# Update on Tracking Studies using JANA2 Framework

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Thanks to Dimitry Romanov (Jefferson Lab) and Shujie for the discussion

# Outline

- EPIC Geometry
  - epic_brycecanyon
  - EPIC Barrel Configuration (used in fast simulation)
  - Material Map
- Basic Performances
  - Hit Points
  - Estimation of Minimum $p_T$
  - Acceptance: Eta vs momentum maps (sim/rec)
- Tracking Performances
  - Efficiency/Acceptance (Truth seeding)
  - Momentum Resolution
  - Pointing Resolution
- Summary and Future Plan

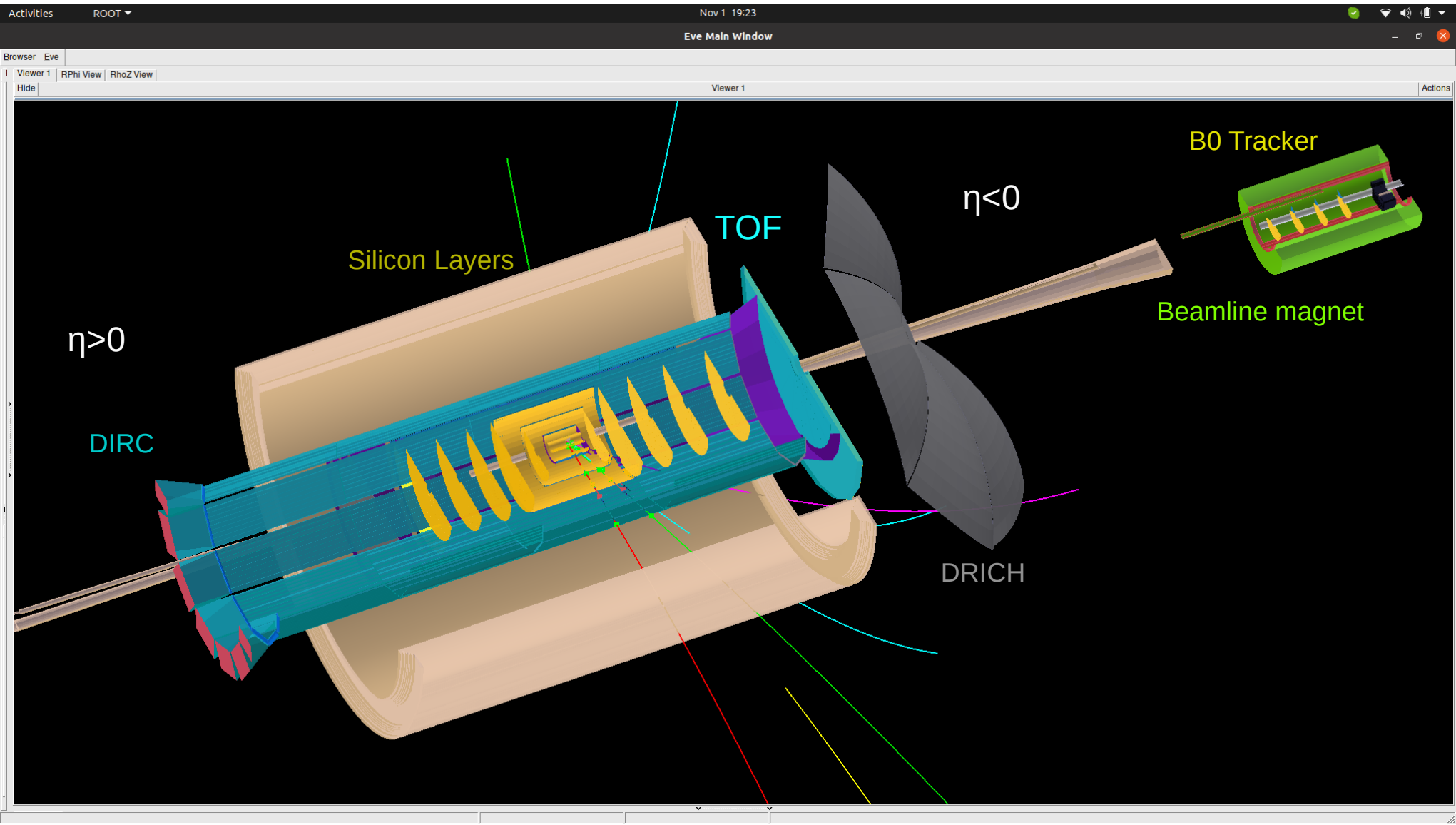
Study by Wenqing based on Juggler and epic_tracking_only geometry

https://indico.bnl.gov/event/17348/contributions/69177/attachments/43845/73961/ePIC_tracking_wenqing_beatrice_101322.pdf

Physics requirements taken from link below

https://docs.google.com/spreadsheets/d/1ynU7Cu7NlwRvMtbtFdlp_B5xXkw8yBAtWJbenMf-P3U/edit#gid=368031287

# EPIC Geometry (epic_brycecanyon)



# EPIC Geometry (epic_brycecanyon)

epic_brycecanyon.xml with calorimeters removed

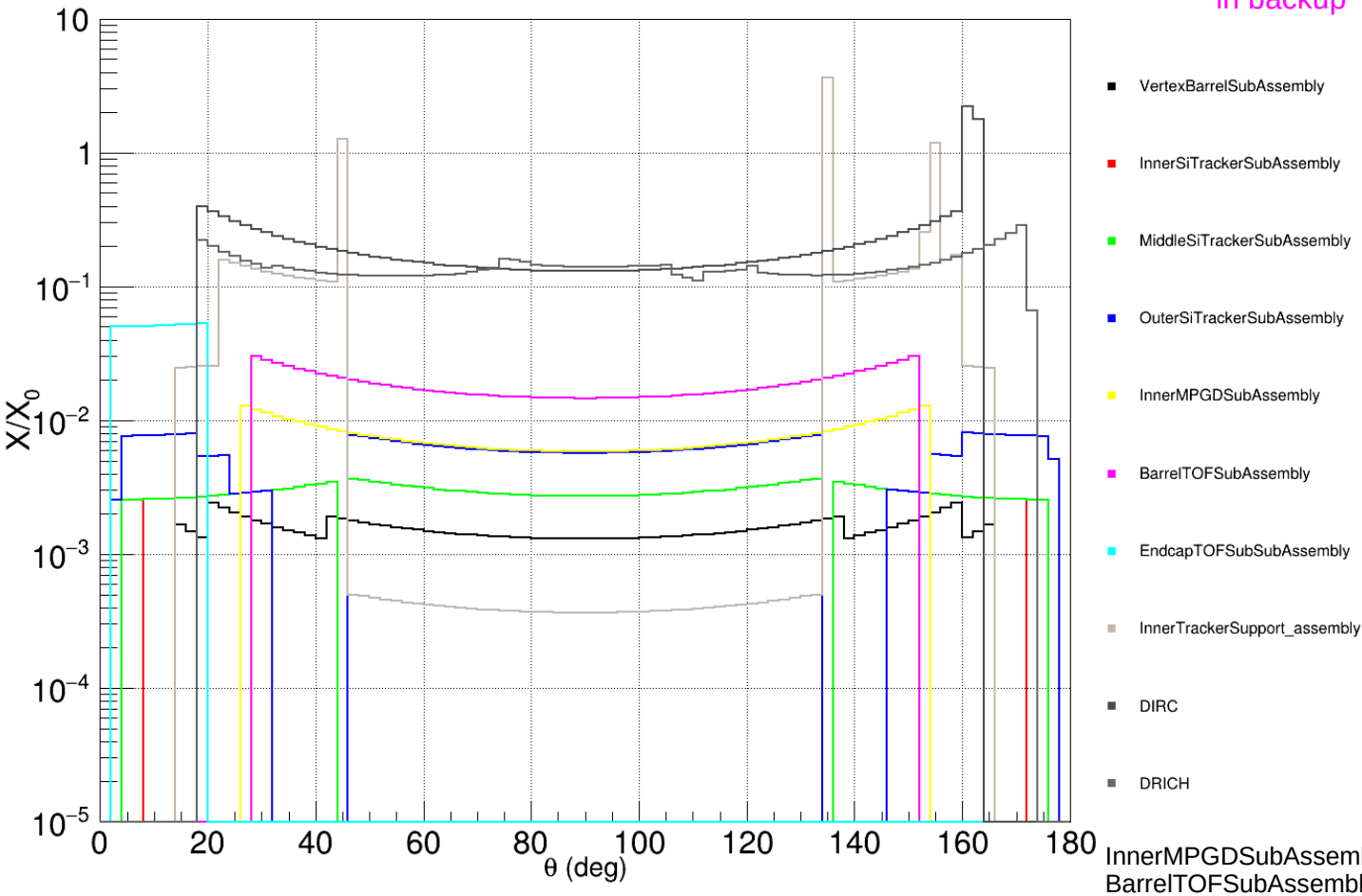
```
    ## Main magnet
  </documentation>
  <include ref="${DETECTOR_PATH}/compact/solenoid.xml"/>

  <documentation level="10">
    ## Central tracking detectors
  </documentation>
  <include ref="${DETECTOR_PATH}/compact/tracking/definitions.xml"/>

  <include ref="${DETECTOR_PATH}/compact/tracking/vertex_barrel.xml"/>
  <include ref="${DETECTOR_PATH}/compact/tracking/silicon_barrel.xml"/>
  <include ref="${DETECTOR_PATH}/compact/tracking/mpgd_barrel.xml"/>
  <include ref="${DETECTOR_PATH}/compact/tracking/silicon_disks.xml"/>
  <include ref="${DETECTOR_PATH}/compact/tracking/support_service_assembly.xml"/>
  <include ref="${DETECTOR_PATH}/compact/tracking/tof_barrel.xml"/>
  <include ref="${DETECTOR_PATH}/compact/tracking/tof_endcap.xml"/>

  <documentation level="10">
    ## PID detectors
  </documentation>
  <include ref="${DETECTOR_PATH}/compact/dirc.xml"/>

  <include ref="${DETECTOR_PATH}/compact/drich.xml"/>
  <include ref="${DETECTOR_PATH}/compact/pfrich.xml"/>

  <documentation level="10">
    ## Central EM calorimetry


    ## Central beam pipe
  </documentation>
  <include ref="${BEAMLINE_PATH}/ip6/central_beampipe.xml"/>

  <documentation level="11">
    ## Far foward detectors
  </documentation>

  <include ref="${BEAMLINE_PATH}/ip6/far_forward_brycecanyon.xml"/>

  <documentation level="11">
    ## Far backward detectors
  </documentation>
  <include ref="${BEAMLINE_PATH}/ip6/far_backward.xml"/>
</lccdd>
```

# EPIC Configuration used in Fast Simulation

```
Detector EPIC: "Detector"
  Name              r [cm]              X0       phi & z res [um] layerEff
0. vertex           0.00              0.0000       -     -          -
1. bpipe            3.18              0.0036       -     -          -
2. VTX1             3.60              0.0005       3     3      0.95
3. VTX2             4.80              0.0005       3     3      0.95
4. VTX3             12.00             0.0005       3     3      0.95
5. BARRSUPPORT      13.50             0.0004       -     -          -
6. BARR1            27.00             0.0025       3     3      0.95
7. BARR2            42.00             0.0055       3     3      0.95
8. MM1    51.00             0.0059     150   150      0.95
9. TOF    64.00             0.0146      35    35      0.95
```

# Material Map

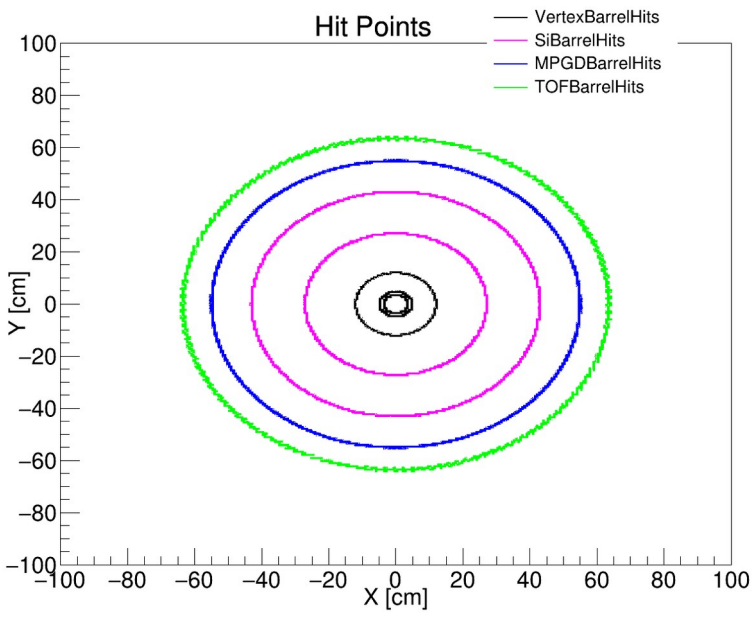
Geometry for each name shown in backup



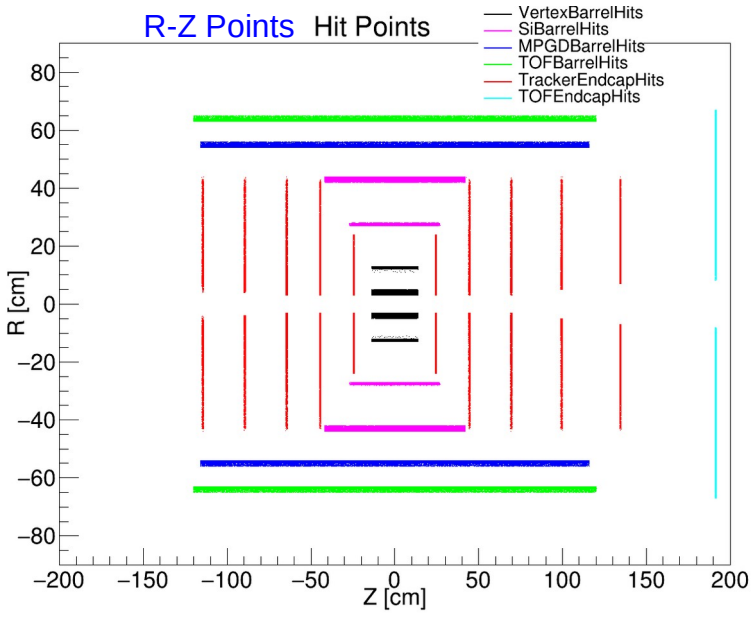

InnerMPGDSubAssembly Material Budget: 0.00586141
BarrelTOFSubAssembly Material Budget: 0.0146295
InnerTrackerSupport_assembly Material Budget: 0.000365749
DIRC Material Budget: 0.130381
BeamPipe_assembly Material Budget: 0.00364154

