

# ND-GAr-Lite Performance Stuff

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# Delta Rays

Studied several properties of the delta rays produced by muons in ND-GAr-Lite.

Using a sample of 5000 muons from a edep-sim particle gun that was parameterized to have a similar momentum distribution as the output from GENIE neutrino events.

Goal to investigate how often and how much delta rays could bias the reconstruction.

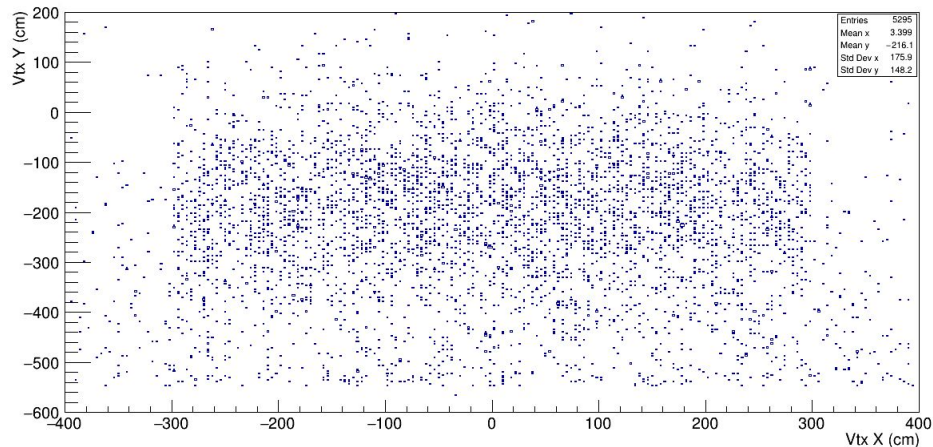
Tracking threshold for electrons in edep-sim in scintillator is 1 mm, or approximately 361 keV.

# $\Delta$ -Ray Vertex and Multiplicity

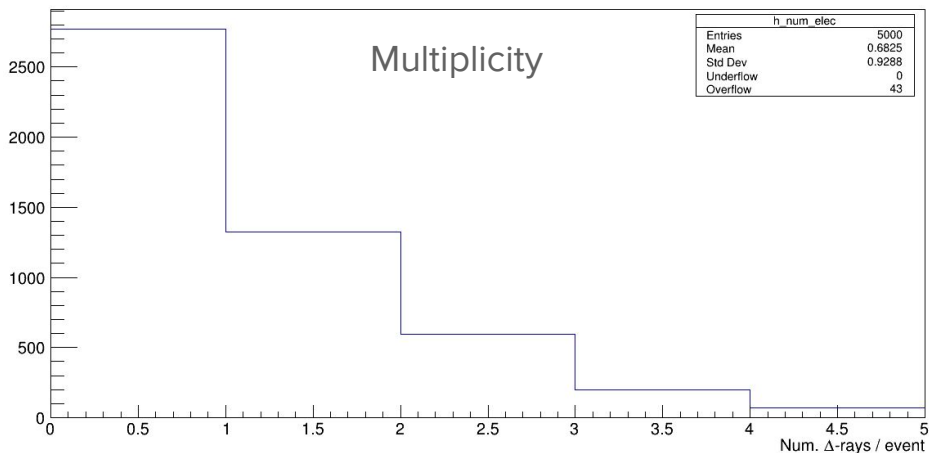
Over half of the muons do not produce a delta ray above tracking threshold.

As expected, most delta rays are produced in the scintillator.

