

# New and Recent Measurements of $F_2$ and $F_L$ at low $Q^2$

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H1 Collaboration

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DIS 2004, Štrbské Pleso

- Introduction
- $F_2$  at high  $x$  using QEDC events
- $F_2$  at low  $x$
- $F_L$  determination

# Deep Inelastic Scattering

virtuality of exchanged photon:

$$Q^2 = -(k - k')^2$$

proton momentum fraction:

$$x = Q^2 / 2P(k - k')$$

inelasticity:

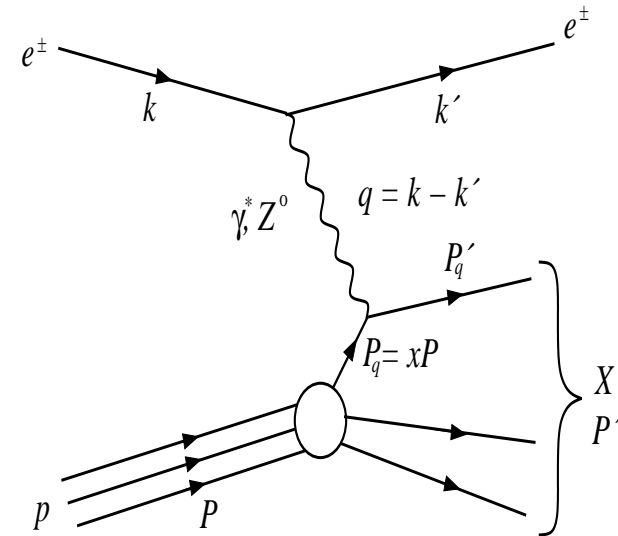
$$y = P(k - k') / Pk$$

NC DIS reduced cross section (for  $Q^2 \ll M_z^2$ ):

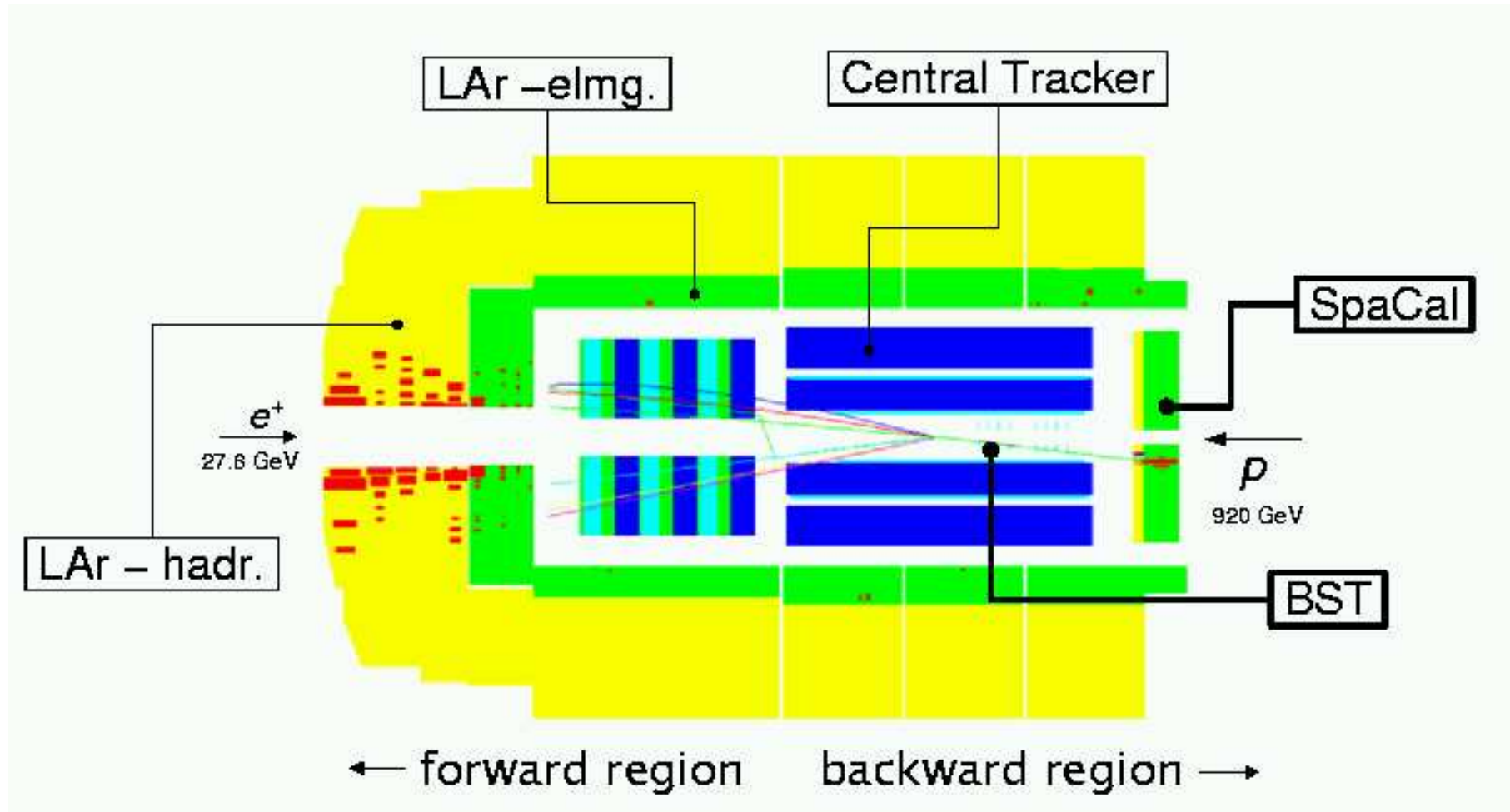
$$\sigma_r = F_2(x, Q^2) - \frac{y^2}{Y_+} \cdot F_L(x, Q^2), \quad Y_+ = 1 + (1 - y)^2$$

