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DUNE
DEEP UNDERGROUND
NEUTRINO EXPERIMENT

ProtoDUNE-SP DD Generator Test: Analysis and Simulation

CALCI Consortium
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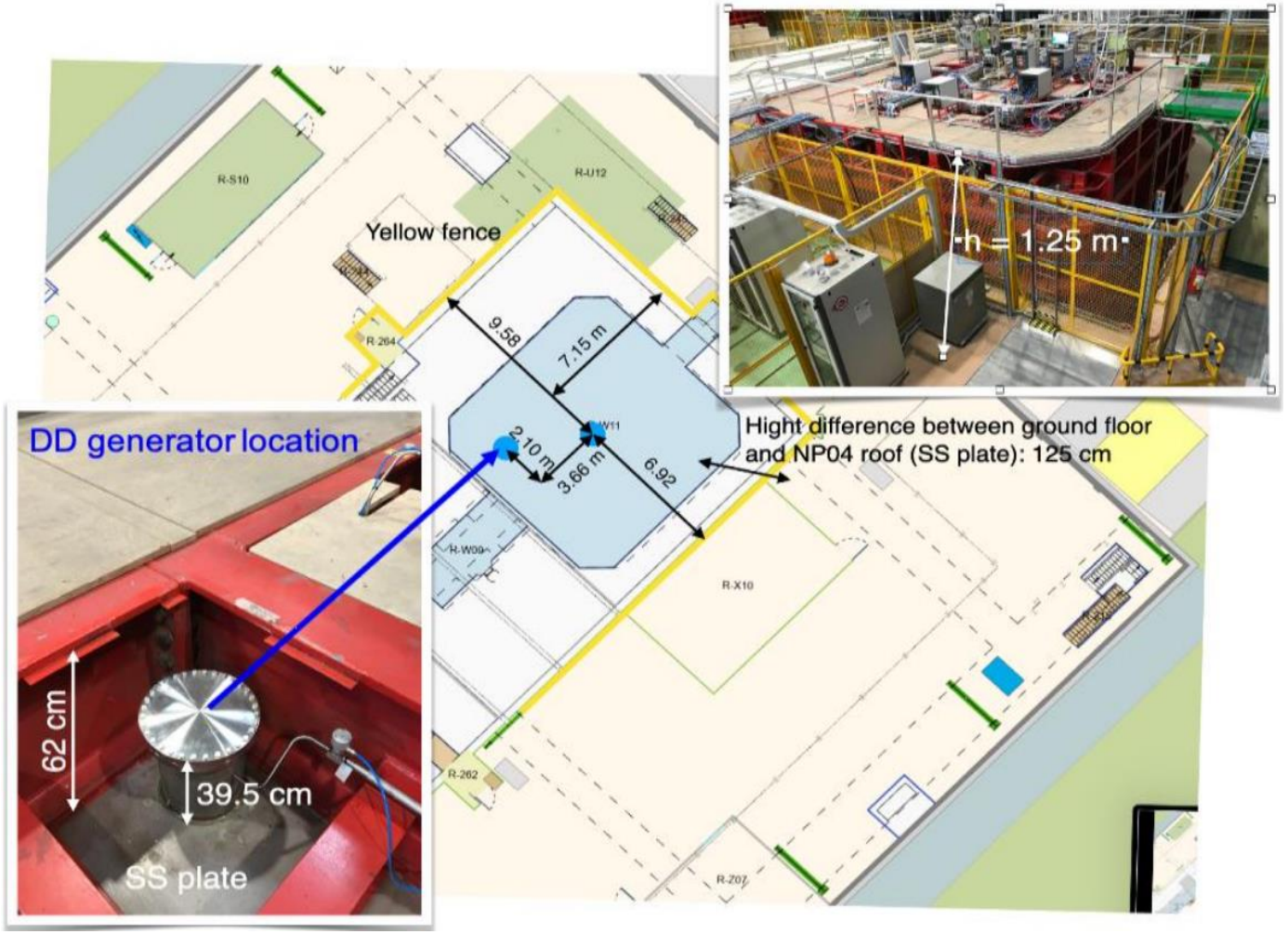
Outline

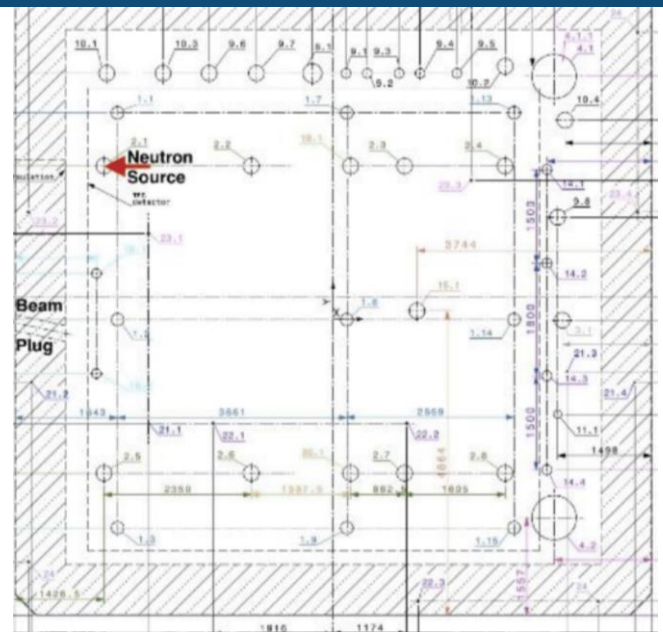
- Motivation
- DDG Test
- Reconstructing Raw Data
- Cosmic Removal
- 1D Spacepoint Distributions
- Simulation Update
- Summary

Motivation For DDG Analysis

- Understanding the neutron spread in ProtoDUNE-SP
- Remove cosmic events from the DDG run
- Associate all gammas from a neutron capture
- 3d space point reconstruction to test the neutron transport model
- Energy reconstruction of the neutron capture events in the DDG run

DDG Test - Setup





DD Generator is deployed at a roof feedthrough near APA 5

(From Mattia's talk for DD generator operation, Collaboration Meeting Sep 2020)

DDG Test – Data Taking

- Data taking was done over 10 days with different trigger modes and neutron intensities
- Random Trigger Mode:
  - DDG Off: E = 650 V/cm; 2 Hz Trigger Frequency
  - DDG Off: E = 350 V/cm; 5 Hz Trigger Frequency
  - DDG On: E = 650 V/cm; 2 Hz Trigger Frequency
  - DDG On: E = 350 V/cm; 5 Hz Trigger Frequency
- Pulsed Trigger Mode (Only for DDG On):
  - E = 350 V/cm, 5% duty Cycle, ~175 µs pulse width, ~4 Hz
  - E = 0 V/cm, 5% duty Cycle, ~175 µs pulse width, ~4 Hz

(For more information refer to Mattia's talk on DD generator operation, Collaboration Meeting Sep 2020)

Reconstructing Raw Data

- We are using "protoDUNE_SP_keepup_decoder_reco.fcl" to reconstruct the raw data
- We are using the following Modules:
  - "hitpdune" for reconstructing hits
  - "reco3d" for extracting spacepoints

