Status of TPOL Reanalysis

- Brief Reminder of Analysis Strategy
- Some Results with HERA II Data
- Open Questions

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TPOL Analysis Chain

TPOL data

Laser beam simulation

Beam line simulation

IP

TPOL Calorimeter (fast) Monte Carlo

Calorimeter Digitization

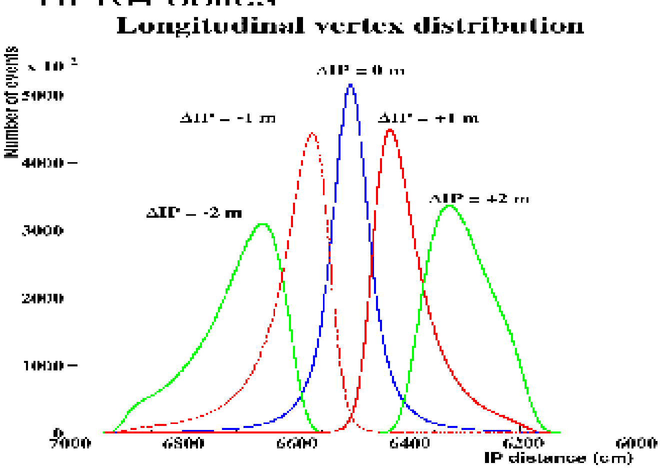
TPOL Analysis

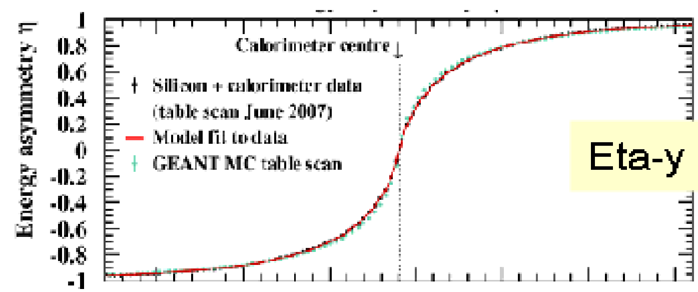
Data

HERA beam layout

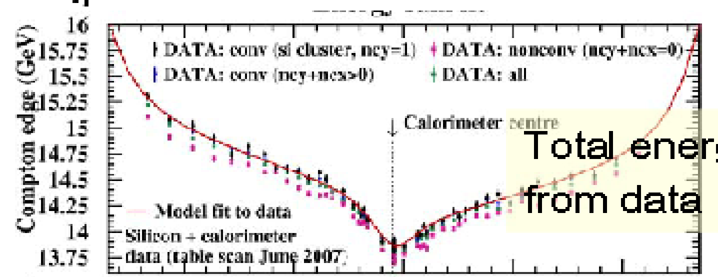
HERA optics

Calculate luminous region





Eta-y from Si data



Total energy response from data

Reanalysis of TPOL Data - Strategy

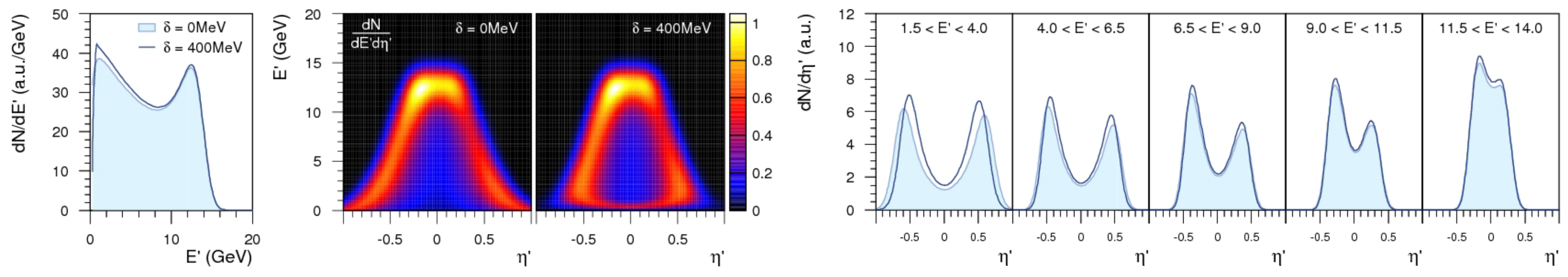
- Use parametrized Monte Carlo (MC) to derive Analysing Power taking into account
  - Linear light polarization from light polarization measurement
  - Electron/positron beam spot size at the calorimeter surface
  - Interaction point (IP) distance
- Take light polarization as input parameter, while beam spot size and IP distance are regarded as free parameters
  - Generate MC on a regular grid of beam spot size and IP distance
  - Use proper interpolation techniques to derive continuous MC predictions
  - For each minute of polarization data fit data distribution widths to find a suitable set of beam parameters in MC mapping functions and read off corresponding Analysing Power
- Why parametrized Monte Carlo?
  - For a sub-1% statistical precision on the Analysing Power for a given set of beam parameters ~100M events are needed
    - ➢ Full simulation with GEANT3 ist far too slow
  - → Detector description should reproduce measurements as good as possible
    - ➢ Current GEANT3 setup in best tuning state does not reproduce the energy asymmetry functions as functions of the vertical and horizontal impact points y and x, $\eta_y(y)$ being a major ingredient to the Analysing Power

