Measurement of Deeply Virtual Compton Scattering Using the ZEUS Detector at HERA

Presentation of the Ph.D. Award of the Association of the Friends and Sponsors of DESY

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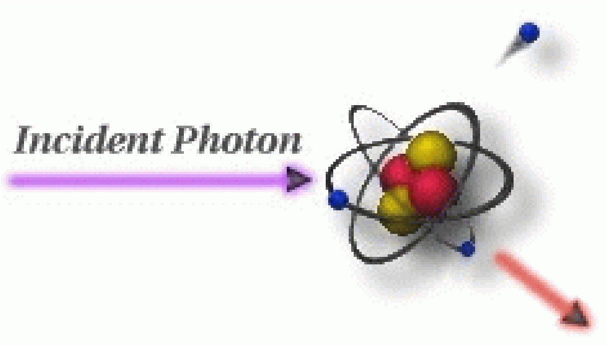
- **General introduction**
- **Introduction to DVCS**
- **Results**
- **Summary**

Introduction: Compton Scattering

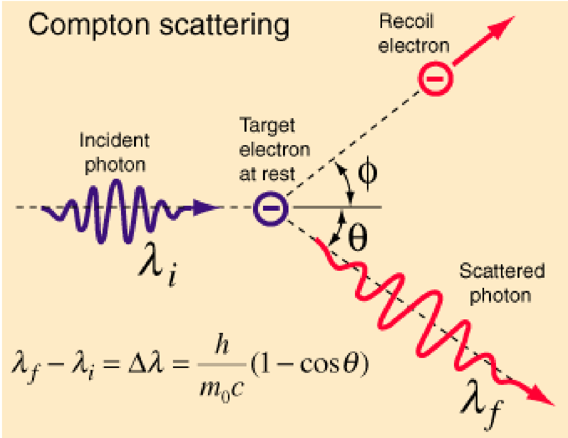


In 1922 the Compton experiment gave clear and independent evidence of particle-like behaviour of the photon.

$$E_{photon} = h \cdot \frac{c}{\lambda}$$

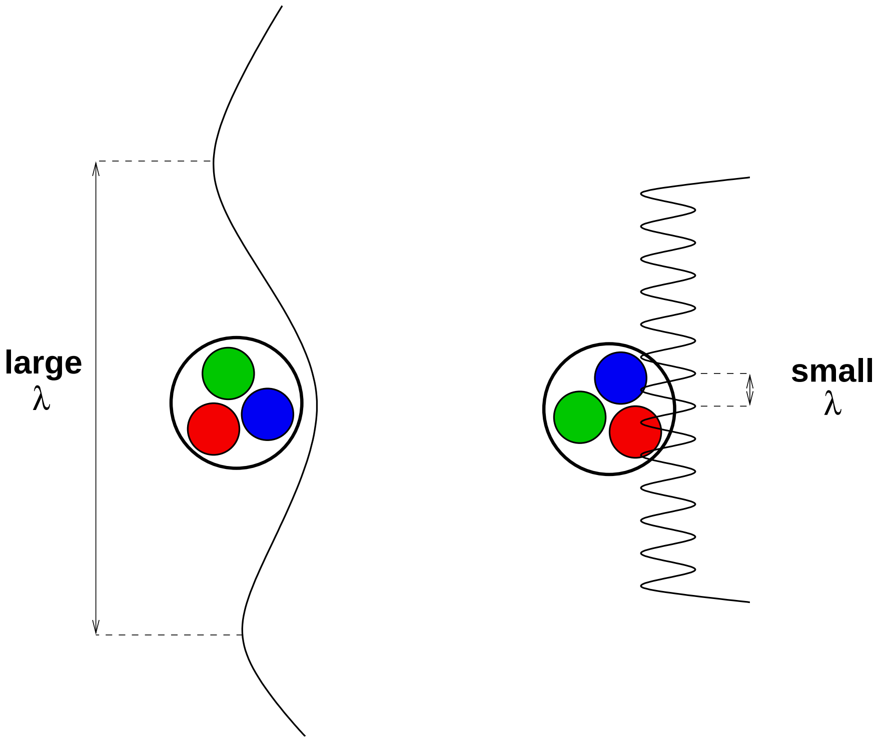
h - Planck's constant, c - speed of light, λ - wavelength

(Compton was awarded the Nobel Prize in 1927 for the "discovery of the effect named after him".)



