Photoproduction-DIS transition
(F_2 at very low Q^2)

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(on behalf of H1 and ZEUS collaborations)

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Content

- Introduction to HERA
- Deep Inelastic Scattering
- Structure function F_2
- Rise of F_2 at low x
- Conclusions

H1 and ZEUS at HERA

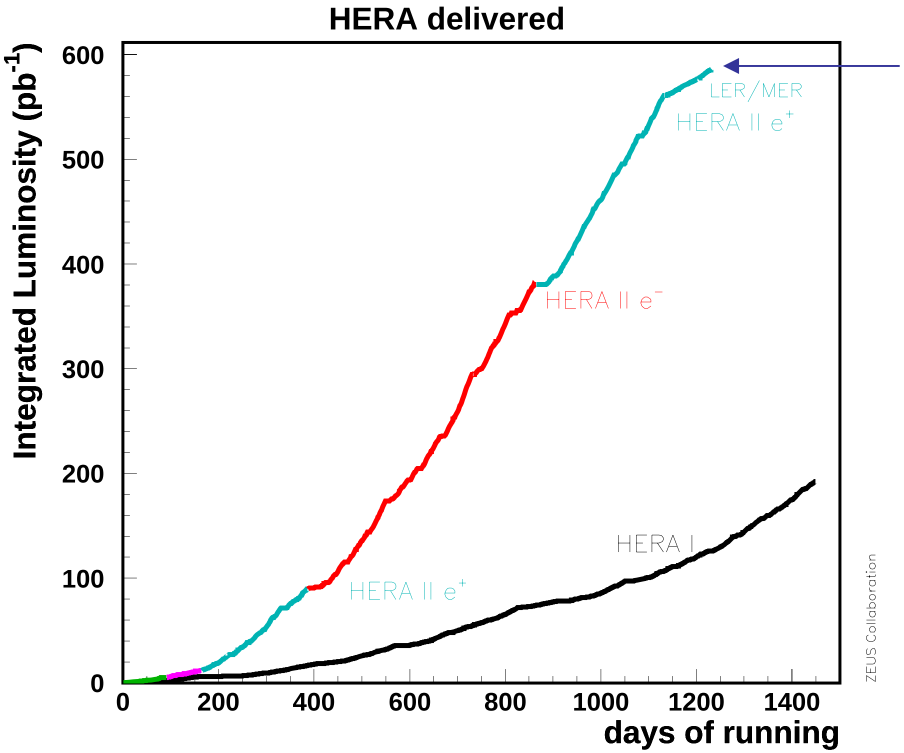
- HERA collider at DESY, Hamburg
- *ep* accelerator ring, 27.6 x 920 GeV, $\sqrt{s_{ep}} = 319$ GeV
- Circumference: 6.3km
- 4 experimantal halls, 2 collider experiments (collected data: 1992-2007)

H1

ZEUS

HERA luminosity

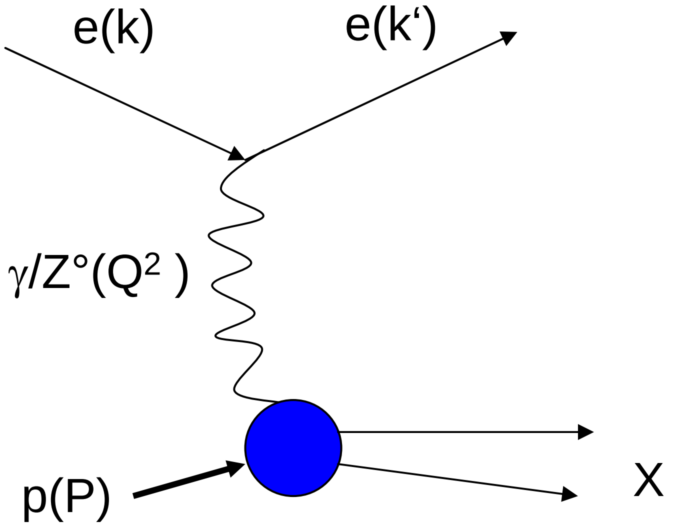
- Luminosity upgrade: mid 2000 – end 2001
- Improvement in machine performance
- Low energy running: March – June 2007



End of HERA operation: June 30, 2007

Inclusive Deep Inelastic Scattering at HERA

Neutral current



$Q^2 = -(k-k')^2$ - four momentum transfer squared in the reaction

$x = \frac{Q^2}{2P(k-k')}$ - fraction of the proton momentum carried by the parton

$y = Q^2 / sx$ - inelasticity

$s = 4E_eE_p$ - center-of-mass energy squared

Cross section and structure functions

NC Cross Section:

NC Reduced cross section: $\tilde{\sigma}_{NC}(x, Q^2)$

$$\frac{d^2\sigma_{NC}(e^{\pm} p)}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4} Y_+ \overbrace{\left[\underset{\uparrow}{\tilde{F}_2} - \underset{\uparrow}{\frac{y^2}{Y_+}} \tilde{F}_L\right]}^{\tilde{\sigma}_{NC}(x,Q^2)}$$

Dominant contribution

Sizeable only at high y (y>~0.6)

