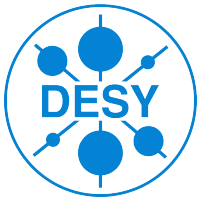

Universität Hamburg

Measurement of the longitudinal structure function F_L at HERA with the ZEUS detector

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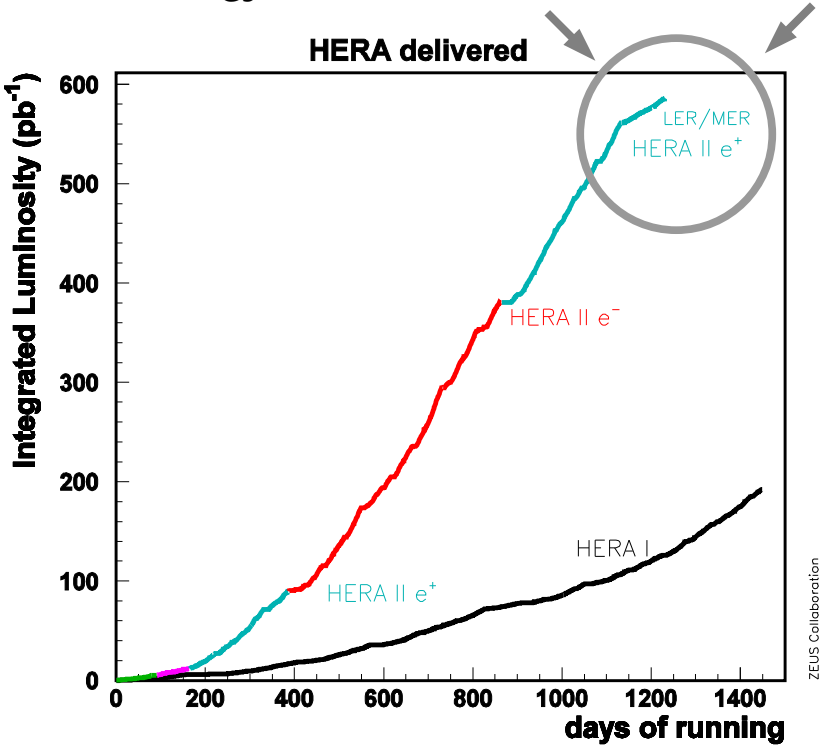
on behalf of ZEUS Collaboration

Outlook

- Deep-inelastic scattering
  - Cross sections and structure functions
  - Longitudinal structure function F_L
- HERA accelerator and ZEUS detector
- F_L at ZEUS
  - Signal extraction
  - Background rejection
- Measured cross sections
- Extracted F_L
  - Comparison with predictions
- Summary

HERA collider at DESY

- HERA is a lepton-proton collider with 2 general purpose collider experiments: H1, ZEUS
- Operation period: 1992 - June 2007 → total delivered luminosity 780 pb^{-1}
- Most of luminosity was taken with proton beam energy of 920 GeV
- In the last year of running HERA smoothly transited to operation with lowered proton beam energy: first 460 GeV and then 575 GeV



- ZEUS collected good data with all 4 proton beam energies:
  - 820 GeV → 48 pb^{-1}
  - 920 GeV → 456 pb^{-1}
  - 460 GeV → 14 pb^{-1}
  - 575 GeV → 7 pb^{-1}

Deep-inelastic scattering

- Deep-inelastic scattering is a key tool to probe the structure of the proton
- Kinematic variables:
  - Q^2 – virtuality of the photon:

$$Q^2 = -q^2 = -(k - k')^2$$

  - s – center of mass energy:

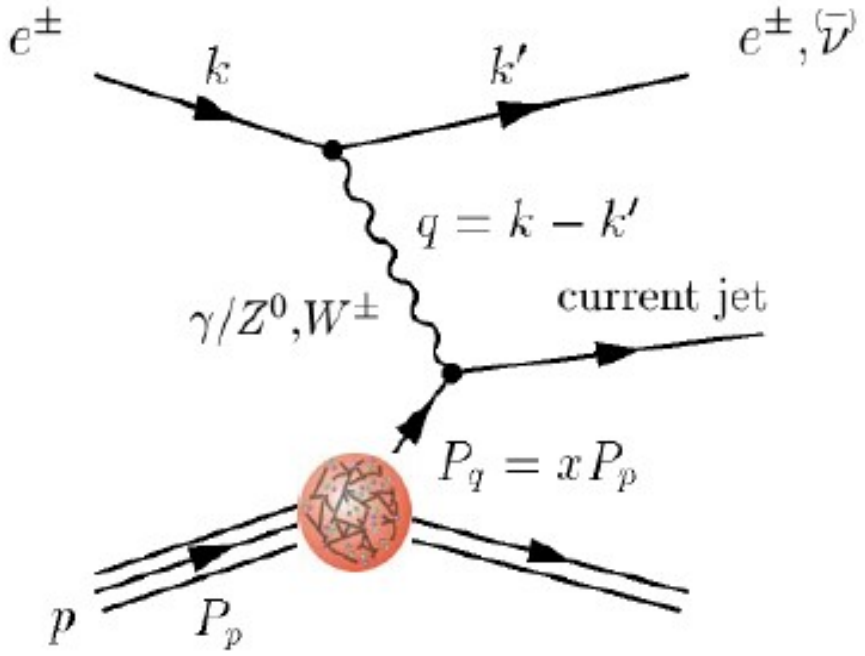
$$s = (p + k)^2$$

  - x – Bjorken scaling variable:

$$x = \frac{Q^2}{2P \cdot q}$$

  - y - inelasticity:

$$y = \frac{q \cdot P}{k \cdot P}$$



DIS cross section and structure functions. F_L.

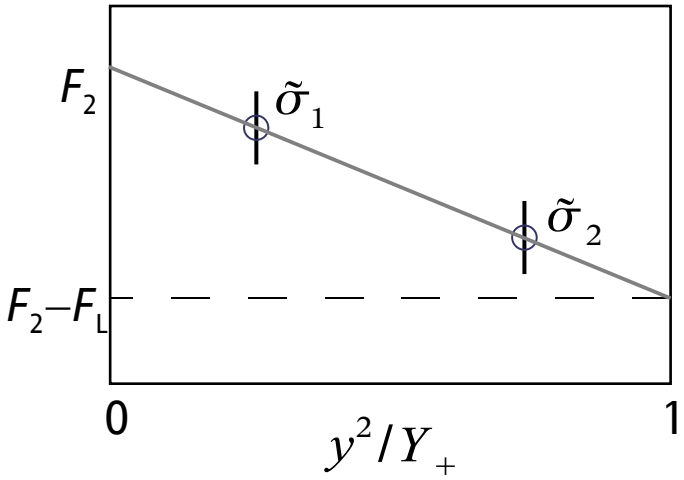
- DIS cross section:
  - product of the leptonic and hadronic tensors
  - can be split up into longitudinal and transversal parts

$$\frac{d^2\sigma^{\pm}}{dx\,dQ^2}(x,Q^2)=\frac{2\pi\alpha^2}{xQ^4}Y_+[F_2(x,Q^2)-\frac{y^2}{Y_+}F_L(x,Q^2)]$$

- Callan-Gross relation:
  - Parton model: $2xF_1=F_2$, i.e. $F_L=0$
  - QCD: $F_L=2xF_1-F_2$
- F_L:
  - directly sensitive to gluon dynamics → good test of perturbative QCD
  - visible only at high y
  - supressed by y^2 factor → difficult to measure

F_L extraction strategy

- Reduced cross section can be measured: $\tilde{\sigma} = F_2(x,Q^2) - \frac{y^2}{Y_+} F_L(x,Q^2)$
- To separate F_2 and F_L:
  - need to measure cross sections at the same x and Q^2 but different y
  - different y → different s → different beam energies



$$F_L(x,Q^2) = \frac{\tilde{\sigma}_1(x,Q^2,y_1) - \tilde{\sigma}_2(x,Q^2,y_2)}{y_2^2/Y_{2+} - y_1^2/Y_{1+}}$$

- Larger y difference + more points → higher F_L measurement accuracy

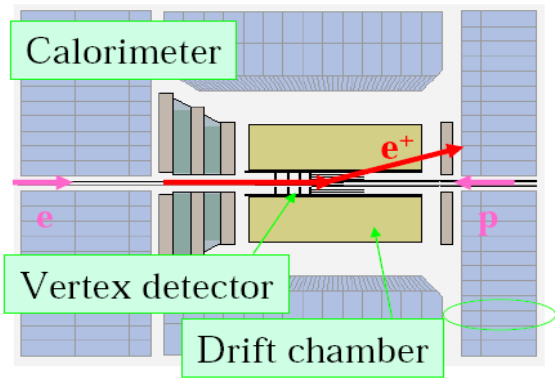
F_L measurement features

- *Scattered electron* is used to reconstruct kinematic variables:

