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The F_L extraction at low $Q^2 (\sim 1\ \mathrm{GeV}^2)$

1. Introduction
2. Cross section
3. Methods to extract F_L
4. Results

Introduction

- in QPM photon interacts with spin 1/2 particle having only longitudinal momentum $\Rightarrow \mathbf{F_L(x) = 0}$ Callan–Gross relation
- in QCD quarks interact via gluons; quark struck by virtual photon has transverse momentum $\sim \mathbf{Q} \Rightarrow \mathbf{F_L(x, Q^2) > 0}$

$\mathbf{F_L}$ due to its origin is directly connected with gluon distributions in the proton $\Rightarrow$ sensitive test of perturbative QCD

Double differential DIS cross section:

$$\frac{d^2\sigma}{dxdQ^2} = \frac{2\pi\alpha^2}{Q^4x} Y_+ (F_2(x, Q^2) - y^2 F_L(x, Q^2))$$

where $\mathbf{Y_+ = 1 + (1 - y)^2}$

$$F_2(x, Q^2) = \frac{Q^2}{4\pi^2\alpha}(\sigma_T(x, Q^2) + \sigma_L(x, Q^2))$$

$$F_L(x, Q^2) = \frac{Q^2}{4\pi^2\alpha}(\sigma_L(x, Q^2))$$

due to positivity of the cross sections:

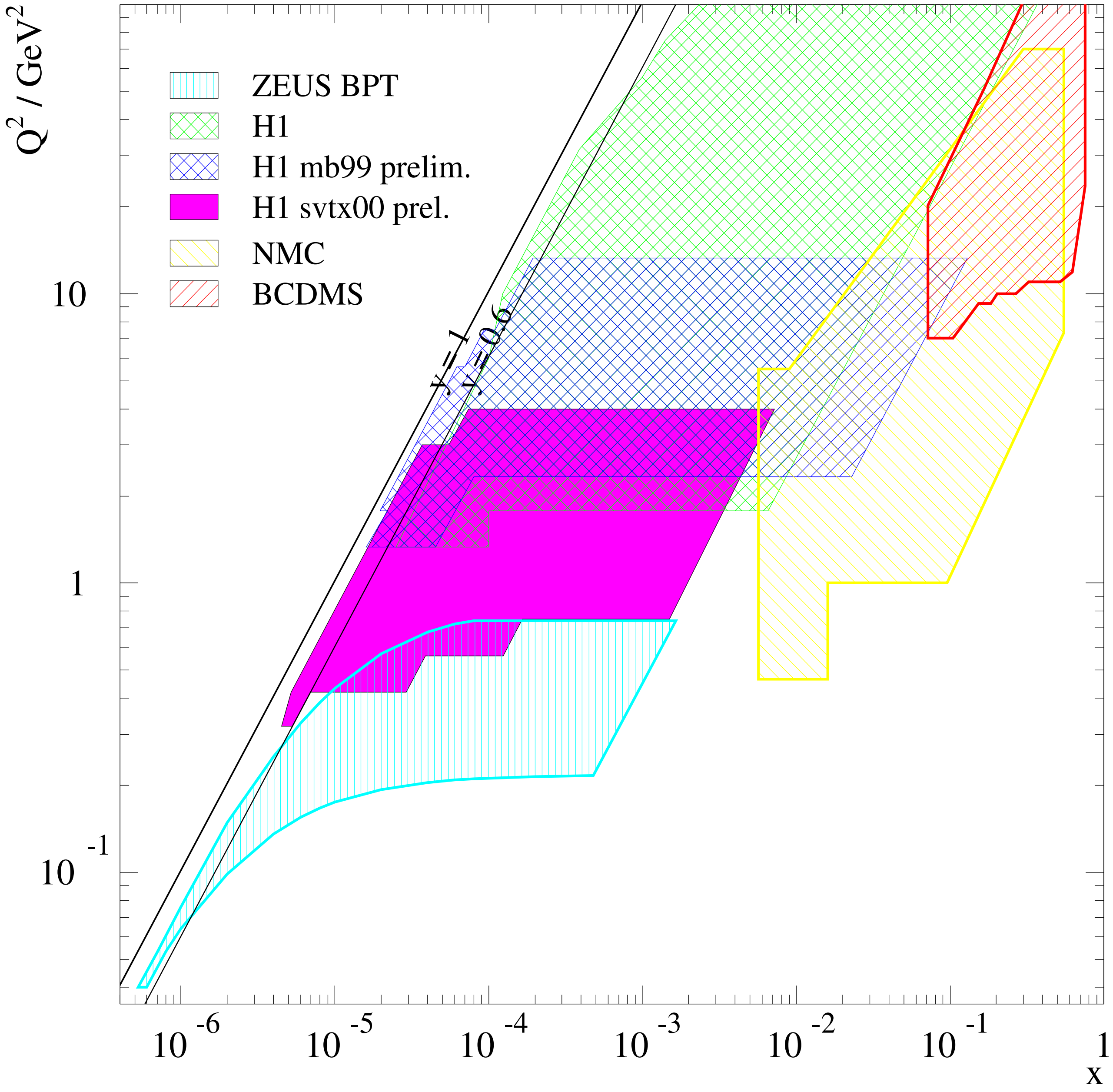
$$0 \leq F_L \leq F_2$$

“Reduced” cross section:

$$\boxed{\sigma_r = F_2(x, Q^2) - \frac{y^2}{Y_+} \cdot F_L(x, Q^2)}$$

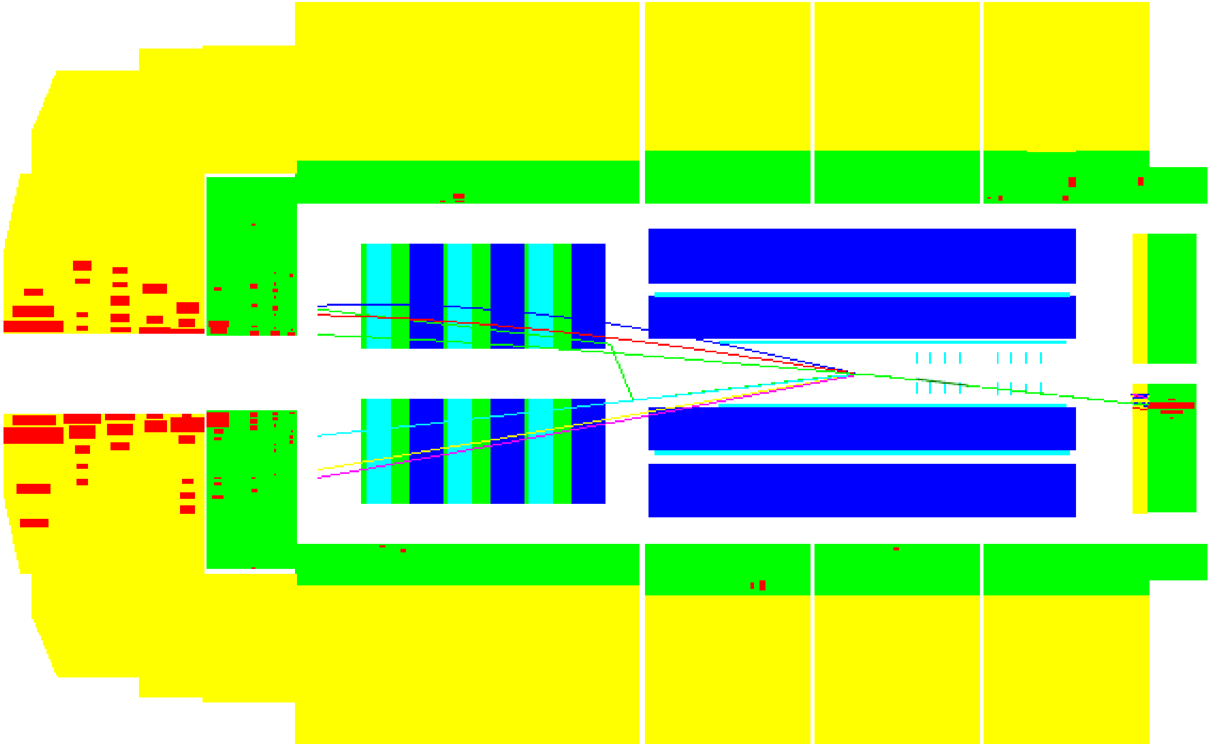
F_L **contribution to** σ_r **sizeable only for high y**

Kinematic plane coverage



- **H1 shifted vertex data in the transition region between perturbative and non-perturbative kinematic range ($Q^2 \sim 1$ GeV^2)**