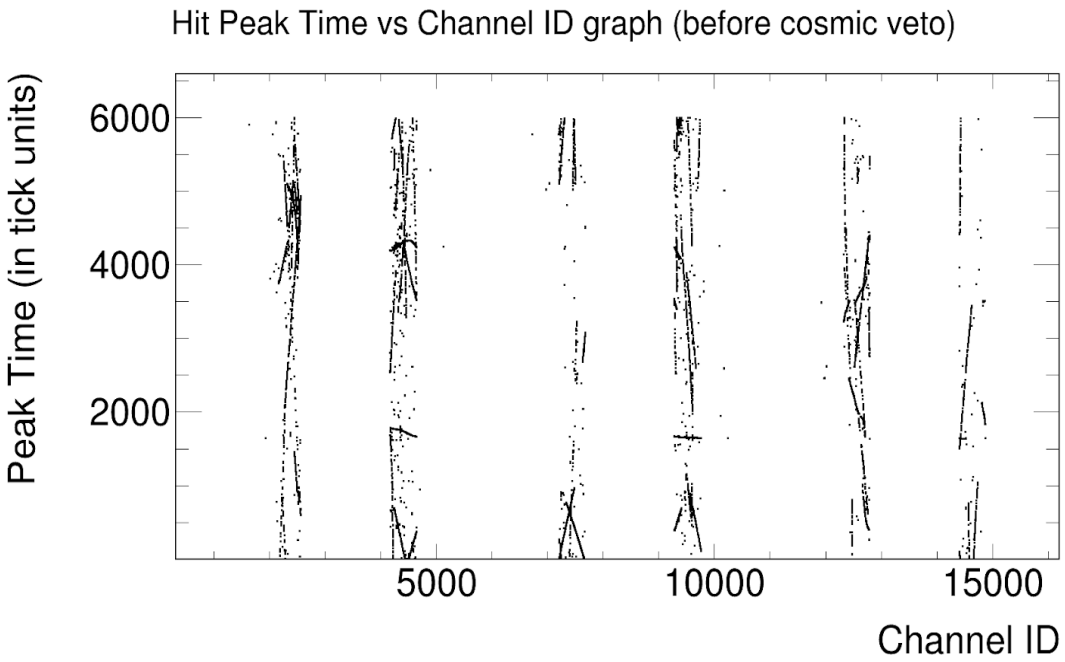


Fig. Hits from the collection plane for an event in the run 11668 (DDG-off). The empty spaces are induction planes.

APA-5 (14400-14900 Channel IDs) is the nearest to the DD Generator

CR Muon Removal is Crucial

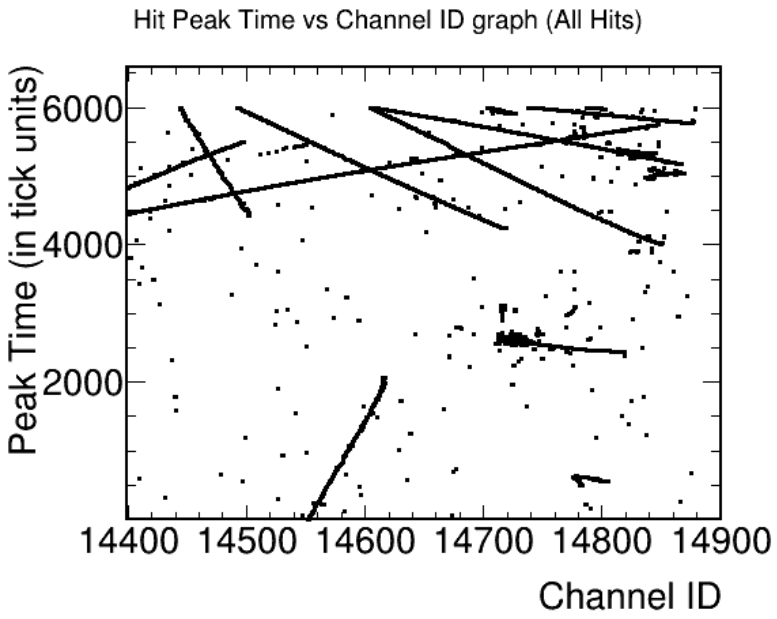
- Neutron Capture signals are overwhelmed by cosmic rays
- CR removal is important for associating all gammas from a neutron capture
- Cosmic background should be removed to test the neutron transport model

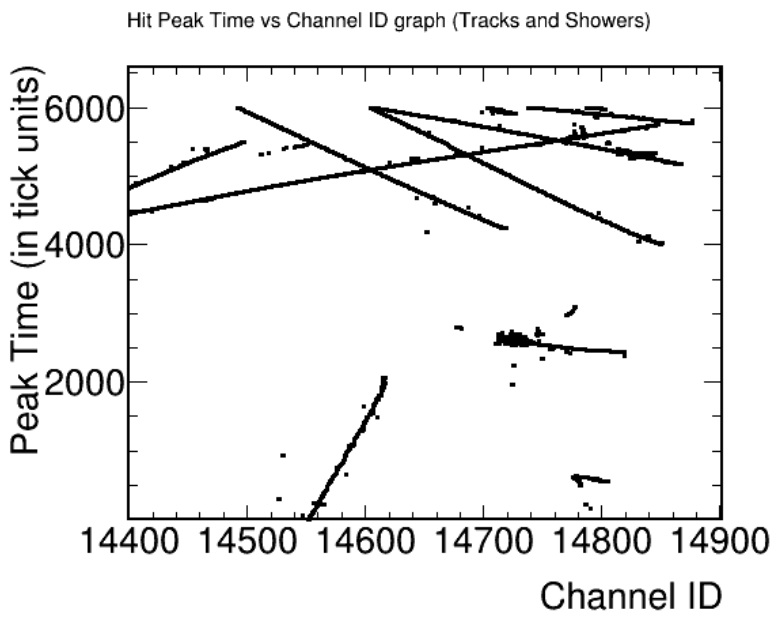
We are using 3 methods to remove cosmics:

- Using Pandora pattern recognition to tag track hits and shower hits
  - Using "pandoraTrack" and "pandoraShower" modules
- Using "trajcluster" module to tag Hit clusters
  - Using the standard protoDUNE trajcluster configuration
- Using "dbscan3d" module to tag Spacepoint clusters
  - Minimum points variable is set to 2
  - Epsilon (radius of the neighborhood) is set to 2cm

Cosmic Removal Using Pandora

Run Number: 11711 – Pulsed Trigger Run (E = 350 V/cm Field)





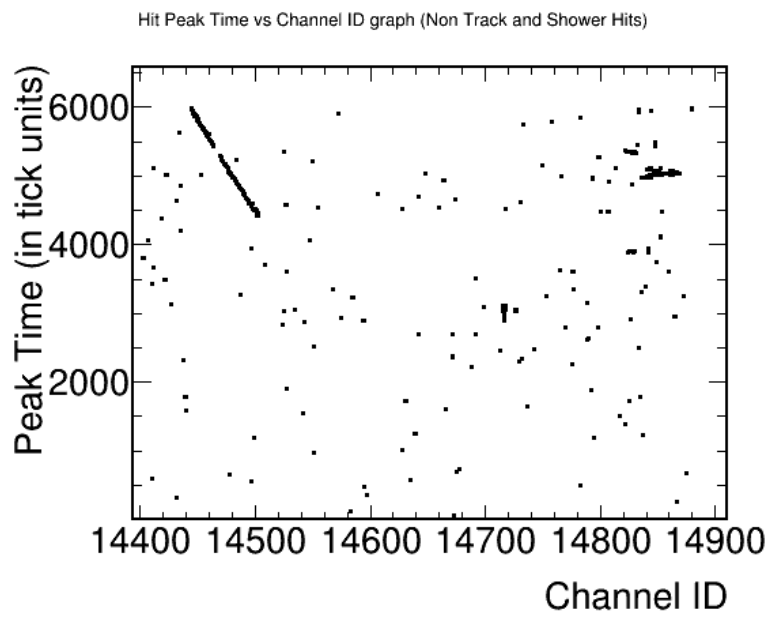


Fig. Peak Time vs Channel ID plots for one event. Hits tagged as Track or Shower are removed. It is not perfect, but it does a good job at removing cosmics.

