The laser-wire Project

PETRA laser-wire

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Overview

Introduction:

- Our fundamental aims

- What we have learnt:
  - The first PETRA laserwire: "One dimension scanning"
  - The second PETRA laserwire: "Two dimension scanning"
  - New laser issues

The laser-wire Project

-Introduction

We are developing a non-invasive, high-resolution means of measuring electron beam size for the ILC:

- wire-scanners would not survive the high beam intensities.
- necessary to determine beam size/emittance.

See next slide...

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- Why do we need to know ILC beam size?

- Luminosity, $L \propto \frac{1}{\sigma_x \sigma_y}$

The smaller the size of the beam, the greater the luminosity of the collider.

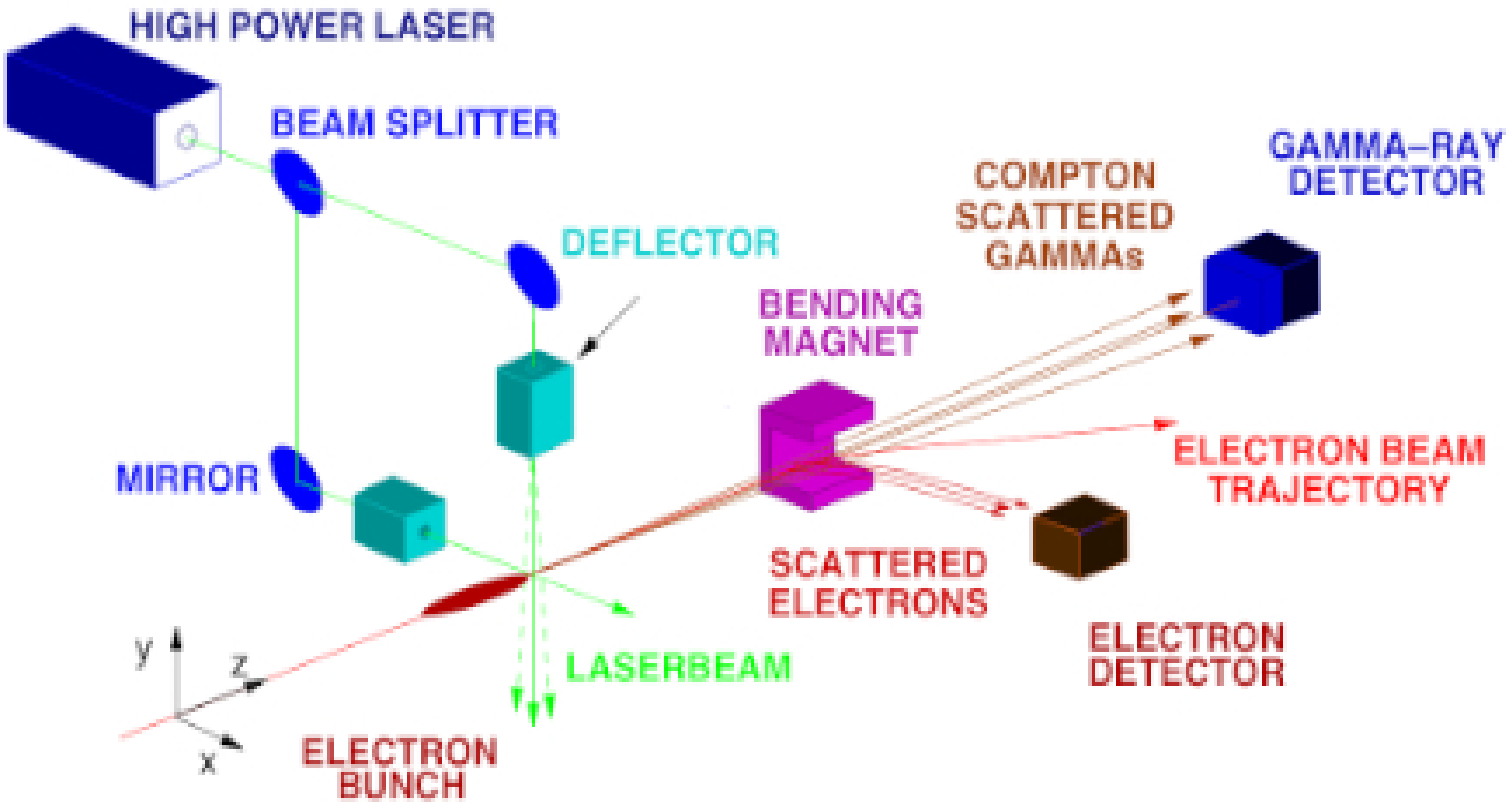
Therefore important for (future) high luminosity colliders, such as the ILC.

Also important for high-brilliance synchrotron light sources, such as PETRA 3.

The laser-wire Project

-Introduction

The laser-wire works by scattering photons off the electron bunch (inverse-Compton scattering), and measuring the scattered photons.



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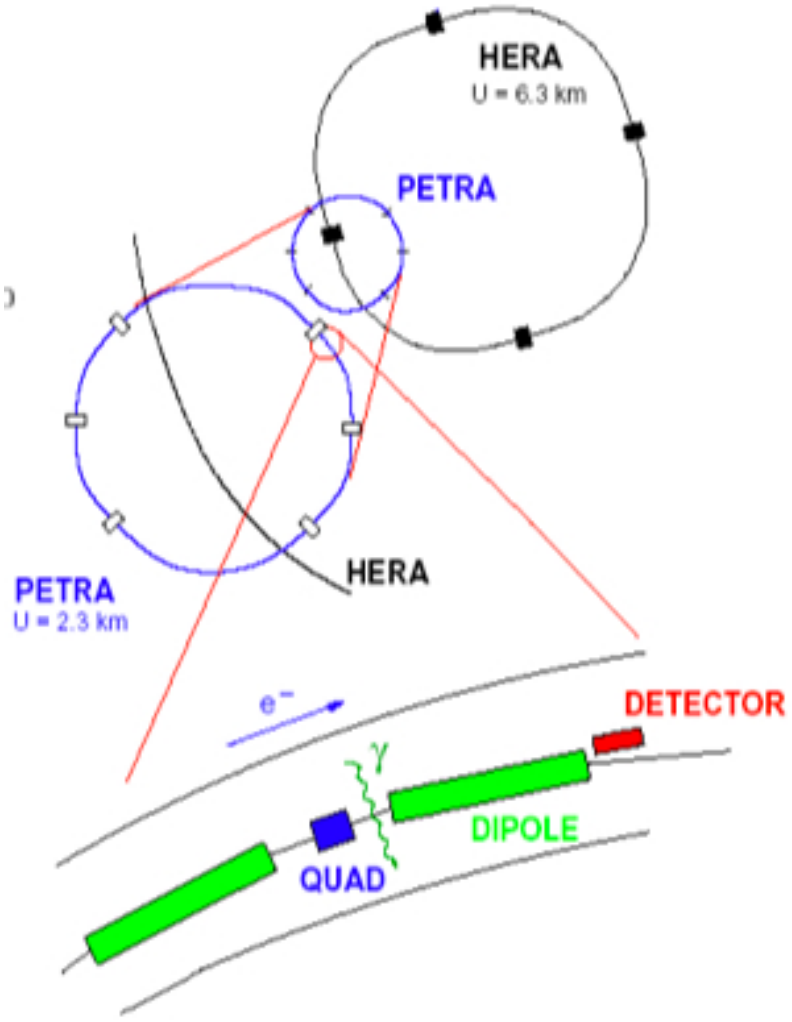
- Details at PETRA



