EicC Vertex & Tracking Detector Simulation and Performance Study

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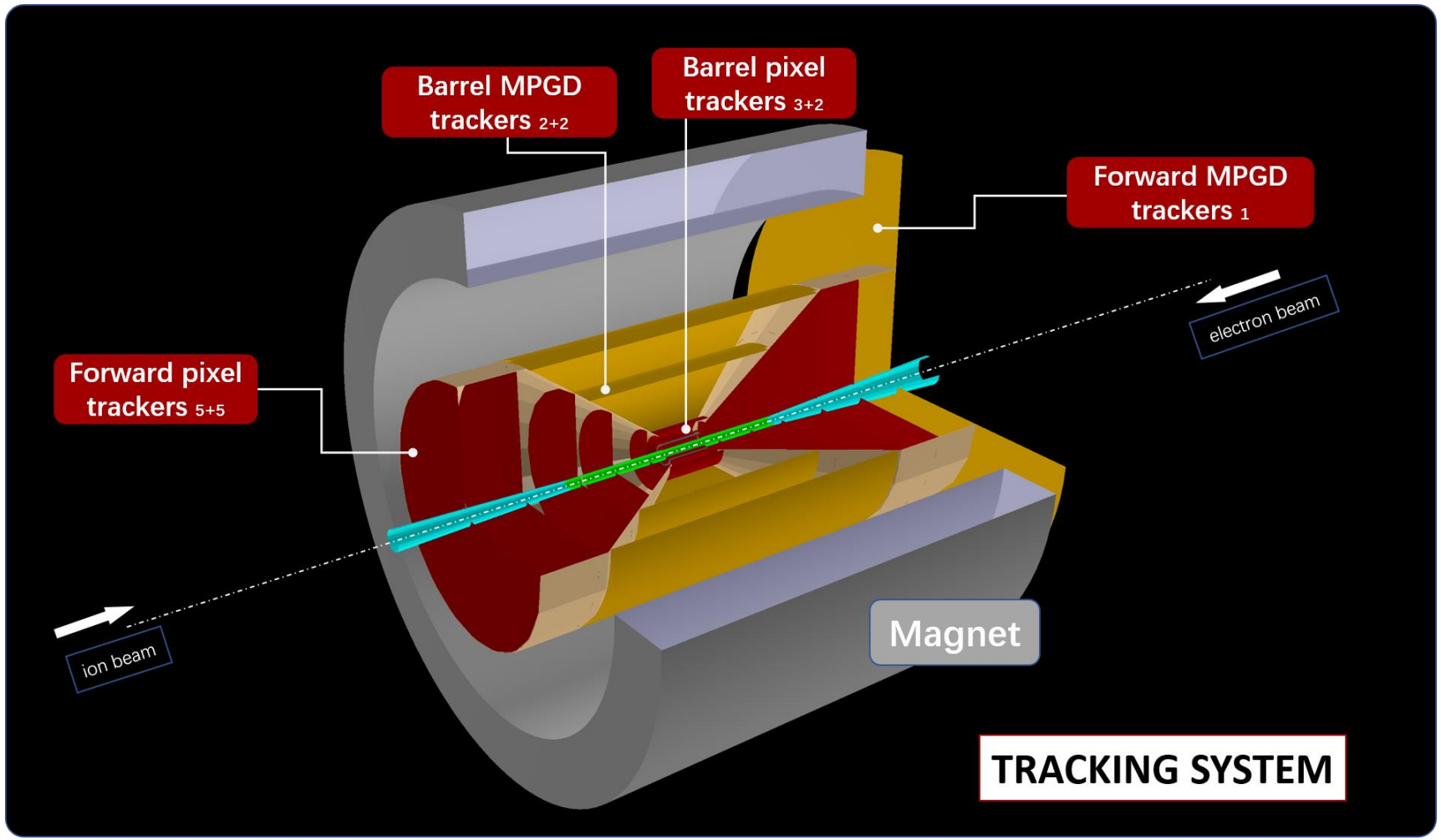
The latest design



Barrel:

R(cm)	Length(cm)	Pitch Size(μm)	Material Bedget (X/X0 %)	Tech
3.30	28	10	0.08	ITS3
4.35	28	10	0.08	ITS3
5.40	28	10	0.08	ITS3
8.00	28	10	0.08	ITS3
15.00	38.70	10	0.08	ITS3
47.72	127.47	150(rp)x150(z)	0.40	MPGD
49.57	127.47	150(rp)x150(z)	0.40	MPGD
75.61	201.98	150(rp)x150(z)	0.40	MPGD
77.46	201.98	150(rp)x150(z)	0.40	MPGD

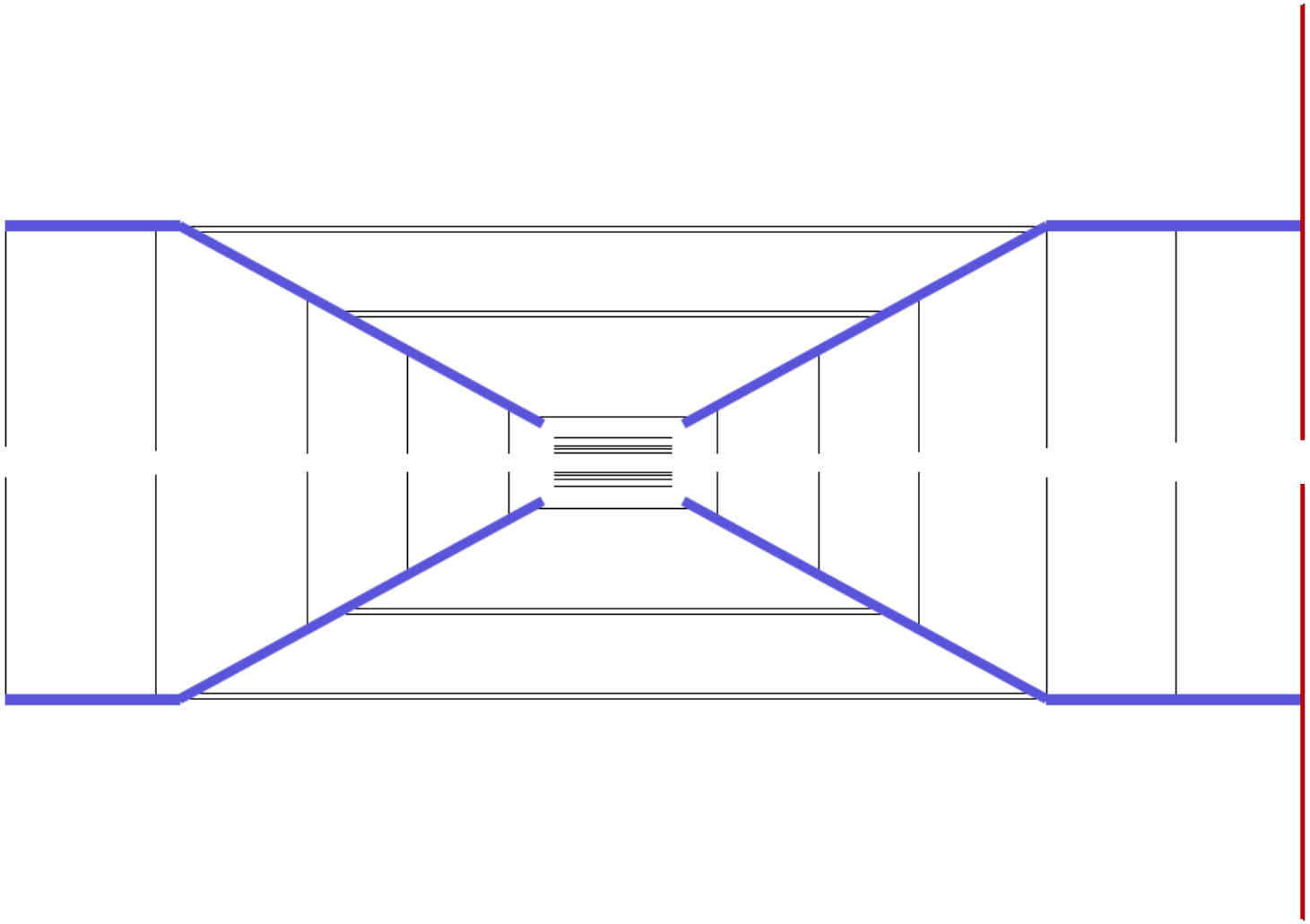
End cap p going:

In R(cm)	Out R(cm)	Z(cm)	Pitch Size(μm)	Material Bedget (X/X0 %)	Tech
3.18	18.62	25	10	0.08	ITS3
3.18	36.50	49	10	0.08	ITS3
3.47	54.66	73	10	0.08	ITS3
5.08	77.46	103.65	10	0.08	ITS3
6.58	77.46	134.33	10	0.08	ITS3
8.16	150.00	165.00	50(rp)x250(r)	0.40	MPGD

End cap e going:

In R(cm)	Out R(cm)	Z(cm)	Pitch Size(μm)	Material Bedget (X/X0 %)	Tech
3.18	18.62	-25	10	0.08	ITS3
3.18	36.50	-49	10	0.08	ITS3
3.18	54.66	-73	10	0.08	ITS3
3.95	77.46	-109.0	10	0.08	ITS3
5.26	77.46	-145.0	10	0.08	ITS3

The issue of the latest design



- The large area of silicon detector at the forward & backward put a heavy burden on the readout system
- ~~Only the radius of the sagitta layers are optimized by single track events~~
- The Layer number and radius (position) are not optimized properly
- **The scale and structure of the detector need dedicated optimization according to our physical requirement !!**

