ATF Extraction Line Laser-Wire

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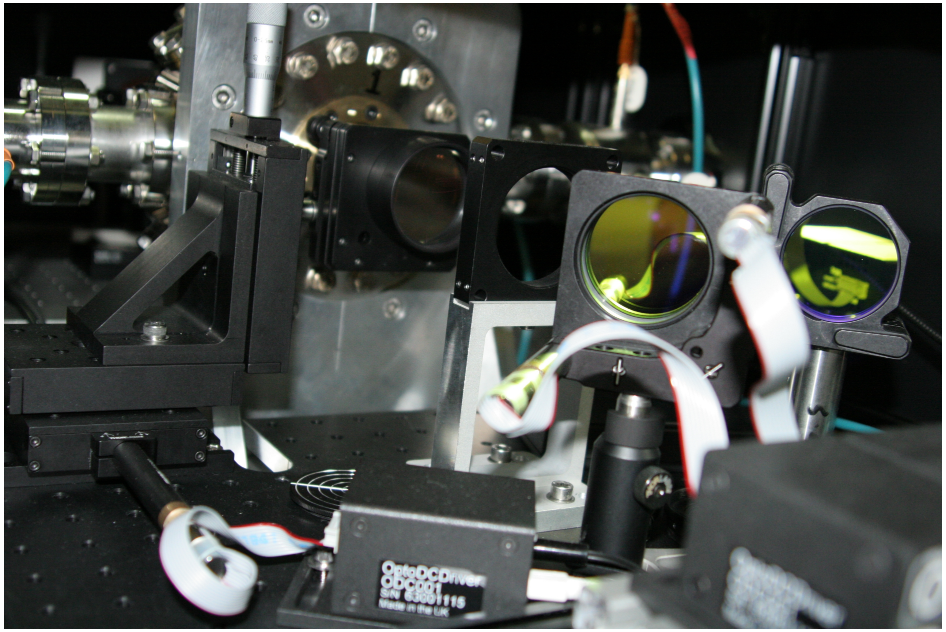
IOP HEPP Particle Physics 2008, Lancaster



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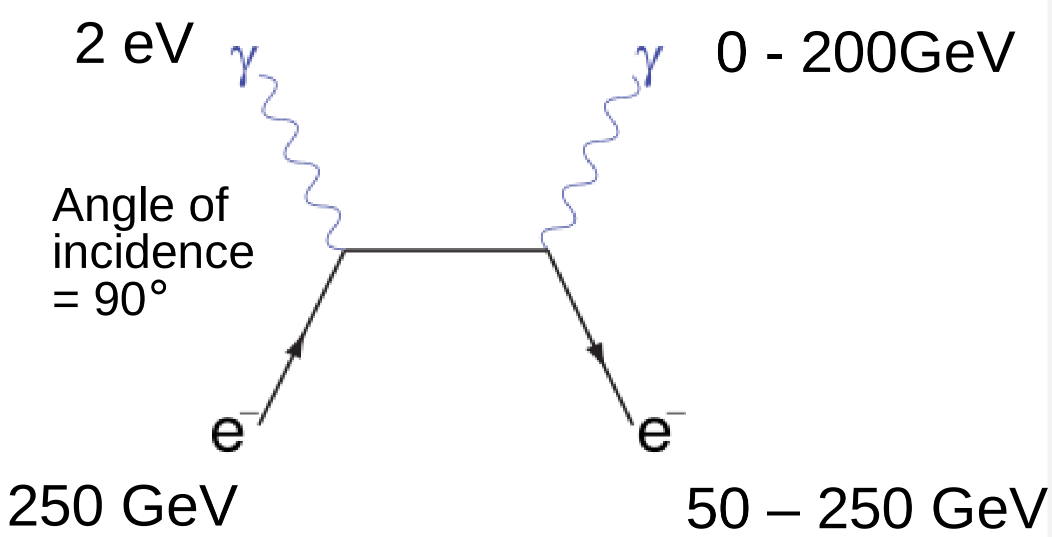
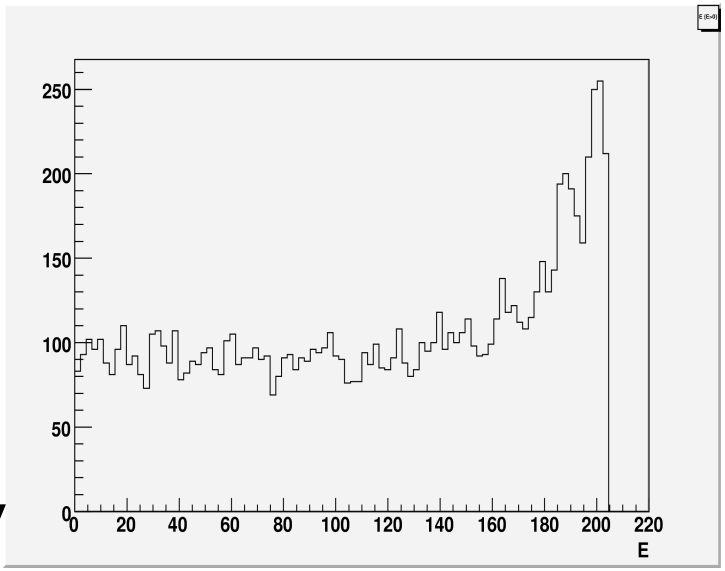
Introduction

- A means of measuring transverse **beam sizes essential** for future high luminosity linear collider.
- Typical beam sizes to be measured ~few *μ*m, worst case *μ*m, to within ~few % in order to measure beam **emittance.**
- **Aim:** to develop a system which can**non-invasively** measure **1 *μ*m beam sizes**
- **Method**: use a finely focused pulsed laser beam and measuring rate of **inverse Compton scattering** as a function of relative **displacement**.