H1 detector and event selection

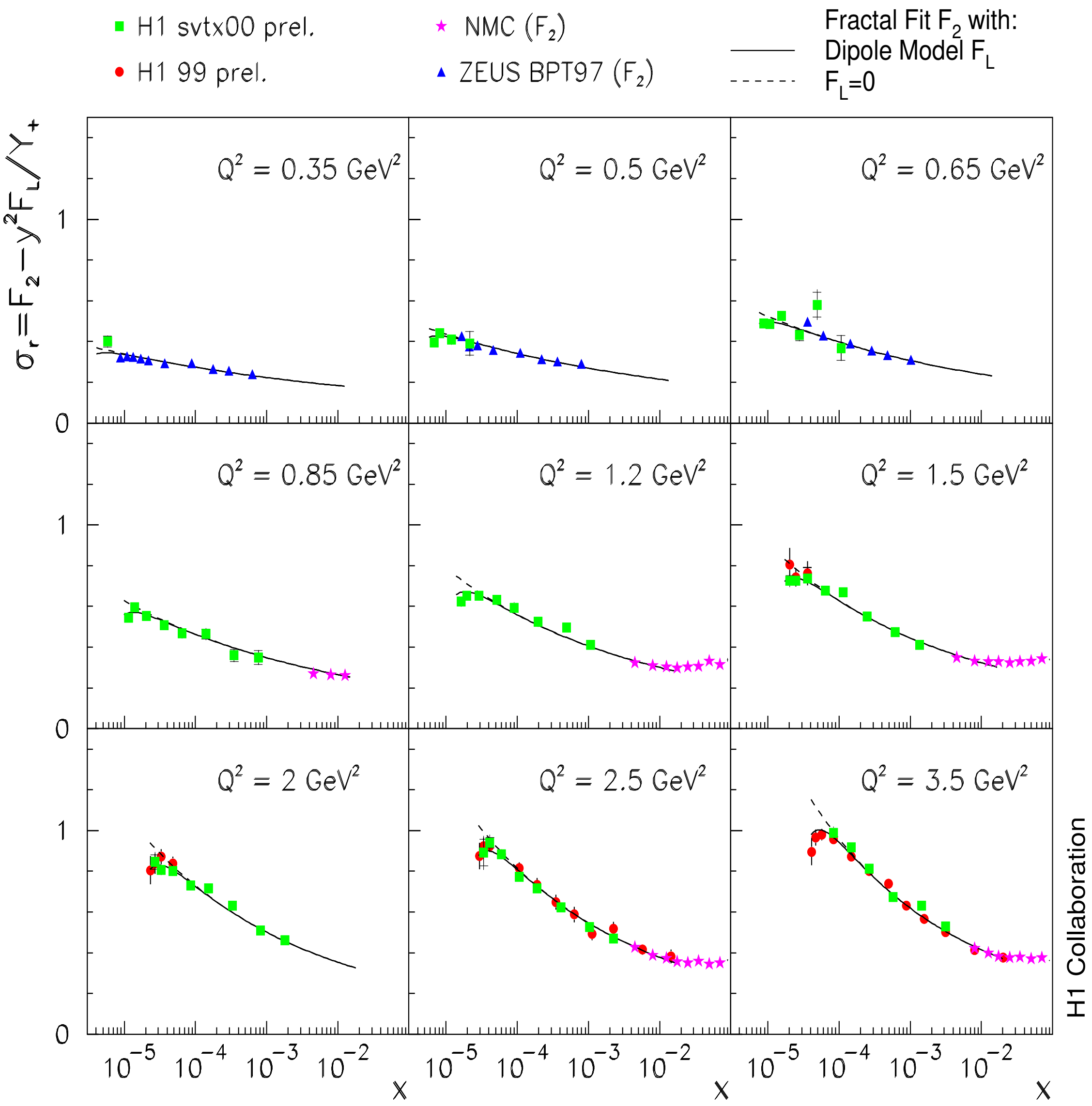


• SPACAL (lead-fibre calorimeter):
most energetic electromagnetic cluster ($E' > 3$ GeV)
• BST (backward silicon tracker, 8 concentric planes perpendicular to beam axis; used for Θ_e measurement and track validation):
track matching electron cluster
vertex reconstructed from electron track
removal of neutral background

for further photoproduction background reduction:
$E - p_z > 35$ GeV

Detailed data selection presented already:
(H1 Collaboration, DIS02 Cracow, by T. Laštovička)

Cross section measurement



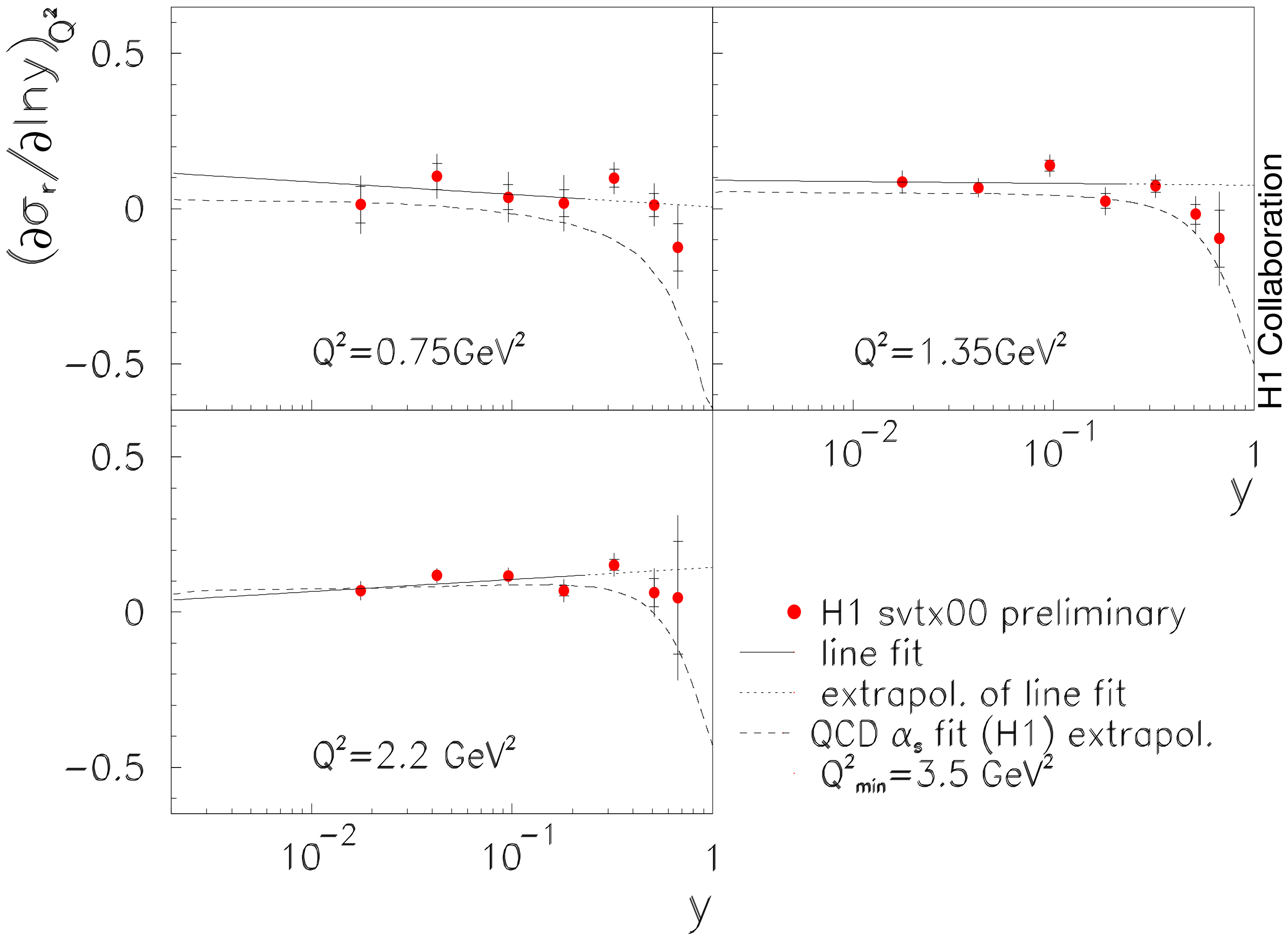
for low x (high y) the rise of the cross section is tamed