Analytic expressions for track parameter resolution

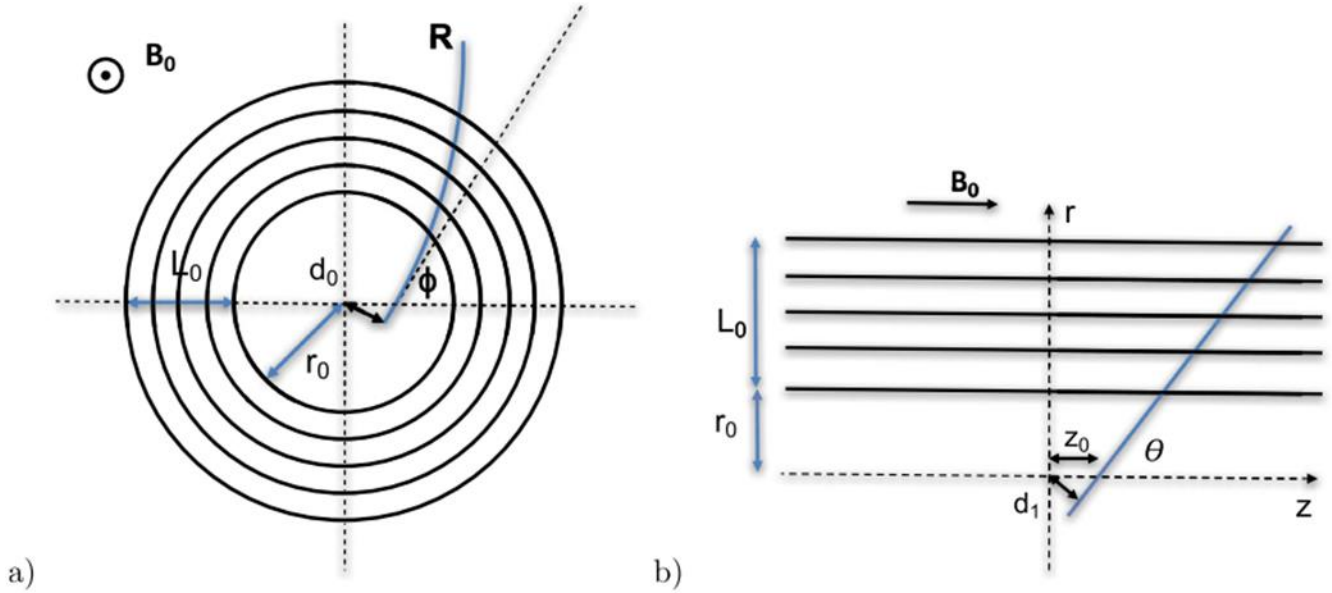
- By simulation
  - Very time consuming
- By analytic expressions
  - We need to know all the factors that affect the resolution
- Track model: $f(x) = \sum_i a_i g_i(x)$ with M unknow parameters
- N measurement y_n,
- The parameters a_i are estimated by

$$\chi^2 = \sum_{m=0}^{N}\sum_{n=0}^{N}\left[y_m - \sum_{i=0}^{M} a_i g_i(x_m)\right] W_{mn} \left[y_n - \sum_{i=0}^{M} a_i g_i(x_n)\right]$$

Track parameter

$$\chi^2 = (\mathbf{y} - \mathbf{Ga})^T \mathbf{W} (\mathbf{y} - \mathbf{Ga})$$

measurement



To minimise χ^2 we have to solve $\frac{\partial \chi^2}{\partial a_i} = 0$ which gives

$$\mathbf{a} = (\mathbf{G}^T \mathbf{W} \mathbf{G})^{-1} \mathbf{G}^T \mathbf{W}\, \mathbf{y} = \mathbf{B}\, \mathbf{y}$$

The error of a can be determined by the errors of y

$$\mathbf{C}_a = (\mathbf{G}^T \mathbf{C}_y^{-1} \mathbf{G})^{-1}$$

$\mathbf{C_y}$ is the covariance matrix of y

Analytic expressions for track parameter resolution

Input parameters for calculation:

- Momentum, Mass of track
- Number of sensitive layers and support layers
- Radius of the layers
- Material budgets of the layers
- Resolutions of r_phi and z direction for each layer
- magnetic field

Example:

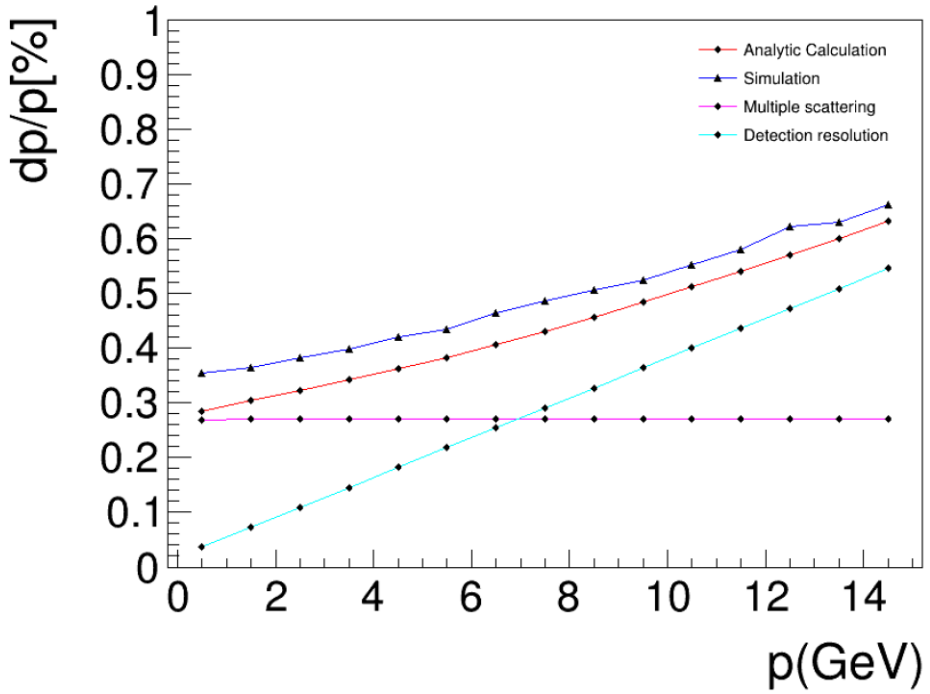
```
B, Theta = 1.5, pi/2.0

nl, sp = 11, 2

xlen = [0.0022, 0.00045, 0.00045, 0.00045, 0.00107, 0.0008, 0.0008,
        0.0040, 0.0040, 0.0040, 0.0040]
radi = [31.0,   33.0,    43.5,    54.0,    68.0,    80.,    150.,
        477.2,    495.7,   756.1,  774.6]
loc0 = [9.9, 0.010/3.464, 0.010/3.464,  0.010/3.464,  9.9,  0.010/3.464,  0.010/3.464,
        0.15/3.464,  0.15/3.464, 0.15/3.464, 0.15/3.464]
loc1 = [9.9, 0.010/3.464, 0.010/3.464,  0.010/3.464,  9.9,  0.010/3.464,  0.010/3.464,
        0.15/3.464,  0.15/3.464, 0.15/3.464, 0.15/3.464]
effi = [0., 1.,     1.,     1.,     0.,     1.,     1.,
        1.,     1.,     1.,     1.]
res  = resolution(1 , 0.106, nl, radi, xlen, effi, loc0, loc1, Theta, B, True, True, 1, sp)
```

