Recent Results from HERA

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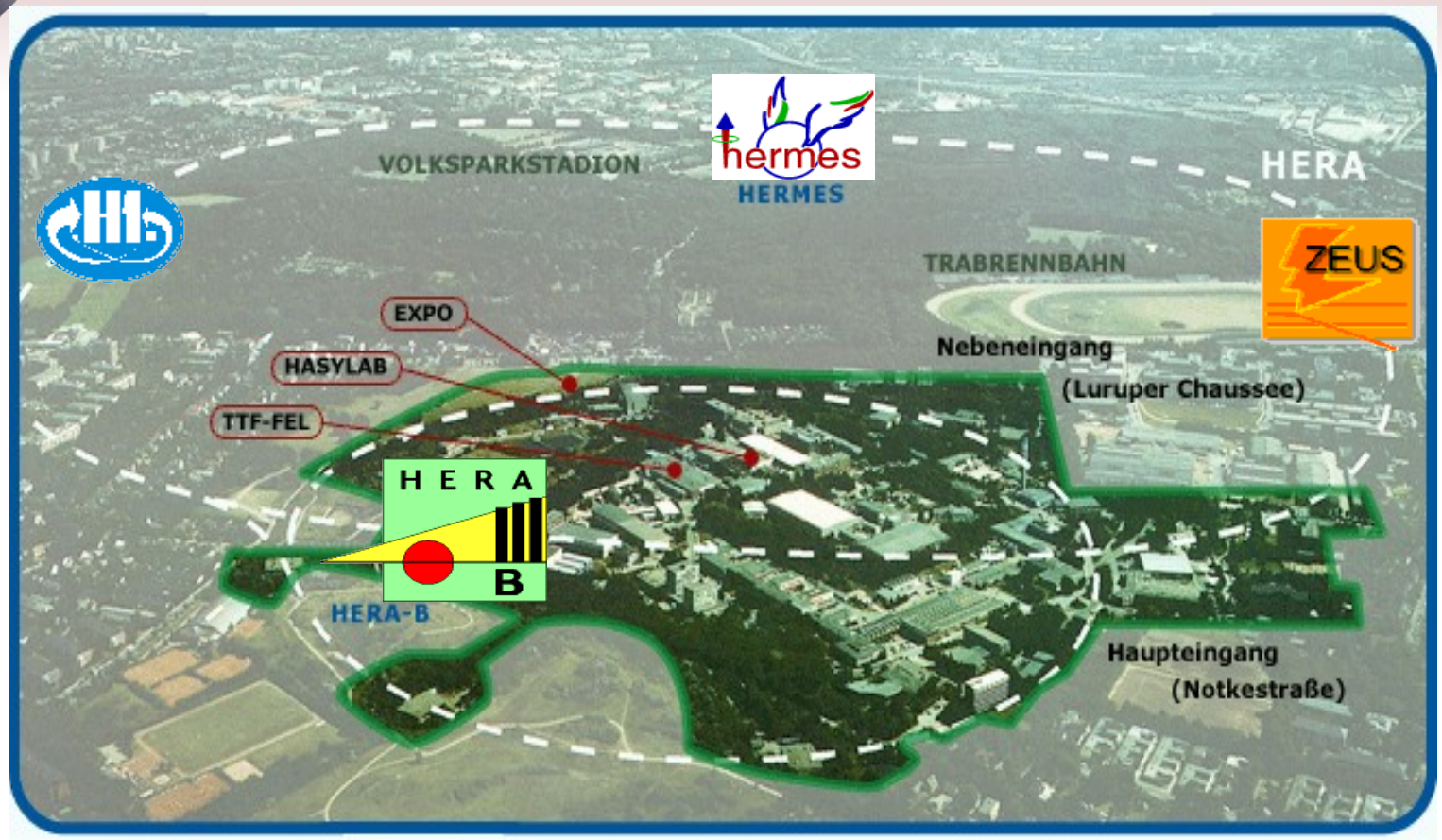
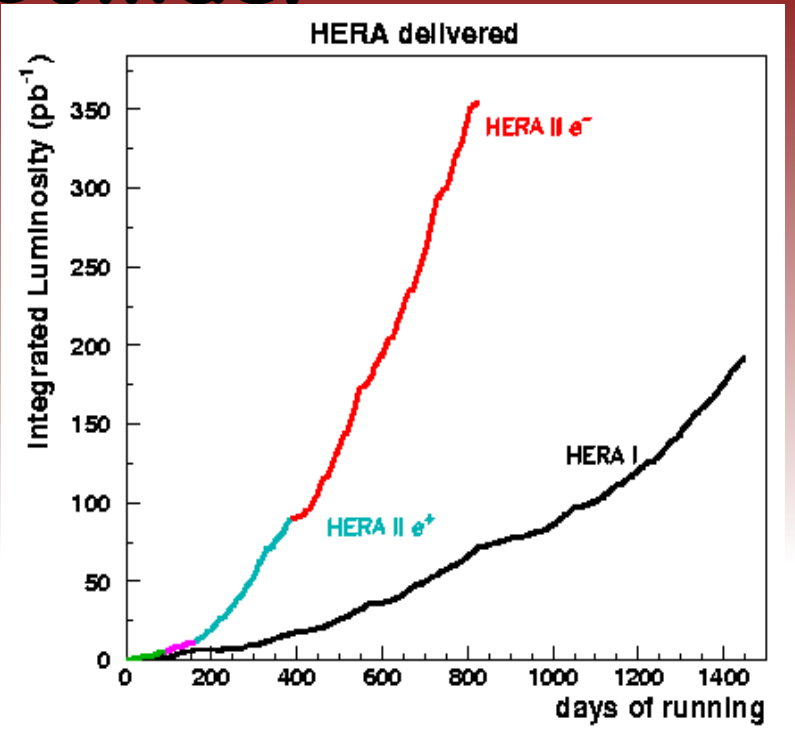
On behalf of H1 and ZEUS Collaborations

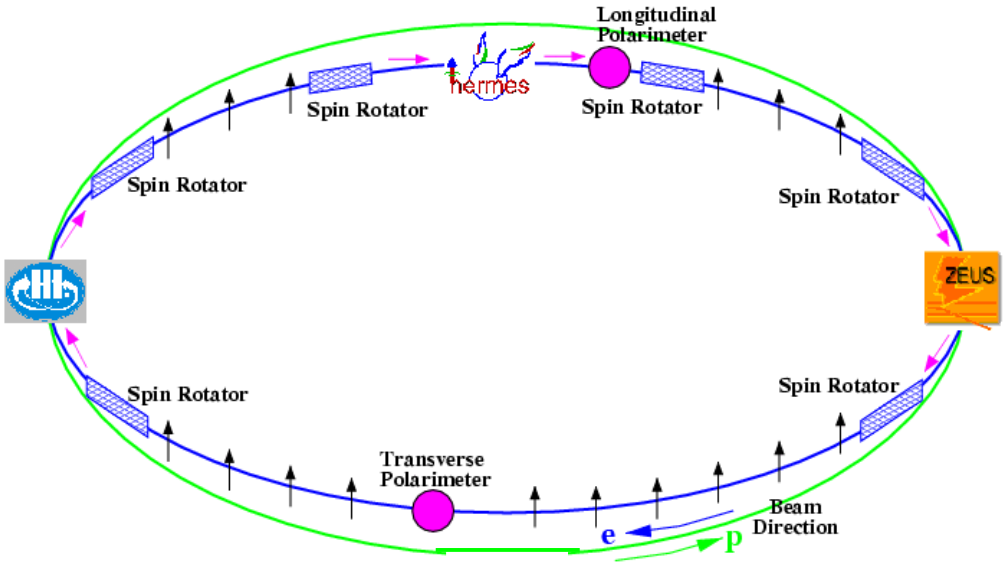


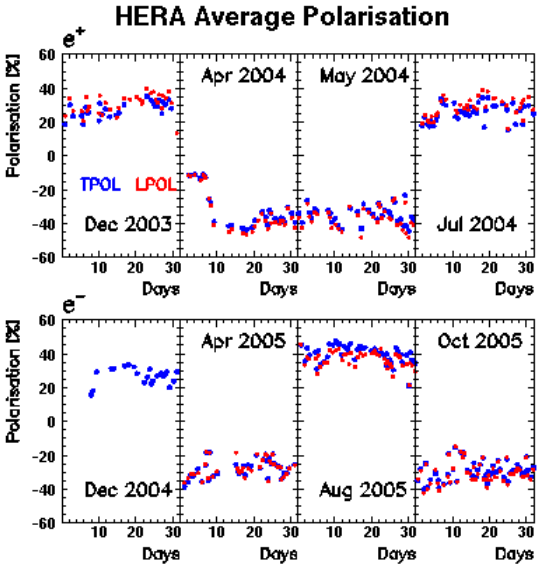
HERA Collider

HERA: ep collider, $\sqrt{s}$ = 320 GeV

- From 2003 (HERA II) polarised lepton beam
- mid 2007: end of machine operation
  - expected luminosity: ~700 pb^{-1}

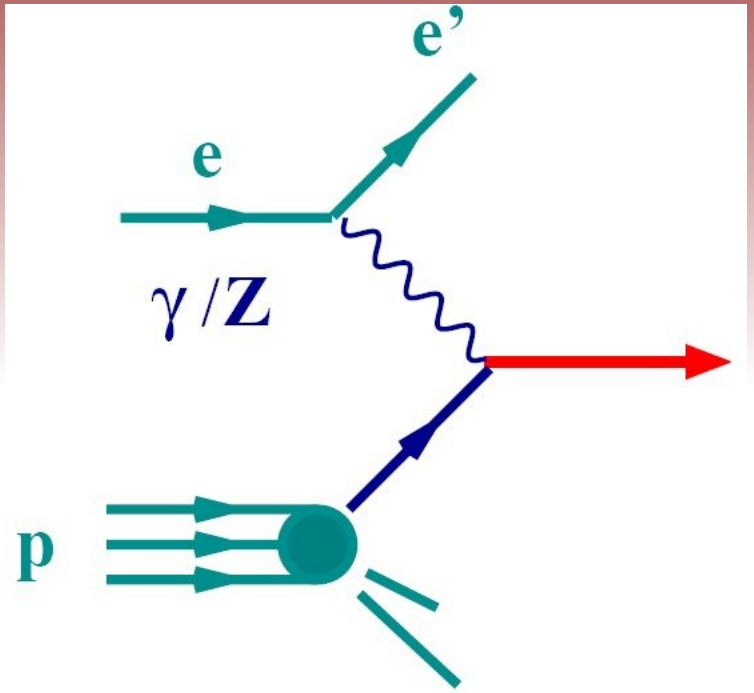






HERA Physics

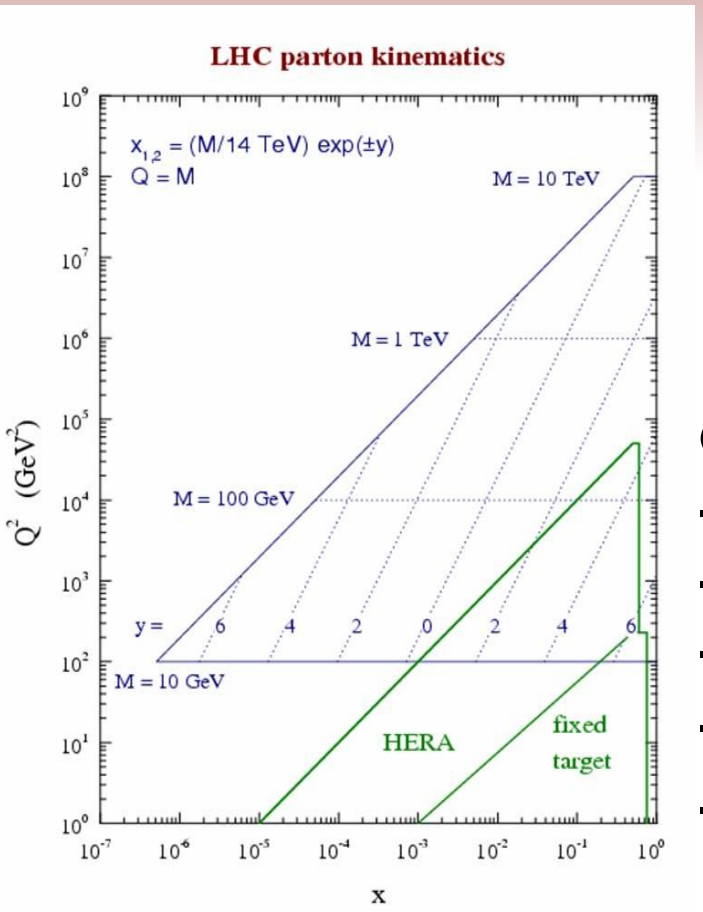
- **HERA: multipurpose collider…**
- **…but mostly a QCD-machine**
  - **ideal machine to make precision QCD studies and test new QCD predictions**