(H1 Collaboration, DIS02 Cracow, presented by T. Laštovička)

$\mathbf{F_L}$ extraction: derivative method

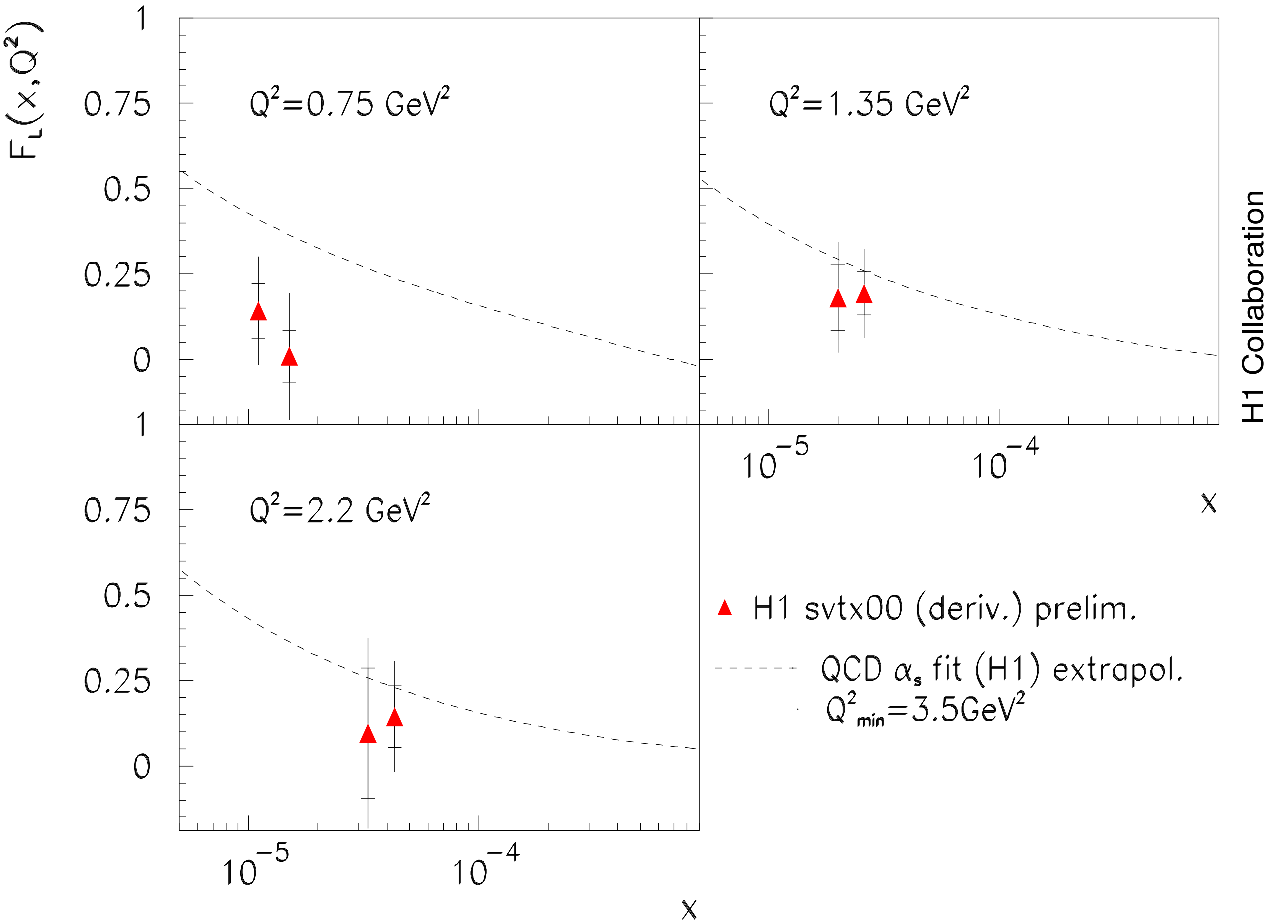
- **derivative of σ_r at fixed Q^2**

$$\left(\frac{\partial \sigma_r}{\partial \ln y}\right)_{Q^2} = \left(\frac{\partial F_2}{\partial \ln y}\right)_{Q^2} - F_L \cdot y^2 \cdot \frac{2-y}{{Y_+}^2} - \underbrace{\frac{\partial F_L}{\partial \ln y} \cdot \frac{y^2}{Y_+}}_{\Downarrow\ \text{negligible}}$$



- **for given $Q^2 \Rightarrow F_2 \sim x^{-\lambda} \sim e^{\lambda \ln y} \approx 1 + \lambda \ln y + \ldots$**
- **for low y $\partial\sigma_r/\partial \ln y$ fitted with line**
- **line extrapolated to high y region**
- **difference between line extrapolation and $\partial\sigma_r/\partial \ln y$ at high y $\Rightarrow F_L$**