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

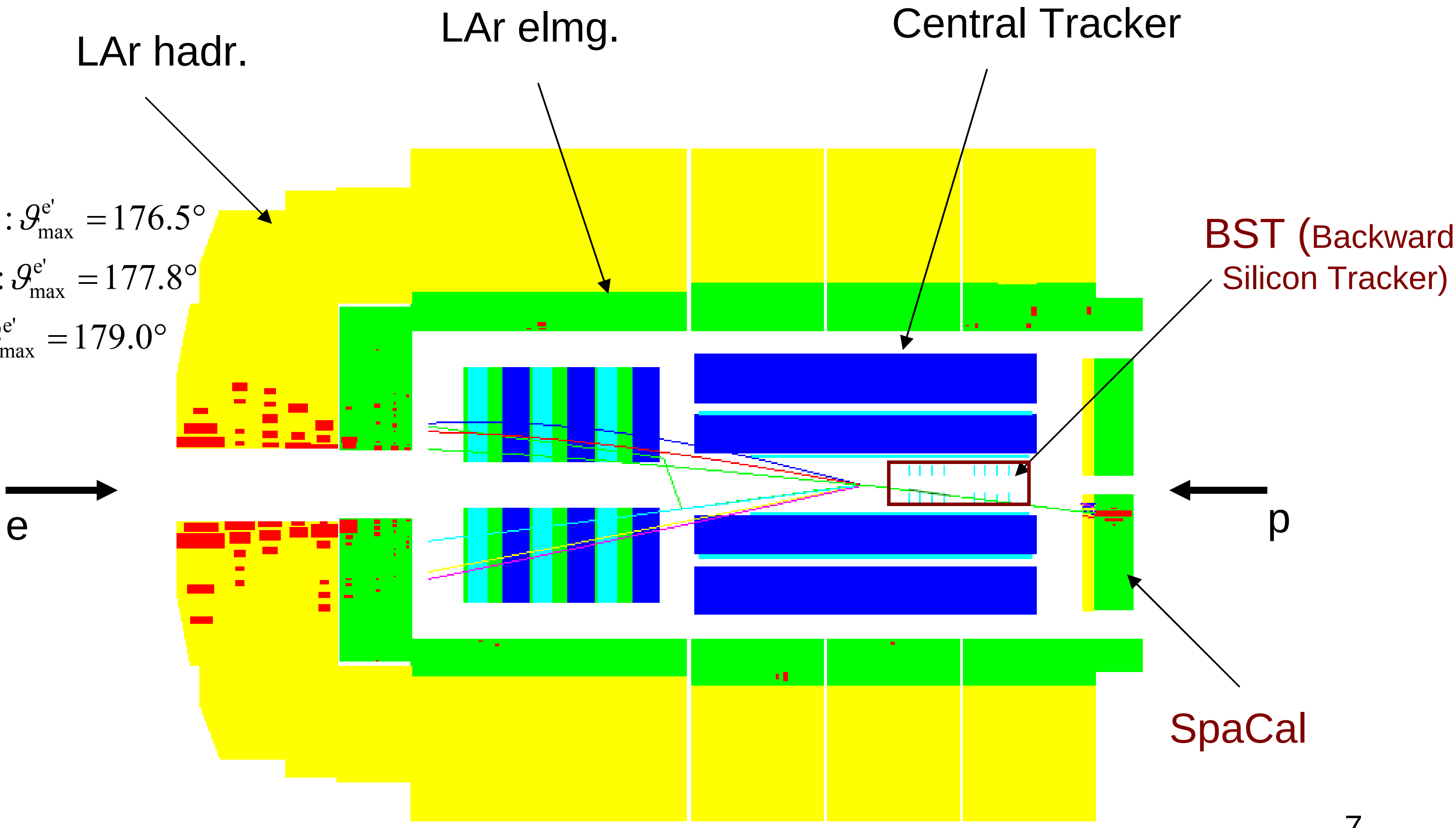
- The proton structure function in QPM:

$$F_2 = \sum_i e_i^2 x[q_i(x) + \bar{q}_i(x)]$$

- sum of the (anti)quarks density distributions weighted with their electric charge squared

