TOF-Japan Meeting

2024/10/02 (Wed)

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TOF Simulation motivation

■Impact of BTOF material budget onto hpDIRC

- Currently, Barrel TOF material budget is required ～1% X/X0

For angular resolution @ hpDIRC surface
(6 GeV/c → Δθ = 0.5 [mrad])

→BTOF design is restricted by the material budget limitation

The design restriction has the potential to be a problem for the detector cooling
(carbon does not have good thermal conductivity, limited amount of water for water cooling)

- If we could increase the material budget…

More flexibility to change to a material with better thermal conductivity (e.g. Aluminum)

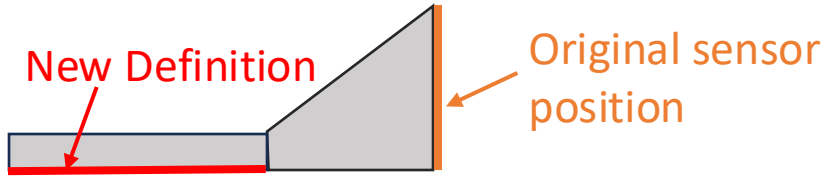
- **BTOF simulation with changing its material budget is necessary to test the effects on hpDIRC**

→ **Quantitative Evaluation the BTOF material budget effects on the angular resolution at the hpDIRC surface**

Determine the upper limit of material budget for BTOF

Simulation

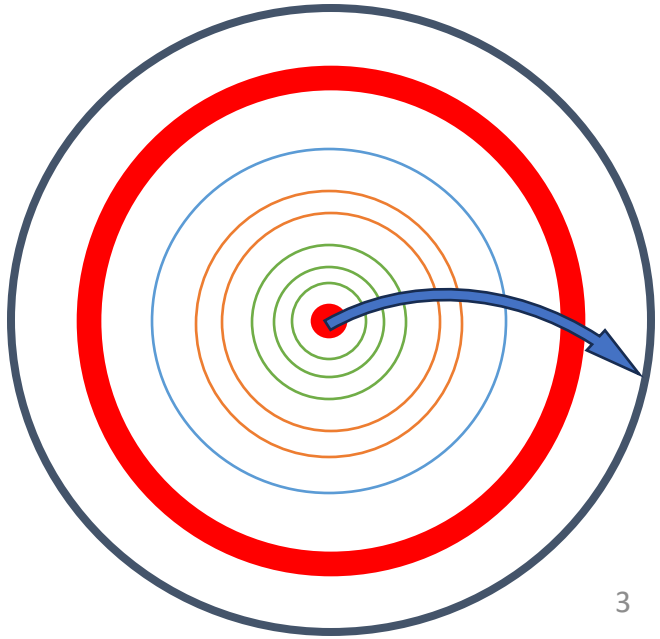
1. Define the surface of hpDIRC using Geant4 (hpDIRC surface)
   - Because no particles are detected on the surface of the hpDIRC
   - To obtain MC information of particles at hpDIRC surface



2. Calculate angle of incident particles from hit information (momentum) to detector
   - MC info(mc.theta)： Use MC information of the detector defined in 1.
   - Track info(track.theta)： Get values from propagation of reconstructed tracks from tracker

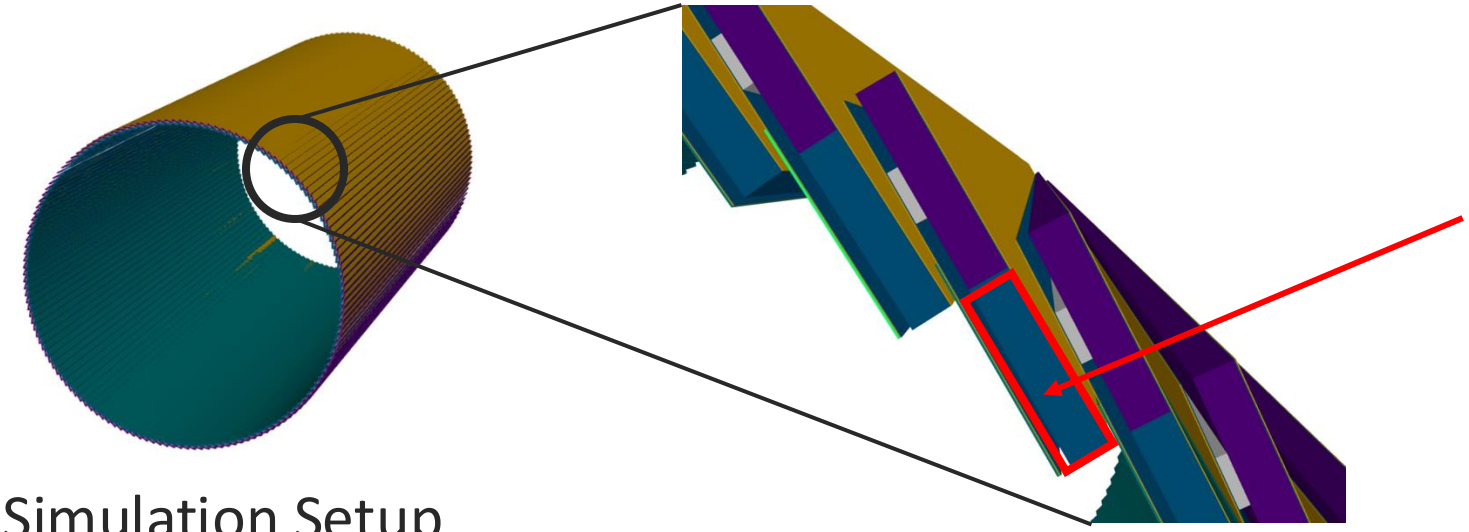
Tracker Detectors (Barrel)
- Silicon Vertex Tracker × 3
- Silicon Barrel Tracker × 2
- Inner MPGD (Micro Pattern Gas Detector)
- Barrel TOF
- Outer MPGD

Kalman filter to reconstruct tracks
Using track parameter information on hpDIRC surface (r = 75.5 cm)



Simulation

3. Change the BTOF material and perform the same simulation



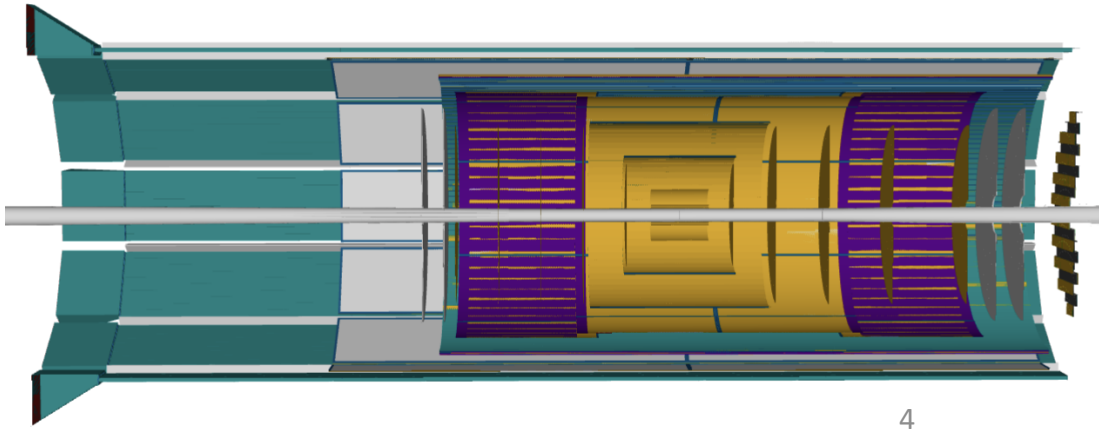
Carbon foam : 0.09 g/cm^3, 5.8mm
~ 0.7 % (X/X0)

