

# 3DST software towards 3DST-S/K



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On behalf of the 3DST-KLOE working group



# Outline

- 3DST software flow
- KLOE software flow
- Plan for a unified group



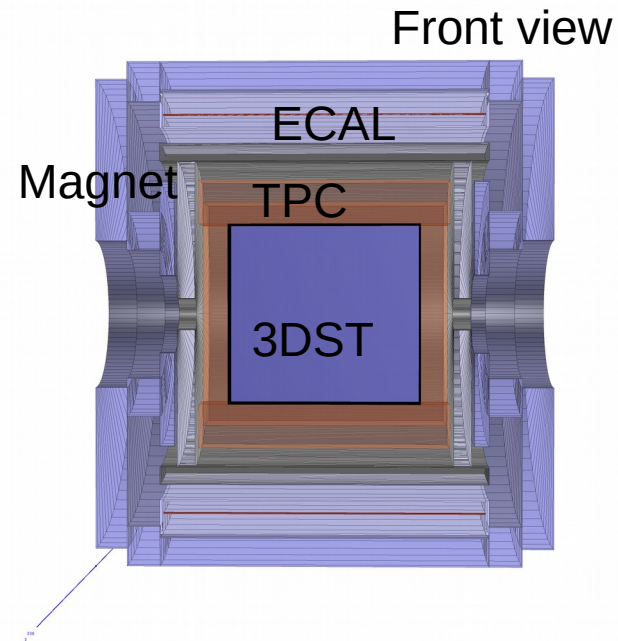
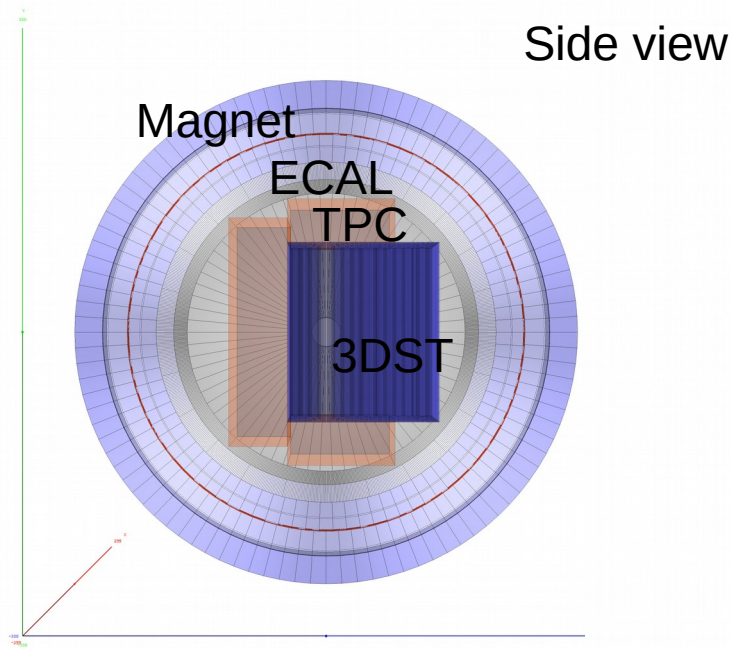
# Flow of 3DST software

- 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

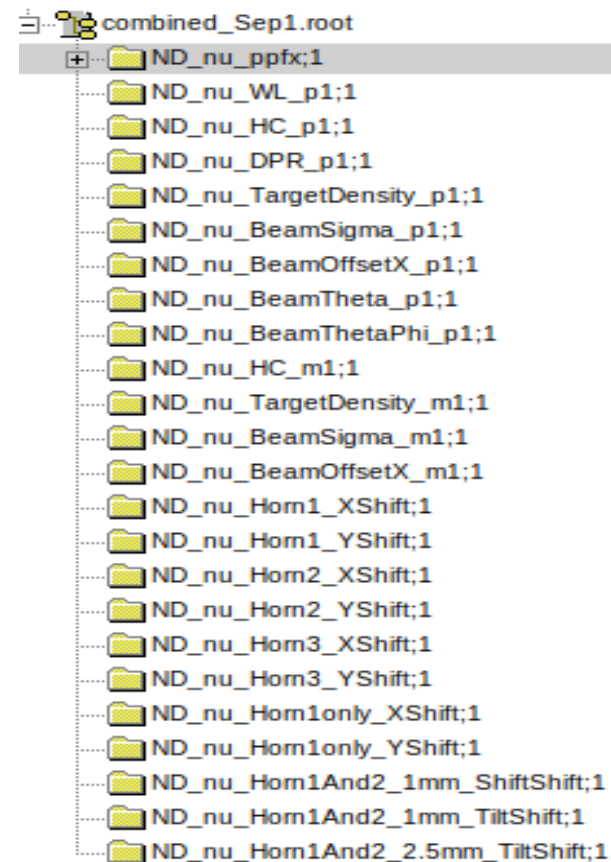
- We set up a basic 3DST concept in DUNE ND system: 3DST surrounded by TPC, ECAL and magnet
- Generated with DUNENDGGD: <https://github.com/gyang9/dunendggd>
- Layer structure: active volume → component volume → sub-detector → detector → detector hall → Rock world





