The Optimization of CEPC DC volume

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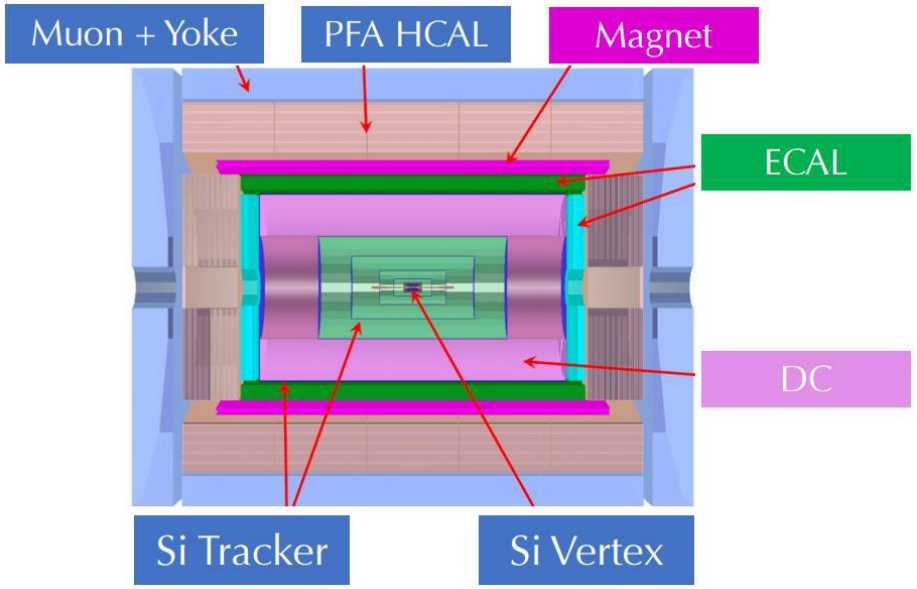
on behalf of the CEPC tracker optimization team

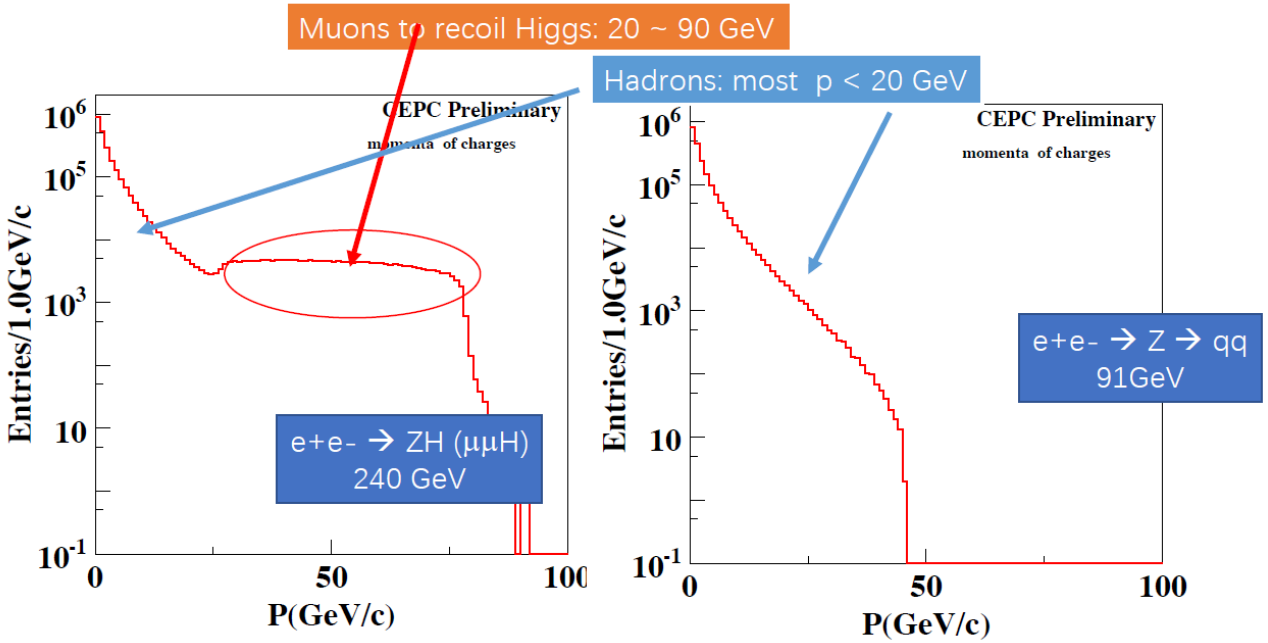
Physics and Detector Plenary Meeting
June 15th, 2022

Introduction

The 4th CEPC conceptual detector



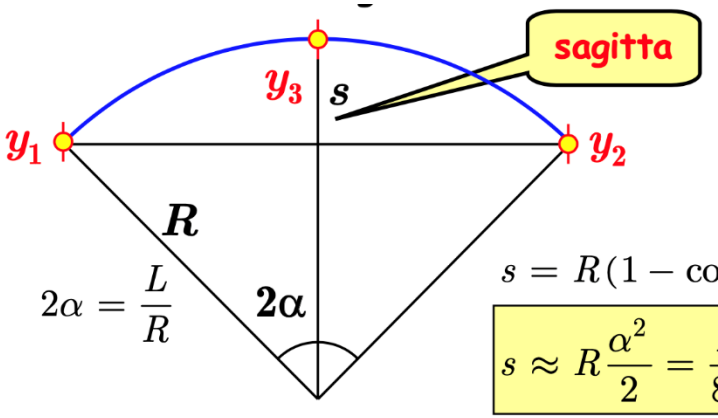
Momenta of tracks @ 240 & 91 GeV



- Tracking system consists with a silicon pixel vertex detector(VXD), a silicon tracker (SIT and SET) of HV-CMOS, and a drift chamber(DC)
  - Particle ID with a drift chamber is a key feature for the 4th conceptual detector
  - Most hadrons (K/pi) of CEPC are below 20 GeV/c
  - The tracker must have sufficient good momentum resolution for tracks < 20 GeV/c (flavor and jet study)
  - VXD has already been optimized by Zeng Hao

Momentum error-Sagitta measurement without multiple scattering

$$\frac{\delta p}{p} = \frac{8p\sigma_{r\emptyset}}{0.3BL^2}$$



$$s = R(1-\cos\alpha)$$

$$s \approx R\frac{\alpha^2}{2} = \frac{L^2}{8R}$$

If α is small

$$s = y_3 - \frac{y_1 + y_2}{2}$$

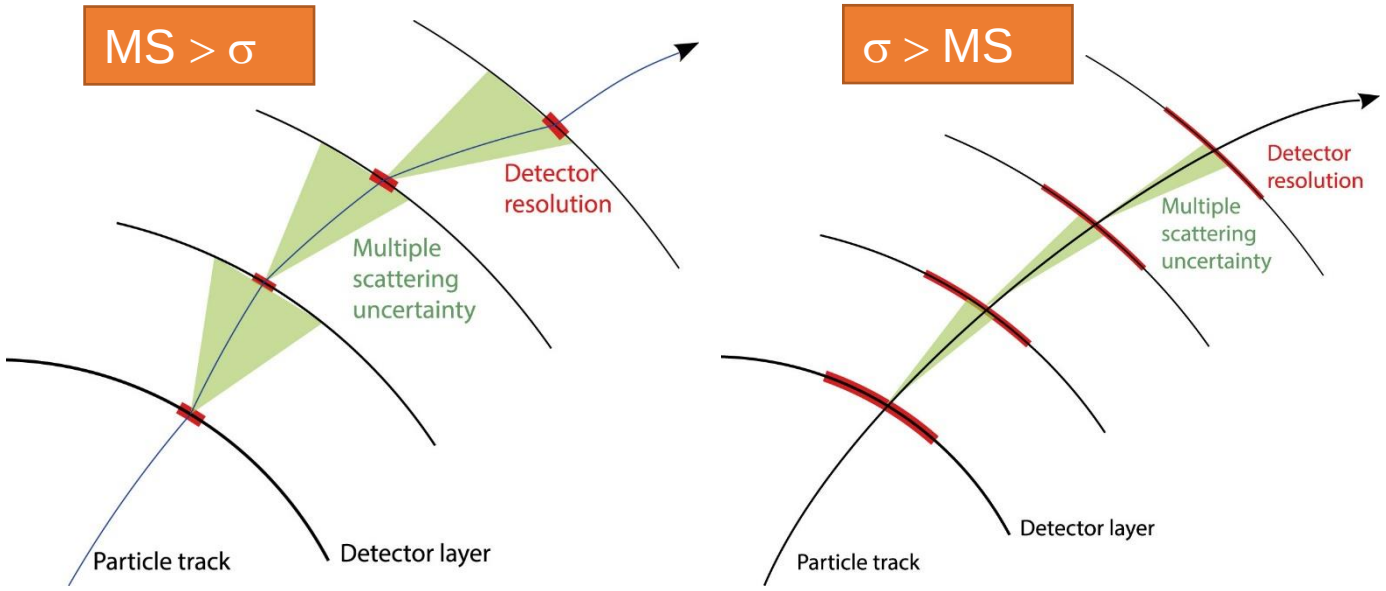
$$\delta s = \delta y_3 - \frac{1}{2}\delta y_1 - \frac{1}{2}\delta y_2$$

