Simulation on silicon tracker for the TAC-PF Detector

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*** on behalf of TAC-PF group**

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Outline

- Turkish Accelerator Center (TAC) project

- TAC Particle Factory (PF) Detector and Tracker

- Simulation works

  Momentum resolution

  Particle track- Energy deposition

  - Spot size calculation

- Conclusion

Turkish Accelerator Center (TAC) Project

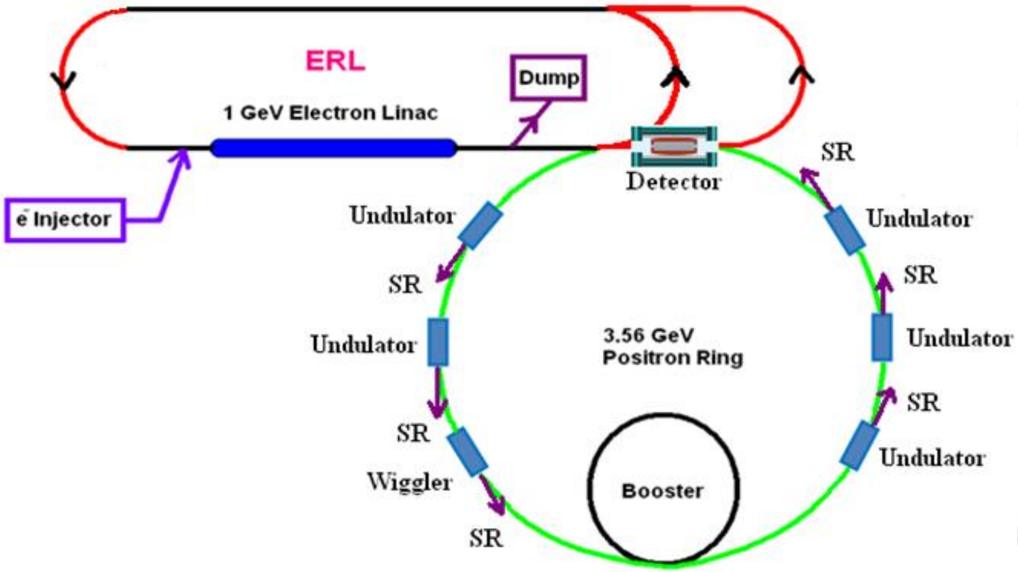
http://thm.ankara.edu.tr/

The mission of TAC is to design, construct and use high energy particle accelerators for scientific researches in Turkey and in the region and to collaborate with international HEP community.

Turkish Accelerator Center (TAC) Project

The ongoing project has three main parts

1) Accelerator Based Light Sources,
2) Proton Accelerator (PA)
3) Particle Factory (PF)



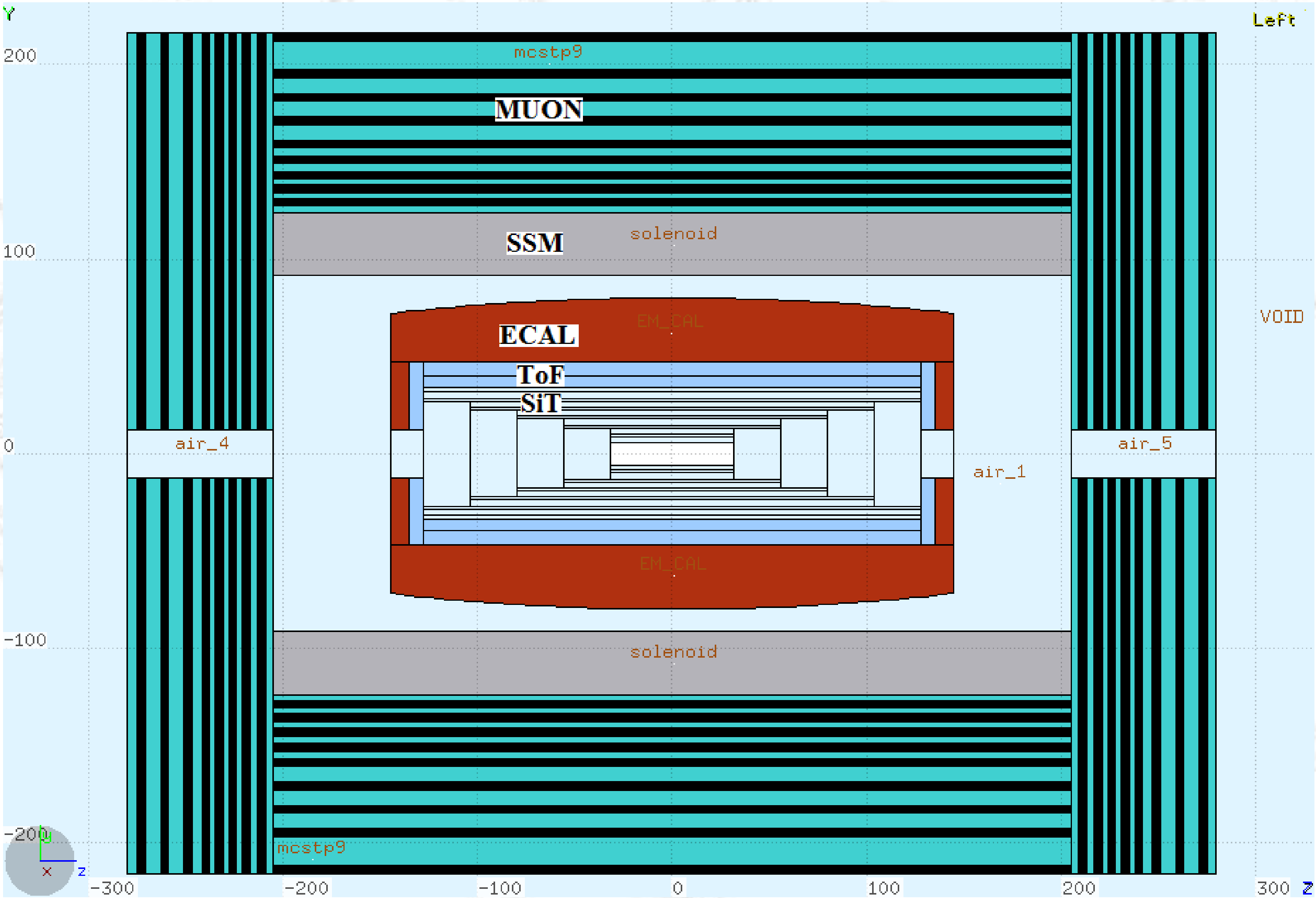
An electron-positron collider as a “super charm factory”

A 1 GeV electron linac and a 3.56 GeV positron ring for linac on ring type collisions and *a dedicated detector “TAC-PF Detector”*

TAC super charm factory collider parameters

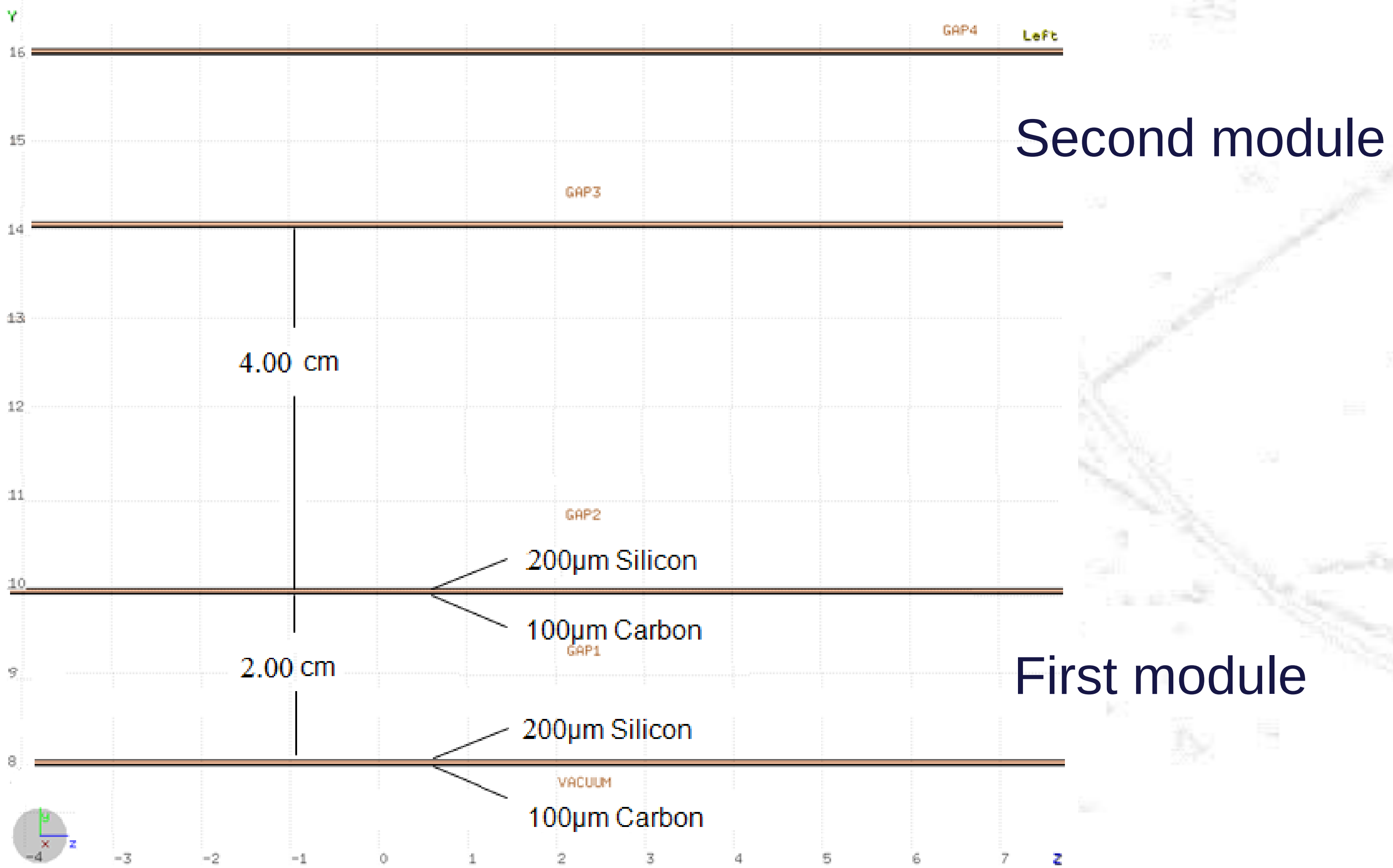
Parameter	**Positron ring**	**Electron ERL**
Positron Beam energy (GeV)	3.56	1
Number of positron per bunch (10^{11})	2	0.2
Beta Functions at IP β_x/β_y (mm)	80/5	80/5
Normalized emittance $\varepsilon_x^N/\varepsilon_y^N$ (μm rad)	111/0.36	31/0.1
σ_x/σ_y (μm)	36/0.5	36/0.5
σ_z (mm)	5	5
Beam –beam tune shift (ξ_x/ξ_y)	0.012/0.13	
Energy loss/Turn (MeV)	0.7	
Number of bunches	300	
Circumference (m)	600	
Beam Current (A)	4.8	0.48
Momentum Acceptence (%)	1	
Luminosity ($cm^{-2}s^{-1}$)	1.4×10^{35}	

