Luminosity measurement

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for the FCAL Collaboration

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

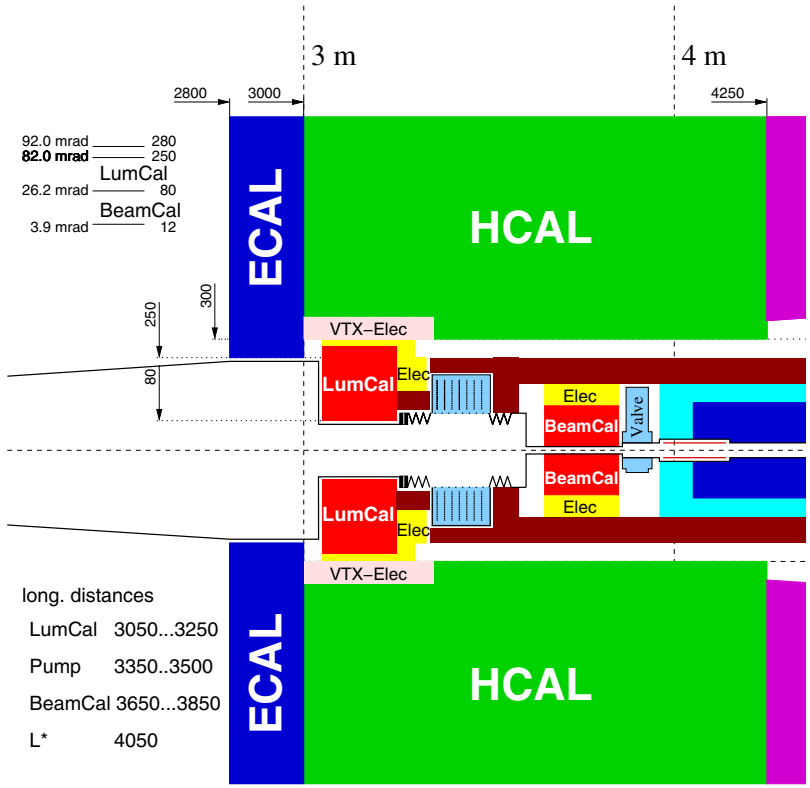
Bhabha Scattering

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

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

Goal of FCAL Collaboration – measure L at ILC with accuracy

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

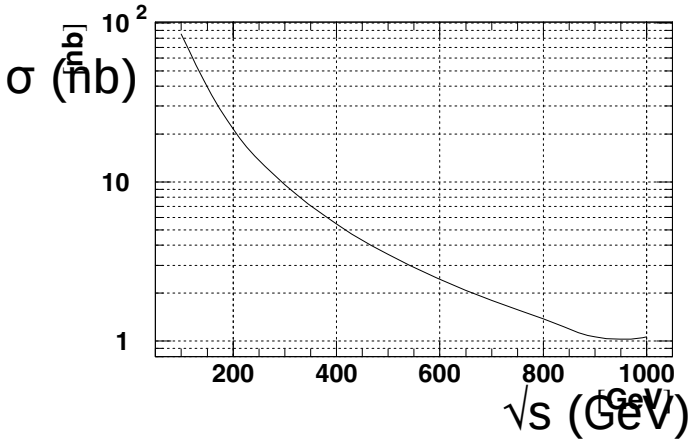


$$(OPAL: \quad \Delta L/L = 3\times10^{-4}(stat) \oplus 5.4\times10^{-4}(theo))$$

$$(ALEPH: \ \Delta L/L = 6\times10^{-4}(stat) \oplus 6.1\times10^{-4}(theo))$$

Luminosity Measurement (for A. Stahl – LC-DET-2005-004)

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



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

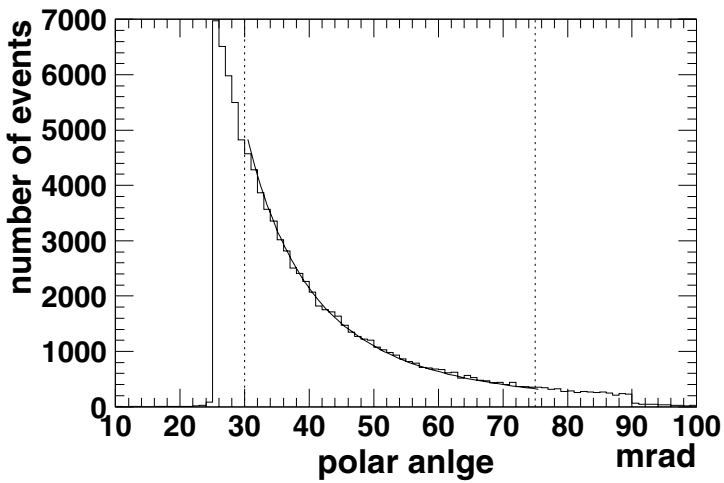
for nominal luminosity $L_N = 3\times10^{34} cm^{-2} s^{-1}$

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

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

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

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



with BHLUMI (Jadach &Waş)

Systematic effects due to Geometry

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

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

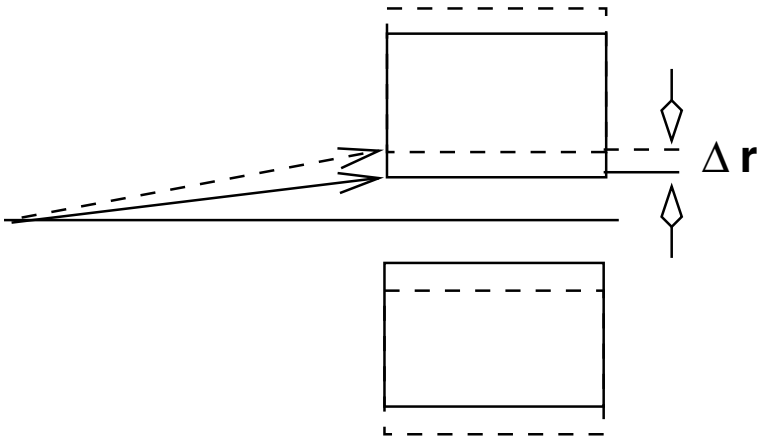
$30 < \theta(e^+)$ or $\theta(e^-) < 75$ mrad (never both, alternate e^+, e^-)