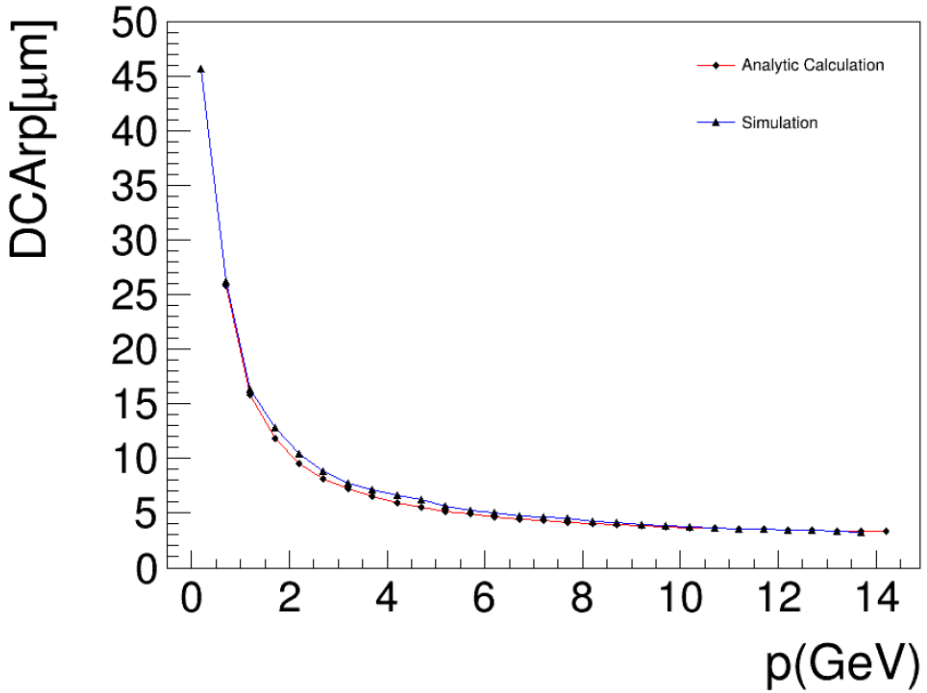
Comparison of dp/p vs pt

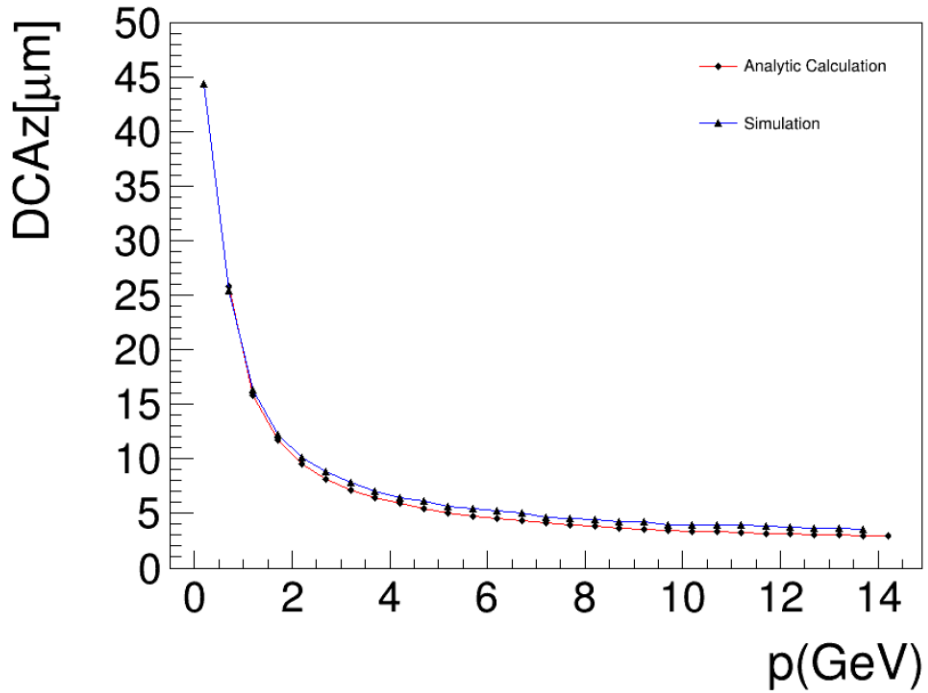
- Compare resolution from MC simulation and analytic calculation:



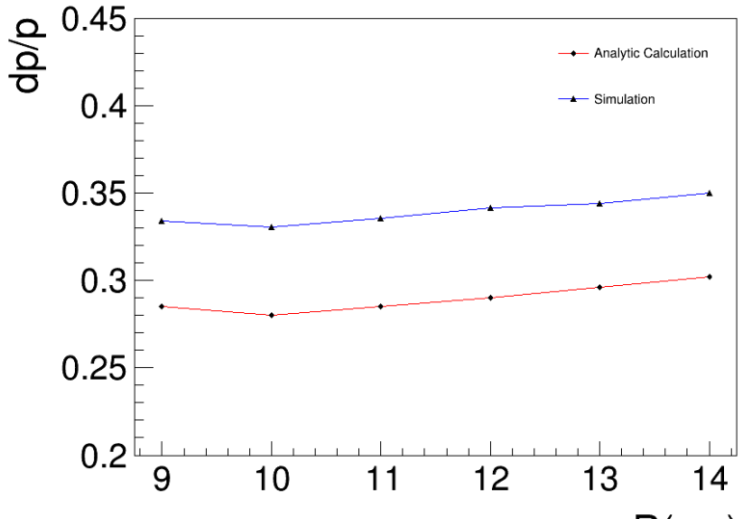
Two contributions: **detector resolution**, **multiple scattering**