Bunch length: ~100ps

Optic lattice studies indicate the mean
Hor. Beam size: ~268μm
Vert. Beam size: ~68μm

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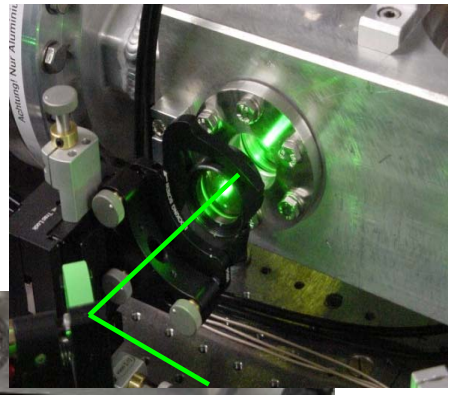
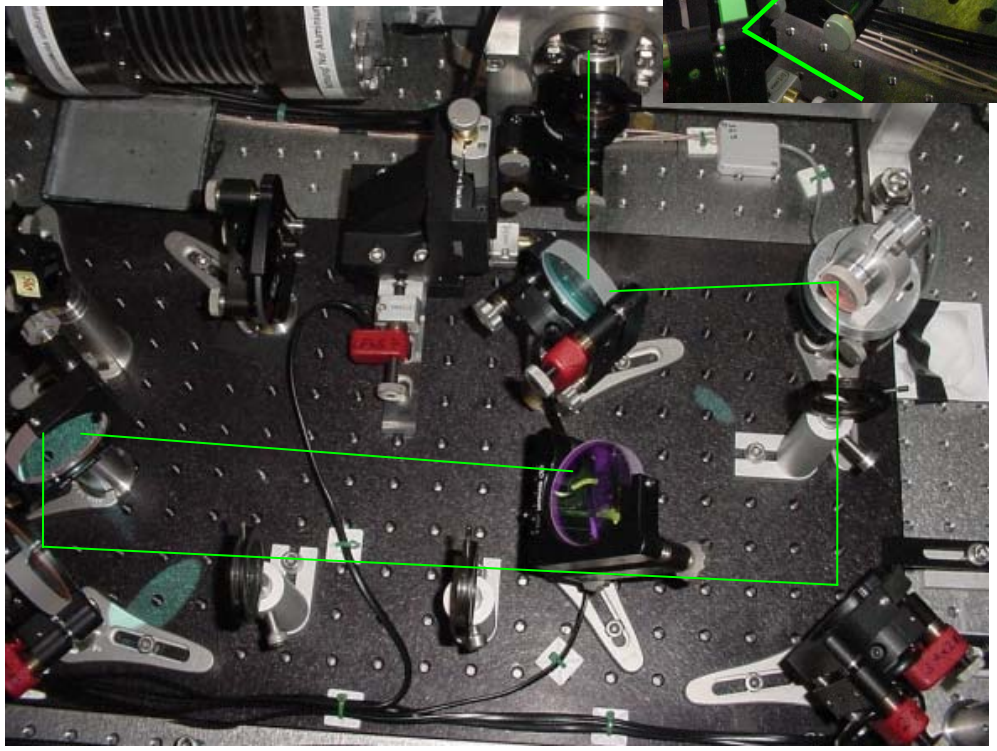
The first PETRA laserwire

Angular tilt range of piezo scanner: ±2.5mrad
Laser beam size at IP: σ = 36 μm
Q-Switched Nd:YAG (532nm) laser.
Peak power (laser exit/IP): 3.63MW/1.46MW.
Pulse length of 12.5ns





- Laser triggering derived from PETRA bunch/revolution clocks (131kHz)
- Piezo scanner position based on laser trigger (30Hz). Scanning platform is linear with voltage and driven by a ramped voltage.
- Record data using
    - Photon Calorimeter
    - Local BPM
    - CCD cameras
    - PETRA (bunch currents etc)

John Adams Institute for Accelerator Science

Royal Holloway University of London

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First issues...

- First data-taking runs:
  - Calorimeter energy spectrum indicated 'Comptons' produced at the IP were not reaching the detector
  - Geant 4 simulation of the beam pipe, detector and Compton process,
- Solution found in form of a new vacuum pipe with window
  - Installed Janurary'05
  - Difficult job due to beam pipe curvature
  - Also Sync. Rad. Heat load on window to contend with.

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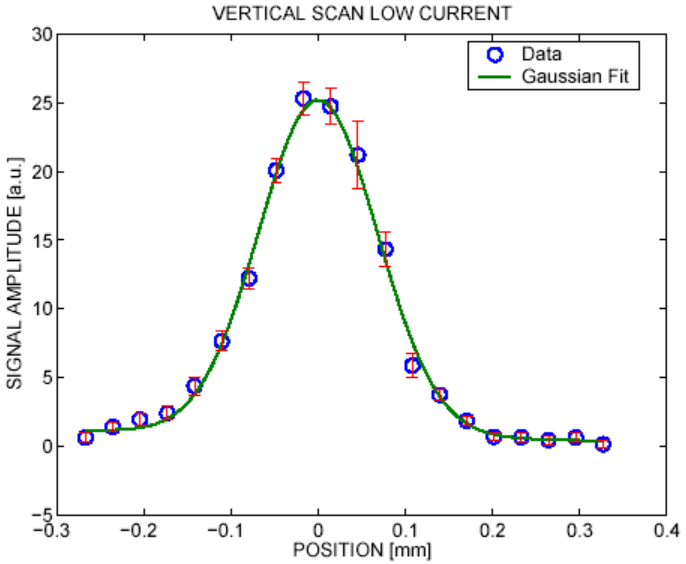
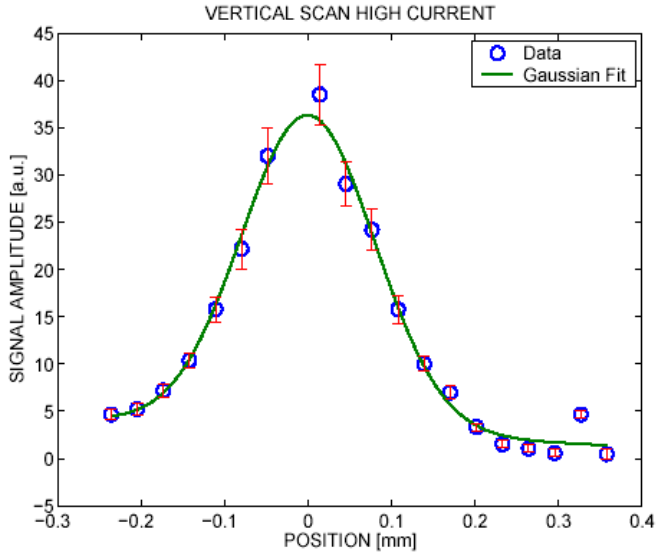
Sample scans (~30Mins /scan)



Low Current (7.1 mA, 14x1 bunch fill)

