Polarisation Measurement at HERA II

DIS workshop 2002, Kraków

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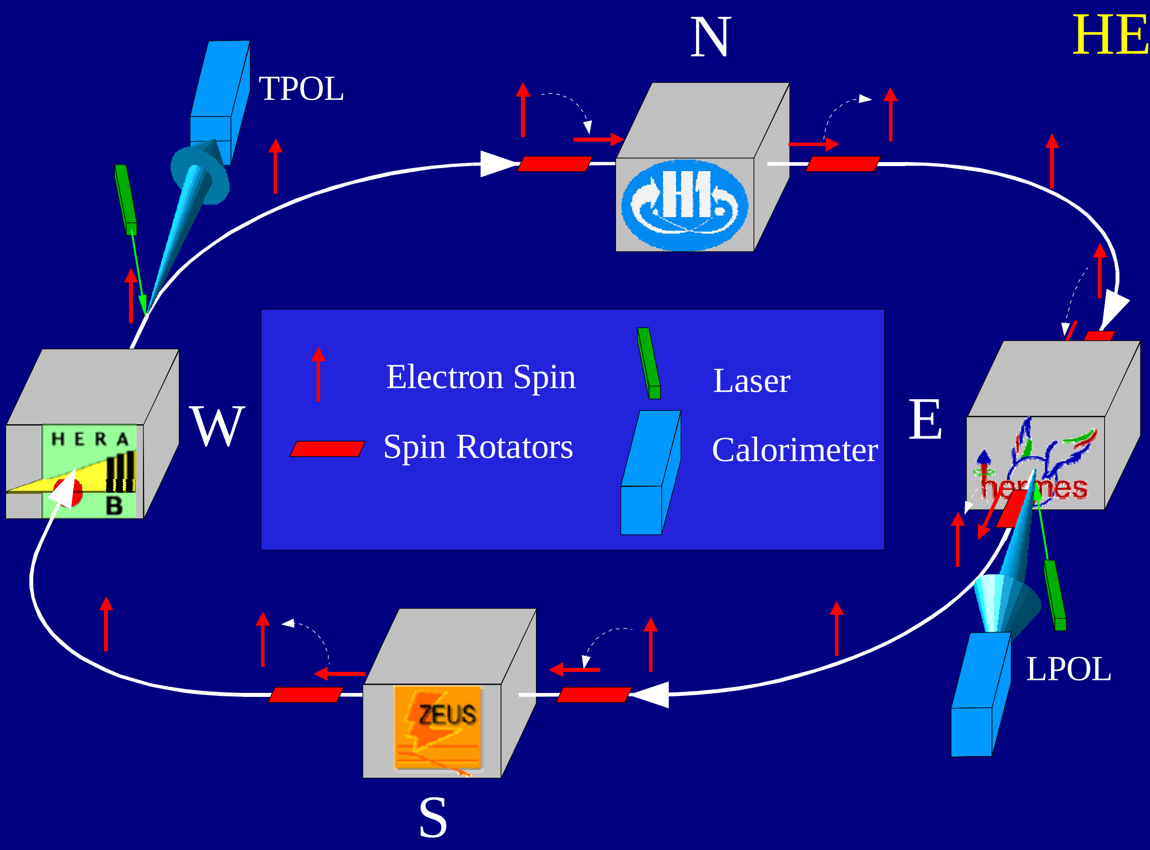
for the POL2000 group

- Introduction & Physics Motivation
- The Longitudinal Polarimeter
- The Transverse Polarimeter
- Summary & Outlook

Introduction

HERA I :

- HERMES: longitudinally polarised leptons, polarised protons
- H1, ZEUS: transversely polarised ("unpolarised") leptons, unpolarised protons



HERA II:

- HERMES: polarised leptons, polarised protons:
  - polarised structure functions, ...
- H1, ZEUS: longitudinally polarised leptons, unpolarised protons:
  - unpolarised structure functions,
  - electroweak physics,
  - searches, ...

Physics Motivation: Charged Current

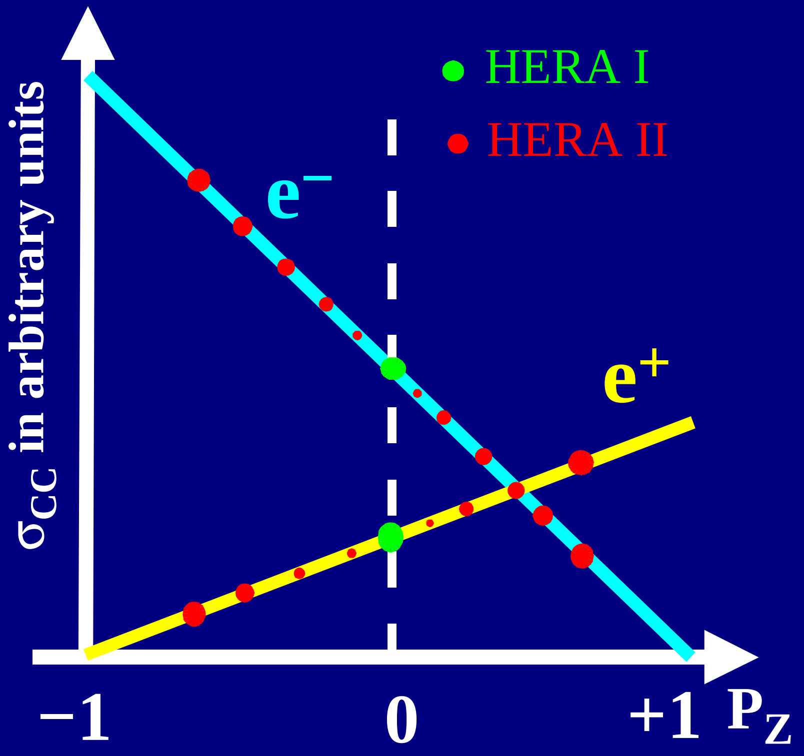
Charged current cross−section depends linearly polarisation:

