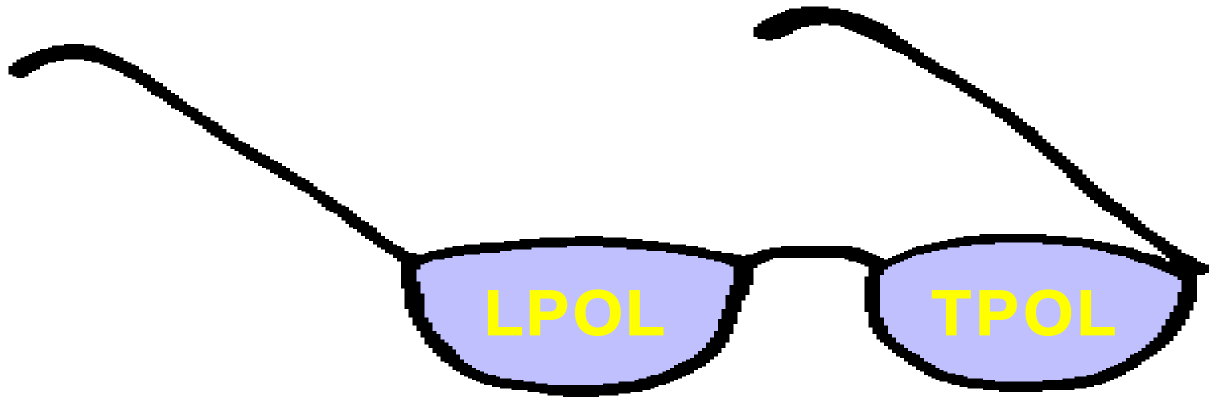
The Polarimeters

François Corriveau,
IPP/McGill University

ZEUS Collaboration
Week, 22.06.2004



- Introduction to Polarisation at HERA
- Status of LPOL and TPOL
- Silicon Detector News
- Analyses: Monte-Carlo and Offline Fits
- Conclusions

The POL2000 Group

HERMES, H1, ZEUS and DESY

ZEUS Members

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R. Hamatsu, H. Kaji, S. Kato, K. Matsuzawa, K. Nagano, O. Ota, Y.D. Ri *(Tokyo Metropolitan University)*

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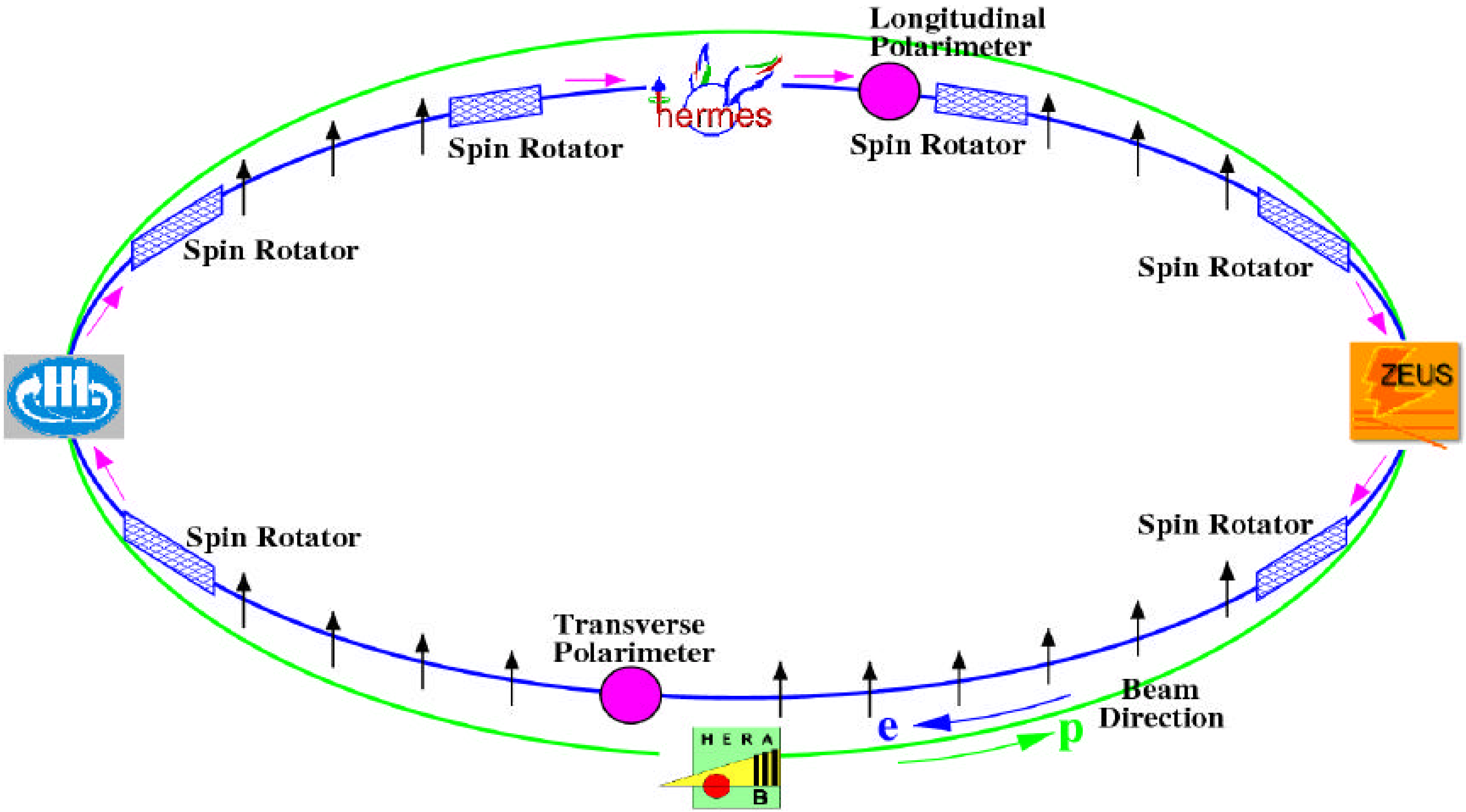
A. Gabareen-Mokhtar *(Tel-Aviv)*

E. Tassi *(Madrid)*

U. Stoesslein *(DESY)*

e± Polarisation

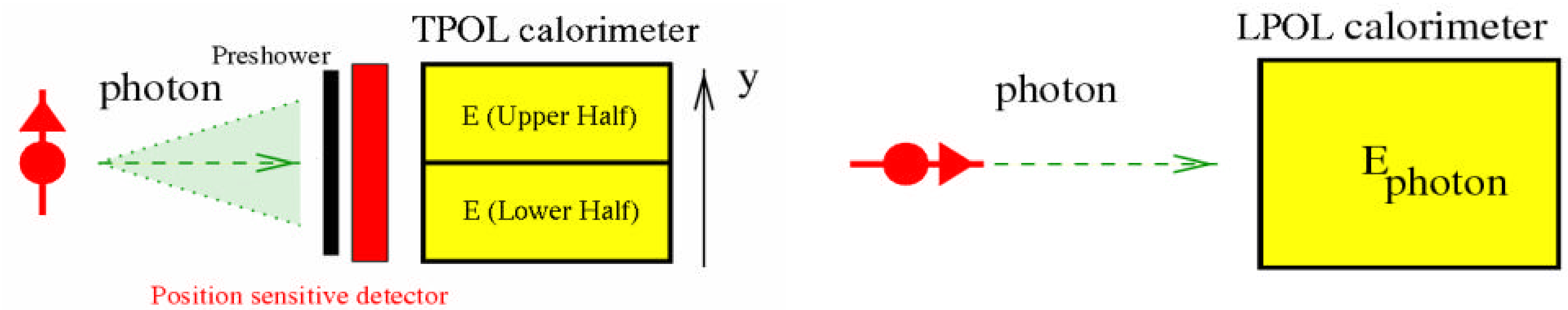


LPOL measures the longitudinal polarisation at HERMES

TPOL measures the transverse polarisation between ZEUS and H1

Polarimeters

Laser light is Compton scattered off the polarised $e^{\pm}$ beam

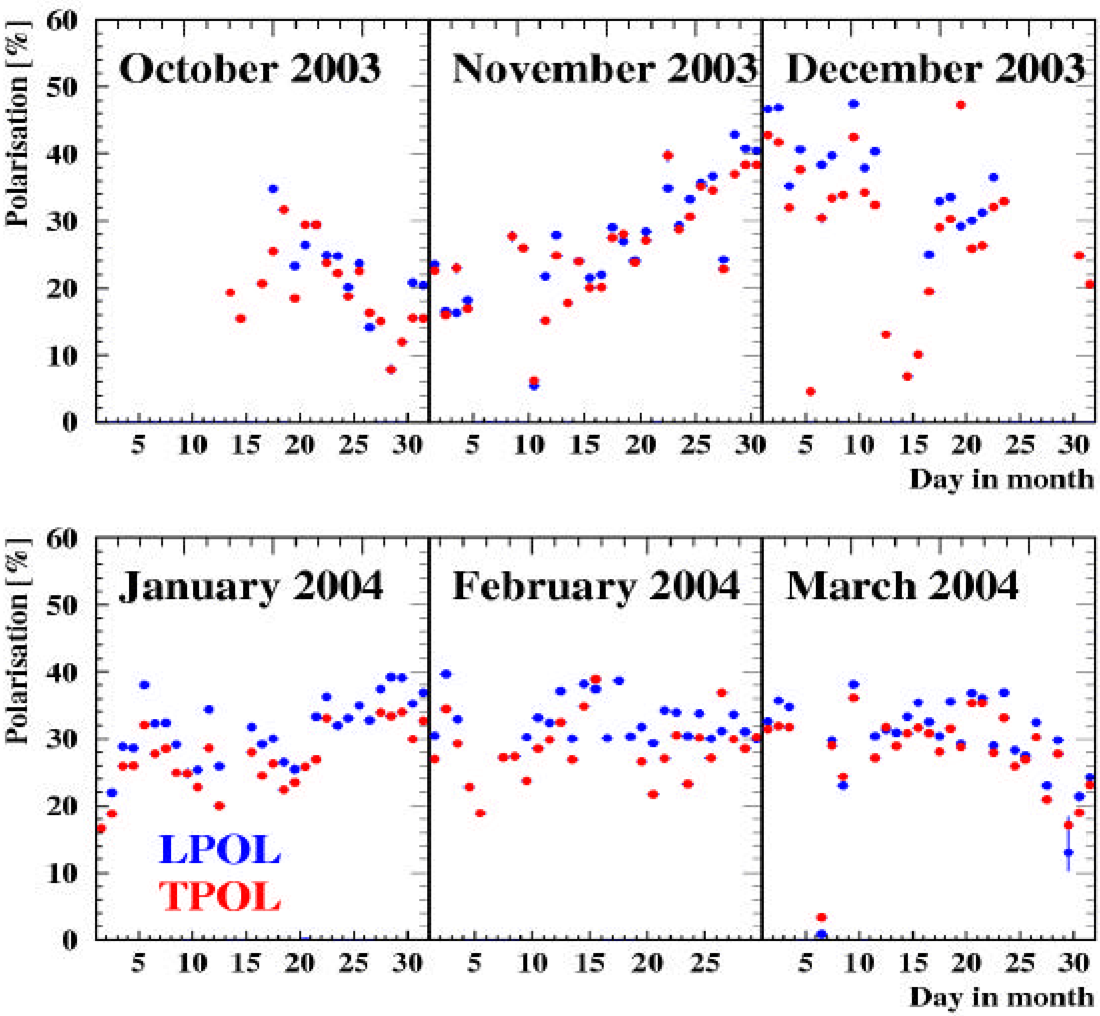


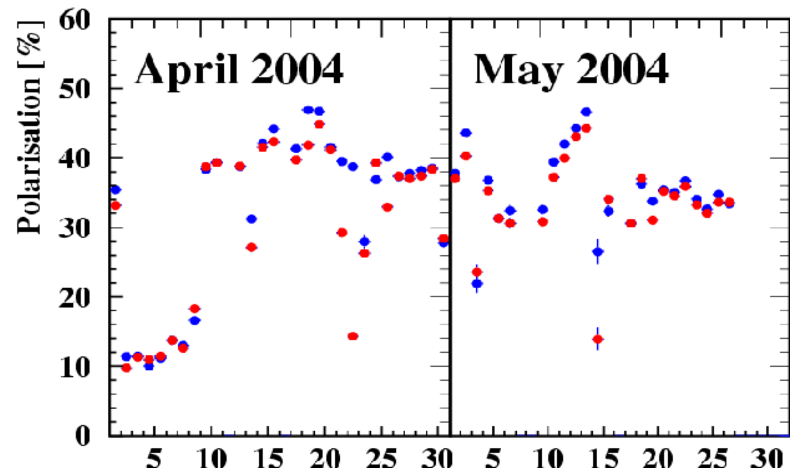
- The vertical asymmetry of the Compton photons is measured
- The laser beam is continuous on all bunches
- Accuracy goal: ≤2%
- Si-strips also measure asymmetry
- Scintillating fibre (calib./monitor.)

