Proposal for a new design of LumiCal

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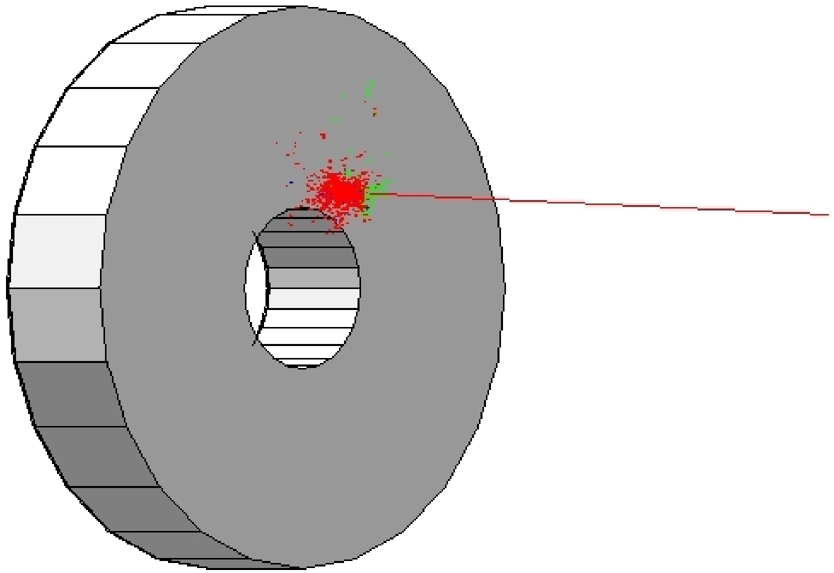

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Motivation

Improve the performance of the LumiCal:

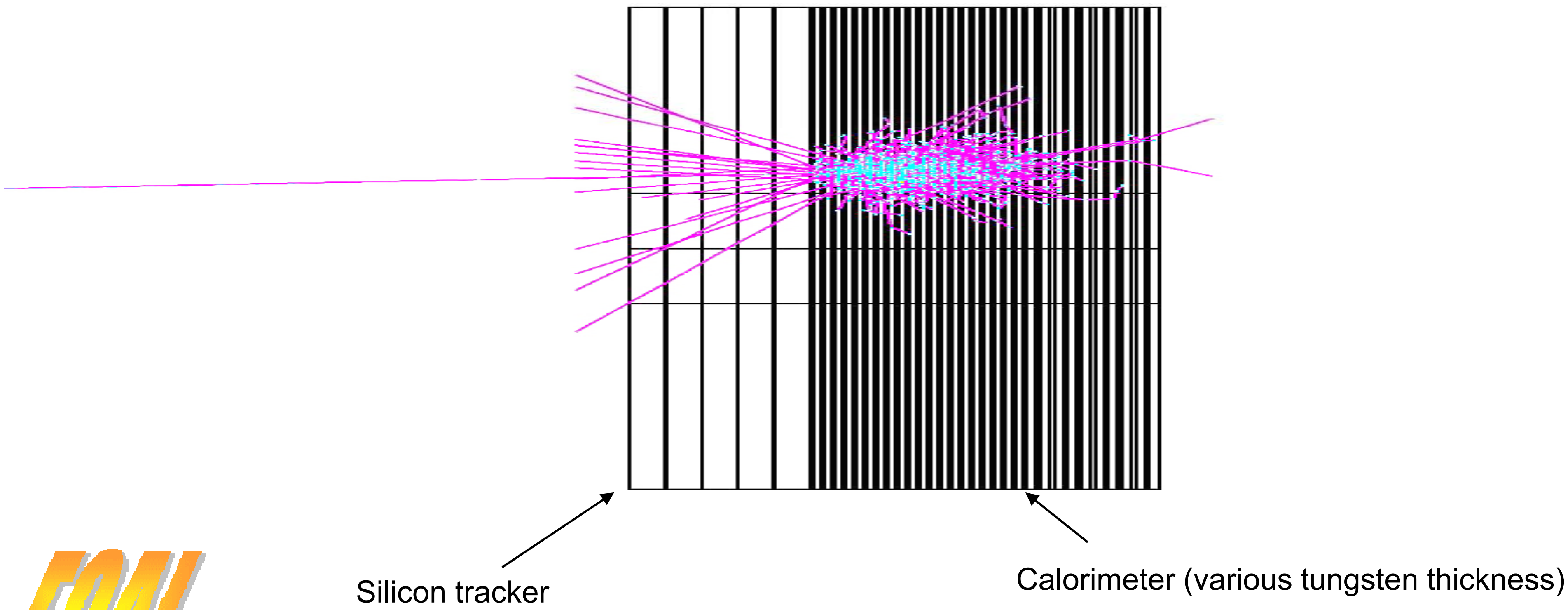
- improve the energy reconstruction
- improve the angle reconstruction

Outline

- **New design concept**
- **Algorithm**
- **Performance**
- **Luminosity measurement**
- **Summary**

