Radial TPC for e^+e^- tracking — Simulations

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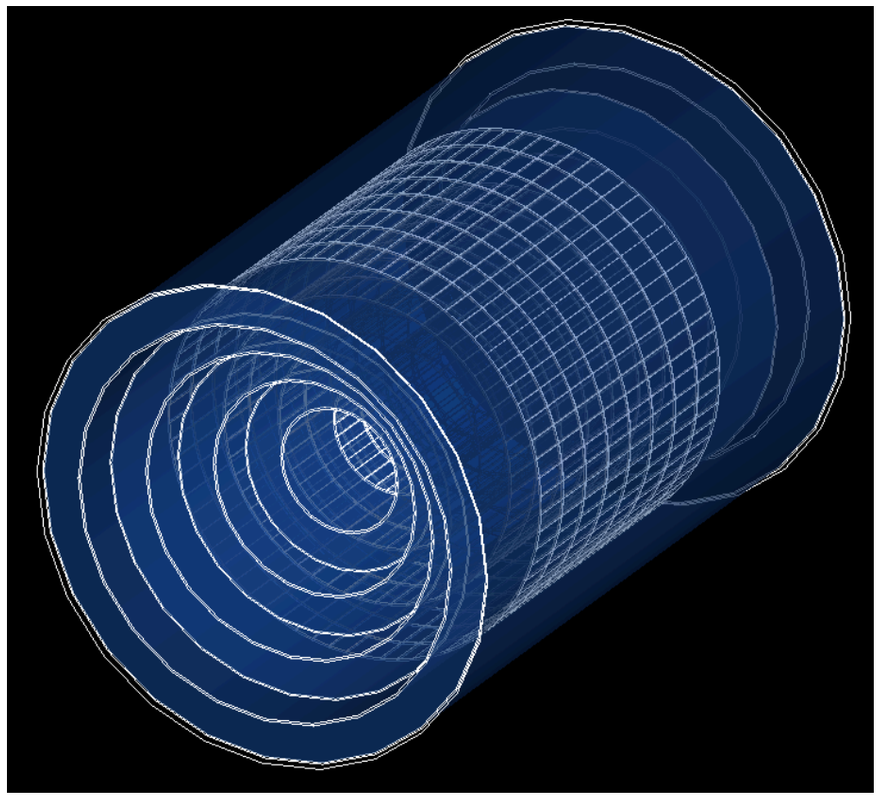
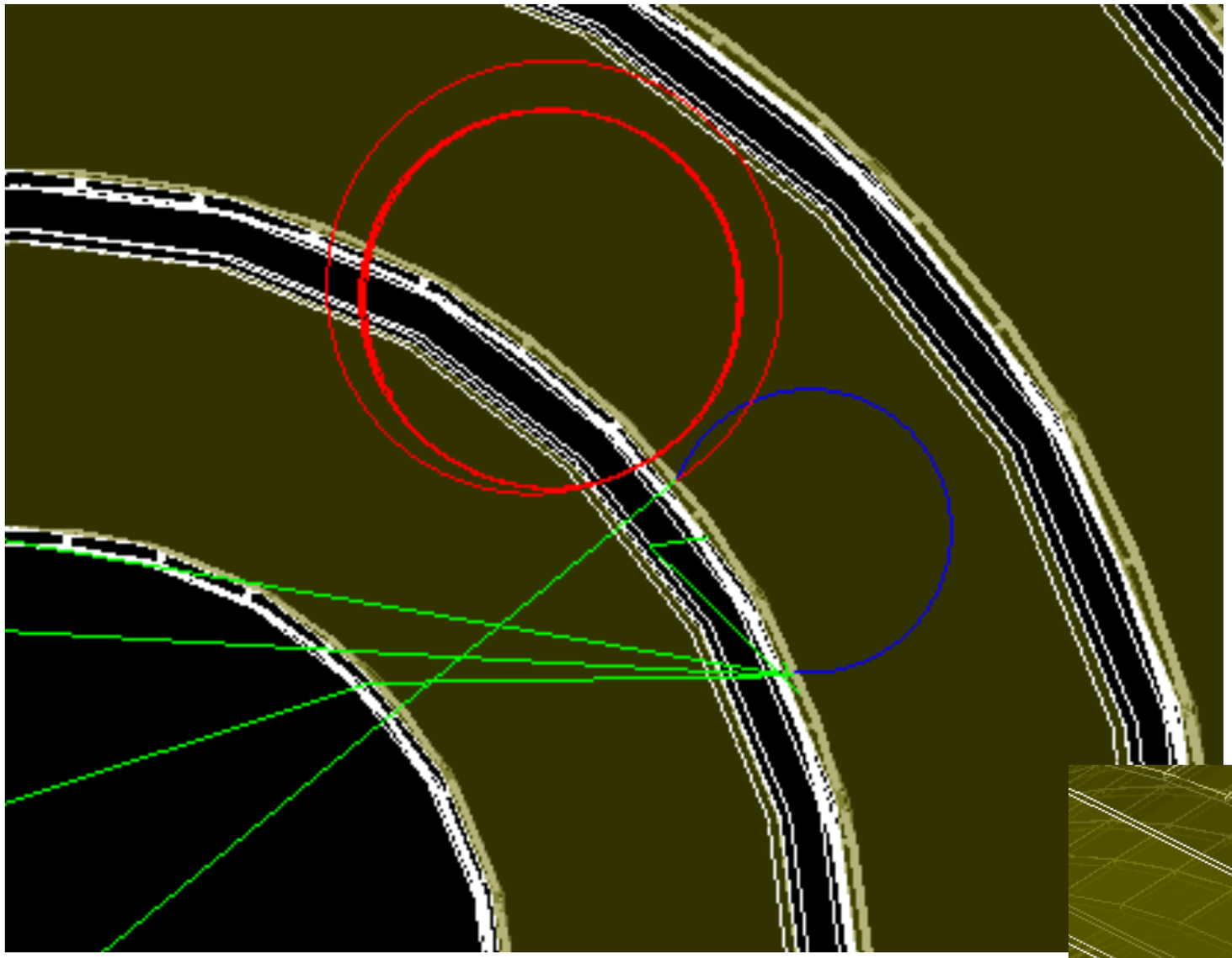
Simulation framework

