

Direct F_L Measurement at High Q^2 at HERA

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on behalf of the H1 Collaboration

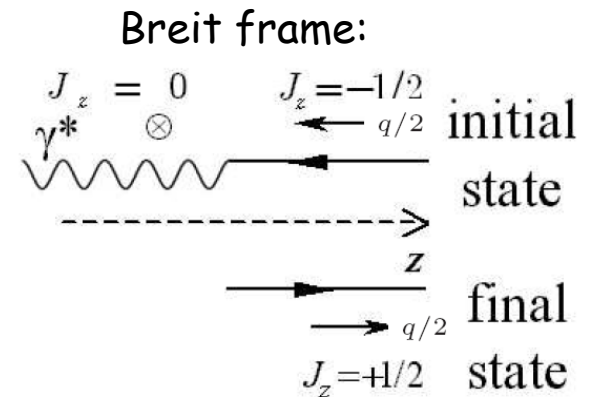
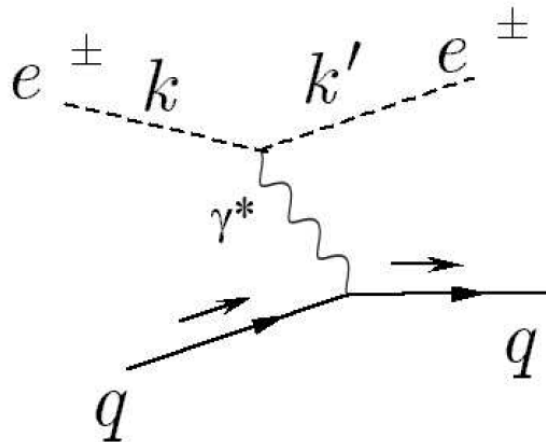
- Motivation
- Main detector components for the high Q^2 analysis
- Published H1 determination of F_L at high Q^2
- Data used for the direct F_L measurement
- Experimental details of the high Q^2 F_L analysis
- F_L measurement at high Q^2 using LAr
- F_L measurement in the full range of medium and high Q^2 using LAr and Spacal data
- Conclusions

Motivation for the F_L measurement

- F_L is an independent structure function which should be measured at HERA to complete the DIS program
- F_L is a pure QCD effect which allows to make critical tests of the perturbative QCD framework used for pdf determinations
- F_L is directly sensitive to gluon density

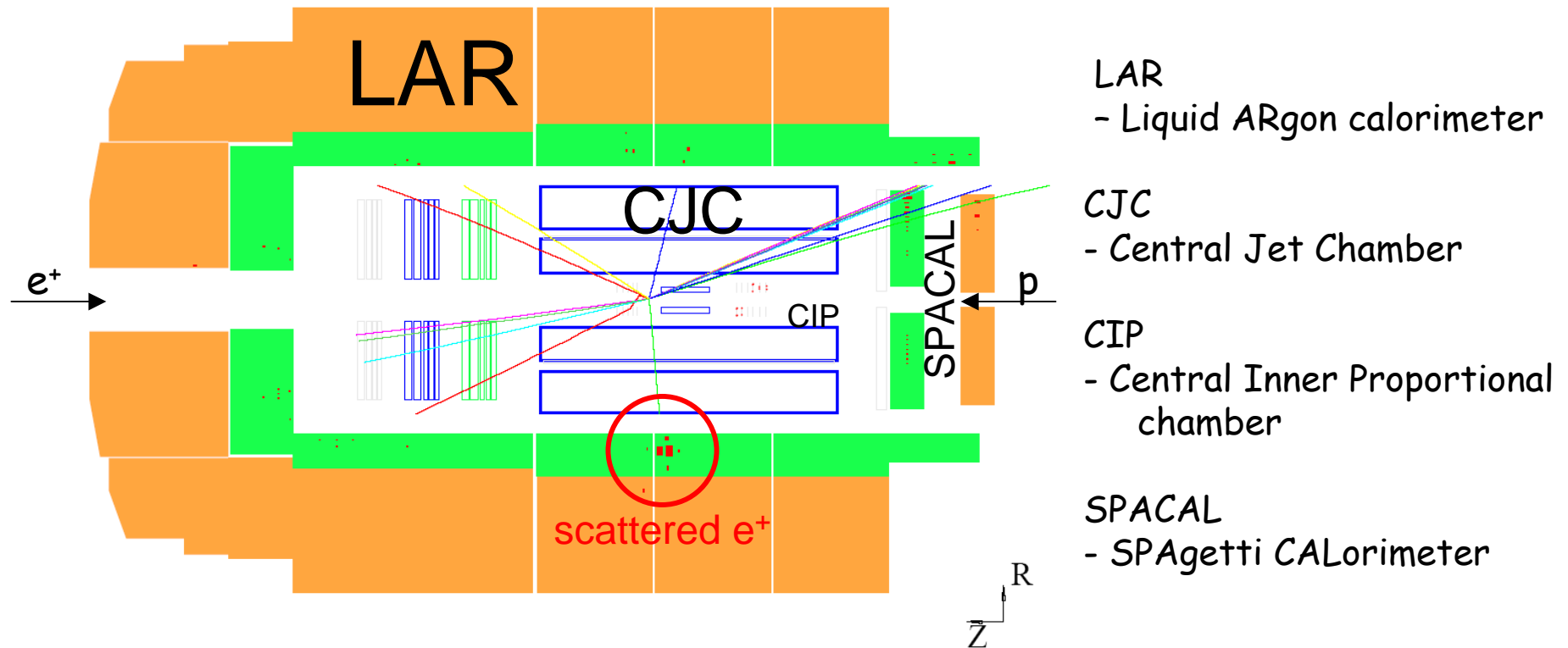
in QPM due to helicity and angular momentum conservation for spin $\frac{1}{2}$ quarks

$$F_L \sim \sigma_L^{\gamma p} = 0$$



Main detector components for the high Q^2 analysis

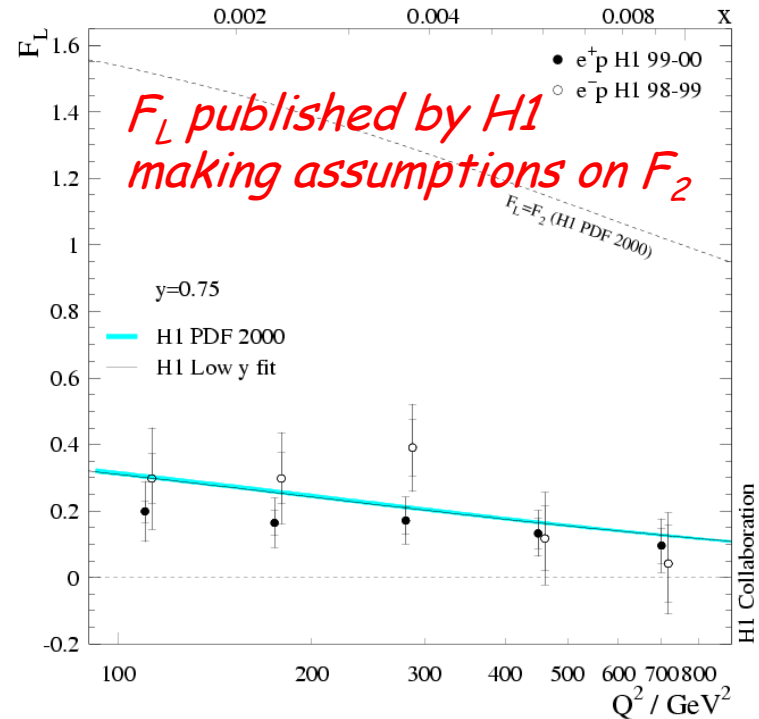
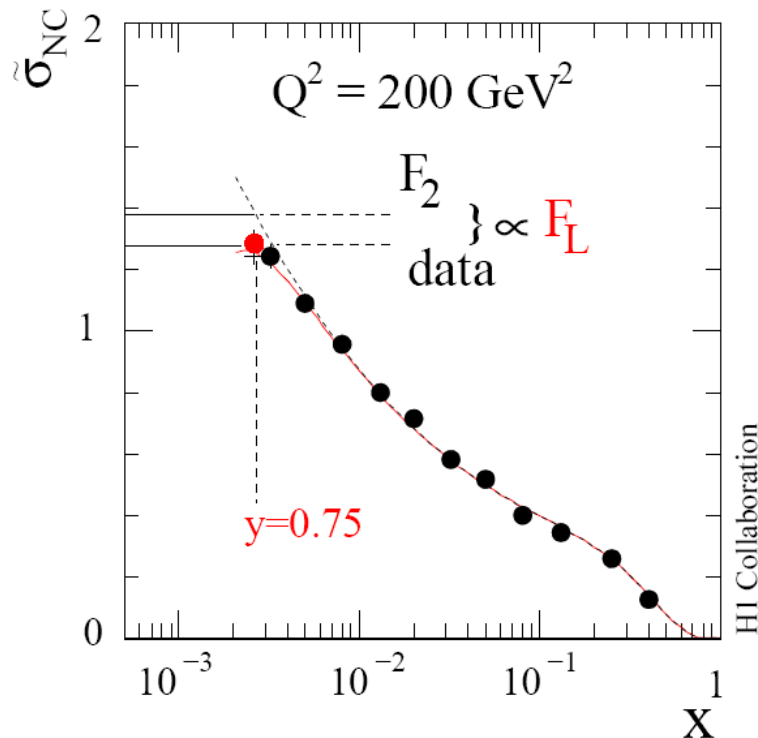
scattered electron with energy $E_e > 3 \text{ GeV}$ in LAR ($\theta < 153^\circ$)