# Neutrino flux generation

- One of the main tasks for 3DST is to do the beam monitoring. Therefore, we will have some self-generated neutrino flux samples with variations of the beam conditions.
- Some of these are available from the samples that used for the beam uncertainty evaluation for the LBL, but some are not.
- To generate the shifted spectrum, we will need to generate beam simulation from the geant level, which means g4lbnf will be used.
- A tool existing created initially for PRISM can help us on some of the tasks : <https://github.com/luketpickering/DUNEPrismTools/>

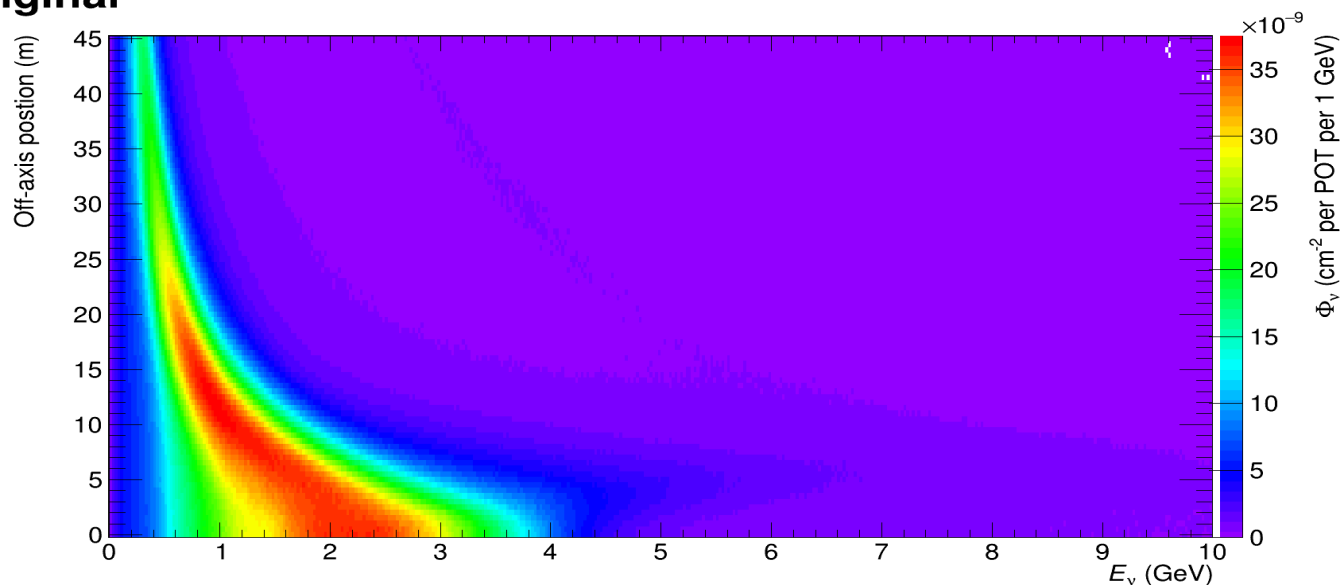




# Neutrino flux generation

- 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**



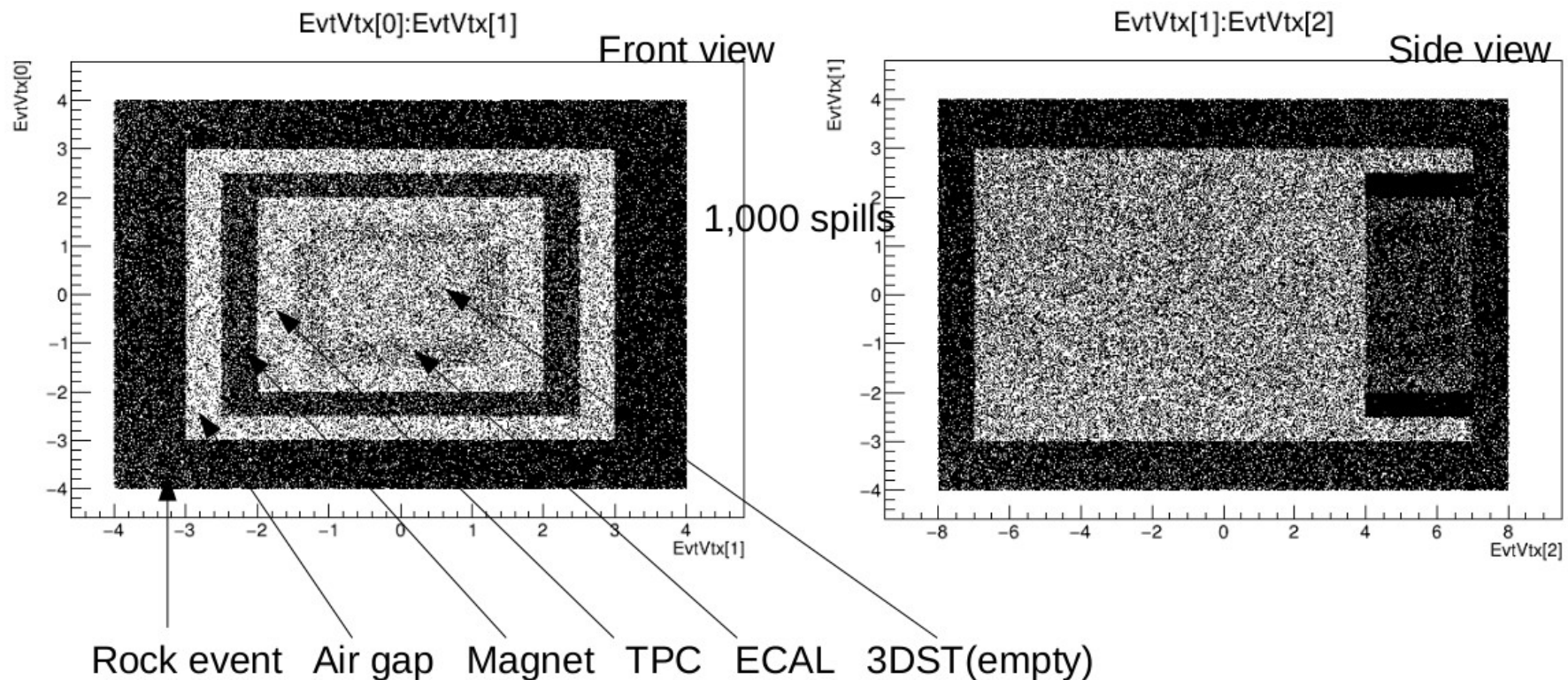




# Neutrino interaction

(showing an old geometry)

- GENIE (v2\_12):
  - whichever version used for the LBL should be used here.
  - running on fermi grid, software consistent with LBL

