

Simulation of Low Energy Events at ProtoDUNE-SP

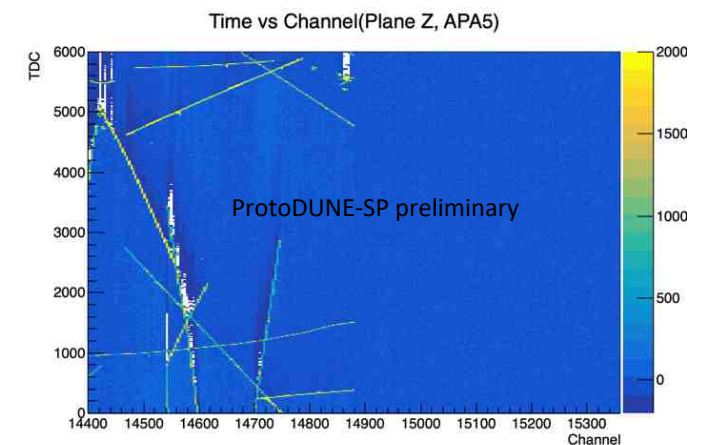
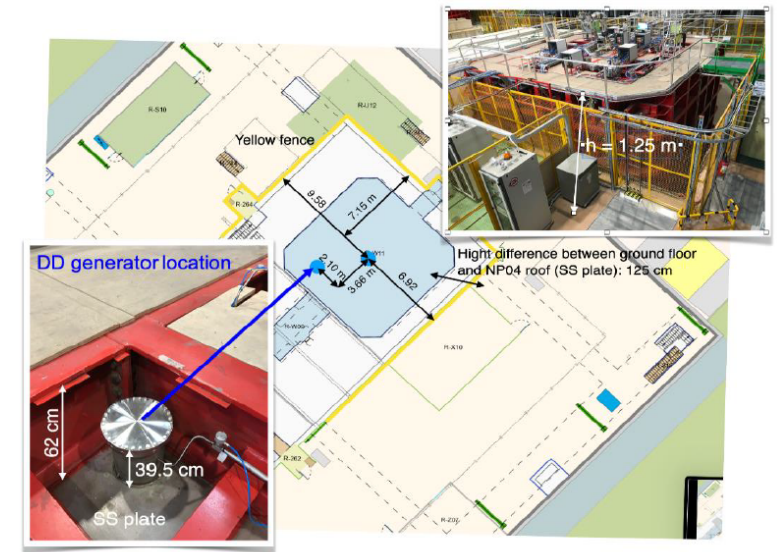
XIX International Workshop on Neutrino Telescopes
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Junying Huang
UC Davis
For the DUNE Collaboration

Motivation for the Simulation

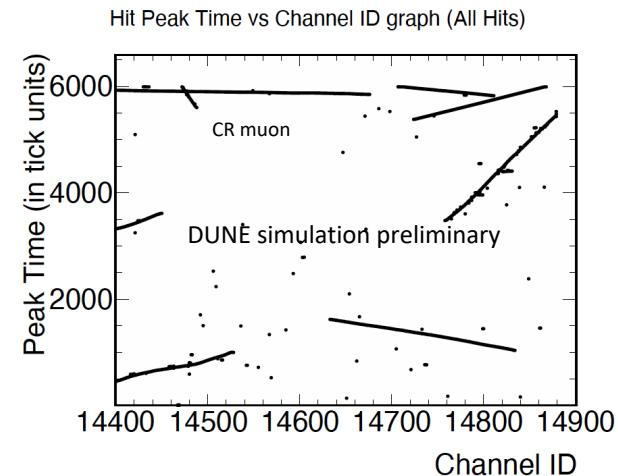
- A DD (Deuterium Deuterium) neutron generator test was done on ProtoDUNE-SP (single phase) at CERN in July 2020.
 - More details were covered in the talk “[Neutron Generator Calibration System for DUNE](#)” by Yashwanth Bezawada yesterday.
- Simulating 2.5 MeV neutrons, propagation, capture and gamma cascade in liquid argon
- Background: Cosmic ray, Ar-39 beta decay
- Y. Bezawada is analyzing the DD generator data.
- I ran simulations of neutron and background to compare with real data and test the algorithm.

