Measurement of the Inclusive $e^{\pm}p$ Scattering Cross Section at High Inelasticity y and of the Structure Function F_L

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(on behalf of the H1 Collaboration)

DIS 2011, Newport News

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- DIS x-section at low Q^2
- x-section measurements
  at high inelasticity y
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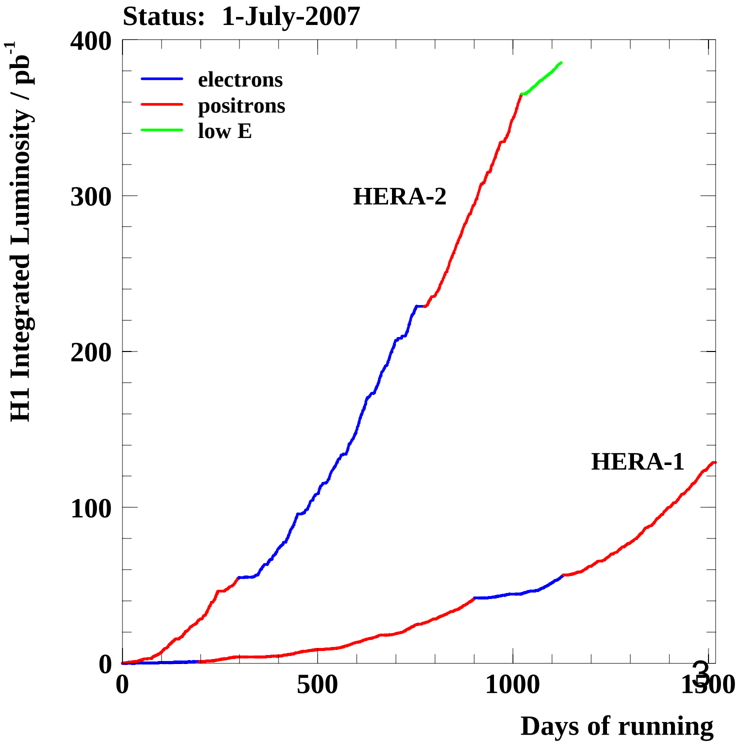
arXiv:1012.4355 [hep-ex]

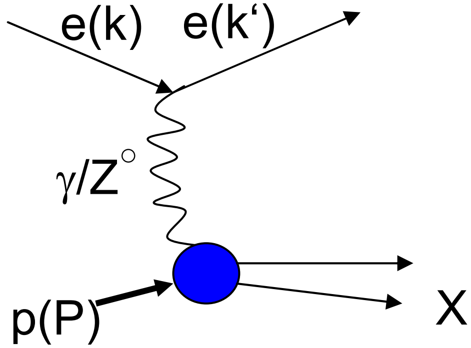
The *ep* collider HERA

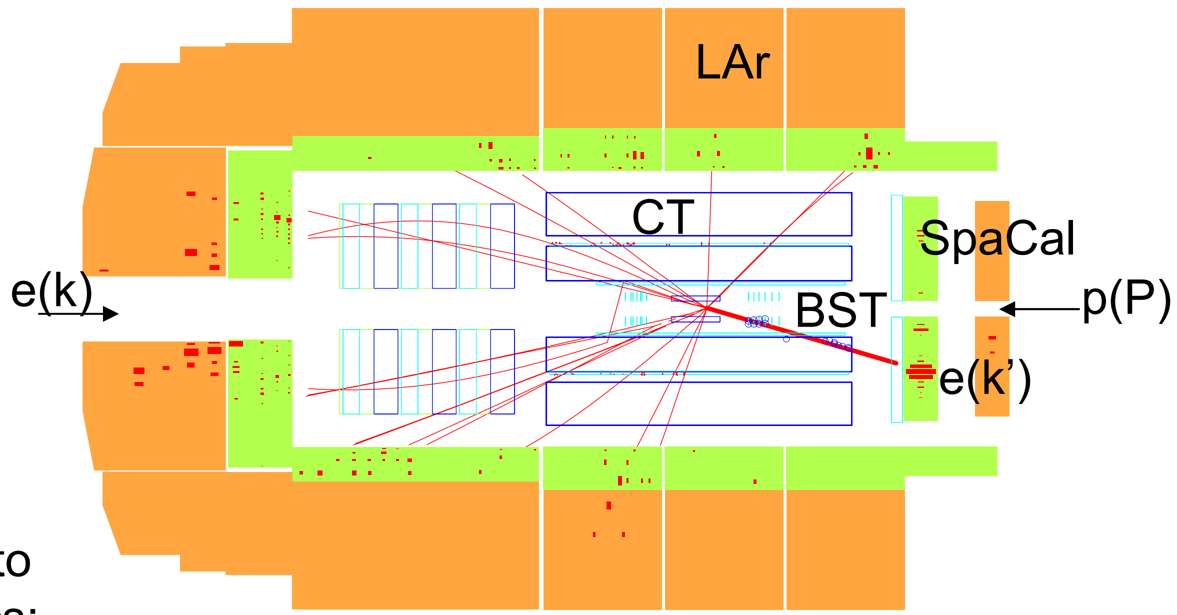
- Circumference: 6.3 km
- 27.5×920(820) GeV, $\sqrt{s_{ep}} = 319\,\mathrm{GeV}$
- 2 collider experiments: H1 and ZEUS

- HERA I: 1992-2000
- Luminosity upgrade: mid 2000 – end 2001
- Higher luminosity: HERA II (2003 – 2007)



Inclusive DIS at HERA





Use the scattered electron to reconstruct event kinematics:

$Q^2 = 4E_e E_e^{'} \cos^2 \frac{\theta_e}{2}$ - four momentum transfer squared in the reaction

$x = \frac{Q^2}{sy}$ - fraction of the proton momentum carried by the parton

$y = 1 - \frac{E_e^{'}}{E_e} \sin^2 \frac{\theta_e}{2}$ - fraction of the lepton’s energy loss

$s = 4E_e E_p$ - center-of-mass energy squared

NC cross section and structure functions

NC Reduced cross section: $\sigma_r(x, Q^2)$

$$\frac{d^2\sigma_{NC}(e^{\pm}p)}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4} Y_+ \left[F_2 - \frac{y^2}{Y_+} F_L \right]$$

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

$$R = \frac{F_L}{F_2 - F_L}$$

Dominant contribution (F_2)

Sizeable only at high *y* (*y* > ~0.6) ($\frac{y^2}{Y_+} F_L$)