This wave-particle duality is now one of the corner stones of our thinking about physics.

ZEUS - HIGH ENERGY EXPERIMENT AT HERA

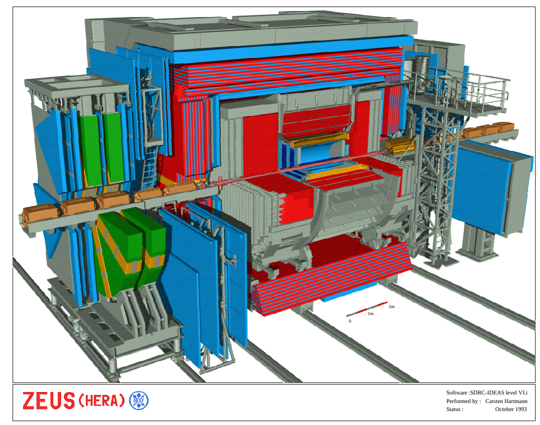


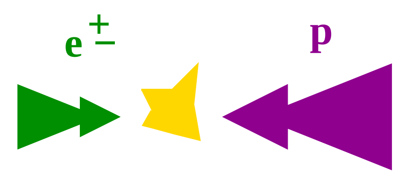
Heisenberg's Uncertainty Principle

$$\Delta p \cdot \Delta x \approx h$$

Distance scale is given by virtuality Q^2:
high Q^2 means a short distance.

ZEUS detector





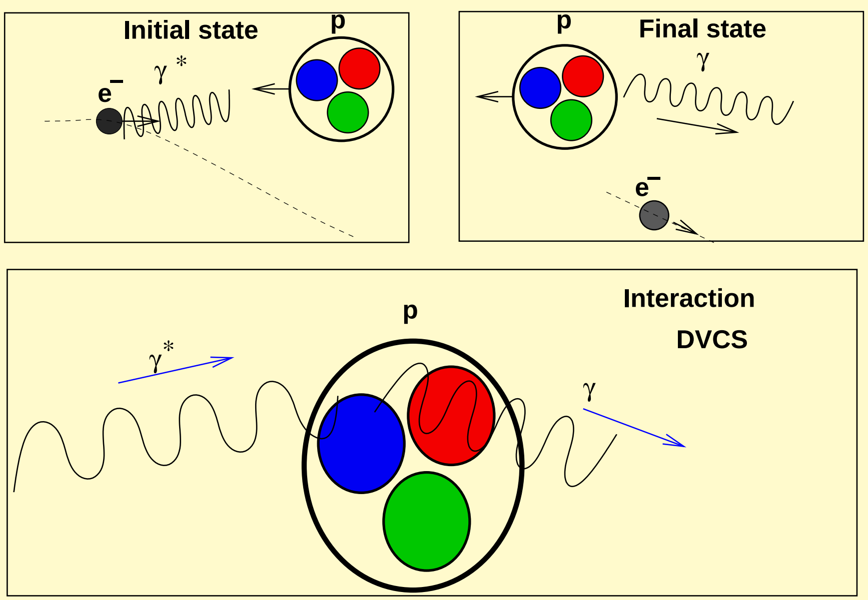
27.5 GeV **820−920 GeV**

Electrons are a source of high energy (so short wavelength) photons. Resolution approaches 0.001 of the proton radius ($10^{-18}\ m$).

Introduction to DVCS

$$ep \to e'\gamma^* p \to e'\gamma p'$$

DVCS: diffractive production of a real photon



Competing process: Bethe-Heitler (BH)
- fully calculable within Quantum Electrodynamics (QED)

$$ep \to e'\gamma p'$$

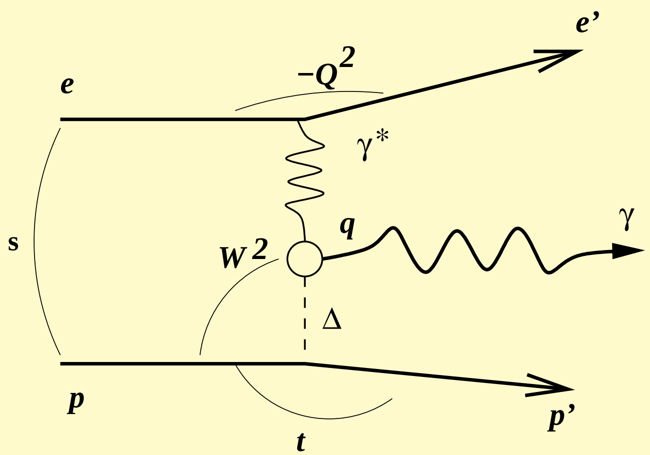
$\sigma^{ep \to e'\gamma p'} = \sigma^{DVCS} + \sigma^{BH} +$ interference

Thanks to an access to interference we can reach wealth of physics.

