HERA-future prospects

HERA-LHC workshop final meeting. 23 March 2005

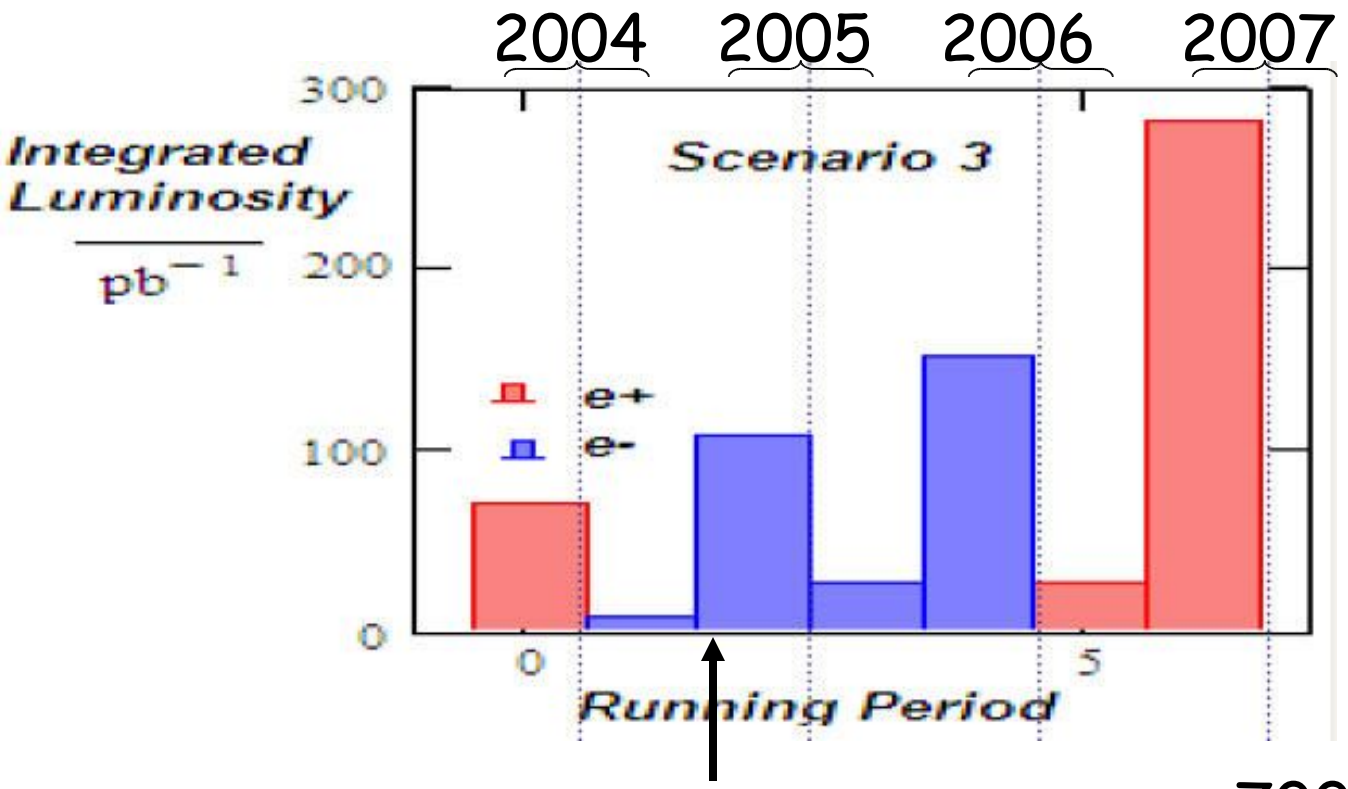
R. Yoshida, ANL

- A short recent history of HERA
- HERA II progress
- What we could achieve
- What we will likely not achieve (as things stand)

HERA: a recent history

- Late 1990's: Based on studies undertaken at "Future HERA Workshop" and other places, HERA II—the luminosity upgraded HERA was put into action. The plan was to increase the luminosity 5 fold and accumulate ~1 fb^{-1} of DIS data using both electrons and positrons which would be polarized.
- Sept. 2000: end of HERA I
- Summer 2001: close detector HERA II commissioning starts
- October 2001: first ep collisions
- November 2001: HERA achieves design specific luminosity : 1.8×10^{30} $cm^{-2}s^{-1}mA^{-2}$
- Background and reliability problems . Additional synchrotron shields installed, aperture limitations fixed.
- May 2002: Reliability improved. Still high background. Systematic studies of background begins.
- End 2002: Background largely understood, improvement plans made.
- March 2003: Shutdown to improve background conditions
- HERA restart: July 2003, by end of year it is clear that background solved.
- Aug 2004, HERA end date mid-2007 end date confirmed
- Switch to electrons October 2004.

HERA II running scenario

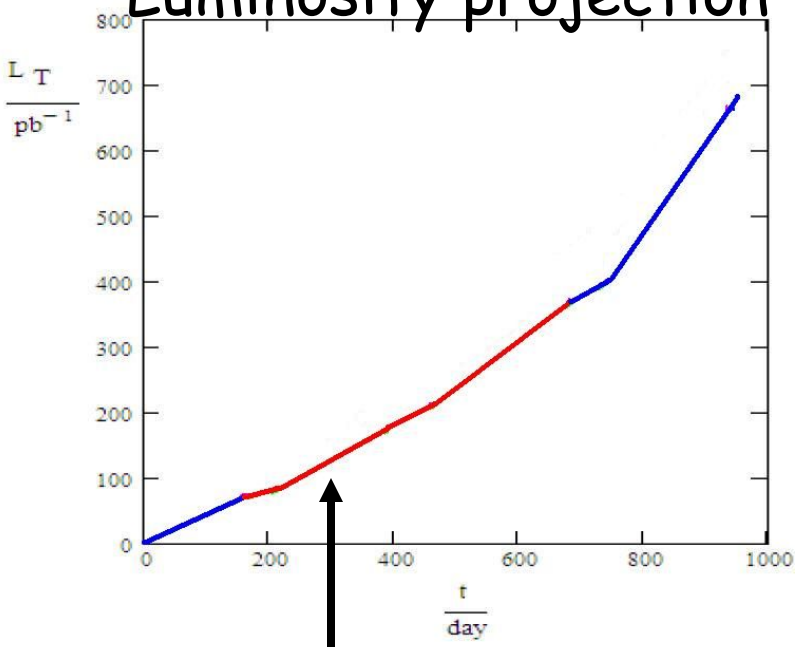


We are here

~700 pb-1 total
half e+ half e-
projected.

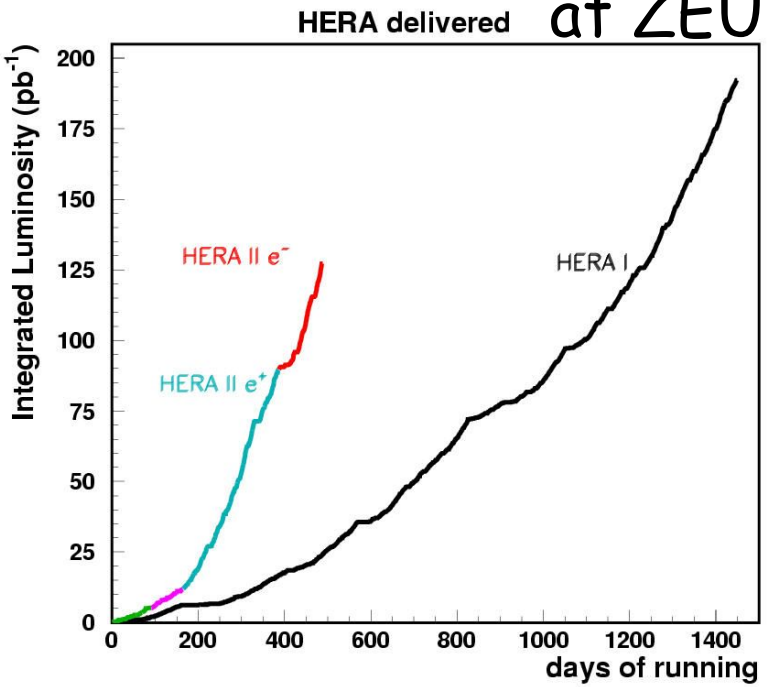
HERA II progress

Luminosity projection



We are here

Actual Luminosity at ZEUS



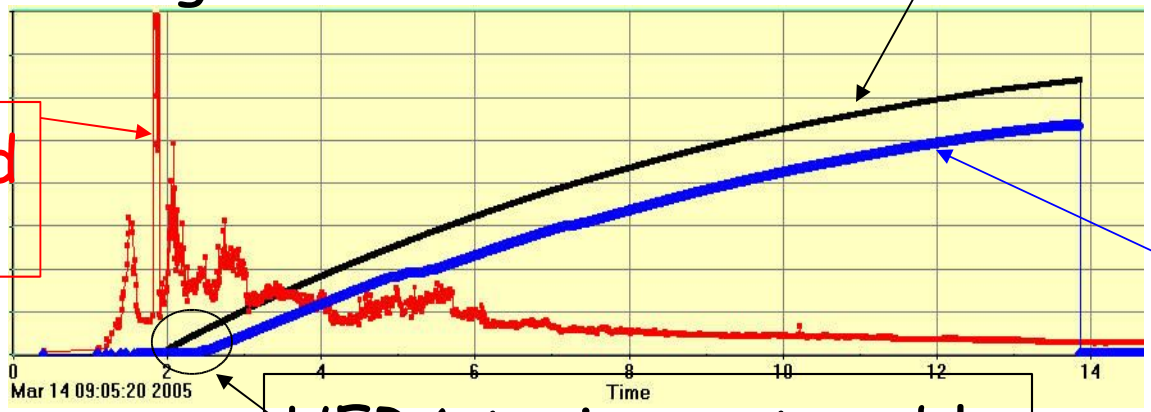
This is "delivered": not all useful for physics…