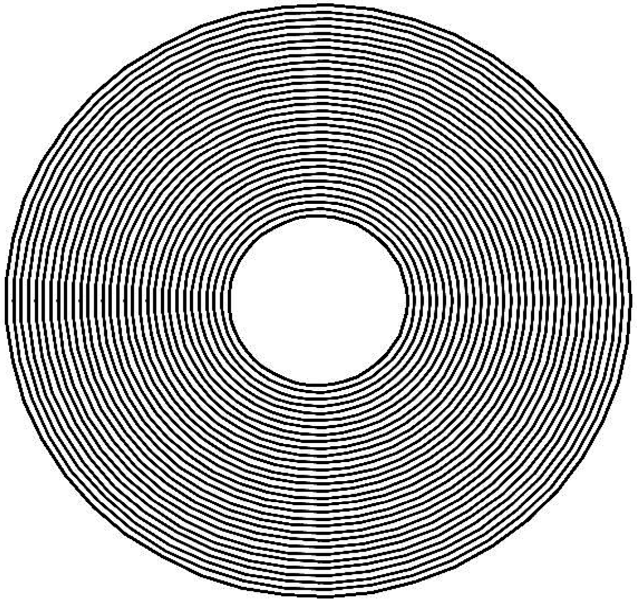
New concept

- LumiCal is composed from two components: Tracker, Calorimeter
- A silicon tracker with fine granularity stands in front of the calorimeter
- Calorimeter has various tungsten thicknesses



Strip silicon tracker

Tracker start	227 cm
Tracker ends	238 cm
Number of layers	5
Gap between the layers	20 mm
Silicon thickness	0.3 mm
Size of the strips	70 µm
Inner radius	80 mm
Outer radius	350 mm



- Strips are used because of less channels in comparison with pads
- There is no electronic and cooling system behind silicon layers when we use the strips => smaller multiple scattering
- We use the information from the calorimeter behind the tracker to reconstruct the tracks in the tracker
- In this study we use 5 layers of θ measurement but in future we will add layers of φ measurement

Shower-peak design calorimeter

Start z-position	238 cm
End z-position	258 cm
Outer radius	350 mm
Inner radius	80 mm
Silicon thickness	0.3 mm
Electronic thickness	2.3* mm

Layer	Tungsten thickness [mm]
1-20	3.4
21-30	5.1

- **Calorimeter has 30 silicon layers**
- **Total tungsten thickness is equal 35 X0**

Layer	Number of cylinders	Number of sectors
1-4	13	48
5-20	104	48
21-30	13	48

Energy reconstruction algorithm

For calorimeters with various tungsten thicknesses we apply different weight factors for the different layer……

$$E = \sum_{i \in layer} E_i \omega_i \Big/ \sum_{i \in layer} \omega_i$$

Algorithm:

- Deposited energy in layers 1-20 with thickness 1 X0 has $\omega_i = 1$
- Deposited energy in layers 21-30 with thickness 1.5 X0 has $\omega_i = 1.5$

Collaboration
High precision design

Position algorithm

1. Compute θ (polar angle) from the calorimeter:

- θ_{calor} is found using the logarithmic algorithm

$$\theta_{calor} = \frac{\sum \Theta_i W_i}{\sum W_i} \qquad W_i = max\left[0, \left(const + \ln\frac{E_i}{E_{tot}}\right)\right]$$

2. Match θ of the tracker:

- In first layer try to find hit strips in angle $\theta_{calor} \pm d\theta_1$, where θ_{calor} was found before.
- If one or more strips are found then look for a match in the next layer in angle $\theta_{prevlayer} \pm d\theta_2$, where $\theta_{prevlayer}$ was completed before.
- Only if all layers are matched the tracker information is used else take θ from calorimeter.

$\sigma_1 \neq \sigma_2$

Tracking algorithm

R_i…………..radial position of the particle in layer
Z_i…………..z position of the layer
σ_i………….. error in R measurement of the hit

$$\tan(\theta) = \frac{\sum_{i \in layer} \frac{R_i Z_i}{\sigma_i^2}}{\sum_{i \in layer} \frac{Z_i^2}{\sigma_i^2}}$$

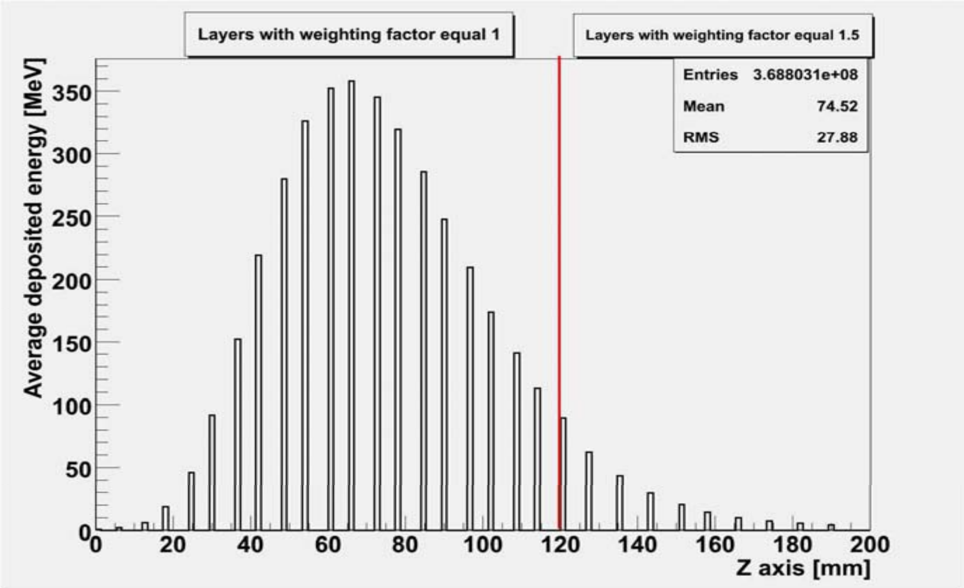
Choosing the σ :

