Precise measurement of DIS at low Q^2 and phenomenological fits

Alexey Petrukhin, DESY/ITEP
(on behalf of the H1 Collaboration)

DIS 2009, Madrid

Content

- Deep Inelastic Scattering
- DIS cross section at low Q^2
- Rise of F_2 at low x
- Model comparisons
- Conclusions

Submitted to EPJ:
H1 Collaboration. DESY-08-171, Apr 2009. 90pp.
arXiv:0904.0929 [hep-ex]

NC cross section and structure functions

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

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

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

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

F_2: Dominant contribution

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

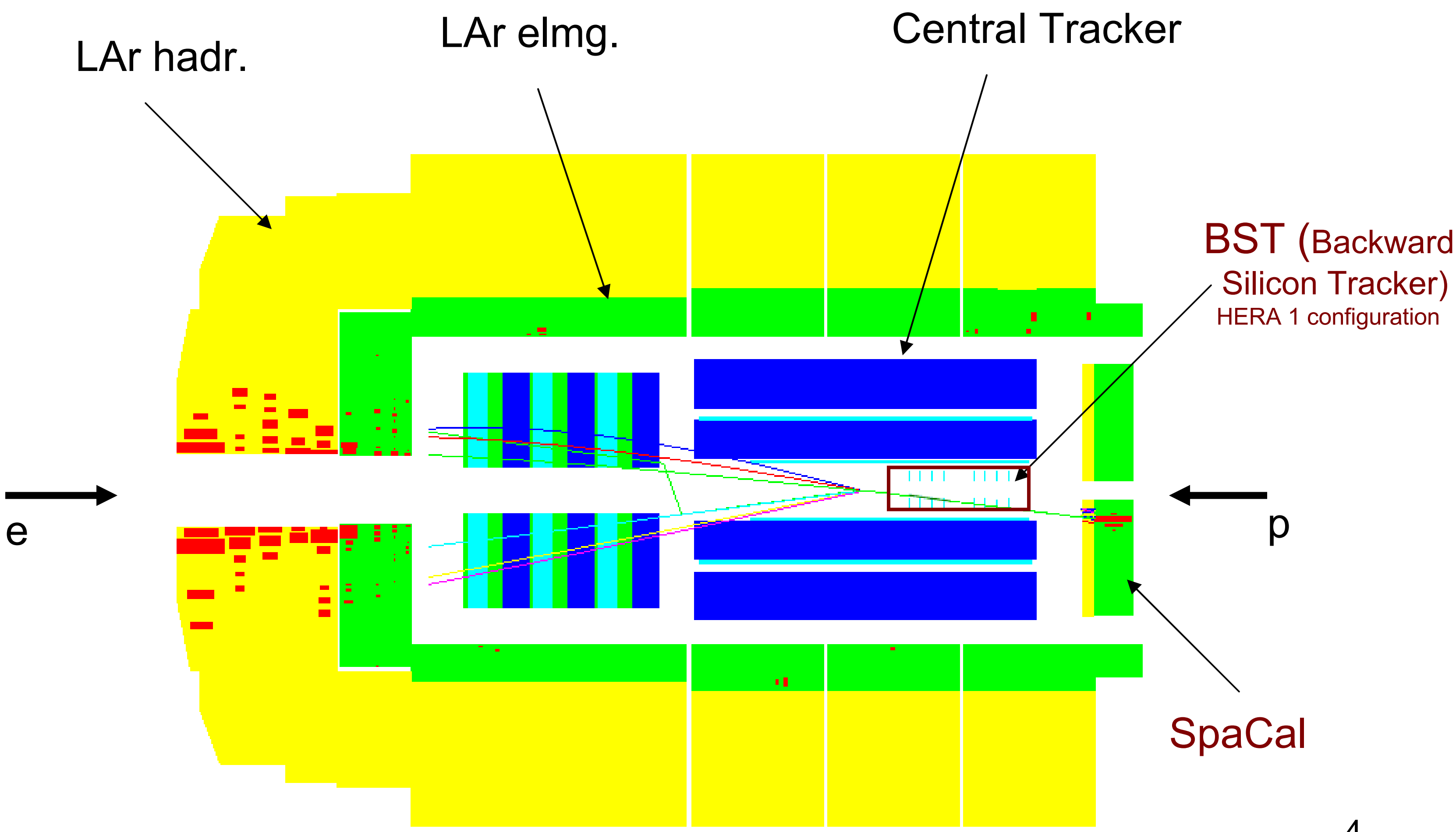
- The proton structure functions in QPM:

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

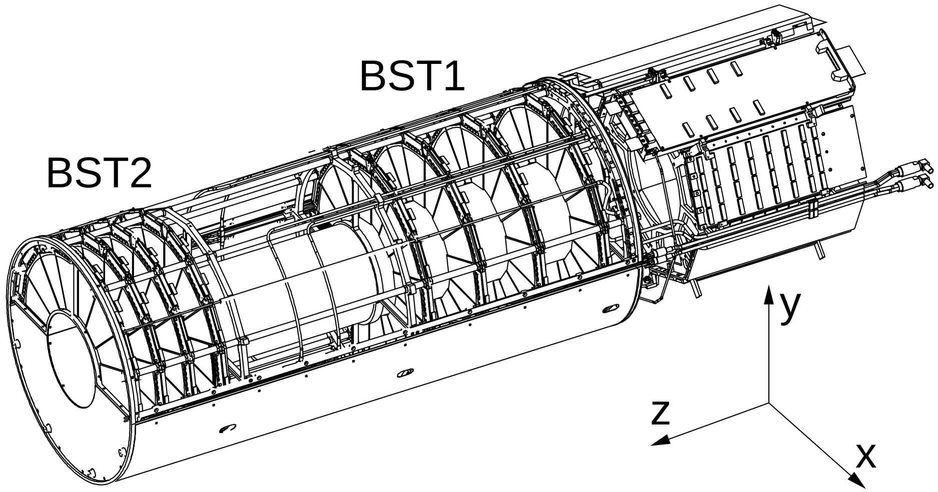
$$F_L(x) = 0$$

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

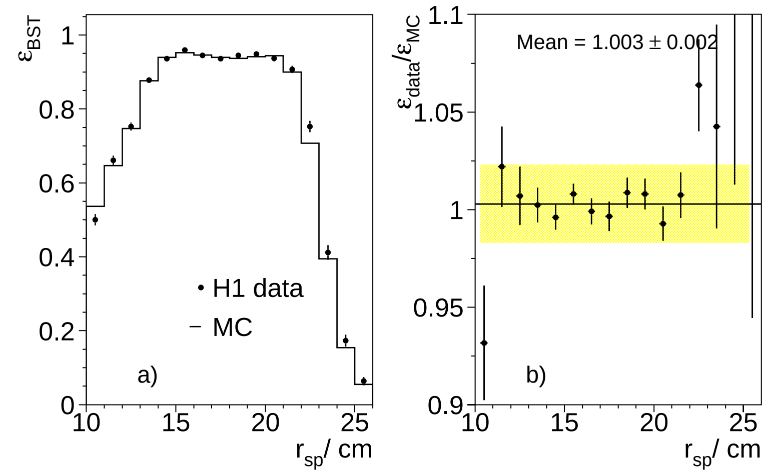
Low Q^2 event in H1 detector



Backward Silicon Tracker



- Consist of 8 planes and 16 sectors
- Acceptance: 164°<θ_e<178°
- Angular resolution: 0.1 mrad
- Hit resolution: ~20μm
- Alignment accuracy: ~0.2 mrad
- Track reconstruction efficiency: ~95%
- Used for reconstruction of vertex and θ_e



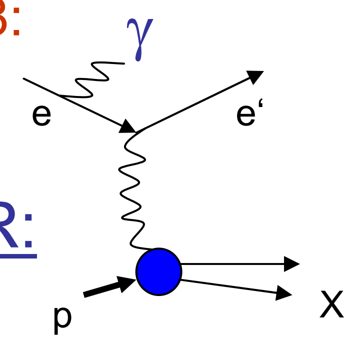
Reconstruction of event kinematics

- 'Electron method'- used for measurements at 0.1<y<0.8:

$$y_e = \frac{2E_e - E_e^{'}(1-\cos\theta_e)}{2E_e} \equiv \frac{2E_e - \Sigma_e}{2E_e} \quad \text{where} \quad \Sigma_e = (E - P_z)_{el}$$

$$Q_e^2 = \frac{E_e^{'2}\sin^2\theta_e}{1-y_e} \quad \text{and} \quad x_e = \frac{Q_e^2}{4E_pE_ey_e}$$

ISR:



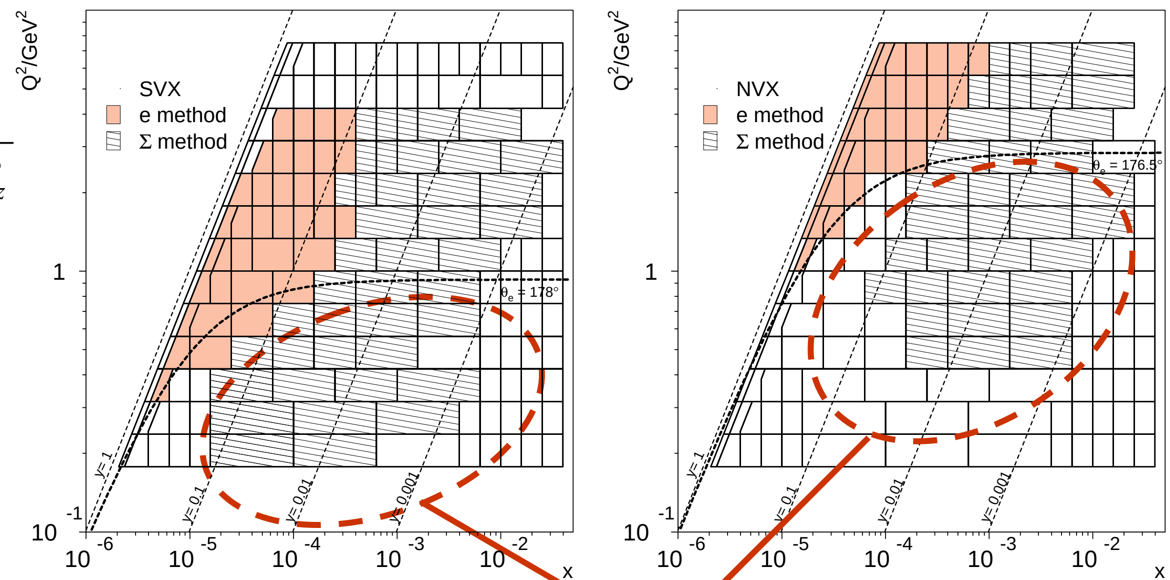
- 'Sigma method'- used for 0.002<y<0.1 and also for low Q^2 by accepting events with Initial State Radiation (ISR):

