Systematic uncertainty of the LPOL

Avetik Airapetian[1] Wouter Deconinck[1] Riccardo Fabbri[2]

University of Michigan

DESY Zeuthen

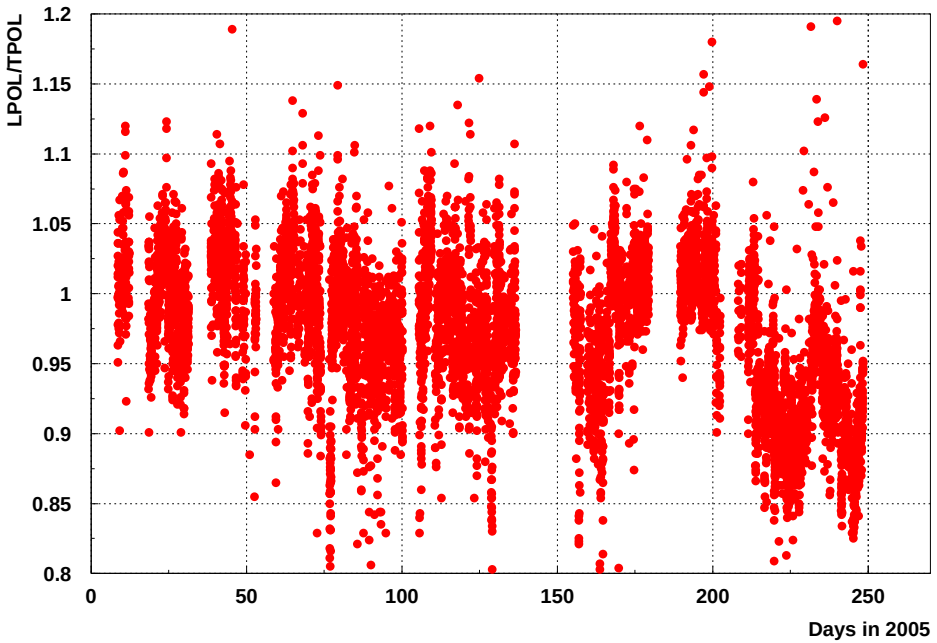
POL2000 Meeting
February 7, 2006

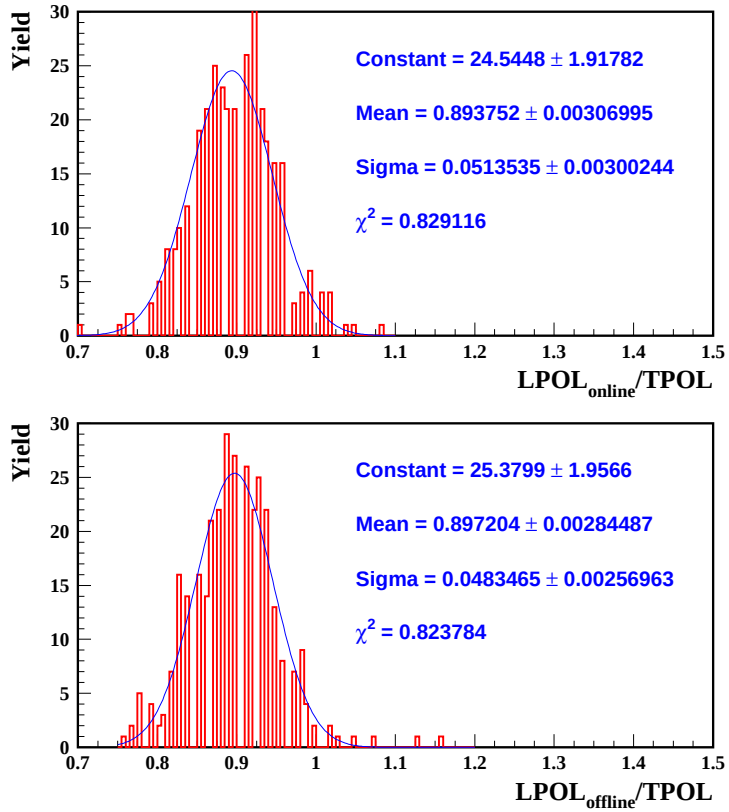
Overview

- Motivation
- Hardware
  - Laser and optical system
  - Interaction region
  - Calorimeter
- Analysis
  - Online quality control
  - Online analysis
- Systematic studies
  - Linearity of calorimeter response
  - High voltage variations
  - Position of the Compton cone
  - Noise induced by calorimeter movement
  - False asymmetry
  - Laser polarization
  - Synchrotron radiation
  - ADC gate variation
  - Laser trigger delay
  - Bunch triggering
  - Optical system
  - Conclusion
- Sandwich calorimeter
  - Test beam measurements
  - Comparison with crystal calorimeter
- Current status
  - Ready for data taking
  - Spares

Motivation

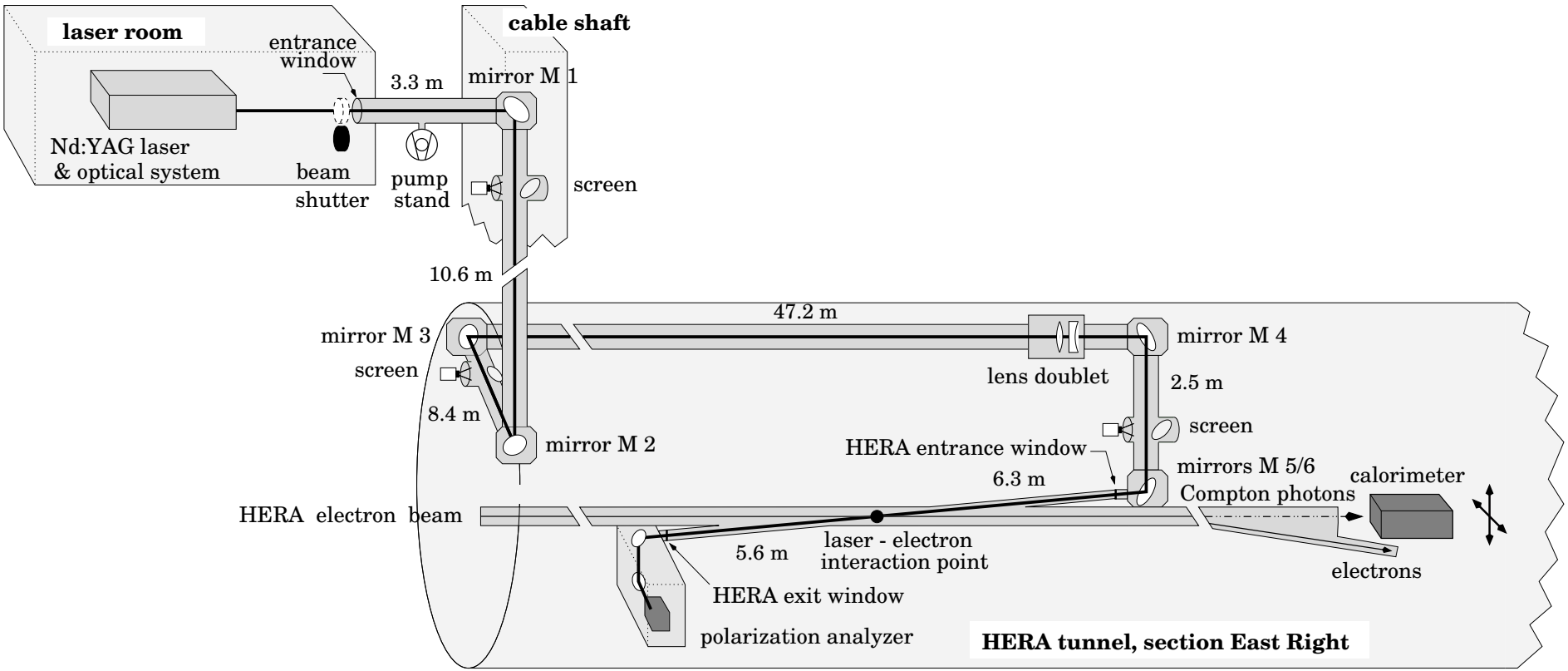
- Crystal calorimeter rebuilt in 2004 after radiation damage
- Disagreement between LPOL and TPOL in August 2005



