UK LC R&D and Laser-wire Update

G. A. Blair
Royal Holloway Univ. London
CLIC Seminar - CERN
27th February 2004

- LC-ABD Proposal
- Overview of the projects
- UK Accelerator Institutes
- Laser-wire update

UK funding for accelerator science for particle physics 2004 - 2007

UK funding agency, PPARC, secured from Govt. £11M for 'accelerator science' for particle physics, spend period April 04 – March 07

Called for bids from universities and national labs; large consortia were explicitly encouraged

Bids peer-reviewed and preliminary new allocations made Oct 21 2003:

LC-Beam Delivery £7.2M

UKNF £2M

2 university-based accelerator institutes

LC-ABD Collaboration

- **Abertay**
- **Bristol**
- **Birmingham**
- **Cambridge**
- **Durham**
- **Lancaster**
- **Liverpool**
- **Manchester**
- **Oxford**
- **Queen Mary, Univ. London**
- **Royal Holloway, Univ. Of London**
- **University College, London**
- **Daresbury and Rutherford-Appleton Labs;**

41 post-doctoral physicists (faculty, staff, research associates) + technical staff + graduate students

1. BDS Lattice Design and Beam Simulations

Bristol, B'ham, Daresbury, Lancaster, Liverpool, Manchester, Oxford QMUL, RAL, RHUL, UCL

1.1 BDS Lattice design:

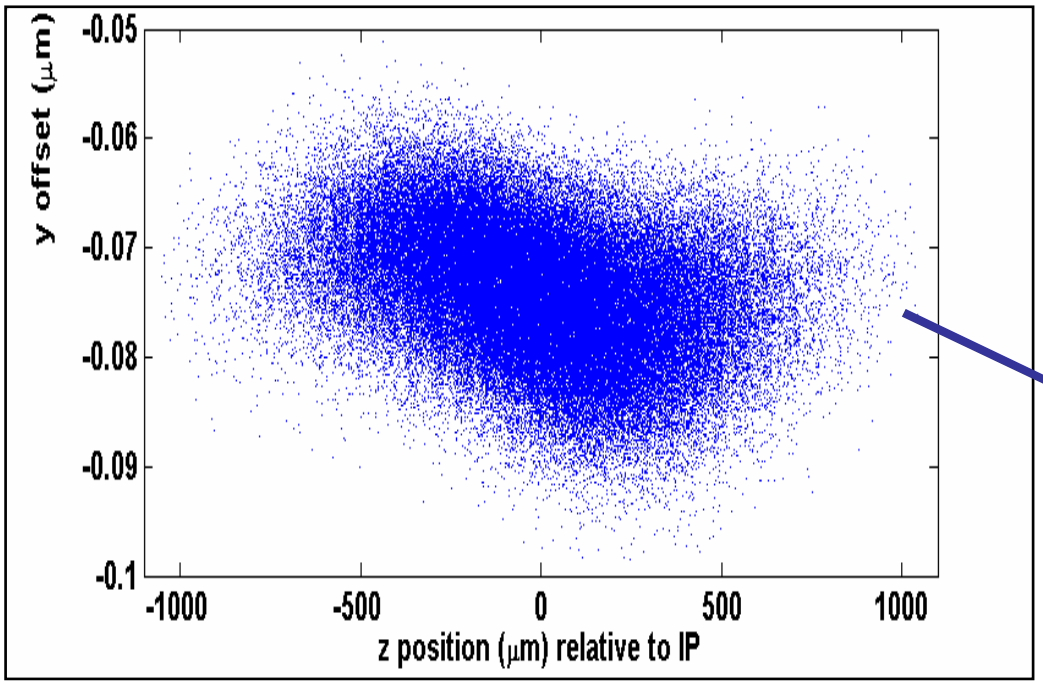
Understand design issues, contribute to global development + optimisation:
working with Saclay on latest TESLA IR optics
very interested in: collimation system, extraction line, diagnostics layout…

1.2 Beam transport simulations, backgrounds + collimation:

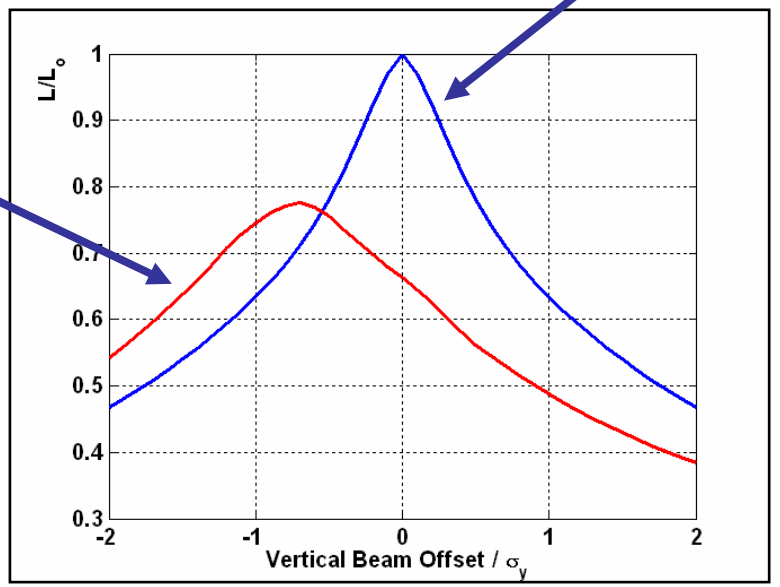
Cradle-to-grave simulations; database of TESLA train Xings, pairs, FB
64 cpu Grid cluster at QMUL for production jobs (30-40 cpu-hours)
BDSIM: development and application.
Halo production and tracking through BDS:
Collimator wakefields + optimisation of spoiler + collimator design
Backgrounds in IR: pairs, gammas, n: -> VXD, calorimetry, FB system …

Example: banana bunches, impact on FB

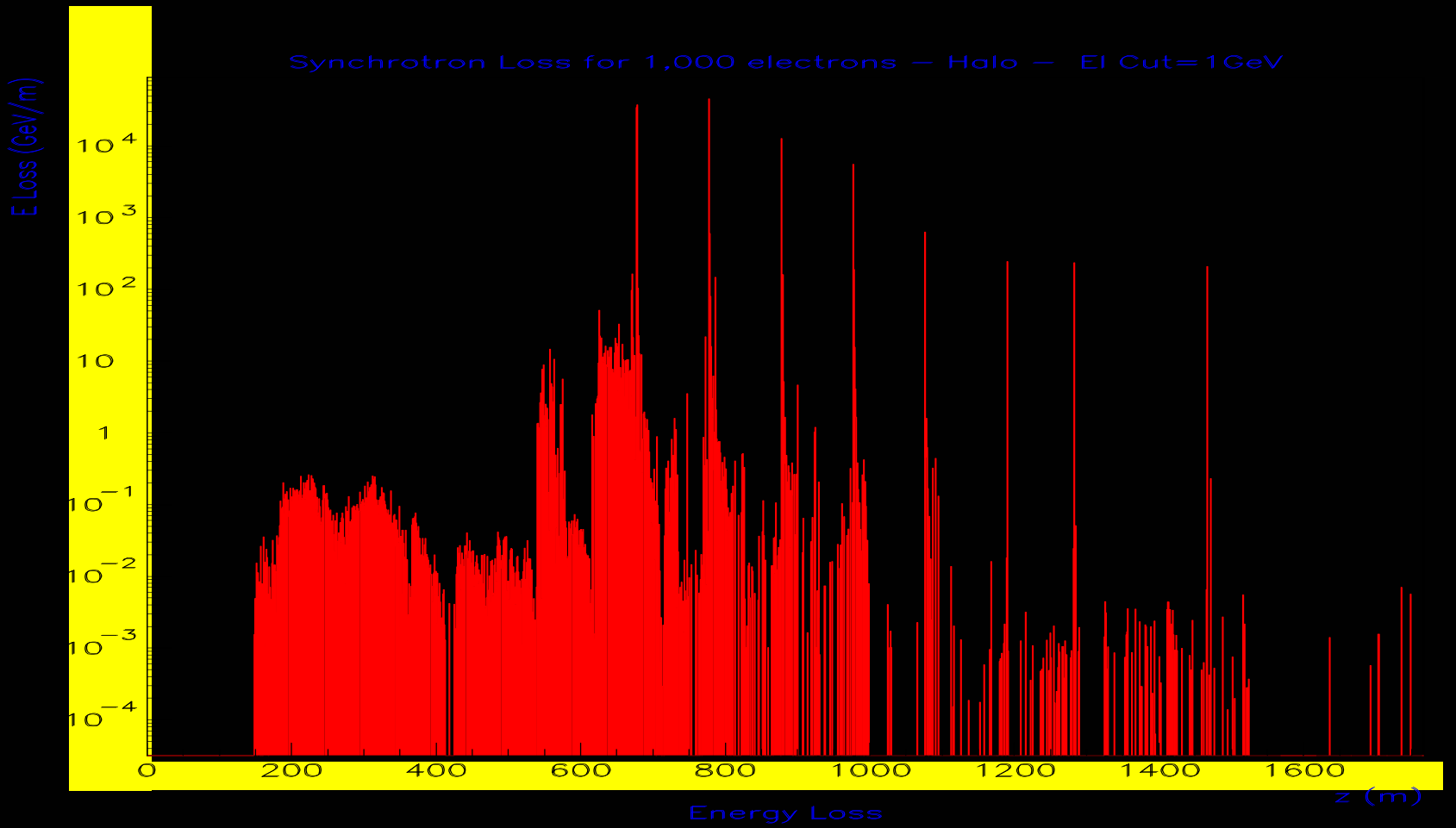
-
- **'Banana' bunch (PLACET/MERLIN)**



Gaussian bunch



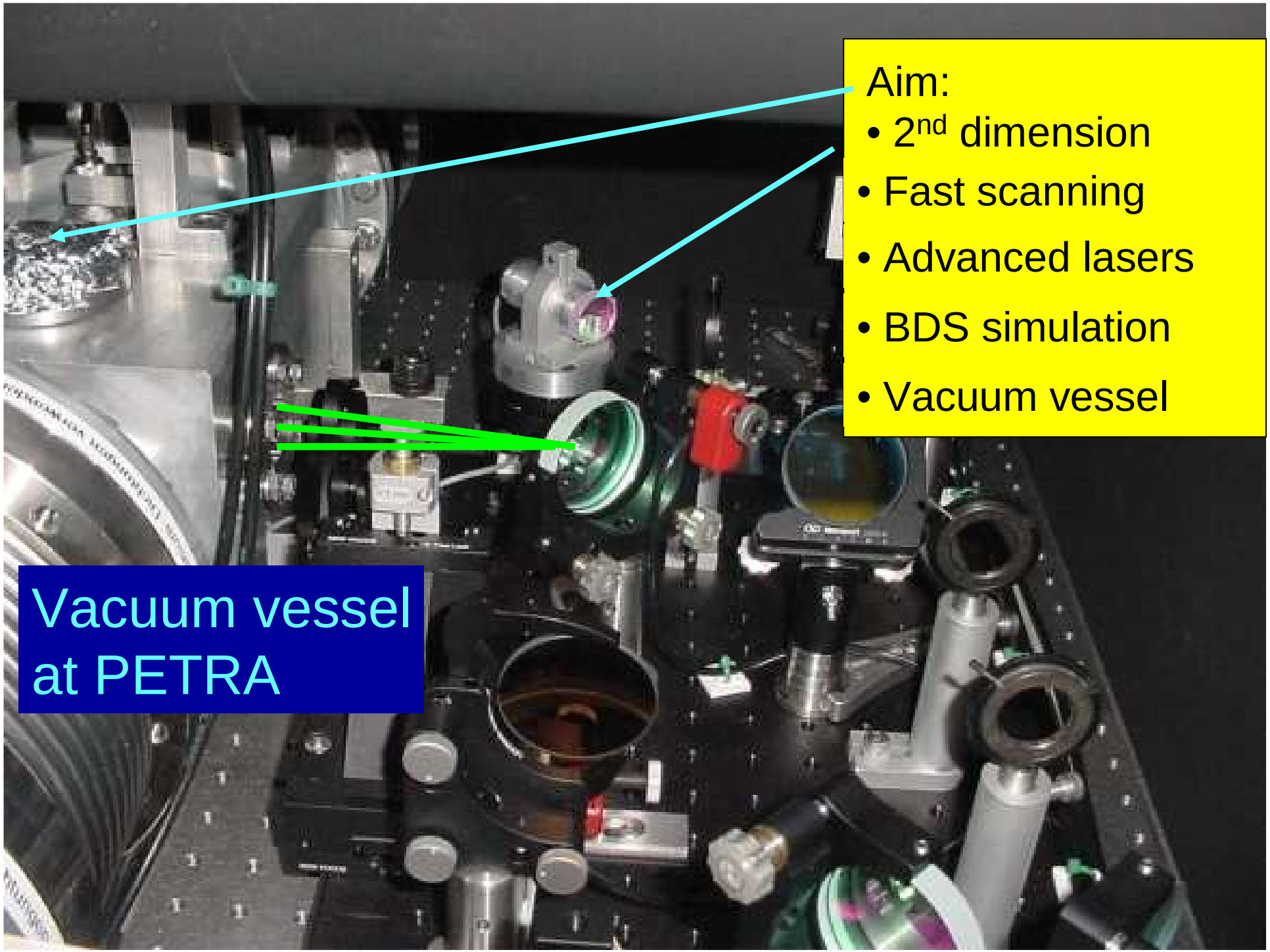
Tracking of halo energy deposition (BDSIM)



2. Beam Diagnostics

2.1 Laserwire (RHUL, UCL, Oxford, RAL):

Ongoing collaboration on PETRA laser-wire project
UK building laser scanning system (multi-direction)
Simulations: halo backgrounds, diagnostics layout