- If only one strip in a layer is hit then σ_1 ~ strip size (70 μm)
- If two or more strip a in layer are hit we have more information $\sigma_1 \neq \sigma_2$ (needs optimization)
- The results presented today are for σ_i=1

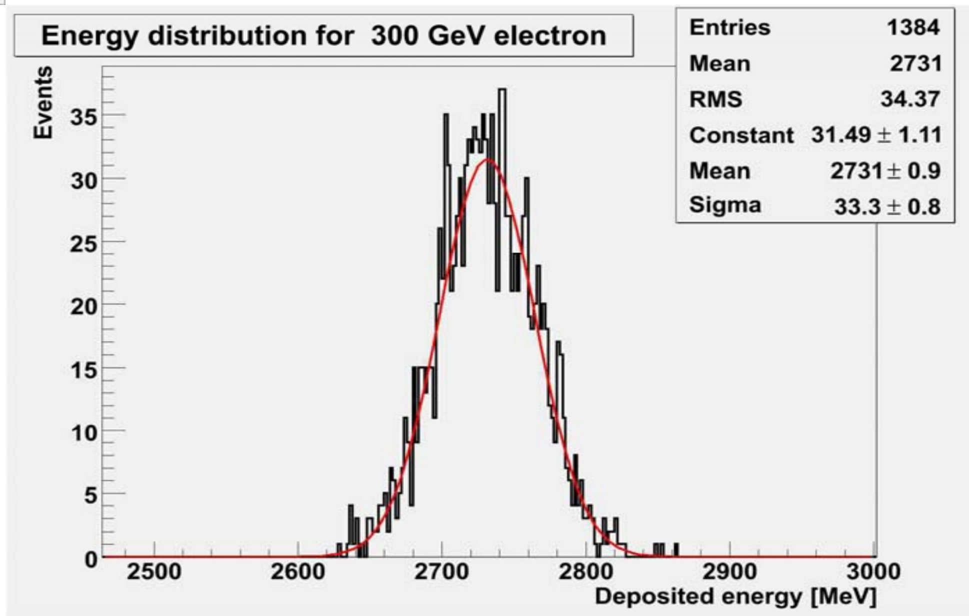
- If more than one strip in the layer is hit compute *R*, as where ω_i =1.

