# Laserwire at PETRA

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Accelerator Physics Topics, LCWS, Paris

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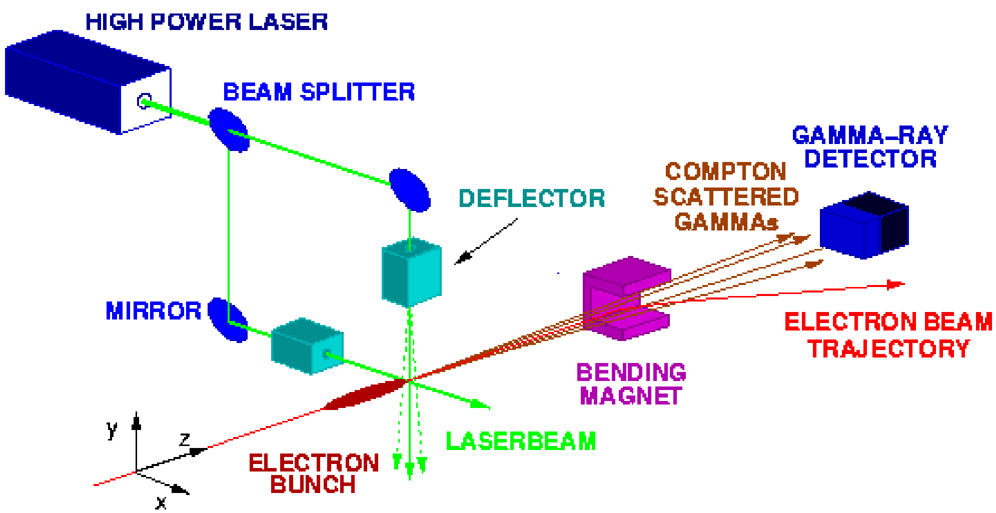
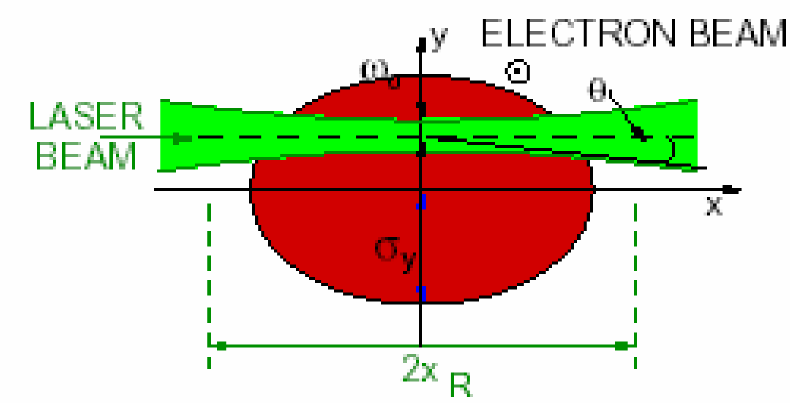
# The next 20 minutes

- Laserwire principle
- Signal and backgrounds
- Environment at PETRA
- Hardware Installation
- Laser parameter measurements
- First Compton signal
- First full profile measurements
  - with orbit bumps (October 2003)
  - using the fast scanner (December 2003)
- Laser beam diagnostics (April 2004)
- Plans for upgrade of PETRA Laserwire
- Conclusion and Outlook

# Laserwire principle




- Laserwire
  - Similar to traditional wire scanners.
  - Signal: Compton scattering
  - Translate laser transversely across electron beam and monitor Compton rate

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

# Signal and Backgrounds

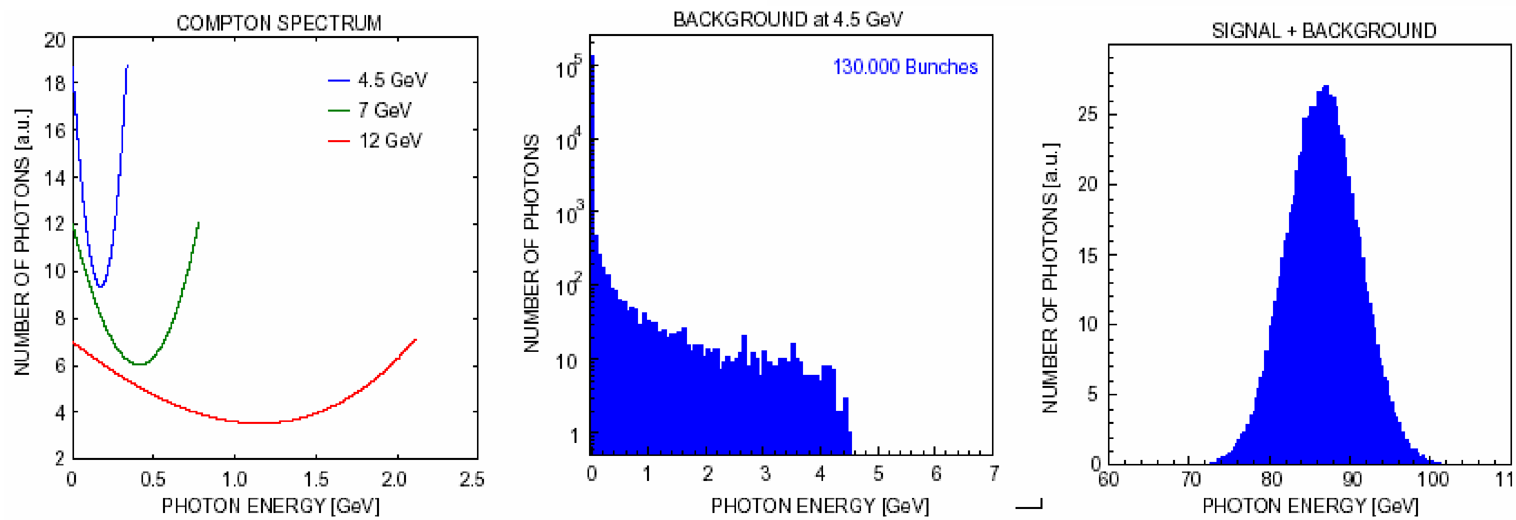
- Signal: Compton scattering
- Background sources:
  - Synchrotron radiation
  - Cosmic rays
  - Bremsstrahlung
- Simulation with Geant4 plus tool kits with realistic set up

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

P = 2 MW

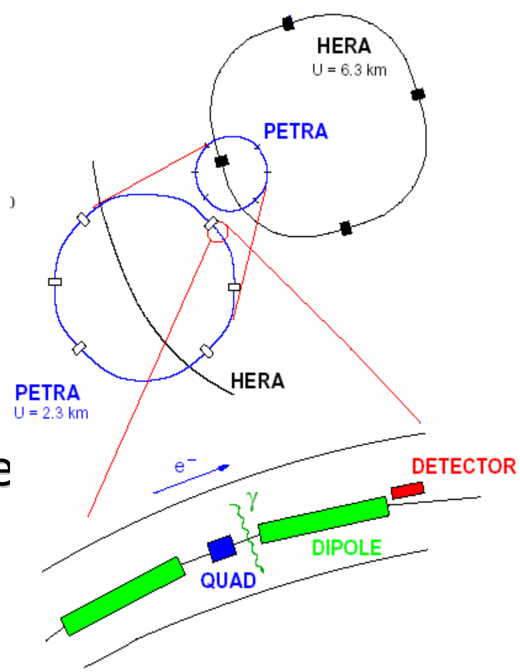
| $\sigma_x/\sigma_y$ [$\mu$m] | Beam Energy [GeV] 4.5 | 7 | 12 |
|---|---|---|---|
| 500/50 | 115/689 | 257/664 | 685/619 |
| 300/30 | 185/1111 | 416/1070 | 1056/998 |
| 100/10 | 415/2485 | 930/2393 | 2362/2231 |

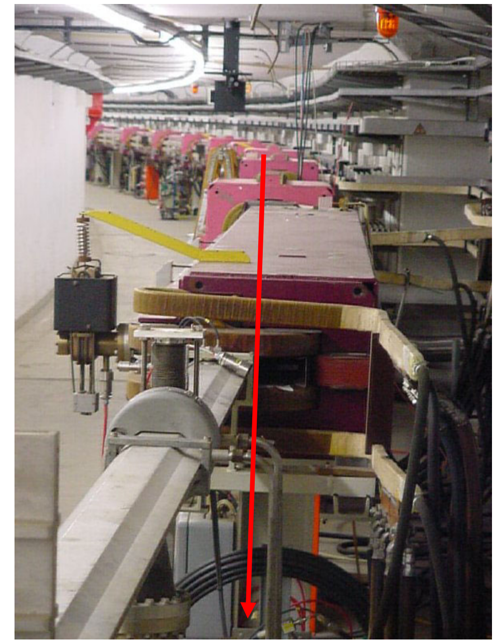
$E_{tot}$[GeV]/$N_\gamma$



# PETRA Environment

- Positron Electron Tandem Ring Accelerator
- Injector for HERA, upgrade to synchrotron light source
- Long free straight section
- Easy installation of hardware due to existing access pipe and hut outside tunnel area
- New IP chamber with viewports and BPM
- Dedicated run time between HERA fills
- Parasitic running during HASYLAB operation
- Training of people to run the machine, bumps



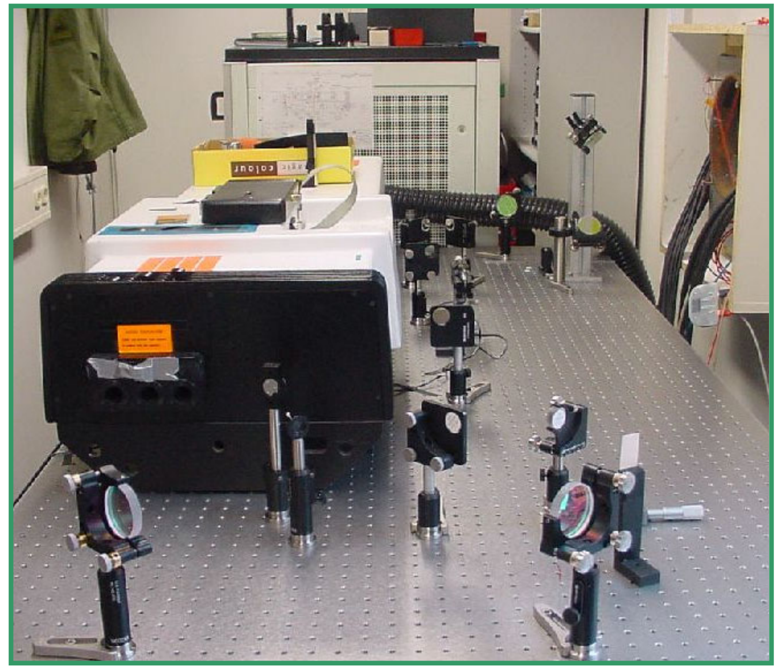



| | | |
|---|---|---|
| Energy | E/GeV | 4.5 to 12 |
| Bunch Length | $\sigma_z$/ps | ~100 |
| Charge/bunch | nC | 3 to 20 |
| Hor. beam size | $\sigma_x/\mu m$ | 1000 to 100 |
| Ver. beam size | $\sigma_y/\mu m$ | 100 to 10 |