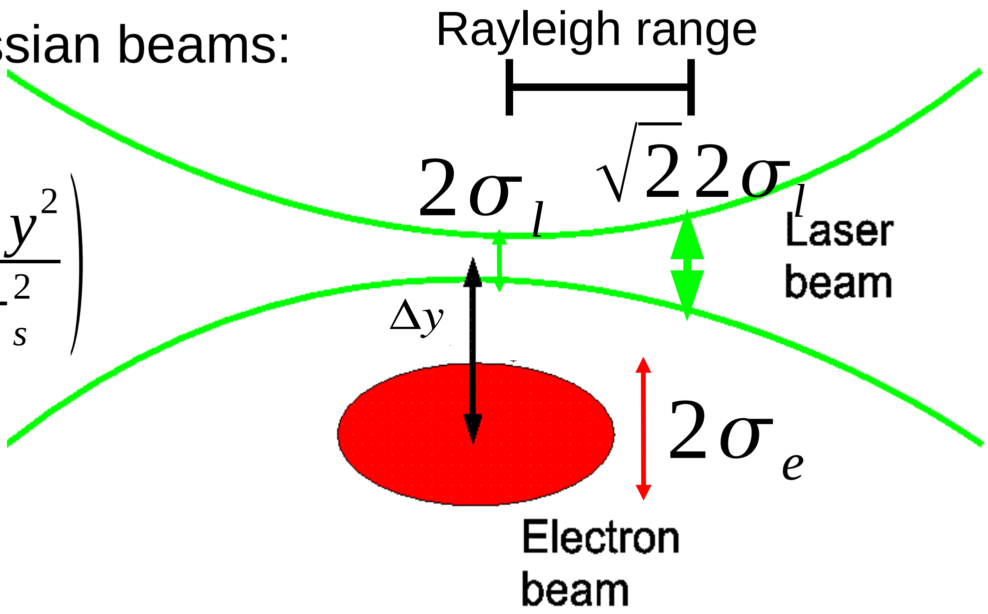


Compton Scattering Rate

- Compton scattering rate for Gaussian beams:

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

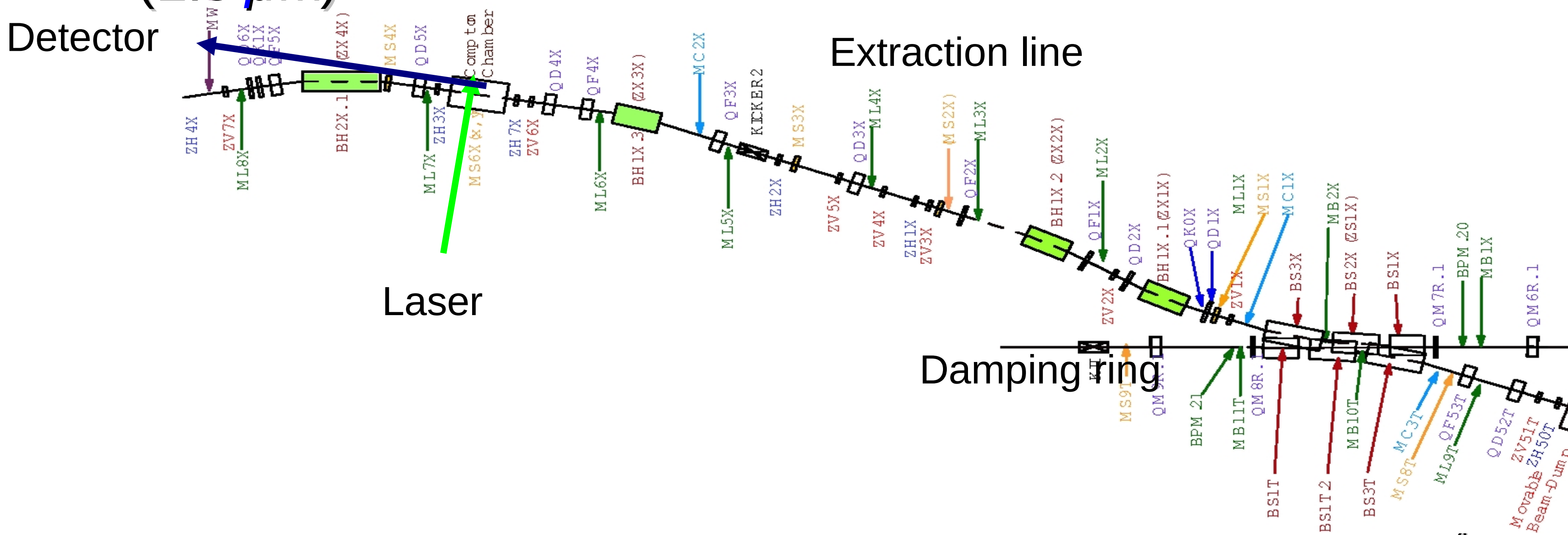
$$\sigma_s^2 = \sigma_e^2 + \sigma_l^2$$