- Structure function F_L ~ gluon density g(x) in NLO QCD and 0 in QPM

Low Q^2 event in H1 detector



H1 NVX BST : $\vartheta^{e'}_{\max} = 176.5°$

H1 SVX BST : $\vartheta^{e'}_{\max} = 177.8°$

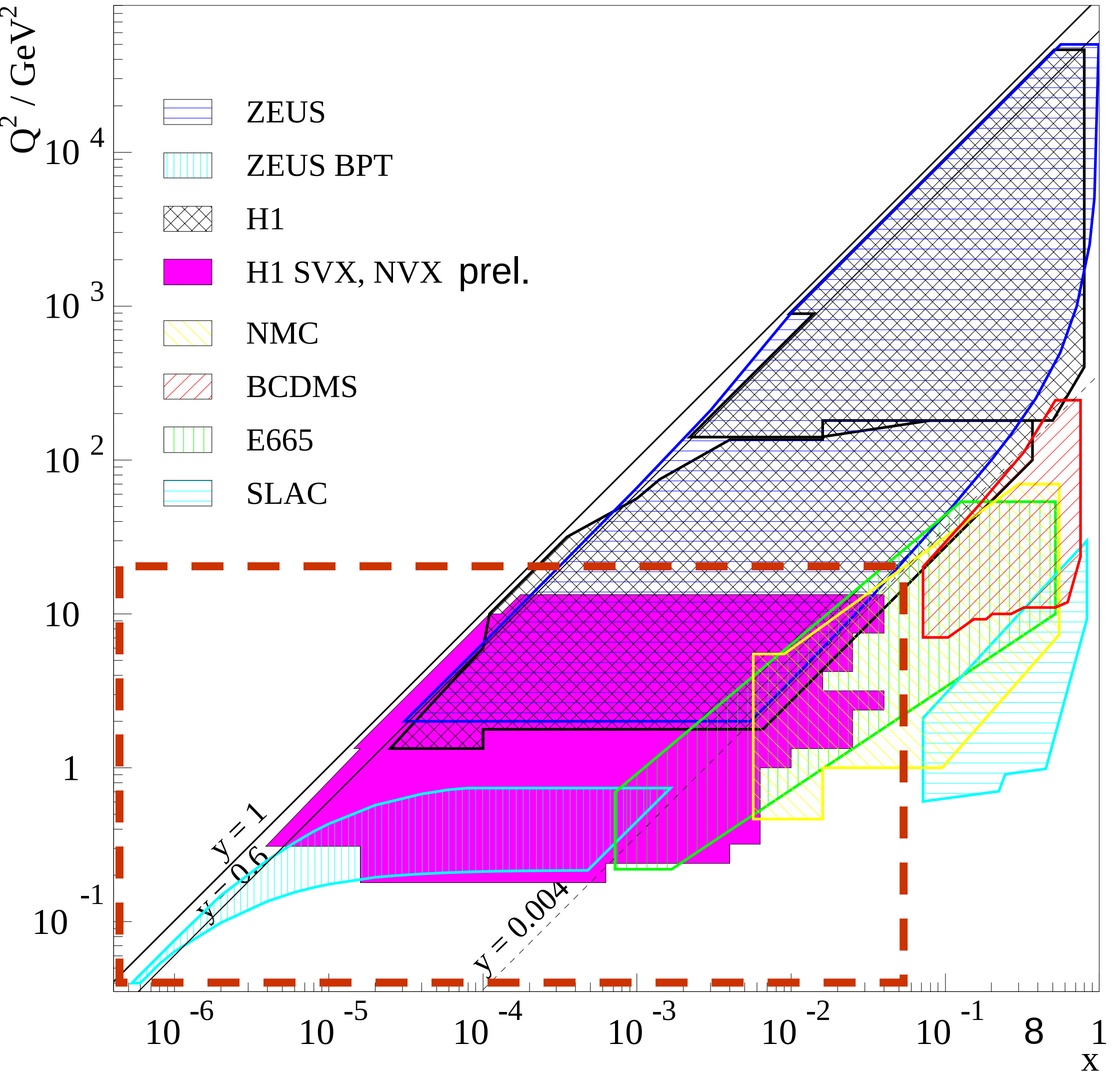
ZEUS BPT : $\vartheta^{e'}_{\max} = 179.0°$

Kinematic plane coverage

- HERA extends kinematic plane coverage to lower x and higher Q^2 by 2 orders of magnitude

- H1 and ZEUS overlap with fixed target results in wide range of x and Q^2

- H1 SVX, NVX: special runs with open triggers for inclusive DIS events
  - Nominal vertex data access high y region
  - Shifted vertex data access lowerst Q^2

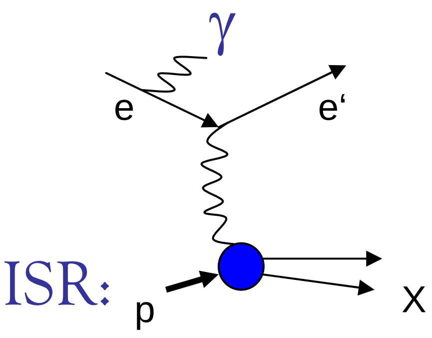


Reconstruction of event kinematics

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

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

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



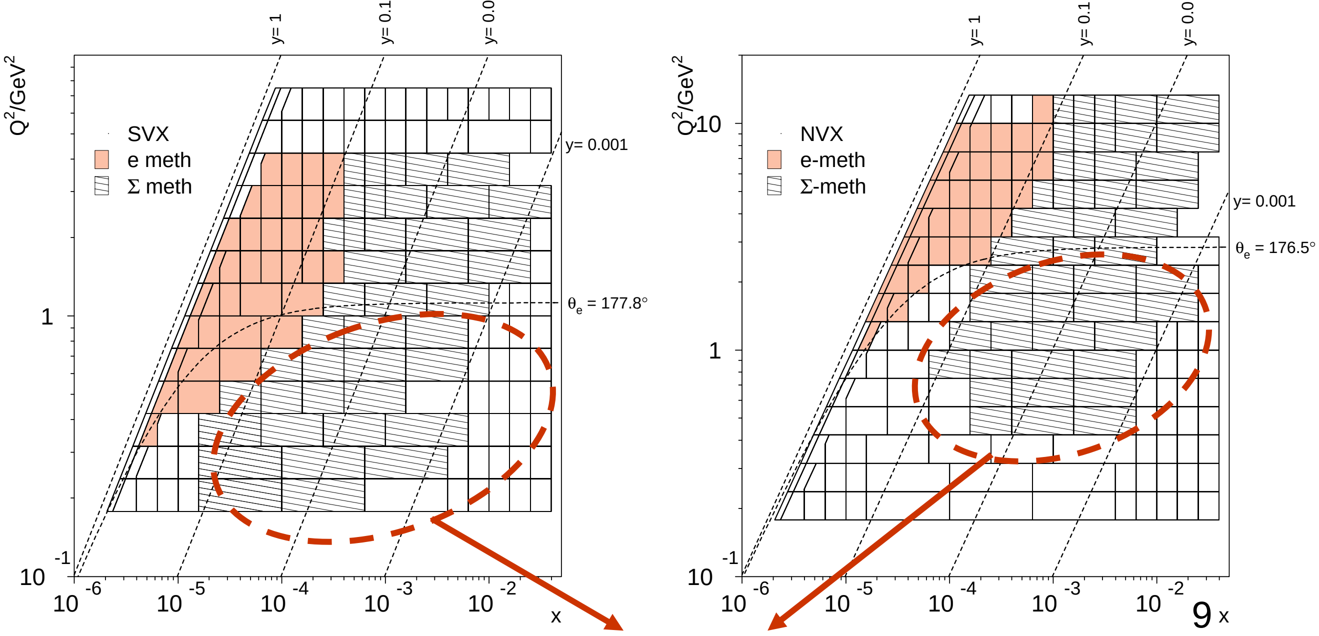
- ‘Sigma method’- used for 0.002<y<0.1 and also for low Q^2 by accepting events with Initial State Radiation (ISR):

