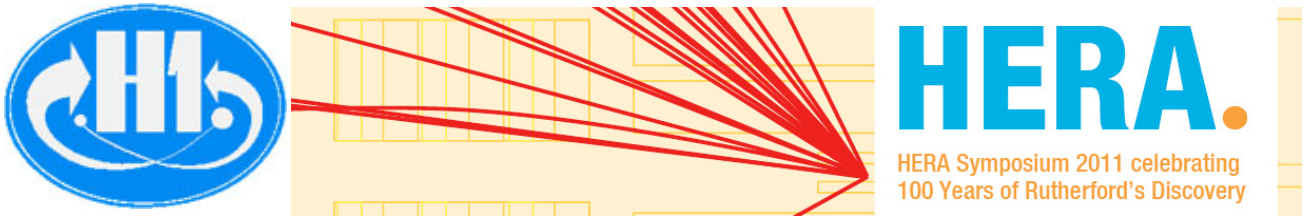


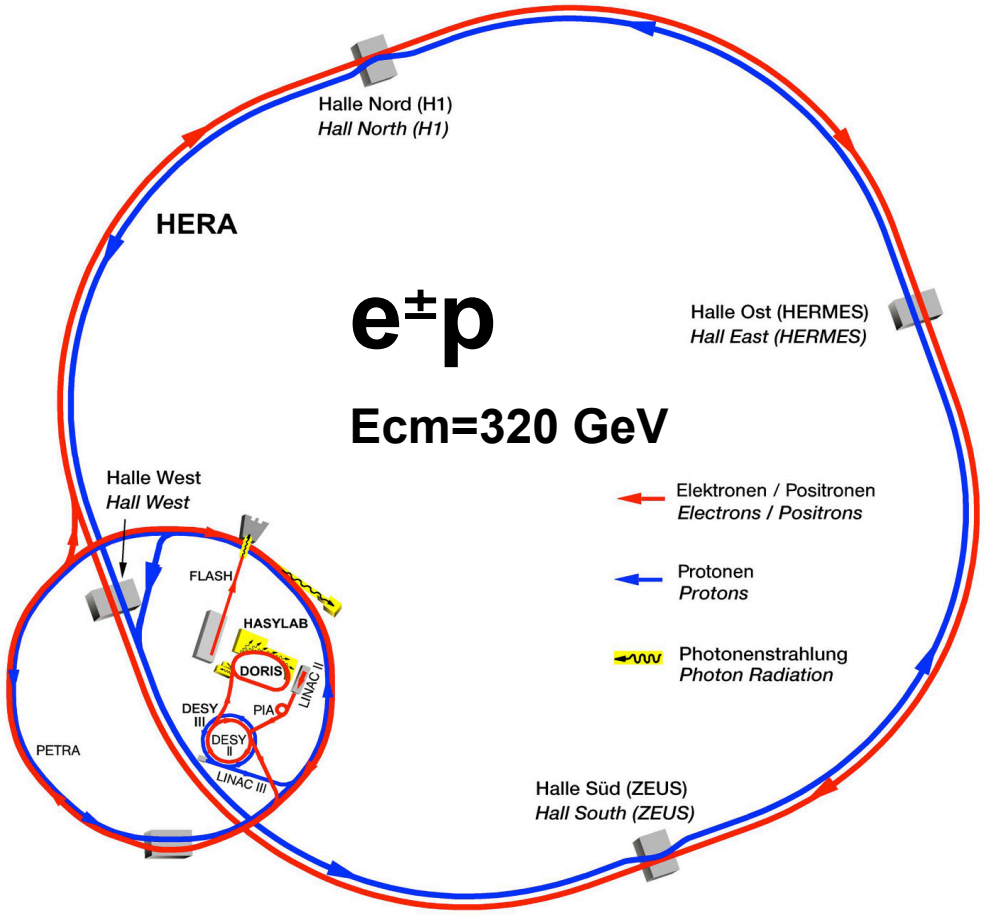
H1 Recent Results

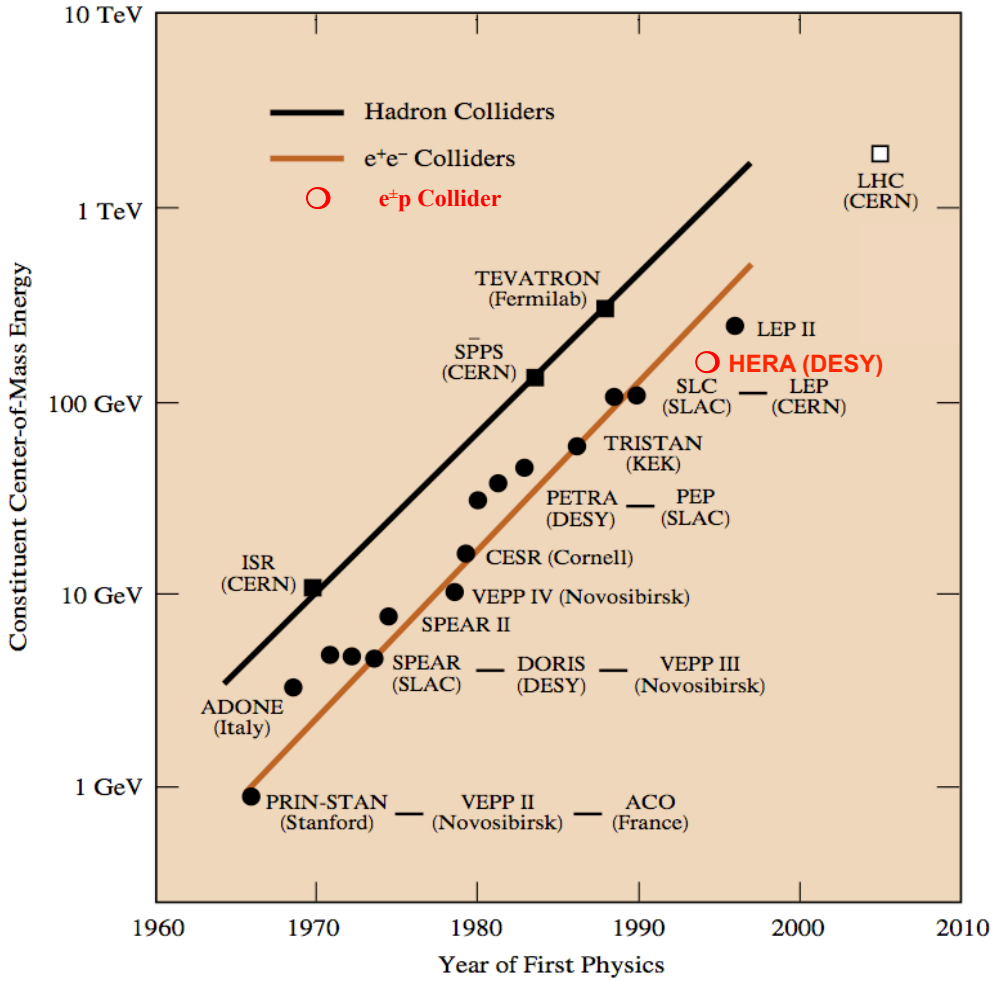
HERA SYMPOSIUM

July 5, 2011

Cristinel Diaconu
CPPM/DESY

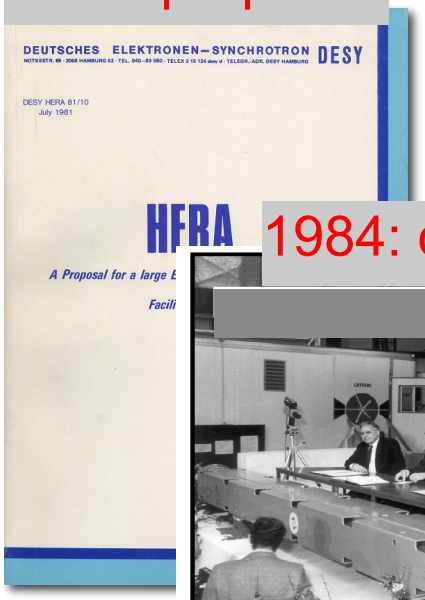
HERA: the unique ep collider





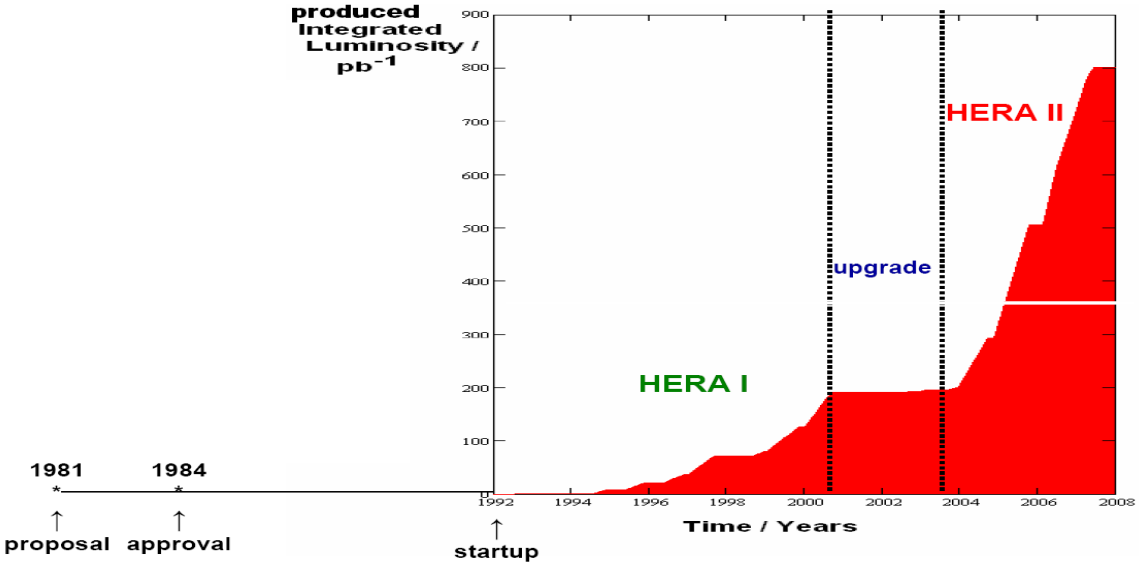
HERA Milestones

1981: proposal



1984: decision

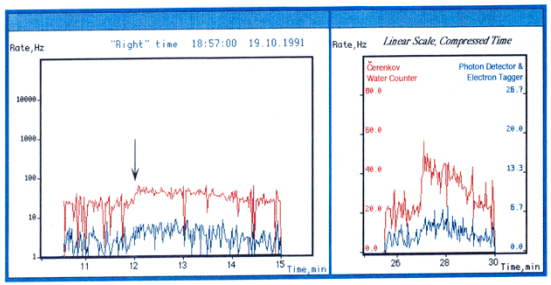
Volker Soergel and the Minister of Science of Germany, Heinz Riesenhuber, at DESY (Hamburg) announcing on 6th of April 1984 that HERA will be built.



1991: first collisions

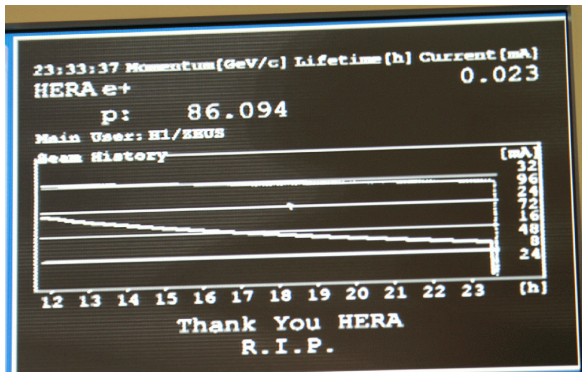
AS OBSERVED BY THE H1 LUMINOSITY-DETECTOR MONITORING SYSTEM

SATURDAY 19 OCTOBER 1991, 18:54



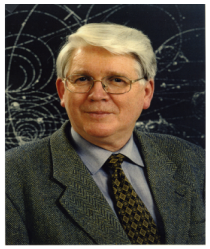
Electron Energy	12 GeV
Proton Energy	480 GeV
Expected Luminosity	$0.95 \times 10^{26} \pm 30\%$ cm^{-2}s^{-1}
Measured Luminosity	$1.03 \times 10^{26} \pm 13\%$ cm^{-2}s^{-1}

2007: end of collisions



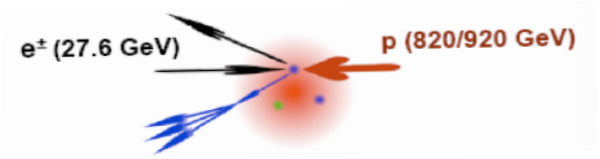
G.A.Voss, B. Wiik, F. Willeke

G. A. Voss

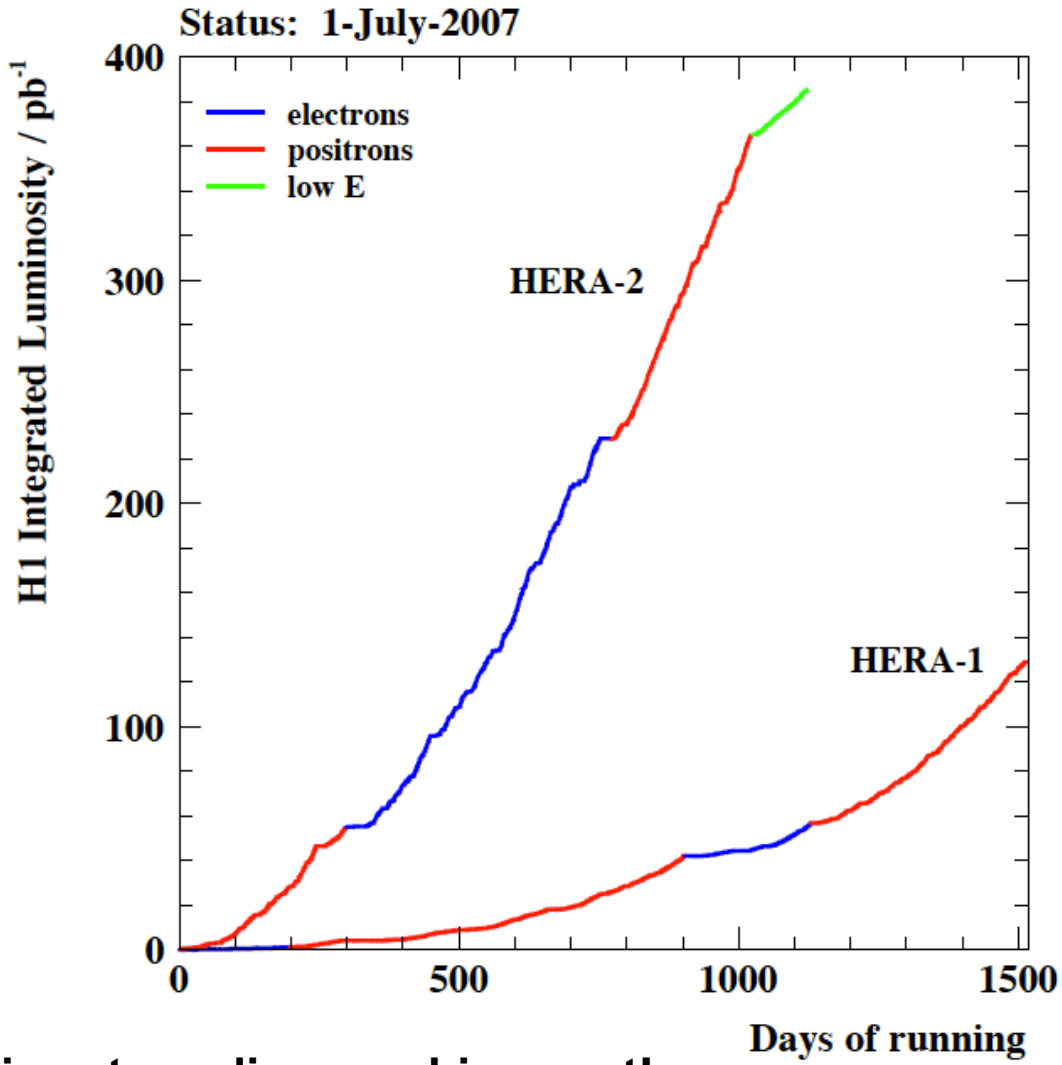


B. H. Wiik

Data sets

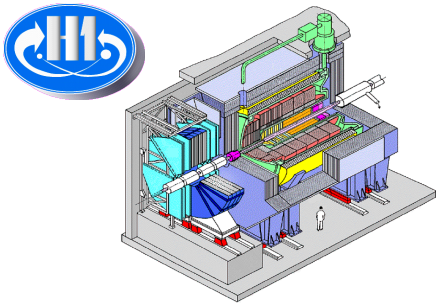


- **HERA I : 115 pb^{-1}**
  - e+/e- 27.6 GeV
  - Protons 820/920 GeV
- **HERA II: 330 pb^{-1}**
  - Polarised e+/e- 27.6 GeV
  - Protons 920 GeV
- **Low energy runs**
  - Protons 460/575 GeV



Thanks to HERA machine people for this extraordinary achievment!