- $\sigma_m = (68 \pm 3 \pm 14)$ μ m at low current



High Current (40.5 mA, 14x1 bunch fill)

- $\sigma_m = (80 \pm 3 \pm 14)$ μ m at high current

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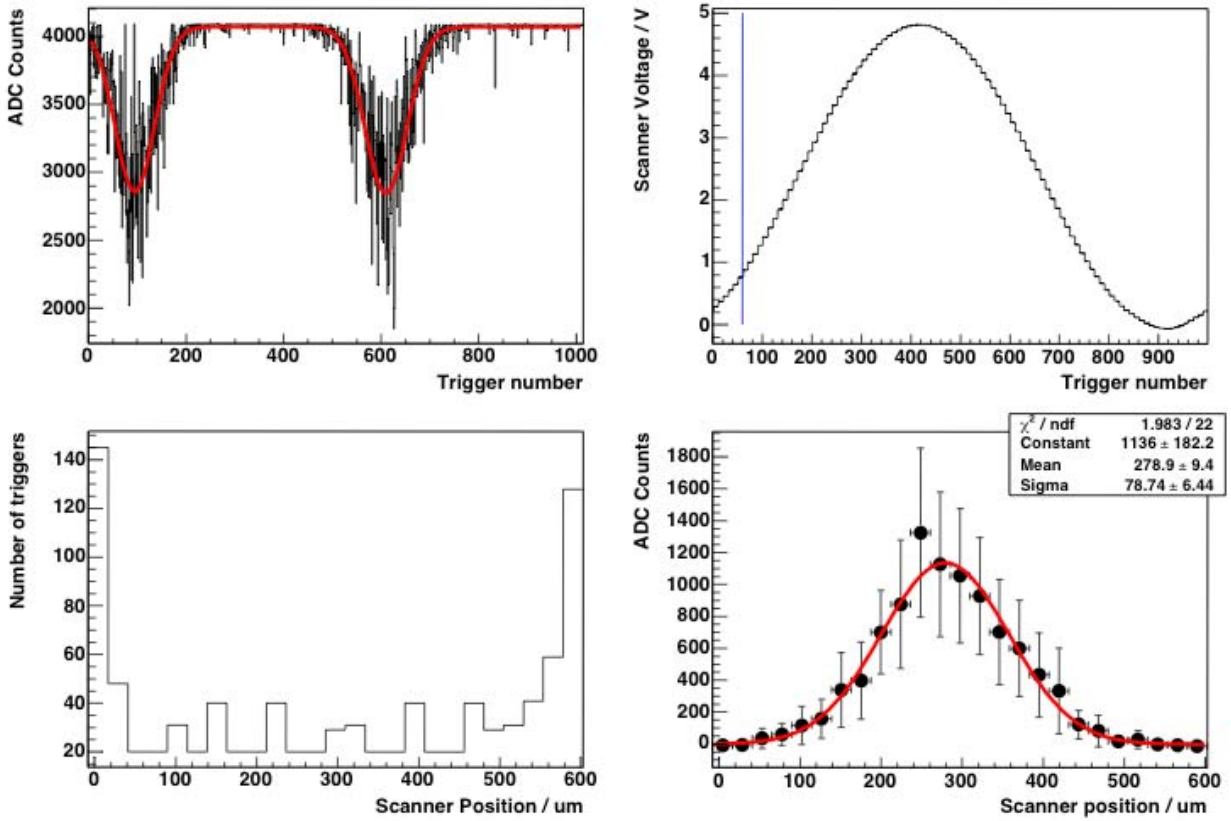
PETRA laser-wire: slow scan

- Data from 11/02/05
- PETRA specs:
  - 7 GeV, 1 bunch
- Scan
  - 100 scan points
  - 10 triggers/point
  - 33.3 second scan time
- Calorimeter DAQ started late
  - Fix in data by fitting the (two) peaks in Compton signal as a function of trigger number.
  - The mean of the two gives the anti-nodes of the scanner oscillation
  - Bin signal in laser beam position
- Result of preliminary analysis
  - σ_m=78.8±6.4 μm



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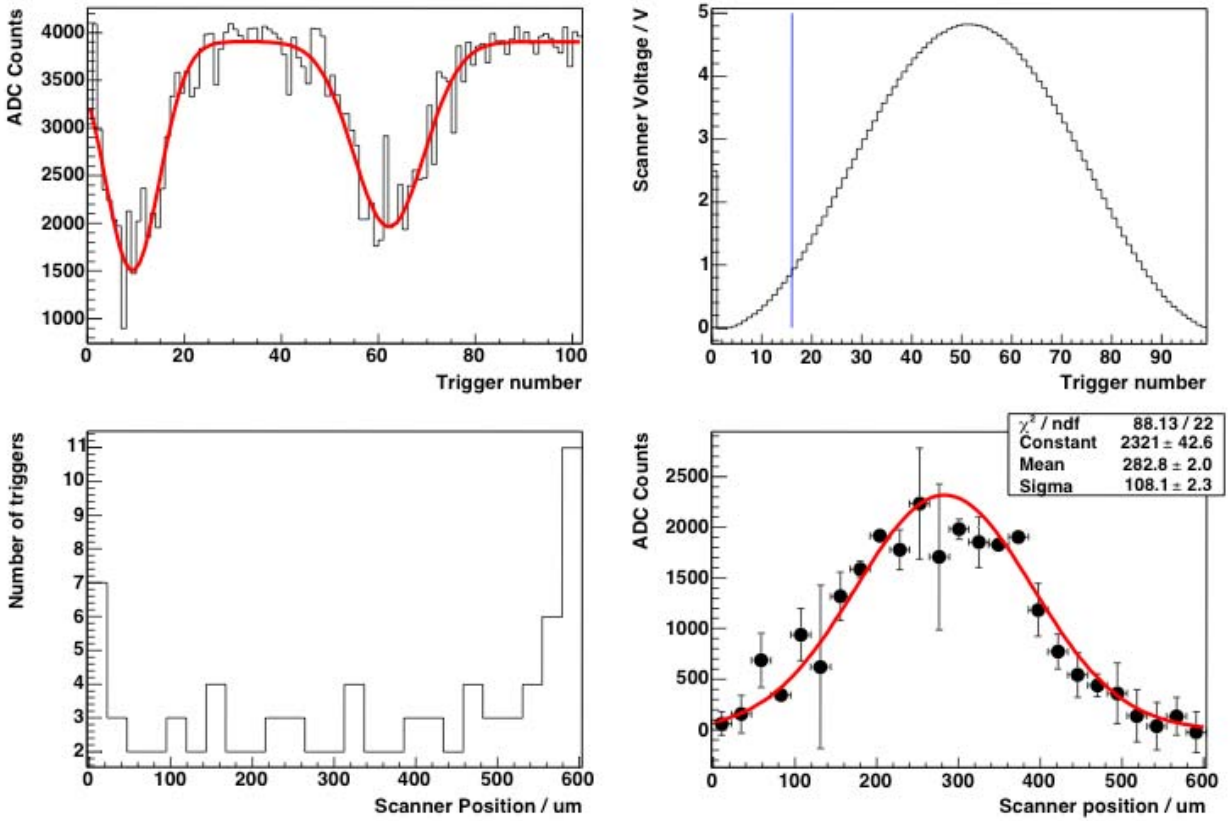
PETRA laser-wire: fast scan

