John Adams Institute J.A.I. for Accelerator Science

Royal Holloway University of London

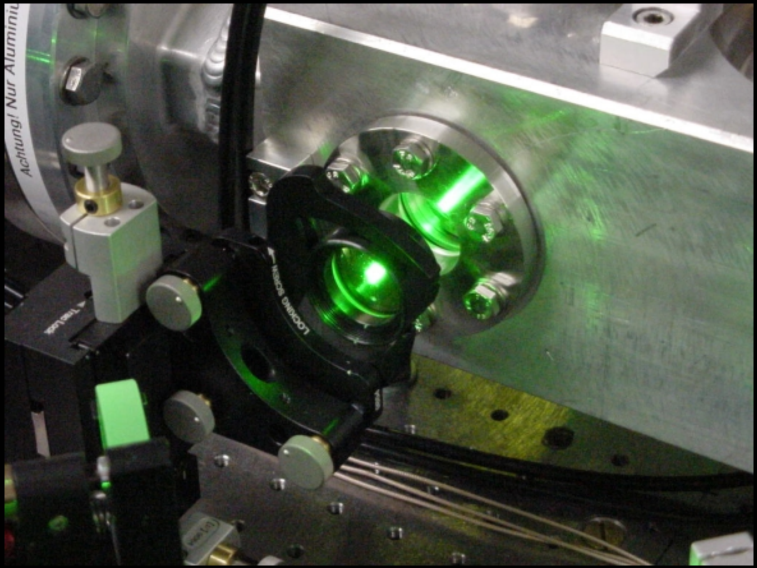
Laser-wire R&D

G.A. Blair

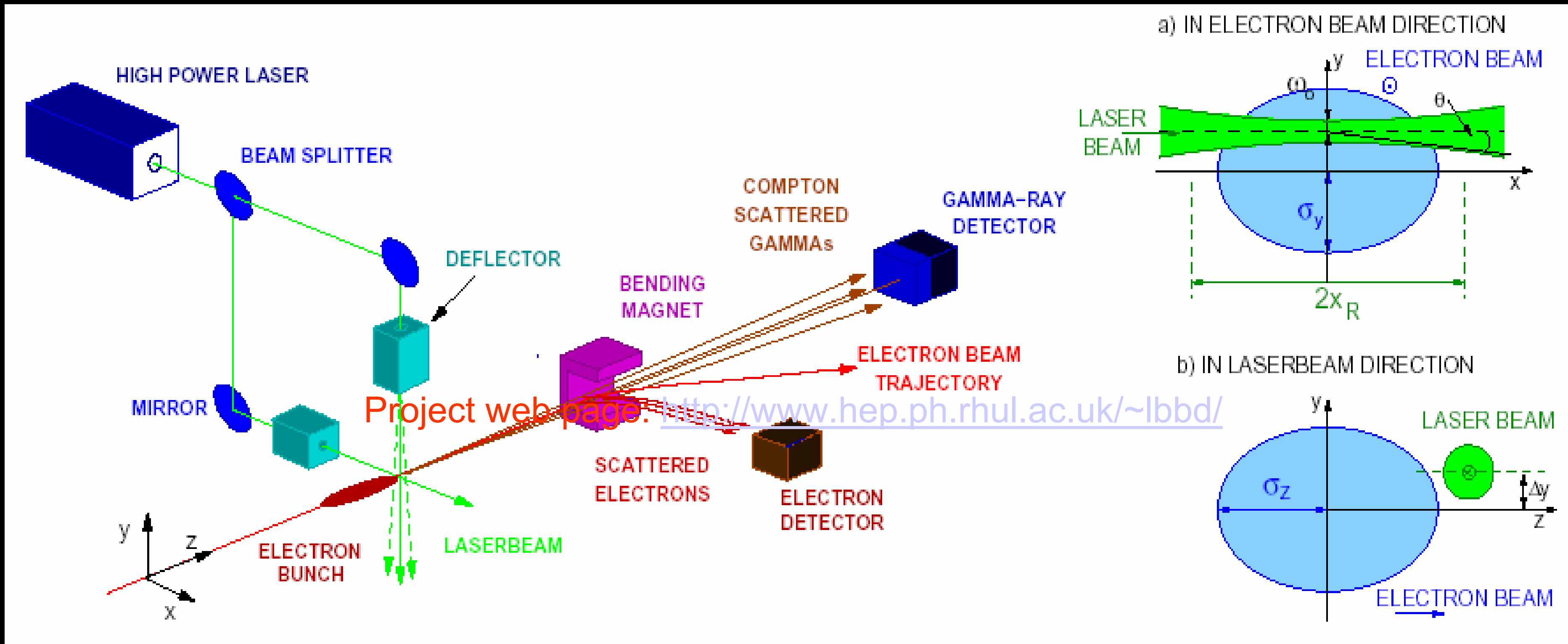
LCWS05, Stanford

20th March 2005

- Overview
- PETRA laser-wire
- ATF laser-wire
- Future plans



Overview



Project web page: http://www.hep.ph.rhul.ac.uk/~lbbd/

- High-power pulsed laser system
- Fast intra-train scanning
- bunch-by-bunch profile

People

BESSY

T. Kamps

CERN

T. Lefevre

DESY

H. C. Lewin, S. Schreiber, K. Wittenburg, K. Balewski

Oxford

B. Foster, N. Delerue, D. Howell

Royal Holloway (UL)

G. Blair, G. Boorman, J. Carter, F. Poirier, M. Price, C. Driouichi

University College London (UL)

