General TOF Meeting

2024/10/02 (Wed)

Shunichiro Muraoka

Hiroshima University

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)

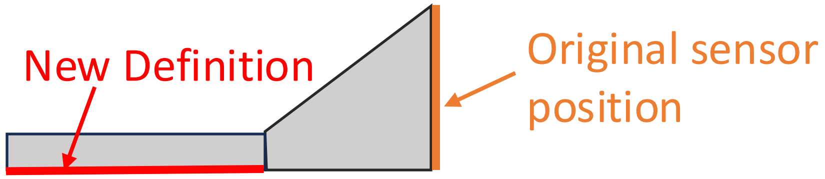
- **BTOF simulation with changing its material budget is necessary to test the effects on hpDIRC**

→ **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

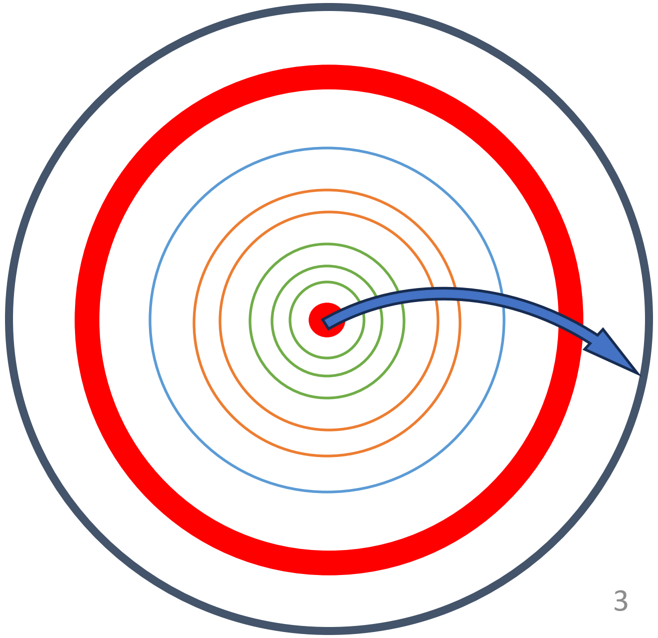
1. Define the surface of hpDIRC using Geant4 (hpDIRC surface)
   - Because no particles are detected on the surface of the hpDIRC
   - <u>To obtain MC information of particles at hpDIRC surface</u>



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

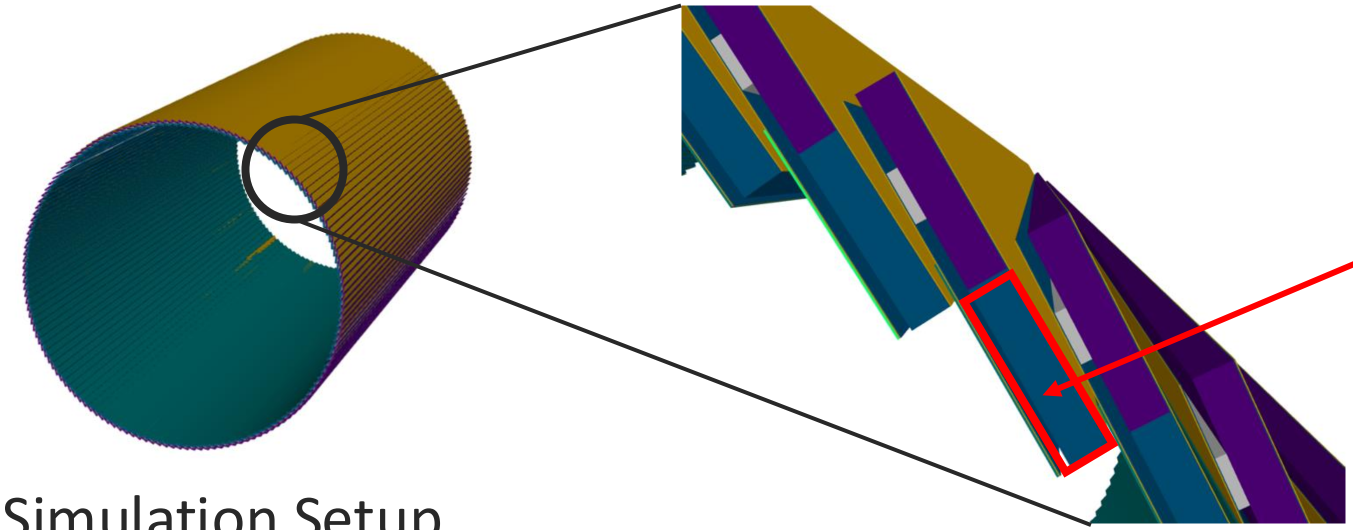
Tracker Detectors (Barrel)
- Silicon Vertex Tracker × 3
- Silicon Barrel Tracker × 2
- Inner MPGD (Micro Pattern Gas Detector)
- Barrel TOF
- Outer MPGD

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



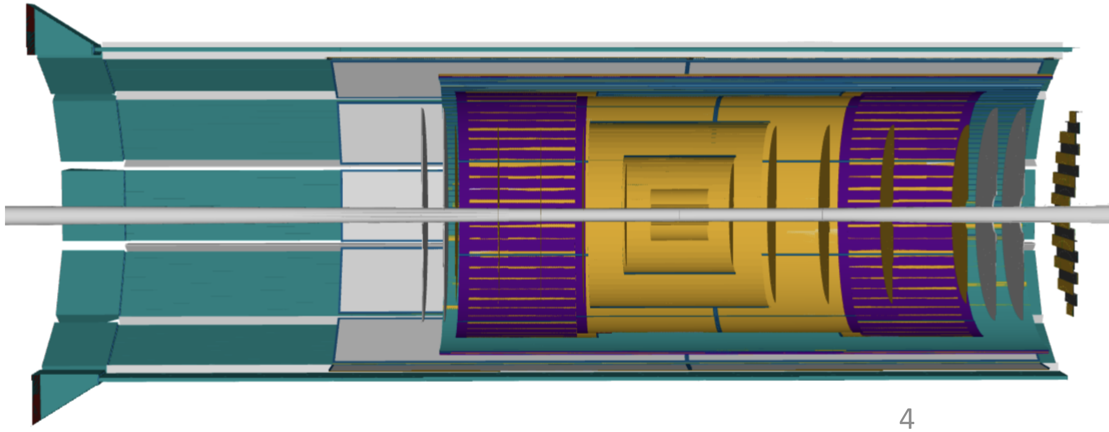
Carbon foam : 0.09 g/cm^3, 5.8mm
~ 0.7 % (X/X0)

↓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 : $0^\circ \leq \phi \leq 360^\circ$, $92^\circ \leq \theta \leq 94^\circ \rightarrow \langle\eta\rangle = -0.05$

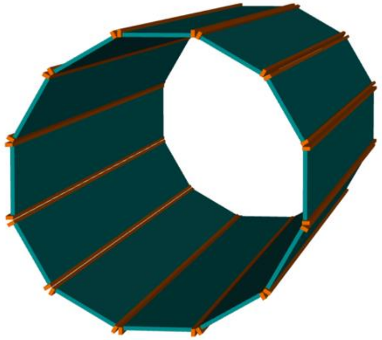


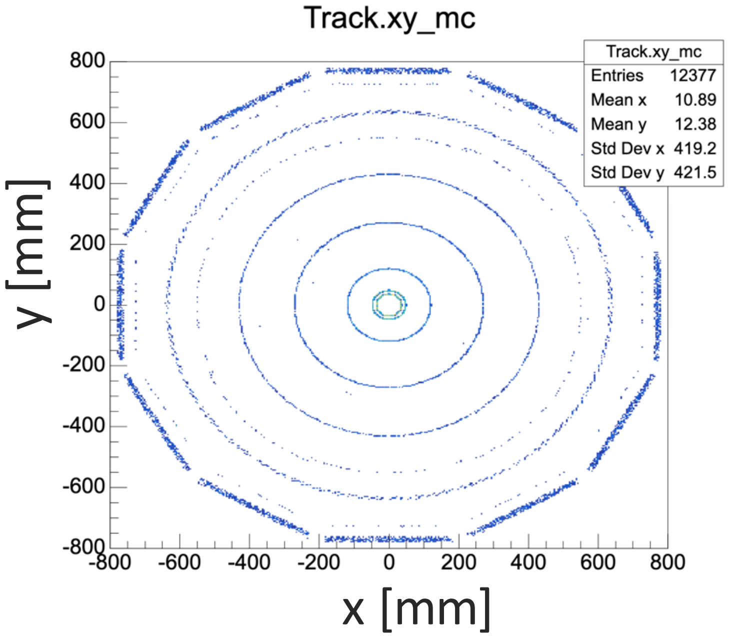
Results - Hit position on hpDIRC surface

