CEPC Tracking System Optimization

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Introduction

- Generally , with the increase of detector layers in TPC, the momentum resolution becomes better , but there is a jump point in some layers and an abnormal phenomenon when the momentum value is 1Gev.
- The effect of detector layers on the momentum resolution under different momentum values is studied.
- It mainly includes two aspects, the first is to keep the material budget of each layer in TPC unchanged, the second is to keep the total material budget in TPC unchanged. Details are as follows.

●Parameter setting (details see backup)

sub detector	N layers	Resoluton(μm)		Material budget (%X_0)
		r-Φ	z_0	
VXD	6	2.8 / 6 / 4 / 4 / 4 / 4	2.8 / 6 / 4 / 4 / 4 / 4	0.15per layer
SIT	4	7.2	86.6	0.65
TPC	10/20/30…/140 /150/160	100	2000	1.2
SET	1	7.2	86.6	0.65

	N=10	N=20	…	N=100	N=110	…	N=160
single	0.00003356	0.00003356	…	0.00003356	0.00003356	…	0.00003356
total	0.0003356	0.0001678	…	0.00003356	0.00003051	…	0.000020975

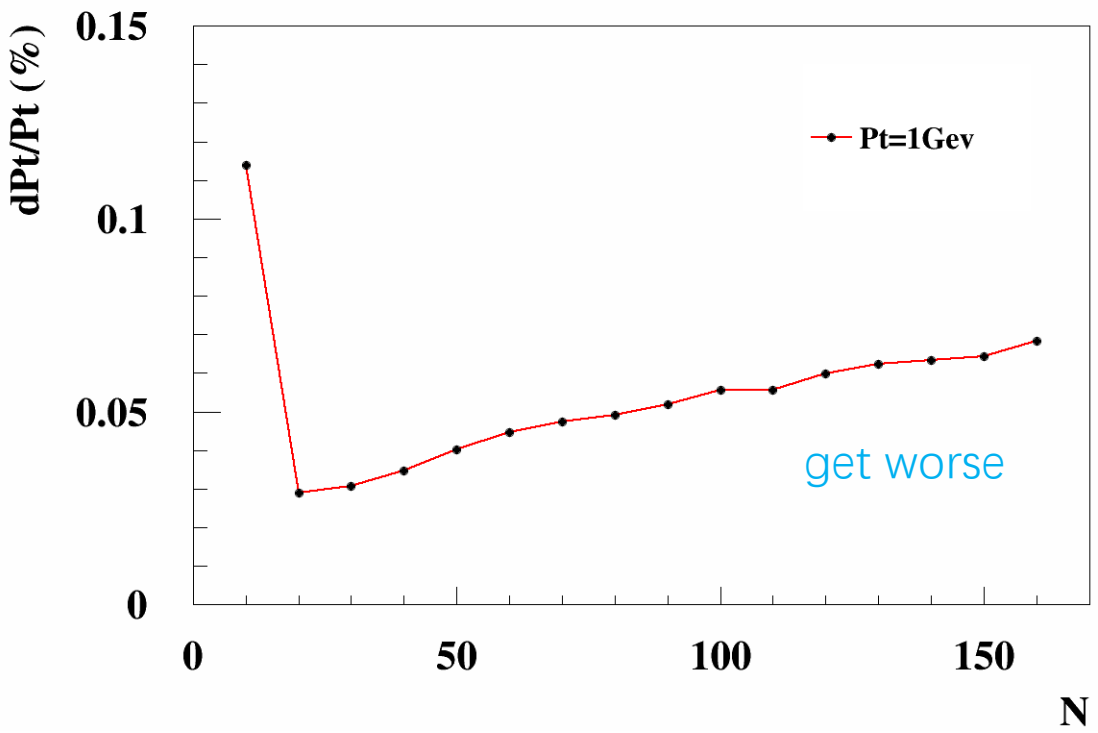
- single

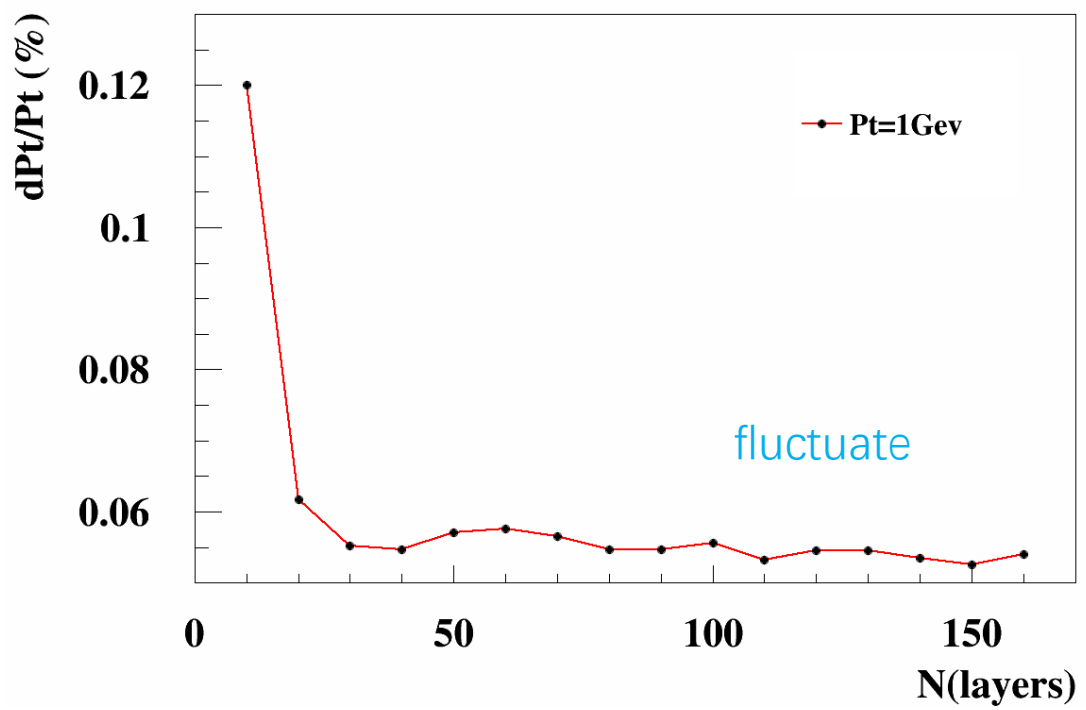
  The material budget of each layer in TPC is 0.00003356.

- total

$$material\ budget = \frac{0.00003356 \times 100}{N}$$

- N represents the number of detector layers in TPC.
- The graph on the left represents the identical material budget for each single layer and the right keeps the total material budget constant.