S. Boogert, S. Malton

KEK

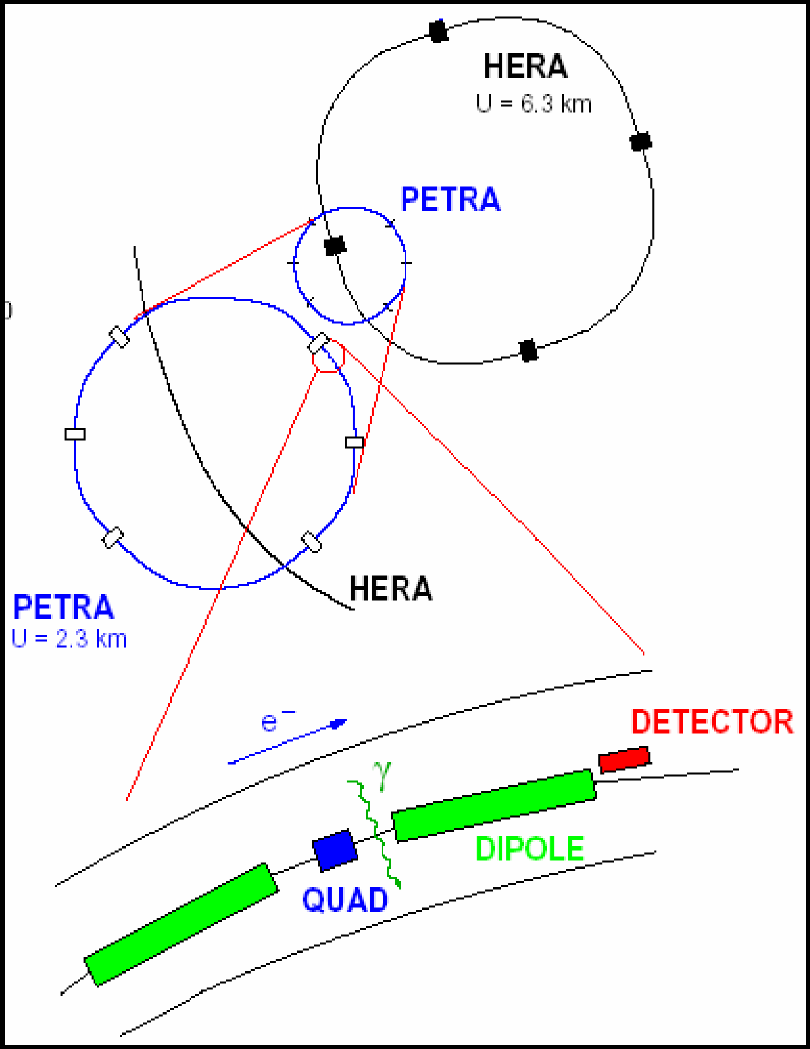
A. Aryshev, H. Hayano, P. Karataev, K. Kubo, N. Terunuma, J. Urakawa

