Full Silicon Tracker Option @ CepC

WEIMING YAO(LBNL), CHENGDONG FU(IHEP)

—FOR SILICON TRACKER STUDY GROUP

CEPC WORKSHOP – EU EDITION

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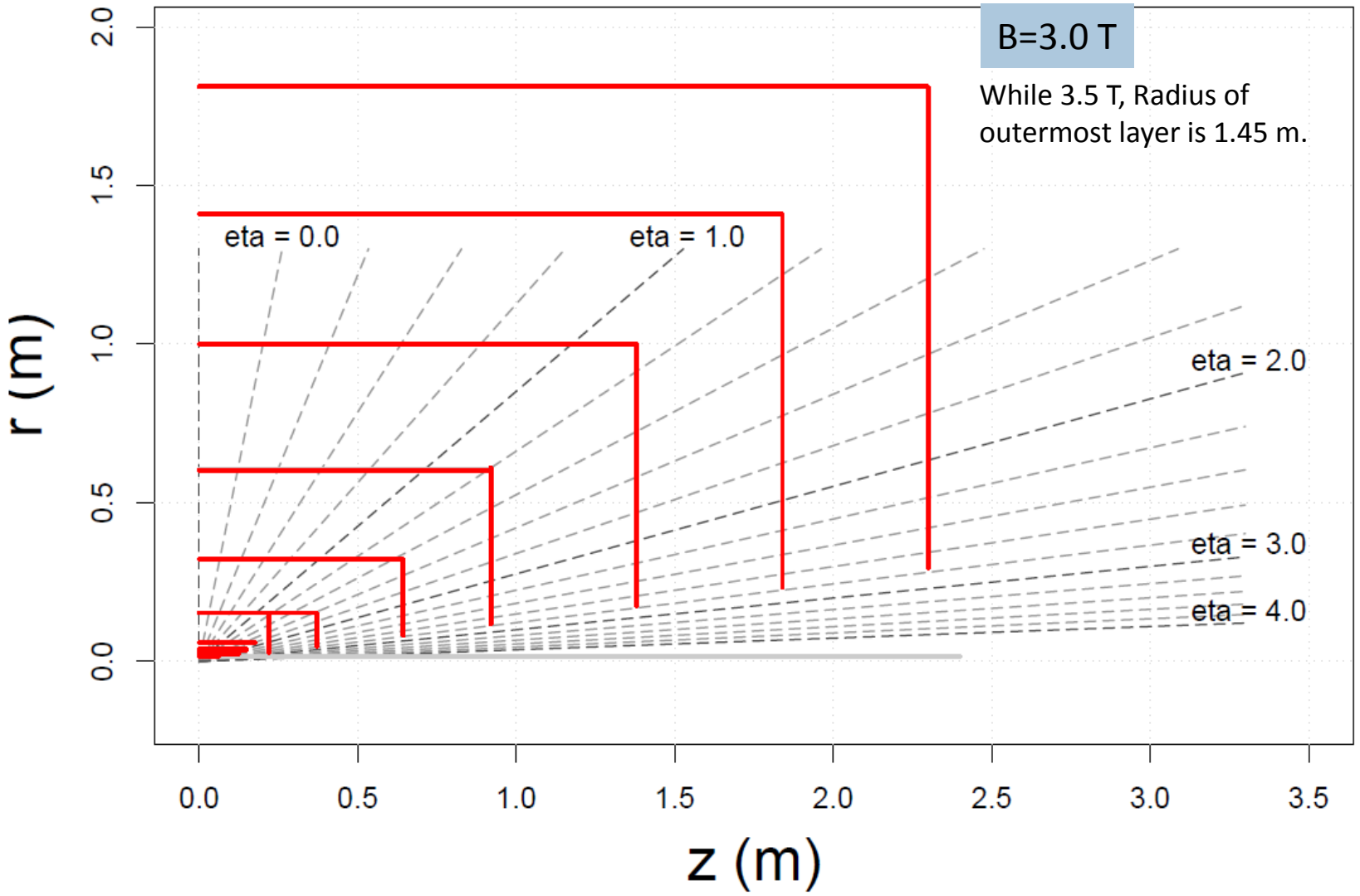
Outline

- Status
- Concept Design
- Software Support and Simulation Study
- Conclusion

Status

- Parts of results are summarized in CDR as part of options for CEPC tracker
- Two designs for full silicon tracker
  - CEPCSID: replacing TPC with extra silicon strip barrel ladders and endcap disks
  - SIDB: expanding the SID design to full tracking volume (Sergei+Argonne), http://atlaswww.hep.anl.gov/hepsim/detectorinfo.php?id=sidcc3
  - The rest of detectors are kept same as CEPC_v4 and SID.
- The B field is assumed to 3.0 T
- The radius of tracking volume is set as 1.87 m, not change the size of calorimeter
- Two tracking algorithms are working based on the smeared hits (no clustering yet)
  - SiliconTracking_MarlinTrk
  - ConformalTracking
- Algorithms and performances studies are ongoing (Weiming, Mingrui + Chengdong)
- After tracking, adaptation of Arbor PFA with full silicon tracks is testing (Manqi+Dan)

Full Silicon Tracker Concepts



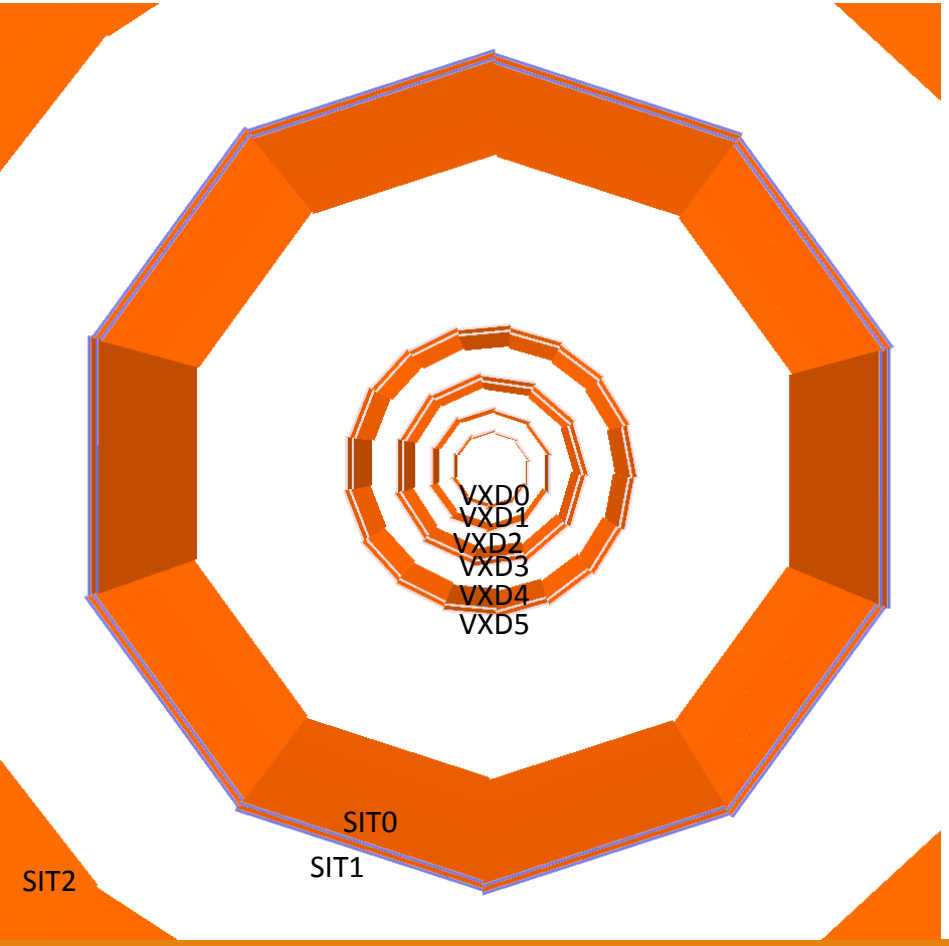
Geometry Size

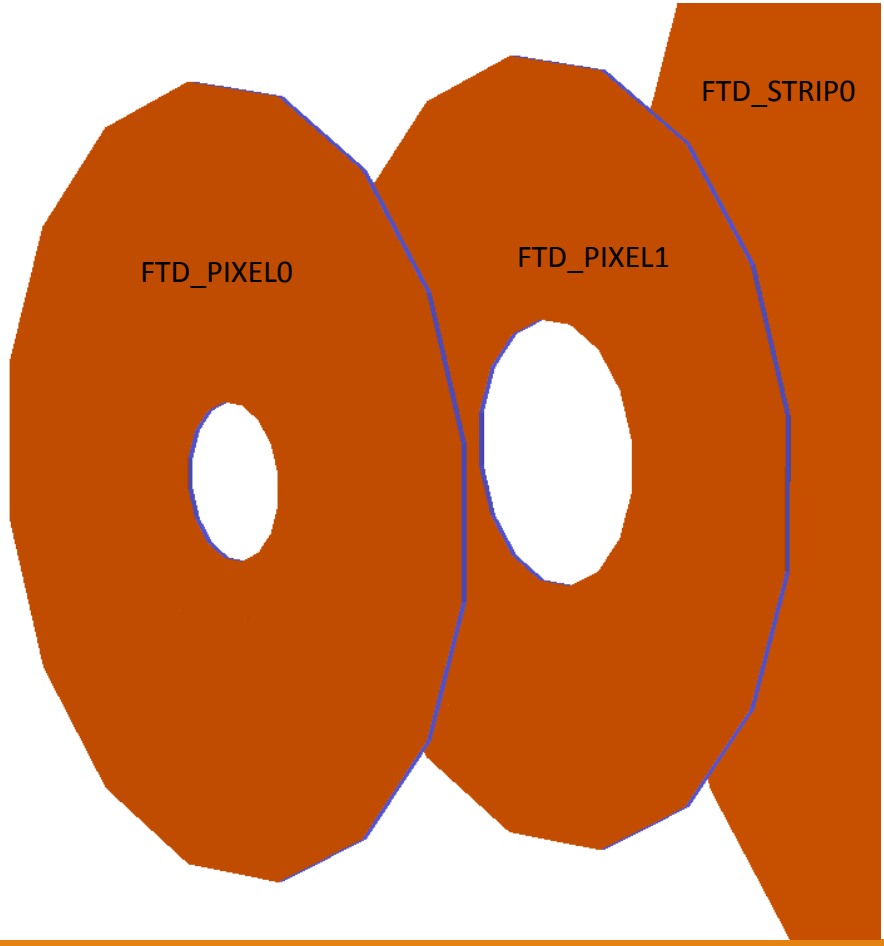
Barrel	R (m)	±Z (m)	Type	Ladders	Resolution(μm)
VXD 0-1	0.016, 0.025	0.078, 0.125	Double pixel-C	10	2.8, 6
VXD 2-3	0.037	0.150	Double pixel	11	4
VXD 4-5	0.058	0.175	Double pixel	17	4
SIT 0-1	0.153	0.368	Double strip	10	7
SIT 2-3	0.321	0.644	Double strip	19	7
SIT 4-5	0.603	0.920	Double strip	38	7
SIT 6-7	1.000	1.380	Double strip	62	7
SIT 8-9	1.410	1.840	Double strip	89	7
SIT 10-11	1.811	2.300	Double strip	115	7