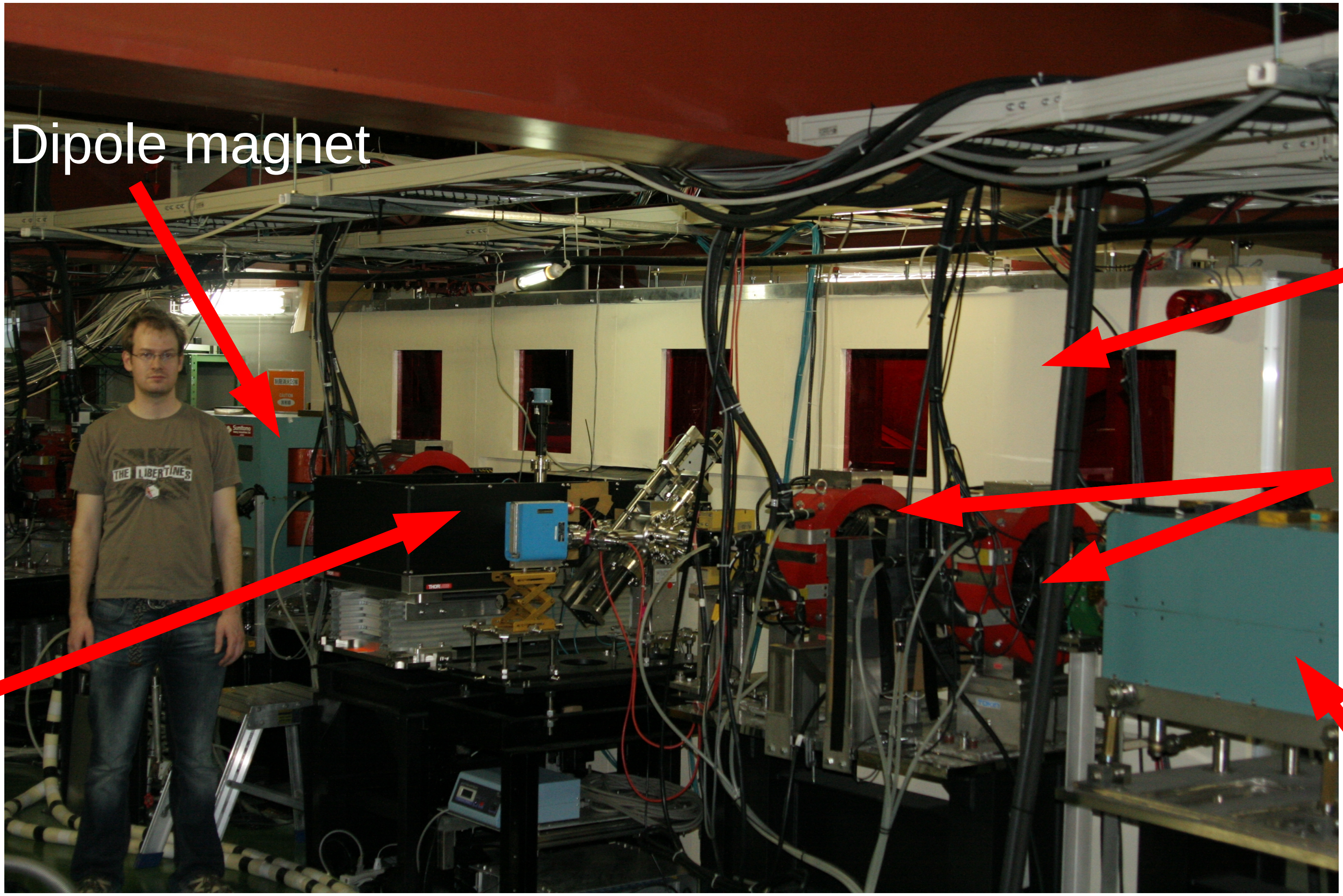
- By measuring Compton rate (N_γ) as a function of relative displacement (Δy), the quadrature sum of the beam sizes (σ_s) can be determined
- If laser beam size is known then the electron beam size can be determined

ATF Electron Beam Optics

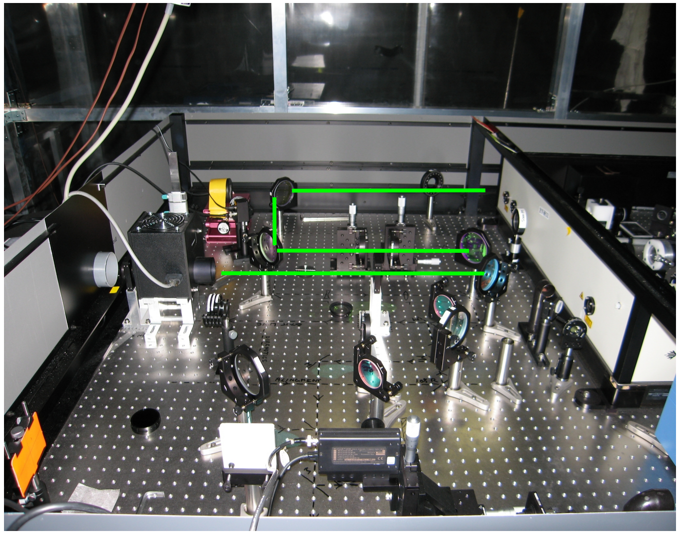
- Modified to produce electron beam sizes from ~50 μm down to the ILC like 20 μm X 1 μm
- ATF beam energy 1.3GeV
- Optics verified using wire scanner.
- Vertical beam size smaller than wire scanner resolution (2.5 μm)