● question

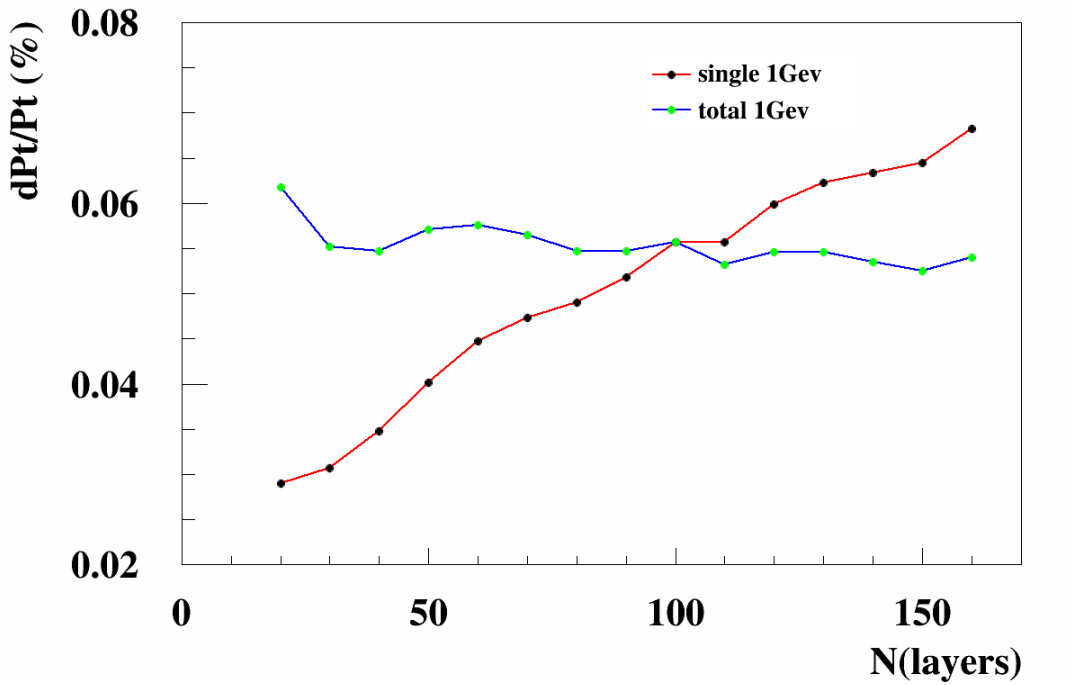
- Why have such a big jump between 10 layers and 20 layers?

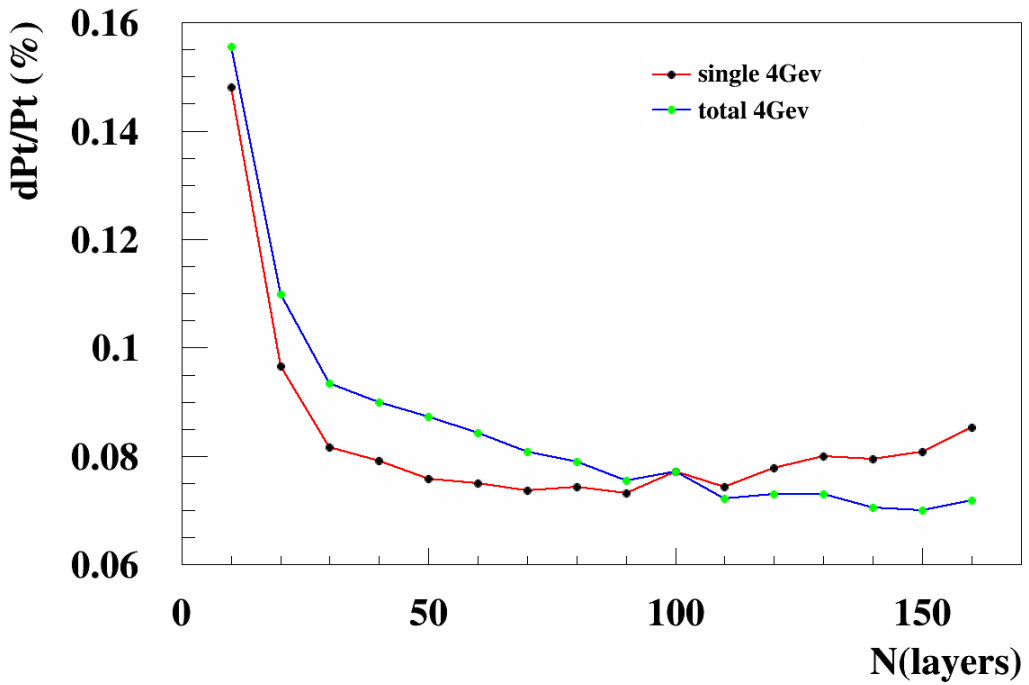
  Maybe it's related to the number of detector layers. The detector layers is neither the more the better nor the less the better and 10 layers may be a critical value.

