Simulation of a TPC Pixel Readout with MarlinTPC

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ILD Meeting 2010 — LCTPC Pre-Meeting
Fukuoka, Japan, 22. 5. 2012

Overview

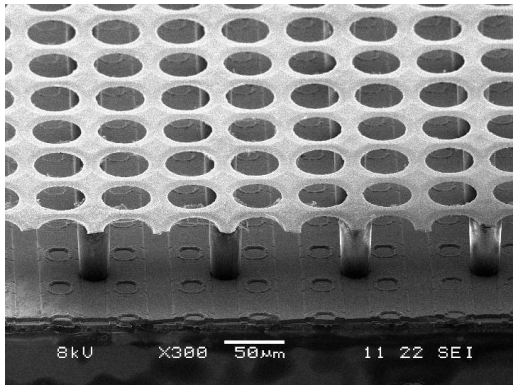
Simulate a full ILD TPC with InGrid-like pixel readout

Detect every primary electron

- Ultimate spatial resolution
- Best possible track separation (only limited by diffusion)
- Reject delta electrons ⇒ improve dE/dx and momentum reslolution

Planned Studies:

- Occupancy at CLIC
  - Full CLIC bunch train of beam background
  - \+ Does not require reconstruction
  - − Uses lots of memory
- Momentum resolution, dE/dx
  - Use single muons
  - Need to cut delta electrons
  - Cluster counting: needed?
- Tracking efficiency
  - Requires full pattern recognition



Simulation and Digitisation

- Simulate primary ionisation clusters (Mokka ✓)
- Drift individual electrons (DriftProcessor ✓)
- Overlay voxels in memory (not implemented yet)
- InGrid-like "TPCPix" readout (new: TPCPixDigitisationProcessor ✓)
  - The "ideal" readout chip
  - Integrated micro mesh ✓
  - Time and charge information per pixel ✓
  - Fast shaping time (like internal ADC per pixel) ✓
  - Unlimited multi-hit capability ✓
  - Currently perfect end plate, no individual chips ✓

  For more realism:
  - Polya-like gas gain fluctuations (not implemented yet)
  - Adjustable cross-talk between pixels (10 %) (not implemented yet)

Reconstruction

No pattern recognition for pixel readout

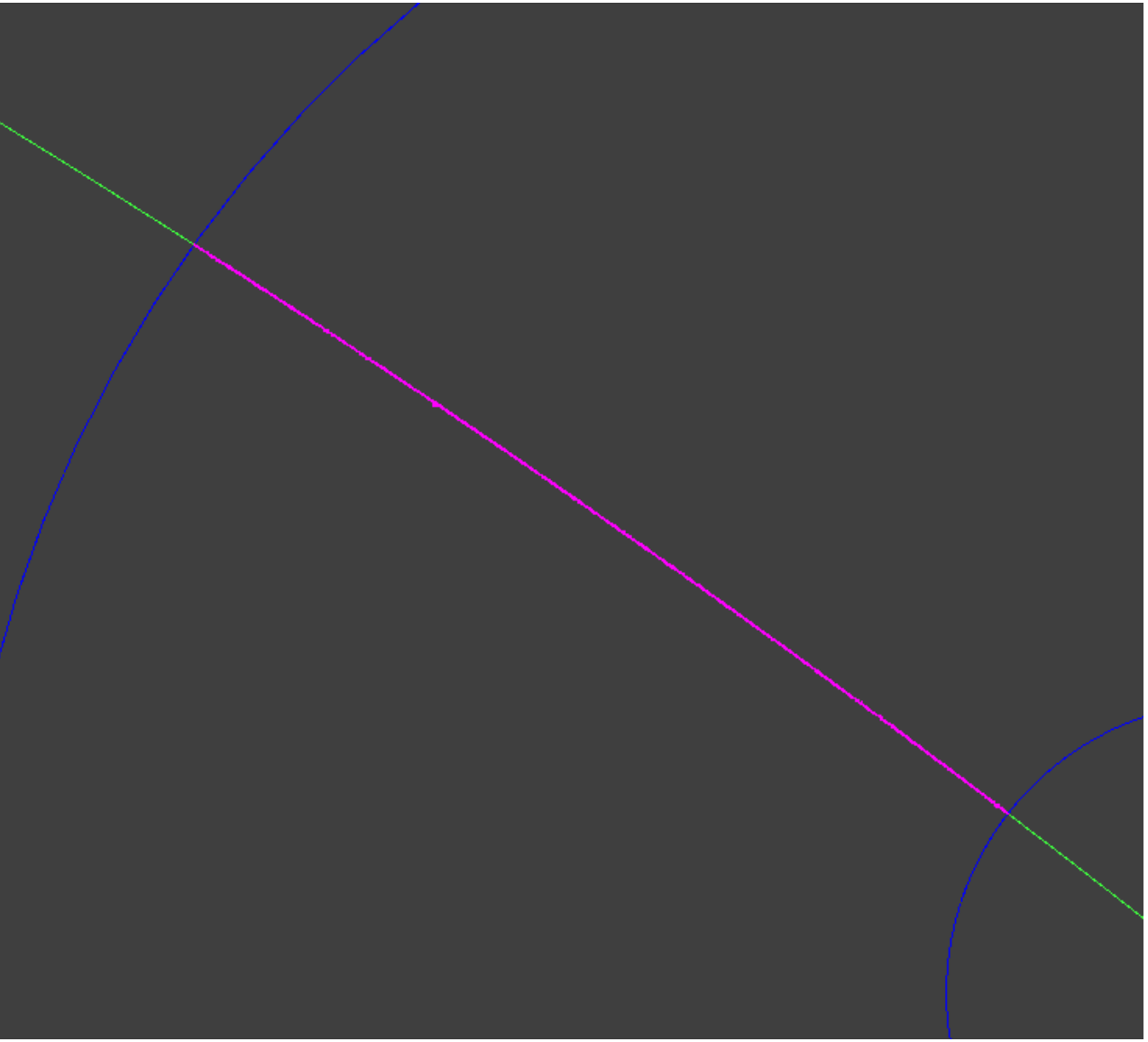
- Current Kalman-Filters work layer (pad row) based
- Hough-transform does not work (too many pixels)

Current solution for single tracks without background and noise

- Fit a helix to all recorded pixels
- Treat all pixels equally (digital readout, charge information not used)
- Perform outlier rejection (delta electrons)
  $\rightarrow$ cut at 2.5 RMS of residual distribution
- Iterate