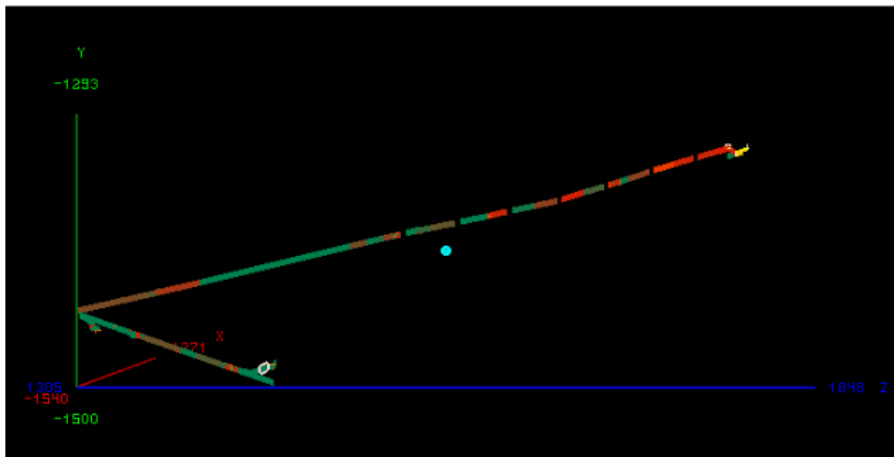




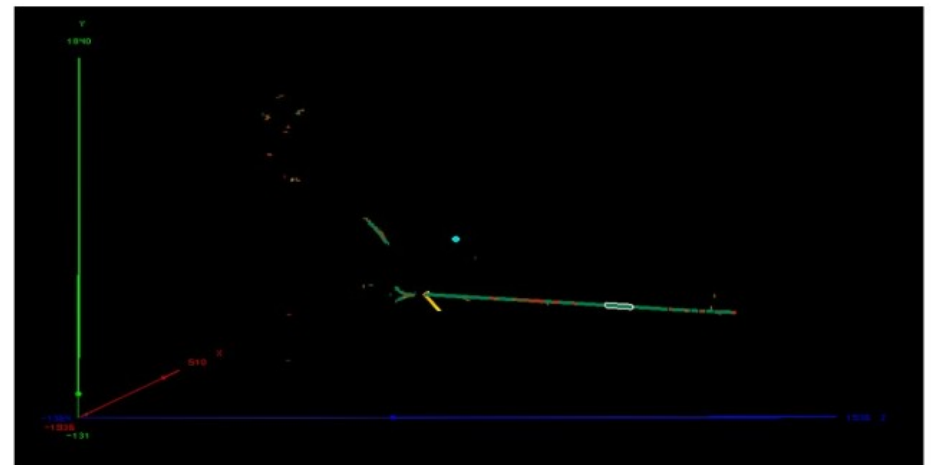
# Energy deposition

- 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  $\pi^0$  in 3DST





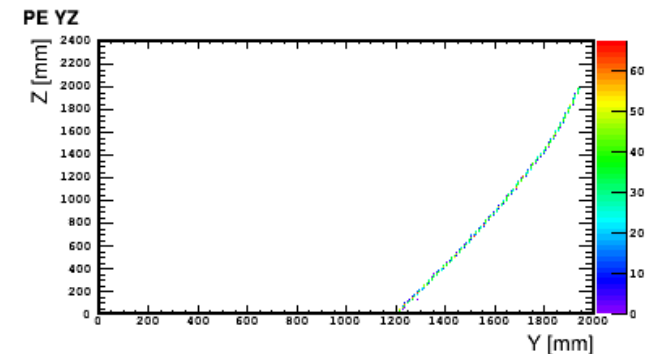
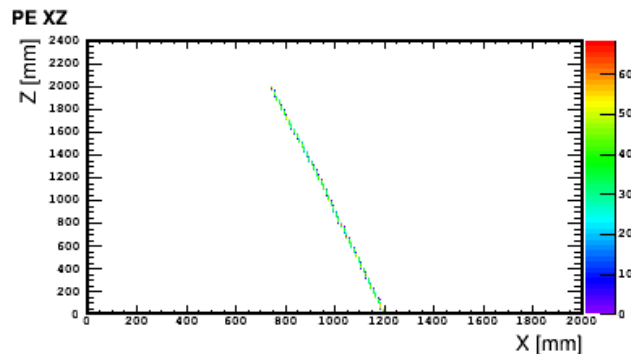
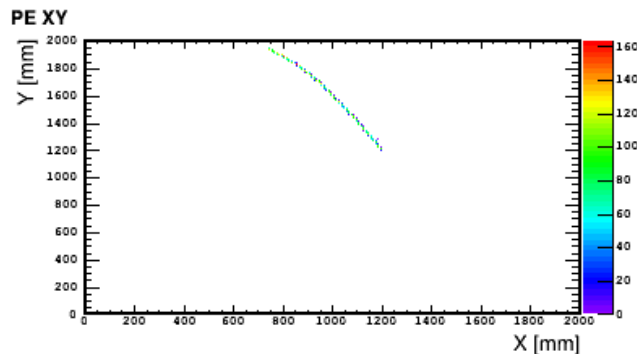


# Electronics simulation

- Electronics responses:

Conversion chain: edep  $\rightarrow$  photon captured in fiber  $\rightarrow$  light attenuation  $\rightarrow$  MPPC response