# Laser

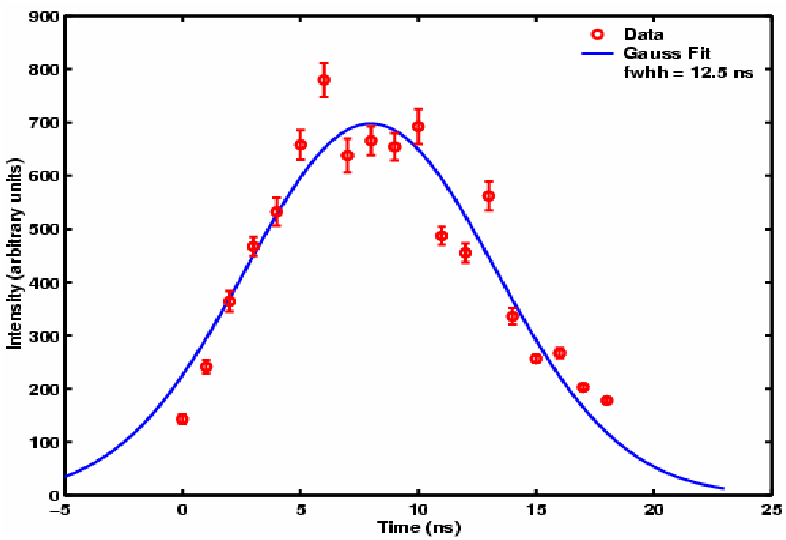
LBBD Laserwire

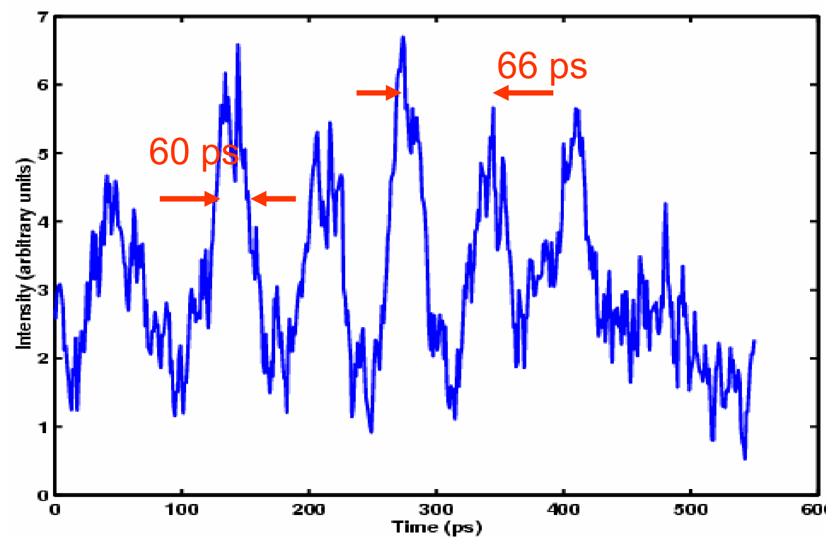
- Claimed from CERN, LEP polarimeter (B Dehning)
- Q-switched Nd:YAG with SHG
- Almost 20 years old
- Complete refurbishment at Oriel workshop, new YAG crystal
- External trigger unit CERN/RHUL enabling synchronisation with PETRA timing
- Transverse mode quality poor with $M^2$ ~ 10 to 15
- Longitudinal mode quality ± 20%, mode beating with picosecond substructure



| | | |
|---|---|---|
| Wavelength | $\lambda$/nm | 1064/532 |
| Energy | E/mJ | 250/90 |
| Pulselength | dt/ns | 10 |
| Rep rate | $f_{rep}$/Hz | up to 30 |
| Beam size | $\sigma_{x,y}$ | $\leq$ 1 mm |