HERA II Progress

Background: In general it is ok

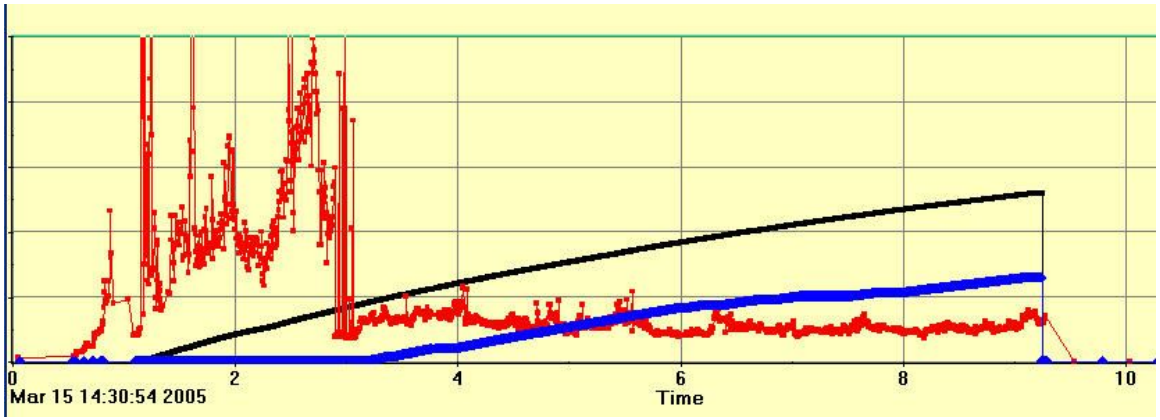
"Delivered lumi"

Background monitor



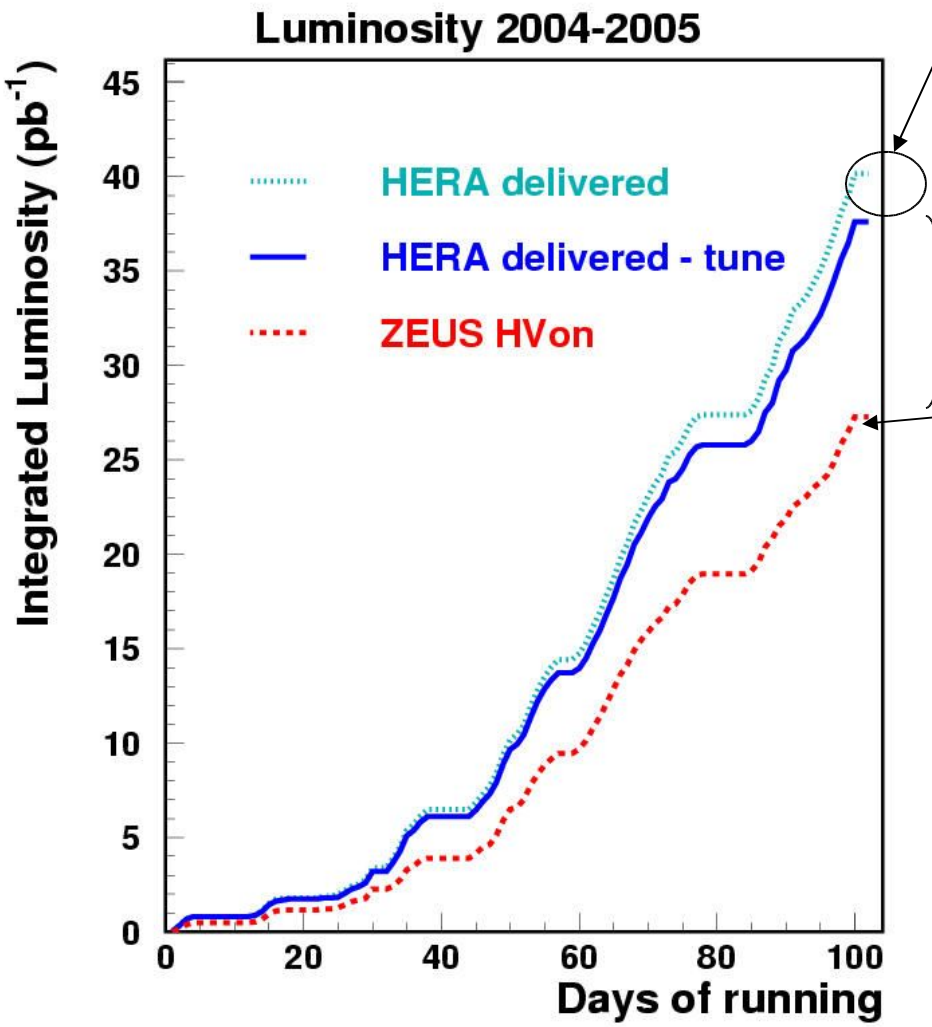
On tape (physics)

HERA tuning: not usable



Sometimes background is not under control.

HERA II progress



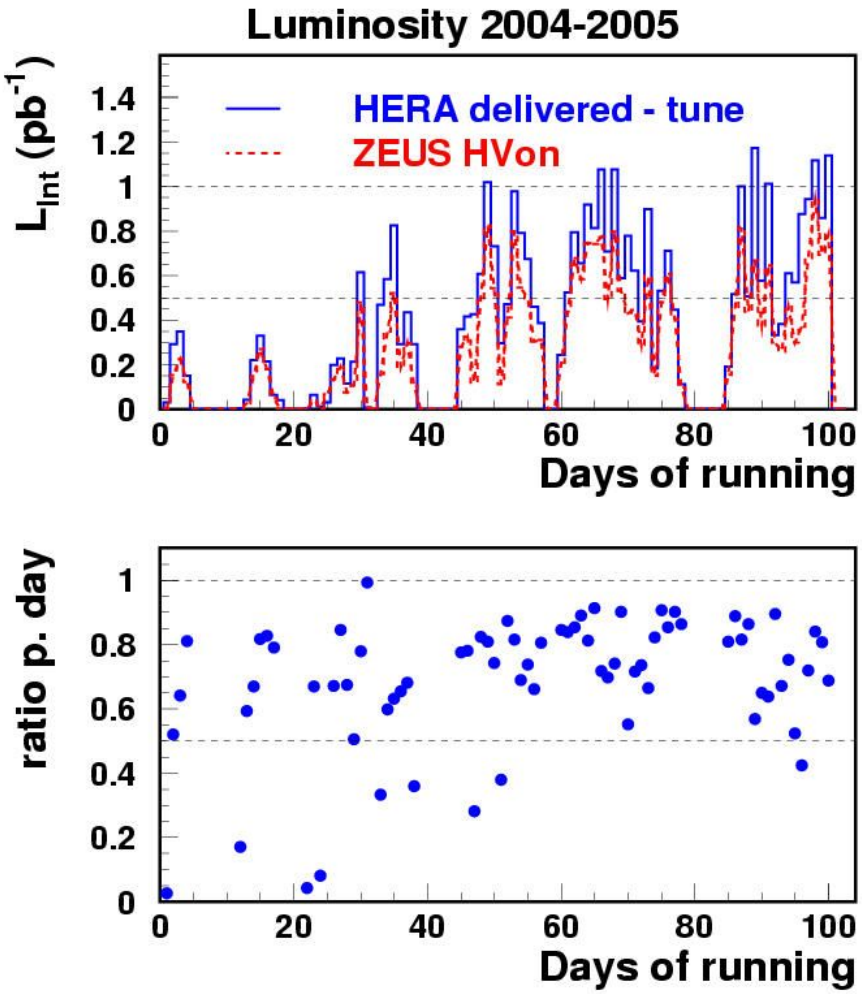
HERA tuning

~1/2 bad background
~1/2 experiment inefficiencies

On Tape: usable for physics

The efficiency potentially can improve by another 10-15%.

