Track Reconstruction for CEPC

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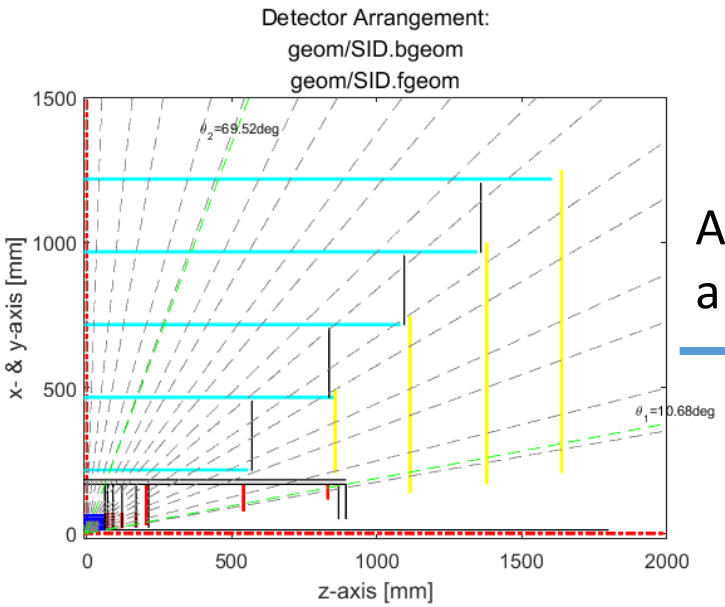
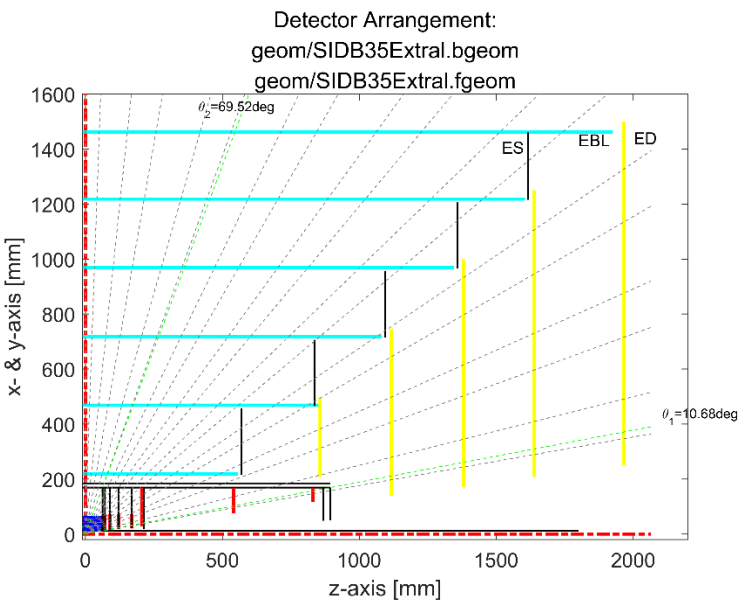
Motivation

- Weiming modified ATLAS Idres tool to predict the expected tracking resolutions using different detector layout for CEPC. (CEPC_FullSilicon_tracker_0510.pdf and CEPC_FullSilicon_tracker_0606.pdf)
- In his report, he considered the following design:
  - Reducing B field 5 T → 3.5T in order to compensate easily.
  - Changing single-sided strip in Barrel → Double-sided w small angle stereo
  - Add extra strip layer in barrel and endcap to compensate a lower B field.
  - Checking the impacts of material budgets
- In order to cross check, I use LDT tool to do the fast simulation with a same geometry as Weiming.
  - Distribution of material budget and space points are the same
  - Resolutions of d0, z0 and 1/Pt have some differences, so we considered some possible reason(fit quality and stereo angle of forward). But finally we do not find the true reason of the differences between this two software.
  - Anyway, we can still do some optimize for CEPC