↓Change material

Aluminum : 2.65 g/cm^3
~ 7.1 % (X/X0)

■Simulation Setup

- EICrecon : Particle collision reconstruction using phythia8, Geant4, and track reconstruction algorithms using ePIC detector structures are available.
- Single particle : π^-(1000 events)
- Momentum : 1, 2, 4, 6, 8, 10 [GeV/c]
- Direction : $0^\circ \leq \phi \leq 360^\circ$, $92^\circ \leq \theta \leq 94^\circ \rightarrow \langle\eta\rangle = -0.05$



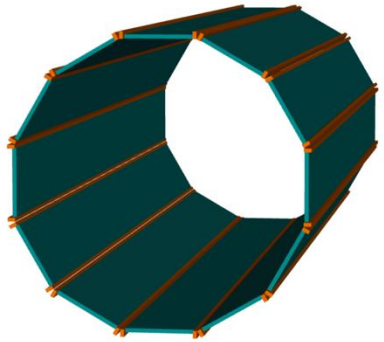
Results - Hit position on hpDIRC surface

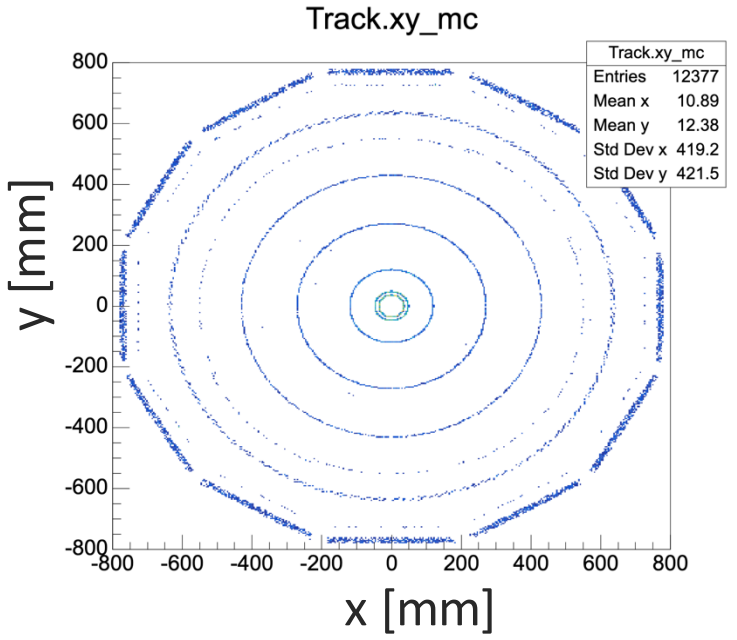
■Generates 1000event single particles (6 GeV/c, $0^\circ \leq \phi \leq 360^\circ, 92^\circ \leq \theta \leq 94^\circ$)

- Get particle information on hpDIRC surface defined by Geant4 (MC info)

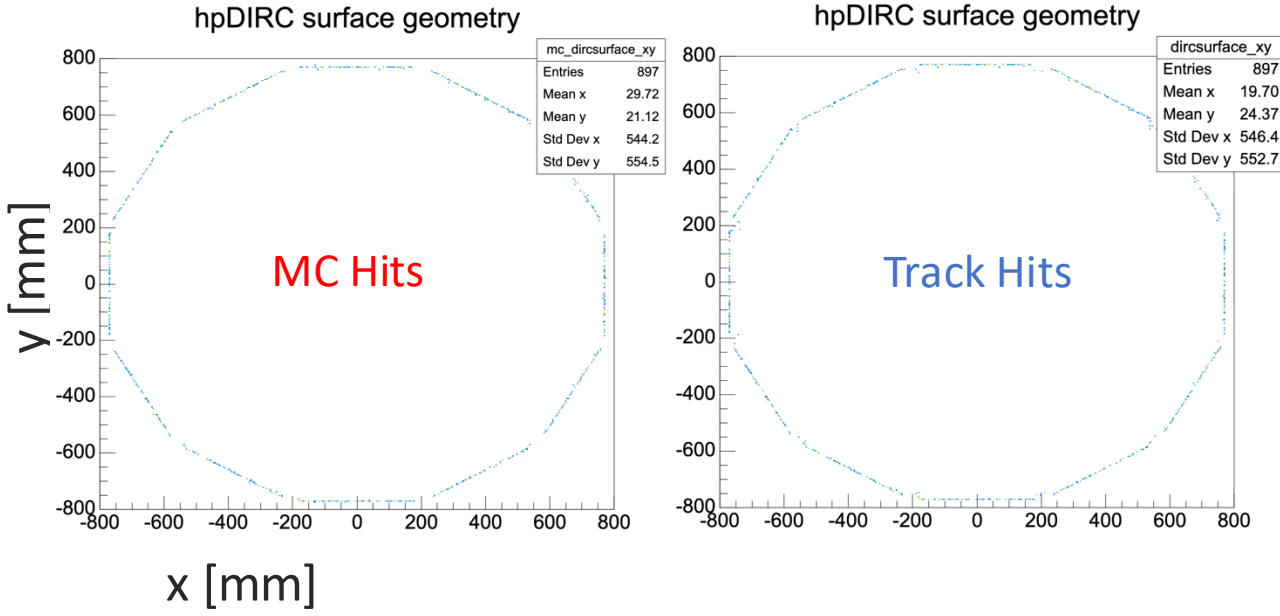
➢ Can get as well as MC information for epic's tracker detector

