Inner Tracker

for Super Charm-Tau Factory

based on compact

Time Projection Chamber

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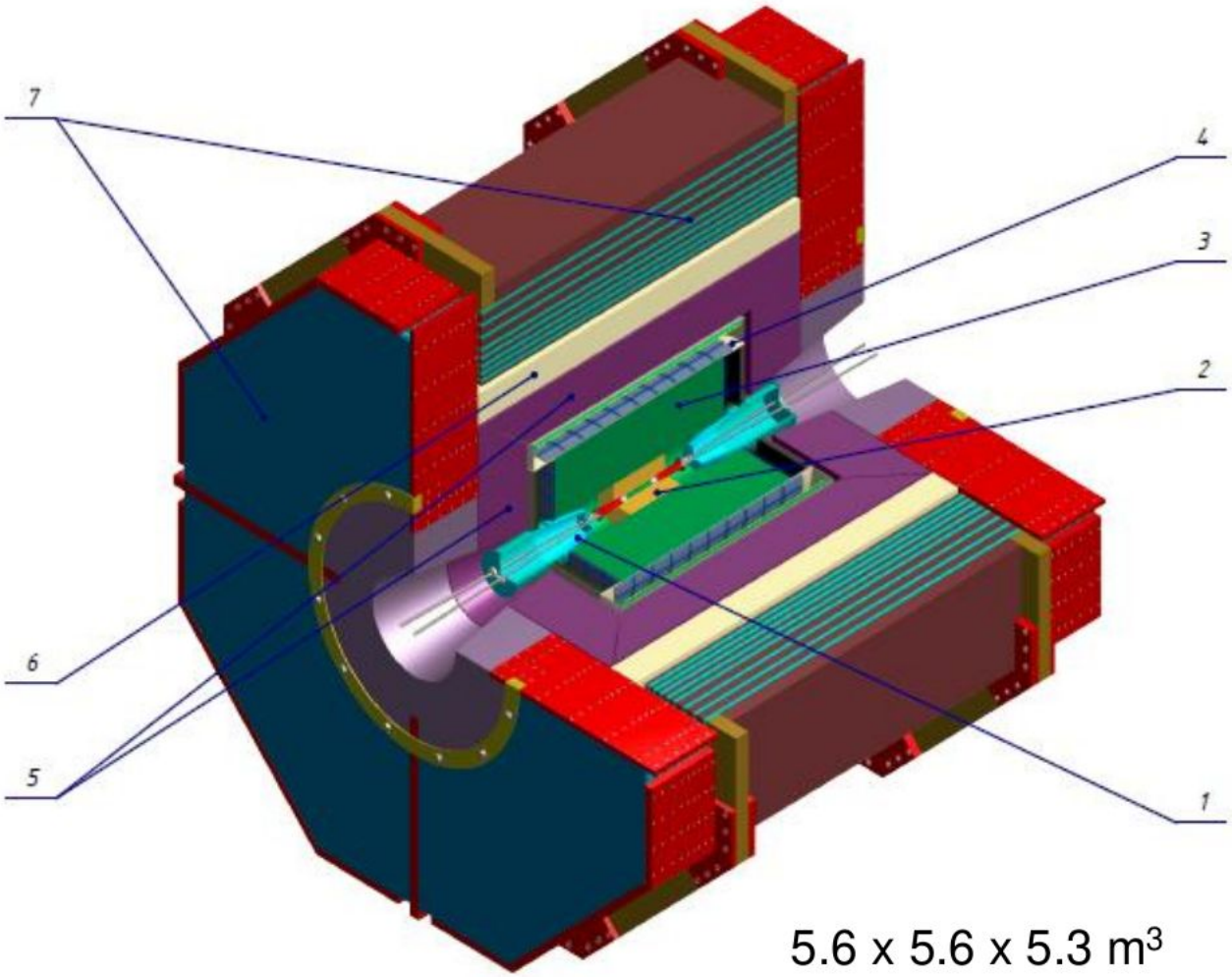
Outline

- TPC geometry and materials
- GEANT4: π-mesons in TPC
- GenFit: momentum resolution in gas
- Reconstruction of momentum in beampipe

Super Charm-Tau Factory Detector



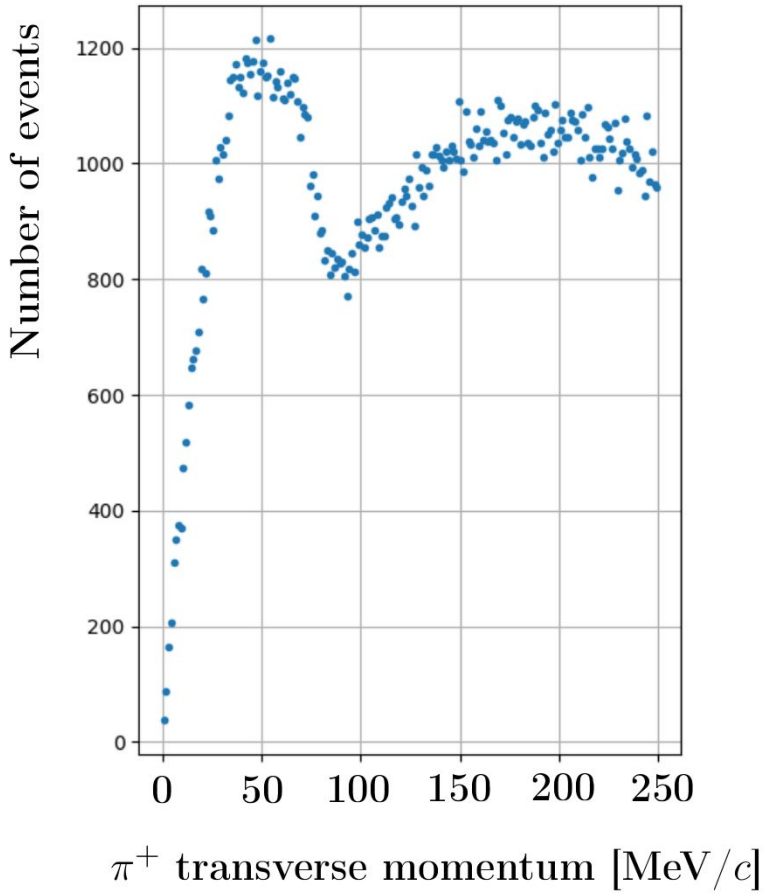
5.6 x 5.6 x 5.3 m^3

1. Vacuum pipe
2. Inner tracker
3. Drift chamber
4. PID
5. Calorimeter
6. SC magnet
7. Muon system

Inner Tracker

Tasks

- Measure soft $\pi^{\pm}$ mesons momentum ($p < 100$ MeV/c)
- Complement the drift chamber in measuring the momenta
- Detect secondary vertices from the decays of short-lived particles (K_S , Λ)



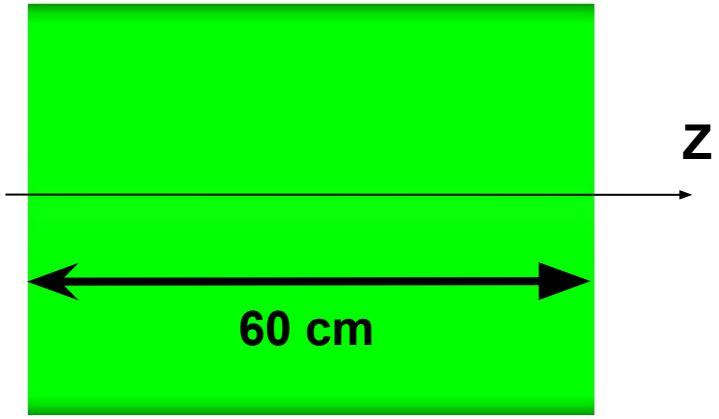
Simulation of π^+ transverse momentum distribution in $e^+e^- \rightarrow DD^*$ (V. Vorobyev)

Requirements

- Cover angle close to 4π
- Handle with high particle flux – luminosity of 10^{35} cm^{-2} s^{-1}
- Provide spatial resolution ~ 100 μm

Vacuum beampipe	
Material	Thickness
Beryllium	**1 mm**
Paraffin	**0.5 mm**
Beryllium	**1 mm**

Thin inner wall	
Material	Thickness
Kapton	**50 µm**
Teflon	**100 µm**
Copper	**5 µm**



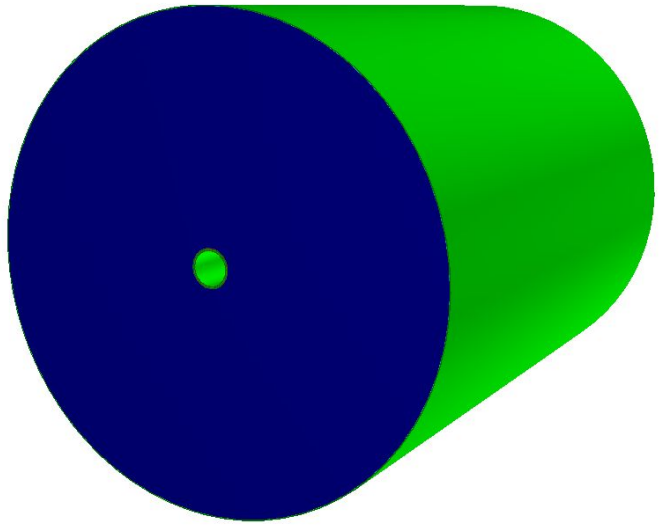
Gas volume	
Material	Thickness
Ar+20%CO_2	**20 cm**

Total length along beam axis: 60 cm

Vacuum beampipe radius: 1.5 cm

TPC – cylindrical geometry

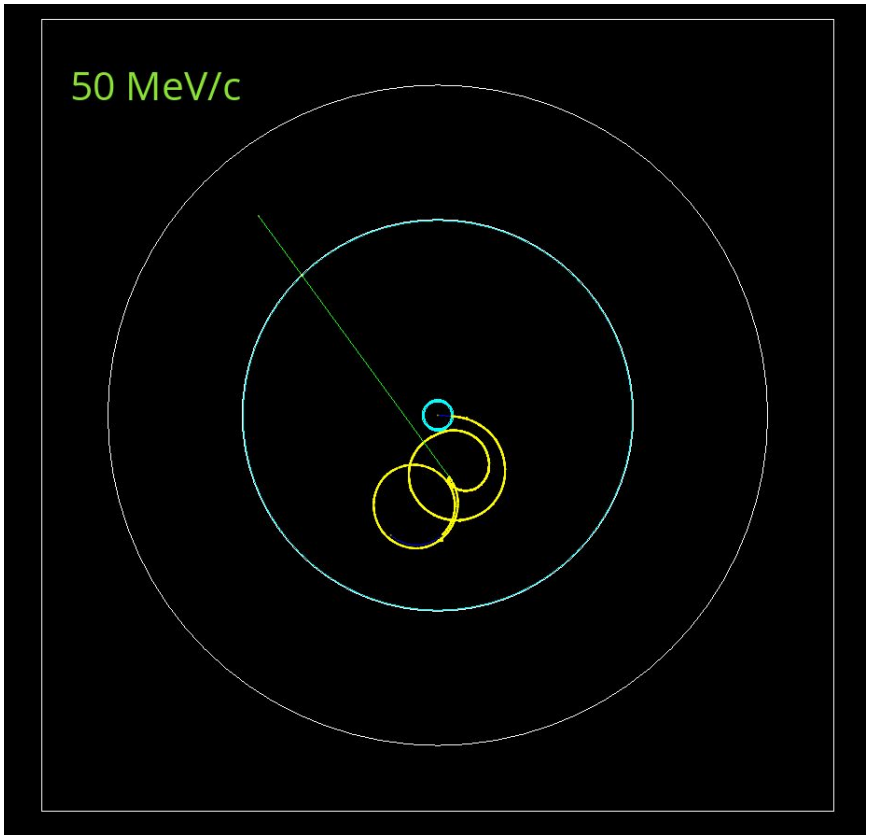
Outer wall	
Material	Thickness
Copper	**15 µm**
Teflon	**100 µm**
G10	**1 mm**