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

$$\Sigma_h = (E - p_z)_{had}$$

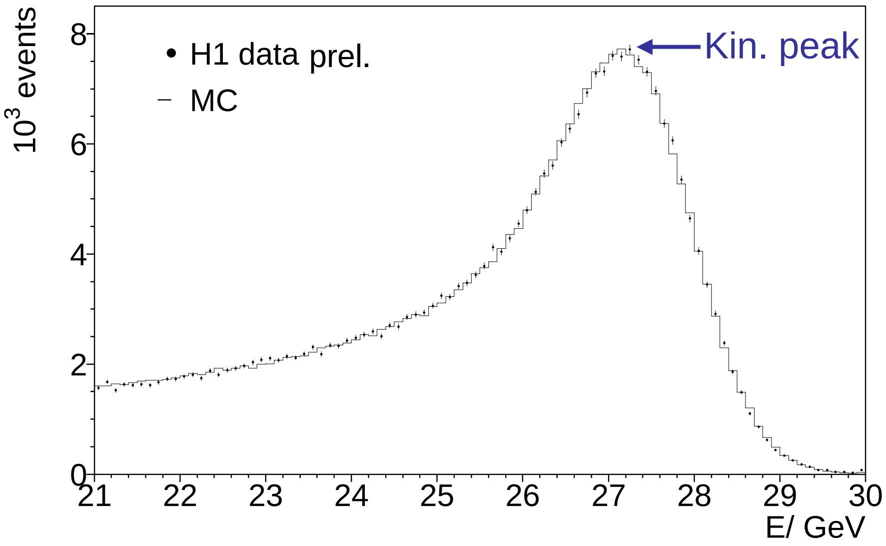
$$Q_\Sigma^2 = \frac{E_e^{'2}\sin^2(\theta_e)}{1-y_\Sigma}$$

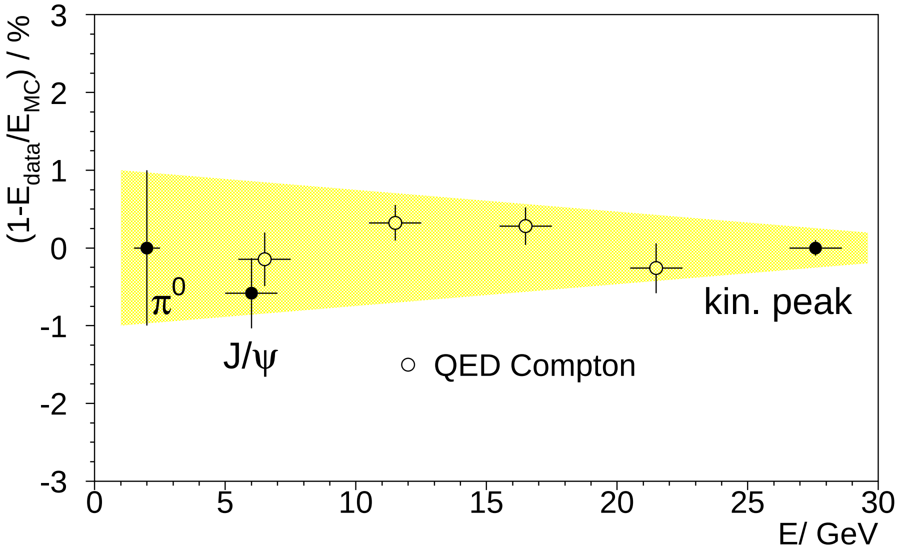
$$x_\Sigma = \frac{Q_\Sigma^2}{2E_py_\Sigma}\cdot\frac{1}{E-p_z}$$