$$y_\Sigma = \frac{\Sigma_h}{\Sigma_h + E_e^{'}(1-\cos\theta_e)} = \frac{\Sigma_h}{E - P_z}$$

$$\Sigma_h = \sum_i (E_i^h - P_{z,i}^h)$$

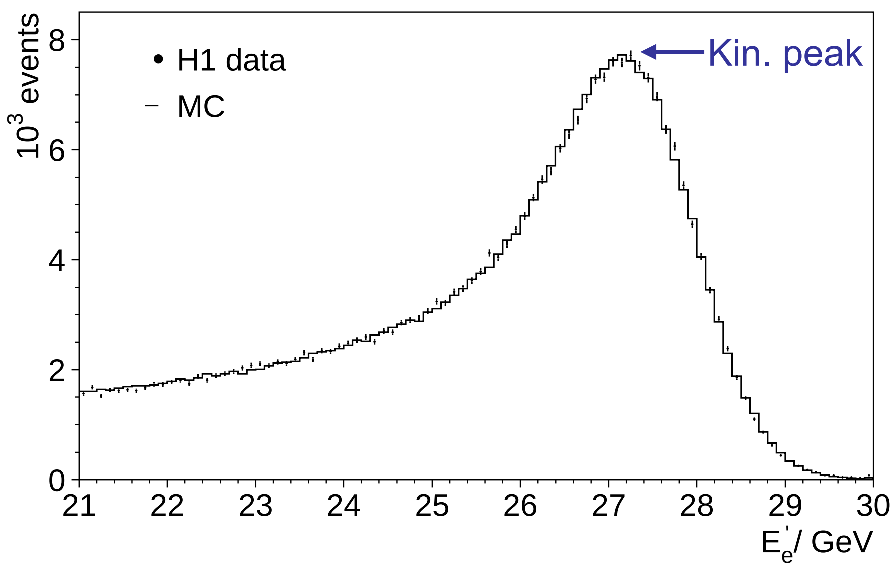
$$Q_\Sigma^2 = \frac{E_e^{'2}\sin^2(\theta_e)}{1-y_\Sigma}$$

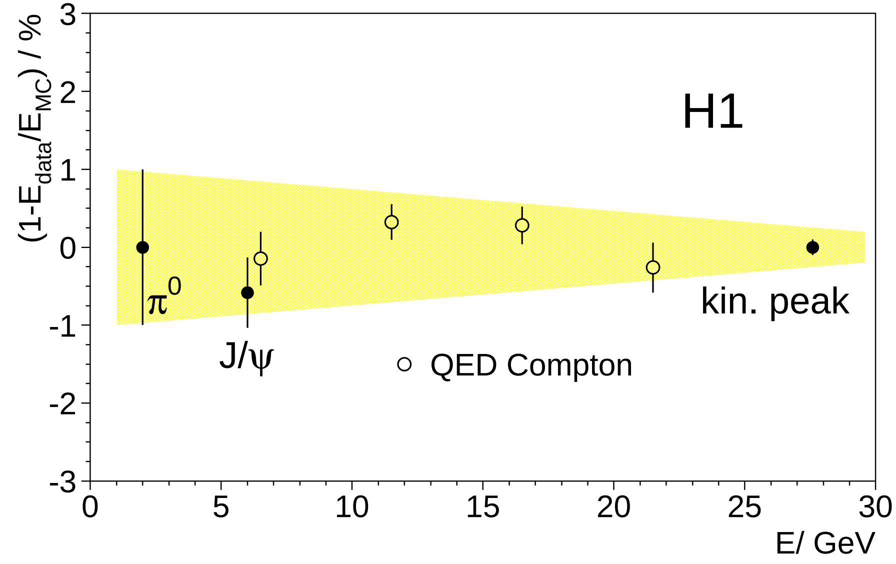
$$x_\Sigma = \frac{Q_\Sigma^2}{2E_py_\Sigma} \cdot \frac{1}{E - P_z}$$