$y_{el} = 1 - \frac{E_e}{2E_e^{\text{beam}}}(1-\cos\theta_e)$	$Q^2_{el} = 2E_e^{\text{beam}} E_e (1+\cos\theta_e)$

- Measurement is performed at low Q^2 → scattered electron is close to the beam pipe

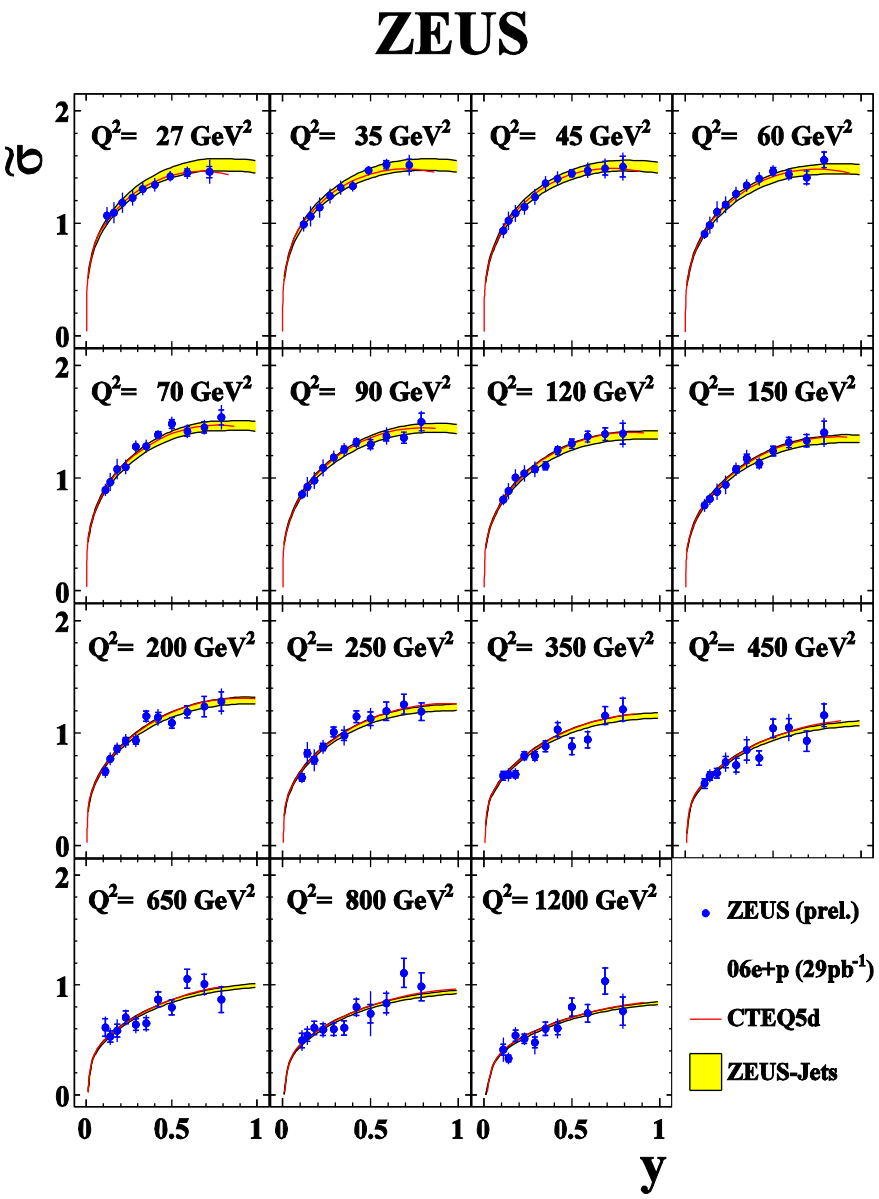
- Both, high and low y regions have to be accessed:
  - *Low y* → high energy scattered electron
  - *High y* → low energy scattered electron