Parametrized Monte Carlo - Ingredients

- Beam line
  - Using HERA optics parameters and magnetic bends to simulate the electron beam
  - Full gaussian beam optic to simulate the laser beam
  - Full 3D interaction probability between electron and laser beam to generate vertex region
- Compton cross section taking both linear and circular light polarization into account
- 66m distance nominal IP to calorimeter surface with apertures
  - As known from measurements taken in tunnel
- Detector simulation
  - Average total and differential response for converted photons both in x and y, both UP-DOWN and LEFT-RIGHT channel pairs
    - ➢ Measured from Silicon-calorimeter data
  - Total energy resolution at the Compton edge
    - ➢ Measured from Silicon-calorimeter data
  - Difference in average total response of converted to nonconverted photons
    - ➢ Measured at Compton edges in Silicon-calorimeter data
  - Difference of differential response of converted to nonconverted photons
    - ➢ Predicted by detailed physical model of $\eta_v(y)$ used in its fit for converted photons and confirmed by GEANT simulations
  - Non-linearity of energy measurement UP-DOWN channels
    - ➢ From GEANT studies
  - Detailed energy resolution model and energy resolution correlation model for UP-DOWN channels
    - ➢ From GEANT studies
  - Digitization of calorimeter channel energy readings
    - ➢ Physical modelling and tuned to data

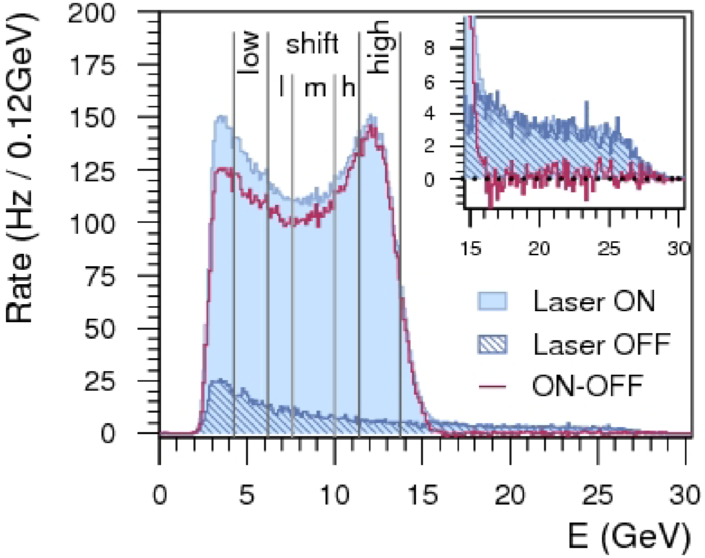
Energy Scale and Offset

- A constant energy contribution added to each energy measurement
  - E.g. as generated by synchrotron radiation originating in the quadrupole
  - Would add a bunch-on-time energy contribution to each high-energy photon detected
    - ➢ Causes effectively a shift of the pedestal values, which cannot be accounted for by the online pedestal subtraction
  - With a sampling fraction of 0.02, 5MeV of synchrotron radiation corresponds to a 200MeV energy contribution
  - → Reduces effectively RMS and shift of means values
- Effect of pedestal shift can be parametrized **linearly** (from MC studies)
- Extend existing maps (for ped=0MeV) by maps with ped=300MeV and ped=600MeV and interpolate between the three maps using regression methods
  - I.e. a total of 3x19x19 MC points…
  - → 3D mapping functions for RMS and shift of means in all energy bins with IP distance, beam spot size and pedestal shift as free parameters