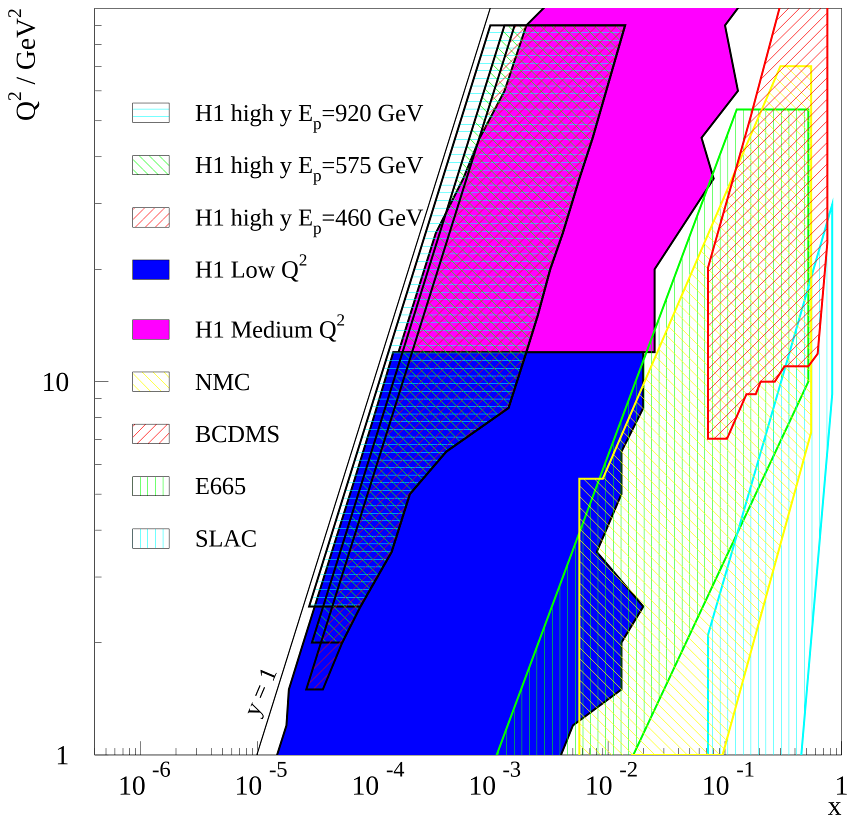
- The proton structure functions in QPM:

$$F_2(x) = \sum_i e_i^2 x[q_i(x) + \bar{q}_i(x)]$$ - sum of the (anti)quarks density distributions weighted with their electric charge squared

$$F_L(x) = 0$$

- In QCD: $F_L(x, Q^2)$ ~ gluon density

Kinematic coverage



$$\sigma_r = F_2 - \frac{y^2}{1+(1-y)^2} F_L$$

- High y: sensitivity to F_L
- Different CME to measure both F_2 and F_L
- Measure in the domain partly covered by previous HERA DIS cross section measurements
- New HERA II data:

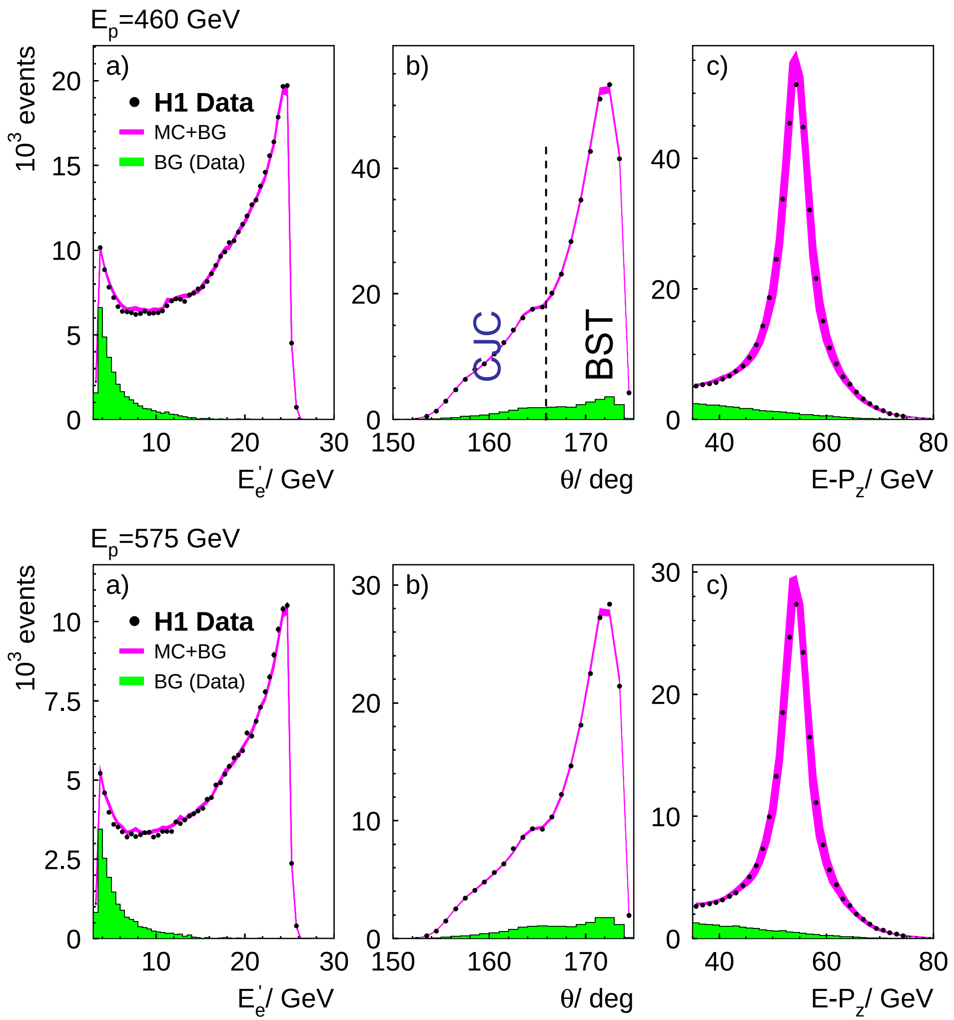
Sample	Q^2, GeV^2	$\mathcal{L}$, pb^{-1}
CJC, 920 GeV	≥8.5	97.6
BST, 920 GeV	≥2,5	5.9
575 GeV	≥1.5	5.9
460 GeV	≥1.5	12.2

← Highest precision at high *y* (CJC, 920 GeV)

← Extension to low Q^2 (BST, 920 GeV)

