ND Temporary Muon Spectrometer (aka SSRI) Simulation Update

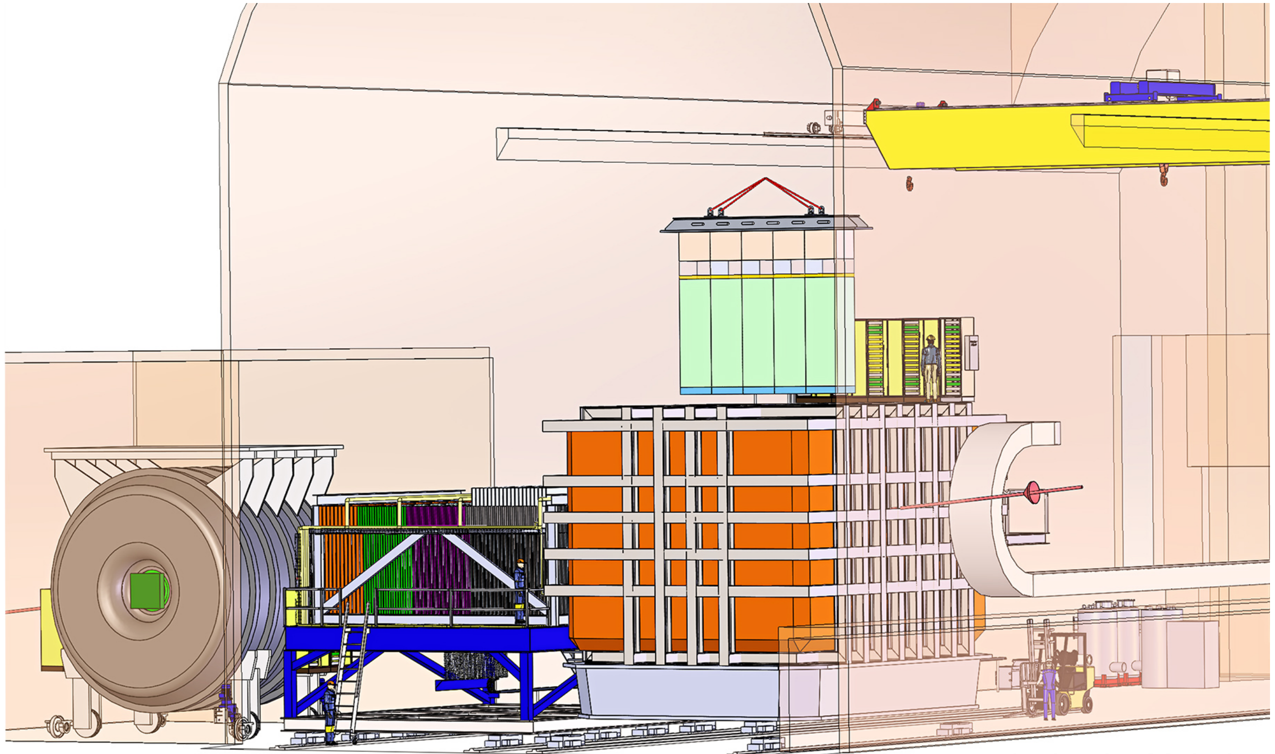
Mathew Muether

July 22, 2020

DUNE ND General Meeting

Refresher: What is this ND Muon Spectrometer?

- The temporary muon spectrometer (TMS) is a magnetized range stack to measure the momentum and charge of muons from the ND-LAr.
- It is meant as an inexpensive option to facilitate day-one ND capabilities for early oscillation physics.
- Tom LeCompte outlined the technical details and potential cost of the instrument in April https://indico.fnal.gov/event/21583



An early design by M. Leitner

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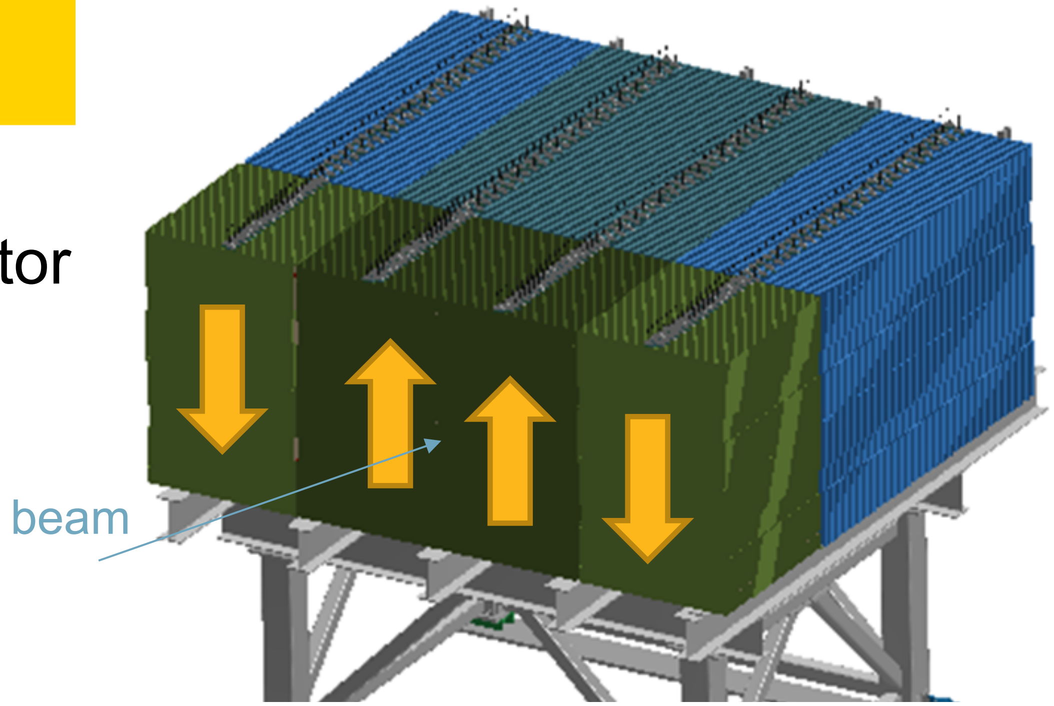
Performance Goals

- Determine the momentum of muons escaping the ND-LAr **no worse than the Far Detector** (~4%).
- Determine the neutrino/anti-neutrino beam composition.
- Ensure broad kinematic acceptance of LAr muons.
- Note: These are the initial design goal and they are still under study.

Current Design

- 100 layers of alternating steel and scintillator
  - 40 layers of 1.5 cm steel
  - 60 layers of 4 cm steel
  - 4 cm gap between layers
  - Each steel layer is comprised of three plates
    - 3.5 m central plate and flanking 1.75 m plates.



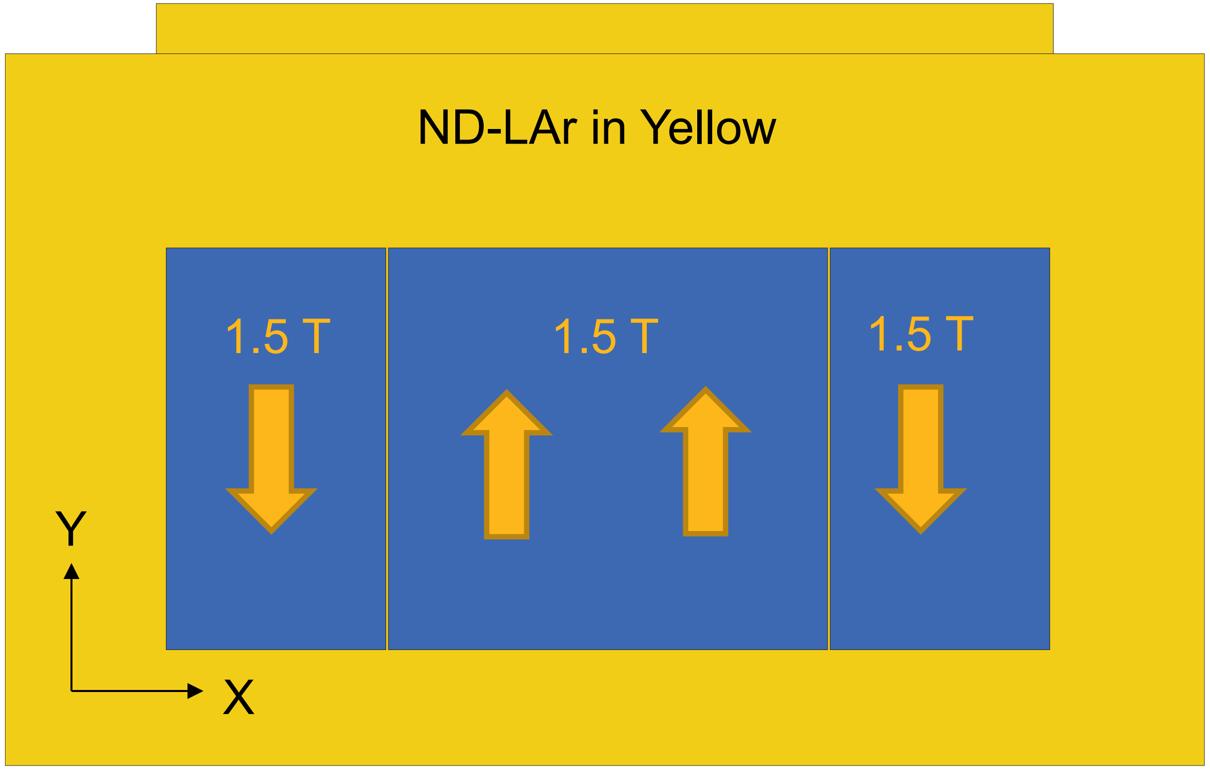
- Each layer has four panels, each containing 48 MINOS-like scintillator slats, 3.5 cm wide, and spanning the vertical extent of the detector.
- It can move in the x-direction (PRISM)
- The 1.5 T field in the central plates point opposite the sides plates.
  - Field direction shown in diagram (yellow arrows).