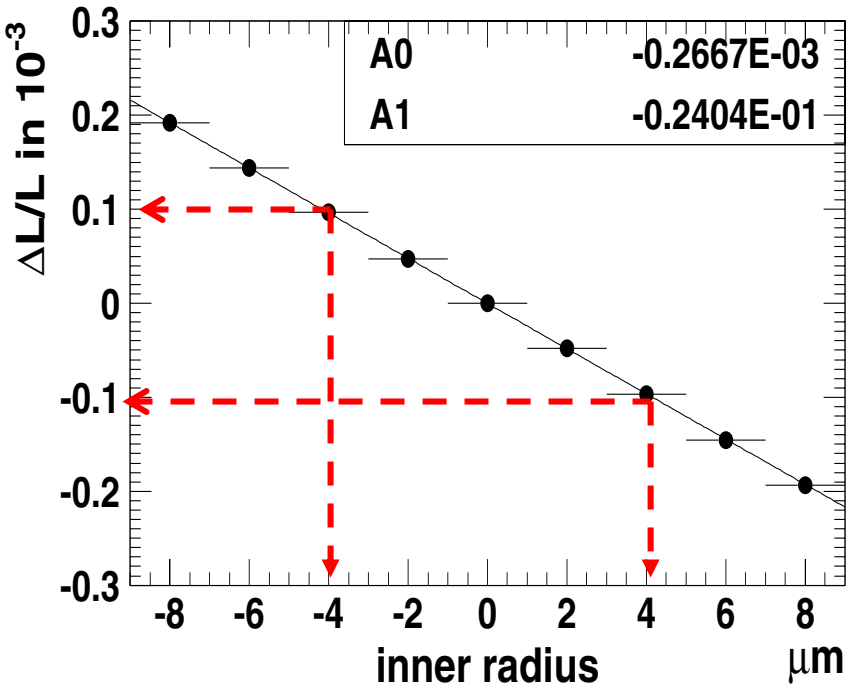
$\Rightarrow$ reduces sensitivity to the IP position

