Hadron Structure 2004

Smolenice Castle, Slovakia

Measurements of proton structure at low Q^2

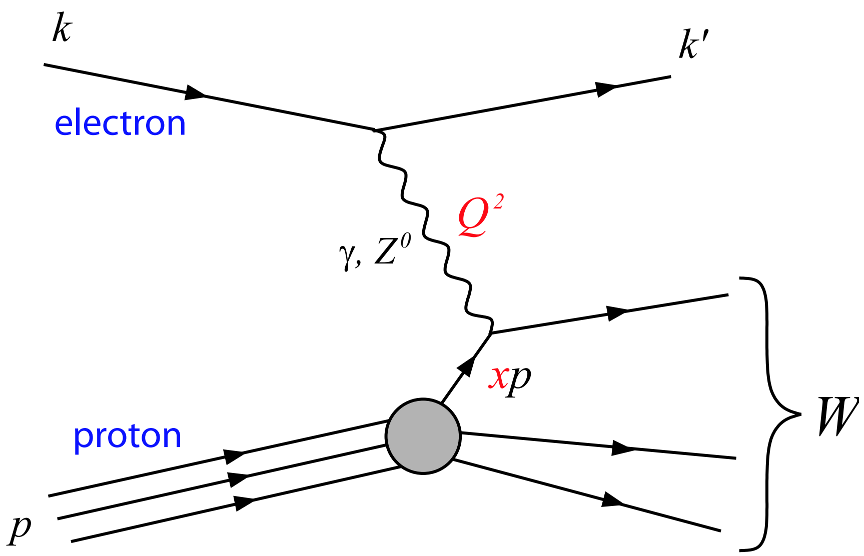
Andrea Vargas

University of Dortmund

- Introduction
- F_2 Measurement at large x
- F_L Determination
- Summary

Deep Inelastic Scattering

Neutral Current: $e + p \to e + X$



- kinematic variables:

  $s = (p+q)^2$ cms energy

  $Q^2 = -(p-k)^2$ momentum transfer

  $x = \frac{Q^2}{2p \cdot q}$ Bjorken-variable

- additional information

  $y \simeq \frac{Q^2}{sx}$ Inelasticity

  $W^2 = Q^2 \frac{1-x}{x} + m_p^2$ cms energy in $\gamma^* p$ system

Structure functions in DIS

Measuring the cross section:

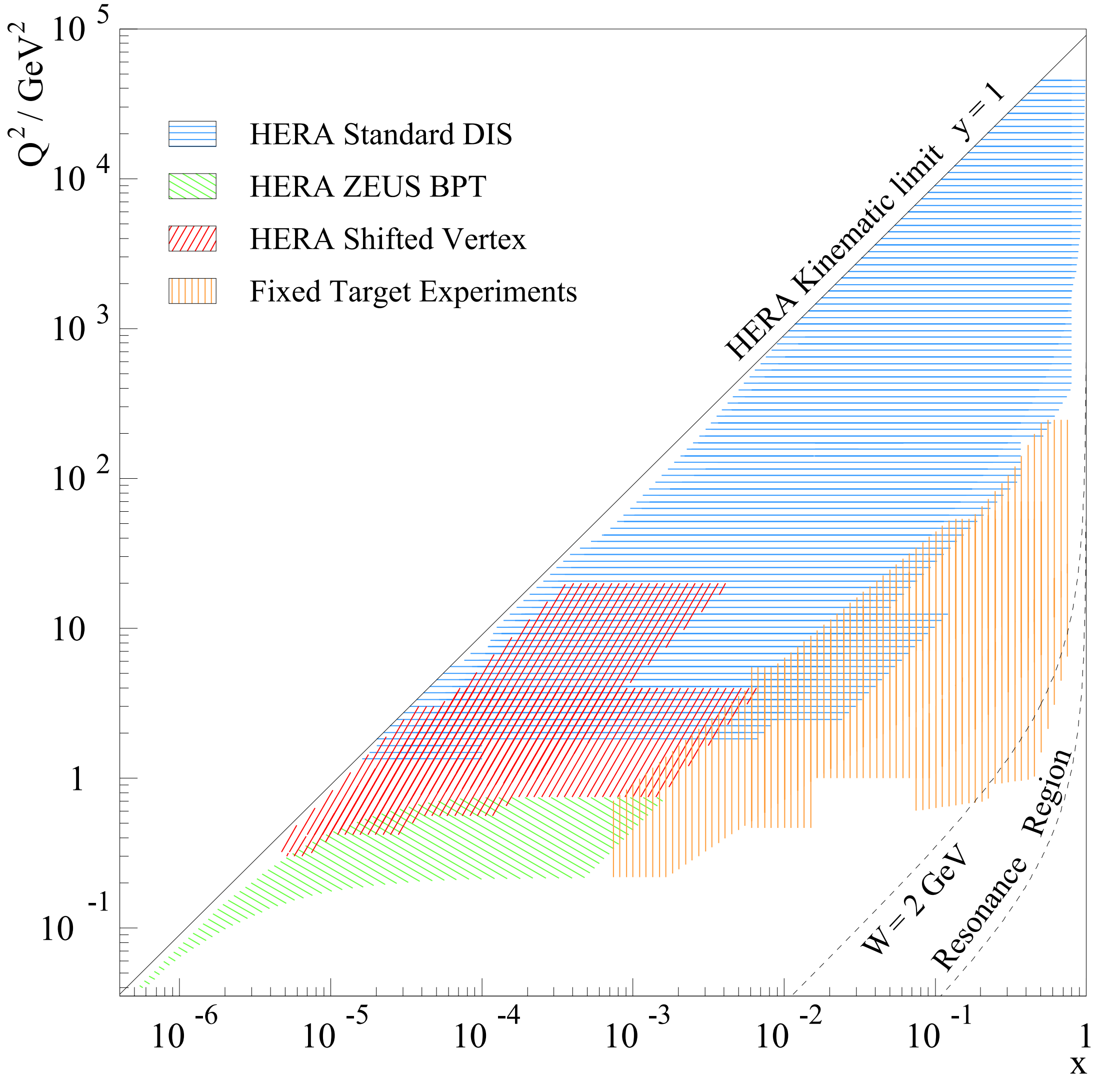
$$\frac{d^2\sigma}{dx dQ^2} = \frac{2\pi\alpha^2}{Q^4 x}\left(Y_+ F_2(x,Q^2) - y^2 F_L(x,Q^2)\right) \qquad Y_+ = 1 + (1-y)^2$$

F_2 is measured, F_L is extracted

- $F_2(x,Q^2) = x\sum_i e_i^2[q_i(x,Q^2) + \bar{q}_i(x,Q^2)]$
  - Dominates the low y region
  - Sensitive to quark content
- $F_L(x,Q^2)$
  - Contributes only at high y
  - QPM: $F_L = 0$

    QCD: $F_L \neq 0$ (gluon emission)