- The energy dependence of the Compton photons is measured
- The laser is pulsed, hence multi-photon spectra
- Accuracy: ~1.9%
- Expectation: $P_{LPOL} = P_{TPOL}$
- A new laser + Fabry-Perot cavity is being installed ⇒ 1%

Polarisation

Average HERA polarisation (LPOL and TPOL)





- Operation continuous and reliable at ~35%
- 55% reachable
- Residual discrepancy LPOL/TPOL ~ 1.03-1.10

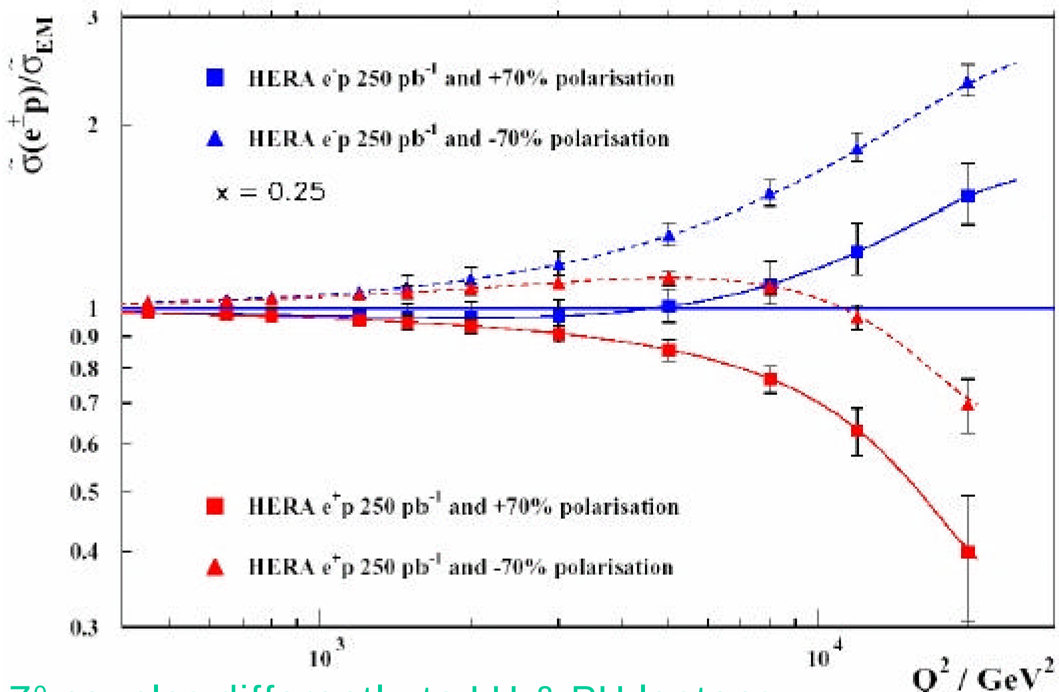
Polarisation

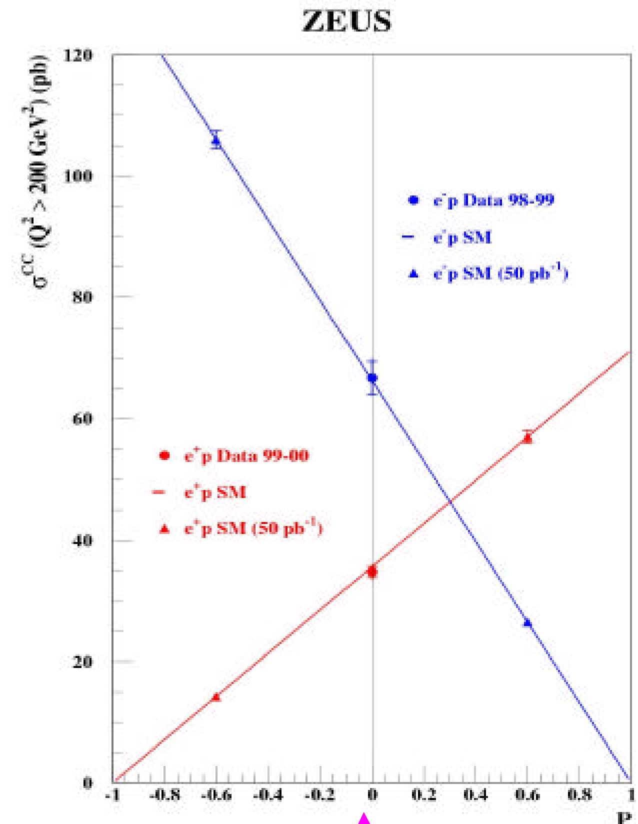
Standard Model: **Neutral Current** **Charged Current**

σ's change at high Q^2
the larger P, the better } test the SM

$e^{\pm}: \sigma(P) = (1 \pm P)\sigma(0)$

Simulation at Lumi.=250pb^{-1},P=+-70%





Z^0 couples differently to LH & RH leptons

W couples only to LH leptons

measured

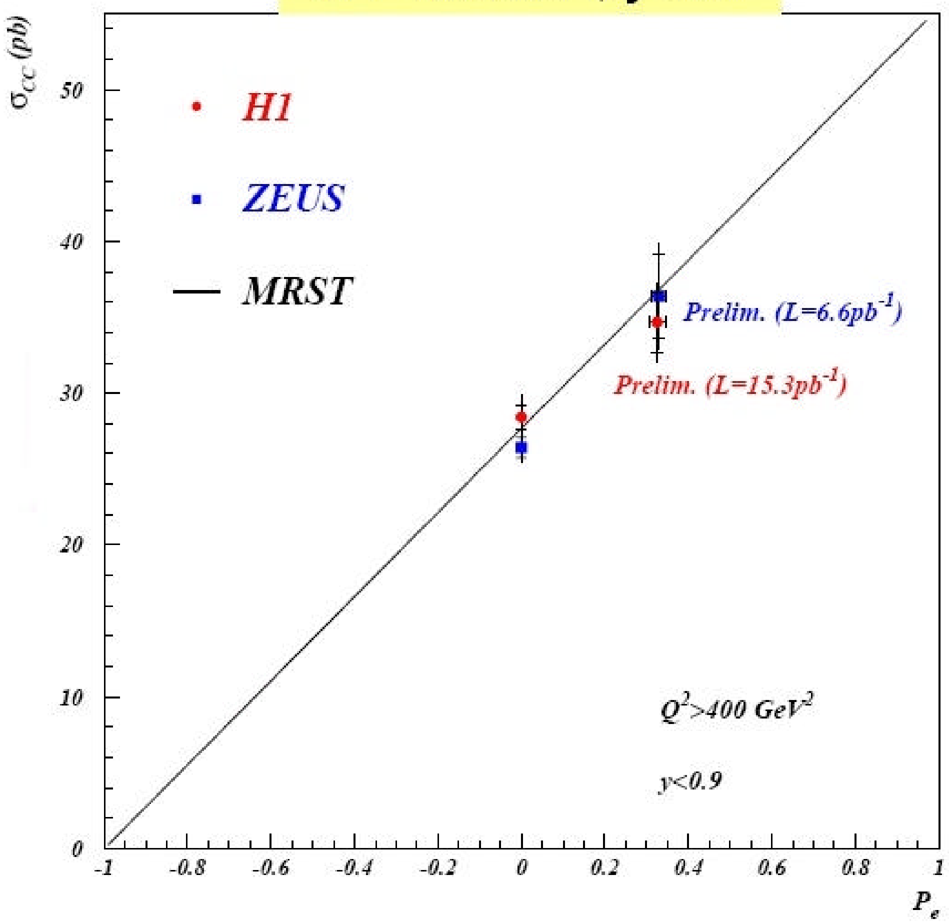
Polarisation

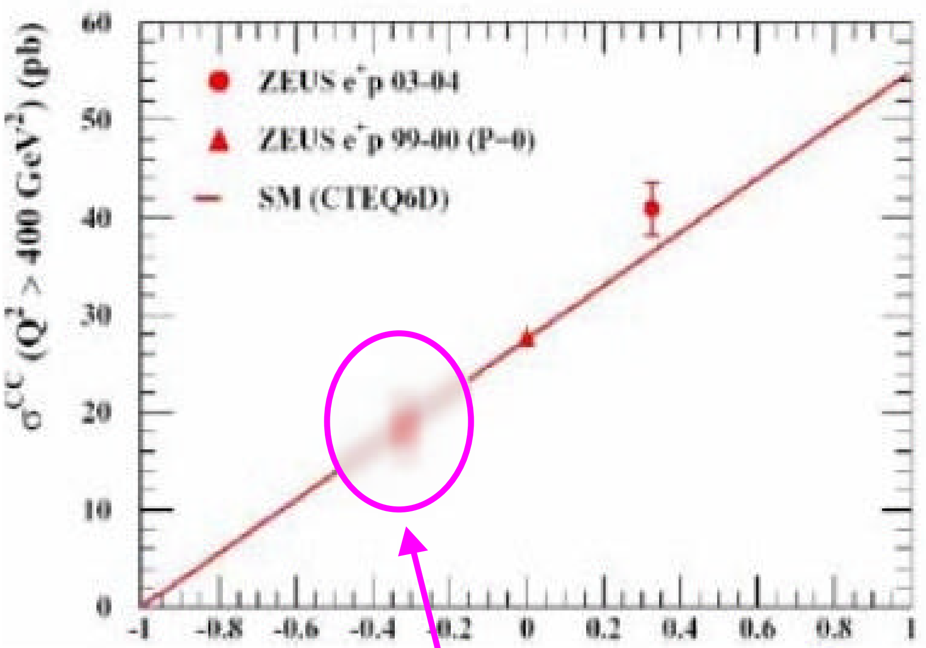
First measurements at P=33%

σ_{CC}^{ZEUS} = 38.1±2.9(stat)±0.8(syst) ±2.0(lumi)±0.8(pol) pb

σ_{CC}^{H1} = 34.67±5.6%(stat)±4.8%(syst) pb

Q²>400GeV², y<0.9





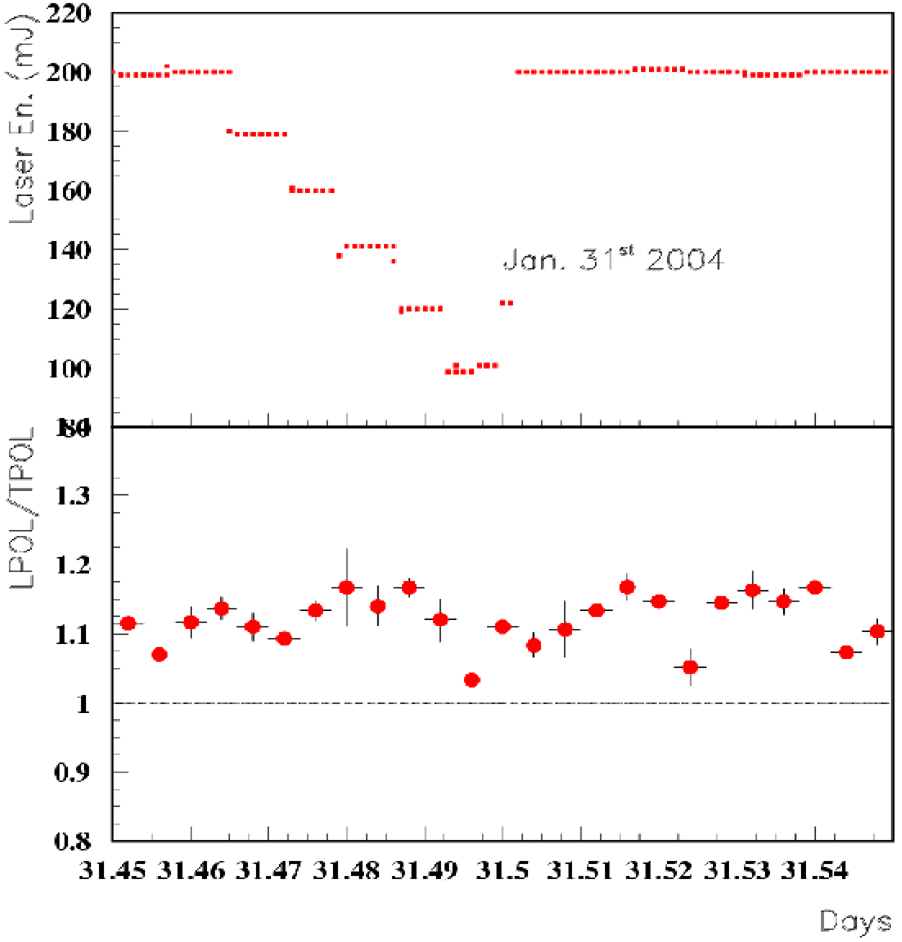
new/preliminary: polarisation flipped

LPOL Systematic Studies

- Possible 2003-2004 systematics investigated:
  - Laser energy
  - Position of Compton cone in calorimeter
  - Laser noise correction
  - False asymmetry

- No dependence of polarisation measurement observed

- LPOL appears consistent with 2000 performance (~2%)