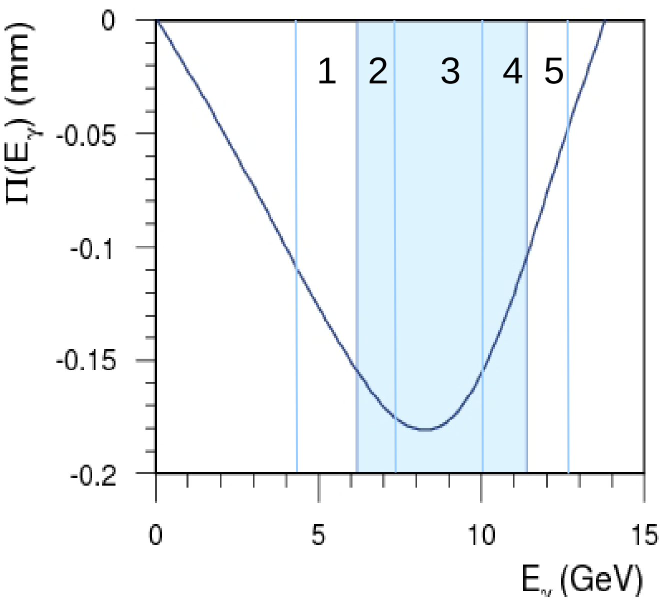


Photon Energy Dependence

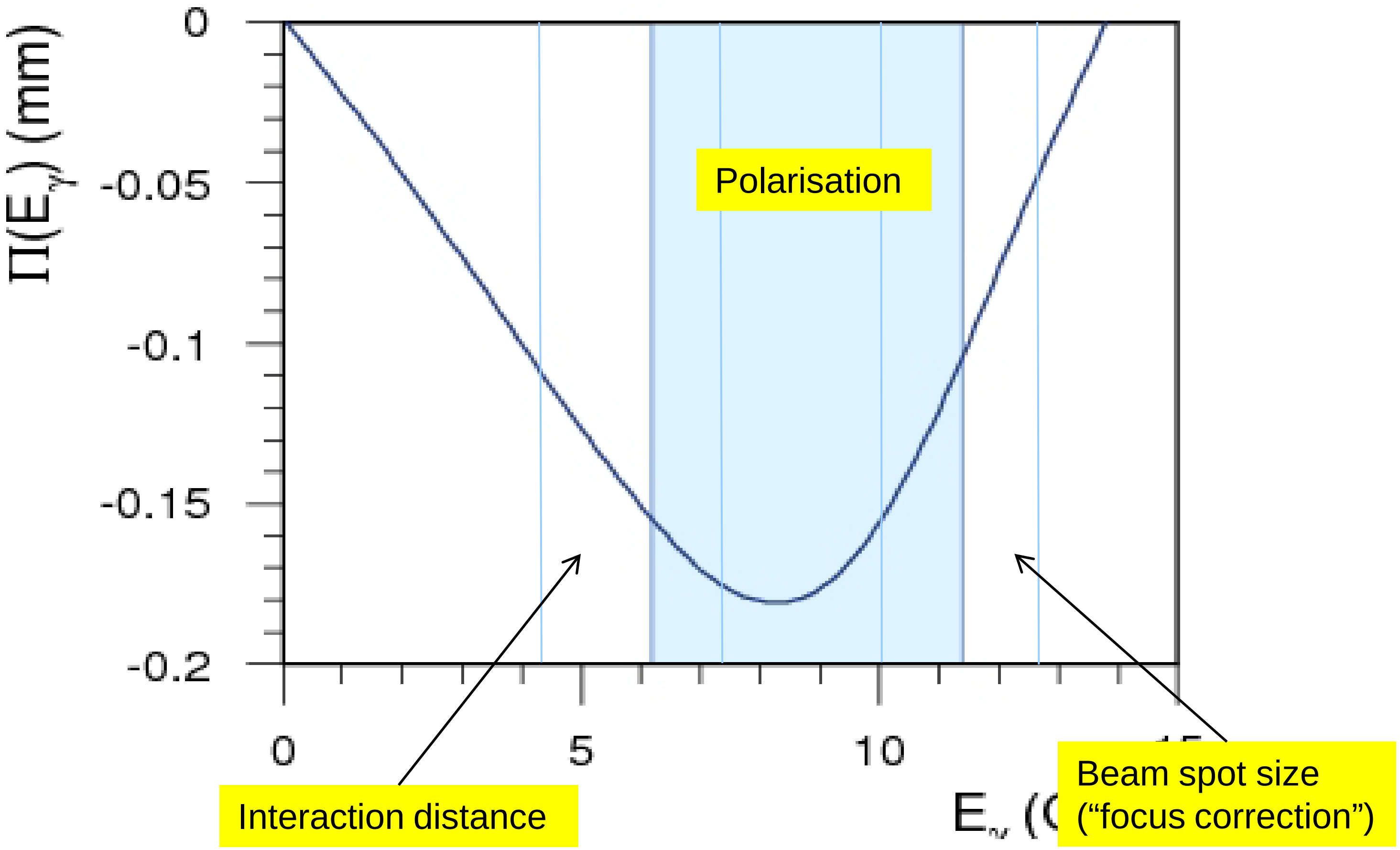
- Analysis done in 6 photon energy bins
  - → Calculate analysing power per energy bin
  - → Maximise information
  - → Allows cross check / consistency checks
- Eta distribution
  - → Tails of distributions show (strong) correlations
    - ➢ Background subtraction, large stat errors
  - → Remove outliers, cut away tails of distributions
    - ➢ Optimized using MC and data background fluctuation samples from laser OFF samples