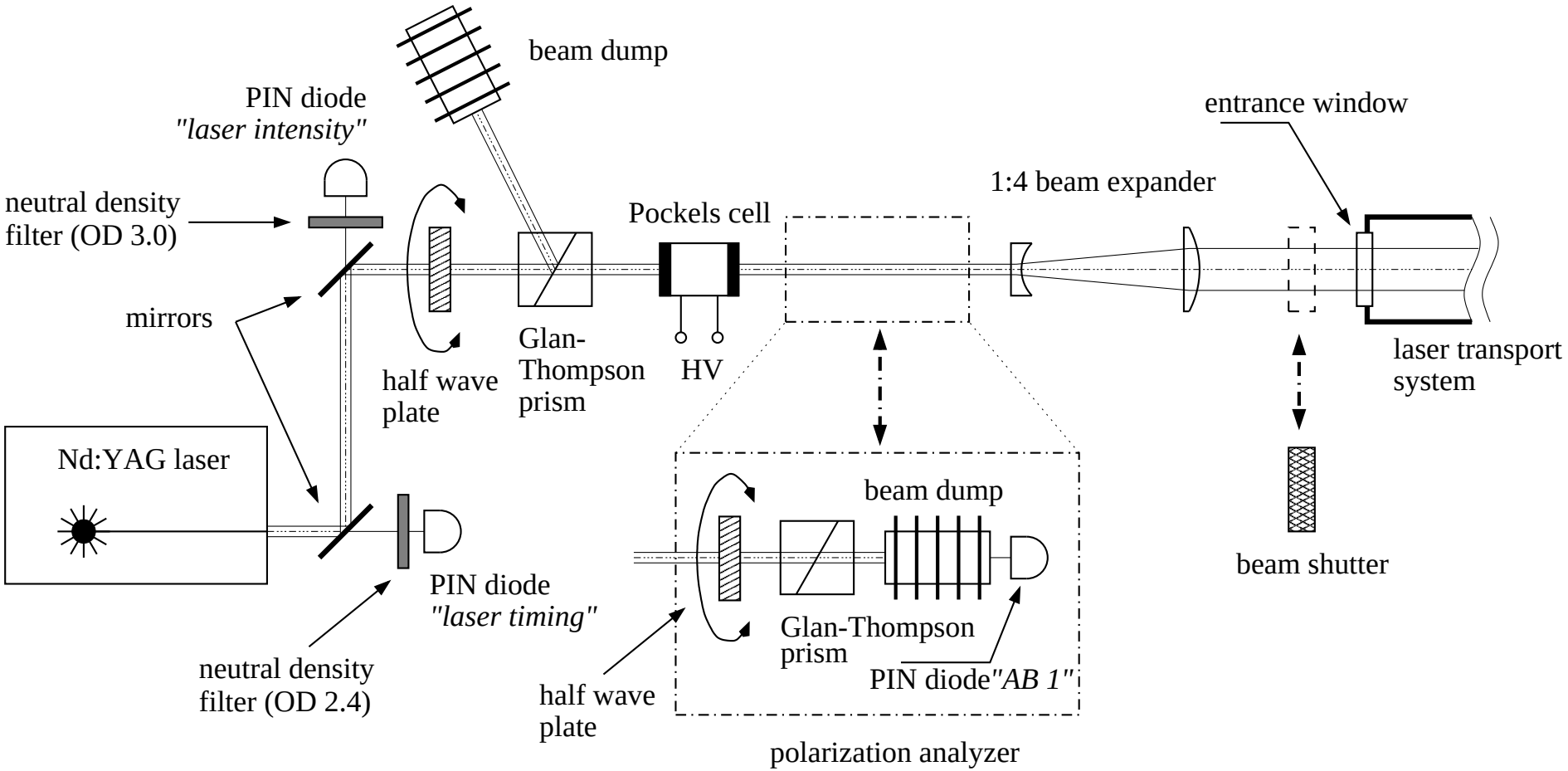


Systematic error for LPOL and TPOL is 10% until proven different

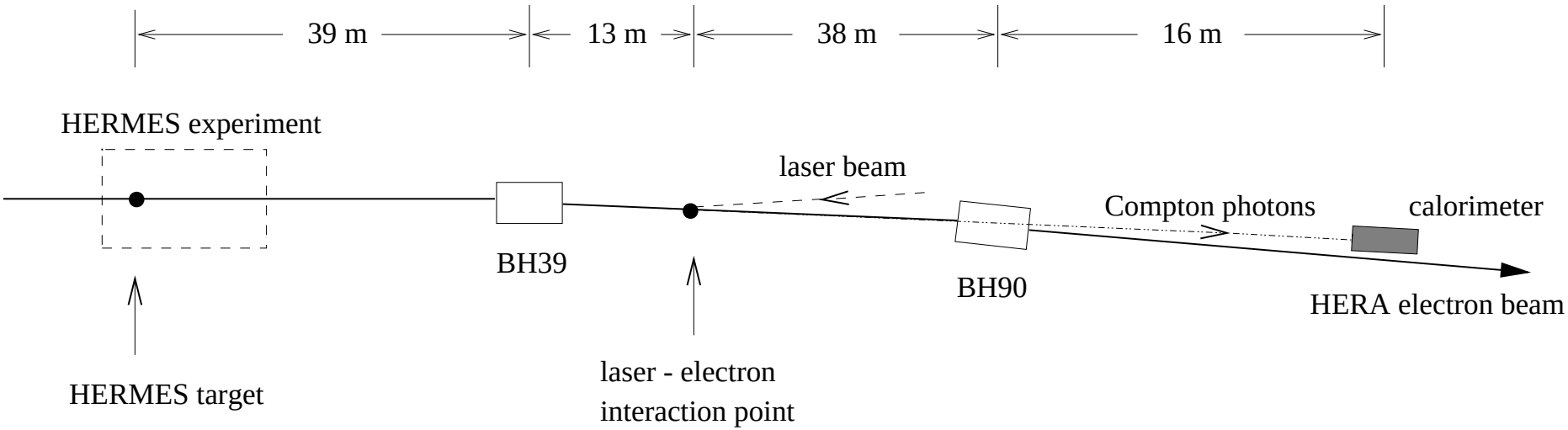
Overview LPOL system



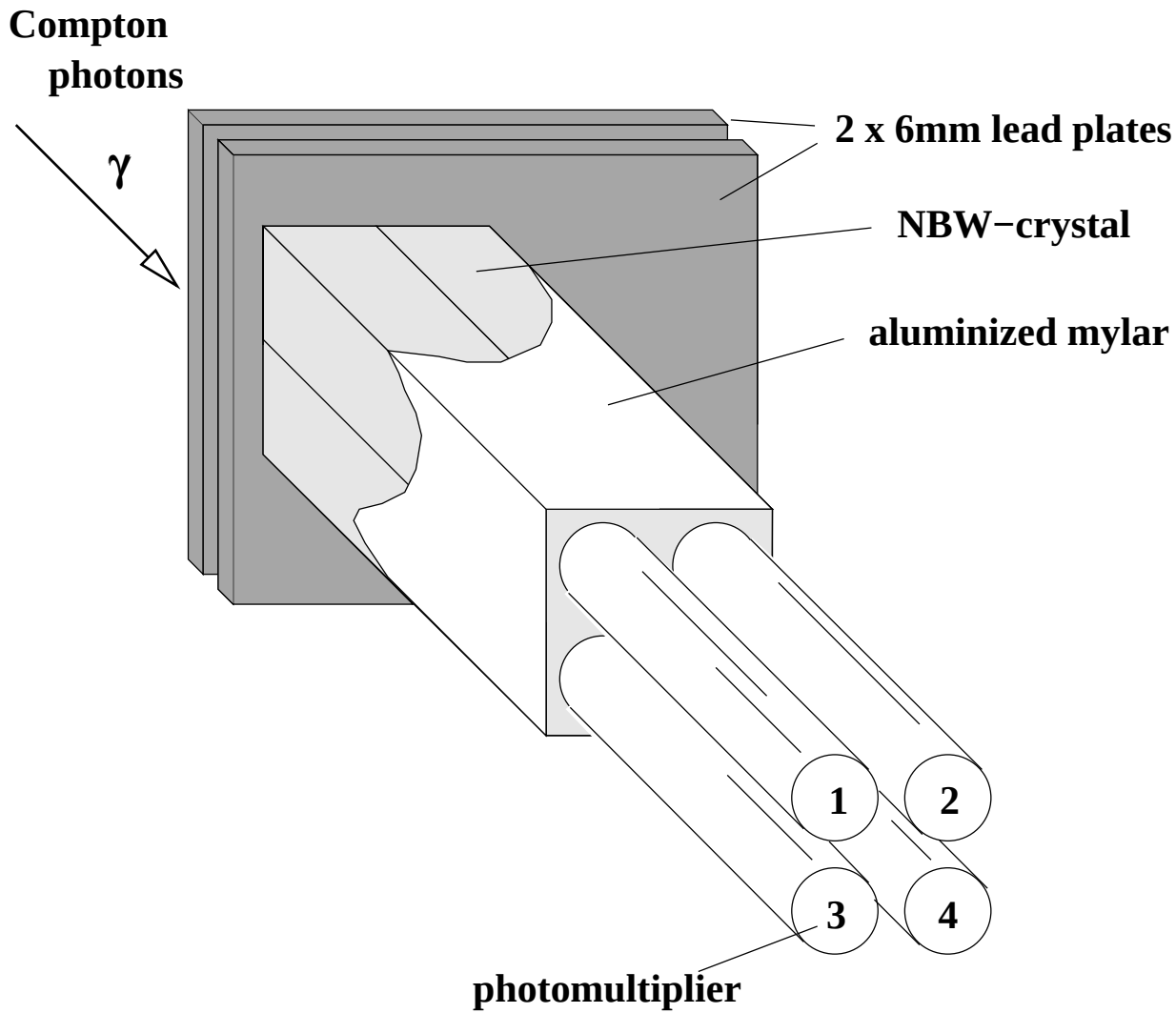
Laser and optics



Interaction region



Calorimeter



Online quality control

- Compton cone centered on the crystals within 1 mm
- Laser firing regulated to correspond with electron bunches
- Interaction with electrons optimized by scanning laser beam
- Crystal response monitored using Hermes gain monitoring system