SLAC

J. Frisch, M. Ross

Project web page: http://www.hep.ph.rhul.ac.uk/~lbbd/

Laserwire - PETRA



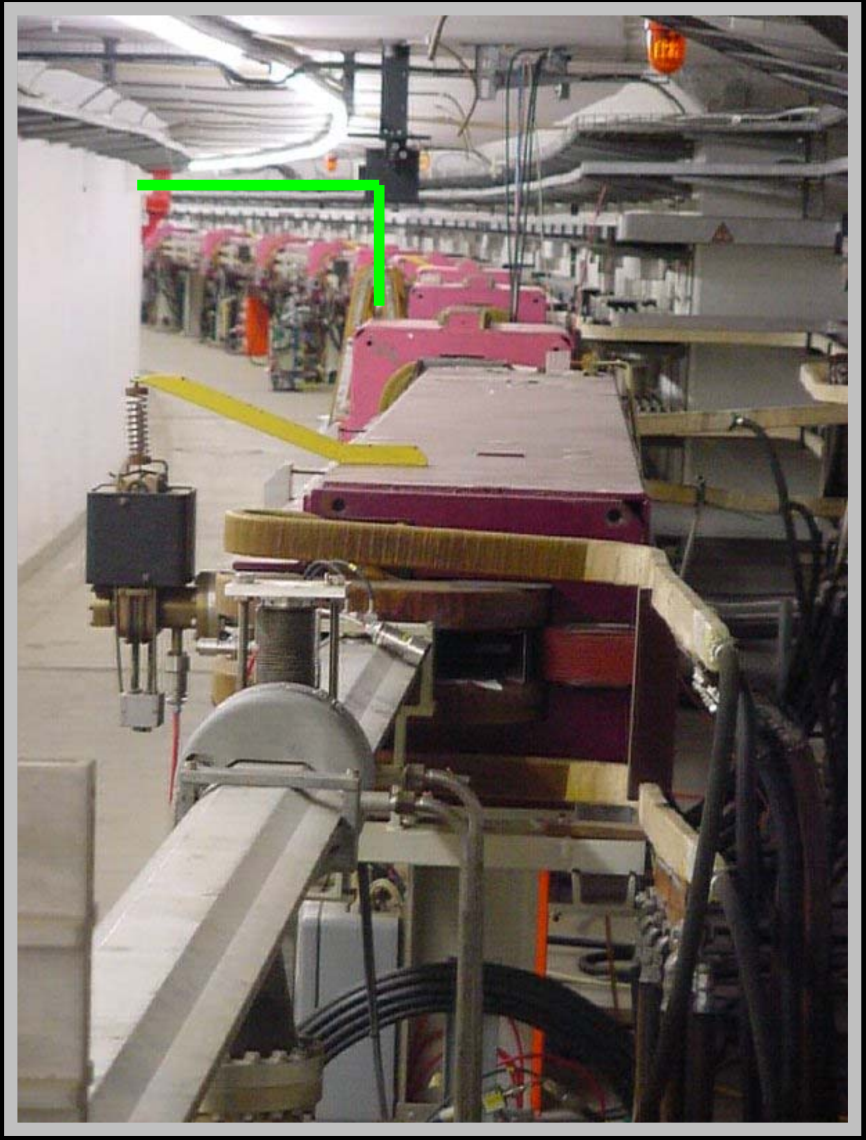
Initially built and tested in London

PETRA beam characteristics

Optics: pem04
Energy 7 GeV

βx 7m
βy 20m
εx 23 nm rad
εy 0.46 nm rad

σx 400 μm
σy 96 μm



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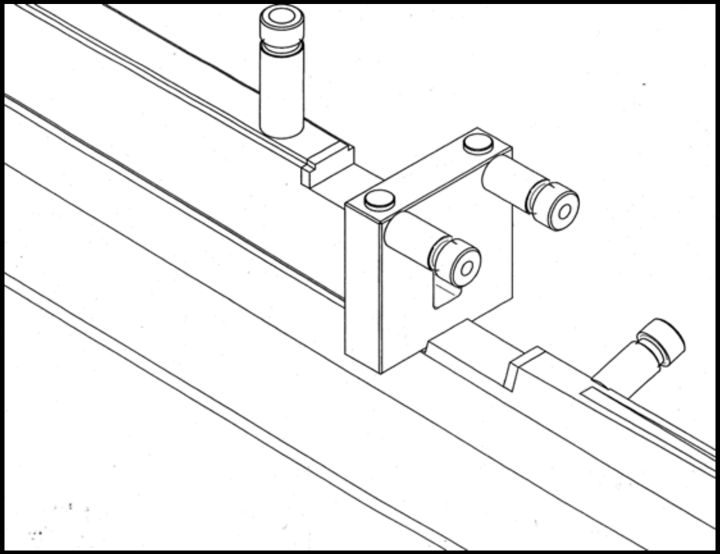
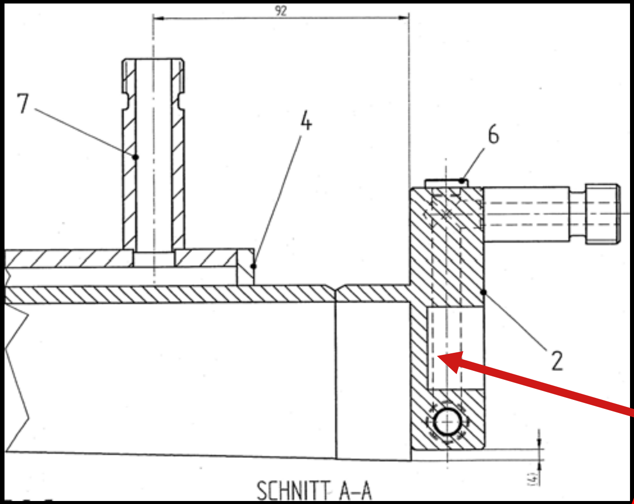
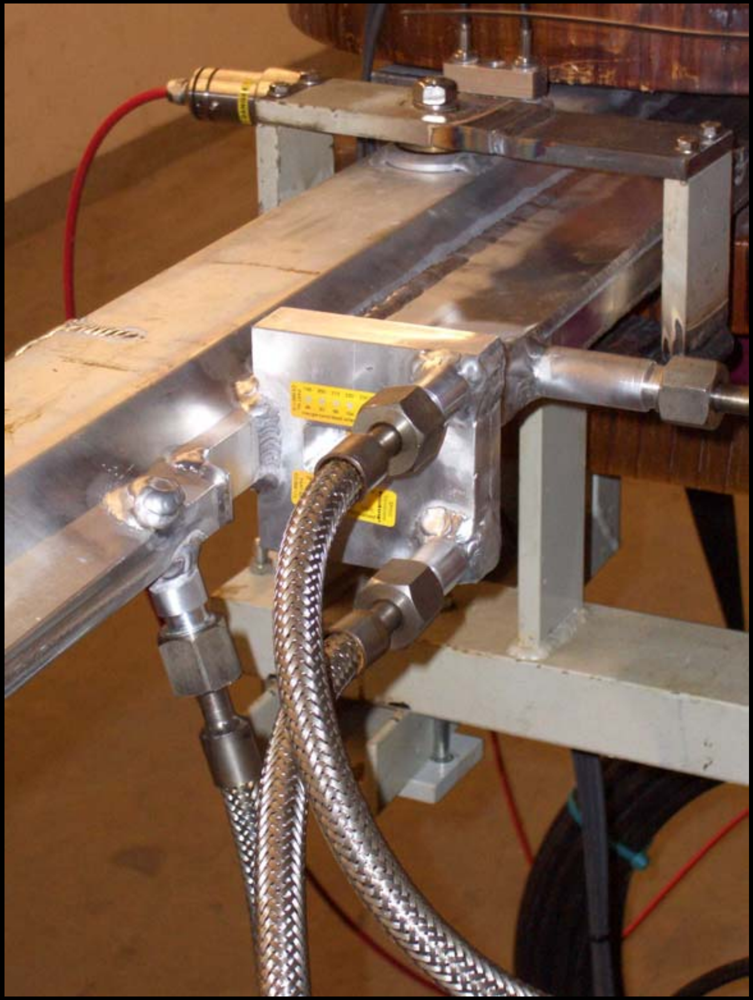
New Signal Window