- Why does the momentum resolution of the left side of the image get worse with the increases of detector layers?

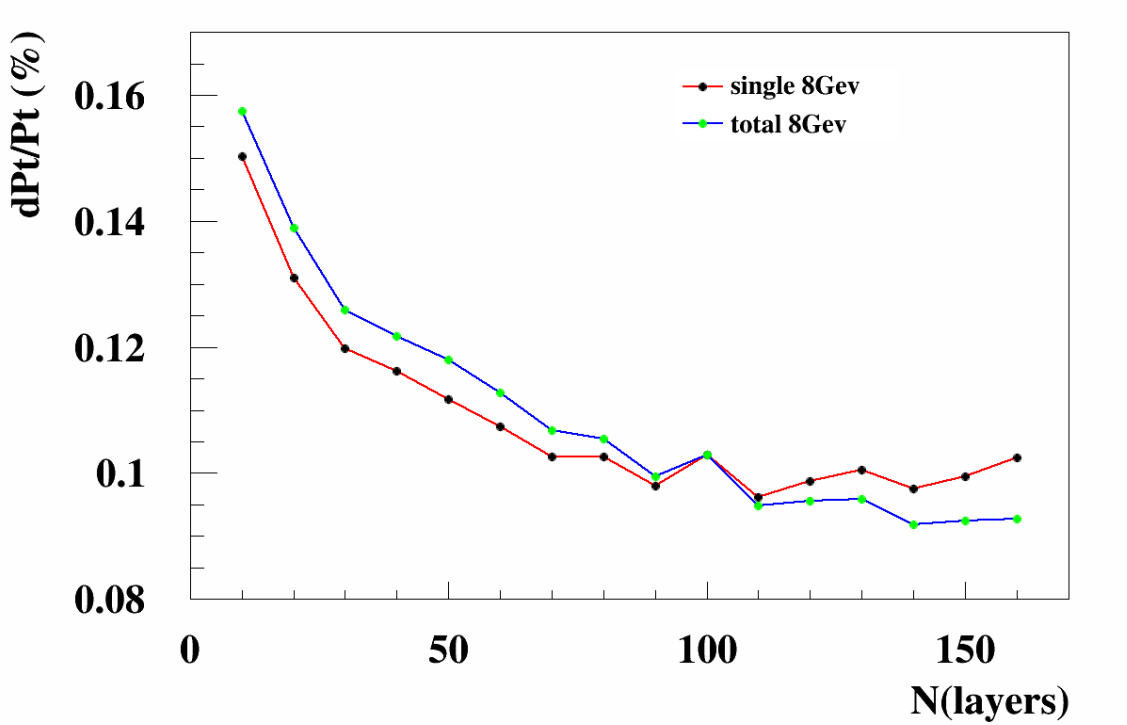
  It is caused by low momentum value and low total material budget.