Analysing power



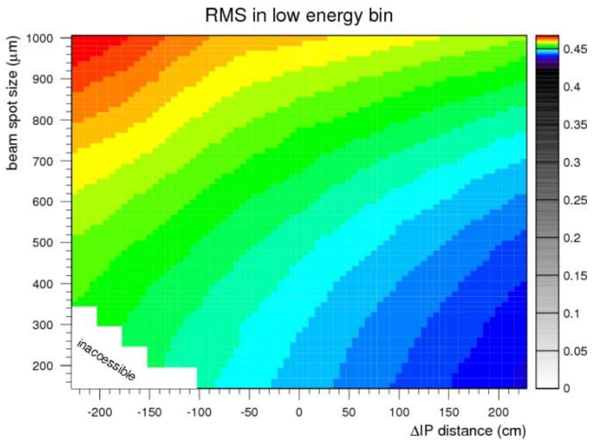
Photon energy bins

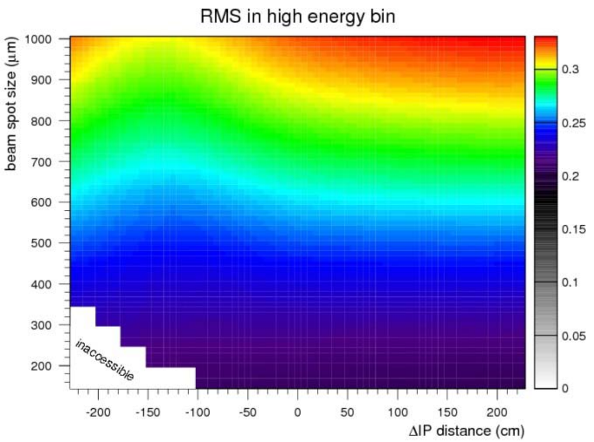


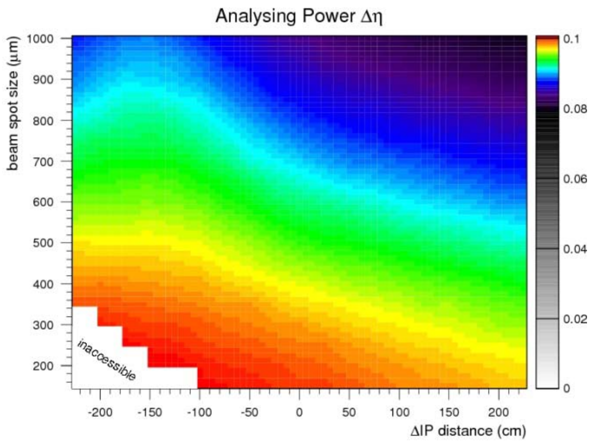
Areas of largest sensitivities

Monte Carlo Maps

- Generated 19x19 points in [IP, bs], S_3= 1 and S_1= 1, 100M events each set
  - → Spans complete available range in IP (allowed by apertures) and beam spot size (allowed by emittance)
- For a given linear light polarization measurement mix eta distributions for S_1 and S_3 to get the corresponding linear light polarization in each helicity
- Calculate RMS and mean values in energy-eta-bins, average RMS over two helicity, get shift of means as difference between helicities
  - → RMS and shift of means maps take linear light polarization into account
- Smooth maps using iterated 2D Savitzky-Golay filtering and cubic splines smoothing along IP distance
  - → Get rid of remaining statistical fluctuations of points
- Interpolate maps using 2D B-splines interpolants
  - → Smooth and continuous RMS and shift of means mapping functions for each energy bin







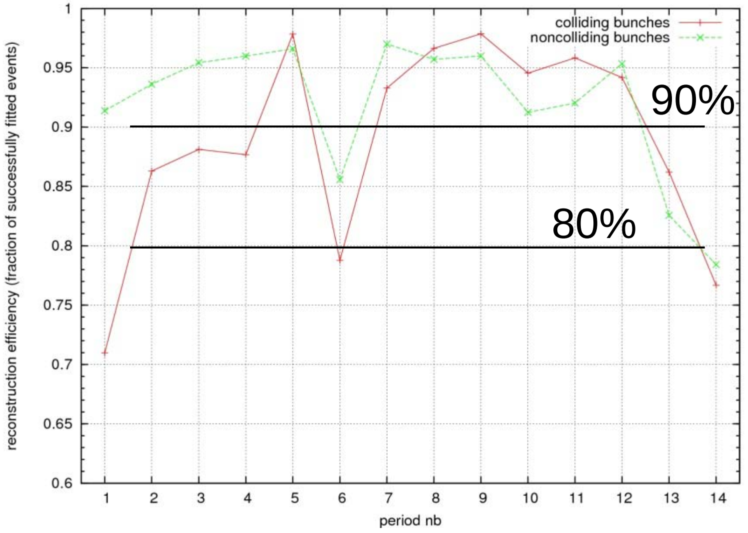
HERA II Data Periods

- Divide complete HERA II data into 14 periods
  - → Distinguished by different HERA optics setups, e+/e- changes, HE, LE or ME proton energies and covering not more than ~3 months

