Preliminary Optimization for the Forth CEPC Tracker

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On Behalf of the CEPC Tracker Team

Outline

1. Introduction—CEPC Physics requirements

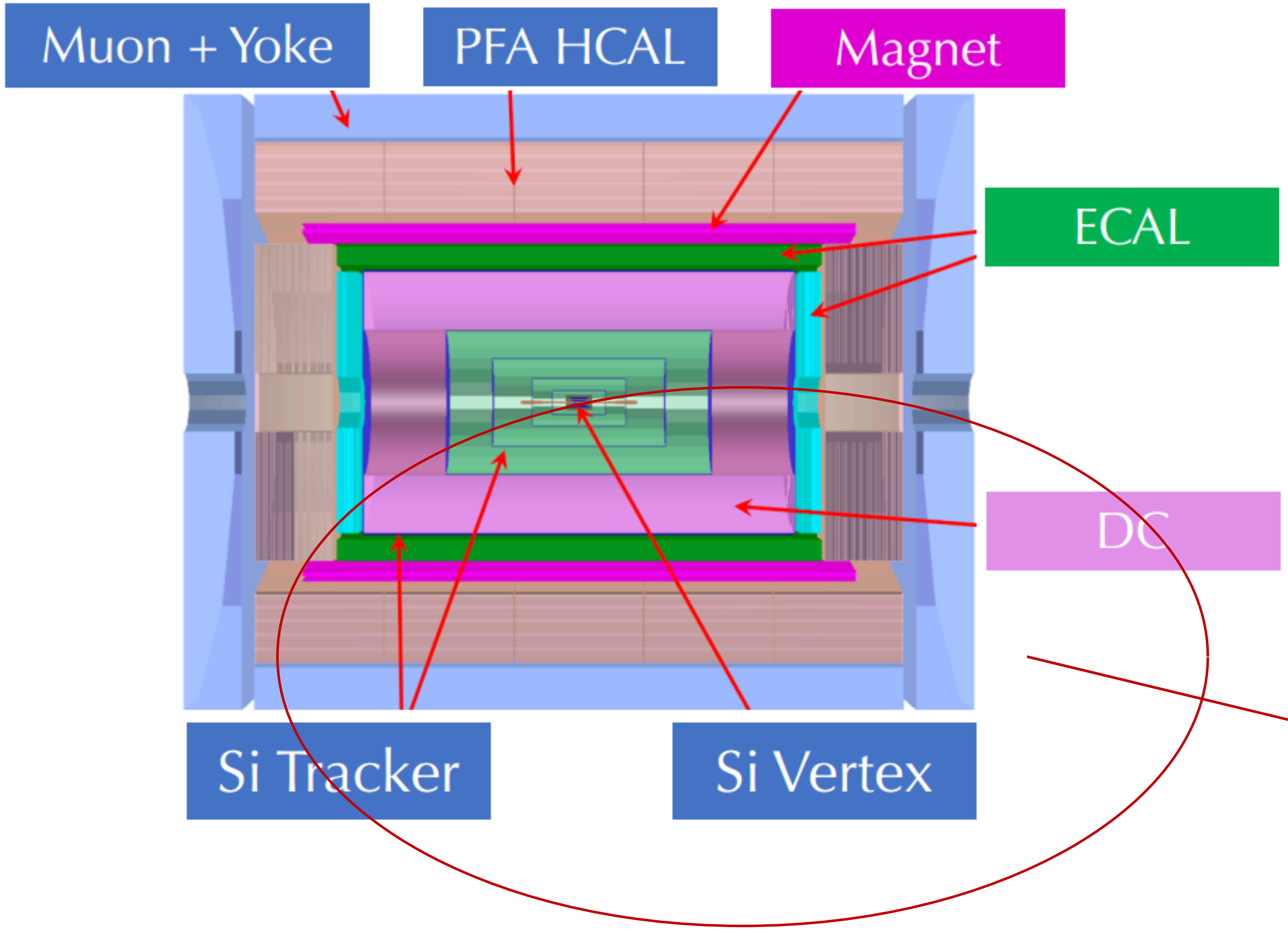
- Higgs physics

Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) = 2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV}) \sin^{3/2}\theta}$
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} = 5 \oplus \frac{10}{p(\mathrm{GeV}) \times \sin^{3/2}\theta} (\mu\mathrm{m})$
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E =$ $3 \sim 4\%$ at 100 GeV
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E = \frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$

- Flavor physics: excellent PID, better than 2σ K/π separation up to ~20 GeV
- EW measurements: High precision luminosity measurement, $\delta L/L \sim 10^{-4}$

Ref : https://indico.ihep.ac.cn/event/13888/session/8/contribution/56/material/slides/0.pdf

1. Introduction—CEPC Detector



The Forth CEPC detector concept

- Silicon Vertex & Silicon Tracker for momentum and impact parameter measurement
- Drift Chamber for PID
- Transverse crystal bar ECAL for π_0/γ reconstruction
- Solenoid magnet between HCAL and ECAL

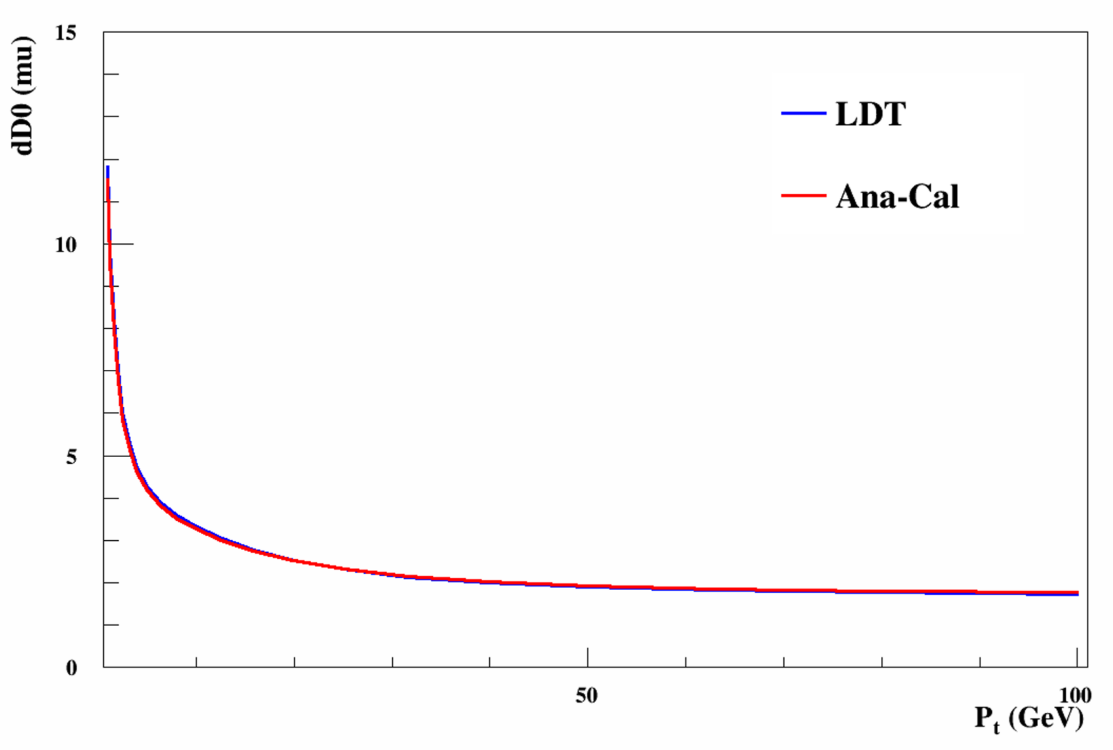
Optimization goal:

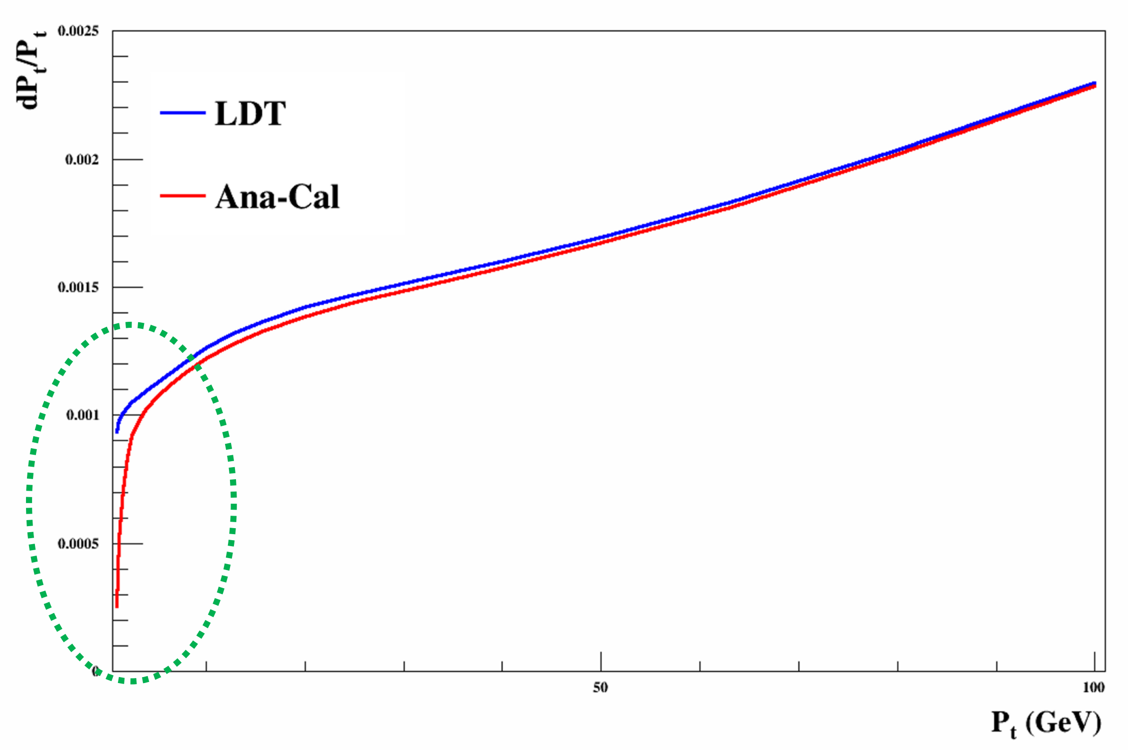
To change the layout and measure the resolutions of d_0 & P_t as good as possible

$(d_0, z_0, \phi, \theta, P_t)$

Ref : https://indico.ihep.ac.cn/event/13888/session/8/contribution/56/material/slides/0.pdf

1. Introduction—Software comparison





- LDT by MatLab

Simulation and reconstructed with Kalman Filter with linear approximation

O(10 minutes)

as result check

- Fast Software by Python

Analytic calculation based on least square method

O(1 minutes), more flexible

as main optimization tools

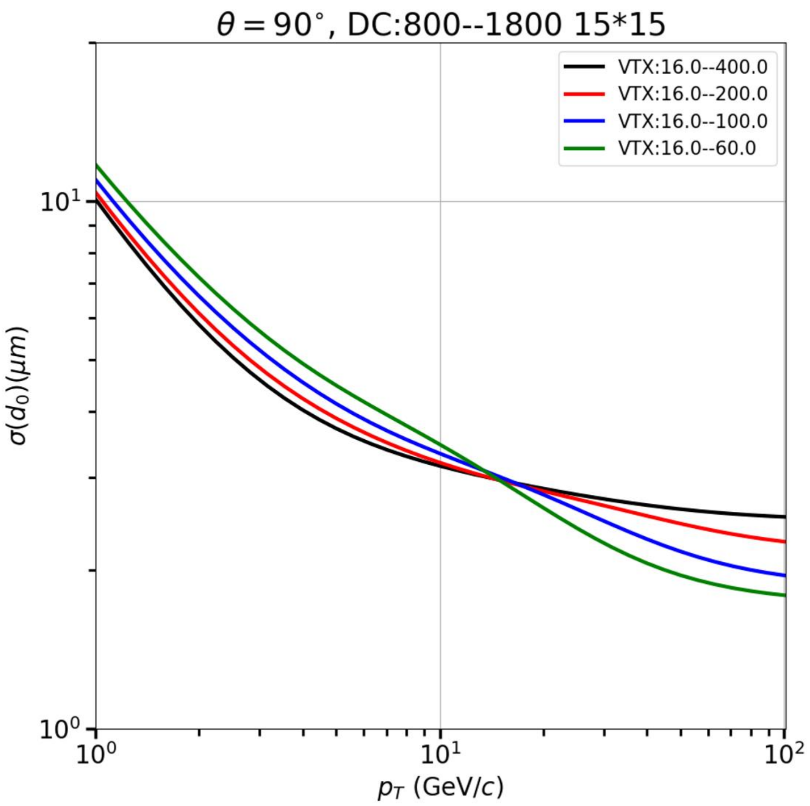
LDT Ref : HEPHY-PUB-863/08. Version 2.0 - 5 June 2008

