

Luminosity measurement

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for the FCAL Collaboration

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

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

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

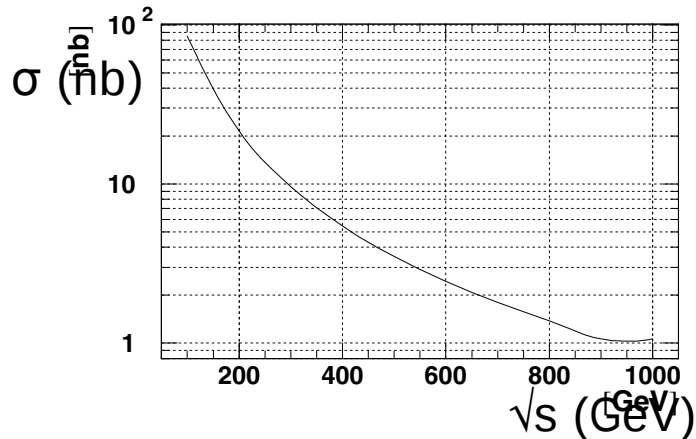
$$\frac{\Delta L}{L} \leq 10^{-4}$$
$$(ALEPH : \Delta L / L = 6 \times 10^{-4} (stat) \oplus 6.1 \times 10^{-4} (theo))$$

The diagram illustrates the longitudinal layout of the LHCb detector. Key components and their positions are as follows:

- ECAL (Electromagnetic Calorimeter):** A large blue vertical bar on the left side of the detector.
- HCAL (Hadronic Calorimeter):** A large green vertical bar on the right side of the detector.
- Subdetectors:**
 - LumCal (Luminosity Monitor):** Red blocks located between the ECAL and HCAL.
 - BeamCal (Beam Calorimeter):** Yellow blocks located between the ECAL and HCAL.
 - Elec (Electronics):** Blue blocks located between the ECAL and HCAL.
 - Valve:** A blue block located between the ECAL and HCAL.
 - VTX-Elec (Vertex Detector Electronics):** Pink blocks located at the top and bottom of the detector.
- Longitudinal Distances (m):**
 - ECAL: 2800 to 3000
 - HCAL: 3000 to 4250
- Angular Coverage:**
 - ECAL: 92.0 mrad to 26.2 mrad
 - HCAL: 26.2 mrad to 3.9 mrad
- Longitudinal Distances (m):**
 - ECAL: 3050...3250
 - HCAL: 3350...3500
 - BeamCal: 3650...3850
 - L*: 4050

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

$26.2 < \text{LumCal} < 80 \text{ mrad}; \quad 30 < \text{Fiducial Volume} < 75 \text{ mrad}$



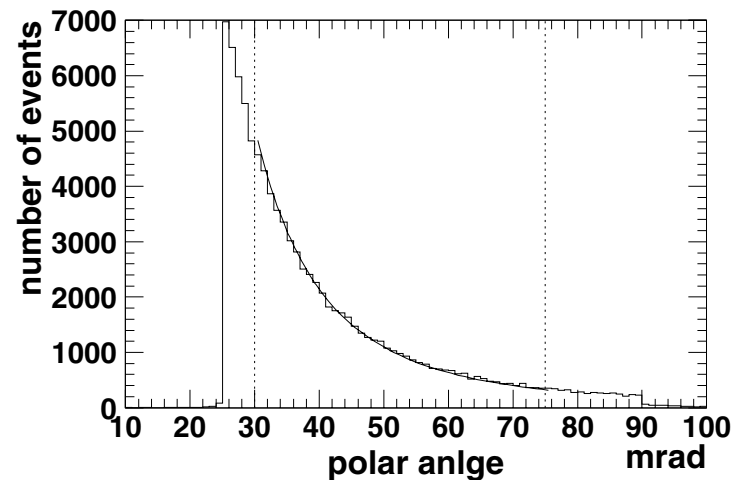
At $\sqrt{s} = 500 \text{ GeV}$ $\sigma (30 < \theta < 75 \text{ mrad}) \approx 3 \text{ nb}$
for nominal luminosity $L_N = 3 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$

$$\Rightarrow N_B = 9 \times 10^8 / \text{year}$$

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

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

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



with BHLUMI (Jadach & Waş)

Systematic effects due to Geometry

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

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

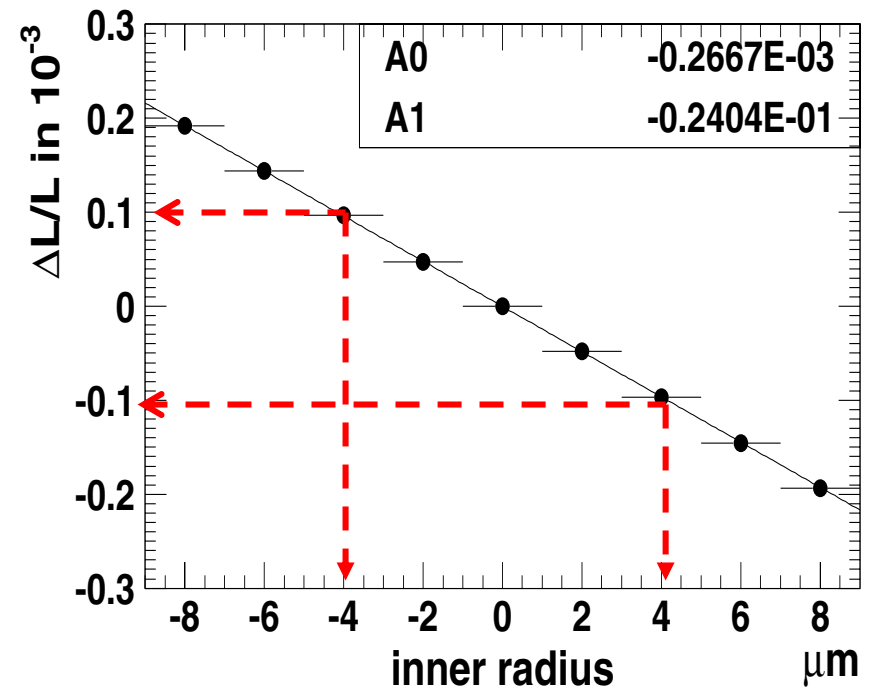
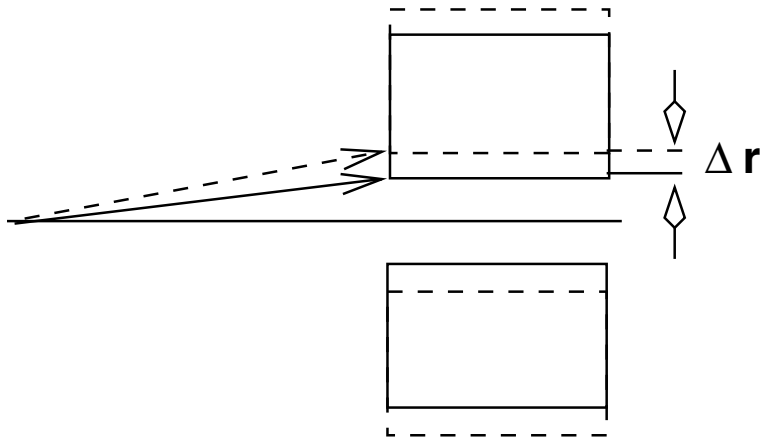
$30 < \theta(e^+) \text{ or } \theta(e^-) < 75 \text{ mrad}$ (never both, alternate e^+ , e^-)