- electrons: $\sigma_{CC}(P) = (1-P)\,\sigma_{CC}(0)$
- positrons: $\sigma_{CC}(P) = (1+P)\,\sigma_{CC}(0)$

=> precise knowledge of polarisation as important as of luminosity!
In order to...

- test SM cross−section,
- extrapolate to $P = \pm 1$
- search for right−handed charged currents

... we need $\delta P/P < 1\%$, otherwise dominant syst. error at high Q^2!



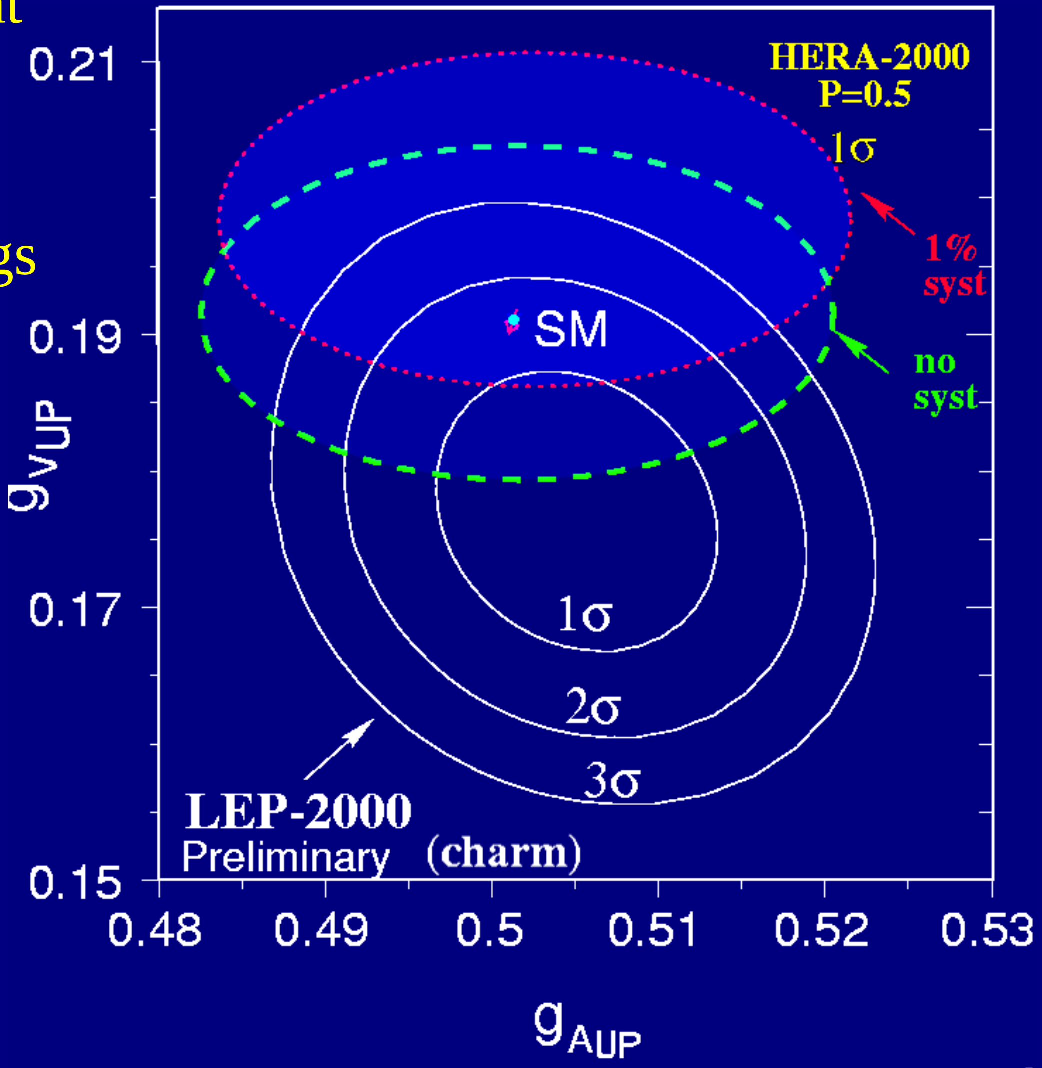
Physics Motivation: Neutral Currents

x−section polarisation dependent due to Z^0 exchange and Z^0 −γ−interference

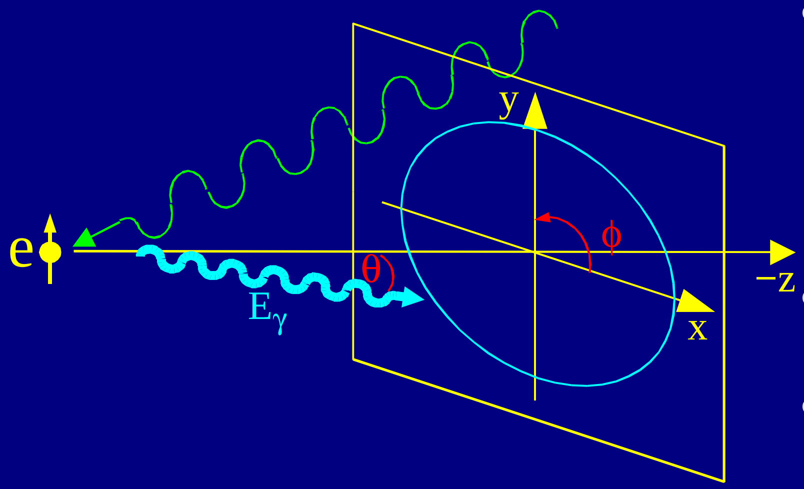
=>vector & axialvector couplings of Z^0 to u and d quarks:

- ~250 pb^{-1} for each lepton charge & polarisation sign
- a_u, a_d also with P=0
- P≥0.5 allows precise extraction of v_u, v_d

...highly sensitive to systematic polarisation deviations!



Compton Scattering