Published H1 determination of F_L at high Q^2

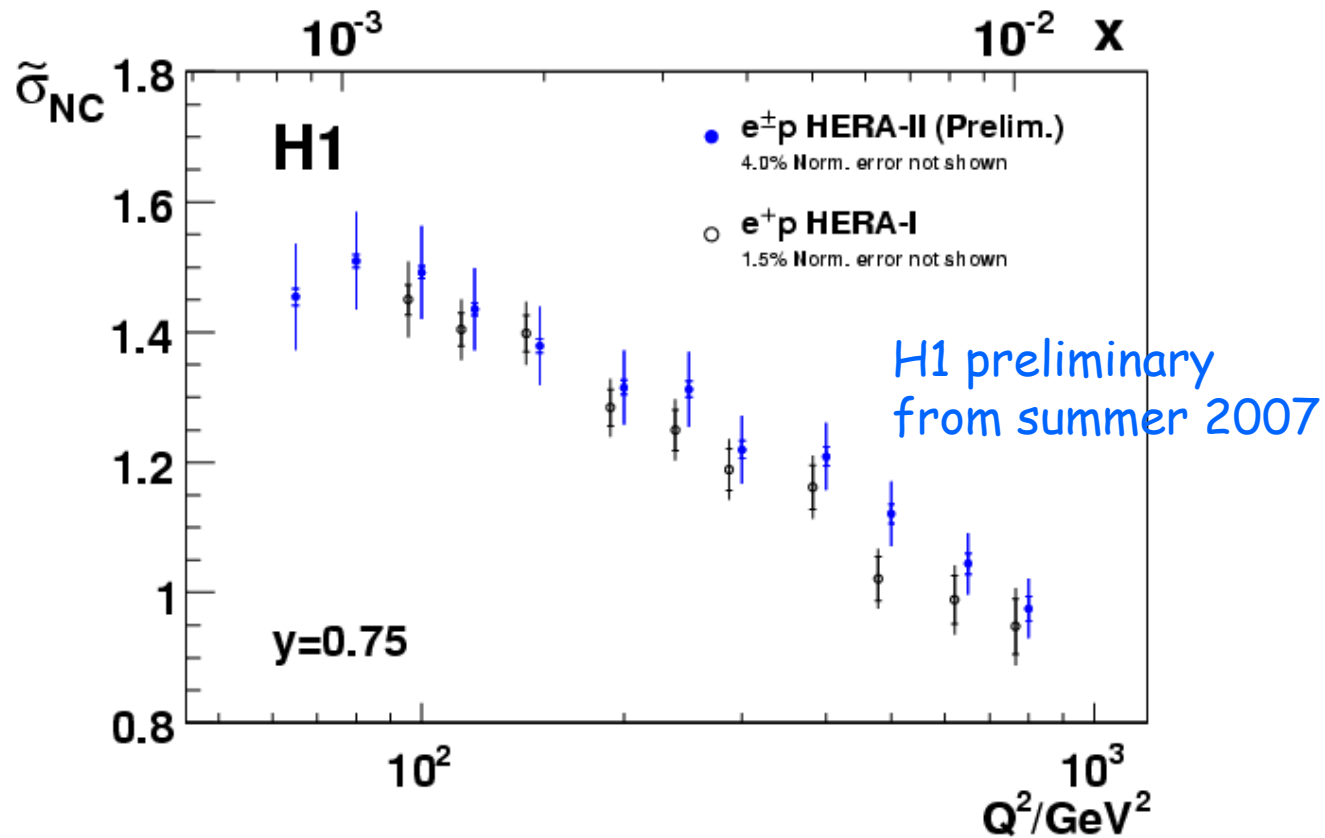
$$\tilde{\sigma}_{NC} = \frac{d^2\sigma_{NC}^{ep}}{dx dQ^2} / \left(\frac{2\pi\alpha^2}{xQ^4} Y_+ \right) = F_2 - \frac{y^2}{Y_+} F_L$$

sensitivity to F_L only at high y
 $Y_+ = 1 + (1 - y)^2$



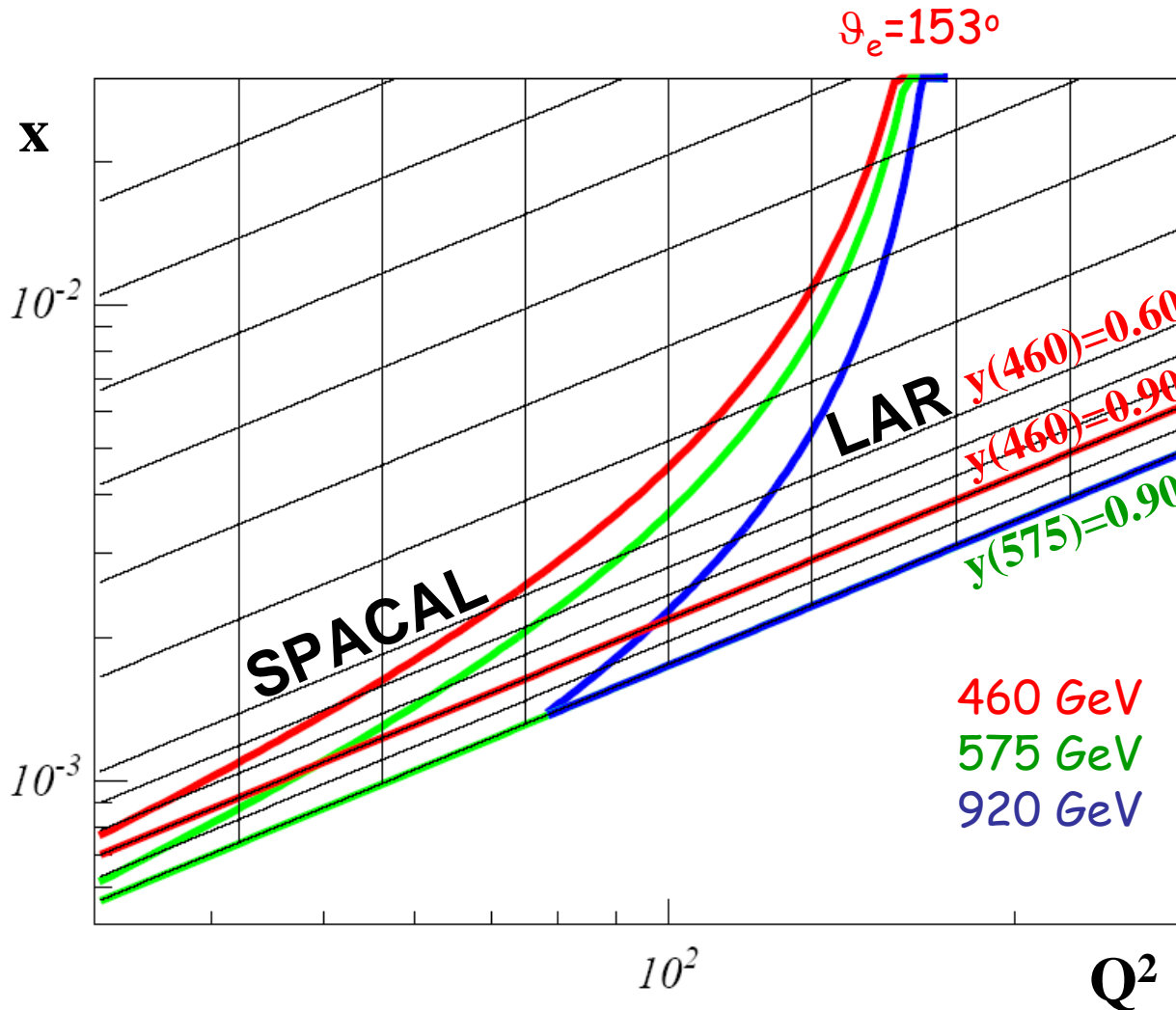
→ to make free from theoretical assumption measurement of F_L one needs different y at the same x & Q^2 , e.g. by changing the proton beam energy

NC cross section measurement at $y=0.75$ at HERA II



→ statistical precision w.r.t. publication is improved by a factor of 3

The data used for the direct F_L measurement



H1 e^+p data 2007:

$E_p = 460 \text{ GeV}$, $L = 12.0 \text{ pb}^{-1}$
 $E_p = 575 \text{ GeV}$, $L = 6.2 \text{ pb}^{-1}$
 $E_p = 920 \text{ GeV}$, $L = 46.3 \text{ pb}^{-1}$

*The same binning in x and Q^2
 for all proton energies
 both for LAr and Spacal*

The first "complete" LAr bin
 is at $Q^2 = 150 \text{ GeV}^2$

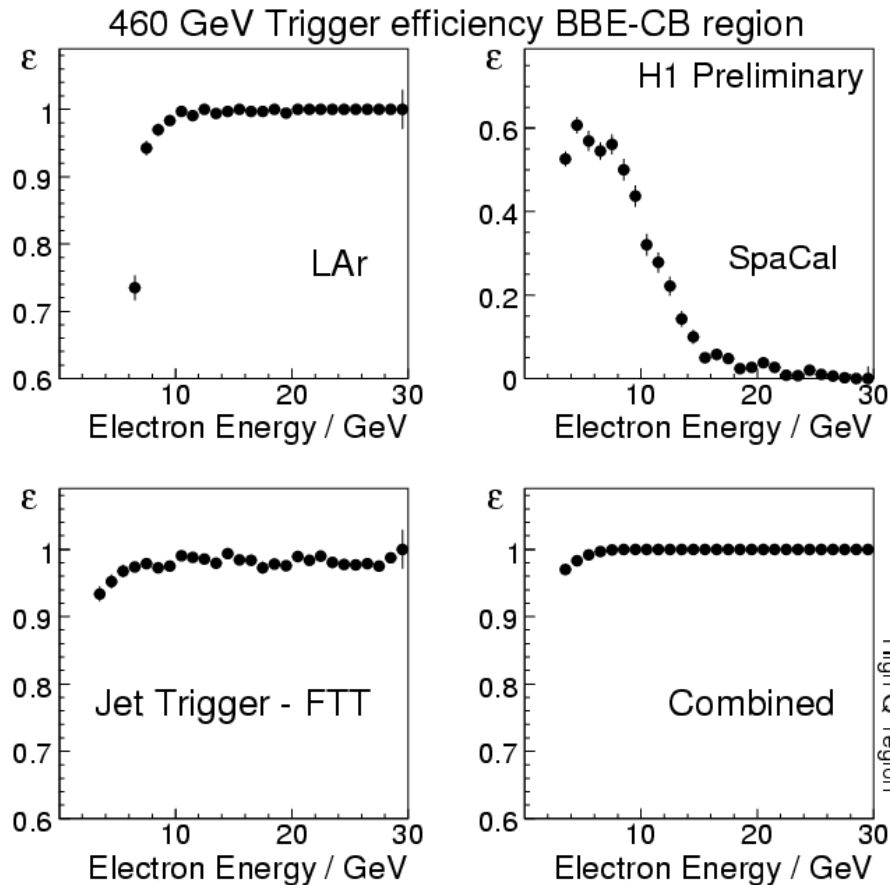
For $35 \leq Q^2 \leq 90 \text{ GeV}^2$ both
 LAr and Spacal are needed

Analysis strategy at high Q^2

High y analysis	Nominal analysis
$E_e > 3 \text{ GeV}$ $0.38 < y_e < 0.90$ ($E_p = 460, 575 \text{ GeV}$)	$0.076 < y_e < 0.38$ (< 0.56 for $E_p = 920 \text{ GeV}$)
<ol style="list-style-type: none"> 1. track pointing to electron cluster in LAr 2. use electric charge of the el. candidate: <ul style="list-style-type: none"> - identify and exclude half of γp bkg require “right” charge of el. candidates - estimate and subtract remaining γp bkg using “wrong” charge el. candidates 3. additional bkg suppression for $E_e < 6 \text{ GeV}$ 	<ol style="list-style-type: none"> 1. electron cluster in LAr is validated by the tracker or CIP 2. γp background is estimated using PYTHIA MC (only $E_p = 920 \text{ GeV}$)
<p><i>in common:</i> $Z_{\text{vtx}} < 35 \text{ cm}$ (to ensure the best quality of reconstruction)</p> <p>$E \cdot P_z > 35 \text{ GeV}$ (to suppress γp bkg and incoming electron initial state radiation)</p> <p>exclude scattered electrons pointing into cracks in the LAr calorimeter</p> <p>identify and exclude (quasi)elastic QED Compton events</p> <p>electron method is used to reconstruct kinematic variables</p>	

Triggers for high Q^2 NC

1. group of **LAr** subtriggers
2. group of **Spacal** subtriggers (hadronic final state particles in Spacal at high y)



3. New trigger hardware for HERA II and low proton energy running period:
 - **Jet Trigger** (real time clustering in LAr)
 - **Fast Track Trigger (FTT)**

Combined eff. of these three independent groups of triggers :