ProtoDUNE-SP at CERN

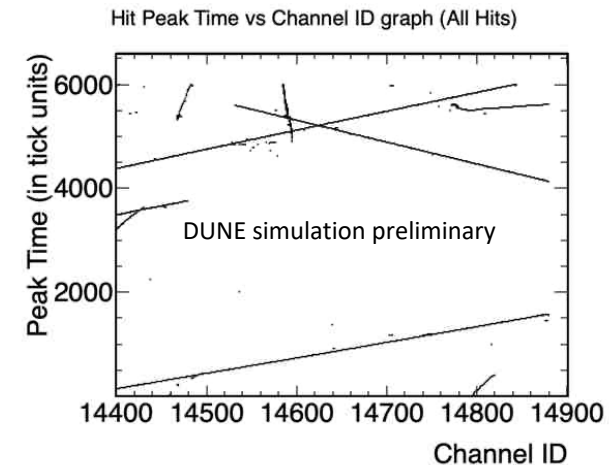


Need to Remove Cosmic Ray Muons

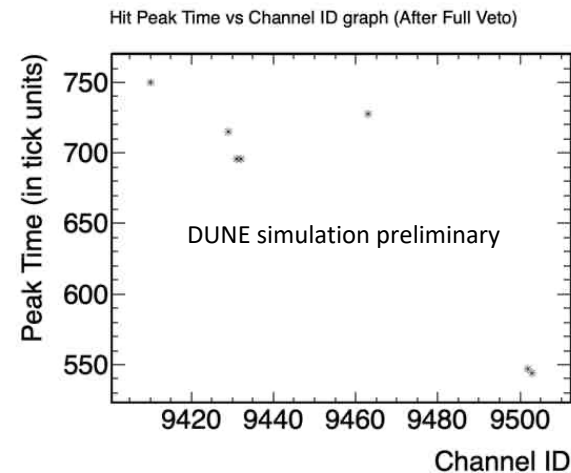
- Plots at right are simulations of one event.
- Simulations are done with DUNE's official software LArsoft. Module for neutrons: NeutronHP.
- In simulation: Separation of neutron and background.
- Channel ID related to position by pitch 4.7 mm.
- ProtoDUNE standard reconstruction: classify cosmic rays and remove
- Most cosmic ray hits removed. Neutrons can be seen in ProtoDUNE-SP.



