Pulsed Neutron Source ProtoDUNE-1 Analysis Update

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Data Collection and Reconstruction

- This analysis uses data from 10 days of running in 2020 during ProtoDUNE-1 using a deuteron-deuteron (DD) generator to produce E=2.5 MeV neutrons:

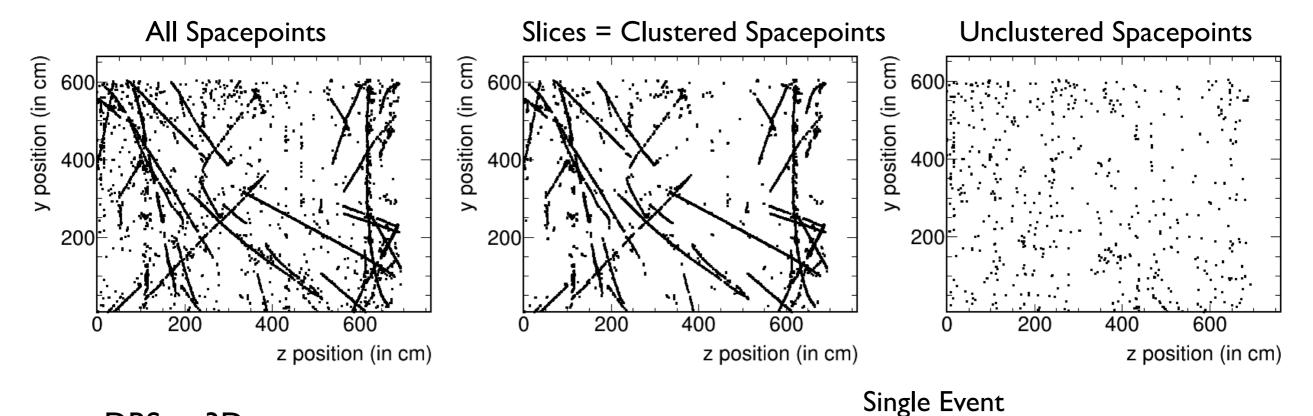$$D + D \rightarrow n + {}^{3}He$$

- Random Trigger Mode:

  - DDG Off: E = 650 V/cm; 2 Hz Trigger Frequency

  - DDG Off: E = 350 V/cm; 5 Hz Trigger Frequency (Analyzed Here)

  - DDG On: E = 650 V/cm; 2 Hz Trigger Frequency

  - DDG On: E = 350 V/cm; 5 Hz Trigger Frequency (Analyzed Here)

- 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

- Data Analysis includes 3 modules:

  - "hitpdune" for reconstructing hits

  - "reco3d" for extracting spacepoints

  - "dbscan3d" described on next slide

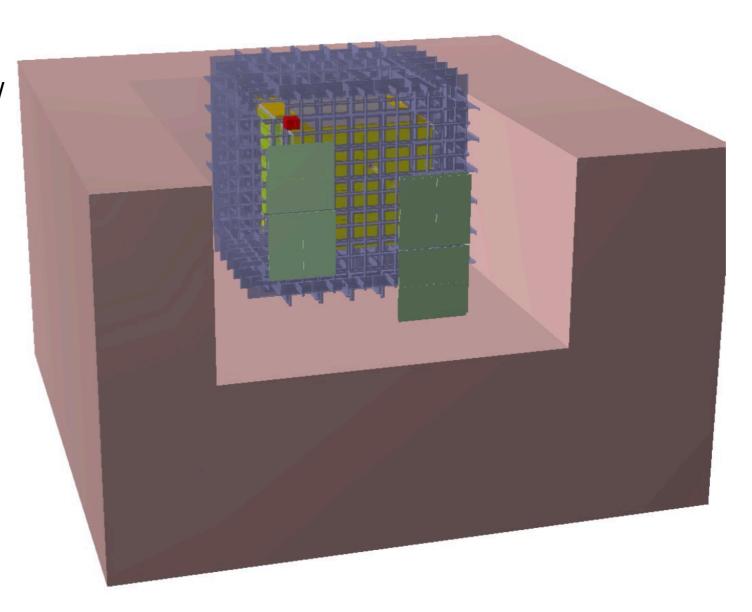LANL DD Generator

Spacepoint Clustering

- Clustering of spacepoints is performed by density-based spatial clustering of applications with noise in 3D (DBScan3D):