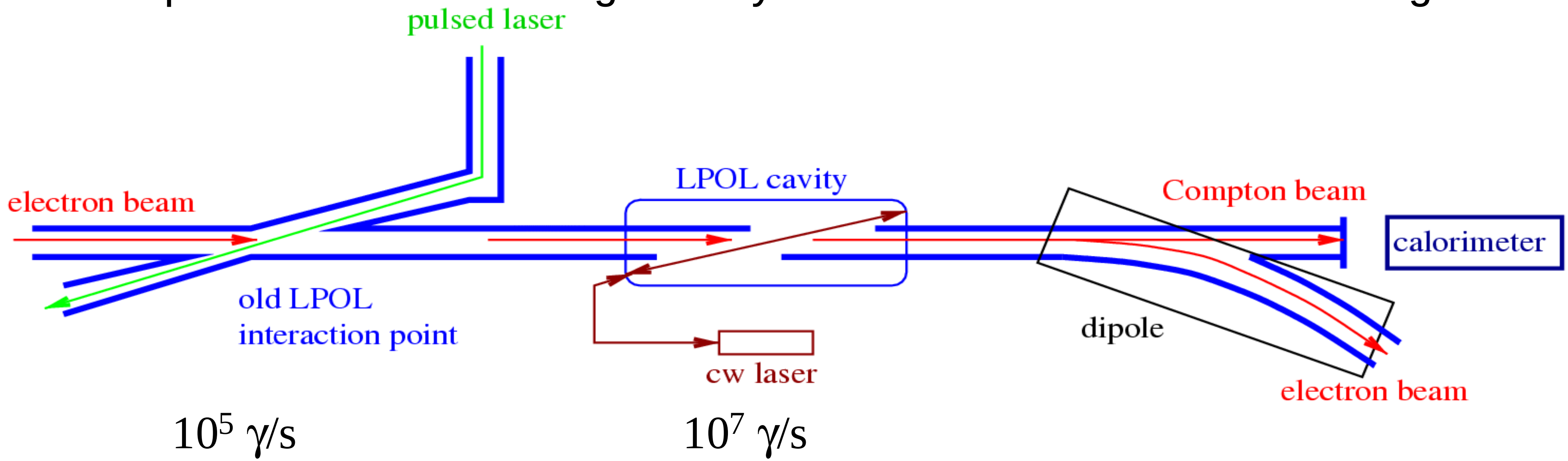


LPOL Status

- Instabilities and loss in relative luminosity were observed after mid-May
- The detector was investigated during the June 3rd access and no apparent cause could be found
- But it then stopped working: signals lost.
- The calorimeter was opened on the 17th, 3 of the 4 crystals were broken and blackened at the front, GMS calibration fibres were burned.
- 2 identical spare crystals have been located, and 2 more from the H1 lumi group, to be calibrated and installed.

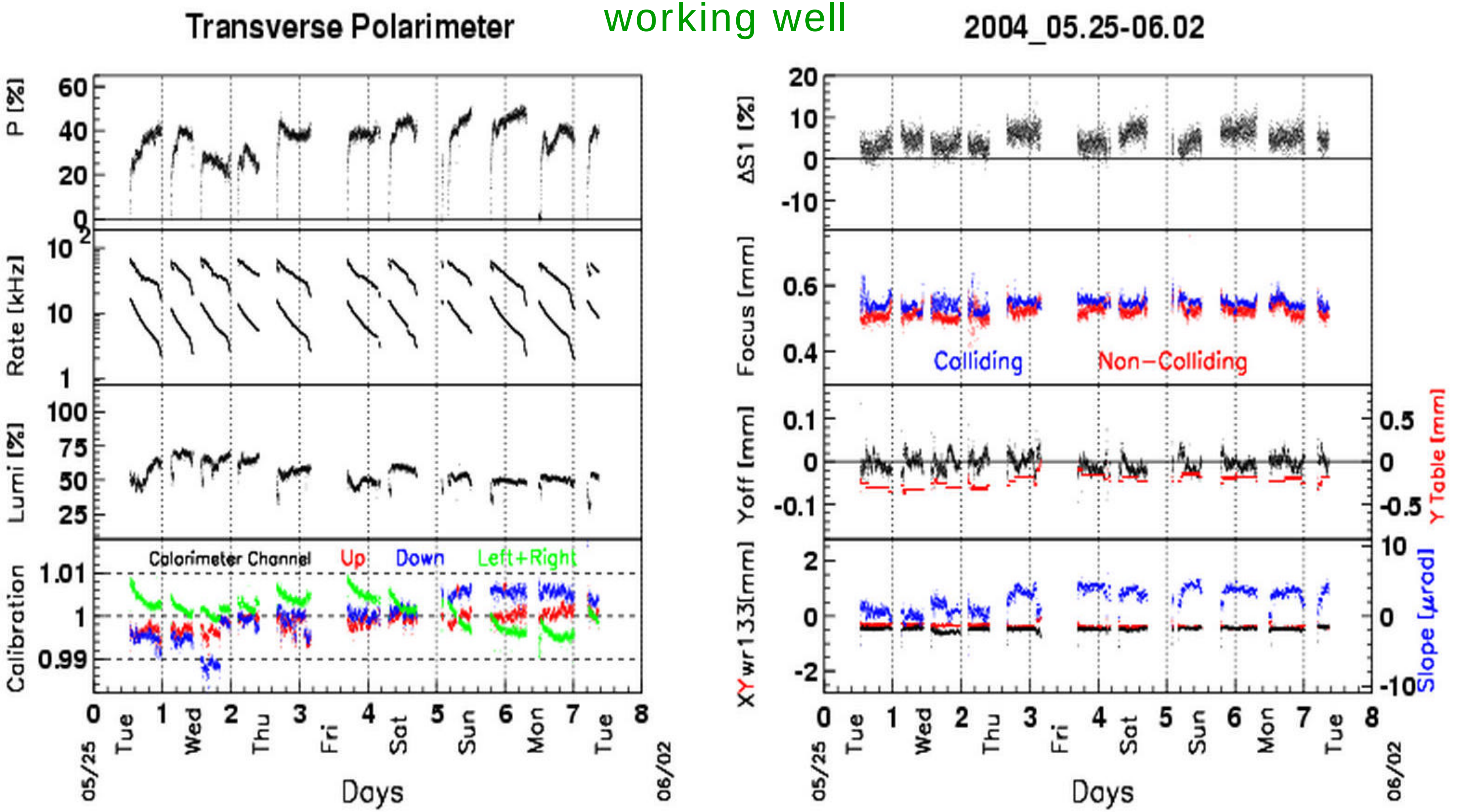
LPOL Cavity

- A Fabry-Perot cavity for fast (a few photons per bunch crossing) and precise (1%) polarisation measurement has been installed in 2003. DAQ is operational.
- Major delays due to radiation damage. Re-install electronics.
- A new radiation resistant W/quartz fiber calorimeter will be built for the end of 2004 (was a crystal calorimeter).
- Improved lead shielding and synchrotron radiation monitoring.