➢ The outermost layer is the hpDIRC surface defined by myself





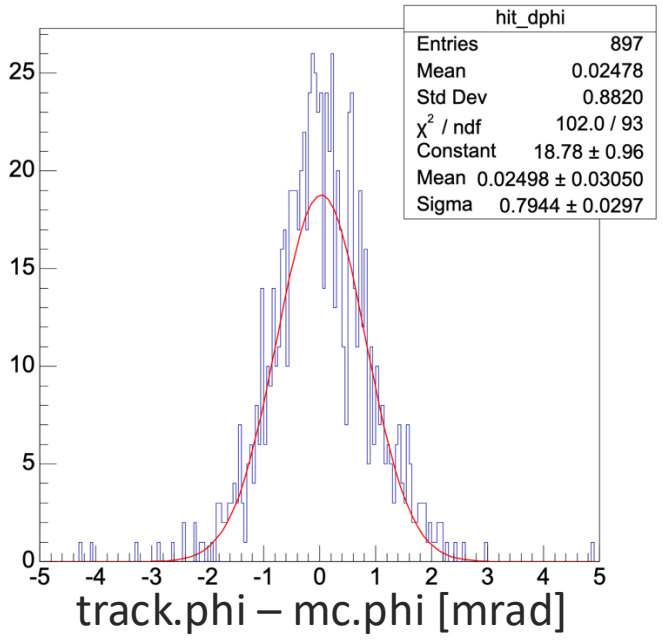
➢ MC information and particle information obtained by propagating tracks on hpDIRC surface



Results - Angular distribution on hpDIRC surface

- Angular resolution calculated from particle momentum in MC and track information
  - $\Delta\theta = \theta(track) - \theta(MC), \qquad \Delta\phi = \phi(track) - \phi(MC)$
  - $\theta = arctan2\left(\sqrt{{p_x}^2 + {p_y}^2}, p_z\right), \qquad \phi = arctan2(p_y, p_x)$
  - The higher the momentum, the better the angular resolution.

Δϕ [mrad] , 92 < θ < 94 , p = 6 GeV



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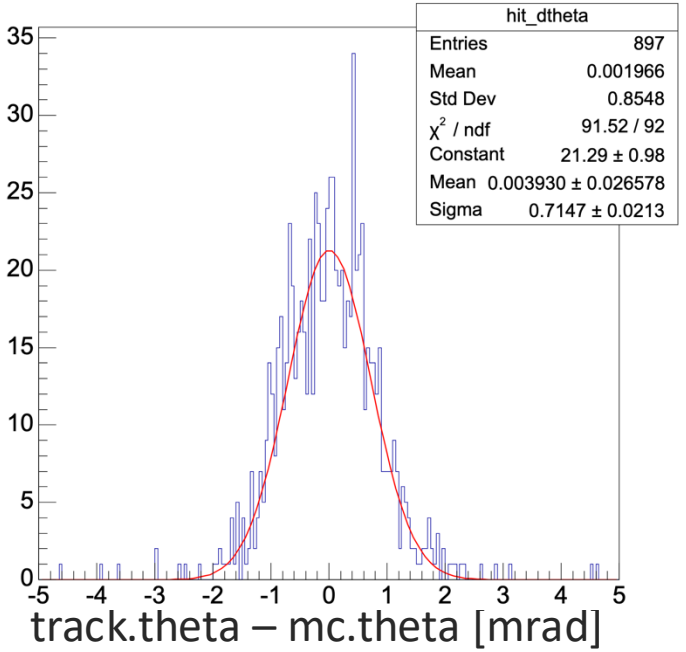
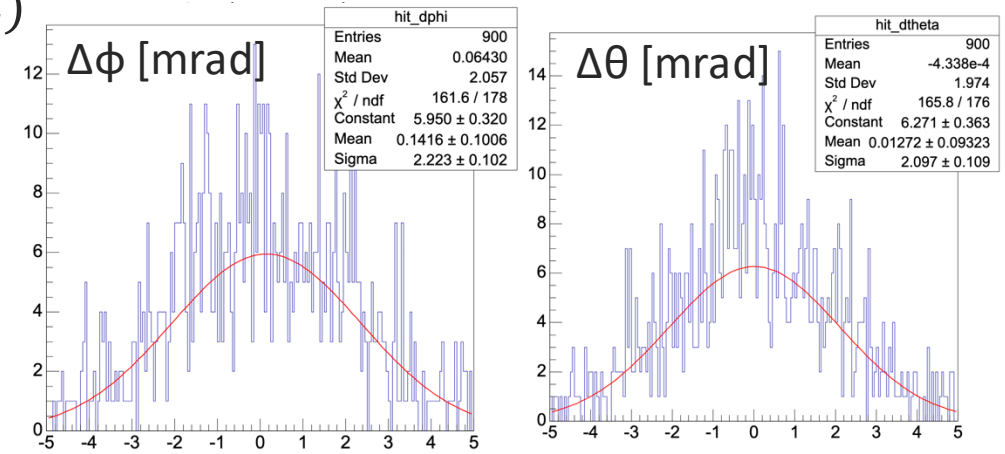
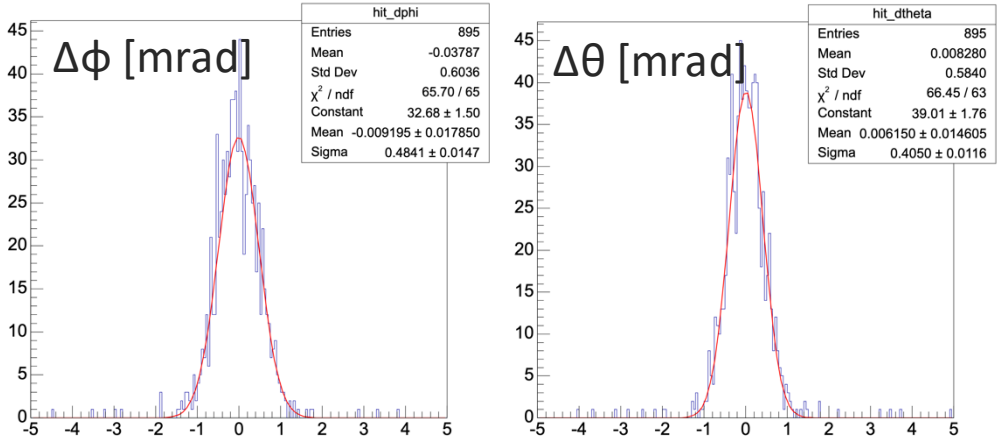