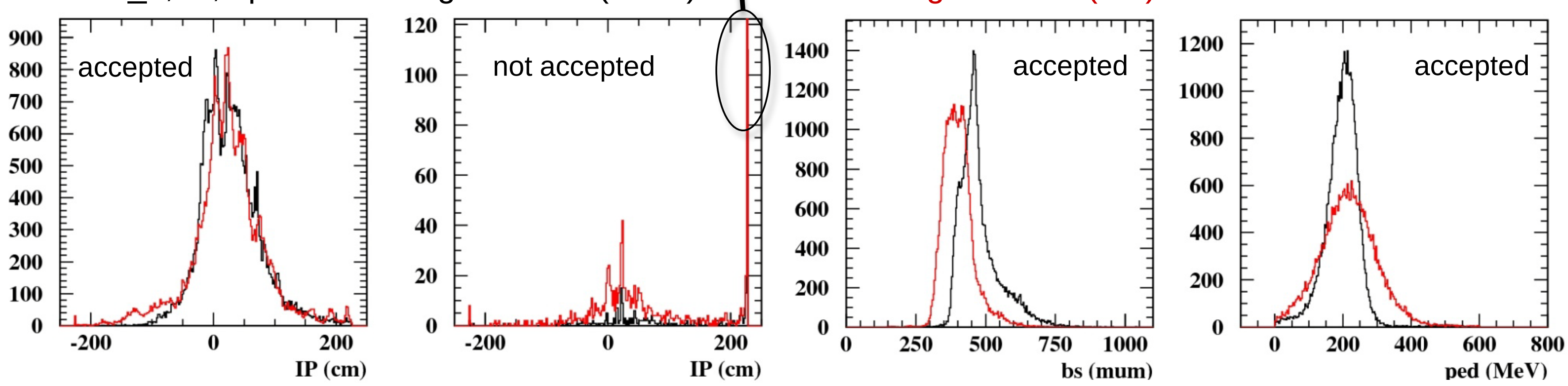
Period	Date	Optic	Beam	Fills
1	Feb.+Oct.-Dec. 2003	1: helum72_03	e+	3171-3267
2	Jan.-Apr. 2004	1	e+	3268-3416
3	May-Aug. 2004	1	e+	3417-3551
4	Dec. 2004 – Mar. 2005	2: helume-_04	e-	3556-3687
5	Mar.-May 2005	2	e-	3689-3804
6	May-June 2005	3: helume-_05	e-	3805-3873
7	Jul.-Sept. 2005	2	e-	3873-4007
8	Sept.-Nov. 2005	2	e-	4008-4128
9	Feb.-June 2006	4: helumsx_06	e-	4139-4376
10	July-Sept. 2006	5: holumm0_06	e+	4377-4515
11	Oct.-Dec. 2006	5	e+	4516-4698
12	Jan.-Mar. 2007	5	e+	4700-4857
13	Mar.-May 2007	6: holum602_07	e+, LE	4858-5015
14	June 2007	7: holum6bs_07	e+, ME	5018-5064

Analysing Data - Interaction Distance

- Fit works and is stable
- Observed problem: around 5% of fits fail (in some periods many more)
- Problem traced to IP distance, which is reconstructed into unphysical regime
- Example of fitted beam parameters IP distance, beam spot size (bs) and pedestal shift (ped): period 5



05_2, e-, optic2: colliding bunches (black) and noncolliding bunches (red)

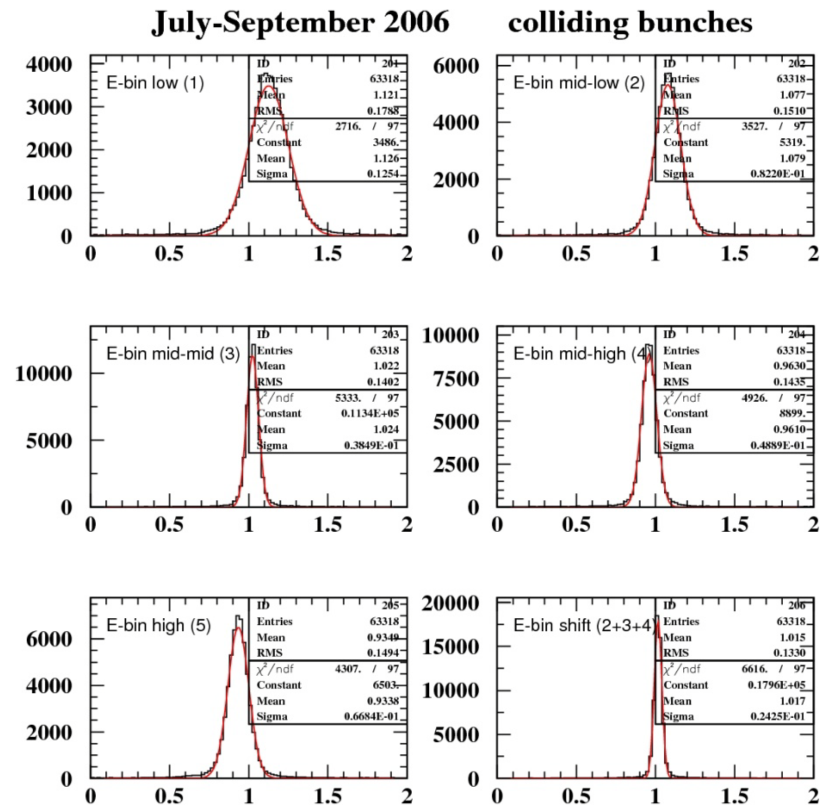


Analysing Data - Energy dependence

- Calculate Polarisation in each of the 5 energy bins, using simultaneous optimisation with IP and Beamspot
- Polarisation should not depend on energy of bin, error will change
- Determine the ratio R of the observed AP to the predicted AP (normalise data to Polarisation)

$$R(\text{bin}) := \frac{\text{shift in data}(\text{bin})}{\mathrm{AP_{MC}}(\text{bin}) \cdot P}$$