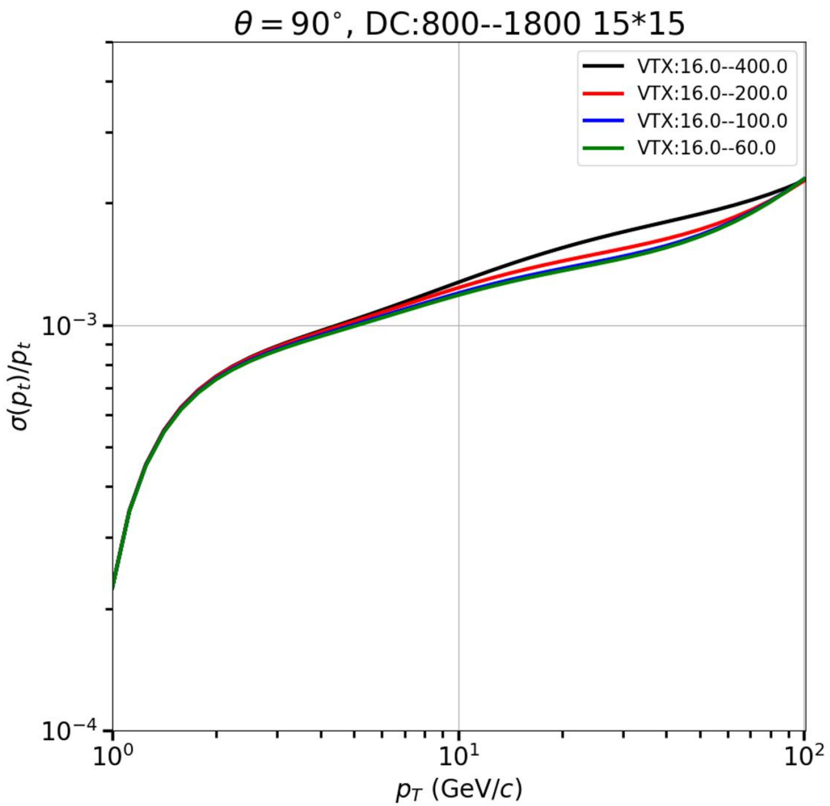
Ref : Nuclear Inst. and Methods in Physics Research, A 910 (2018) 127–132

2. Initial tracker parameters

Layers	Radius(mm)	$\sigma_{R\phi}$(mu)	σ_Z(mu)	Thickness(X_0 %)
Beam Pipe	14.5	-	-	0.15
VTX	Six layers	2.8/6/4/4/4/4	2.8/6/4/4/4/4	0.10
Support of VTX layers	-	-	-	0.10
VTX-shell	One layer	-	-	0.15
SITs	Three layers	7.2/7.2/7.2	86.6/86.6/86.6	0.65
DC inner shell	One layer	-	-	0.104
DC wires (15x15mm) and gas	…	100	2828	0.0081+0.00413
DC outer shell	1803.0	-	-	1.346
SET	1811.0	7.2	86.6	0.65

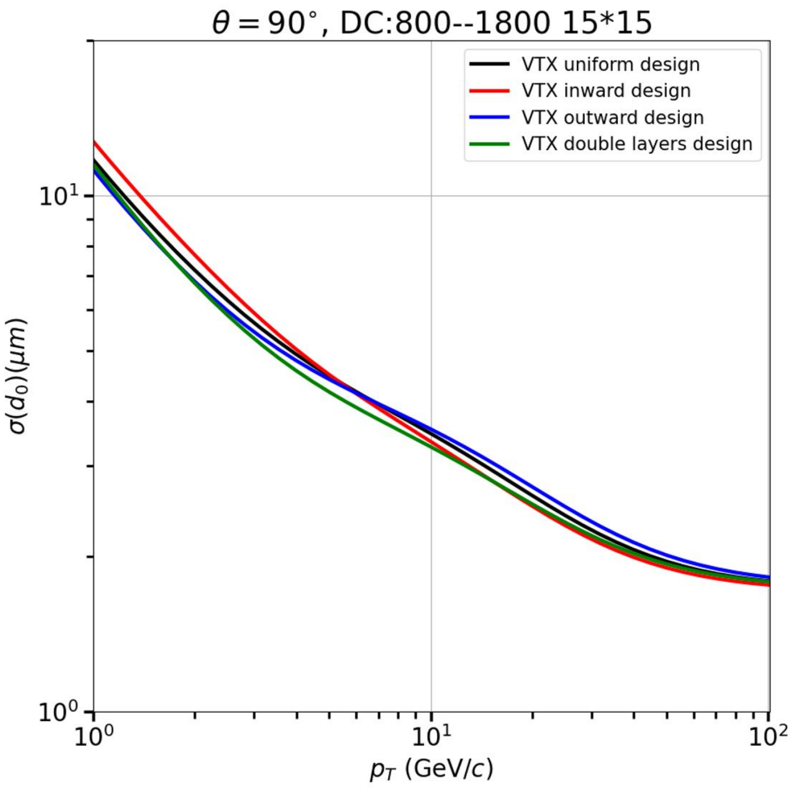
2.1 VTX – Inner radius fixed, changing Rout

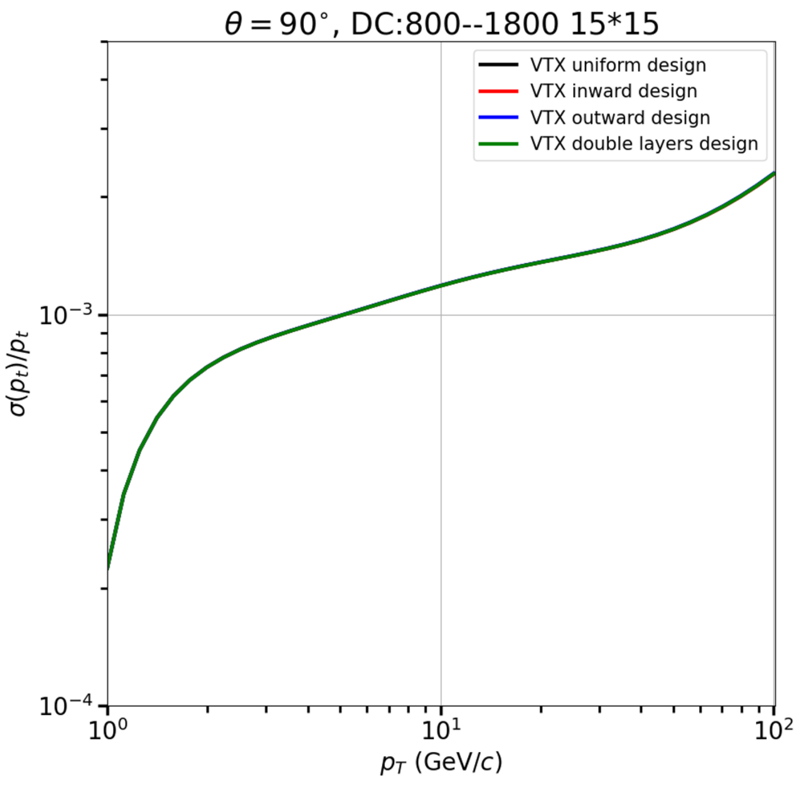




- Smaller Rout, a little worse $\sigma(d_0)$ at low Pt, but much better at high Pt
- Smaller Rout, better $\sigma(P_t)/P_t$
- Smaller Rout, less silicon cost
- 16.0 – 60.0 mm is recommended