Extended by ISR

Electron energy scale calibration

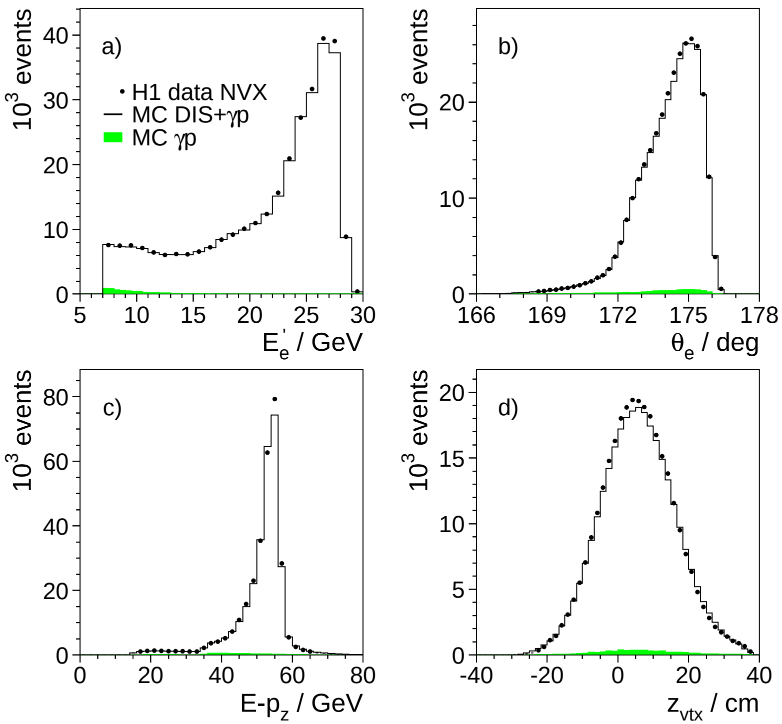


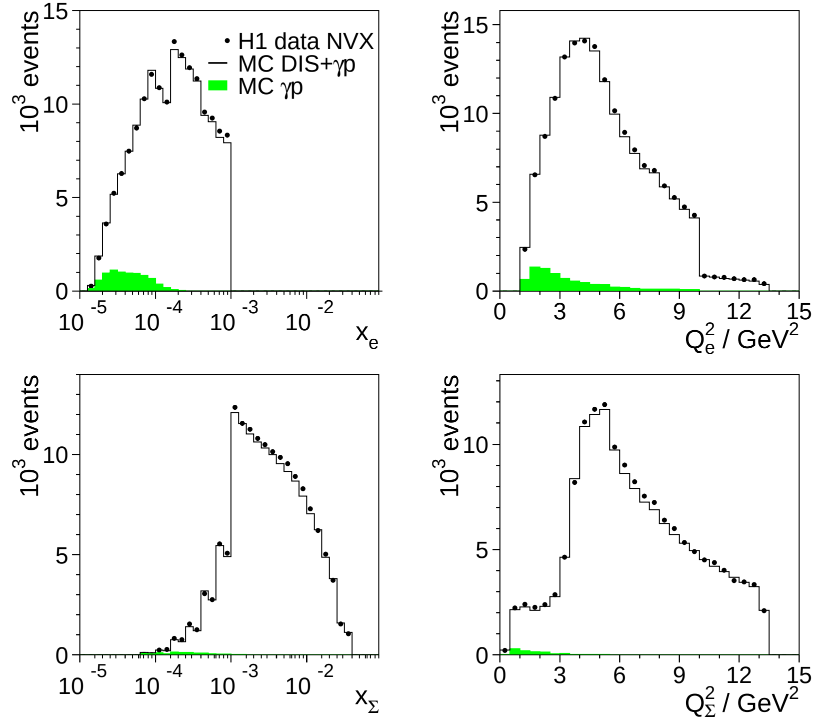


- Use multi-step calibration. Correct for the gain difference of PMTs and for non-uniformities of SpaCal
- Use π^0 events to calibrate low energy, correct for non-linearity and check intermediate range with J/ψ and QED Compton events