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

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

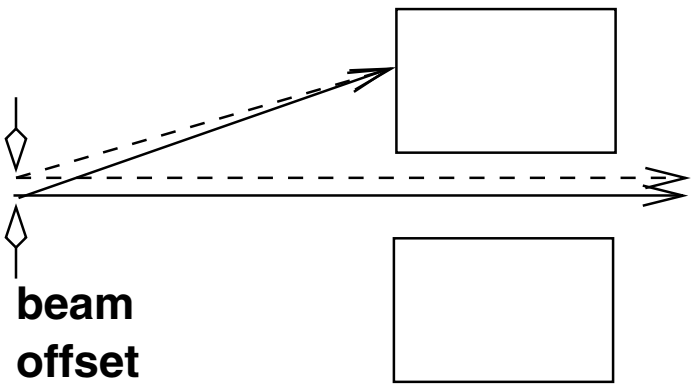
Inner diameter of LumCal

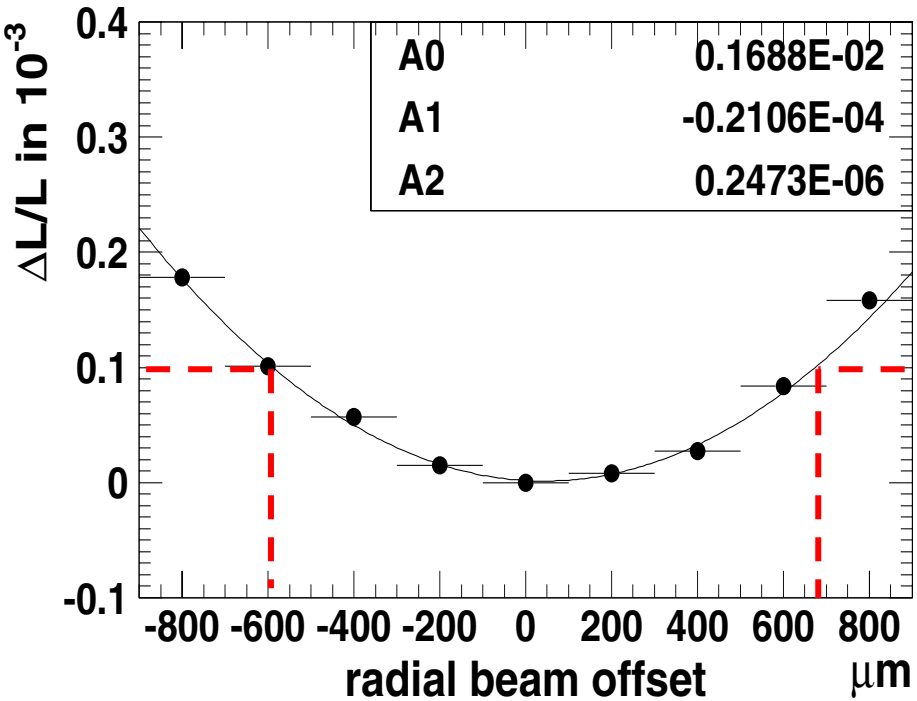




$$\frac{\Delta L}{L} \leq 10^{-4} \qquad \Rightarrow \Delta r \leq 4\mu m$$

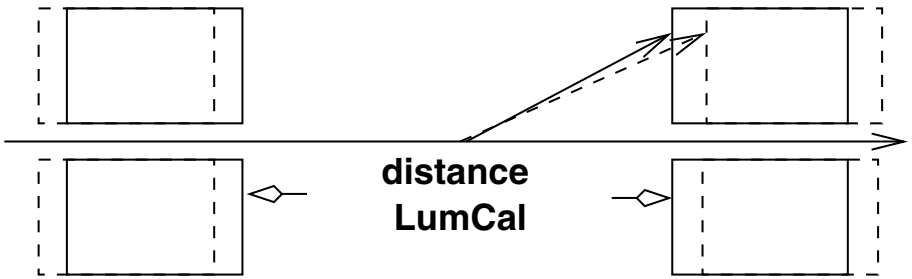
Radial beam position

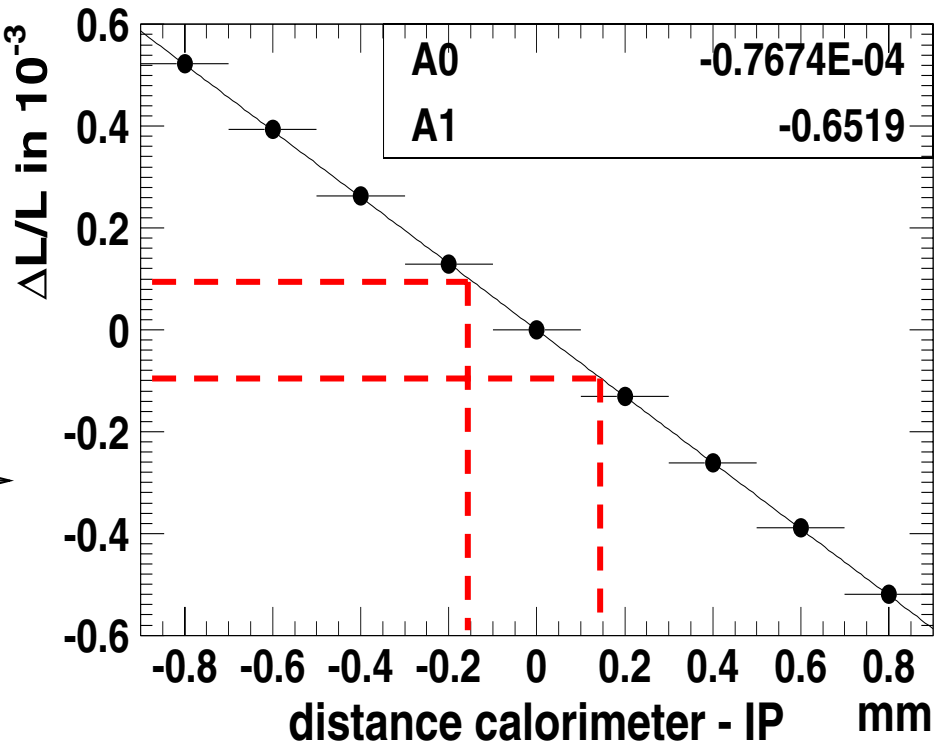




$$\frac{\Delta L}{L} \leq 10^{-4} \qquad \Rightarrow rad.offset \leq 600\mu m$$

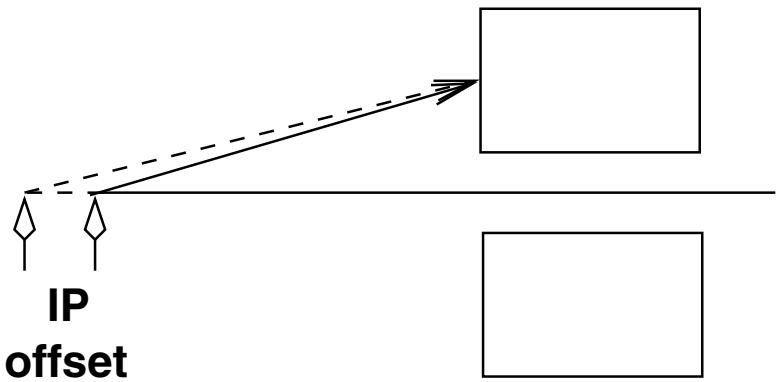
Longitudinal distance of forward and backward calorimeters

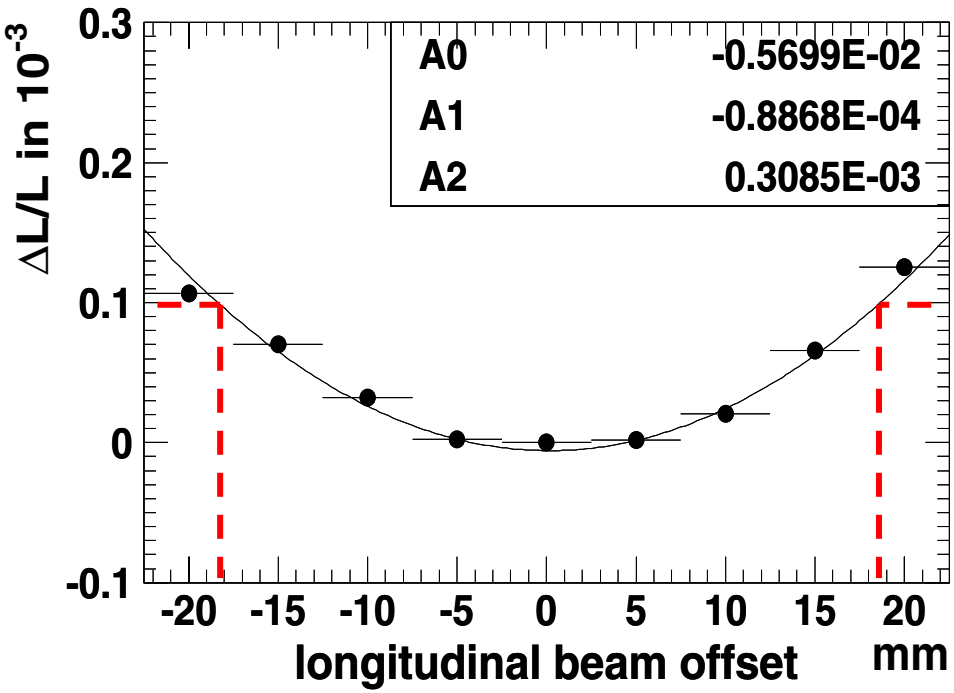




$$\frac{\Delta L}{L} \leq 10^{-4} \qquad \Rightarrow dis.cal.IP \leq 100\,\mu m$$

