

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

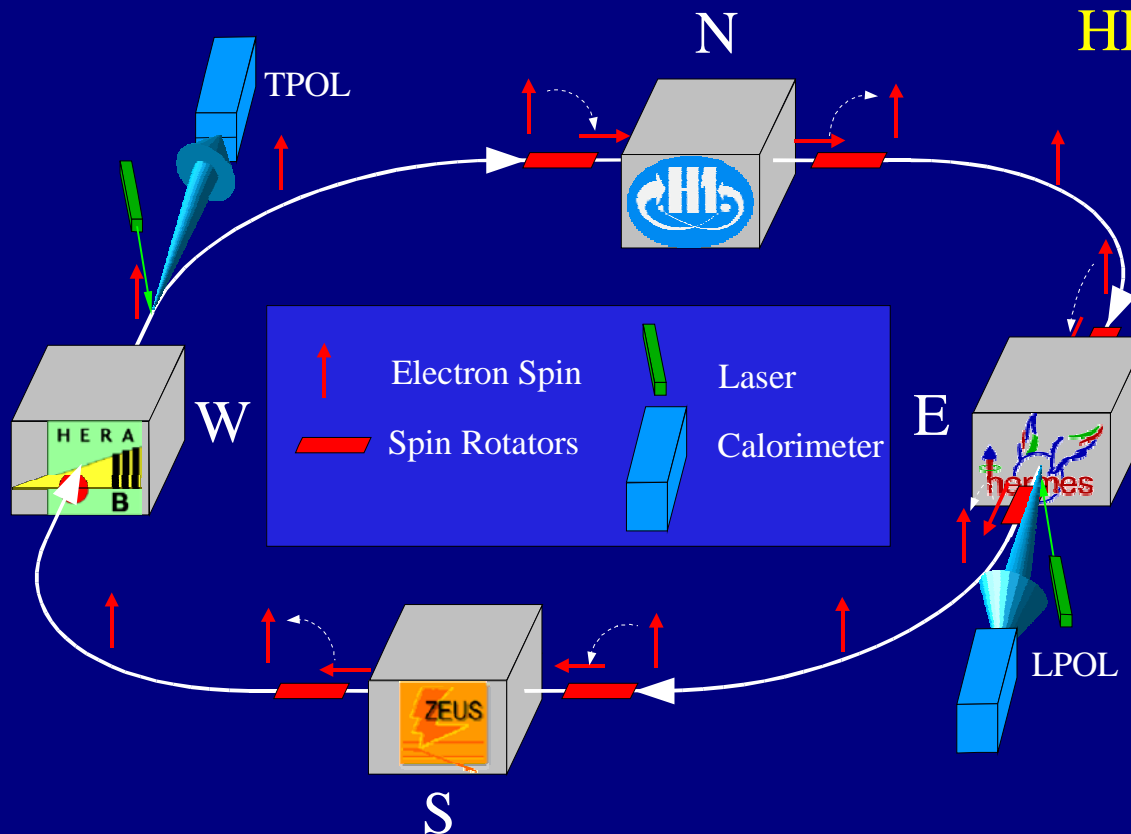
Introduction

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:

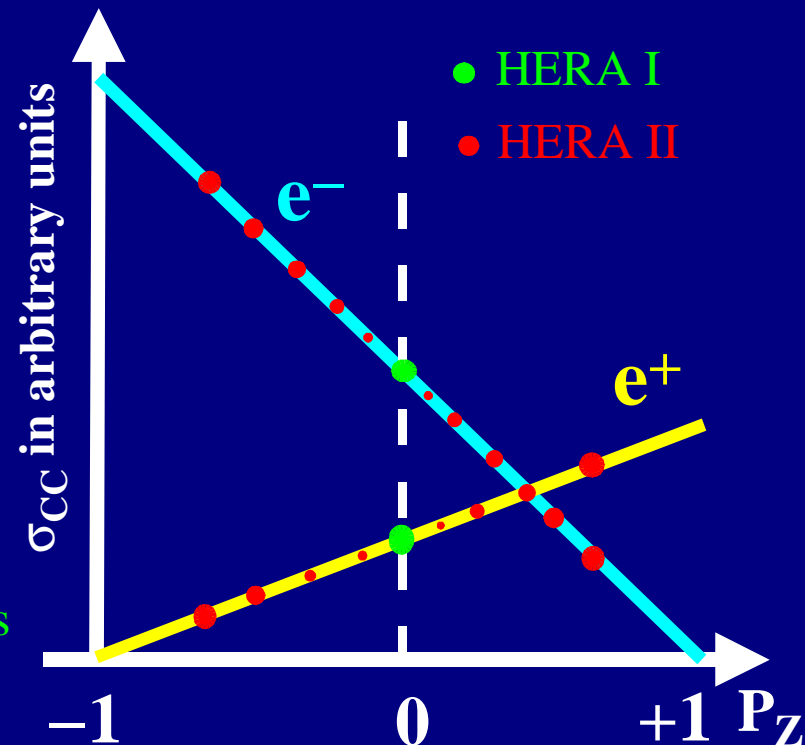
- electrons: $\sigma_{CC}(P) = (1-P) \sigma_{CC}(0)$
- positrons: $\sigma_{CC}(P) = (1+P) \sigma_{CC}(0)$

=> 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 !