Endcap	Rin (m)	Rout (m)	±Z (m)	Type	Resolution(μm)
FTD_PIXEL 0	0.030	0.150	0.220	Single pixel	4
FTD_PIXEL 1	0.051	0.150	0.371	Single pixel	4
FTD_STRIP 0-1	0.082	0.321	0.644	Double strip	7
FTD_STRIP 2-3	0.117	0.610	0.920	Double strip	7
FTD_STRIP 4-5	0.176	1.000	1.380	Double strip	7
FTD_STRIP 6-7	0.234	1.410	1.840	Double strip	7
FTD_STRIP 8-9	0.293	1.811	2.300	Double strip	7

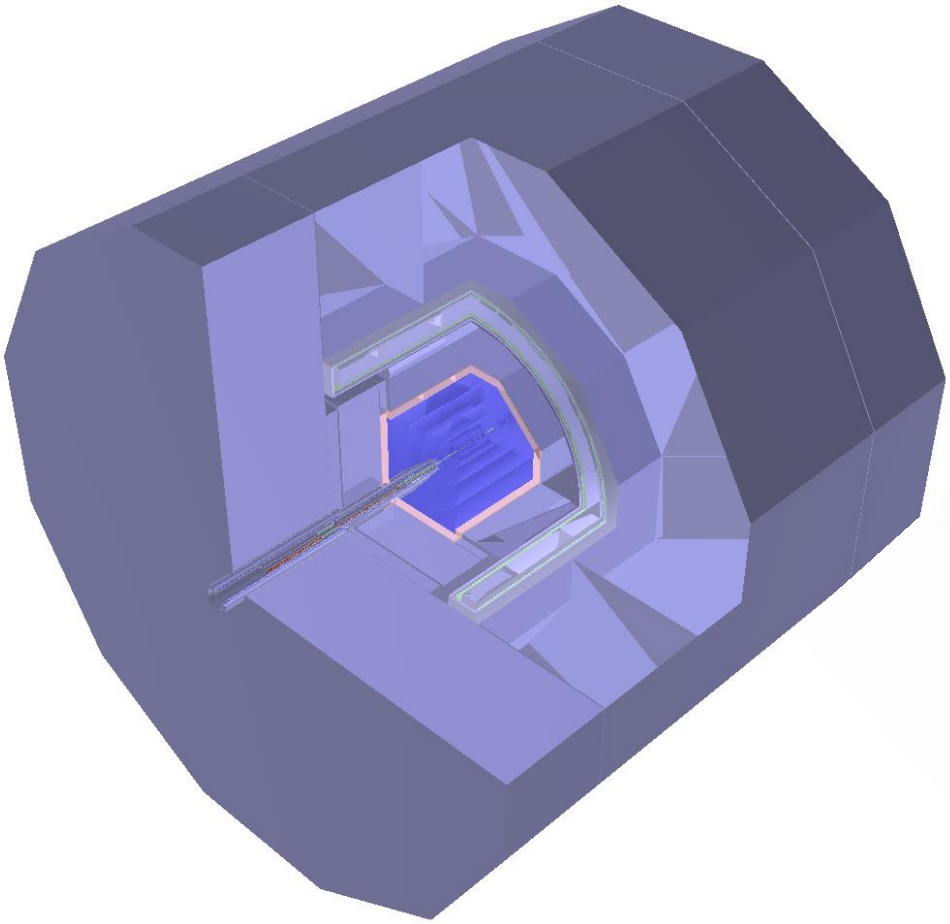
Geometry Type

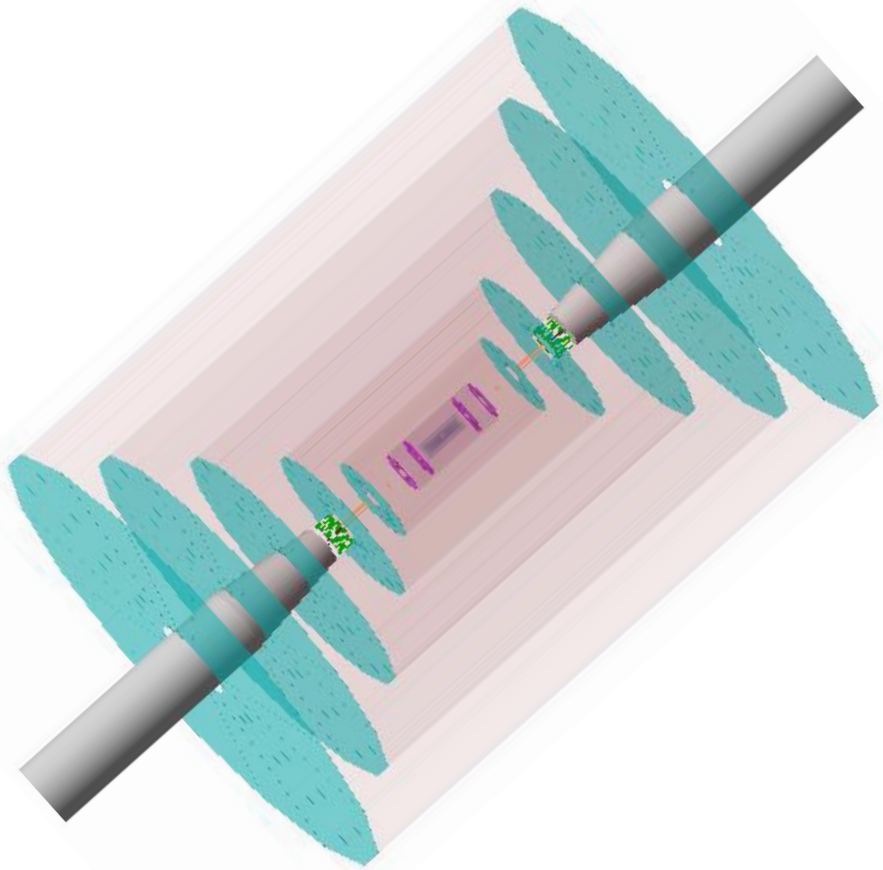
- Three options for barrel ladders
  - Detached two layers with overlap
  - Detached two layers without overlap √
  - Conjunct layer with two silicon layers
- Two options for endcap petals
  - Detached two layers
  - Conjunct layer with two silicon layers √





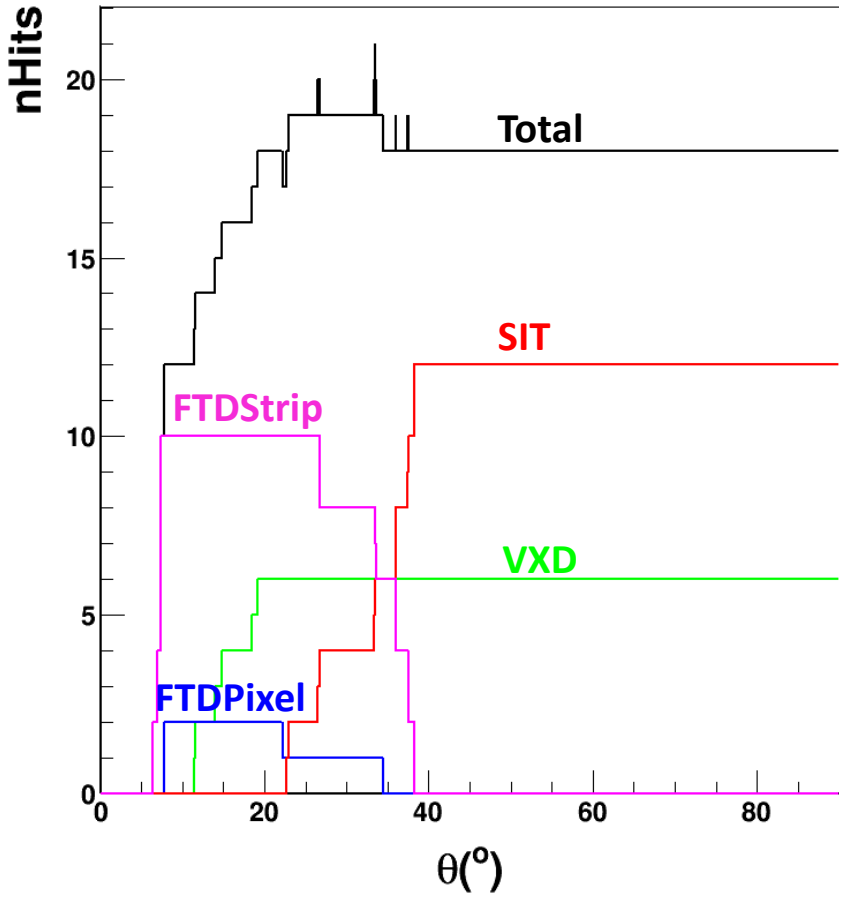
Overviewer

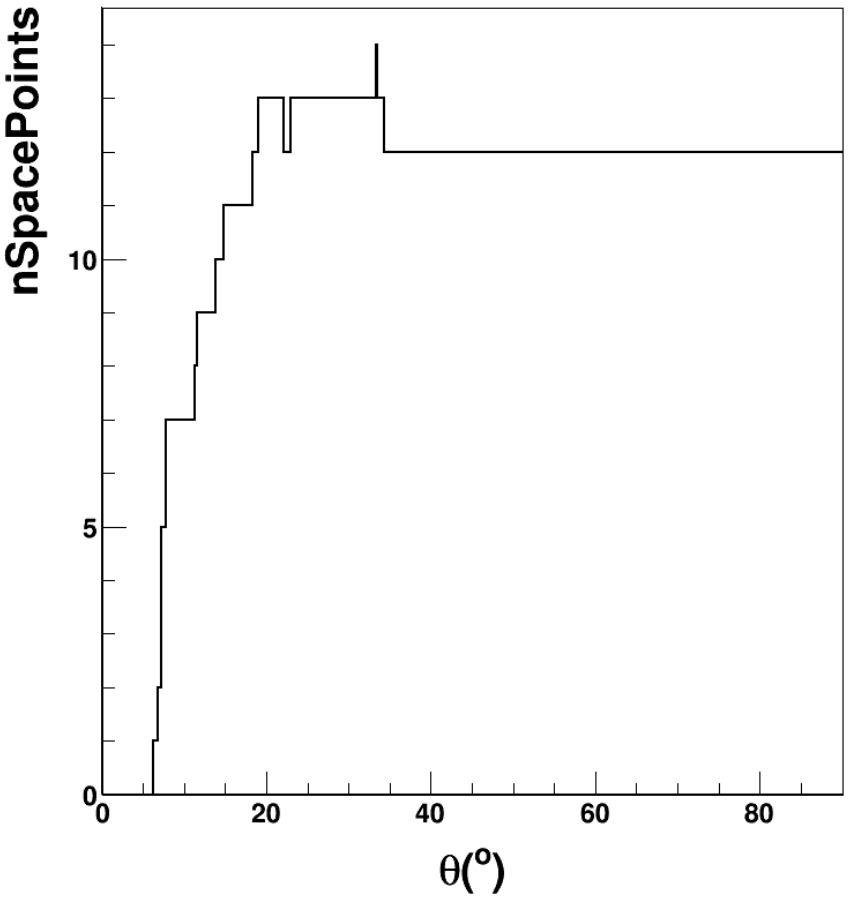




Expected Hit Number

- 7.8°<θ<11.5° (0.98<cosθ<0.99) >7
- 11.5° <θ<14° (0.97<cosθ<0.98) >9
- 14° <θ<18.5° (0.948<cosθ<0.97) >11
- 18.5°<θ<90° (cosθ<0.948) >12