Introduction to DVCS cont.

$$ep \to e'\gamma^* p \to e'\gamma p'$$

Feynman's diagram for DVCS:



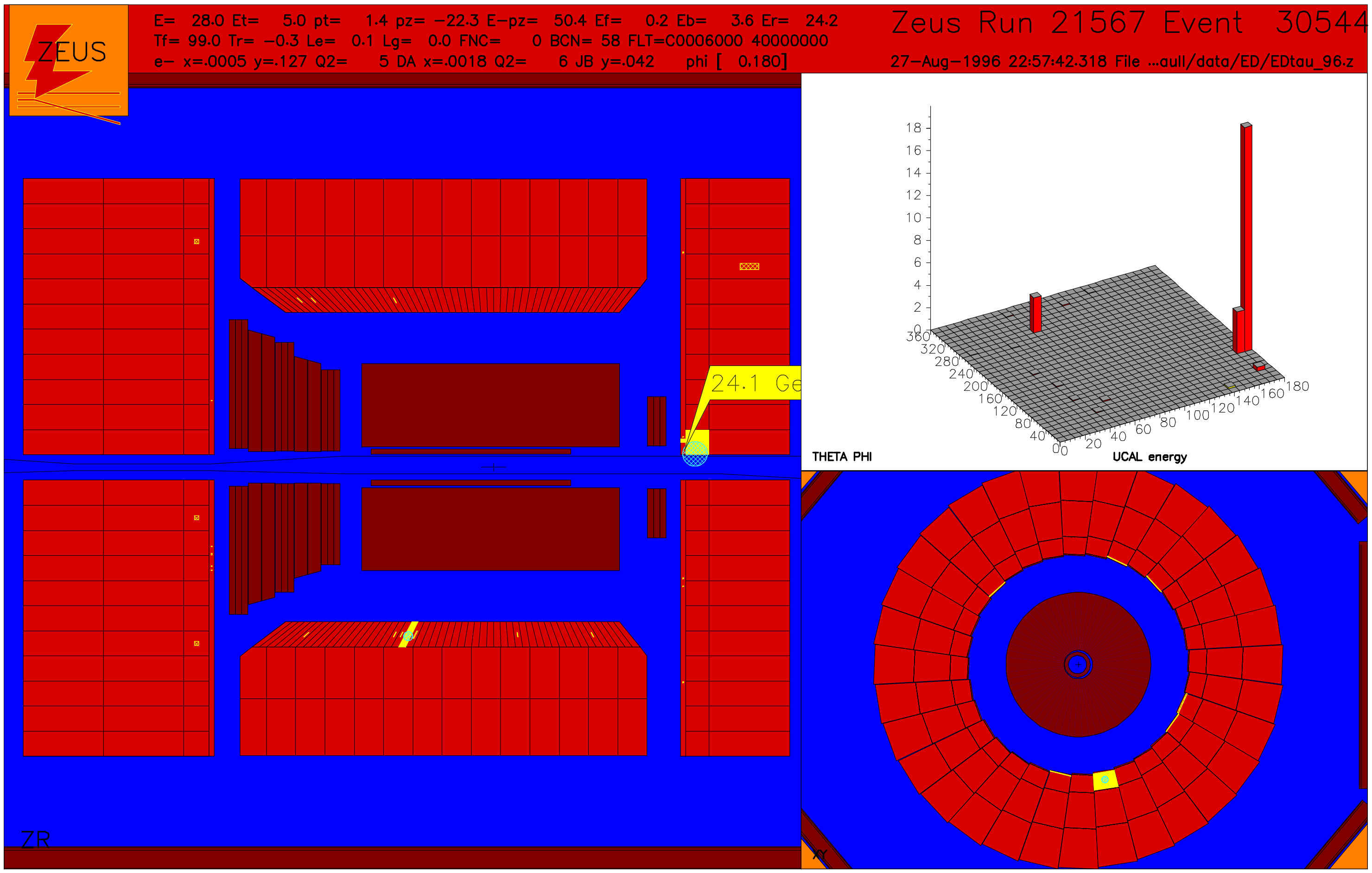
The DVCS process similar to a diffractive vector meson (VM) production, in which instead of a photon is a VM.