$$R = \sum_{i \in strip} R_i \omega_i \Big/ \sum_{i \in strip} \omega_i$$

Calorimeter performance

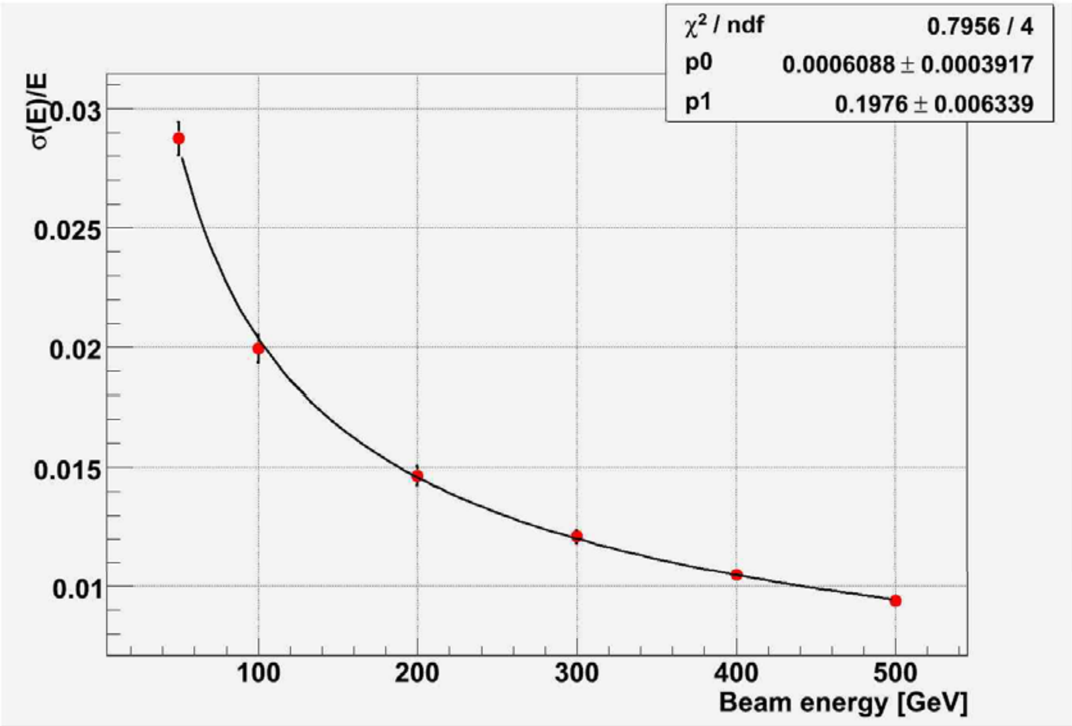


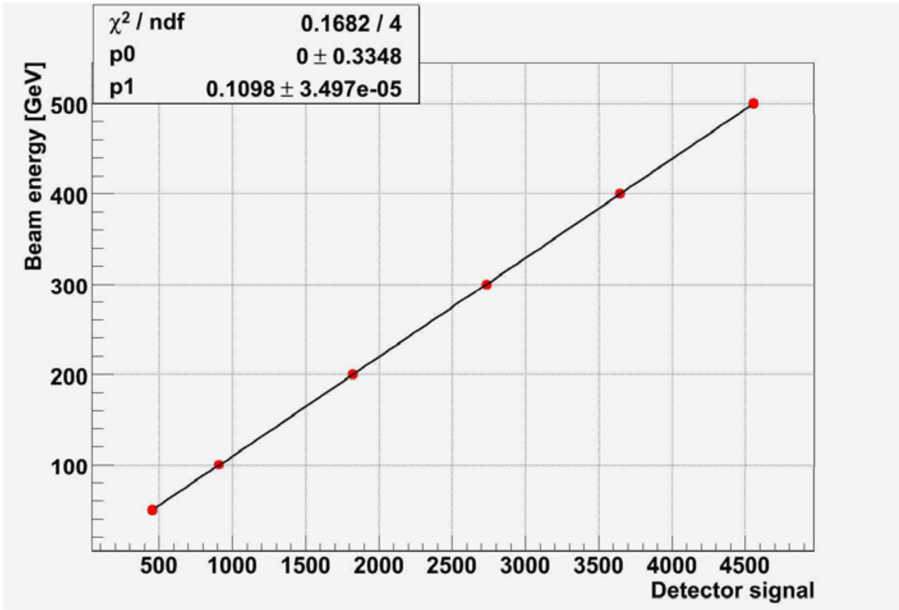
Weight factors:
ω_1=1 applied for the layers in front of red line
ω_2=1.5 applied for the layers behind of red line



Calorimeter performance

Calibration and energy resolution

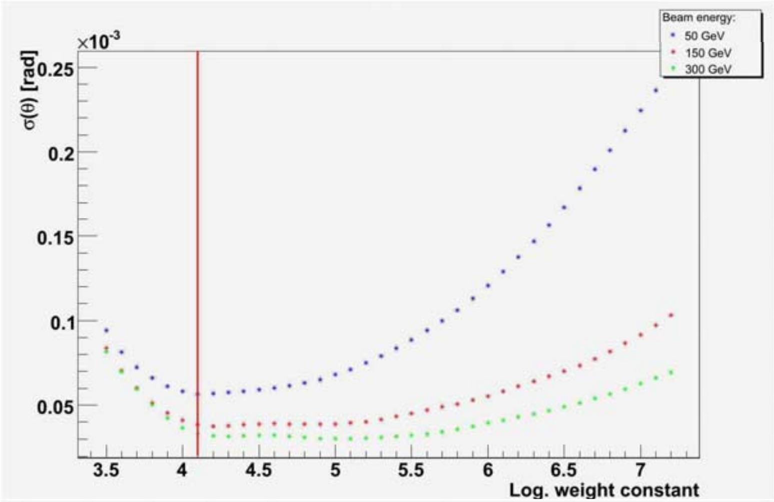


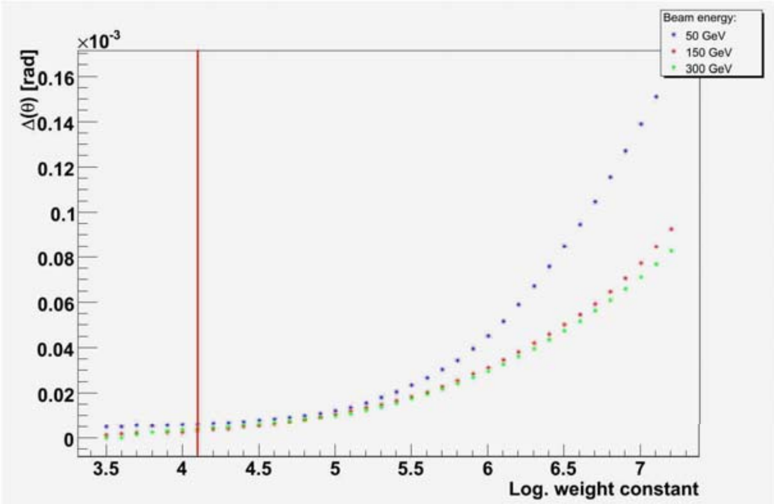


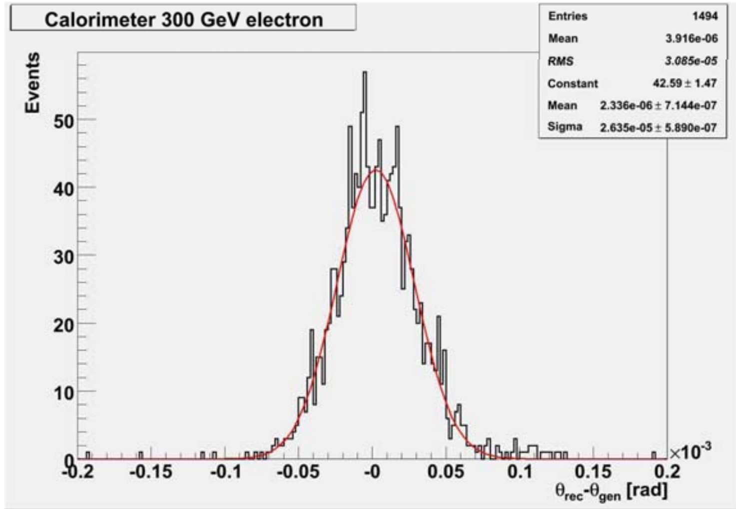
$$\frac{\sigma(E_{samp})}{E_{samp}} = \frac{0.1976}{\sqrt{E_{beam}}} + 0.0061$$

