Simulation of Low Energy Events at ProtoDUNE-SP

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Motivation for the Simulation

ProtoDUNE-SP at CERN

➢A DD (Deuterium Deuterium) neutron generator test was done on ProtoDUNE-SP (single phase) at CERN in July 2020.
  ➢More details were covered in the talk "Neutron Generator Calibration System for DUNE" by Yashwanth Bezawada yesterday: Link

➢Simulating 2.5 MeV neutrons, propagation, capture and gamma cascade in liquid argon

➢Background: Cosmic ray, Ar-39 beta decay

➢Yashwanth Bezawada developed the analysis algorithm.

➢I ran simulations of neutron and background to compare with real data and test the algorithm.

Time vs Channel(Plane Z, APA5)
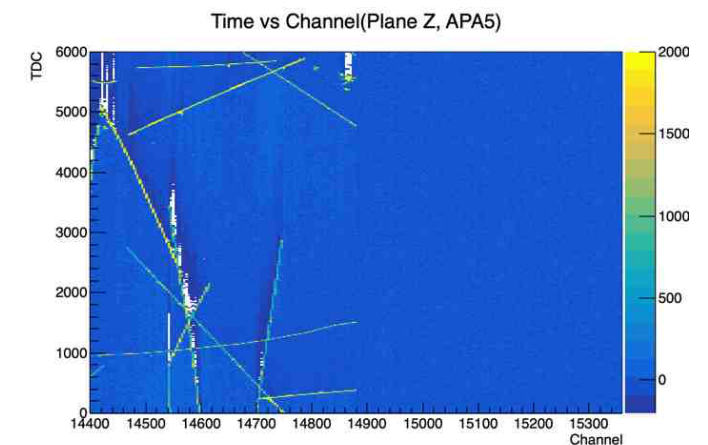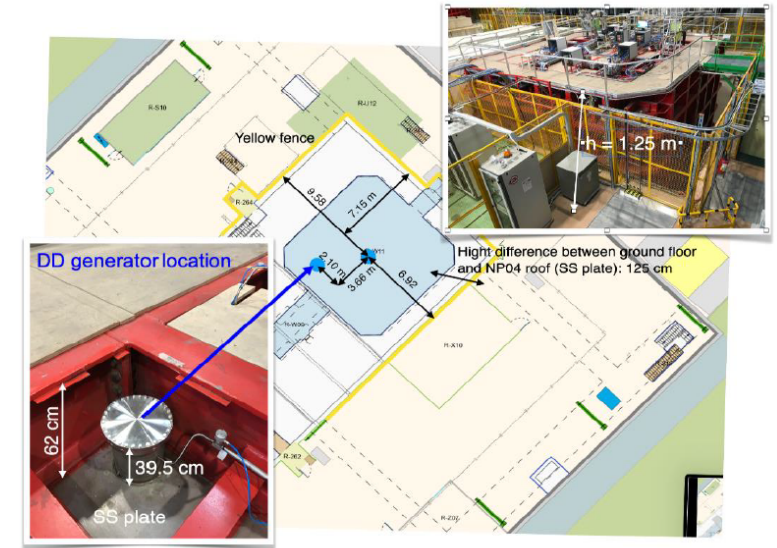
Need to Remove Cosmic Ray Muons

- Plots at right are simulations of one event.

- Simulations are done with DUNE's official software LArsoft. Module for neutrons: NeutronHP.

- In simulation: Separation of neutron and background

- ProtoDUNE standard reconstruction: classify cosmic rays and remove

- Channel ID related to position by pitch 4.7 mm.