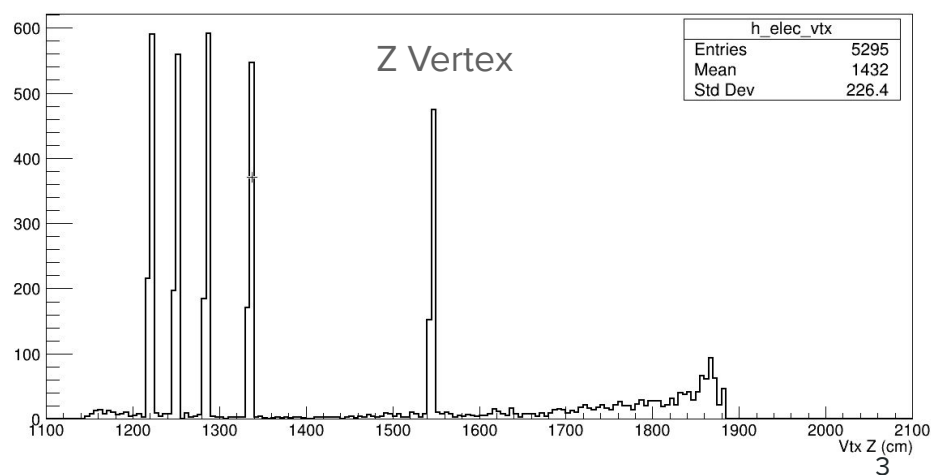
XY Vertex



Multiplicity



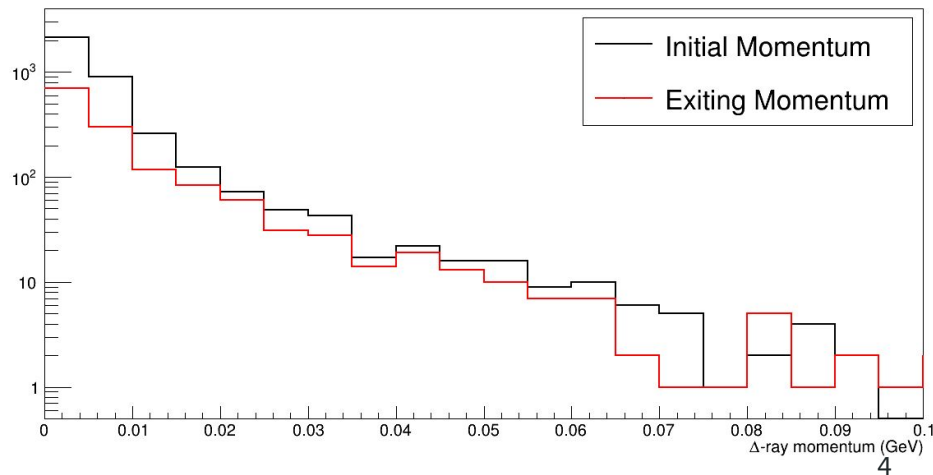
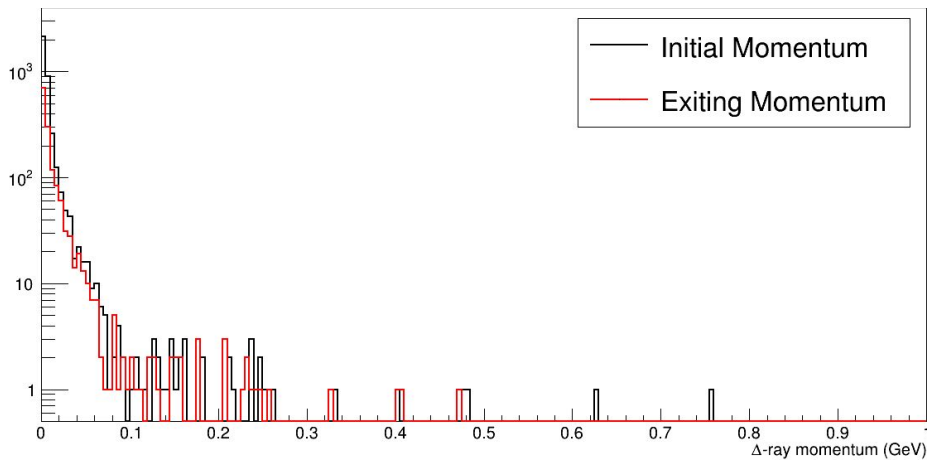
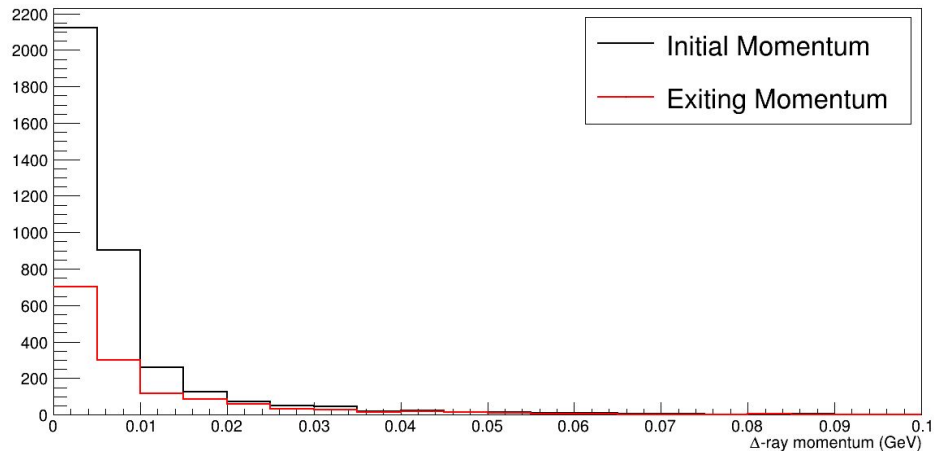
Z Vertex



# $\Delta$ -Ray Momentum

Momentum distribution for delta rays produced in the scintillator, and if they leave the scintillator.

All plots display the same events with different scales.