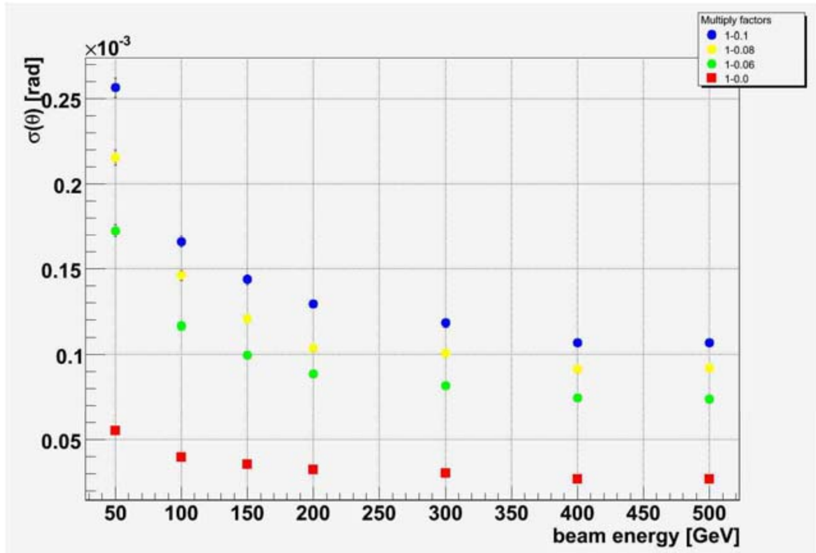
Calorimeter performance

Polar resolution and bias





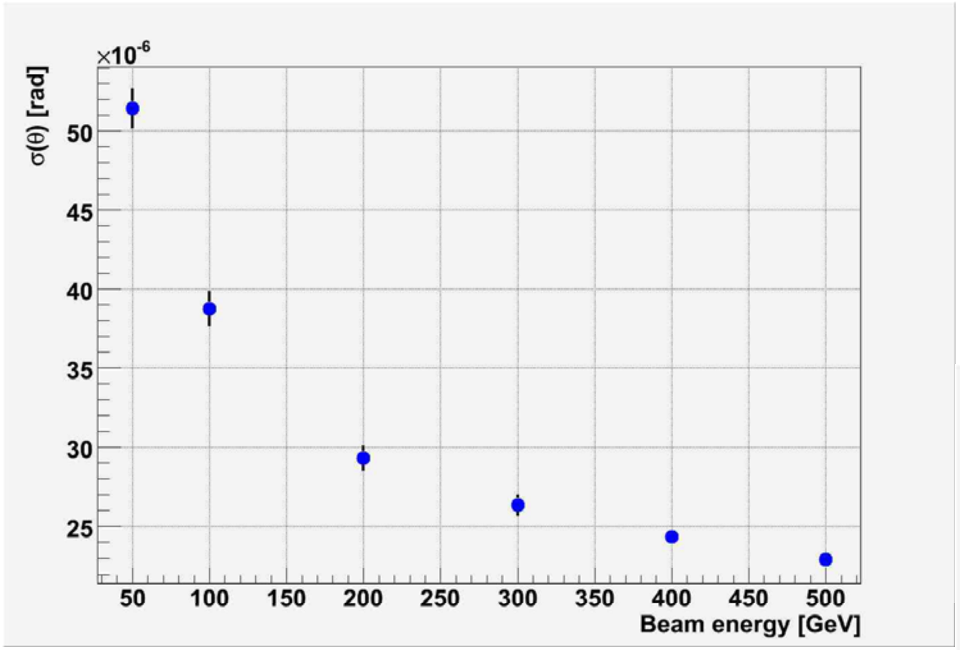


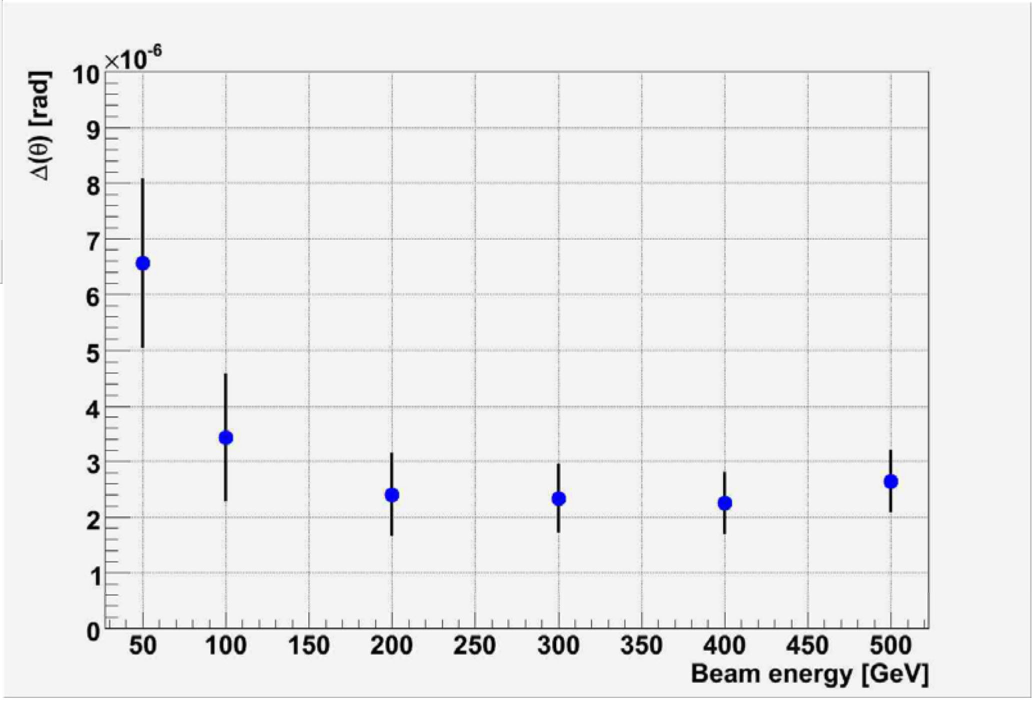


Collaboration
High precision design

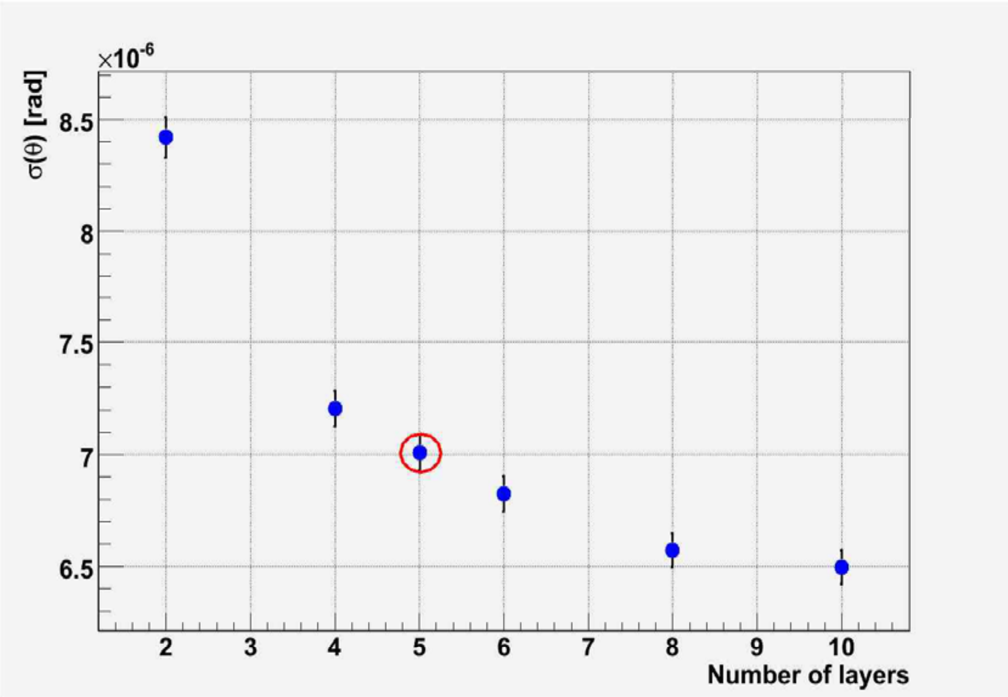