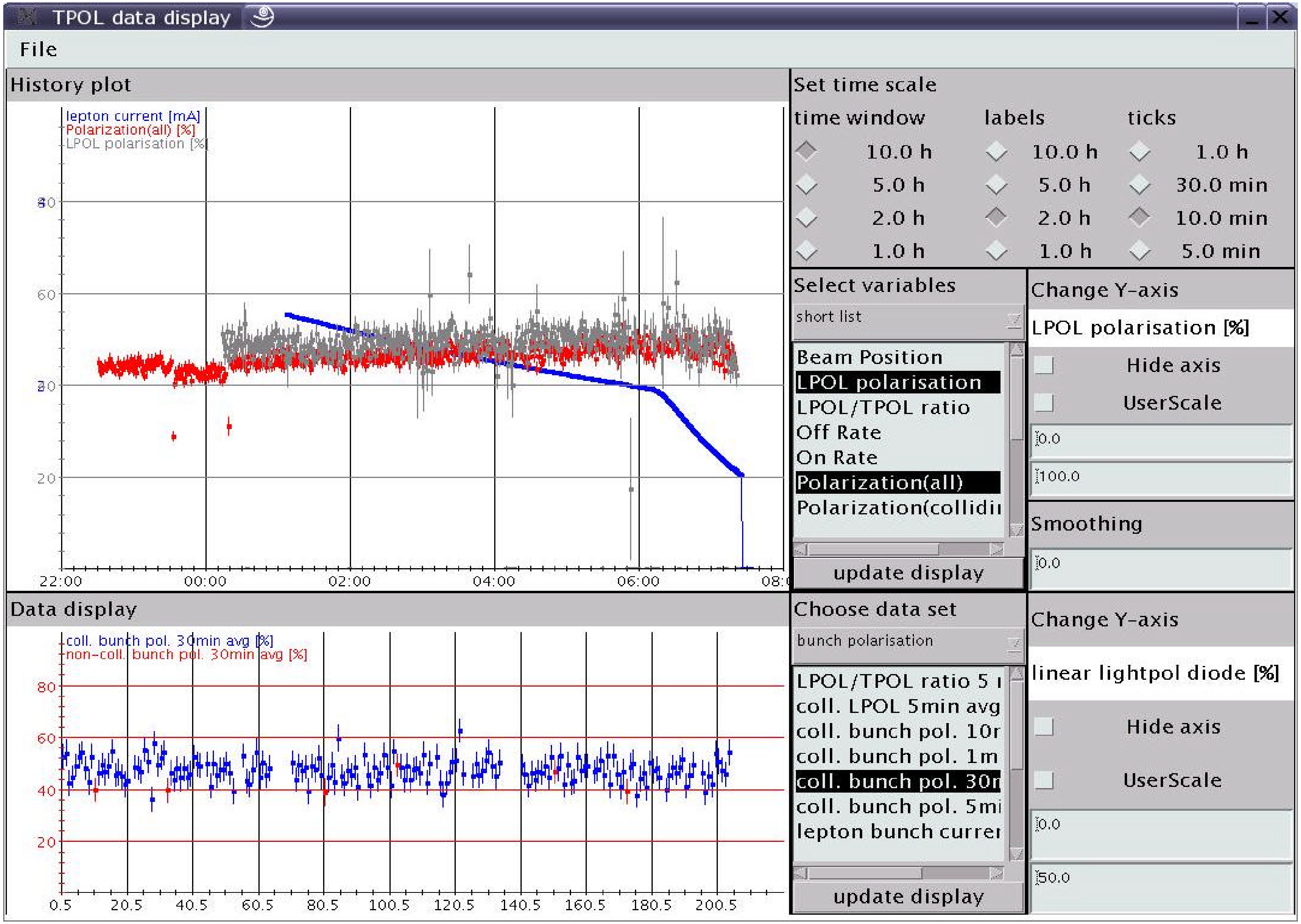


TPOL Weekly Plots

working well



TPOL Systematic Studies

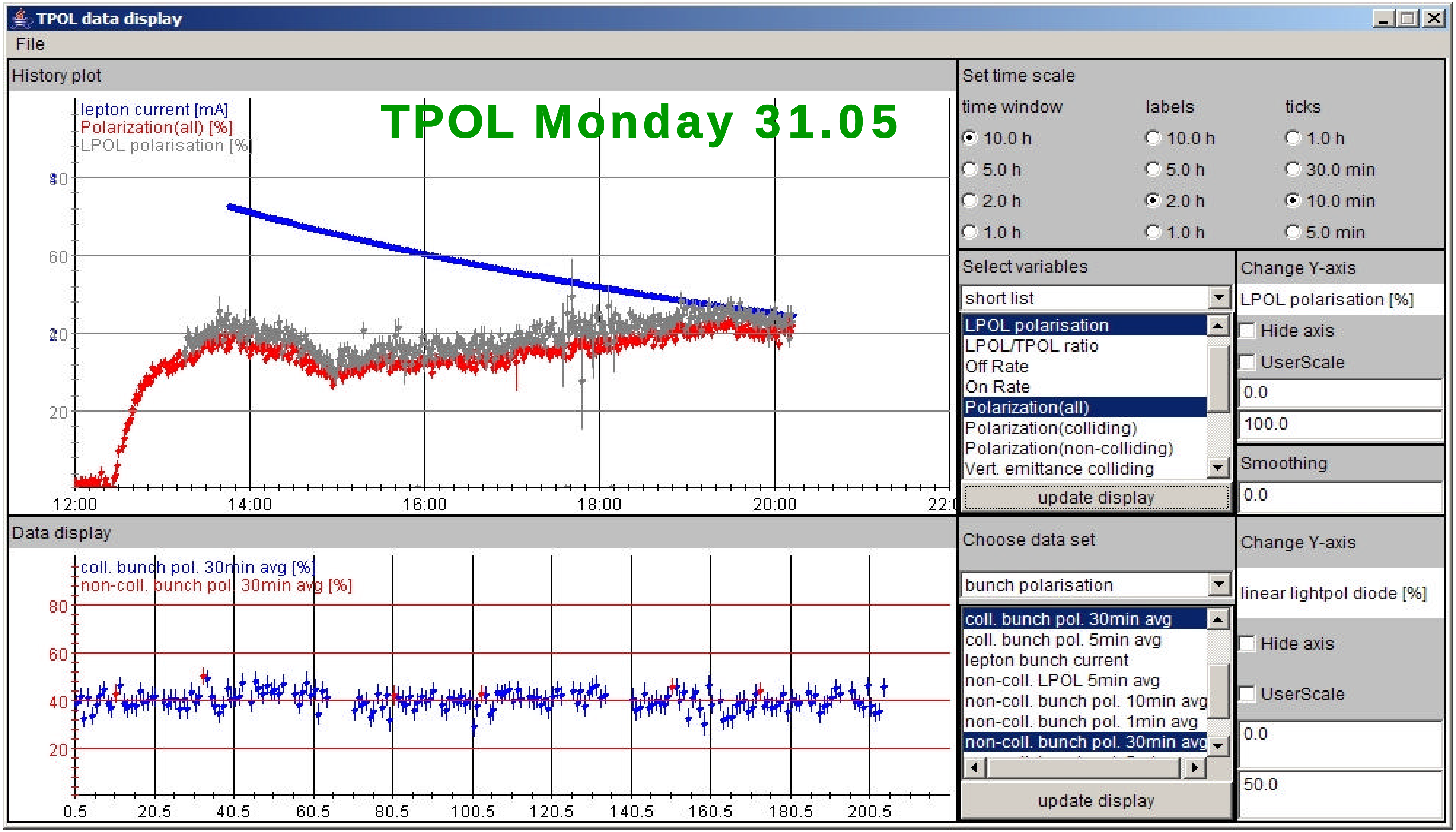


HERMES high density target at end of run

31/05/2004

LPOL/TPOL ratio unchanged

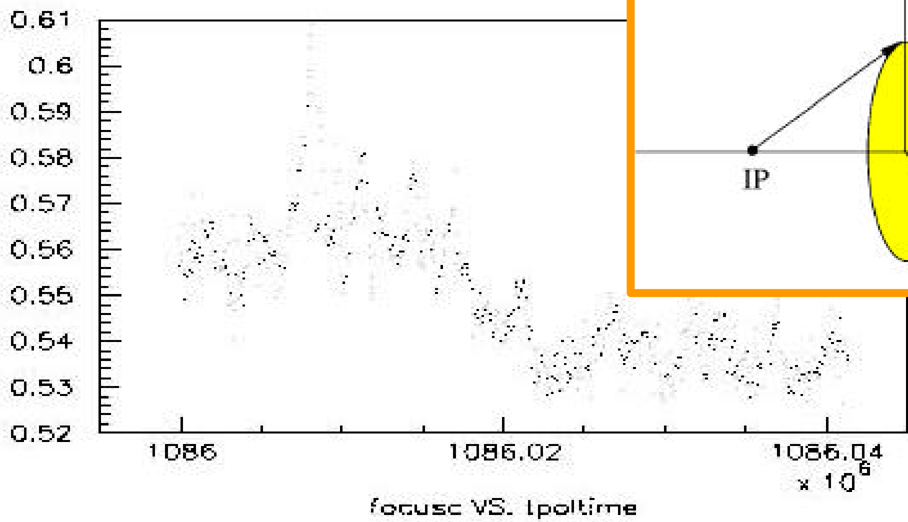
TPOL Systematic Studies

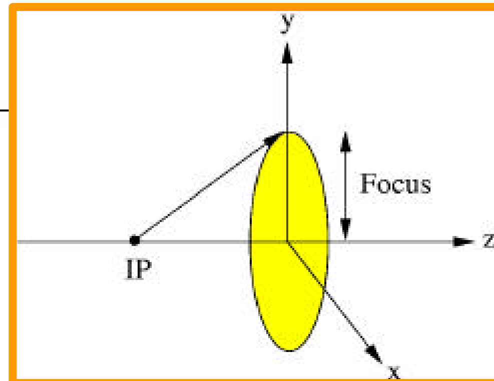


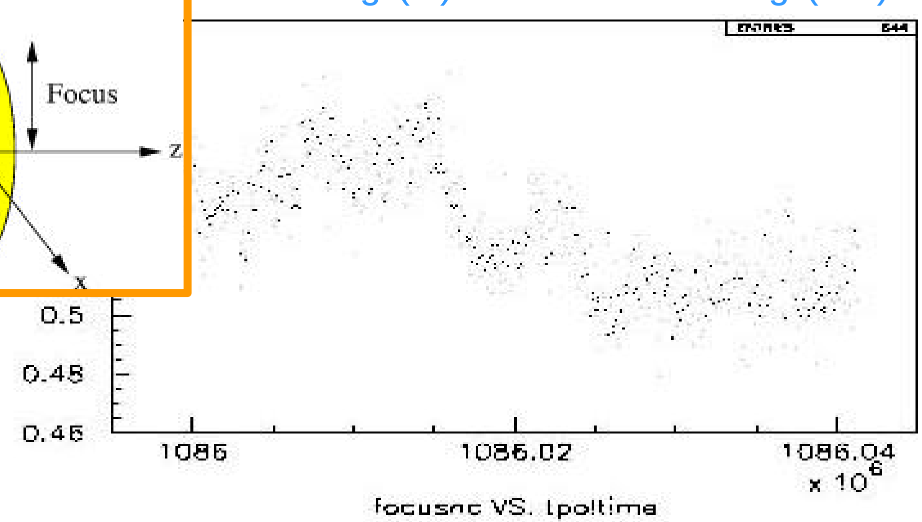
TPOL Systematic Studies

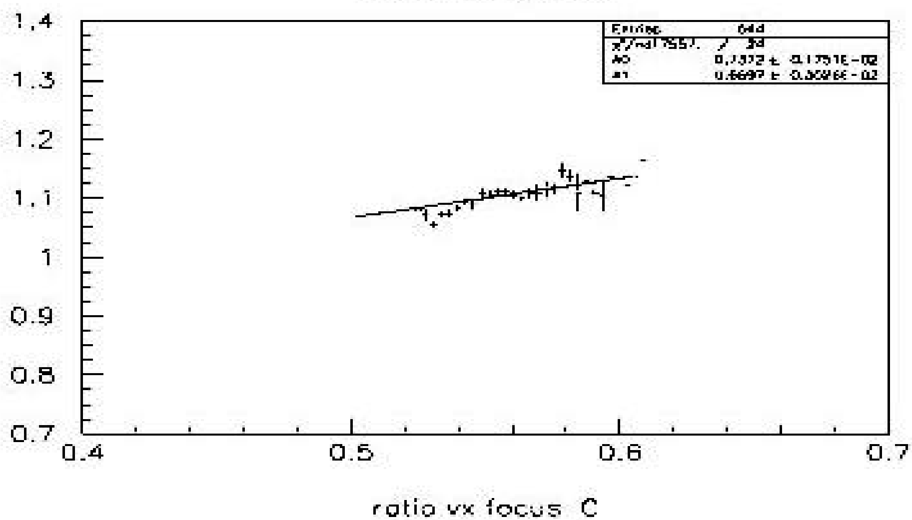
12h Long Run 31.05

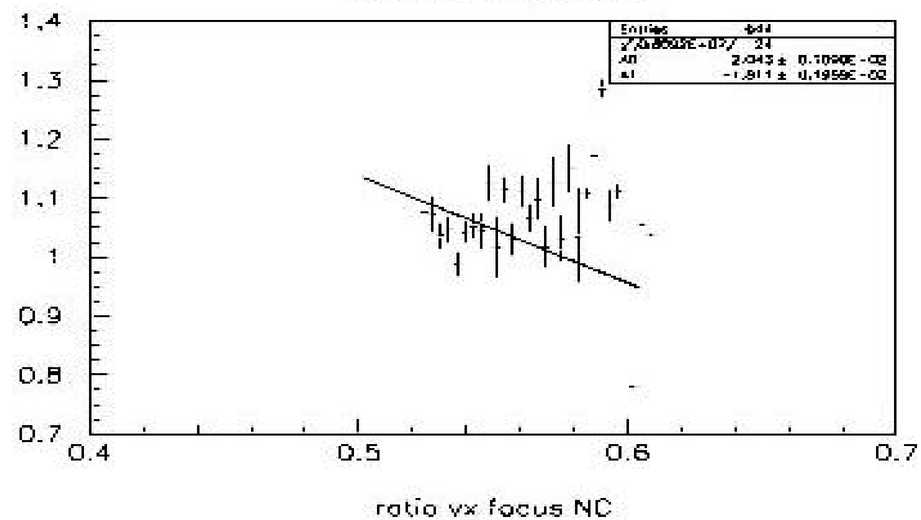
Compton cone focus vs time, ratio vs focus
colliding (C) and non-colliding (NC) bunches











LUMI-POL Efficiencies

Cross-checks with U.Stoesslein's code

ZEUS runs were used to scan the Oracle database for the polarisation data:

- both analyses agree, the TPOL up to 20%-losses are very similar.
- the only difference is that for LUMI the negative polarisation measurements are cut out: these are anyway runs with very low polarisation values.
- need for proper DQM, to be derived from offline algorithm (underway)

- for the very few missing records during a run (because of TPOL lumi scan or other calibration scan), no rejection is performed and a crude but sufficient interpolation is done/assumed. Threshold: 300 secs.

- the main losses mostly occur at the end of runs: TPOL actually stops acquiring data earlier than ZEUS or there is a gap longer than assumed.

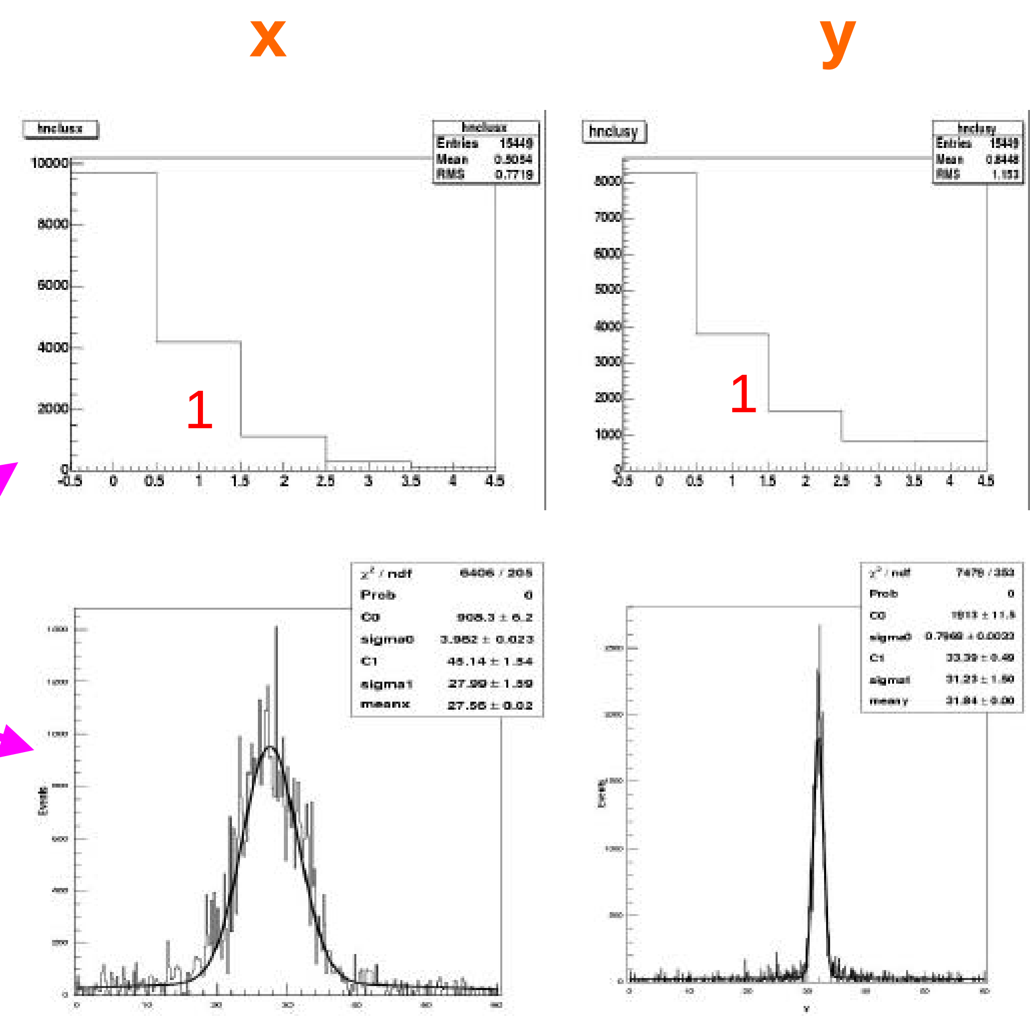
- The TPOL autopilot was checking for two types of HERA messages: RUN END IN 5 MINUTES and PLEASE SWITCH YOUR HV OFF. If either of those messages was received, the polarisation measurement was stopped. The former action has now been disabled. This brings at least five more minutes of TPOL data at the end of each run and thus account for the larger part of the losses.

