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

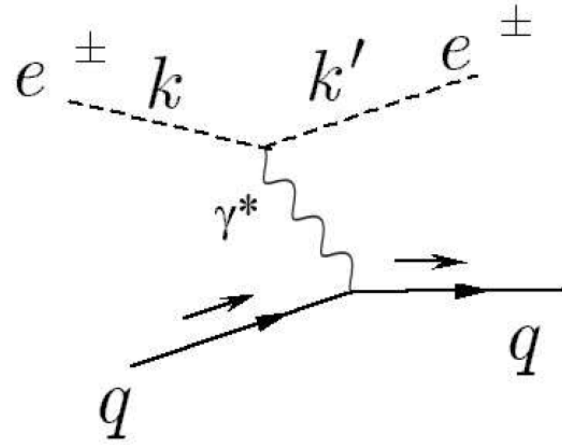
- F_L is an independent structure function which should be measured at HERA to complete the DIS program

- F_L is a pure QCD effect which allows to make critical tests of the perturbative QCD framework used for pdf determinations

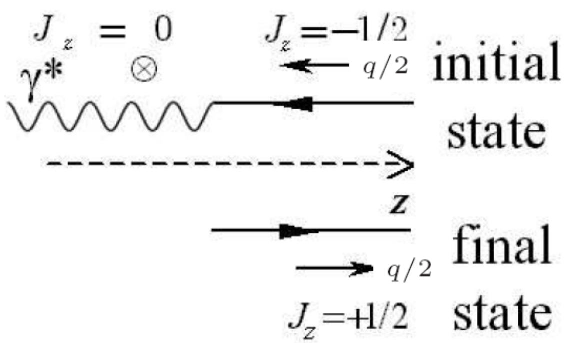
- F_L is directly sensitive to gluon density

in QPM *due to helicity and angular momentum conservation for spin ½ quarks*

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

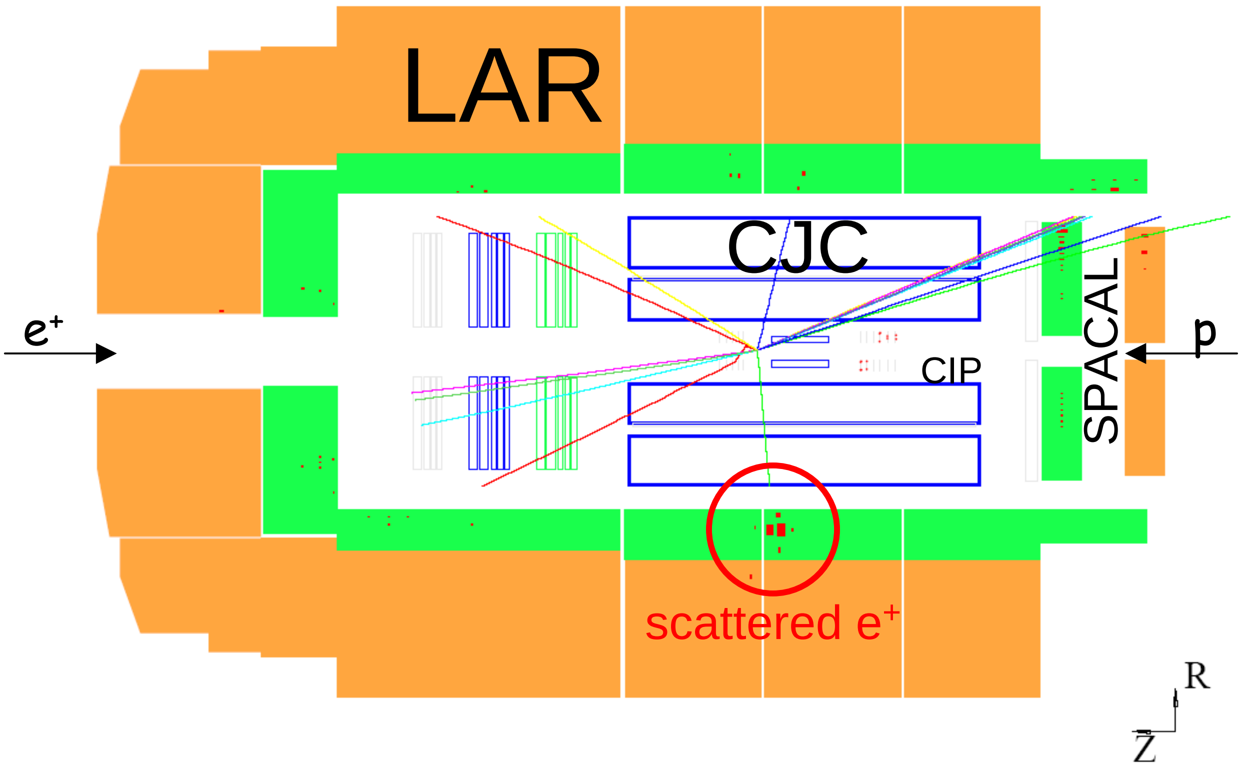


Breit frame:



Main detector components for the high Q^2 analysis

scattered electron with energy $E_e > 3$ GeV in LAR ($\vartheta < 153^o$)



LAR
- Liquid ARgon calorimeter

CJC
- Central Jet Chamber

CIP
- Central Inner Proportional chamber

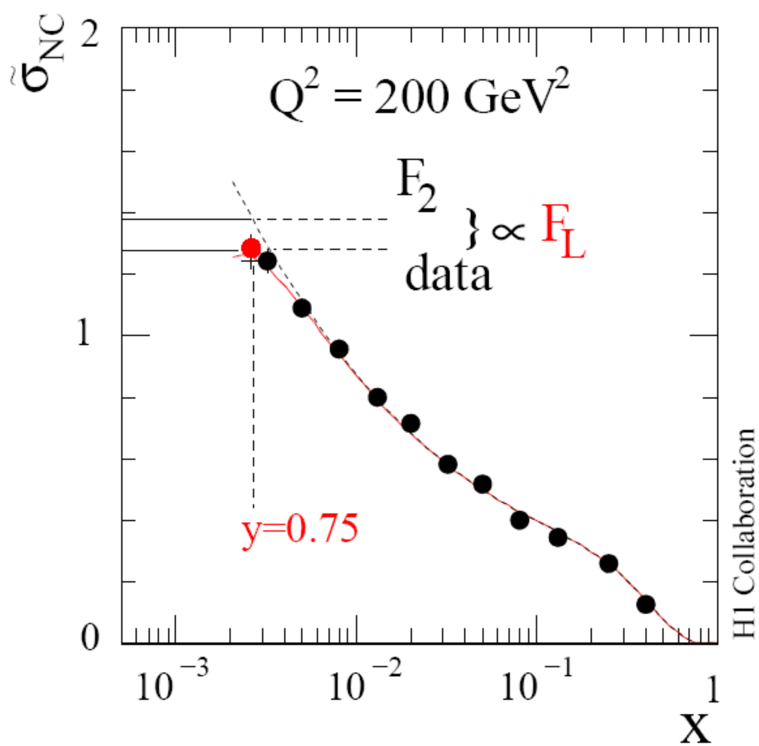
SPACAL
- SPAgetti CALorimeter

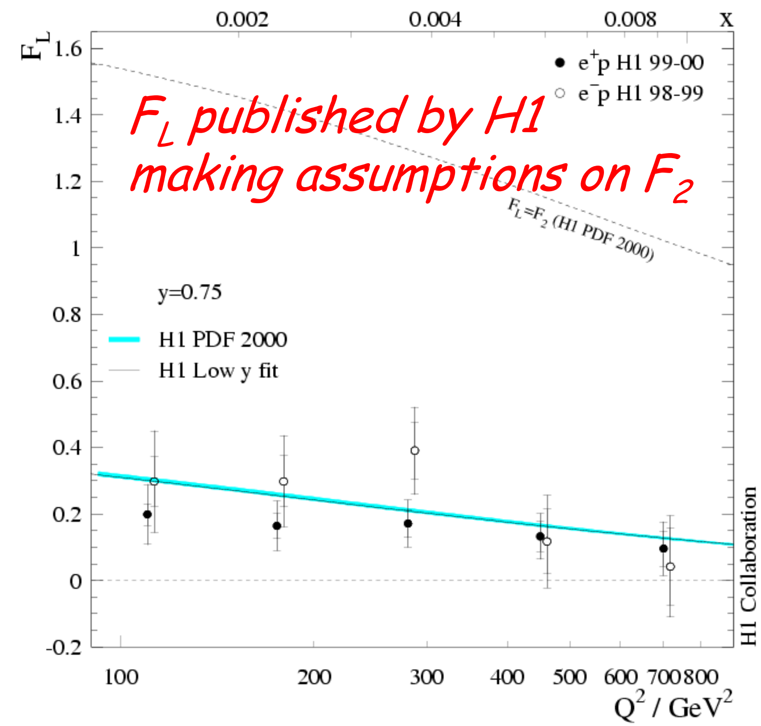
Published H1 determination of F_L at high Q^2