Geometry



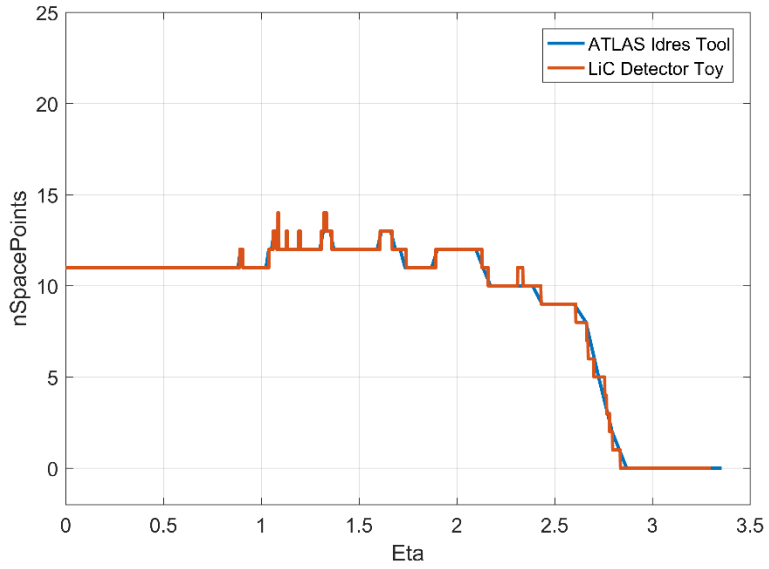
Add Stereo and extraL

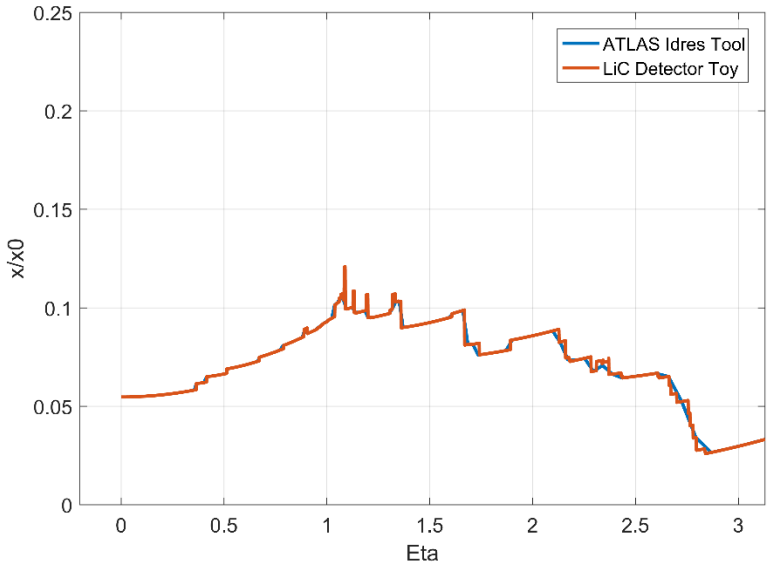


Silicon Detector

- B field: 5 T -> 3.5 T
- Vertex:
  - Pixels (5 Barrels + 4 Disks + 3 Forward Disks)
  - Stereo angle: 90°
- Tracker
  - Strips (5+1 Barrels + 4+1Disks) -> Compensate
  - Stereo angle: 7° (It has some differences in geometry files)
- Geometry files: Step1_SIDB35Extral.bgeom and Step1_SIDB35Extral.fgeom

