Luminosity measurement

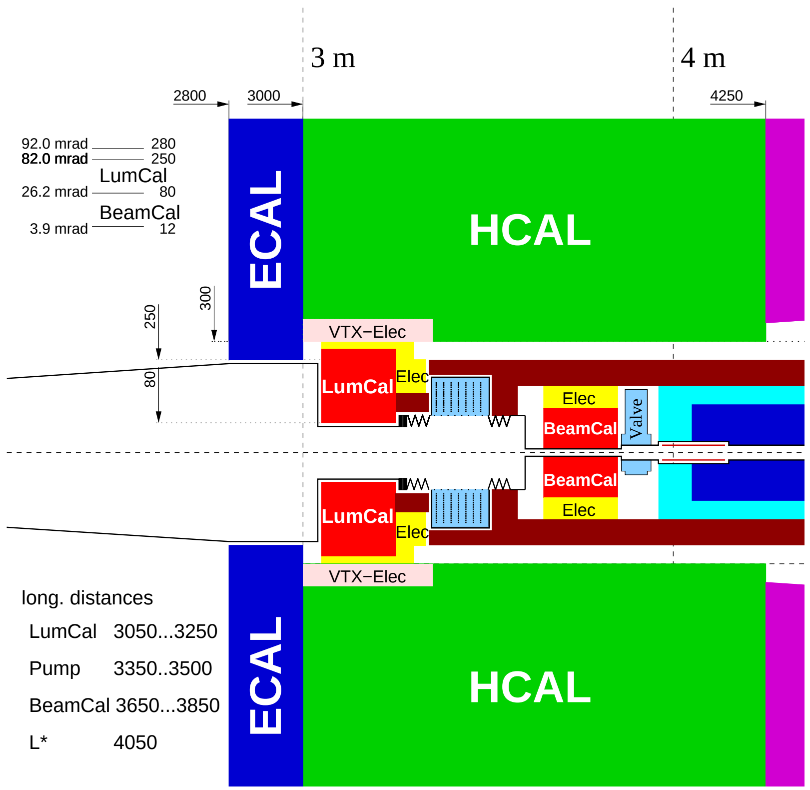
Halina Abramowicz
Tel Aviv University
for the FCAL Collaboration

- Bhabha scattering and LumCal
- Requirements on LumCal
- Laser control test

Bhabha Scattering

$$e^+e^- \rightarrow e^+e^-$$

$$L = \frac{N_{LumCal} - N_{bgr}}{\varepsilon \ \sigma_{Bhabha}}$$



Goal of FCAL Collaboration – measure L at ILC with accuracy

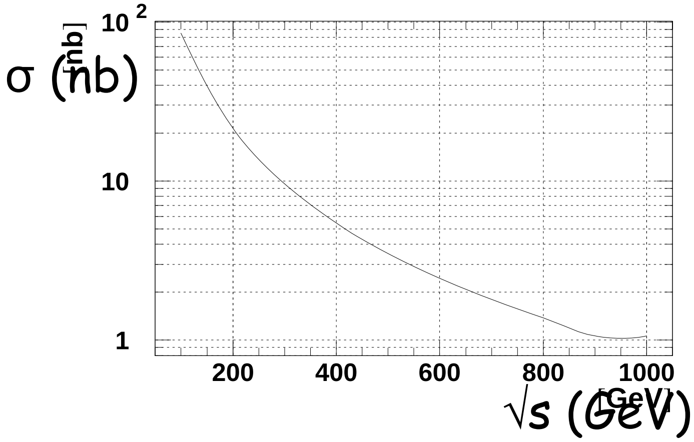
$$\frac{\Delta L}{L} \leq 10^{-4}$$

$$(OPAL: \quad \Delta L / L = 3 \times 10^{-4} (stat) \oplus 5.4 \times 10^{-4} (theo))$$

$$(ALEPH: \ \Delta L / L = 6 \times 10^{-4} (stat) \oplus 6.1 \times 10^{-4} (theo))$$

Luminosity Measurement

26.2 < LumCal < 80 mrad; 30 < Fiducial Volume < 75 mrad



At √s = 500 GeV σ (30 < θ < 75 mrad) ≈ 3 nb

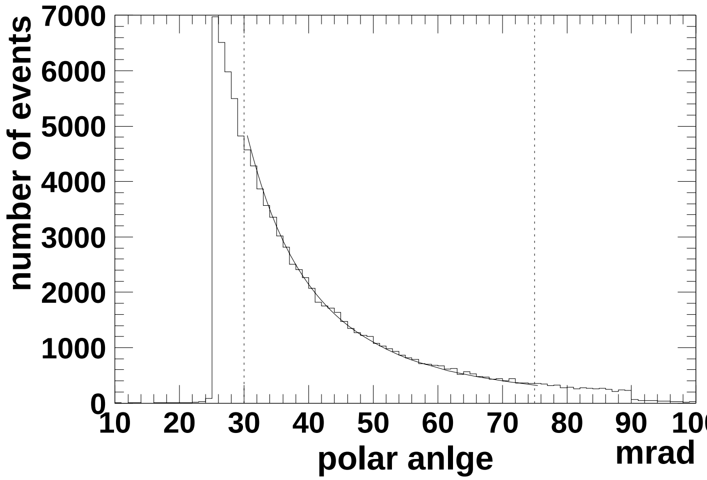
for nominal luminosity $L_N = 3\times10^{34}\, cm^{-2}s^{-1}$

$$\Rightarrow N_B = 9\times10^8\ /\ year$$

$$\frac{d\sigma_B}{d\theta} \approx \frac{32\pi\alpha^2}{s}\frac{1}{\theta^3}$$

$$\sigma_B \propto \frac{1}{\theta_{\min}^2}$$

$$\theta_{\min} = \frac{r_{\min}}{d_{IP}}$$



with BHLUMI (Jadach &Waş)

Fast Simulations

Systematic effects due to Geometry

Selection: $E(e^+)$, $E(e^-)$, $\theta(e^+)$, $\theta(e^-)$ as generated

$E(e^+) > 0.8\ E_{beam}$, $E(e^-) > 0.8\ E_{beam}$

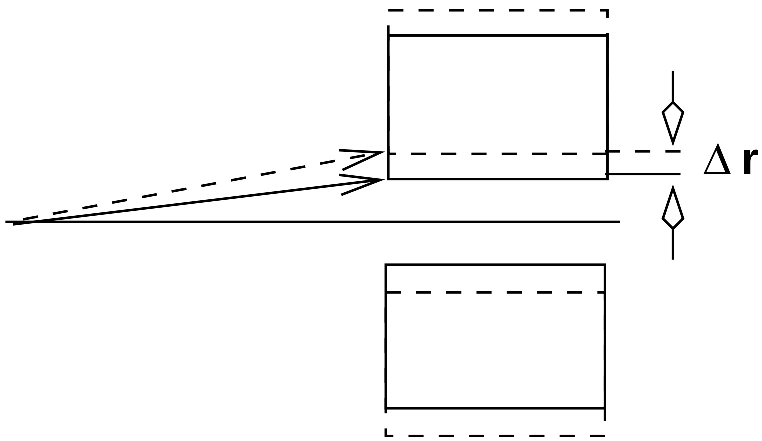
$30 < \theta(e^+)$ or $\theta(e^-) < 75$ mrad (never both, alternate e^+, e^-)

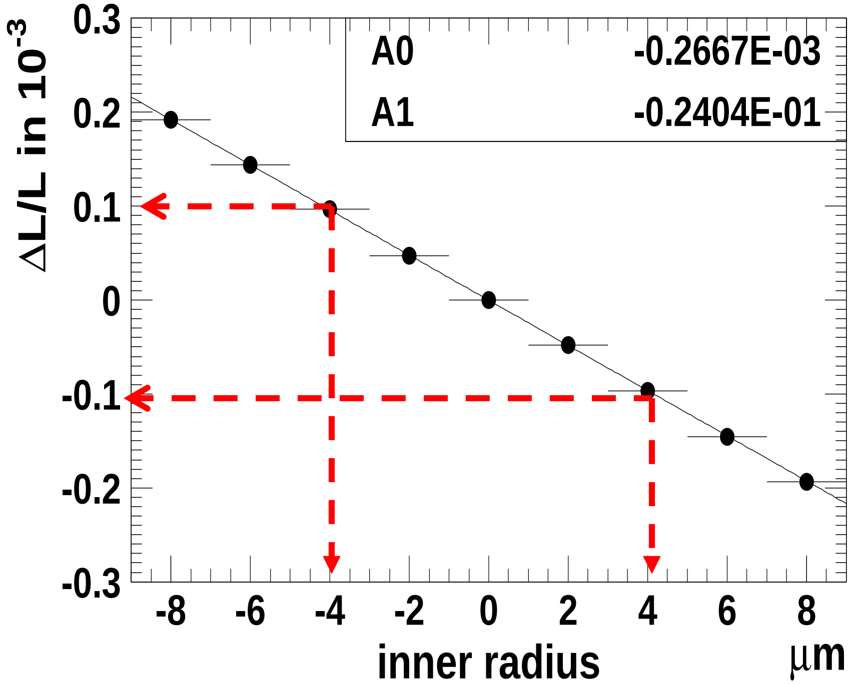
$\Rightarrow$ reduces sensitivity to the IP position

Methodology: misreconstruction of θ, Energy applied and cuts reapplied.

