Update of FastTrkSim

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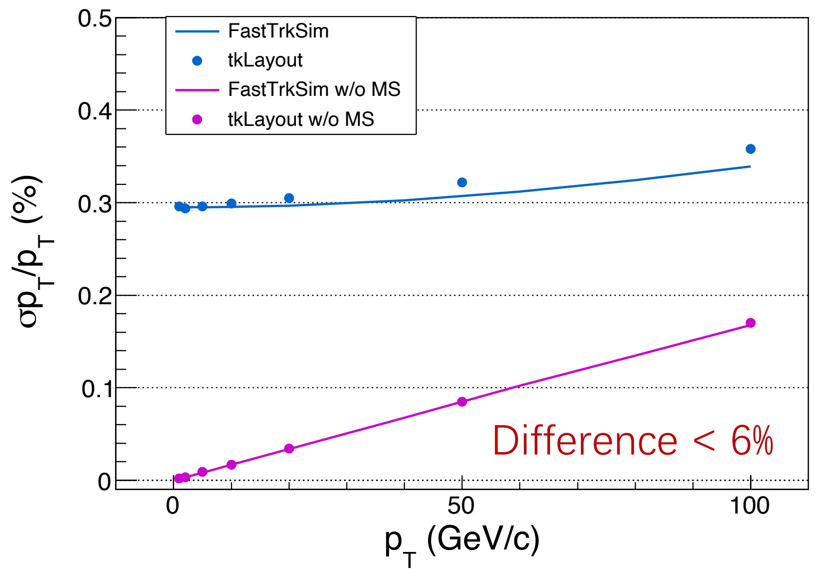
Introduction of FastTrkSim

- Aim to fast calculation or simulation for tracker layout optimization
- 1st version
  - Estimation of p_T resolution
    - Difference < 6% compared with tkLayout
  - Can not provide the resolution of impact parameters and angles including M.S. effect
- Updating to 2nd version
  - To achieve the resolution of all helix parameters with contribution of M.S.