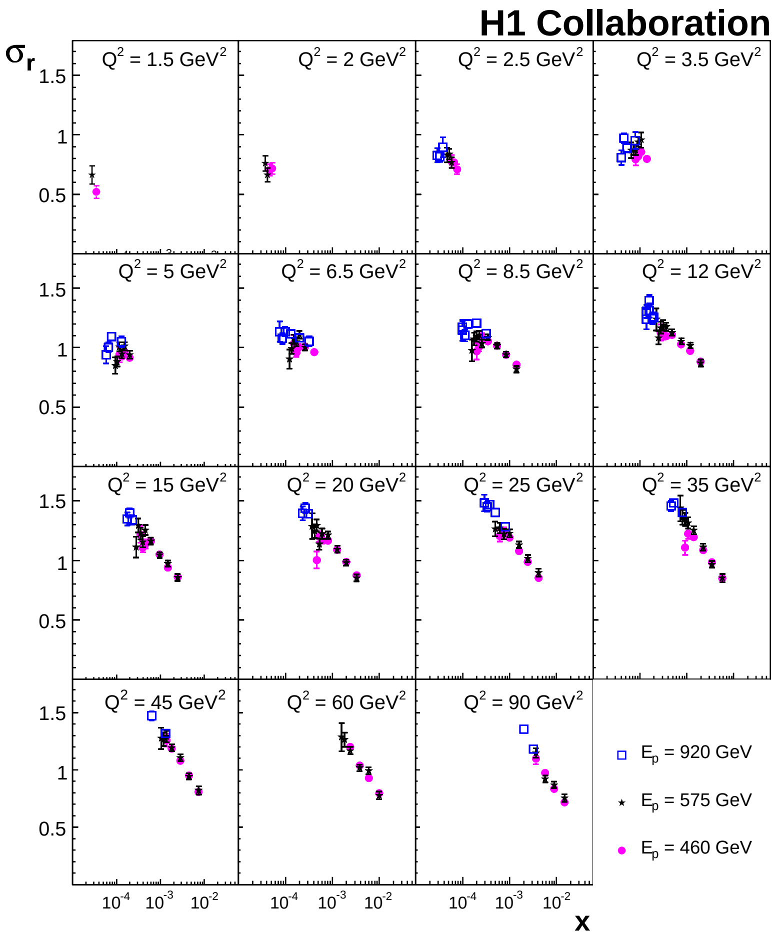
} Lowest Q^2 for direct F_L measurement (575 GeV, 460 GeV)

Control distributions



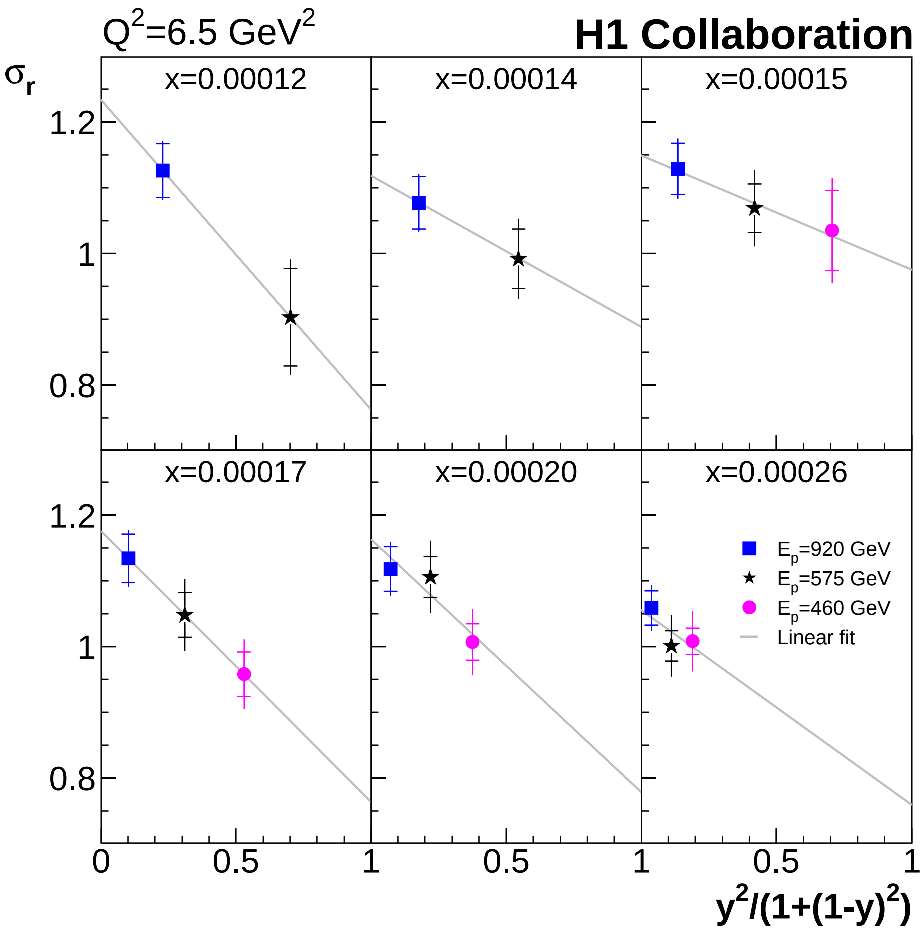
Background under control using data-driven method

σ_r for E_p=460, 575 and 920 GeV



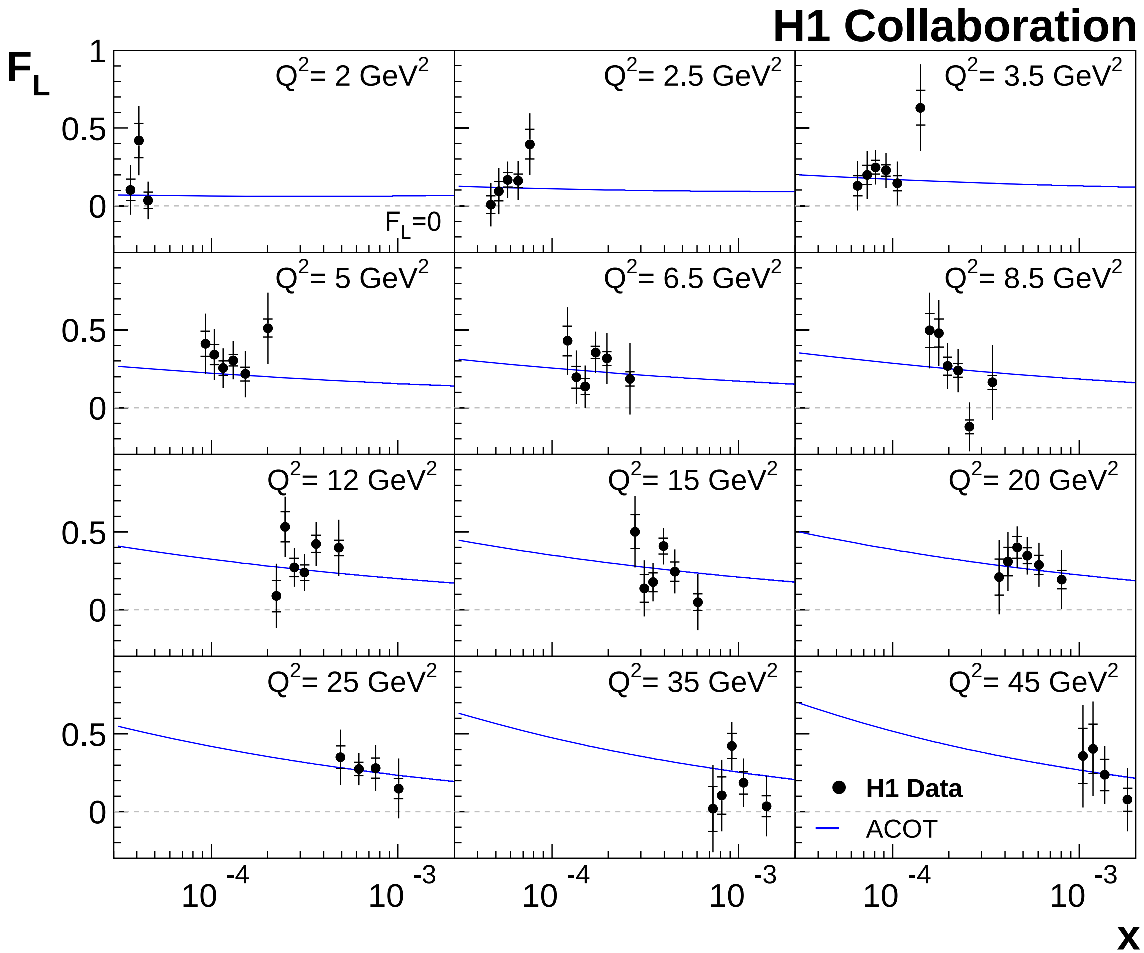
- New x-section measurements for different E_p at HERA II
- For E_p=920 GeV, these data are combined with previous H1 measurements
  [H1 Collab., Eur.Phys.J. C63, 2009 625],
  [H1 Collab., Eur.Phys.J. C64, 2009 561],
  [H1 Collab., Eur.Phys.J. C21, 2001 33]
  leading to factor of 2 improvement in precision at high *y*