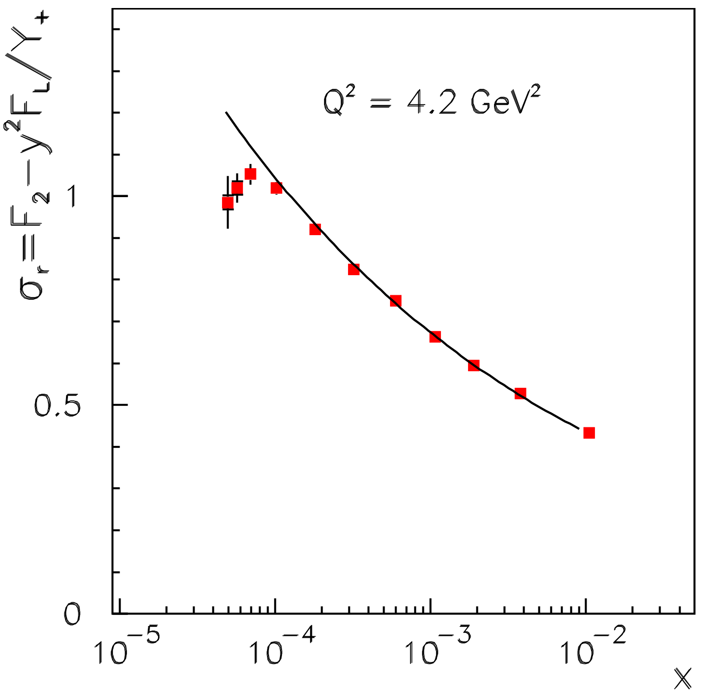
F_L extraction: derivative method



- **derivative method**

– assumption that $\partial F_2/\partial \ln y$ linear in $\ln y$
– information about F_2 extrapol. from low y to high y region
– only points with y $<$ 0.2 (for linear fit) and y $>$ 0.4 (for F_L extraction) used $\Rightarrow$ part of the information lost
– a few close in y points
– precision does not allow to resolve x dependence of F_L

F_L determination: new method



- **shape method:**

– one F_L point per Q^2 bin but with higher precision
– shape of σ_r driven by kinematic factor y^2/Y_+
– constant F_L for small x range

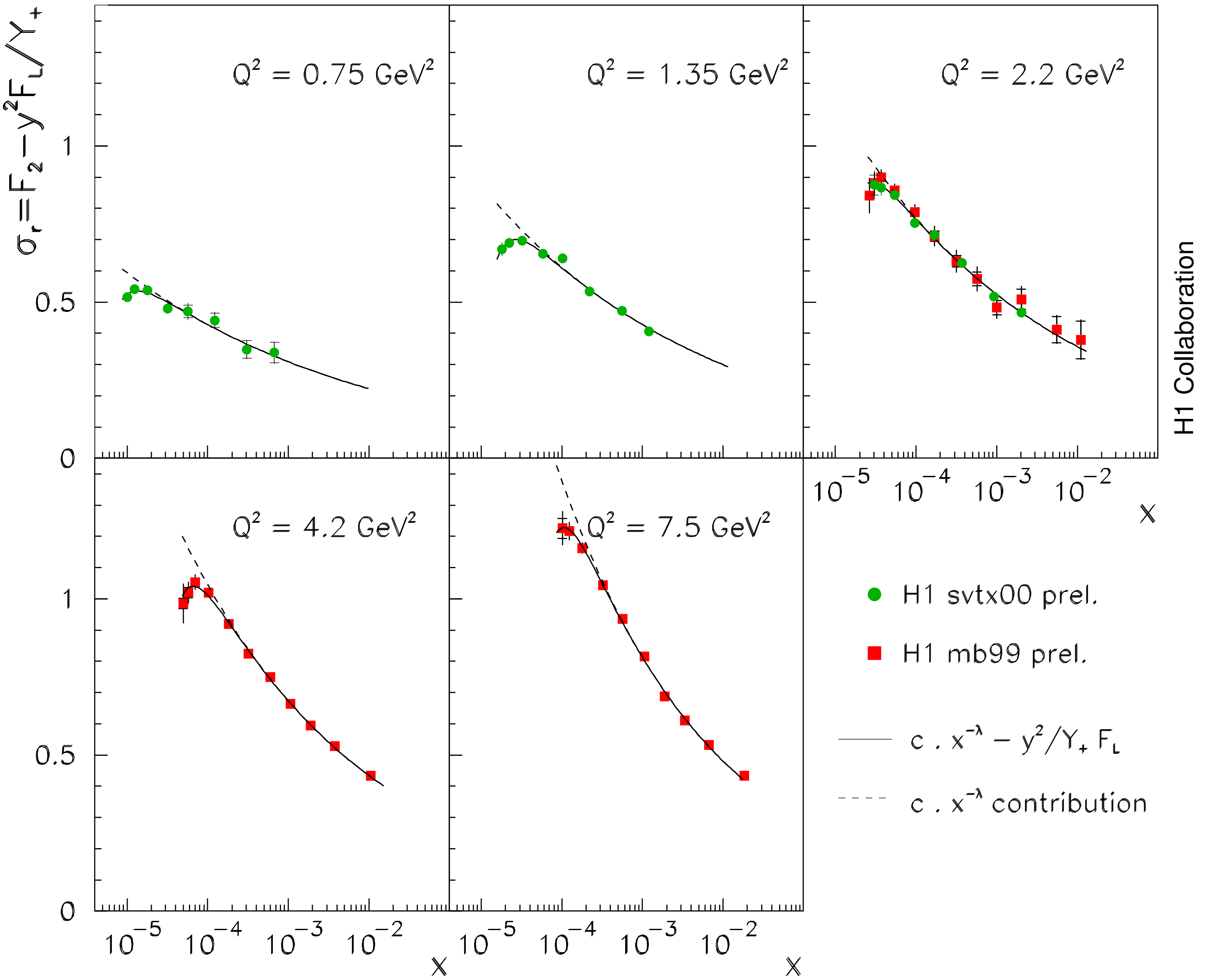
$$\sigma_{\mathbf{FIT}} = \mathbf{c} \cdot \mathbf{x}^{-\lambda} - \frac{\mathbf{y^2}}{\mathbf{1 + (1 - y)^2}} \mathbf{F_L}$$