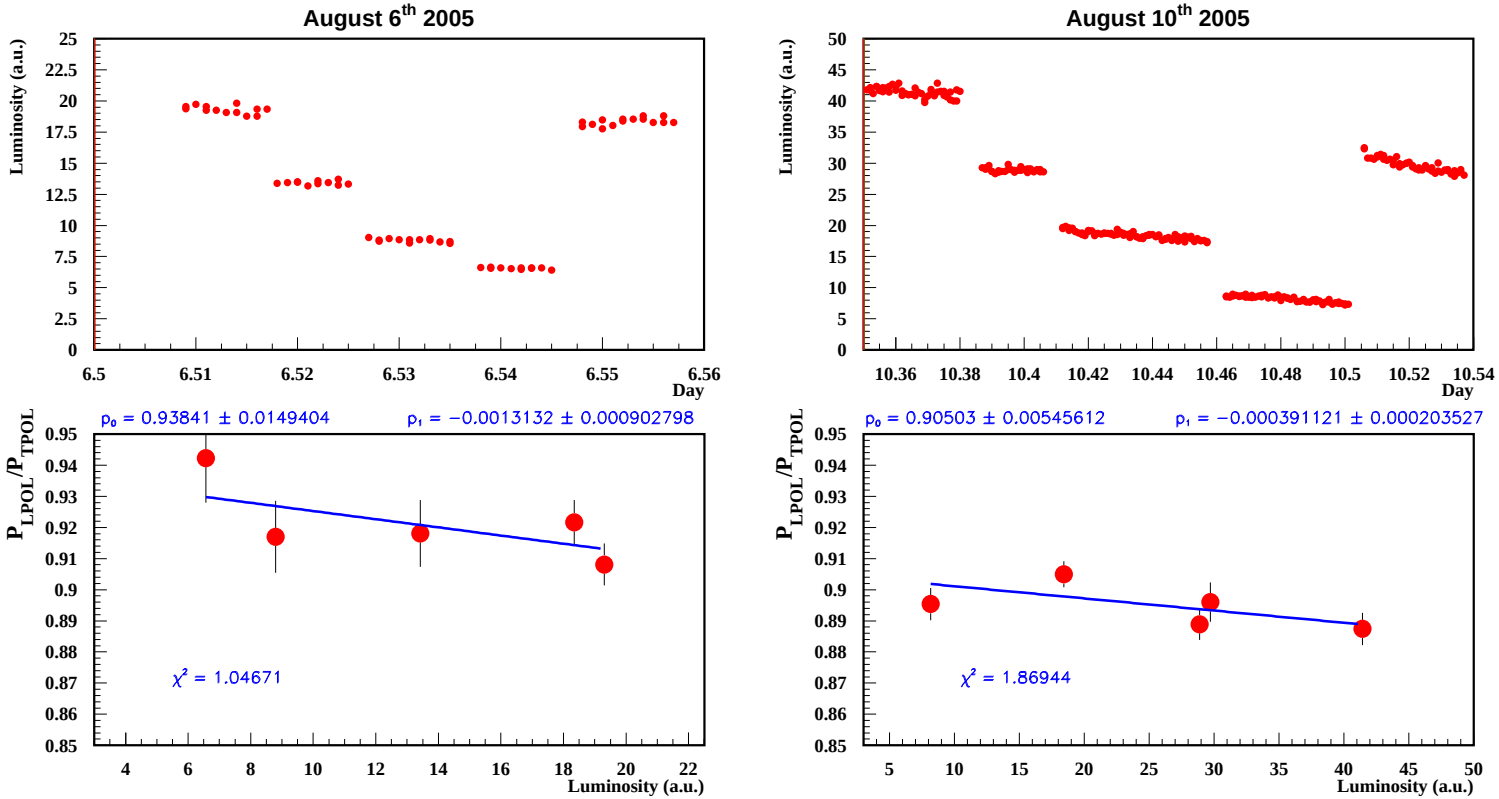
Online analysis

Noise

- Signals are splitted and delayed by 96 ns
- Delayed signal in same ADC $\rightarrow$ noise
- Pedestal subtracted
- Plot by Riccardo

