QCD and Proton and Phot
Structure since DIS2001

Jim Whitmore

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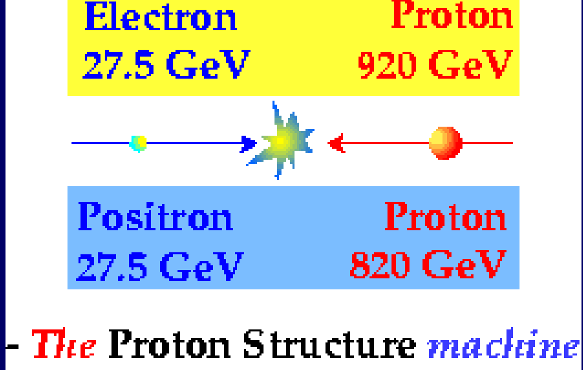
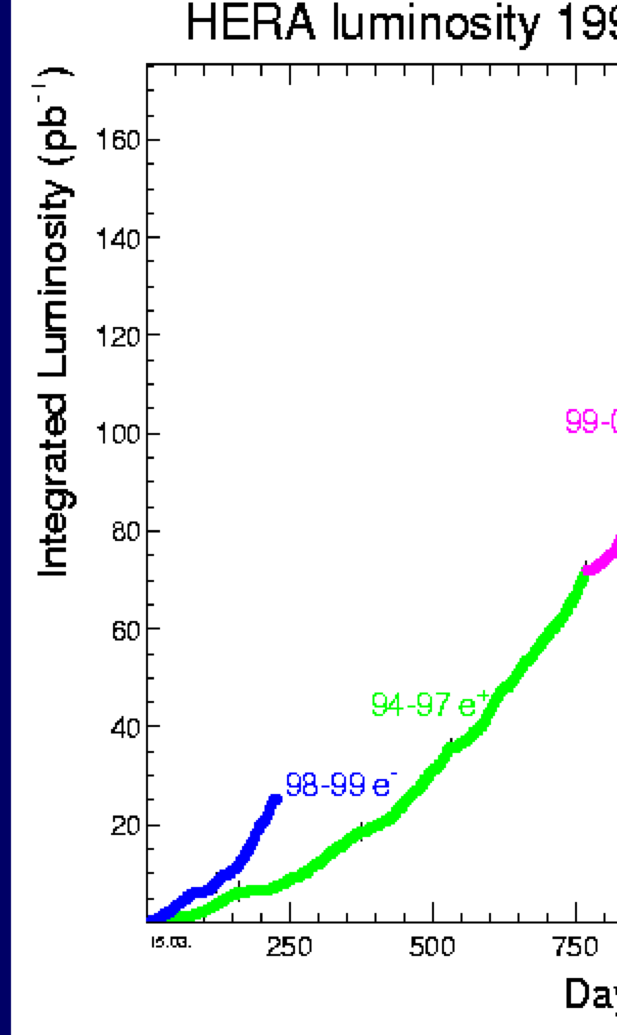
- Proton structure – F^p_2, NLO Fits, Uncerta
- Photon structure – F^γ_2, charm content, P
- QCD results – α_s



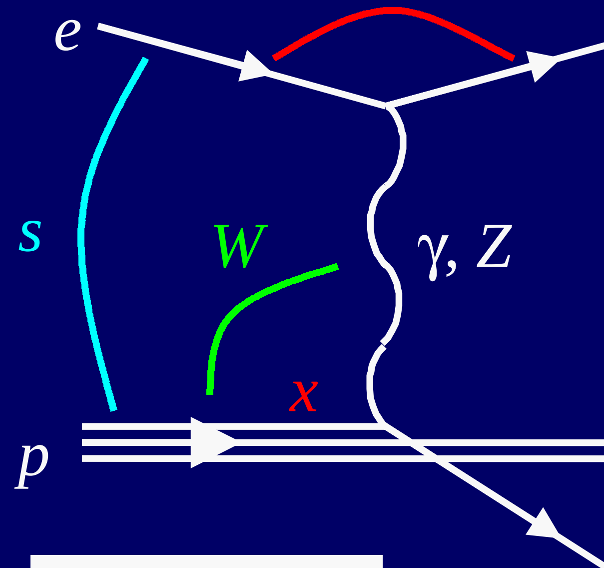
Luminosity Analyzed:

	Luminosity (pb^{-1}) H1	Luminosity (pb^{-1}) ZEUS
e^-P	16	16
e^+P	100	110



- s: e-p (c.m. energy)^2
- $Q^2 = -q^2$: 4-momentum transfer squared, "size" of the photon
- x: fraction of proton momentum carried by quark = $Q^2/2p.q$
- y: inelasticity parameter
- W: γ-p c.m. energy

$\sqrt{s} = 300 - 318$ G



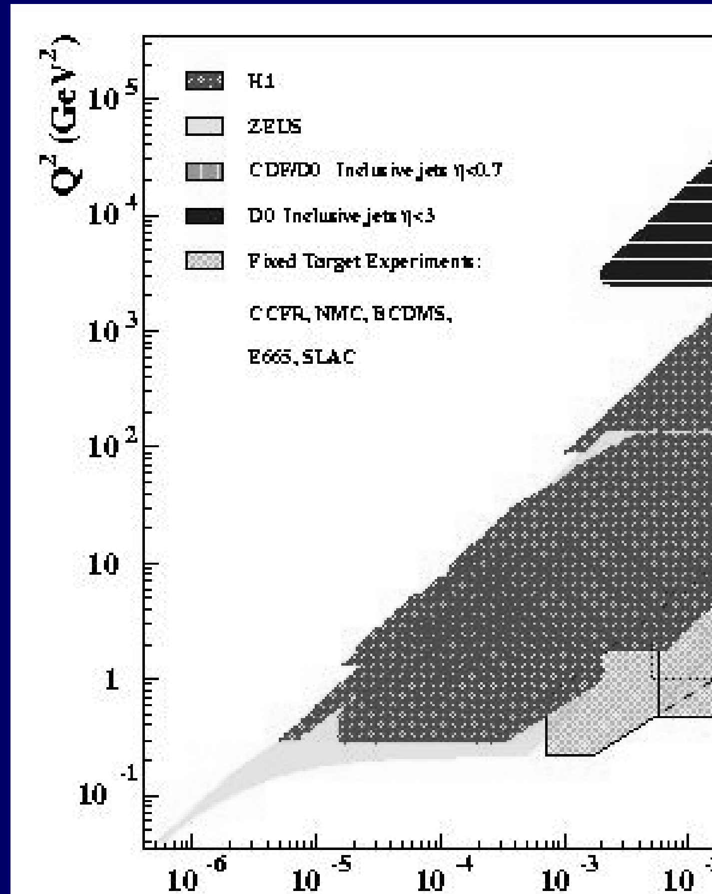
$$Q^2 = sxy$$

measurements have
3% precision (syst.)

- For $Q^2 \sim 1$ GeV^2: the transition from photoproduction ($Q^2 \sim 0$) to DIS

- For $Q^2 > 4$ GeV^2: pQCD region

- For $Q^2 > 10^4$ GeV^2: EW sector, overlap with Tevatron data, probes distances to ~ 1/1000th of proton size



Sections:

$$\frac{\ldots}{dx\,dQ^2} = \frac{\ldots}{xQ^4}(Y_+ F_2 - y^2 F_L + \ldots$$

$$F_2^{NC} = x \sum_{Quarks} A_f(Q^2)[q(x,Q^2) + \bar{q}(x,Q^2)]$$

$$Y_\pm \equiv 1 \ldots$$

F_L is the …

$\propto$ gluon …

Photon, Z couples to all quark flavours

$$xF_3^{NC} = x \sum_{Quarks} B_f(Q^2)[q(x,Q^2) - \bar{q}(x,Q^2)]$$

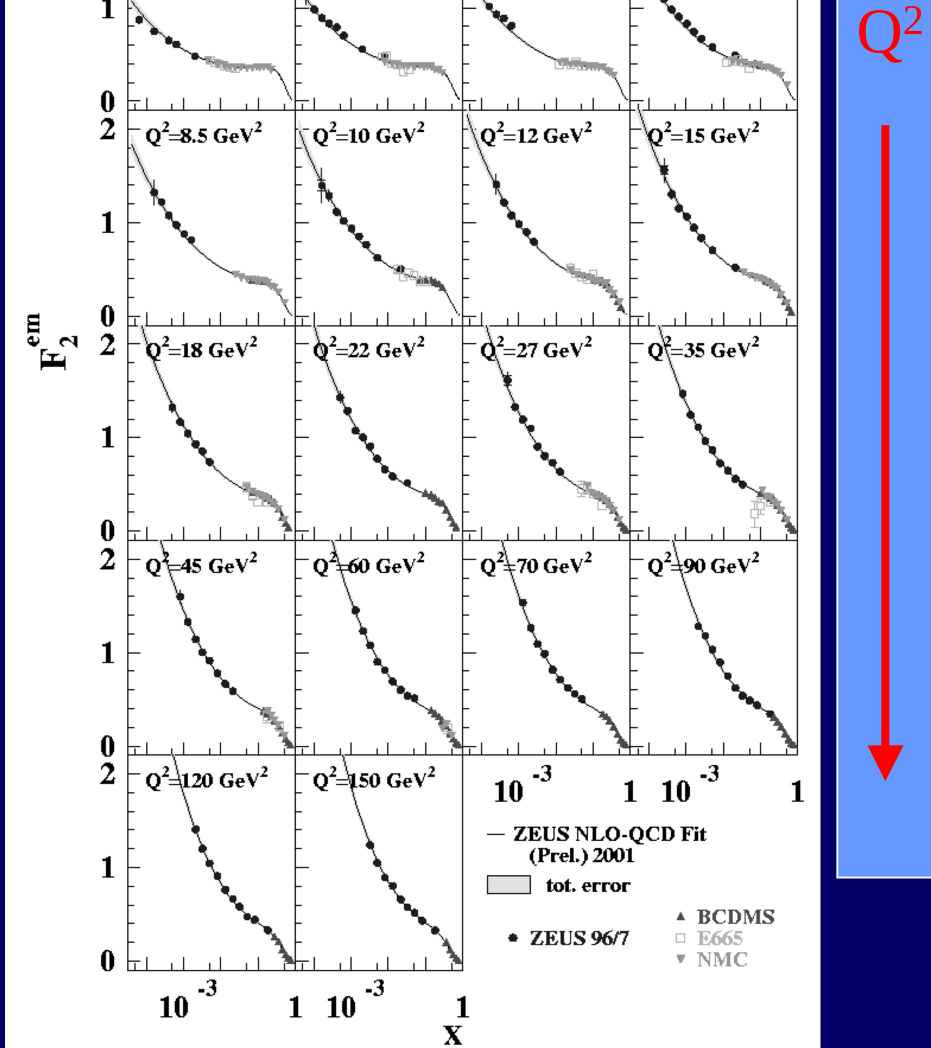
$$\chi_Z = \frac{1}{4\sin^2\vartheta_W \cos^2\vartheta_W} \frac{Q^2}{Q^2 + M_Z^2}$$