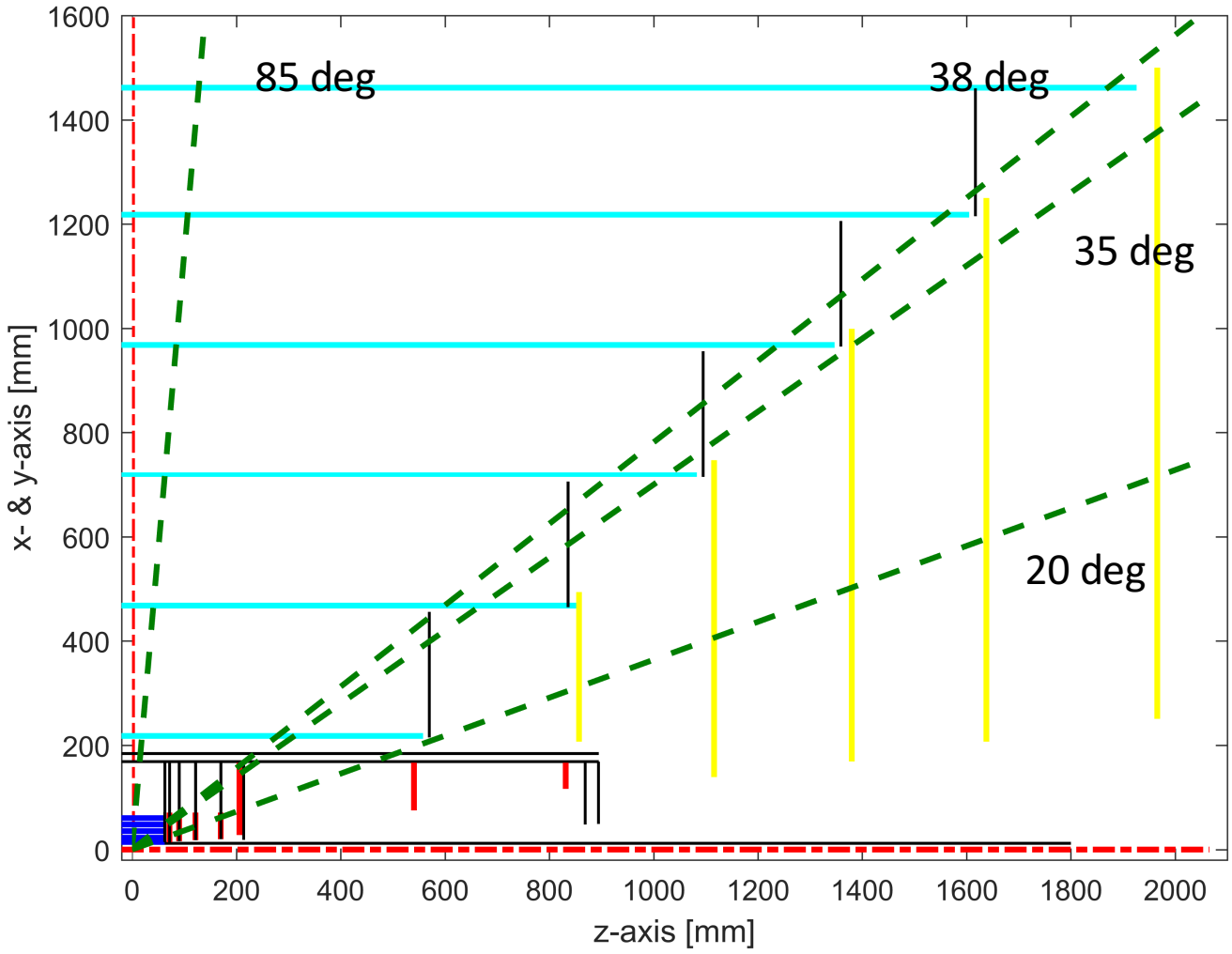
Hit and Material Budget



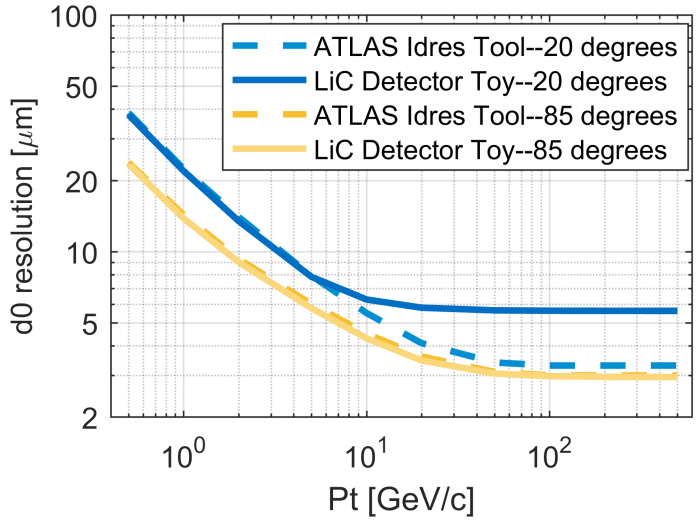


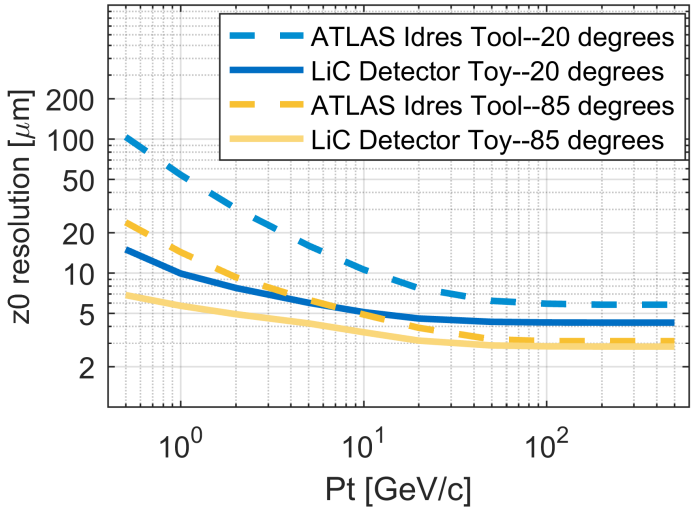
- Material vs eta： The results are similar between LiC Detector Toy and ATLAS Idres Tool
- The minor differences are due to the different steps. In LDT, the minimum step is 0.5 deg
- There is a bug -> When the polar angle theta is less than 5 degrees, the software cannot run correctly. I have fixed the bug, but it can only be used for space points and material budget calculation. Anyway, it does no matter for resolution study.