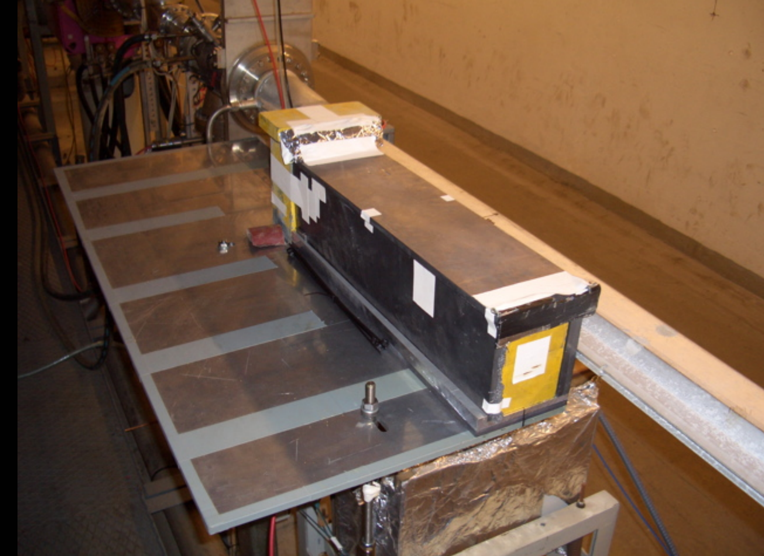






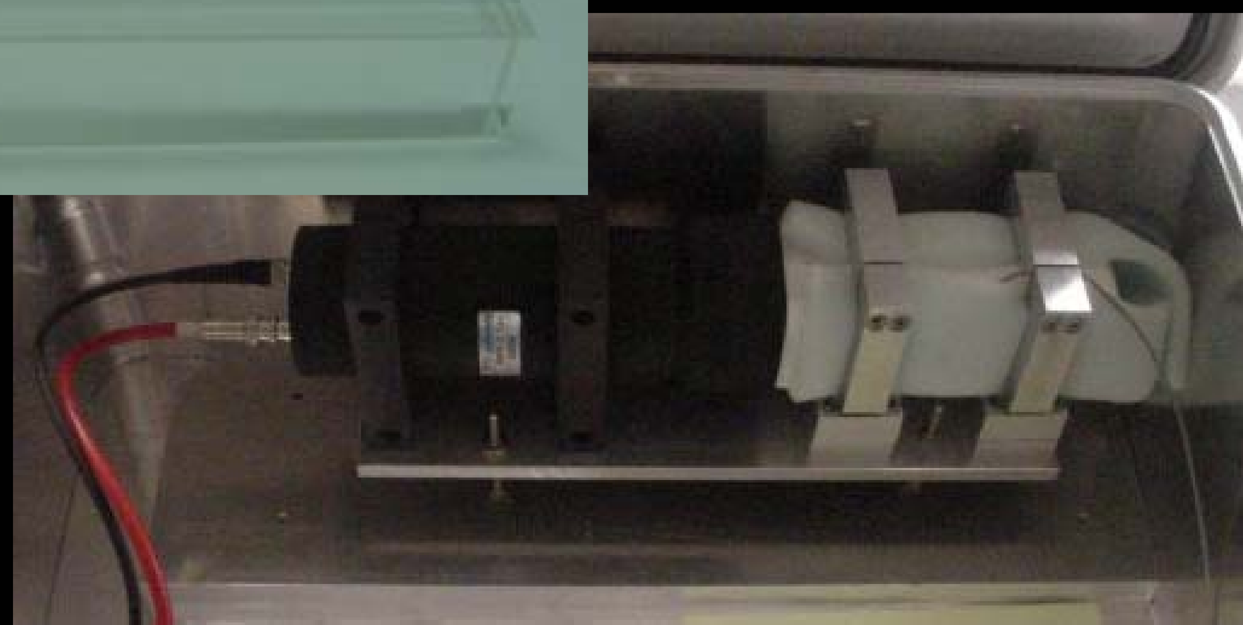
6mm Aluminium Window

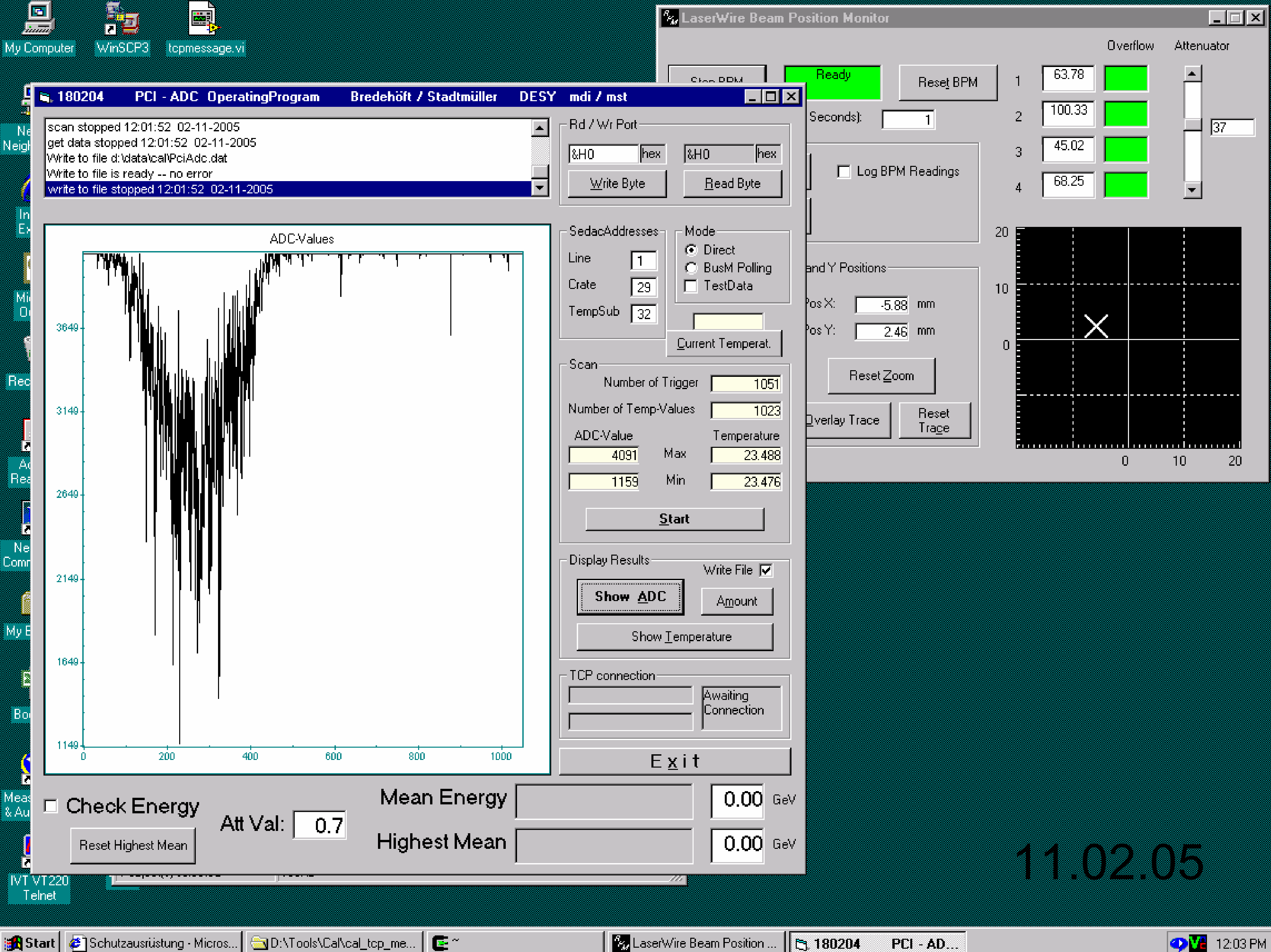
Detector



Detector crystals: $PbWO_4$

3x3 matrix of 18x18x150 mm crystals





My Computer
WinSCP3
tcpmessage.vi
LaserWire Beam Position Monitor
Overflow
Attenuator
Ready
Reset BPM
Seconds):
1
63.78
100.33
45.02
68.25
37
Log BPM Readings
and Y Positions
Pos X:
-5.88
mm
Pos Y:
2.46
mm
Reset Zoom
Overlay Trace
Reset Trace
180204 PCI - ADC OperatingProgram Bredehöft / Stadtmüller DESY mdi / mst
scan stopped 12:01:52 02-11-2005
get data stopped 12:01:52 02-11-2005
Write to file d:\data\cal\PciAdc.dat
Write to file is ready -- no error
write to file stopped 12:01:52 02-11-2005
Rd / Wr Port
&H0
hex
&H0
hex
Write Byte
Read Byte
ADC-Values
SedacAddresses
Line
1
Crate
29
TempSub
32
Mode
Direct
BusM Polling
TestData
Current Temperat.
Scan
Number of Trigger
1051
Number of Temp-Values
1023
ADC-Value
Temperature
4091
Max
23.488
1159
Min
23.476
Start
Display Results
Write File
Show ADC
Amount
Show Temperature
TCP connection
Awaiting Connection
Exit
Check Energy
Reset Highest Mean
Att Val:
0.7
Mean Energy
0.00
GeV
Highest Mean
0.00
GeV
11.02.05
IVT VT220 Telnet
Start
Schutzausrüstung - Micros...
D:\Tools\Cal\cal_tcp_me...
LaserWire Beam Position ...
180204 PCI - AD...
12:03 PM