The physics at HERA



The proton structure

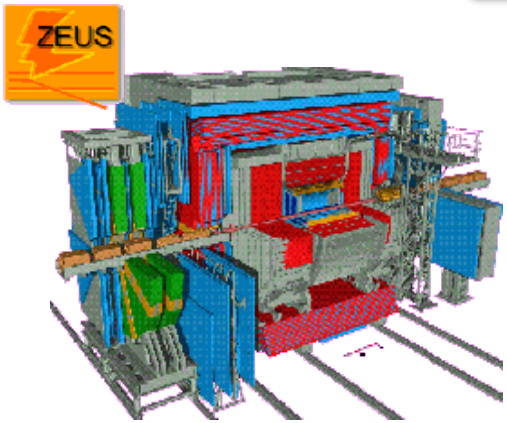
with unprecedented precision

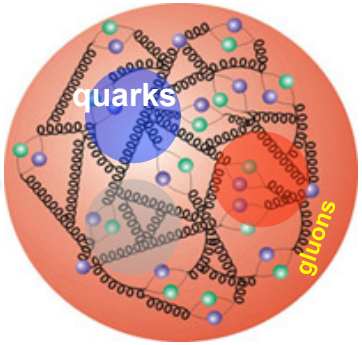
Parton distribution functions for the future

The strong force

in a clean "laboratory"

Jets, Diffraction, Low x





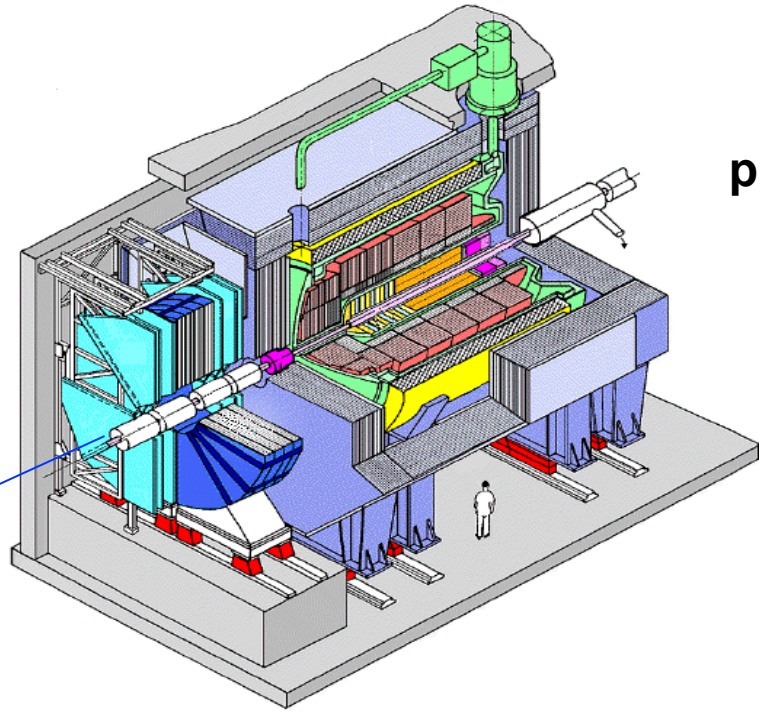
The proton spin surgery

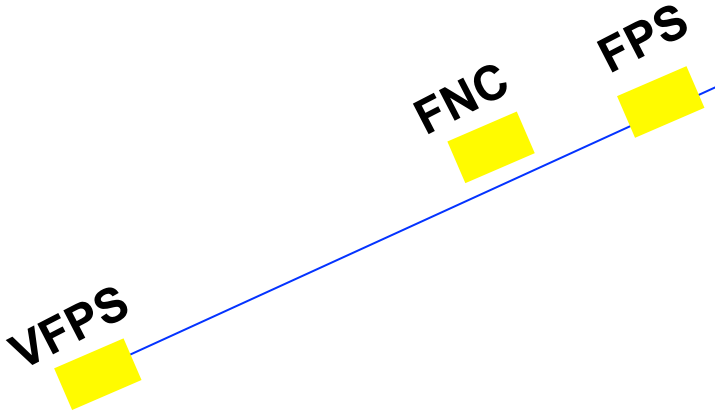
Searches for new physics

at the ep energy frontier

H1

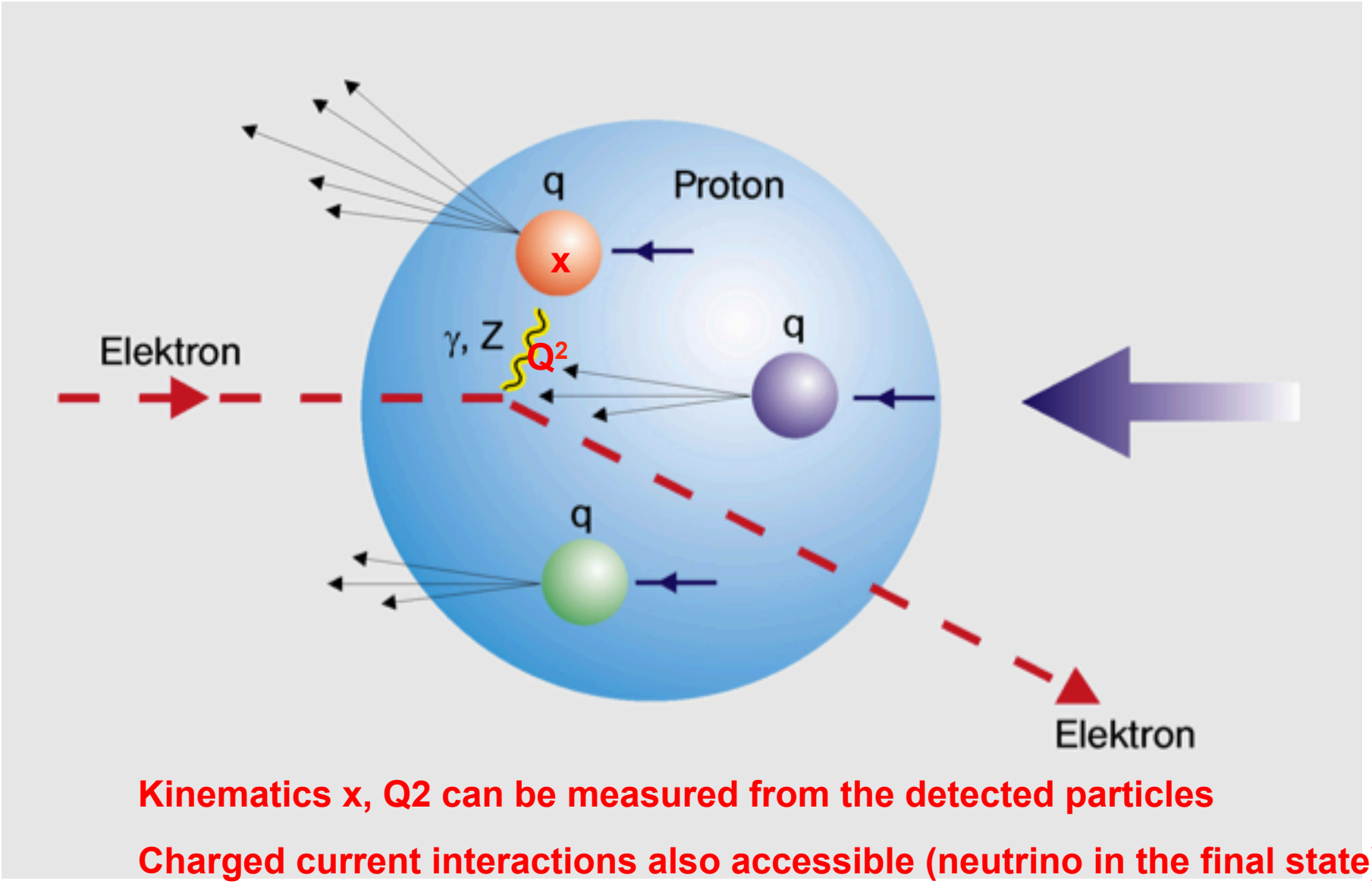
- HERA II
- Several improvements for HERA II
  - Tracking : silicon detectors, prop. chambers
  - Trigger : Fast Track Trigger
  - « Tunnel » devices:
    - (V)FPS (Very) Forward Proton Spectrometer
    - FNC Forward Neutron Counter





- Massive GRID usage for MC production
- Major data reprocessing in 2009/2010

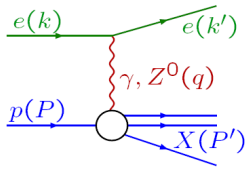
Deep-Inelastic Scattering



Kinematics x, Q2 can be measured from the detected particles

Charged current interactions also accessible (neutrino in the final state)

DIS: Cross sections, structure functions, partons



$$\tilde{\sigma}^{\pm}_{NC} = \frac{\mathrm{d}^2\sigma^{e^{\pm}p}_{NC}}{\mathrm{d}x\mathrm{d}Q^2}\frac{xQ^4}{2\pi\alpha^2 Y_+} = \tilde{F}_2 - \frac{y^2}{Y_+}\tilde{F}_L \mp \frac{Y_-}{Y_+}x\tilde{F}_3, \quad Y_\pm = 1 \pm (1-y)^2$$

Leading Order picture of the proton

Parton Distribution Functior

F_2 $\left[F_2, F_2^{\gamma Z}, F_2^Z\right] = x\sum_q \left[e_q^2, 2e_q v_q, v_q^2 + a_q^2\right](q + \bar{q})$ quarks

gluons from scaling violations

F_3 $\left[xF_3^{\gamma Z}, xF_3^Z\right] = 2x\sum_q \left[e_q a_q, v_q a_q\right](q - \bar{q})$ (valence) quarks

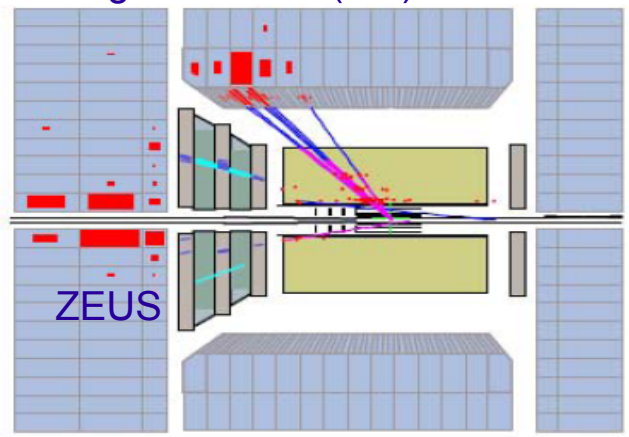
F_L $F_L \sim x\alpha_s g$ gluons

CC: similar decomposition, but different quarks combinations accessed

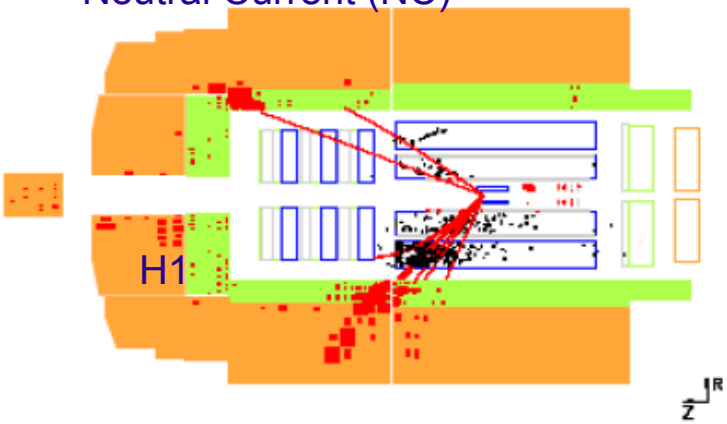
flavour sensitive (separate in e+p/e-p)

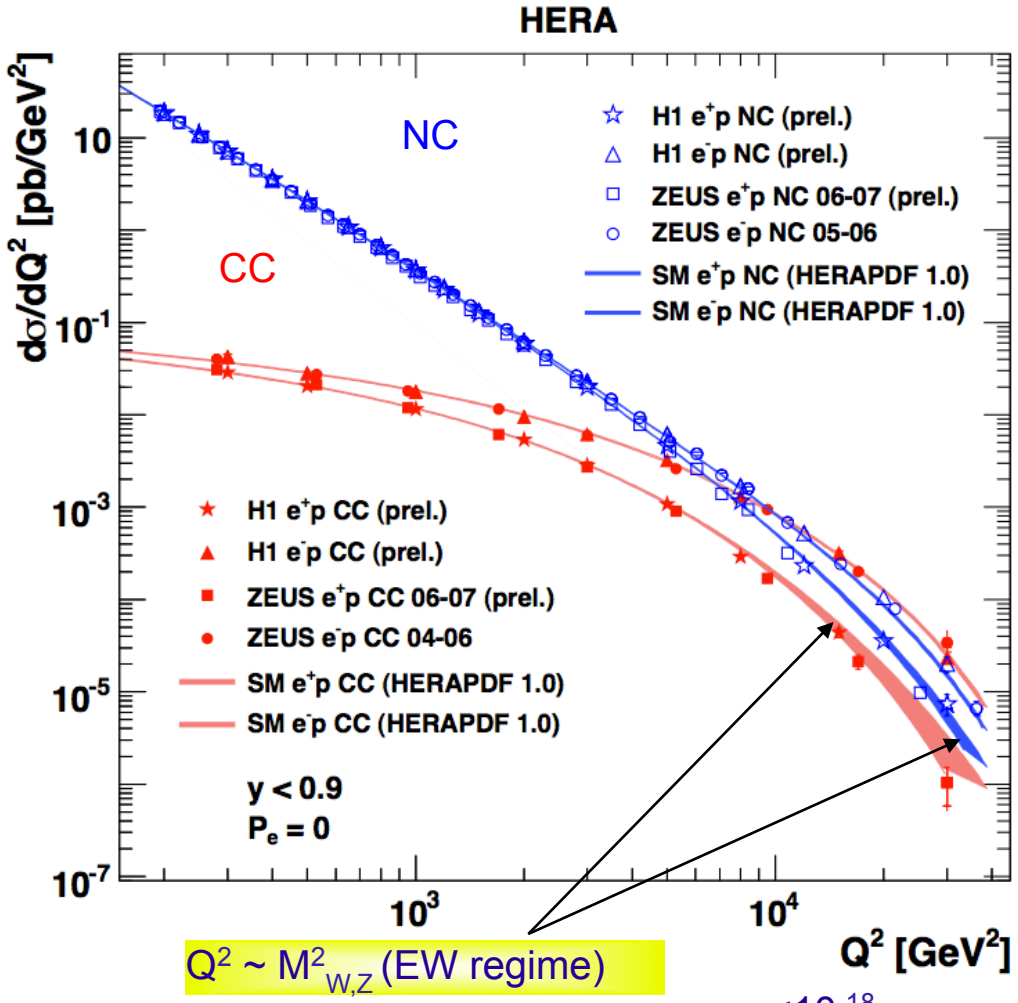
DIS at HERA

Charged Current (CC)



Neutral Current (NC)



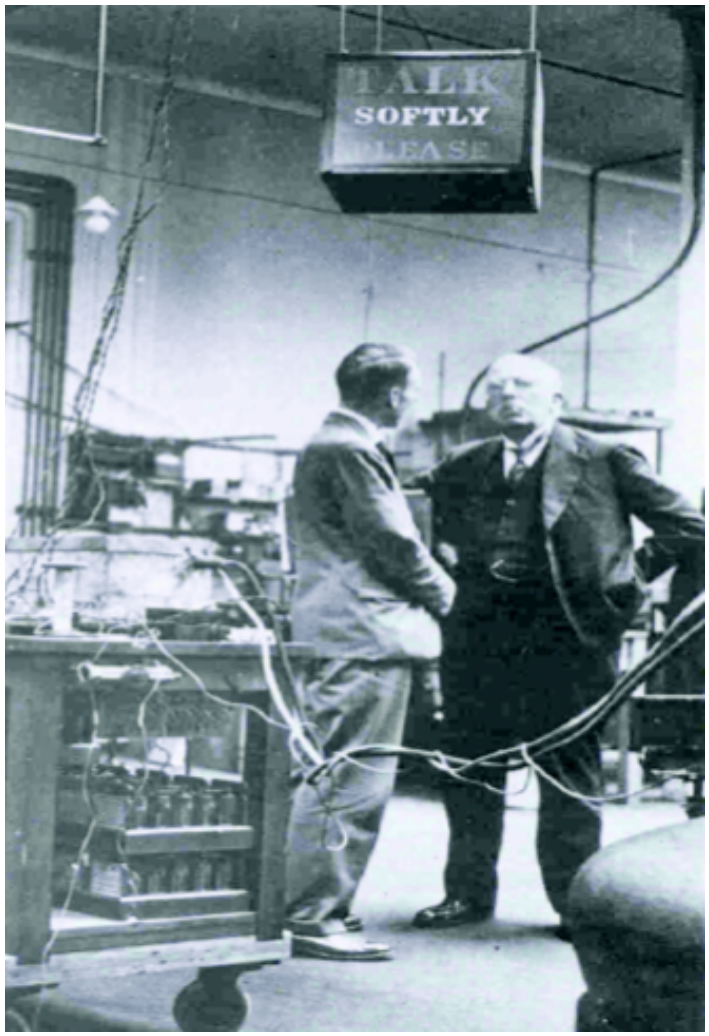


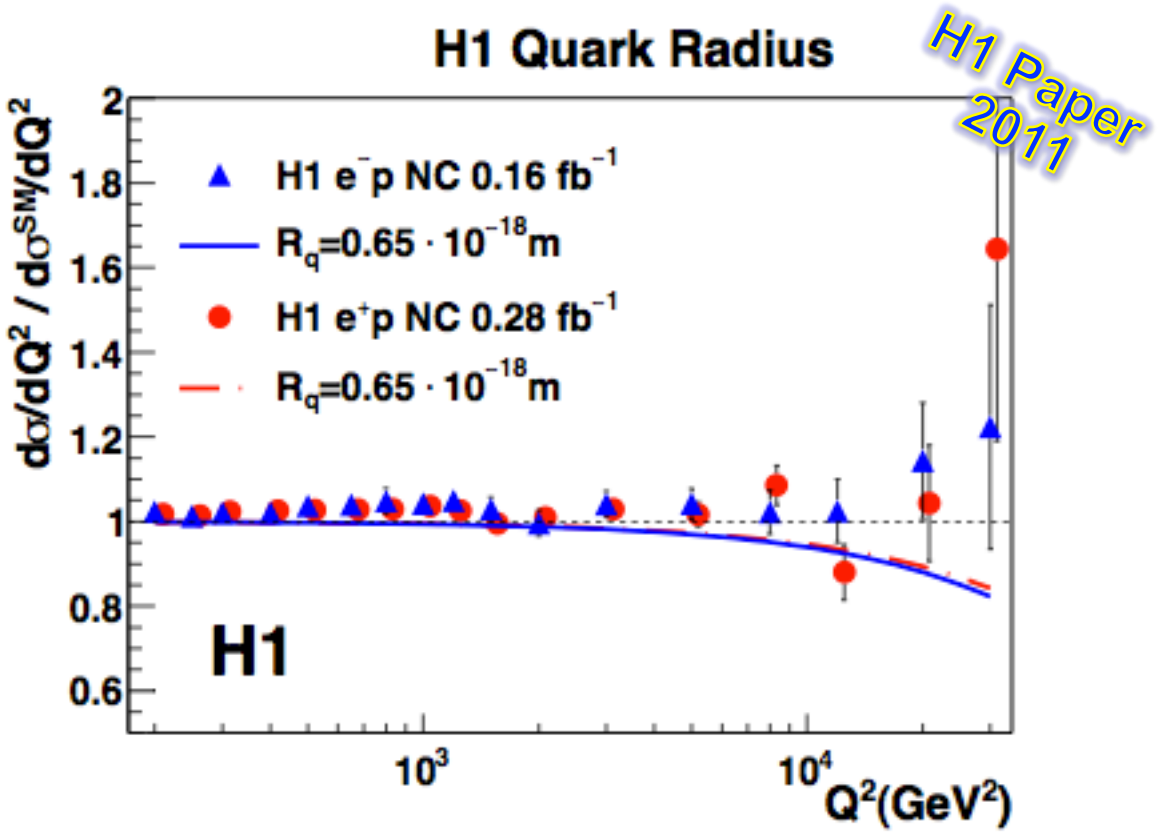
$Q^2 \sim M^2_{W,Z}$ (EW regime)