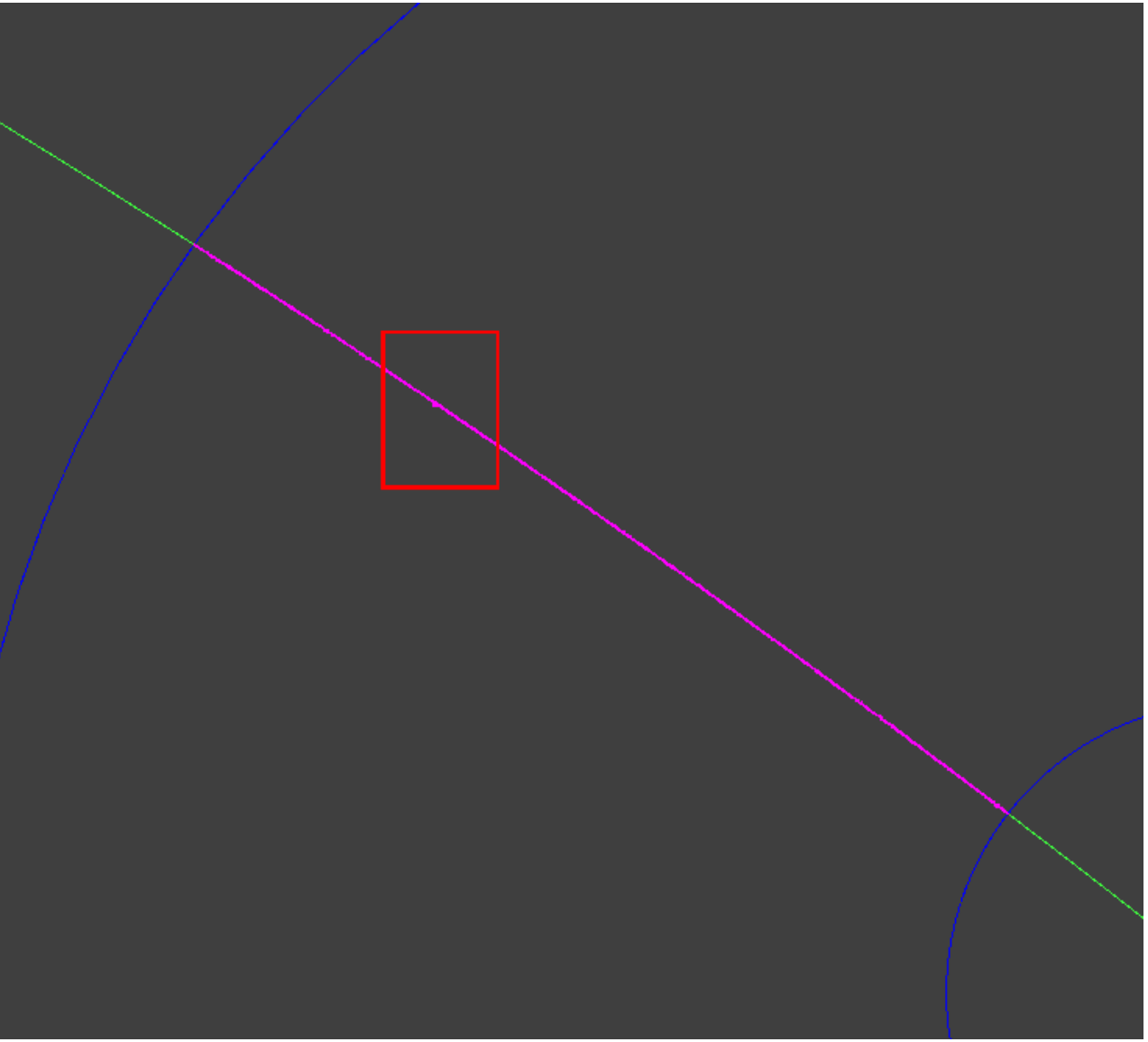
Event Displays

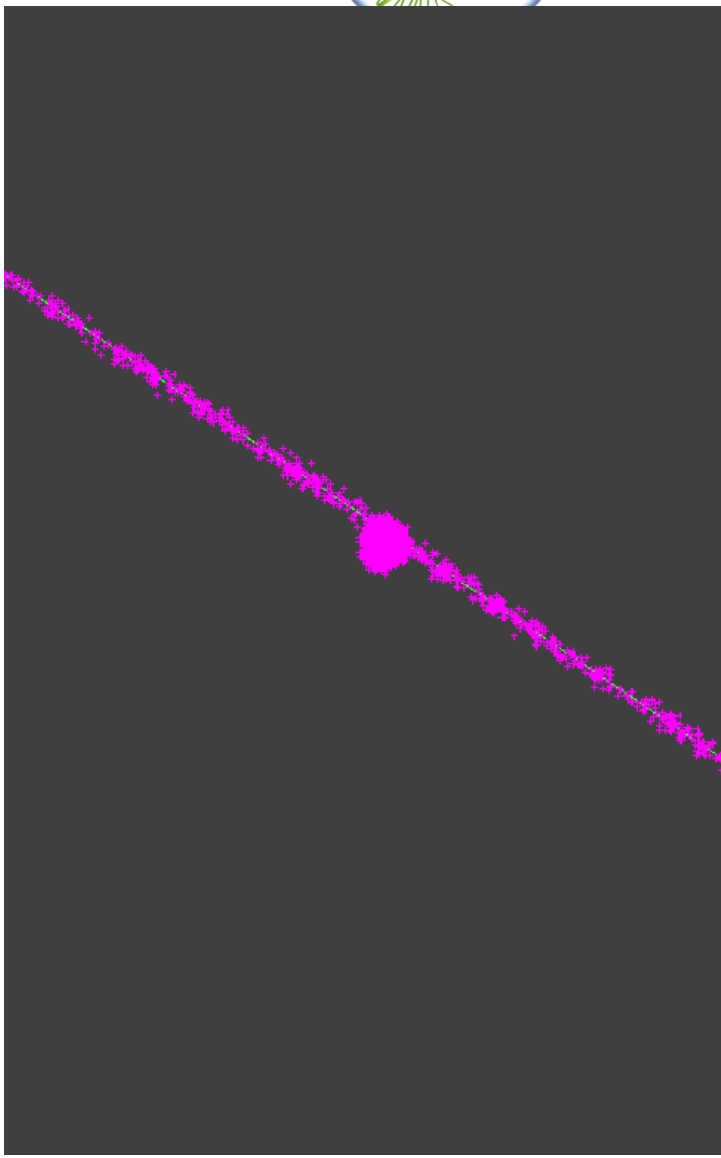
xy Projection



Event Displays

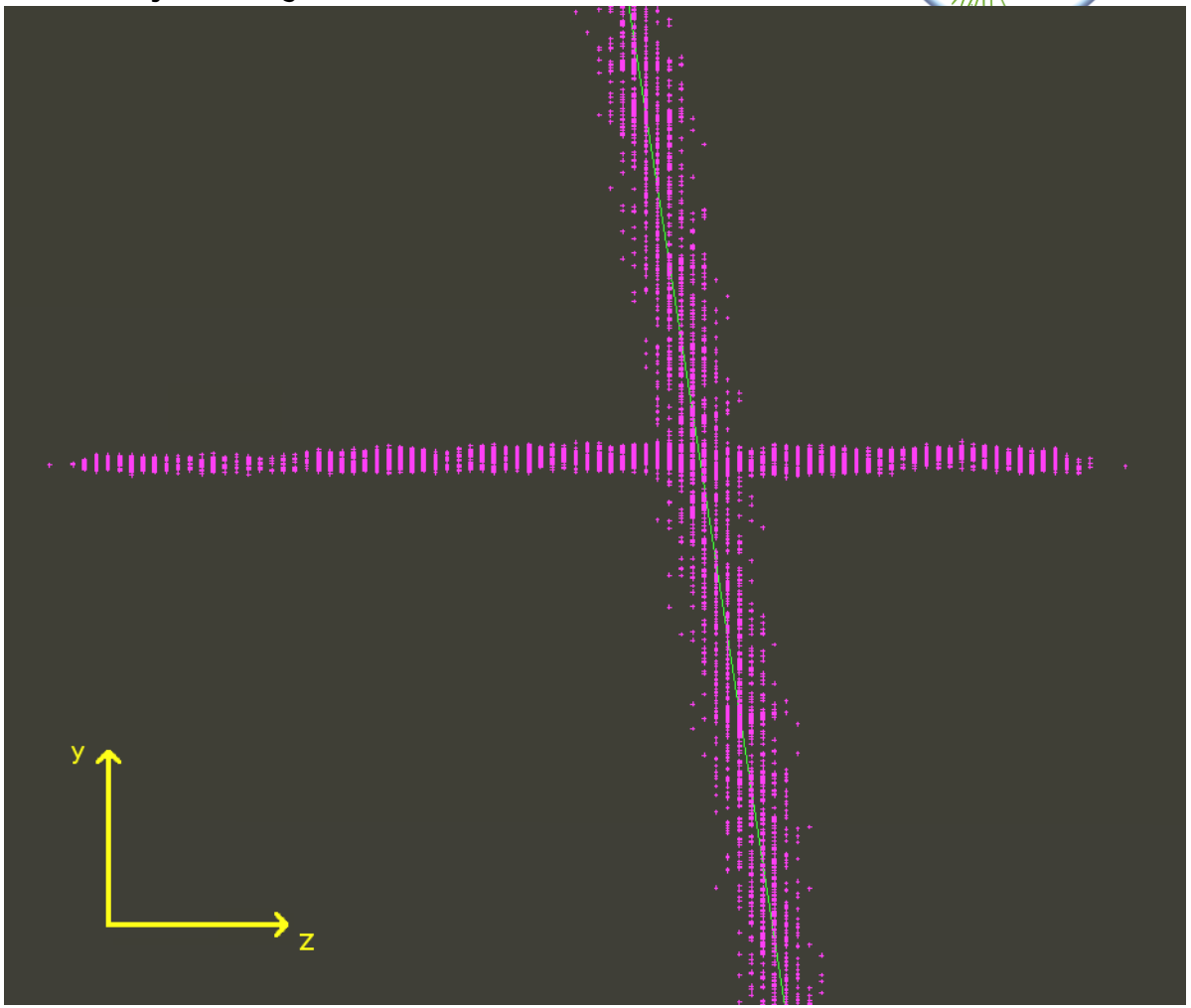
xy Projection