Aim:
• 2nd dimension
• Fast scanning
• Advanced lasers
• BDS simulation
• Vacuum vessel
Vacuum vessel at PETRA

Longitudinal bunch length

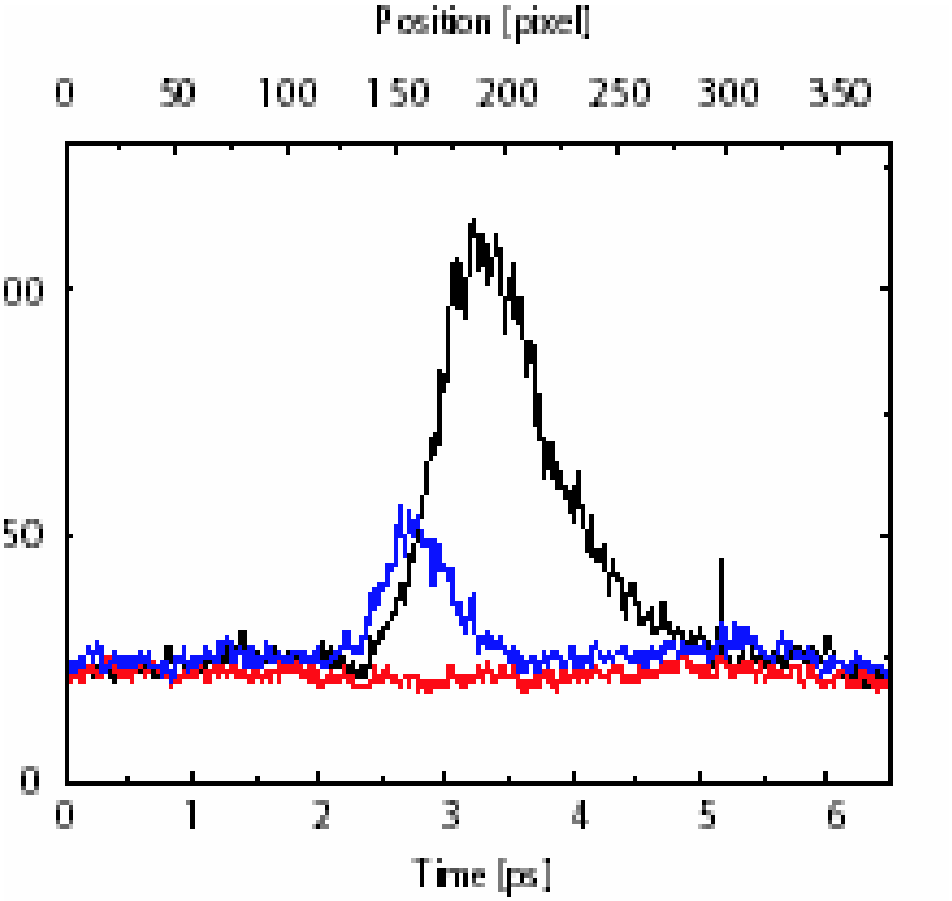
2.2 Bunch length/profile measurement (Abertay, DL Oxford):

Very successful electro-optic bunch length expt. at FELIX

600fs achieved; aiming for 200fs

R&D on Smith-Purcell radiation bunch profile monitor (Frascati) possible deployment at FELIX

Sub-ps bunch length measurement (EO)



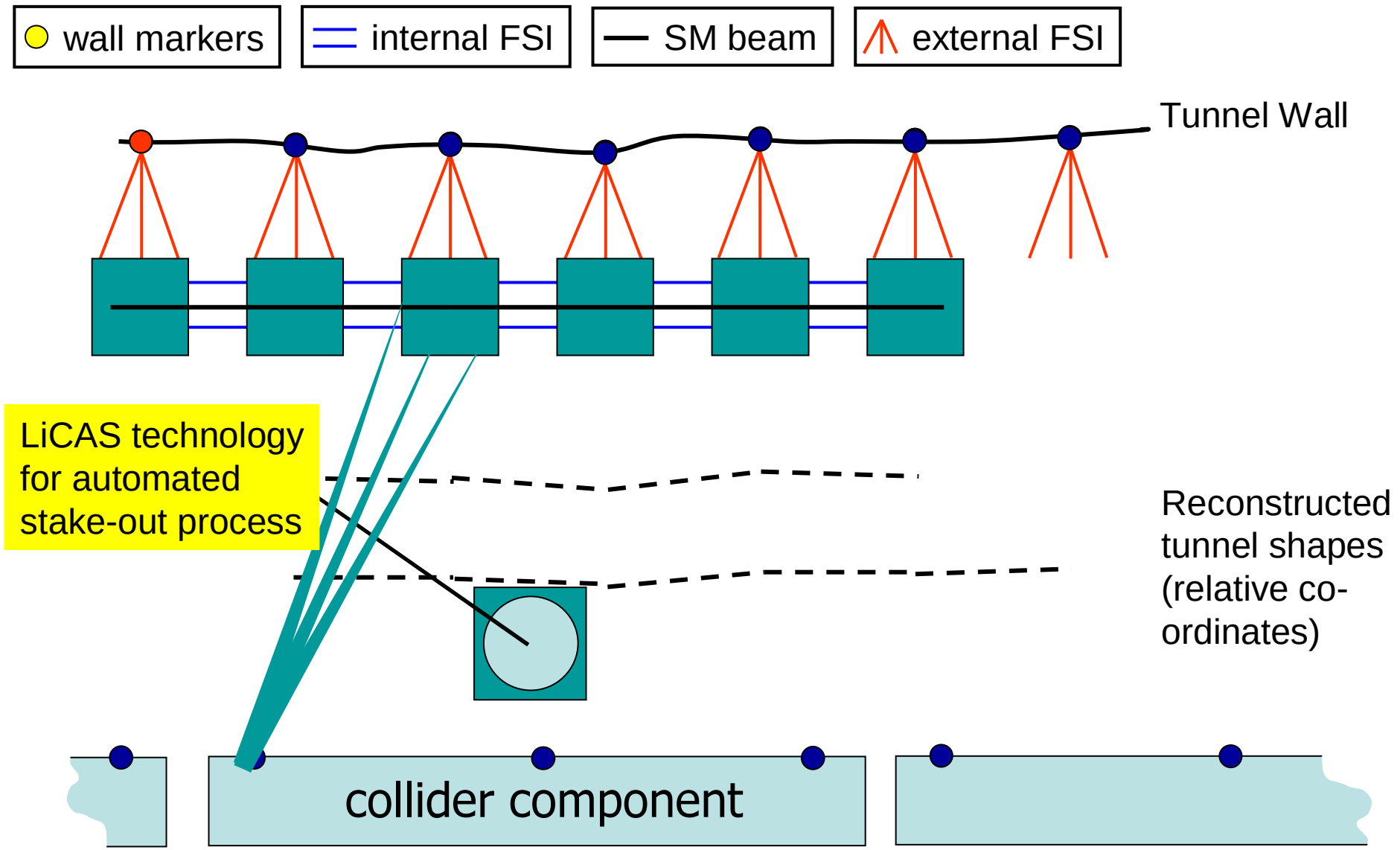
600 fs achieved.

Ongoing project

at FELIX;

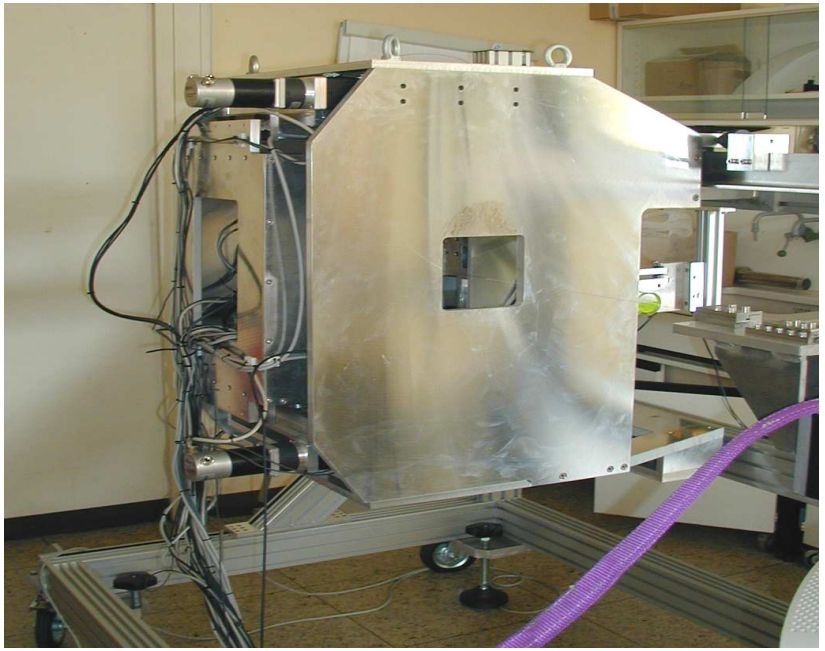
aiming for 200 fs

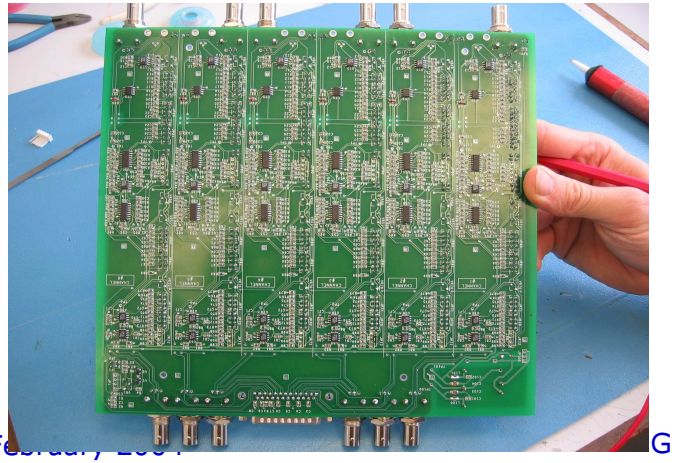
3. Alignment + Survey: LiCAS (Oxford)



LiCAS Development

- **Prototype survey car:**
- **2004: Single-car sensor**
- **2005: 3-car prototype deployed in dedicated 70m tunnel at DESY**
- **2007: 5-car prototype available for use in TESLA XFEL tunnel**





Prototype readout board

4. Final-focus Luminosity Stabilisation

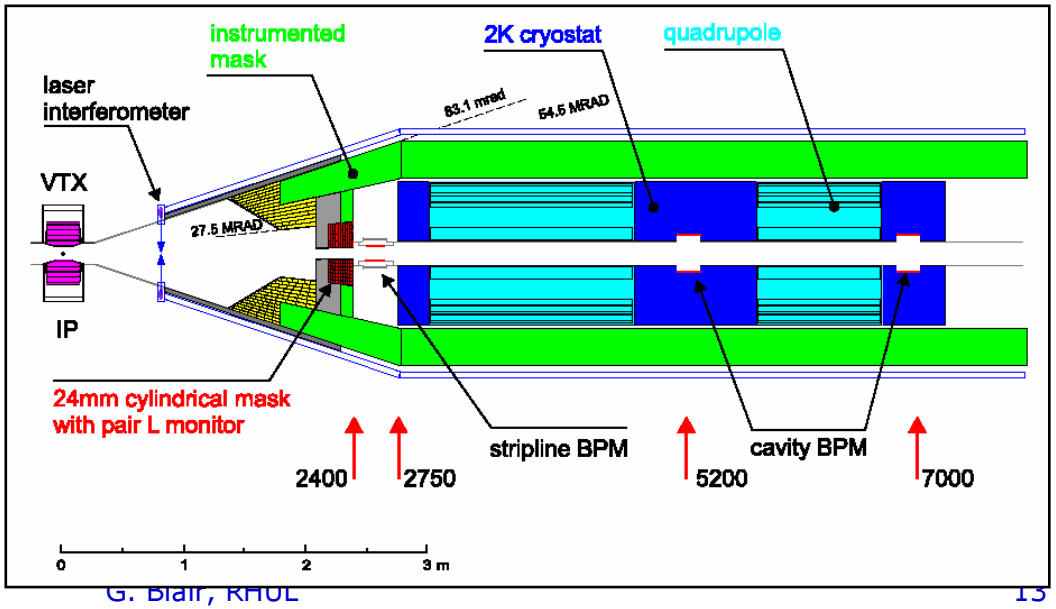
(QMUL, Oxford, Daresbury)

Beam-based feedback:

Worked primarily on intra-train FB as complement to 'IP FB' (train-train) + active mech. stabilisation schemes (warm design)

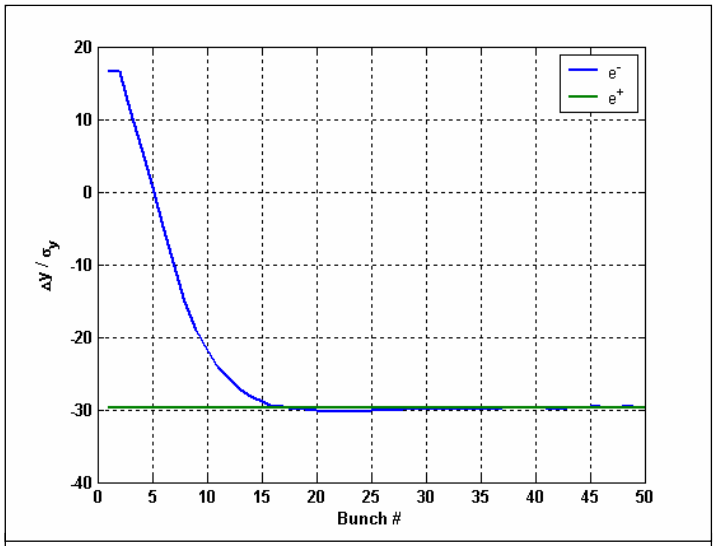
Simulated intra-train FB for J/NLC, TESLA, CLIC