Layer Materials

- Mechanical properties have not been studied in detail

VXD(ILD-like)	silicon	kapton	aluminium	foam	Total support
Thickness(mm)	0.05	0.05	0.01	0.94	1

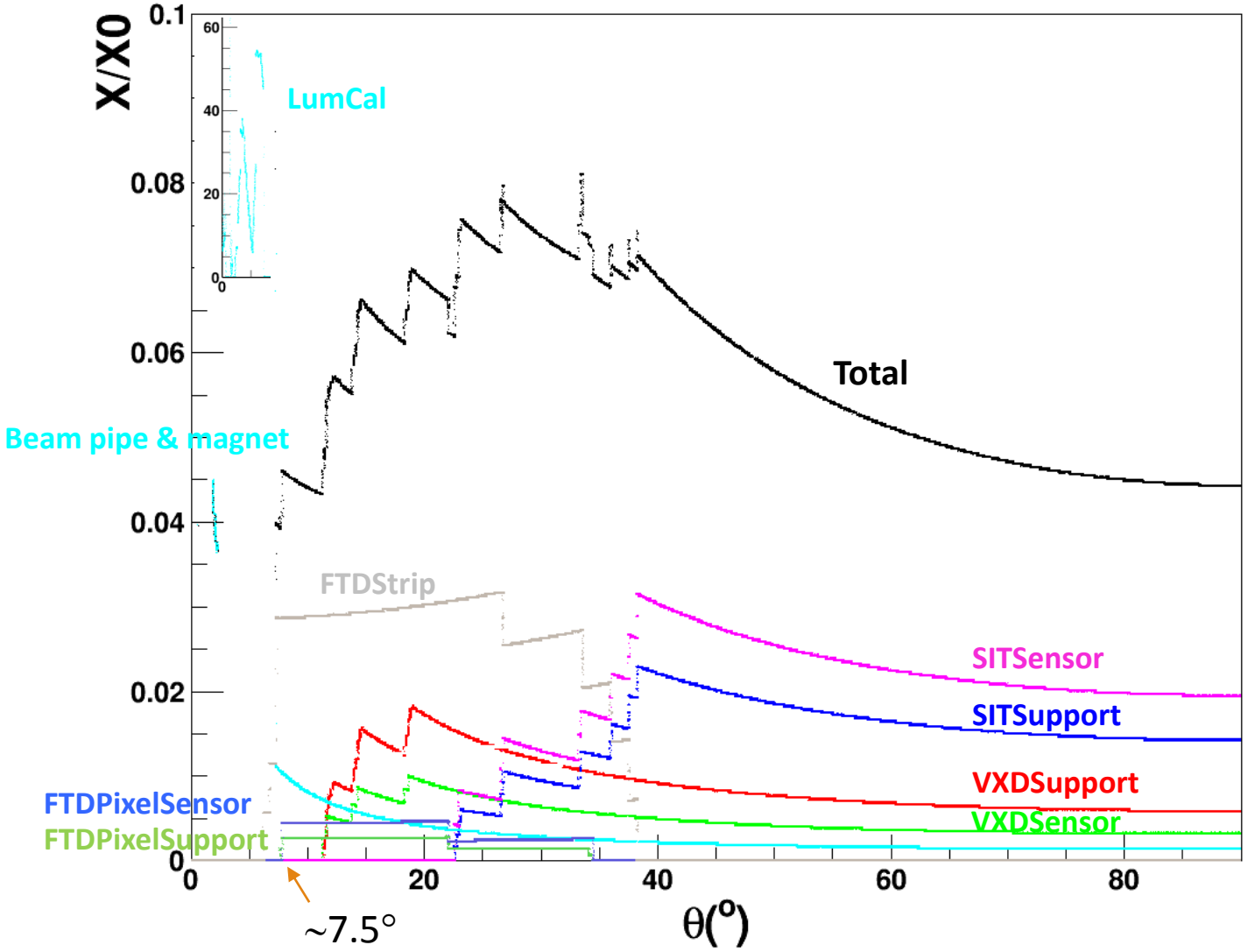
SIT(SiD-like)	silicon	peek	Carbon fiber	Rohacell 50D	epoxy	Carbon fiber	Total support
Thickness(mm)	0.15+0.0024	0.1	0.08	0.9	0.08	0.08	1.2424

FTD_PIXEL	silicon	Carbon fiber	Rohacell50D	peek	Total support
Thickness(mm)	0.2+0.0048	0.16	1.8	0.2	2.1648

FTD_STRIP	silicon	peek	Carbon fiber	Rohacell 50D	epoxy	Carbon fiber	silicon	Total support
Thickness(mm)	0.15	0.2	0.16	1.8	0.175	0.16	0.15+0.0048	2.4998

Material Budget

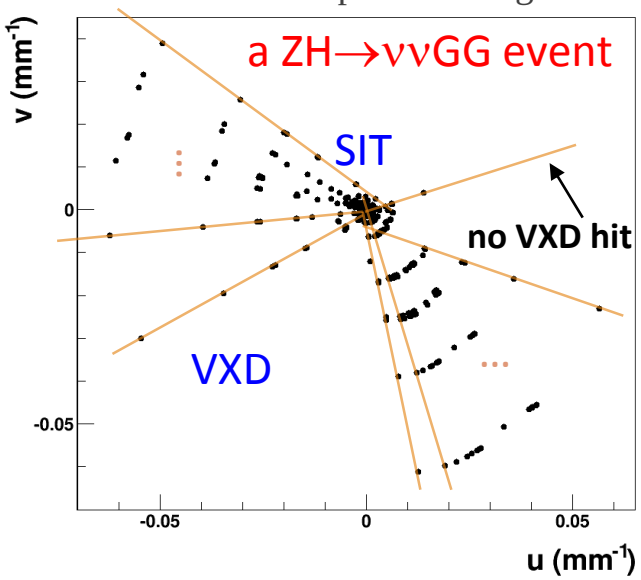
- From ~4.5% of X0 to ~8.1% (cosθ<0.99)



Simulation and Reconstruction Tools

- MokkaC—a developed Mokka version @CepC
  - http://cepcgit.ihep.ac.cn/cepcsoft/MokkaC

- Tracking and fit
  - SiliconTracking_MarlinTrk
  - ConformalTracking
    - used as the main track pattern recognition algorithm at CLIC, and FCC-ee are also performing



    - Implemented into CepC software, and ongoing

✓ Conformal space:

$$u = \frac{x}{x^2 + y^2}, \qquad v = \frac{y}{x^2 + y^2}$$

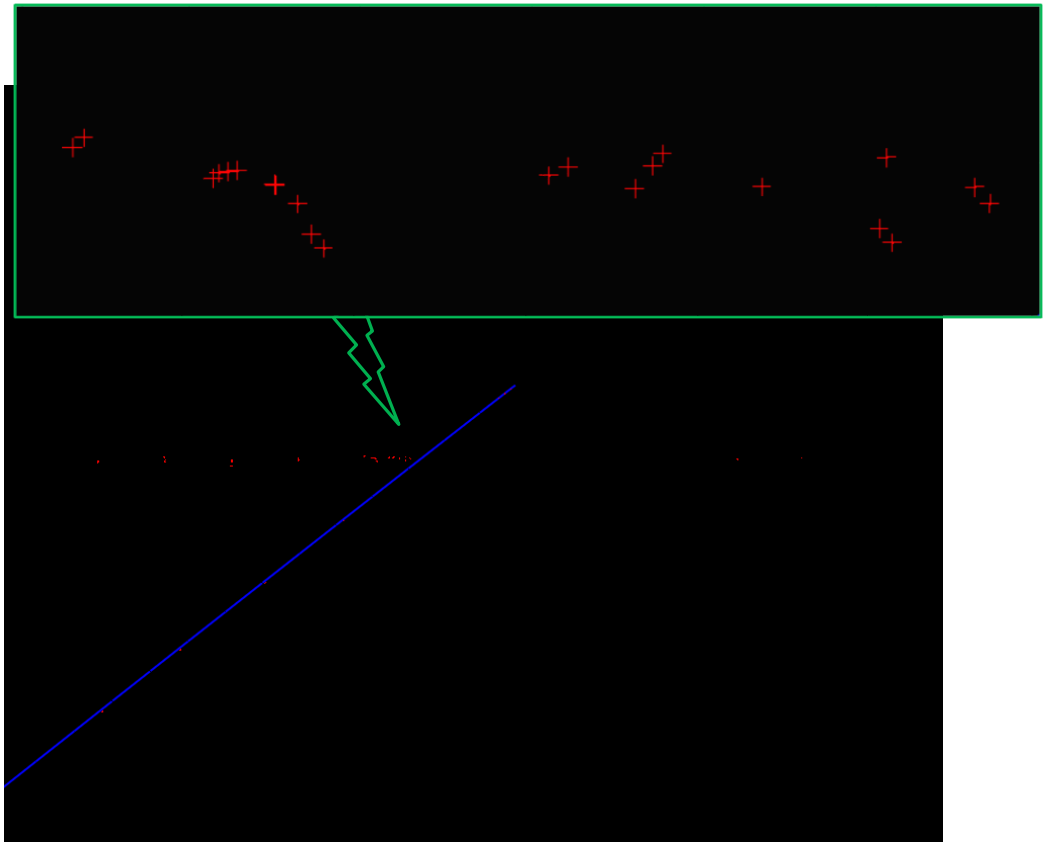
✓ In conformal space, a track in magnetic field is a straight line

✓ Track finding becomes straight line searching by pattern recognition (cellular automaton)

- Arbor PFA

Issues in Tracking

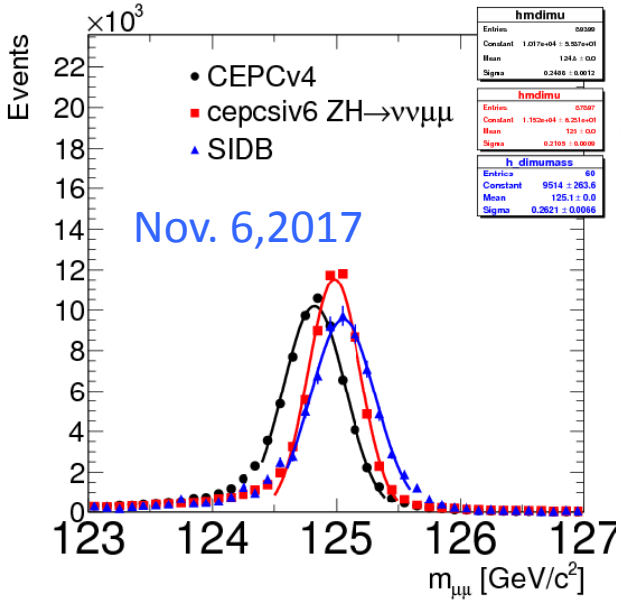
- SiliconTracking_MarlinTrk
  - Silicon tracking is seeded by set of layers, but only the best candidate saved for each seed, which causes some inefficiencies by picking a wrong hit nearby.
- ConformalTracking
  - Crash caused by expending too much memory, once many hits in a small region from secondary interactions
  - Clustering will help
  - As temporary fix, if too many hits from secondary, they are not chosen as candidate track hits, before tracking
- Clustering becomes important with a realistic tracking

