$\sigma(\gamma^* \, proton)$ for $Q^2 \to 0$

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1. Aim
2. Relation between $\sigma(\gamma^* \, proton)$ and F_2
3. Phase space of new data
4. Comparison of F_2 ZEUS BPT and BPC
5. The properties of F_2/q
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Aim

- New low-x and low-Q^2 data published since DIS 2000 :
  ZEUS : BPT-data DESY Preprint 2000-71 (May 2000) and PL B487 (2000)53
  H1 : DESY Preprint 2000-181
- Previous F_2-data well described by

  $$F_2(x, Q^2) = m \cdot \log\ (1 + Q^2/Q_0^2) \cdot \log\ (x_0/x)$$

  for $x < 0.001$ and all Q^2
- The parametrisation satisfies $F_2 \rightarrow 0$ for $Q^2 \rightarrow 0$ (CVC)
- BPT-data by ZEUS extend phase space allowing for stringent test down to Q^2= 0.045 GeV^2
- Investigate transition of $\sigma(\gamma^*\ proton)$ to the $\gamma\, p$–limit
- Compare extrapolation with measurements of $\sigma(\gamma\ proton)$ by H1 at W=200 GeV and ZEUS (prel) at W=207 GeV

$\sigma(\gamma^* \ proton)$ versus F_2

- $\sigma^{\gamma^* p}$ is related to F_2 in ep scattering

$$\sigma^{\gamma^* p}(W^2, Q^2) = \frac{4\pi^2\alpha}{Q^4} \cdot \frac{4M_p^2 x^2 + Q^2}{1-x} \cdot F_2(W^2, Q^2)$$
$$\approx \frac{4\pi^2\alpha}{Q^2} \cdot F_2(W^2, Q^2)$$

- Empirical fact : F_2 at low x linear in $q = \log\,(1+Q^2/Q_0^2)$

- Note : $Q^2 \to 0$ implies $q \sim Q^2/Q_0^2$

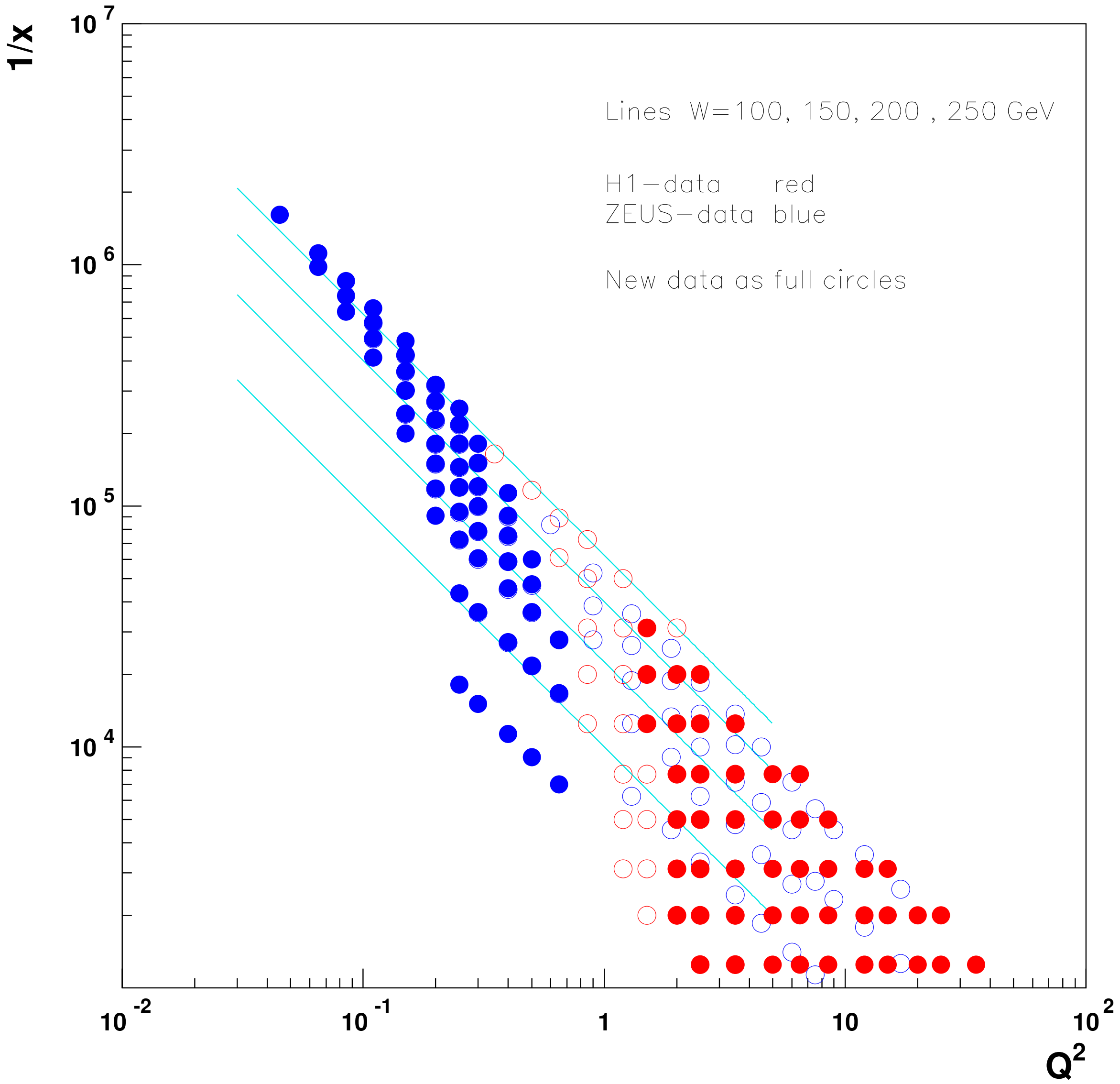
- Rewrite :

