

Recent Results from the H1 Experiment

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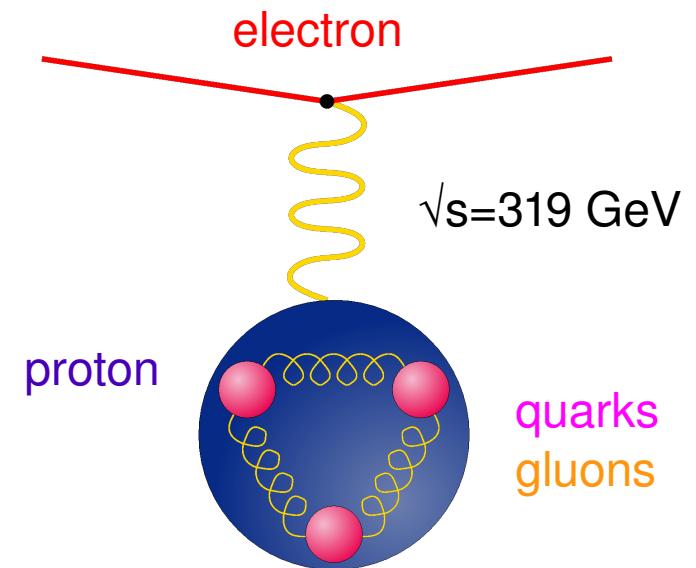
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HERA Symposium
July 07, 2009
DESY



HERA program

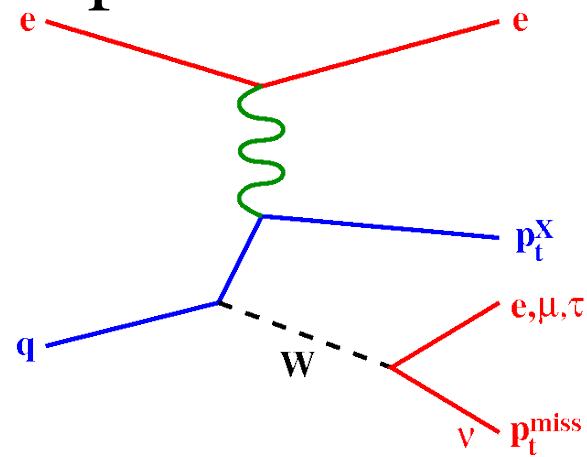
- Searches
- Proton structure
- QCD tests
- Diffraction



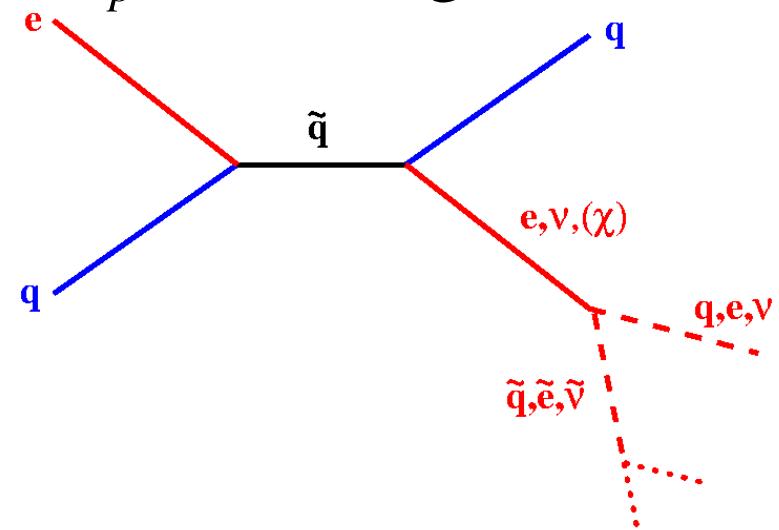


Rare processes/Searches

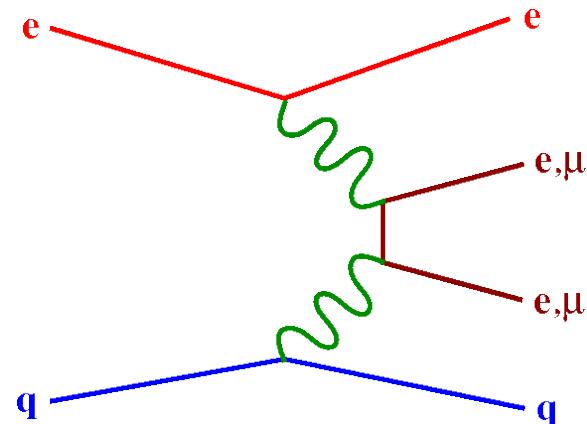
- W production



- R_p -violating SUSY

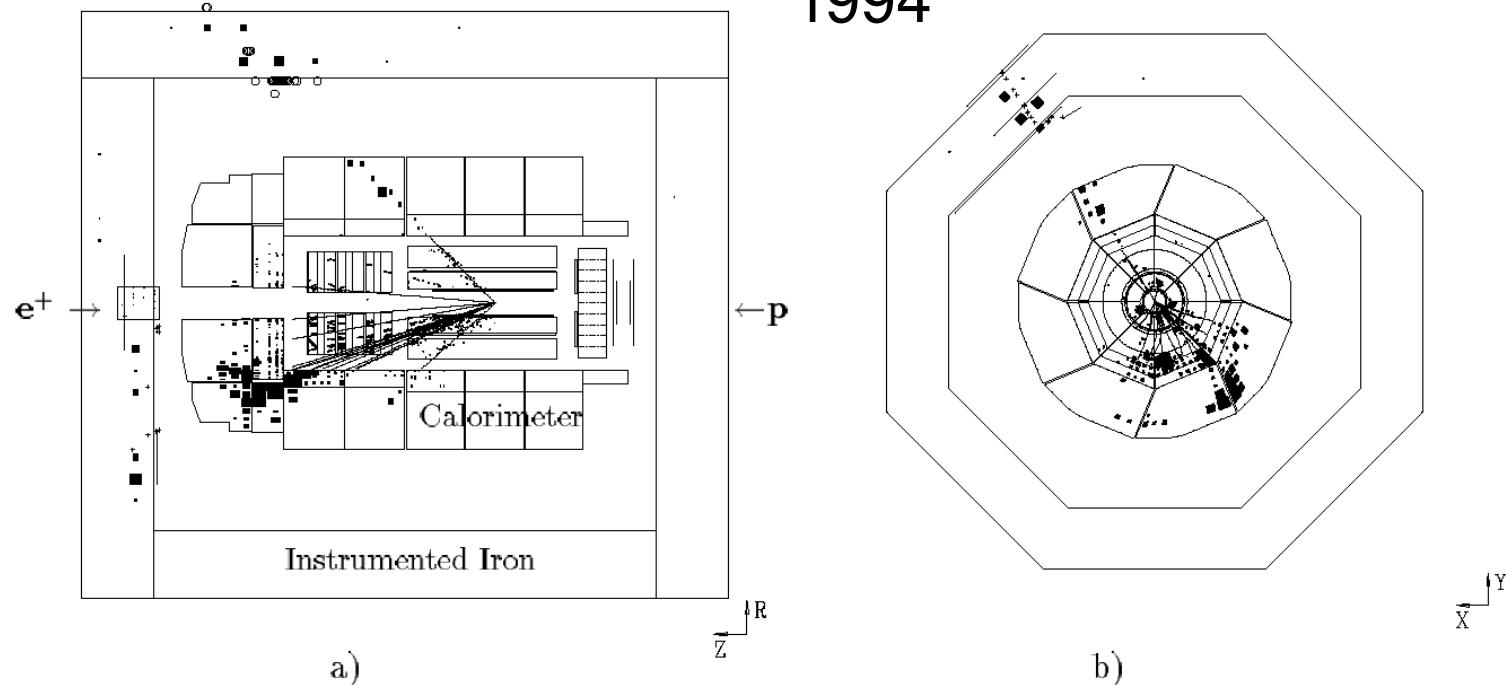


- Multi-lepton events





Isolated Leptons: „The Event“

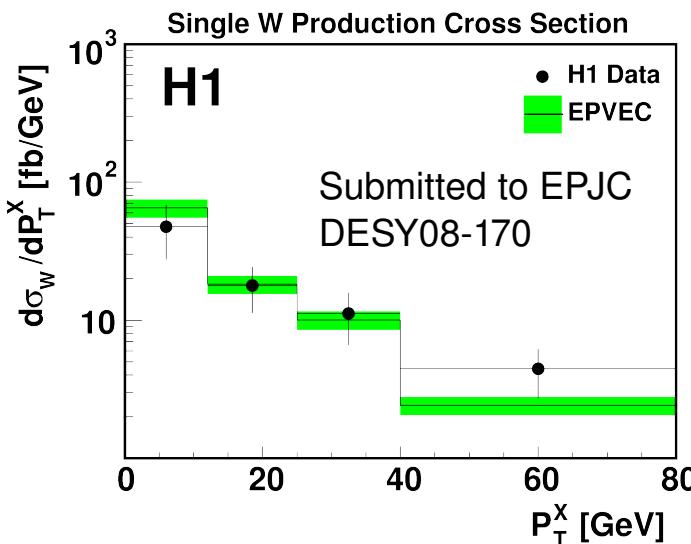
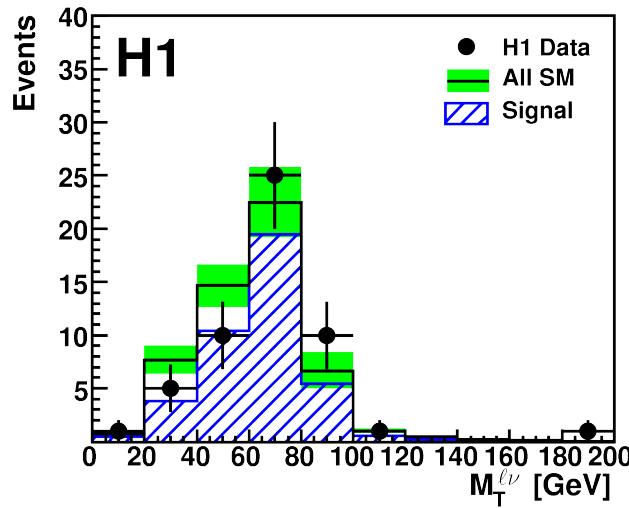
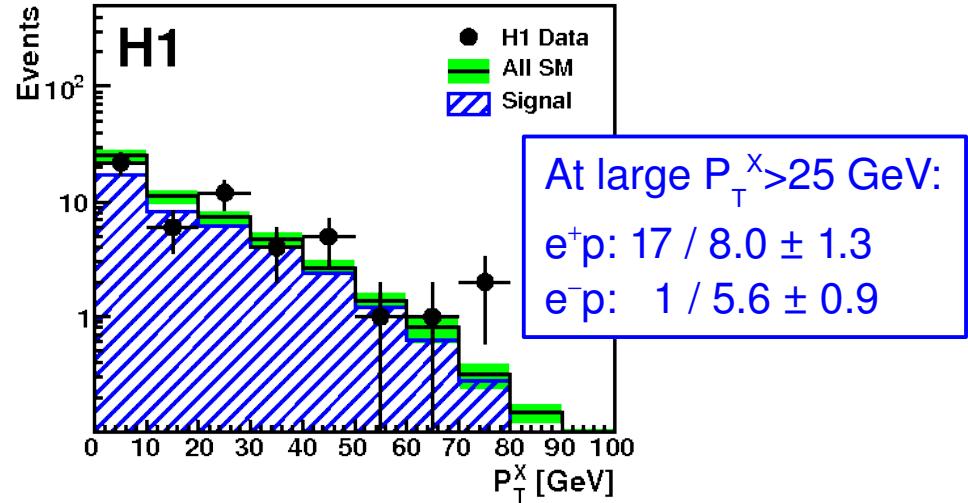
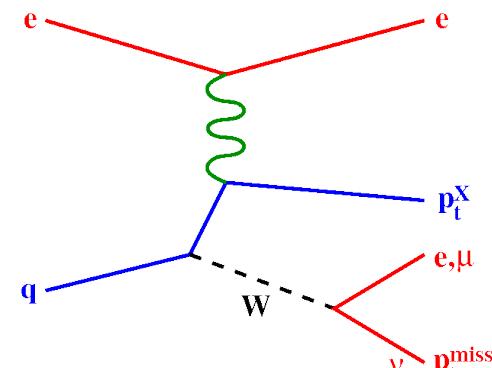
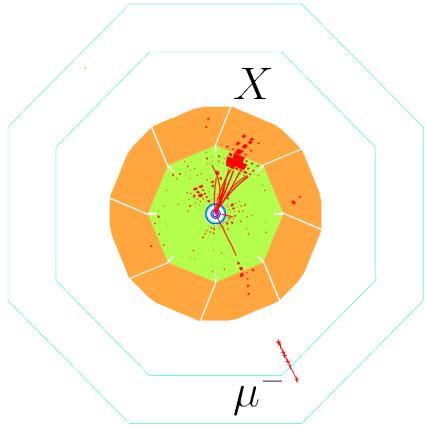


- „At the HERA electron-proton collider an event has been observed in the H1 detector which shows an isolated muon recoiling against a hadronic system, both of high transverse momentum.“
- based on 4 pb^{-1}



Isolated Leptons / W production

Striking signature: $\ell = e, \mu$ and ν in the same event, with high P_T



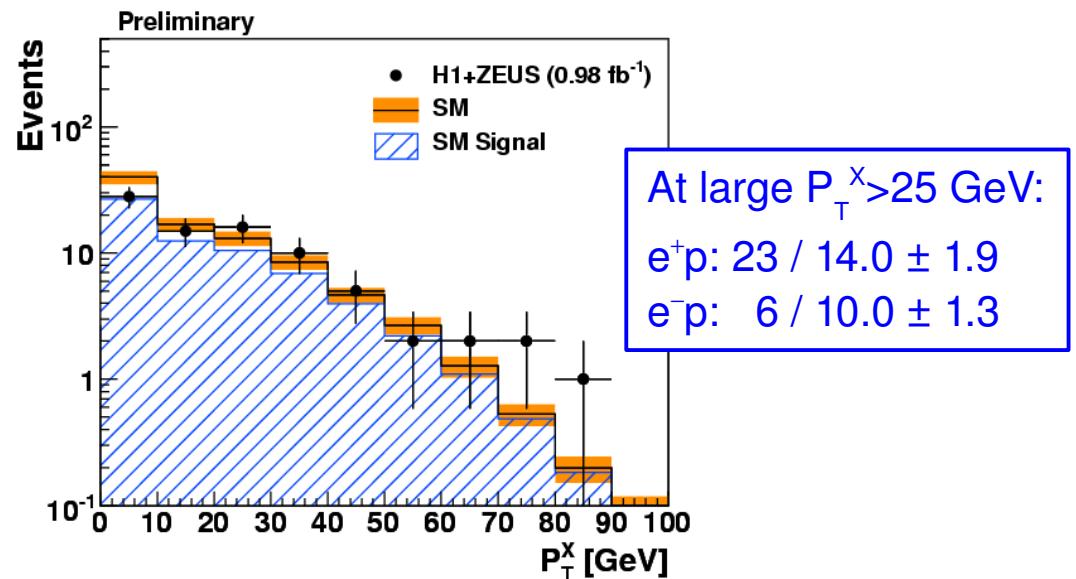
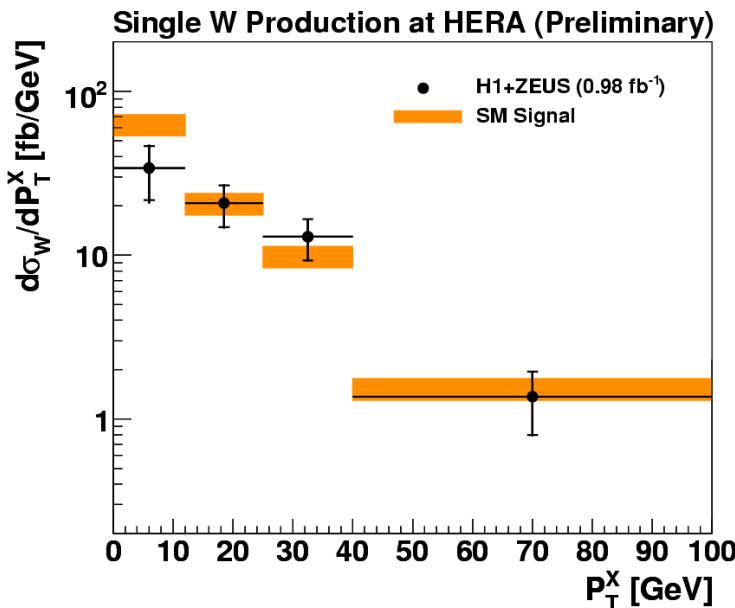
Full HERA data
now published

Extracted W
Cross section
 $\sigma = 1.14 \pm 0.25$
 ± 0.14 pb



Isolated Leptons / W prod.