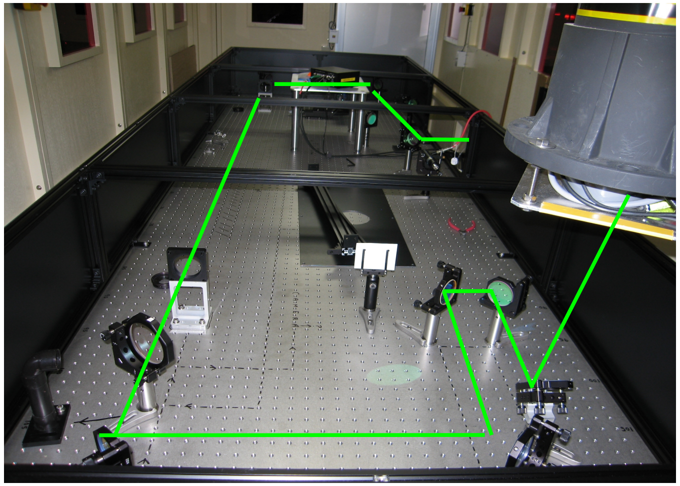


ATF Extraction Line



Laser

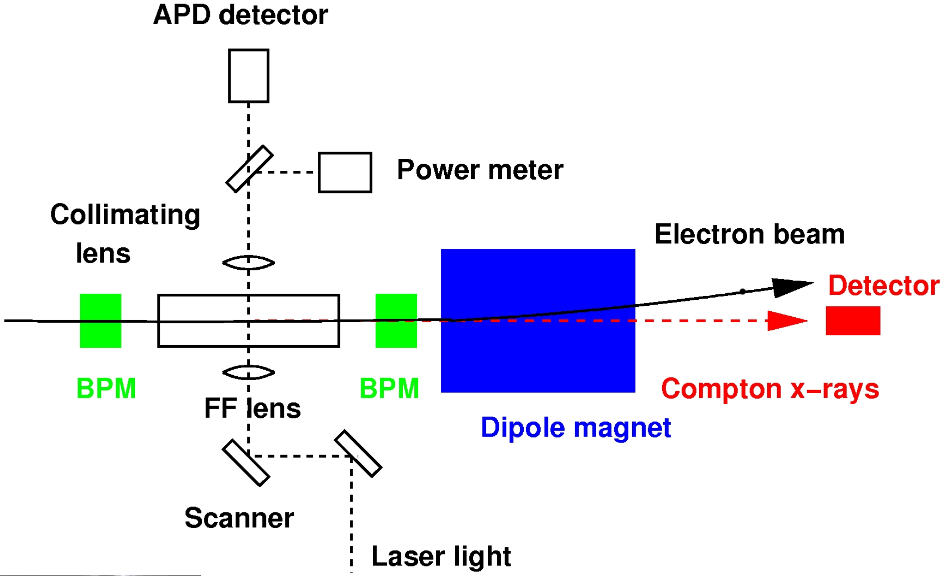




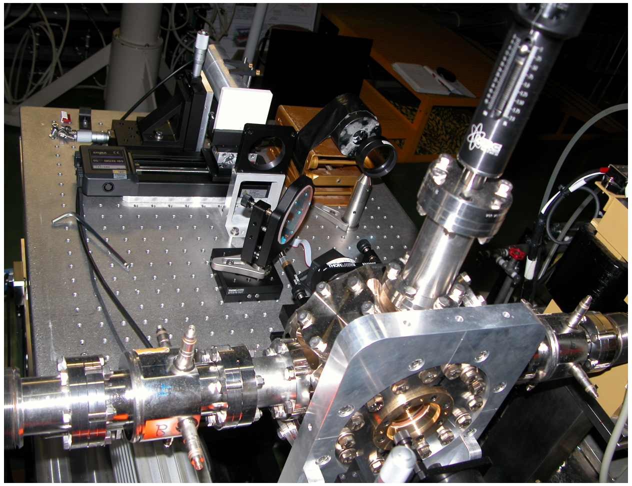
- High energy green (λ=532nm) laser pulses
- Amplify a single pulse from passively mode-locked seed laser
- Frequency locked to ATF RF distribution system at 357MHz
- Pulse duration ~150ps
- Pulse energy ~30mJ
- Laser light is transported collimated to extraction line by series of mirrors and aligned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

