Measurement of Deeply Virtual Compton Scattering cross section by H1 collaboration at HERA

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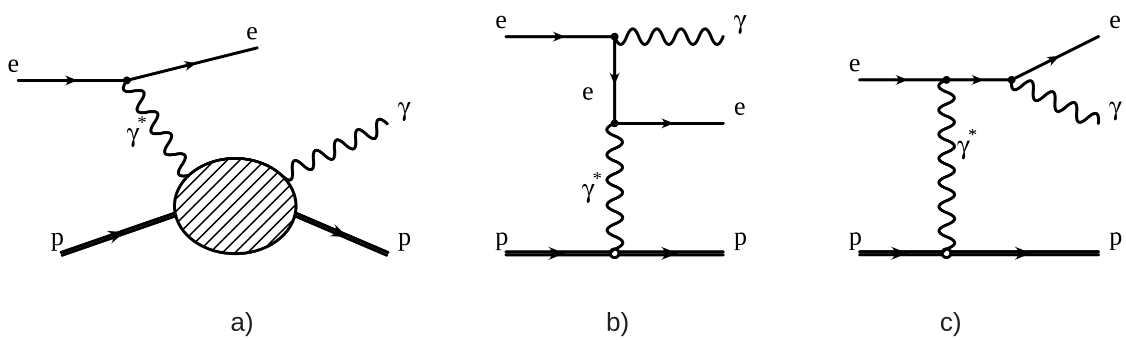
Compton Scattering Processes

$$e + p \to e + p + \gamma$$

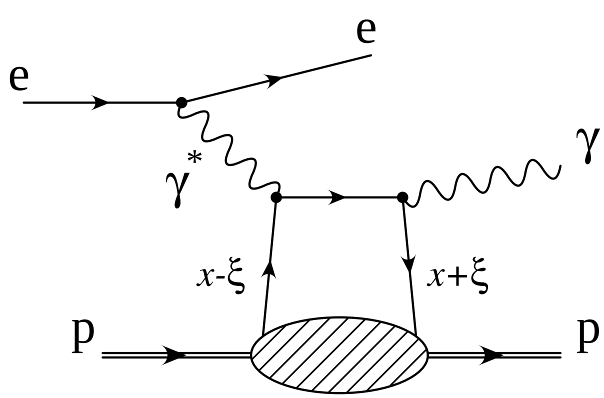
Compton Scattering Process is since long under experimental study at HERA:

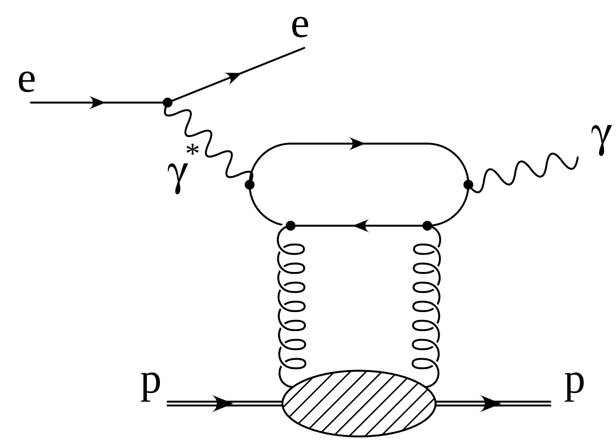
- Elastic Compton, Bethe-Heitler (BH) process – luminosity measurement
- Inelastic Compton – measurement of F_2 structure function (see talk of Ewelina)
- Deeply Virtual Compton Scattering (DVCS) – this talk



DVCS physics

Factorization theorem: can be calculated in perturbative QCD.





