$F_L(x,Q^2)$
Measurements with H1
Results and Plans

Max Klein on behalf of H1

Cross Section Measurements
Extractions of F_L
Studies and Simulations

Workshop on Deep Inelastic Scattering DIS 2006 Tsukuba/Japan 23.4.2006

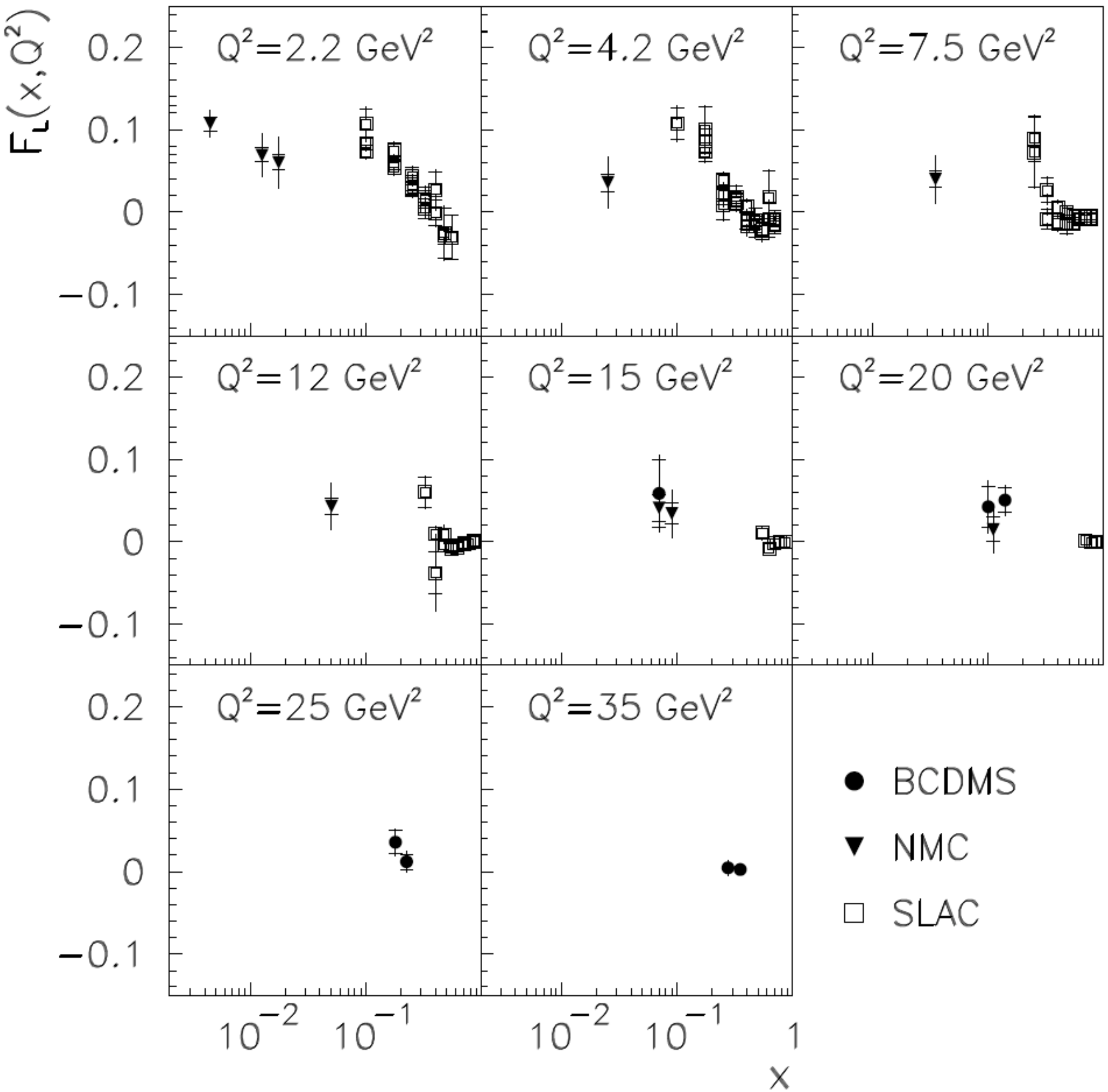
FL measurements in lepton-nucleon, fixed target experiments at Large x