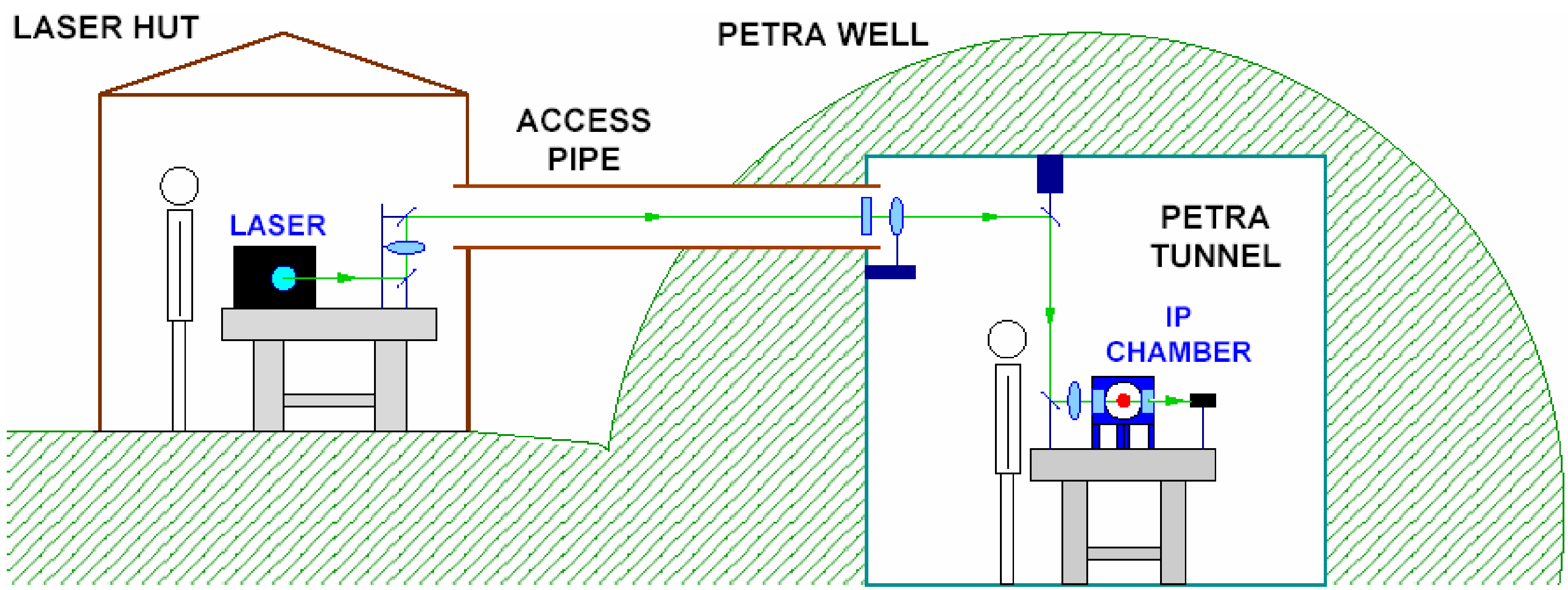
# Laser time structure



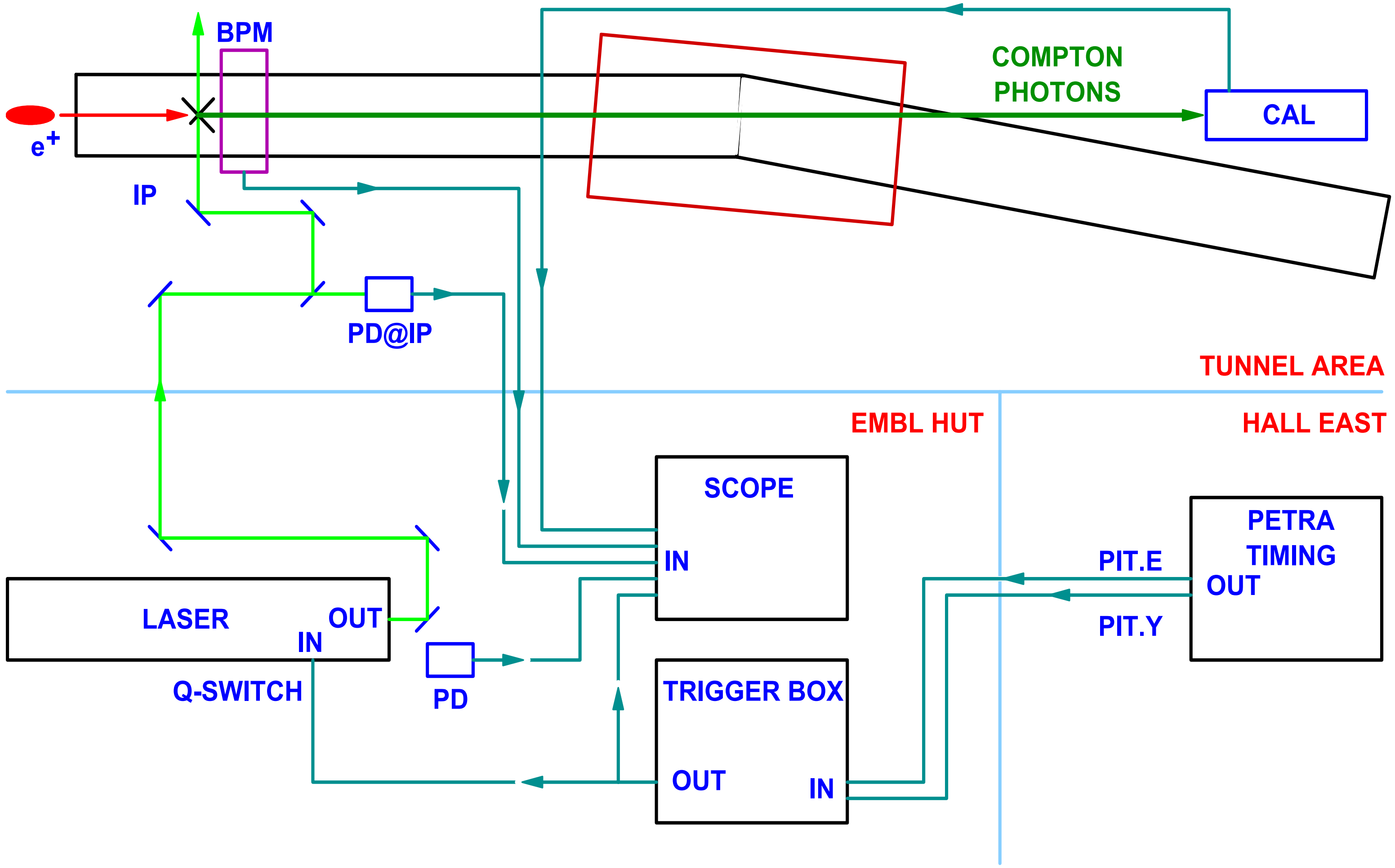




- Longitudinal profile measured with streak camera (Hamamatsu FESCA 200), triggered with laser pulse pickoff on photo diode
- Scan window of 200 ps width with 5 ps resolution moved over pulse
- Envelope 12.5 ns pulse length (FWHH)
- Structure under envelope
  - almost full contrast, ~ 70 ps peak to peak, ~ 70 ps peak width
  - unstable, beating changes from shot to shot
- ➢ Need etalon (short term), injection seed (mid term), or new laser (long term) to fix

# Setup at PETRA

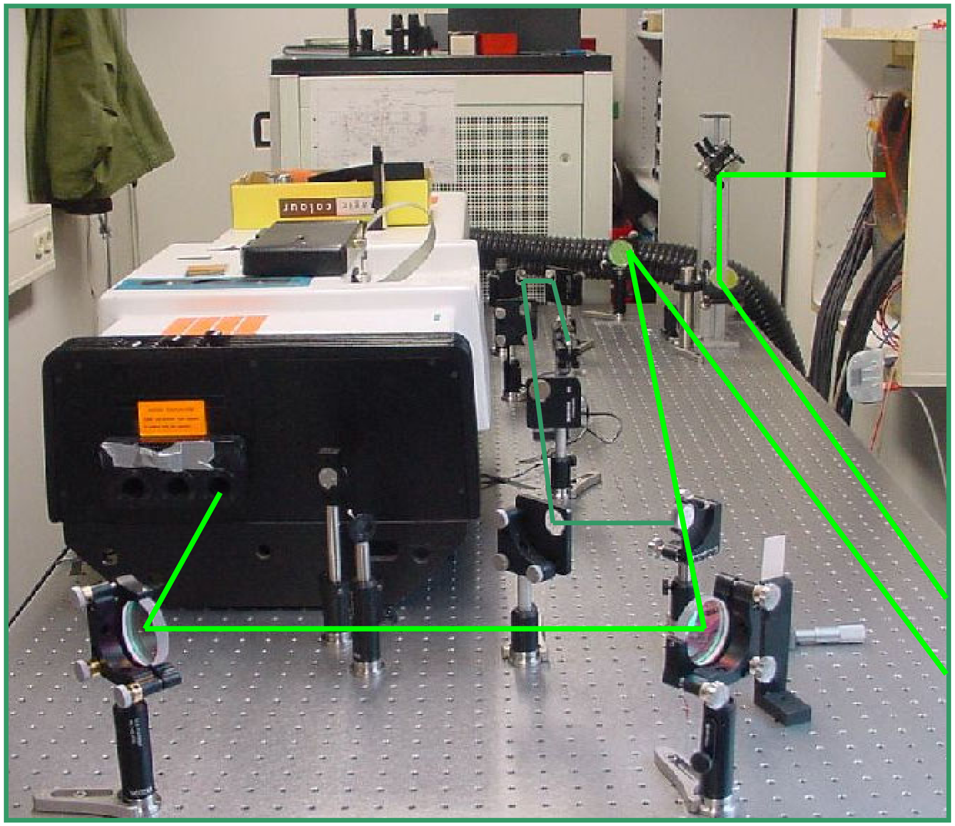


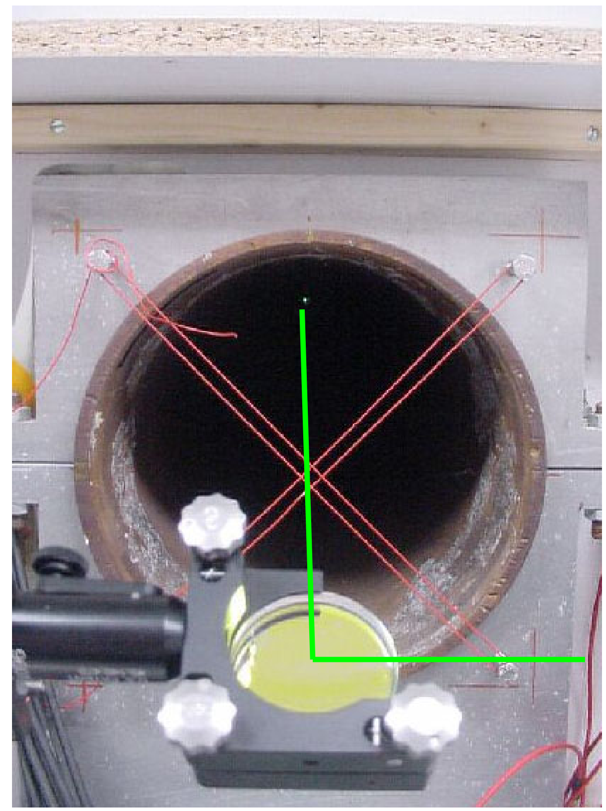
# Setup at PETRA (cnt'd)



# Installation at PETRA

LBBD Laserwire





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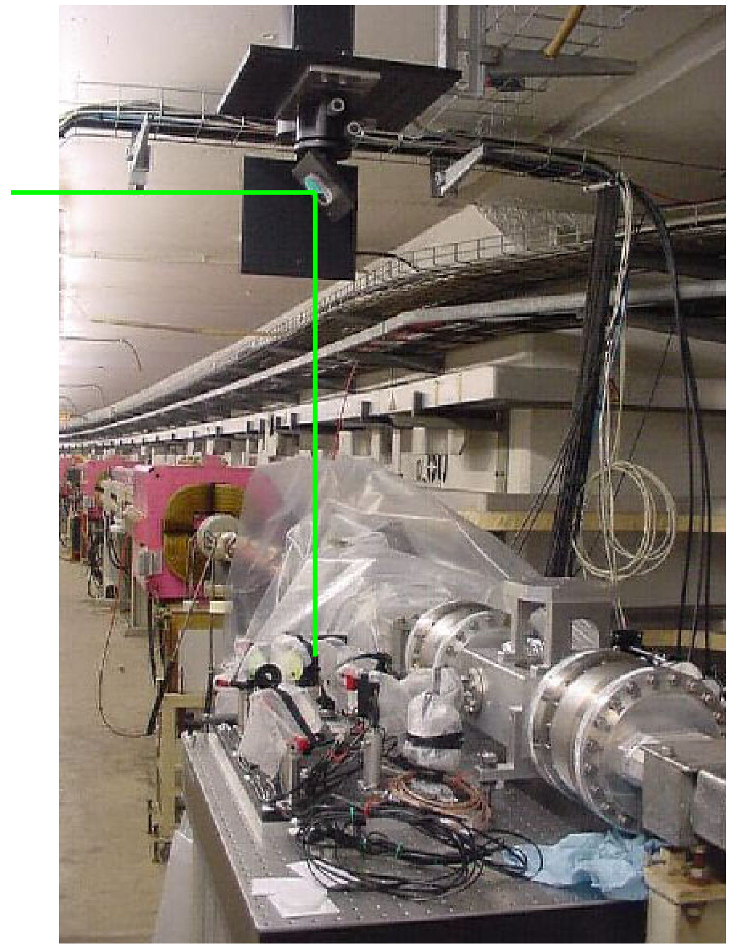