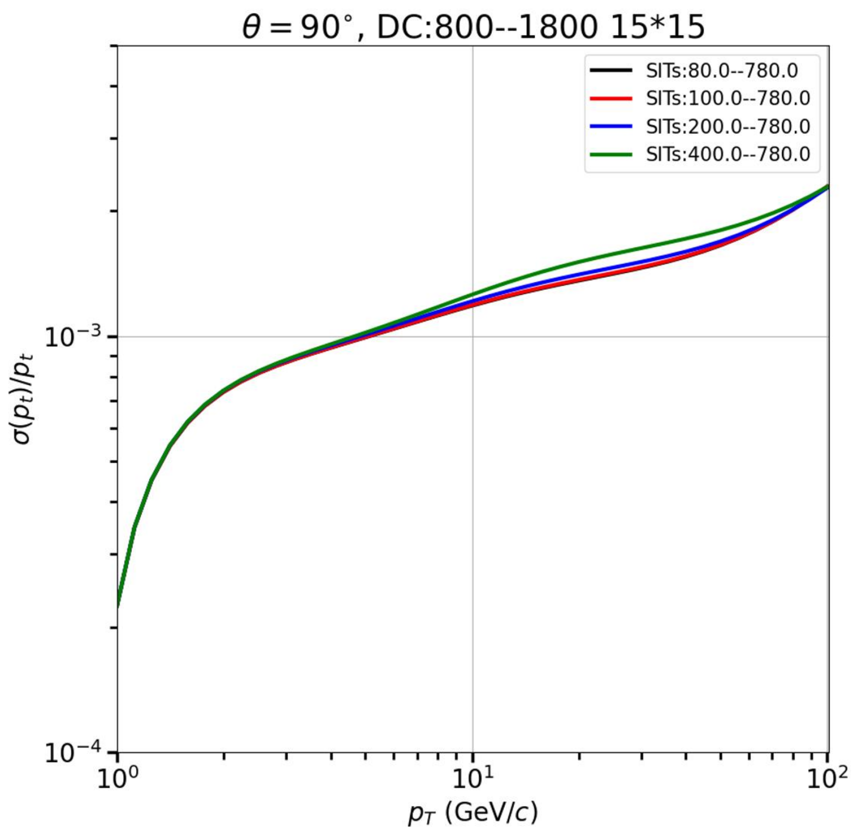
2.1 VTX – Optimize layout with fixing Rin, Rout = 16, 60 mm

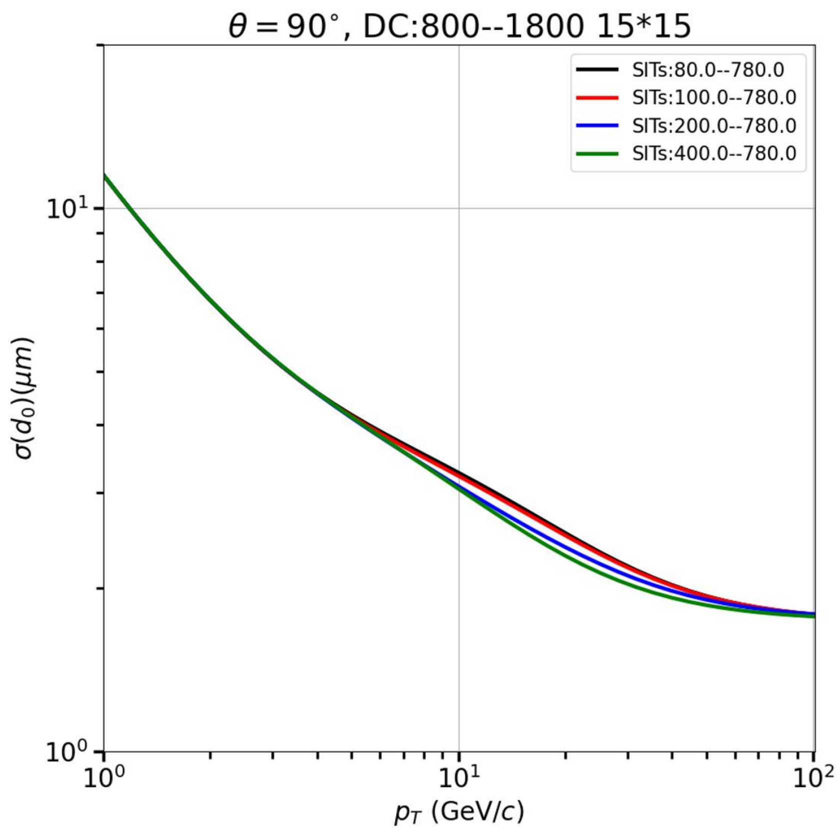




- Double layers design, less material of supports
- Double layers design, better $\sigma(d_0)$
- Little influence on $\sigma(P_t)/P_t$
- Double layers and equally spacing are favored