$$\sigma_r = \frac{Q^4 x}{2\pi\alpha^2 Y_+}\sigma(x,Q^2)$$

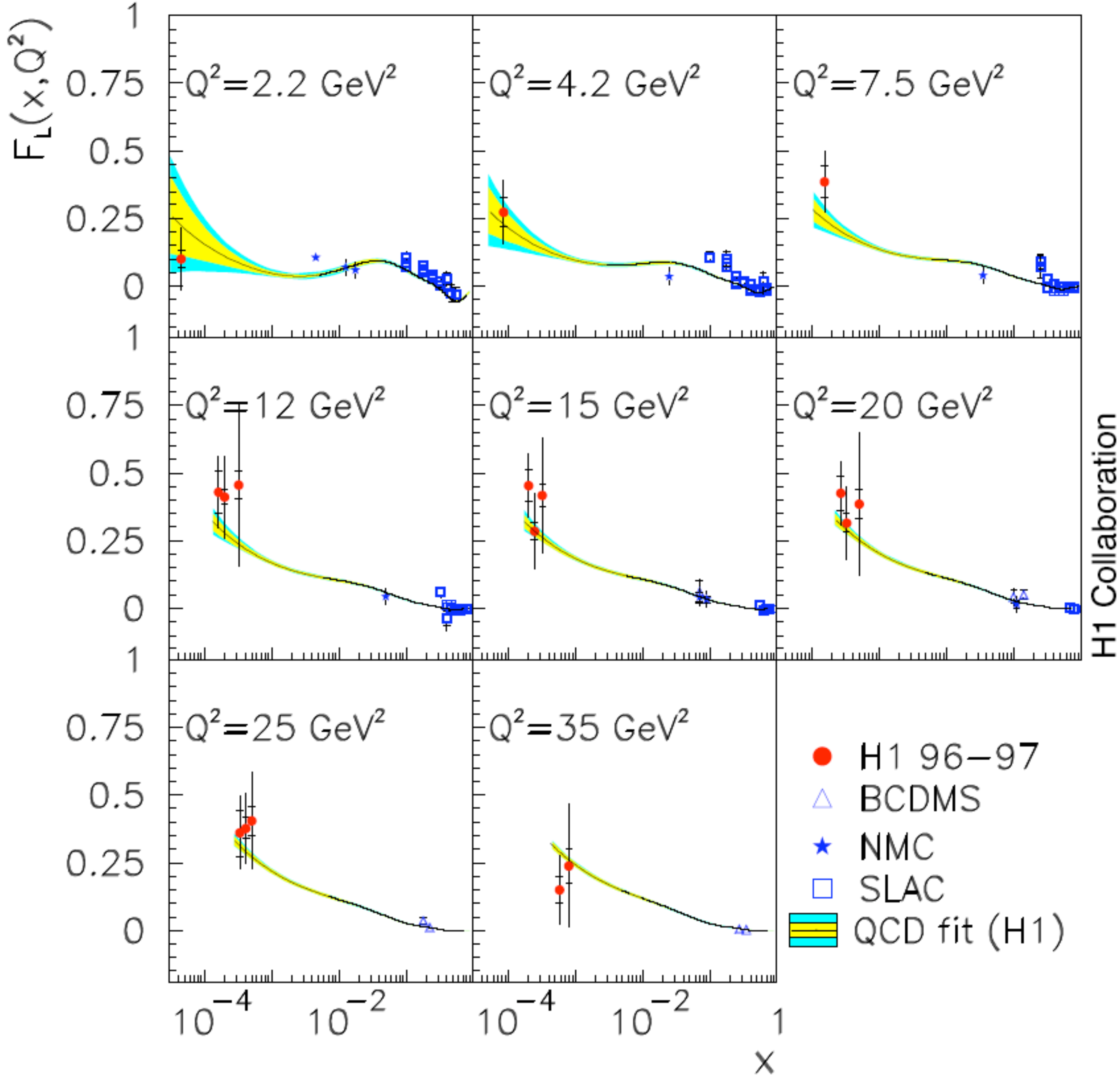
$$\sigma_r = F_2 - f(y)\cdot F_L$$

$$f(y) = \frac{y^2}{Y_+}$$

$$Y_+ = 1 + (1-y)^2$$

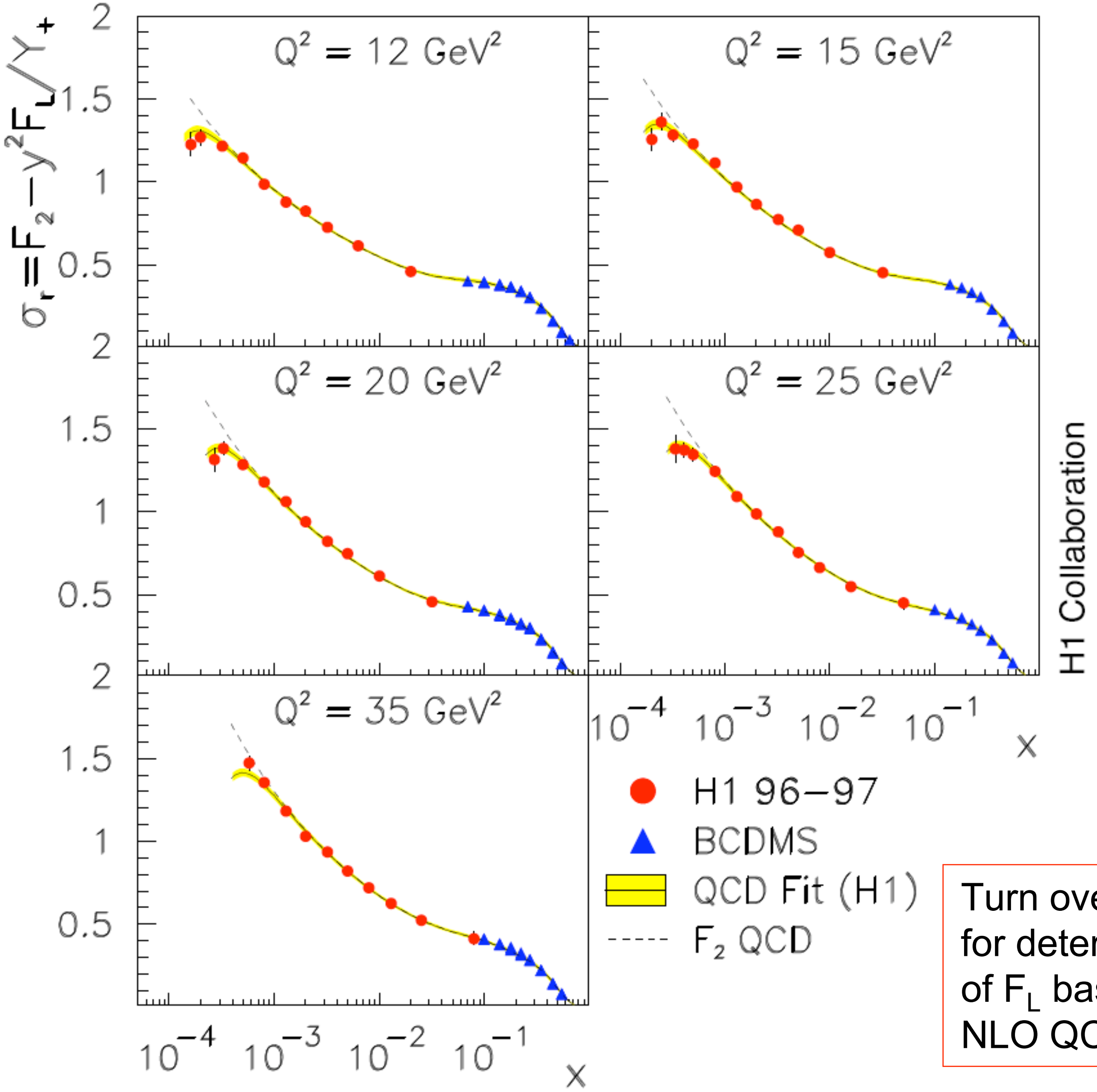


Measuring
$R = F_L/(F_2 - F_L)$
or F_L is
apparently
not easy…



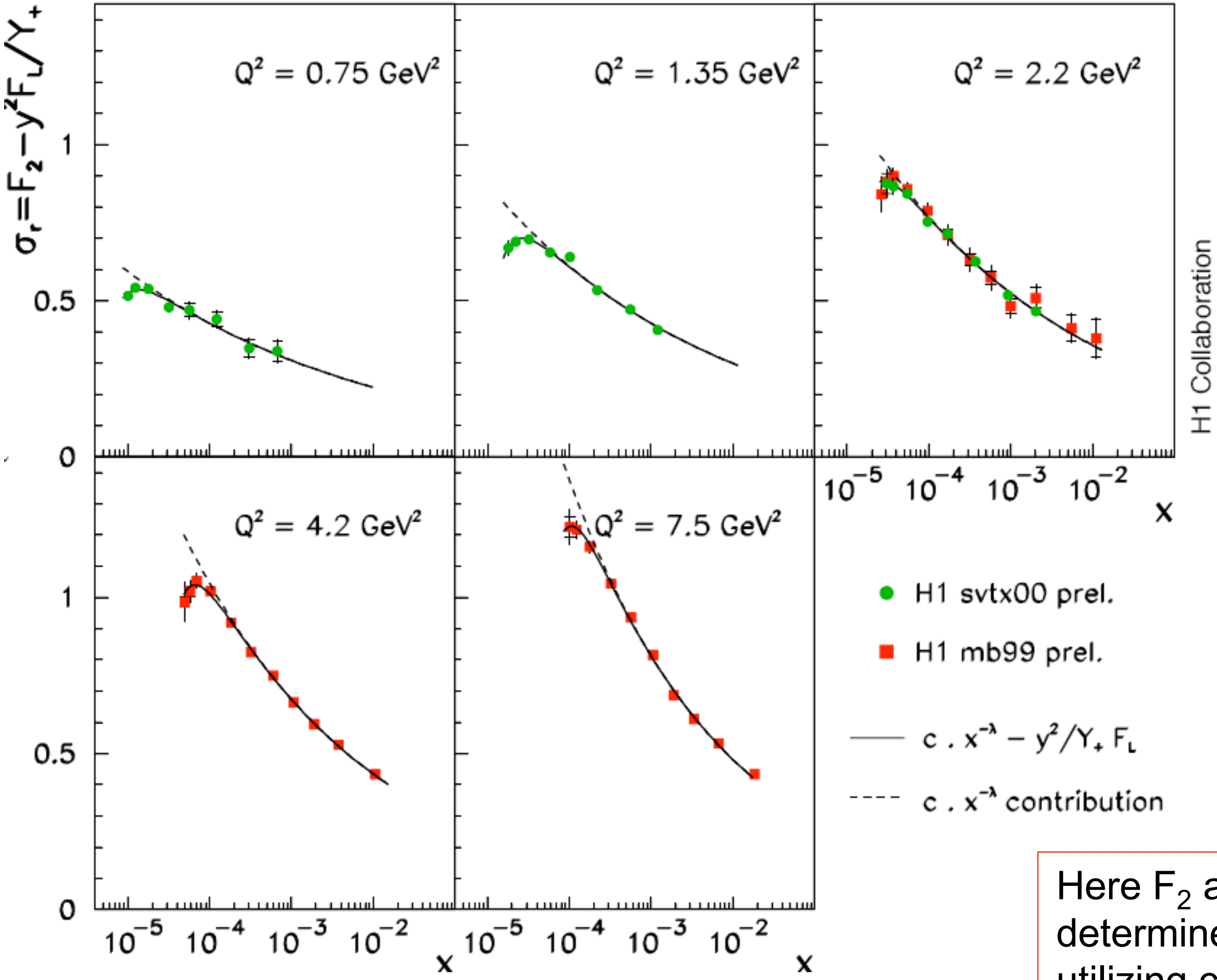
$F_L(x,Q^2)$
Q^2=2.2 GeV^2
Q^2=4.2 GeV^2
Q^2=7.5 GeV^2
Q^2=12 GeV^2
Q^2=15 GeV^2
Q^2=20 GeV^2
Q^2=25 GeV^2
Q^2=35 GeV^2
H1 Collaboration
H1 96–97
BCDMS
NMC
SLAC
QCD fit (H1)
x

H1 Cross Section Data



Turn over used for determination of F_L based on NLO QCD F_2

Reduced cross section low Q^2 - H1 preliminary data

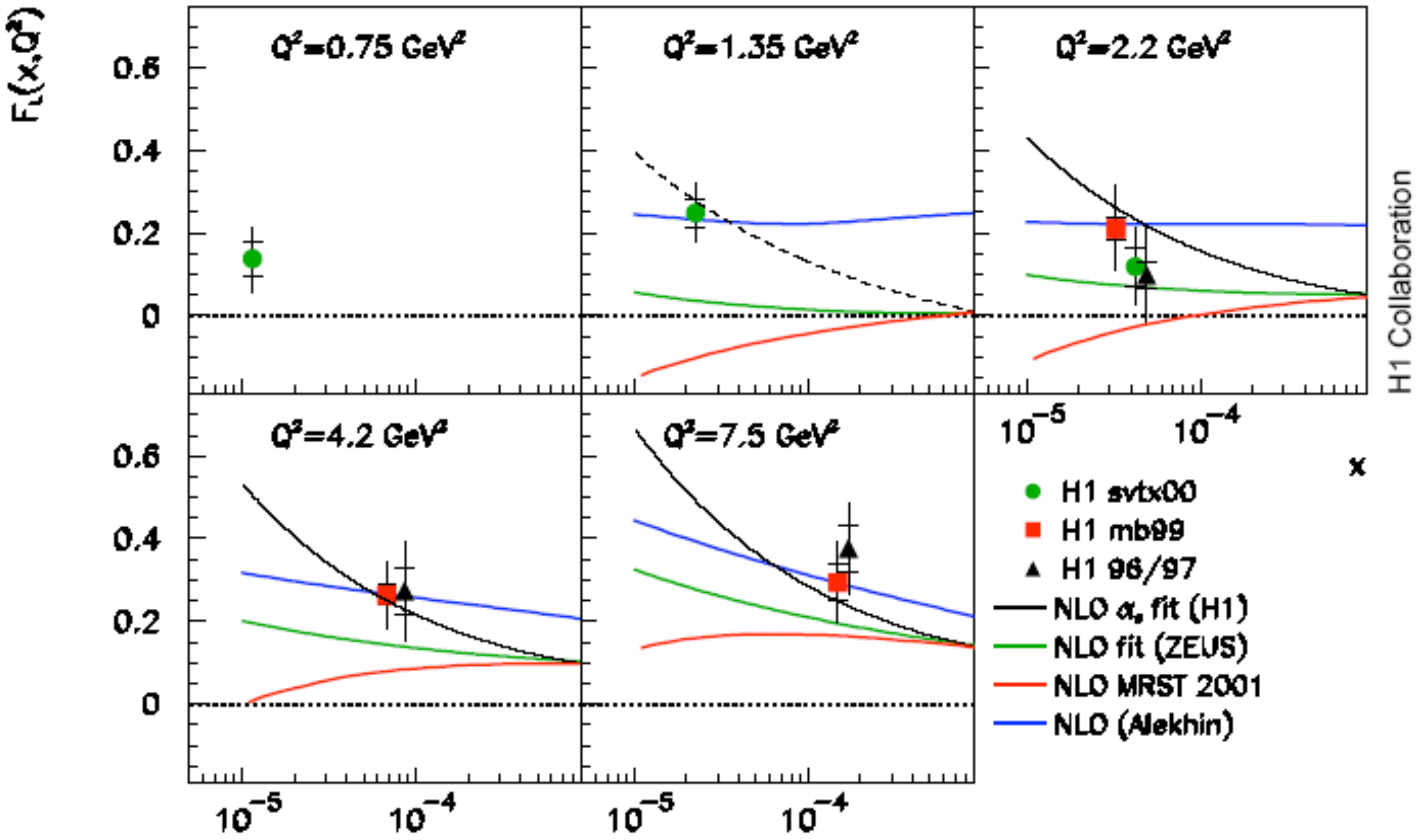


$$\sigma_r = F_2 - f(y) F_L$$

$$F_2 = a x^{-\lambda}, F_L = c$$

Here F_2 and F_L determined simultaneously utilizing characteristic y^2 shape of cross section

Results on extracting FL at low Q^2 - H1 preliminary



MK DIS2006

Challenges and Remarks

$$\sigma_r = F_2 - y^2/[1+(1-y)^2]\cdot F_L$$

Since y is usually small (0.001 - 0.9 for H1) and $F_L < F_2$, the longitudinal structure function is hard to access

Its contribution is sizeable only at large y > 0.6. At low Q^2, y is approximately given by $1-E_e'/E_e$,
Thus it is required to identify the scattered electron in a large background of hadrons, mainly from photoproduction but also from deep inelastic scattering (high y is low x, i.e the HFS is scattered backwards.)

With fixed beam energies, the F_2 and F_L terms cannot be accurately disentangled. Approximately, one can extract F_L by assuming one knows F_2, the reverse is always done when F_2 is extracted. H1 thus decided so far to extract F_2 for y < 0.6 and F_L for y > 0.6, and base QCD analyses on the reduced cross section σ_r.

Yet the values of F_L quoted depend on the NLO QCD fit [to the H1 data] at larger Q^2 or they exploit the y shape of the F_L cross section term and the simple rise of F_2 with decreasing x. In all cases one assumes F_2 to be known, or to be jointly determined with F_L, at lowest x where only the cross section is measured. Such methods could hardly be exploited in fixed target experiments due to the limited range in y and due to the more complicated behaviour of F_2 at larger x. Indirect methods remain to be not satisfactory.

A direct measurement unfolds both structure functions simultaneously. It determines F_L in the region of high y at the lower beam energy, i.e. not at the smallest x. Thus it cannot fully replace the indirect determinations. Those, however may be verified and if they are, we may obtain data on F_L over nearly one order of magnitude in x at low Q^2.

A direct measurement requires to vary the beam energy. Lowering the proton beam energy has been preferred in order to keep E_e' large for reaching a fixed high y, and for electron acceptance uniformity.