$\Rightarrow$ reduces sensitivity to the IP position

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

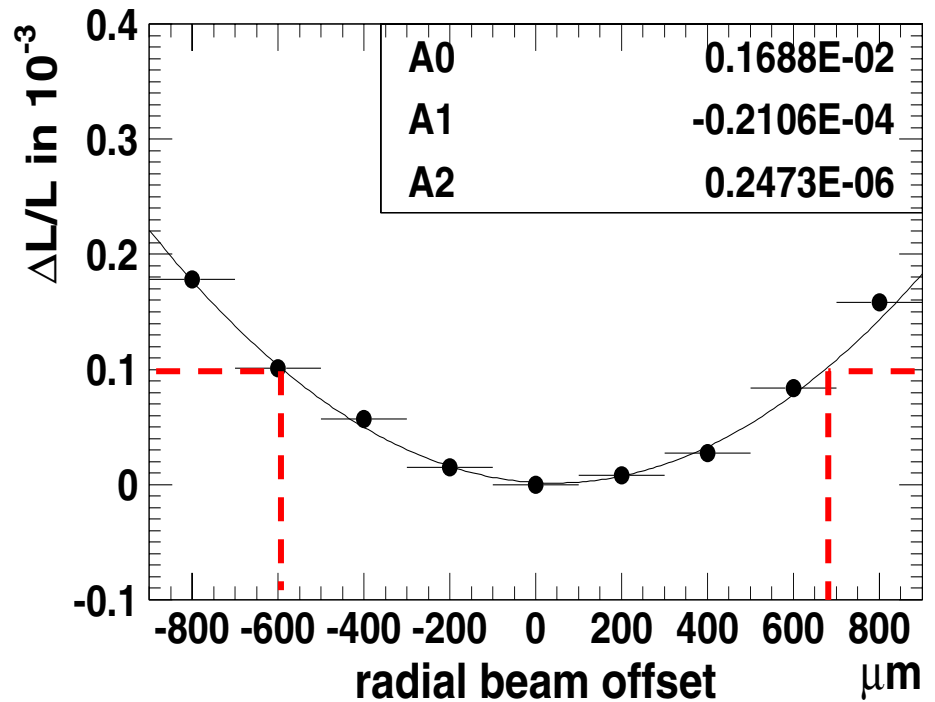
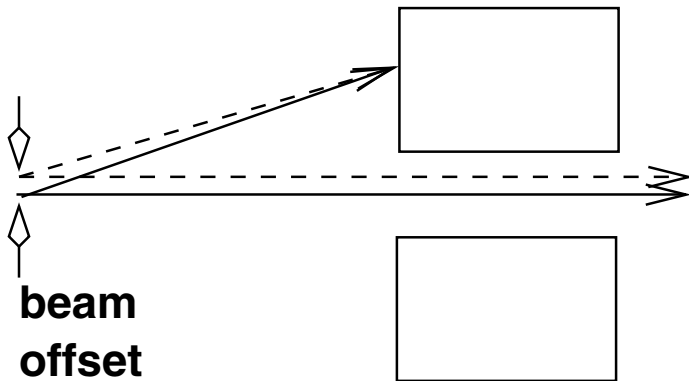
Systematic error $\leftrightarrow$ change in the number of events

Inner diameter of LumCal



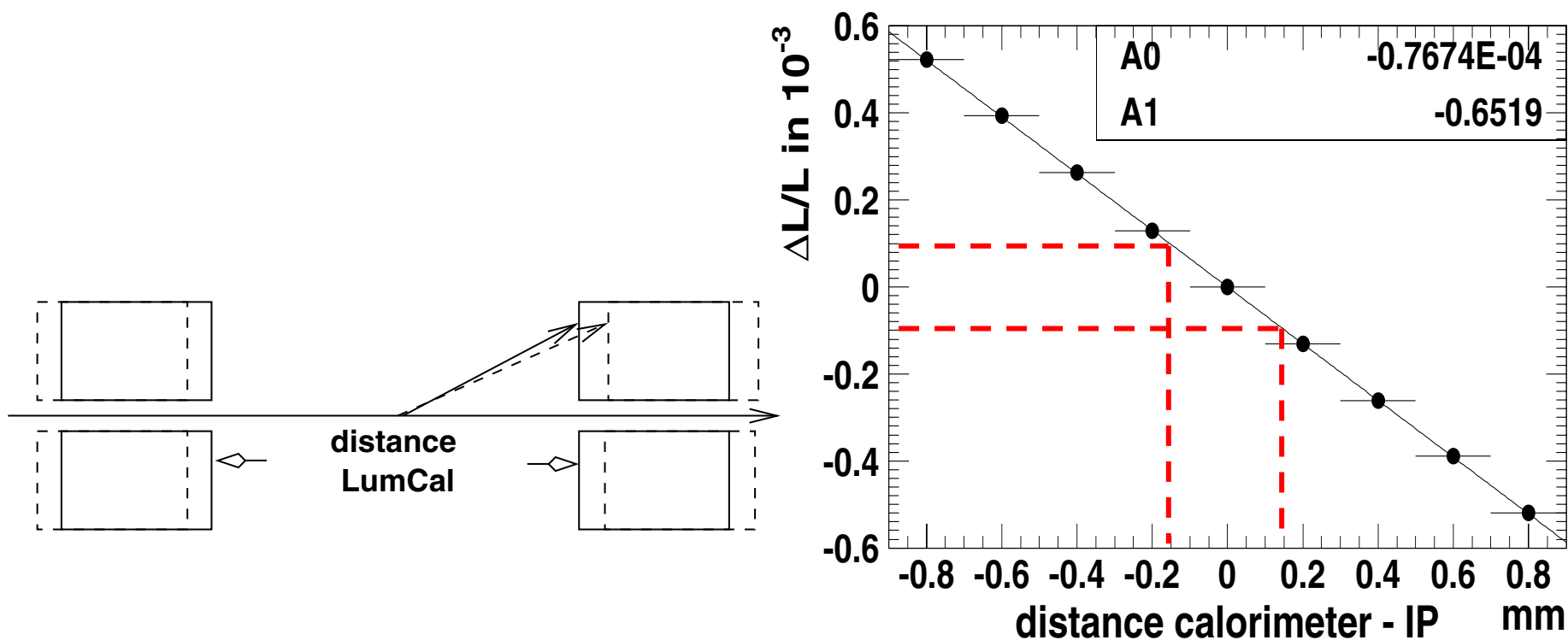
$$\frac{\Delta L}{L} \leq 10^{-4} \Rightarrow \Delta r \leq 4 \mu m$$