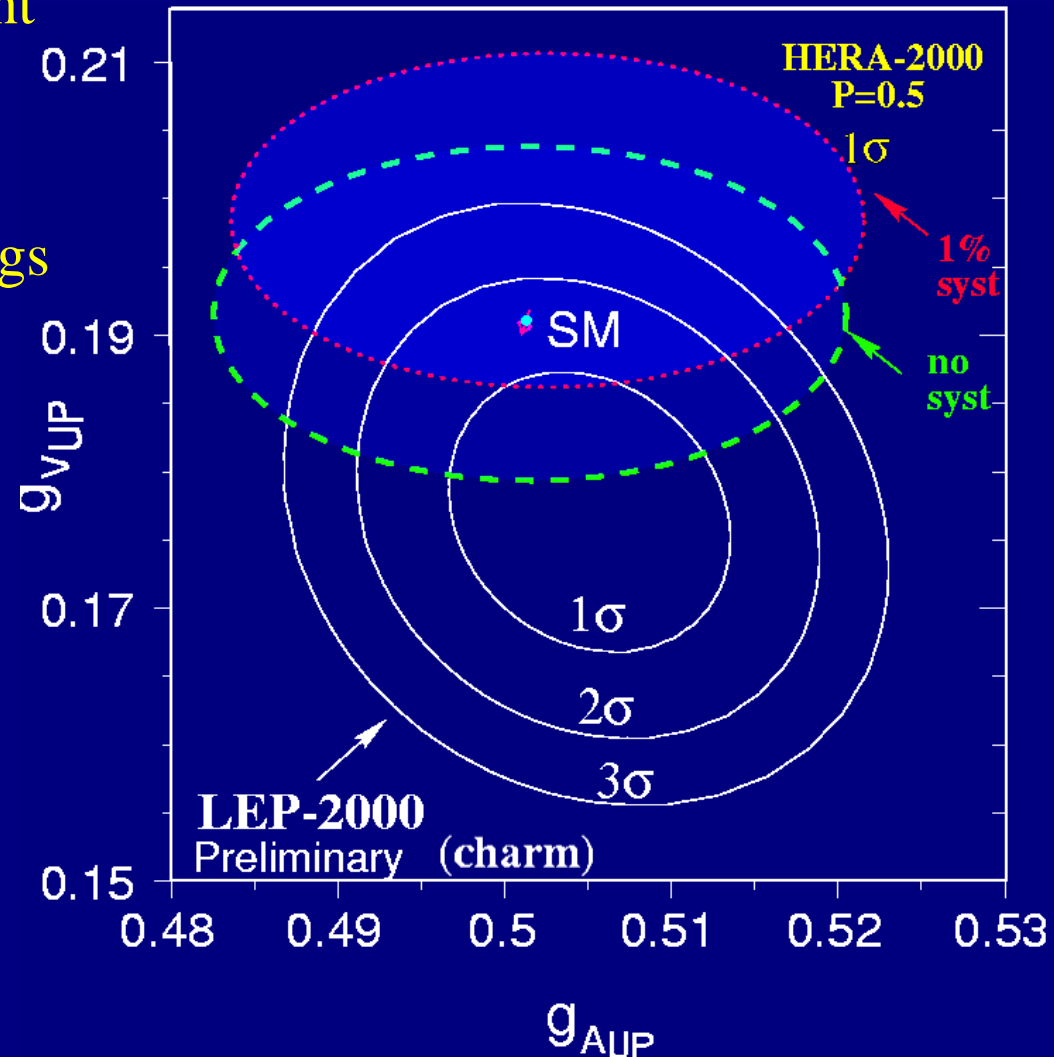
Physics Motivation: Neutral Currents

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

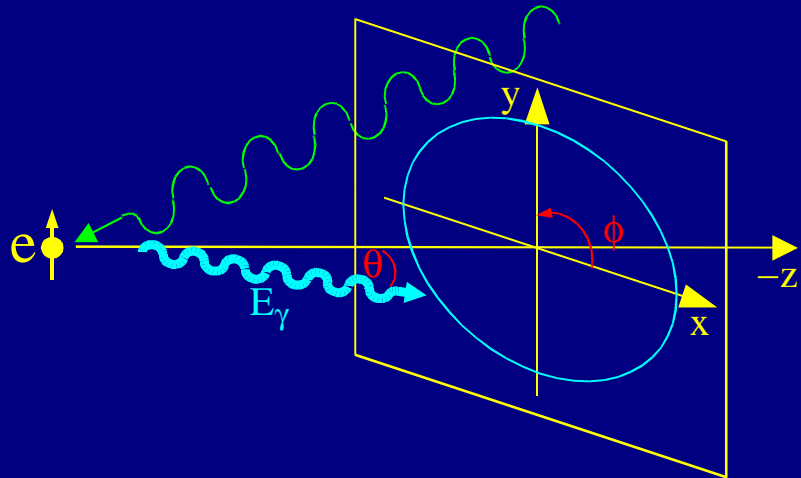
=>vector & axialvector couplings
of Z^0 to u and d quarks:

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

...highly sensitive to systematic polarisation deviations!



Compton Scattering



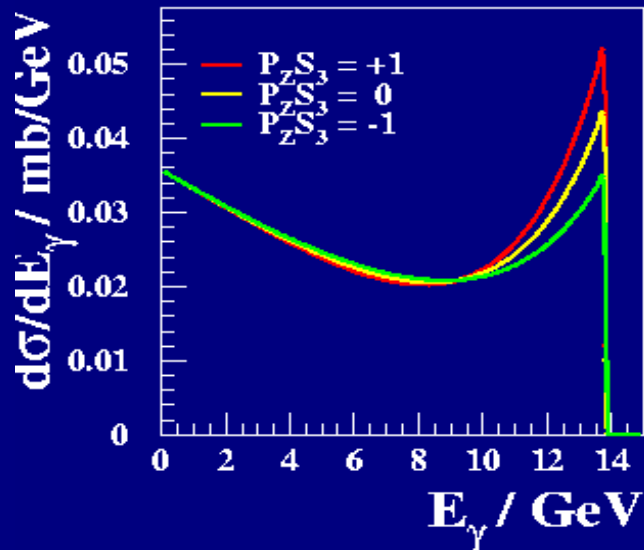
- Kinematics described by 2 variables:
 - polar angle $\theta \Leftrightarrow E_\gamma$ (photon energy)
 - azimuthal angle $\phi \Rightarrow y$ (vert. coordinate)