$r_{quark} < 10^{-18}$m

"p"/1000

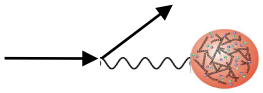
The ultimate resolution: search for deviations at the highest Q^2





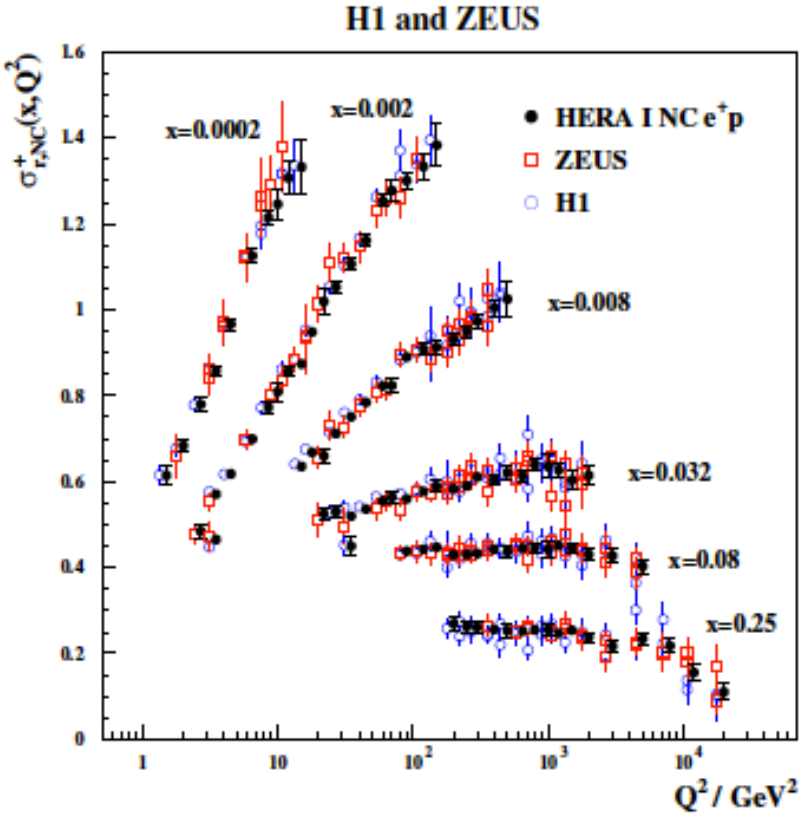
Proton structure from HERA data

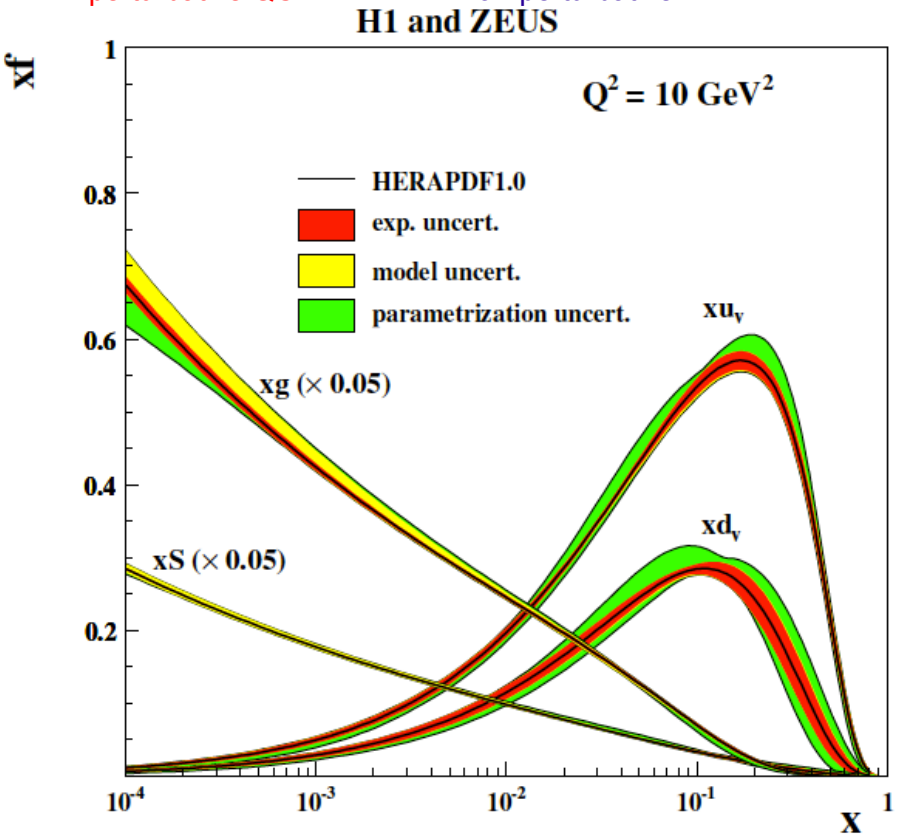
- **Combination of data with consistent treatment of systematics**
- **Extraction of parton distribution functions (PDFs) using HERA data only**
  - **A milestone of HERA physics program: HERAPDF 1.0 (2009)**



$$\sigma_{DIS} \equiv \mathcal{C}_{\text{lepton-parton}} \otimes f(x, Q^2)$$

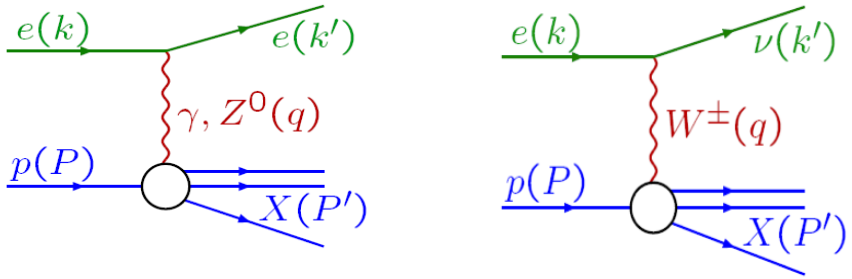
perturbative QCD — non-perturbative



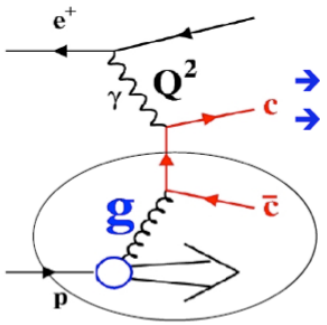


The road to precision

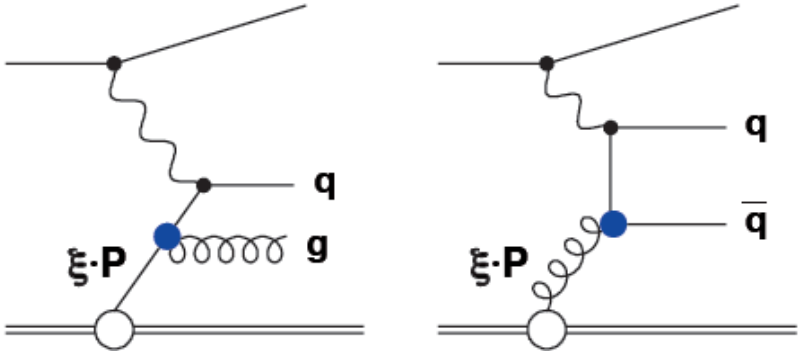
Inclusive



Charm



Jets



2009: HERAPDF 1.0
precision at low Q2 (HERA I)

+pheno. studies: charm, low energy data

2010: HERAPDF 1.5 : the high Q2 data

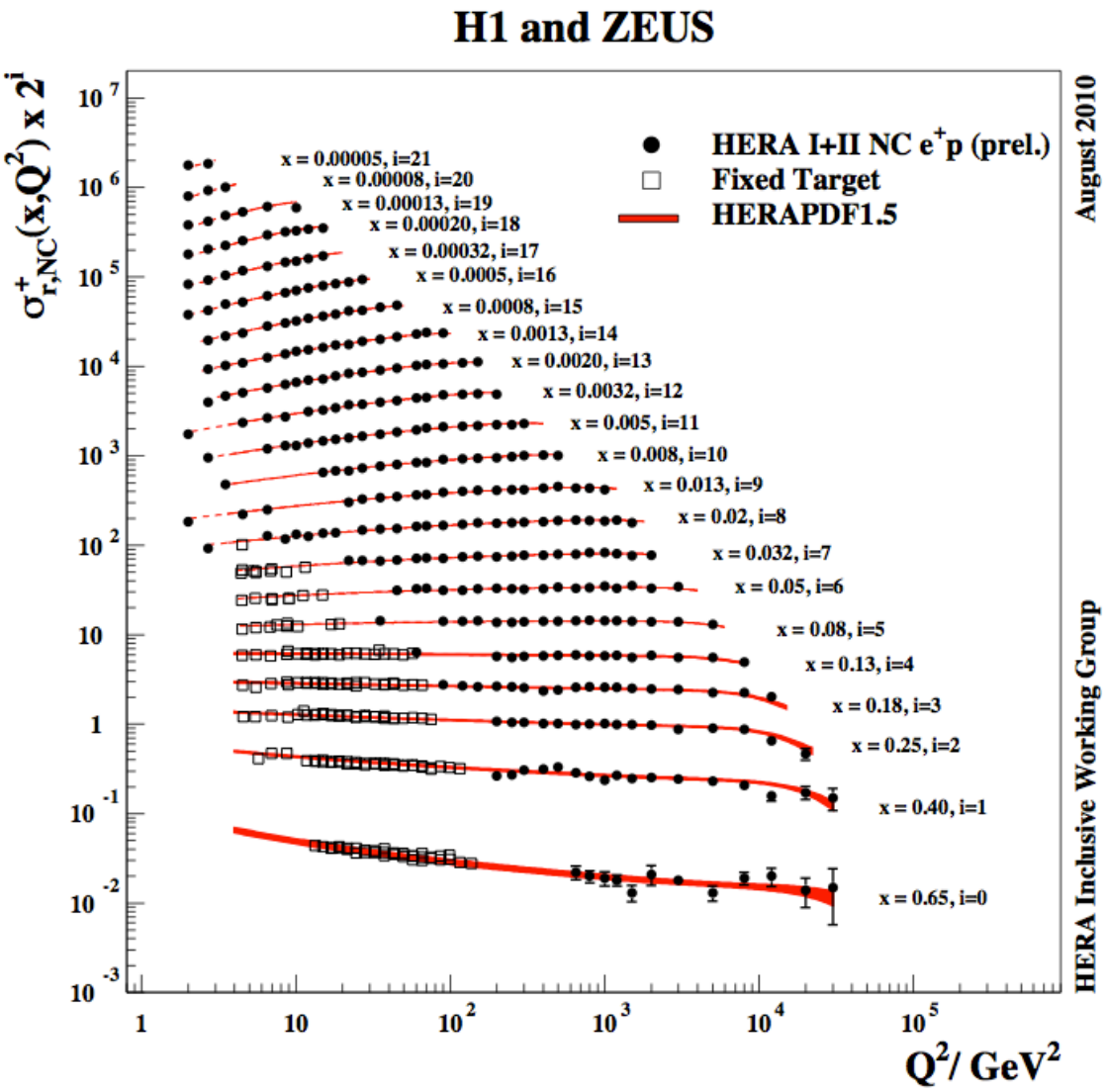
2011: HERAPDF 1.6 : jets and strong coupling

2011: HERAPDF 1.7 : Inclusive+Charm+Jets

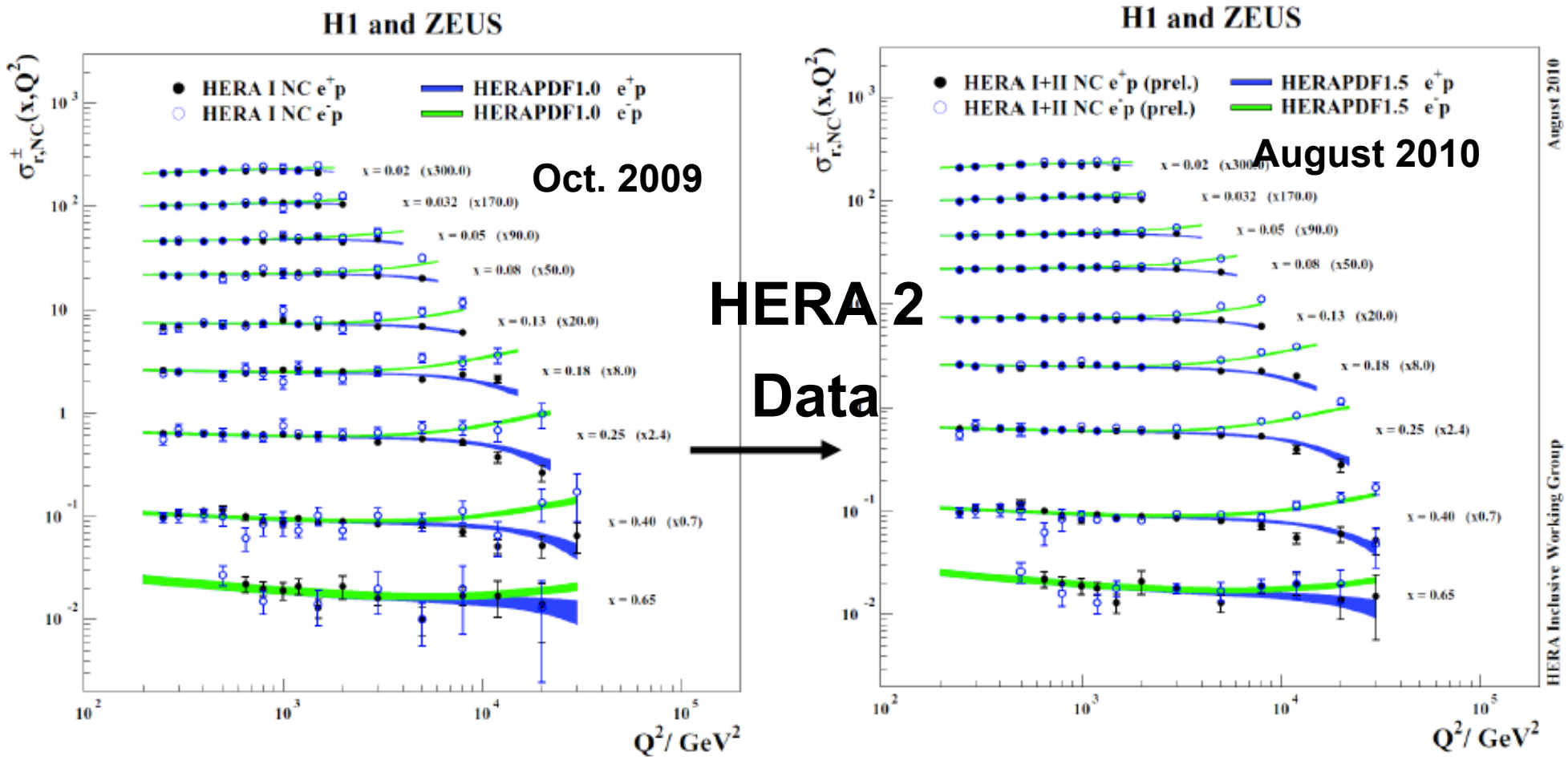
In work: HERAPDF 2.0

HERA I+II Data

- **Very good agreement with perturbative QCD**
  - **Scaling violations precisely measured**
- **Consistent treatement of systematic errors and gain in precision**



