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Software status and a quick acceptance look as an example

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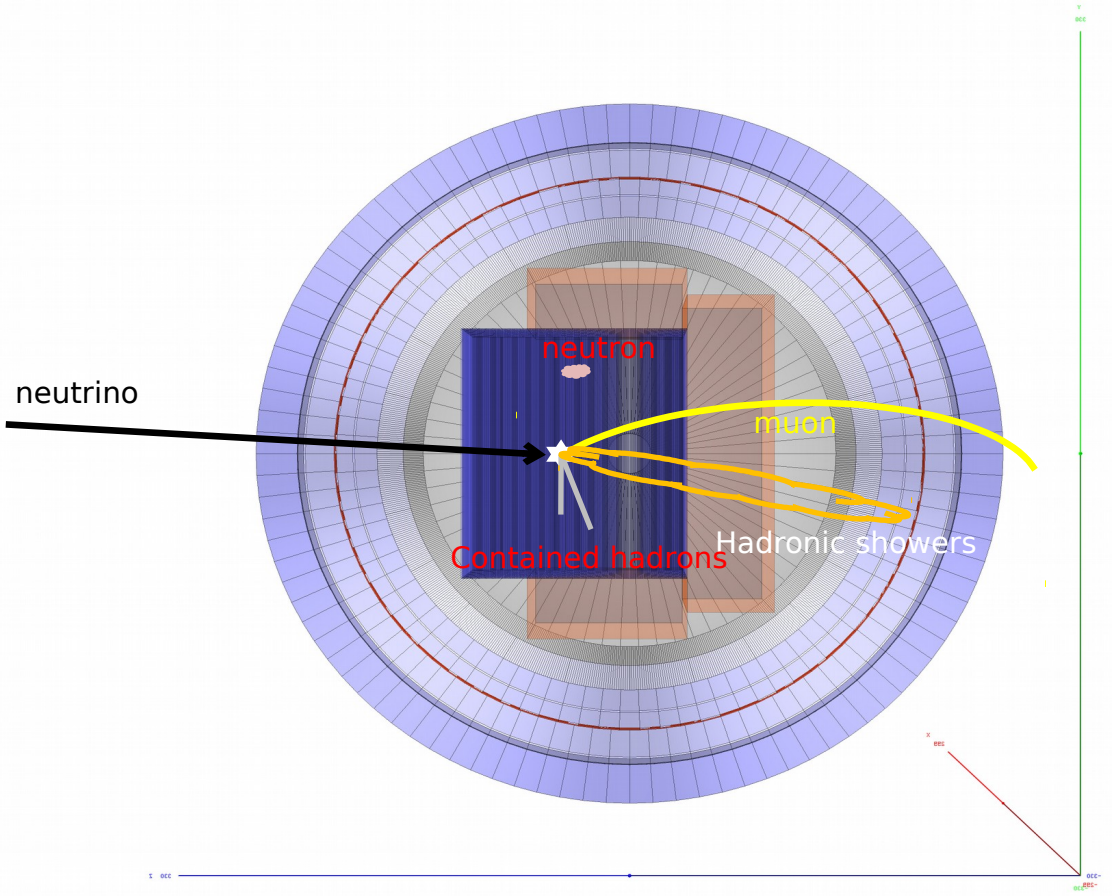
What we need to understand an interaction?



- Muon trajectory
- Hadrons in ECAL
- Contained hadrons
- Protons
- Neutrons

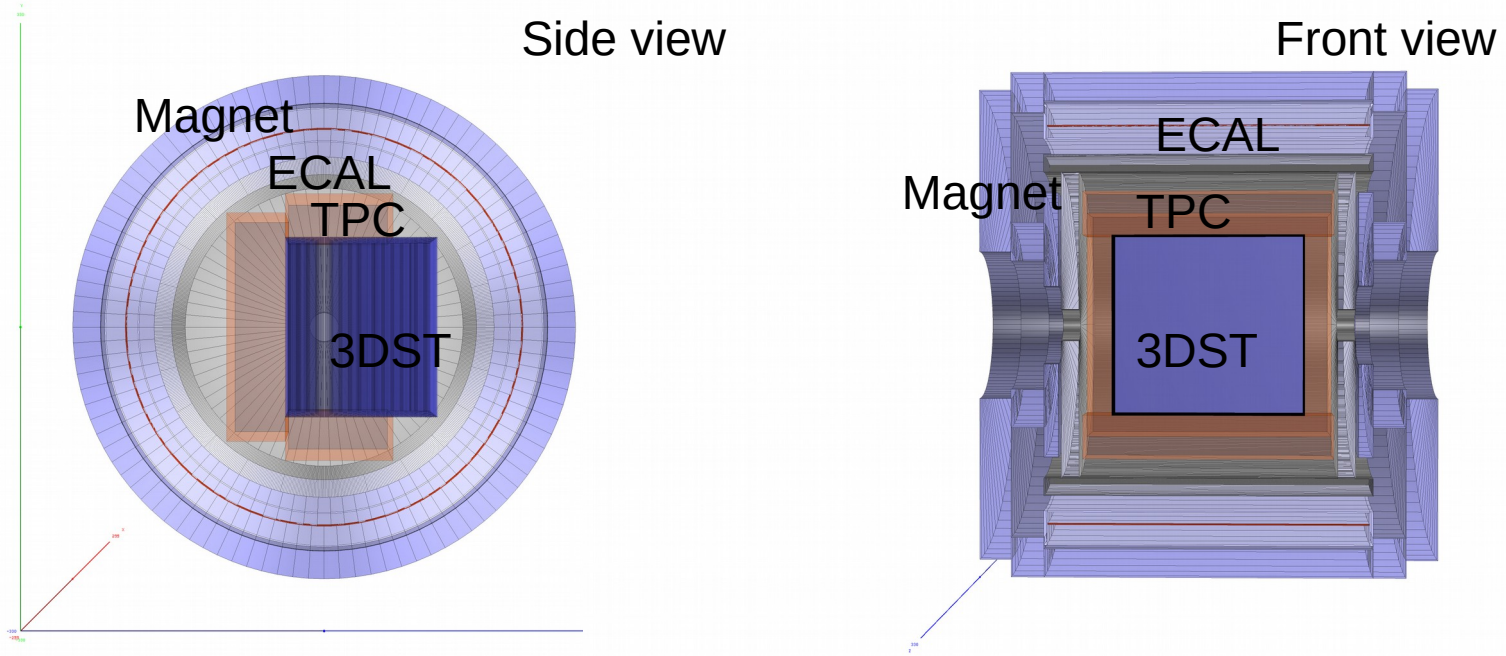
- We need energy and direction information for above to reconstruct a neutrino

Flow of 3DST software

- Geometry
  - independent → DUNENDGGD
- Neutrino flux generation
  - consistent with LBNF → G4LBNF
- Neutrino interaction generation
  - consistent with LBL → GENIE
- Energy deposition of final state particles
  - consistent with LBL → edep-sim
- Electronics simulation - independent tool
- Reconstruction - independent tool
- Analyses - independent tools