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

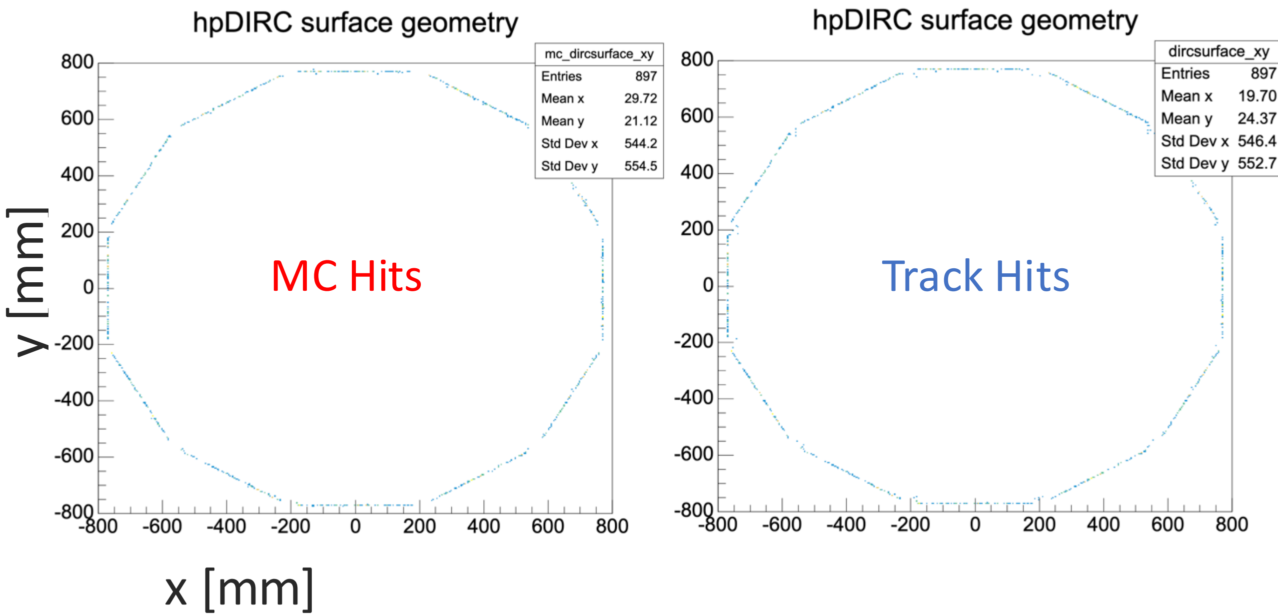
- Get particle information on hpDIRC surface defined by Geant4 (MC info)

➢ Can get as well as MC information for epic's tracker detector
➢ The outermost layer is the <u>hpDIRC surface</u> defined by myself





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

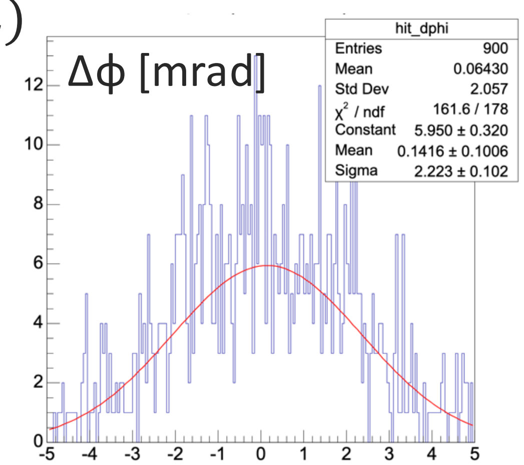


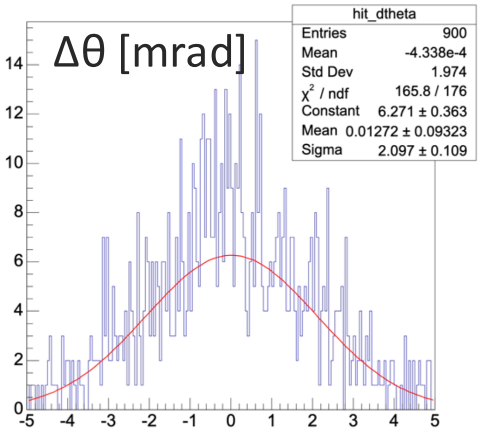
Results - Angular distribution on hpDIRC surface

■Angular resolution calculated from particle momentum in MC and track information

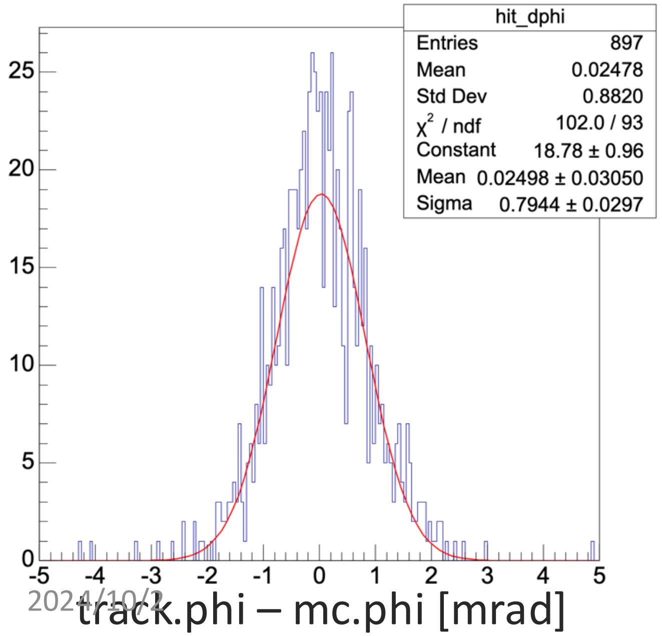
- $\Delta\theta = \theta(track) - \theta(MC)$, $\Delta\phi = \phi(track) - \phi(MC)$
- $\theta = arctan2\left(\sqrt{{p_x}^2 + {p_y}^2}, p_z\right)$, $\phi = arctan2(p_y, p_x)$
- The higher the momentum,
  the better the angular resolution.