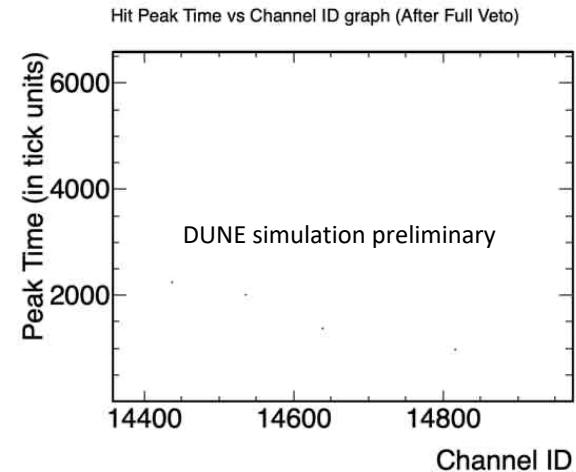
Background and neutrons



Background only



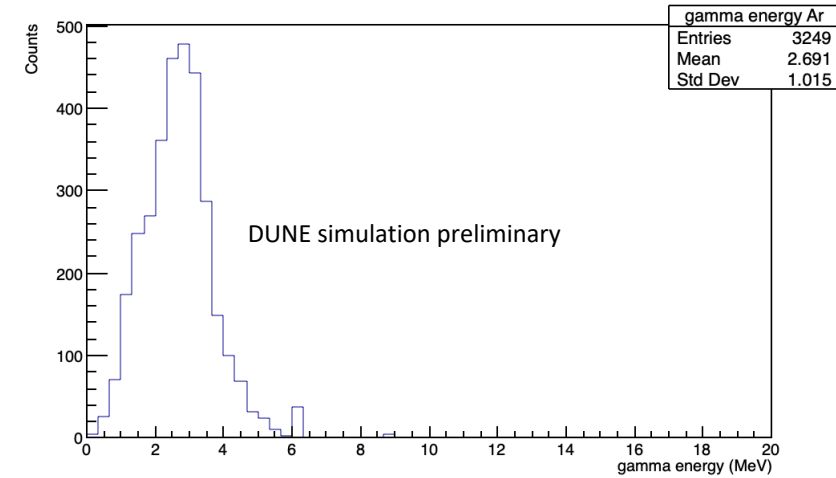
Simulation of Neutrons only



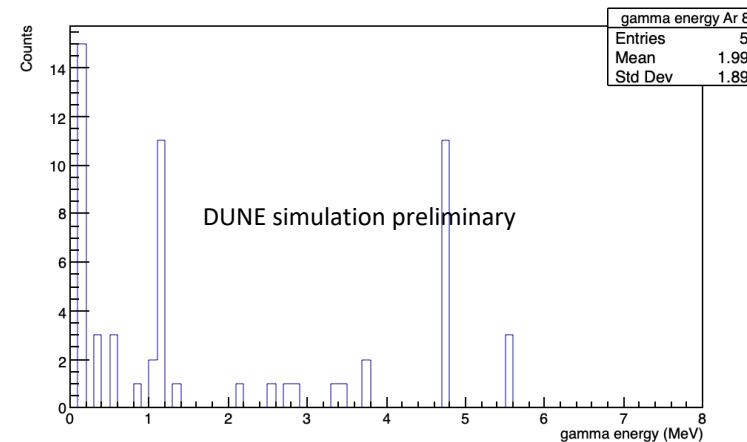
Background after cosmic removal

Neutron Capture Gamma Energy Distribution

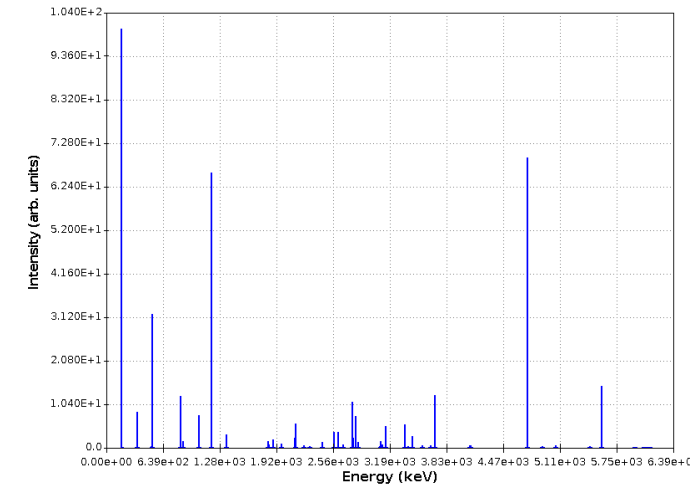
- Identify neutron capture in argon.
- Plots on the right are gamma energy distribution of neutron capture in liquid argon.
- DUNE default LArsoft GEANT4 low energy gamma energy distribution (QGSP_BERT_HP) does not match the NNDC data.
- Tuned to match the NNDC (National Nuclear Data Center) data.