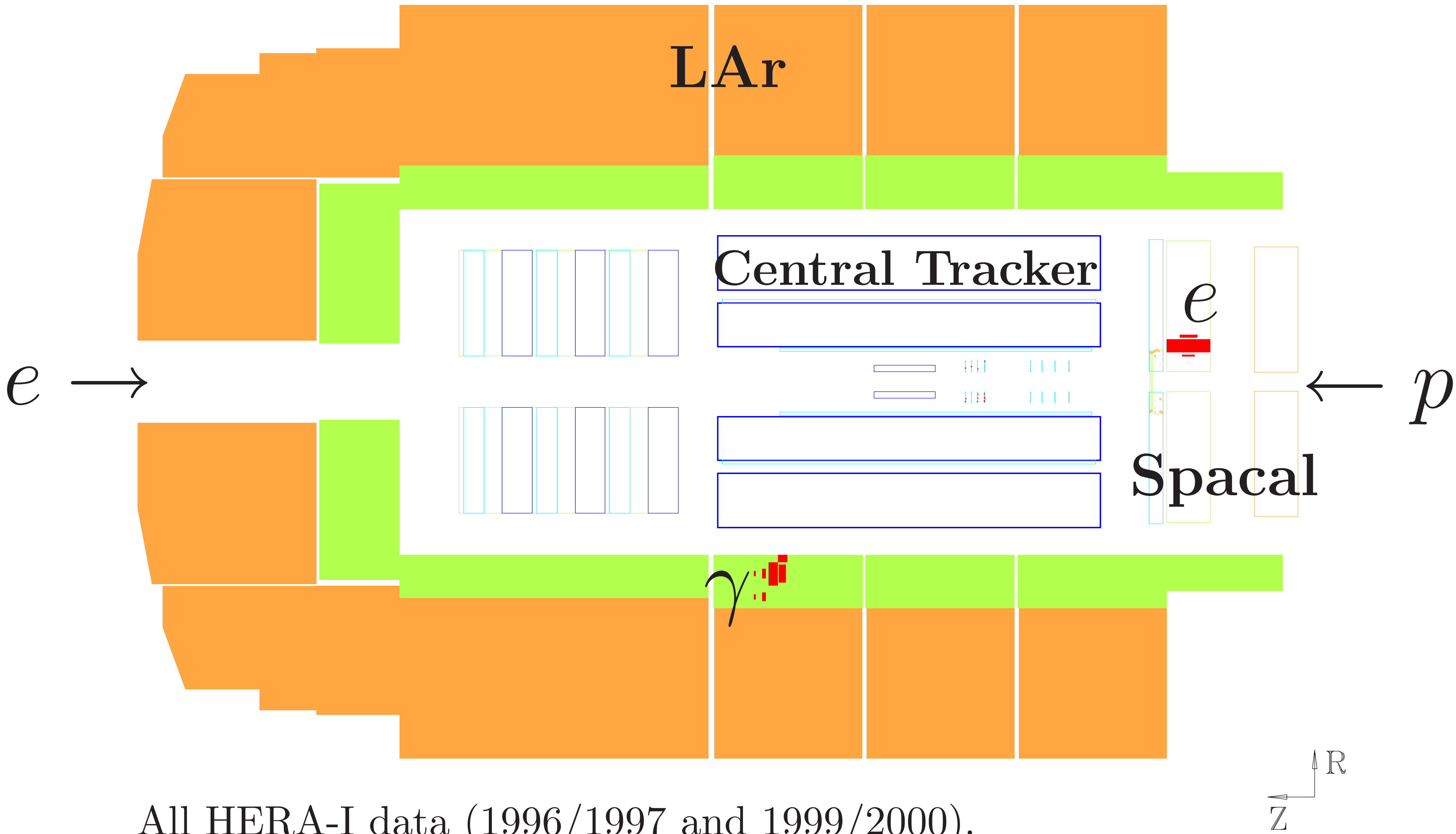
ξ – "skewedness", measures momentum difference between emitted/absorbed parton.

Generalized Parton Distributions:

- $H^{q,g}(x,\xi,t)$ – reduce to ordinary PDFs for $\xi \to 0, t \to 0$, i.e. $H^q(x,0,0) = q(x)$ where $q(x)$ is quark parton distribution.
- $E^{q,g}(x,\xi,t)$ has no PDF equivalent

At low x, sensitivity to NLO processes, in particular to $H^g(x,\xi,t)$. Contribution of $E^{q,g}(x,\xi,t)$ is small.

DVCS event in H1 detector



All HERA-I data (1996/1997 and 1999/2000).

Total $\mathcal{L} = 46.5 \mathrm{pb}^{-1}$

Monte Carlo simulation and Event Selection

Signal MC simulation is based on MILOU generator which includes NLO QCD cross-section calculation for DVCS, BH process + interference. Includes higher order radiative corrections.

COMPTON 2.1 simulates elastic and inelastic BH events; DIFFVM for ω and ϕ meson production.