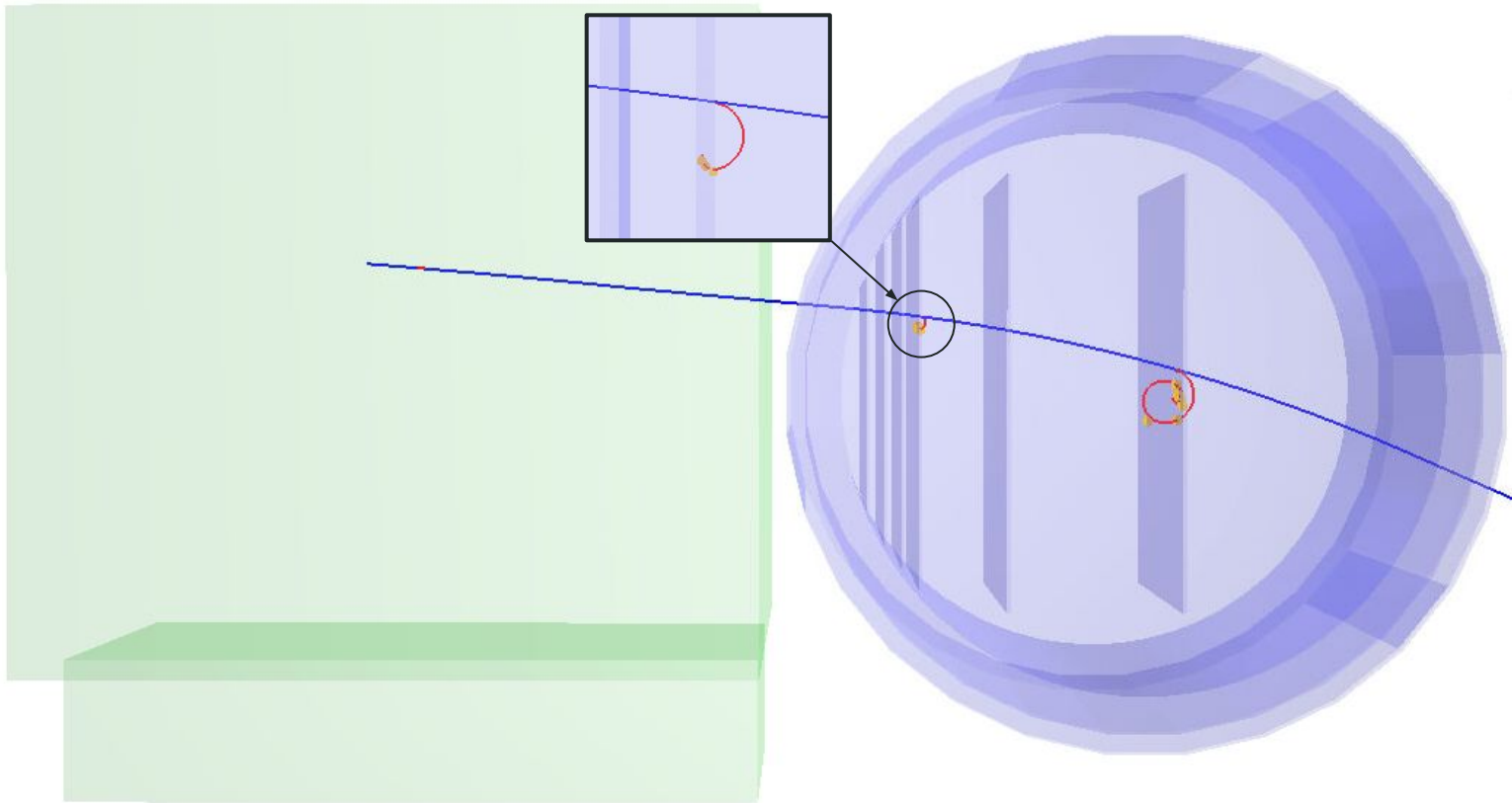


# Comments on $\Delta$ -Rays

A single muon travelling through ND-GAr-Lite will produce one or more delta rays above threshold less than half the time → on average 0.68 delta rays per event.

Most delta rays are produced with less than 40 MeV/c of momentum, and about 38.5% of delta rays exit the scintillator bar where they were produced.

A small fraction of delta rays (about 1% or less) are produced with 100 MeV/c or greater momentum.

