ATF Extraction Line Laser-Wire System

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- Introduction
- Experimental installation
- Experimental results
- Recent upgrades
- Conclusions

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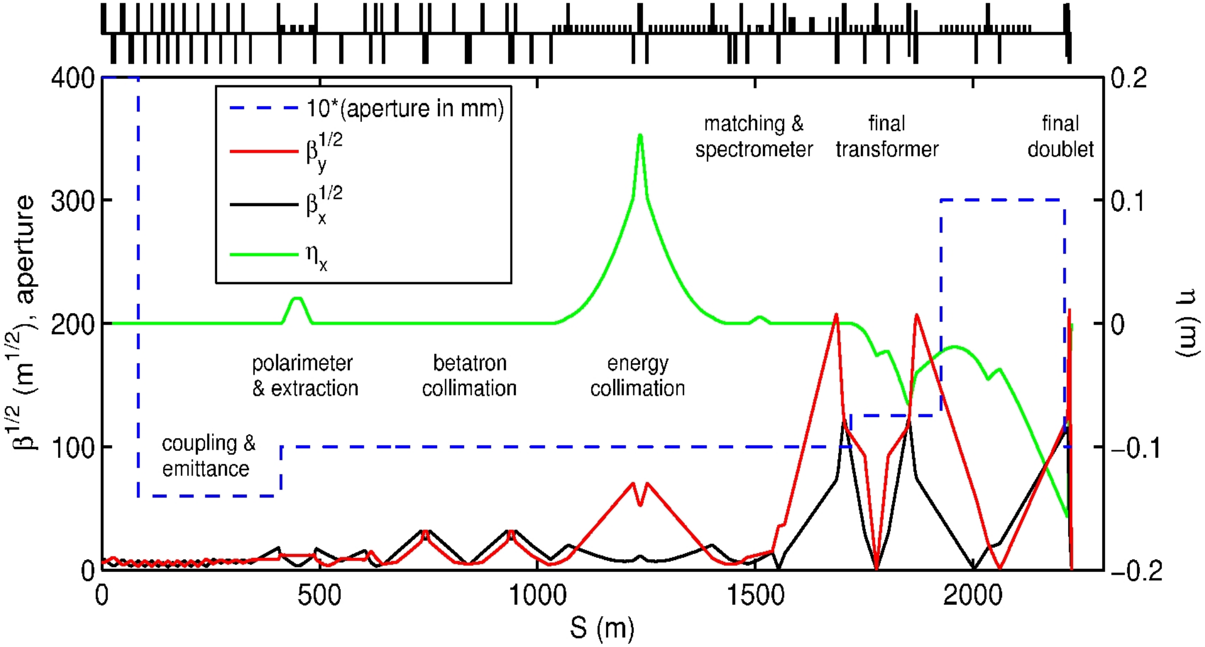
Introduction

- Need for non-invasive transverse beam size monitor system for the ILC well established
- Essential for emittance measurement and beam parameter optimisation



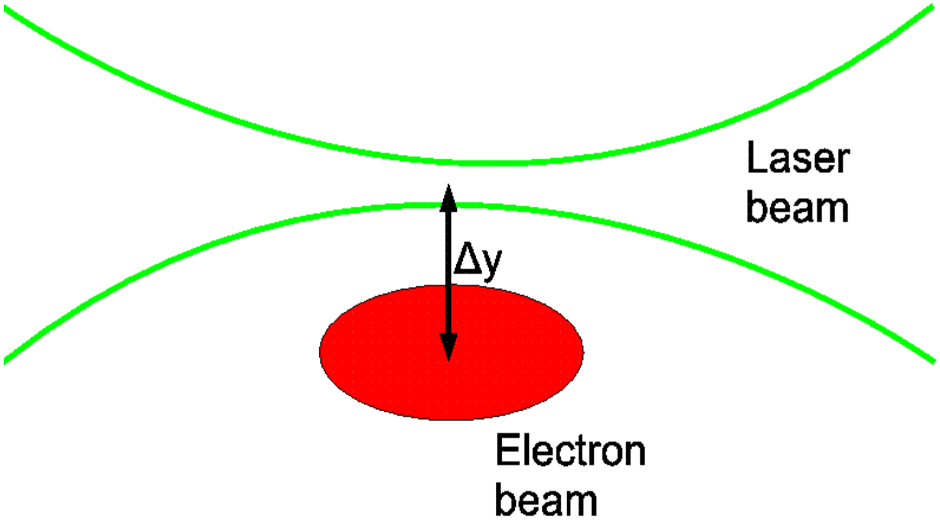
- We aim to develop a system capable of measuring 1 μm beam sizes

