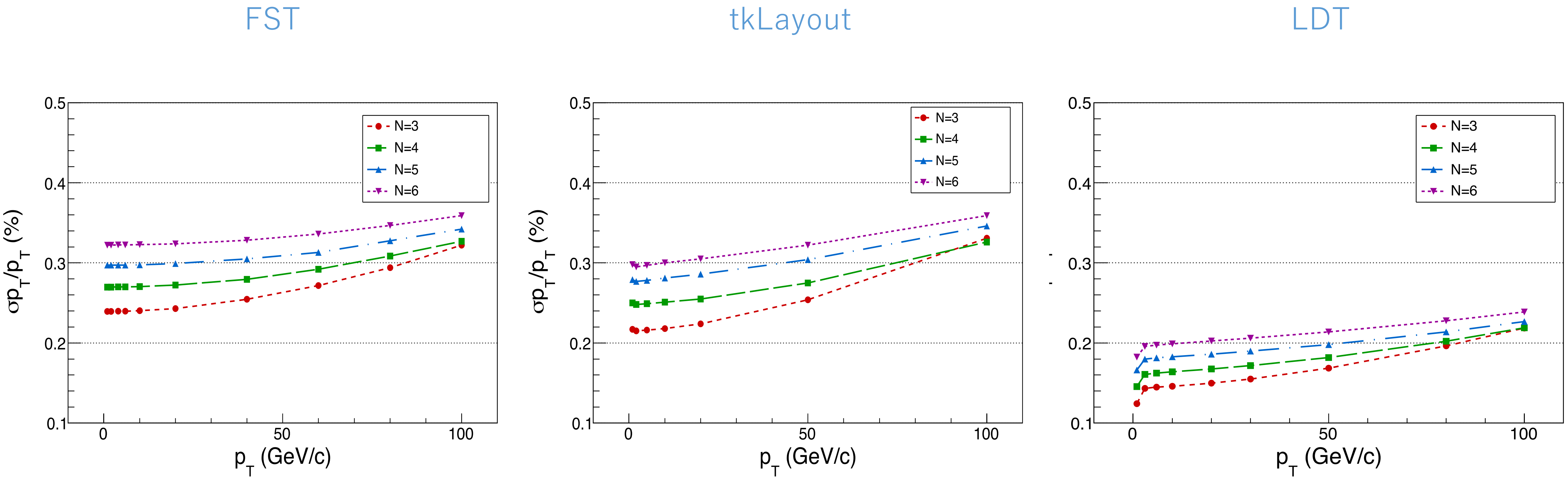
Status on LDT runs

01/04/2021

Contents

・ Investigation regarding the momentum resolution difference



FST
tkLayout
LDT
σp_T/p_T (%)
p_T (GeV/c)
N=3
N=4
N=5
N=6

Reference : Momentum Resolution without MS

Momentum Resolution

The covariance matrix is

$$\mathbf{V_p} = \frac{1}{F_0F_4 - F_2F_2}\begin{pmatrix} F_4 & 0 & -F_2 \\ 0 & \dfrac{F_0F_4 - F_2F_2}{F_2} & 0 \\ -F_2 & 0 & F_0 \end{pmatrix}$$

we are mostly interested on the error on the curvature

$$\sigma_c^2 = \frac{F_0}{F_0F_4 - F_2F_2} = \frac{\sigma^2}{L^4}C_N$$

$$C_N = \frac{180N^3}{(N-1)(N+1)(N+2)(N+3)}$$

it can be shown that the error on the curvature do not depend on the position of the origin along the track

Let's recall from the discussion on the sagitta

$$R = \frac{p}{0.3B} \qquad \frac{\delta p}{p} = \frac{\delta R}{R}$$

also recall that

$$c = \frac{1}{2R} \qquad \sigma_c = \frac{1}{2R^2}\delta R$$

and finally the momentum error

$$\frac{\delta p}{p^2} = \frac{\sigma}{0.3BL^2}\sqrt{4C_N}$$

σ, L would be parameters

the formula shows the same basic features we noticed in the sagitta discussion

we have also found the dependence on the number of measurements (weak)

Reference : Momentum Resolution from MS contribution

Track Fit With Multiple Scattering

The methods developed to fit a track to the measured points can be used to perform a fit taking into account M.S.