$$Q^2 = -q^2 = -(k - k')^2$$

$$x = \frac{Q^2}{2p \cdot q} \qquad y = \frac{p \cdot q}{p \cdot k}$$

$$s = (p + k)^2 \qquad Q^2 = x \cdot y \cdot s$$

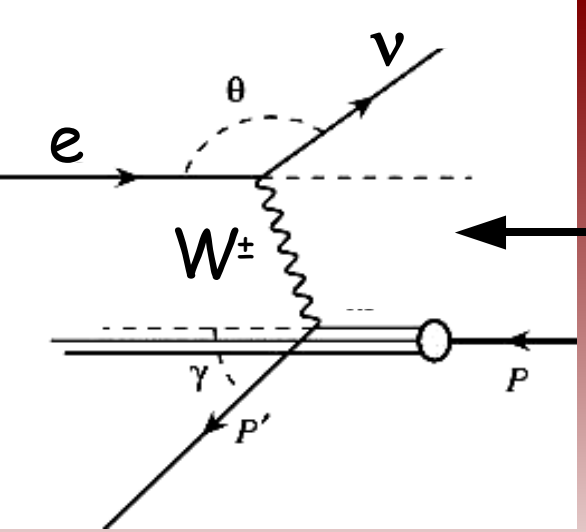


Covered in this talk:

- **Proton PDF**
- **Diffractive PDFs**
- **Heavy Flavour PDFs**
- **Jets & α_s extraction**
- **Searches for new physics**

Not covered – lots of great physics…

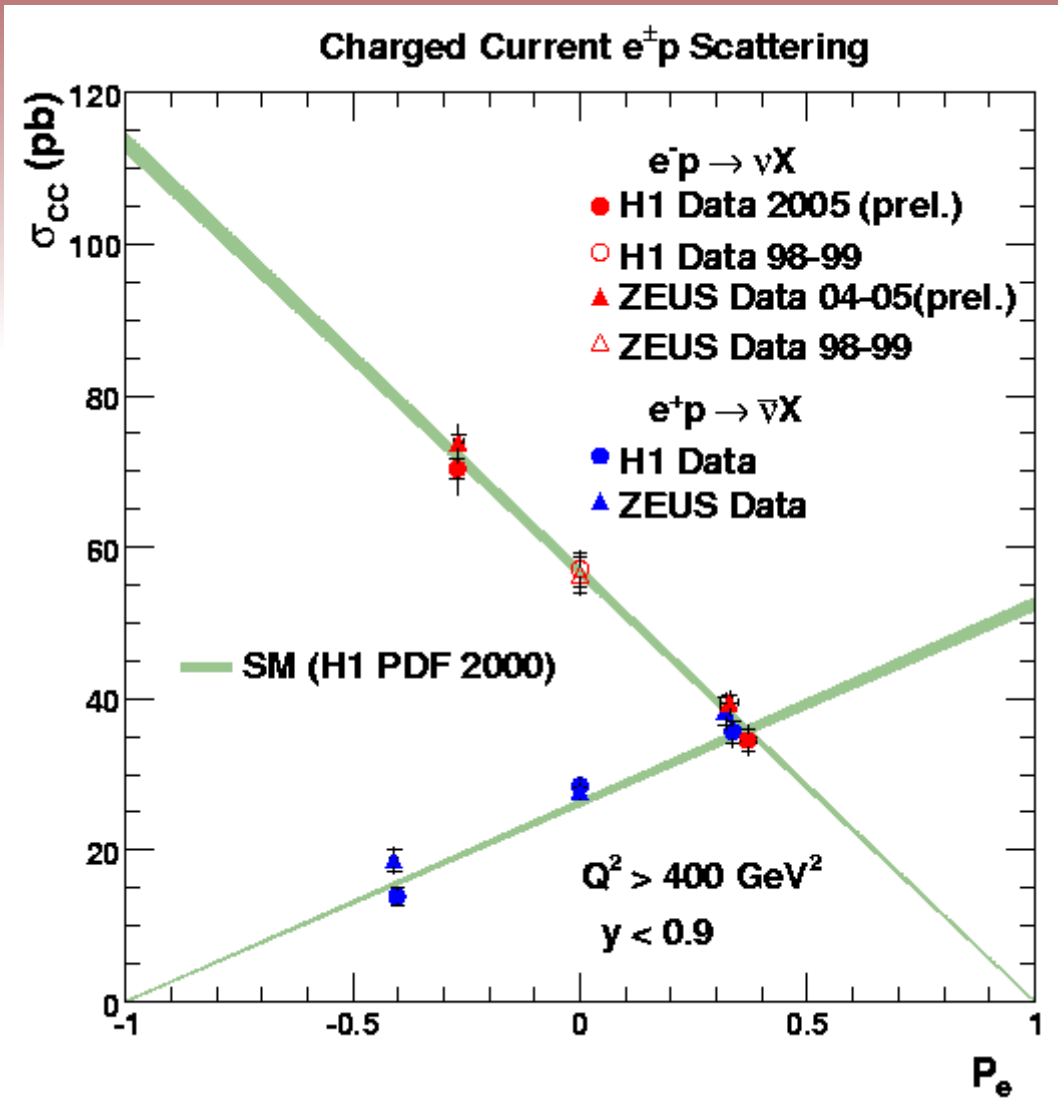
HERAII: Polarized CC DIS



in SM for electrons only left-handed CC cross section expected

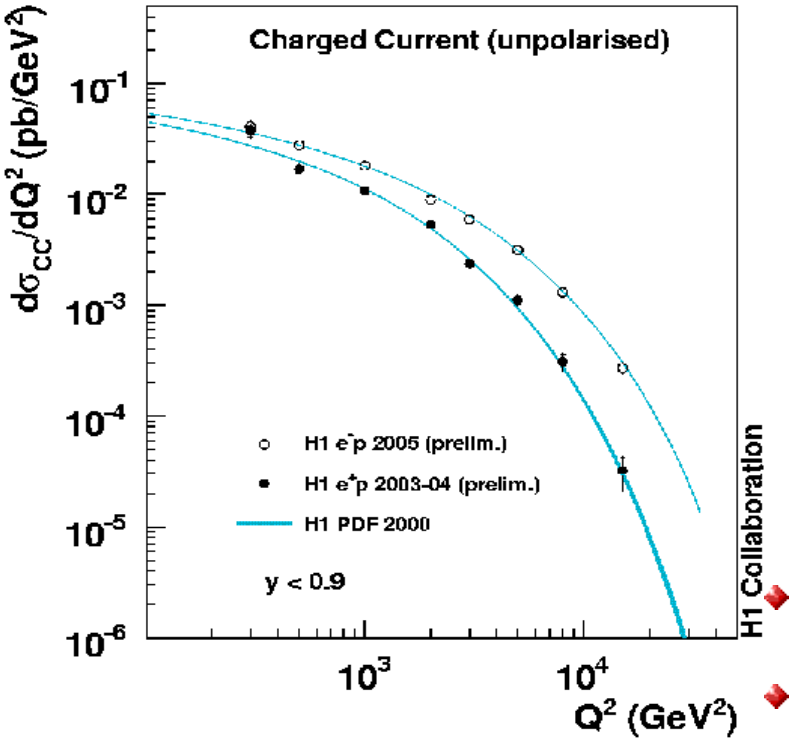
- **CC DIS cross section measured as a function of polarization of lepton beam**
- **SM linear relation between cross section and polarization clearly seen**
- **good agreement between experiments and between data and SM**
- **Right-handed CC DIS cross section consistent with zero**
- **W_R limits @ 95% CL:**

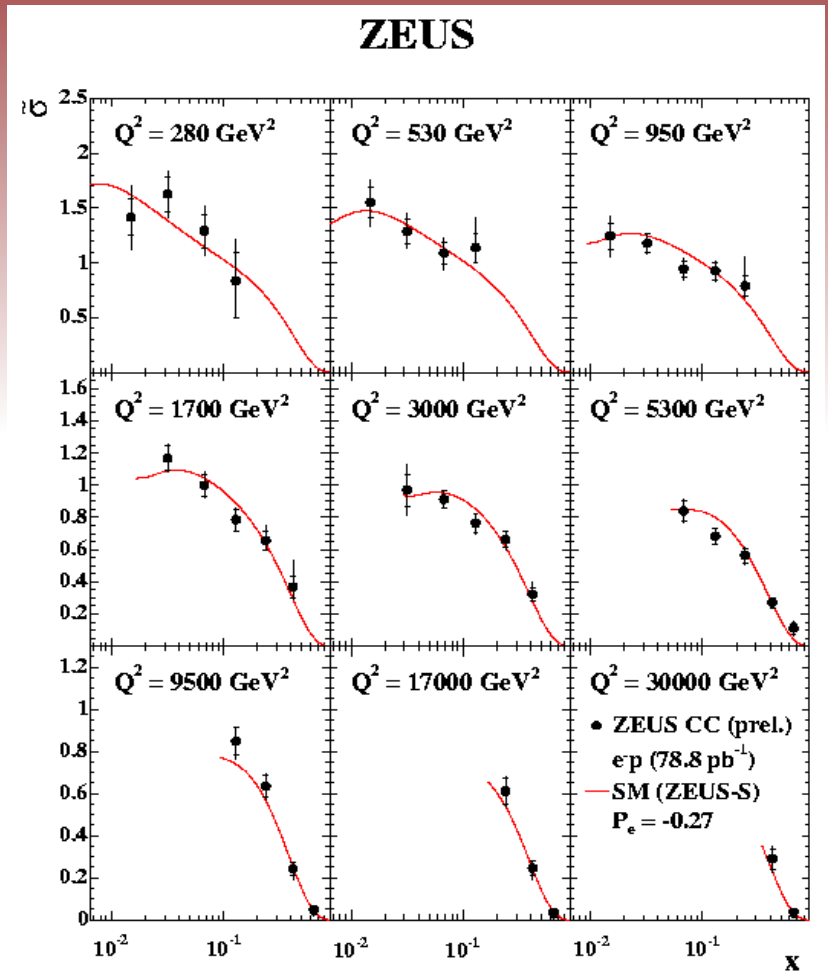
H1: $M(W_R) > 186$ GeV, ZEUS: $M(W_R) > 180$ GeV



HERAII: Polarized CC DIS

- **Single and double differential cross sections measured by both experiments**
- **Good agreement with SM predictions**