LW Principle

- Compton scattering rate:

$$N_\gamma = N_b \frac{P_L \sigma_C \lambda}{c^2 h} \frac{1}{\sqrt{2\pi}\sigma_s} exp\left(\frac{-\Delta y}{2\sigma_s^2}\right)$$

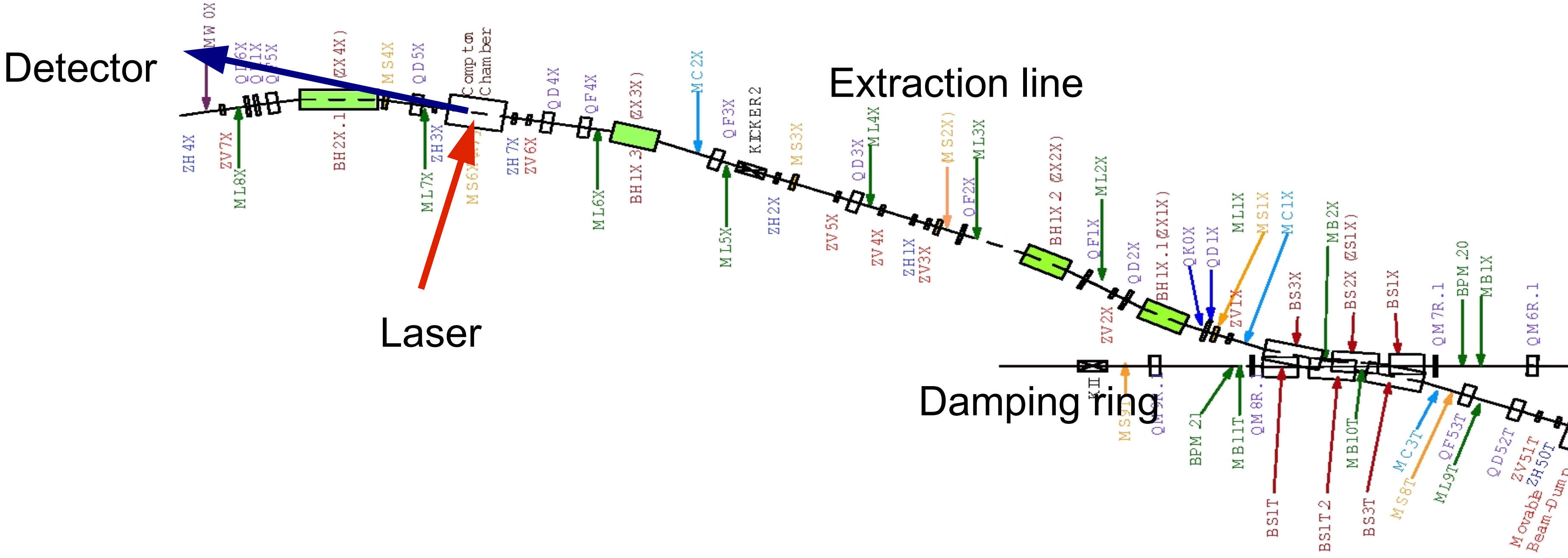
$$\sigma_s^2 = \sigma_e^2 + \sigma_l^2$$



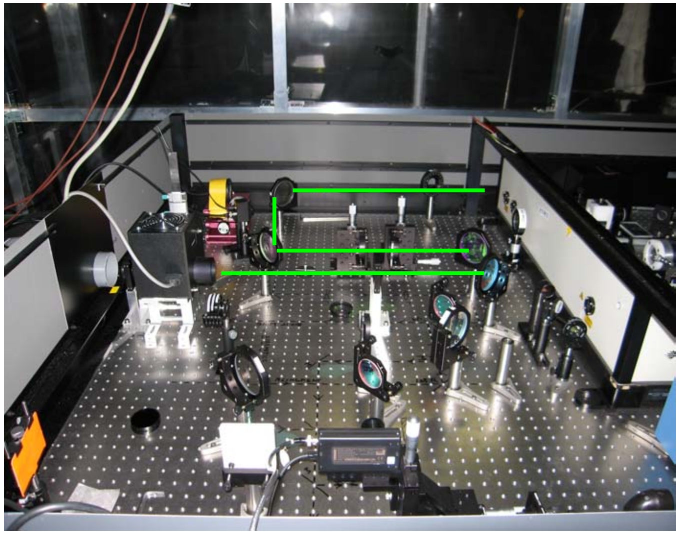
- By measuring Compton rate (N_γ) as a function of relative displacement (Δy), the quadrature beam size (σ_s) can be extracted
- If laser beam size is known then the electron beam size can be extracted