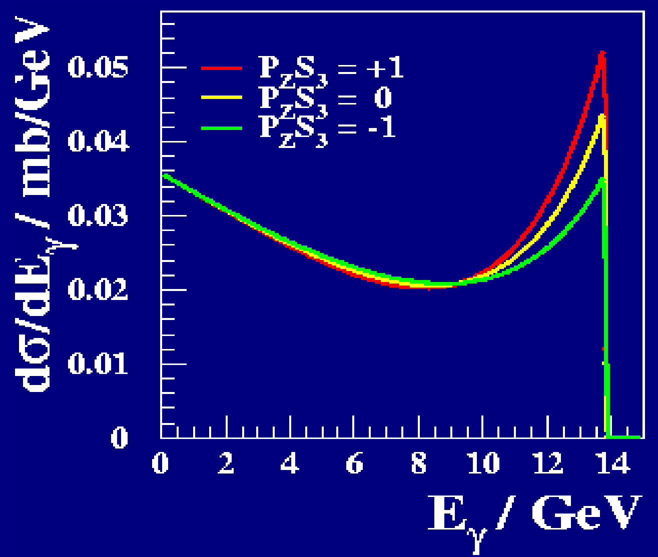
- Kinematics described by 2 variables:
  - polar angle θ <=> E_γ (photon energy)
  - azimutal angle ϕ => y (vert. coordinate)
- S1, S3: lin. & circ. laser polarisation
- P_Y,P_Z: transv. & long. e polarisation

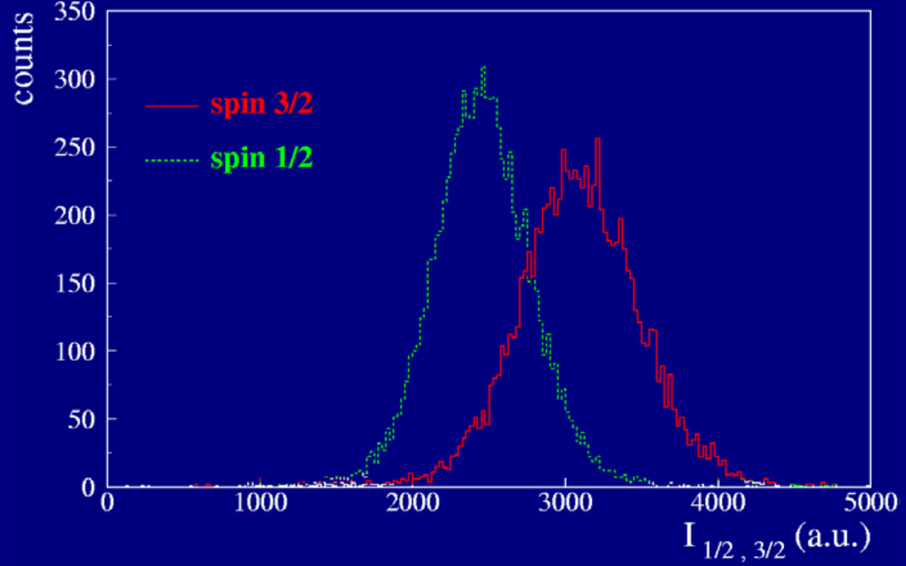
$$\frac{d^2\sigma}{dE\,d\phi} = \Sigma_0(E) + S_1\,\Sigma_1(E)\cos 2\phi + S_3\left(P_Y \Sigma_{2Y}(E)\sin\phi + P_Z \Sigma_{2Z}(E)\right)$$

- LPOL: needs only energy dependence
- TPOL: needs energy and y, i.e. full 2D cross section

Important: use asymmetry between $S_3 = +1$ and $S_3 = -1$

LPOL: Principle of Measurement





"Single Photon Mode": $n_\gamma \cong 0.001$

- can use single photon cross−section
- compton edge −> energy calibration
- but at LPOL location in HERA: Bremsstrahlung background to high s/b ≅ 0.2 => stat. error too large