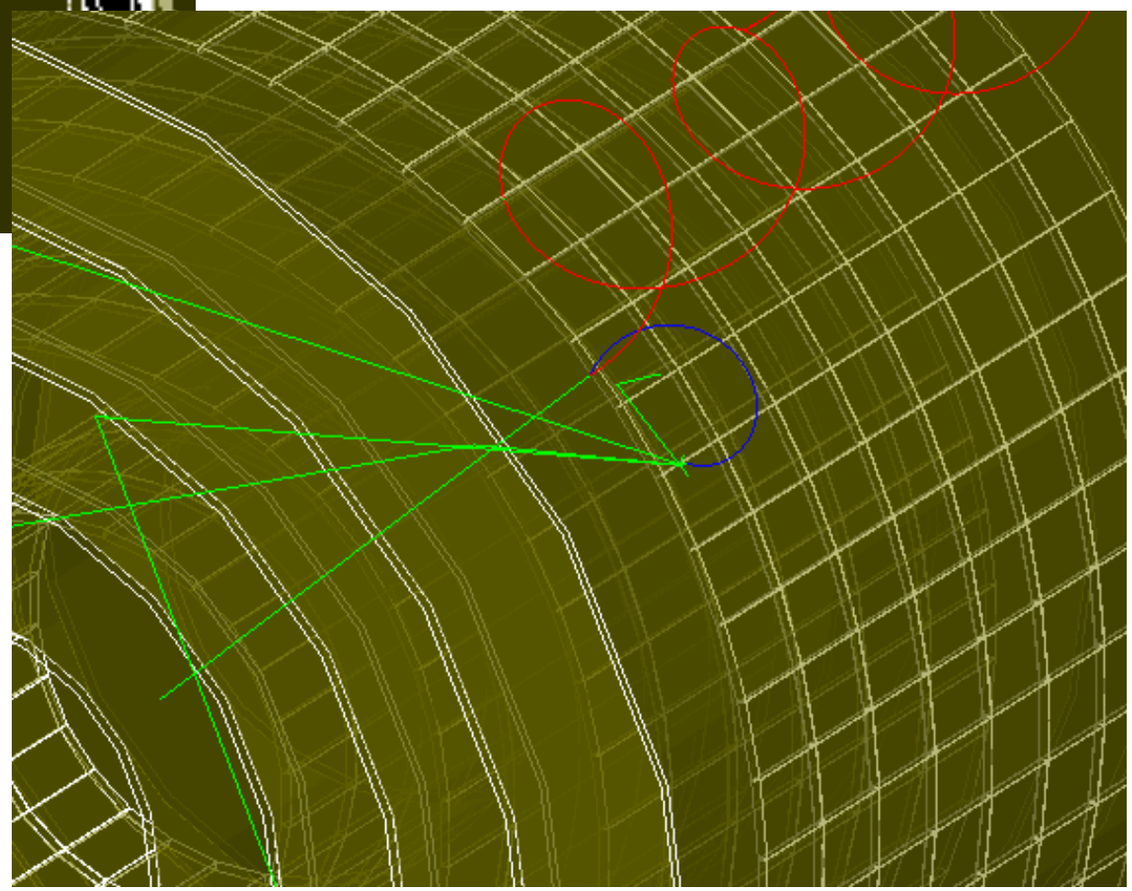
- A simulation framework was setup by the Tokyo group, starting from the Pioneer framework