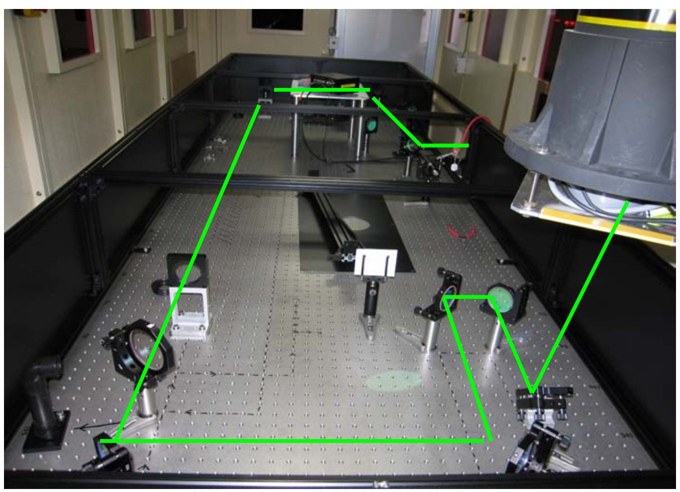
ATF Electron Beam Optics

- Modified to produce electron beam sizes from ~50 μm down to the ILC like 20 μm X 1 μm
- Optics verified using wire scanner.
- Vertical beam size smaller than wire scanner resolution (2.5 μm)



Laser

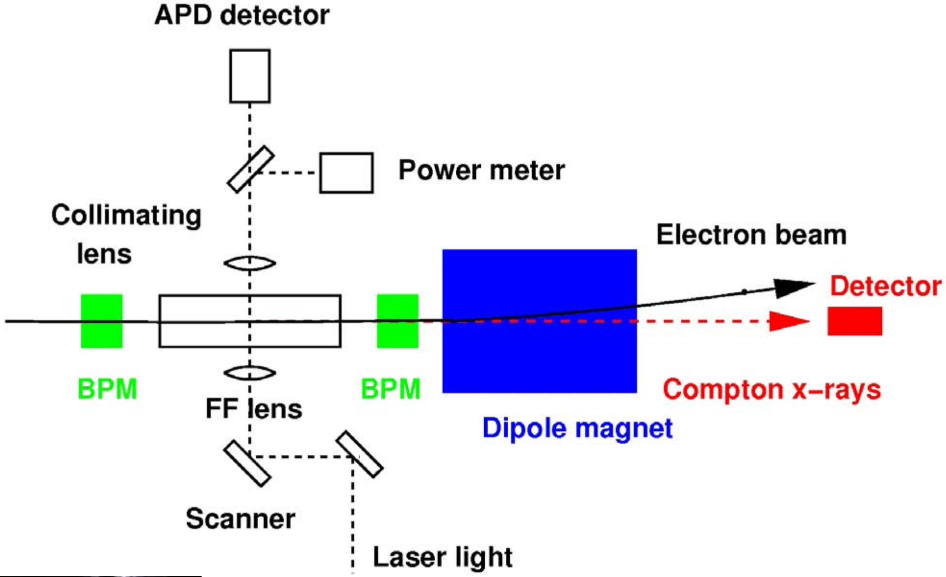




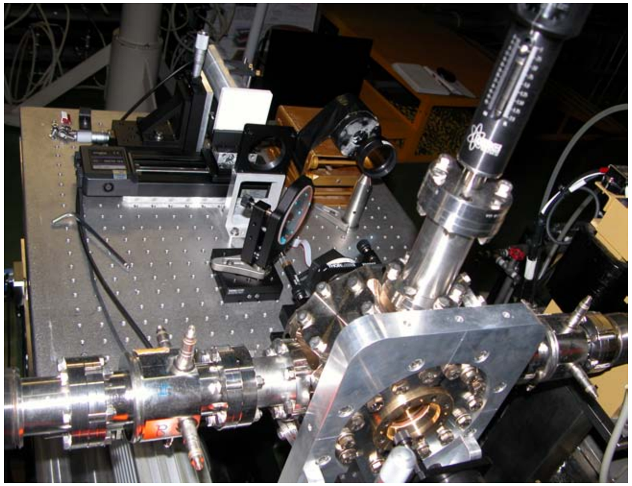
- High energy green (λ=532nm) laser pulses
- Amplify a single pulse from passively mode-locked seed laser
- Frequency locked to ATF RF distribution system at 357MHz
- Pulse duration ~150ps
- Pulse energy ~30mJ
- Laser light transported to extraction line by series of mirrors, collimated, and aligned using irises