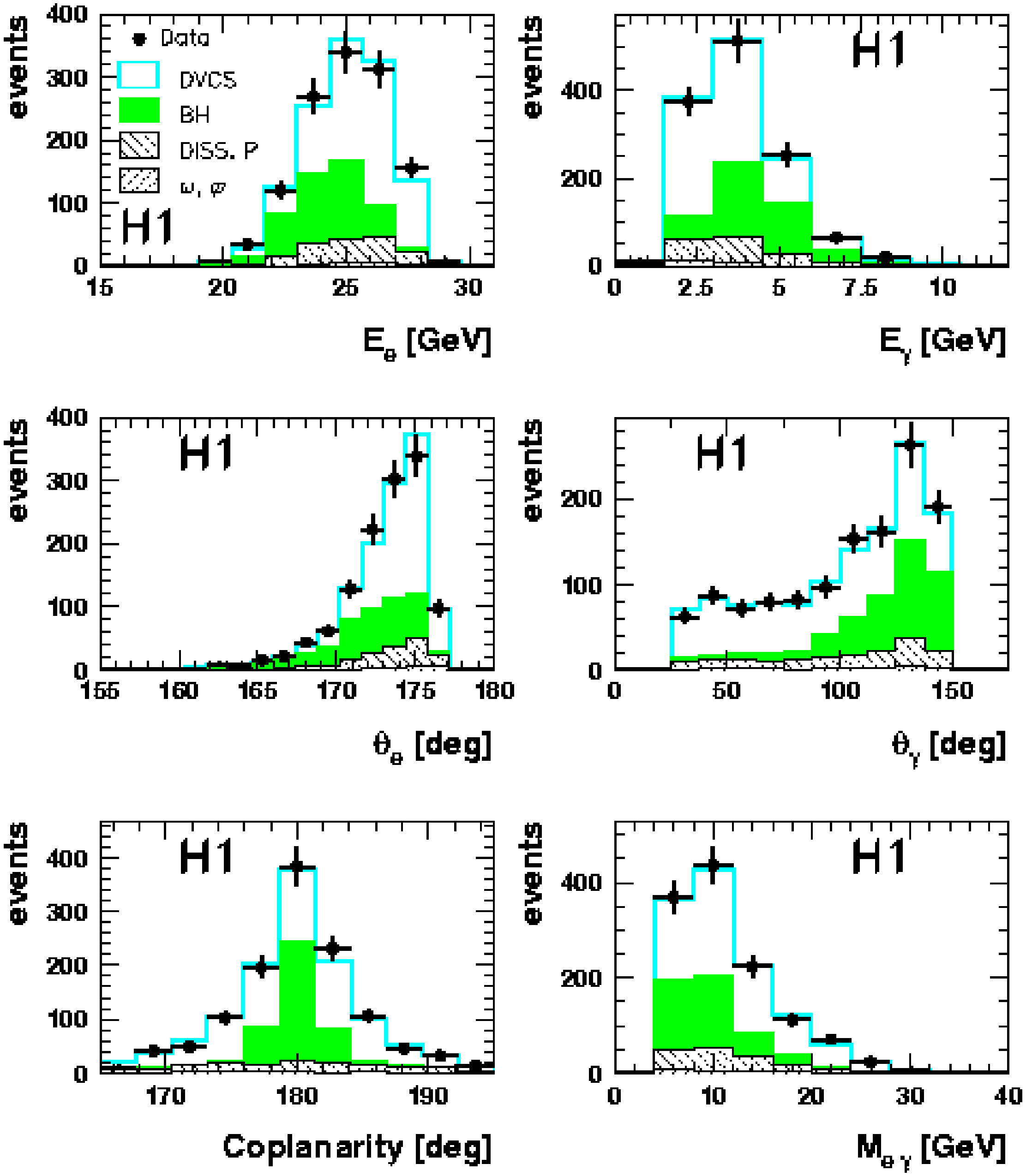
Kinematics reconstruction based on polar angles θ_e, θ_γ:

$$\begin{aligned} Q^2 &= 4E^2_{e\,beam}\frac{\sin\theta_\gamma(1+\cos\theta_e)}{\sin\theta_\gamma+\sin\theta_e-\sin(\theta_e+\theta_\gamma)} \\ x &= \frac{E_{e\,beam}}{E_{p\,beam}}\frac{\sin\theta_\gamma+\sin\theta_e+\sin(\theta_e+\theta_\gamma)}{\sin\theta_\gamma+\sin\theta_e-\sin(\theta_e+\theta_\gamma)} \\ W^2 &= \frac{Q^2}{x}(1-x) \end{aligned} \tag{1}$$

Selection criteria:

- Scattered electron in Spacal: $153^o < \theta_e < 175^o$, $E_e > 15$ GeV
- Photon in LAr: $25^o < \theta_\gamma < 145^o$, $p_\perp^\gamma > 1(1.5)$ GeV

Control plots



← Excellent agreement between data and MC for the scattered e, γ energy, angle, $e - \gamma$ coplanarity and $e - \gamma$ invariant mass. Significant BH background. Proton dissociation background is included in the signal MC (about 10%).

Cross Section Measurement

The background (diffractive ω, ϕ, inelastic Compton, proton dissociation) is subtracted bin by bin.

The elastic BH process interfere with DVCS, but this interference averages out for the measurement integrated in ϕ_γ (angle between $e - e'$ and $\gamma^* - \gamma$ planes) $\rightarrow$ and also bin by bin subtracted.