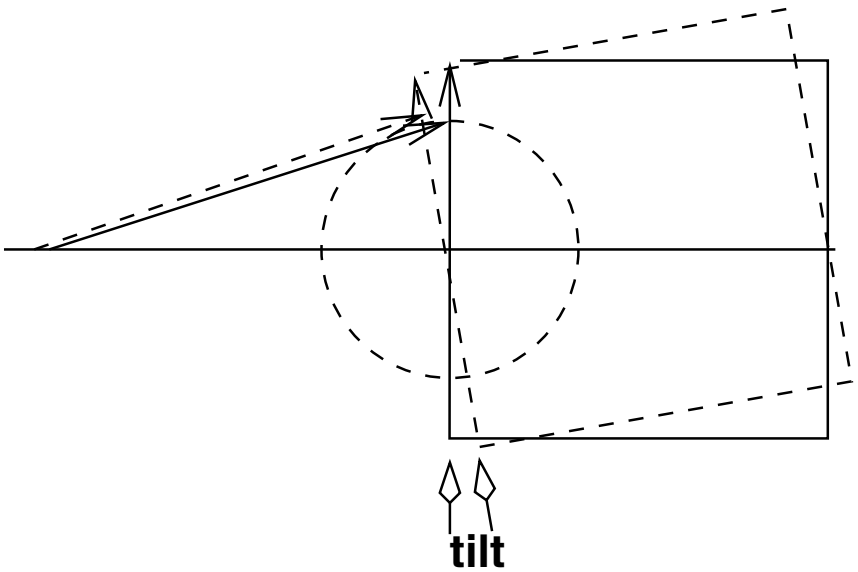
Longitudinal offset of the IP

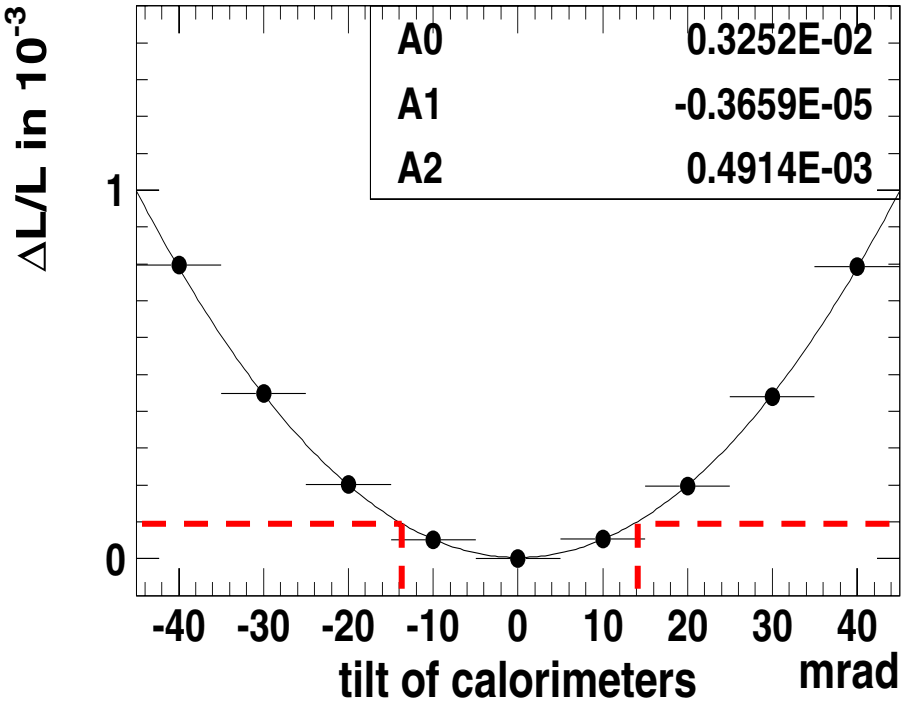




$$\frac{\Delta L}{L} \leq 10^{-4} \qquad \Rightarrow long.IPoffset \leq 2cm$$

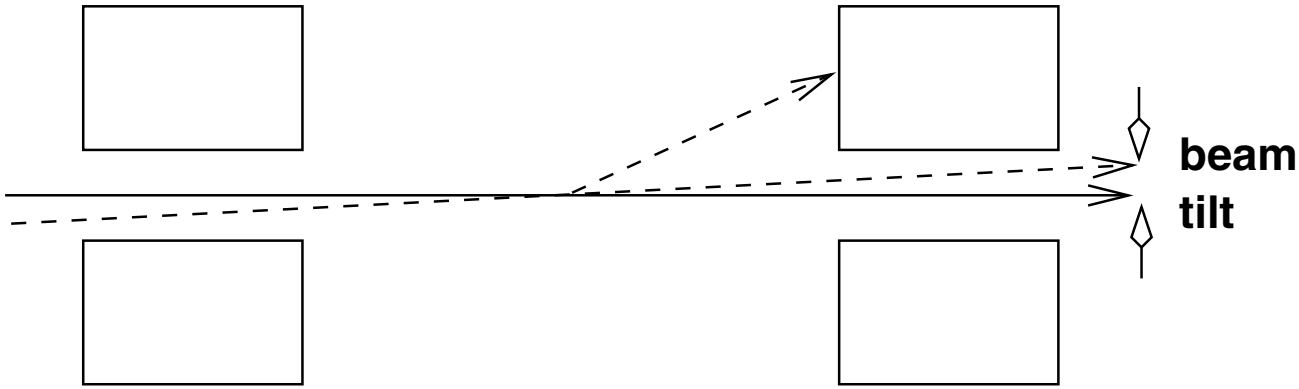
Tilt of the calorimeter

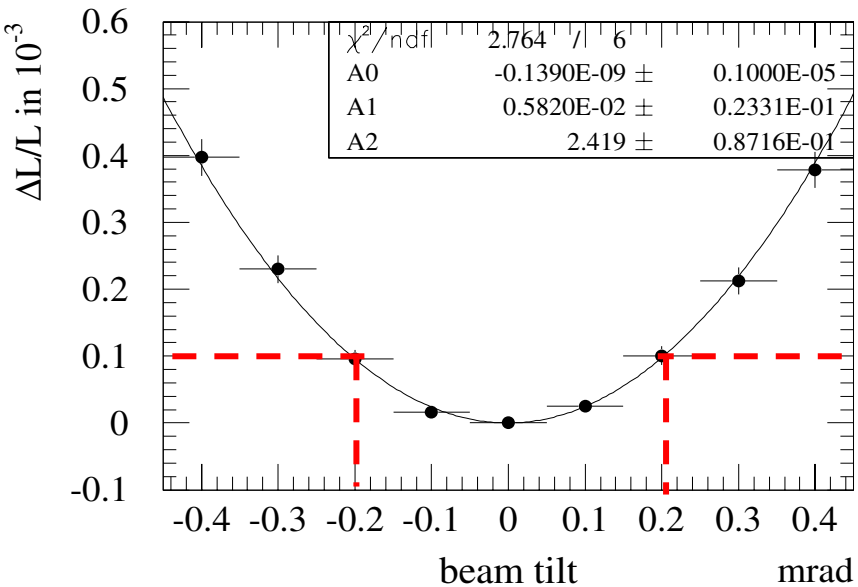




$$\frac{\Delta L}{L} \leq 10^{-4} \qquad \Rightarrow tilt \leq 10 mrad$$

Beam tilt