Cosmic Removal – Hits near Tracks

- We want to remove/tag hits which are within 20cm from a track/shower hit
- Wire Pitch is 4.7mm; This turns into ± 42 Channel ID
- Electron Drift Velocity is 0.16 cm/us and sampling rate is 2 MHz; This turns into ± 250 tick units in Peak Time

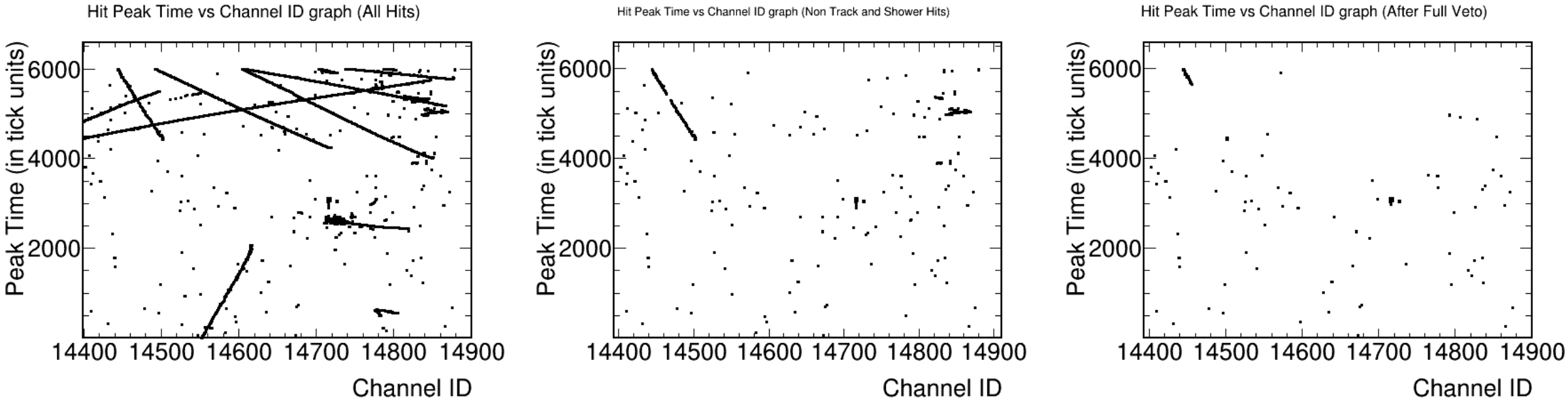


Fig. Peak Time vs Channel ID plots for one event. Hits tagged as Track or Shower are removed. Additionally, all hits within 20cm of a track/shower hit

Cosmic Removal Using Trajcluster

Run Number: 11711 – Pulsed Trigger Run (E = 350 V/cm Field)

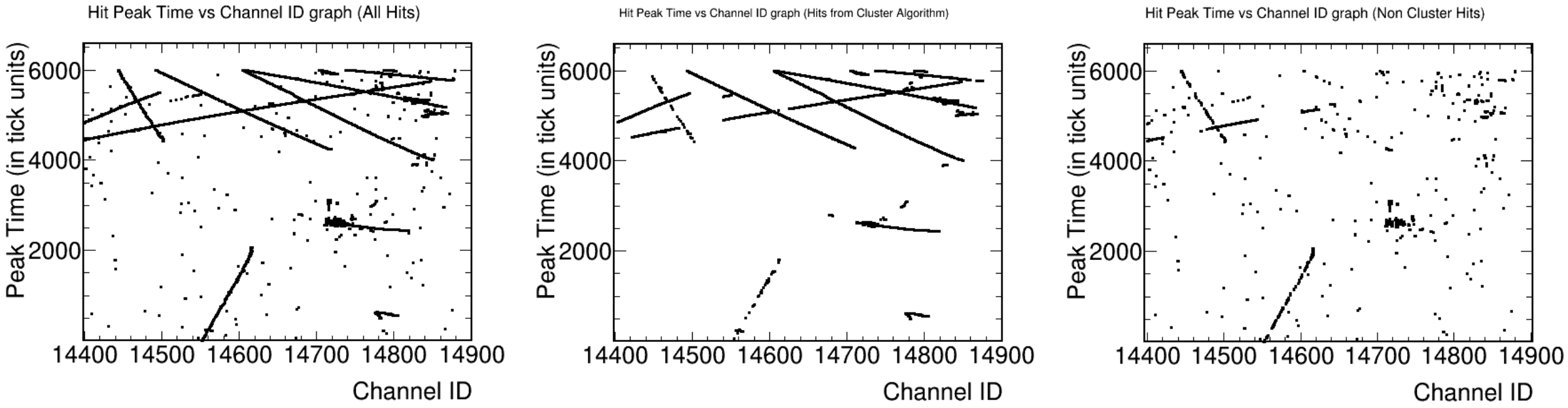
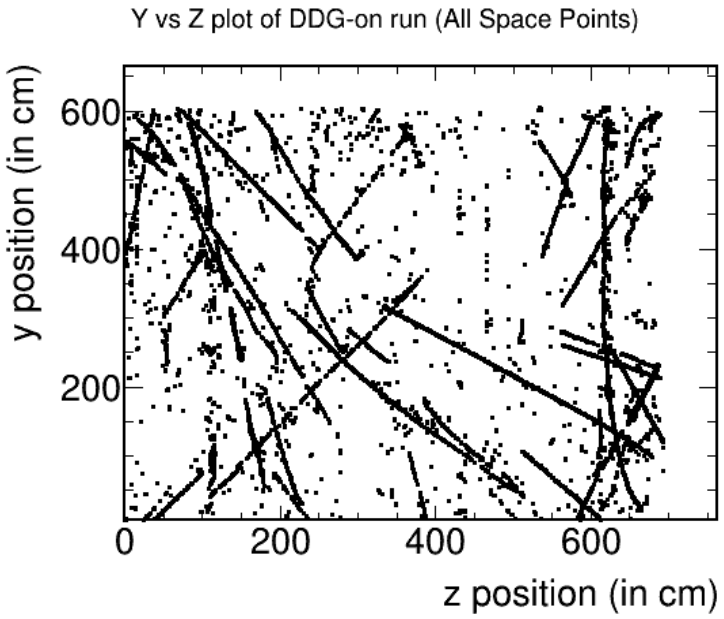


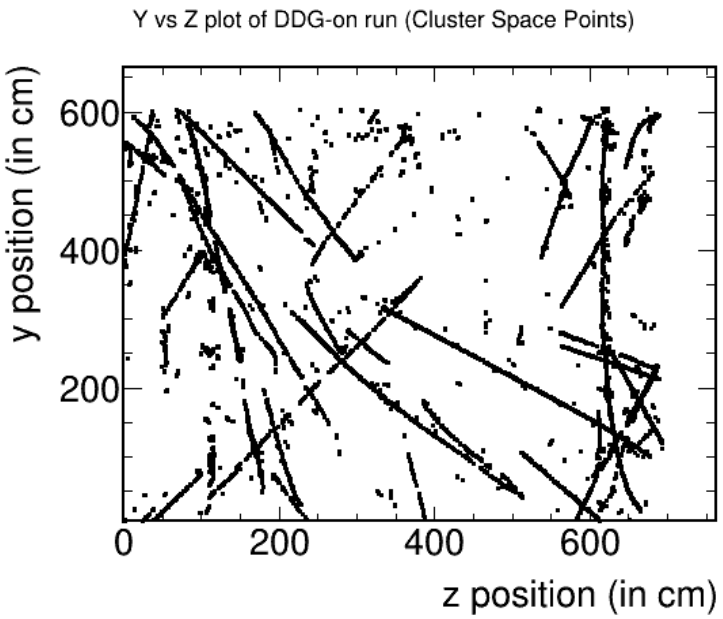
Fig. Peak Time vs Channel ID plot for one event. Hits tagged as clusters are removed. It performs worse than Pandora. But the trajcluster focus has been on precision reconstruction of low energy particles. So, this might not be the right way to remove cosmics.