The data is corrected for acceptance and radiative corrections.

The cross section is reported in terms of $\gamma^* p \rightarrow \gamma p$:

$$\frac{d^3\sigma[ep \rightarrow e\gamma p]}{dy\, dQ^2\, dt}(Q^2, y, t) = \Gamma(Q^2, y)\,\frac{d\sigma[\gamma^* p \rightarrow \gamma p]}{dt}$$

using the photon flux Γ:

$$\Gamma = \frac{\alpha(1 - y + y^2/2)}{\pi\, y\, Q^2}, \qquad y = \frac{W^2 + Q^2}{s}$$

Systematic Uncertainties on the $ep \to ep\gamma$ Cross Section

The main contributions:

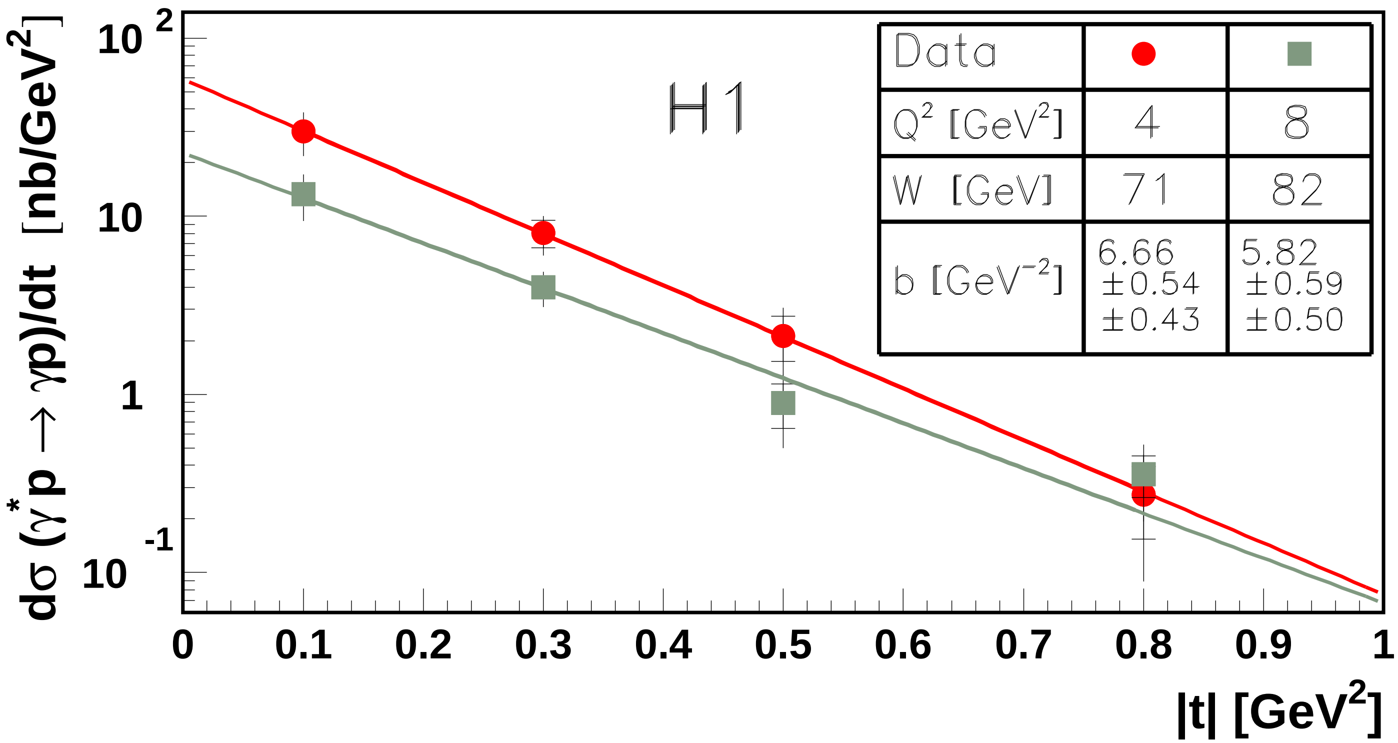
- Subtraction of proton dissociation background: $8 - 5\%$ (50% of the subtracted contribution)
- Acceptance correction (t-dependence): typically 5%, up to 12% for high t
- Bin center corrections (Q^2, W dependence): $5 - 7\%$
- Uncertainty in vertex position: $< 5\%$

Total systematic uncertainty: typically 20%, total statistical uncertainty: typically 20%

The proton dissociation background can be reduced with the new high acceptance proton tagger (VFPS). The acceptance/bin center correction systematic uncertainties are reduced with more data. The vertex position uncertainty can be minimized by using backward silicon tracker

$\to$ significant improvements in precision are expected with HERA-II data.