Kinematic variables

$\sqrt{s}$	ep energy	$\sqrt{s}$: 300 – 318 GeV
Q^2	virtuality	$5 < \mathrm{Q}^2 < 100\ \mathrm{GeV}^2$
W	$\gamma^* p$ energy	$40 < \mathrm{W} < 140\ \mathrm{GeV}$
t	(4-momentum transfer)^2	$\int_{-\infty}^{0} dt$
x	Bjorken scaling variable	$10^{-4} < \mathrm{x} < 10^{-2}$

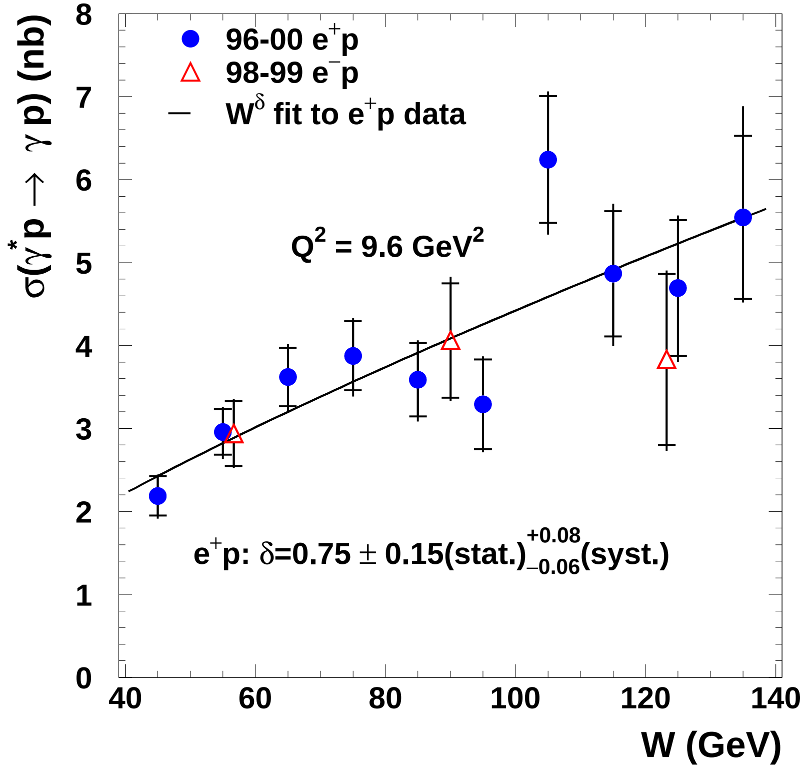
In this analysis essentially all HERA I data (1996-2000) analysed.

DVCS EVENT IN THE ZEUS DETECTOR



Only an electron and a photon observed in the detector.

RESULTS: POSITRONS VS. ELECTRONS IN W



There is no difference between e^+p and e^-p.

First measurement of σ for e^-p (17 pb^{-1}) and so many statistics for e^+p (95 pb^{-1}).

Measurement insensitive to the interference term.

Parameterisation of the form $\sigma \sim W^\delta$

$$e^+p : \delta = 0.75 \pm 0.15(\text{stat.})^{+0.08}_{-0.06}(\text{syst.})$$

$$e^-p : \delta = 0.45 \pm 0.36(\text{stat.})^{+0.08}_{-0.07}(\text{syst.})$$

Rapid rise of σ with $W \Rightarrow$ hard nature of the process.