$$\Downarrow$$

Phys.Lett.B520:183-190,2001

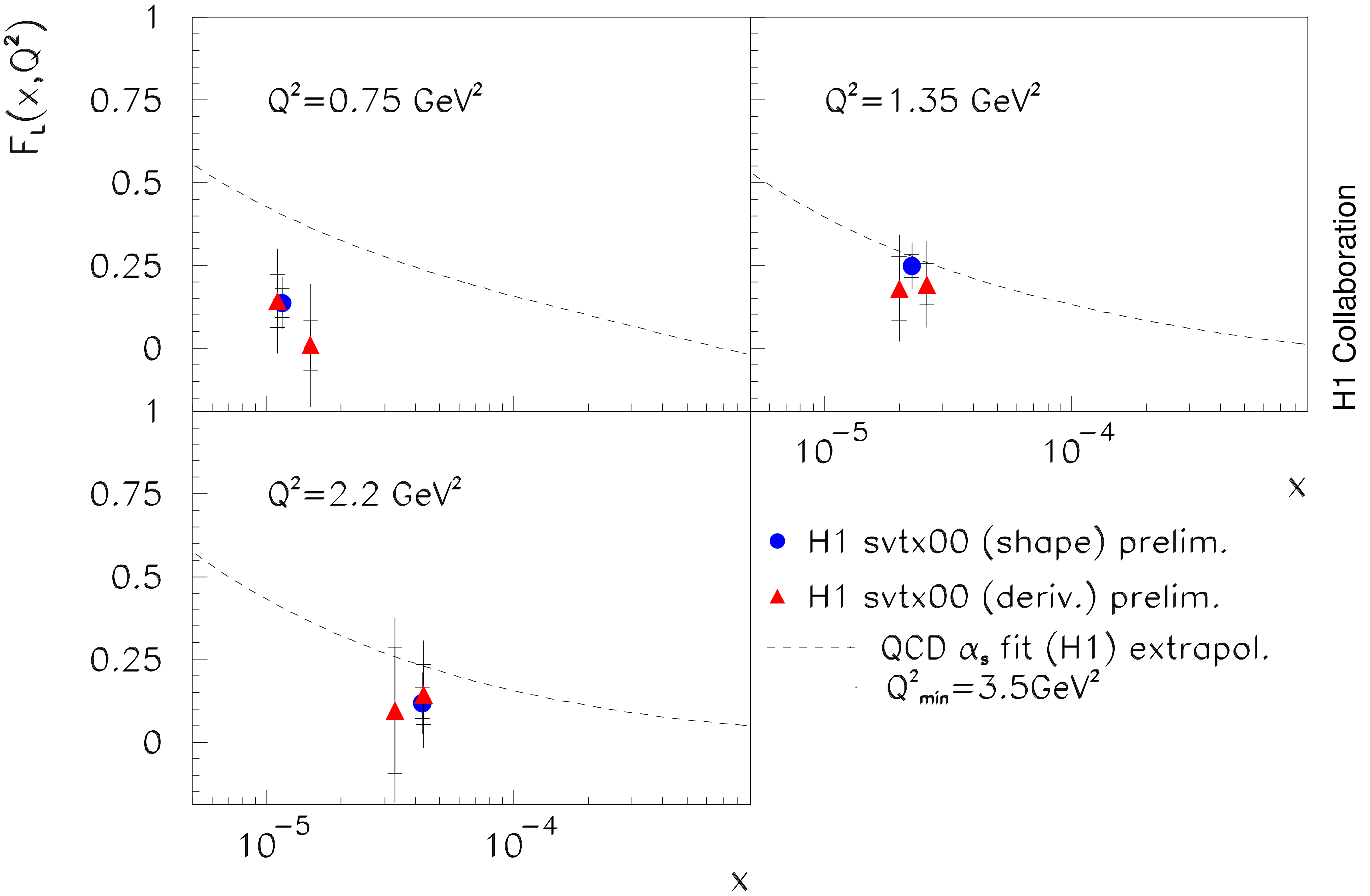
– fit in Q^2 bins
– F_L extracted at $< y >$,
weight: $w_i = y^2/(Y_+ \cdot {\sigma_i}^2)$