- nearly 1 fb^{-1} of H1 and ZEUS data analysed
- analysis performed in common phase space
- combine cross sections for W production



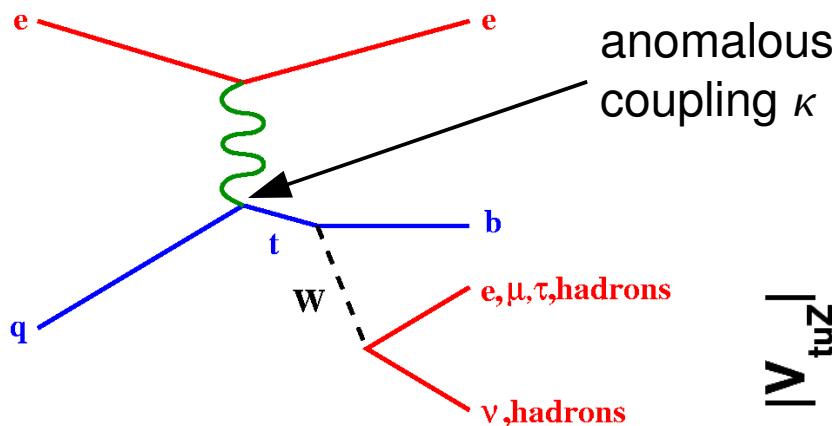
combined W cross section
 $\sigma = 1.07 \pm 0.16 \pm 0.08 \text{ pb}$

SM prediction $\sigma = 1.26 \pm 0.19 \text{ pb}$

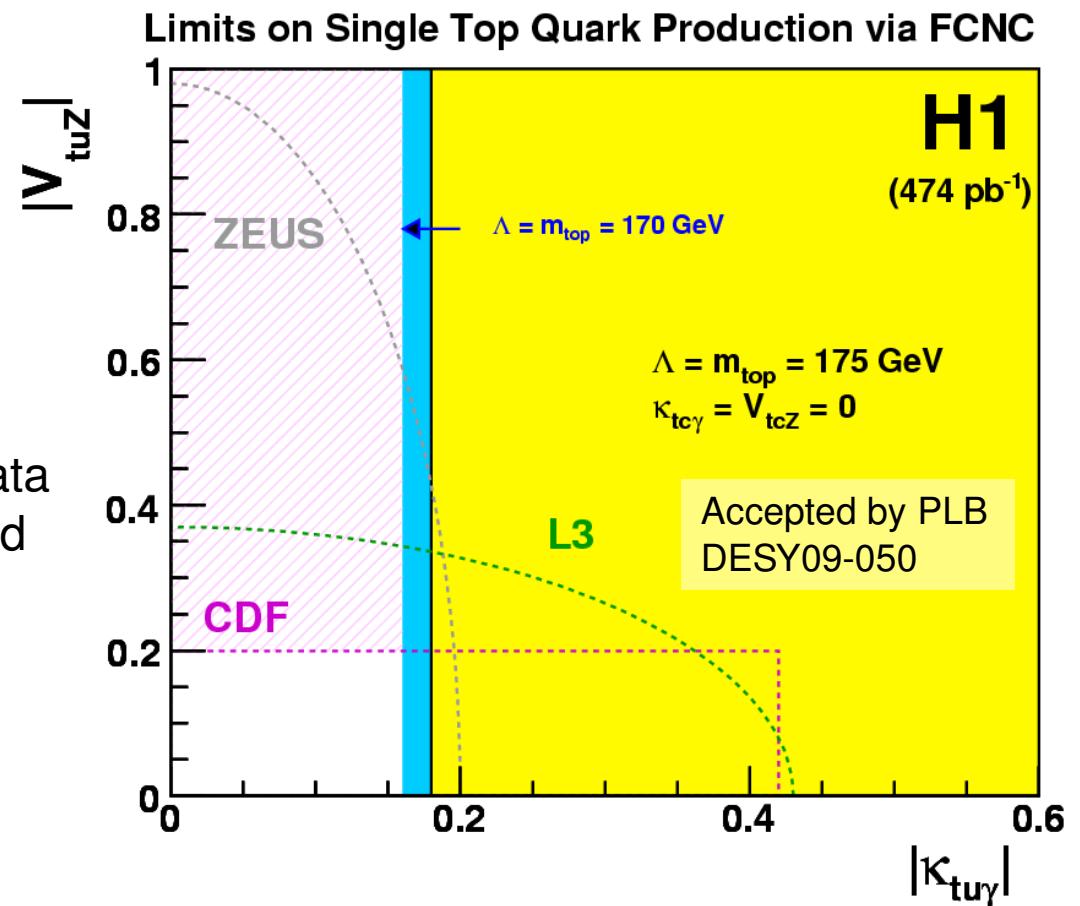
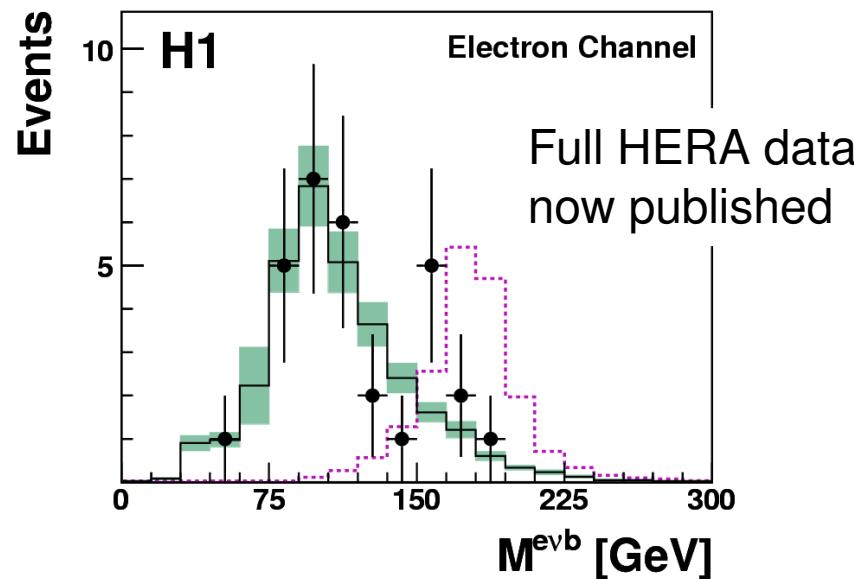
The end of a 15 year long story



Single Top Production

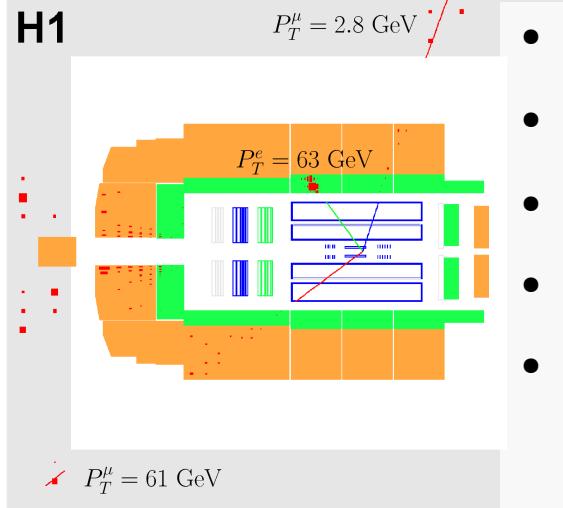


- possible source of isolated lepton events
- search in $e, \mu, \text{hadronic}$ W decay channel

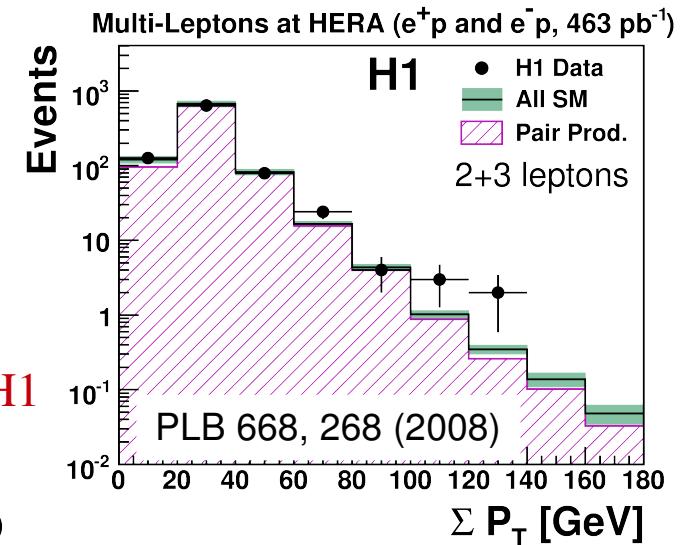
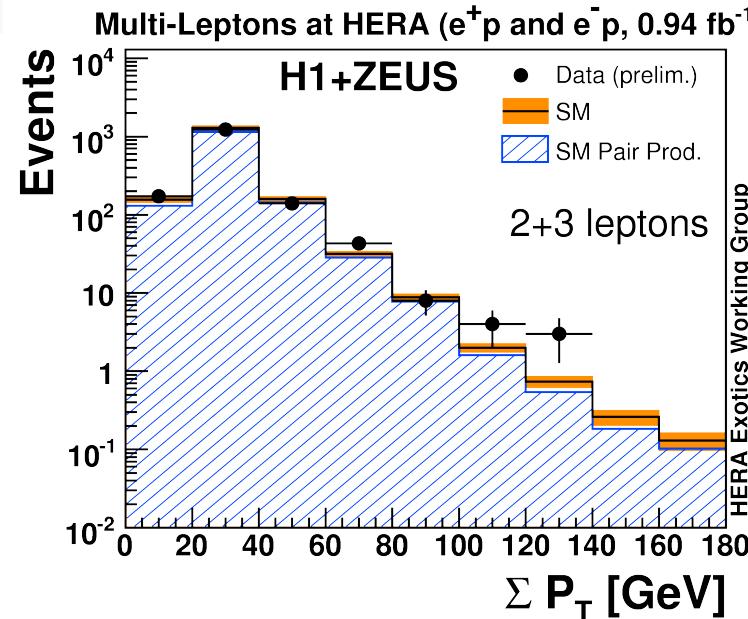
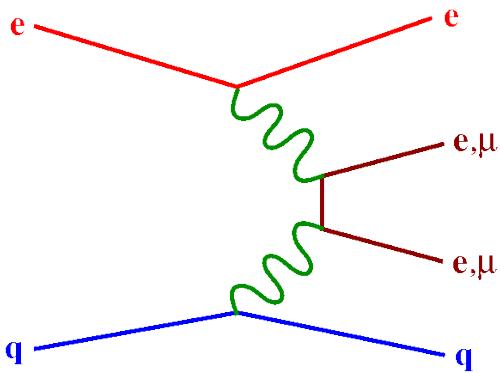




Multi-Leptons



- 2 or 3 high P_T leptons: $\ell=e,\mu$
- SM signal $\gamma\gamma \rightarrow \ell^+\ell^-$
- Full HERA data published
- Events at high transverse momentum
- Limited statistics \rightarrow combine ZEUS+H1

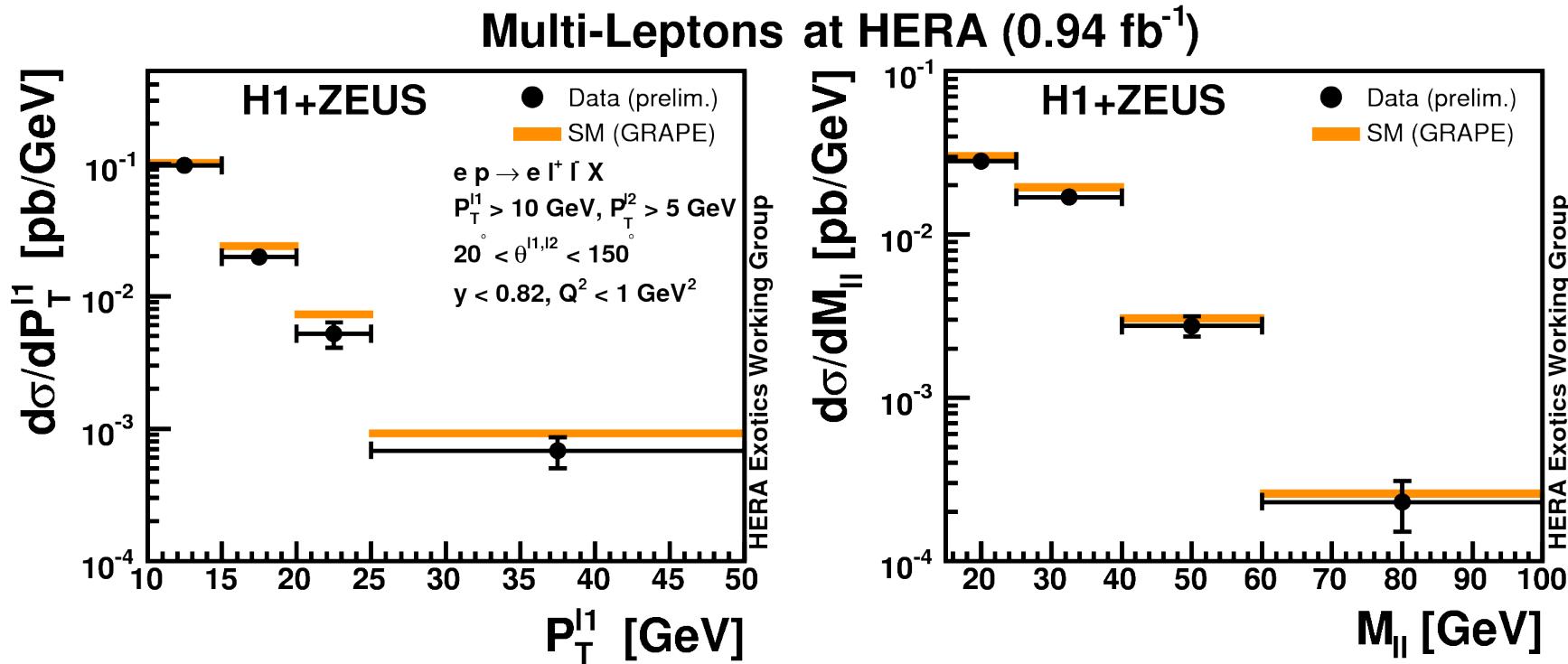


H1+ZEUS at $\Sigma P_T > 100 \text{ GeV}$

	DATA	SM prediction	
e^+p	7	1.94 ± 0.17	2.6σ
e^-p	0	1.19 ± 0.12	



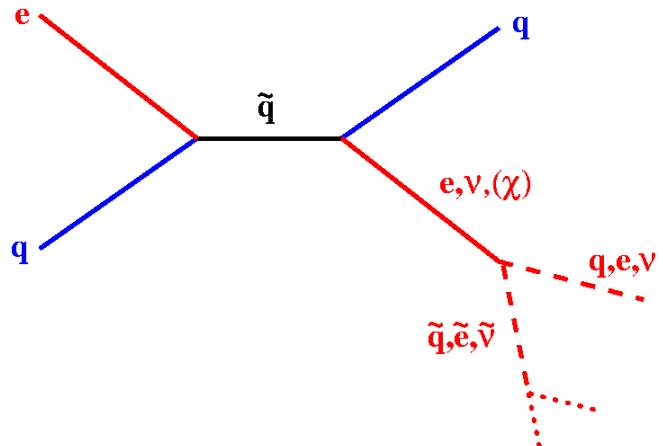
Cross-section $\gamma\gamma \rightarrow \ell^+\ell^-$



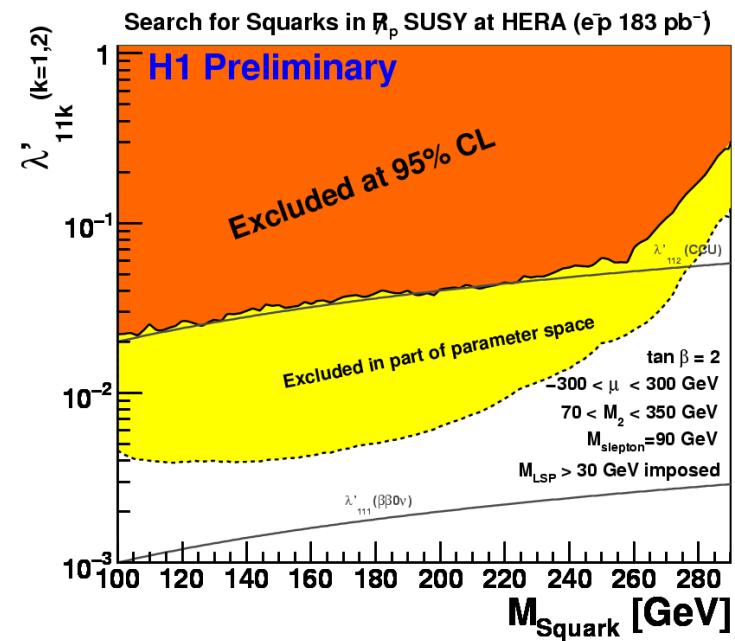
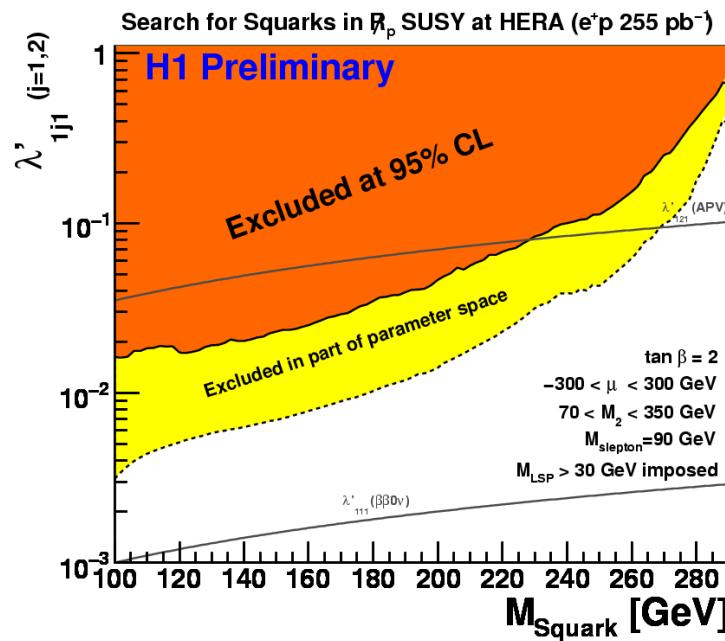
- H1+ZEUS combined cross-section of $\gamma\gamma \rightarrow \ell^+\ell^-$ at high P_T
- Good agreement with SM prediction
- will be first paper published by „H1 and ZEUS Collaborations“



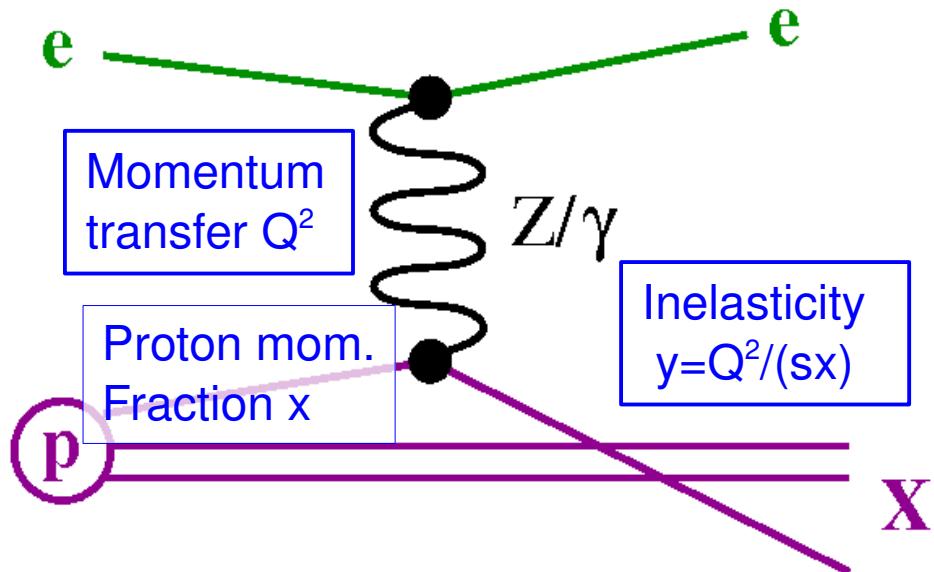
R_p -violating SUSY



- resonant production of single squarks
- many different decay channels possible
- branching fractions depend on SUSY parameters: M_2 , μ , $\tan \beta$
- search in many topologies
- scan SUSY parameter space



Structure functions



Reduced cross-section:

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

- $Q^2 \lesssim 5 \text{ GeV}^2$: phenomenological models
- $Q^2 \gtrsim 2 \text{ GeV}^2$: perturbative QCD, DGLAP evolution