All Spacepoints   Slices = Clustered Spacepoints   Unclustered Spacepoints
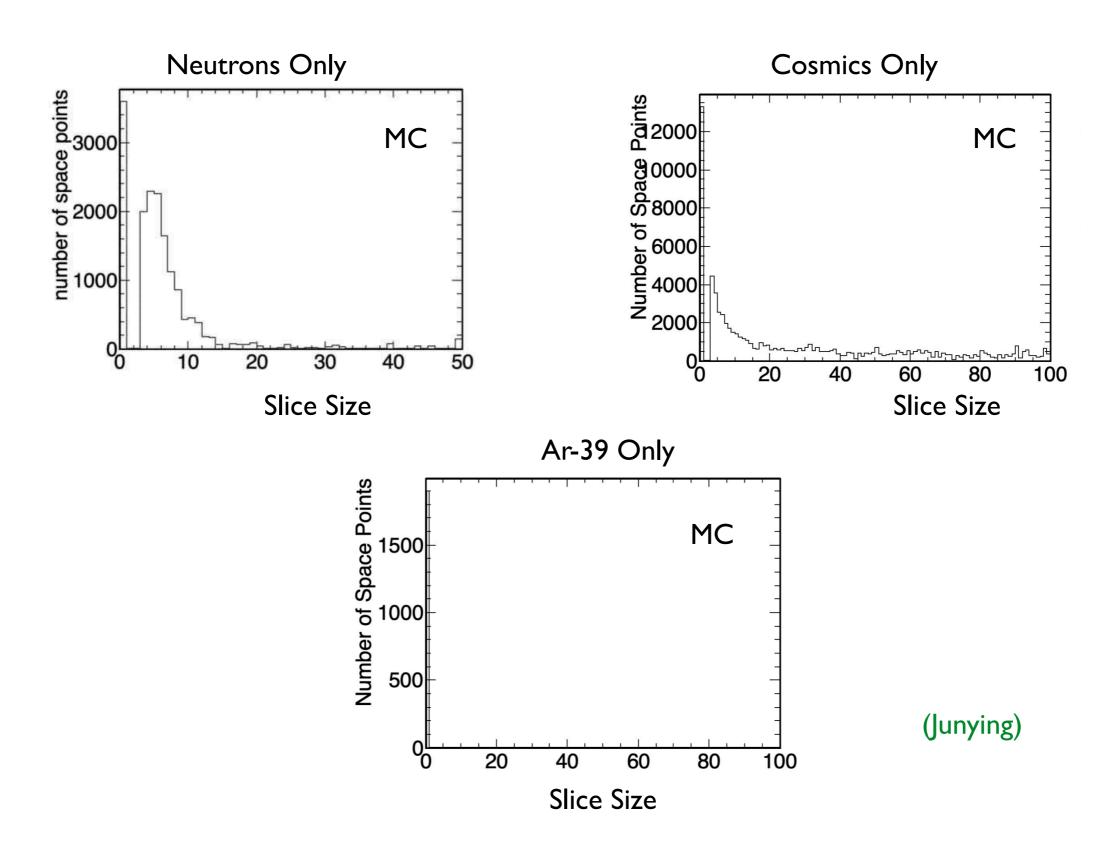
Single Event

- DBScan3D parameters:

  - Neighborhood radius (epsilon) 2 cm,

  - Minimum spacepoints per cluster 3.

  - Cosmic rays partially removed by a cut on slice size, described next.

- We further uses clusters of spacepoints (slices) as neutron candidates for further analysis.

Monte Carlo Simulation

- GEANT geometry modified to include DD shielding material.

- 1500 neutrons per event injected w/ textfile generator.