92 < θ < 94 , p = 2 GeV



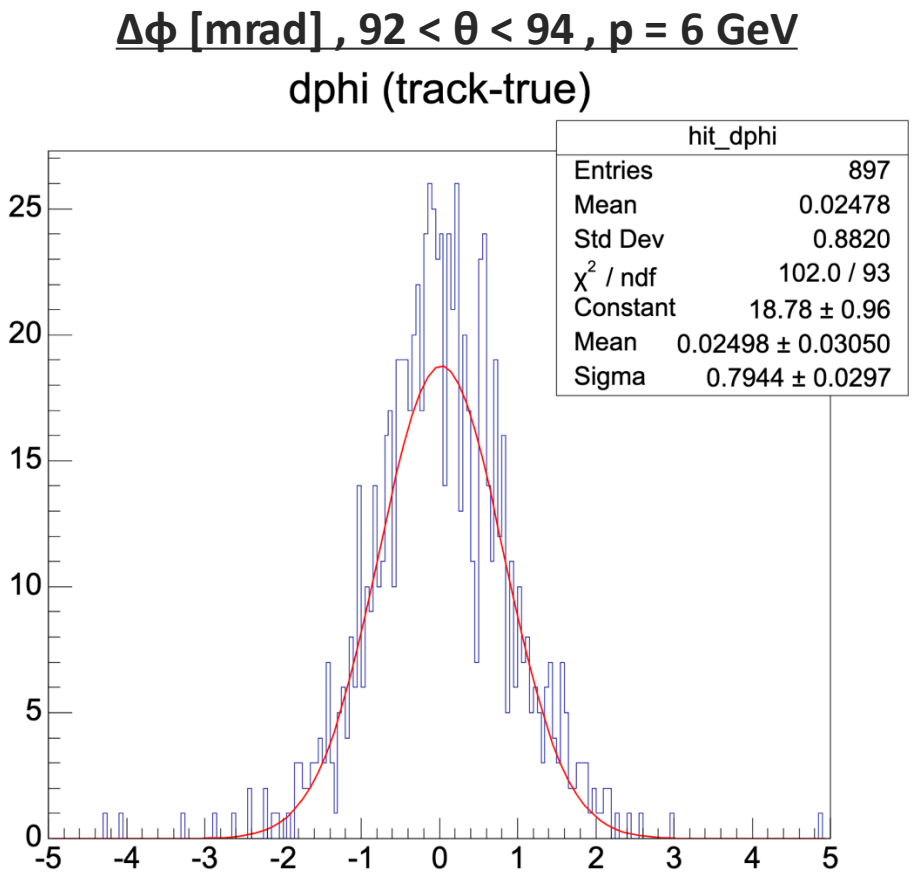
92 < θ < 94 , p = 10 GeV

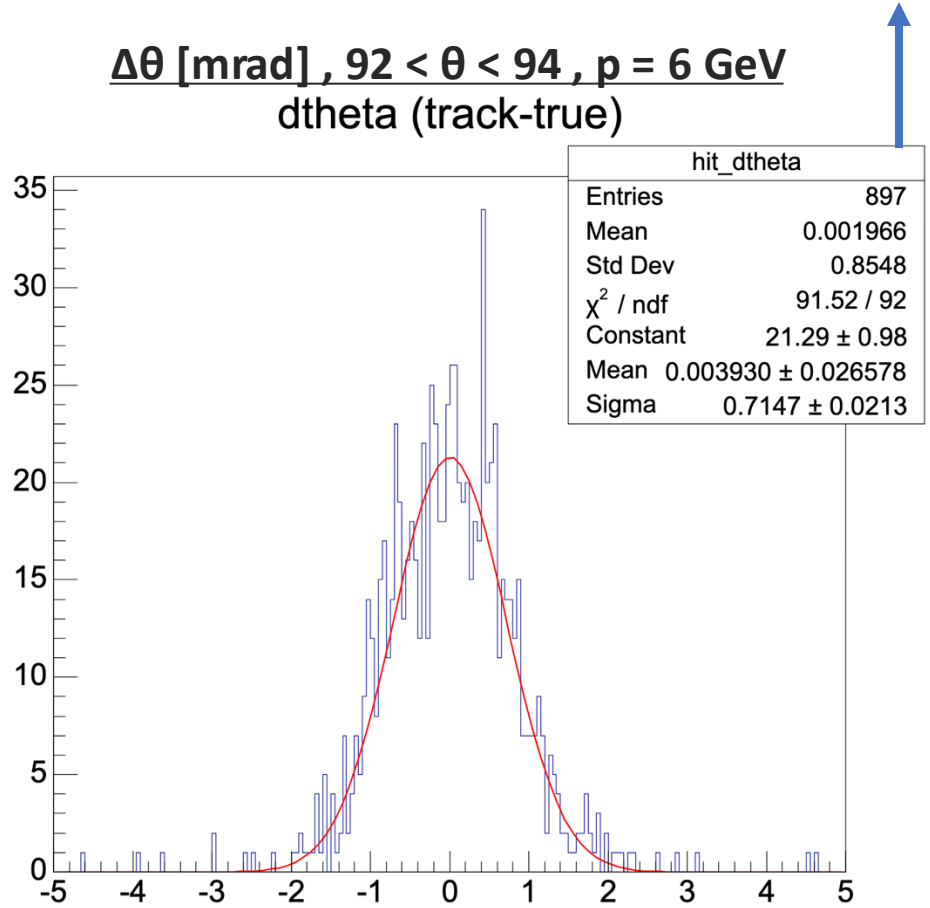


Angular distribution on hpDIRC surface

- Single particle : π^- (1000 events)
- Momentum : 1,2,4,6.8,10 [GeV/c]
- Direction : $0^\circ \leq \phi \leq 360^\circ$, $92^\circ \leq \theta \leq 94^\circ \rightarrow \langle\eta\rangle = -0.05$

$\sigma = 0.7147 \pm 0.0213\ [mrad]$
要求を満たしていない





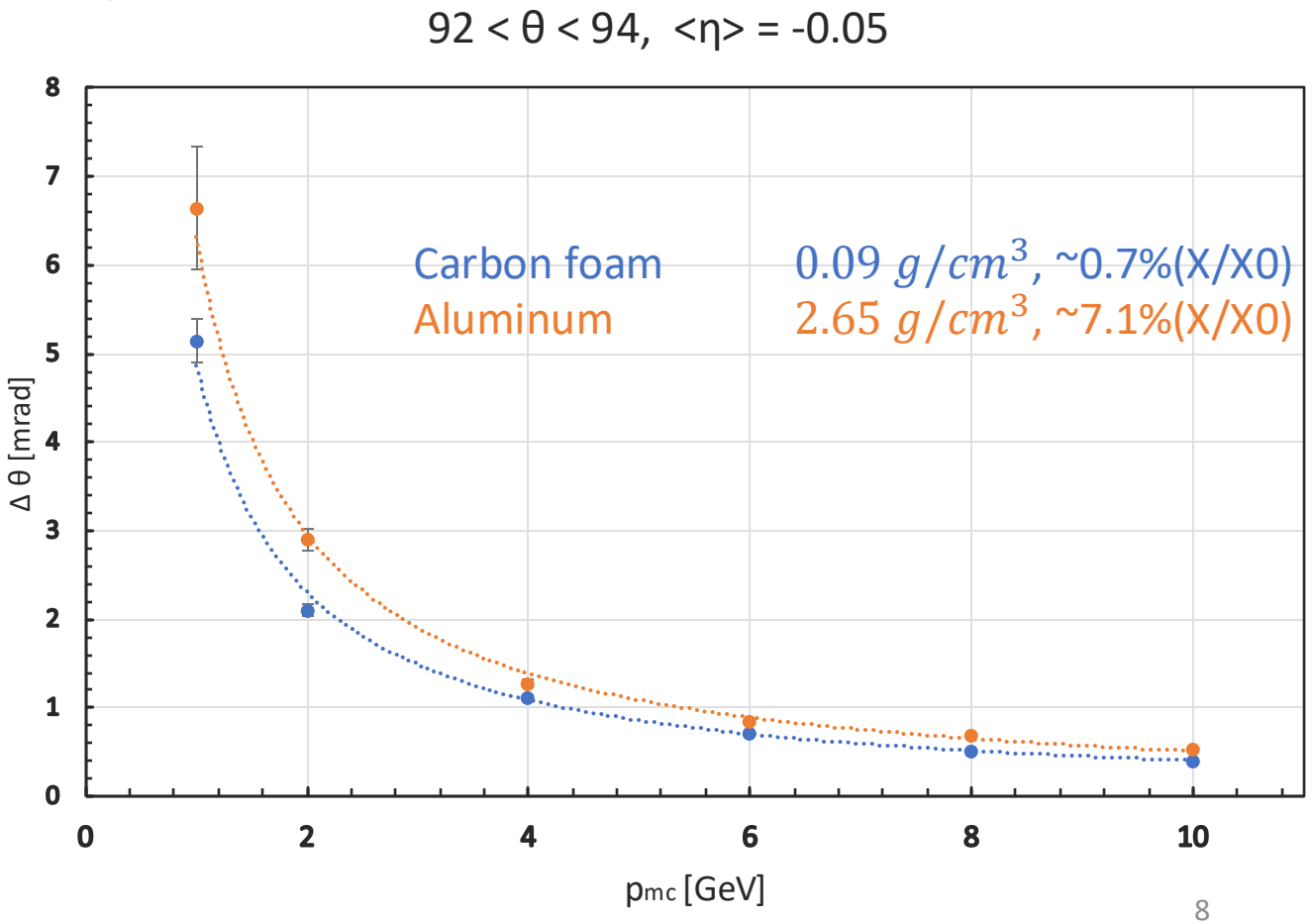
Results - Angular resolution on hpDIRC surface