- A basic simulation of **4 coaxial TPCs** was included in the geometry model, based on cylindrical layers:

  - inner wall (50 μm Kapton), intended for gas containement and possibly serving as cathode electrode
  - gas volume (He:C_4H_{10} 90:10)
  - dummy readout structure (5 mm FR4)
  - BESIII C-GEM strip pitch
  - GEANT hits corresponding to single ionization clusters
  - 1 T uniform magnetic field



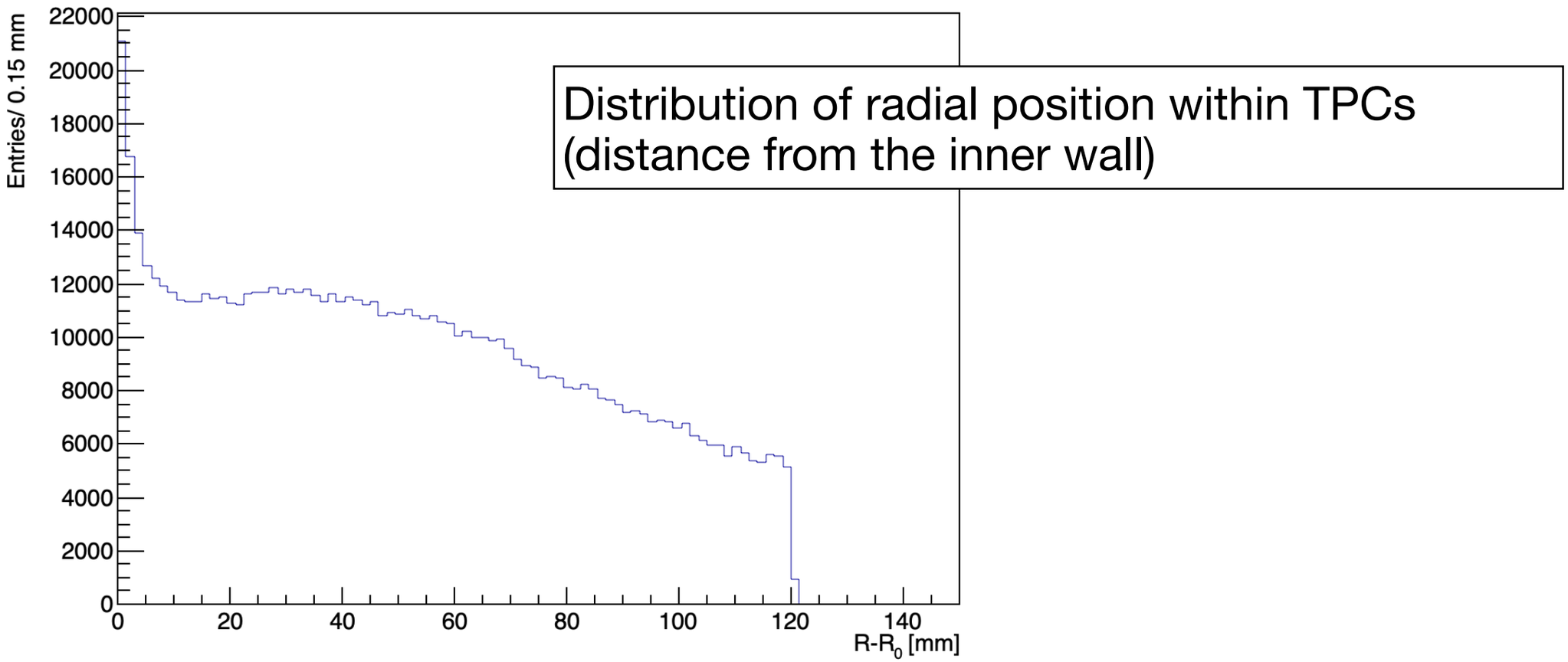




Geometry optimization

- For a good efficiency and momentum resolution, it is critical to have **at least half a turn** within a single chamber for most of the tracks (i.e. tracks not exiting the outer TPC wall)