- the covariance matrix is computed
- the same fit procedure is applied

Let's now try to understand qualitatively the effect of multiple scattering on the determination of tracks parameters:

- the size of the effect goes as $1/p$
- then the effect is important for low momentum track

Assume we are dominated by multiple scattering

- the momentum resolution is given by

$$\frac{\delta p}{p^2} = \frac{\sigma}{0.3BL^2}\sqrt{4A_N}$$

the coordinate error due to M.S. is

$$\sigma \sim \frac{L}{N}\delta\theta = \frac{L}{N}\frac{0.0136}{p\beta}\sqrt{\frac{X}{X_o}}$$

we have then

$$\frac{\delta p}{p} \sim \frac{0.0136}{\beta}\sqrt{\frac{X}{X_0}}\frac{1}{0.3BL}\frac{\sqrt{4A_N}}{N}$$

We conclude:

- for low momentum the percentage momentum resolution reach a almost constant value (still dependent on β)

$$\frac{\delta p}{p} \rightarrow \text{constant}$$

- The momentum resolution only improves as $1/L$
- The additional factor $1/N$ can help but in this case uniform spacing is essential

```
error distribution                :  0
0 normal-sigma(RPhi) [1e-6m] :          2.8,            6,            4,            4,            4
           sigma(z)     [1e-6m] :          2.8,            6,            4,            4,            4
1 uniform-d(RPhi) [1e-6m]     :
           d(z)     [1e-6m]     :

Silicon Inner Tracker (SIT)

Number of layers                :  12
Description (optional)          :  |---------------------------------------------Inner tracker----------------------------
Names of the layers (opt.)      :  SIT1,        XSIT1,       XSIT2,       SIT2,        SIT3,        XSIT3,       XSIT4,
Radii [mm]                      :  152.9,       153.1,       154.4,       155.4,       981.9,       982.1,       983.4,
Upper limit in z [mm]           :  371.0,       371.0,       371.0,       371.0,       2350,        2350,        2350,
Lower limit in z [mm]           :  -371.0,      -371.0,      -371.0,      -371.0,      -2350,       -2350,       -2350,
Efficiency RPhi                 :  0.99,        0,           0,           0,           0.99,        0,           0,
Efficiency 2nd coord. (eg. z):     0,           0,           0,           0.99,        0,           0,           0,
Stereo angle alpha [Rad]        :  7*(pi/180),  7*(pi/180),  7*(pi/180),  7*(pi/180),  7*(pi/180),  7*(pi/180),  7*(pi/180),
Thickness [rad. lengths]        :  0.00213,     0.00468,     0.00468,     0.00213,     0.00213,     0.00468,     0.00468,
error distribution              :  0
0 normal-sigma(RPhi) [1e-6m] :     7
           sigma(z)     [1e-6m] :  7
1 uniform-d(RPhi) [1e-6m]     :
           d(z)     [1e-6m]     :

Time Projection Chamber (TPC)
sigma^2=sigma0^2+sigma1^2*sin(beta)^2+Cdiff^2*6mm/h*sin(theta)*Ldrift[m]
Number of layers                :  65, 65,
Radii [mm]                      :  242, 882, 1071, 1711,
Upper limit in z [mm]           :  2225
Lower limit in z [mm]           :  -2225
```

is this the same ?

by the way, how the resolutions are treated in LDT ?

Multiple Scattering

the projected angular distribution, with an rms width given by Lynch & Dahl [40]:

$$\theta_0 = \frac{13.6\text{ MeV}}{\beta cp}\, z \sqrt{\frac{x}{X_0}} \Big[1 + 0.088 \log_{10}(\frac{x z^2}{X_0 \beta^2})\Big]$$
$$= \frac{13.6\text{ MeV}}{\beta cp}\, z \sqrt{\frac{x}{X_0}} \Big[1 + 0.038 \ln(\frac{x z^2}{X_0 \beta^2})\Big] \qquad (34.16)$$

Here p, βc, and z are the momentum, velocity, and charge number of the incident particle, and x/X_0 is the thickness of the scattering medium in radiation lengths (defined below). This takes into account the p and z dependence quite well at small Z, but for large Z and small x the β-dependence is not well represented. Further improvements are discussed in Ref. [40].

Eq. (34.16) describes scattering from a single material, while the usual problem involves the multiple scattering of a particle traversing many different layers and mixtures. Since it is from a fit to a Molière distribution, it is incorrect to add the individual θ_0 contributions in quadrature; the result is systematically too small. It is much more accurate to apply Eq. (34.16) once, after finding x and X_0 for the combined scatterer.