- Data from 16/02/05
- 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
  - Slightly larger beam size than slow scan



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PETRA laser-wire: summary

- First runs with fast scanning and new beam pipe window
  - Very promising first results
  - Other data could be incorporated:
    - BPM measurements
    - Orbit bump scan
    - CCD measurements
  - More routine data analysis
- Results
  - Scan consistent with results of over one year ago
  - Faster scan indicates larger electron beam size (real effect or measurement artifact?)
- More detailed analysis to be employed
  - Binning is rather inelegant method
- Large pulse-to-pulse fluctuations in Calorimeter readout
  - Believed to be due to mode-beating effects in laser pulse

- Future plans
  - Continue to automate the DAQ and analysis
    - Real diagnostic device opposed to developing experiment
  - Check travel range calibration
  - Upgrade laser
    - Q-switched or Mode locked
  - Vertical optical system
    - Measure both vertical and horizontal beam sizes
    - No need for beam bump
  - PETRA 3
    - Excellent diagnostic for light sources
    - Investigating sites within PETRA

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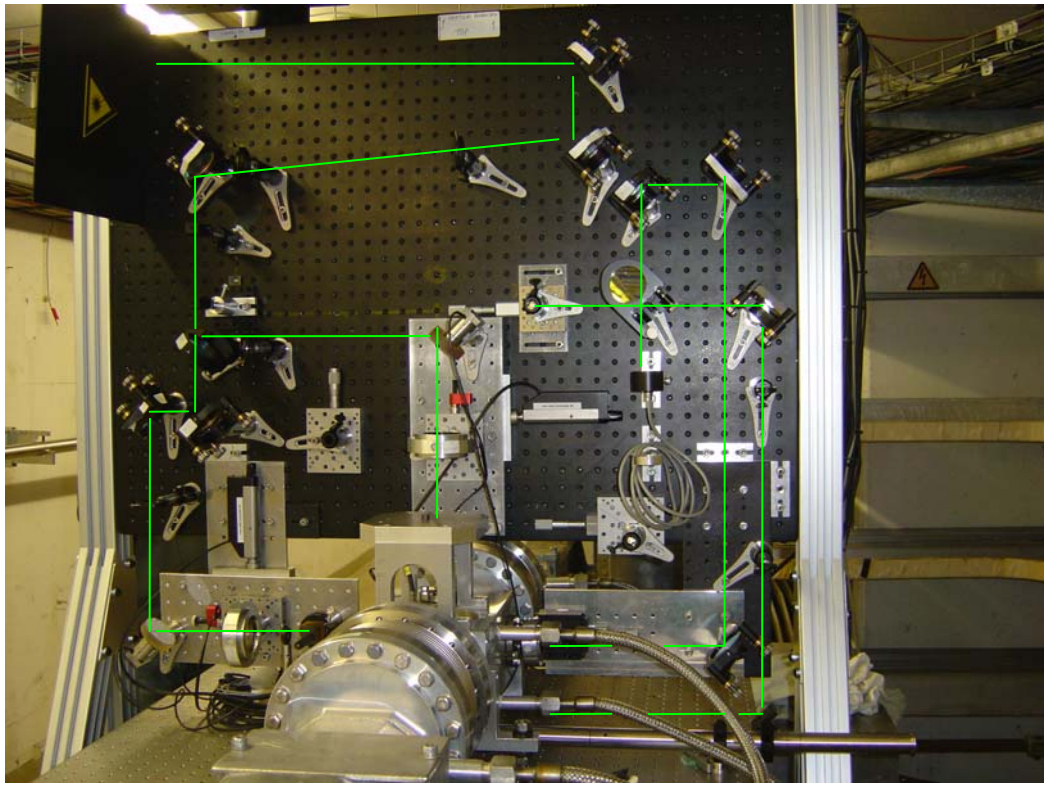
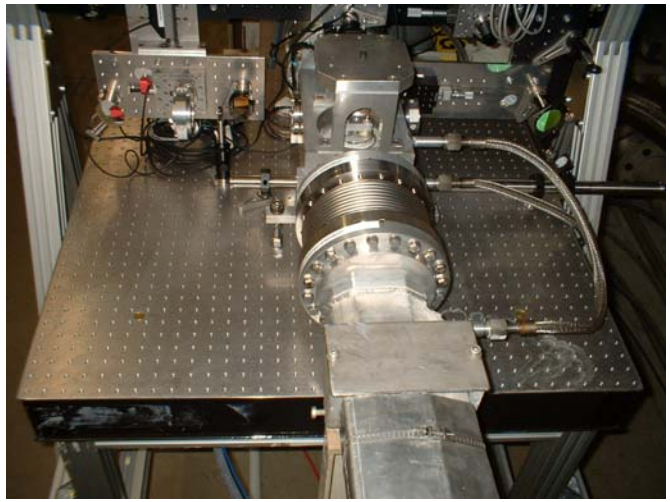
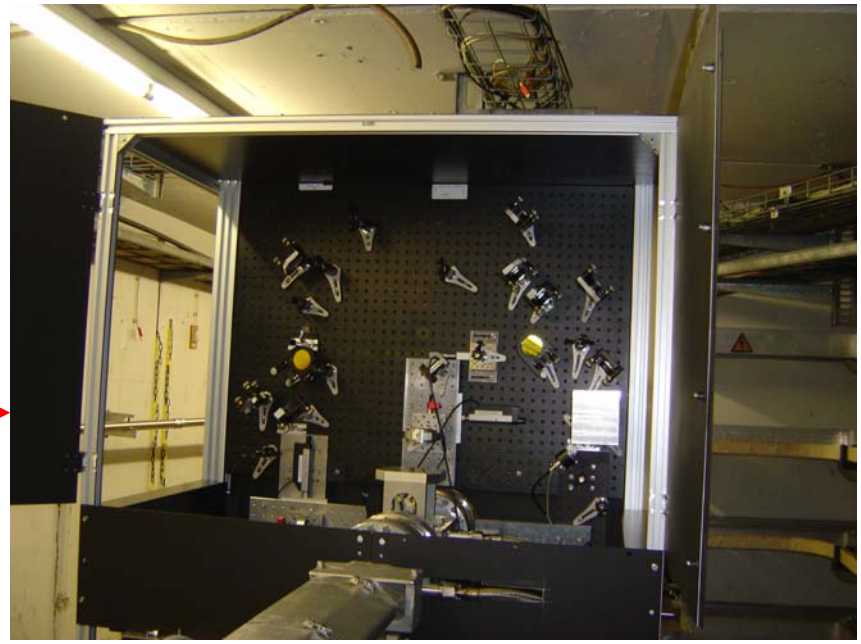
Our current laser-wire: vertical breadboard





New cover installed last week.