Structure functions F_2 and F_L

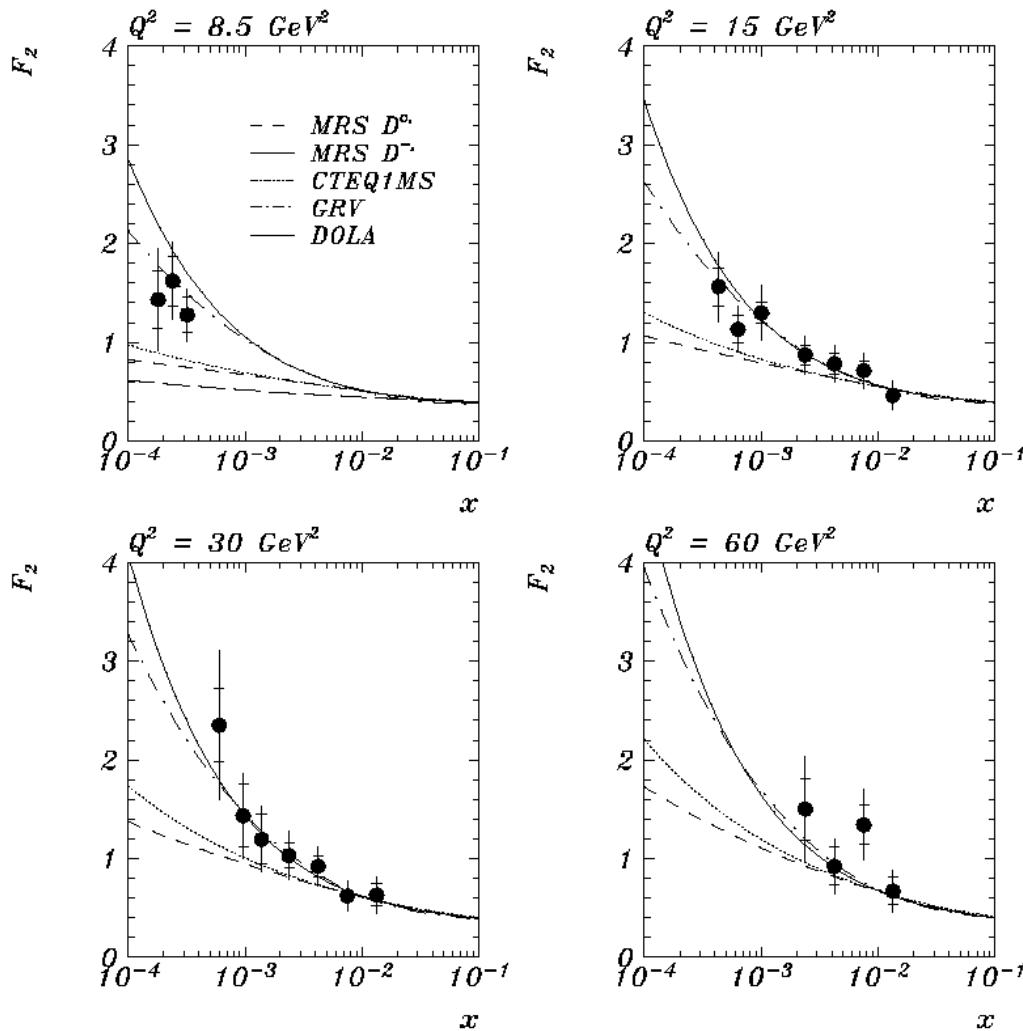
F_2 : valence and sea quarks
gluon enters through scaling violations

F_L : direct sensitivity to the gluon density,
suppressed by helicity factor



Structure functions

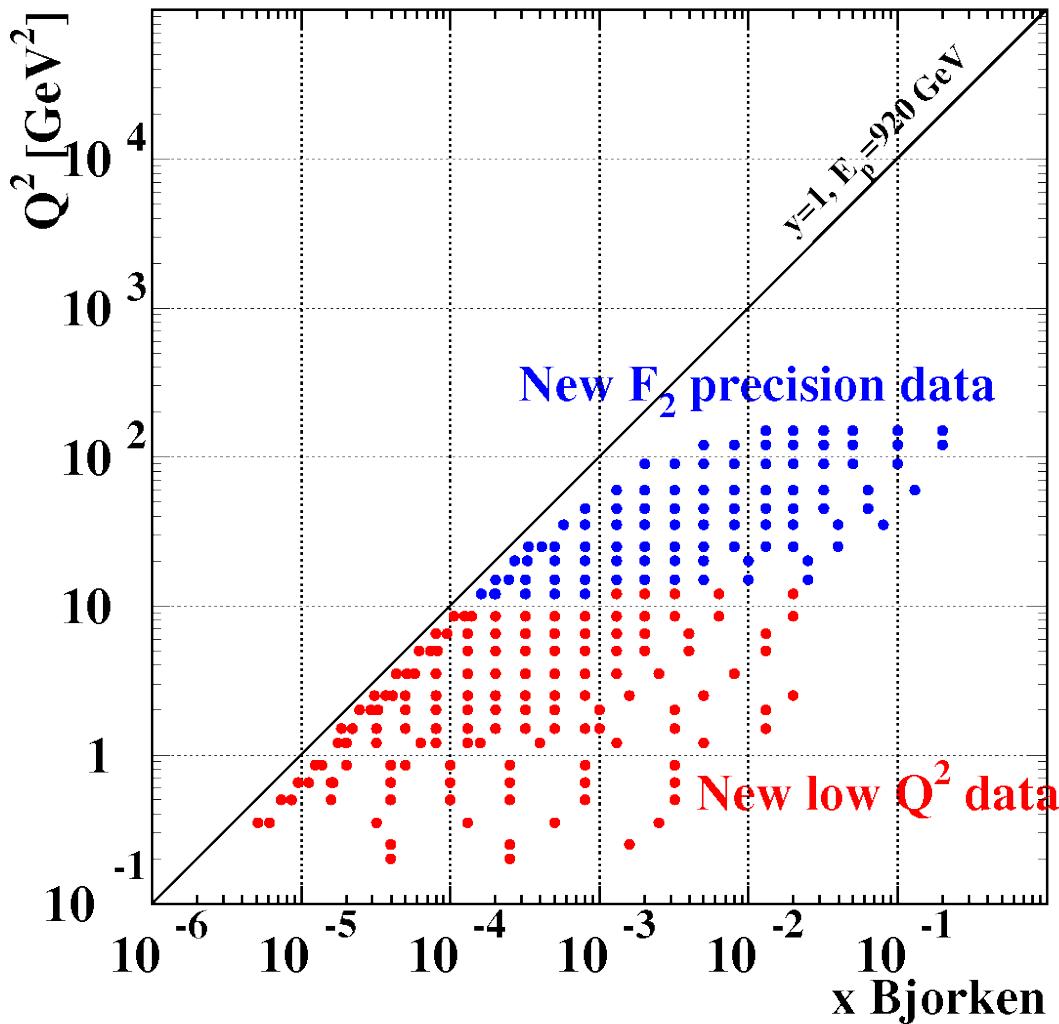
1993



- the first F_2 published by H1
- based on 22.5 nb^{-1}
- typical uncertainty 25%
- comparison with QCD and Regge parameterisations



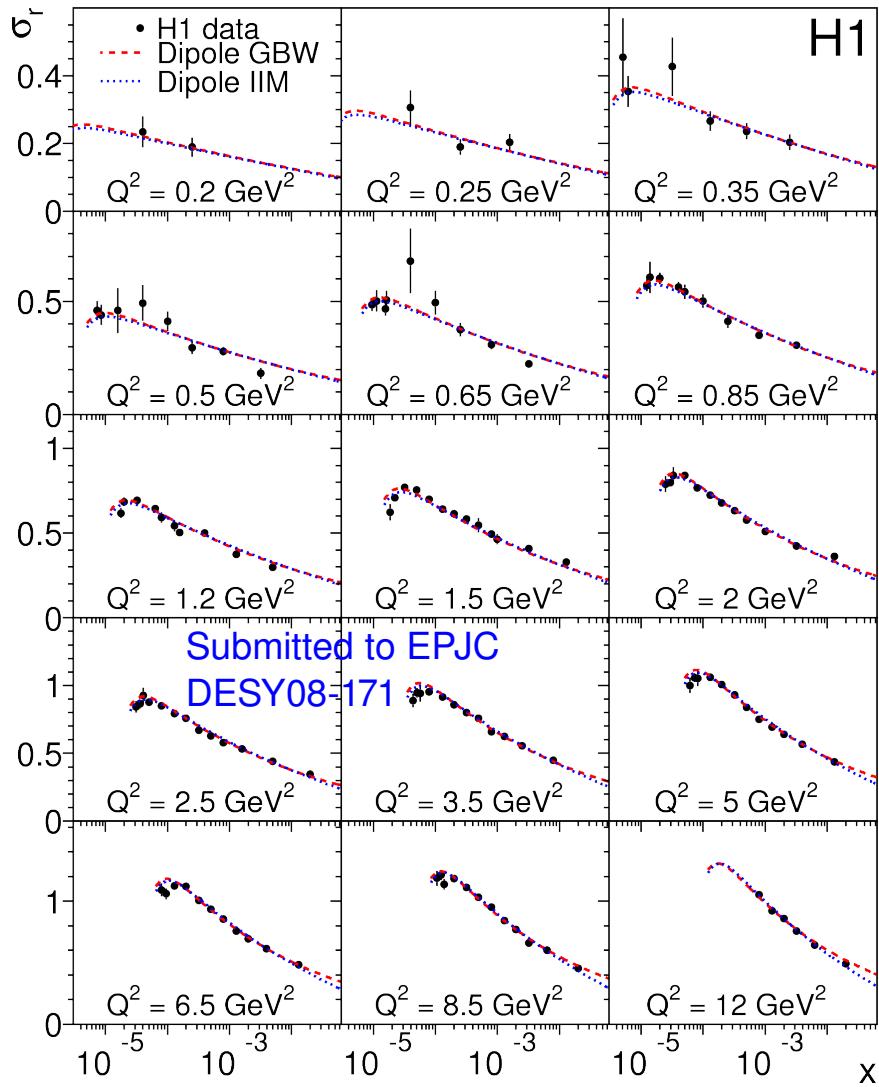
New data on σ_r and F_2



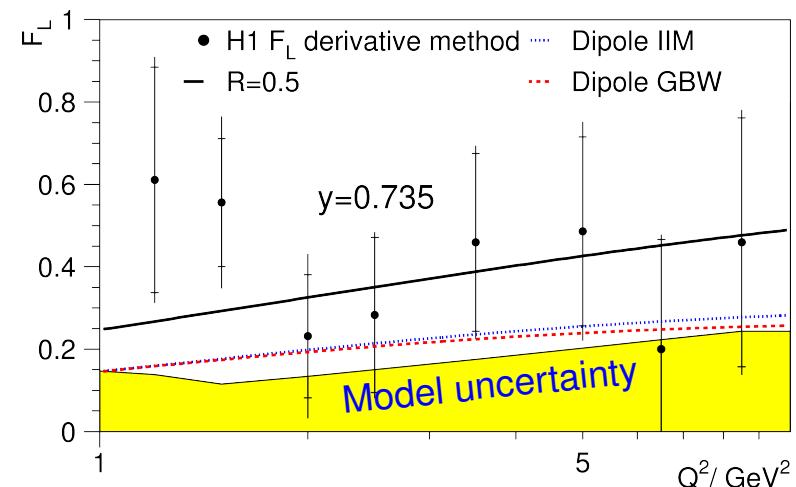
- New data published by H1
 - Medium Q^2
 $12 \leq Q^2 \leq 100$ GeV 2
Precision 1.3 to 2%
 - Low Q^2
 $0.2 \leq Q^2 \leq 12$ GeV 2
Precision 2 to 3%



DIS at low Q^2 and low x



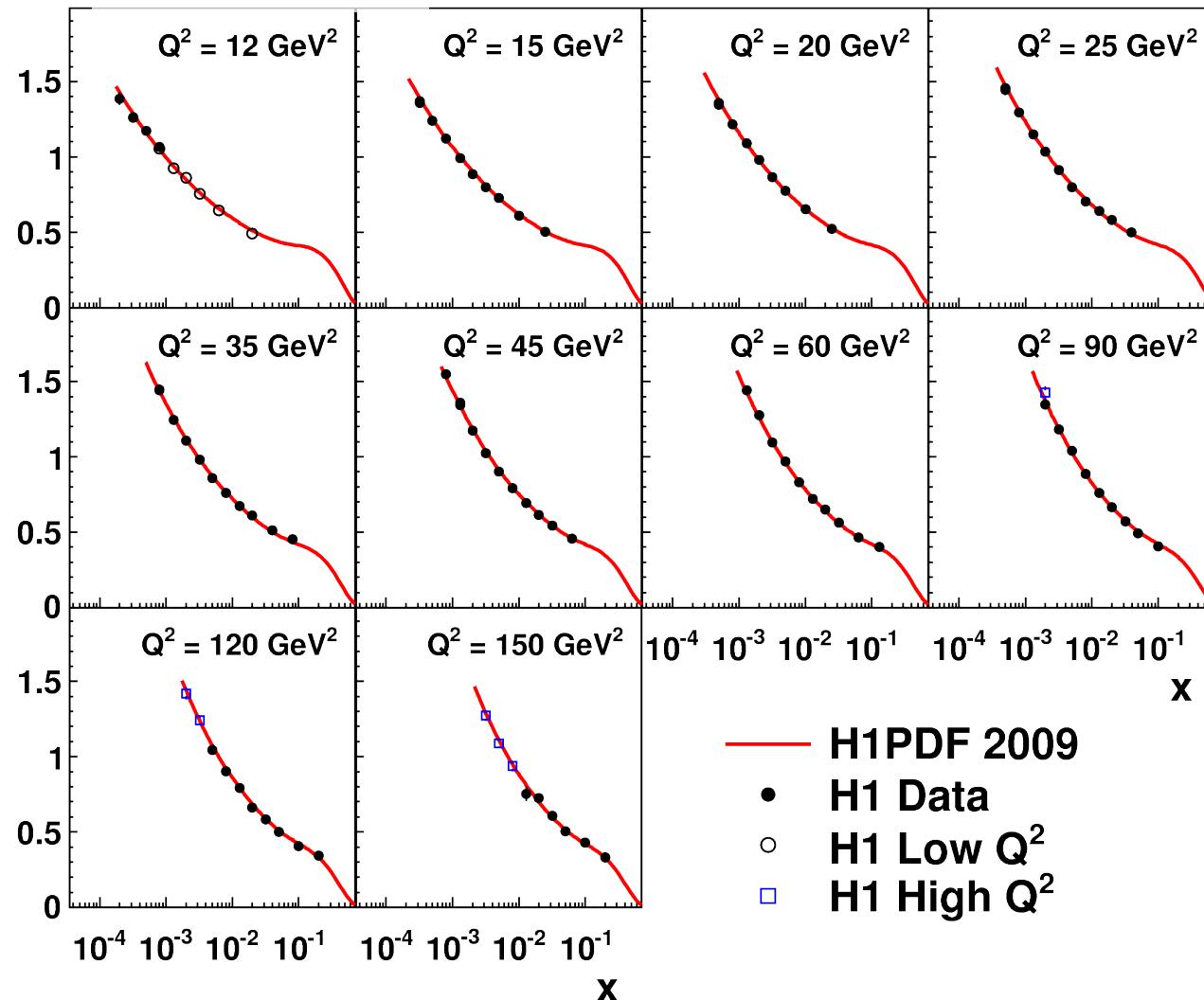
- Full H1 data for low Q^2 published
- Precision 2–3%
- Combination of several H1 datasets
- Fits to power-law, fractal and dipole models
- F_L extracted using indirect methods, consistent with models





F₂ precision data

Submitted to EPJC
DESY09-005

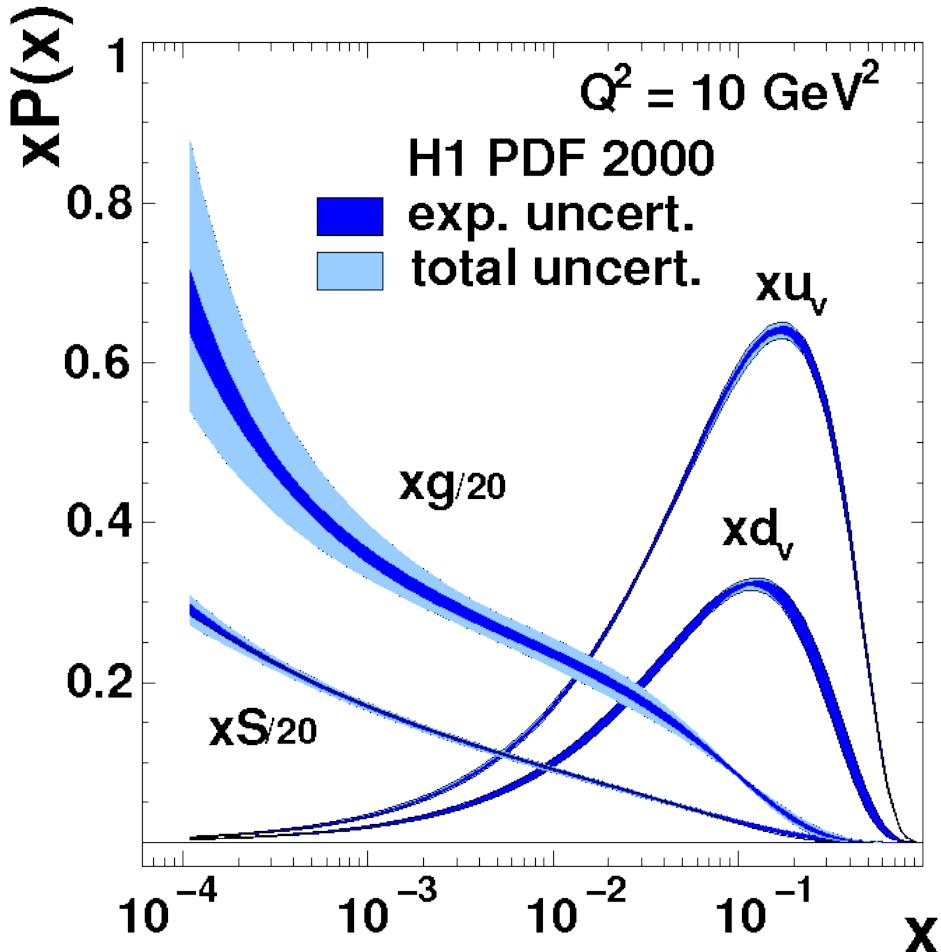


- Full HERA I data for $12 < Q^2 < 150 \text{ GeV}^2$
- Most precise F_2 data in this Q^2 range, uncertainty 1.3–2%
- Combination of two independent datasets
- New QCD fit, very good consistency with DGLAP prediction