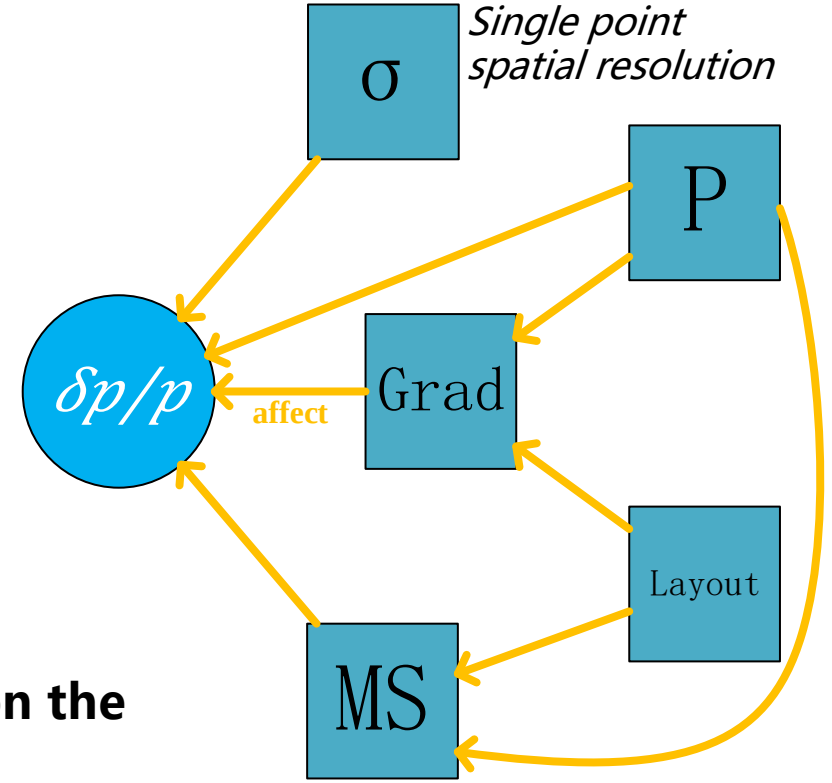
Important features

- ✓ **the percentage error is proportional to the p itself**
- ✓ **the error is inversely proportional to *B***
- ✓ **the error is inversely proportional to $1/L^2$**
- ✓ **the error is proportional to spatial resolution**

- **Necessary to have more measurements at the middle for better resolution**
- **The optimal allocation of measurements is 1:2:1**

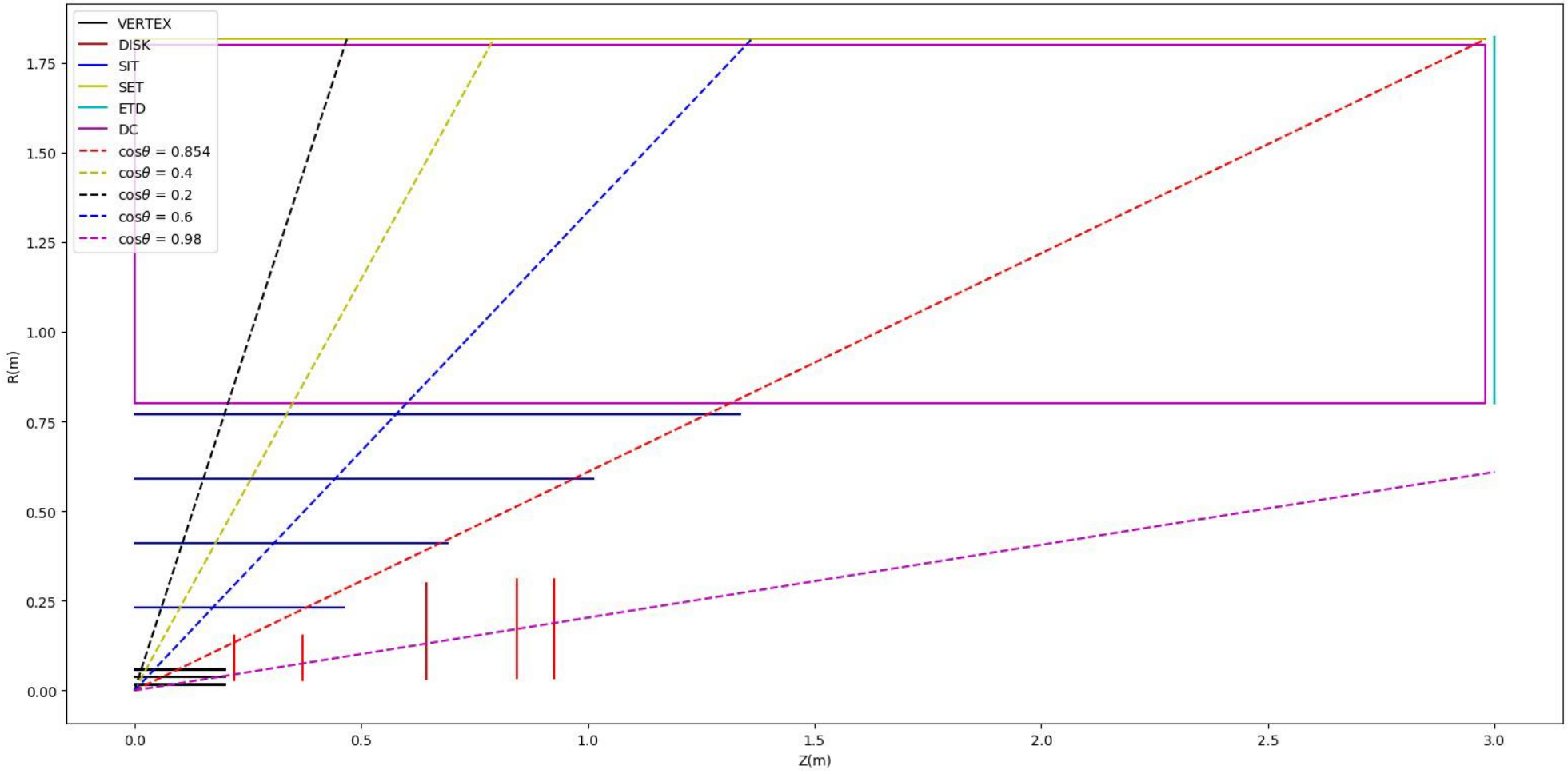
Momentum error with multiple scattering





- **It is found to be complicated, when considering more factors on the momentum measurement.**
- **The left figures indicate that the MS affect the tracks, and the MS was influenced by the amount of materials, layout, momentum, and so on**
- **There are quite a few factors affect the momentum measurement, the relationships among them are shown in the right**

