Analysis Plan for the DDG test at CERN

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UCDAVIS
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CALCI Consortium meeting
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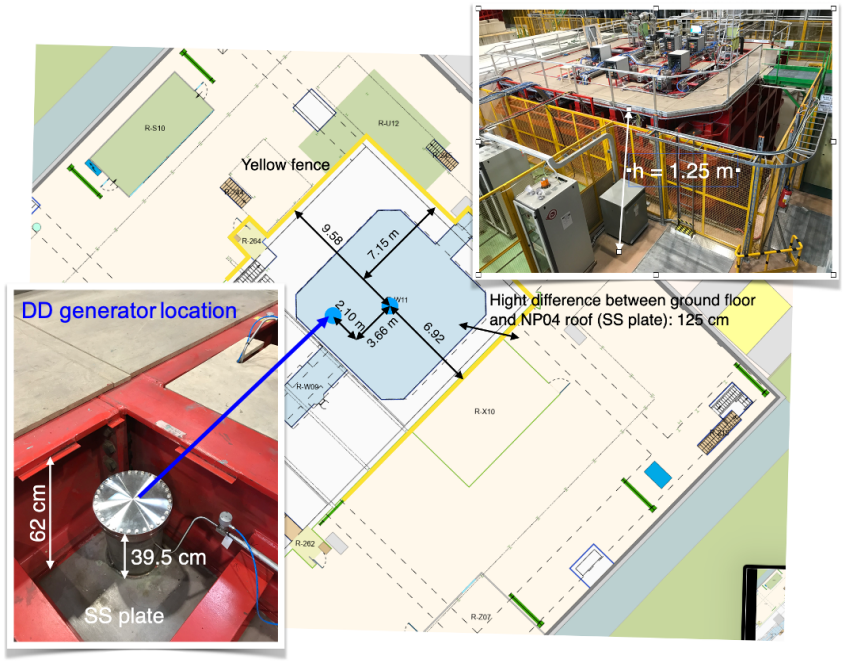
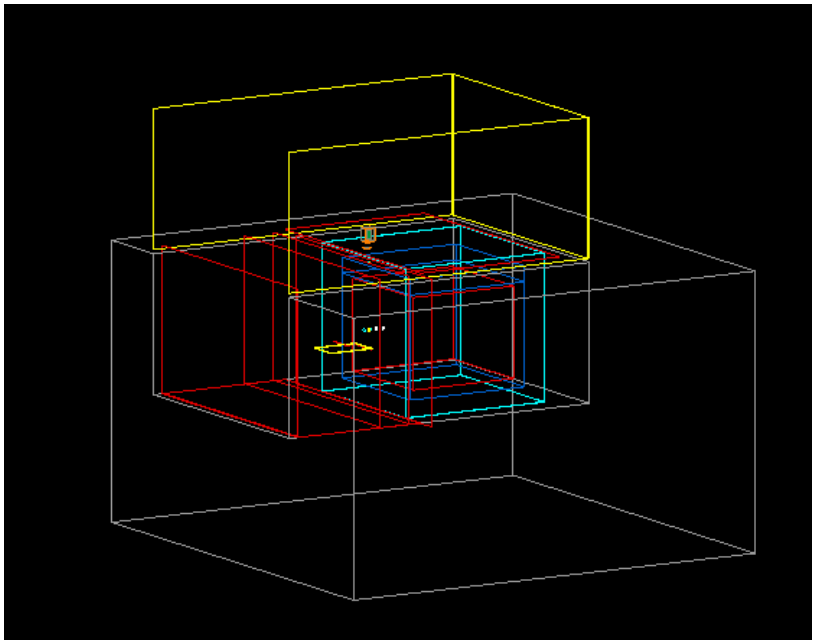
DDG Test at ProtoDUNE-SP

- We took DD neutron generator data at the ProtoDUNE-SP detector from 07/09/20 to 07/20/20.
- The Goal was to test the neutron transport model in Geant4. We gained experience in DD generator operation and shield.
- Many thanks to Sowjanya (LANL) for providing the DD generator. We also thank Filippo (CERN), Francesco (CERN), Stephen (Fermilab), Mattia (LANL) for helping with the DDG installation and operation at CERN.