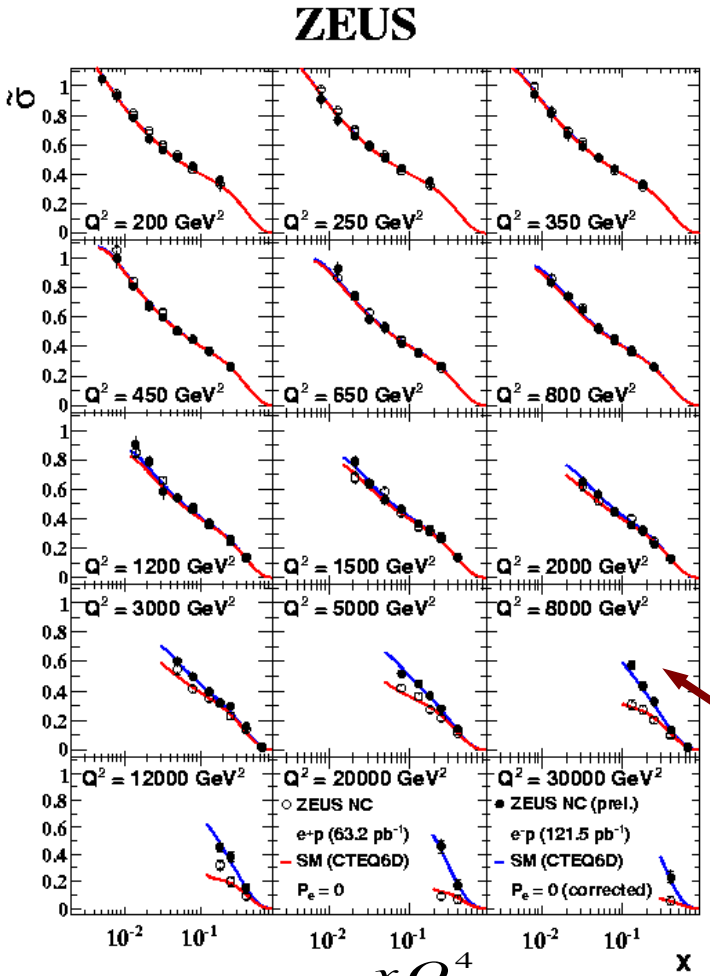




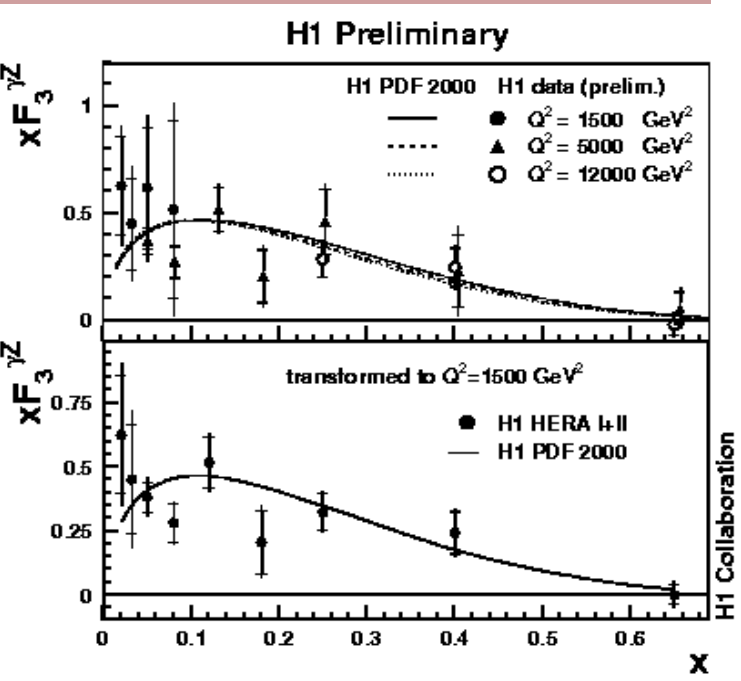
- **Much larger statistics than before**
- **Results bring better understanding of PDFs**

HERAII: xF_3 Determination

at high Q^2 σ_{NC} differs significantly for e^+p and e^-p

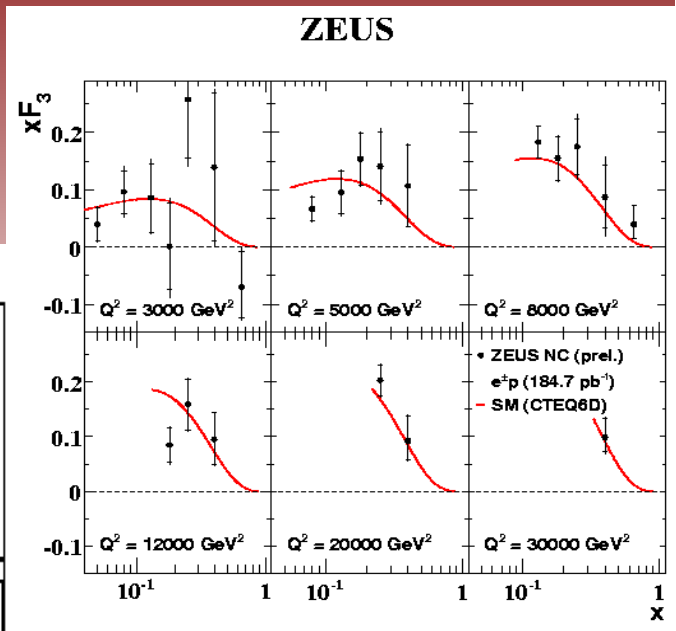


$$\tilde{\sigma} = \sigma \frac{x Q^4}{2\pi\alpha^2}$$



$$\sigma^{e\text{-}p}_{NC} - \sigma^{e+p}_{NC} \sim xF_3$$

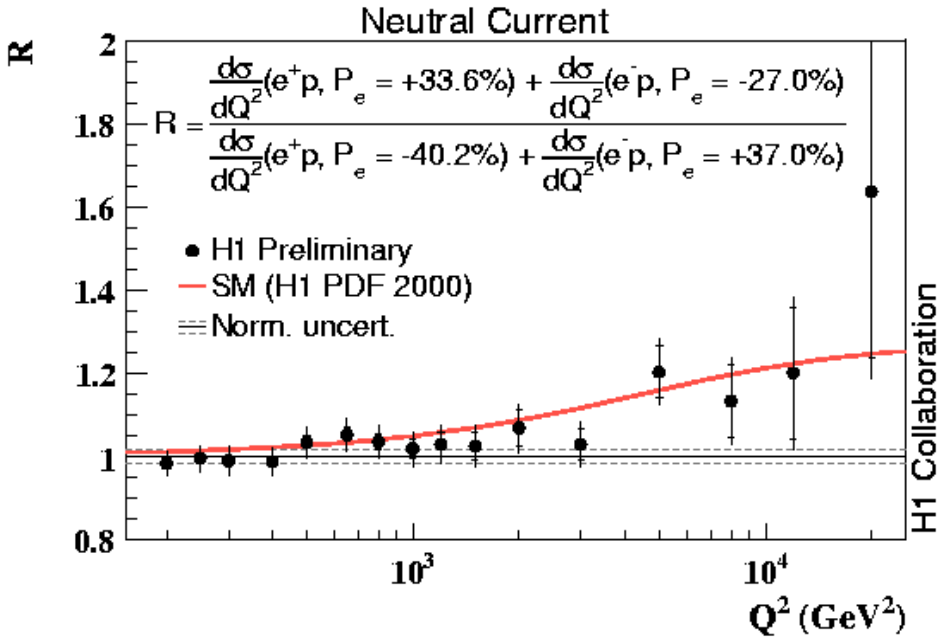
$$xF_3 \propto \sum_q x(q - \bar{q})$$

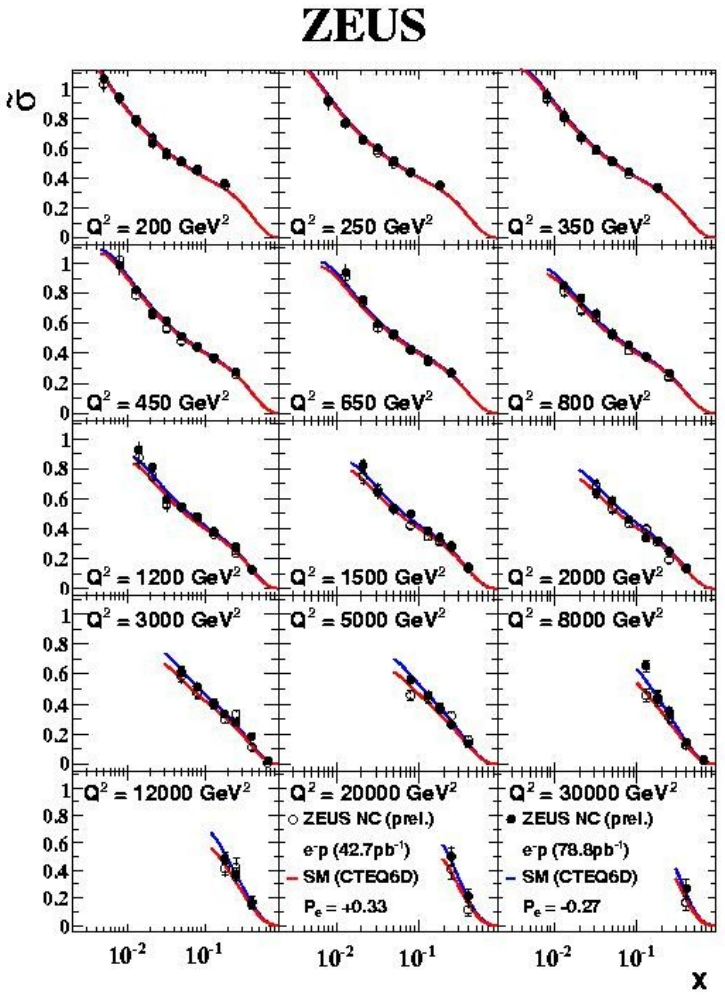


- **xF3 constrains valence quarks in p**
- **improved statistics**
- **agreement with global PDFs**

HERAII: Polarized NC DIS

- **Parity violation observed at high Q^2** (through γ-Z interference and pure Z-exchange)
- **EW parameters (quark couplings to Z, $\sin\theta_W$, M_Z) accessible through γ-Z and Z terms**