↑  
dominant

↑  
sizeable only at high y



# DIS event in H1 detector



# H1 backward detectors

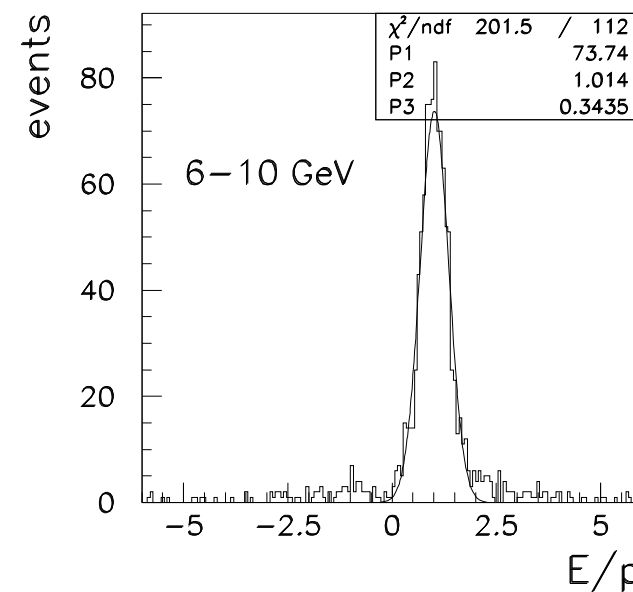
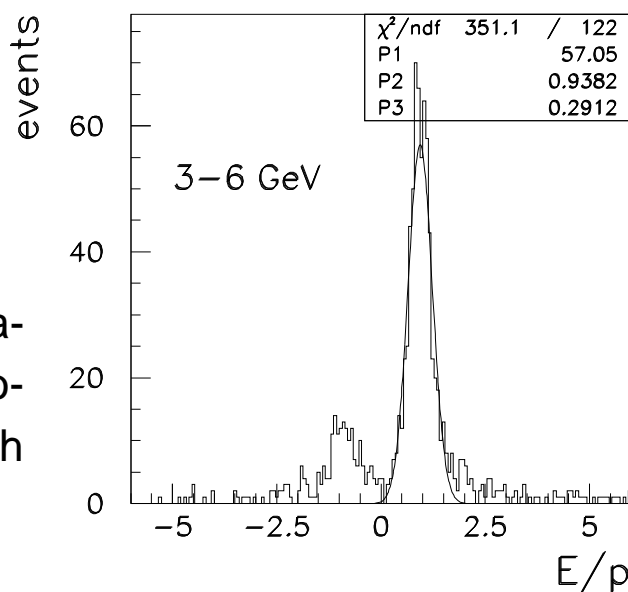
## SpaCal Calorimeter

- $153^\circ < \Theta < 177^\circ$
- lead - scintillating fibers
- 1192 square cells
- calibration accuracy:  
~ 0.3% at 27.6 GeV (DA meth.)  
~ 2% at 7 GeV (SpaCal-BST match.)

## Backward Silicon Tracker

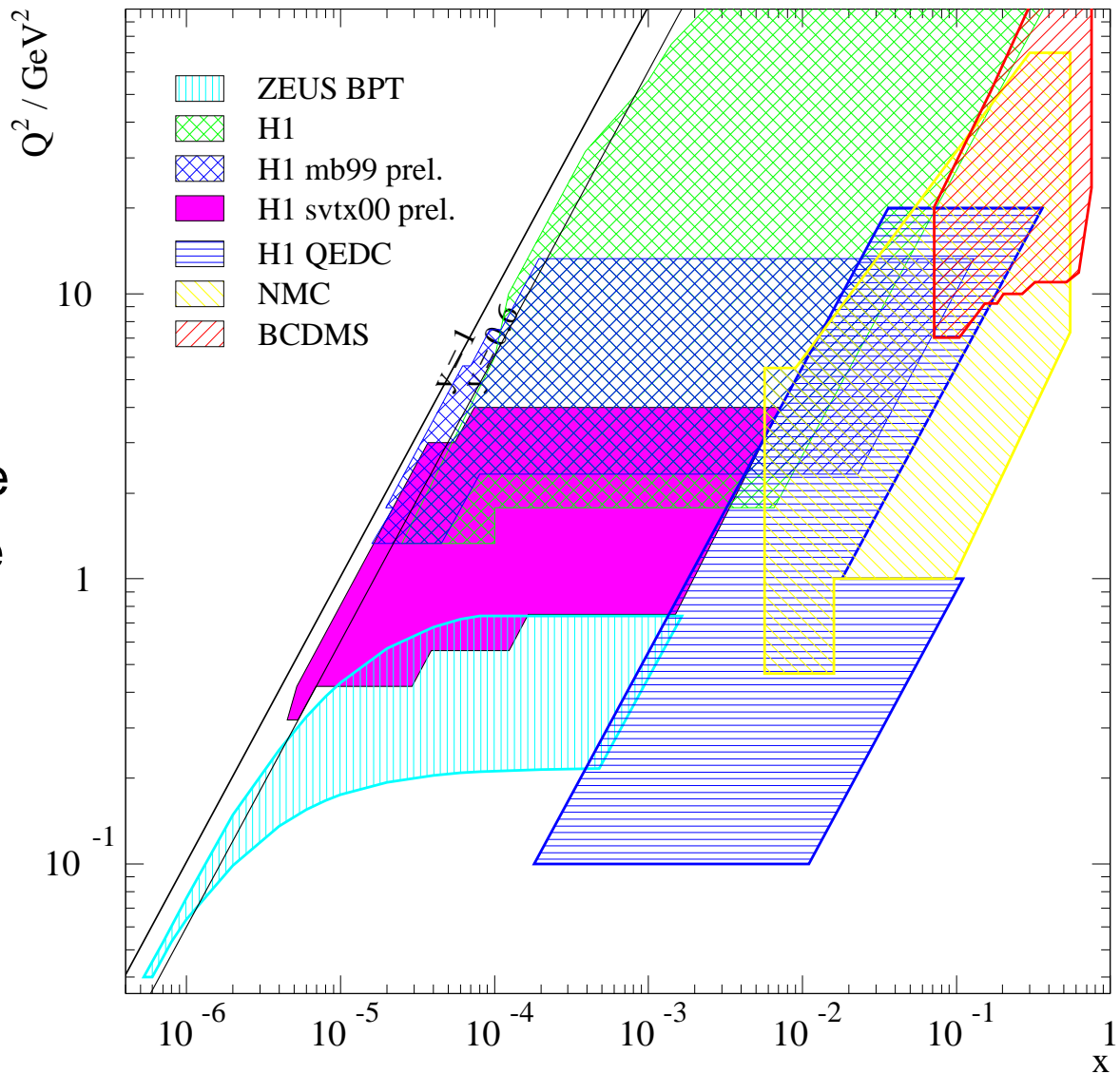
- $171.5^\circ < \Theta < 176.5^\circ$
- 8 planes x 16 sectors
- track reconstruction  
efficiency ~ 95%
- hit resolution ~  $20\mu m$

Ratio of energy measured in SpaCal to momentum measured with BST.



# Kinematic plane coverage

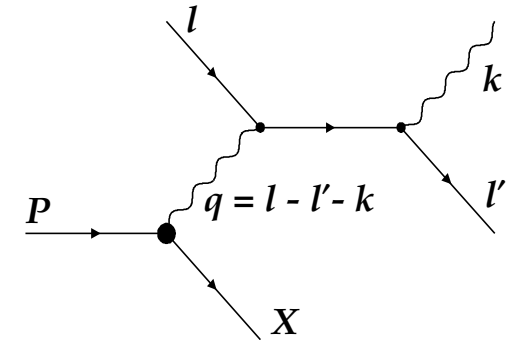
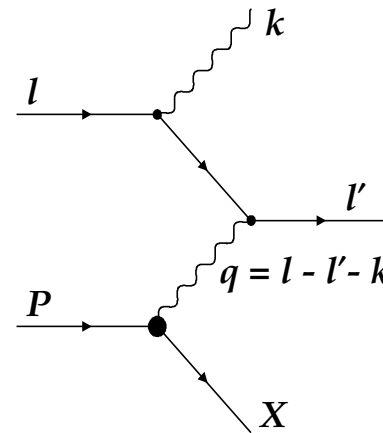
- QEDC data in the high  $x$  region
- 2000 svtx in the transition region between perturbative and non-perturbative kinematic range ( $\sim 1 \text{ GeV}^2$ )
- 99 mb and 2000 svtx access high  $y$  region