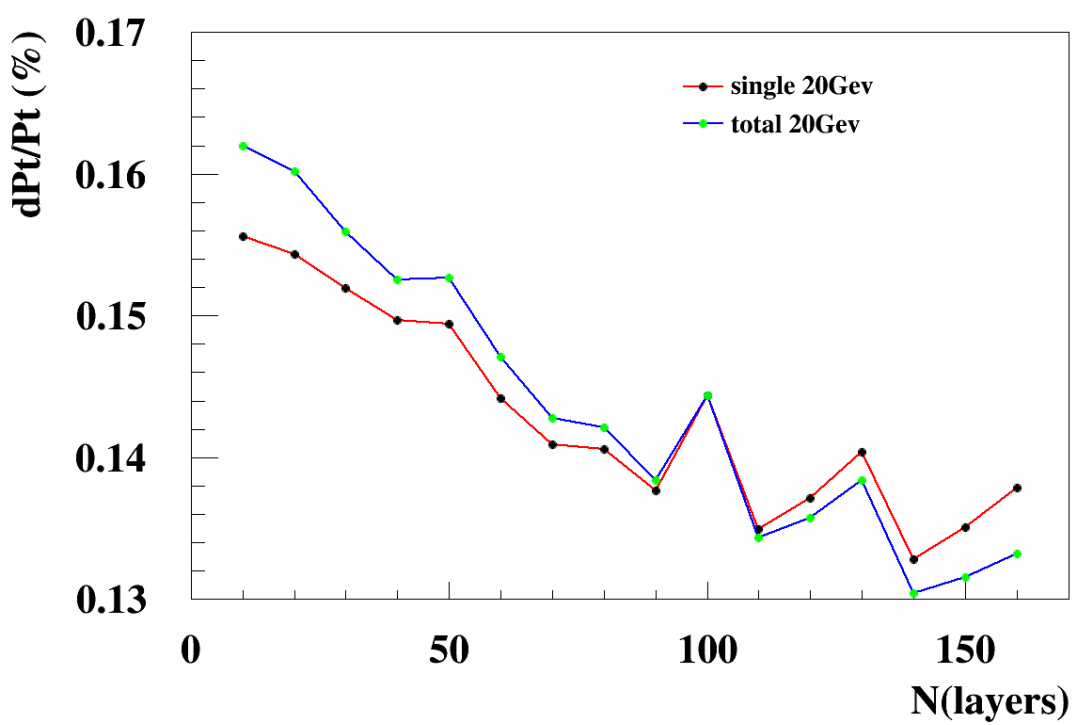
- A jump point is a maximum or minimum point that appears in a certain area.