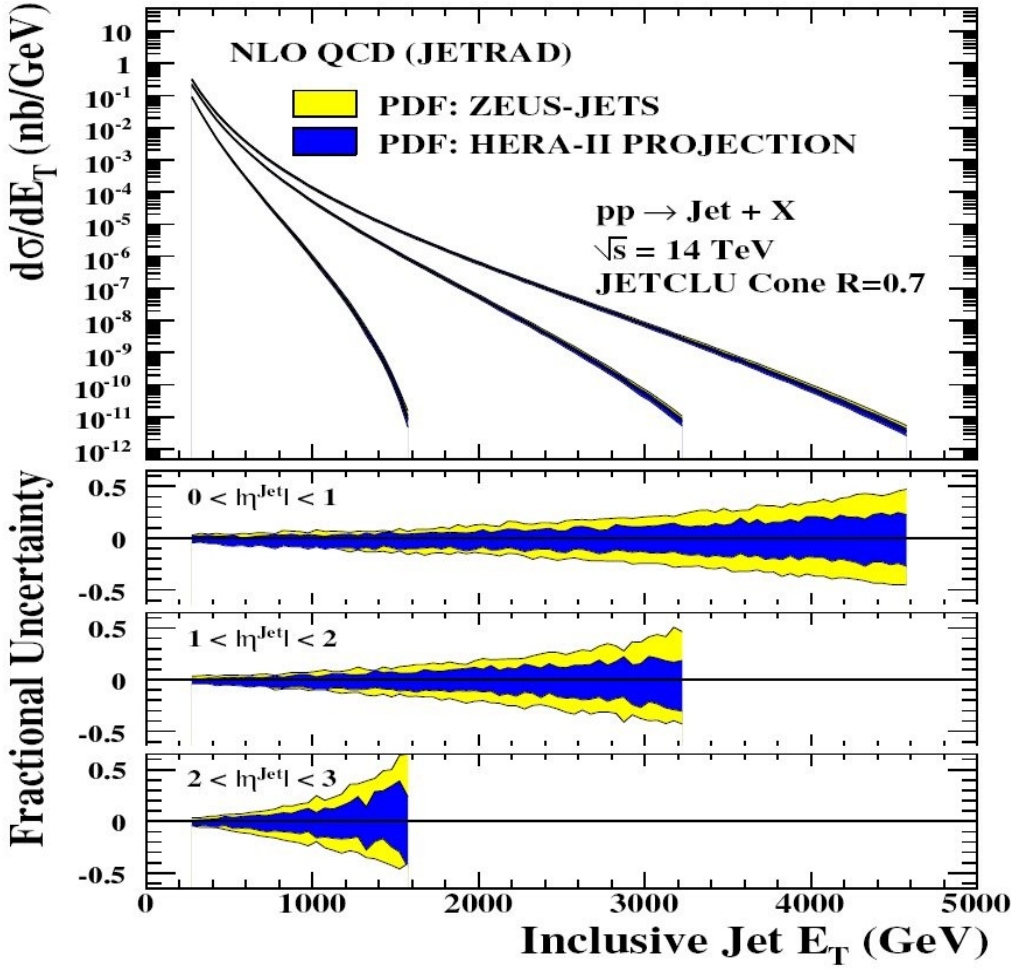




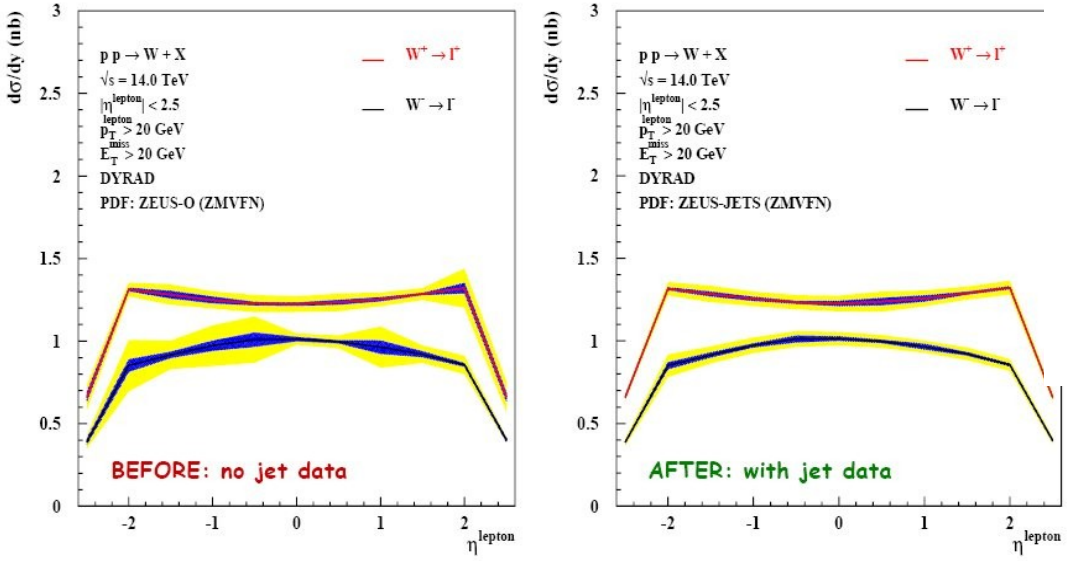
Results bring better understanding of PDFs

QCD Fits with HERAI Data

- **Jet data included in fits in rigorous way**
- **Fits within single experiment!**
- **Expected significant impact on LHC measurements**

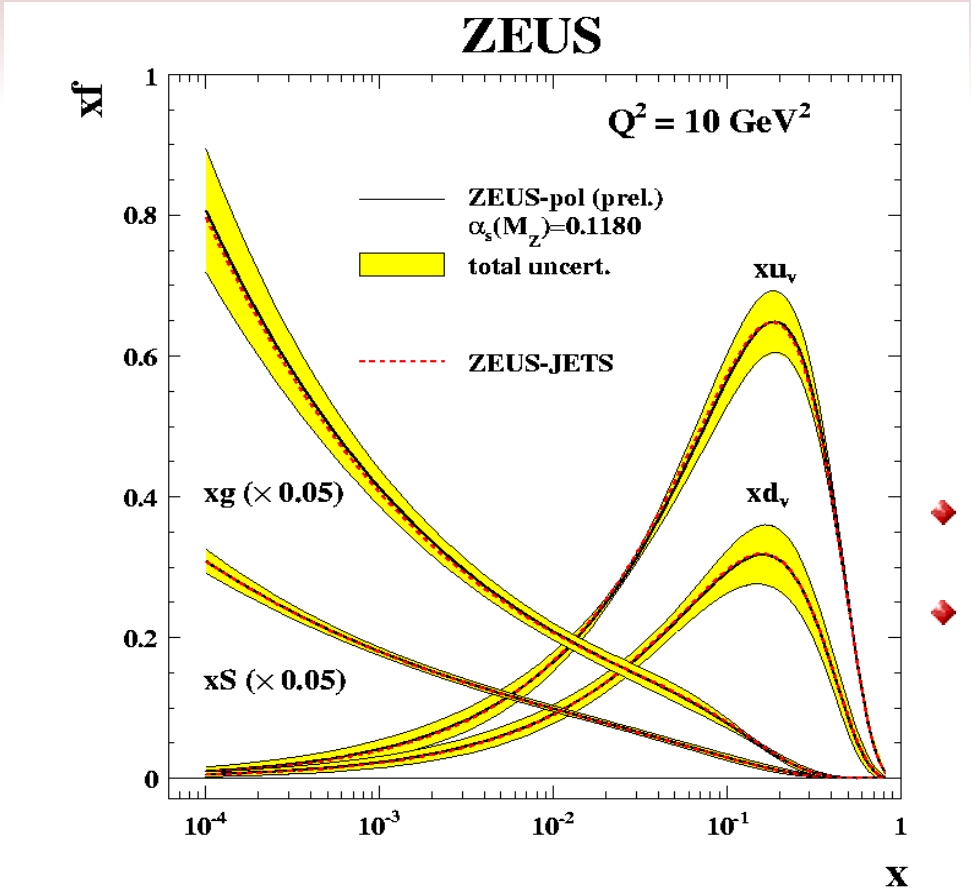


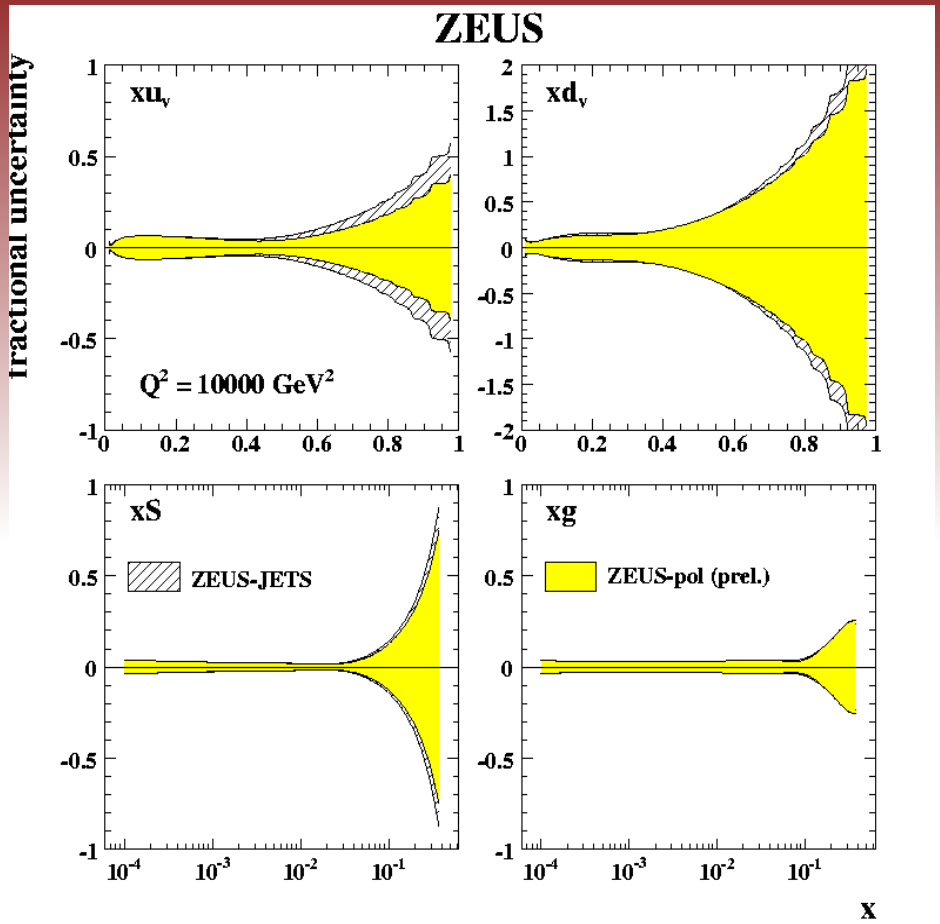
W± production (plots from Kunihiro Nagano)



QCD Fits with HERAII Data

- **First QCD fits with HERAII polarized data**
  - **04-05 polarized e^-p NC&CC inclusive cross sections**





- **Central values almost unchanged**
- **Uncertainties reduced – high x and xu_v quark**

$$\sigma_{NC} \propto (4u+d), \quad \sigma_{Cc}^{e-p} \propto u$$

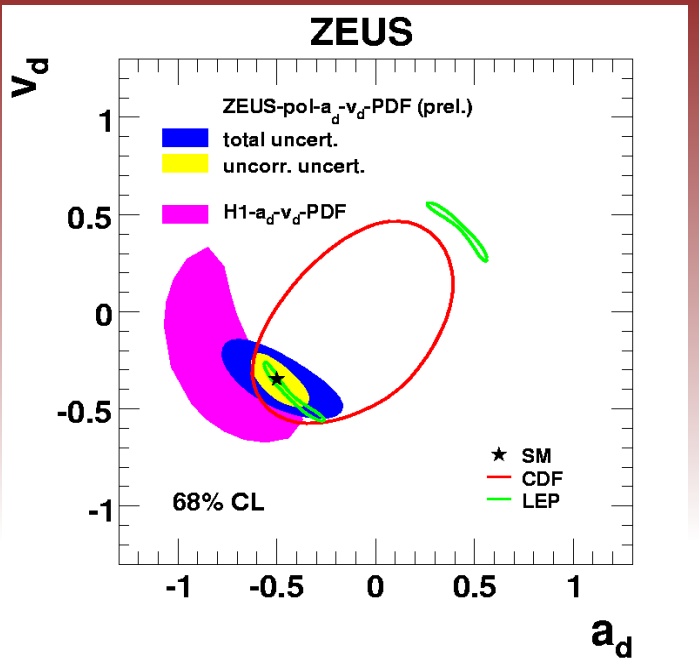
- **Also at v. high Q^2 - good news for LHC**

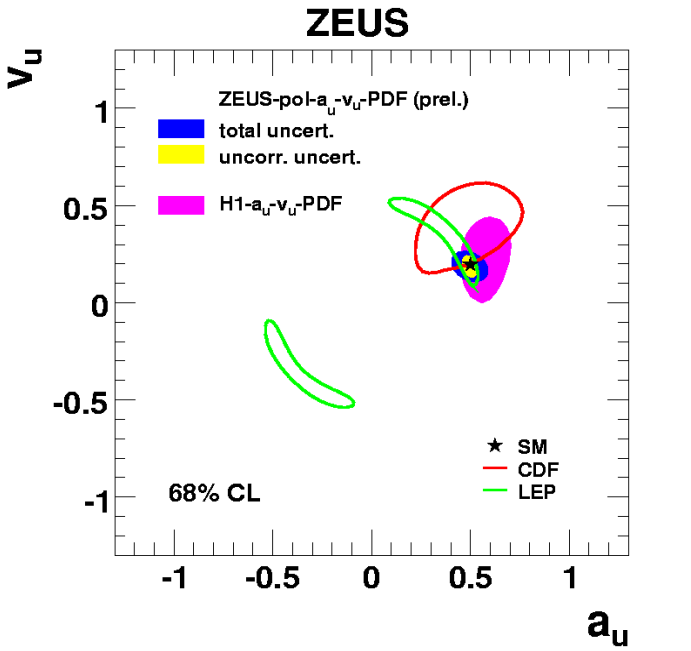
Combined QCD & EW Fits

- Polarization gives direct sensitivity to EW
- In global fit EW parameters and PDFs are determined simultaneously (correlations taken into account)
- from 4 parameters 2 constrained and 2 fitted
- ZEUS EW fit gives excellent constrain on quark couplings (best or comparable), other fits as well
  - well consistent with SM
- M_W determined as well

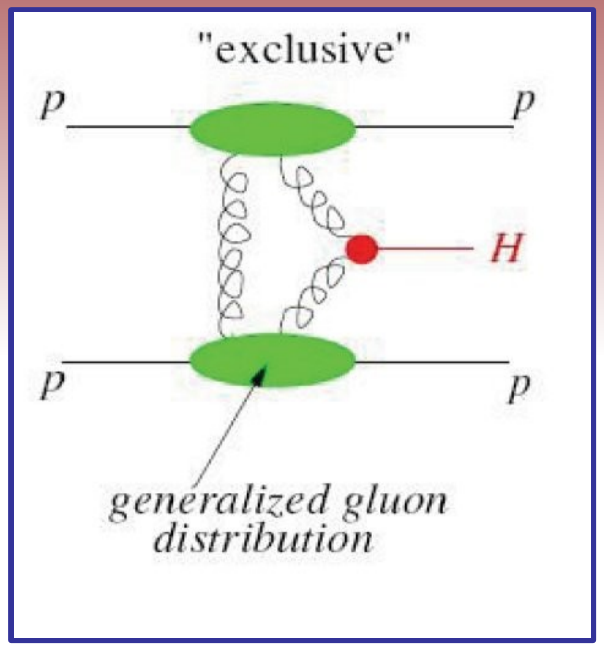
$M_W = 79.1 \pm 0.77$ (stat +uncorr) ± 0.99 (corr.sys.) GeV (ZEUS prel.)