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

sensitivity to F_L only at high y

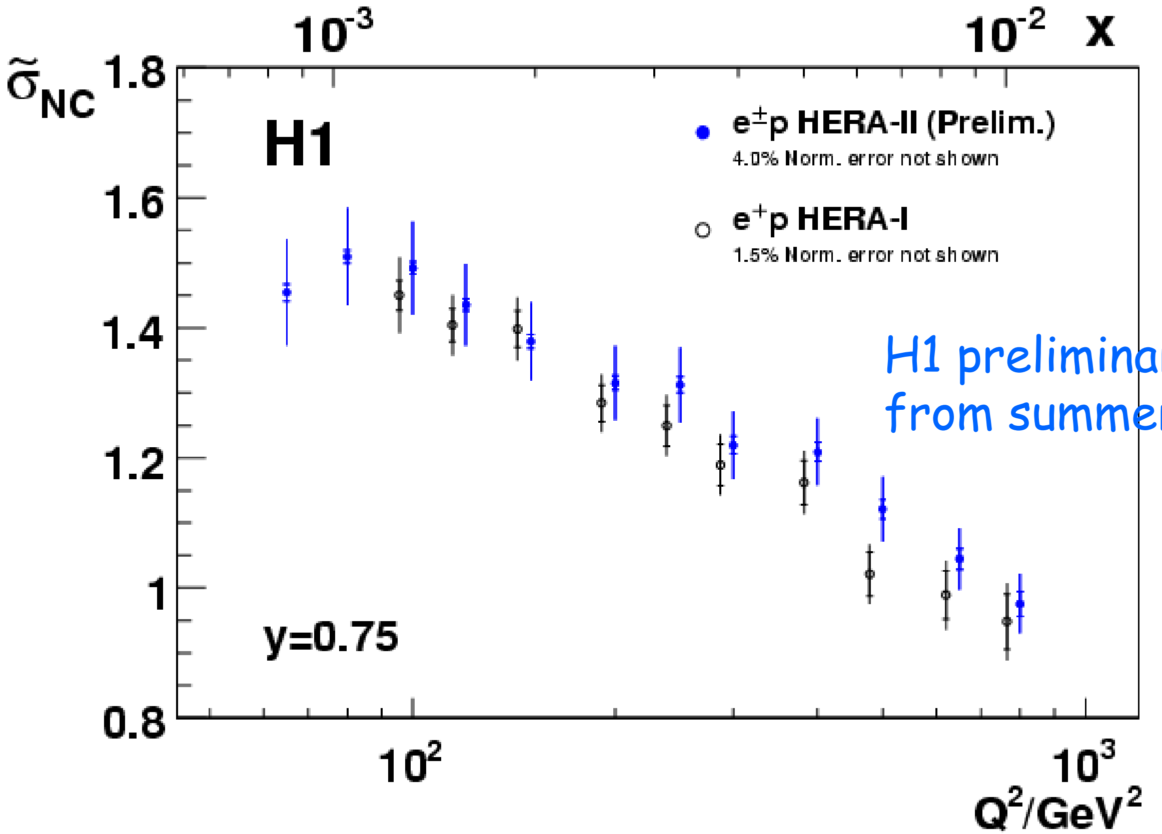
$$Y_+ = 1 + (1-y)^2$$





→ 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

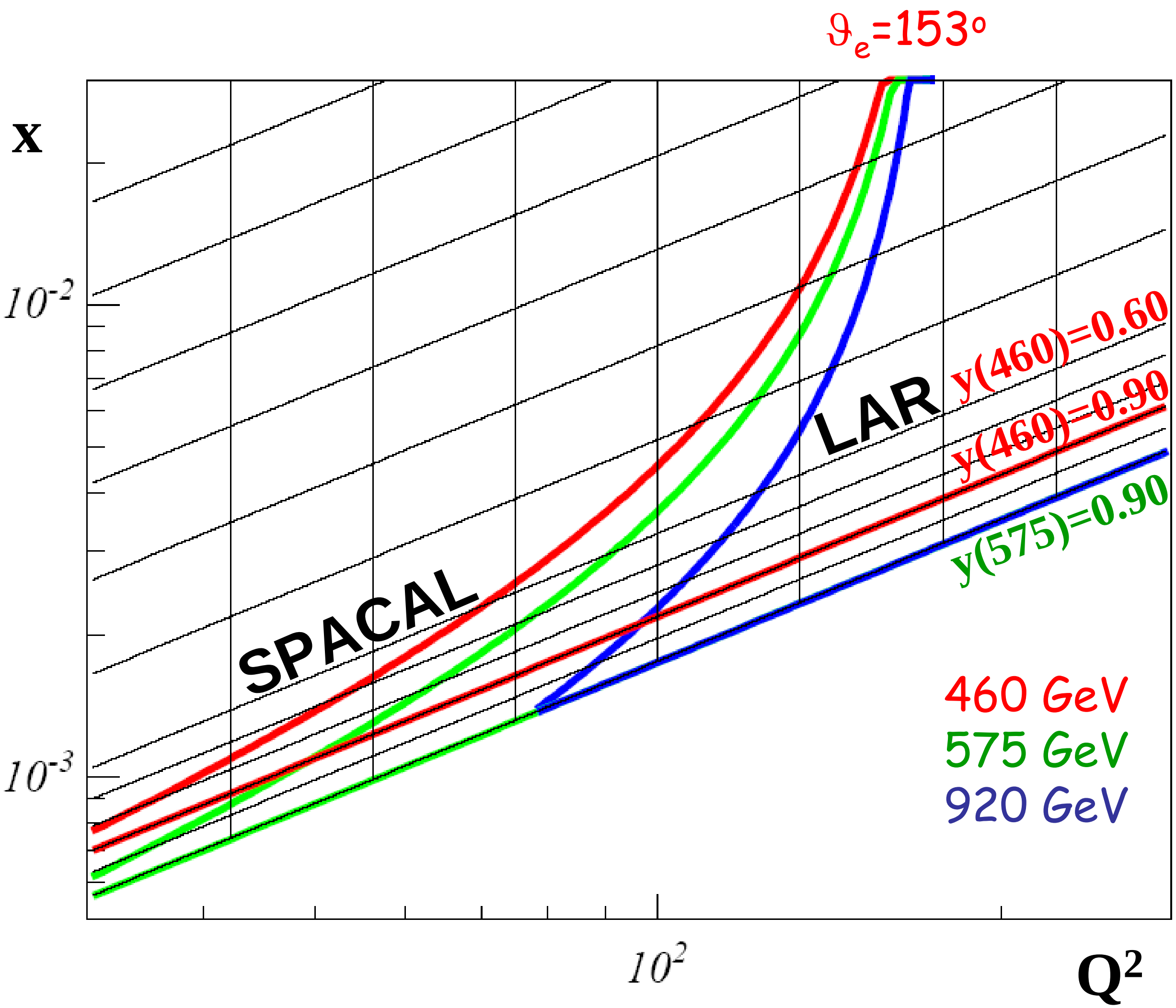
NC cross section measurement at y=0.75 at HERA II



H1 preliminary from summer 2007

→ 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 GeV, L = 12.0 pb^{-1}
E_p = 575 GeV, L = 6.2 pb^{-1}
E_p = 920 GeV, L = 46.3 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 GeV^2

For 35 $\leqslant Q^2 \leqslant$ 90 GeV^2 both LAr and Spacal are needed

Analysis strategy at high Q^2

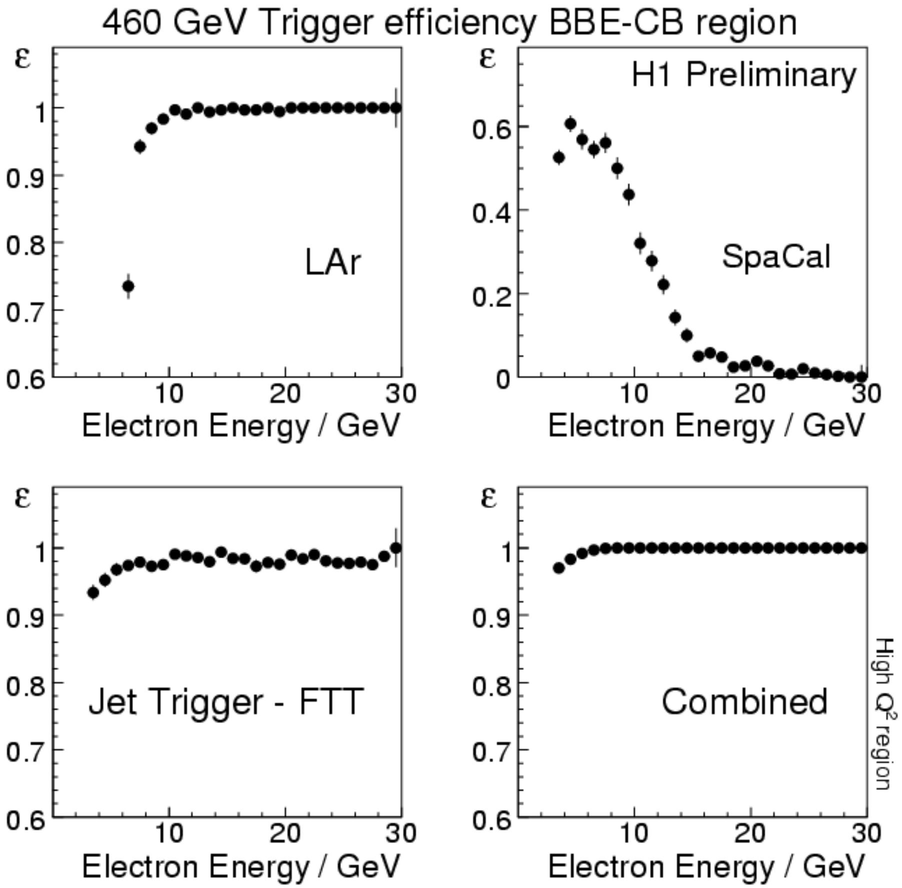
High y analysis	Nominal analysis
$E_e > 3$ GeV $0.38 < y_e < 0.90$ (E_p= 460, 575 GeV)	$0.076 < y_e < 0.38$ (< 0.56 for E_p= 920 GeV)
1. track pointing to electron cluster in LAr 2. use electric charge of the el. candidate: - identify and exclude half of γp bkg require “right” charge of el. candidates - estimate and subtract remaining γp bkg using “wrong” charge el. candidates 3. additional bkg suppression for E_e<6 GeV	1. electron cluster in LAr is validated by the tracker or CIP 2. γp background is estimated using PYTHIA MC (only E_p= 920 GeV)

in common: $\|Z_{vtx}\|$ < 35 cm (to ensure the best quality of reconstruction)
$E-P_z$ > 35 GeV (to suppress γp bkg and incoming electron initial state radiation)
exclude scattered electrons pointing into cracks in the LAr calorimeter
identify and exclude (quasi)elastic QED Compton events

electron method is used to reconstruct kinematic variables

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 :

~ 97% for E_e = 3 GeV and
~ 100% for E_e > 6 GeV

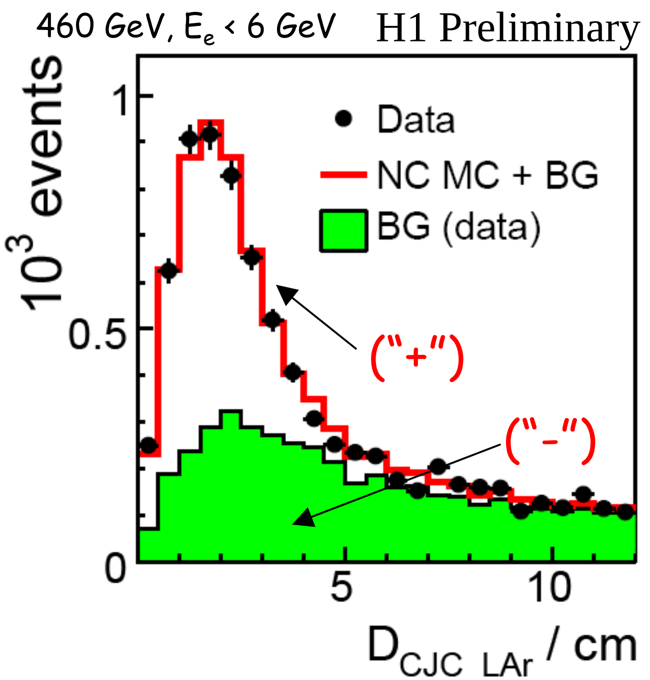
γp background identification and statistical subtraction of the remaining γp bkg at high y

