CDR Samples & Initial Validations

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DESY ND Workshop
Oct. 23, 2019

Fermilab

Overview of Generated Samples & Next Steps

- Need a common set of GENIE samples used by all sub-detector groups in preparation for CDR (preferably all samples combined in some type of a spill structure)
- Each ND subgroup would then take these GENIE samples and simulate detector effects – my focus in this talk is on MPD so will focus on how MPD is using these samples:
  - Eldwan and I recently added a parametrization module in GArSoft for working with these samples (https://github.com/tmohayai/ParamSim)
    - Level of parametrization: momentum & angular smearing – for long tracks use Gluckstern, and for short tracks, use range – then reasonable tracklength threshold cut (tracklength > 5 cm for all particles but we may remove this feature to give analyzers more freedom to choose the threshold for each FS particle), & PID parametrization from Tom Junk
    - To make proper use of the GENIE samples in GArSoft, however, we need to covert to art – R. Hatcher's AddGENIEtoArt module does exactly that – currently being investigated by A. Furmanski
- In this talk: validation of the samples – rock, MPD, 3DST, LArTPC + more detail about the parametrized simulation

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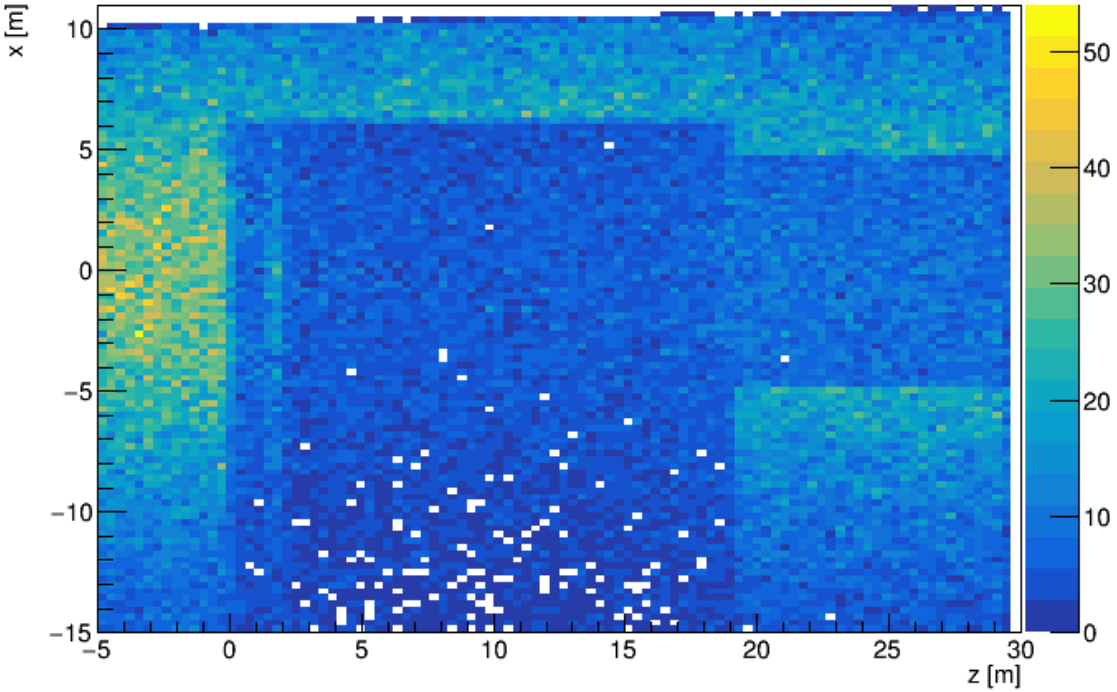
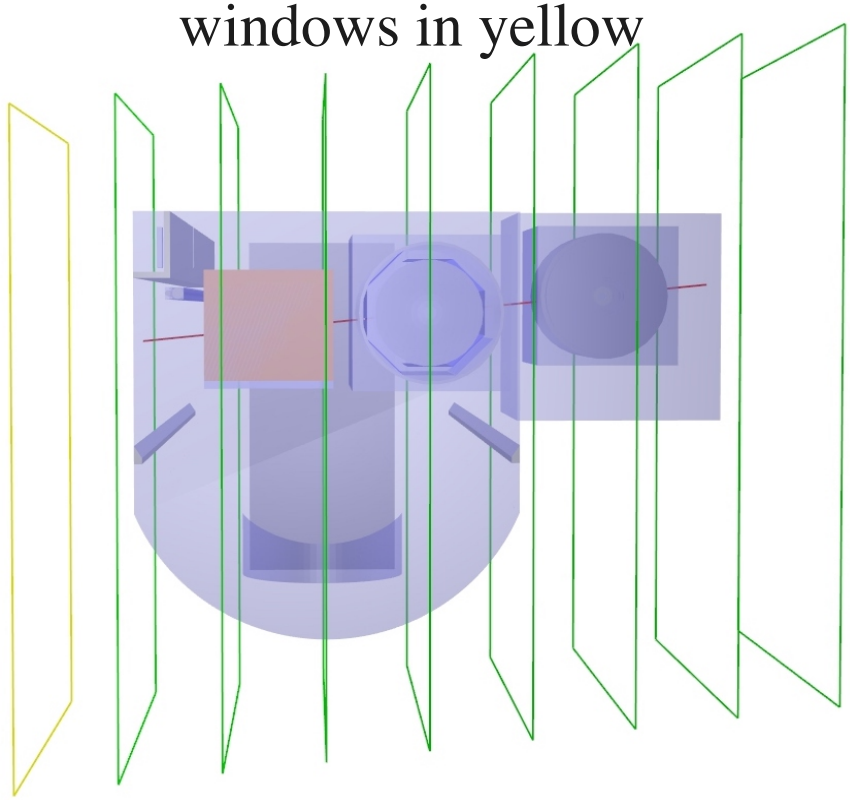
Rock ν-interaction Vertices

- Rock interaction vertices – first step to generating the rock samples for overlay with MPD (and other sub-detectors)
- As expected, the vertices carve out the rock surrounding the detector hall



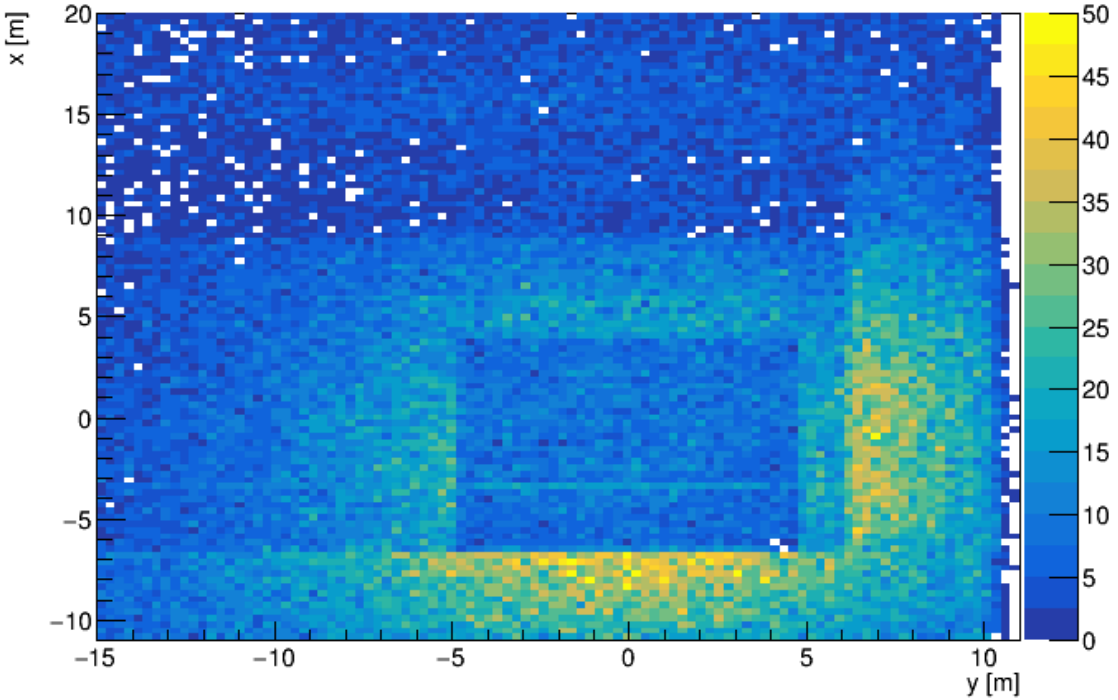
detector hall along with its flux windows in yellow

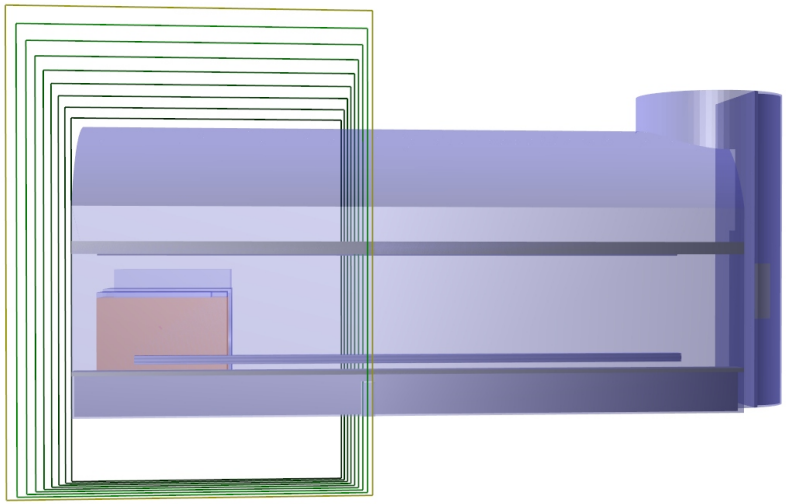


Note: geometry used for detector hall has no sub-detectors in the hall

Rock ν-interaction Vertices

- Rock interaction vertices
- xy projection of the vertices – on the right: xy orientation of the detector hall for comparison