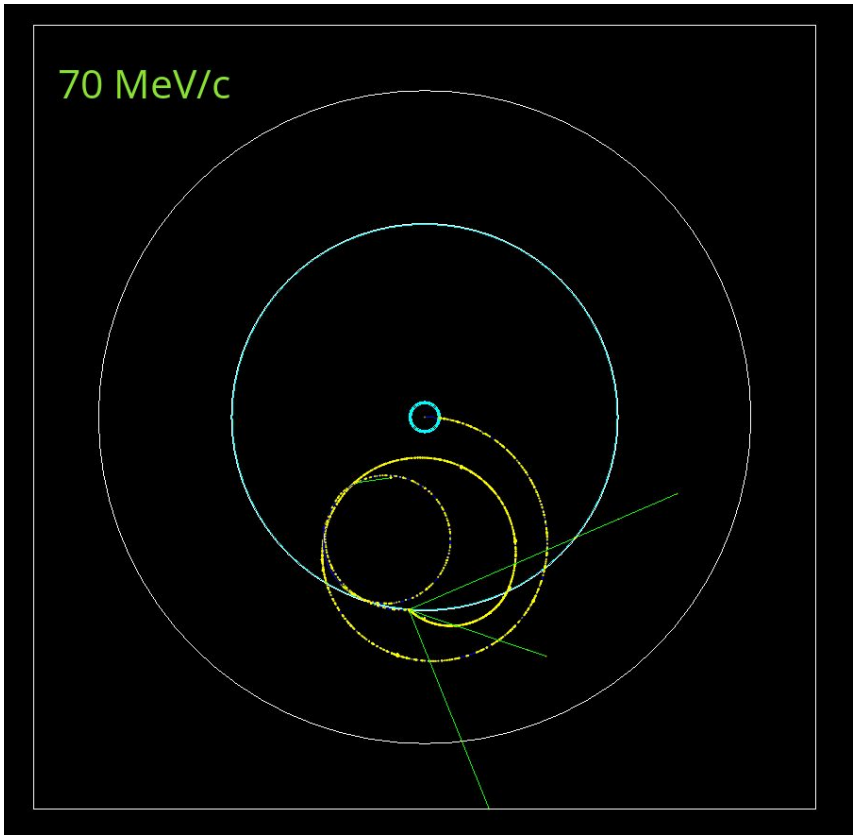


GEANT4-simulation: passage of π-mesons through TPC materials

Magnetic field along beam axis: 1.5 T

$p_{initial}$ – initial momentum of π-meson inside beampipe

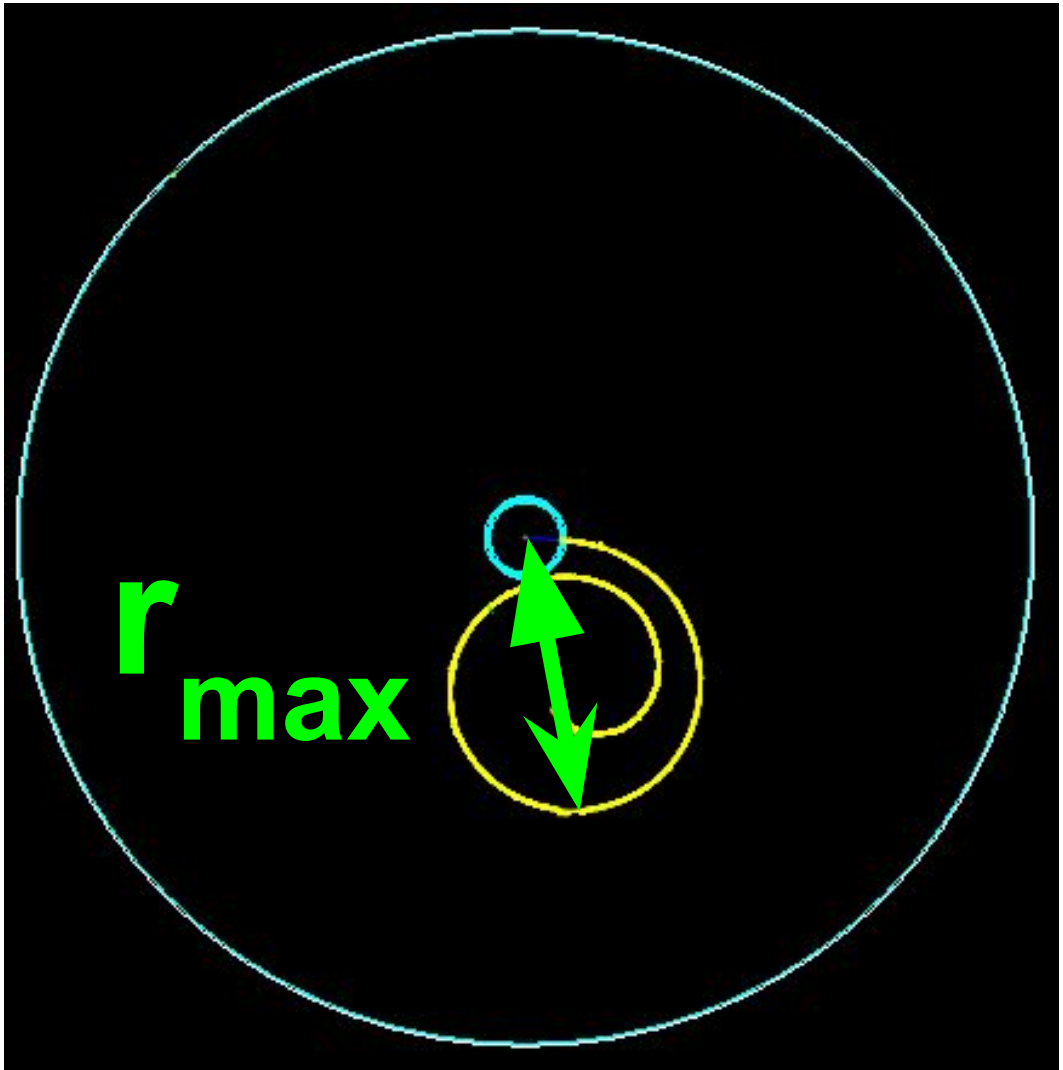


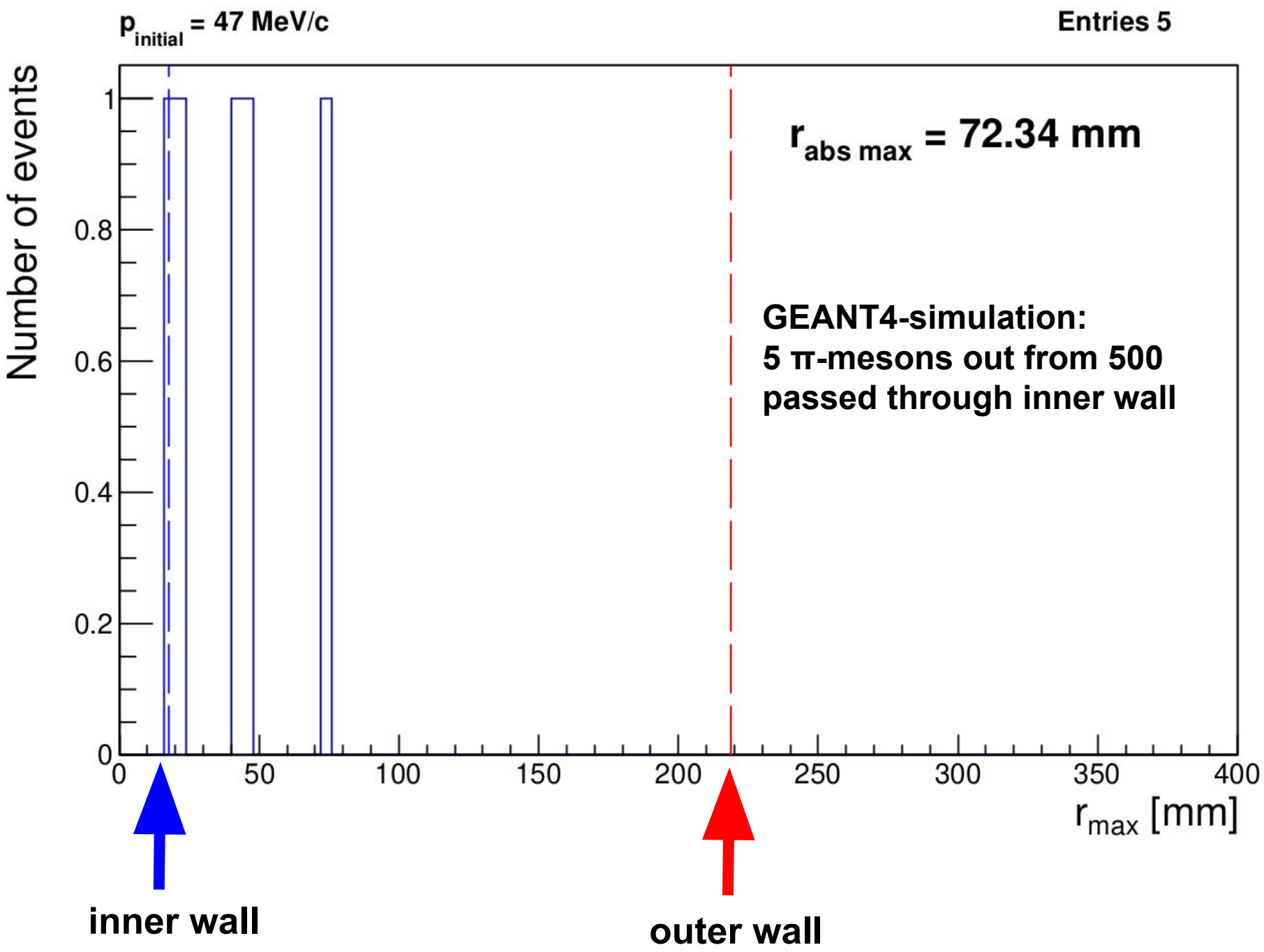


Distance to beam axis r , there $r^2 = x^2+y^2$

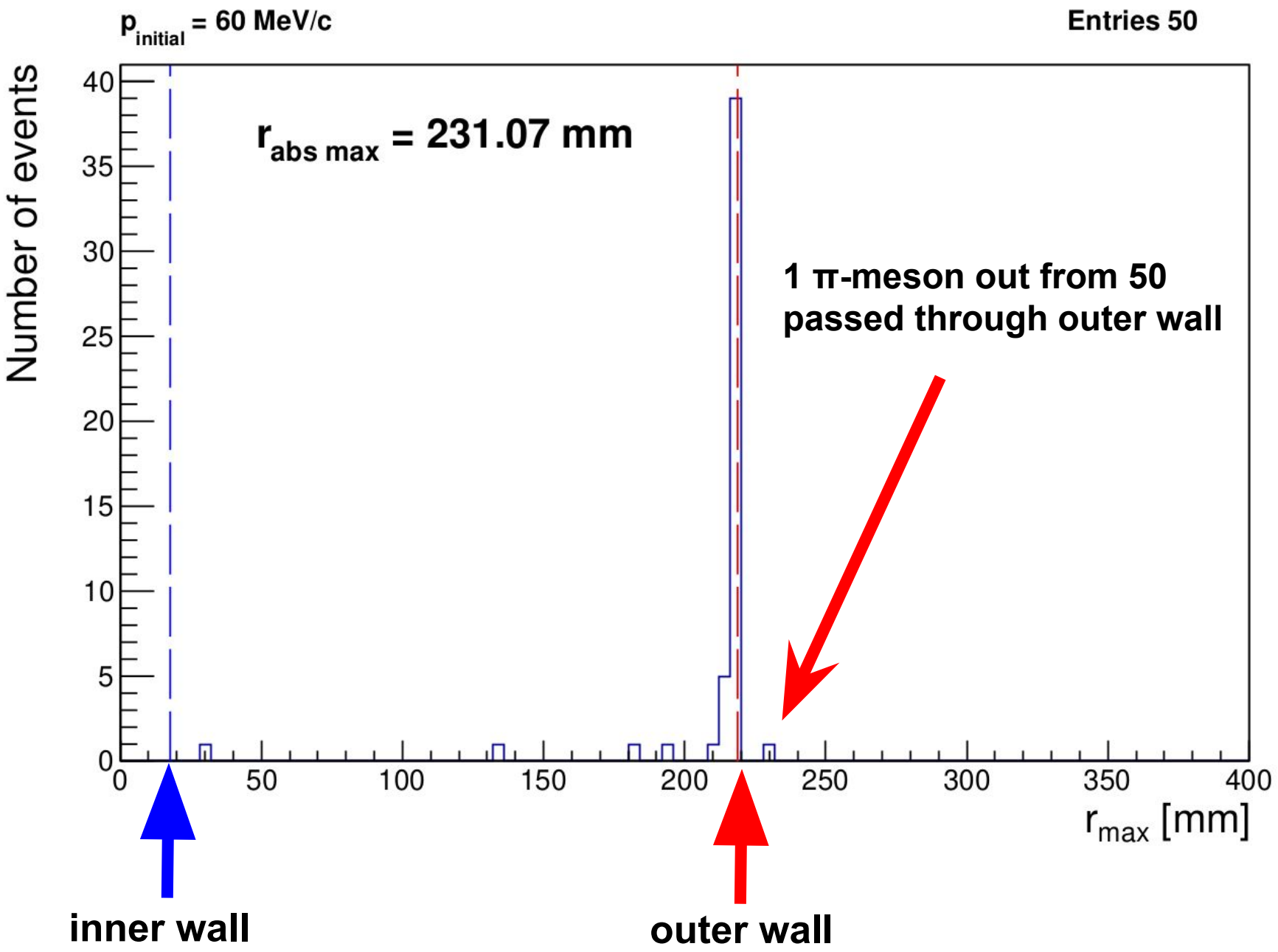
The most distant hit → r_{max}

Many events → $r_{abs\ max}$ (absolute maximum radius among events)

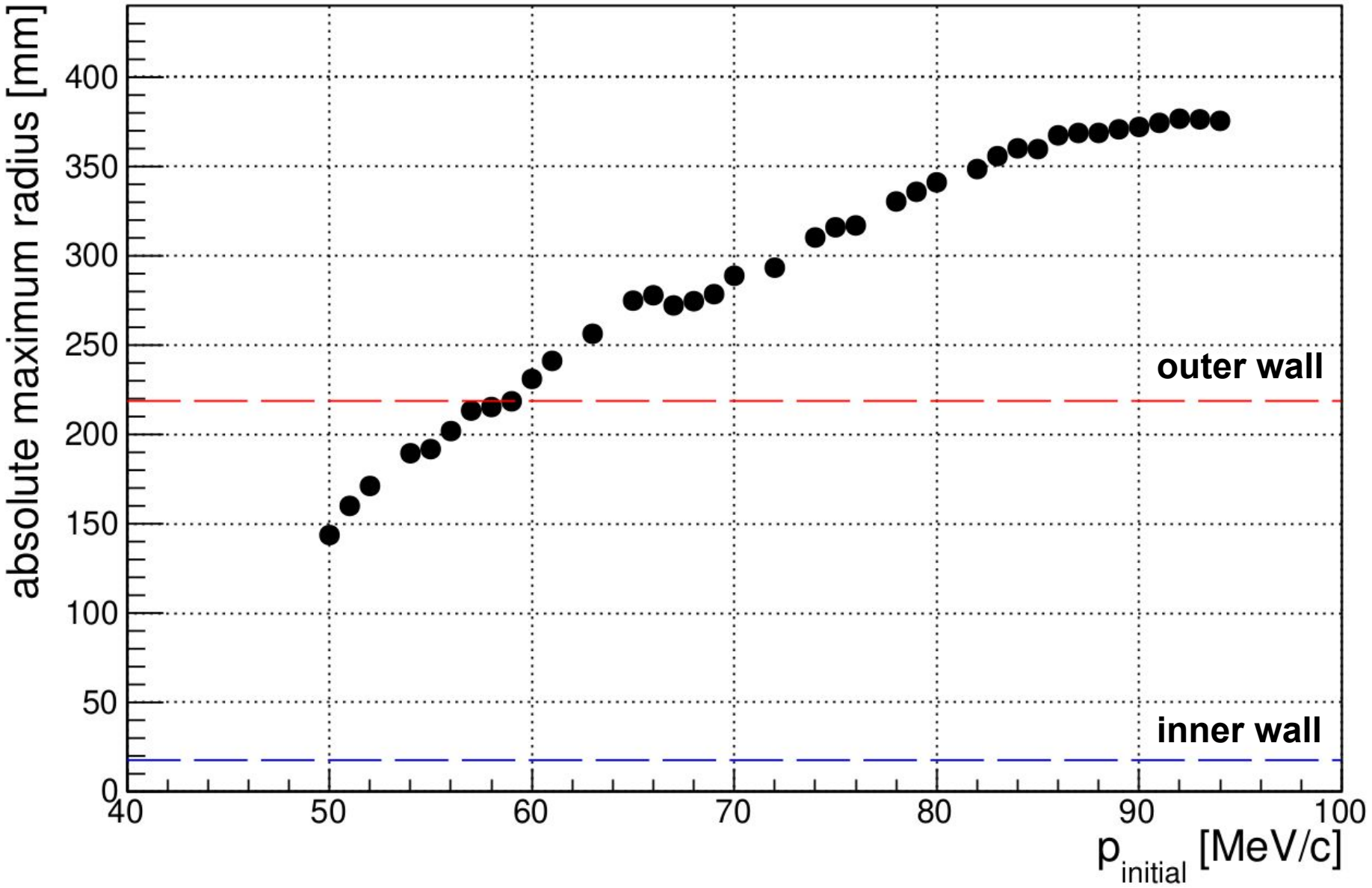


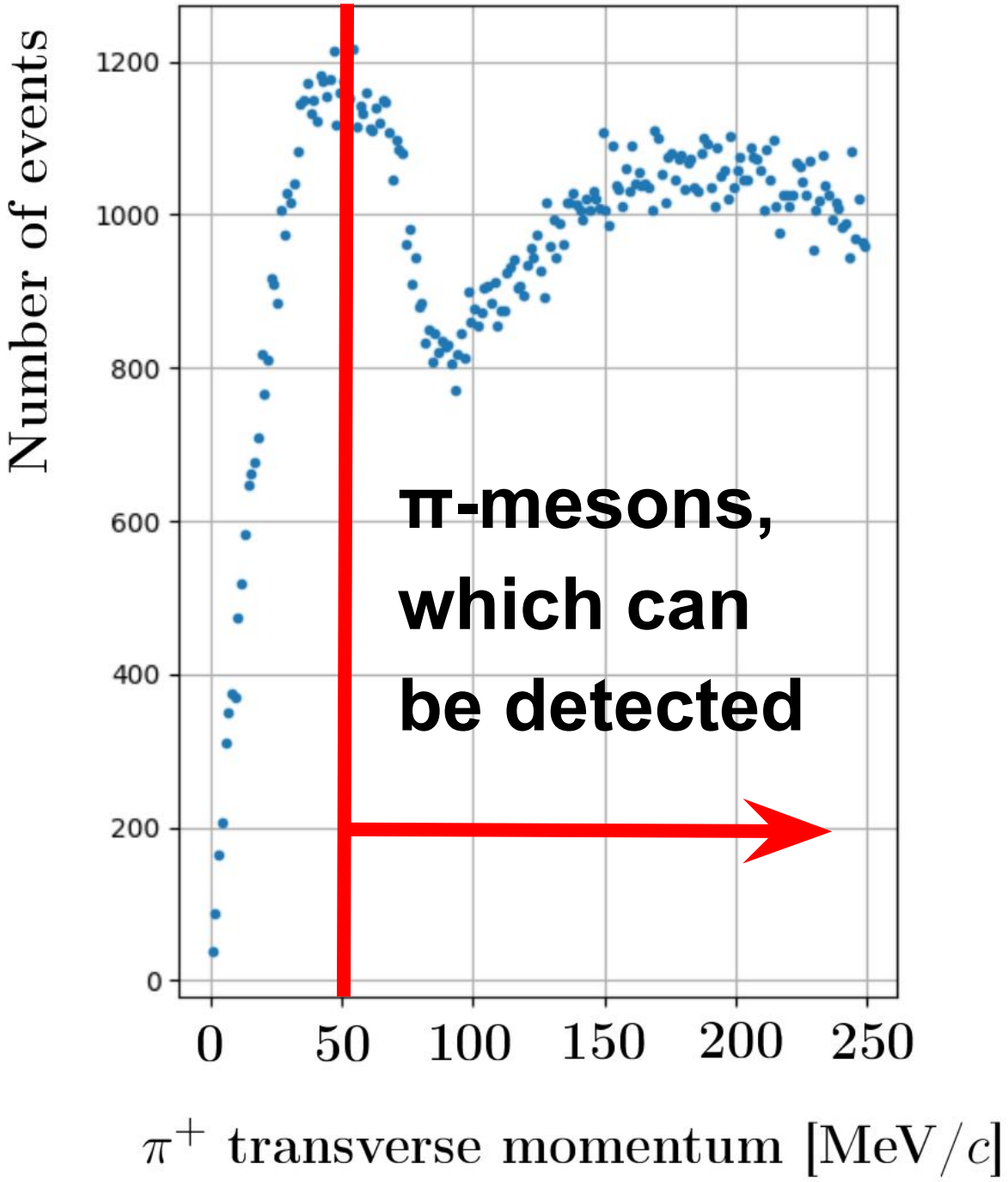

$p_{initial}$ = 47 MeV/c
Entries 5
Number of events
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
350
400
r_{max} [mm]
$r_{abs\ max}$ = 72.34 mm
GEANT4-simulation:
5 π-mesons out from 500
passed through inner wall
inner wall
outer wall