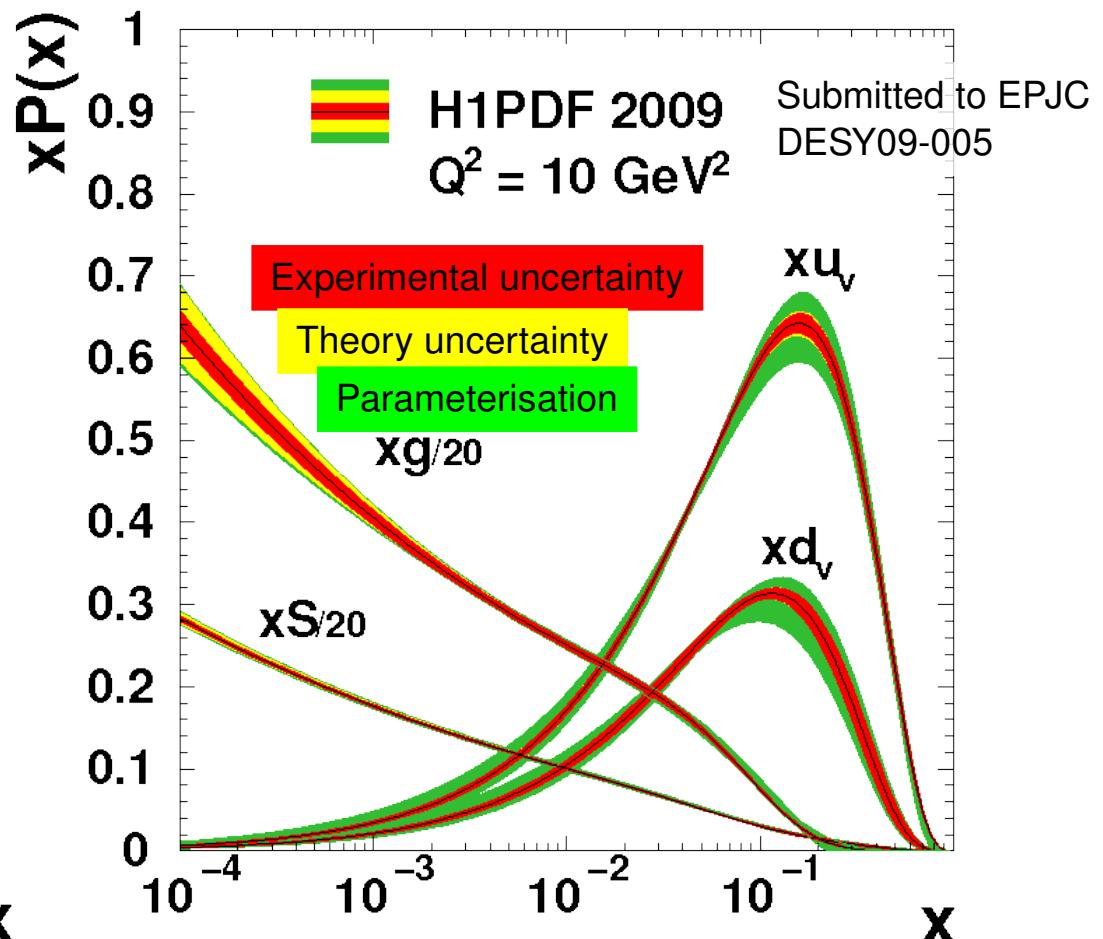
Combination with ZEUS:
further improvement of
uncertainties



H1 QCD fit



- H1PDF 2009 fit to all H1 HERA-I data
- Gain in precision compared to H1PDF2000



further improvements in
HERAPDF0.2 fit (H1+ZEUS)

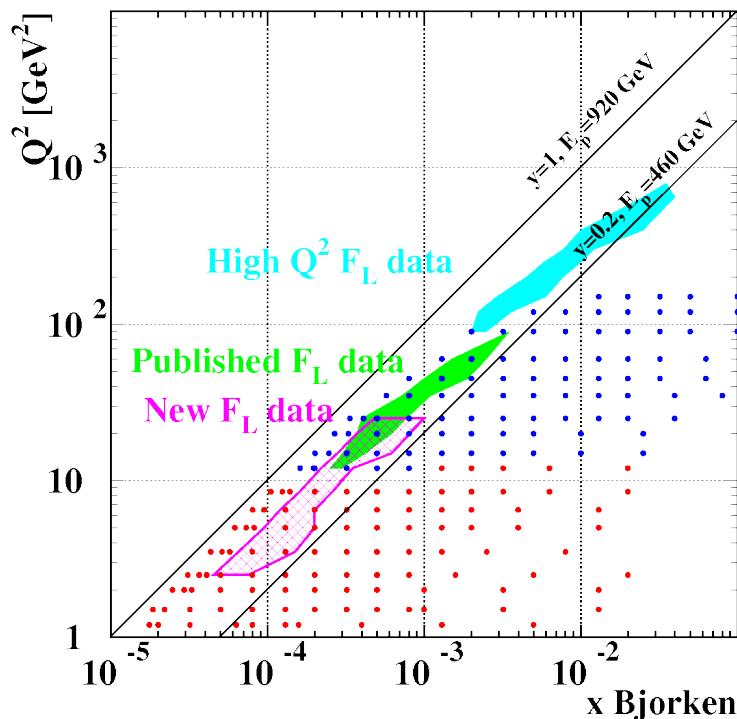


Measurement of F_L at low Q^2

First H1 F_L measurements shown in 2008:

High Q^2 data: $100 \leq Q^2 \leq 800 \text{ GeV}^2$

Medium Q^2 data: $12 \leq Q^2 \leq 100 \text{ GeV}^2$



New measurements:

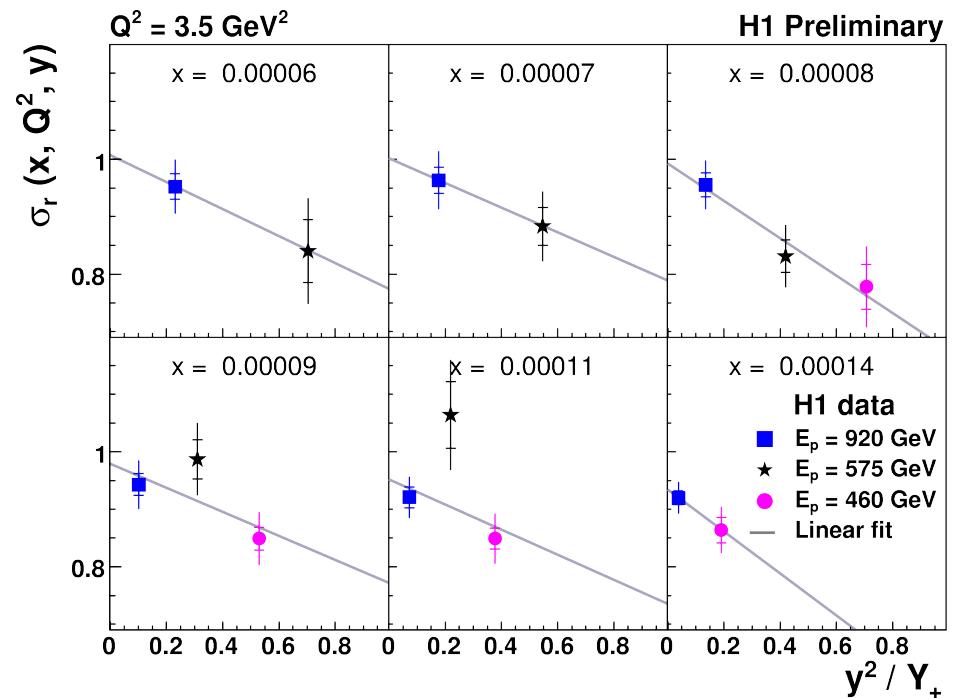
Low Q^2 data: $2.5 \leq Q^2 \leq 25 \text{ GeV}^2$

Direct Measurement of F_L :

$$\sigma_r \propto F_2 - (y^2/Y_+) \cdot F_L \quad \text{and} \quad y = Q^2/(sx)$$

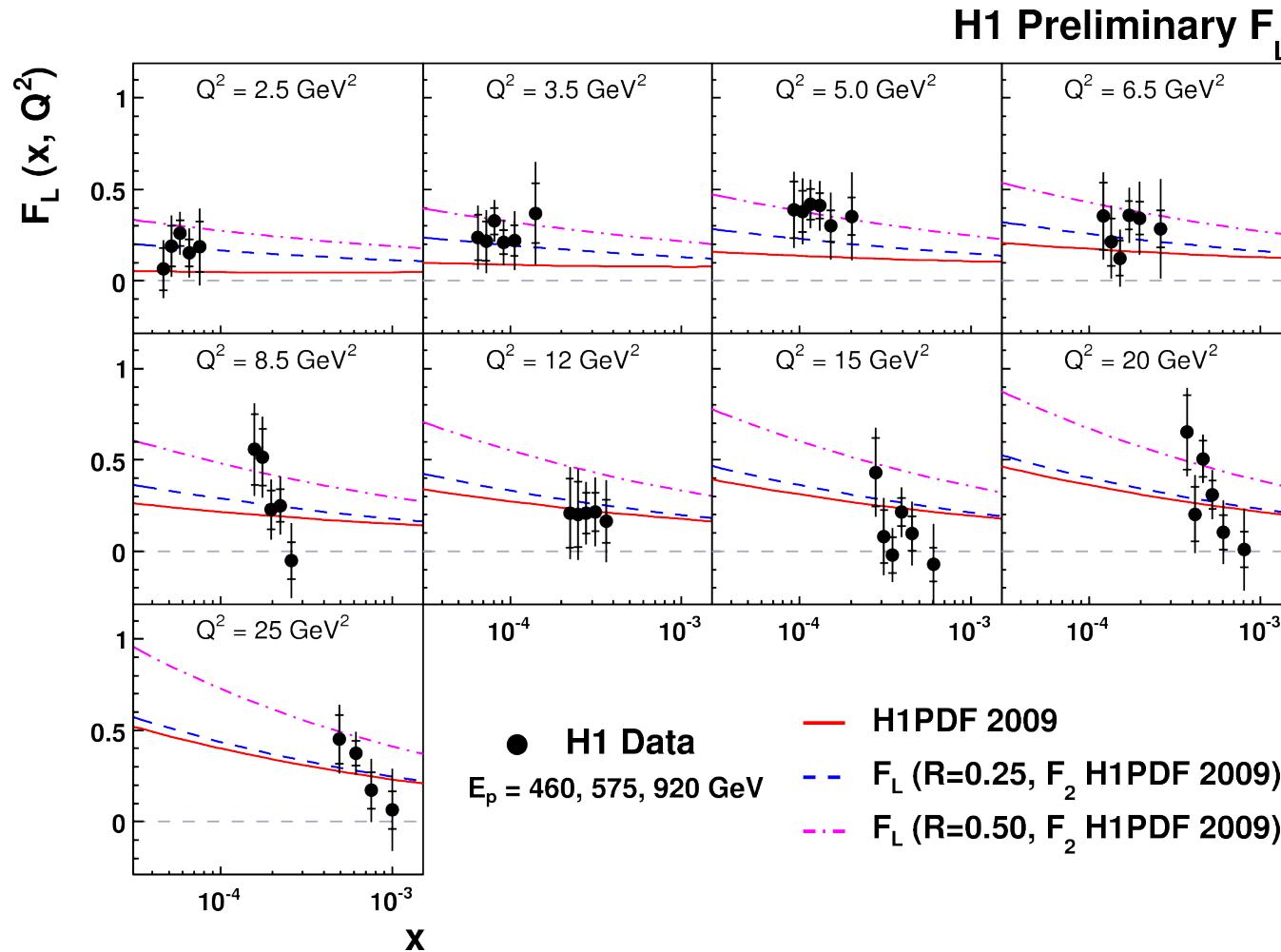
Change y for fixed Q^2, x by changing s

Rosenbluth plot: extract F_L from slope of σ_r as a function of y^2/Y_+





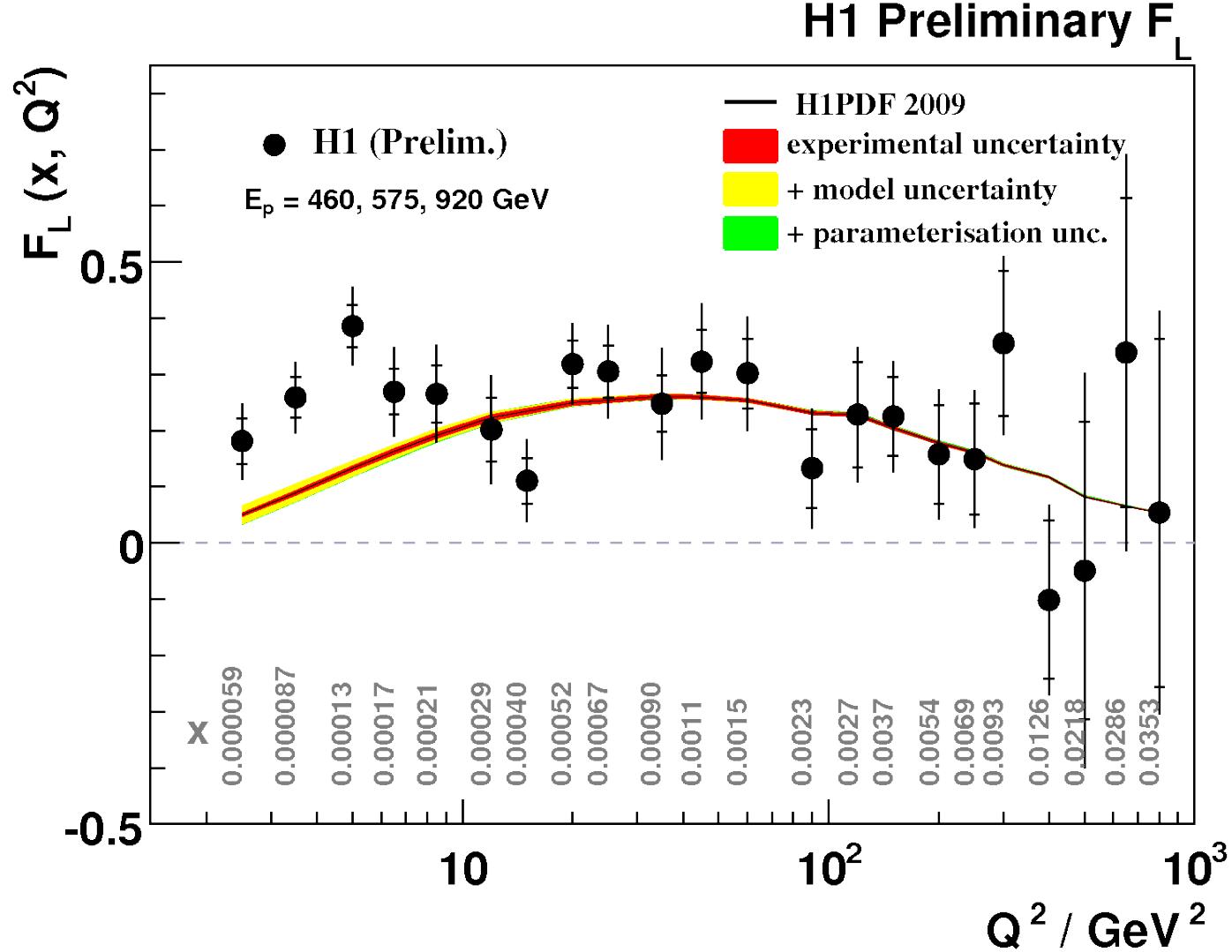
F_L data at low Q^2



- Kinematic range $2.5 \leq Q^2 \leq 25 \text{ GeV}^2$
- Non-zero F_L is confirmed at low Q^2
- Consistent with QCD fits



F_L dependence on Q^2

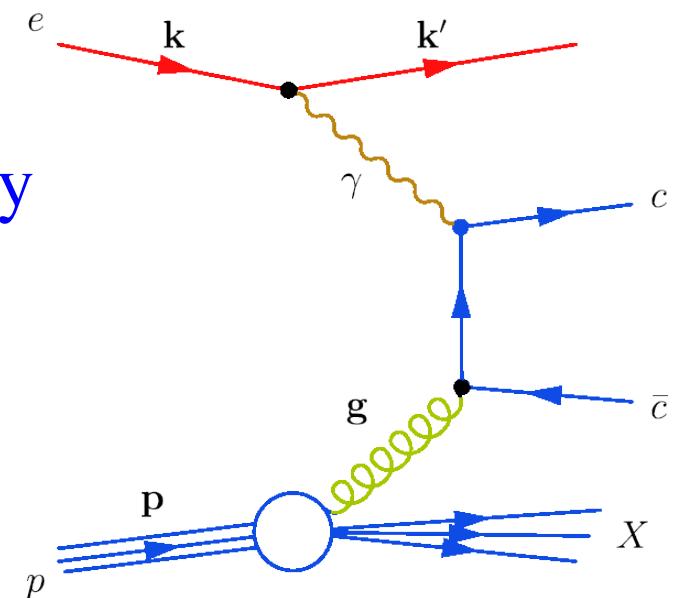


- F_L averaged over x in bins of Q^2
- H1 measurements cover the range $2.5 \leq Q^2 \leq 800 \text{ GeV}^2$



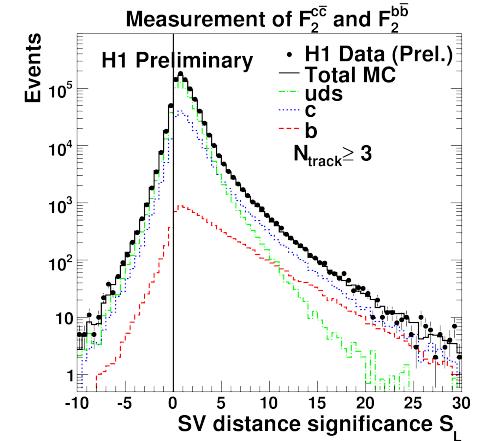
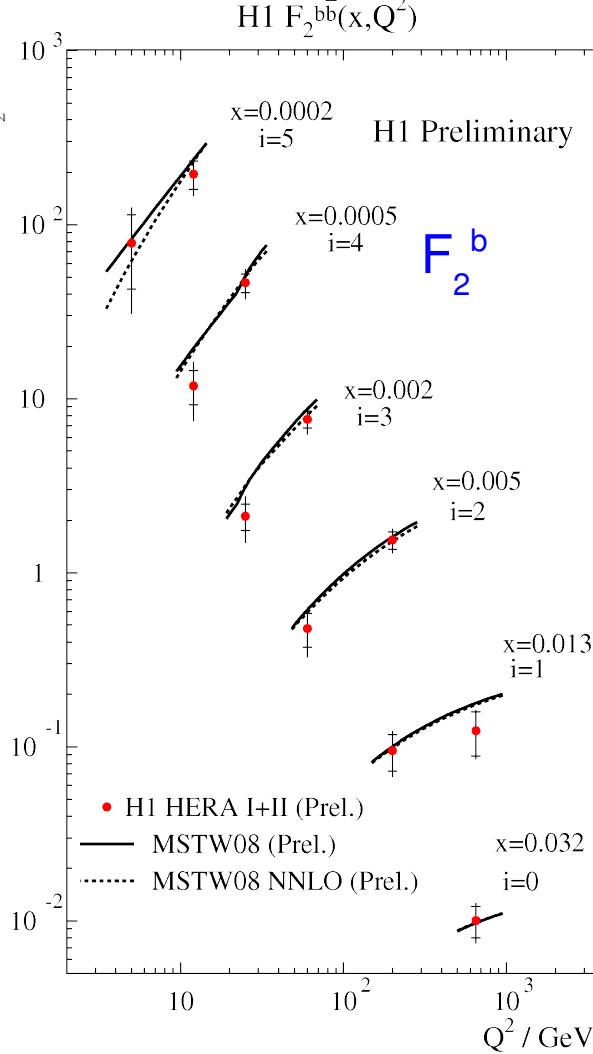
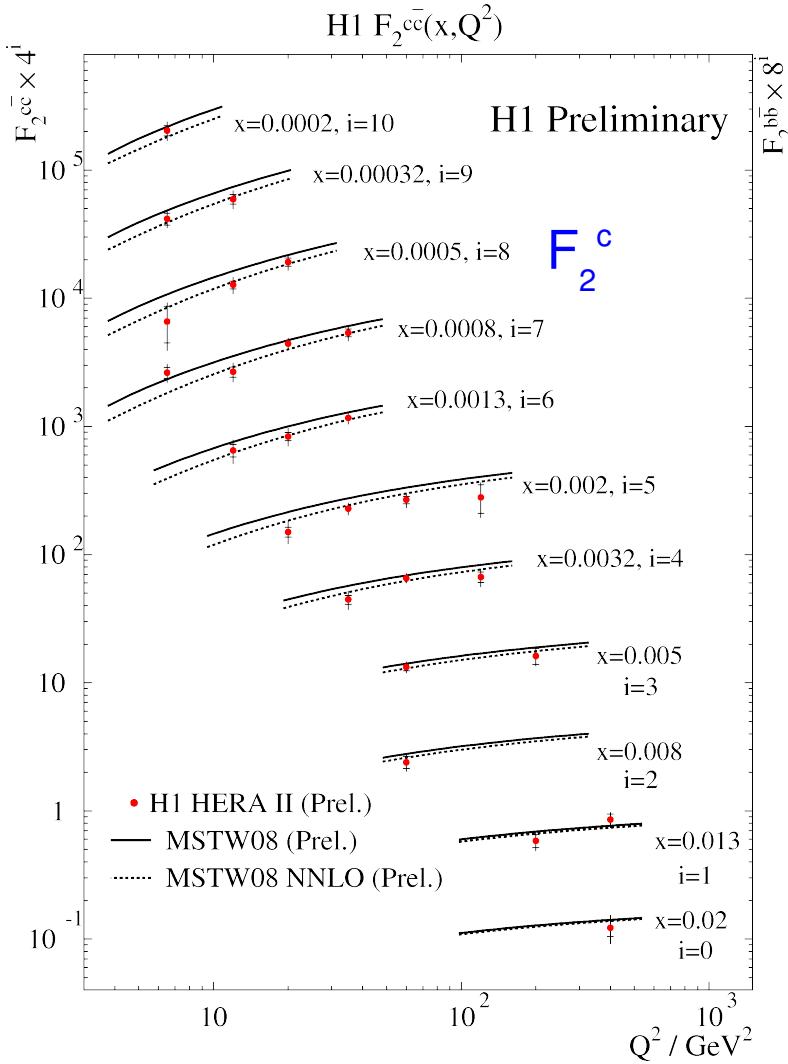
F_2^b and F_2^c structure functions