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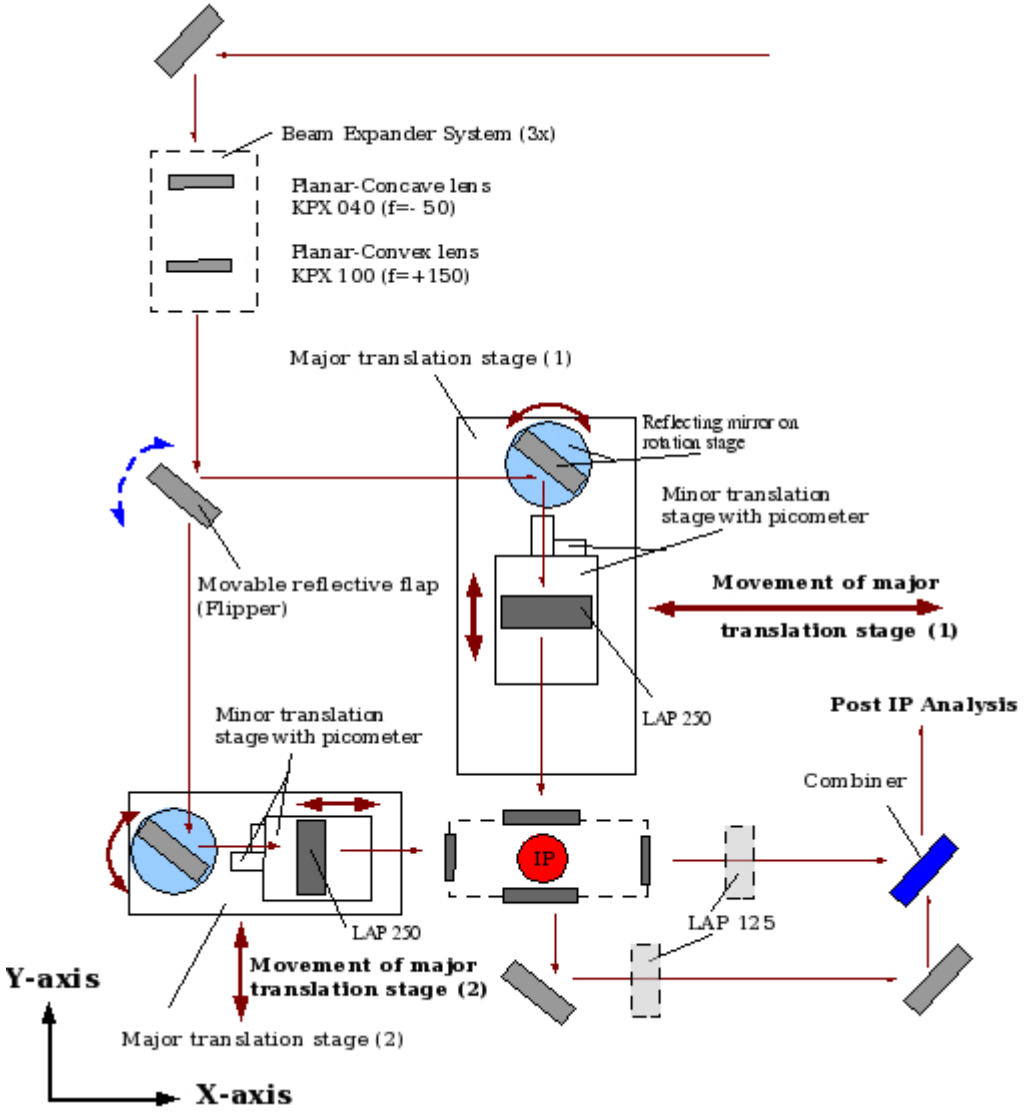
PETRA laser-wire



Summary:

- beam pipe coming out of page.

- 3x beam expander, increases laser width to ~10mm

- mirror flipper, used to select path of laser (horizontal or vertical profile scanning)

- stepping motor translation stages for coarse beam finding. Identical stages for each axis. Piezo scanning mirror for normal electron beam scanning (maximum scan range of 5 mrad, ~ 1000 um at IP).

- LAP250 (f=250mm) focus laser beam to IP. Laser beam size at IP ~ 25um

- Post IP section with photodiode and CCD camera, for examining left-over laser light.

Data-taking with new laser (PETRA)

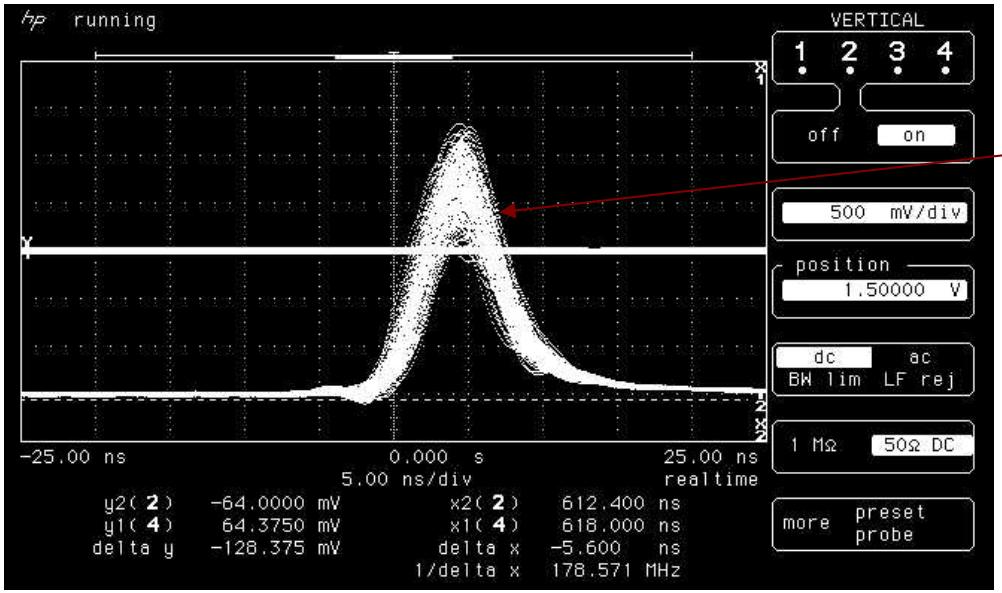
New Laser specs: (April '06)

- Model – Surelite I-20 (injection seeded)
- 532 nm wavelength
- ~ 5 ns pulse length, time jitter ~ 2–6 ns
- M^2 = 1.4
- 6MW peak power
- Non-ideal (poor) modal quality leading upto IP. (square-donut shape)
- Power fluctuations of >10%

Issues to consider:

- Large time jitter of laser pulses - why?
- Are there still mode-beating effects?
- Does the poor modal quality of the laser matter?

Oscilloscope Screen-shots

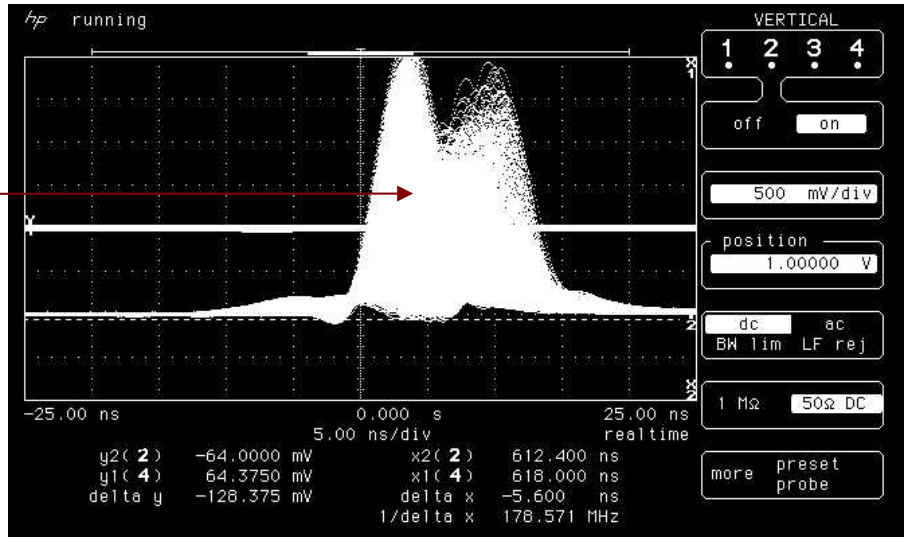


Here laser is unseeded.