Note: We are using the standard protoDUNE trajcluster configuration (../srcs/dunetpc/dune/ClusterFinderDUNE/clusterfinder_dune.fcl)

Cosmic Removal Using DBScan 3D

Run Number: 11711 – Pulsed Trigger Run (E = 350 V/cm Field)





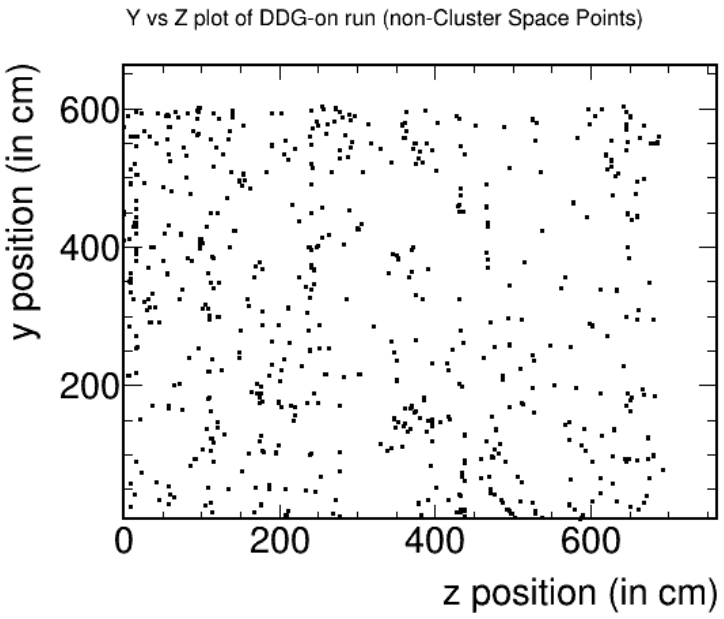
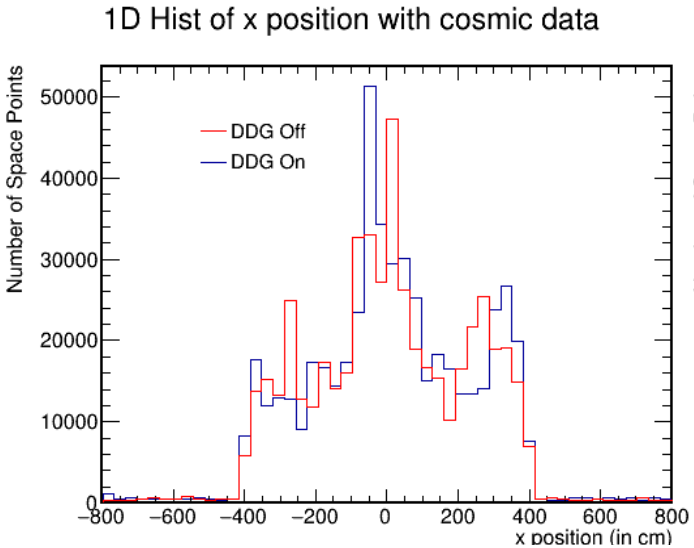
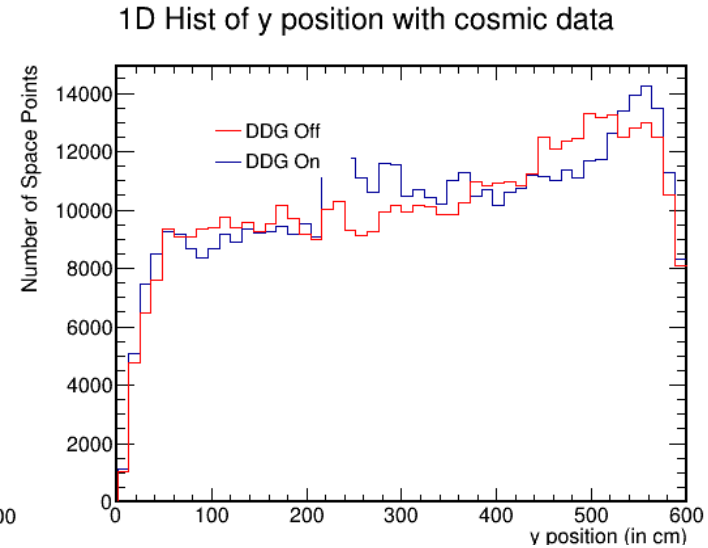
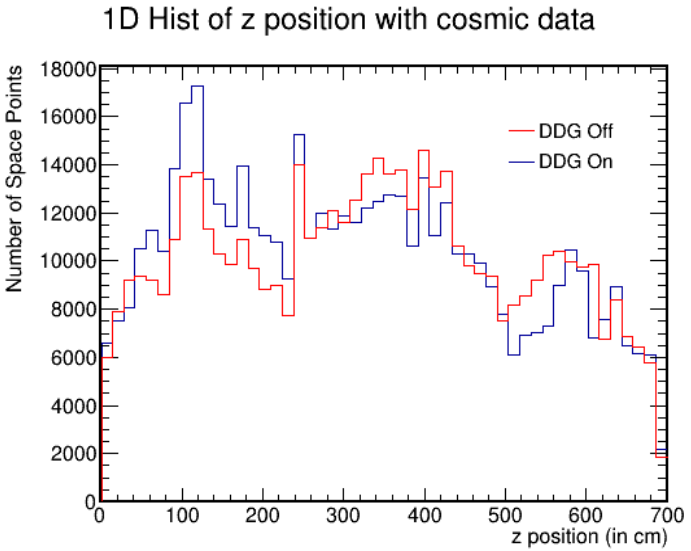


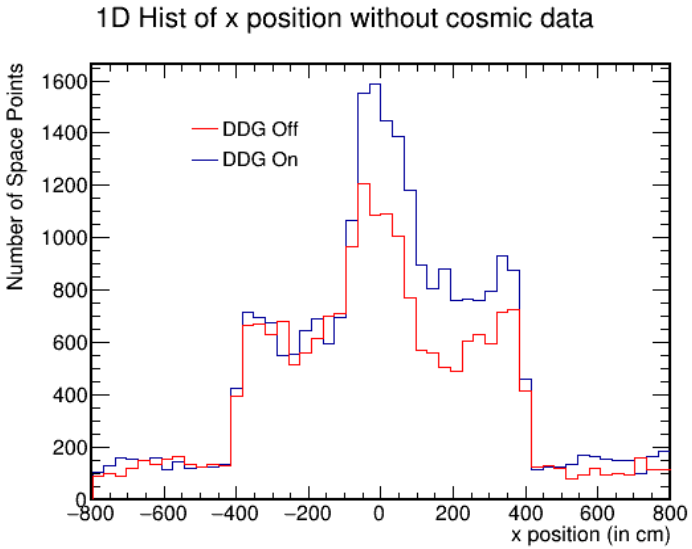
Fig. Y vs Z plot of spacepoints for one event. Hits tagged as clusters are removed. Clustering is performed on the reconstructed 3D spacepoints. Minimum points are set to 2 and epsilon is set to 2cm.