- The precision of energy calibration: 0.2% at 27.6 GeV to 1% at 2 GeV

Control distributions

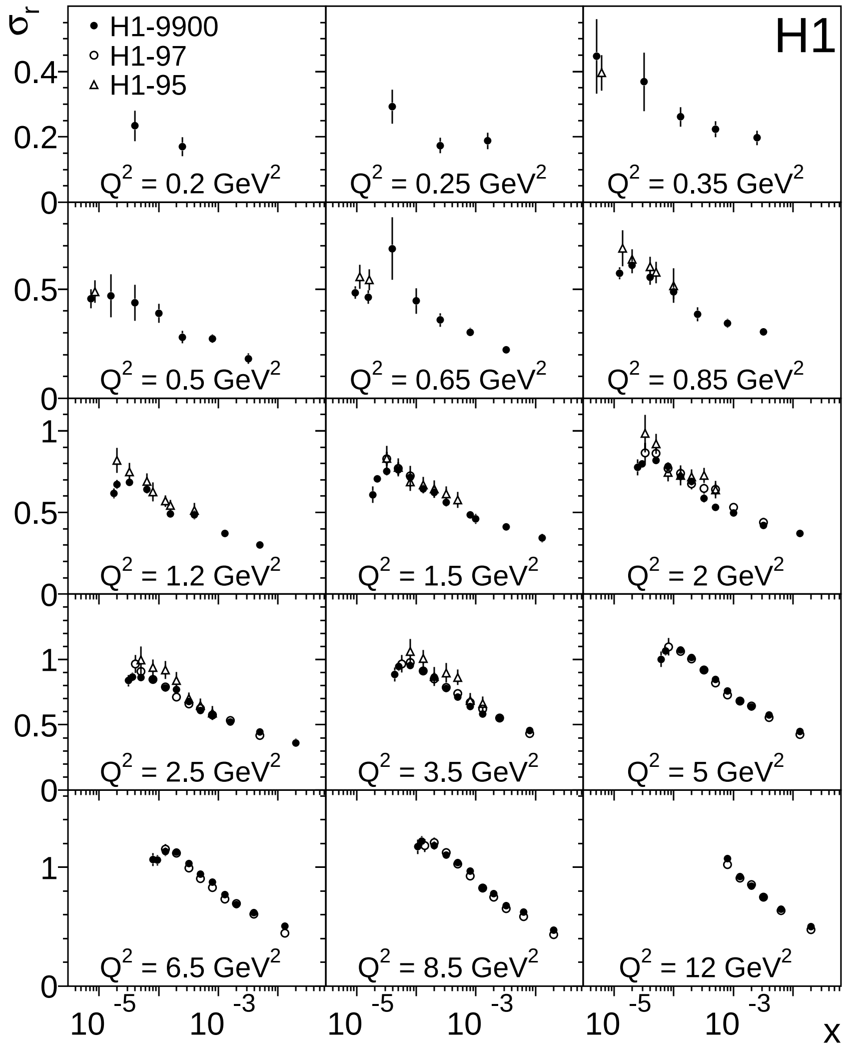




- Require a BST reconstructed vertex, SpaCal cluster and BST track matching this cluster

- Good understanding of detector acceptance and control of the γp background

σ_r at low Q^2

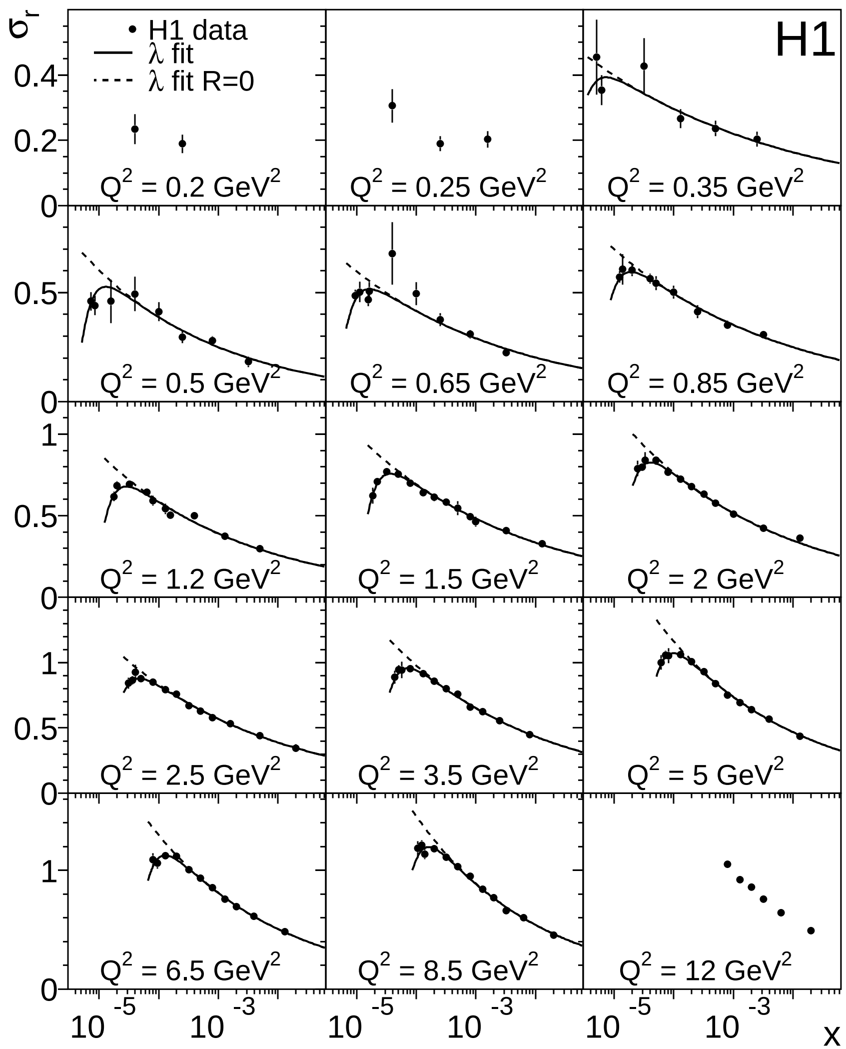


- New H1-9900 results extend H1 measurements to low Q^2 and high x by using of ISR events
- Significant overlap between H1-9900 data and previously published results
- New (9900) data agree well with H1-97, these are corrected by +3.4% due to luminosity tagger acceptance change
- The 95 SVX data are consistent within 95 data normalisation uncertainty

Combination of H1 data

- Combine 95, 97, SVX and NVX data taking into account bin-to-bin correlated systematic uncertainties
- For E_p=820 GeV data, perform CME correction for $y<0.35$. Keep data separate for $y \geq 0.35$
- Systematic errors assumed to be uncorrelated between the different data sets
- Good agreement between H1 data: $\chi^2/n_{dof}=86/125$
- The precision of the combined data set is high, up to 1.5% in the central Q^2,x region of the measurement

Combined reduced cross section [F_2-f(y)F_L]