HERA II progress

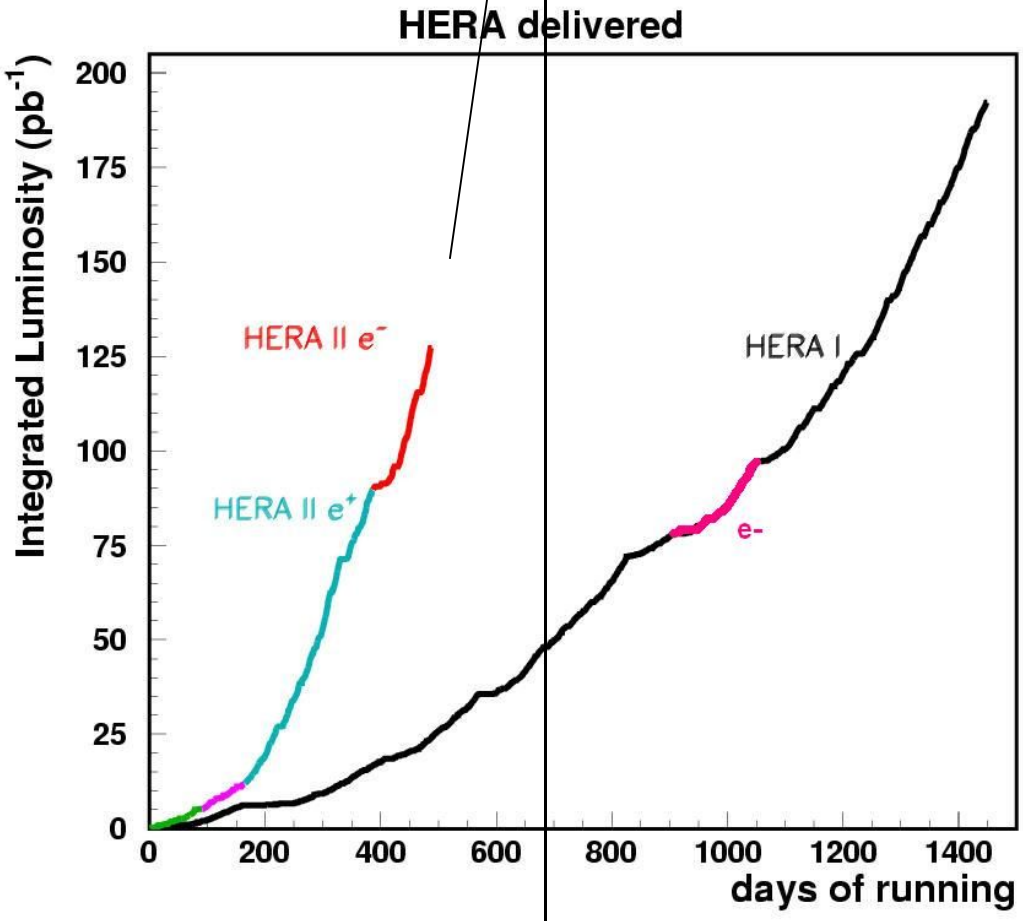


Recently taking ~.7 pb-1/day (ZEUS)

- P nor e current saturated yet (~20% head room for both?)
- HERA operational effic. can improve.
- 1 pb^{-1}/day taken seems achievable soon.
- ~750 days of operation left in HERA II: 700 pb^{-1} reasonable.

Short term outlook:

~2005 shutdown

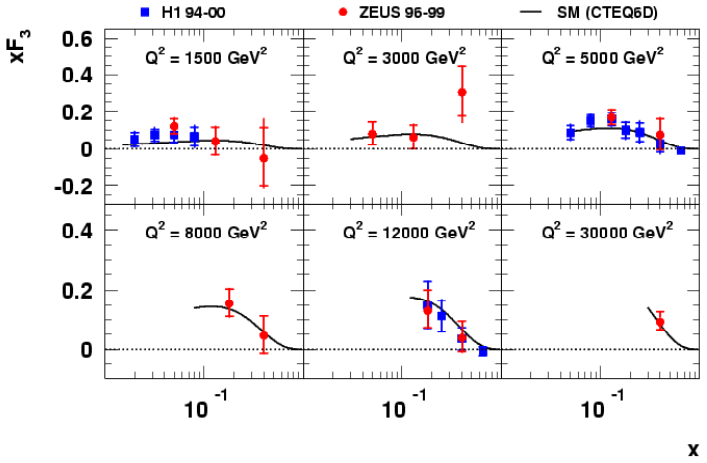


e$^-$P HERA I: 15 pb^{-1}

e$^-$P HERA II: 30 pb^{-1}

now

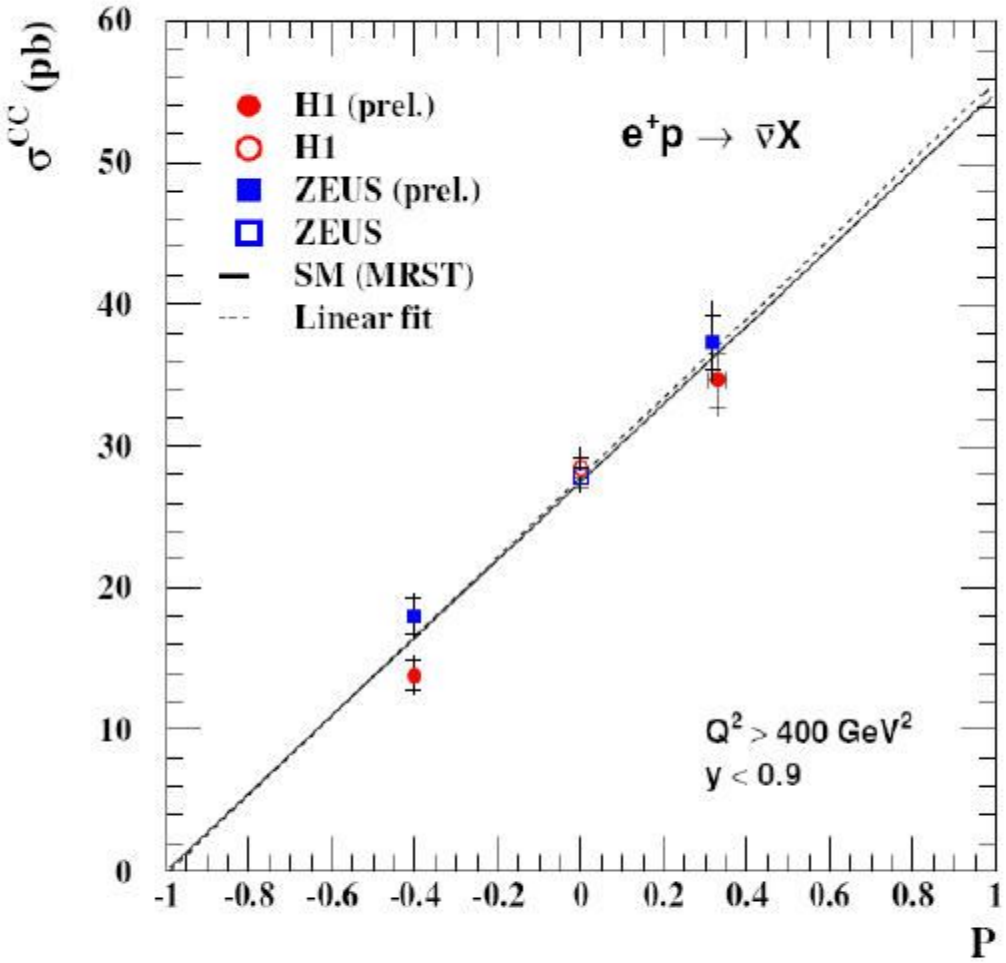
>150 pb^{-1} until summer ?



xF3 will improve

Also certain searches: excited neutrinos, lepton flavour vio. etc

HERA II



In the SM LH coupling $\bar{\nu}$ is excluded unless RH currents exist

Expect zero cross section at P=-1 and linear dependence on P

HERA II: can now prescribe positron beam helicity also in ep collider mode

Polarisation dependence firmly established for the first time.

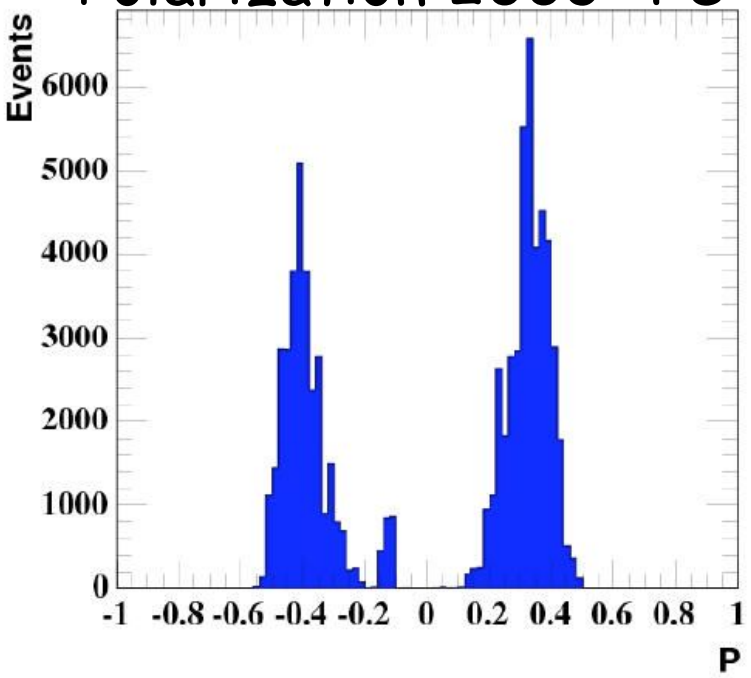
(remember CHARM $\bar{\nu}Fe \to \mu^+(P)X$ M.Jonker et al, PL 86(1979)229)