TAC-PF detector



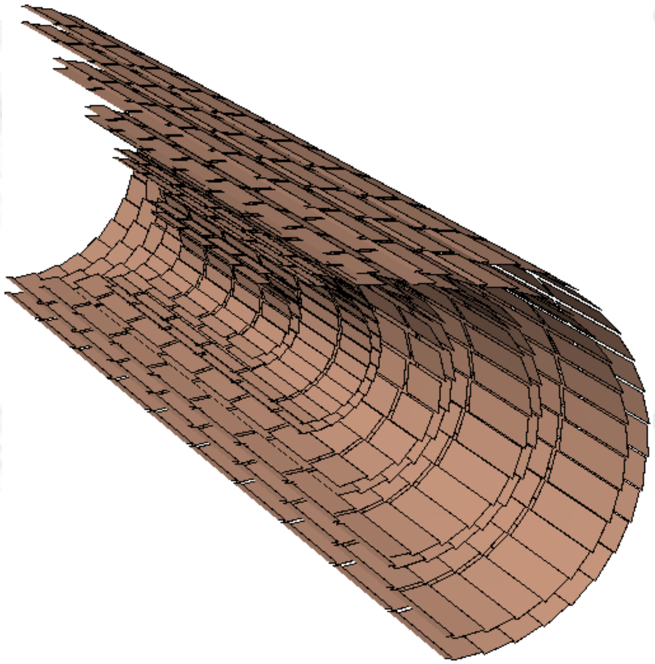
TAC-PF tracker

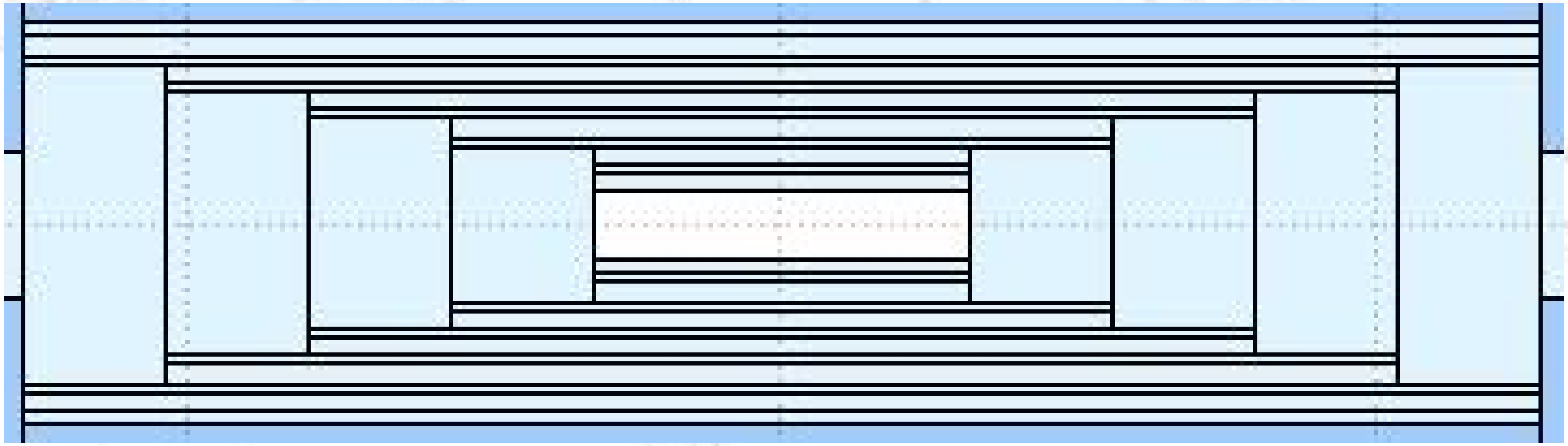
Five individual modules with 4 cm distances between them.
Each module has two parallel silicon strip detector planes.
(carbon+ silicon + 2 cm gap + carbon + silicon)



TAC-PF tracker

	Radius [cm]	z extend [cm]	number of Si sensor
1 - 2 layer	8.0-10.0	32.0	192+240
3 - 4 layer	14.0-16.0	56.0	638+726
5 - 6 layer	20.0-22.0	80.0	600+690
7 - 8 layer	26.0-28.0	104.0	1080+1160
9 - 10 layer	32.0-34.0	128.0	1650+1750



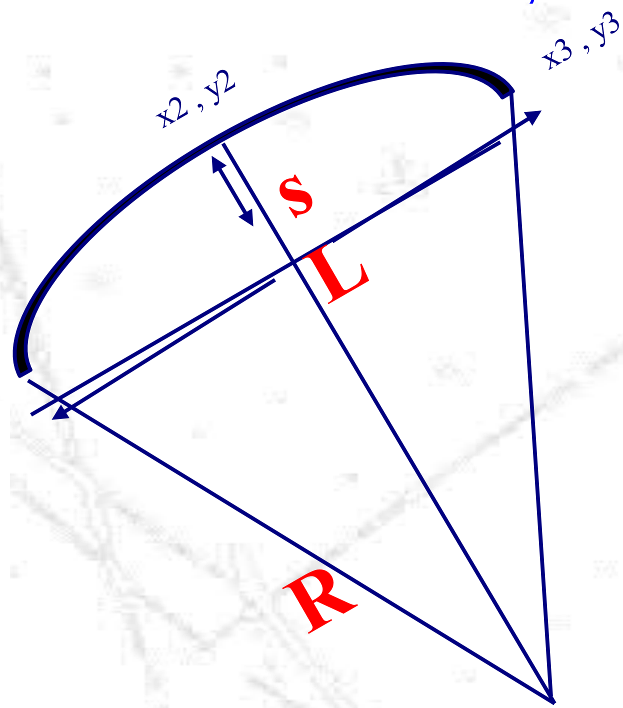


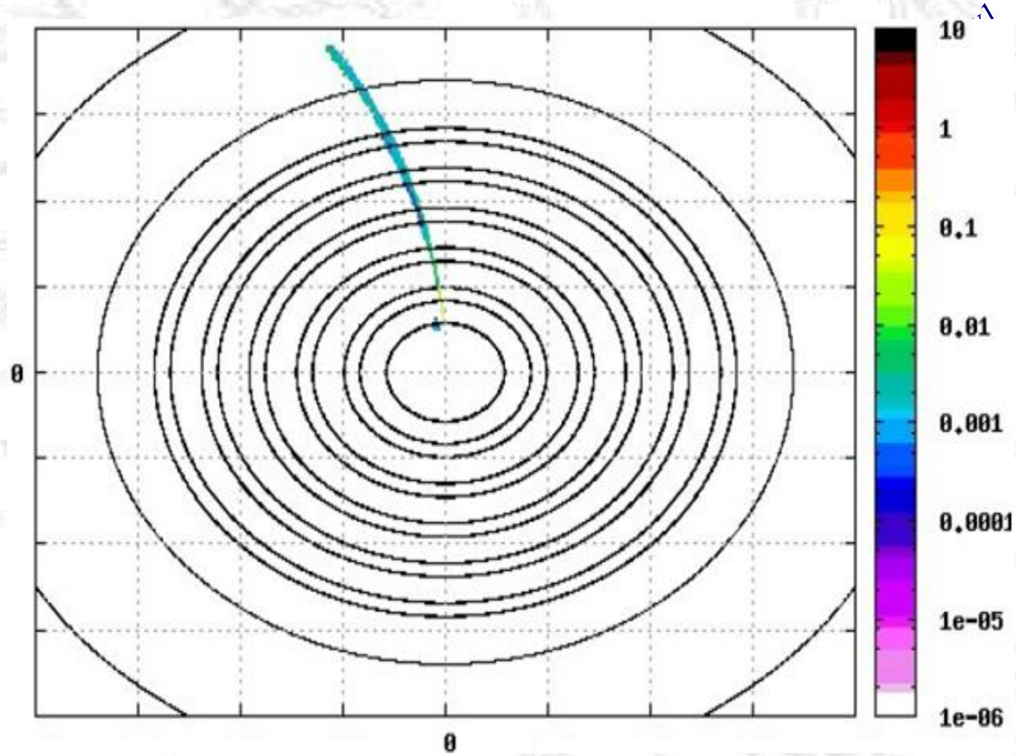
TAC-PF tracker – Momentum resolution

Two main parameters contribute on transverse momentum resolution;

1. Contribution from measurement error:

Sagitta s defines trajectory uncertanities and measured inside the magnet region via the measurement of three space points





$$\frac{\sigma p_T}{p_T} = ?$$

TAC-PF tracker – Momentum resolution

Measurement of curvature R and lever arm L provides Sagitta determination

$$s = \frac{L^2}{8R} \quad \text{as} \quad \frac{\sigma p_T}{p_T} = \frac{\sigma s}{s} \quad \text{thus} \quad \frac{\sigma p_T}{p_T} = \frac{8 \mathrm{p}_T}{0.3BL^2}\sigma s \; ; \quad \frac{\sigma p_T}{p_T} \propto P_T$$

σs; sagitta measurement error

The resolution becomes worse with momentum and improves as $1/BL^2$

2. Multiple Scattering contribution to momentum uncertainty:

Due to presence of material inside the tracker, will result in wiggling of the track and consequently to mis-measurements of the curvature.