- Most cosmic ray hits removed.
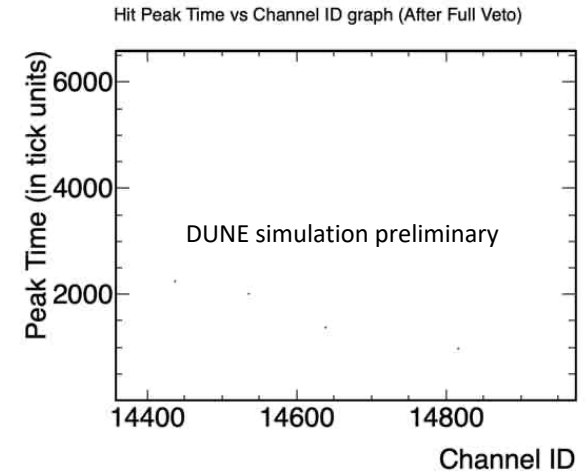
- Neutrons can be seen in ProtoDUNE-SP.
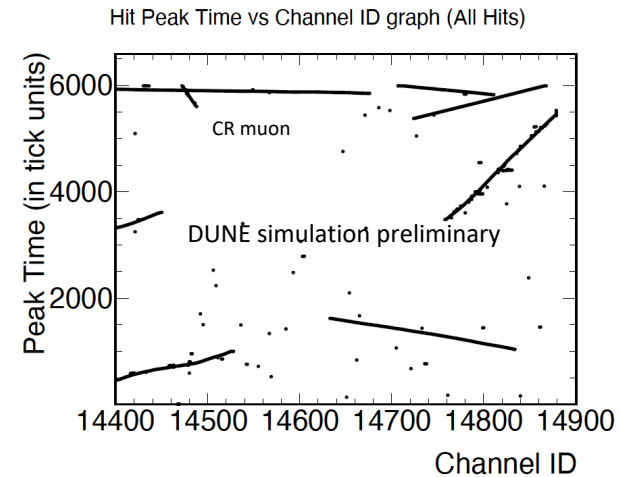
Background and neutrons
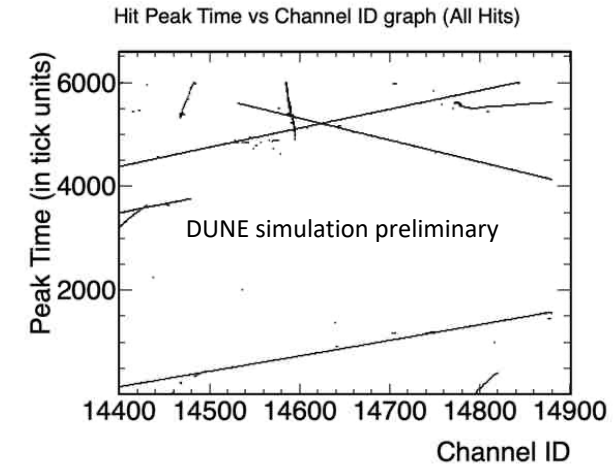
Background only
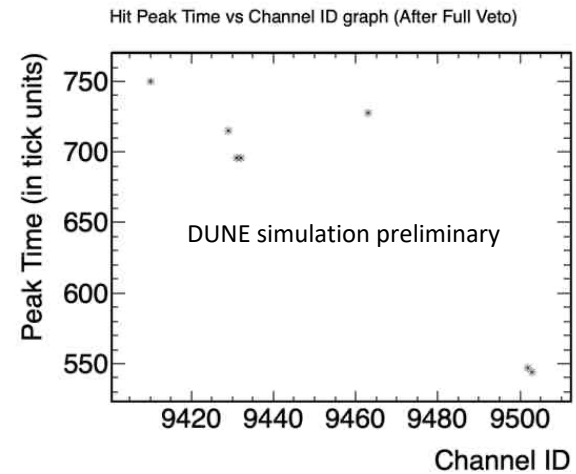

Simulation of Neutrons only

Background after cosmic removal

Neutron Capture Gamma Energy Distribution

➤ Identify neutron capture in argon.

➤ Plots on the right are gamma energy distribution of neutron capture in liquid argon.

➤ DUNE default LArsoft GEANT4 low energy gamma energy distribution (QGSP_BERT_HP) does not match the NNDC data.