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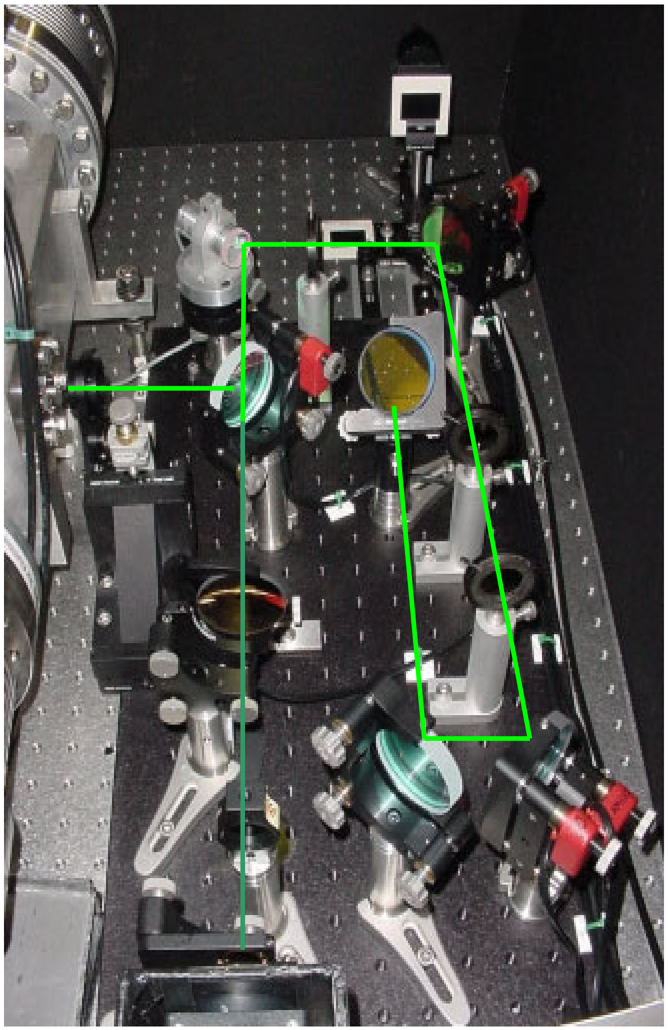
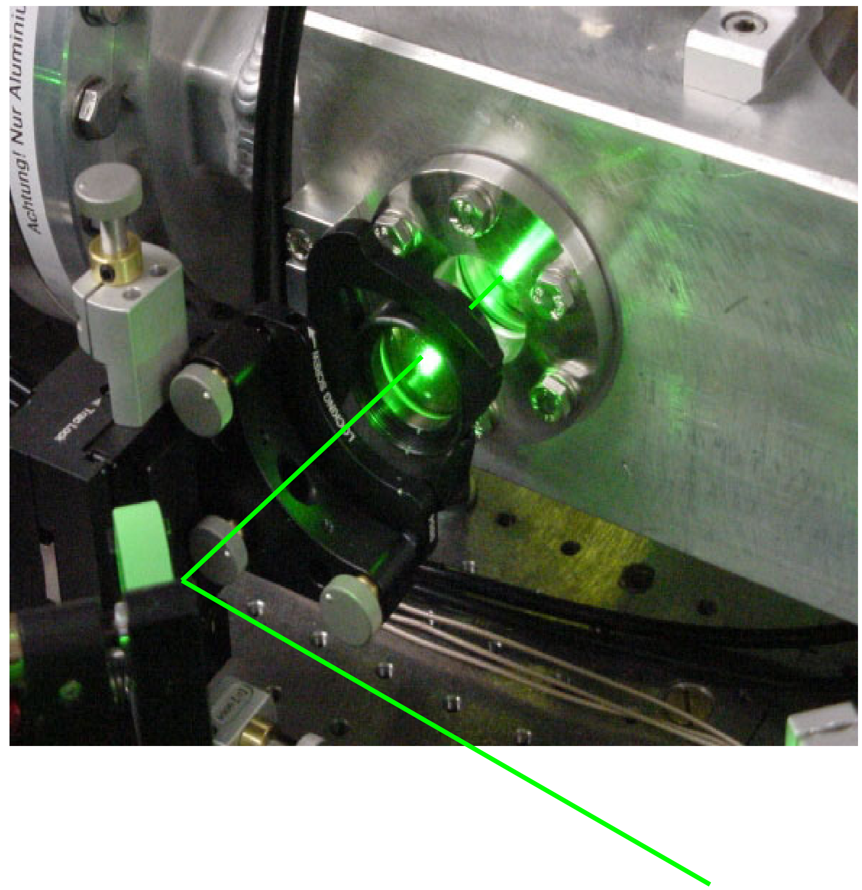
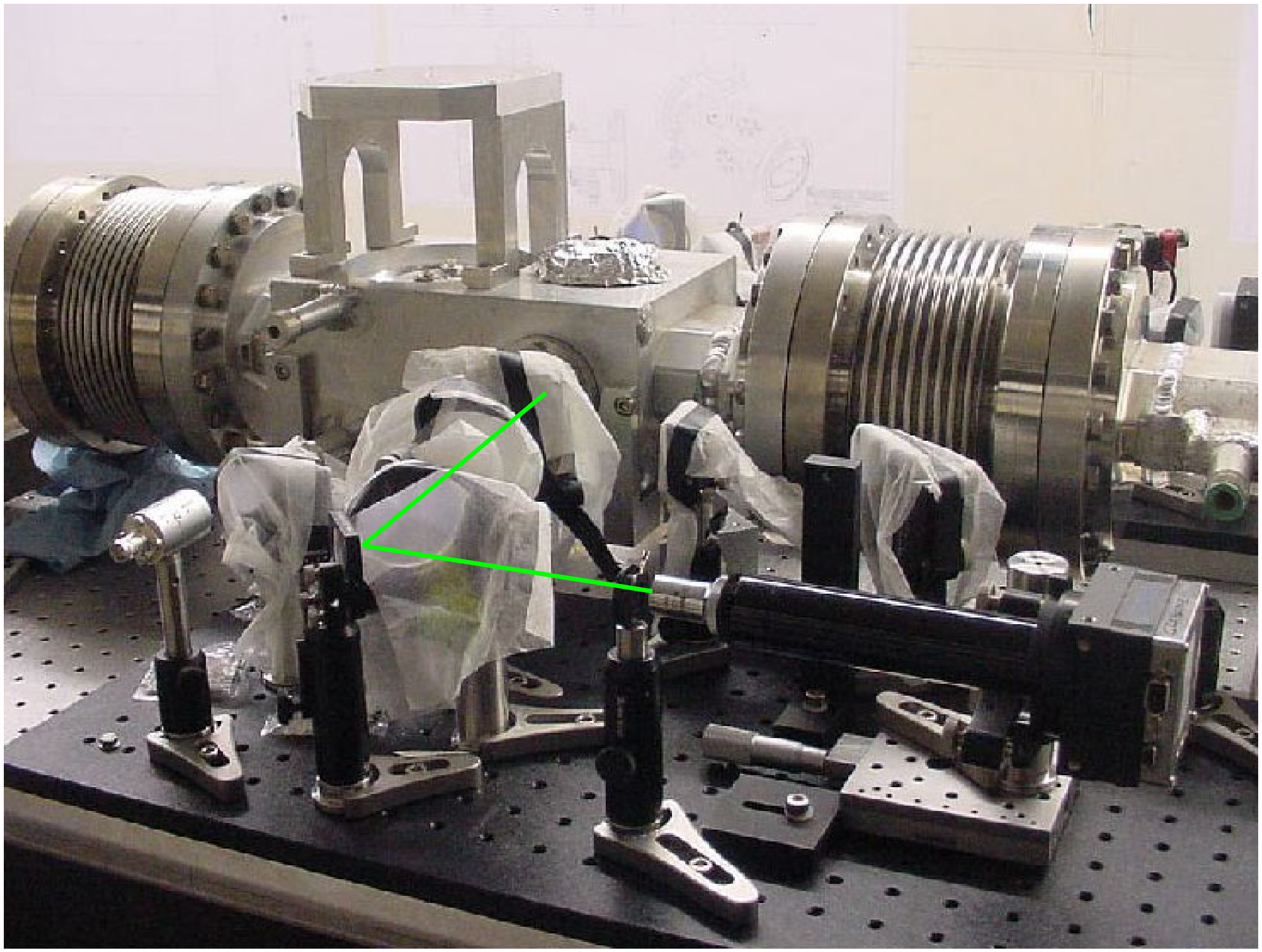