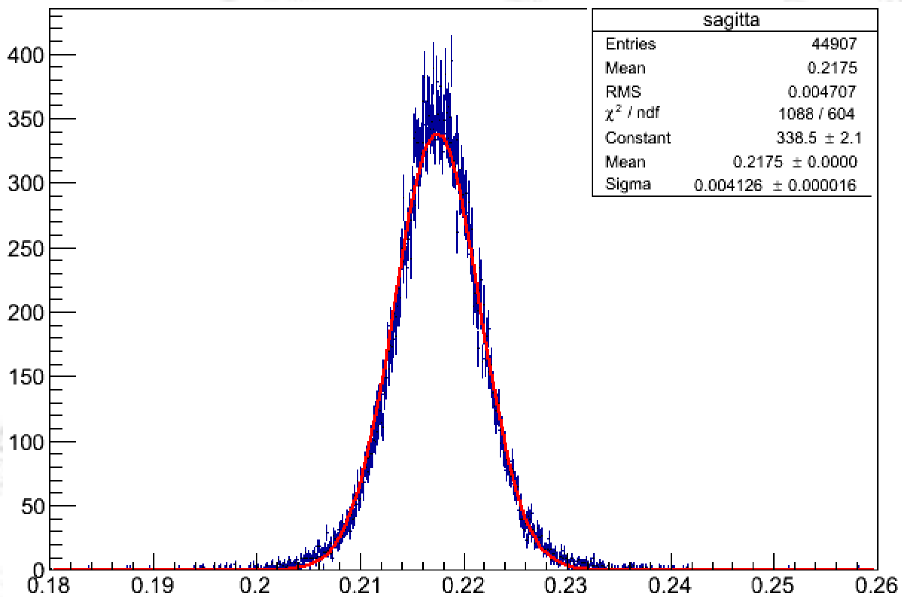
$$\frac{\sigma p_T}{p_T} = \frac{0.05}{BL}\sqrt{\frac{x}{X_0}}$$

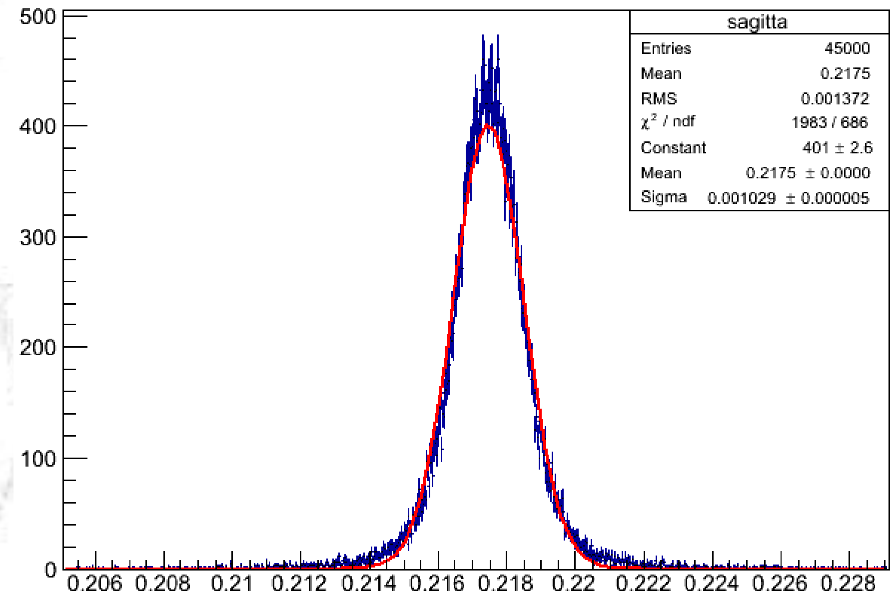
It is momentum independent and improved only as 1/BL

Together with total momentum resolution

$$\frac{\sigma p_T}{p_T} = \frac{8\sigma s p_T}{0.3BL^2} \oplus \frac{0.05}{BL}\sqrt{\left(\frac{x}{X_0}\right)}$$

Simulation works - Momentum resolution





FLUKA with precision physics (1GeV e+ @ 1T)

From this graph $\frac{\sigma s}{s} = 0.01897$ ~ 1.9%

Precision physics include both multiple scattering term and measurement term

$$\frac{\sigma_S}{s} = \frac{\sigma p_T}{p_T} = \frac{8\sigma s p_T}{0.3BL^2} \oplus \frac{0.05}{BL}\sqrt{\left(\frac{x}{X_0}\right)}$$

FLUKA with precision physics and suppress multiple scattering (1GeV e+ @ 1T)

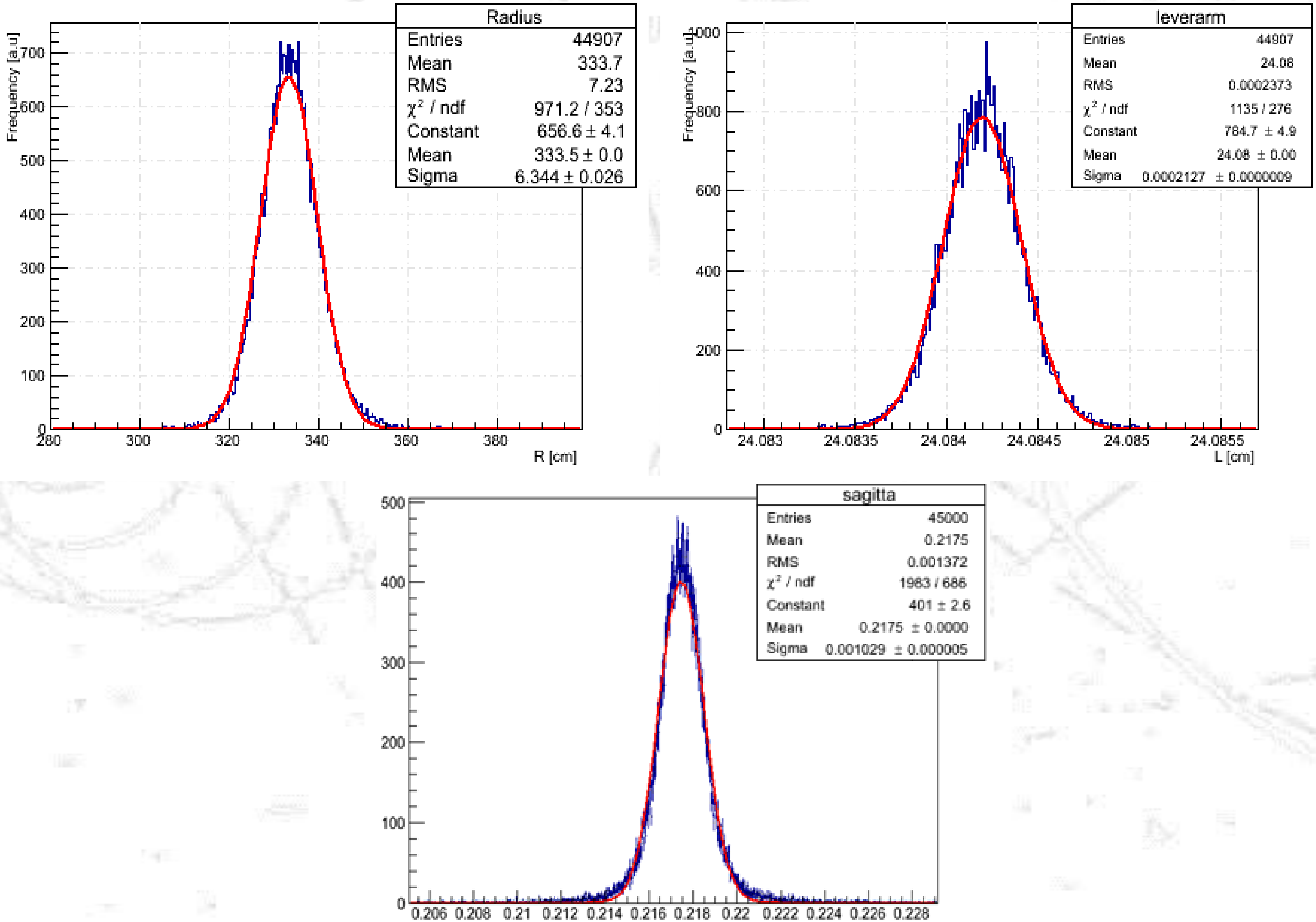
From this graph $\frac{\sigma s}{s} = 0.004731$ ~ 0.5 %

This value includes only measurement term. To suppress multiple scattering in silicon MULSOPT card is used.