# QED Compton

$$q^2 \sim 0 \iff \vec{q} \parallel \vec{P}$$

Compton scattering of a quasi real photon off an electron



$$Q^2 = -q^2 = -(l - l' - k)^2, \quad x = \frac{Q^2}{2P \cdot (l - l' - k)}$$

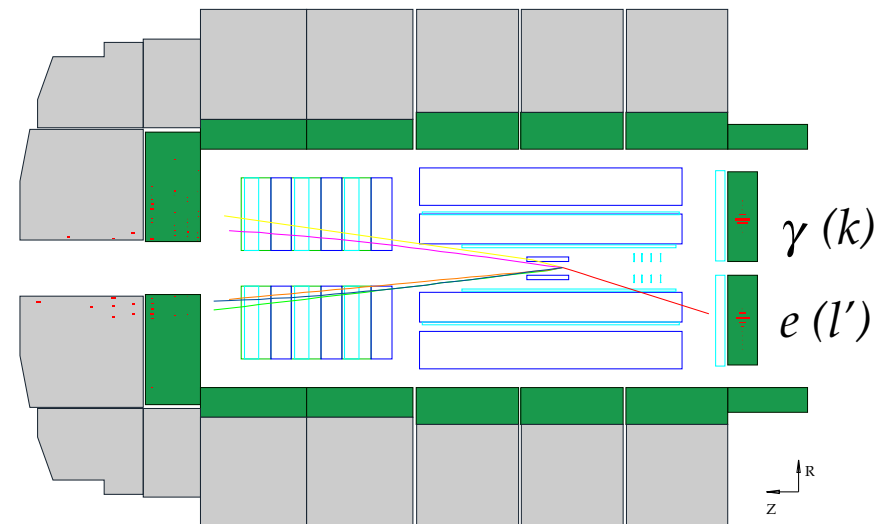
Contributions to QEDC cross section:

- elastic  $W = m_p$ , well known contribution (expressed by form factors)
- resonance  $m_\pi + m_p < W < 2 \text{ GeV}$ ,  $\Delta$  (1236),  $N^*$  (1520) ..., well known (relatively small)
- continuum inelastic  $W > 2 \text{ GeV}$ , p breaks, cross section expressed by  $F_2$  and  $F_L$ , since  $y$  small  $\Rightarrow F_L$  negligible.

# QED Compton

## Experimental signatures:

- two elm. clusters in SpaCal
- clusters back-to-back in azimuthal plane
- at least one track
- some activity in LAr cal.
- vtx in central region

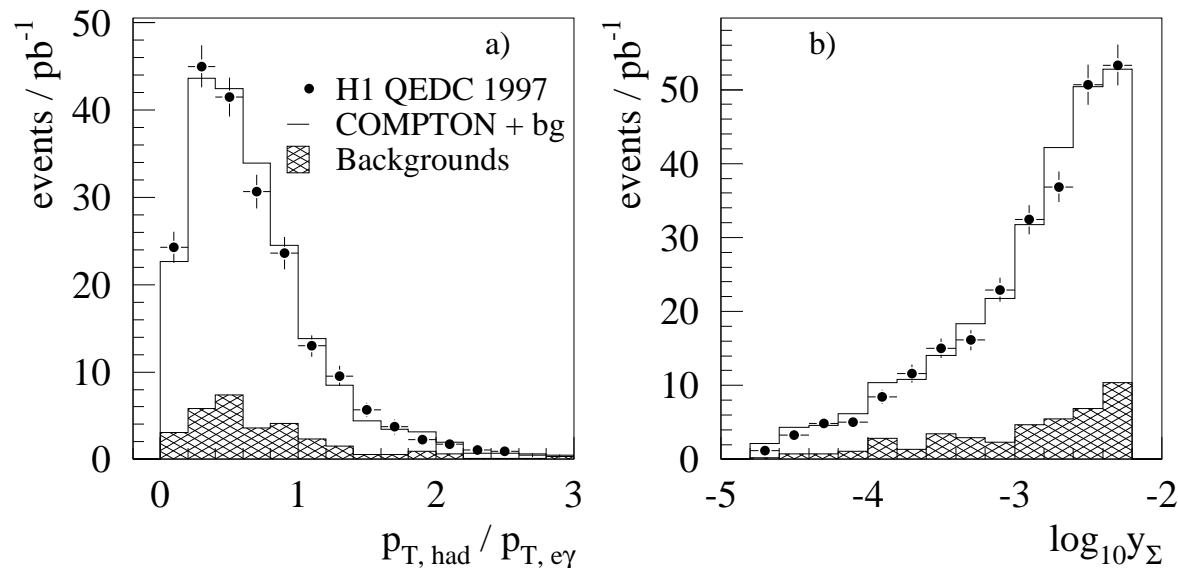


**Phase space limitations:** At high  $y$  DIS background (with  $\pi^0$  faking outgoing photon) dominates  $\Rightarrow$  analysis restricted to low  $y$  region.

# QEDC – MC simulation

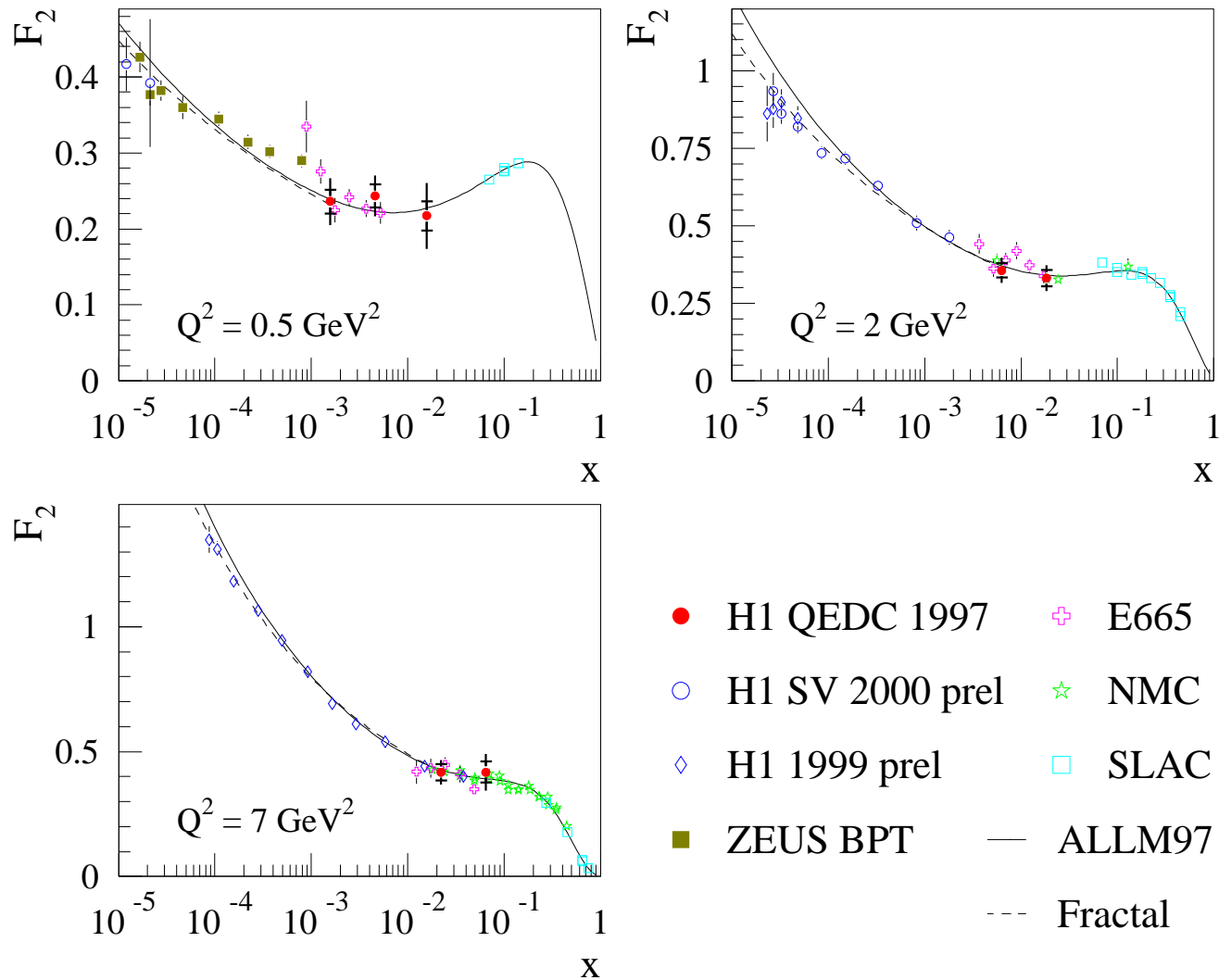
SOPHIA MC for low  $Q^2$  or low  $W$ :