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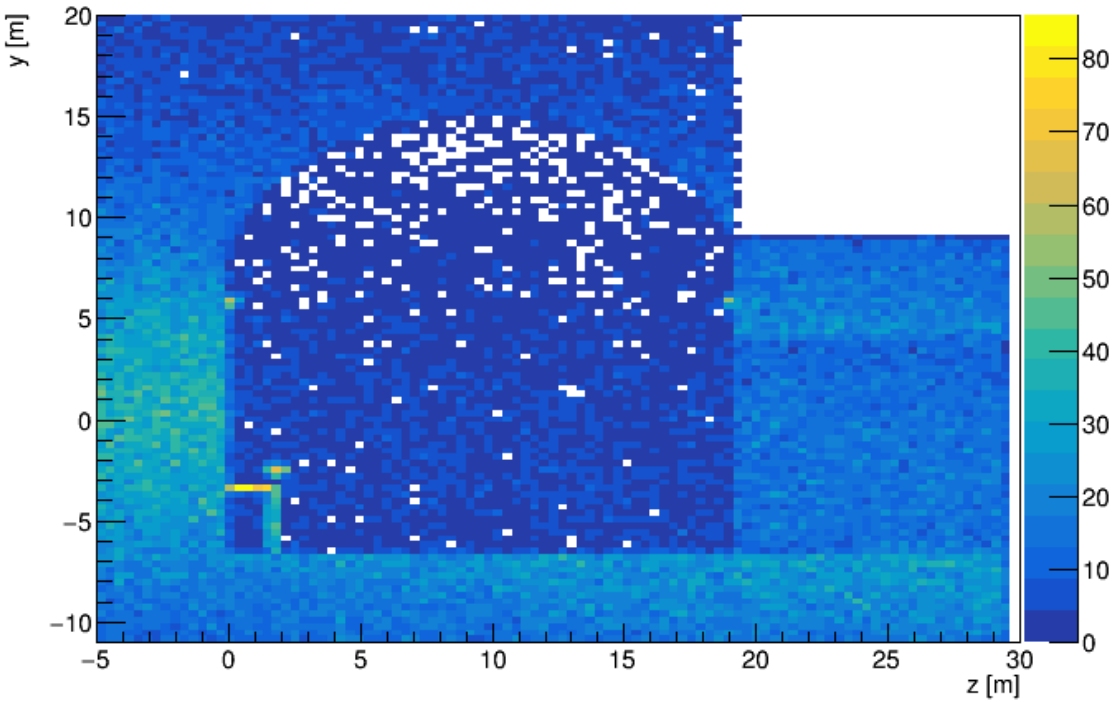
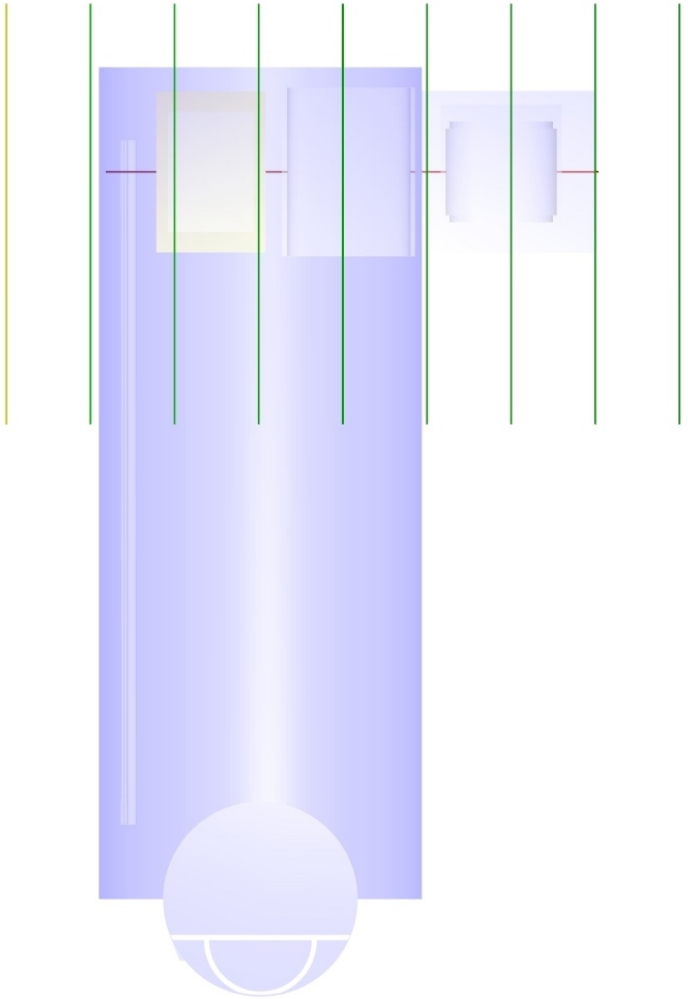


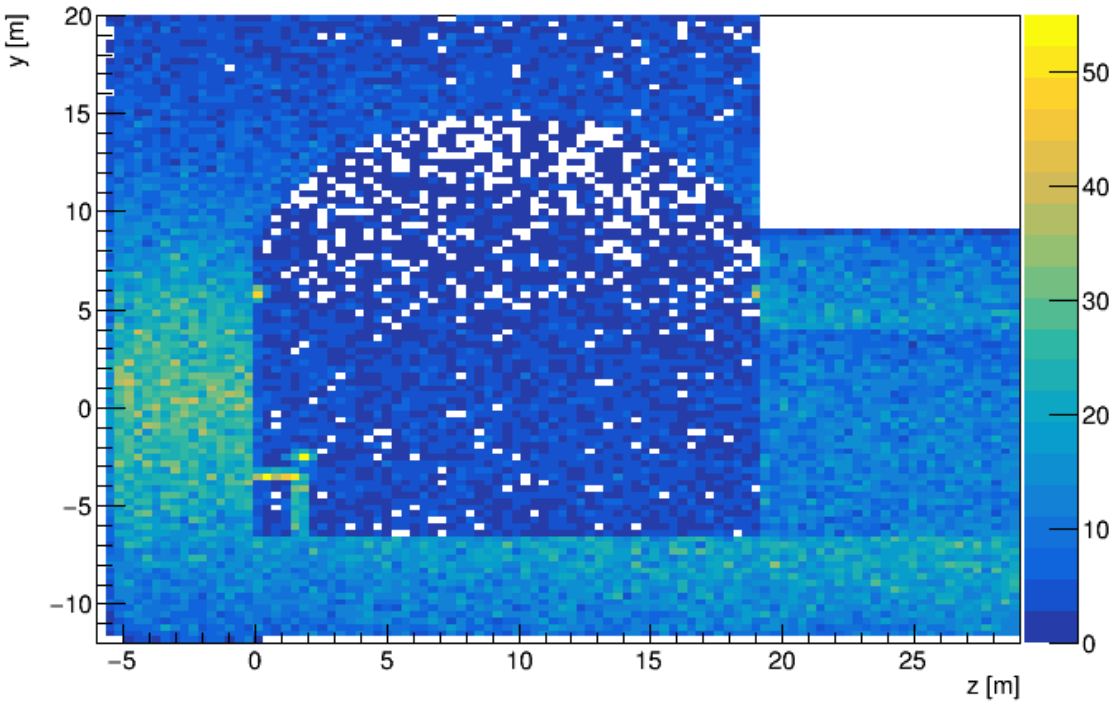


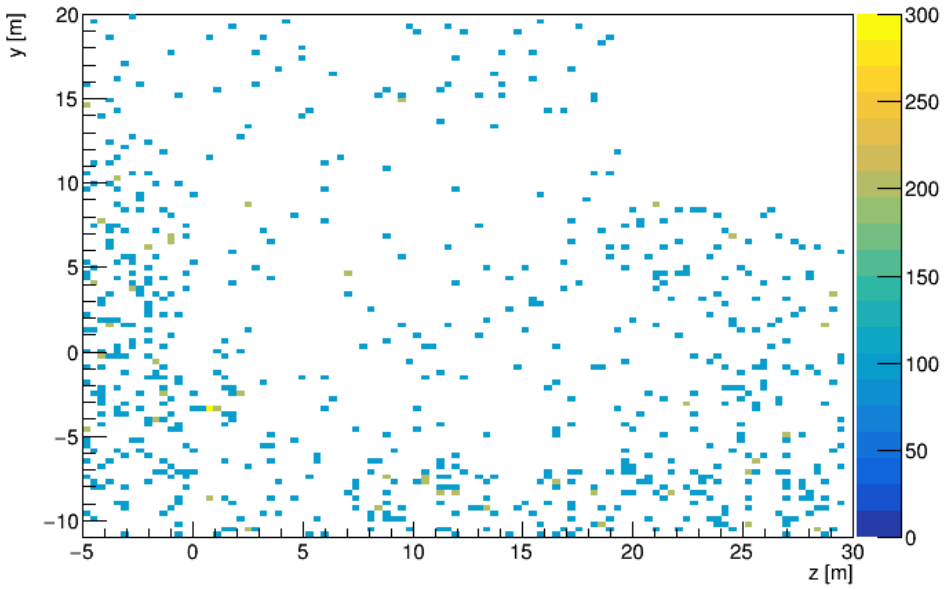
Rock ν-interaction Vertices

but not all rock ν-interaction vertices need to be kept

Primary Particles from Rock ν-interaction Vertices

- Stable final state μs (as an example) produced from ν-rock interactions get propagated in rock volume using GEANT4 – this slide shows where they start from and where the ones that make it to the detector hall start from:
  - As expected, they start at the vertex but only those that make it to detector hall are kept