Geometry Description

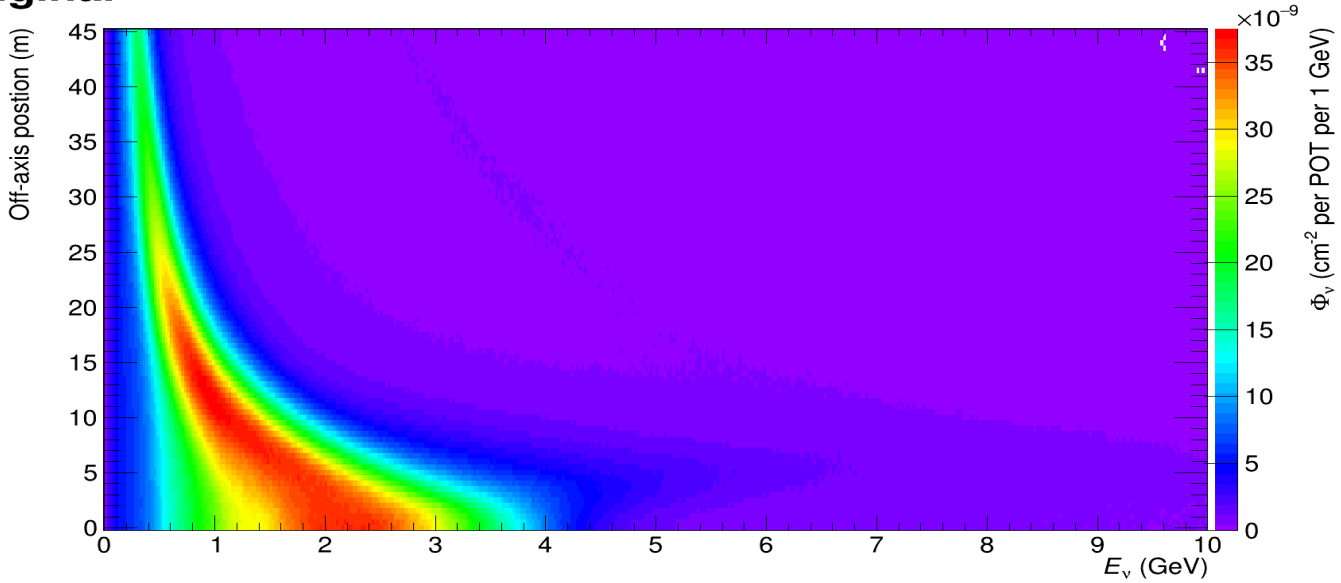
- We set up a basic 3DST concept in DUNE ND system: 3DST surrounded by TPC, ECAL and magnet
- Generated with DUNENDGGD: https://github.com/gyang9/dunendggd
- Layer structure: active volume → component volume → sub-detector → detector → detector hall → Rock world



Neutrino flux generation

- Steps:
  1. dk2nu generation: dk2nu is a ntuple tree containing hadron decay and neutrino information, with beam parameter set we need.
  2. following plots: extract flux from each dk2nu beam parameter setup
  3. Combining all those variations
  4. Demonstrate the usefulness of 3DST with our studies

Original

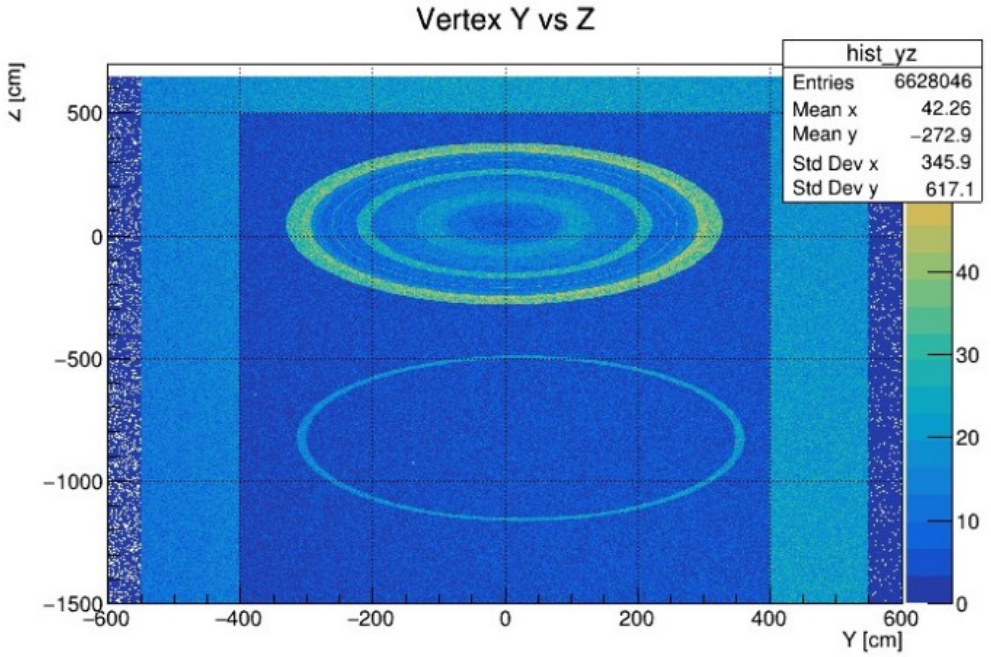


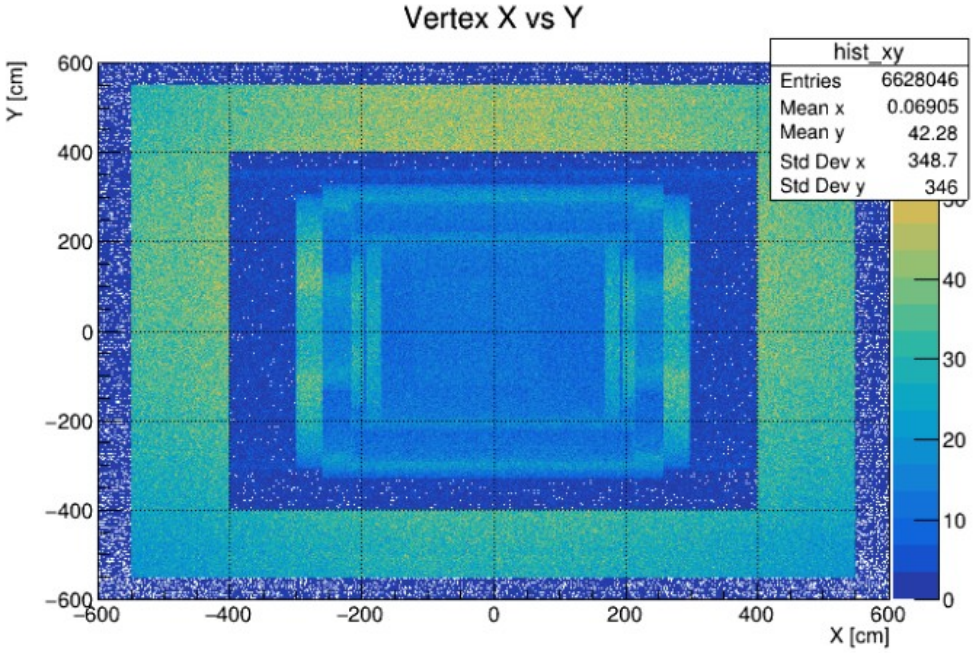
Neutrino interaction

- GENIE (v2_12):

  - whichever version used for the LBL should be used here.