Simulation works - Momentum resolution

FLUKA results for e+ @ 1 GeV and 1T

suppressing multiple scattering



Simulation works - Momentum resolution

$$\frac{\sigma p_T}{p_T} = \frac{8\sigma s p_T}{0.3BL^2} = 0.0046 = 0.46\ \%$$

$$\frac{\sigma p_T}{p_T} = \frac{0.05}{BL}\sqrt{\frac{x}{X_0}} = 0.0167 = 1.67\ \%$$

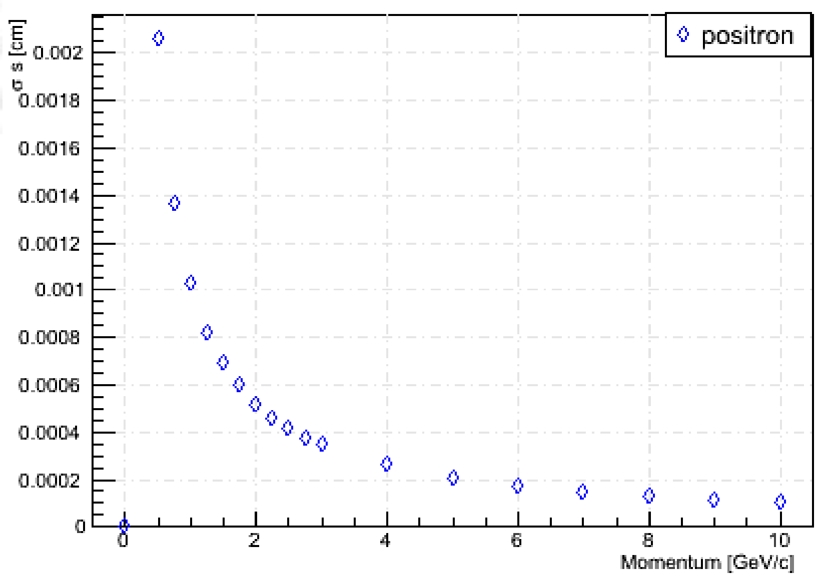
$\sigma_S = 0.001\,\text{cm} = 0.00001\,\text{m}$ @ 1 GeV and 1T

x_o =0.0936 m (Si), 0.25 m (C)

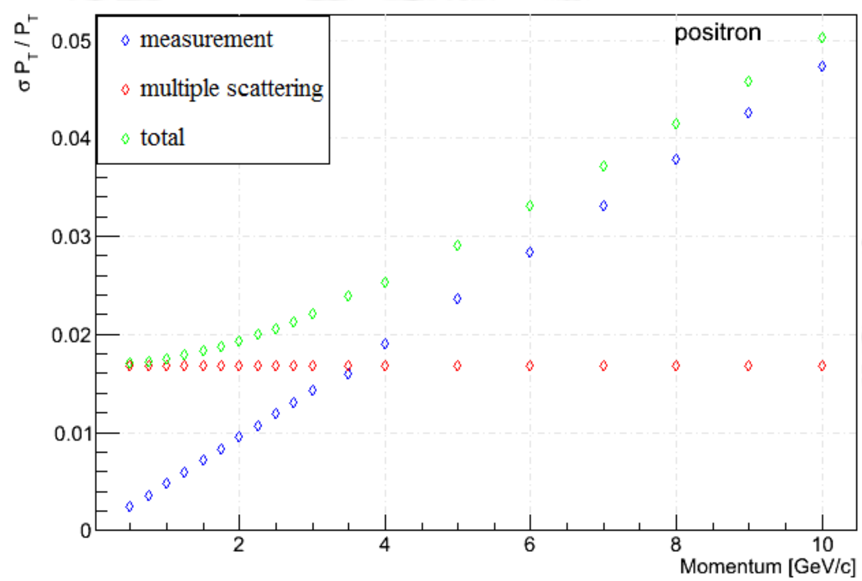
$L = 24.08\,\text{cm} = 0.2408\,\text{m}$

$$\frac{\sigma p_T}{p_T} = a p_T \oplus b \qquad \frac{\sigma p_T}{p_T} = 0.46 \oplus 1.67 = 1.74\ \%$$

Sagitta measurement error variation with momentum

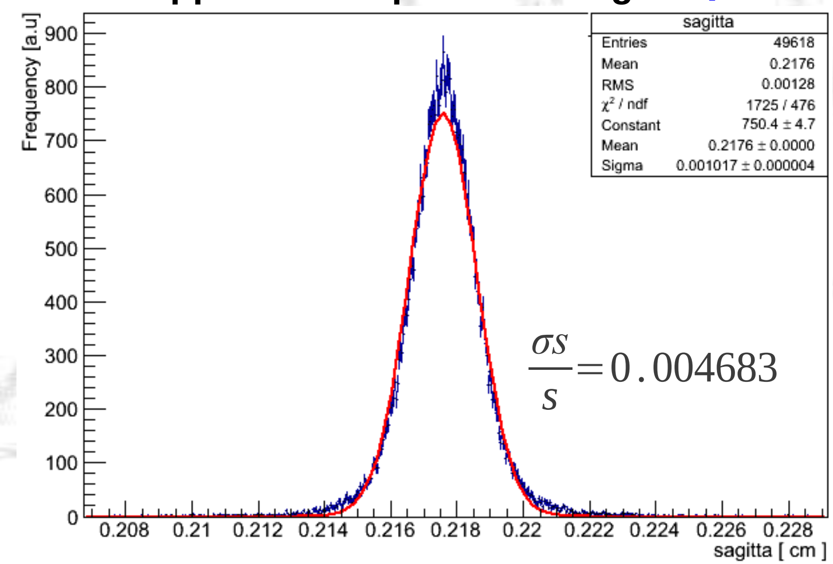


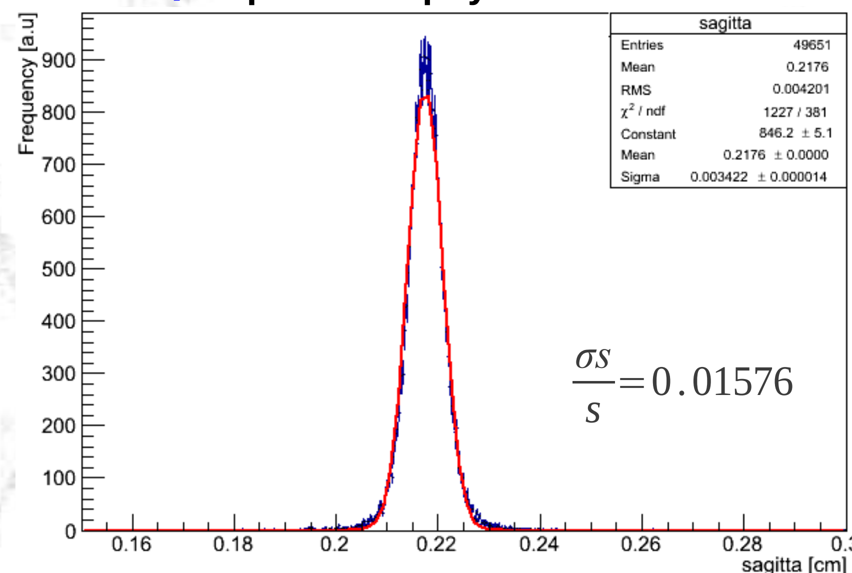
Relative momentum resolution variation with momentum



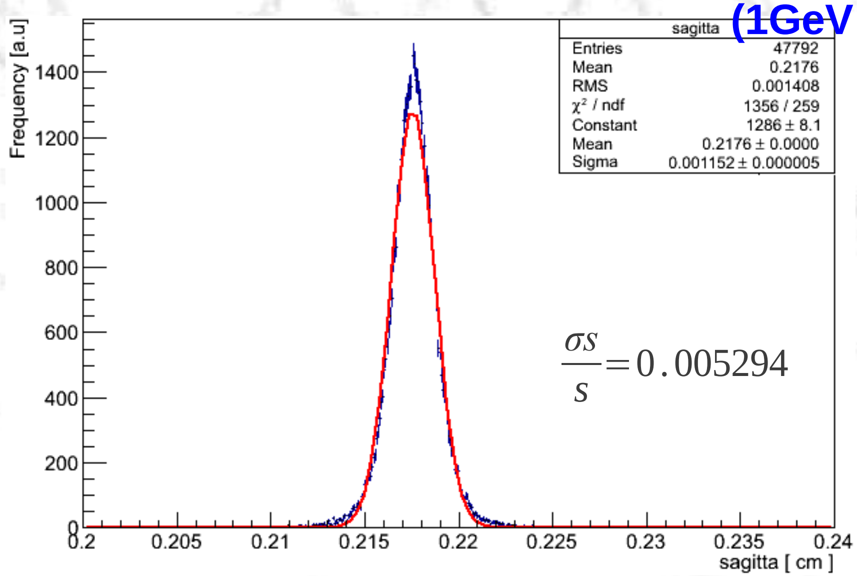
Simulation works - Momentum resolution

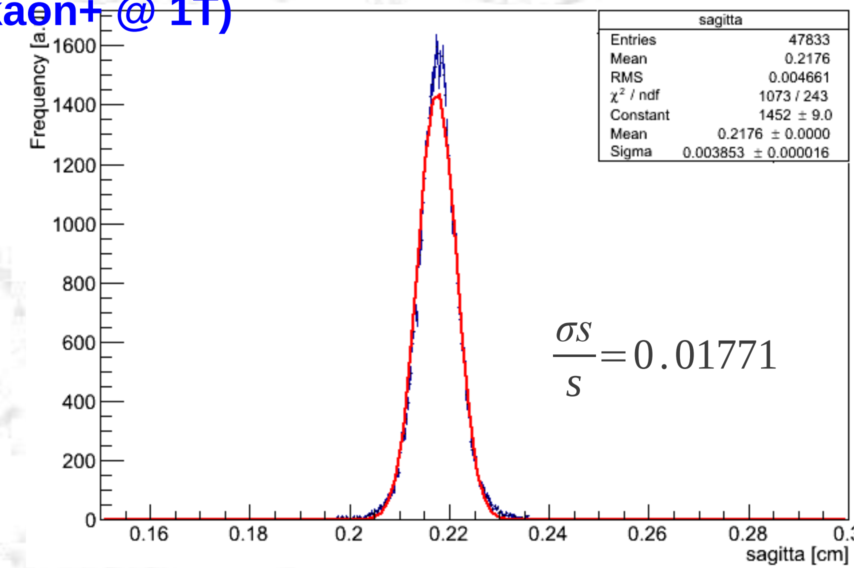
precision physics and suppress multiple scattering **(1GeV pion+ @ 1T)** **precision physics**