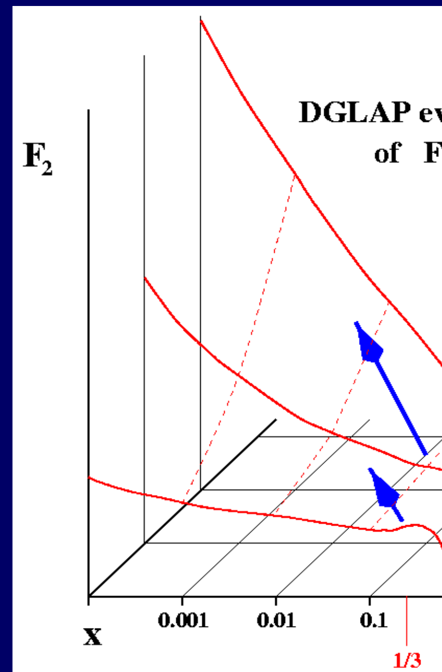
Z exchange…

xF_3 is the parity violating term – sensitive to val… quarks and is only significant at $Q^2 \sim M_Z^2$

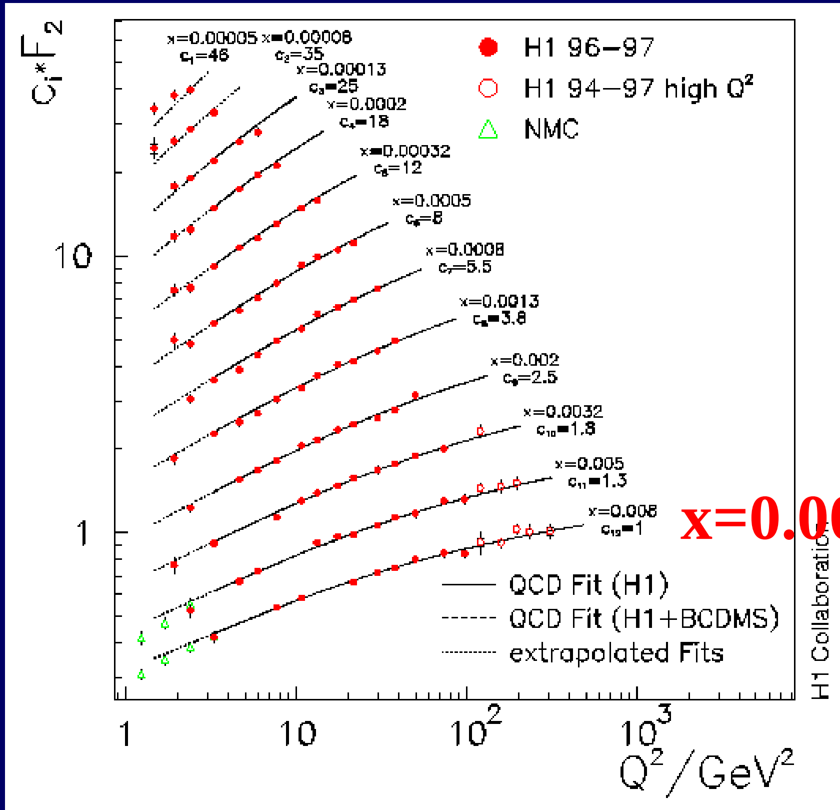
Functions

- Strong rise
  towards low

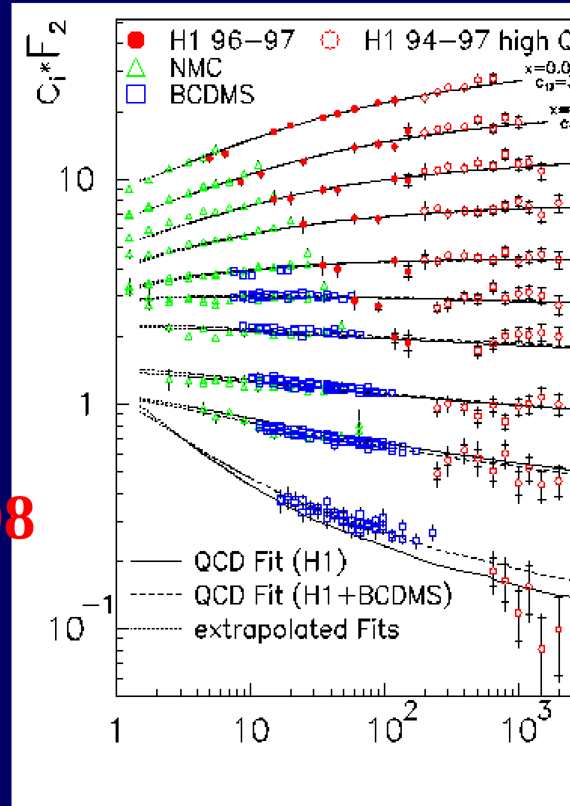




x=0.00005



x=0.008



- **Due to gluon radiation**
- **Nice matching with fixed target data**

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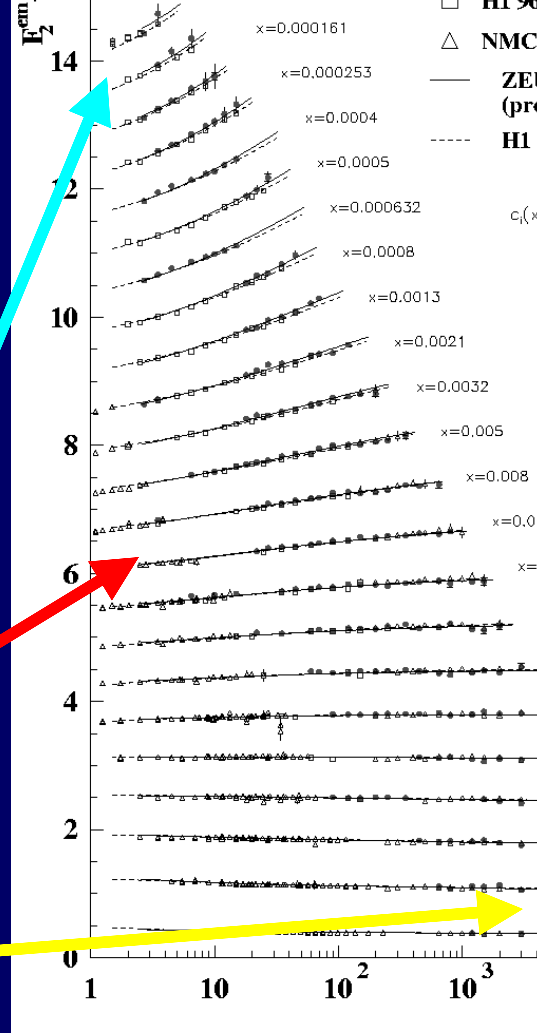
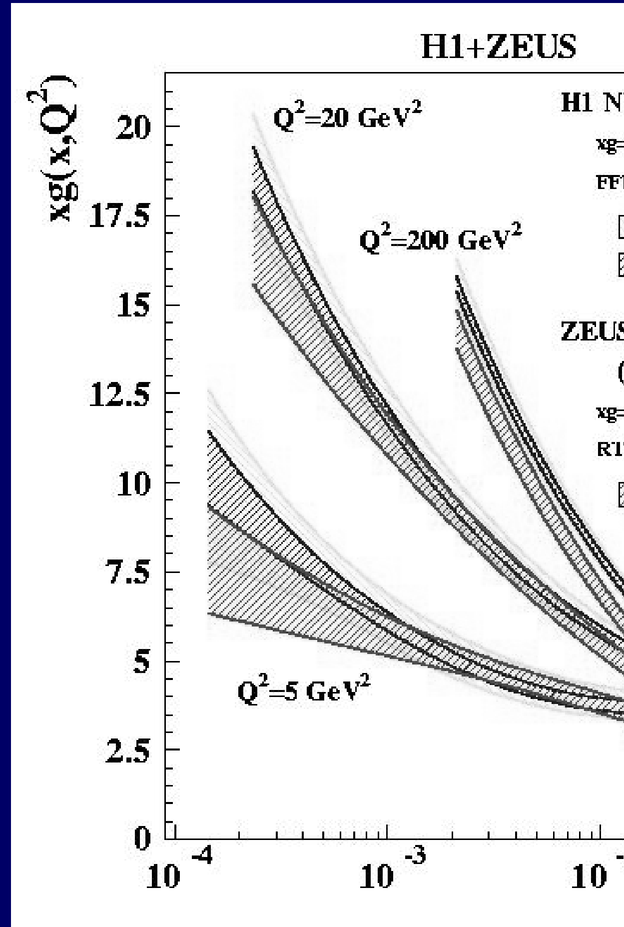
- Are the data described by DGLAP QCD?
- Determine the PDFs (q,g) and $\alpha_S(M_Z^2)$
- The ZEUS and H1 data and fits show some differences at small x
- But they generally agree very well
- Limited statistics at large Q^2