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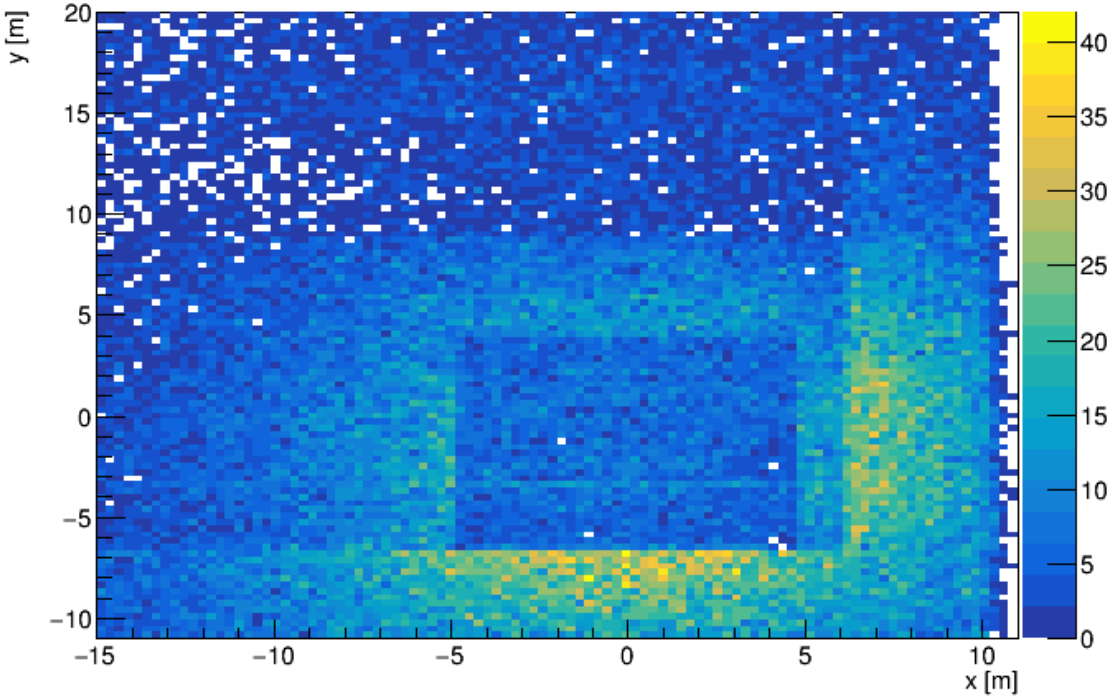

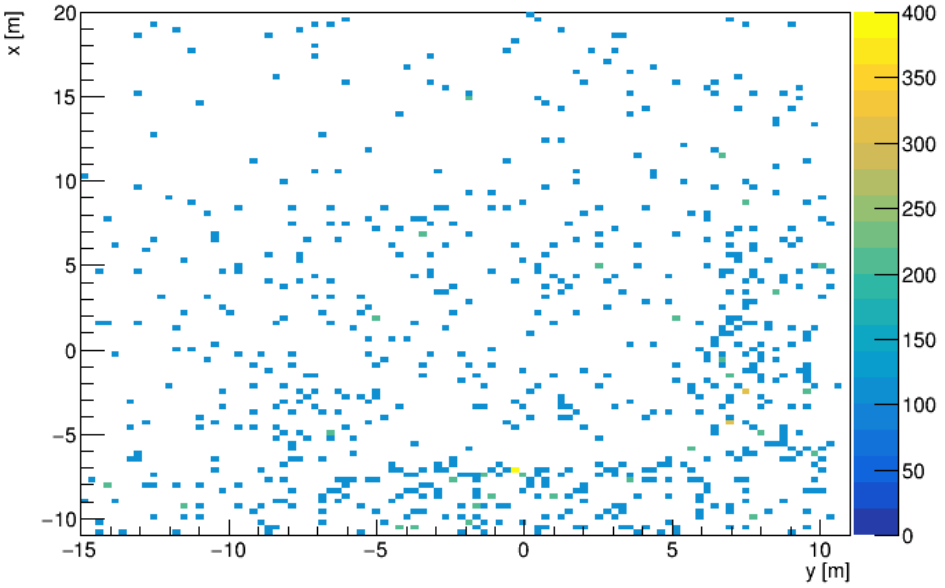

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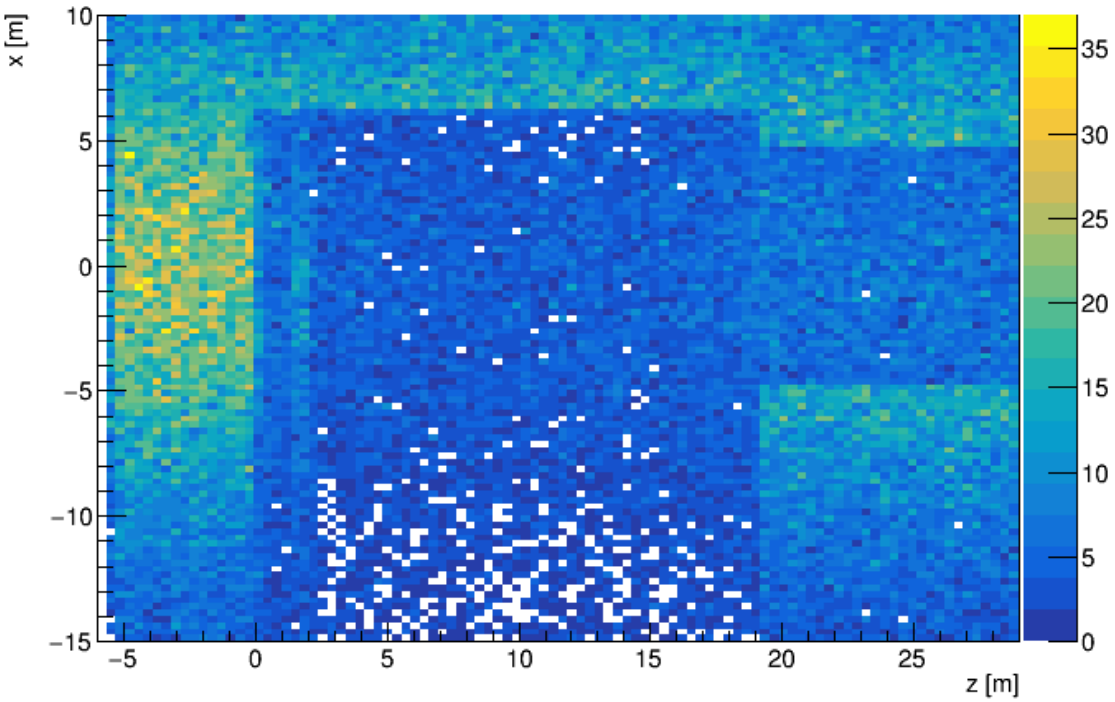