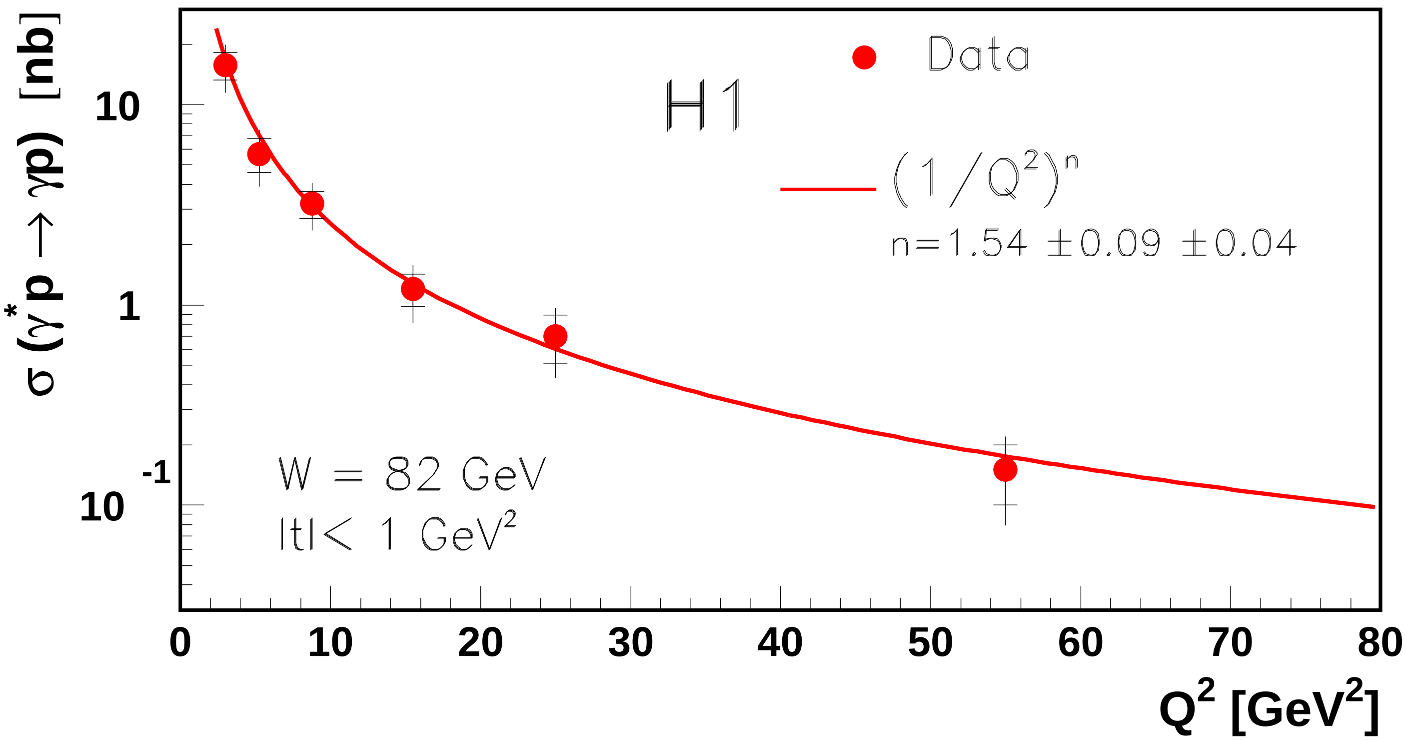
Results: t-dependence



- t is calculated as $t \simeq -\left|\vec{p}_{\perp,\gamma} + \vec{p}_{\perp,e}\right|^2$
- Data collected in 96/97 is used for $Q^2 = 4$ GeV bin, data collected in 99/00 is used for $Q^2 = 8$ GeV bin.
- Exponential fit in t: $d\sigma/dt = d\sigma/dt|_{t=0} \times \exp(-bt)$

Within the errors, b does not depend on Q^2.
Average b at $Q^2 = 8\mathrm{GeV}^2$: $b = 6.02 \pm 0.35_{\mathrm{stat}} \pm 0.39_{\mathrm{syst}}\ \mathrm{GeV}^{-2}$