The Silicon Detector

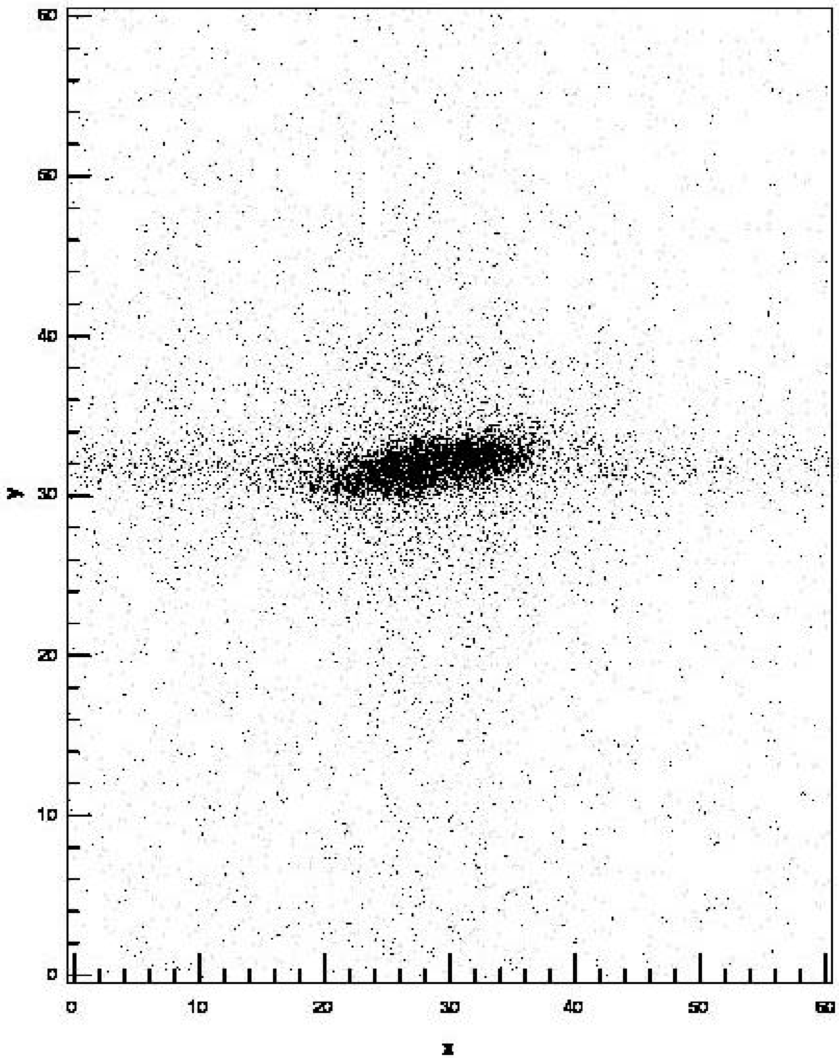
C.Fry, A.Tapper

- Measures x and y position
- provides the η-y calibration
- 768 y-strips, 256 x-strips

- clustering algorithm “center of mass” with signal $\geq 5\times$RMS
  - # of clusters
  - profiles and fits
- 10^5 events in 150 seconds
- 1.8% useful (1×1 cluster)
- fit an ellipse to the beam



Beam Ellipse



Data fitted with 2D Gaussian:

$$f(x,y) = Ce^{-\frac{1}{2}\left(v_{xx}(x-x_0)^2 + 2v_{xy}(x-x_0)(y-y_0) + v_{yy}(y-y_0)^2\right)}$$

beamsizes and tilt: σ_x, σ_y and α are known functions of v_{xx}, v_{xy} and v_{yy}

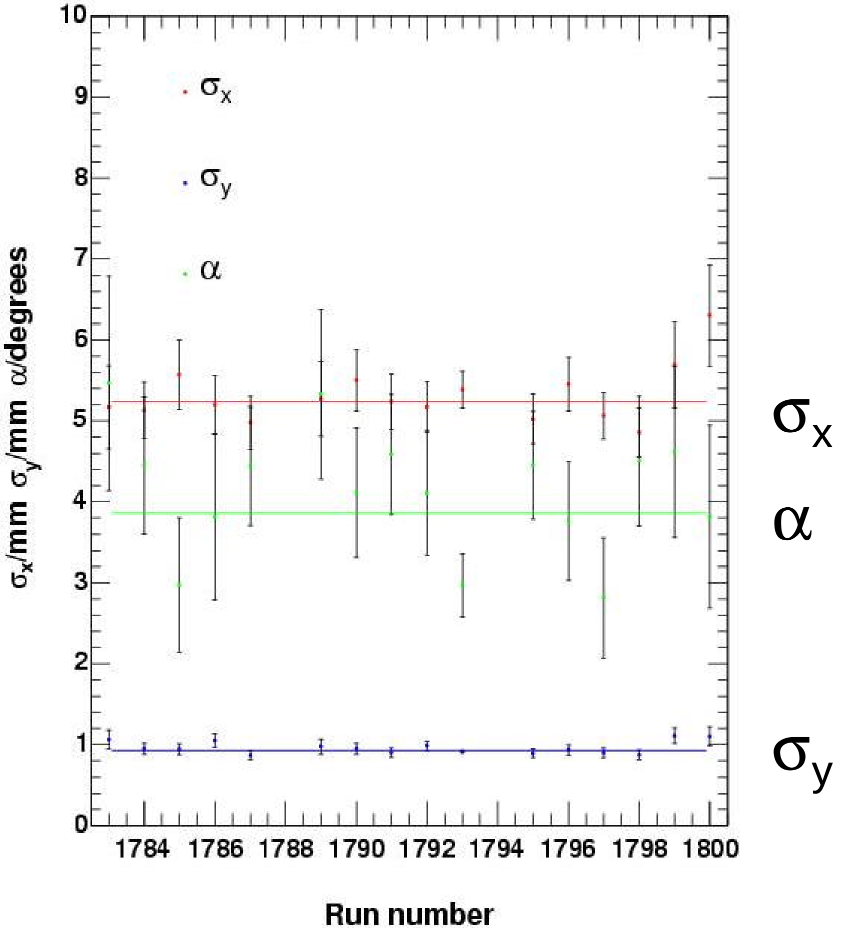
Results:

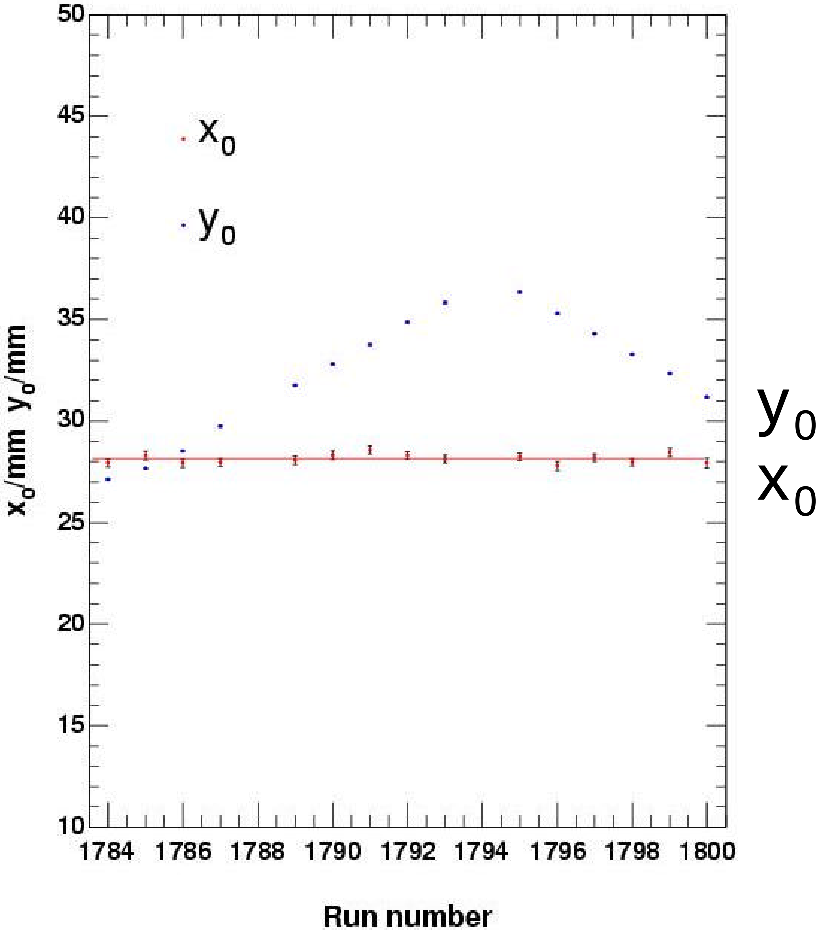
$\chi 2/\mathrm{ndf} = 1.01$

$x_0 = 27.22 \pm 0.21$ mm
$y_0 = 31.86 \pm 0.04$ mm
$\sigma_x = 5.05 \pm 0.37$ mm
$\sigma_y = 0.98 \pm 0.08$ mm
$\alpha = 4.84 \pm 0.94$ degrees

Beam Ellipse

Cross-check with data from a (vertical) table scan: consistent!

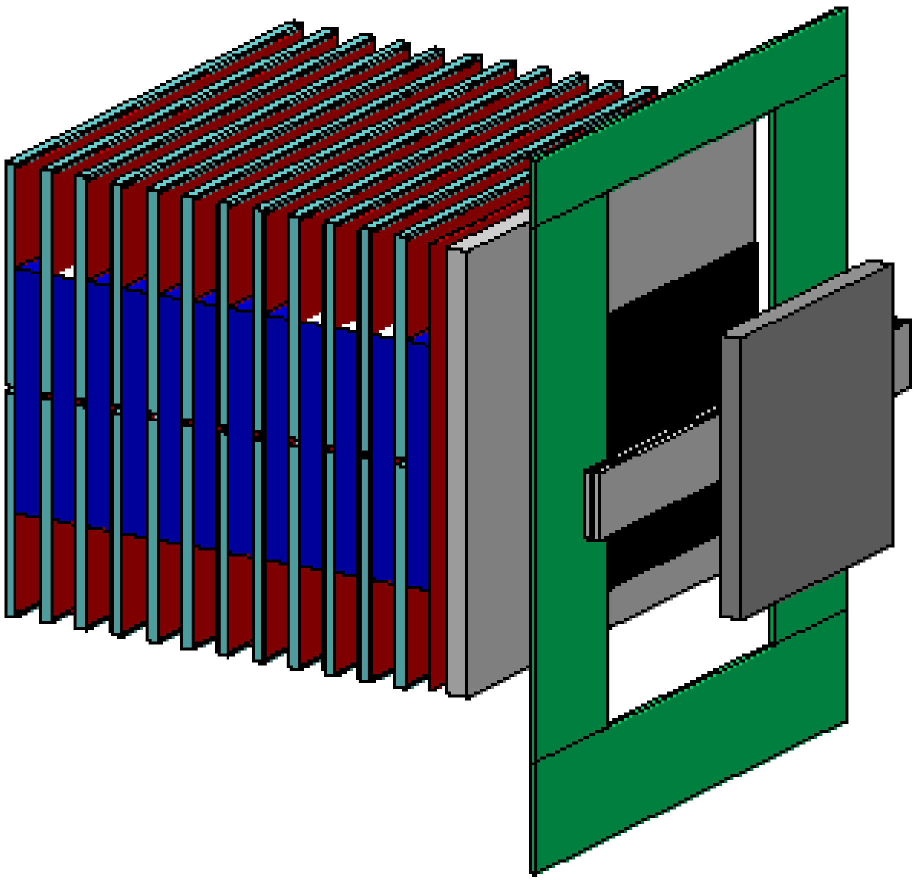




Plans to measure the beam ellipse at each fill

Monte Carlo

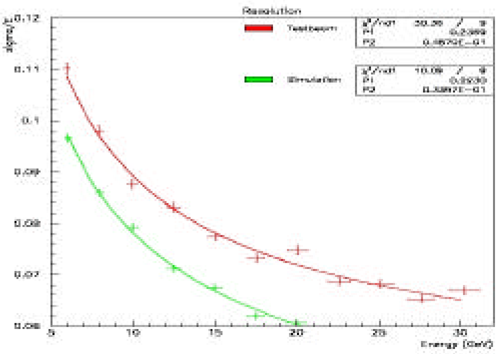
Geant3 studies: J.Sully



Goals:

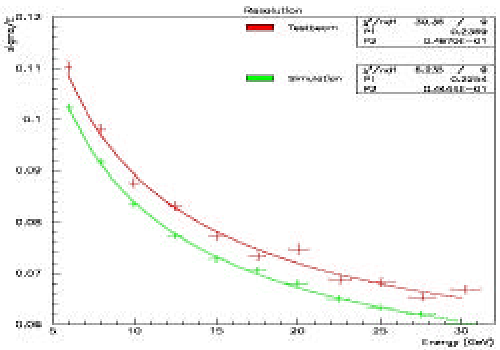
- reproduce the CERN test beam data
- obtain the η-y relation (energy asymmetry)
- understand the analysing power, hence the absolute polarisation scale

Test Beams: resolution



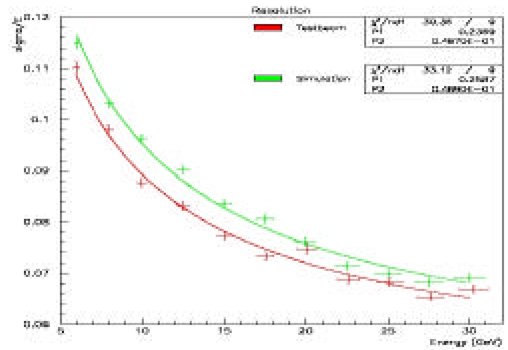
Run Options:

Gap: 0.00 cm
Scintillator Offset: On



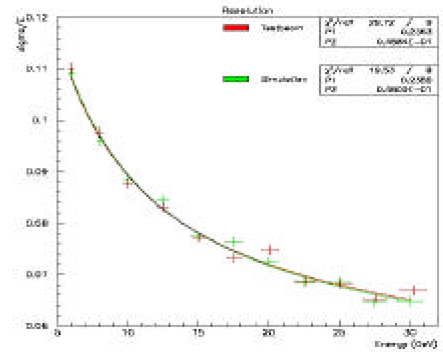
Run Options:

Gap: 0.05 cm
Scintillator Offset: On



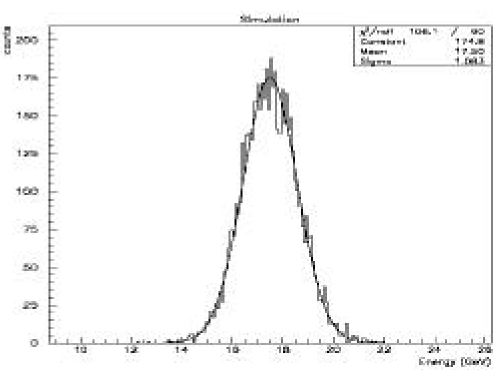
Run Options:

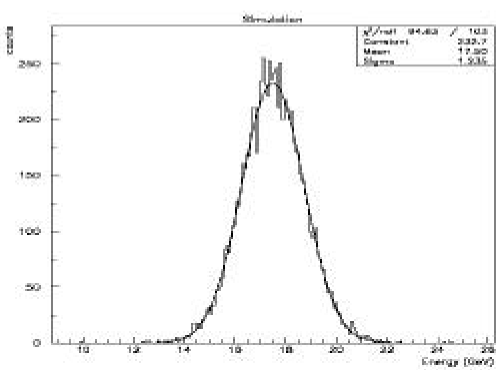
Gap: 0.10 cm
Scintillator Offset: On

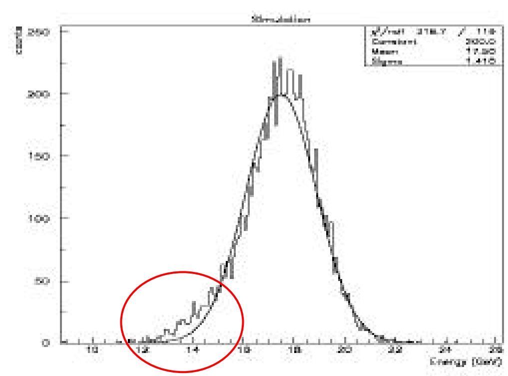


Run Options:

Gap: 0.075 cm
Scintillator Offset: On







but..