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:

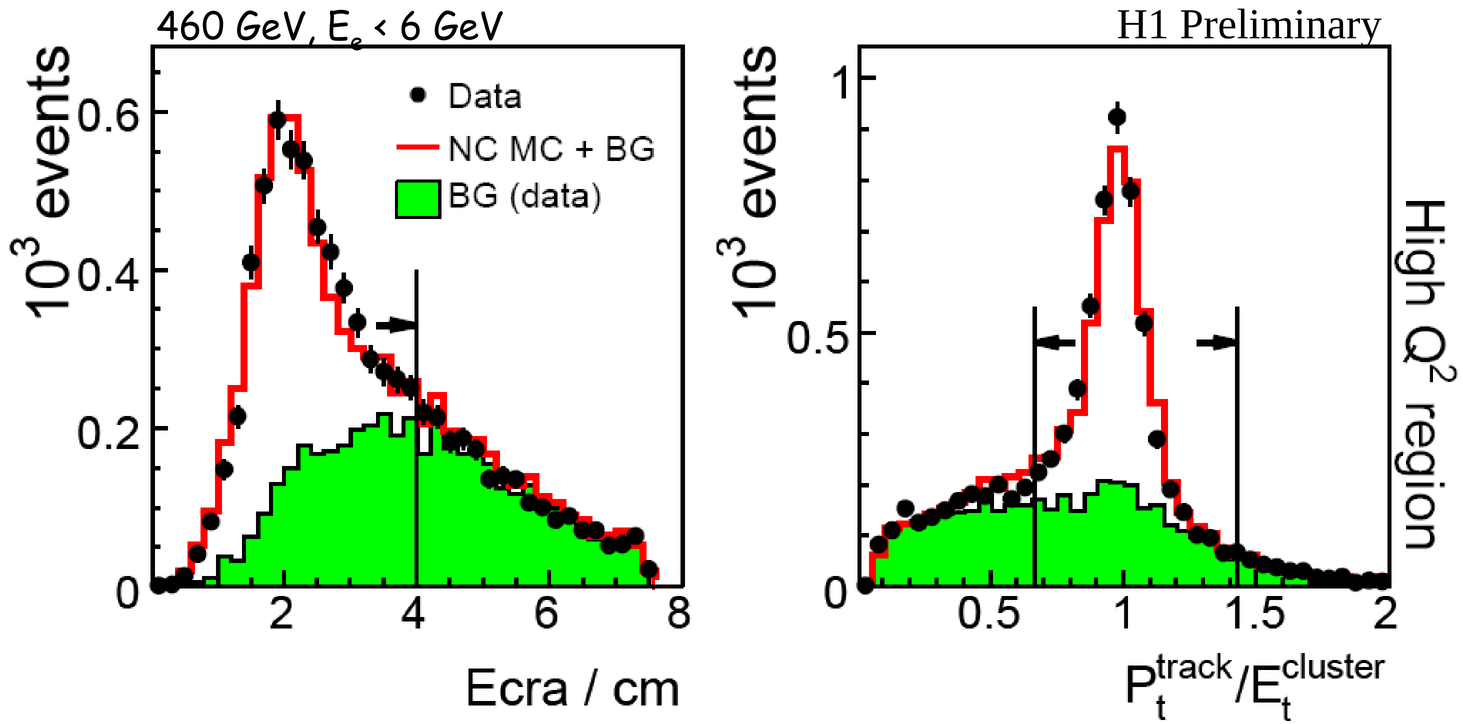
- Charge asymmerty in γp data due to antiprotons
  determined using "wrong charge" el. candidates in the $e^{\pm}p$ HERA II data and in γp events identified by elec. tagger
- Charge asymmetry of the fake electron candidates in the signal NC MC (DJANGO)
- Wrong charge determination for the true electrons

→ 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: Ecra < 4 cm
- matching between track momentum and cluster energy: $0.7 < E_t^{cluster}/P_t^{track} < 1.5$



→ 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

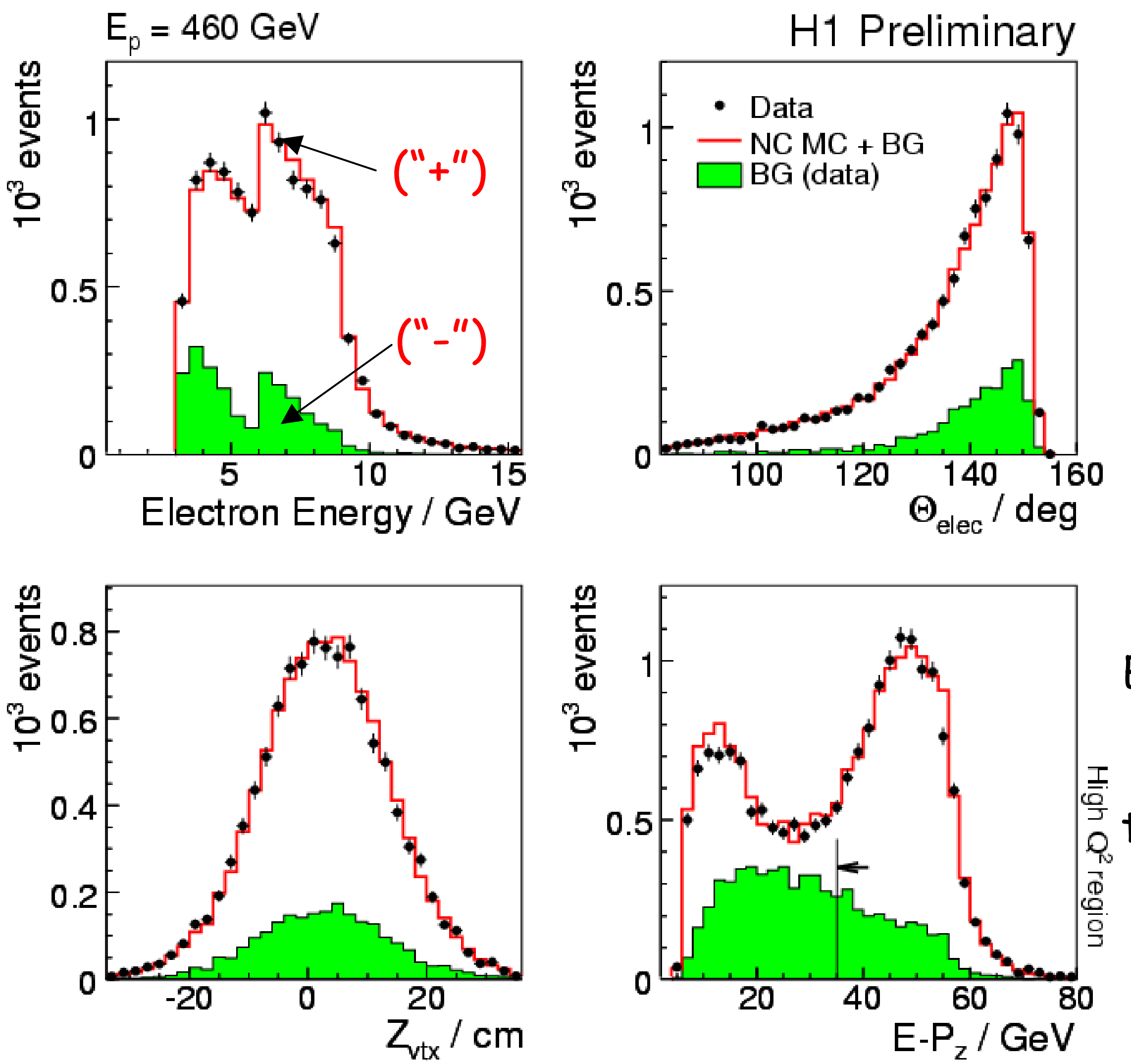
Further items in the high y analysis

- Primary vertex reconstruction efficiency at high y (~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

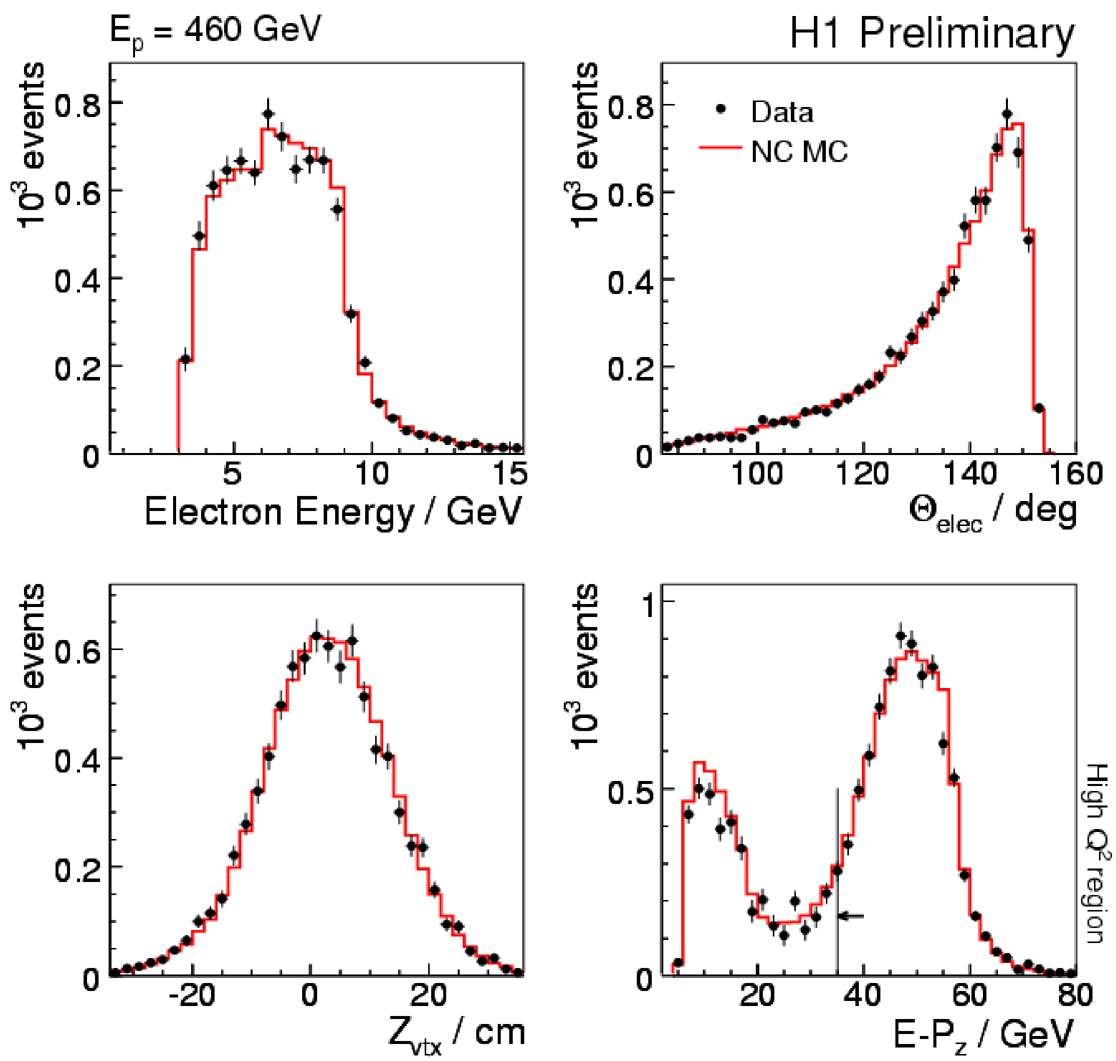
→ step at E_e = 6 GeV is due to additional requirements