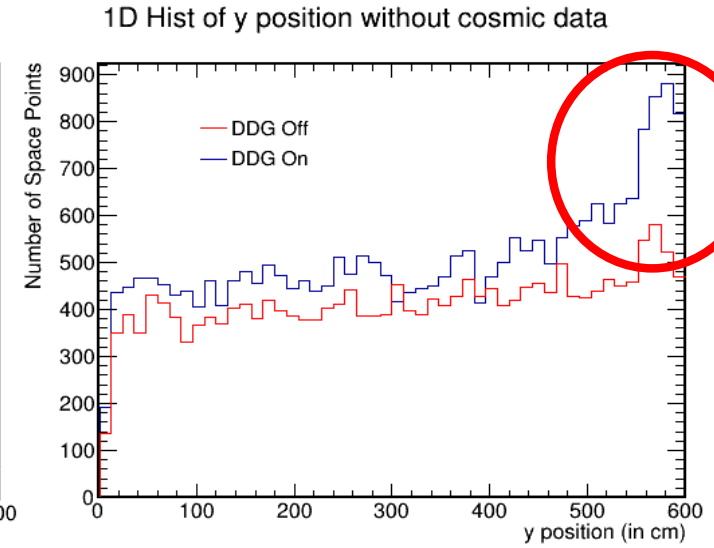
1D Spacepoint Distributions (DBScan)

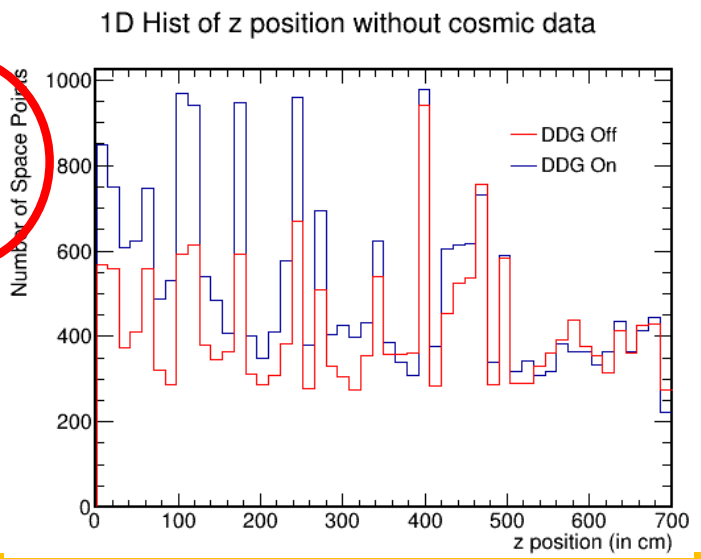








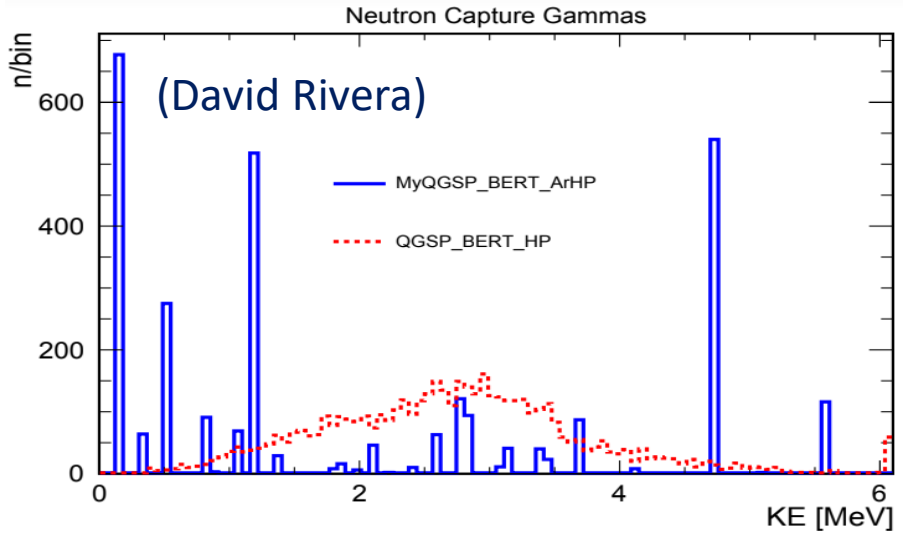




- We can see the excess in the y distribution due to closer proximity to the DDG
- Both on and off distributions have 27 events

New Gamma Generator in LArSoft

- The current Geant4 neutron capture simulation in LArSoft is wrong
- The current gamma energy distribution does not fit the NNDC data
- We are trying to implement a new gamma generator in LArSoft



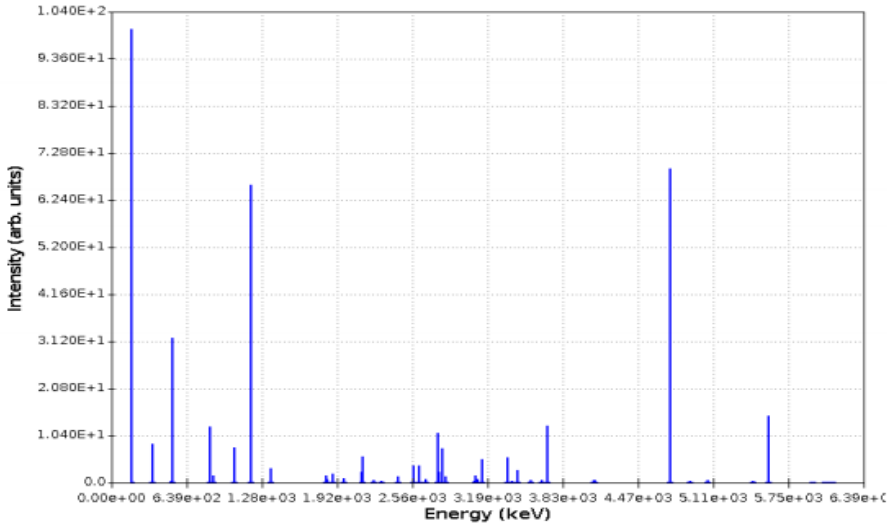


Fig. Simulated gamma energy distribution from neutron captures on the left plot; NNDC data on the right plot

(Work done by Jingbo Wang and Junying Huang)

Summary

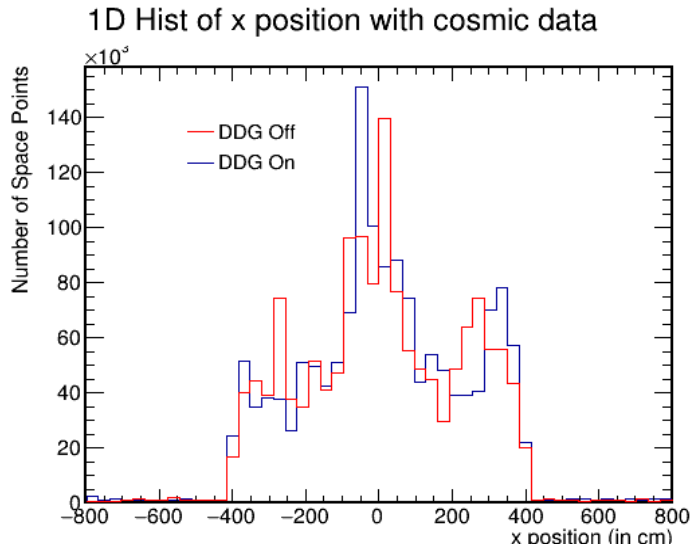
- Able to reconstruct raw datafiles and run the analysis
- Cosmic removal was tested with 3 different methods – Pandora and DBScan 3D perform better
- Can clearly see the excess spacepoints near the DDG in the y distribution
- Implementing a new gamma generator in LArSoft