Testbeam
Simulation

Test Beams: resolution

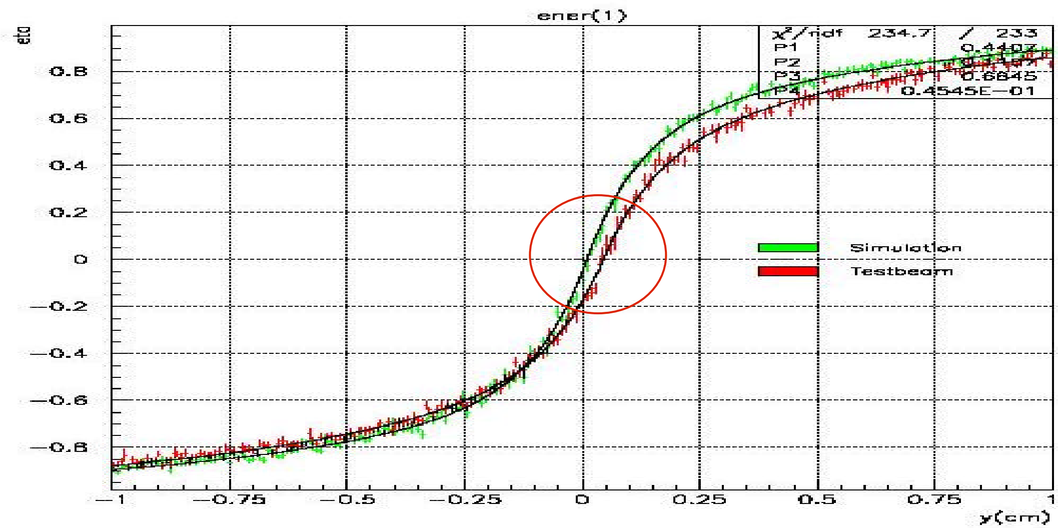
Tests:

- Gaps: 0.075 cm looks promising, but a 750μm gap is not reasonable/likely when the scintillator plates are separated by a 40μm aluminiun foil.

- CERN test beam energy spread: values quoted for σ/E range from 2.5% to 3.5%. The nominal value is 3% but so significant effect is observed to explain the discrepancies.

- Next steps: smearing the resolution further would help, but data hints at issues to be further investigated: leakage/acceptance, silicon clustering and trigger in the test beams.

Test Beams: h-y relation

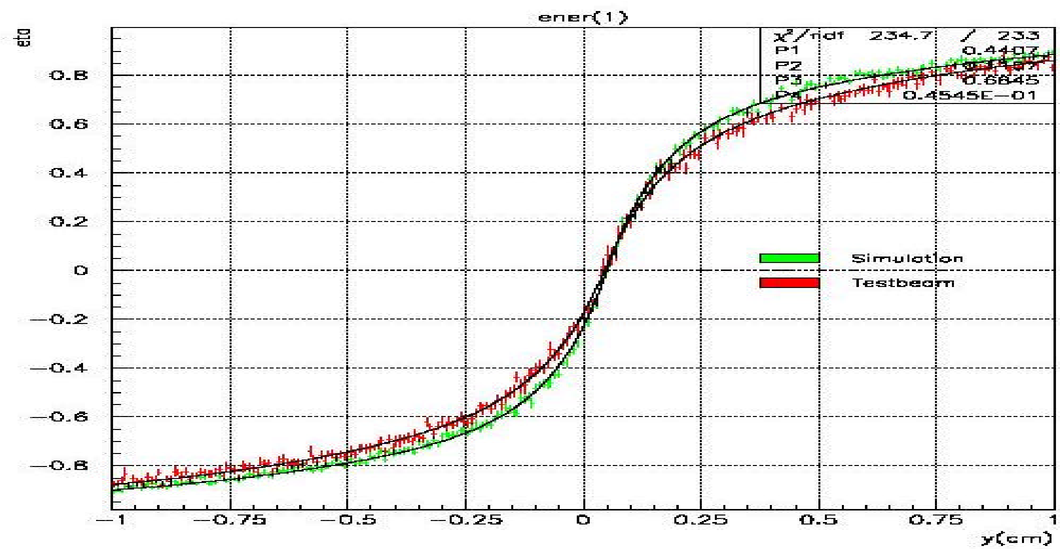


Energy asymmetry η
vs vertical position y

Run Options:

Gap: 0.00 cm

Scintillator Offset: Off

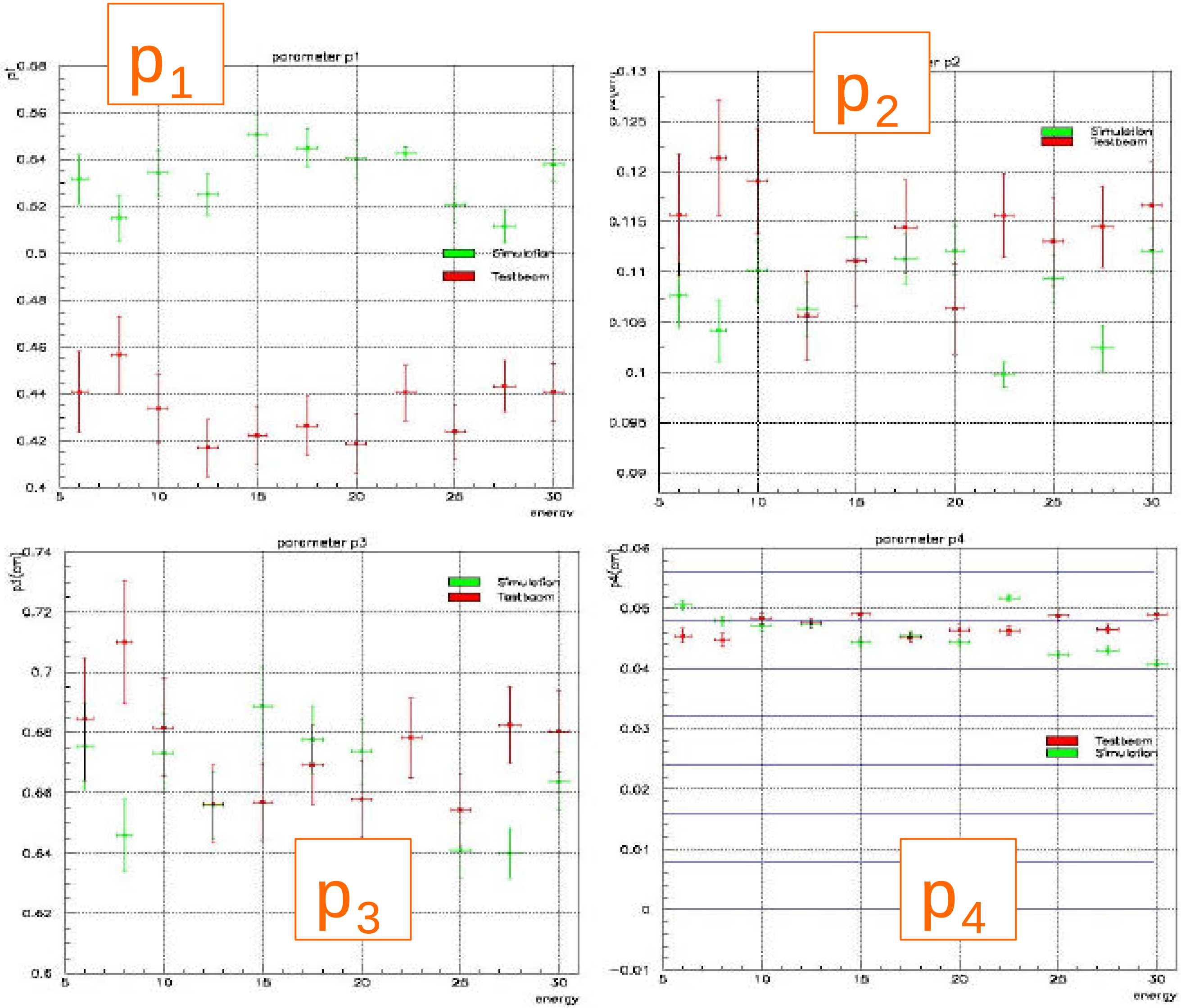


Run Options:

Gap: 0.05 cm

Scintillator Offset: On

Test Beams: η-y relation



Run Options:

Gap: 0.05 cm

Scintillator Offset: On p_4

$$h = \frac{|y-p_4|}{y-p_4} \bullet \left(1 - p_1 e^{-\frac{|y-p_4|}{p_2}} - (1-p_1) e^{-\frac{|y-p_4|}{p_3}} \right)$$

Reasonable fit in all parameters vs beam energy except for p_1.

Ongoing studies: resolution, leakage, triggering, clustering.

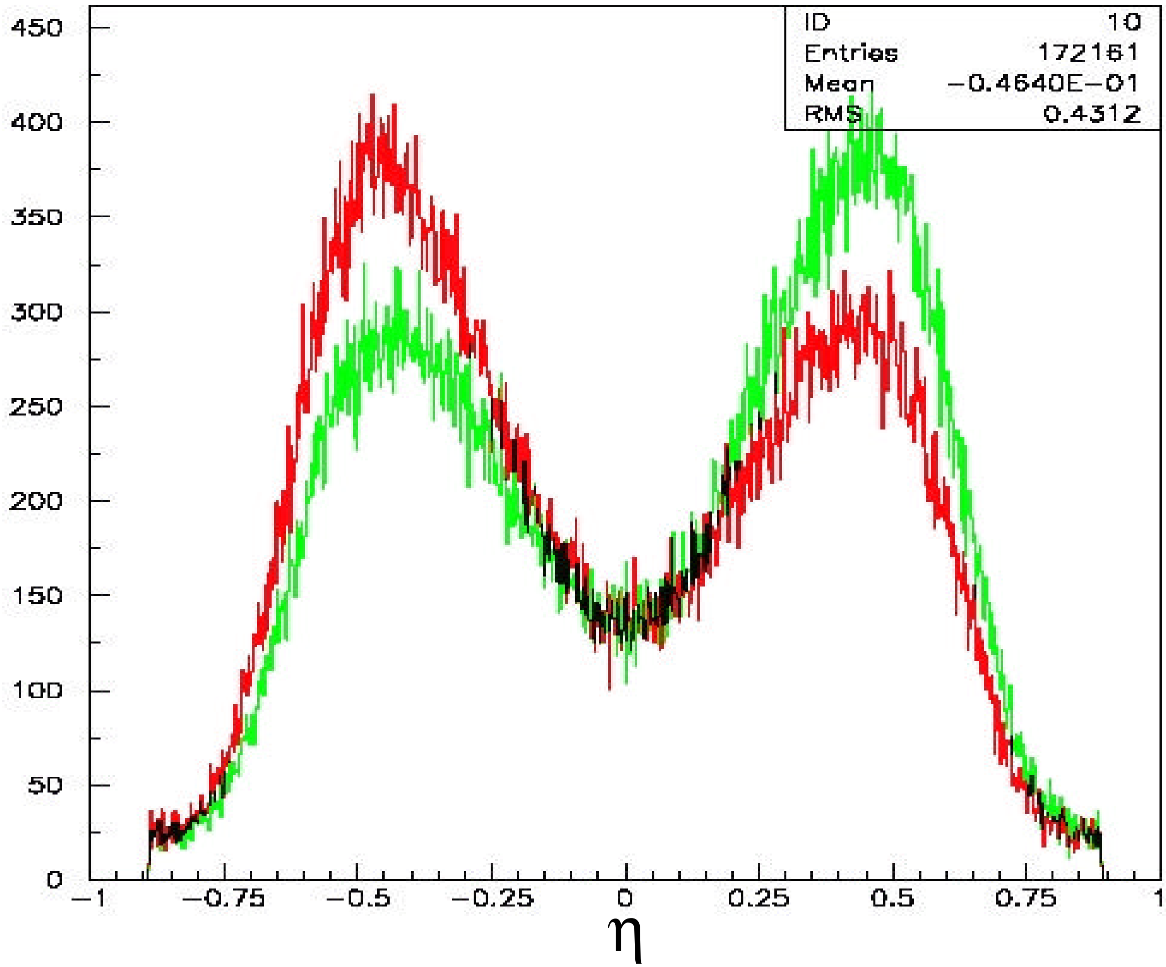
Testbeam

Simulation

Analysing Power

$$P = \frac{1}{A}\left(\langle h_L\rangle - \langle h_R\rangle\right)$$

Preliminary studies, large number of Compton events needed.