  - Isotropic with E=2.5 MeV

  - protodune_corsika_cmc for Cosmics

  - protodunesp_39ar for Ar39

- Updates to γ generation from neutron capture (new physics list available in LArSoft)
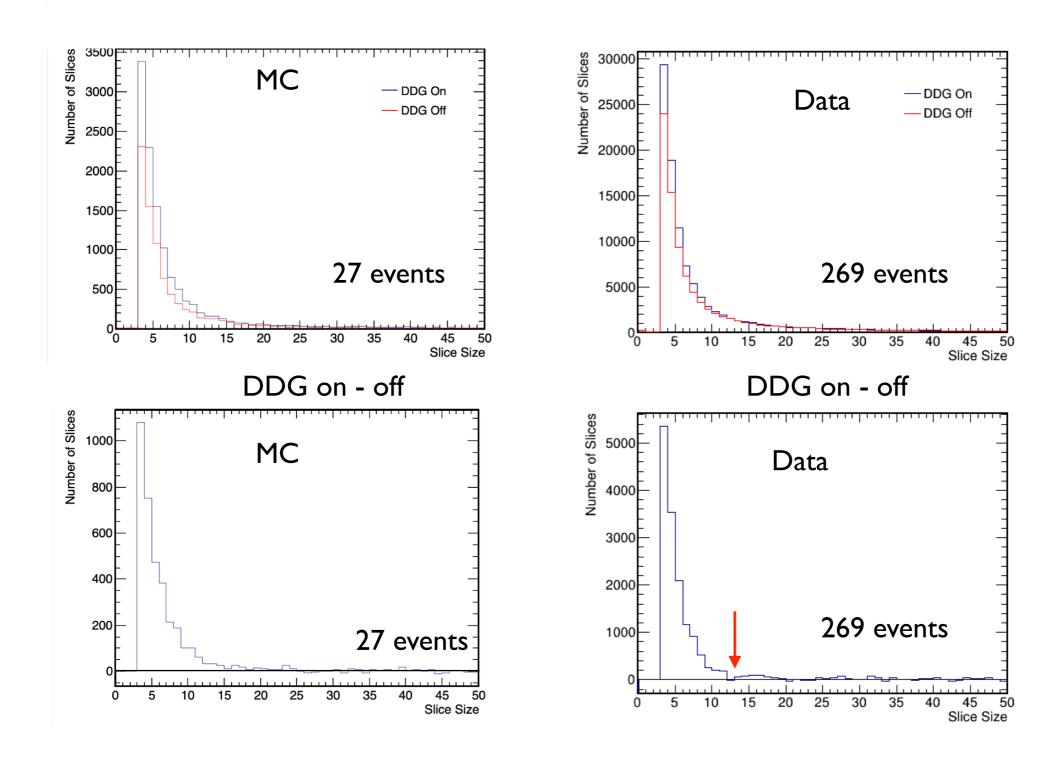
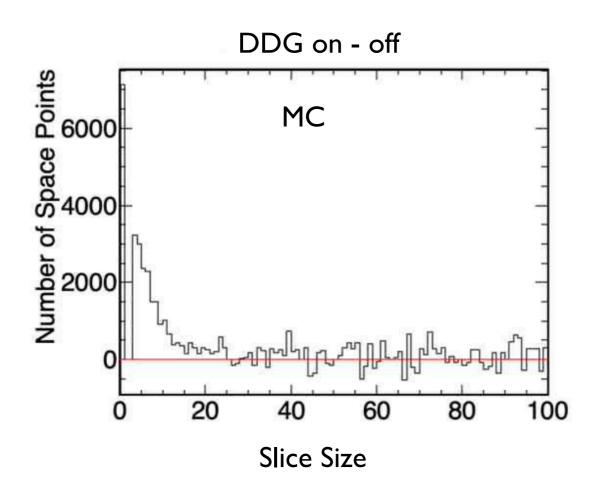- Same reconstruction chain as data.