Systematic error $\leftrightarrow$ change in the number of events

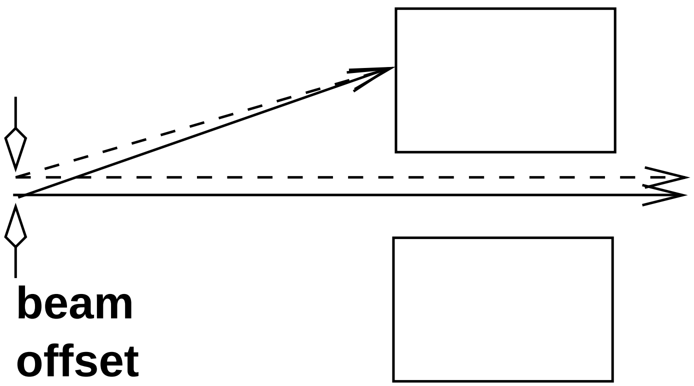
Inner diameter of LumCal

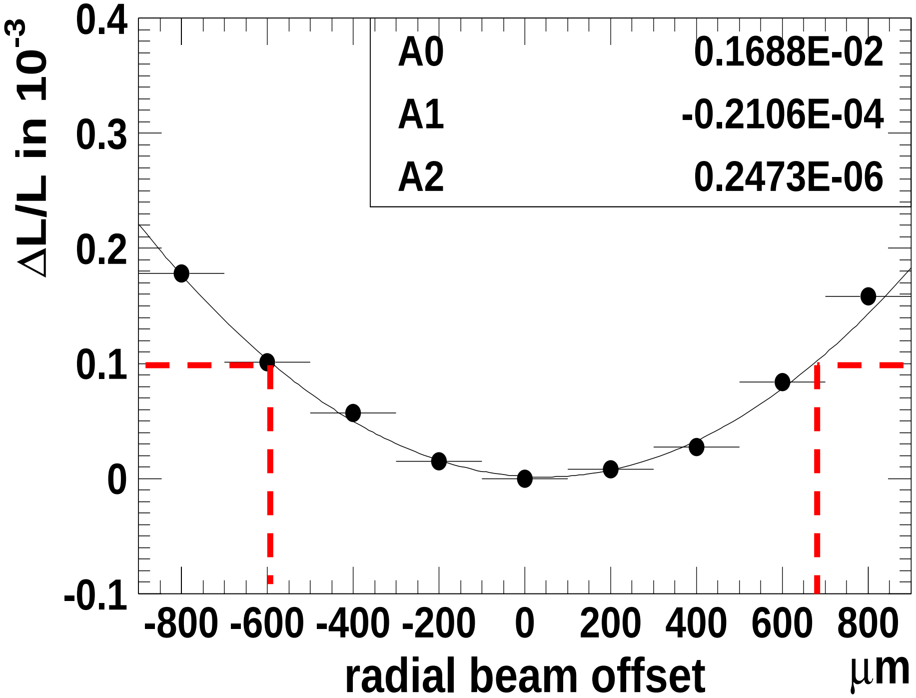




$$\frac{\Delta L}{L} \leq 10^{-4} \quad \Rightarrow \Delta r \leq 4\,\mu m$$

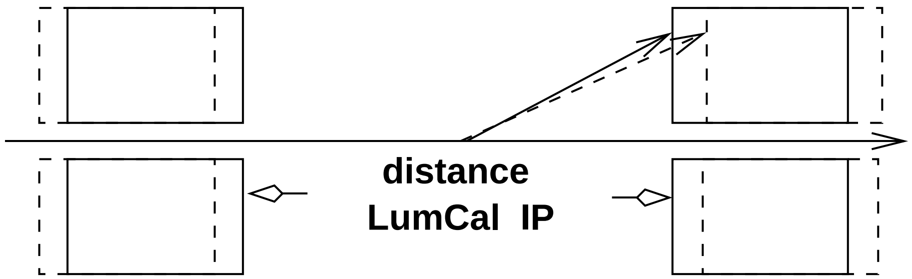
Radial beam position

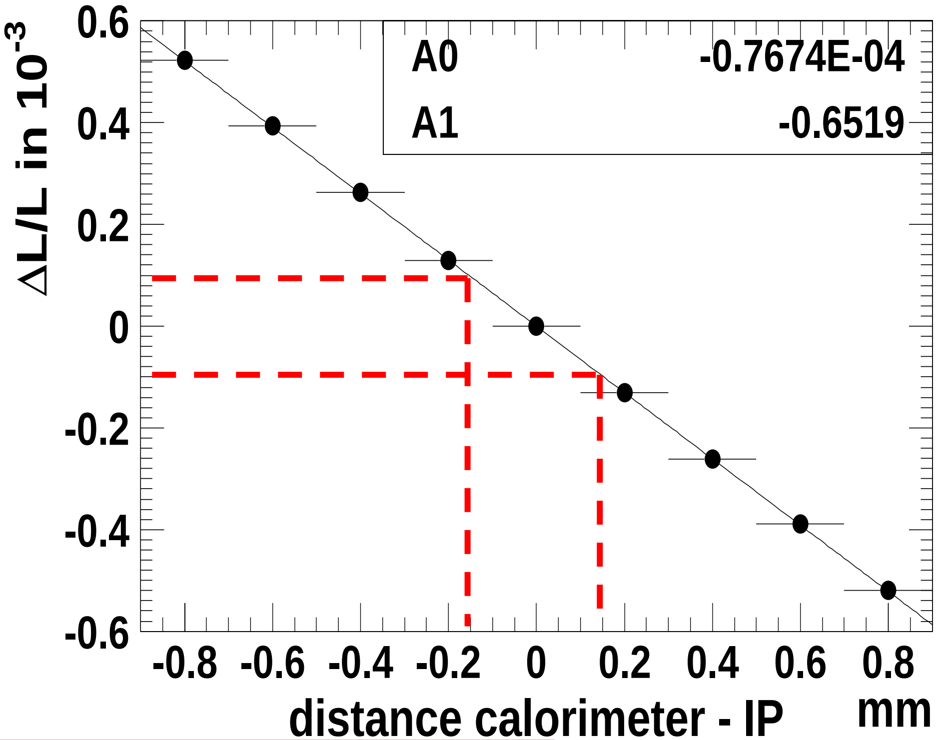




$$\frac{\Delta L}{L} \le 10^{-4} \quad \Rightarrow rad.offset \le 600\,\mu m$$

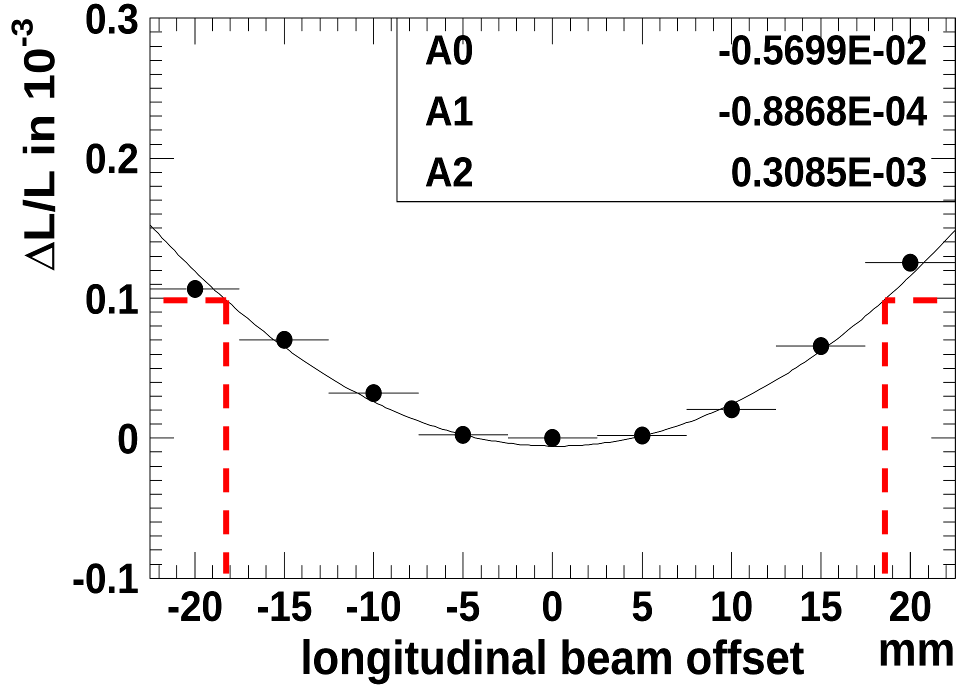
Longitudinal distance of forward and backward calorimeters