GEANT4 physics list: QGSP_BERT_HP



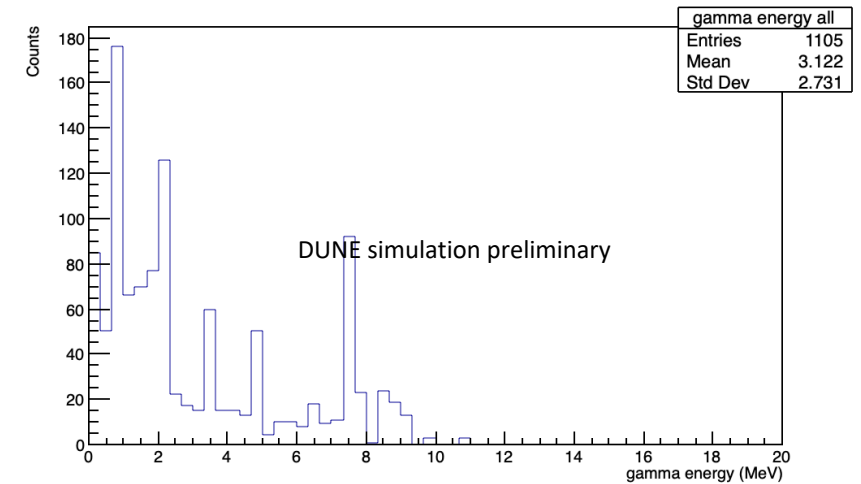
GEANT4 tuned to NNDC



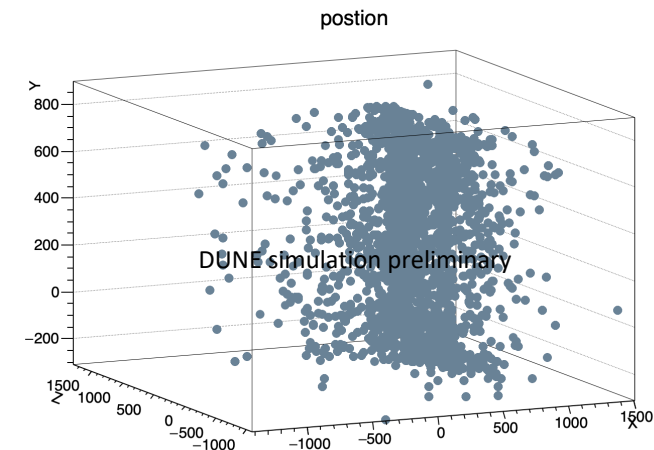
NNDC Data

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-optimal position of DDG limited by technical issues.
- 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