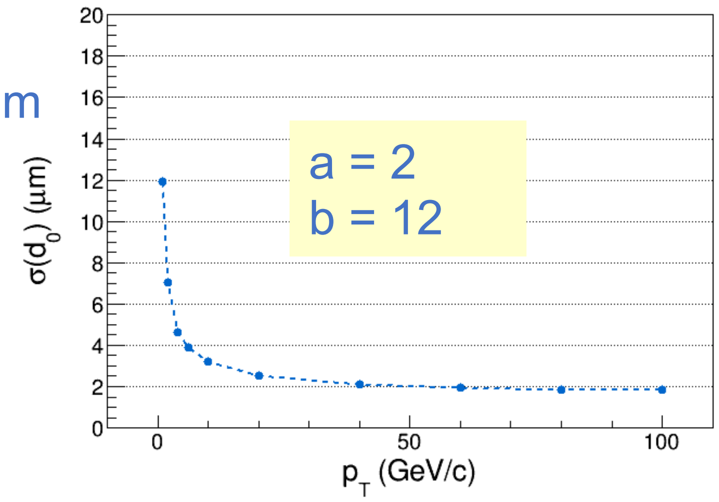
FastTrkSim vs tkLayout

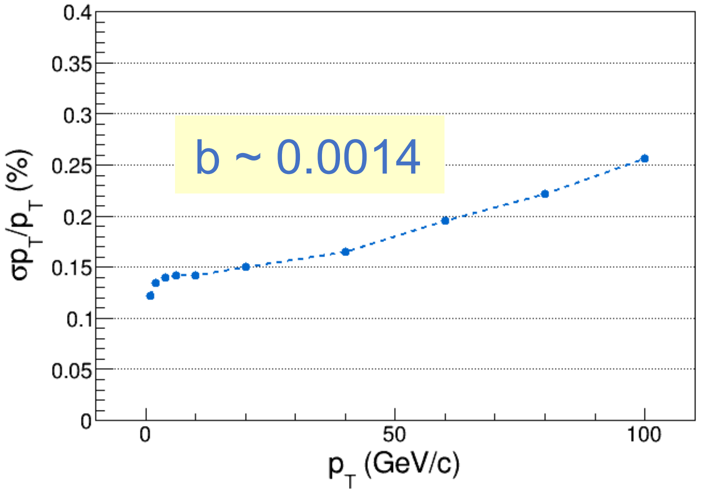


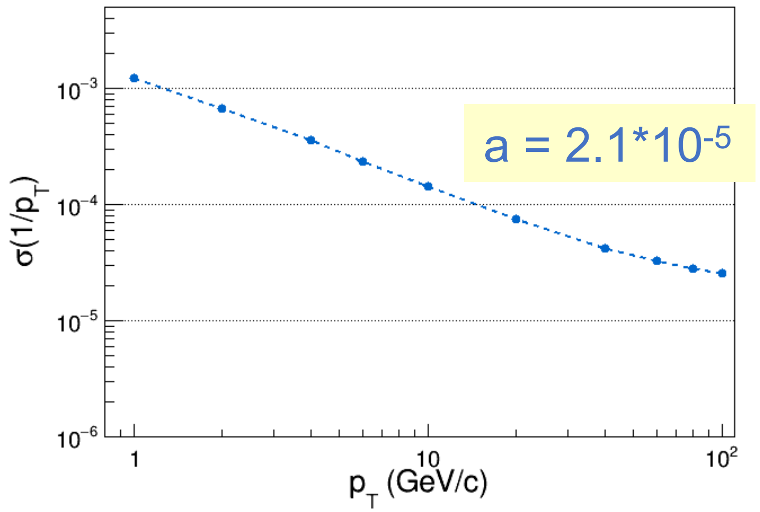
Preliminary results with full Si layout

θ= 90º

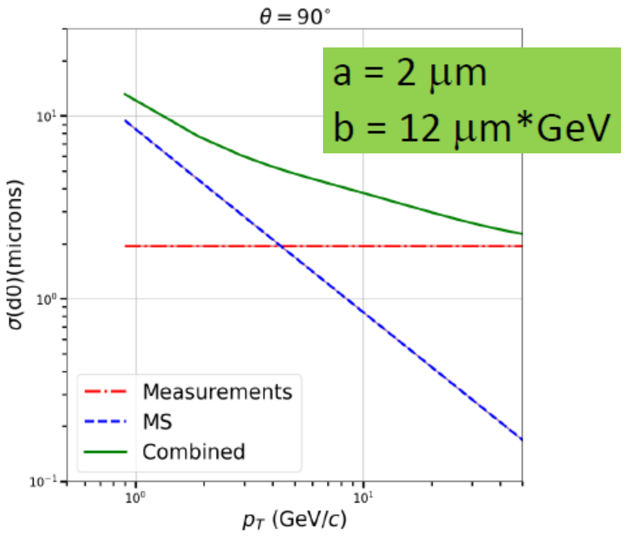
FastTrkSim

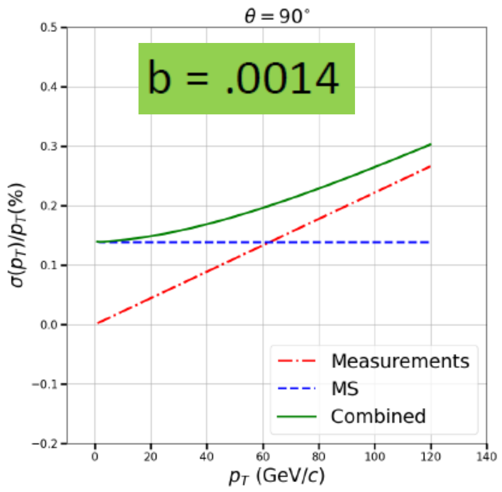


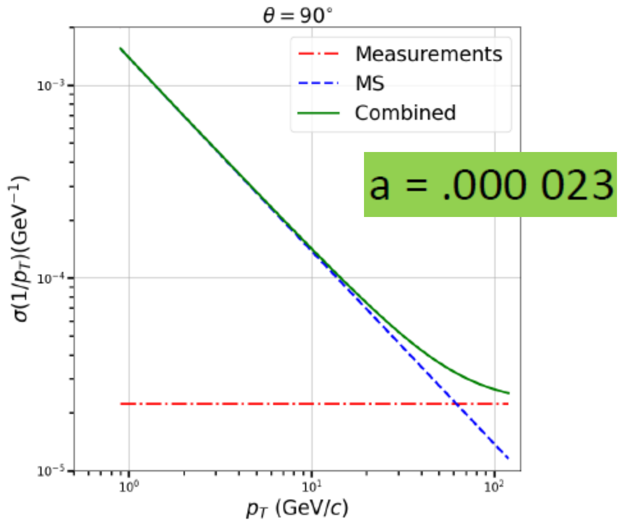