  - running on fermi grid, software consistent with LBL





Energy deposition

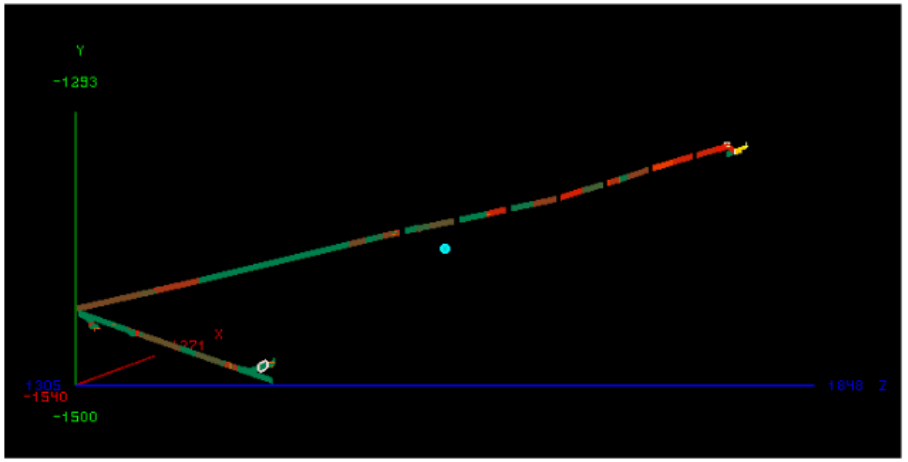
- Edep-sim:

  - GEANT4 based. Usually set all volumes to be active in order to do detailed final state particle studies.

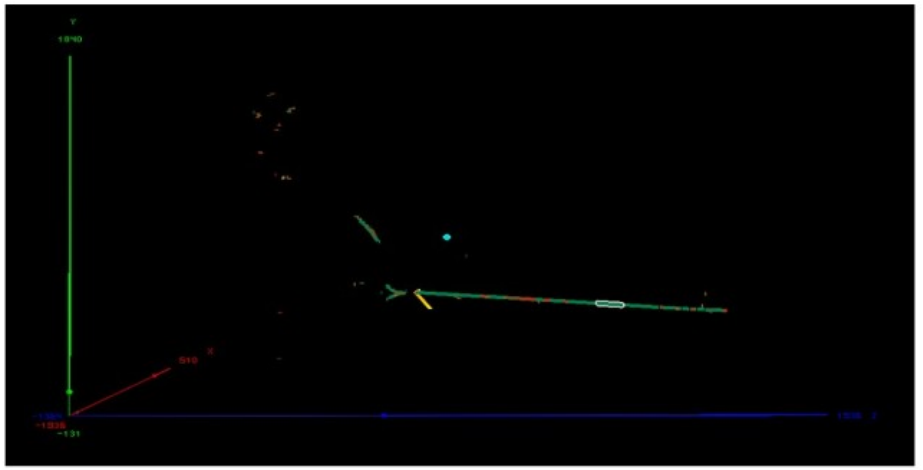
  - running on Fermi grid, consistent with LBL

- You can also run it locally: https://github.com/ClarkMcGrew/edep-sim

CC pi+ in TPC



CC pi0 in 3DST



Electronics simulation

- Electronics reposnses:

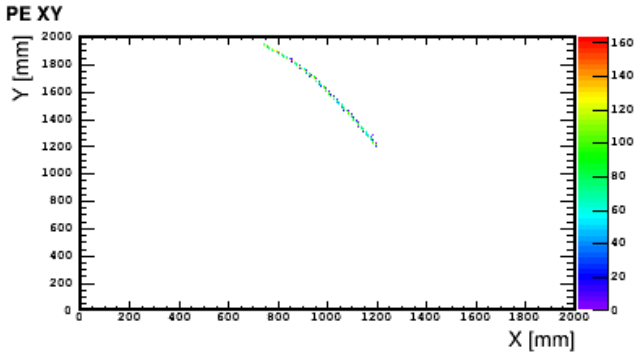
  Conversion chain: edep → photon captured in fiber → light attenuation → MPPC response

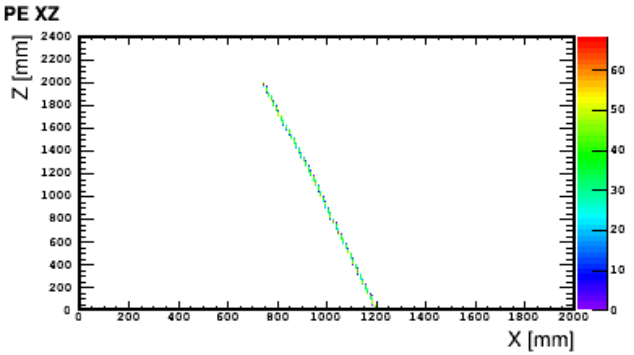
- Input edep-sim and output :

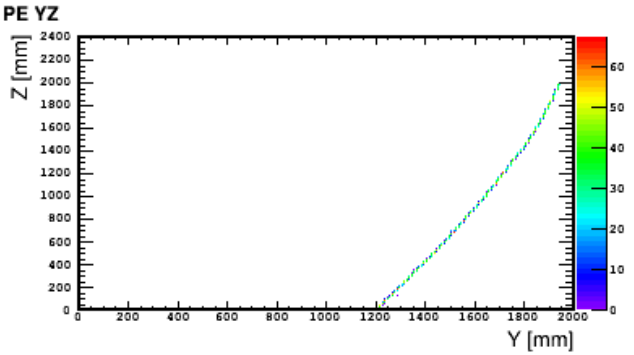
  - analysis tree containing final state particle high-level information

  - three 2D readout maps with electronics response applied

- In a sub-location of a package: https://github.com/gyang9/DUNE3dstTools/tree/master/src/elecSim







Reconstruction

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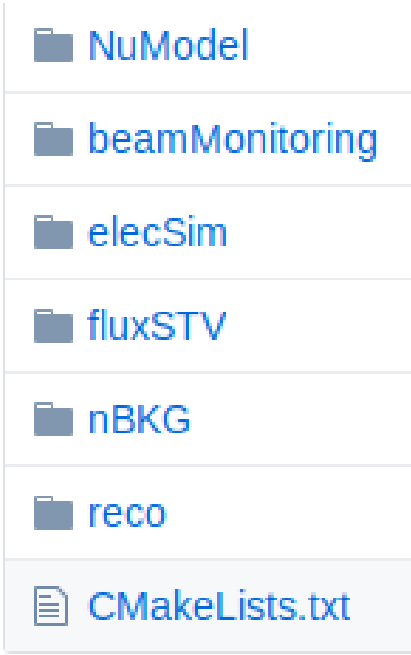
- Developing a new reconstruction tool dedicated for 3DST and superFGD by Clark McGrew and Sergey Martynenko

- Functioning packages:
  - Read the input file containing fiber hit information;
  - Create 3D Hits from fiber hits;
  - Adjust charge for 3D Hits;
  - Cluster 3D Hits (DB Scan);
  - Define hits order inside each cluster (Minimum Spanning Tree);
  - Split clusters into Track-Like objects (find vertices);

- In development:
  - Track fit;
  - Shower search;
  - Other?