Location of FB BPM:

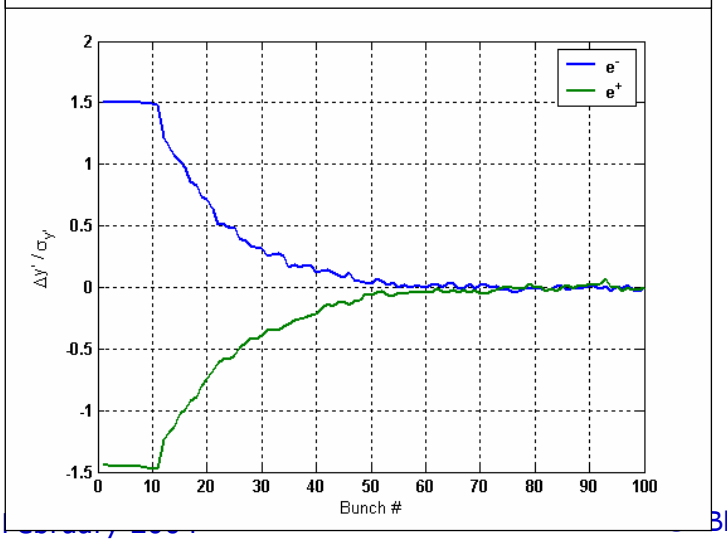


FONT Luminosity Recovery (TESLA)

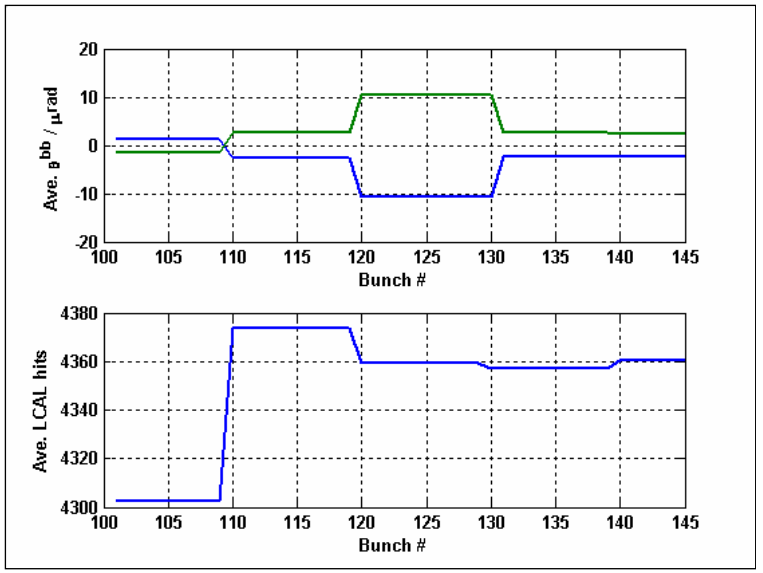
Posn. FB



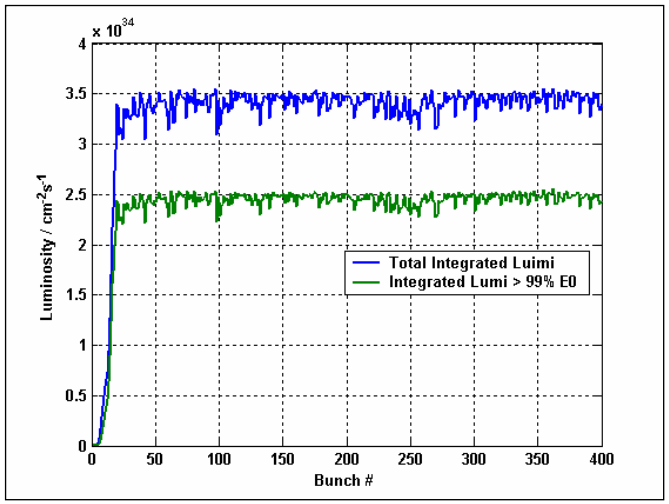
Angle FB



Lumi scan

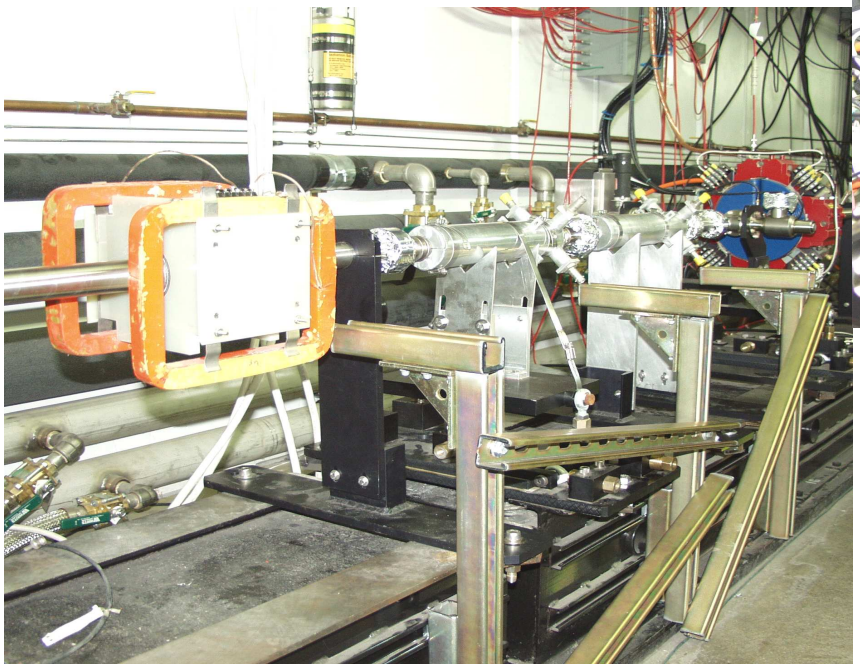


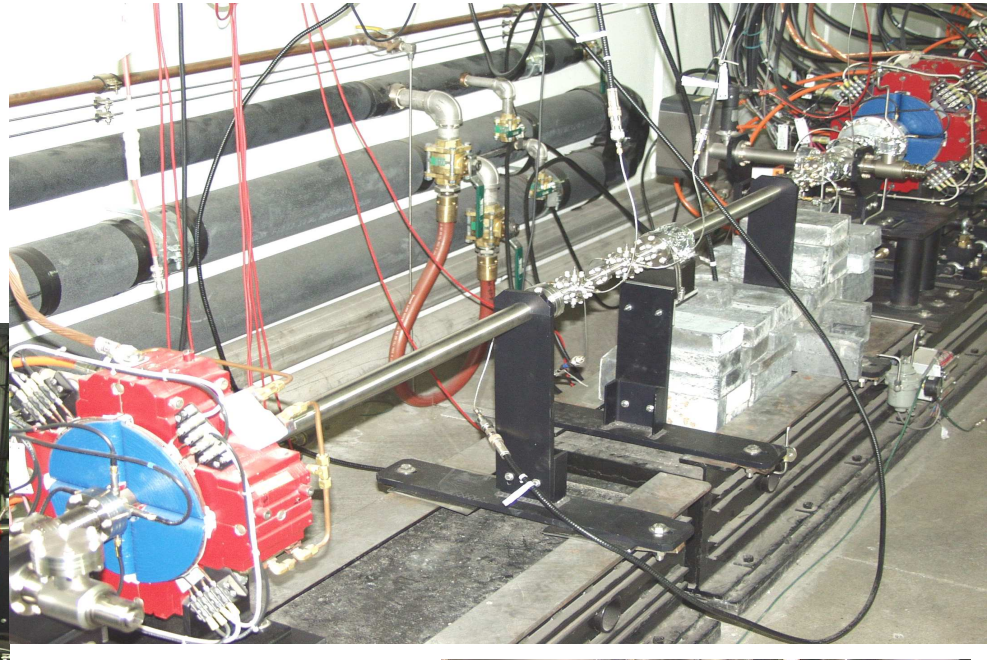
Optimised Lumi



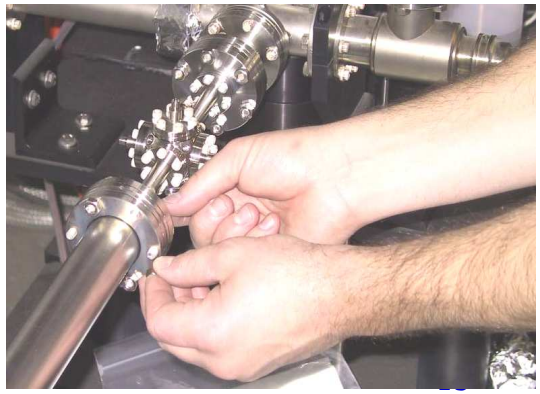
FONT prototype at SLAC NLCTA

Dipole and kickers

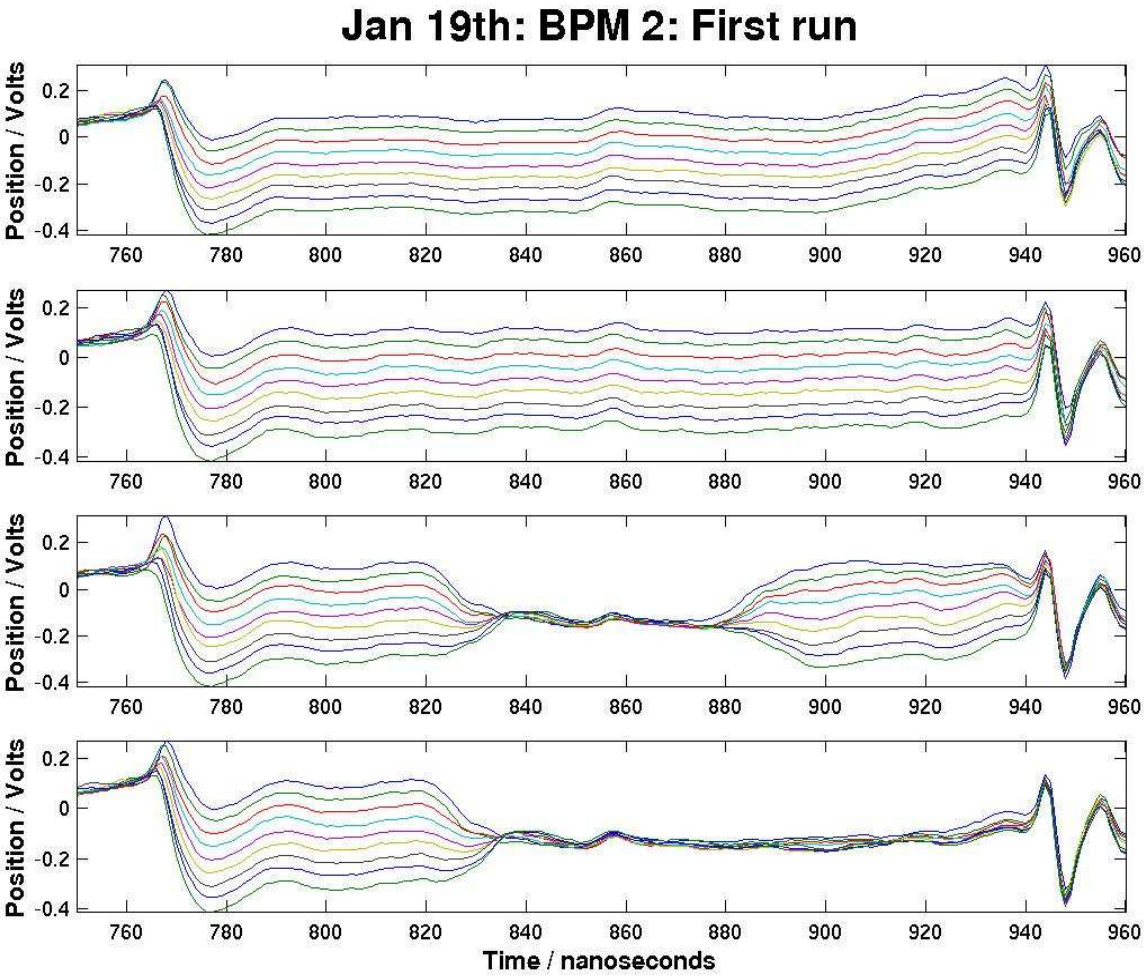




Advanced BPMs



FONT2 initial results: feedback mode



Beam starting positions

Beam flattener on

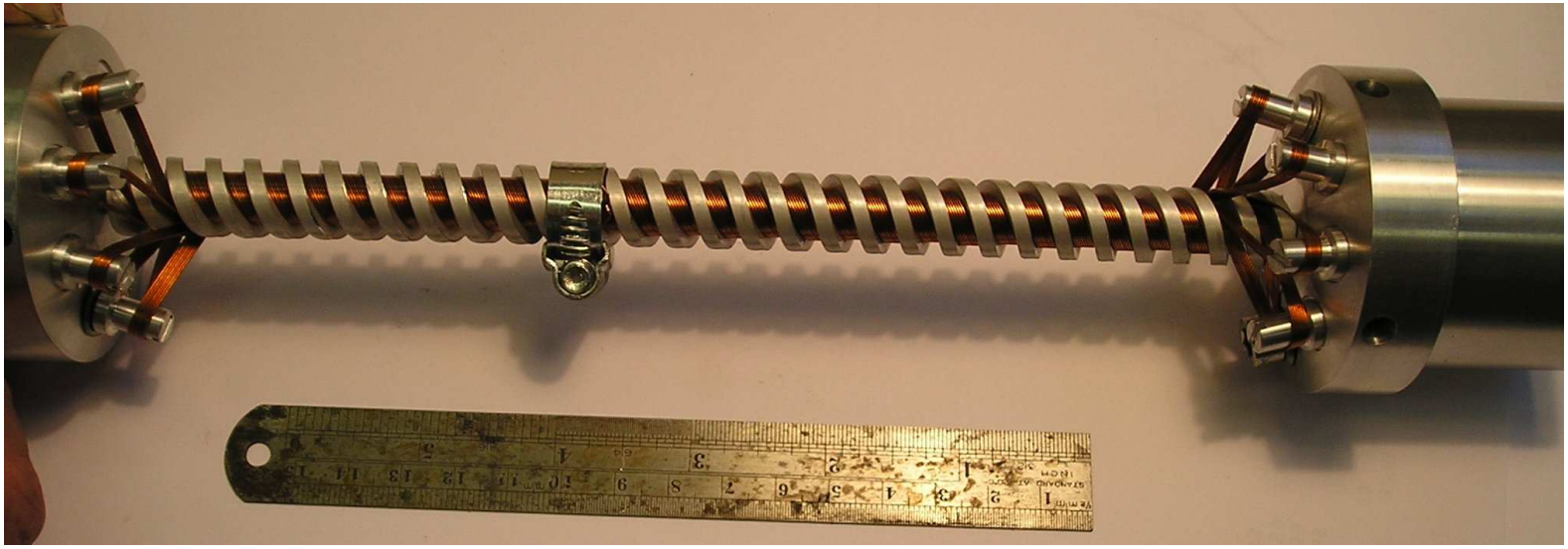
Feed forward on

Feedback on

5. Polarisation, Positron Source Undulator + Crab Cavity (Daresbury, Durham, Liverpool)

5.1 e+ source undulator design:

Baseline method for TESLA, in consideration for NLC
Polarised e+ -> helical undulator (E166 expt)
Design work for TESLA helical undulator in progress:



5.2 Crab cavity design (for IR with crossing angle):

Overlap of interest with angle FB systems; UK RF company interest

6.BPM Spectrometry(Cambridge, UCL)

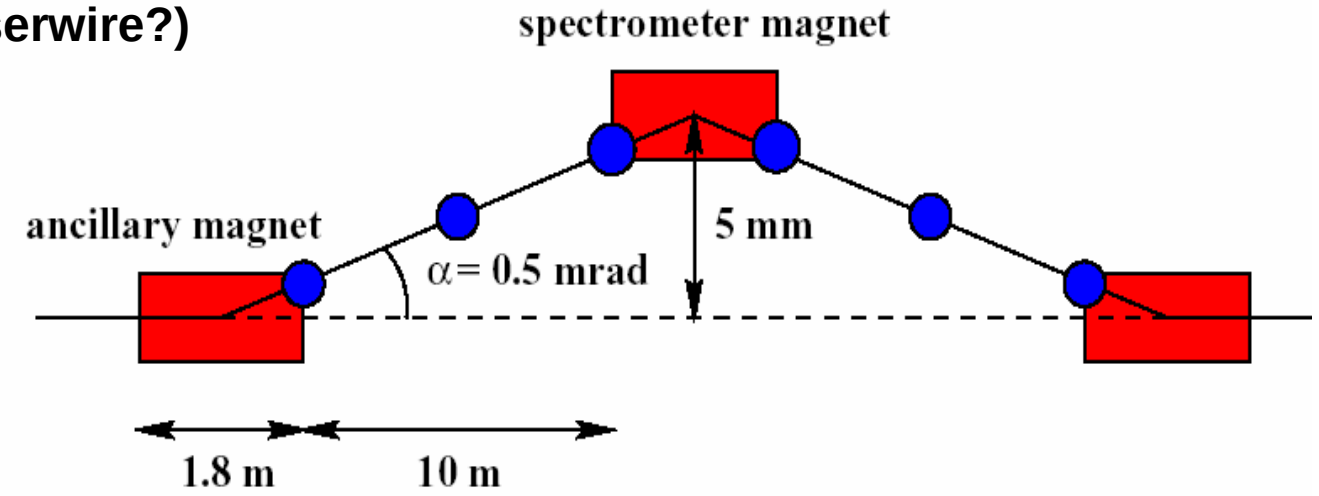
6.1 Measurement of Luminosity

Energy Spectrum (MOLES):

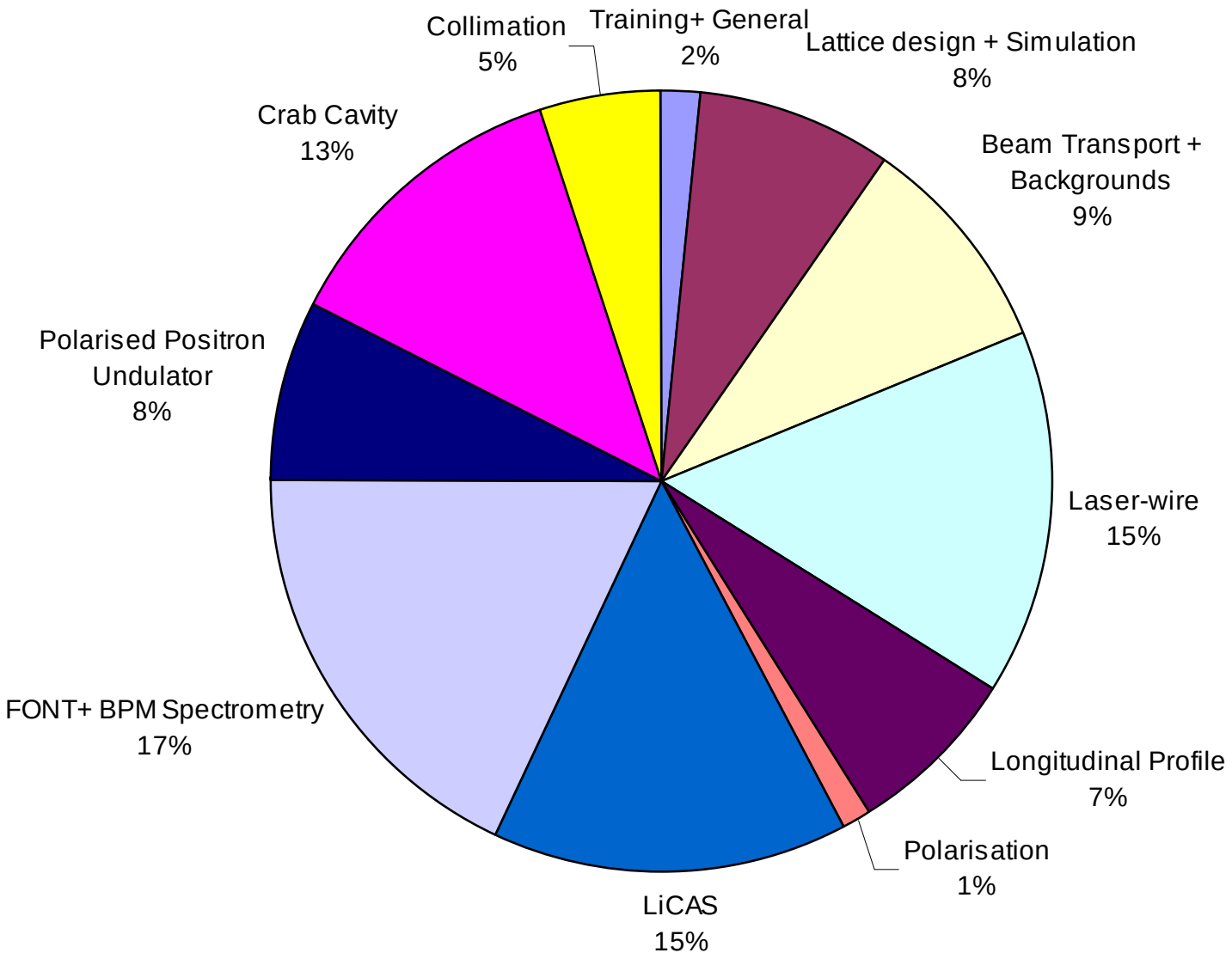
Absolute E (survey, alignment)

E jitter (fast BPMs)

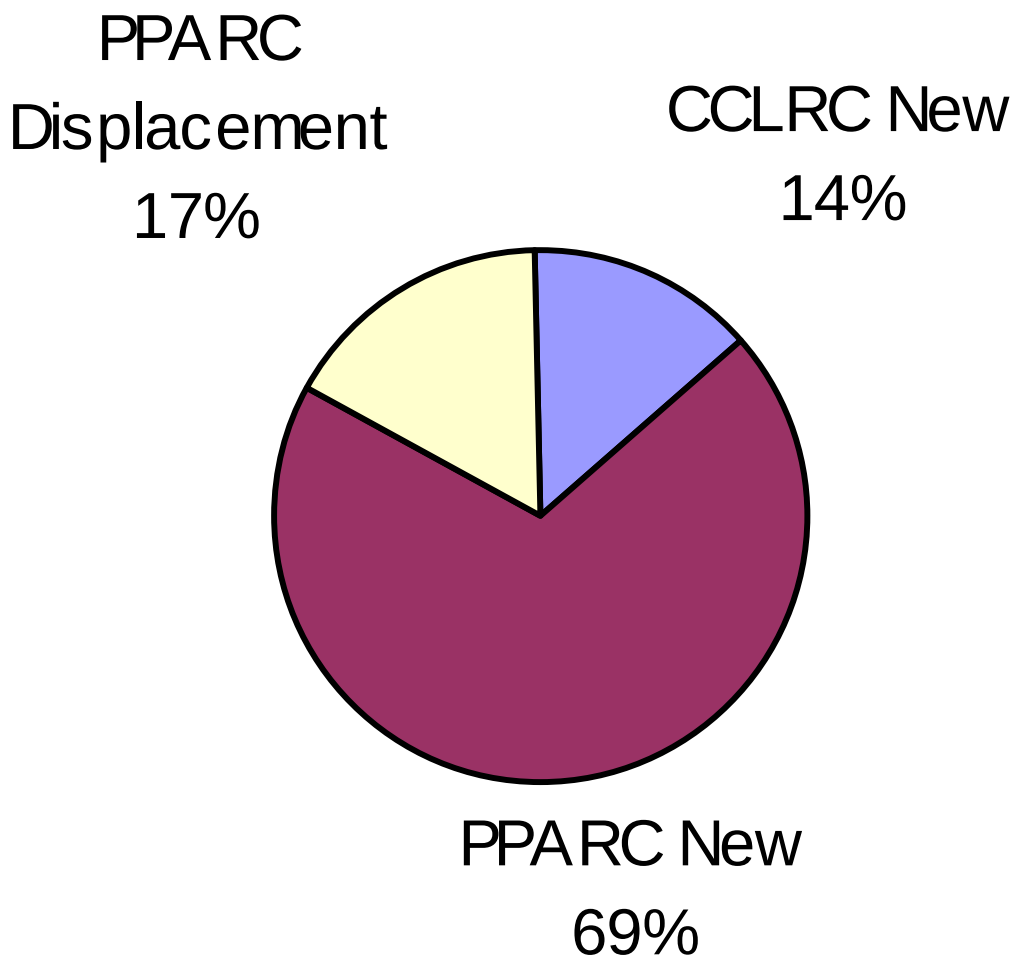
E dispersion (laserwire?)



Overview of Projects



Financial Summary



Total £10.5M

Accelerator Institutes

- 2 New institutes for Accelerator science:

Cockcroft: Lancaster,Liverpool, Manchester – based at/near DL campus.

12 New academic positions.

Oxford/RHUL: Based at both institutes (plus base at RAL)

6 new academic positions.

Summary and Outlook

- **UK has Embarked on a substantial UK LC BDS work programme**
- **Have expertise in some areas, learning in many others**
- **Aiming to build a strong, coherent design team:**
  - **intellectually interested in BDS**
  - **aim to prepare UK funding agencies for the LC**
- **Collaborating w. European partners via 'FP 6' programme: EUROTeV**
- **Accelerator Institutes – a revived academic discipline in the UK.**
- **Many new posts about to be available at the institutes and also in LC-ABD programme.**

Laser-wire Update

- Motivation for the project
- Laserwire at PETRA
  - Environment at PETRA
  - Installation of Hardware
  - First measurements
- Conclusions and Outlook

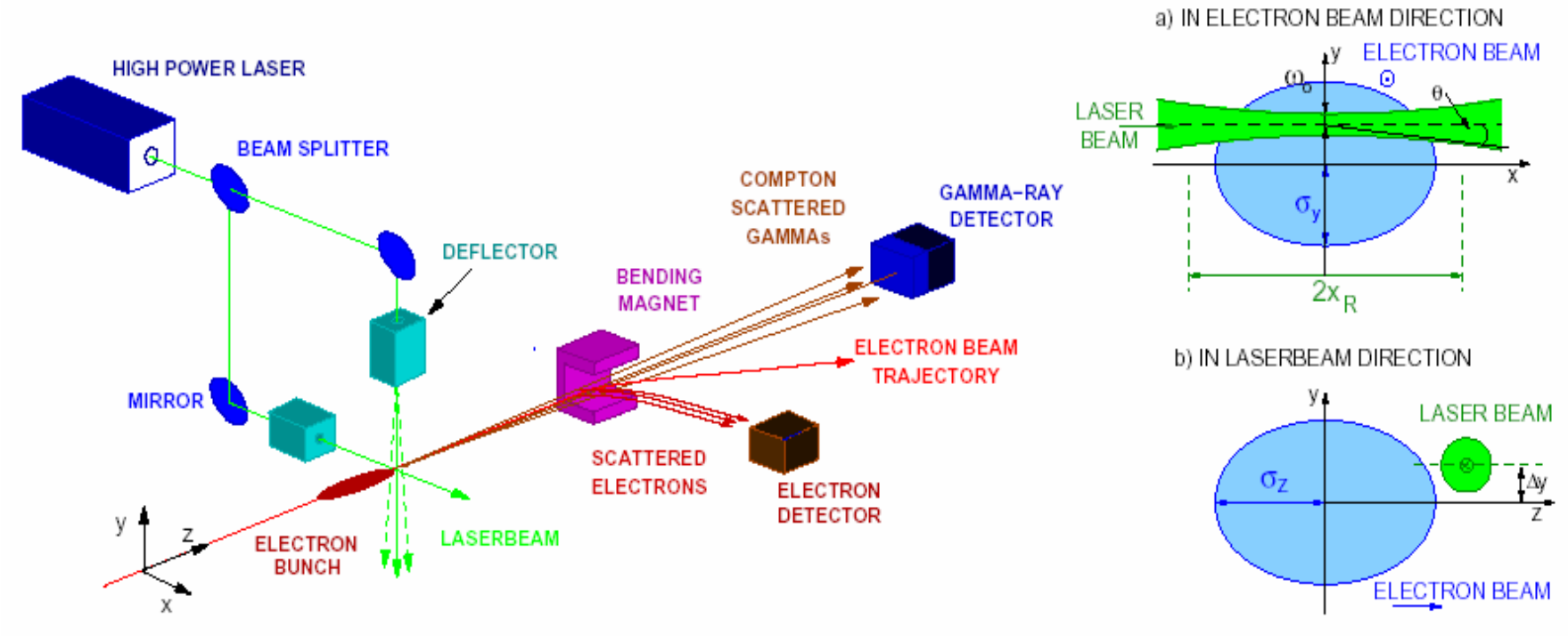
Collaborators

- DESY
- BESSY
- UK: RHUL, UCL, RAL, Oxford.
- CERN: (Laser, plus collaboration)