➤ Tuned to match the NNDC (National Nuclear Data Center) data.
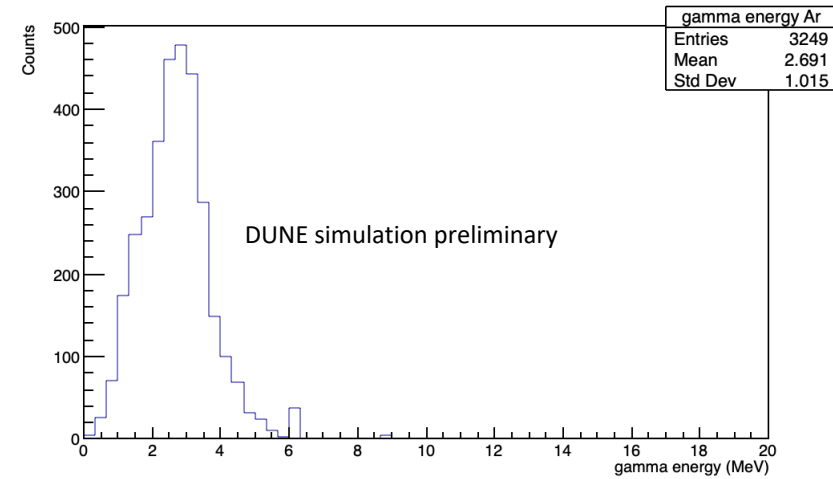
GEANT4 physics list: QGSP_BERT_HP
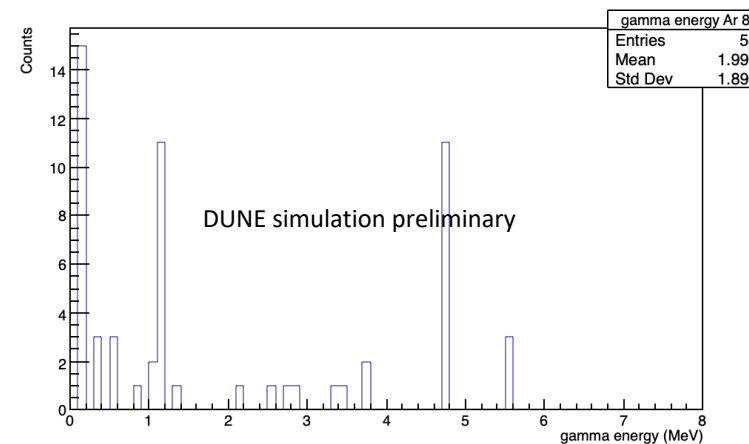
GEANT4 tuned to NNDC
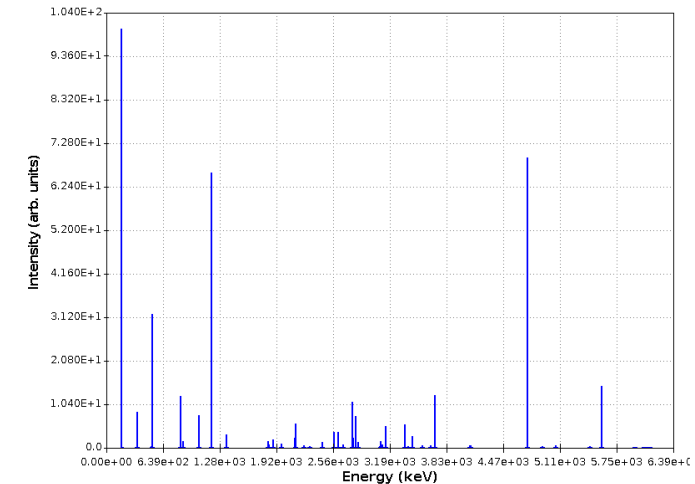
NNDC Data

Neutron Interaction outside Argon

➤ Neutron capture from DD generator not only happen in liquid argon, but also in other detector materials (e.g. cryostat…)in ProtoDUNE-SP detector. Only about 1% reach the argon active volume, due to non-optimum position of DDG.

➤ In GEANT4: classify by gamma position.