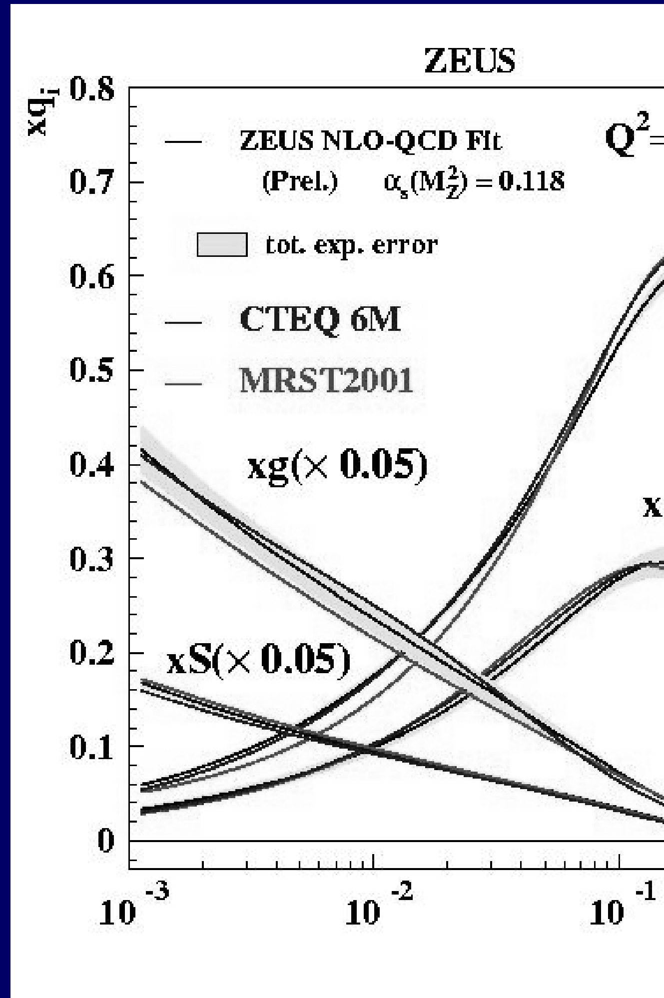


H1 and ZEUS Gluon Density

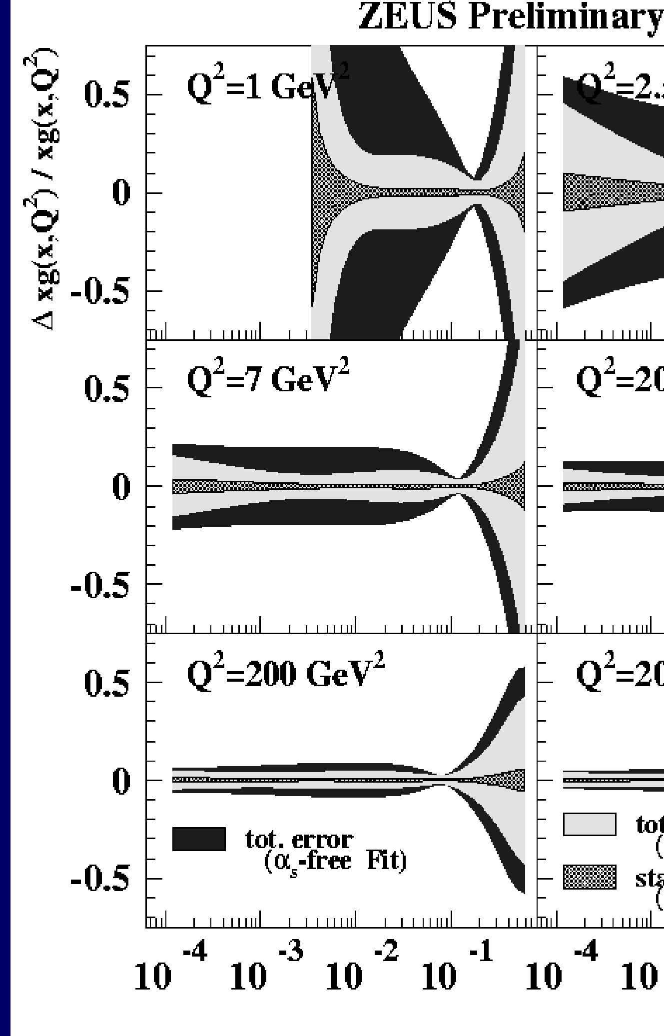
- See the evolution of gluon density as a function of Q^2
- Comparing the H1 and ZEUS distributions:
- At the time of DIS2001:
- Some differences observed, probably due to:
  - heavy flavour scheme
  - $xg(x)$ parameterisation
- α_S correlation clearly visible in error on $xg(x)$
- (See the talks by Tassi and Reisert – SF WG May 1)

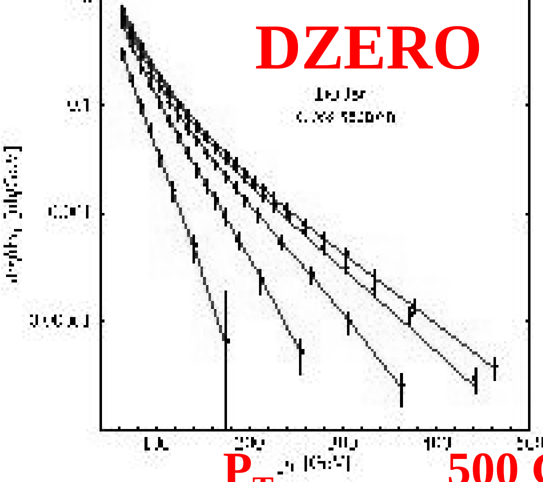


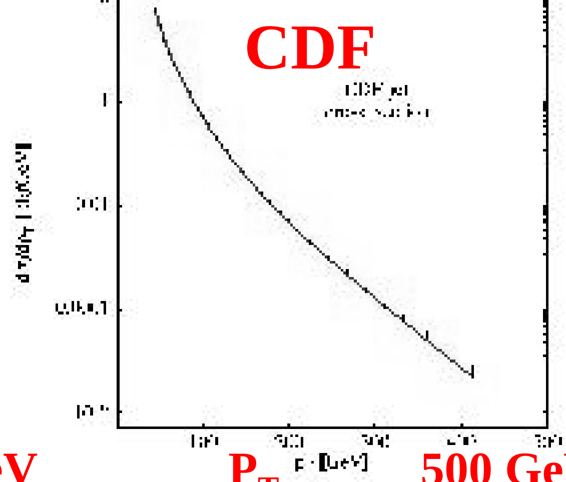
- General agreement between all three
- within the uncertainties of the fitted PDFs



- Much work has gone into determining the uncertainties on the PDFs (=>predictions)
- Correlations between the experimental uncertainties have been taken into account
- The low Q^2 and high x regions have the largest uncertainties

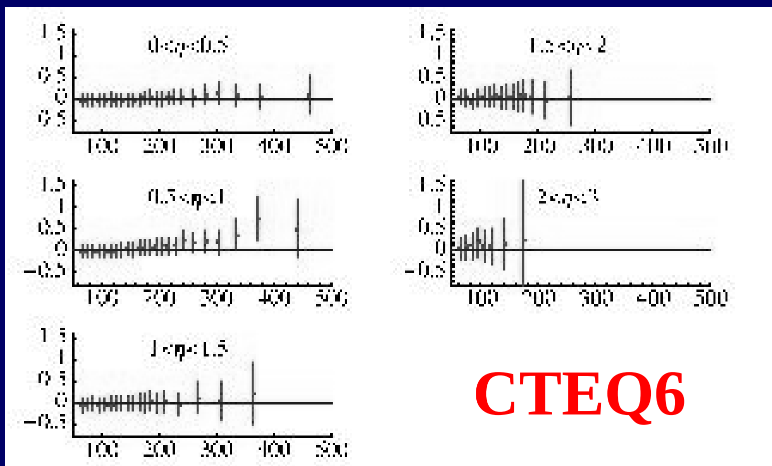


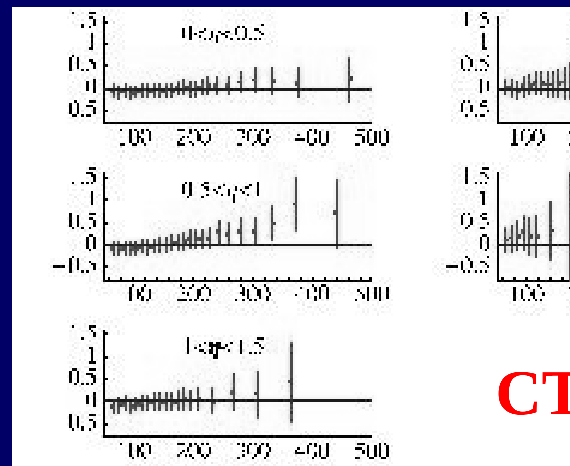




- Fits c… the T… jet d…
- Impr… in CT… over…

Ratio of (Data-CTEQ)/CTEQ:





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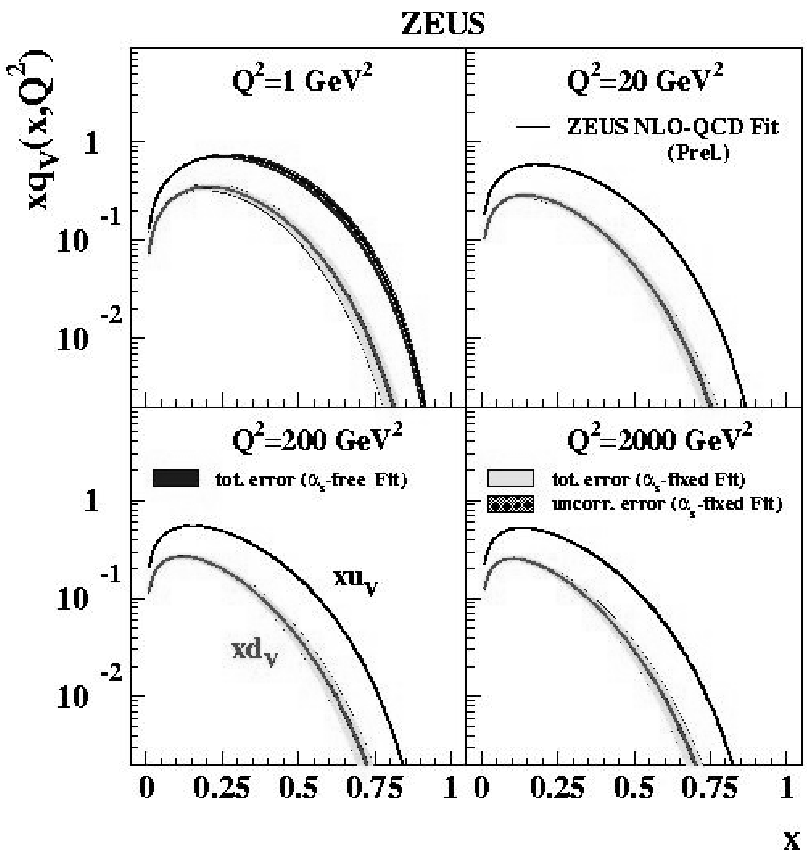
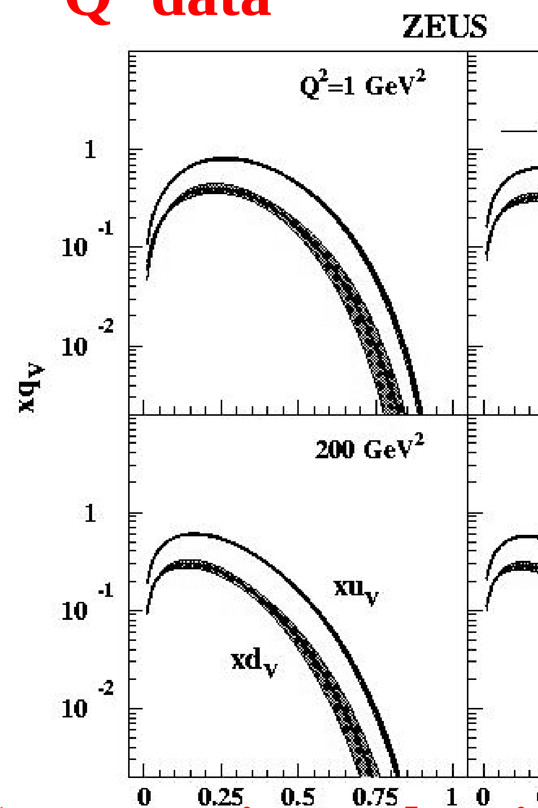
ZEUS Standard fit