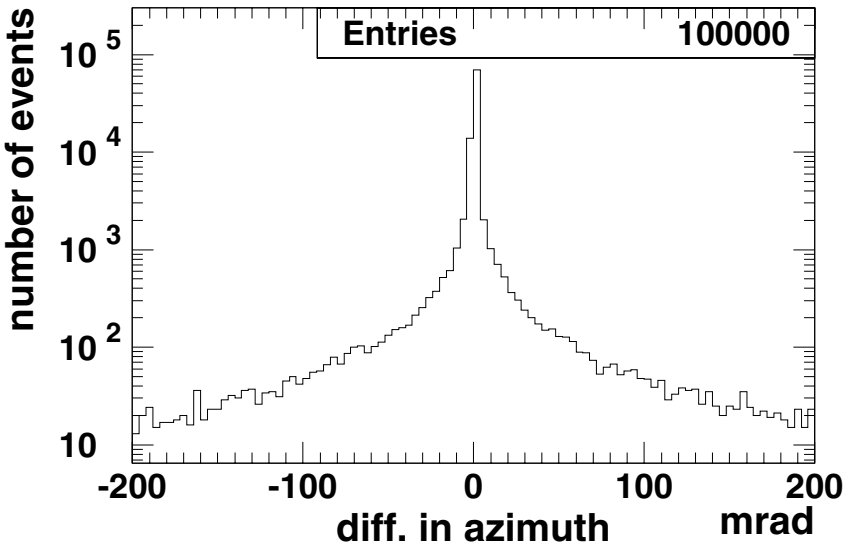


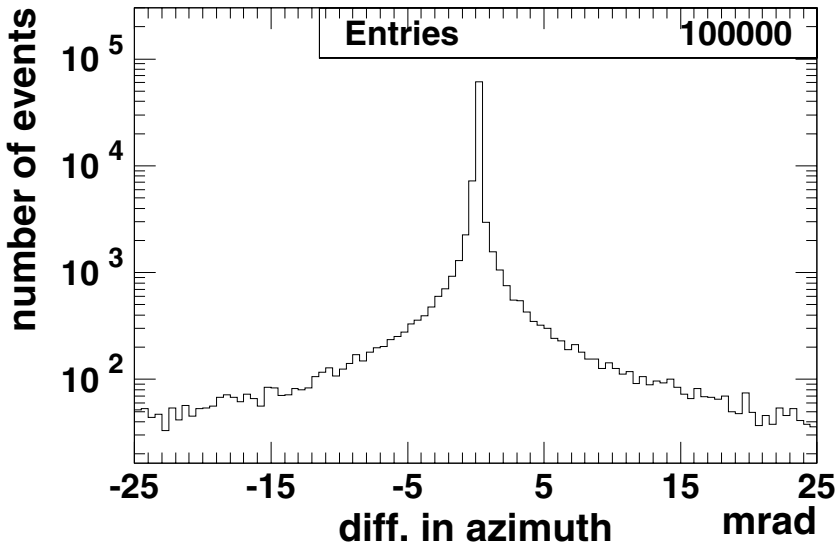


$$\frac{\Delta L}{L} \le 10^{-4} \Rightarrow bm\,tilt \le 0.2\,mrad$$

Twist between the F/B calorimeter

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



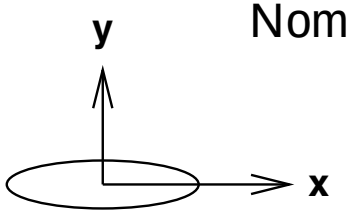


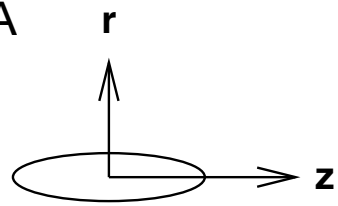
$\Delta\varphi$ < 20 mrad $\Rightarrow$ reject 10% of the events