92 < θ < 94 , p = 2 GeV

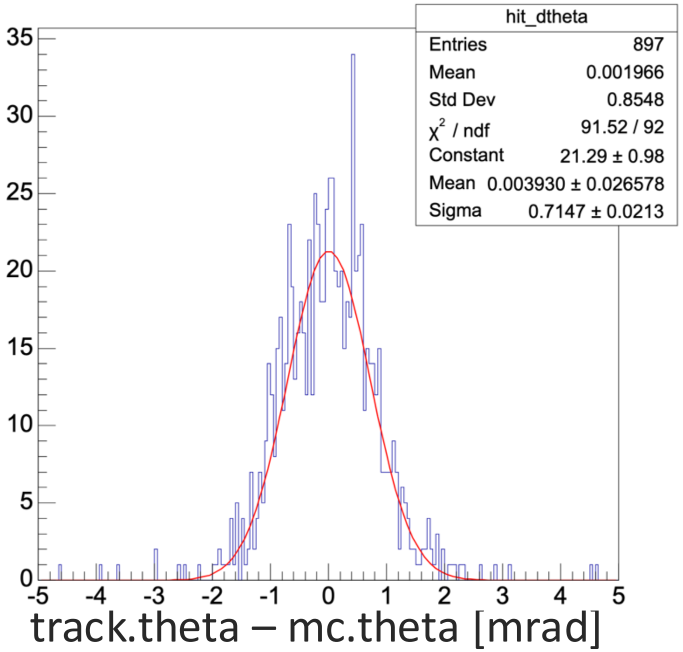




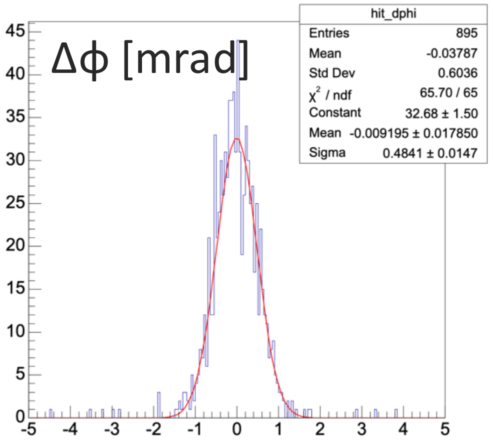
Δϕ [mrad] , 92 < θ < 94 , p = 6 GeV

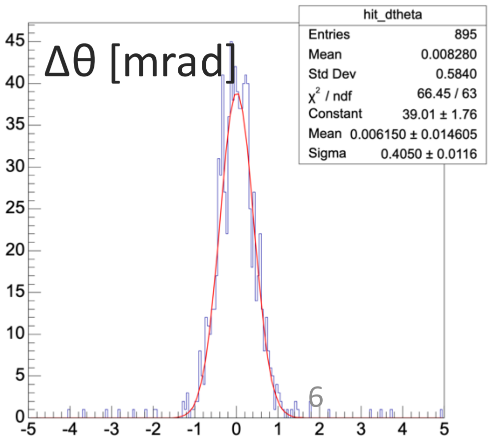


Δθ [mrad] , 92 < θ < 94 , p = 6 GeV



92 < θ < 94 , p = 10 GeV





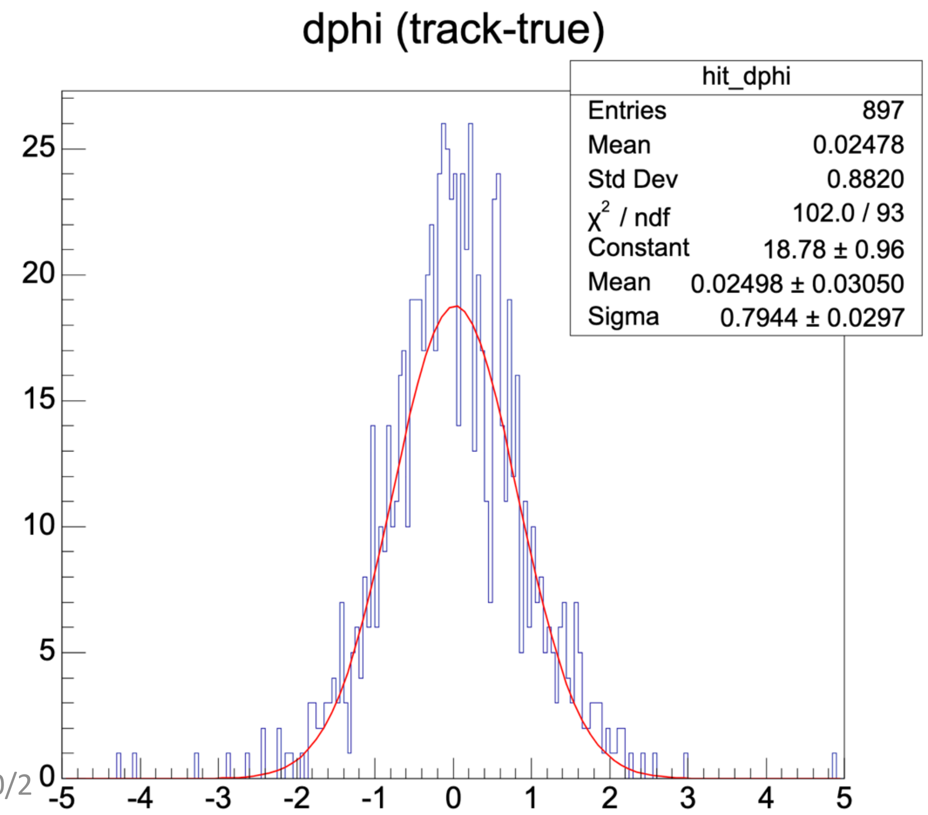
Angular distribution on hpDIRC surface

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

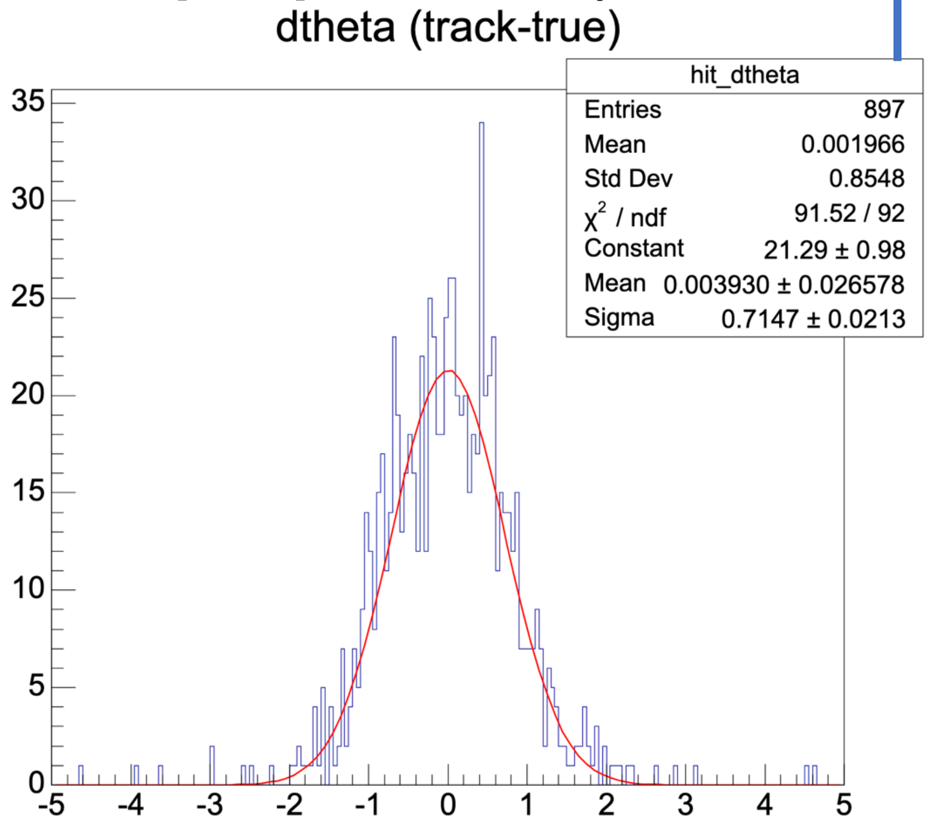
$\sigma = 0.7147 \pm 0.0213\ [mrad]$

Even if we use the carbon form (default setting), we cannot fulfill the request from hpDIRC
(delta_angle=0.5mrad@6GeV)

Δϕ [mrad] , 92 < θ < 94 , p = 6 GeV



Δθ [mrad] , 92 < θ < 94 , p = 6 GeV



Results - Angular resolution on hpDIRC surface

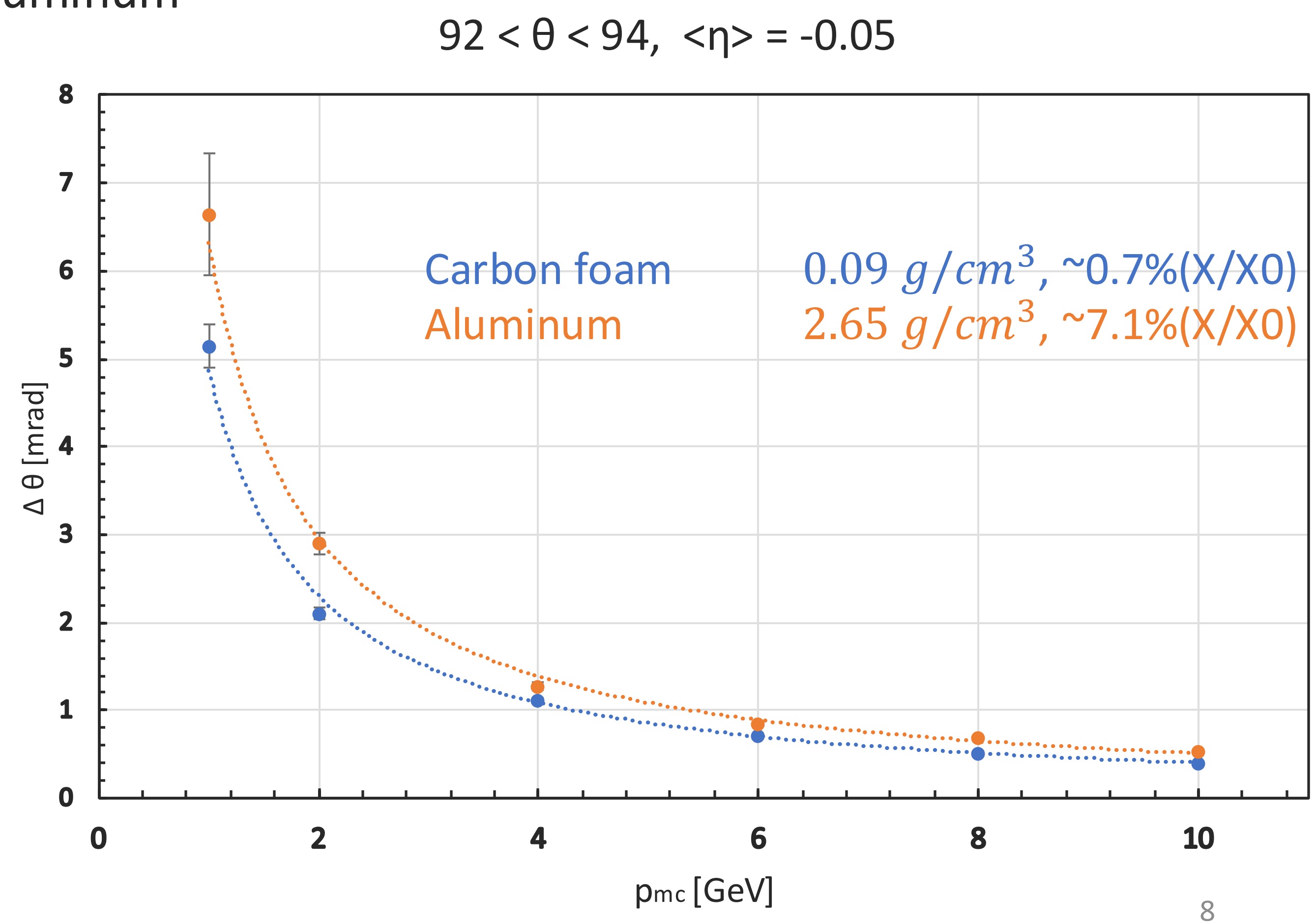
■Results for some changes in particle momentum and BTOF material.