➤ Future plan: energy reconstruction, and compare with real data.
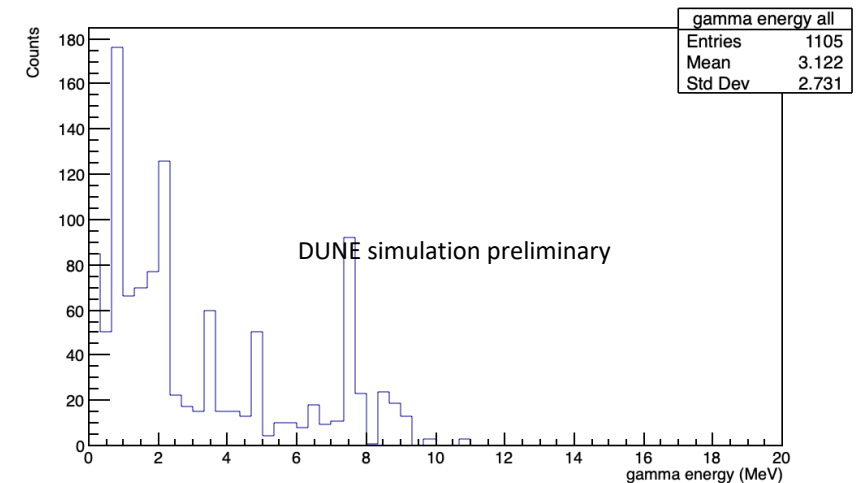
All neutron capture gammas
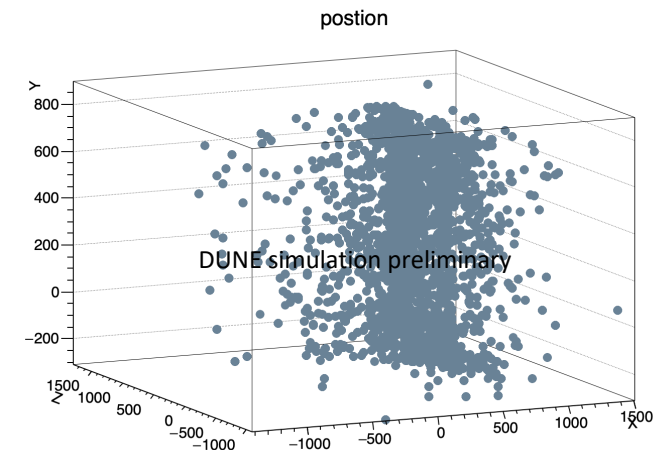
3D neutron capture position distribution in ProtoDUNE outside argon

Summary

➢Already done:

   ➢Tested cosmic ray removal algorithm.

   ➢Verified that neutrons can be seen.

   ➢Tuned LArsfot GEANT4 neutron capture to match NNDC.

➢Future plan:

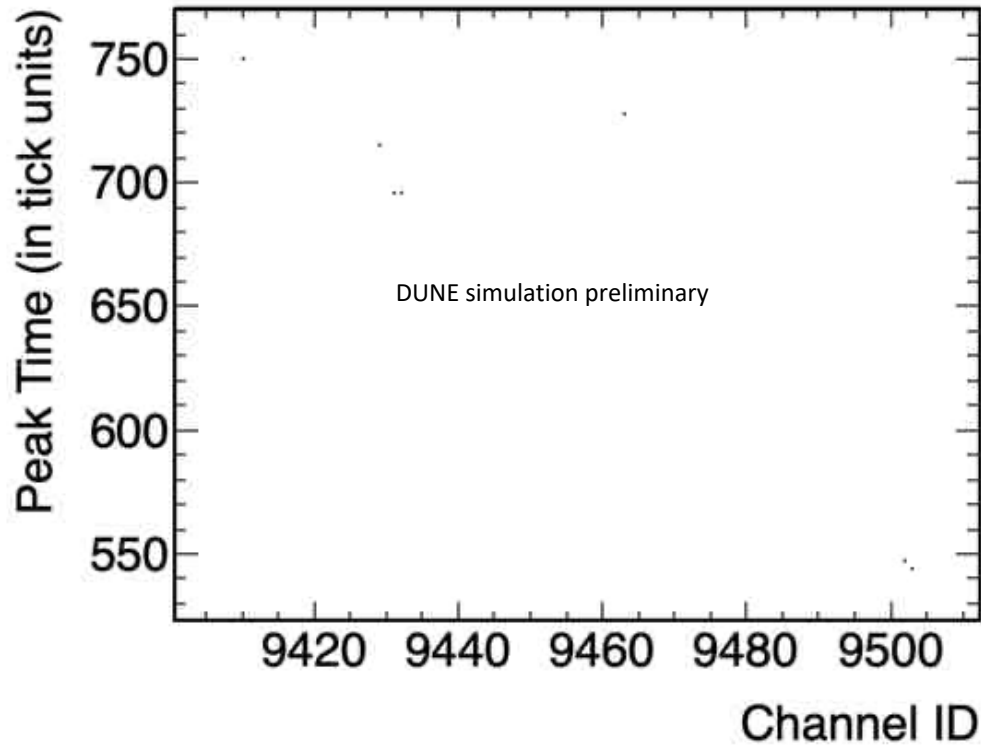   ➢Identify neutron capture in argon and other materials.