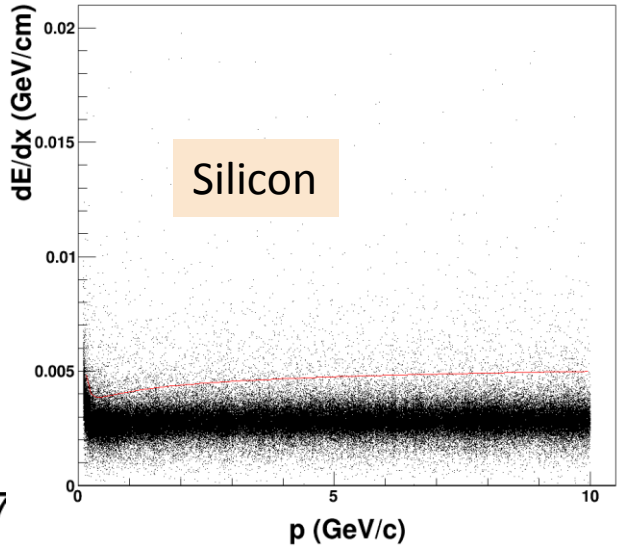


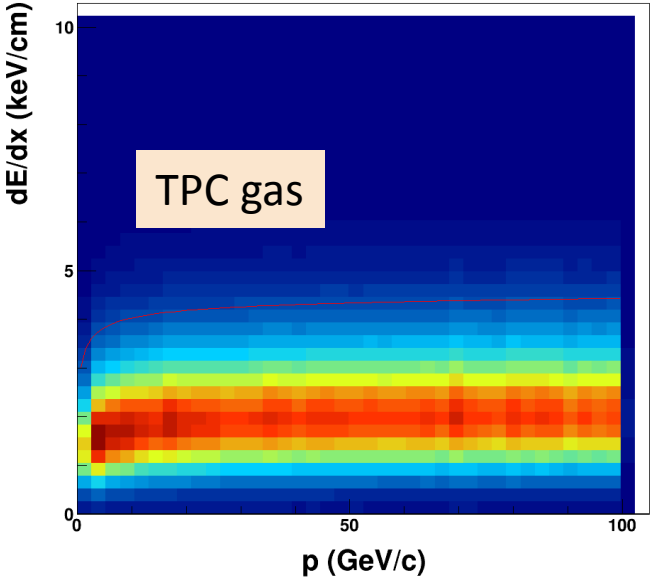
Issues in Fitting

- dE/dx in Geant4 and track fitting are different, which cause the momentum values from Kalman Fit deviate from the true values
- The Higgs mass seems ok for silicon tracking, but the shift was visible in TPC+SI
  - Why? Not yet understood

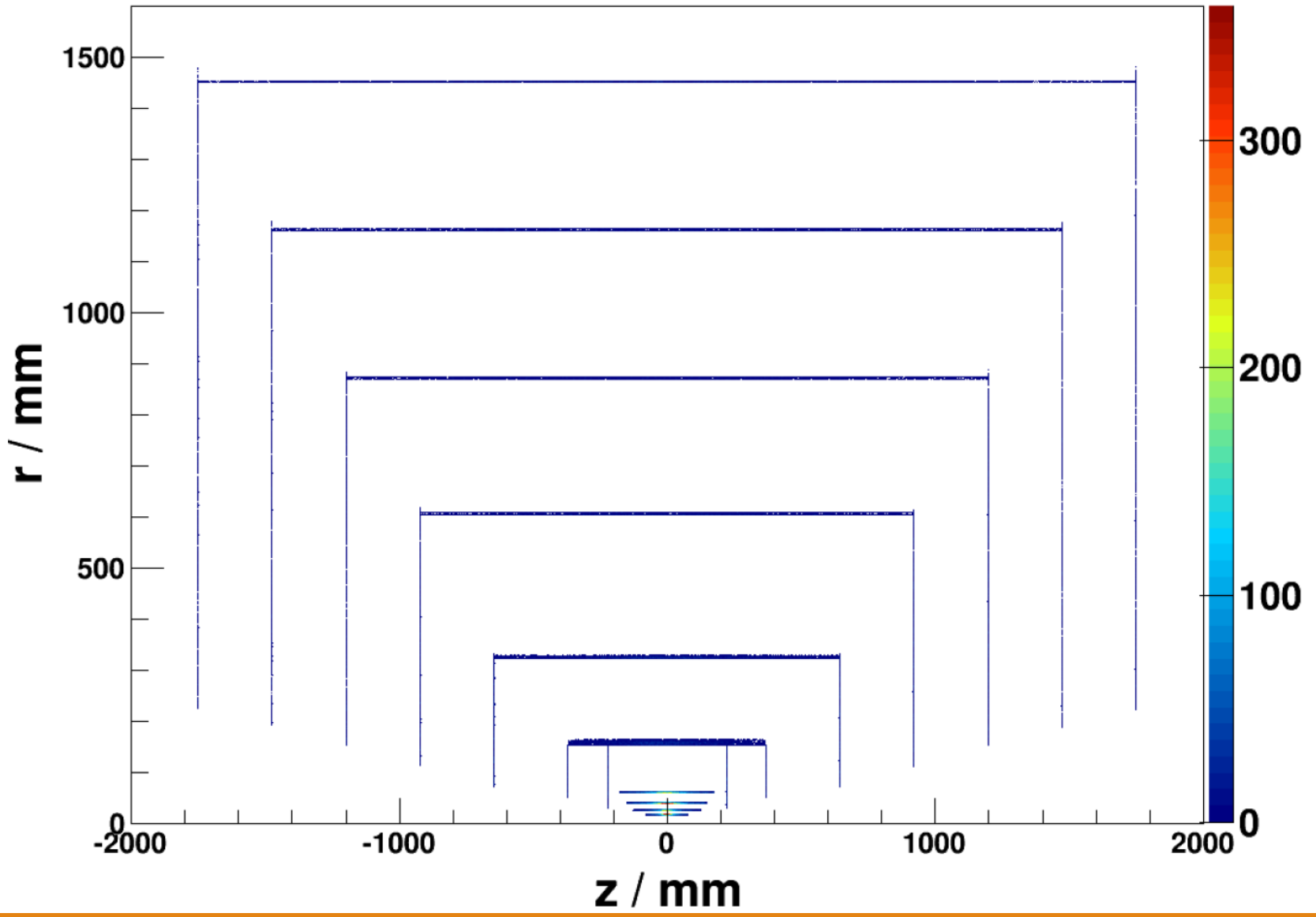
Red line for calculated values in Kalman Fit





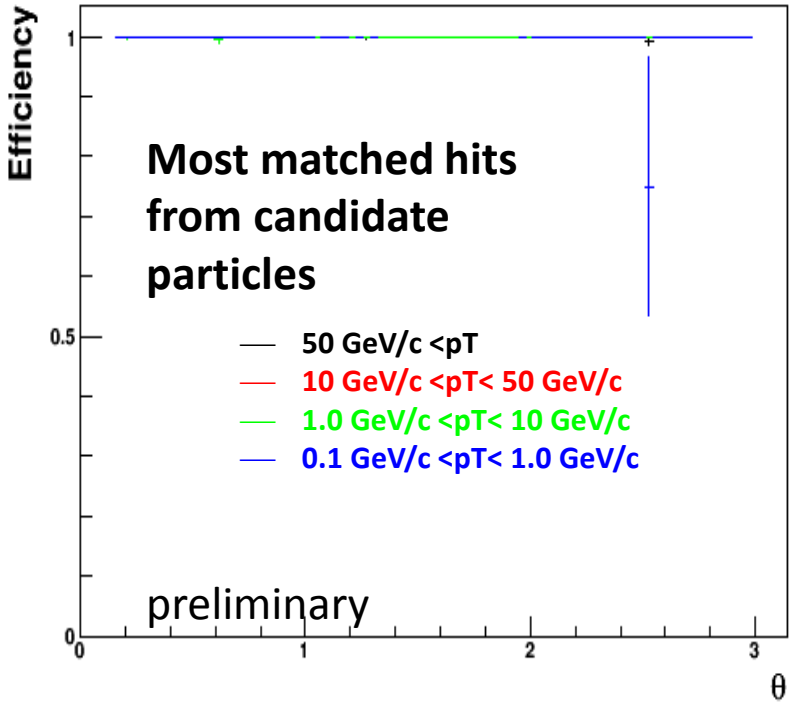


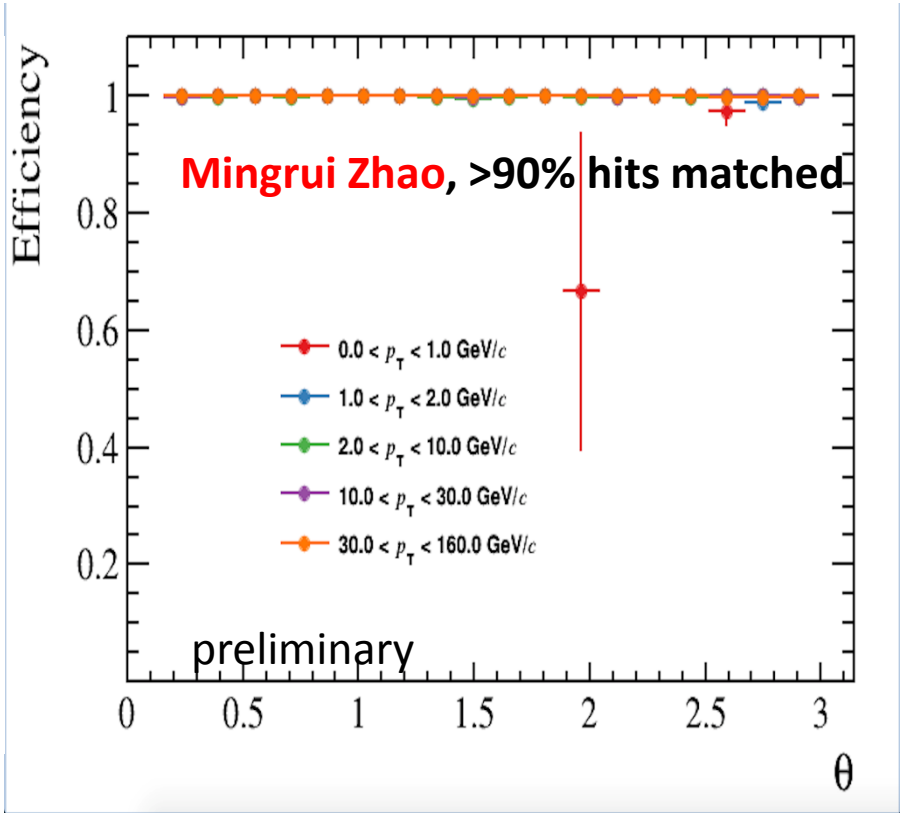
Hit Level



Tracking Efficiency (Single Muon)