$$\sigma^{\gamma^* p}(W^2, Q^2) = \frac{4\pi^2\alpha}{Q_0^2} \cdot \frac{q}{Q^2/Q_0^2} \cdot \frac{F_2(W^2, q)}{q}$$

- F_2/q governs transition $\sigma(\gamma^* \ p) \to \sigma(\gamma \ p)$

- Theory : the transition is smooth

Low-x and low-Q^2 data



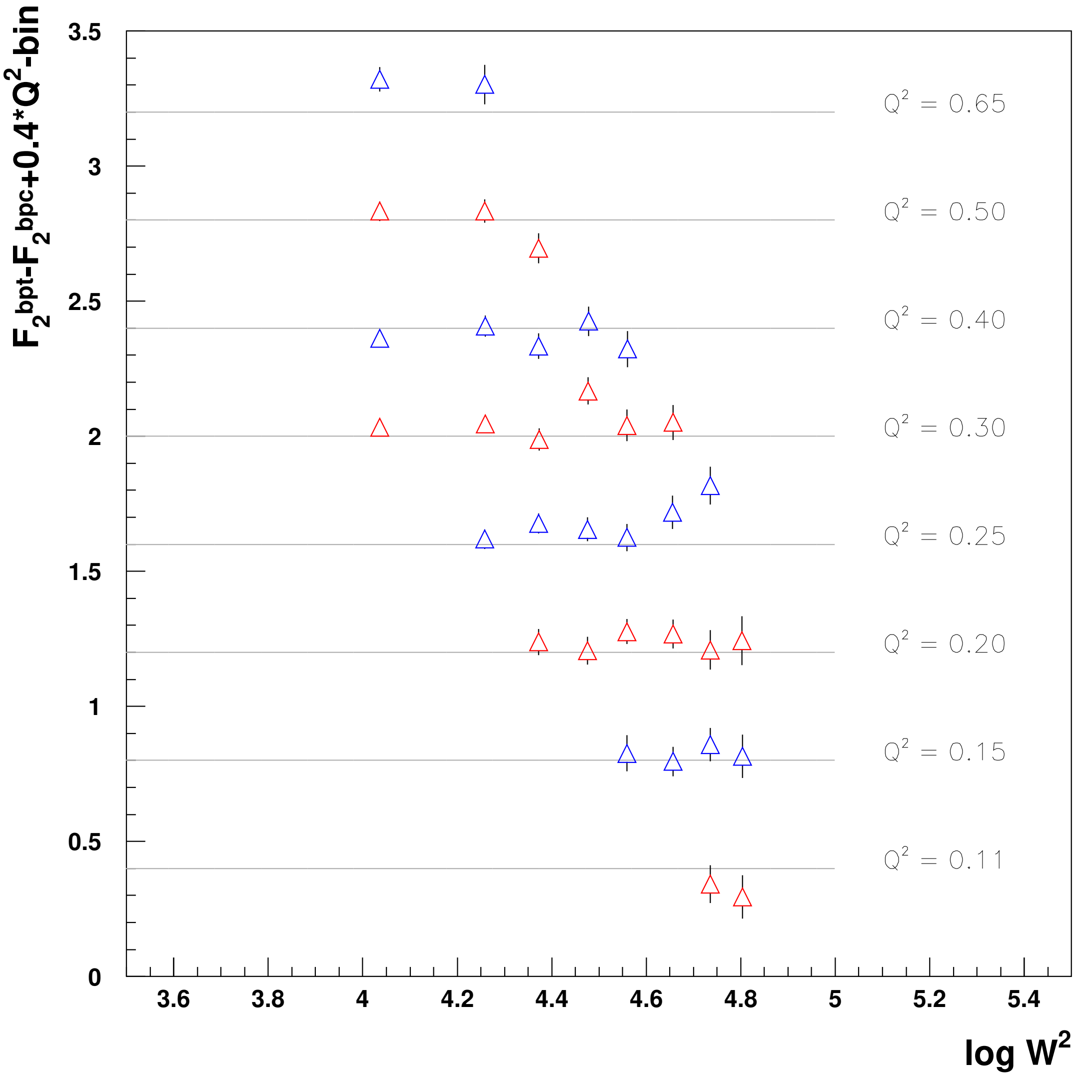
- H1 data : Nucl.Phys. B497 (1997) 3
  Eur.Phys.J C (2001) = DESY 00-181
- ZEUS data : DESY 00-71 (bpt); Phys.Lett. B407 (1997) 432 (bpc) ; Eur.Phys.J C7 (1999) 609 (svx)