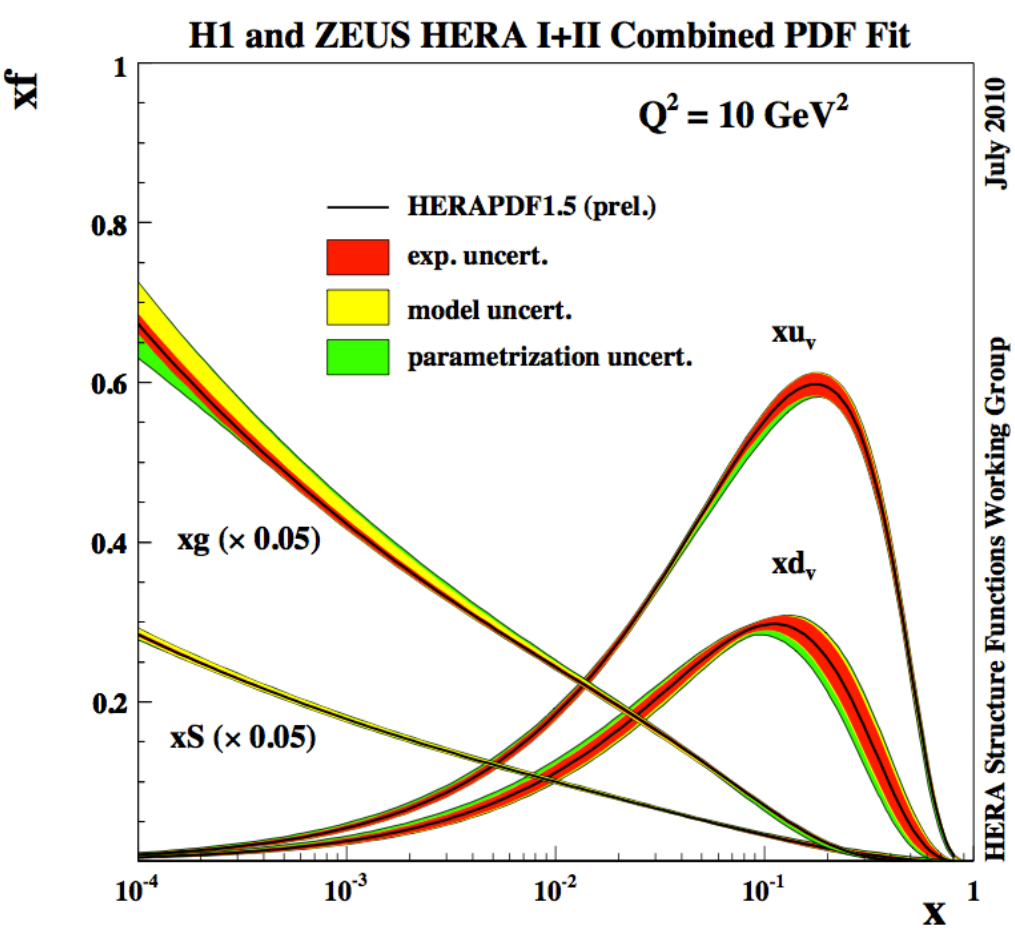
The precision at high Q^2

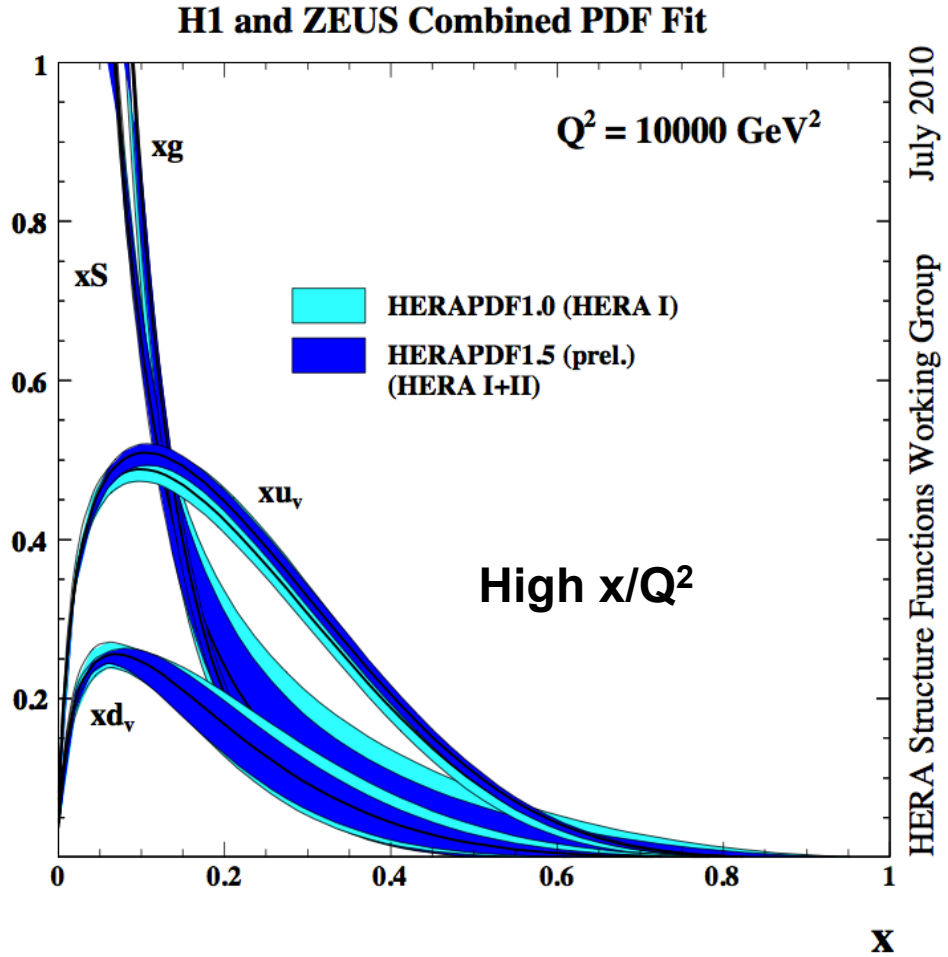


HERA 2 Data

$$\tilde{F}_2 - \frac{y^2}{Y_+}\tilde{F}_L \mp \frac{Y_-}{Y_+}x\tilde{F}_3 \quad \rightarrow \quad 2x\sum_q \left[e_q a_q, v_q a_q\right](q - \bar{q})$$

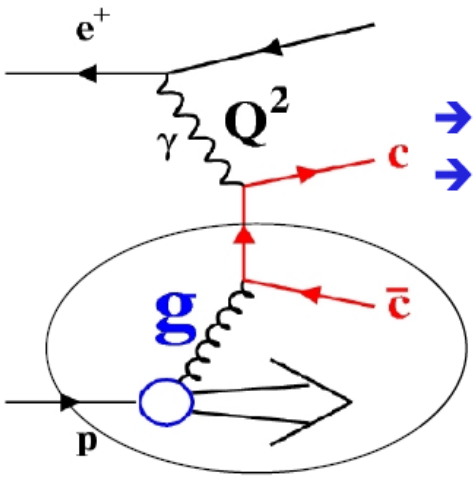
HERAPDF 1.5





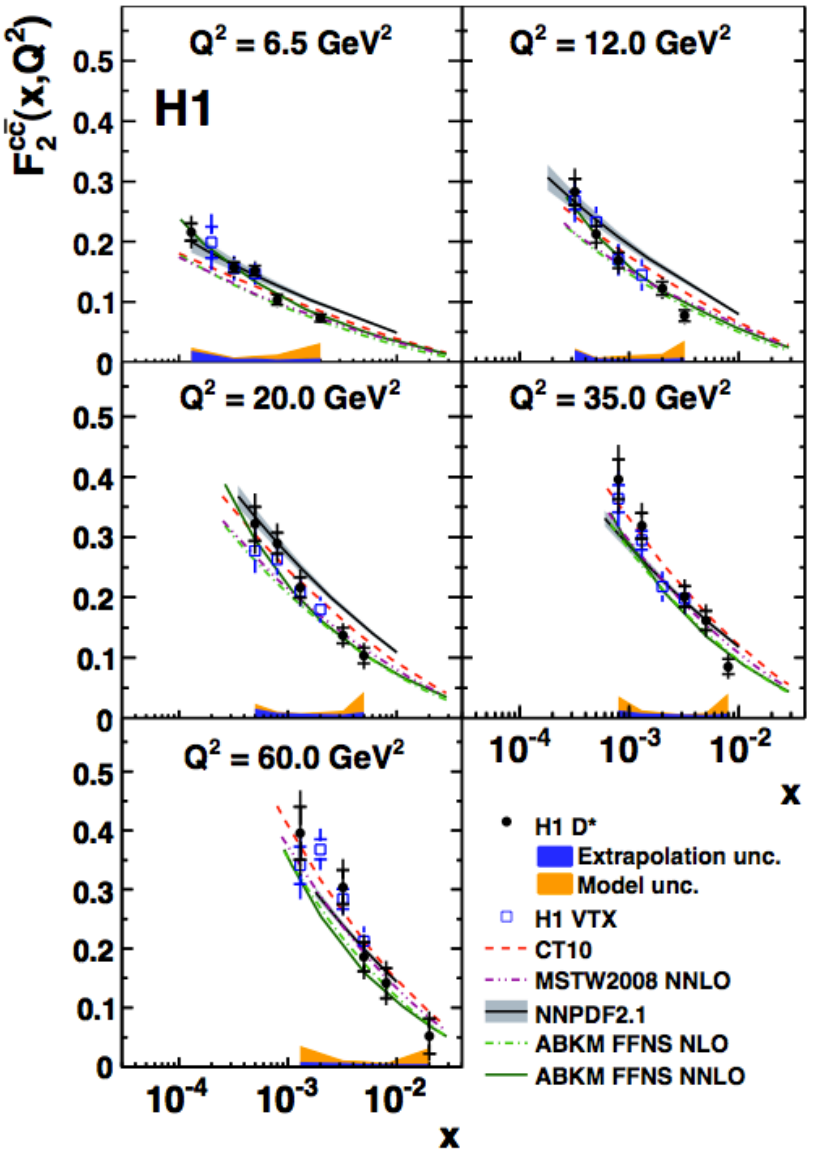
High Q2 data improve the precision at high x

The precision piece of charm physics: D* at low Q2



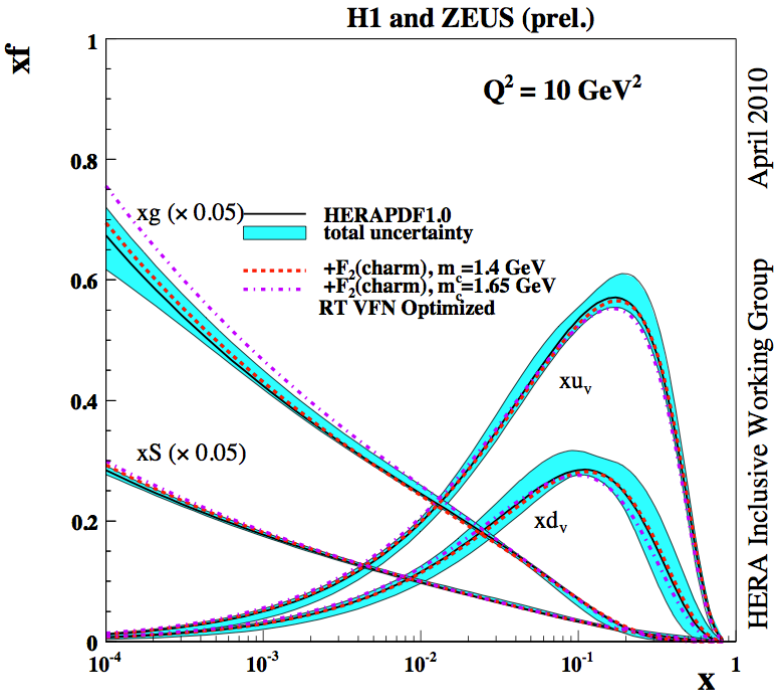
➔ D*, D+, etc.
➔ Displaced tracks

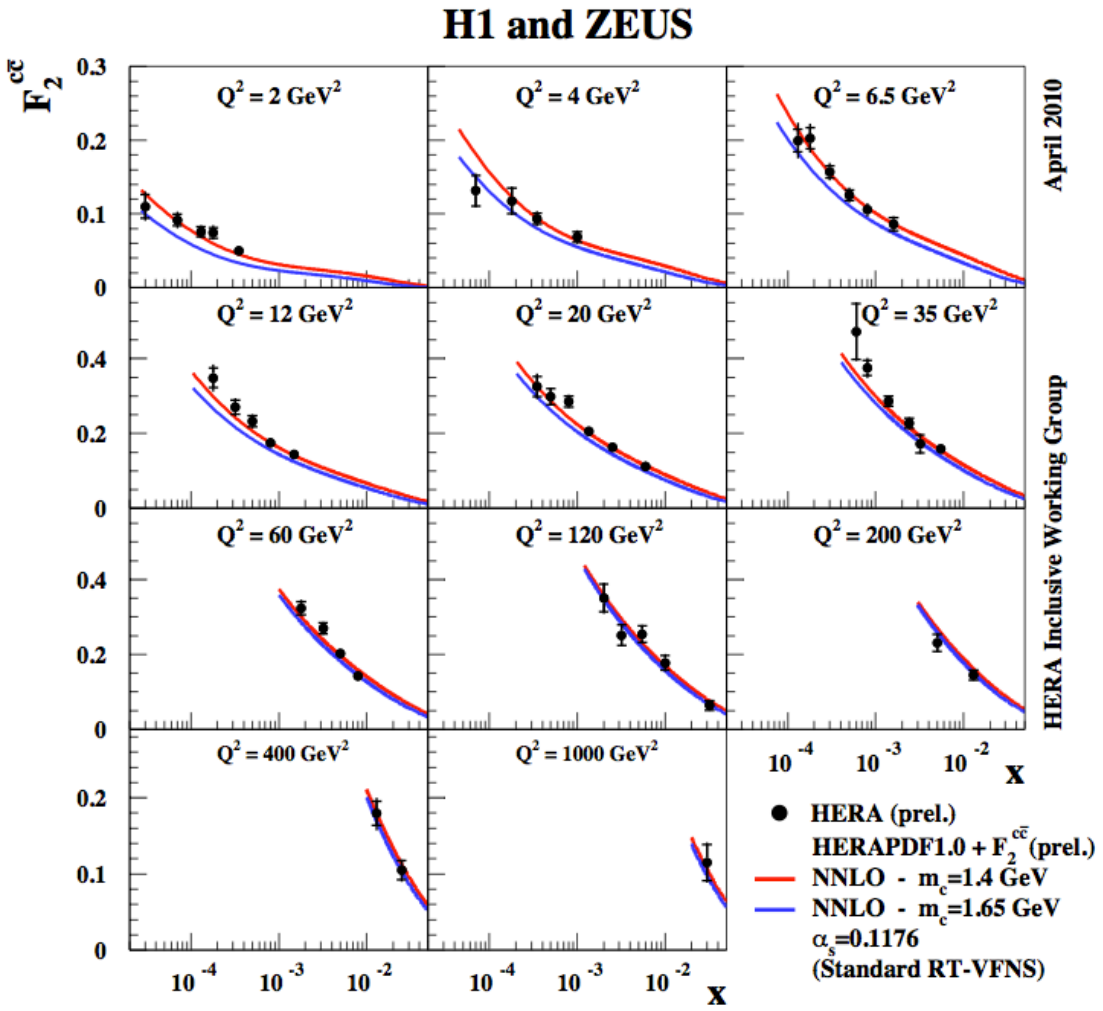
- **Precise HERA II data published**
  - **Displays the potential to constrain the theory**
- **Ready for the final H1/ZEUS combination**



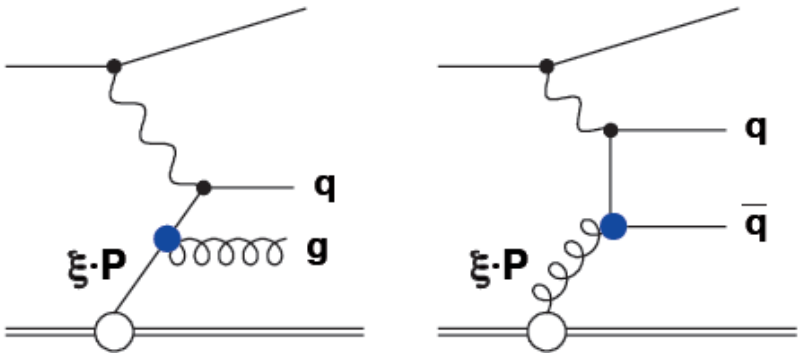
Charm combined data

- **Included in the fit at NNLO**
  - **Well described over the measurement phase space**
- **Precision to 5-10%**
  - **Sensitivity to m_c**