■Results for some changes in particle momentum and BTOF material.

- Part of BTOF Carbon foam changed to Aluminum
- The value of Δθ increases

But…

- Current structure
  does not satisfy hpDIRC requirements.



Back up

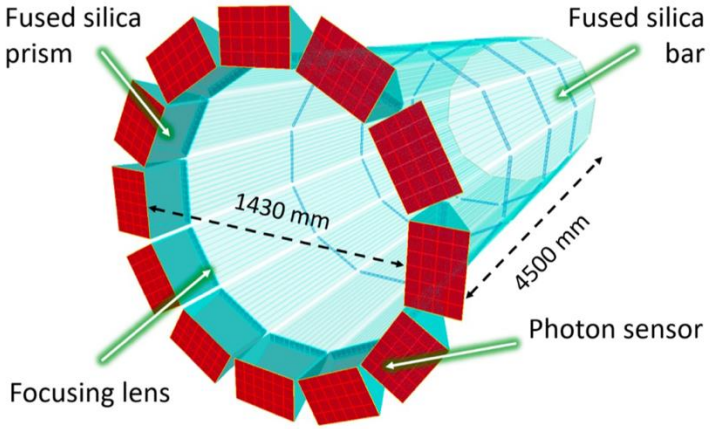
Motivation

■Estimating the impact of BTOF material budgets on the backward detector (hpDIRC)

- ➢ hpDIRC (high performance Detection of Internally Reflected Cherenkov light)
- Cherenkov Particle Identification Detector
- Particle identification from the emission angle of Cherenkov light emitted by charged particles

→ Angular resolution at the surface is important

(6 GeV/c → Δθ = 0.5 [mrad])

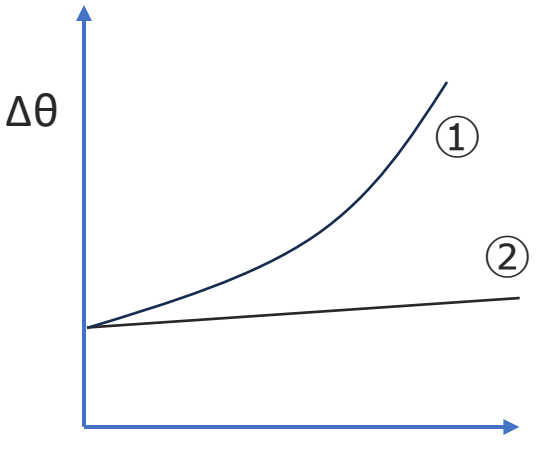


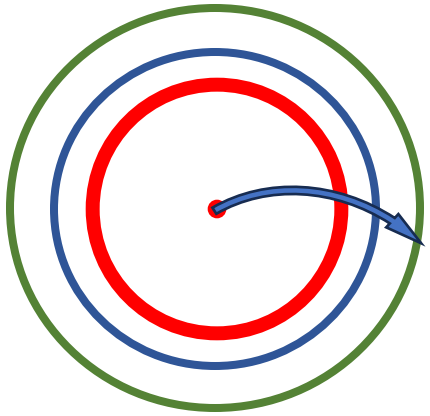
- ➢ Increase in BTOF material budget

→Angular resolution degrades due to multiple scattering effects? ①

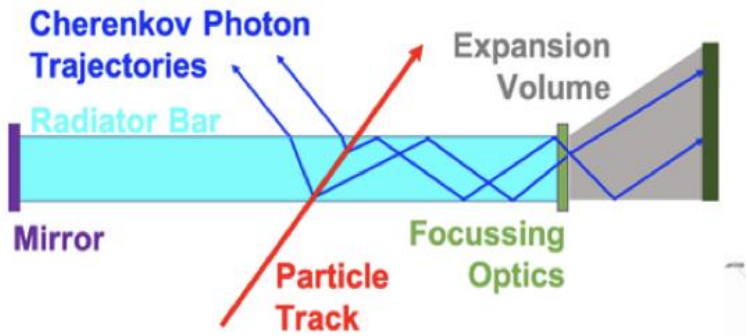
or

→ The presence of MPGD reduces the effects of multiple scattering? ②





TOF (64cm), Outer MPGD (72.5cm). DIRC (75.5cm)



Motivation

■ Estimating the impact of BTOF material budgets on the backward detector (hpDIRC)

➢ hpDIRC (high performance Detection of Internally Reflected Cherenkov light)

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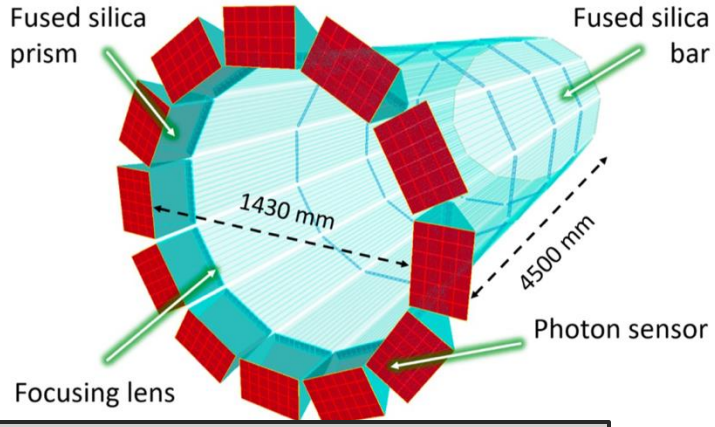