- S_1, S_3 : lin. & circ. laser polarisation
- P_Y, P_Z : transv. & long. e polarisation

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

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

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

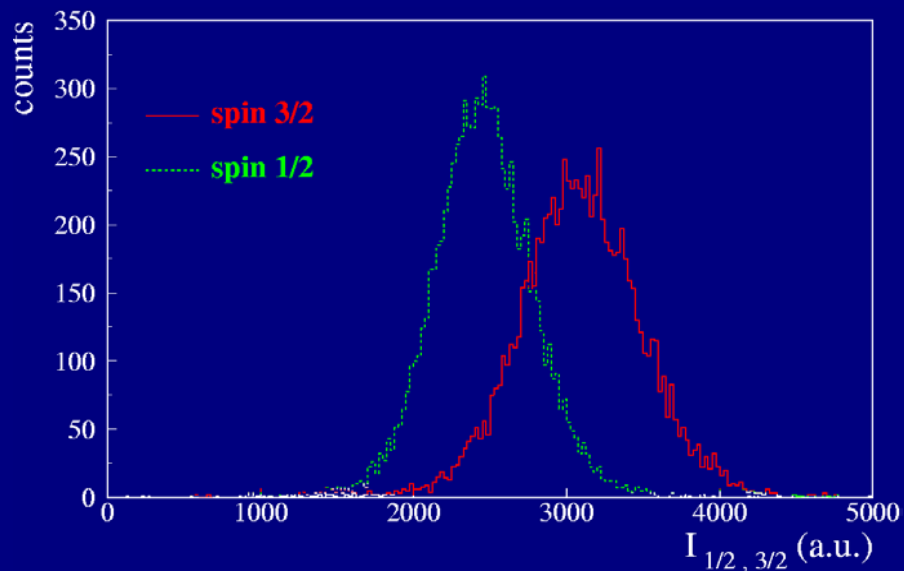
LPOL: Principle of Measurement



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

- can use single photon cross-section
- compton edge \rightarrow energy calibration
- but at LPOL location in HERA: Bremsstrahlung background to high $s/b \cong 0.2 \Rightarrow$ stat. error too large