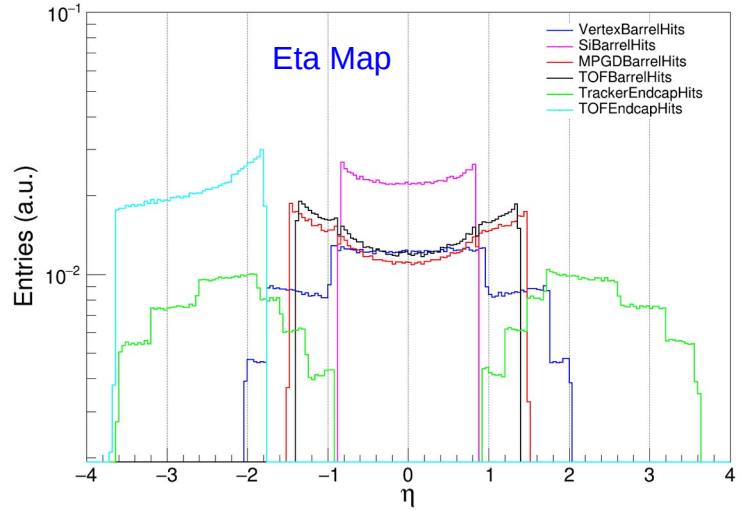
# Hits Points

X-Y Points




R-Z Points



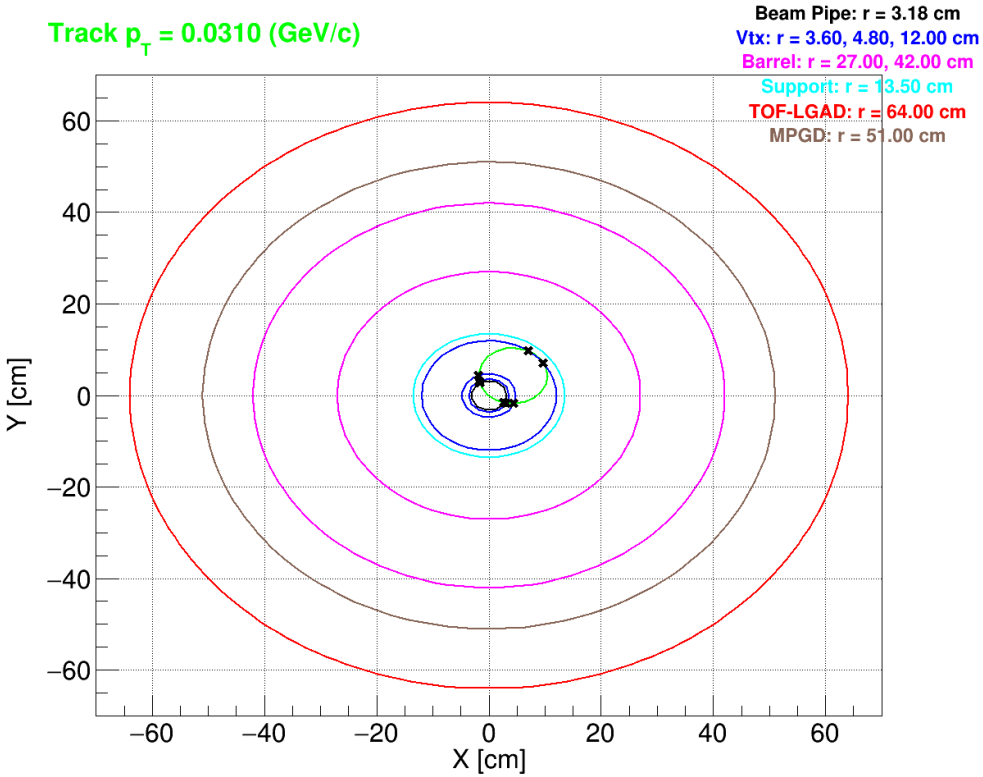
# Estimation of Minimum $p_T$

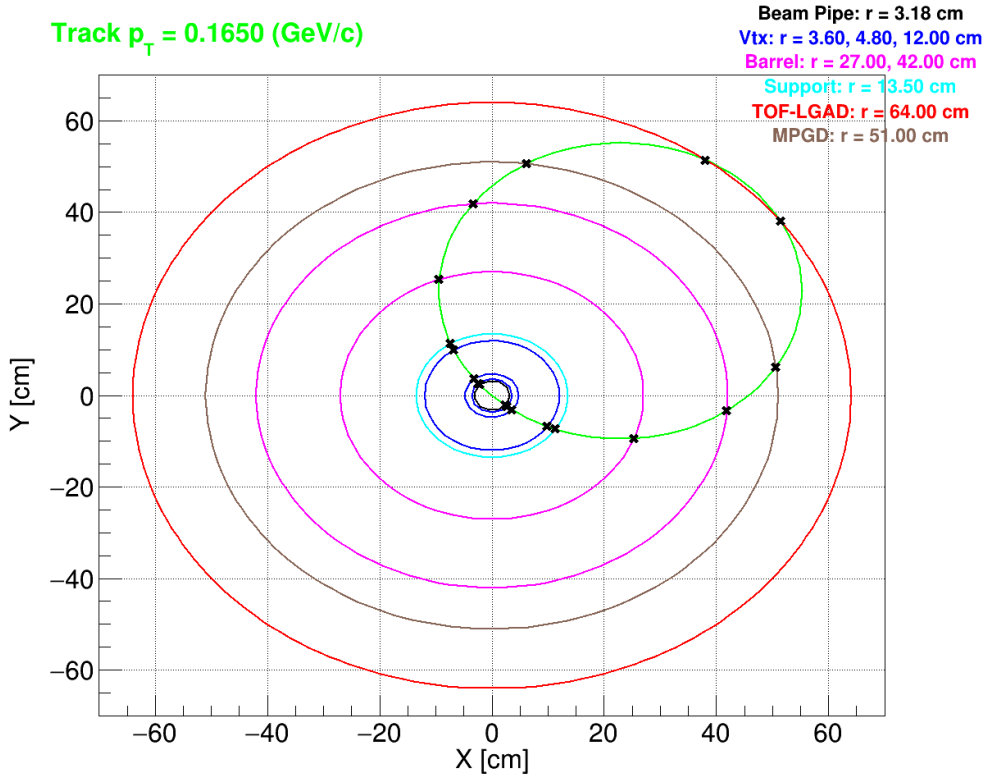
Third layer

$p_T$ = 0.3 B [T] R[m] = (0.3*1.7*0.12)/2 = 0.0306 GeV/c

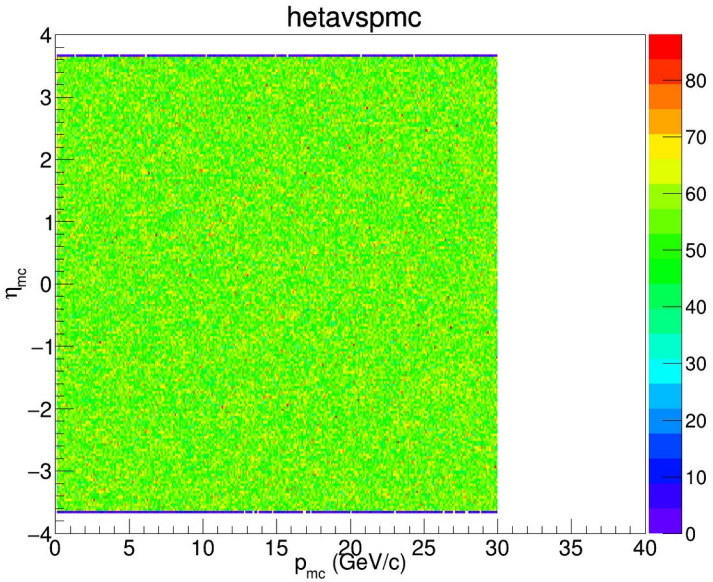
Last layer

$p_T$ = (0.3*1.7*0.64)/2 = 0.1632 GeV/c



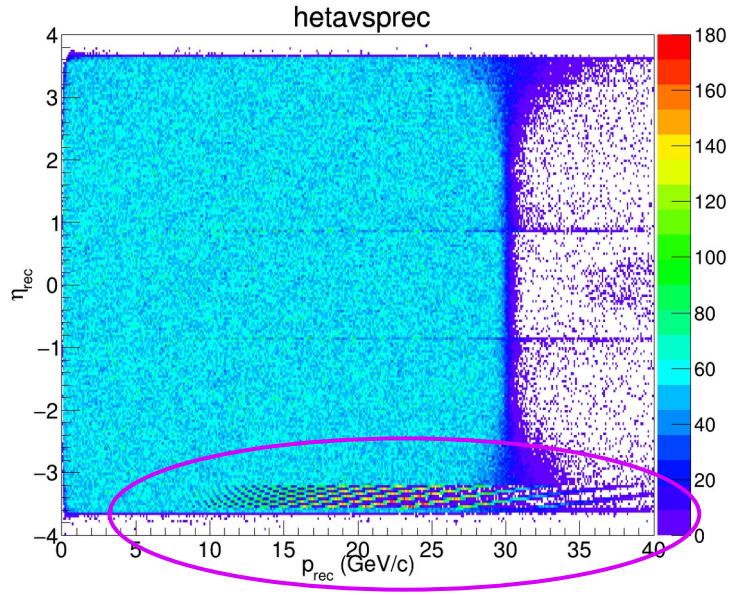
# Acceptance: Eta vs momentum maps (sim/rec)

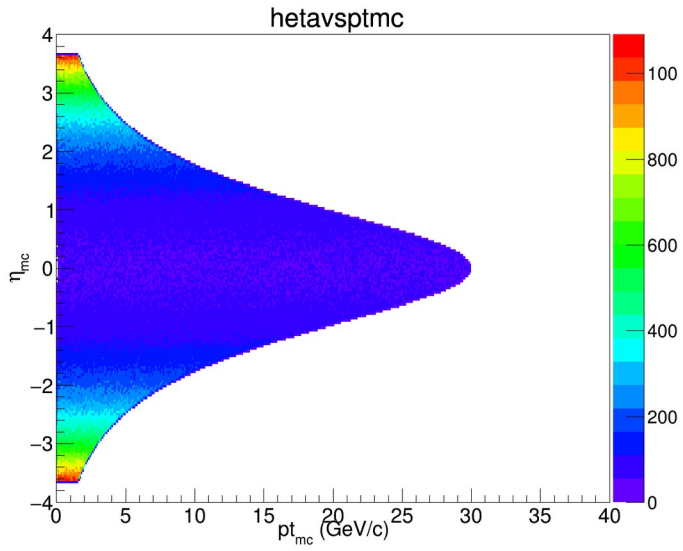


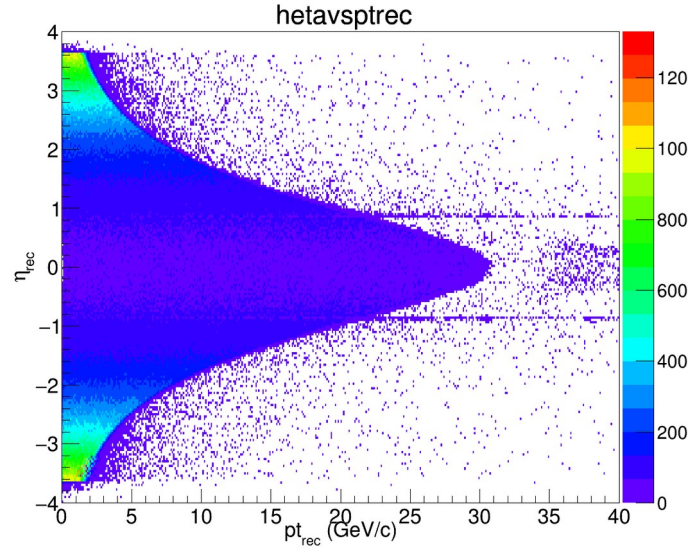

epic_brycecanyon.xml

3M pi+ [0.1-30. GeV/c]

Structures in Reco Momentum



# Debugging

100 k pi+ [0.1,30 GeV/c]

Removed far forward and far backward detectors

```
    uses the beampipe OD to help define its placement.

    The IP subsystems include the Far forward and backward regions. The list of subsystem includes:
     - Interaction region beampipe
     - B0 tracker
     - Off-momentum tracker
     - Far forward roman pots
     - Zero Degree Calorimeter
     - Beam line magnets.
     - and more...
  </documentation>


  <documentation level="5">
    ## Main magnet
  </documentation>
  <include ref="${DETECTOR_PATH}/compact/solenoid.xml"/>

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    ## Central beam pipe
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  <include ref="${BEAMLINE_PATH}/ip6/central_beampipe.xml"/>
</lccdd>
```
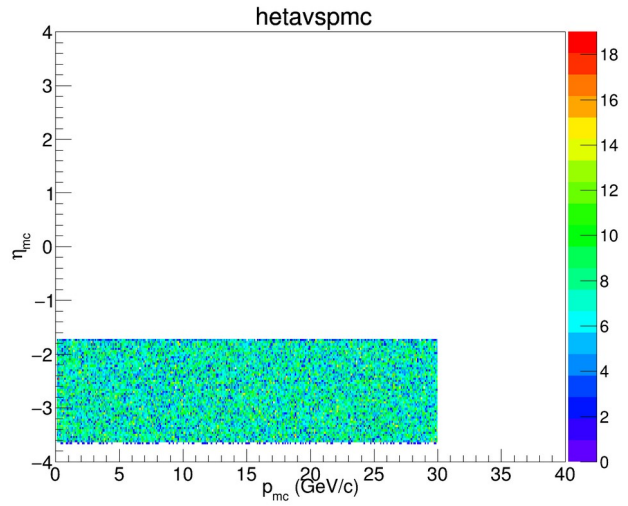
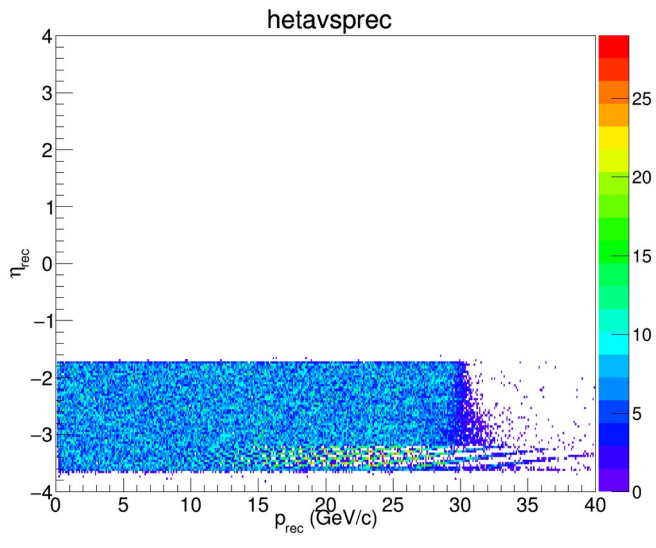
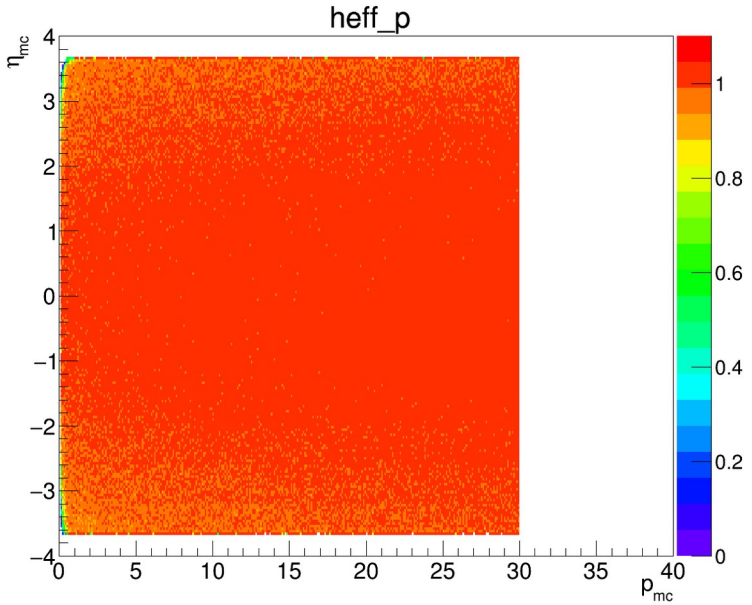
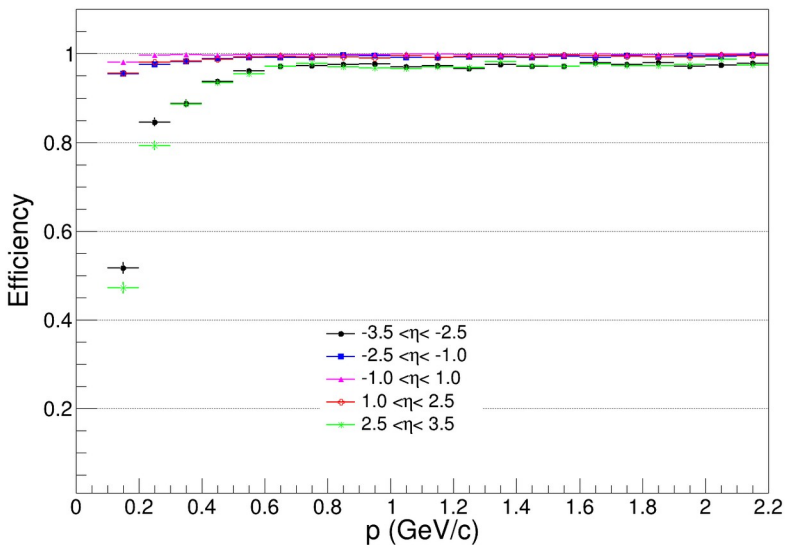