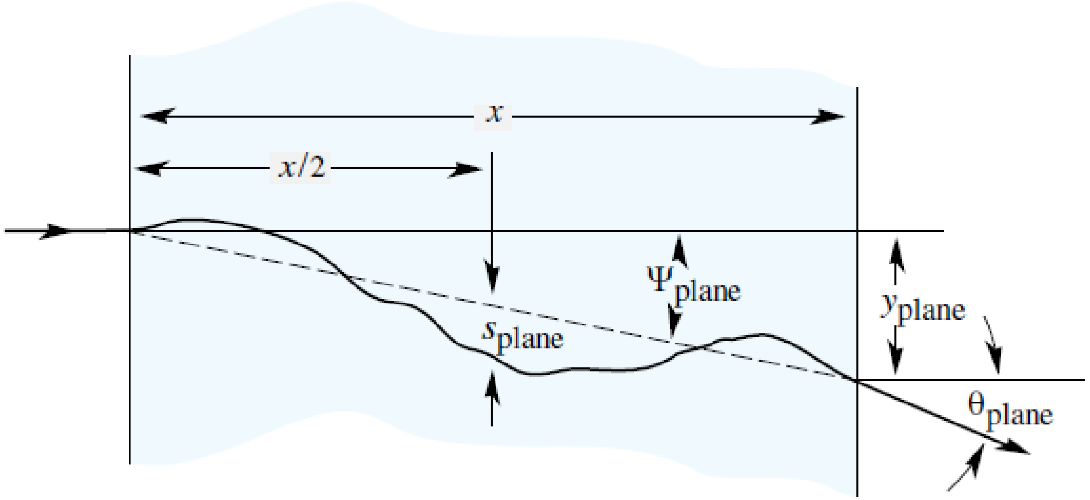


Figure 34.10: Quantities used to describe multiple Coulomb scattering. The particle is incident in the plane of the figure.

from PDG

Particle simulation part in the LDT（“Simulation.m”）

if MS option is set

MS effect

random number (for direction)

Change direction

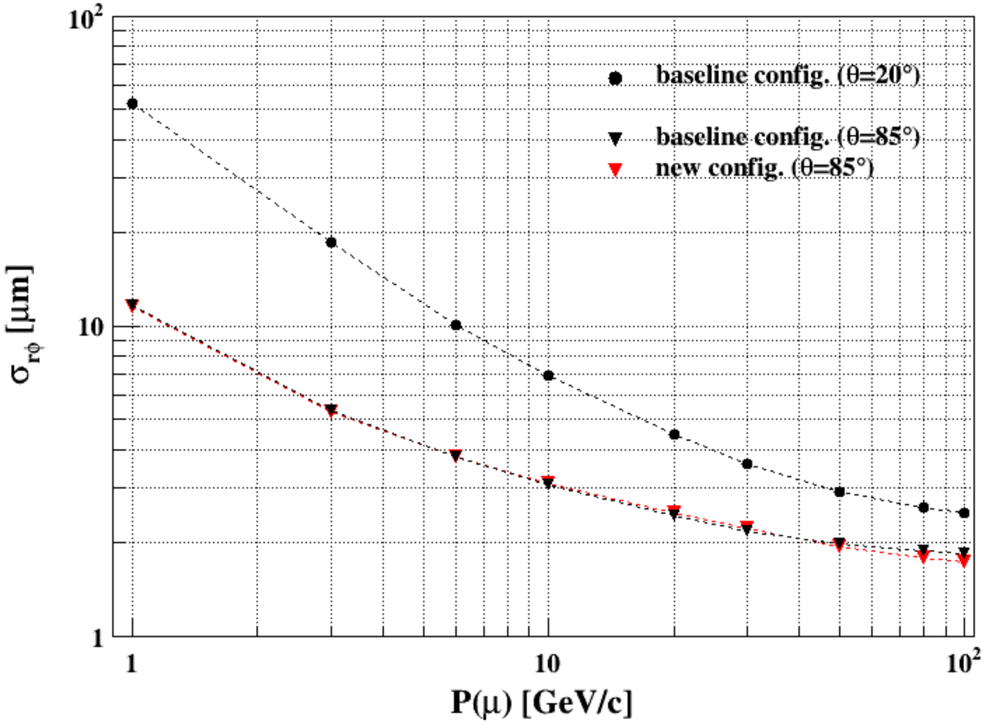
```
znow=param_start(2);% current z position
bprop=0;
fprop=0;
maxzmax=max(zpos.bmax);
minzmin=min(zpos.bmin);

for k=2:(FLayer+BLayer)      % loop over all layers, terminated by break statement
    if Flags.MulSca
        pT=convf*Bz/parami(5); % Transv. momentum computed from curvature
        p=pT/sin(parami(3));    % absolute Momentum

        if reftype(k-1) X=bXlen(bnow)/(sin(parami(3))*cos(parami(4)));
        else            X=fXlen(fnow)/abs(cos(parami(3)));  end
        sigms=0.0136*sqrt((Mass^2+p^2)/p^4)*sqrt(X)*(1+0.038*log(X));
        % s.d. of projected multiple scattering angle
        Xstore(k-1)=X;  varMS_store(k-1)=sigms^2;

        ran=(randn(1,2).*[1 1/sin(parami(3))])*sigms; %changes in direction
        if parami(3)>pi/2 ran(1)=-ran(1); end


        parami(3)=parami(3)+ran(1); % Kick in theta
        parami(4)=parami(4)+ran(2); % Kick in phi (beta)
        pT=p*sin(parami(3));        % recompute pt with new theta
        parami(5)=convf*Bz/pT;      % Curvature from transverse momentum

        if k==2 pstartMS=parami; end