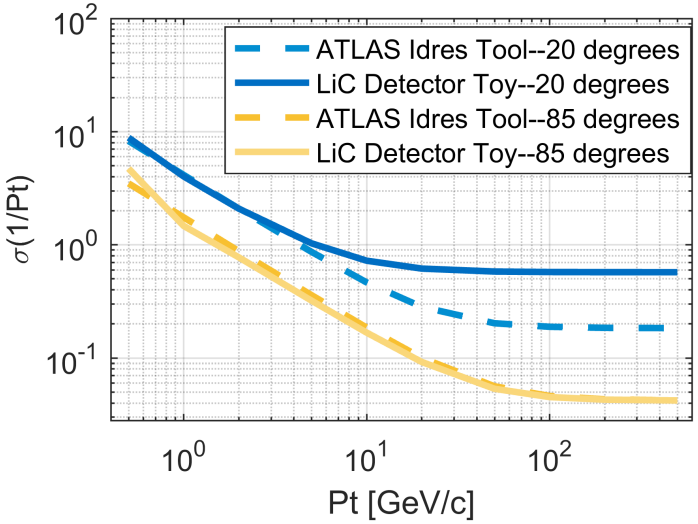
The Angle of Track Incidence



Resolution 20-85

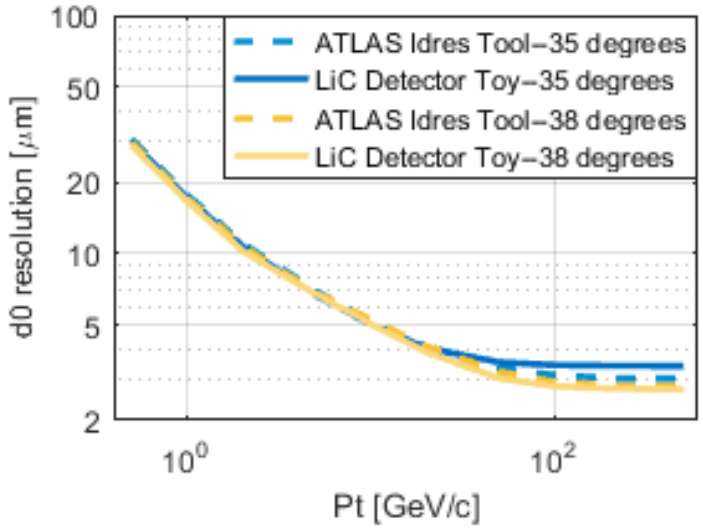


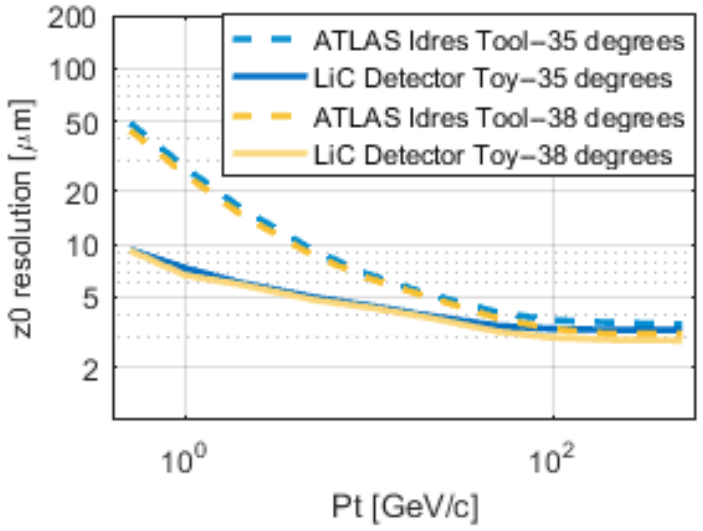


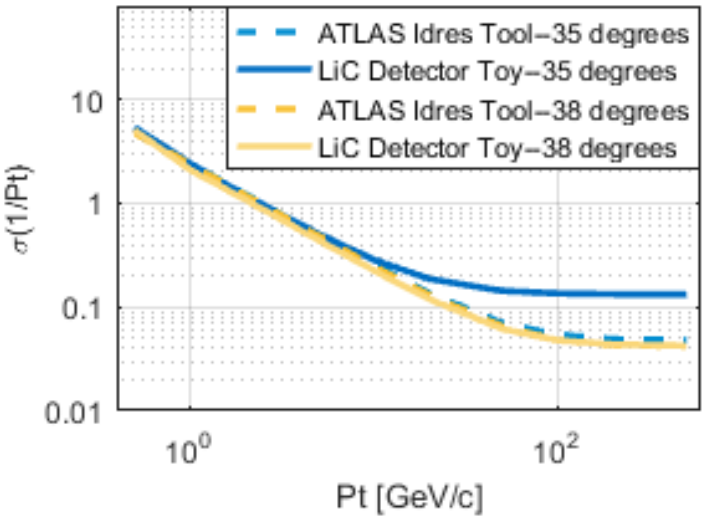


- D0, 1/Pt resolution are still similar in 85 degrees, but it have some differences in 20 degrees.
- Z0 resolution are different in low Pt, but will be agreement in high Pt.

Resolution 30-35







- It seems that the resolutions of d0 and 1/Pt are similar in the barrel area, while different in forward area.
- The resolution of z0 are different between the two software no matter in barrel area or forward area.