- Main issue is background at low scattering angles

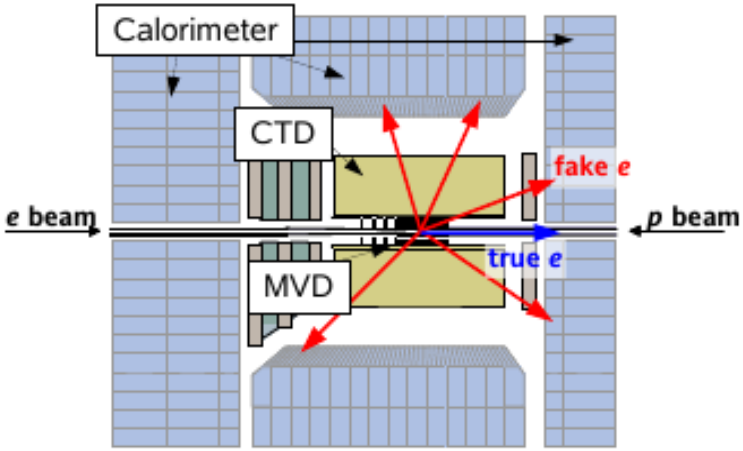
Cross sections at high y with ZEUS

- To show the *feasibility of the measurement* at *high-y* region at ZEUS the cross sections were extracted with extended (compare to previous measurement) kinematic region:
  - $0.1 < y < 0.8$
  - $25\ \text{GeV}^2 < Q^2 < 1300\ \text{GeV}^2$
- Measurement was successfully performed and shown at DIS07



Photoproduction background

- Main background for the measurement are photoproduction events:
  - Electron radiates almost real photon which interacts with proton
  - True electron goes down to the beam pipe
  - One of the particles (γ or π) is misidentified as electron



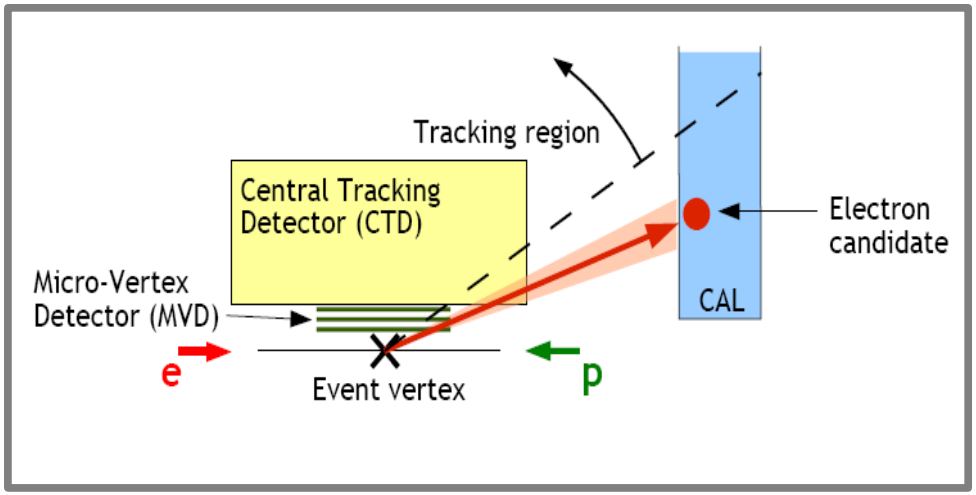
- Procedure to control photoproduction background:
  - Reject hadrons with ***shower shapes*** requirements
  - Reject photons with ***track*** requirement
  - Use photoproduction Monte Caro to account for remaining background

→ tracking and good simulation are very important

Backward tracking

- Most of background are photons close to the beam pipe
- ZEUS tracking system acceptance is *limited* in the backward direction to $\theta_e < 154°$

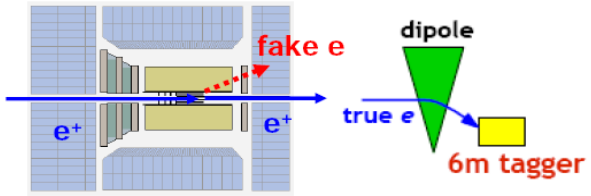
  → new tool has been developed to extend acceptance down to $\theta_e < 168°$
- How does it work:
  - Road from vertex to the electron candidate is created
  - Hit finding in the area around the road is performed



- Backward tracking tool has:
  - *Good efficiency* for DIS events
  - *Good background rejection power*
- Upcoming: charge extraction