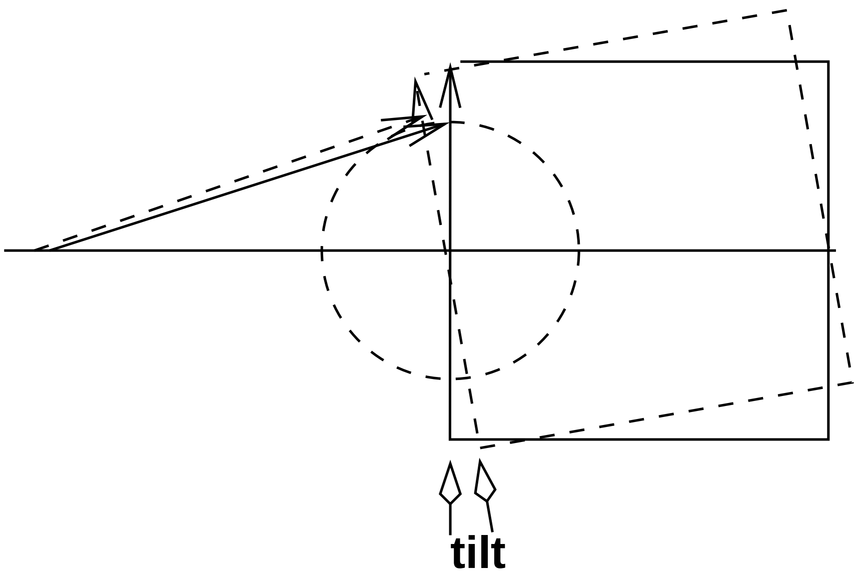
$$\frac{\Delta L}{L} \leq 10^{-4} \quad \Rightarrow dis.cal.IP \leq 100\,\mu m$$