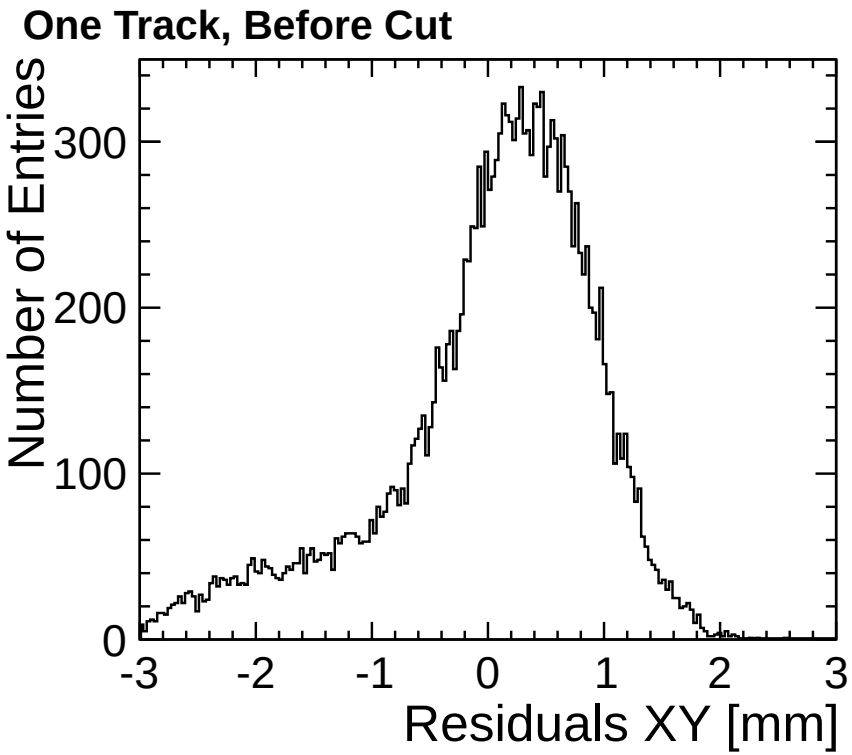
Event Displays

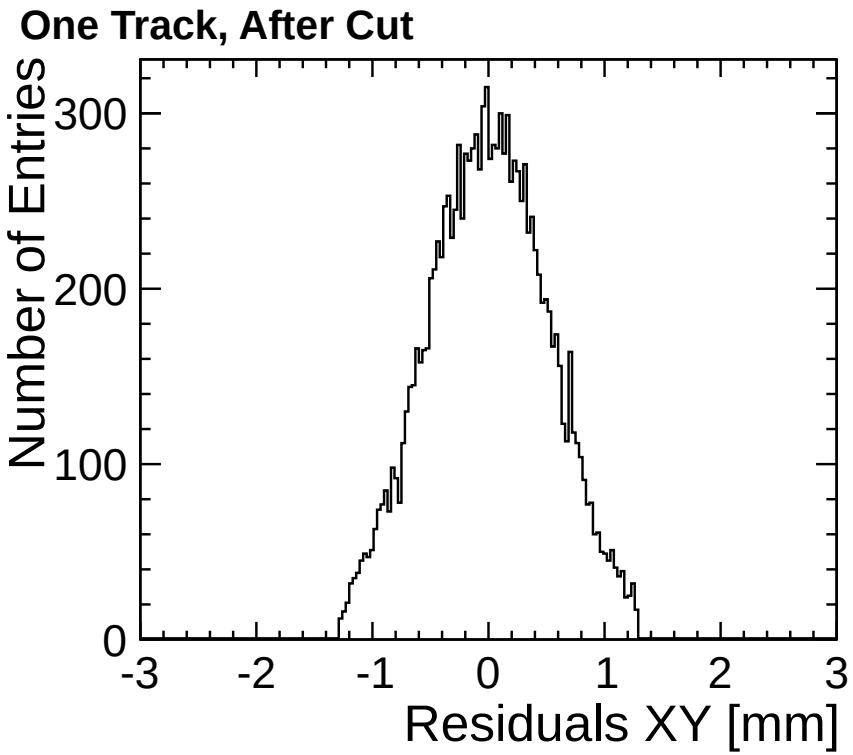
yz Projection



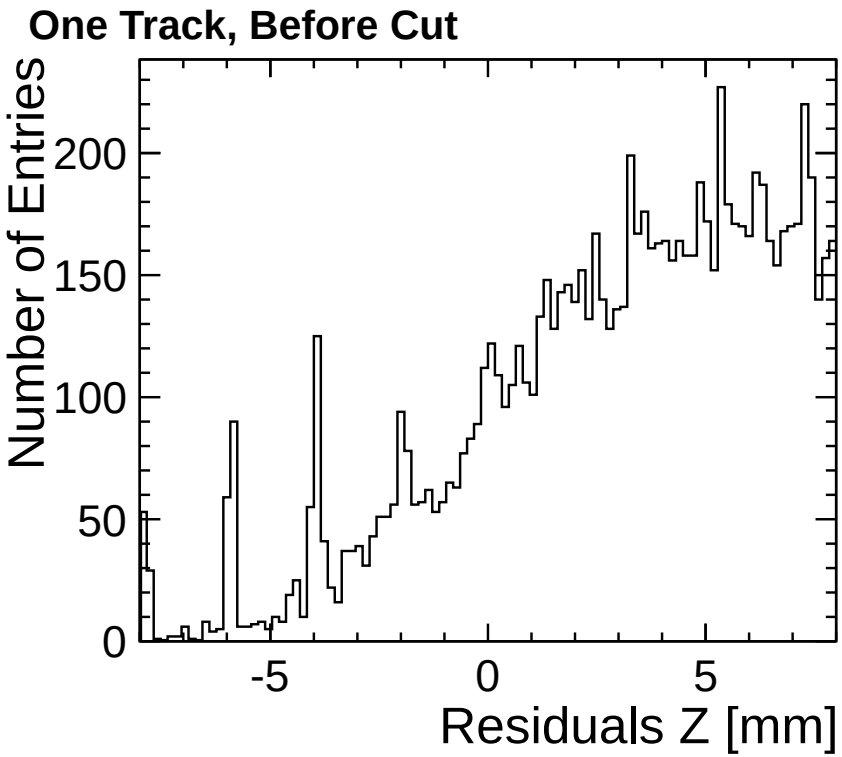
Binning in z due to 40 MHz readout frequency $\hat{=}$ 2 mm drift distance