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



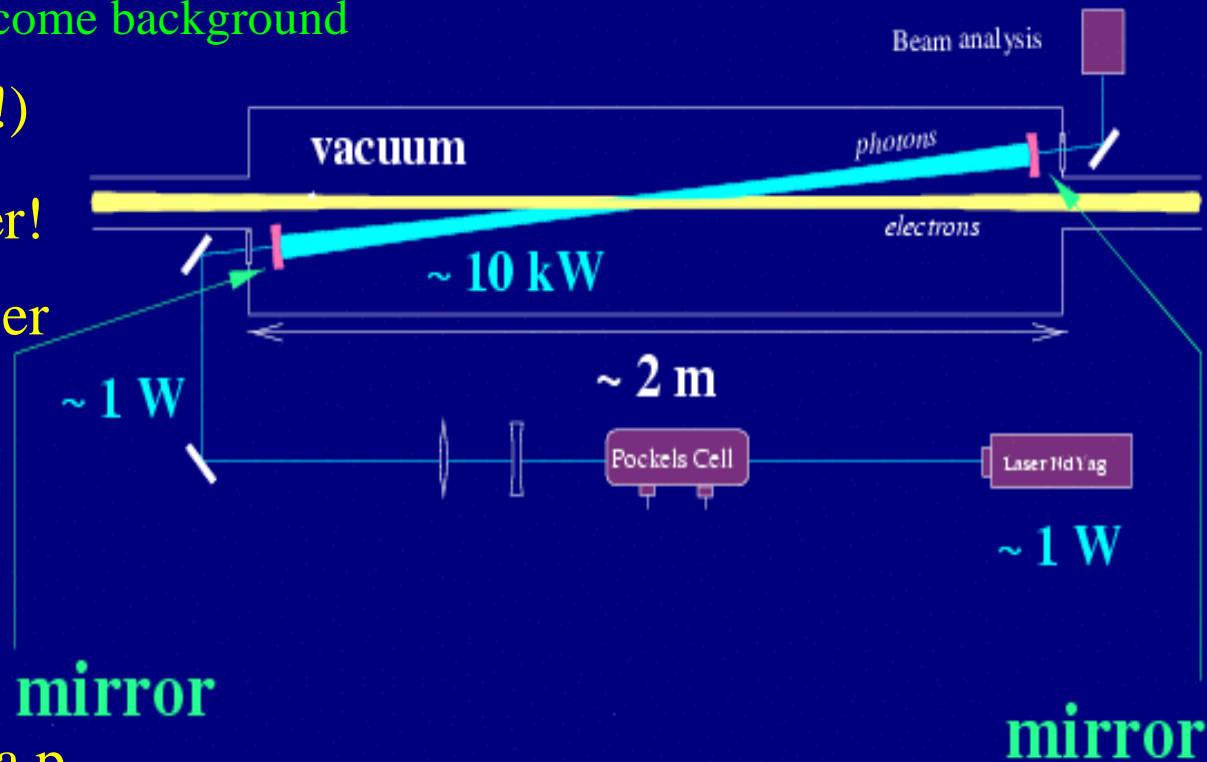
- no background problem
- stat. error $\cong 0.01$ per minute
- but: need precise knowledge of energy response of calorimeter
- syst. error = $\pm 1.6\%$ (rel.)
- high power laser only at 100Hz (HERA bunch spacing $\cong 10$ MHz)

Upgrade of the LPOL

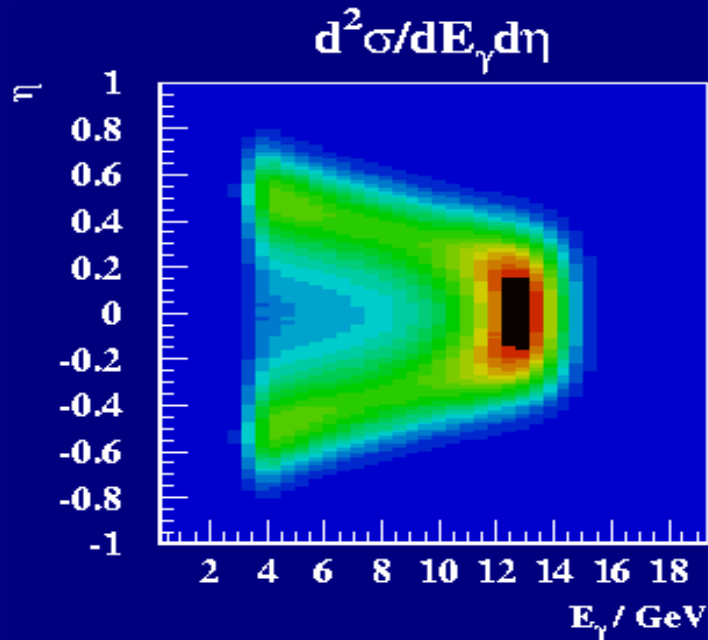
- Aim: "Few Photon Mode": $n_\gamma \geq 0.1 \Rightarrow$ overlay of up to 2 or 3 γ s
 - can still use single photon spectra to extract polarisation
 - \Rightarrow Compton edge calibration, less syst. uncertainties
 - enough statistics to overcome background

\Rightarrow 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
- \Rightarrow go for real thing a.s.a.p.