RESULTS: POSITRONS VS. ELECTRONS IN Q^2

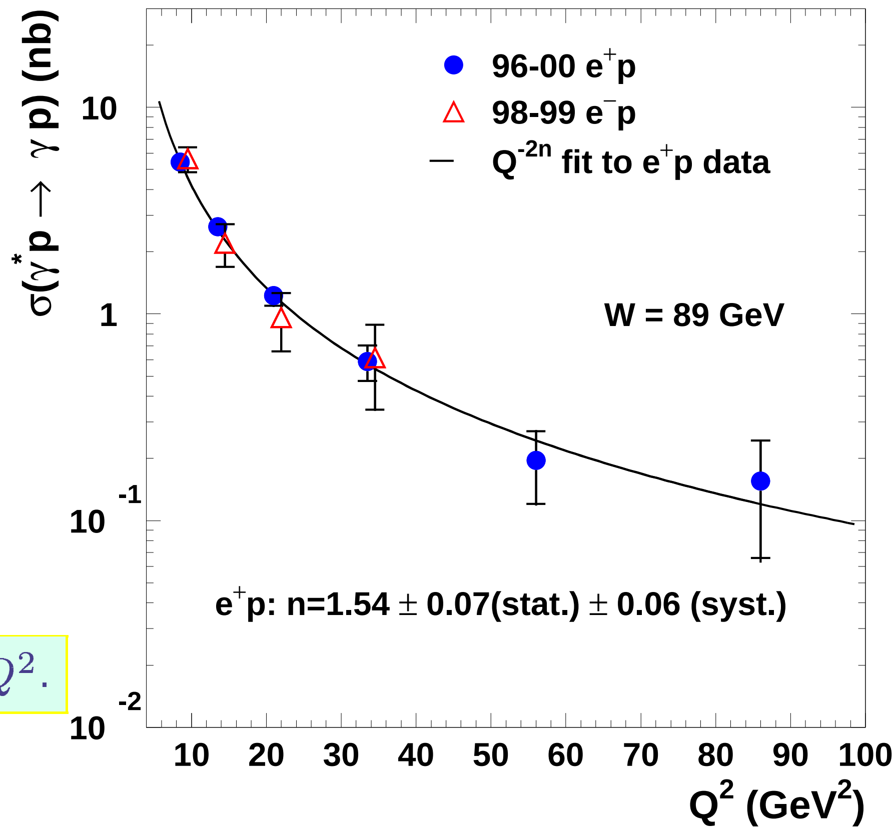
Within uncertainties there is no difference between e^+p and e^-p.

Parameterisation of the form $(Q^2)^{-n}$

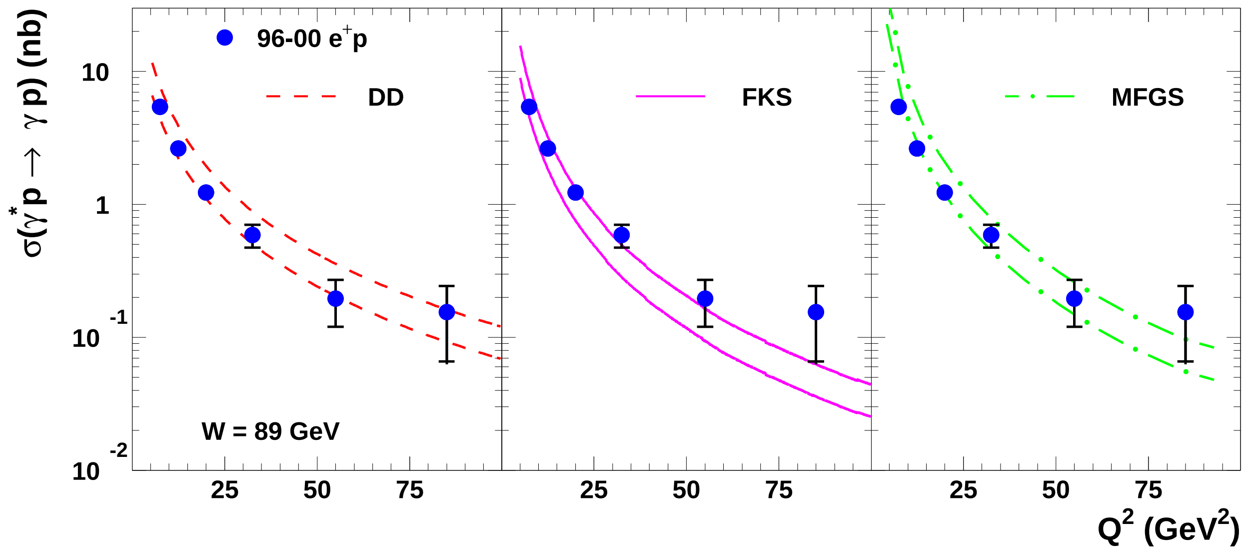
$$e^+p : n = 1.54 \pm 0.07(\text{stat.}) \pm 0.06(\text{syst.})$$

$$e^-p : n = 1.69 \pm 0.21(\text{stat.})^{+0.09}_{-0.06}(\text{syst.})$$

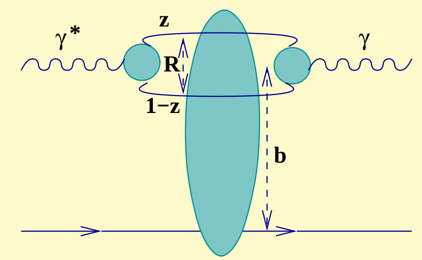
For DVCS $n < 2.0$ (VM) less suppressed with Q^2.