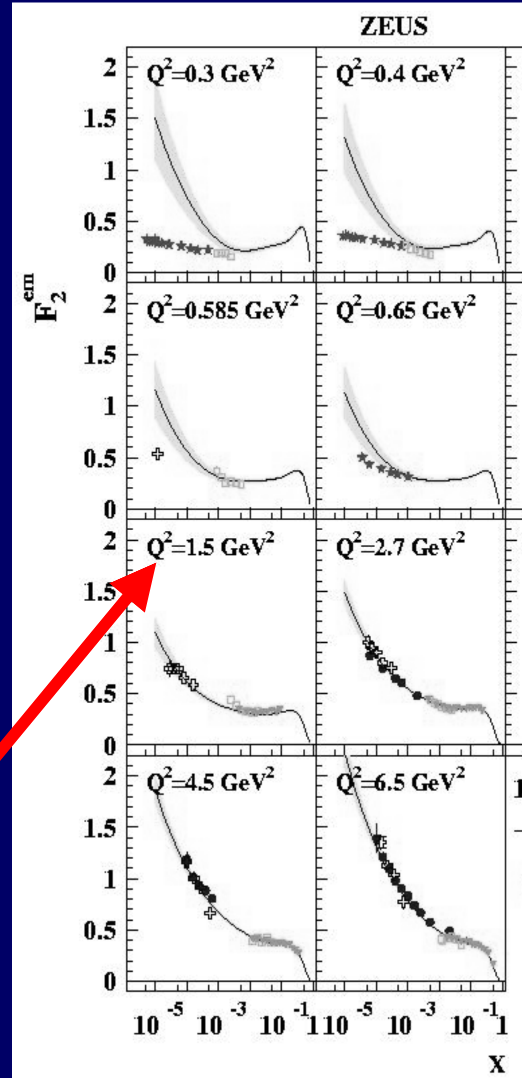
ZEUS only fit, us

Q^2 data

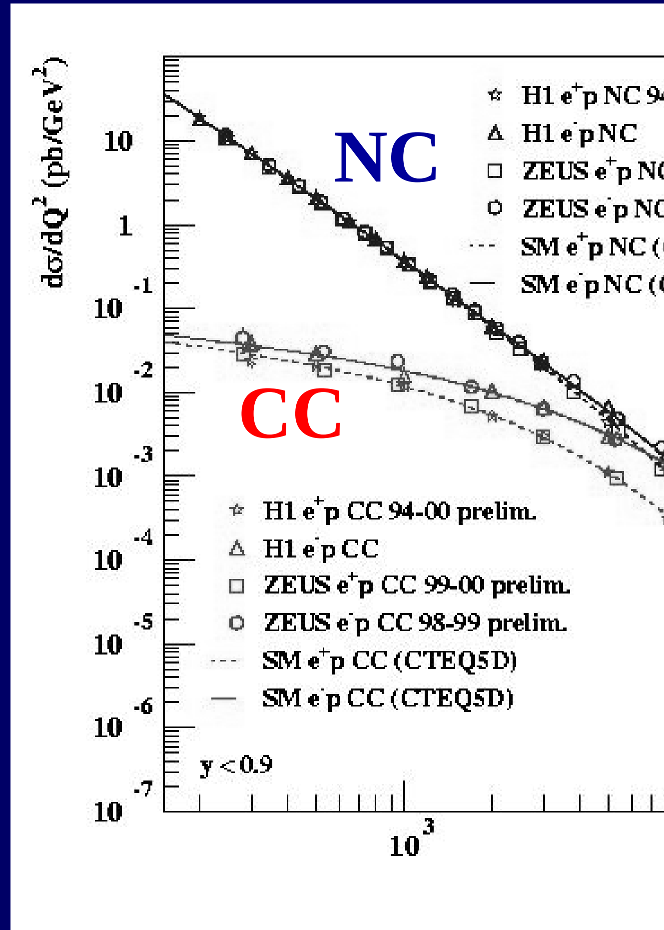


(See Tassi's and Reis

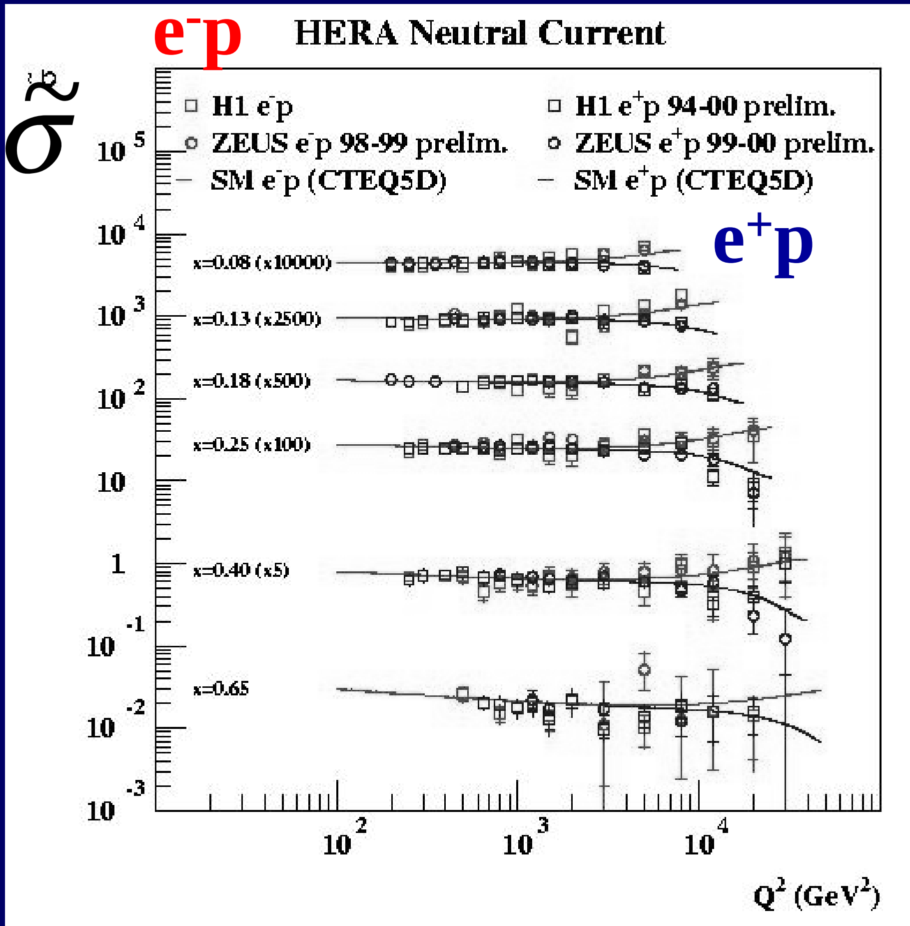
- ZEUS fits to data with $Q^2 > 2.5$ GeV^2
- Then extrapolate back to lower Q^2
- The fit does not describe the data – when using the existing parameterizations – below ~1.5 GeV^2



- Clearly see effect of W/Z exchange in cross sections at high Q^2
- Standard Model shows good agreement over 6 orders of magnitude
- QCD + EW effects completely explain data
- These cross sections are sensitive to individual quark flavors



cross sections"



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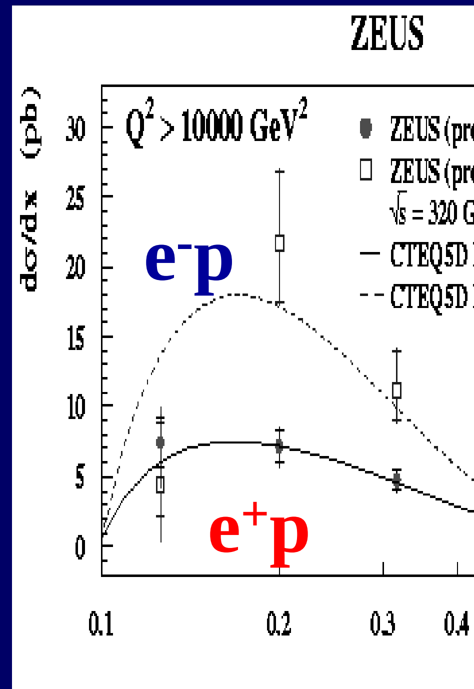
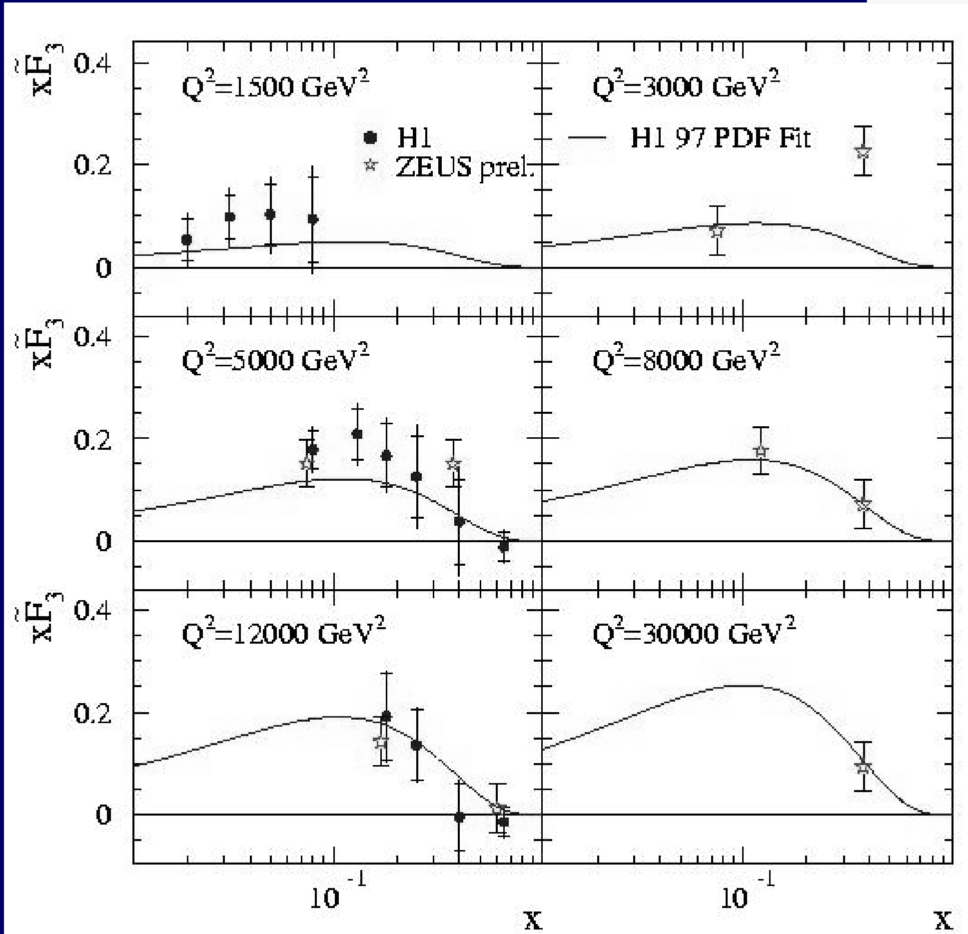
- e^-p has ***CONSTR***
  γ - Z interference
- e^+p has ***DESTRU***
  γ - Z interference