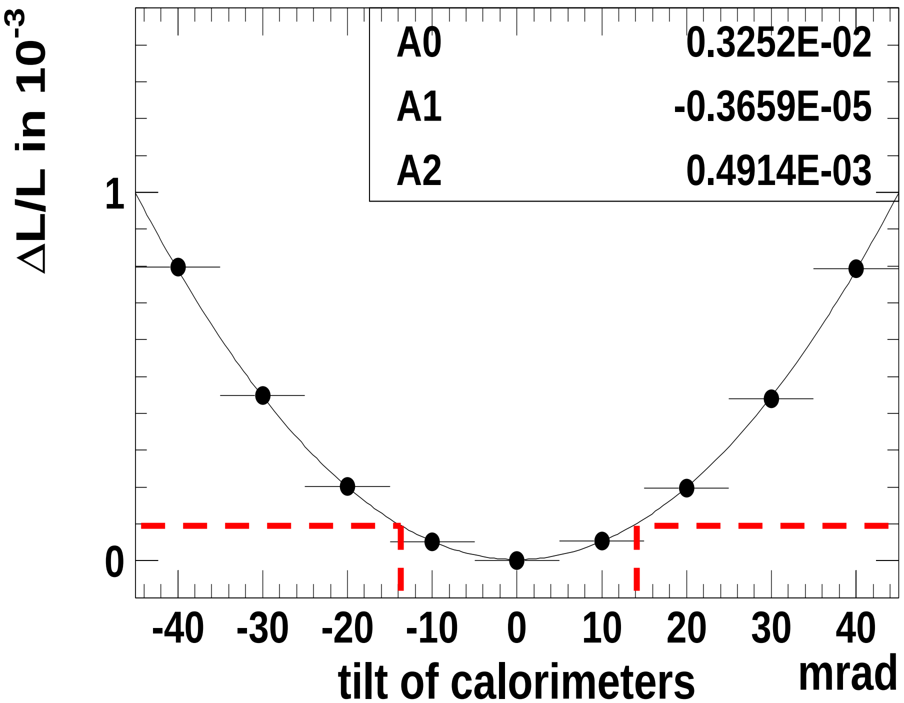
Longitudinal offset of the IP



$$\frac{\Delta L}{L} \leq 10^{-4} \quad \Rightarrow long.IPoffset \leq 2cm$$

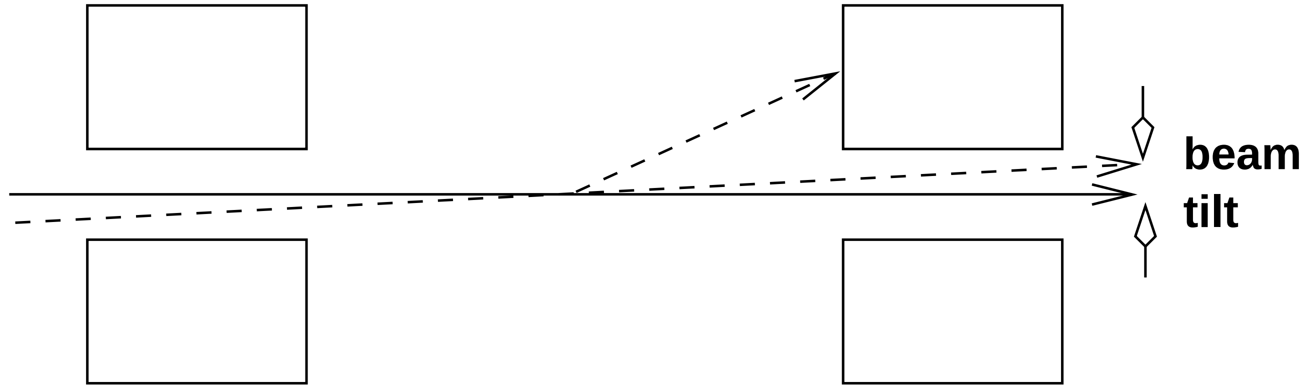
Tilt of the calorimeter

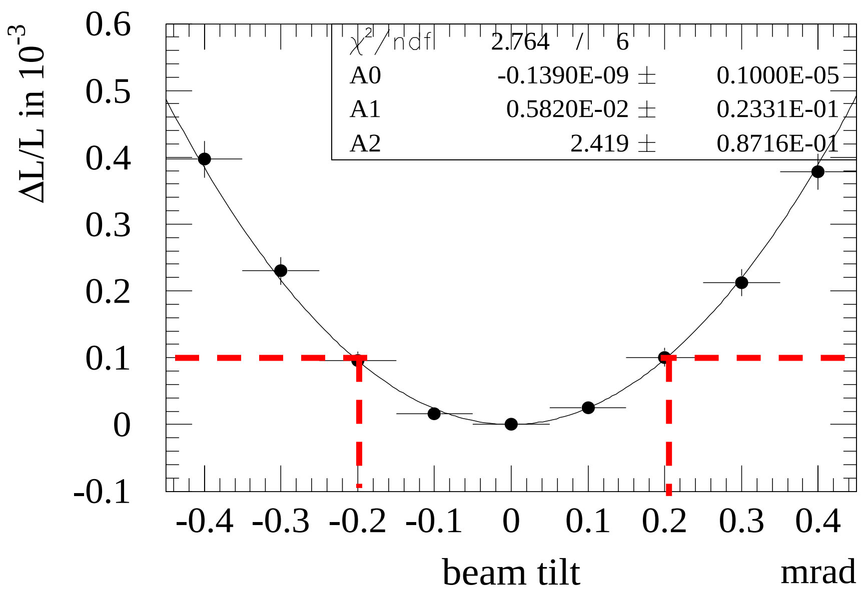




$$\frac{\Delta L}{L} \leq 10^{-4} \quad \Rightarrow tilt \leq 10mrad$$

Beam tilt

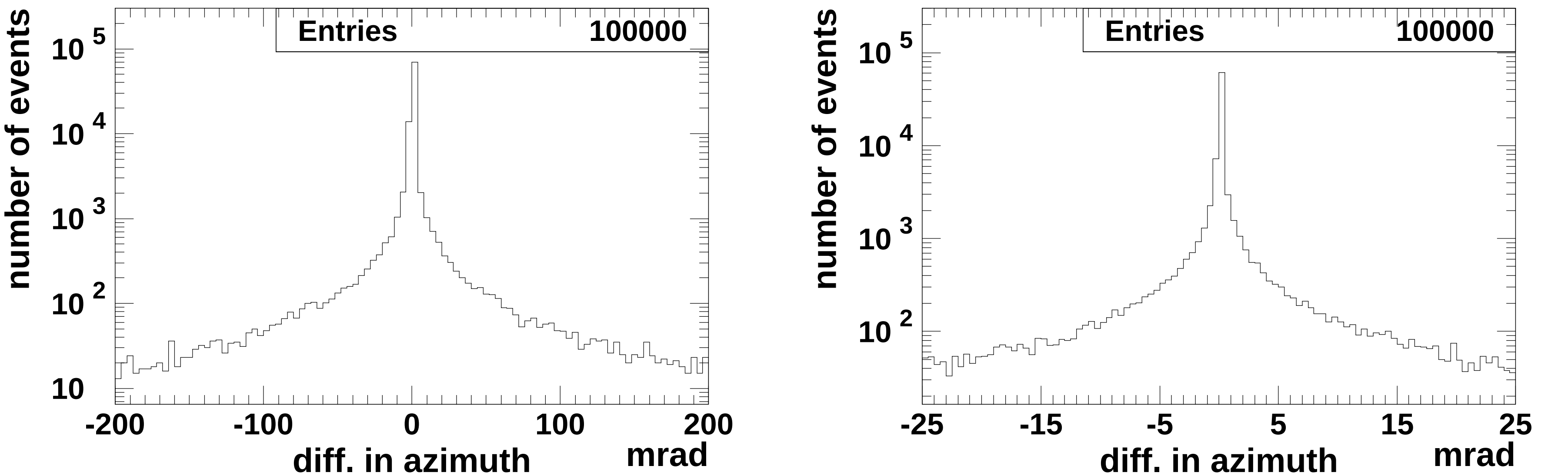




$$\frac{\Delta L}{L} \leq 10^{-4} \Rightarrow bm\,tilt \leq 0.2\,mrad$$

Twist between the F/B calorimeter

$\Delta\varphi$ cut $\Rightarrow$ reduces radiative tail

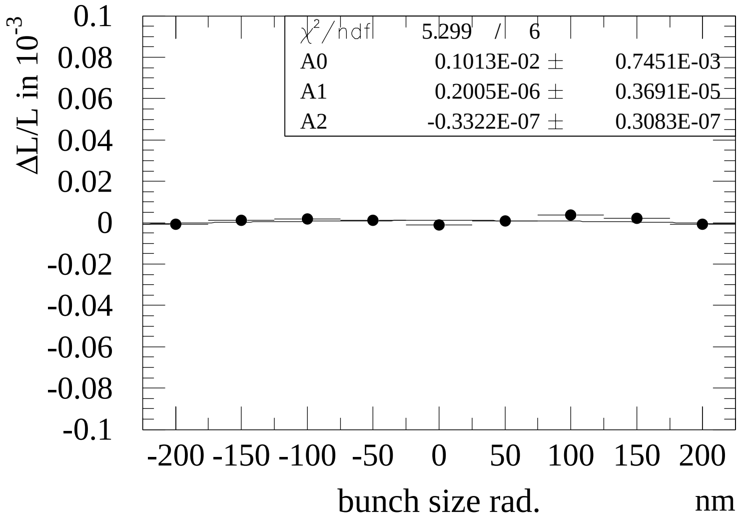


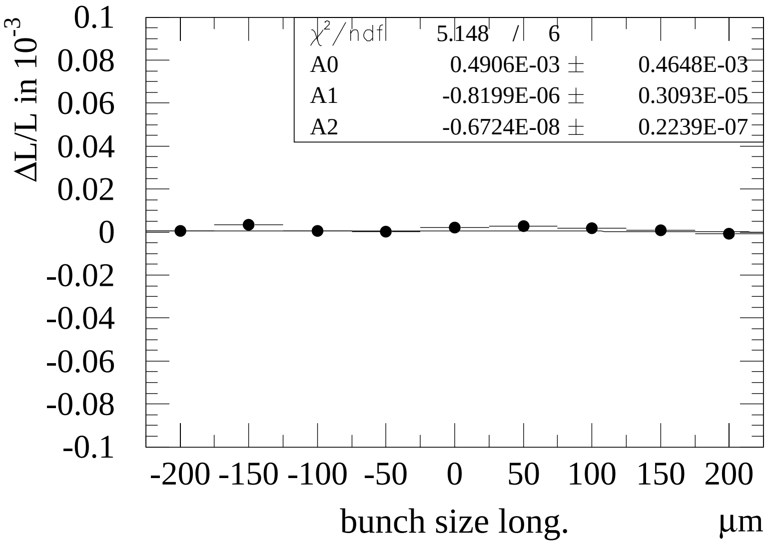
$\Delta\varphi$ < 20 mrad $\Rightarrow$ reject 10% of the events

$$\frac{\Delta L}{L} \leq 10^{-4} \Rightarrow \sigma_{\Delta\varphi} \leq 0.1\, mrad$$