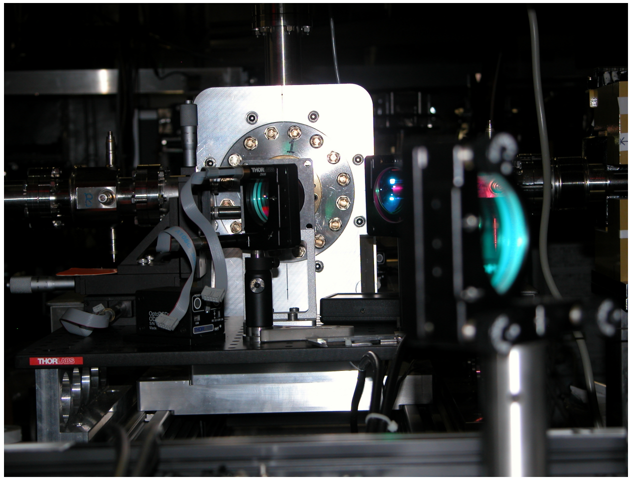
Interaction point

- FF lens mounted on a 3 axis translation system

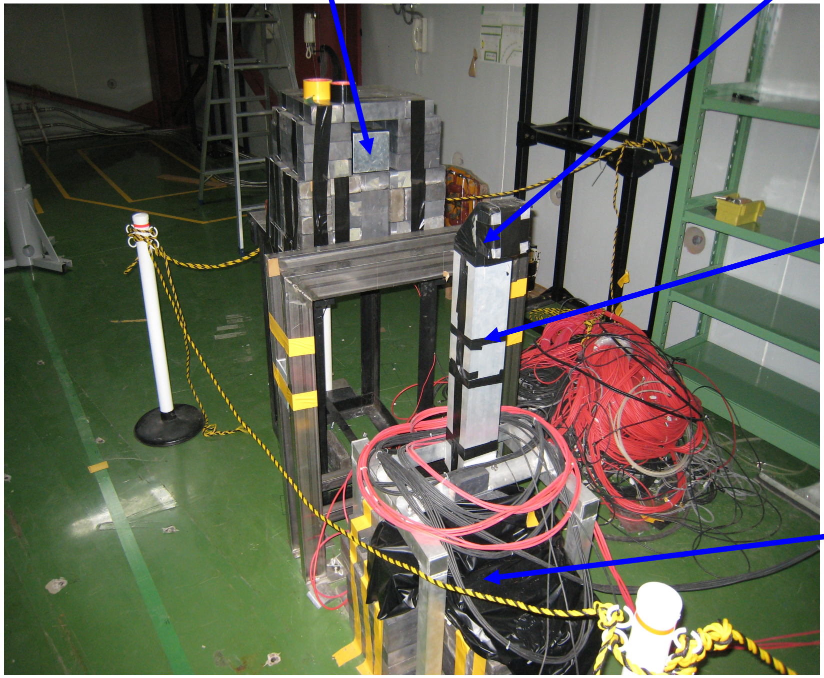


- Light steered onto final focus (FF) lens using 2 mirrors





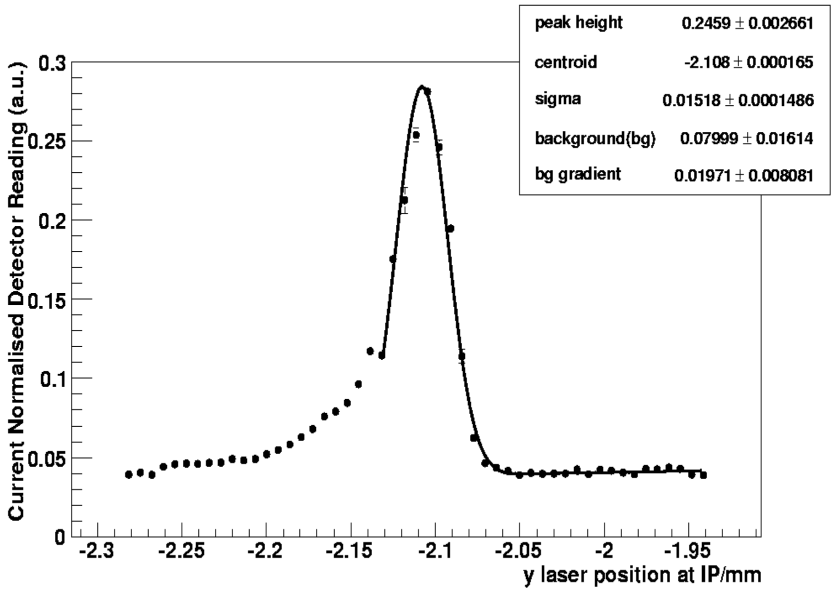
Detectors

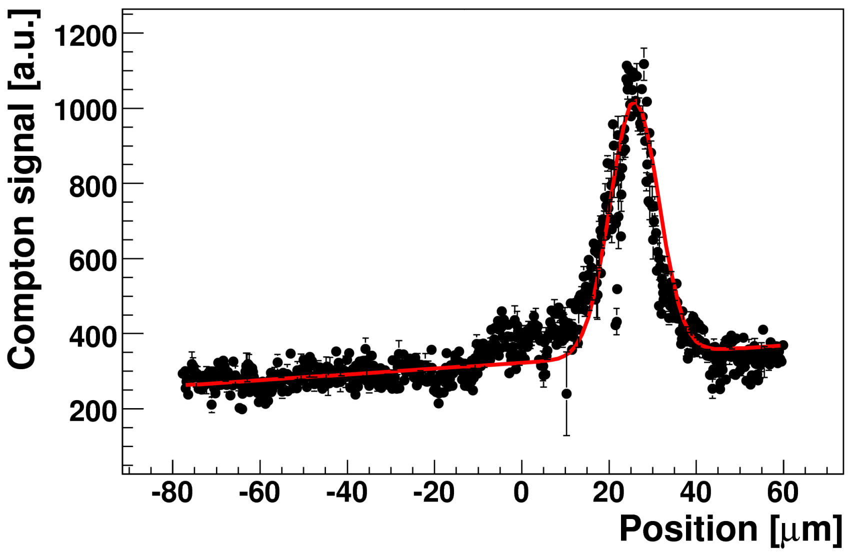


- 2 detectors for measuring the LW Compton rate (N)
- SP-15 aerogel Cerenkov detector:
- Cerenkov threshold = 2.983 MeV
- Lead glass calorimeter:
- 365mm long
- Signal pulses from PMTs digitised using multi channel gated analogue to digital converter

Vertical Beam Profile

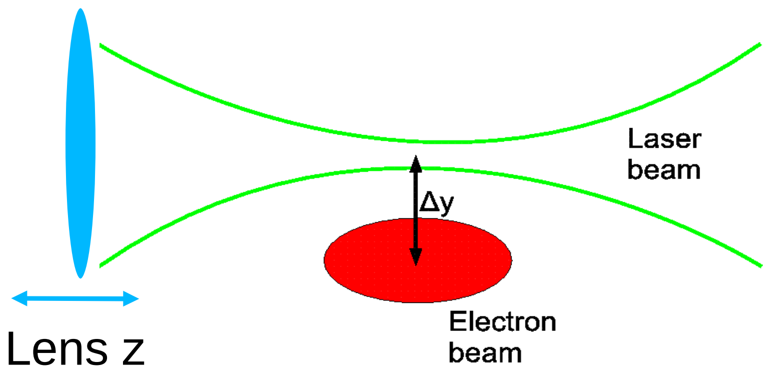
Summer 2006. 15 μm | Summer 2007. 5.4 μm