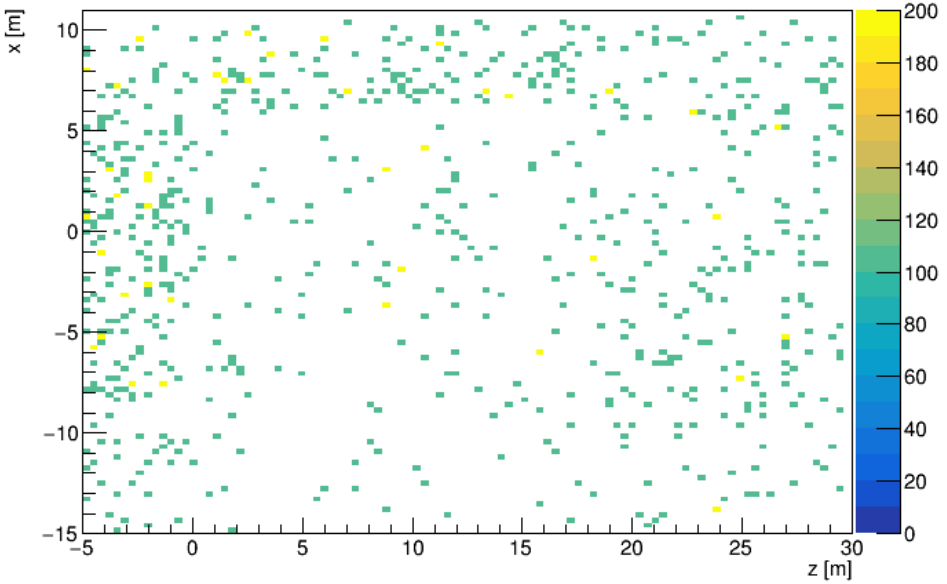

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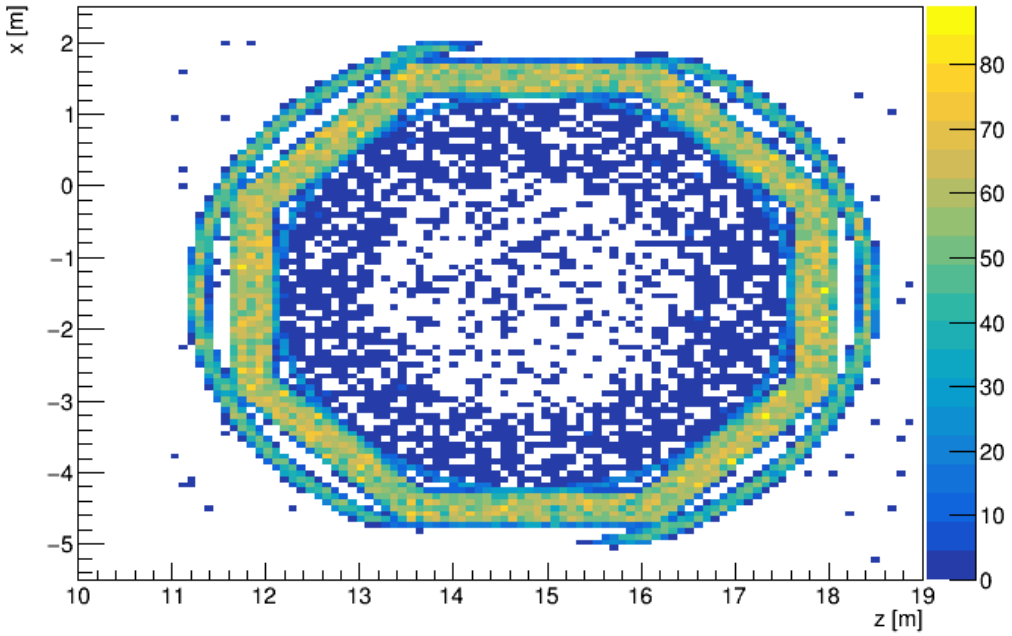
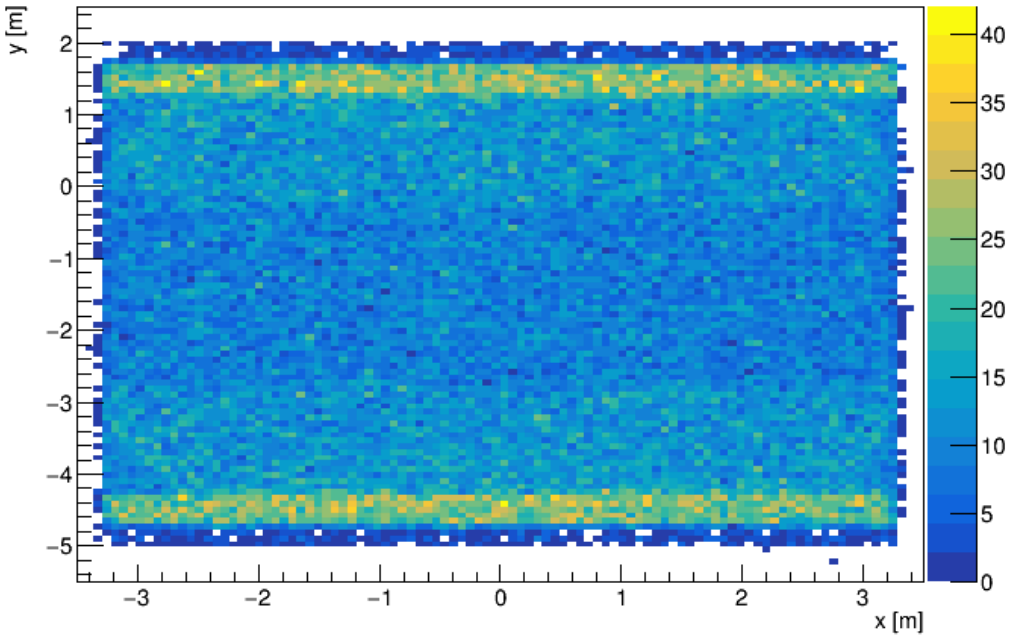
ν-interactions Vertices in MPD

- Top volume MPD used for generating the sample consists of the TPC, ECAL, & Magnet
- This will be overlayed with rock samples – preliminary look at the vertices indicates that a notable number of neutrinos interact in the ECAL & magnet





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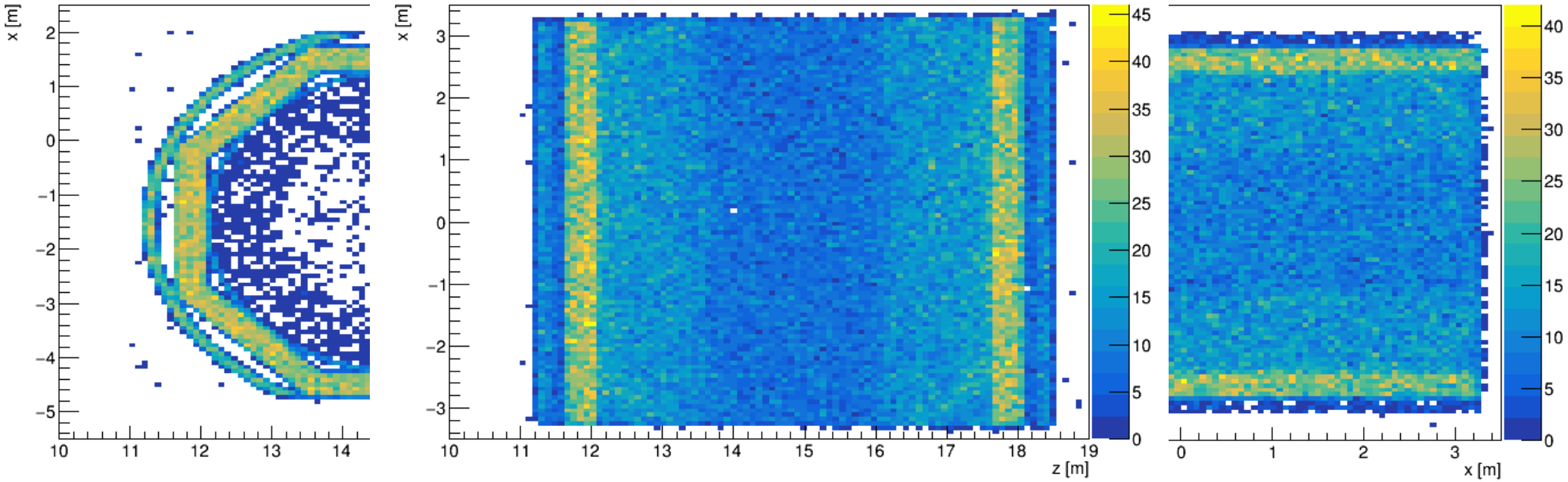

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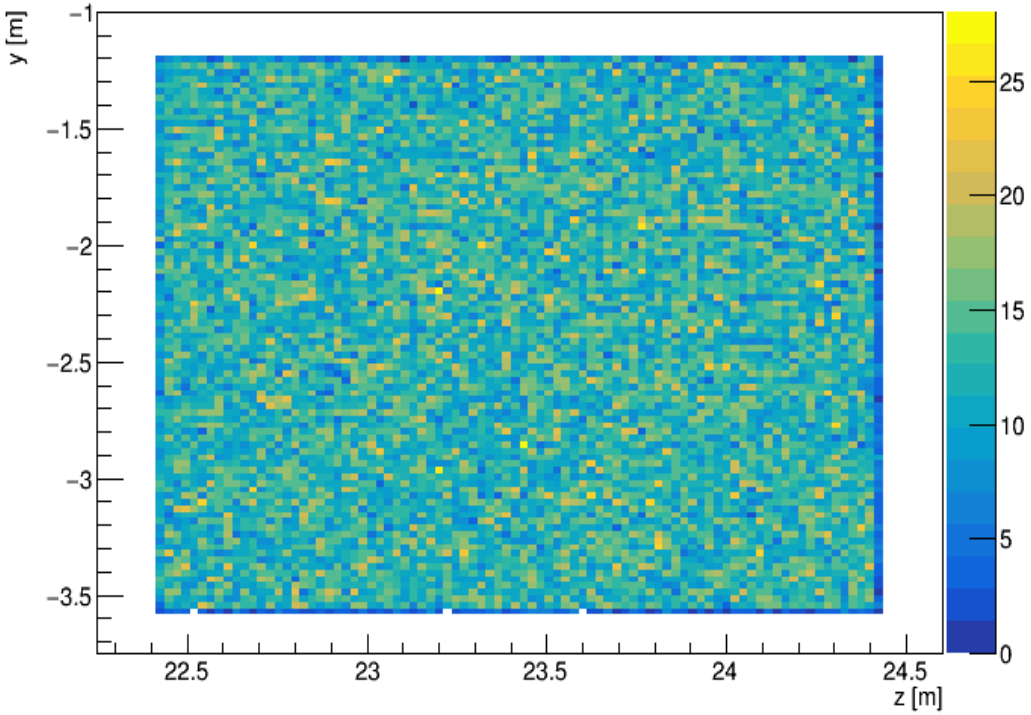
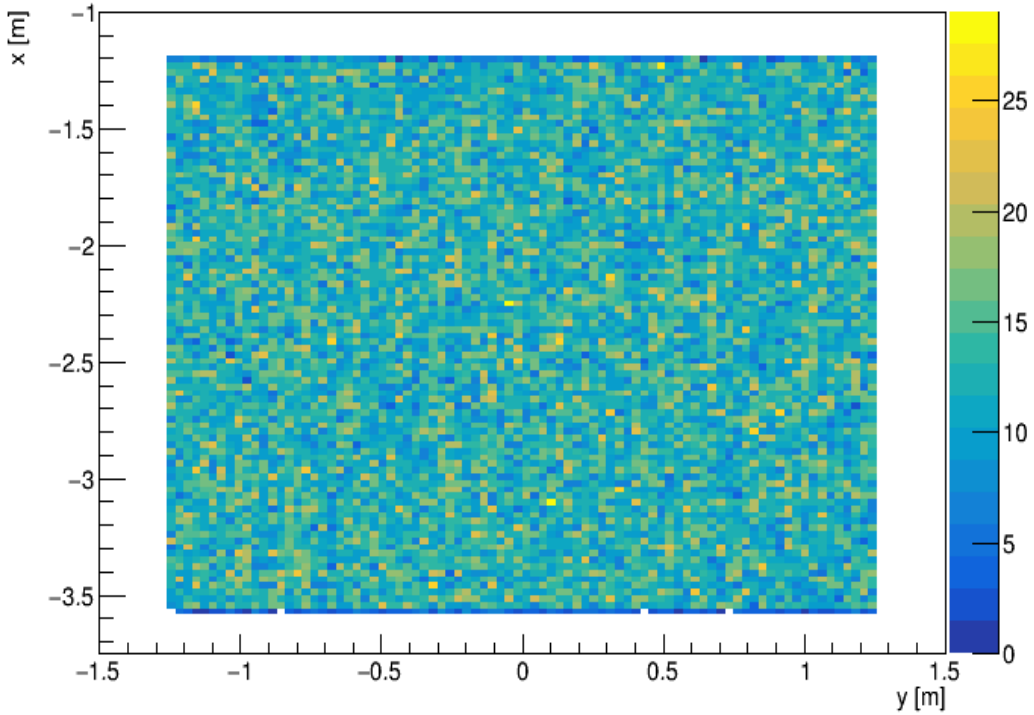
ν-interactions Vertices in 3DST

