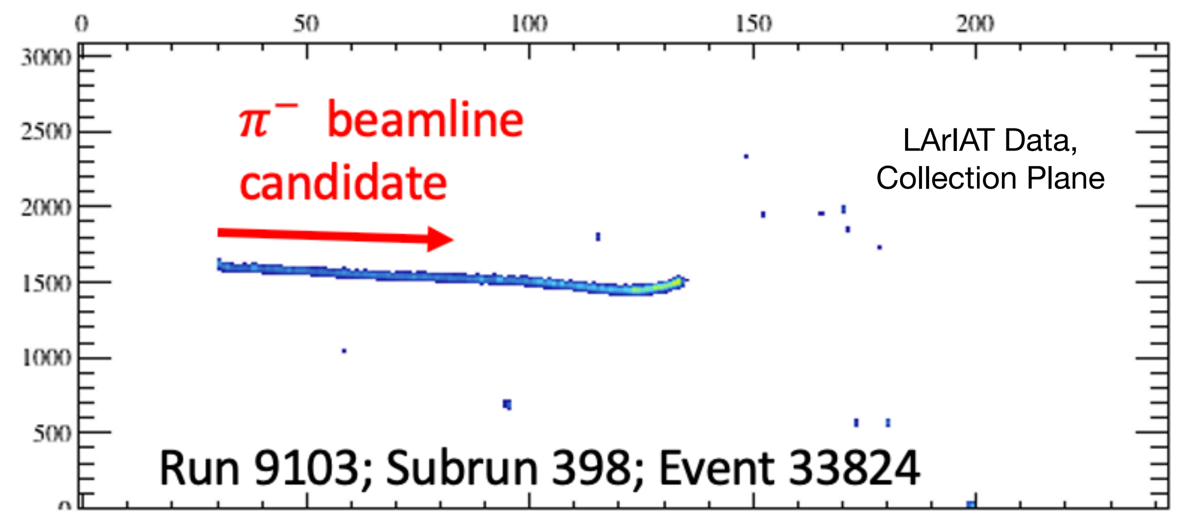
Muon capture at rest process $\qquad$ Pion capture at rest process

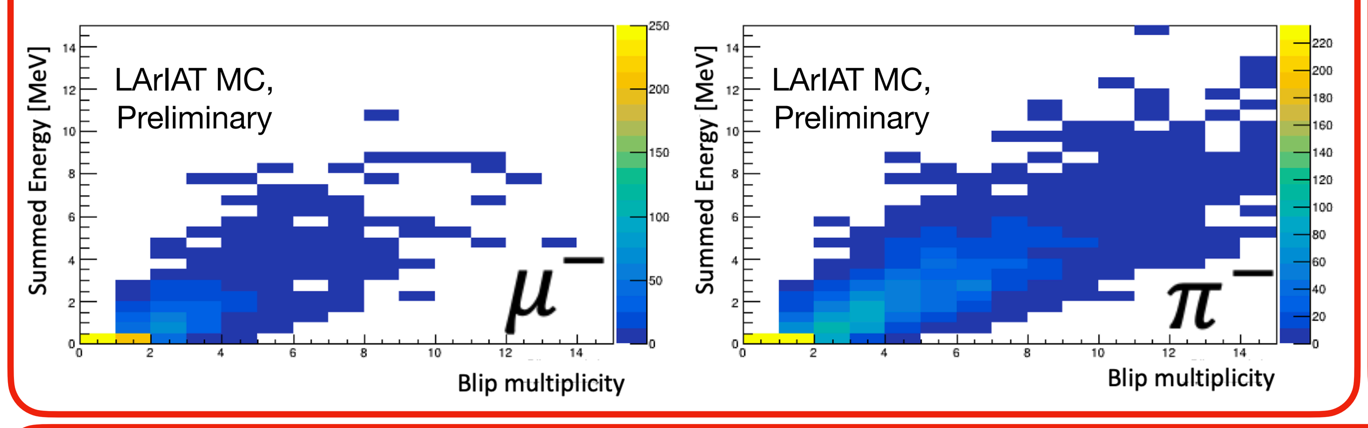
- Reconstruction of gammas from nuclear capture (Blips) can help with this!