$$\sigma_{e^+p\to\bar{\nu}X}(P_{e^+}=-1)=0.2\pm1.8(sta)\pm1.6(sys)pb$$

$$\chi^2_{dof}=5.4/4$$

- combined H1 and ZEUS
- result consistent with 0

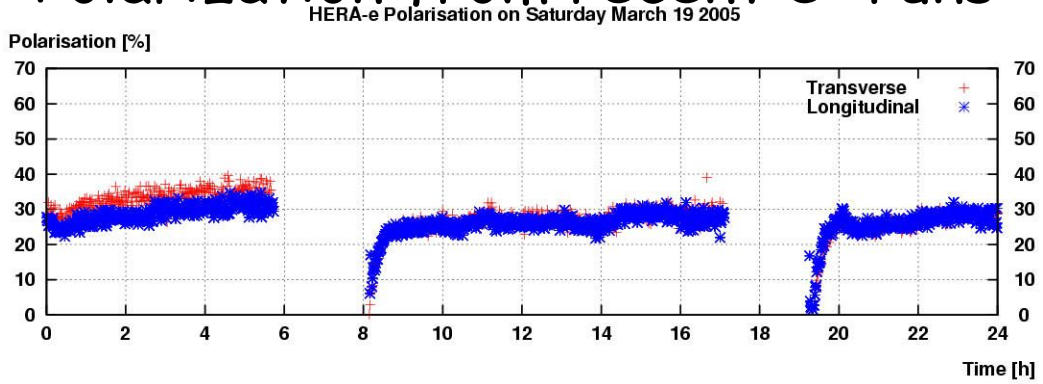
Polarization 2003-4 e+



Up to 50% polarization is theoretically possible:

For e+ ~40% achieved
For e- up to now ~30%-- this is being worked on.

Polarization from recent e- runs



HERA II: NC DIS cross-sections (polarized electrons)

$$\frac{d^2\sigma^{NC}}{dx\,dQ^2}(e^-_{L,R}) = \frac{2\pi\alpha^2}{xQ^4}\left[\left(1+(1-y)^2\right)F_2^{L,R} + \left(1-(1-y)^2\right)xF_3^{L,R}\right]$$

EW couplings

$$F_2^{L,R} = \sum_q [xq(x,Q^2) + x\bar{q}(x,Q^2)]\cdot A_q^{L,R},$$
$$xF_3^{L,R} = \sum_q [xq(x,Q^2) - x\bar{q}(x,Q^2)]\cdot B_q^{L,R}.$$

Quark distributions (QCD)

$$\chi_Z = \frac{1}{4s_W^2 c_W^2}\frac{Q^2}{Q^2+M_Z^2}$$

=0.67 at Q2=10k

v_e ← unpol. case → $(v_e^2+a_e^2)$

=~-0.036

$$A_q^{L,R} = Q_q^2 + 2Q_eQ_q(v_e \pm a_e)v_q\chi_Z + (v_e \pm a_e)^2(v_q^2+a_q^2)(\chi_Z)^2,$$
$$B_q^{L,R} = \pm 2Q_eQ_q(v_e \pm a_e)a_q\chi_Z \pm 2(v_e \pm a_e)^2 v_q a_q (\chi_Z)^2,$$
$$(L=+, R=-)$$

a_e ← unpol. case → $2a_ev_e$

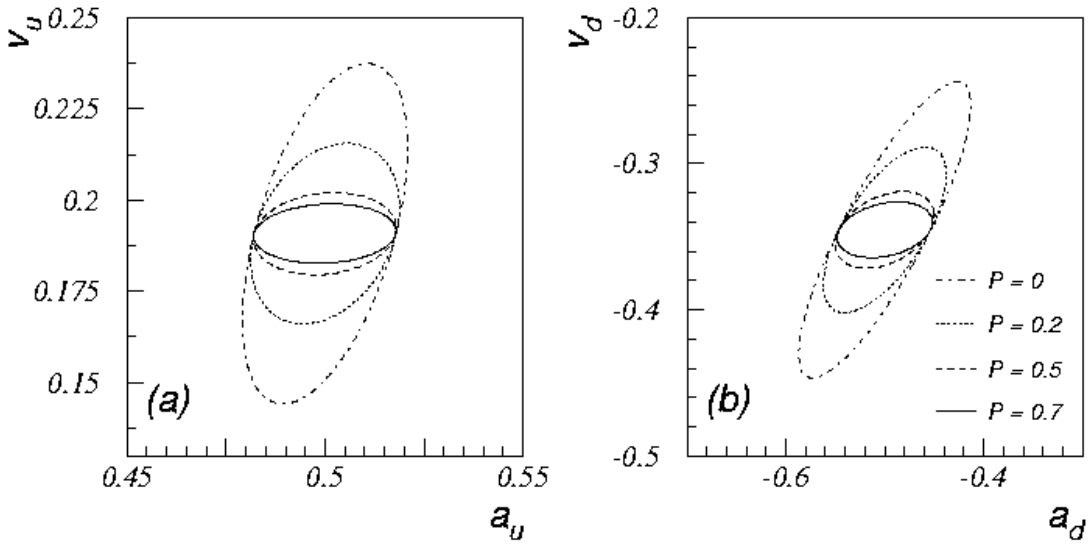
Sensitivity to a_q already in unpolarized xF3

Vector and Axial-vector coupling of light quarks:

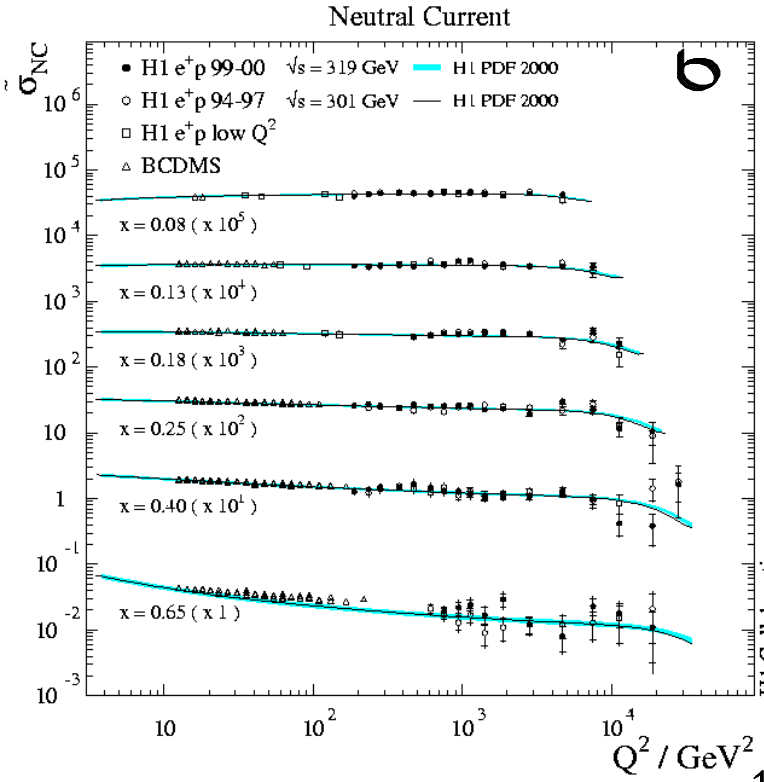
$Q^2 = 10^4$ GeV^2	$v_q = 0,\ a_q = a_q^{SM}$	$v_q = v_q^{SM},\ a_q = 0$
$1 - \frac{F_2^0(x,Q^2;v_q,a_q)}{F_2^0(x,Q^2)}$	~ 0.05	~ 0.12
$1 - \frac{xF_3^0(x,Q^2;v_q,a_q)}{xF_3^0(x,Q^2)}$	~ 0.03	1
$1 - \frac{F_2^p(x,Q^2;v_q,a_q)}{F_2^p(x,Q^2)}$	~ 0.2	~ 0.02
$1 - \frac{xF_3^p(x,Q^2;v_q,a_q)}{xF_3^p(x,Q^2)}$	~ 0.7	1