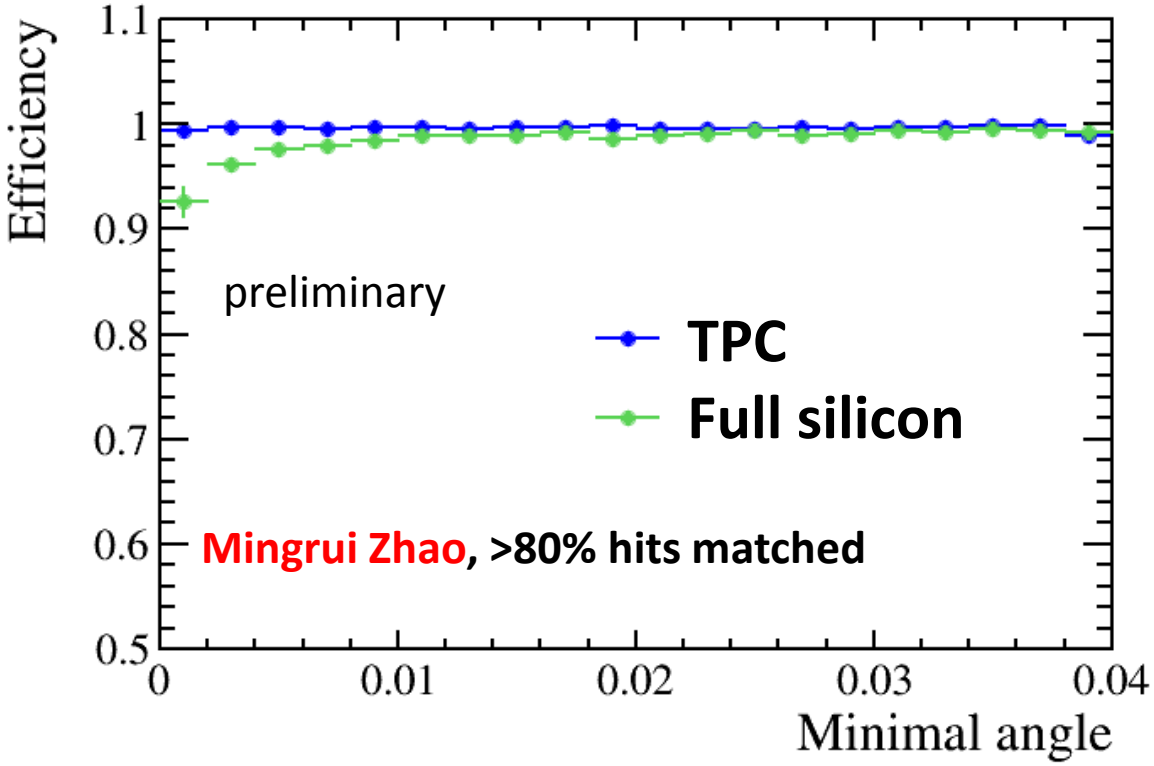
- At different efficiency calculation, the efficiencies are close to 100% for single muon.
  - $\varepsilon = \frac{N_{condi\&matched}}{N_{condi}}$
  - interested condition: such as vertex, particle type, momentum, etc.
  - Matching (different): hits from MCParticle ↔ candidate hits in track

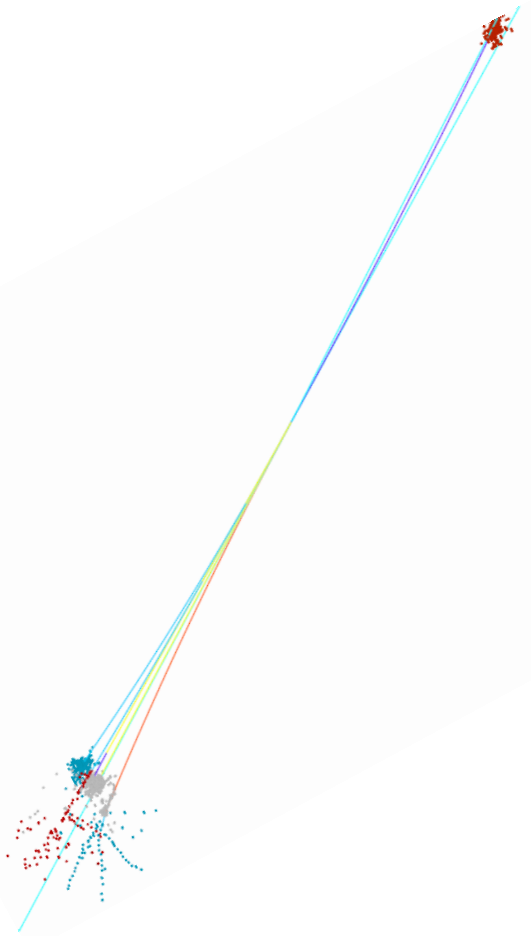




Tracking Efficiency ($Z \rightarrow \tau\tau$, $\tau \rightarrow 3+ \pi$)

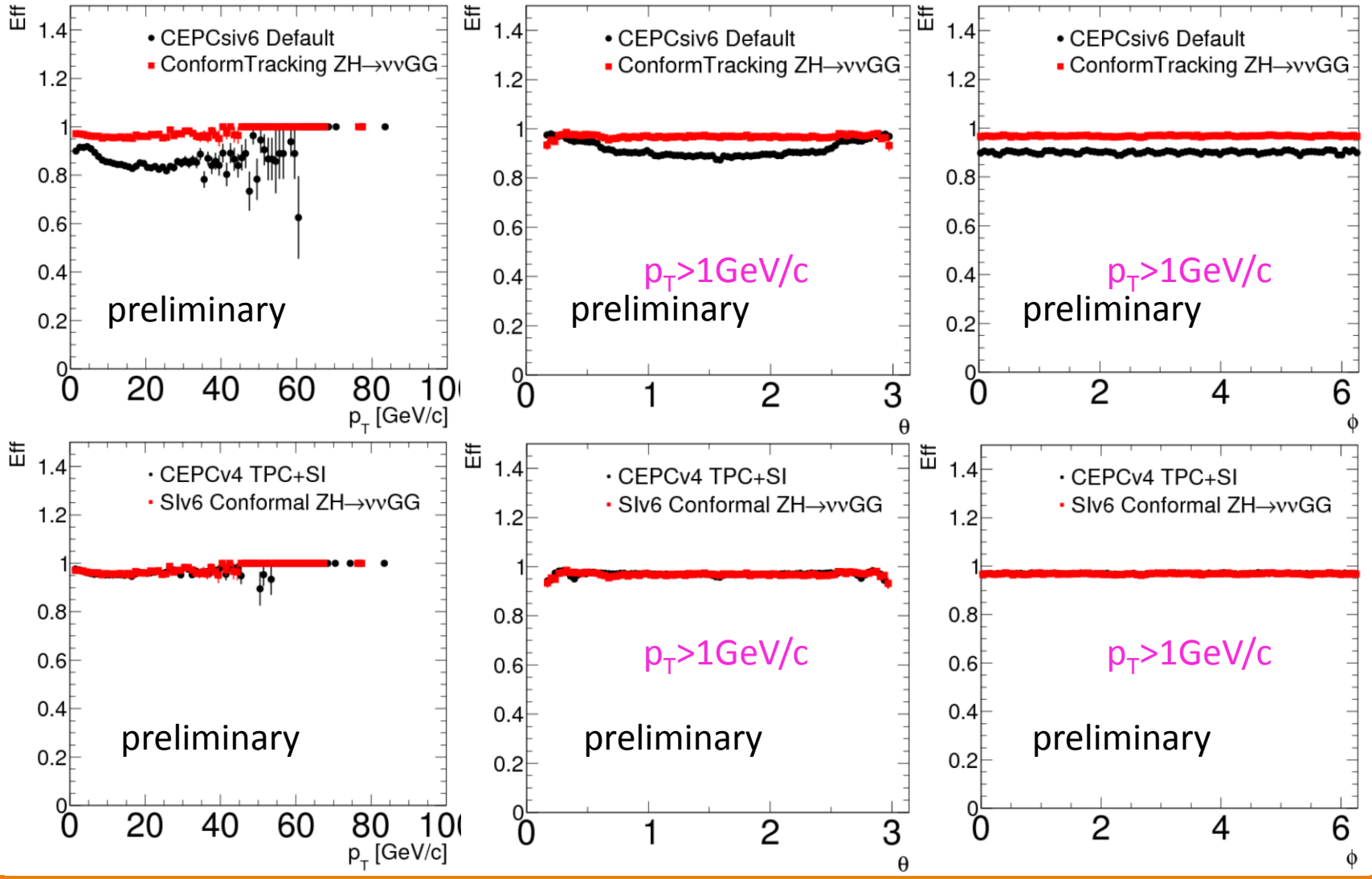
- The efficiencies of full silicon tracker by ConformalTracking become low while two pion are very close
  - Relative to the cut on matched hit number
  - Minimal angle: angle between two pions



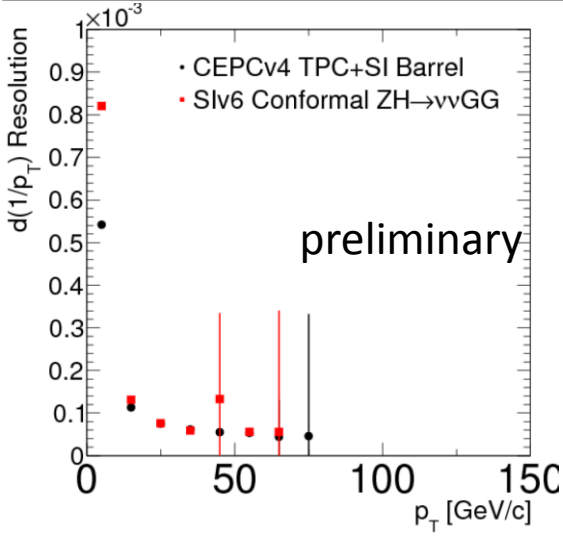


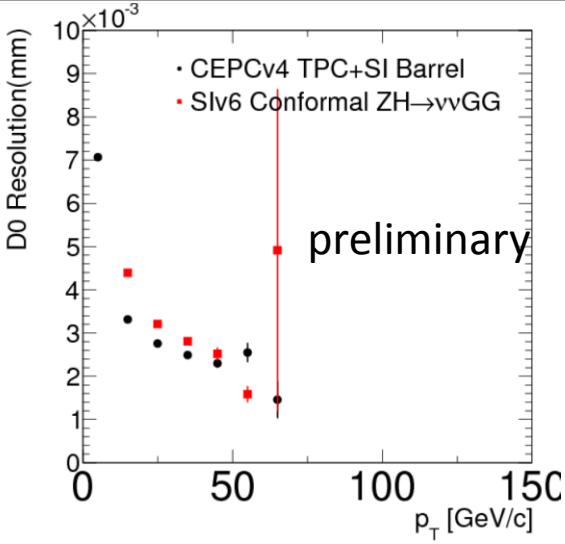
Tracking Efficiency (ZH→ννGG)

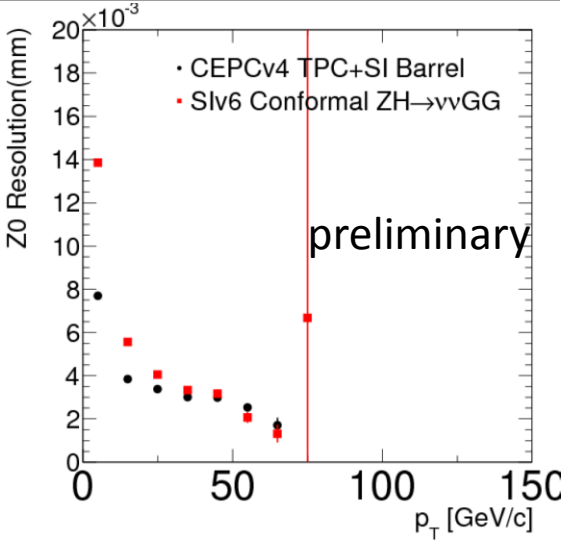
- Efficiencies from ConformalTracking are close to **TPC case**, larger than SiliconTracking_MarlinTrk.
- Therefore, ConformalTracking will be considered as main tracking for **full silicon tracker** in future.