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

But…

- Current structure (Carbon foam) does not satisfy hpDIRC requirements.

- Please tell me your opinion on this simulation



Back up

Data generation

■Data Generation Settings

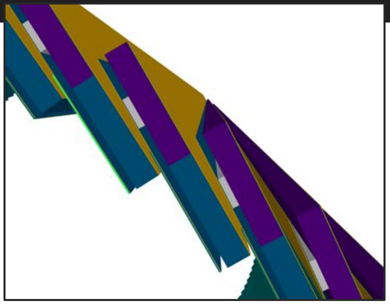
- EICrecon : Particle collision reconstruction using phythia8, Geant4, and track reconstruction algorithms using ePIC detector structures are available.
- ddsim
- Single particle : π^-(1000 events)
- Momentum : 1, 2, 4, 6, 8, 10 [GeV/c]
- Direction : $0^\circ \leq \phi \leq 360^\circ$,
  $92^\circ \leq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

```
ddsim --compactFile=$DETECTOR_PATH/epic.xml
      -N=1000
      --random.seed 1
      --enableGun
      --gun.particle "pi-"
      --gun.momentumMin "10*GeV" --gun.momentumMax "10*GeV"
      --gun.thetaMin 92.0*deg --gun.thetaMax 94.0*deg
      --gun.distribution uniform
      --outputFile epic_fakedirc_pi_10GeV_1000event_ddsim.edm4hep.root
```

Detector settings

■BTOF material (epic/compact/tracking/tof_barrel.xml)

```xml
</comment>
<module name="BarrelTOF_Module1" vis="TOFBarrelModuleVis">
  <module_component name="sensor" material="Silicon" sensitive="true" width="BarrelTOF_Sensor_width" length="BarrelTOF_length1" thickness="BarrelTOF_Sensor_thickness" vis="TOFSensorVis" >
    <position x="BarrelTOF_Sensor_position" y="0" z="0" />
  </module_component>
  <module_component name="hybridtop" material="Kapton" sensitive="false" width="BarrelTOF_Module_width" length="BarrelTOF_length1" thickness="BarrelTOF_Hybrid_thickness" vis="TOFHybridVis" >
    <position x="BarrelTOF_Service_position" y="0" z="0" />
  </module_component>
  <module_component name="cfskintop" material="CFRPMix2" sensitive="false" width="BarrelTOF_Module_width" length="BarrelTOF_length1" thickness="BarrelTOF_CFSkin_thickness" vis="TOFCSkinVis" >
    <position x="BarrelTOF_Service_position" y="0" z="0" />
  </module_component>
  <module_component name="coolingtube" material="Aluminum" sensitive="false" width="BarrelTOF_CoolingTube_width" length="BarrelTOF_length1" thickness="BarrelTOF_CoolingTube_thickness" vis="TOFCoolingTubeVis" >
    <position x="BarrelTOF_CoolingTube_position" y="0" z="0" />
  </module_component>
  <module_component name="coolant" material="NOVEC7200" sensitive="false" width="BarrelTOF_Coolant_width" length="BarrelTOF_length1" thickness="BarrelTOF_Coolant_thickness" vis="TOFCoolantVis" >
    <position x="BarrelTOF_Coolant_position" y="0" z="0" />
  </module_component>
  <module_component name="cfoam" material="Aluminum5083" sensitive="false" width="BarrelTOF_CFoam_width" length="BarrelTOF_length1" thickness="BarrelTOF_CFoam_thickness" vis="TOFCFoamVis" >
  <!-- <module_component name="cfoam" material="CarbonFoam" sensitive="false" width="BarrelTOF_CFoam_width" length="BarrelTOF_length1" thickness="BarrelTOF_CFoam_thickness" vis="TOFCFoamVis" > -->
    <position x="BarrelTOF_CFoam_position" y="0" z="0" />
  </module_component>
  <module_component name="choneycomb" material="CFRPMix" sensitive="false" width="BarrelTOF_CHoneycomb_width" length="BarrelTOF_length1" thickness="BarrelTOF_CHoneycomb_thickness" vis="TOFCHoneycombVis" >
    <position x="BarrelTOF_CHoneycomb_position" y="0" z="-1*BarrelTOF_CFoam_thickness" />
  </module_component>
  <module_component name="cfskinbottom" material="CFRPMix2" sensitive="false" width="BarrelTOF_Module_width" length="BarrelTOF_length1" thickness="BarrelTOF_CFSkin_thickness" vis="TOFCSkinVis" >
    <position x="BarrelTOF_Service_position" y="0" z="0" />
  </module_component>
  <module_component name="hybridbottom" material="Kapton" sensitive="false" width="BarrelTOF_Module_width" length="BarrelTOF_length1" thickness="BarrelTOF_Hybrid_thickness" vis="TOFHybridVis" >
    <position x="BarrelTOF_Service_position" y="0" z="0" />
  </module_component>
```