$F_2(x,q)^{BPT}$ - $F_2(x,q)^{BPC}$

34 F_2-measurements at common (Q^2, y)-points

Test : $F_2^{bpt} - F_2^{bpc} = 0$

$\langle F_2^{bpt} - F_2^{bpc} \rangle$=0.031 $\pm$ 0.008 (χ^2/dof=50/33)



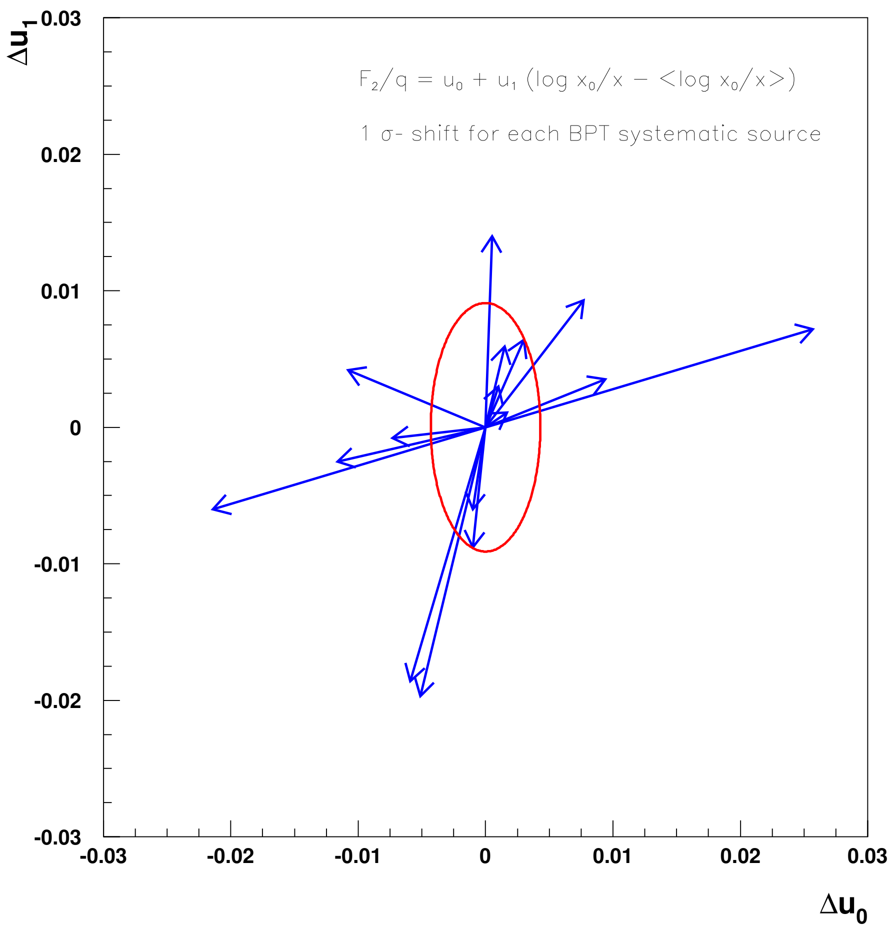
Conclusion : Systematic uncertainties important