Backup Slides
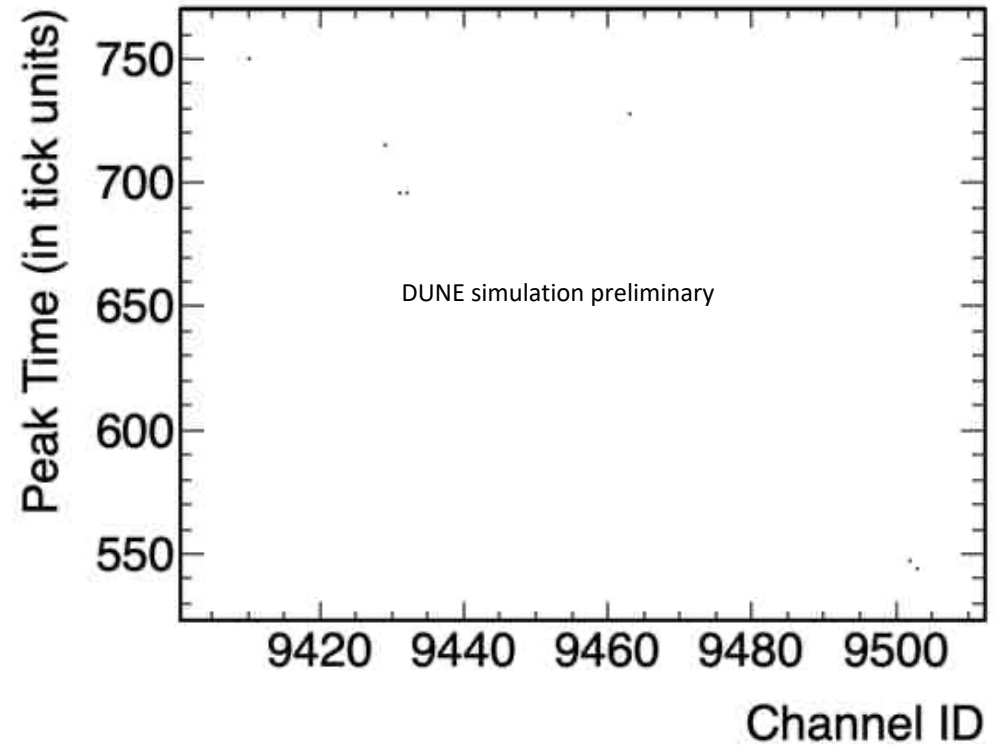
How to use the fixed simulation

How to use the fix: upgrade to v09_15_00 and change physics list from : QGSP_BERT_HP to MyQGSP_BERT_ArHP

Neutron before and after cosmic removal

Hit Peak Time vs Channel ID graph (All Hits)

DUNE simulation preliminary

Hit Peak Time vs Channel ID graph (After Full Veto)

DUNE simulation preliminary

Detector 3D coordinate

➢X: -700 to 700

➢Y: 0 to 600

➢Z: 0 to 700

➢DDG: 700, 600, 700