- Top volume 3DST
- To be overlayed with rock samples by 3DST sub-detector experts





ν-interactions Vertices in 3DST

- Top volume 3DST
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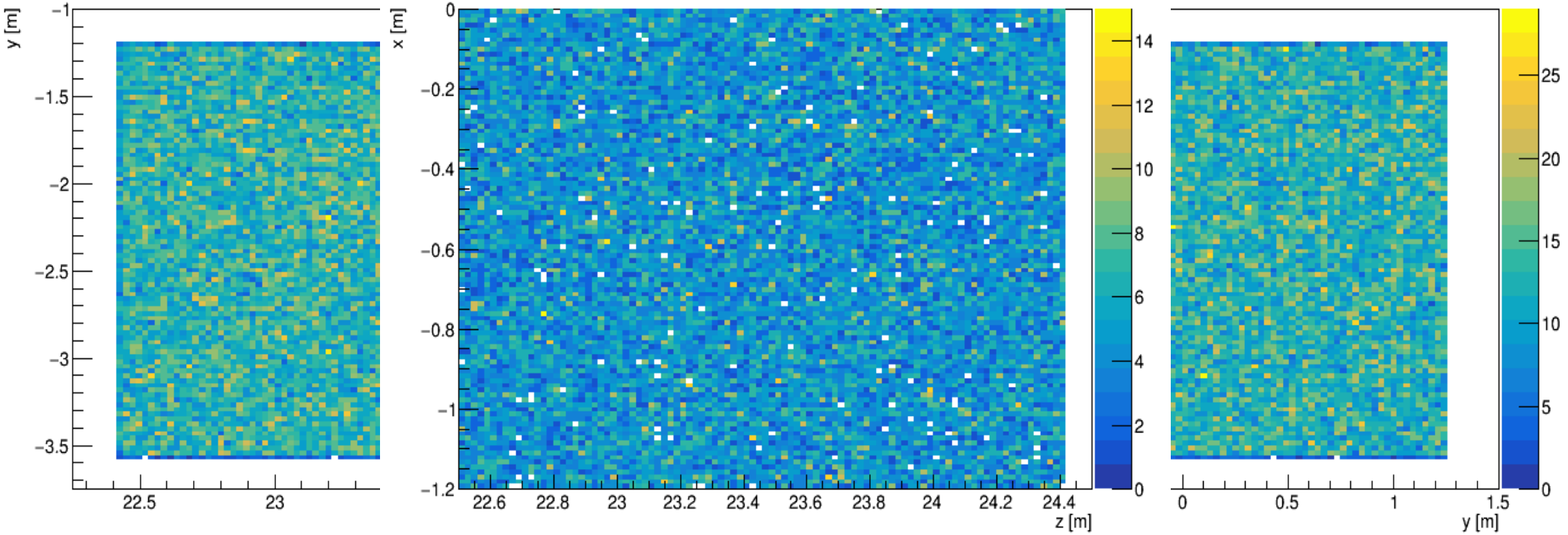

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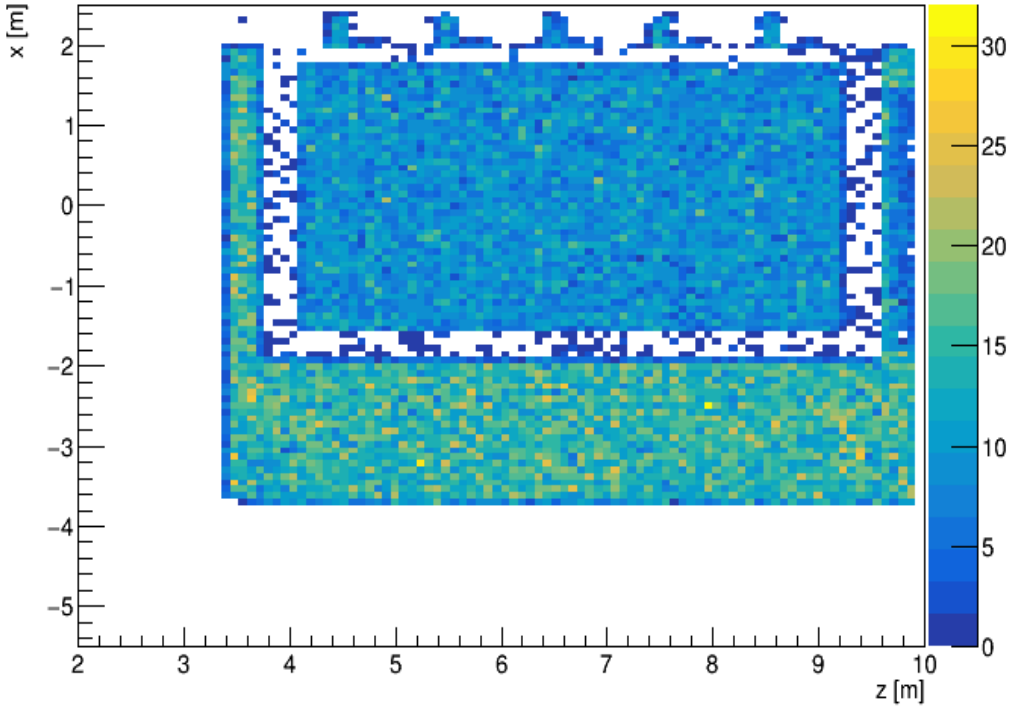
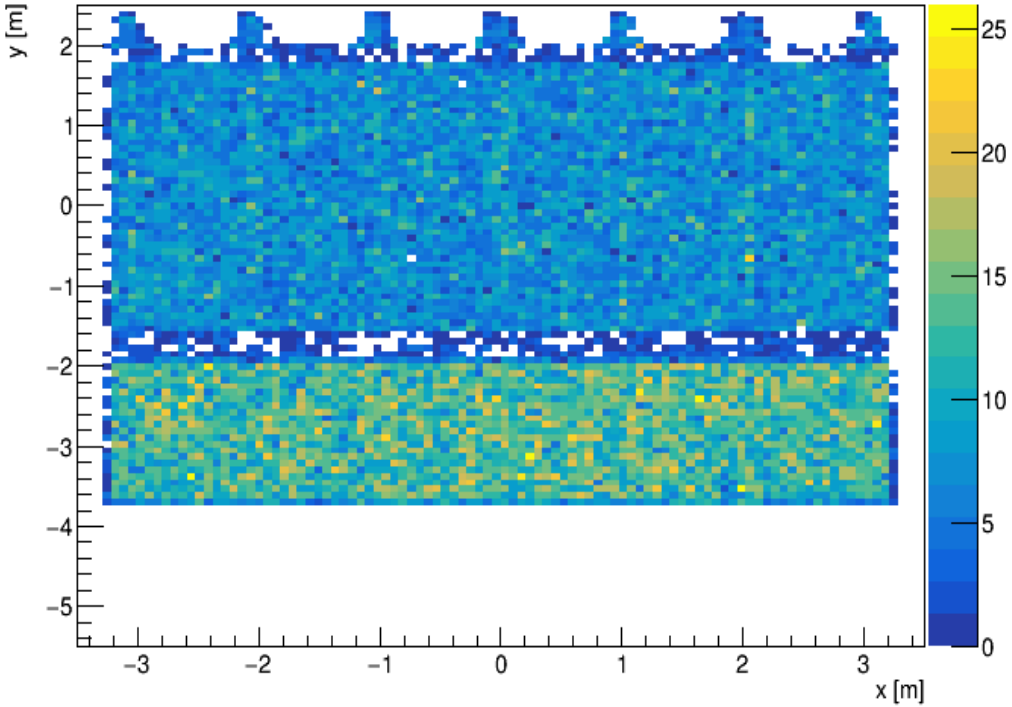
ν-interactions Vertices in LArTPC