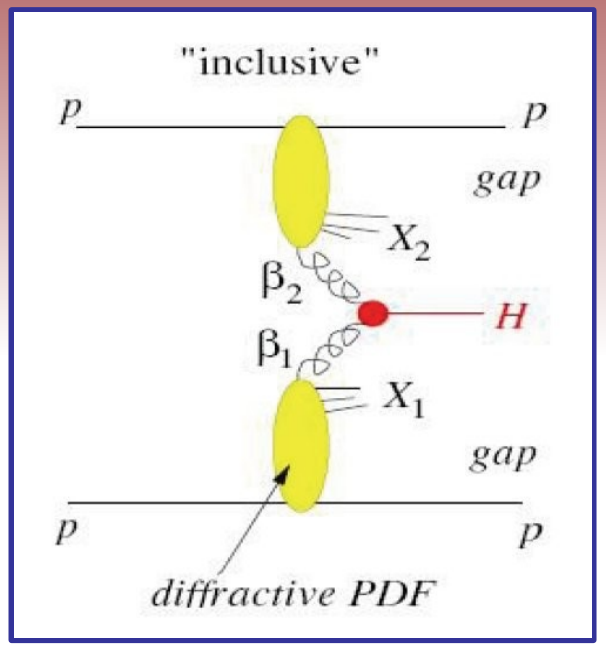
  - consistent with world average

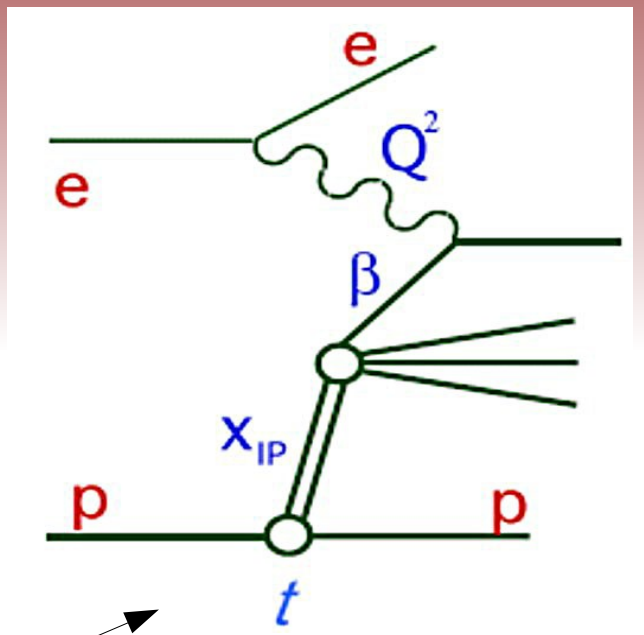




Diffractive PDFs



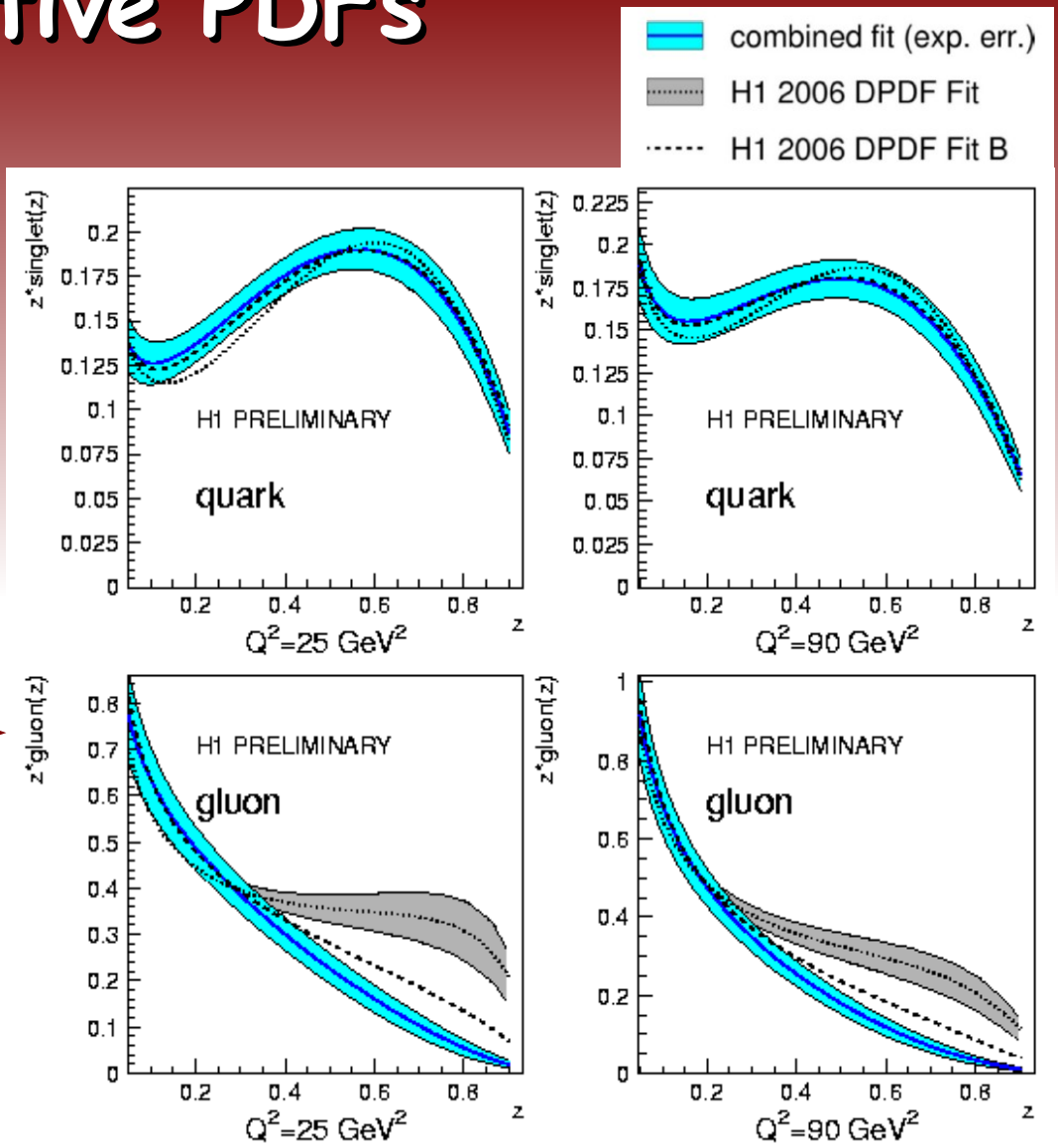




- **Diffractive Higgs production at LHC needs knowledge of DPDFs and GPDs**
- **Global fits to HERA diffractive data give DPDFs**

Diffractive PDFs

- ~10% of inclusive measurements has Large Rapidity Gap (LRG)
- proton vertex factorization gives universal diffractive PDFs (DPDFs)
- Two diffractive measurements combined in one NLO fit
  - Differential LRG dijet cross sections in DIS
  - Reduced cross in diffractive DIS with rapidity gaps (F_2^D)

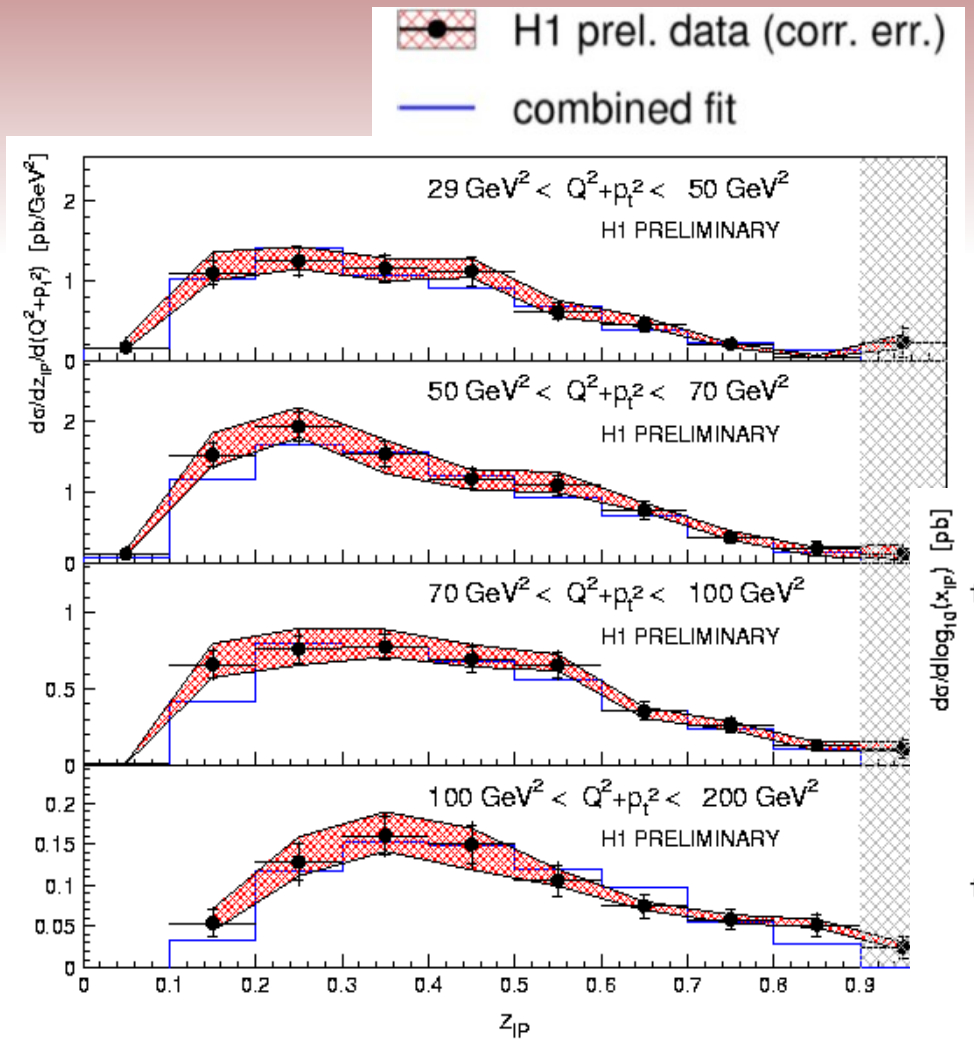


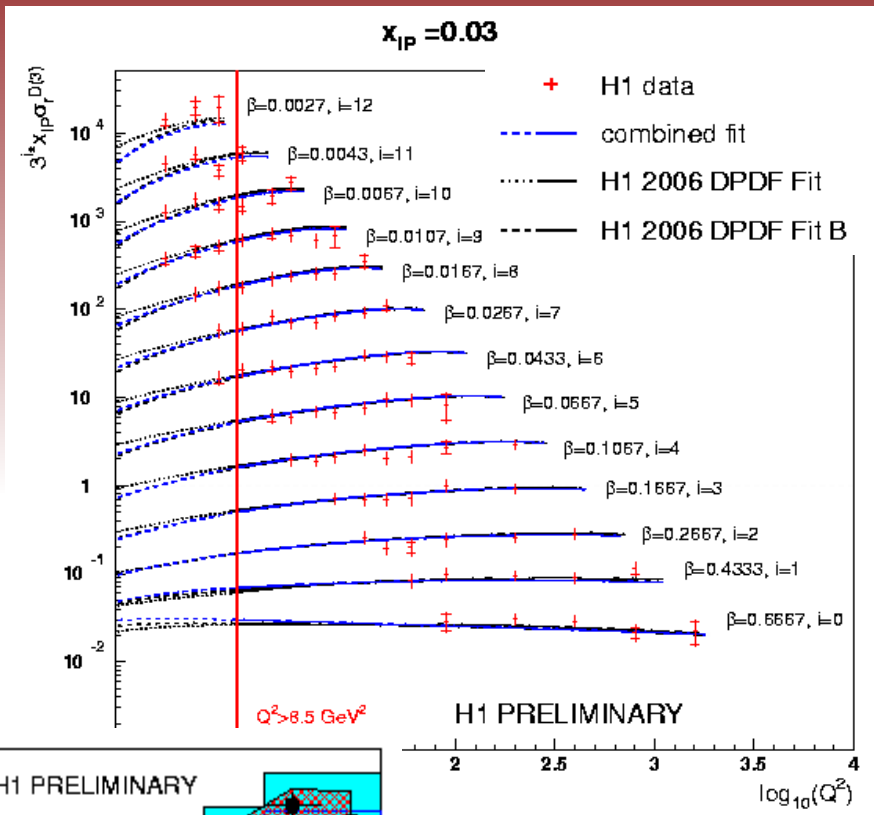
- Diffractive gluon and quark densities well constrained for $0.05 < z_{IP} < 0.9$