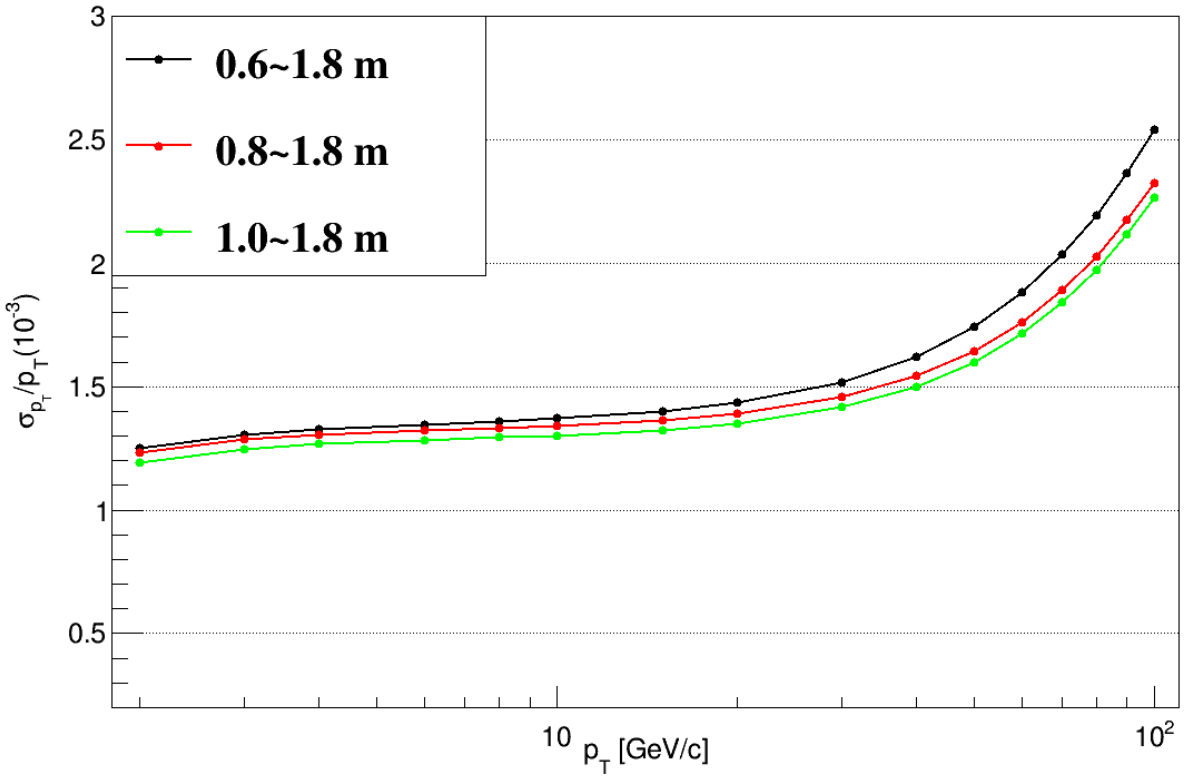
Preliminary layout: DC ~ 800 - 1800 mm



Tools

- Two fast tools
  - ✓Analytic calculation based on python developed by Gang Li et al
  - ✓LDT: a matlab fast simulation package developed by Wiener group
- Full simulation implemented in CEPCSW, reconstructed by
  - ✓GenFit: developed by Yao Zhang et al
  - ✓MarlinTrk: ILCSoft tracking maintained by Chengdong Fu

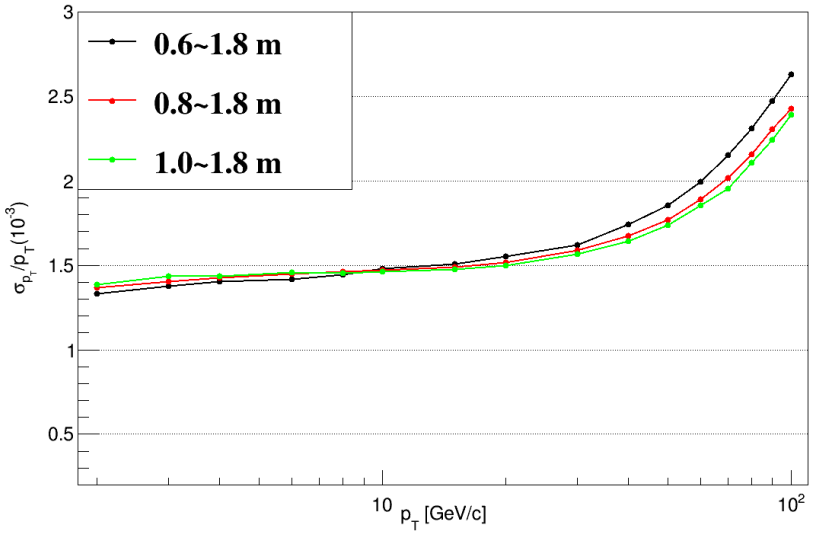
Validation: Analytic calculation comparison w/o DC hits



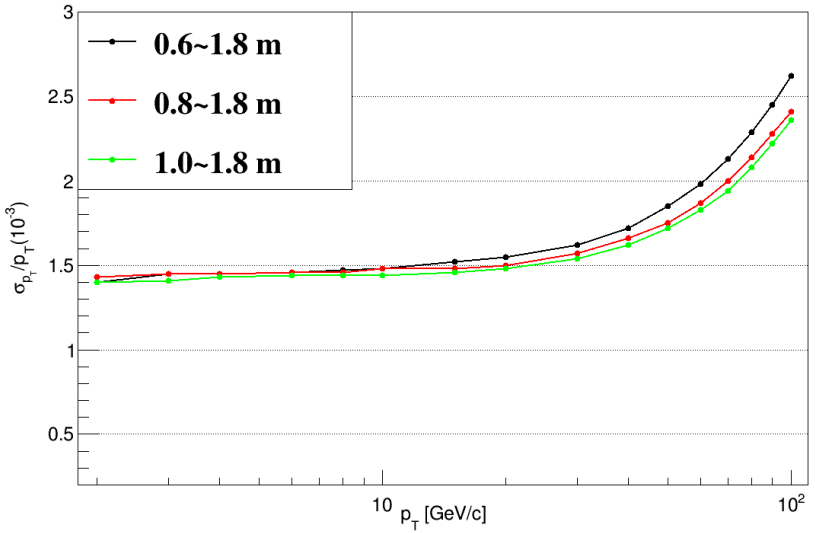
- The three lines has a small difference without DC hits but with DC materials
- SIT's location has a small effect on momentum measurement
- DC = 1.0-1.8m is better

Validation: GenFit and MarlinTrk, w/o DC Hits

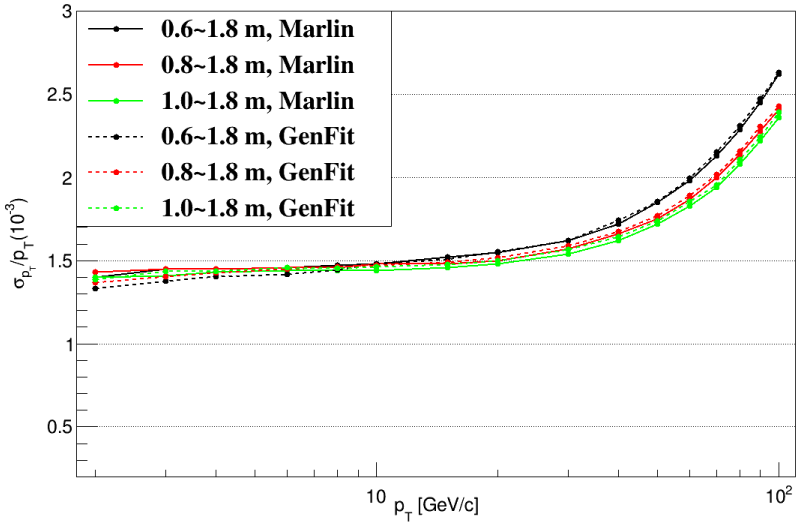
GenFit:



Marlin:

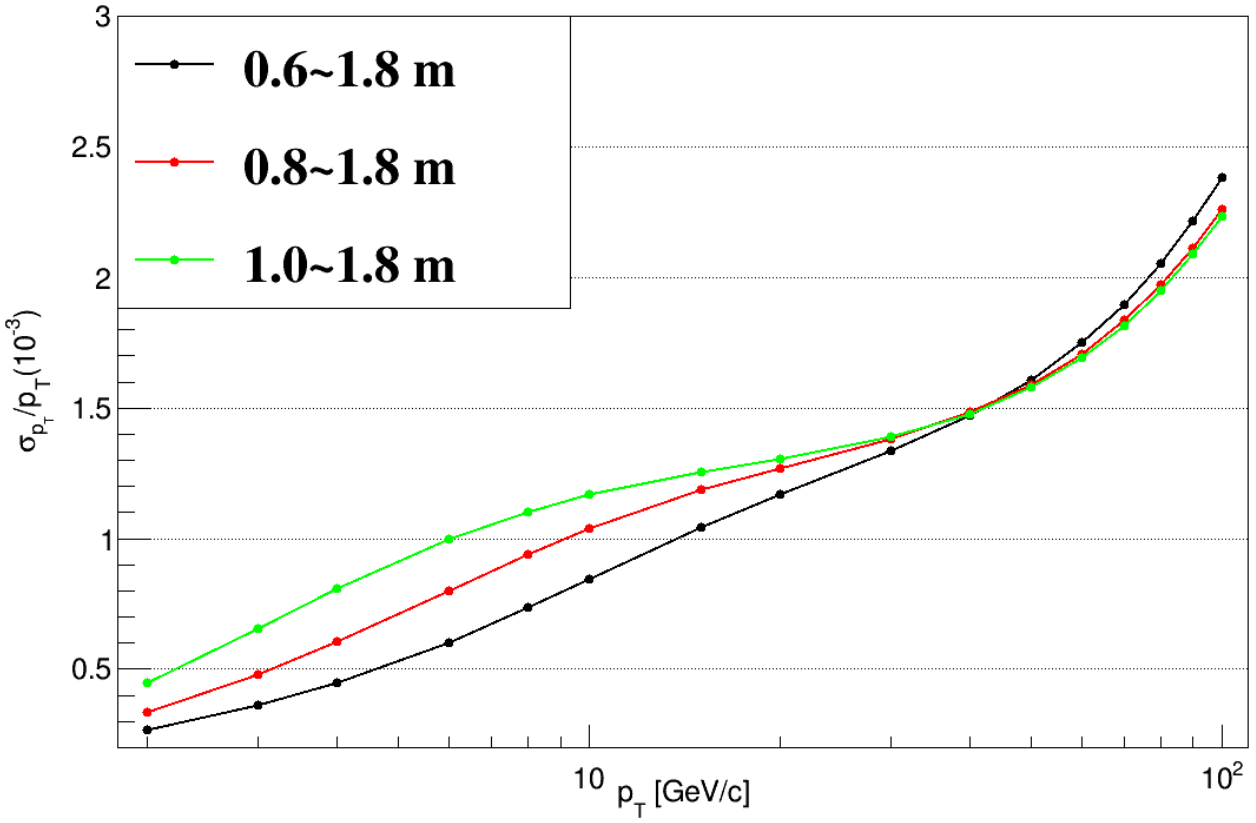


Comparison:



- The results are very similar when we don't use the DC hits,
- There are a little differences between these two, especially at low momentum

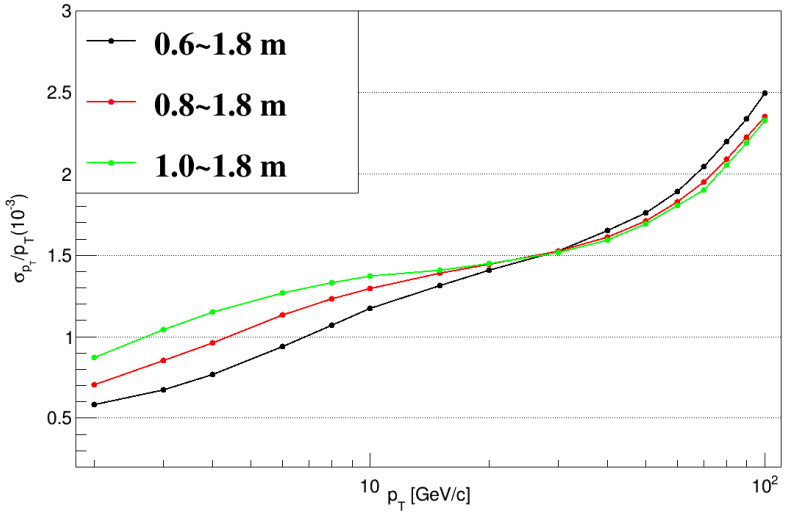
Validation: Analytic calculation with DC hits



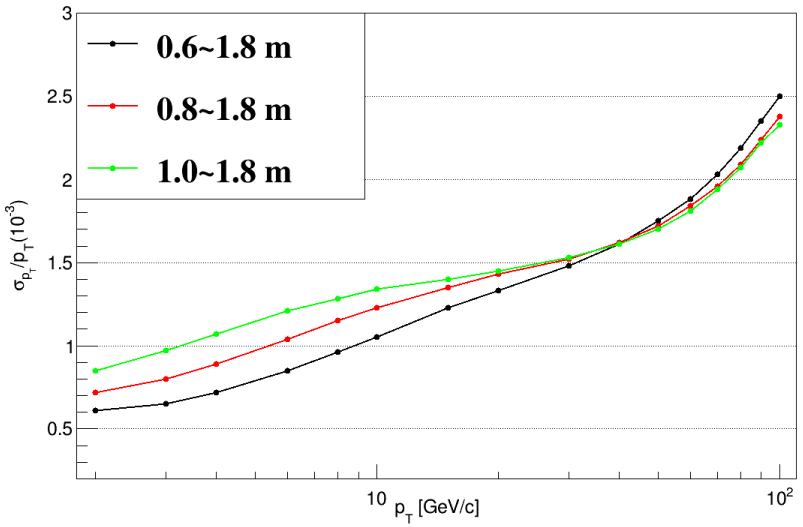
- The difference becomes **more significant** when DC Hits are used, in particular at low momentum
- DC = 0.6-1.8m is better for tracks < 40 GeV/c

Validation: GenFit and MarlinTrk , with DC Hits

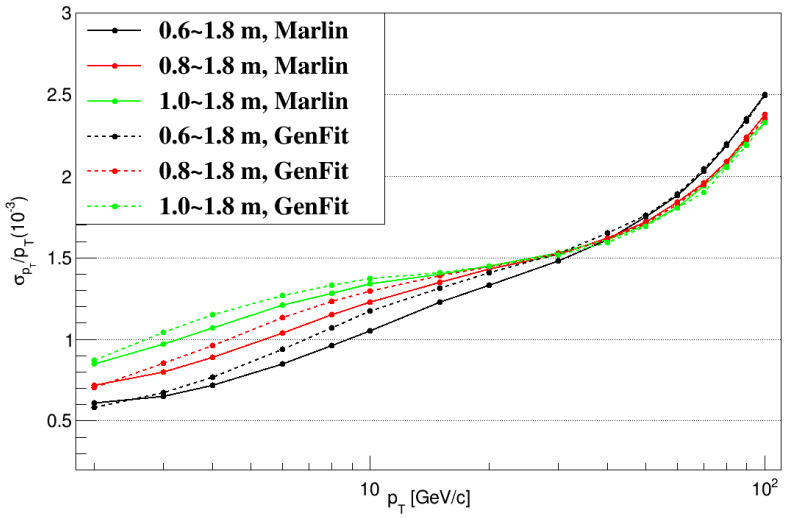
GenFit:



Marlin:



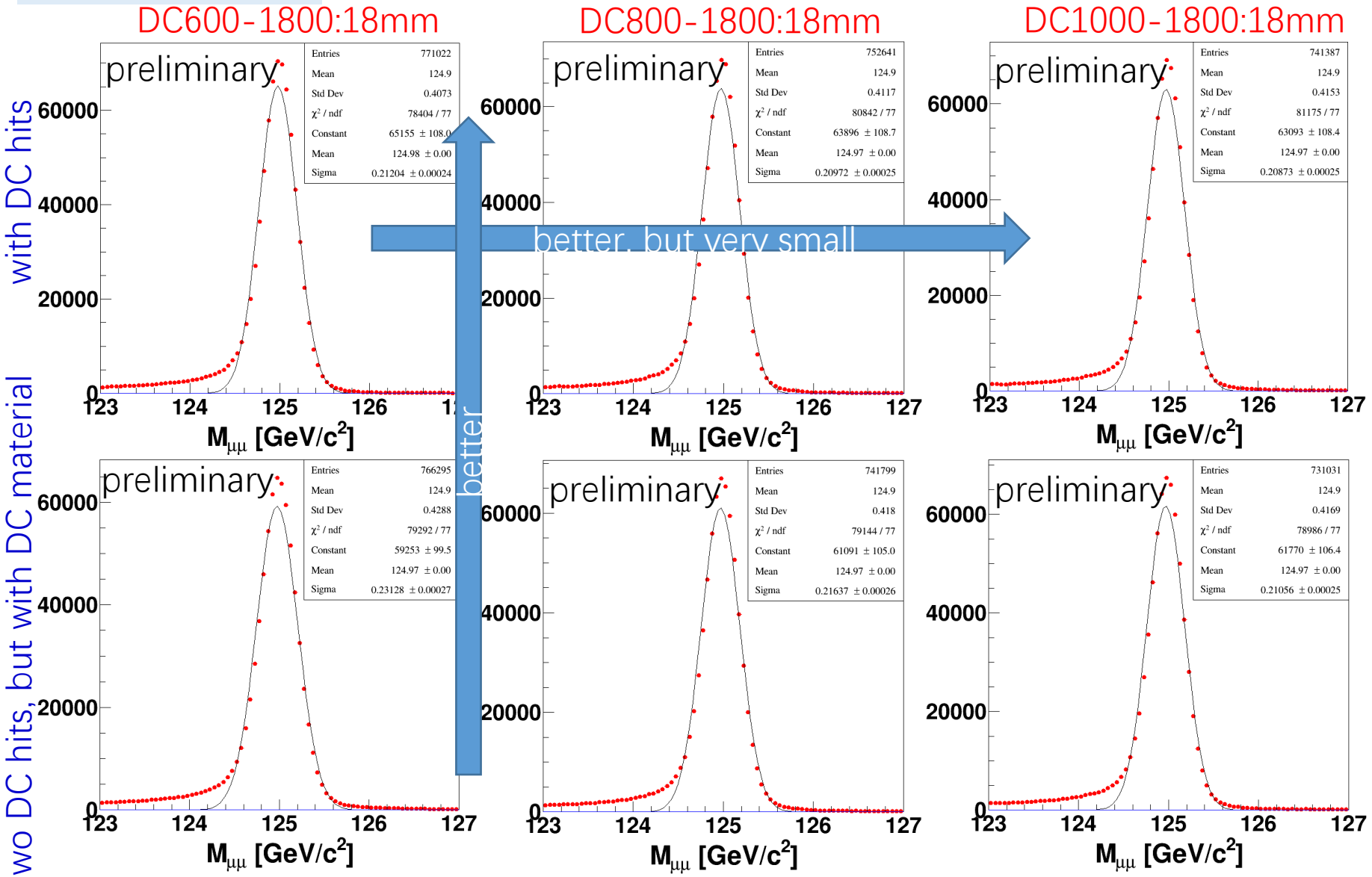
Comparison:



- When the DC hits used, the trends of two reconstructions consistent
- Even there still some differences at low momentum
- Same conclusion: DC = 0.6-1.8m is better for tracks < 40 GeV/c

Resolution of Higgs Mass (H→μμ)

Rough gaussian fit



Resolution of Higgs Mass (H→μμ)

DC volume	0.6-1.8(m)	0.8-1.8(m)	1.0-1.8(m)
w/ DCHits(GeV)	0.212	0.210	0.209
w/o DCHits(GeV)	0.231	0.216	0.211

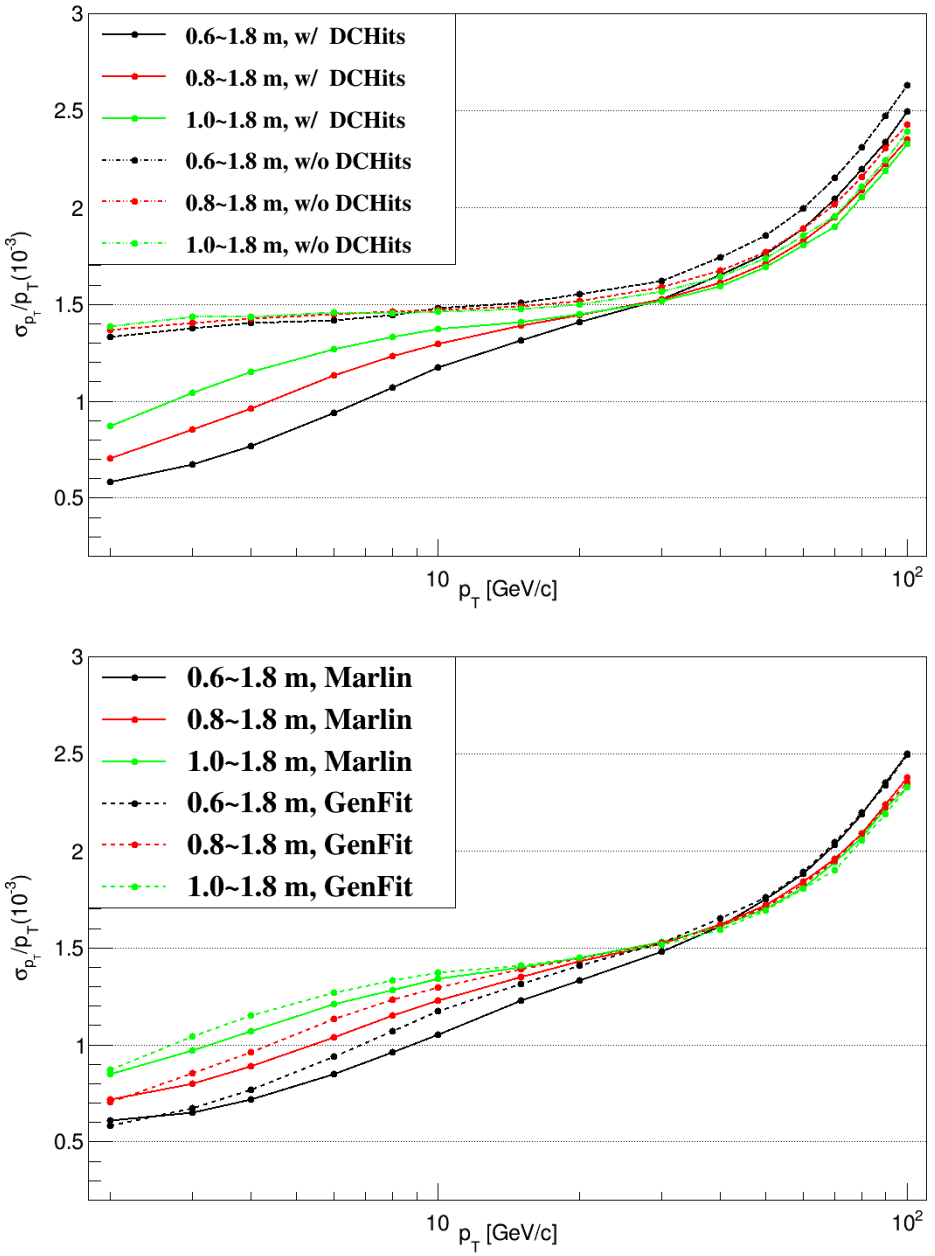
- For Higgs physics(at high momentum), the DC volume has little effect on momentum measurement
- Using DC will significantly improve higgs momentum measurement