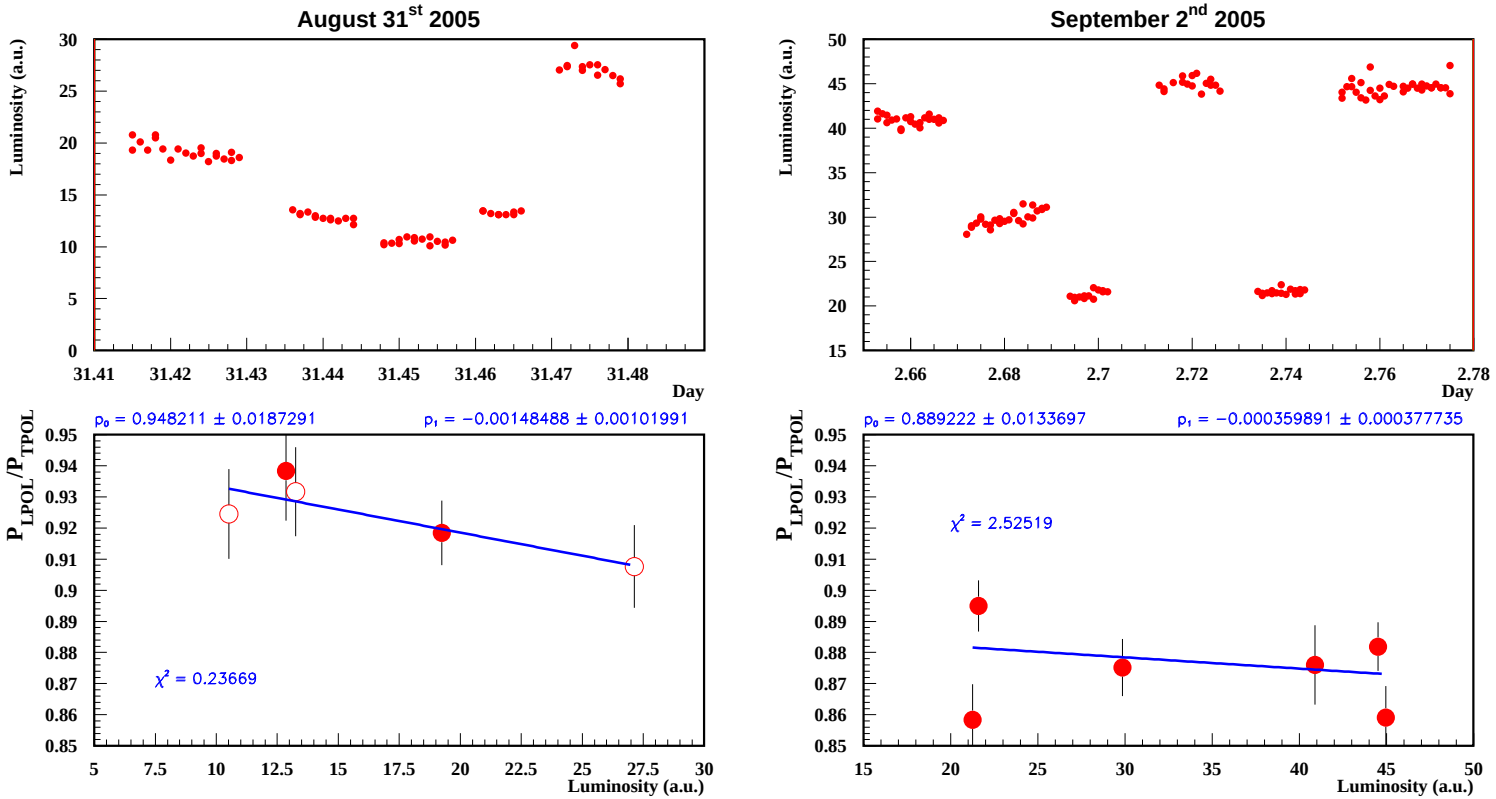
Linearity of calorimeter response

Variation of laser intensity over order of magnitude



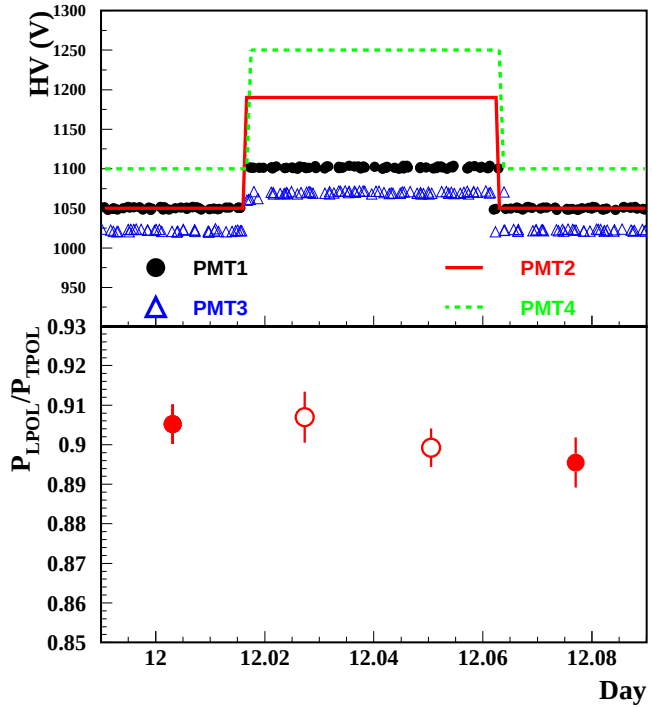
Linearity of calorimeter response

Variation of laser intensity over order of magnitude



No systematic effect on LPOL/TPOL ratio, all measurement within 2%

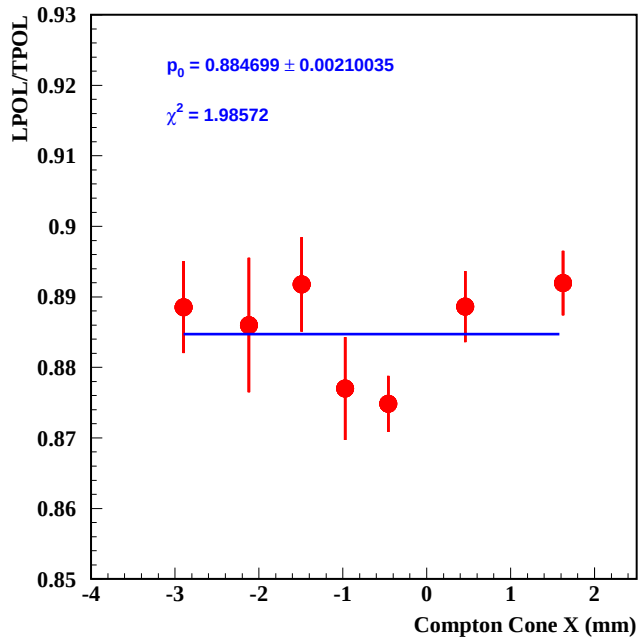
High voltage variations



Change of the HV by more than 10% → less then 1% effect

Position of the Compton cone

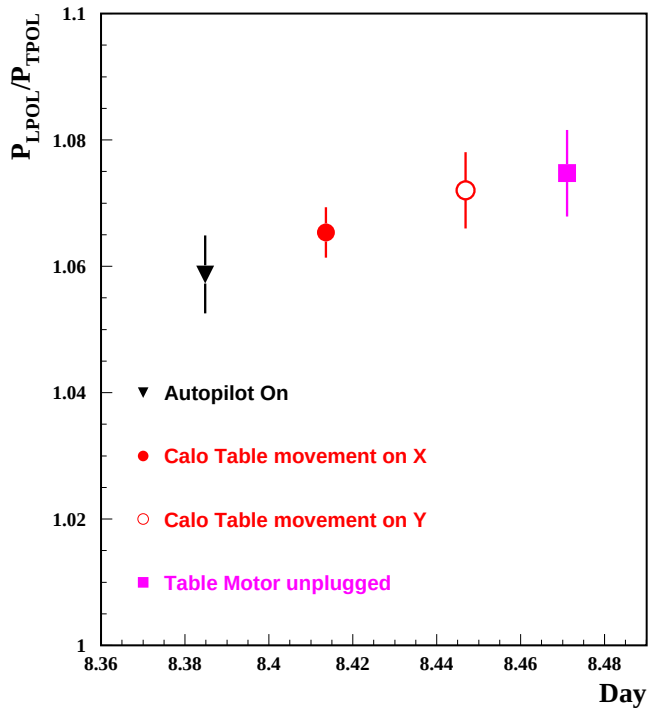
- Scanned horizontal range from -3 to +2 mm
- Movement limited by the beam pipe in positive direction



Variation within 2% (vertical scan not done yet)

Noise induced by calorimeter movement

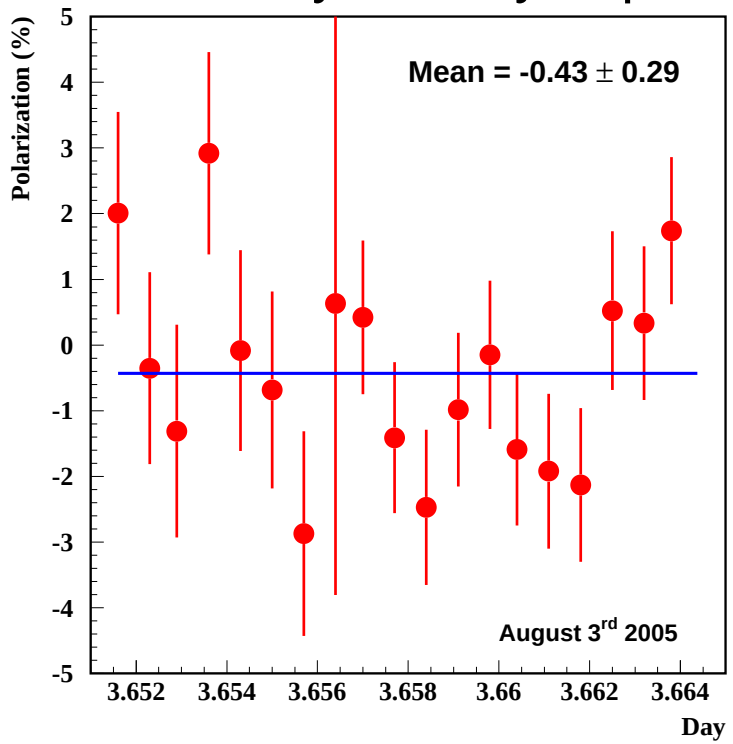
- Normally online software keeps beam centered within 1 mm
- Requires frequent movements, which could cause interference