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

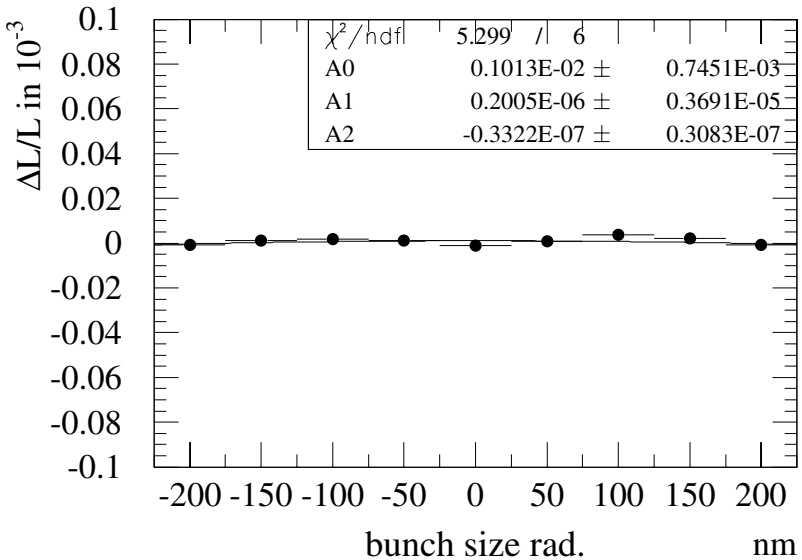
Beam size at IP

Nominal beam size at TESLA

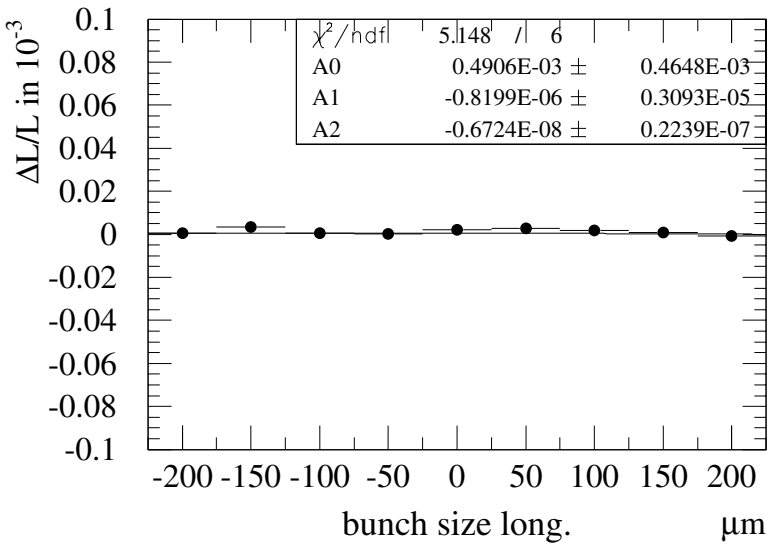




553 nm

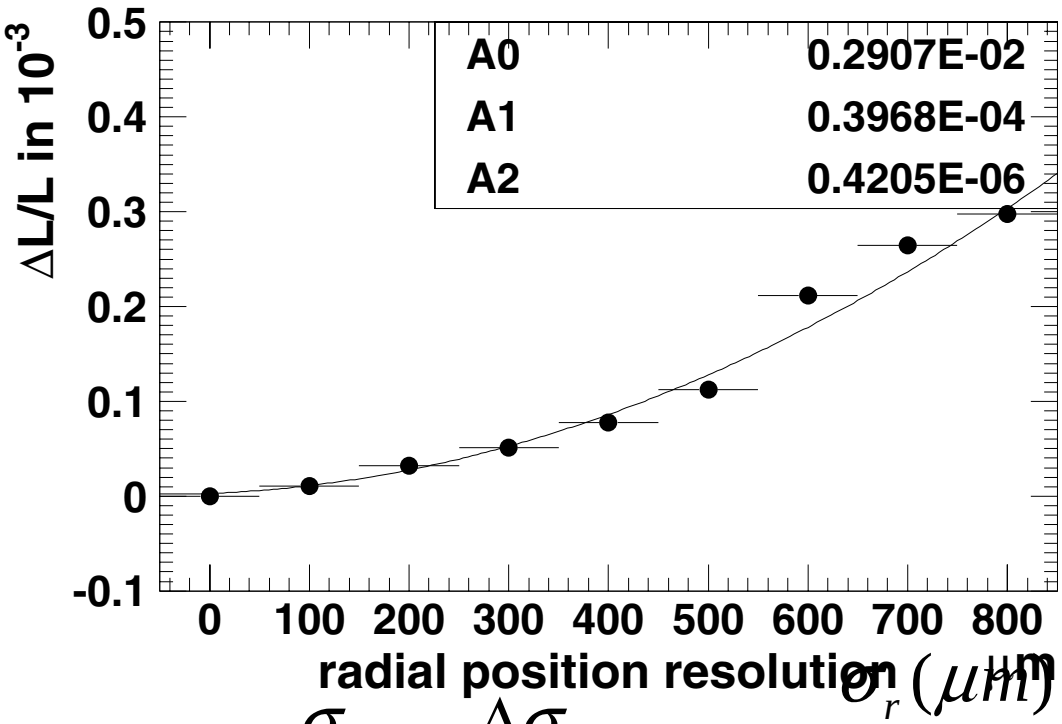


300 µm



No relevant variation

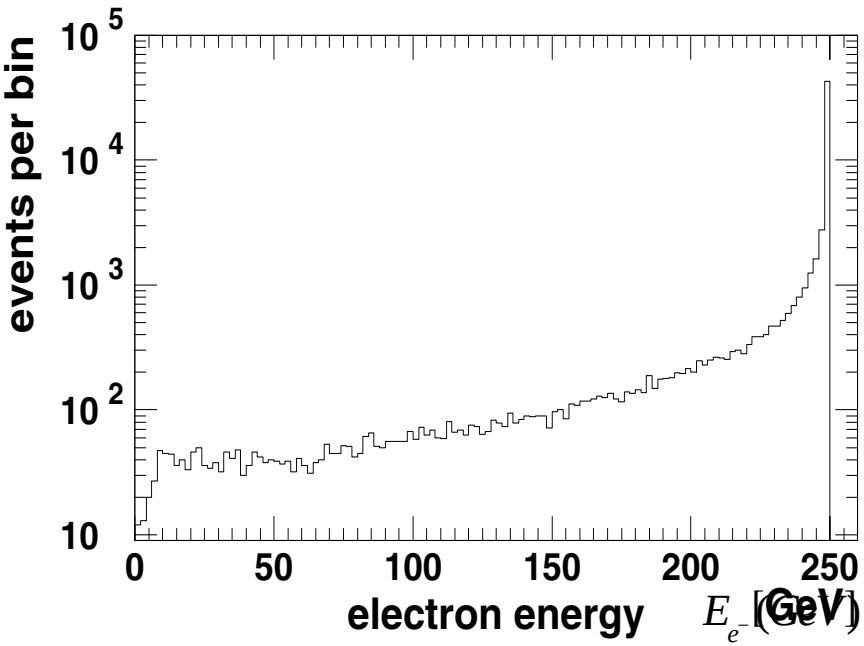
Position resolution

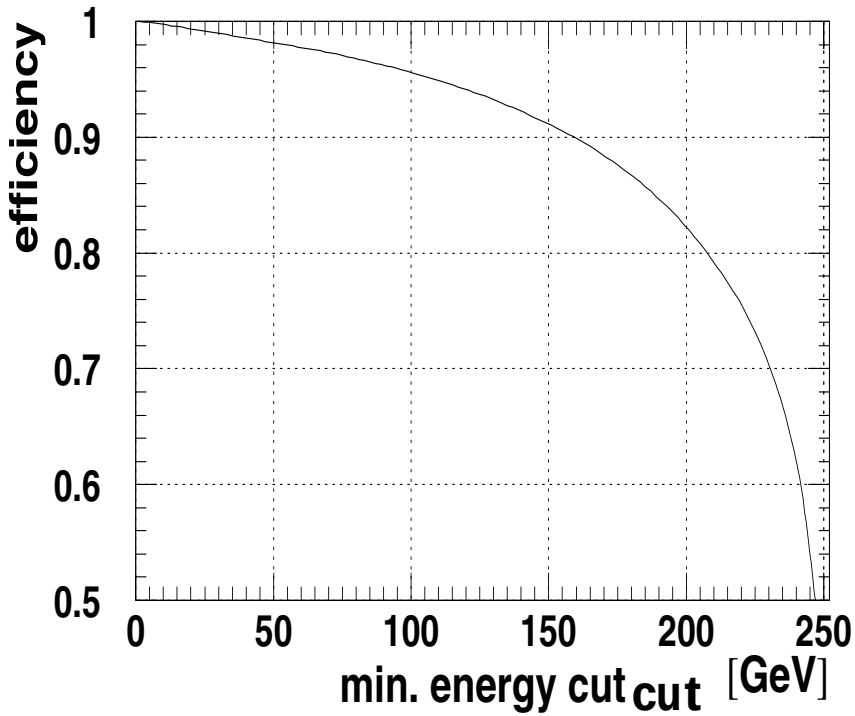


$$\frac{\Delta L}{L} = 8\times10^{-6}\,\frac{\sigma_r}{100\mu m}\,\frac{\Delta\sigma_r}{100\mu m}$$

$$\sigma_r = 500\mu m \quad \Delta\sigma_r = \pm 20\% \;\Rightarrow\; \frac{\Delta L}{L} = 0.4\times10^{-4}$$