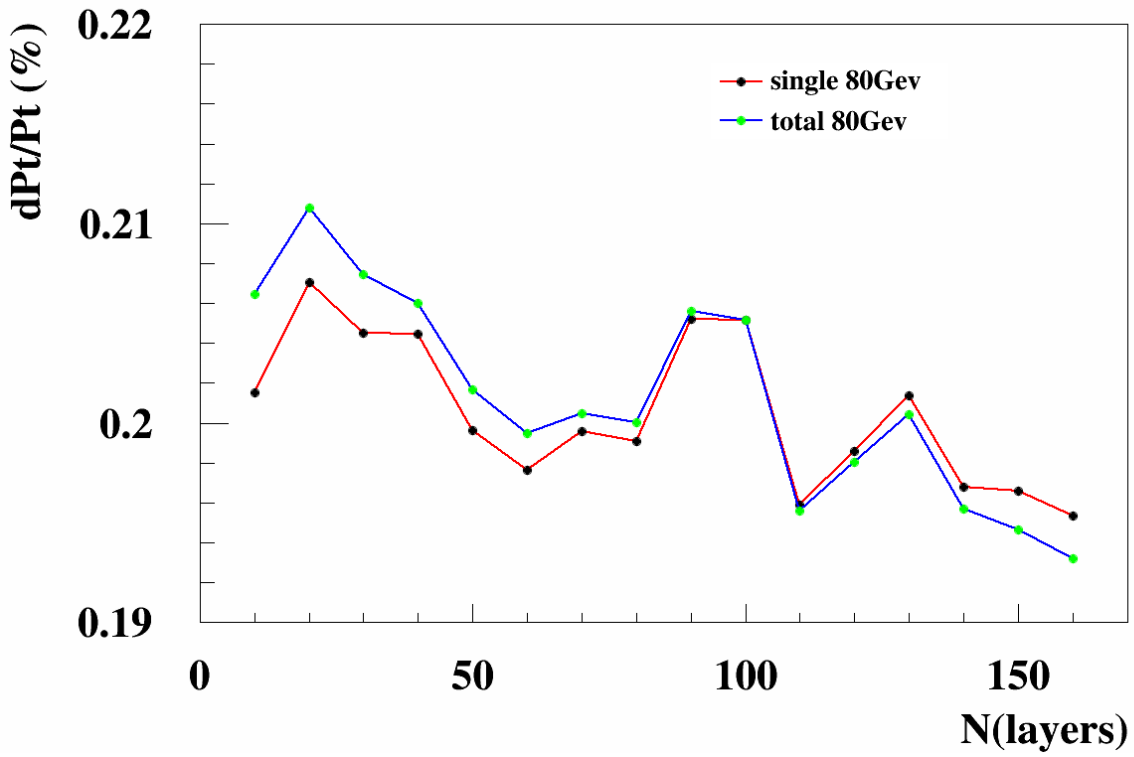


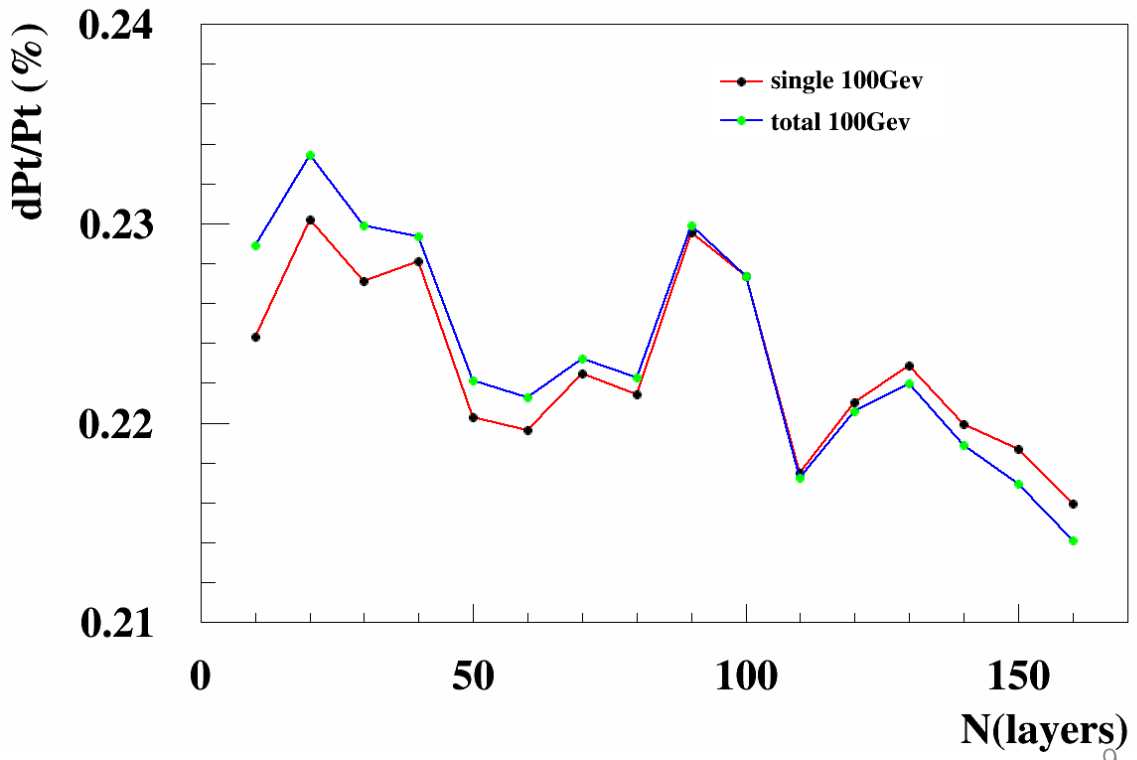
- The momentum resolution is better when the number of detector layers is 110.
- The momentum resolution fluctuates up and down with the change of detector layers.





- A detector with 110 layers might be a good choice.
- The relationship between the momentum resolution and the number of layers may be up and down.