(1GeV kaon+ @ 1T)

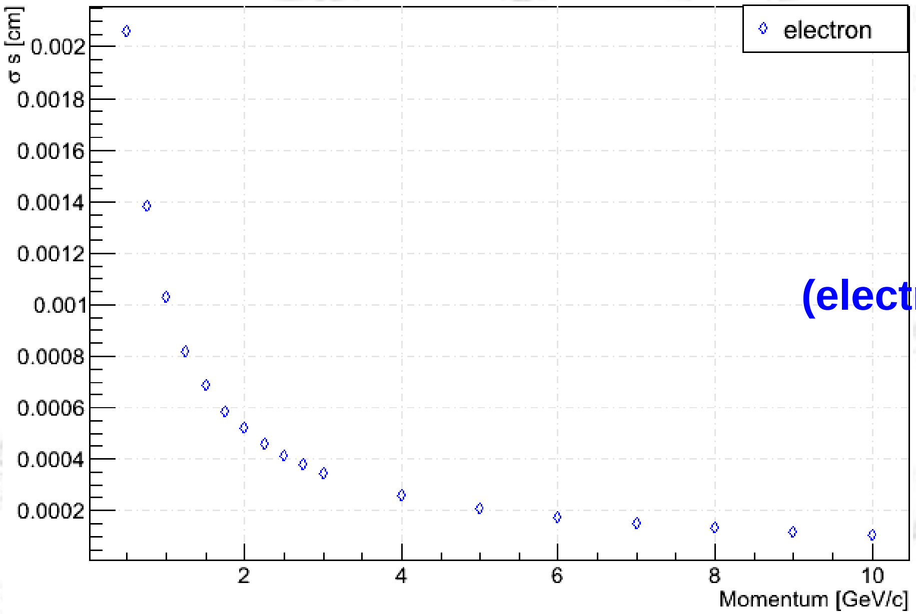




Simulation works - Momentum resolution

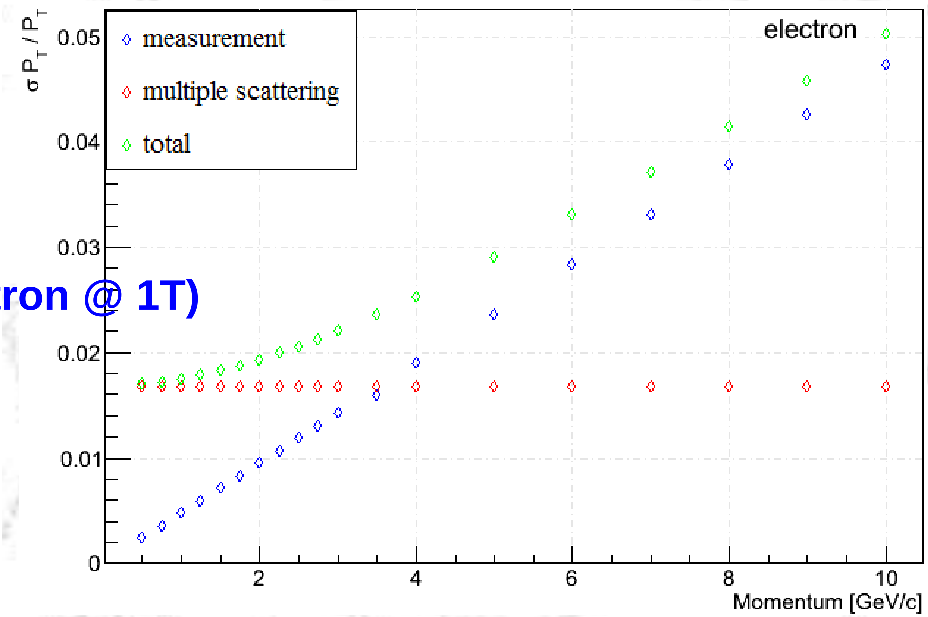
(1GeV@ 1T)	Measurement [%]	Multiple Scattering term [%]	σ_{Pt} / P_T [%]
Positron	0.46	1.67	1.74
Pion+	0.47	1.50	1.57
Kaon+	0.53	1.69	1.77

Simulation works - Momentum resolution

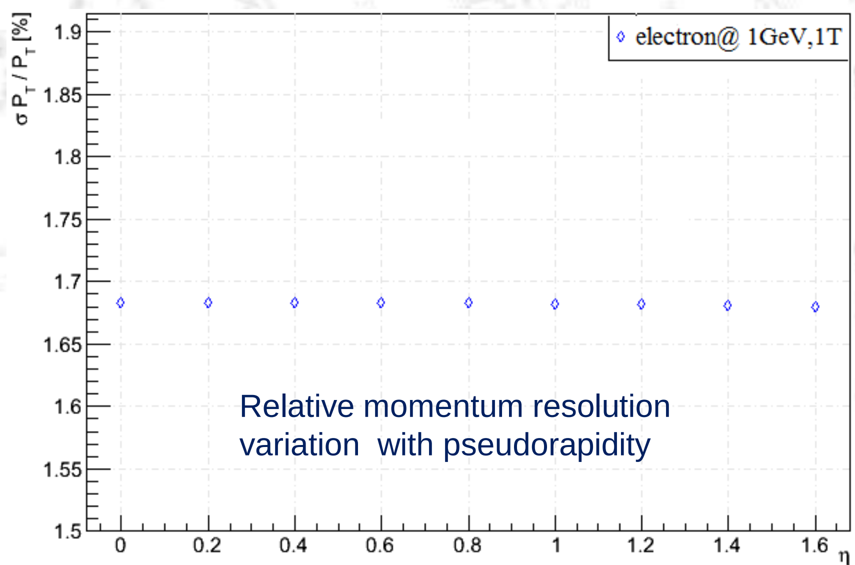


Sagitta measurement error variation

(electron @ 1T)