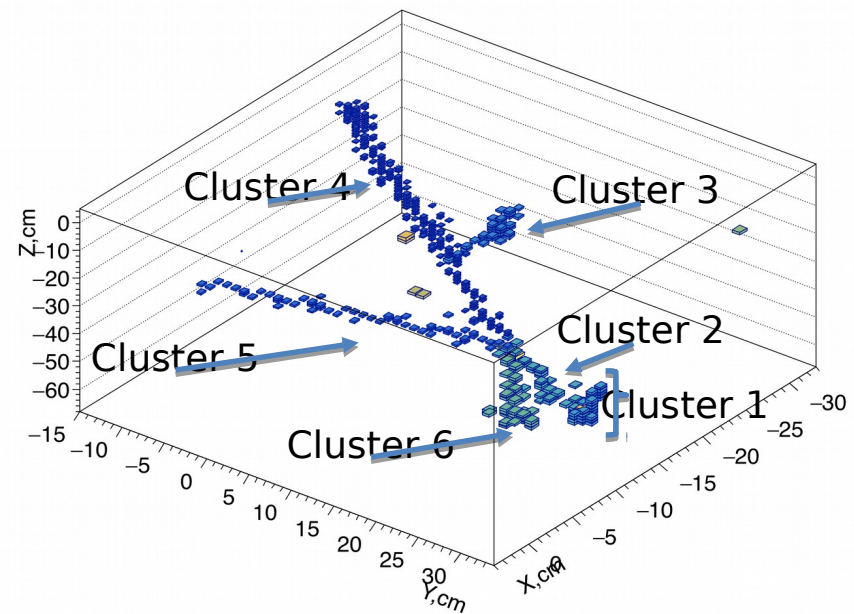
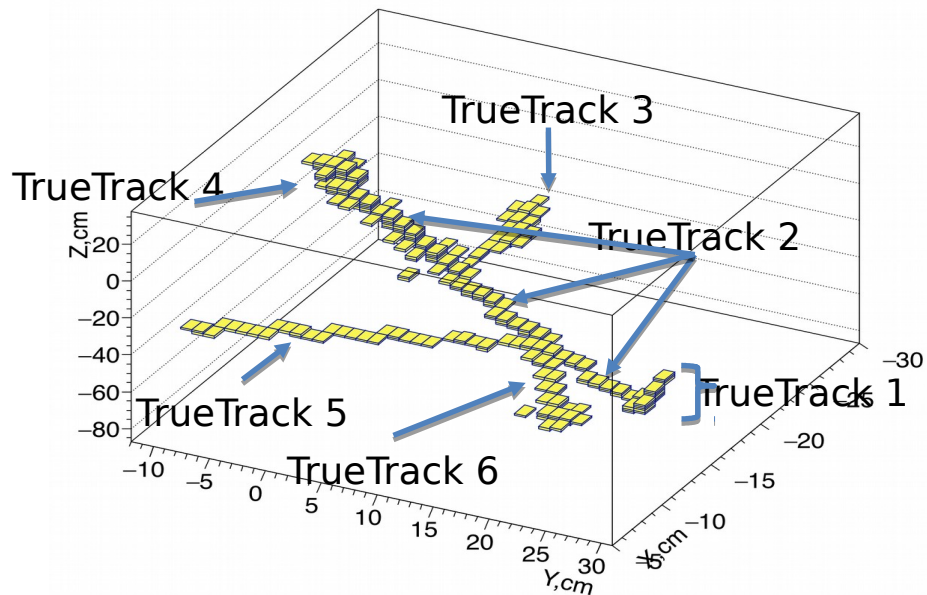
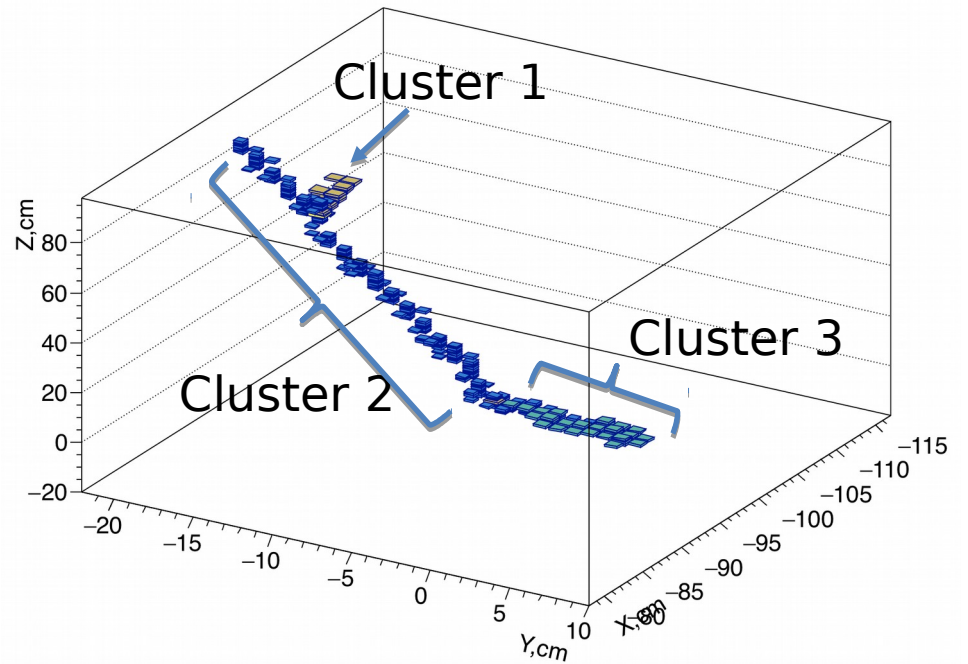
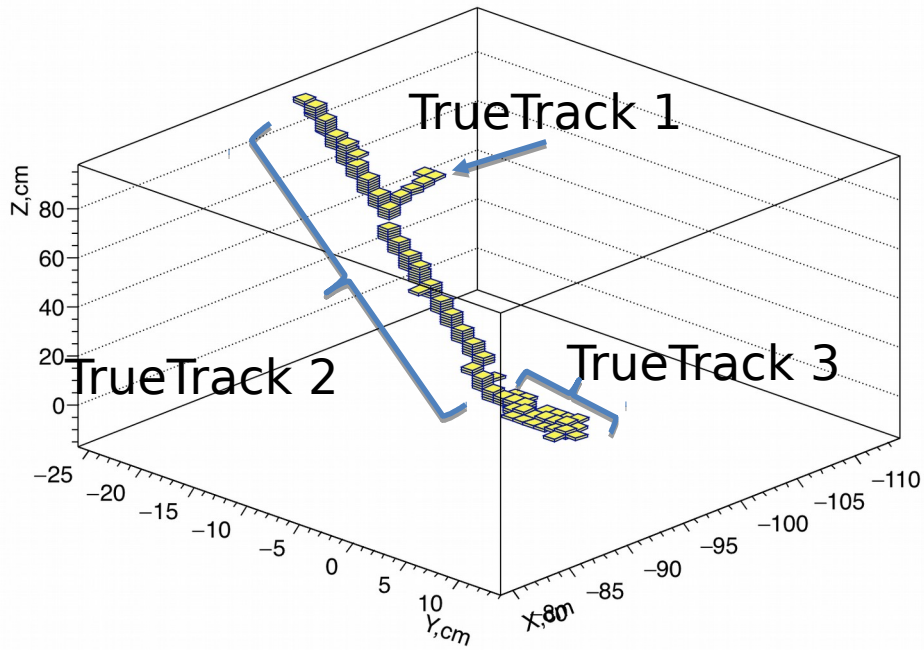
- Input edep-sim and output :
  - analysis tree containing final state particle high-level information
  - three 2D readout maps with electronics response applied
- In a sub-location of a package:  
<https://github.com/gyang9/DUNE3dstTools/tree/master/src/elecSim>





# Reconstruction

- 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?