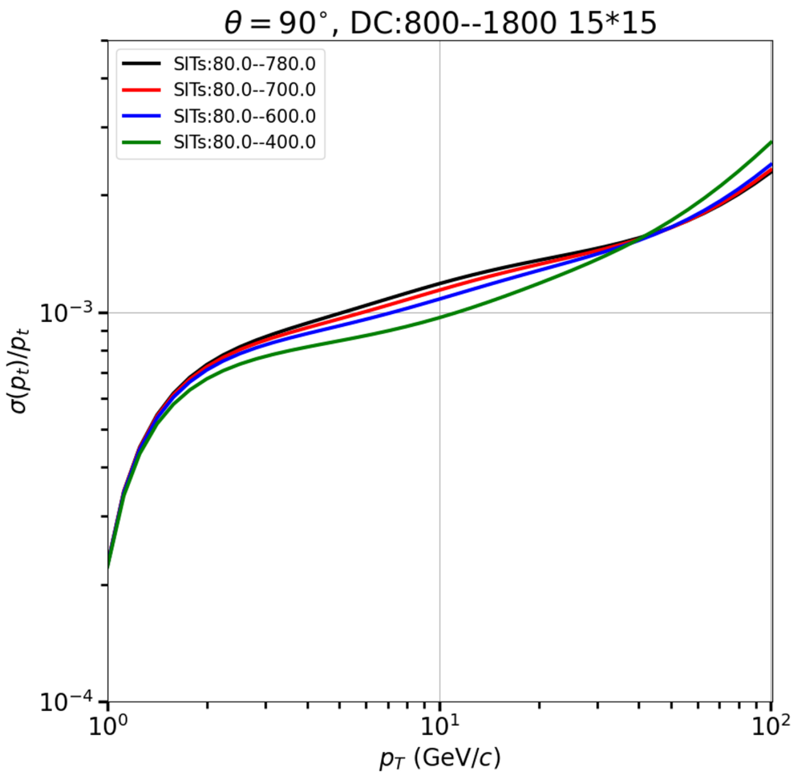
2.2 SITs – inner radius

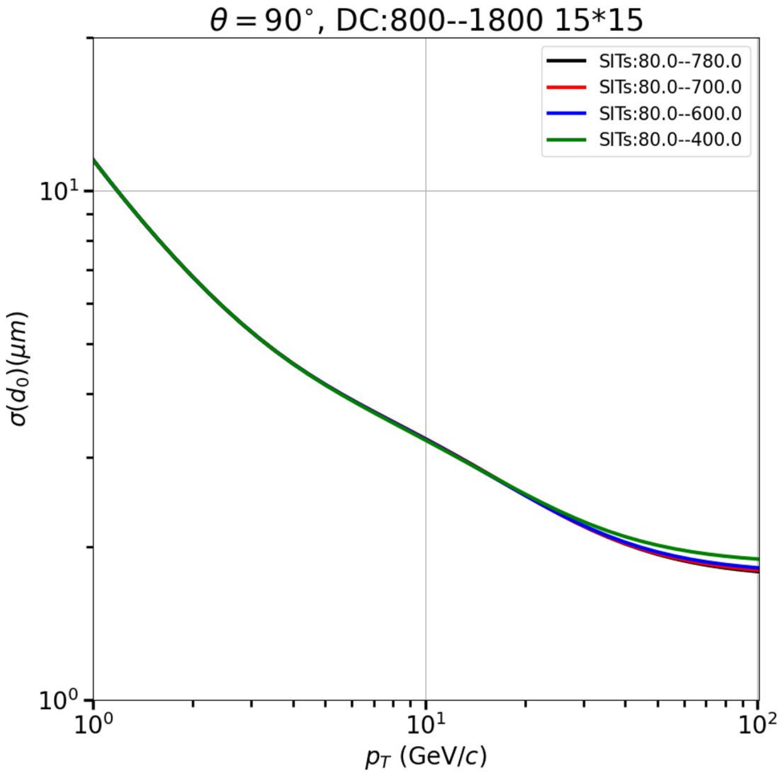




- Smaller Rin, better $\sigma(P_t)/P_t$
- Smaller Rin, a little bit worse $\sigma(d_0)$
- Smaller Rin, less cost
- 80.0 mm is recommended

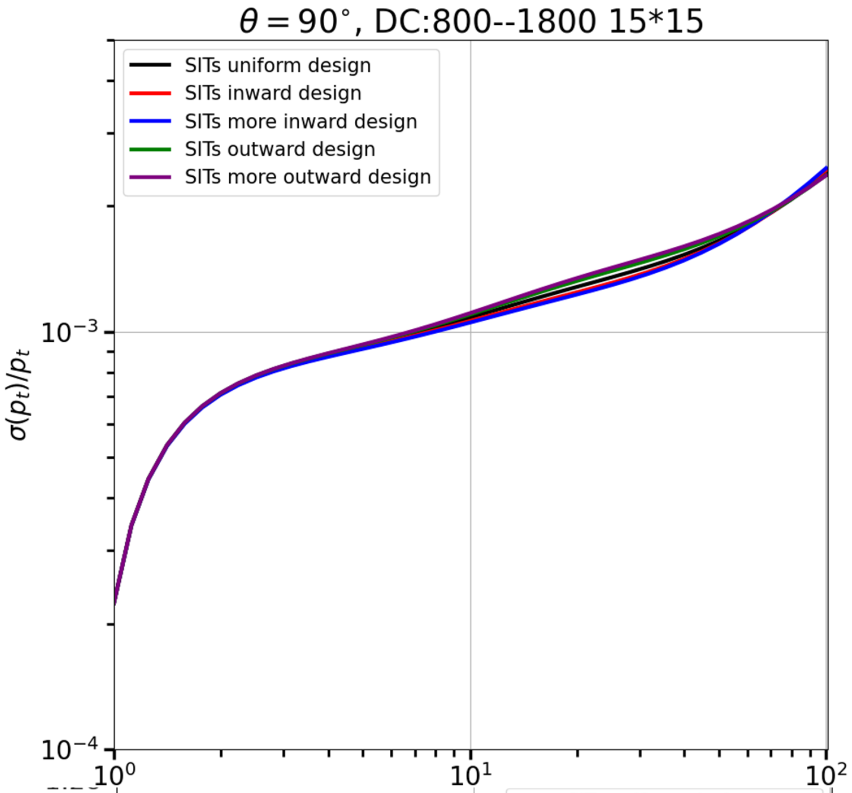
2.2 SITs – outer radius (volume)