Energy calibration

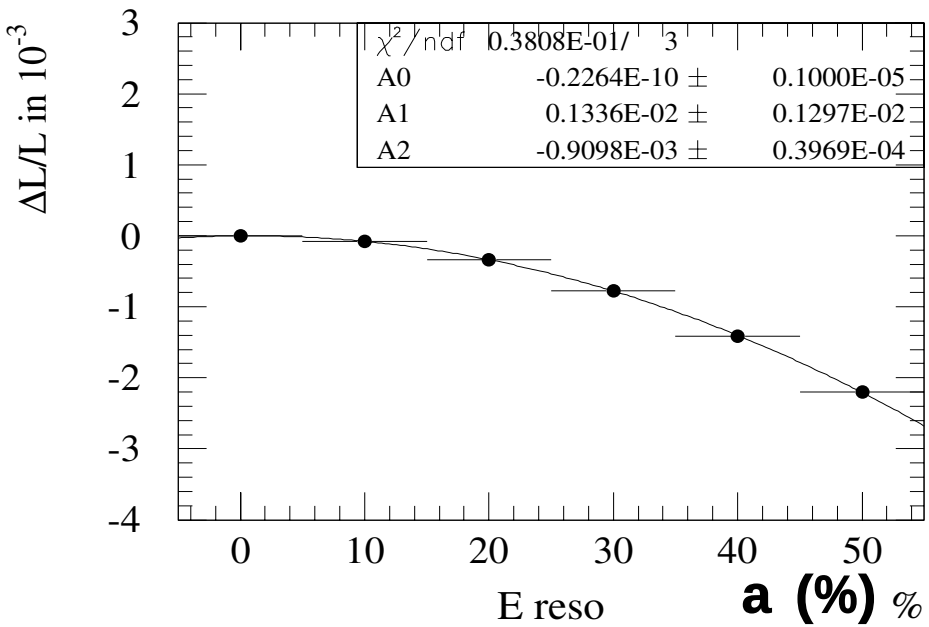




$$E(e^+,e^-) > 0.8E_{beam} \quad \Rightarrow \quad Eff = 82,52\%$$

$$\frac{\Delta E}{E} < 10^{-4} \quad \Rightarrow \quad \frac{\Delta L}{L} < 0.7\times 10^{-4}$$

Energy resolution

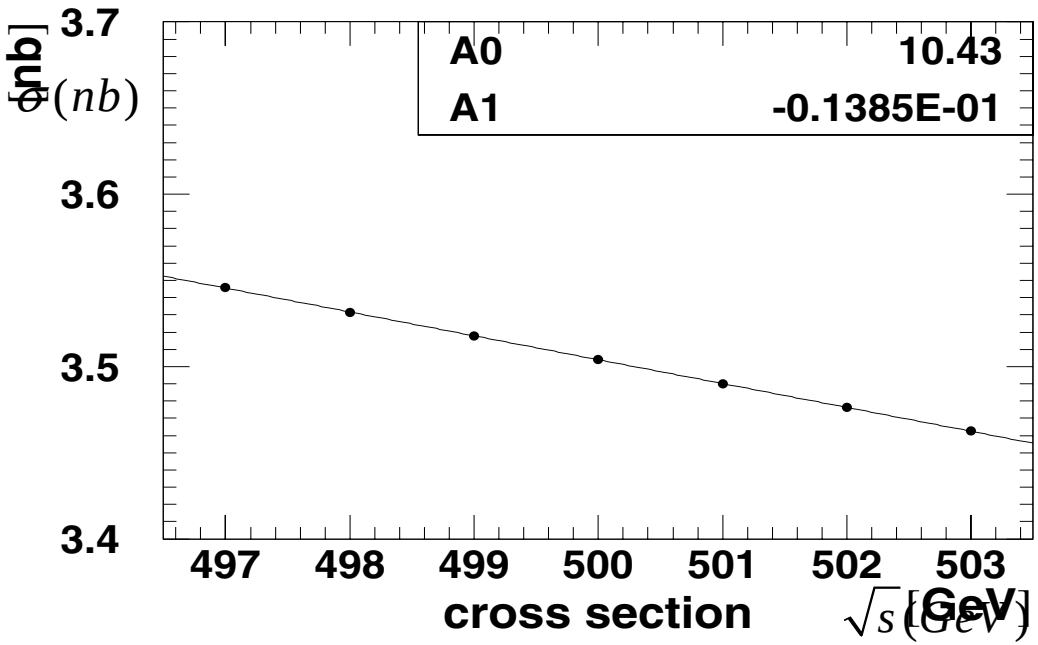


$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}}$$

$$\frac{\Delta L}{L} \approx -2\times10^{-6} \bullet a \bullet \Delta a$$

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

Center of Mass Energy



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

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

Requirement analysis dependent

Summary

$\Delta L/L$	TDR 0.2×10^{-4}	TDR 1.0×10^{-4}	New 0.2×10^{-4}	New 1.0×10^{-4}
Inner radius	0.5µm	2.7µm	0.8µm	4.2µm
Radial offset	180µm	400µm	290µm	640µm
Distance to cals.	40µm	200µm	76µm	300µm
Long. Offset	5mm	11mm	8mm	18mm
Tilt of cal.	6mrad	14mrad	6mrad	14mrad
Beam tilt	0.28mrad	0.63mrad	0.28mrad	0.63mrad
Beam size	negligible	negligible	negligible	negligible
Position resolution	3%	15%	10%	48%
Energy resolution	identical	identical	identical	identical
Beam energy	identical	identical	identical	identical