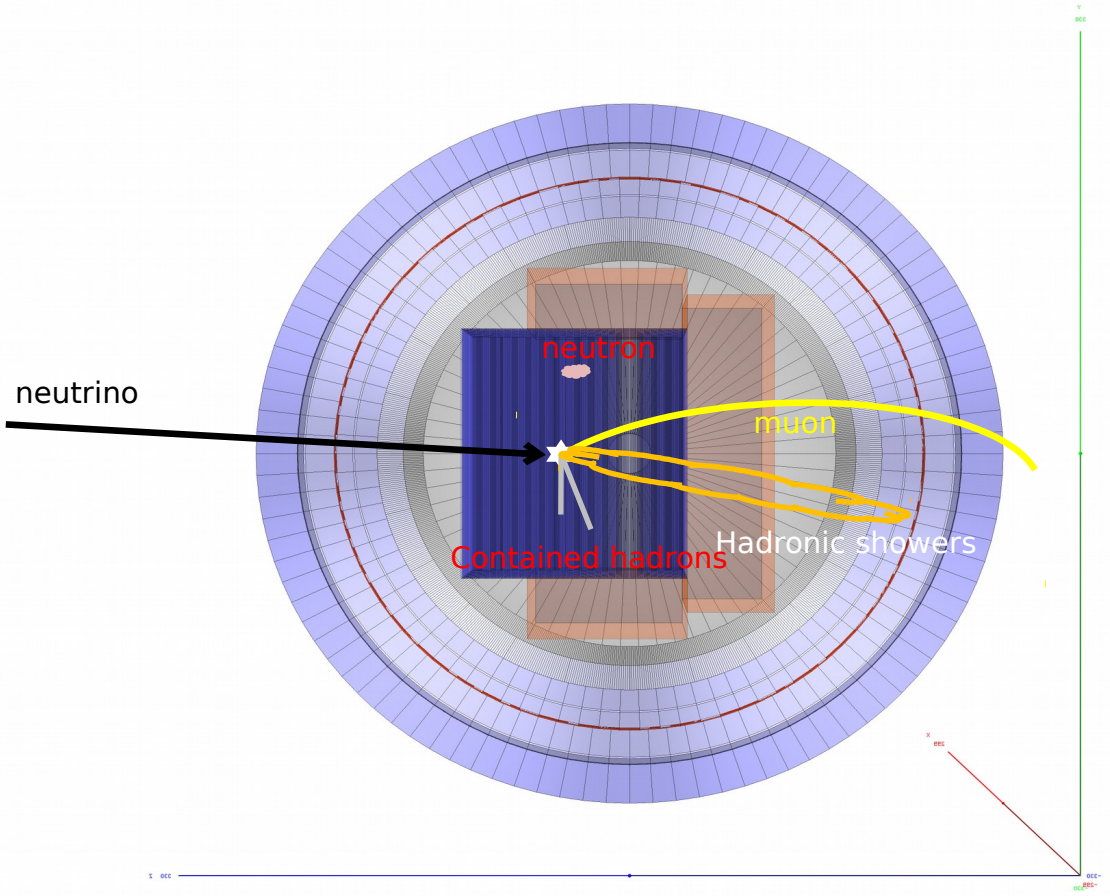
Analysis

- A package has been created compiling all current analysis tools: https://github.com/gyang9/DUNE3dstTools



- Neutrino on CH and Ar interaction tuning with GENIE and NUWRO
- Beam monitoring sensitivity to various beam condition changes
- Electronics Simulation
- Single transverse variable for flux constriant
- Neutron background study to obtain pure neutron sample on the space of arm and time
- Reconstruction from 3 2D maps

What we need to understand an interaction?



- Muon trajectory
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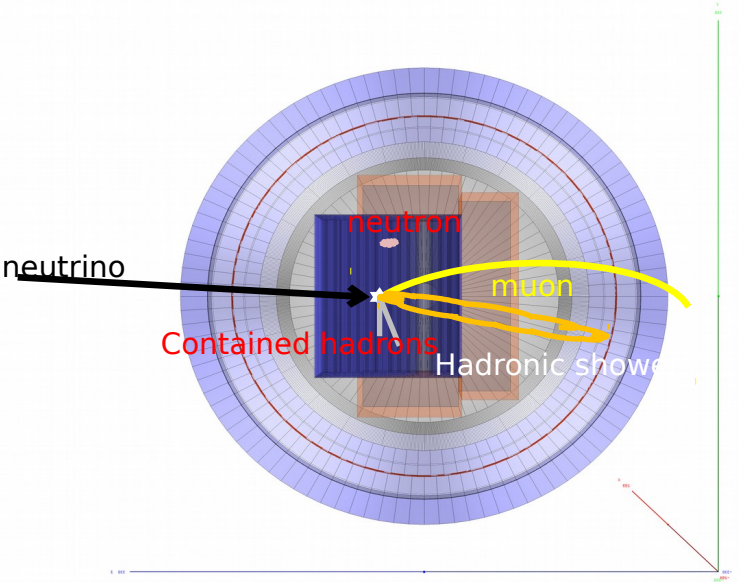
- We need energy and direction information for above to reconstruct a neutrino

Example of processed edep-sim files

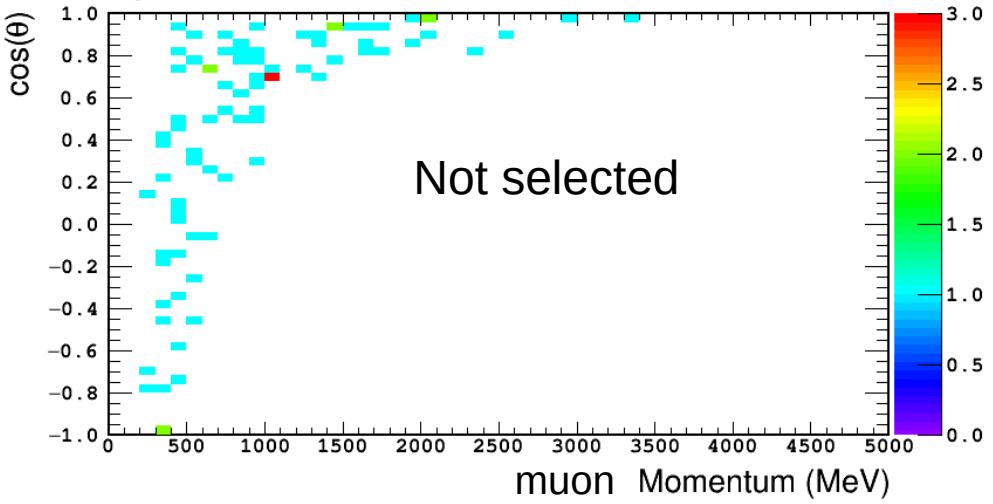
- Based on true interaction mode, we can classify events to different channels : 0pi, 1pi+-, 1pi0, mpi.
- Look at lepton first, it is easy with high efficiency: Requirement is pixel plane projected 20 cm travel length