- Investigate F_2 contribution from beauty and charm
- b, c quarks: produced dominantly by boson-gluon fusion
 - sensitivity to the gluon PDF
- Experimental methods:
b and c hadron lifetime, D^*





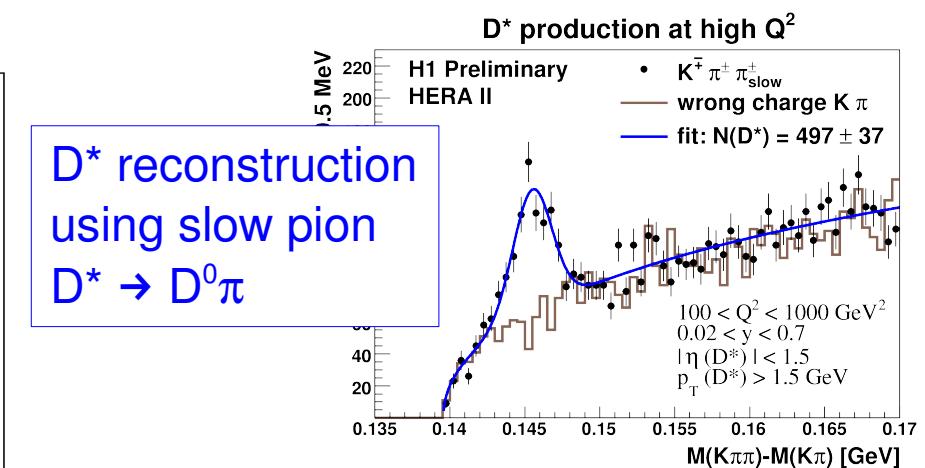
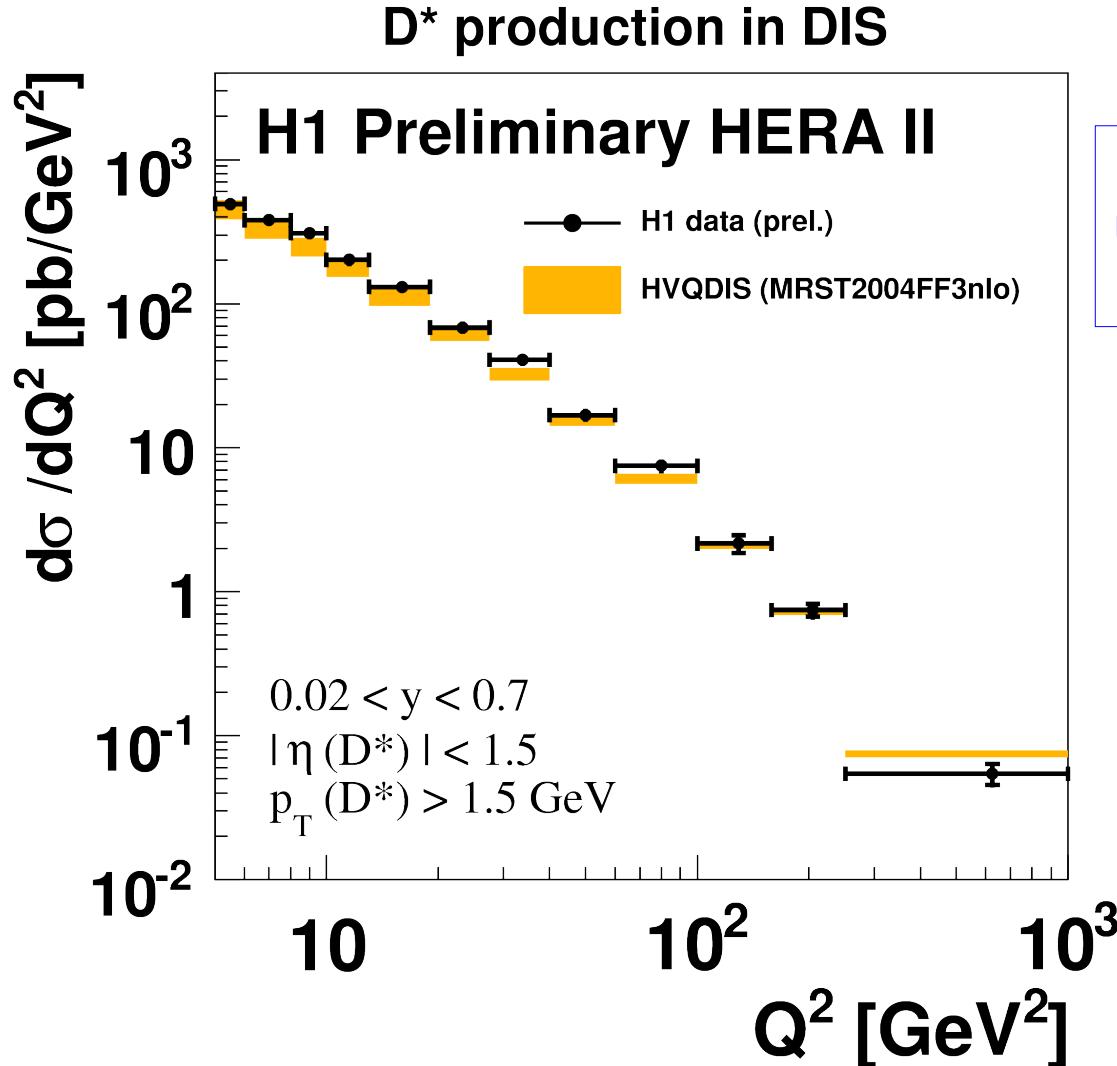
Lifetime analysis



- Lifetime analysis of full HERA II data
- $5 < Q^2 < 650 \text{ GeV}^2$
- Uncertainty:
 - 8% for F_2^c
 - 20% for F_2^b
- Agreement with NLO QCD



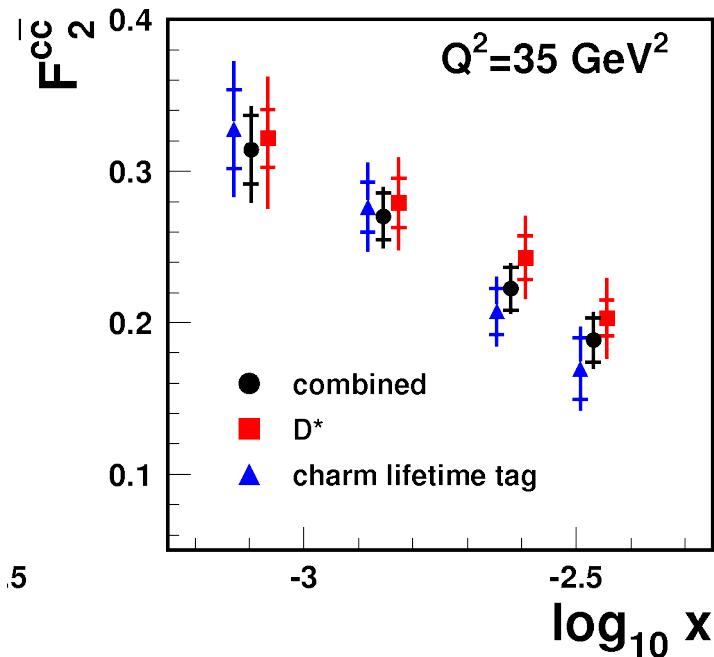
D* production in DIS



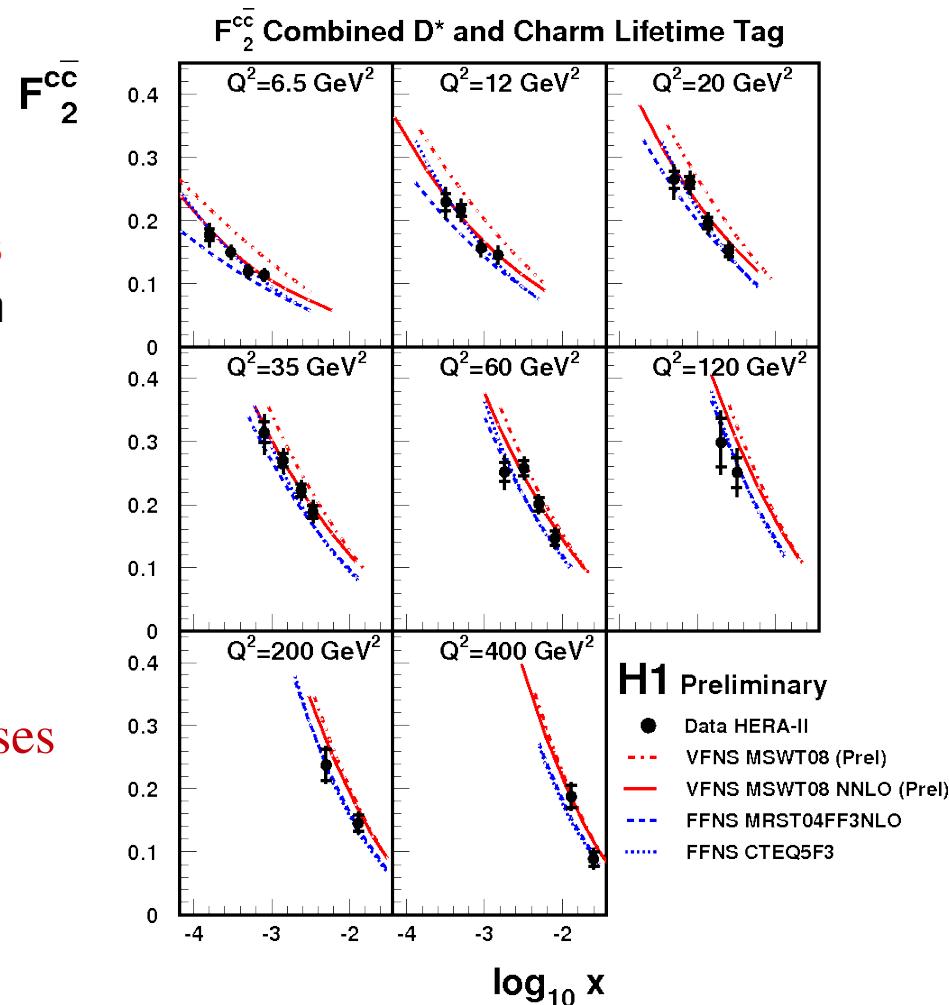
- D^* cross sections measured for $5 \leq Q^2 \leq 1000 \text{ GeV}^2$
- Good description by NLO calculation
- extrapolate to full phase-space, determine F_2^c



Combined F_2^c



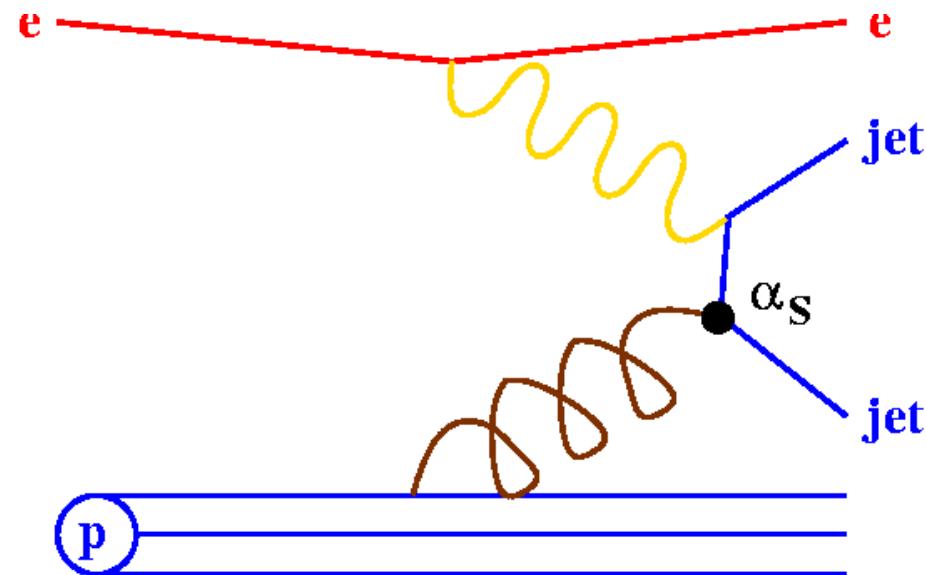
Extract F_2^c from
 D^* cross sections
and combine with
lifetime-tag F_2^c



- Consistent results from lifetime and D^* analyses
- Combine the two measurements
- Significant improvement in precision
- Data constrain PDFs and heavy quark treatment in QCD fits

Hadronic final states

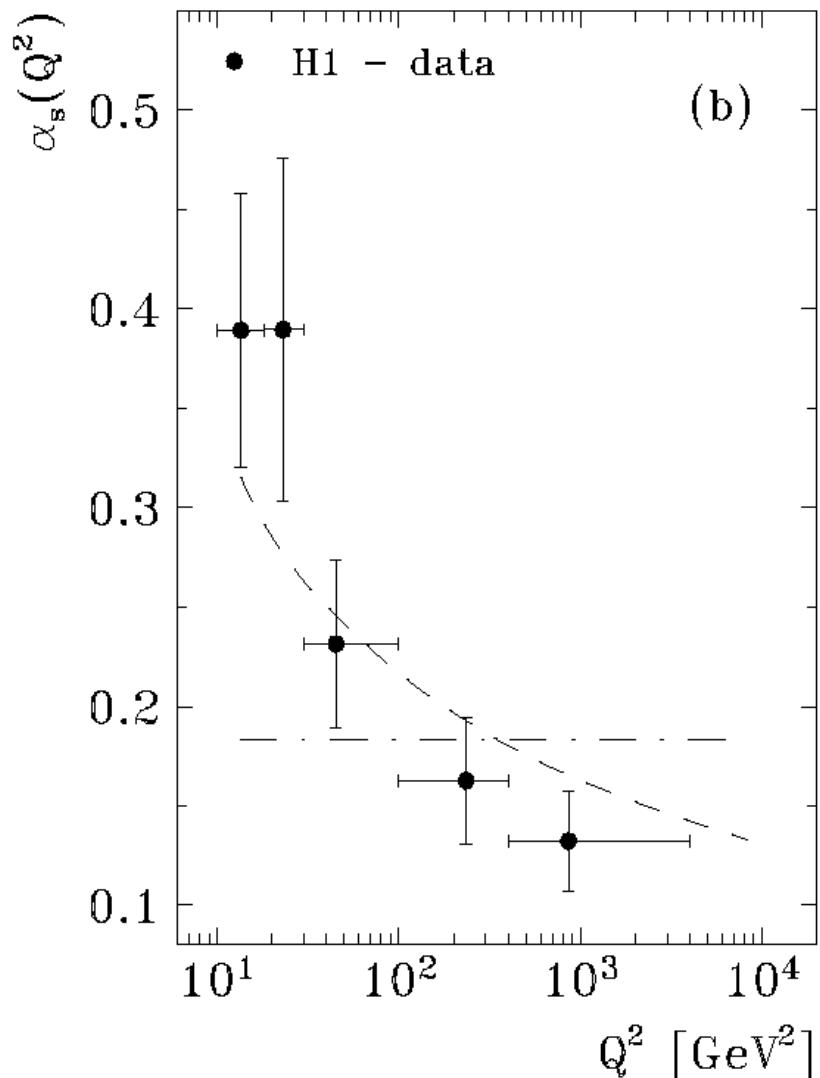
- Determination of α_s from jets at high Q^2