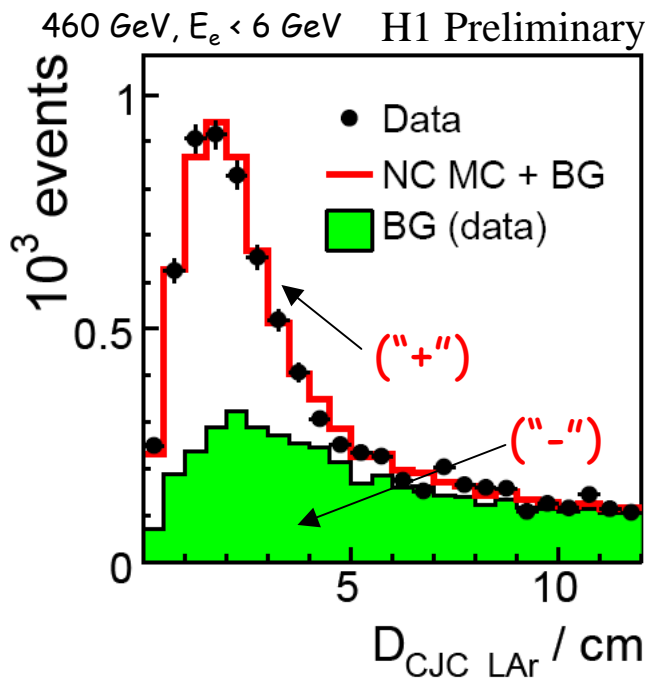
$\sim 97\%$ for $E_e = 3 \text{ GeV}$ and
 $\sim 100\%$ for $E_e > 6 \text{ GeV}$

γp background identification and statistical subtraction of the remaining γp bkg at high y

Electric charge of the scattered el. candidate is determined by the track from the primary interaction, pointing to the electron cluster in LAr :

→ distance between extrapolated track and cluster center of gravity < 12 cm

1. identify and exclude half of γp bkg require “right” charge of the el. candidates
2. estimate and statistically subtract remaining γp bkg using “wrong” charge el. candidates



Taken into account in statistical subtraction of bkg:

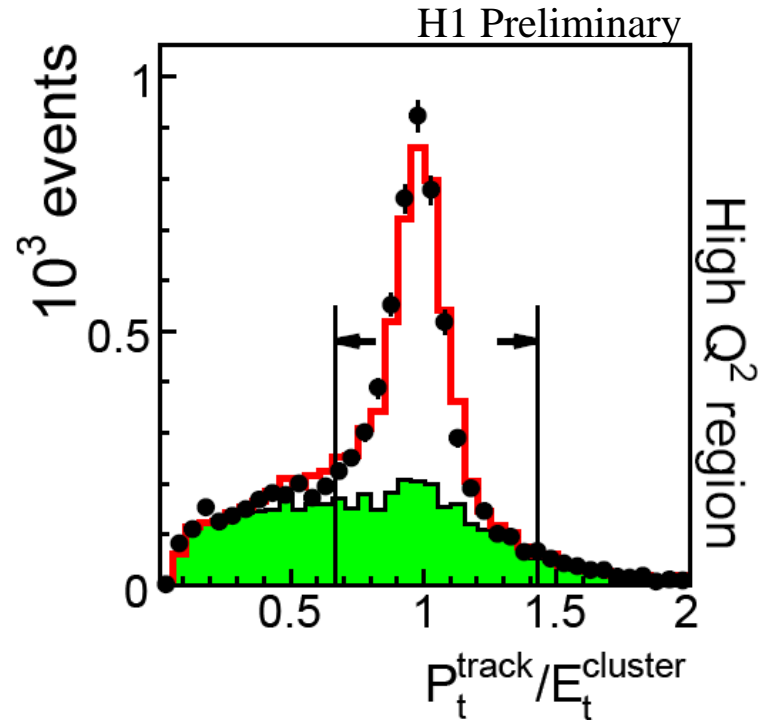
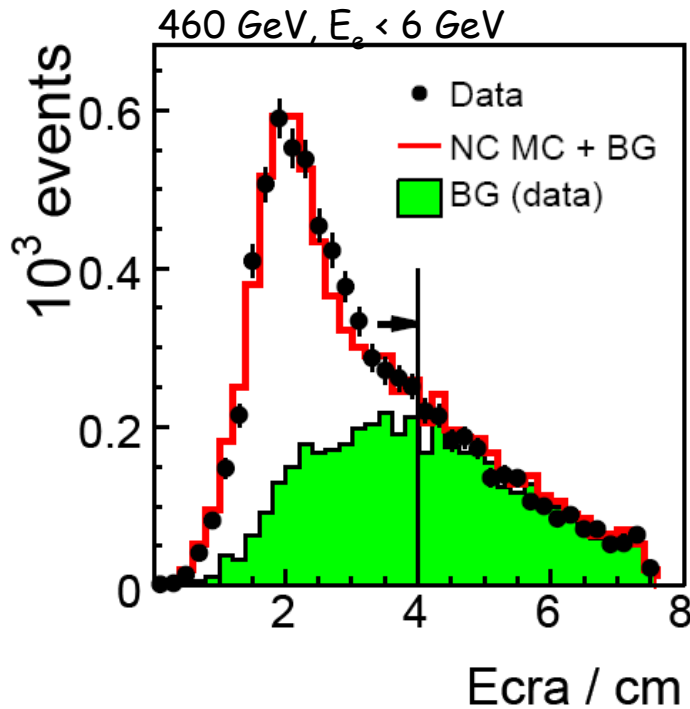
- **Charge asymmetry in γp data** due to antiprotons determined using “wrong charge” el. candidates in the $e^\pm p$ HERA II data and in γp events identified by elec. tagger
- Charge asymmetry of the fake electron candidates in the signal NC MC (DJANGO)
- Wrong charge determination for the true electrons

→ **Efficiency of the track-cluster matching** is determined using electrons verified by CIP in the elastic QED compton events, in the ISR events, in the high E_e ordinary NC events

Additional γp background suppression at $E_e < 6$ GeV

additional selection requirements at $E_e < 6$ GeV

- **small transverse size** of the electron cluster in LAr: $E_{\text{cra}} < 4$ cm
- **matching between track momentum and cluster energy**: $0.7 < E_{\text{t}}^{\text{cluster}}/P_{\text{t}}^{\text{track}} < 1.5$

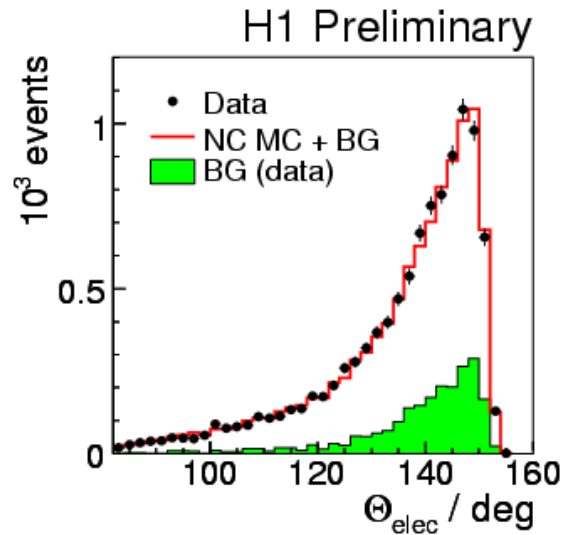
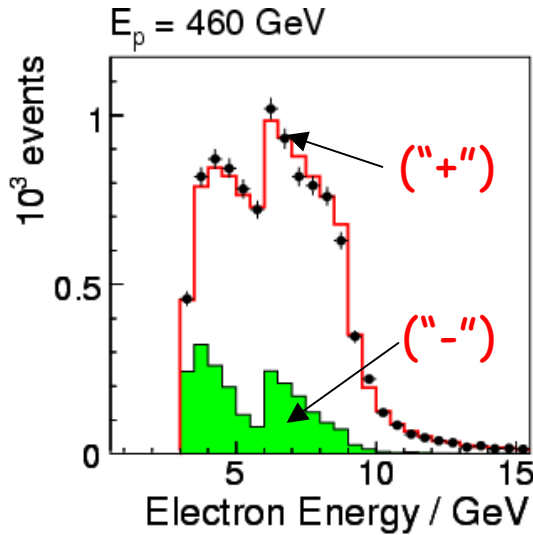


- **additional reduction of γp background** by a factor of 2
- **efficiency** of the additional requirements is determined using electrons verified by CIP in the elastic QED compton events

Further items in the high y analysis

- Primary vertex reconstruction efficiency at high y ($\sim 100\%$)
- Electron energy calibration at low E_e
- Hadron energy calibration in Spacal
- Normalisation of the γp PYTHIA MC (for $E_p = 920$ GeV only)
using electron tagger located downstream the el. beam at $z = -6$ m
- Checks that the QED Compton identification does not reject NC events (with DJANGO NC MC) and that remaining QED Compton background in data is negligible
- Radiative corrections at high y
DJANGO vs. analytical calculations in HECTOR

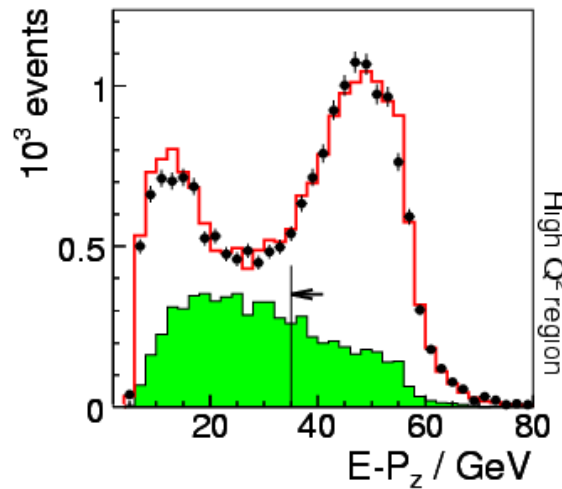
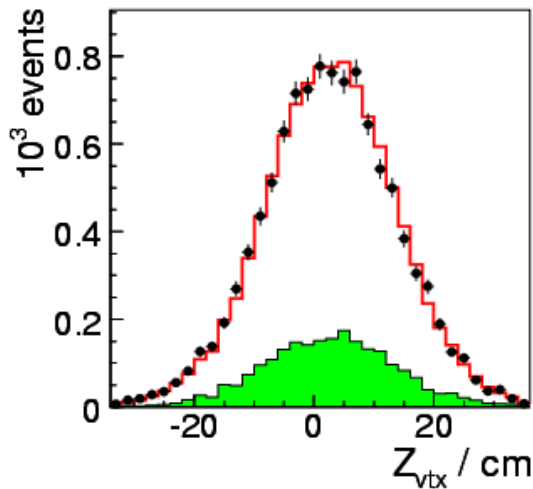
NC events ($0.7 < y < 0.9$) before γp bkg subtraction