Radial beam position



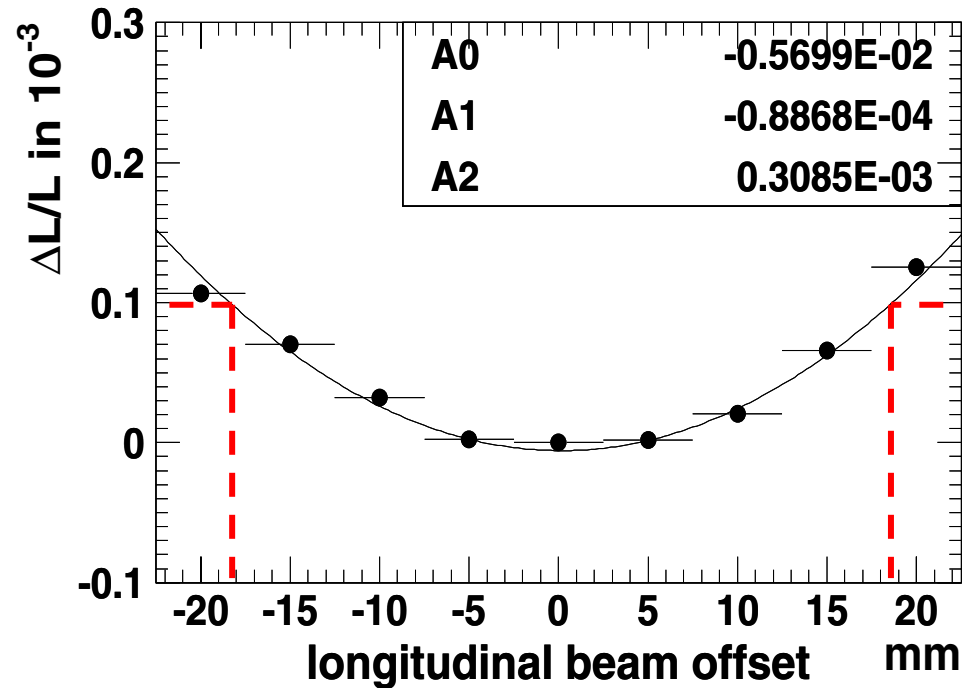
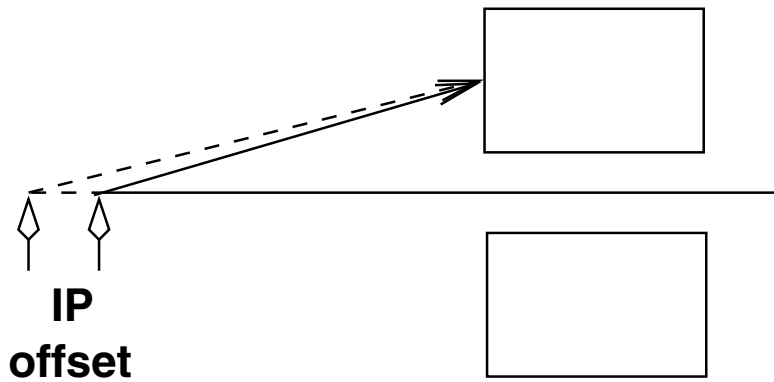
$$\frac{\Delta L}{L} \leq 10^{-4} \Rightarrow \text{rad.offset} \leq 600 \mu\text{m}$$