Beam size at IP

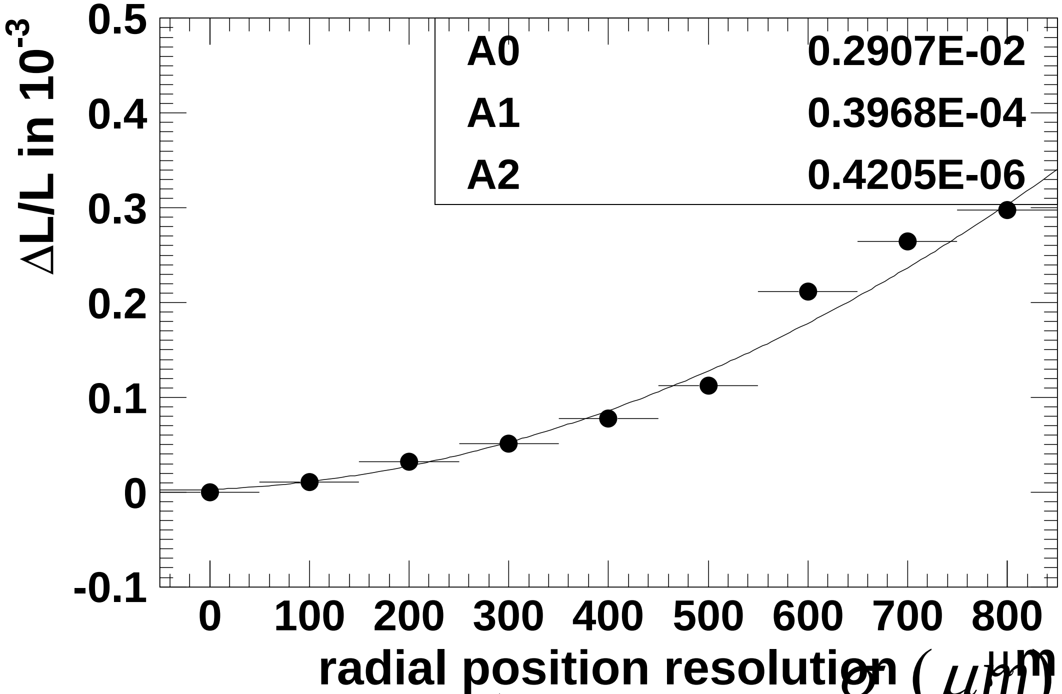
Beams at TESLA





No relevant variation

Position resolution

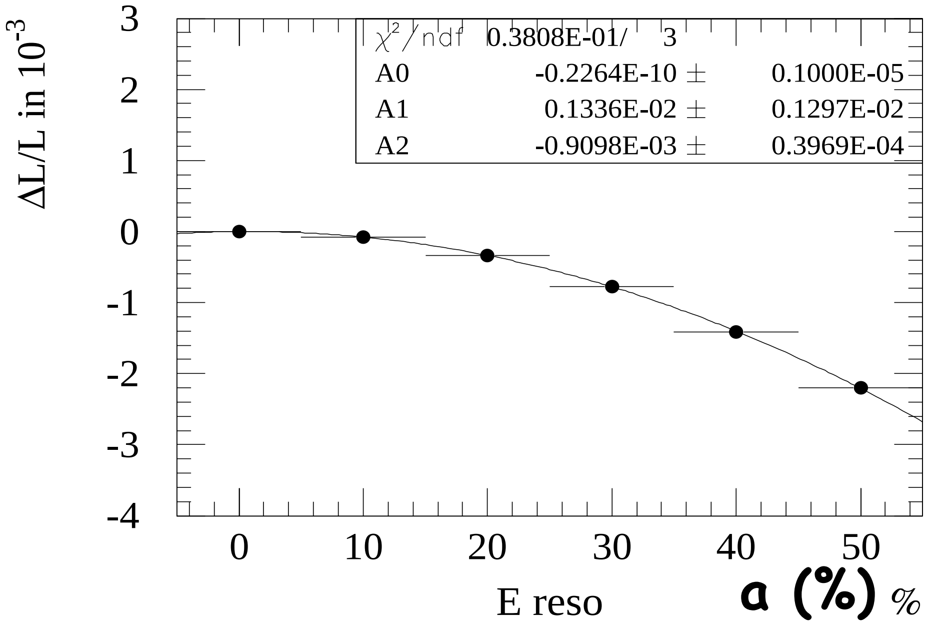


$$\sigma_r\ (\mu m)$$

$$\frac{\Delta L}{L} = 8\times 10^{-6}\,\frac{\sigma_r}{100\,\mu m}\,\frac{\Delta\sigma_r}{100\,\mu m}$$

$$\sigma_r = 500\,\mu m \qquad \Delta\sigma_r = \pm 20\% \;\Rightarrow\; \frac{\Delta L}{L} = 0.4\times 10^{-4}$$

Energy resolution

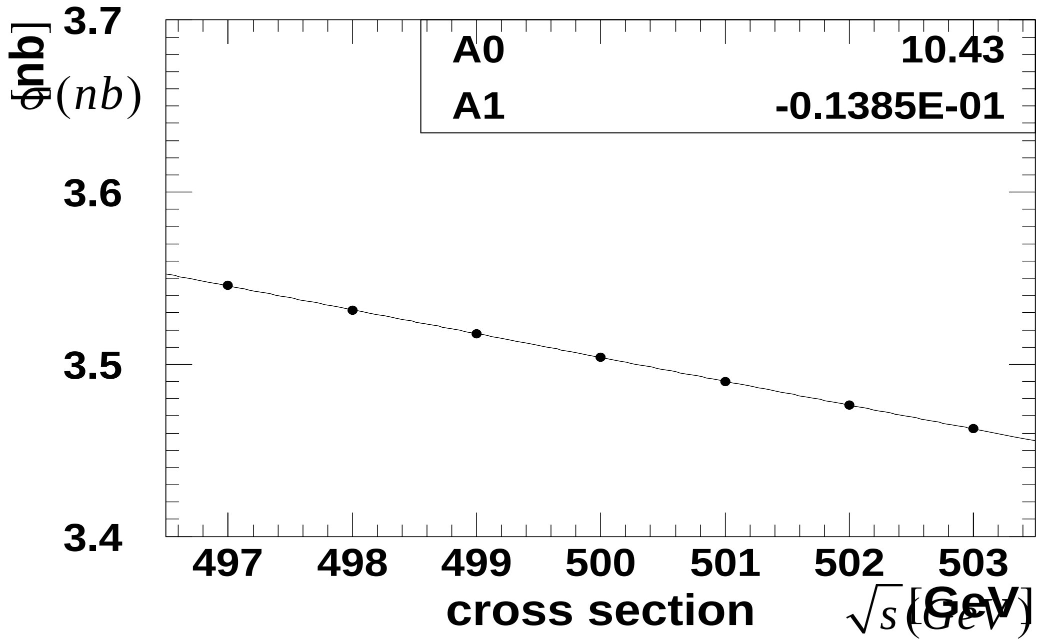


$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}}$$

$$\frac{\Delta L}{L} \approx -2\times 10^{-6} \bullet a \bullet \Delta a$$

$$For\ \frac{\sigma_E}{E} = \frac{20\%}{\sqrt{E}} \quad \Rightarrow \ \Delta a = 2\%$$

Center of Mass Energy



$$\sigma(500) = 10.43 - 0.014\sqrt{s}$$

$$\frac{\Delta\sigma}{\sigma} = \frac{0.014\Delta\sqrt{s}}{\sigma} \leq 10^{-4} \quad \Rightarrow \Delta\sqrt{s} \leq 25\, MeV \;!!!$$

Requirement analysis dependent

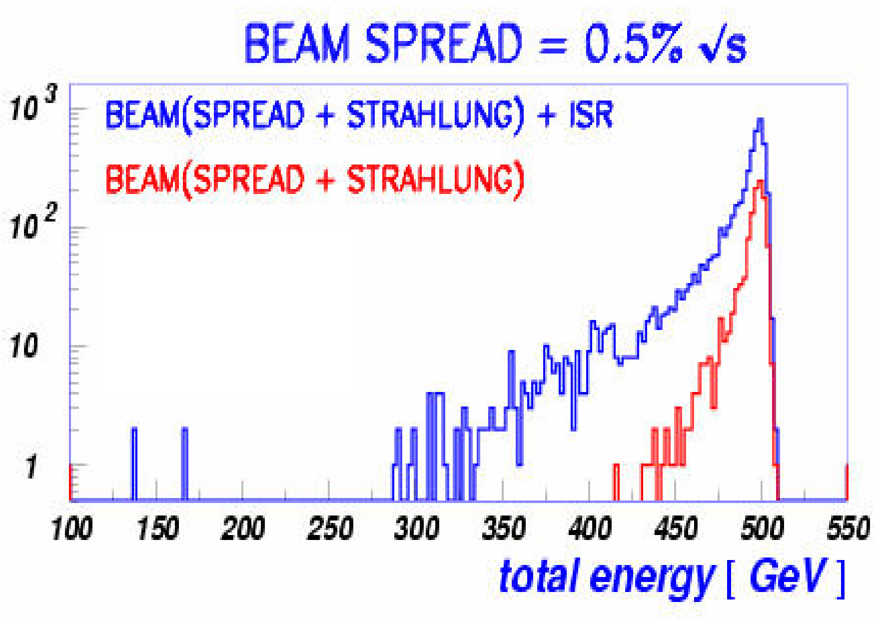
Full Simulations (BRAHMS)

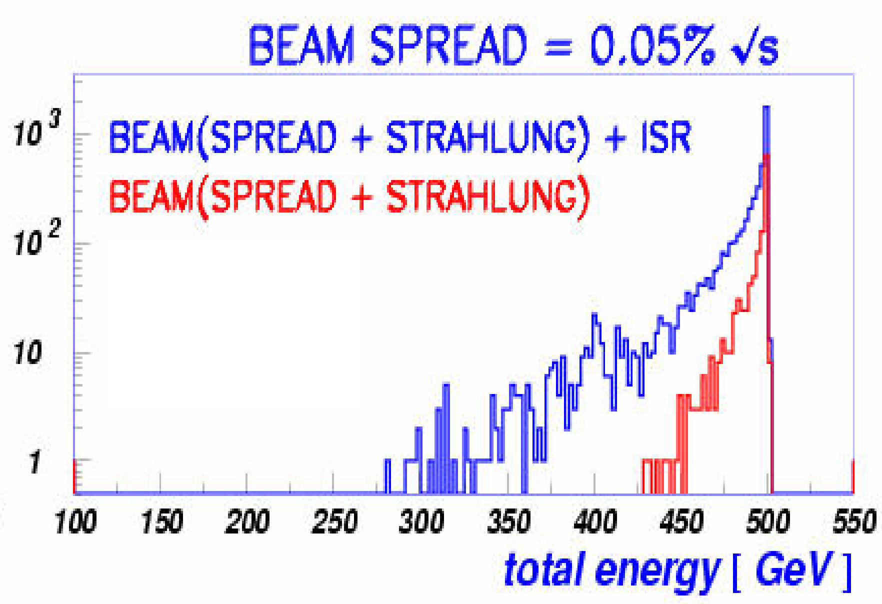
Beamstrahlung and Beam Spread

Bhabha scattering - BHWIDE generator.