- Measured σ_r at low $0.2 \le Q^2 \le 12$ GeV^2 and $5 \cdot 10^{-6} < x < 0.02$
- Rise of F_2 towards low x may be described by $F_2 = c(Q^2)x^{-\lambda(Q^2)}$ for x<0.01
- Fit x-dependences of σ_r in Q^2 bins and extract $c(Q^2)$, $\lambda(Q^2)$ and $R(Q^2)$:

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

- Note: this extraction of $R(Q^2)$ relies on the simple model used for F_2

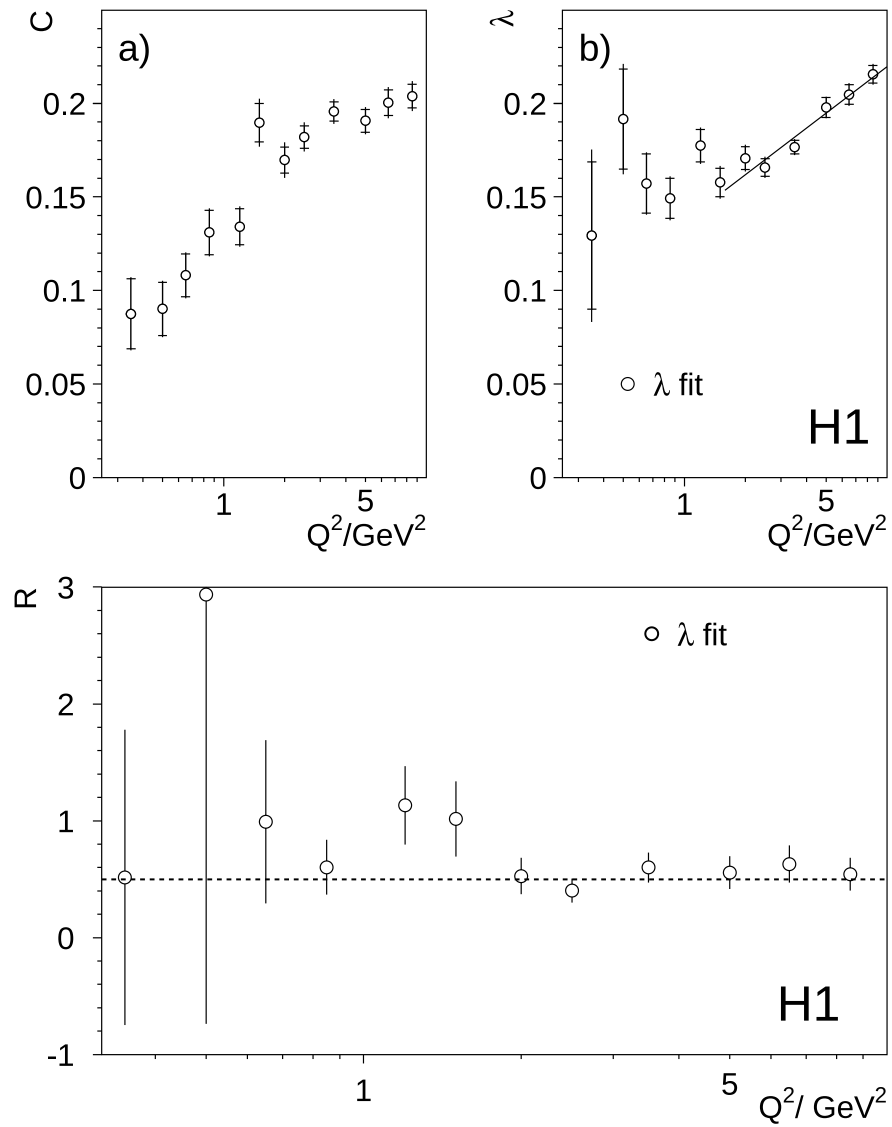
Fit results

- λ~ln(Q^2/Λ^2) and $c(Q^2)$~const. for Q^2>1 GeV^2

- Around Q^2=1 GeV^2 λ deviates from linear ln(Q^2/Λ^2) dependence

H1 Collaboration, C. Adloff et al., Phys.Lett. B520(2001)183 [hep-ex/0108035]

- The value of average R obtained from this model is consistent with R=0.5, higher vs direct F_L measurements



Models

- Fractal fit: based on the concept of self similarity. Structure function F_2 parameterised using 4 parameters Q_0, D_0, D_1, D_3 with D_2=1.08 :

$$F_2(Q^2,x) = D_0 Q_0^2 \left(1+\frac{Q_0^2}{Q^2}\right)^{1-D_2} \frac{x^{-D_2+1}}{1+D_3-D_1\ln x}\left(x^{-D_1 \ln\left[1+\frac{Q^2}{Q_0^2}\right]}\left(1+\frac{Q^2}{Q_0^2}\right)^{D_3+1} - 1\right)$$

- No Fractal parameterisation for F_L, use $F_L = \frac{R}{R+1} F_2$ with R as an additional parameter