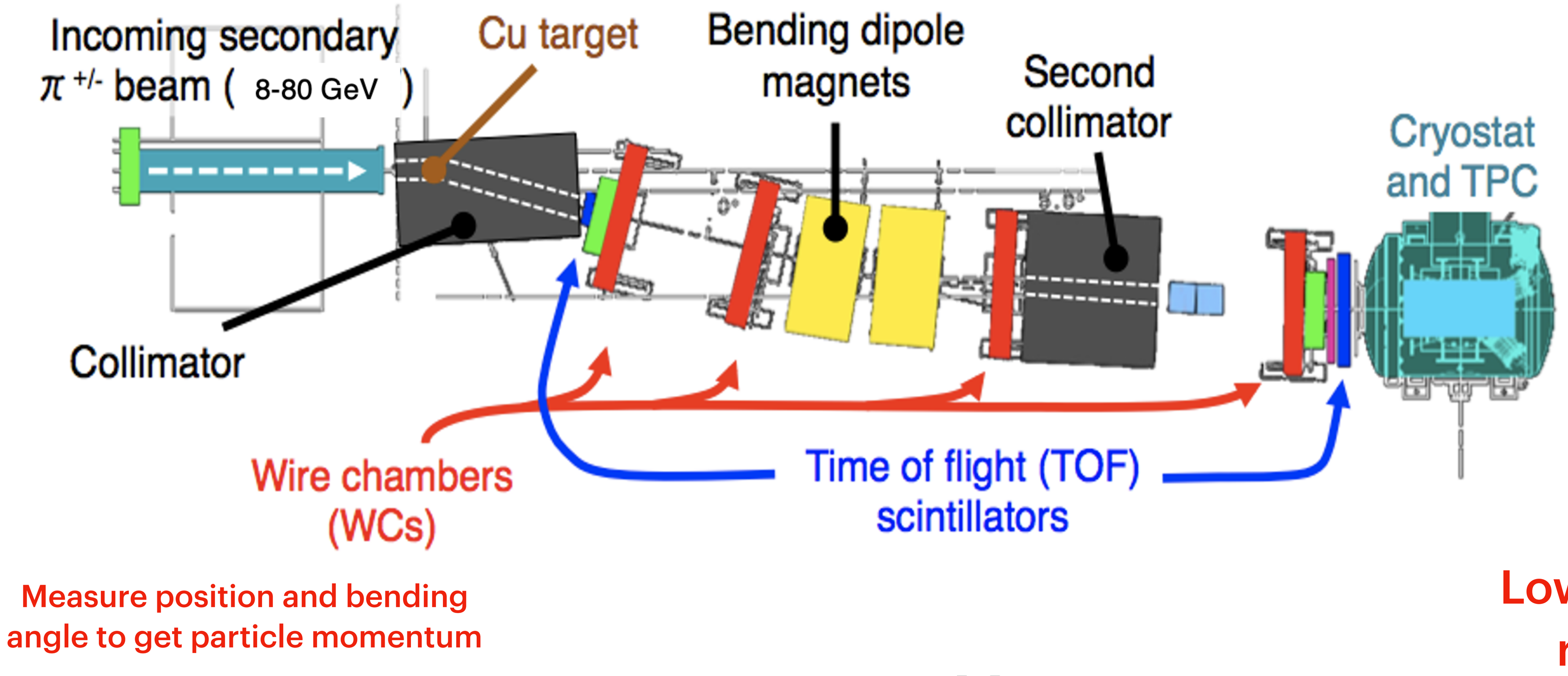
Unusual topologies $\mu^+\mu^-/\pi^+\pi^-$ for BSM. Gammas produced by muon/pion capture, these gammas produce electrons (Blips) from induced interactions.





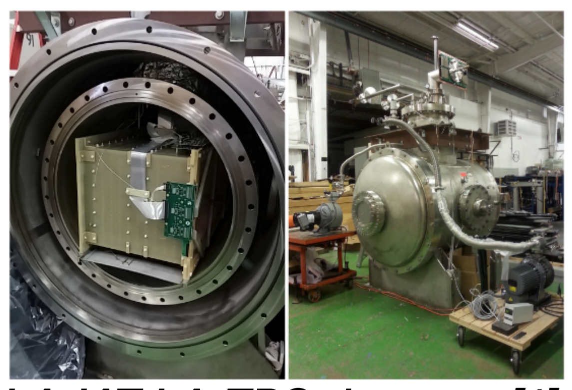


Why LArIAT?

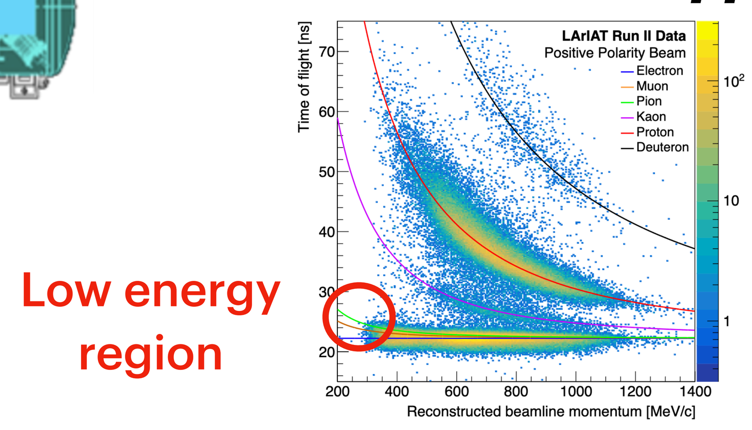


Fermilab test beamline [1].