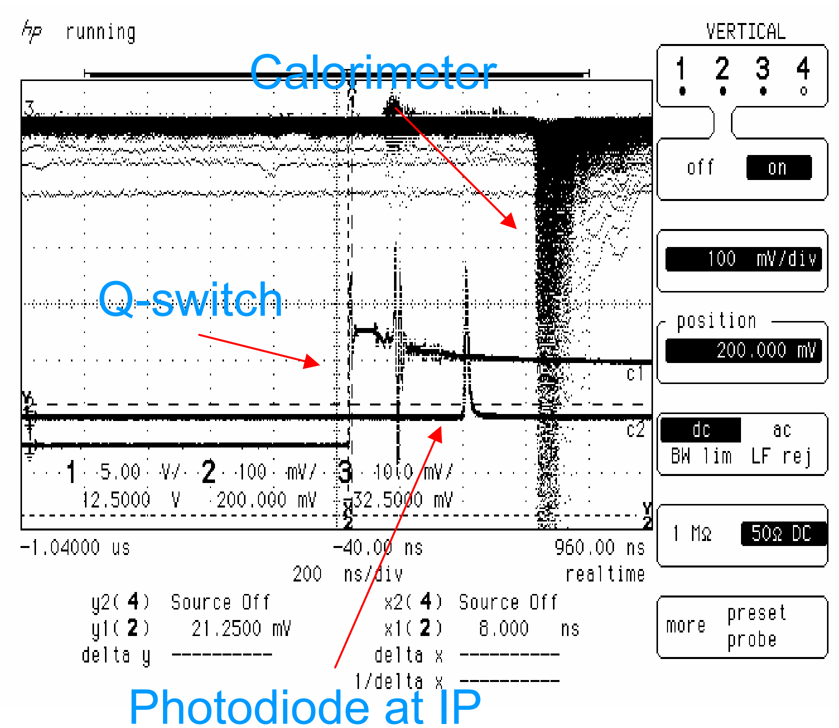
# Installation at PETRA

LBBD Laserwire

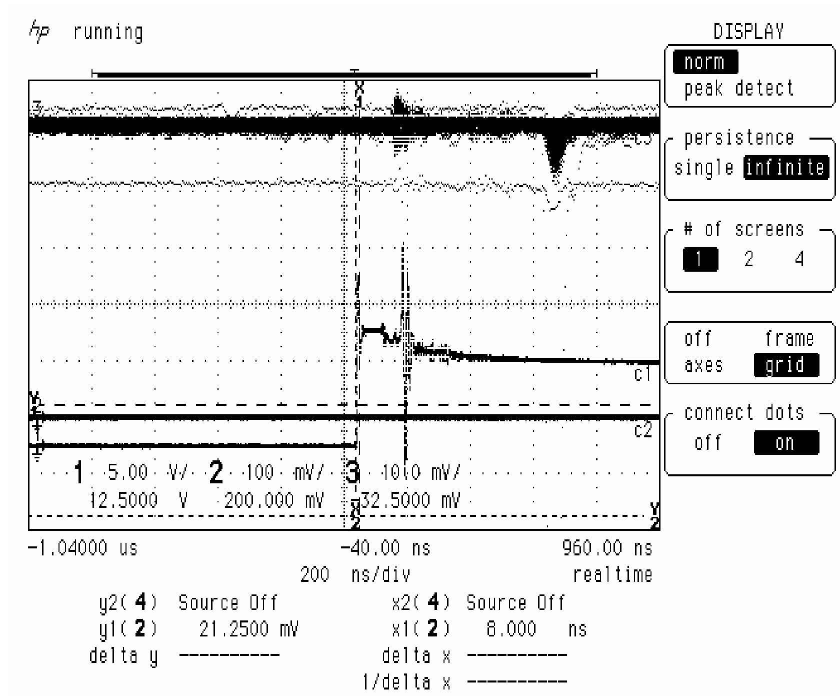


# First Photons 31.07.03

## Laser on




## Laser off

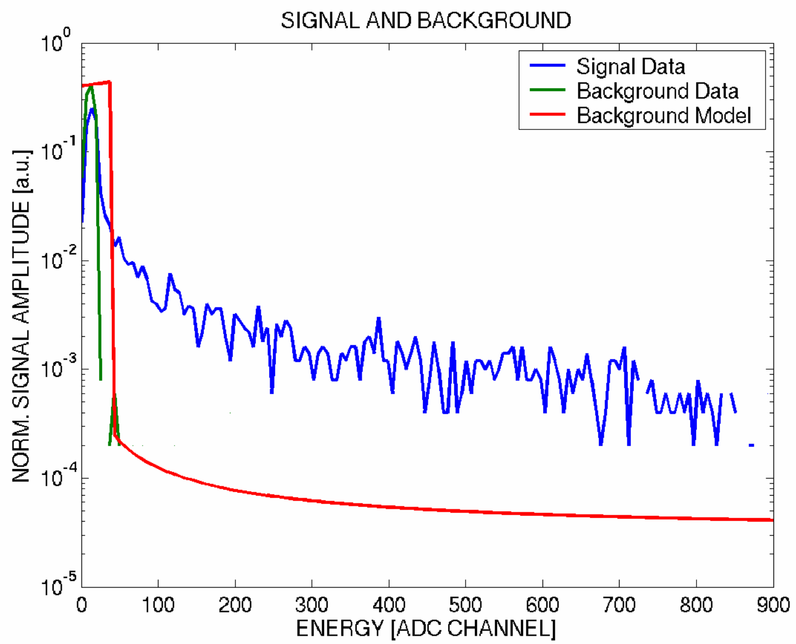


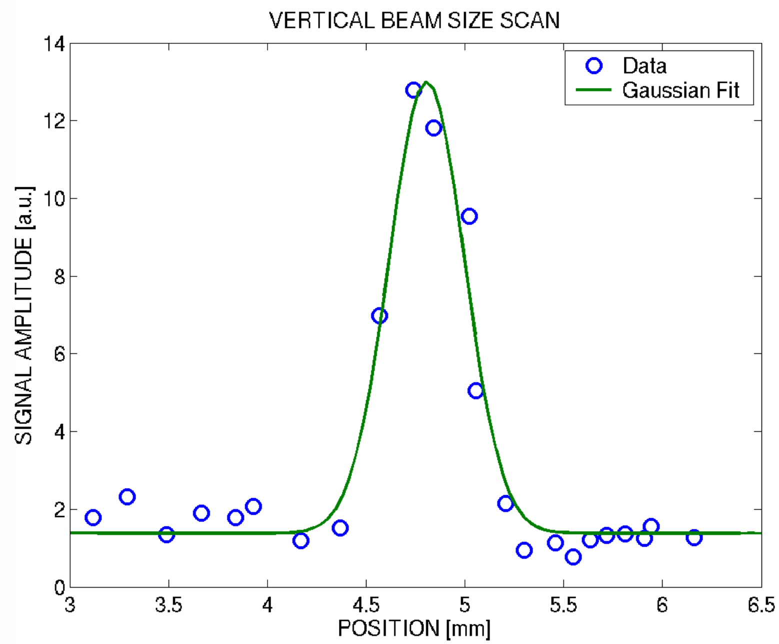
# Beam Profile Measurements

LBBD Laserwire

- Positron beam in PETRA at 7 GeV
- Two runs so far (one week with few hours of beam per day)
  - October: Tests with orbit bumps and piezo scanner
  - December: Operation of piezo scanner
- Bunch pattern 14 x 1 bunch evenly filled
- Low current setup 7.1 mA, first bunch 0.458 mA (3.9 nC)
- High current 40.5 mA, first bunch 2.686 mA (22.3 nC)
- Vertical and horizontal orbit bumps to steer positron beam into laser beam, 50 m bump length with 10 mm max offset
- Optimization of laser trigger point
- Laser energy measured to 40 mJ (specs 90 mJ), $P_L$ = 4 MW
- Scanning of laser beam with piezo

# Result Orbit Bump Scan (Oct run)

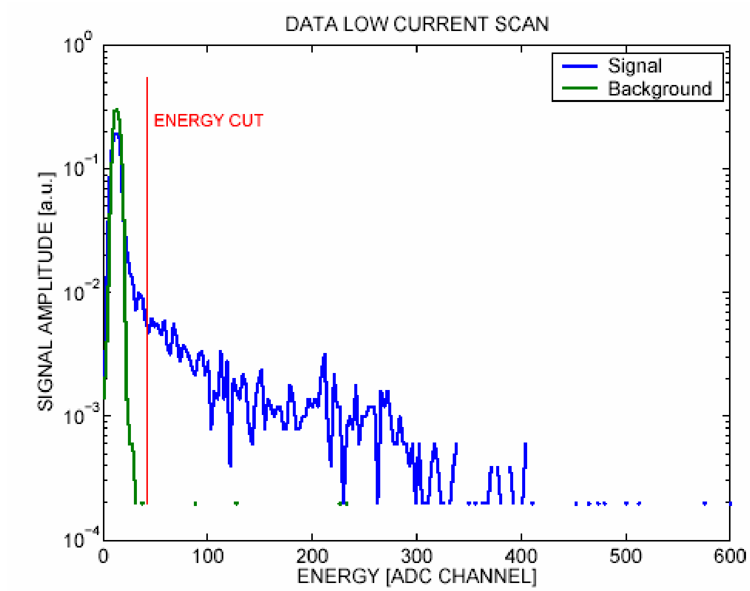


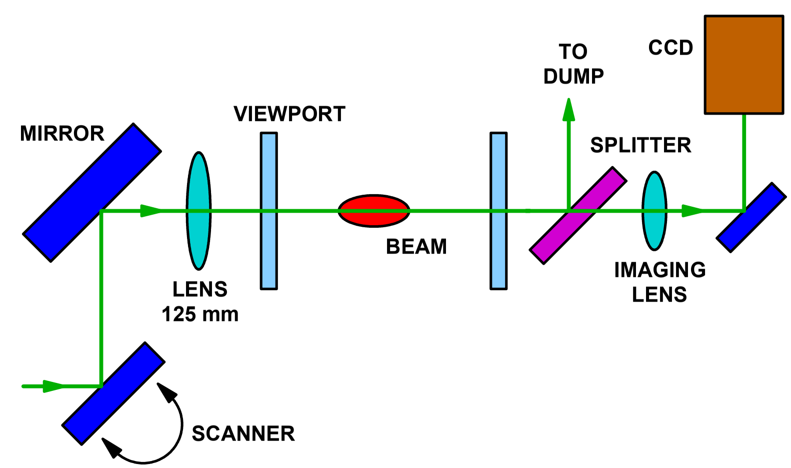




- Laser at rest and movement of orbit by 3.5 mm in ~ 0.1 mm steps
- Background substracted from signal at each point
- Gaussian fit of beam shape
  - $\sigma_m = (0.175 \pm 0.020_{stat} \pm 0.038_{sys})$ mm
- Large background variation during scan
  - Different local vacuum pressure in beam pipe

# Fast Scanner Operation (Dec run)

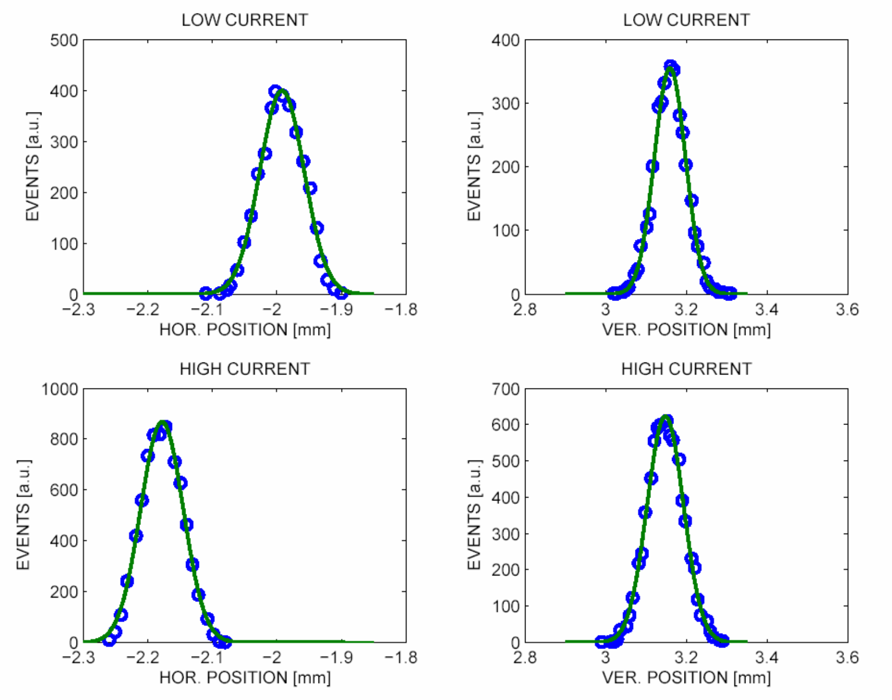
- First scan with signal on scope
- Then sampling of peak using ADC
- Changing piezo voltage from 0 to 9.5 V in 0.5 V steps
  - ± 2.5 mrad scan range
  - ~700 μm
- 5000 events at each position
- In total 20 position points
- Complete scan done in ~40 min
- Background scan with 20k events
  - Mainly synchrotron radiation and bremsstrahlung
- Signal rate expected at peak
  - 100 gammas x 380 MeV avg energy
- Strong fluctuations because of laser mode beating
- Oscillating pedestal in ADC data