Sigma d0 of Fit

Unit: Micron	20 deg	35deg	38deg	85 deg
10 GeV	6.272313	5.087098	5.090781	4.307247
100 GeV	5.635646	3.445702	2.890544	2.987153

$$Parameters = (\Phi_c, z_c, \theta_c, \beta_c, \kappa_c)$$

$$d0 = f(\Phi_c, \beta_c, \kappa_c)$$

$$V(d0) = SVS^T \quad \sigma_{d0fit}$$

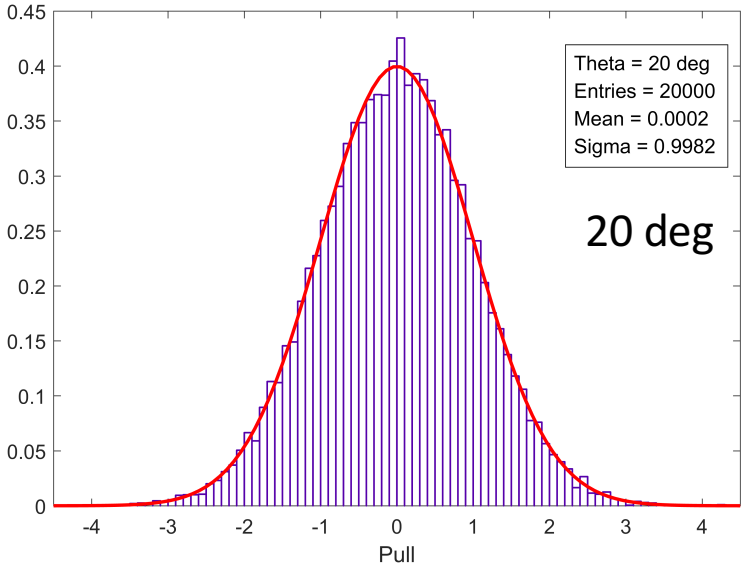
$$V = \begin{bmatrix} cov(\Phi_c, \Phi_c) & cov(\Phi_c, \beta_c) & cov(\Phi_c, \kappa_c) \\ cov(\beta_c, \Phi_c) & cov(\beta_c, \beta_c) & cov(\beta_c, \kappa_c) \\ cov(\kappa_c, \Phi_c) & cov(\kappa_c, \beta_c) & cov(\kappa_c, \kappa_c) \end{bmatrix}$$