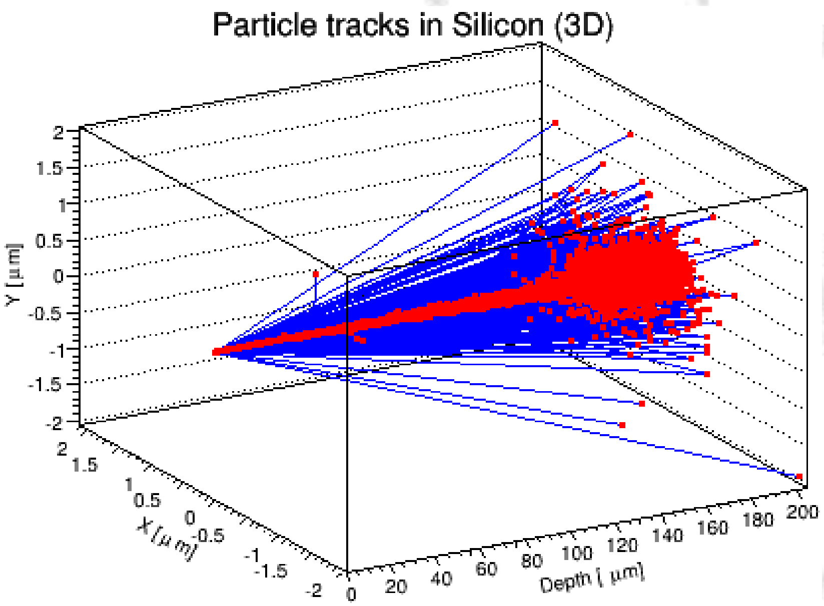


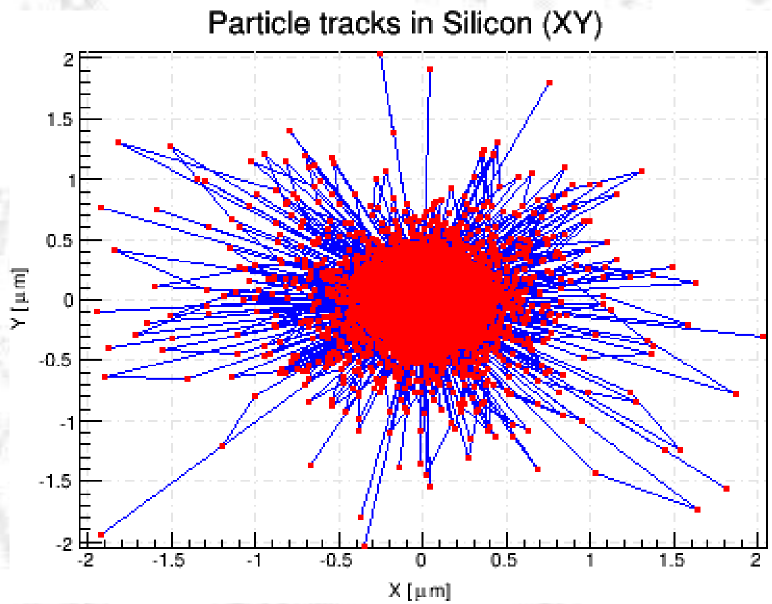
Relative momentum resolution variation

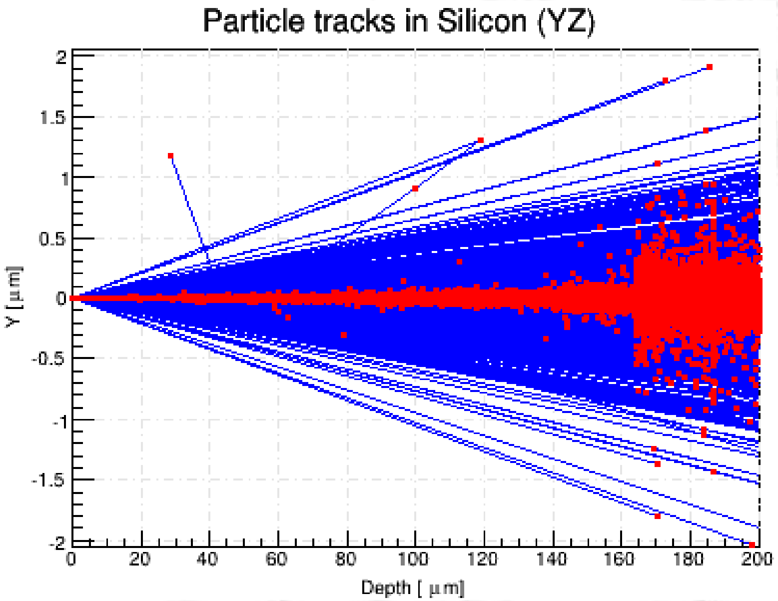


Relative momentum resolution variation with pseudorapidity

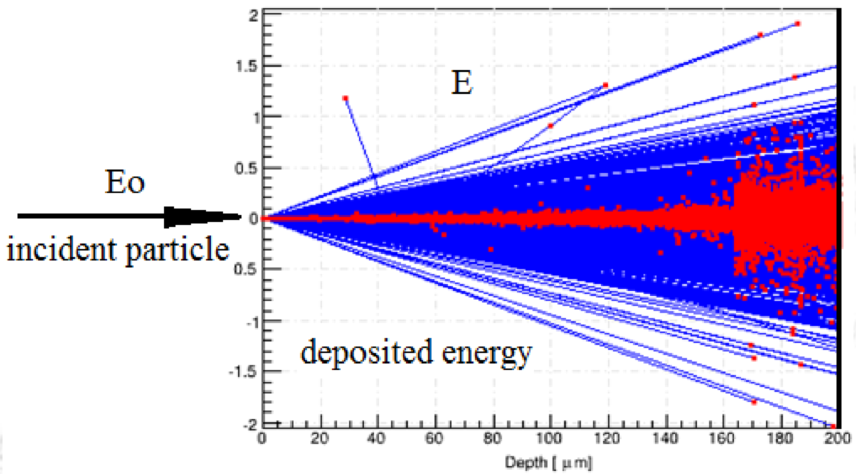
Simulation works – Particle tracks- Energy deposition



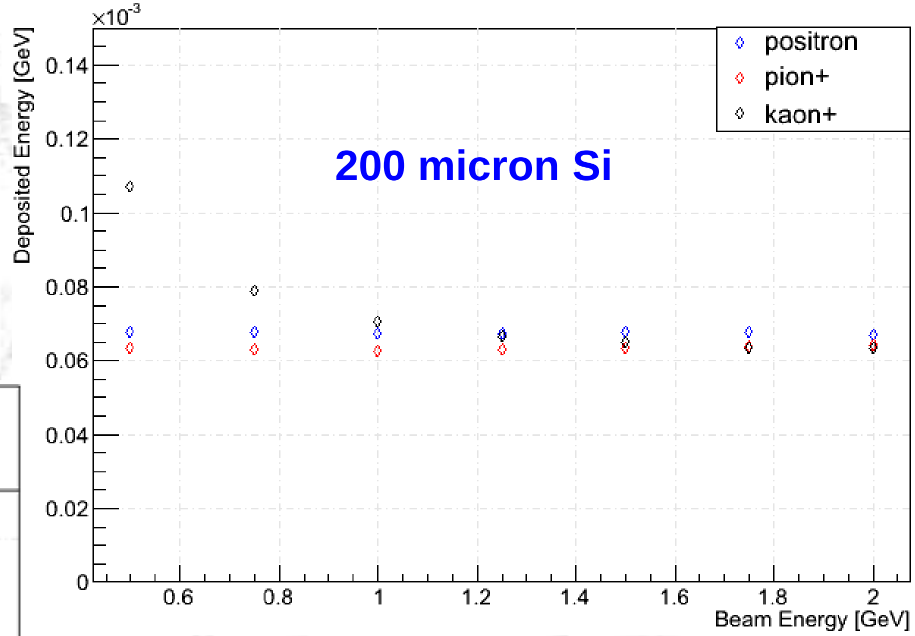


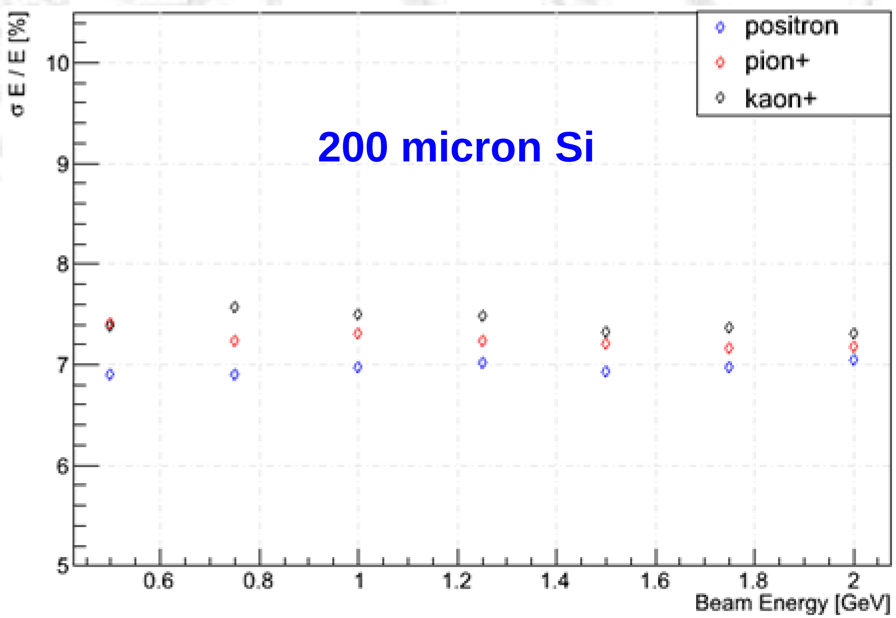


Simulation works - Energy deposition



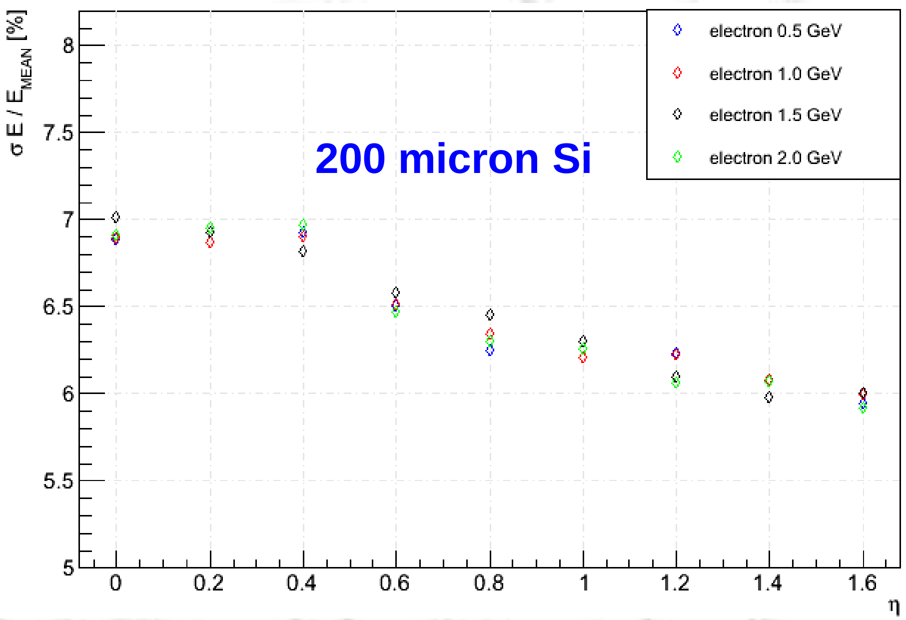
Deposited energy variation with incident particle energy





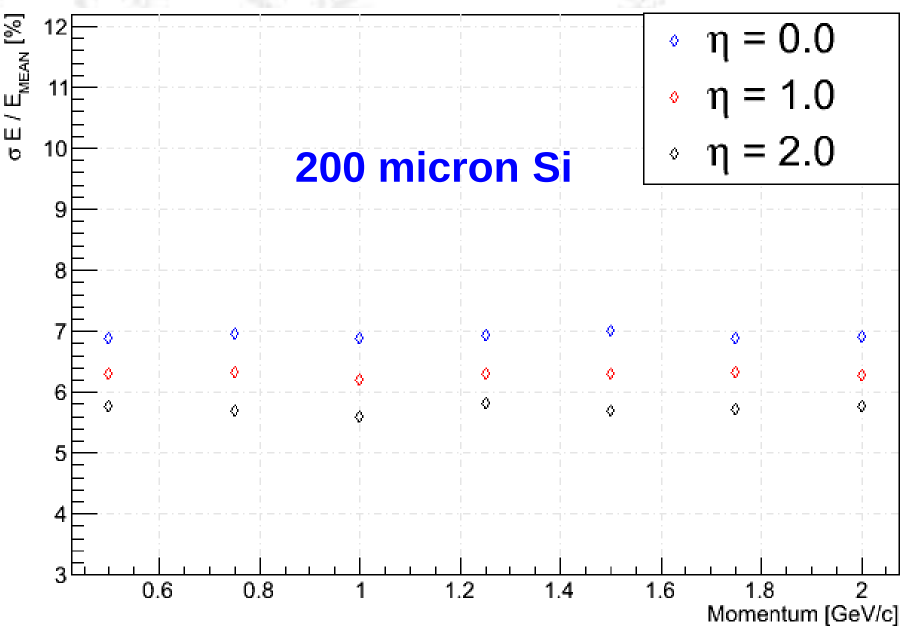
Deposited energy resolution variation with incident particle energy