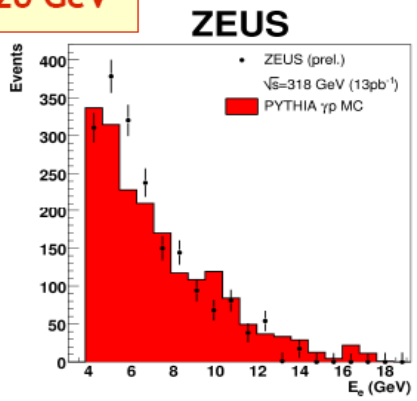
Understanding of photoproduction: 6 meter tagger

- After rejecting photoproduction events with tracking tools and shower shapes requirements some events still remain
  - use Monte Carlo to account for that

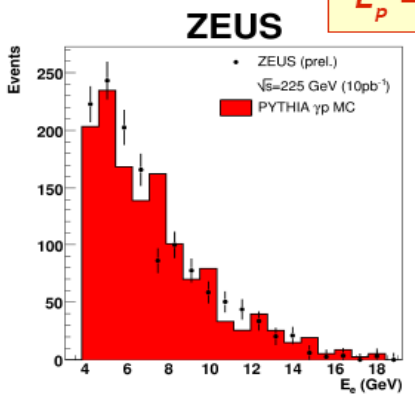


- At ZEUS photoproduction events can be tagged directly with a small tagger(~5.5 m from interaction point):
  - for electrons with energies from 4 GeV to 9 GeV acceptance is 100%
- Pythia minimum bias PHP MC describes well energy distributions of fake electrons in the main detector
  - For each beam energy normalization factor is extracted