# Reconstruction

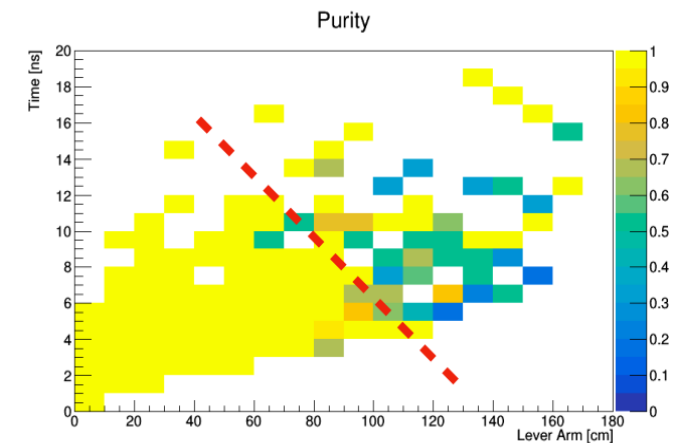
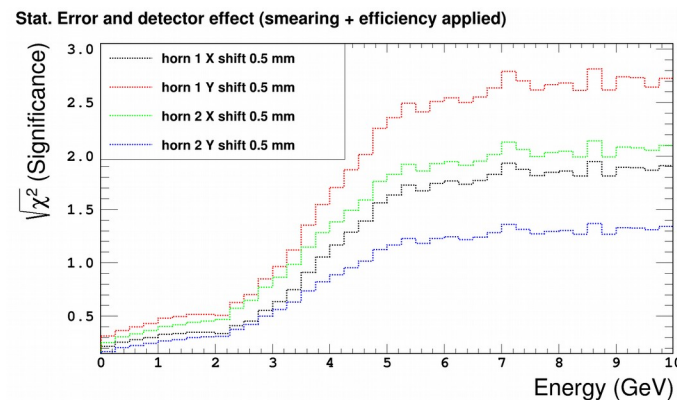
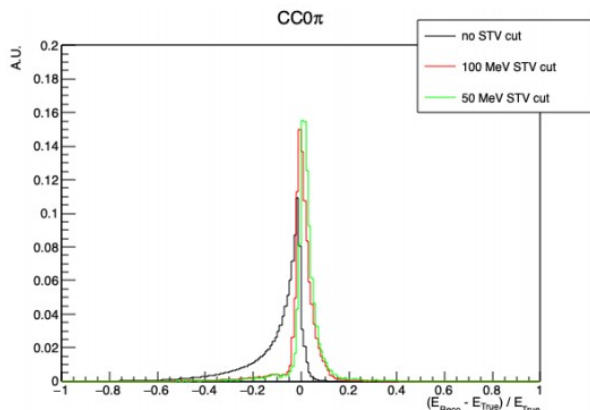
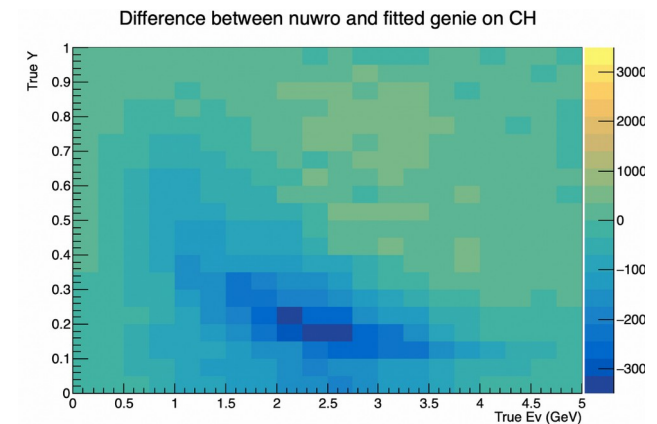
- Work is being done by Sergey Martynenko at SBU
- Sergey's conclusion at this point:
  - Test reconstruction techniques as a set of separate root scripts:
    - 3D hits are created and clustered;
    - Clusters are split into track-like objects;
  - First look at the effectiveness of pattern recognition algorithms:
    - Hit finding works well with crosstalk (small amount of Ghost Hits);
    - Charge Adjustment works with crosstalk;
    - Clustering and track splitting works well with crosstalk, but quantitatively tested only without crosstalk
  - Temporary code is on GitHub:
    - <https://github.com/rennney/CubeRecon>
  - Future:
    - Understand True information in MC with crosstalk to quantify clustering properly;
    - Define efficiency for complex events;
    - Continue working on Track fitting and Shower search algorithms