```

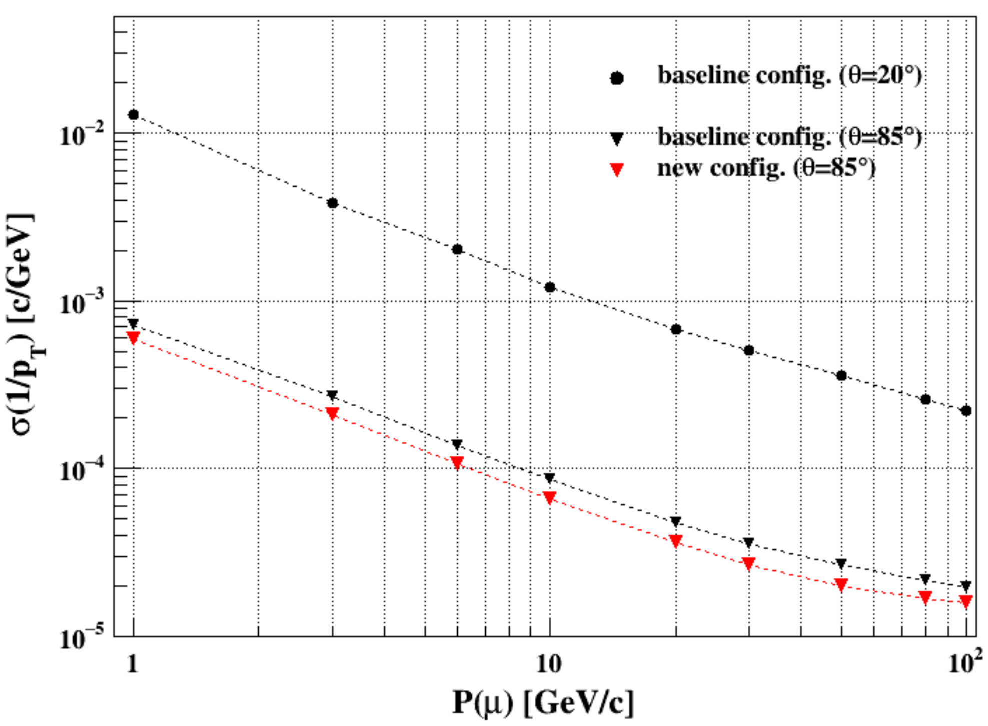
further details, is under investigation

Comparison with baseline concept.

Change : SIT3/4 is set at the middle of SIT1/2 & SET1/2 , as SDT configuration
but, material budget for SIT3/4 is set as empty, for a test.