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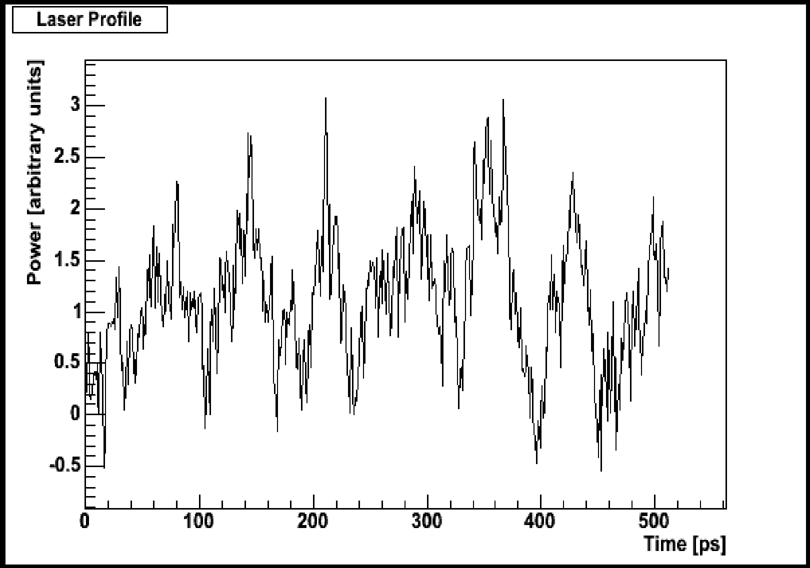
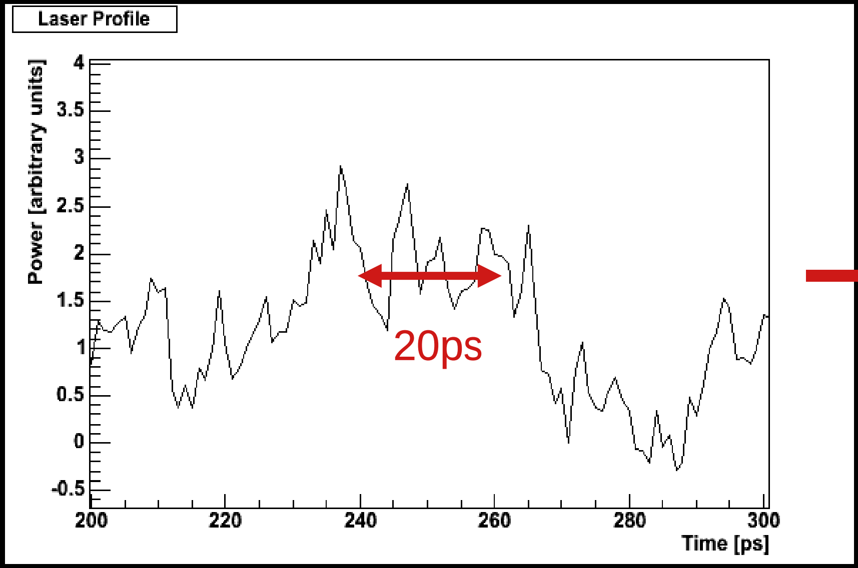
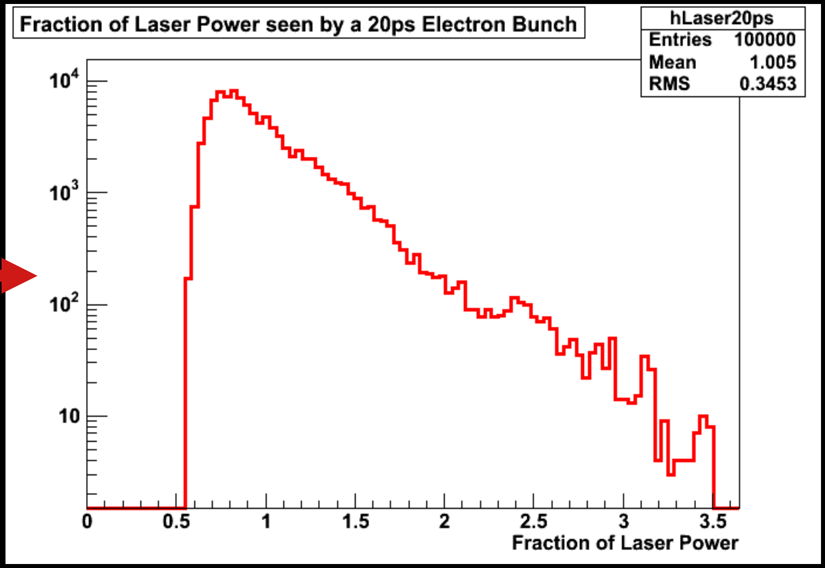
Laser Power Substructure

- The Laser power profile has temporal substructure
  - So not always delivering full power to the electron beam
- Integrate over laser power with a 20ps Gaussian to produce an effective laser power distribution seen by an electron bunch







Data and Simulations

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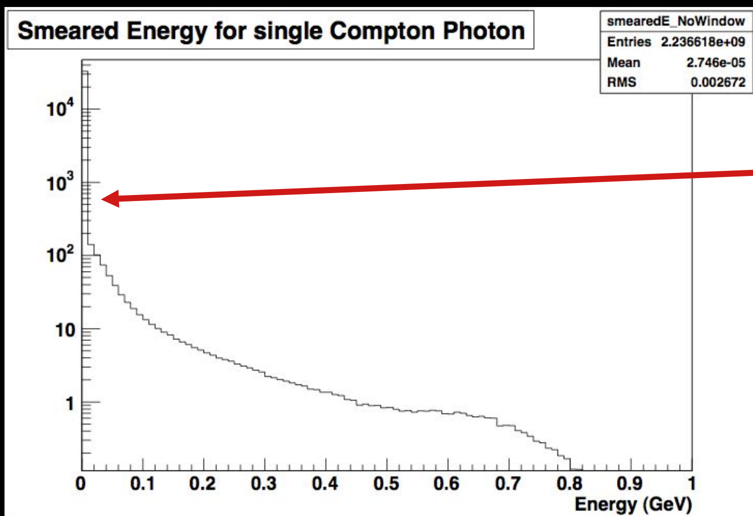
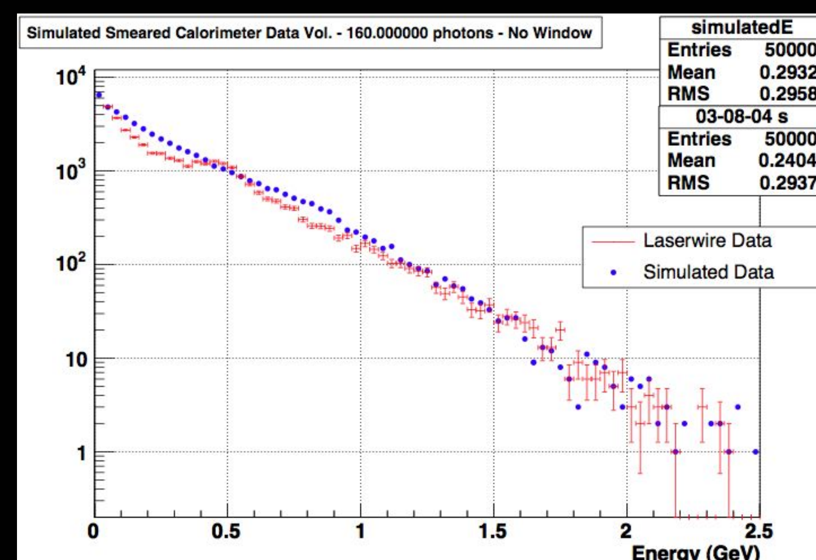
Before Exit Window Installed