# Analysis

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

NuModel	Ar-C model tuning
beamMonitoring	Beam monitoring
elecSim	Electronics simulation
fluxSTV	Single transverse variable with neutron measurement
nBKG	Neutron out-of-FV background evaluation (from Manoa)
reco	Reconstruction (from Sergey)
CMakeLists.txt	





# Analysis

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

📁 NuModel

- Neutrino on CH and Ar interaction tuning with GENIE and NUWRO

📁 beamMonitoring

📁 elecSim

- Beam monitoring sensitivity to various beam condition changes

📁 fluxSTV

📁 nBKG

- Electronics Simulation

📁 reco

- Single transverse variable for flux constraint

📄 CMakeLists.txt

- Neutron background study to obtain pure neutron sample on the space of arm and time
- Reconstruction from 3 2D maps



# Flow of KLOE (from Matteo)

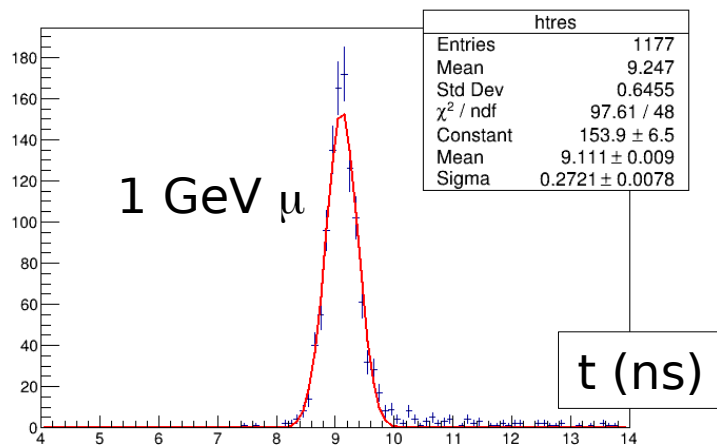
- Aim:
  - evaluate (KLOE + 3DST + STT) performances
  - compare them with (KLOE + STT only) ones
- Ingredients:
  - Flux: Optimized 3-Horn Design (<https://home.fnal.gov/~ljf26/DUNEFluxes/>)
  - Geometry: based on <https://github.com/gyang9/dunendggd>
  - Neutrino Event Generator: GENIE
  - Energy Deposition: Edep-sim (<https://github.com/ClarkMcGrew/edep-sim>)
  - Digitization, Reconstruction and Analysis: independent tools (<https://baltig.infn.it/dune/kloe-simu>)





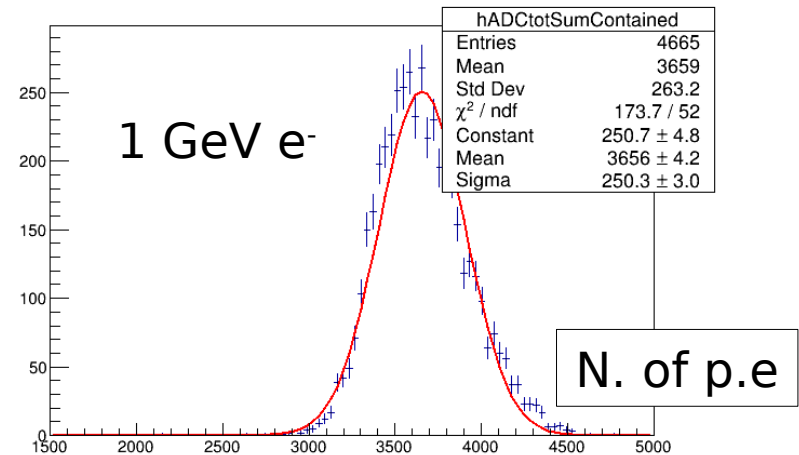
# Flow of KLOE: Geometry (from Matteo)

- Implementation of a recipe from KLOE Collaboration to reproduce measured time and energy resolution of EM calorimeter



The resolution is 260 ps, in agreement with a scaling law of  $\sim 54 \text{ ps}/\sqrt{E(\text{GeV})}$  considering a 40 MeV equivalent energy release.