➢ Increase in BTOF material budget

→Angular resolution degrades due to multiple scattering effects? ①

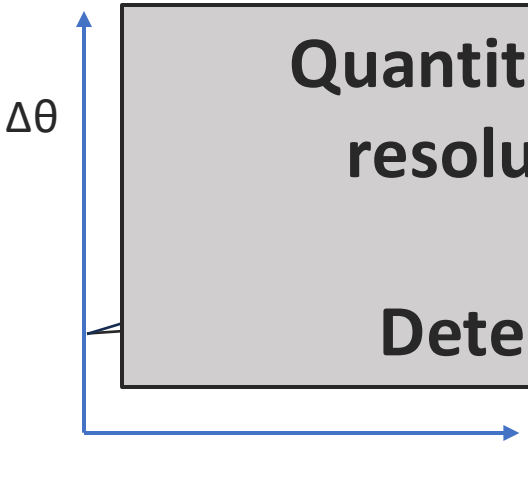
or

→ The presence of MPGD reduces the effects of multiple scattering? ②

Quantitative evaluation of the relationship between angular resolution and BTOF material budget on hpDIRC surfaces

↓

Determine the upper limit of material budget for BTOF



TOF (64cm), Outer MPGD (72.5cm). DIRC (75.5cm)

Results - Hit position on hpDIRC surface

■Generates 15000event single particles (6 GeV/c, $0^\circ \leq \phi \leq 360^\circ$, $92^\circ \leq \theta \leq 94^\circ$)

- Get particle information on hpDIRC surface defined by Geant4 (MC info)

➢ Can get as well as MC information for epic's tracker detector

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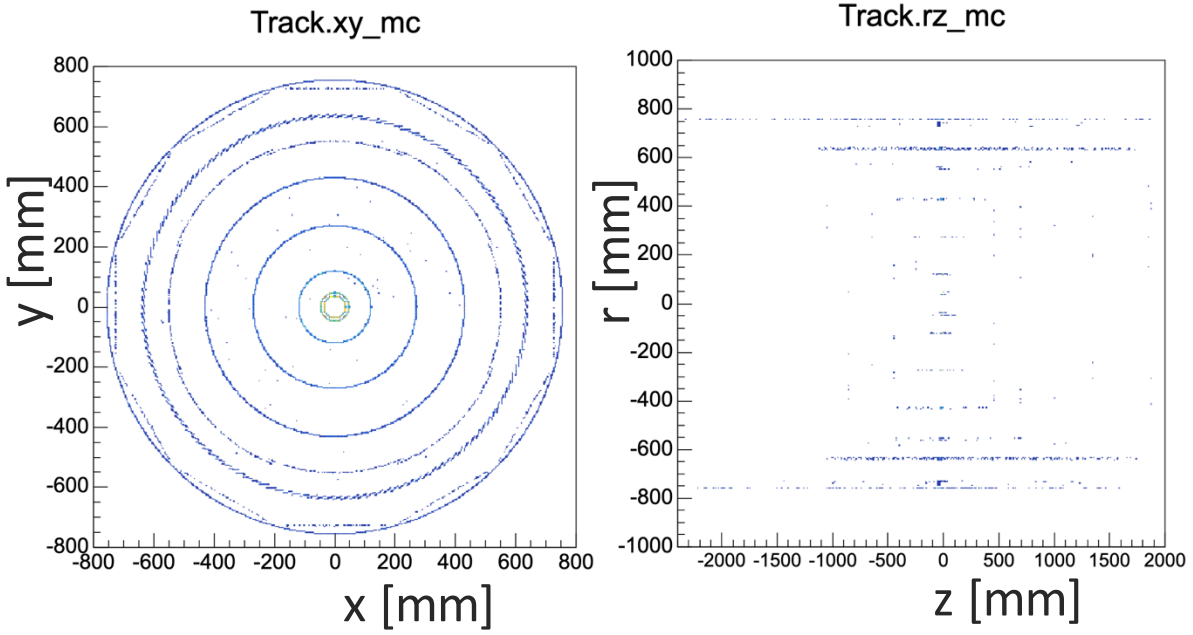
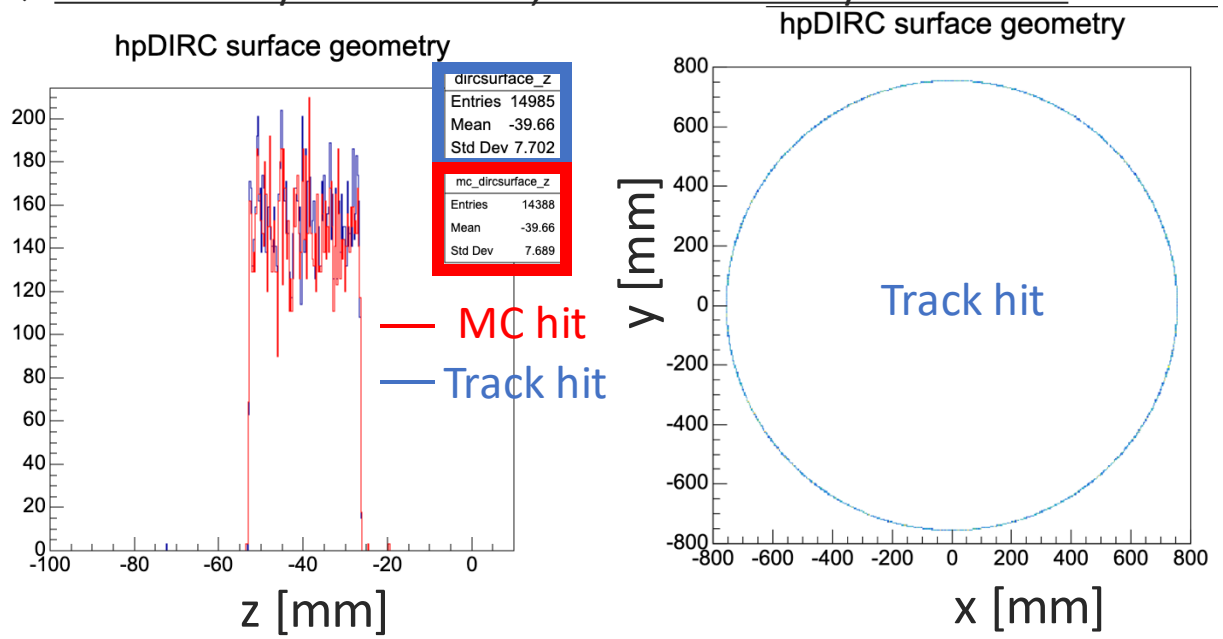