E-Pz is under control in the full range

the requirement E-Pz>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

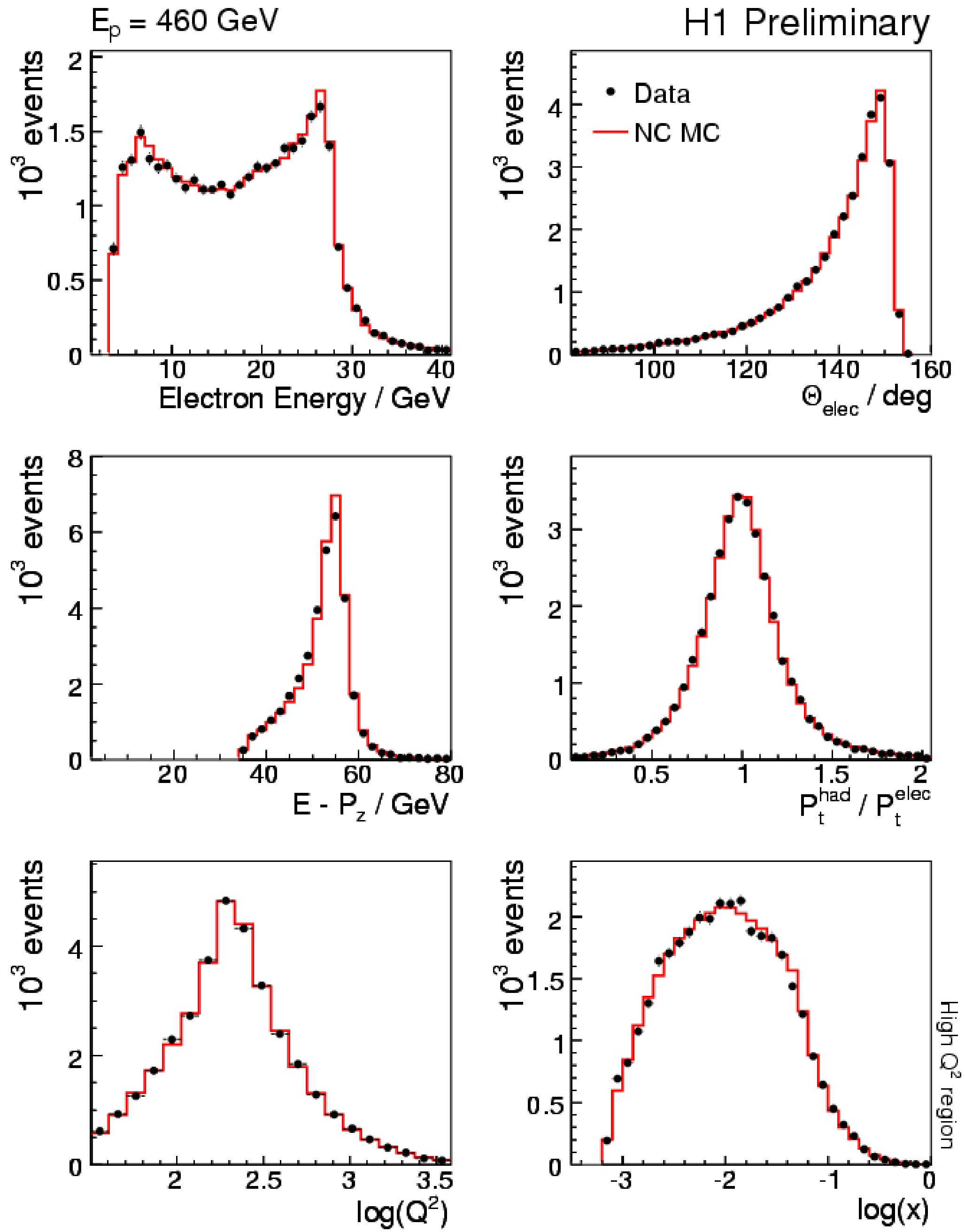
→ step at E_e = 6 GeV is due to additional requirements