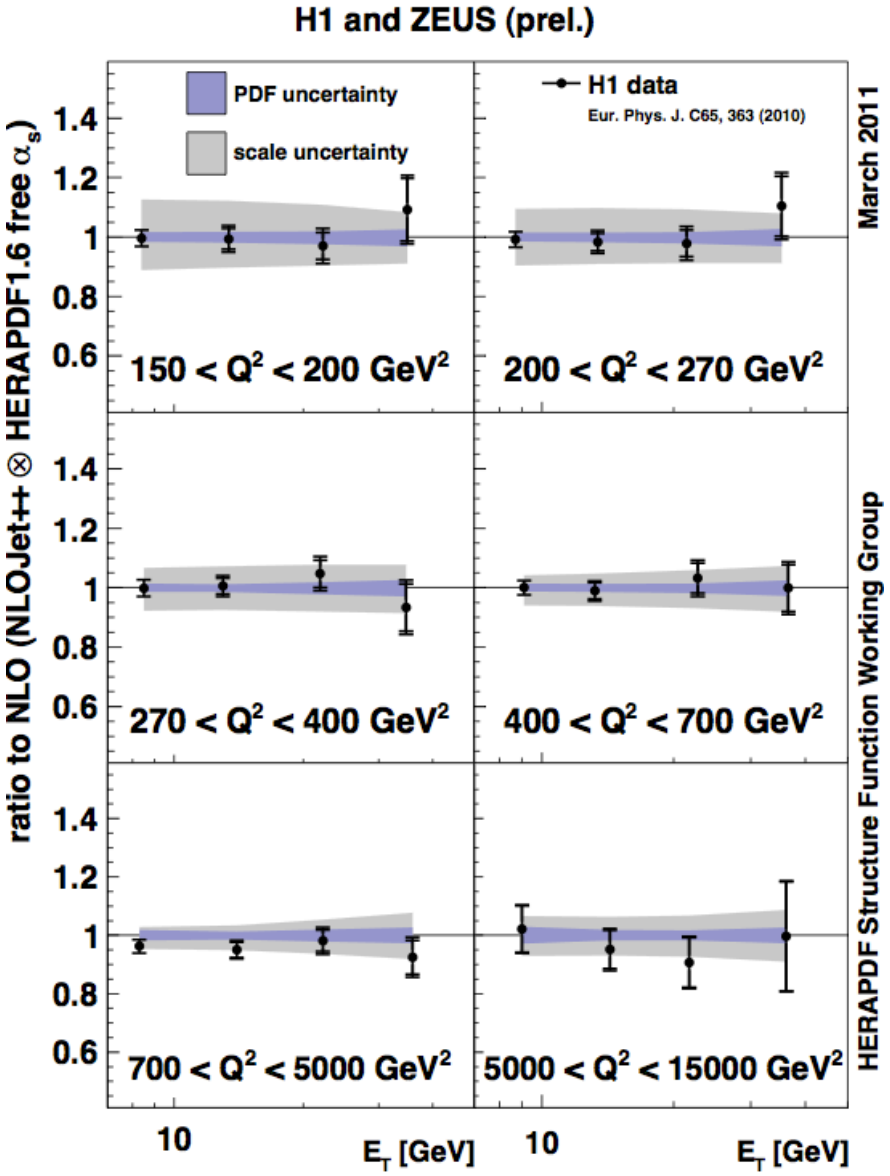




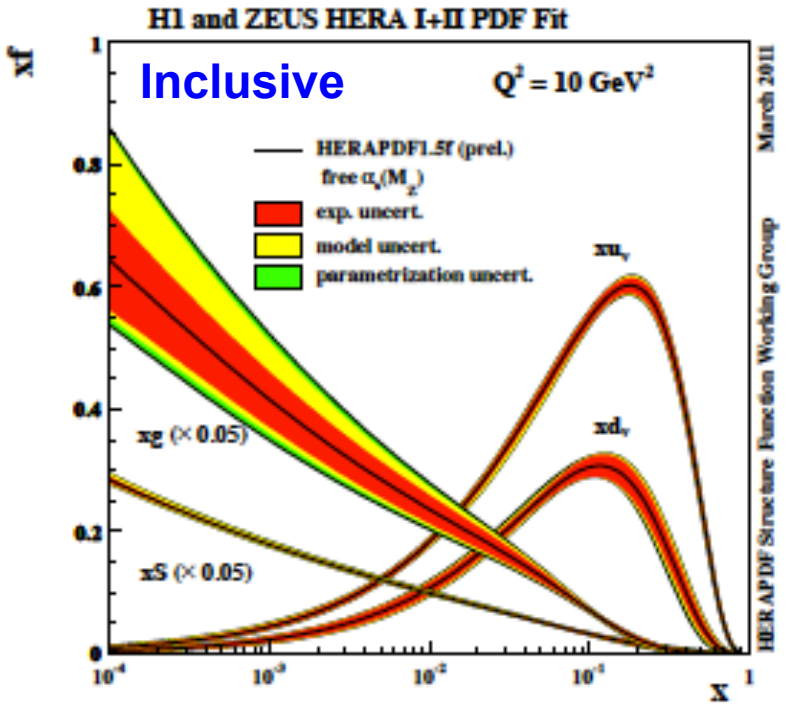
Jets in DIS

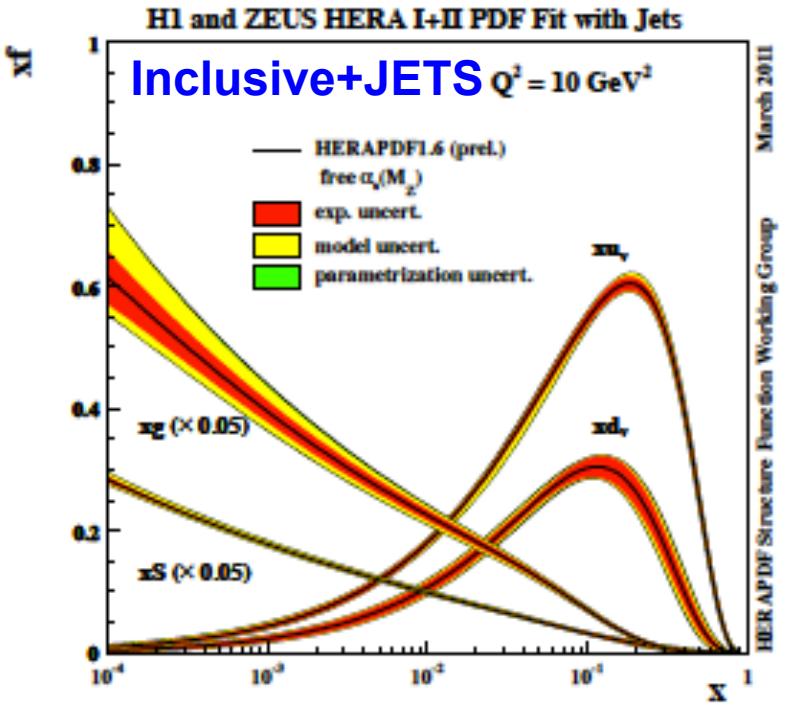


- **Precise data from H1 and ZEUS used previously to determine the strong coupling at fixed PDF**
- **A common fit PDF×α_s is performed**

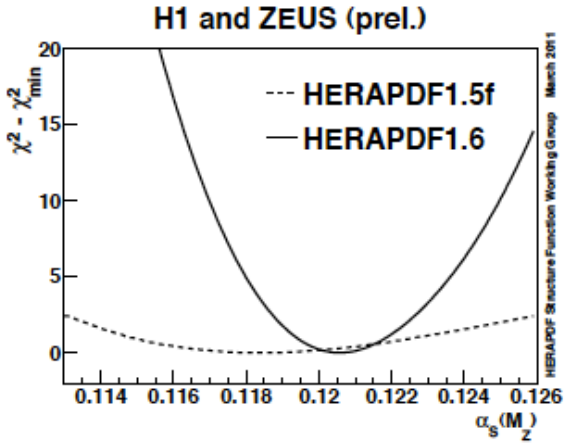


HERAPDF 1.6



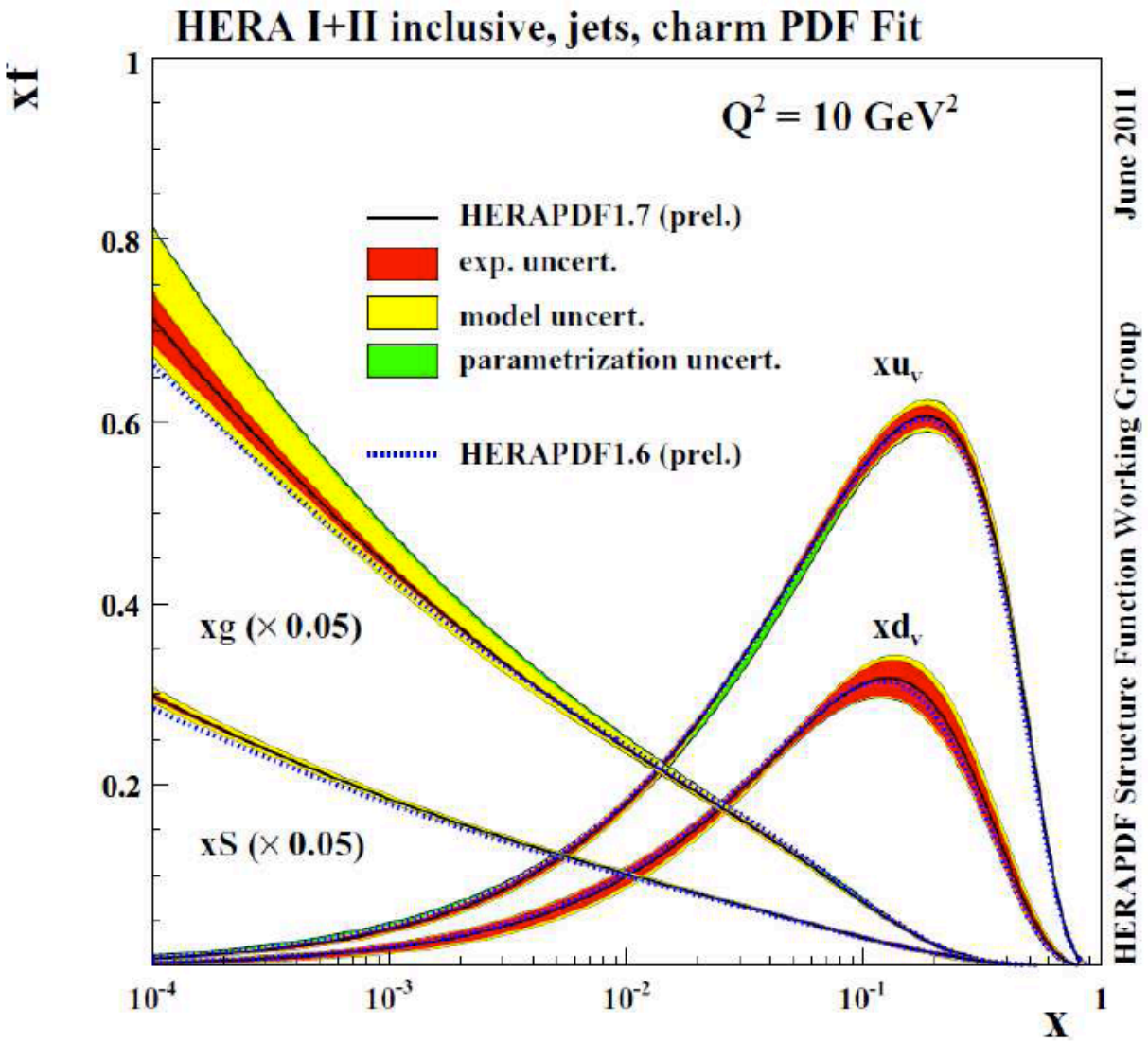


- **The jets measurements included in the fit**
  - **stabilise the gluon**
  - **constrain the strong coupling**



HERAPDF 1.7

- HERA « global » fit
  - Inclusive data
  - Charm data
  - Jets in DIS data
- Very good consistency
- Proof of a concept for the next generation of PDF fits from HERA



The measurement of the structure function F_L

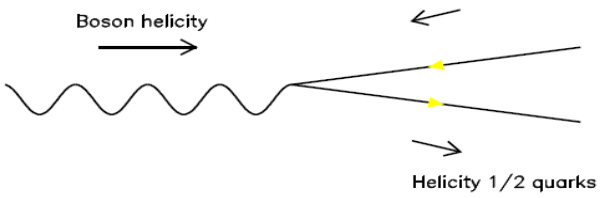
$$\sigma \sim F_2(x,Q^2) + f(y)\, F_L(x,Q^2)$$

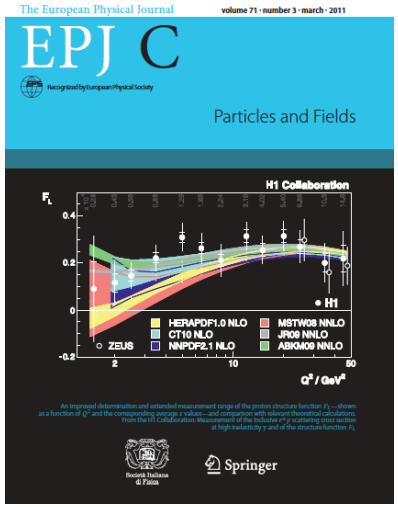
ys=y's'=Q²/x **Measurement using the low energy runs data**

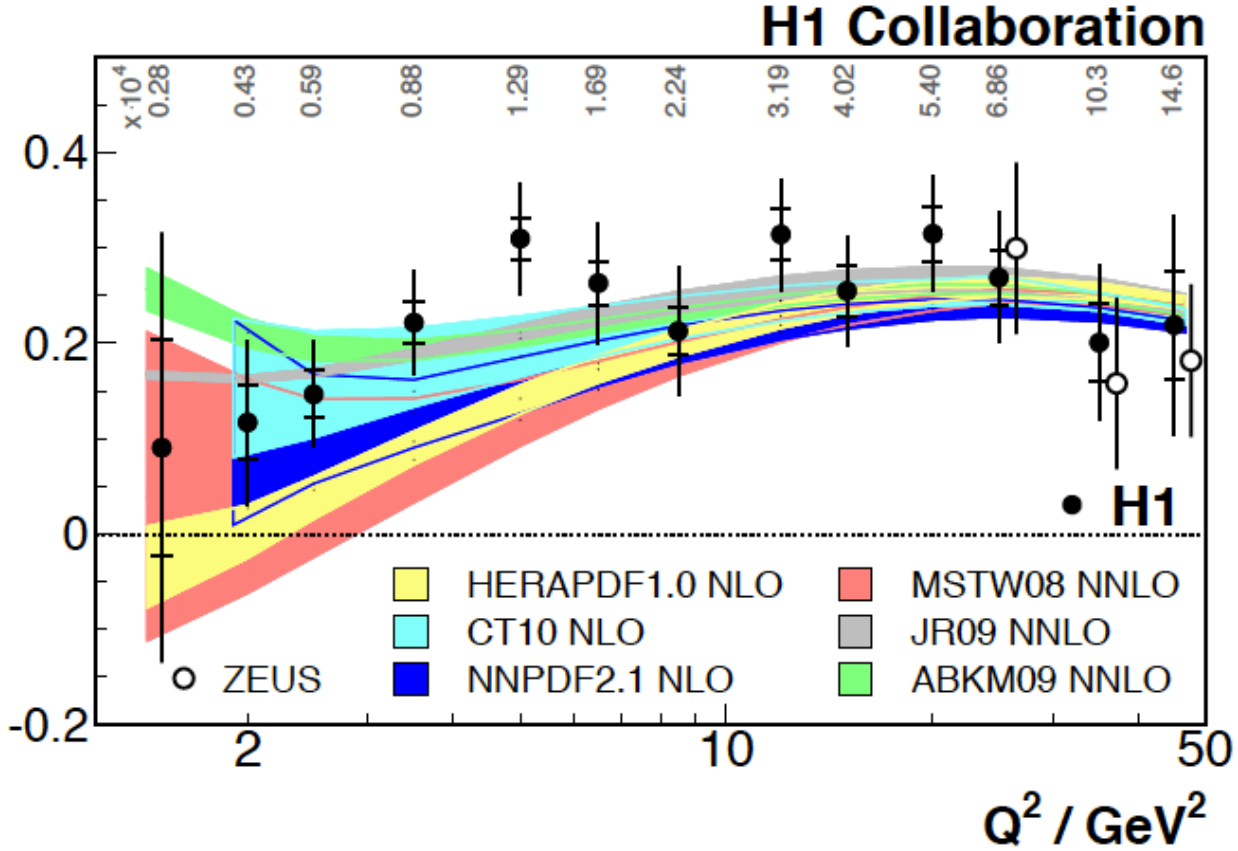
H1 Paper 2011

Breit Frame

Virtual Boson Quark Lines



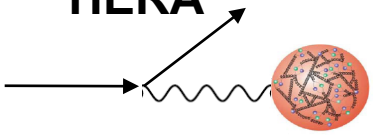




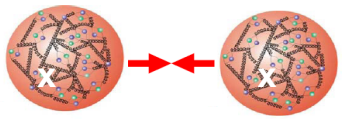
More measurements at higher x/Q² available

From HERA to LHC

HERA



LHC

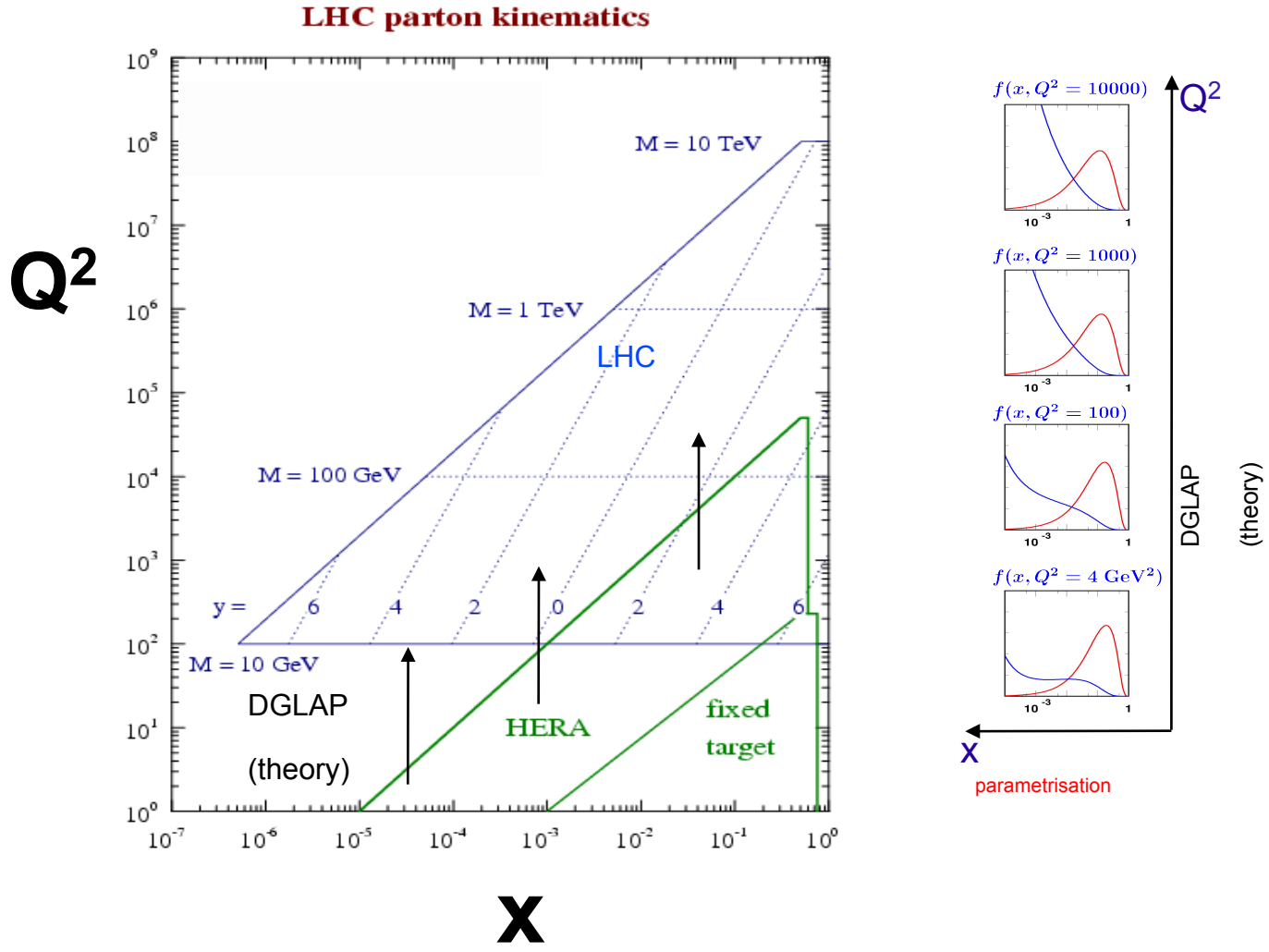


Example

W (at rest) corresponds to

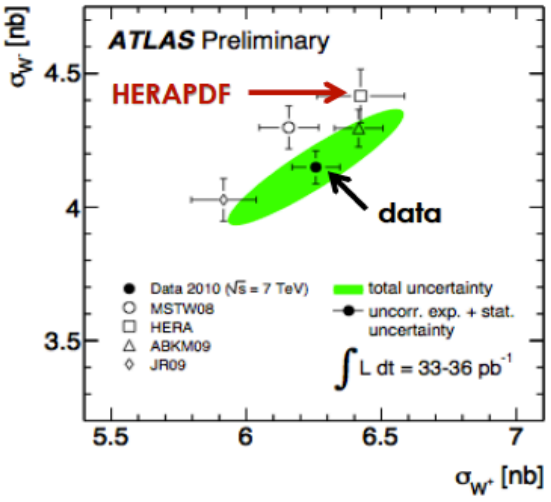
$Q^2=M_W^2 = 6400\ GeV^2$

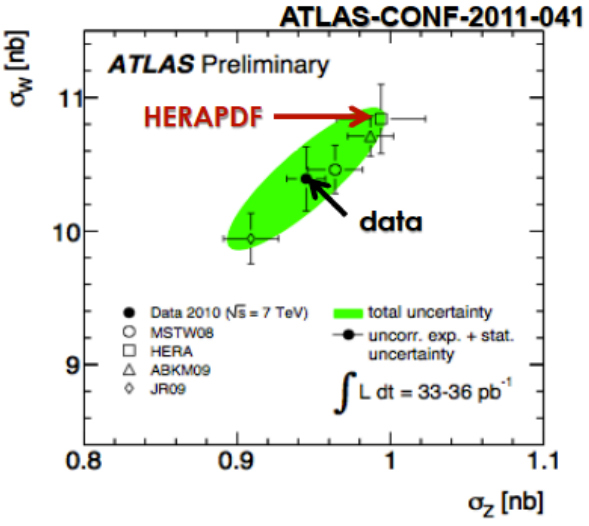
x=0.005 for LHC (14 TeV)