Systematic uncertainties of $F_2(x,q)^{BPT}$

- ZEUS made careful study of 15 systematic error sources
- Previous low-x F_2-data well described by

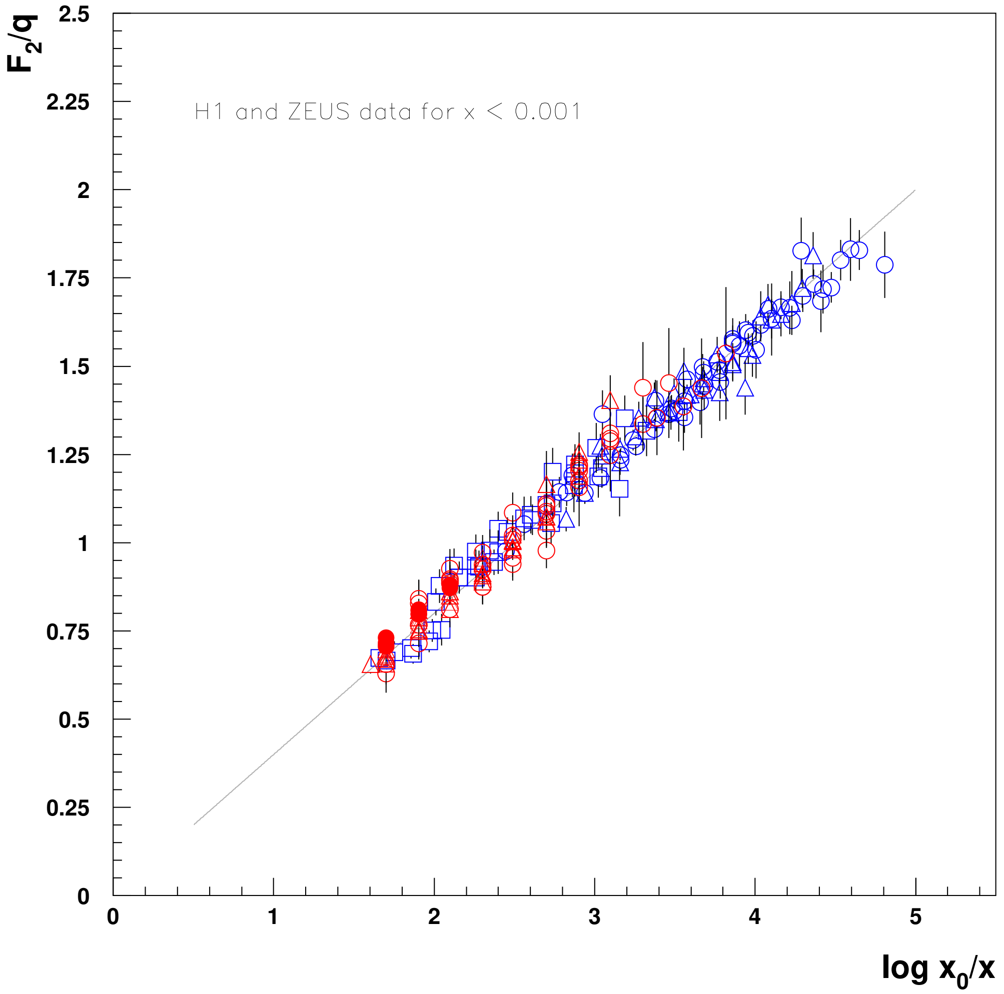
$$\frac{F_2(x,q)}{q} \quad = \quad u_0 + u_1(\log\ (x_0/x) - \langle \log\ (x_0/x)\rangle)$$