- precise description of  $\gamma$  hadron interactions reproducing large set of available data.
- includes: major baryon resonances, direct  $\pi$  production, diffractive production of light vector mesons, multiparticle production based on Dual Parton Model with Lund string fragmentation.



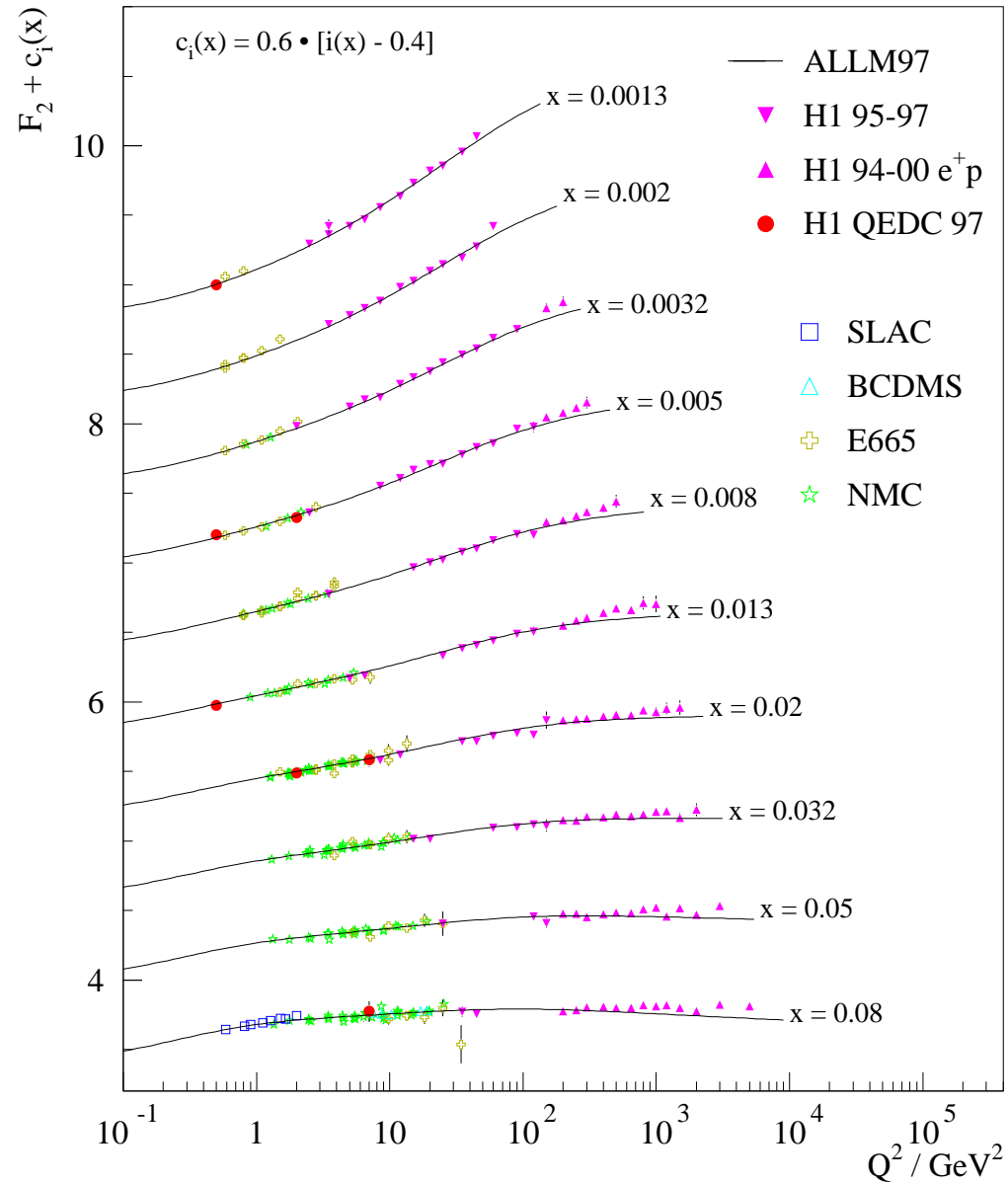
Good description of hadronic final states in forward direction by the COMPTON MC which implements SOPHIA package.

# $F_2$ measurement with QEDC



Good agreement with fixed target data.