Summary and plan

- If two different detectors have the same total material budget at a certain layers, the momentum resolution of the larger total material budget is better than the less one when the number of layers is lower than the certain layers.
- When it is greater than the number of layers, the result is just the opposite.
- The exact mathematical expression needs to be studied further.

backup

```
01 LiC Detector-Toy (barrel)
02 SDT-CEPC
03 Version:                    20201012
04 Vertex Detector (VXD)
05
06 Number of layers            :   8
07 Description (optional)      :   |-Beamt.--|-----------------------------------Vertex detector--------------------|
08 Names of the layers (opt.)  :   XBT,      VTX1,     VTX2,     VTX3,      VTX4,      VTX5,      VTX6,      XVTXSHELL
09 Radii [mm]                  :   14.5,     16.0,     18.0,     37.0,      39.0,      58.0,      60.0,      65.0
10 Upper limit in z [mm]       :   4225,     62.5,     62.5,     125,       125,       125,       125,       145
11 Lower limit in z [mm]       :  -4225,    -62.5,    -62.5,    -125,      -125,      -125,      -125,      -145
12 Efficiency RPhi             :   0,        1.0,      1.0,      1.0,       1.0,       1.0,       1.0,       0.0
13 Efficiency 2nd coord. (eg. z): -1
14 Stereo angle alpha [Rad]    :   pi/2
15 Thickness [rad. lengths]    :   0.0015,  0.0015,   0.0015,   0.0015,    0.0015,    0.0015,    0.0015,    0.0015
16 error distribution          :   0
17 0 normal-sigma(RPhi) [1e-6m] :  2.8,  6,  4.0,  4.0,  4.0,  4.0
18          sigma(z)    [1e-6m] :  2.8,  6,  4.0,  4.0,  4.0,  4.0
19 1 uniform-d(RPhi) [1e-6m]   :   4.0
20           d(z)     [1e-6m]   :   4.0
21
22 Silicon Inner Tracker (SIT)
23
24 Number of layers            :   5
25 Description (optional)      :   |------------Silicon Inner tracker-------------|----TPC Inner Wall ----|
26 Names of the layers (opt.)  :    SIT1,         SIT2,       SIT3,      SIT4,         XTPCW1
27 Radii [mm]                  :    78.0,         318,        558.0,     798.0 ,       799.0
28 Upper limit in z [mm]       :   150.0,        750.0,      1300.0,    2900.0,       2900.0
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28 Upper limit in z [mm]       :   150.0,        750.0,      1300.0,    2900.0,       2900.0
29 Lower limit in z [mm]       :  -150.0,       -750.0,     -1300.0,   -2900.0,      -2900.0
30 Efficiency RPhi             :     1.00,         1.00,       1.00,      1.0,          0.0
31 Efficiency 2nd coord. (eg. z):     -1
32 Stereo angle alpha [Rad]    :    pi/2
33 Thickness [rad. lengths]    :  0.0065,      0.0065,     0.0065,    0.0065,       0.002
34 error distribution          :      0
35 0 normal-sigma(RPhi) [1e-6m] :    7.2
36          sigma(z)    [1e-6m] :   86.6
37 1 uniform-d(RPhi) [1e-6m]   :    7.2
38           d(z)     [1e-6m]   :   86.6
39
40 Time Projection Chamber (TPC)
41 sigma^2=sigma0^2+sigma1^2*sin(beta)^2+Cdiff^2*6mm/h*sin(theta)*Ldrift[m]
42 Number of layers             :  10
43 Radii [mm]                   :  800,1800
44 Upper limit in z [mm]        :  2900
45 Lower limit in z [mm]        : -2900
46 Efficiency RPhi              :  1
47 Efficiency z                 :  1
48 Thickness [rad. lengths]     :  0.00003356
49 sigma0(RPhi) [1e-6m]         :  100
50 sigma1(RPhi) [1e-6m]         :  0
51 Cdiff(RPhi)  [1e-6m/sqrt(m)] :  0
52 sigma0(z)    [1e-6m]         :  2828
53 sigma1(z)    [1e-6m]         :  0
54 Cdiff(z)     [1e-6m/sqrt(m)] :  0
55
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56 Silicon Tracker (SET)
57
58 Number of layers             :    2
59 Description (optional)       :  TPC outer wall  |--------------External Tracker-------------
60 Names of the layers (opt.)   :     XTPCW2,   SET1
61 Radii [mm]                   :    1801.0,    1811
62 Upper limit in z [mm]        :     2900,     2900
63 Lower limit in z [mm]        :    -2900,    -2900
64 Efficiency RPhi              :      0.0,      1.0
65 Efficiency 2nd coord. (eg. z):                -1
66 Stereo angle alpha [Rad]     :               pi/2
67 Thickness [rad. lengths]     :     0.010,  0.0065
68 error distribution           :         0
69 0 normal-sigma(RPhi) [1e-6m] :       7.2
70          sigma(z)    [1e-6m] :      86.6
71 1 uniform-d(RPhi) [1e-6m]    :       7.2
72           d(z)     [1e-6m]   :      86.6
73
74 Magnetic field and beam spot
75
76 Solenoid magnetic field [T]  :    3.0
77 Range in x [mm]              :   -0.0    0.0
78 Range in y [mm]              :   -0.0    0.0
79 Range in z [mm]              :   -0.0    0.0
80
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11 Lower limit in z [mm]       :  -4225,    -62.5,    -62.5,    -125,     -125,     -125,     -125,     -145
12 Efficiency RPhi             :   0,        1.0,      1.0,      1.0,      1.0,      1.0,      1.0,      0.0
13 Efficiency 2nd coord. (eg. z):  -1
14 Stereo angle alpha [Rad]    :   pi/2
15 Thickness [rad. lengths]    :   0.0015,  0.0015,   0.0015,   0.0015,   0.0015,   0.0015,   0.0015,   0.0015
16 error distribution          :   0
17 0 normal-sigma(RPhi) [1e-6m] :  2.8,  6,  4.0,  4.0,  4.0,  4.0
18          sigma(z)    [1e-6m] :  2.8,  6,  4.0,  4.0,  4.0,  4.0
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```