LArIAT: Liquid Argon In A Testbeam

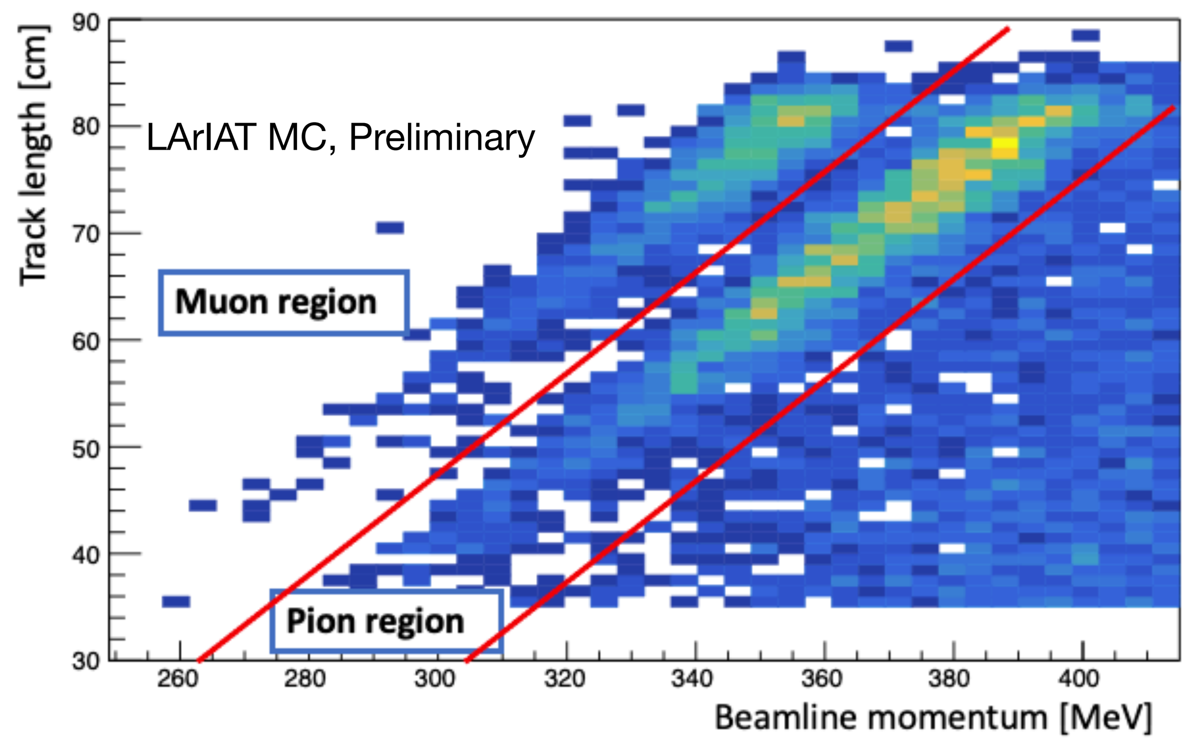


LArIAT LArTPC detector [1].



TOF vs reconstructed momentum [1].

Muon and Pion selection



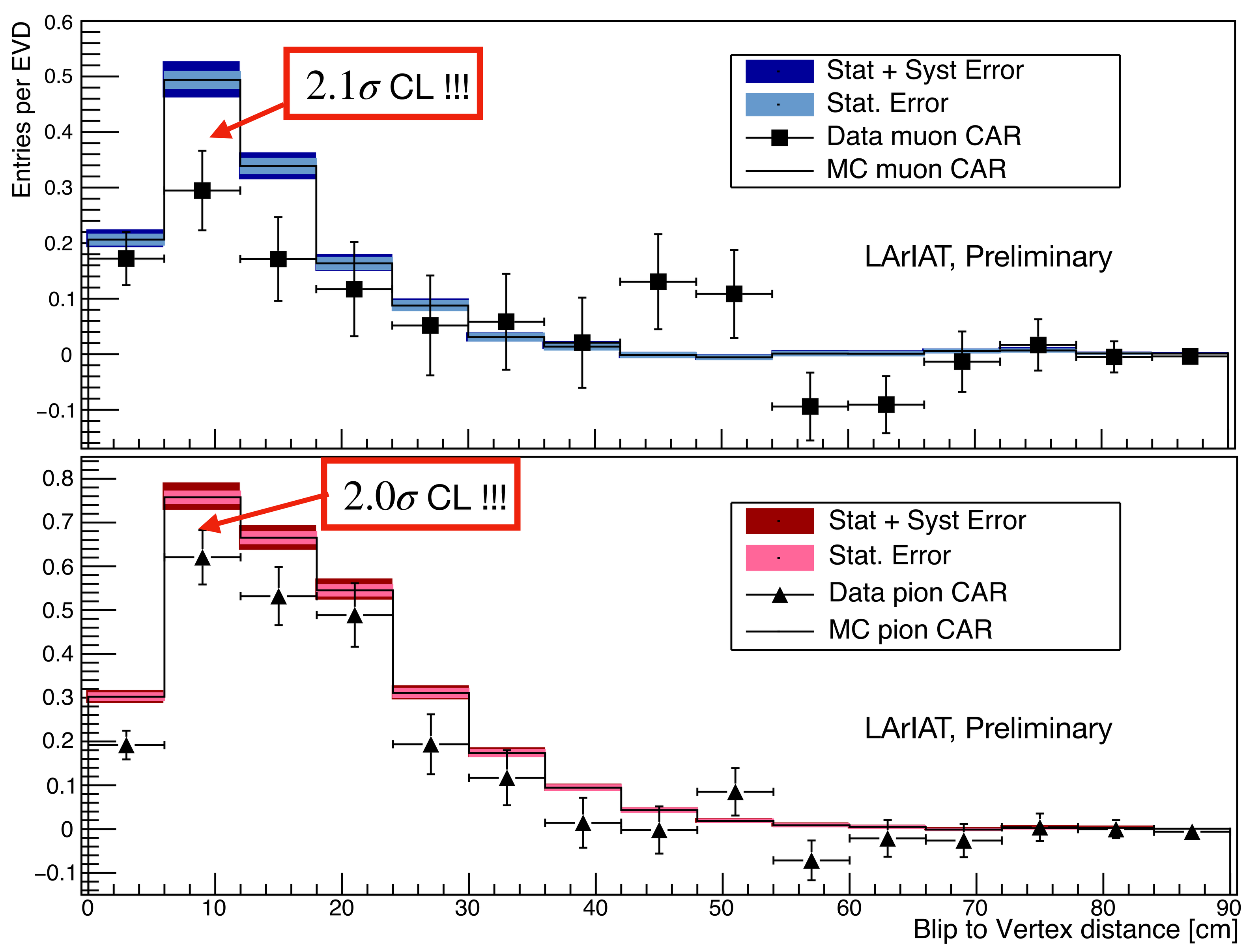
Initial precuts on beam momentum, Bragg peak, start and end positions of the primary particle.

Using beam momentum and track stopping point inside of the TPC we separate stopping muons from stoping pions.