Extended by ISR

Electron energy scale calibration



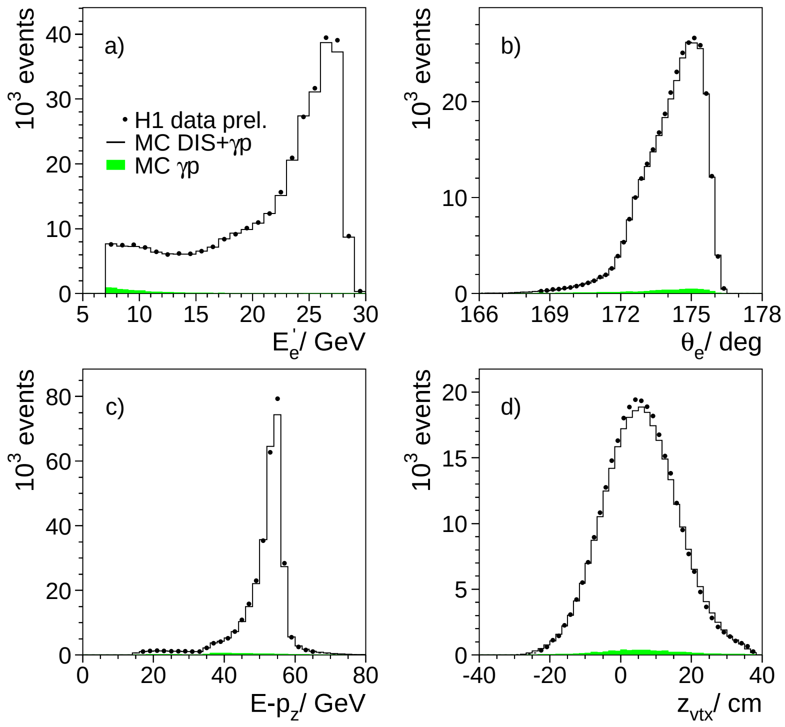


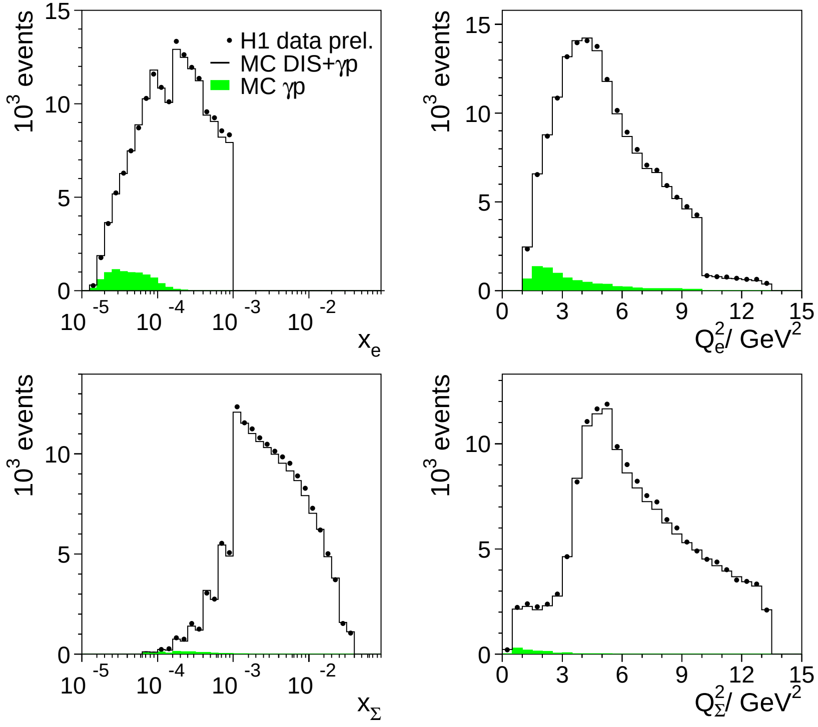
- Use multi-step calibration. Correct for the gain difference of PMTs and for non-uniformities of SpaCal