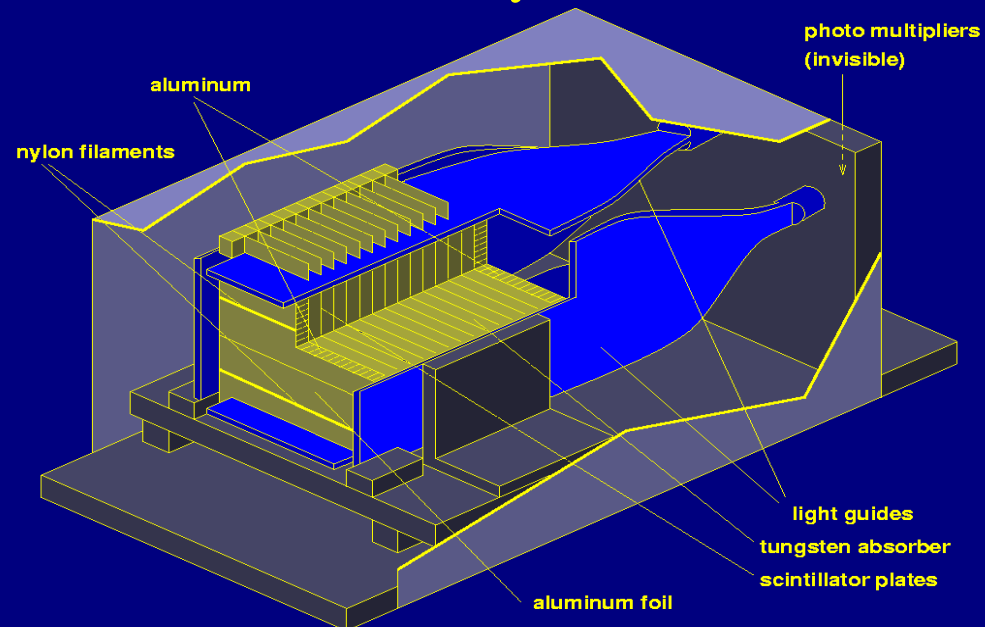


TPOL: Principle of Measurement



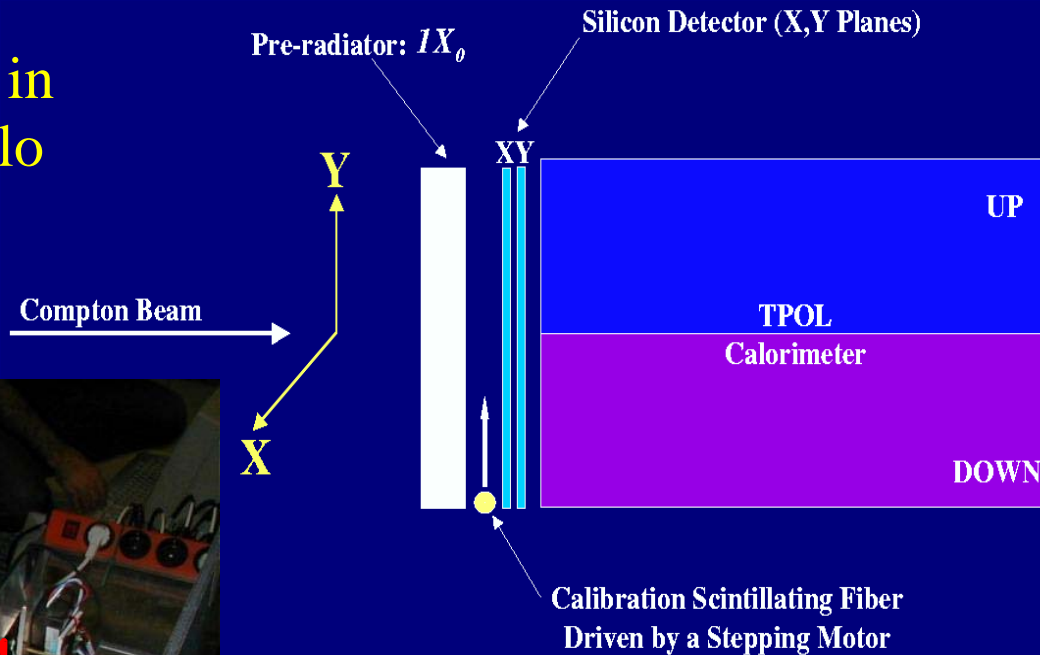
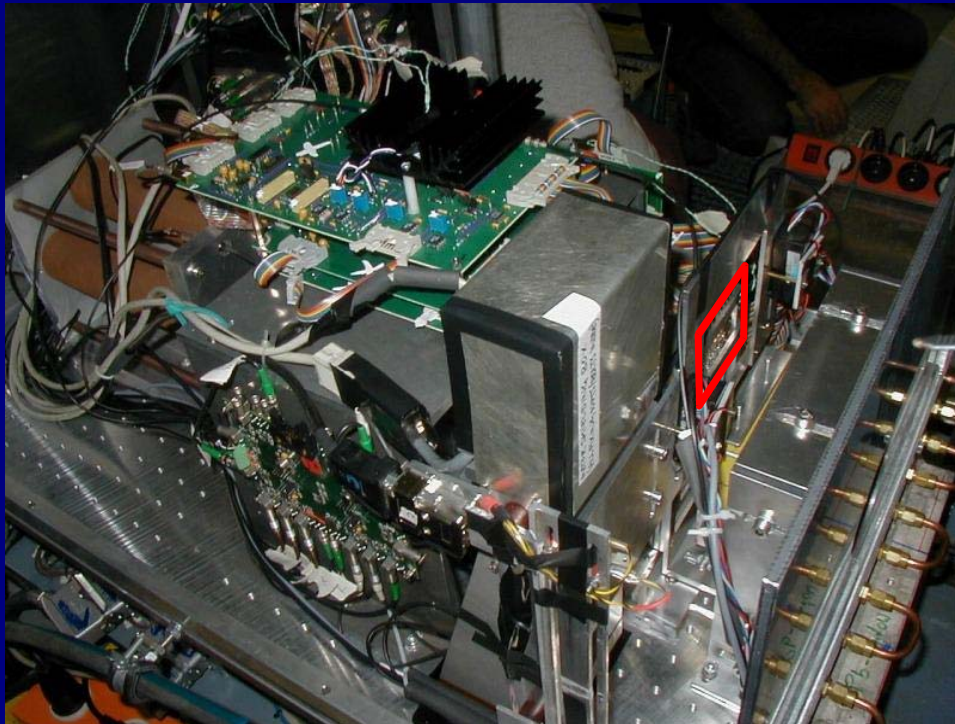
- have to measure E_γ and y !
- Calorimeter has upper and lower half:
 - $E_\gamma = E_{\text{up}} + E_{\text{down}}$
 - $y = y(\eta), \quad \eta = (E_{\text{up}} - E_{\text{down}})/(E_{\text{up}} + E_{\text{down}})$
- use asymmetry w.r.t. laser helicity
=> less sensitive to systematics