F_L extraction: shape method

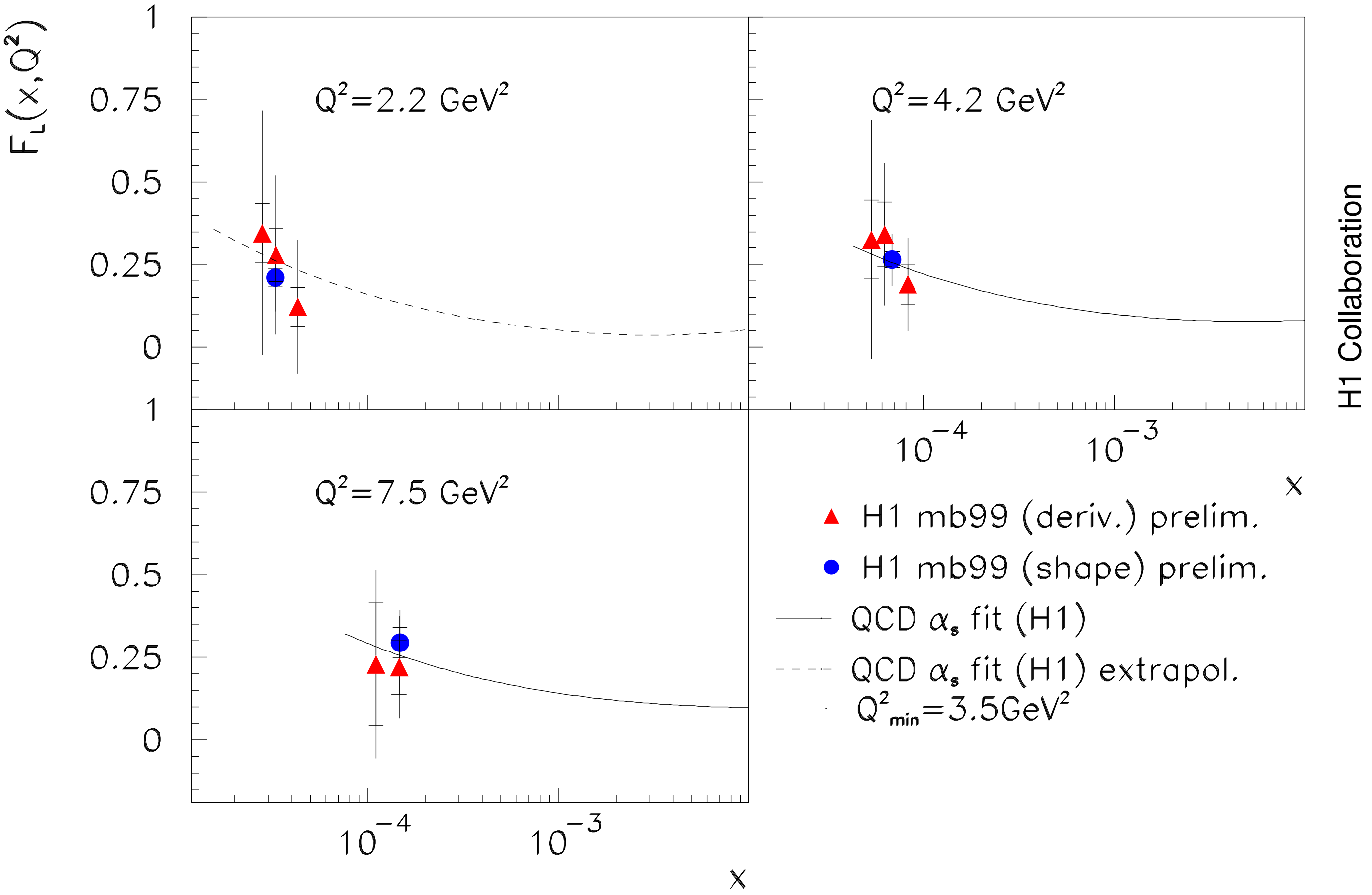


- excellent description of σ_r by the "shape" fit in full kinematic region
- λ in good agreement with previous measurements