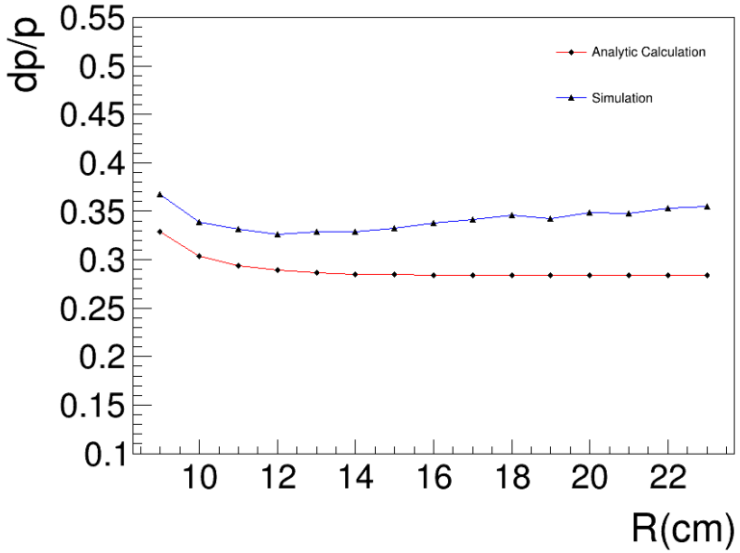
Comparison of DCArp and DCAz vs pt

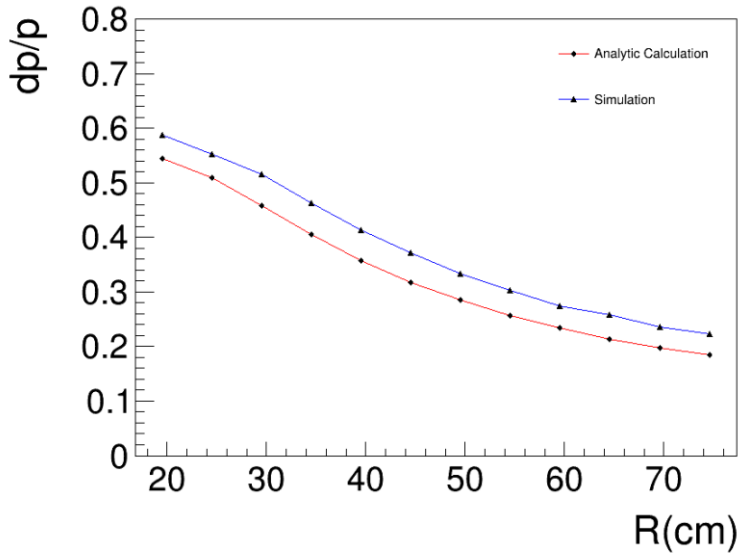


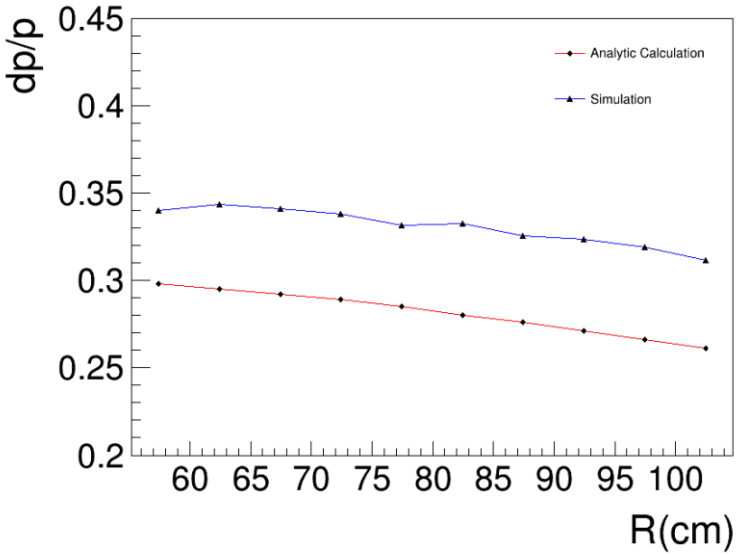


Comparison of dp/p vs Radius of layers

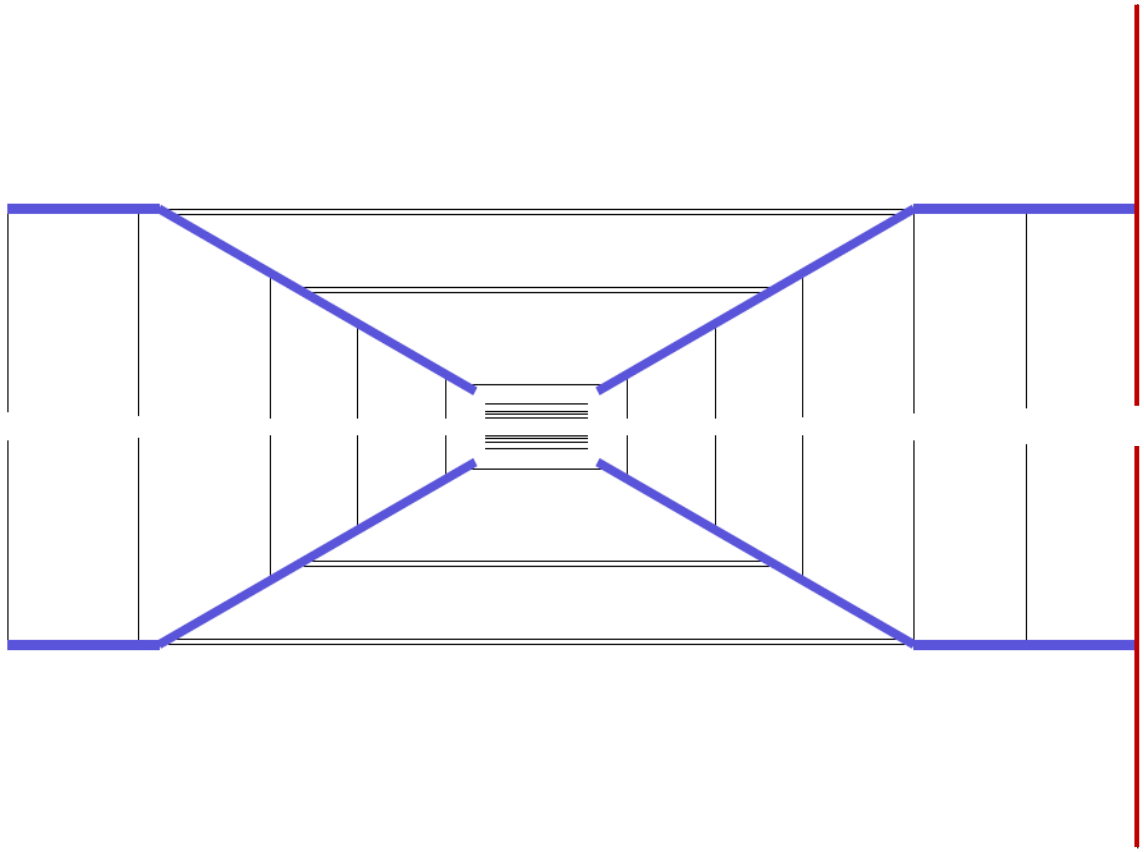








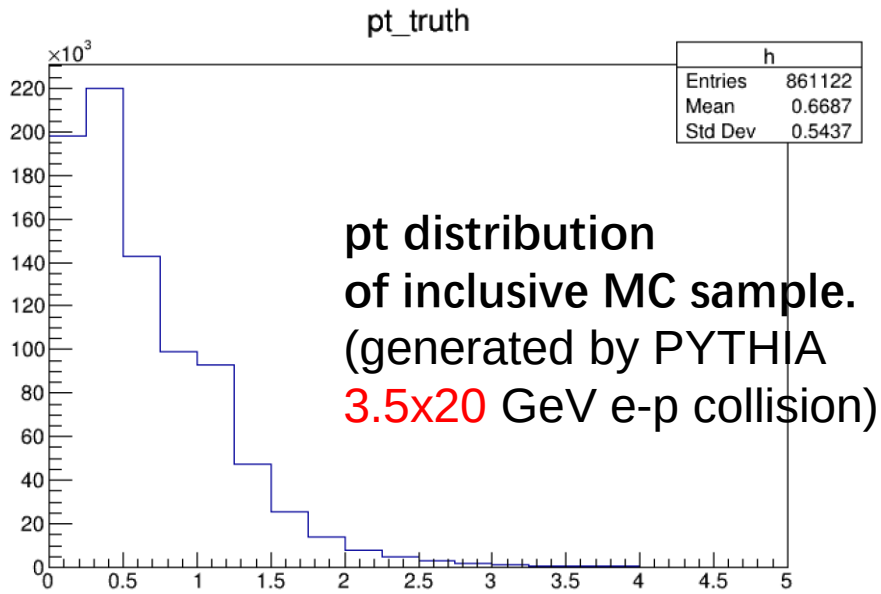
Optimization of the Radius of tracking detector



- **The scale and structure of the detector need dedicated optimization according to our physical requirement !!**

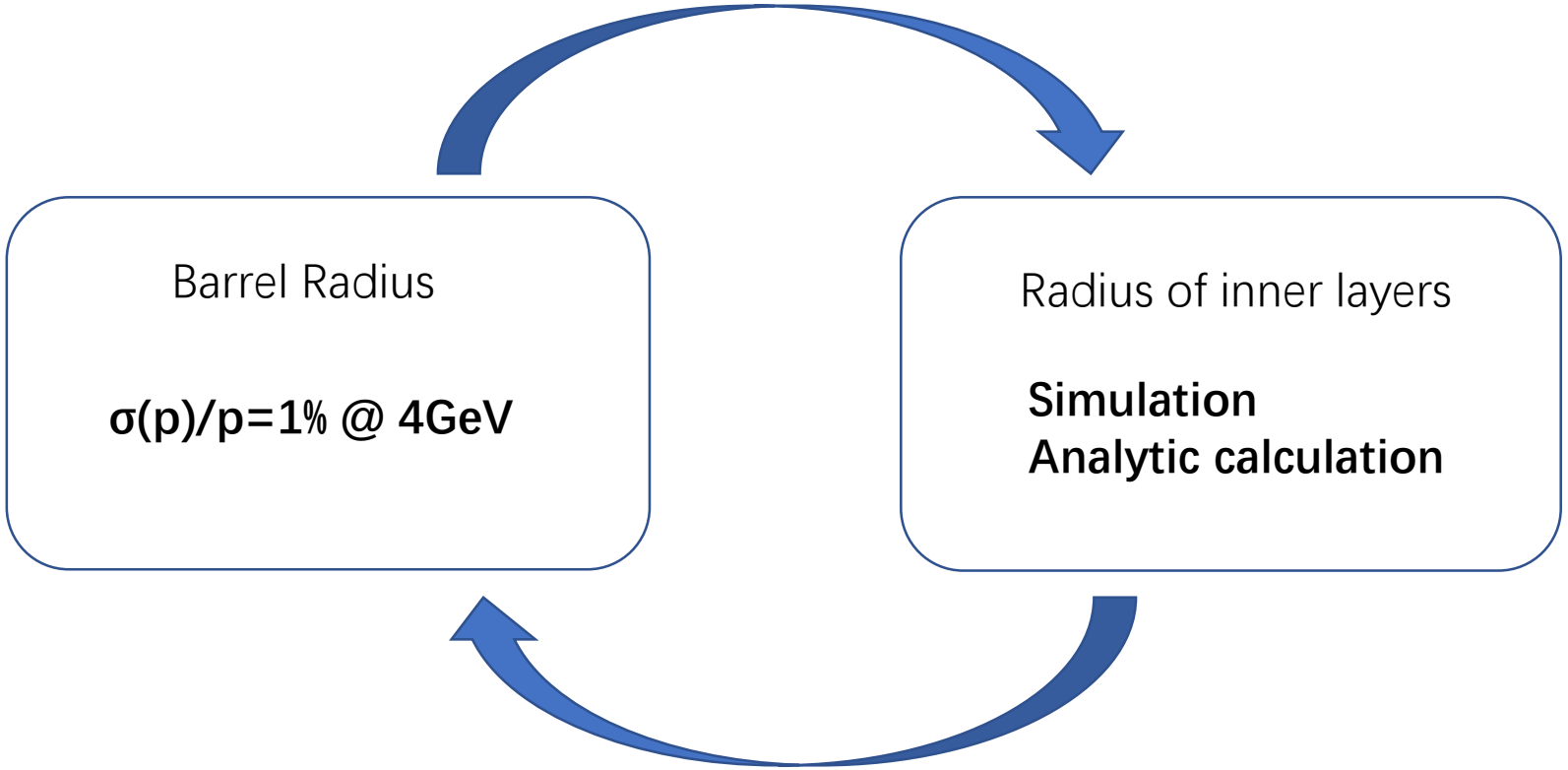
Physics requirements for EicC

- Barrel (-1 < η < 1.6):
  - σ(p)/p<1% @ 1GeV; X/X0 <5%



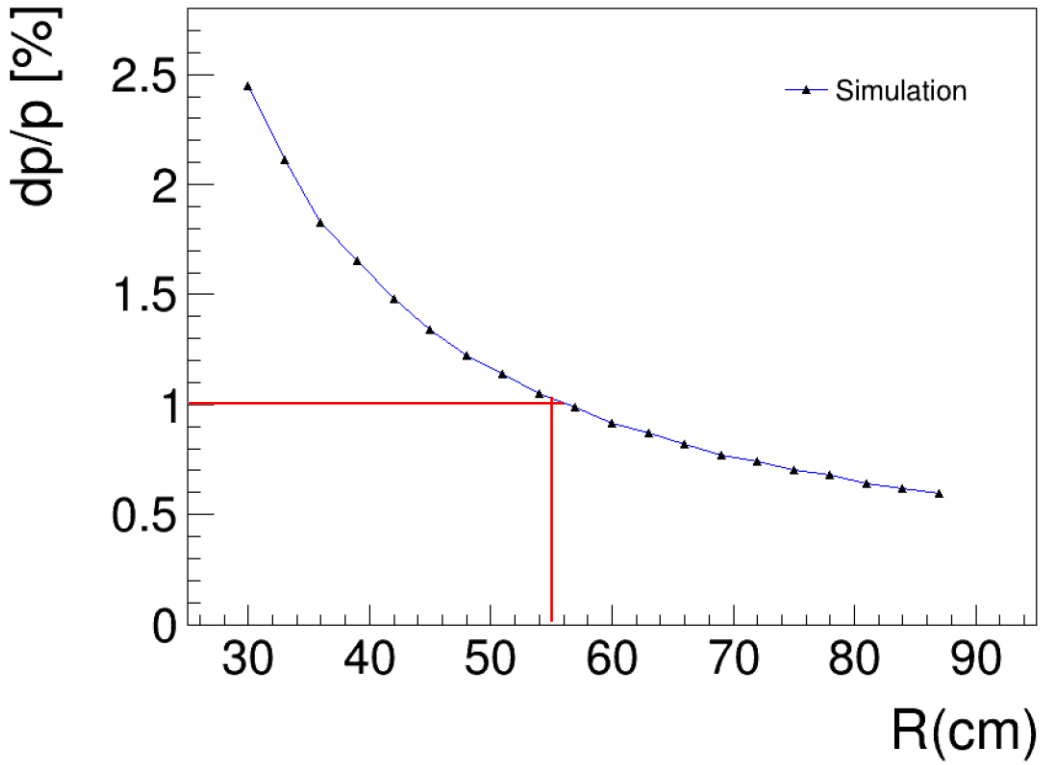
pt distribution of inclusive MC sample. (generated by PYTHIA 3.5x20 GeV e-p collision)