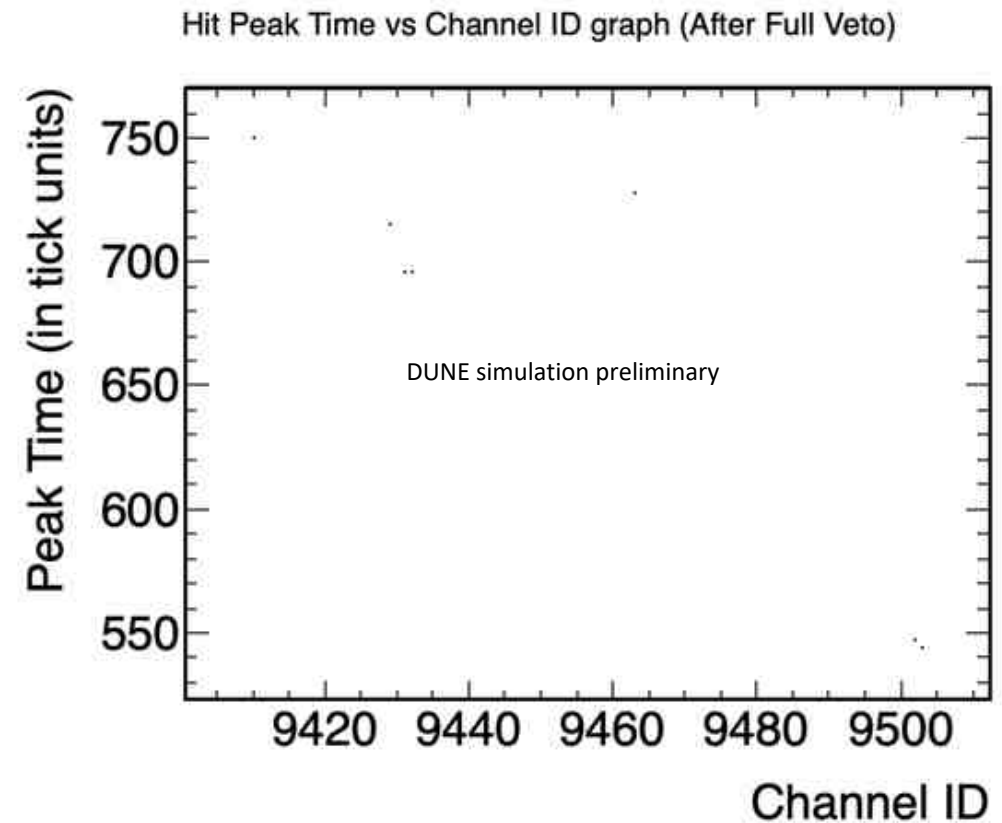
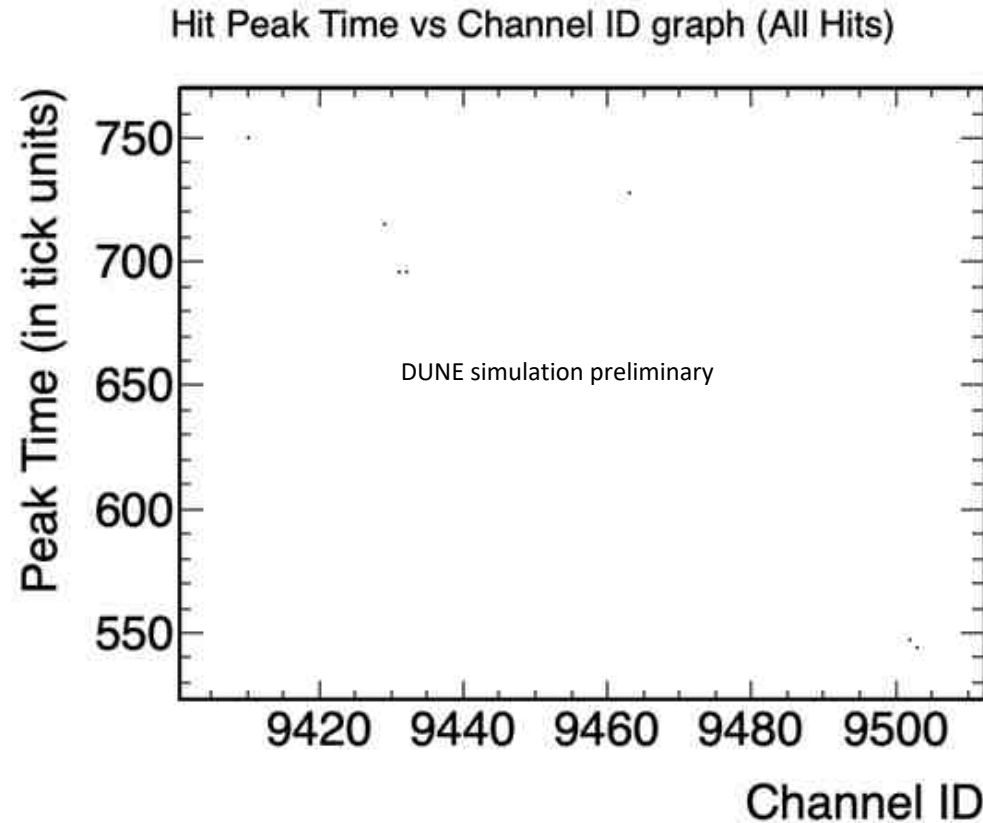
- Already done:
 - Tested cosmic ray removal algorithm.
 - Verified that neutrons can be seen.
 - Tuned LArsoft GEANT4 neutron capture to match NNDC.
- Future plan:
 - Identify neutron capture in argon and other materials.

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



Detector 3D coordinate

- X: -700 to 700
- Y: 0 to 600
- Z: 0 to 700
- DDG: 700, 600, 700