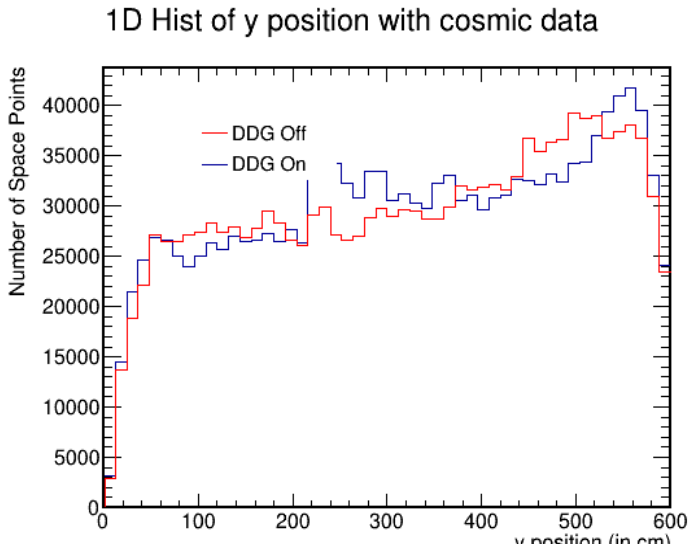
To Do/Underway:

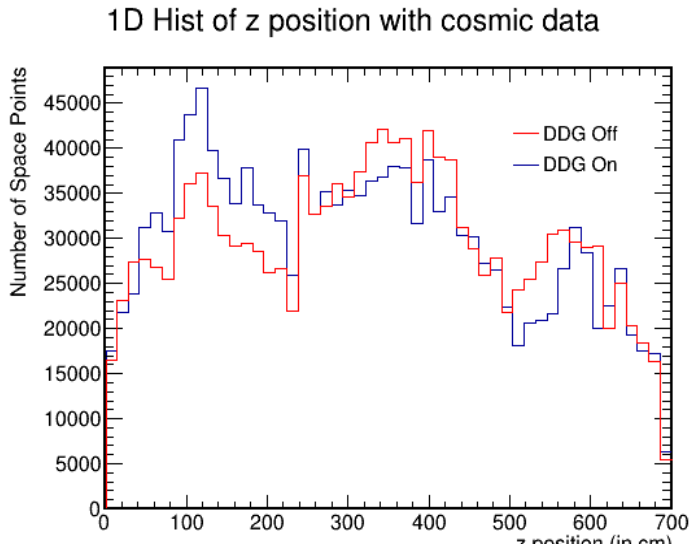
- Energy Reconstruction of the hits
- Comparing simulations and raw data

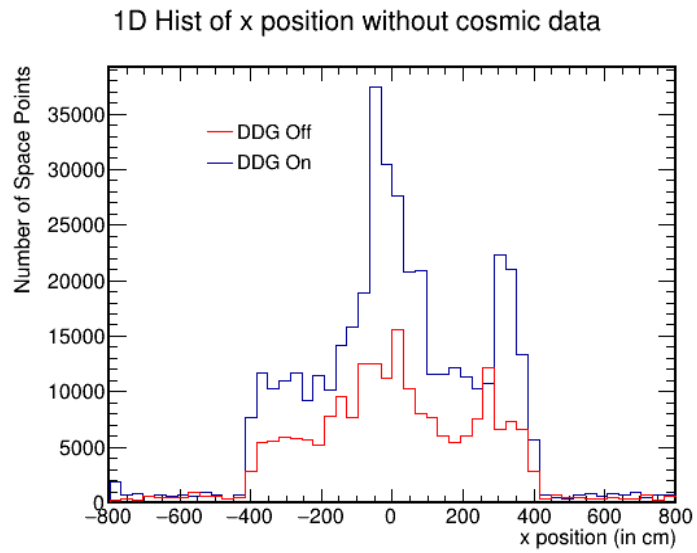
Backup Slides

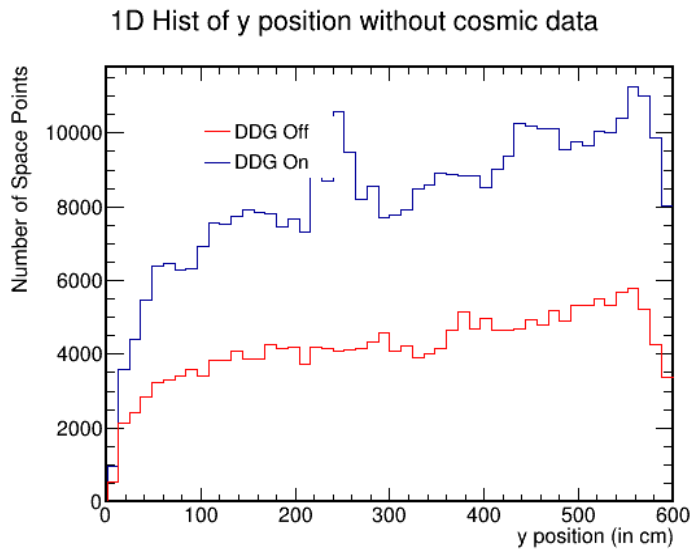
1D Spacepoint Distributions (Trajcluster)