GEANT4-simulation, 50 initial π-mesons



GEANT4-simulation

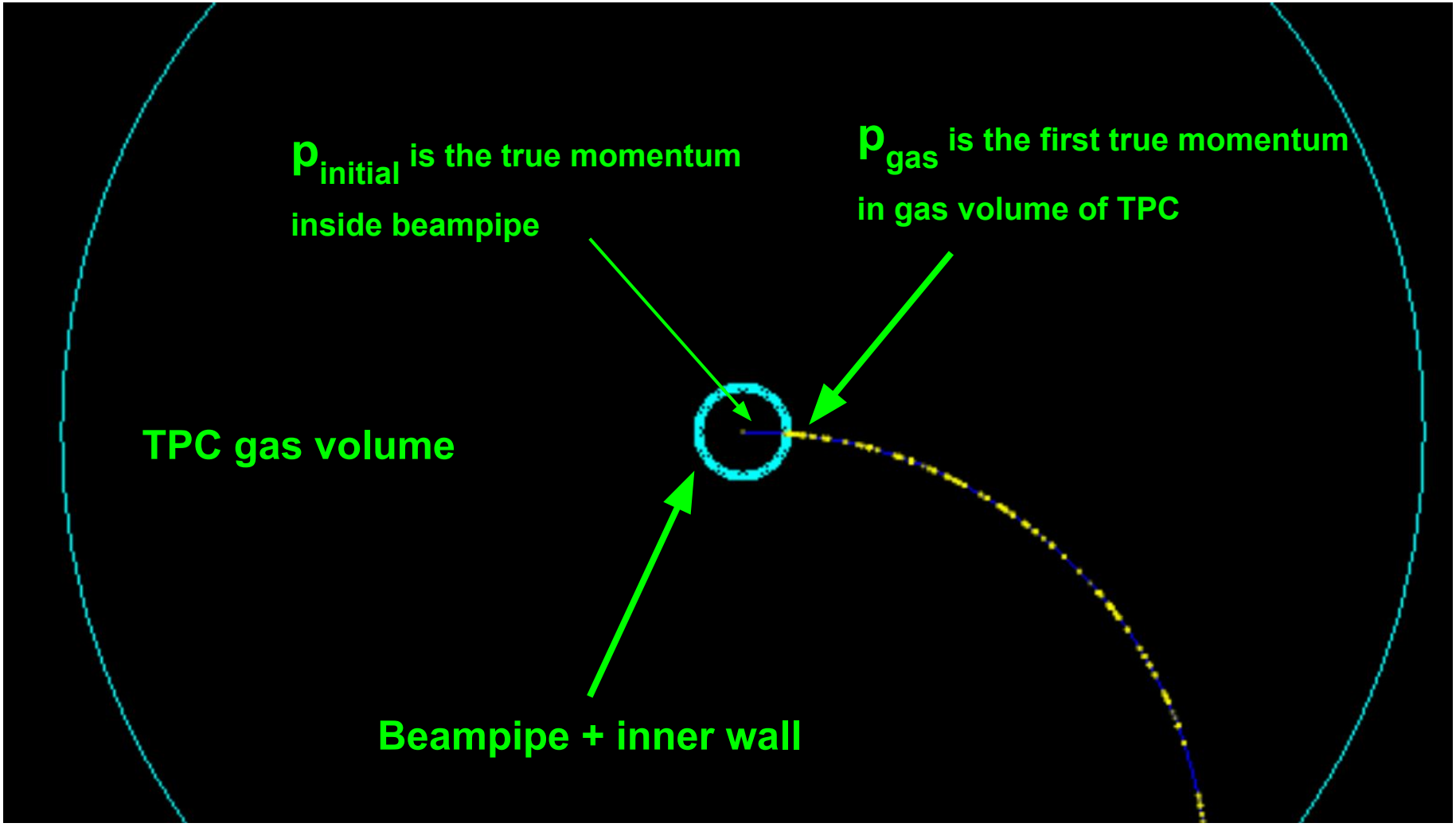



Number of events
1200
1000
800
600
400
200
0
0
50
100
150
200
250
π-mesons,
which can
be detected
π^+ transverse momentum [MeV/c]

GEANT4-simulation example of π-meson trajectory

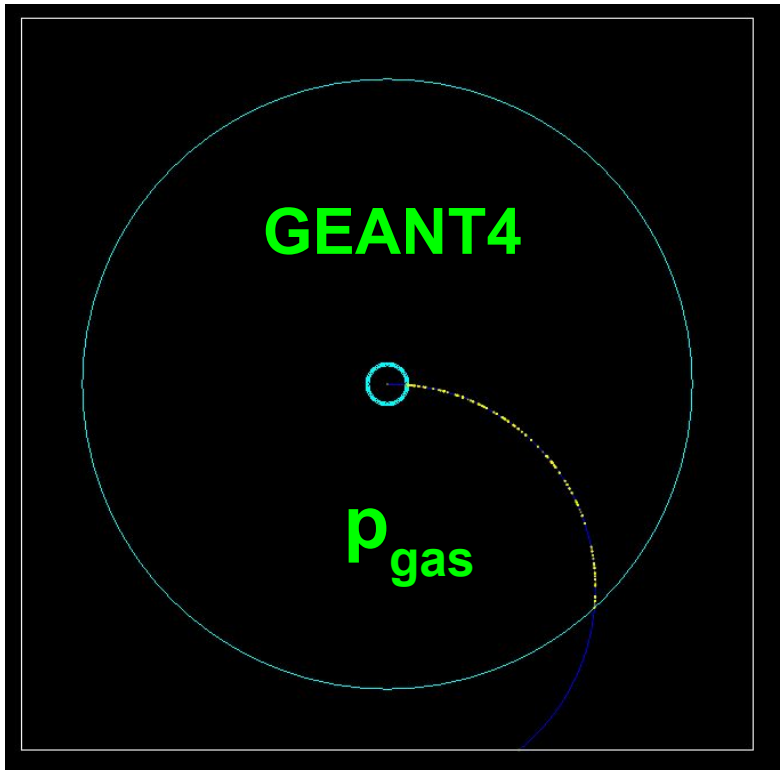
$p_{initial}$ = 80 MeV/c

p_{gas} = 75 MeV/c

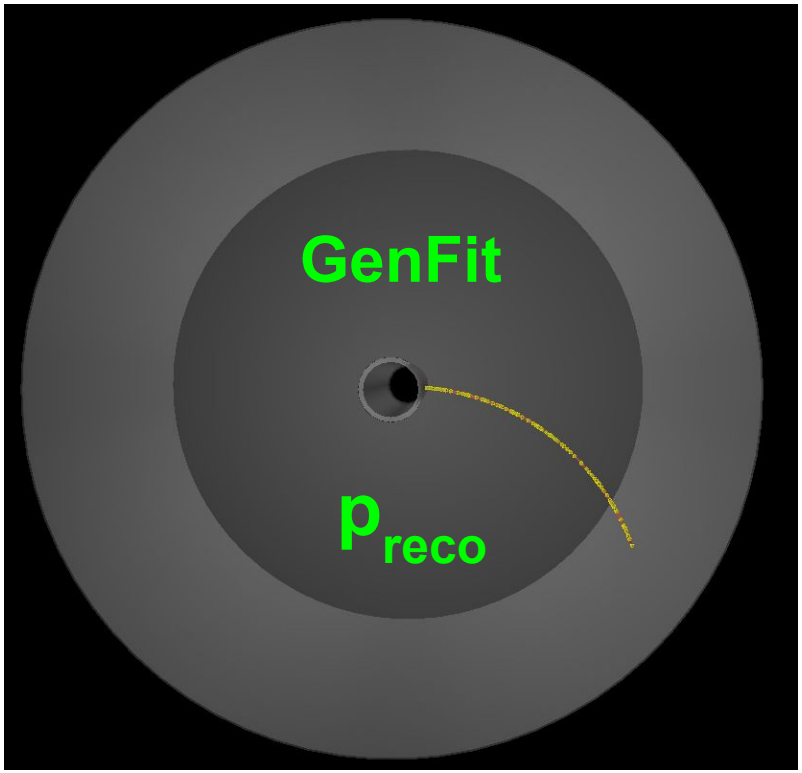


GenFit takes hits from GEANT4 and approximates these hits with helix (Kalman filter) in order to reconstruct p_{gas}

The output of Genfit is p_{reco}

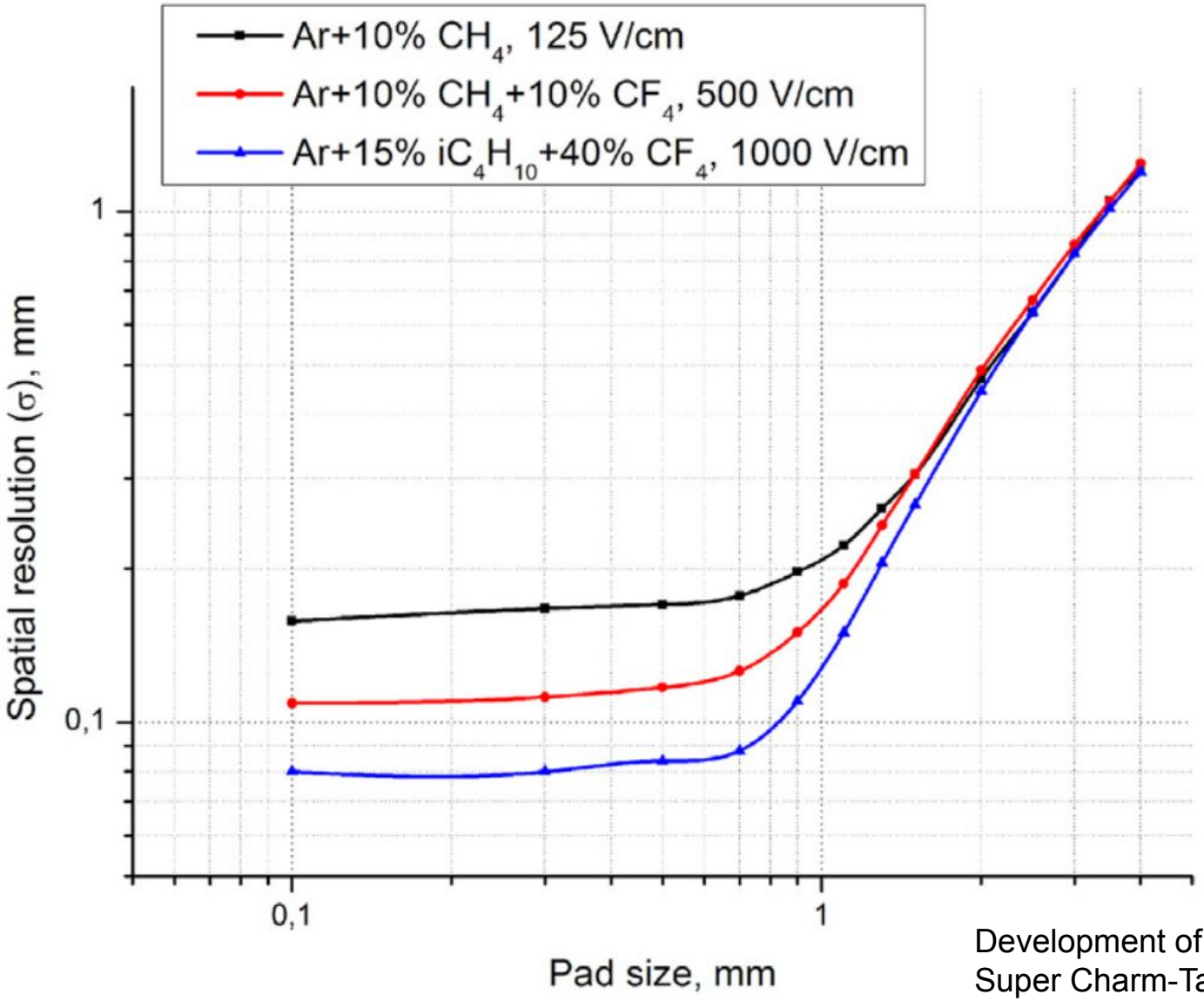


import hits (coordinates)



TPC coordinate resolution was set to be $\sigma_x = \sigma_y = \sigma_z = 100$ μm

Spatial resolution of the end-cap detector (quadruple GEM)



Garfield++ simulation

The optimal pad size is between 0.7 mm and 1 mm

Development of compact TPC for future Super Charm-Tau Factory detector

https://doi.org/10.1016/j.nima.2022.167225

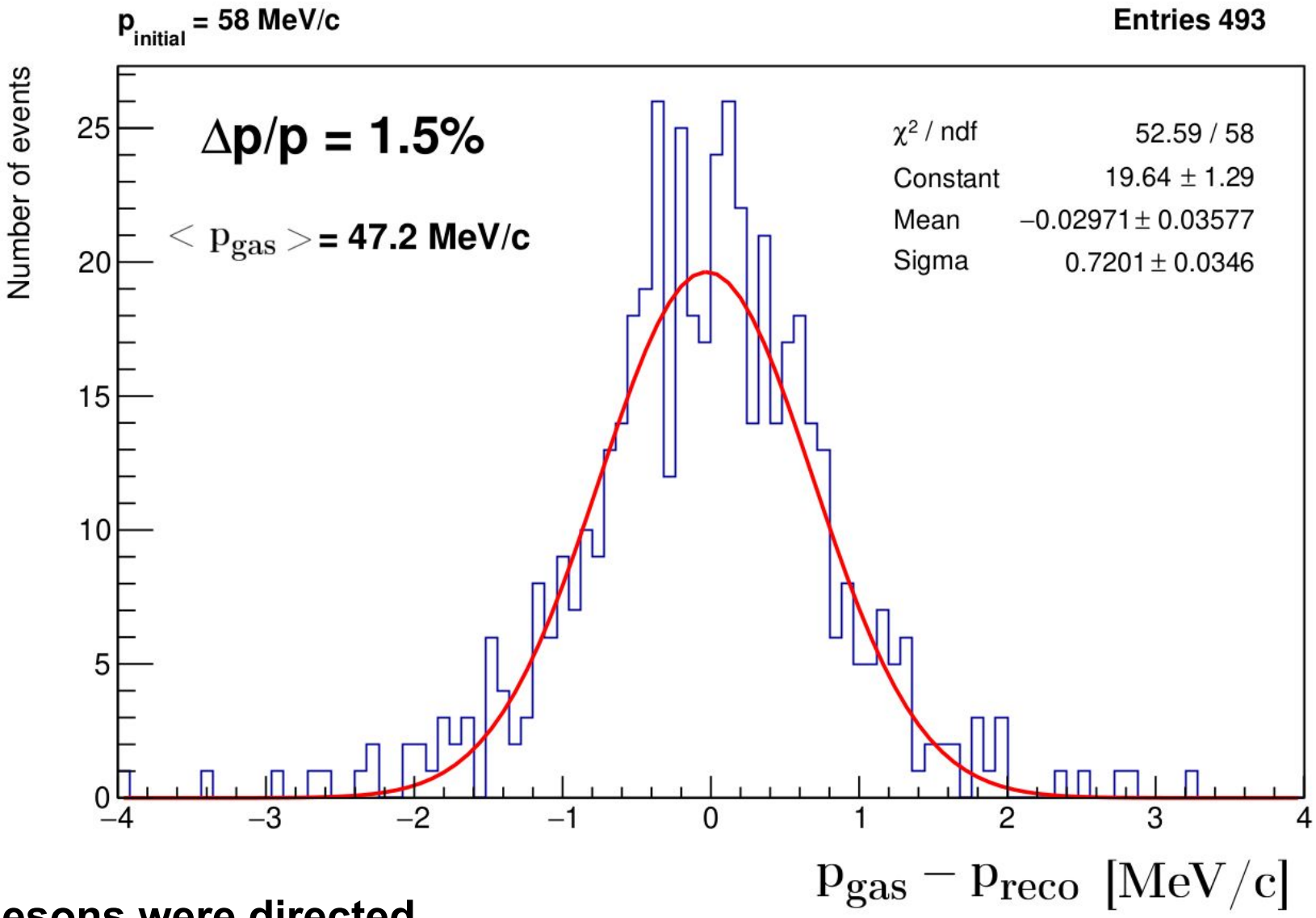
Momentum resolution in gas:

momentum scan

(π-mesons were directed

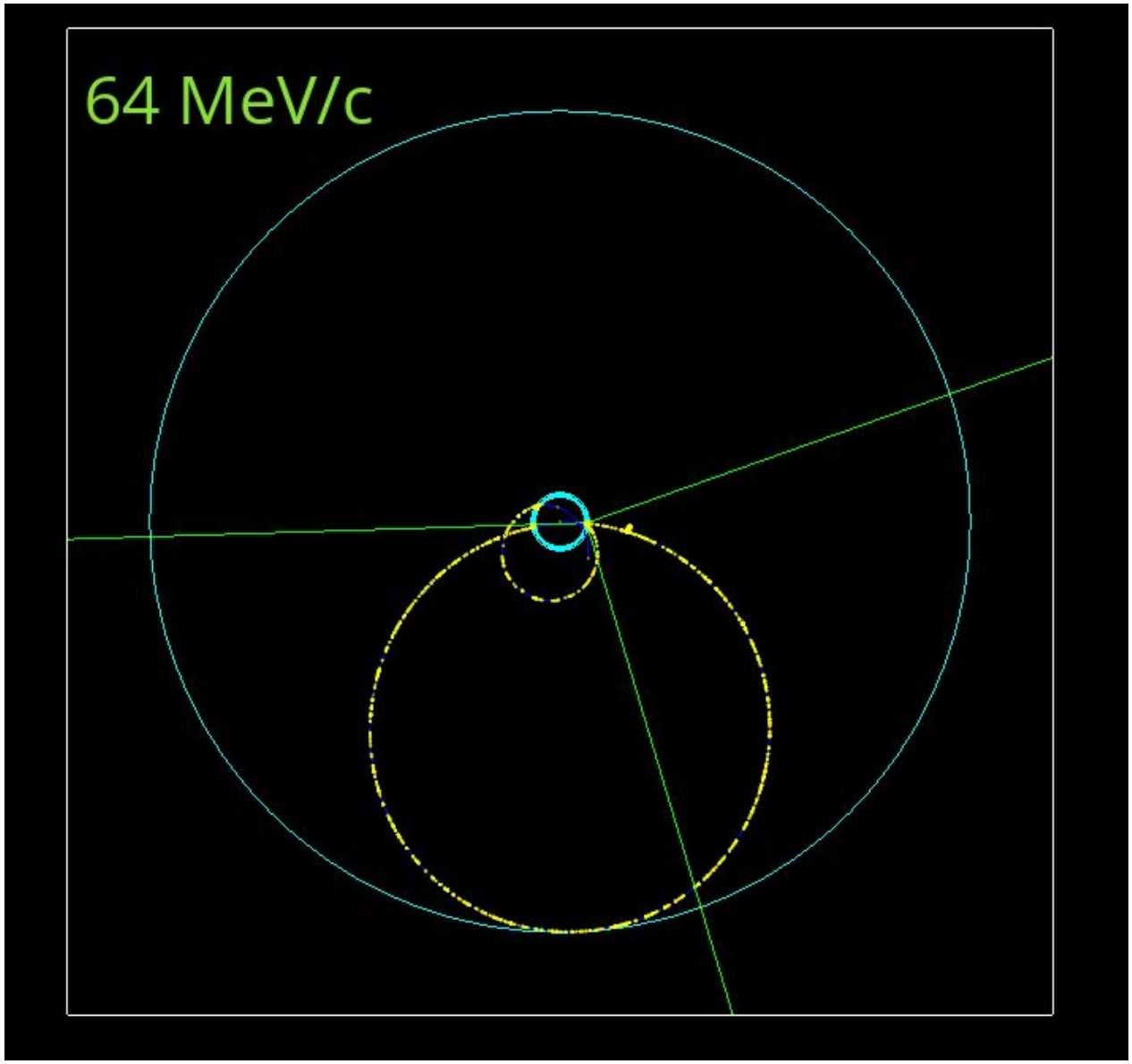
perpendicular to beampipe wall)

Momentum residuals distribution example



π-mesons were directed perpendicular to beampipe wall

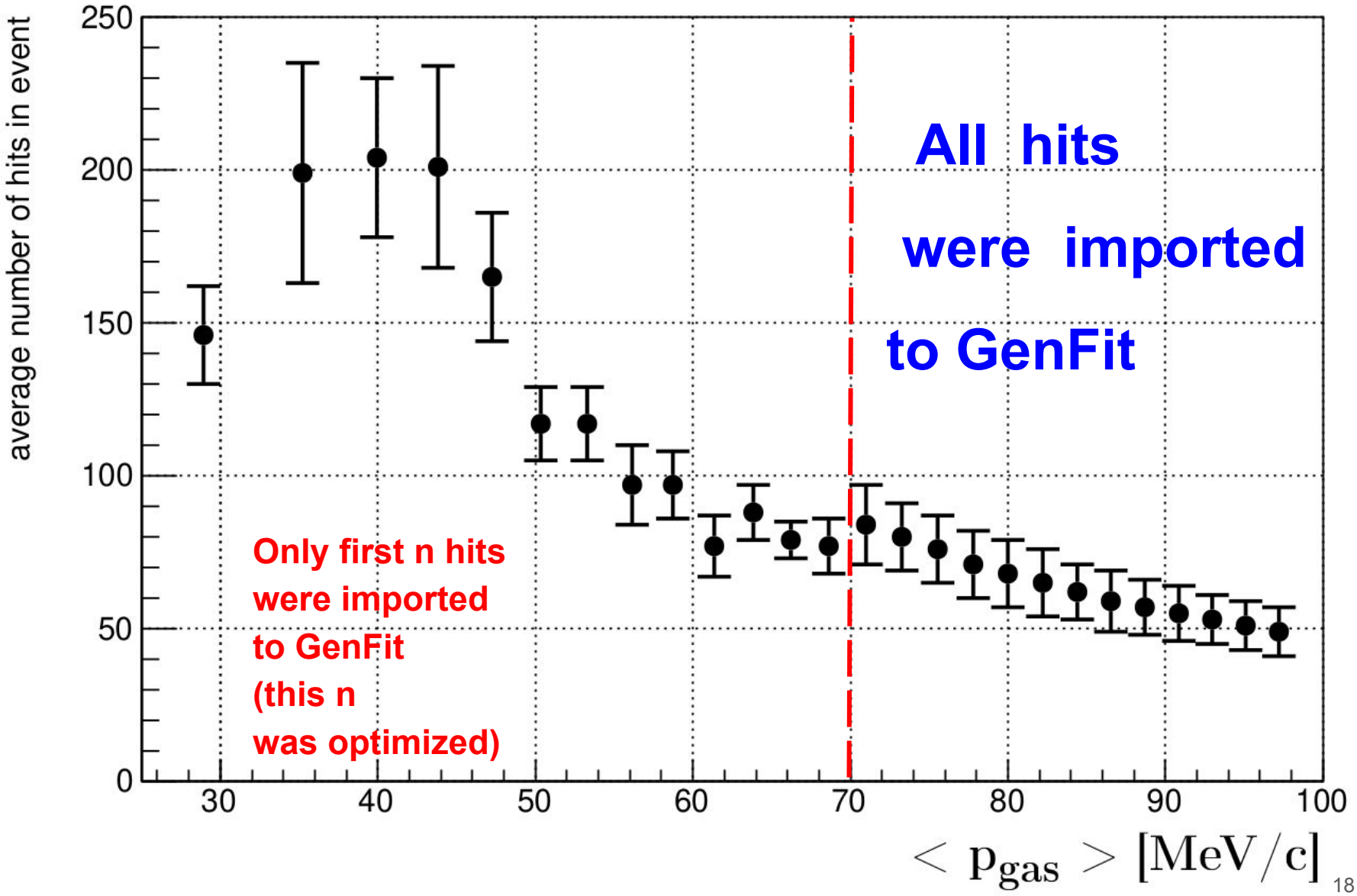
GEANT4 simulation



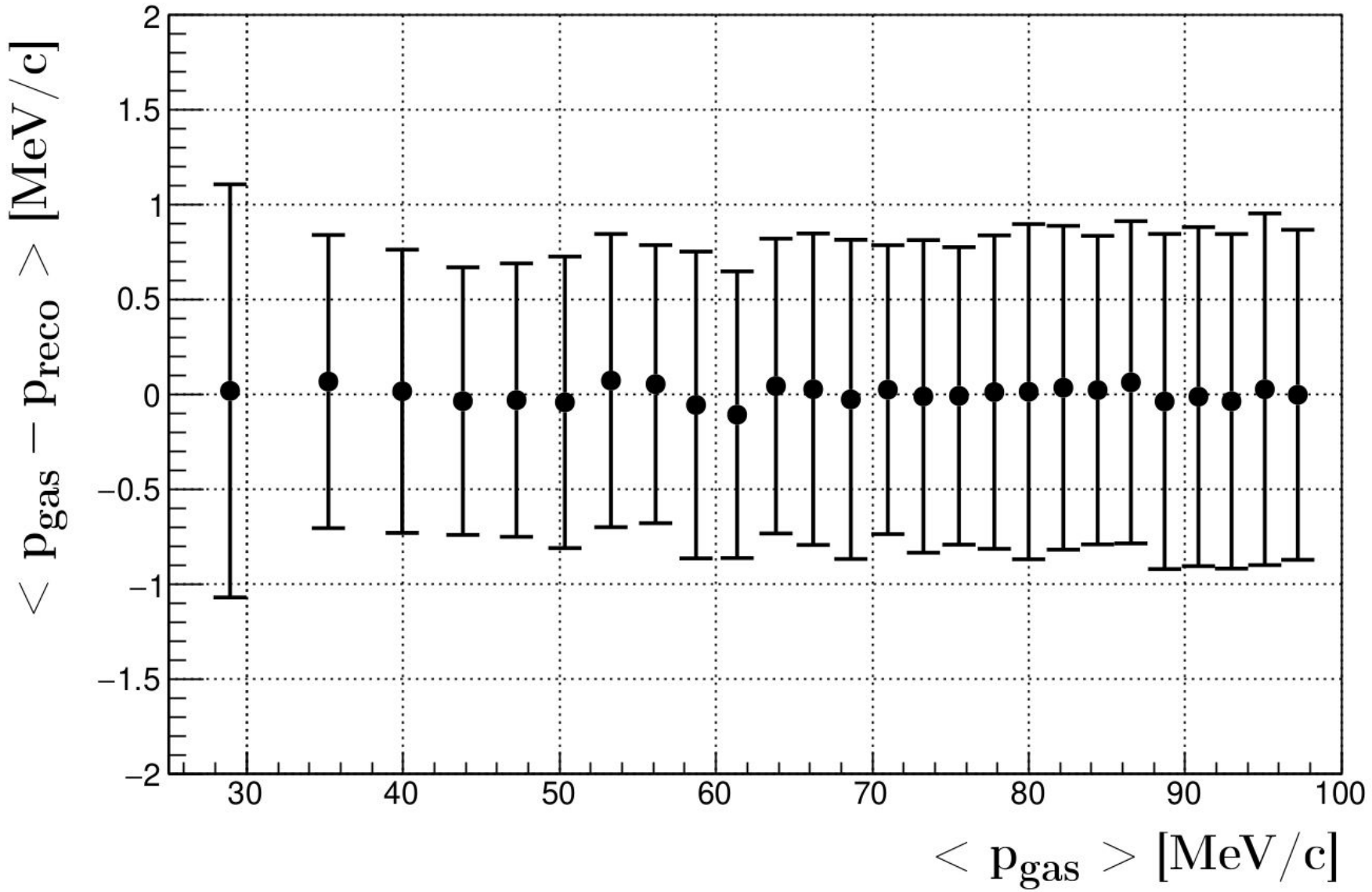
Helix can be totally inside TPC volume for some values of initial momentum.

In this case we have to restrict number of hits in order to provide correct results from Genfit.

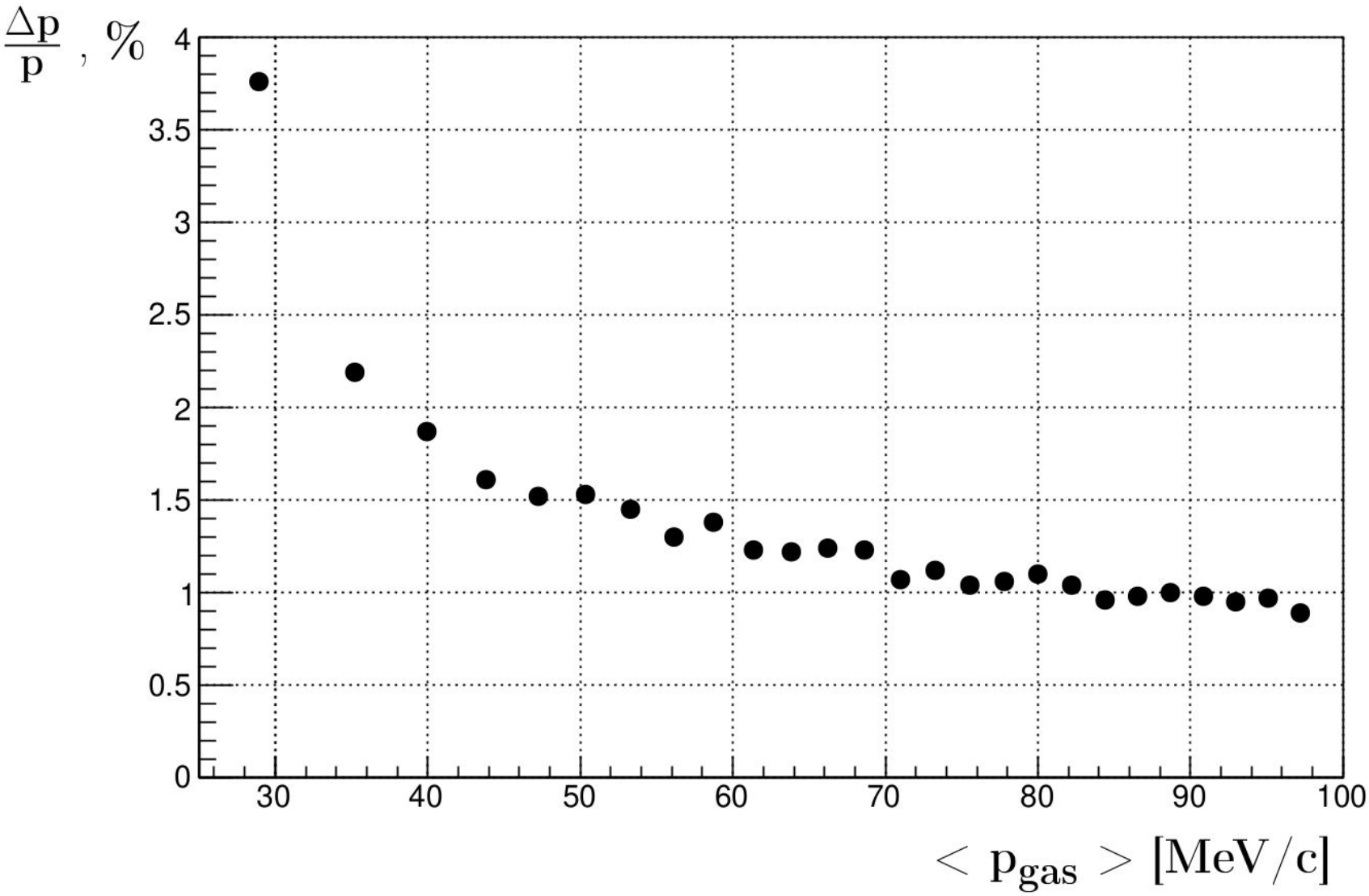
<number of hits> on < p_{gas} >



$\langle p_{reco} \rangle = \langle p_{gas} \rangle$ (with good accuracy)