$E_p = 460$ GeV

γp background (green)
concentrates at low E_e

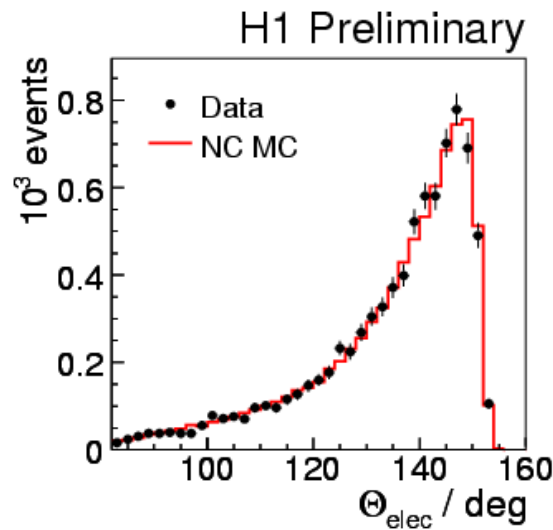
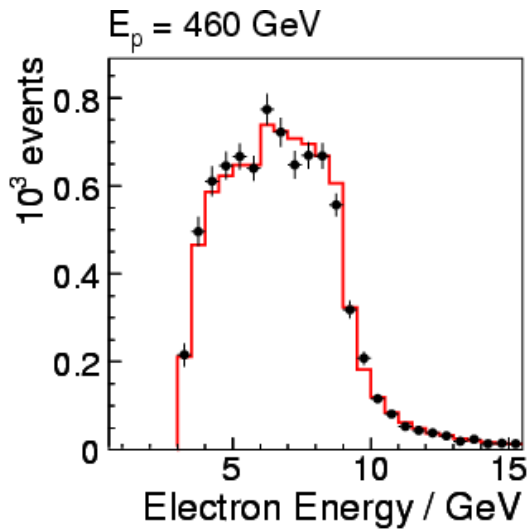
→ step at $E_e = 6$ GeV is due
to additional requirements



$E-P_z$ is under control in
the full range

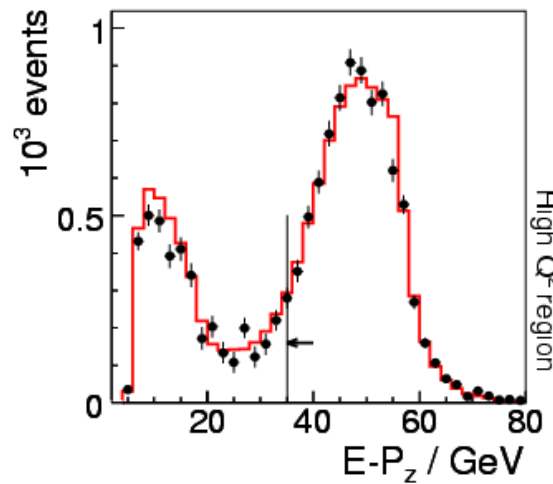
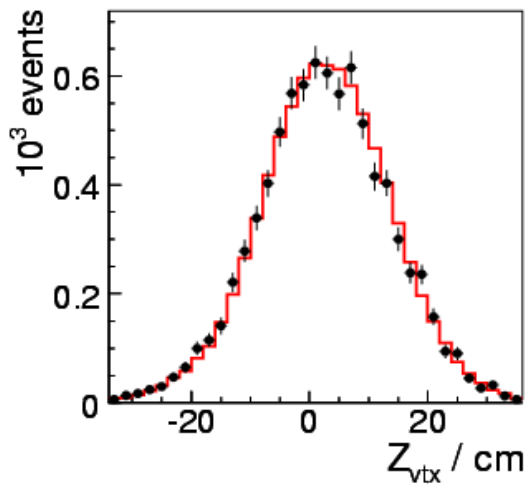
the requirement $E-P_z > 35$ GeV :
- rejects γp background
- rejects initial state radiation (ISR)

NC events ($0.7 < y < 0.9$) after γp bkg subtraction



$E_p = 460$ GeV

→ step at $E_e = 6$ GeV is due to additional requirements

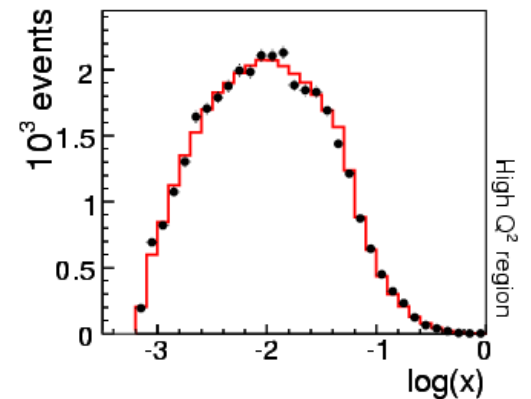
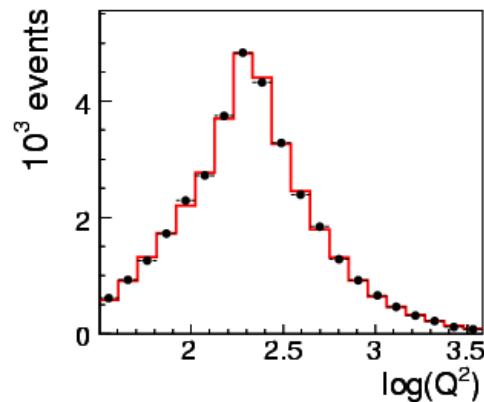
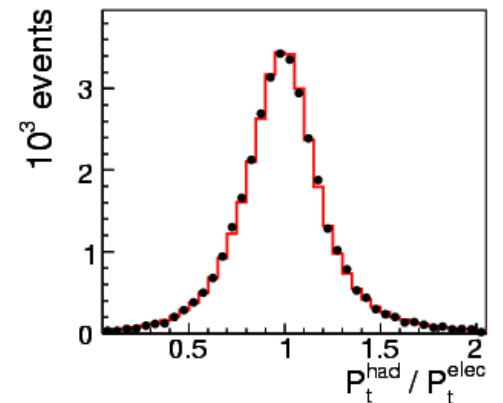
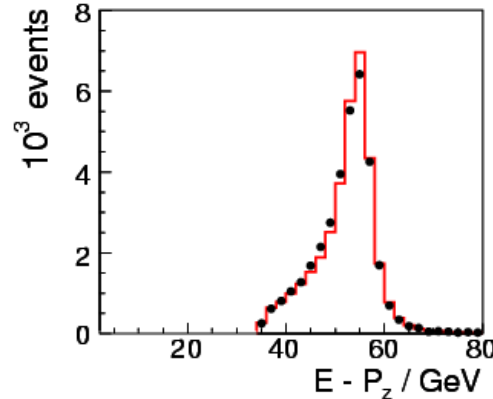
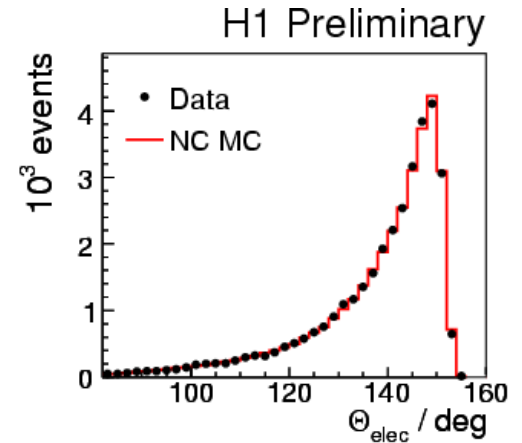
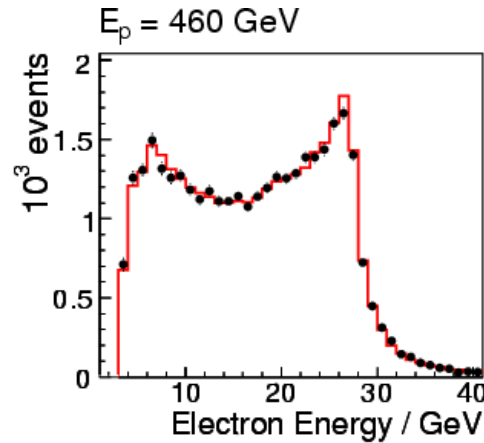


$E-P_z$ is under control in the full range

the requirement $E-P_z > 35$ GeV :
 - rejects gp background
 - rejects initial state radiation (ISR)

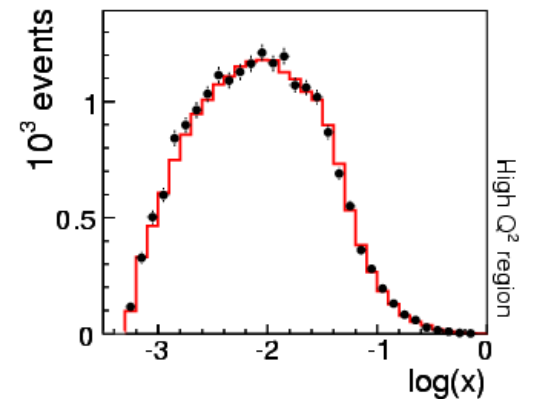
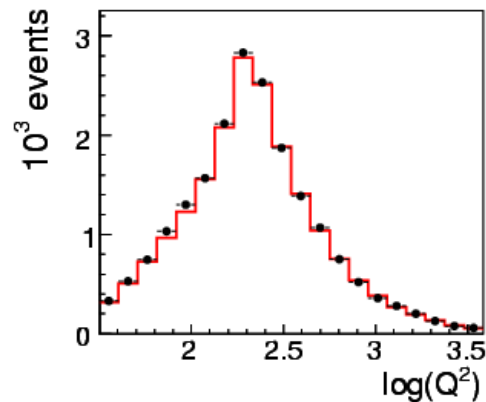
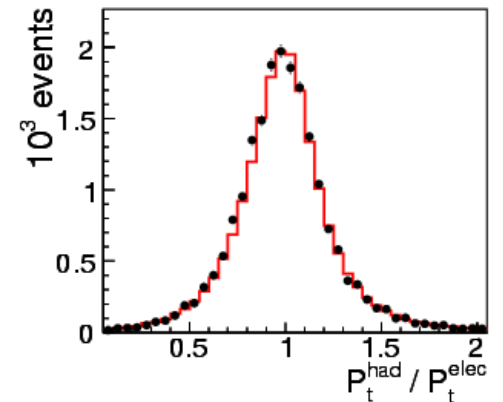
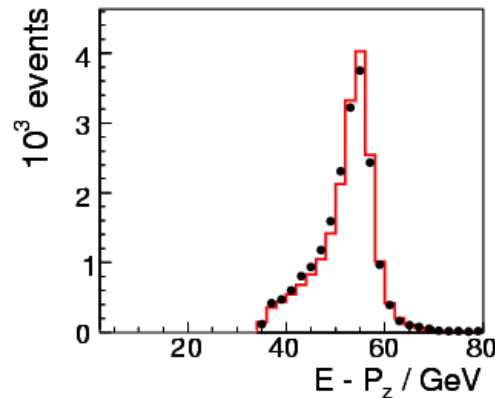
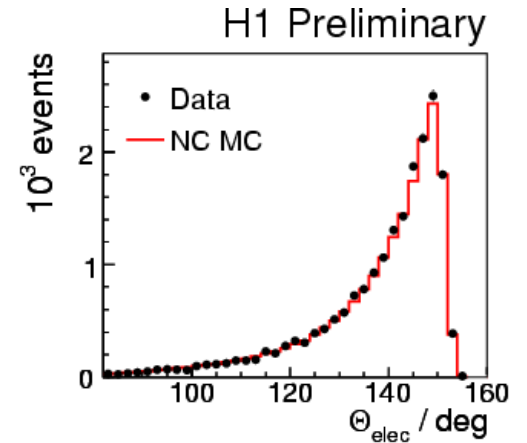
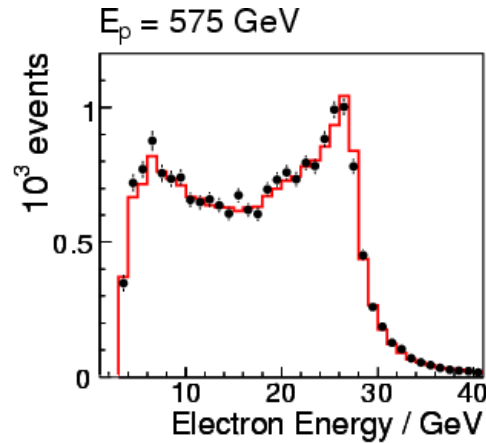
$E_p = 460 \text{ GeV}$