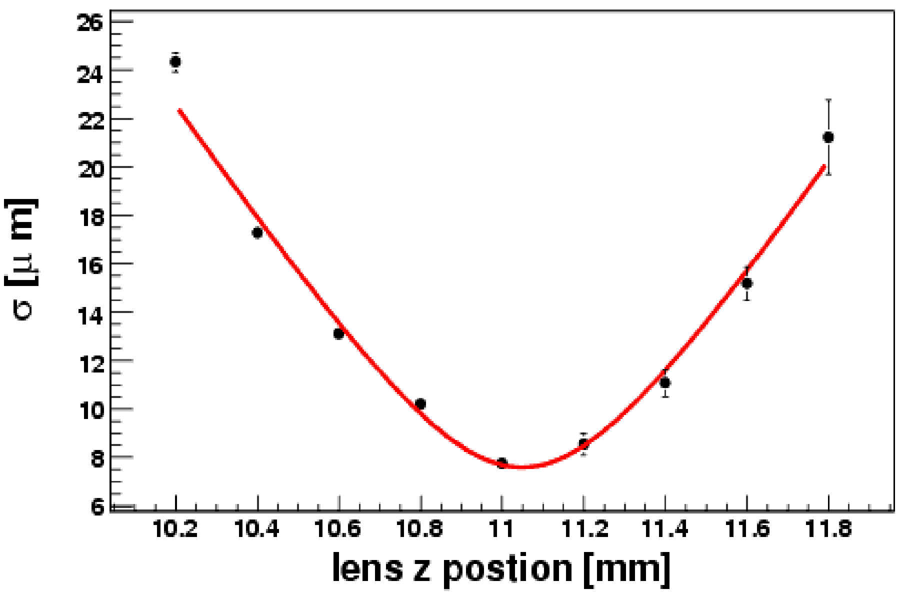


- Summer 2006 measurements asymmetric
- Laser beam alignment w.r.t. FF lens optimised
- Summer 2007 scan more symmetrical; spot size smaller

Laser Waist



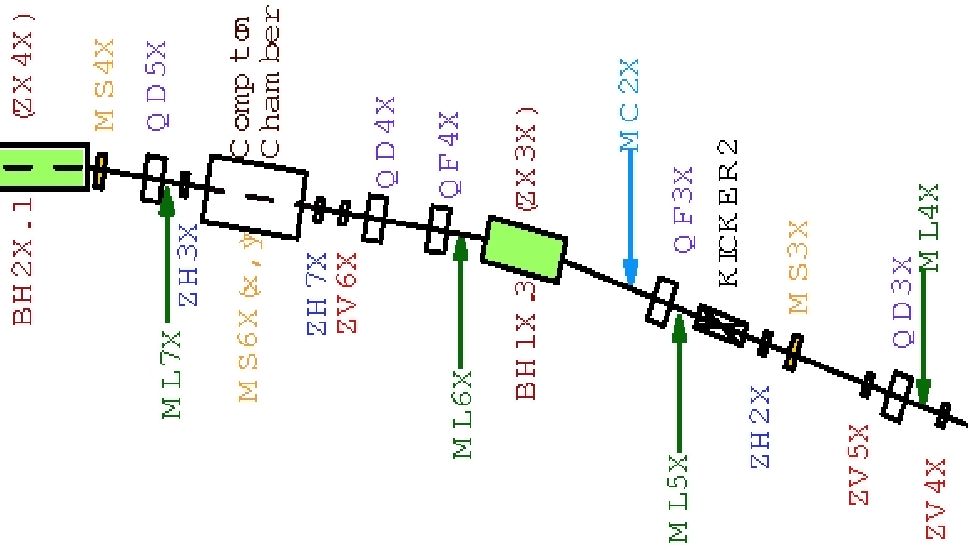
- Moved lens relative to electron beam
- Scanned laser beam vertically
- Find focus of laser beam