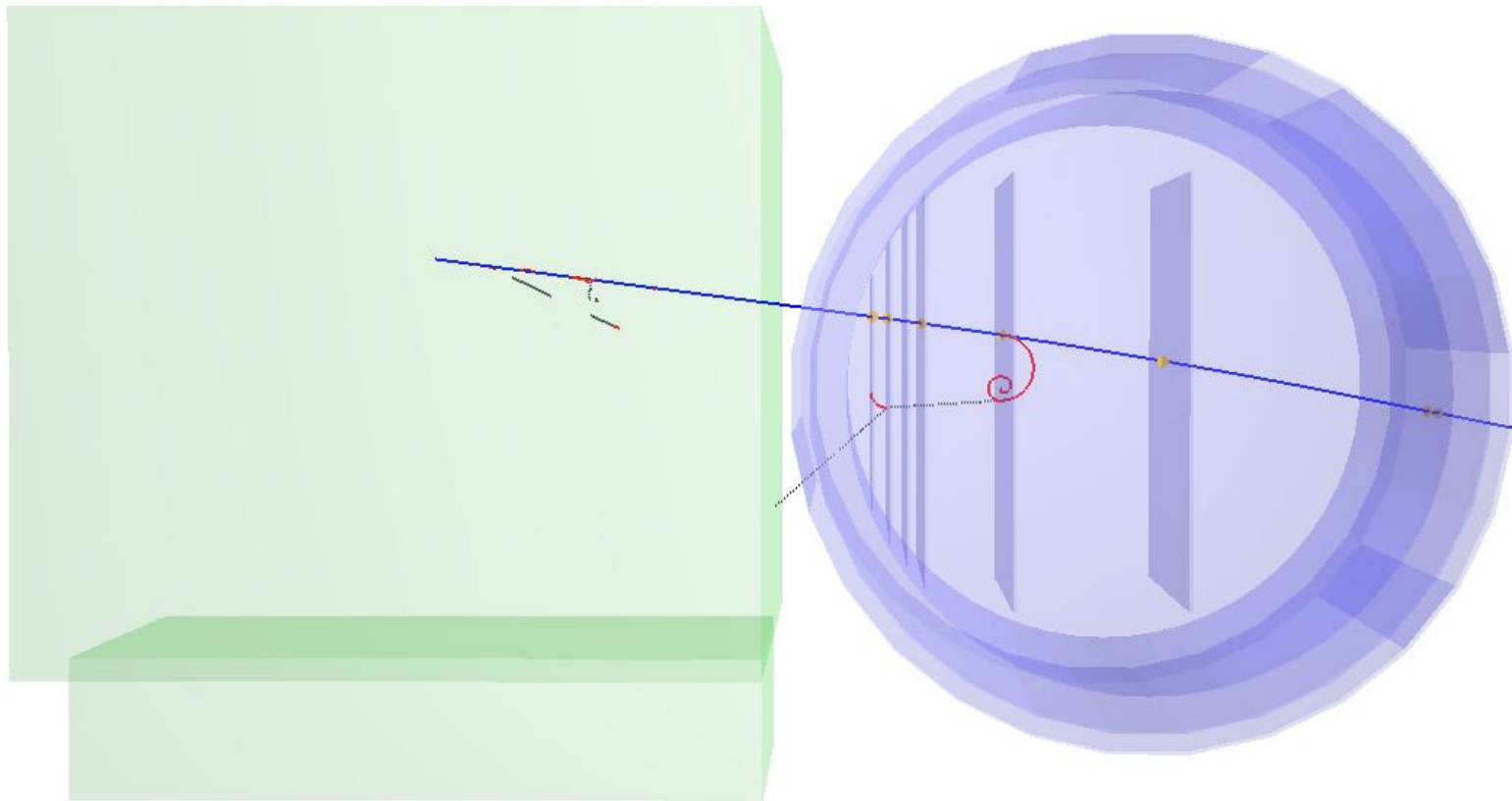


Event Displays!

Muon: 4.04 GeV/c

Delta ray #1: 12.3 MeV/c

Delta ray #2: 64.3 MeV/c



Event Displays!

Muon: 15.50 GeV/c  
Delta ray: 61.1 MeV/c

# Benchmarking Momentum Resolution (again)

Using the “optimized” six plane arrangement, check the momentum resolution for reconstructed tracks.

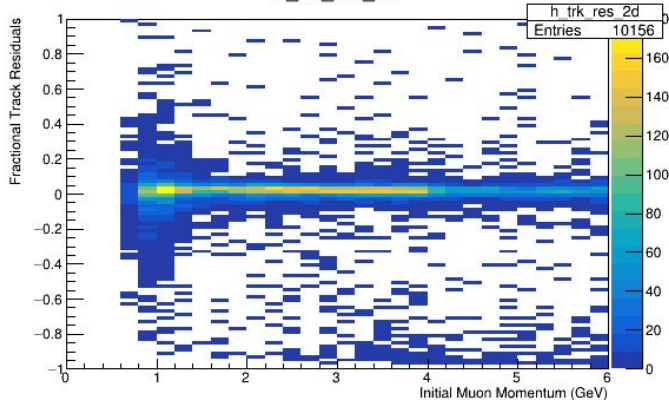
Efficiency is the driver of the optimization, but need to verify that the momentum resolution is still good enough.

Performed using edep-sim muon gun simulations to avoid track matching ambiguities (and for simulation/reco speed).