NC events
in the full y range
($0.076 < y < 0.90$)
after
 γp bkg subtraction



$E_p = 575 \text{ GeV}$

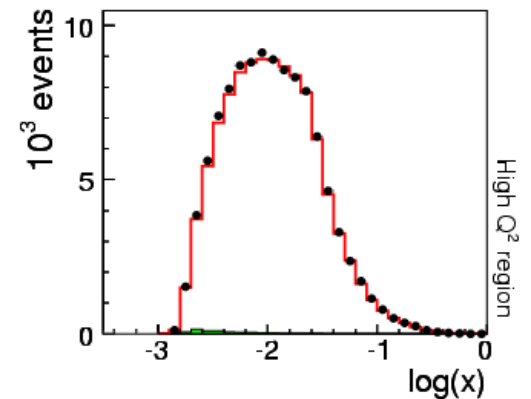
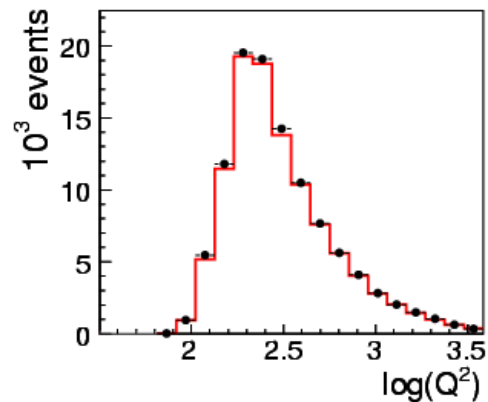
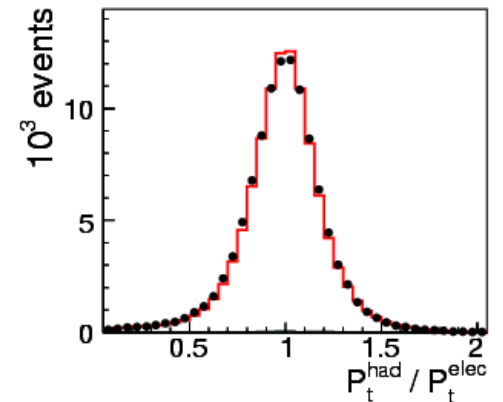
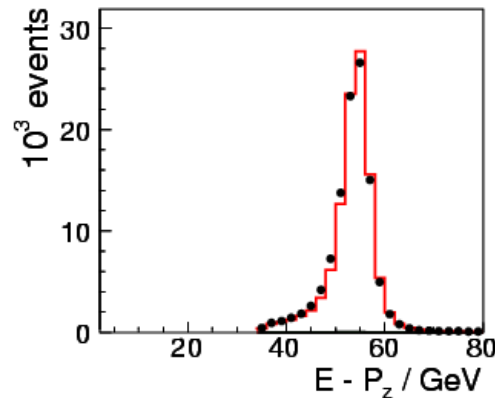
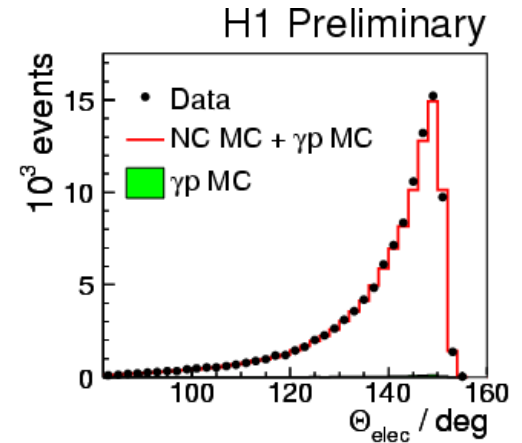
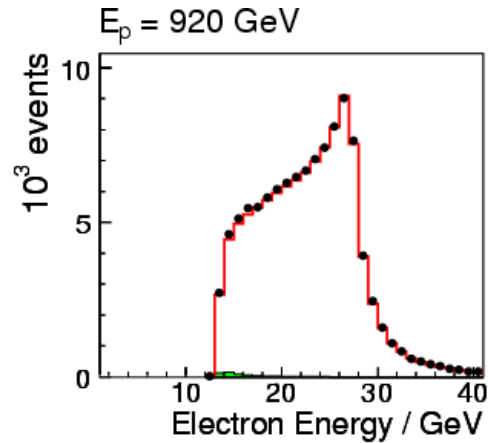
NC events
in the full y range
($0.076 < y < 0.90$)
after
 γp bkg subtraction



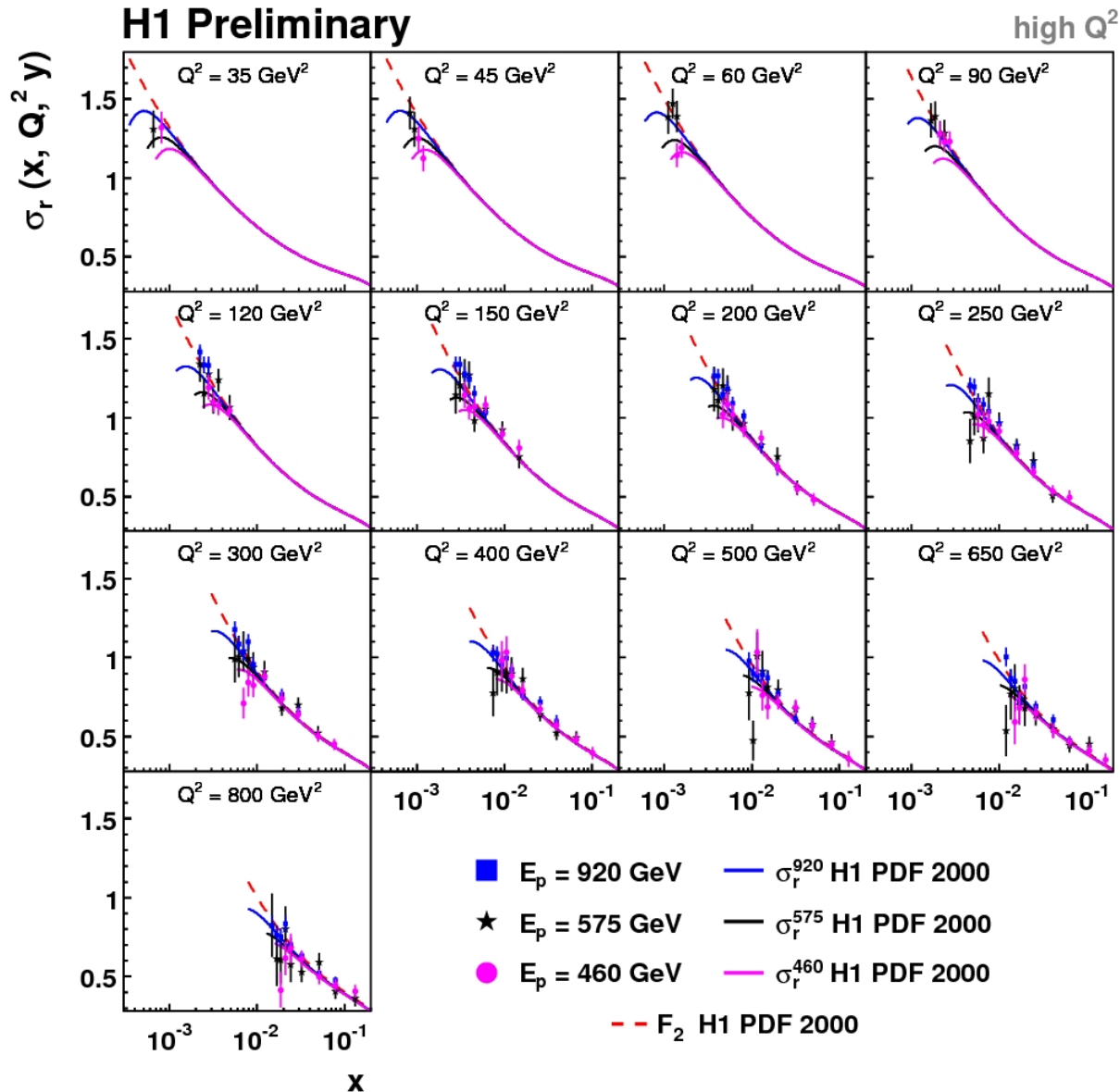
$E_p = 920 \text{ GeV}$

NC events
in the full y range
($0.076 < y < 0.56$)

γp bkg (green) estimated
using PYTHIA MC



NC cross section at high Q^2 for $E_p = 460, 575, 920$ GeV



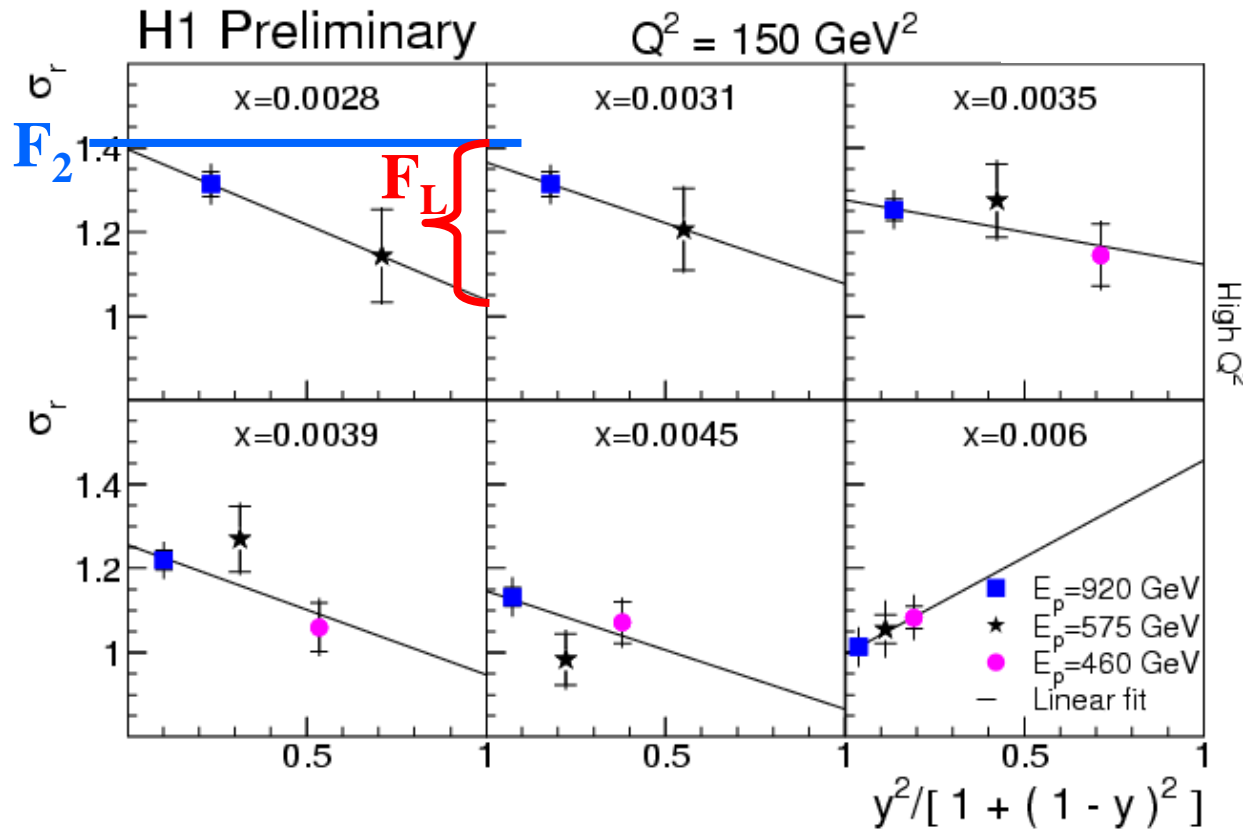
Three cross section measurements at each x and Q^2