"Multiphoton Mode": $n_\gamma \cong 1000$

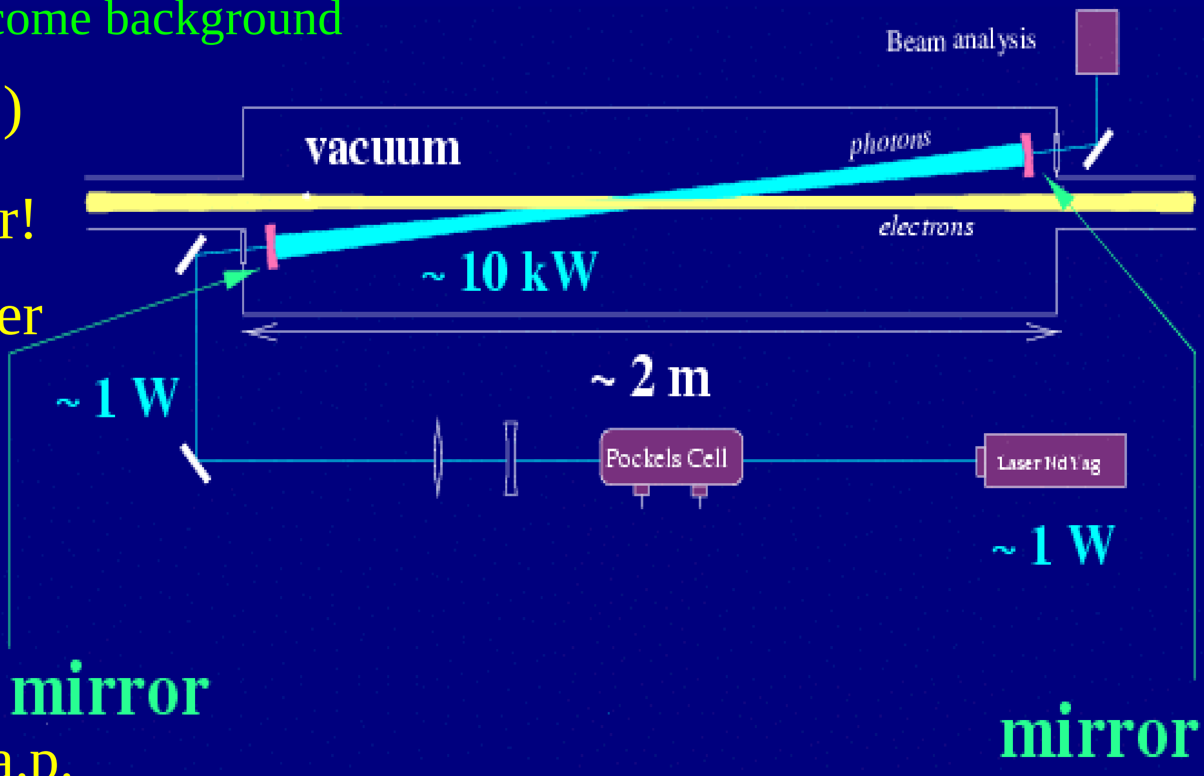
- no background problem
- stat. error ≅ 0.01 per minute
- but: need precise knowledge of energy response of calorimeter
- syst. error = ± 1.6% (rel.)
- high power laser only at 100Hz (HERA bunch spacing ≅ 10MHz)

Upgrade of the LPOL

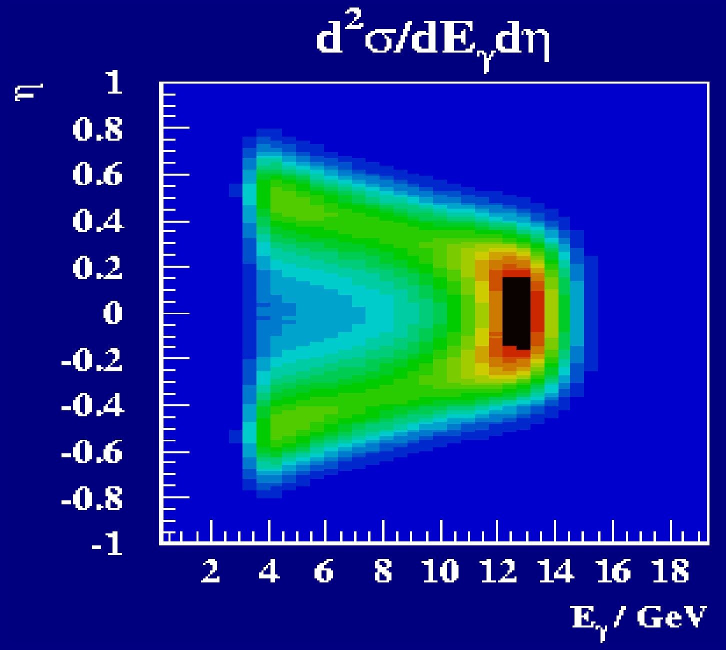
- Aim: "Few Photon Mode": $n_\gamma \geq 0.1$ => overlay of up to 2 or 3 γs
    - can still use single photon spectra to extract polarisation
    - => compton edge calibration, less syst. uncertainties
    - enough statistics to overcome background

=> expect $\delta P/P \cong 0.001$ (!)

- but: need 10kW cw laser!
- solution: use 1W cw laser
  + Fabry−Perot cavity
  with $Q \cong 10000$
- Status: prototype cavity
  built and working
  => go for real thing a.s.a.p.