Beamstrahlung - Circe generator.

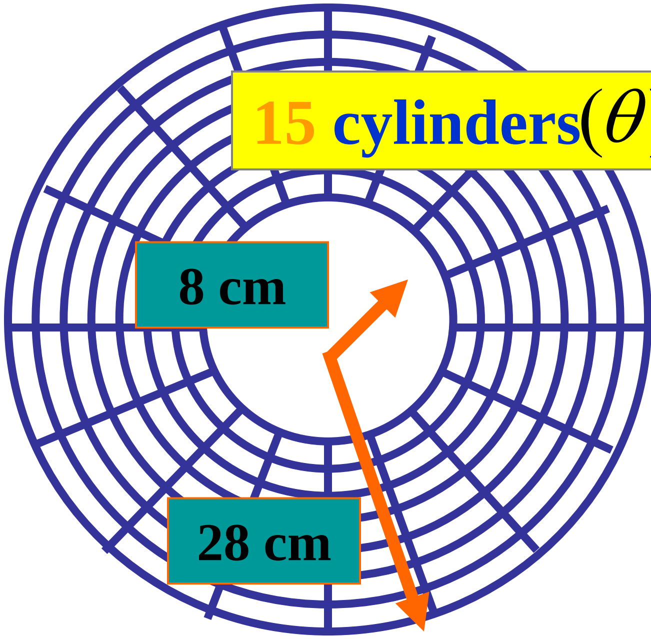
Beam spread - included separately.





Pad Design

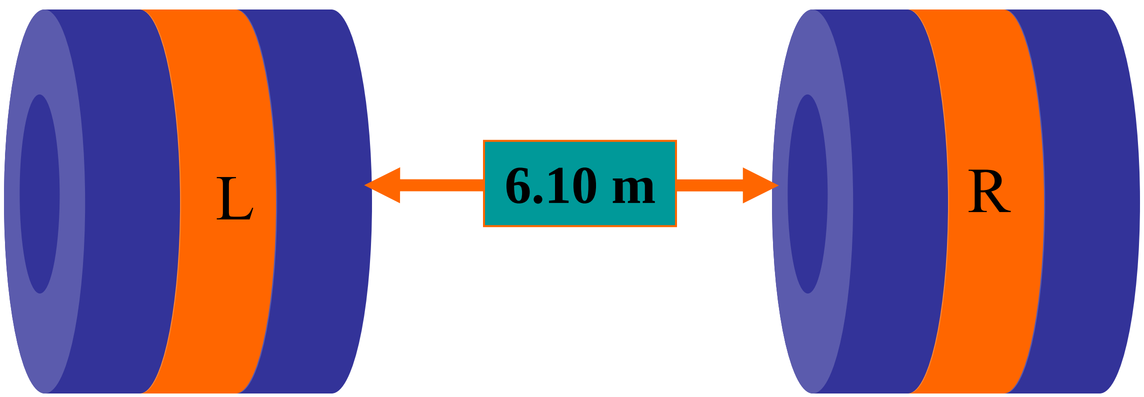
15 cylinders(θ)* 24 sectors(ϕ)* 30 rings(z)= 10800 cells



0.34 cm	0.31 cm
Tungsten	Silicon

X_0=0.65 cm

R_M =1.1 cm

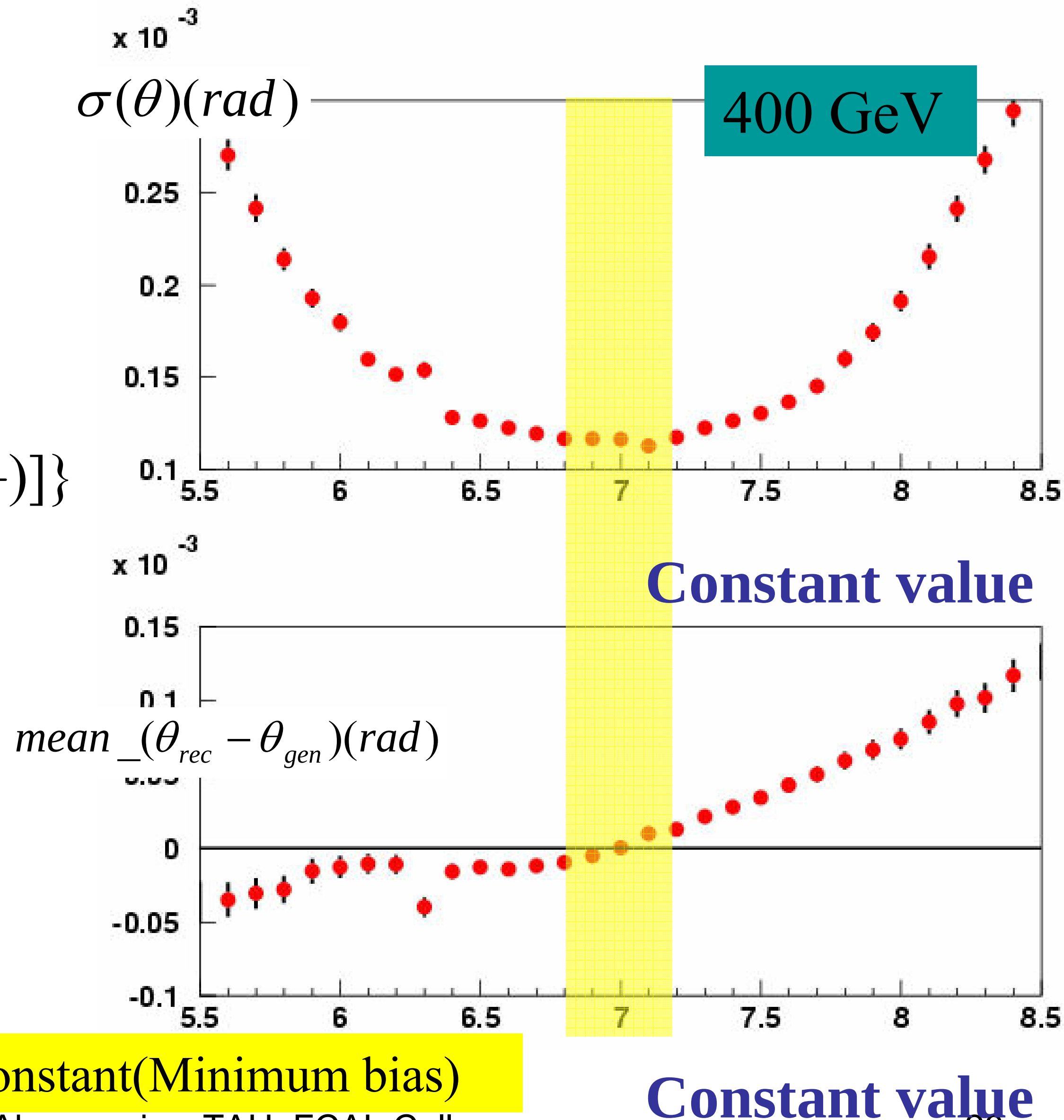


Cell Size

1.3 cm * 2 cm >
1.3 cm * 6 cm <
~1 Radiation Length
~1 Moliere Radius

Optimized Shower Position Reconstruction

$$W_i = \max\{0, [\,\textbf{Const} + \ln(\frac{E_i}{E_T})]\}$$



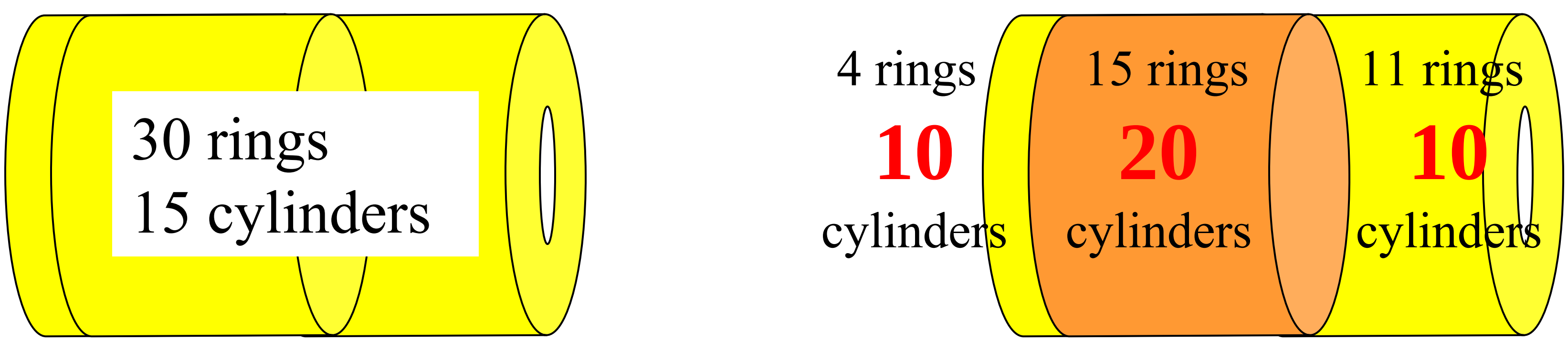
Constant (Best resolution) = Constant(Minimum bias)