- Top volume ArgonCubeDetector
- A separate sample already overlayed with rock but this could be used for other combined GArTPC-LArTPC studies





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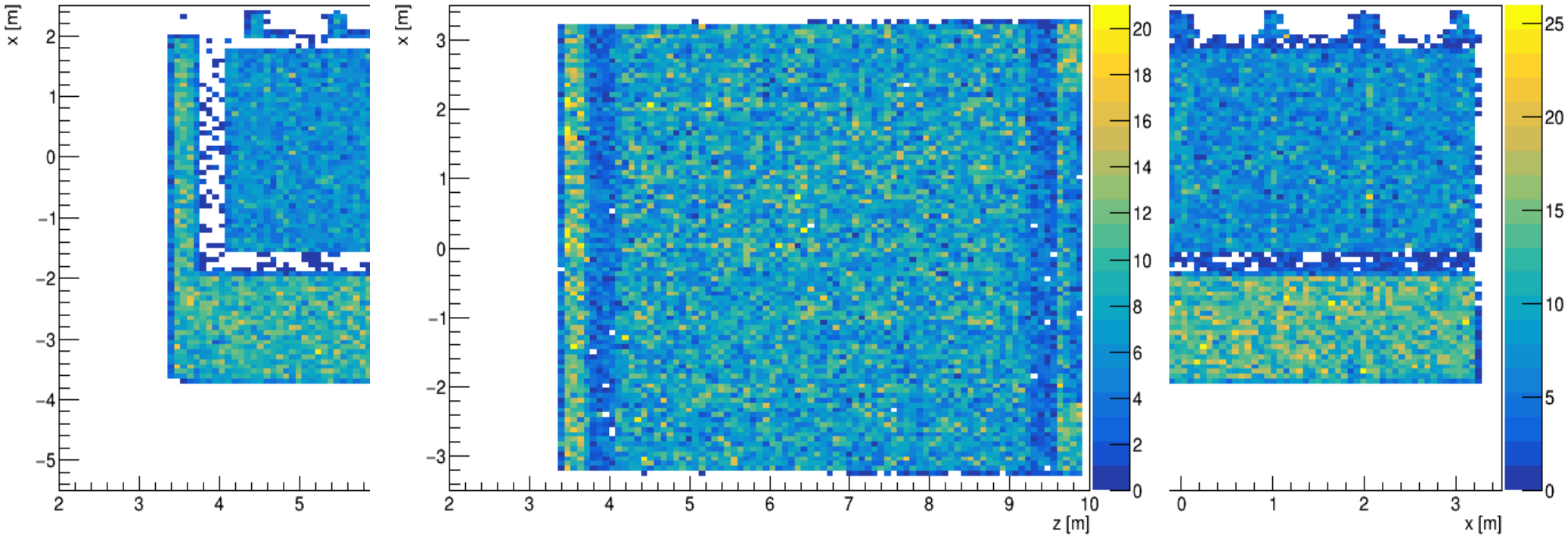

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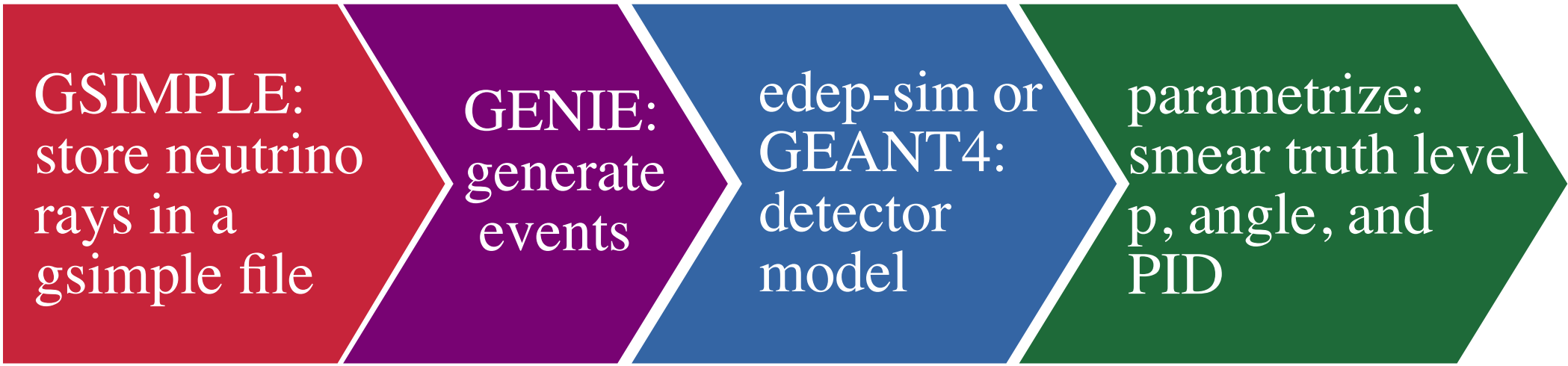
MPD Parametrized Simulation – For Use with Generated Samples

- Why a parametrized simulation:
  - ★ CDR timeline is aggressive – a dedicated simulation effort based on parametrization of common assumptions can help
- End goal: create a module that can read both edep-sim and GEANT4 ntuples containing the truth-level information and produce CAF files
- Module for reading edep-sim already in place and first iteration working. Whether edep-sim or GEANT4, the roadmap is the same:



- New module for reading a GArSoft ntuple (or GEANT4) by **Eldwan and myself**
- An overview of the existing features of this module to follow

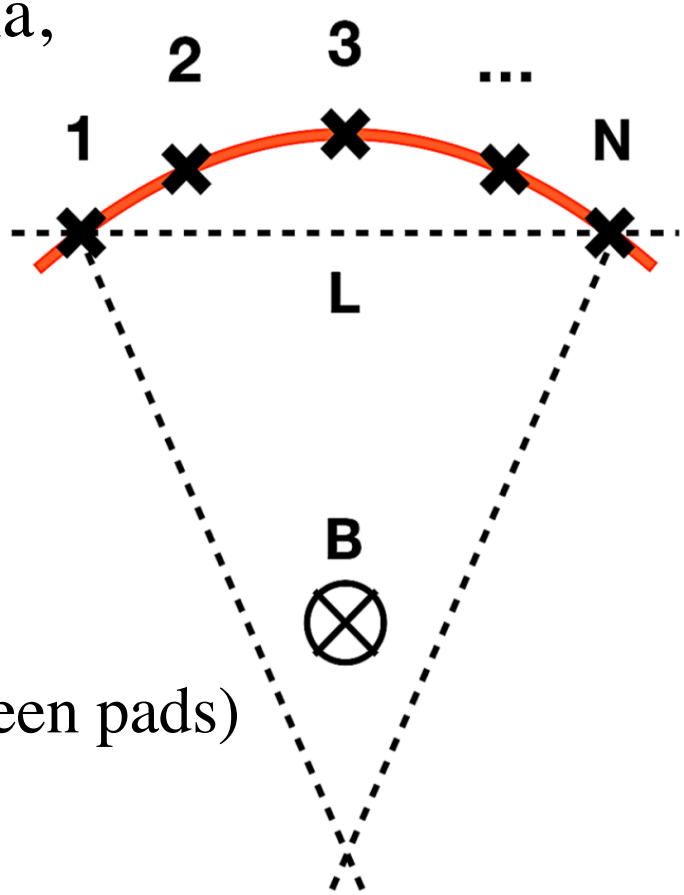
Momentum Smearing

- Momentum smearing: if track is long, smear transverse and total momentum using the σ from Gluckstern formula,

Measurement Term

$$\left(\frac{\sigma_{P_\perp}}{p_\perp}\right)^2 = \left(\frac{\sigma_{\text{point}}\ p_\perp}{0.3\ B\ L^2}\sqrt{\frac{720}{N+4}}\right)^2 + \left(\frac{0.05}{B\ L}\sqrt{\frac{1.43\ L}{X_0}}\right)^2$$