Longitudinal distance of forward and backward calorimeters



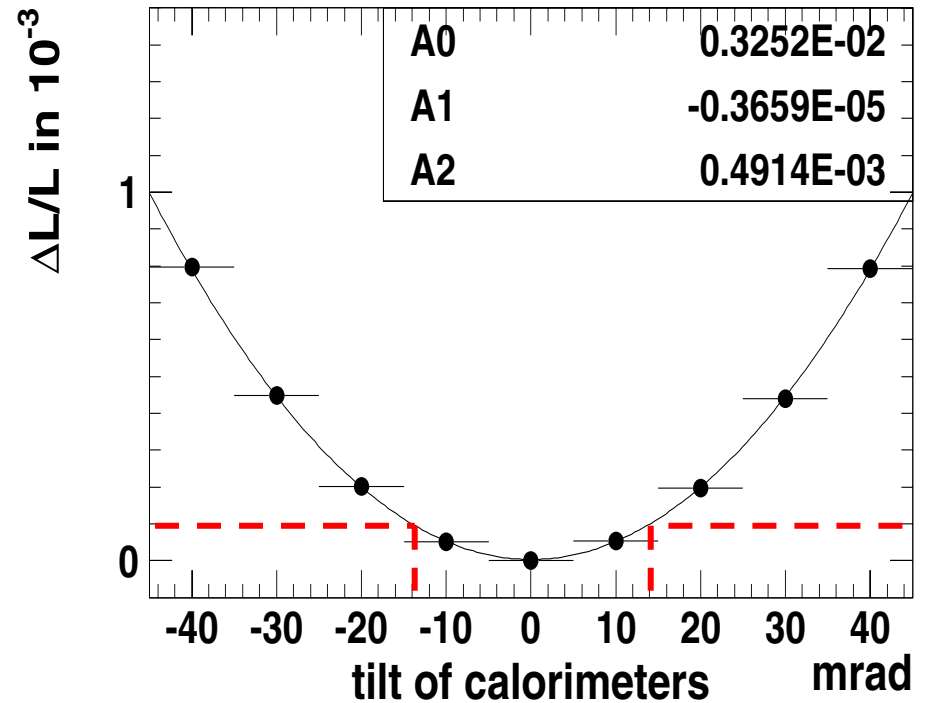
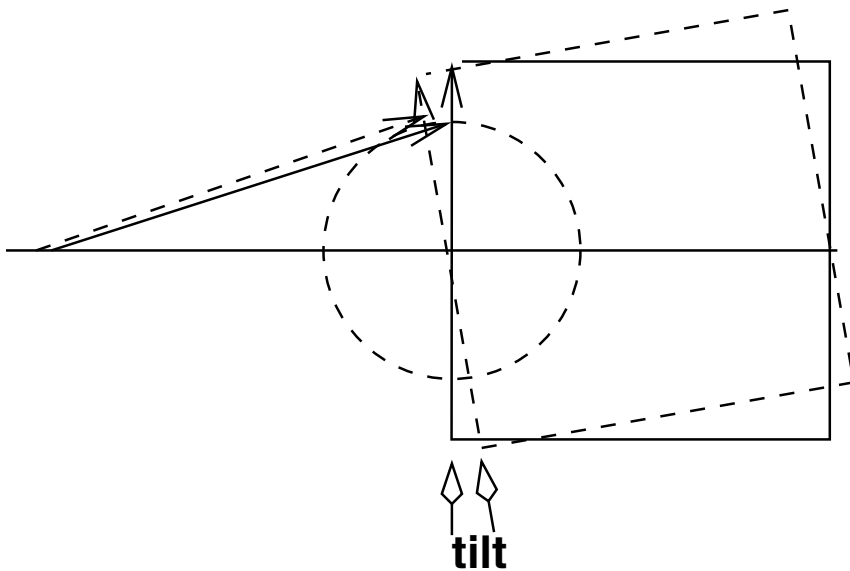
$$\frac{\Delta L}{L} \leq 10^{-4} \Rightarrow dis.cal.IP \leq 100 \mu m$$

Longitudinal offset of the IP



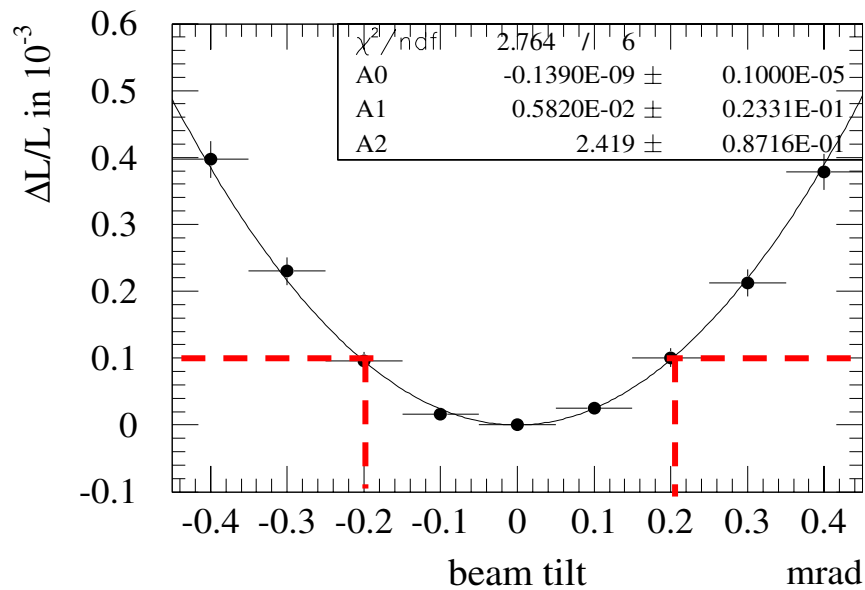
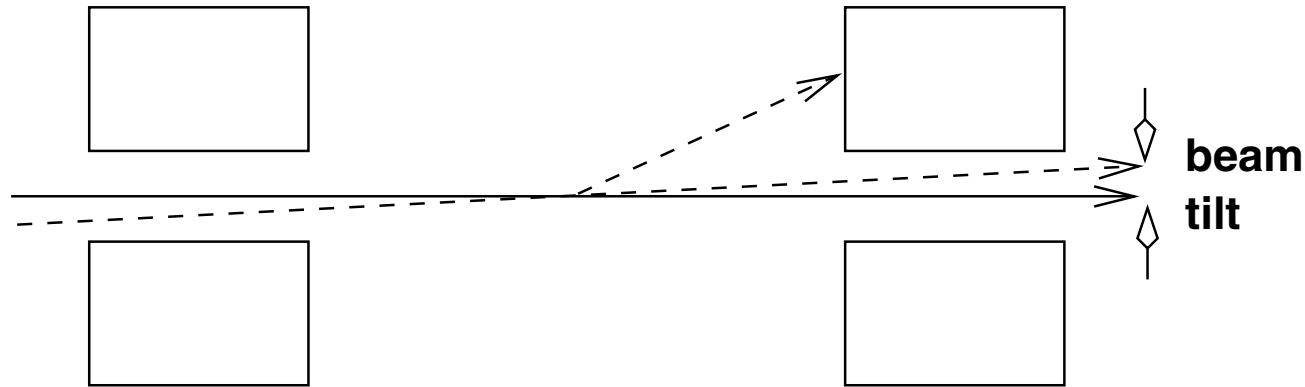
$$\frac{\Delta L}{L} \leq 10^{-4} \Rightarrow \text{long.IPoffset} \leq 2\text{cm}$$