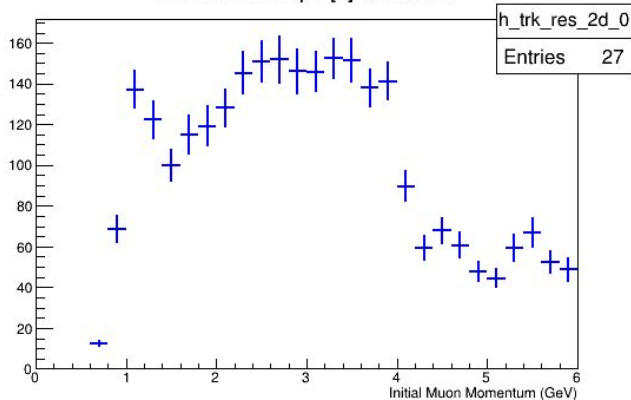
Momentum used in the following plot is the initial momentum from the interaction in the LAr.



h\_trk\_res\_2d



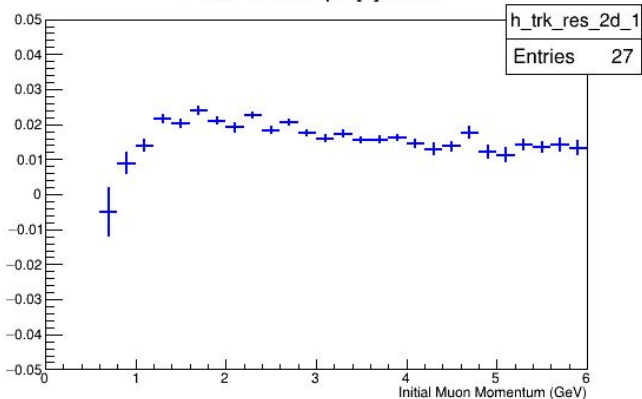
Fitted value of par[0]=Constant



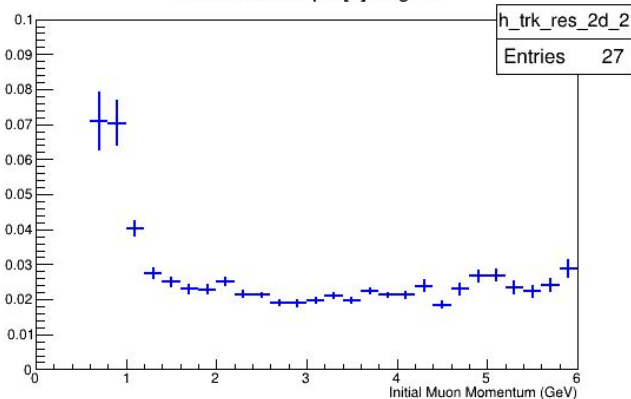
Fitting each 200 MeV wide momentum bin with a single Gaussian.

Momentum resolution really good for most bins.

Fitted value of par[1]=Mean



Fitted value of par[2]=Sigma



Low momentum bins noticeably worse (below 1 GeV).

Overcorrecting for energy loss from scintillator.

## Six Planes Tracking Resolution

# Muons Starting in ND-GAr-Lite

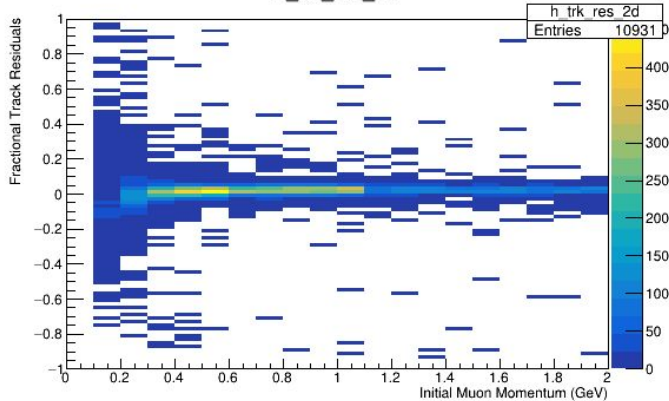
Wanted to double check the resolution at low momentum (below 1 GeV initial momentum).

When computing the residual for a muon from the LAr, what is the correct true momentum to compare to the reconstructed track?

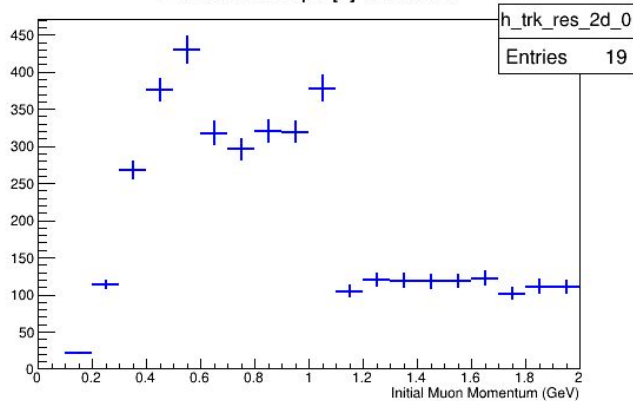
Currently estimating the muon momentum as it enters the cryostat/magnetic field (specifically crossing the first plane), but this is not perfect.