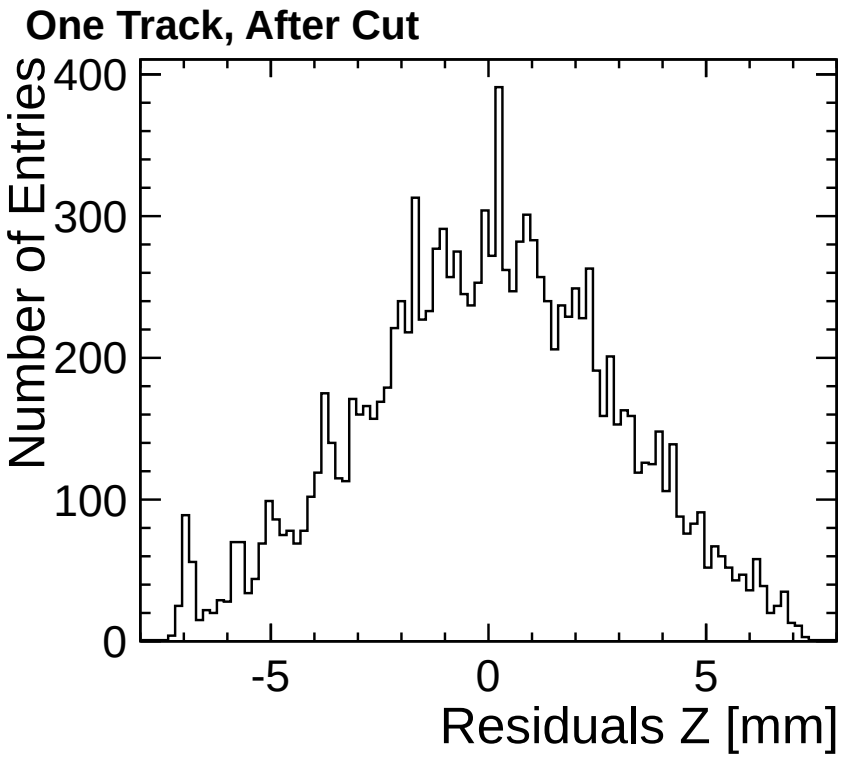
Residuals in xy





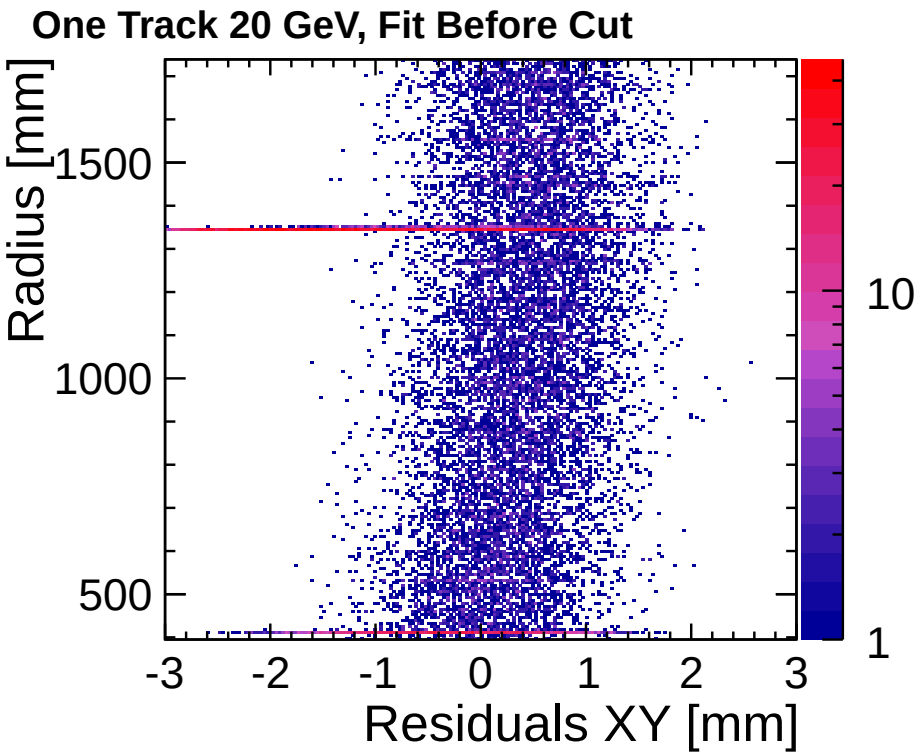
Residuals in z

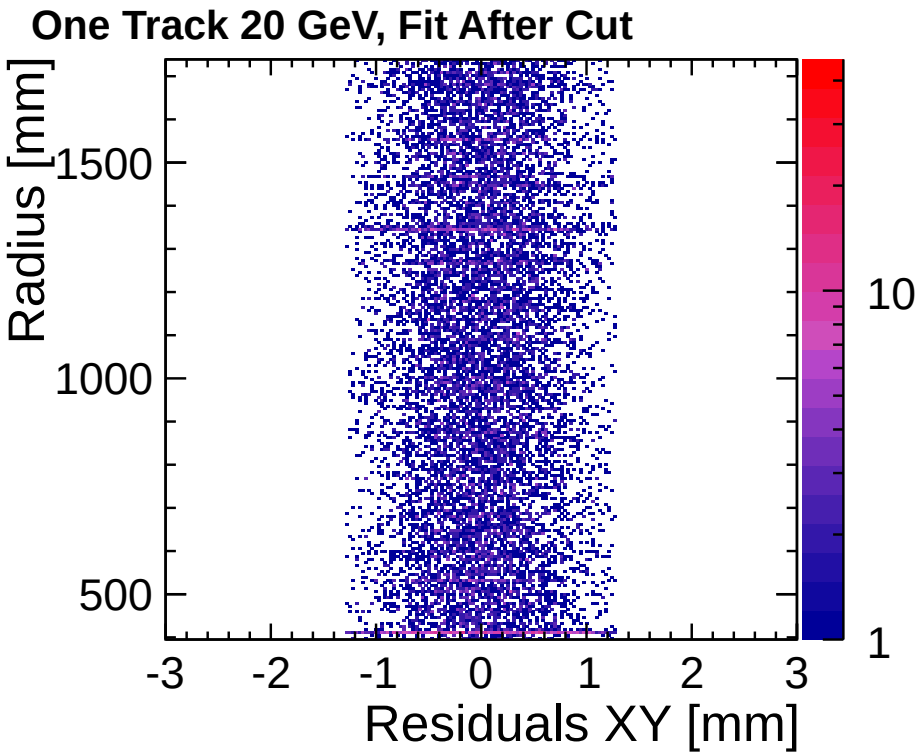




Peaks are due to z binning in micro curlers

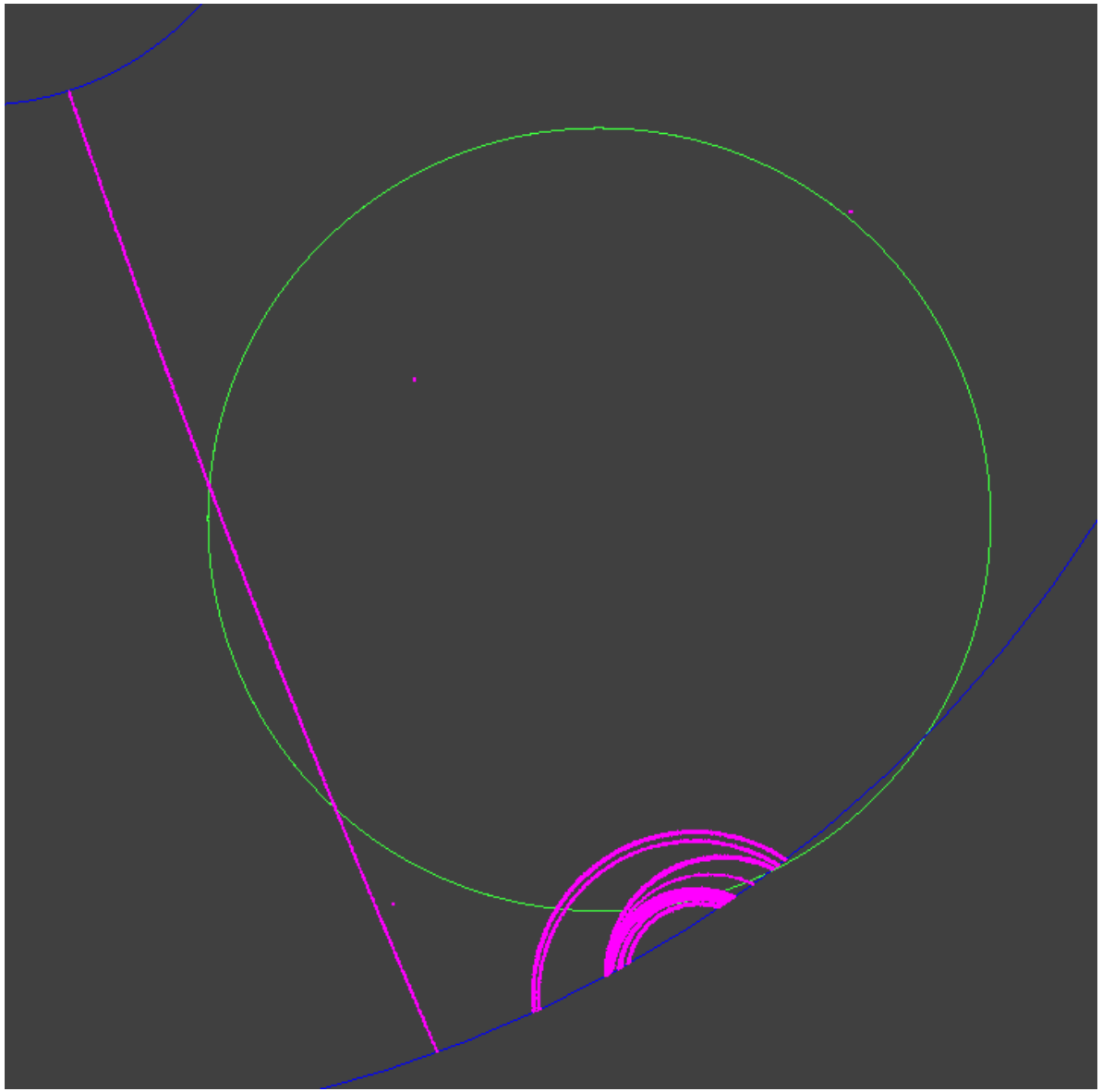