Tilt of the calorimeter



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

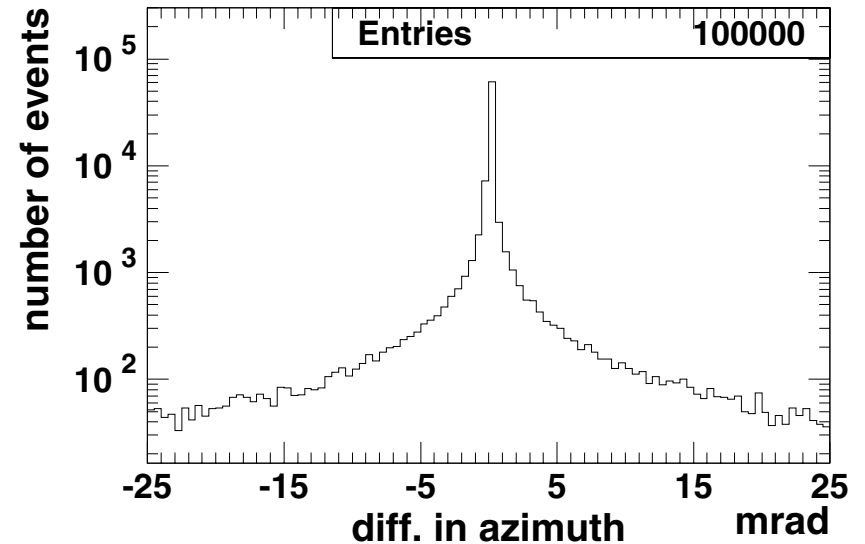
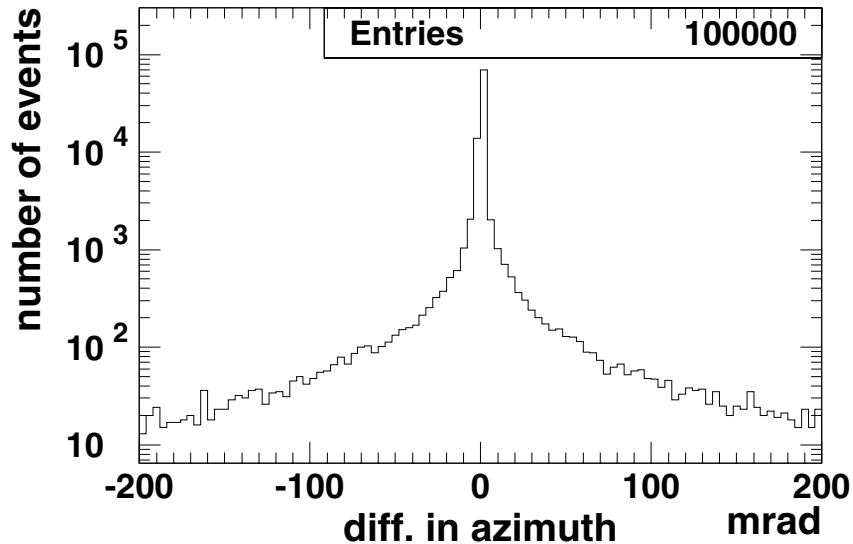
Beam tilt



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

Twist between the F/B calorimeter

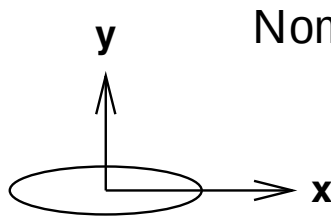
$\Delta\phi$ cut $\Rightarrow$ reduces radiative tail



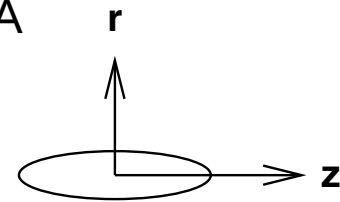
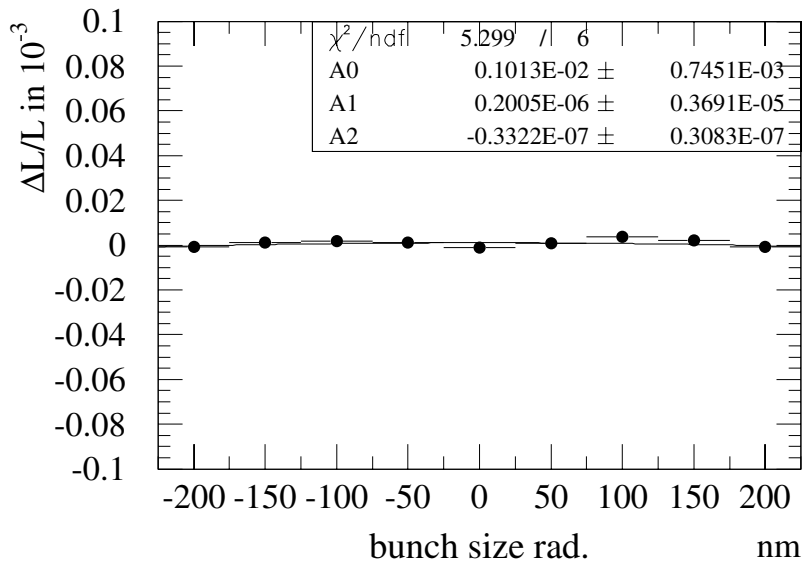
$\Delta\phi < 20$ mrad $\Rightarrow$ reject 10% of the events