for confirmation between baseline and SDT



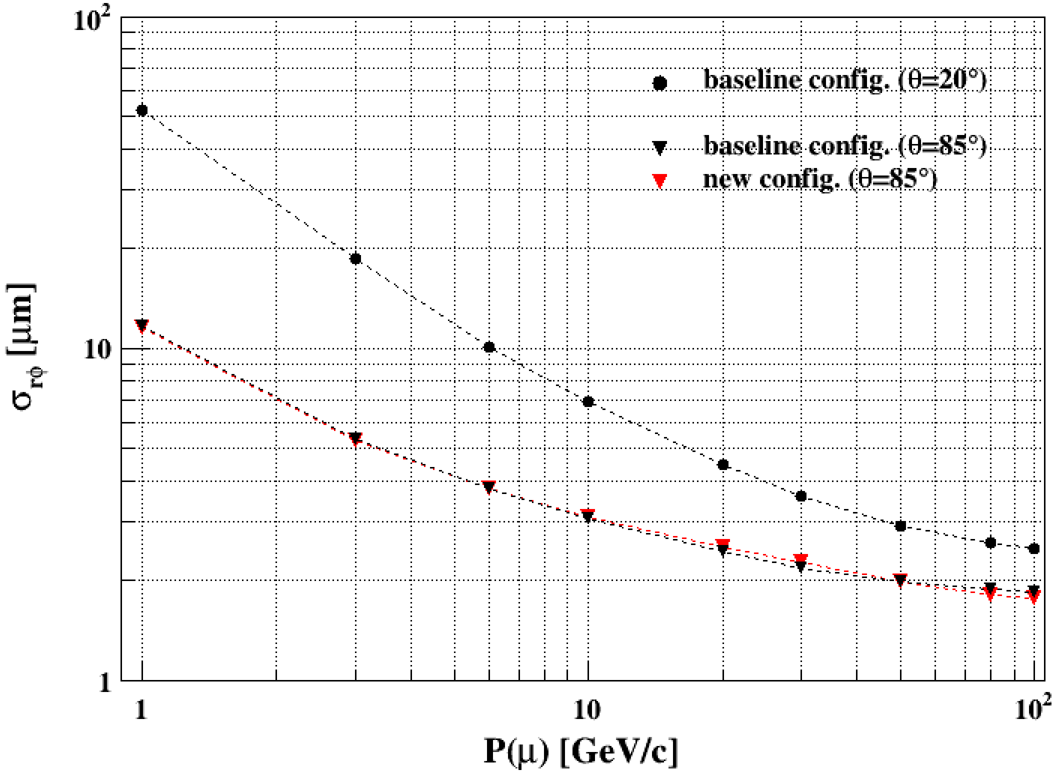


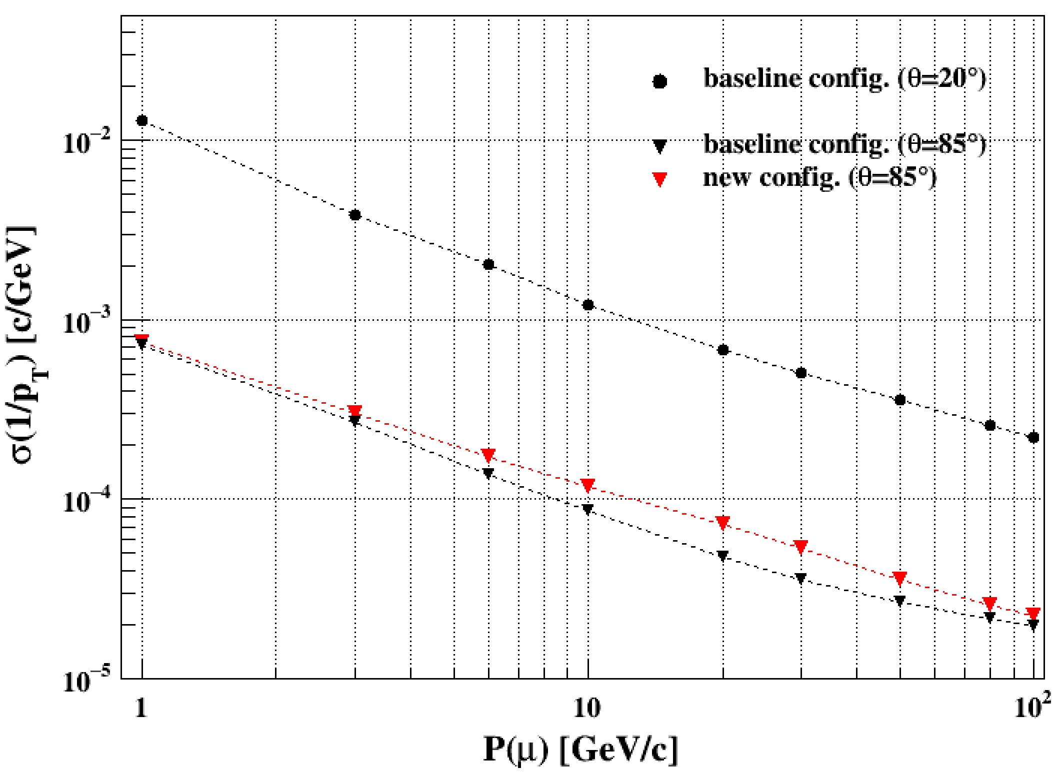
Ref: from the past result

Comparison with baseline concept.

Change : SIT3/4 is set at the middle of SIT1/2 & SET1/2 , as SDT configuration
material budget for SIT3/4 is set as normal.

for confirmation between baseline and SDT





from the past result

if it is compared with that of 2 pages before, the position of SIT3/4 is different.