Need to be understood



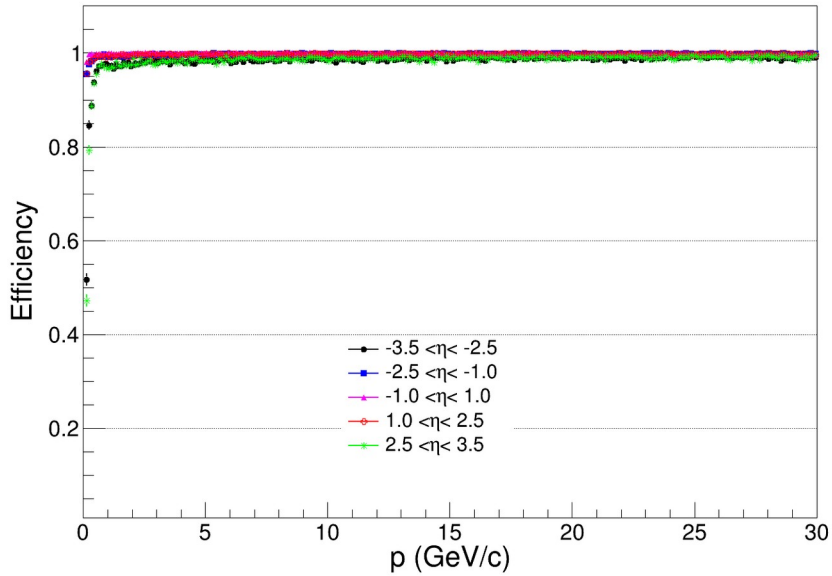



# Efficiency/Acceptance (Truth seeding)



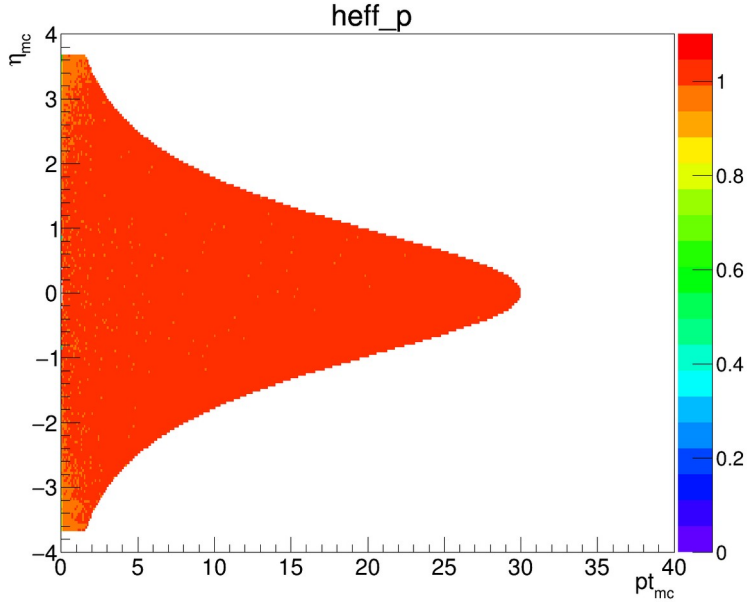



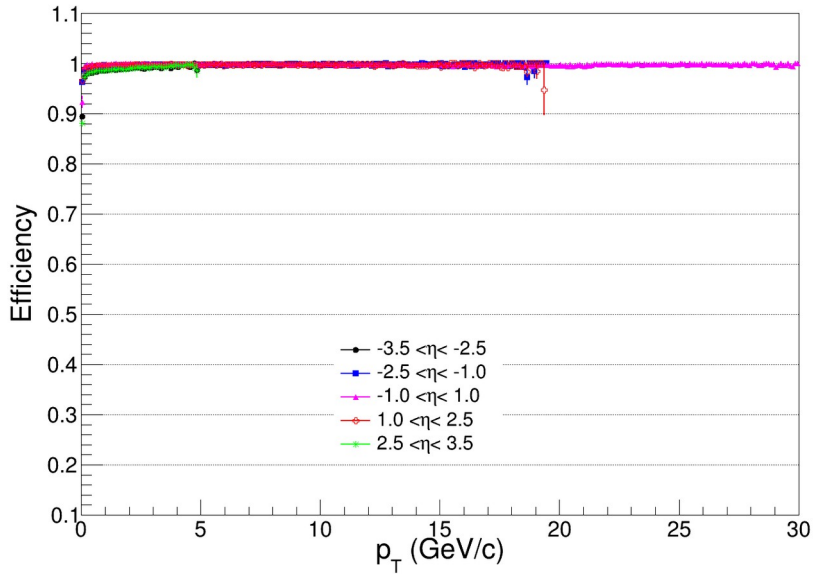

3M pi+ [0.1-30. GeV/c]

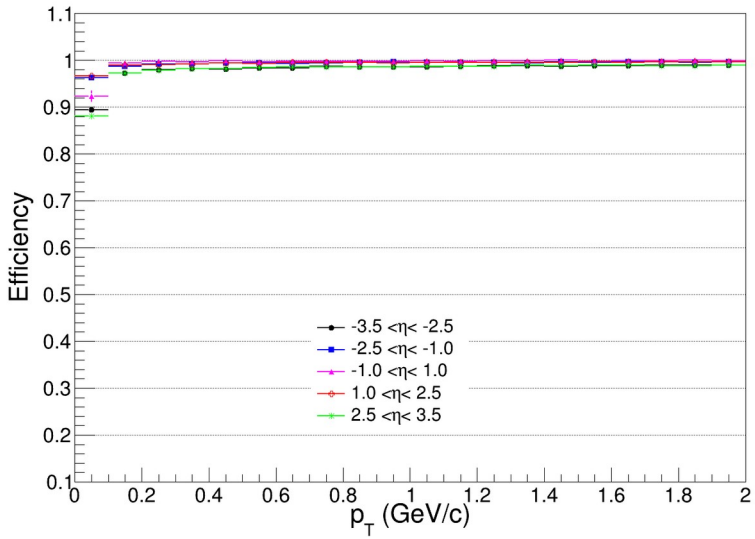



- Acceptance vs momentum
- Acceptance is looking good
- Still to be checked the number of hits and Chi2 as suggested

# Efficiency/Acceptance (Truth seeding)

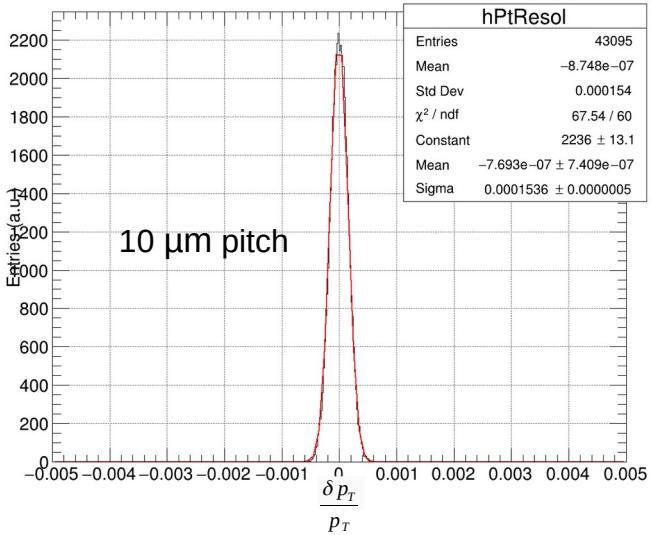


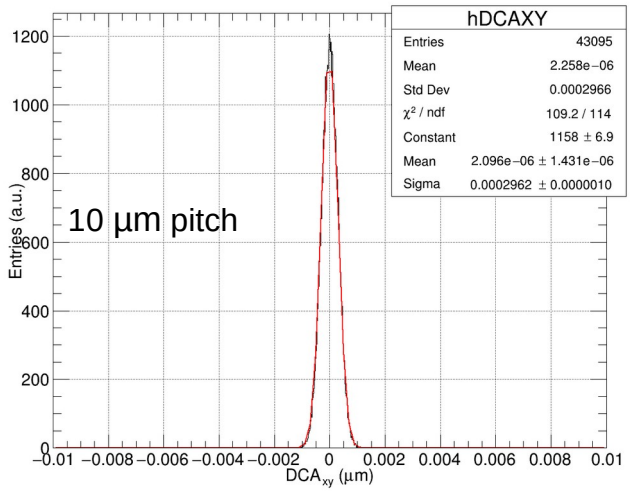

- Acceptance vs transverse momentum
- Acceptance is looking good
- Still to be checked the number of hits and Chi2 as suggested

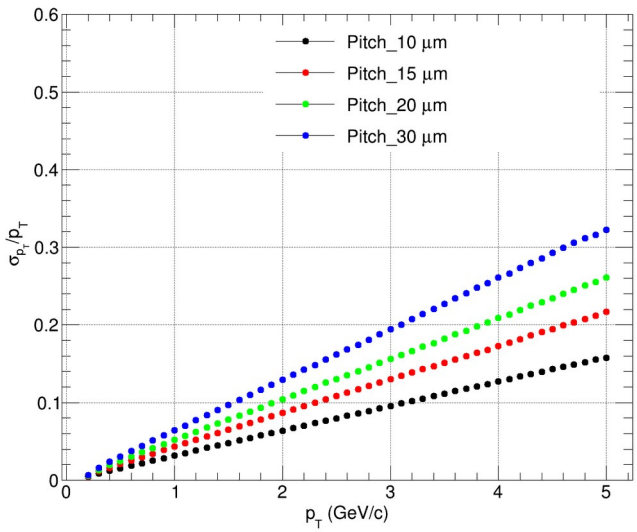
# Tracking Performances (Fast Simulation)



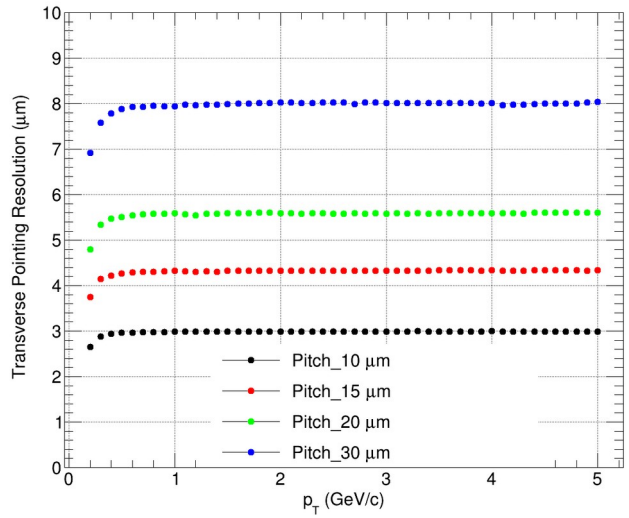

Changing pixel pitch of 10, 15, 20, 30 µm for Si layers (Barrel region)

Spatial Resolution only
No Multiple scattering



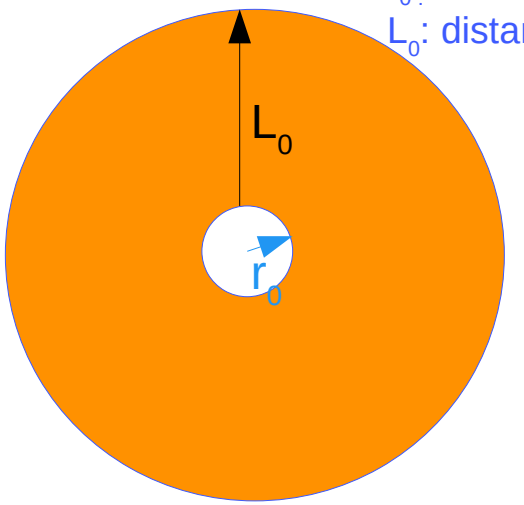




Fast sim developed by
S. Kumar, Annalisa,
F. Colamaria



# $DCA_{xy}$ Resolution

arXiv:1805.12014




$r_0$ : distance of near hit

$L_0$: distance between near and farthest hit from the beamline

**$DCA_{xy}$ increases at larger η because $r_0/L_0$ increases**

$DCA_{xy}$ resolution:

$$\Delta d_0|_{res.} \approx \frac{3\sigma_{r\phi}}{\sqrt{N+5}}\sqrt{1+\frac{8r_0}{L_0}+\frac{28r_0^2}{L_0^2}+\frac{40r_0^3}{L_0^3}+\frac{20r_0^4}{L_0^4}}$$

$$\Delta d_0|_{m.s.} \approx \frac{0.0136\,\mathrm{GeV/c}}{\beta p_T} r_0\sqrt{\frac{d}{X_0\sin\theta}}\sqrt{1+\frac{1}{2}\left(\frac{r_0}{L_0}\right)+\frac{N}{4}\left(\frac{r_0}{L_0}\right)^2}$$

($r_0/L_0$) is very important for $DCA_{xy}$ resolutions

$$\sigma_{d_0} = \sqrt{\sigma^2_{d0_{SR}} + \sigma^2_{d0_{MS}}}$$

## Barrel

r0 = 3.6; L0 = 64.0-3.6; N = 7;