Close contact with:

- SLAC
- KEK

Principle and Goals



		CLIC	NLC/GLC	TESLA
BDS	σ_x/ μm	3.4 to 15	7 to 50	20 to 150
	σ_y/ μm	0.35 to 2.6	1 to 5	1 to 25
IP	σ_x/ nm	196	335	535
	σ_y/ nm	4.5	4.5	5

Laserwire for PETRA

- 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
- Q-switch Nd:YAG with SHG
- From CERN LEP polarimeter
- ➢ Trans Mode: large M^2 ~9
- ➢ Long Mode: stability ± 20%, beating → ps substructure
- ➢ Homegrown timing unit for external triggering

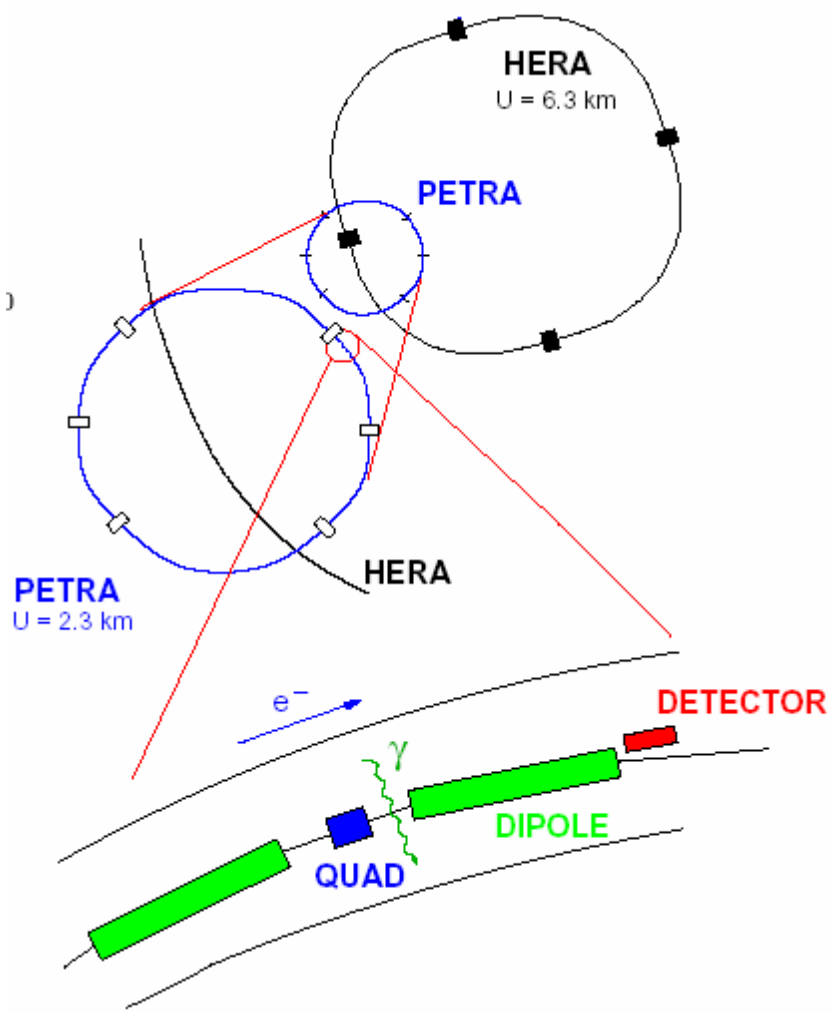
PETRA parameter

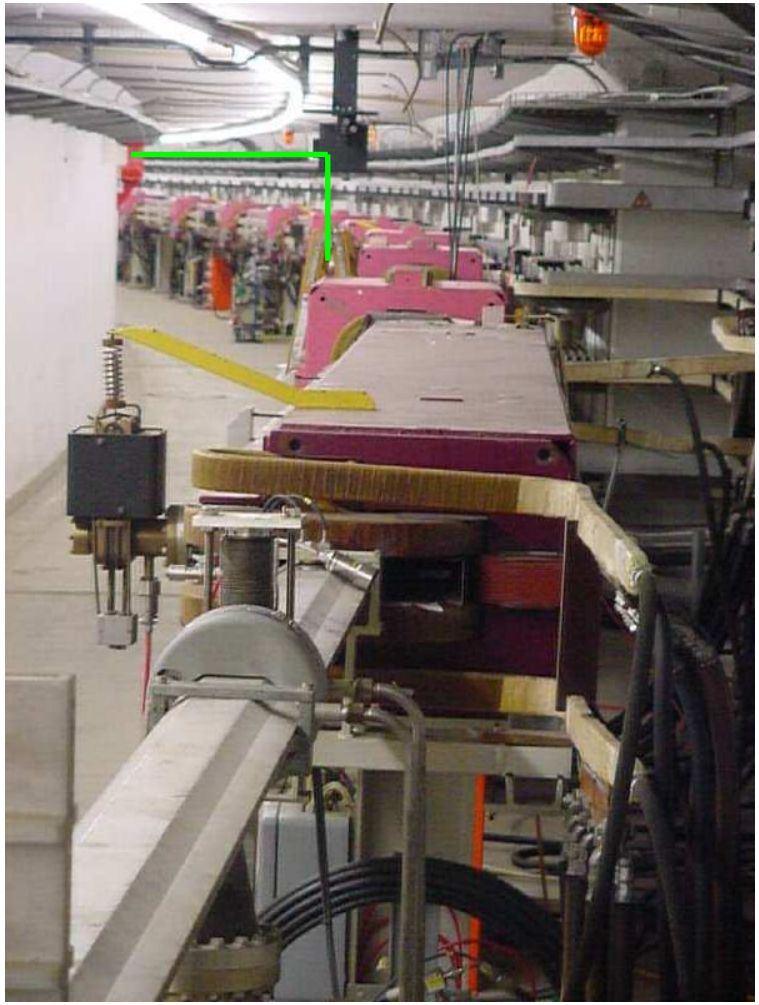
Energy	E/GeV	4.5 to 12
Bunch Length	σ_z/ps	~100
Charge/bunch	nC	1 to 3
Hor. beam size	σ_x/μm	500 to 100
Ver. beam size	σ_y/μm	~100

Laser parameter

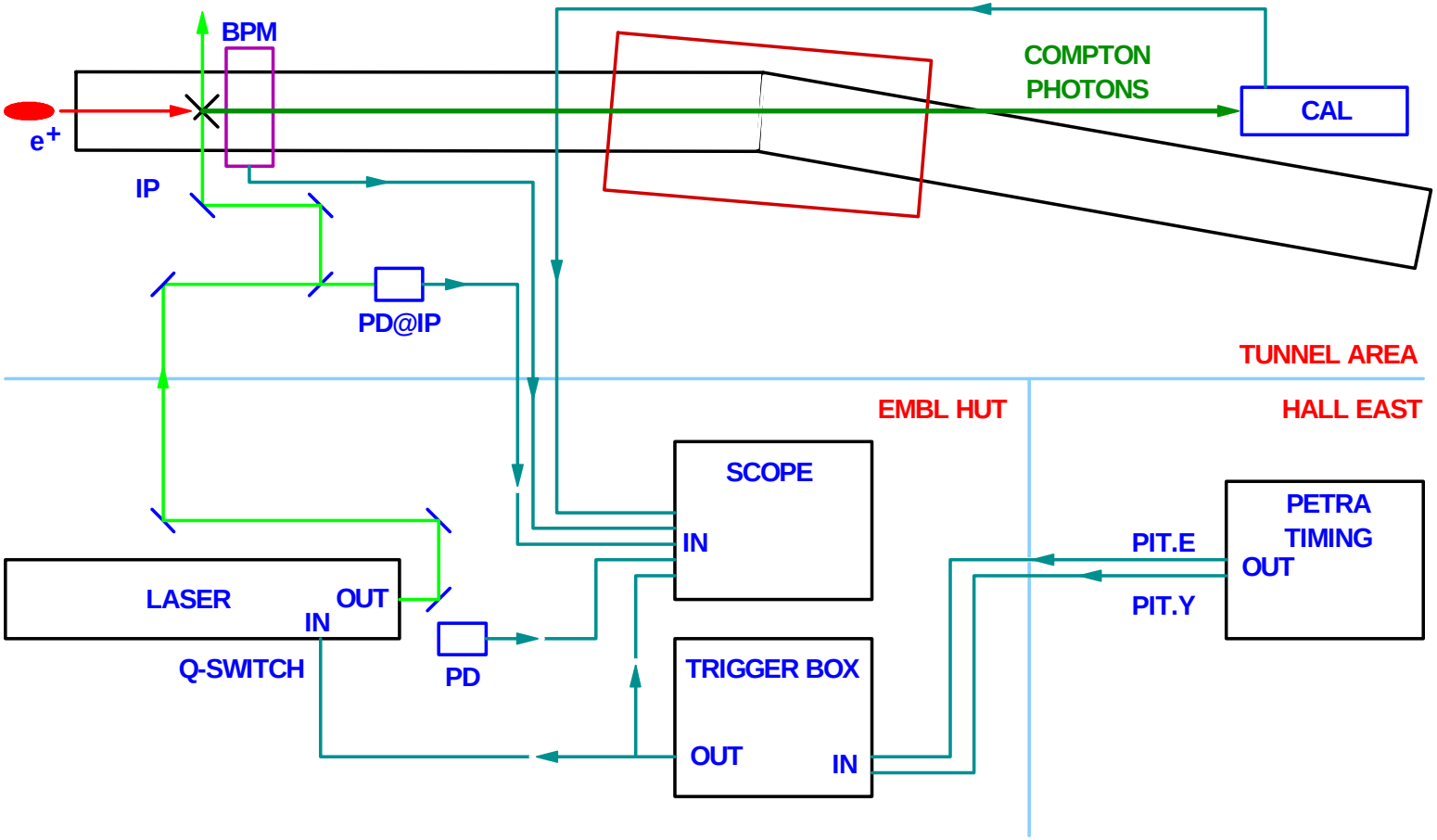
Wavelength	l/nm	1064/532
Energy	E/mJ	250/90
Pulselength	dt/ns	10
Reprate	f_{rep}/Hz	30
Beam size	$\sigma_{x,y}$/mm	~7
Divergence	θ/mrad	0.7