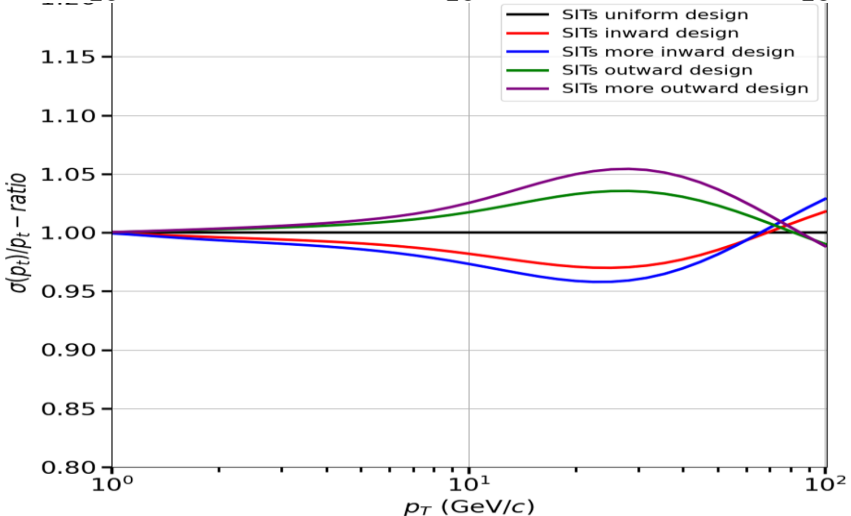


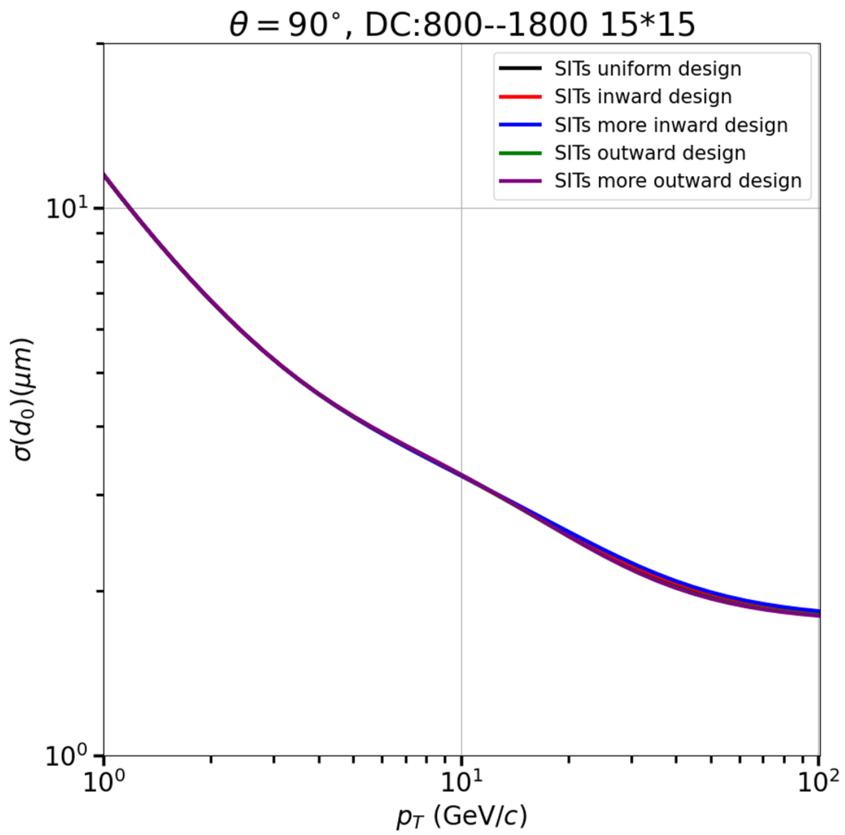


- Smaller Rout, better $\sigma(P_t)/P_t$ at intermediate Pt, while a little worse at high Pt
- Smaller Rout, slightly worse $\sigma(d_0)$
- Smaller Rout, less cost
- 600.0 mm is recommended

2.2 SITs – layout (position of the middle layer)

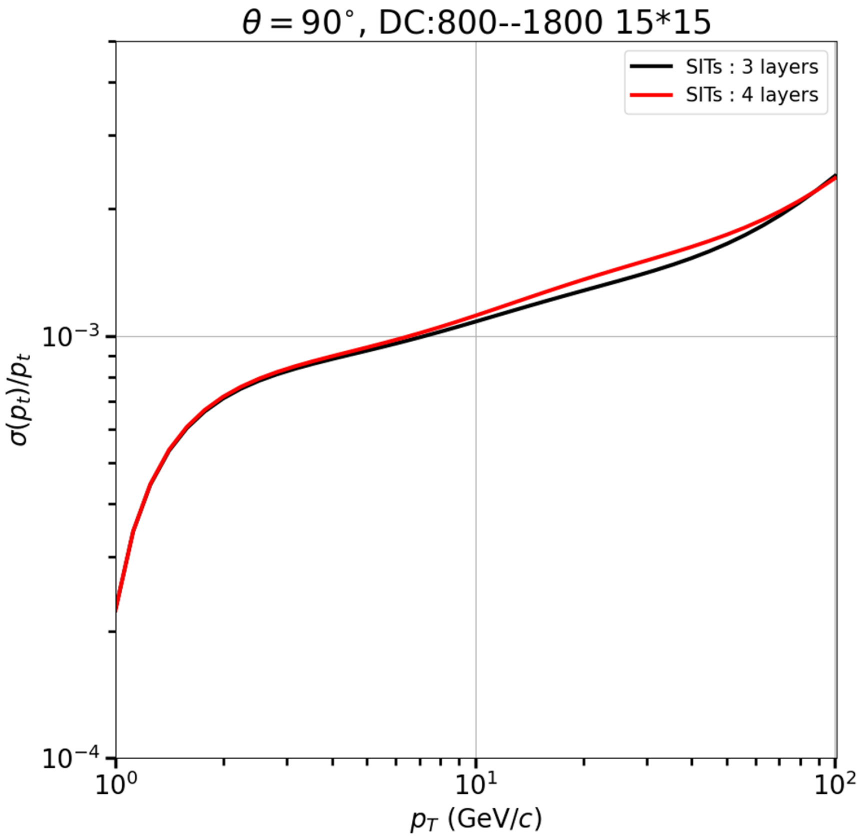


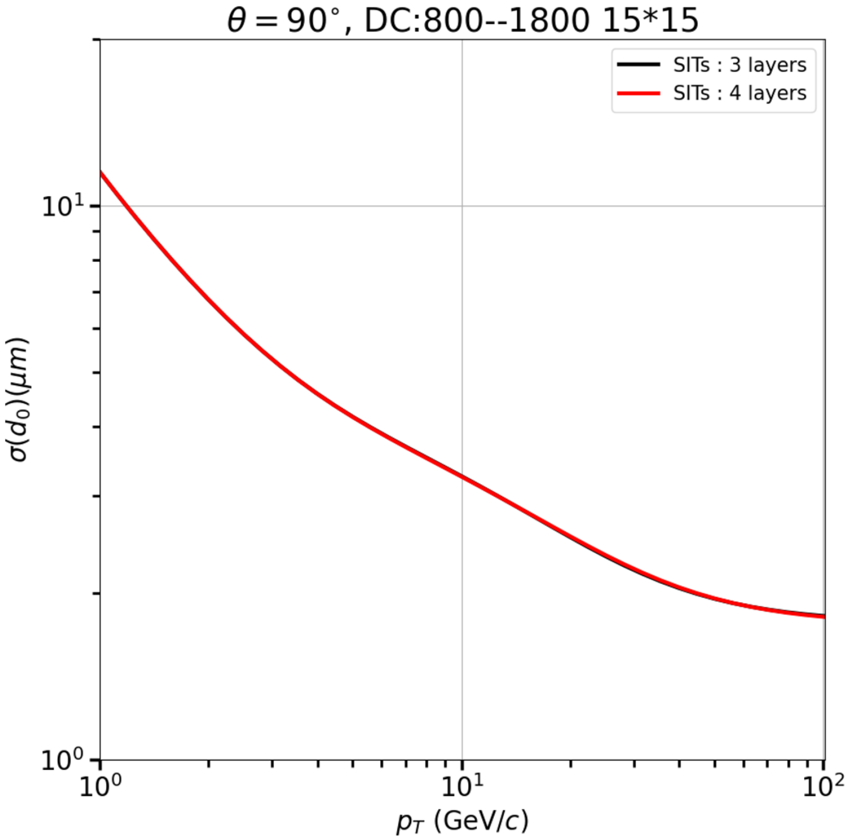




- Inward layout, better $\sigma(P_t)/P_t$ except > 50 GeV
- Little influence on $\sigma(d_0)$
- Inward design is recommended