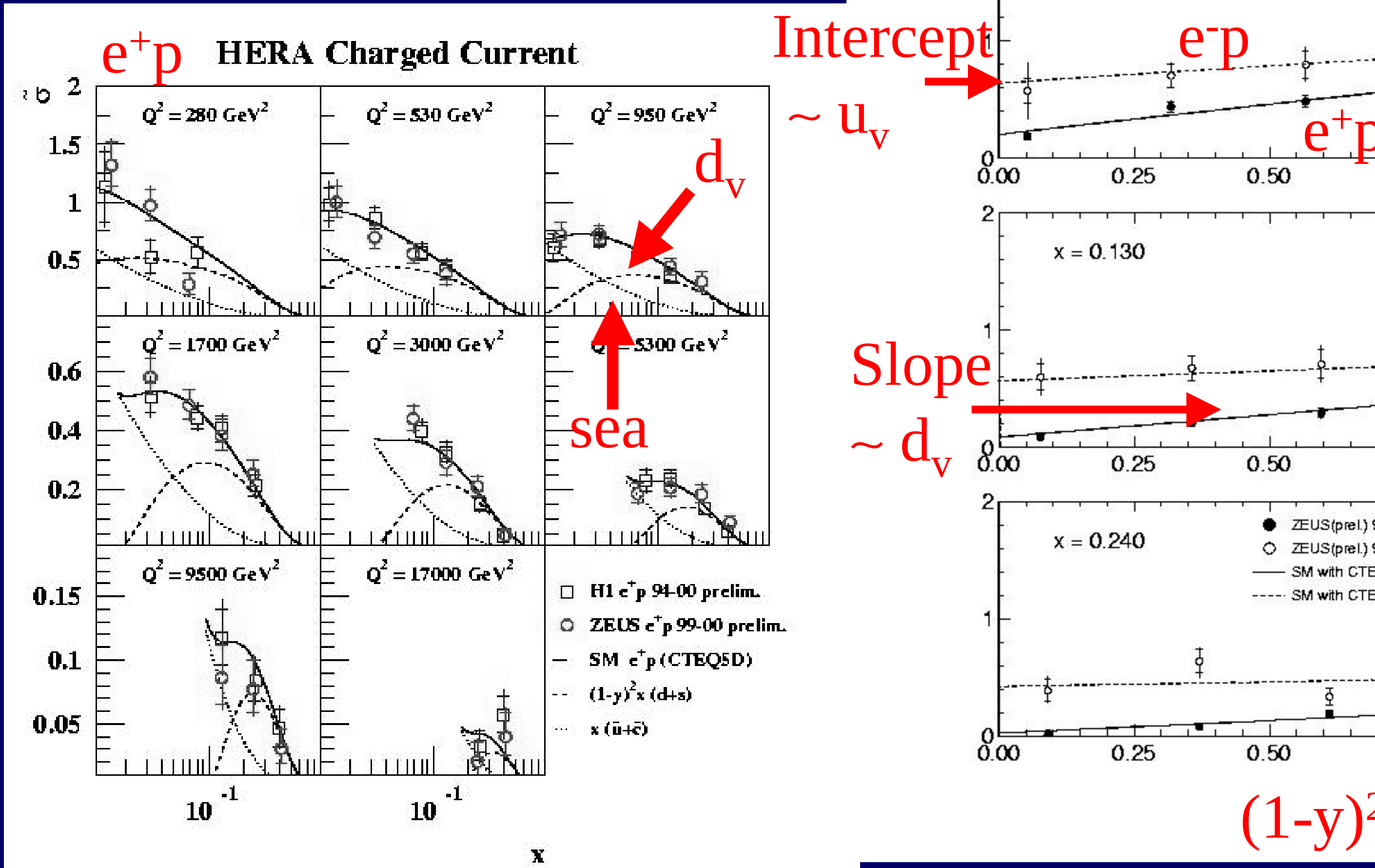
densities: xF_3

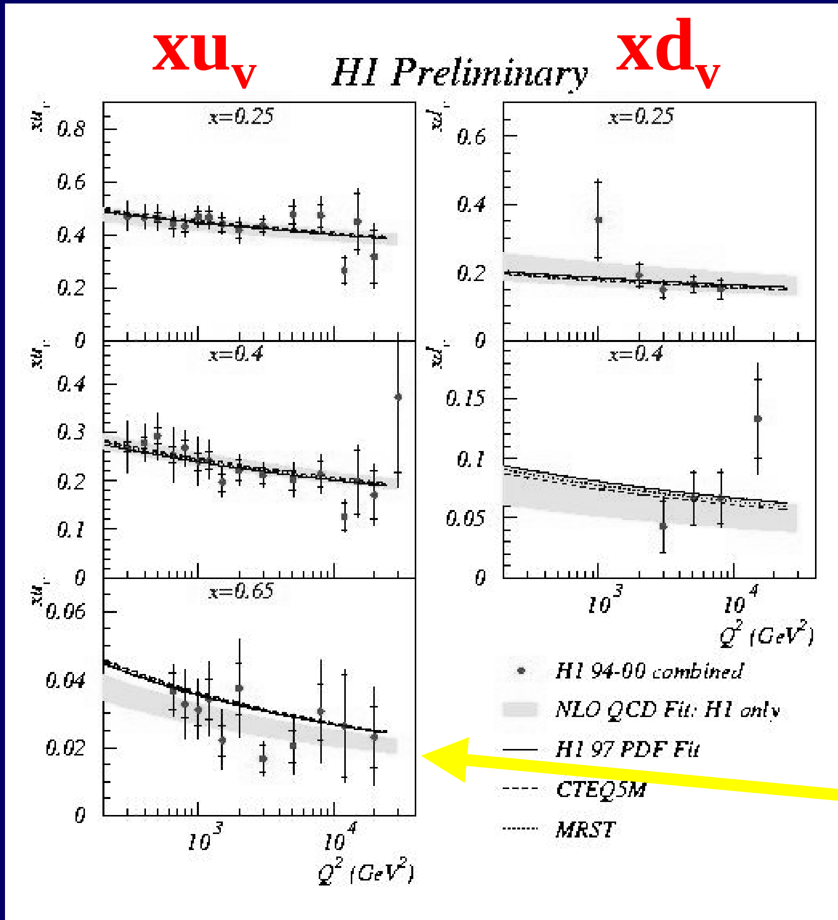


- Consistent wi
  expectations a
  Q^2
- Limited statis
  precision
- Need HERA I

$$\tilde{\sigma}_{CC} \approx x \cdot \left[\bar{u} + \bar{c} + (1-y)^2 (d+s)\right] \quad \text{for } e^+p$$

$$x \cdot \left[u + c + (1-y)^2 (\bar{d} + \bar{s})\right] \quad \text{for } e^-p$$





- Both H1 and ZE
able to determi
valence quark d
using only HERA
(both medium a
Q^2 data)
- Precision ~10-2
- u_v at high x is ~
lower than that
with fixed targe
(result from H1)

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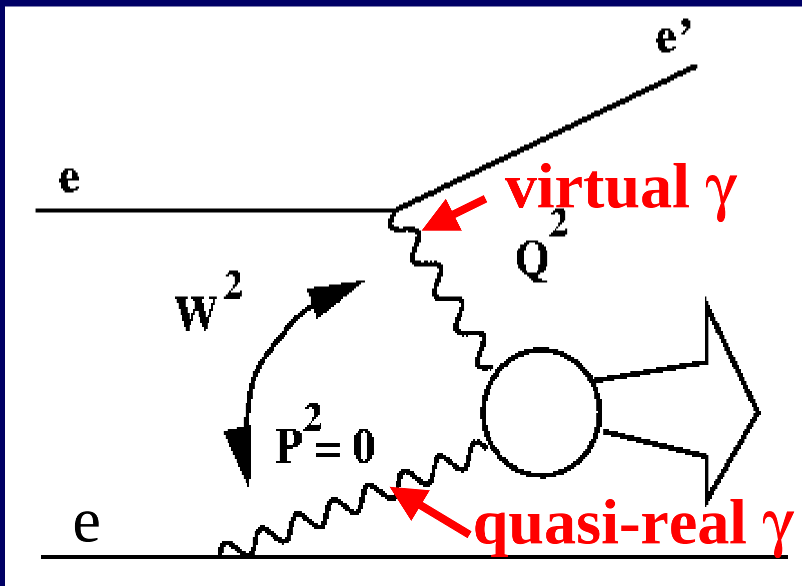
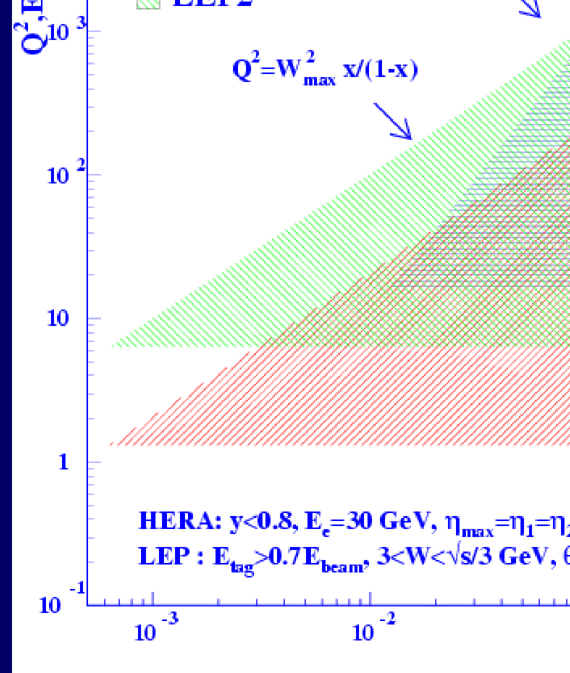
Photon

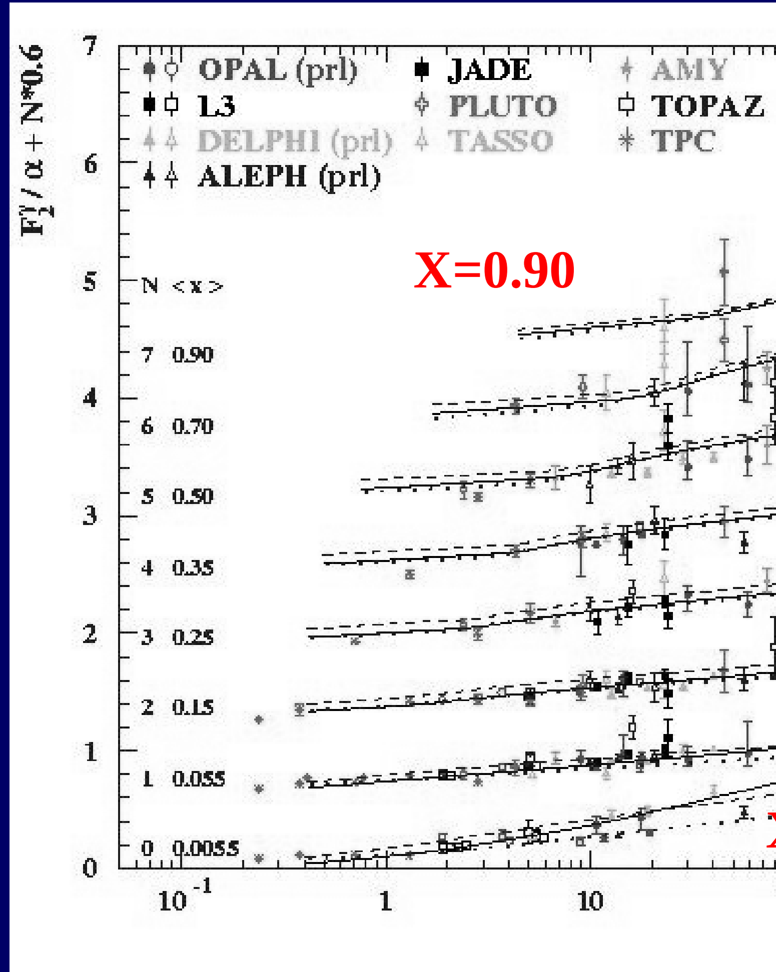
Deep inelastic scattering on a quasi-real photon at LEP