DDG location

- Beam plug location was considered but not chosen due to time limit
  - Neutron capture yield inside the active TPC is 0.37% (confirmed by both LArsoft and Geant4 simulations)
- Roof feedthrough location was chosen for the test (practical but not ideal)
  - Corner feedthrough: neutron capture yield inside the active TPC is 0.11% (Geant4)





Experimental Setup

PNS Grp: UCDavis, LANL + CERN

Problem: There is no gamma shield due to technical limitations. The neutron capture signals close to the top of the TPC suffer from contaminations from 2.2 MeV gammas

Neutron Source Run Types

- Random trigger mode:
  - DDG ON, E=650 V/cm, 2 Hz random trigger
  - DDG OFF, E=650 V/cm, 2 Hz random trigger
  - DDG ON, E=350 V/cm, 5 Hz random trigger
  - DDG OFF, E=350 V/cm, 5 Hz random trigger

- Pulsed trigger mode:
  - DDG ON, E=350 V/cm, 5% duty cycle, ~175 μs pulse width, ~4 Hz
  - DDG ON, E=0 V/cm, 5% duty cycle, ~175 μs pulse width, ~4 Hz

Current Analyzers

- **UC Davis:** Jingbo Wang, Luca Luca Pagani, Yash Bezawada, Junying Huang, Robert Svoboda
- **LANL:** Mattia Fani, Sowjanya Gollapinni
- **CERN:** Francesco Pietropaolo, others?
- **University of Pittsburgh:** Logan Rice
- **LIP:** Sofia Andringa
- **Colorado State University:** Alex Flesher, Mike Mooney

Analysis Tasks

- **Raw signal processing:**
  - Noise filtering, ROI finding
- **Cosmic veto:**
  - Remove track related hits.
- **3d position reconstruction:**
  - Position of isolated space points to test neutron spread model
- **Neutron capture clustering:**
  - Associate all gammas from a neutron capture
- **Energy analysis:**
  - Low energy specific reconstruction: ADC to charge, electron lifetime correction, recombination correction.

Simulation Tasks

- **Compare neutron transport simulation with data**
  - Produce a distribution of energy deposition
- **Detector response to low-energy gammas**
  - Model the response to167 keV, 1.2 MeV and 4.7 MeV gammas
  - Test Noise modeling/filtering, study threshold effect
  - Study electron lifetime and recombination correction
- **Background simulation**
  - 39-Ar and cosmic rays (chance of seeing 39-Ar decay within the neutron capture event is 18%)
- **Clustering**
  - What's the best clustering radius? How much background is clustered?
  - 2D or 3D clustering? Which performs better?
- **Photodetector response to neutrons**
  - Precise t_0 determination. Is it possible?

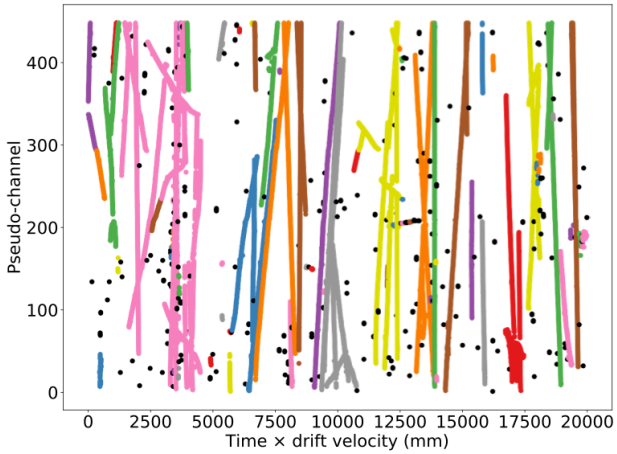
Analysis Timeline

10-Aug	17-Aug	24-Aug	31-Aug	7-Sep	14-Sep	21-Sep	Analyzer
Raw signal Processing							Junying Huang
Cosmic veto							Yash Bezawada, Alex Flesher
	3D reconstruction of isolated space points						Mattia Fani?
		Run batch reconstruction					Jingbo Wang
	Neutron capture clustering						Luca Pagani, Jingbo Wang
			Energy analysis				Jingbo Wang, Sofia Andringa?
						Report in DUNE collaboration meeting	Luca Pagani
LArsoft simulation to support data analysis							All analyzers. Please sign up