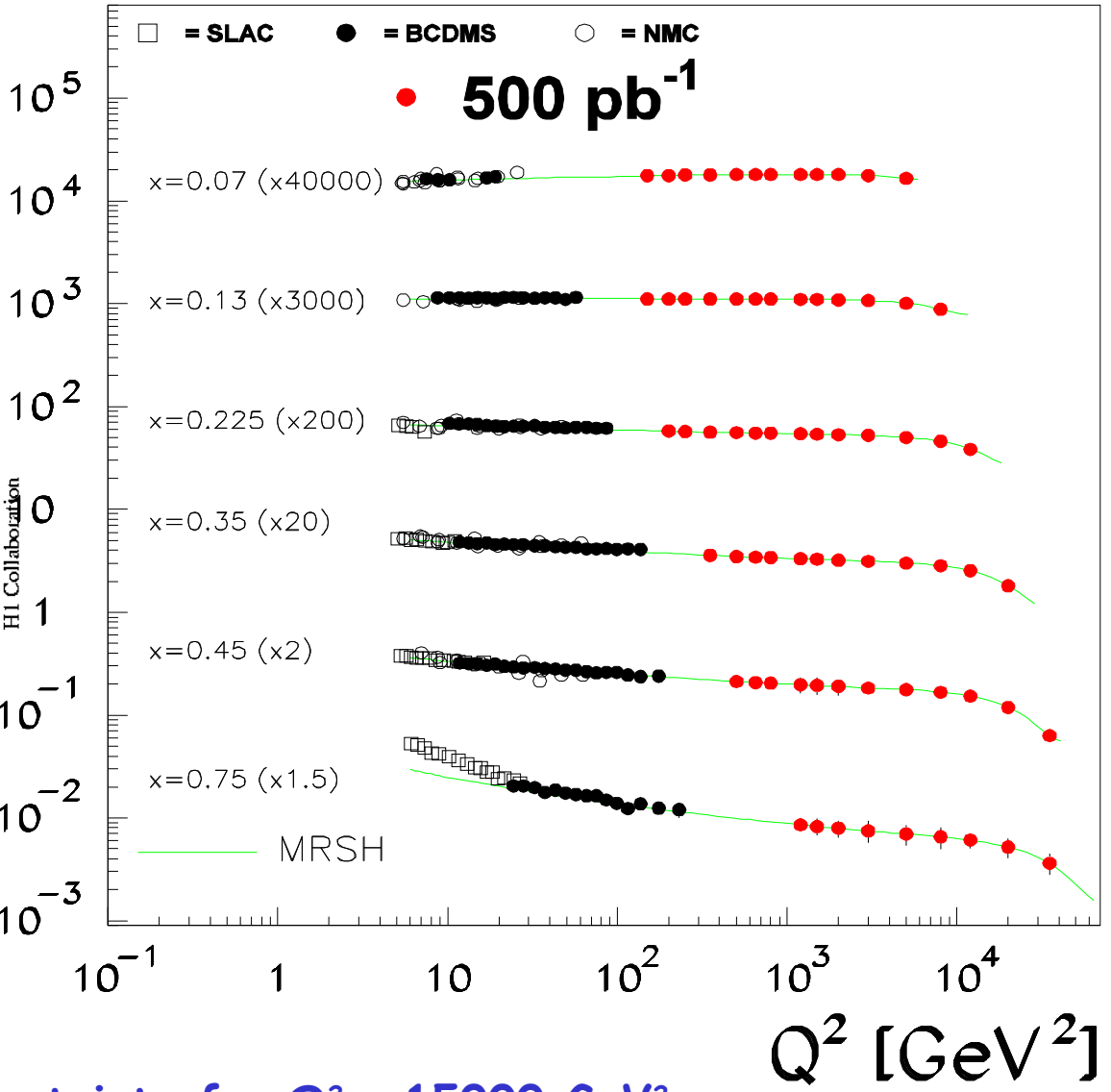
Gain sensitivity to vector coupling with polarization.

Importance of polarization.



Future measurement on Neutral Current cross section

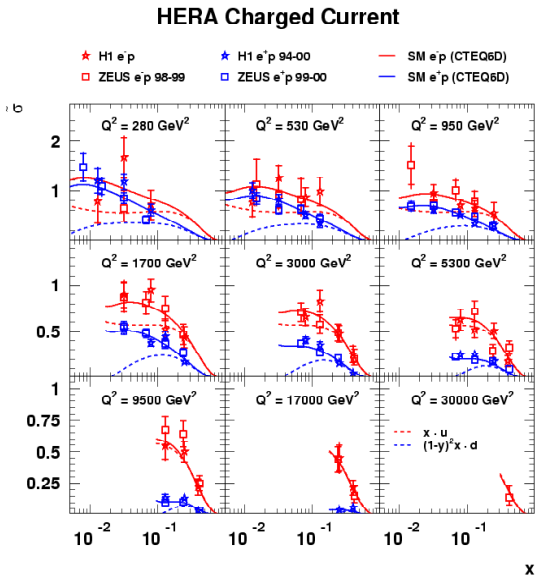


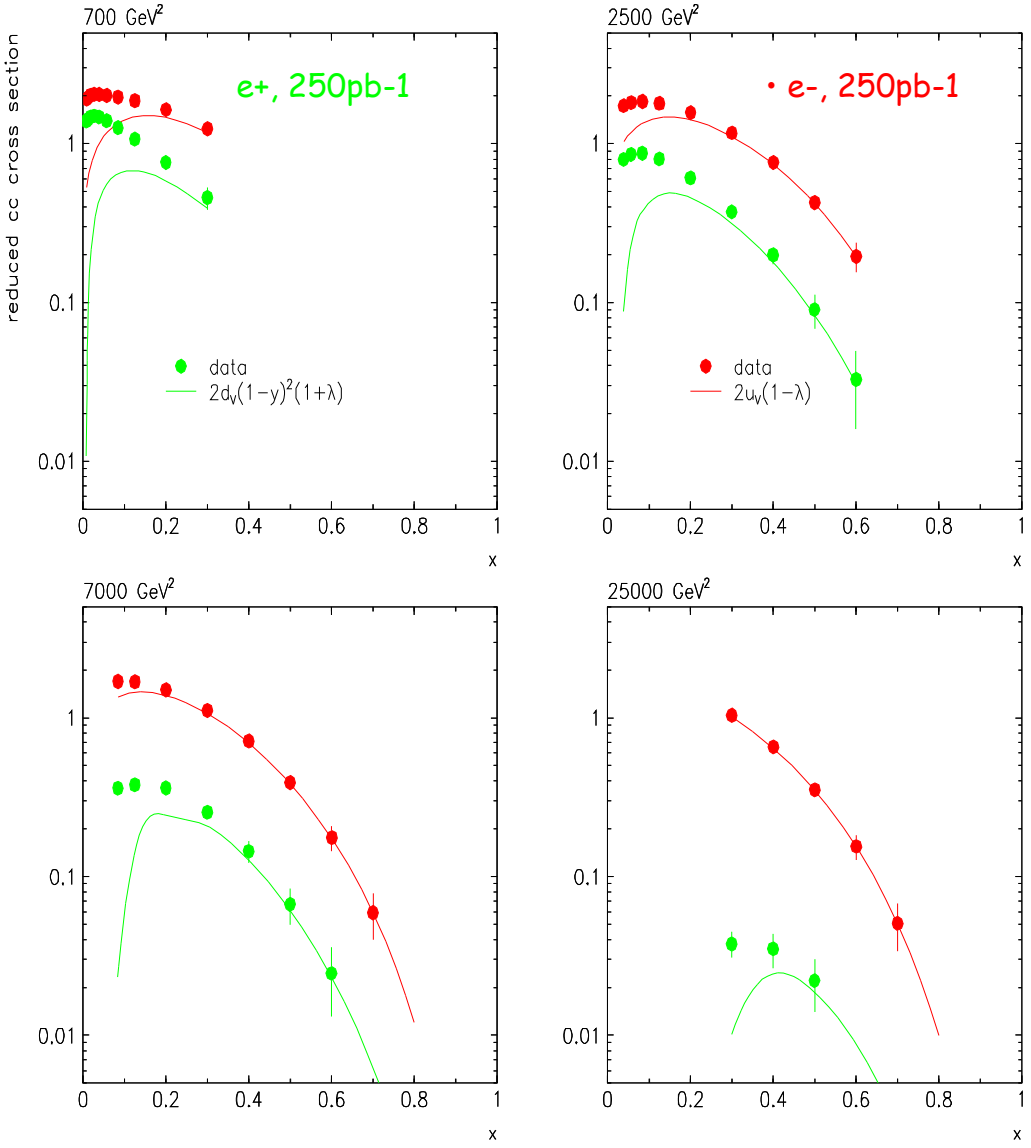


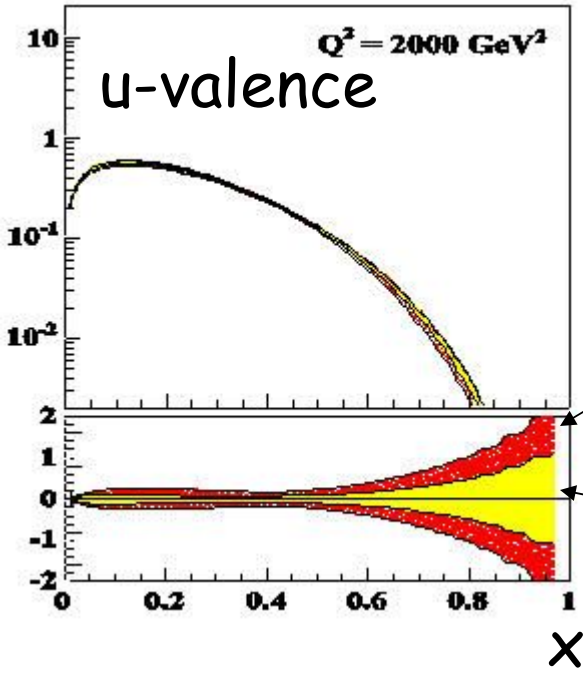
M. Klein

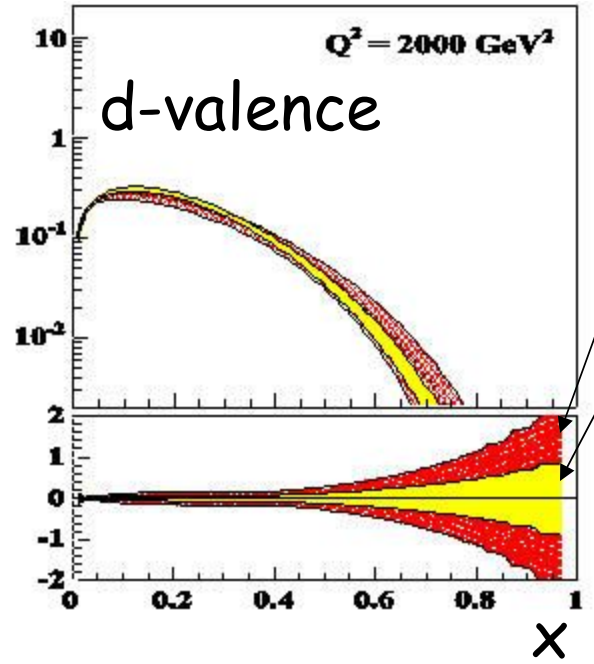
- 10% uncertainty for Q^2 > 15000 GeV^2

Future CC cross section measurements at HERA in e±p









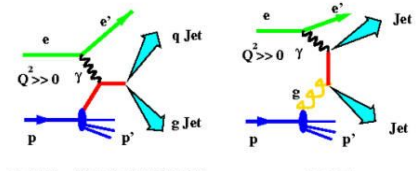
Fractional error from HERA data now.