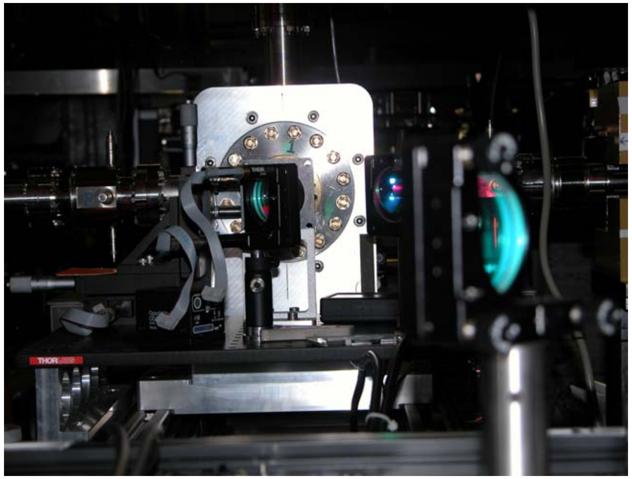
Interaction Point

- FF lens mounted on a 3 axis translation system



- Light steered onto final focus (FF) lens using 2 mirrors

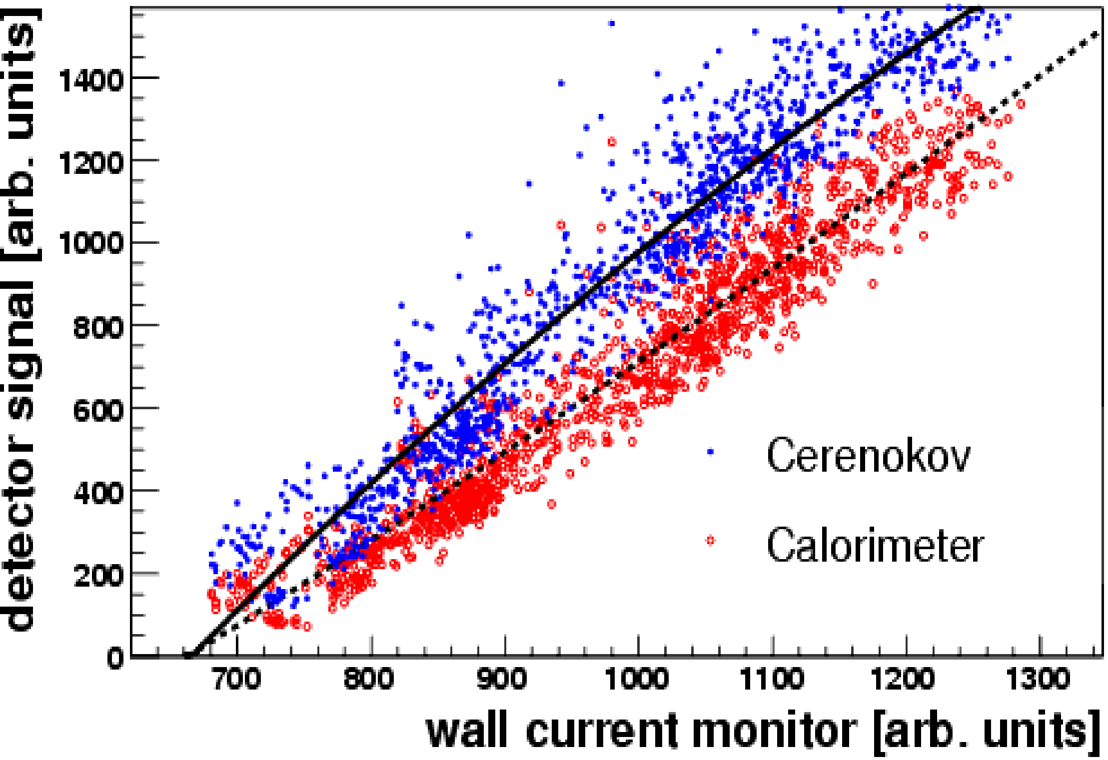




Detectors

- 2 detectors for measuring the LW Compton rate (N)
- SP-15 aerogel Cerenkov detector:
- Cerenkov threshold = 2.983 MeV
- Lead glass calorimeter:
- 365mm long
- Signal pulses from PMTs digitised using multi channel gated analogue to digital converter