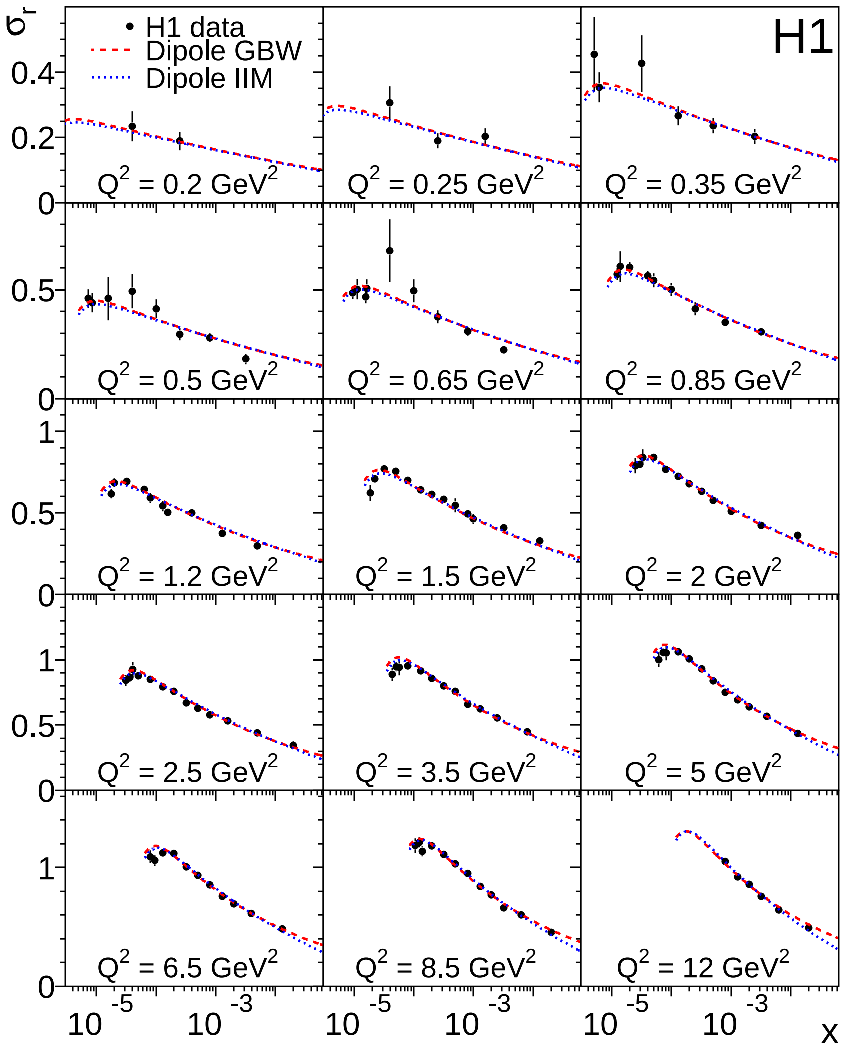
- Colour Dipole Model (CDM) fits: 3 parameter fits. γ^*p scattering via γ^* splitting into dipole which scatters off the proton. In the GBW (Golec-Biernat & Wusthoff) model the dipole-proton cross section is given by

$$\hat{\sigma}(x,r) = \sigma_0 \left\{1-\exp\left[-r^2/\left(4r_0^2(x)\right)\right]\right\} \quad \text{with} \quad r_0^2(x) \sim (x/x_0)^{\lambda}$$

- r corresponds to transverse quark-antiquark separation. λ, x_0 and σ_0 are parameters of the model. For $r >> r_0$, GBW model predicts a saturation with a constant $\hat{\sigma} \approx \sigma_0$ at $x = x_s$
- Another Dipole fit IIM (Iancu, Itakura & Munier) uses different model of cross section $\hat{\sigma}$

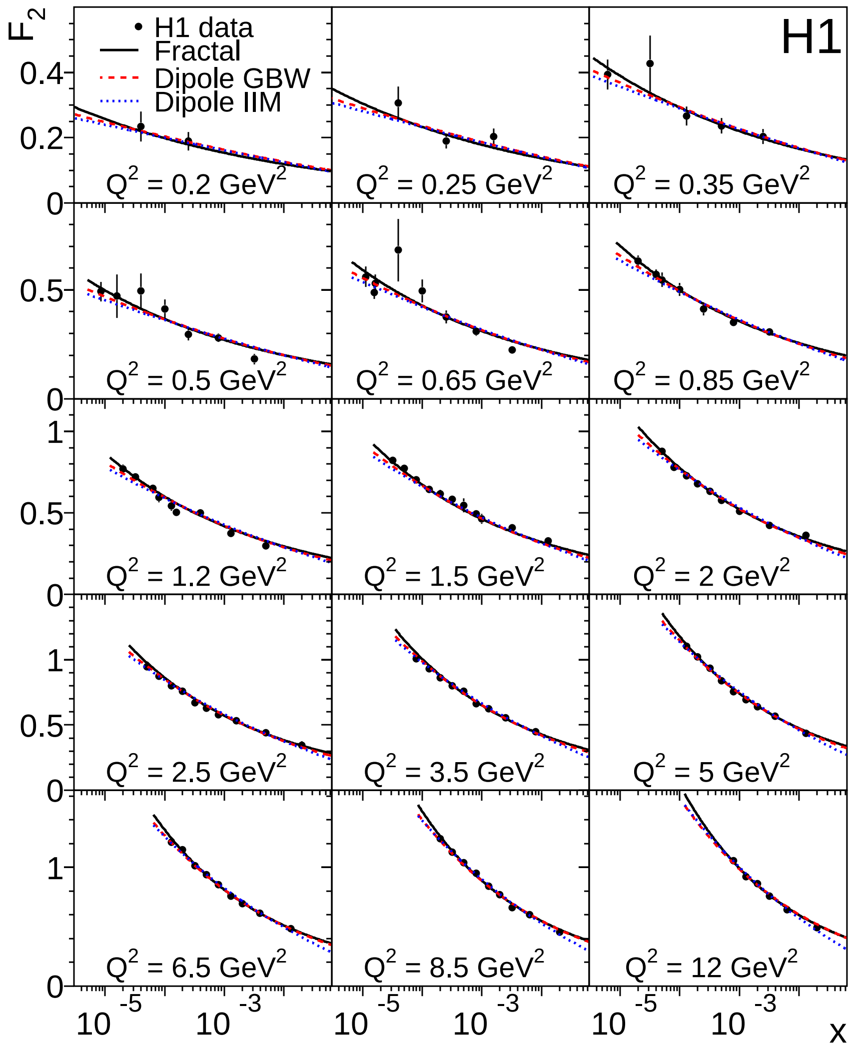
- These two models are considered here as representative for a much larger variety of Dipole models