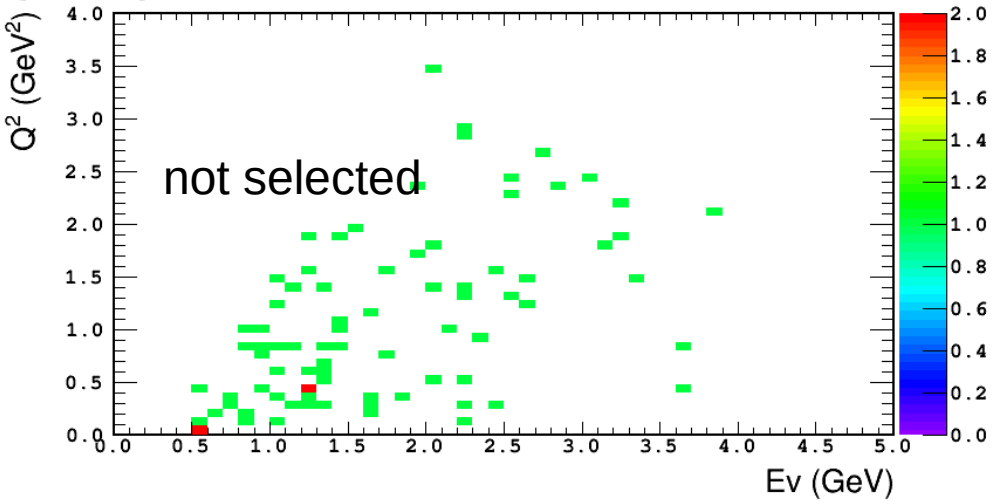
- We can get selected and rejected events on various phase space in order to understand the event selection