$\sigma_{r\phi} = 10\,\mu m/\sqrt{12}$

Expected DCAxy Resol Barrel (SR): 3.14743 μm

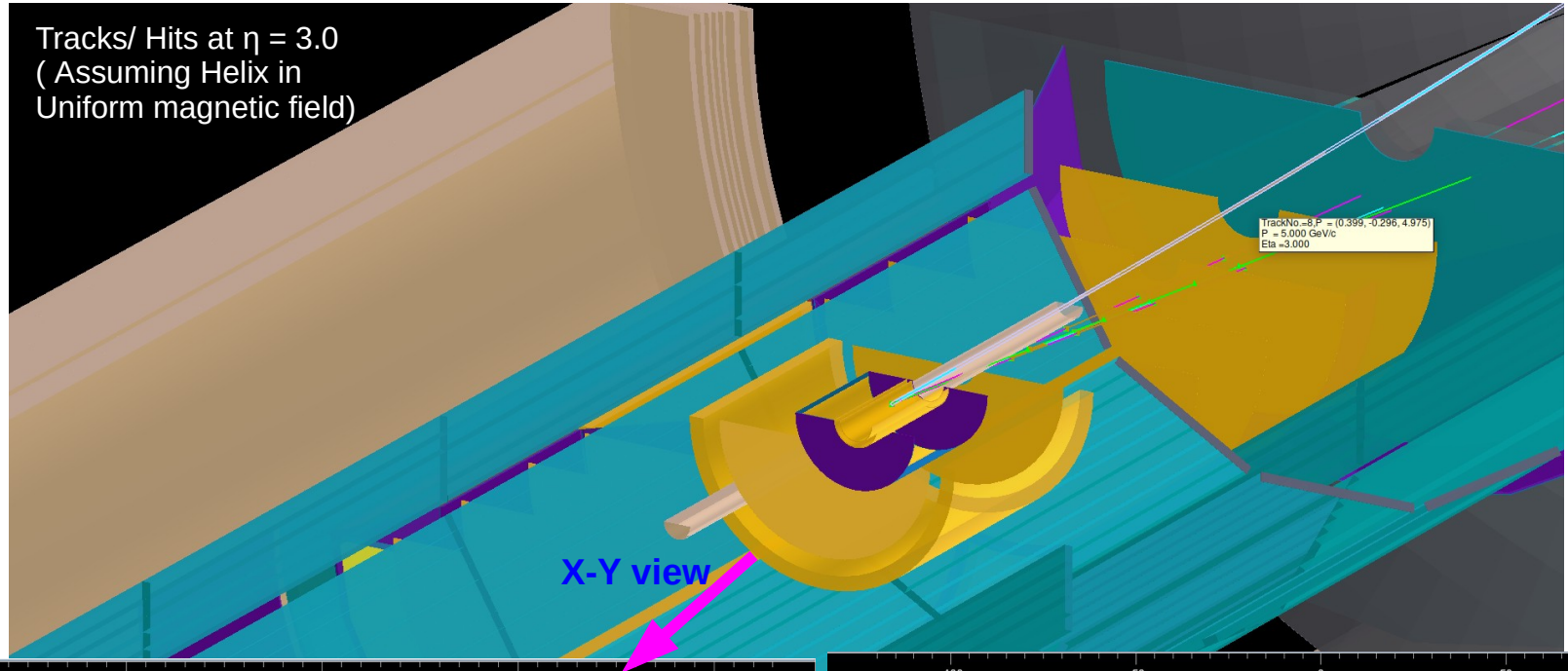
## Forward/Backward

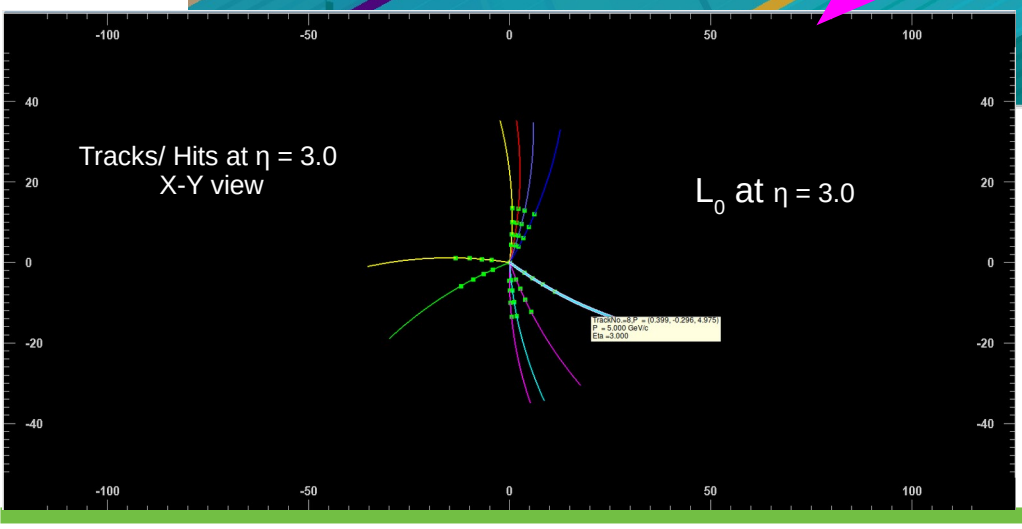
Double_t rmin[5] = {3.67617,3.67617,4.07617,5.37617,7.07617};
Double_t rmax[5] = {24.00010,42.500107,43.12010,43.12010,43.12010};
Double_t z[] ={25., 45., 70., 100., 135.};
Double_t $L_0$ = 43.12010-3.67617; N = 4; // number of points

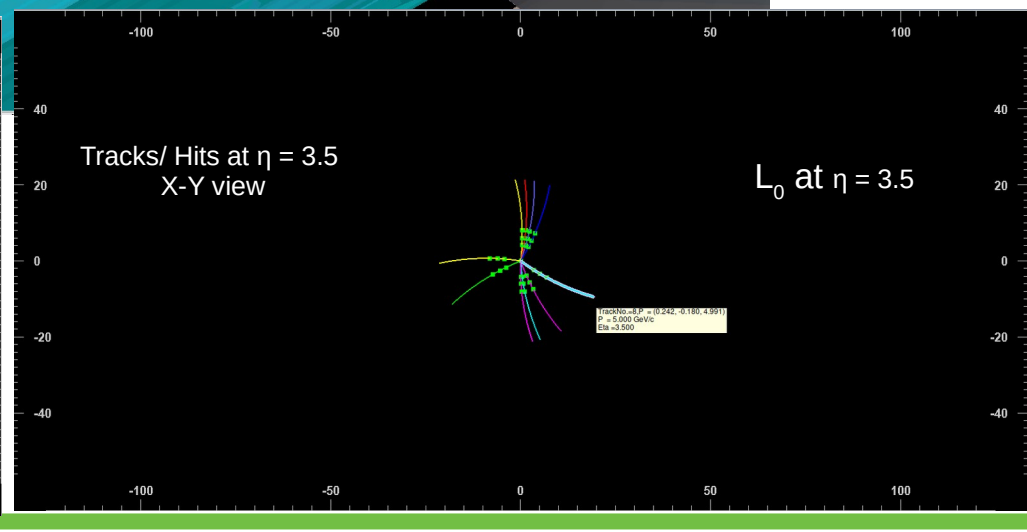
$\sigma_{r\phi} = 10\,\mu m/\sqrt{12}$

Expected DCAxy Resol Forward (SR): 4.10559 μm
if ($L_0$ = 20cm then Expected DCAxy = 5.543 μm)