Predictions for the longitudinal structure function

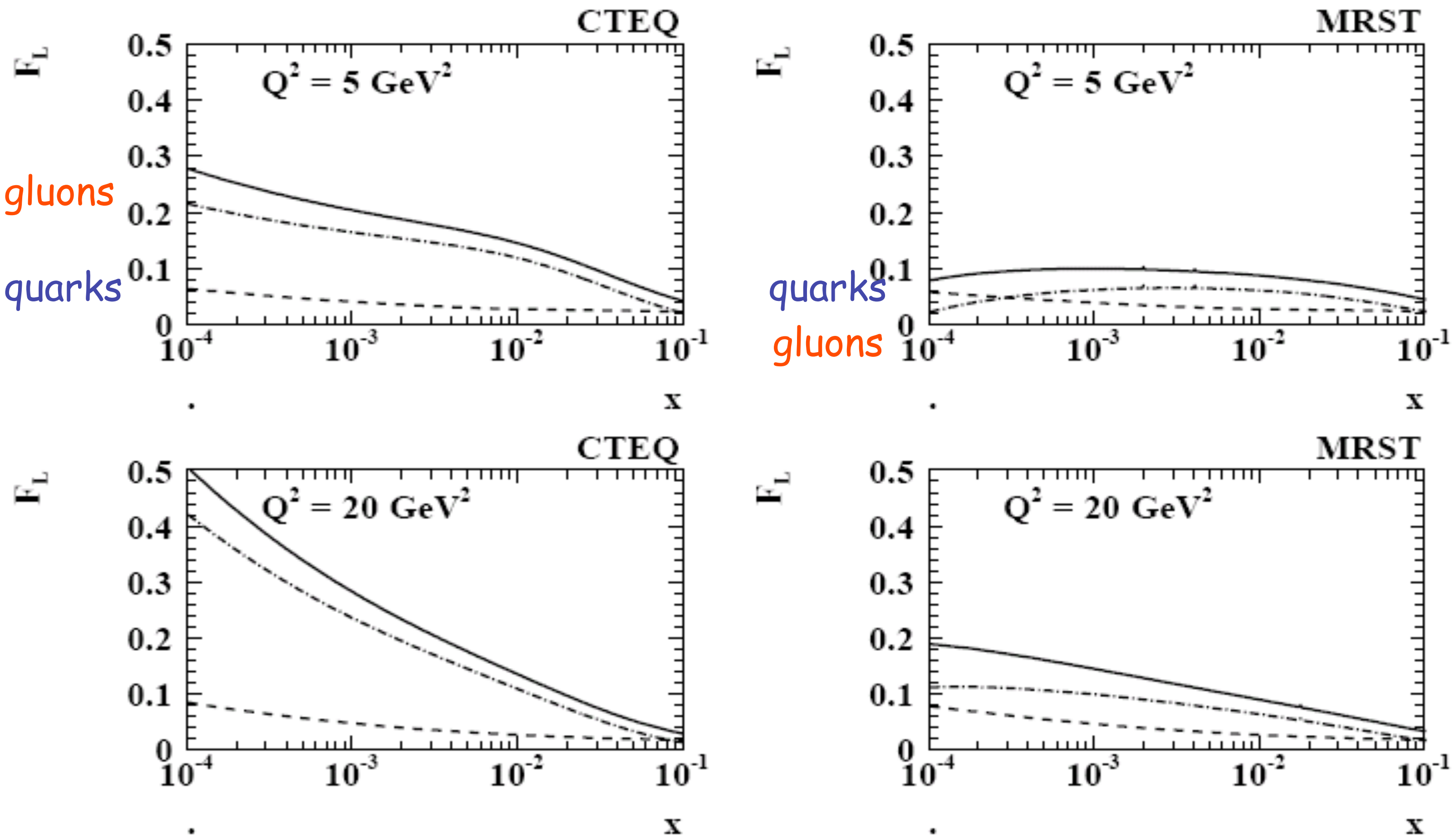


Figure 2. Calculation of the longitudinal structure function $F_L(x, Q^2)$ (solid lines) using the CTEQ6 (left) and the MRST2002 (right) parton distributions and Eq.2 for 4 flavours and α_s to NLO. Note that not only the predicted values for F_L differ but as well drastically the relative contributions from gluons (dashed dotted lines) and sea quarks (dashed lines). For MRST at low x, contrary to common belief, $F_L(x, Q^2)$ is not gluon dominated. Both sets of parton distributions describe the H1 data on F_2 well.

$$F_L = \frac{\alpha_s}{4\pi} x^2 \int_x^1 \frac{dz}{z^3} \cdot \left[\frac{16}{3} F_2 + 8 \sum e_q^2 \left(1 - \frac{x}{z}\right) zg \right]$$

G. Altarelli and G. Martinelli, Phys.Lett. B76 (1978) 89.

Hamburg, October 27th, 2005 H1-10/05-622

Running at Low Proton Beam Energies

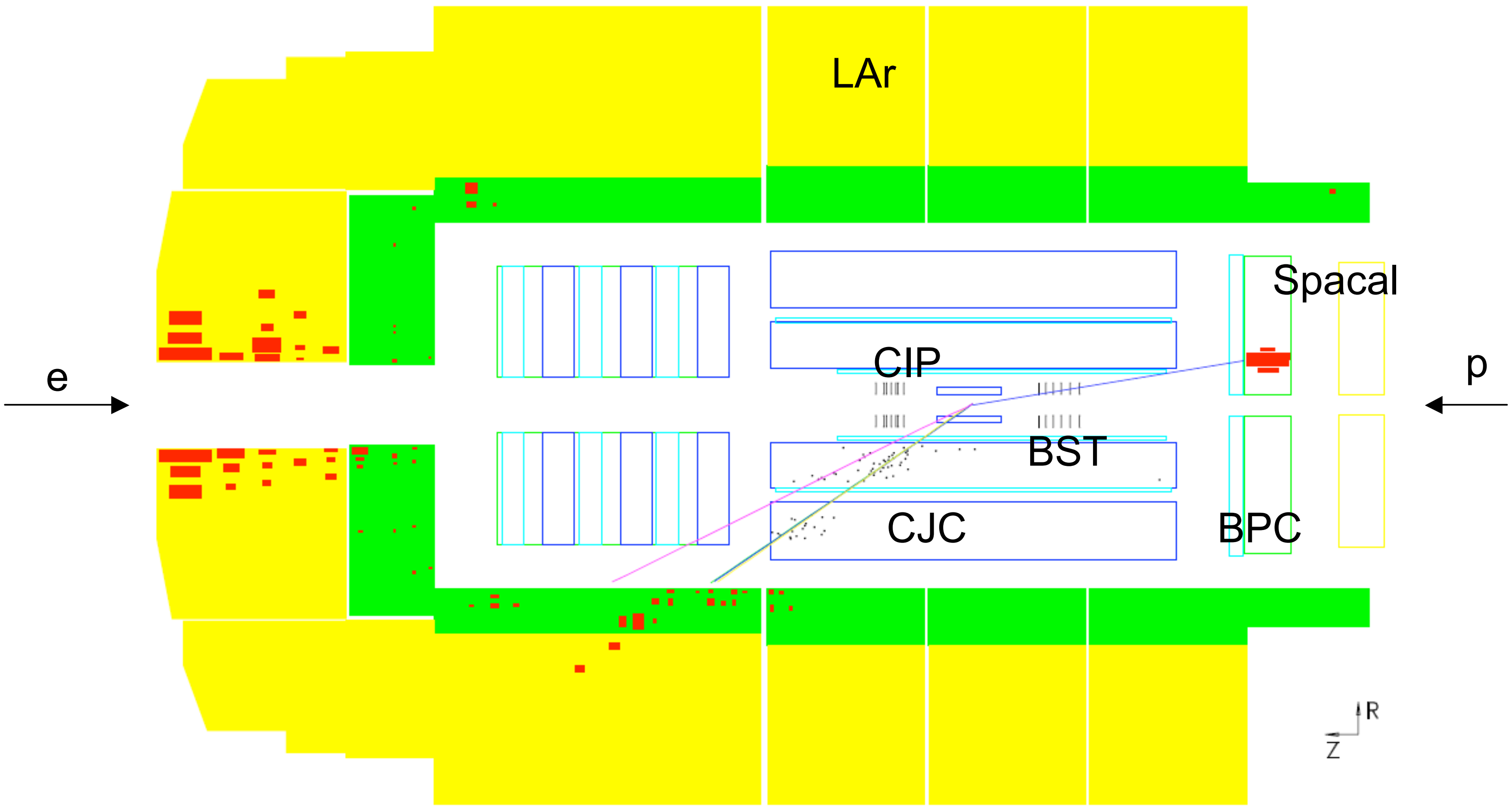
H1 Collaboration

Expression of Interest submitted to the DESY Physics Research Committee, PRC 11/05

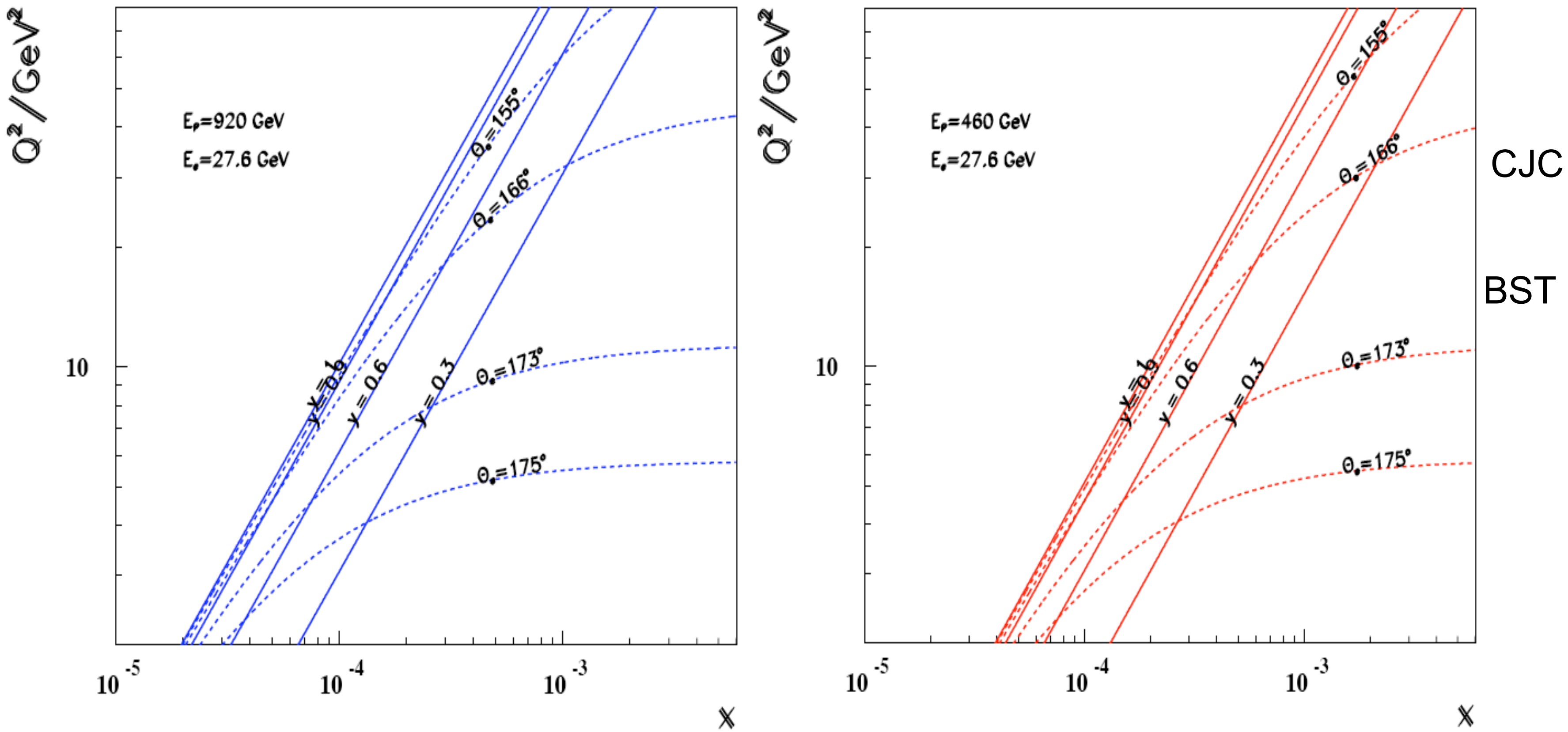
Abstract

The H1 Collaboration is interested in a run with reduced proton beam energy of about three months duration in order to measure the inclusive and the diffractive longitudinal structure functions at low x and Q^2 from data corresponding to an integrated luminosity of about 10 pb^{-1}. This run has been considered to be essential to complete the HERA *ep* programme, which is largely devoted to the understanding of a gluon dominated high density system of partons. It is proposed to be performed in the year 2007.