[10.1016/S0168-9002\(01\)01502-9](https://doi.org/10.1016/S0168-9002(01)01502-9)



an energy resolution of  $5.7\%/\sqrt{E(\text{GeV})}$

- Implementation of STT tracker around 3DST: on going



# Flow of KLOE: Digitization, Reconstruction & Analysis

(from Matteo)

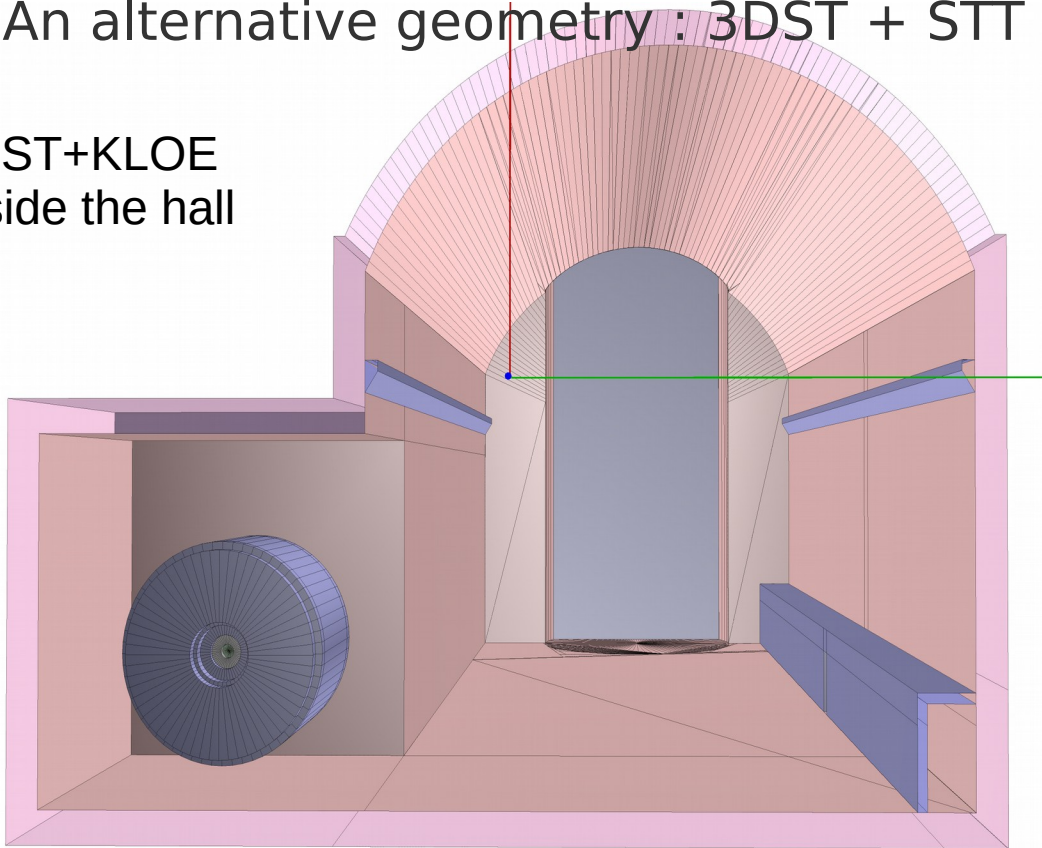
- Digitization:
  - Calorimeter: energy deposit → photons → attenuation → photo-electrons → time and ADC signal
  - STT: smearing of hit position
- Reconstruction:
  - STT:
    - Track ID using MC truth info
    - Track Fit with a circle or using GENFIT
  - Calo:
    - Cluster reco using MC truth info
- Analysis:
  - Momentum measurement from STT track Fit
  - Energy measurement from EM Calo Cluster
  - Particle ID using MC truth



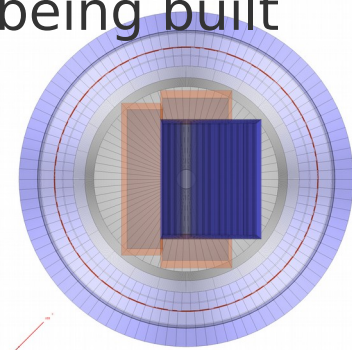
# Detector hall and Geometry

- Detector hall is ready (written by 3DST group with DUNENDGGD)
- 3DST + TPC inside KLOE
- An alternative geometry : 3DST + STT + KLOE, being built

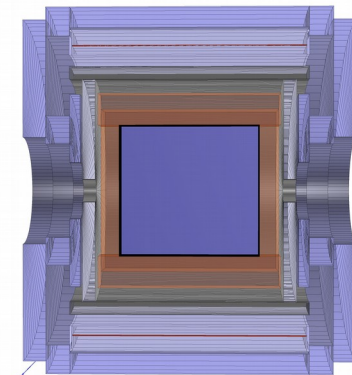
3DST+KLOE  
Inside the hall



Side view



front view





# Summary and plans

- The 3DST and KLOE software flow has been built and used for a while → robust.
- 3DST group is working with KLOE group to form a single group in order to maximize our capability.
  - Two geometry options :
    - 3DST + TPC + KLOE → contact persons: Davide and Guang
    - 3DST + STT + KLOE → contact persons: Matteo and Lea
  - We will have a consistent geometry, event generation and Geant4 tool.
  - All low level samples will be generated in a consistent way then input into higher level analysis tools.