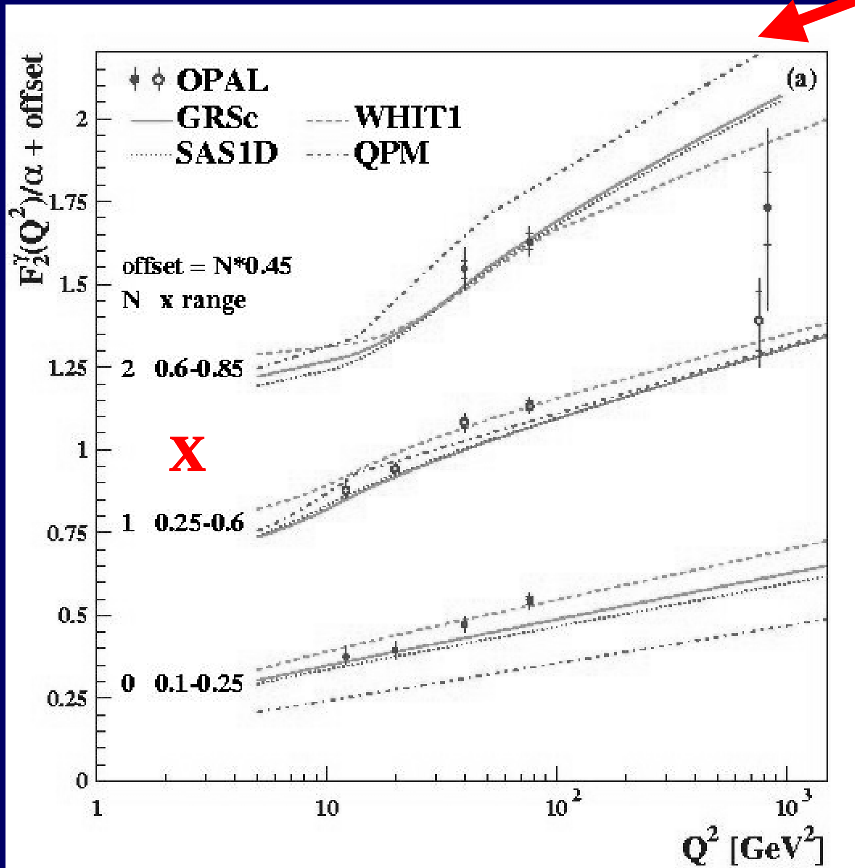
Difficult measuremen large part of the final including the untagge escapes down the bea

- demonstrates positive scaling violation of F_2 as a function of Q^2 for all x
- Agrees with QCD
- This is in contrast to that for the proton, where the positive scaling violations observed at low x turn into negative scaling violations at large x

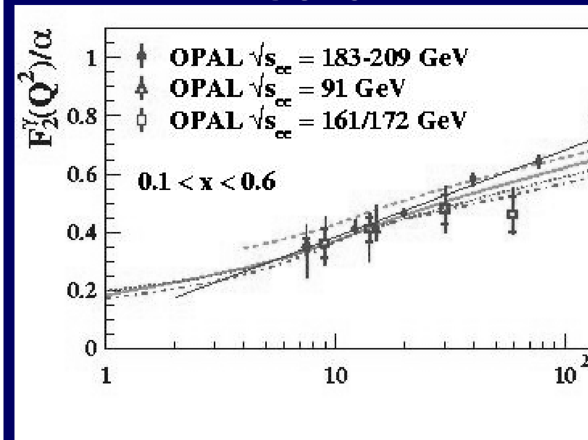


- (Updated Nov. 2001, R.

OPAL (<Q^2>~780 GeV^2)

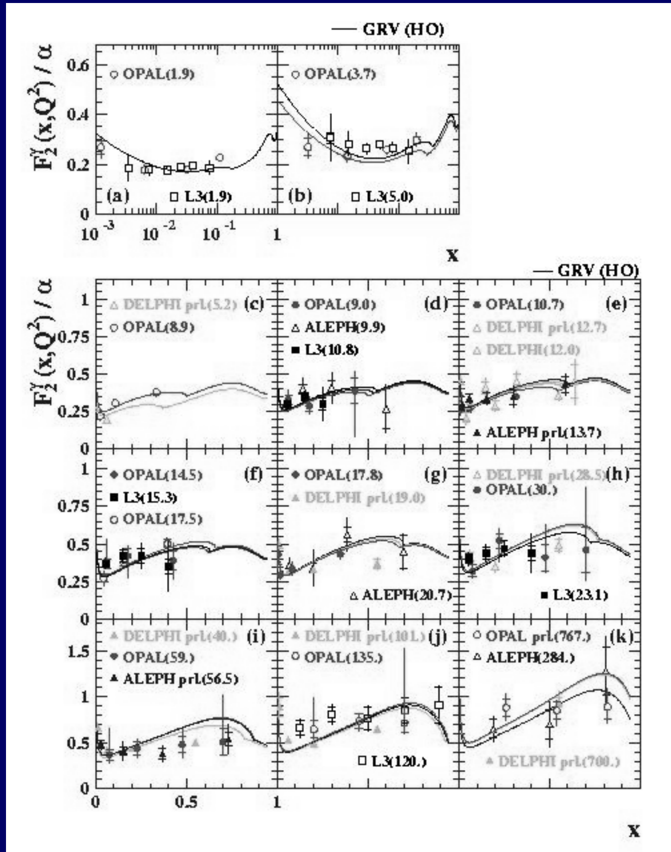


- QPM – only p…
  component –
  disfavored
- Evolution with…
- Integrated ov…
  medium x:

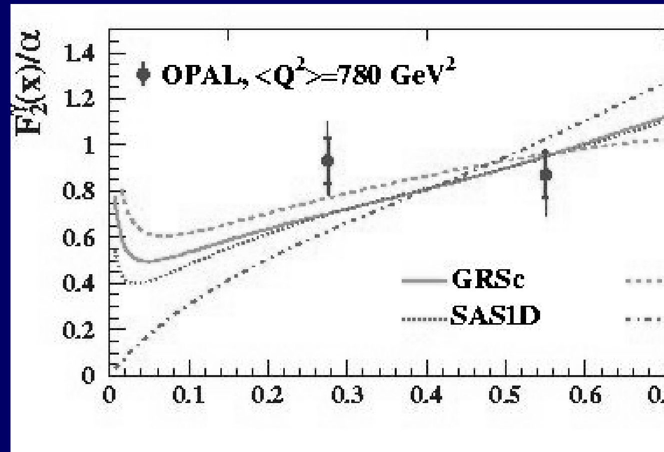


- LO GRSc, SaS1D…
  and GRV-HO are…
  adequate (20%)…

- Is there a rise at small x, as in F_2 for the prot



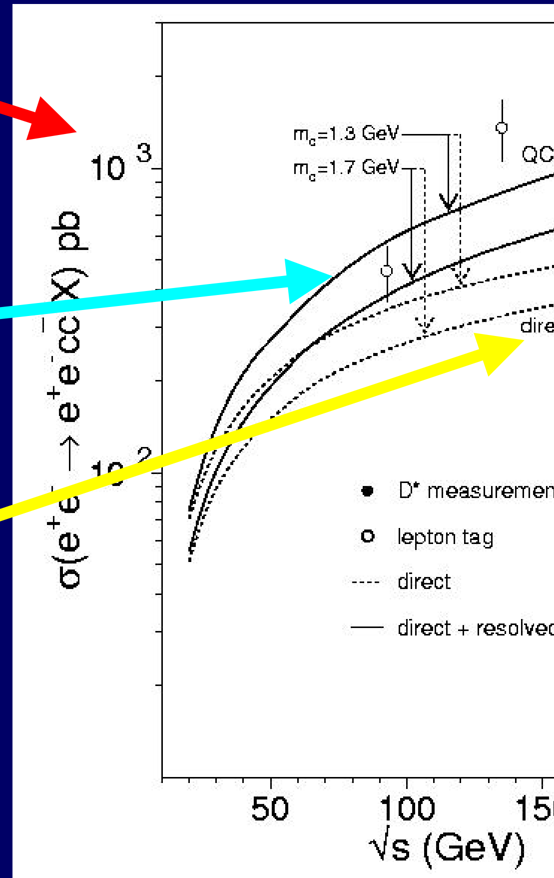
- Final results from



- These data are flat
medium x
- Except for the QPM
PDFs describe the
(20% level)

- (Updated Nov. 2001, R. Nisius)

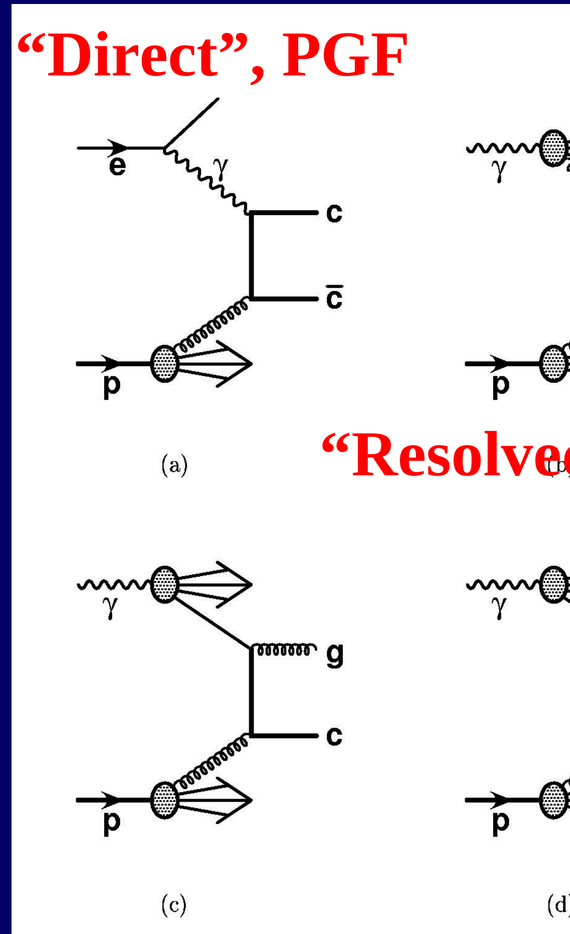
- Cross section for charm production:
- Calculation including the “resolved” photon contribution shows good agreement, while the “direct only” fails to describe the data
- “Evidence for charm in the photon”? Maybe, but the dominant diagram in the single resolved is PGF