Run a new simulation where muons start inside the cryostat/magnetic field such that the true muon momentum is perfectly known (i.e. the initial momentum).

h\_trk\_res\_2d



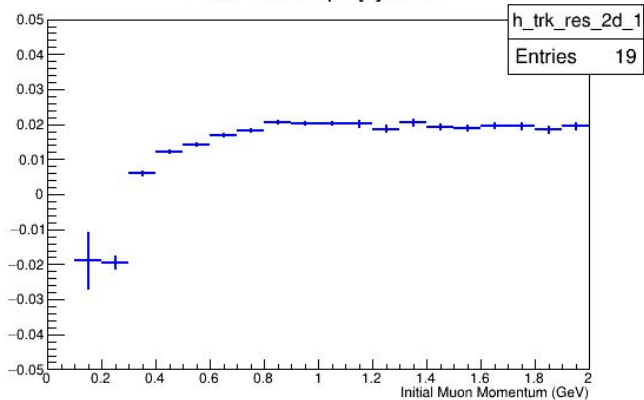
Fitted value of par[0]=Constant



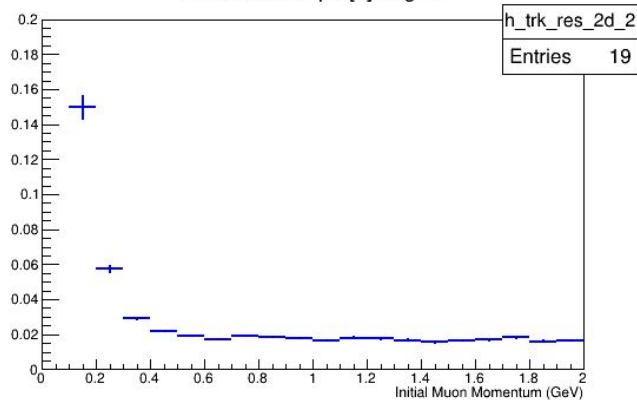
Fitting each 100 MeV wide momentum bin with a single Gaussian.

Similar conclusions to previous muon sample.

Fitted value of par[1]=Mean



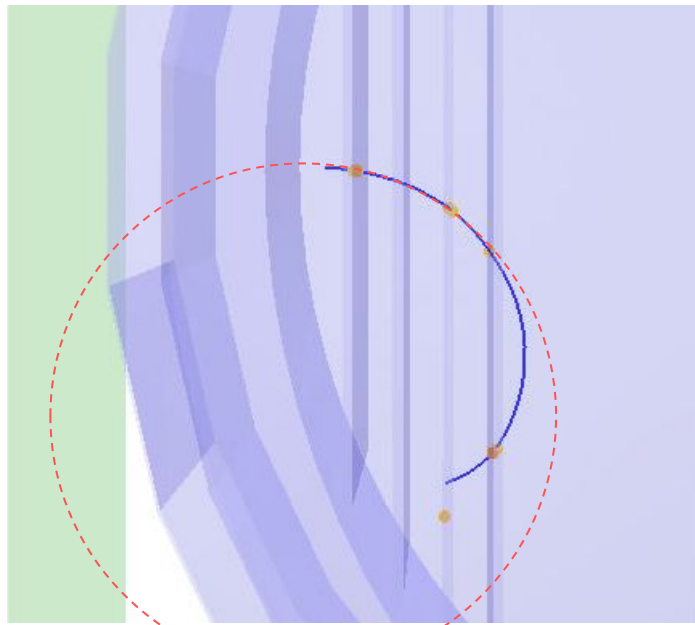
Fitted value of par[2]=Sigma



Note that since the muons start inside ND-GAr-Lite, the lower bound starts at 100 MeV.

Many of the muons in the first bin would likely not reach ND-GAr-Lite.