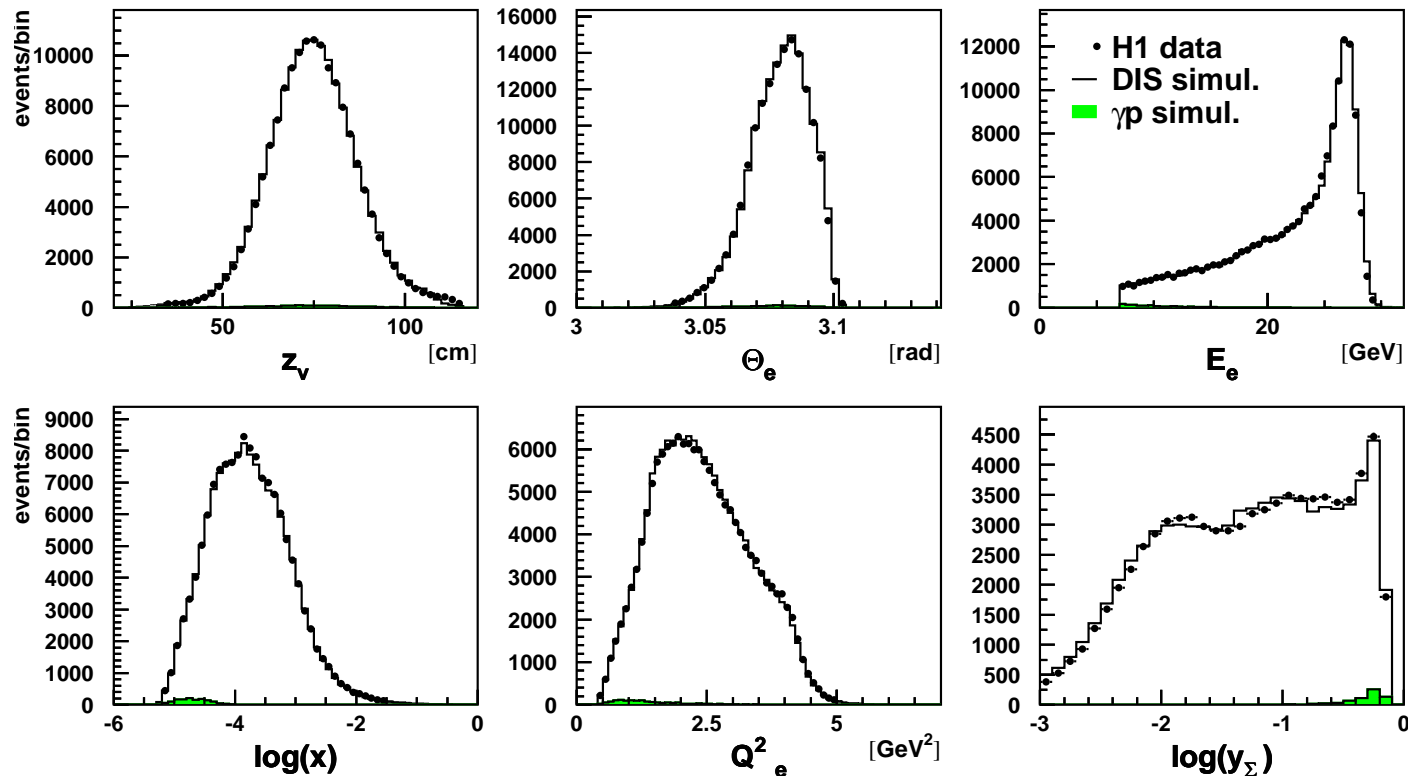
# $F_2$ measurement with QEDC



# Cross section analysis at low $x$

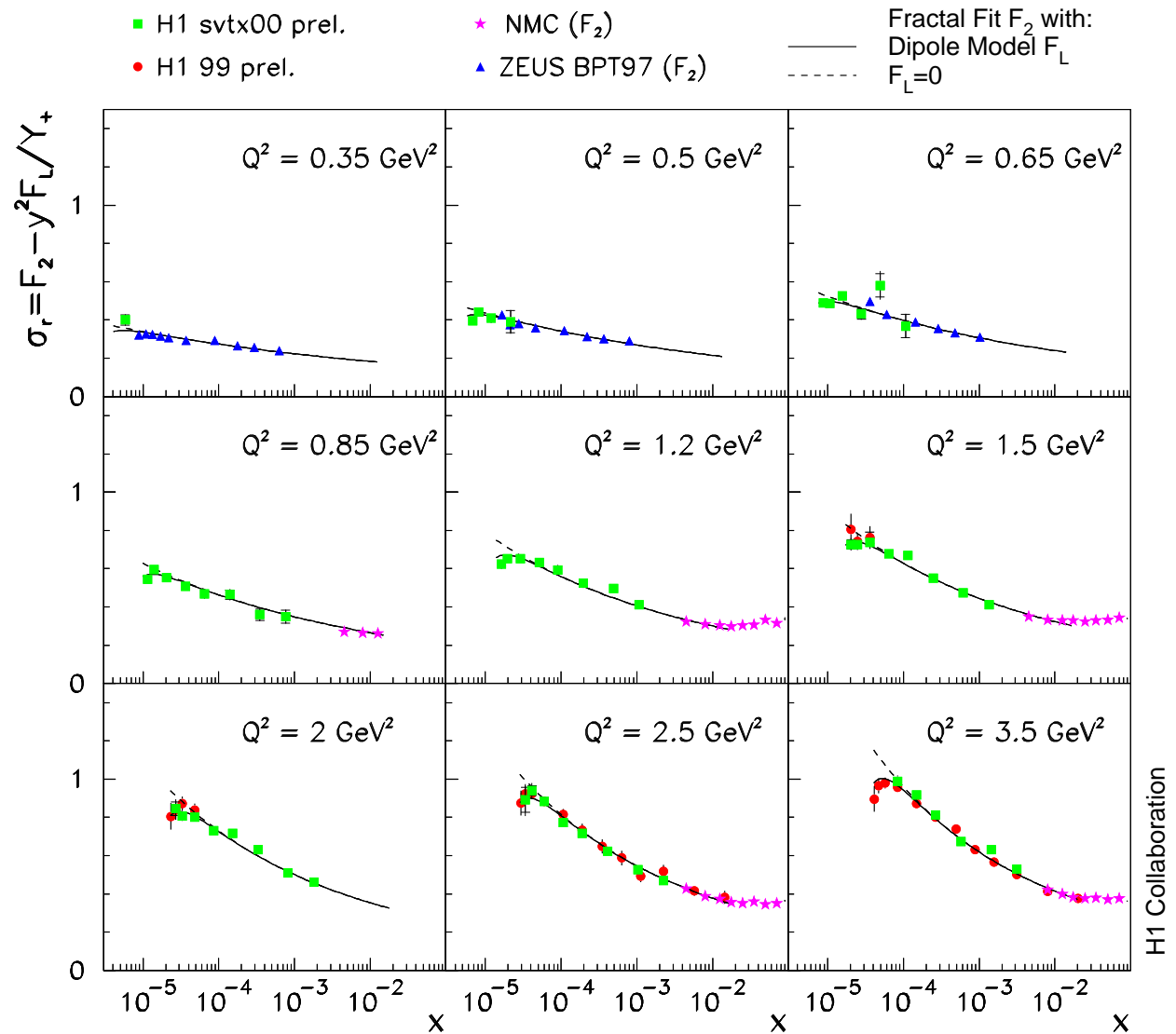
## Event selection:

- inclusive SpaCal trigger ( $\mathcal{L}_{99mb}=2.7\text{pb}^{-1}$ ,  $\mathcal{L}_{00svtx}=0.6\text{pb}^{-1}$ )
- cluster in electromagnetic SpaCal
- BST validated track matching SpaCal cluster
- vertex in interaction region ( $\sim 0\text{cm}$  for 99mb,  $\sim 70\text{cm}$  for 00svtx)