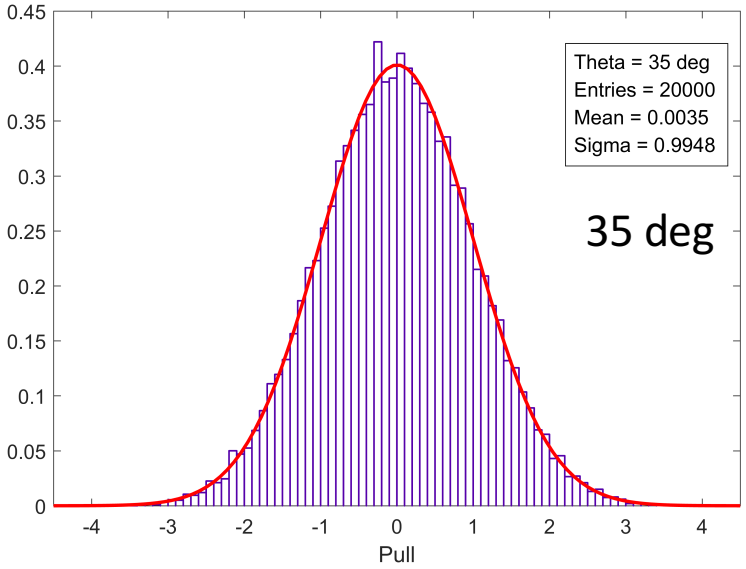
$$S = \begin{bmatrix} \frac{\partial f}{\partial \Phi_c} & \frac{\partial f}{\partial \beta_c} & \frac{\partial f}{\partial \kappa_c} \end{bmatrix}$$

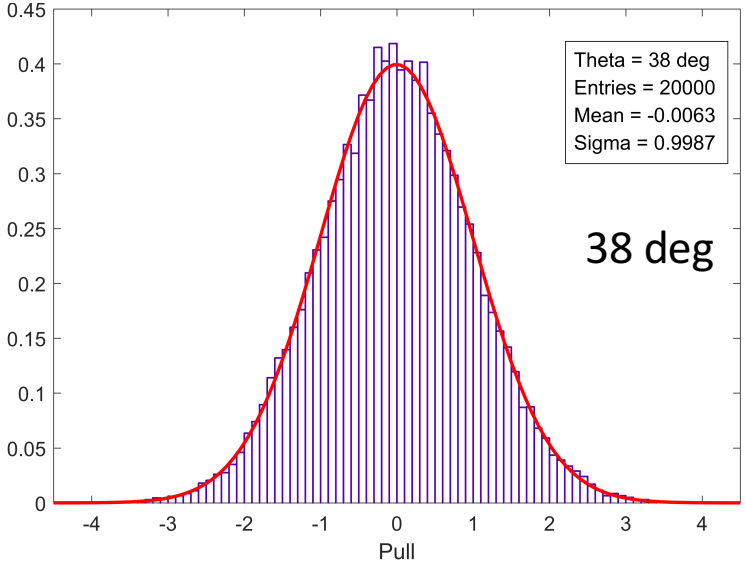
$$Pull = \frac{d0_{fit} - d0_{true}}{\sigma_{d0fit}}$$