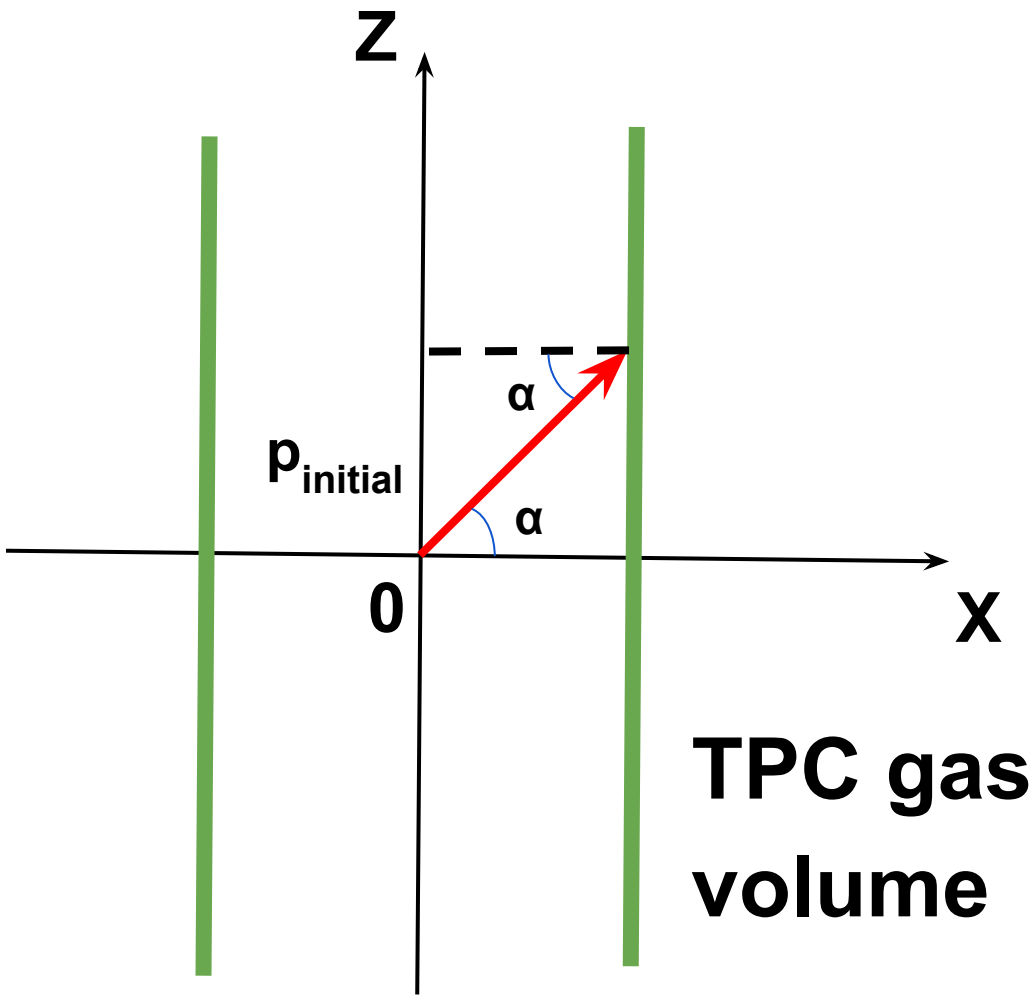


Momentum resolution on $<p_{gas}>$



Angle of π-meson incidence in ZX-plane: $\alpha=\alpha_{initial}$

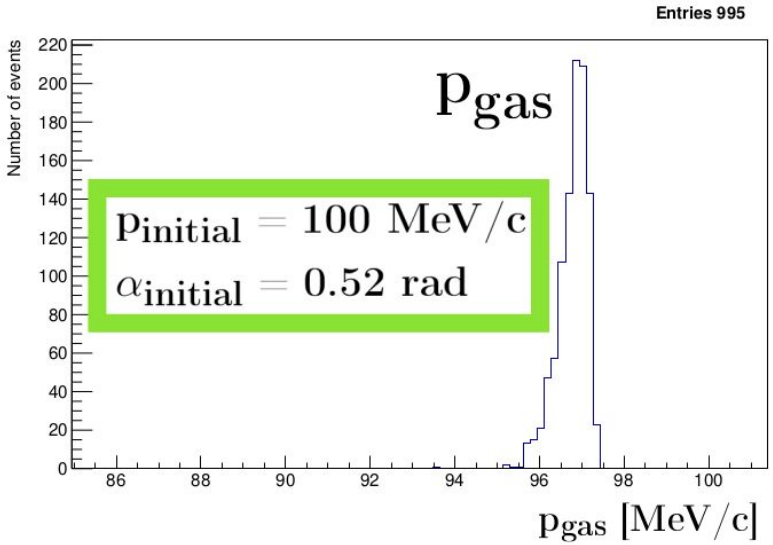
Top view on beampipe

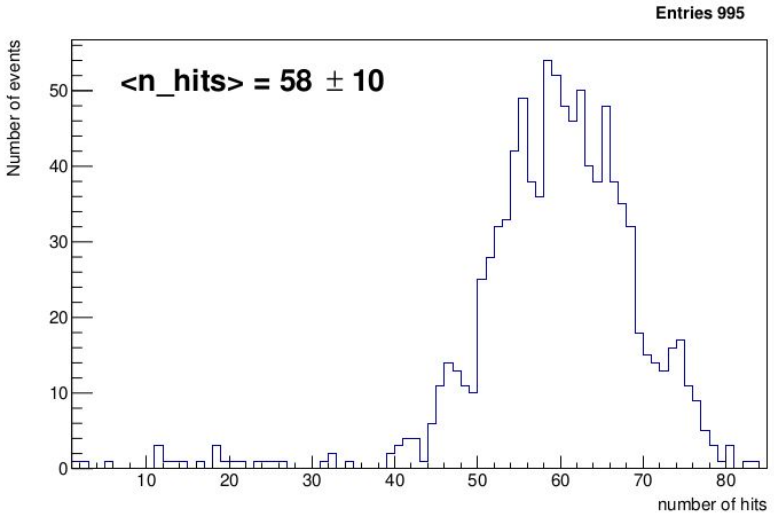


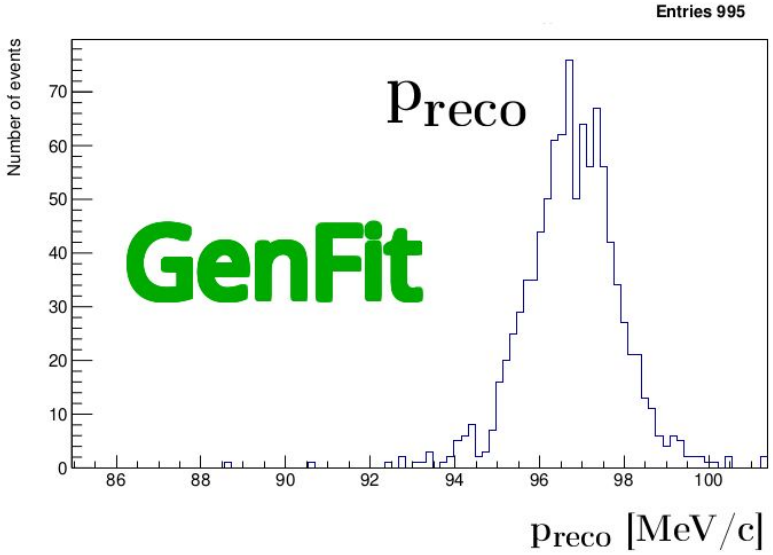
TPC gas volume

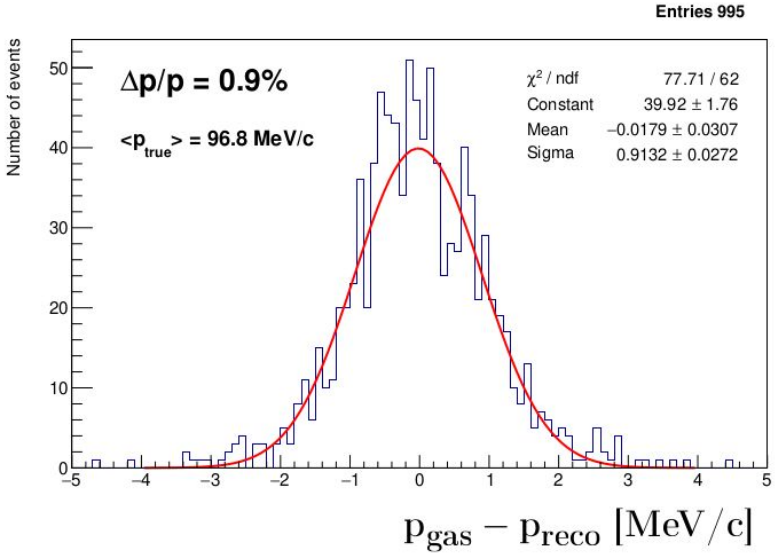
Study of dp/p on α was performed

GEANT4 + GenFit simulation results

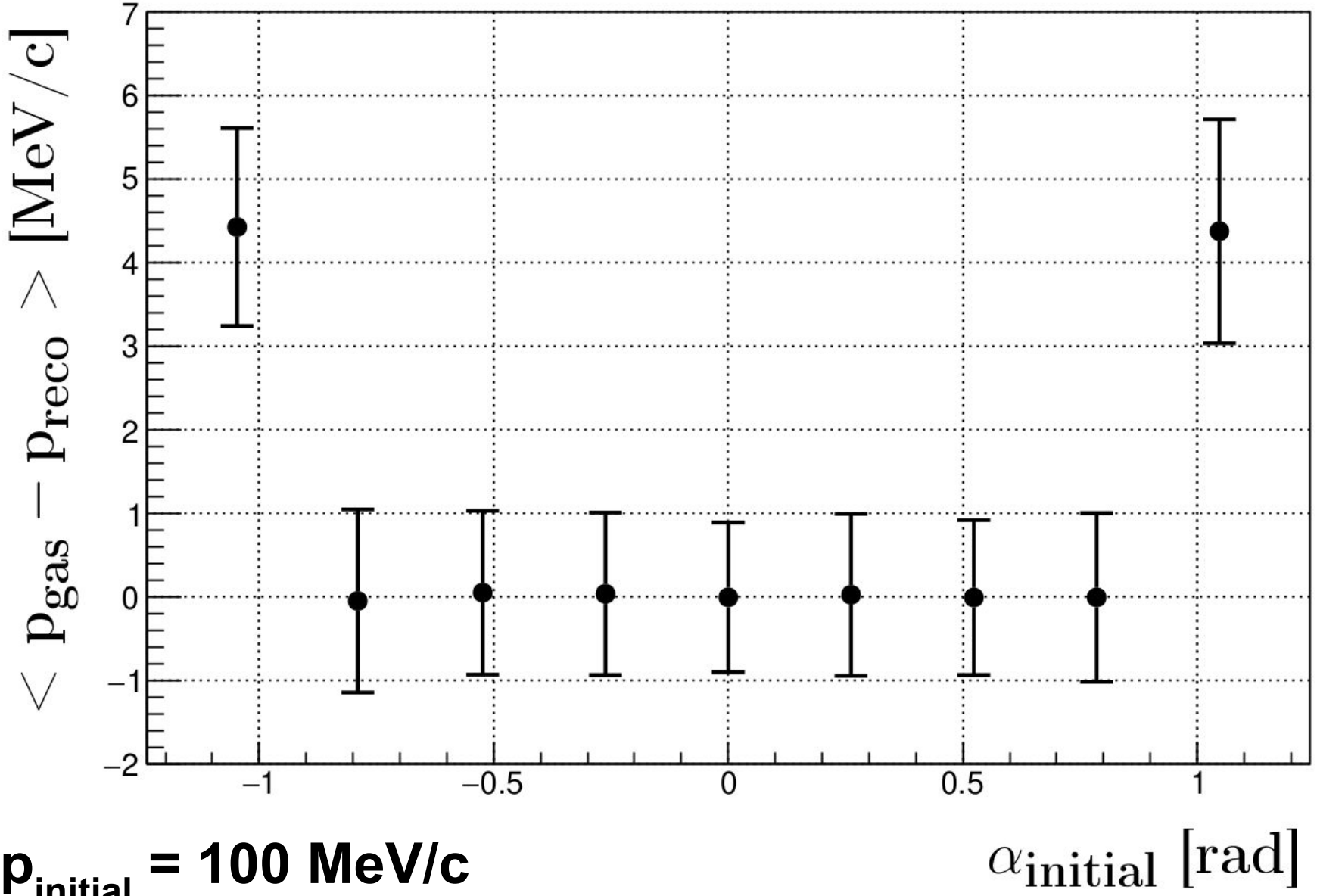






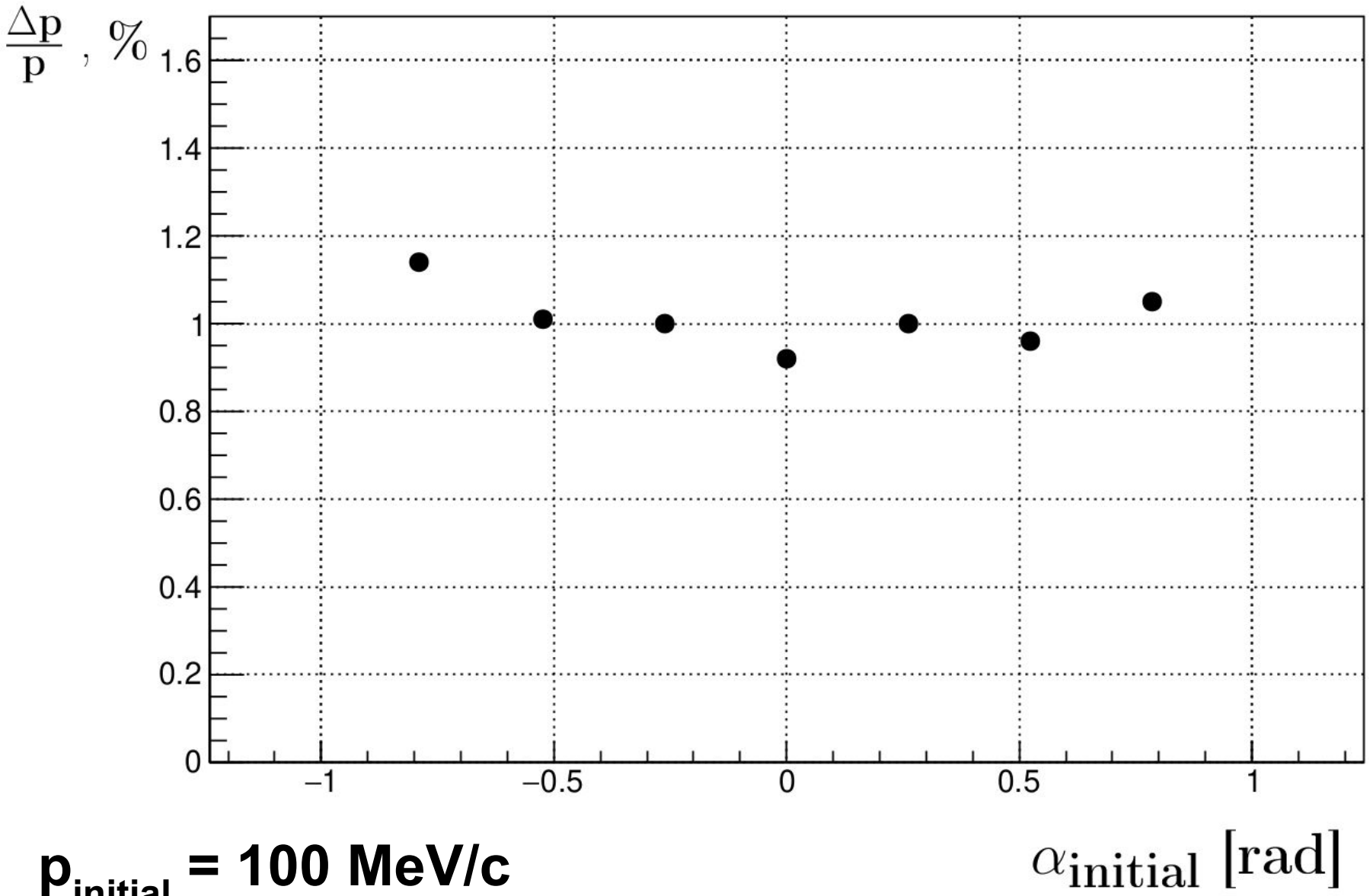


$\langle p_{reco} \rangle = \langle p_{gas} \rangle$ (only for angle less than 1 rad)