→ In each energy bin and for each minute of polarisation measurement



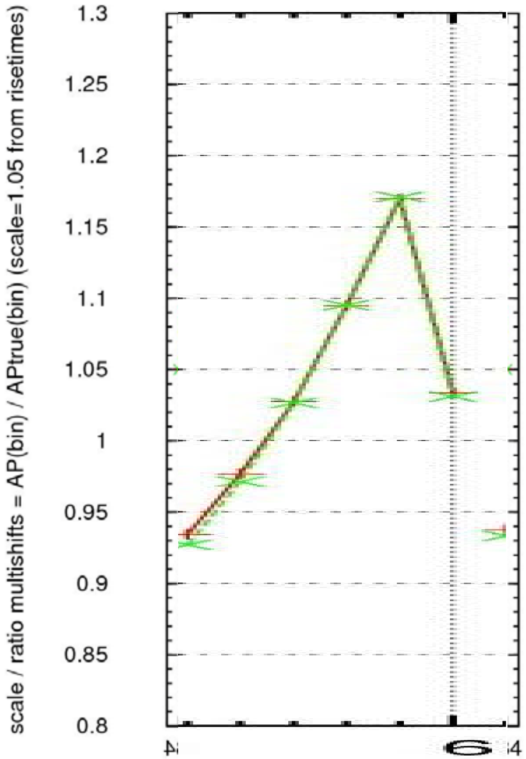
Energy Dependence of Analysing Power

$$R(\text{bin}) = \frac{\text{shift in data}(\text{bin})}{\mathrm{AP}_{\mathrm{MC}}(\text{bin}) \cdot P} = \frac{\mathrm{AP}_{\mathrm{true}}(\text{bin}) \cdot P_{\mathrm{true}}}{\mathrm{AP}_{\mathrm{MC}}(\text{bin}) \cdot P_{\mathrm{true}} \cdot \text{scale}}$$

$$\Rightarrow \frac{AP_{\mathrm{MC}}}{AP_{\mathrm{true}}}(\text{bin}) = \frac{\text{scale}}{R(\text{bin})}$$

Reconstructed AP appears to be depend strongly on E

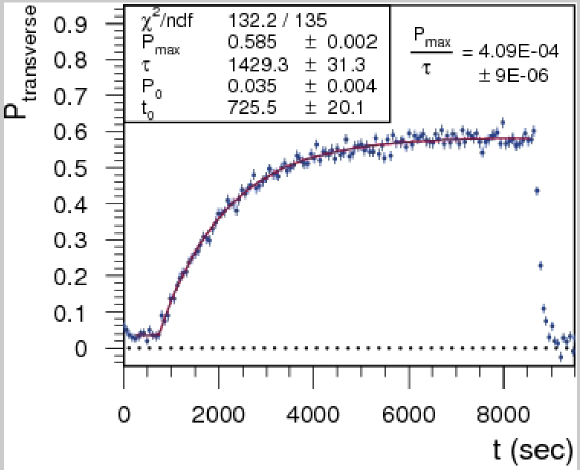
- Too low at low energies
- Too high at high energy
- overall 5% offset compared to external scale (rise time)



Risetime calibration in 2007:

Define scale independent of other measurements

Precision around 2-3%

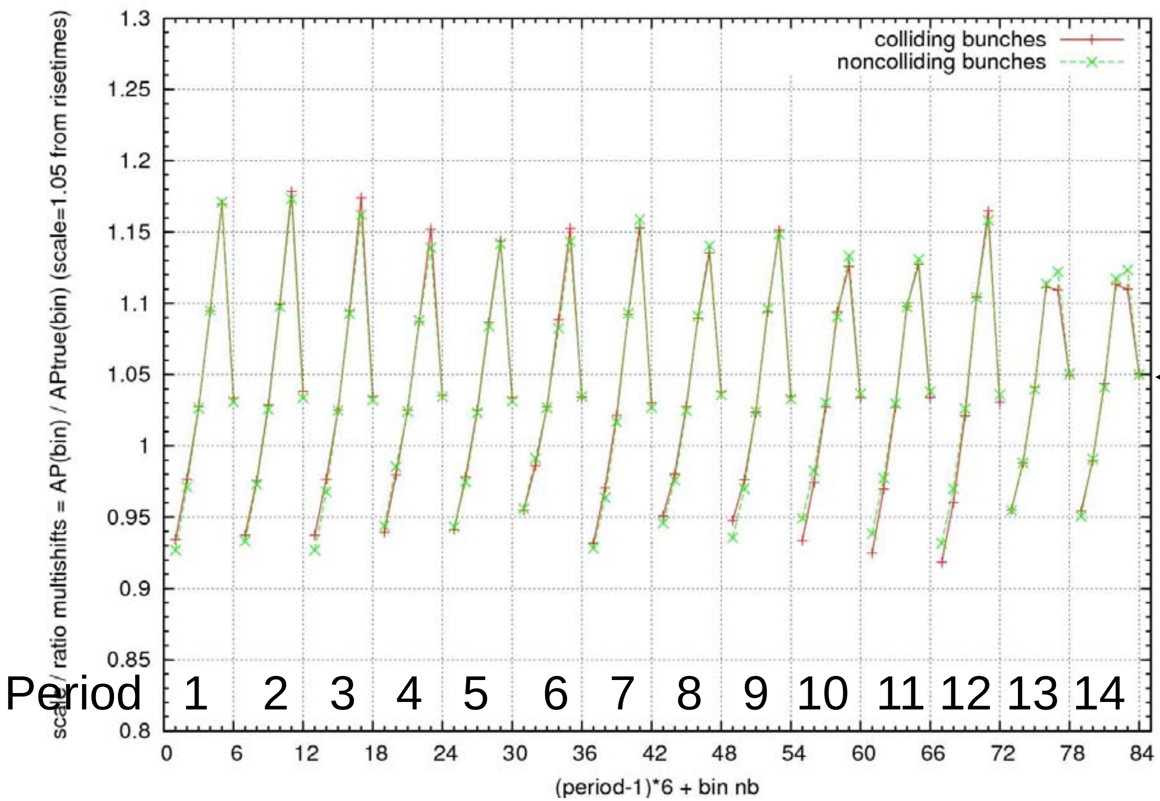


Analysing Data for all of HERA II running

- Given an absolute polarization scale, the ratio can be calculated into a ratio of MC Analysing Power to ‚true‘ Analysing Power:

$$R(\text{bin}) = \frac{\text{shift in data}(\text{bin})}{\mathrm{AP}_{\mathrm{MC}}(\text{bin}) \cdot P} = \frac{\mathrm{AP}_{\mathrm{true}}(\text{bin}) \cdot P_{\mathrm{true}}}{\mathrm{AP}_{\mathrm{MC}}(\text{bin}) \cdot P_{\mathrm{true}} \cdot \text{scale}}$$

$$\Rightarrow \frac{AP_{\mathrm{MC}}}{AP_{\mathrm{true}}}(\text{bin}) = \frac{\text{scale}}{R(\text{bin})}$$

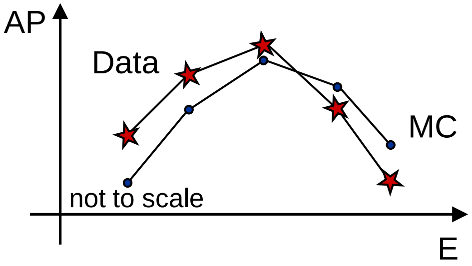


Simliar behaviour for all HERAII periods

Dependence is rather stable

Comparison to rise time

scale = 1.05
from rise times



Systematic Studies

- Performed systematic studies using MC
  - Beamline
    - Laser: size of waist and at mirror + position of waist
    - Horizontal emittance and its coupling to vertical emittance (beam spot size)
    - Horizontal table position
    - Vertical table position w and w/o gain difference calibration (centering)
    - Different optics setups
  - Generator
    - Spread of Compton scattering angles w and w/o energy dependence
    - Laser photon energy
    - Spread of the final photon distribution (i.e. beamline+Compton)
    - IP distance outside acceptance
  - Detector
    - Photomultiplier gain difference w and w/o table centering
    - Absolute gain calibration
    - Energy resolution correlations ρ_{UD}, $\rho_{E\eta}$ and both
    - Energy resolution: statistical term a, constant term b and both
    - Energy linearity
    - Spread of impact points y, i.e. change of $\eta(y)$ and E(y), w and w/o E dependence
    - Free distortion of $\eta(y)$ with mirrored-Moyal-like function (an antisymmetric wiggle…)
    - Distortion of $\eta(y)$ by changing shower parameters: lengths of core and halo and their energy fraction
    - Crosstalk in cables (mix channel energies à la $E_1=E_1 + f*(E_2)^{\alpha}$) with α=1, 2, 0.5
      - Note: pedestal shift corresponds to α=0

Systematic Errors (preliminary)

Error	Size	Comment
Background subtraction	0.001	
Electronic noise	<0.001	Small, not final
Linear light polarisation	0.001	
Table/ Calo centering	0.002	
Calo Gain calibration	0.005	
HERA / laser IP		
Laser beam	0.002	
HERA emittance	<0.001	Small
HERA energy		Small
HERA optics	0.006	
Method		
IP distance	0.005	Estimate
Focus correction	0.007	Estimate
Intrinsic method	0.005	
Detector Model		
Energy resolution	0.004	
Correlations	0.010	
Calo linearity	0.002	
Eta-y from Silicon		Small, not ready

Preliminary final error
(intrinsic error, ignoring
the scale and energy problem)

1.8%

Summary

- Analysis chain for TPOL has been established
- All HERAII data have been processed and analysed
- Preliminary list of systematic errors is available
- Problems

  $\rightarrow$ Energy dependence of analysing power different between data and MC

  $\rightarrow$ Offset in analysing power relative to rise time curve exists

Where does the Energy Dependence come from?

- Performed systematic studies concerning
  - Measurement of $\eta(y)$ again, this time with the questions:
    - ➢ Is $\eta(y)$ possibly energy dependent?
      - Fitted silicon data in different, smaller energy bins – No!
    - ➢ Is the $\eta(y)$ measurement biased?
      - Fitted $\eta(y)$ from MC table scan using the same analysis machinery – No biases!
    - ➢ Has the $\eta(y)$ changed over time, e.g. due to radiation damage?
      - Compared $\eta(y)$ from table scan June 2007 with table scan August 2005 – No differences in $\eta(y)$ observed!
    - ➢ Does GEANT also show such an energy dependence? – Yes, even worse!