Calorimeter performance

Polar resolution and bias

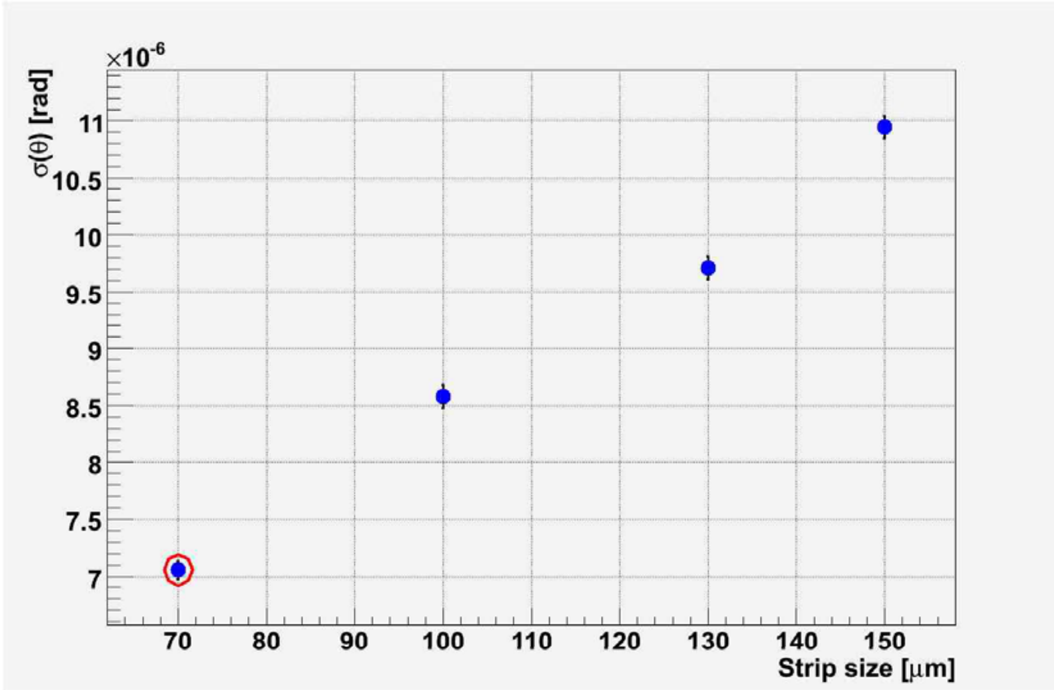




Estimation of tracker parameters



- Strip size …………. 70 µm
- Silicon thickness ….0.3 mm
- Gap ……………….. 3.4 mm