Optimization of the Barrel



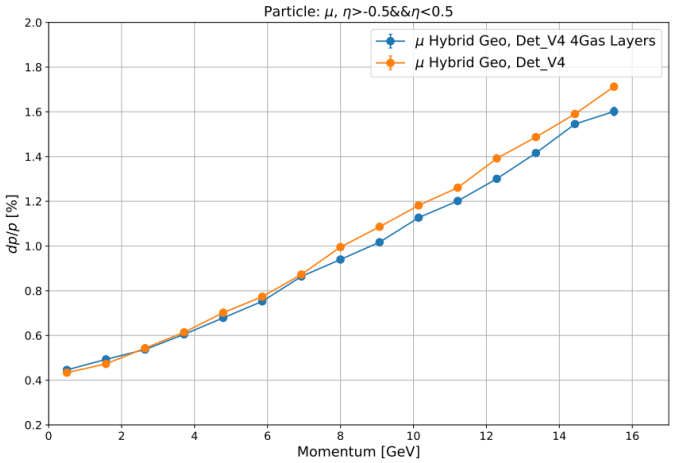
Barrel Radius

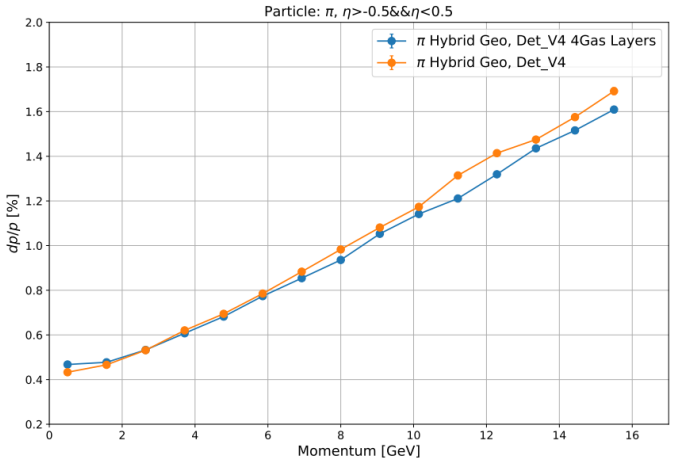
Optimized based on vertex(ITS3*3)+barrel(ITS2*2+MPGD*2), using tracks with pt = 4 GeV

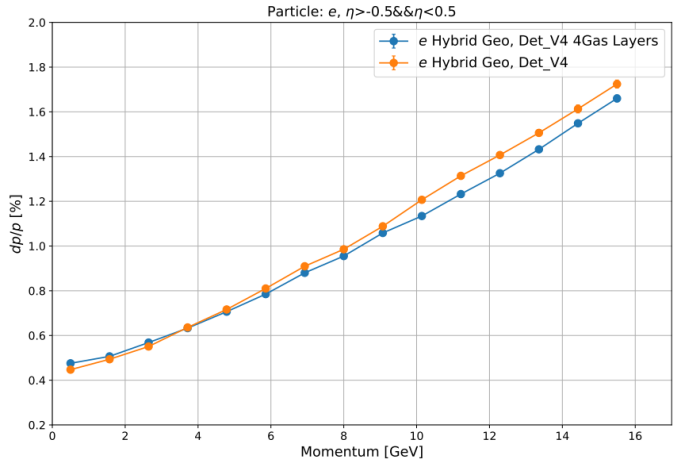


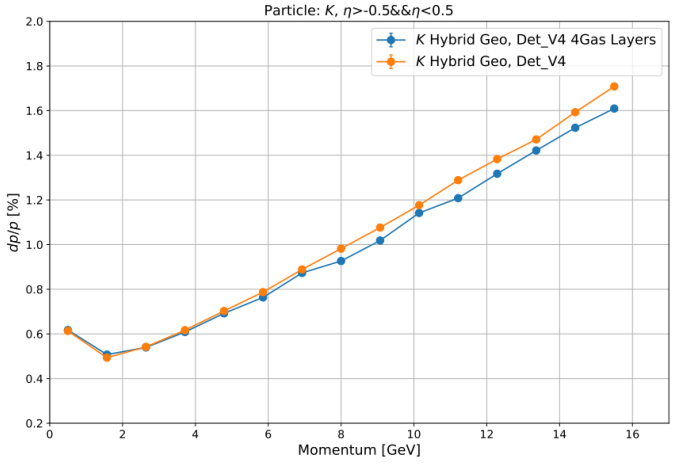
2 MPGD Layers vs. 4 MPGD Layers

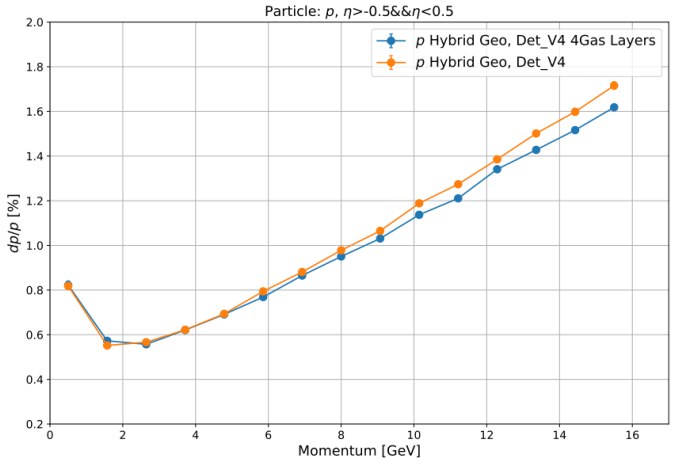
Performances are almost the same for tracks with p<4 GeV;