Simulation works - Energy deposition

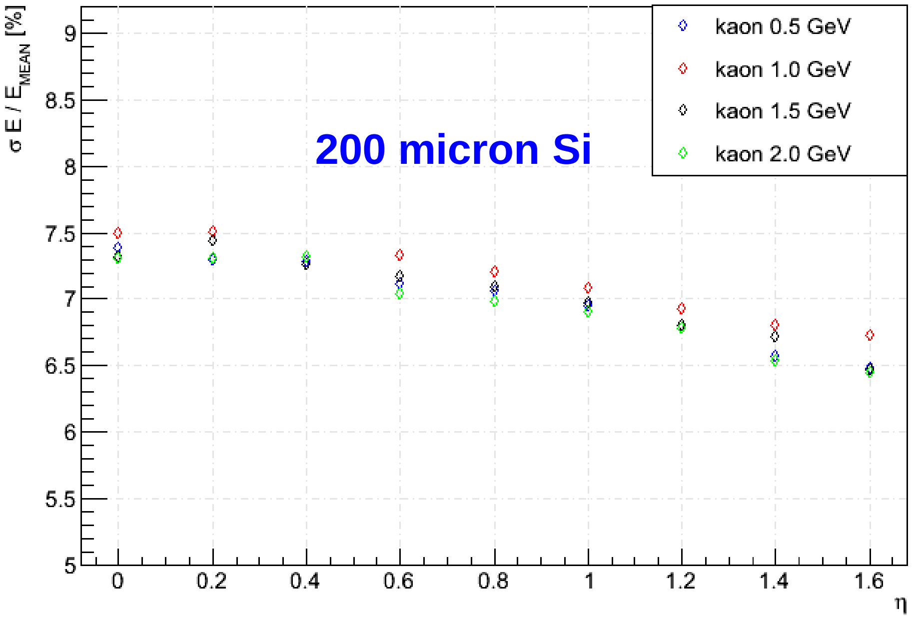


Deposited energy resolution vs η at different electron energies

Deposited energy resolution vs momentum at different ηs

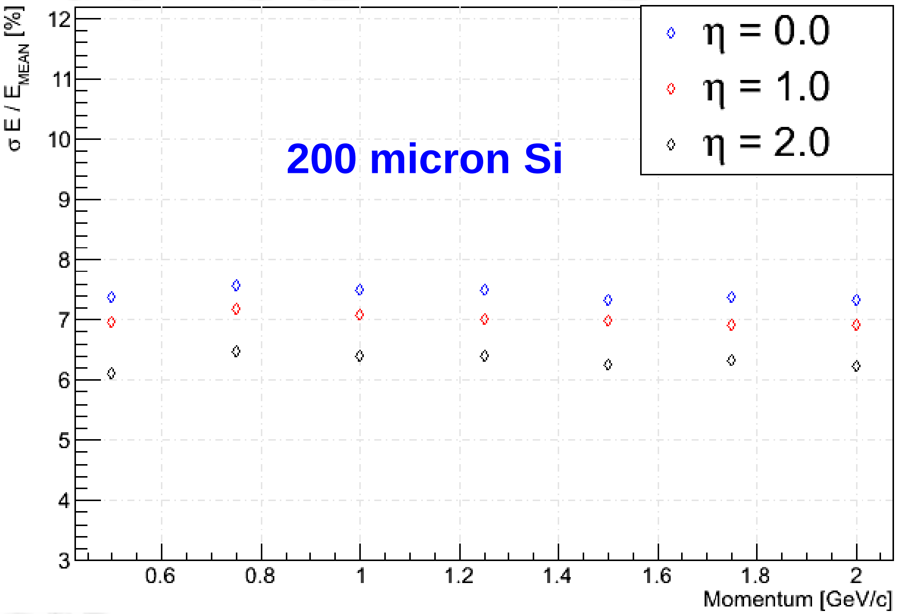


Simulation works - Energy deposition

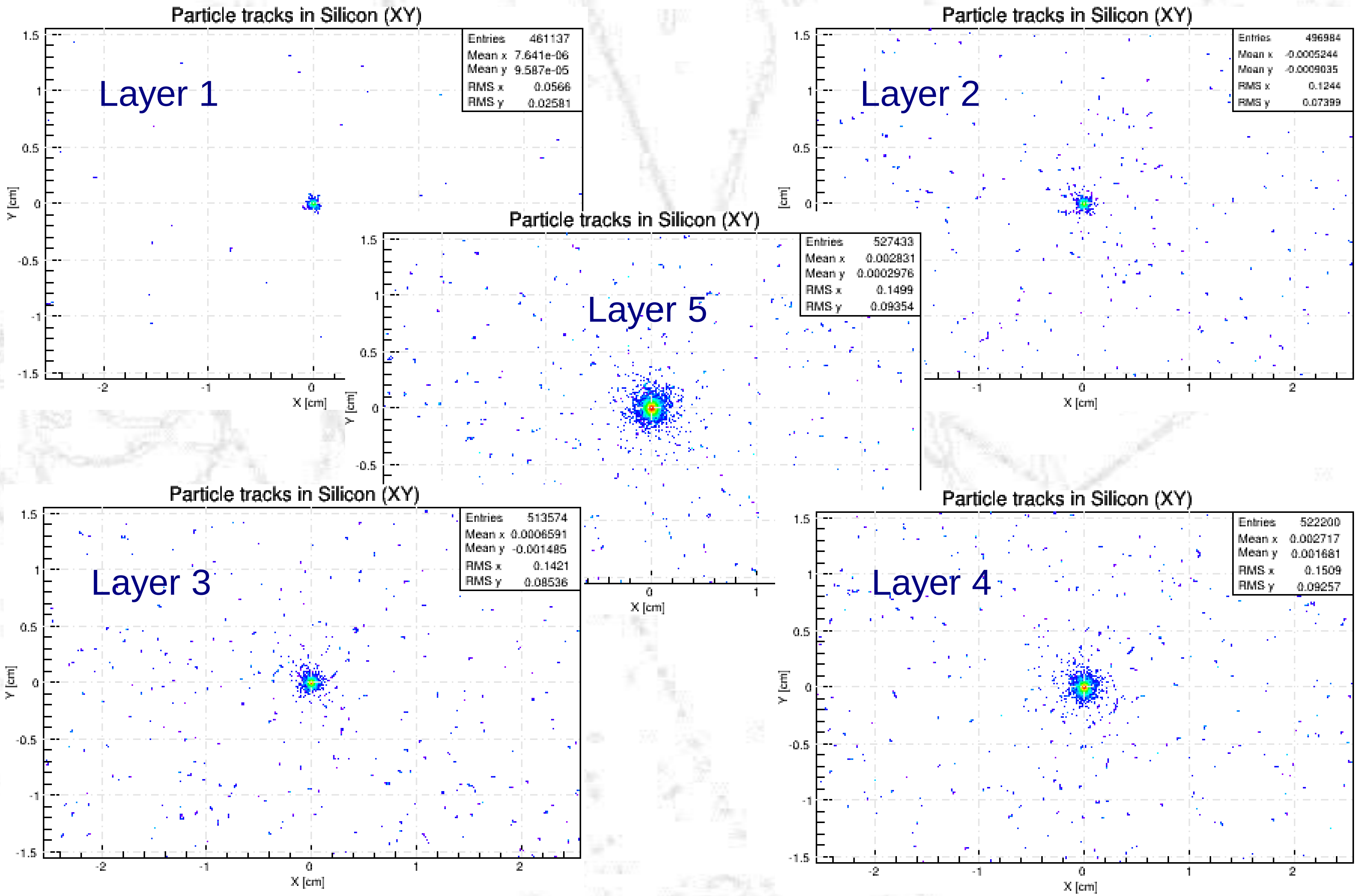


Deposited energy resolution vs η
at different kaon energies

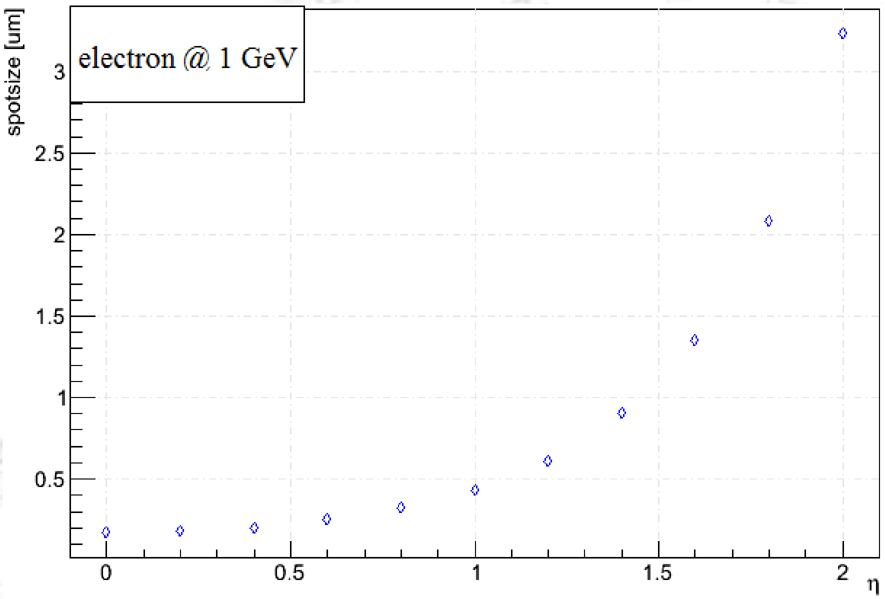
Deposited energy resolution vs momentum
at different ηs