- 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

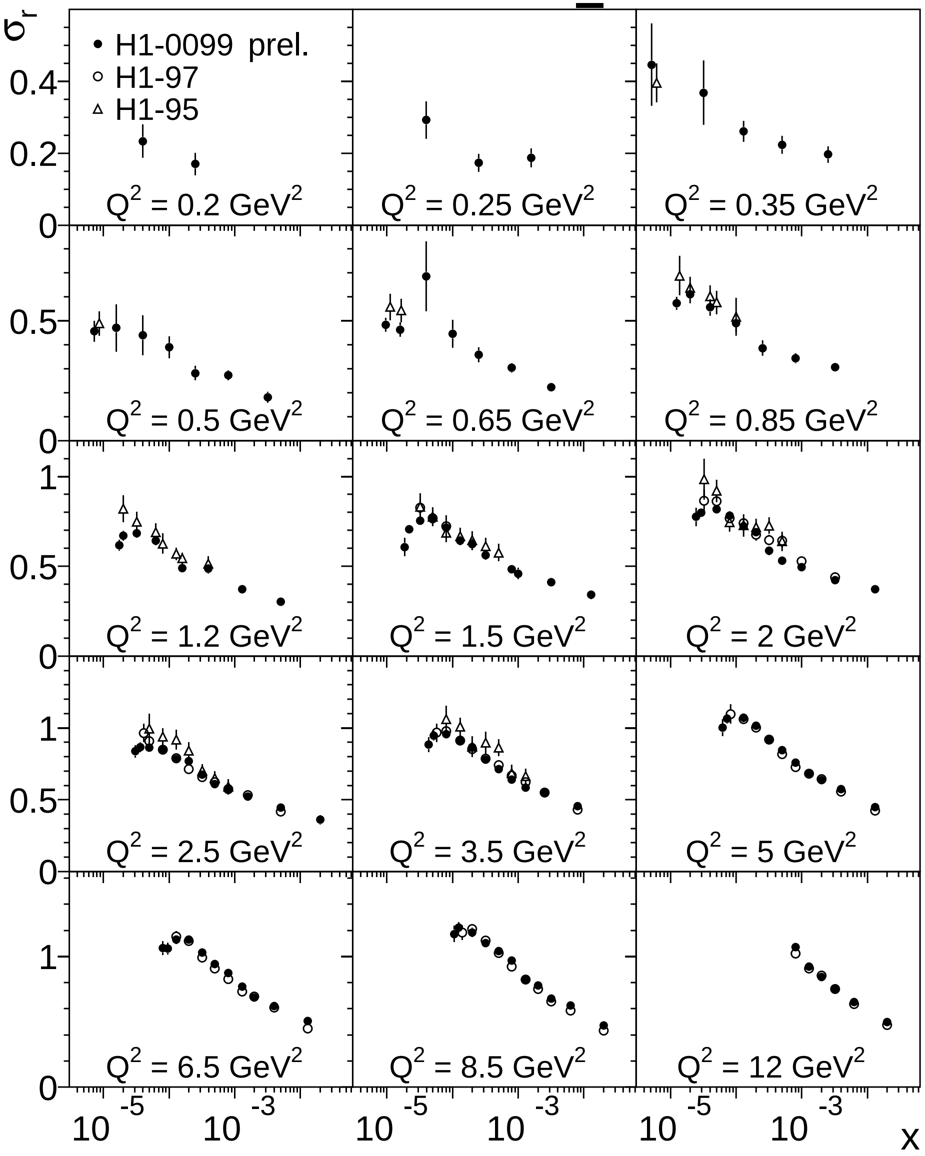




- Require a BST reconstructed vertex inside of the interaction region, SpaCal cluster and BST track matching this cluster

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

σ_r at very low Q^2



- New preliminary results extend H1 measurements to low Q^2 and high x by using of ISR events

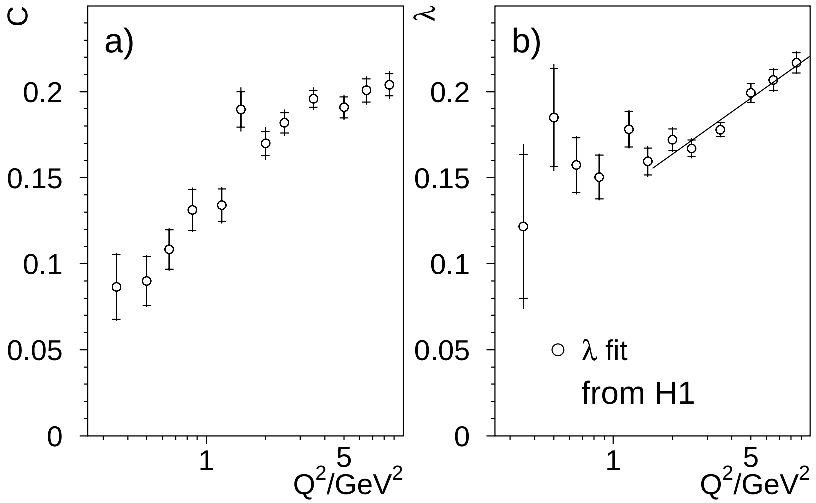
- Significant overlap between H1-0099 prel. data and previously published results

- New prel. data agree well with H1-97 and a bit lower than H1-95 (within normalization uncertainty of 1995 data)

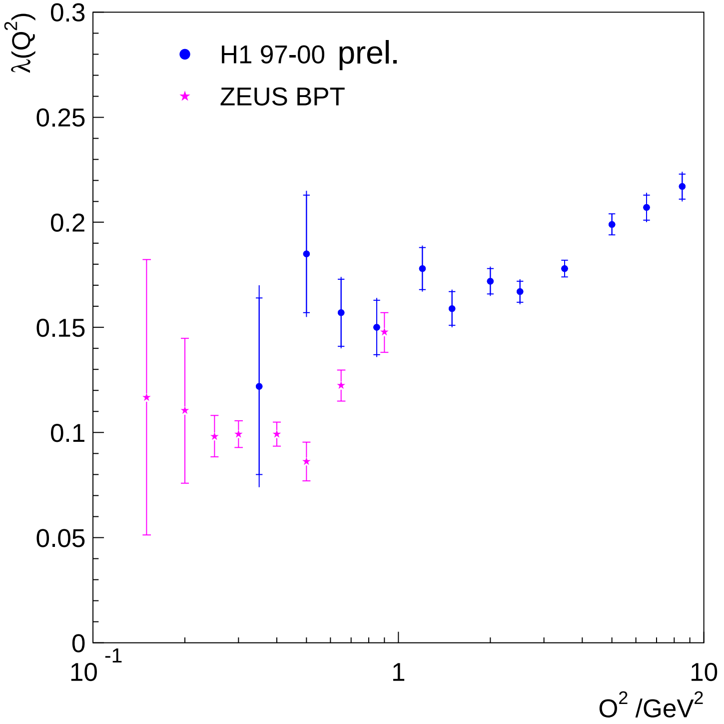
Rise of F_2 towards low x

- F_2 used to fit x-dependences in Q^2 bins for $x<0.01$ and $W>12$ GeV: $F_2=c(Q^2)\bullet x^{-\lambda(Q^2)}$