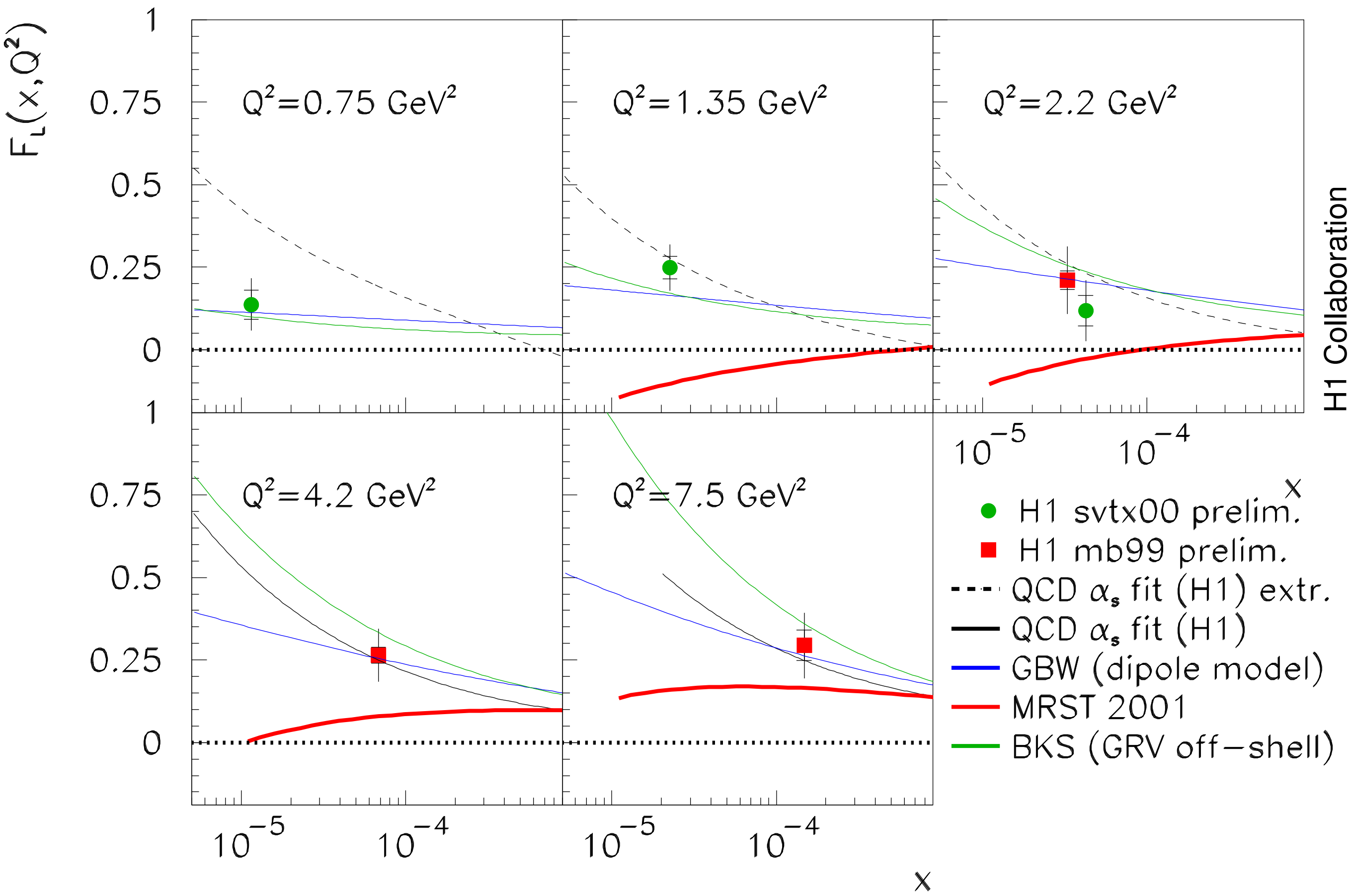
F_L extraction



- F_L extracted by "shape" method consistent with "derivative" method results
- errors for "shape" method significantly smaller



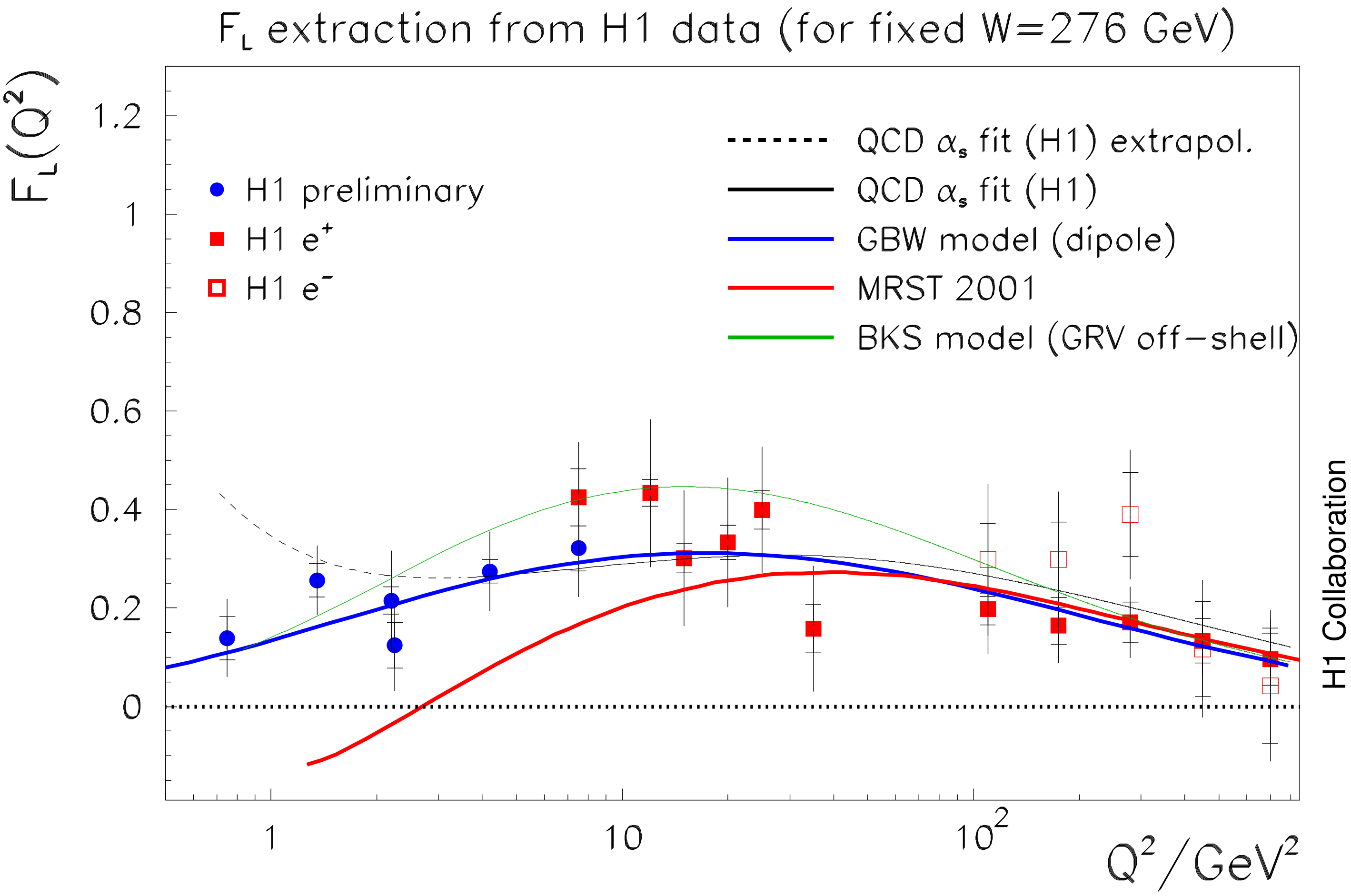
F_L extraction



- GBW (dipole model) – K. Golec-Biernat, M. Wüsthoff *Phys. Rev.* D59, 014017 (1999)
- BKS (GRV off-shell) – B. Badełek, J. Kwieciński, A. Staśto *Z.Phys.* C74 297 (1997)
- MRST 2001 – A. Martin, R. G. Roberts, W. J. Stirling, R. S. Thorne *Phys. Lett.* B531 216 (2002)

- extracted $F_L > 0$ in all Q^2 bins
- the DIS cross section is able to constrain theoretical predictions

Summary of F_L extraction from H1 data



- for the first time F_L extracted at low $Q^2 (\sim 1 GeV^2)$ low x region
- precision of extraction improved