Departures of the theory curves from F_2 are due to F_L

use relative normalisation of $E_p = 460, 575, 920$ GeV from the low y data for the F_L measurement

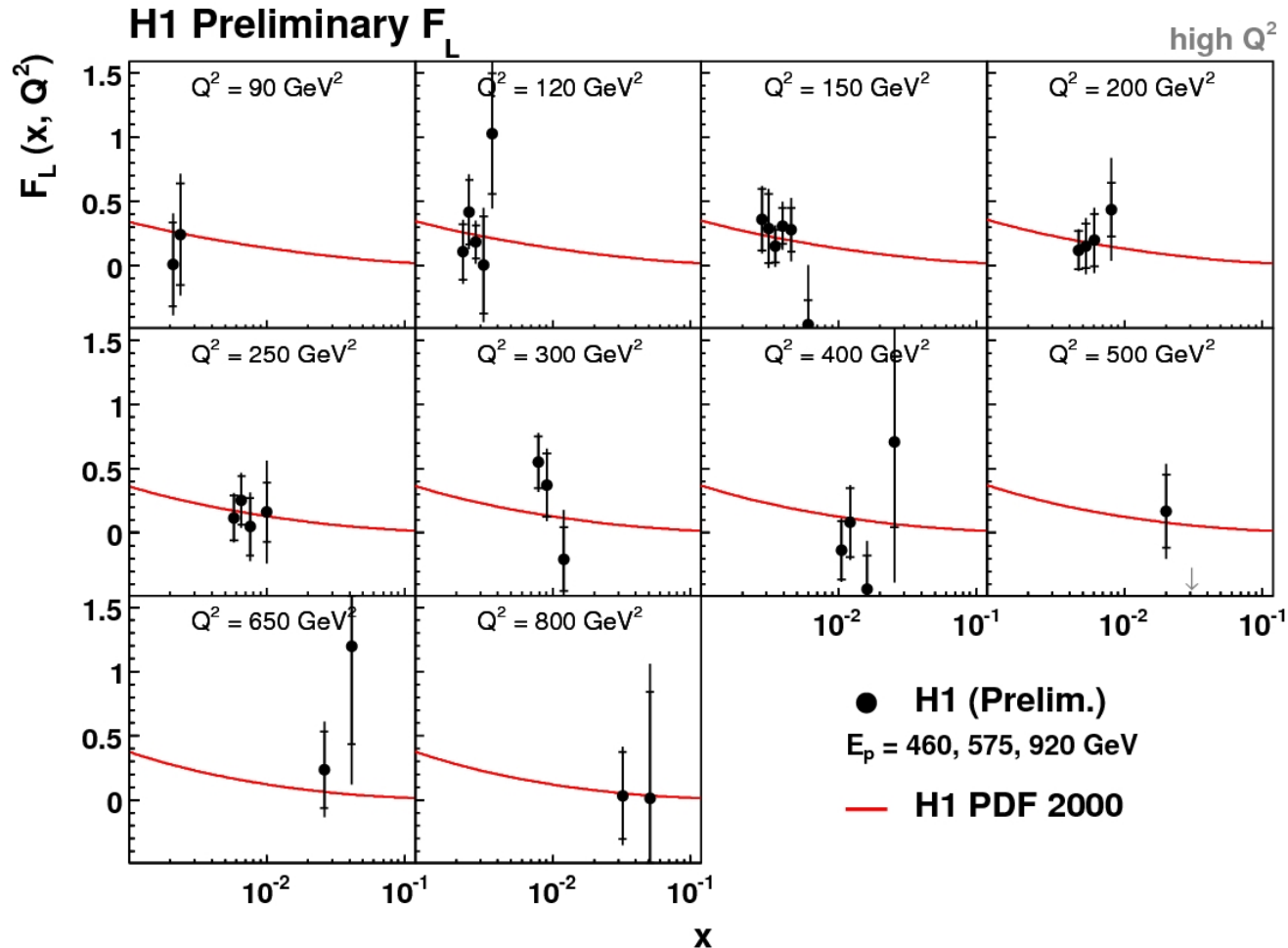
NC cross sections at the same x for $Q^2 = 150 \text{ GeV}^2$

$$\tilde{\sigma}_{NC} = F_2 - \frac{y^2}{1 + (1 - y)^2} F_L$$



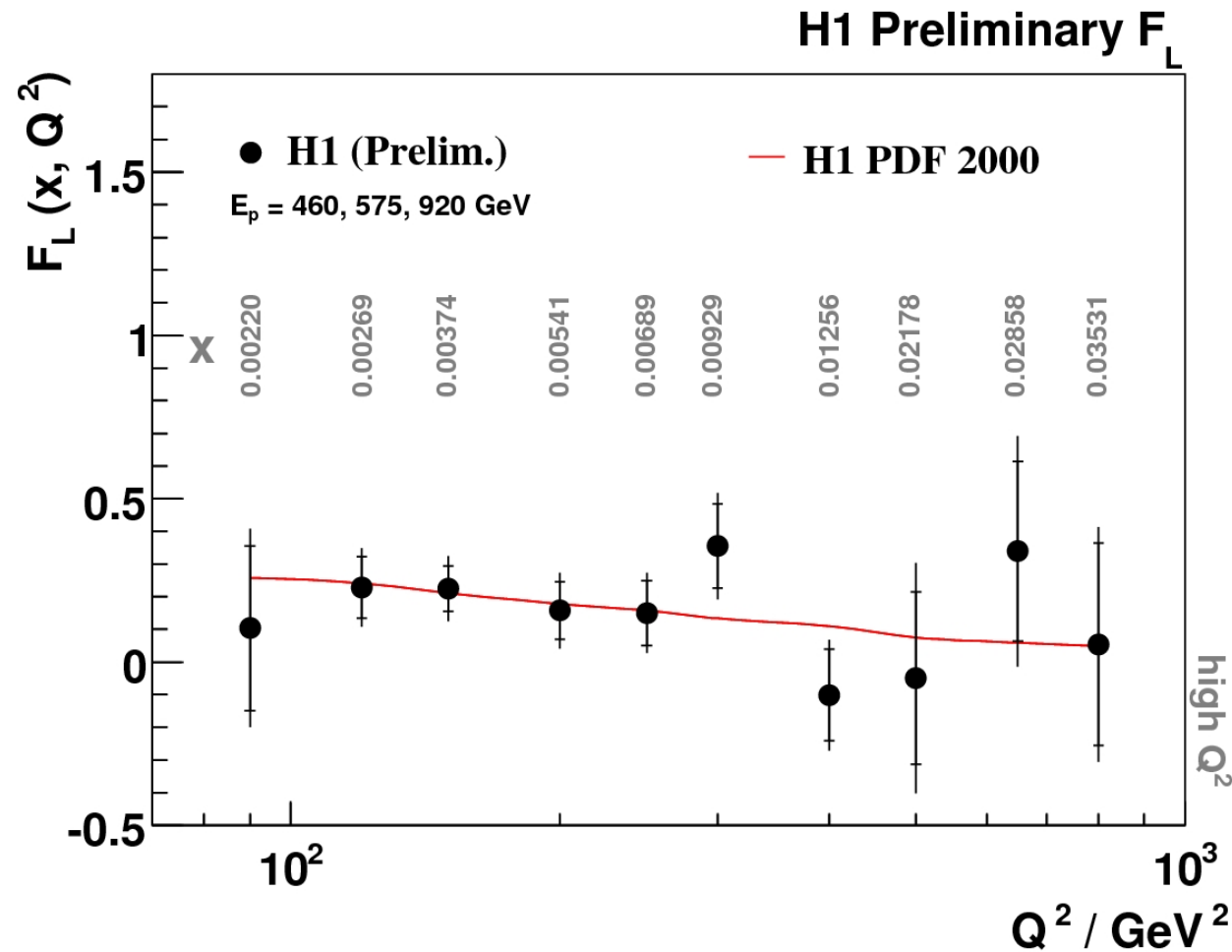
→ only cross section measurements with statistical precision better than 10% are used to estimate F_L , only F_L measurements with absolute error on F_L $\delta(F_L) < 1.1$ are shown