Residuals in xy vs. r





Bad Fit

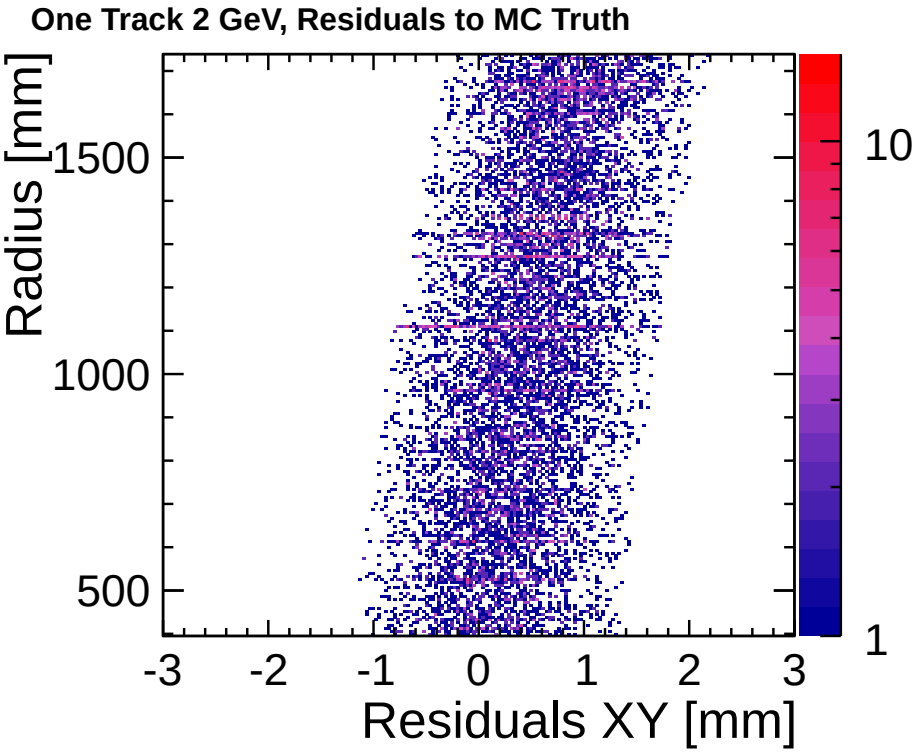
Cutting outliers does not always work...

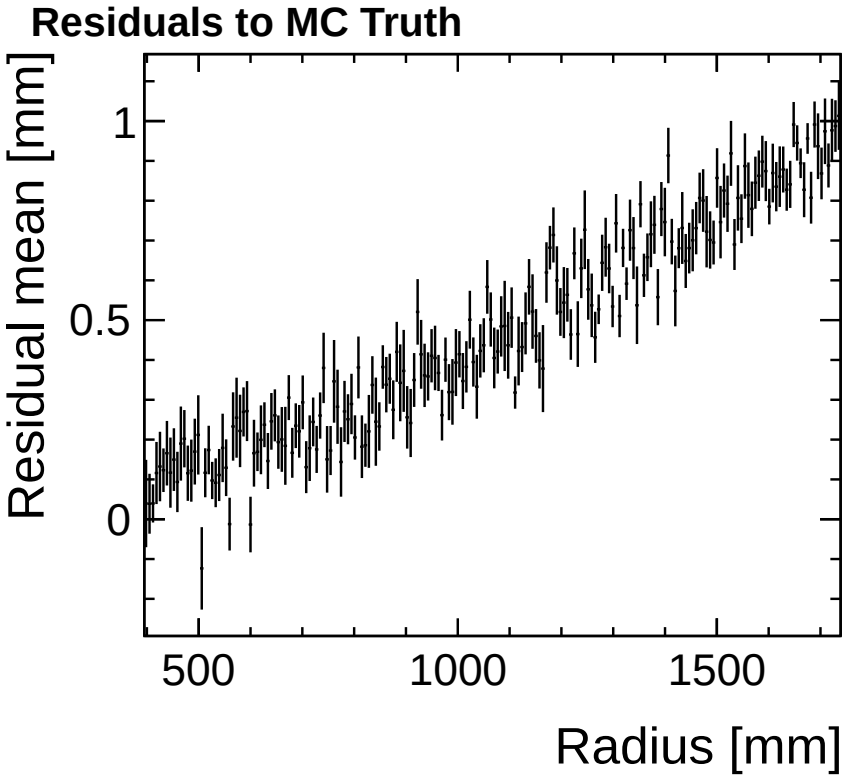


Deviation from the MC Truth

MC truth = perfect helix at the particle origin (IP)