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

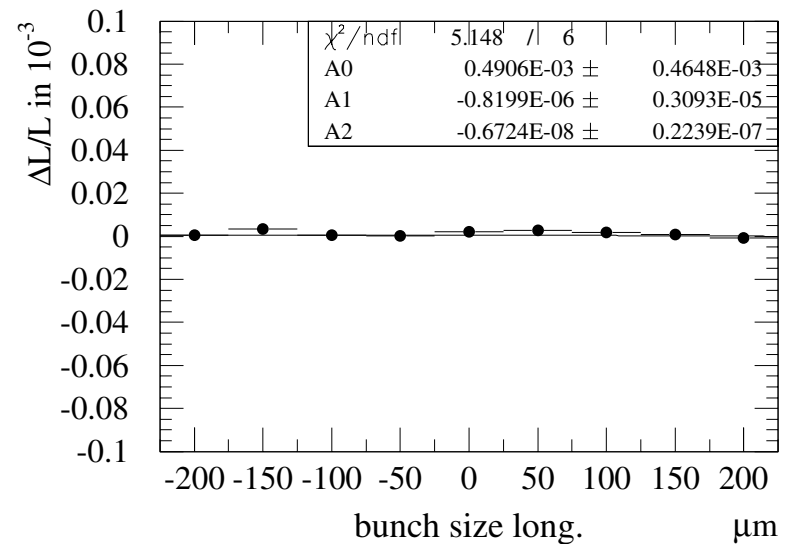
Beam size at IP



553 nm

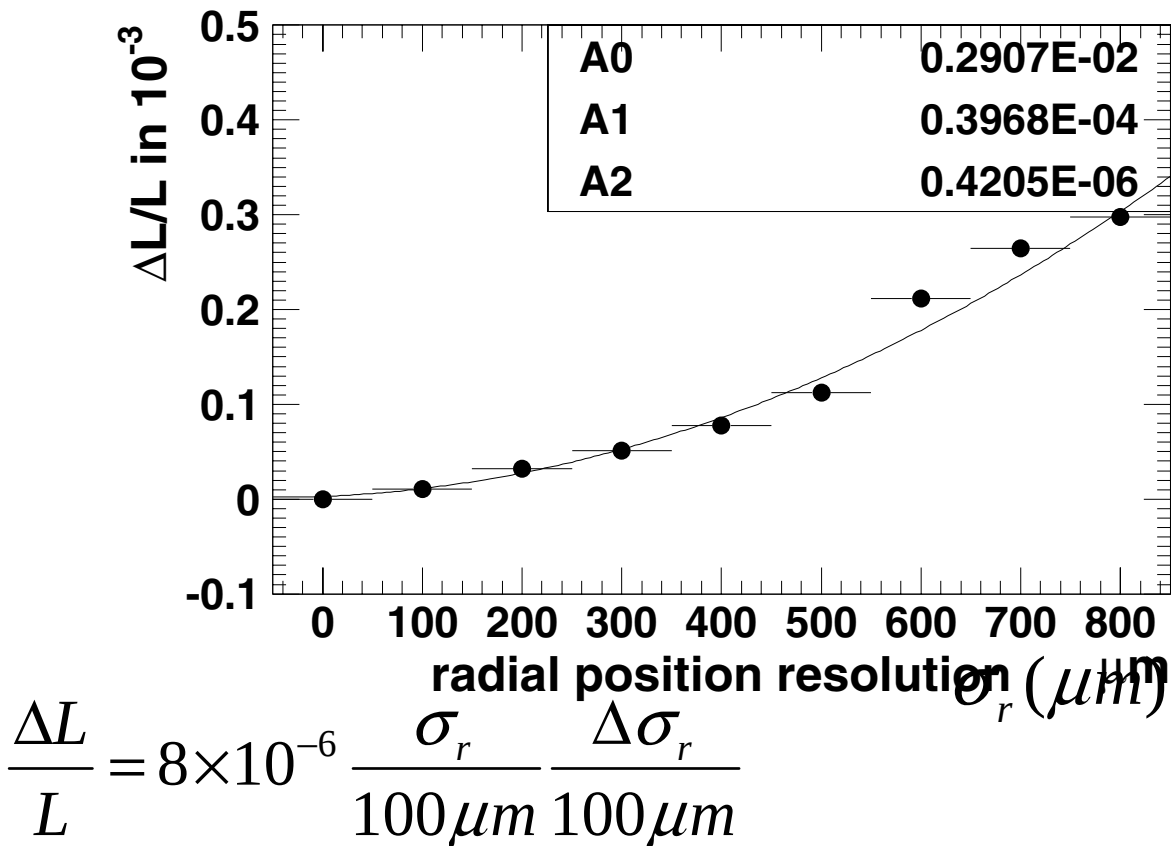


300 μm



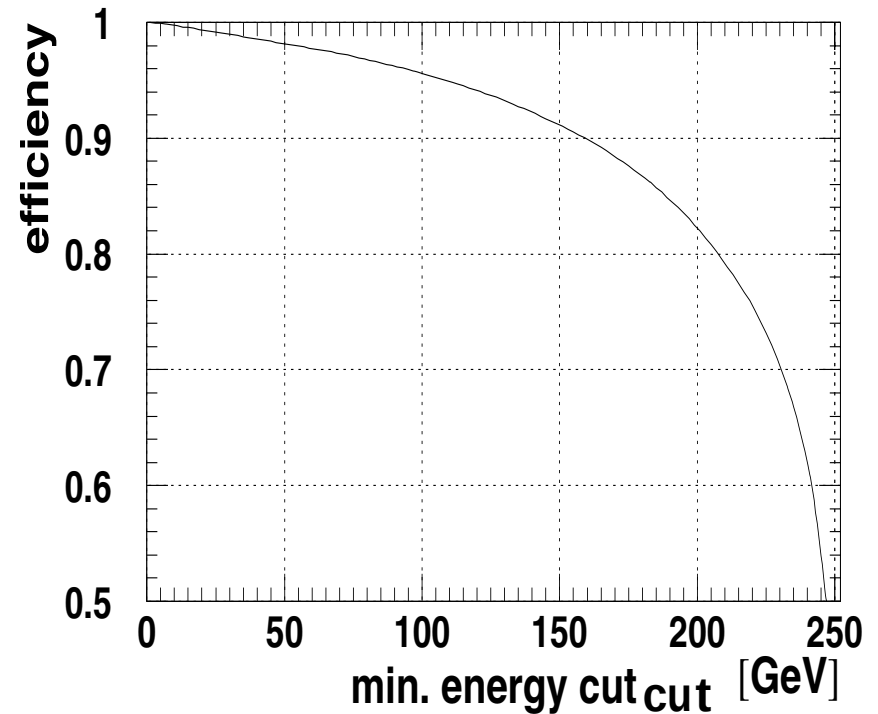
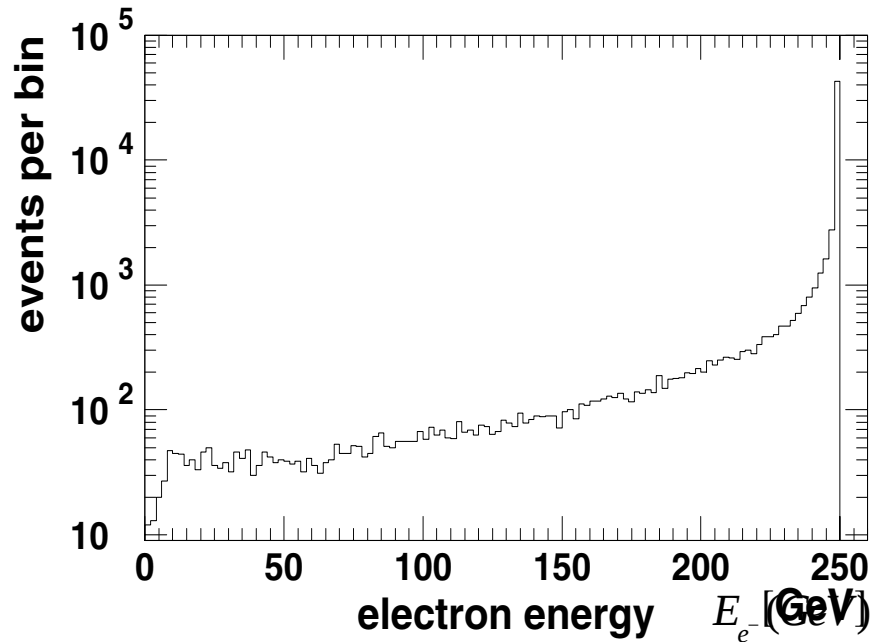
No relevant variation