E_p = 920 GeV



E_p = 460 GeV

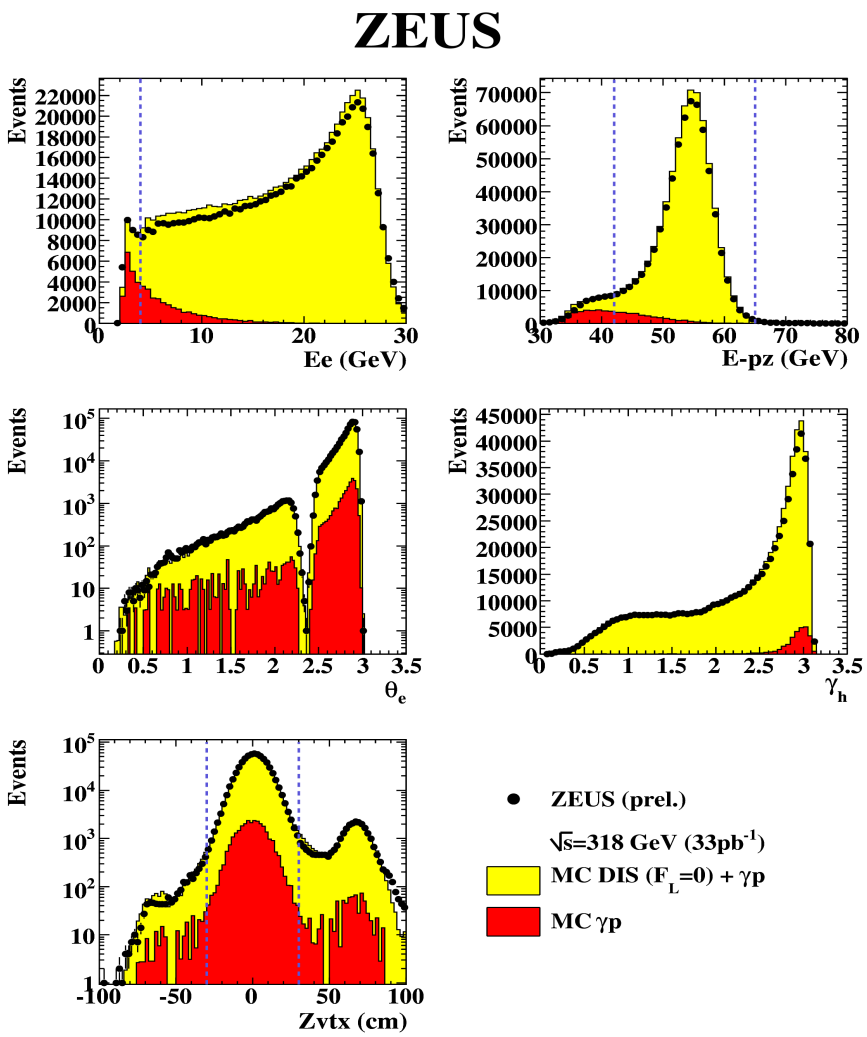


Analysis samples and selection. Systematic checks

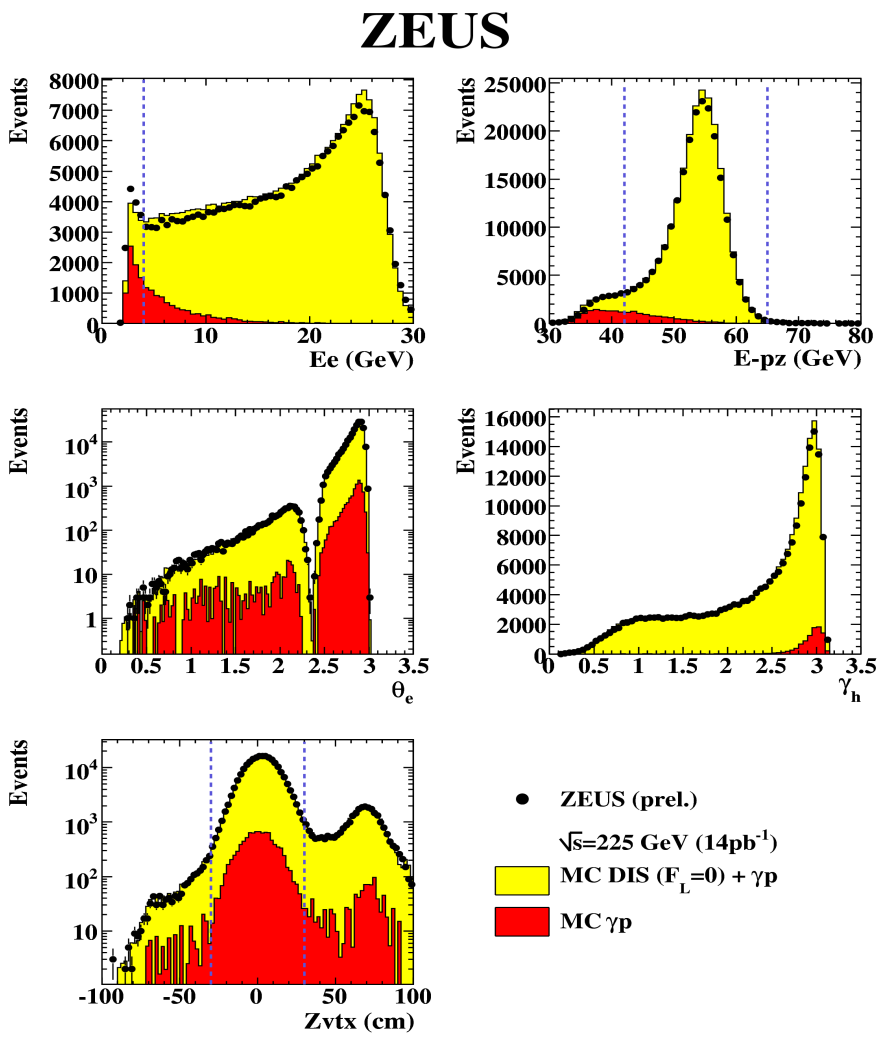
- Present measurement has been done with two data sets:
  - Ep=920 GeV → 32.8 pb^{-1}
  - Ep=460 GeV → 14 pb^{-1}
- Identical selection was applied on both samples:
  - Scattered electrons energy above 6 GeV
  - 42 GeV < E-pz < 65 GeV
  - |Zvtx| < 30 cm
- ***Systematic checks:*** energy scale, electron finding, position reconstruction, vertex uncertainty, hit finding, photoproduction normalization, uncorrelated luminosity, E-pz, relative normalization
- Systematics were estimated conservatively → room for improvements