2 GeV muon



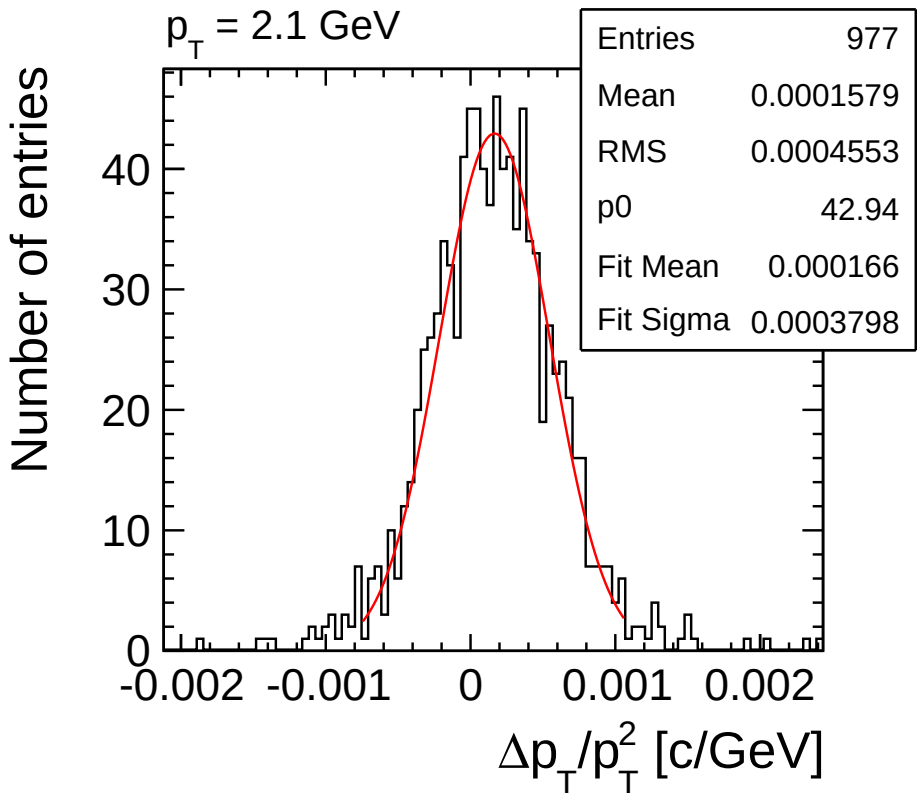


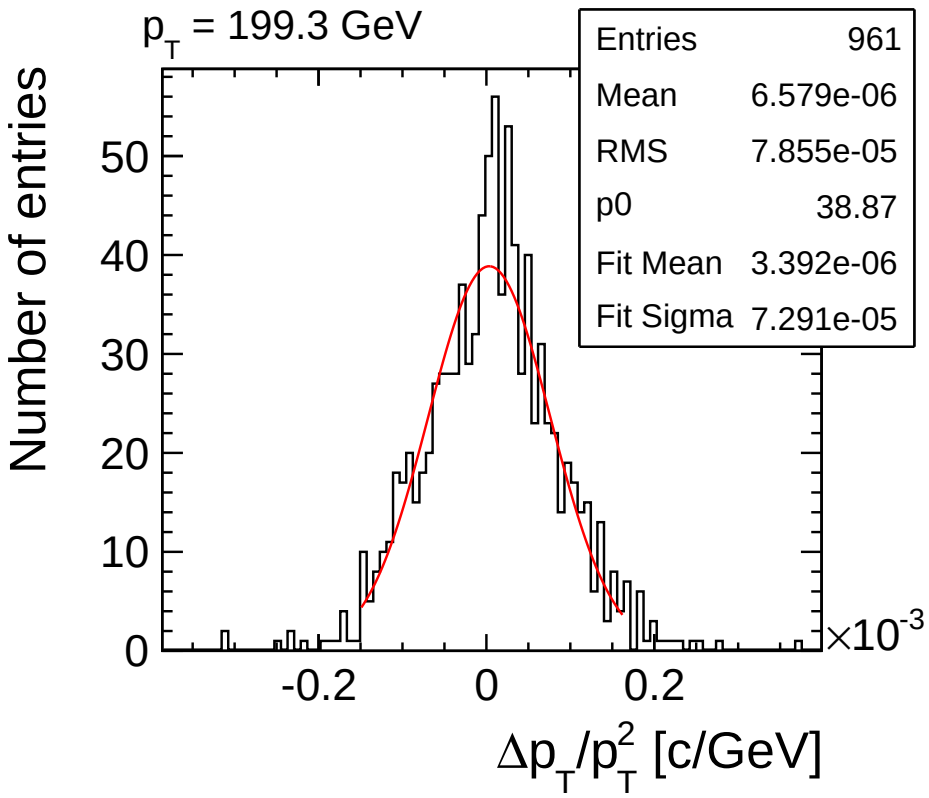
Deviation can be due to

- Energy loss (not a perfect helix)
- Multiple scattering

Momentum Resolution 1

1000 muons from the IP

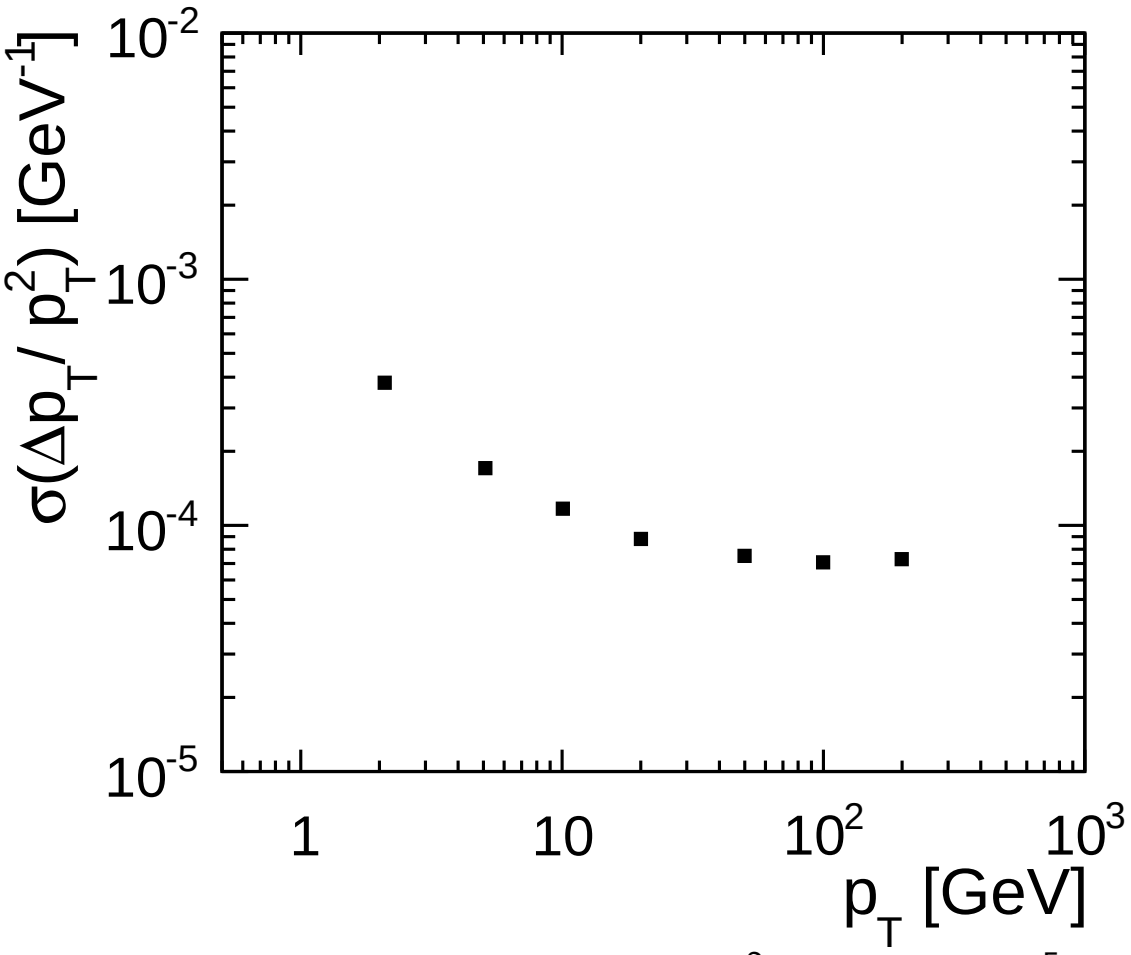




- Slight shift to positive values ⇒ measured momentum is too large

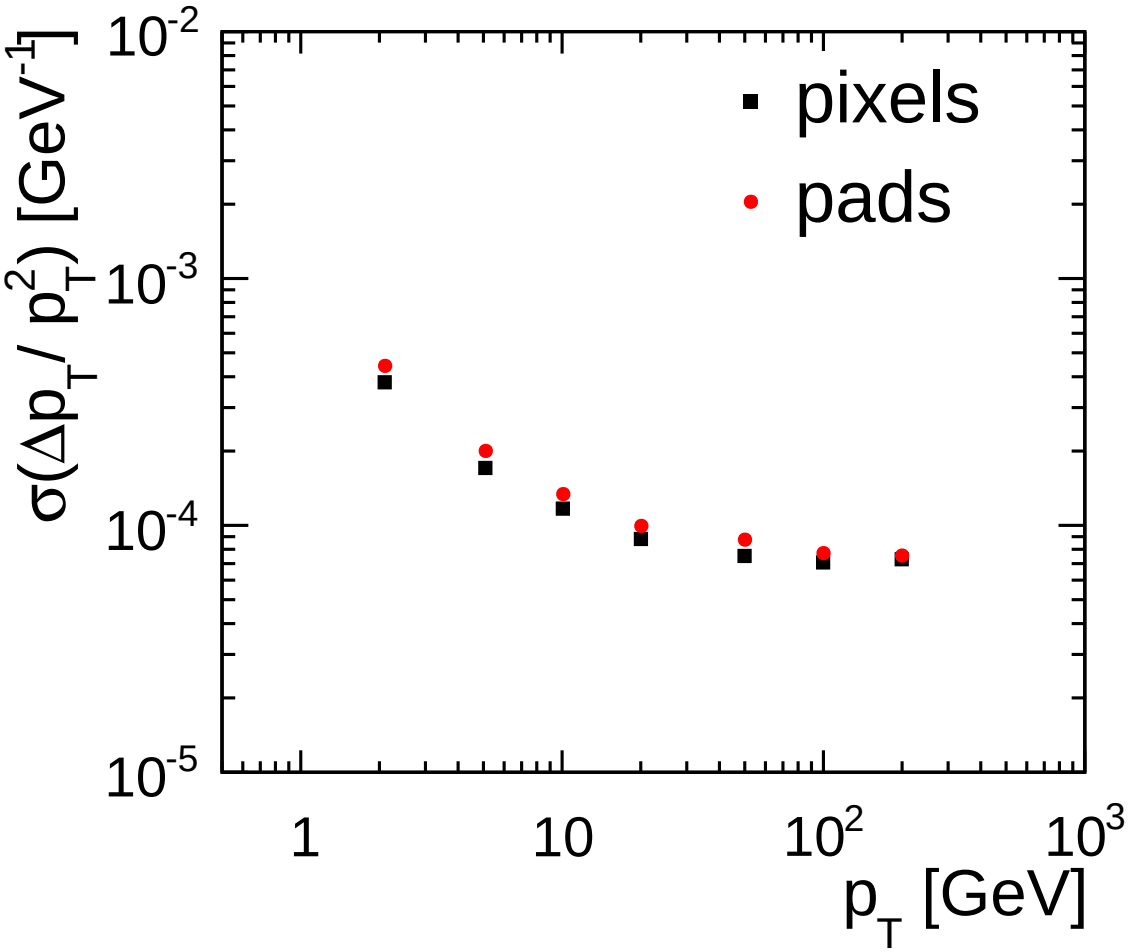
Momentum Resolution 2

1000 muons from the IP



- Momentum resolution@200 GeV $\sigma(\Delta p_T/p_T^2) = 7.3 \cdot 10^{-5}$

Momentum Resolution 2



- Momentum resolution@200 GeV $\sigma(\Delta p_T/p_T^2) = 7.3 \cdot 10^{-5}$