Analytical calculation from Gang





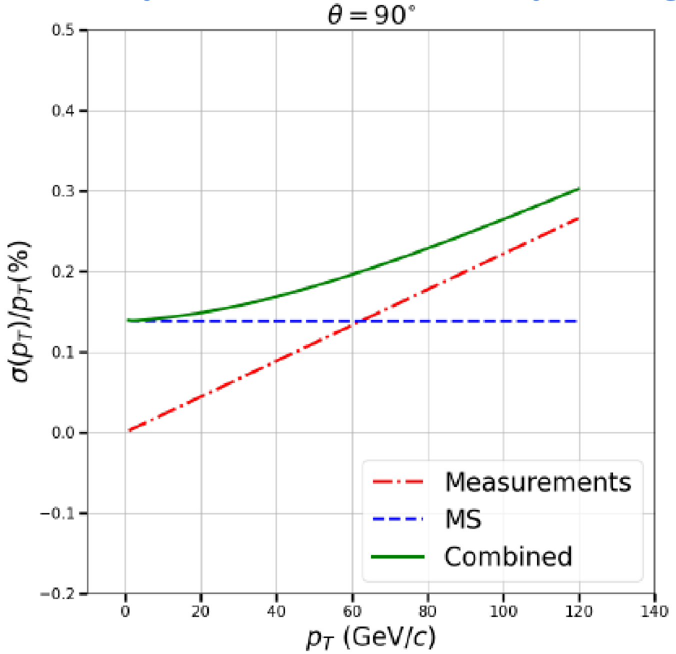


- The results are consistent with Gang's calculation

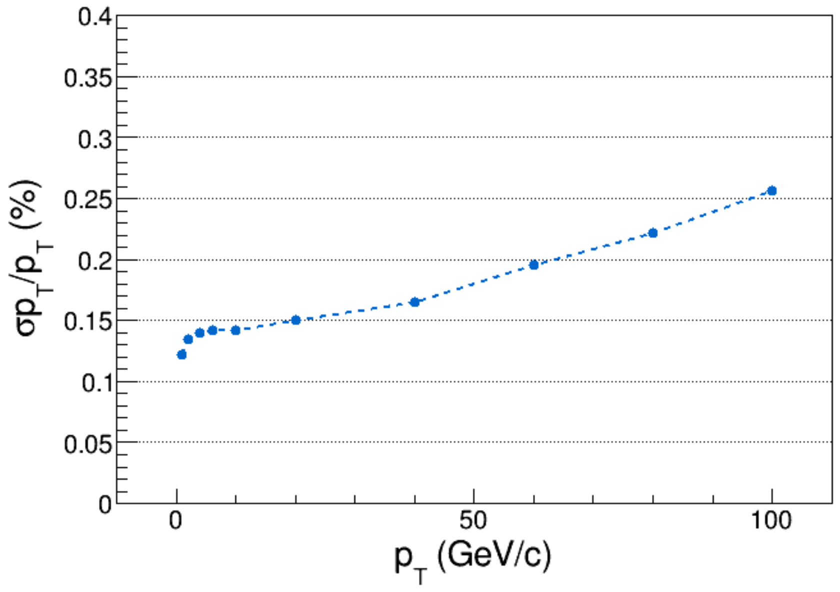
Validation of resolution around 1GeV

- Difference between analytical calculation and LDT simulation observed
- Try to understand the difference around 1GeV/c