Determination of α_s

1994



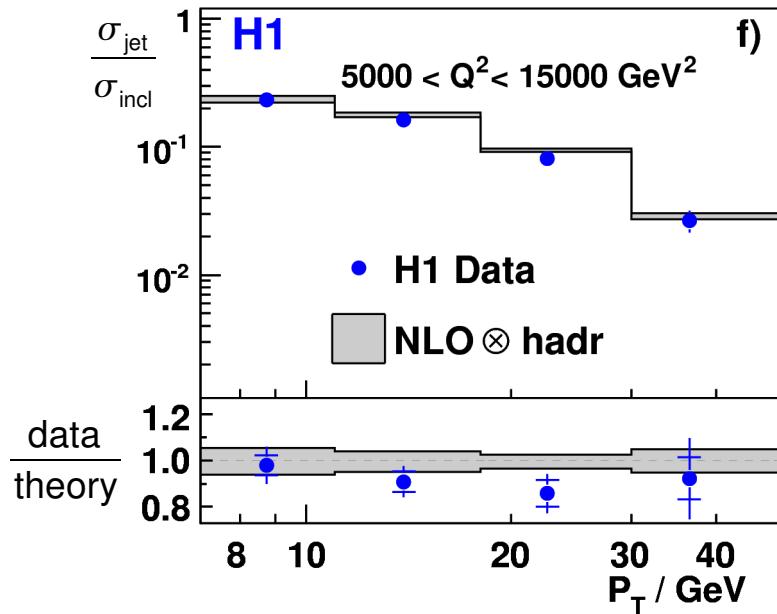
- Analysis of jet rates
- based on $\sim 0.3 \text{ pb}^{-1}$
- α_s is compared to QCD running and flat distribution

$$\alpha_s(M_Z) = 0.123 \pm 0.018$$



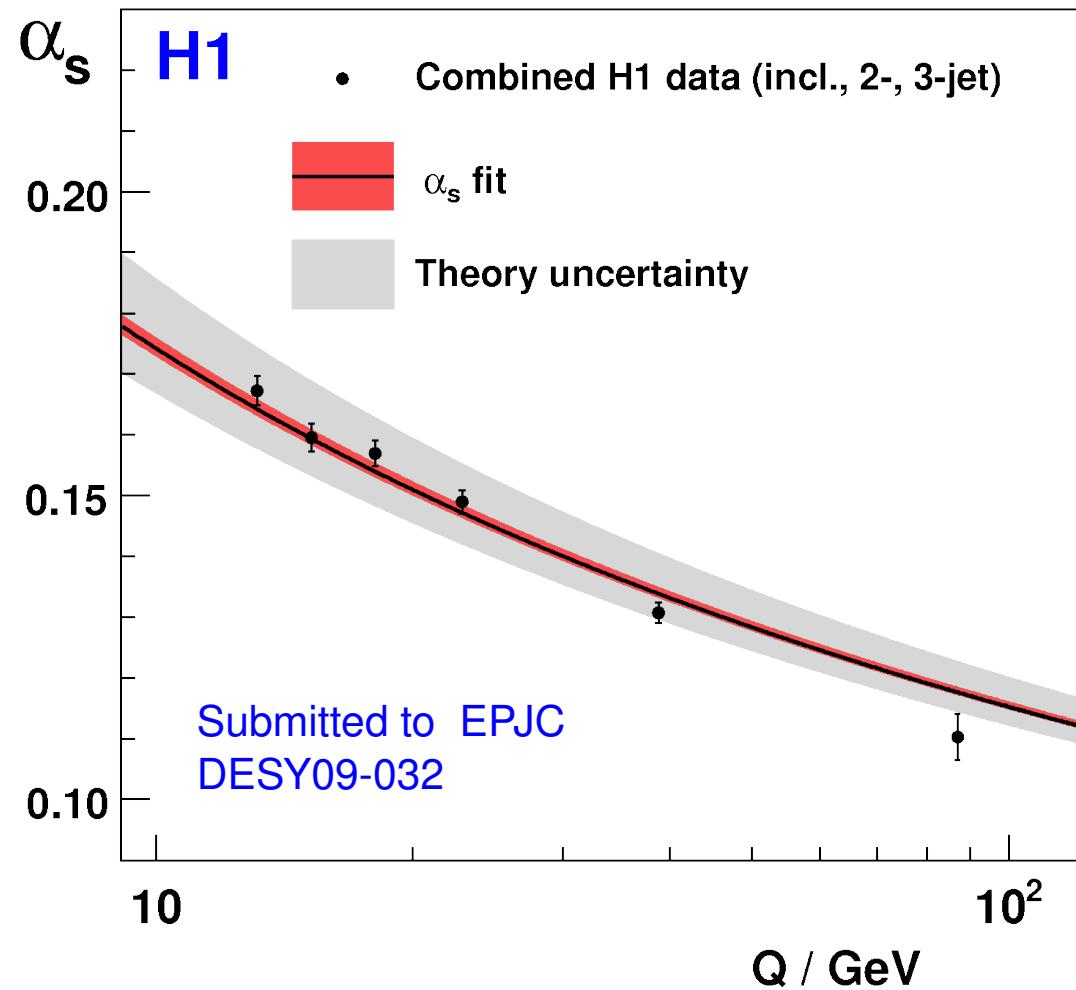
High Q^2 jets and α_s

Inclusive jet rate, highest Q^2 bin



- Analysis of inclusive, 2-jet, 3-jet rates
- Full HERA data now published
- α_s is extracted from a simultaneous fit to $\sigma^{\text{jet}}/\sigma^{\text{incl}}$, $\sigma^{\text{2-jet}}/\sigma^{\text{incl}}$, $\sigma^{\text{3-jet}}/\sigma^{\text{incl}}$

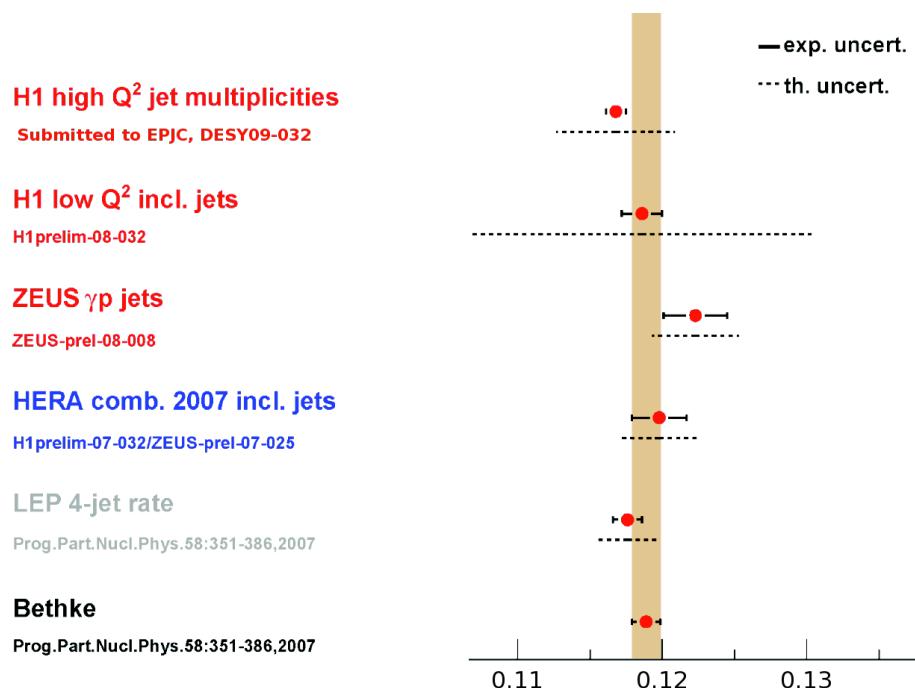
Normalised Jet Cross Sections



Result on α_s

- Result: strong coupling extracted from H1 jet data

$$\alpha_s = 0.1168 \pm 0.0007 \text{ (exp)} \pm^{0.0046}_{0.0030} \text{ (theo)} \pm 0.0016 \text{ (PDF)}$$

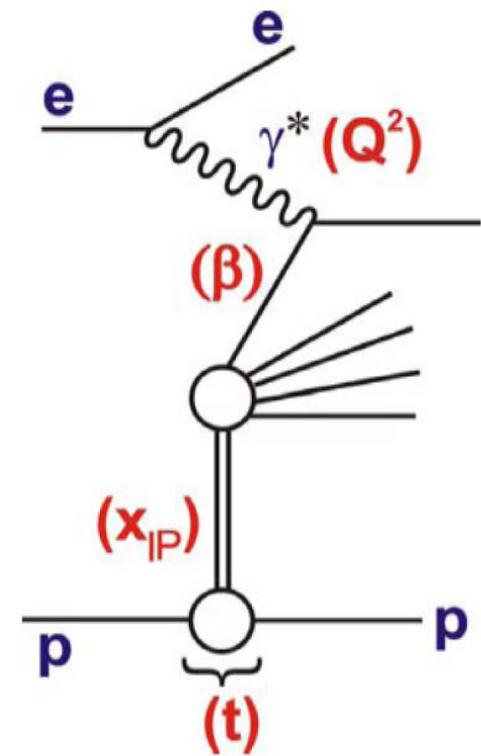


- Experimentally most precise single measurement of α_s (0.6%)
- Theory (NLO) error dominated by scale uncertainties (3-4%)



Diffraction

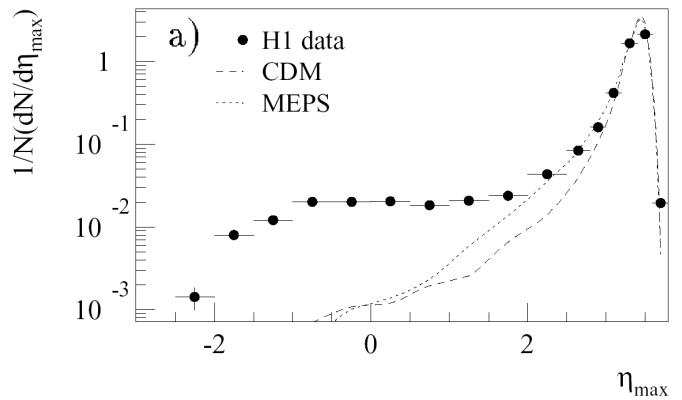
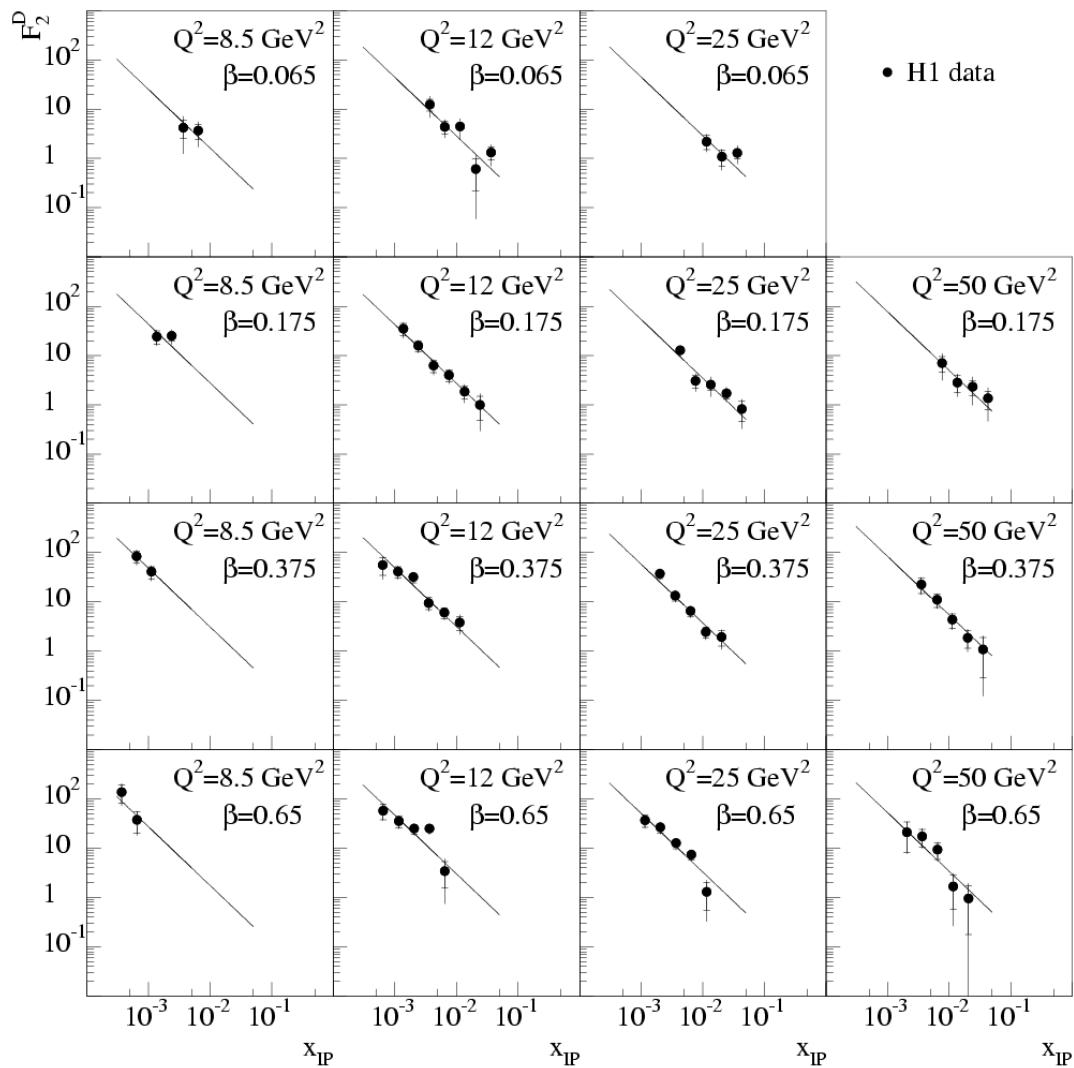
- Leading proton cross-sections
- First measurement of F_L^D





Diffraction

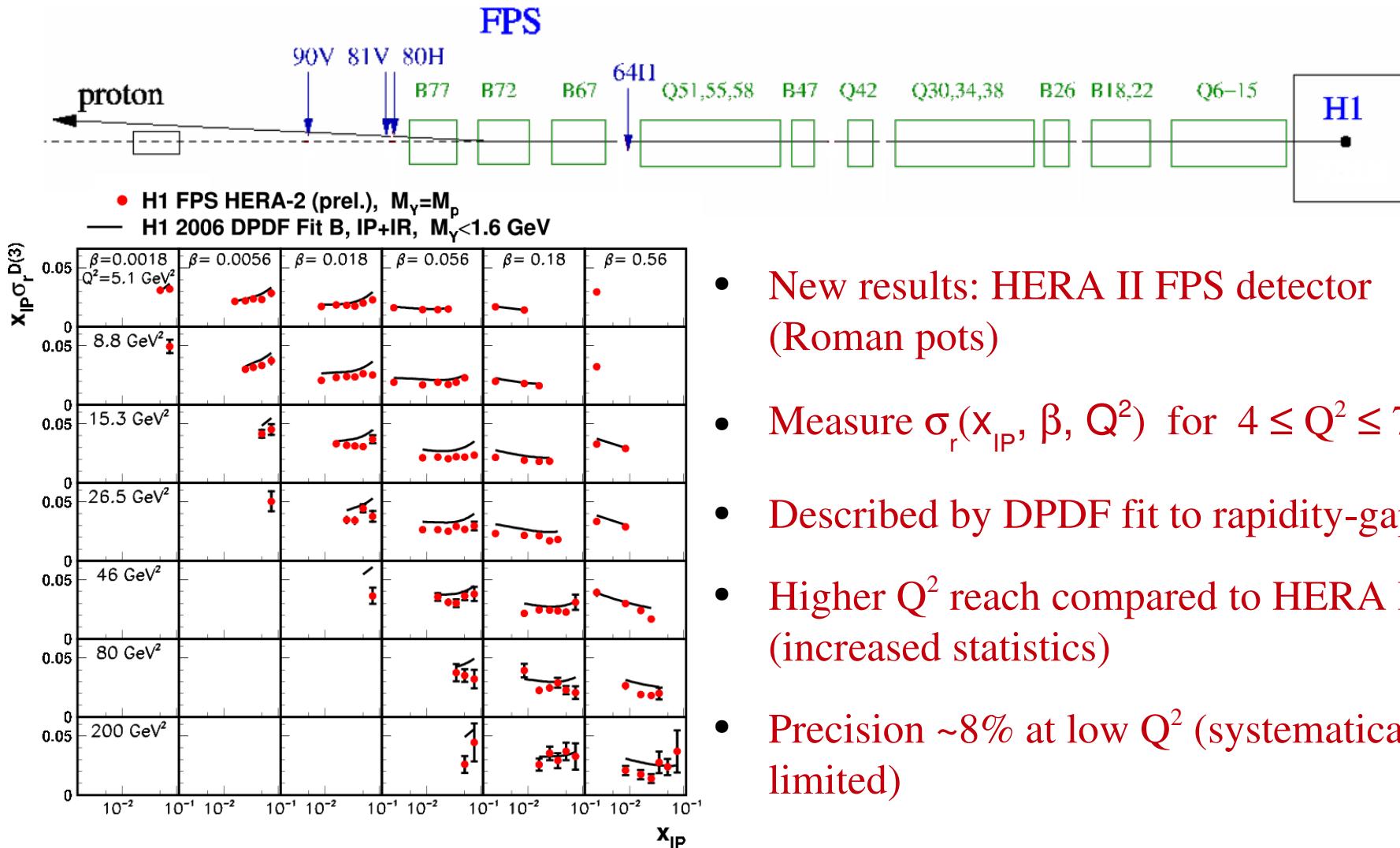
1995



- selection of events with rapidity gap
- first H1 measurement of the diffractive contribution to the proton structure function F_2
- based on 271 nb^{-1}



Leading protons at HERA II



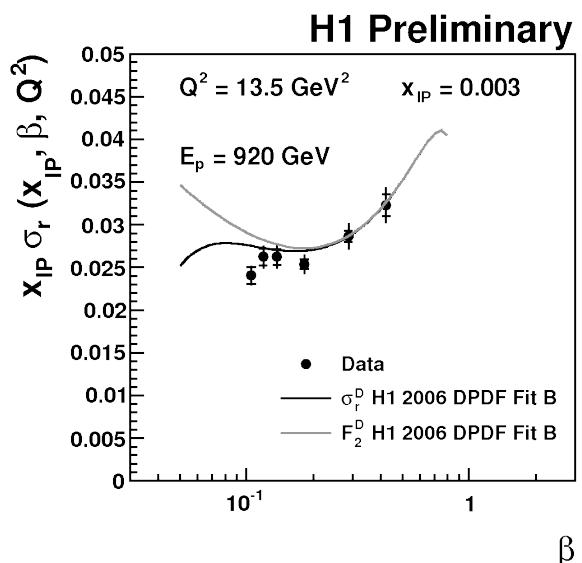
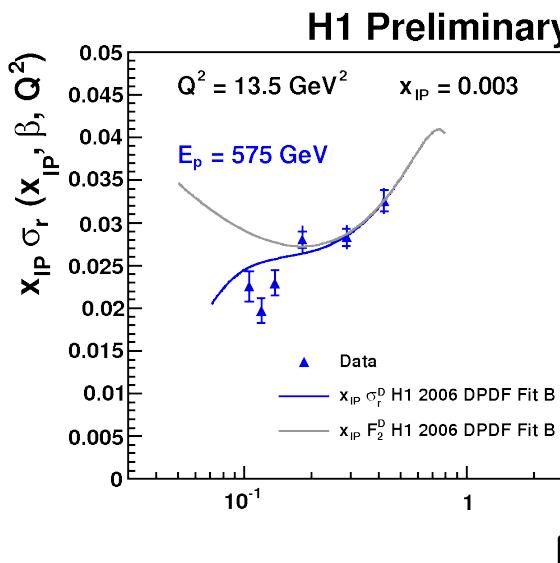
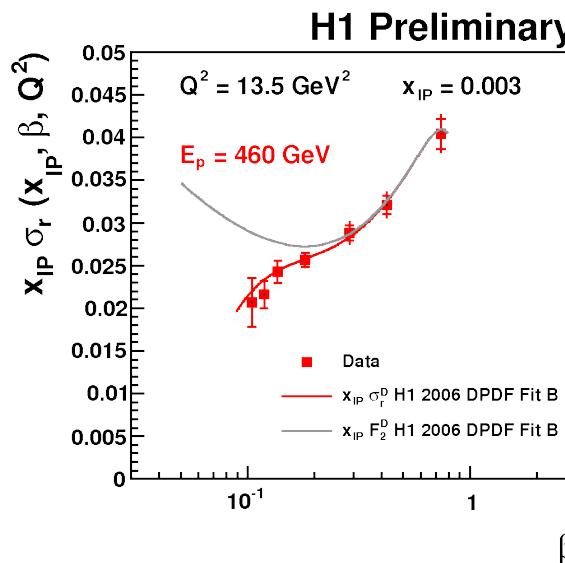
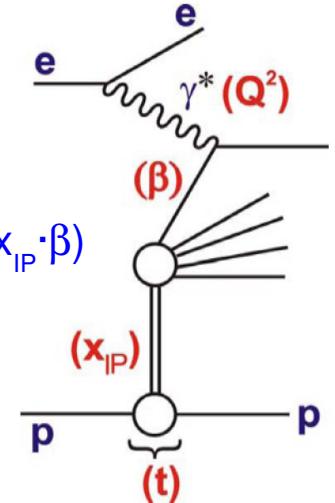