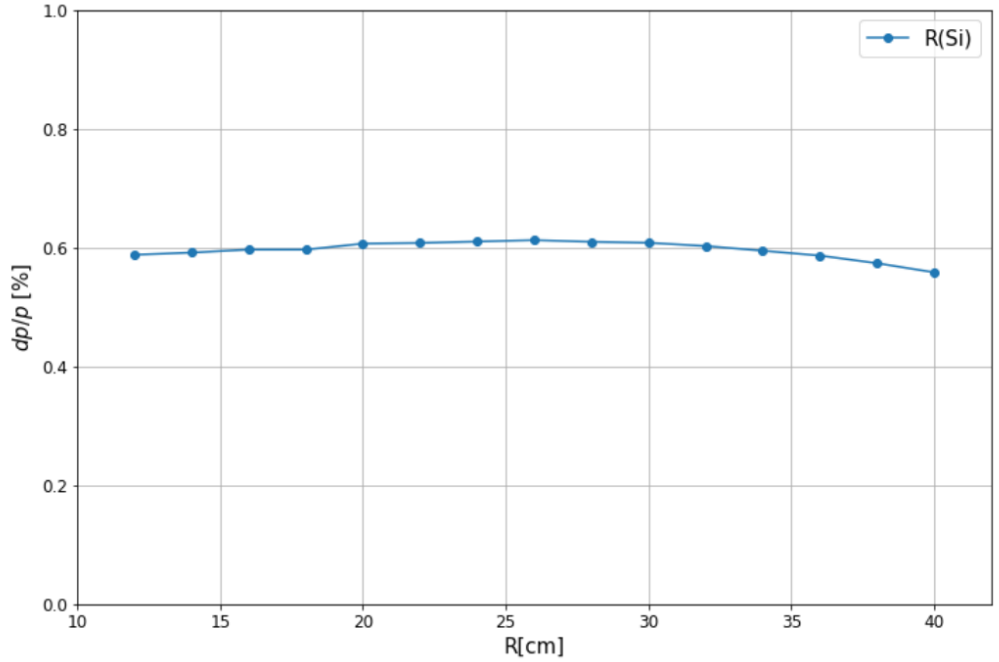






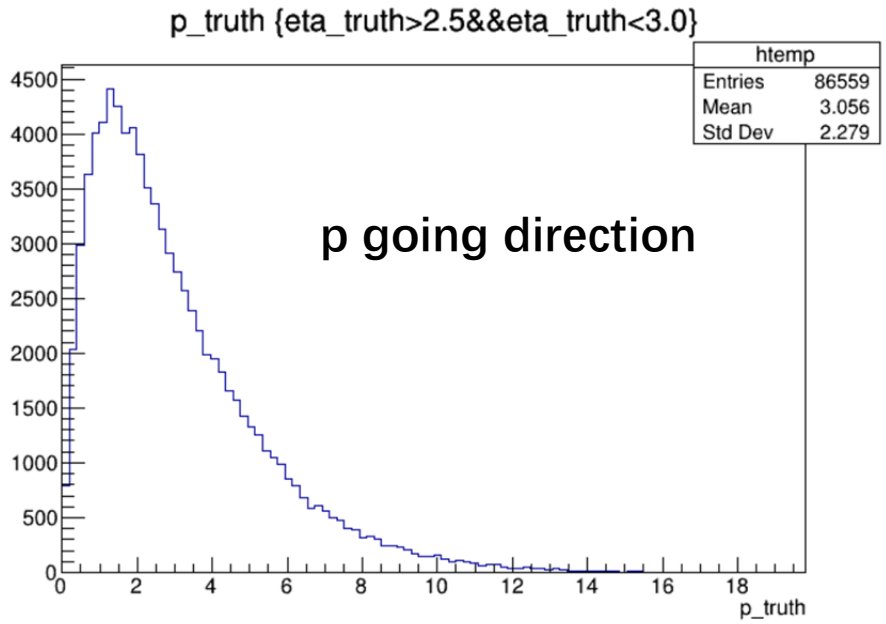
Radius of Si layers

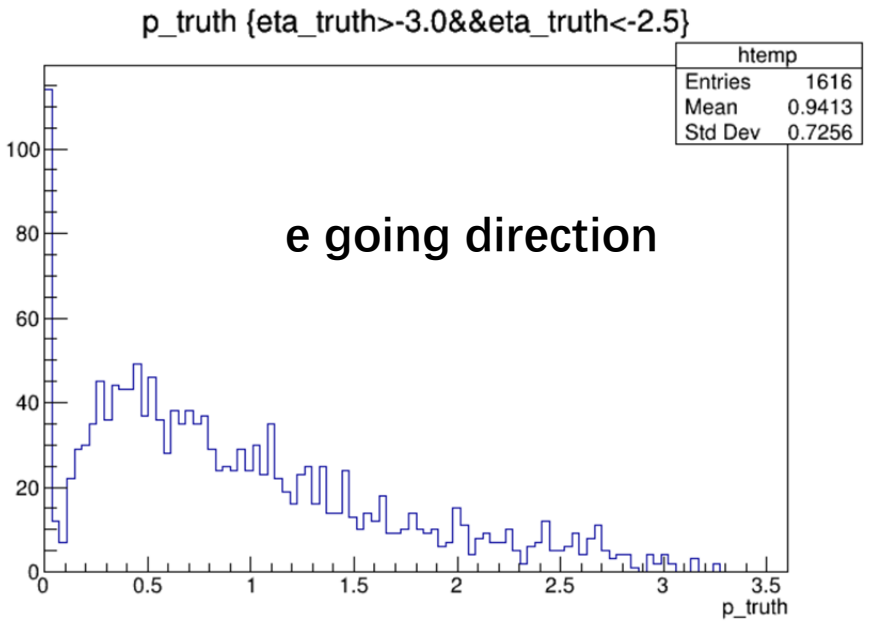
- Optimization with Inclusive MC
- The distance of 2 Si layers are fixed to 4 cm



Optimization of Endcaps

Momentum distribution of inclusive MC sample.
(generated by PYTHIA 3.5x20 GeV e-p collision)

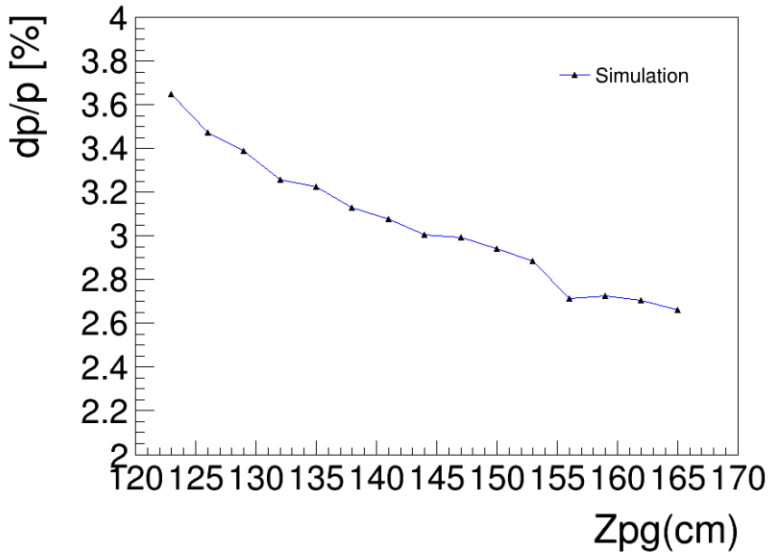




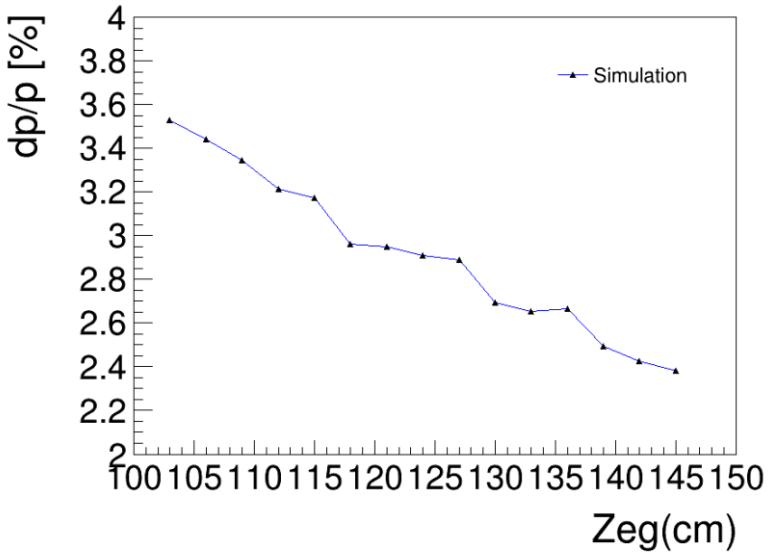
Optimization of Endcaps

Optimized based on: e going direction (ITS2*5)
p going direction (ITS2*5+MPGD*1)

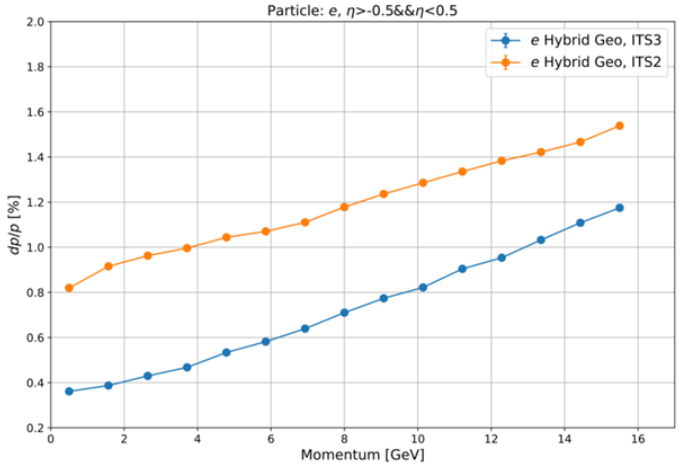
η[2.5, 3] p[8, 12]

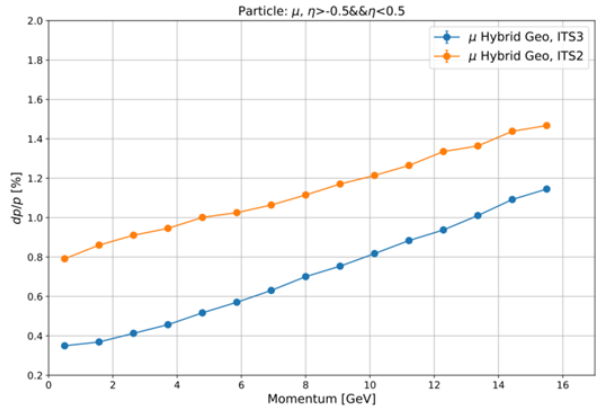


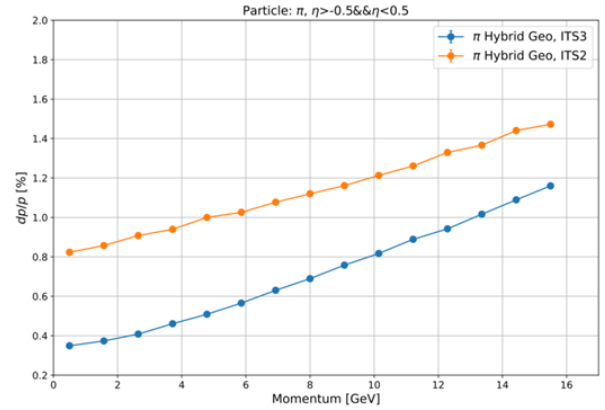
η[-3, -2.5] p[3, 5]