Simulation Team

- In response to the October IPR review an initial team to simulate and study the TMS was formed by the US Project with the goal of having a preliminary assessment for the summer 2020 review circuit.
- **The Initial Team: Tim Bolton (K-State), Gavin Davies (Univ. of Mississippi), Zelimir Djurcic (ANL), Dan Dwyer (LBNL), Vic Guarino(ANL), Mike Kordosky (W&M), Tom LeCompte (ANL), Chris Marshall (Rochester), Mat Muether (Wichita), Holger Meyer (Wichita), Roberto Petti (Univ. of SC), Palash Roy (Wichita)**
- New Members: Norman Martinez (K-State), Munera Alrashed (K-State), Clarence Wret (Rochester)

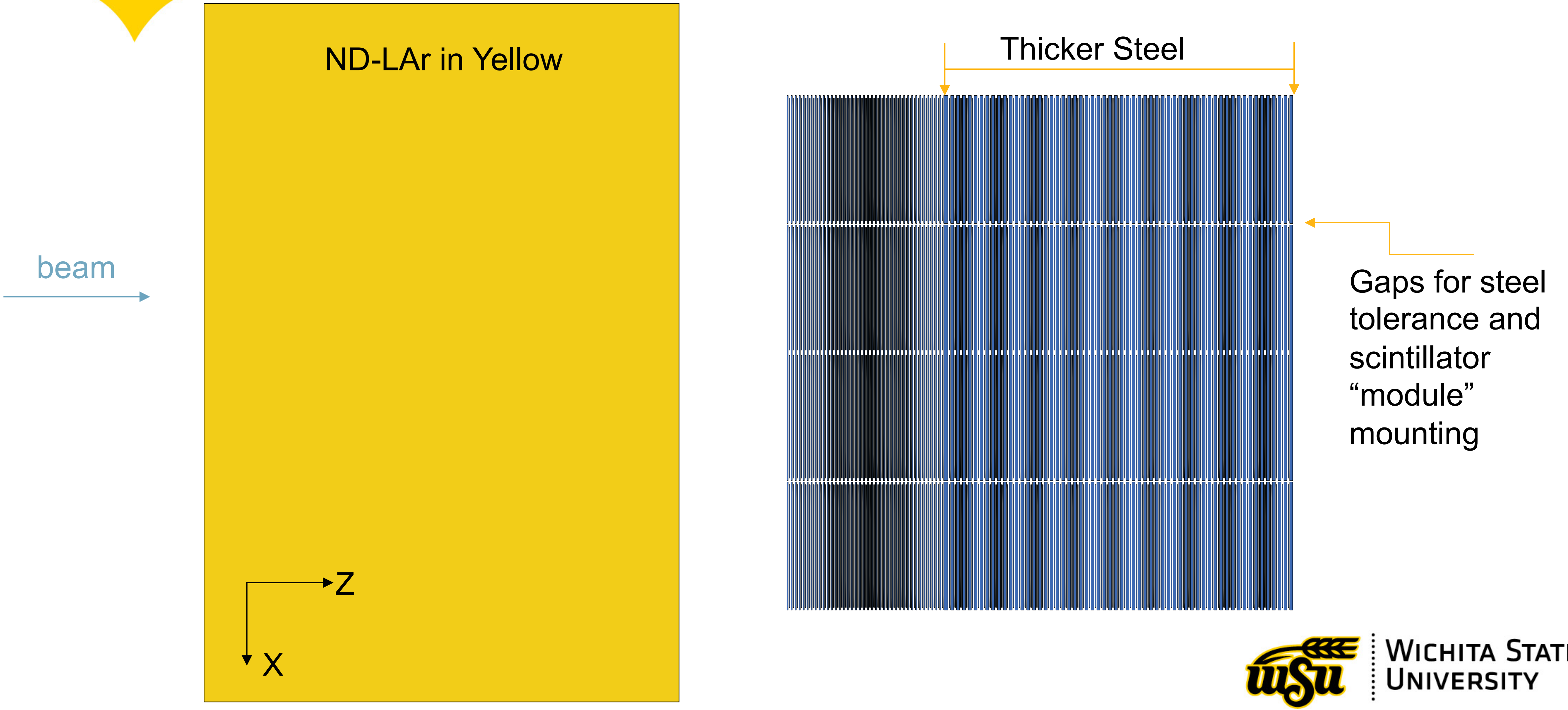
Detector GDML Models (Palash Roy/M. Muether)

- We have generated GDML of the detector using dunendggd.
  - Scintillator: 1.05 g/cc, 92% C, 8% H
  - Steel: 7.93 g/cc, 73% iron, 18% chromium, 9% nickel, 0.1% carbon.
- The model includes the steel plates and scintillator strips, but no coils or support structure yet.



