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

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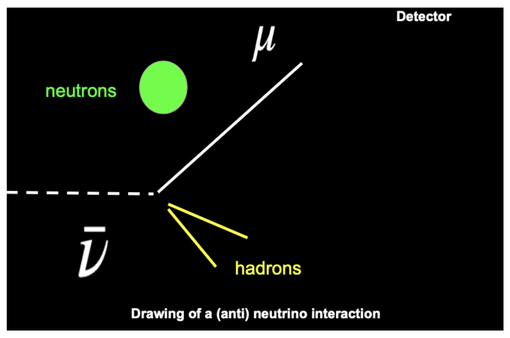
Motivation

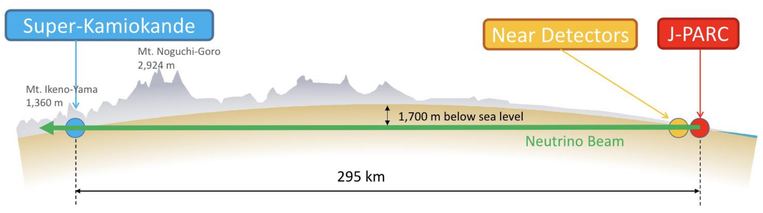
Goal: Identify neutron induced proton and pion production in the SFGD prototype to understand and improve the neutron energy reconstruction

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

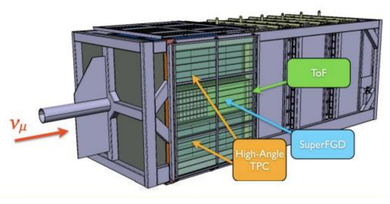
Neutron detection and kinetic reconstruction capabilities were studied exposing a SFGD prototype detector to a neutron beam at LANL[2]



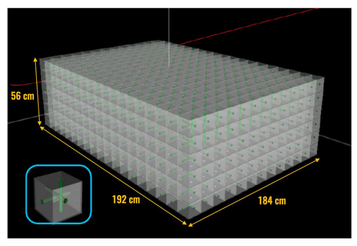
SFGD Detector



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)



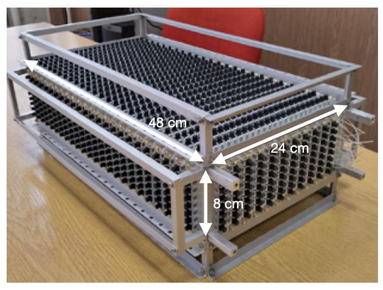
- **Fully active volume**
- **Fast timing:** single fiber of ~0.9 ns timing resolution
- **Fine granularity:** spatial resolution ~3 mm
- **High light yield:** Each read out of ~ 52 PE/MeV

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].

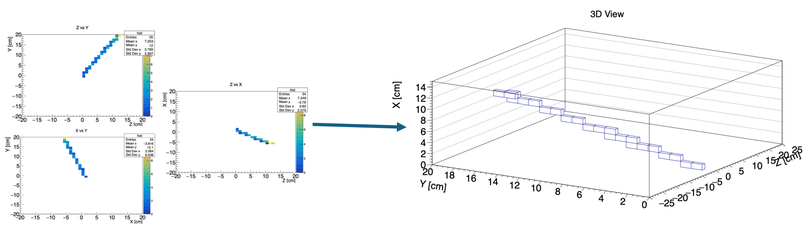


Event Reconstruction and Selection

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

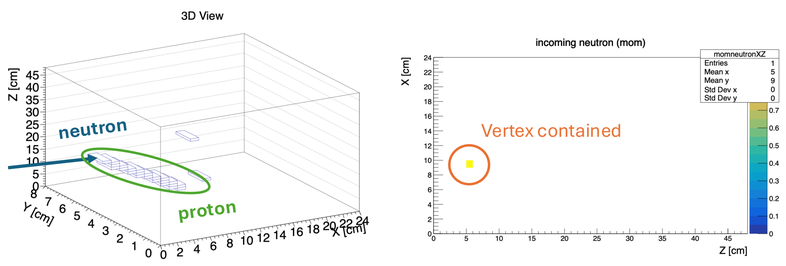
Event Reconstruction:

- 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



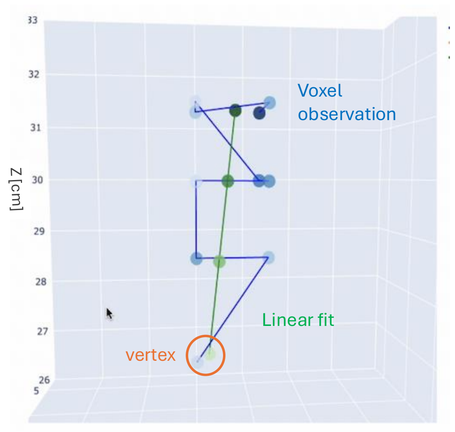
Event Selection:

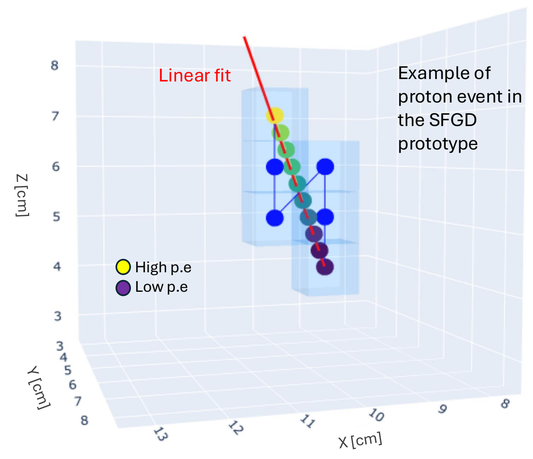
- Event with one spatial cluster (single cluster)
- Event with more than three voxels in single cluster
- Primary vertex (earliest voxel in z-axis) must be contained inside of detector volume
- Full event interaction should be contained in the detector volume
- Reject events with poor linearity