Where does the Energy Dependence come from?

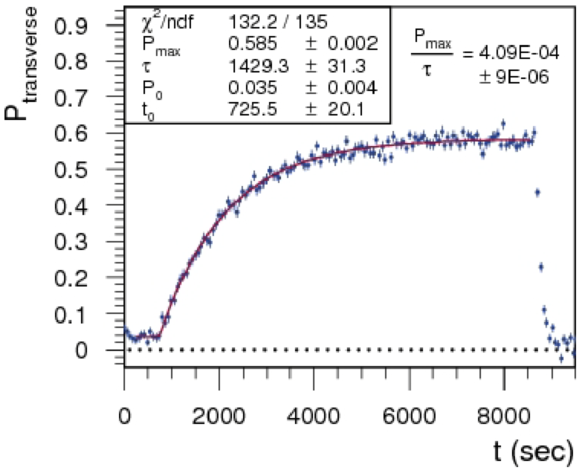
- Short summary: the complete system with the analysis based on MC maps is very stable, systematic variations of input parameters cause only small deviations in resulting Analysing Power after reconstruction
  - → Nice for systematics, bad when searching for something…
  - → Table of preliminary systematics soon…
- It is very hard to find something at all, which can provide some kind of an energy dependent AP change or change the shift bin AP significantly (i.e. reduce it)
  - → Have either a reconstruction or change the AP energy dependence, but not both!
- Best candidates: everything that distorts $\eta(y)$
  - → But no hints of biases, energy dependent $\eta(y)$ silicon data
  - → Amount of pedestal shift and/or cross talk does change the energy depence
  - → But: from the measured $\eta(y)$ a pedestal shift and linear cross talk should be visible in the tails of the function -> tails should not go to 1 in their presence!
    - ➢ Found in table scan June 2007 a pedestal shifts of ~20MeV and no cross talk
    - ➢ The fitted pedestal shift in data is ~200MeV for the corresponding period
    - ➢ Pedestal shift in our sense must be some kind of a virtual parameter, fixing some things, but does not make distributions entirely correct

Analysing Power Scale - Rise Time Measurements 2007

- In June 2007 a series of rise time measurements have been performed to provide for the possibility to check the absolute scale of the polarimeters
  - TPOL and Cavity were operational
  - 11 rise times are available of different ‚quality'
- Fit rise times with function

$$P(t) = \begin{cases} P_0 + (P_{\max} - P_0) \cdot (1 - e^{-(t-t_0)/\tau}) & \text{if } t \geq t_0 \\ P_0 & \text{otherwise} \end{cases}$$

  → 4 free parameters: starting and maximal polarisation P_0 and P_{max}, beginning of rise time t_0 and rise time τ



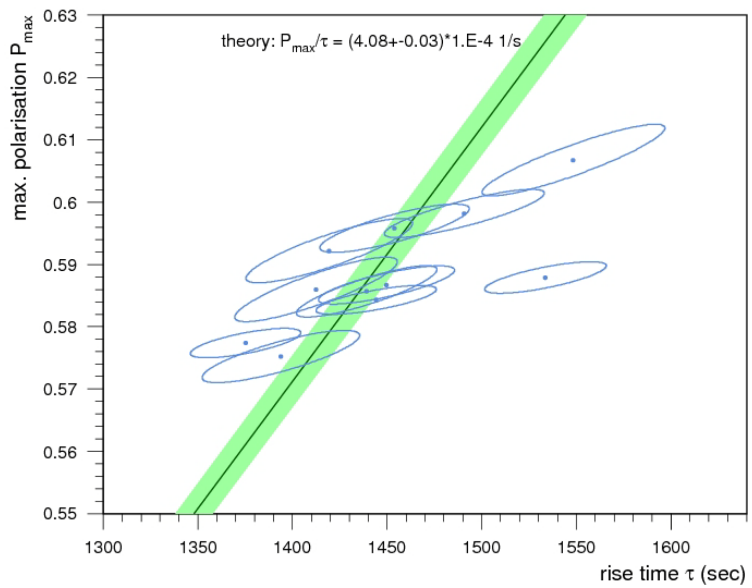
- For each rise time curve fit all possible reasonable time ranges $[t_{start},t_{end}]$
  - As fit results vary with the set of measurements taken into account
  - Determine average fit parameters and their average errors
- Communicated HERA ratio as used by the Cavity (JINST 5 P06005 (2010), arXiv:1005.2741v1):

$$\frac{P_{\max}}{\tau} = (4.08 \pm 0.03) \cdot 10^{-4} 1/s$$

Analysing Power Scale - Rise Time Measurements 2007

- At least during the time of the rise times, end of June 2007, the online Analysing Power scale seems to be good
  - – Average scaling factor 1.0033 +- 0.0088
  - → Online AP is by construction good, it has been tuned to rise times
- New polarization scale disagrees
  - – Average scaling factor: 1.0504 +- 0.0089
  - → New analysing power (3d fit) is about 5% too high
  - → Need to understand this!

online analysis



new analysis