Maximum Peak Shower Design

Our basic detector is designed with

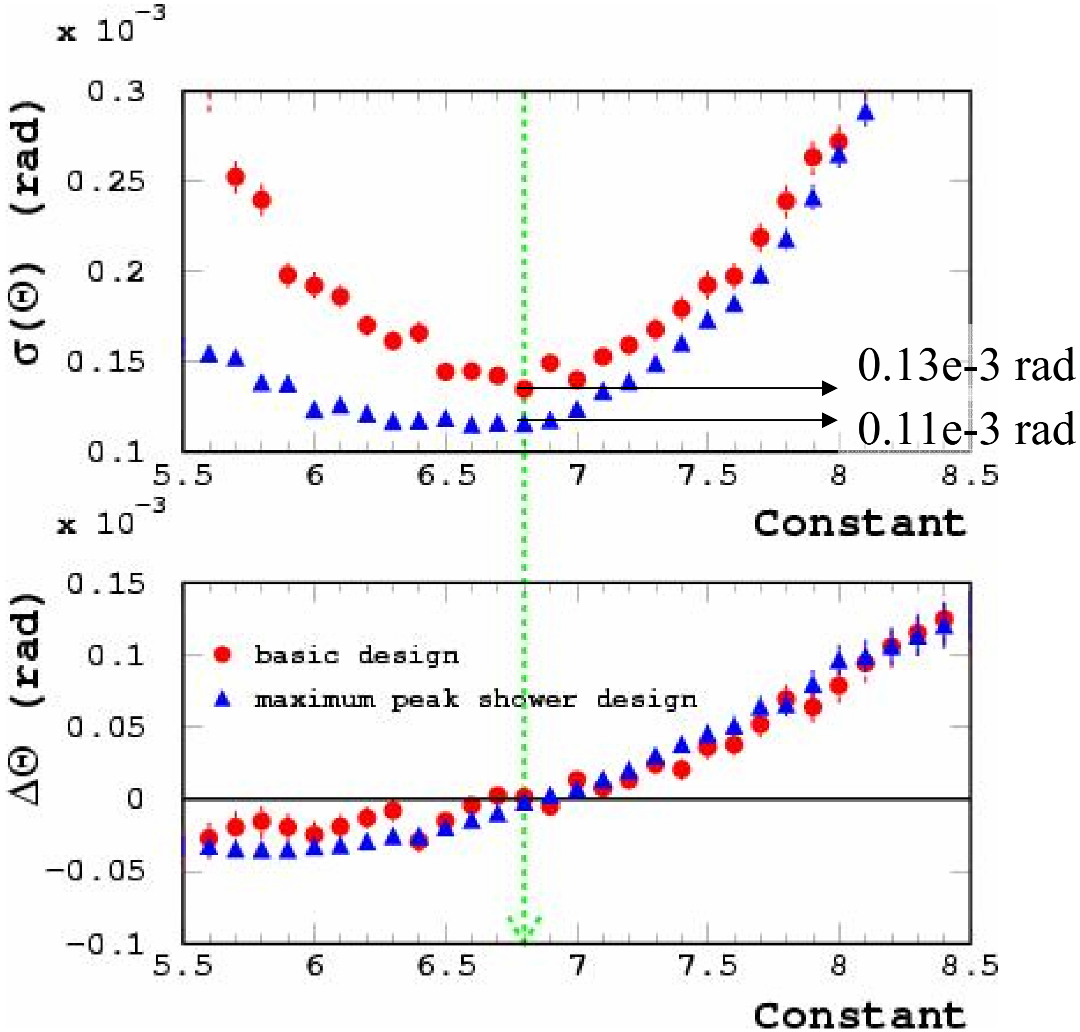
30 rings * **24** sectors * **15** cylinders = **10,800** channels

Do we use these channels in the most effective way ?



24 sectors * **15** rings * (10 cylinders + 20 cylinders) = **10,800** channels

Polar Reconstruction



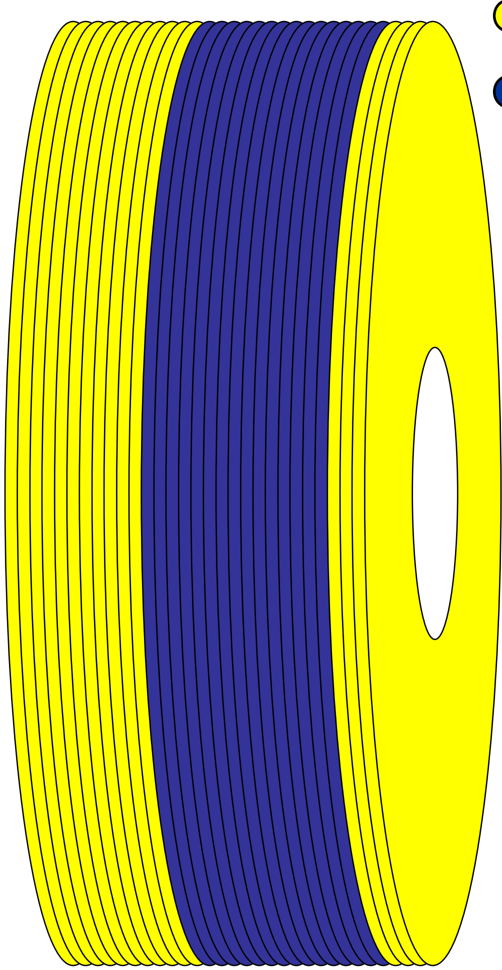
Maximum peak shower design

Basic Design

Angular resolution improvement without changing the number of channels

Other properties remain the same

Present Understanding (pad option)



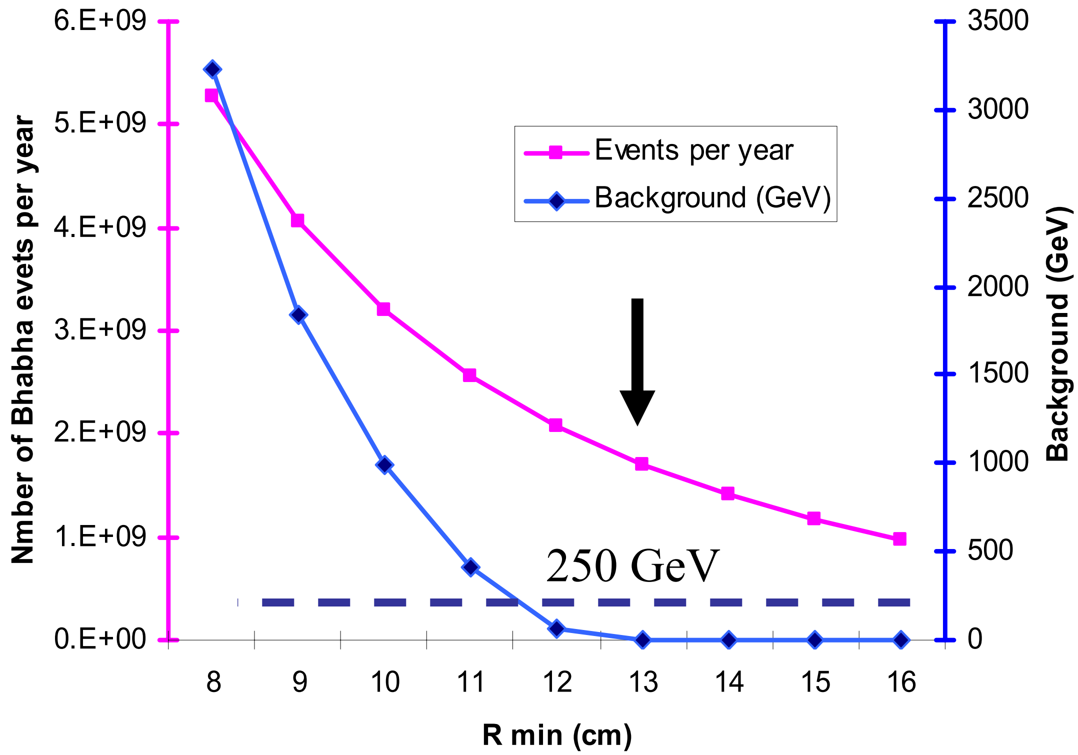
- 10 cylinders (θ)
- 60 cylinders (θ)