E-Pz is under control in the full range

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

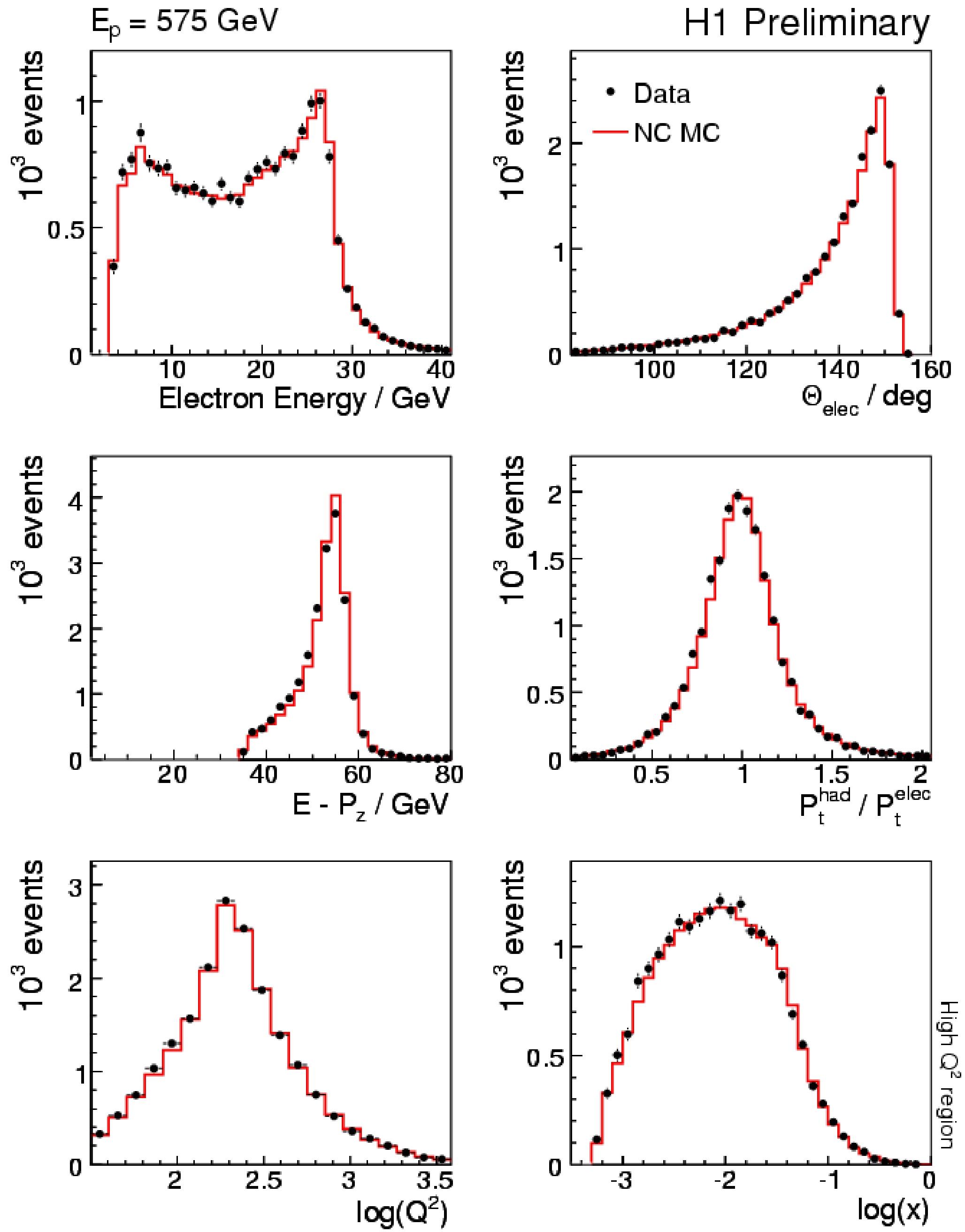
E_p = 460 GeV

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



E_p = 575 GeV

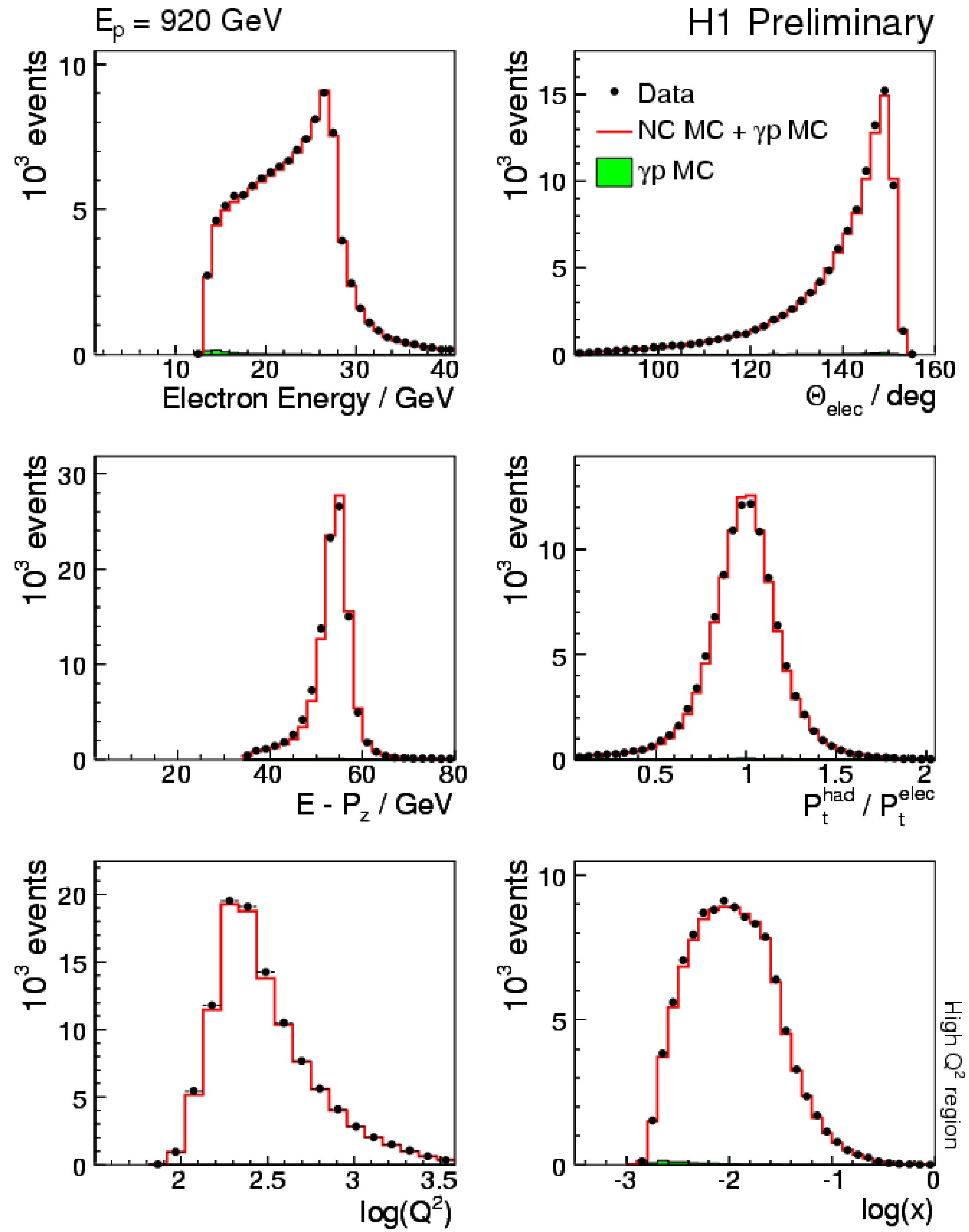
NC events
in the full y range
(0.076<y<0.90)
after
γp bkg subtraction



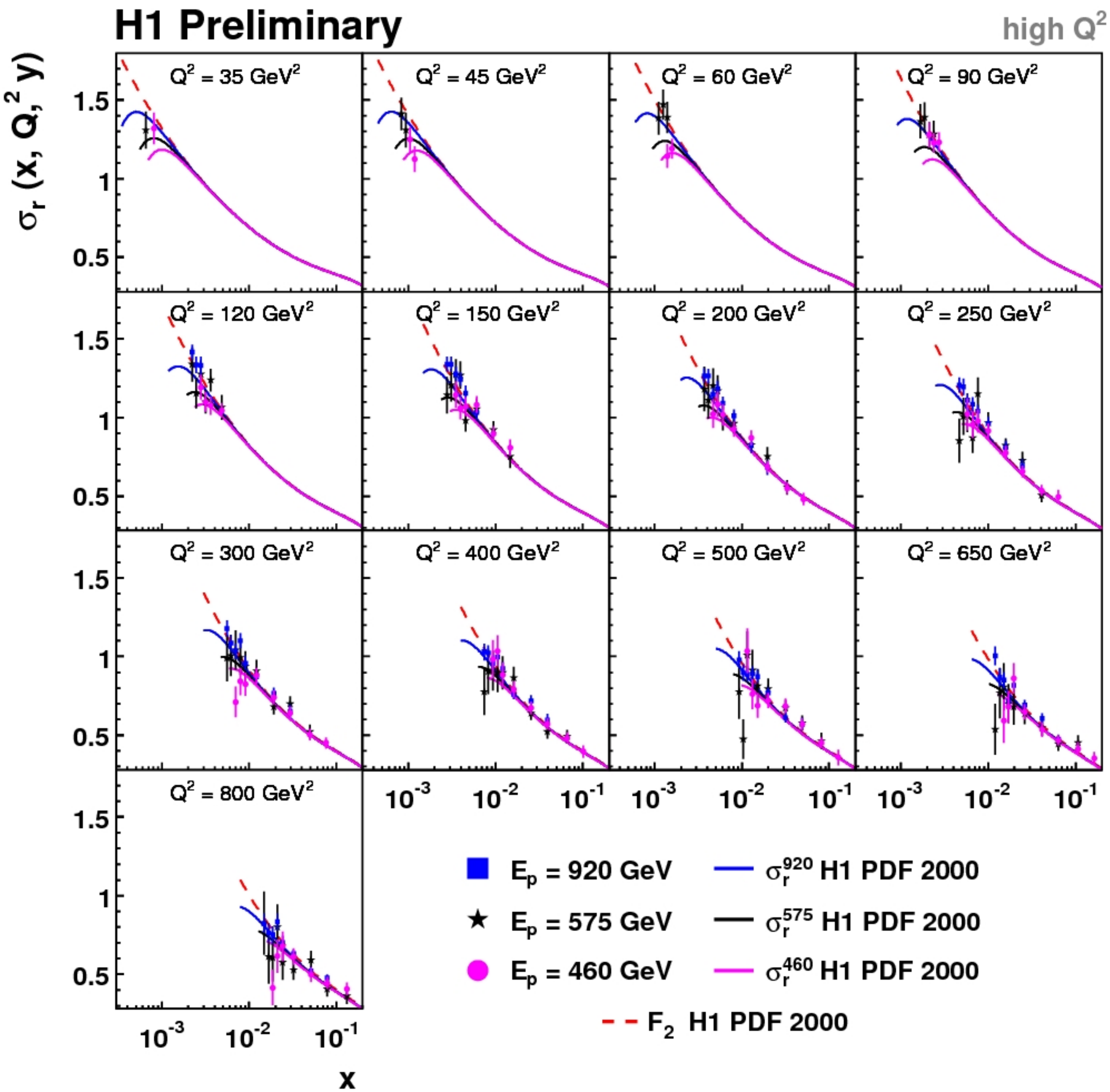
E_p = 920 GeV

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



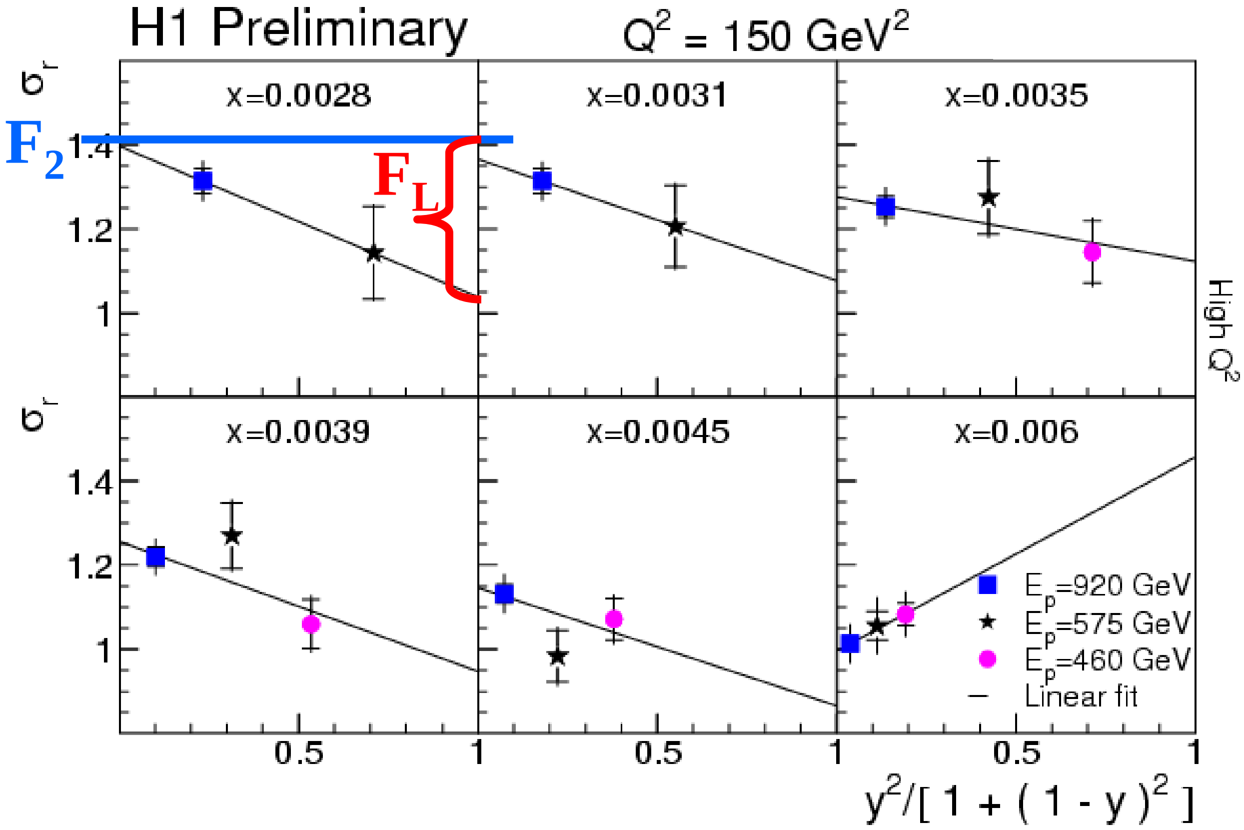
Three cross section measurements at each x and Q^2

Depatures 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 $Q^2 = 150$ GeV^2