F_L determination



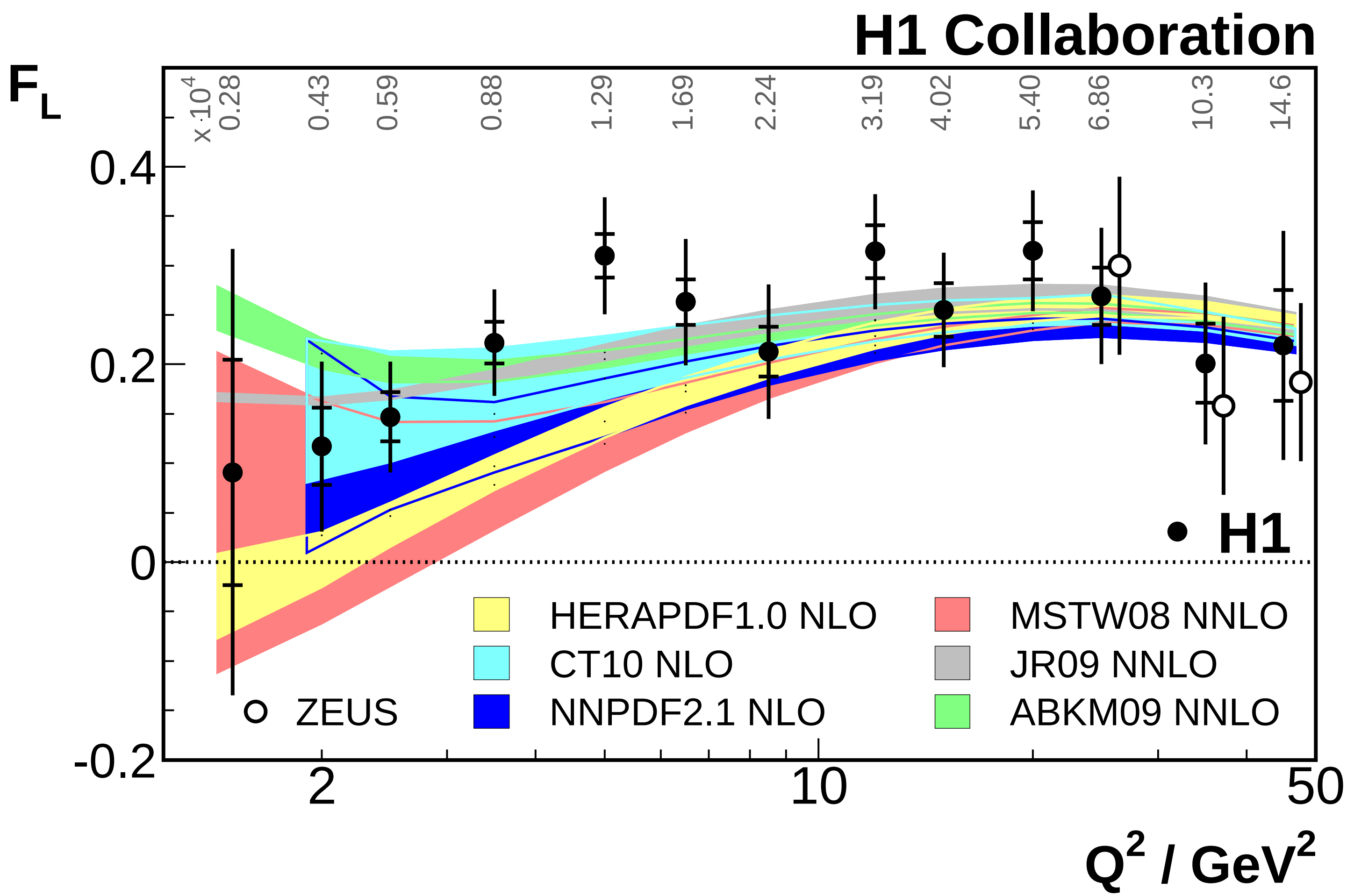
- F_L determined from measurements at different CME
- F_L is proportional to the variation of σ_r as a function of $y^2/(1+(1-y)^2)$
- Improved determination procedure, taking into account correlations due to systematic uncertainties