2.2 SITs – Add one more layer



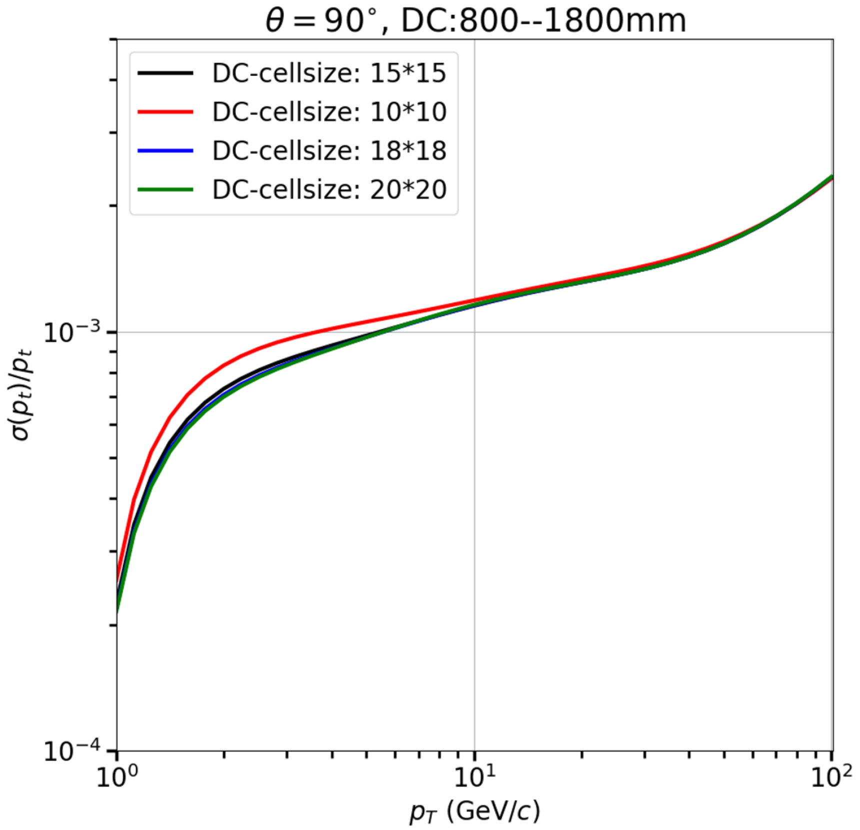


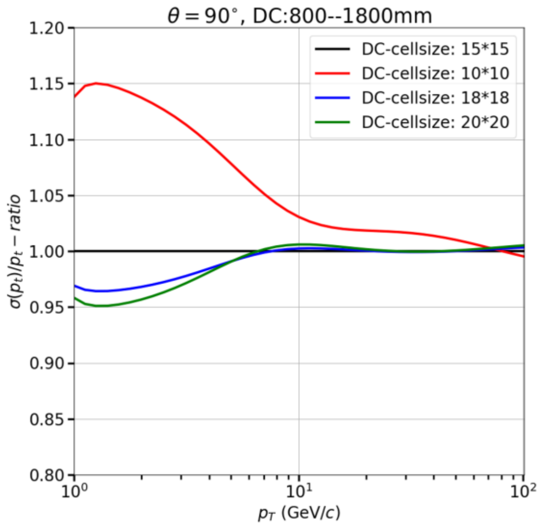
- More material & more multiple-scattering
- No improvement to $\sigma(P_t)/P_t$ & $\sigma(d_0)$
- 3 layers of SITs is recommended

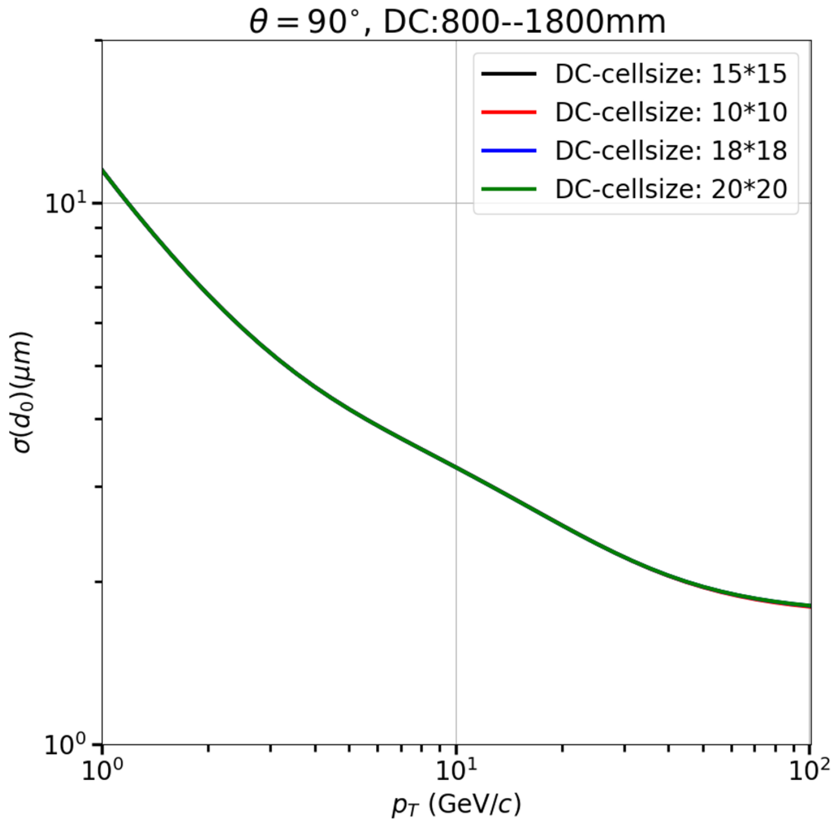
2.3 DC – Volume

- Mainly determined by PID
- δR >=1.0 m
- Keep 800 – 1800 mm by now
- To be updated according to PID study