Kinematic Plane



Medium-High Q^2

asymptotic freedom

perturbative QCD

Low Q^2

Transition to γp

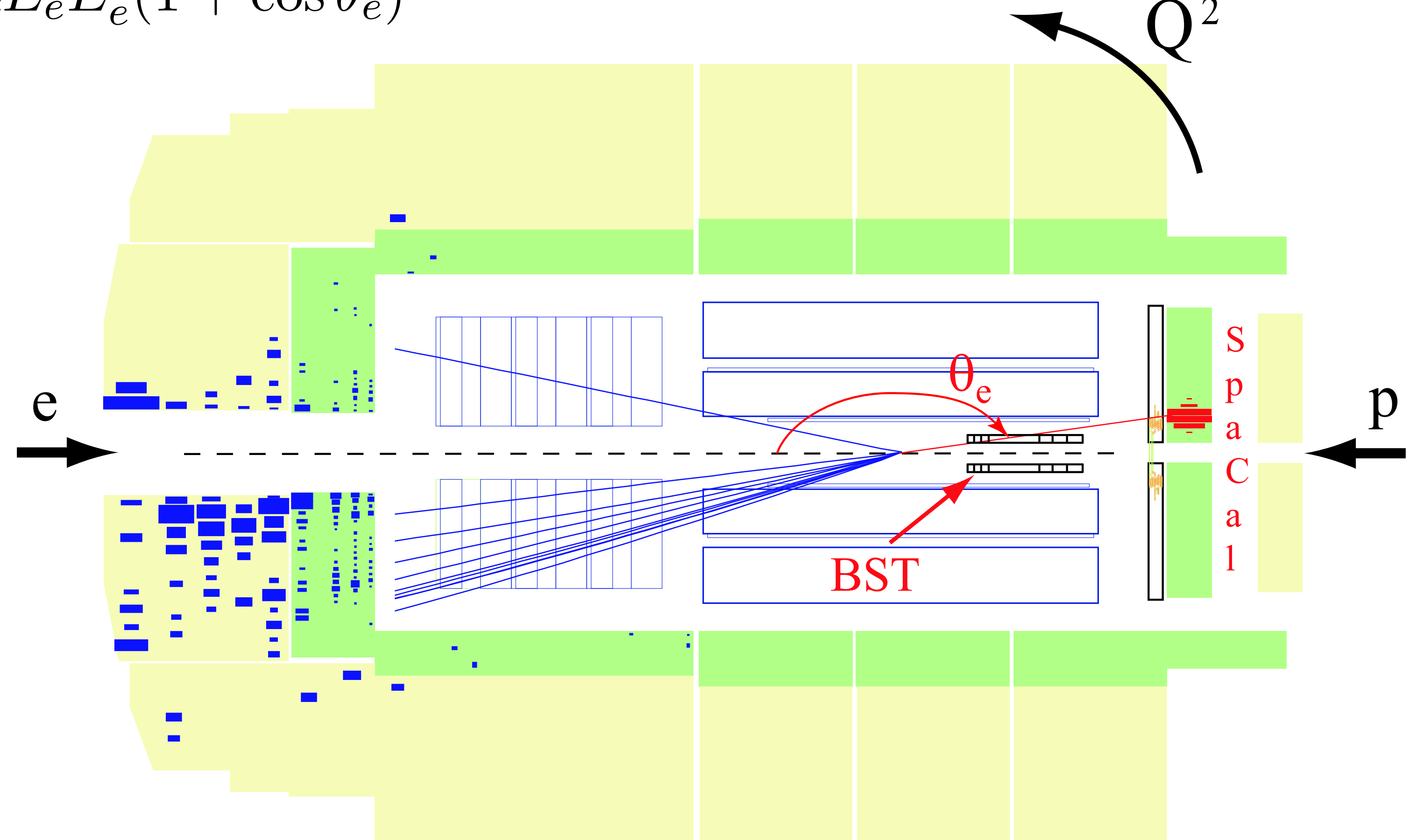
$\alpha_s(Q^2)$ *large:*

Phenomenological models

Experimental techniques at low Q^2

Standard DIS measurement: $Q^2 \geq 2\text{GeV}^2$

$$Q^2 = 4E_e E'_e(1 + \cos\theta_e)$$

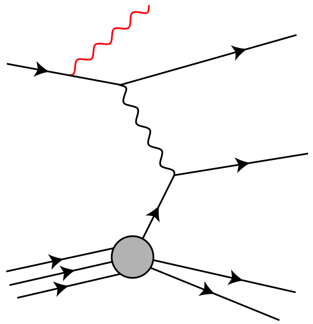


measure low $Q^2 \Rightarrow$ larger θ_e

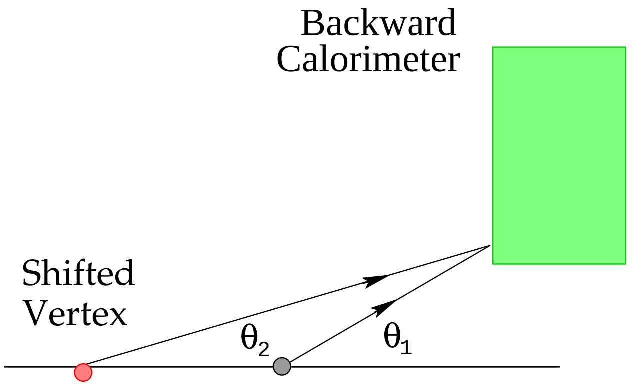
Experimental techniques at low Q^2

Measuring large scattering angles $\Rightarrow$

- Detectors close to the beam pipe (ZEUS BPC/BPT)
- Radiative events

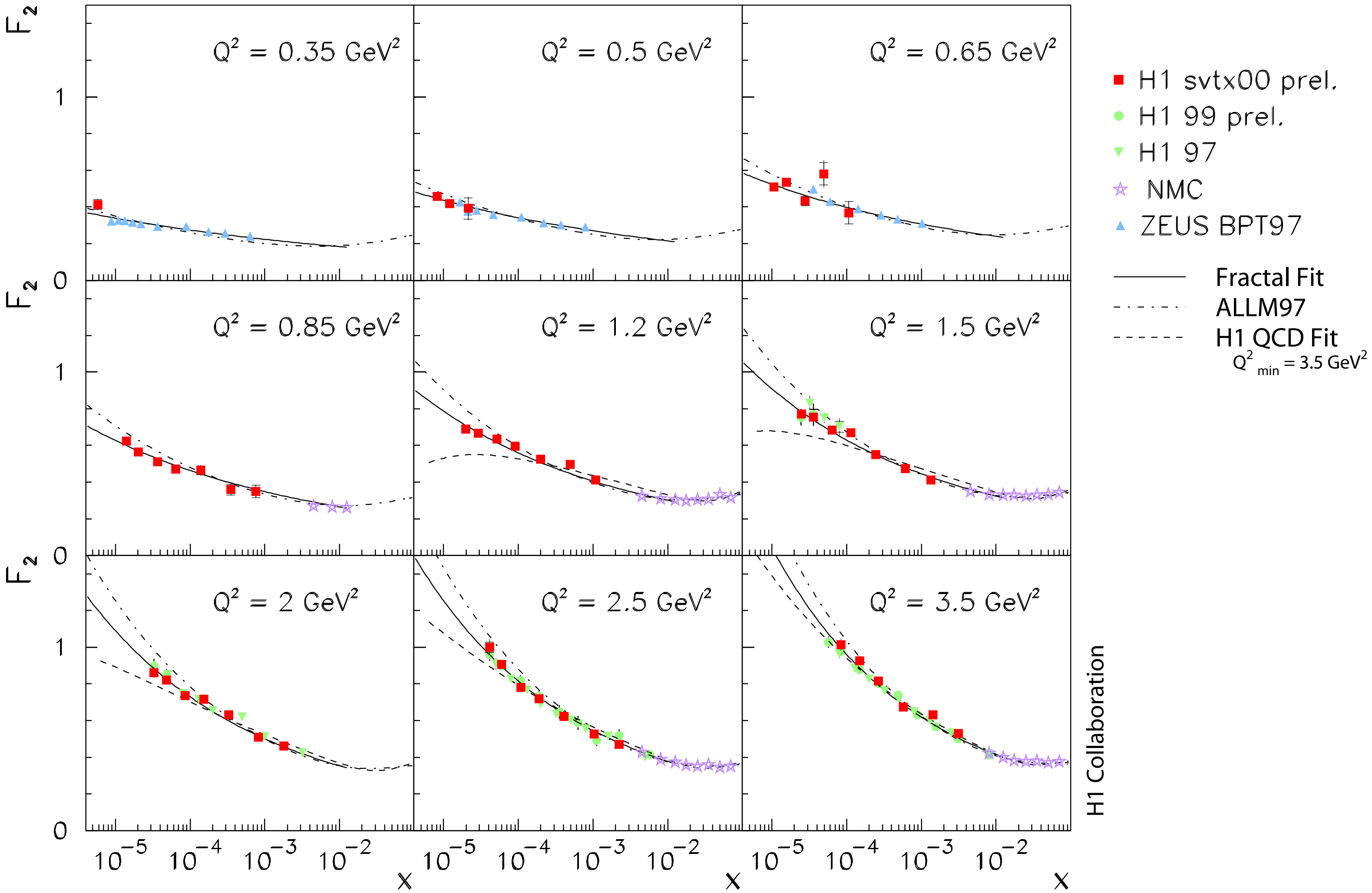


- Shifted vertex runs