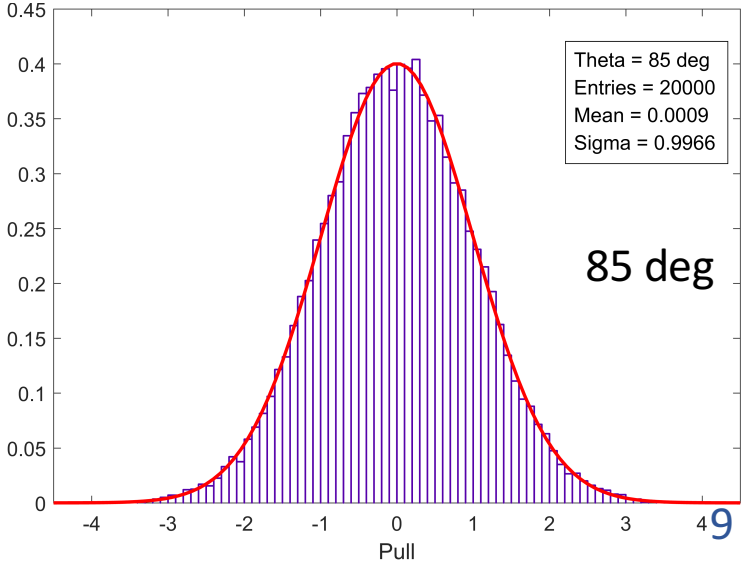
- We check the fit quality, and get the pull distribution of d0

Pull d0


Theta = 20 deg
Entries = 20000
Mean = 0.0002
Sigma = 0.9982
20 deg
Pull


Theta = 35 deg
Entries = 20000
Mean = 0.0035
Sigma = 0.9948
35 deg
Pull


Theta = 38 deg
Entries = 20000
Mean = -0.0063
Sigma = 0.9987
38 deg
Pull


Theta = 85 deg
Entries = 20000
Mean = 0.0009
Sigma = 0.9966
85 deg
Pull

Hit positions in 20° before track fit

LDT

Z	r	sigFirst	sigSecond
0.0330	0.0120	0.0000E+00	0.0000E+00
0.0401	0.0146	5.7700E-06	5.7700E-06
0.0621	0.0226	5.7700E-06	5.7700E-06
0.0627	0.0228	0.0000E+00	0.0000E+00
0.0630	0.0229	0.0000E+00	0.0000E+00
0.0718	0.0261	5.7700E-06	5.7700E-06
0.0721	0.0263	0.0000E+00	0.0000E+00
0.0902	0.0328	5.7700E-06	5.7700E-06
0.0905	0.0330	0.0000E+00	0.0000E+00
0.1216	0.0443	5.7700E-06	5.7700E-06
0.1219	0.0444	0.0000E+00	0.0000E+00
0.1700	0.0619	5.7700E-06	5.7700E-06
0.1703	0.0620	0.0000E+00	0.0000E+00
0.2060	0.0750	1.4400E-05	1.4400E-05
0.2140	0.0779	0.0000E+00	0.0000E+00
0.4633	0.1687	0.0000E+00	0.0000E+00
0.5059	0.1842	0.0000E+00	0.0000E+00
0.8570	0.3121	1.4400E-05	1.0000E-04
1.1160	0.4064	1.4400E-05	1.0000E-04
1.3800	0.5025	1.4400E-05	1.0000E-04
1.6380	0.5964	1.4400E-05	1.0000E-04
1.9656	0.7157	1.4400E-05	1.0000E-04