Variation within 1%

False asymmetry

Pockel's cell turned off $\longrightarrow$ zero asymmetry expected

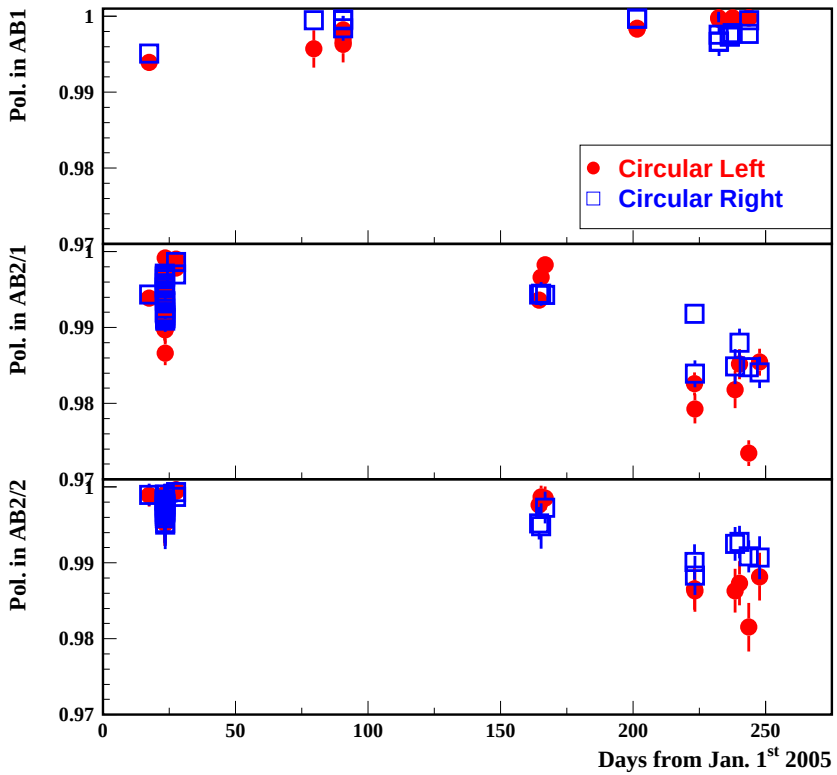


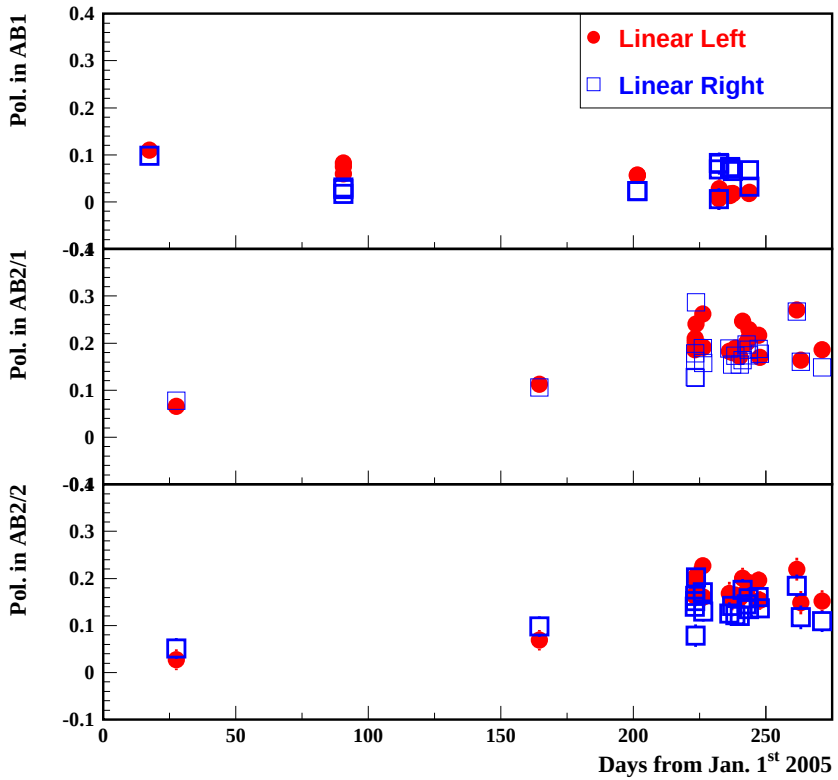
Zero asymmetry measured

Laser polarization

Circular laser polarization S_3 enters directly in the electron polarization

$$P_{measured} = P_{real} \cdot S_3$$





Circular polarization above 98%

Linear polarization low

Laser polarization

Polarization is measured in three places

- AB1: on the optical bench in the laser hut
- AB2/PIN1: analyzer box after the IP (transmitted by GT prism)
- AB2/PIN2: analyzer box after the IP (reflected by GT prism)

Reasons for lower polarization in AB2

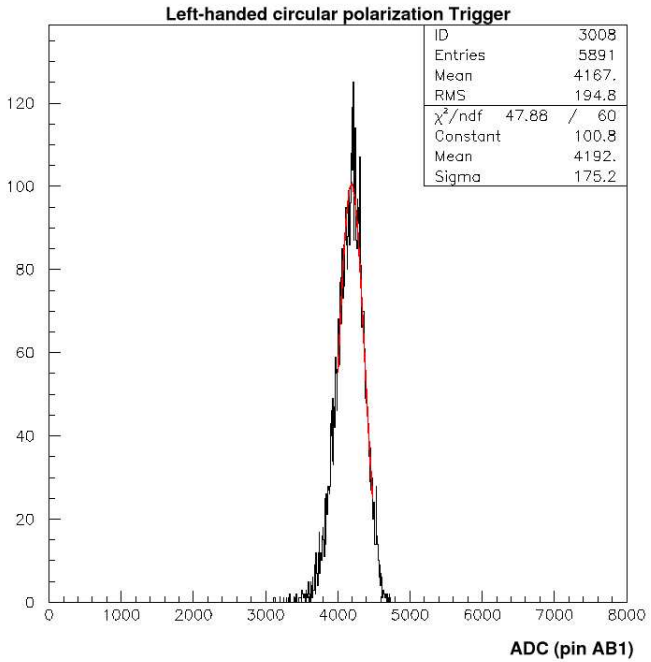
- Damage of the mirrors negligible (laser has a diameter of 4 cm)
- Entrance and exit windows stress-induced birefringence
- Reflection angles in AB2 are not 90°

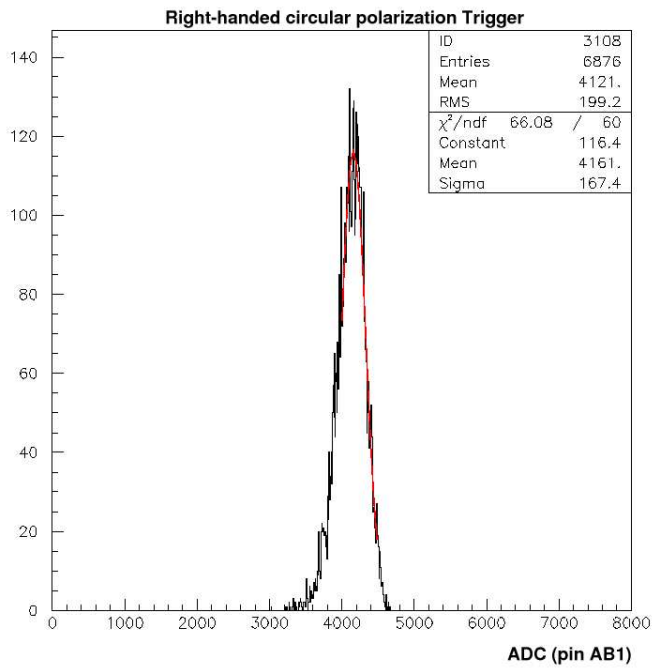
Entrance window was cracked, replaced during the shutdown.

Maximum effect of bad circular polarization is 2%

Laser polarization

Difference in intensity of left and right states can generate asymmetry
Measure in AB1 without GT or $\lambda/2$, and select photons with left, respectively right





No difference between intensity of left and right polarization states

Synchrotron radiation

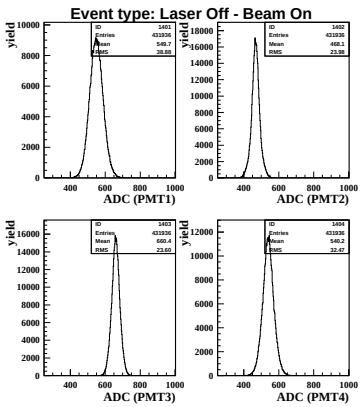
- Synchrotron radiation from Hermes target magnet
- Bremsstrahlung not important in multiphoton mode

Check

- Temperature sensor, counting rates

Synchrotron radiation

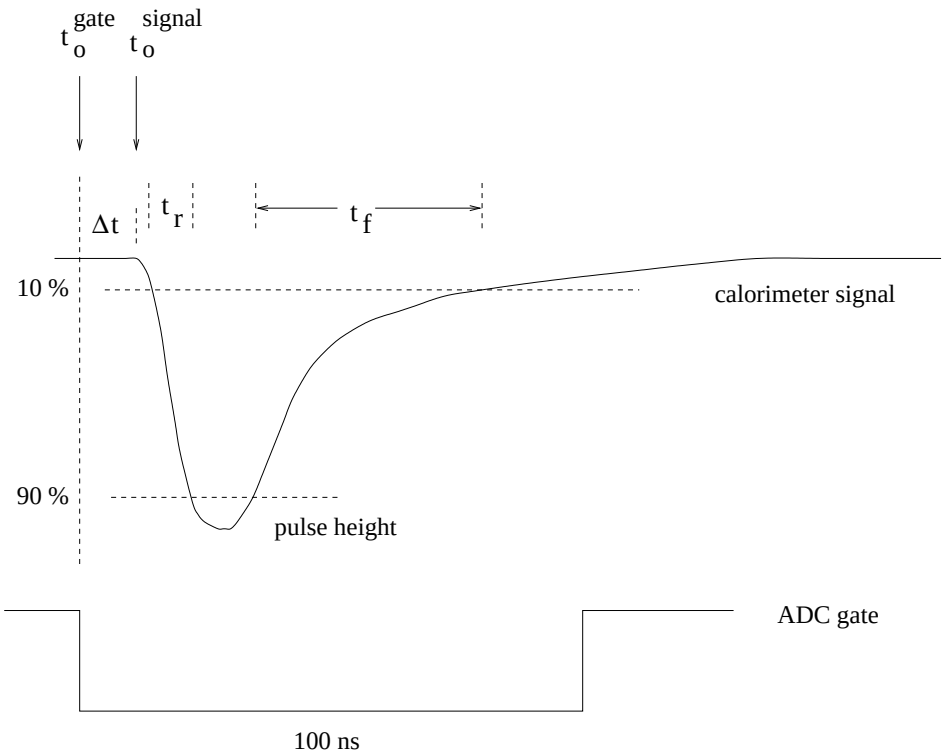
- When laser off: compare filled and empty bunches



Within statistics, left and right are equal.