Comments on tools

- Good agreement between AnaCalc & LDT
- Good agreement between GenFit and MarlinTrk w/o DC measurement
- Rough agreement between GenFit and MarlinTrks w/ DC measurement
- **All trends of different tools are consistent**

Conclusion & discussion

- DC useful for momentum measurement
  - Shapes and trends are constantly consistent for all results
  - More consistent results of different methods need more tuning
- Larger DC favored by low momentum (<20 GeV) tracks
- Larger DC also benefits PID



Backup

1.4 Tracker parameters （-1800）

Components	Radius(mm)	$\sigma_{R\phi}$(μm)	σ_Z(μm)	Thickness(X_0 %)
Beam Pipe	10.35	-	-	0.172
VTX	12.3/14.4/35.5/37.5/58.3/60.3	2.8/6/4/4/4/4	2.8/6/4/4/4/4	0.156/0.156/0.154/0.154/0.153/0.153#
VTX-shell	65.245	-	-	0.139
SITs	81.5/332.2/582.7; 81.5/430.9/780.6; 81.5/520.8/920.5;	7.2/7.2/7.2	86.6/86.6/86.6	0.661/0.651/0.650#
DC inner wall	611.9;809.9;989.9	-	-	0.110
DC cell (66;55;45 x18x18mm)	612;810;990-1800	100	2828	0.00127×layernum##
DC outer wall	1801.93	-	-	1.349
SET	1811.3	7.2	86.6	**0.182***
TotalAir				0.262**

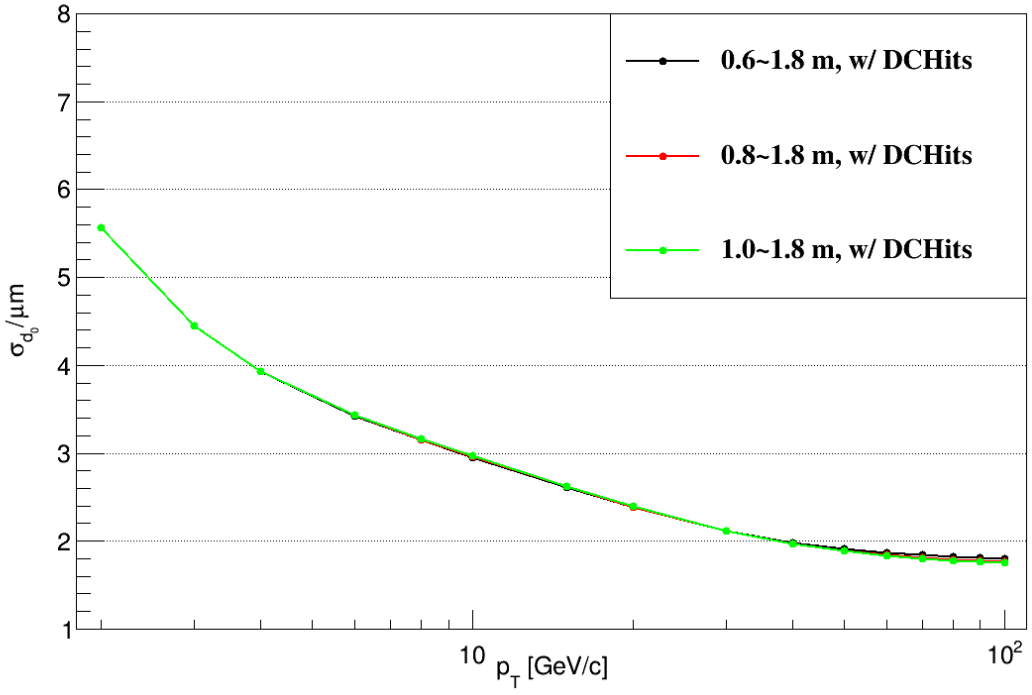
#average for ϕ(0,2π)

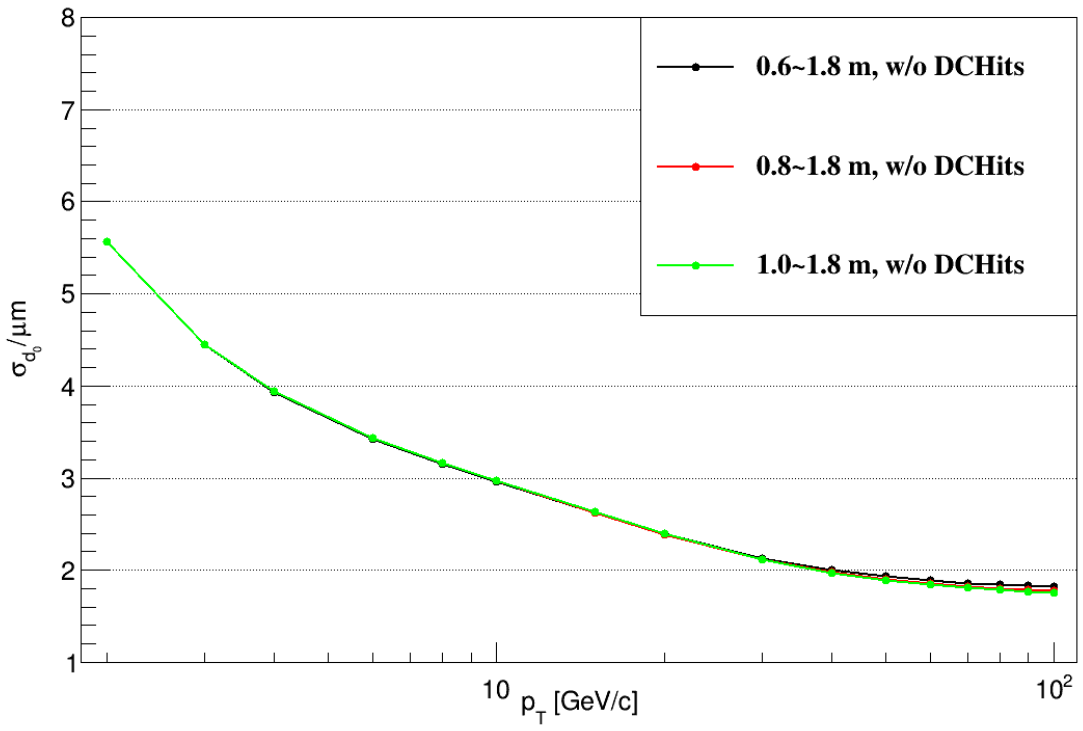
##GasHe_90Isob_10 without wire, if Air, 0.00592% per cell

* Sensor face to IP, 0.468% lie after sensor

** Dominant lie between SITs

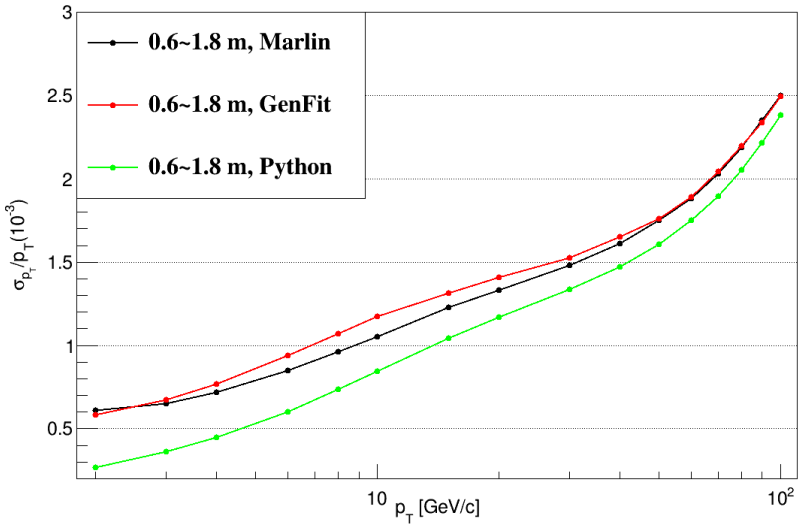
The effect on impact parameter(By analytic calculation)