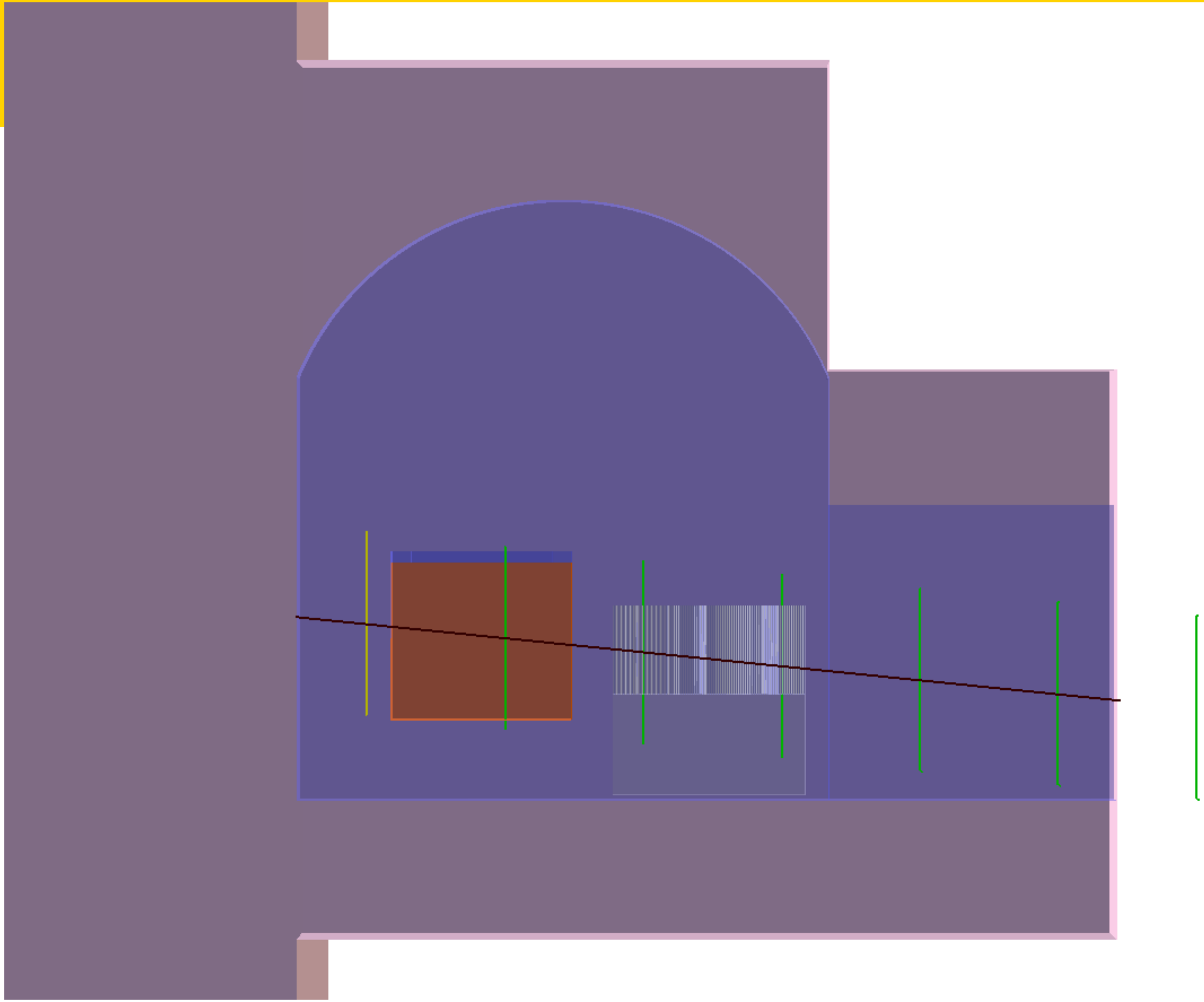
Upstream view

Top View


beam
ND-LAr in Yellow
Z
X
Thicker Steel
Gaps for steel tolerance and scintillator "module" mounting

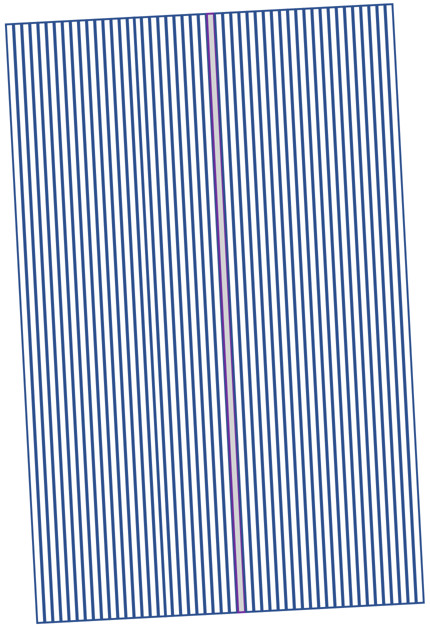
In hall side view

- We simulate with the ND-Lar, Detector Hall and surrounding rock volumes.

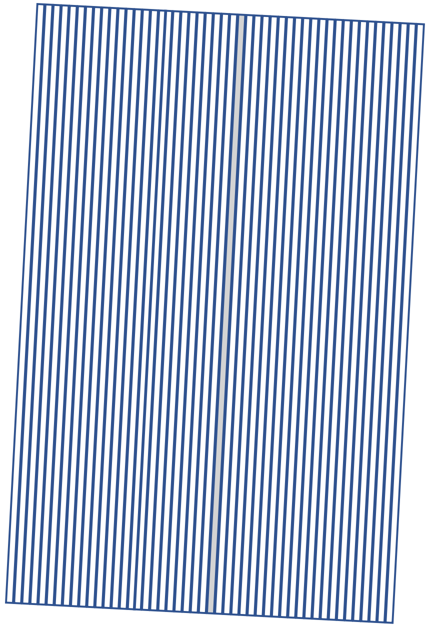


Additional Geometries

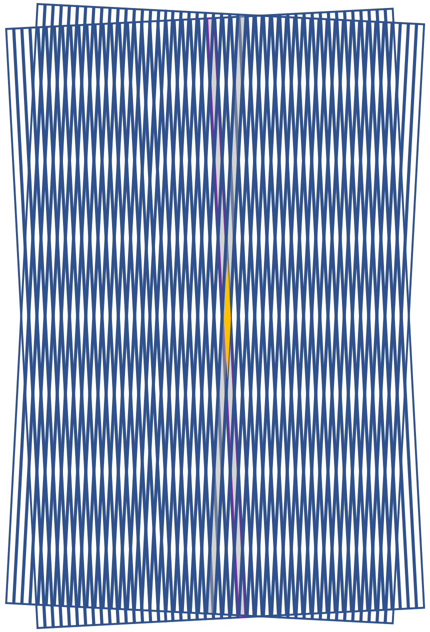
- We have also generated geometries with no magnetic field and with rotated scintillator modules for stereo info.
- Additional simulation samples are in production.
- The rest of the talk with focus on initial results from the base design.



Odd numbered gaps



Even numbered gaps



Both planes viewed together

Gray slat indicates a hit

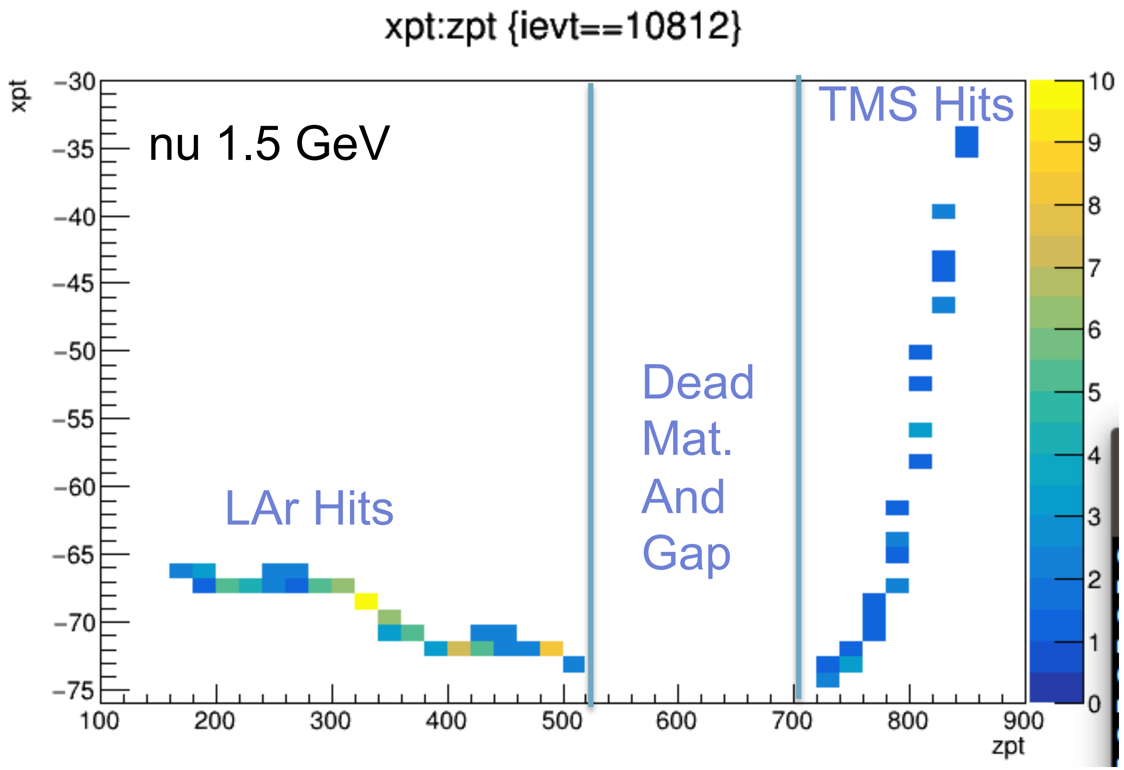
Orange diamond is the intersection of the two individual hits