- Used BDSim to simulate the PETRA Laserwire set up
- Produced a single Compton distribution
  - Observed that 99% of photons were not making it past the beam pipe material
- Extrapolated to N photons using Poisson statistics
- Accounted for Laser Power Substructure
- Compared to non-scanning data set taken in Aug 2004, using 160 photons:



$$\langle N_\gamma \rangle = \frac{P_{\rm L}\sigma_{\rm C}}{ch\nu_0}\frac{1}{\sqrt{2\pi}\sigma_s}\exp\left(\frac{-y^2}{2\sigma_s^2}\right)\int_{-\infty}^{\infty} dz \frac{1}{\sqrt{2\pi}\sigma_{\rm f}}\exp\left(\frac{-z^2}{2\sigma_{\rm f}^2}\right)$$

P.Tenenbaum & T.Shintake,
Ann.Rev.Nucl.Part.Sci.49:125-162,1999

- Expected Number of Photons for 1mA bunch current at PETRA is:
  - ~160 photons

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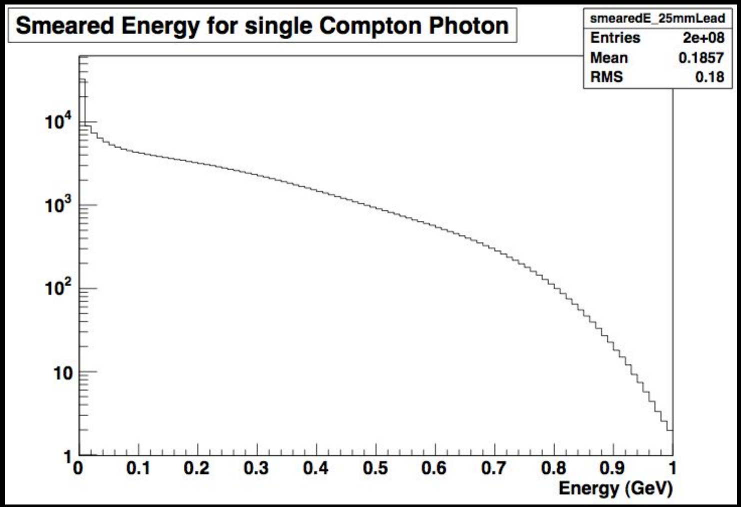
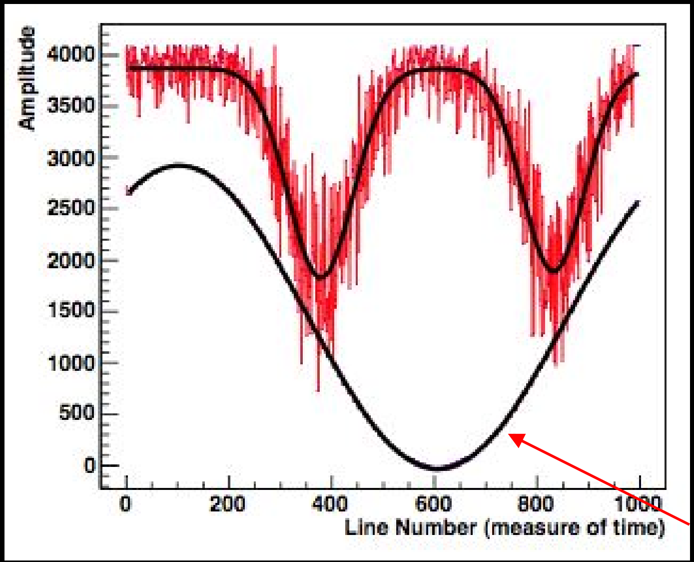
Data and Simulations

After Exit Window Installed





- The new window required that 25mm Lead be placed in front of Calorimeter as too much energy was incident upon it.
- Voltage supply on PMT also needed to be reduced from 1115kV to 715kV.
  - Introduced a Gain reduction factor of 12.48 according to manufacturers guidelines
- New simulations (with window and 25mm Lead) confirm we should see a great improvement in the signal.

Simulations to emphasise the need for A high quality laser

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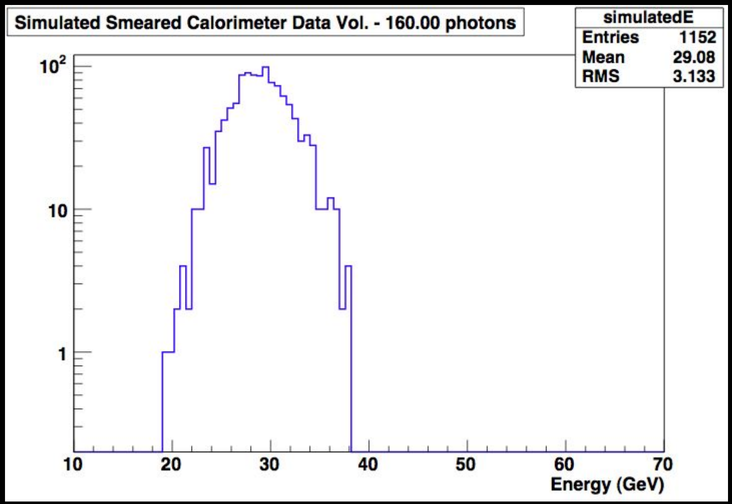
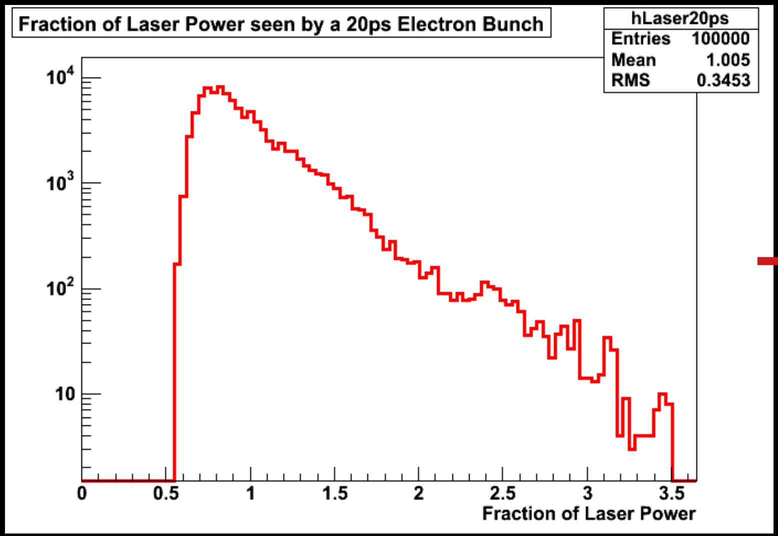
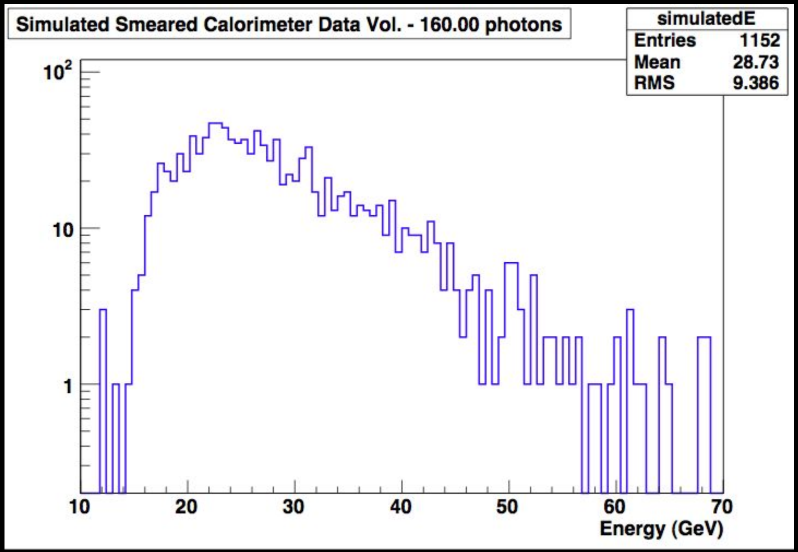