0pi channel with muon selection

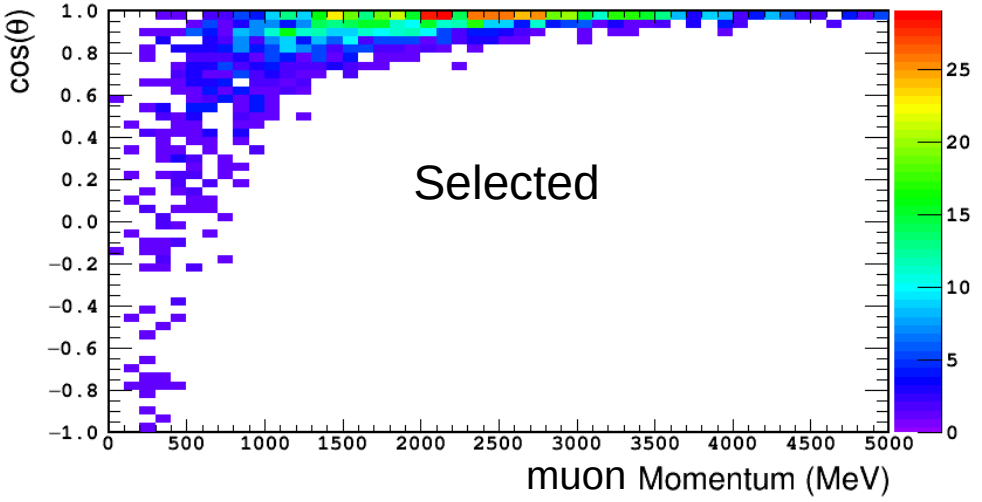
0Pi escape



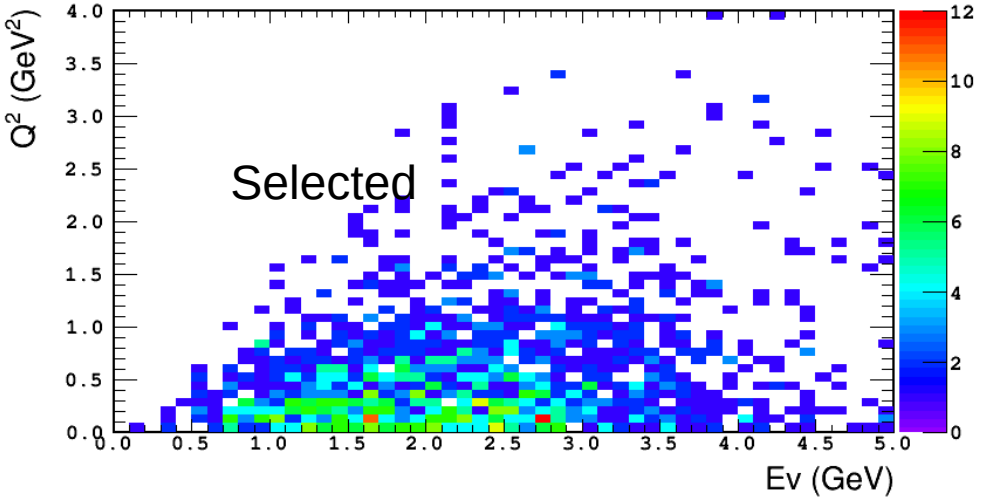
0pi escape



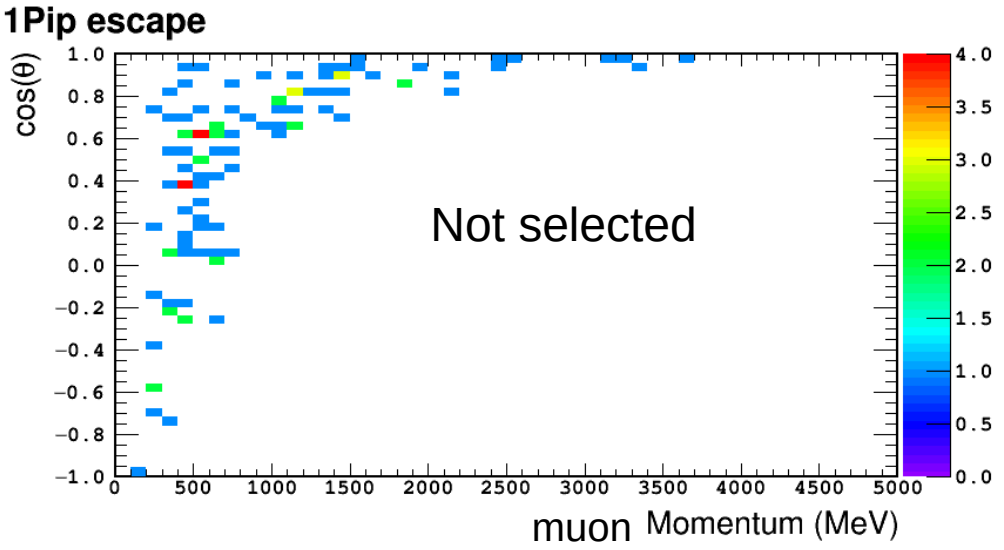
0pi tracked

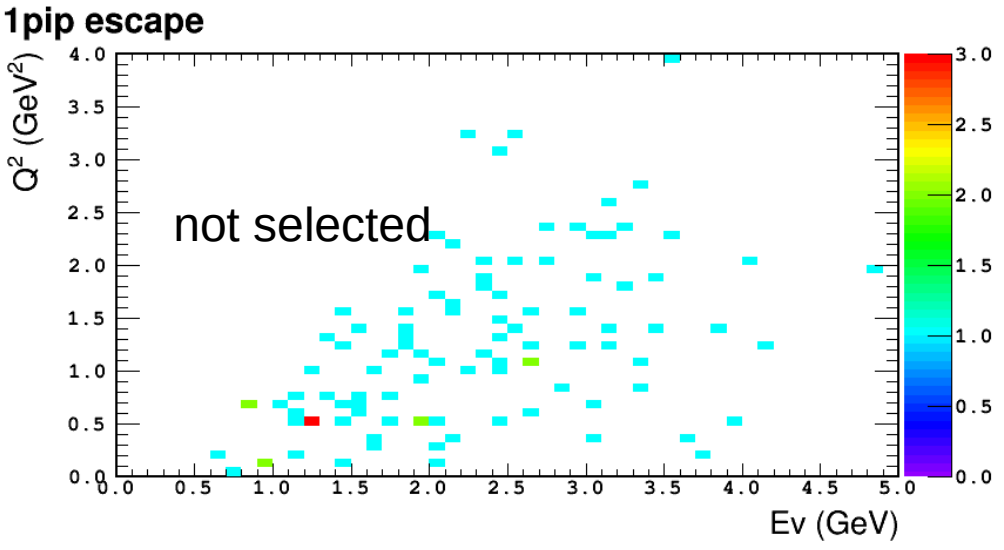


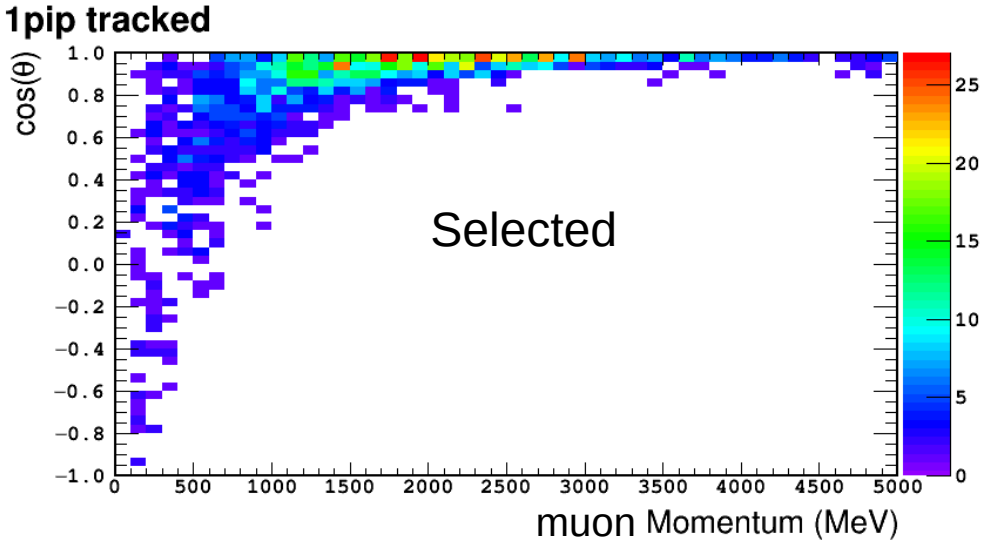
0pi tracked

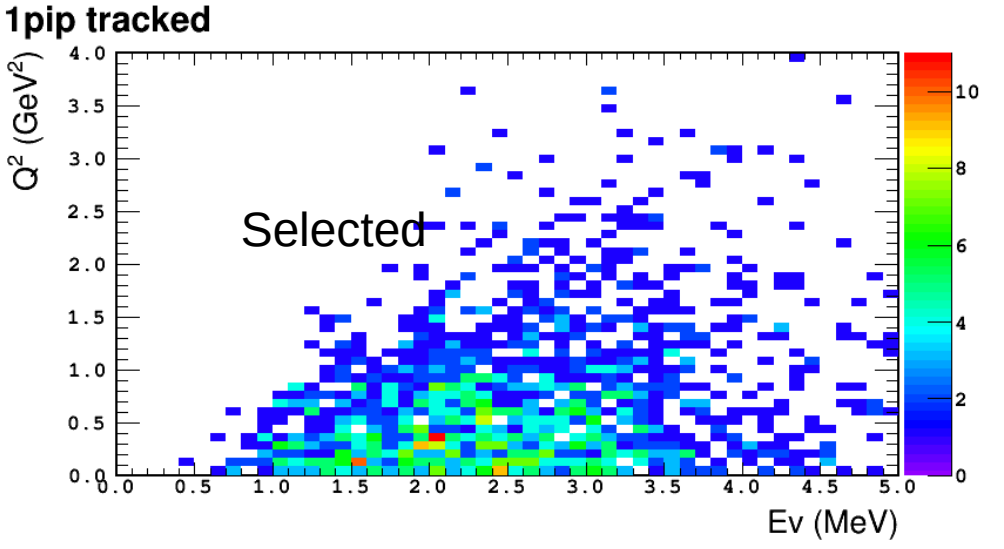


1pi+- channel with muon selection

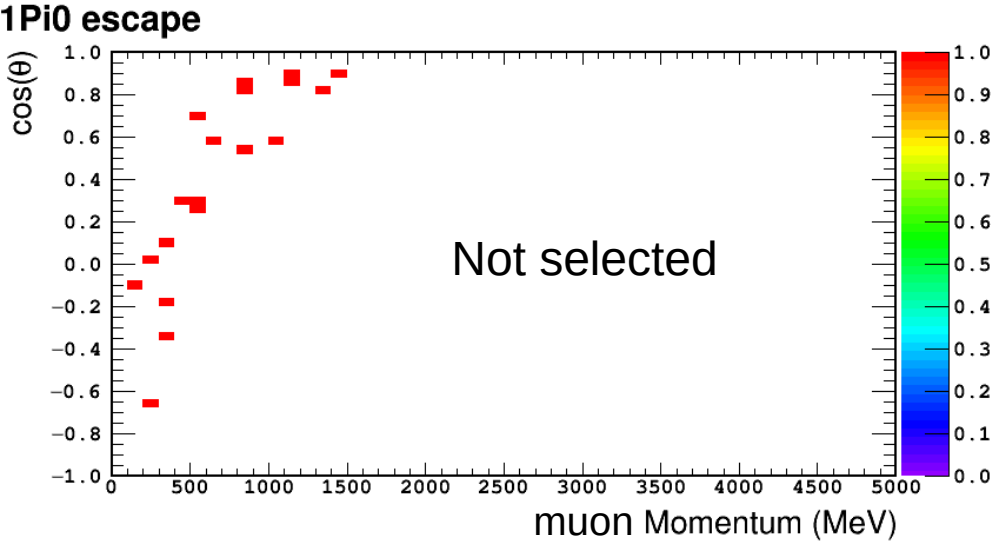


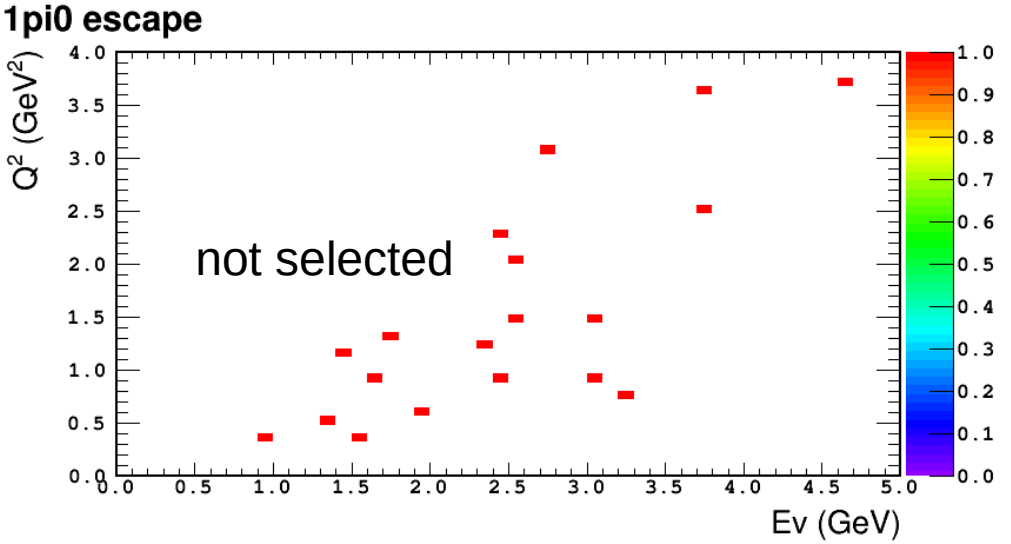


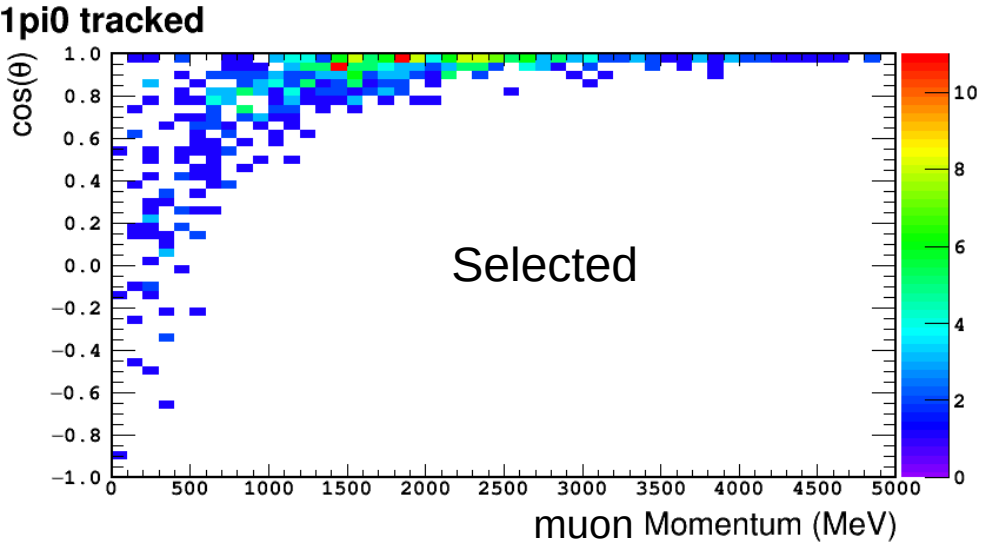


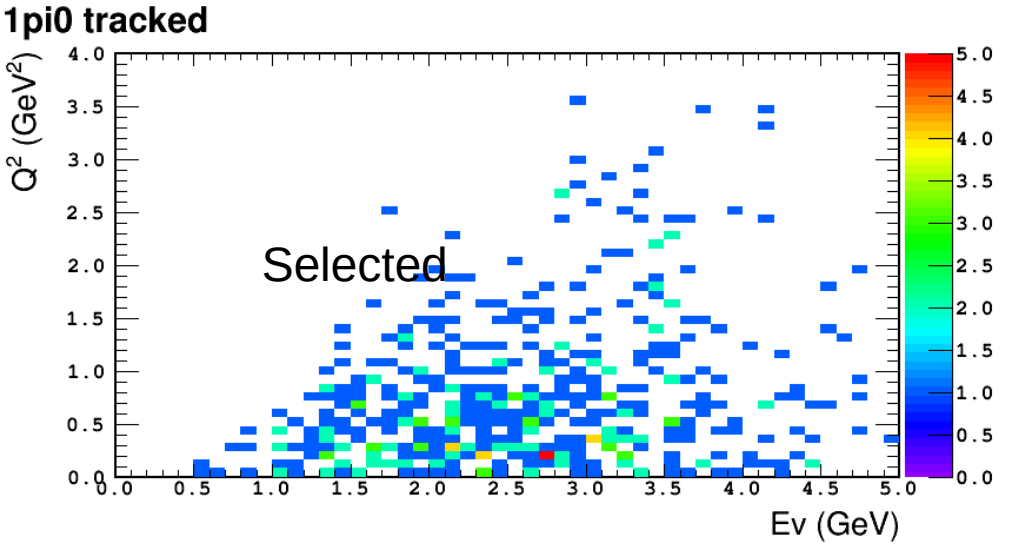