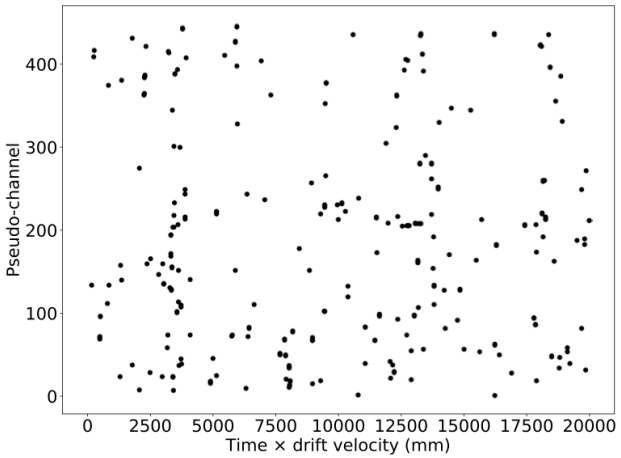
- Many of the anlyzers are new to LArsoft and ProtoDUNE-SP data analysis. We will work closely with the ProtoDUNE analysis group and the Calibration working group.
- The goal of the analysis is to prepare the first report to the next DUNE collaboration meeting in late September.
- We will reach the analyzers in the following days. Please let us know which part of the analysis you are interested in.