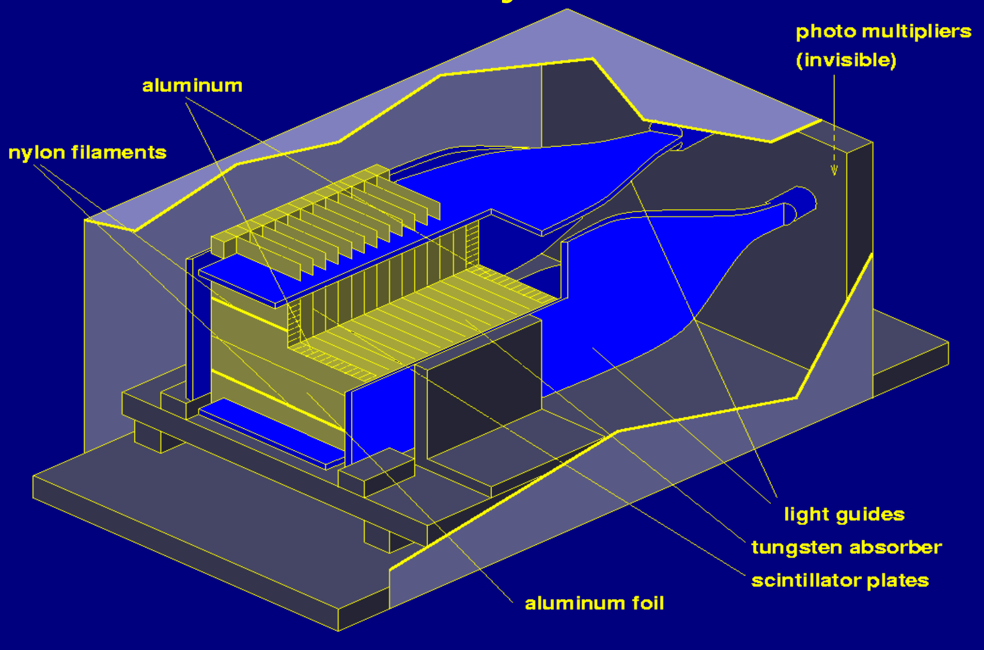


TPOL: Principle of Measurement



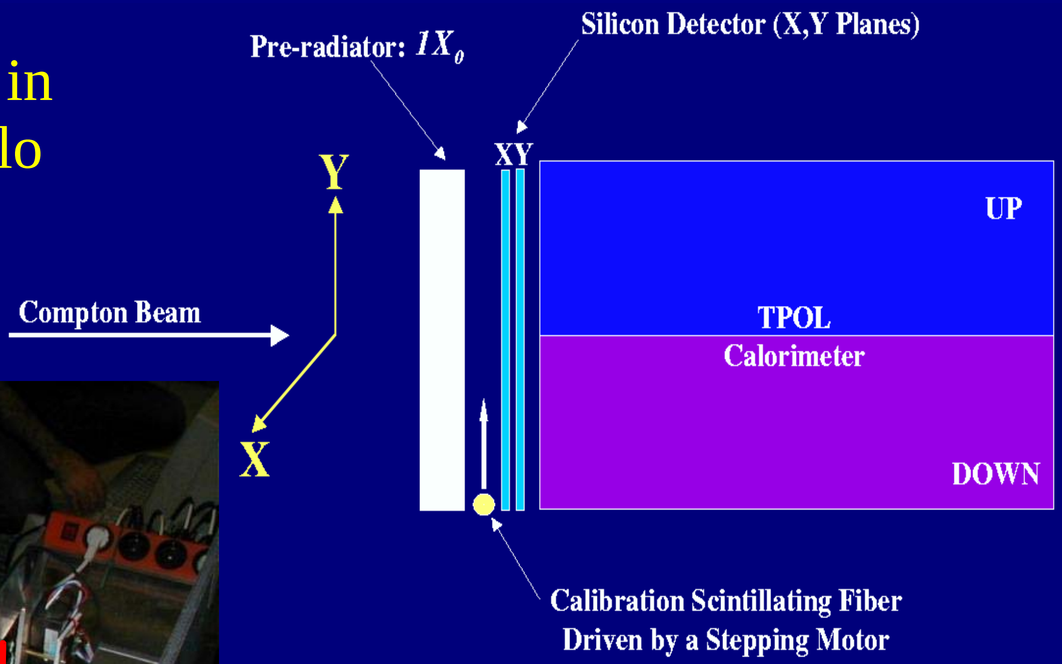
- have to measure E_γ and y!
- Calorimeter has upper and lower half:
  - $E_\gamma = E_{up} + E_{down}$
  - $y = y(\eta)$, $\eta = (E_{up} - E_{down})/(E_{up} + E_{down})$
- use asymmetry w.r.t. laser helicity
  => less sensitive to systematics