This screen-shot shows dozens of pulses overlapping (infinite persistence setting).

Here the laser is seeded. (Same oscilloscope settings as before).

Notice the drift of the pulse in time (butterfly-like shape).



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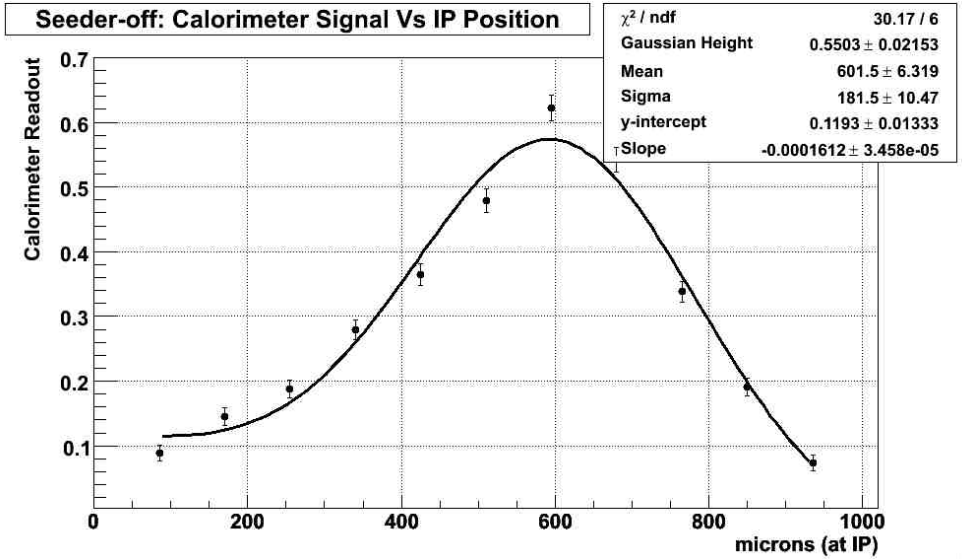
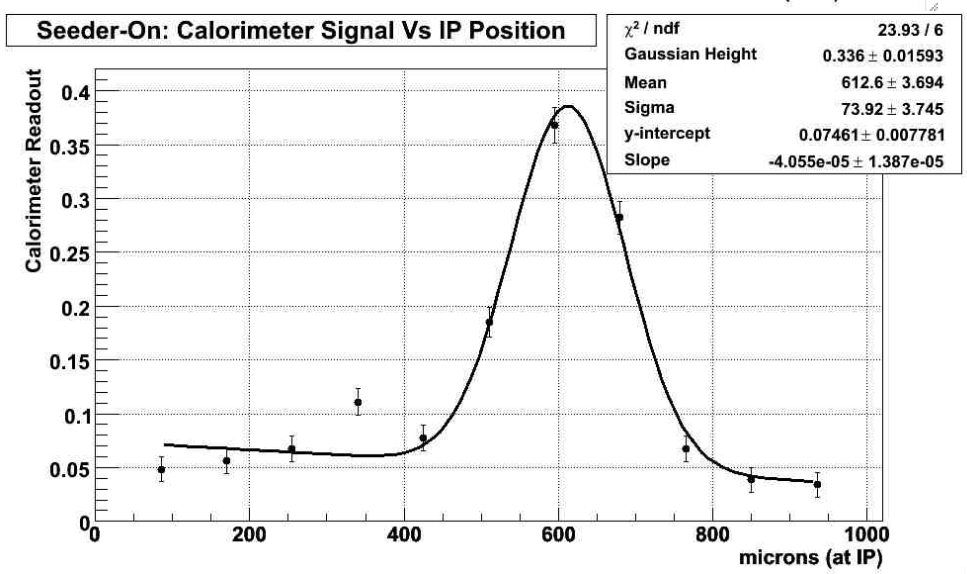
Scans with new laser