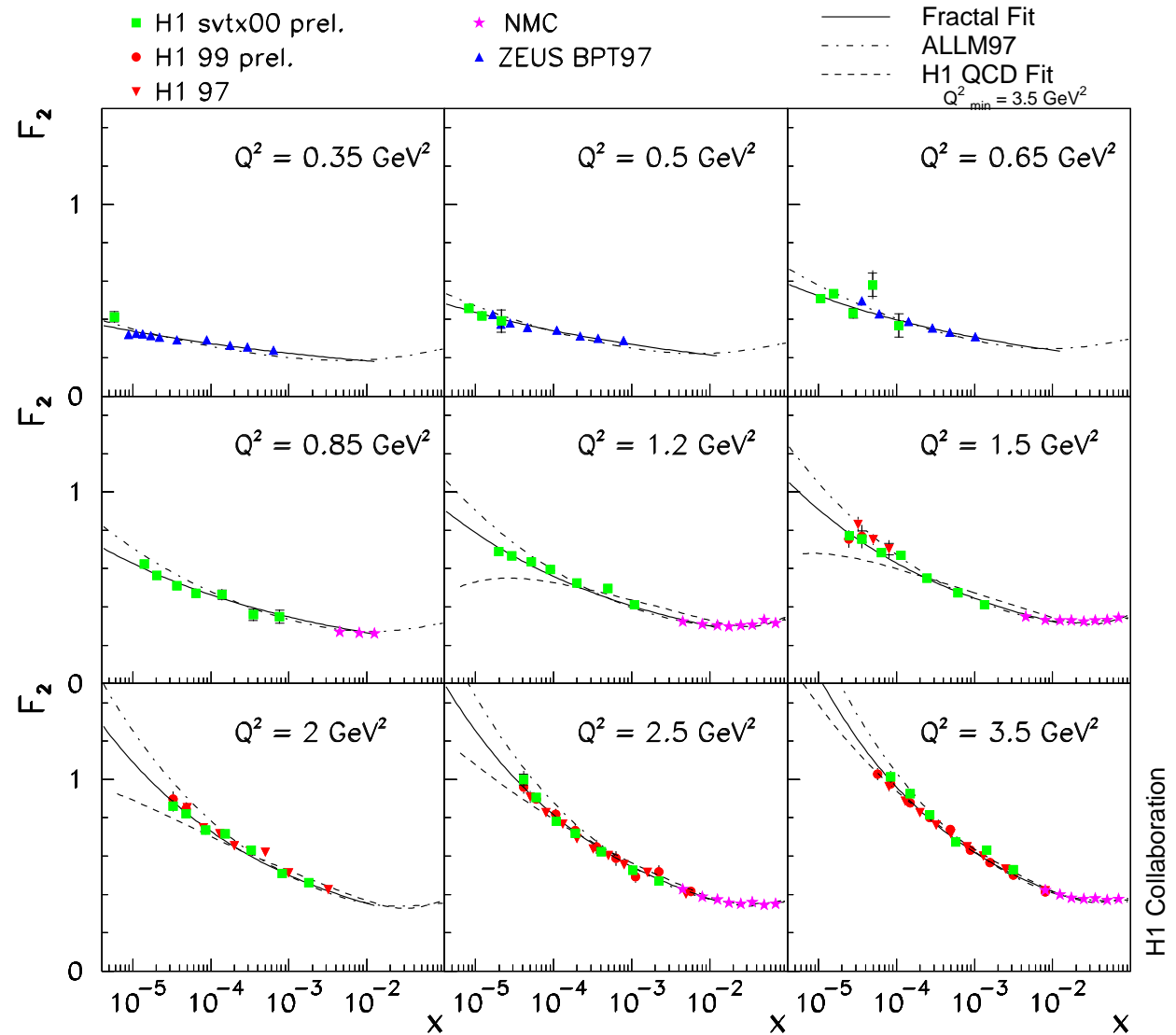
# Reduced cross section $\sigma_r$

- high precision measurement (2-3% in bulk region)
- wide inelasticity range covered ( $0.002 < y < 0.89$ )



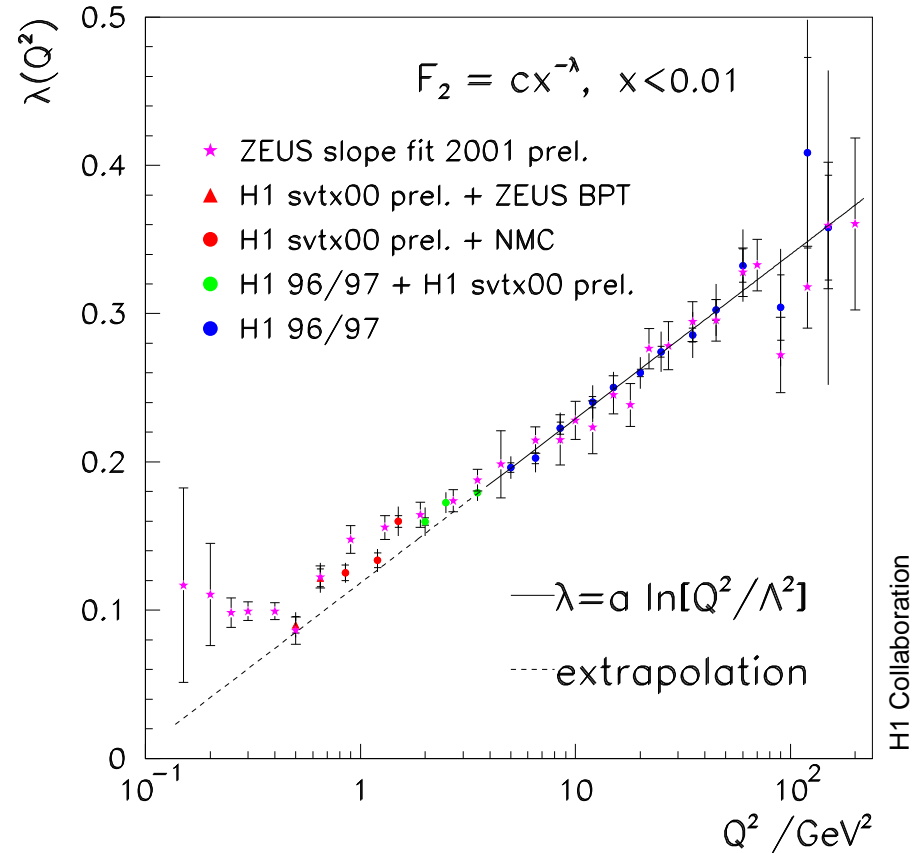
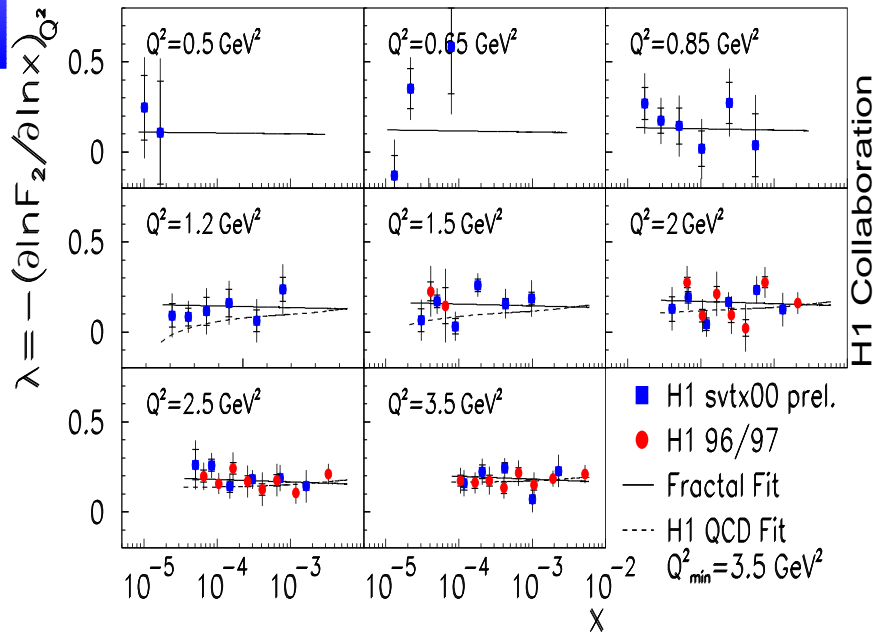
# Structure function $F_2$