Position resolution



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

Energy calibration

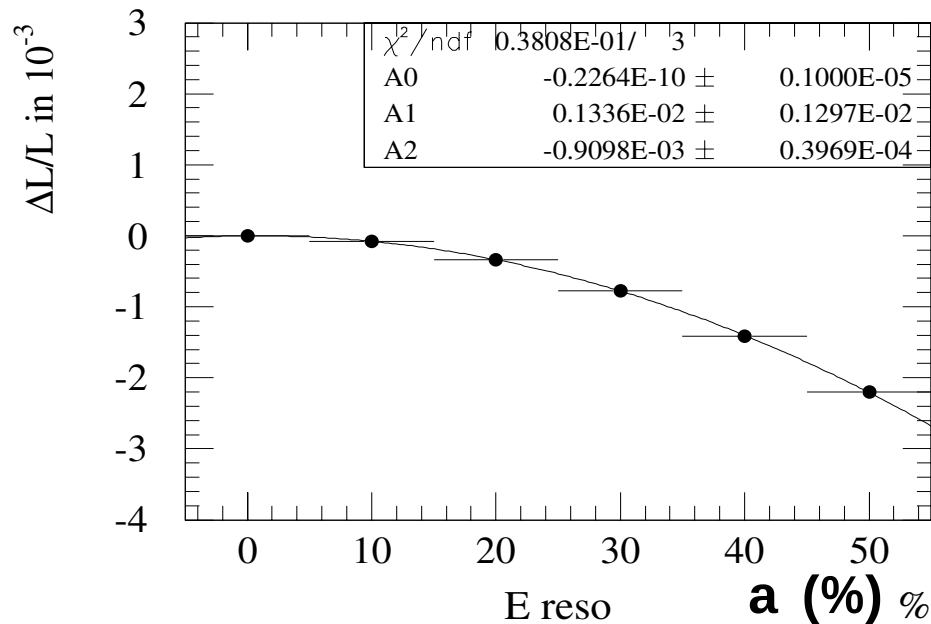


$$E(e^+, e^-) > 0.8E_{beam} \Rightarrow Eff = 82,52\%$$

value
(GeV)

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

Energy resolution

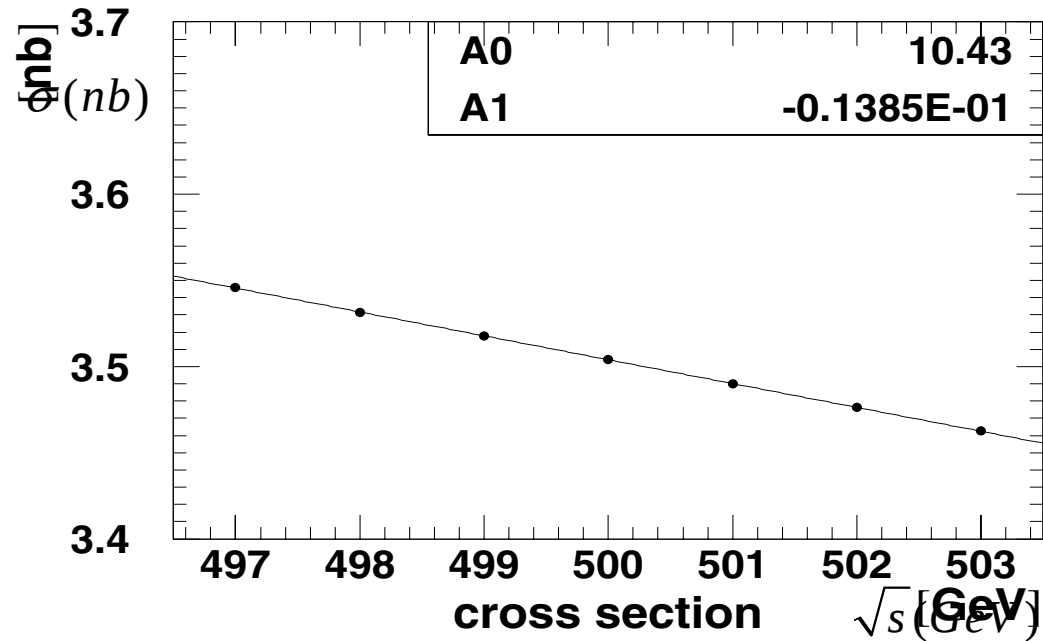


$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}}$$

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

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

Center of Mass Energy



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

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

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	0.5 μ m	2.7 μ m	0.8 μ m	4.2 μ m
Radial offset	180 μ m	400 μ m	290 μ m	640 μ m
Distance to calcs.	40 μ m	200 μ m	76 μ m	300 μ m
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