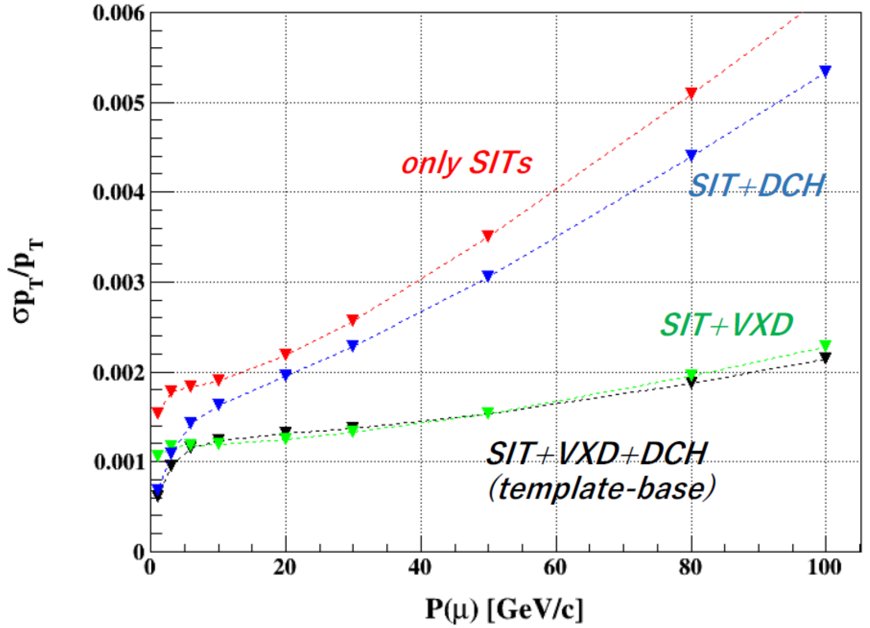
Analytical calculation by Gang



FastTrkSim



Simulation with LDT by Ryuta



From Tracker discussion on Feb 1, 2021

Parabolic approximation in analytical calculation

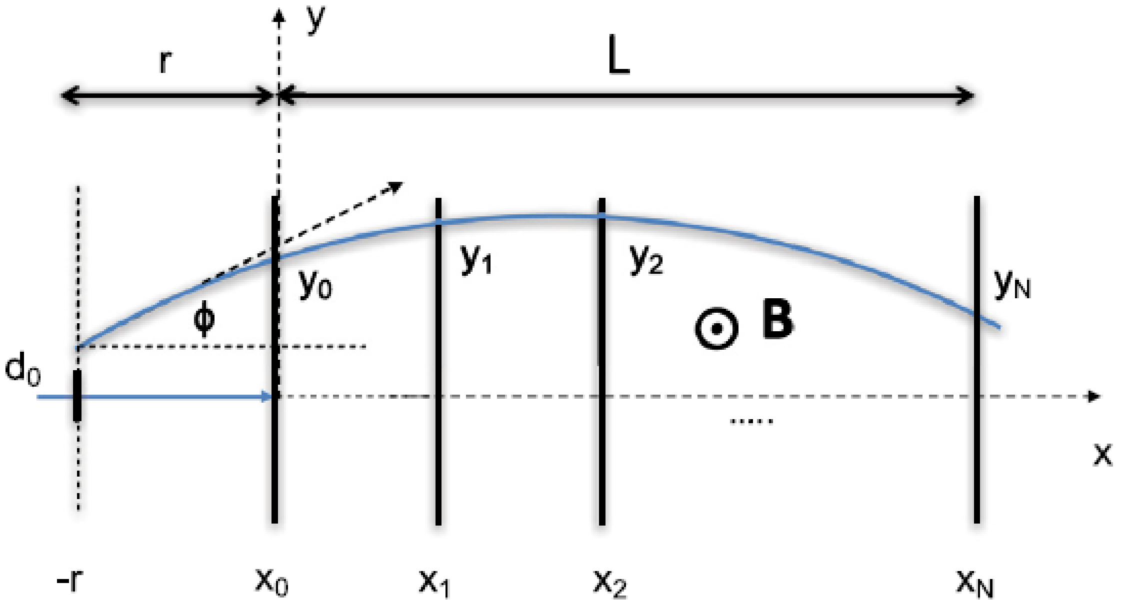


Fig. 4. A parabolic track through $N + 1$ equal and equidistant detector planes.

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Estimate resolution of track parameters from covariance matrix

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

5. Parabolic track

We assume the geometry shown in Fig. 4 where a particle of momentum p describes a circle of radius R[m]=p[GeV/c]/(0.3B[T]) in the magnetic field. We approximate this circle by $f(x) = a_0 + a_1 x + a_2 x^2/2$ with $a_2 = 1/R$, such that the momentum resolution becomes

$$\frac{\Delta p}{p} = \frac{p}{0.3B} \Delta a_2 \tag{25}$$

As for the straight line track we assume a_1 to be small such that $\tan\phi \approx \phi \approx f'(x) = a_1 + a_2 x$ along the track. We have $g_0 = 1, g_1 = x, g_2 = x^2/2$ and therefore