$p_{initial}$ = 100 MeV/c

Momentum resolution on angle



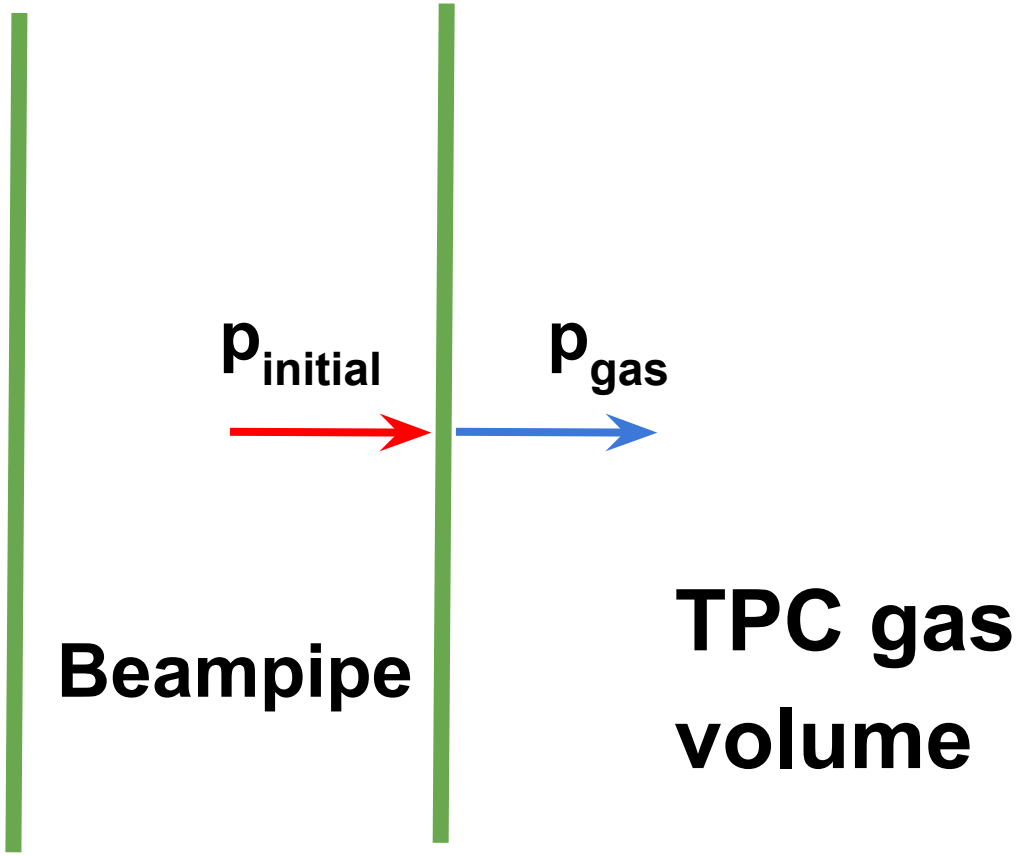
$p_{initial}$ = 100 MeV/c

GEANT4 can be used to bound $p_{initial}$ and p_{gas}

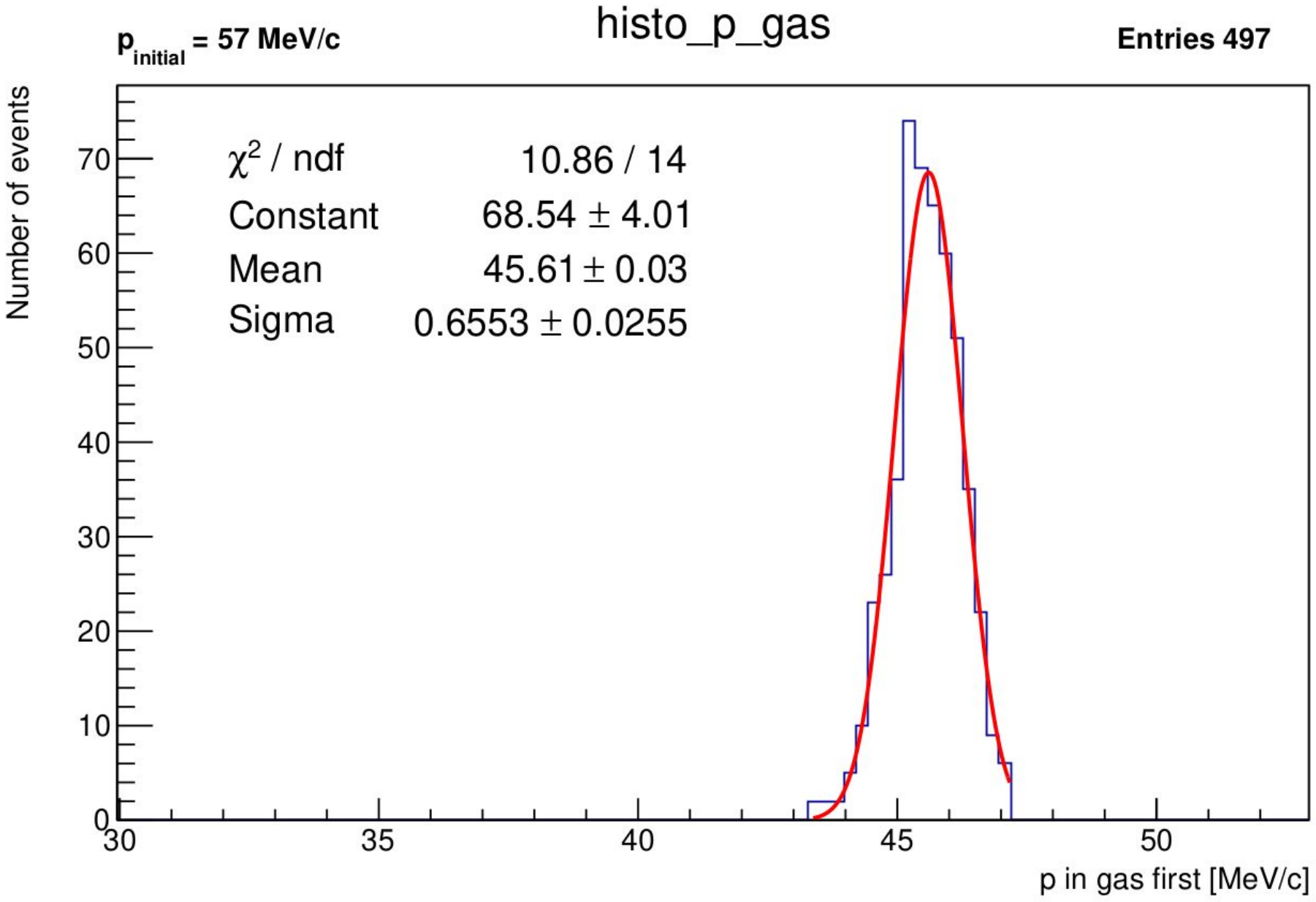
$$p_{gas} = p_{initial} - p_{loss}$$

We can estimate $p_{initial}$ by known p_{gas} and known materials

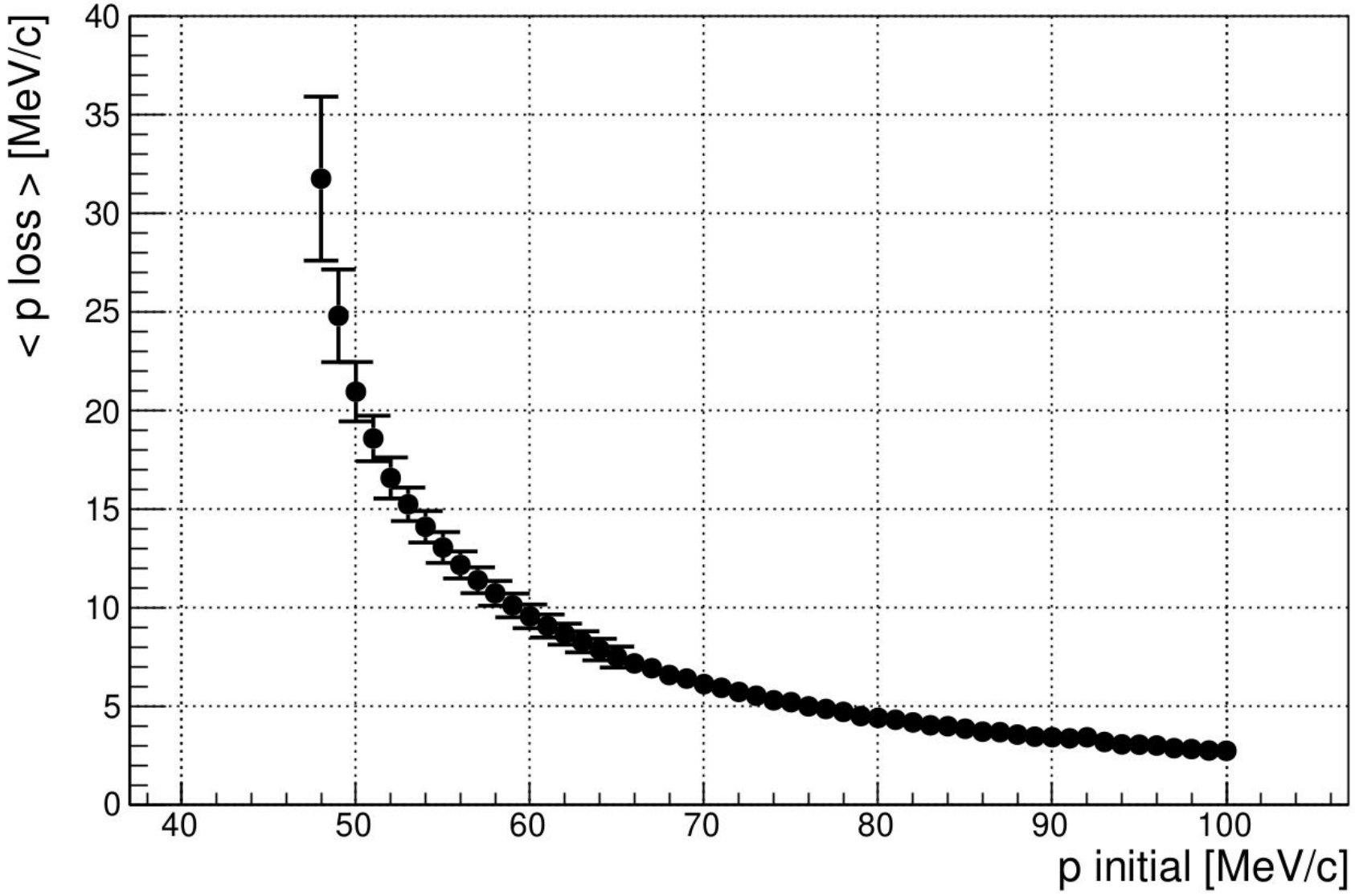
Then we obtain dp/p for <u>initial momentum</u> reconstruction



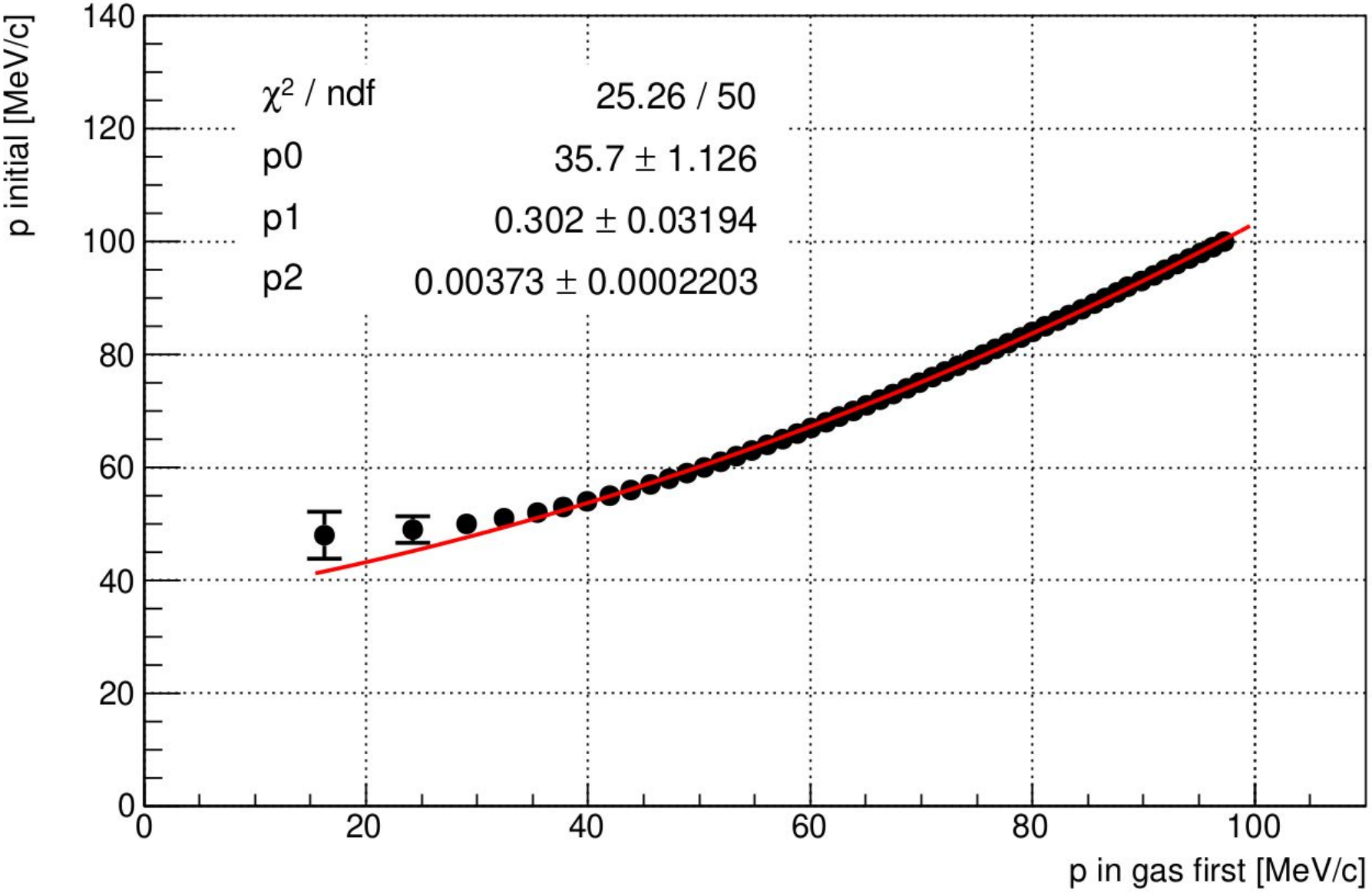
GEANT4: $p_{initial}$ is fixed, p_{gas} fluctuates