ProtoDUNE neutron source hits

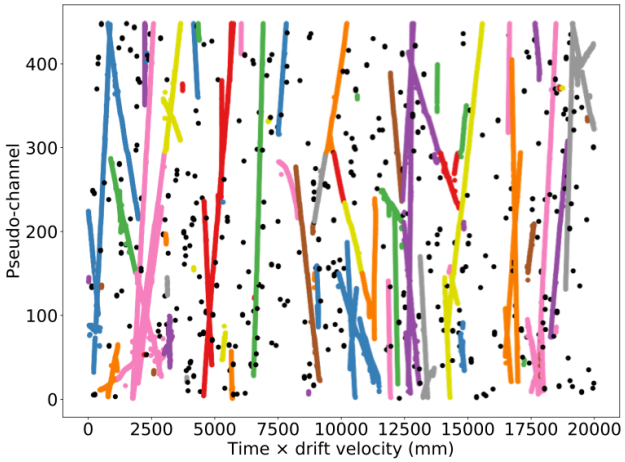
DBSCAN example. Neutron source off



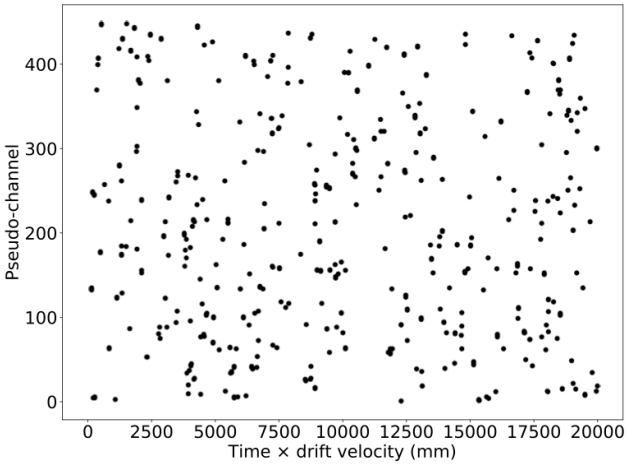
DBSCAN example. Neutron source off



DBSCAN example 5. Neutron source on



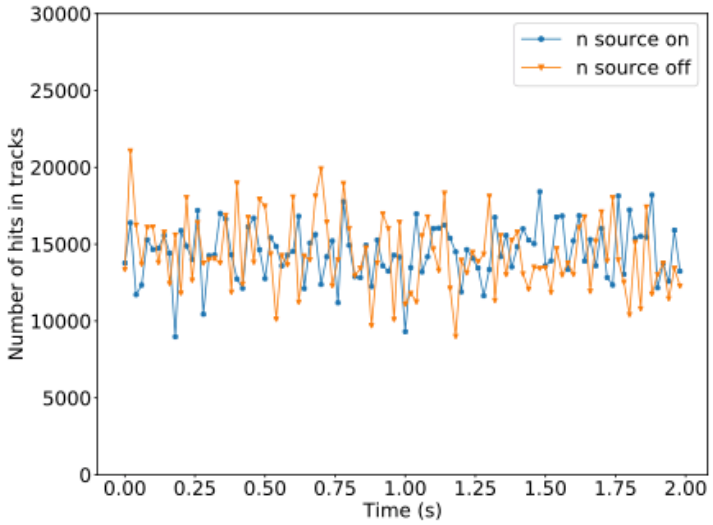
DBSCAN example 5. Neutron source on

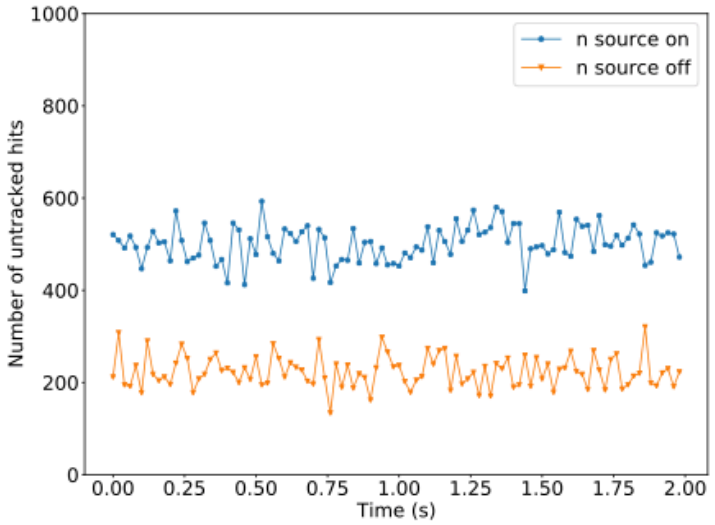


Philip Rodrigues: http://www-pnp.physics.ox.ac.uk/~rodrigues/protodune-neutron-source-2020-07-14.pdf

ProtoDUNE neutron source hits

Clustered and unclustered hit rates



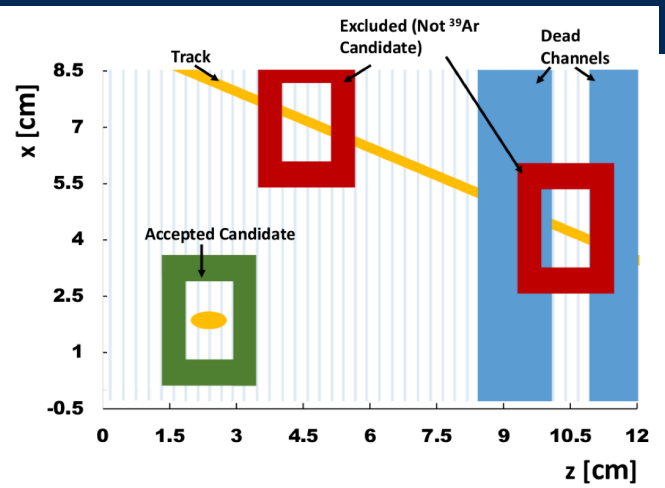


- Left: Number of hits clustered by DBSCAN (ie, tracked) in each 20ms window *vs* time
- Right: Number of unclustered hits (ie, neutron/EM candidates) in each 20ms window *vs* time
- (Just ran on 100 20ms windows to save time/memory)
- Tracked hits don't change with neutron source on. Untracked hits increase by about a factor of 2
- Clear evidence of neutron-like hits when source is on

Philip Rodrigues: http://www-pnp.physics.ox.ac.uk/~rodrigues/protodune-neutron-source-2020-07-14.pdf

Track Veto Update

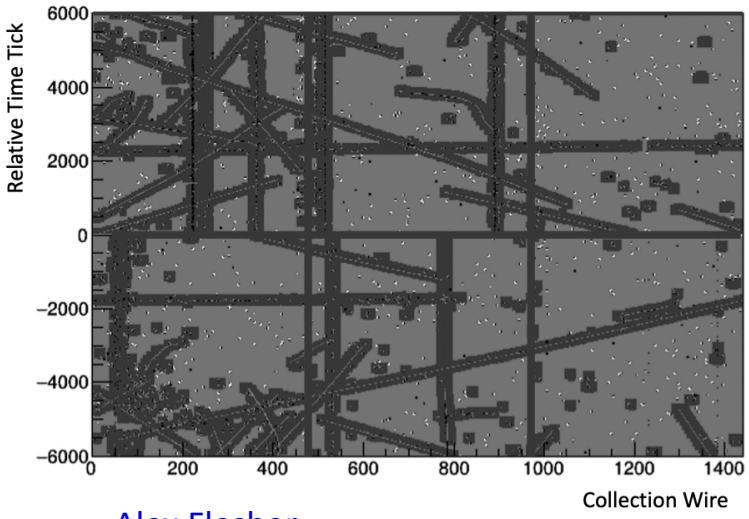
- Alex performed a track veto analysis for the ProtoDUNE-SP neutron data using similar method as that in MicroBooNE