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



TPOL upgrade: Silicon Strip Detector

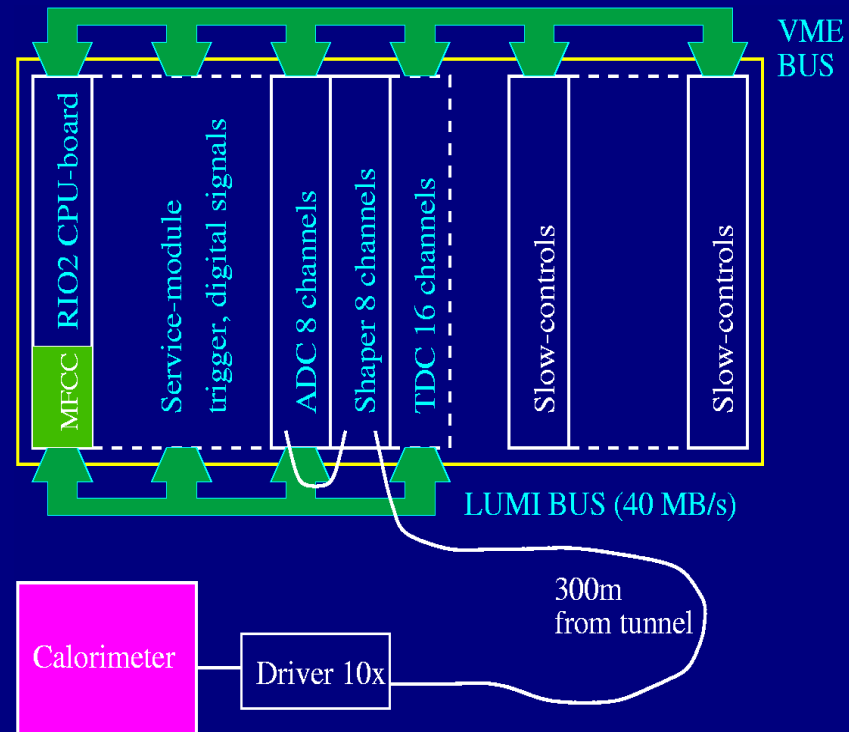
- new SI strip detector in y and x in front of calo as calibration device



- 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 (@ $I_e = 3\text{mA}$): $\delta P_{\text{stat}} = 0.015$
=> @ $I_e = 60\text{mA}$: $\delta P_{\text{stat}} = 0.0044$
- but what about δP_{syst} ?