Run Options:

Emittance: 2.0 mm μrad

Gap: 0.00 cm

Scintillator Offset: Off

WITH material in front

Analysing Power: 0.092

WITHOUT material in front

Analysing Power: 0.095 (vs 0.0961)

CONVERSION: 1.035 (vs 1.0372)

(compared to what is used in the online)

Linear polarisation $S_1 = 0.05$

Circular polarisations $S_3 = +1$ (green), $S_3 = -1$ (red)

More tests with variations on gap, S_1, emittance, etc..

Focus should be ~0.5mm, but 0.75 mm found.

Multi-step Offline Analysis

H.Kaji → O.Ota

Compton cross-section + Background subtraction

$$\frac{d^2 s}{dEdf} = \Sigma_0 + S_1\Sigma_1(E)\cos 2f + S_3(P_Y\Sigma_{2Y}(E)\sin f + P_Z\Sigma_{2Z}(E))$$

$$\vec{P} = (P_X, P_Y, P_Z)$$ polarisation vector

$$\vec{S} = (S_1, S_2, S_3, S_4)$$ Stokes vector

First fit: sum of both laser helicities

$$\frac{d^2 s}{dEdf}(R+L) = 2\Sigma_0(E) + (S_1^R + S_1^L)\Sigma_1(E)\cos 2f + (S_3^R + S_3^L)(P_Y\Sigma_{2Y}(E)\sin f + P_Z\Sigma_{2Z}(E))$$

$$\eta = \frac{|y|}{y}\left(1 - C_1 e^{-\frac{|y|}{\lambda_1}} - (1 - C_1 - C_2)e^{-\frac{|y|}{\lambda_2}} - C_2 e^{-\frac{|y|}{\lambda_3}}\right)$$

Second fit: difference of both laser helicities

$$\frac{d^2 s}{dEdf}(R-L) = (S_1^R - S_1^L)\Sigma_1(E)\cos 2f + (S_3^R - S_3^L)(P_Y\Sigma_{2Y}(E)\sin f + P_Z\Sigma_{2Z}(E))$$

Multi-step Offline Analysis

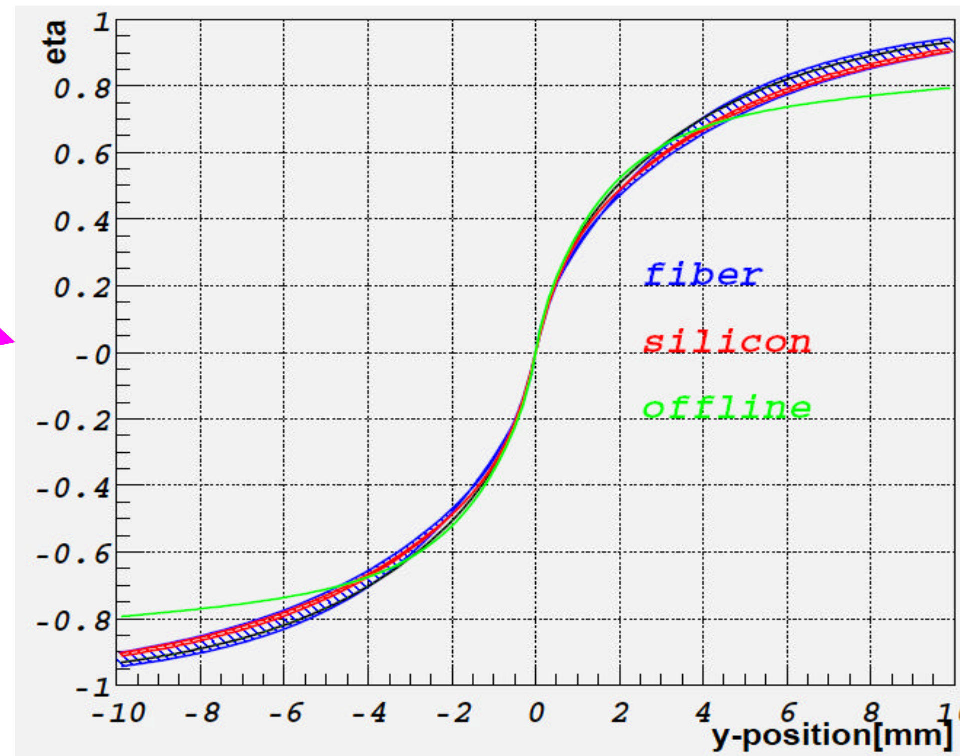
H.Kaji → O.Ota

15 parameters:

S_1, S_3, η-y (5), resolution, offsets (2), beamsize, normalisation, distance, ..

η-y parameters:

3 possible sources



beamsize:

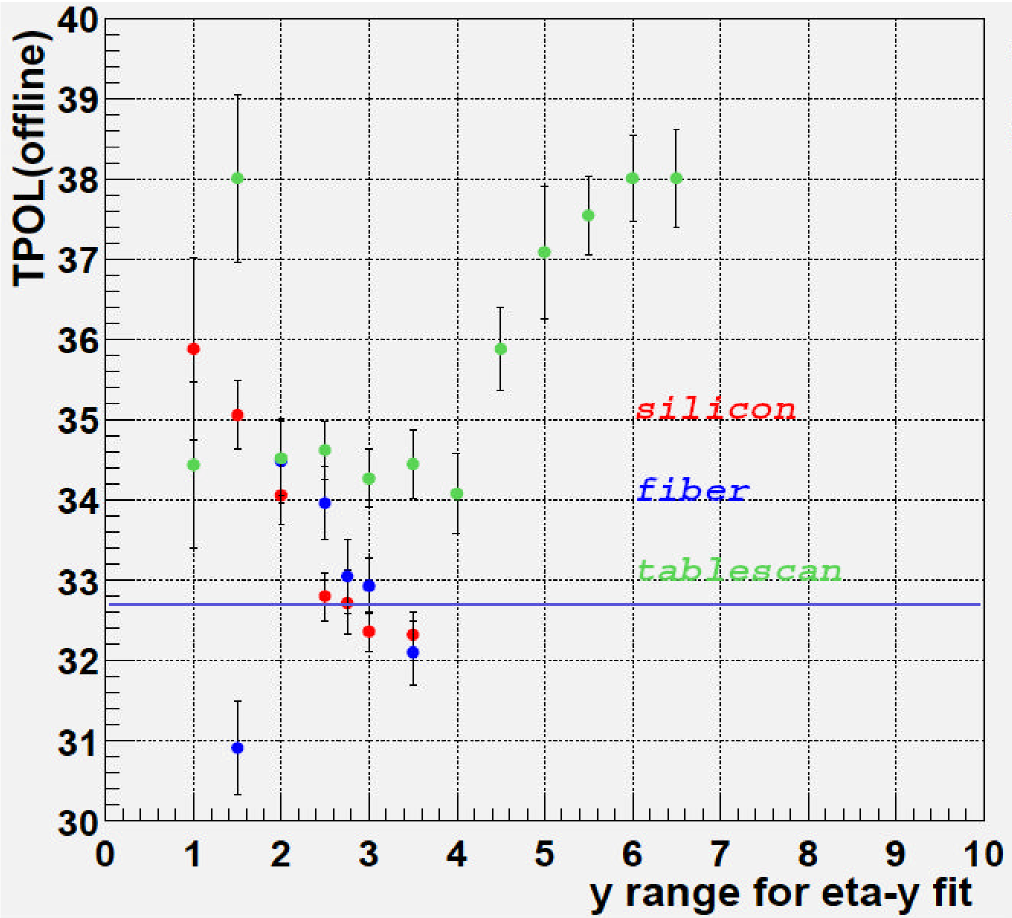
available from online

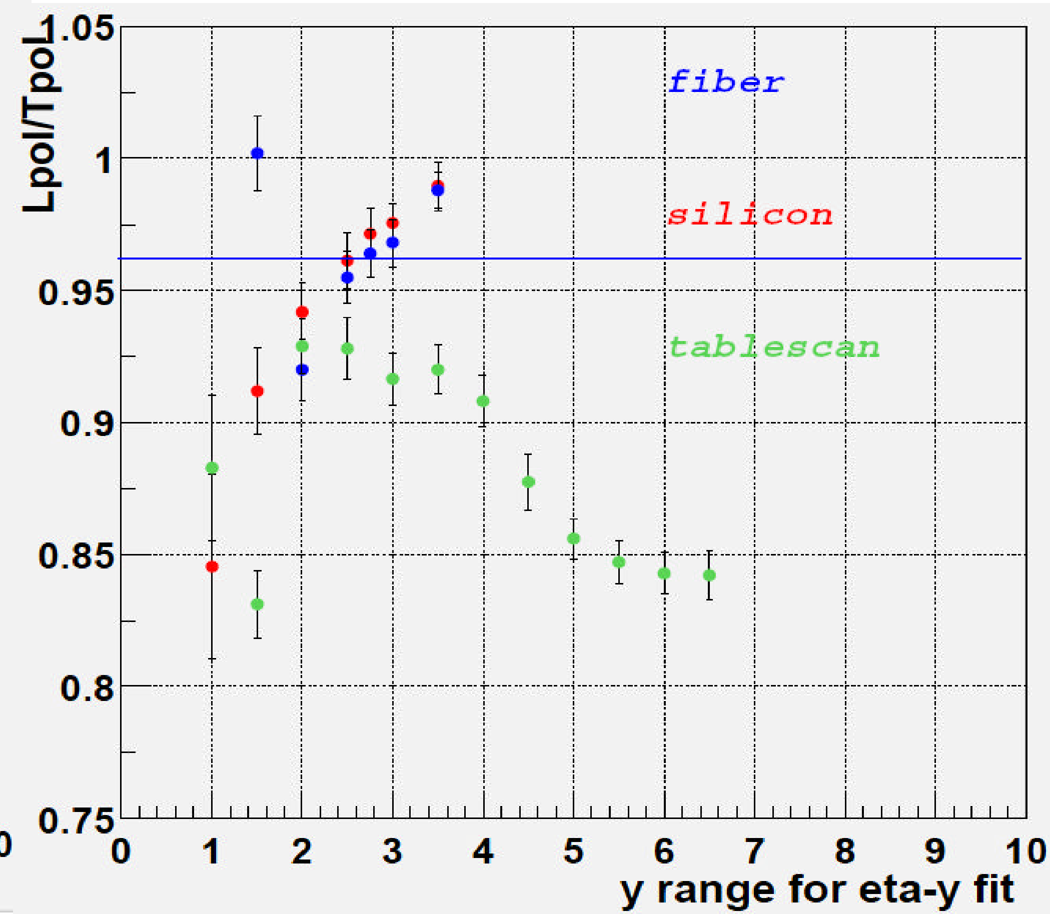
linear component S_1:

from first minutes of data or online

Many fits performed by fixing or not those parameters. Results are generally unstable (and LPOL/TPOL ≠ 1) unless η-y and S_1 are fixed.

Multi-step: η-y fixed





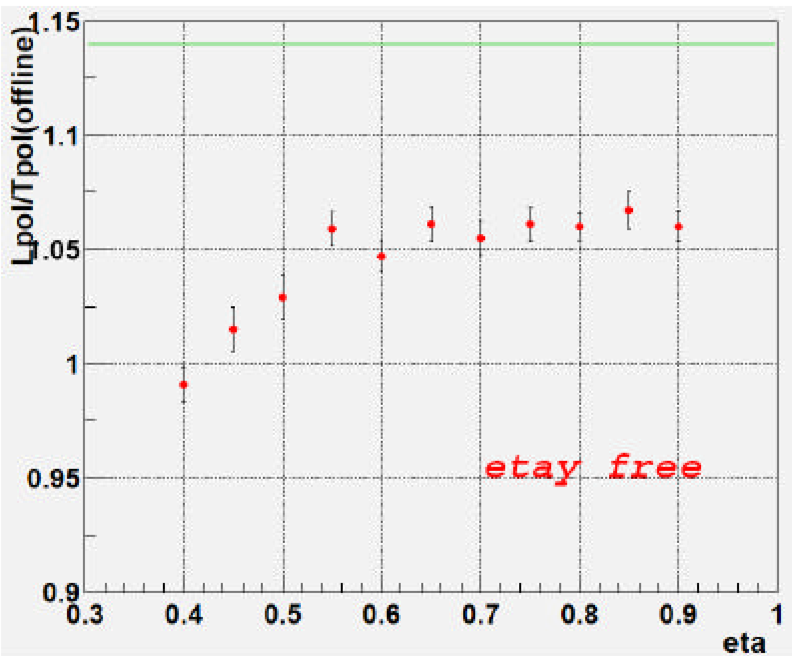
Offline method is unstable in y-range whatever η-y curve is used.