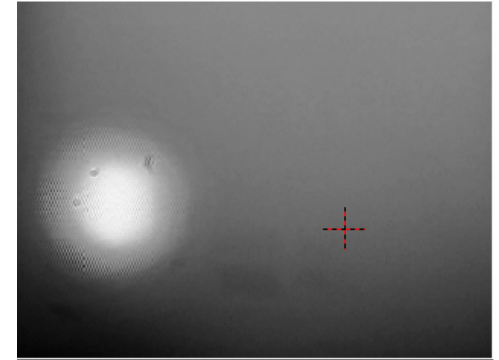
Main difference due to larger distance to IP

Laser measurement of displacement

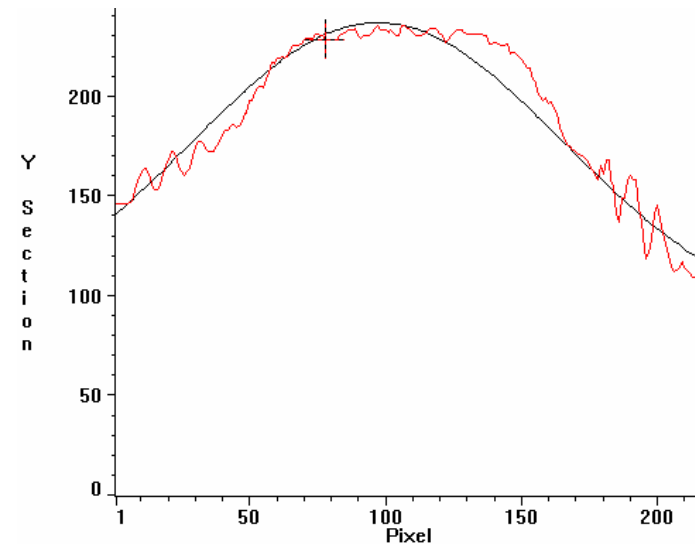
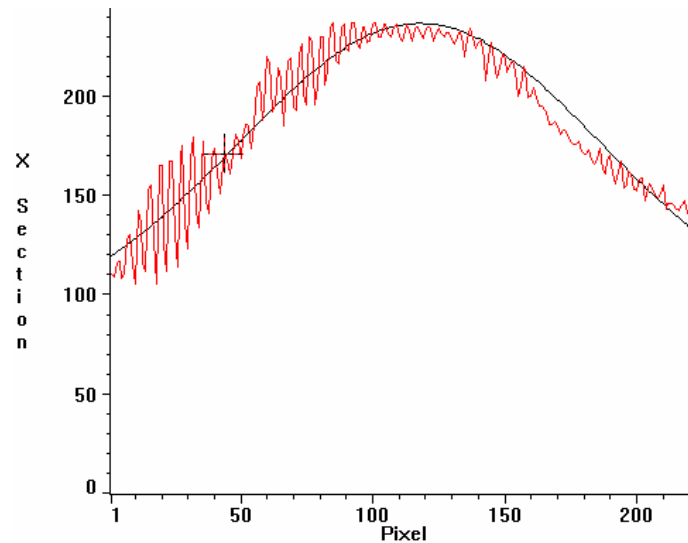
CCD sensor – web camera 640x480 pixels

lens removed, grey filter added

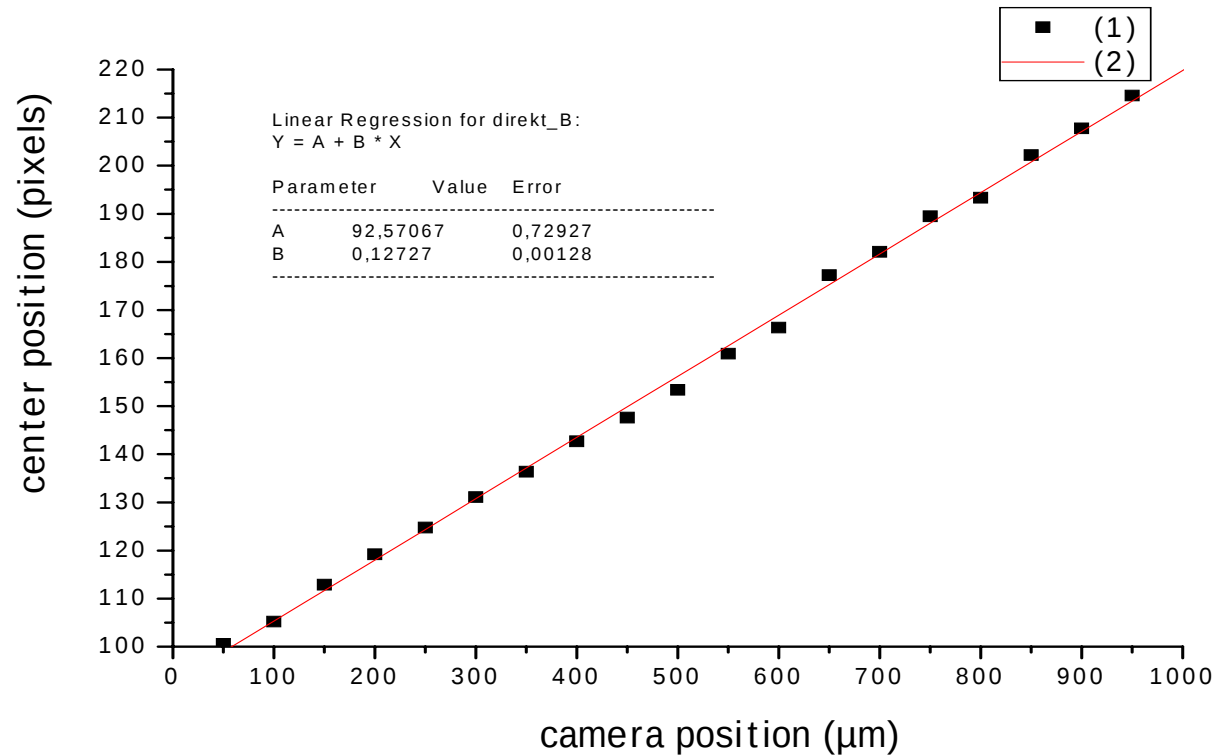
He-Ne laser, beam diameter 50-100 μm



steps of 50 μm



Position measurement



0.127 pixel/ μm