- Study effect induced by 1-σ shift



Properties of the observable F_2/q

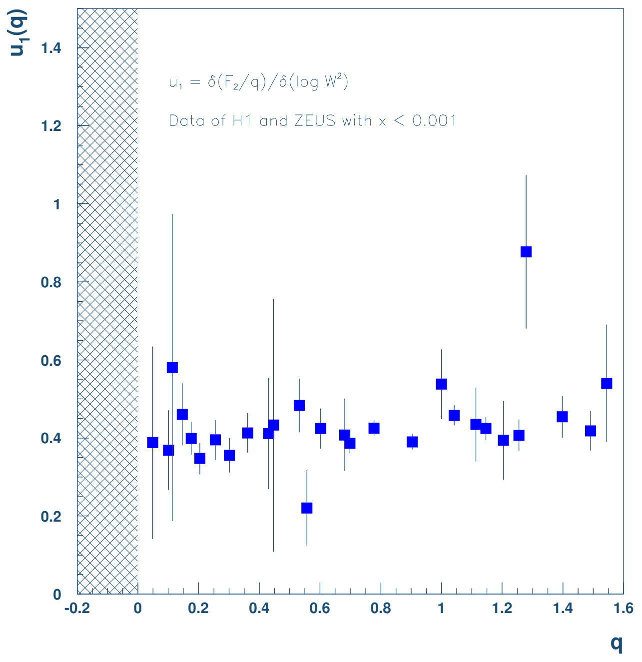
- Plot F_2/q of old and new data for $x < 0.001$ and all Q^2

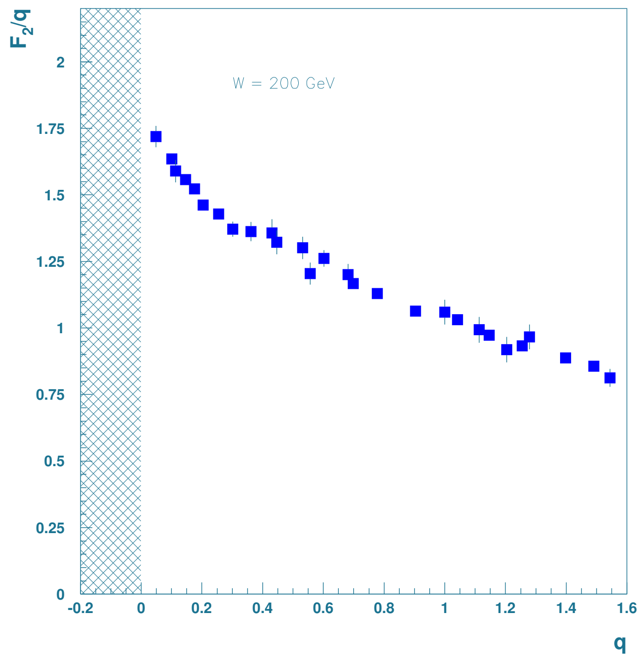


- Confirm the empirical fact : $F_2/q \sim \log\ (1/x)$ and no visible Q^2-dependence

F_2/q versus q

- Relevant kinematic variables for transition $\sigma(\gamma^* \; p) \to \sigma(\gamma \; p)$ are q (or Q^2) and W^2
- Analyse the F_2/q-data for fixed q in terms of $\log\, W^2$
  - linear in $\log\, W^2$: plot slopes versus q
  - plot absolute value for $W = 200$ GeV