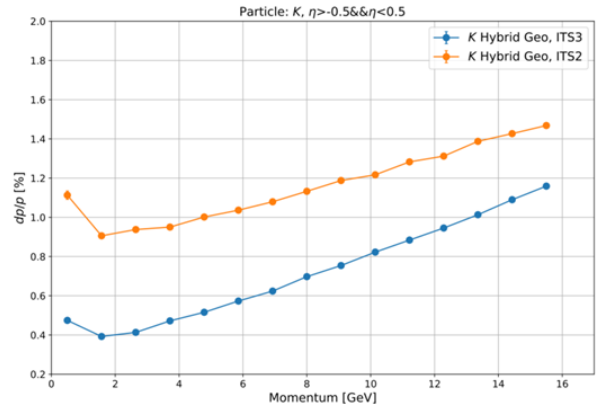


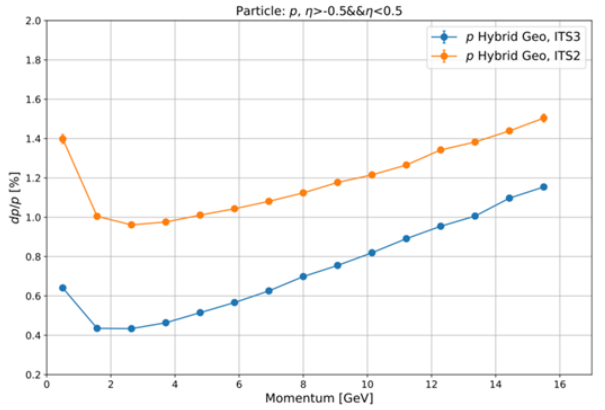
Performance ITS2 vs ITS3



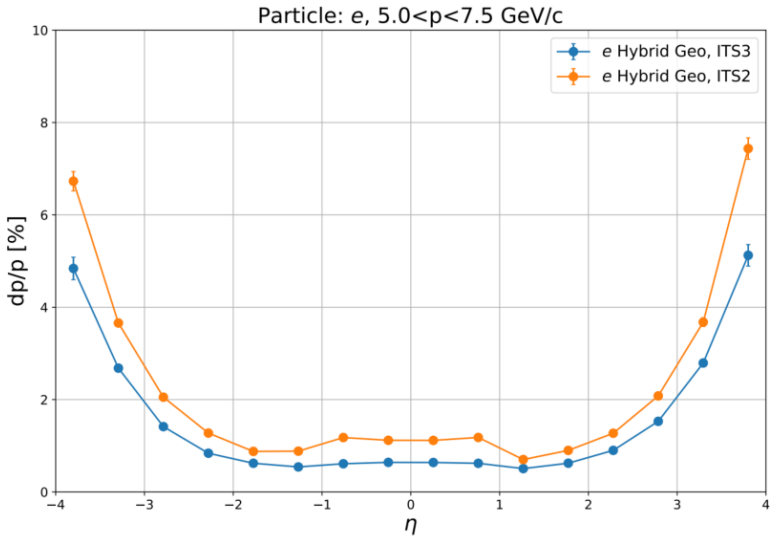


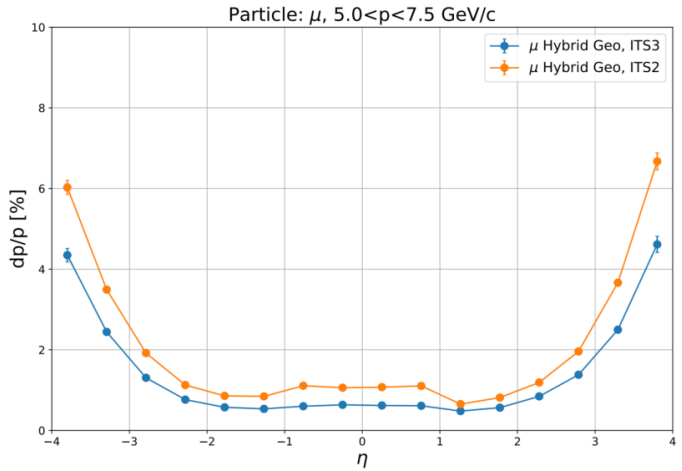


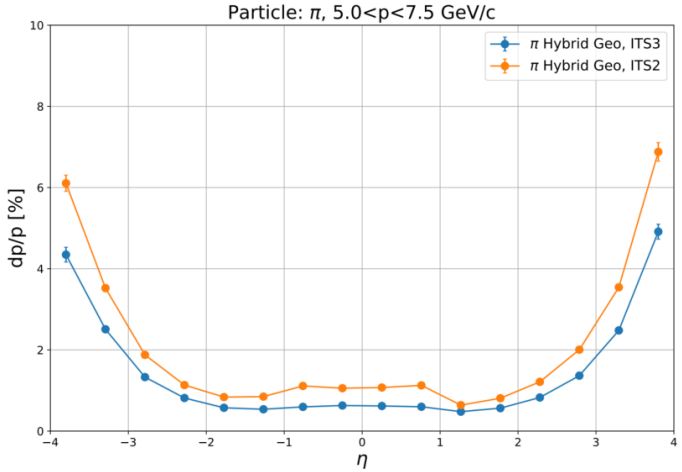


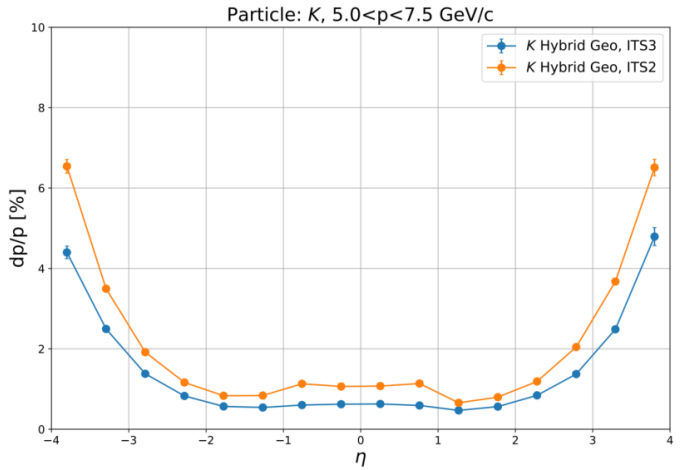


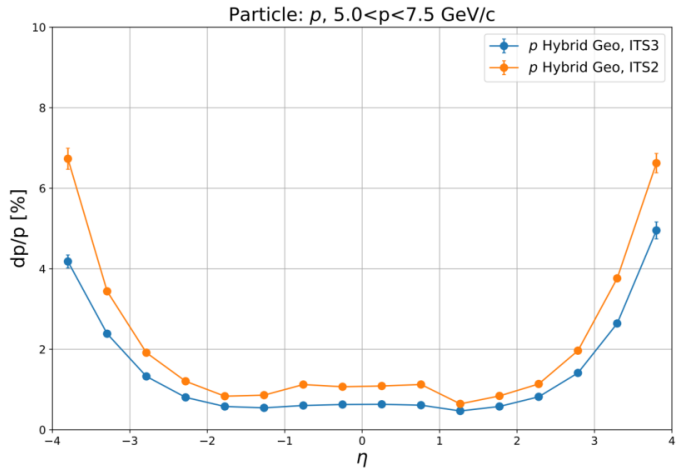
Performance ITS2 vs ITS3



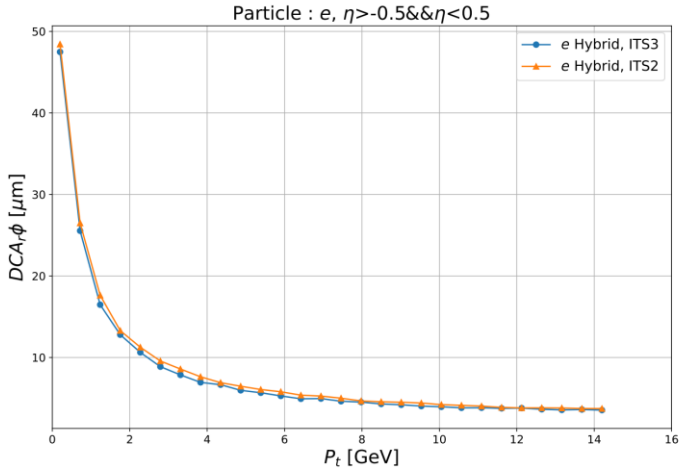


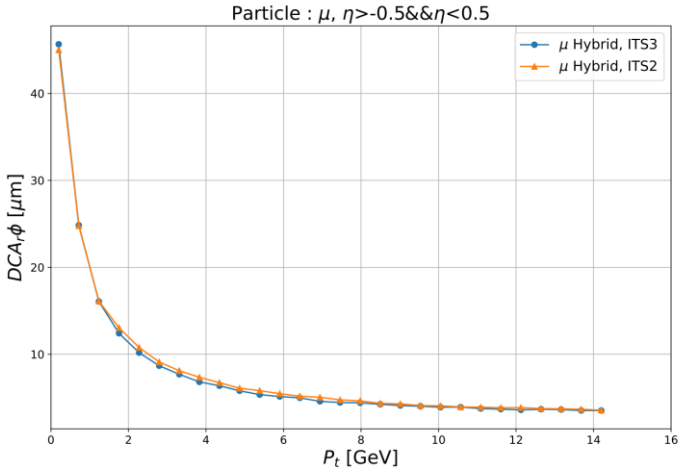


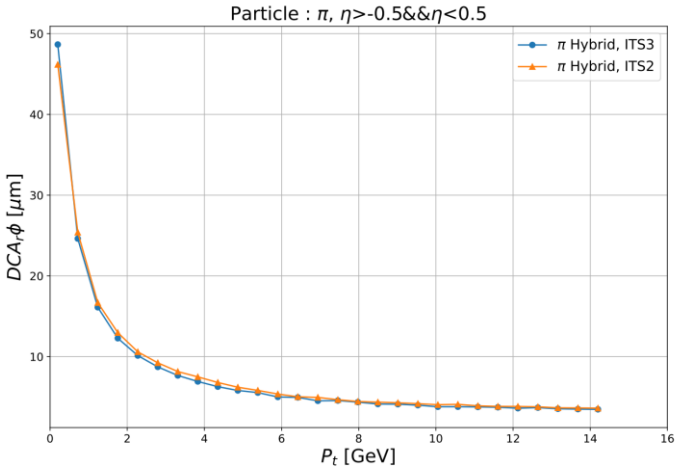


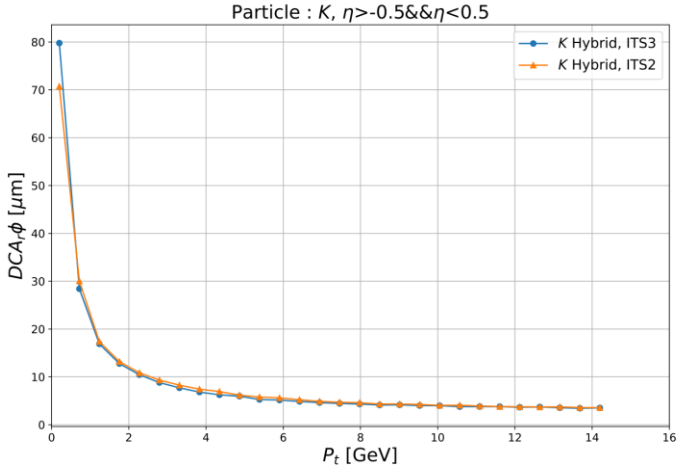