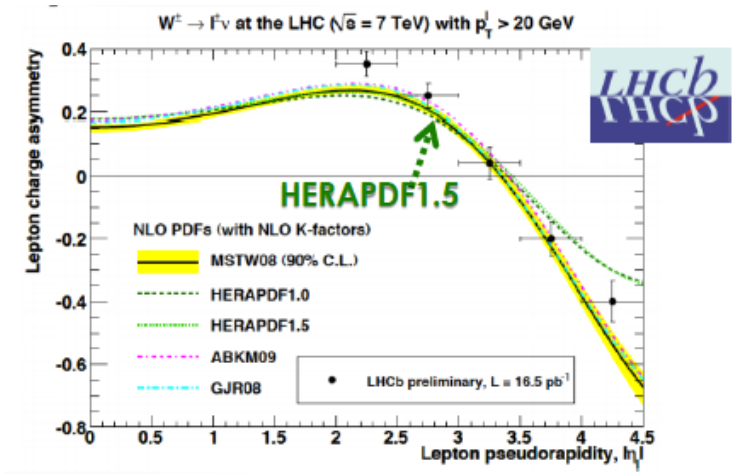


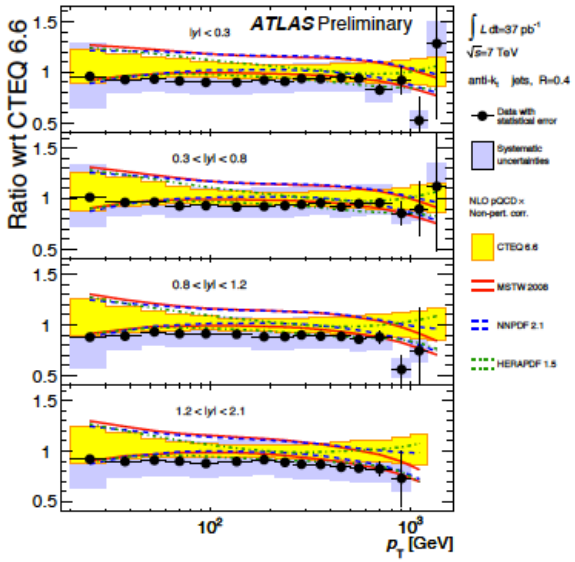
HERA data is a support for predictions at LHC

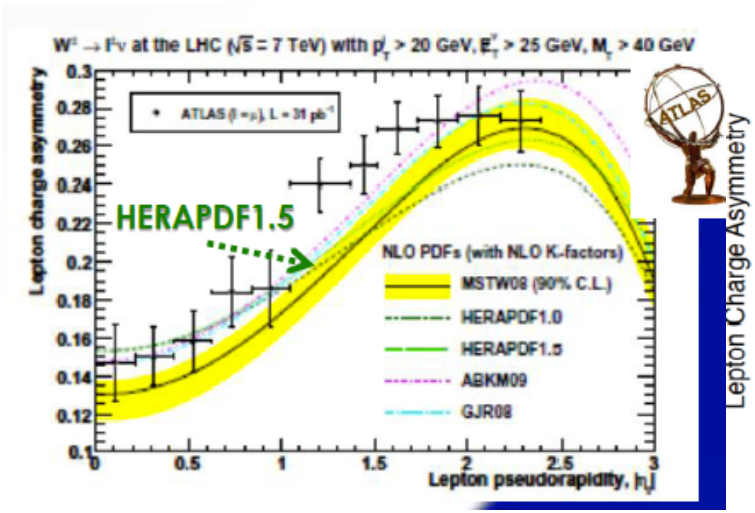
HERAPDF is used at LHC

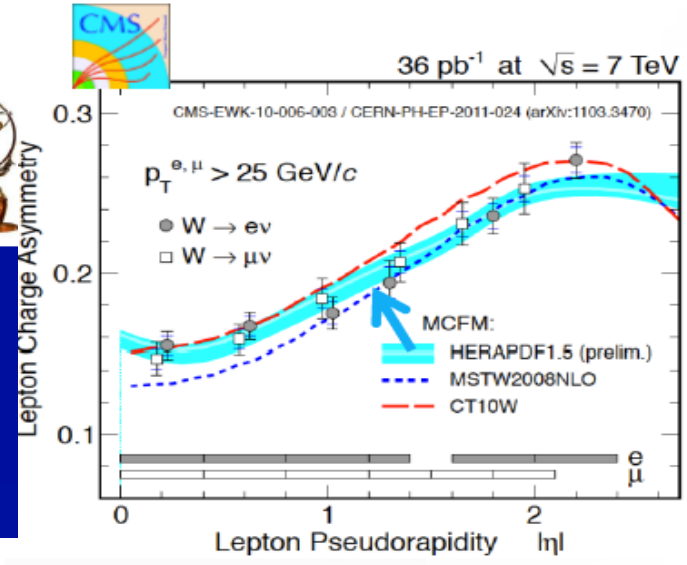




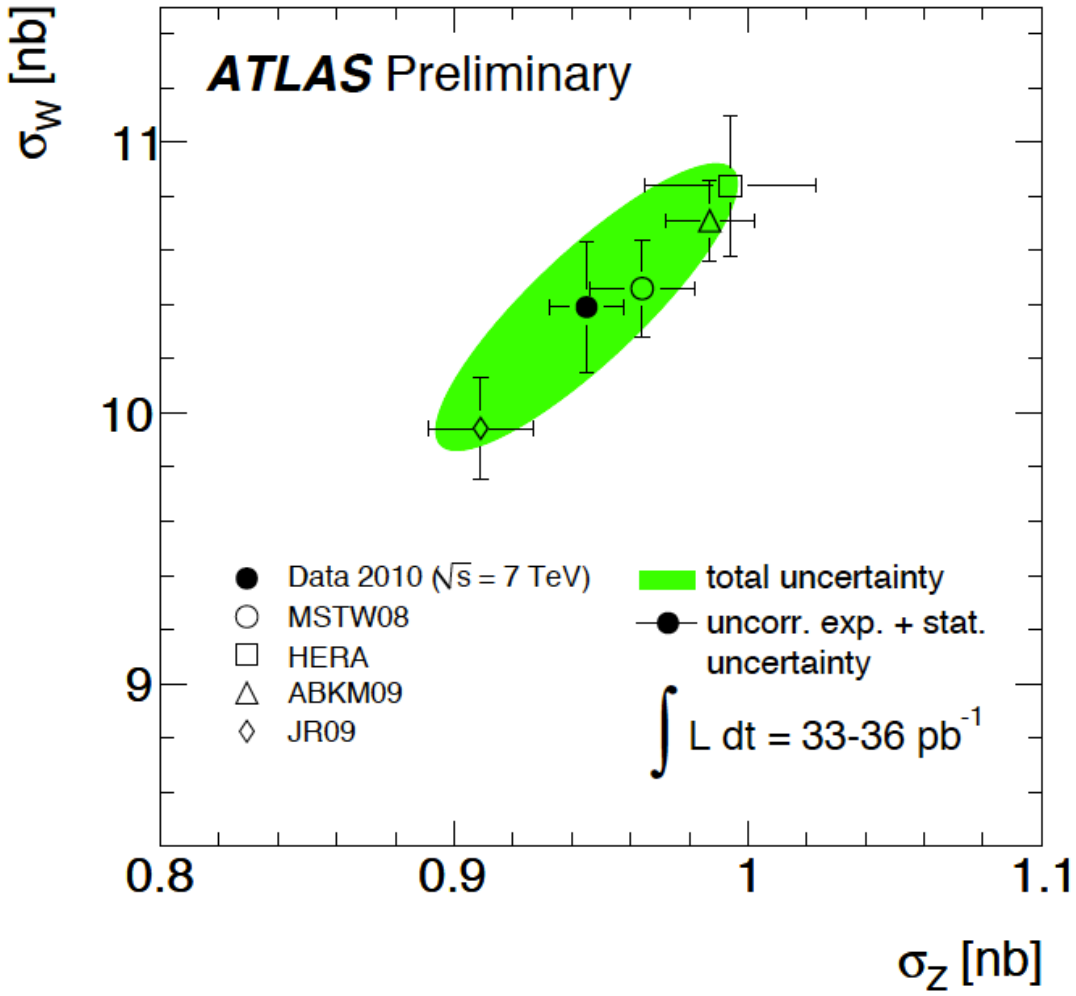


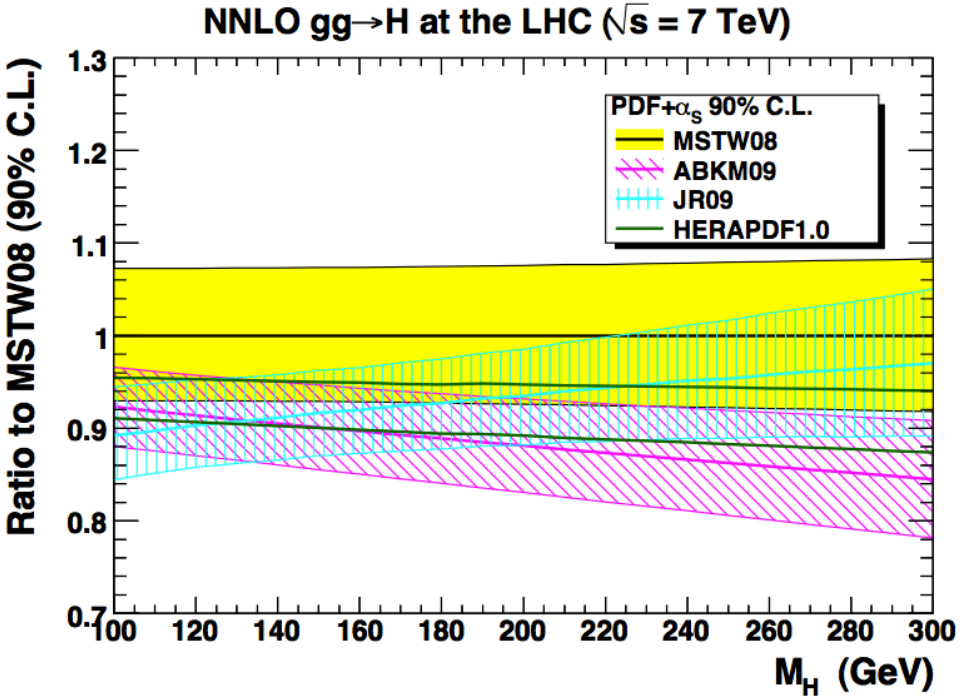






Towards precision at LHC



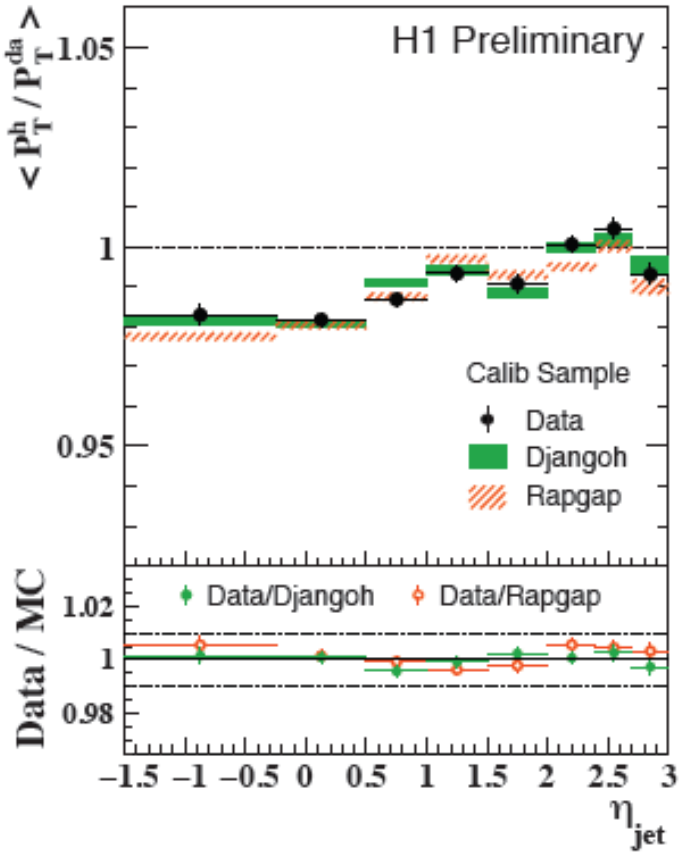


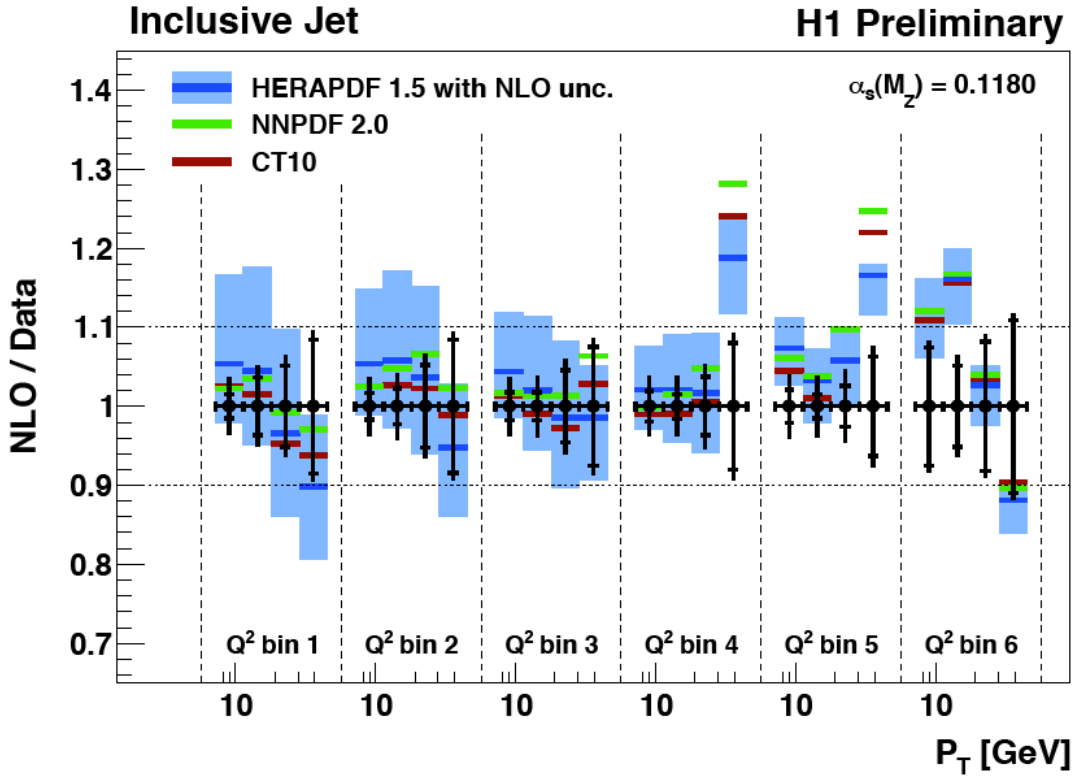
Jet production measurement with increased precision

New H1 measurement of jet production using HERA II data

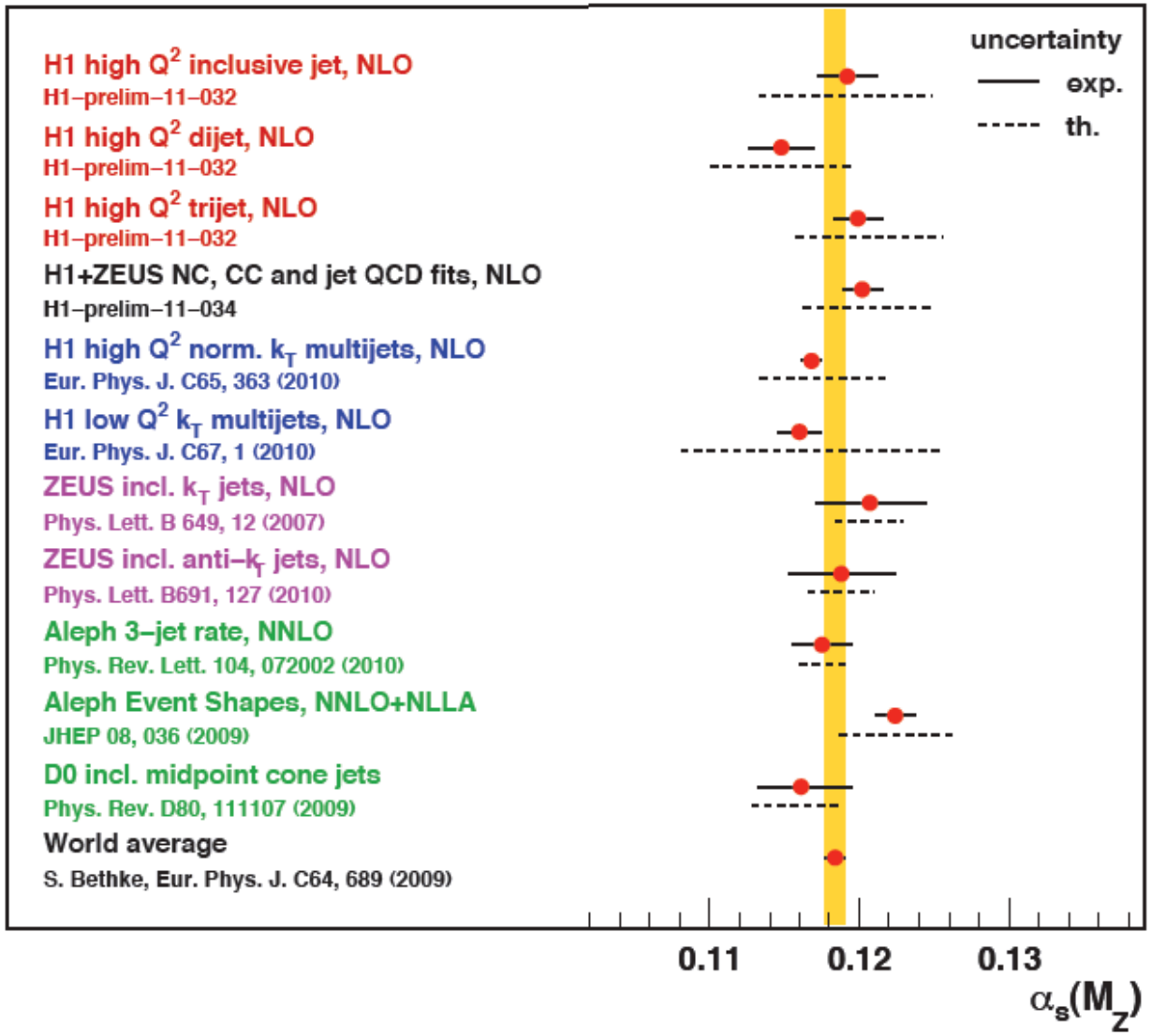
Hadronic energy scale to 1% (from 1.5-2% before)