With a MC sample of 500k (G4 QGSP_Bert_HP Physics list) events a final selection of
2132 muon captured-at-rest events (79% purity)
3931 pion captured-at-rest events (76% purity)

Data has 87 muon captured at rest and 209 pion captured at rest candidates.

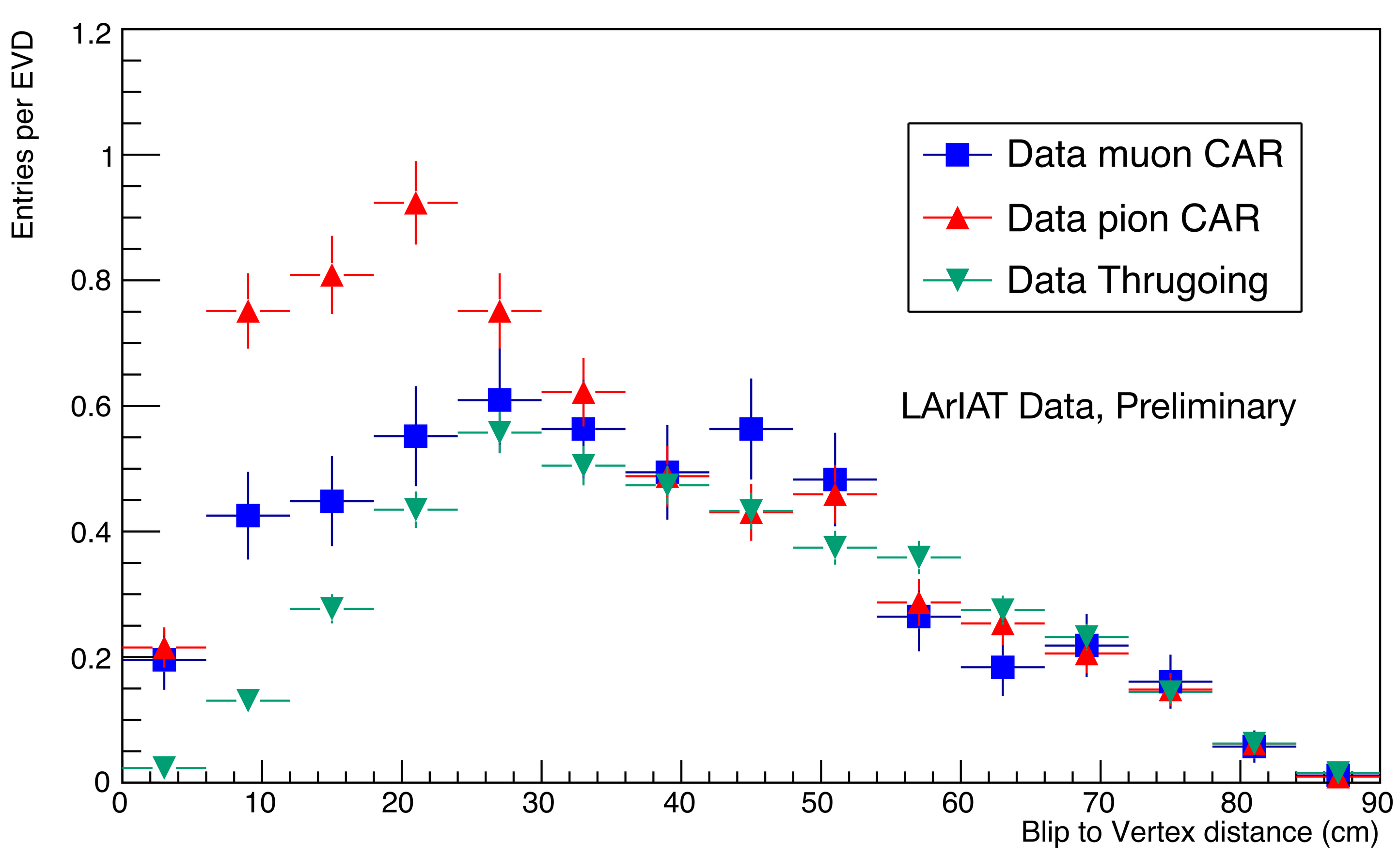
Data-MC comparison



Dataset	Blips per EVD
Muon Data	0.74 ± 0.19
Muon MC	1.22 ± 0.08

Dataset	Blips per EVD
Pion Data	1.86 ± 0.17
Pion MC	2.34 ± 0.09

Data based observations



- Muon Captured at rest to through-going 4.2σ CL of statistical incompatibility
- Pion Captured at rest to through-going $\gg 5\sigma$ CL of statistical incompatibility
- Muon to pion captured at rest 3.6σ CL of statistical incompatibility

We have provided the first observation of the products of stopped pion and muon nuclear capture on argon, and have shown that capture products of the two particle types are clearly distinguishable from one another in neutrino LArTPC data (arXiv.2408.05133)

References

[1] Acciarri, R. et al. (2020). The Liquid Argon In A Testbeam (LArIAT) experiment. Journal of Instrumentation, 15(04), P04026.
[2] Abratenko, P. et al. (2022). Search for long-lived heavy neutral leptons and Higgs portal scalars decaying in the MicroBooNE detector. American Physics Society, PhysRevD.106.092006

Acknowledgments

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Particle identification for proton and pion event discrimination using the SuperFGD prototype detector