F_L vs x,Q^2



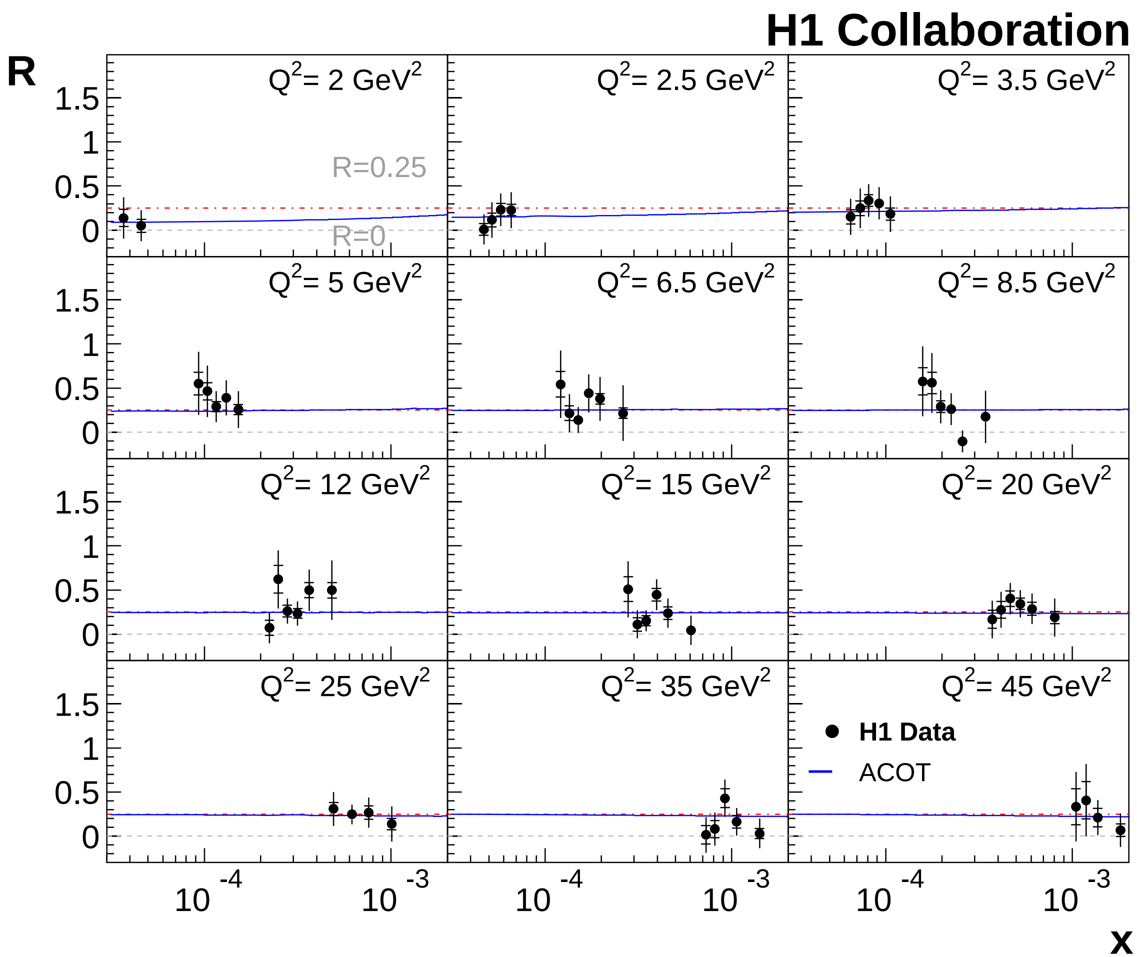
- The measurement spans over 2 decades in x at low $0.00002<x<0.002$
- Measured F_L is consistent with predictions of the NLO DGLAP fit in the ACOT scheme

HERA F_L and different predictions



- Measurement extends to $Q^2 \geq 1.5$ GeV^2
- Within the uncertainties all predictions describe the data reasonably well
- Good agreement between H1 and ZEUS measurements

The ratio *R*



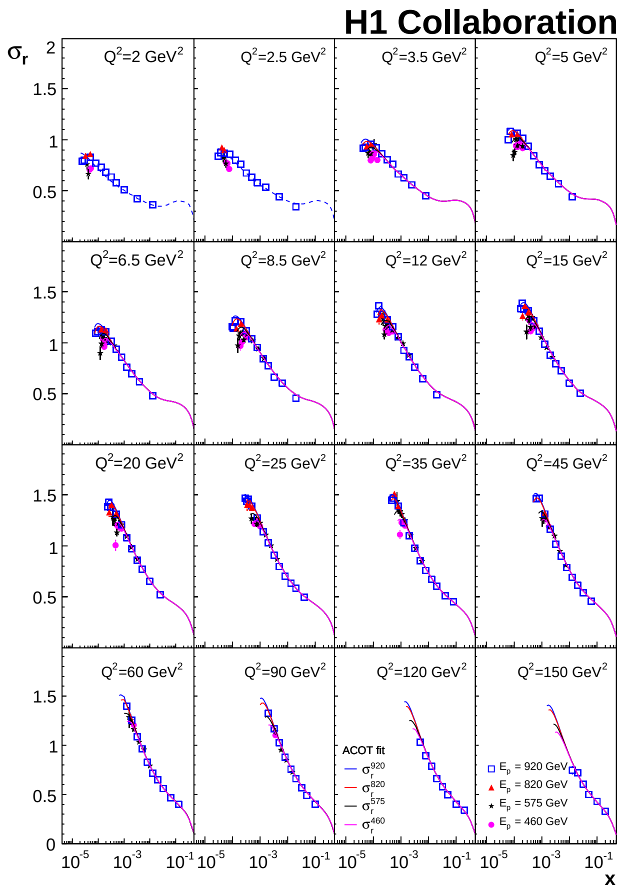
$$R = \frac{F_L}{F_2 - F_L}$$

Data are consistent with const R = 0.26±0.05

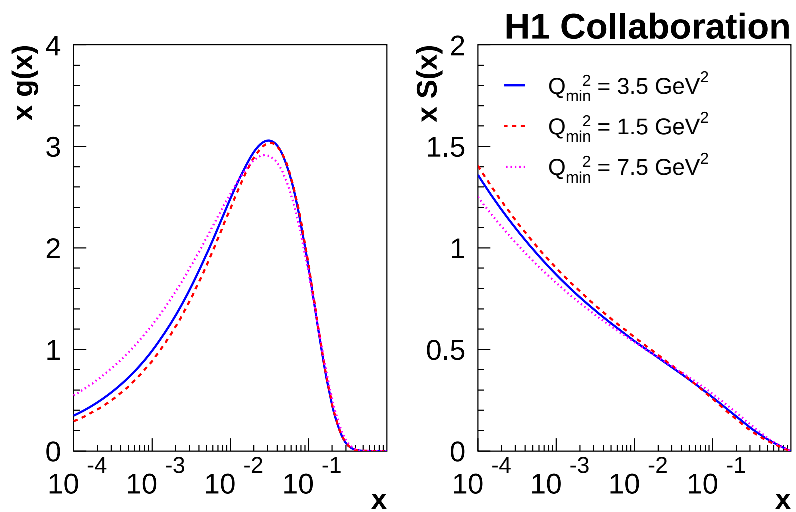
Phenomenological analysis settings

- Combined H1 data for E_p=820–920 GeV, 0.2≤Q^2≤150 GeV^2 [H1 Collab., Eur.Phys.J. C63, 2009 625], [H1 Collab., Eur.Phys.J. C64, 2009 561], [H1 Collab., Eur.Phys.J. C21, 2001 33]
- Combined for y_{460}≤0.35 low E_p=460 and 575 GeV data
- 'H1fitter' fitting program, based on NLO DGLAP QCDNUM [arXiv:1005.1481] evolution code. The fitter has been extended to include non-DGLAP models (dipole, λ-fit)
- See more about H1 and HERA fits in talks of Allen Caldwell, Krzysztof Nowak and Ringaile Placakyte