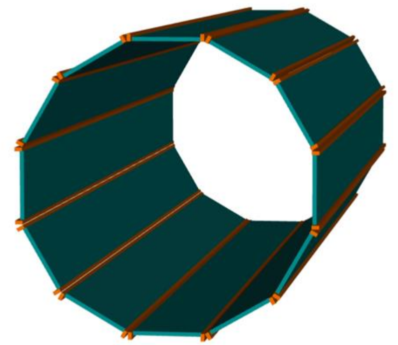
Changed material
Default material

Detector settings

■ hpDIRC surface (Referring to https://github.com/eic/athena/compact/fake_dirc.xml)

```xml
<lccdd>

  <define>
    <constant name="DIRCModule_count"          value="12" />
    <constant name="DIRCBar_thickness"         value="17*mm" />
    <constant name="DIRCBar_length"            value="DIRC_length-8*cm" />
    <constant name="DIRCSkinFront_thickness"   value="2.5*mm" />
    <constant name="DIRCSkinBack_thickness"    value="2.5*mm" />
    <constant name="DIRCFrame_width"           value="20*mm"/>
    <constant name="DIRCFrame_length"          value="DIRC_length"/>
    <constant name="DIRCFrame_thickness"       value="40*mm"/>
    <constant name="DIRCModule_rmax"           value="DIRC_rmin + DIRCBar_thickness + DIRCSkinFront_thickness + DIRCSkinBack_thickness"/>
    <constant name="DIRCModule_thickness"      value="DIRCModule_rmax - DIRC_rmin" />
    <constant name="DIRCFrame_rmax"            value="DIRC_rmin + DIRCFrame_thickness" />
    <constant name="DIRCModule_halfangle"      value="180*degree/DIRCModule_count" />
    <constant name="DIRCModule_width"          value="2*DIRC_rmin * tan(DIRCModule_halfangle)"/>
    <constant name="DIRCModule_rmin"           value="DIRC_rmin + 1*cm"/>
  </define>

  <detectors>
    <detector id="BarrelDIRC_ID" name="FakeDIRC" type="epic_FakeDIRC" readout="DIRCBarHits" vis="DIRCVis">
      <dimensions rmin="DIRC_rmin" rmax="DIRC_rmax" length="DIRC_length" />
      <position x="0" y="0" z="DIRC_offset" />
      <comment> Fake DIRC modules </comment>
      <module name="DIRCModule" vis="DIRCModuleVis">
        <module_component name="FrontSkin"
              material="CarbonFiber"
              sensitive="false"
              width="DIRCModule_width"
              thickness="DIRCSkinFront_thickness"
              vis="DIRCSupportVis"
              length="DIRCBar_length" />
        <module_component name="QuartzBar"
              material="Quartz"
              sensitive="true"
              width="DIRCModule_width"
              thickness="DIRCBar_thickness"
              vis="DIRCBarVis"
              length="DIRCBar_length" />
        <module_component name="BackSkin"
              material="CarbonFiber"
              sensitive="false"
              width="DIRCModule_width"
              thickness="DIRCSkinBack_thickness"
              vis="DIRCSupportVis"
              length="DIRCBar_length" />
        <frame material="StainlessSteel"
              width="DIRCFrame_width"
              length="DIRCFrame_length"
              vis="DIRCFrameVis"
              thickness="DIRCFrame_thickness" />
      </module>
```

```xml
      </module>
      <comment> Fake DIRC layers </comment>
      <layer module="DIRCModule" id="1" vis="DIRCLayerVis">
        <barrel_envelope
          inner_r="DIRC_rmin"
          outer_r="DIRC_rmax"
          z_length="DIRC_length" />
        <rphi_layout
          phi_tilt="0"
          nphi="DIRCModule_count"
          phi0="0"
          rc="0.5*(DIRCModule_rmin+DIRCModule_rmax)"
          dr="0" />
        <z_layout
          dr="0.0*mm"
          z0="0.0*mm"
          nz="1" />
      </layer>
    </detector>
  </detectors>

  <readouts>
    <readout name="DIRCBarHits">
      <segmentation type="CartesianGridXY" grid_size_x="3.0*mm" grid_size_y="3.0*mm" />
      <id>system:8,layer:4,module:8,section:4,x:32:-16,y:-16</id>
    </readout>
  </readouts>

</lccdd>
```



About Analysis Code

■MC information (edm4hep::SimTrackerHit)

```cpp
std::vector<std::string> sim_data_names = {
    "VertexBarrelHits",         // Vertex
    "SiBarrelHits",             // Barrel Tracker
    "MPGDBarrelHits",           // MPGD
    "TOFBarrelHits",             // Barrel TOF
    "OuterMPGDBarrelHits",      // MPGD DIRC
    "TrackerEndcapHits",        // End Cap tracker
    "TOFEndcapHits",            // End Cap TOF
    "DIRCBarHits",
};
for(int i = 0; i < sim_data_names.size(); i++ ) {
    auto data_name = sim_data_names[i];
    const auto &hits = *static_cast<const edm4hep::SimTrackerHitCollection*>(event->GetCollectionBase(data_name));
    const char* Data_name = data_name.c_str();  //fprintfに出力する際に文字化けを防ぐための措置
    for(auto hit: hits) {
        auto& mcinfo = hit.getMCParticle();
        auto& pos = hit.getPosition();
        auto& mom = hit.getMomentum();
        auto r = sqrt(pos.x*pos.x + pos.y*pos.y + pos.z*pos.z);
        auto rt = sqrt(pos.x*pos.x + pos.y*pos.y);
        auto p = sqrt(mom.x * mom.x + mom.y * mom.y + mom.z * mom.z);
        auto pt = sqrt(mom.x * mom.x + mom.y * mom.y);
        auto eta = -log(tan(atan2(sqrt(mom.x*mom.x+mom.y*mom.y),mom.z)/2.));
        auto phi = atan2(mom.y, mom.x);
        auto theta = atan2(sqrt(mom.x*mom.x + mom.y*mom.y),mom.z);


        if (mcinfo.getGeneratorStatus() != 1) continue;
        auto pdg = mcinfo.getPDG();
        auto& mcmom = mcinfo.getMomentum();
        auto status = mcinfo.getGeneratorStatus();
        auto mcp = sqrt(mcmom.x * mcmom.x + mcmom.y * mcmom.y + mcmom.z * mcmom.z);
        auto mceta = -log(tan(atan2(sqrt(mcmom.x*mcmom.x+mcmom.y*mcmom.y),mcmom.z)/2.));
        Track_xy_mc -> Fill(pos.x, pos.y);
        if(pos.x > 0)Track_rz_mc -> Fill(pos.z, rt);
            else Track_rz_mc -> Fill(pos.z, -rt);
        fprintf (outputfileMC, "%s  r:%f, rt:%f, p:%f, eta:%f, phi:%f, theta:%f, cp:%f, mceta:%f, pdg:%d\n",Data_name, r, rt, p, eta, phi, theta, mcp, mceta, pdg);
    }
}
```

About Analysis Code

■Track information (Referring to https://github.com/eic/EICrecon/src/algorithms/tracking/TrackPropagation.cc)

```cpp
const auto &dirc = *static_cast<const edm4hep::SimTrackerHitCollection*>(event->GetCollectionBase("DIRCBarHits"));
for(auto hit: dirc) {
    auto& mcinfo = hit.getMCParticle();
    auto& mcpos = hit.getPosition();
    auto& mcmom = hit.getMomentum();

    if (mcinfo.getGeneratorStatus() != 1) continue;
    if (i != 0 ) continue;

    auto mcr = sqrt(mcpos.x*mcpos.x + mcpos.y*mcpos.y + mcpos.z*mcpos.z);
    auto mcrt = sqrt(mcpos.x*mcpos.x + mc  <error-type> &mcmom
    auto mcp = sqrt(mcmom.x * mcmom.x + m                      om.z * mcmom.z);
    auto mcpt = sqrt(mcmom.x * mcmom.x + mcmom.y * mcmom.y);
    auto mceta = -log(tan(atan2(sqrt(mcmom.x*mcmom.x+mcmom.y*mcmom.y),mcmom.z)/2.));
    auto mctheta = atan2(sqrt(mcmom.x*mcmom.x + mcmom.y*mcmom.y),mcmom.z);
    auto mcphi = atan2(mcmom.y, mcmom.x);
    // auto mceta = -log(tan(atan2(sqrt(mcpos.x*mcpos.x+mcpos.y*mcpos.y),mcpos.z)/2.));
    // auto mctheta = atan2(sqrt(mcpos.x*mcpos.x + mcpos.y*mcpos.y),mcpos.z);
    // auto mcphi = atan2(mcpos.y, mcpos.x);

    std::unique_ptr<edm4eic::TrackPoint> hpdirc_point;
    const auto hpdircR = mcrt;
    const auto hpdircMinZ = -2526.0;
    const auto hpdircMaxZ = 1850.0;
    auto hpdircBounds = std::make_shared<Acts::CylinderBounds>(hpdircR, (hpdircMaxZ-hpdircMinZ)/2);
    auto hpdirc_t = Acts::Translation3(Acts::Vector3(0, 0, (hpdircMaxZ+hpdircMinZ)/2));
    auto hpdirc_trf = Acts::Transform3(hpdirc_t);
    hpdirc_surface = Acts::Surface::makeShared<Acts::CylinderSurface>(hpdirc_trf, hpdircBounds);
    try {hpdirc_point =  m_propagation_algo.propagate(edm4eic::Track{}, trajectory, hpdirc_surface);}
    catch(std::exception &e) {throw JException(e.what());}
    if(!hpdirc_point) {
    fprintf (outputfileTrack,"could not propagate!\n");
    continue;
    }
        auto pos = hpdirc_point->position;
        auto mom = hpdirc_point->momentum;
        auto length = hpdirc_point->pathlength;
        auto theta = hpdirc_point->theta;
        auto phi = hpdirc_point->phi;
        auto eta = -log(tan(atan2(sqrt(mom.x*mom.x + mom.y*mom.y),mom.z)/2.));
        auto r = sqrt(pos.x*pos.x + pos.y*pos.y + pos.z*pos.z);
        auto rt = sqrt(pos.x*pos.x + pos.y*pos.y);
        Track_xy -> Fill(pos.x, pos.y);
        Hitpoints_dircsurface_xy -> Fill(pos.x, pos.y);
        Hitpoints_dircsurface_z -> Fill(pos.z);
        if(pos.x > 0)Track_rz -> Fill(pos.z, rt);
                else Track_rz -> Fill(pos.z, -rt);
        hit_propagate_eta -> Fill(eta);
        hit_propagate_phi -> Fill(phi);
        hit_propagate_theta -> Fill(theta);
        fprintf (outputfileTrack,"Reconstructed DIRC hit  x:%f, y:%f, z:%f, r:%f, rt:%f, theta:%f, phi:%f\n", pos.x, pos.y, pos.z, length, rt, theta, phi);
        fprintf (outputfileTrack, "MC DIRCsurface x:%f, y:%f, z:%f, r:%f, rt:%f, theta:%f, phi:%f, p:%f\n", mcpos.x, mcpos.y, mcpos.z, mcr, mcrt, mctheta, mcphi, mcp);
```

```cpp
        auto reso_eta = (eta - mceta)/mceta * 100;
        auto reso_phi = (phi - mcphi)/mcphi * 100;
        auto reso_theta = (theta - mctheta)/mctheta * 100;
        auto deta = (eta - mceta)* 1000;
        auto dphi = (phi - mcphi)* 1000;
        auto dtheta = (theta - mctheta)* 1000;

        hit_true_eta -> Fill(mceta);
        hit_true_phi -> Fill(mcphi);
        hit_true_theta -> Fill(mctheta);
        hit_resolution_eta -> Fill(reso_eta);
        hit_resolution_phi -> Fill(reso_phi);
        hit_resolution_theta -> Fill(reso_theta);
        hit_deta -> Fill(deta);
        hit_dphi -> Fill(dphi);
        hit_dtheta -> Fill(dtheta);

        Hitpoints_dircsurface_mc_xy -> Fill(mcpos.x, mcpos.y);
        Hitpoints_dircsurface_mc_z -> Fill(mcpos.z);

        fprintf (outputfileMC, "DIRCsurface  r:%f, rt:%f, p:%f, eta:%f, phi:%f, theta:%f\n", mcr, mcrt, mcp, mceta, mcphi, mctheta);
        i++;
    }
```