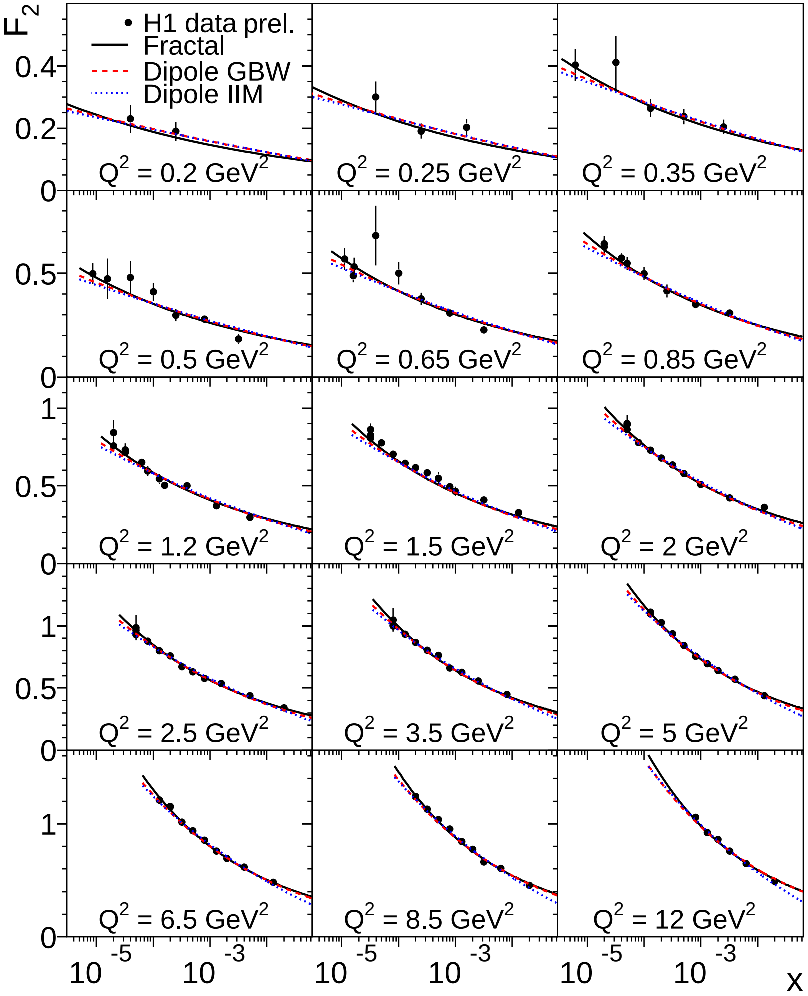
- $\lambda \sim \ln(Q^2/\Lambda^2)$ and $c(Q^2)\sim$const. for $Q^2>1$ GeV^2



- Around $Q^2=1$ GeV^2 λ deviates from log-dependence



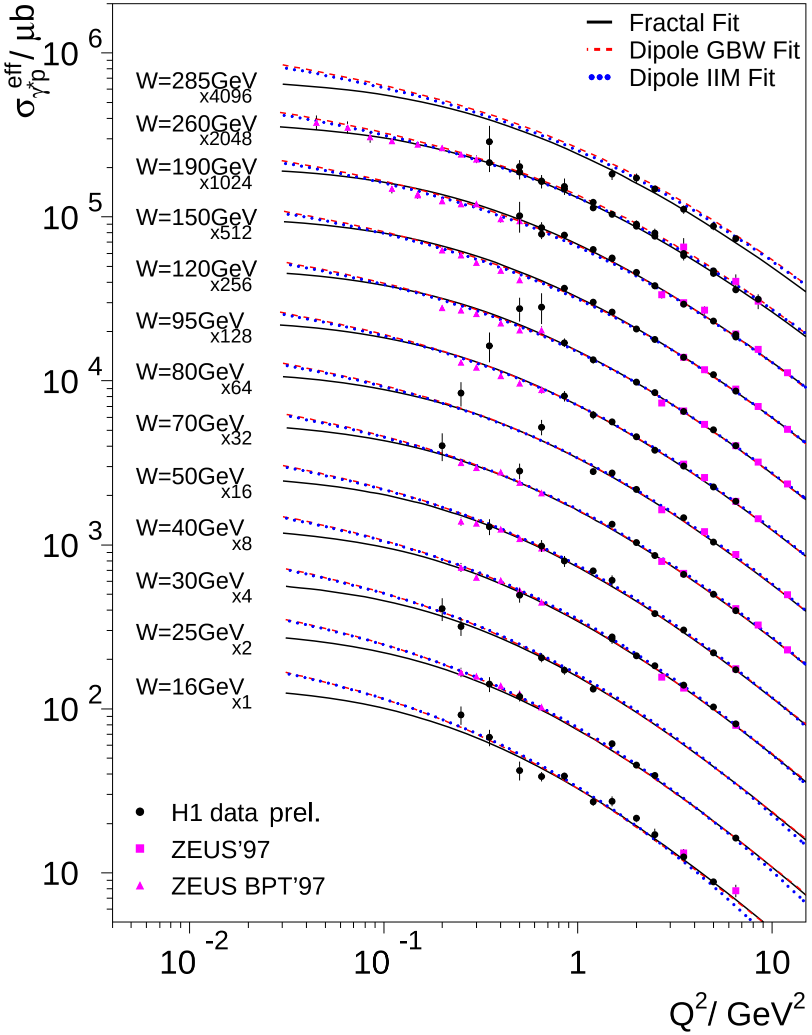
F_2 at very low Q^2



- F_2 rises towards low x for all measured Q^2 bins
- H1 prel. data agree with different theoretical models:
  - ✓ Fractal fit – based on the concept of self similarity 5 parameter model
  - ✓ Dipole 3 parameter fits – γ^*p scattering via γ^* splitting into dipole which scatters off the proton. Two different dipole - proton cross section models: GBW (Golec-Biernat & Wusthoff) and IIM (Iancu, Itakura & Munier)