Q^2 dependence

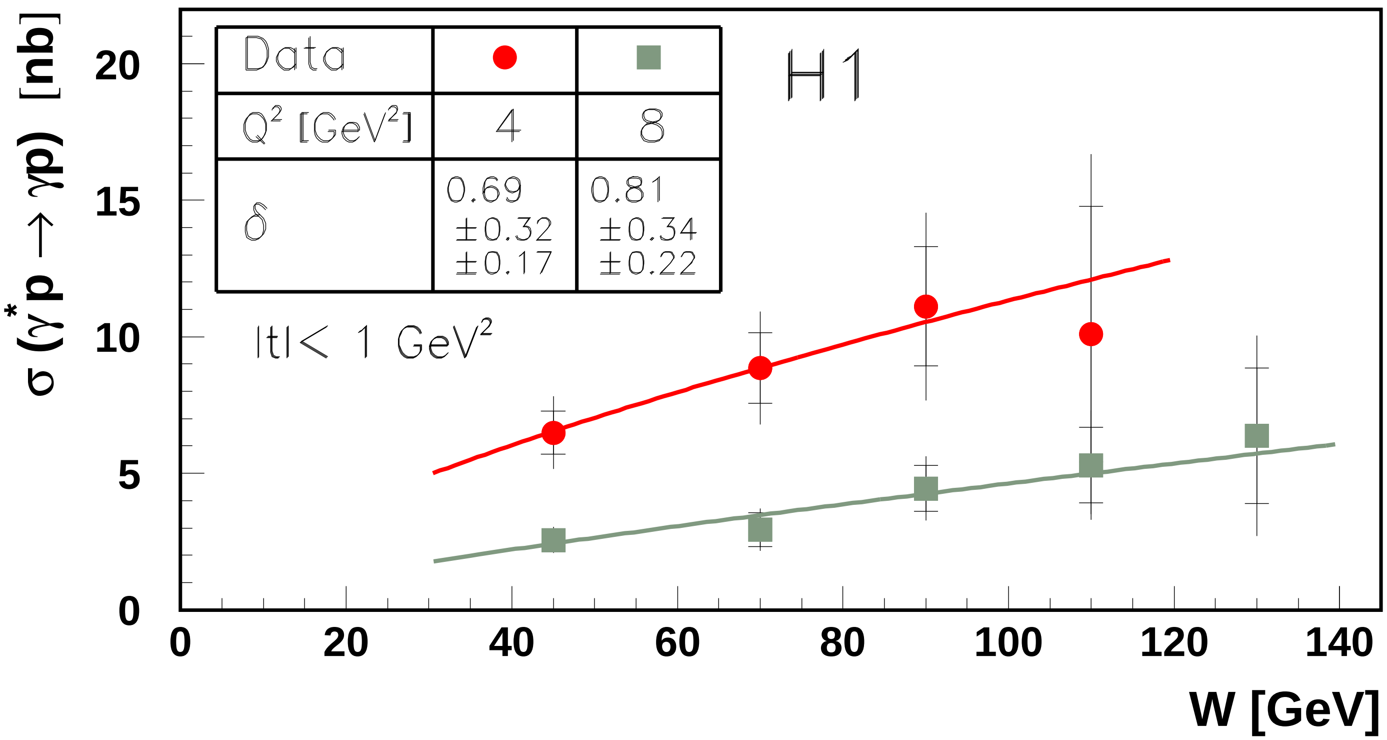


Average data of 96/97 and 99/00. Very good fit using parametrization:

$$\sigma(\gamma^* p \longrightarrow \gamma p) = A \times \left(\frac{1}{Q^2}\right)^n$$

Fitted n is consistent for different Q^2 ranges.