$F_L(x, Q^2)$ at high Q^2 using the LAr data only

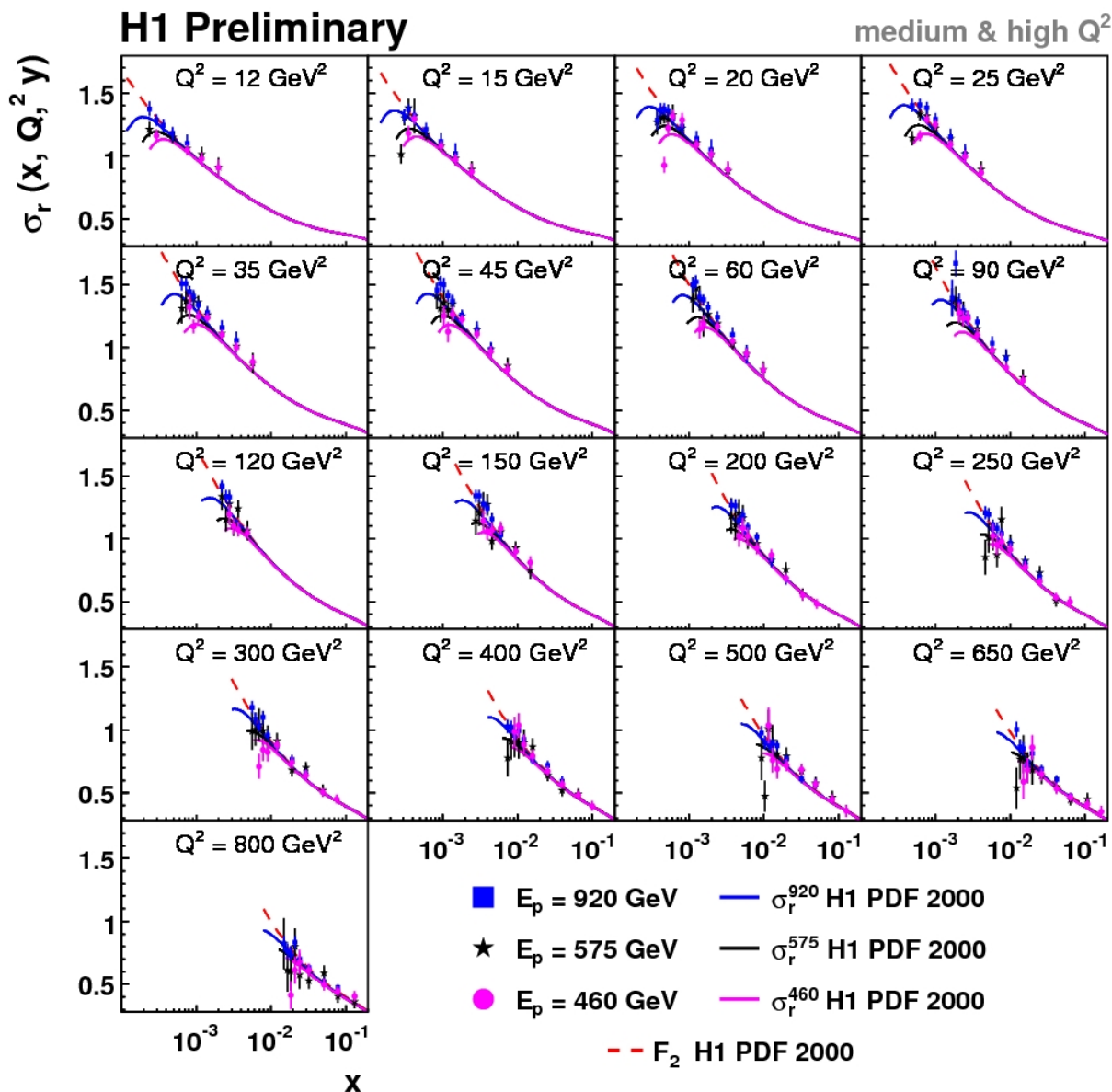


→ average F_L measurements at the same Q^2 using total errors
 (usually one point per Q^2 bin has superior precision w.r.t. others)

Averaged $F_L(Q^2)$ at high Q^2 using the LAr data only



NC cross section for $E_p = 460, 575, 920$ GeV

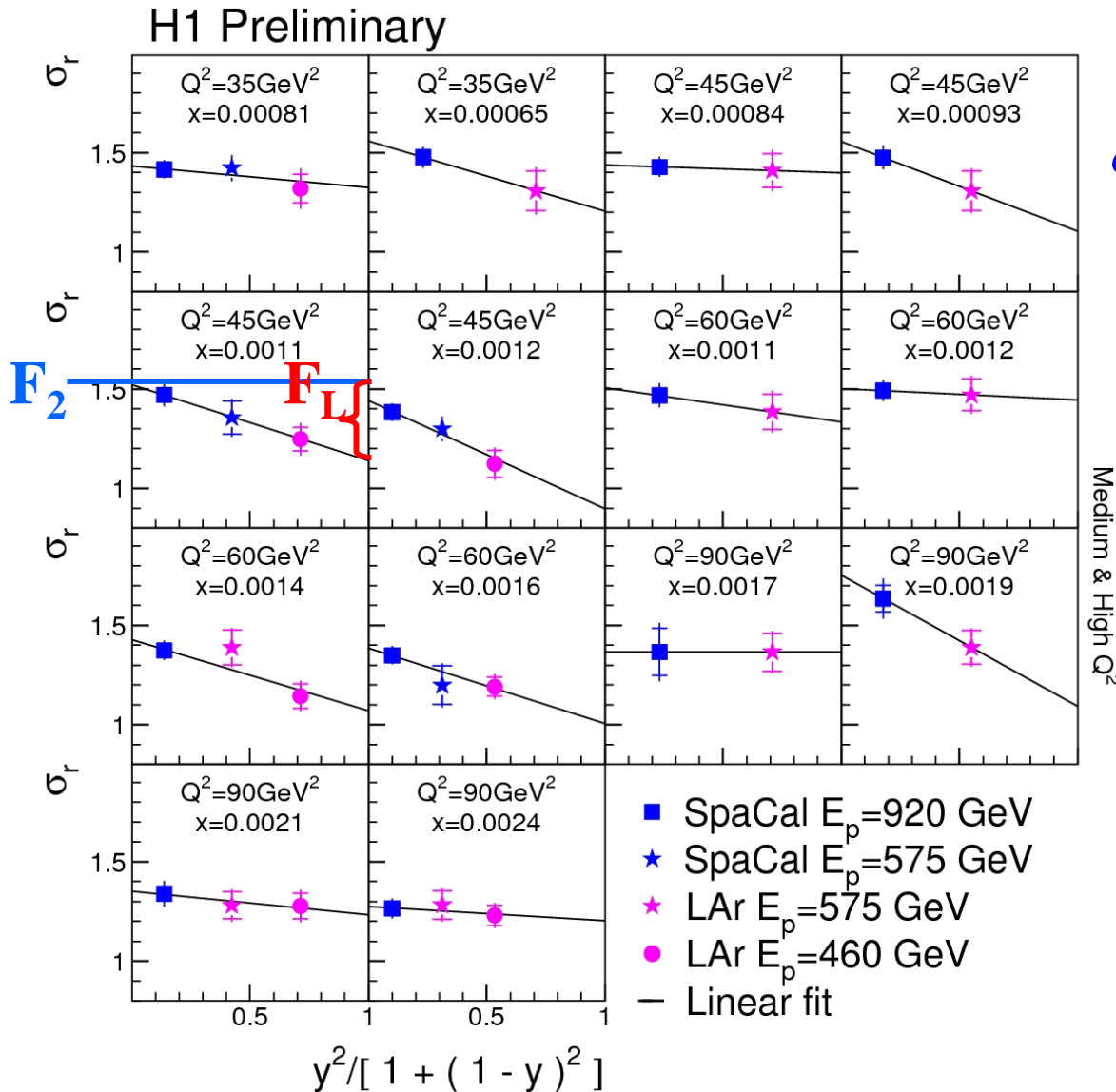


The full range of medium and high Q^2 obtained using Spacal and LAr data

→ talk of B. Antunovic for the Spacal data

use relative normalisation (the same for LAr and Spacal) of $E_p = 460, 575, 920$ GeV from the low y data for the F_L measurement

NC cross sections at the same x & Q² which involve both the LAr and Spacal data



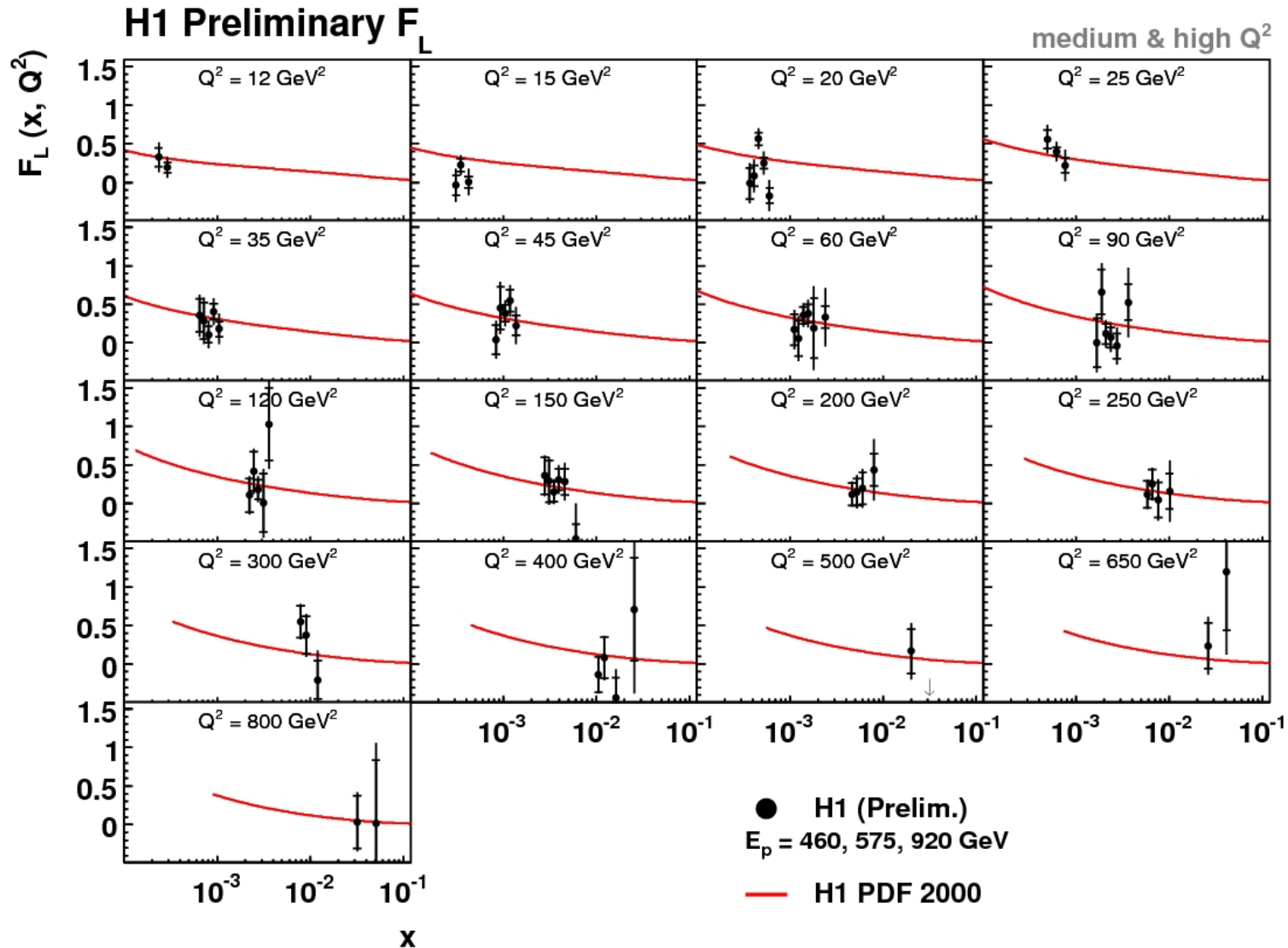
$$\tilde{\sigma}_{NC} = F_2 - \frac{y^2}{1+(1-y)^2} F_L$$