σ_r and QCD fits

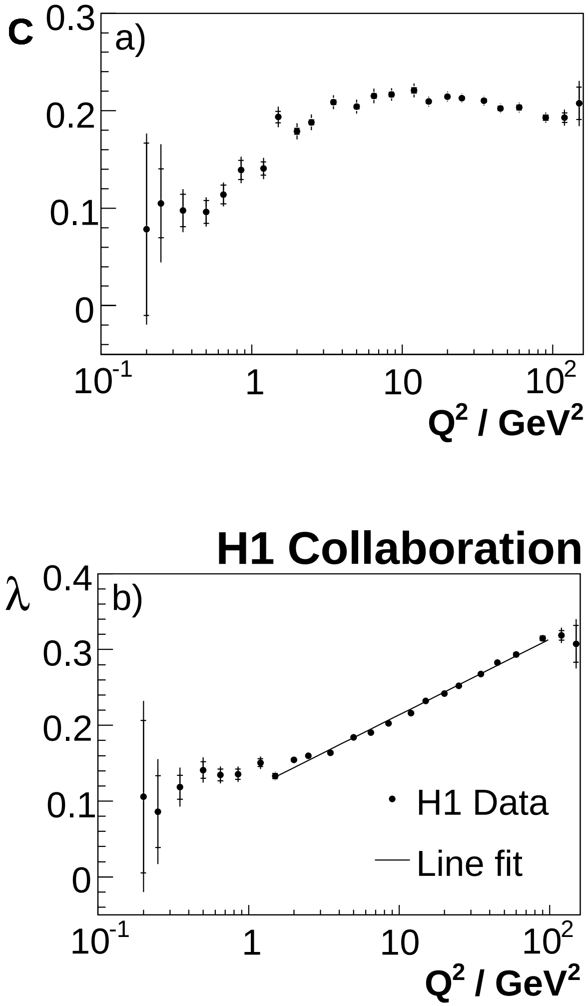


- Two calculation schemes for QCD fits: ACOT and RT with different computation of the heavy quark structure functions and of the structure function F_L
- Better quality of ACOT fit: χ^2/dof=715/781 vs RT fit with χ^2/dof=765/781
- With increasing of Q^2_{min} cut:
  - fit quality is improved
  - gluon is increased, sea becomes smaller at low *x*



Q^2_{min} / GeV^2	1.5	2	2.5	3.5	5	7.5
χ^2/n_{dof}	824.8/834	777.9/818	748.7/801	715.2/781	677.6/759	626.9/712

λ fit



- At low Q^2 and $x \to 0$ rise of F_2 towards low x may be described by

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

- Fit x-dependences of σ_r in Q^2 bins with two free parameters $c(Q^2)$, $\lambda(Q^2)$ and fixed R=0.26

$$\sigma_r(x,Q^2) = F_2(x,Q^2) \cdot \left[1 - \frac{y^2}{1+(1-y)^2} \cdot \frac{R}{1+R} \right]$$

- Fit results
  - For $Q^2 \geq 2$ GeV^2
    - λ exhibits a linear increase as function of lnQ^2
    - Normalisation C is constant
  - For $Q^2 < 2$ GeV^2
    - λ deviates from that linear dependence
    - Normalisation C rises with increasing of Q^2

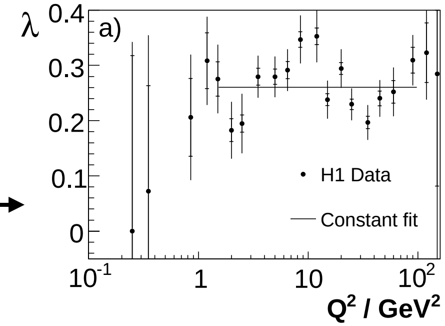
With offset method for syst. errors quality of the fit is poor: χ^2/dof=538/350

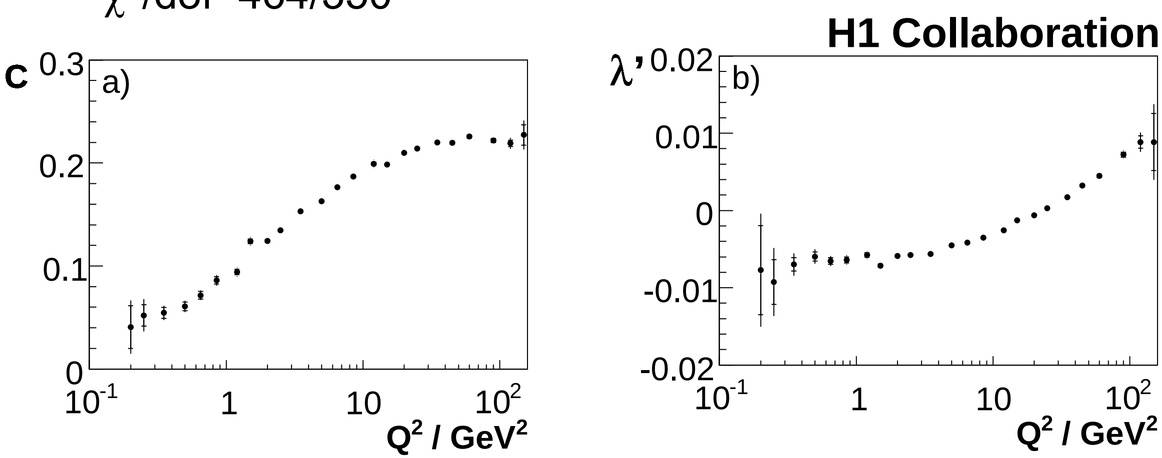
Introduce a λ' fit

- Parameterisation of the F_2 is extended by one parameter to allow for deviations from a simple power law

$$F_2(x,Q^2) = c(Q^2)\cdot x^{-\lambda(Q^2)+\lambda'(Q^2)\ln x}$$

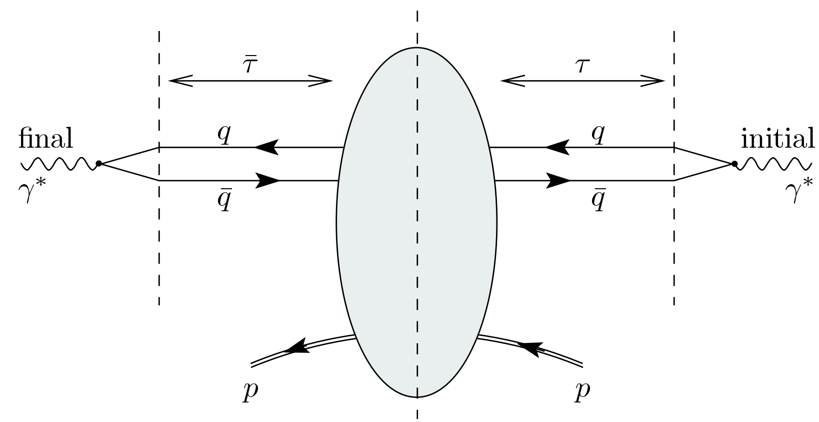
- Fit returns significantly improved χ^2/dof=405/326
  - λ exhibits a constant behaviour (λ ~0.25)
  - strong correlations between λ and λ'
- Fix λ=0.25 and let $C(Q^2)$, $\lambda'(Q^2)$ float which yields χ^2/dof=464/350