DIS event in H1

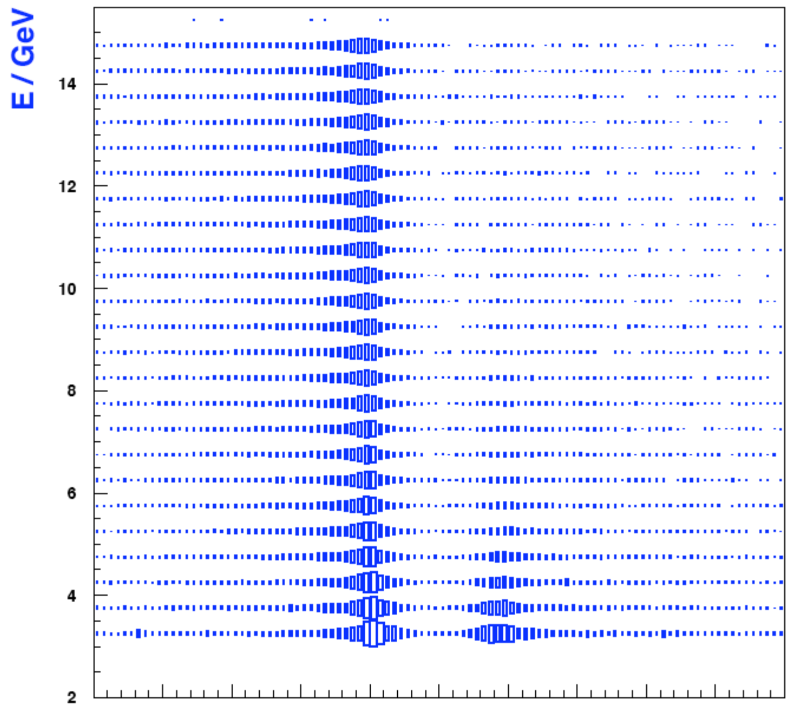


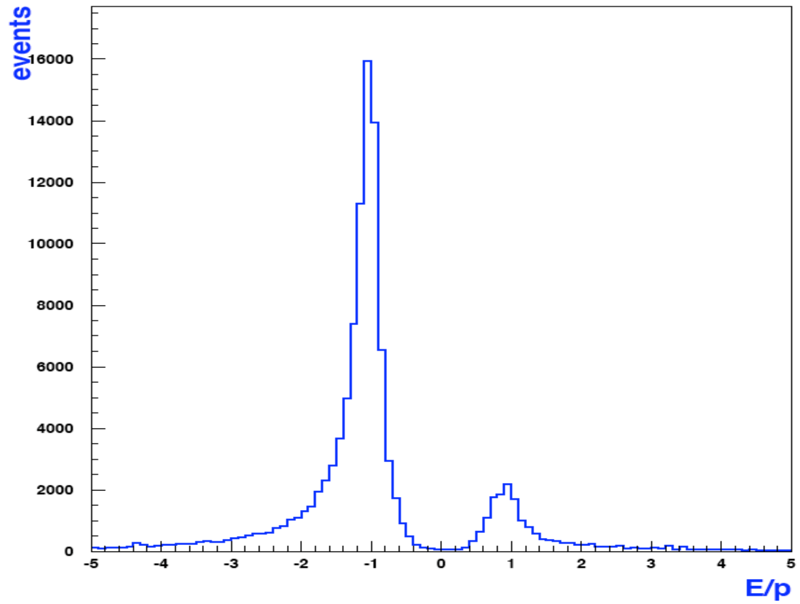
Kinematic Coverage



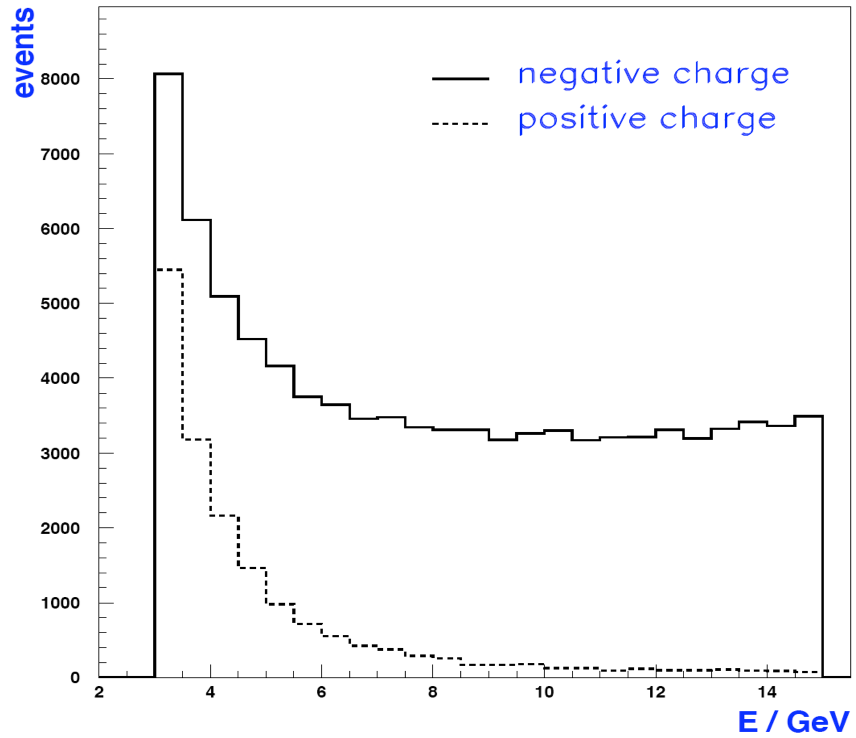
The low Q^2 acceptance limit is given by the high E_p, large theta cut - inner radius of SPACAL, ~173°.
The large Q^2 acceptance limit is given by the low E_p, low theta cut - outer radius of SPACAL, ~ 155°.
A shift of the vertex by +20 cm in + z direction for the high E_p run made acceptance more uniform.

large Q^2 study with e^- 05 data



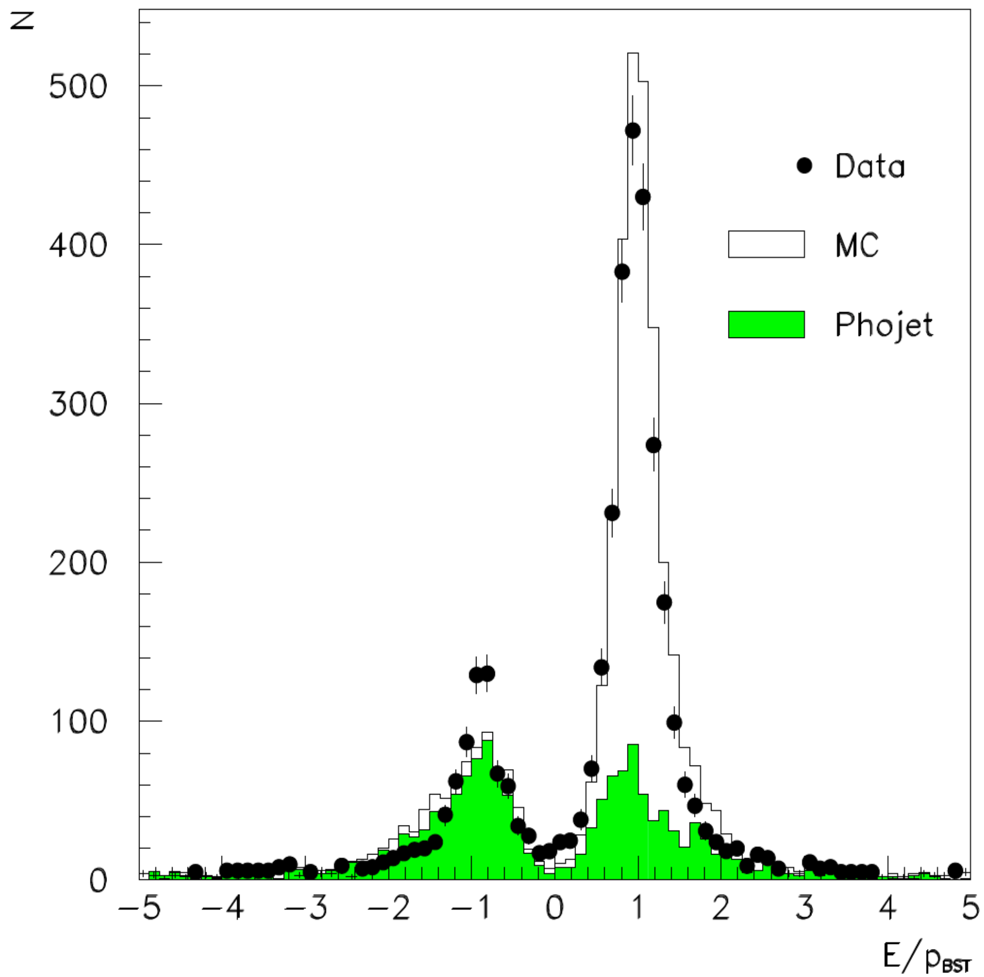


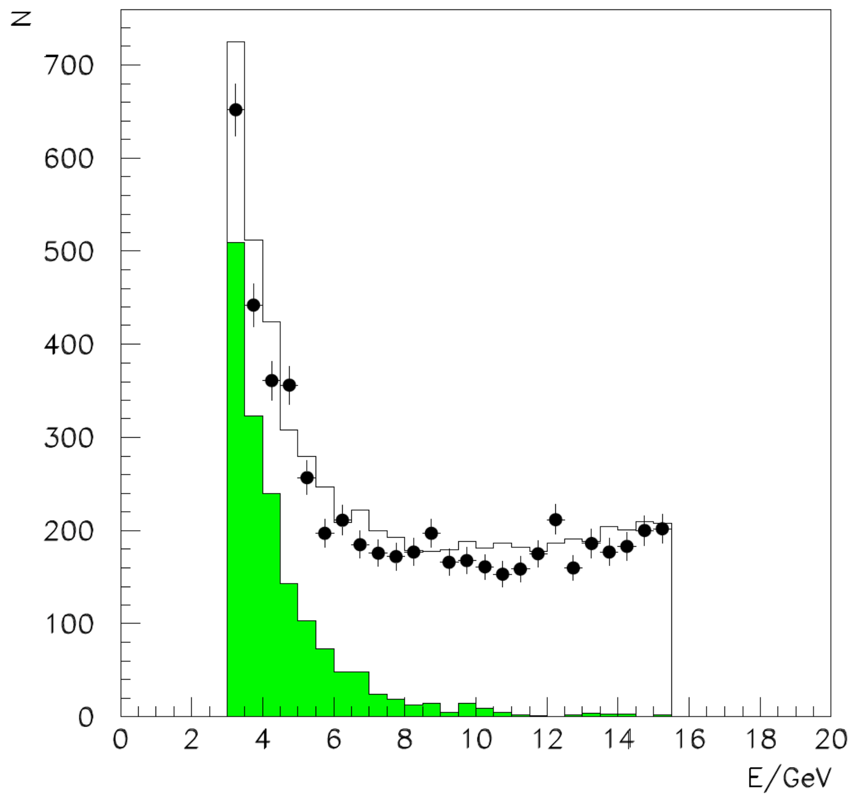
MK DIS2006



R_cluster < 4cm - against hadrons, use ISR
E-pz > 35 GeV - against radiative events
BPC-Spacal match
Trigger: E' > 3 GeV, CIP t0 [96% efficiency]
CJC track, matched to Spacal (R > 40 cm)
charge measured with CJC+event vertex -->
statistical subtraction of background
With e+ and e- data no symmetry assumption on the background is necessary (anti-p)

low Q^2 study with 99 BST data (r-u strips)