## Six Planes Tracking Resolution

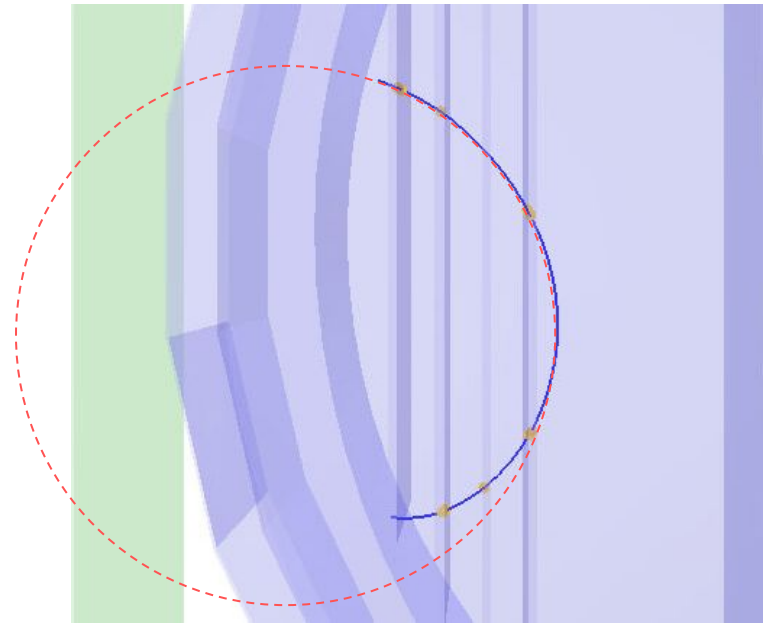


Muon

True P: 0.201 GeV/c

Reco P: 0.175 GeV/c

$\Delta P/P$  : -0.13



Muon

True P: 0.222 GeV/c

Reco P: 0.208 GeV/c

$\Delta P/P$  : -0.06

Low Momentum Reconstruction Difficulties

# Comments on Momentum Resolution

For most of the momentum range the resolution is 4% or less, with many bins near 2%.

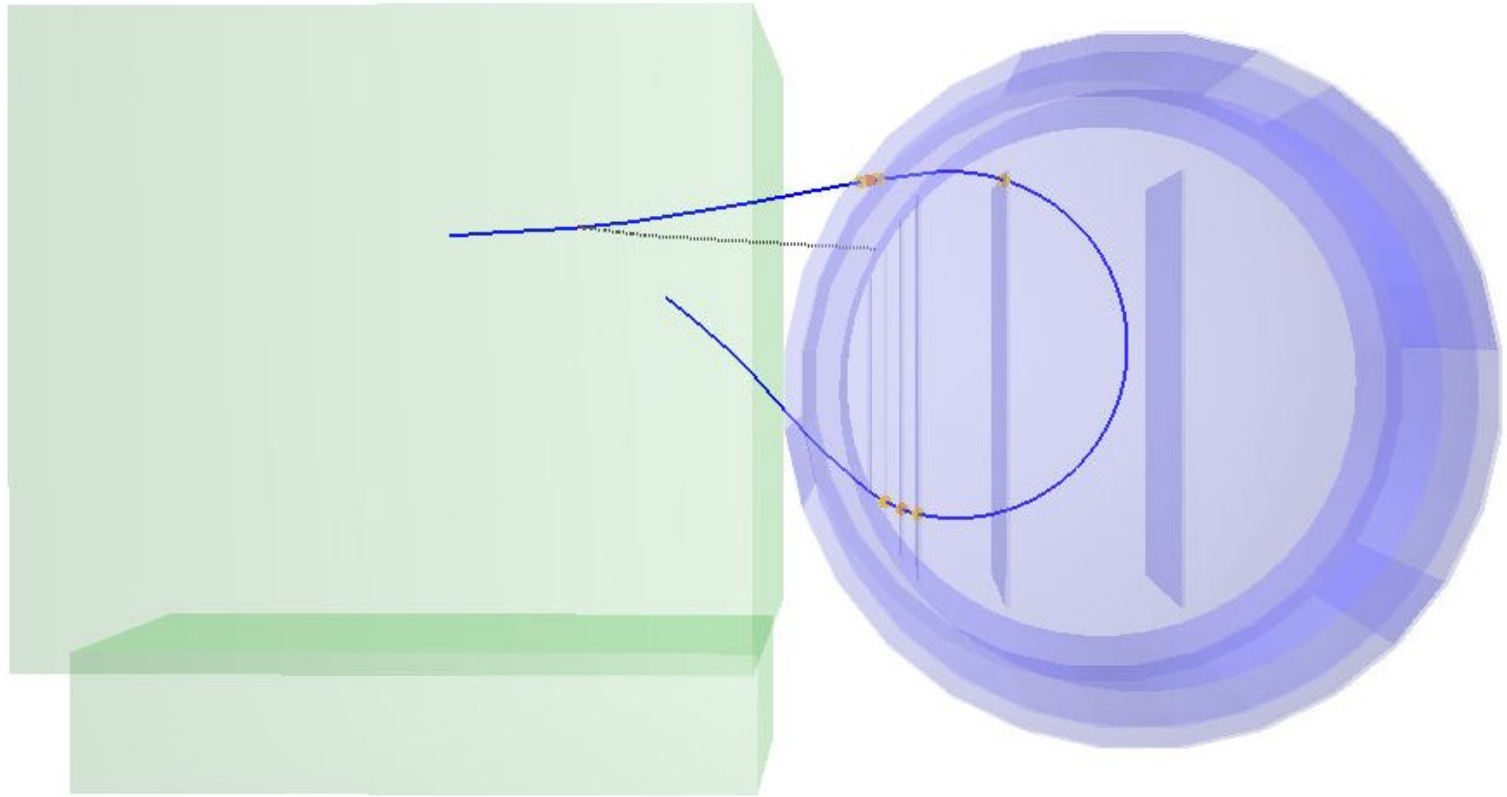
The lowest momentum bins (below 1 GeV) are noticeably worse, reaching 7%. Some of this is likely due to limitations in the reconstruction and energy loss correction.