- obtained from  $\sigma_r$  for  $y < 0.6$  using dipole model for  $F_L$
- $F_2$  rise towards low  $x$  observed for all  $Q^2$



# $x$ and $Q^2$ dependence of $F_2$

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



- $\lambda$  const. at fixed  $Q^2$  for  $x < 0.01$   
 $\Leftrightarrow F_2(x, Q^2) = c(Q^2) \cdot x^{-\lambda(Q^2)}$

- $\lambda \sim \ln(Q^2/\Lambda^2)$  and  $c(Q^2) \sim \text{const.}$  for  $Q^2 > 3.5 \text{ GeV}^2$
- around  $Q^2 = 1 \text{ GeV}^2$   $\lambda$  deviates from log-dependence
- from soft hadronic interactions expected that  $\lambda \rightarrow 0.08$  for  $Q^2 \rightarrow 0$

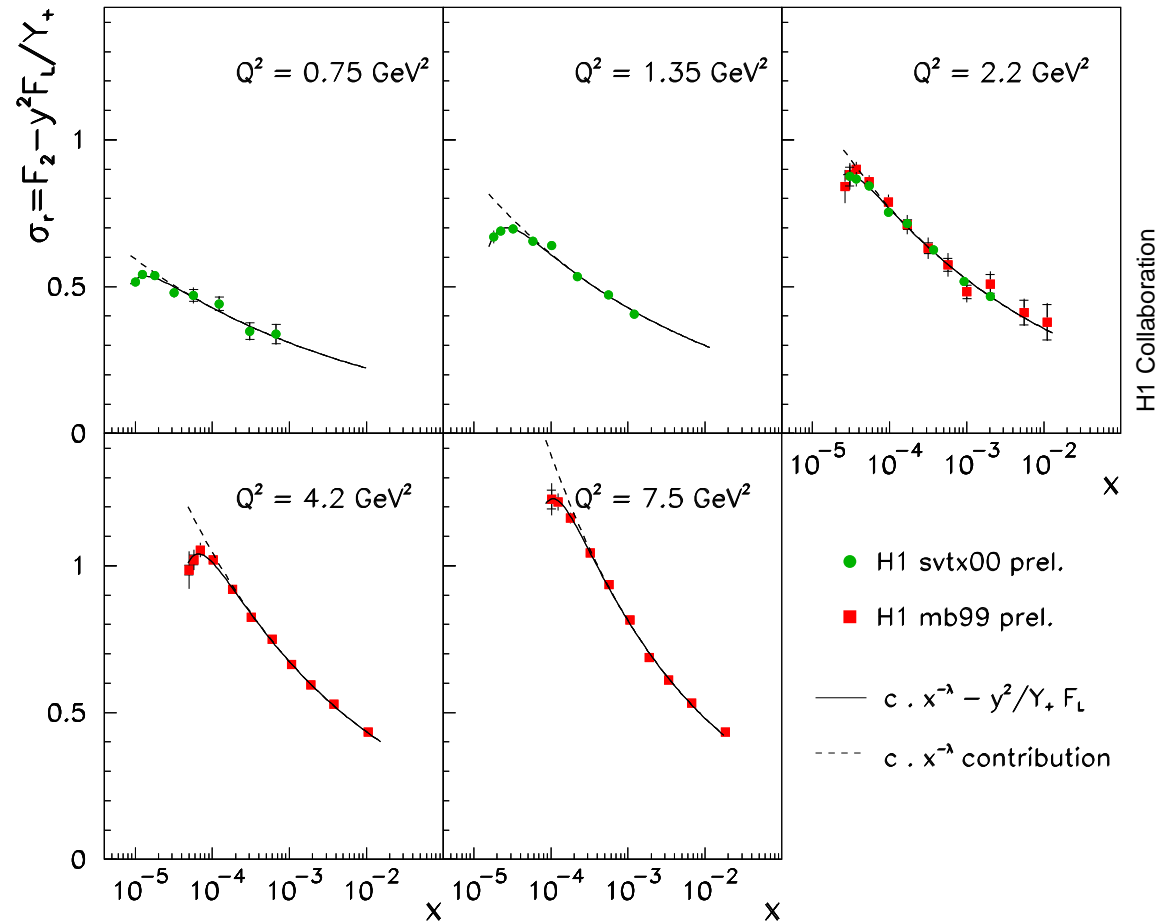
# $F_L$ determination - “shape” method

- shape of  $\sigma_r$  driven by kinematic factor  $y^2/Y_+$  rather than by  $F_L$
- constant  $F_L$  for small  $x$  range
- whole  $x$  range of measured data used to fit  $F_2$  and  $F_L \Leftrightarrow$  no extrapolation of  $F_2 \Leftrightarrow$  full information used  $\Rightarrow$  smaller errors
- fit in  $Q^2$  bins:

$$\sigma = F_2 - y^2/Y_+ \cdot F_L$$

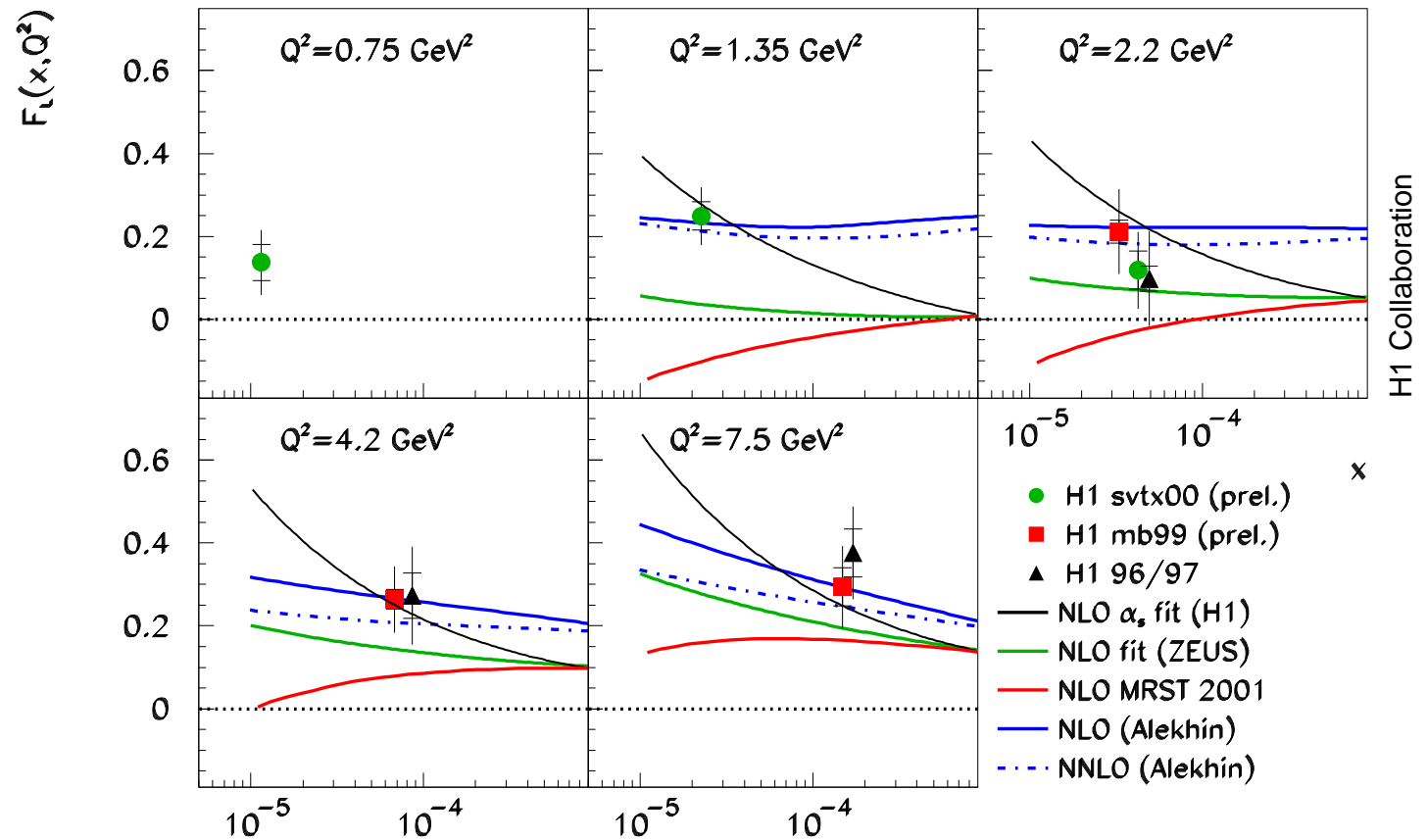
$$\uparrow$$

$$c \cdot x^{-\lambda}$$



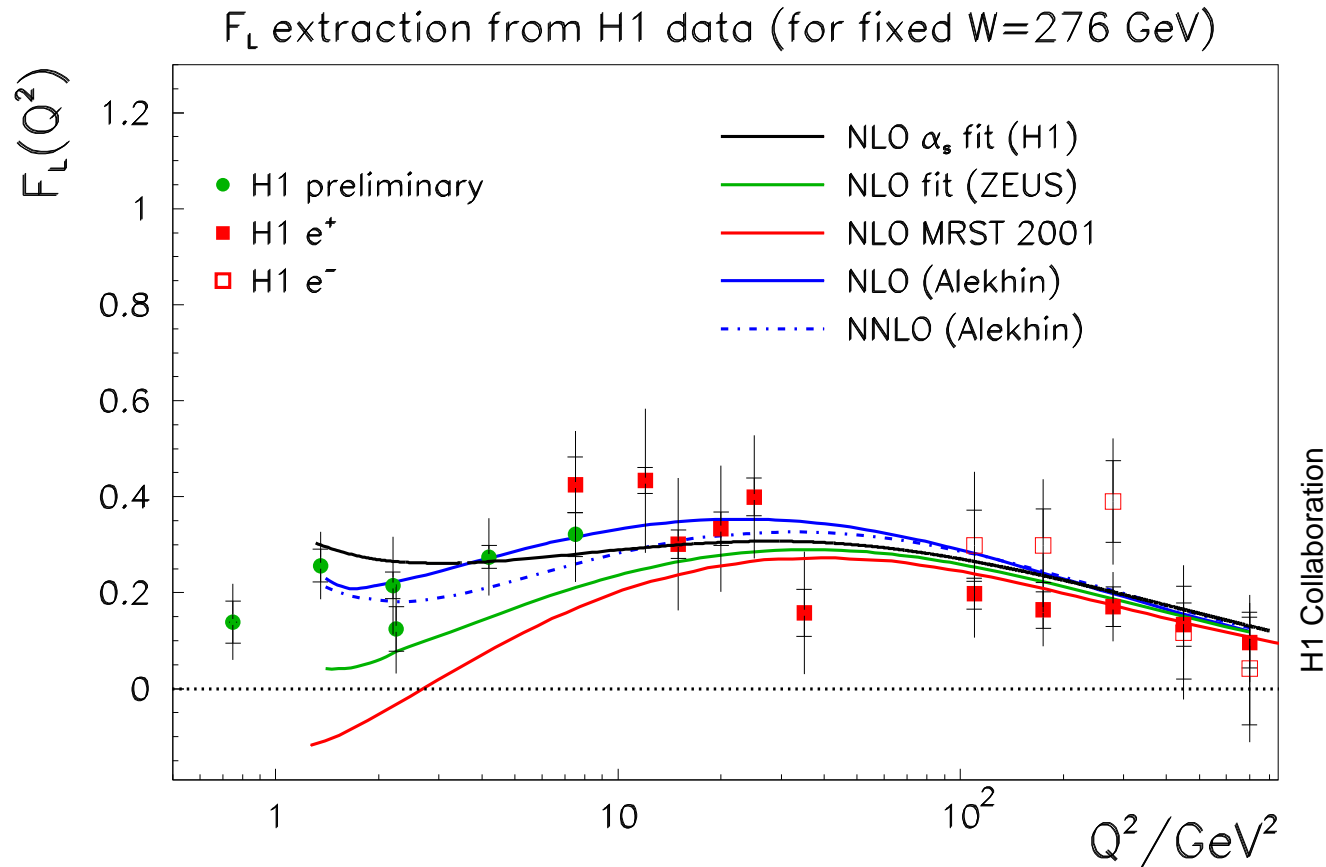
excellent description of  $\sigma_r$  by the “shape” fit in full kinematic region

# $F_L$ results



- extracted  $F_L > 0$  in all  $Q^2$  bins
- extracted  $F_L$  is able to constrain theoretical predictions
- measurement of  $x$  dependence of  $F_L$  is desirable – can be achieved by running with dedicated low  $E_p$  beam

# $F_L$ results



- H1 NLO QCD fit consistent with the data in the DIS region
- Alekhin NLO (and NNLO) in agreement with data
- MRST 2001 NLO QCD fit too low at low  $Q^2$
- ZEUS NLO QCD fit also tends to be low at low  $Q^2$

## Summary

- $F_2$  measurement for low  $Q^2$  extended into high  $x$  region with QED Compton events – results found to be consistent with fixed target data
- $F_2$  measured with high precision for low  $Q^2 \sim 0.1 - 10 \text{ GeV}^2$
- $F_L$  from H1 data precise enough to constrain theoretical predictions
- to perform precise measurement of  $F_L$  runs with lowered proton beam energy necessary

## *Further plans*

- 2000 bulk data – structure functions analysis with even higher precision.  
Aim: 1% for  $F_2$ .
- 2004 data – more precise  $F_L$  determination thanks to improved backward tracking detectors.  
  
... but ...
- 1999 mb and 2000 svtx data – still new ideas of extension of the measurement in the kinematic space  $\Rightarrow$  Alexey Petrukhin's talk