- New precision of H1 prel. data:1.5% for $Q^2 > 5\mathrm{GeV}^2$

The very low Q^2 data



$$\sigma^{eff}_{\gamma^* p} = \sigma_T + [1 - f(y)]\sigma_L$$

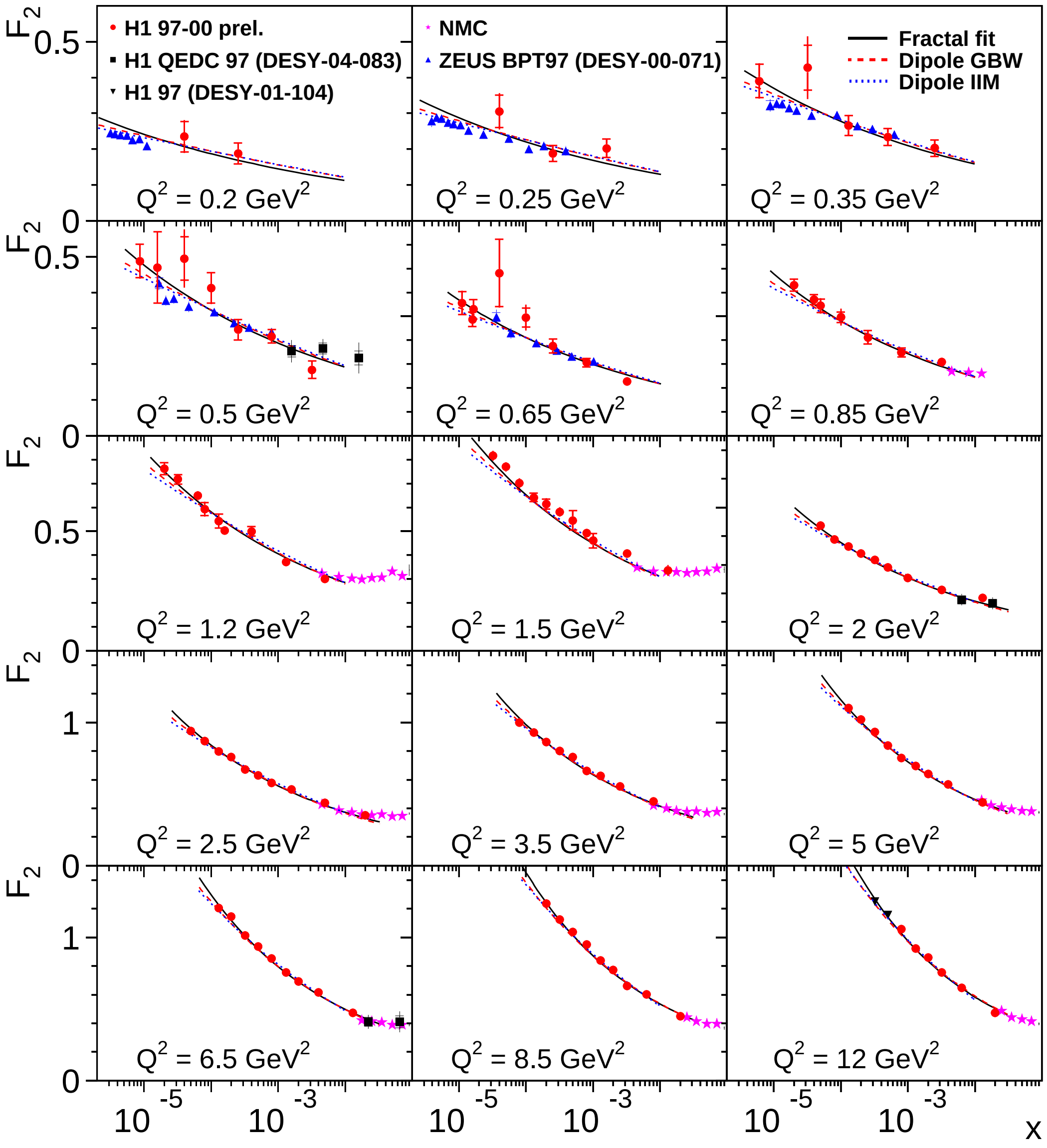
$$f(y) = y^2 / [1 + (1 - y)^2]$$

$$\sigma^{eff}_{\gamma^* p} = \frac{4\pi^2\alpha}{Q^2(1-x)}\sigma_r$$

$$\sigma^{eff}_{\gamma^* p} \approx \sigma_{\gamma^* p} \quad \text{for W} \le 200\,\text{GeV}$$

- H1 preliminary data cover the gap between published ZEUS results and agree with them in the regions of overlap

The very low Q^2 data



- Data from H1, ZEUS and NMC
- Fits to H1 97-00 prel. data only
- HERA data are described by phenomenological predictions

Conclusions

- HERA analyses enter final stage
- New precise low Q^2 and high x preliminary results are covering the gap at Q^2 ~1 GeV^2
- They are consistent with other data in the regions of overlap
- Precision of ~2–3 % achieved for σ_r
- The HERA data is well described by Dipole and Fractal models