Idres

Z	r	sigFirst	sigSecond
0.0330	0.0120	1.0000E+06	1.0000E+06
0.0401	0.0146	5.7700E-06	5.7700E-06
0.0621	0.0226	5.7700E-06	5.7700E-06
0.0627	0.0228	1.0000E+06	1.0000E+06
0.0630	0.0229	1.0000E+06	1.0000E+06
0.0718	0.0261	5.7700E-06	5.7700E-06
0.0721	0.0263	1.0000E+06	1.0000E+06
0.0902	0.0328	5.7700E-06	5.7700E-06
0.0905	0.0330	1.0000E+06	1.0000E+06
0.1216	0.0443	5.7700E-06	5.7700E-06
0.1219	0.0444	1.0000E+06	1.0000E+06
0.1700	0.0619	5.7700E-06	5.7700E-06
0.1703	0.0620	1.0000E+06	1.0000E+06
0.2060	0.0750	1.4400E-05	1.4400E-05
0.2140	0.0779	1.0000E+06	1.0000E+06
0.4633	0.1687	1.0000E+06	1.0000E+06
0.5059	0.1842	1.0000E+06	1.0000E+06
0.8570	0.3121	1.4400E-05	1.0000E-04
1.1160	0.4064	1.4400E-05	1.0000E-04
1.3800	0.5025	1.4400E-05	1.0000E-04
1.6380	0.5964	1.4400E-05	1.0000E-04
1.9656	0.7157	1.4400E-05	1.0000E-04

- We check the hit positions before track fit, but they are the same
- In LDT, 0 stands for passive barrel, while 1.000E+06 stands for passive barrel in Idres

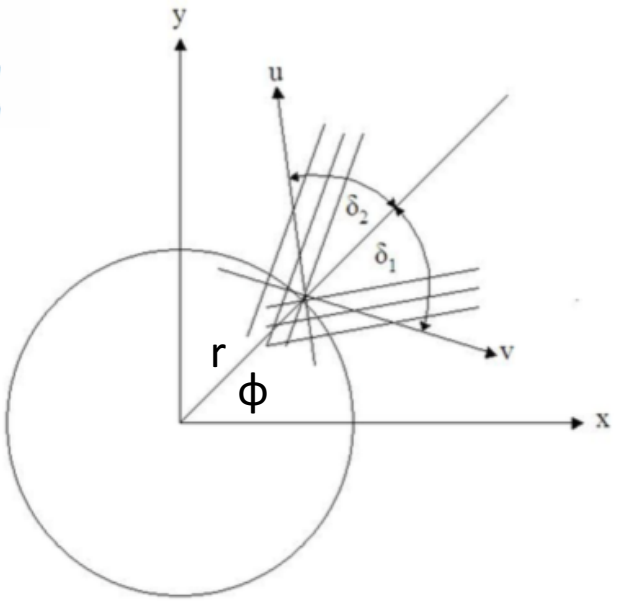
Forward Disk Resolution

LDT:

```
Description (optional)     : |---forward vertex det (pixels)---|
Names of the layers (opt.):  VXF1,     VXF2,     VXF3,     VXF4,
z positions [mm]           :  71.8,     90.2,     121.6,    170,
Inner radius [mm]          :  14,       16,       18,       20,
Outer radius [mm]          :  71,       71,       71,       71,
Efficiency u               :  0.99,     0.99,     0.99,     0.99,
Efficiency v               :  0.99,     0.99,     0.99,     0.99,
Angle 1st coord. (u) [Rad]:  0
Angle 2nd coord. (v) [Rad]:  90*pi/180
Thickness [rad. lengths]   :  0.00148,  0.00148,  0.00148,  0.00148
error distribution         :  0
0 normal-sigma(u) [1e-6m] :  5.77,     5.77,     5.77,     5.77,
          sigma(v) [1e-6m] :  5.77,     5.77,     5.77,     5.77,
```

Idres:

```
! Pixel endcap
!  Ri       Ro       z        %X0   resRphi  resR
disc
! VXF1-4
     0.014    0.071    0.0718   0.148  5.77E-06  5.77E-06
     0.016    0.071    0.0902   0.148  5.77E-06  5.77E-06
     0.018    0.071    0.1216   0.148  5.77E-06  5.77E-06
     0.020    0.071    0.1700   0.148  5.77E-06  5.77E-06
```



- We compared the u/v with r/rPhi. Finally, we think they are the same thing

Conclusion

- Although the LDT and Idres give different resolutions, we can still do some optimize for CEPC
- How to meet the CEPC tracker design requirements?
  - $\sigma(1/pt) = 2\text{-}5 \times 10^{-5}$
  - $\sigma(d0) < 5$ μm, $\sigma(z0) < 5$ μm
  - Less material budgets
  - Hermeticity detector down to 10 degree in theta?
  - What's the maximum theta coverage
  - What's the closet radius for pixel detector?