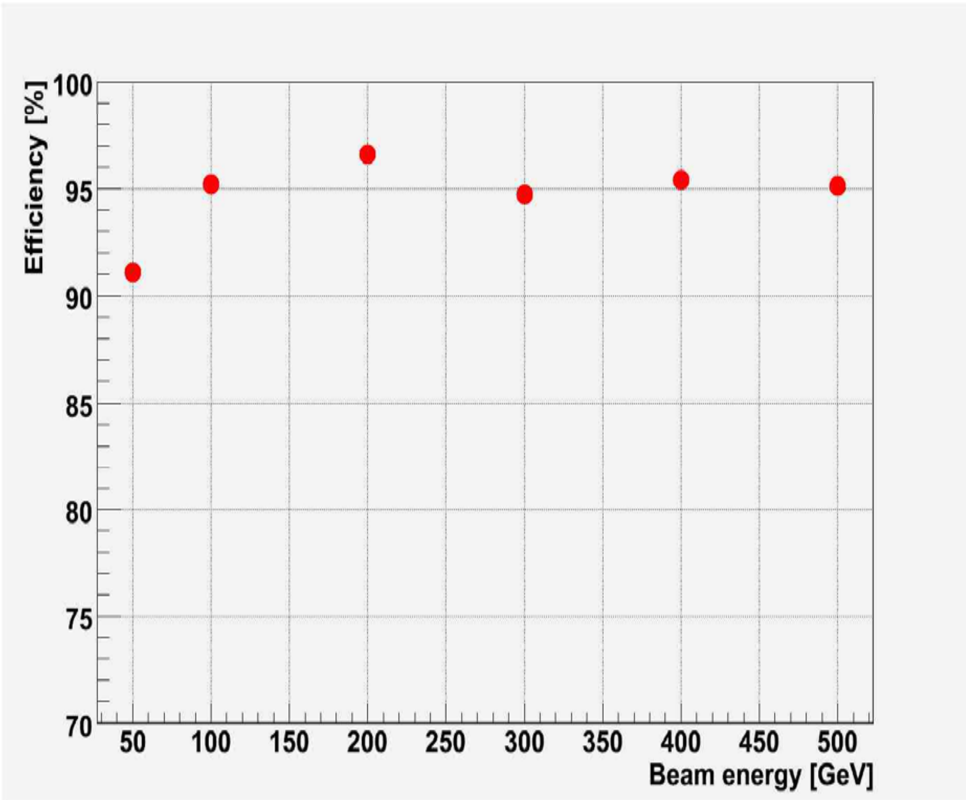


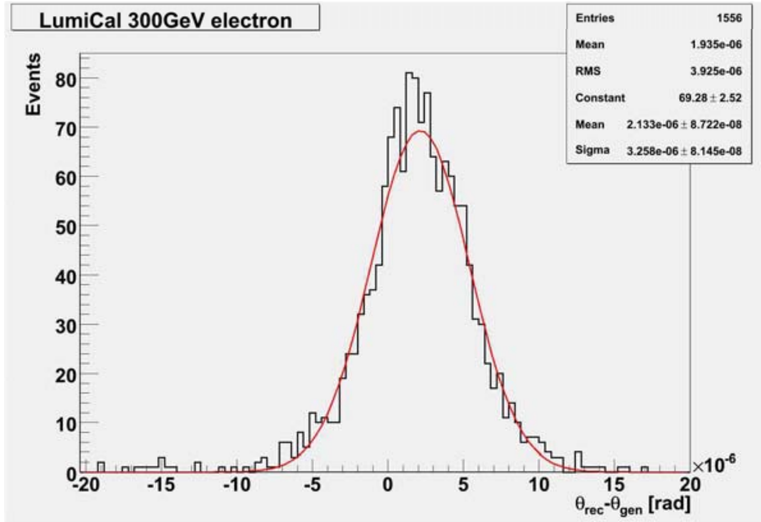
- Number of layers … 5
- Silicon thickness …..0.3 mm
- Gap ……………….. 3.4 mm

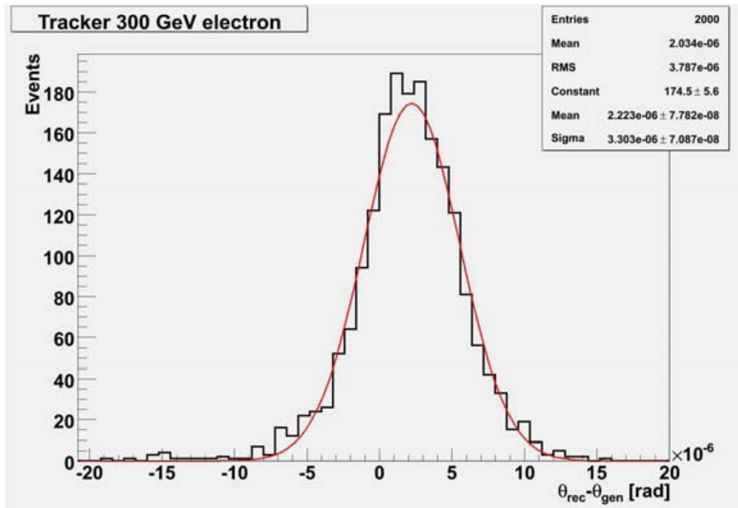
- $\Delta(\theta)$ remains constant ~ 2.5×10^{-6} rad