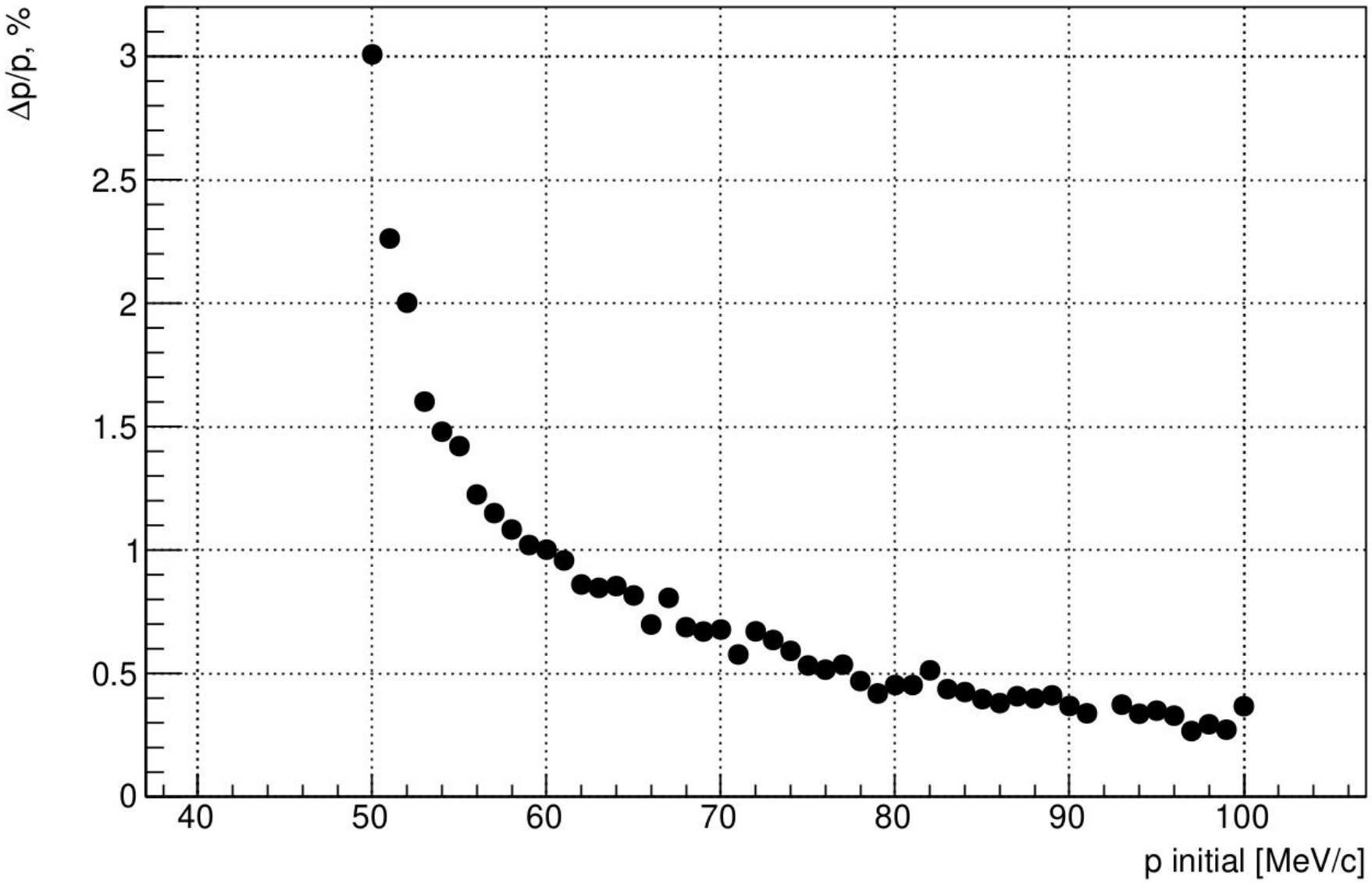
GEANT4: $\langle p_{loss} \rangle$ on $p_{initial}$



GEANT4: $p_{initial}$ on p_{gas} + parabola fit

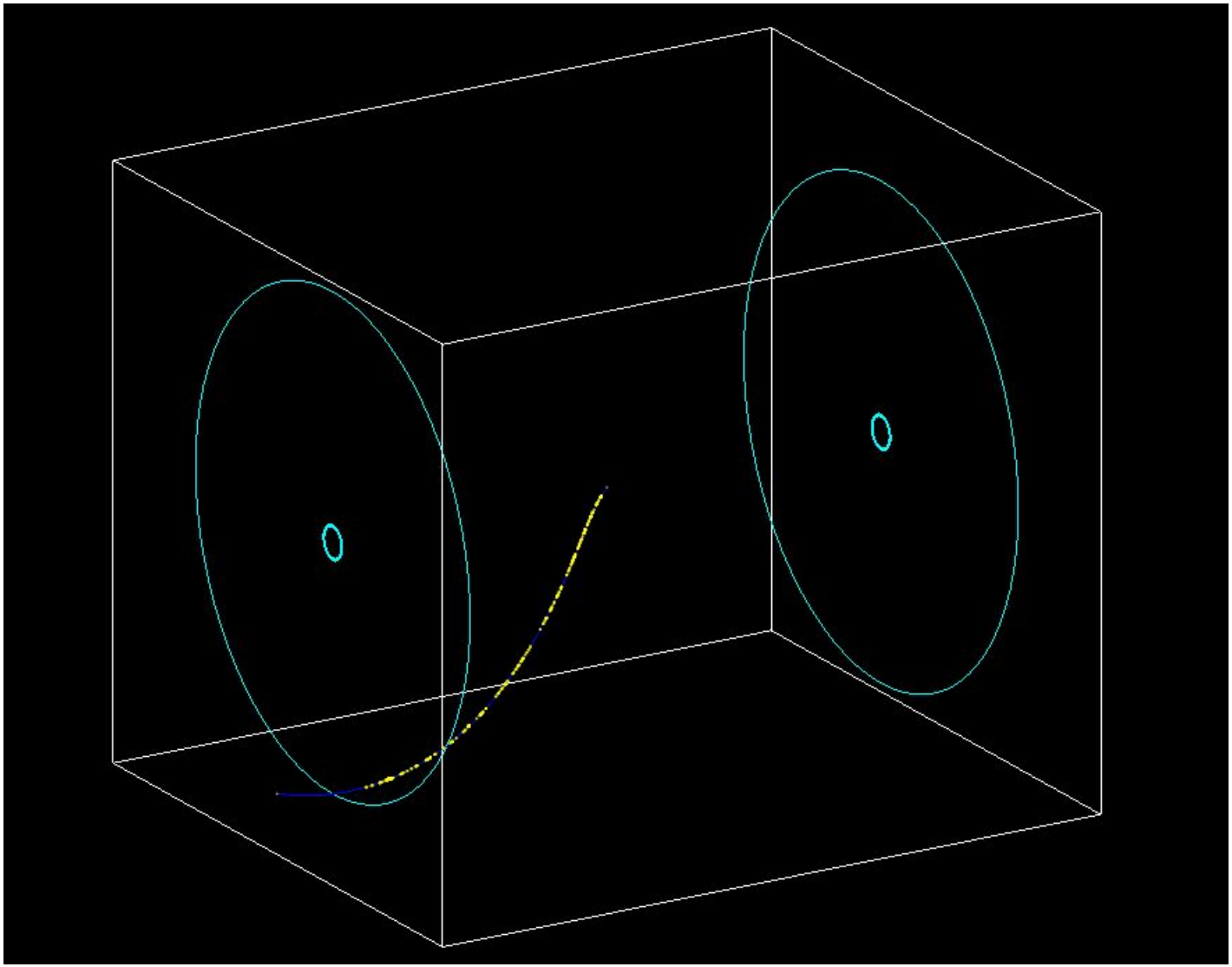


GEANT4: momentum resolution on $p_{initial}$

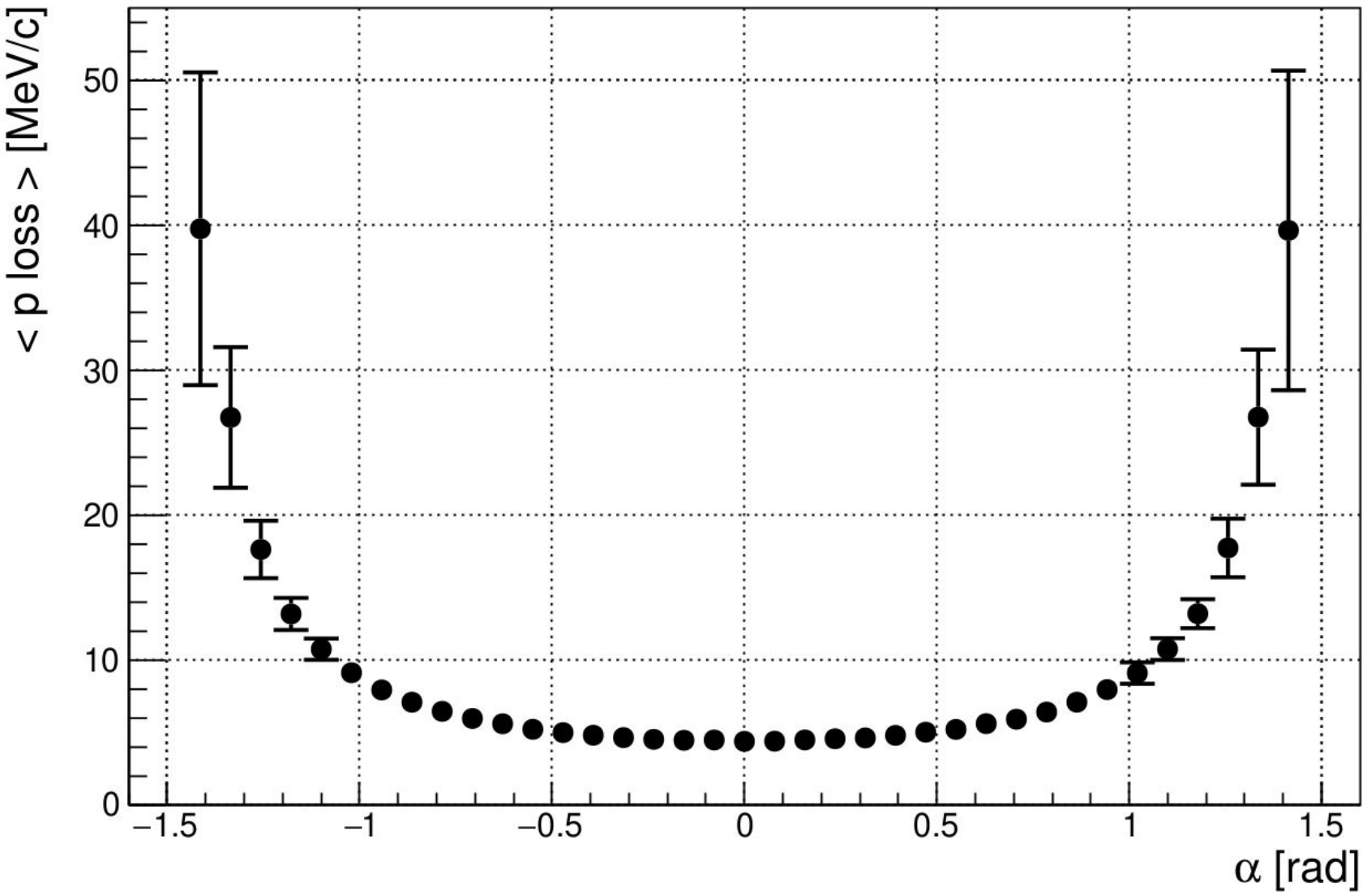


Reconstruction of momentum inside beampipe

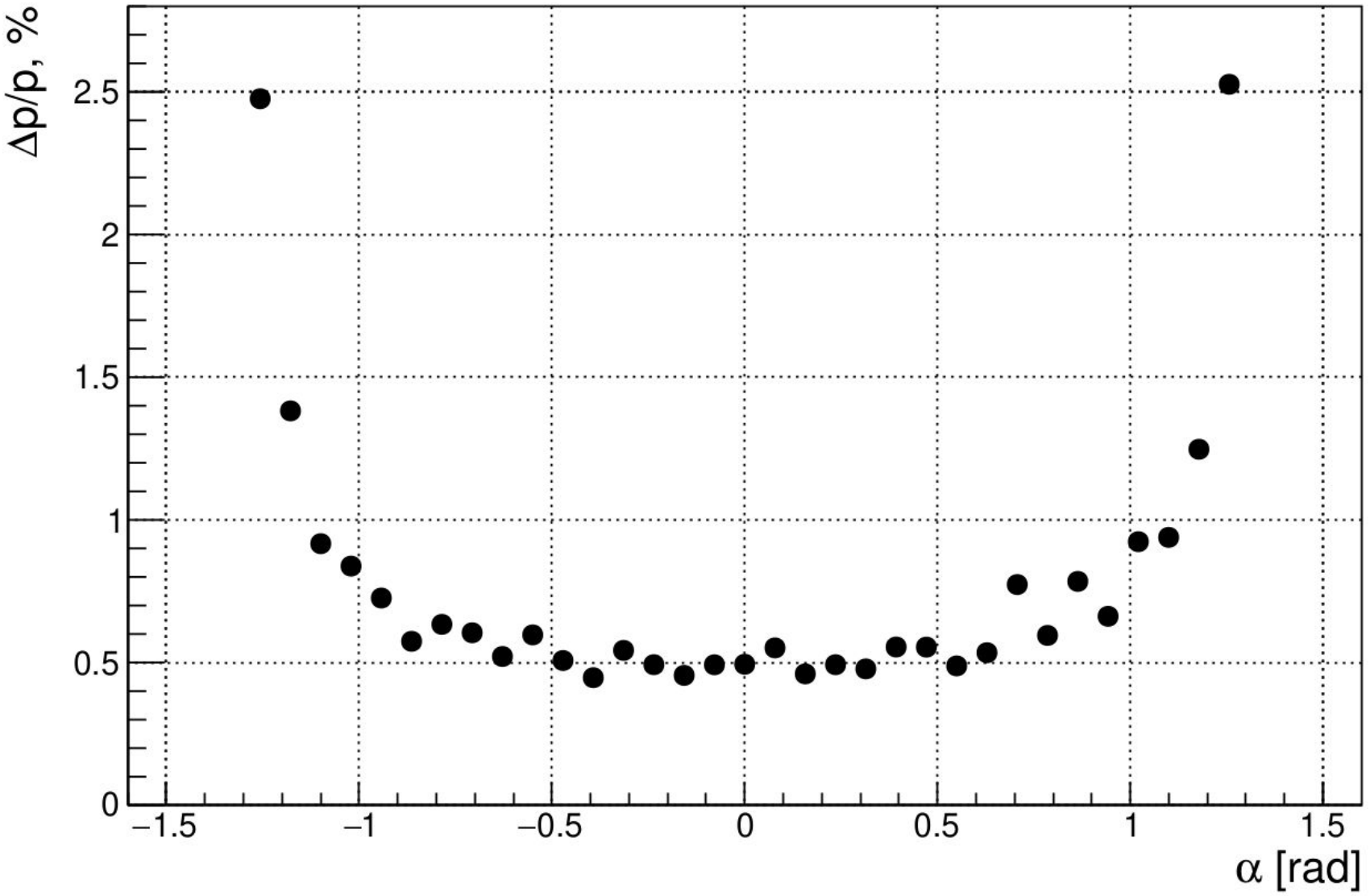
GEANT4 simulation example of non-perpendicular π-meson start: $p_{initial}$ = 80 MeV/c, $\alpha_{initial}$ = π/4 rad



GEANT4: $p_{initial}$ = 80 MeV/c; $\langle p_{loss} \rangle$ on $\alpha_{initial}$



GEANT4: $p_{initial}$ = 80 MeV/c; dp/p on $\alpha_{initial}$



Reconstruction of momentum inside beampipe

Conclusions on GEANT4 + GenFit simulation

Minimum initial π-mesons **momentum to pass** through walls of TPC:

- **inner wall – 47 MeV/c**
- **outer wall – 60 MeV/c**

Reconstruction of first **momentum in gas** is possible for incident **angle less than 1 rad** with:

- **dp/p < 3.5% for p_{gas} in range 30–50 MeV/c**
- **dp/p < 1.5% for p_{gas} > 50 MeV/c**

Reconstruction of momentum **inside beampipe** is possible with (not accounting momentum reconstruction in gas):

- **dp/p 3% – 1% for $p_{initial}$ in range 50–60 MeV/c**
- **dp/p 1% – 0.5% for $p_{initial}$ in range 60–80 MeV/c**
- **dp/p < 0.5% for $p_{initial}$ > 80 MeV/c**

Thank you for attention!