➢ MC information and particle information obtained by propagating tracks on hpDIRC surface

→ MC : 14388/15000event, Track : 14985/1500event



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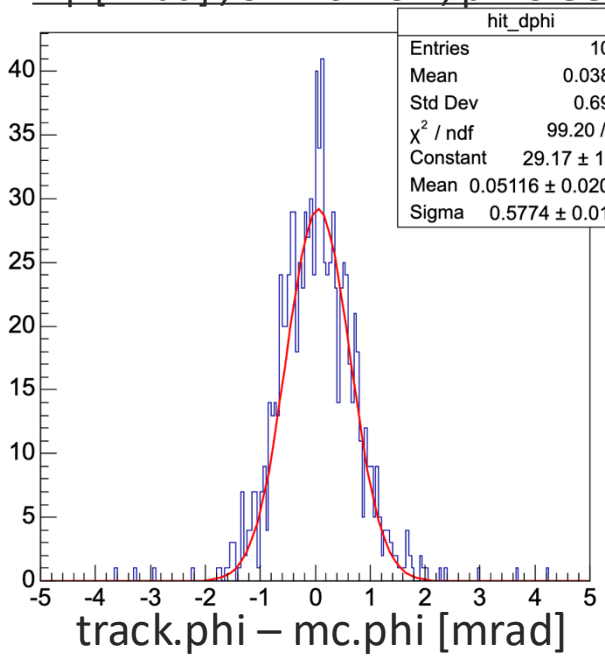
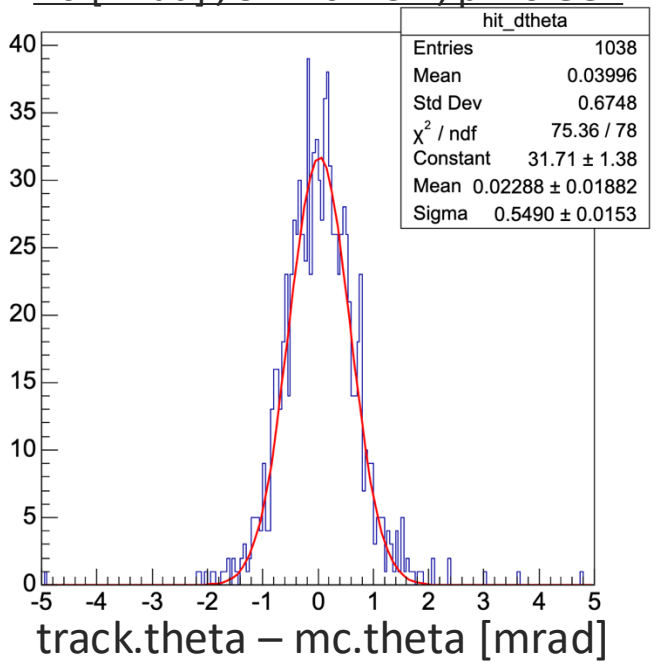
  - The higher the momentum, the better the angular resolution.

Δϕ [mrad] , 92 < θ < 94 , p = 6 GeV



Δθ [mrad] , 92 < θ < 94 , p = 6 GeV



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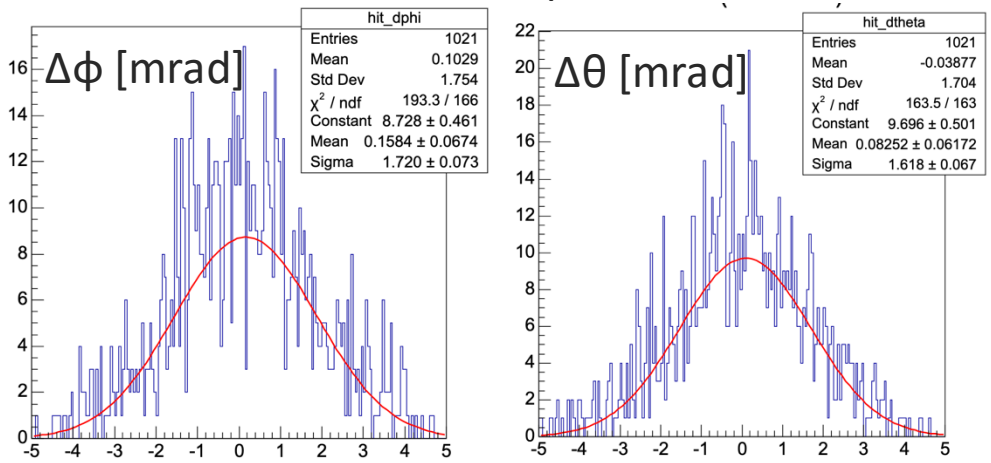

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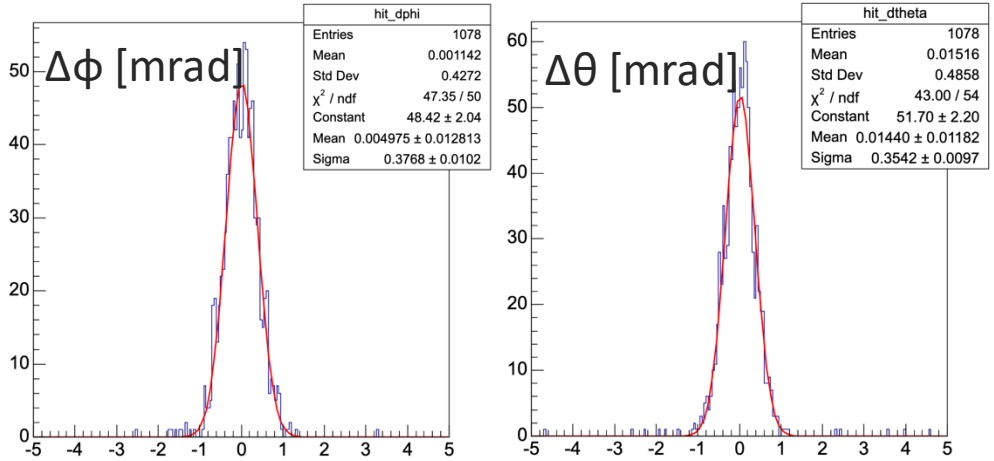