Scattering Term



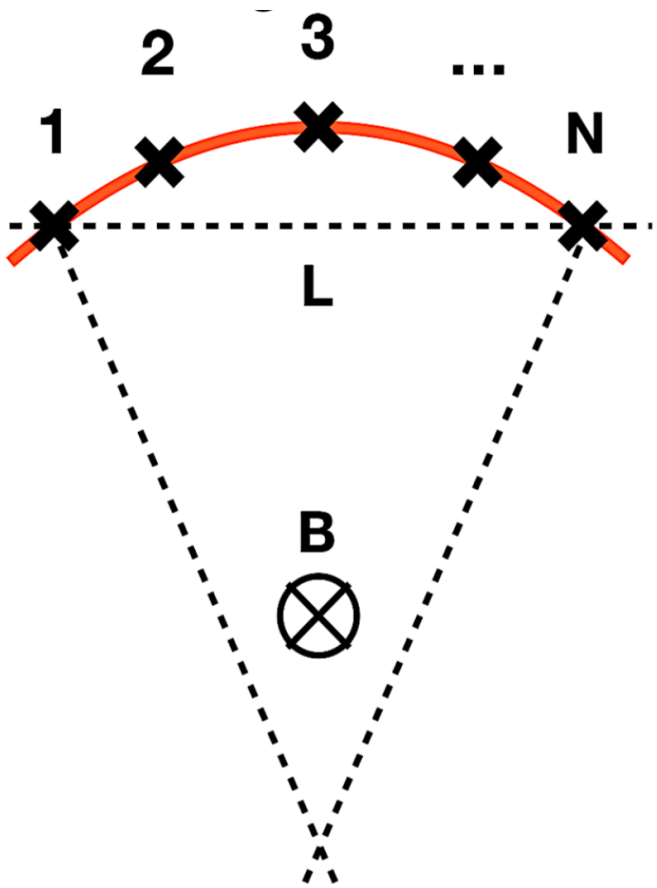
σ_p: 1e-3 m (distances between the readout pads)
B: 0.4 T
N: # of trackpoints (tracklength / distances between pads)
L: tracklength $\perp$ to beam direction
X_0: 13 m

- Momentum smearing: if track is short, use range – smear by a percentage and take the average of the momenta at every track point

Angular Smearing

- Angular smearing: if track is long, smear angle (wrt incoming ν-beam) using the σ from Gluckstern formula,

$$\sigma_\theta^2 = \left(\frac{\sigma_L}{L}\sqrt{\frac{12(N-1)}{N(N+1)}}\right)^2 + \left(\frac{0.015}{\sqrt{3}p}\sqrt{\frac{L}{X_0}}\right)$$



σ_L: 1e-3 m (distances between the readout pads)
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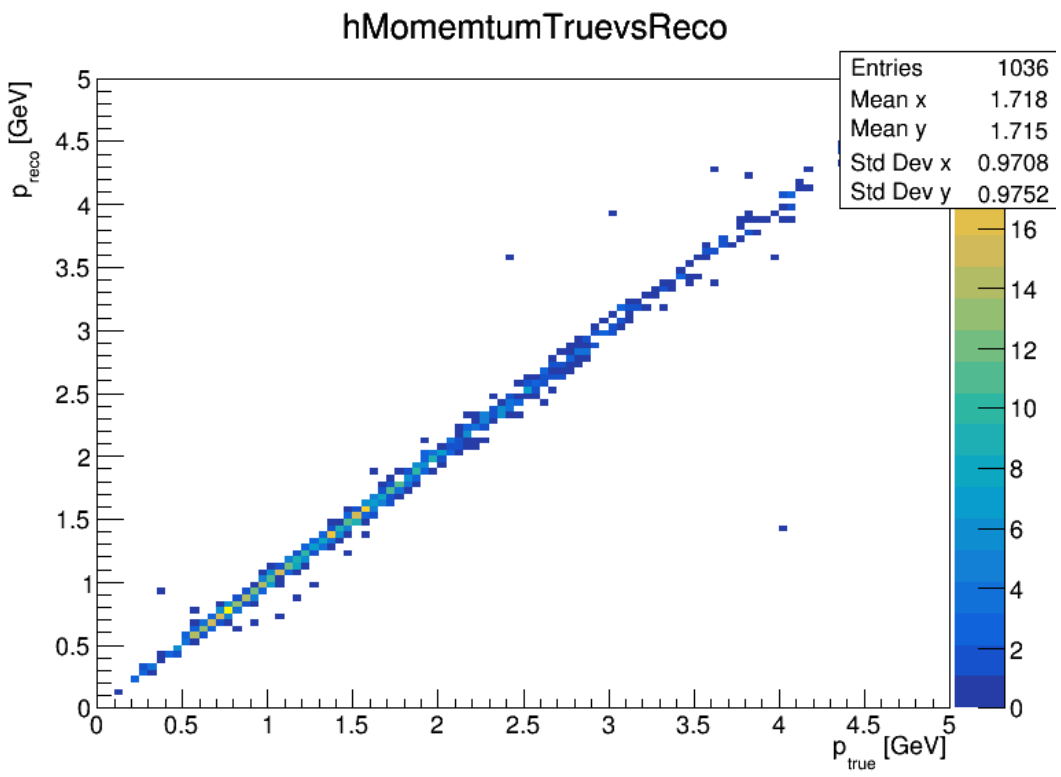
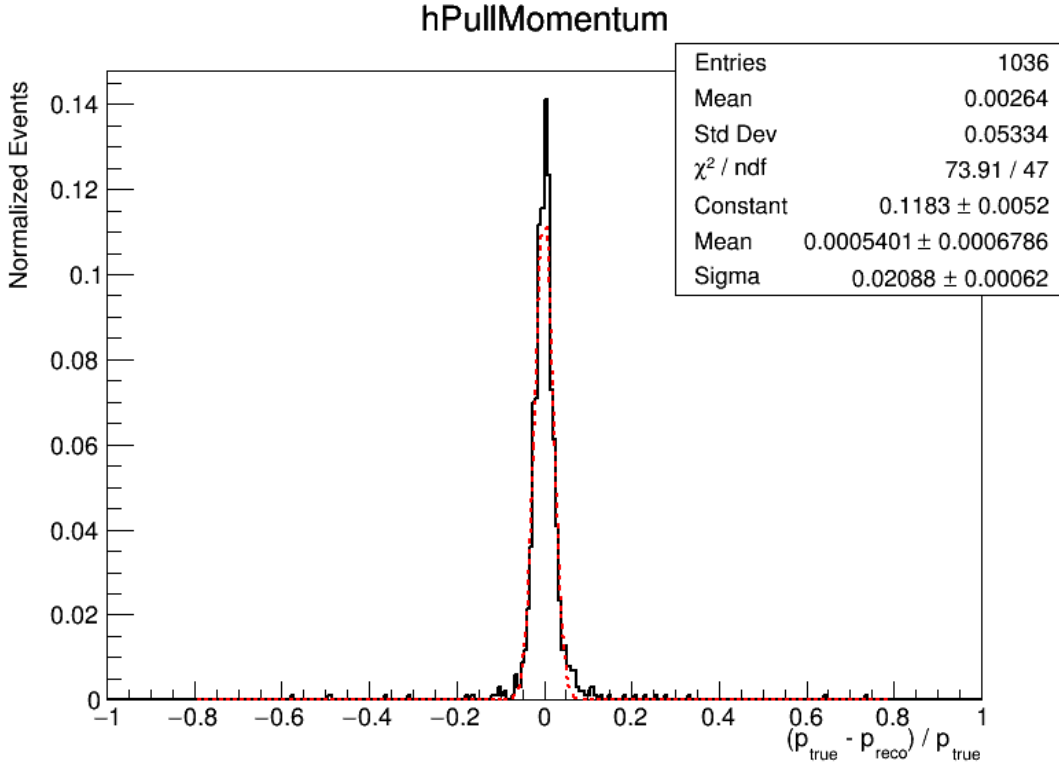
- Angular smearing: if track is short, use range – smear by a percentage and take the average of the angles at every track point

Momentum Resolution

- With the new parametrized PID, the μs selected are the ones that are μs 100% of the time
- Momentum resolution has improved from when only Gluckstern smearing was done