- Slightly better than resolution for pads($\sigma(\Delta p_T/p_T^2) = 7.5 \cdot 10^{-5}$@200 GeV)

  1×6 mm^2 pads, Mokka driver in default mode + MarlinReco / LEPTracking

Summary

- Digitisation for TPC pixel readout
- Helix fitting works for single tracks
- Outlier rejection removes most of the delta components

Results

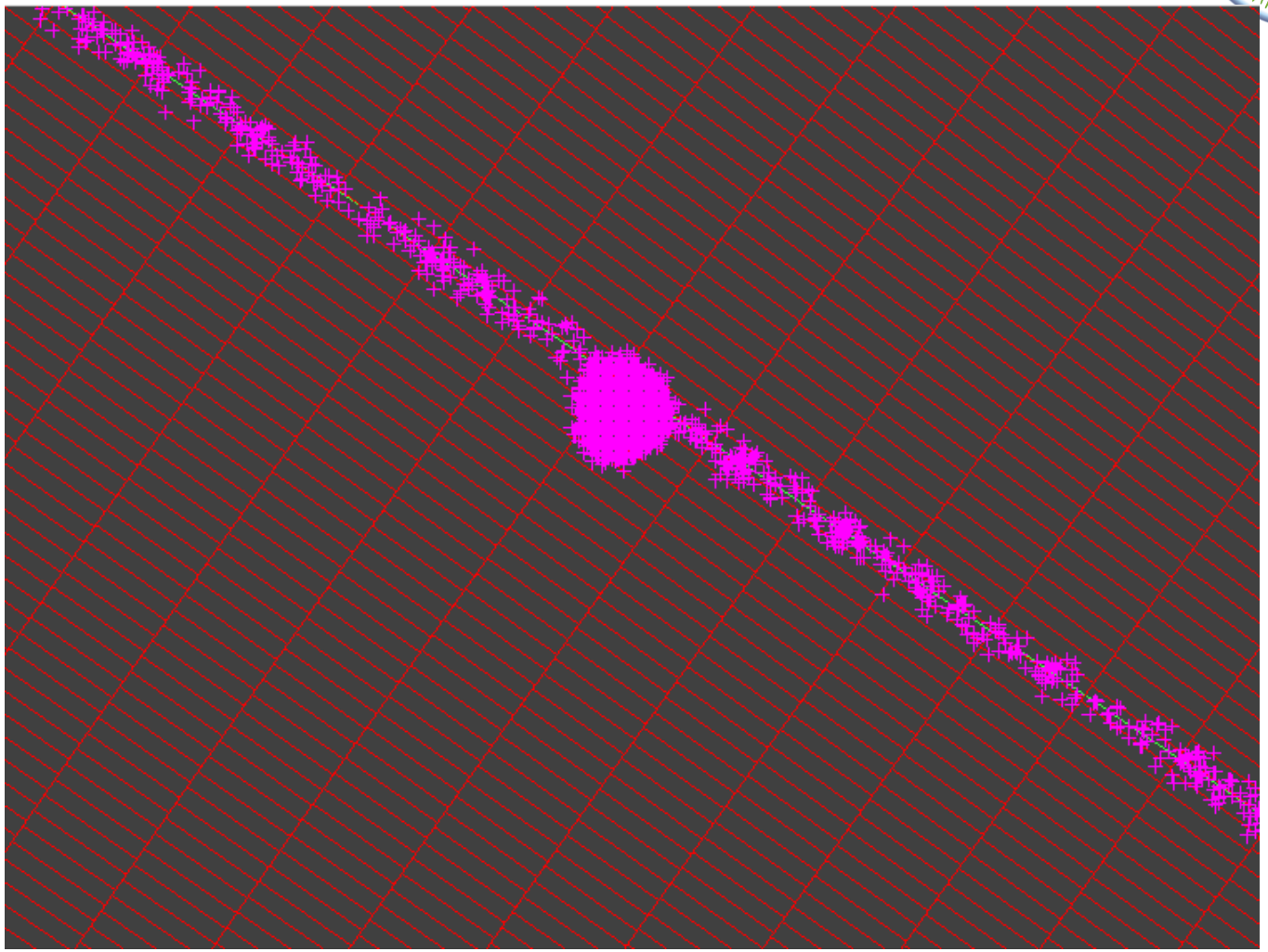
- Deviation from helix due to multiple scattering in the field cage and energy loss
- Perfect helix is a good approximation inside the TPC
- Momentum resolution reaches $\sigma(\Delta p_T/p_T^2) = 7.3 \cdot 10^{-5}$
- To be understood: Why is the reconstructed momentum too large?