W^2 dependence



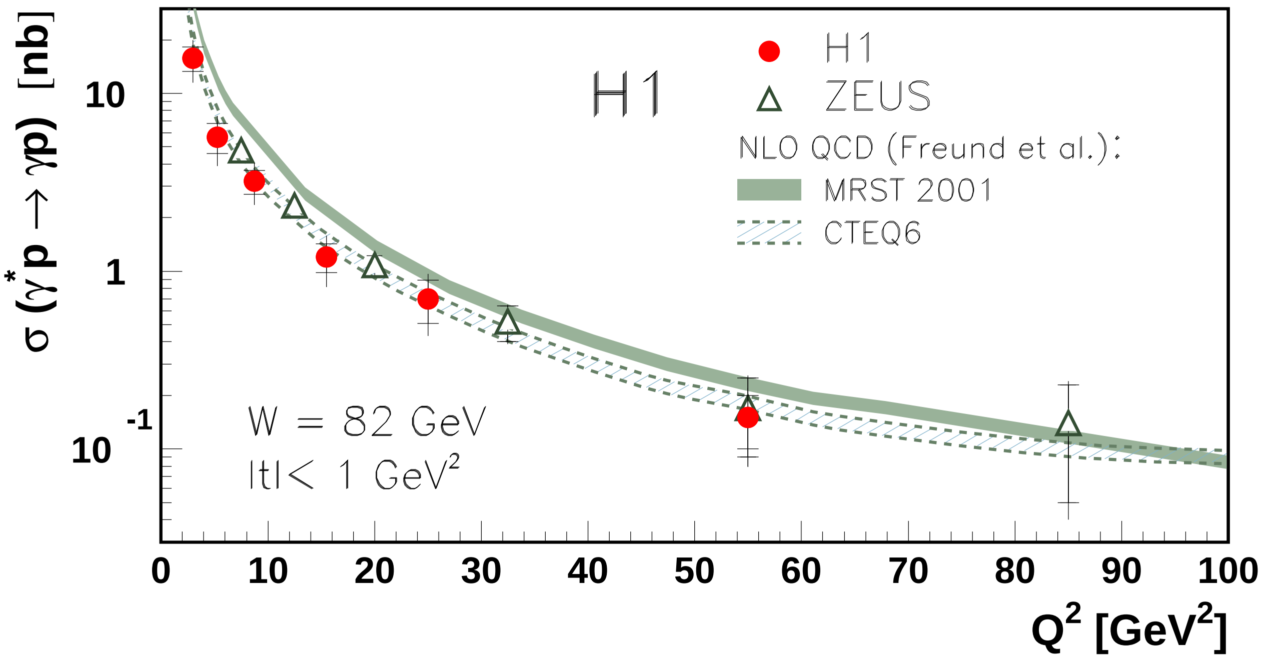
Fit power law dependence:

$$\sigma(\gamma^* p \to \gamma p) = A \times W^{\delta}.$$

Good description of the data, within the errors δ does not depend on Q^2.

Average $\delta_{comb} = 0.77 \pm 0.23(\text{stat}) \pm 0.19(\text{syst})$

Comparison with Zeus and Models: Q^2 dependence



$\leftarrow$ bands include exp. error in b

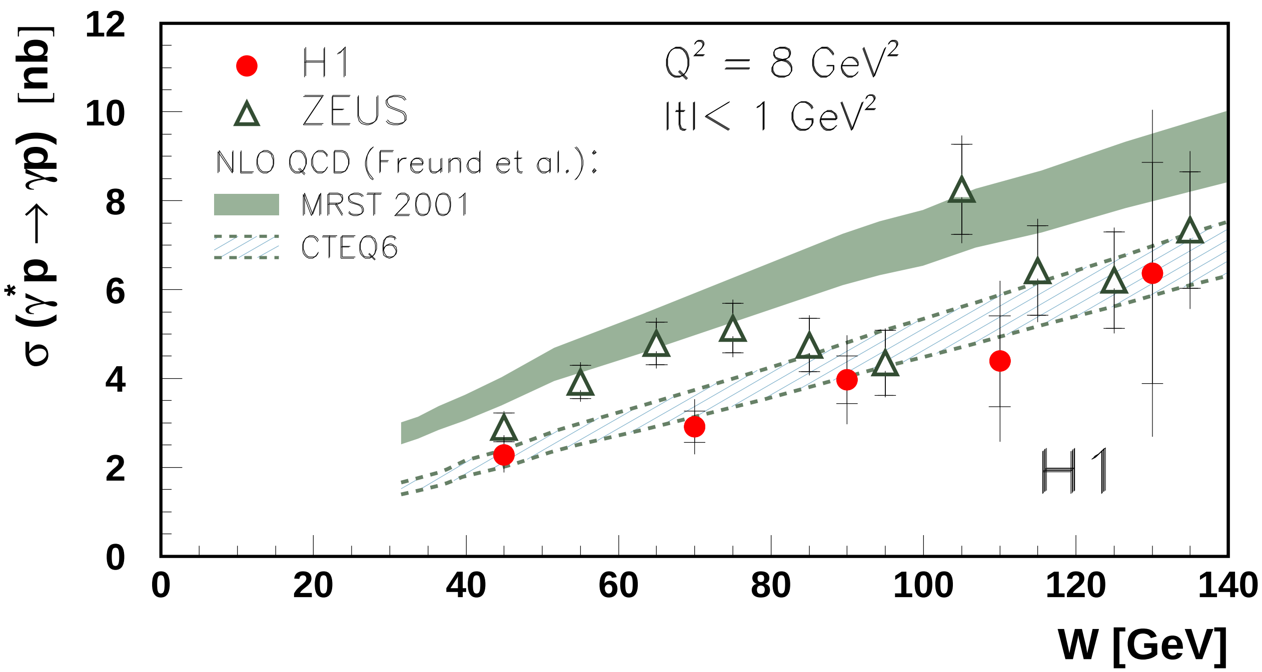
NLO Freund and McDermott calculation for $|x| > \xi$ uses ordinary PDFs of MRST2001 or CTEQ6 at the starting scale Q_0^2, i.e:

$$H^q(x, \xi, t; Q_0^2) = q(x; Q_0^2) \exp(-b|t|),$$

which are then QCD evolved. For $|x| < \xi$ smooth polynomial damping is used.