Control distributions

Ep=920 GeV



Ep=460 GeV



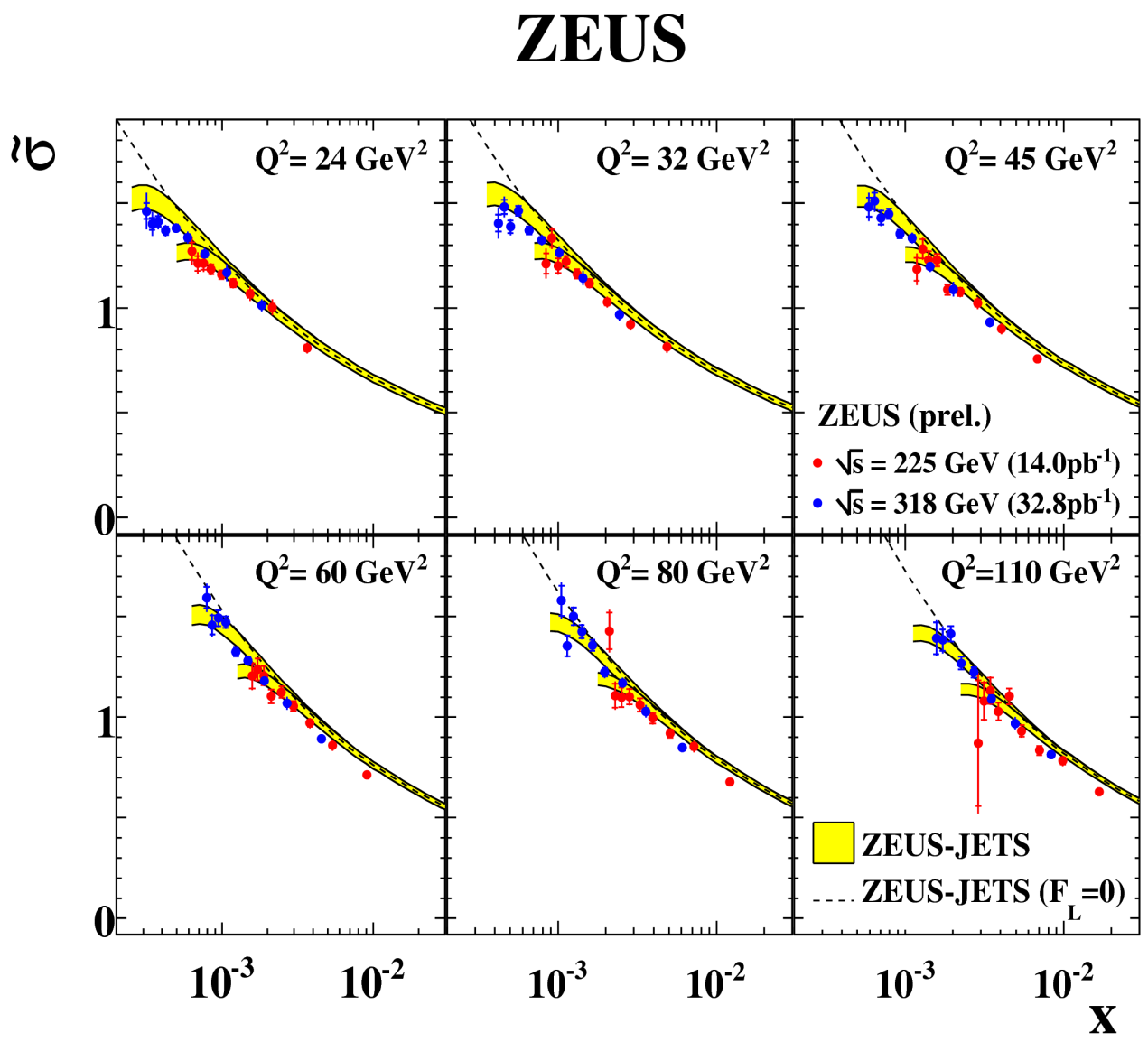
MC samples were generated with F_L=0 to avoid possible bias from predictions