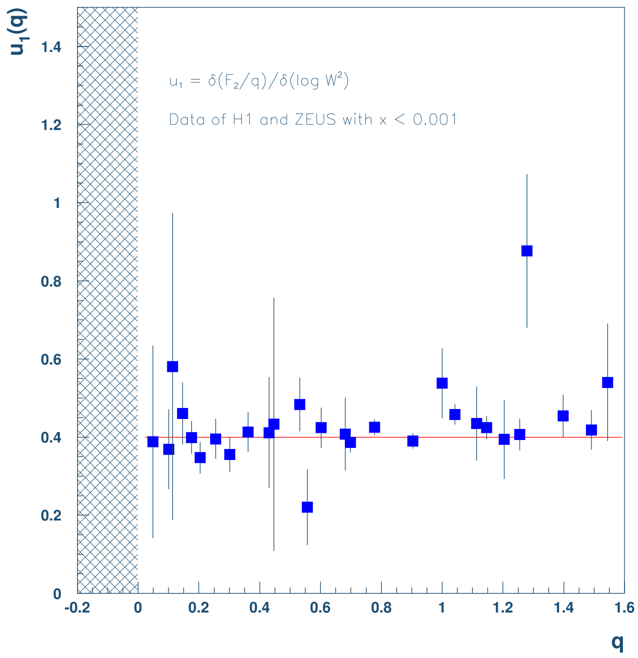


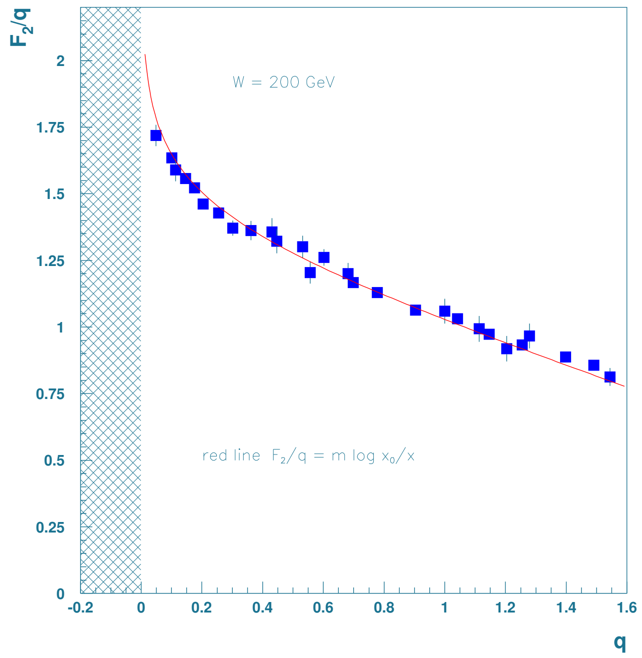


- How to close the gap from $q = 0.05$ to 0 ?

Compare with parametrisation

- Red line shows expectation from parametrisation $F_2/q = m \log x_0/x$



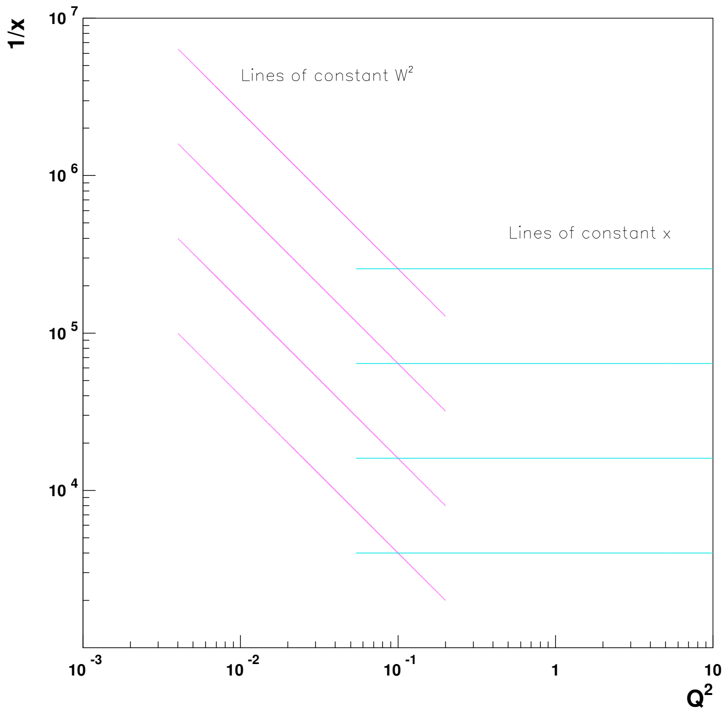


- d $F_2/q = m$ d $\log W^2$ - $m(1 + Q_0^2/Q^2)$ d q
- Left figure : slopes constant as expected
- Right figure : agreement where measured
  - large q : slope is Q^2-independent
  - small q : Q_0^2/Q^2-term causes ∞
- Transition must be smooth !