BST + two CTD tracks

no E-pz cut

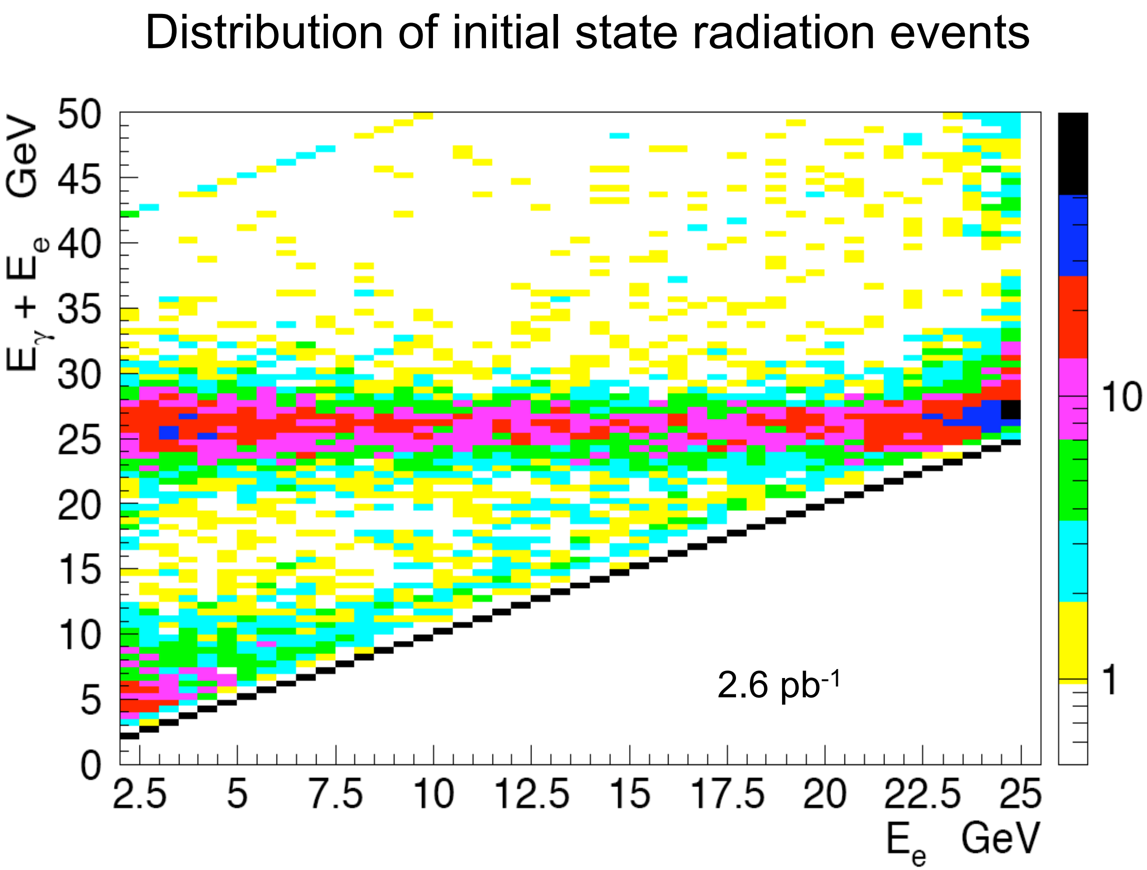
R_cluster < 4 cm

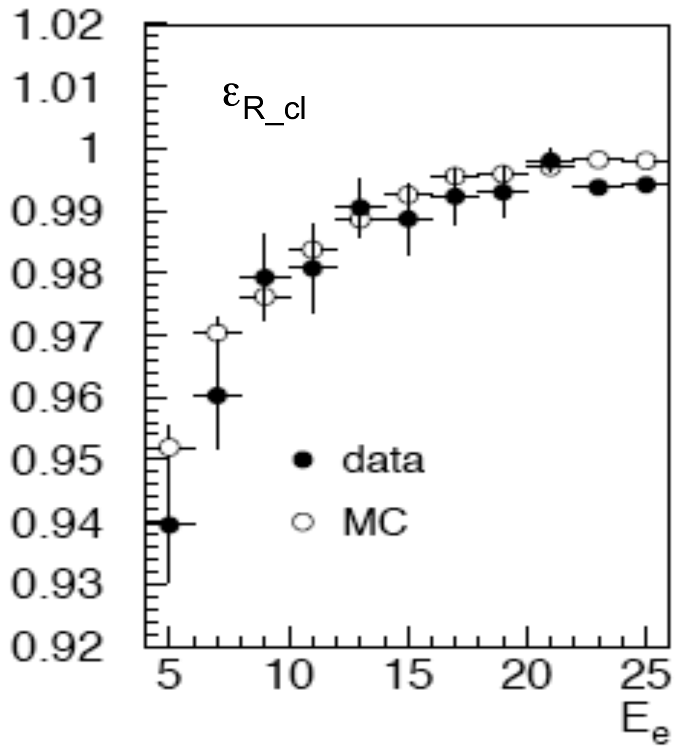
BDC-Spacal match

Trigger: E>3 GeV + 1 central track

Similar for new BST in u/v configuration

Further studies of systematics, e.g.





Drop of cut efficiency for R_cluster < 4cm as measured with tagged ISR events, ΣE > 22 GeV, due to shower broadening and overlap of electron with soft FSR photon --> shower library to improve simulation.

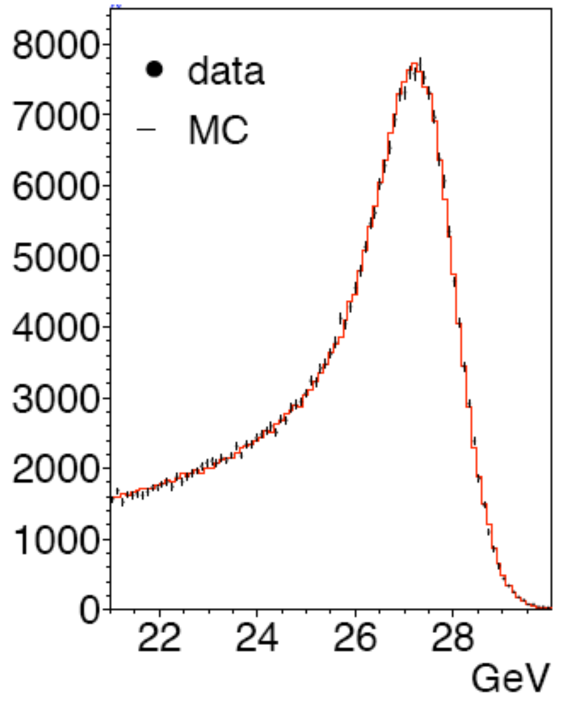
Systematic Uncertainties

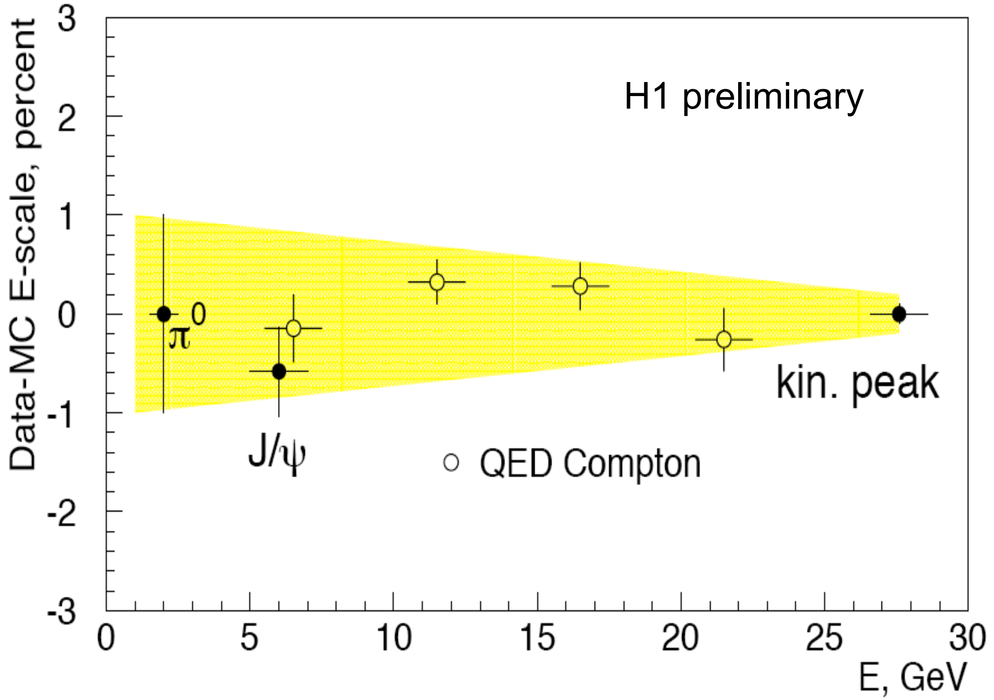
Important are relative cross section accuracy and data/MC calibration

Requires very well controlled data taking and high efficiency of all components.

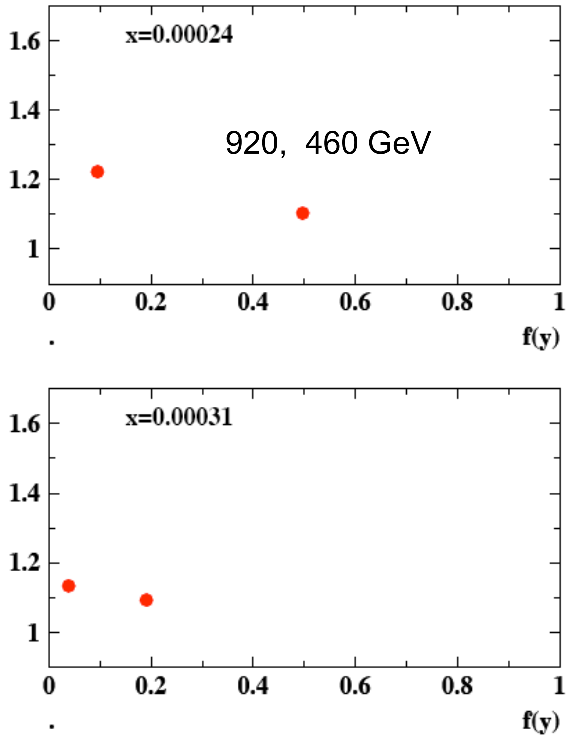
- Correlated errors
  - Energy of scattered electon : from 2% at 3 GeV to 0.2% at 30 GeV.
  - Angle of scattered electron : 0.2 mrad in BST and 1 mrad at $\Theta_e < 165°$.
  - Residual photoproduction background (from a fit on negative tracks in positron run) $0.267-0.8\,y + 0.6\,y^2$ at $y > 0.65$
- Uncorrelated efficiencies:

  electron identification, trigger, vertex, radiative corrections : 1%

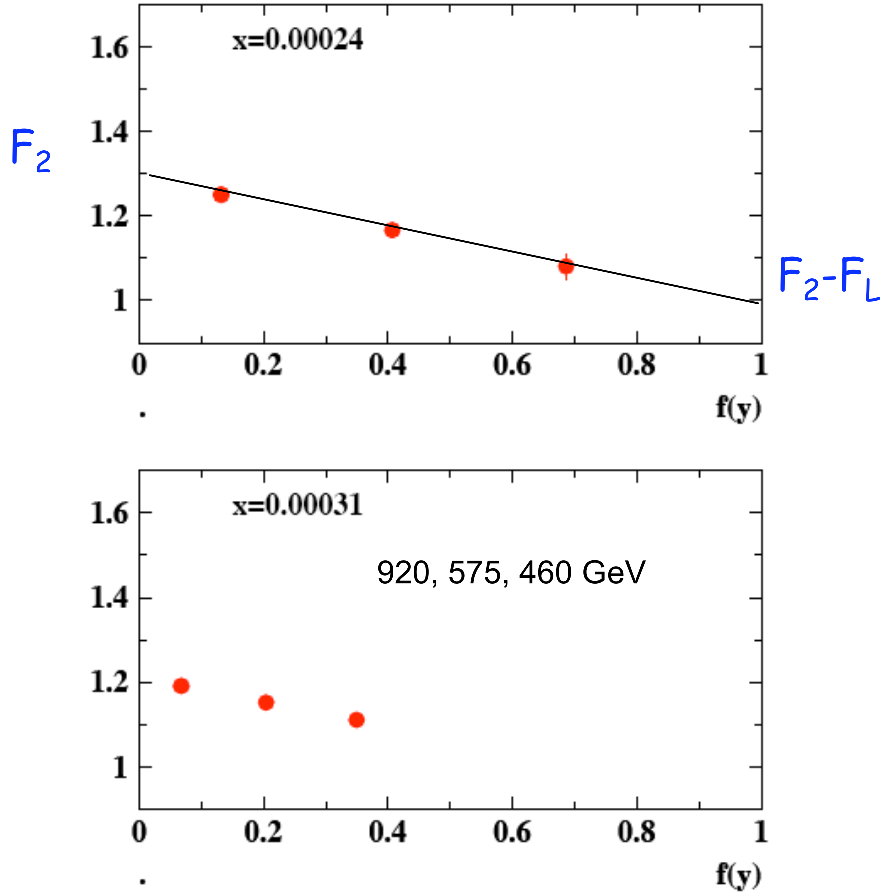




Rosenbluth Representation of Cross Section



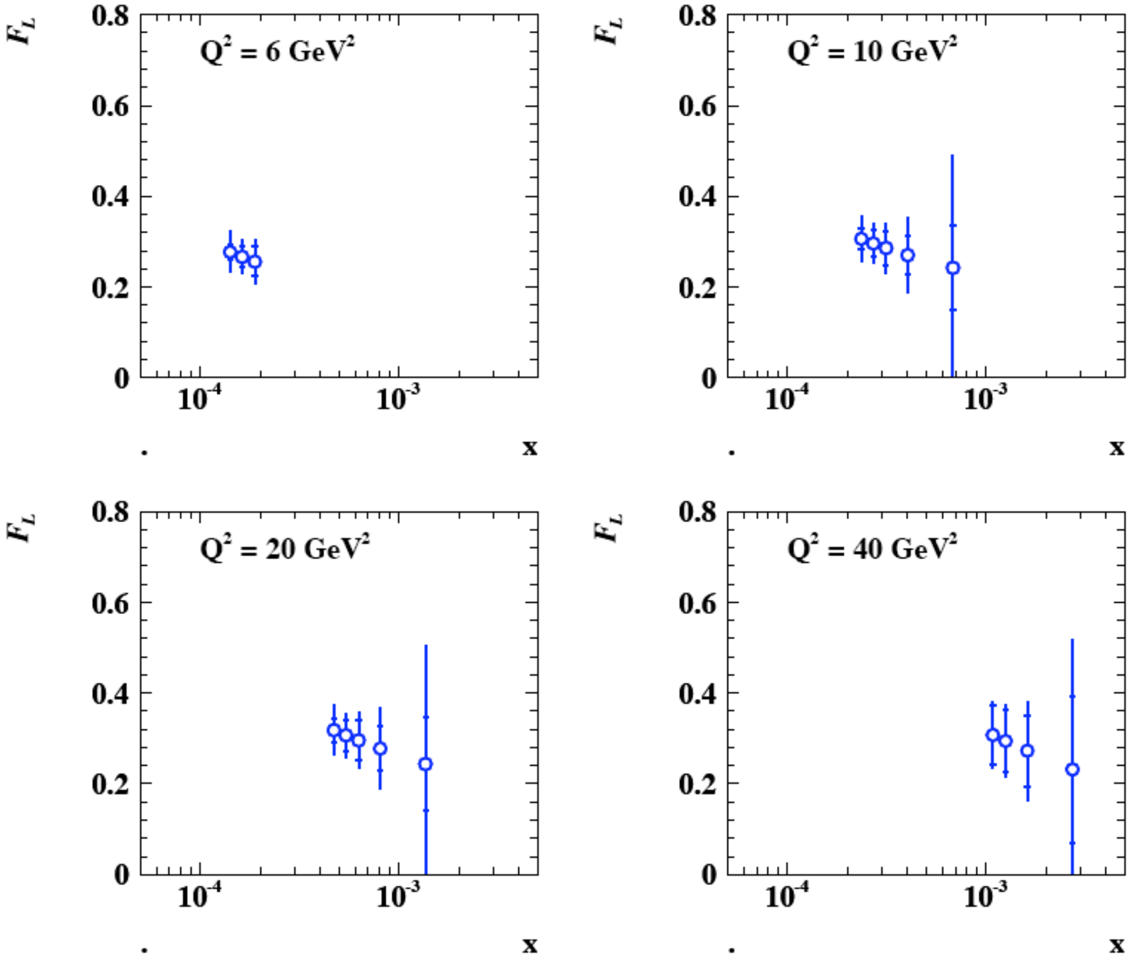
$$\sigma_r = F_2 - f(y) \cdot F_L$$



Binning crucial: used Q^2, ν=sy/2M
Choice of 3rd energy value to divide f(y) linearly
Thus 575 GeV if 460 GeV is chosen as lowest energy.
At larger x all measurements are at low y (f(y))
and thus the sensitivity to F_L decreases rapidly.
For full range a new precise measurement of F_2 results.

stat. errors only plotted

F_L - simulation for two energies

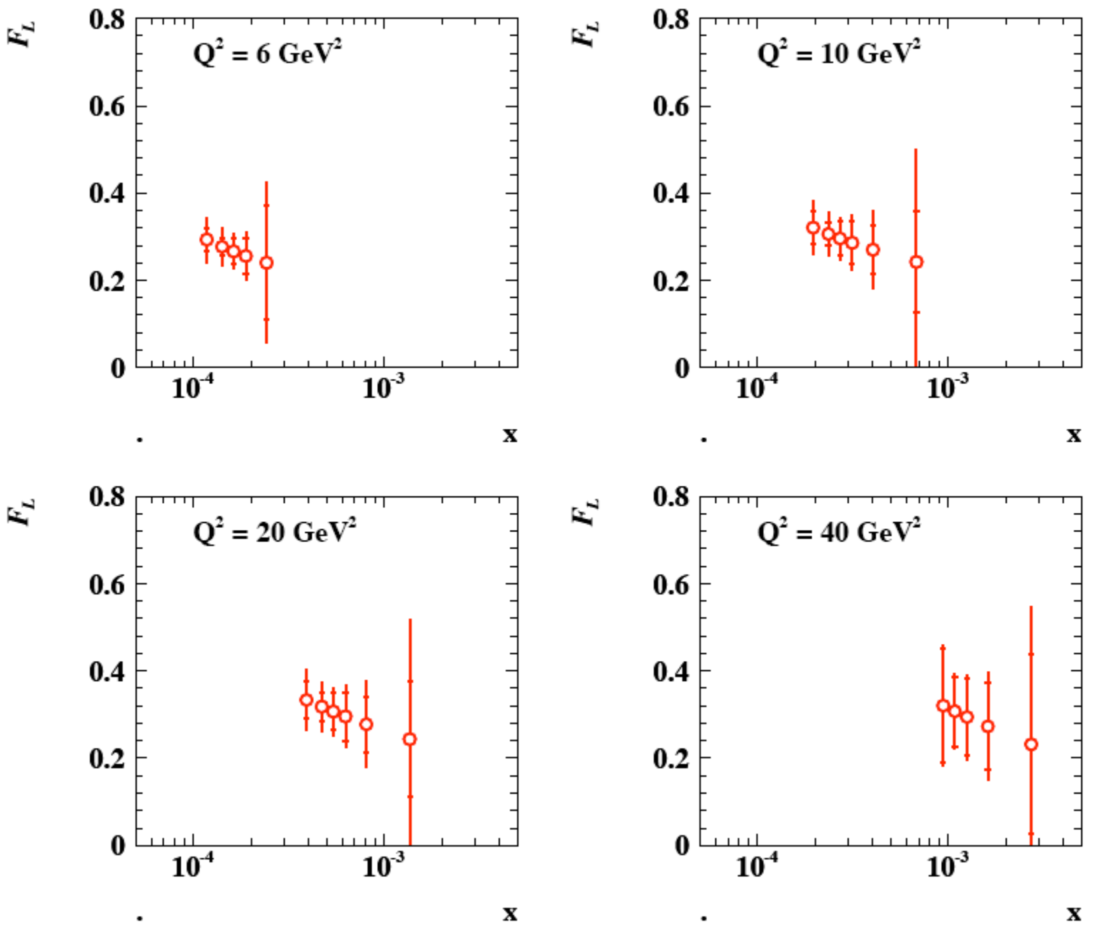


920 GeV
30 pb^{-1}

460 GeV
10 pb^{-1}

Error between 0.05 and 0.1, statistical and systematics about matched,
At high y efficiency and yp background sources of uncertainty similar.

F_L - simulation for three energies



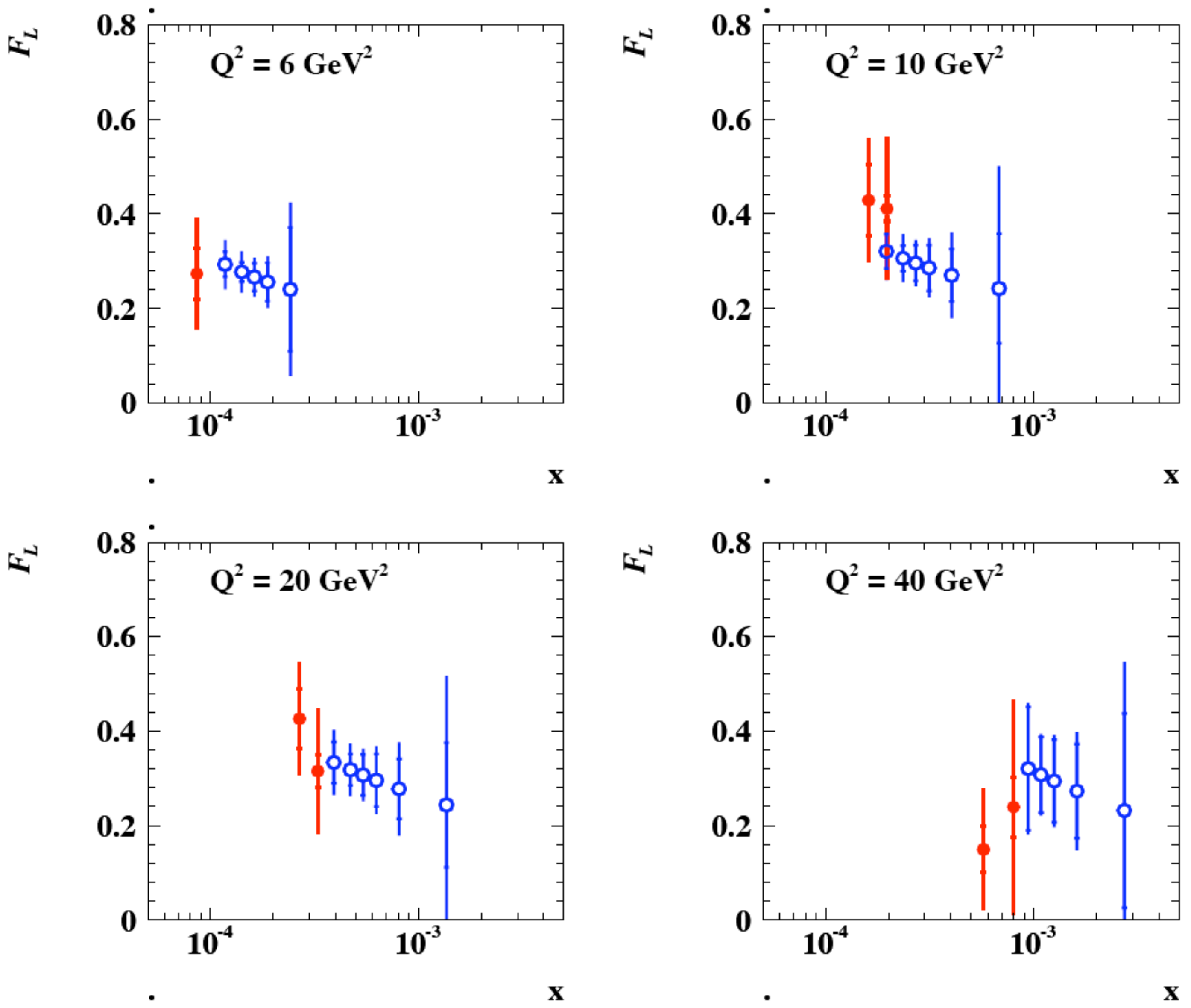
920 GeV
30 pb^{-1}

575 GeV
3.5 pb^{-1}

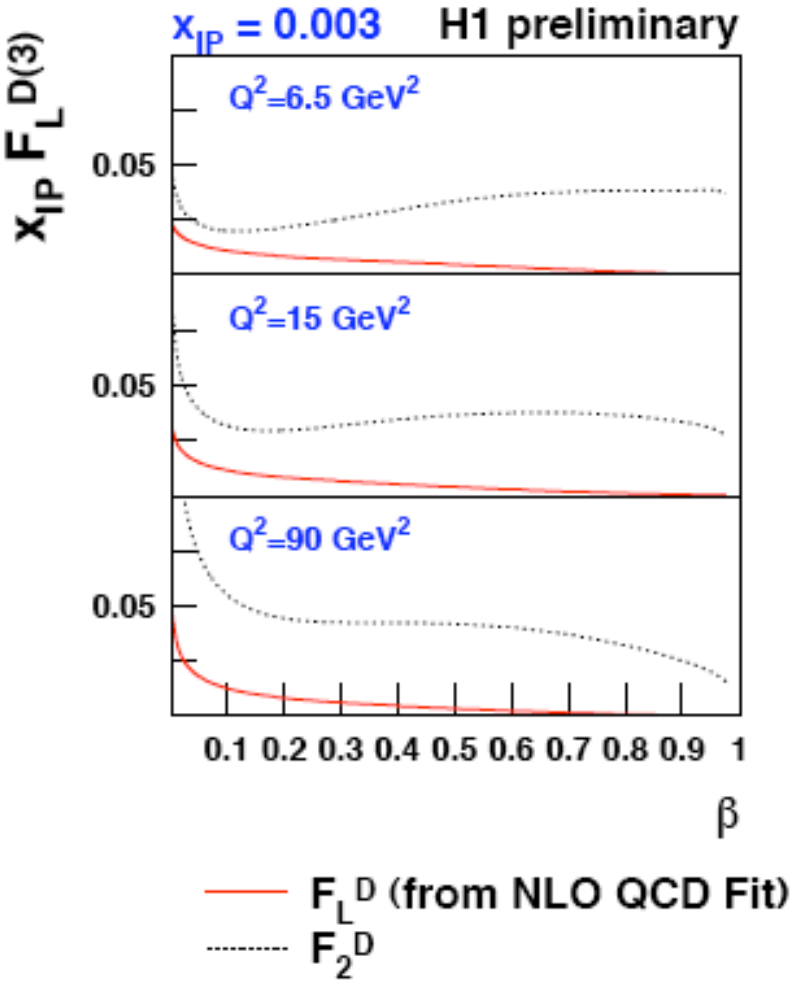
460 GeV
5 pb^{-1}

More than one low Ep? Depends on set-up time and further considerations,
e.g. for diffraction statistics very crucial, x range extension modest,
gain for systematics perhaps important - needs further study.