Zeus data, published at $W = 89$ GeV, is corrected to $W = 82$ GeV using quoted by Zeus $\delta = 0.75$.

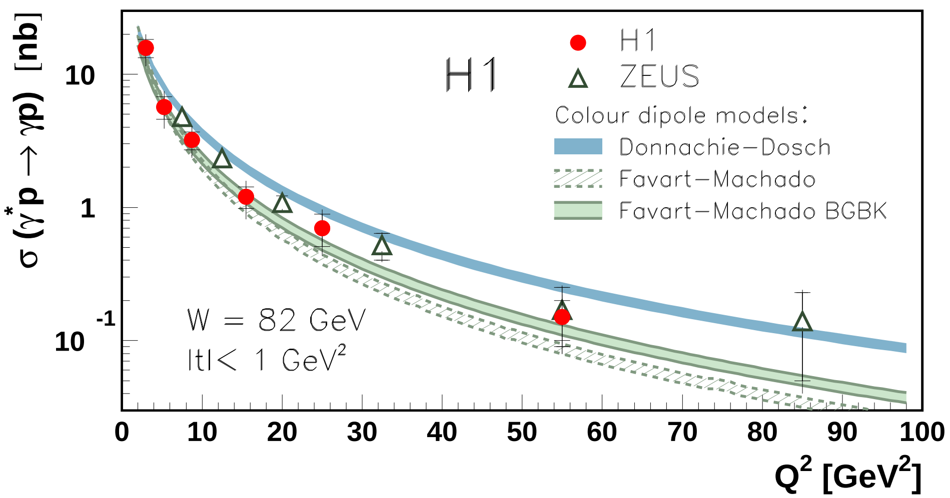
Comparison with Zeus and Models: W dependence

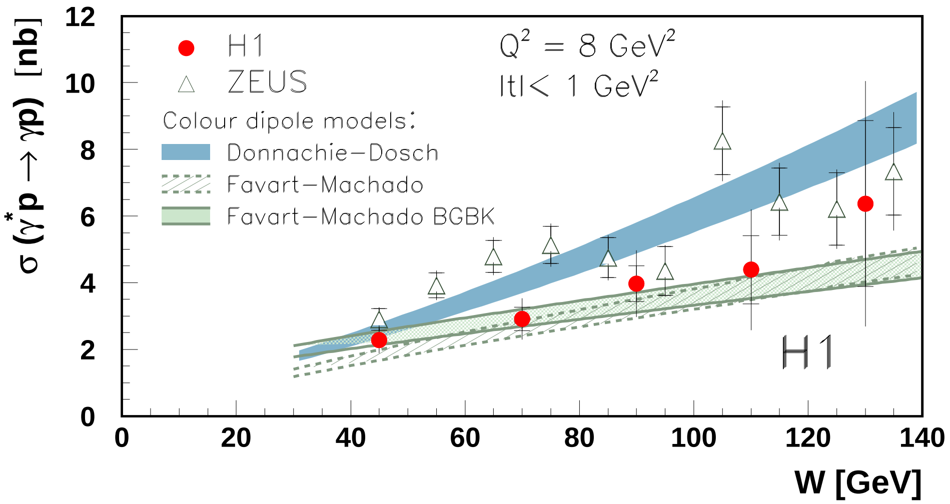


Good agreement between the new H1 result and NLO QCD calculation using CTEQ6 parton density parameterizations.

Zeus data, published at $Q^2 = 9.6$ GeV^2, is corrected to $Q^2 = 8$ GeV^2 using quoted by Zeus $n = 1.54$.

Comparison to Other Predictions





Color Dipole Models assume factorization of DVCS into incoming γ wave function, $q\bar{q}-p$ cross section and outgoing γ wave function.
Favart-Machado BFGK add DGLAP evolution following BFGK approach.

$\rightarrow$ fair description of the data in shape and normalization. Addition of DGLAP evolution improves agreement for Favart-Machado calculation.

Conclusions and Outlook

- Analysis of complete HERA-I DVCS sample has been performed.
- The t dependence of the cross section is measured for the first time.
- The measurement is in good agreement with NLO QCD calculations of Freund and McDermott.

HERA-II data with more statistics, new detectors (VFPS) and improved analysis techniques should further improve precision of the measurement and allow more differential analysis of the cross section.

Also, charge asymmetry measurement will allow to measure real part of the DVCS amplitude $\rightarrow$ better constraint to the theory predictions.