- A 'perfect' laser that always delivered its average energy to the 20ps electron bunch
  - Energy resolution ~10%
- Current laser, with temporal substructure gives rise to an Energy resolution on order of ~35%





Geant4 Simulations (BDSIM)

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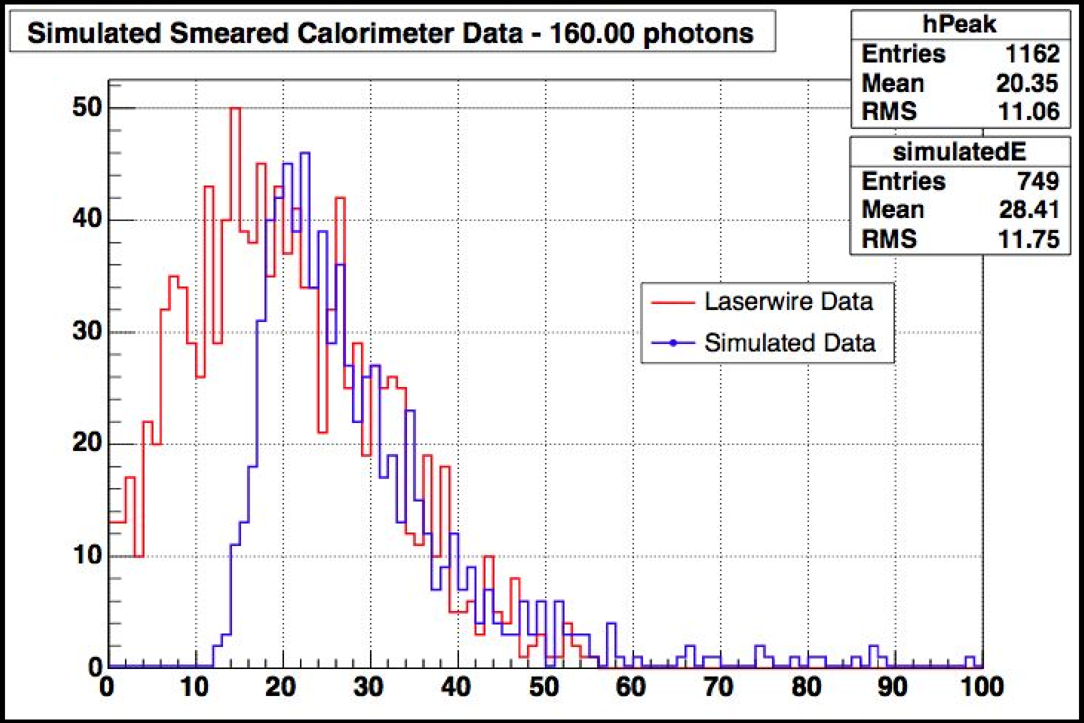


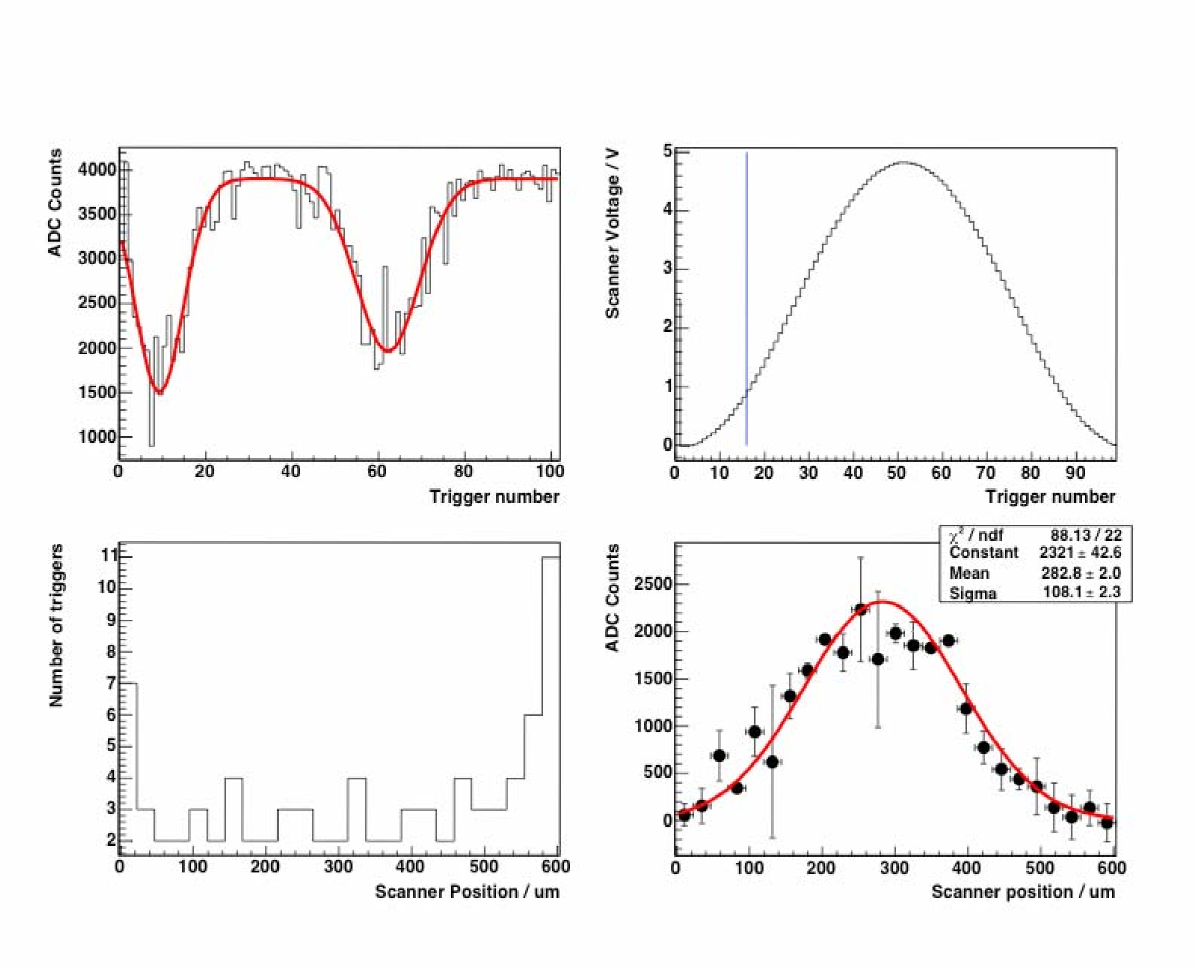
Still some effects to understand
Low energy cut on showers could explain difference