Any effect would show up in the left plots

ADC gate variation

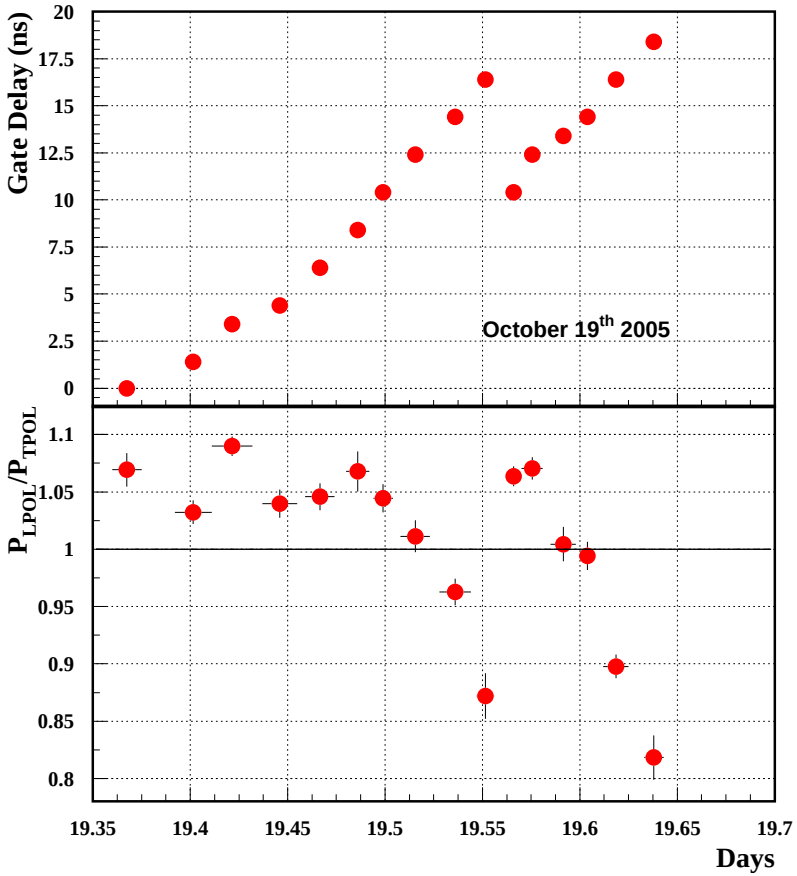


- LPOL DAQ uses integrating ADC: gate pulse is 100 ns
- Wrong timing: cut in tail/head of signal
- Additional 100 ns delayed signal line (noise) enters as signal

Is the timing correct?

ADC gate variation

Shift the gate artificially and see what happens



Results

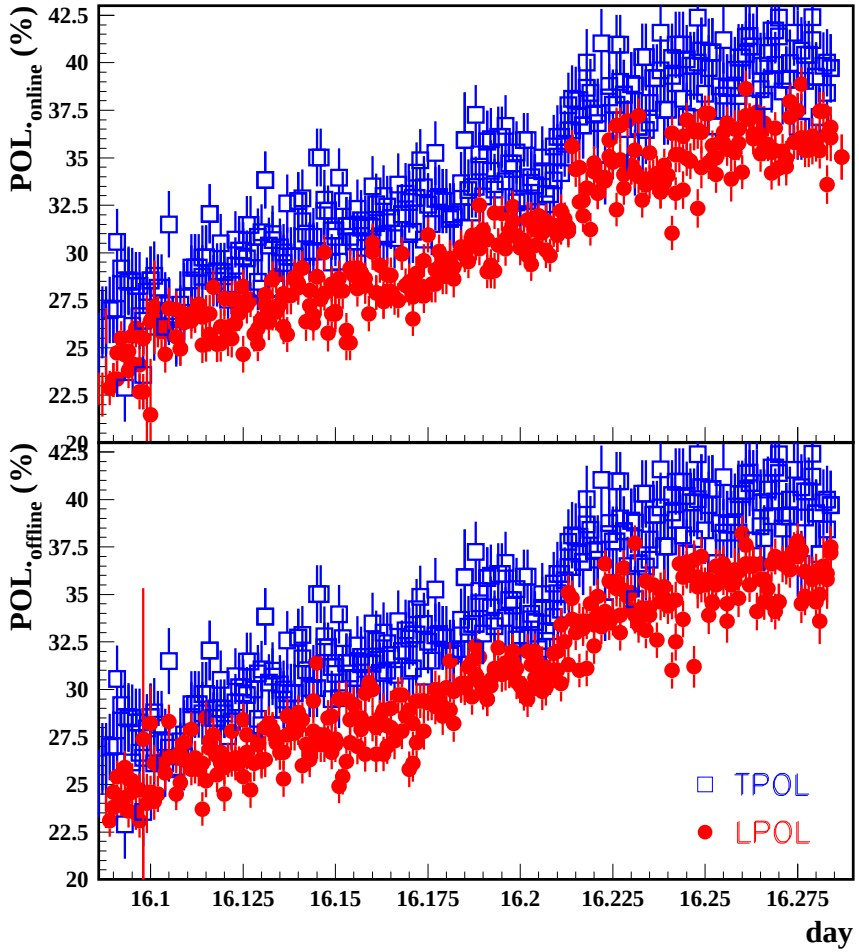
- Effect only after 10 ns artificial shift (as expected: 10 ns is designed safety)
- When delay too large, “alarms” go off

Changes in the gate timing, despite safety margin, would have been noticed.

ADC gate variation

Additional test

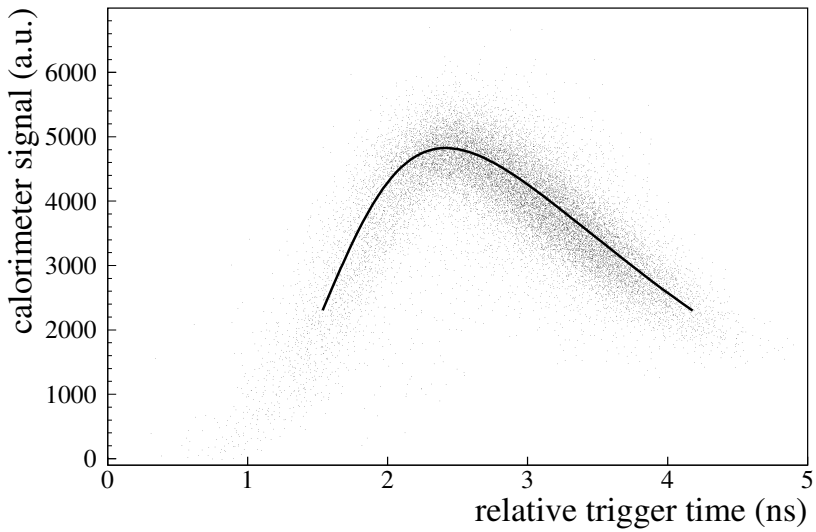
- Assumption: size of noise is constant over one month
- Average noise from one fill in July 2005 can be used to analyze whole July 2005
- Use average noise from July 2005 to correct data in August 2005: still disagreement with TPOL



Average noise from July 2005 and August 2005 are equal.