Laserwire for PETRA

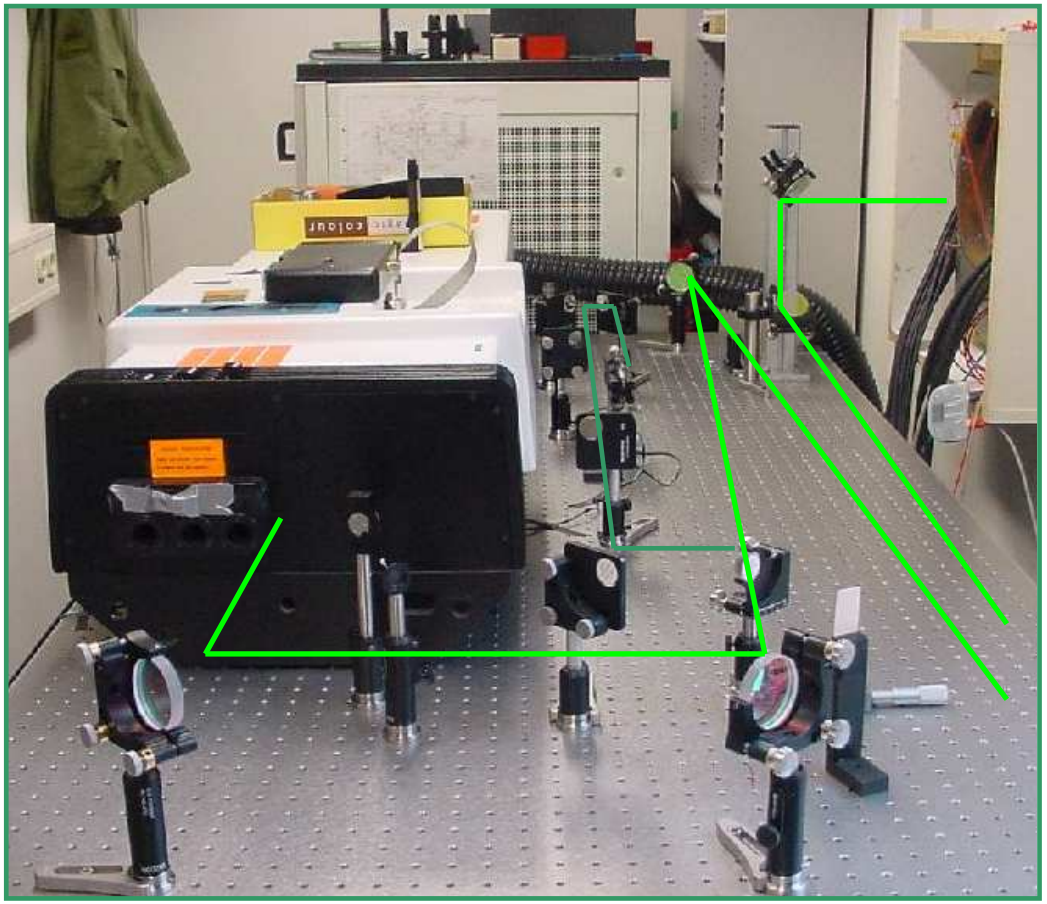


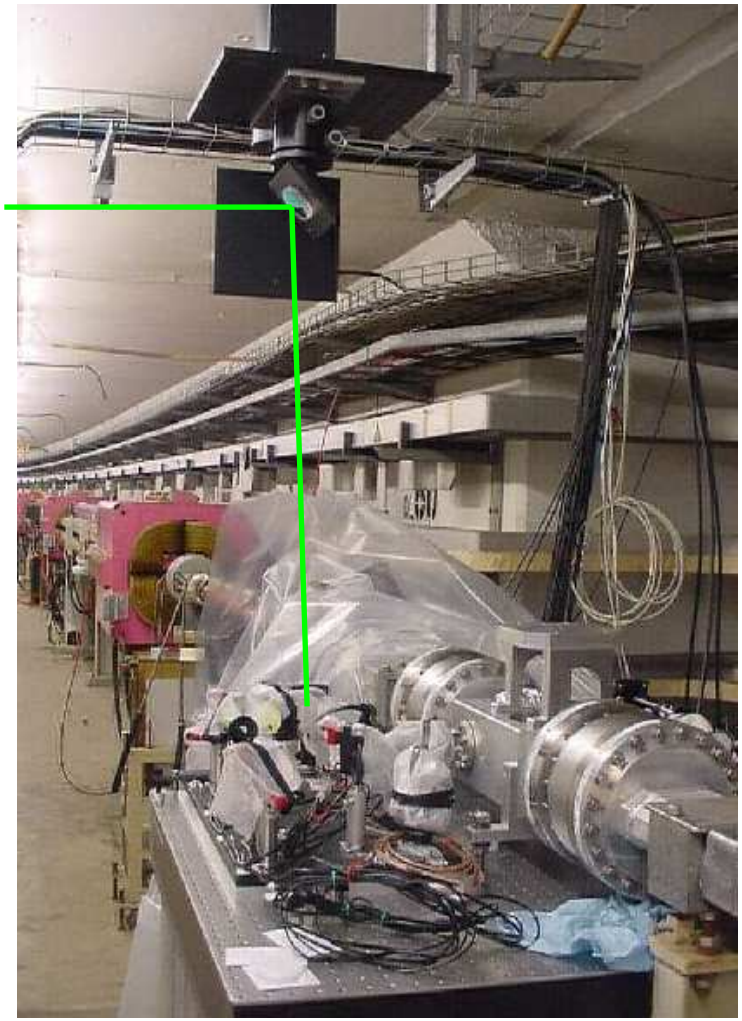


Setup at PETRA



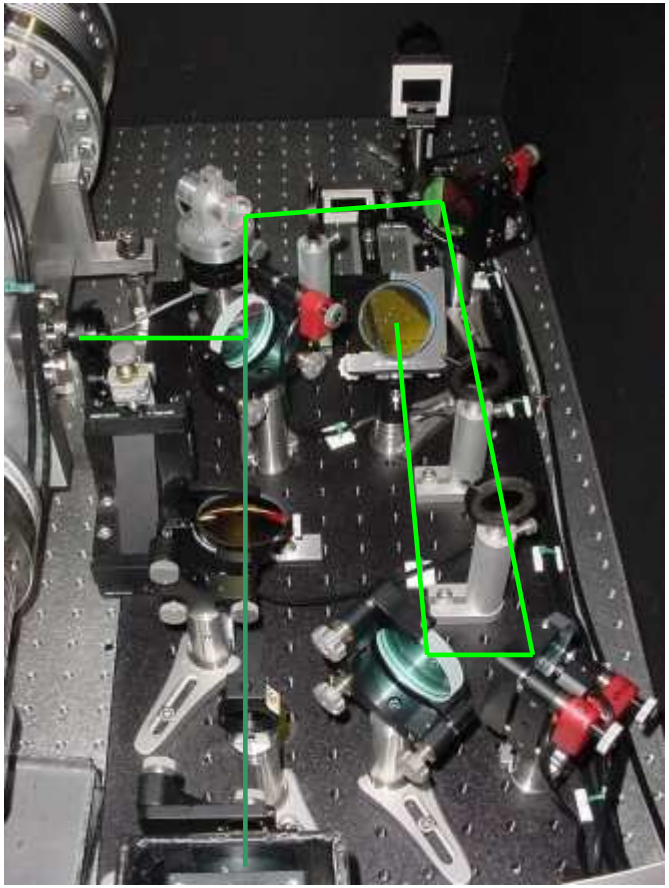
Installation at PETRA

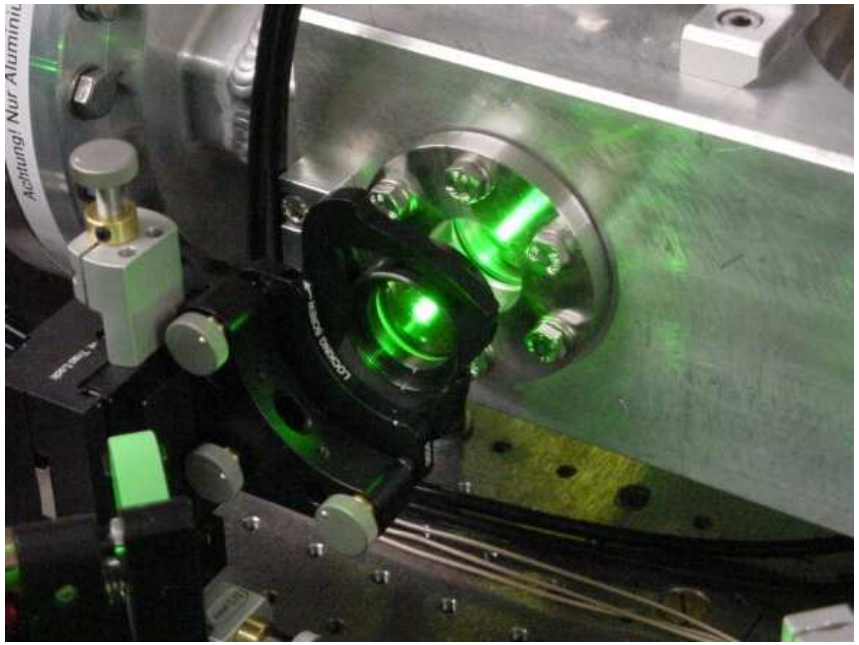




Lab Measurements at RHUL

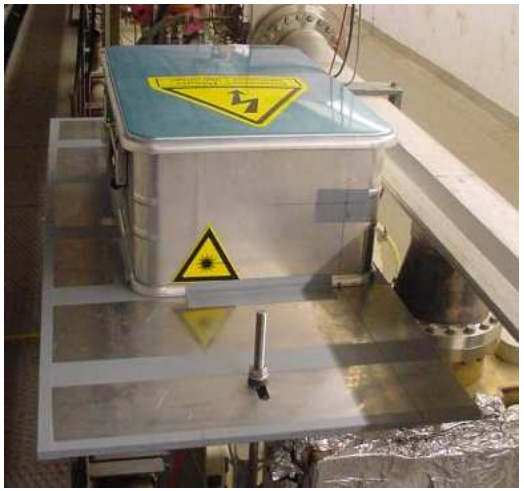
Installation at PETRA

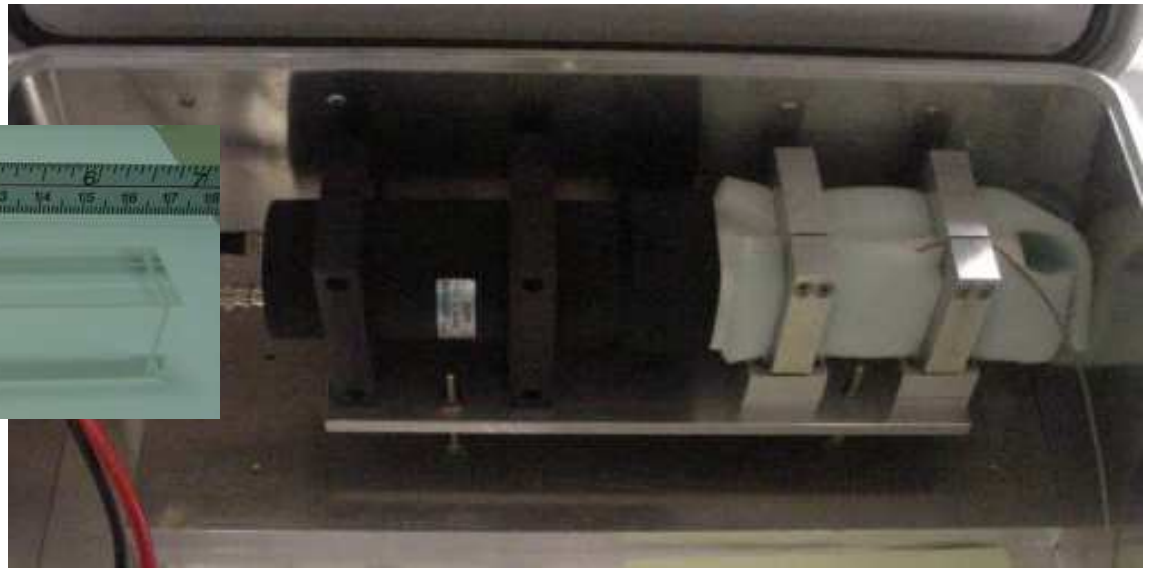




Detector

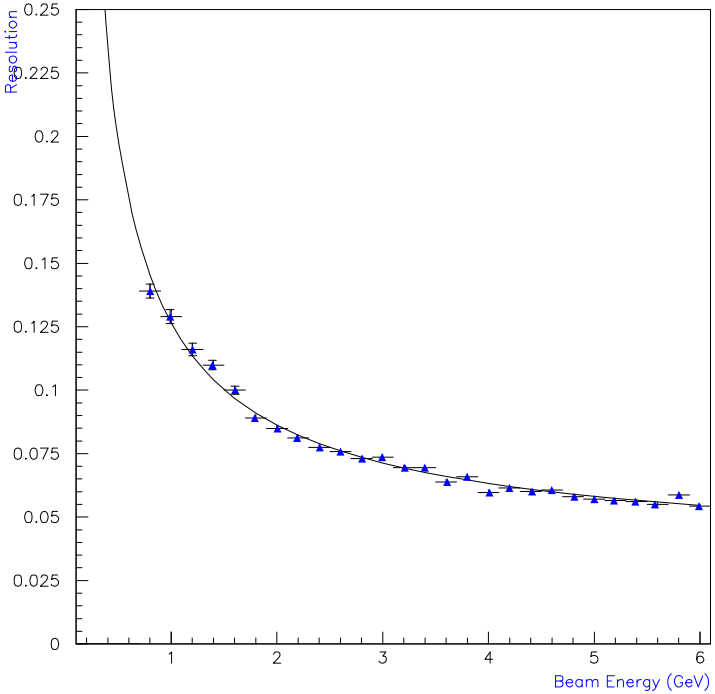
- Requirements for detector material
  - short decay time (avoid pile up)
  - short radiation length
  - small Moliere radius
- Cuboid detector crystals made of PbWO4
- 3x3 matrix of 18x18x150 mm crystals
- Energy resolution
  better than 5%