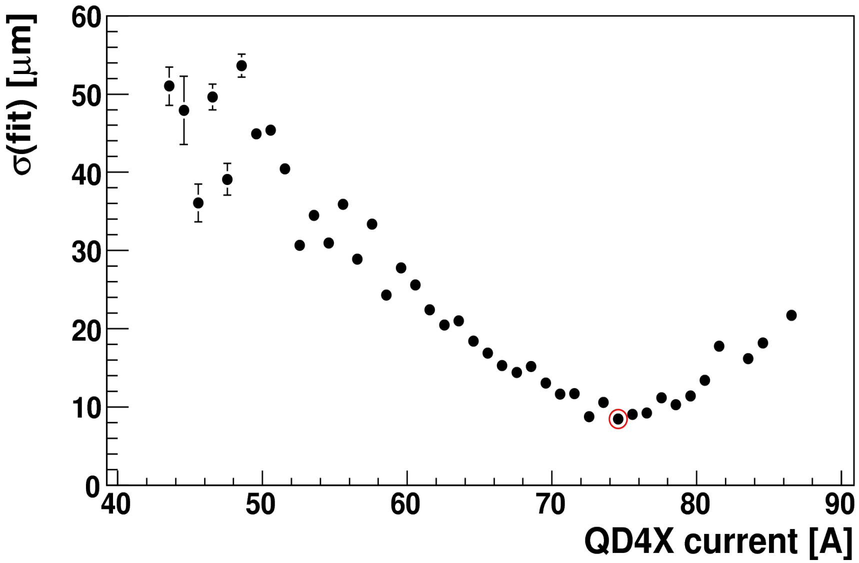


$$\sigma_z = \sigma_0 \left(1 + \left(\frac{z}{z_R} \right) \right)$$

- Minimum consistent with optical measurements of laser and lens

Quadrupole Scan



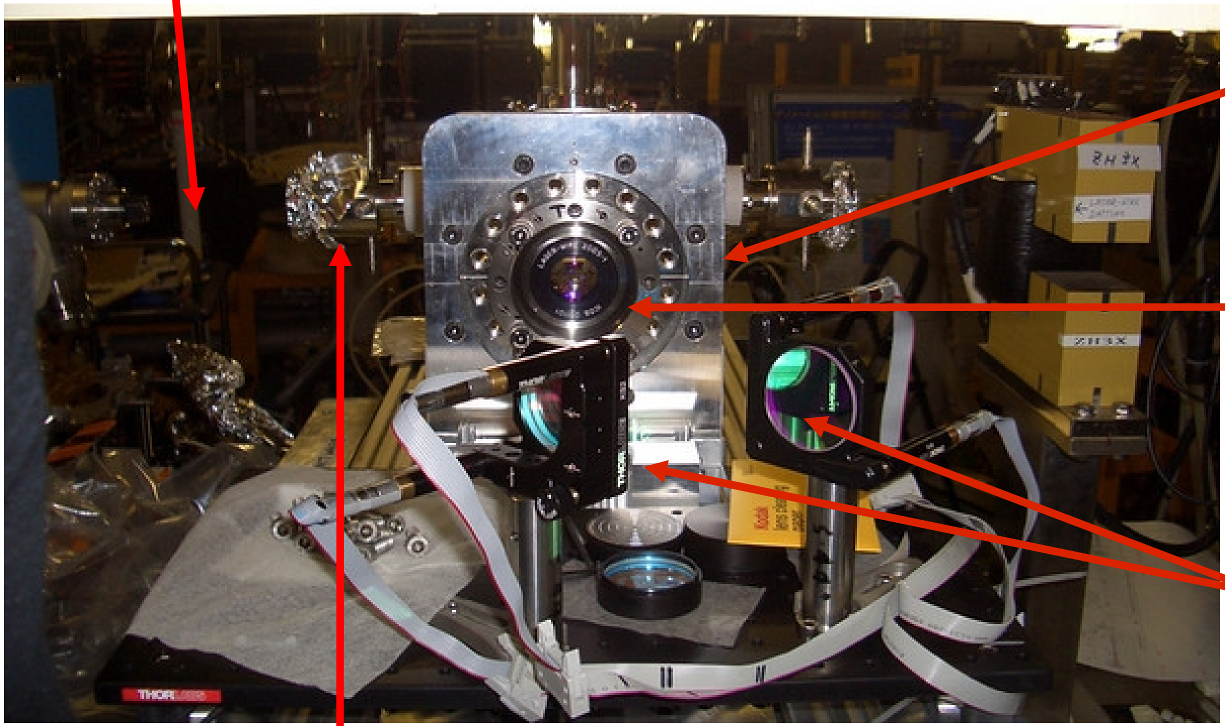


- Changed current in two upstream quadrupoles, QD4X and QF4X
- Scanned laser beam at each quad current setting
- Clear size variation between 50 and 8 microns