Silicon tracker efficiency

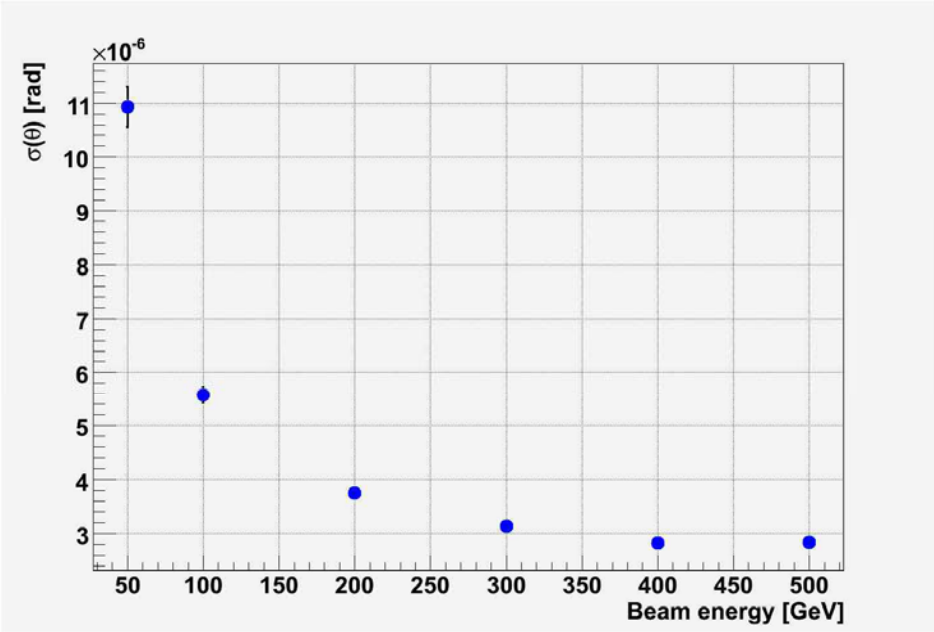
Percentage of events reconstructed in tracker:

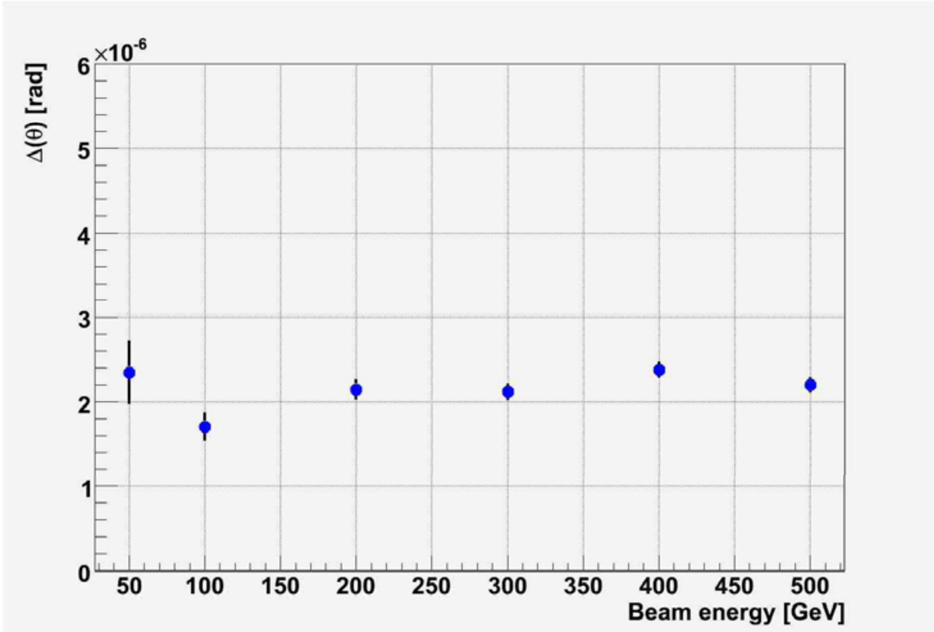






New LumiCal polar reconstruction





Luminosity measurement

Beam energy [GeV]	ΔL/L
50	1.01×10^{-4}
400	9.62×10^{-5}
500	9.94×10^{-5}

High statistics studies of luminosity error

- The angle θ_{gen} was generated using BHWide
- Fast detector simulation was done using the results presented in previous page.
- Then the luminosity error was then computed as

$$\frac{\Delta L}{L} = \left| \frac{N_{rec} - N_{gen}}{N_{gen}} \right|_{\min}^{\max}$$

where,

N_{gen}..............number of particle generated in acceptance region

N_{rec}.............. number of particle reconstructed in acceptance region

Summary

- A new concept of LumiCal was studied. First results were obtained. It was done in stand alone G4.

- Similar energy resolution (slightly better) was obtained using the varying tungsten structure - further design optimization is needed

- Significant improvement in polar resolution about factor of 5-10, was obtained using the tracker information

- Improvement in the theta bias of about a factor of 1.2 - 3, without energy dependent was obtained using the tracker information.

- The new design leads to better performance. The estimated error in luminosity is about 10^{-4} and even better for the higher energies.

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Summary - outlook

- Furthered optimization of the new design is required (thickness of the silicon, gap between the layers, size of the tungsten, size of the pads,…). After optimization we expect even better performance.

- Further optimization of the parameters in the algorithm (different weight, better matching algorithm,…).

- Study the new design in more real environment including background and electronic simulation.

Thank you for your attention