Confirms a QCD prediction
[A. De Rujula et al., Phys. Rev. D10, 1649 (1974)] :
rise of F_2 slower than power $1/x$, faster than power $\ln 1/x$

Dipole model fits



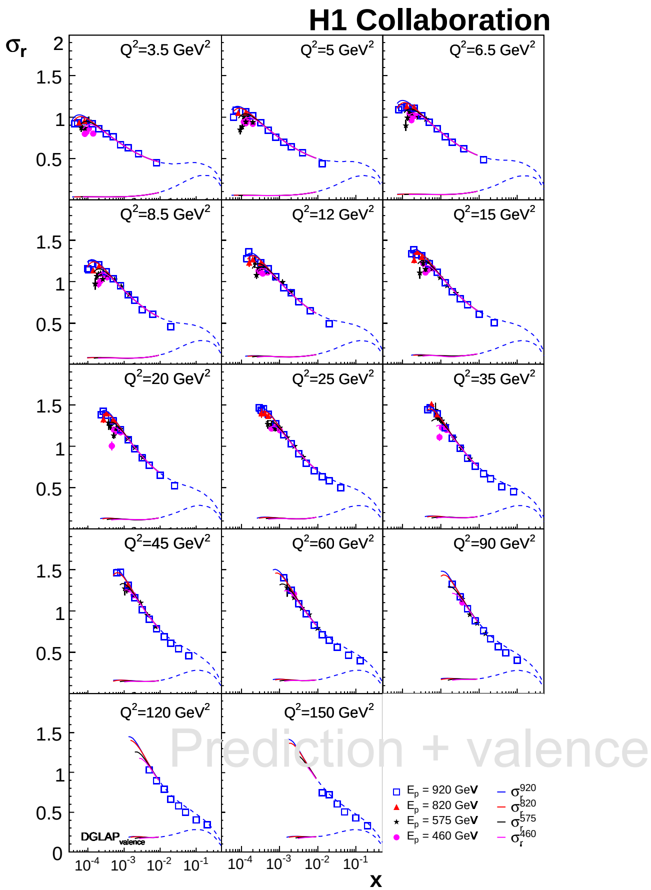
- At low x and Q^2 the virtual photon-proton scattering can be described using the color dipole model (CDM):

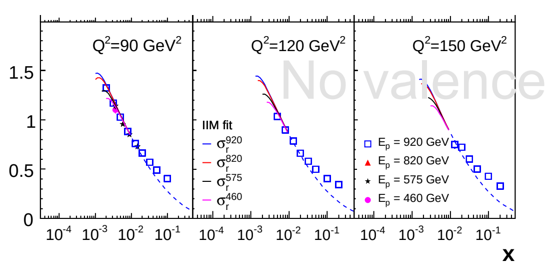
  $$\gamma^*(q) + p(p) \rightarrow \gamma^*(q) + p(p)$$

  the initial γ^* splitting into a quark-antiquark pair (dipole), this pair scattering on the proton and the $q\bar{q}$ subsequently fusing into the final state γ^*

- We considere here three CDM as representative for a much larger variety of Dipole models: GBW (Golec-Biernat & Wusthoff), IIM (Iancu, Itakura & Munier) and B-SAT (Kowalski, Motyka & Watt)
- CDM are applicable for x<0.01 where the gluon and sea dominate. All models neglect valence contributions which are sizeable: 5-15%

σ_r and CDM fits





- Test CDModels with and without DGLAP-based correction for valence contribution

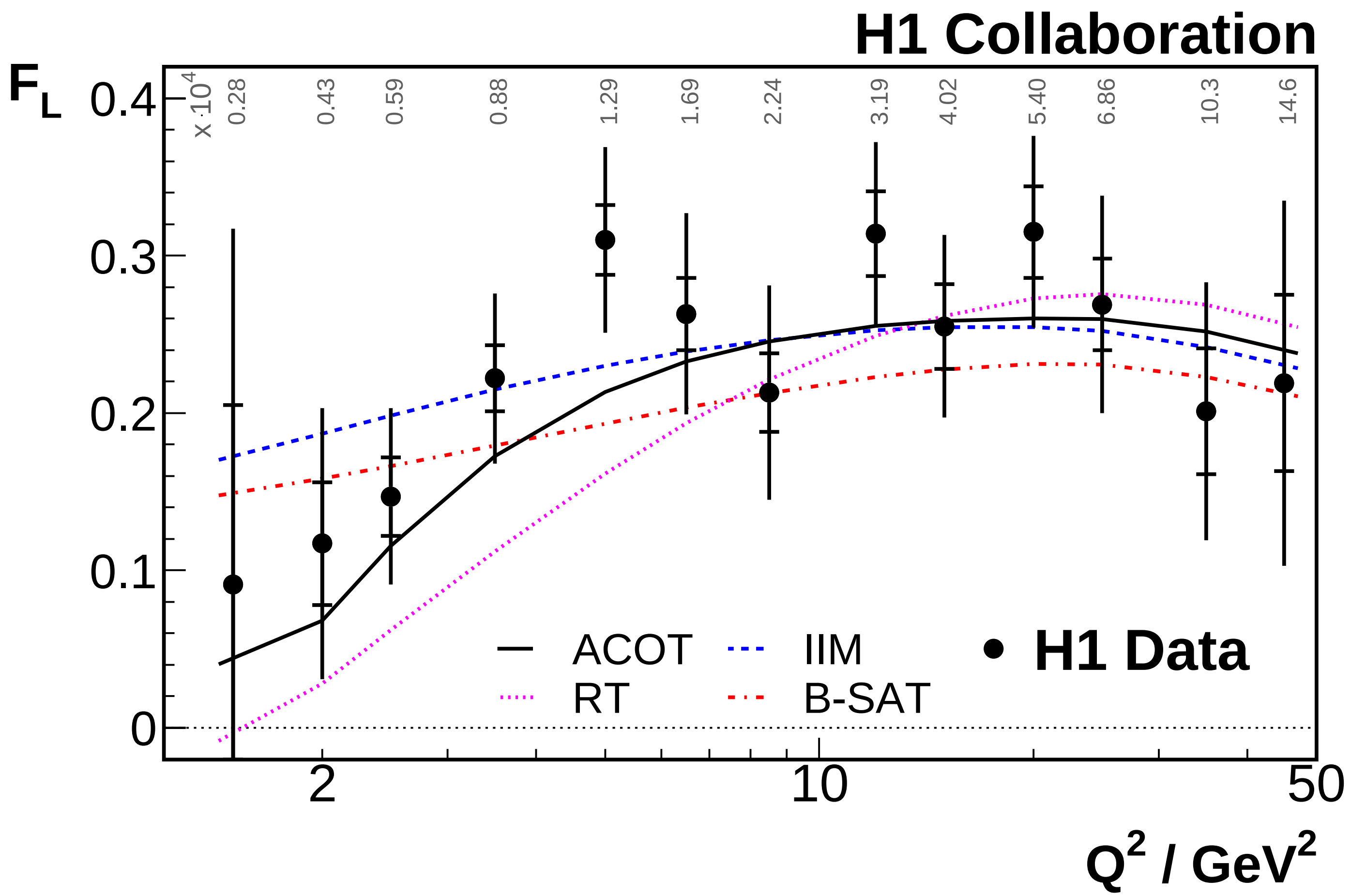
- Fits to data in $3.5 \leq Q^2 \leq 150$ GeV² and $x<0.01$ where both CDM and DGLAP are working