Event Trajectory

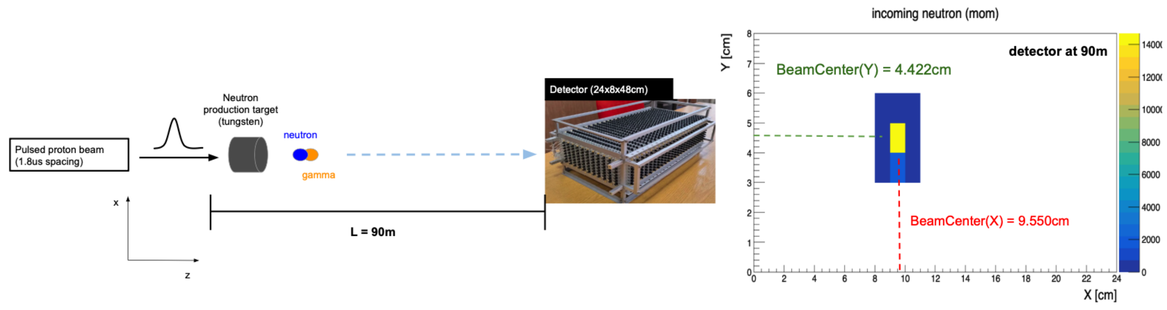
- Apply linear fit using linear regression
- Interpolation used to determine positions along the fit
- Develop the path of the charged particle



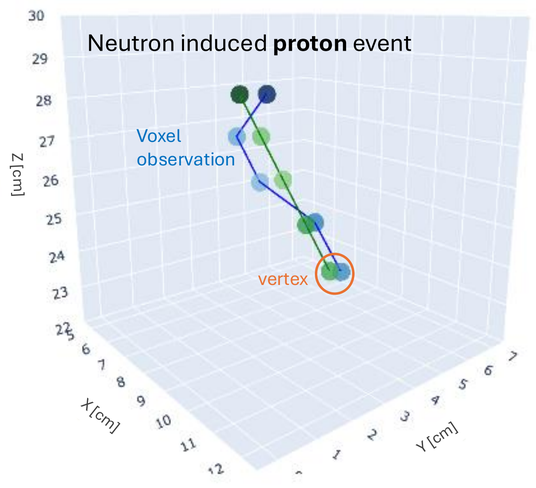


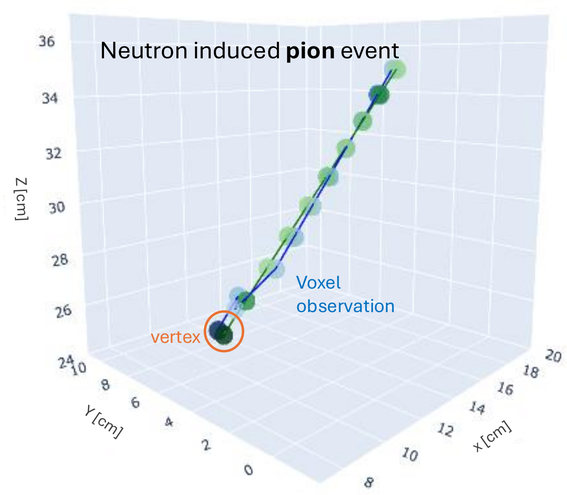
PID for proton or pion event

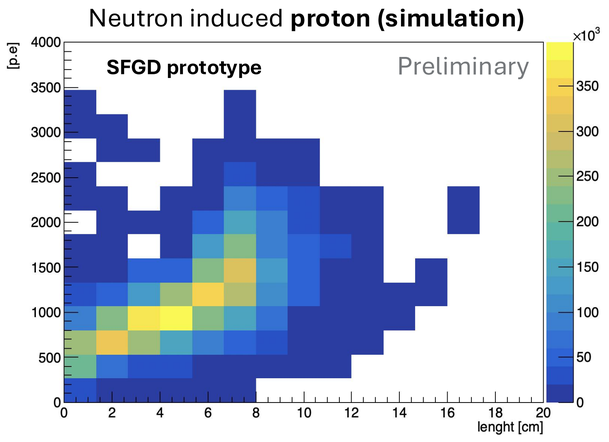
Using a simulated neutron sample traveling trough the SFGD prototype detector:

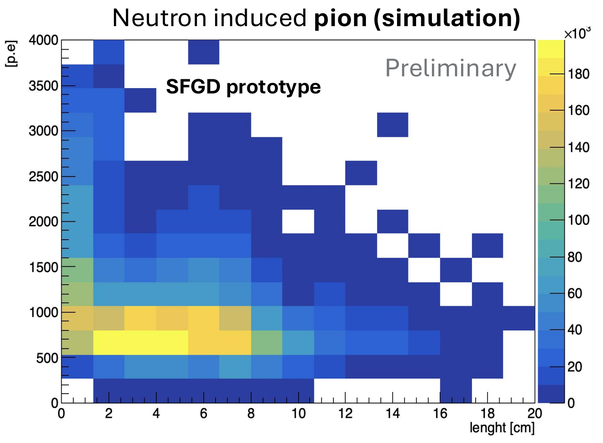


- To identify the type of the particle (proton and pion), the distance between consecutive positions (x,y,z) is calculated, along with the difference in their p.e.









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:

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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.