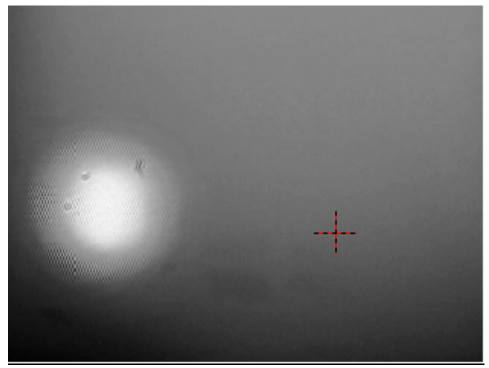
Main difference due to larger distance to IP

Laser measurement of displacement

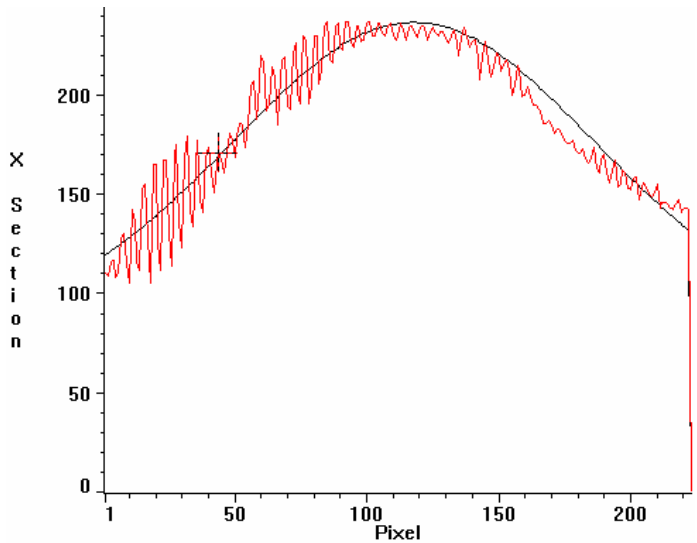
CCD sensor – web camera 640x480 pixels

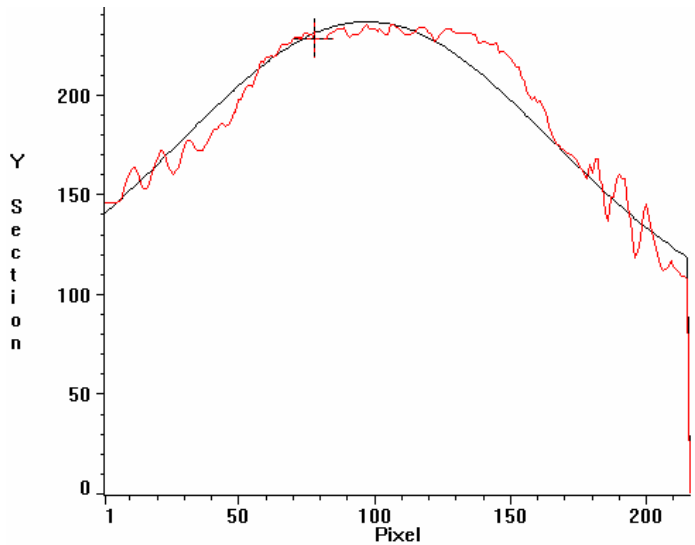
lens removed, grey filter added

He-Ne laser, beam diameter 50-100 μm

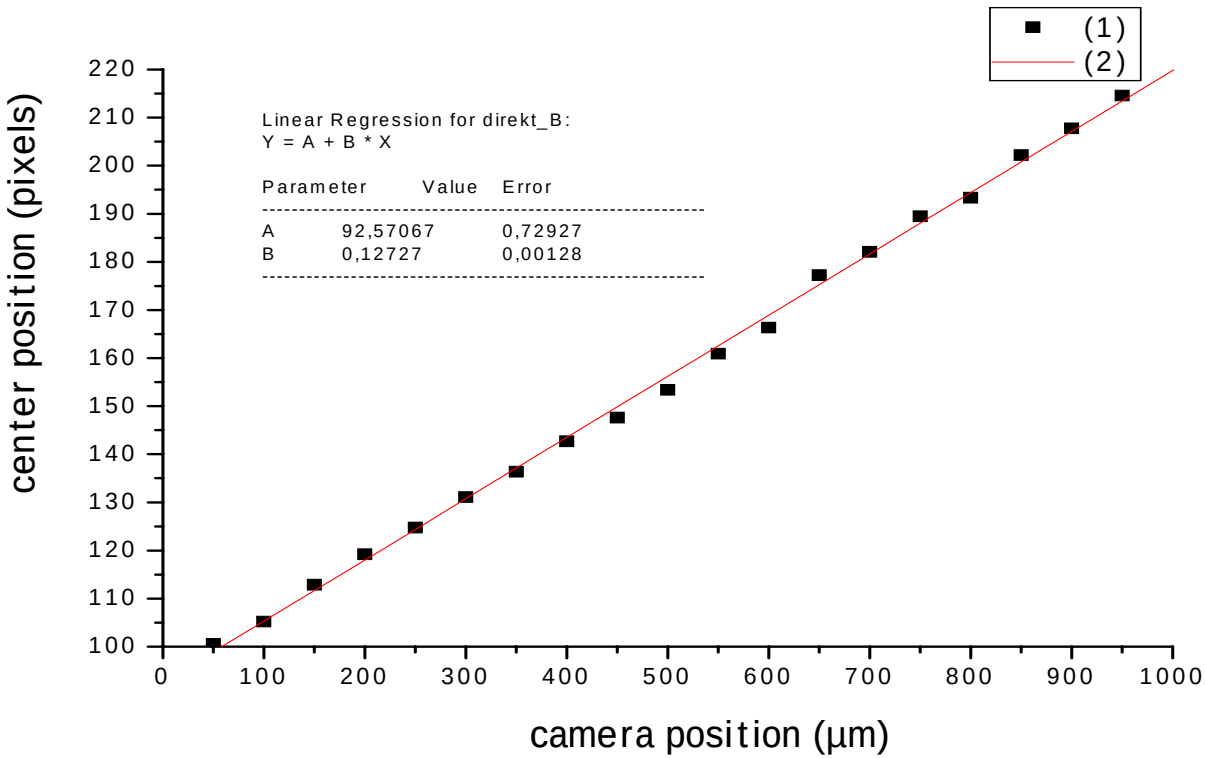


steps of 50 μm





Position measurement



0.127 pixel/µm