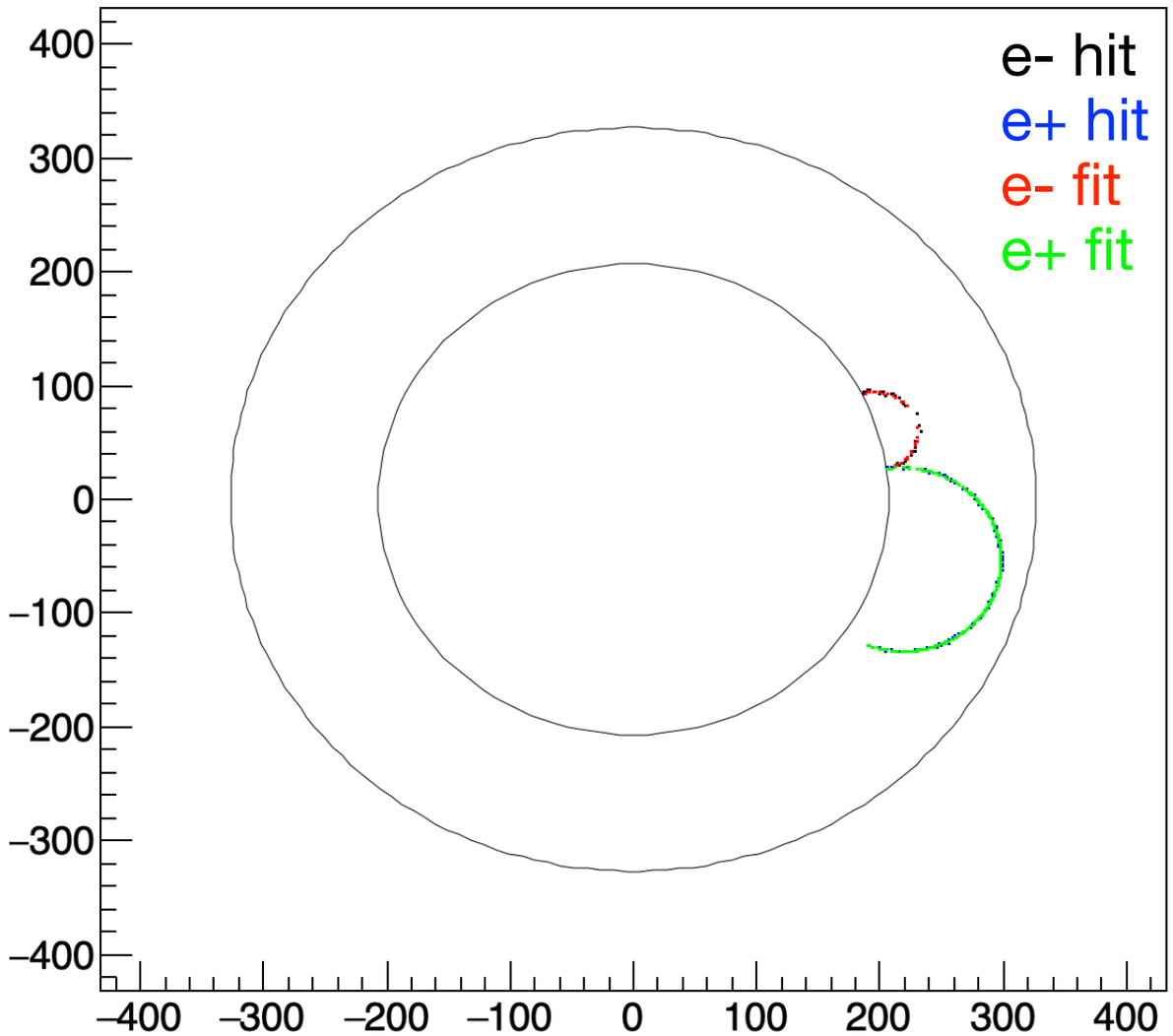
- Results shown here are for 12 cm radial extent of the TPCs -> 15 cm between conversion layers —> total detector radius ~ 80 cm