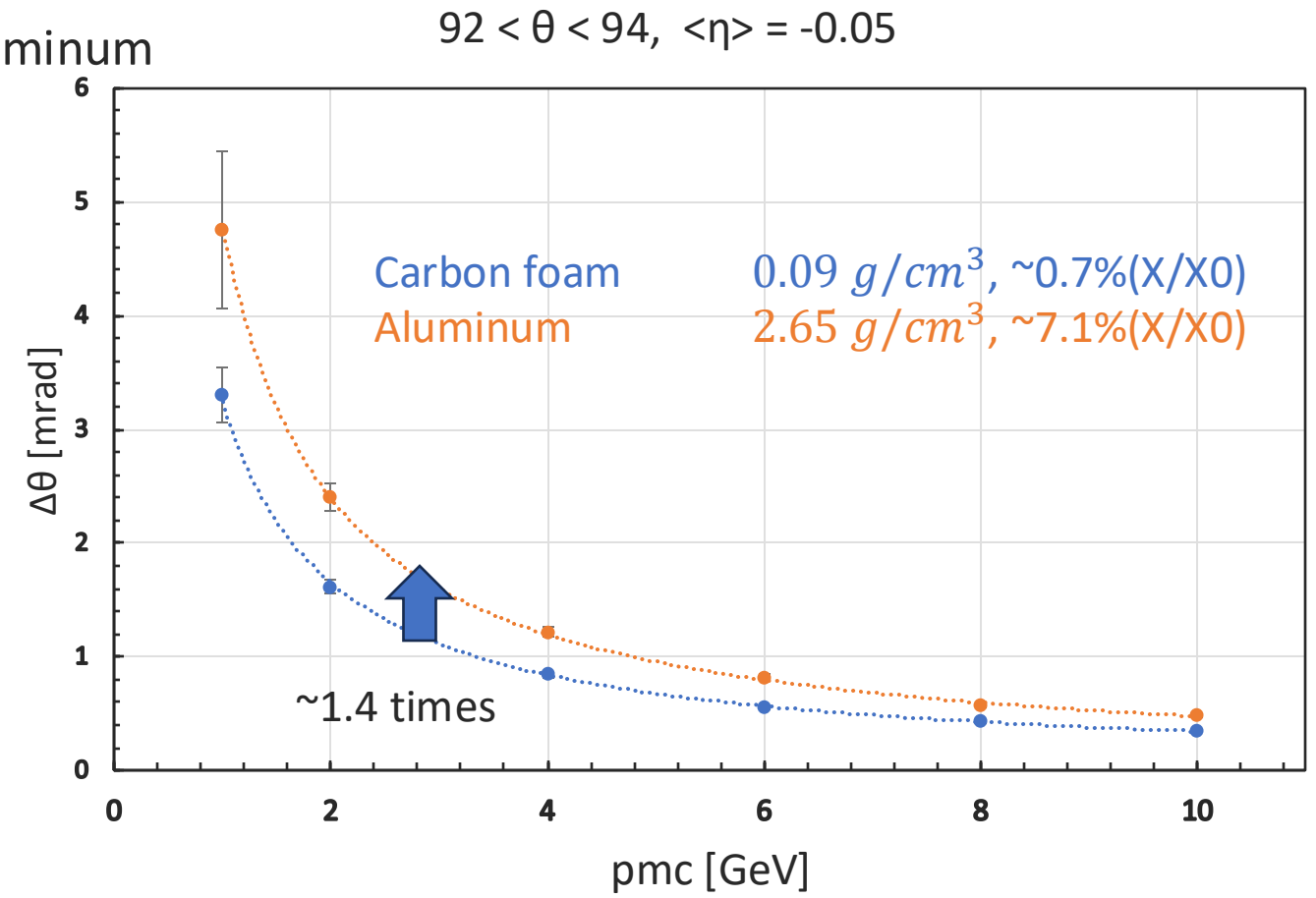
Results - Angular resolution on hpDIRC surface

■Results for some changes in particle momentum and BTOF material.

- Part of BTOF Carbon foam changed to Aluminum
- The value of Δθ increases

But…

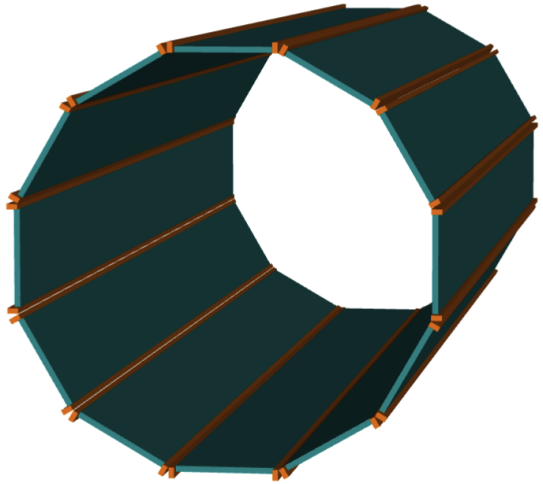
- Angular resolution Δθ is bad
- Maybe there is a mistake in the calculation method, etc.



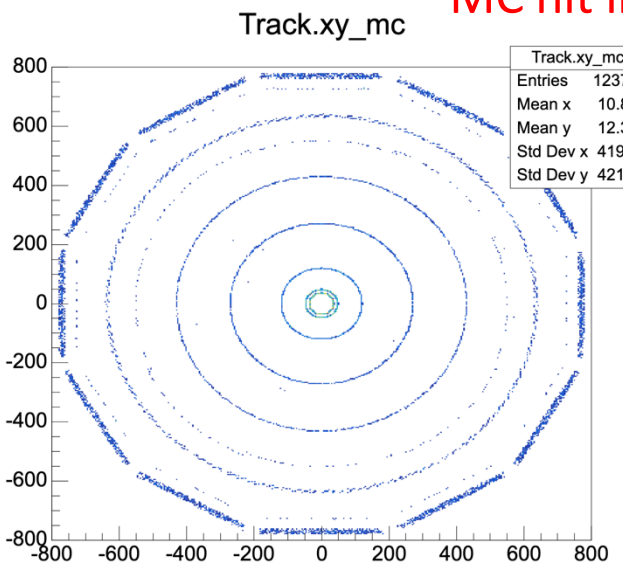
hpDIRC surface geometry (defined by Geant4)

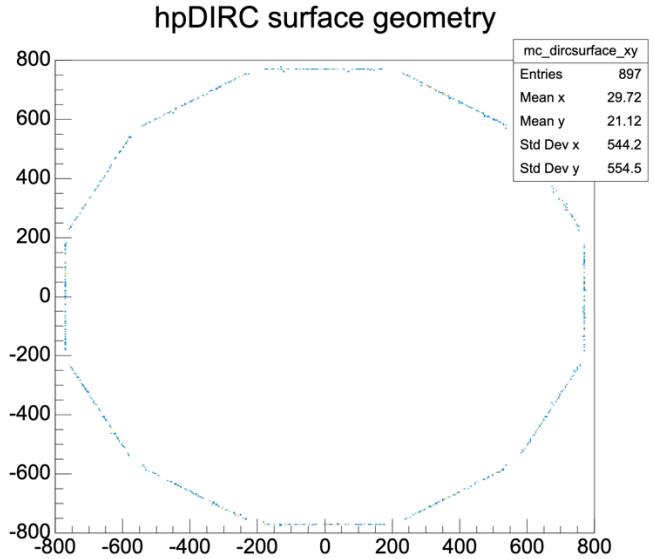
New geometry

Improved structure of regular dodecagonal columns instead of cylindrical



MC hit information





Track propagate