Slice Size

Neutrons Only

Cosmics Only

Ar-39 Only

(Junying)

Simulated slice size for neutrons, cosmics, and Ar-39.
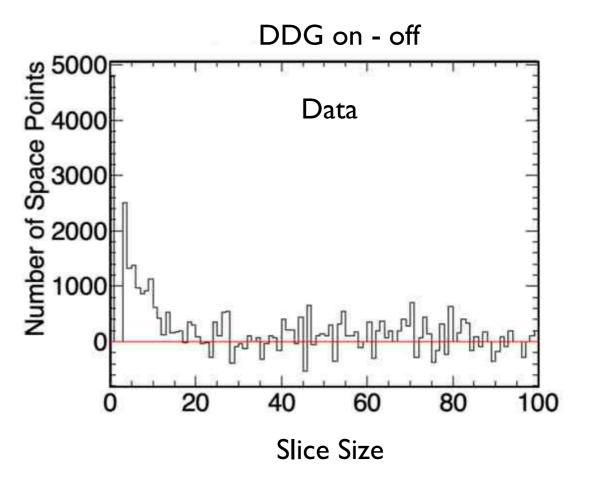
Cut on Slice Size

We cut at slice size <13 to remove (some) cosmics.
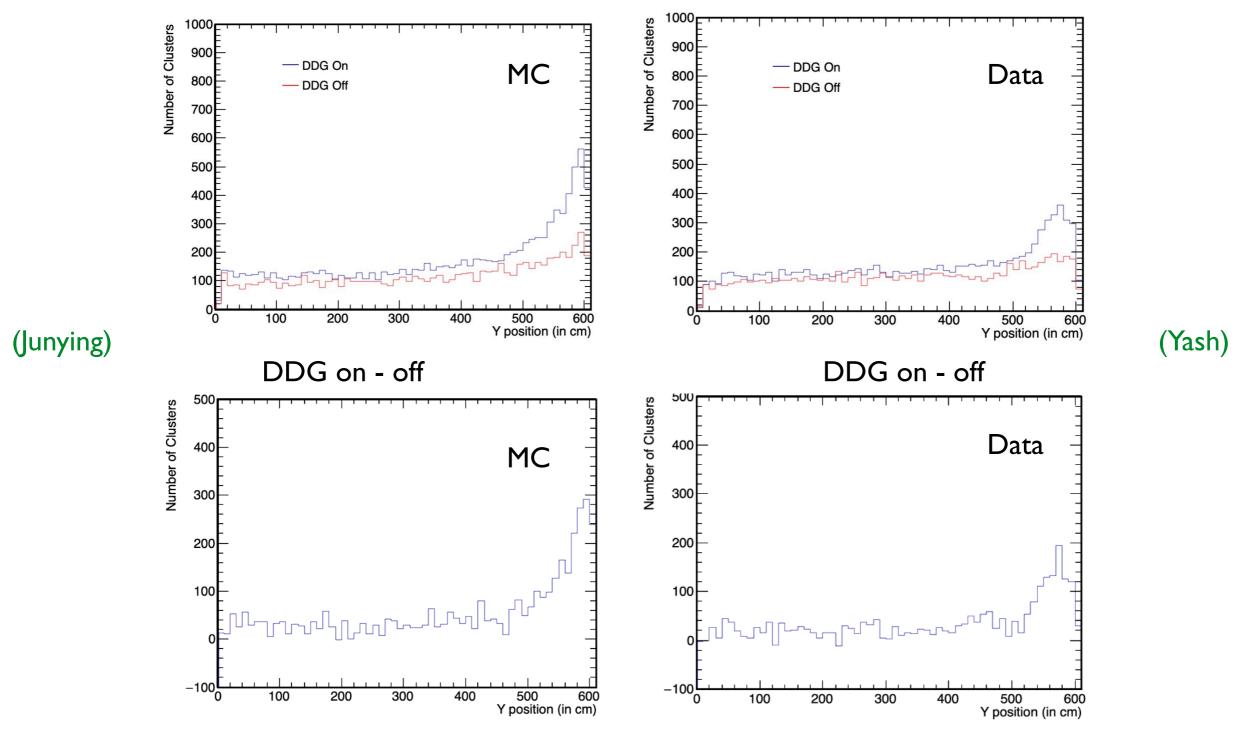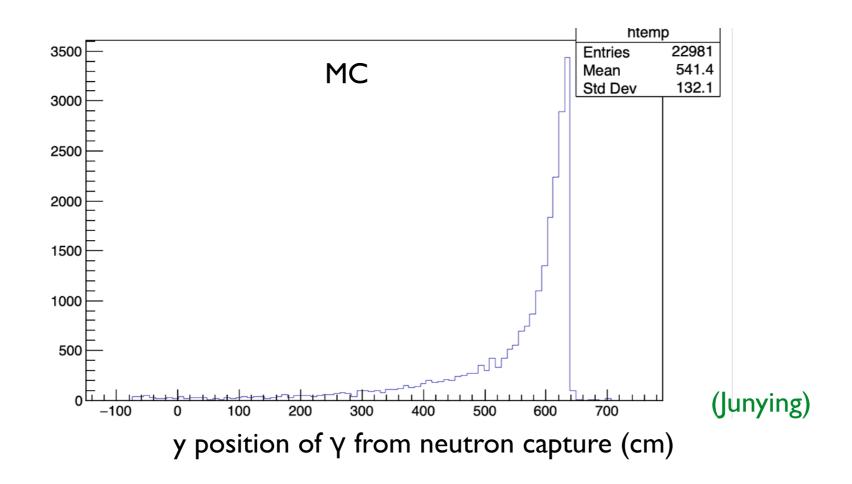
Slice Size Data vs MC