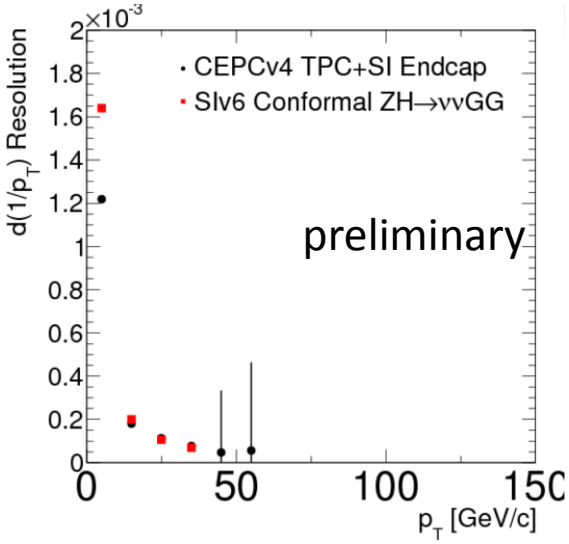


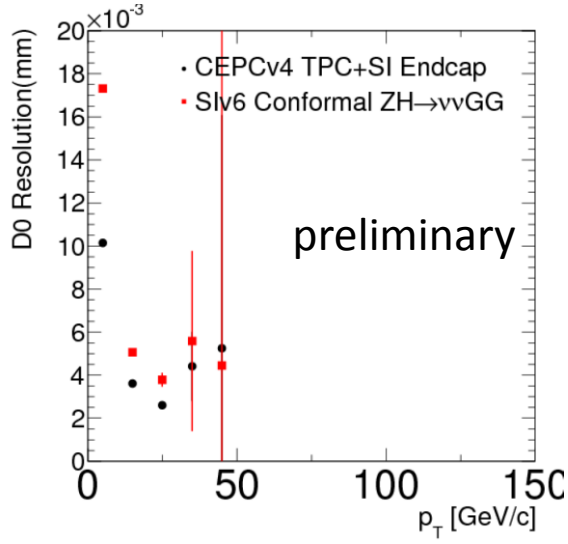
Resolution (ZH→ννGG)

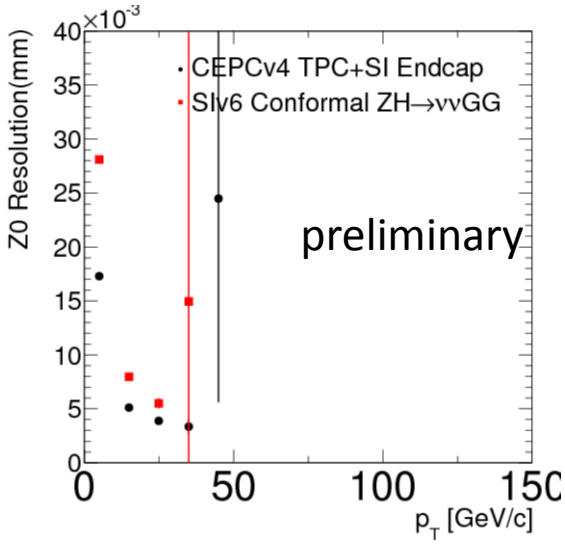












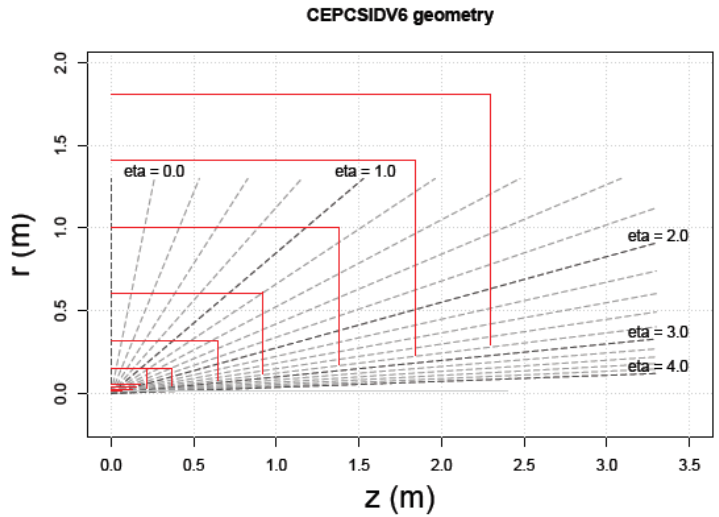
Conclusion

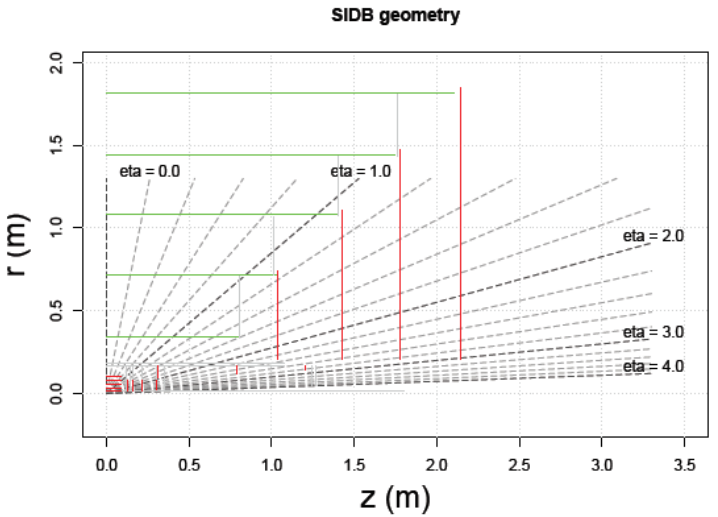
- The concepts of full silicon tracker have been implemented and seem working.
- ConformalTracking works on temporary clustering methods, and the performances of tracking and fitting are understood.
- Better clustering algorithm is needed, as next work plan
- There are rooms for improvement (such as material) and new ideas from LHC upgraded detectors.
  - More optimization will be started, once the tracking algorithm becomes better.
- The results are considered to update in CDR as one of tracking options for CEPC.

backup

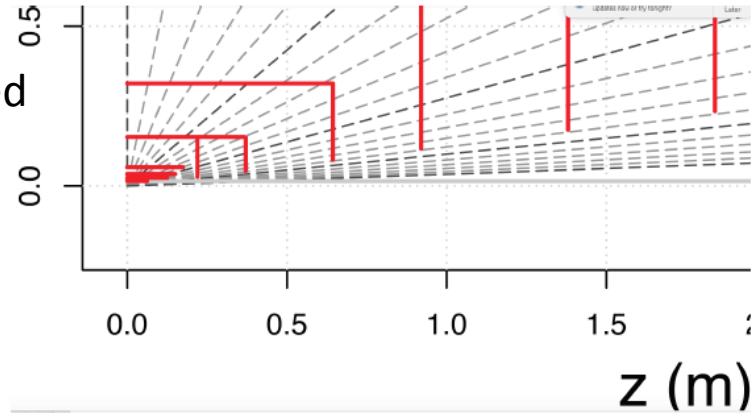
Thank you for your attention!