Distribution of radial position within TPCs (distance from the inner wall)

Geant hits & track fit

- With 500 μm smearing of GEANT hits in each of the two coordinates in the plane orthogonal to the tracks
  - only 1 hit used for each strip
- 17% conversion + fit efficiency

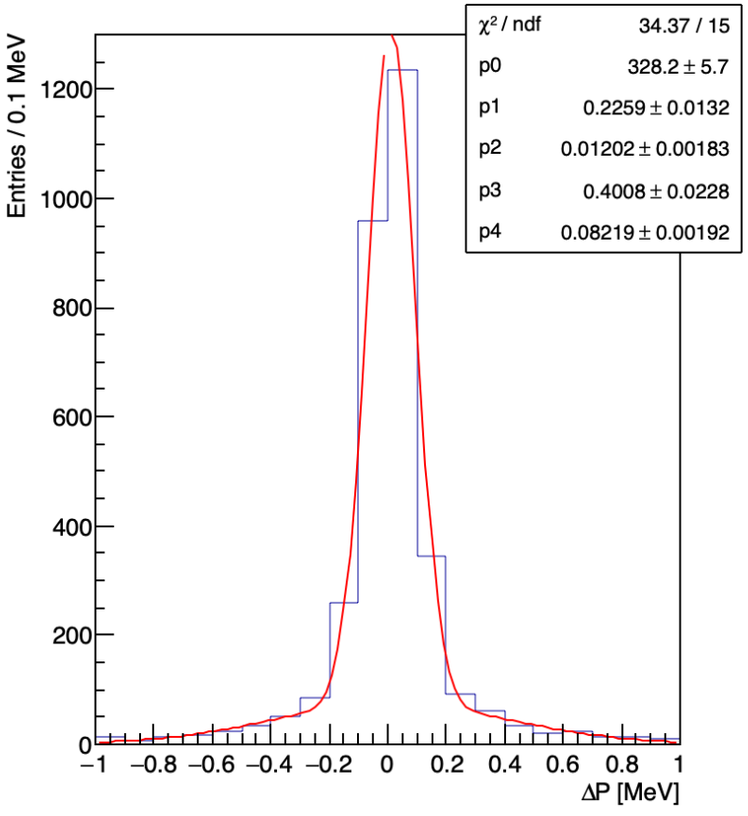


Geant hits & track fit

- With 500 μm smearing of GEANT hits in each of the two coordinates in the plane orthogonal to the tracks
  - only 1 hit used for each strip
- 17% conversion + fit efficiency

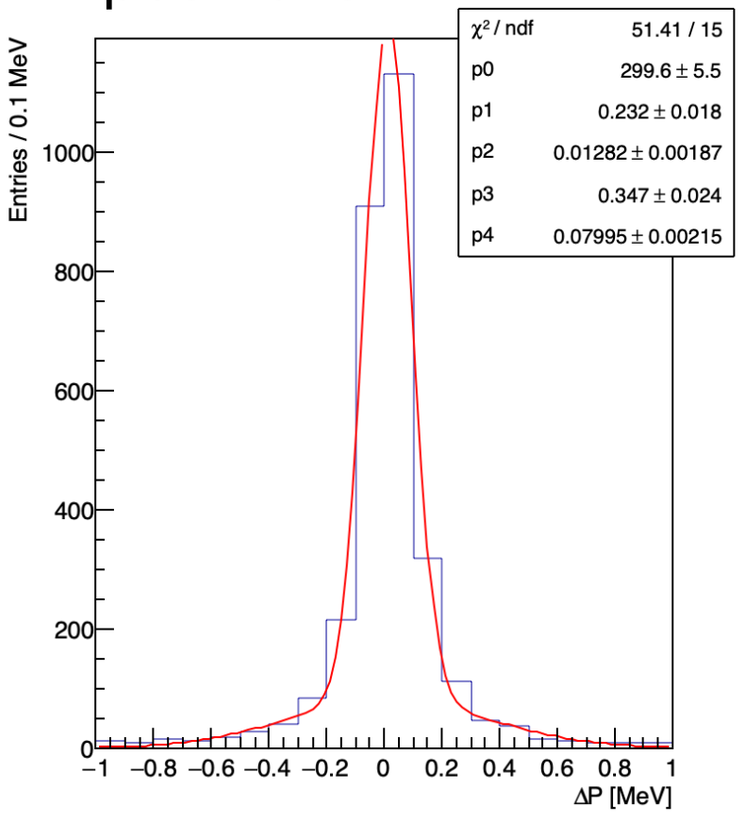
Momentum resolution (reco - true at the exit of the converter)