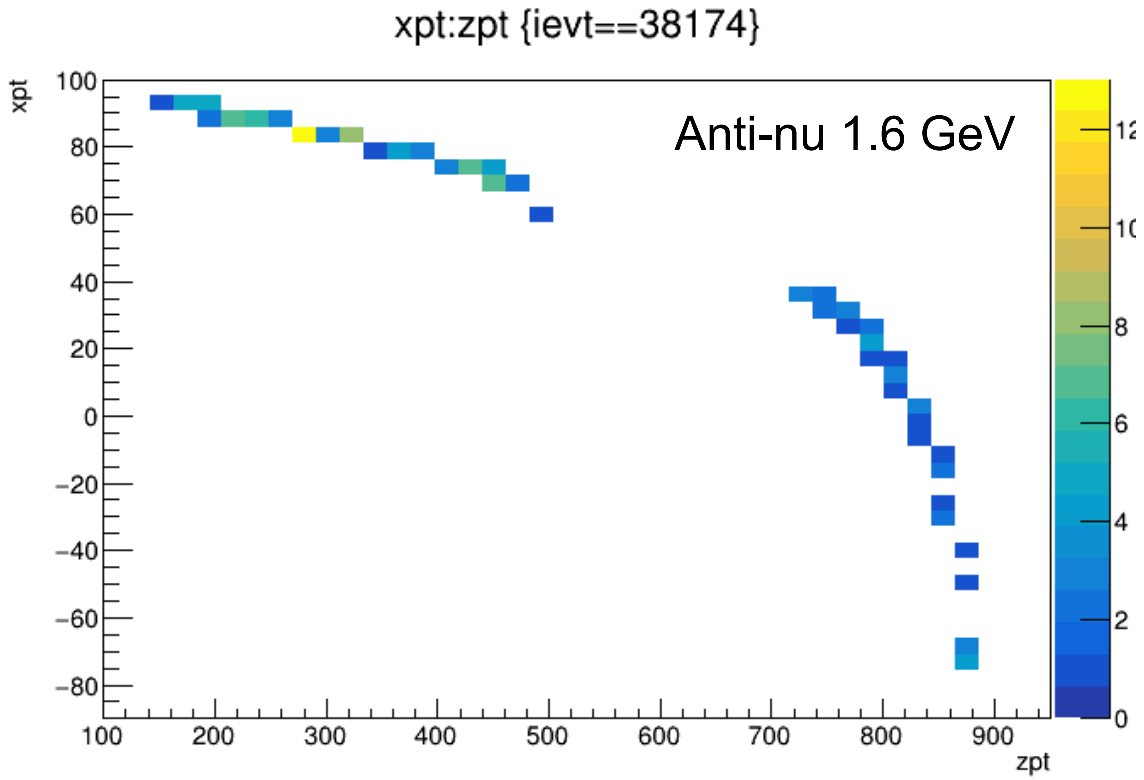
Simulation/Analysis

- We use gevgen and Edep sim to generate 1M FHC and RHC interactions with the geometry described above.
- Analysis, from **Gavin Davies and Chris Marshall**, is adapted from Chris Marshall's truth-based ND-LAr studies.
- The next slides show initial results for interactions in the LAr and contained by the TMS.

Select Events: X vs Z.

Typical Events 1.2-1.6 GeV





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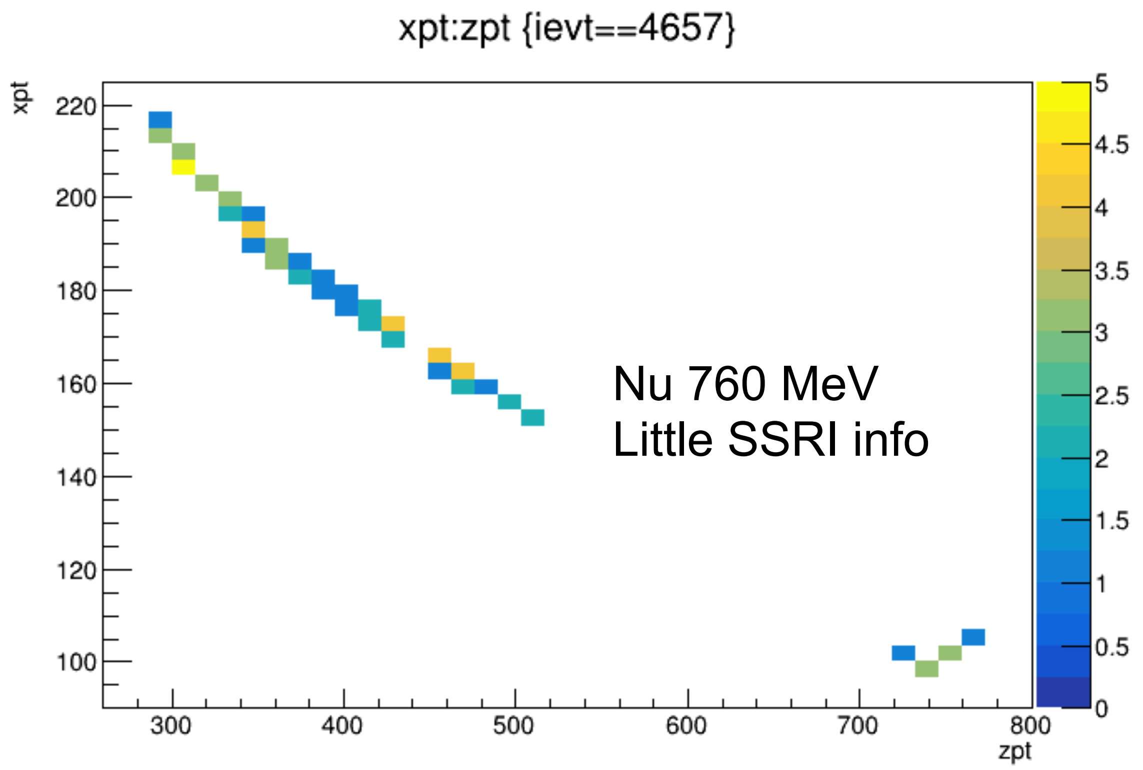
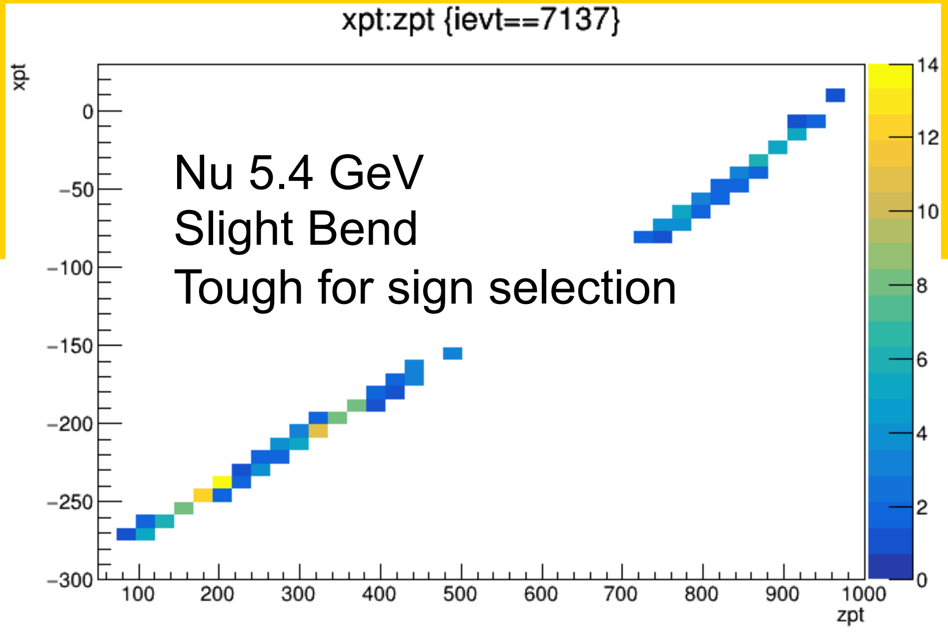
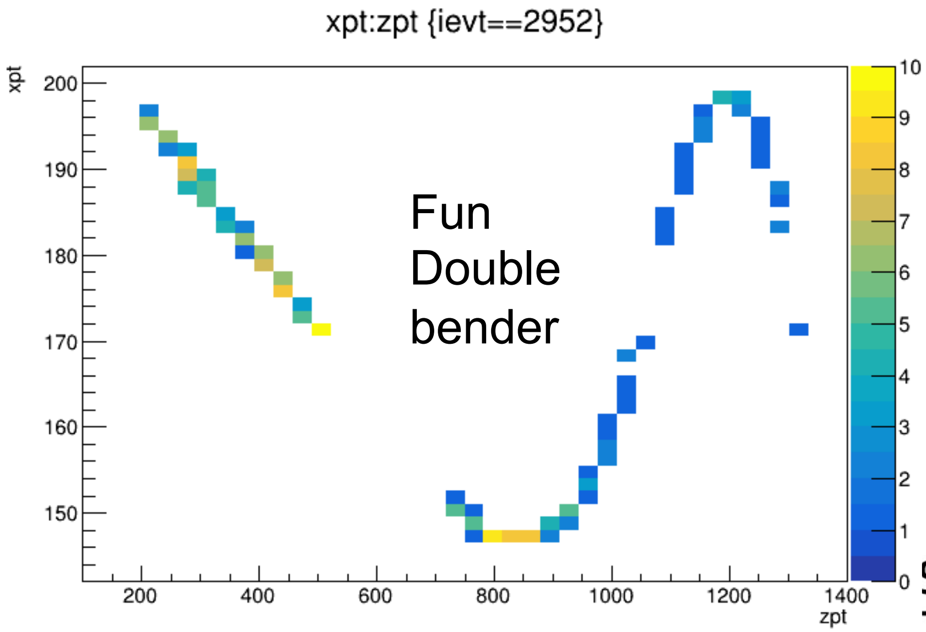
Select Events: X vs Z.