$$\mathbf{G}^T = \begin{pmatrix} 1 & 1 & 1 & 1 & \dots & 1 \\ 0 & \frac{L}{N} & \frac{2L}{N} & \frac{3L}{N} & \dots & L \\ 0 & \frac{1}{2}\left(\frac{L}{N}\right)^2 & \frac{1}{2}\left(\frac{2L}{N}\right)^2 & \frac{1}{2}\left(\frac{3L}{N}\right)^2 & \dots & \frac{1}{2}L^2 \end{pmatrix} \tag{26}$$

Comparison of G matrix

Parabolic approximation / Precise calculation with helix

p_T=1GeV/c

Parabolic approximation:

1	0	0
1	2	0.0018
1	21	0.19845
1	23	0.23805
1	42	0.7938
1	44	0.8712
1	62	1.7298
1	173	13.468
1	282	35.7858
1	1034	481.12
1	1794	1448.3

Precise calculation with helix:

-0.999922	16	0.115203
-0.999902	18	0.145805
-0.999584	37	0.616135
-0.999538	39	0.684555
-0.998978	58	1.51432
-0.998906	60	1.62059
-0.998151	78	2.73949
-0.989117	189	16.1329
-0.972821	298	40.326
-0.628013	1050	562.927
0.563325	1810	2541.09

p_T=100GeV/c

Parabolic approximation:

1	0	0
1	2	0.0018
1	21	0.19845
1	23	0.23805
1	42	0.7938
1	44	0.8712
1	62	1.7298
1	173	13.468
1	282	35.7858
1	1034	481.12
1	1794	1448.3