# $DCA_{xy}$ Resolution (Forward/Backward)

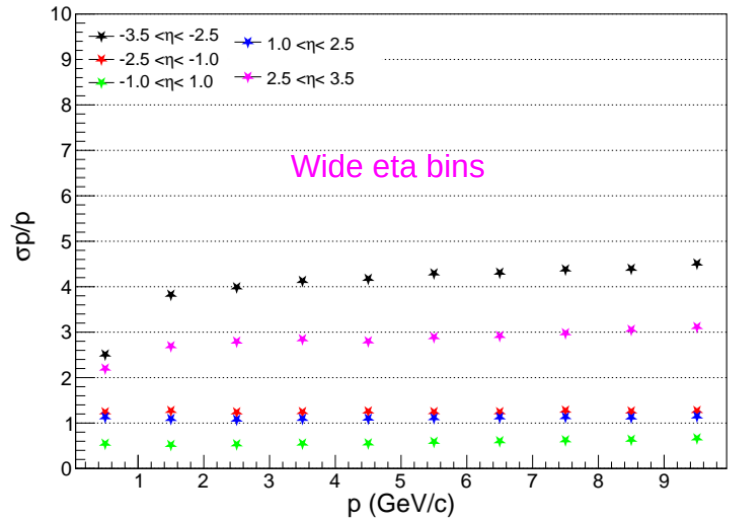


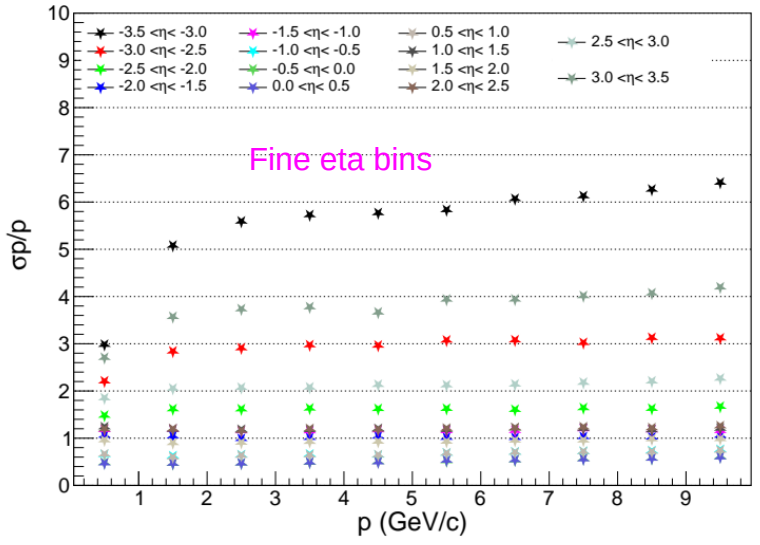



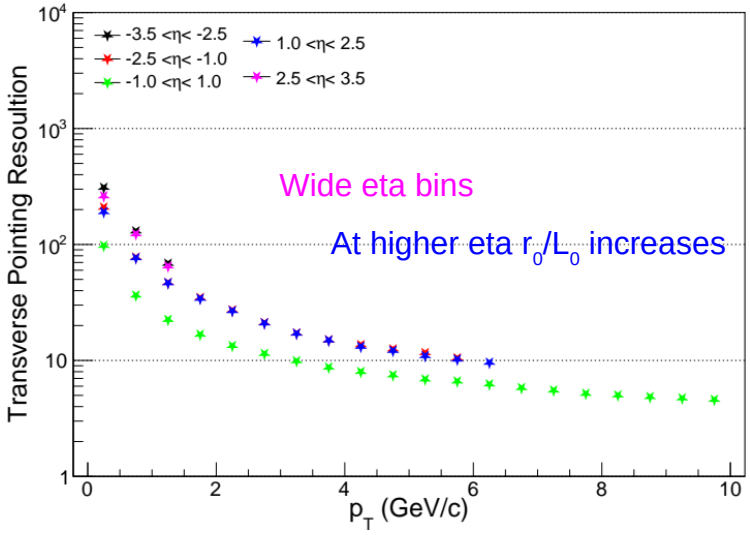



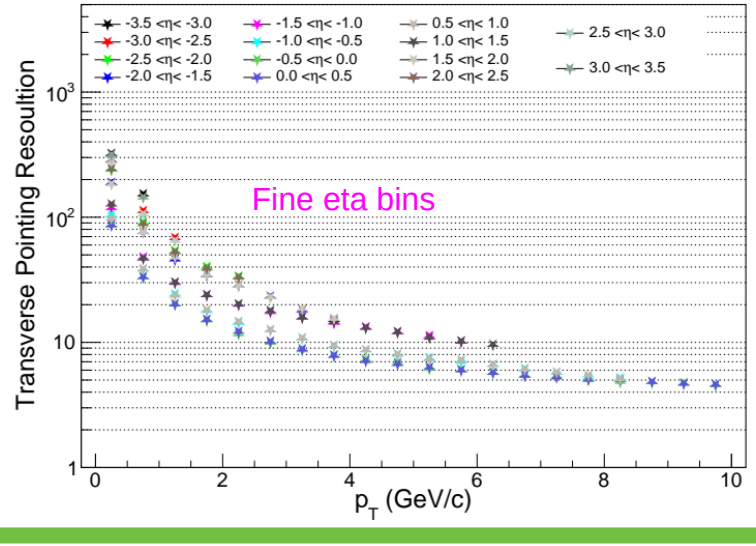
# Tracking Performances

epic_brycecanyon.xml



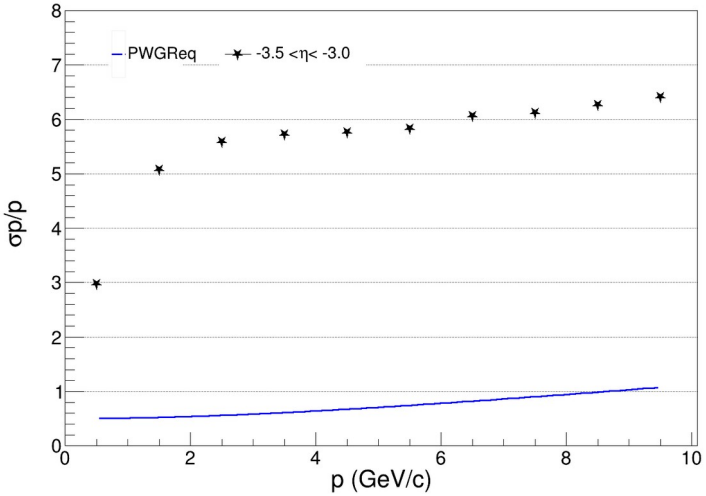



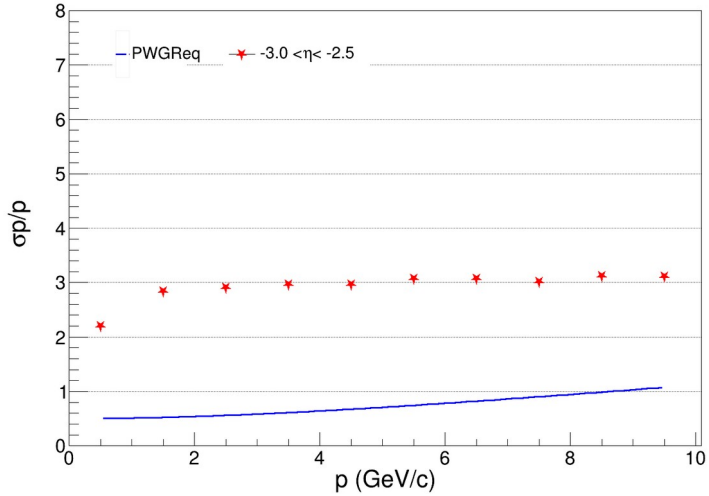



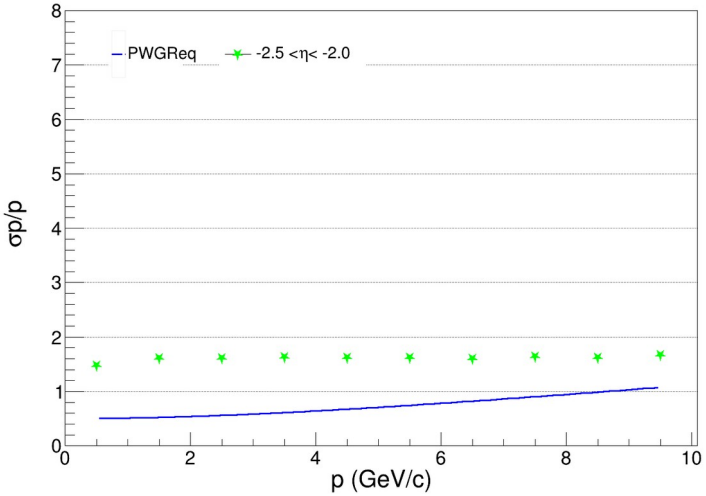



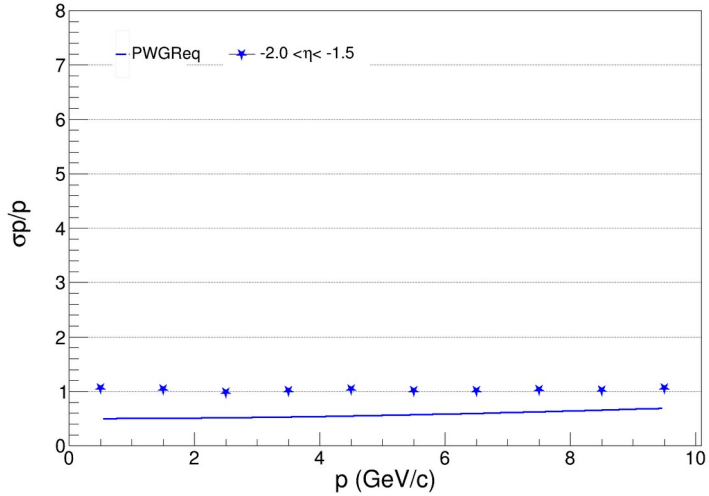
# Tracking Performances

Blue line for Physics Requirements, Markers for DD4HEP Simulation, Magenta dotted line for Fast Sim (Kalman filter)



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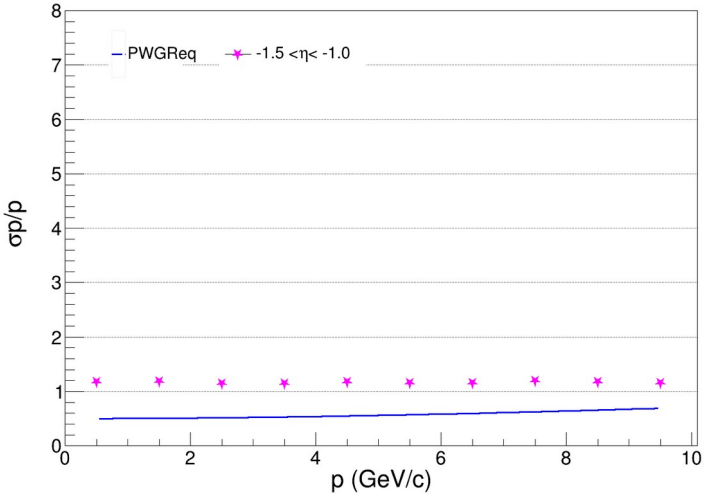
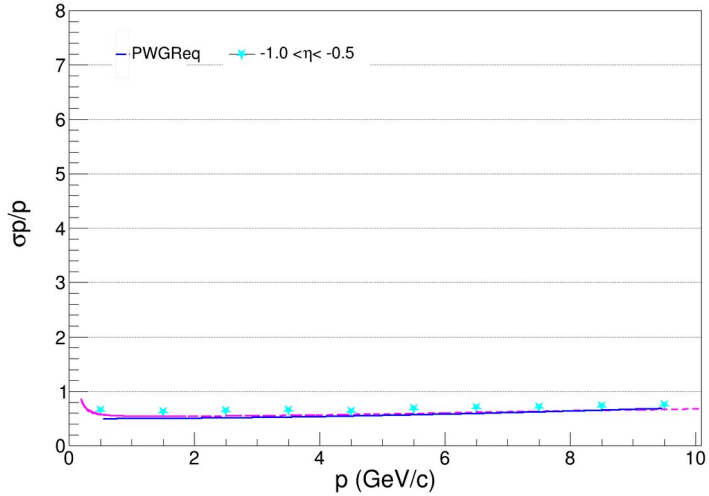
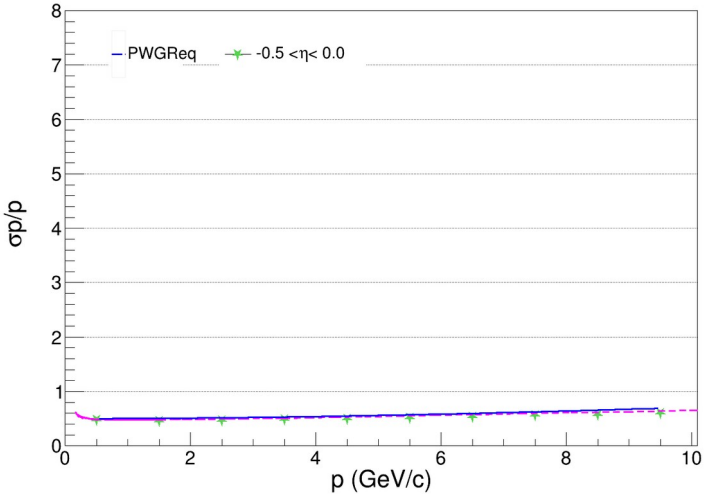
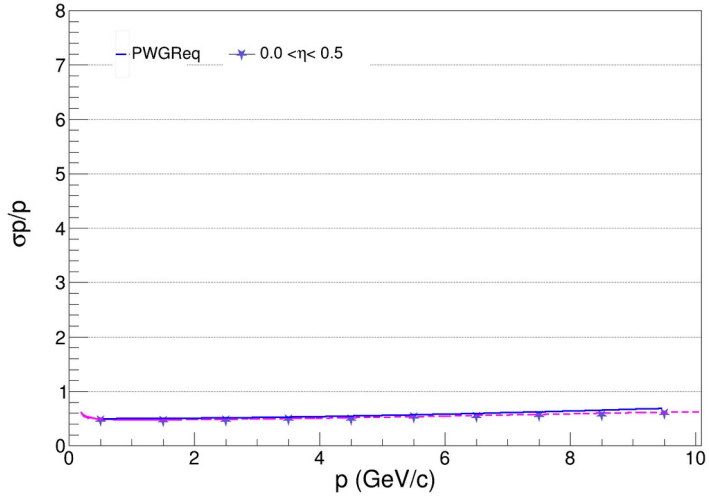


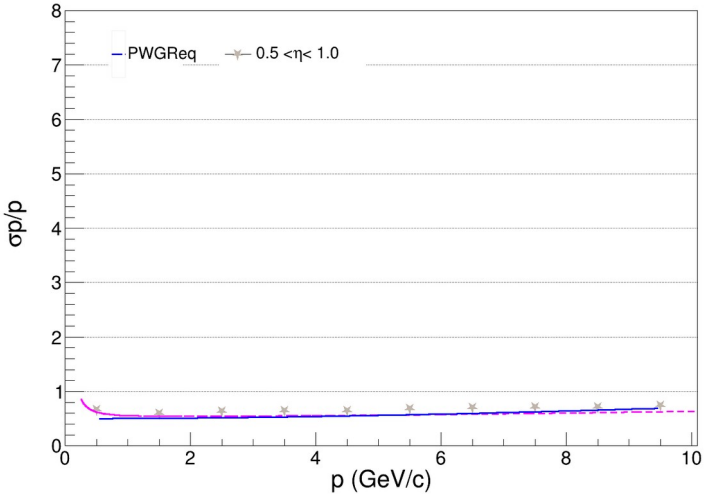



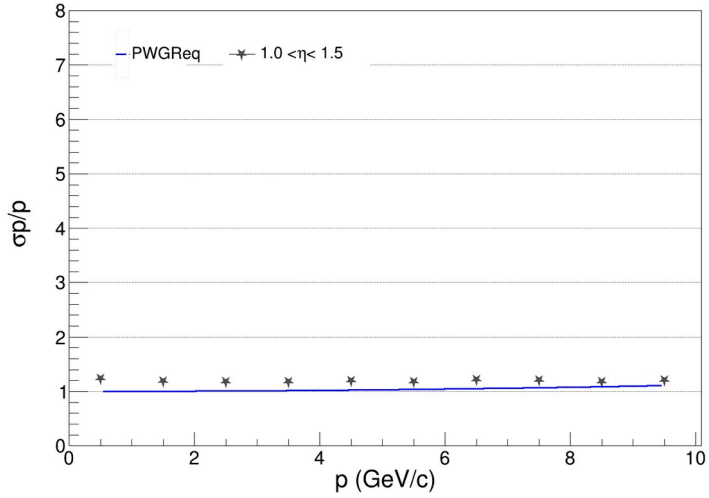



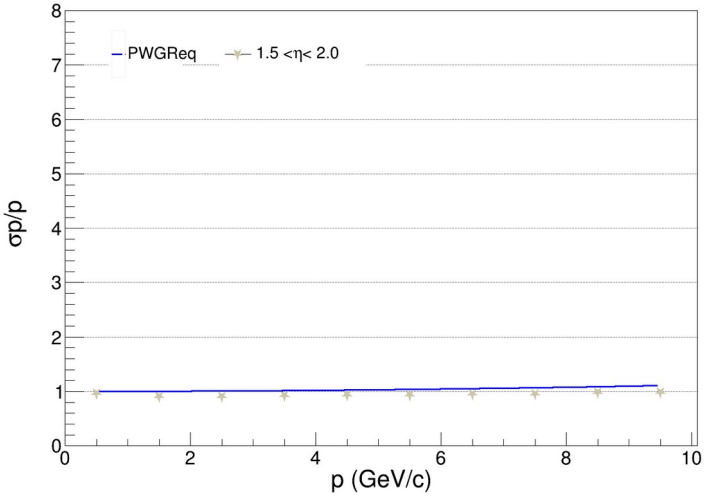



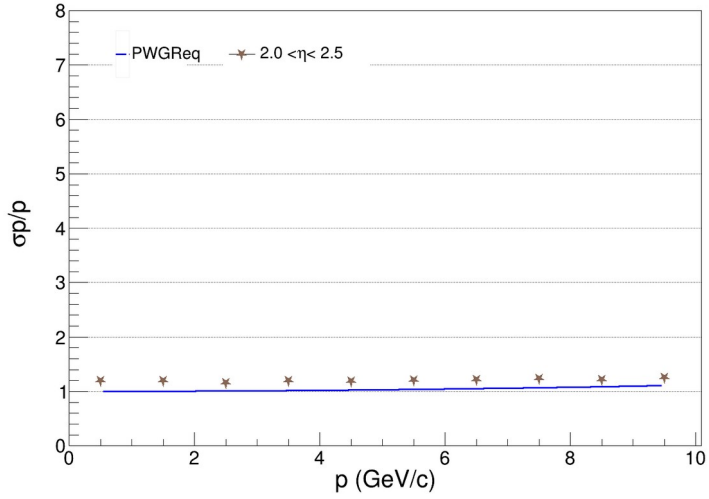
# Tracking Performances

Blue line for Physics Requirements, Markers for DD4HEP Simulation, Magenta dotted line for Fast Sim (Kalman filter)



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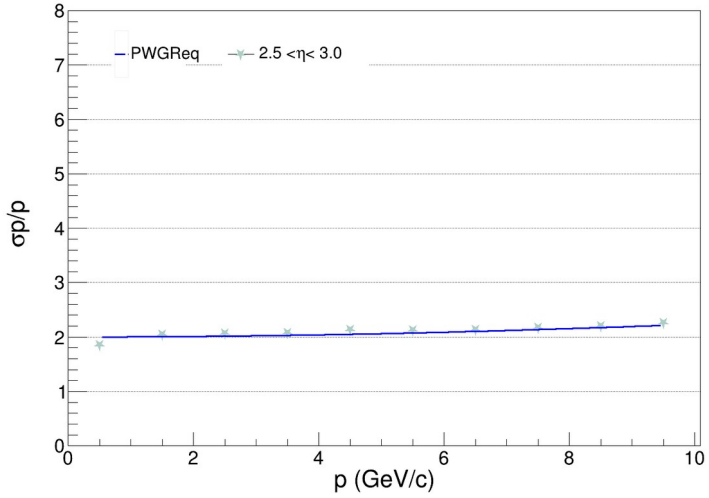