Upgrades – Summer 2007

Beam line

Chamber can now be moved along 2 axes transverse to electron beam

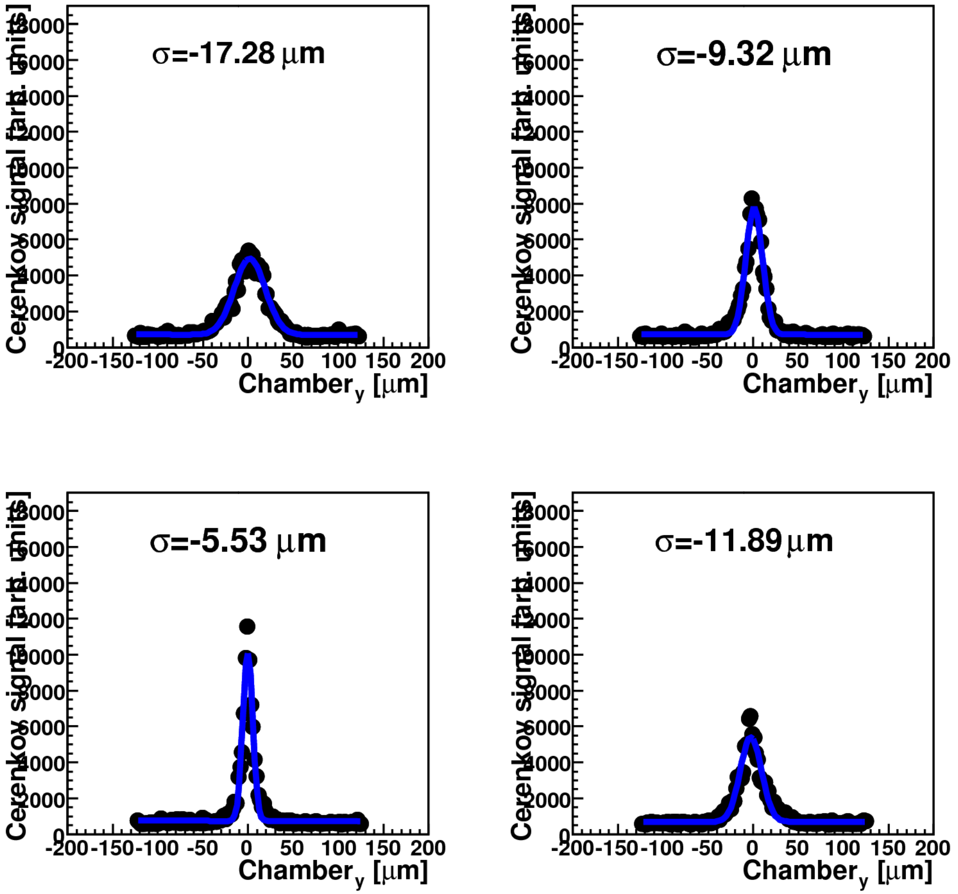


New custom f#~2 lens now fixed to chamber

Two scanning mirrors

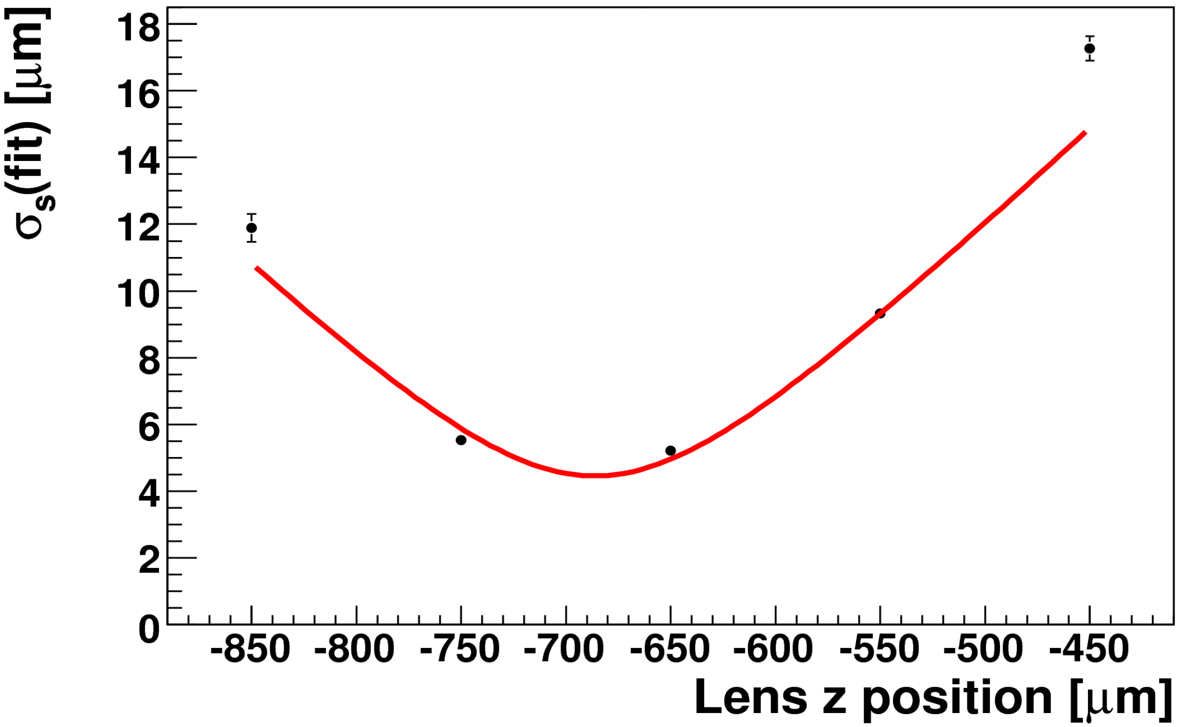
Strip line beam position monitors fixed to chamber

New Results- Feb 2008



- A waist scan using the new system
- Each profile is taken at a different lens z position

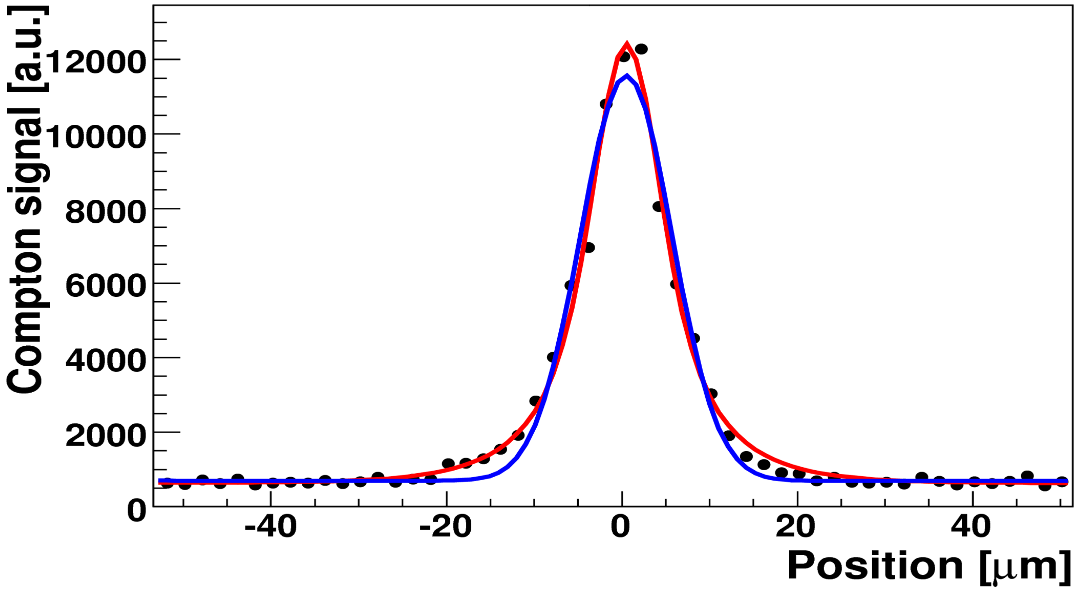
New Results- Feb 2008



- Fit function: laser propagation function
- Fit result: $\sigma_0 = 4.5 \pm 0.1\, \mu m$

$$\sigma_l(z) = \sigma_0 \sqrt{1 + \left(\frac{(z - z_0) M^2 \lambda}{\pi \sigma_0^2} \right)^2}$$

Improvements to Fit



- Working on including effects of **Rayleigh range** of the laser beam and the **horizontal electron beam size** in the fit function
- Measuring input parameters: **quality factor of laser, f# of lens, astigmatism effects etc.** accurately to extract electron beam size

Summary

- Explained basic principles of laser wire
- Described experimental set up at ATF
- Presented early results
- Described upgrades in 2007
- Presented more recent results

- System now works well down to a few microns
- Plans: work is now underway to correct astigmatism in the laser. This will help bring the resolution nearer the goal of 1µm.