Fractional error after
500 pb-1 e+p
500 pb-1 e-p

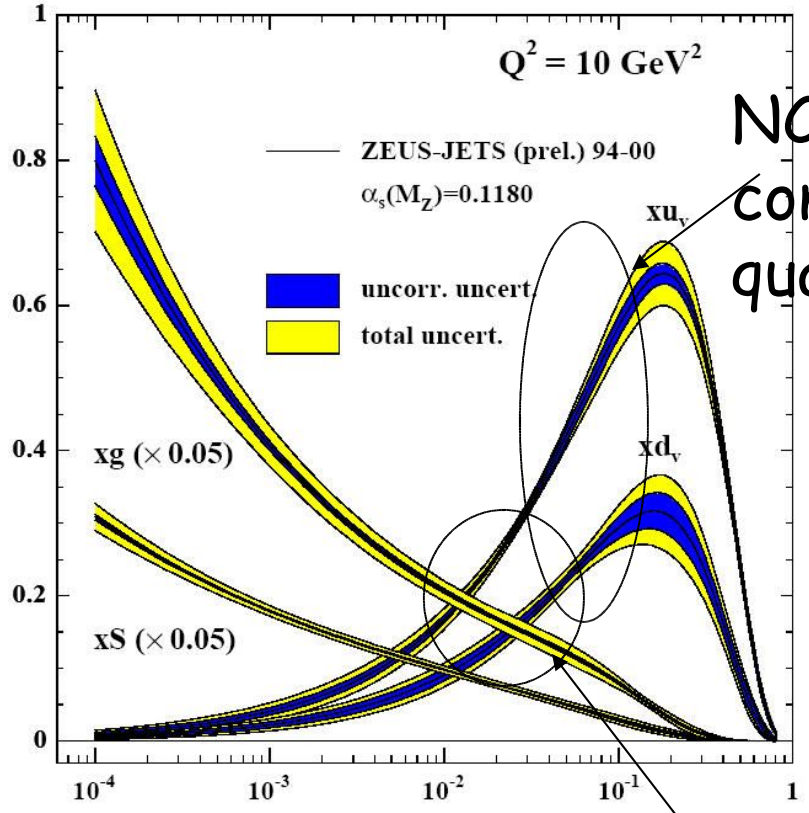
The HERA high-x measurements can replace low-Q^2 data.

C. Gwenlan

Recent developments in HERA I analysis: HERA jet data improves constraint on gluons.

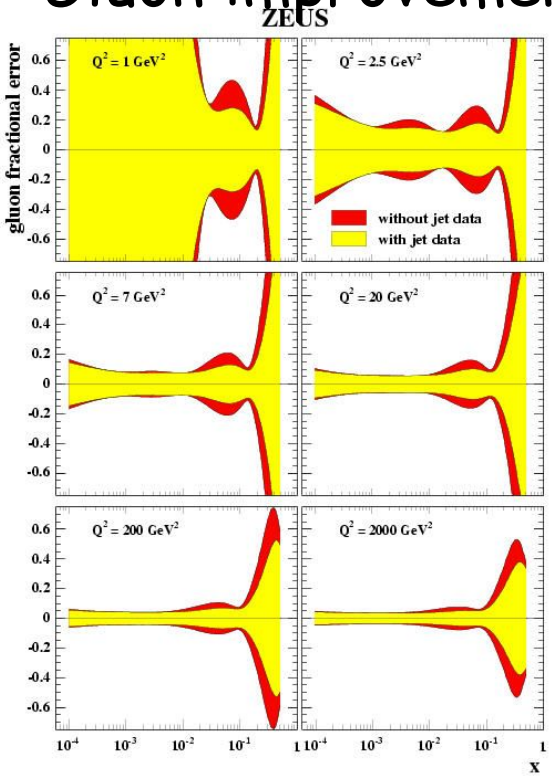


QCI



NC and CC constrain quarks

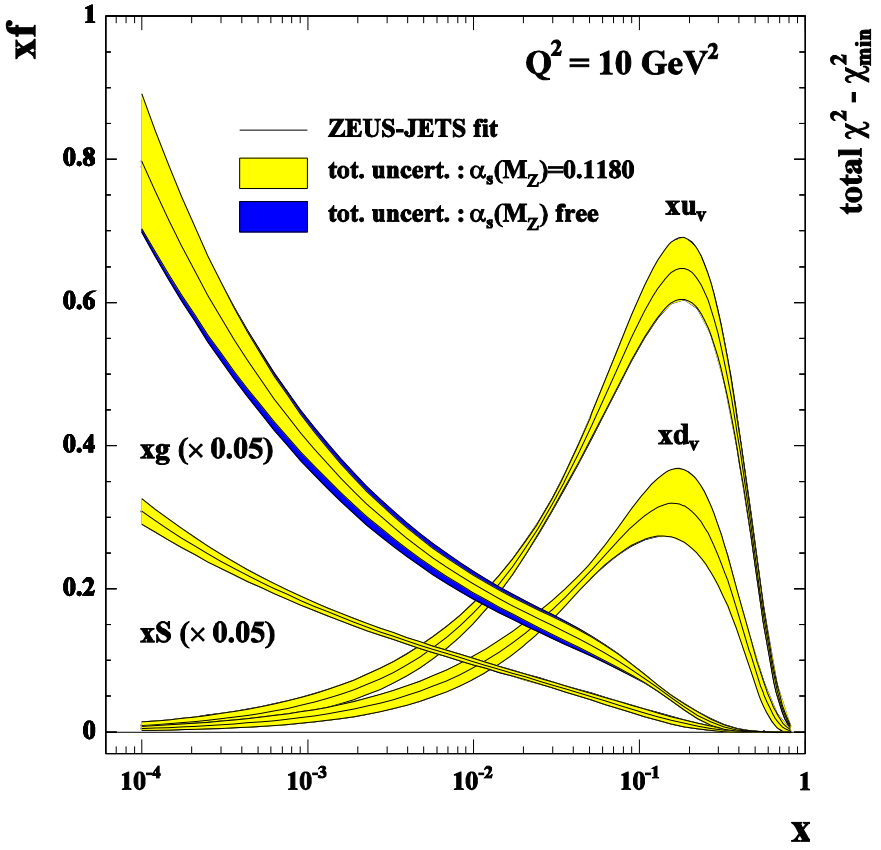
Gluon improvement

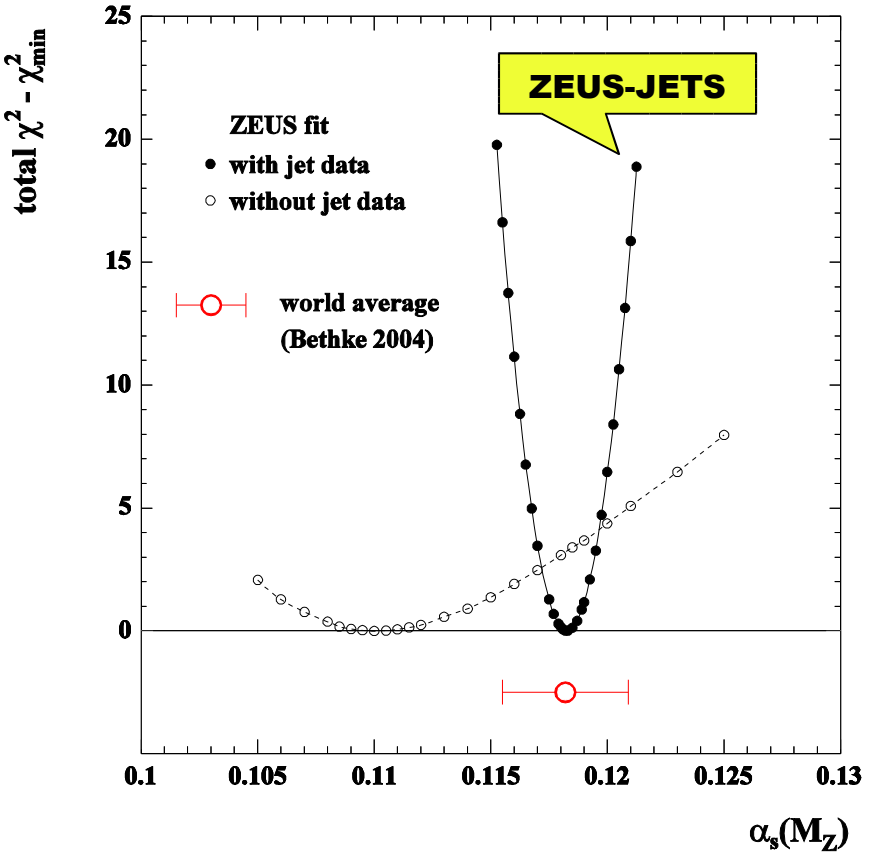


Jet data constrain the medium x gluon

Extraction of $\alpha_s(M_Z)$

- Extra constraint on gluon provided by jet data allows accurate extraction of α_s -> treat $\alpha_s(M_Z)$ as free parameter
  - Value extracted: $\alpha_s(M_Z)=0.1183\pm0.0028(\text{exp.})\pm0.0008(\text{model})$
  - gluon uncertainties increased when α_s free (gluon and α_s correlated)