F_L - simulation for 3 energies and the published points

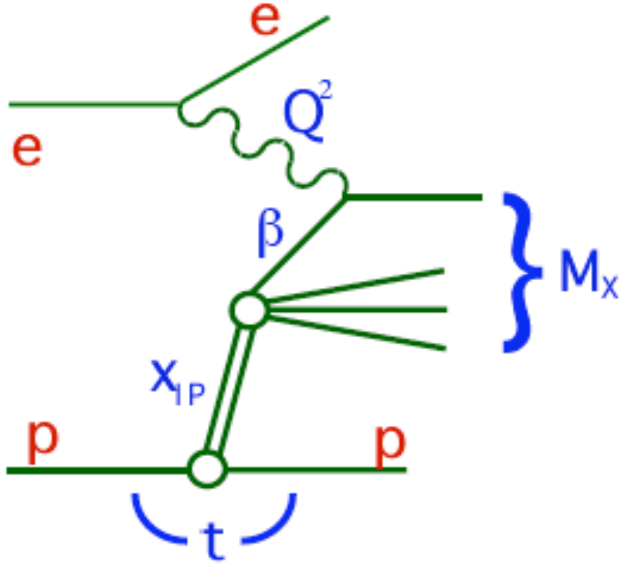


F_L in diffraction

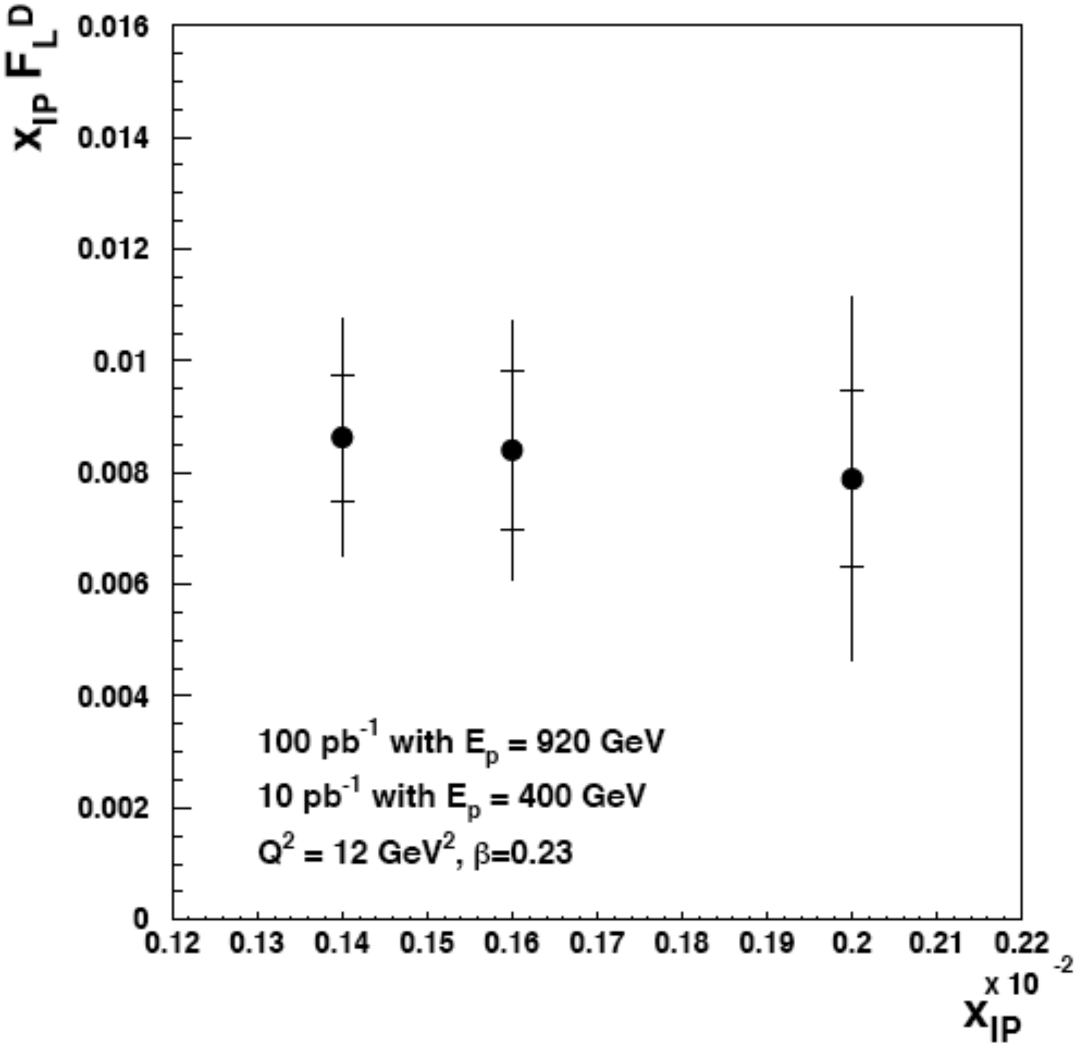


$$\frac{d^3\sigma^{ep\rightarrow eXY}}{dx_{I\!P}\, d\beta\, dQ^2} = \frac{2\pi\alpha^2}{\beta Q^4} \cdot Y_+ \cdot \sigma_r^D(x_{I\!P}, x, Q^2)$$

$$\sigma_r^D = F_2^D - \frac{y^2}{Y_+} F_L^D$$



Simulation of diffractive F_L^D Measurement with H1



Summary

F_L may be measured by H1 in the range of 5-40 GeV^2 and low x, 10^{-4} - 4 10^{-3} , with an absolute accuracy of up to 0.05 which corresponds to about 5 sigma depending on F_L

F_L^D may be measured at about 3 sigma, depending on F_L^D.

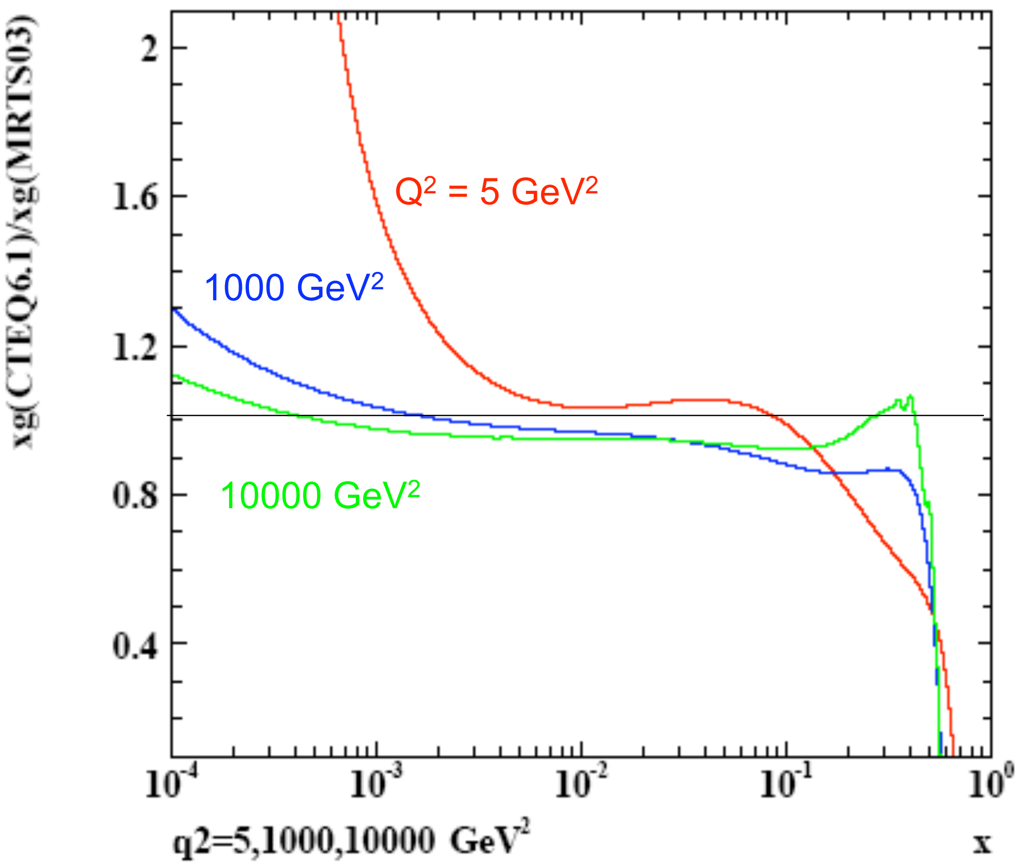
This programme requires an amount of about 10pb^{-1} of luminosity at low E_p, which is estimated to take 3 months of running time.

The feasibility of such a run depends on the HERA performance. The H1 Collaboration needs to about double the e^+ HERA I luminosity, i.e. to collect another 100 pb^{-1} with e^+ in order to judge on the validity of the isolated lepton excess observed in positron-proton scattering. The restart of HERA after the shutdown has been promising.

The H1 Collaboration has submitted an expression of interest for this measurement to the DESY Physics Research Committee. A recommendation of the PRC is expected in May 2006.

Backup slides

Ratio of Gluon Distributions from Global Fits

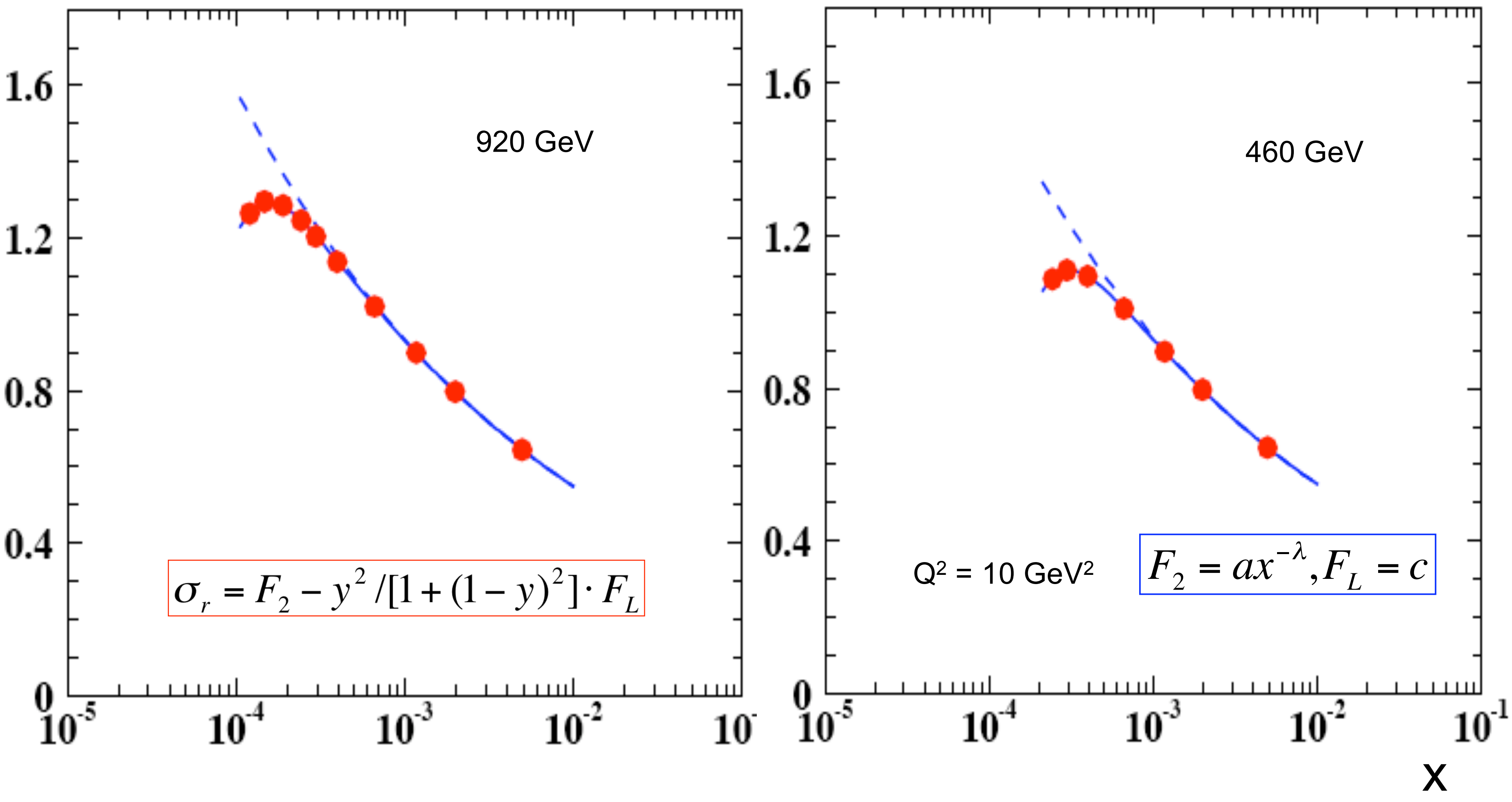


At small and medium x, at the LHC xg is still uncertain to 10%, **high x not settled either**

$$xg(x) = 1.8[\frac{3\pi}{2\alpha_s}F_L(0.4x) - F_2(0.8x)] \simeq \frac{8.3}{\alpha_s}F_L(0.4x)$$