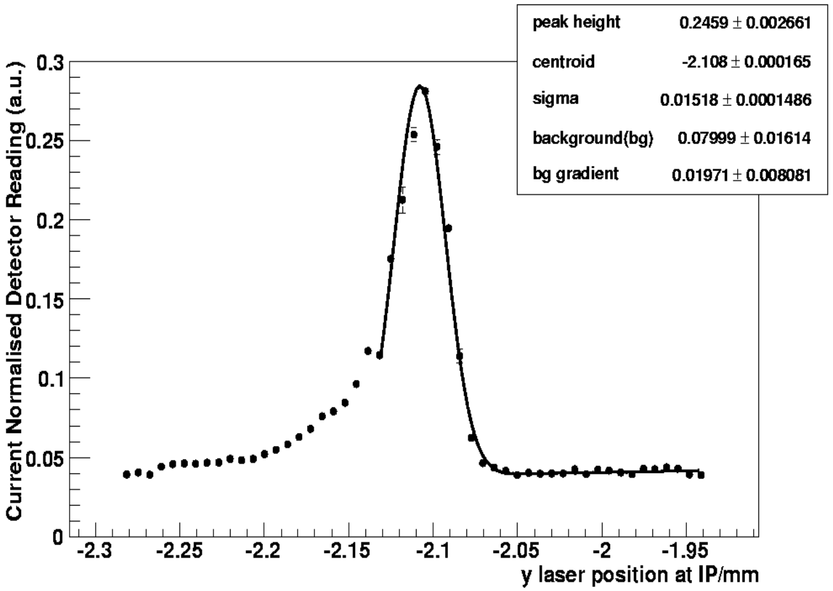
Detector Linearity

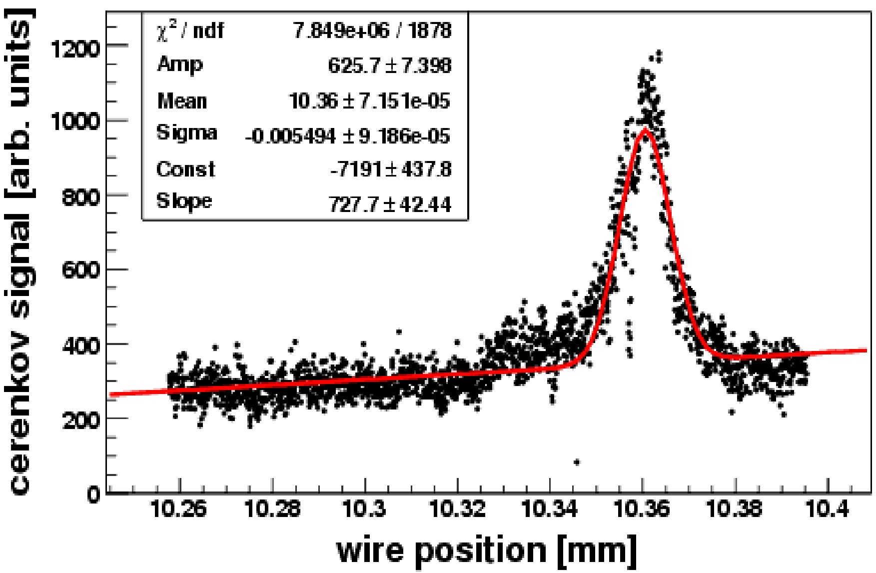


- With 6 μm laser and ~1 μm electron beams overlapping, took 20 mins of data
- Bunch charge varied from 0.1 X 10^{10} to 1.4 X 10^{10} eV
- Data fitted to second order polynomial