Back-up slides

Background tracks in TPC

Primary processes:

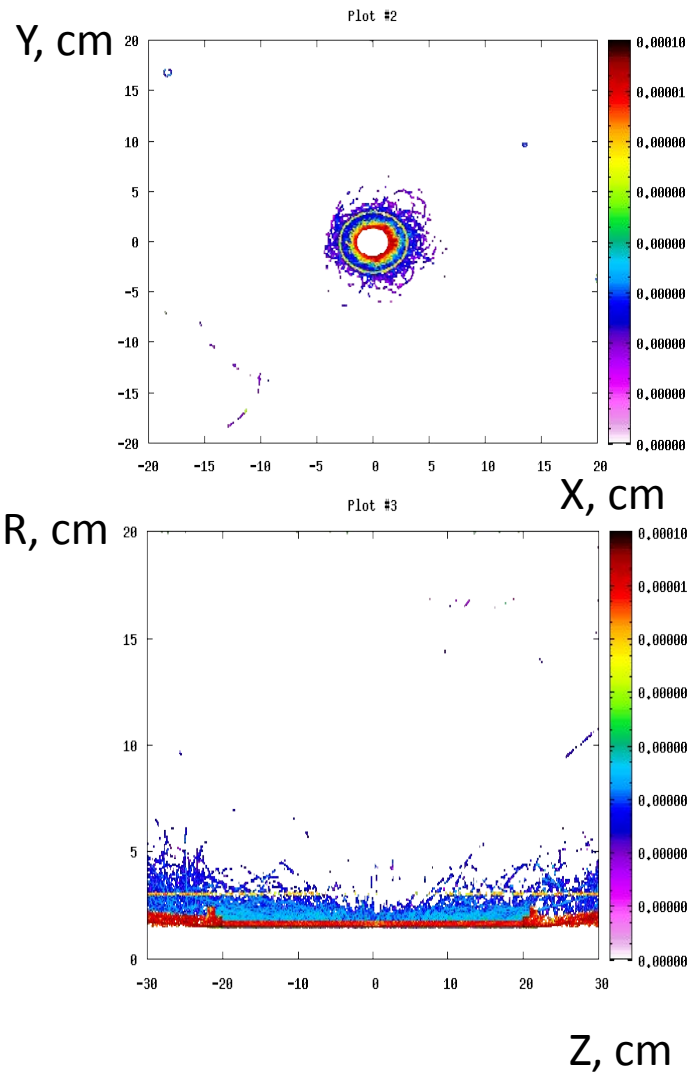
Two-photon process $e^+e^- \rightarrow \gamma^*\gamma^* \rightarrow e^+e^-e^+e^-$
(tracks in the center of TPC (near Z=0 cm))

Radiative Bha-Bha $e^+e^- \rightarrow e^+e^-\gamma$
(tracks on the sides of TPC (near Z=±30 cm))

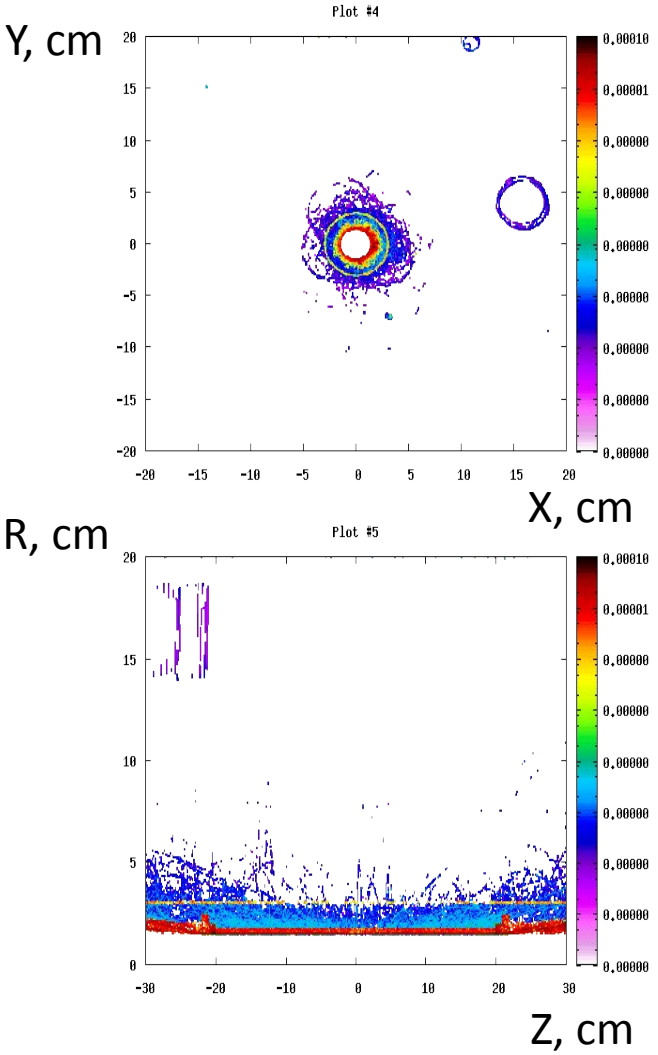
Background tracks in TPC

Examples of TPC occupancy (energy depositions) within 6 μs

Sample 1

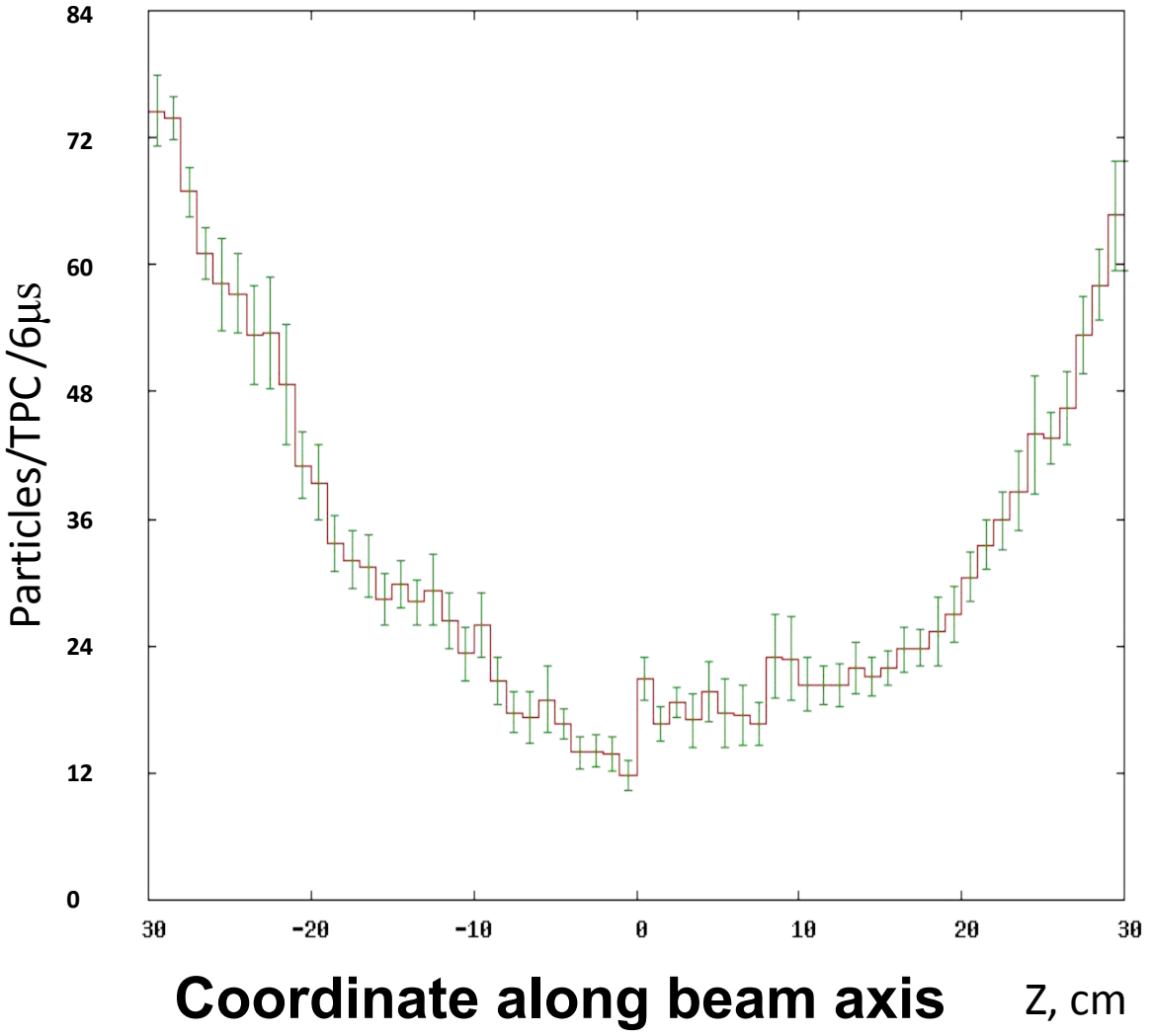


Sample 2

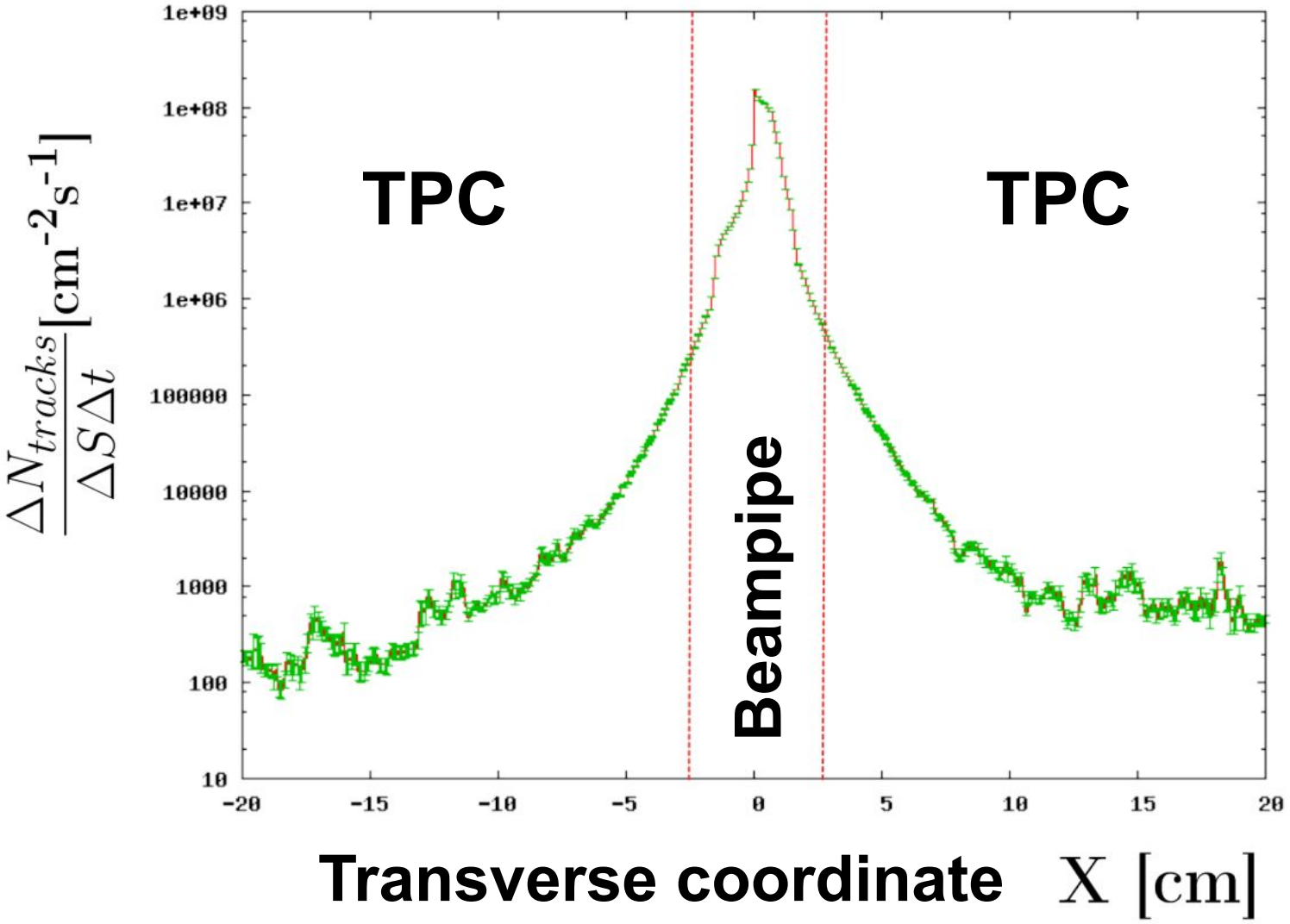


Background tracks in TPC

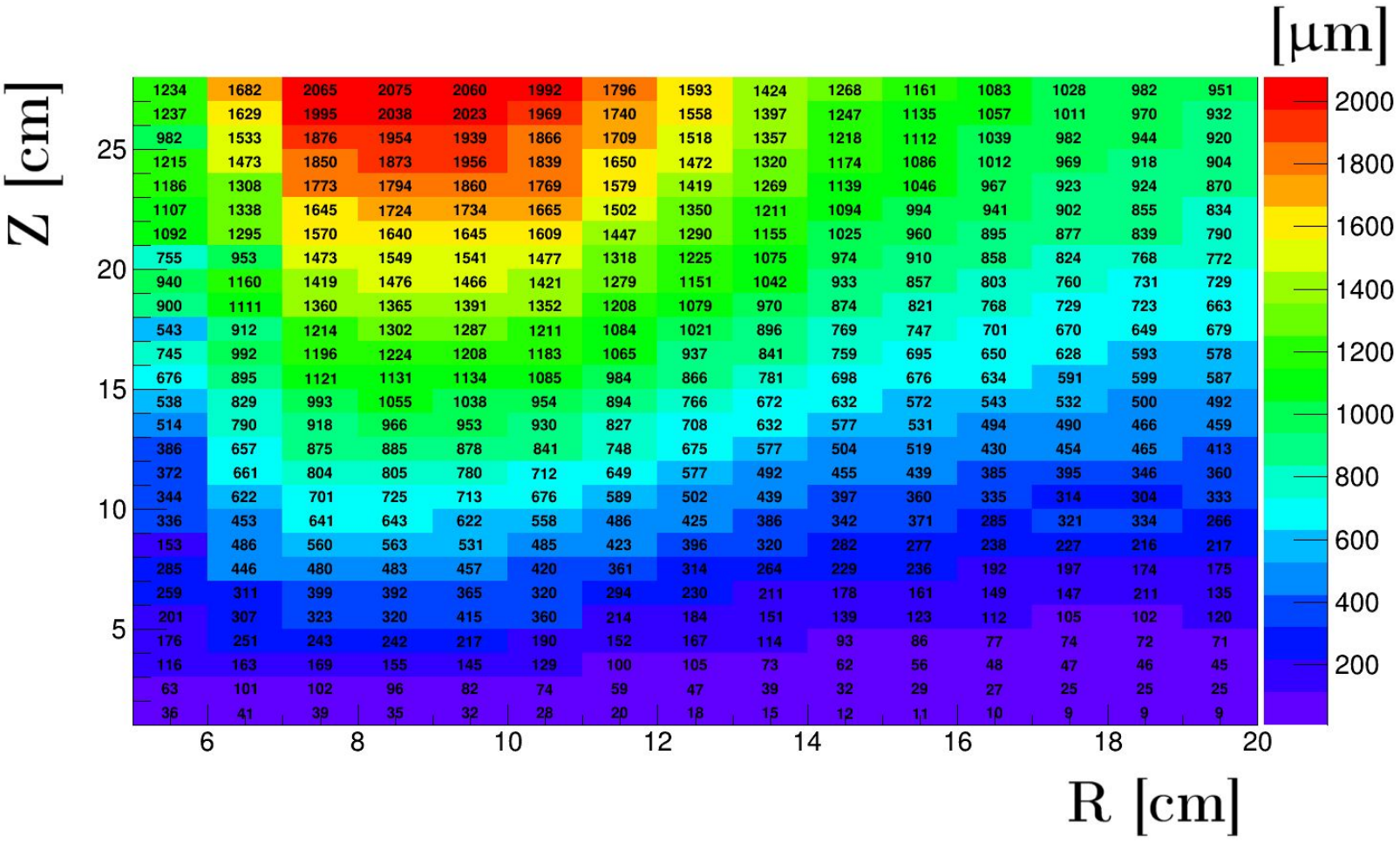
Number of charge particle tracks per TPC cross-section within 6 μs (1200 brunch crossings)



Background tracks in TPC have influence on electric field due to space charge



Map of trajectory deviations due to space charge from background tracks – deviations can be compensated in off-line analysis (experience of ALICE at CERN)



Gas Ar(45%)-iC_4H_{10}(15%)-CF_4(40%) ; E=1000 V/cm ; Gain 10^4 ; IBF=1%

More details: https://doi.org/10.1016/j.nima.2022.167225