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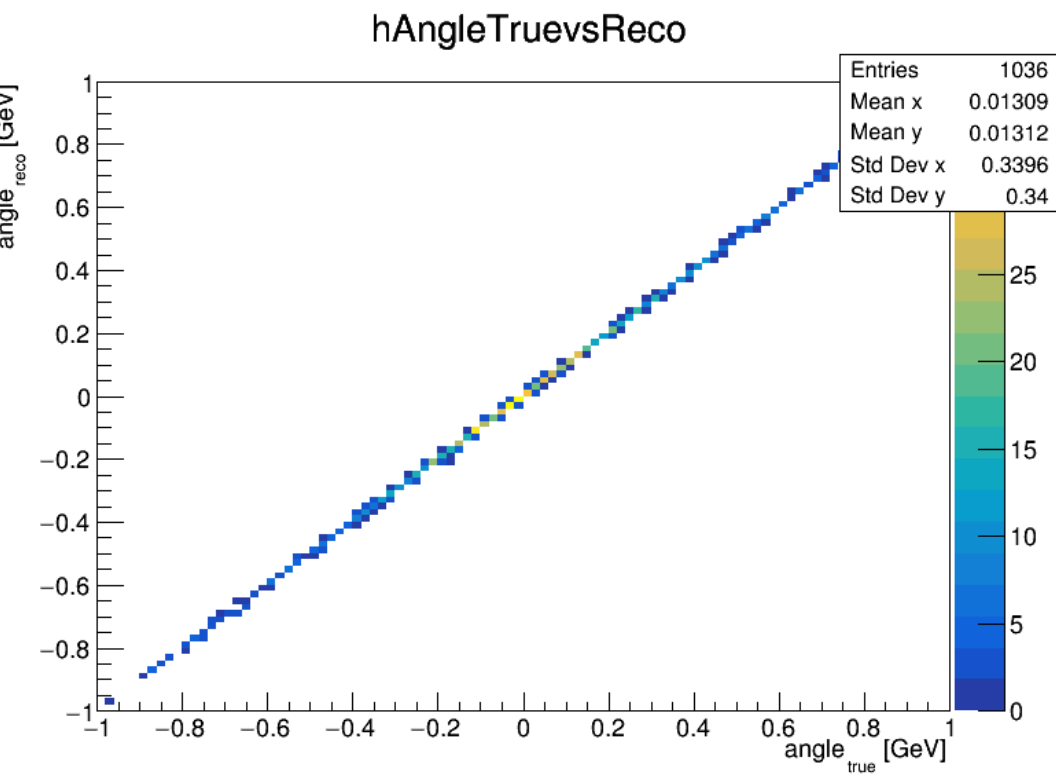
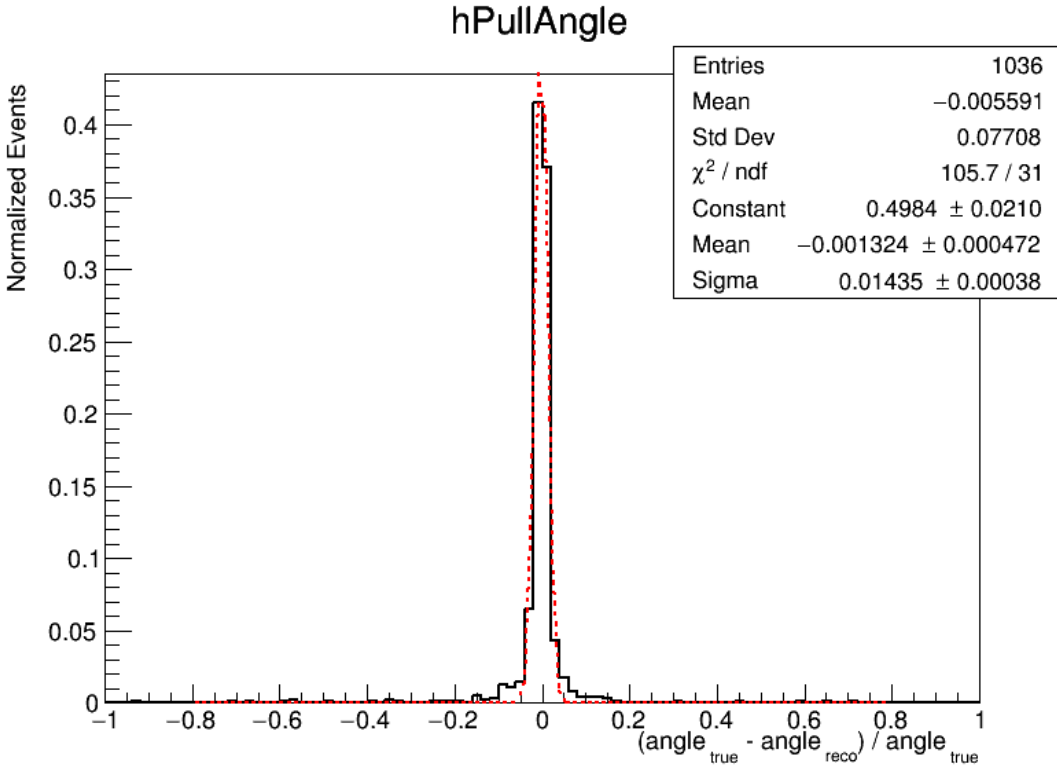
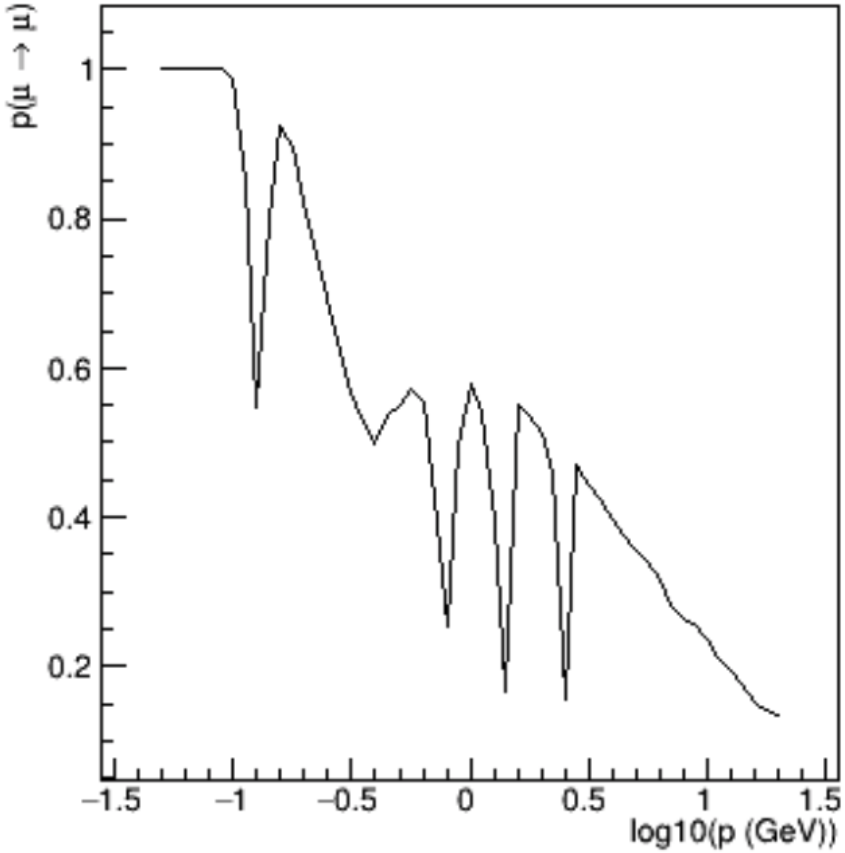
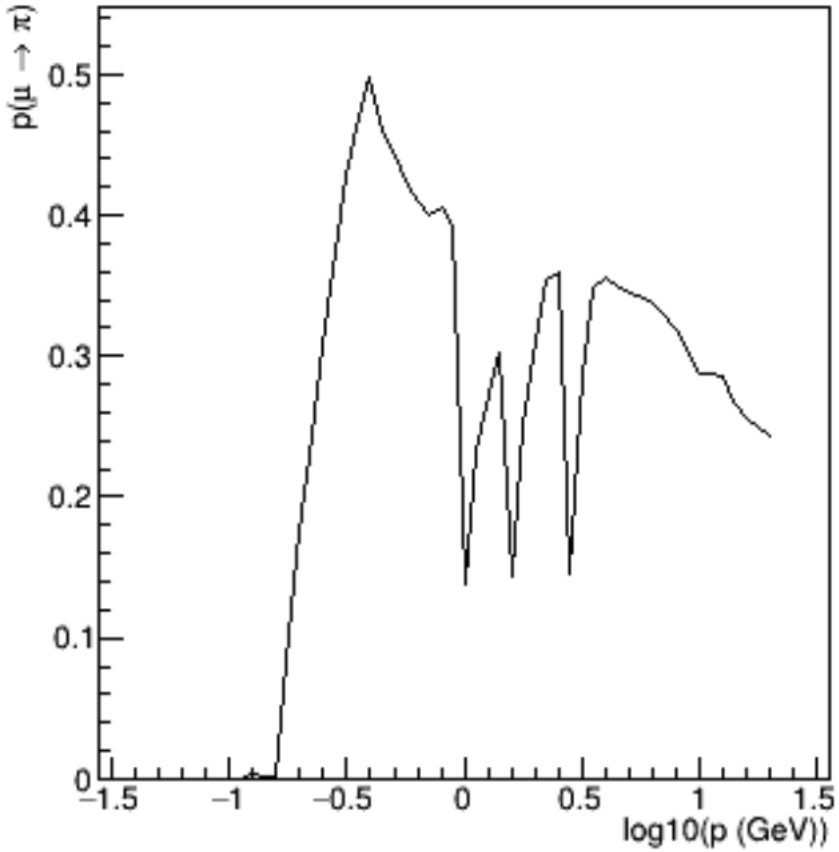




PID Parametrization from Tom Junk

- Based on the dE/dx curve: come up with probability distributions of whether you id or mis-id a particle in a given momentum range
- Take a look at this page for more information: **https://home.fnal.gov/~trj/mpd/dedx_sep2019/**





Next Steps in MPD Generations

From Andy Furmanski

- His plan was to use a ghep-to-art module from Robert H. to overlay the rock events and MPD events in one stage
- Overlay 240 rock interactions and one MPD interaction, but most of the rock interactions will not lead to particles in the MPD and end somewhere in the detector hall
- This overlay stage is fast, except all of the input ghep files need to be transferred to the worker node on the grid, which is the rate-limiting step and seems to sometimes cause errors
- We could save some time only transferring some of the files each time, but then the random sampling of rock-overlays would be less random
- The downstream processing (G4, Detsim, Reco, Ana) takes approximately 40s per event. Each 1000 event MPD file will therefore take approximately 12h to process on the grid
- According to Andy, everything is now ready for this large-scale processing. Andy plans to submit all of these jobs tomorrow (Wednesday)

Summary & Next Steps

- We have the first set of CDR rock and sub-detector samples
- For second set of sub-detector samples, on the MPD-side, we plan to separately generate events in each top volume of the MPD such as Magnet, ECAL, and gas TPC active volume
- Andy F. is generating MPD events using the first set of the CDR samples and GArSoft, this leads to a series of "anatree" ntuples
  - Once the anatree ntuples are there, the GEANT4 MPD events then would get passed to the parametrization module that Eldwan and I put together and the end result is an ntuple that can then be used by the analyzers for various MPD analysis