Diana Leon Silverio – South Dakota School of Mines and Technology

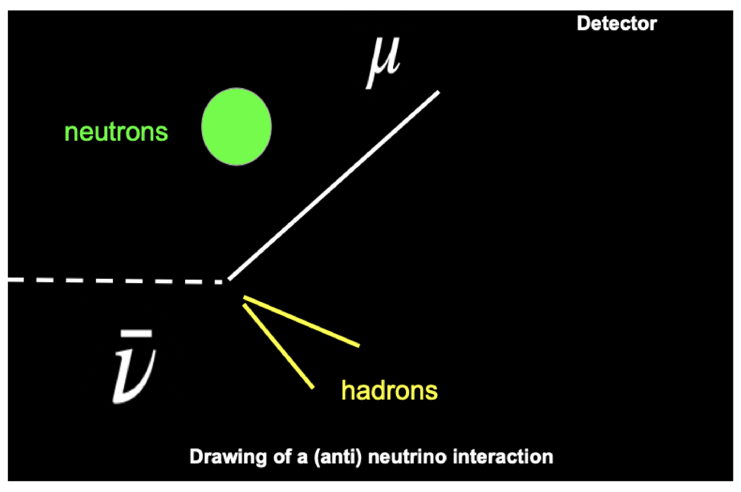
SOUTH DAKOTA MINES

Motivation

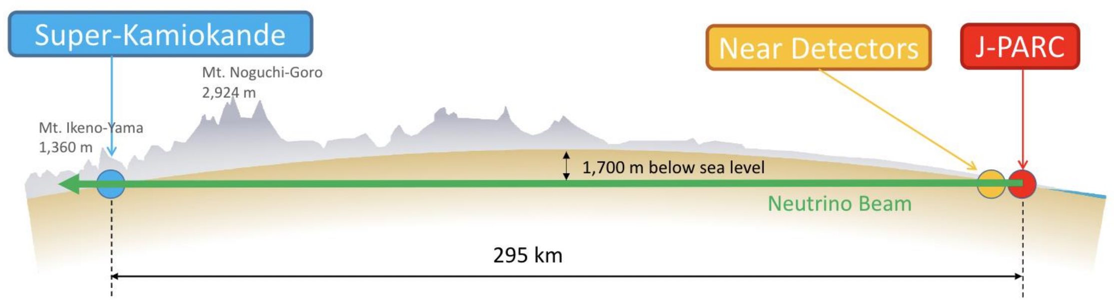
Goal: Identify neutron induced proton and pion production in the SFGD prototype to understand and improve the neutron energy reconstruction

The neutron kinematics is one of the missing piece for (anti) neutrino energy reconstruction but currently no accessible to long-baseline experiments [1]

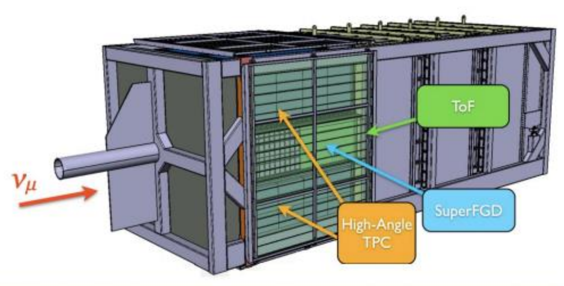
Neutron detection and kinetic reconstruction capabilities were studied exposing a SFGD prototype detector to a neutron beam at LANL[2]



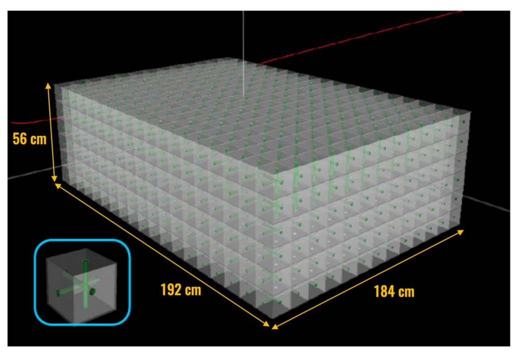
SFGD Detector



A novel 3D-project scintillator detector, called super fine-grained detector (SFGD) [1, 3]:



- Fully active plastic scintillator tracker in the upgraded near detector of T2K.
- ~2M plastic scintillators cubes of 1cm^3
- Photons read out through wavelength shifting (WLS) fibers and detected by Multimode Pixel Photon Counters (MPPC)

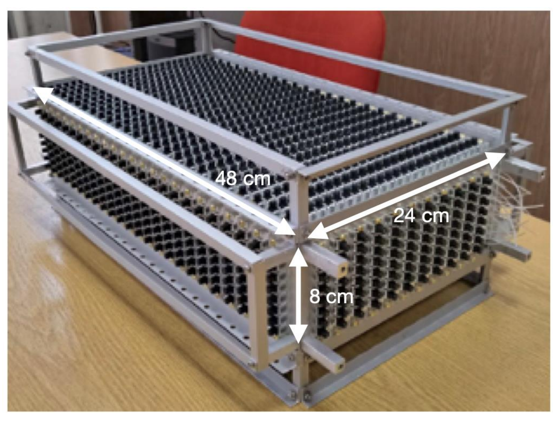


- **Fully active volume**
- **Fast timing:** single fiber of ~0.9 ns timing resolution
- **Fine granularity:** spatial resolution ~3 mm
- **High light yield:** Each read out of ~ 52 PE/MeV

SFGD Prototype at LANL

Two SFGD prototypes with plastic scintillators cubes of 1cm x 1cm x 1cm cube size were assembled:

- SFGD prototype of size 24 x 8 x 48 cm
- US-Japan prototype (US-JP) (size 8 x 8 x 32 cm)