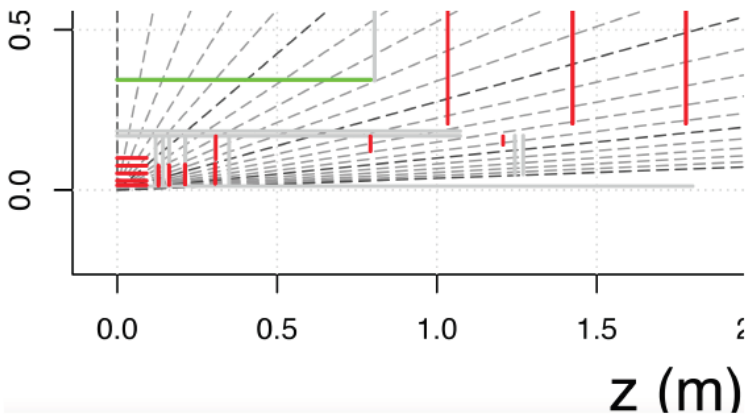
Full Silicon Tracker Concepts



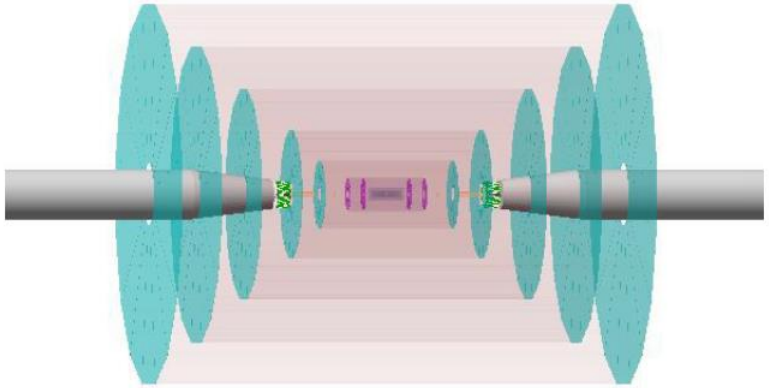


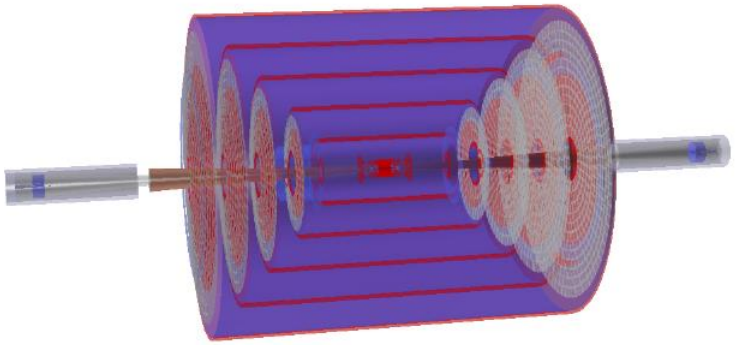
Zoomed

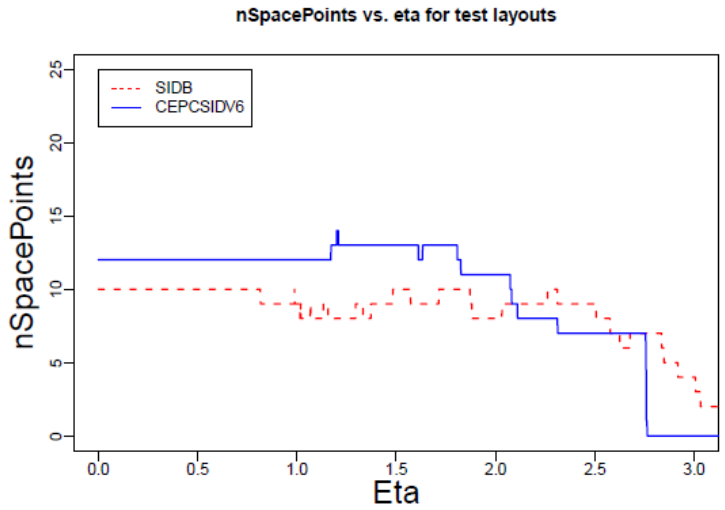


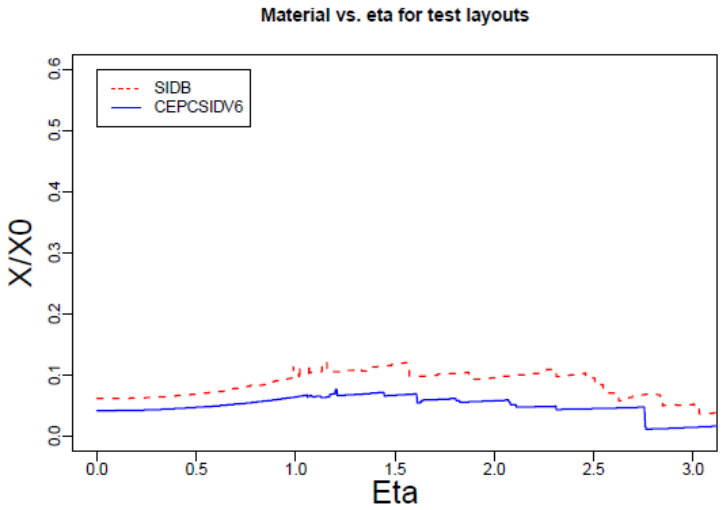


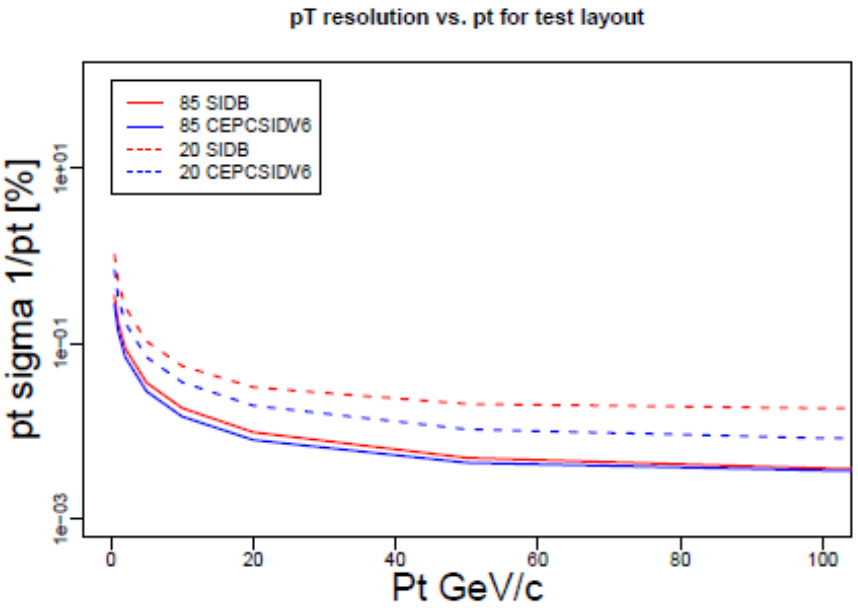
	CEPC-SID				SID-like			
Barrel	R		±z	Type	R		±z	Type
layer 0	0.153		0.368	D	0.344		0.793	S
layer 1	0.321		0.644	D	0.718		1.029	S
layer 2	0.603		0.920	D	1.082		1.391	S
layer 3	1.000		1.380	D	1.446		1.746	S
layer 4	1.410		1.840	D	1.820		2.107	S
layer 5	1.811		2.300	D				
Endcap	R_{in}	R_{out}	±z	Type	R_{in}	R_{out}	±z	Type
Disk 0	0.082	0.321	0.644	D	0.207	0.744	1.034	D
Disk 1	0.117	0.610	0.920	D	0.207	1.111	1.424	D
Disk 2	0.176	1.000	1.380	D	0.207	1.477	1.779	D
Disk 3	0.234	1.410	1.840	D	0.207	1.852	2.140	D
Disk 4	0.293	1.811	2.300	D				

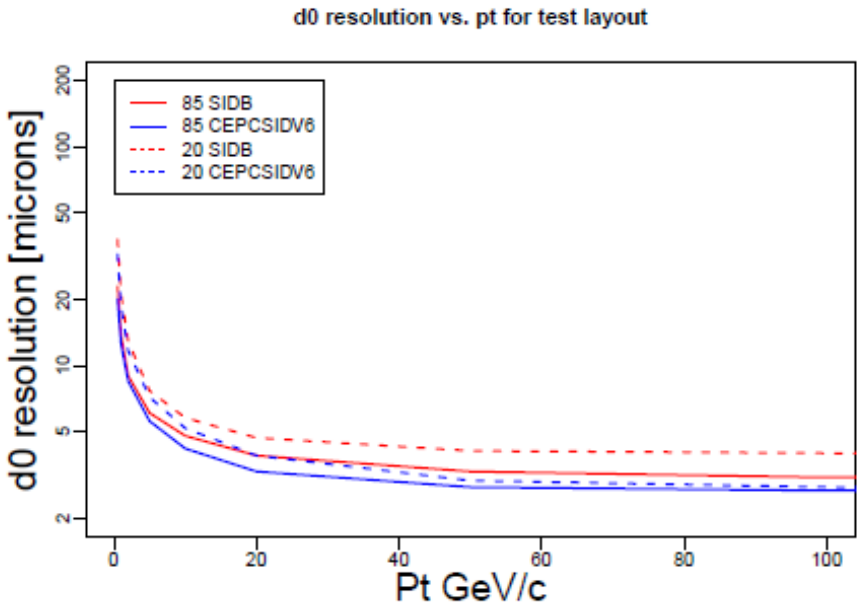


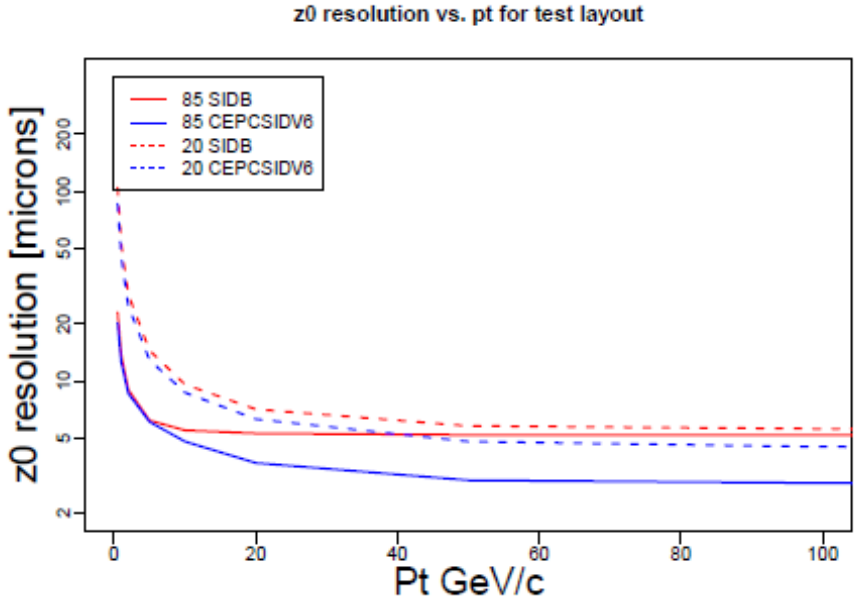



nSpacePoints vs. eta for test layouts
SIDB
CEPCSIDV6
nSpacePoints
Eta
0
5
10
15
20
25
0.0
0.5
1.0
1.5
2.0
2.5
3.0

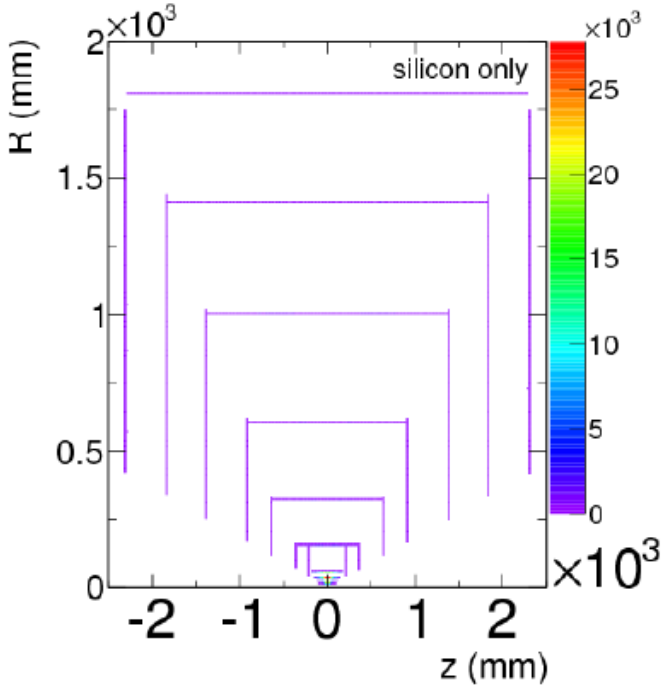

Material vs. eta for test layouts
SIDB
CEPCSIDV6
X/X0
Eta
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.0
0.5
1.0
1.5
2.0
2.5
3.0

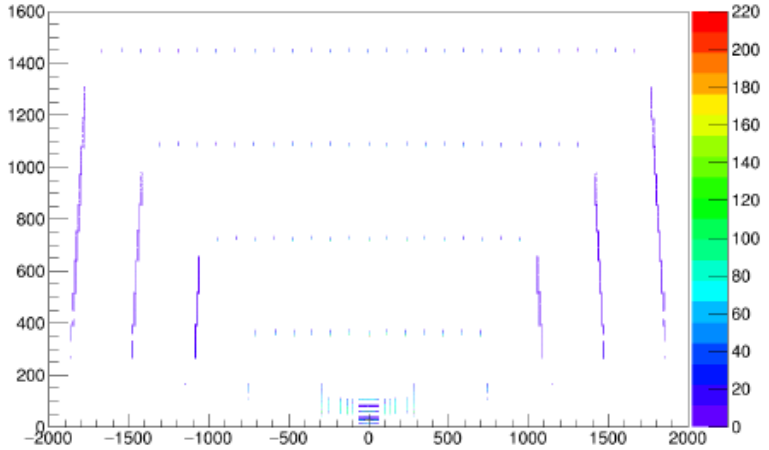

pT resolution vs. pt for test layout
85 SIDB
85 CEPCSIDV6
20 SIDB
20 CEPCSIDV6
pt sigma 1/pt [%]
1e-03
1e-01
1e+01
0
20
40
60
80
100
Pt GeV/c


d0 resolution vs. pt for test layout
85 SIDB
85 CEPCSIDV6
20 SIDB
20 CEPCSIDV6
d0 resolution [microns]
2
5
10
20
50
100
200
0
20
40
60
80
100
Pt GeV/c