y-position of slices
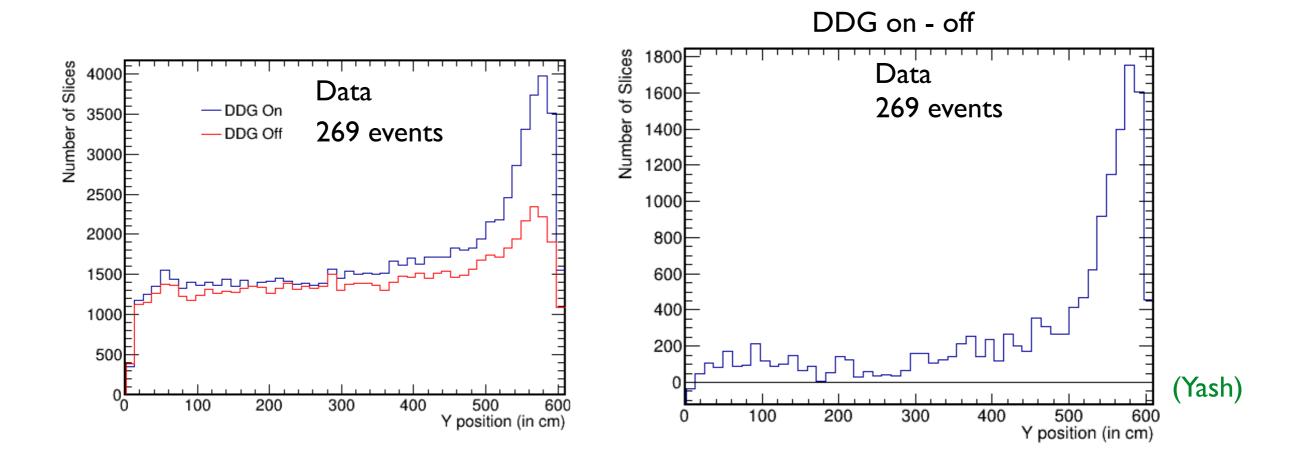

(Junying)

(Yash)

- Apparent Inefficiency near top of detector observed in Data but not MC.

- DD induced signal clearly seen in both MC and data.... but are these neutrons?

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Neutron Captures

MC

 y position of γ from neutron capture (cm)

(Junying)

- MC confirms that we are seeing gammas from neutron capture in the LAr.

- Attenuation looks daunting, however we are at neutron kinetic energy E=2.5 MeV

- ARTIE experiment preliminary results confirm anti-resonance feature at 57 keV.

Increased Statistics

(Yash)

- Currently using less than 1% of collected data.

- Current team focus is on using grid submission to handle more events:

  - Recent increase to 269 events (factor of 10) with more to come.

Conclusion

- Monte Carlo simulation of DD data describes key features in the data.

- An efficiency effect at top of detector still needs to be understood.

- We see a clear neutron capture signal in the LAr from the DD generator.

- Planned Improvements:

  - More statistics in data and MC (less than 1% of data is used so far)

  - Normalization of MC to data.

  - Second clustering with larger neighborhood radius approporiate for neutrons (energy of neutron from sum of hits associated with space points?)

  - Comparisons with Pandora.

  - See Jingbo's talk for future improvements to performance of DD generator.