H1 Preliminary 2011





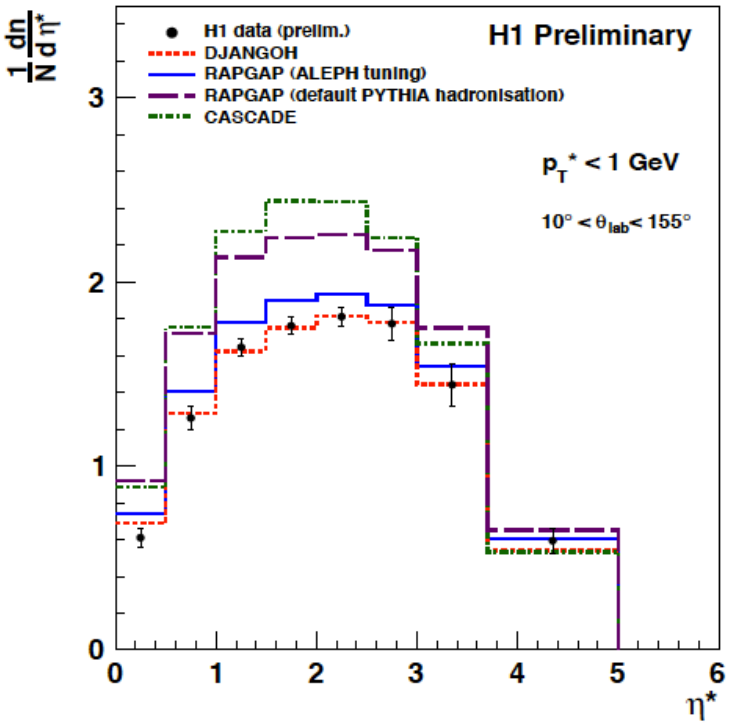
The strong coupling measurements



Charged particle production at HERA II

Measurement extended to forward region (possible due to the recent reprocessing)

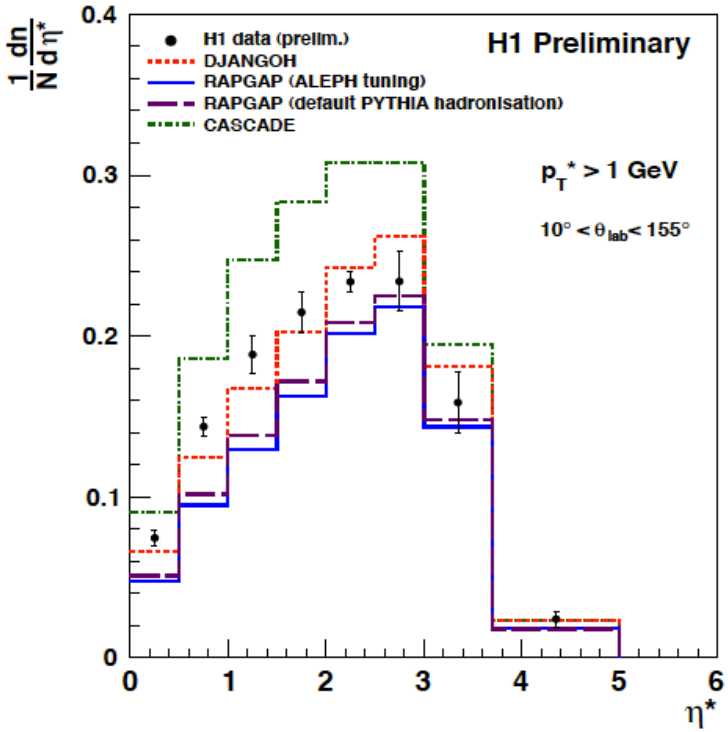
Charged particles with $p_T^* < 1$ GeV:



Strong sensitivity to hadronisation parameters.

Weak sensitivity to different parton dynamics.

Charged particles with $p_T^* > 1$ GeV:



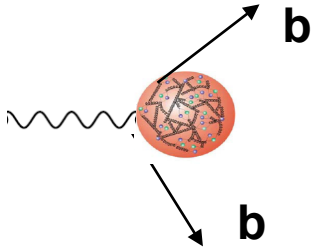
Strong sensitivity to different parton dynamics.

Weak sensitivity to hadronisation parameters.

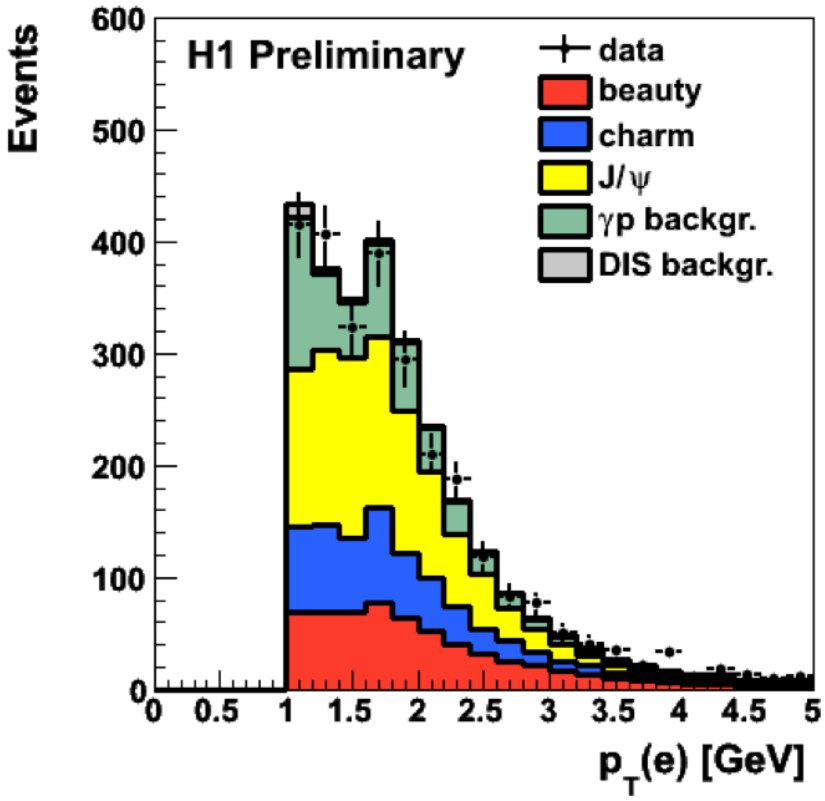
H1 Preliminary 2011

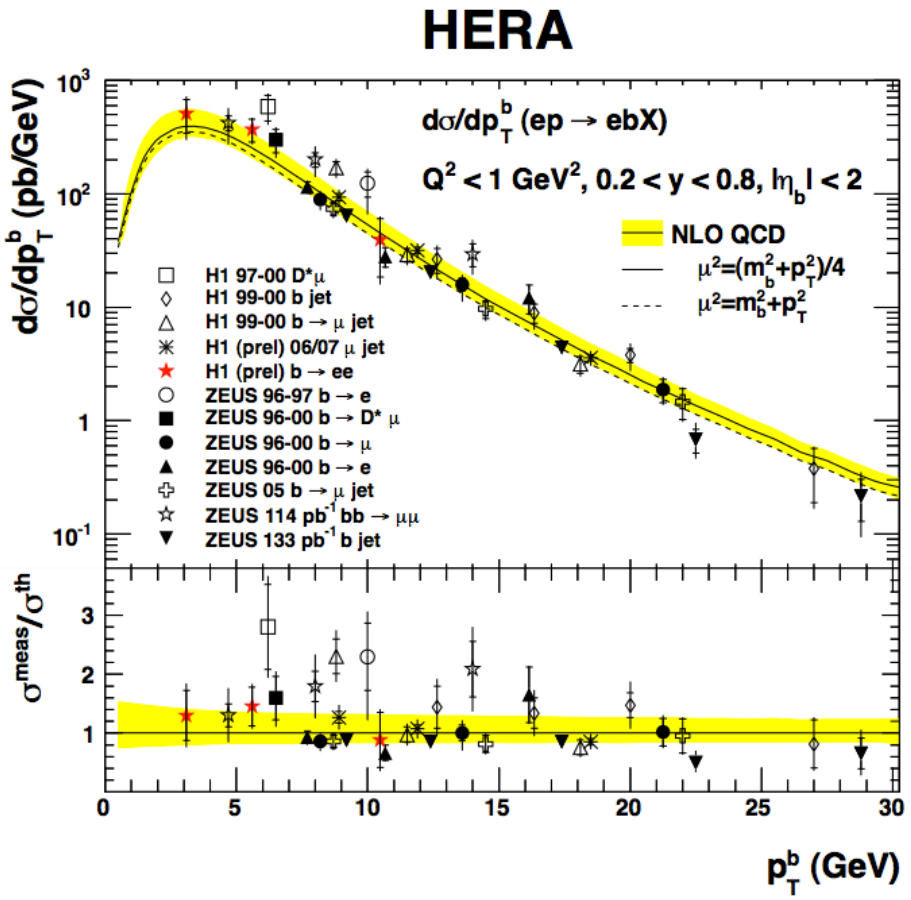
H1 Preliminary 2011

b photoproduction at low PT using electrons



A triumph of the experimental capabilities at HERA II (FTT) and of refined analysis techniques (low energy electrons)

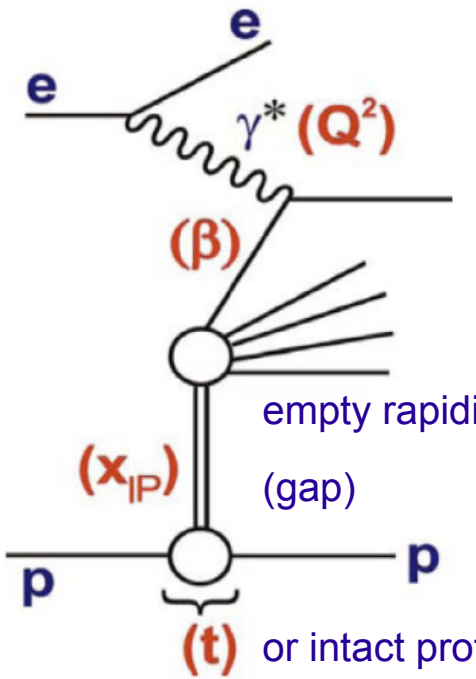




Hard Diffraction at HERA

10% of DIS events are diffractive:

produced via an colourless exchange



X

empty rapidity region

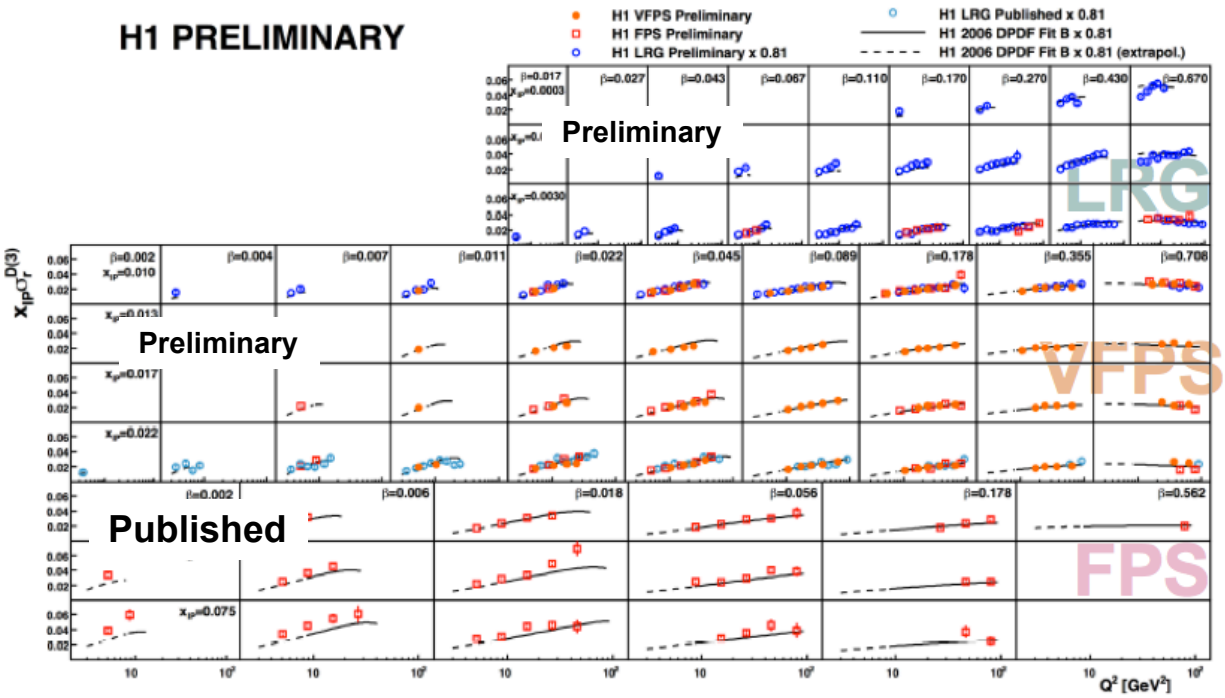
(gap)

Y

or intact proton detected

down the beampipe

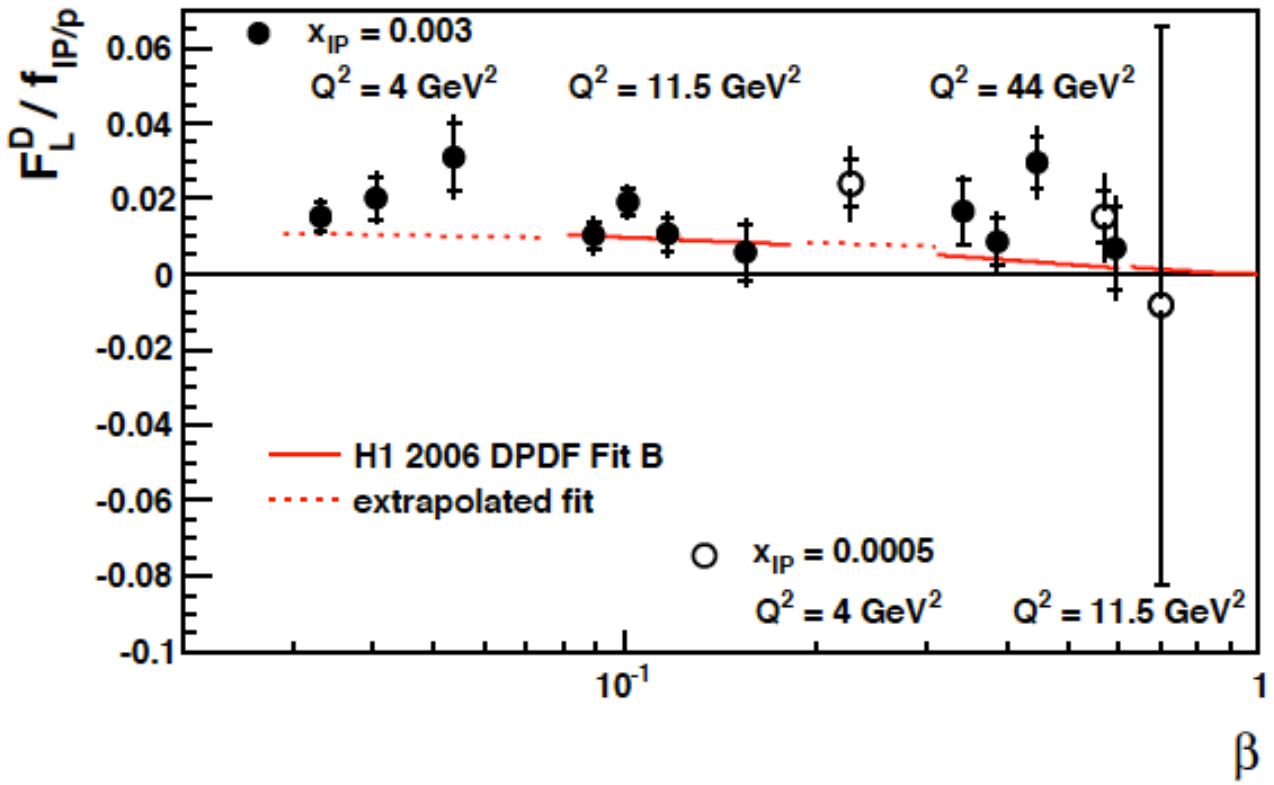
(roman pots)



The structure function F_L^D

$$\sigma^D \sim F_2^D(x, Q^2) + f(y)\, F_L^D(x, Q^2)$$

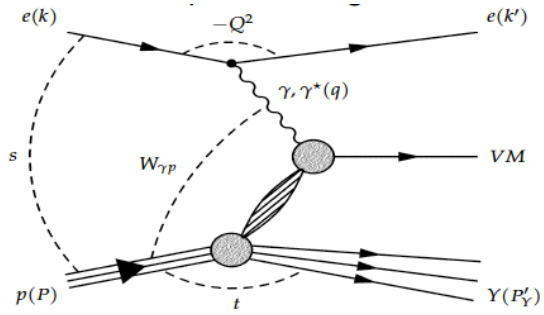
H1 Paper 2011



An unique result from low energy runs (an the harvest continues…)