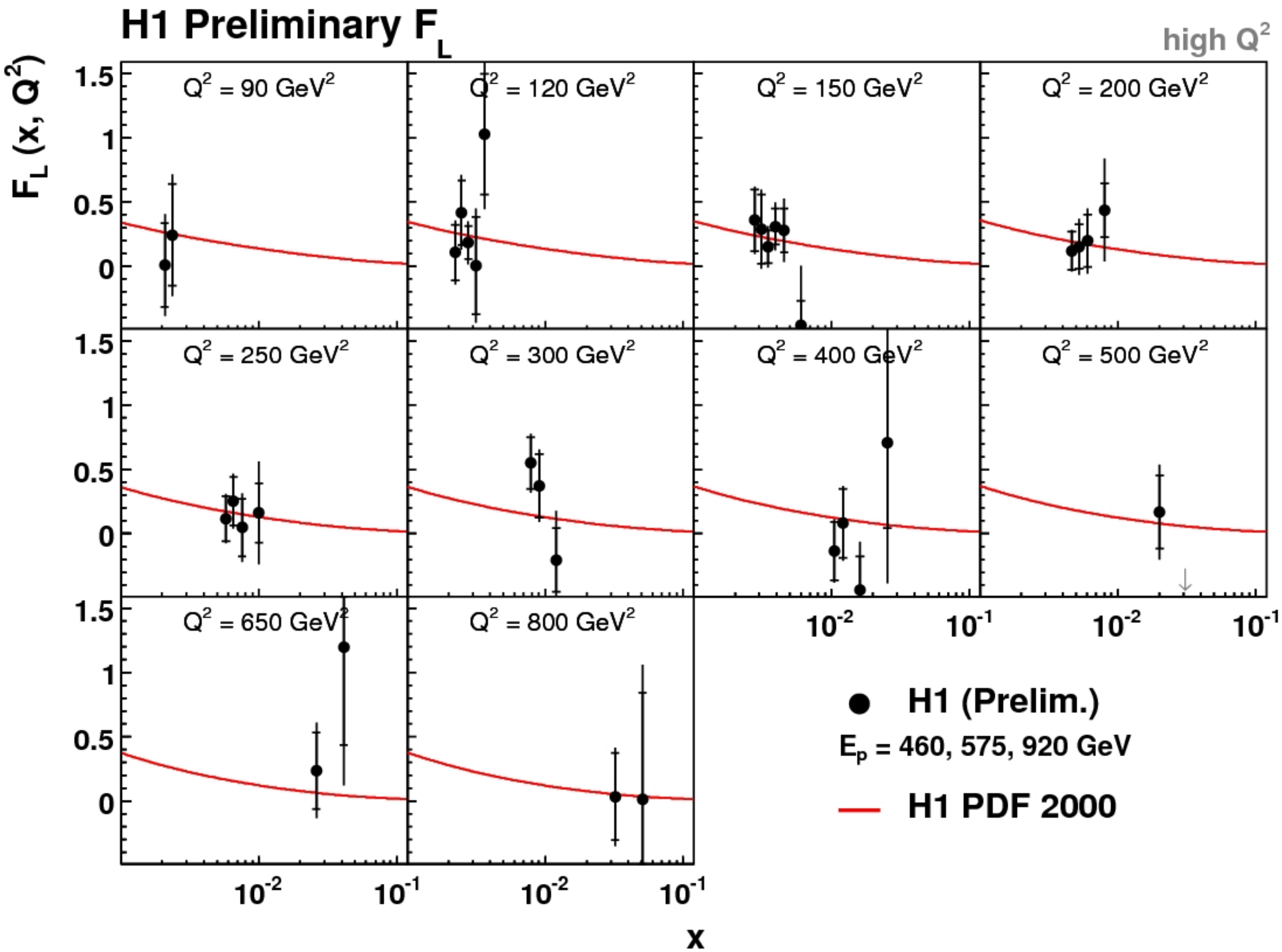
$$\tilde{\sigma}_{NC} = F_2 - \frac{y^2}{1+(1-y)^2} F_L$$



From linear fits at each x and Q^2 one determines F_L and F_2

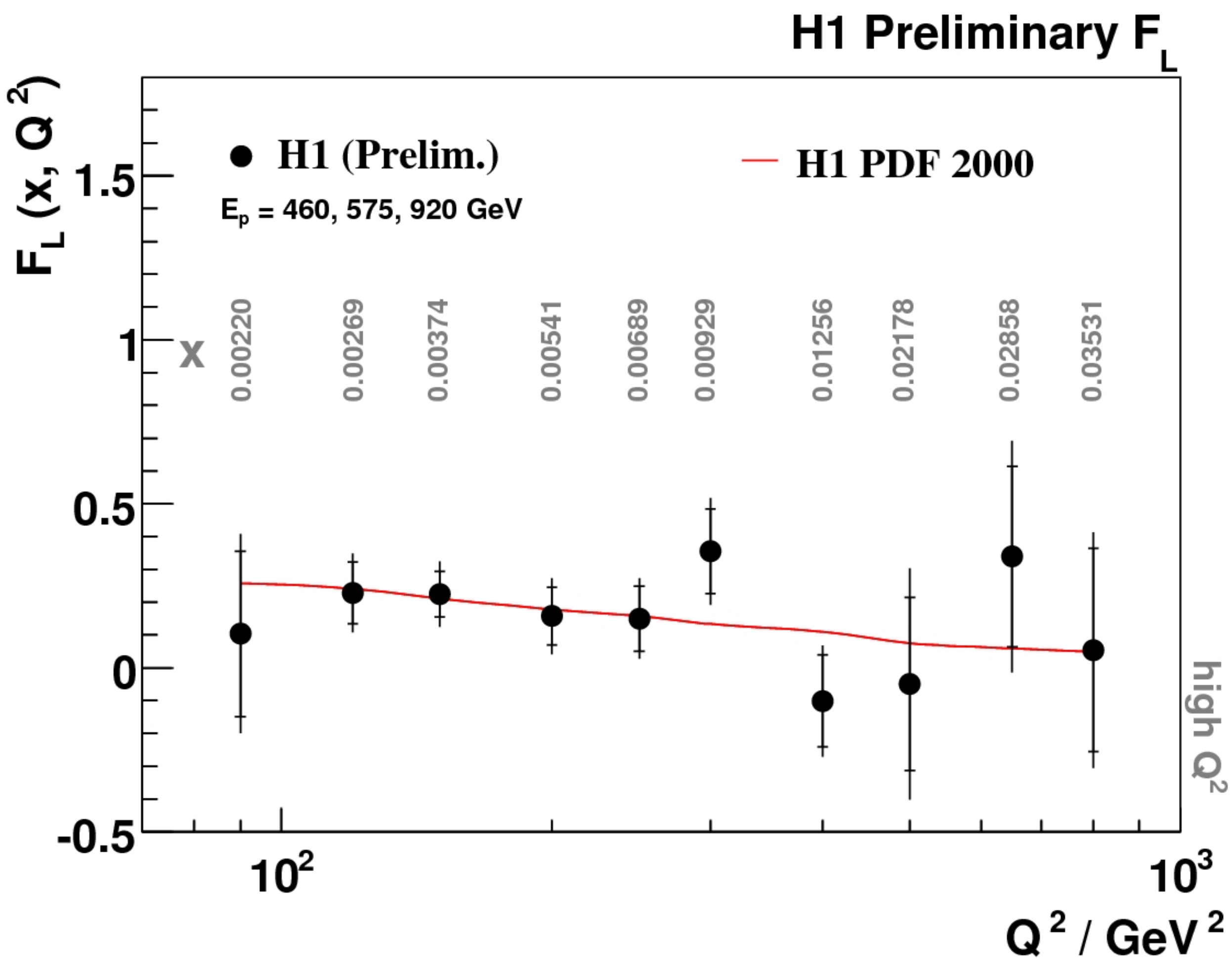
→ only cross section measurements with statistical precision better than 10% are used to estimate F_L , only F_L measurements with absolute error on F_L $\delta(F_L) < 1.1$ are shown

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



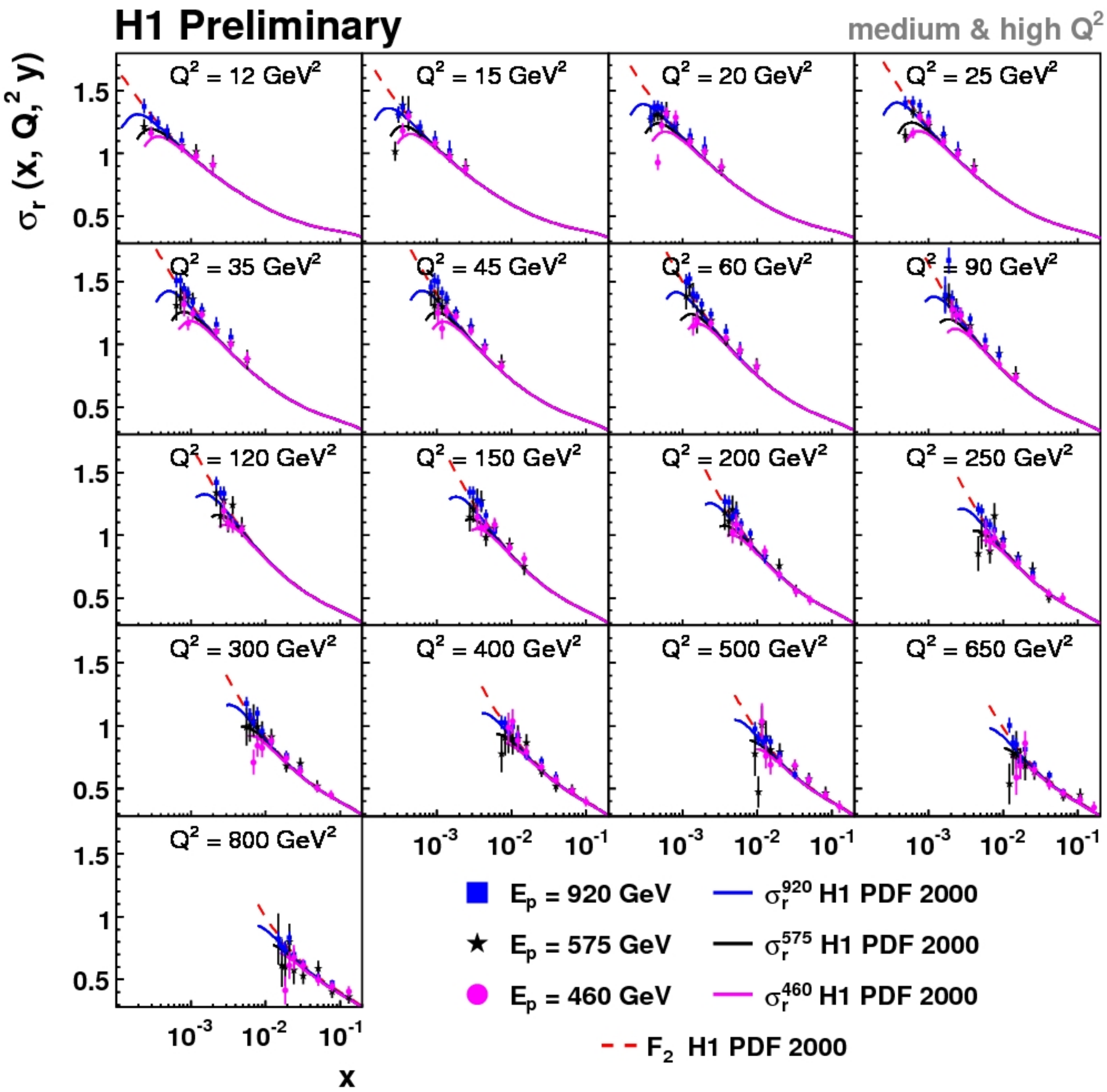
→ average F_L measurements at the same Q^2 using total errors
(usually one point per Q^2 bin has superior precision w.r.t. others)