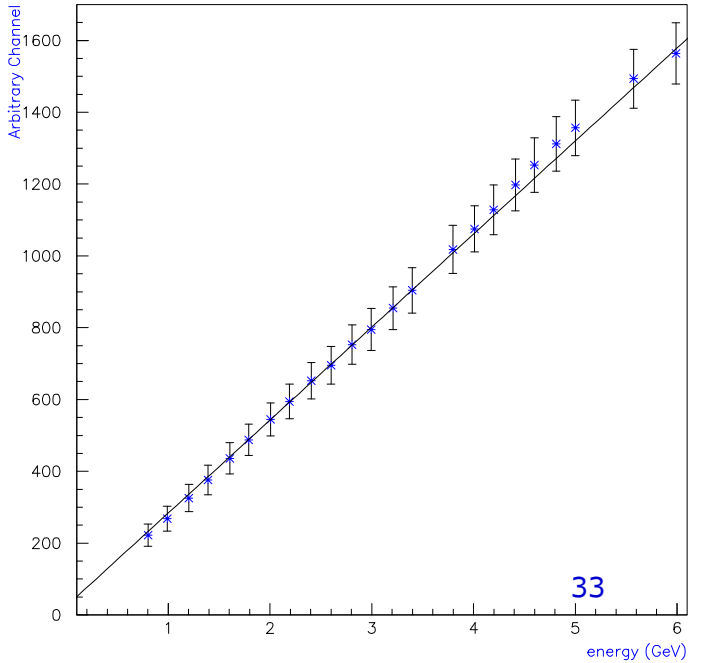




Detector Calibration

- 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



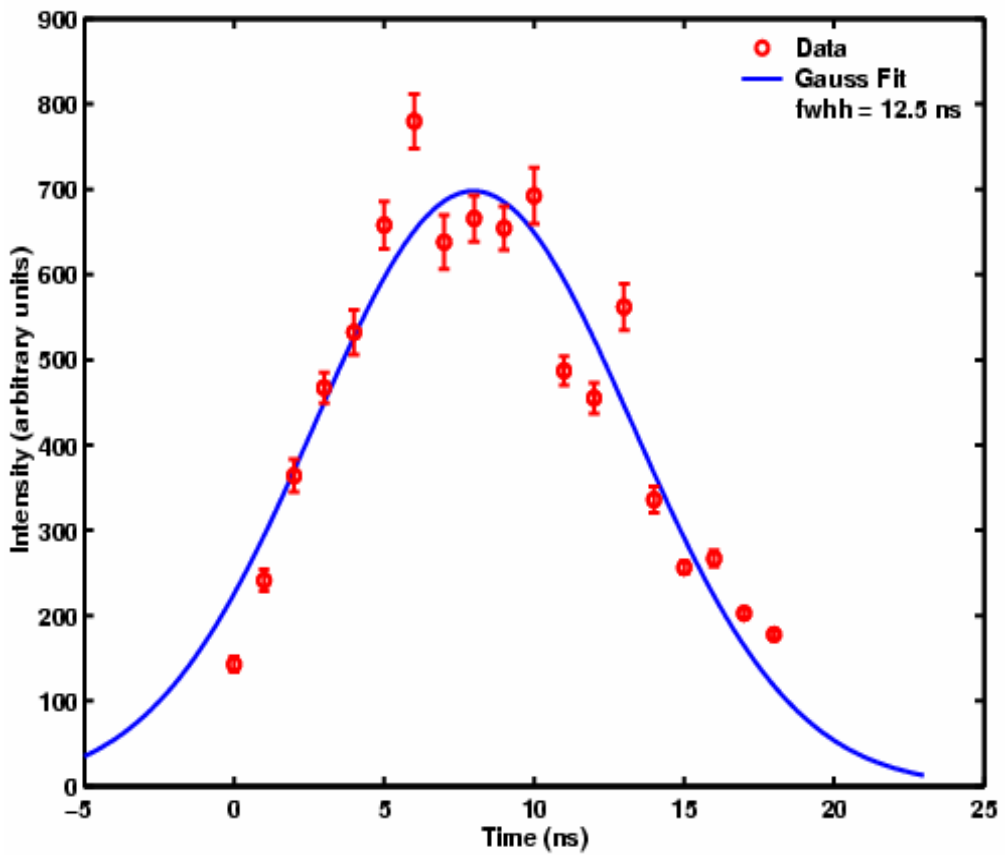


The Laser

- The laser has been given to us by B. Dehning from CERN. It was used at LEP to measure beam polarization
- It's a Nd:YAG Q-switched system, running with 30 Hz
- pulse energy measured: 40 mJ, power: 4 MW
- synchronization to PETRA beam by triggering the Q-switch Pockels-cell
- transverse beam quality is modest (multimode)
- measured spot size at IP: $\sigma_L = (80 \pm 10)\ \mu m$

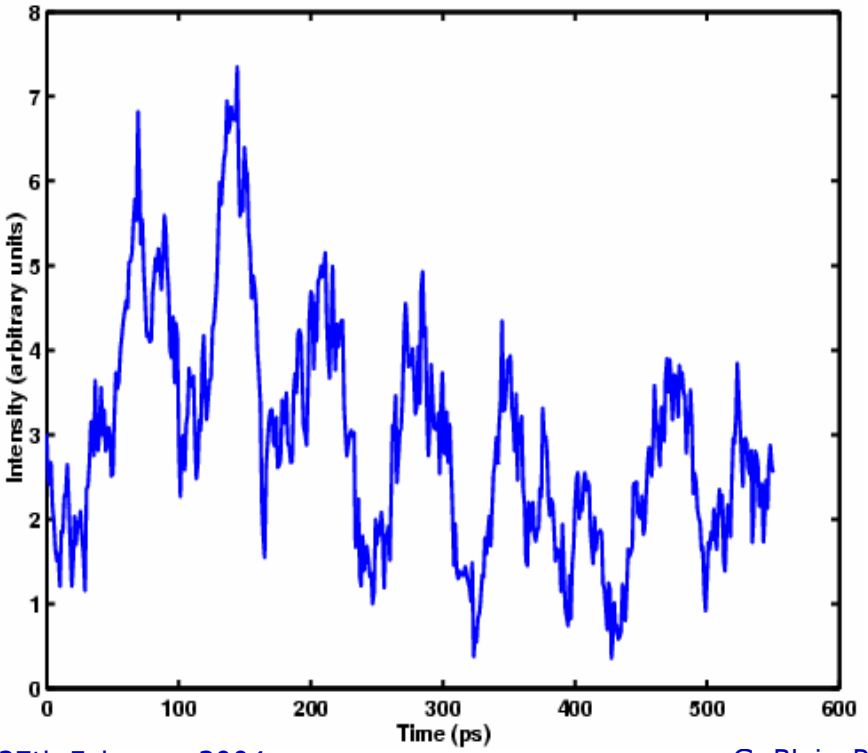
Averaged Laser Time Profile

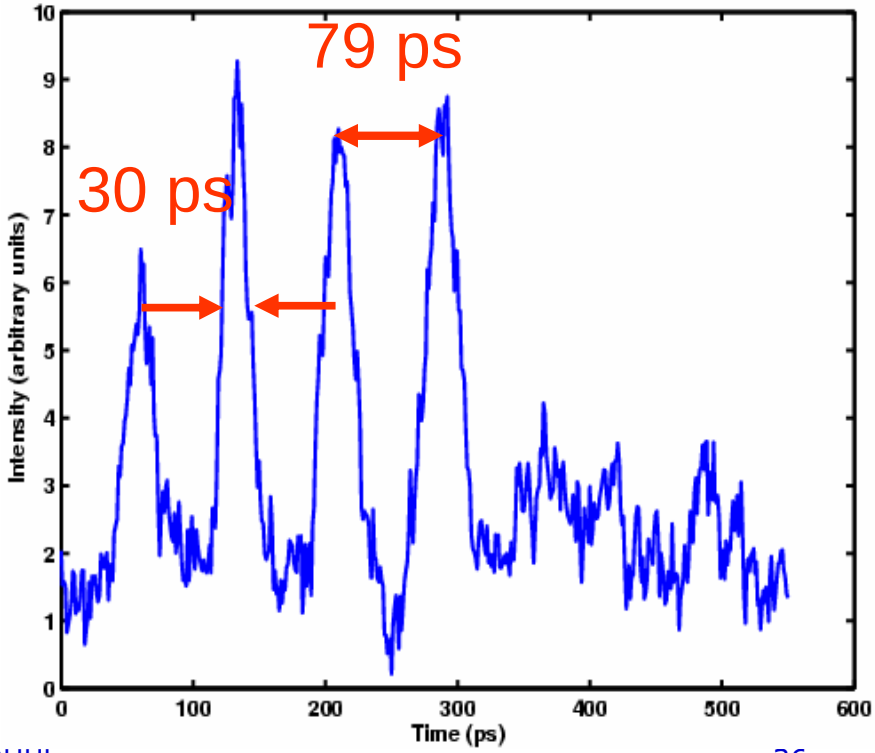
- Measured averaged profile:
  fits to gaussian with a width of 12.5 ns (as expected)



Longitudinal laser structure

- The longitudinal structure is due to longitudinal mode beating – this was expected
- The beating changes from shot to shot



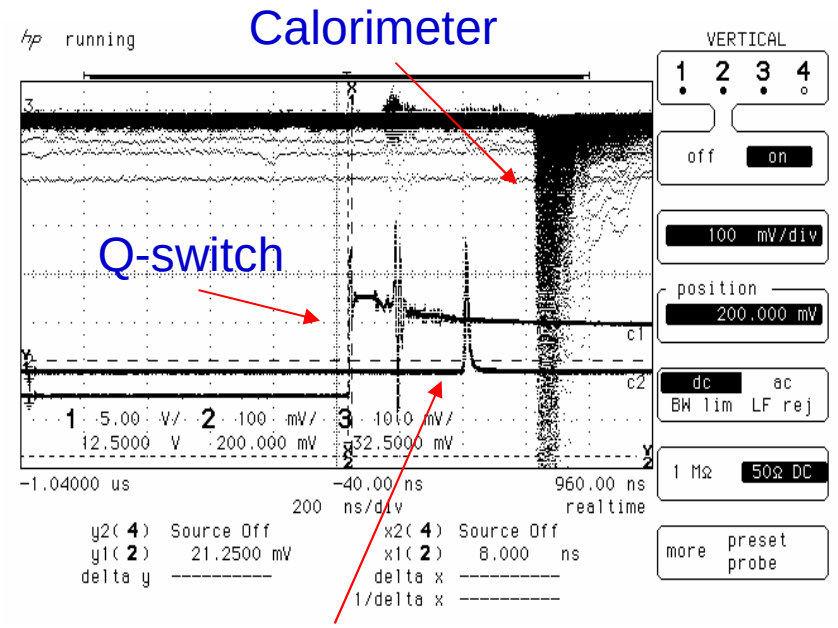


Laser Summary

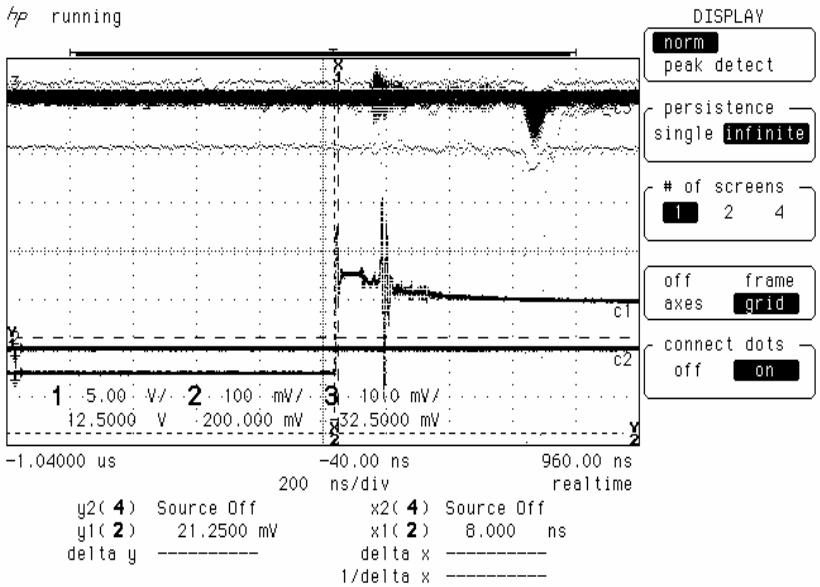
- As expected for a this type of laser, the longitudinal profile shows substructure due to mode beating
- The spikes have a width of 30 to 60 ps and a distance of 60 to 80 ps
- Unfortunately, the structure is not stable and changes from shot to shot
- To overcome this, the laser has to be equipped with a frequency stabilized seed laser or eventually with an Etalon
- Hot spots a problem (temp stability)

First Photons 31.07.03

Laser on

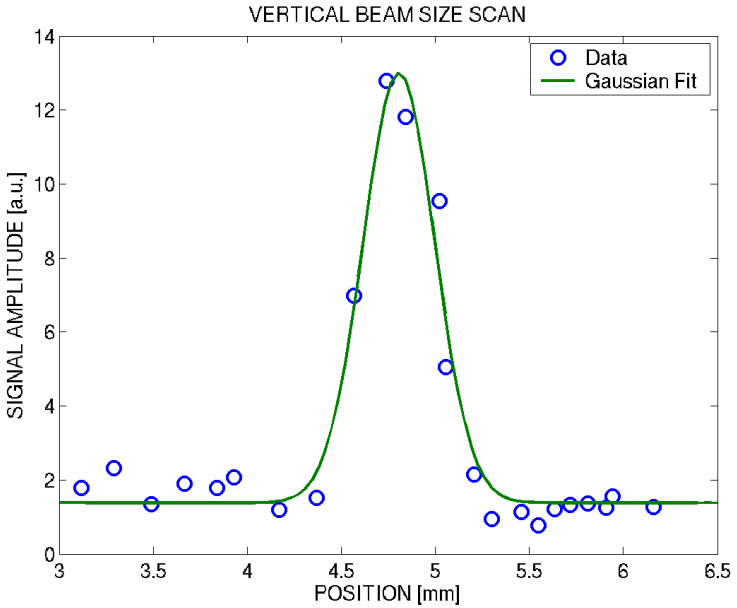


Laser off



Result Orbit Scan

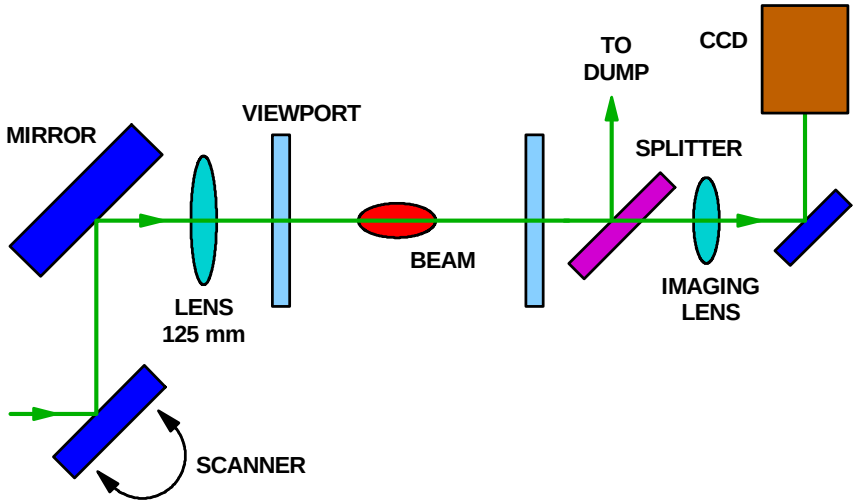
- Gaussian approximation of beam shape
  $\sigma_m = (0.175 \pm 0.020_{stat} \pm 0.038_{sys})$ mm