H1 Preliminary 2011

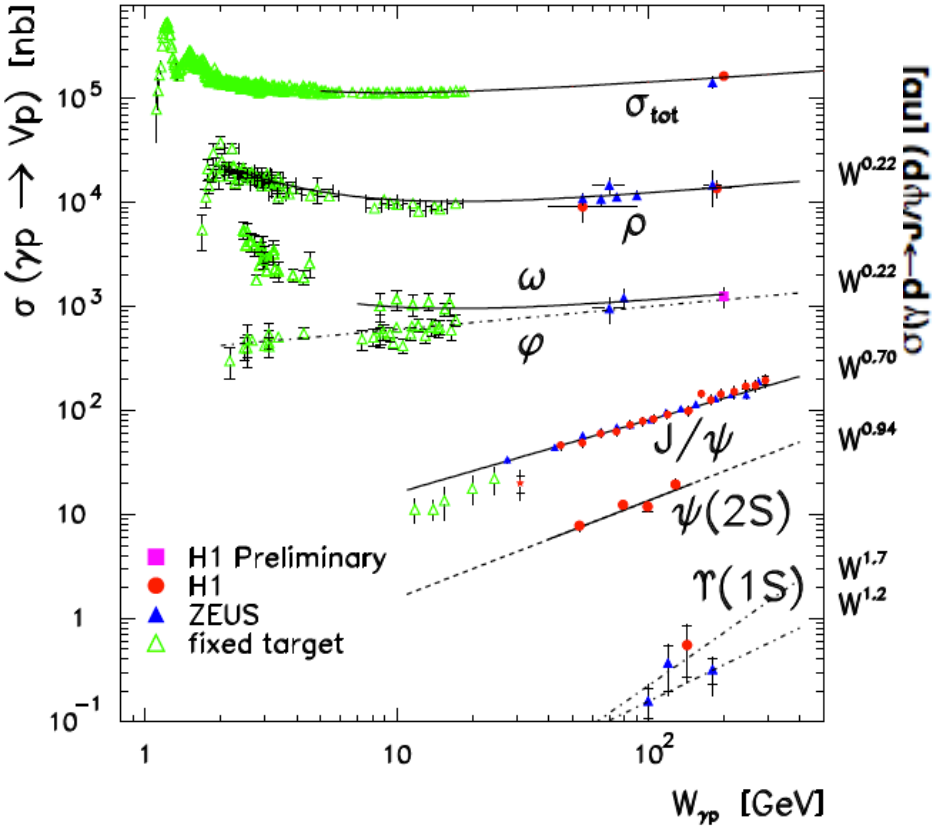
Vector mesons at low gamma-p energy (W)

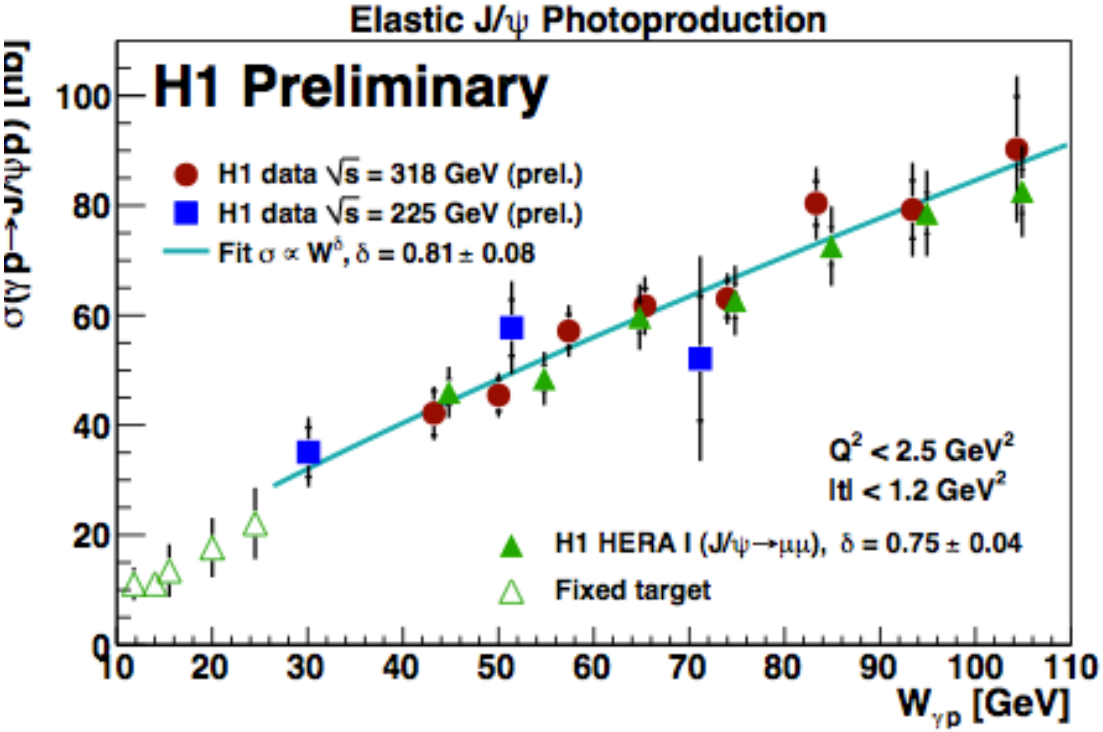


$J/\psi \rightarrow ee.$

$W_{\gamma p} \propto \sqrt{E_p}$

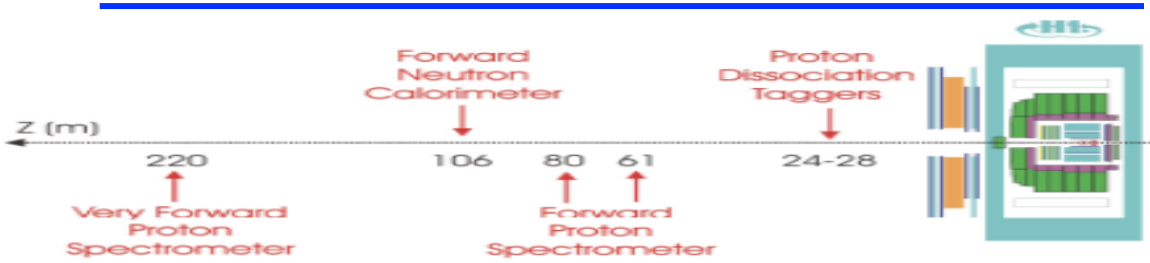
Use low energy runs

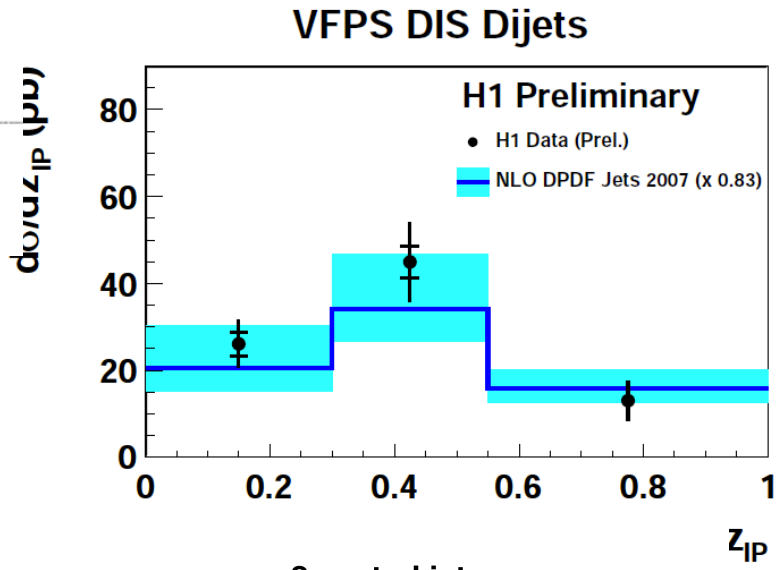




(V)FPS tagged di-jets in DIS

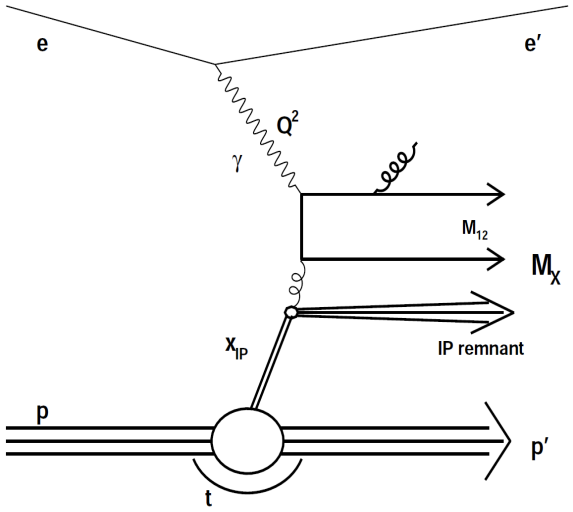
H1 Preliminary 2011



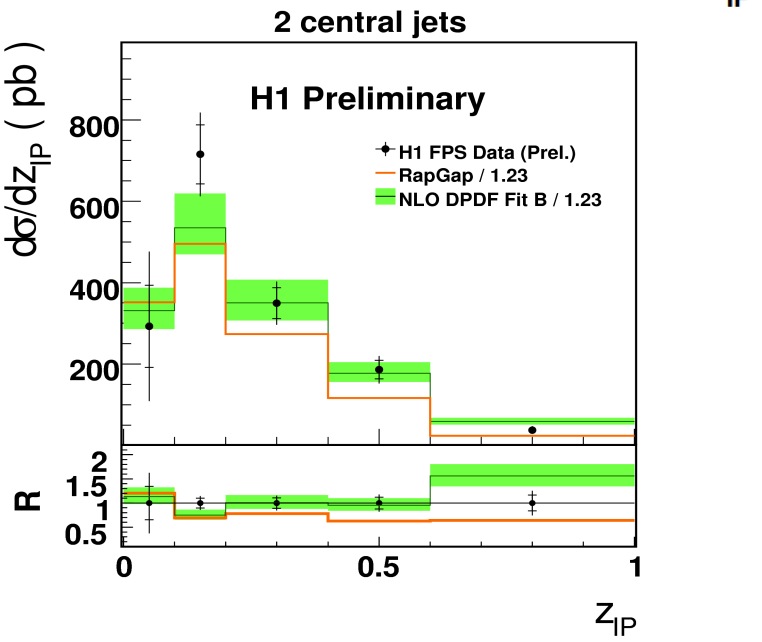


Exclusive final states measurements

Provide new tests of diffraction

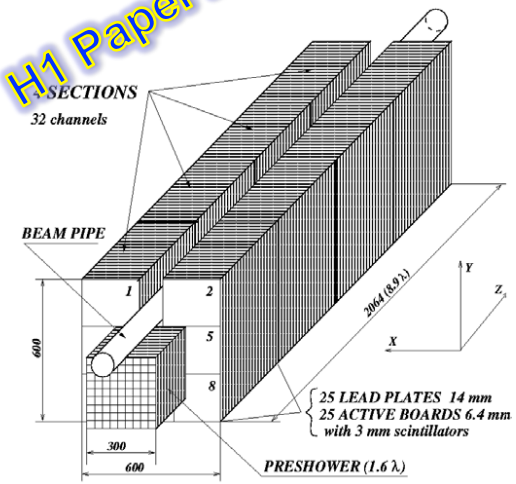


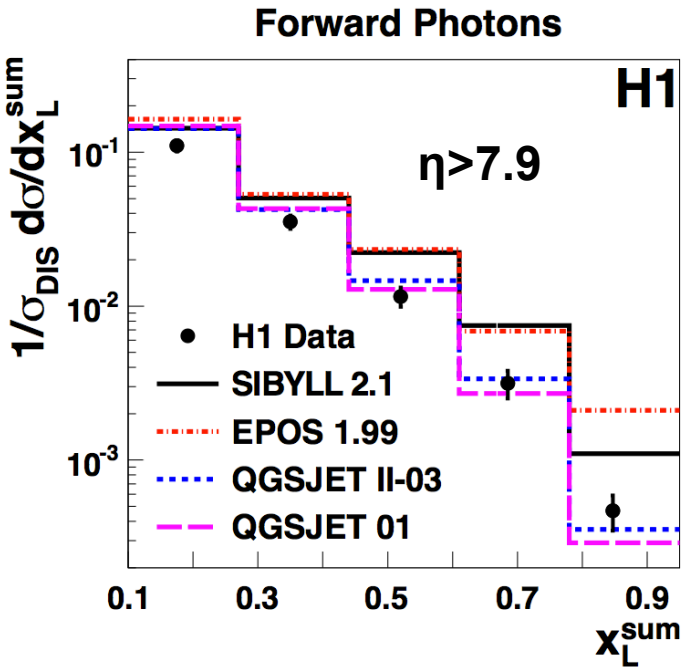
$$z_{IP} = \frac{Q^2 + M_{12}^2}{x_{IP}\, ys}$$

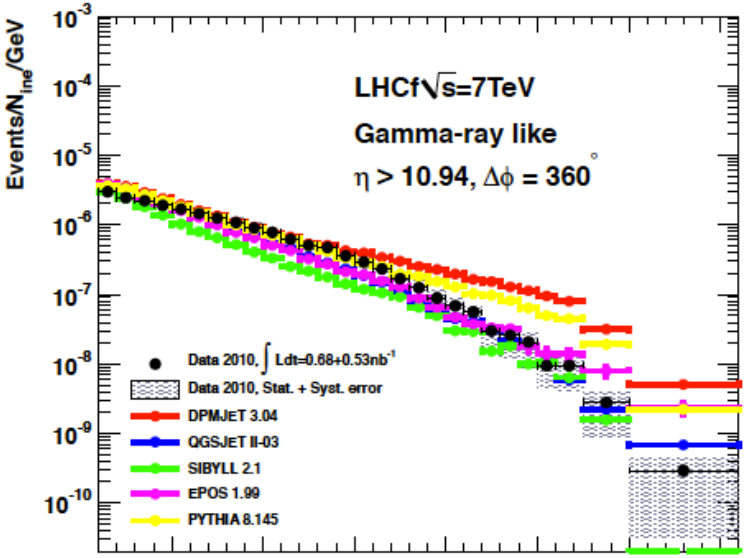


High energy photons in the forward direction

H1 Paper 2011







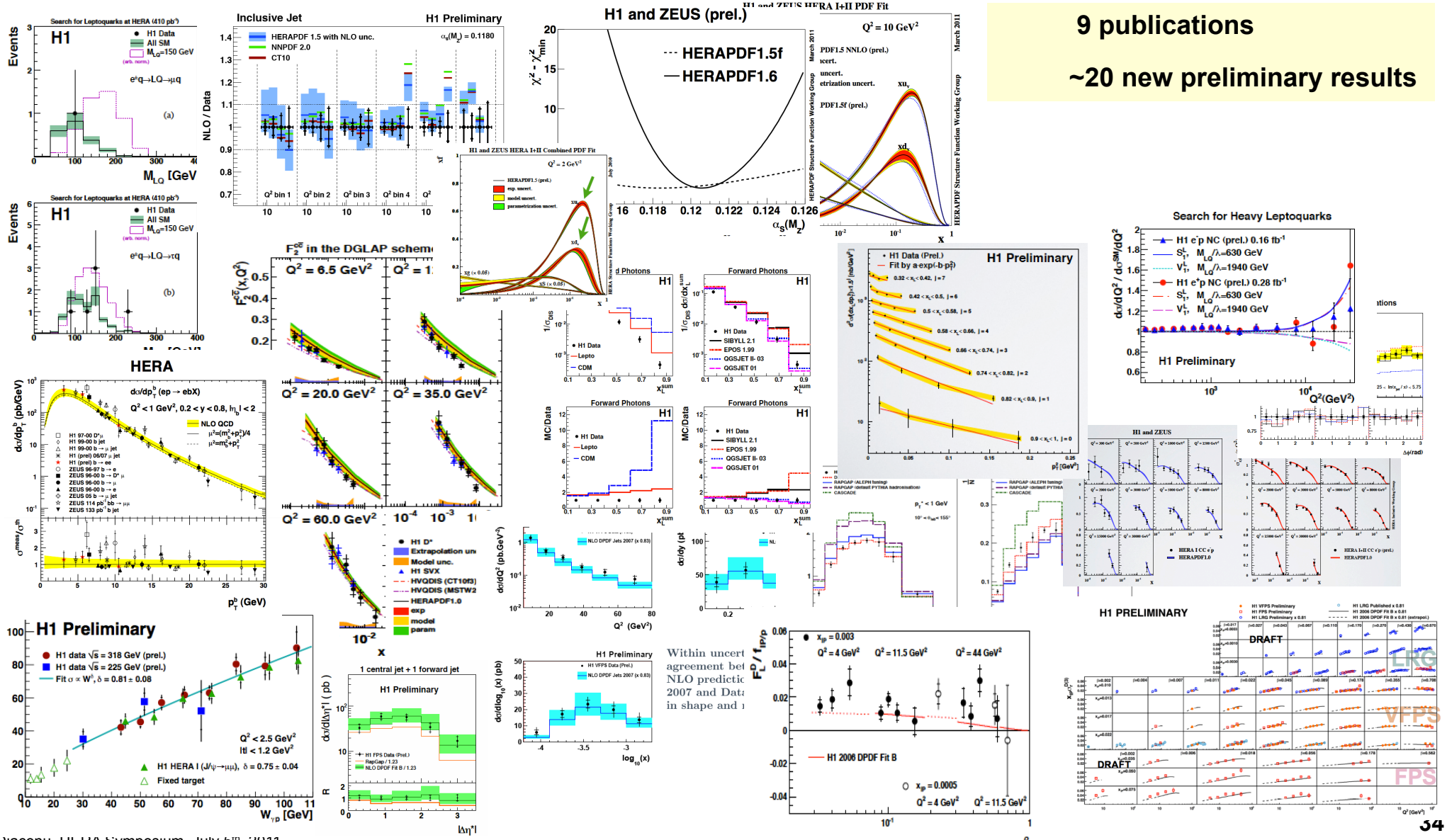
Measurement possible due to high luminosity integrated at HERA II

Useful for cosmic rays models and soon comparable with LHCf results

H1 physics output in the last year

9 publications

~20 new preliminary results



H1 25 years

H1 1985: Letter of intent

More than 1000 researchers have contributed to the H1 experiment over 2.5 decades

H1 2010

Conclusions

- **The physics harvest continues at H1/HERA**
  - **New results made possible by improved data and analysis techniques**
  - **The full potential of the HERA II run is now exploited**
    - **~30 preliminary notes to be published in the next 2-3 years**
- **Fundamental results in preparation:**
  - **HERAPDF 2.0 and beyond**
  - **Ultimate precision strong coupling measurements**
  - **Inclusive diffraction and DPDFs**
  - **H1-ZEUS combinations provide the HERA Legacy**
- **Transfer of expertise to LHC and beyond is ongoing**