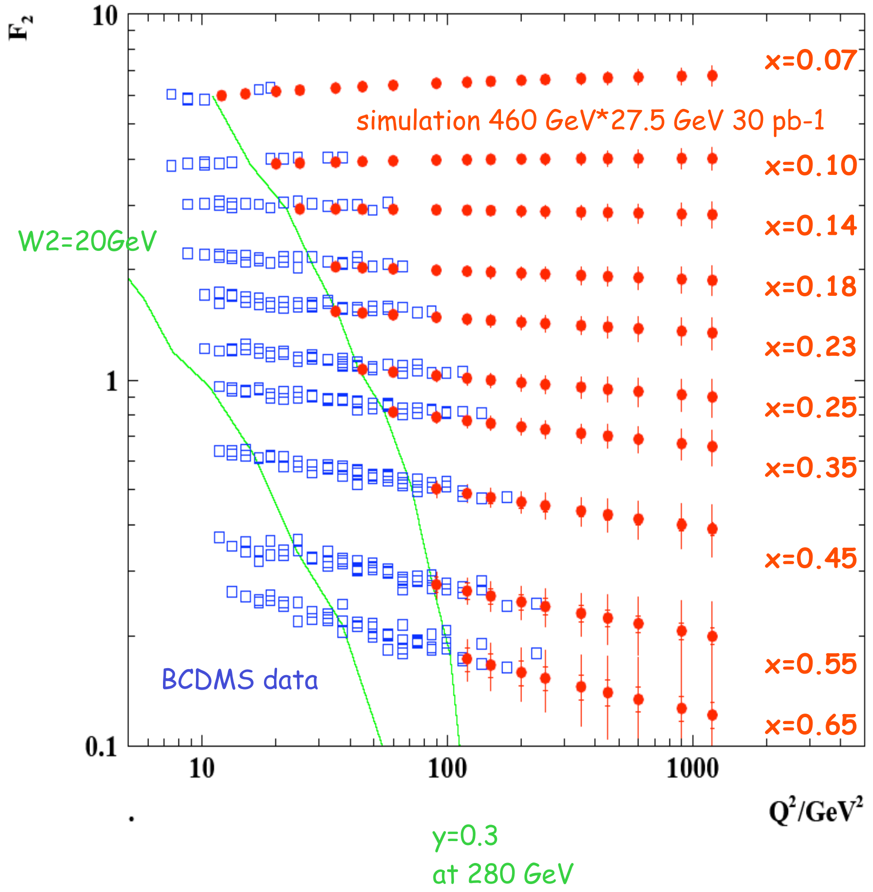
F_L is a direct measure of xg and needs to be measured directly

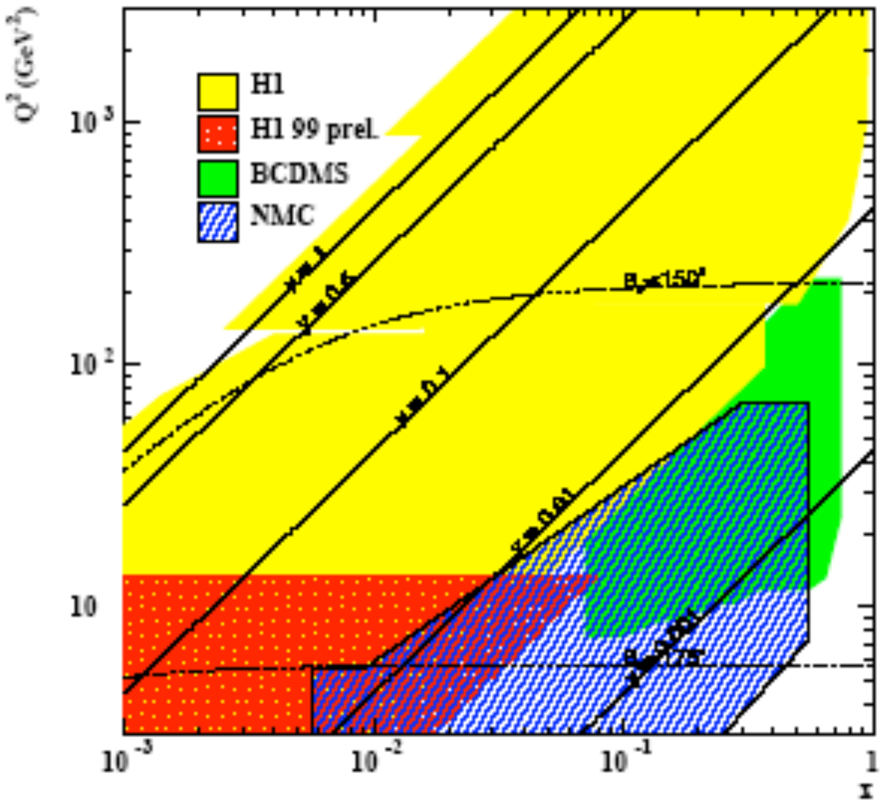
Simulation of Cross Section Measurements



stat. errors only “plotted”

Low Ep data access larger x

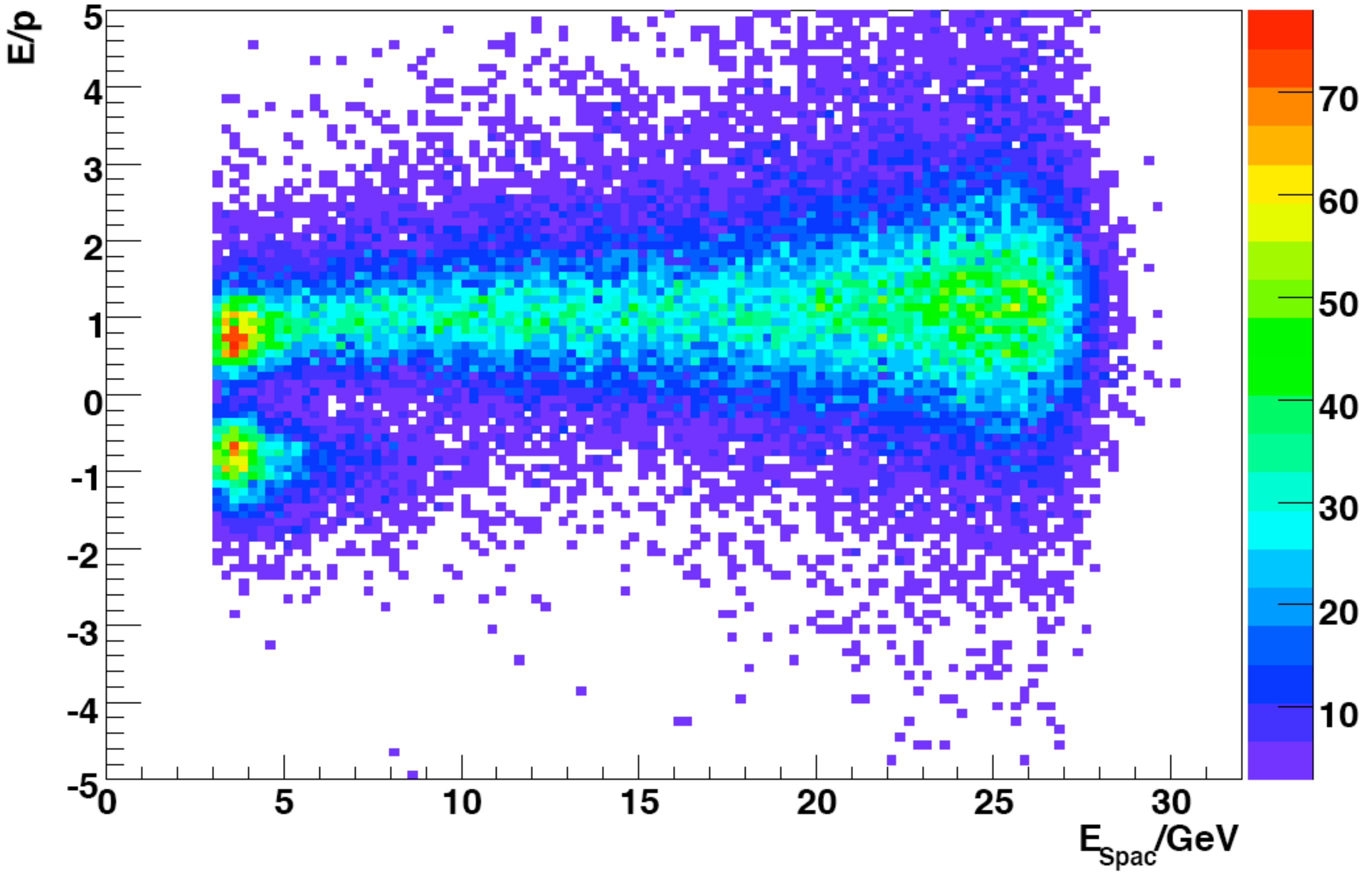




extend measurements to lowest y with

- Simulation of resonance region (SOPHIA)
- Low noise calorimetry (upgraded electr.)
- Forward tracking (upgraded FST, FTD)
- Maximum statistics desirable.

New BST



Error Estimates

ERRORS IN PERCENT, Q2 ~ 9.4 GEV2, PROTON BEAM ENERGIES 920 vs 460 GeV

<X>	0.00023	0.00026	0.00030	0.00040
<Y> at 460 GeV	0.835	0.728	0.628	0.483
<FL>	0.303	0.293	0.283	0.266
STATISTICAL ERROR	7.0	9.9	13.1	15.8
SYST: EFFICIENCIES	6.4	9.3	13.8	28.0
SYST: GAMMA-P	13.0	4.6	1.0	0.0
SYST: ELEC. ENERGY	4.7	2.9	9.3	4.7
SYST: ELEC. ANGLE	6.2	0.3	3.2	7.5
SYST: TOTAL	16.4	10.8	17.0	29.4
SYST+STAT	17.9	14.6	21.4	33.4

Systematic Uncertainty of Diffractive Simulation

Uncertainties correlated between beam energies:

- $\delta E'_e = 0.2\%$ (kinematic peak) $\ldots 2\%$ ($E'_e = 3$ GeV)
- $\delta\theta'_e = 0.2$ mrad
- Hadronic energy scale $\delta M_X = 4\%$ (as now)
- Photoproduction background $\delta\gamma p = 25\%$ (as now)
- Proton dissociation corrections $\delta_{\mathrm{pdiss}} = 6\%$ (as now, assumed 100% correlated)

Uncorrelated uncertainty = 2.4%, mainly from acceptance corrections with RAPGAP