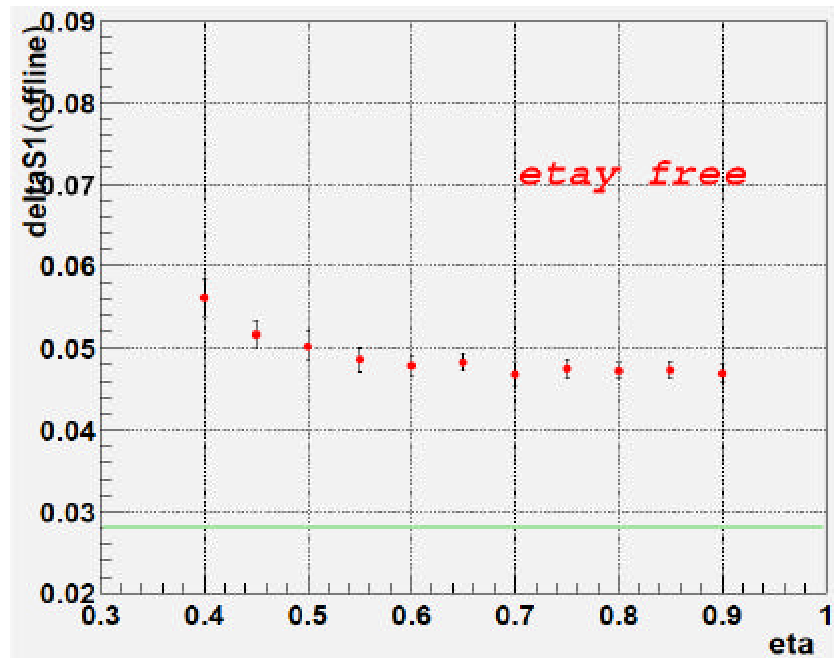
Also: offline method is strongly correlated to beamsize, can fit it stably but the values are too large.

One-step Offline Analysis

an alternative, by S.Schmitt (H1)
and O.Ota

- 3D data set (energy, η asymmetry, helicity state)
- large number of parameters, but their correlations are conserved
- the fit is stable and actually faster
- the η-y relation can now be fitted freely

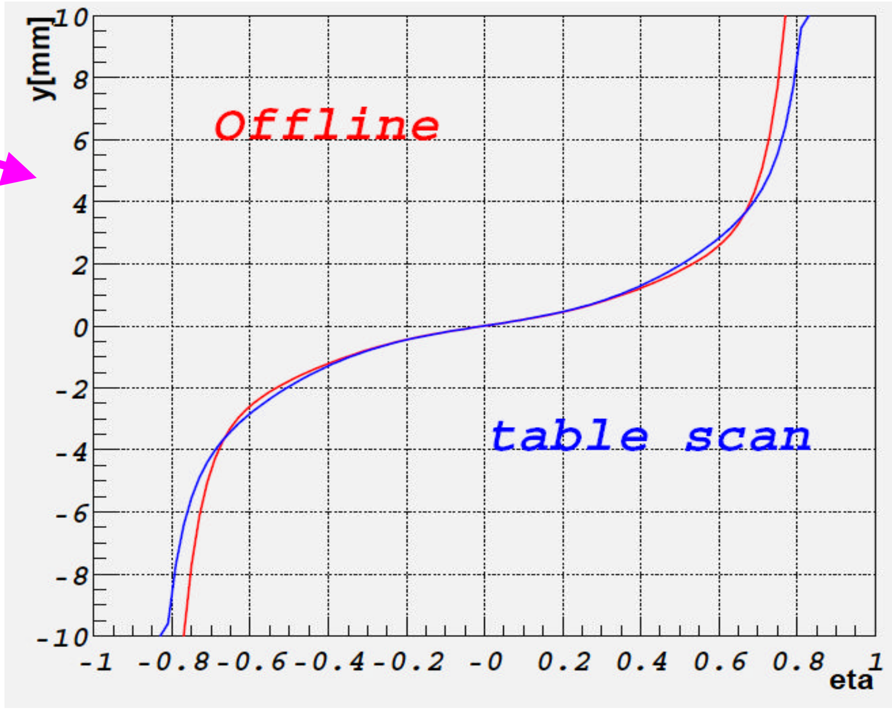




In reasonable η region, the new offline method is stable with η-y free, but..

One-step Offline Analysis

- .. but the η-y curves from offline or silicon detector are different:



- and with η-y free, the new offline method can again not absorb the beam size dependence yet.
- rely on η-y from silicon data
- not enough non-colliding bunch data statistics
- should provide reliable DQM and more precise polarisation values
- show very promising results
- mass production should be implemented/automatized soon

Conclusions

- LPOL and TPOL have been very stable most of 2004
- Important progresses made in understanding the systematics and solving the LPOL/TPOL ratio puzzle
- LPOL has recently suffered a calorimeter crystal breakdown and is being rebuilt, back on shortly
- The LPOL cavity will be made radiation hard, ready in the Summer
- Major efforts from the ZEUS-TPOL group:
    - <u>Silicon detector</u> (planned for each fill, also as HERA beam diagnostics?)
    - <u>Monte-Carlo</u>
    - <u>Offline analysis</u> (η-y relation, beamsize dependence, reduce LPOL/TPOL)
- Quoted precision should go down soon from official 5% to ~2-3%

ZEUS-TPOL page: www-zeus.desy.de/~francois/ZEUS_ONLY/tpol

H1-TPOL page: www-h1.desy.de/~pol2000

The End

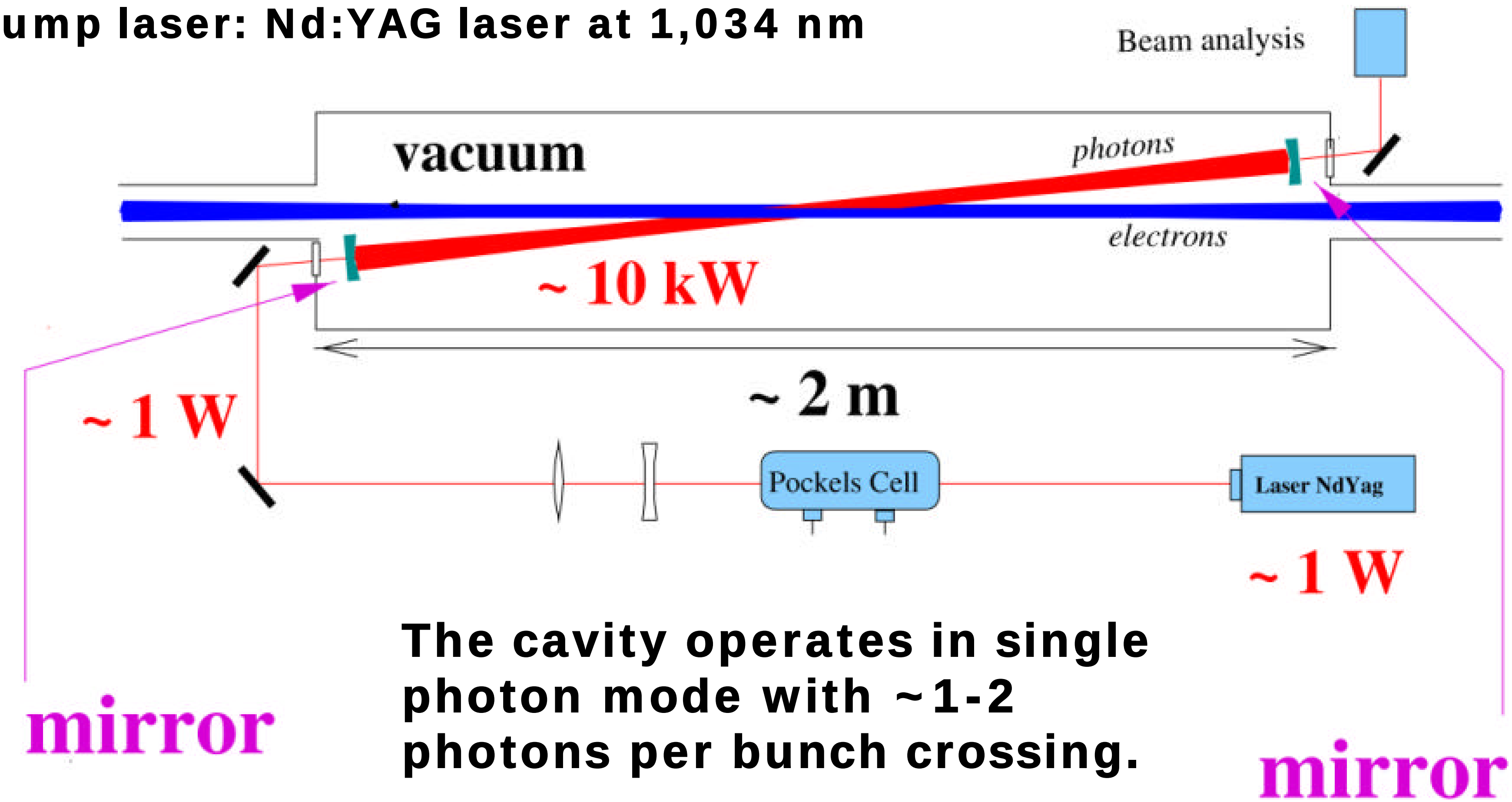
Extra Slides

LPOL Cavity

A Fabry-Pérot cavity is installed around the electron beam-pipe

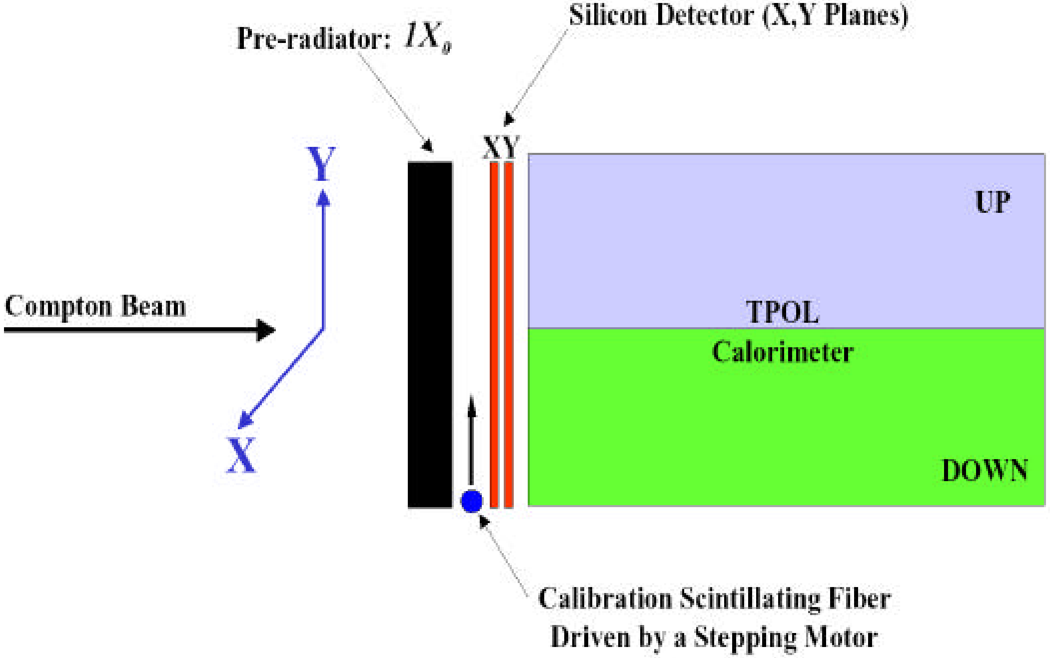
the ~10^4 magnification makes it equivalent to a 10 kW cw laser

Pump laser: Nd:YAG laser at 1,034 nm



The cavity operates in single photon mode with ~1-2 photons per bunch crossing.

TPOL



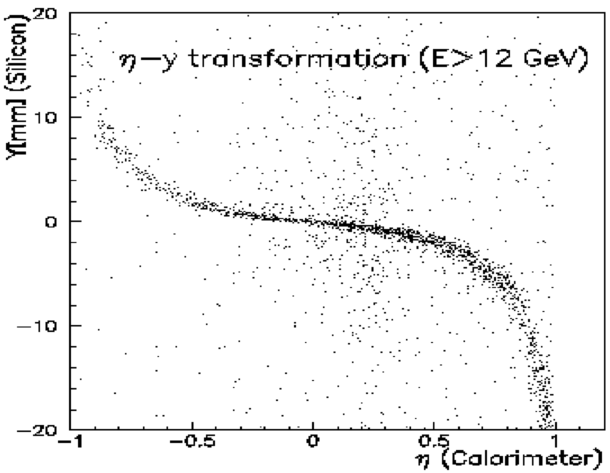
Now:

- fast DAQ (bunch-by-bunch)
- Si-detector to measure position and provide in-situ ?-y calibration
- Scint. Fibre to calibrate / monitor

Step 1: energy asymmetry

$$h = \frac{E_{UP} - E_{DOWN}}{E_{UP} + E_{DOWN}}$$

Step 2: convert ? into y



Step 3: extract polarisation

$$y_L - y_R \sim P_y \cdot \text{analysing power}$$