Vertical Beam Profile

2006. 15 μm summer 2007. 5.4 μm



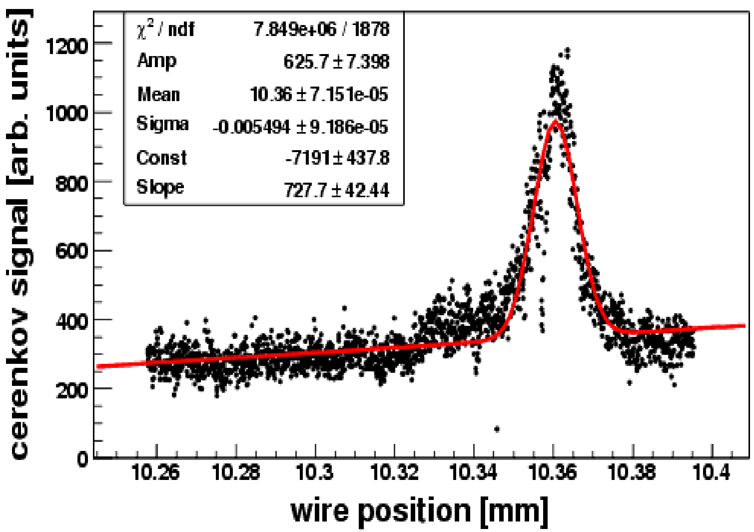


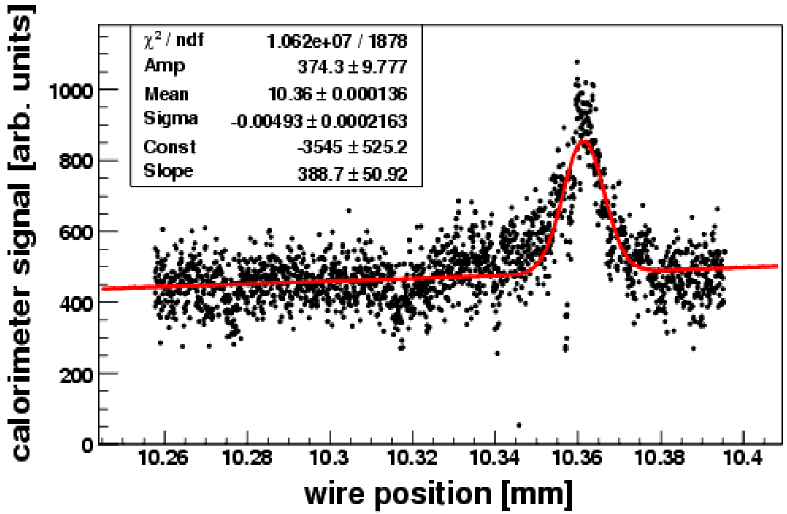
- Previous (summer 06) measurements asymmetric
- Laser beam alignment w.r.t. FF lens optimised
- New scan symmetric; spot size smaller

Normalisation

Top: Cerenkov
Bottom: Calorimeter

- Fluctuation in bunch charge, laser power and beam position possible sources of error
- Charge variation: in WCM 5.5%, in ICT 8.8%
- Fluctuation in detector signals when beams not in collision 13%
- In future, laser power, bunch charge, beam positions will be monitored