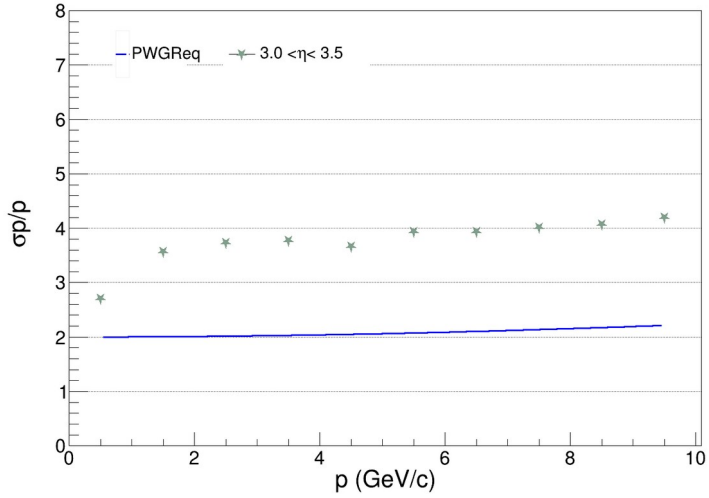


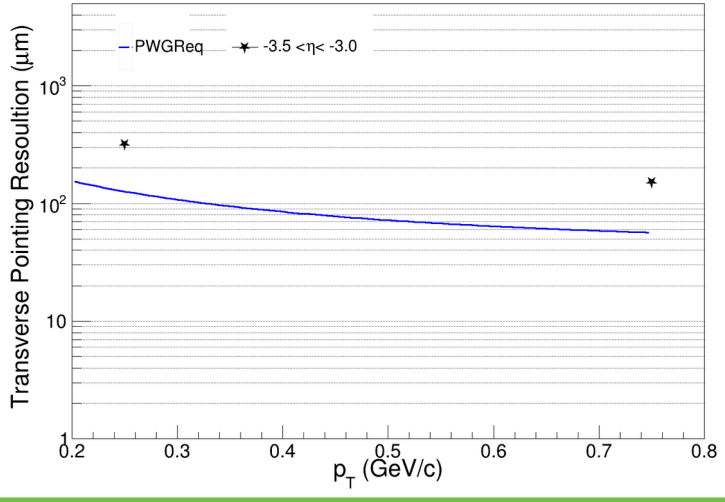


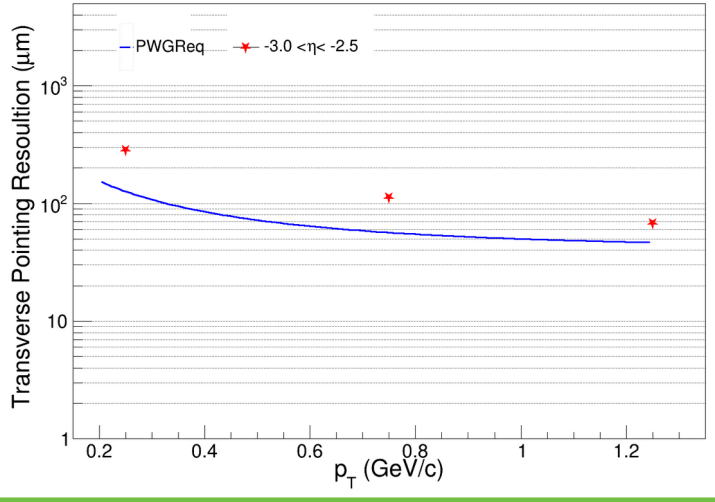

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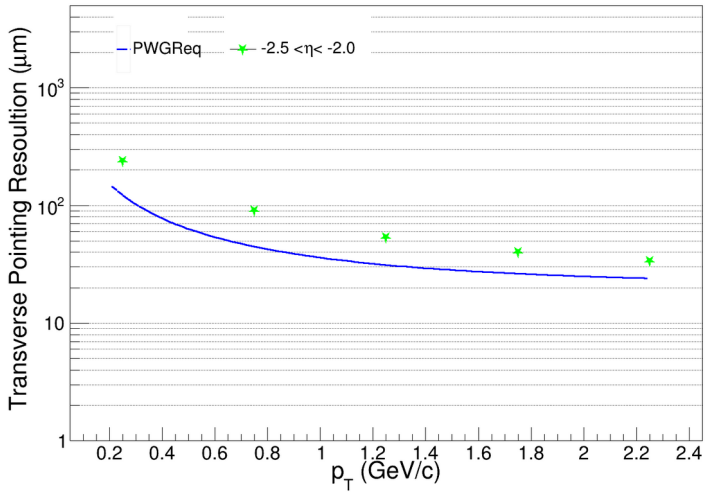


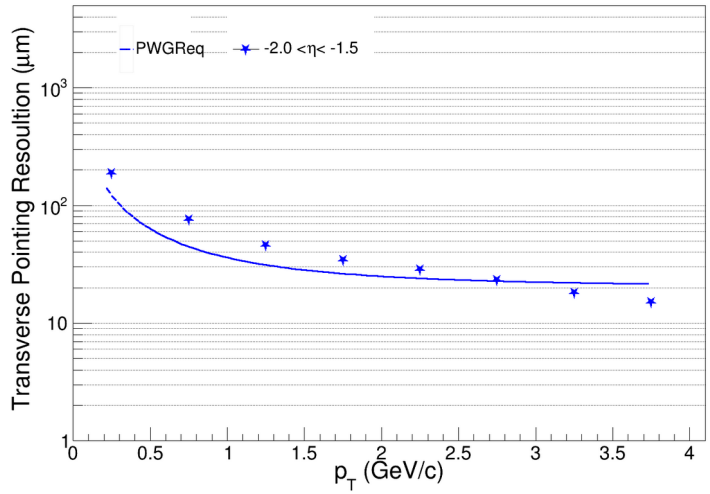


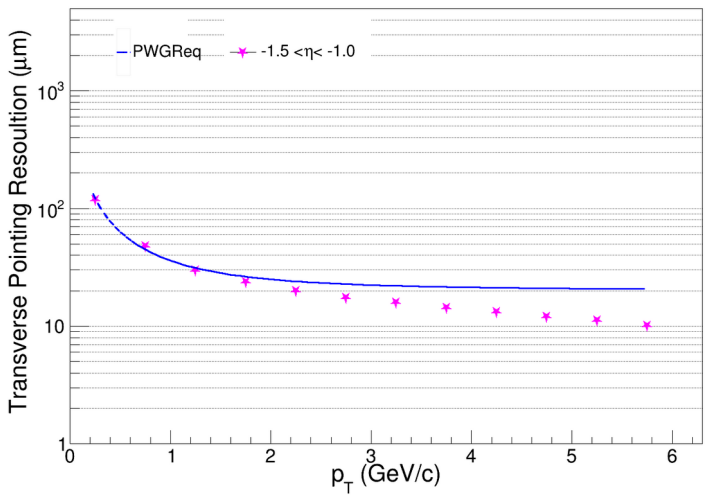


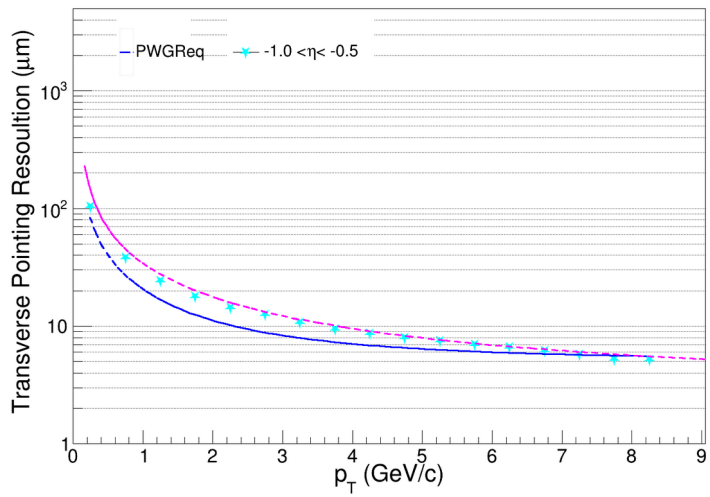

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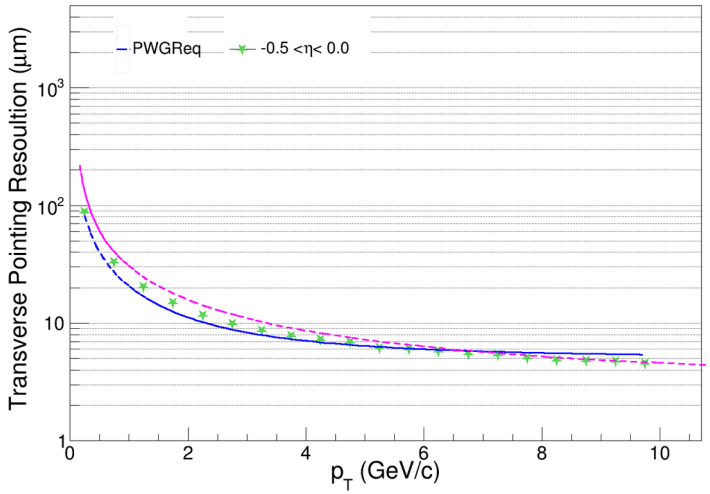


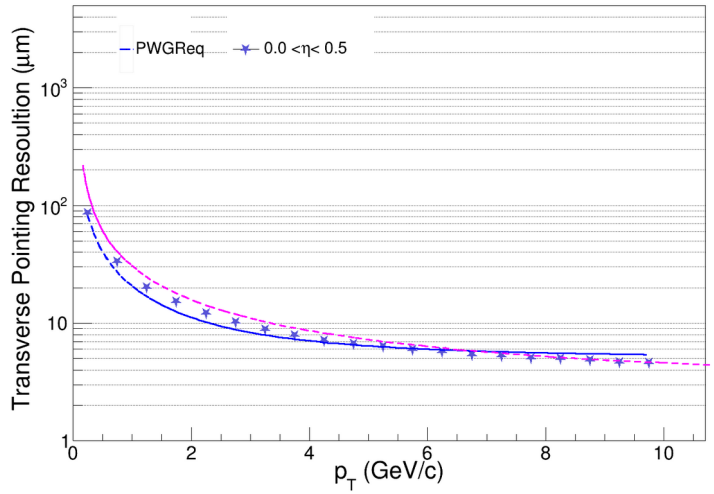


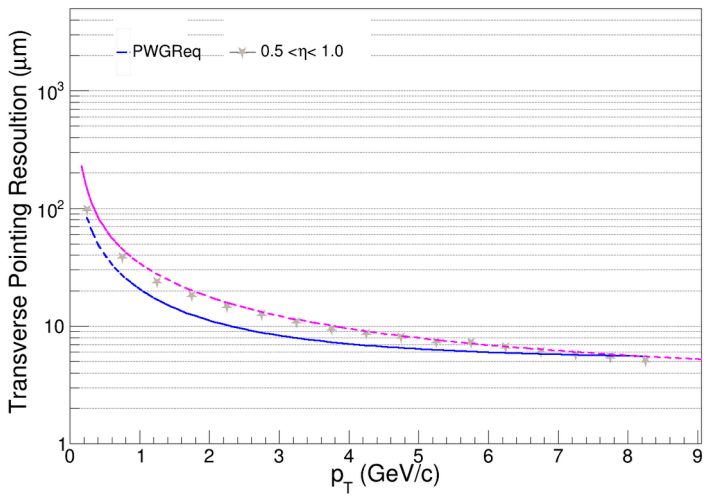


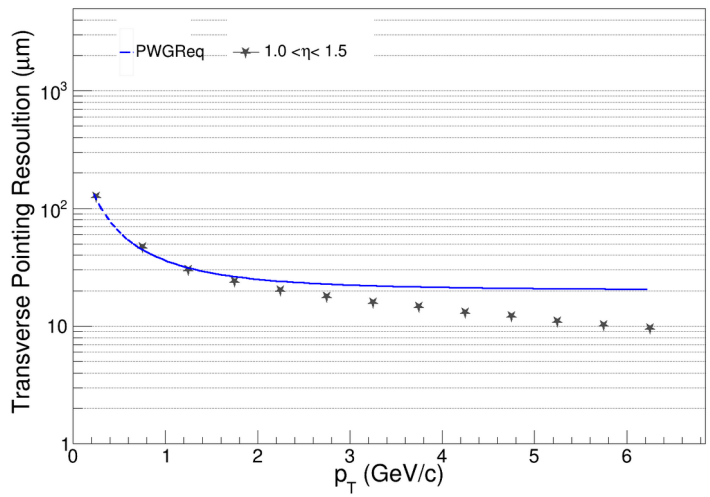

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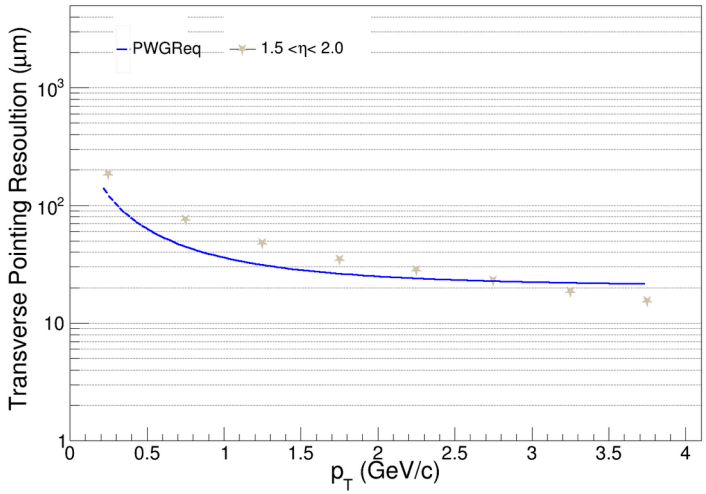
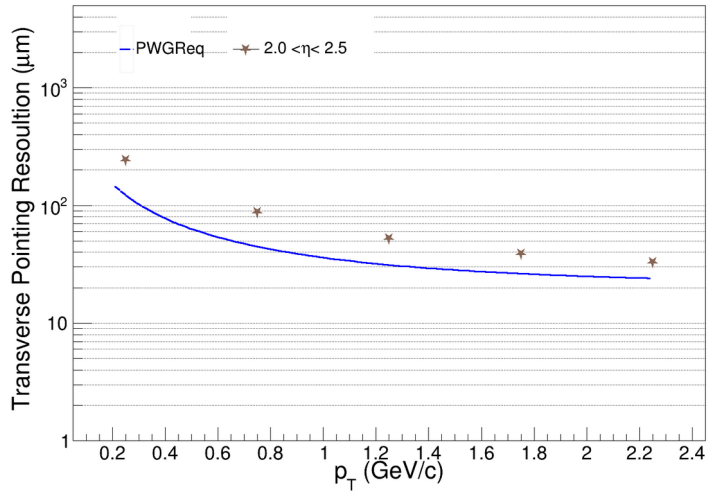
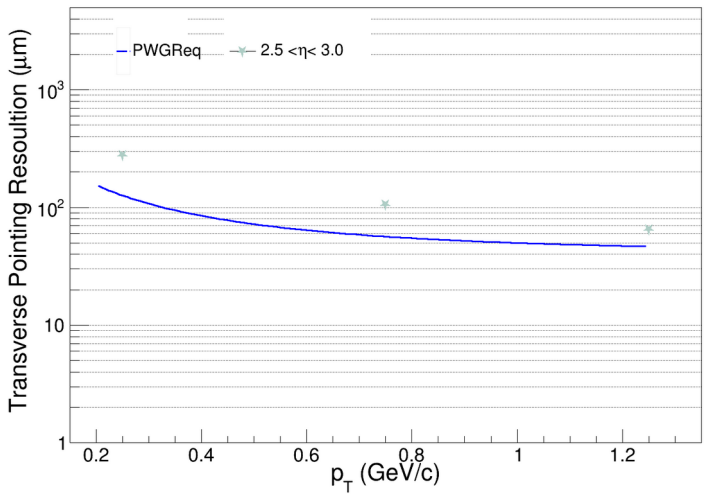
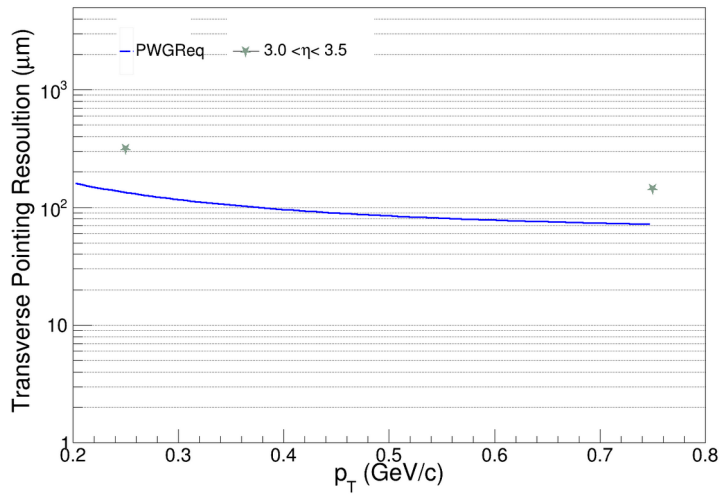