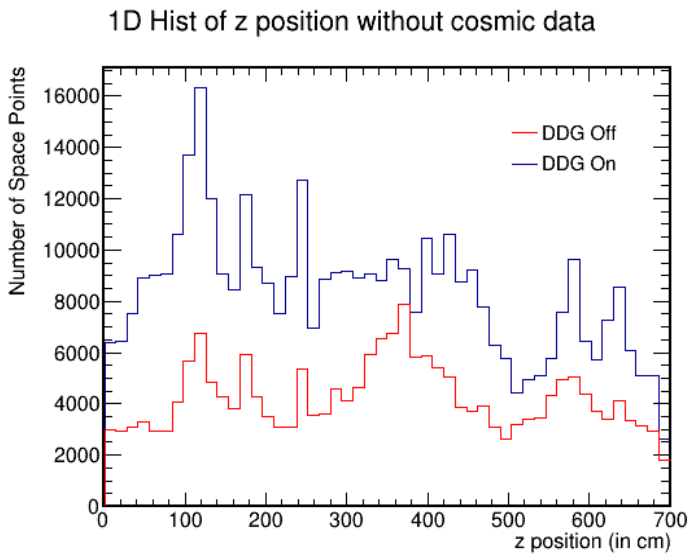




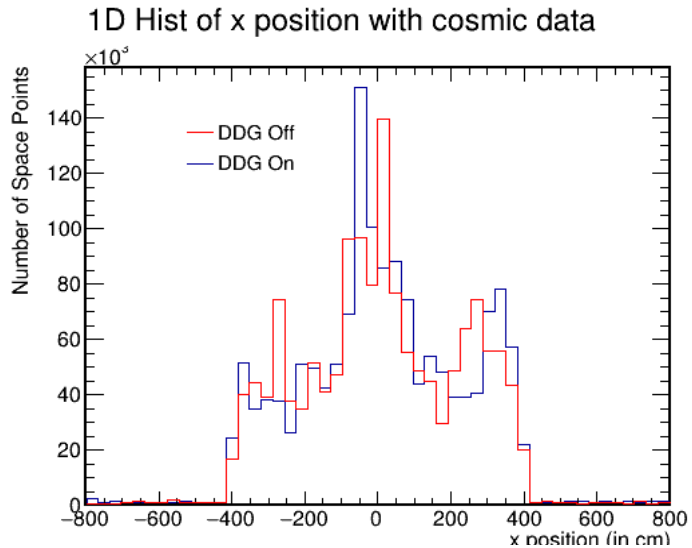


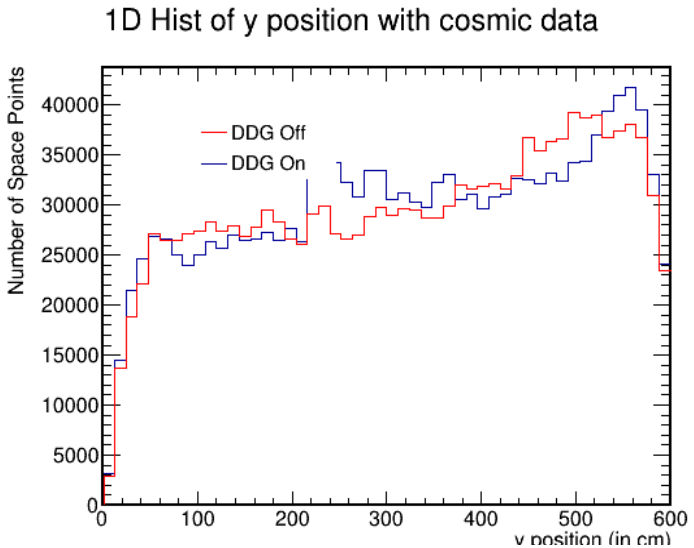


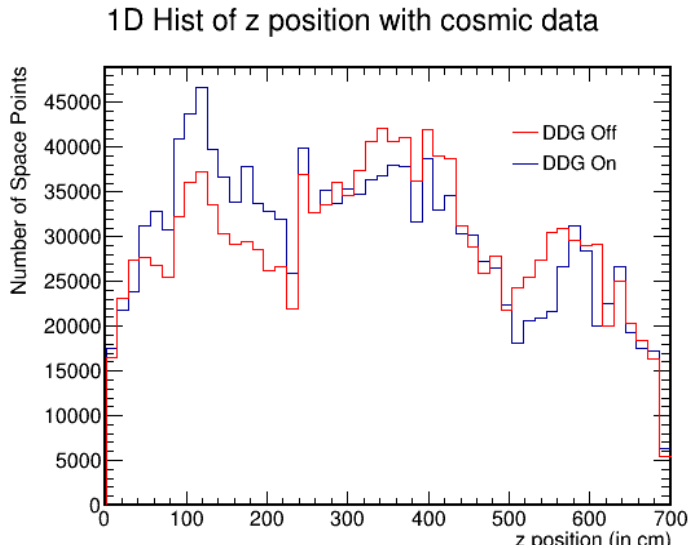


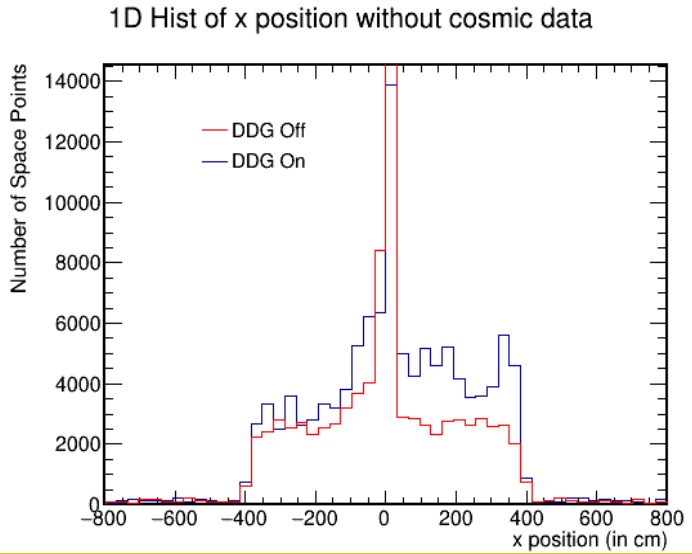


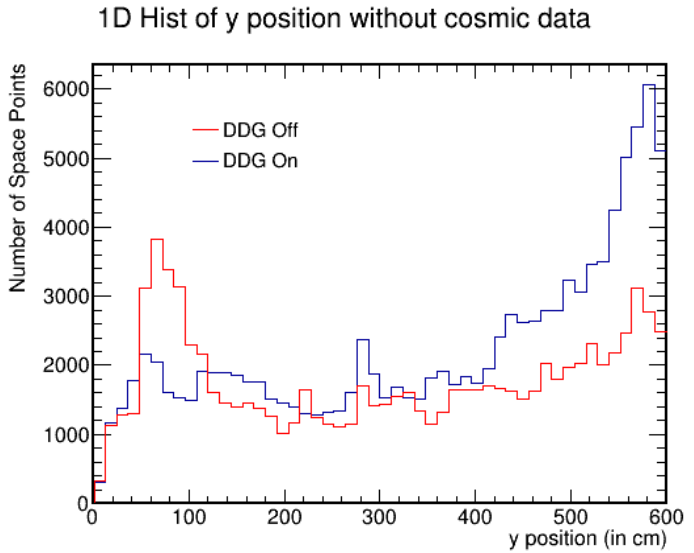
1D Spacepoint Distributions (Pandora)

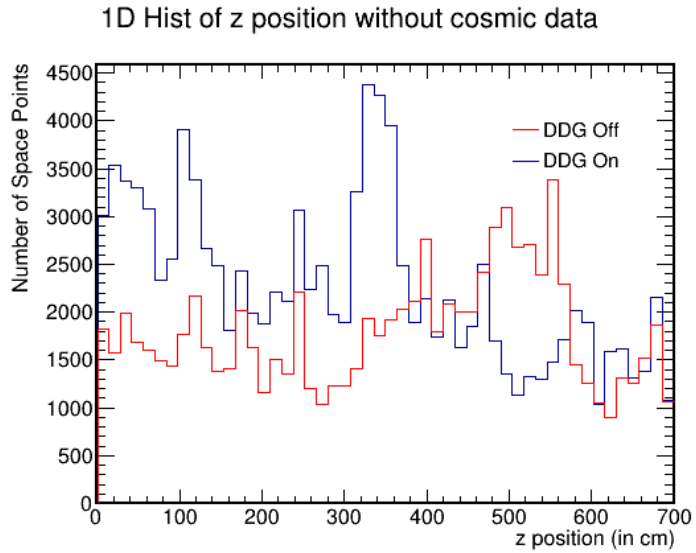






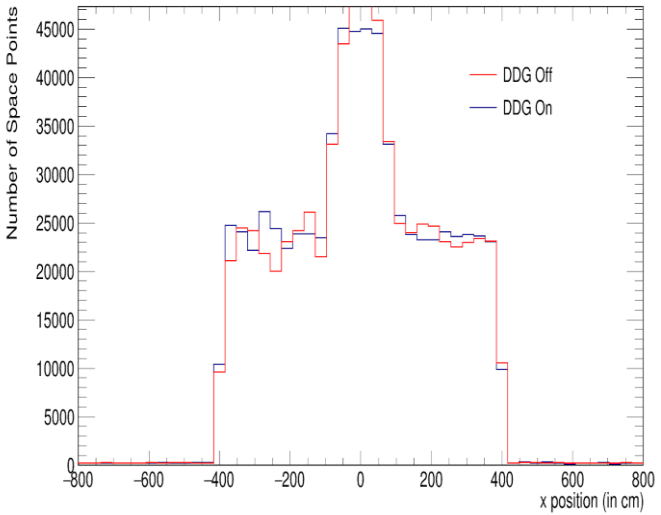




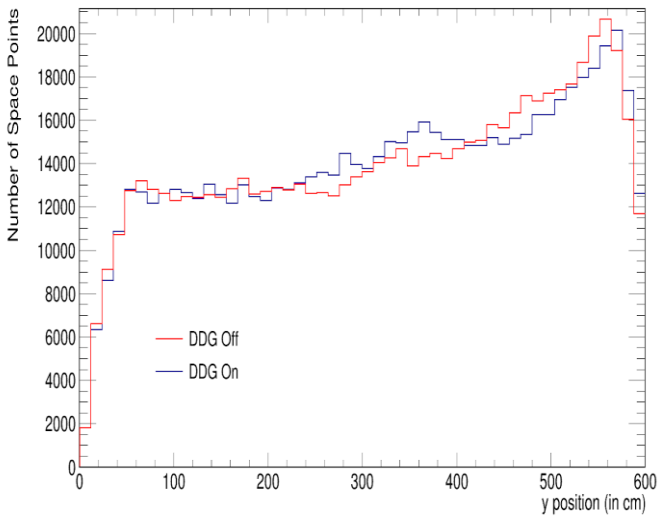


1D Space Point Distributions (DBScan)