From linear fits
at each x and Q²
one determines
F_L and F₂

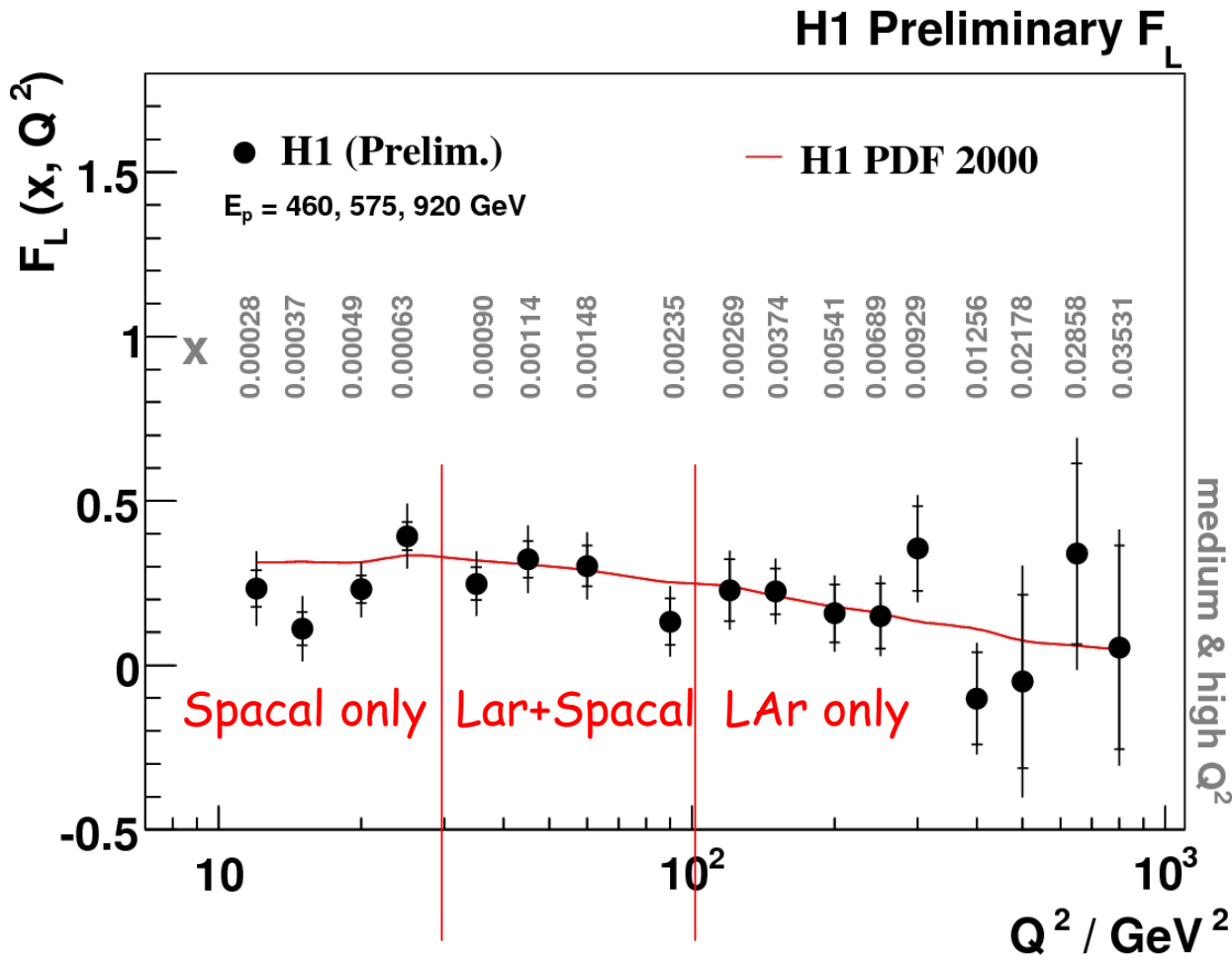
blue points - Spacal
red points - LAr

→ nice interplay of the
two fully independent
analyses using different
detectors - LAr and Spacal

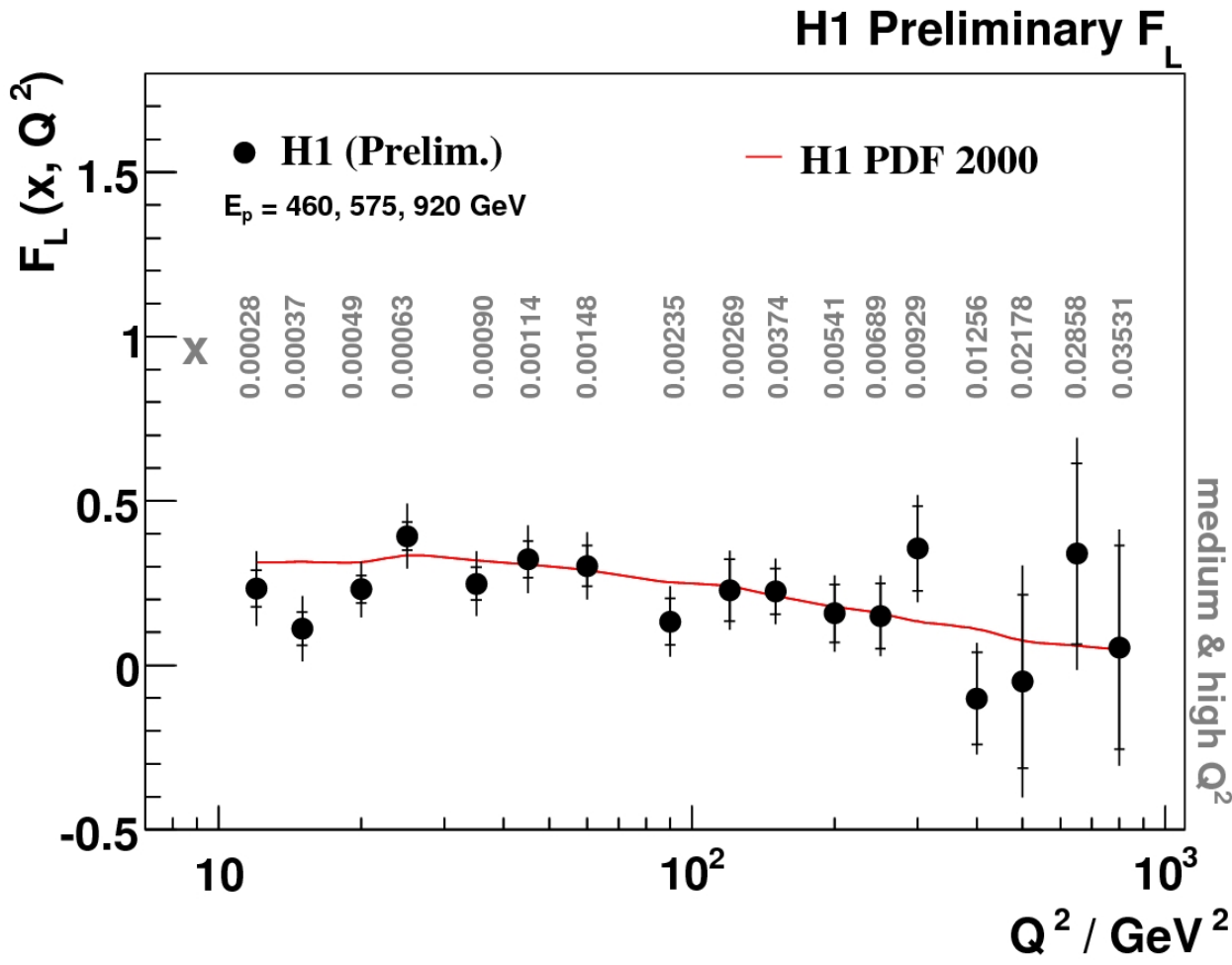
$F_L(x, Q^2)$ in the full range of medium and high Q^2 using the LAr and Spacal data



Averaged $F_L(Q^2)$ in the full medium and high Q^2 range

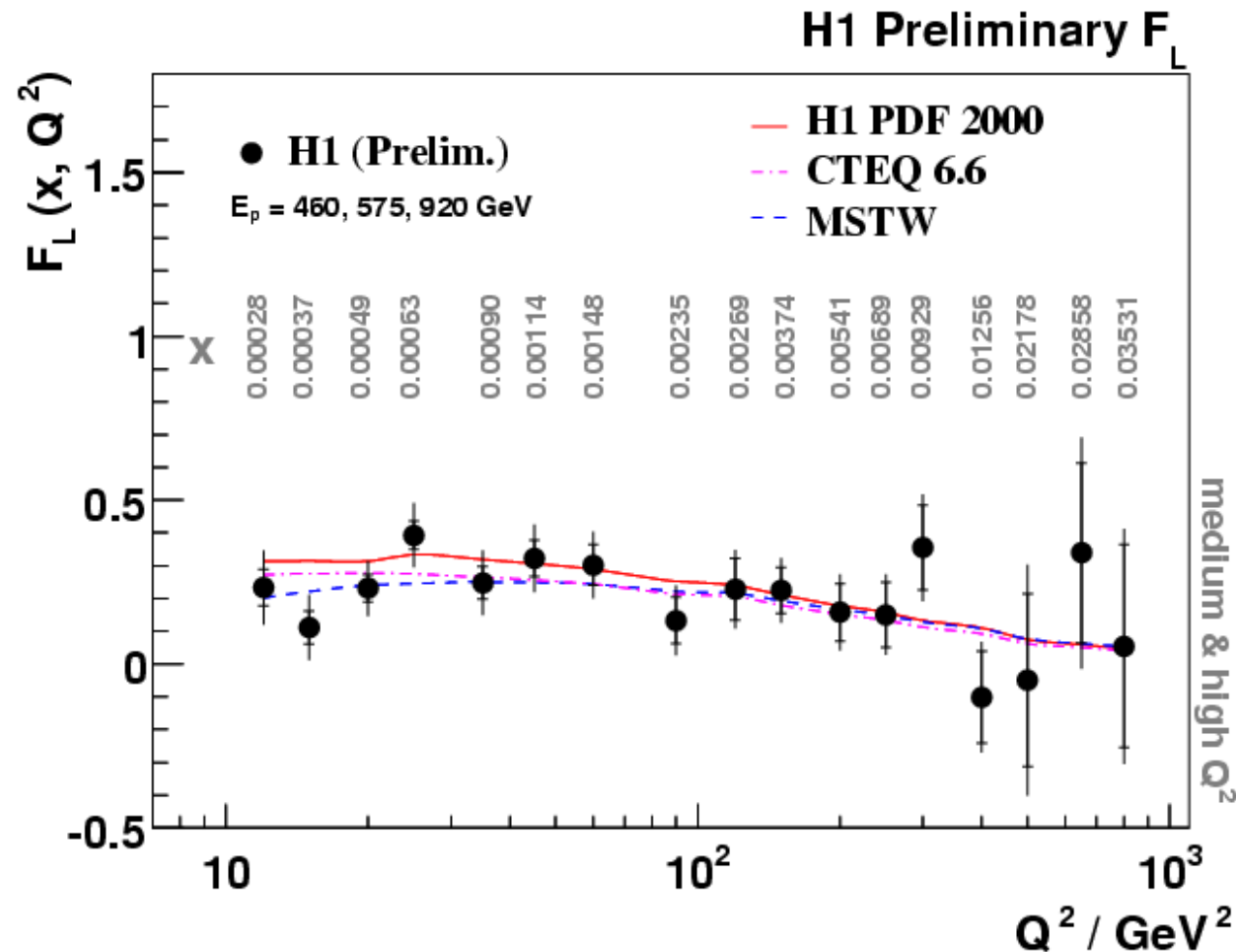


Averaged $F_L(Q^2)$ in the full medium and high Q^2 range



x values for each $F_L(Q^2)$ measurement are given in the plot

F_L comparisons with CTEQ and MSTW



Thanks to W.K.Tung/P. Nadolsky and R. Thorne for providing theory calculations on an hour(s) time scale

Conclusions

- The longitudinal structure function F_L is measured at high Q^2 and in the full range of medium and high Q^2 : $12 \leq Q^2 \leq 800 \text{ GeV}^2$, using the e^+p 2007 H1 data collected with $E_p = 460, 575$ and 920 GeV
- Nice interplay of the two fully independent analyses which use two different detectors - LAr and Spacal
- The measured $F_L(x, Q^2)$ is in agreement with the recent theoretical calculations in the QCD framework

→ *direct FL measurement at lowest Q^2 still to come*