Direct measurement of F_L^D

- Diffractive cross-section can be decomposed into structure functions:

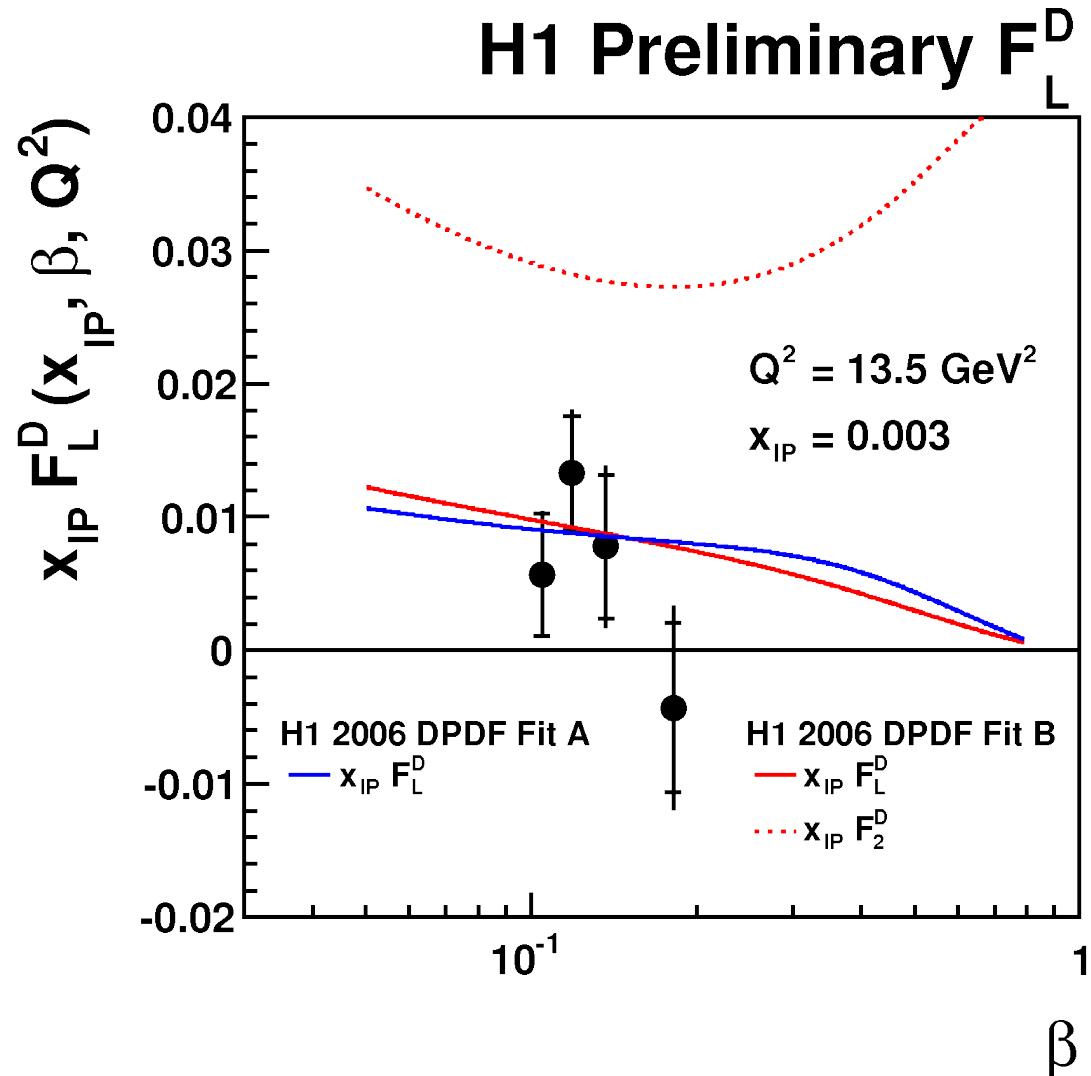
$$\sigma_r^D \propto F_2^D - \frac{y^2}{1 + (1-y)^2} F_L^D$$

- Measure $\sigma_r(x_{IP}, \beta, Q^2)$ at fixed Q^2 , x_{IP} as a function of β
- Extract F_L^D from σ_r data at different beam energies and low β





The H1 F_L^D data



- First measurement of the longitudinal diffractive structure function F_L^D
- Non-zero F_L^D at 3σ
- Consistent with DPDF fit



Summary

- Many new results from H1
 - Milestones of the physics program are achieved
- Some Highlights
 - H1+ZEUS combined searches
 - Precision data on inclusive cross-sections and F_2
 - Precision normalized jet cross-sections and α_s
 - New measurement of F_L at low Q^2
 - First measurement of F_L^D
- Very productive phase, more results expected soon



Analyses for EPS-HEP

- searches
 - single top quark production
 - excited quarks; electrons; neutrinos
 - general search
 - isolated leptons, W production
 - combined isolated leptons, W prod.
 - Multi-Leptons
 - combined Multi-Leptons
 - squarks in R-Parity violating SUSY
- inclusive
 - x-section at low Q^2 and x
 - x-section at medium Q^2
 - HERA I combined x-section
 - QCD fit of the combined data
 - F_L at low; medium; high Q^2
 - high Q^2 NC and CC
- heavy flavour
 - charm fragmentation into $D^{*\pm}$
 - F_2^c and F_2^b using the H1 vertex detector
 - inelastic photoproduction of J/ψ
 - search for a D^*p resonance
 - D^* in photoproduction; at low Q^2 ; large Q^2
 - beauty photoprod. with muons and jets
 - F_2^c from D^* in DIS
 - comb. of F_2^c from D^* and displaced tracks
- QCD tests
 - jets and α_s at high Q^2 ; low Q^2
 - incl. photoprod. of ρ^0 , K^{*0} and ϕ
 - strangeness at low Q^2 in DIS
 - $K^{*\pm}$ production at low Q^2 in DIS
 - 3- and 4-jet production at low x
 - isolated photons DIS; photoproduction
 - hadronic final state charge asymmetry
 - multiple interactions in photoprod.
- diffraction
 - Photons with Large Momentum
 - diffractive ρ and ϕ in DIS
 - DVCS and its Beam Charge Asym.
 - dijets and PDFs in Diffractive DIS
 - diffractive photoproduction of jets
 - diff. longitudinal structure function F_L^D
 - DIS with a leading proton
 - leading neutron production in DIS
 - Pomeron trajectory with ρ photoprod.



Backup



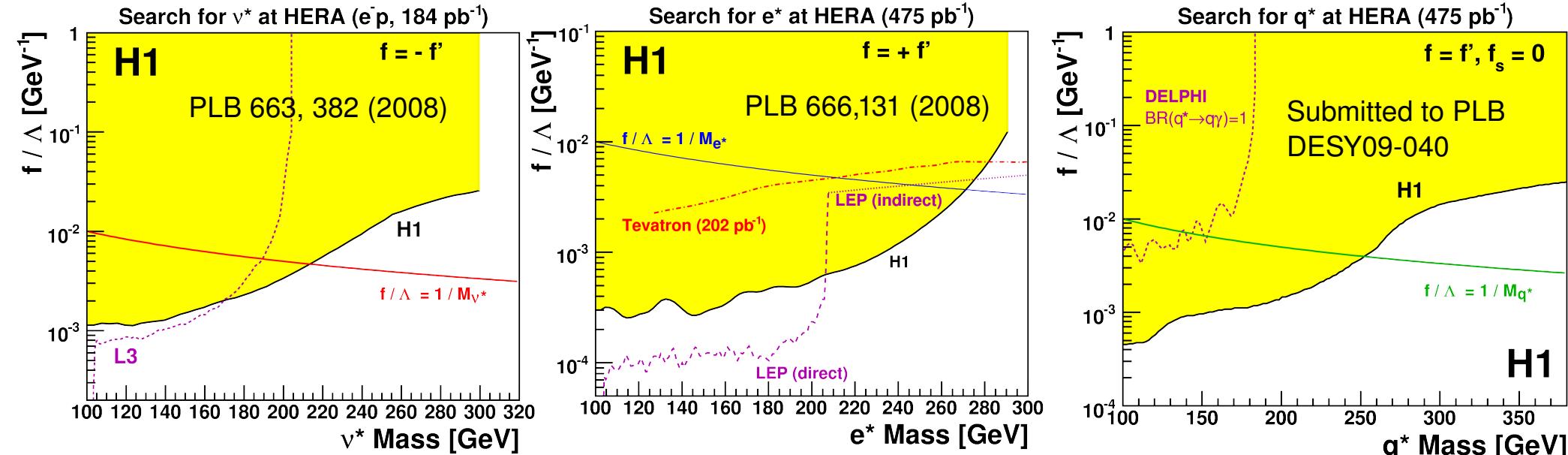
H1 and HERA



- ep Collider HERA
 $E_p = 920 \text{ GeV}$, $E_e = 27.6 \text{ GeV}$
 $\sqrt{s} = 319 \text{ GeV}$
- Collider experiments H1 and ZEUS
- H1 Luminosity
 184 pb^{-1} in e^-p
 294 pb^{-1} in e^+p
- Low energy run:
 12 pb^{-1} at $E_p = 460 \text{ GeV}$
 6 pb^{-1} at $E_p = 575 \text{ GeV}$

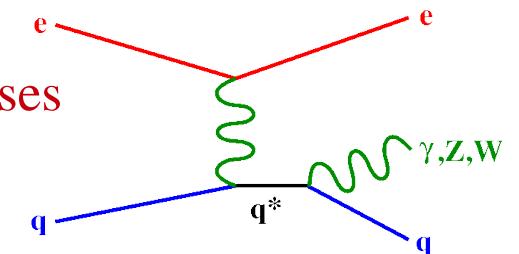
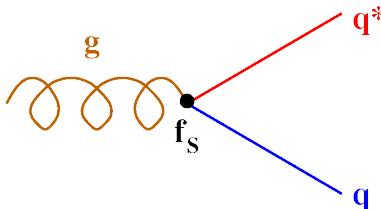


Excited Fermion limits



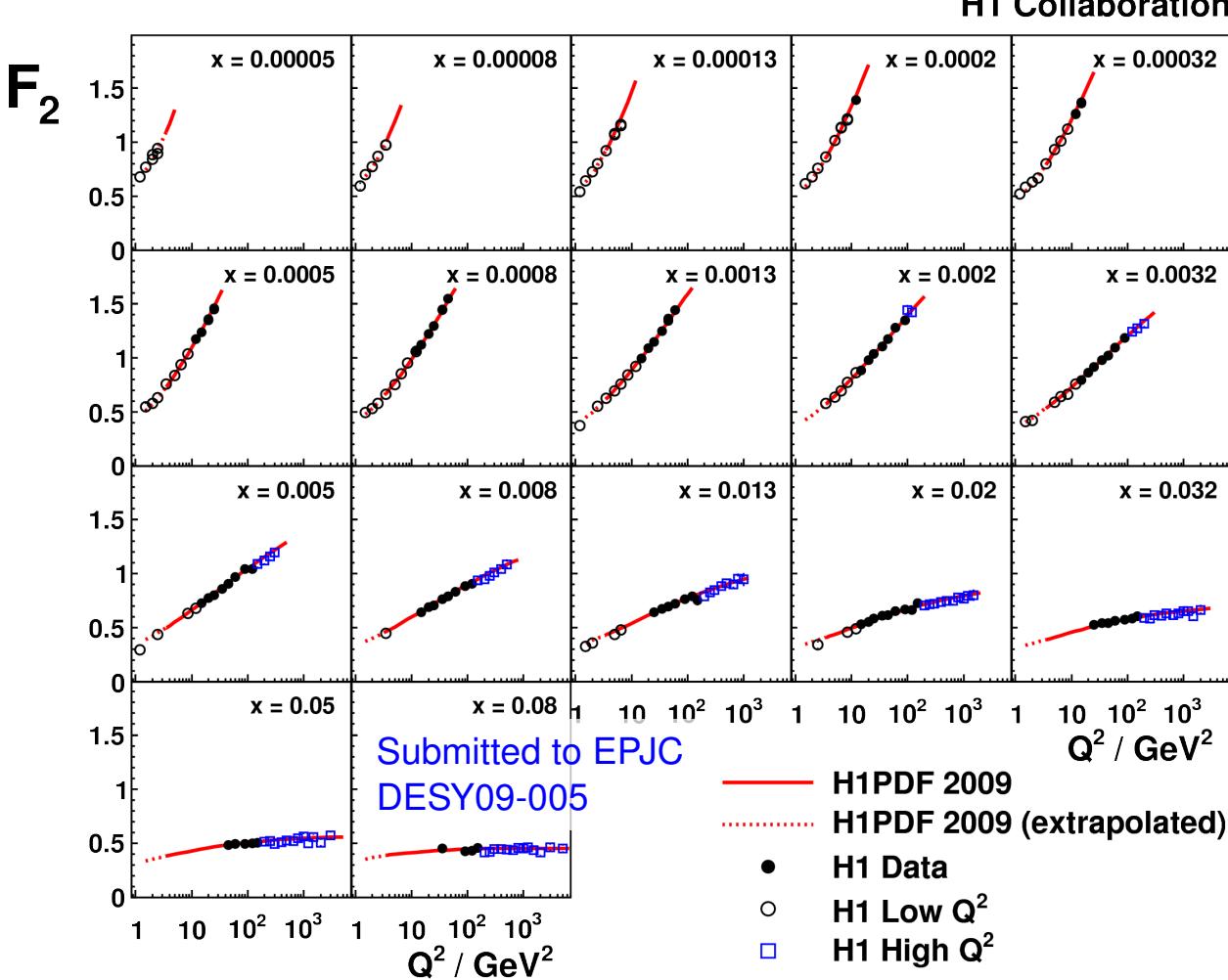
- Full HERA statistics analysed and published
- Best collider limits on compositeness scale f/Λ for high ν^* masses
- Best excited quark limits for $f_s=0$

complementary to Tevatron
assumption $f_s=f$





H1PDF 2009 QCD fit

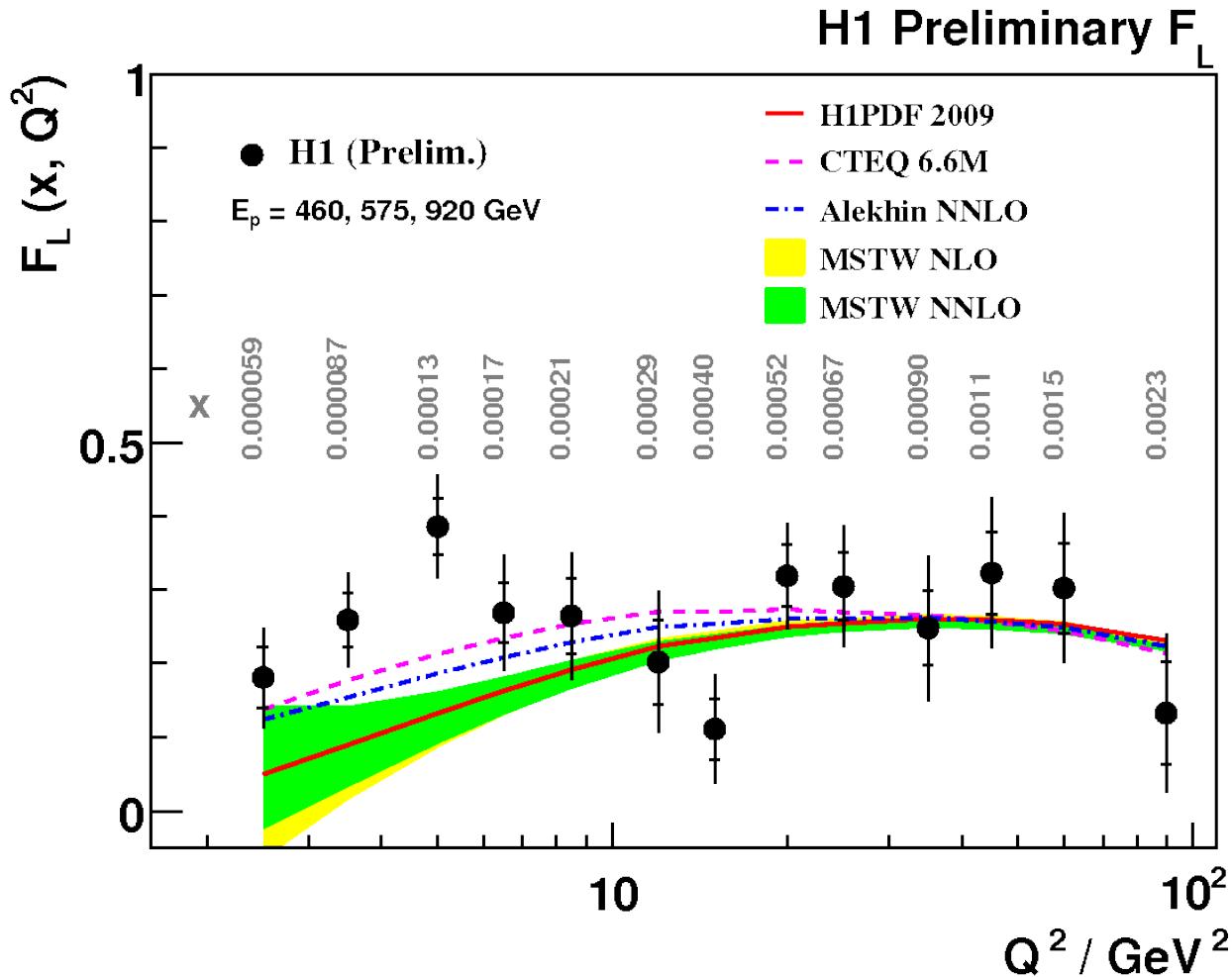


- QCD fit to all H1 HERA-I data, NC and CC
- VFNS heavy flavour treatment (Thorne/Roberts)