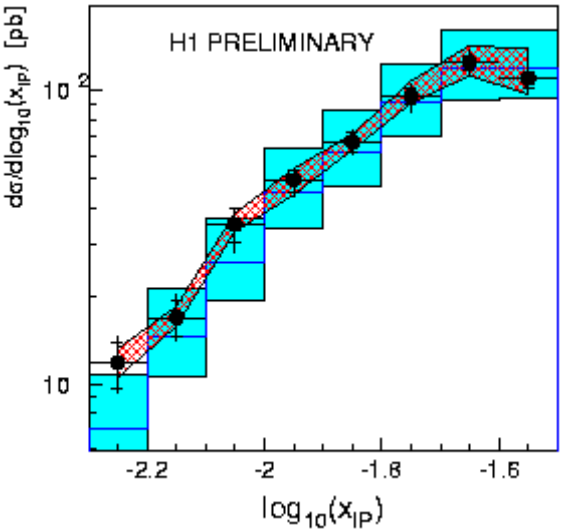
z: longitudinal mom. fraction of parton entering hard sub-process w.r.t. diff. exchange

Diffractive PDFs

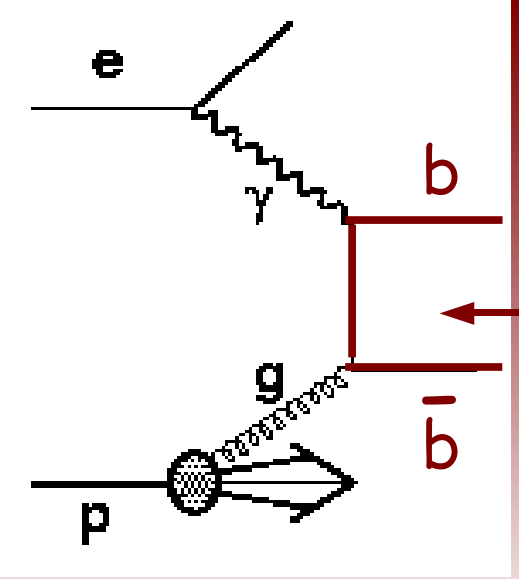
- **Combined fit of F_2^D and jet data describes well both data sets**



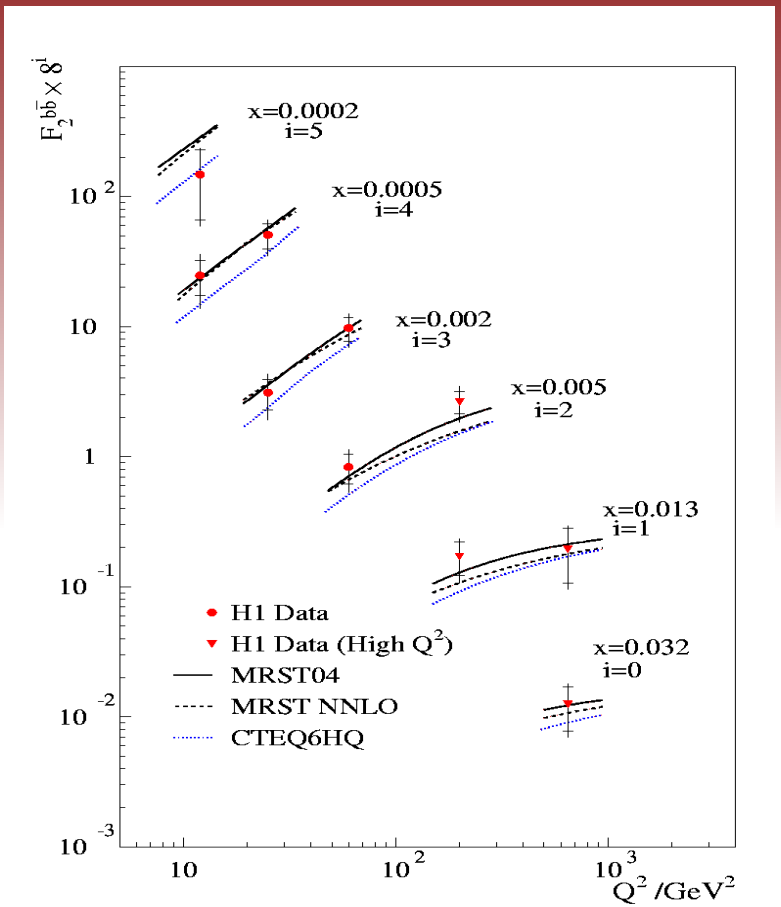




Heavy Flavor Production



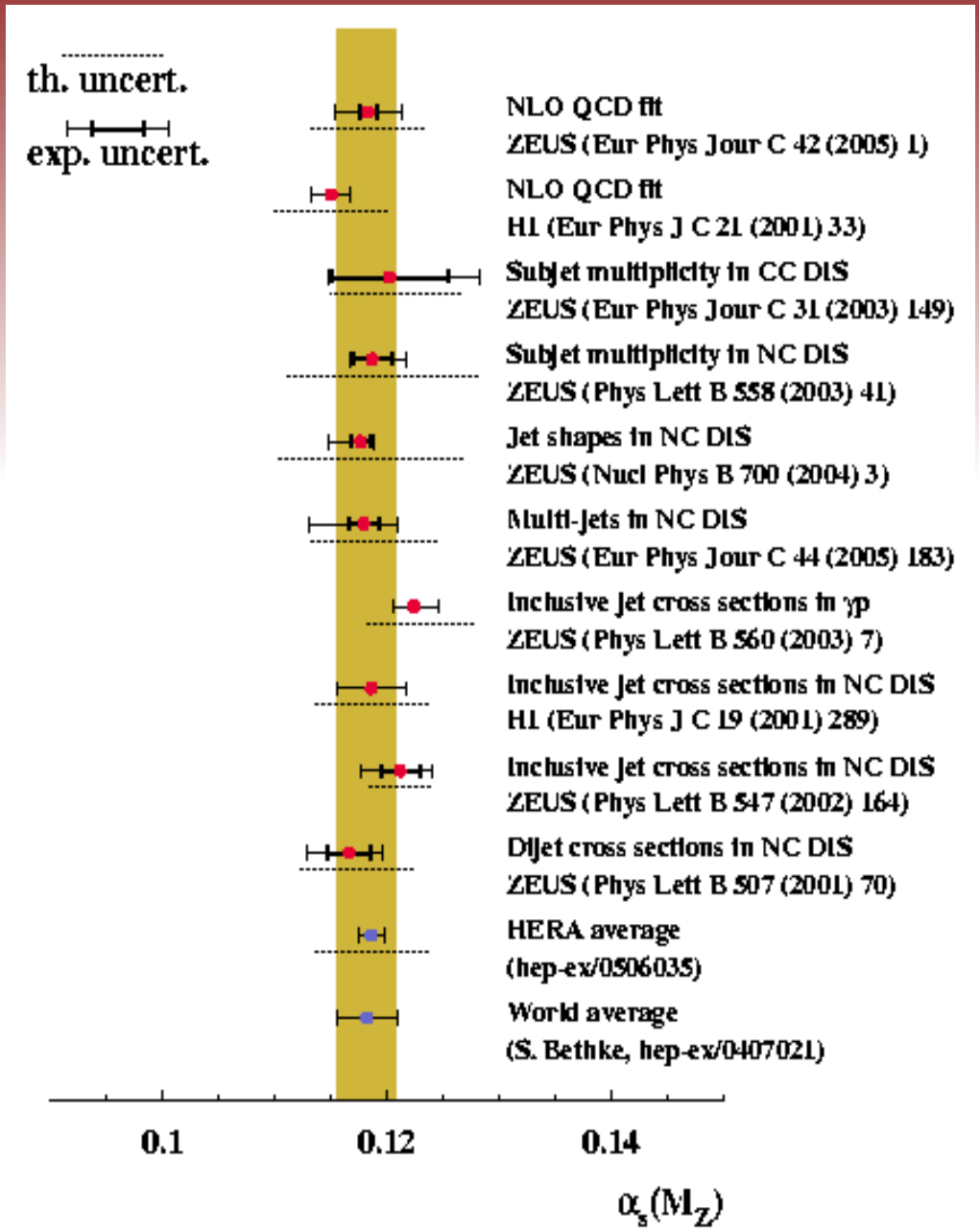
Boson-Gluon Fusion (BGF)



- **presently b-production cross section @ HERA reasonably well described by NLO QCD**
- **H1 and ZEUS measured F_2^{cc}**
- **measurement of F_2^{bb} by H1**
- **HERAII data will improve significantly HERA heavy flavor measurements**
- **good agreement between data and pQCD**
- **could be used as additional constrain on gluon PDF**
  - **c&b produced via BGF-direct access to gluon**

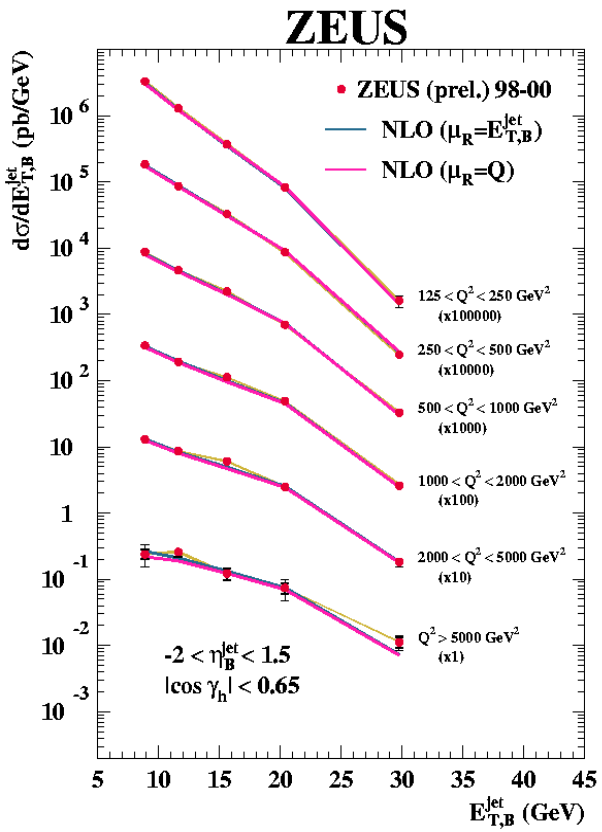
α_s Determination @ HERA

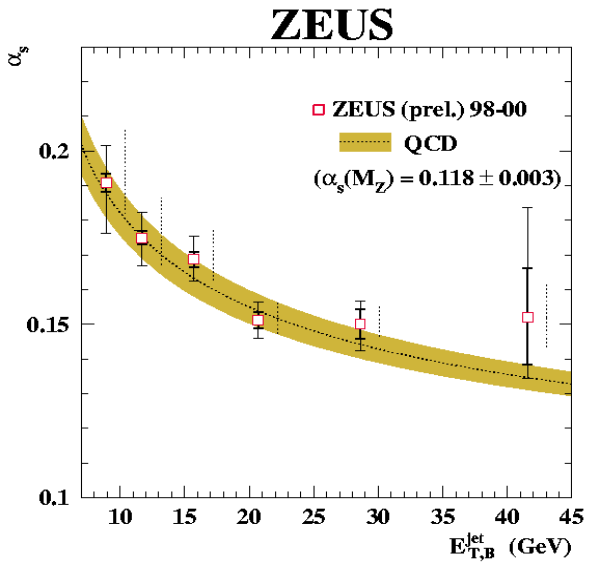
- @ HERA α_s determined in variety if measurements
  - scaling violation
  - jet production & jet properties in DIS and photoproduction
- measurements of high precision
- HERA average in agreement with world average
- α_s running established