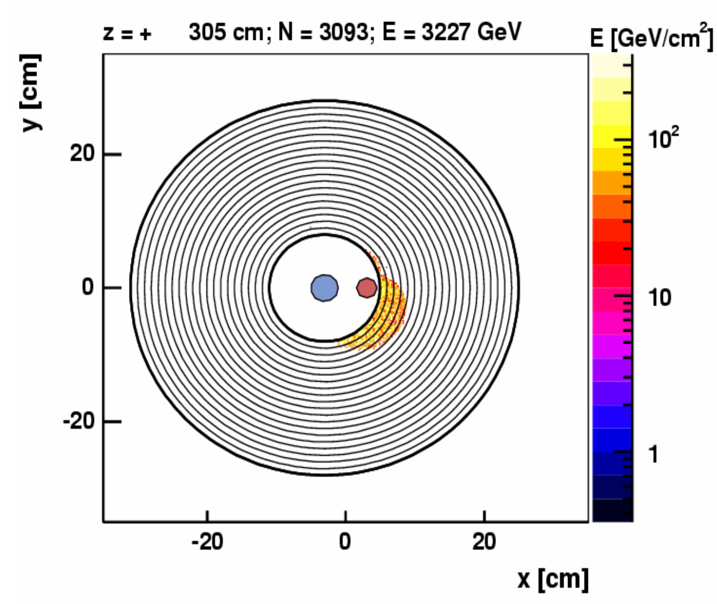
Based on optimizing theta measurement

Parameter	Opal	LumiCal
Distance from the IP	±2.5 m	±3.05 m
Sampling layers	19	30
Cylinders	32	60 (middle layers), 10 (first and last layers)
Sectors	32	24
Pitch in r (mm)	2.5	3.3 (middle layers), 20 (first and last layers)
Pitch in θ (rad)	0.001	0.001 (middle layers), 0.006 (first and last layers)
Pitch in ϕ (deg)	11.25	15
Pitch in z	1 X_0 2 X_0 (last 4 layers)	1 X_0
r_{min} (mm)	62	80
r_{max} (mm)	142	280
θ_{min} (mrad)	25	26
θ_{max} (mrad)	57	91
$Z_{max} - Z_{min}$ (cm)	14	20
Electronics channels in one detector arm	19,456	25,200

X- angle background

Beamstrahlung pair background





Christian Grah,
DESY-Zuethen

Future R&D plans

Additional hardware design constrains and electronics simulation (digitisation, reality noise parameters, silicon production constrains)

Additional background studies (two photon events, beamstrahlung hitting the detector)

Luminosity with polarised beams

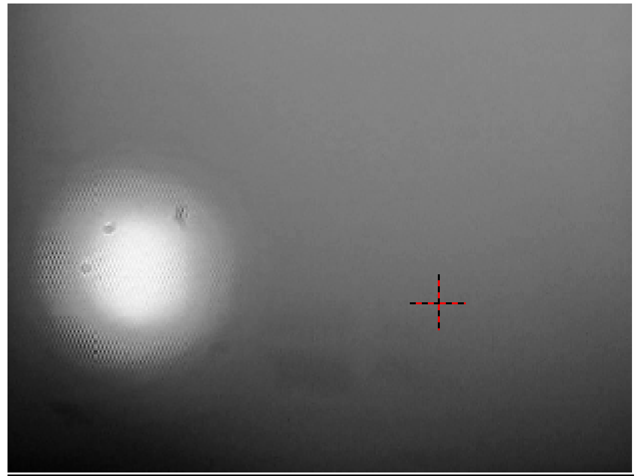
Luminosity with a crossing angle

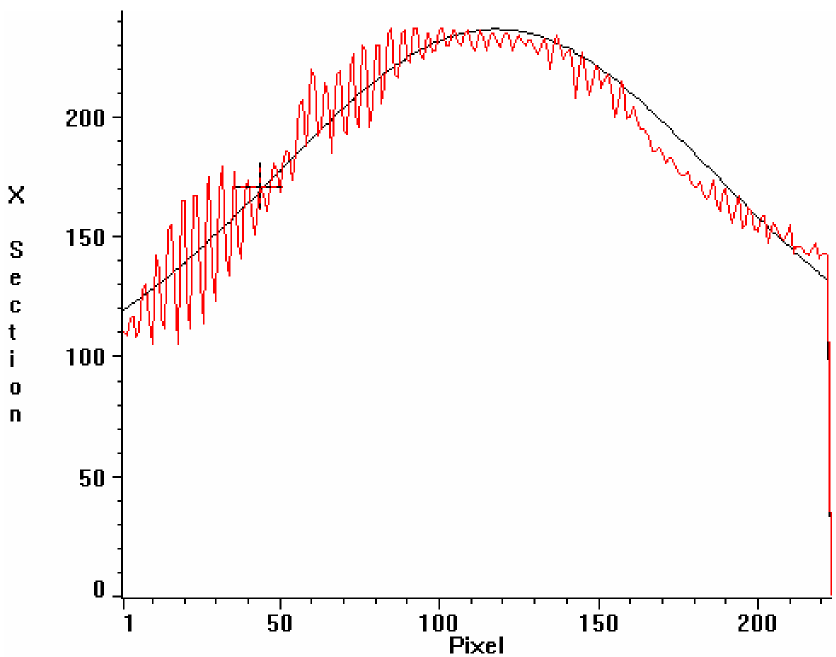
Sensors design & tests

Electronics design

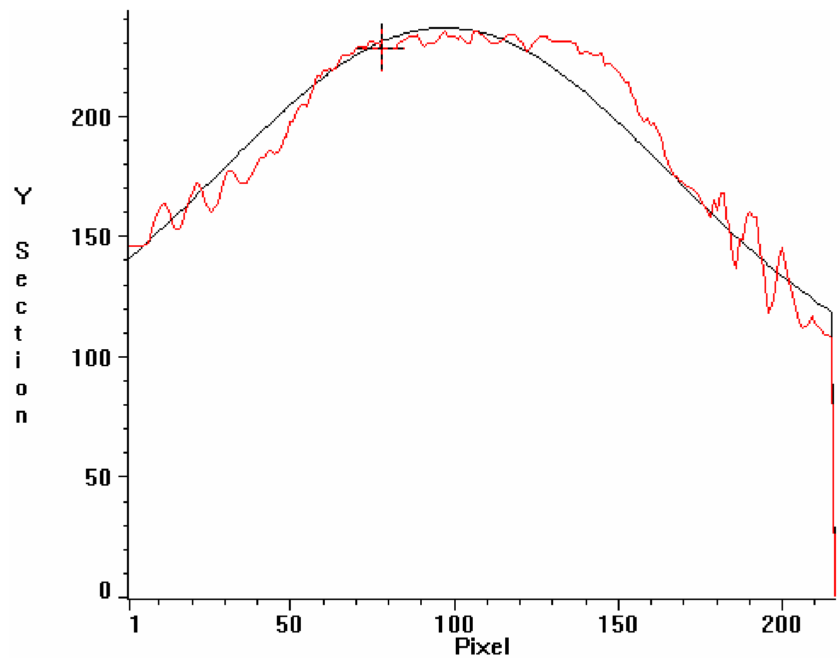
Prototype

→ **Final Design**





X Section
0
50
100
150
200
1
50
100
150
200
Pixel



Y Section
0
50
100
150
200
1
50
100
150
200
Pixel

Position measurement