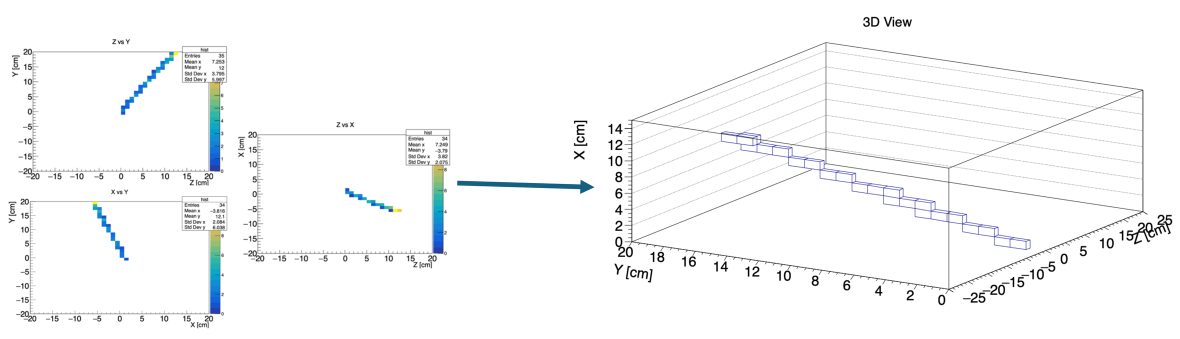
Both prototypes were exposed to a neutron beam in LANL in for about two months (December 2019 and December 2020) [2].

Event Reconstruction and Selection

The following Particle Identification (PID) study will be done considering only SFGD prototype.

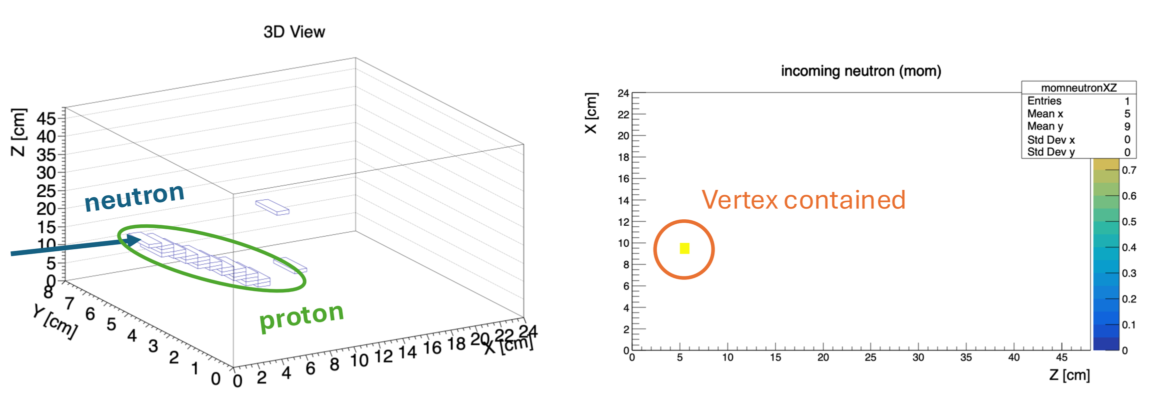
Event Reconstruction:

- The event requires more than 3 hits with PE > 20
- The voxels (hits in 3D space) are defined by the three 2D-view matching of time-clustered hits (ZX, XY, and ZY)
- Using DBSCAN to group voxels into clusters



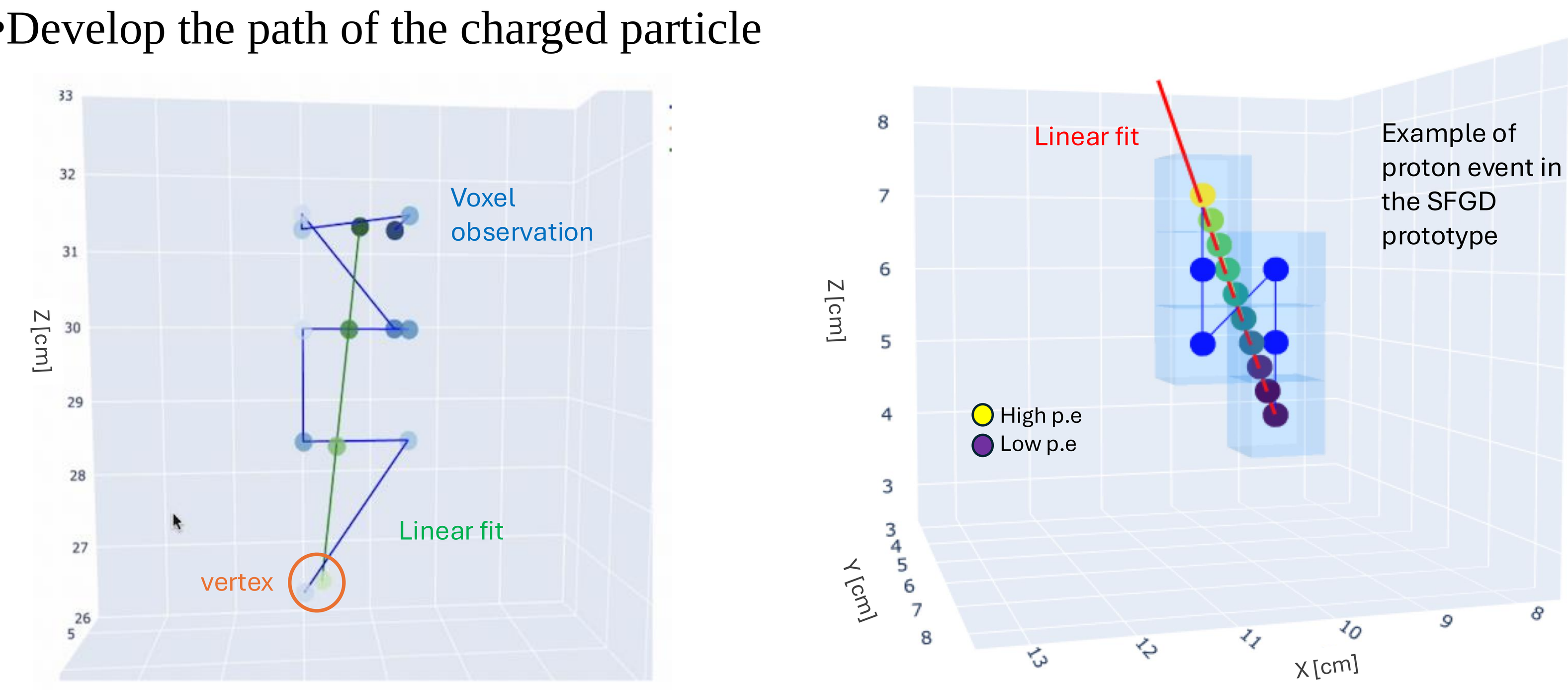
Event Selection:

- Event with one spatial cluster (single cluster)
- Event with more than three voxels in single cluster
- Primary vertex (earliest voxel in z-axis) must be contained inside of detector volume
- Full event interaction should be contained in the detector volume
- Reject events with poor linearity



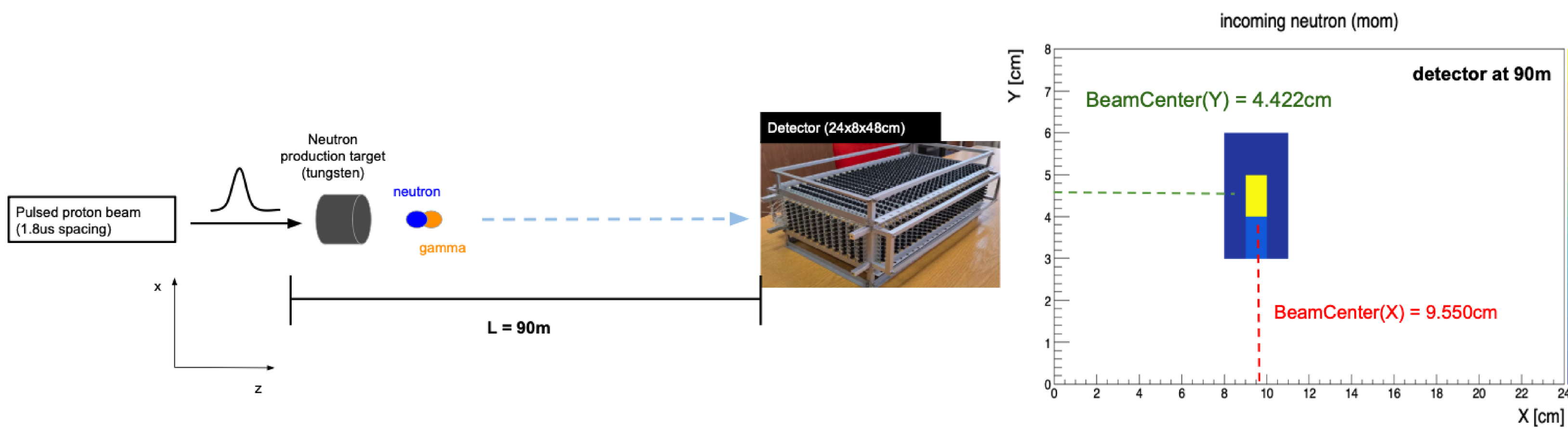
Event Trajectory

- Apply linear fit using linear regression
- Interpolation used to determine positions along the fit
- Develop the path of the charged particle