Challenging events

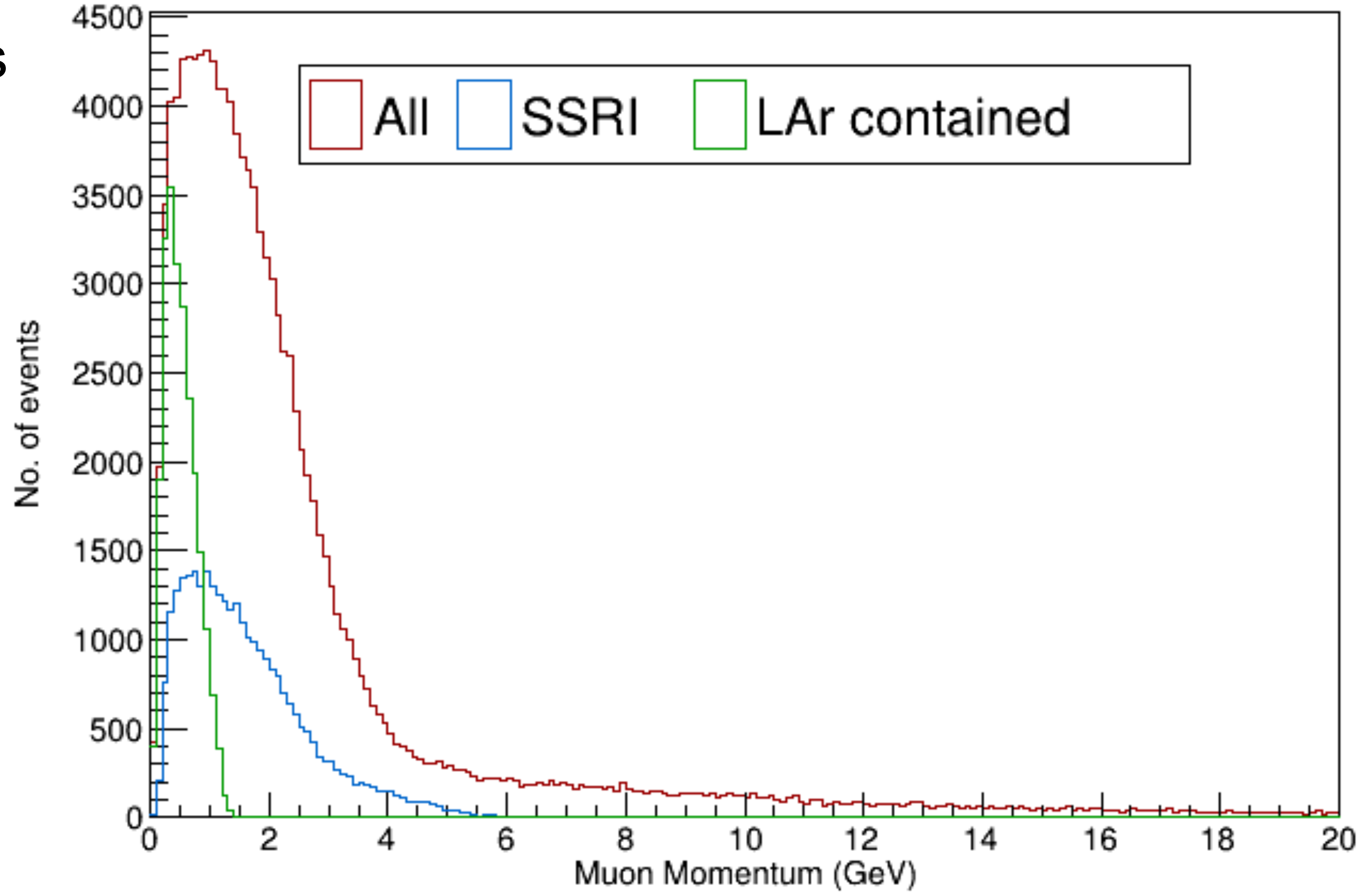






Muon Momentum Acceptance

- SSRI contains muons up to ~6 GeV.



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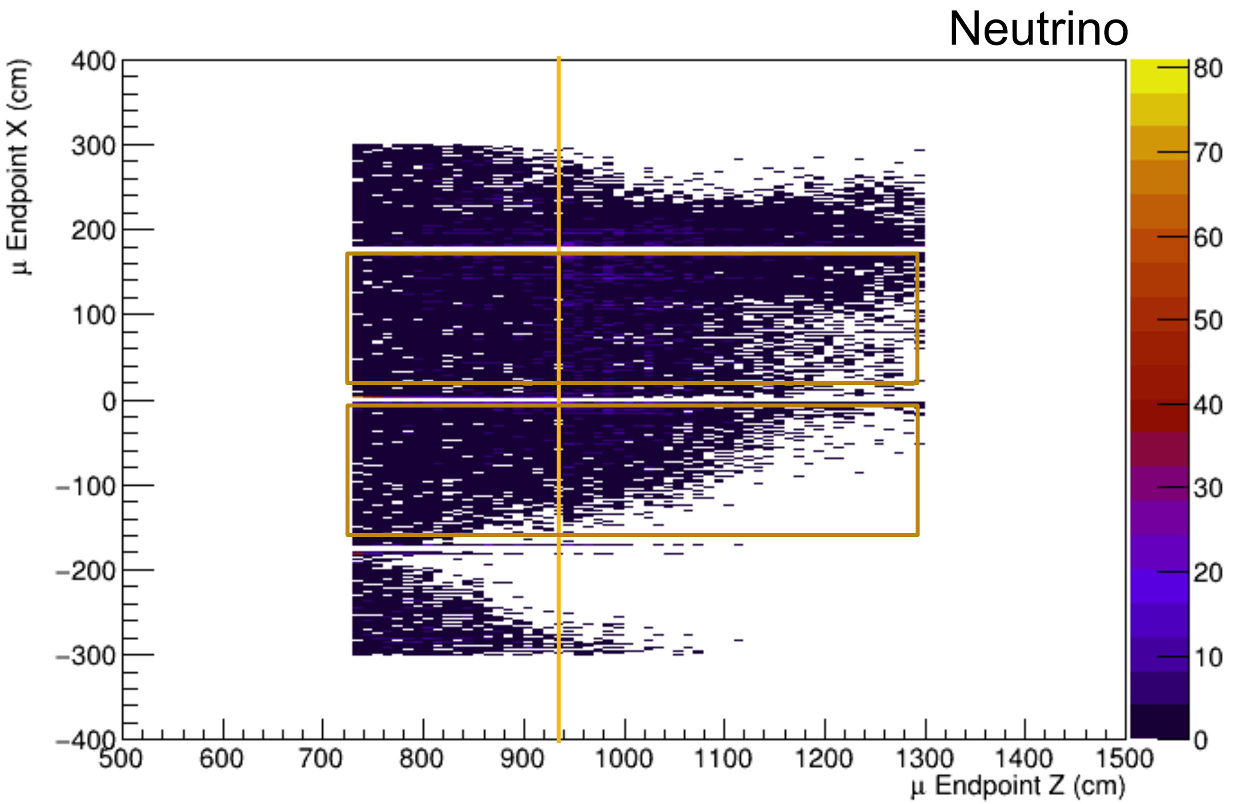
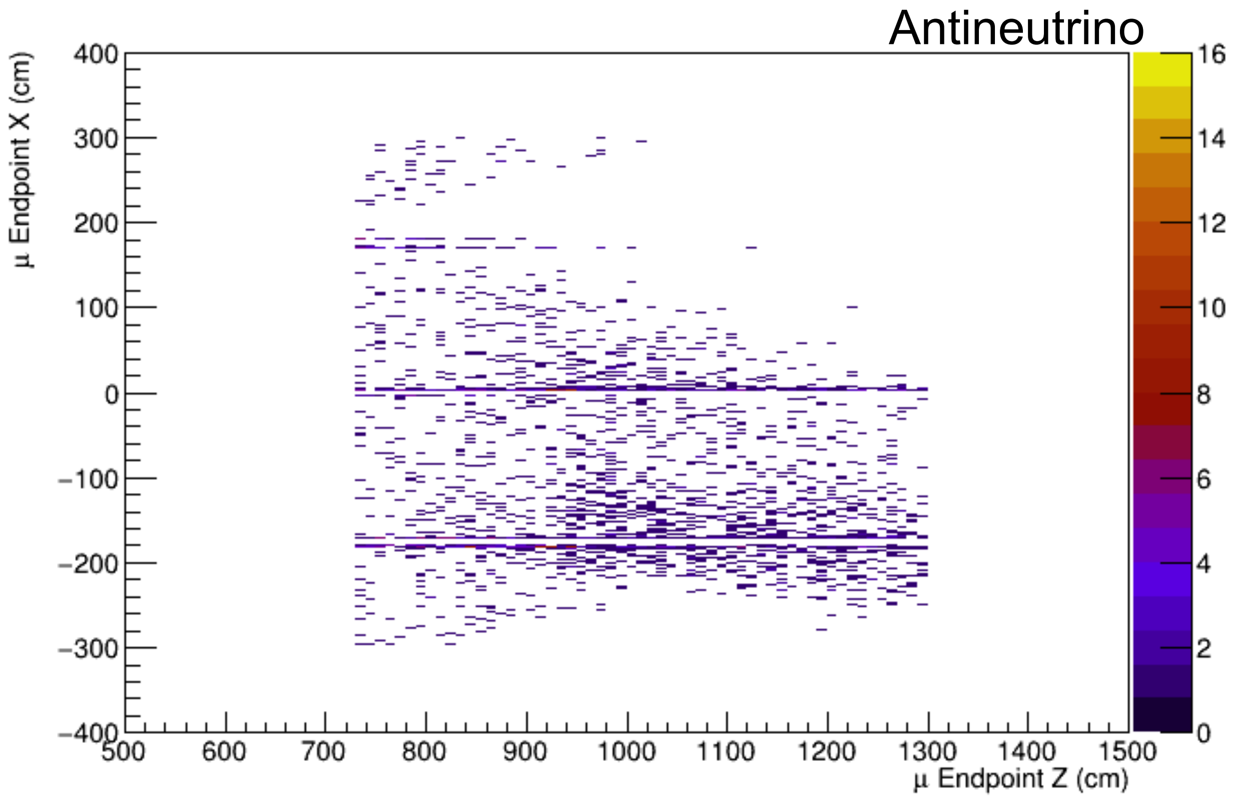
Event Distribution (FHC)