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



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

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

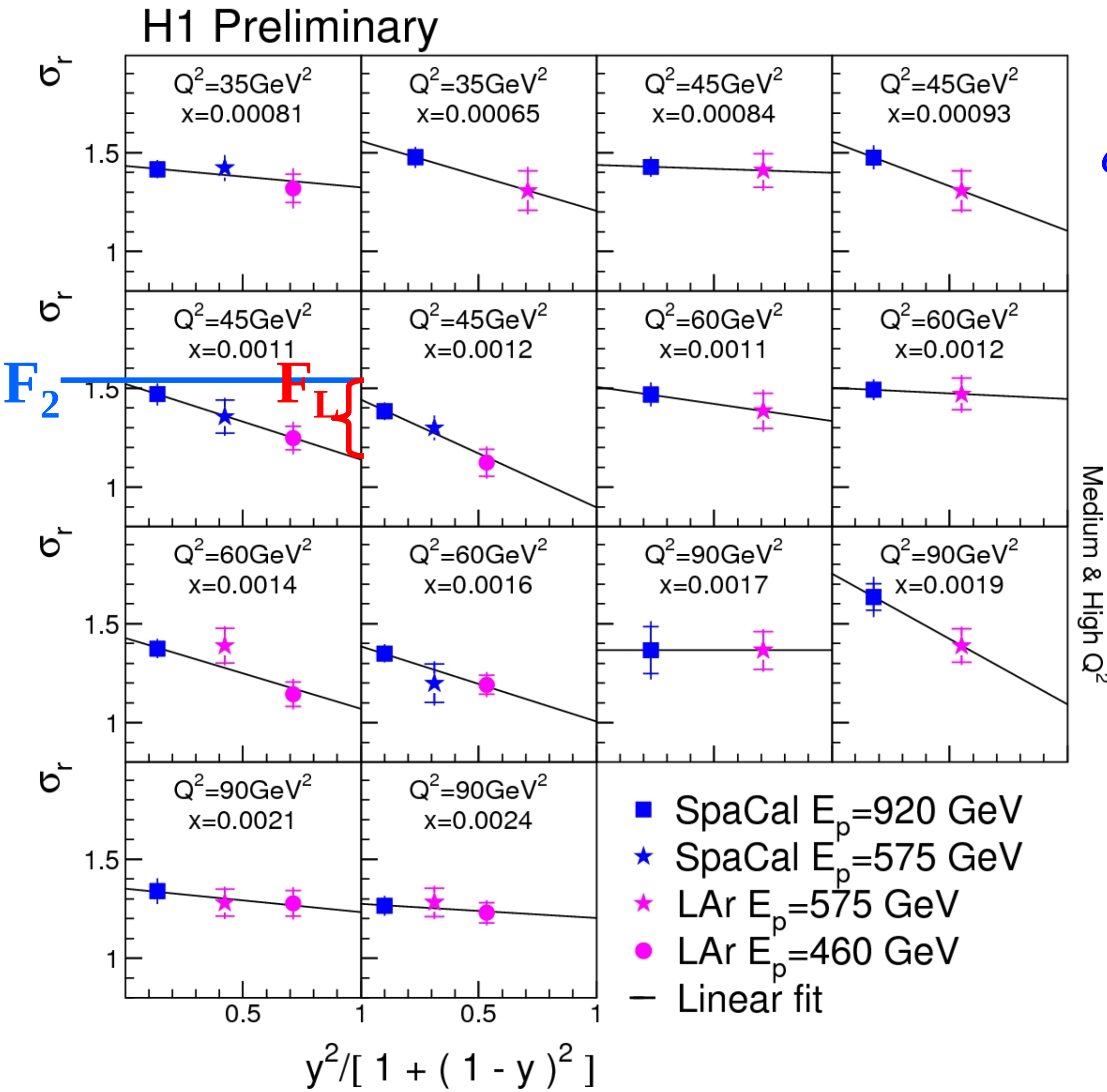


The full range of medium and high Q^2 obtained using Spacal and LAr data

→ 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 & Q^2 which involve both the LAr and Spacal data



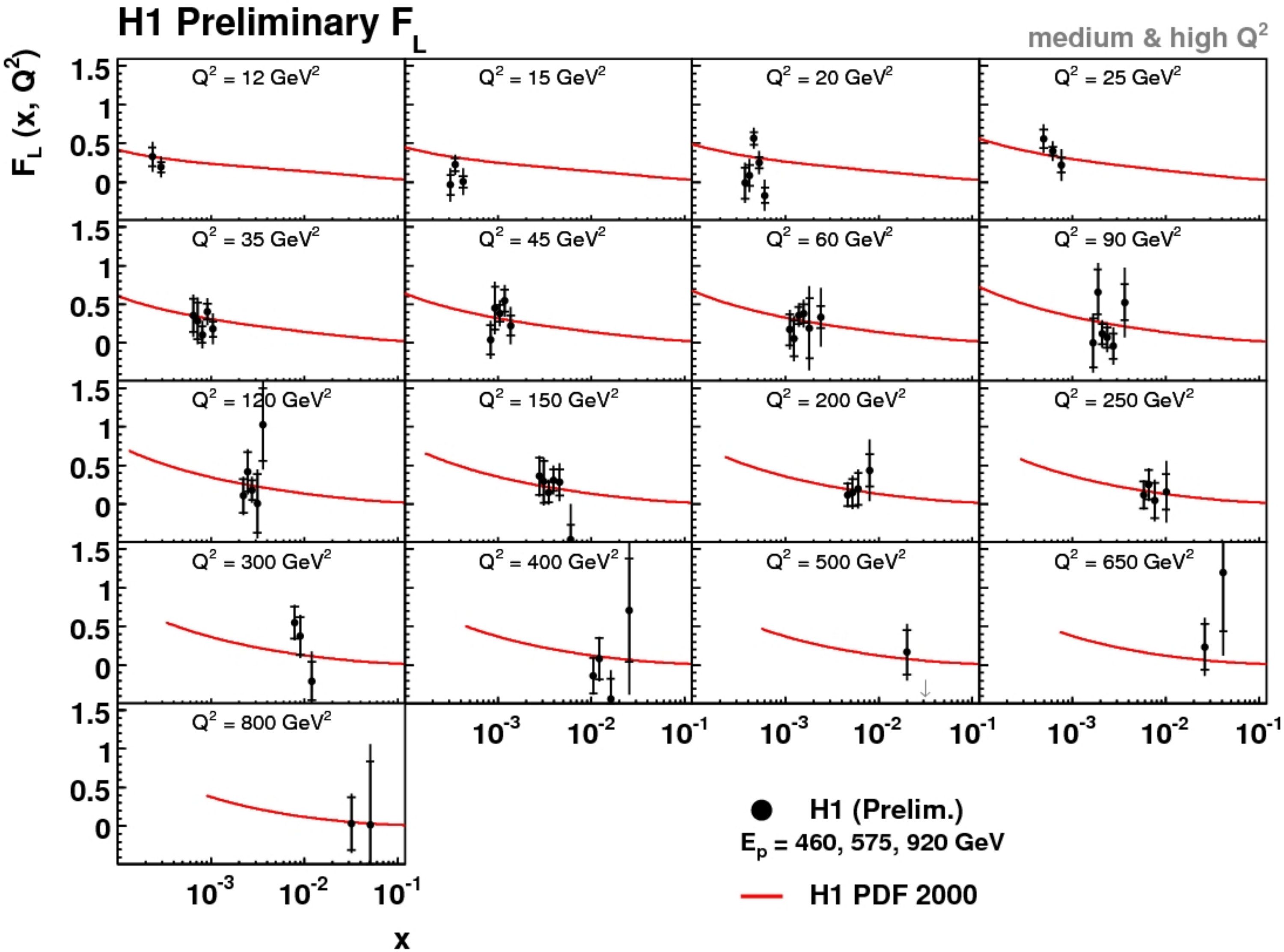
$$\tilde{\sigma}_{NC} = F_2 - \frac{y^2}{1+(1-y)^2} F_L$$