Laser trigger delay

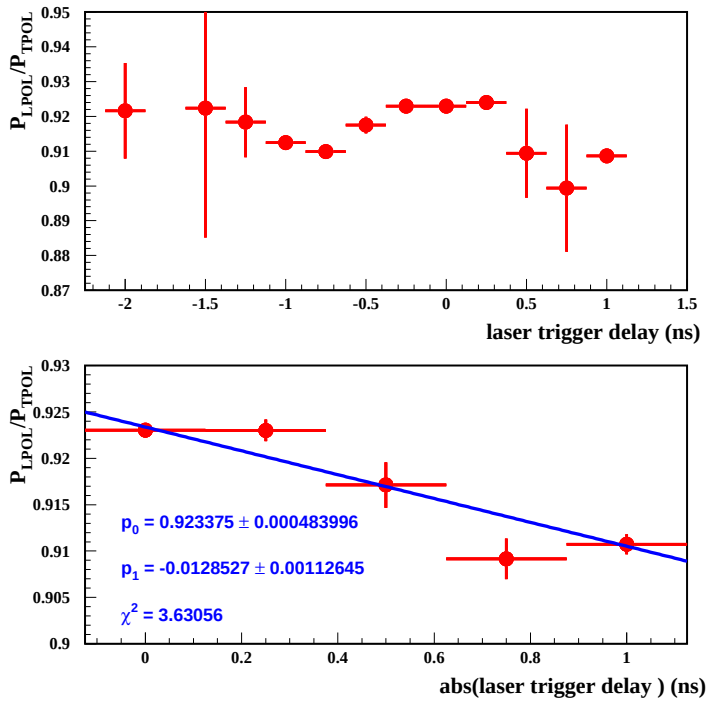
Laser pulse (3 ns long) jitters within ± 1.5 ns $\rightarrow$ electron bunches (1 ps)
"scan" laser pulse



Laser timing is corrected to fire for maximum intensity at bunch crossing: laser trigger delay

Laser trigger delay

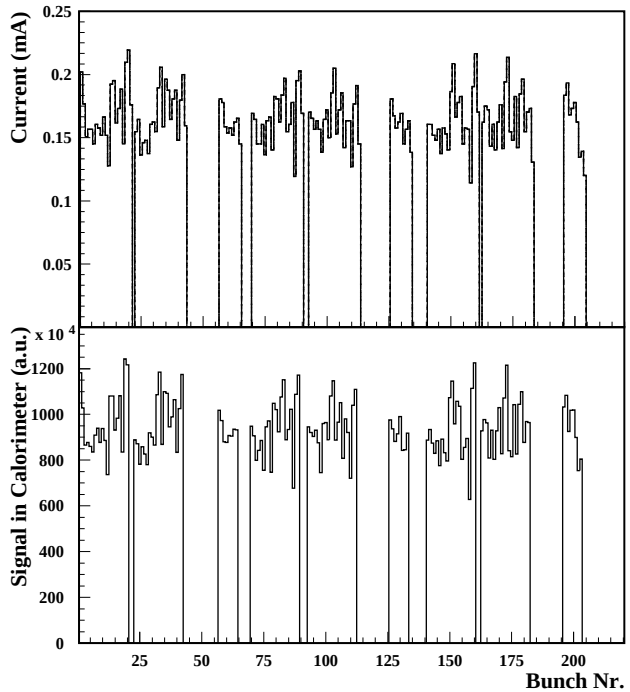
Laser delay sometimes jumps around $\longrightarrow$ laser firing not optimal
Does this only affect the laser intensity or also the polarization measurement?



Possible systematic effect smaller than 2%.

Bunch triggering

Sometimes bunch pattern loaded incorrectly $\longrightarrow$ one bunch per train missing



Calculations: maximum 0.2% difference in polarization

Optical system

During shutdown: complete check of optical system

- Liquid level in PC still fine before shutdown
- All mirrors inspected
  - M3 damaged (spot of mm size), replaced
  - M5/6 both dusty, coating damaged, replaced
  - All other mirrors perfect
- Lens doublets checked for damage $\longrightarrow$ perfect
- Entrance and exit window checked $\longrightarrow$ entrance window replaced
  If damage to entrance window caused disagreement, laser polarization should have been lower
- Focussing at interaction point checked $\longrightarrow$ within 20 cm of BPMs

No obvious problems with optical system

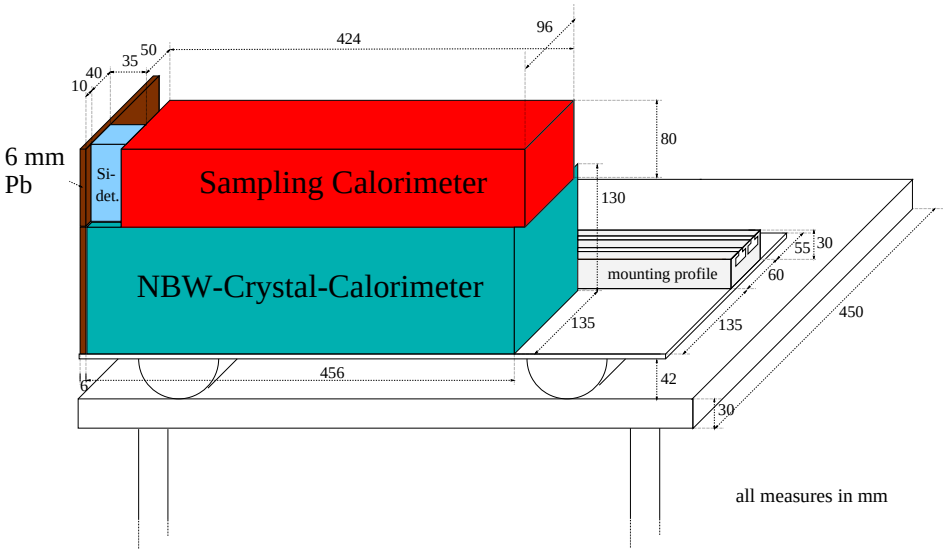
Conclusion

- Numerous systematic studies done
- All effects below 2% and mostly statistical
- One effect that can be corrected for: laser light polarization (2%)

Did we miss something? Were we (un)lucky?

No reason could be found to assign a systematic uncertainty larger than 2% to the LPOL