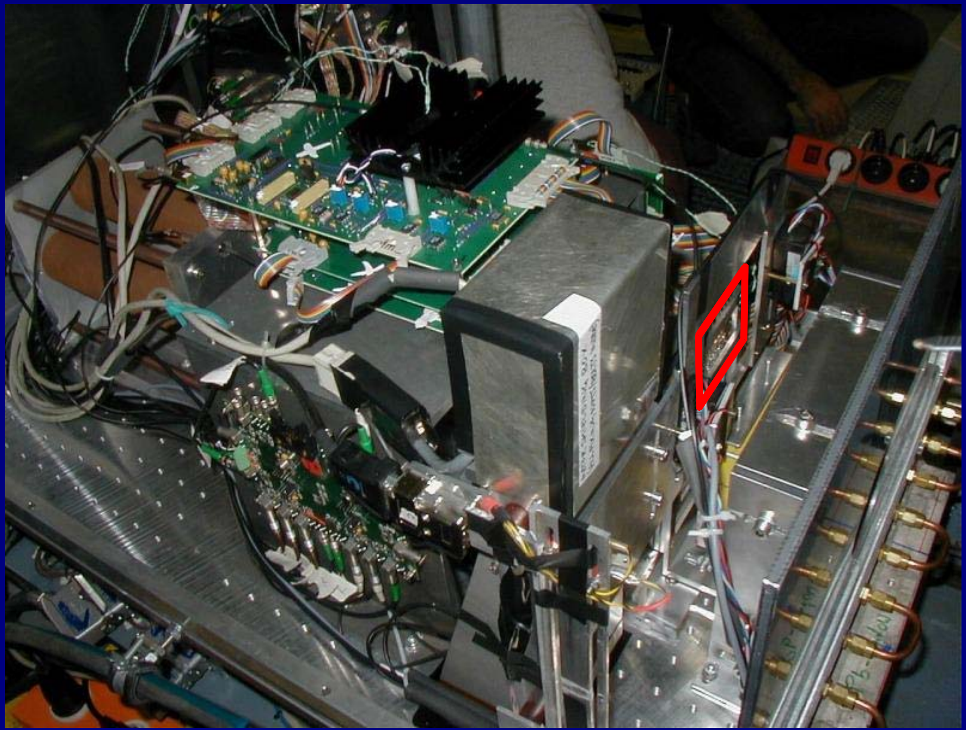
- main uncertainty:
  η-y-transformation
  - depends on transverse shower shape in calorimeter
  - up to now:
    known from testbeam only....



TPOL upgrade: Silicon Strip Detector

– new SI strip detector in y and x in front of calo as calibration device



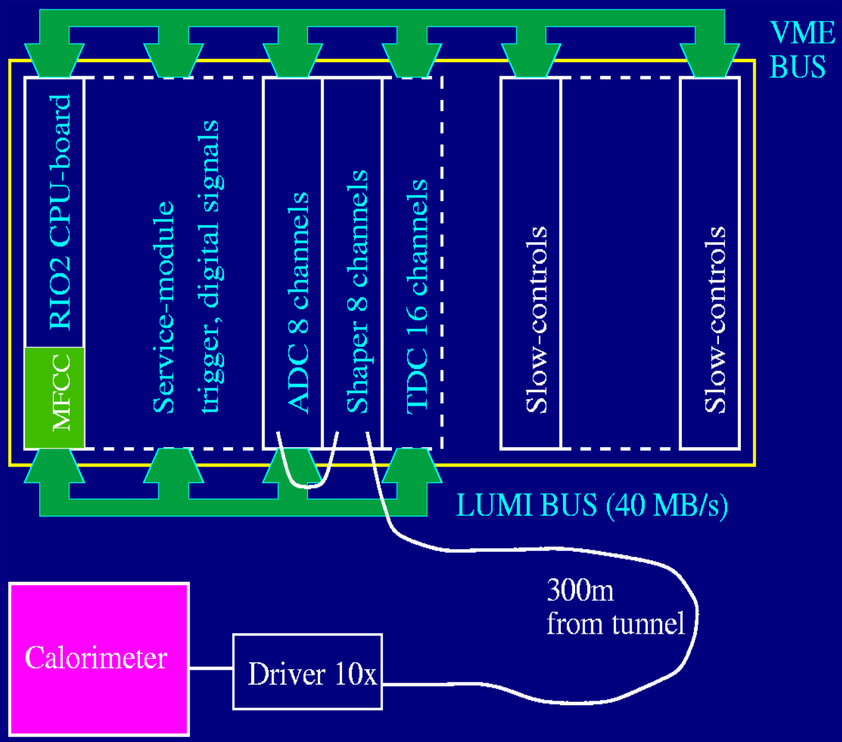


– first in−situ measurements of η-y-transformation with new SI tracker done

– Studies in progress!

TPOL upgrade: Data Acquisition

- completely new DAQ: hardware, software, slowcontrols,...
- less noisy,
  eventwise pedestal subtraction
- much faster readout (100kHz)
  => bunch by bunch measurements
- first data (@I_e =3mA): δP_{stat} = 0.015
  => @I_e = 60mA : δP_{stat} = 0.0044
- but what about δP_{syst}?



reminder: aim for $\delta P_{tot}/P < 1\%$,
otherwise dominant systematic error for H1 and ZEUS measurements at high Q^2!