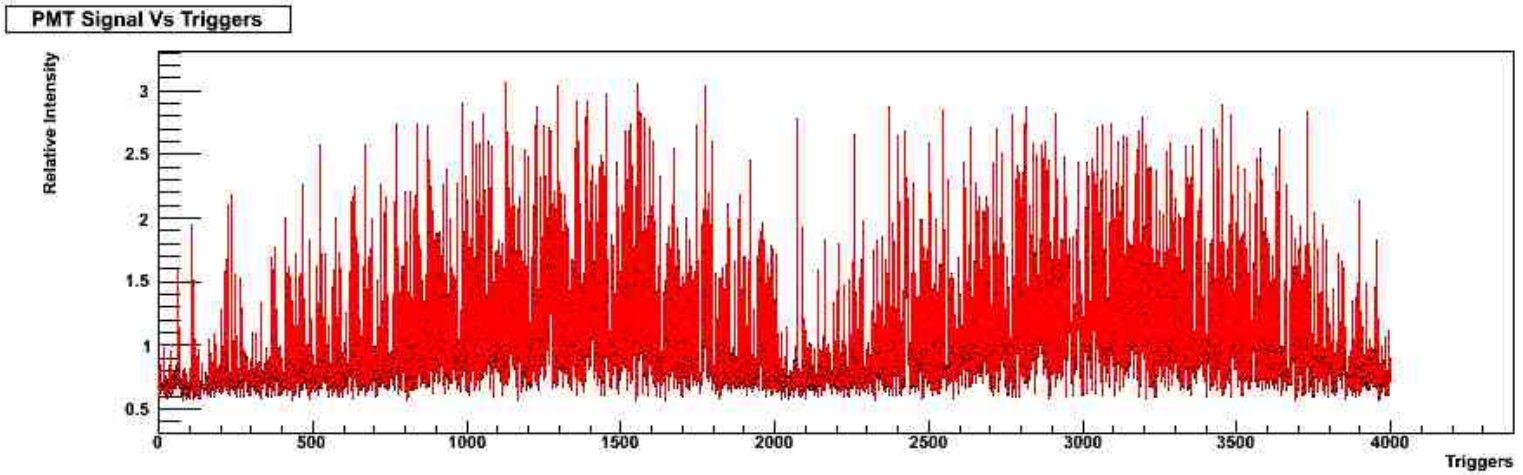


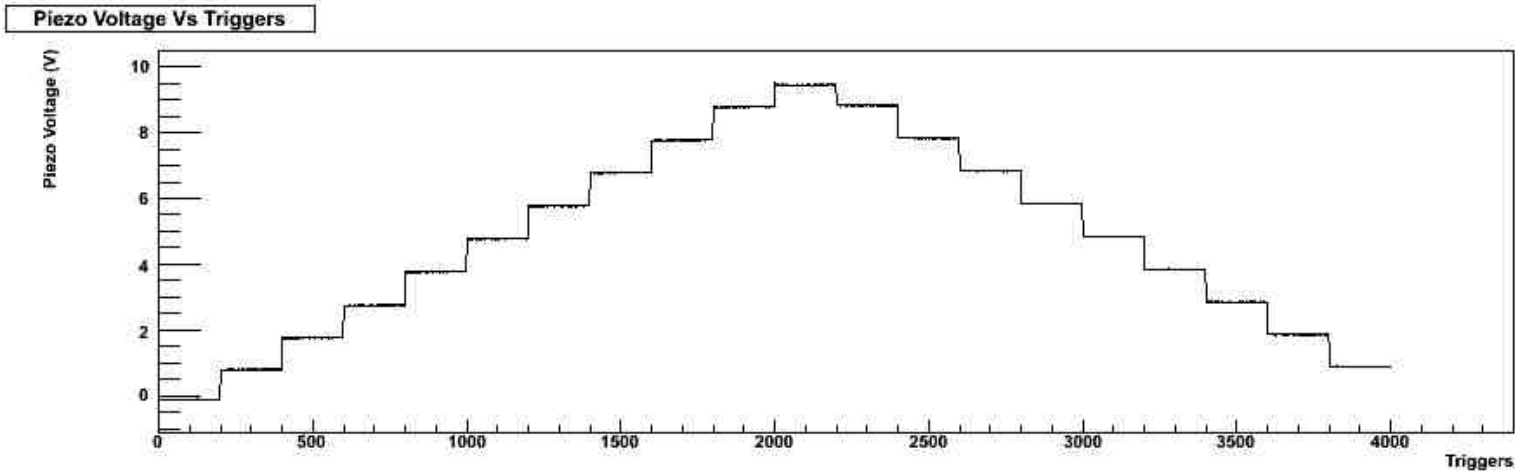
Clear differences between injection seeded and non-injection seeded results. Why is this?

PMT data with unseeded laser

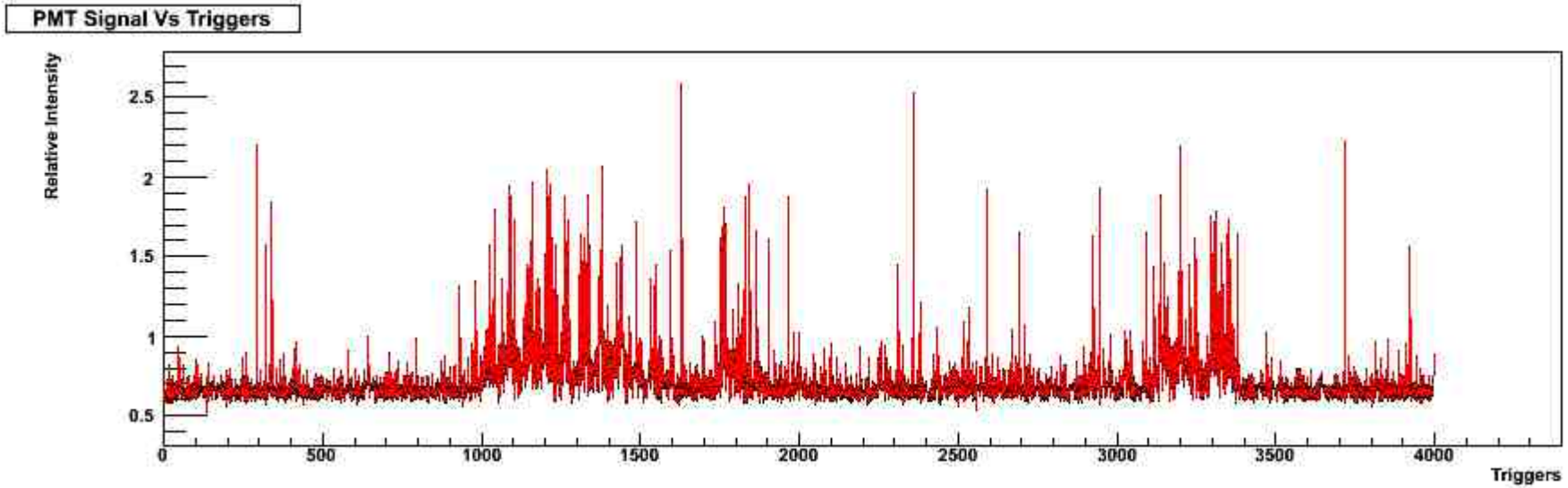
Top plot shows the raw PMT output Vs trigger number.
Bottom plot shows piezo scanner voltage Vs trigger number.

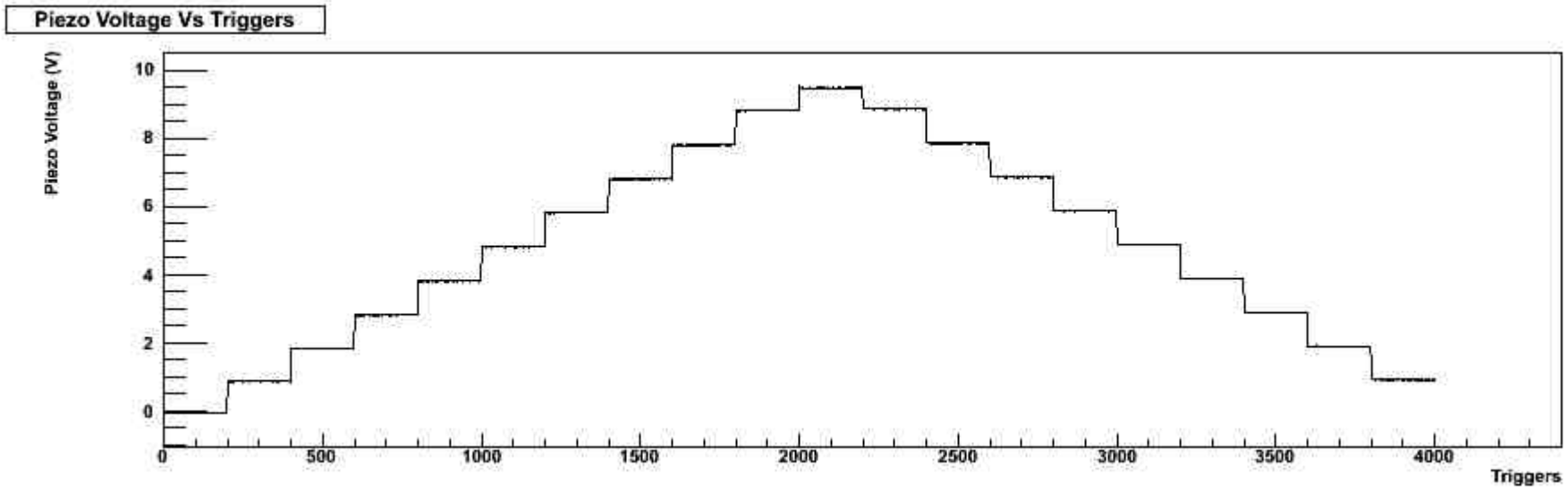
Note: 0V-10V piezo scanner voltage corresponds to movement of 1000 microns at the IP.