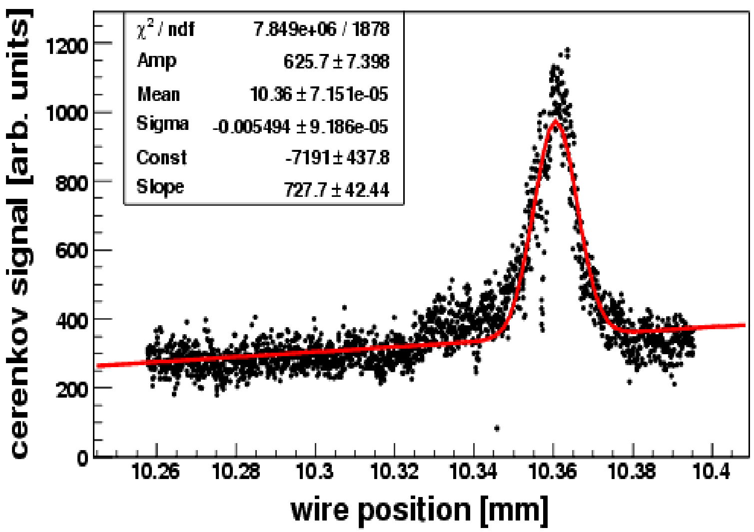


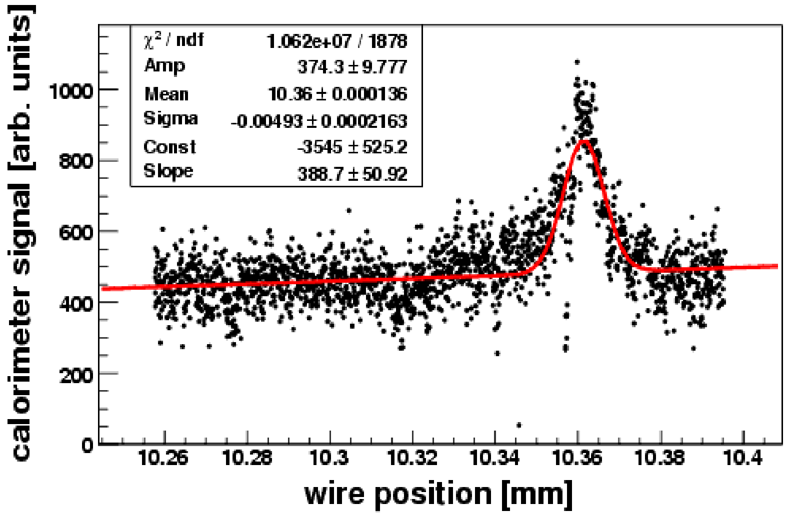


Signal to Noise

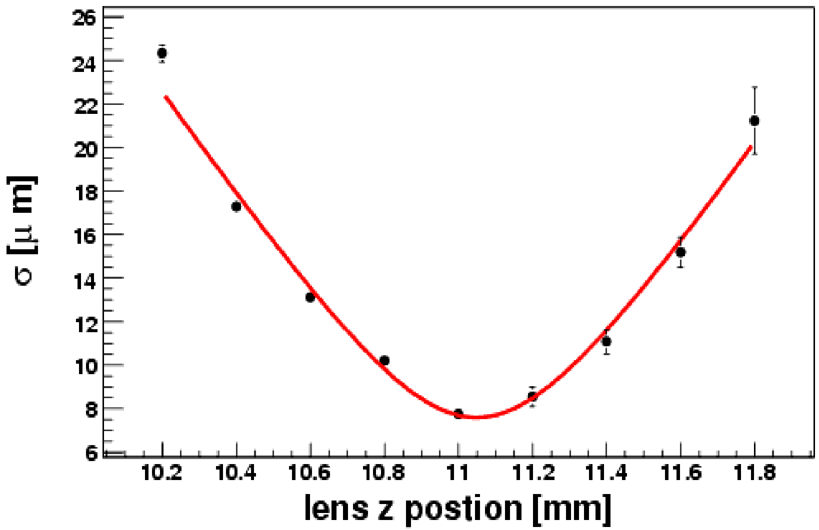
Top: Cerenkov
Bottom: Calorimeter

- Cerenkov signal to noise 1.8
- Calorimeter signal to noise 0.8
- Cerenkov does not detect particles below 3MeV
- Calorimeter measures both Compton and background below 3MeV, so more sensitive but suffers more from background





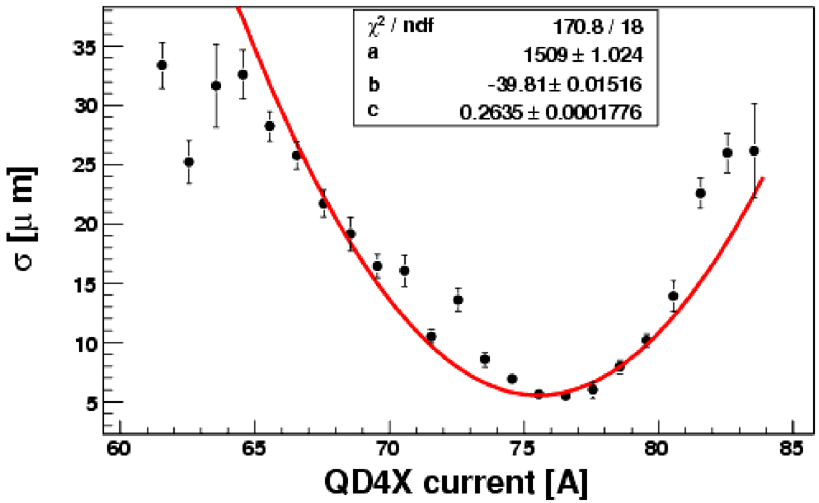
Laser Waist



- Moved lens relative to electron beam
- Scanned laser beam vertically
- Find focus of laser beam