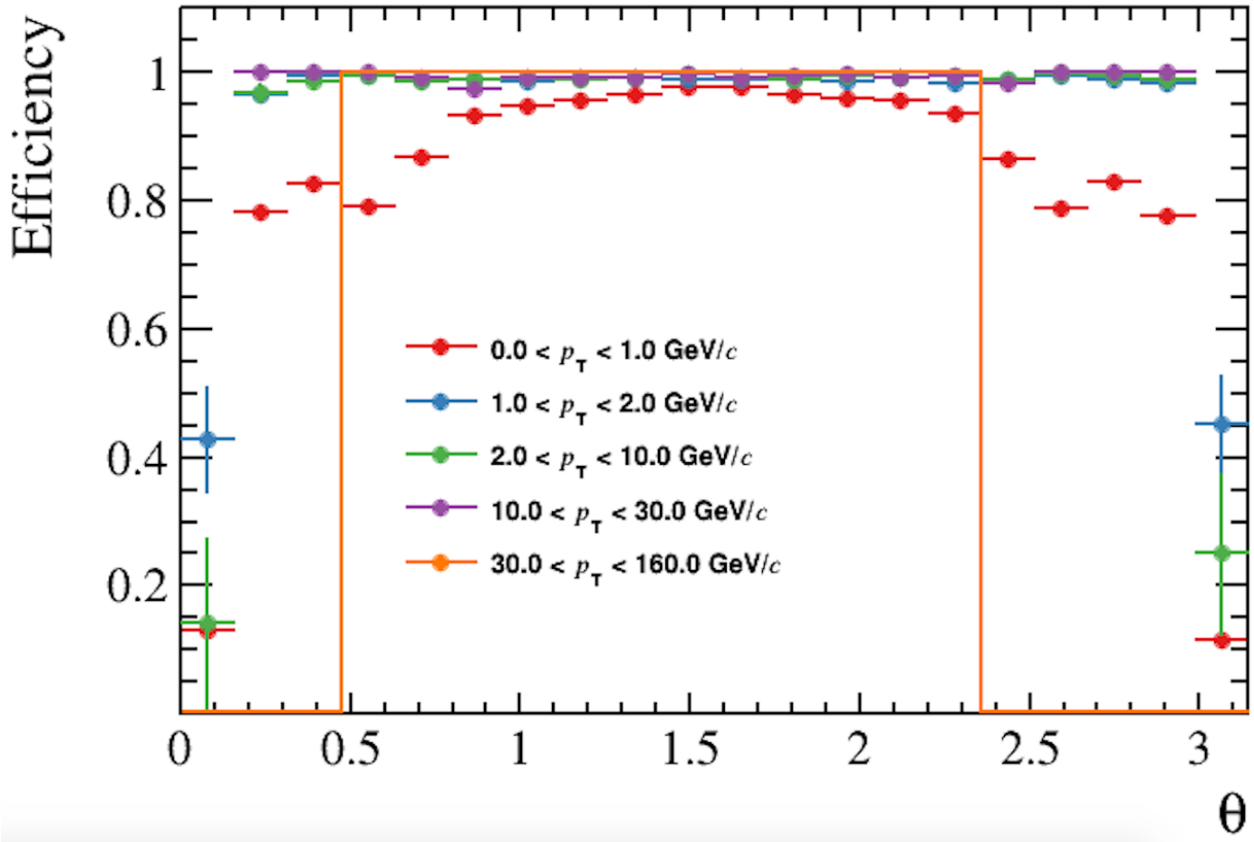

z0 resolution vs. pt for test layout
85 SIDB
85 CEPCSIDV6
20 SIDB
20 CEPCSIDV6
z0 resolution [microns]
2
5
10
20
50
100
200
0
20
40
60
80
100
Pt GeV/c

Hit Level

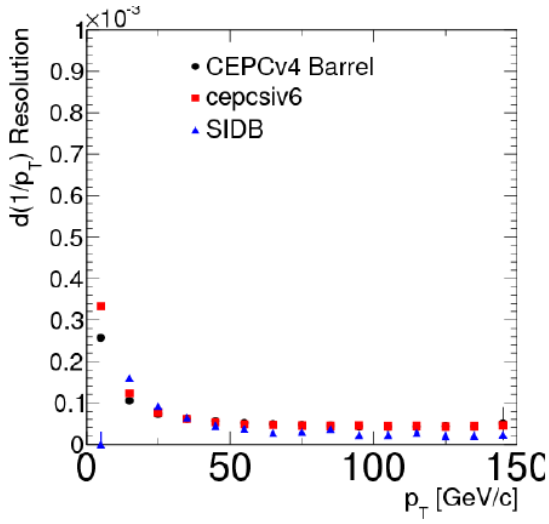

silicon only
R (mm)
z (mm)
×10^3
2
1.5
1
0.5
0
-2
-1
0
1
2
25
20
15
10
5
0

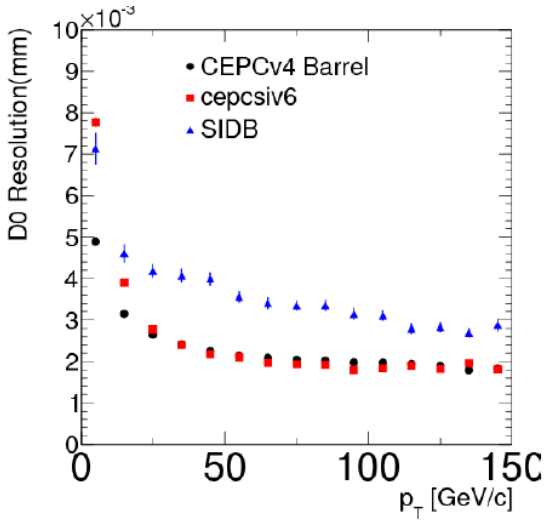

1600
1400
1200
1000
800
600
400
200
0
−2000
−1500
−1000
−500
0
500
1000
1500
2000
220
200
180
160
140
120
100
80
60
40
20
0

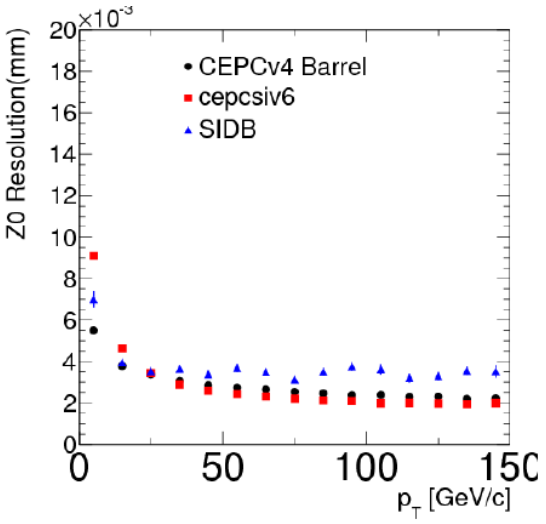
Tracking Efficiency (ZH→ννGG)

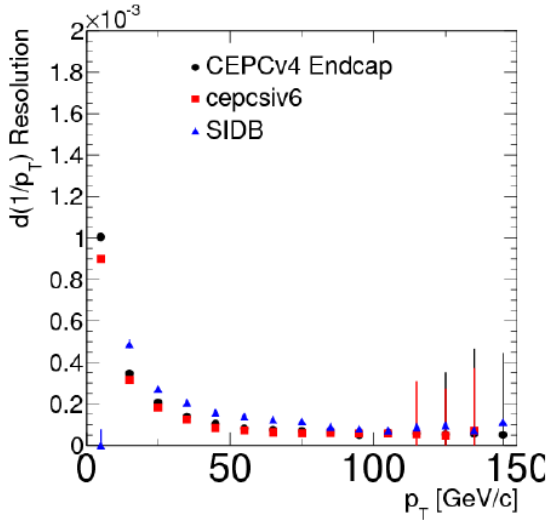


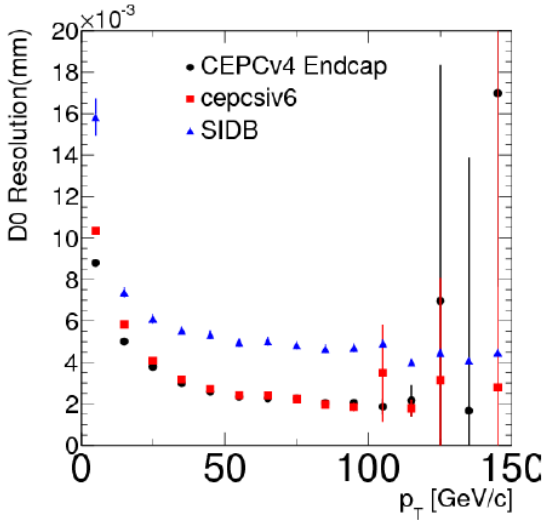
Resolution

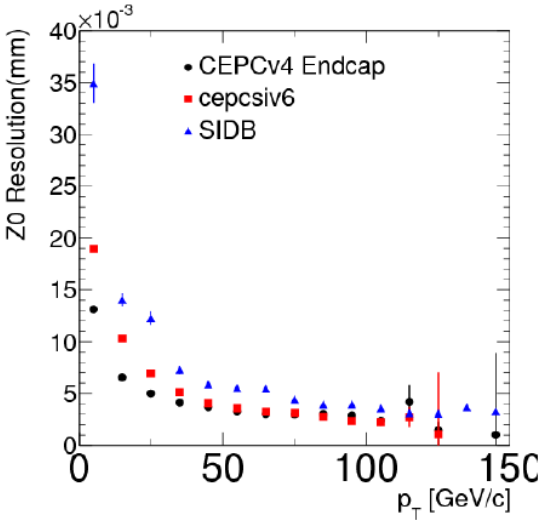

×10⁻³
d(1/p_T) Resolution
CEPCv4 Barrel
cepcsiv6
SIDB
p_T [GeV/c]


×10⁻³
D0 Resolution(mm)
CEPCv4 Barrel
cepcsiv6
SIDB
p_T [GeV/c]


×10⁻³
Z0 Resolution(mm)
CEPCv4 Barrel
cepcsiv6
SIDB
p_T [GeV/c]


×10⁻³
d(1/p_T) Resolution
CEPCv4 Endcap
cepcsiv6
SIDB
p_T [GeV/c]


×10⁻³
D0 Resolution(mm)
CEPCv4 Endcap
cepcsiv6
SIDB
p_T [GeV/c]


×10⁻³
Z0 Resolution(mm)
CEPCv4 Endcap
cepcsiv6
SIDB
p_T [GeV/c]

- Silicon usages (double strip layer counted twice):

Area m^2	Pixel	Strip	Total
CEPC V4	1.3	154.2	155.6
CEPCSID	1.3	307.3	308.6
CEPCSID/CEPC	1.0	2.0	1.96