Get the parameters of the reconstructed track at any r.

(Trajectory
→ CentralCKFActsTrajectories)

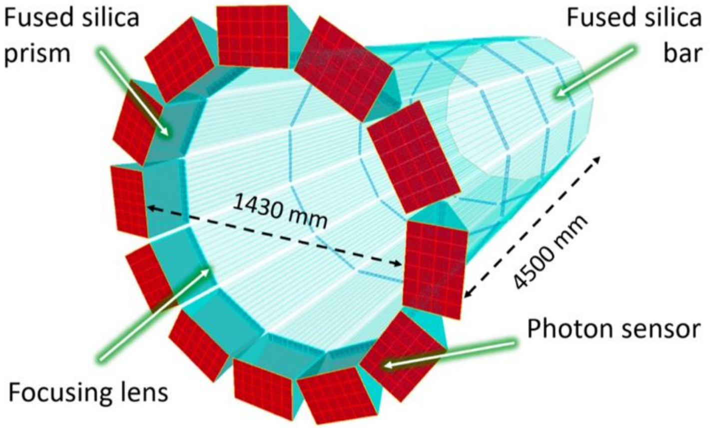
Motivation

■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 → $\Delta\theta = 0.5$ [mrad])

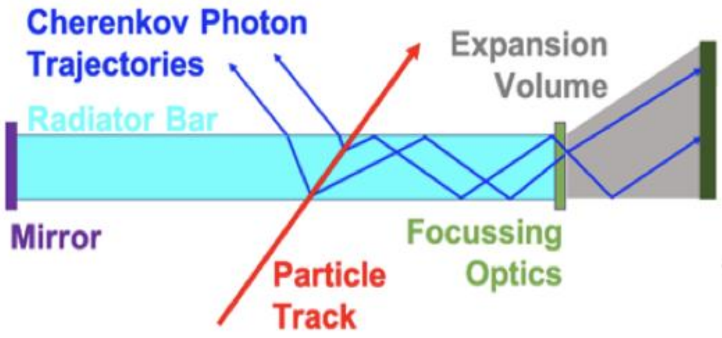


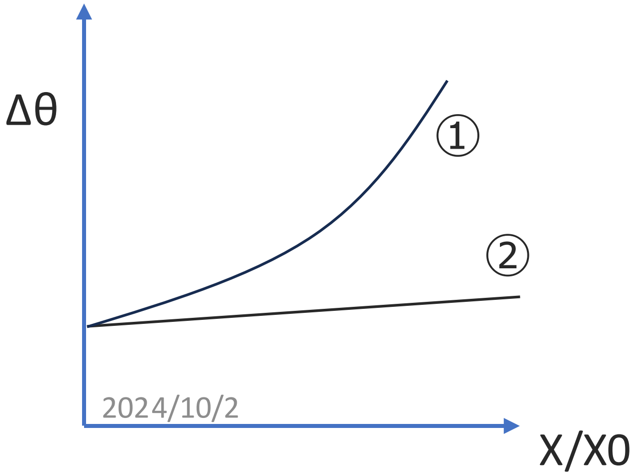
- ➢ Increase in BTOF material budget

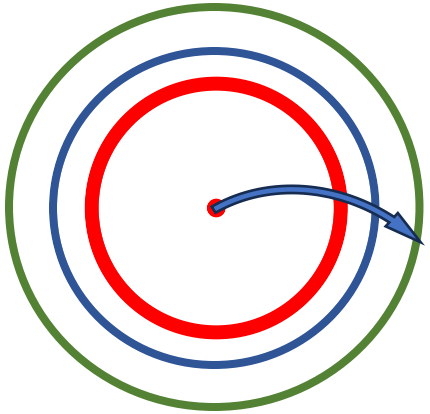
→Angular resolution degrades due to multiple scattering effects? ①

or

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







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

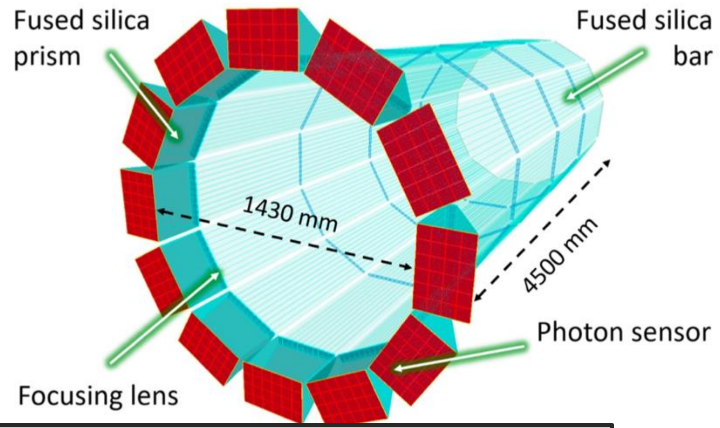
Motivation

■<u>Estimating the impact of BTOF material budgets on the backward detector (hpDIRC)</u>

- ➢ 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

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

↓

Determine the upper limit of material budget for BTOF

Δθ

X/X0

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

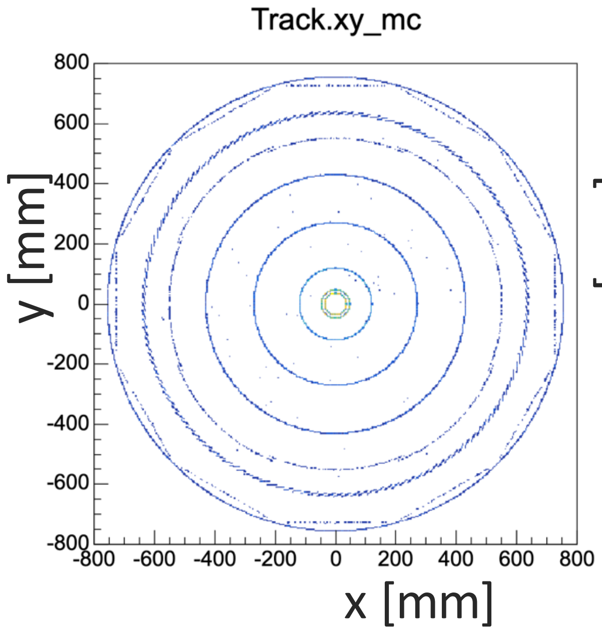
Results - Hit position on hpDIRC surface