Simulation works – Particle tracks- Spot size



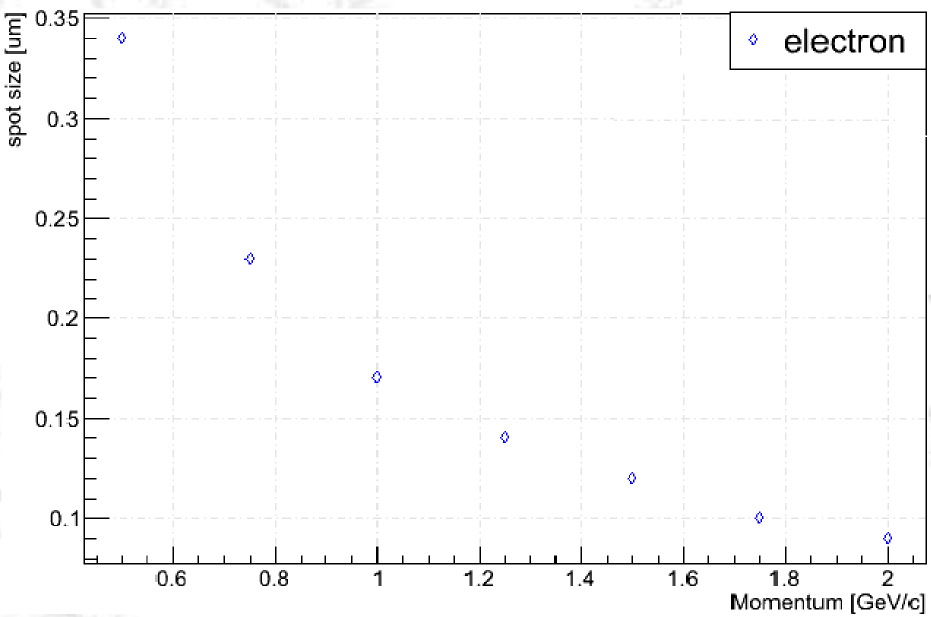
Spot size



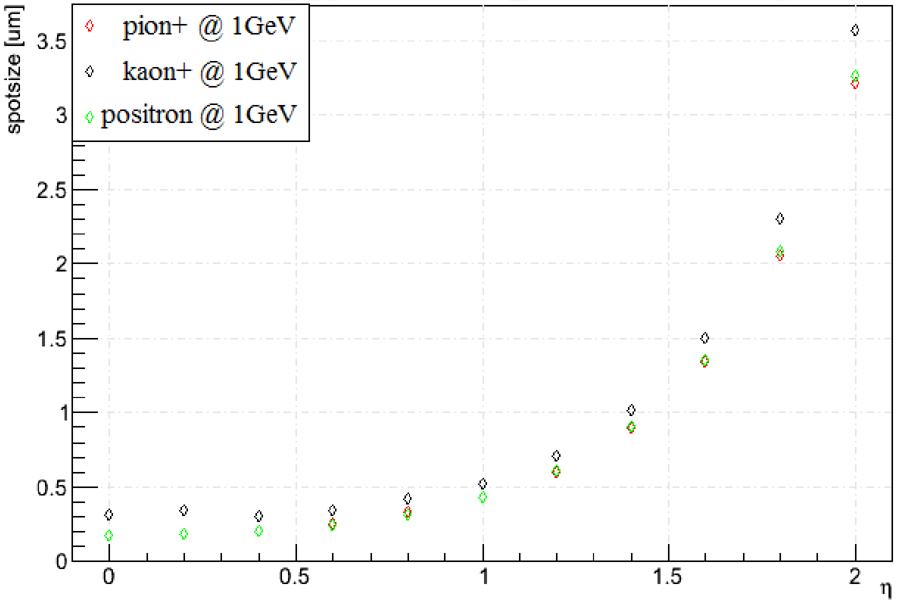
Spot size variation with pseudorapidity

Calculated spot size is the standard deviation of the charged particles path due to the scattering in Si layer.

Spot size variation with incident particle momentum

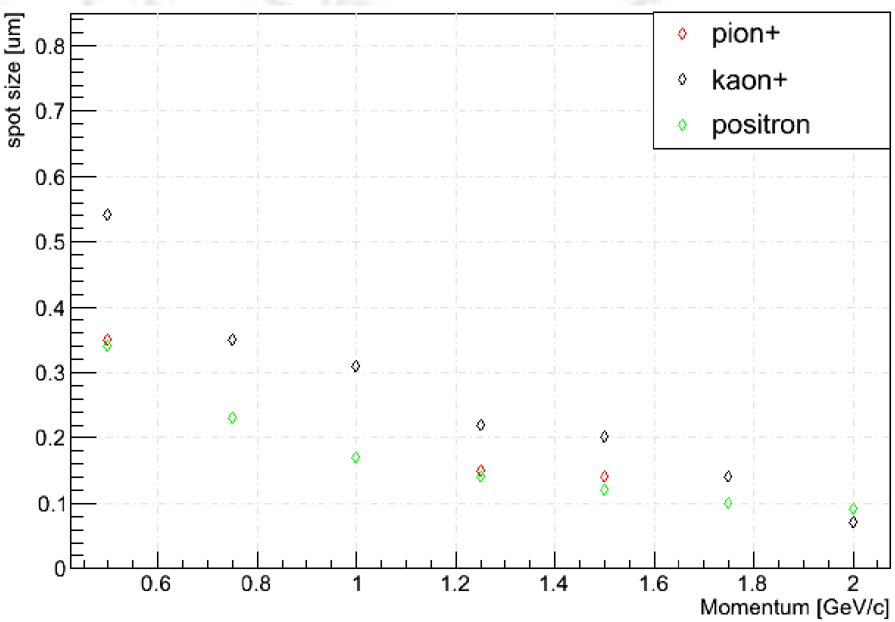


Spot size



Spot size variation with pseudorapidity for different type charged particles

Spot size variation with incident particles momentum

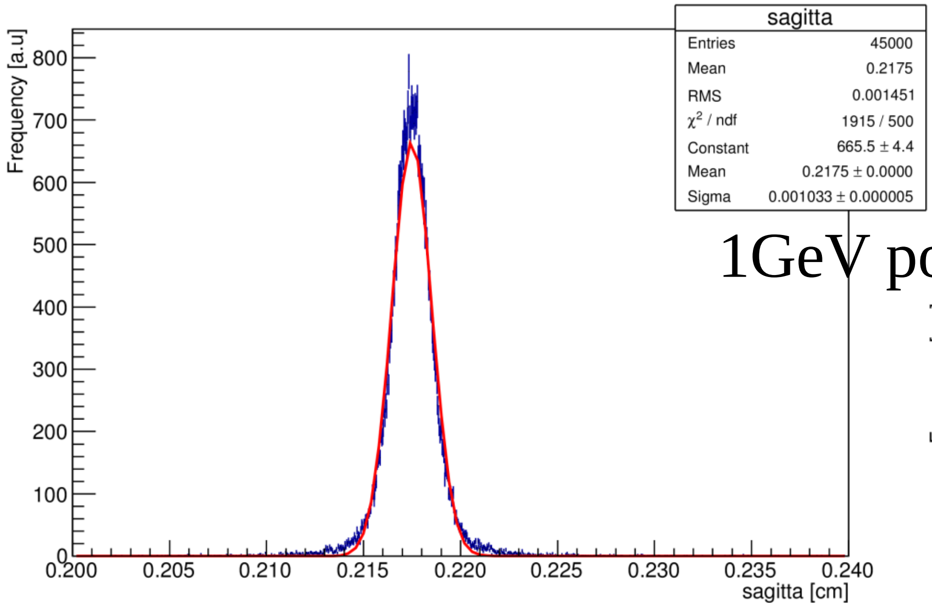


Conclusion

Simulation shows for the designed tracker structure with 200 micron Si layer that;

- **Gives momentum resolution ~ 0.5 % from the measuremets**
  ~ 1.6 % due to the multiple scatt.
- **Energy deposition rate is OK for the energy loss measuremets and energy resolution ~ 7 % up to 2 GeV**
  gets better with increasing η
- **As the calculated spot sizes small, the proposed pitch width of 50 micron would be fine below 2 GeV.**

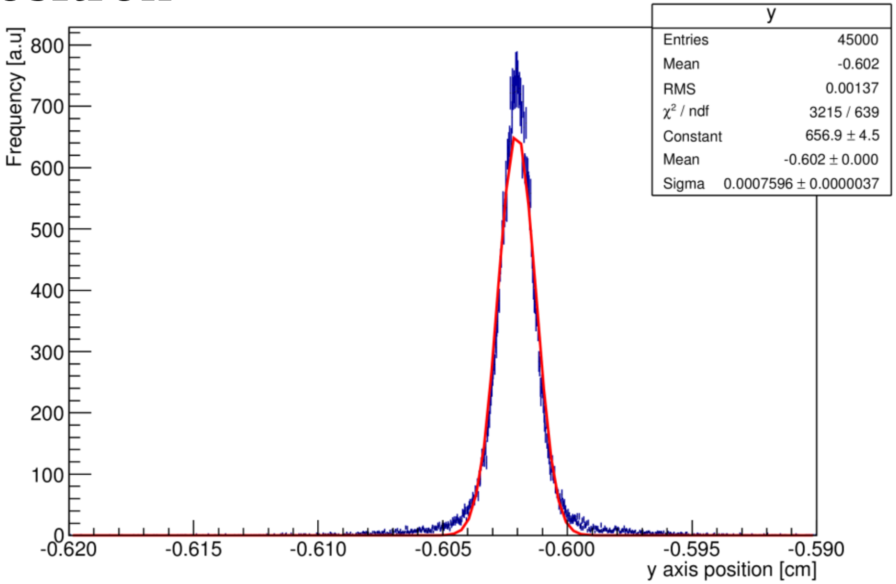
Sigma s-sigma y



$\sigma s = 10.3 um, \sigma y = 7.6 um$

$$\sigma_s = \sigma_y \sqrt{\frac{3}{2}}$$

1GeV positron



$$\sigma = \frac{d}{\sqrt{12}}$$

σ; Spot size

d ; the width of the pitch that would record the signal