$\sigma(\gamma^* p)$ in the transition region

$Q^2 \ll 0.1$ GeV^2
function of W^2

$Q^2 > 0.1$ GeV^2
function of x



Replace $\frac{x_0}{x} \to \kappa = \frac{x_0}{x} \frac{Q^2}{Q^2+Q_w^2}$

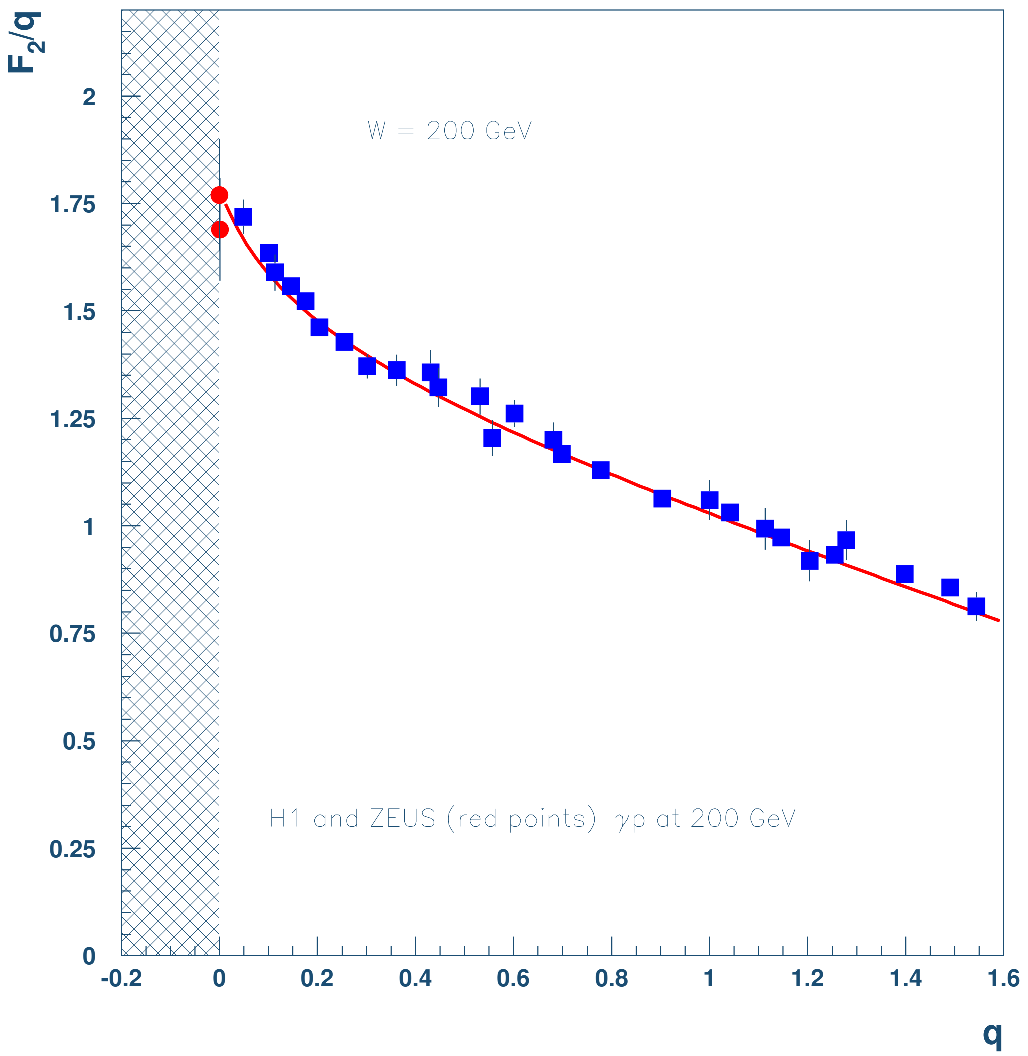
$\kappa \to W^2/W_0^2$

$\kappa \to x_0/x$

(a) κ interpolates between W^2 and x
(b) for $Q_w^2 < 0.1$ previous representation unaffected

A solution

- Extrapolate linearly from $q = 0.05$ to 0
- New formula : $F_2/q = m \log\left(\frac{x_0}{x}\frac{Q^2}{Q^2+Q_w^2}\right)$



- For $Q_w^2 \approx 0.05$ GeV^2 agreement with $\sigma(\gamma p)$ (red points) measured by H1 and ZEUS

Conclusions

- All F_2-data are consistent with each other
- Systematic uncertainties are well estimated and must be taken into account
- F_2/q is the key quantity in the study of $\sigma(\gamma^* \ proton) \rightarrow \sigma(\gamma \ proton)$:
  - the low-x and low-Q^2 data are well described by

$$F_2(x,q)/q = m \log \ (x_0/x)$$

  - The parametrisation can be extended to the $\gamma \, p$–limit with the modification

$$\frac{x_0}{x} \rightarrow \frac{x_0}{x} \frac{Q^2}{Q^2 + Q_w^2}$$

- For $Q_w^2 \approx$ 0.05 GeV^2 the extrapolation to $\sigma(\gamma \ proton)$ agrees with the measurements of H1 at W=200 and ZEUS (prel) at W=207 GeV
- $\sigma(\gamma \ proton)$ is logarithmic in W^2