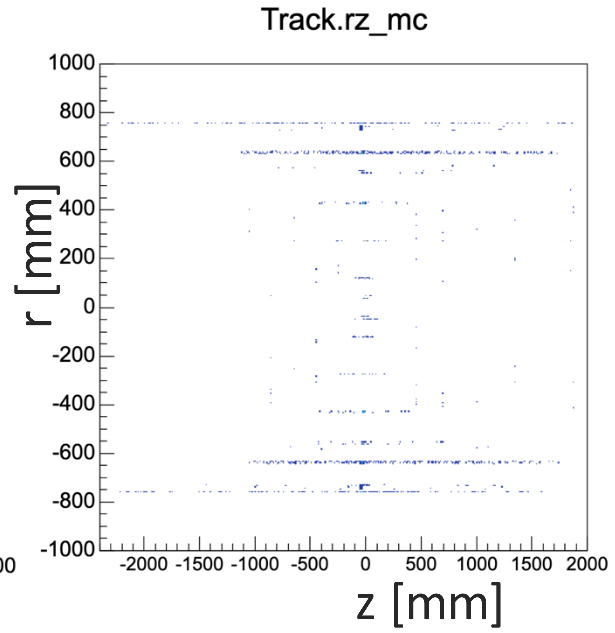
■Generates 15000event single particles (6 GeV/c, $0^{\circ} \leq \phi \leq 360^{\circ}, 92^{\circ} \leq \theta \leq 94^{\circ}$)

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

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

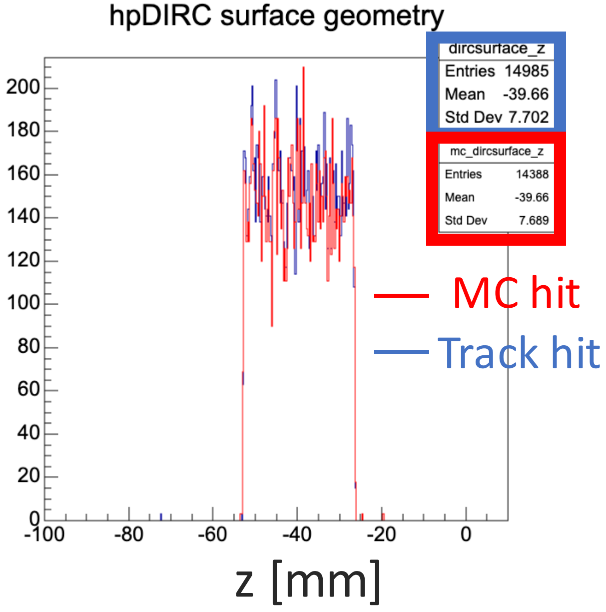
➢ The outermost layer is the hpDIRC surface defined by myself

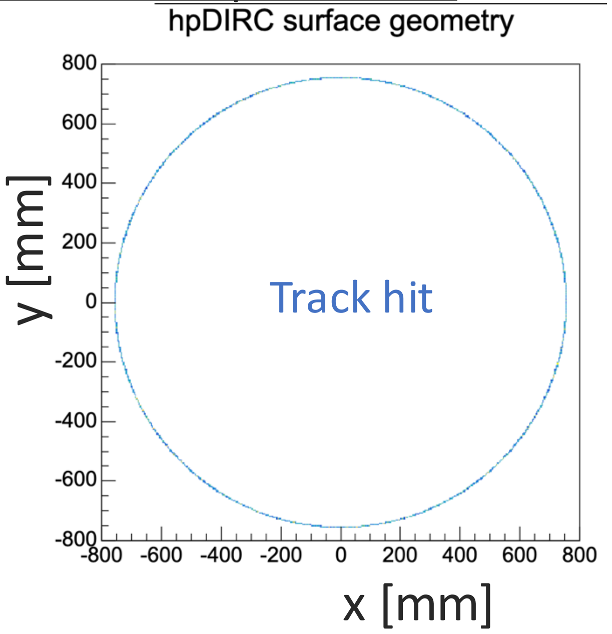




➢ MC information and particle information obtained by propagating tracks on hpDIRC surface

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

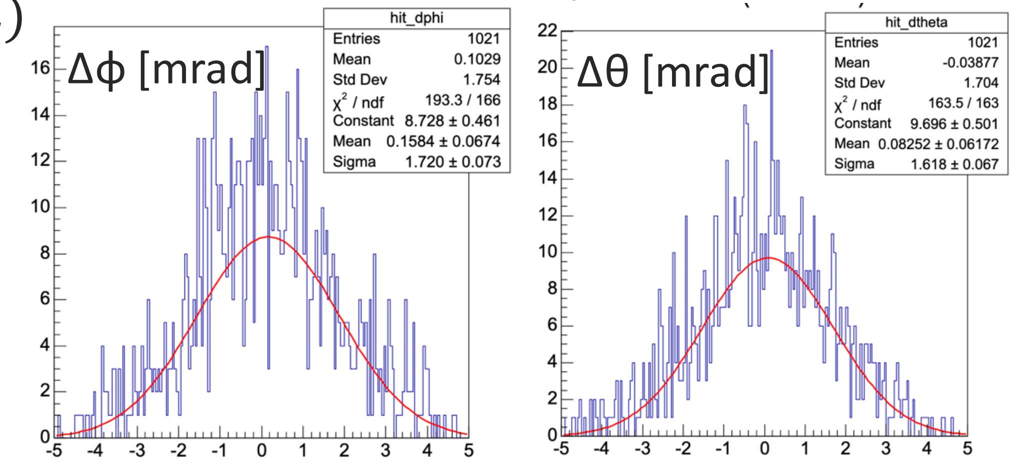




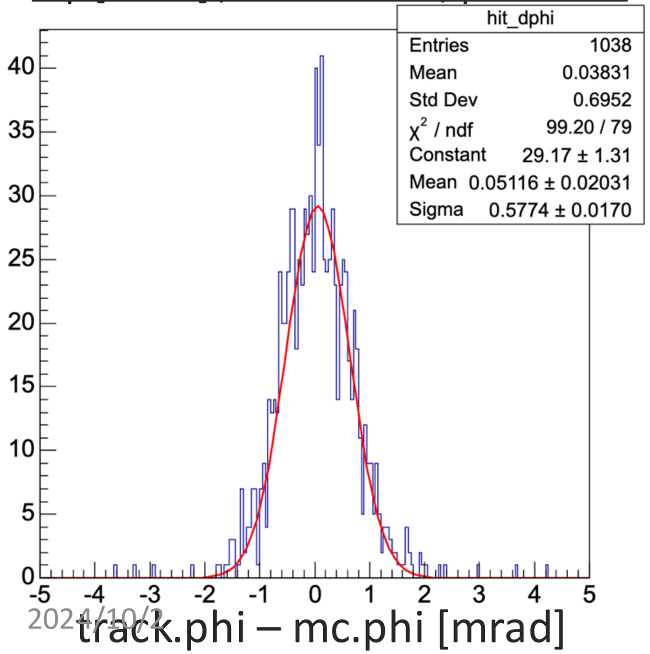
Results - Angular distribution on hpDIRC surface

- 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.