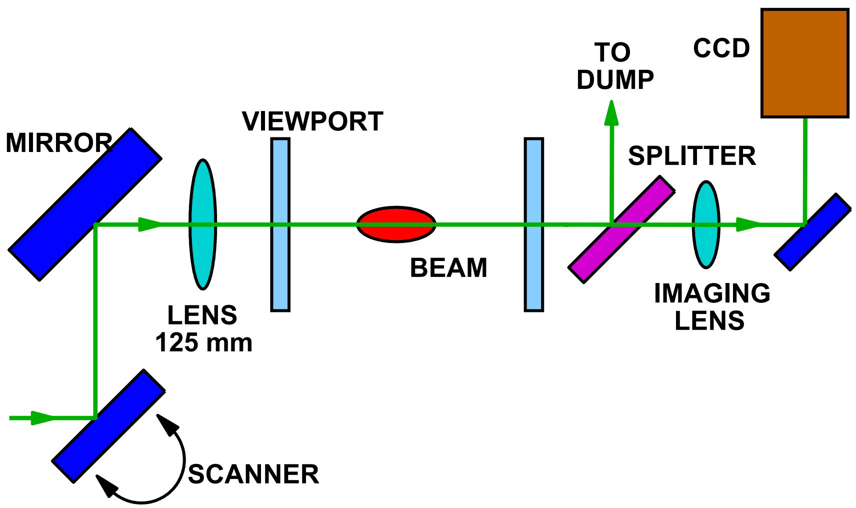



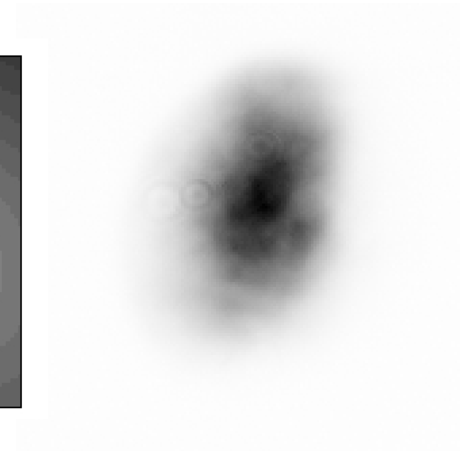
# Positron Beam Orbit Stability

- BPM read out every second and data written to disk
- Low current:
  - $x = -1.99 \pm 0.04$ mm
  - $y = +3.16 \pm 0.04$ mm
- High current:
  - $x = -2.18 \pm 0.04$ mm
  - $y = +3.15 \pm 0.04$ mm

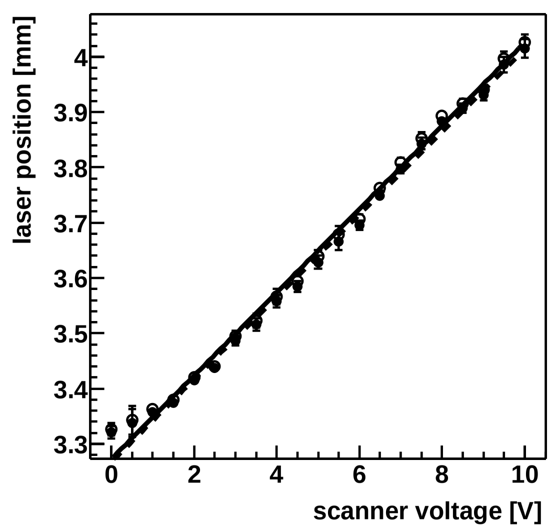


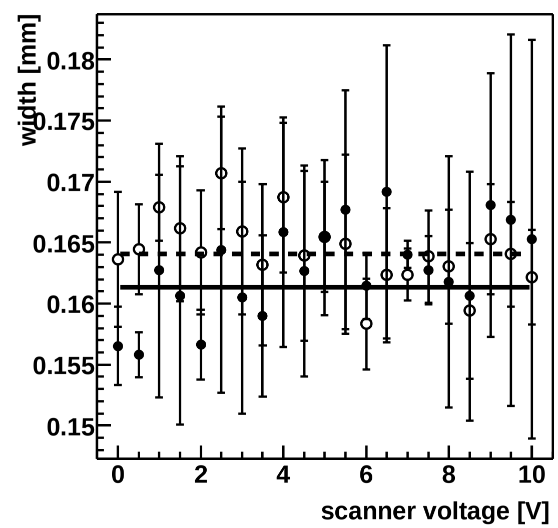
# Laser IP focus beam size



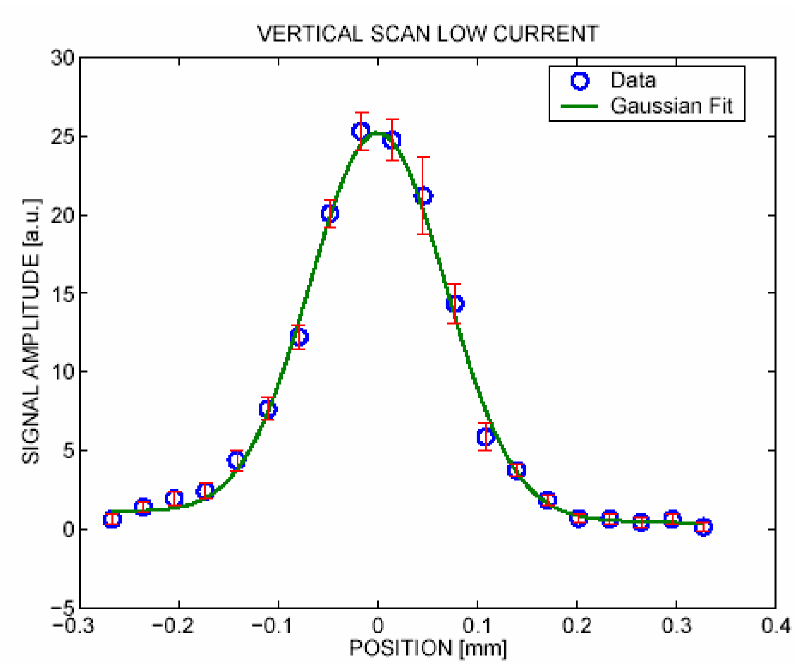
- CCD camera to monitor beam size
  - 8.3 μm pitch (8bit ADC)
- Monitor beam size during scan
  - ω(IP) ≈ 160 μm
- Optical calibration (imaging lens & ccd position)

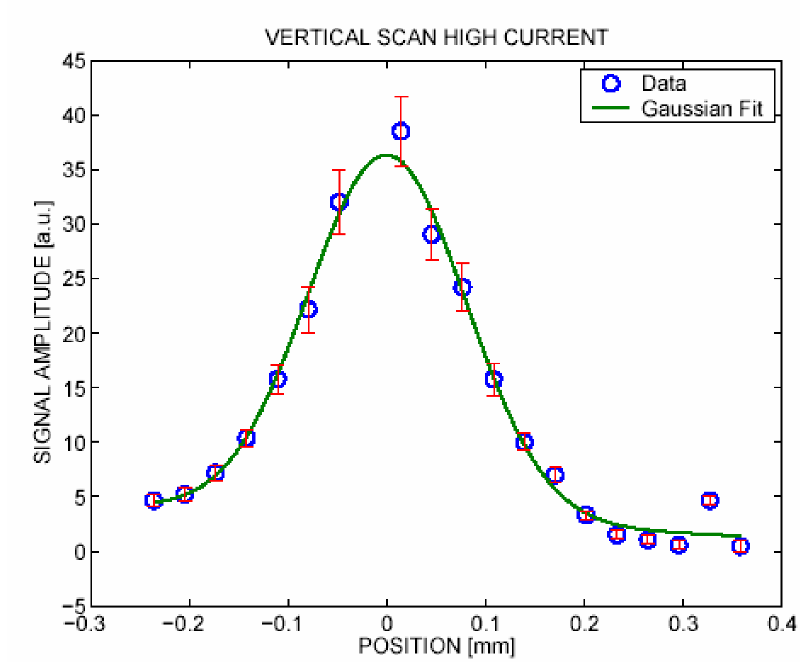


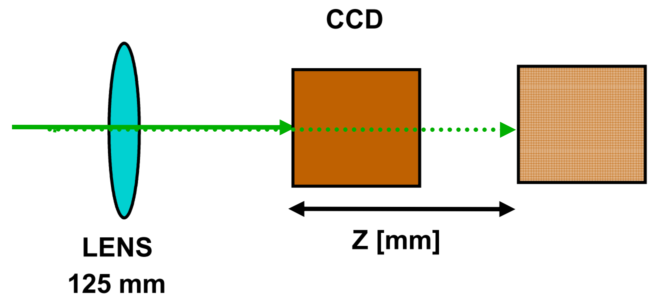
# Results from Scanner Operation

- Sloped Background + Gaussian signal, approximation of beam shape
  - $\sigma_m = (68 \pm 3 \pm 14)$ μm at low current
  - $\sigma_m = (80 \pm 6 \pm 16)$ μm at high current



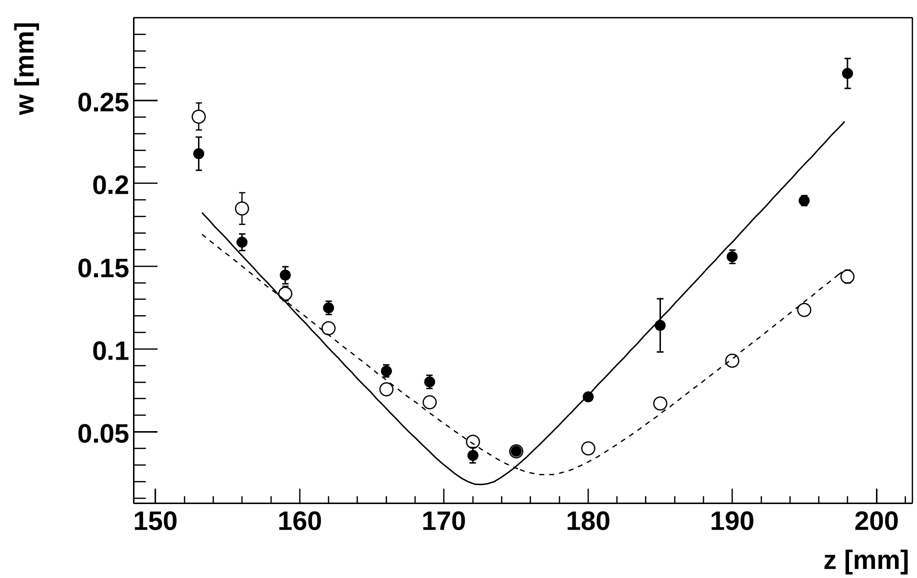



# Laser focus at IP (Apr)




- Inconsistent results for first fast scan
  - $\omega$(IP) ~160 μm
  - $\omega$(Compton) ~70 μm
  - Should be consistent, at least
    - $\omega(IP) \leq \omega(Compton)$