σ_r and and Dipole models



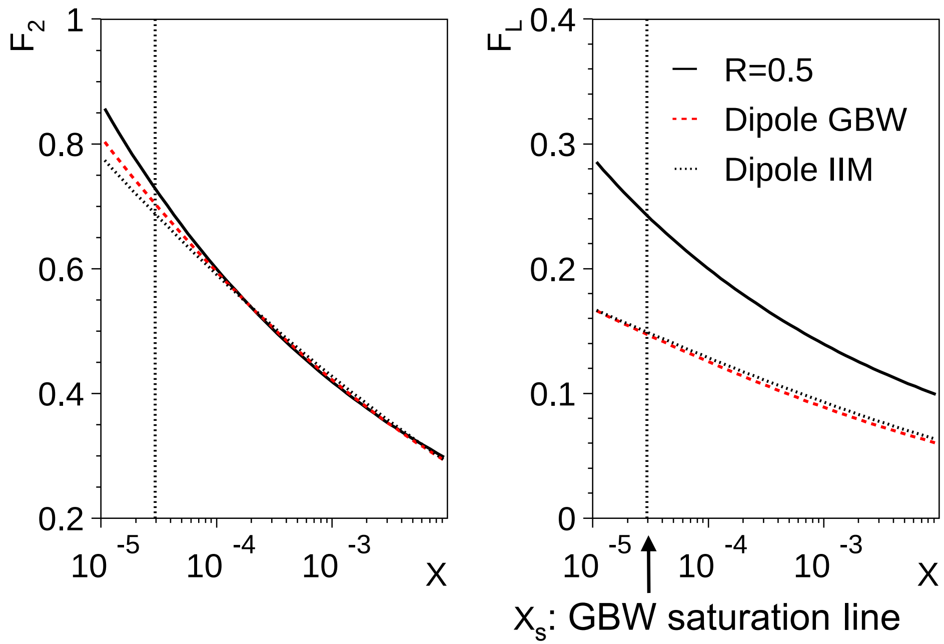
- H1 cross section data are well described by GBW & IIM Dipole fits
- GBW fit yields a χ^2/n_{dof} = 183.1/(149-3) and IIM a χ^2/n_{dof} = 178.2/(149-3)

F_2 and models



- Restrict F_2 extraction to y<0.6 where effect from F_L is small
- Steeper rise of F_2 from Fractal fit as compared to Dipole fits
- The Fractal fit describes data well with χ^2/n_{dof} = 155.3/(149-5)

F_2 and F_L from models



$$F_L = \frac{R}{1+R} \cdot F_2$$

- F_2 for Q^2=1.2 GeV^2 from the Fractal and Dipole fits to H1 data. F_L from Dipole fits and using F_2 from Fractal fit assuming R=0.5
- Good agreement between 3 models in F_2 apart from lowest x. Dipole models predict softer F_2 dependence for $x < x_s$
- The F_L predictions of Dipole models are nearly half of the Fractal result
- Formally allow F_L in Dipole models to scale independently of F_2

$$F_L(x,Q^2) = F_L^{Dipole}(x,Q^2)(1+B_L)$$

- B_L= 0.54±0.15 (GBW) and B_L= 0.17±0.14 (IIM), i.e. IIM model gives consistent description of data
- Steeper F_2 in lambda and Fractal fits lead to large R. Softer F_2 of IIM allows to describe data with smaller F_L

Conclusions

- The analysis of the H1 low x and Q^2 data from HERA-1 is submitted for publication [H1 Collaboration. DESY-08-171, Apr 2009. 90pp. arXiv:0904.0929 [hep-ex]]
- A coherent data set is presented, combining data from dedicated running periods in 1995-2000
- The measurement of the reduced cross section reaches 1.5% precision
- The transition region from non-perturbative to deep inelastic behaviour is generally well described by the phenomenological models
- In the deep inelastic region, the data are used as input for the new NLO QCD analysis of H1 [H1PDF2009, cf talk of J.Kretzschmar]
- A power law parameterisation of F_2 leads to R, which is about twice larger compare to Dipole models and the direct measurements of F_L [cf talk of A.Glazov]