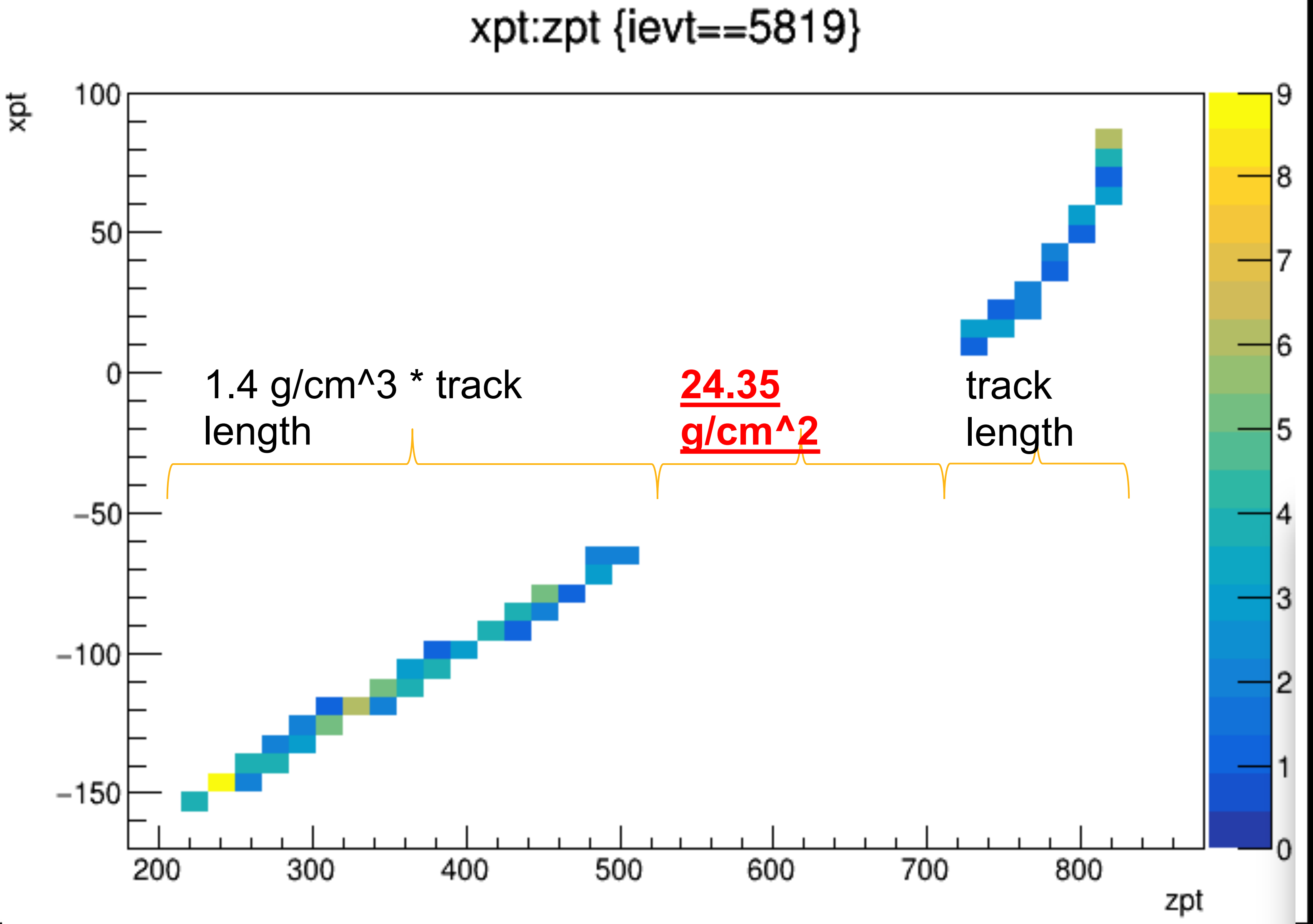
- SSRI containment based on last hit position, front-entering muons
- Cut on events in the uniform region to avoid complications from gaps.