- Check using Nd:YAG at PETRA, using spare final focus lens
  - $\omega$(IP) ~ 50 μm
- Consistent with size extracted from Compton signal



# Conclusions and Outlook

LBBD Laserwire

## Conclusions

- Laserwire at PETRA setup and in operation
- Measured vertical beam size
  - using orbit bumps
  - with fast piezo scanner
- Results agree with std error with expectation from PETRA operation

## Next steps

- Understand low Compton rate
  - Laser characterisation (profile and power)
  - Study Compton path from IP to detector
  - Detector calibration
- Improve Compton rate
  - Background suppression with shielding
  - Improve trans. and long. laser profile
- Technical issues (software integration, trigger upgrade, other systematic checks)
- Machine studies
  - Profile measurements at different energies and optics setups
- Higher scanning speeds!
- Second dimension

# People

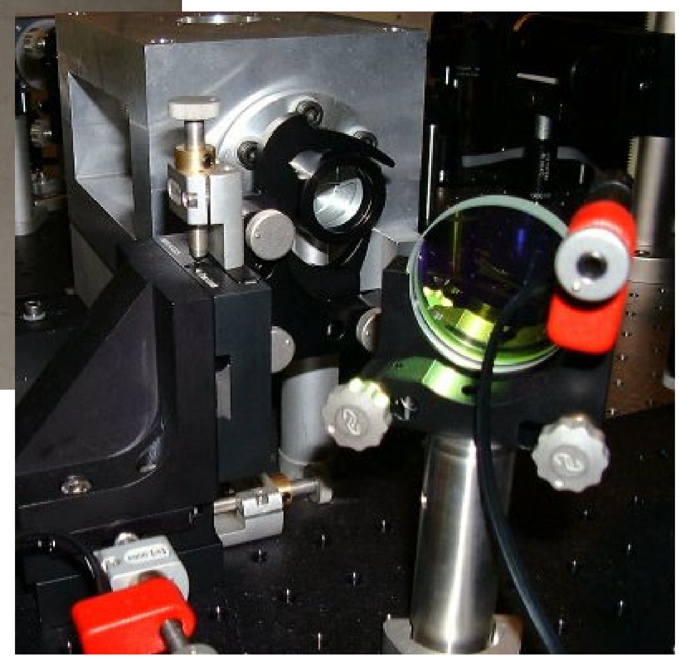
K Balewski, G Blair, S Boogert, G Boorman,
J Carter, J Frisch, T Kamps, T Lefevre,
H C Lewin, F Poirier, I N Ross, M Ross,
S Schreiber, M Wendt, K Wittenburg,

Thanks to DESY and shift crews !

# Appendix: Measurements at RHUL

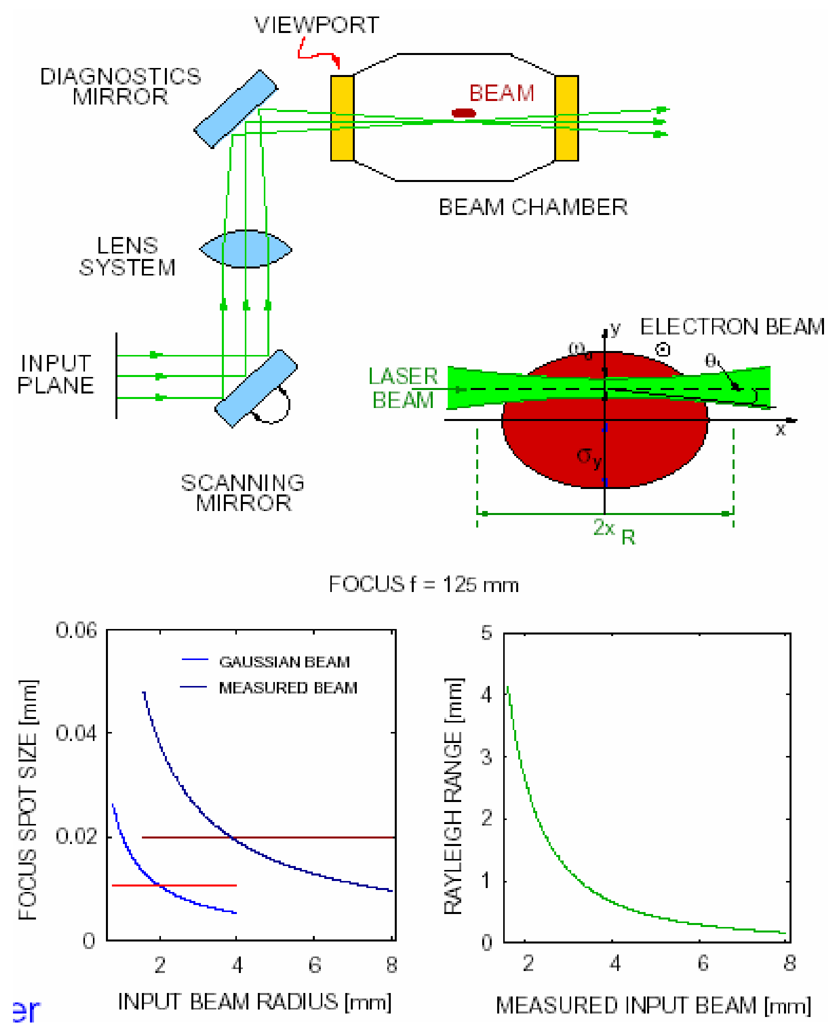
- Laser focusing and diagnostics
- Laser beam transport in IP region
- Scanning tests

# Lab Measurements at RHUL



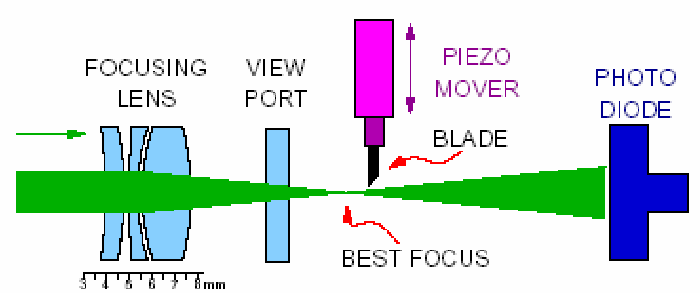
# Laser Focusing/Diagnostics

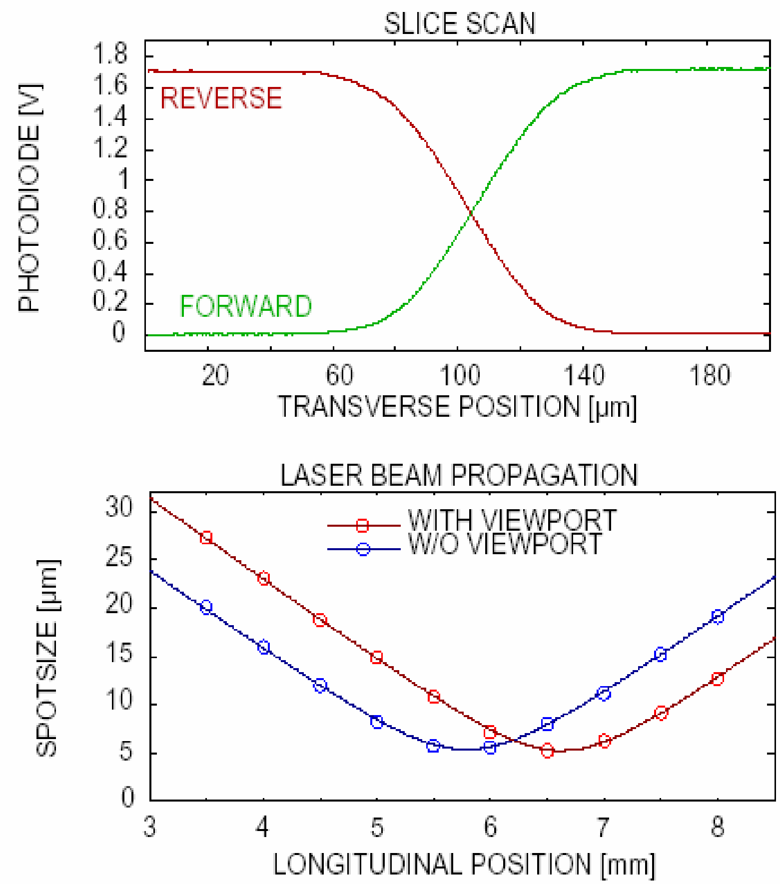
- Requirements
  - RMS spotsize at interaction smaller than electron beam size, here 10 to 30 um
  - Rayleigh range larger than horizontal beam, here 100 to 300 um
  - Resistant against high power beam
  - Beam stay clear distance
  - Include diagnostics
- Solution commercially available laser objective
- Imaging system for diagnosics



# Lab Measurements at RHUL

- Measurement of spot size at focus and beam propagation with knife edge technique
- Slicing of beam at several longitudinal positions
- Piezo movement controlled by interferometer
  - high precision ~30 nm
- Tested with beam at CTF2 Laserwire experiment