PMT has been in high SR background for a couple of years – so we plan a longer run to re-calibrate calorimeter plus PMT

Fast scanning (very preliminary)

- Data from16/02/05
- PETRA conditions
  - 7 GeV, 1 bunch
- Scan
  - 100 scan points
  - 1 triggers/point
  - 3.33 seconds for whole scan
- Clear signal observed
  - Thanks to the new window
- Analysis as before

- Result
  - **σ_m=108.1± 2.3 μm**



S. Boogert, S. Malton

ATF Laser-wire Motivation

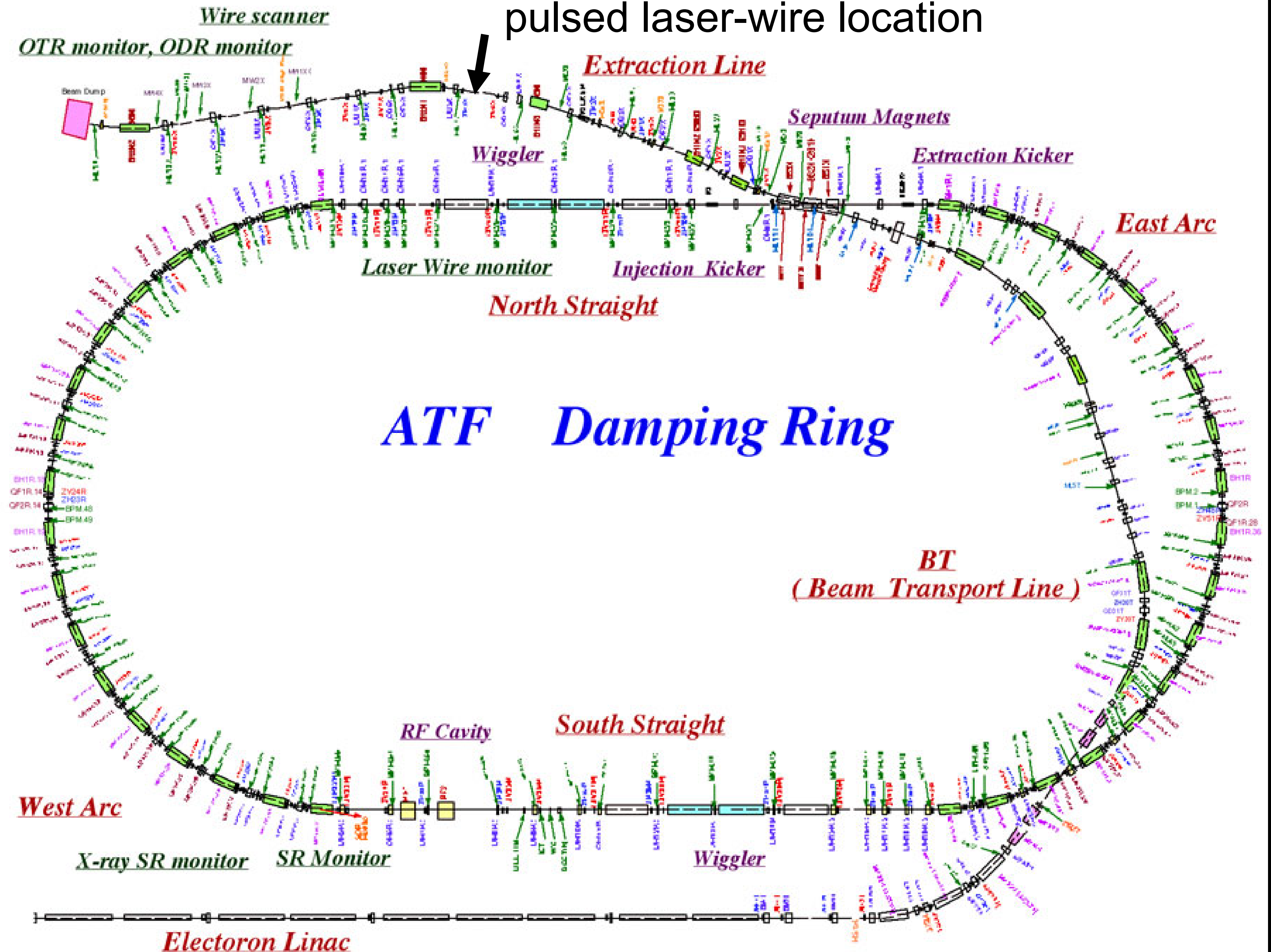
J. Frisch, Nanobeam 2002: For a 1% measurement, laser wavelength is given by:

$$\lambda = \frac{4}{9}\pi\frac{\sigma_y^2}{\sigma_x}$$

So, for the current ILC design, λ should be <~360 nm (driven by aspect ratio considerations)
and laser spotsize <~σ_y /3 = 0.6 μm

At ATF, we will aim to measure 1 micron electron spotsize with green (532 nm) light.
Aim at intra-rain (fast) scan for 300ns bunch spacing.

The final spotsize measurable at ILC will have implications for The length and layout of the BDS diagnostics section. The ATF results will be crucial to determine the technical boundaries.


pulsed laser-wire location
Wire scanner
OTR monitor, ODR monitor
Extraction Line
Septum Magnets
Wiggler
Extraction Kicker
East Arc
Laser Wire monitor
Injection Kicker
North Straight
ATF Damping Ring
BT
(Beam Transport Line)
RF Cavity
South Straight
West Arc
X-ray SR monitor
SR Monitor
Wiggler
Electoron Linac

This year's plans for the ATF extraction line laser-wire

- March 2005:
  "study trip": Understand the possible setup [optics/infrastructure], prepare our DAQ, study the laser,…
- May/June 2005:
  Laser measurements, study the beam optics, validate the DAQ
- Summer/September 2005:
  Install the laser transport and delivery (Optics, Scanning,…), install our vacuum vessel at the ATF and final focusing lens
- November/December 2005:
  Laser-wire run

Laser-wire Future

- Major new Laser lab being set up
- Build international group based at JAI in advanced lasers for accelerators.
- Install micron laser wire in ATF Extraction line
- Build expertise in ultra-fast EO scanning
- Improve PETRA LW performance - Eurotev
- Plan move to PETRAIII location + new optics