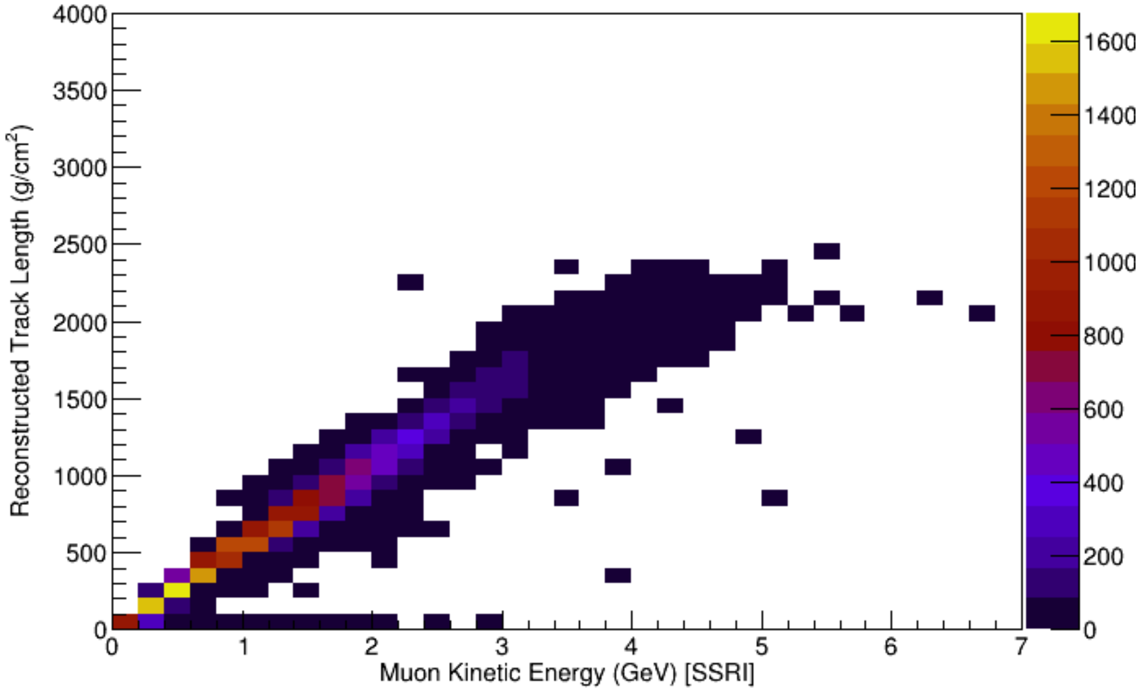
Simple Truth Based Tracking

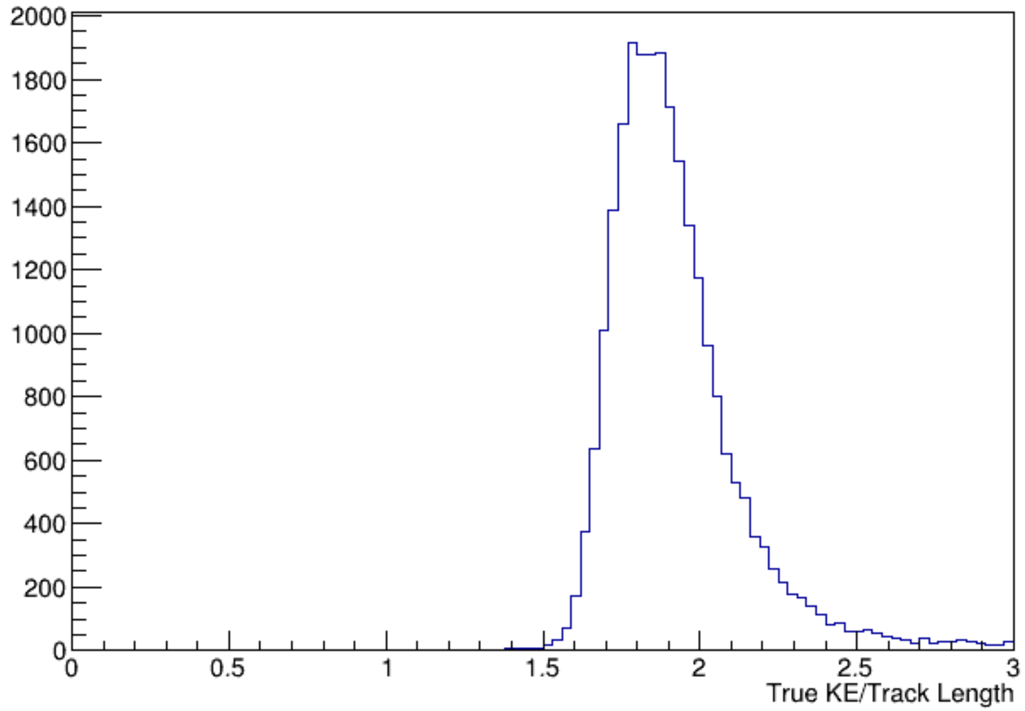
- Walk hits in active detector volumes and calculate g/cm^2 for each segment.
- Using average material density between LAr and SSRI.
- Last hit in LAr and first SSRI hit do not necessarily give exiting and entering positions.
  - Cleaning this up will improve the analysis.



Momentum Reconstruction

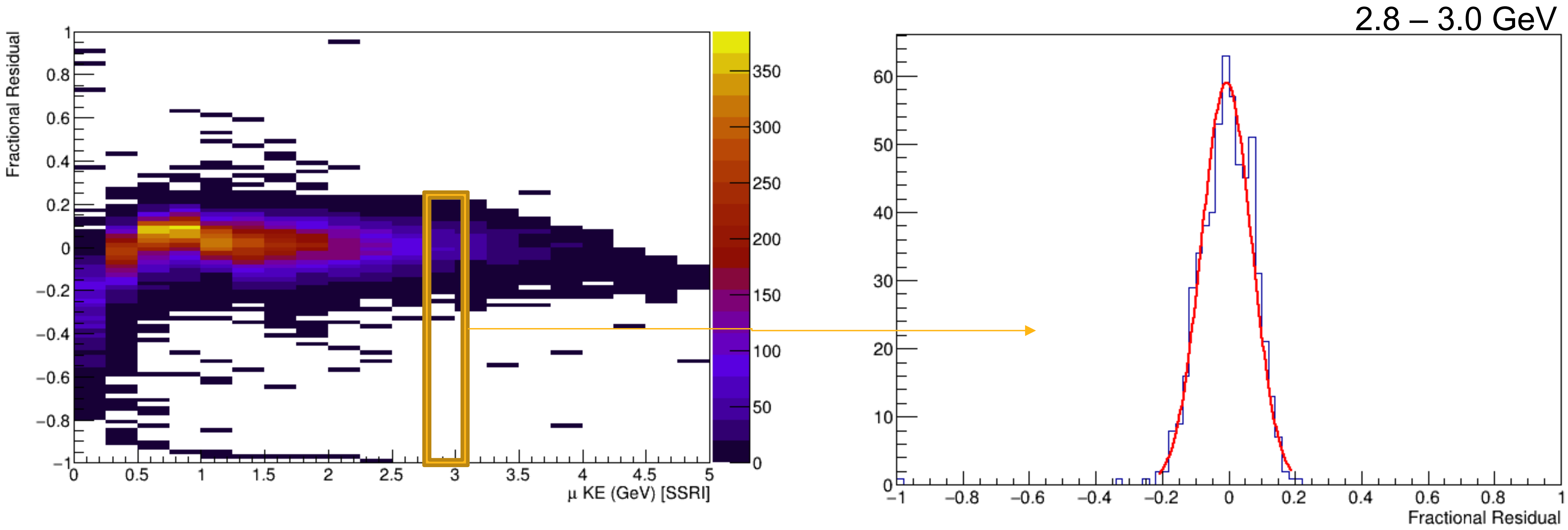
- Simple Energy Estimator: Track Length * 1.9 MeV/(g/cm^2) = True Muon KE





Fractional Residual

- Calculate RMS from residual (Reco-True) in KE bins
  – Both total RMS and from gaussian fits.