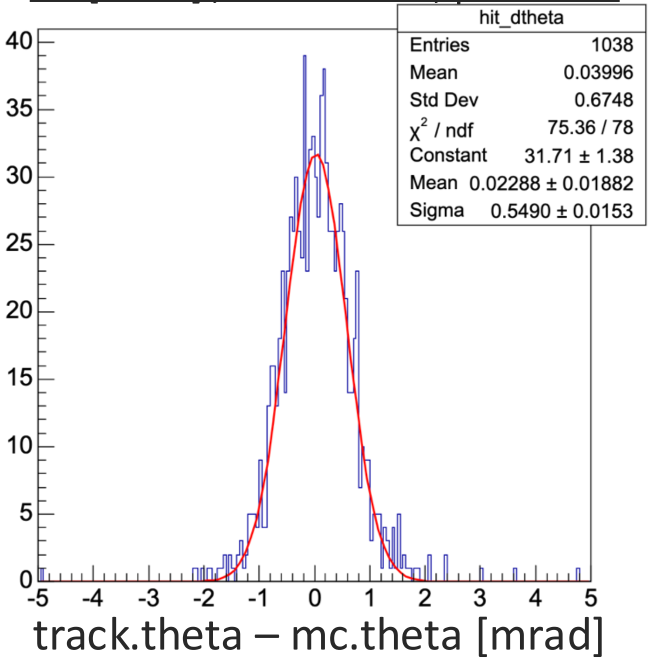
92 < θ < 94 , p = 2 GeV



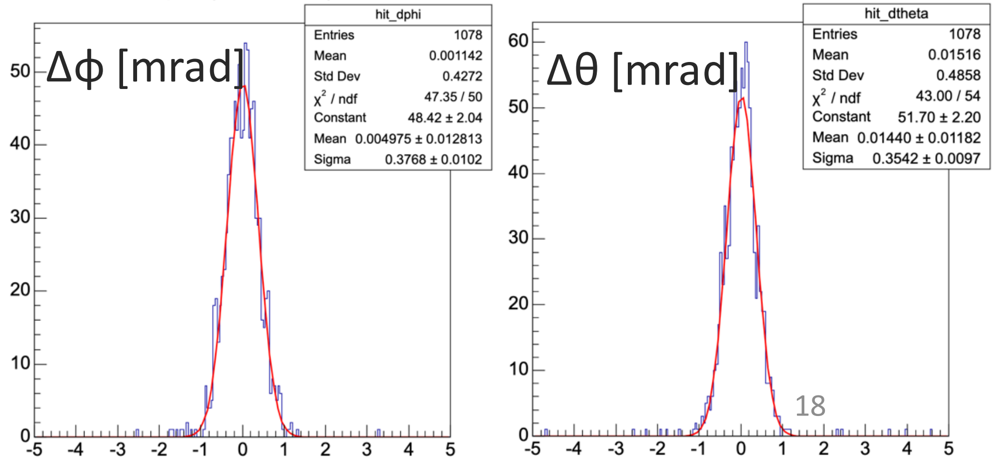
Δϕ [mrad] , 92 < θ < 94 , p = 6 GeV



Δθ [mrad] , 92 < θ < 94 , p = 6 GeV



92 < θ < 94 , p = 10 GeV



Results - Angular resolution on hpDIRC surface

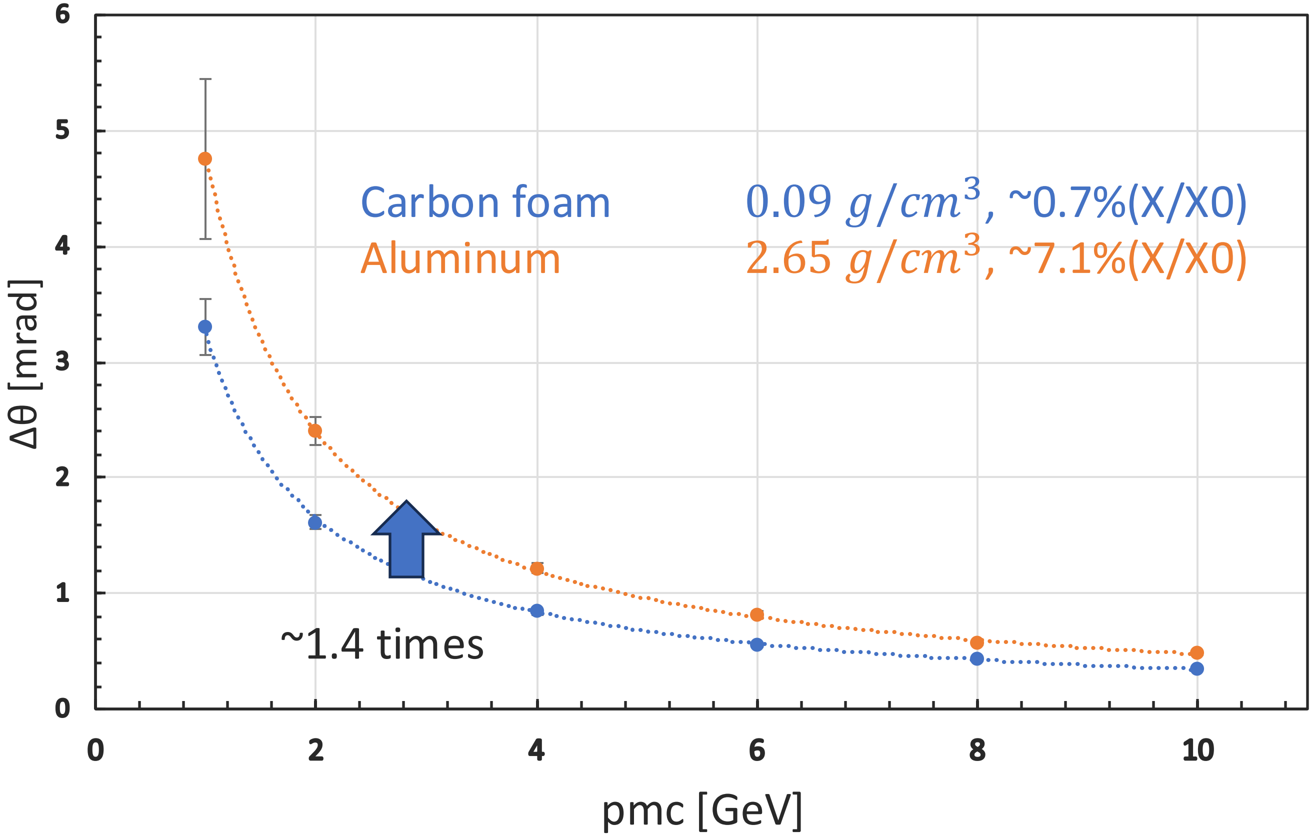
■ Results for some changes in particle momentum and BTOF material.

- 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.

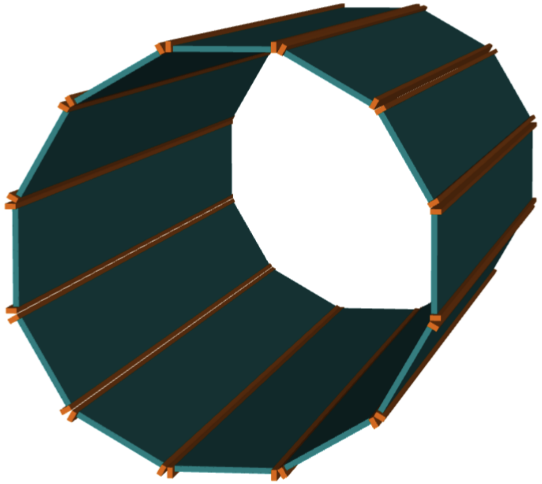
92 < θ < 94, <η> = -0.05



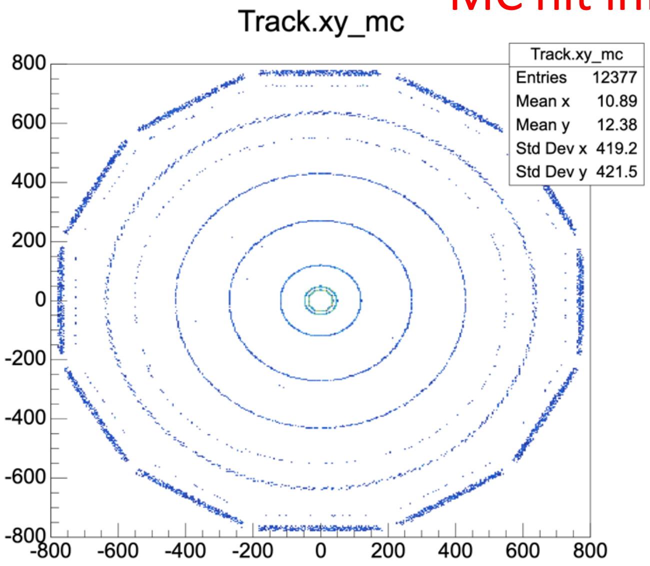
hpDIRC surface geometry (defined by Geant4)

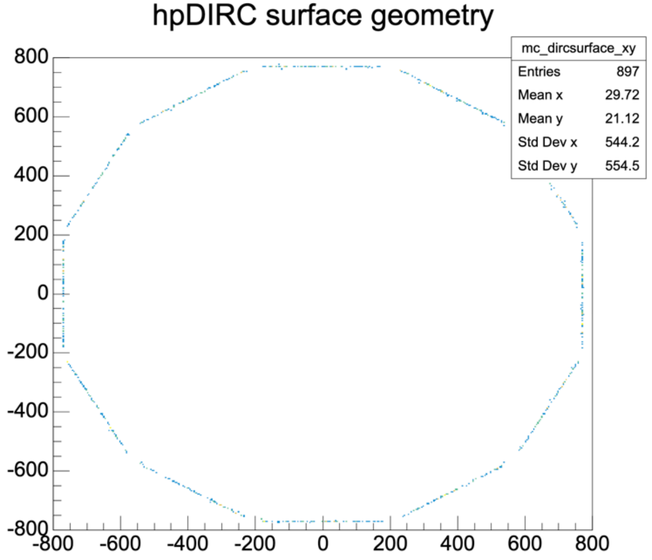
■New geometry

Improved structure of regular dodecagonal columns instead of cylindrical



MC hit information





Track propagate