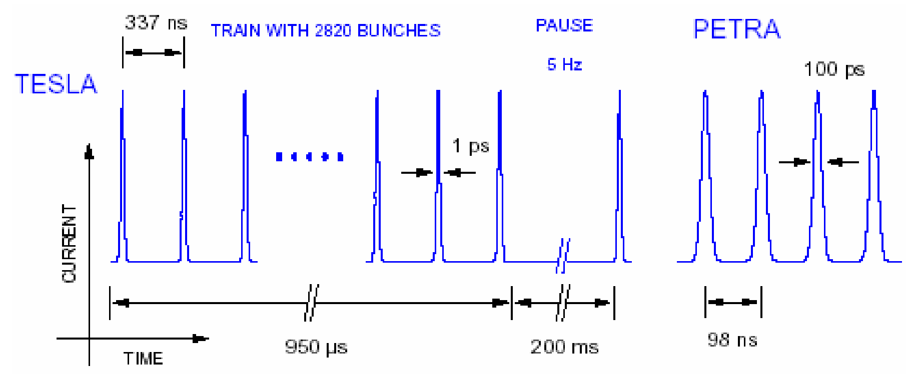


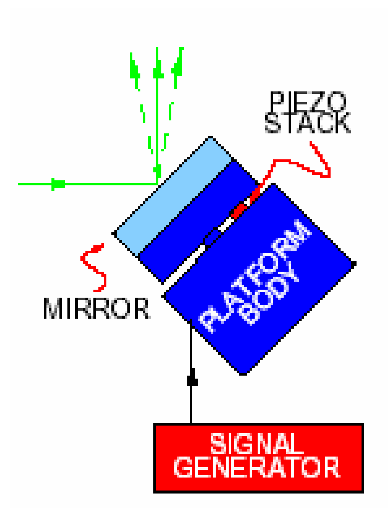



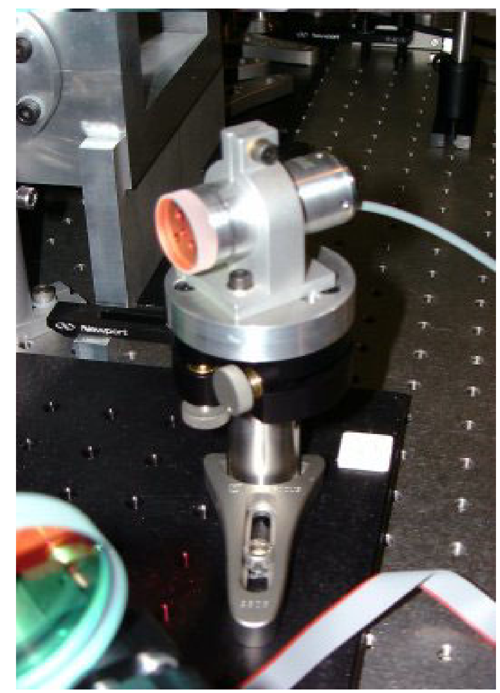

| | $\sigma_o$ [$\mu$m] | $z_{off}$ [mm] |
|---|---|---|
| with | $5.34 \pm 0.02 \pm 0.07$ | $5.79 \pm 0.01 \pm 0.08$ |
| without | $5.21 \pm 0.03 \pm 0.07$ | $6.62 \pm 0.01 \pm 0.08$ |

# Fast Scanning

- Profile scans within one bunch train of TESLA requested
- Scan resolution to scan at least a few points per sigma
- Flexible scan pattern for systematic studies
- Piezo driven platform with high-reflective mirror
- Discrete and continuous operation (up to 1 kHz)
- High damage threshold
- Tested in lab with home-build driver unit and amplifier



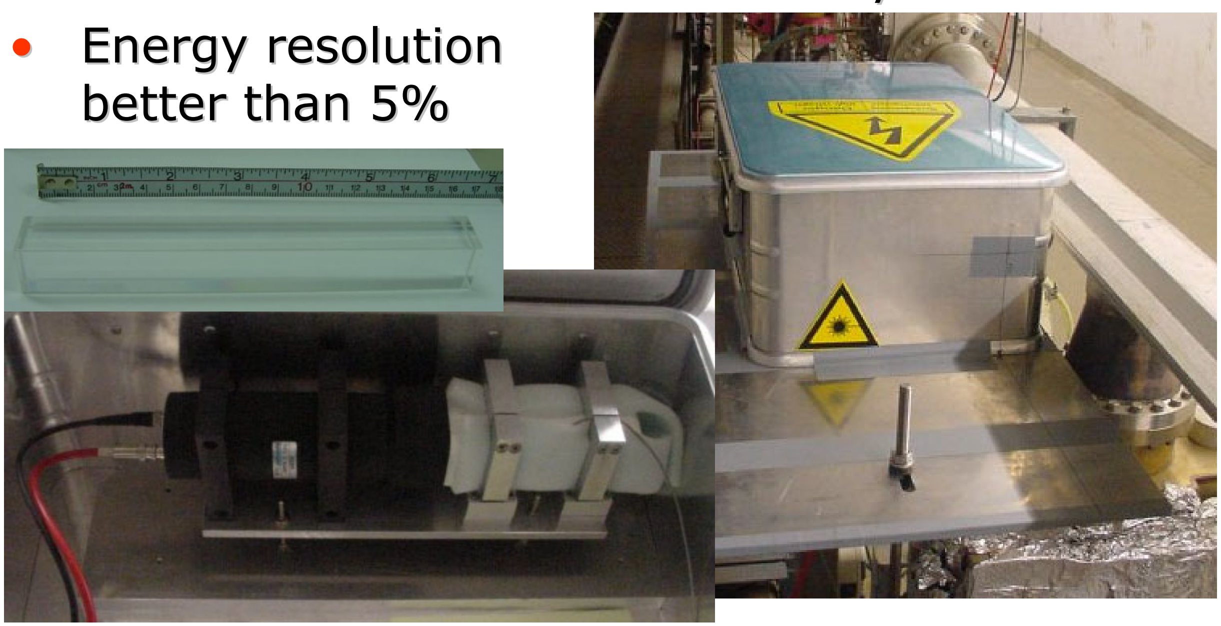



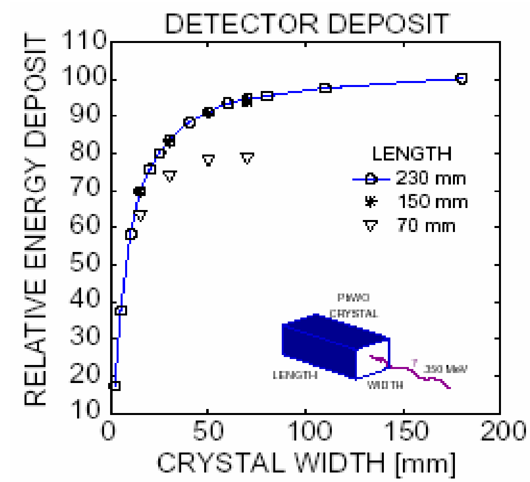
# Appendix: Detector

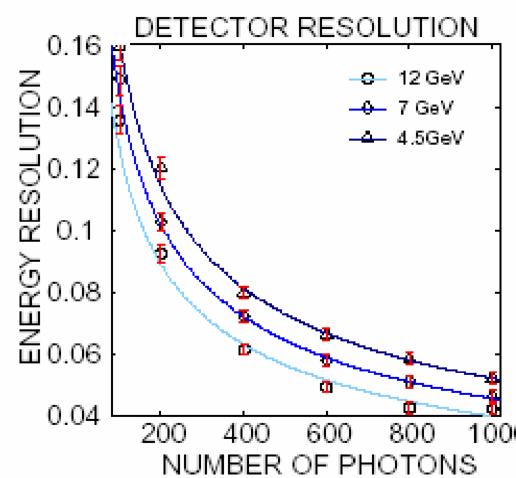
- Detector specifications and design
- Detector test beam measurements

# Detector Specification

- Requirements for detector material
  - short decay time (avoid pile up)
  - short radiation length
  - small Moliere radius
- Cuboid detector crystals made of PbWO4
- 3x3 matrix of 18x18x150 mm crystals
- Energy resolution better than 5%





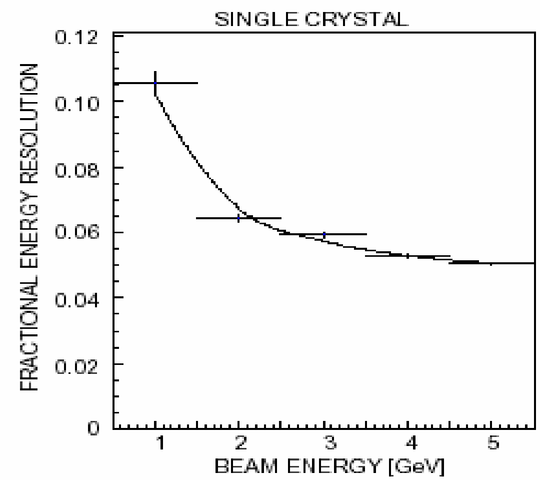



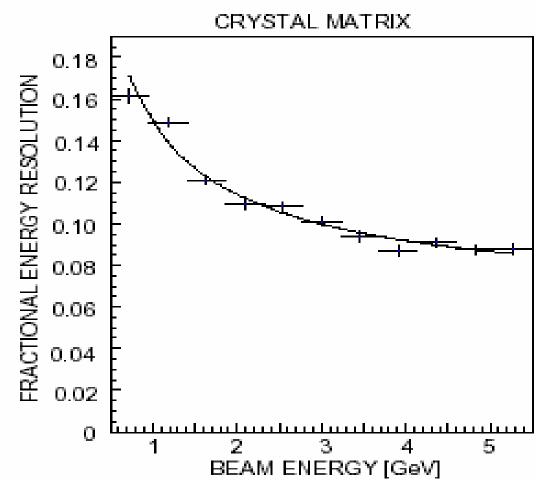
# Detector Calibration

- Detector studies with DESY II testbeam
- Beamline with electrons with energy from 450 MeV to 6 GeV
- Ten detector crystals were calibrated using a single PMT
- Combination of nine crystals in matrix
- Resolution
  - High intrinsic resolution
  - Full matrix less good

$$R^2 = \left(\frac{\sigma_E}{E}\right)^2 = \left(\frac{p_1}{\sqrt{E}}\right)^2 + \left(\frac{p_2}{E}\right)^2 + p_3^2$$

$p_1$: stochastic contrib., $p_2$: noise
$p_3$: constant (inhomogeneity)



# Detector Alignment Studies

- Asymmetric (slope) bumps to check acceptance of detector
- Inward/outward bumps with ~0.5mrad slope
- Moving detector by 5cm (in 1cm steps) to outward direction
- Signal highest when detector is closer to beampipe
- Signal highest when beam ist bend inwards
- Final position 2cm away from original
- Obstacle in ideal line?
- ➢ Need more tests
- ➢ Lead shield to minimize synchtrotron rad bkg