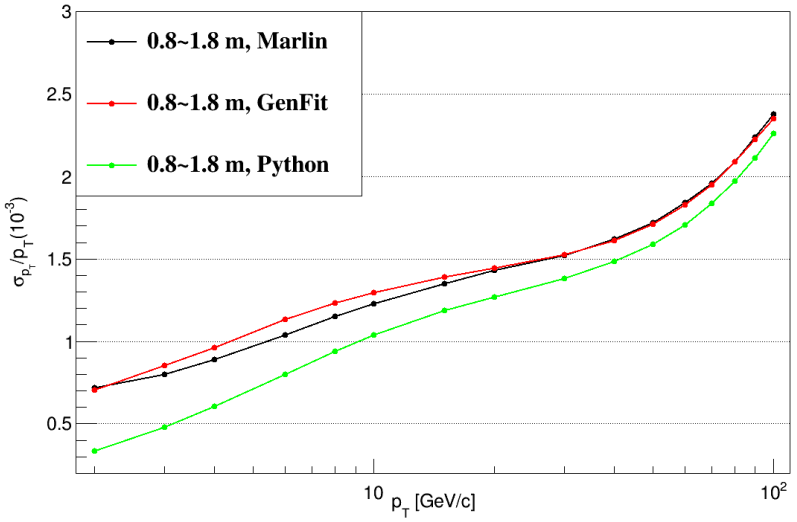


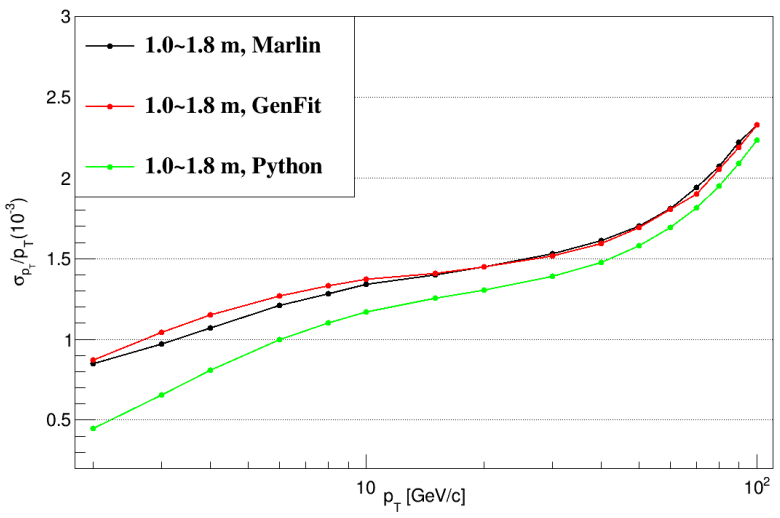


- There is nearly no effect on IP when we changed the volume of DC & the location of SIT outer.

Validation： compare the results under the same DC volume

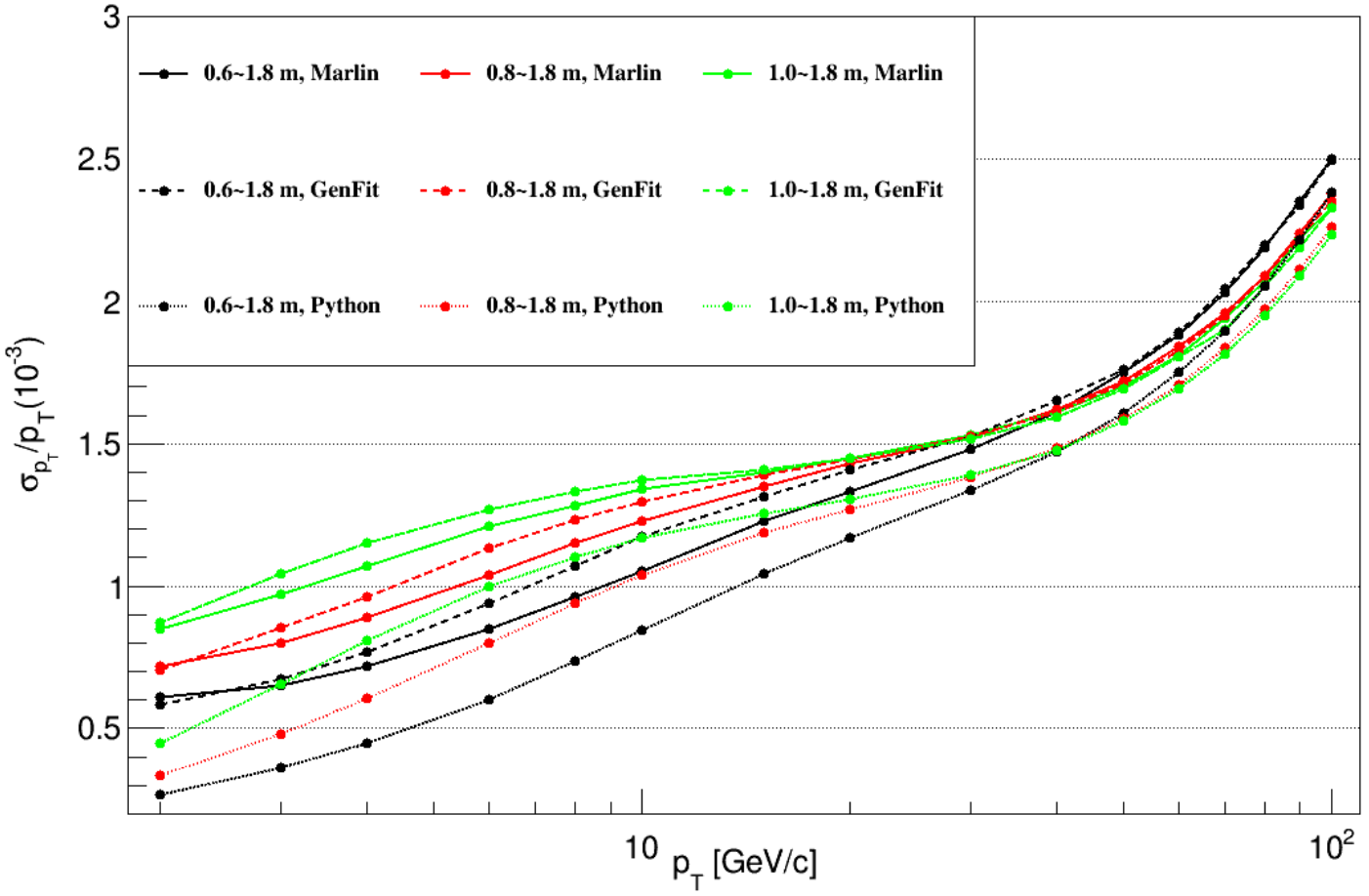






- We can find the trends of curves are similar, although analytic calculation's momentum error is much lower than the full simulations