2.3 DC – cell-size

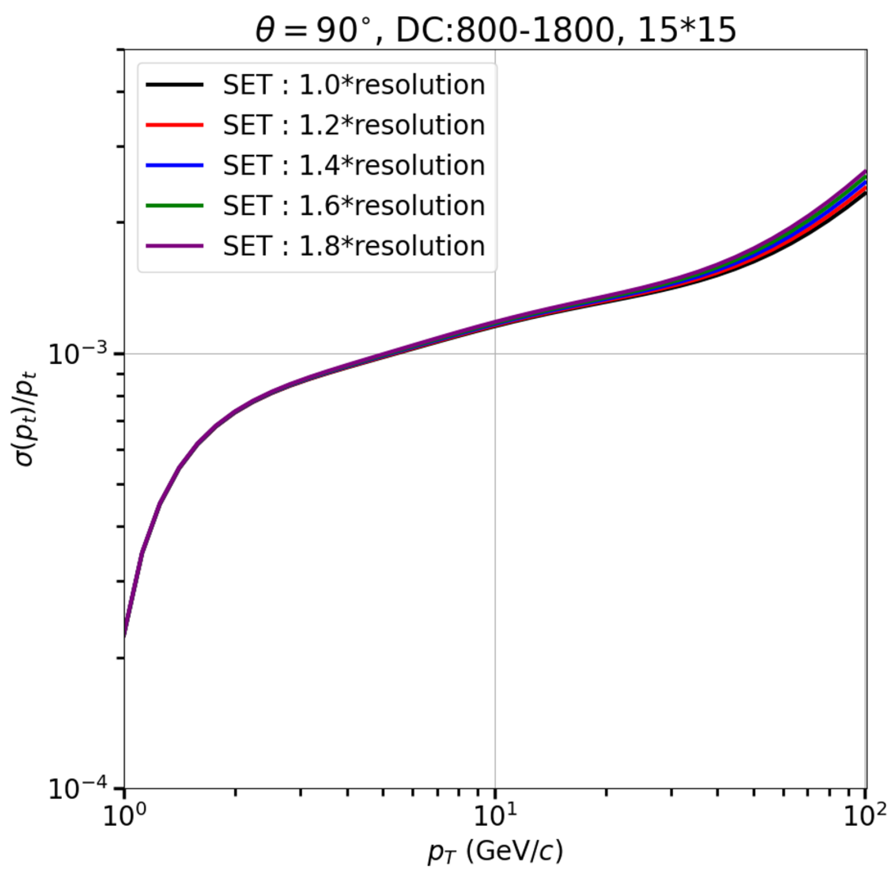


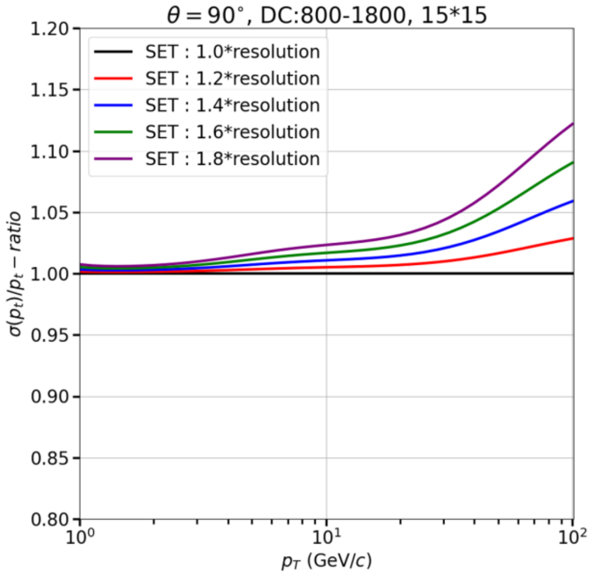


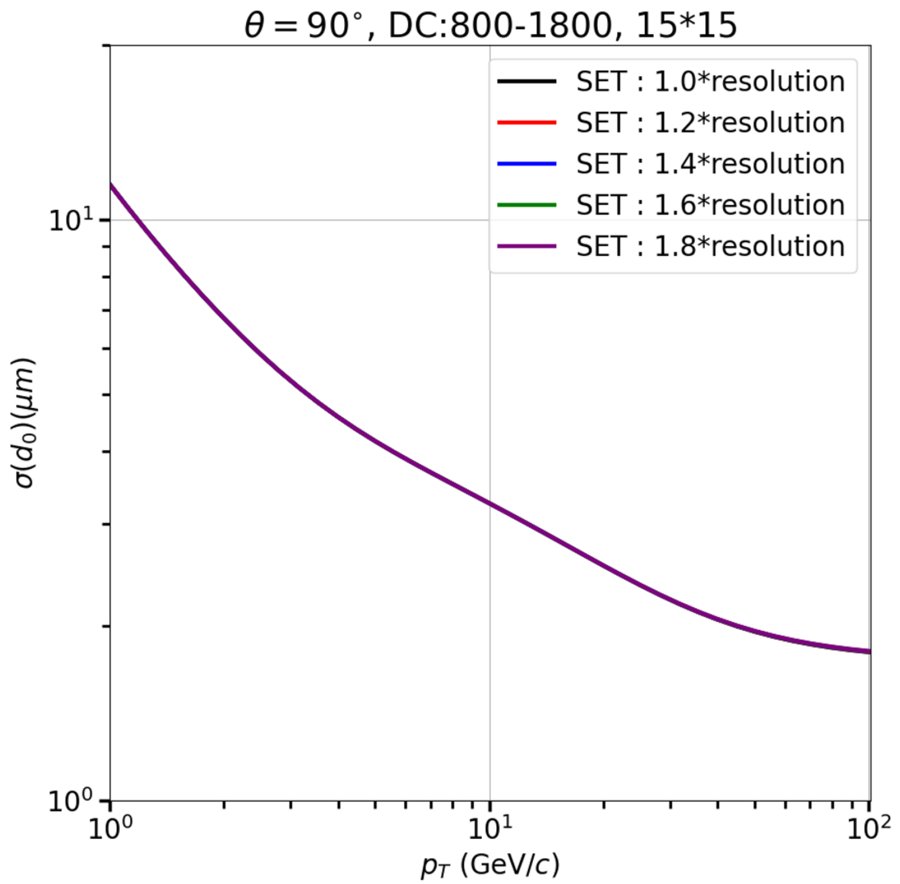


- Larger cell-size, less material & less multiple-scattering → better $\sigma(P_t)/P_t$ at low Pt
- Larger cell-size, easier engineering
- Hardly affects $\sigma(d_0)$
- So larger cell-size favored

2.4 SET – resolution







- Little effect on $\sigma(P_t)/P_t$ when spatial resolution getting worse
- No influence on $\sigma(d_0)$
- Less cost when loosing the requirement on spatial resolution
- Could take larger pixel size

3. Summary

Tracker layer optimization gives some preliminary recommendations

- VTX
  - smaller Rin & Rout of the VTX get better $\sigma(d_0)$ and $\sigma(P_t)/P_t$
  - double layers design favored
- SIT
  - Favors smaller Rin & Rout, and inward layout
- Drift chamber
  - Volume determined by PID
  - Tracking favors larger cell-size
- SET
  - The requirement on spatial resolution could be loosed

3. Summary – Recommended parameters

Layers	Radius(mm)	$\sigma_{R\phi}$(mu)	σ_Z(mu)	Thickness($1\%/X_0$)
Beam Pipe	14.5	-	-	0.15
VTX	16/18/37/39/58/60	2.8/6/4/4/4/4	2.8/6/4/4/4/4	0.10
Support for each VTX layer	-	-	-	0.10
VTX-shell	65.0	-	-	0.15
SITs	80/253/600	7.2/7.2/7.2	86.6/86.6/86.6	0.65
DC inner shell	798	-	-	0.104
DC wires (20*20mm) and gas	800 -- 1800	100	2828	0.0108+0.0031
DC outer shell	1803.0	-	-	1.346
SET	1811.0	11.5	138.5	0.65