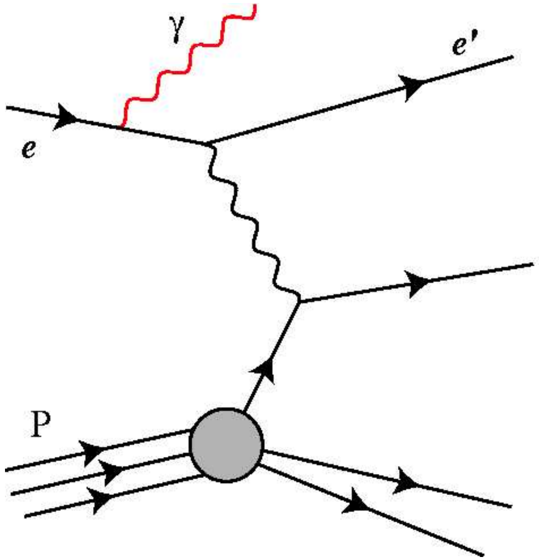
$$\theta_2 > \theta_1$$

Shifted Vertex F_2 Measurements



ISR Measurement Method

Signature:

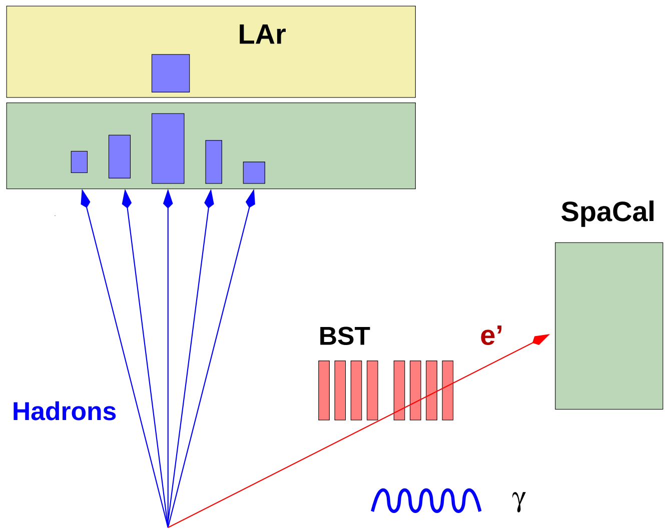


γ emitted from incoming $\mathbf{e}$:

- cms is reduced $\Rightarrow$ accessing the **high** x region is possible!
- Alternative ISR F_2 analysis: γ *explicity detected*

New method:

- γ is undetected
- x, Q^2, E_e reconstructed:
  - ⋆ final state
  - ⋆ energy momentum conservation



ISR Measurement in Shifted Vertex run

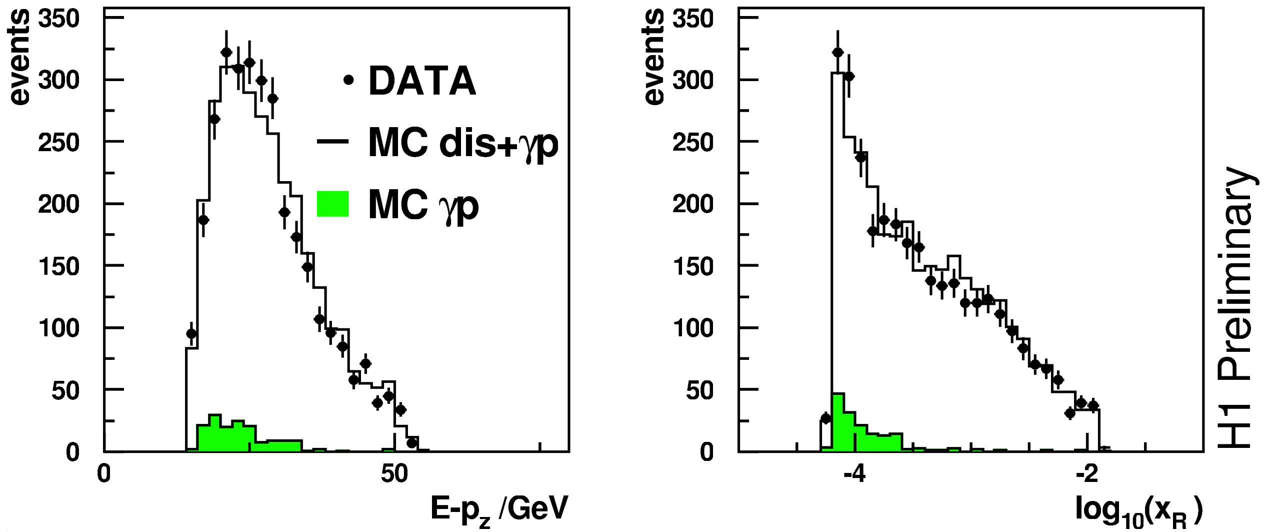
Reminder: $\Sigma-$method

- Incoming energy:

$$2E_e = (E - P_z)_{tot}$$

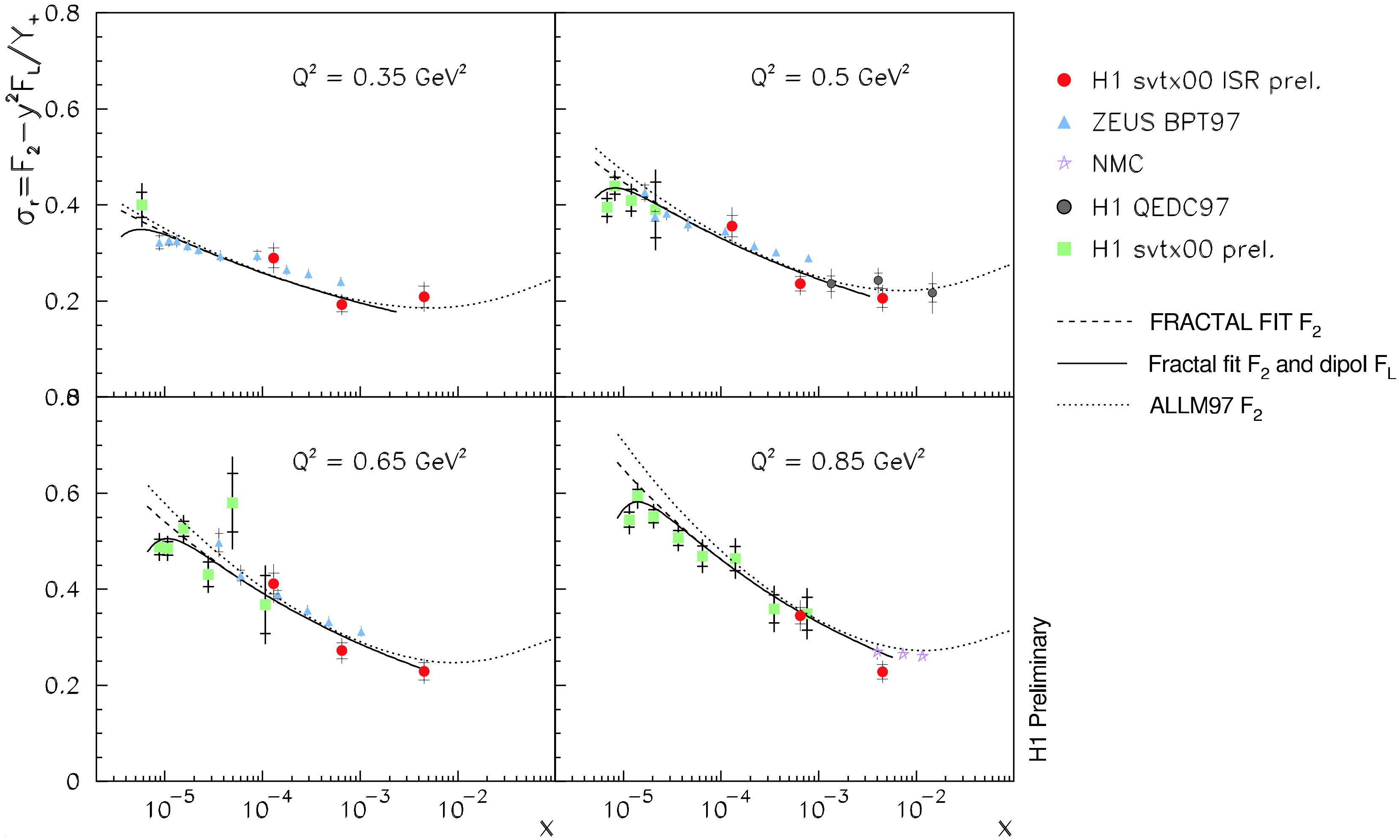
- Kinematic:

$$X_R = \frac{Q^2_\Sigma}{4E_eE_p}$$



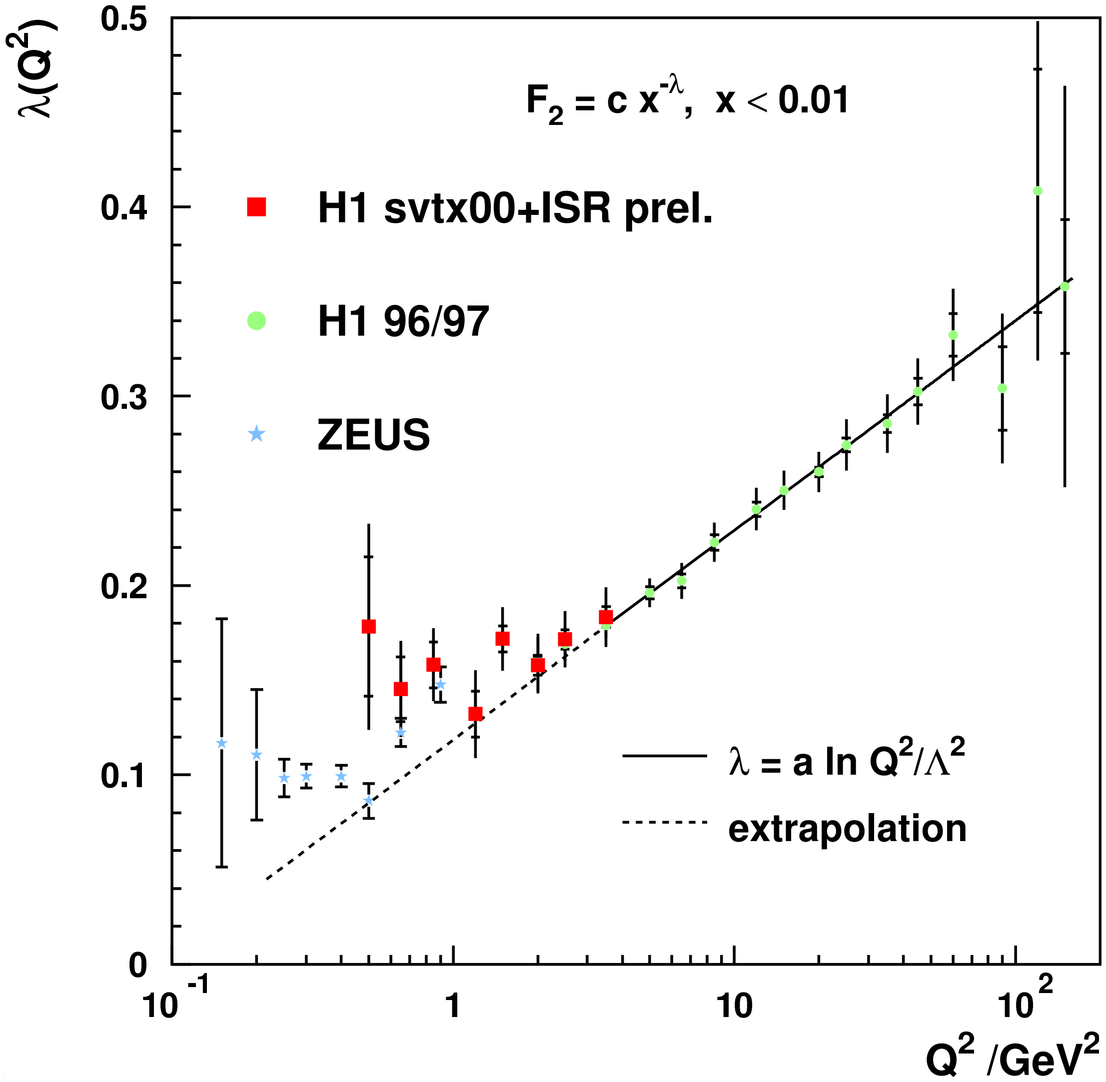
BST $\Rightarrow$ suppression of γp background

Cross Section Measurement using ISR events



high x at low Q^2 is accessed

Improved extractions of λ



$$\lambda = \left(\frac{\partial \ln F_2}{\partial \ln x}\right)_{Q^2}$$

- Rise of F_2 at $x < 10^{-2}$

well parametrized by

$$F_2 = c(Q^2)x^{-\lambda(Q^2)}$$

- At $Q^2 \geq 3$GeV^2:

$$\lambda \approx \ln Q^2 \quad c \approx \text{const}$$

Partonic degrees of freedom

- At $Q^2 \leq 2$GeV^2:

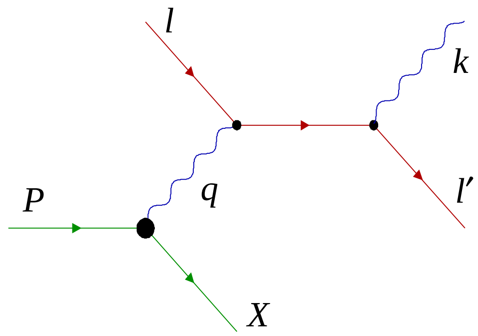
$$\lambda \to 0.08$$

Transition to hadronic degrees of freedom

Inelastic QED-Compton events

Signature:

- ⋆ $e + p \rightarrow e + \gamma + X$
- ⋆ $\vec{q} \parallel \vec{l}$

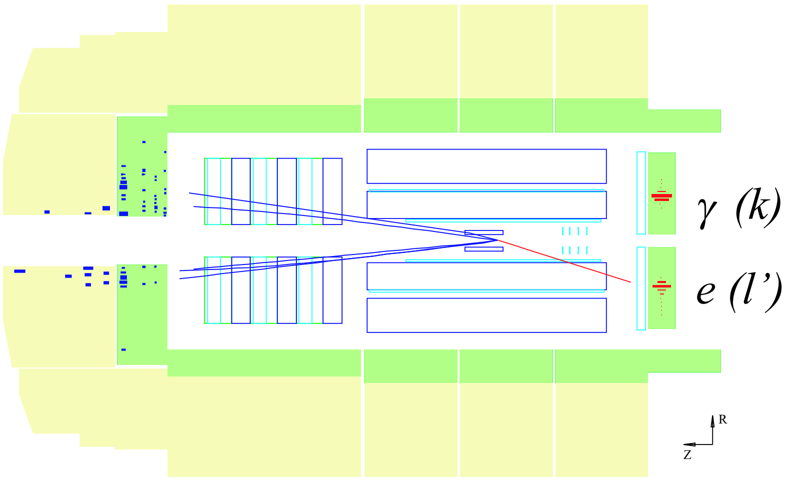


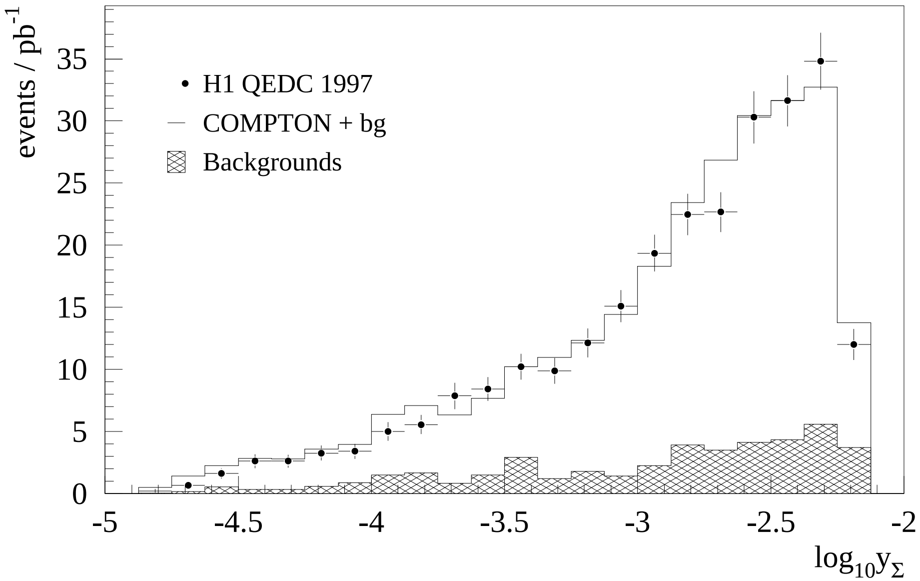
Medium-High x is measured

$$x \epsilon (0.001 - 0.06)$$

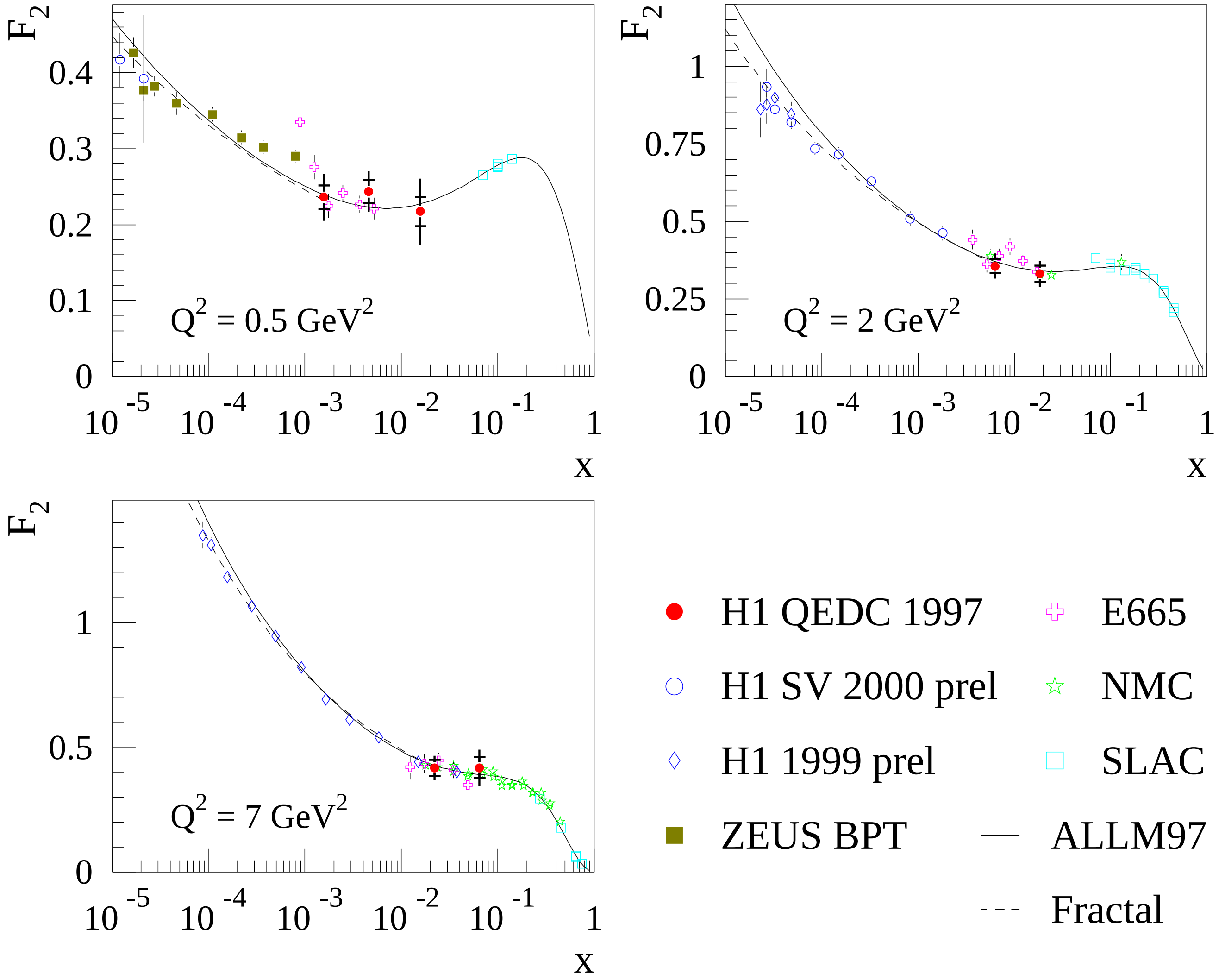
- ▷ *understanding of HFS at low W*
- ▷ *Use SOPHIA MC model*

QEDC Event in H1 Detector





F_2 measurement with QED-Compton events



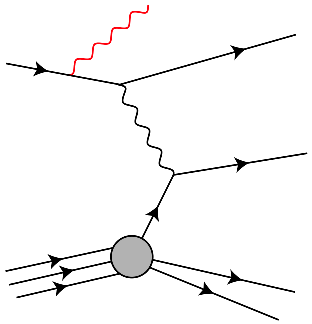
Good agreement with fixed target experiments