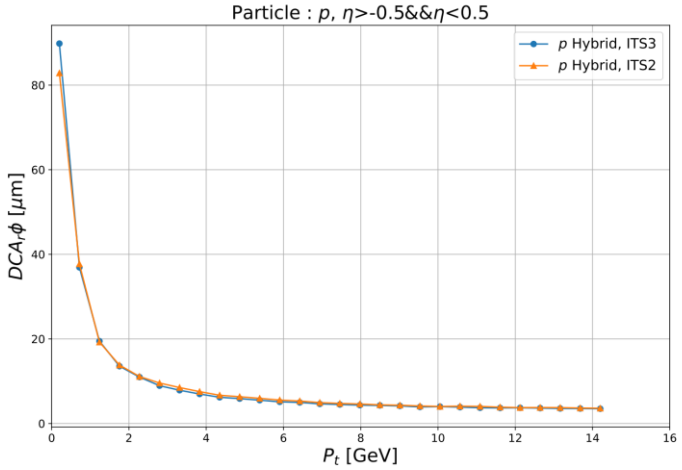
Performance ITS2 vs ITS3



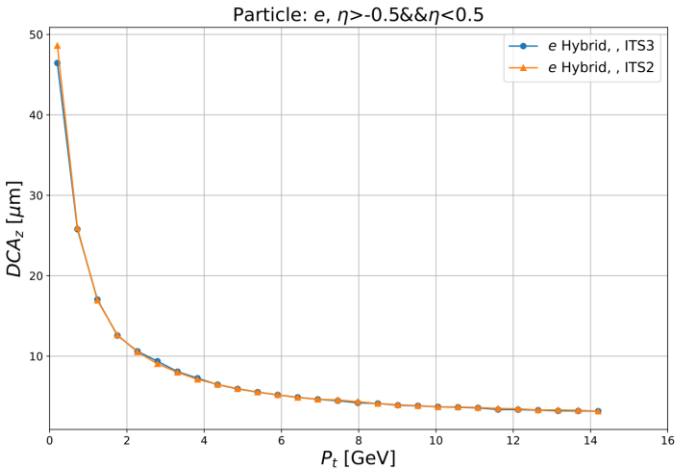


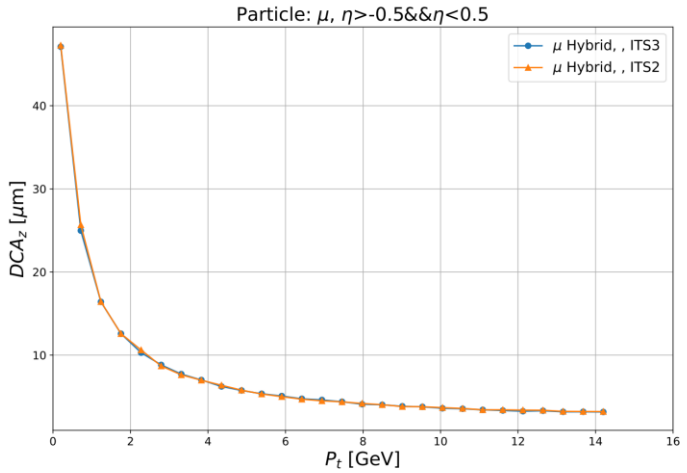


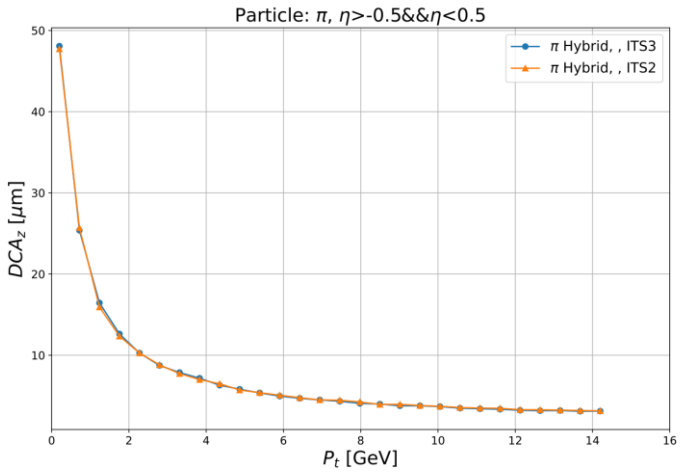


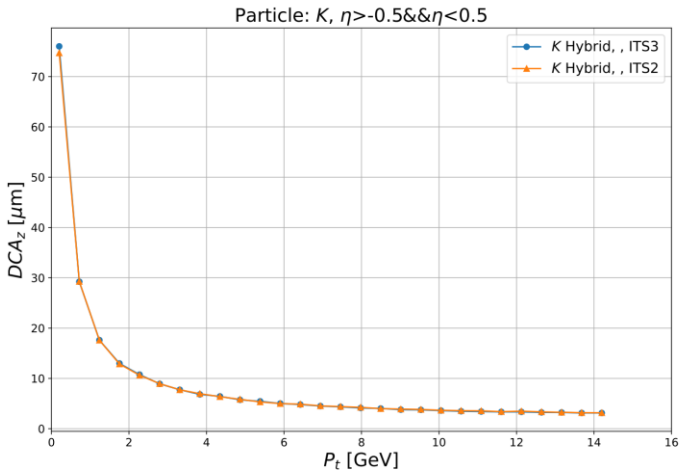


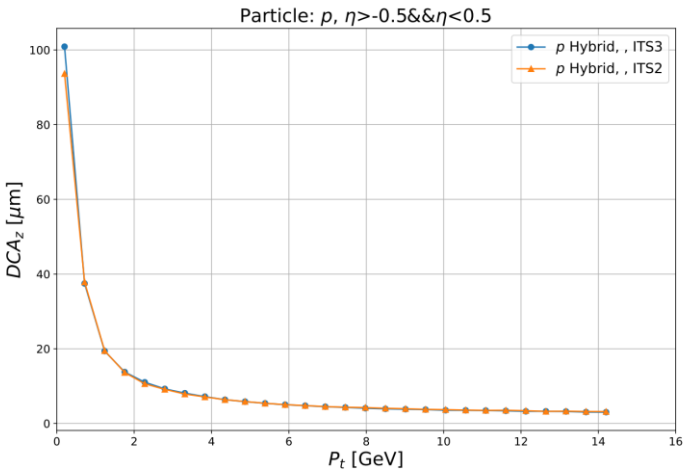
Performance ITS2 vs ITS3



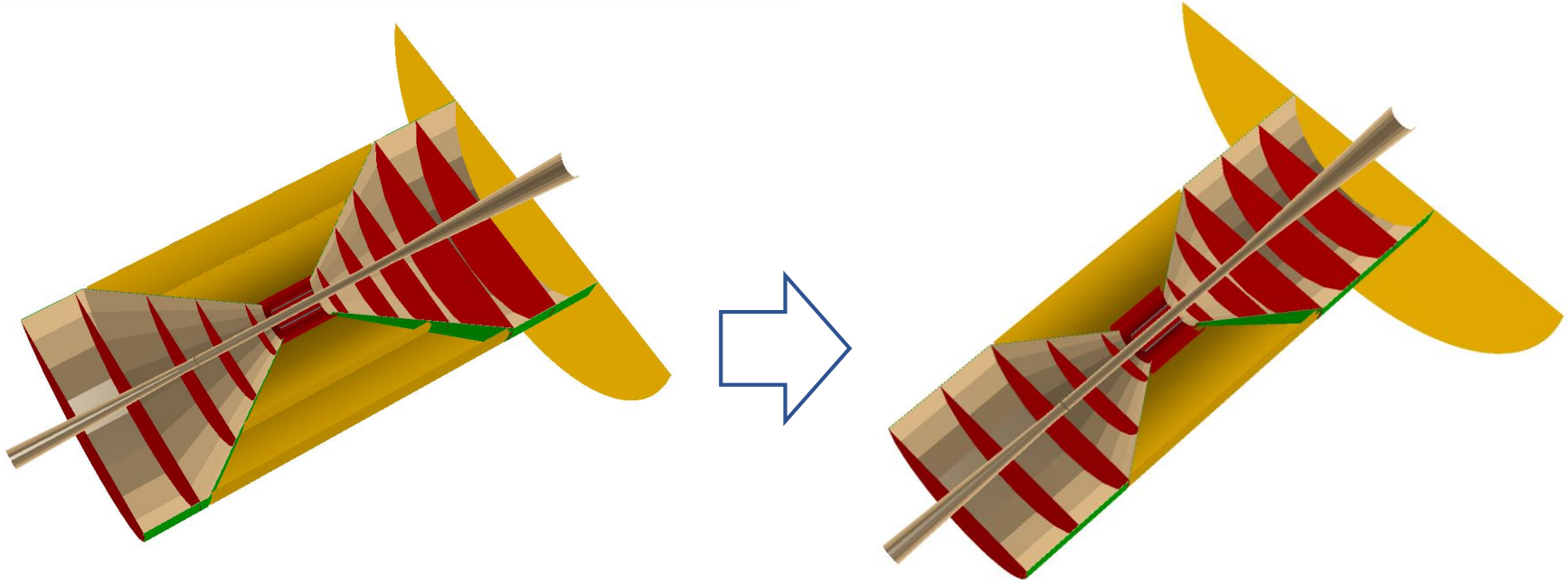








Summary



Radius of Barrel: 77.56 cm -> 55 cm
Barrel MPGD : 4 Layers -> 2 Layers
The size of Si: ~70%
The size of MPDG: ~35%