From linear fits at each x and Q^2 one determines F_L and F_2

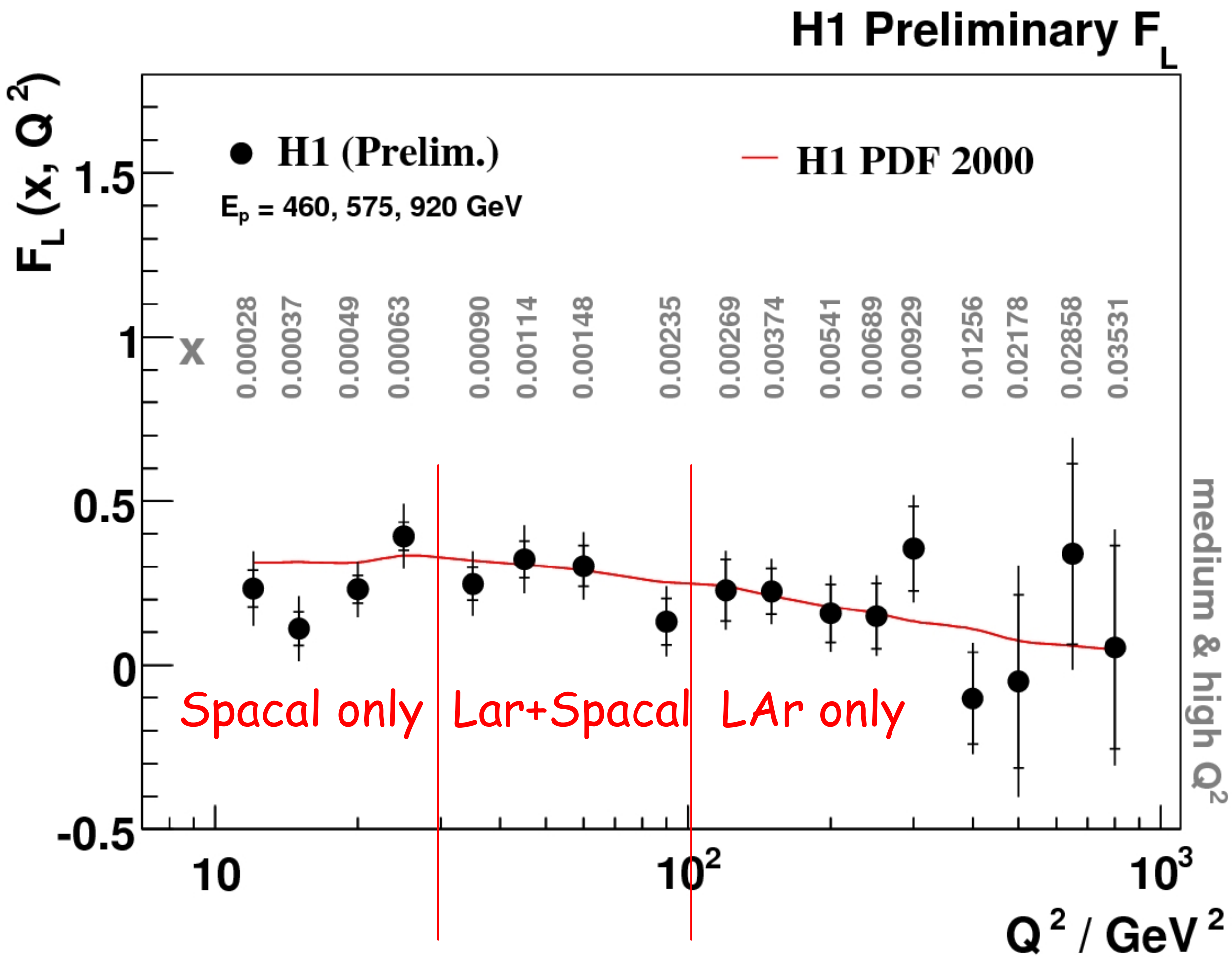
blue points - Spacal
red points - LAr

→ 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

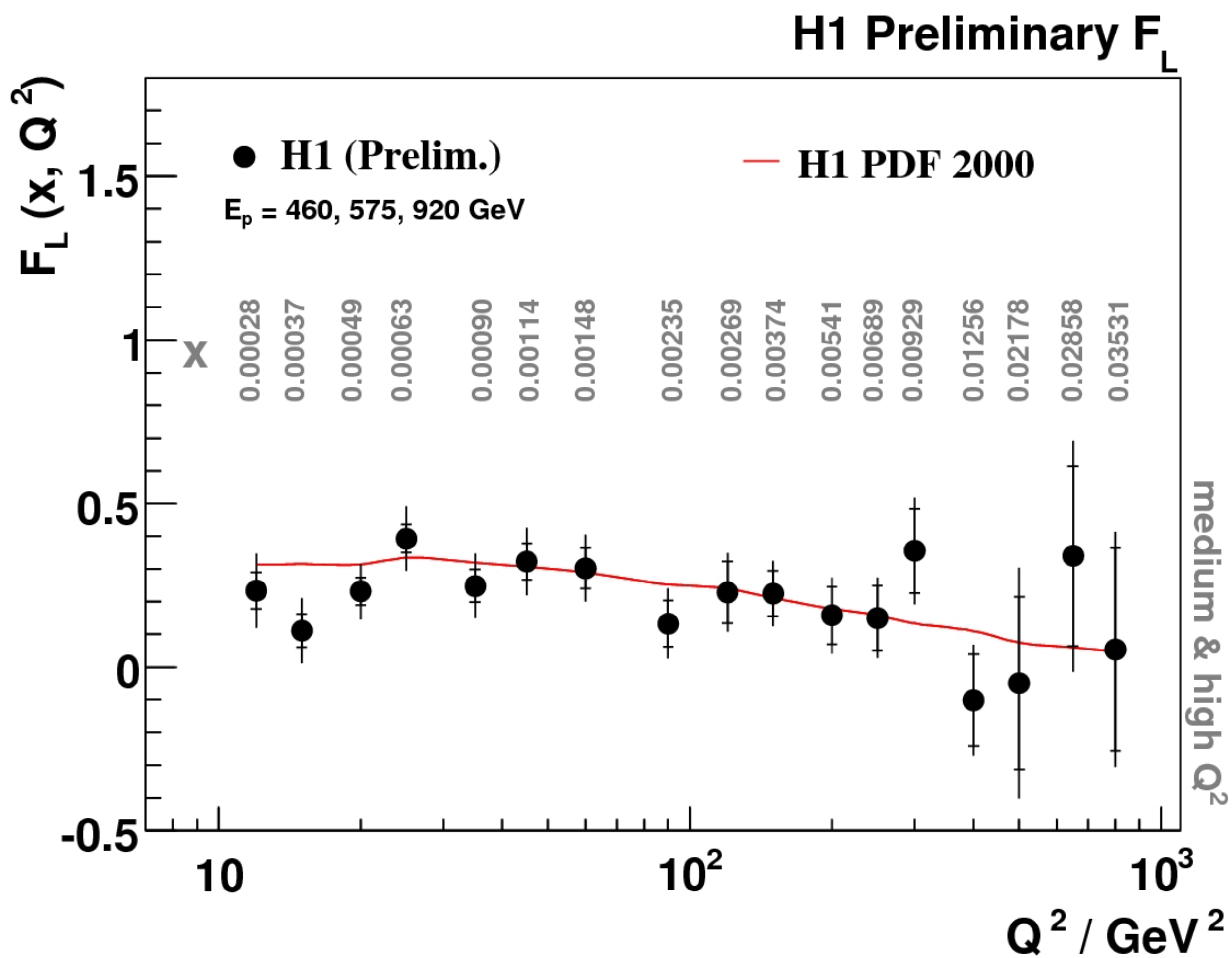


Averaged $F_L(Q^2)$ in the full medium and high Q^2 range



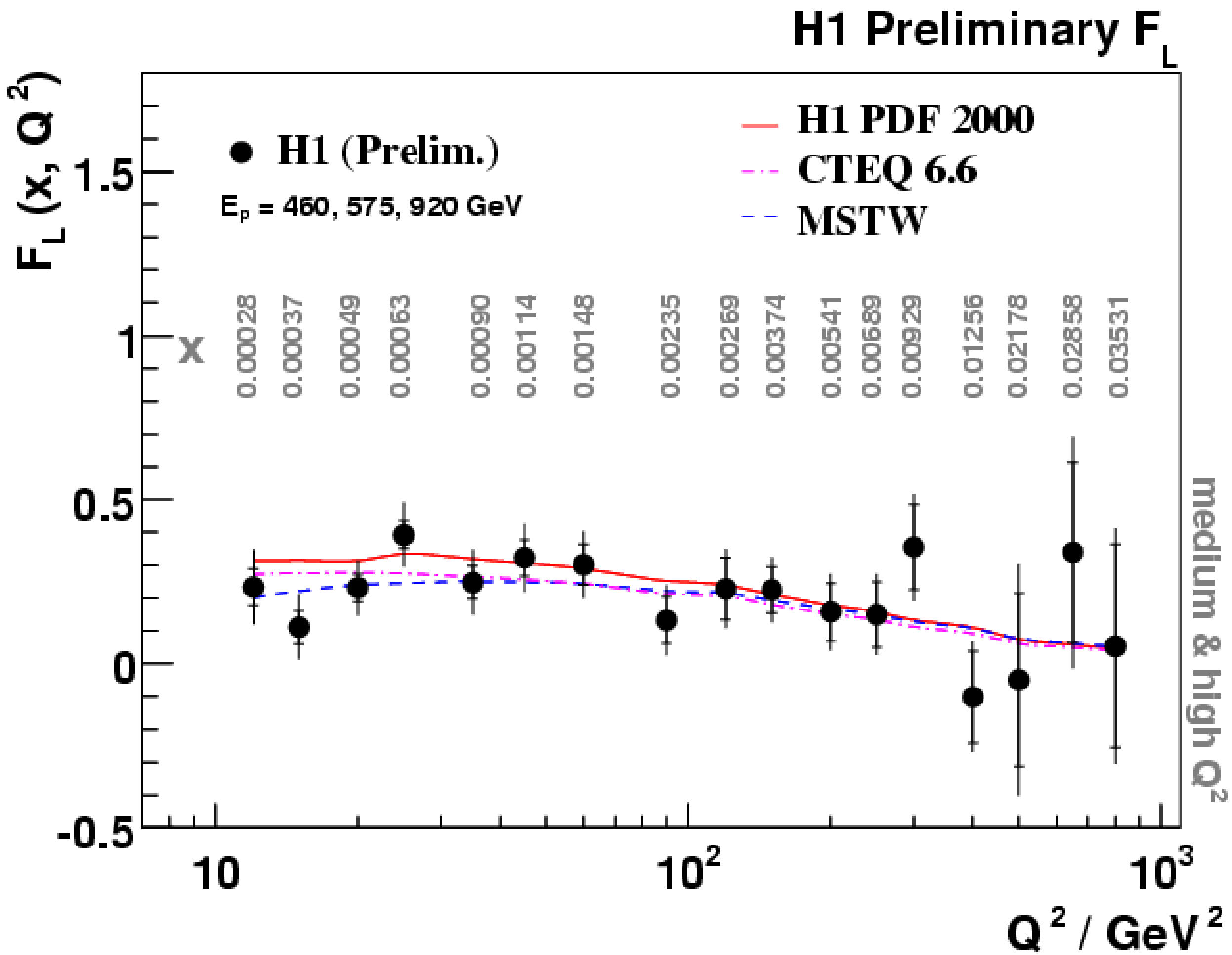
x values for each $F_L(Q^2)$ measurement are given in the plot

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



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

F_L measurements are in agreement with QCD calculations

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 : $12 \leqslant Q^2 \leqslant 800$ 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 agrement with the recent theoretical calculations in the QCD framework

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