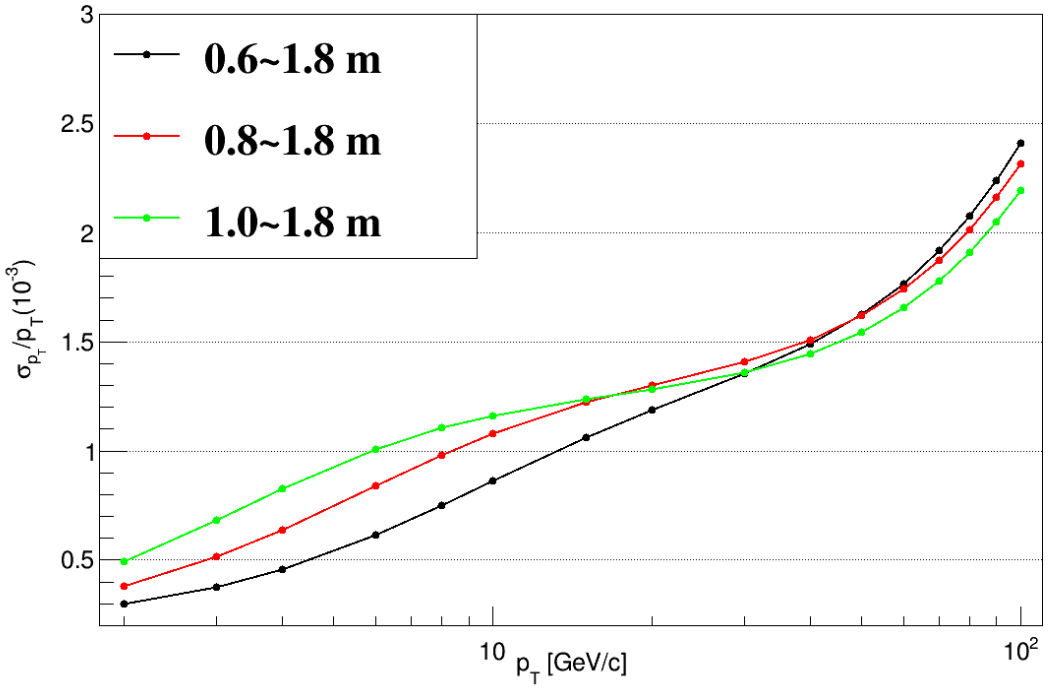
Validation: Compare full simulations & fast calculation together



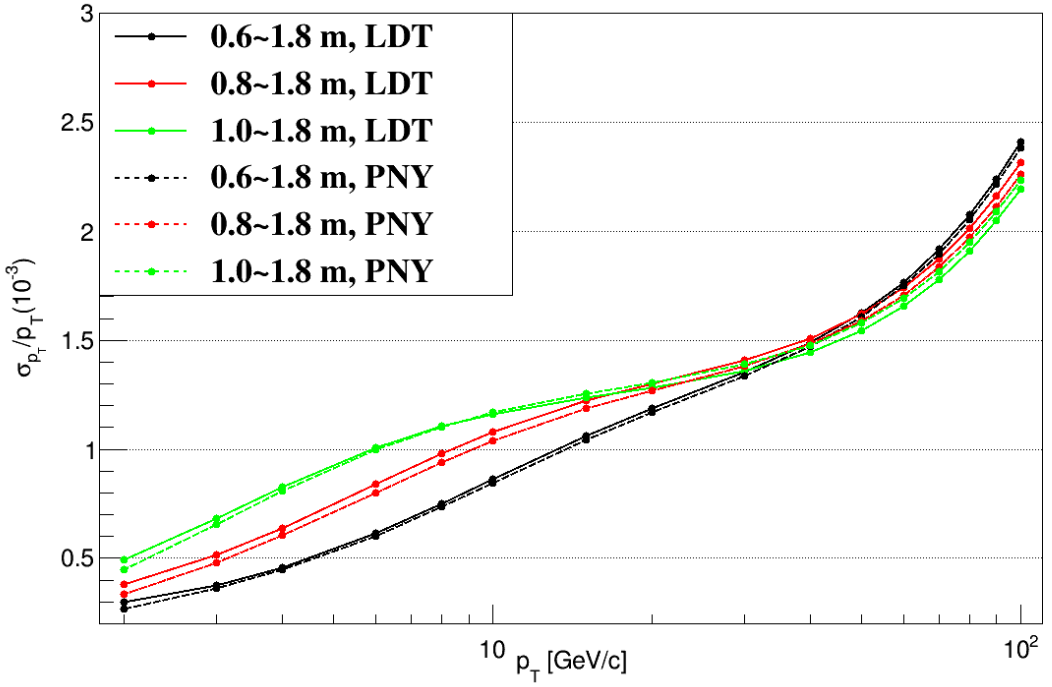
- Trends of the curves are similar
- DC = 0.6-1.8m is better

Validation： LDT's results (p and ip) with DC hits

By LDT:

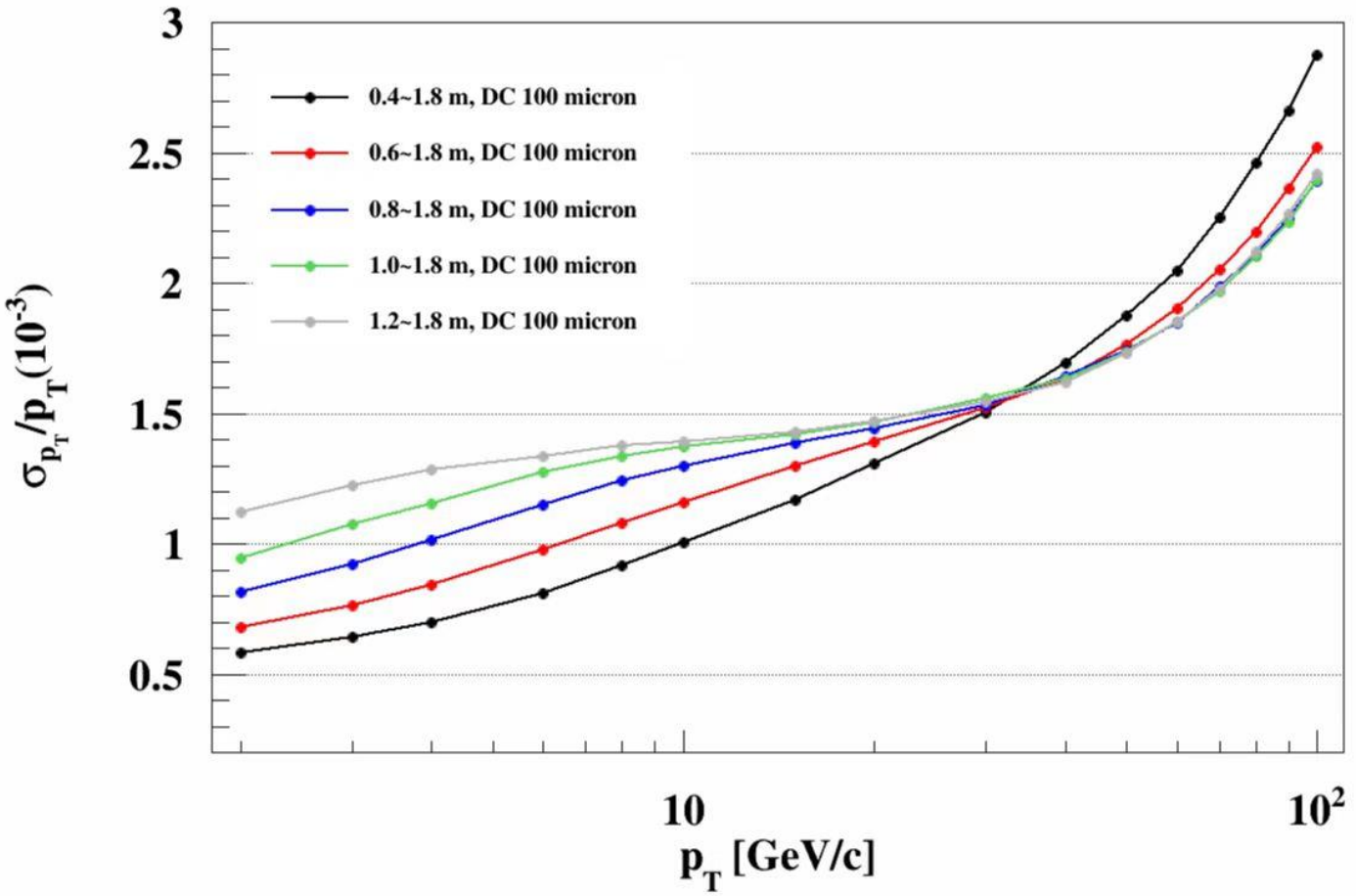


Compare with analytic calculation:



- The LDT's results is almost the same with analytic calculation
- DC = 0.6-1.8m is better

More options of DC volume



- When momentum below 30GeV, it looks like the volume of DC the bigger, the better, but at high momentum, the momentum error will grow a lot when we choose DC = 0.4-1.8m
- DC = 0.6-1.8m is better, which can consider both the measurement of high and low momentum well