α_s from Jets in NC DIS

- **Differential jet cross sections measured in Breit Frame**
  - **results well described by pQCD**





- $\alpha_s(M_Z)$ **extracted from** $d\sigma/dE^{jet}_{T,B}$ **and** $d\sigma/dQ^2$
  - **fit for $Q^2 > 500$ GeV^2 gives smallest uncertainty:**

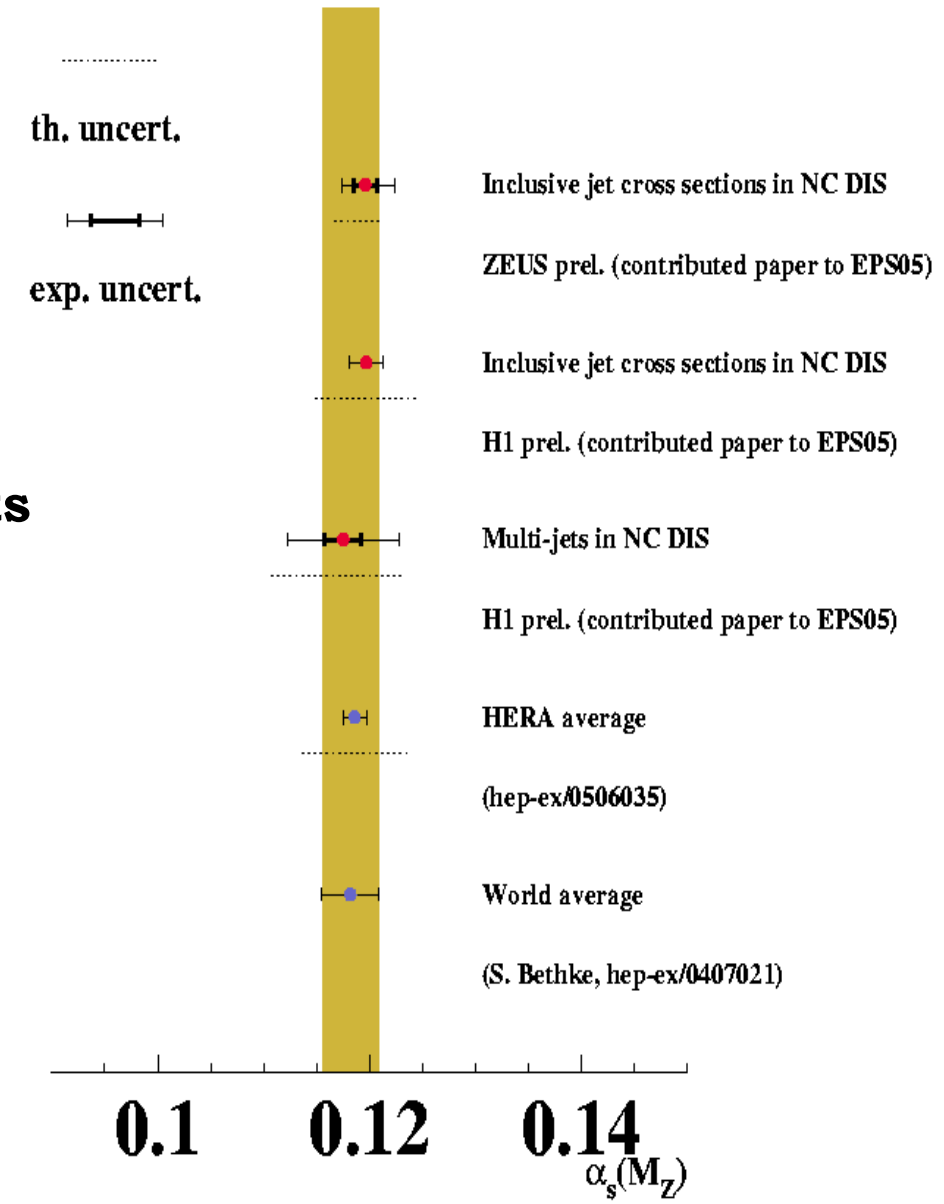
$$\alpha_s(M_Z) = 0.1196 \pm 0.0011\,(\text{stat.})\ ^{+0.0019}_{-0.0025}\,(\text{exp.})\ ^{+0.0029}_{-0.0017}\,(\text{th.})$$

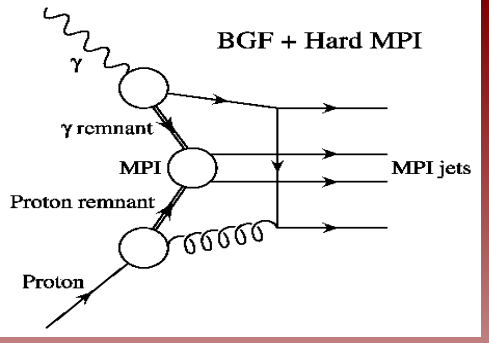
in agreement with world average, very high precision

- α_s **running tested with** $d\sigma/dE^{jet}_{T,B}$ **and** $d\sigma/dQ^2$
  - **in agreement with pQCD prediction**

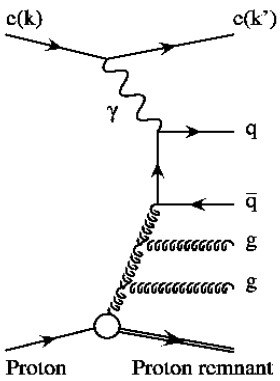
α_s from Jets

- **New high precision measurements of α_s from jet cross sections (not included in HERA average yet)**





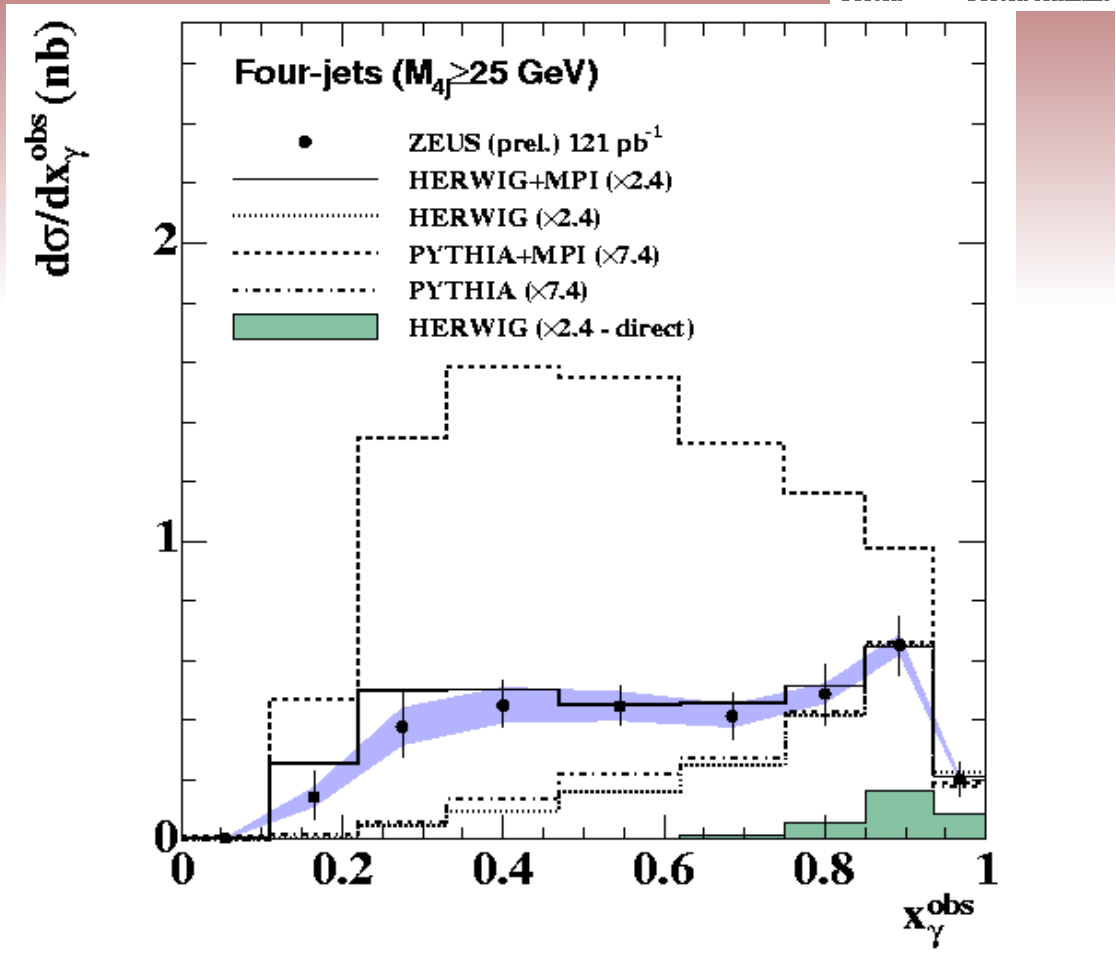
Multijet Production



- **ZEUS measured 3- and 4-jet production in PhP**

first 4-jet results from HERA

- **multiparton interactions (MPI) pay significantly role (also at LHC)**
- **MPI can be adjusted to agree with data**



x_γ^{obs}: fraction of γ energy that goes into n-jet system

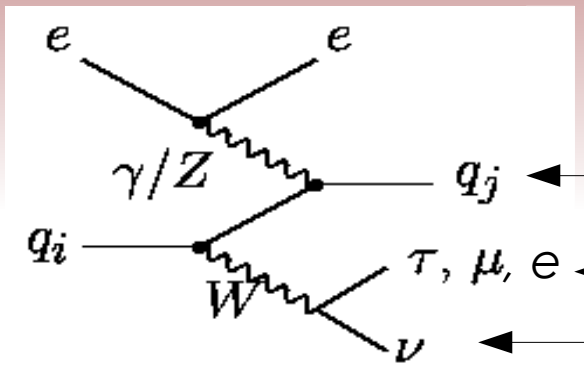
Searches for New Physics

- **Searches for new Resonances or Contact-Interactions:**
  - **Leptoquarks**
  - **Lepton Flavor Violation**
  - **Contact Interactions**
  - **Extra Dimensions**
  - **Quark Radius**
  - **Excited Fermions**
  - **SUSY in MSSM R_P conserving model**
  - **SUSY in R_P violating model**
- **Exclusive final states:**
  - **Isolated leptons (e, μ, τ) and missing p_T**
  - **Single top limits**
  - **Multi-leptons events**
  - **Double-charged Higgs limits**
  - **General search**
  - **Magnetic Monopoles**
  - **Pentaquarks**

