Simulation of Low Energy Events at ProtoDUNE-SP

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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.
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

Simulation of Neutrons only

Background 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.

DUNE simulation preliminary

GEANT4 physics list: QGSP_BERT_HP

GEANT4 tuned to NNDC

NNDC Data

JUNYING HUANG | SIMULATION OF LOW ENERGY EVENTS AT PROTODUNE-SP
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.

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

Hit Peak Time vs Channel ID graph (All Hits)

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