reminder: aim for $\delta P_{\text{tot}}/P < 1\%$,
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:

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

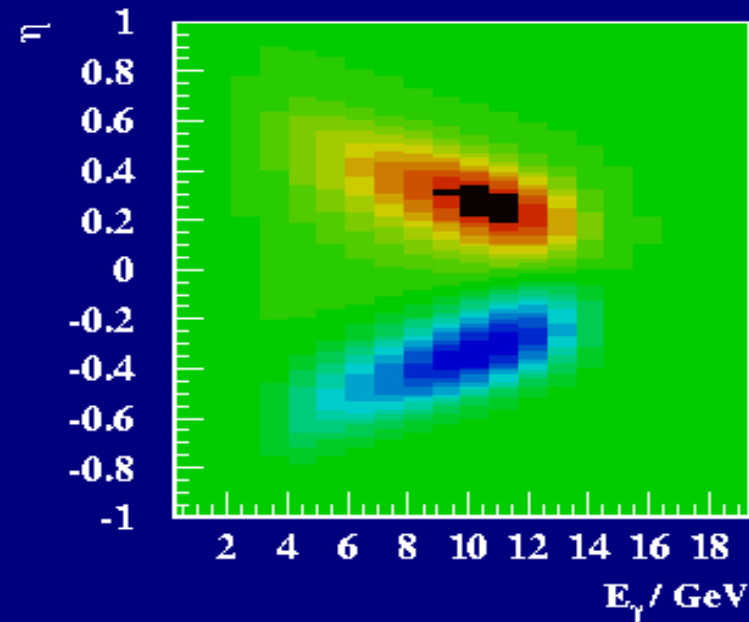
Π : "analysing power" taken from risetime calibration & MC

- 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!