For these low momentum muons the overall track resolution will (probably) be driven by the measurement in the LAr.

The momentum resolution overall is good enough to function as a muon spectrometer.

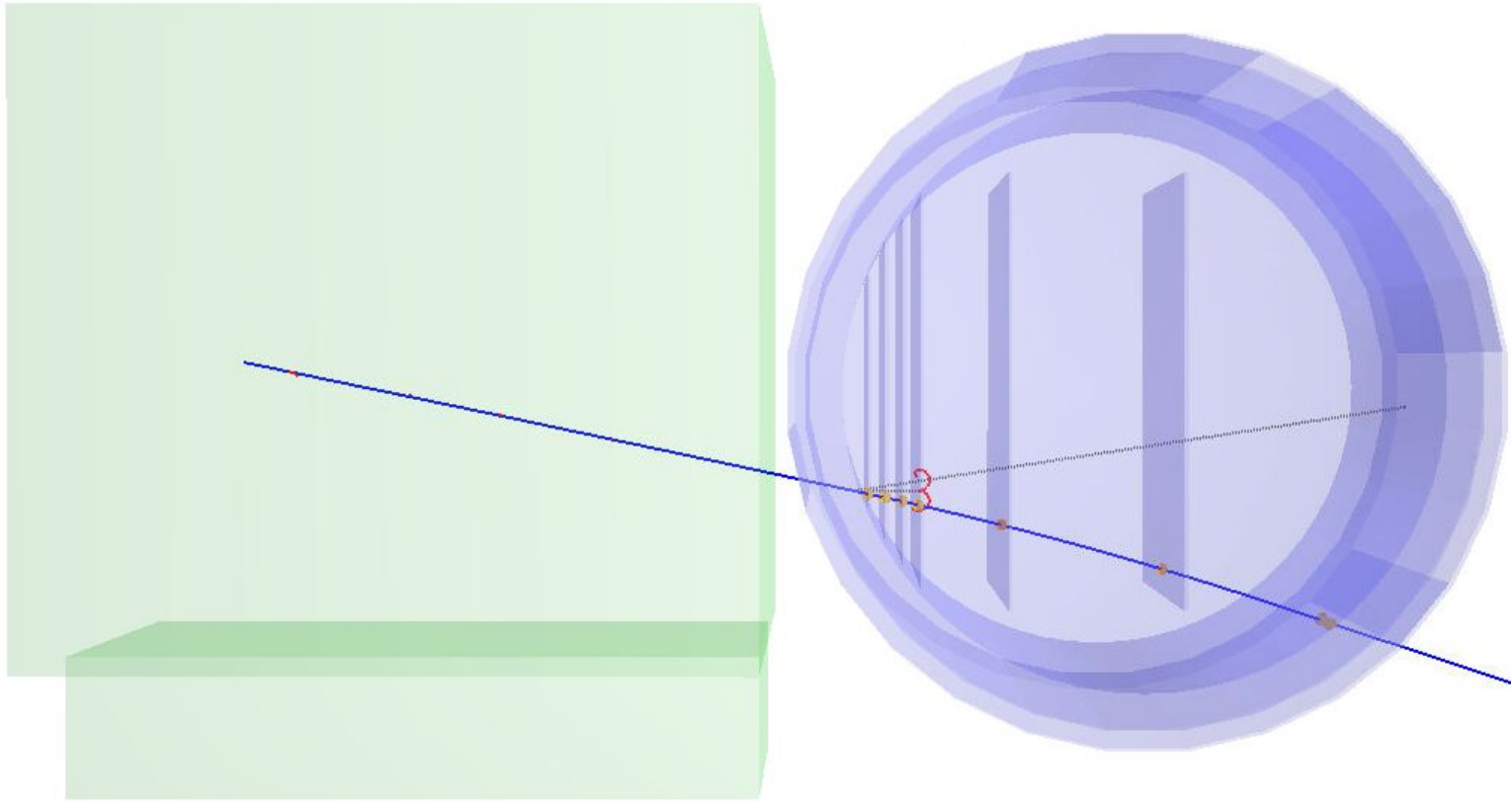
# Extra

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Muon: 1.32 GeV

Event Displays!



Event Displays!

Muon: 9.11 GeV  
Photon: 46 MeV  
e+/e- pair: 23 MeV