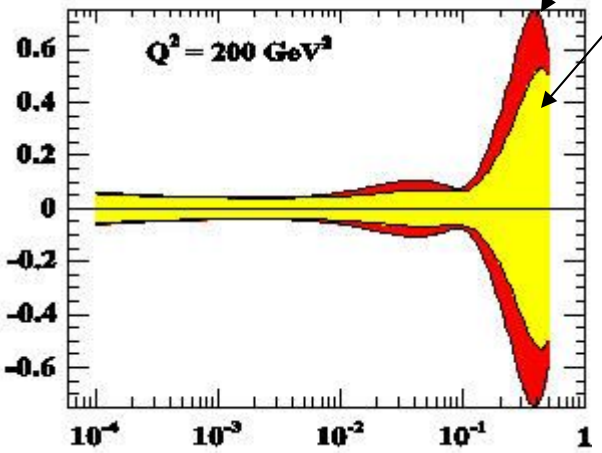




without jets

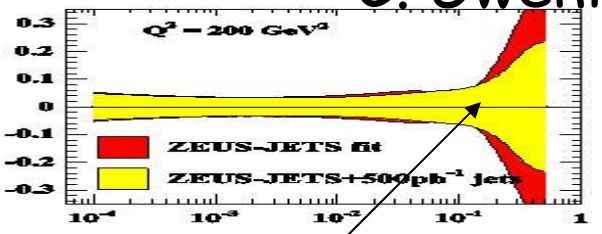
with HERA jets now

Fractional error on the gluon



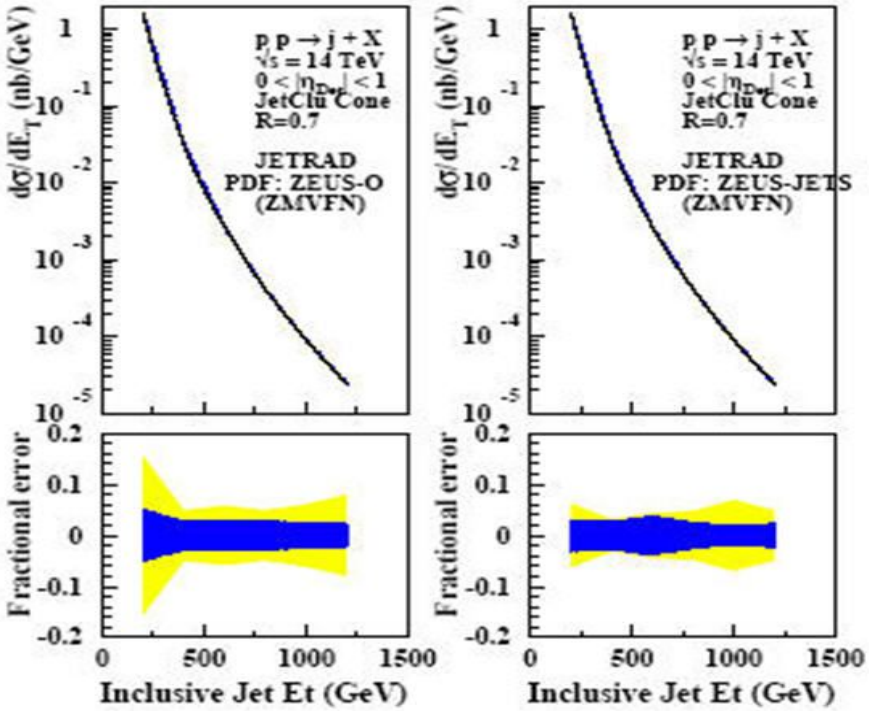
X

C. Gwenlan



X

With 500 pb^{-1} jets

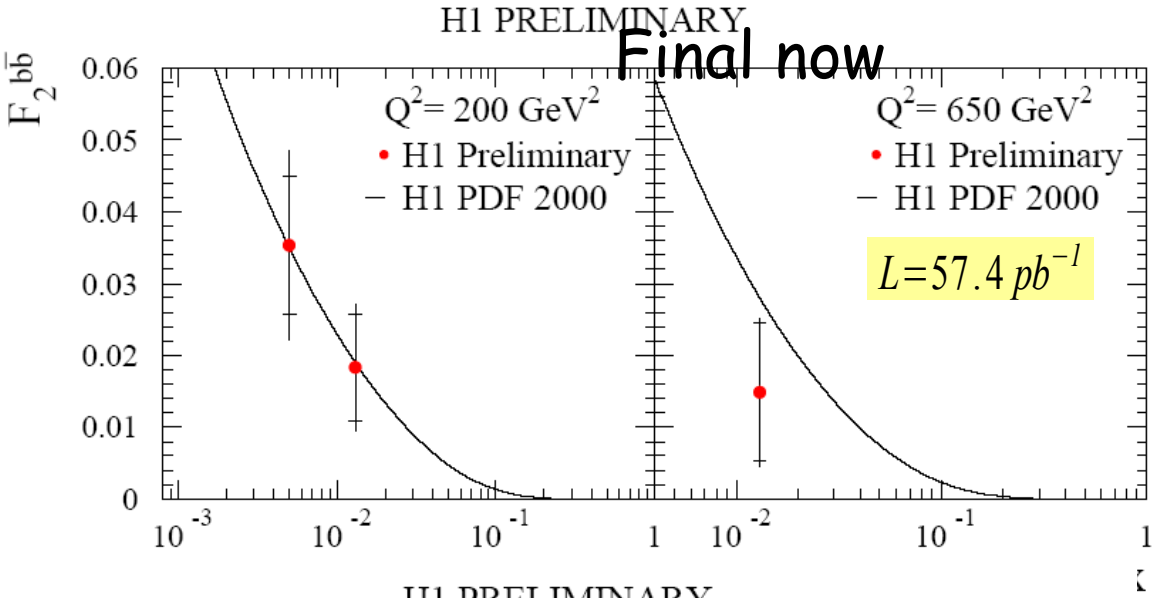


→ With 500 pb^{-1} jets?

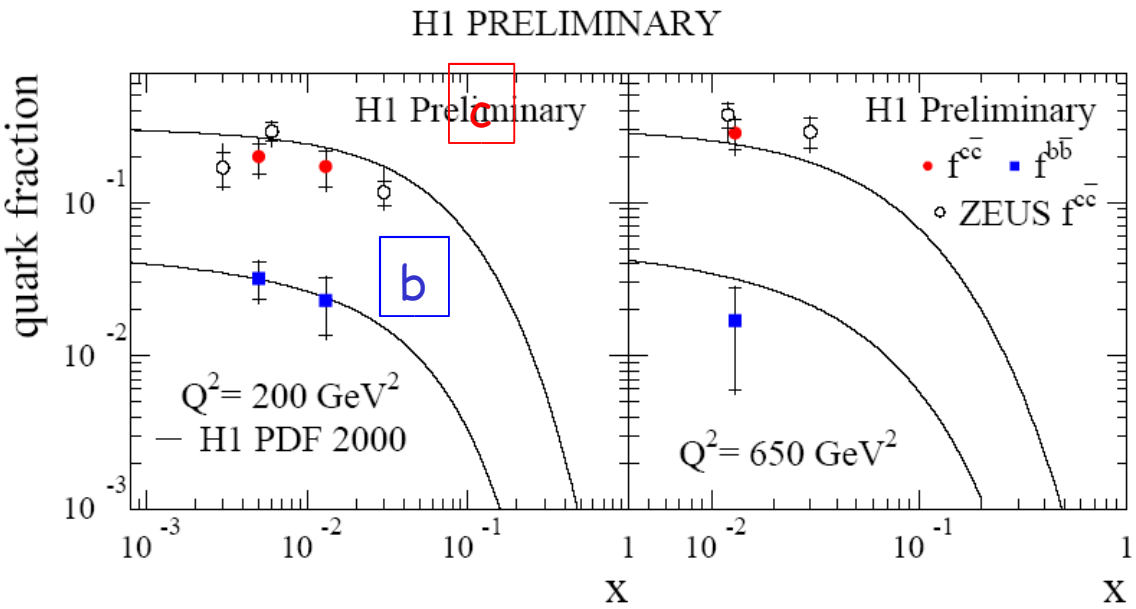
K. Nagano

Micro-vertex detector (new for ZEUS in HERA II): more wide-acceptance HQ measurements coming

Inclusive beauty production in deep inelastic scattering



First measurement of bottom structure function, uses b lifetime tagging.