Next steps

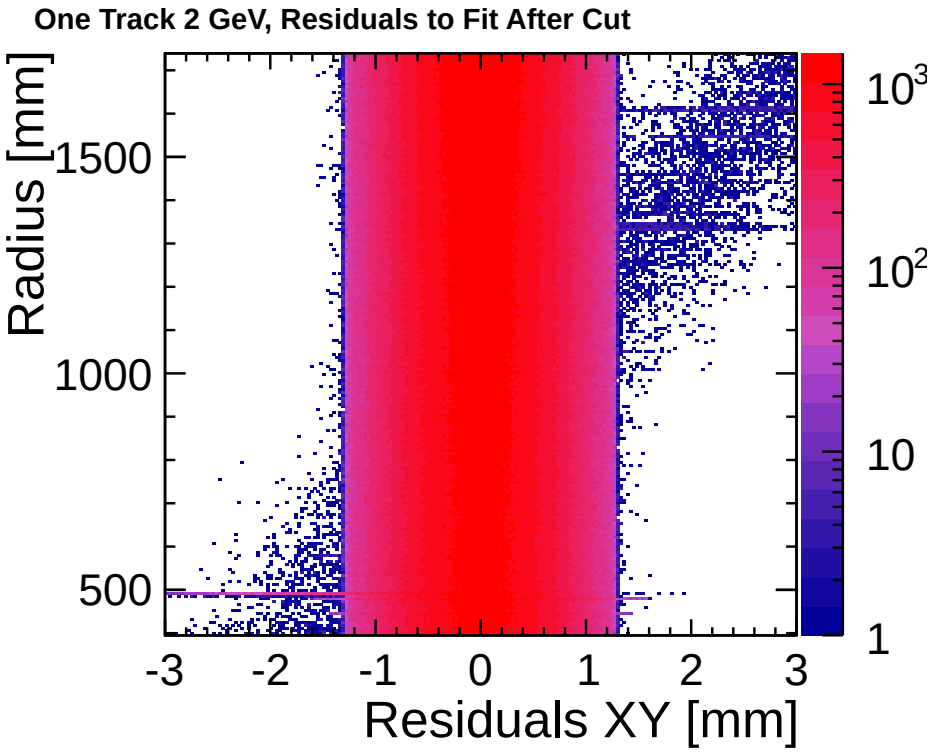
- Implement gas gain fluctuations and cross talk
- Look at dE/dx
- Occupancy study
- Pattern recognition = ???

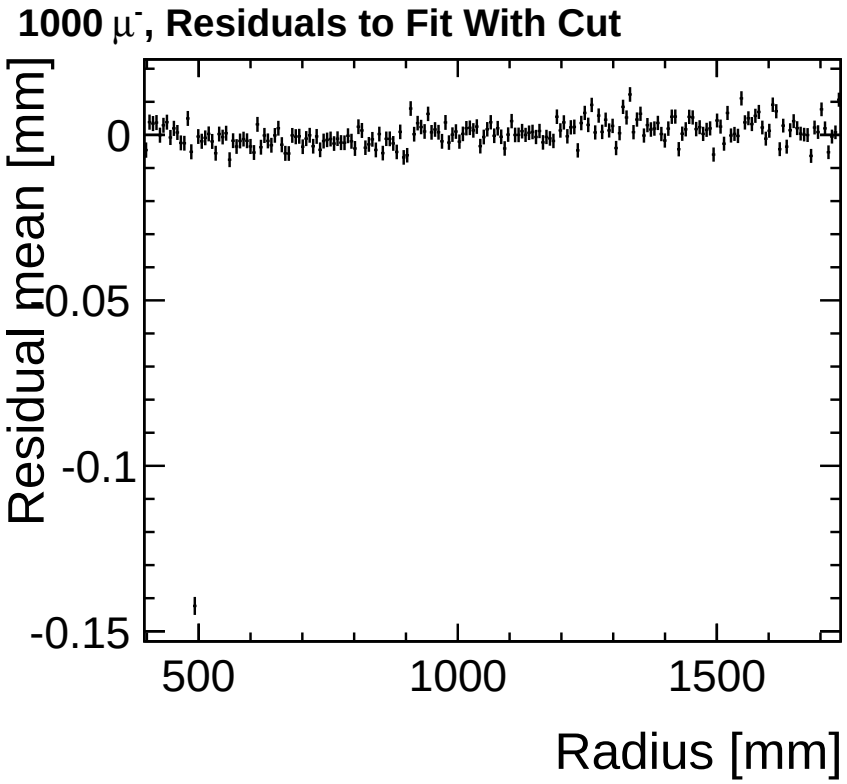
Backup

Comparison with Pad Size



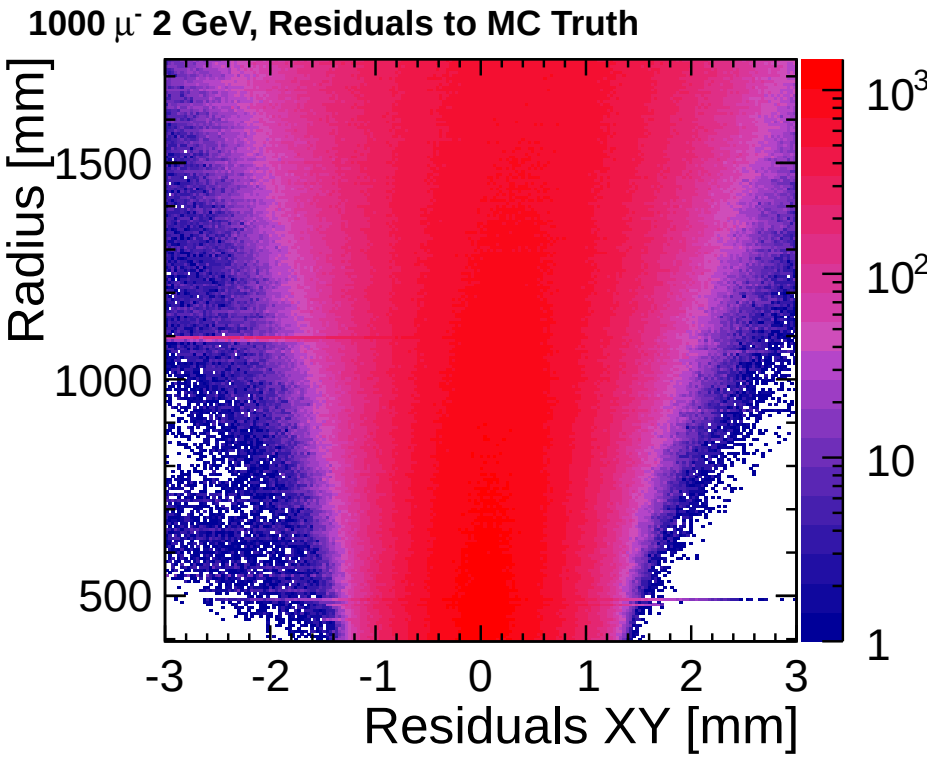
Residuals for 1000 muons

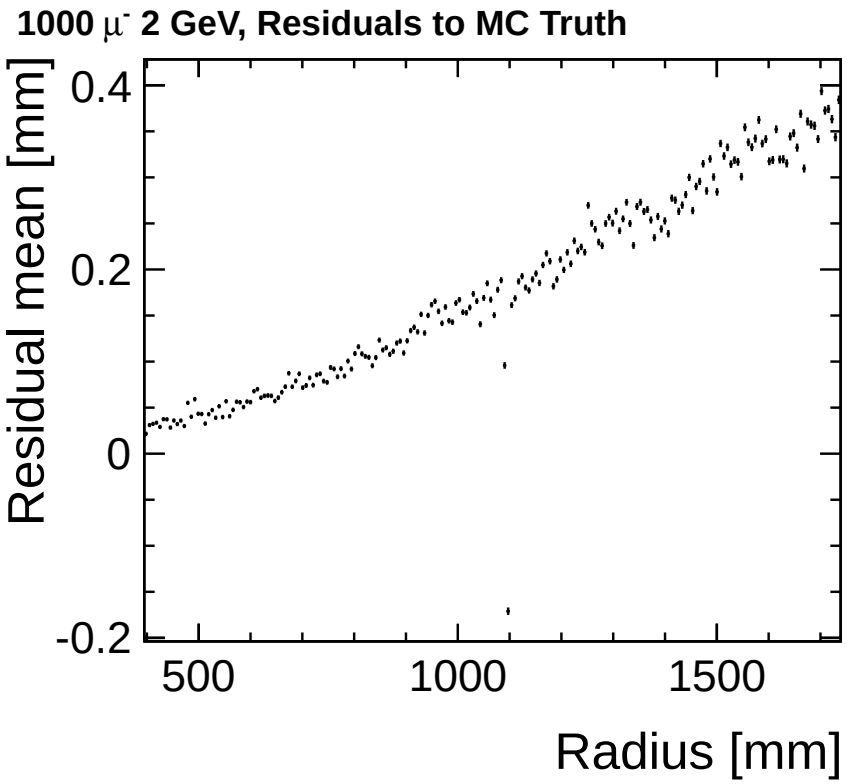




No deviation from perfect helix

Residuals for 1000 muons





MC helix of particle at the IP