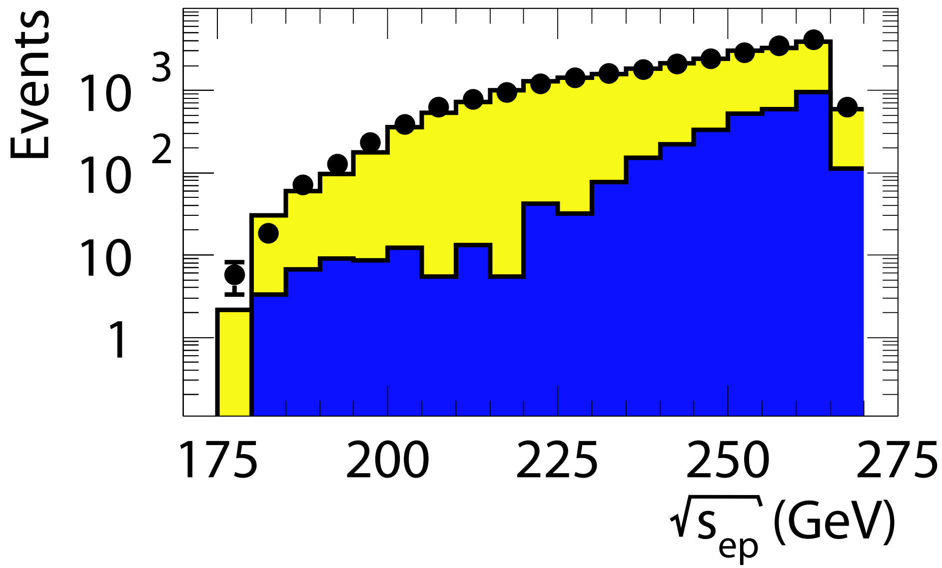
Measurement of F_L

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}x dQ^2} = \frac{2\pi\alpha^2}{Q^4 x}\left\{\left[1+(1-y)^2\right] F_2(x,Q^2) - y^2 F_L(x,Q^2)\right\}$$

- F_L: contribution to σ only at high y
- Direct measurement requires data at different s

- Using ISR events:



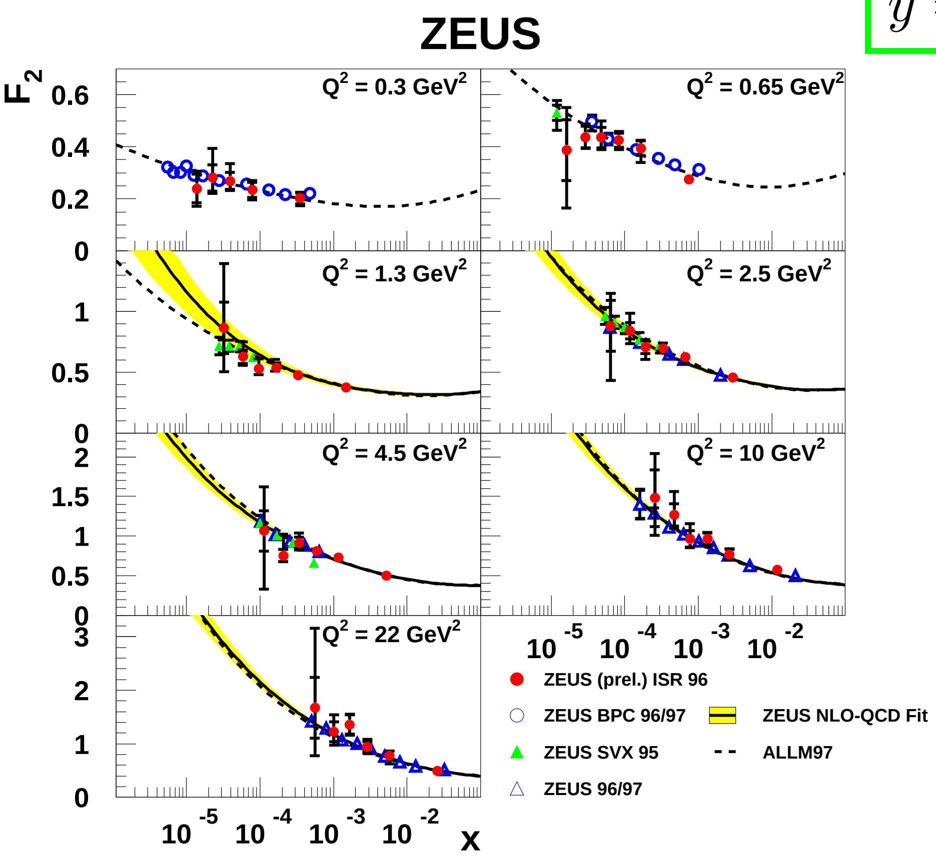


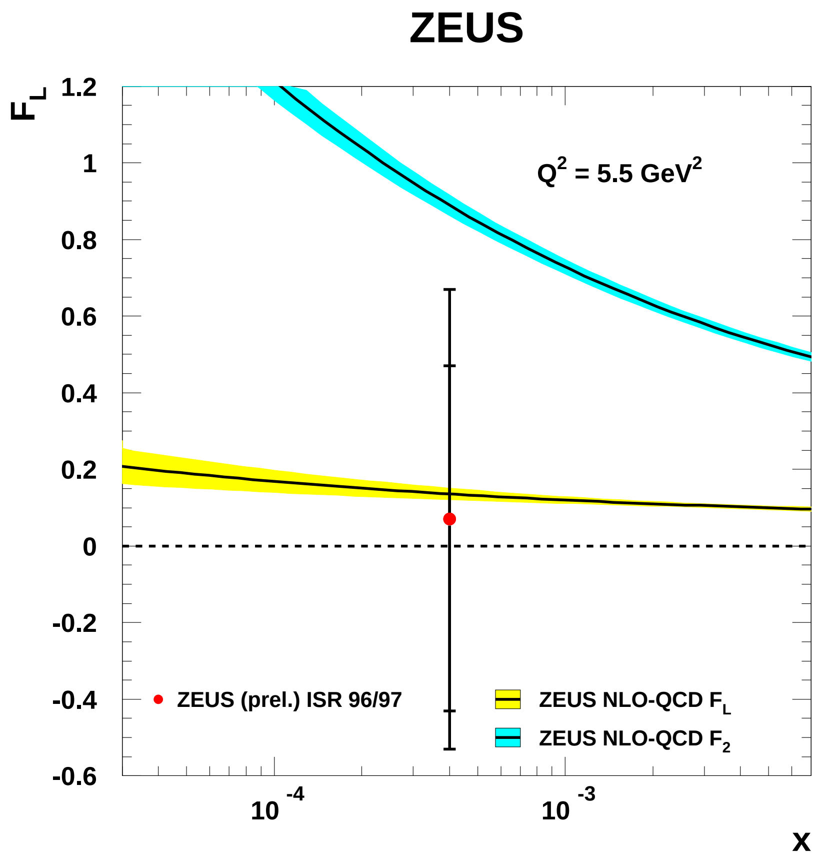
At fixed Q^2, x

varying $s \Rightarrow y$ vary

Measurement of F_L

$y = 0.11 - 0.23 \quad Q^2 = 1 - 30\text{GeV}^2$





- Ratio $N_{data}/N_{MC}(F_L = 0)$ is analysed $\Rightarrow F_L$

First direct determination of F_L from ISR
result is consistent with QCD

Extraction of F_L

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

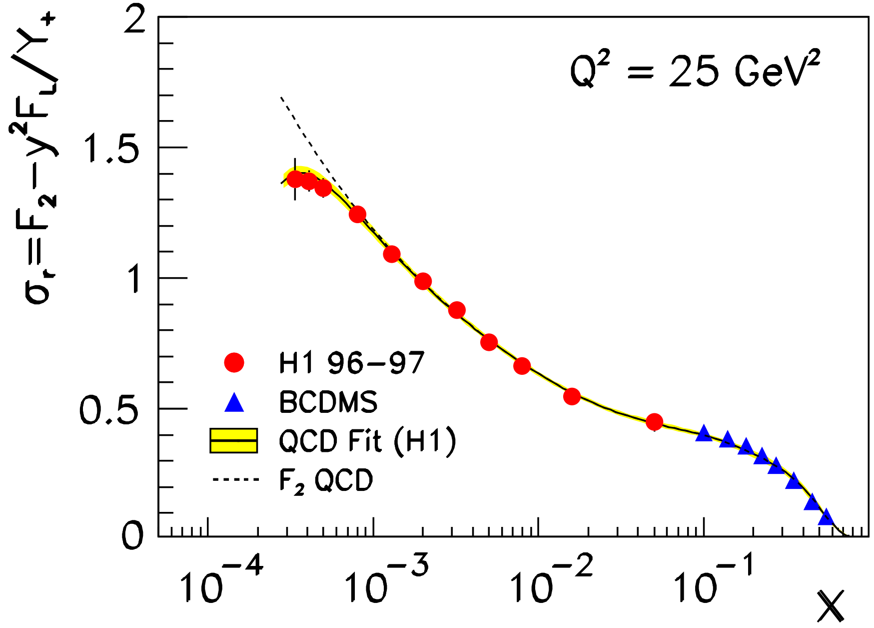
- Indirect determination:

extrapolating F_2 to higher y

$F_L \propto F_2$ - σ_r

→ Derivative method

→ Shape method



F_L extraction: Derivative method

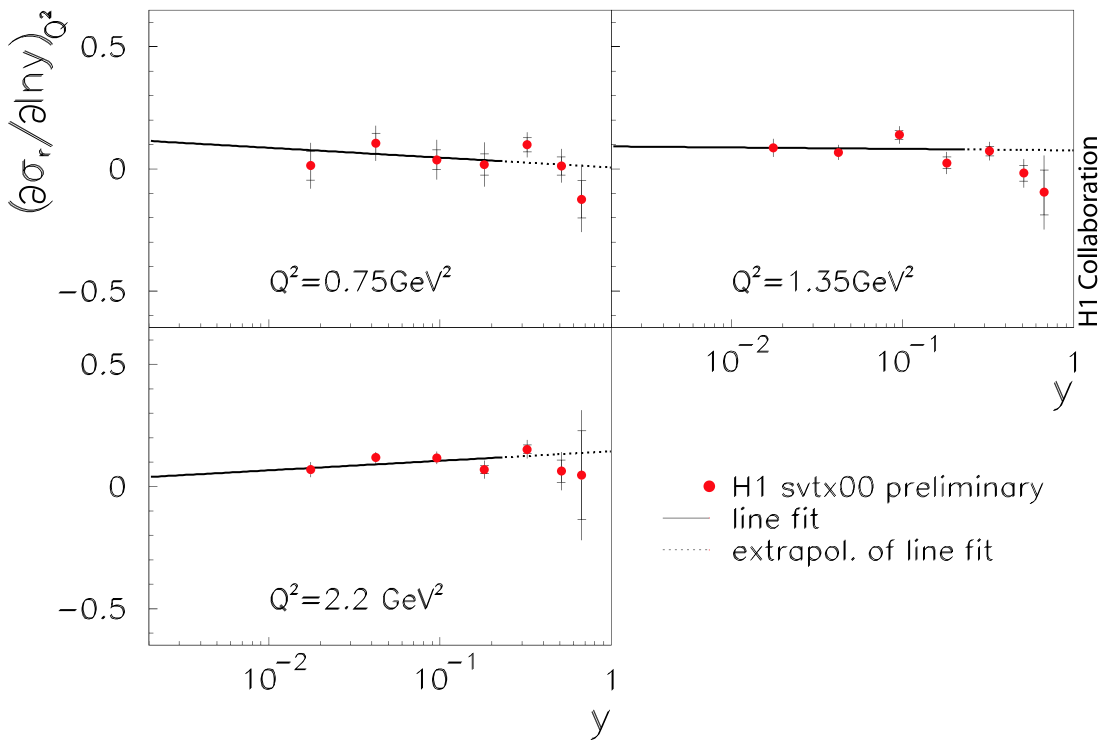
$$\left(\frac{\partial \sigma_r}{\partial \ln y}\right)_{Q^2} = \left(\frac{\partial F_2}{\partial \ln y}\right)_{Q^2} - \frac{2y^2(2-y)}{1+(1-y)^2} F_L$$

- straight line fits:

  low $y < 0.2$ points

- linear behaviour of F_2 at high y

F_L: deviation of measured points from linear behaviour at high y



F_L extraction: Shape method

$$\sigma_{fit} = cx^{-\lambda} - \frac{y^2}{1+(1-y)^2} F_L$$

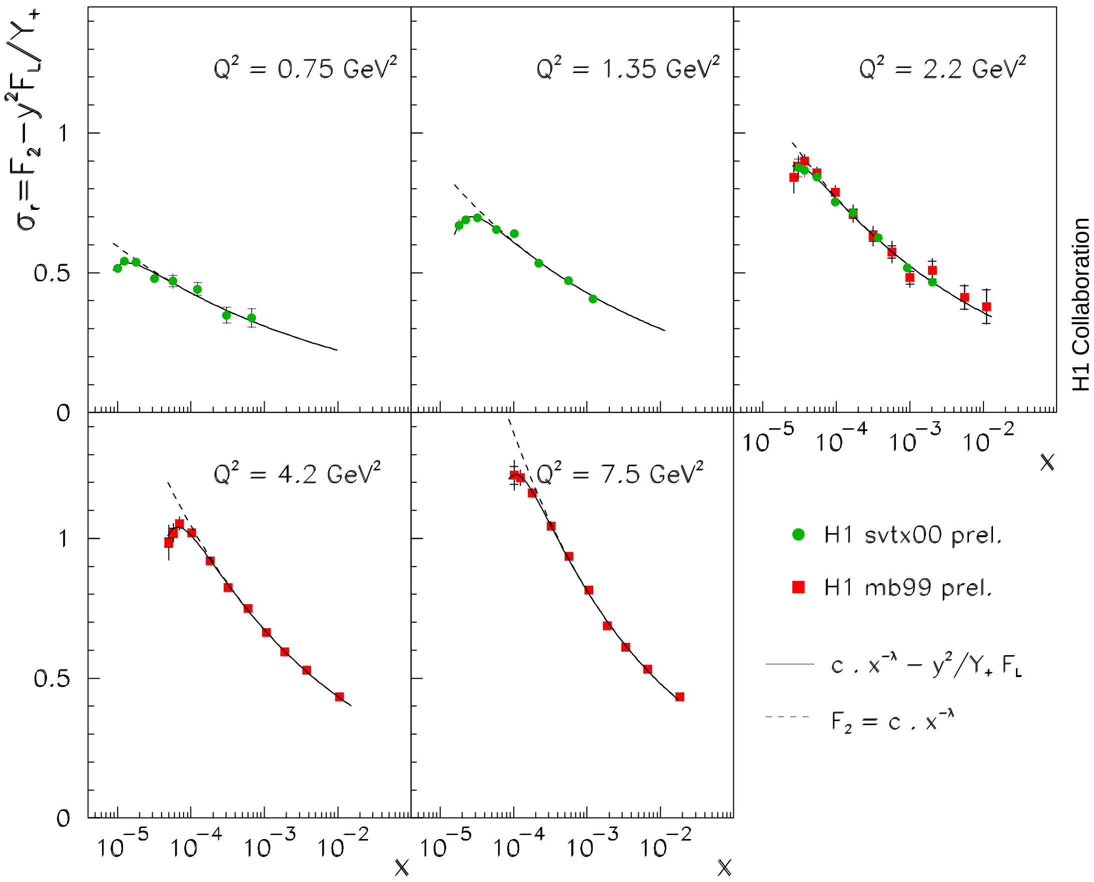
- at high y:

$$\frac{y^2}{1+(1-y)^2}$$

dominates the shape of σ_r

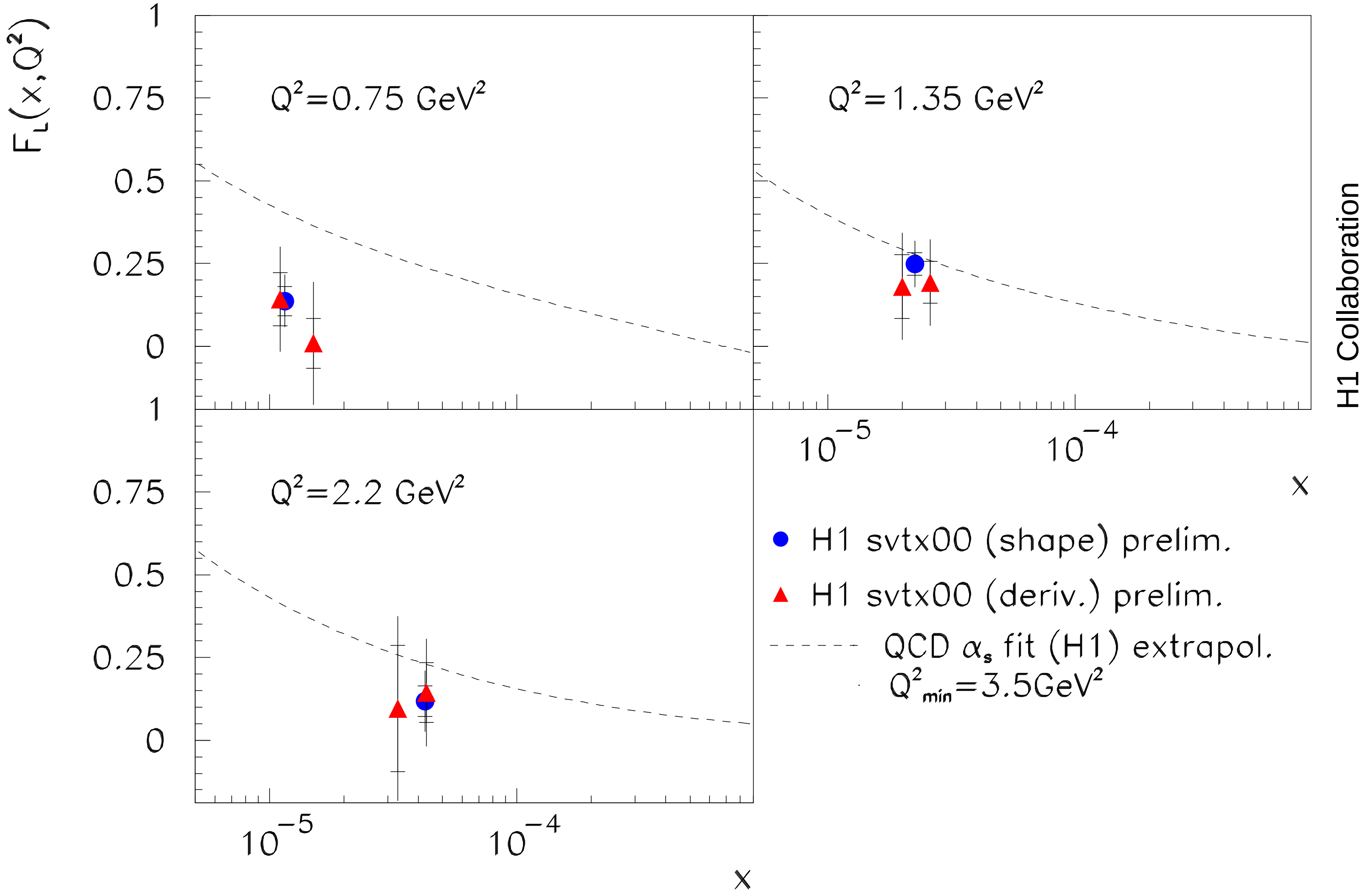
- $F_L = F_L(Q^2)$

F_L: *extracted from σ_{fit}*



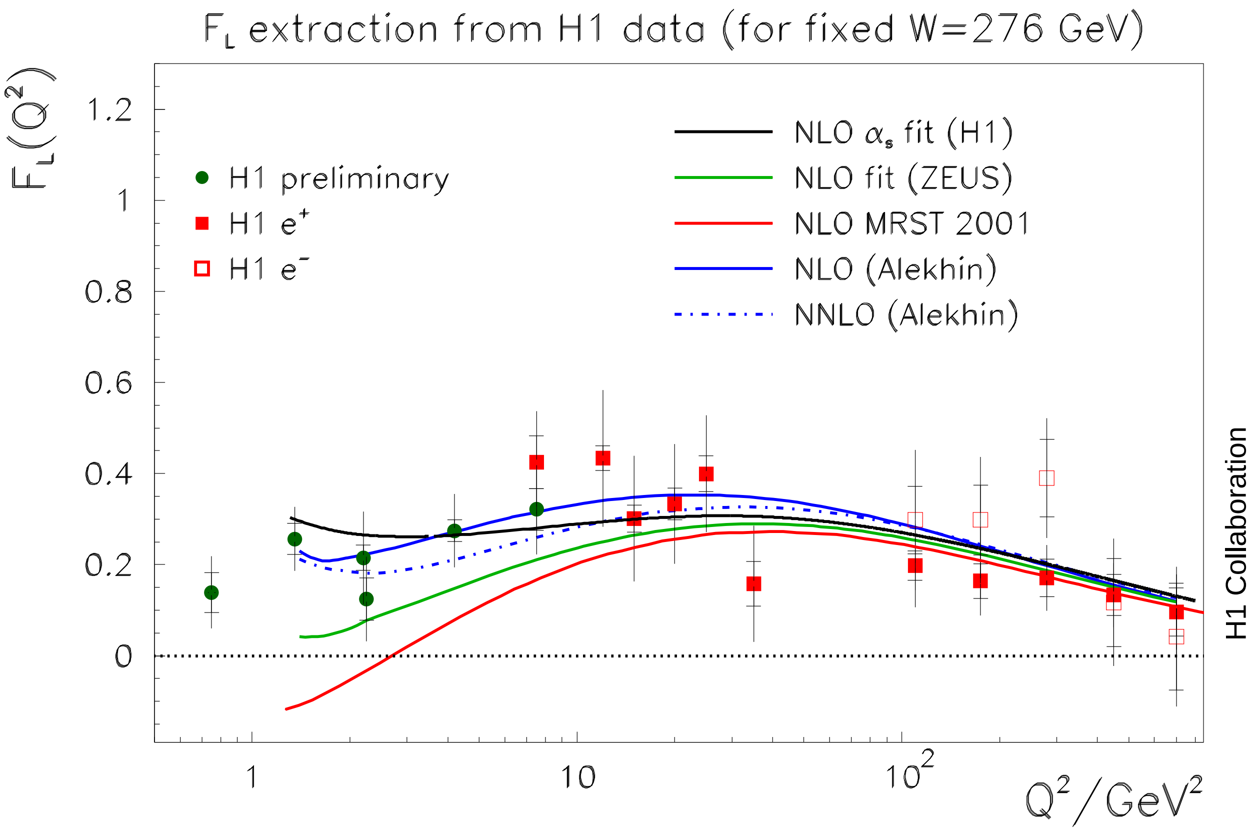
good agreement with measured cross section

Shape method vs. Derivative method



Shape method: more precise

$F_L(Q^2)$ at Fixed $y = 0.75$



- New constrains from low Q^2 data
- Agreement with NLO pQCD fits
- H1 non-negligible positive F_L at low Q^2 $\Rightarrow$ positive g

Summary

- F_2 is measured with *two new methods*
  - *QEDC:*

    $Q^2 \to 0.1$ GeV^2 $\quad 0.001 \leq x \leq 0.1$
  - *ISR:*

    $0.35 \leq Q^2 \leq 0.85$ GeV^2 $\quad 10^{-4} \leq x \leq 5 \cdot 10^{-3}$
- *Structure function* F_L
  - *Measured with ISR*
  - *Extracted with Derivative and Shape method*
- $F_L(Q^2)$ at $W = 276$GeV

  → *non-negligible positive* F_L *at low* Q^2