```
29 Lower limit in z [mm]       :  -150.0,       -750.0,      -1300.0,    -2900.0,      -2900.0
30 Efficiency RPhi             :    1.00,        1.00,        1.00,       1.0,          0.0
31 Efficiency 2nd coord. (eg. z):    -1
32 Stereo angle alpha [Rad]    :    pi/2
33 Thickness [rad. lengths]    :  0.0065,      0.0065,      0.0065,     0.0065,       0.002
34 error distribution          :     0
35 0 normal-sigma(RPhi) [1e-6m] :    7.2
36          sigma(z)    [1e-6m] :   86.6
37 1 uniform-d(RPhi) [1e-6m]   :    7.2
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45 Lower limit in z [mm]       : -2900
46 Efficiency RPhi             :  1
47 Efficiency z                :  1
48 Thickness [rad. lengths]    :  0.0003356
49 sigma0(RPhi) [1e-6m]        :  100
50 sigma1(RPhi) [1e-6m]        :  0
51 Cdiff(RPhi)  [1e-6m/sqrt(m)] :  0
52 sigma0(z)    [1e-6m]        :  2828
53 sigma1(z)    [1e-6m]        :  0
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62 Upper limit in z [mm]       :     2900,      2900
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64 Efficiency RPhi             :      0.0,       1.0
65 Efficiency 2nd coord. (eg. z):                -1
66 Stereo angle alpha [Rad]    :                pi/2
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75
76 Solenoid magnetic field [T]  :    3.0
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78 Range in y [mm]             :   -0.0    0.0
79 Range in z [mm]             :   -0.0    0.0
```