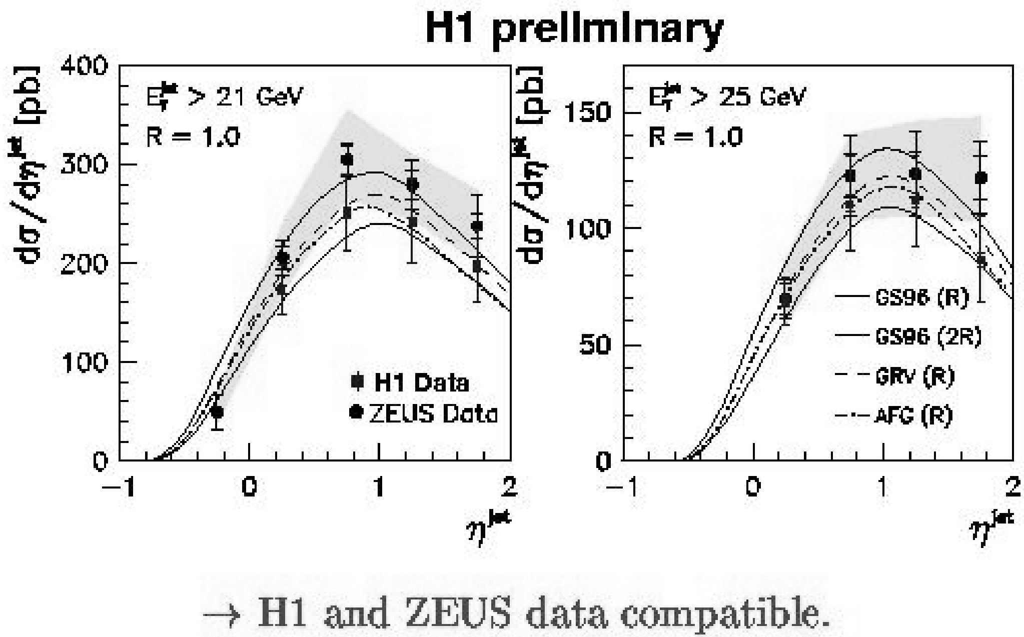
- **Dijet production from LO “resolved” processes in quasi-real photoproduction at HERA**
- **Look** at the angle between the jet-jet axis and the beam in the dijet rest frame, ie cos θ*:

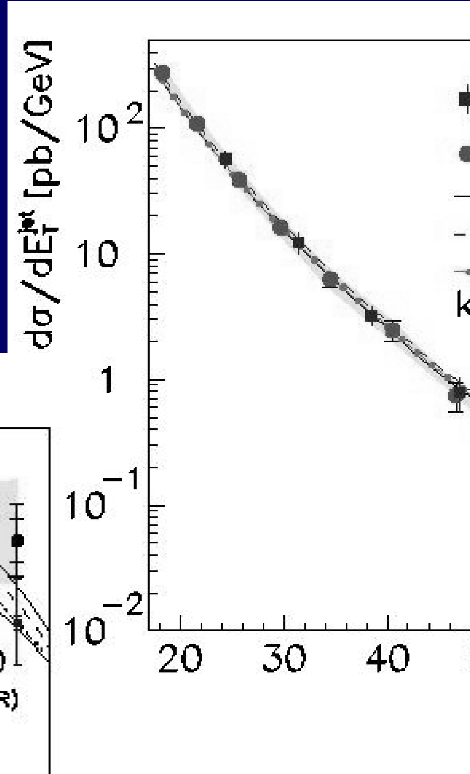
$\cos\theta^* = \tanh[(\eta_1 - \eta_2)/2]$

$$x_\gamma^{obs} = \frac{E_T^{jet1} e^{-\eta^{jet1}} + E_T^{jet2} e^{-\eta^{jet2}}}{2yE_e}$$



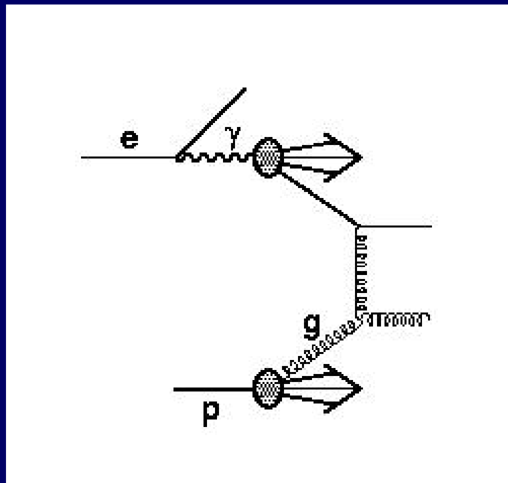
- **Compare H1 and ZEUS data (in the same kinematic regime):**

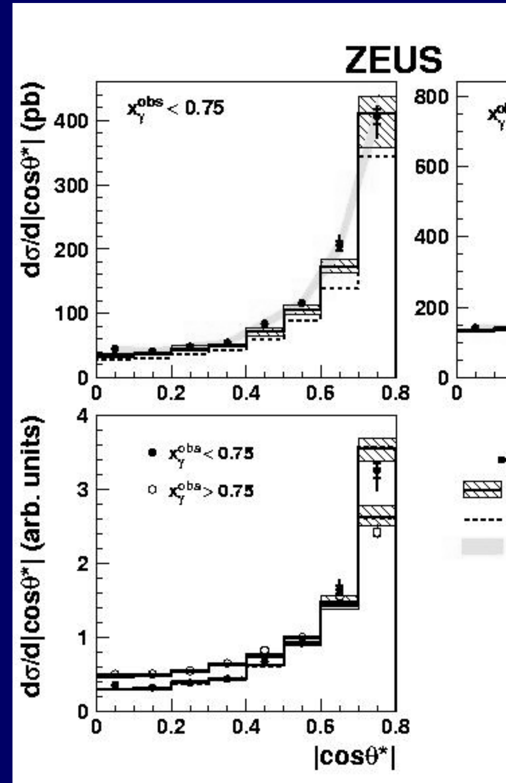




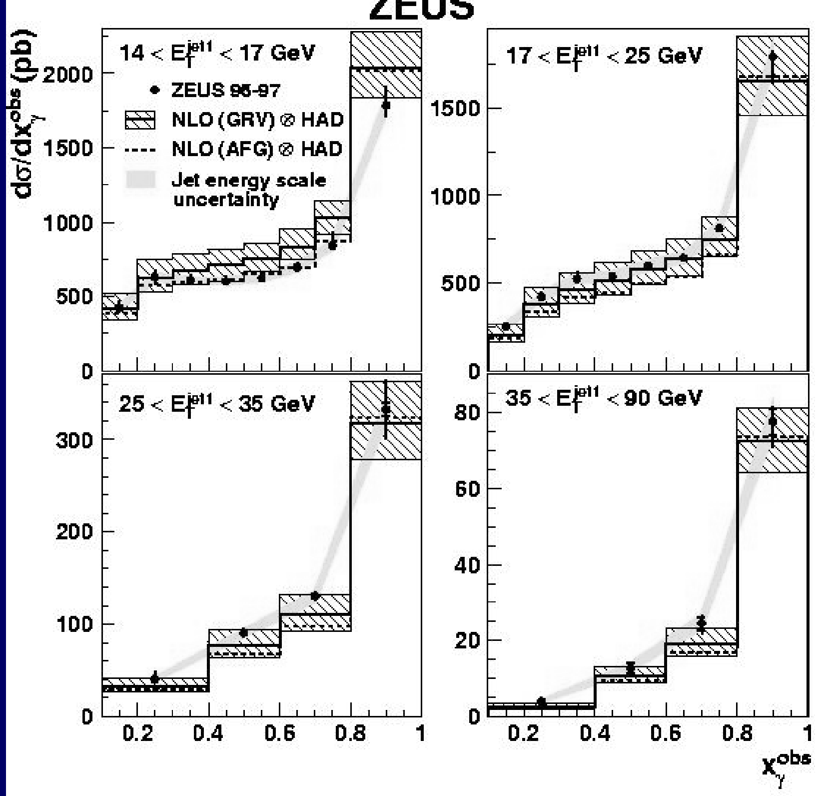
quark prop. $\alpha\ (1-|\cos\theta^*|)^{-1}$

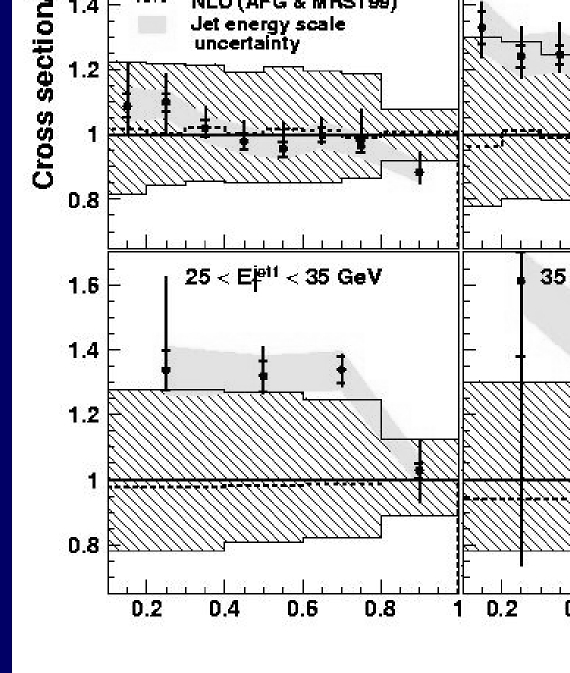
gluon prop. $\alpha\ (1-|\cos\theta^*|)^{-2}$



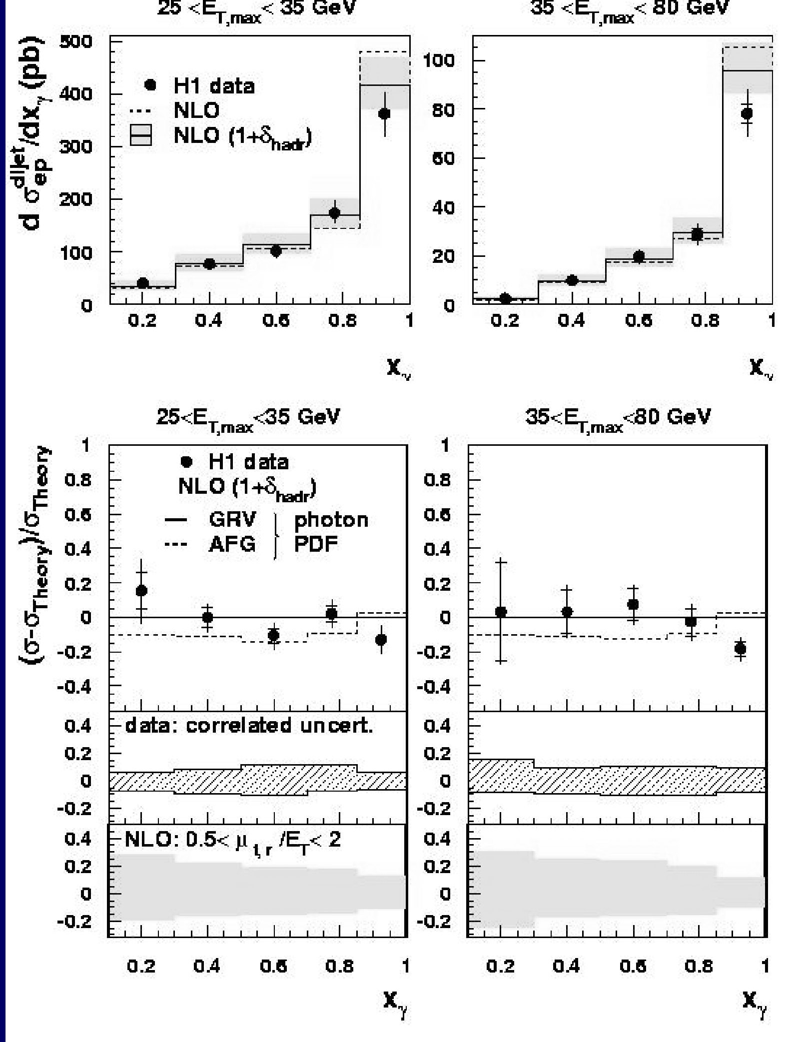


- **The agreement with the NLO calculation shows that the parton-parton dynamics a**





- High x_γ data are well described by NLO
- Low x_γ data are a… NLO, more so at…
- Suggests γ PDFs… quite correct?