1pi0 channel with muon selection



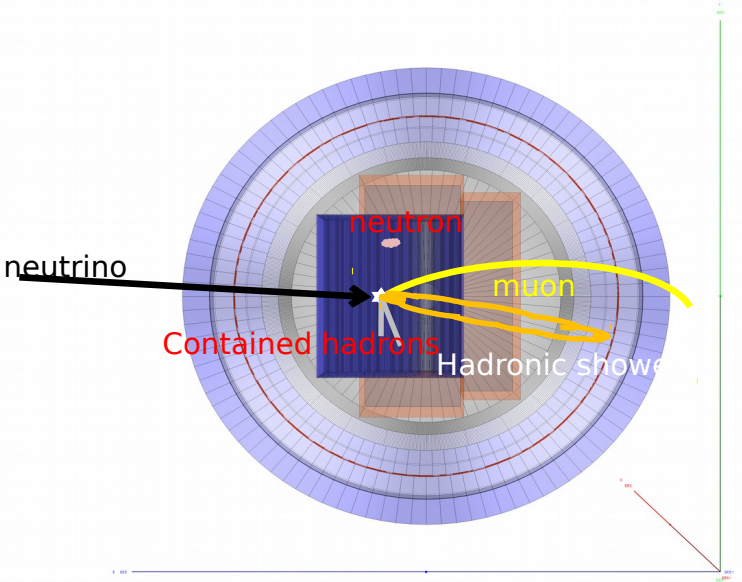






Example of processed edep-sim files

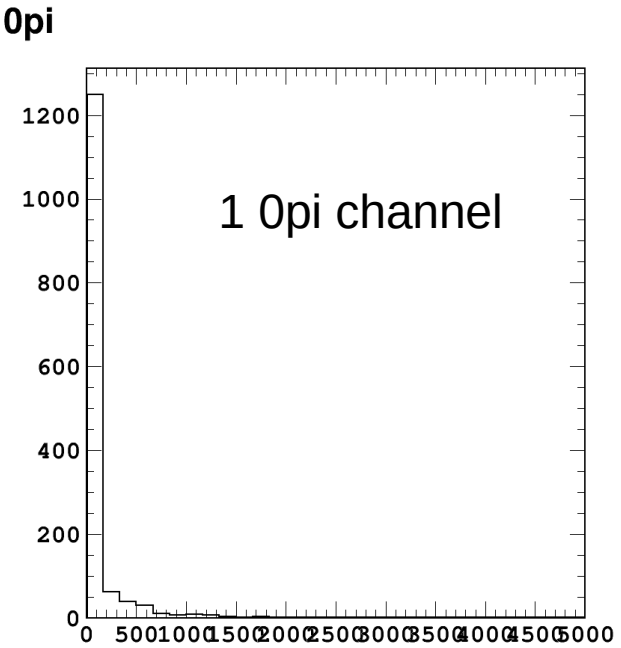
- Next, I assume 3DST can handle contained stuff
- Next, neutron is a separate topics as it may suffer from background and energy measurement precision

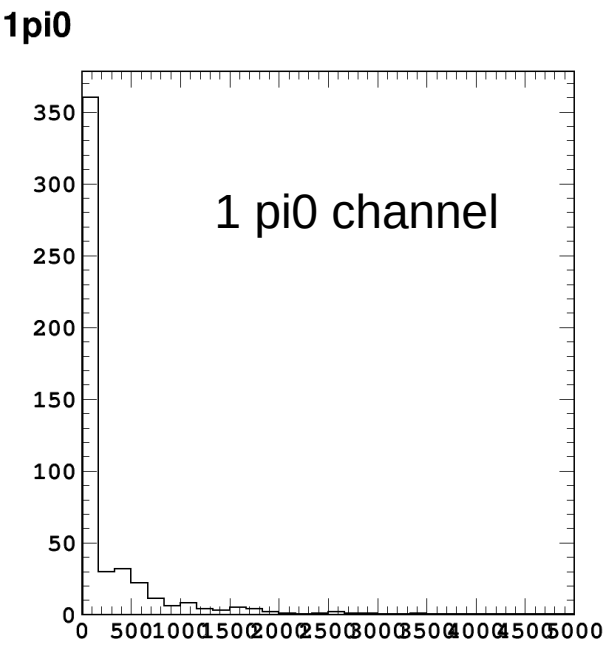


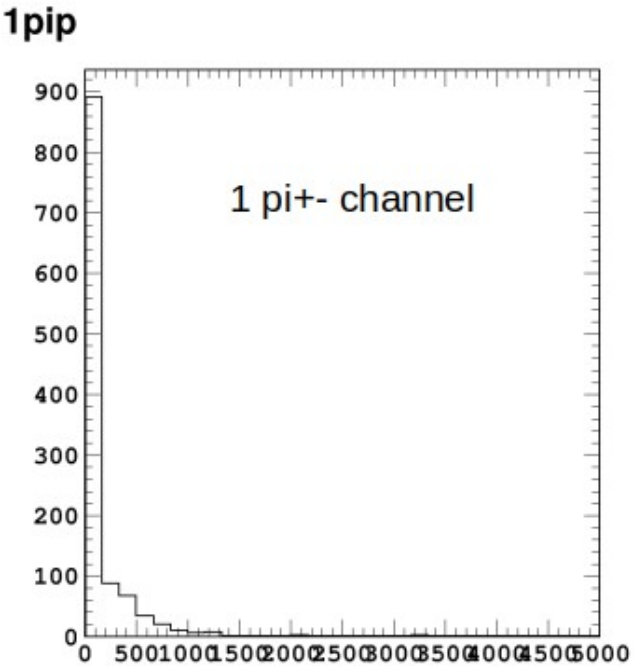
- We can separate each hadron to check the situation when it enters ECAL
- For hadrons in ECAL, KLOE ECAL performance is very crucial here