- The addition of valence contribution improves description of the data at high *x* but overall fit quality is not better

Fit Conditions	GBW	IIM	B-SAT	ACOT	RT
	χ^2/n_{dof}				
Nominal fit	718.8/352	397.6/352	424.9/352	715.2/781	764.5/781
$Q^2 \geq 3.5$ GeV²	559.7/252	259.4/252	261.7/252		
DGLAP$_{\mathrm{valence}}$	739.5/252	287.6/252	371.4/252	248.3/249	288.8/249

⇒ Best fit for DGLAP-ACOT, closely followed by IIM

F_L vs phenomenological models



- At Q^2>10 GeV^2: good agreement between data and all considered models
- At low Q^2: RT fit falls below data. Other models describe measured F_L well

Summary

- The new most precise H1 measurement of the inclusive $e^{\pm}p$ scattering cross section at high inelasticity y and of the structure function F_L is presented
- The analysis is published in EPJC [H1 Collab., Eur. Phys. J. C71, 2011 1579. arXiv:1012.4355 [hep-ex]]
- F_L is measured for the first time at HERA down to Q^2 = 1.5 GeV^2
- Data are consistent with constant R ~ 0.26 and generally well described by the phenomenological models
- From the considered models NLO DGLAP ACOT fit provides the best description of our data

Back up

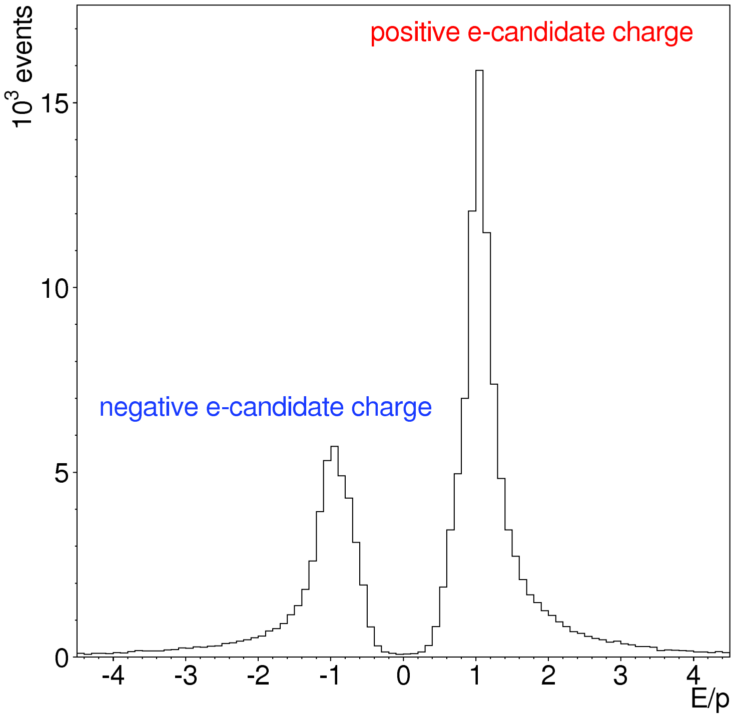
Background estimation

- Measure particle charge using curvature of the associated track

- *e⁺p* scattering:
  - \+ Scattered lepton has the beam charge (positive)
  - \- Background from hadronic particles, γ conversions is almost charge symmetric:

$$N^{+}_{BG} \approx N^{-}_{BG}$$

- Require positive charge for the signal sample. Estimate remaining background using negative sample



F_2-F_L Fitter: new method

Instead of σ-average, extract F_2/F_L directly

$$\chi^2(F_2, F_L, \alpha) = \sum_i \frac{[(F_2^i - f(y^i)F_L^i) - \sum_j \Gamma_j^i \alpha_j - \mu^i]^2}{\Delta_i^2} + \sum_j \alpha_j^2 + \sum_i \left(\frac{F_L^i - \frac{R}{R+1} F_2^i}{\Delta_{F_L}} \right)^2$$

Plays role at low *y* only

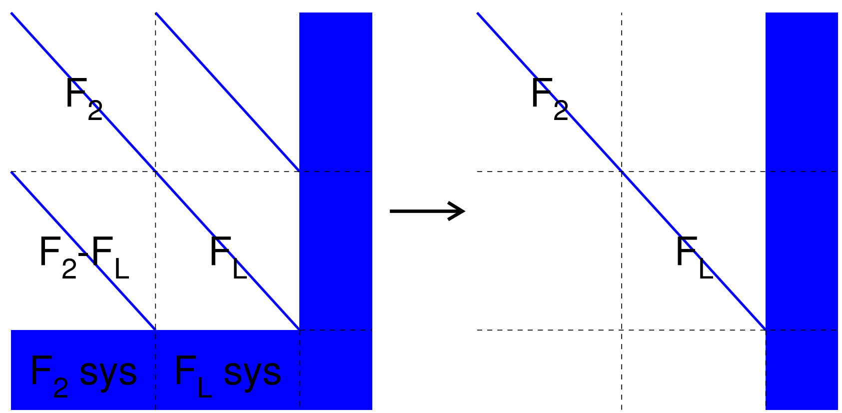
Minimization vs F_2, F_L and syst. sources α leads to a simple system of linear equations:

$$R = \frac{F_L}{F_2 - F_L} \approx 0.25$$

μ^i – measured x-section

Δ_i – its uncertainty

α_j – correlated error sources



which can be easily solved numerically.