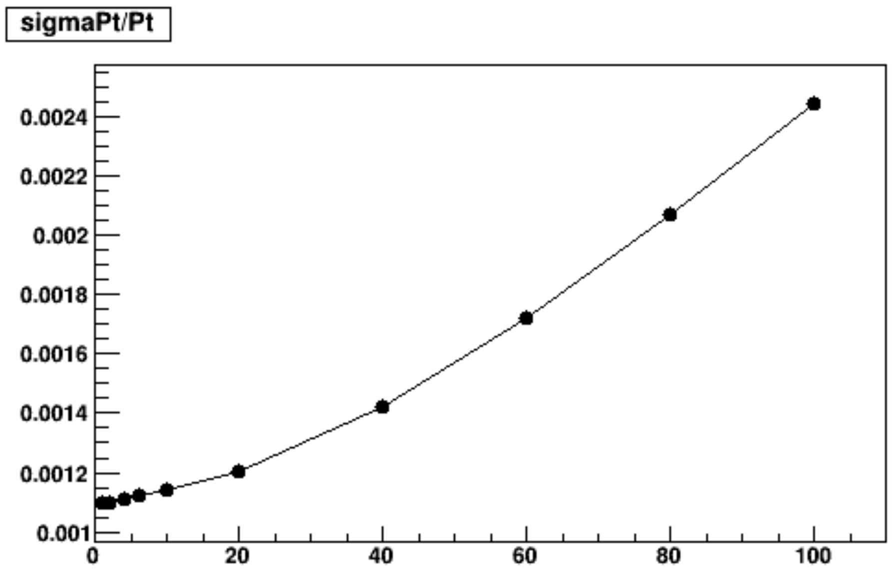
Precise calculation with helix:

-1	16	0.1152
-1	18	0.1458
-1	37	0.61605
-1	39	0.68445
-1	58	1.5138
-1	60	1.62
-1	78	2.7378
-0.999999	189	16.0745
-0.999997	298	39.9618
-0.999967	1050	496.131
-0.9999	1810	1474.29

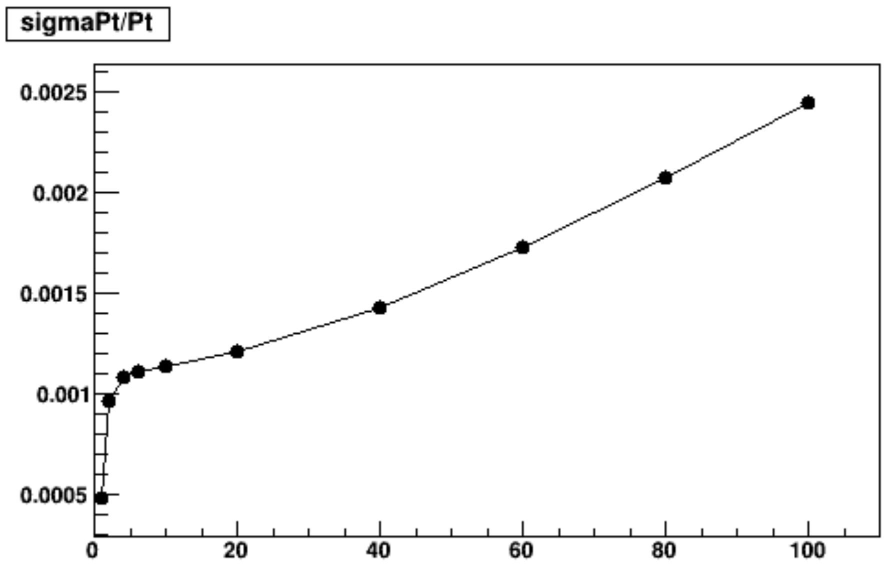
- The difference of G matrix is big at low transverse momentum (~1GeV/c)

Validation of G matrix in FastTrkSim

Parabolic approximation



Precise calculation with helix



- The drop of momentum resolution curve at around 1GeV/c might be reasonable
- Could be validated with full simulation

Summary and plan

- FastTrkSim is being updated to achieve the resolution of all helix parameters with contribution of M.S.
- Preliminary results are consistent with Gang's calculation
- The drop of momentum resolution curve at around 1GeV/c might be reasonable
- Plan
  - Check the resolution of all track parameters with different θ
  - Add the drift chamber to the layout