Protons entering ECAL

- Large number of protons stopped in 3DST while some going into ECAL

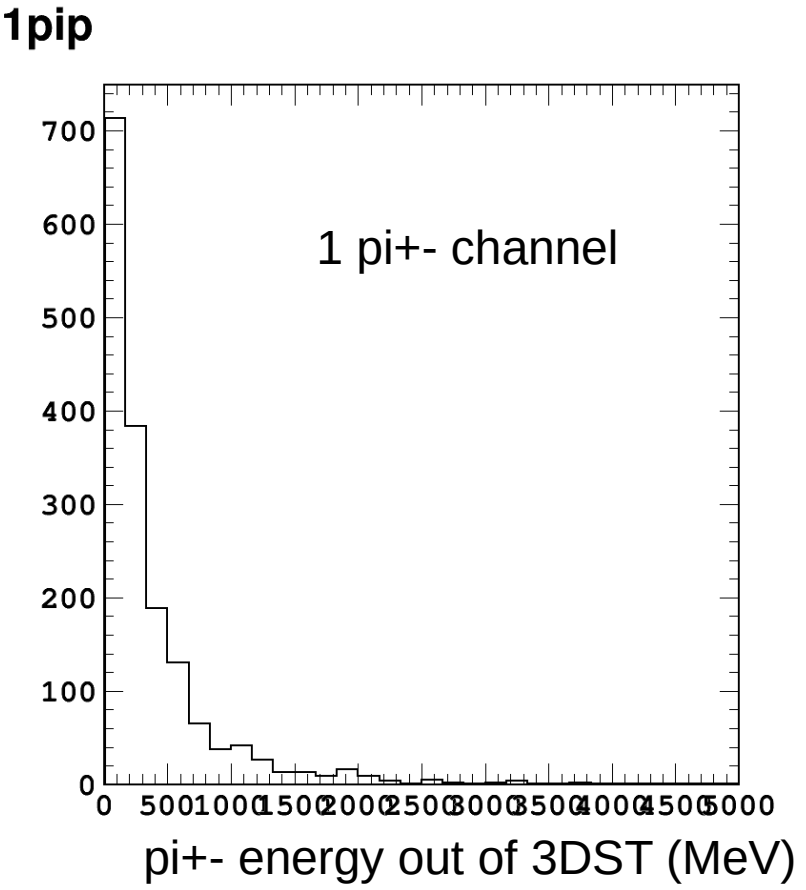






pi+- entering ECAL

- Charged pion can be reconstructed with TPC information largely



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Summary

- Simulation chain based on true information is ready for physics case demonstration
- In order to get a full picture, try to understand the performance of ECAL:

  - ability of energy and direction reconstruction of pions (pi0 and pi+-) and protons