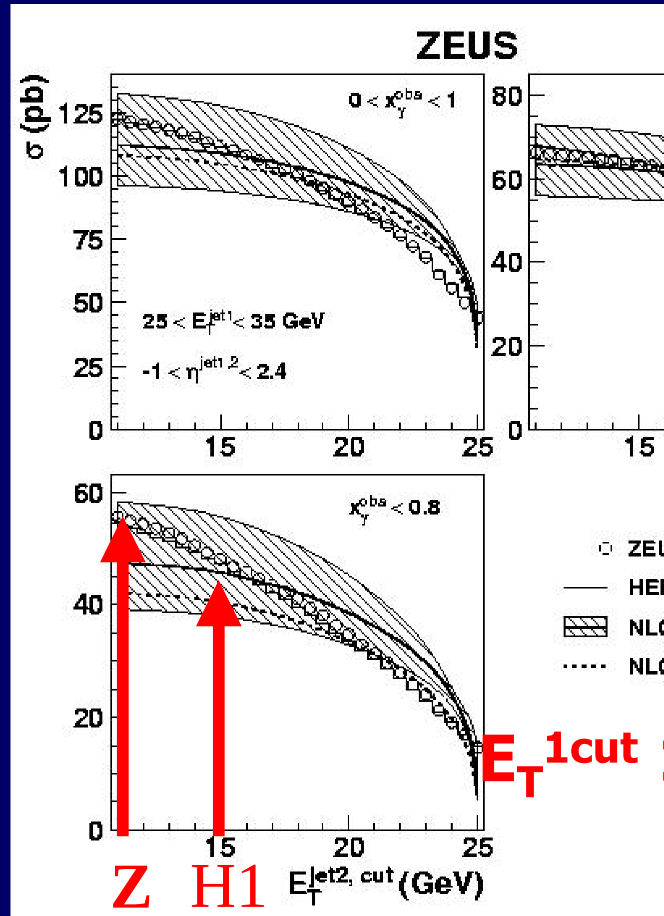


below NLO

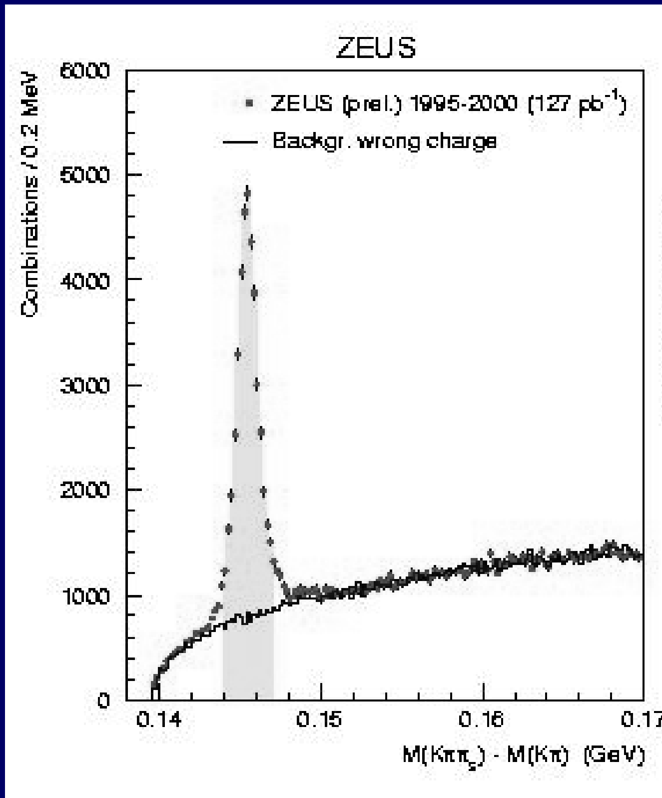
- Low x_γ data are in agreement with N both E_T ranges
- Suggests γ PDFs a
- The PDFs are dete at low scales; the evolution reprodu data at high scale

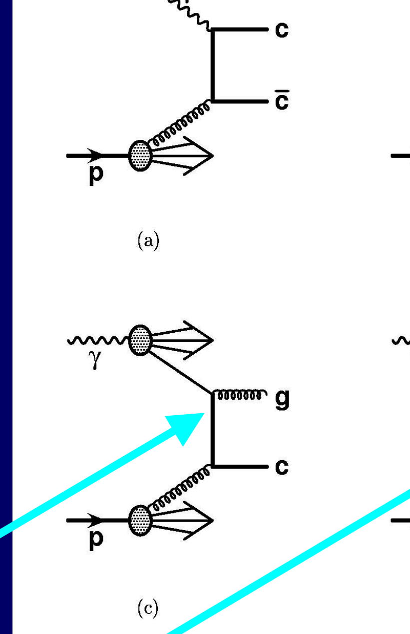
H1 and ZEUS data:

- Can we understand this possible discrepancy?
- H1: $E_T^{1cut} > 25$ GeV
- $E_T^{2cut} > 15$ GeV
- ZEUS: $E_T^{1cut} > 14$ GeV
- $E_T^{2cut} > 11$ GeV
- Maybe?



- D* sample is large; select dijets
- Look at the angle of the jet-jet axis and the beam in dijet frame ie $|\cos \theta^*|$



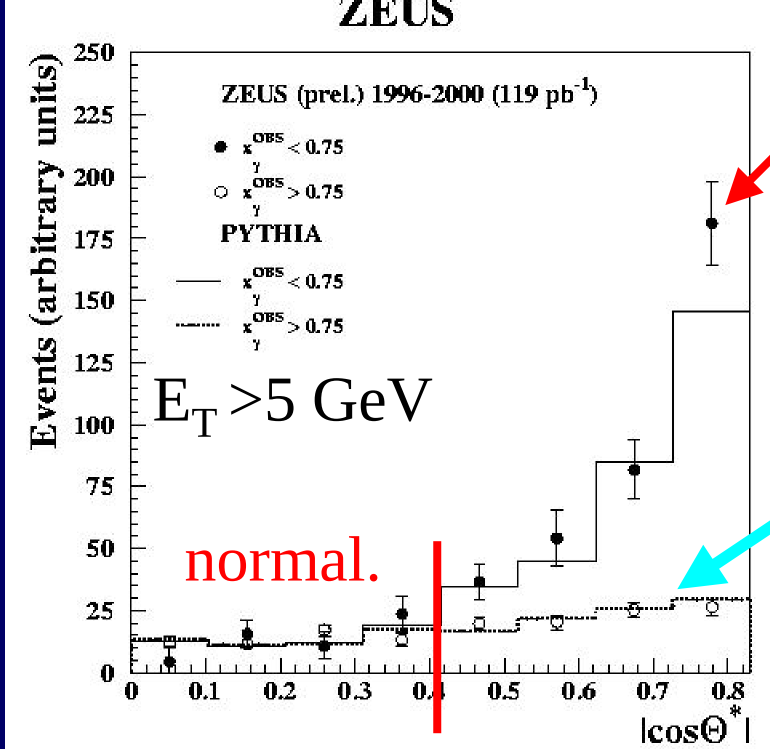


quark propagator α (1-|co

gluon propagator α (1-|co

→ hence the gluon ha

steeper distribution in |co

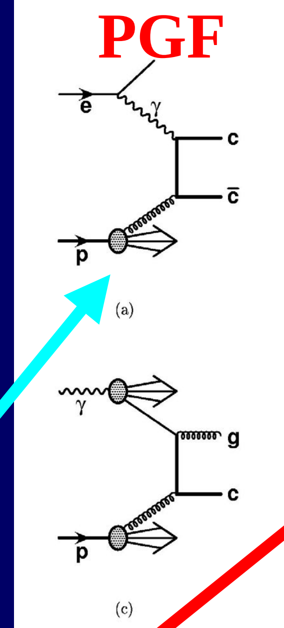


“resolved”

$X_\gamma < 0.75$

“direct”

$X_\gamma > 0.75$



- The “resolved” distrib. is much steeper than “direct”
- → a gluon propagator

- Sugge
  charm in
- (See Padh

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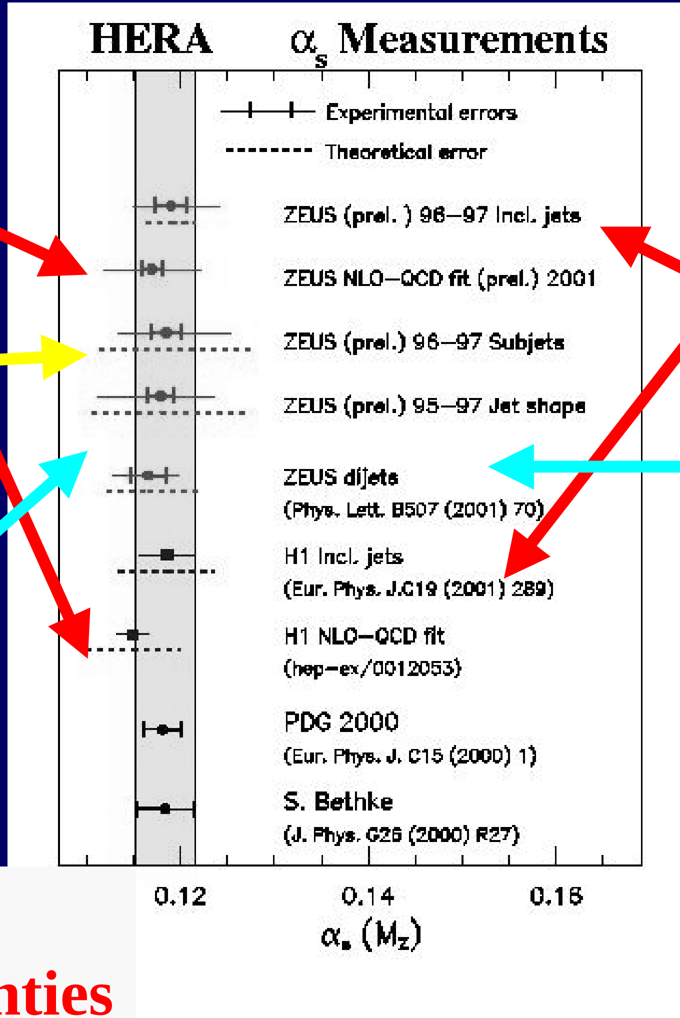
Values as of EPS01:

- From NLO QCD fits
- From numbers of subjets
- From jet shapes



- Fro[…] inclu[…] rate[…]
- Fro[…] rate[…]

Precision limited by theoretical uncertainties

- Progress on proton structure:
  - a) Much effort on uncertainties
  - b) High Q^2 data needs HERA II
- Progress on photon structure
  - a) Final LEP data now coming
  - b) Need new fits to LEP/HERA
- QCD
  - a) Theory uncertainties domina