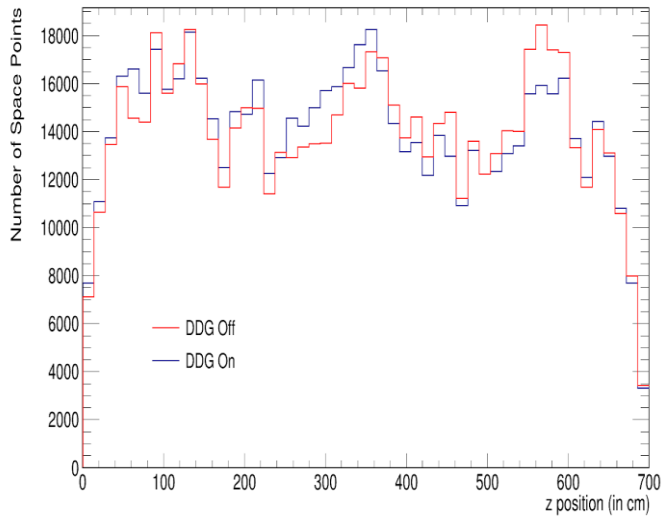
1D Hist of x position with cosmic data



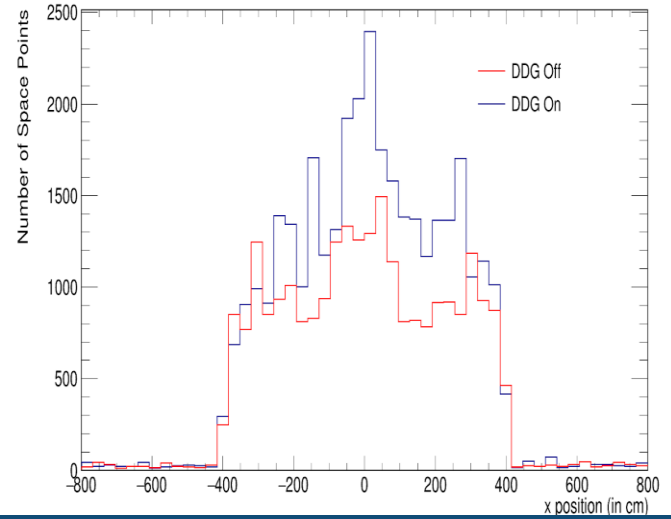
1D Hist of y position with cosmic data



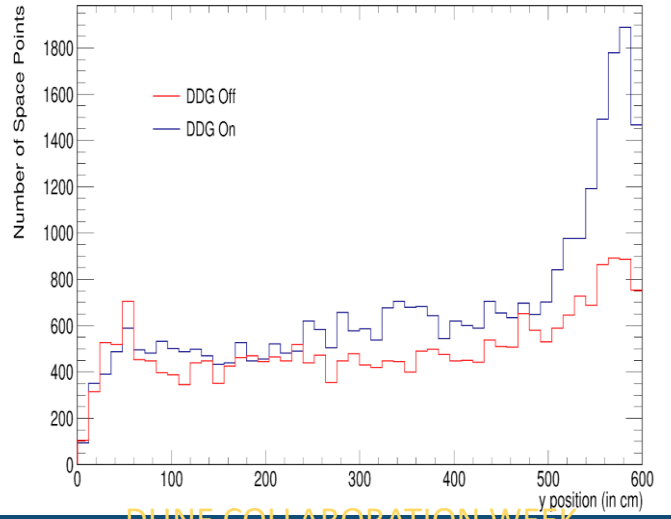
1D Hist of z position with cosmic data



1D Hist of x position without cosmic data



1D Hist of y position without cosmic data



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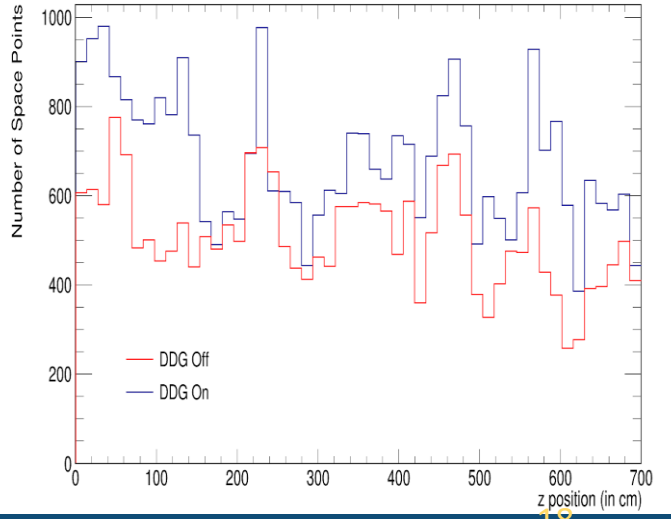
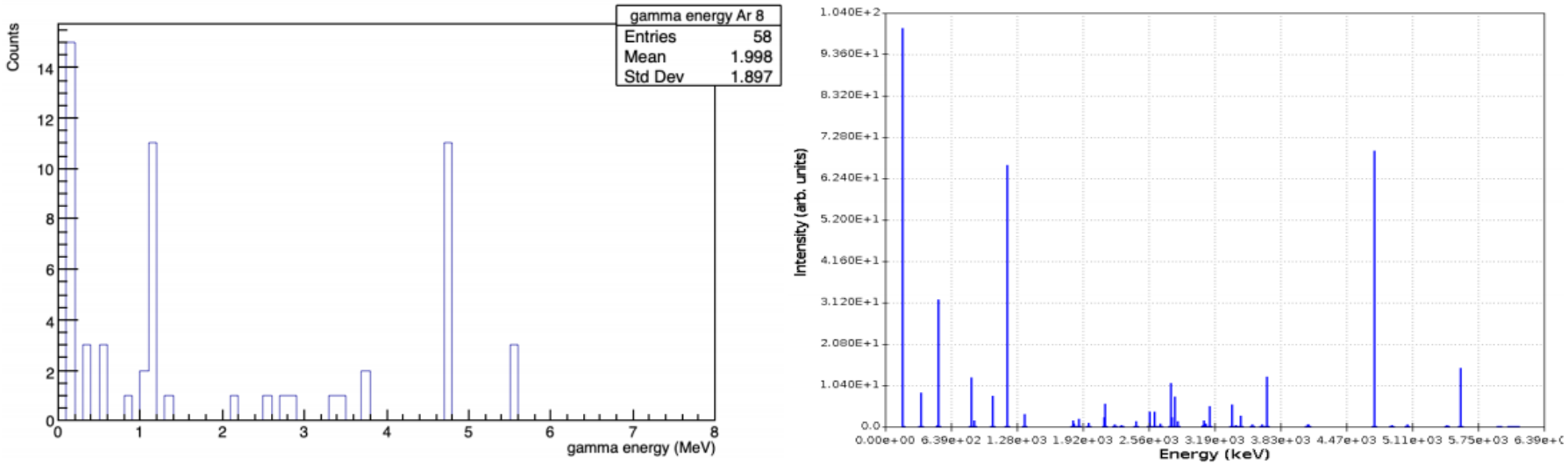


Simulation Update

- Able to run MC simulation with Ar-39 background, cosmic rays and neutrons
- The simulated gamma energy distribution from neutron captures matches the NNDC data
- Can run the analysis module on the simulated data



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