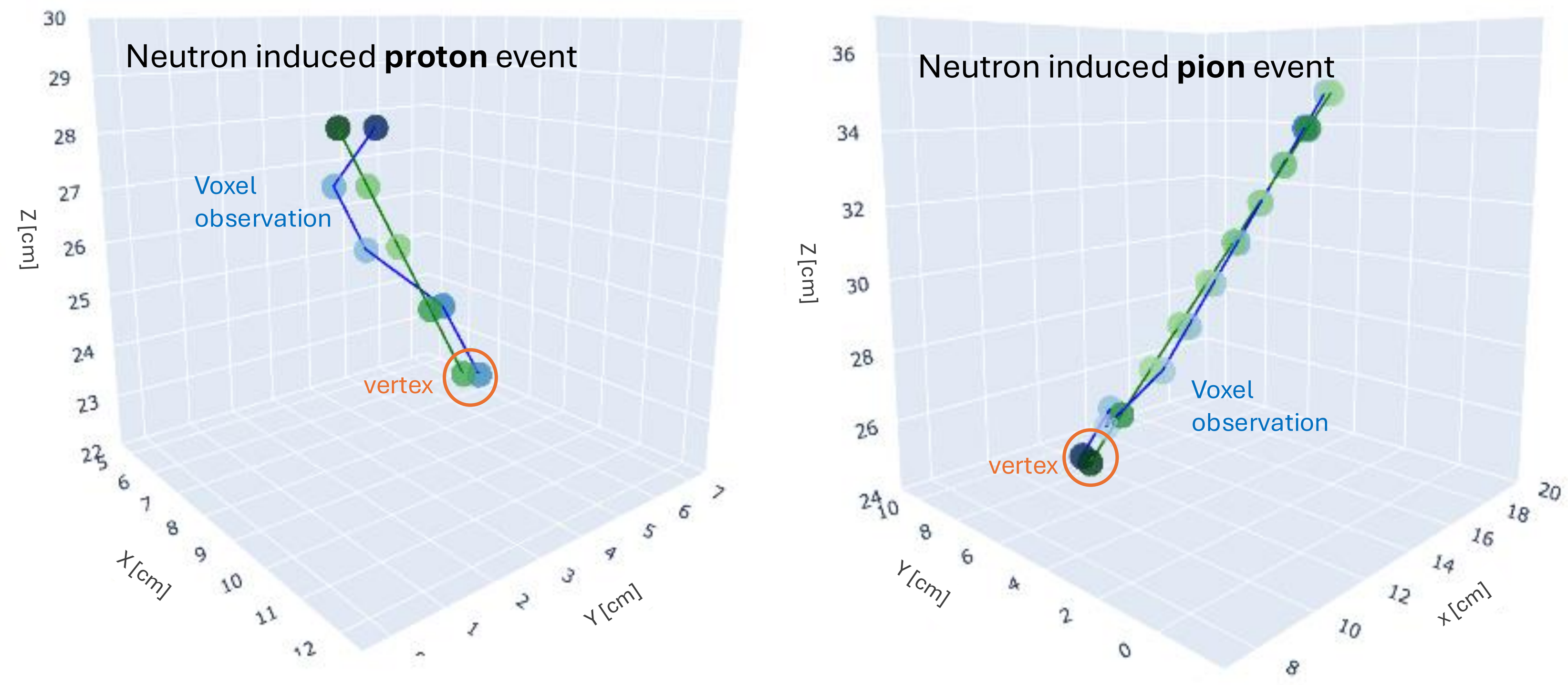


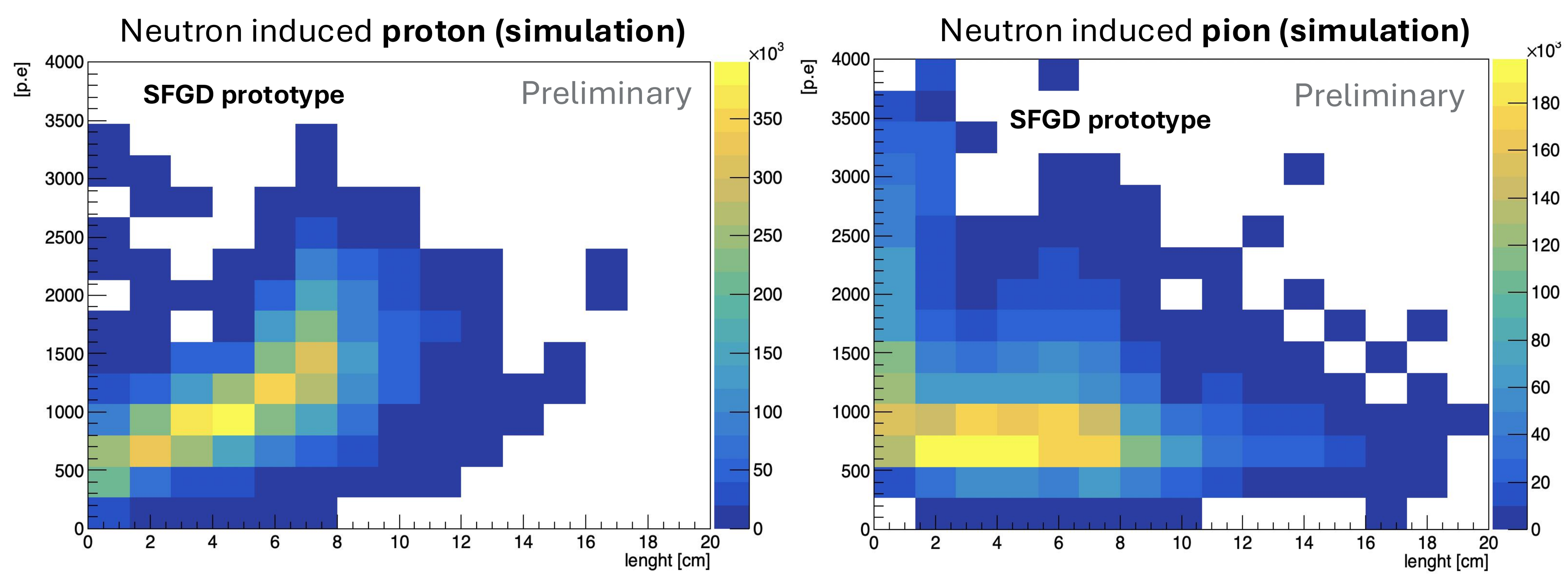
PID for proton or pion event

Using a simulated neutron sample traveling trough the SFGD prototype detector:



- To identify the type of the particle (proton and pion), the distance between consecutive positions (x,y,z) is calculated, along with the difference in their p.e.





Conclusion

- A preliminary PID based on dE/dl has been developed
- The tools are currently under validation using simulated neutron samples for the SFGD prototype. Preliminary results are promising
- All the lessons learned could be helpful for T2K SFGD near detector

Acknowledged:

This work is supported by the U.S. Department of Energy Office of Science (DE-SC0023026).

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References:

[1] Fedotov, S. "New 3D fine-grained scintillation detector for the T2K experiment." *Journal of Instrumentation* 15.07 (2020): C07042.

[2] Agarwal, Arun, et al. "Total neutron cross-section measurement on CH with a novel 3D-projection scintillator detector." Physics Letters B 840 (2023): 137843.

[3] Douqa, Dana. "The SuperFGD for the T2K near detector upgrade." *Journal of Physics: Conference Series.* Vol. 1690. No. 1. IOP Publishing, 2020.

[4] Riccio C. "Total neutron cross-section measurement on CH with a novel 3D-projection scintillator detector", NuFact 2022.