TPOL: Online Analysis

- integrate $d^2\sigma/dE_\gamma d\eta$ over most sensitive E_γ and η range
- form asymmetry w.r.t. to laser helicity:

$$\frac{(\sigma_R - \sigma_L)}{(\sigma_R + \sigma_L)} \cong 2\,|S_3|\,P_Y \frac{\iint \Sigma_{2Y}\, dE_\gamma d\eta}{\iint \Sigma_0 dE_\gamma d\eta} =: 2\,|S_3|\,P_Y\,\Pi$$

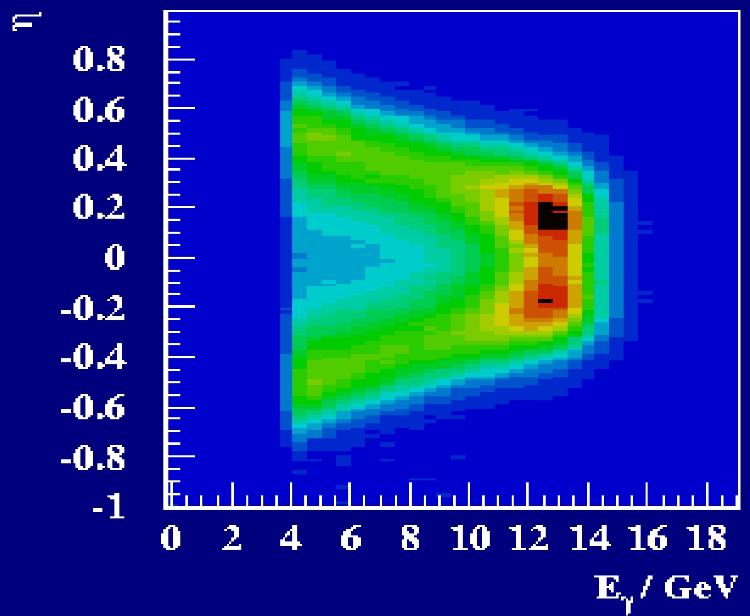
Π: "analysing power" taken from risetime calibration &MC

- fast & simple method
- BUT: only valid if ALL parameters are:
  - **equal to MC values**
  - **and constant over time.**
  - especially: η–y–transformation has to be "known" a priori!
- o.k. within ~3.4%...
  ... probably not true down to subpercent level!

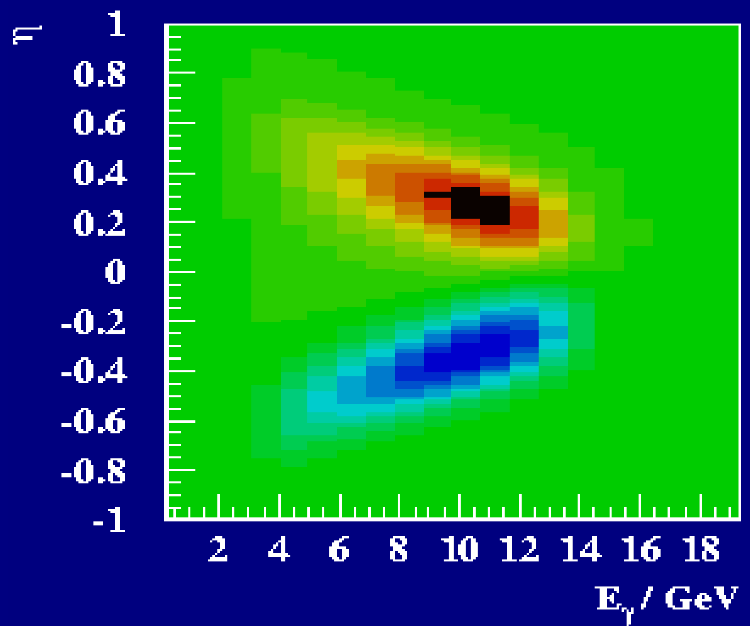
TPOL: Analysis Upgrade

- Idea: fit double differential x–section => no assumptions about:
  - linear laser polarisation
  - η–y–transformation
  - calibration, alignment, resolution ...