PMT data with seeded laser





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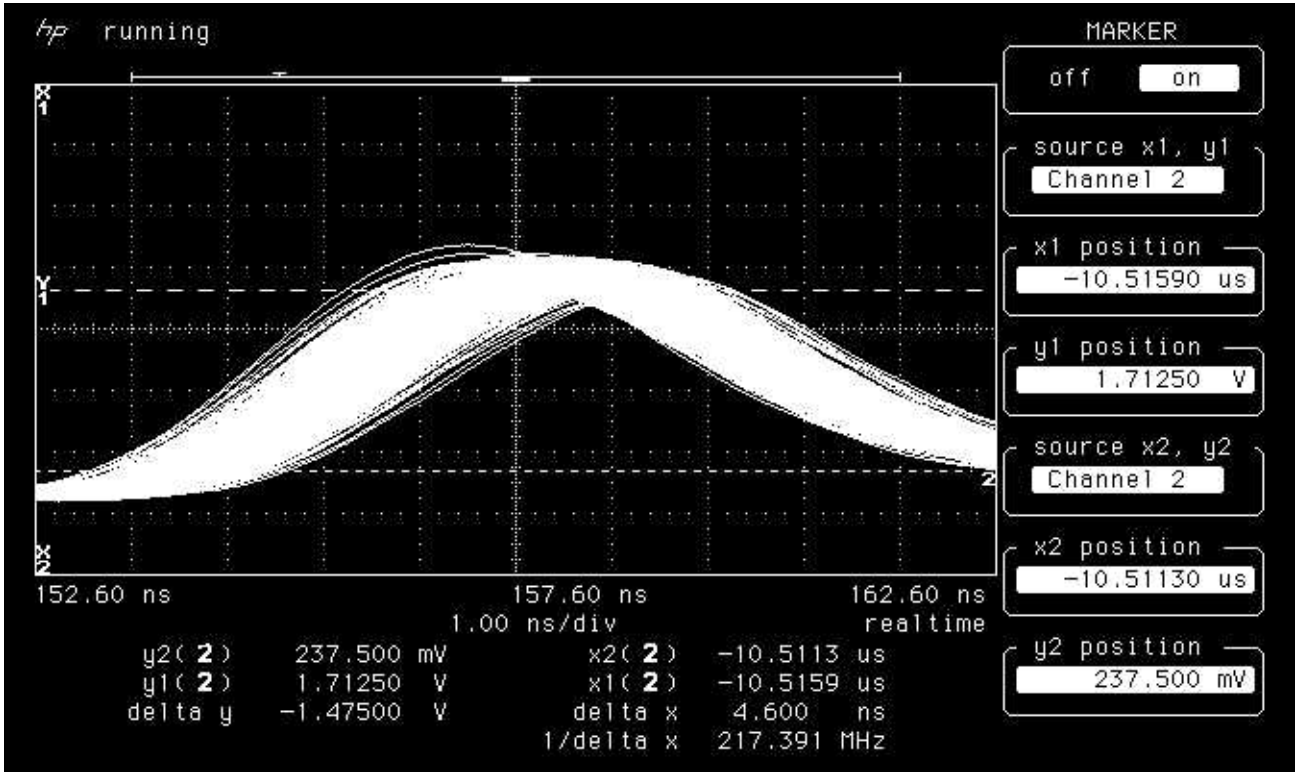
New laser repairs: (Measurements from last week)

•Damaged polarizing (Brewster) plate discovered. Replacement of plate resulted in reduced power fluctuations (< 5%), reduced time jitter (< 2ns), and slight improvement of modal quality.



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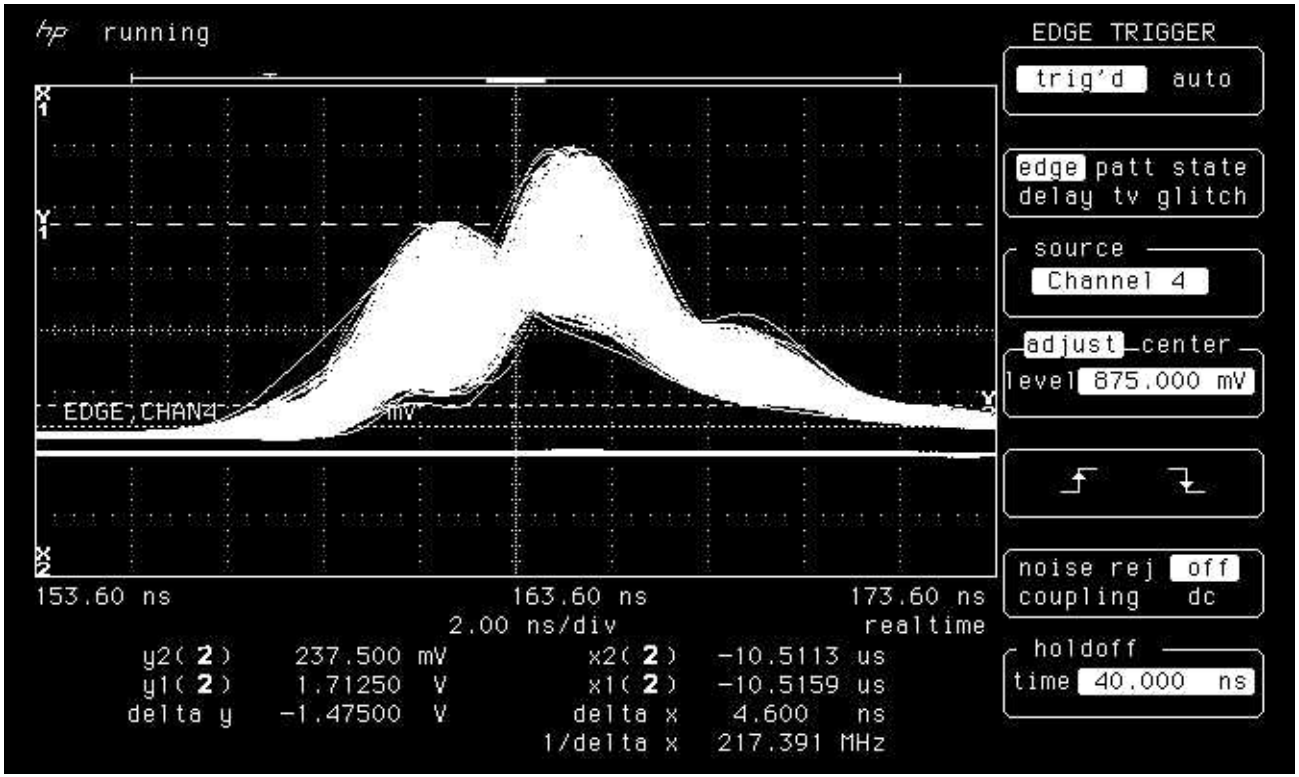
But....:

- We observe this butterfly effect after ~20-30 mins of laser running (seeder-on).



Suspicion is that it is related to seeder overheating!

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PETRA laser-wire

- Investigations are still underway.

- Unfortunately, we have not been able to take data since the laser has returned from repairs.