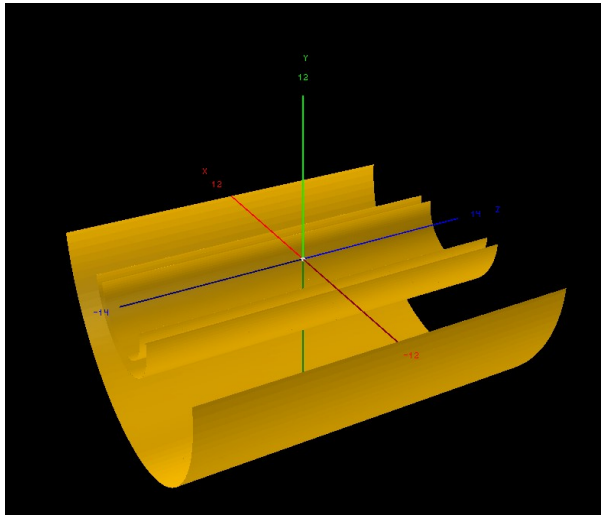



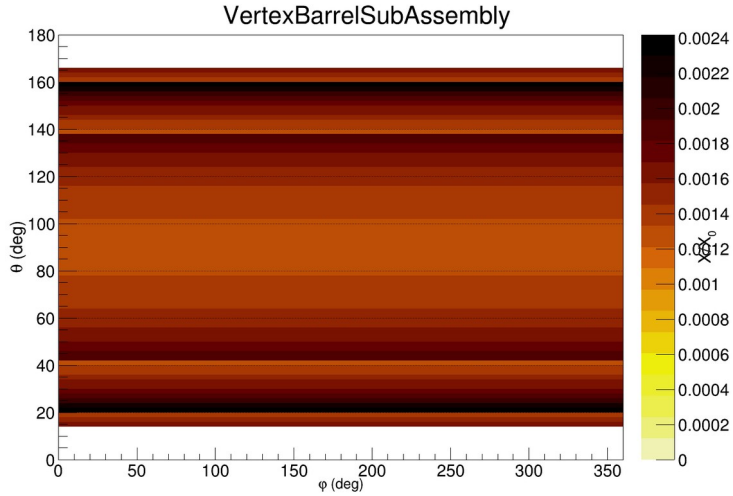
# Summary and Future Plan

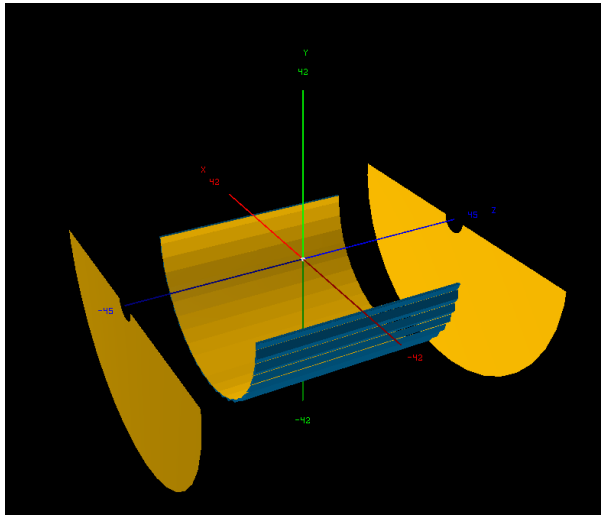
- Check the acceptance with truth seeding.
- Check at the first look of tracking performance and validation of fast simulation tool.
- Check the material map of the geometry component wise.
- Next
  - Number of hits per track, Chi2/ndf
  - Started looking at the realistic seeding
  - Comparison with Juggler result is welcomed (by Wenqing)

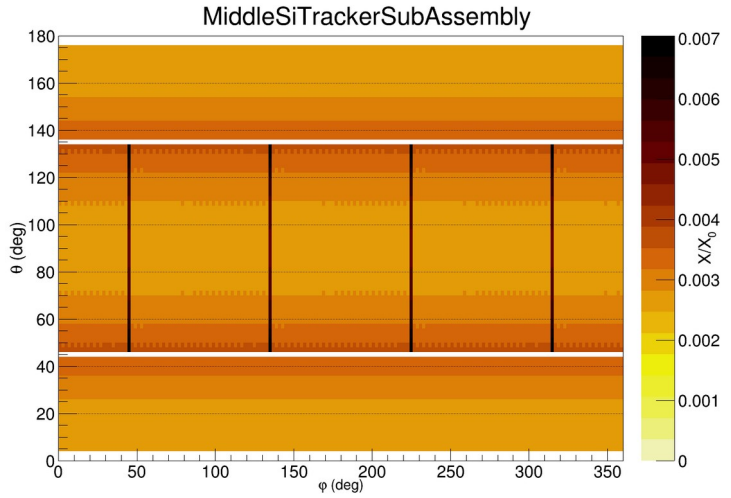
Thank You !!!

# Material Budget Plots







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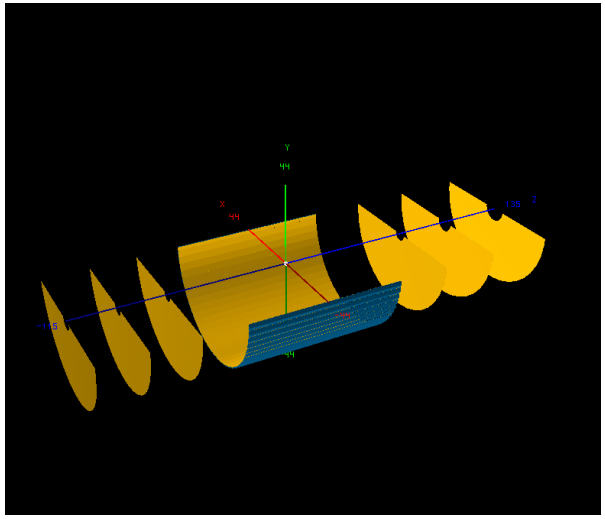

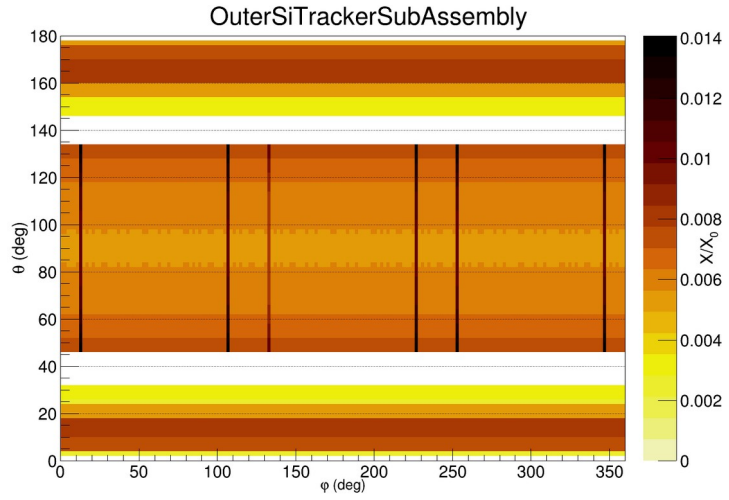


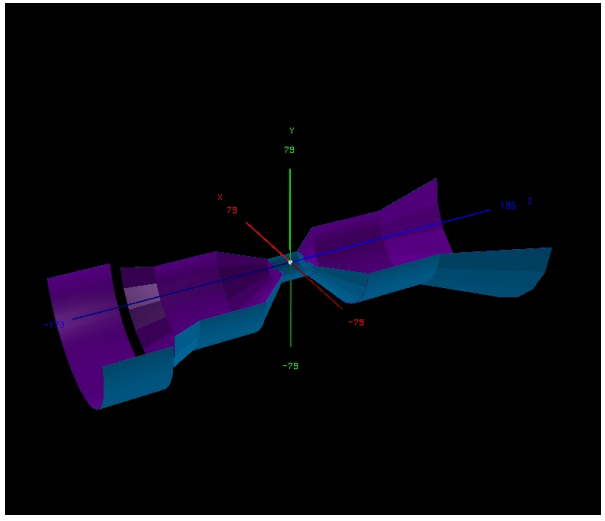

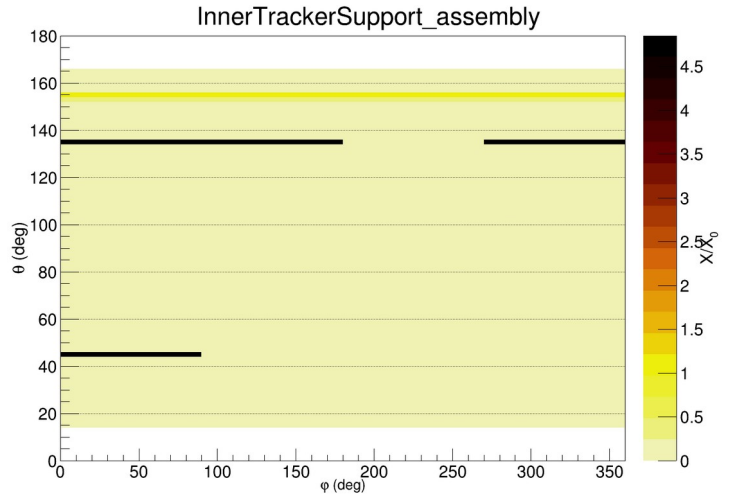

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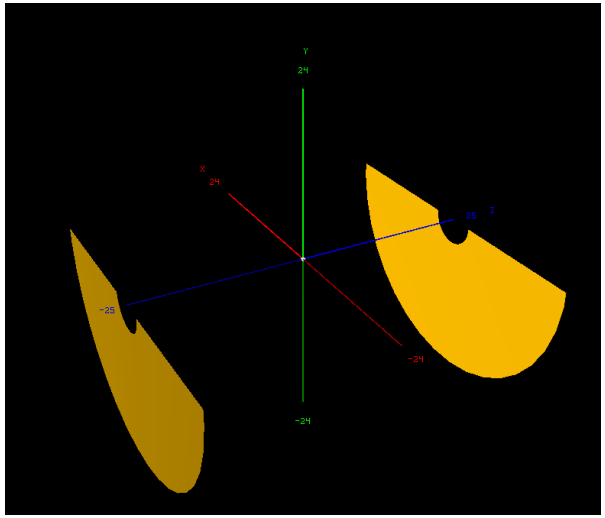