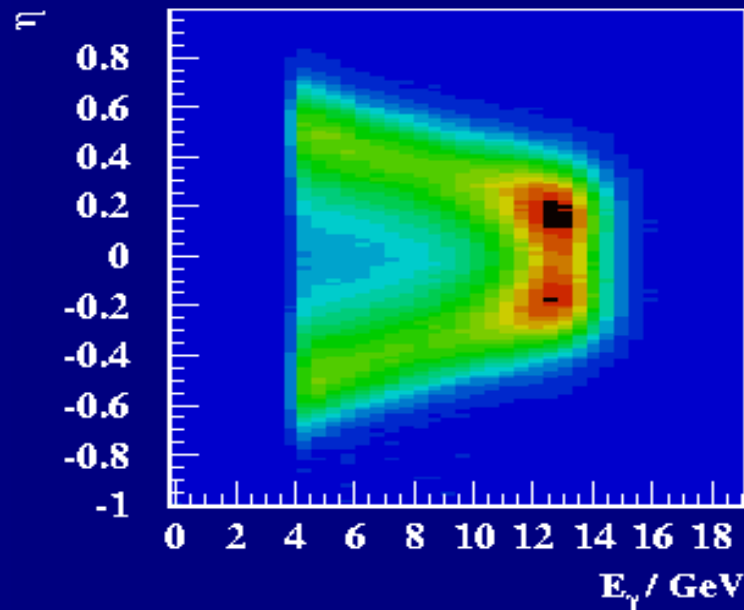
TPOL: Analysis Upgrade

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

RIGHT-LEFT



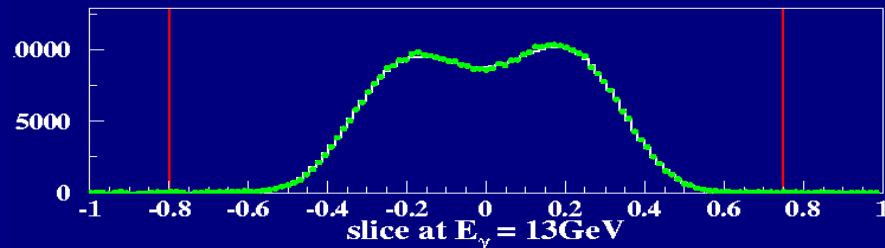
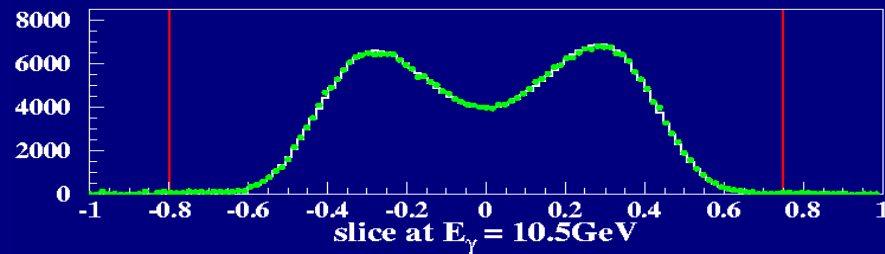
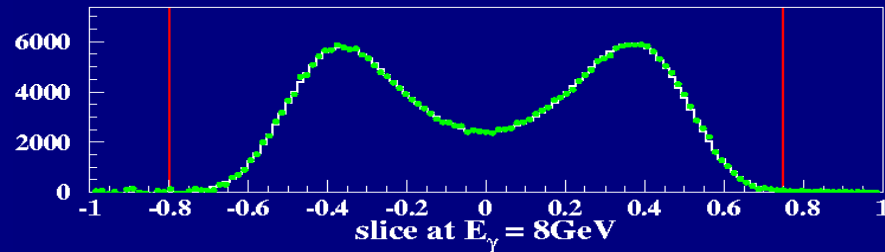
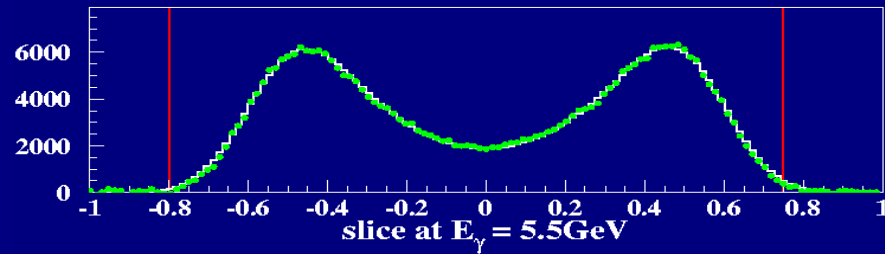
RIGHT+LEFT



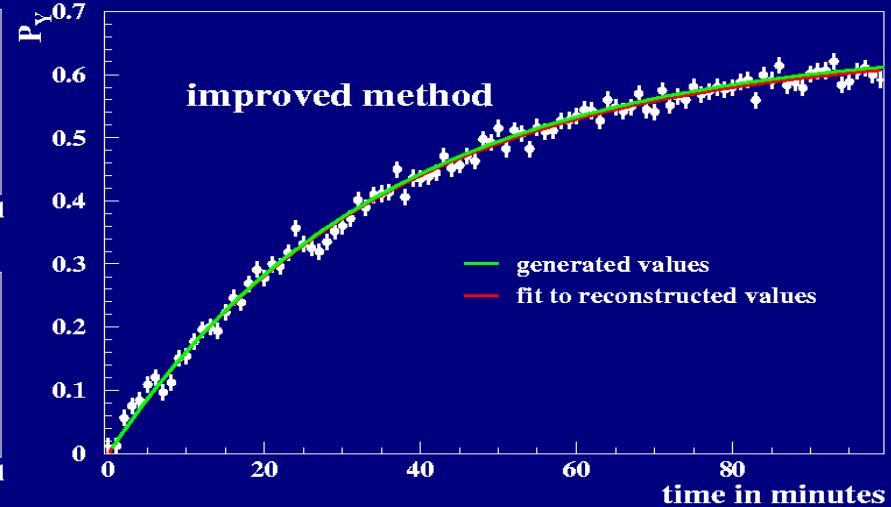
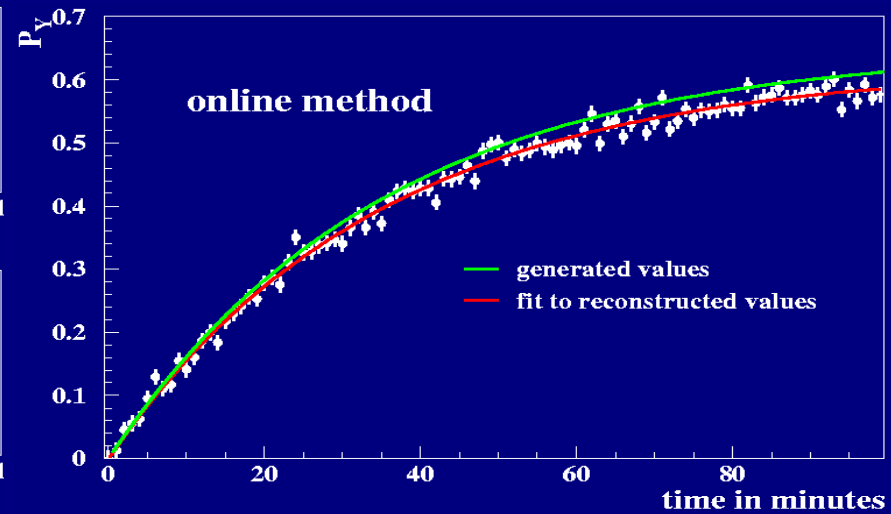
- First step : fit sum of spectra for laser both helicities => calibration
- Second step: fit difference => polarisation
- analysis not final yet
- no final systematic error yet

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!