Reduced cross sections vs. x

- Q^2 range: 24 GeV-110 GeV
- Turnover at low x is not obvious

→ Measurement at higher y is needed

- F_L is extracted from difference in cross sections at same x and Q^2



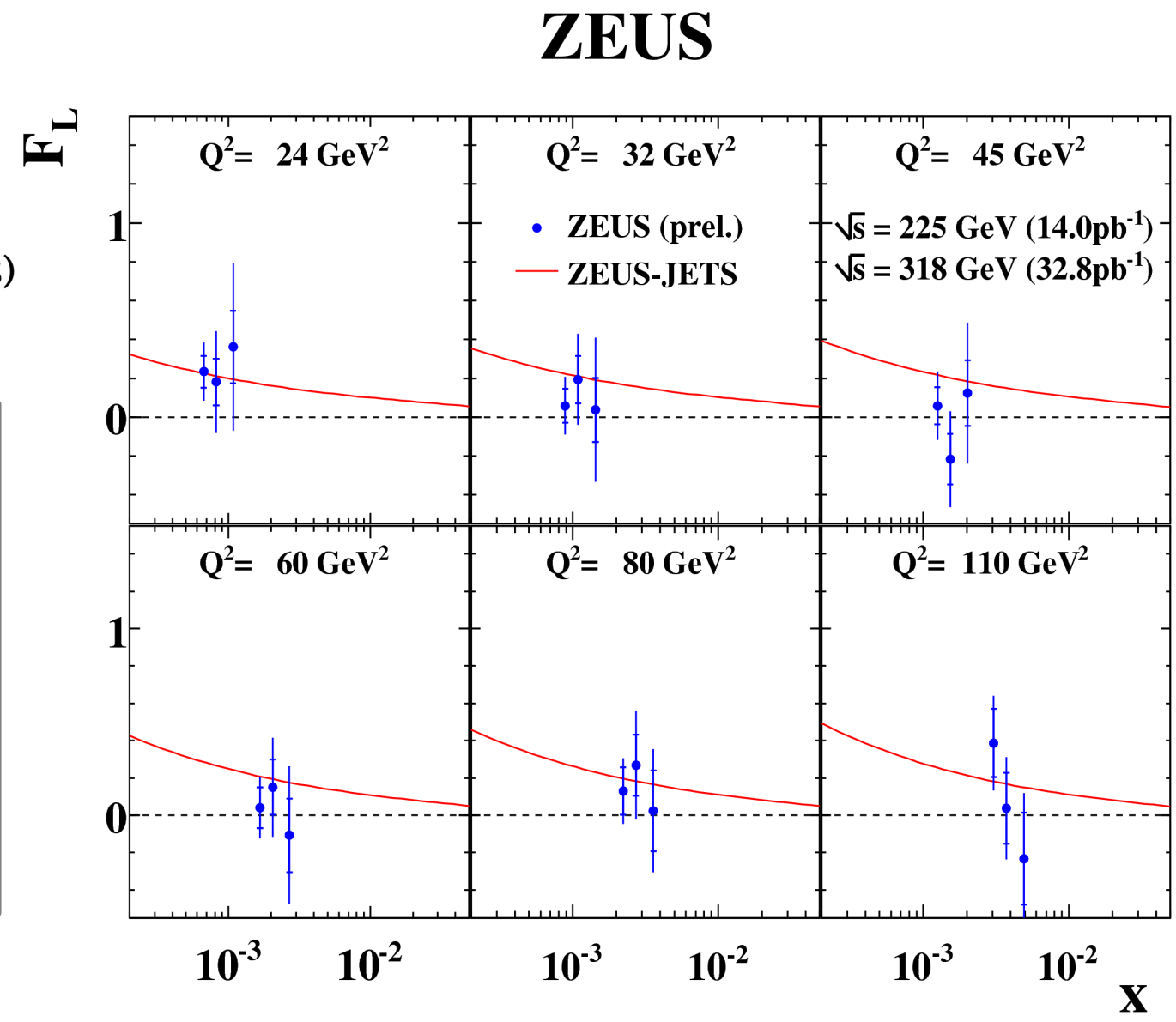
ZEUS F_L

- Extracted values of F_L are consistent with ZEUS-JETS predictions and with 0 as well
  (due to large uncertainties)

→ Room for improvements:

- Lower energies of scattered electron
- Reduction of systematics
- Third beam energy data set

- Analysis in progress



Summary

- ZEUS has performed a *direct measurement of the longitudinal structure function*
  - Two data sets were used, with Ep=920 GeV and Ep=460 GeV
  - Q^2 range: 24 GeV-110 GeV
  - Measured values of F_L are consistent with ZEUS-JETS predictions as well as with $F_L = 0$

- Improvements to come:
  - Inclusion of third data set (Ep=575 GeV)
  - Extension of measurement to higher y and lower Q^2 region
  - Reduction of systematic uncertainties