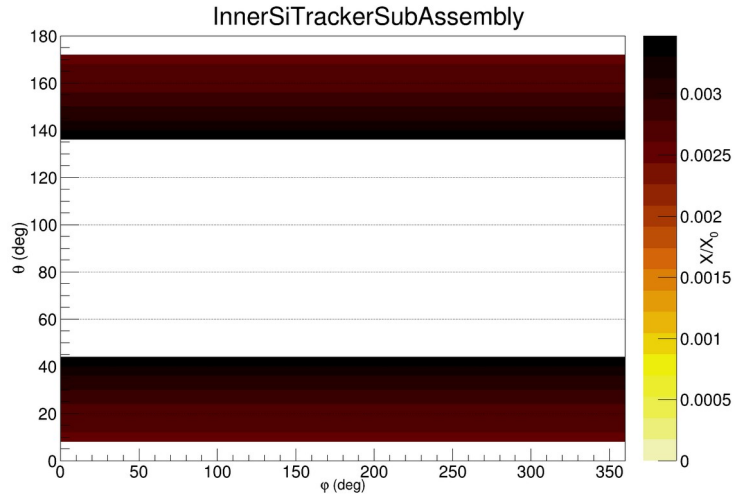


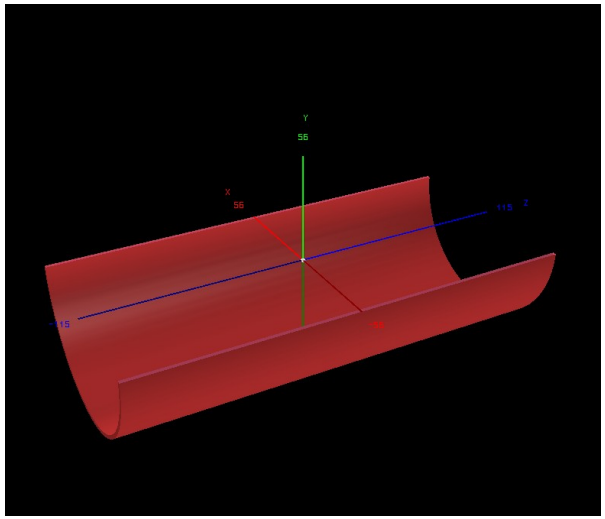

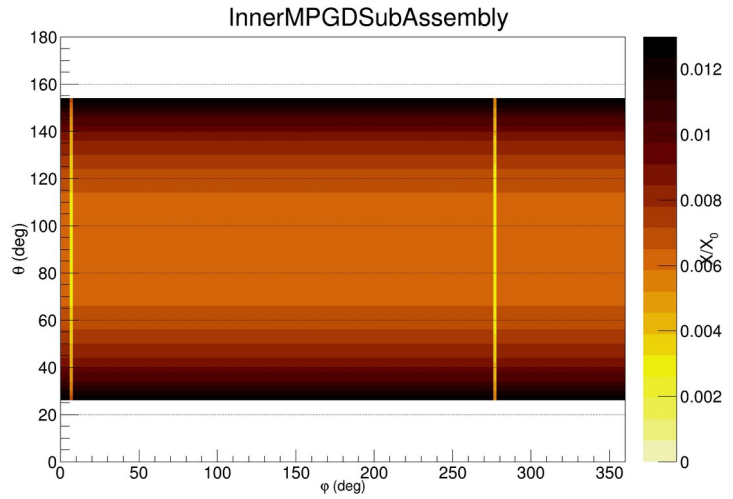

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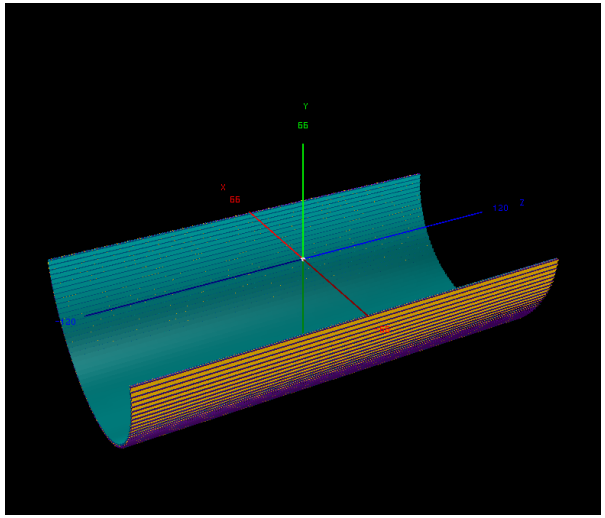
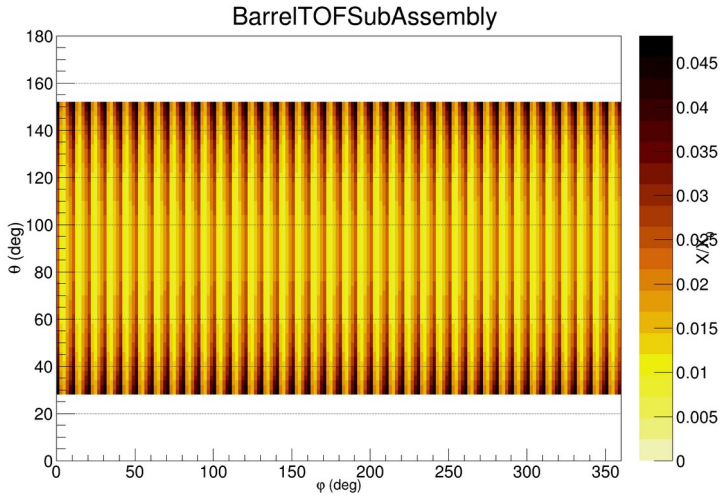
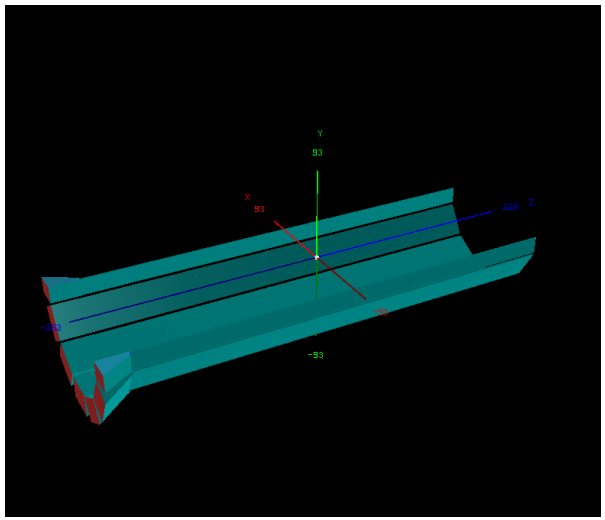
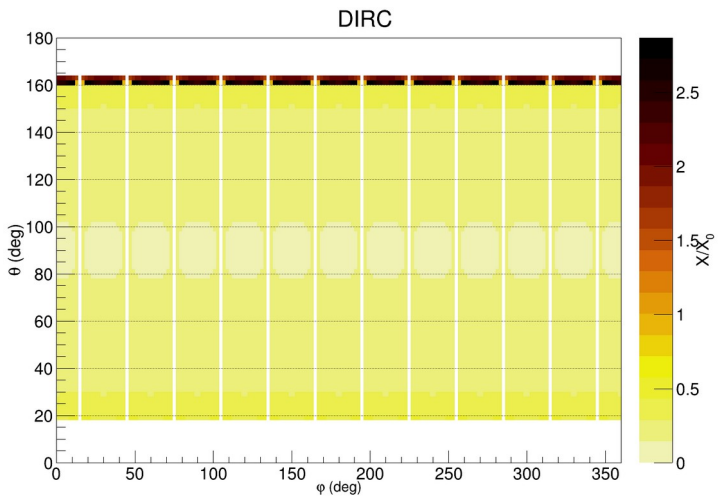


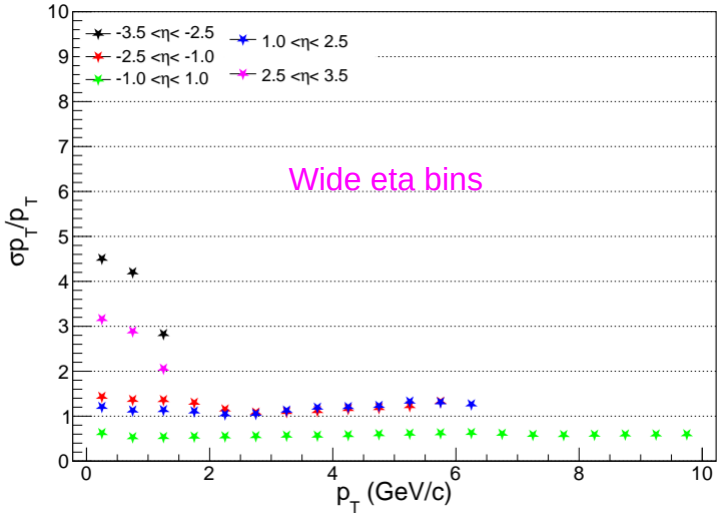


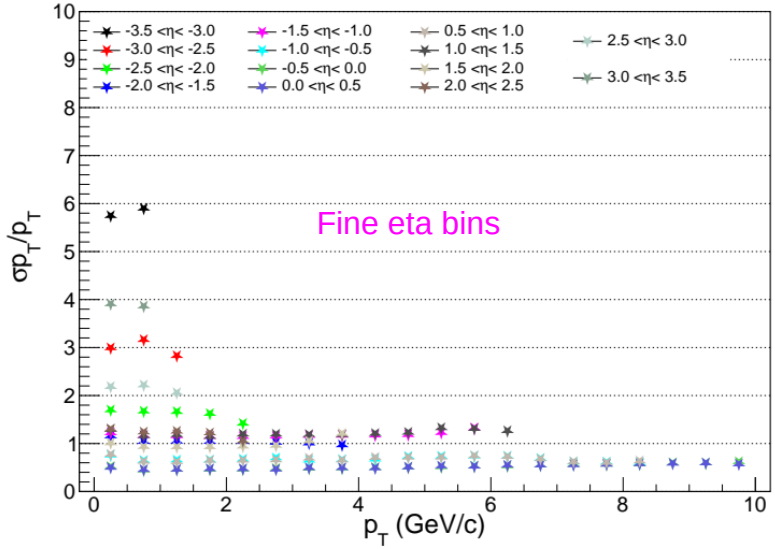



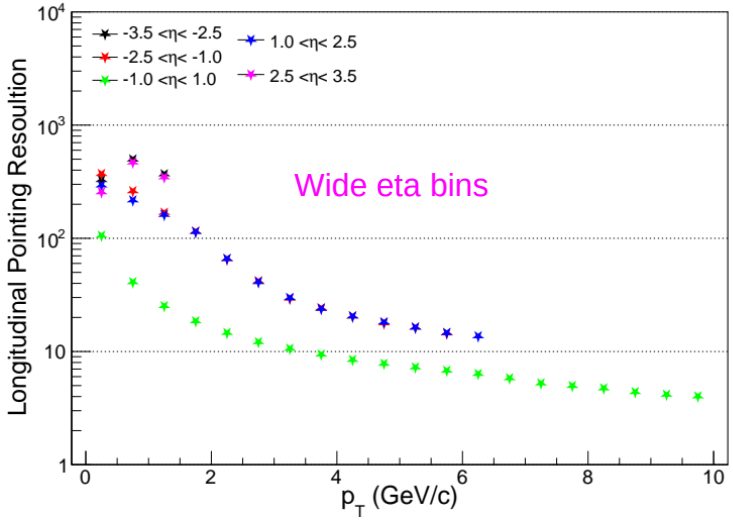


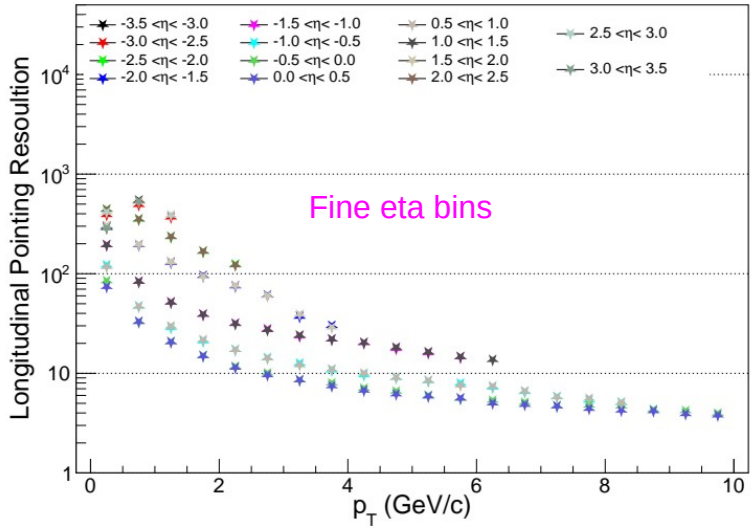
# Tracking Performances

epic_brycecanyon.xml



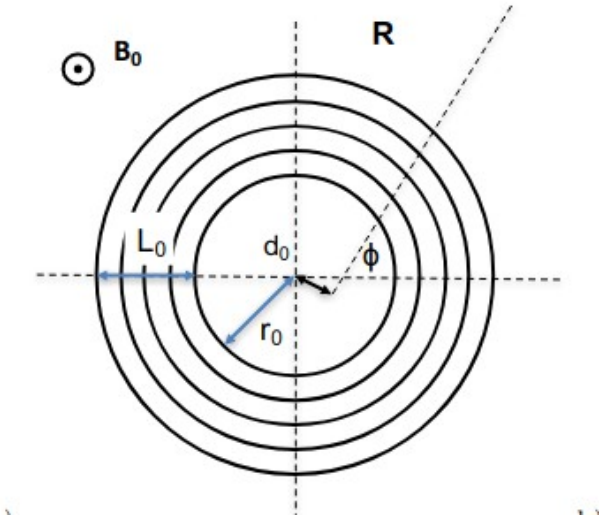
# Momentum Resolution

Zbynek Drasal, Werner Riegler

arXiv:1805.12014

## Tracking Performances: Momentum and DCA resolutions

Momentum Resolution:affects width of invariant mass peak




$p_T$ resolution:

$$\frac{\Delta p_T}{p_T}\Big|_{res.} = \frac{\sigma_{r\phi}\, p_T}{0.3\, B_0 L_0^2}\sqrt{\frac{720N^3}{(N-1)(N+1)(N+2)(N+3)}} \quad \text{Linear term}$$

$$\approx \frac{12\,\sigma_{r\phi}\, p_T}{0.3\, B_0 L_0^2}\sqrt{\frac{5}{N+5}}$$

$$\frac{\Delta p_T}{p_T}\Big|_{m.s.} = \frac{N}{\sqrt{(N+1)(N-1)}}\,\frac{0.0136\,\mathrm{GeV/c}}{0.3\beta\, B_0 L_0}\sqrt{\frac{d_{tot}}{X_0\,\sin\theta}}\left(1+0.038\ln\frac{d}{X_0\,\sin\theta}\right)$$

Constant term (at β<1 increase)

Based on Gluckstern Approach (equal distance between planes and equal spatial resolutions)

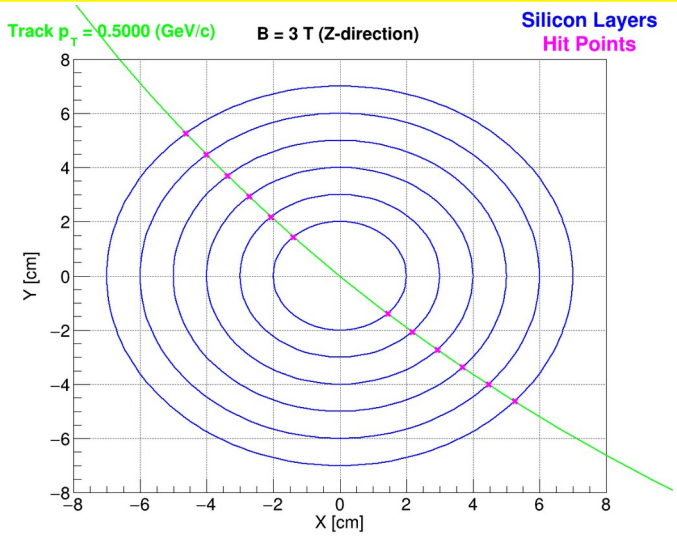
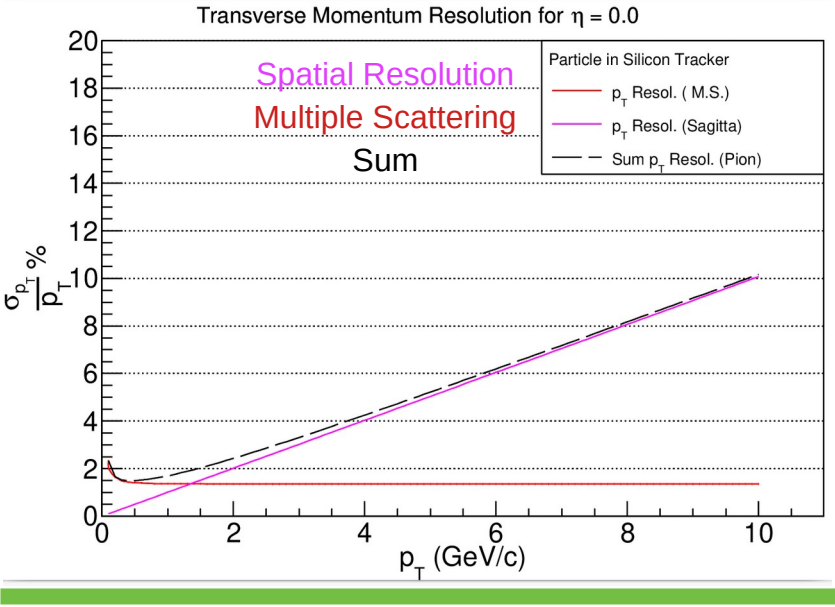
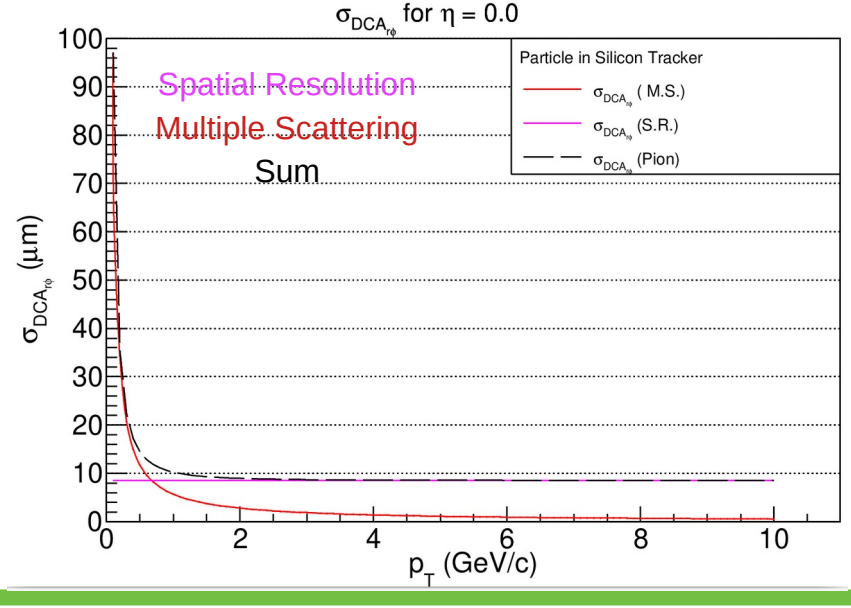
**SR (Spatial Resolution):** Uncertainity associated with finite size of pixels

**MS (Multiple Scattering):** Uncertainity associated with thickness of Material

$$\frac{\sigma_{pT}}{p_T} = \sqrt{\left(\frac{\sigma_{pT_{SR}}}{p_T}\right)^2 + \left(\frac{\sigma_{pT_{MS}}}{p_T}\right)^2}$$

# Simple Example

Consider an example of silicon layers of 50 μm thickness

$r_0$ = 2 cm  $L_0$ = 7-2 = 5 cm;

$$\sigma_{r\phi} = 10\,\mu m$$