Sandwich calorimeter

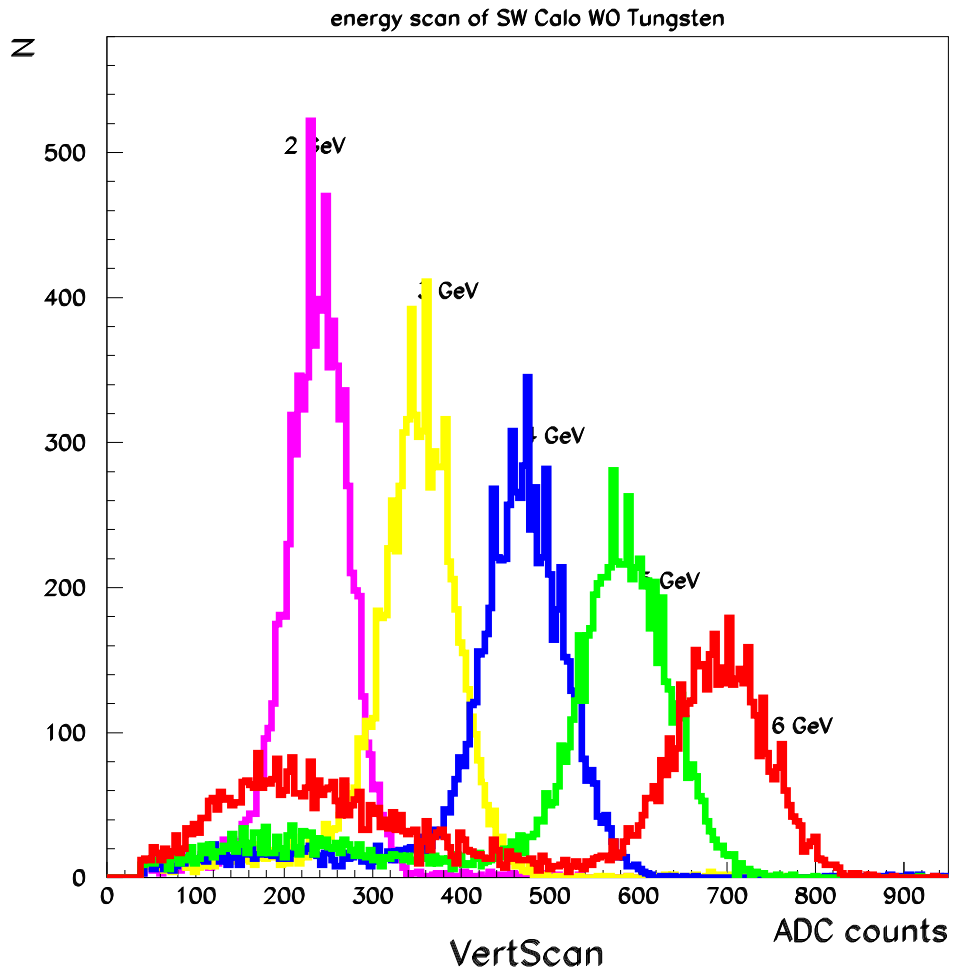


- Independent measurement
- Unfortunately not at the same time

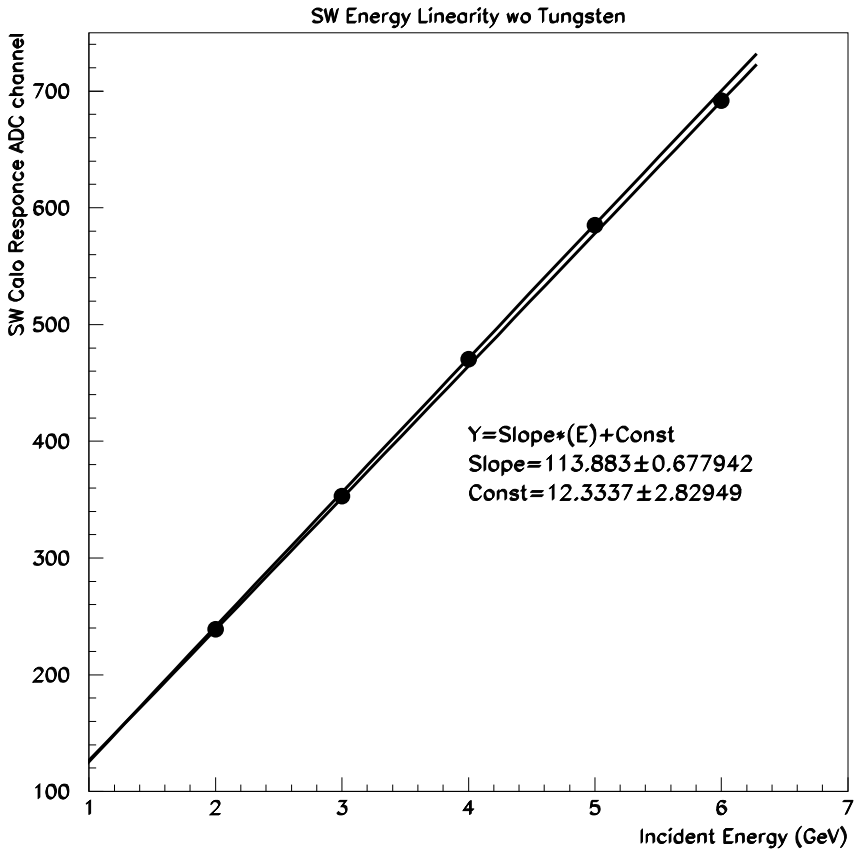
Test beam measurements

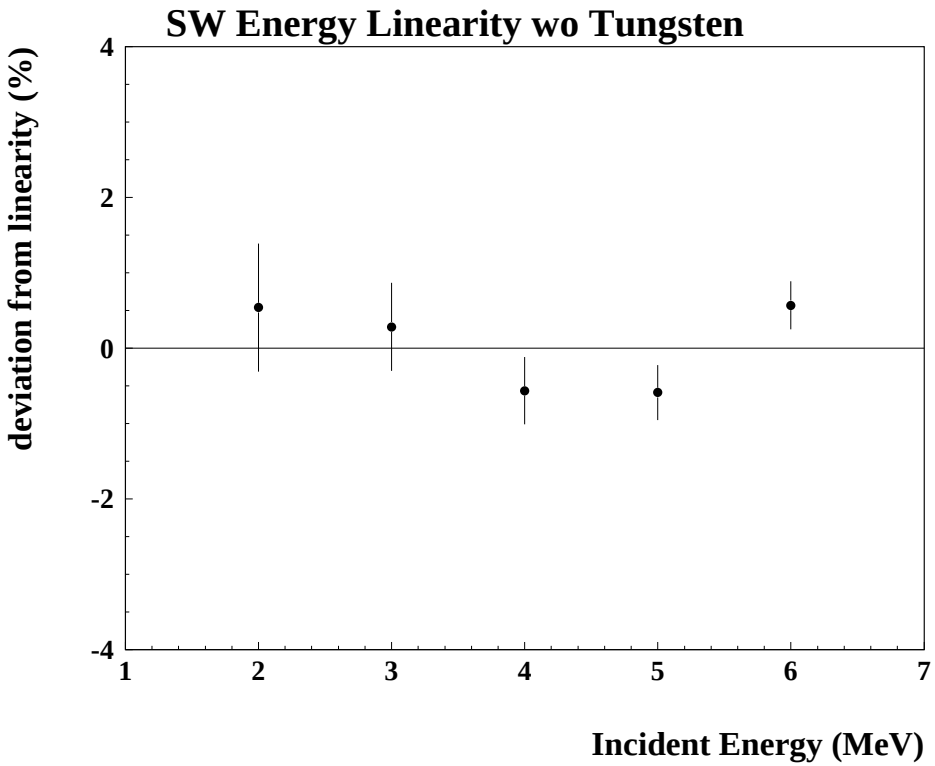
Linearity measurement

- From 2 GeV to 6 GeV
- Within 5 mm from center of calorimeter (but beam diameter 5 mm)
- With and without tungsten front plate



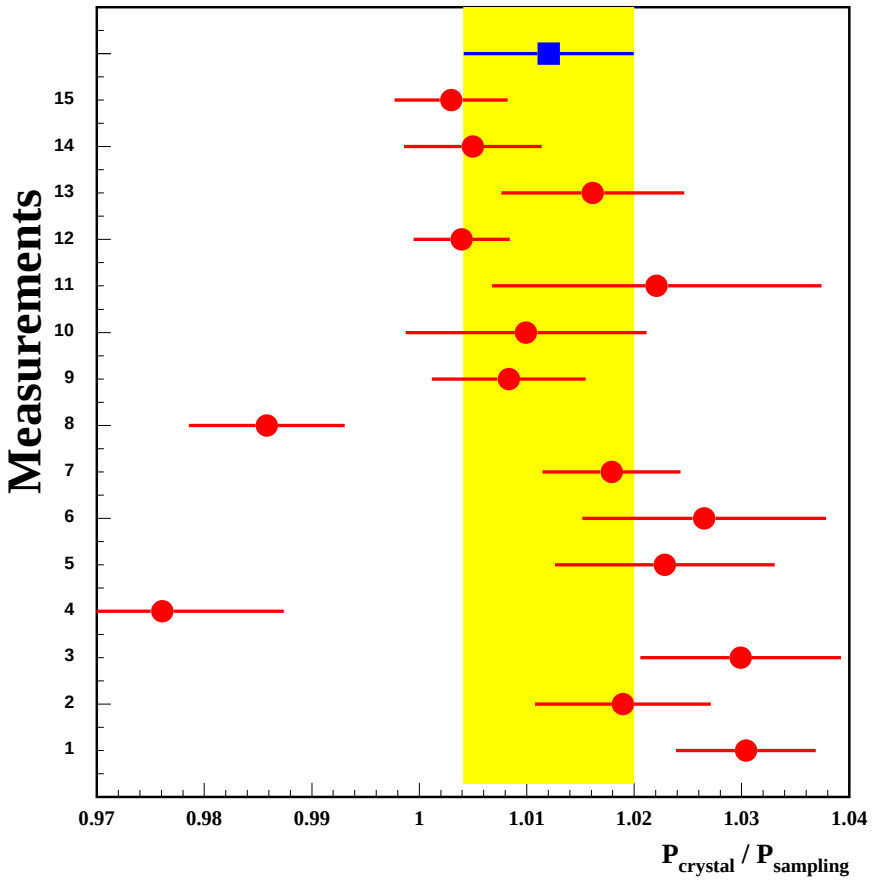
Test beam measurements





Linearity is almost perfect (but we're cheating, it's rebuilt. . .)

Comparison with crystal calorimeter



Several measurements

- January until June 2005
- One (#15) in September 2005

Analyzing power

- Small non-linearity
- 5% different from expected
- Well understood

Agreement within 2% (no measurements during August. . .)

Ready for data taking

- Found the beam again in AB2 (after replacement of M5/6 and entrance window alignment was lost)
- Laser polarization back to 97% (still need to do HV scan for Pockel's cell)

Spares

- Laser flashlamps
  - 3 left (and one just installed) $\rightarrow$ until end of May
  - company will send check instead of lamps...
- Pockel's cell
- Crystals: supposedly ready and somewhere...but not here