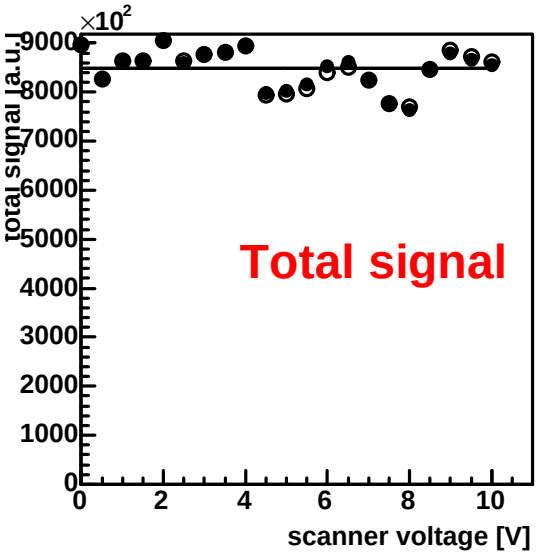
- Vertical beam size
  $\sigma_e = \mathrm{sqrt}(\sigma_m - \sigma_L)$
  laser $\sigma_L = (40 \pm 10)$ μm
  $\sigma_e = (170 \pm 23 \pm 37)$ μm
- Result of fit sensitive to background modelling
- Systematic error dominated by vertical orbit jitter
- More measurements and understaning of bkg sources necessary

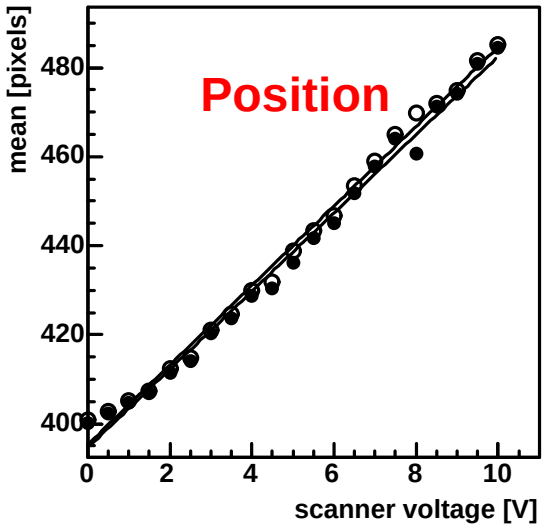
Fast Scanner Operation

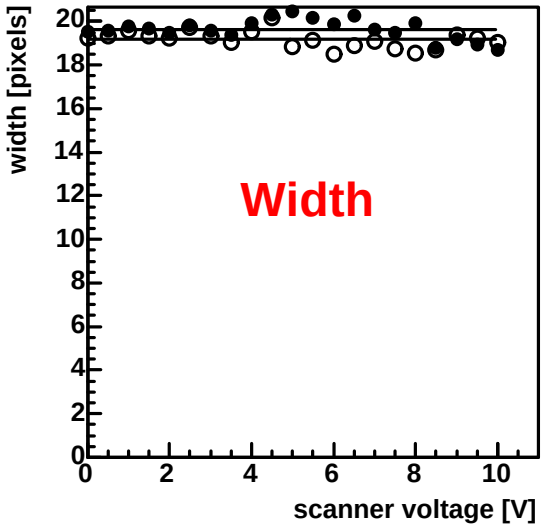
- Next scan with remote controlled fast scanner
- Orbit position stable
- Scan range: ± 2.5 mrad
  - Scan line = range * f_{lens}= 0.625 mm (± 20%)
- Change amplitude of scanner power supply (1-100V)
- Take 5k counts
- Record laser IP image with CCD
- Move laser beam
- Take 5k counts ...



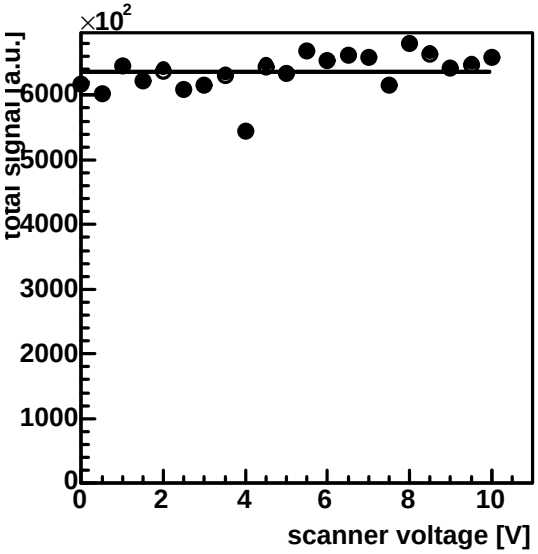
CCD Diagnostics

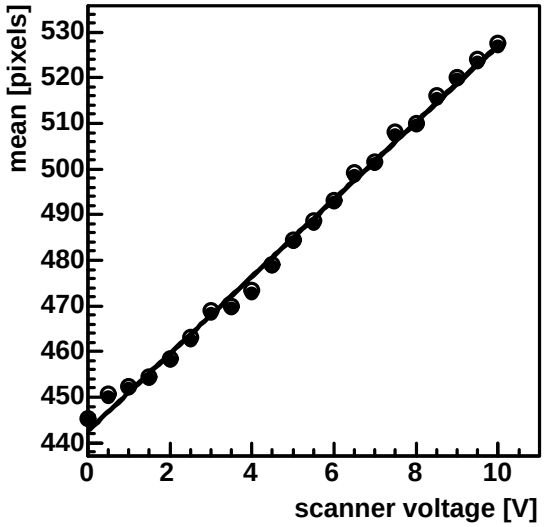


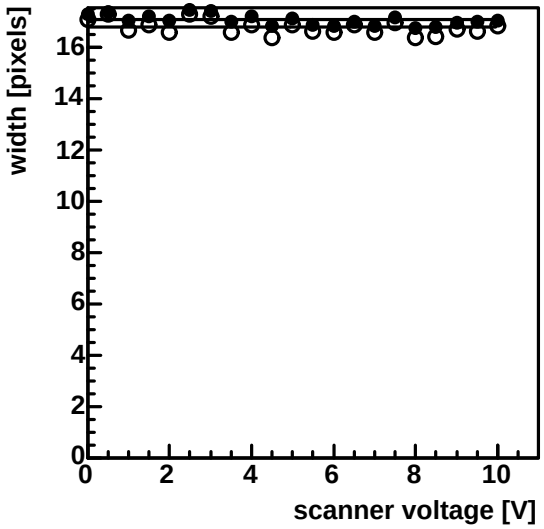




Scan 1



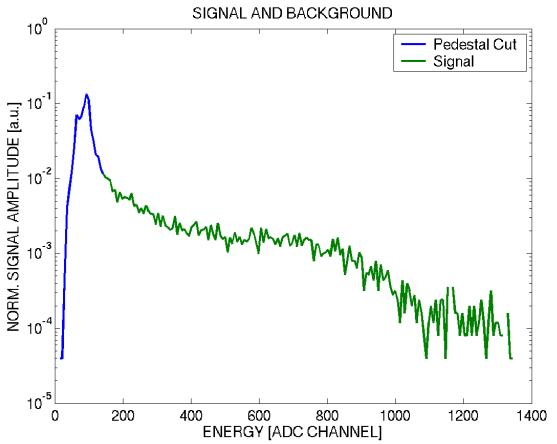


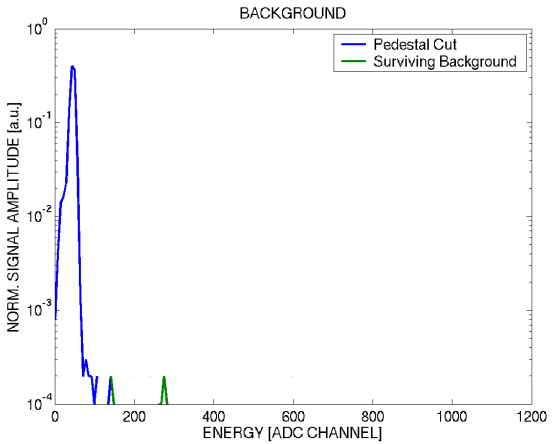


Scan 2

Data and Analysis

- Seven scan points recorded
- 5 min / point
- 40 min for full scan
- Positron beam position stable within ± 40 μm
- Moving low energy pedestal
- No background model
- Orbit stable → bkg const.
- Simple pedestal cut instead
- Sufficient background rejection





New Setting 5.12.03

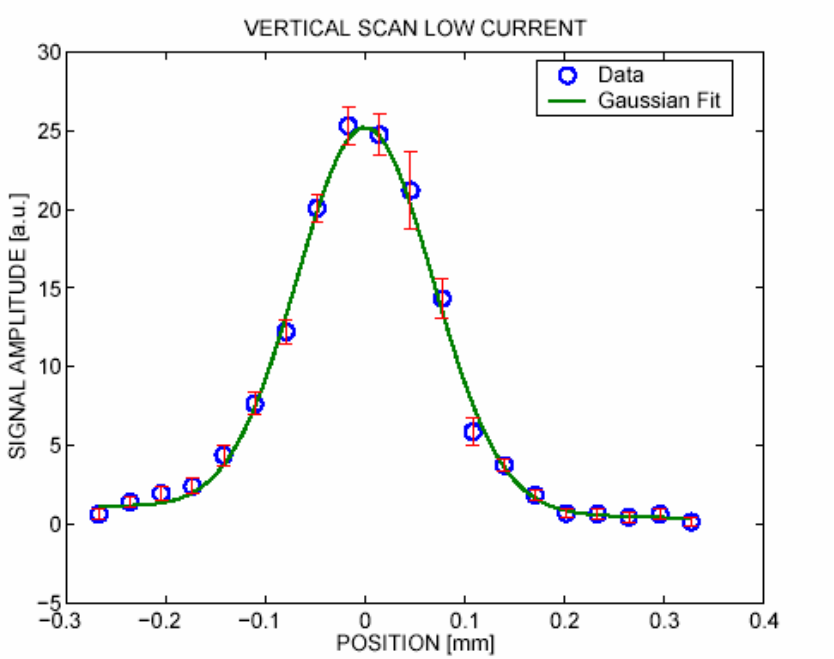
- Positron beam in PETRA
- Beam energy: 7 GeV
- Positron beam optics not as in October scans.
- Bunch pattern: 14 x 1 bunch evenly filled
- Low current: 7.1 mA, first bunch 0.458 mA
  - Bunch charge = avg. current / (reprate * Nbunches) = 3.9 nC
- High current: 40.5 mA, first bunch 2.686 mA
  - Bunch charge = 22.3 nC
- Vertical and horizontal orbit bumps to steer positron beam into laser beam
  - Closed symmetric bumps using four steerers
- Scanning of laser beam using the fast piezo scanner

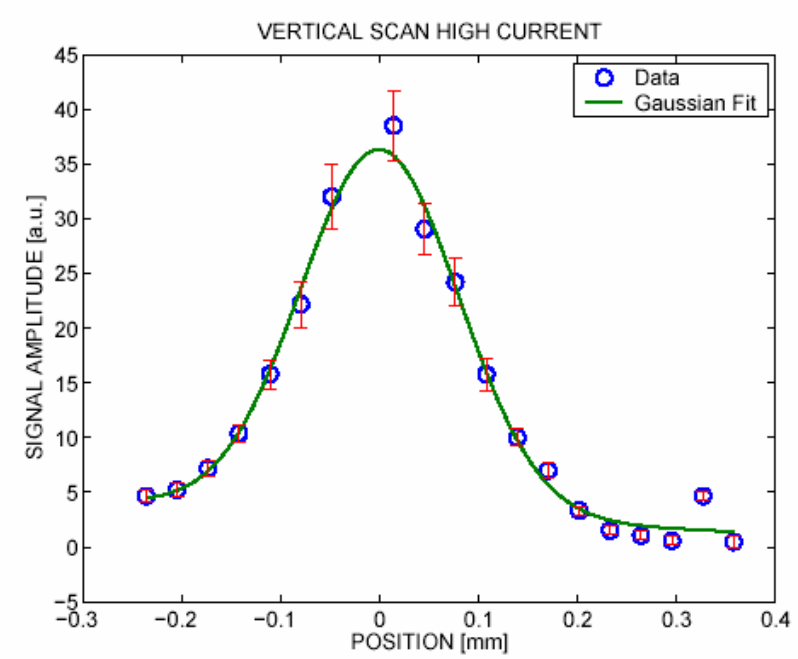
Results 04.12.03 Data

- Gaussian approximation of beam shape

  σ_m =(68 ± 3 ± 20) μm at low current

  σ_m =(80 ± 6 ± 20) μm at high current





Immediate Plans

- Laserwire at PETRA produced first compton photons and measure vertical beam size Next steps:
- Re-calibrate calorimeter (radiation damage?)
- Full characterisation of laser: beam size, divergence, and power (stability) with slot scans and imaging techniques
- Update all readout software, merge BPM,CCD and PMT software
- New Trigger box and calorimeter readout.
- Systematic scans with the fast scanner
- Go to smaller laser spot sizes and reduce error bars
- Build second dimension scanner.
- Push up the piezo-scanning speed
- Try to upgrade/replace the laser

Future Programme

- Laserwire-UK meeting held at Oxford in Jan 04
- New ideas for high power tests with micron spot sizes, possibly at ATF in KEK?
- Incorporate new BPMs and TRDs in integrated vacuum vessel.
- Investigate new CCD readout speeds, combined with fast position-sensitive detectors.
- Set up advanced laser-systems post LC technology choice.
- Start designing a complete laser-wire emittance measurement system for the LC BDS.

Summary:

- Very active ongoing programme at PETRA.
- Exciting new plans and ideas.