$$\sigma_z = \sigma_0 \sqrt{1 + \left(\frac{z}{z_R} \right)^2}$$

Quadrupole Scan

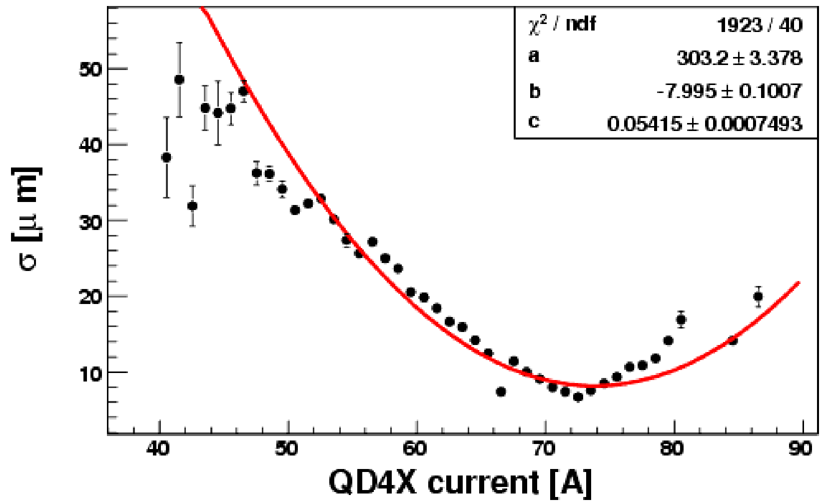


- Varied two upstream quadrupoles
- Scanned laser beam vertically

$$\sigma = a + bI + cI^2$$

Quadrupole Scan

- Another quad scan
- Clear size variation between 50 and 5 microns

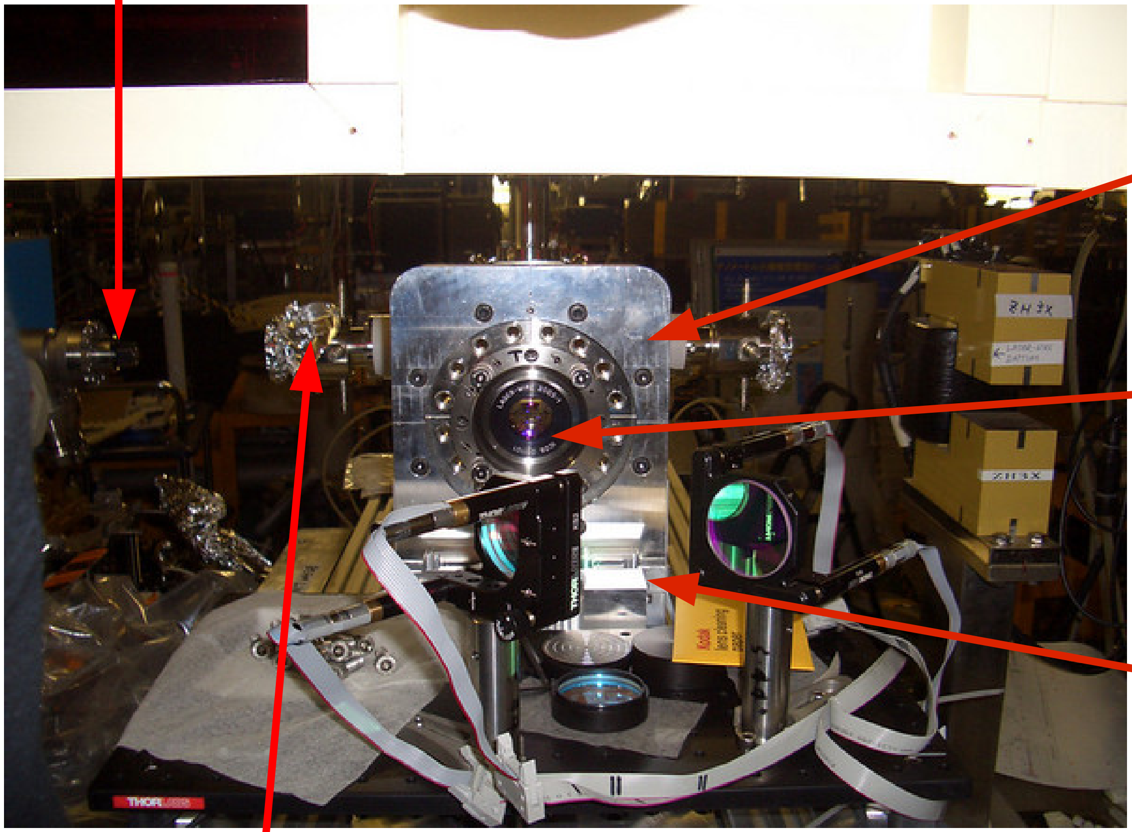


$$\sigma = a + bI + cI^2$$

Recent Upgrades

Beam line

Chamber now moves along 2 axes transverse to electron beam



New custom f#~1 lens now fixed to chamber

Two scanning mirrors

Strip line beam position monitors fixed to chamber

Summary

- Smallest measurable beam size 5.4 μm
- Electron beam size changed -> clear variation in measured beam size
- Lead glass calorimeter installed. Suffers from low energy background
- Studies indicate calorimeter slightly more linear than Cerenkov detector
- Both detectors acceptable for beam size measurement
- Recent upgrades should lead to ILC design goal of 1 μm