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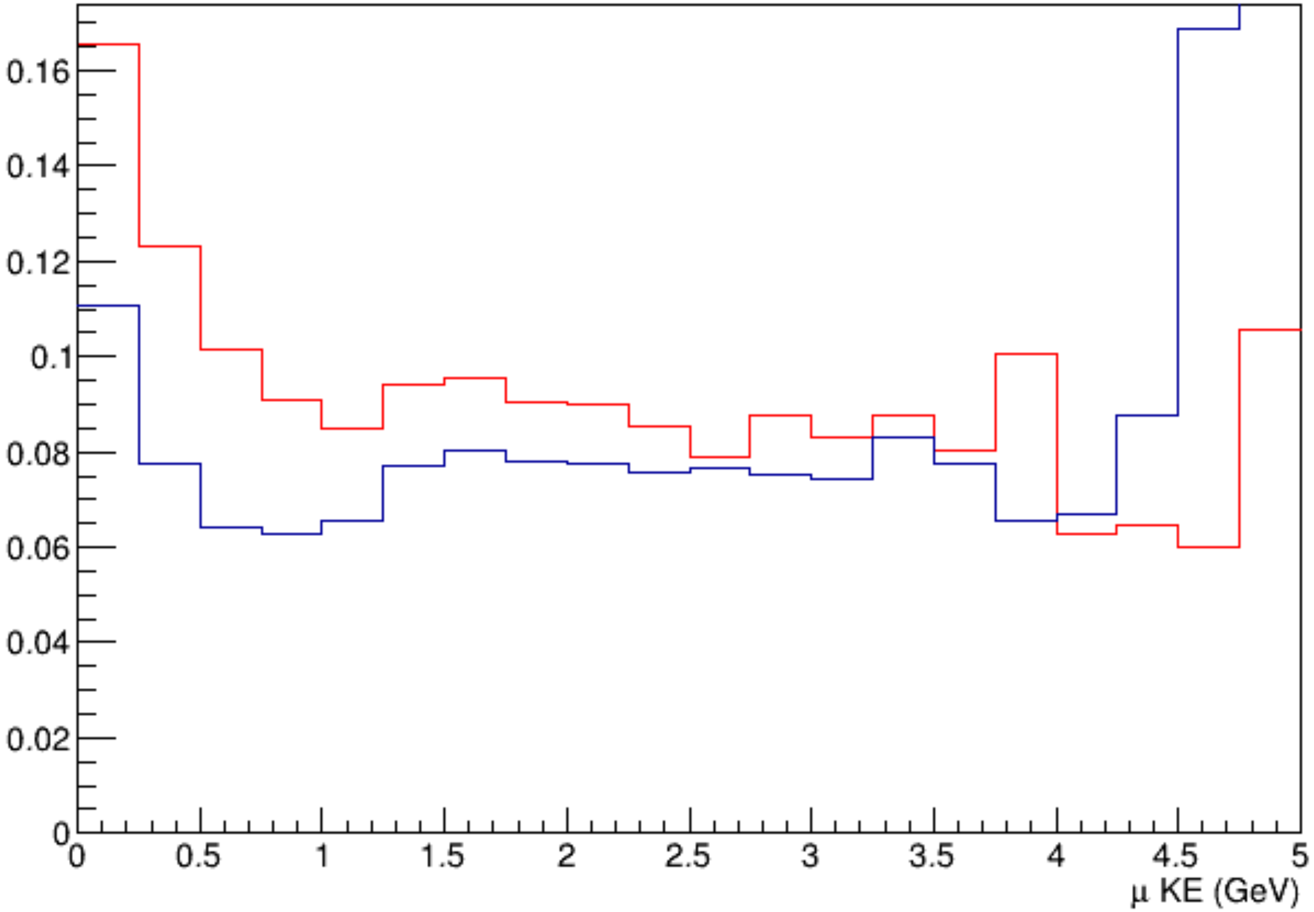
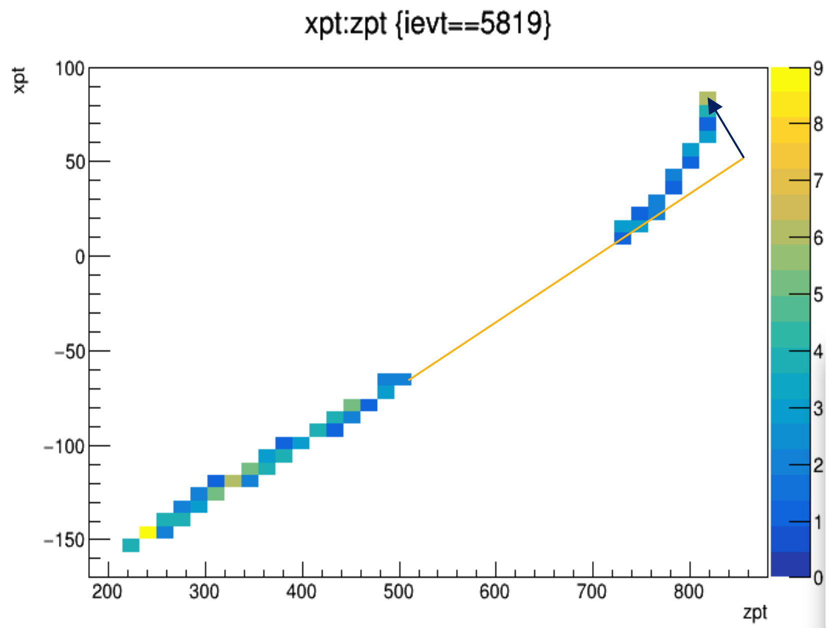
Initial fractional momentum resolution estimate

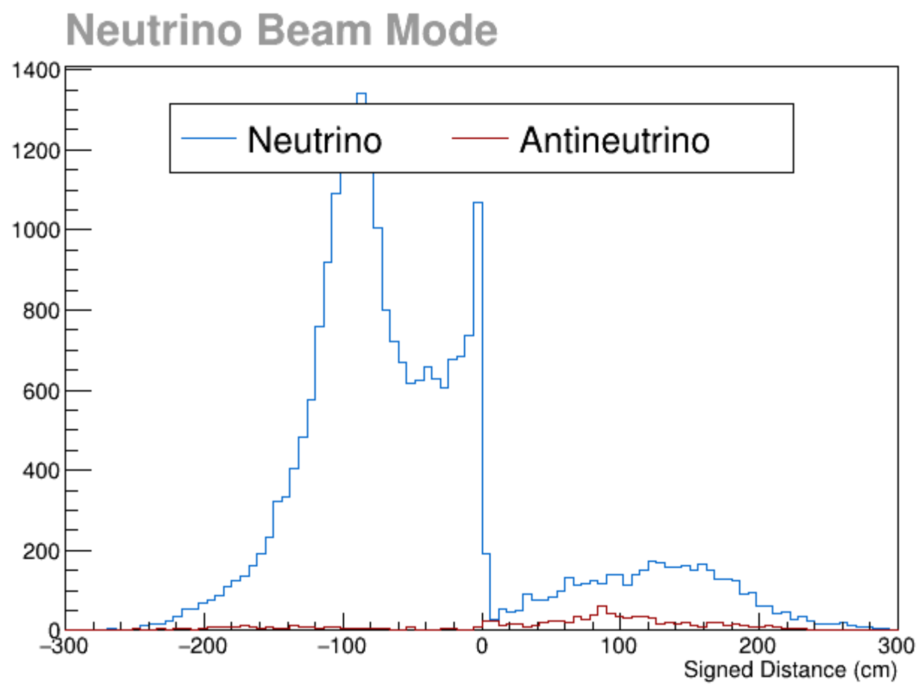
- Red – Full RMS, Blue – From Fit
- ~7% in the core and 9% from the full distribution.
- We expect this will improve with proper tracking, a more robust energy estimator and better handling of dead materials. (All in progress.)

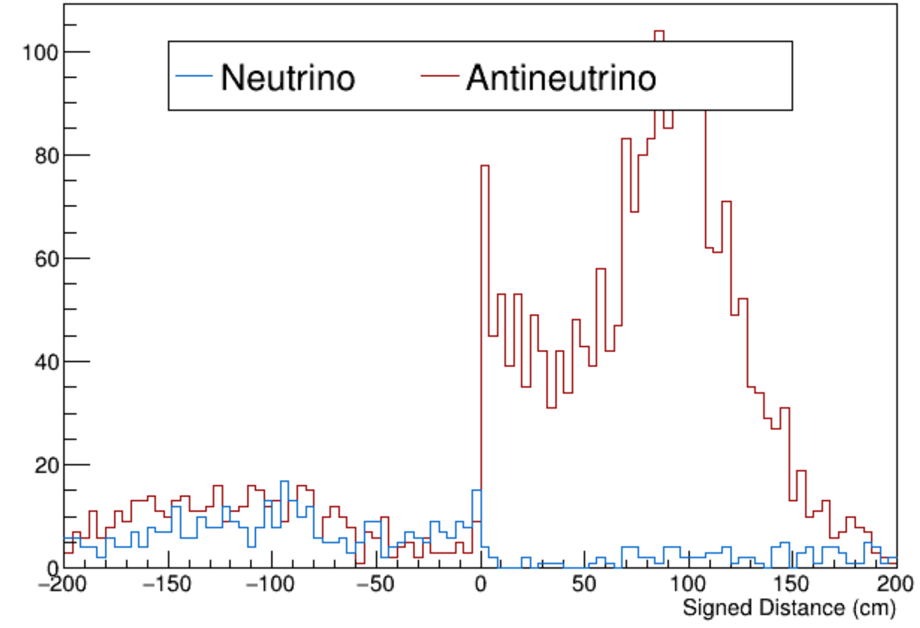


A very preliminary look at sign selection.

- Using a simple signed distance of track end from trajectory between LAr and SSRI.
- ~85-90% pure below (above) 0.
- This is very crude but promising.







Conclusions and Next Step

- Initial analysis of the baseline SSRI design demonstrates measurement capabilities for muon momentum and charge.
- The group is moving forward with developing proper event tracking, improved energy estimators, more accurate field mapping, pile-up effect etc.
- We are studying alternate design choices to optimize cost and performance.
- We are continuing to study and update design requirements.

Moving Forward (Organization) (my understanding at least)

- This effort will move forward as part of the ND-GAr/TMS consortium under guidance from A. Weber and A. Bross.
  - This is part of the US project since April. T. LeCompte is L2 manager for Muon Spectrometer and Technical Lead for the MPD pre-Consortium.
- The current TMS/SSRI analysis group meets on Mondays at 2 pm central. **#nd_tms on SLACK.**
- There is a new “Muon Spectrometer” Near Detector Indico category. We have created https://indico.fnal.gov/event/44540/ and are adding existing documentation and a technical note here.
- Thanks for your attention.

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