RIGHT+LEFT



RIGHT-LEFT

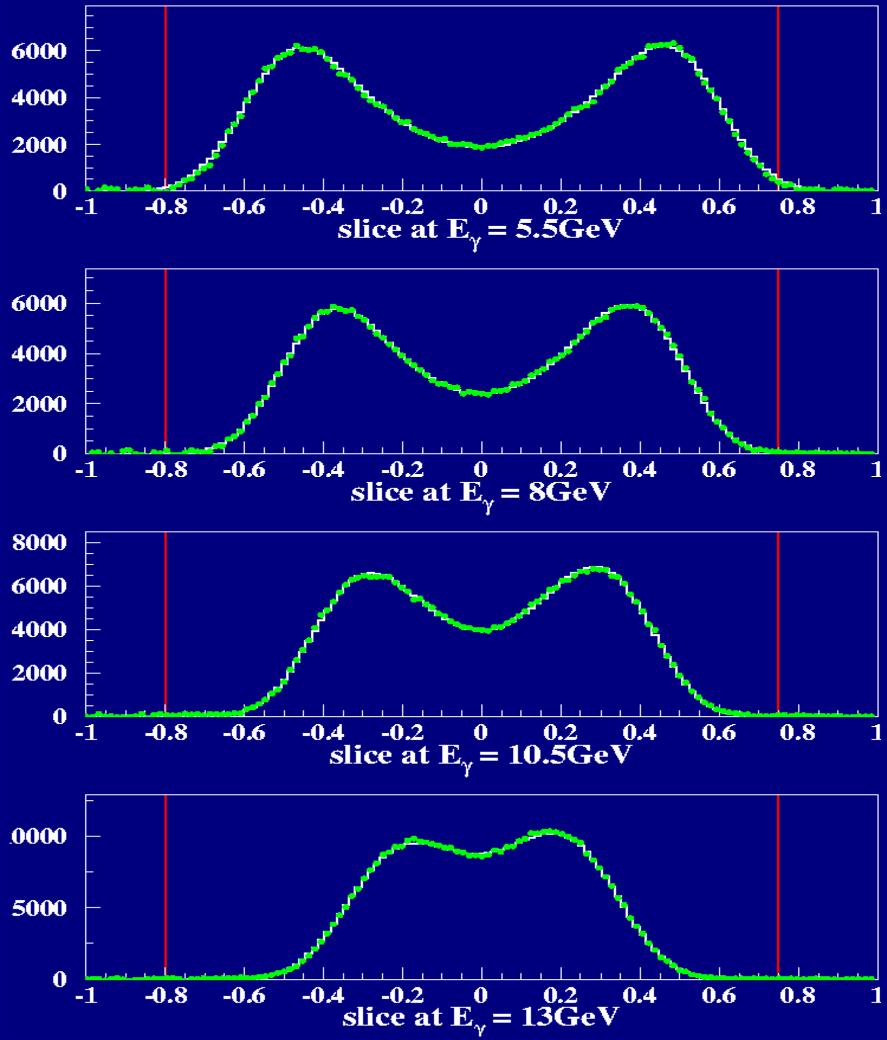


- First step : fit sum of spectra for laser both helicities => calibration
- Second step: fit difference => polarisation

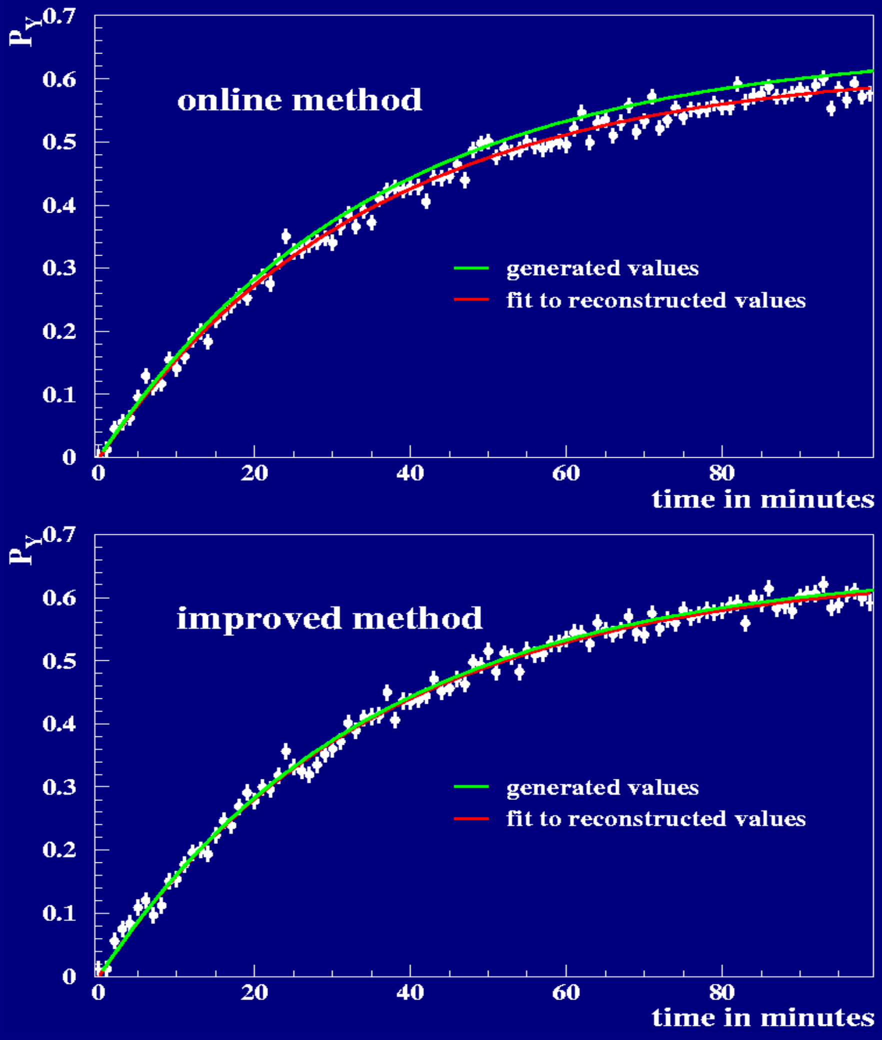
- analysis not final yet
- no final systematic error yet

TPOL: Analysis Upgrade (cont'd)

Ex.1: some slices of fit to data



Ex.2: MC with risetime



Summary & Outlook

- Longitudinal Polarimeter:
  - operational, no major changes w.r.t. HERA I
  - laser cavity upgrade to come!
- Transverse Polarimeter:
  - upgrade on
    - DAQ: mostly finished
    - Silicon strip detector: working
    - Analysis: in progress
  - understanding device down to < 1% seems feasible

The POL2000 group and the HERA experiments
are looking forward to taking
new data with polarised lepton beam!