HERAPDF0.2 Fit



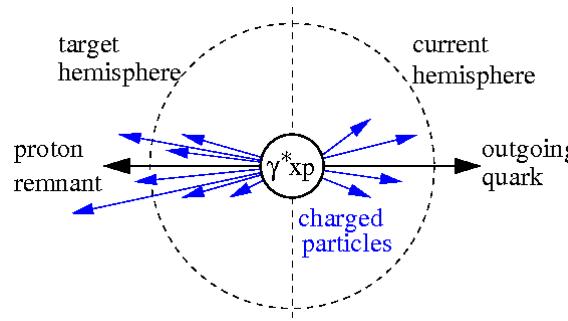
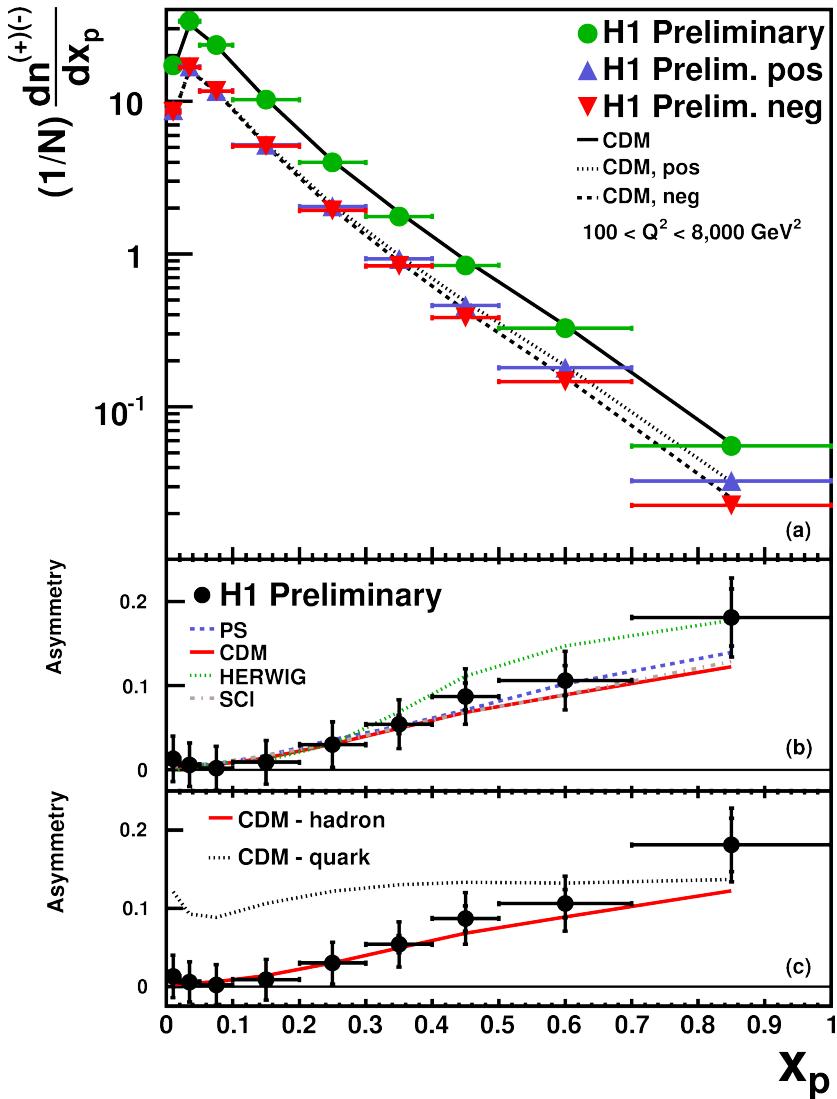
F_L as a function of Q^2



- Low Q^2 regions: largest spread in theoretical predictions
- Sensitivity to PDFs



Particle charge asymmetry

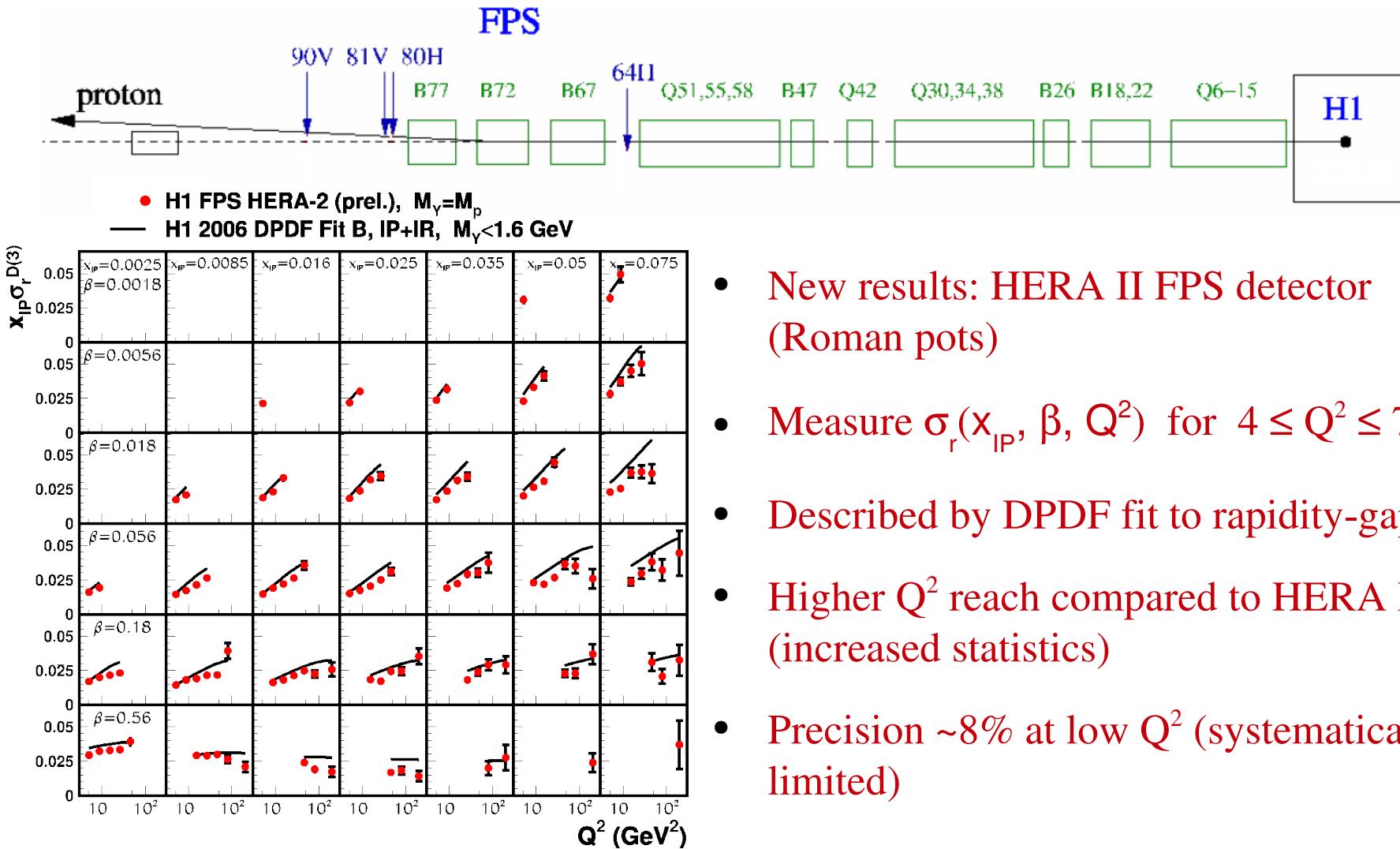


Momentum fraction
in current hemisphere
of the Breit frame
 $x_p = 2p/Q$

- Measure rate of charged particles produced in the current hemisphere at high $Q^2 > 100$ GeV 2
- Asymmetry of positive to negative charged tracks, up to 0.2 at high x_p
- In agreement with fragmentation models

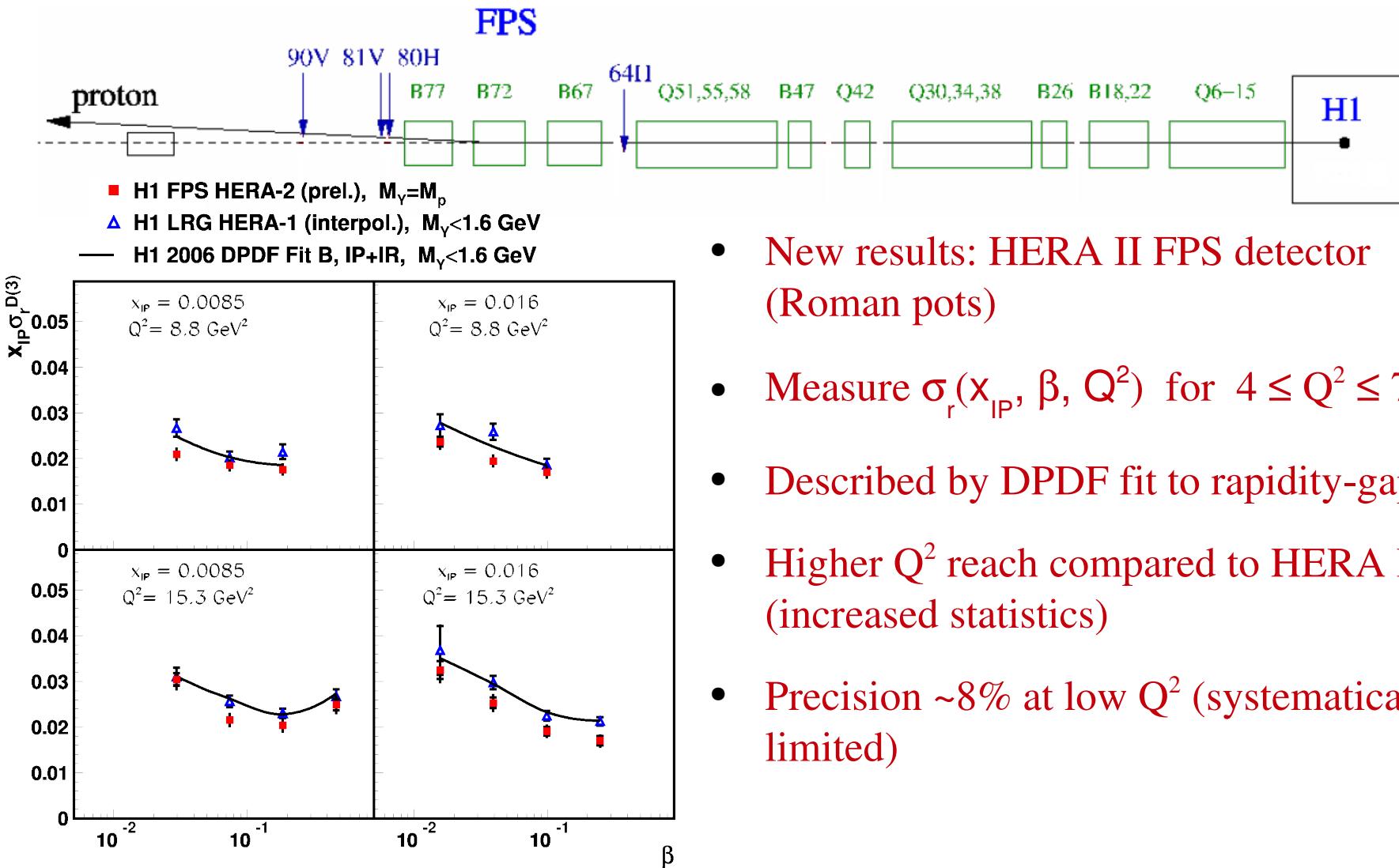


Leading protons at HERA II





Leading protons at HERA II

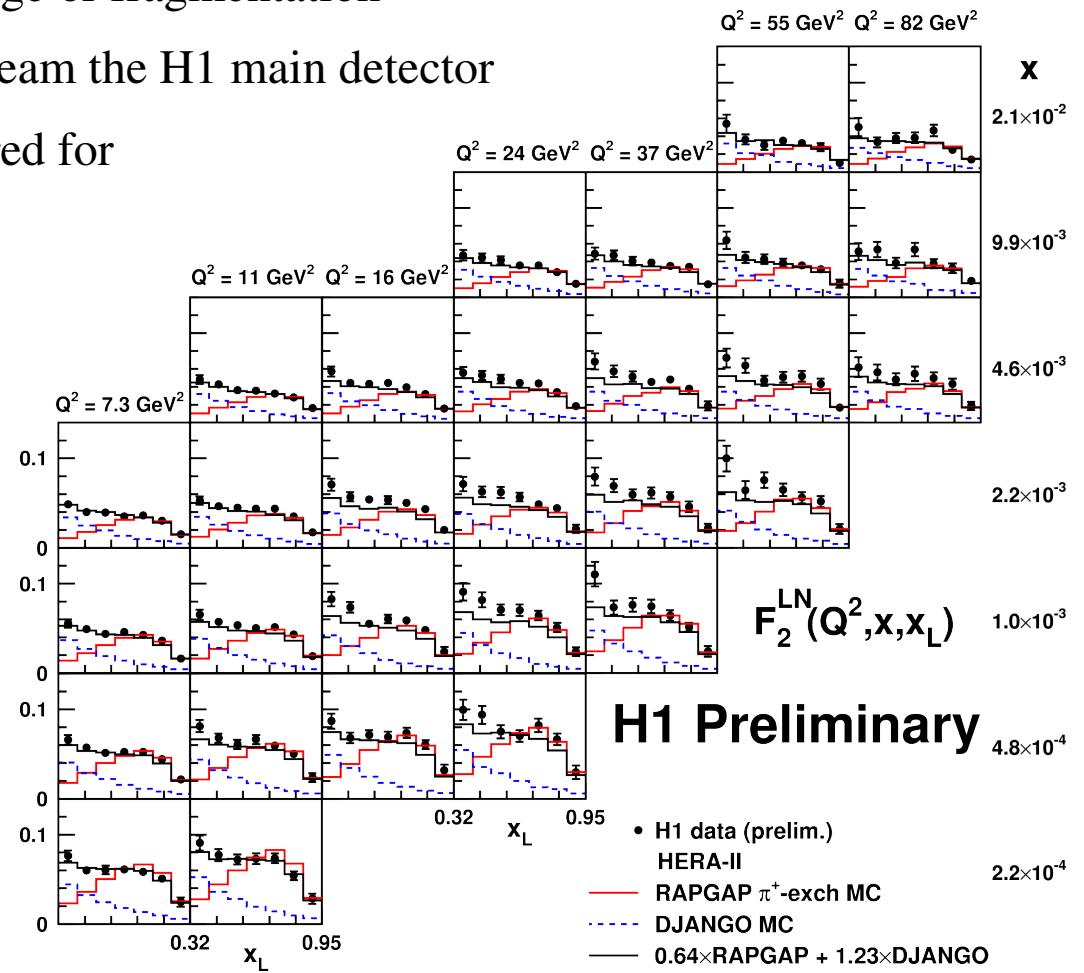
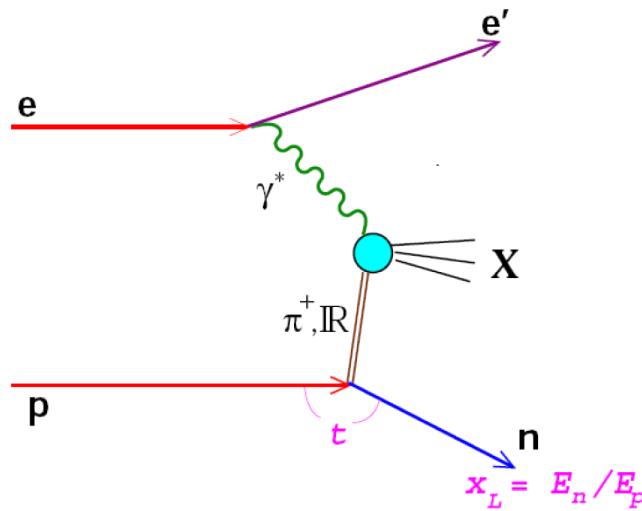


- New results: HERA II FPS detector (Roman pots)
- Measure $\sigma_r(x_{IP}, \beta, Q^2)$ for $4 \leq Q^2 \leq 700 \text{ GeV}^2$
- Described by DPDF fit to rapidity-gap data
- Higher Q^2 reach compared to HERA I FPS (increased statistics)
- Precision $\sim 8\%$ at low Q^2 (systematically limited)



Leading neutrons at HERA II

- Leading neutrons: produced by π^+ exchange or fragmentation
- Forward Neutron Counter, 106m downstream the H1 main detector
- Structure function $F_2^{LN}(Q^2, x, x_L)$ is measured for $6 < Q^2 < 100 \text{ GeV}^2$

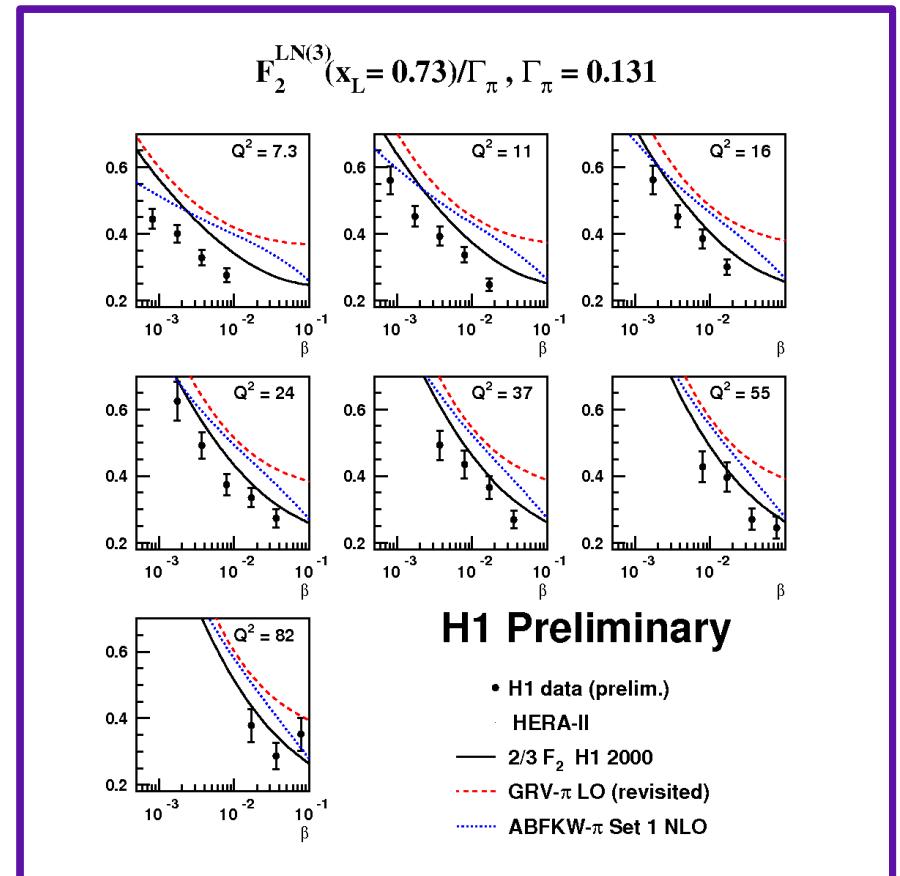
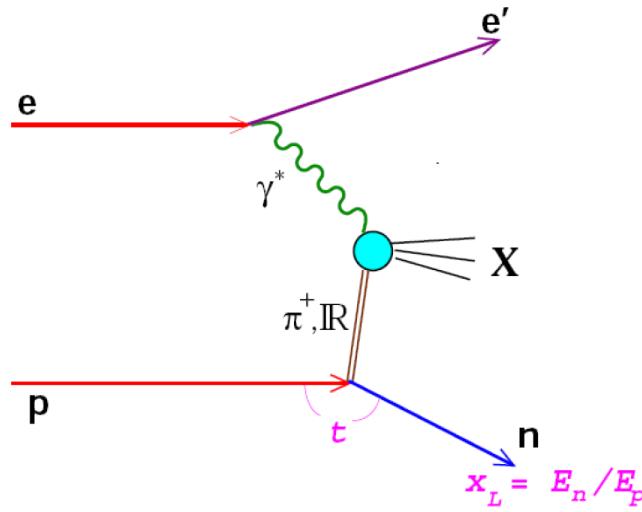


- Data described by π^+ exchange
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- Extract π structure function from data at high x_L



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