COMPARISON WITH COLOUR DIPOLE MODEL



DVCS process in CDM



$d\sigma/dt \sim \exp(-b|t|)$

b is a parameter

$4 < b < 7\ \mathrm{GeV}^{-2}$

Three models tested

DD: soft and hard pomeron exchange

FKS: σ_D depends on (W, R), does not depend on Q^2

MFGS: σ_D depends on W, R and Q^2

Direct measurement of b is needed!

Comparison with calculations based on pQCD with GPD

⋆ Several theoretical approaches tested.

Different parton distribution functions investigated (CTEQ, MRST) and order of calculations (L-LO, M-NLO).

$$d\sigma/dt = \exp(-b|t|)$$

b unknown, in particular $b(Q^2)$

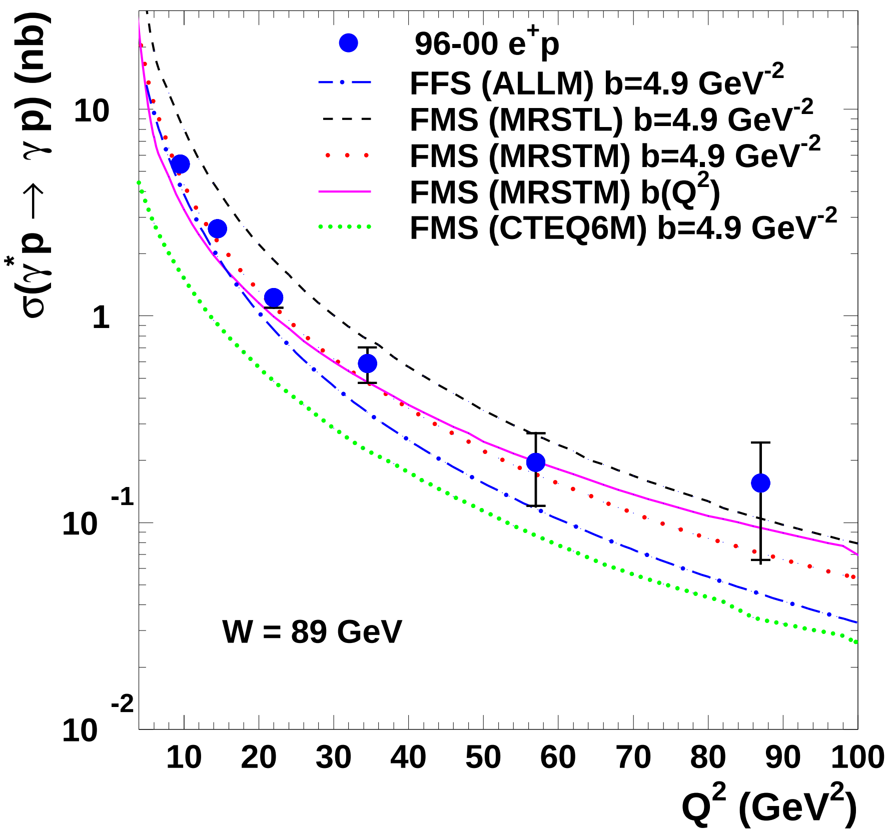
Results

⋆ The best description for MRSTM

⋆ $b = b(Q^2) = 8 \cdot (1 - 0.15 \cdot ln\frac{Q^2}{2})$

Conclusion

⋆ Direct measurement of $b(Q^2)$ is desired!



SUMMARY

- Theoretically DVCS is of great interest,
  - ⋆ very important in Quantum Chromodynamics due to its easy/simple final state
- Experimentally it is just started,
- First significant measurement for e^+p and first in the world result for e^-p,
- Parameterisation of $\sigma(W)$ shows hard nature of the process,

★ Need of direct b measurement,

- Results published in Phys. Lett. B 573 (2003) 46-62

ACKNOWLEDGEMENTS