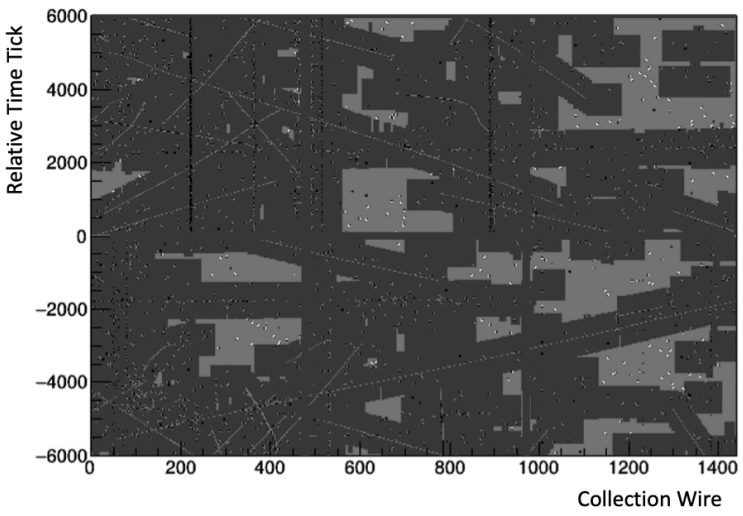
See MicroBooNE Public Note 1050

equivalent to the veto size used for MicroBooNE

24 Wires x 144 Time Ticks



80 Wires x 480 Time Ticks

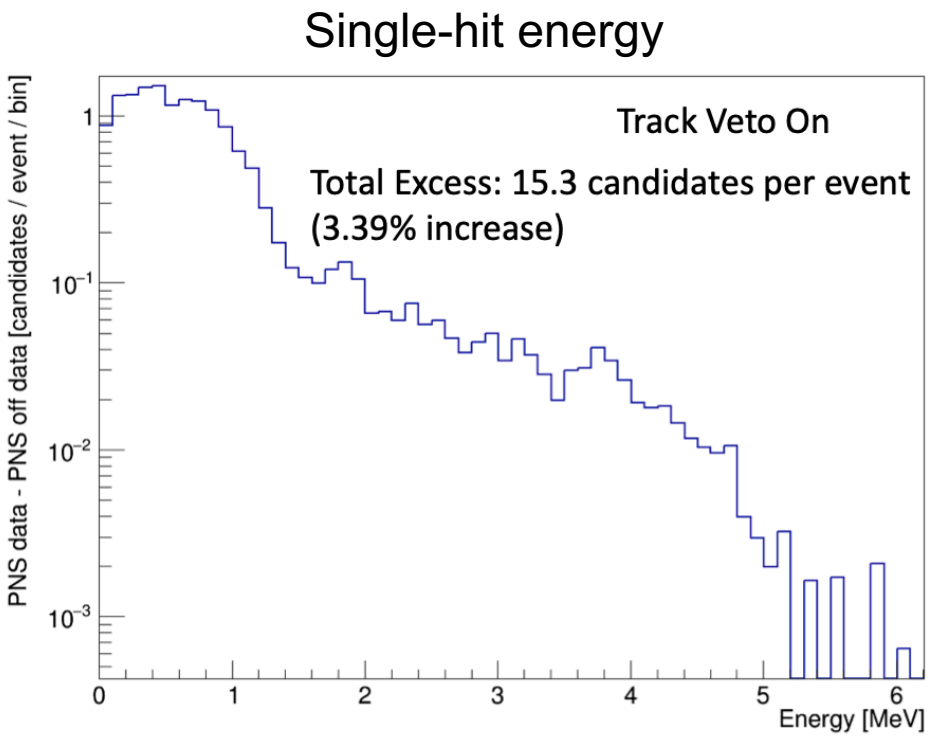


Alex Flesher, https://indico.fnal.gov/event/44544/contributions/192106/attachments/131894/161713/DUNE_CalibWG_Update_aflesher.pdf

Energy of point-like hits

PNS Studies:

- ^{39}Ar analysis took a small excursion into studying Neutron generator data
  - Finding out if Track Veto would help this effort
- 11632 is PNS on; 11639 is a nearby reference run with the PNS off
  - Only looking at the 4 APAs online in both runs
- Utilizes the same point-like reconstruction for ^{39}Ar, optimized for higher energy hits
  - Uses 5 wire x 61 time tick window instead of 3 wire x 41 ticks (for ^{39}Ar)



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Summary

- We successfully ran the DD neutron generator before the ProtoDUNE-SP detector shutdown and took TPC data.
- We have started analyzing the data, aiming at a talk in the September DUNE meeting.
- We will have a PNS working group meeting on Wednesday next week, and we expect to see updates from analyzers.