in orange topics covered by this talk

Events with Isolated Leptons and High Missing p_T

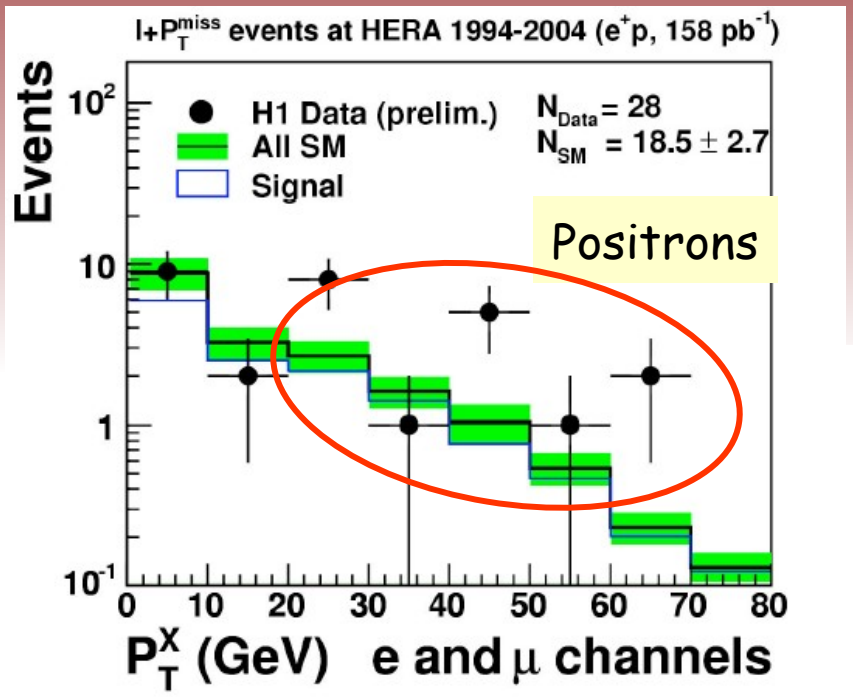
- **main SM process – single W production with lepton decay**



had. system, p_T^X

isolated lepton

missing high p_T

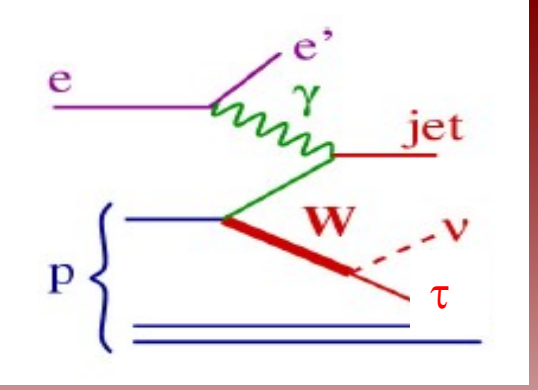


- **H1: excess of data events over SM prediction in positron data (excess not seen in e⁻p!)**
- **Excess NOT confirmed by ZEUS**
  - **comparison difficult – different phase-space**
  - **need all HERAII data**

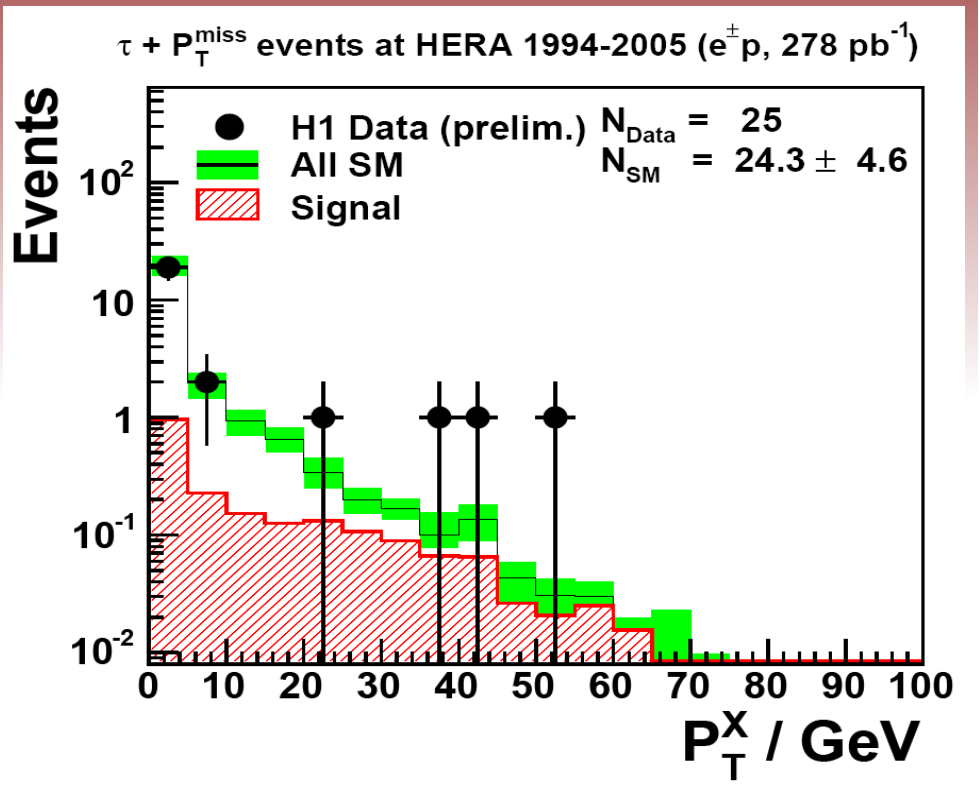
P_T^X > 25 GeV	e channel	μ channel	Combined e & μ
Electrons, 98-05 121 pb-1	2 / 2.4 ± 0.5	0 / 2.0 ± 0.3	2 / 4.4 ± 0.7
Positrons, 94-04 158 pb-1	9 / 2.3 ± 0.4	6 / 2.3 ± 0.4	15 / 4.6 ± 0.8

puzzle still not solved but might be best chance for discovery...

Isolated High-p_T taons



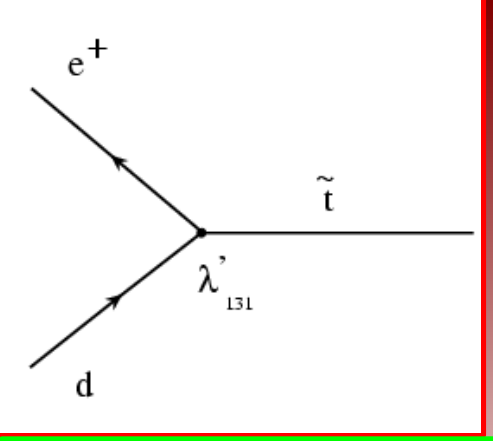
- **in HERA I data ZEUS observes 2 events with expectation of 0.2 for $p_T^X > 25$ GeV**
- **H1 has performed analysis of combined HERA I+II samples**
- **only 1-prong decay, limited θ range**



H1 prelim 94-05	Observed	SM expectation	Signal
All P_T^X	25	24.3 ± 4.6	2.0 ± 0.4
$P_T^X > 25$ GeV	3	0.74 ± 0.15	0.43 ± 0.09

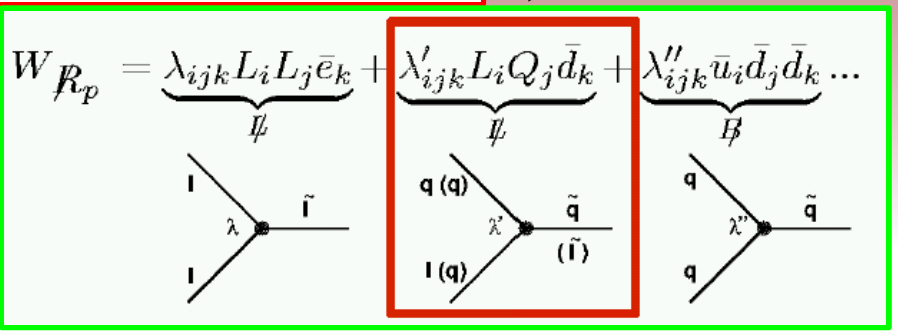
- **few events observed at high p_T^X but statistics limited**

Stop Production

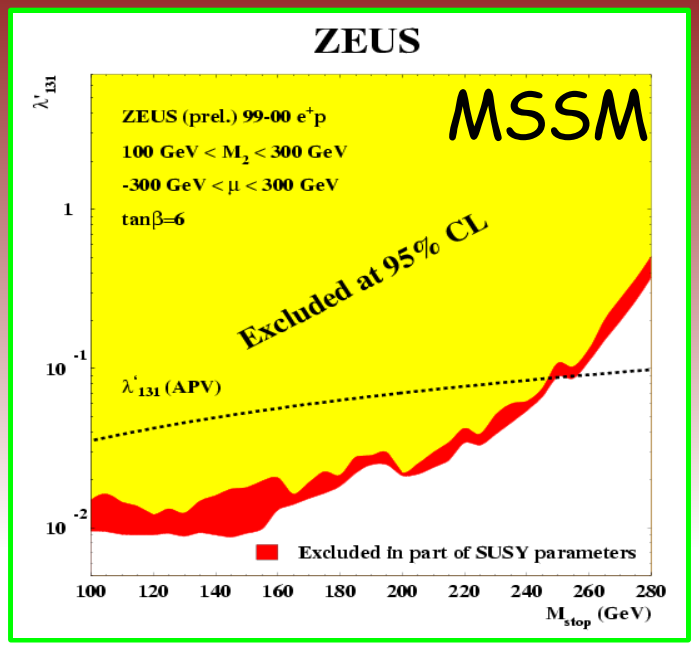


lepton-hadron colliders

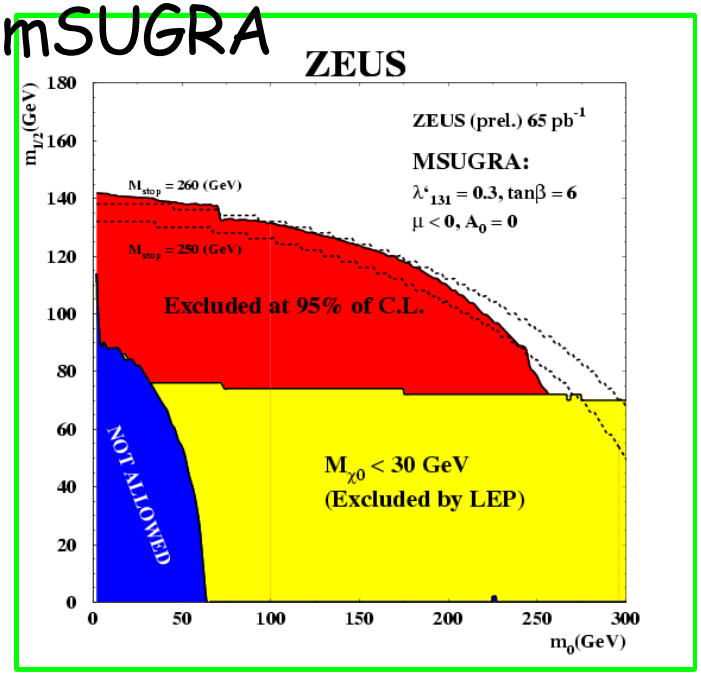
$$W_{\not R_p} = \underbrace{\lambda_{ijk} L_i L_j \bar{e}_k}_{\not L} + \underbrace{\lambda'_{ijk} L_i Q_j \bar{d}_k}_{\not L} + \underbrace{\lambda''_{ijk} \bar{u}_i \bar{d}_j \bar{d}_k}_{\not B} \ldots$$



- **Stop produced as resonance in s-channel via λ'_{131} coupling**
- **3 main decays considered (direct and gauge)**
- **no resonance observed**
- **limits set**
  - **2 scenarios considered: MSSM and mSUGRA**
  - **excluded scenarios with M_t<260 GeV**



mSUGRA



Summary & Conclusions

- **Measurements from HERA add great deal to our understanding of QCD which is essential for LHC physics**
  - **First measurement of polarized CC cross section consistent with linear dependence predicted by SM**
  - **Parton distributions estimated within single experiment with uncertainties of a few % over most of x range**
  - **α_s determined from scaling violation and jet data with high precision**
  - **Heavy flavor production shows agreement with QCD; new precision measurements expected with HERA II data**
  - **Many searches for physics beyond SM ongoing**