electrons



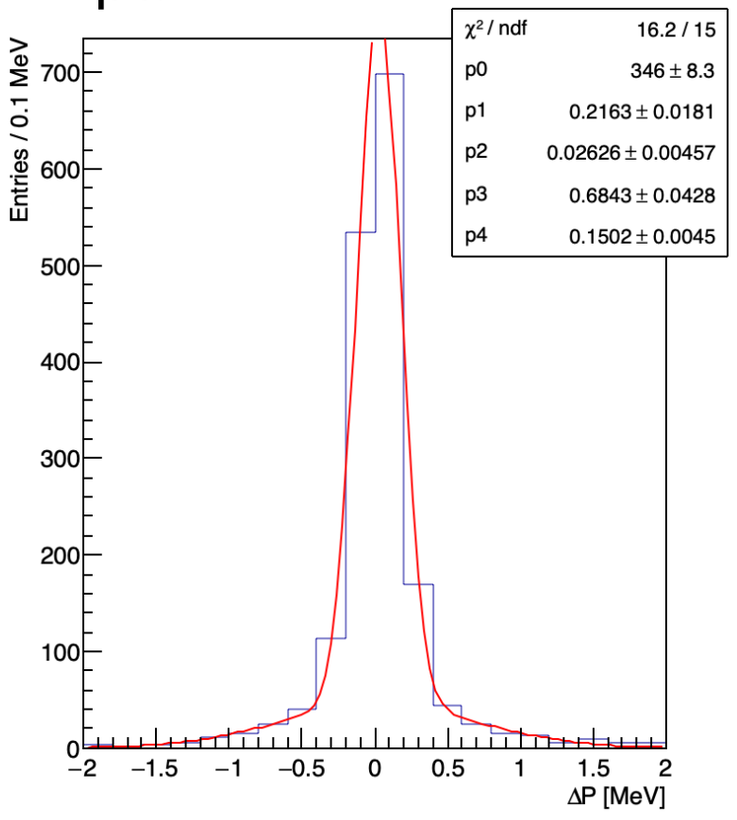
σ_{core} = 82 keV (f_{core}: 77%)

positrons



σ_{core} = 80 keV (77%)

pair



σ_{core} = 150 keV = 0.28% (78%)

Worst case scenario

- A scenario where the performance is the same as the chambers tested on beam in May 2024:
  - Ar:CO2 (70:30) mixture
  - 2.4 mm strip pitch
  - 800 μm single-hit resolution (on each coordinate)
- Efficiency: 16%
- Core resolution: 354 keV = 0.66% (f_{core}: 61%)

Intermediate scenarios

	σ_{CORE} [keV]	f_{CORE}	Efficiency
Nominal	150	78%	17%
Gas (He:C4H10 —> Ar:CO2)	340	79%	16%
Strip pitch (0.65 mm —> 2.4 mm)	152	61%	16%
Single-hit resolution (500 µm —> 800 µm)	179	76%	17%
All	354	66%	16%

Ideal scenario

	σ_{CORE} [keV]	f_{CORE}	Efficiency
Nominal	150	78%	17%
Single-hit resolution (500 μm —> 0 μm)	109	88%	18%

Discussion

- It is critical to operate the detector with a very light gas mixture
  - $He:C_4H_{10}$ (90:10) is very light and common in drift chambers, but unusual for MPGDs—> to be tested
- Single hit resolution of 500 μm is a reasonable target to keep the pair tracker resolution (0.28%) subleading w.r.t. the active converter (0.4%)
  - in any case, cannot do better than 0.21% (MS limited)
- Pattern recognition not considered here:
  - strip crossing gives ghost hits —> track finding is not trivial
- Next steps in simulation:
  - realistic simulation of drift and hit reconstruction instead of smearing the GEANT hits
  - development of pattern recognition algorithms