Charm F_2 data with D* (ZEUS) and tagging (H1) agree. Reach now high Q2

Charm is 20% of F_2. Beauty only 2%, below valence quark region

Luminosity needs for HERA II physics:

some compromises with baseline necessary

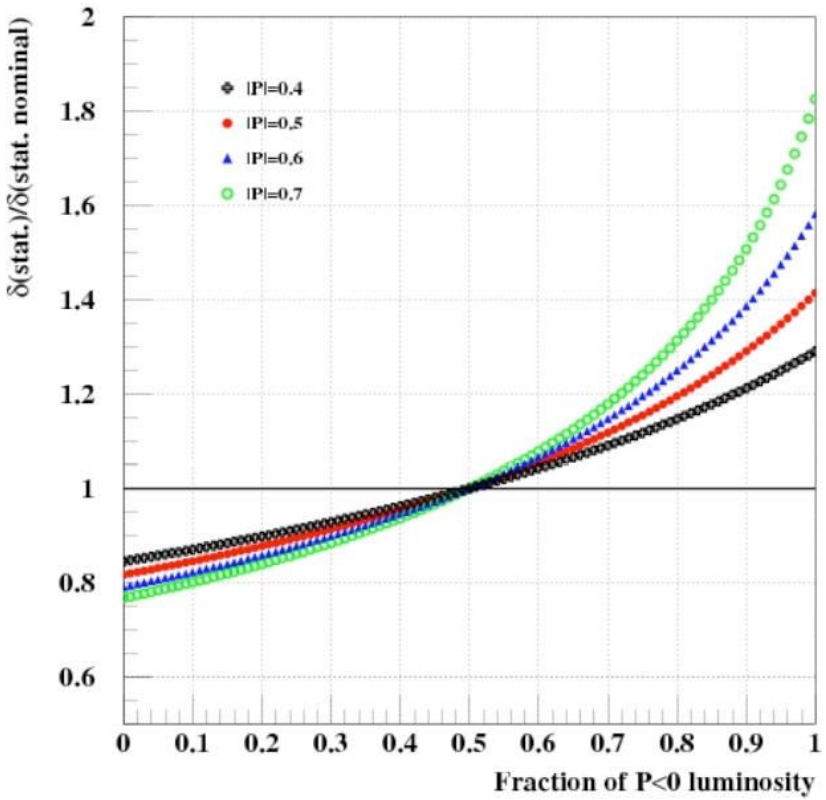
Baseline

Required Luminosity (pb^{-1})

Physics	e^+_L	e^+_R	e^-_L	e^-_R	Total	E_p<920GeV
EW: EW parameters	250	250	250	250		
δM_W ~50 MeV			1000			
Large-x:F_2 for x>0.7					1000	
or						100
xF_3		500	250			
d_V from CC		500				
Med-x:F_2^b				500		
strange quark		250	250			
Small-x:High Q^2 VM					500	
Extend W coverage						50
F_L						30
Exo: rule out anomalies		200				
study anomalies	250	250	250	250		

Are any of these goals in conflinct?

There is not much conflict
between partons, searches, EW studies



Statistical improvement
in CC sample by
taking unequal sample
of P>0 and P<0:
--not much

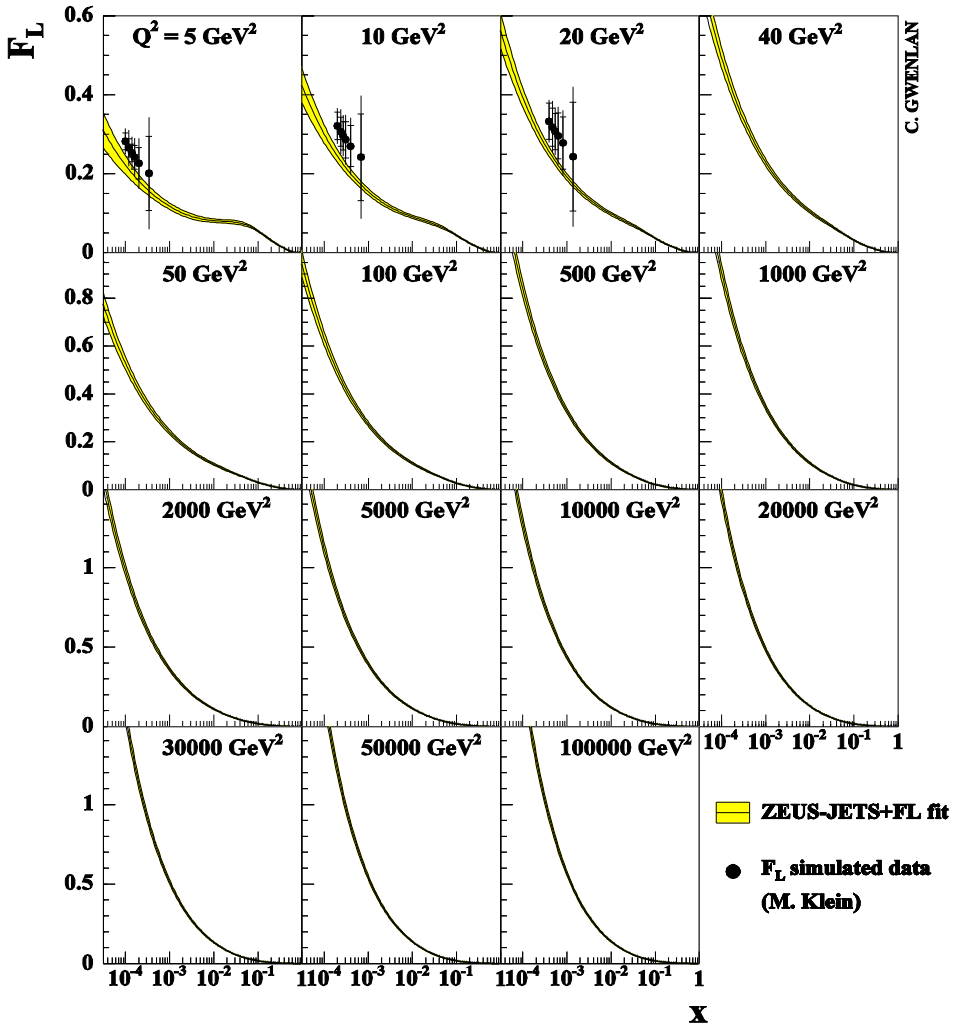
Low energy running: currently time cost prohibitive

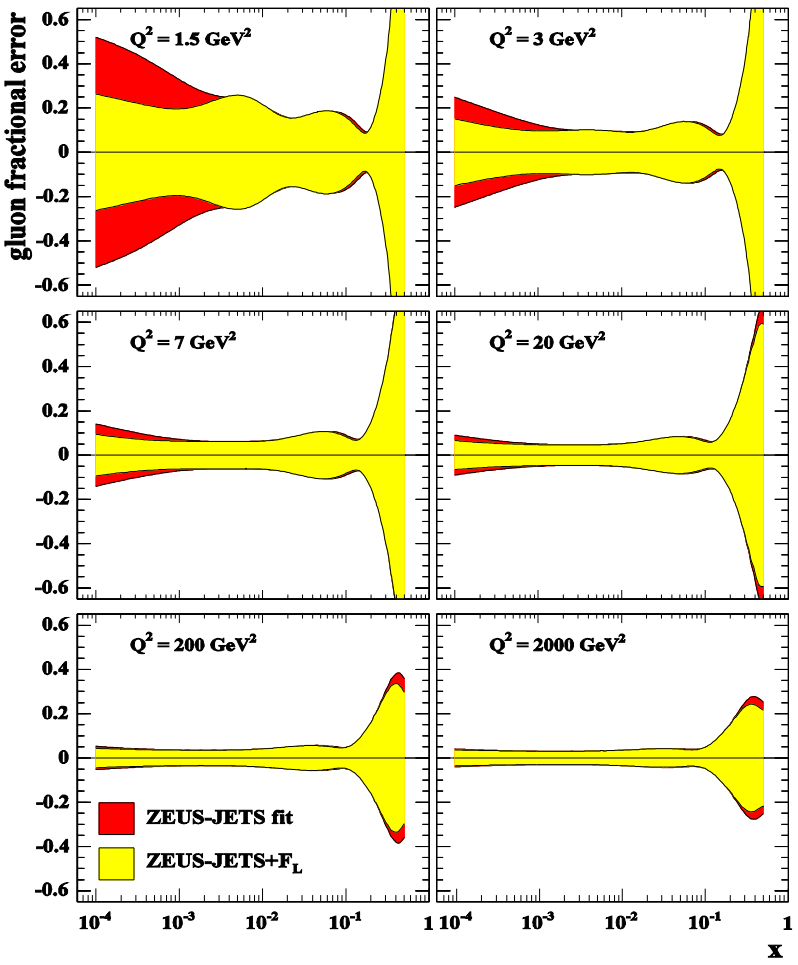
E_p (GeV)	920	575	465	400
L (pb^{-1})	10	5	3	2

Lumi ~$(Ep)^2$

Setup time for 3 configs.

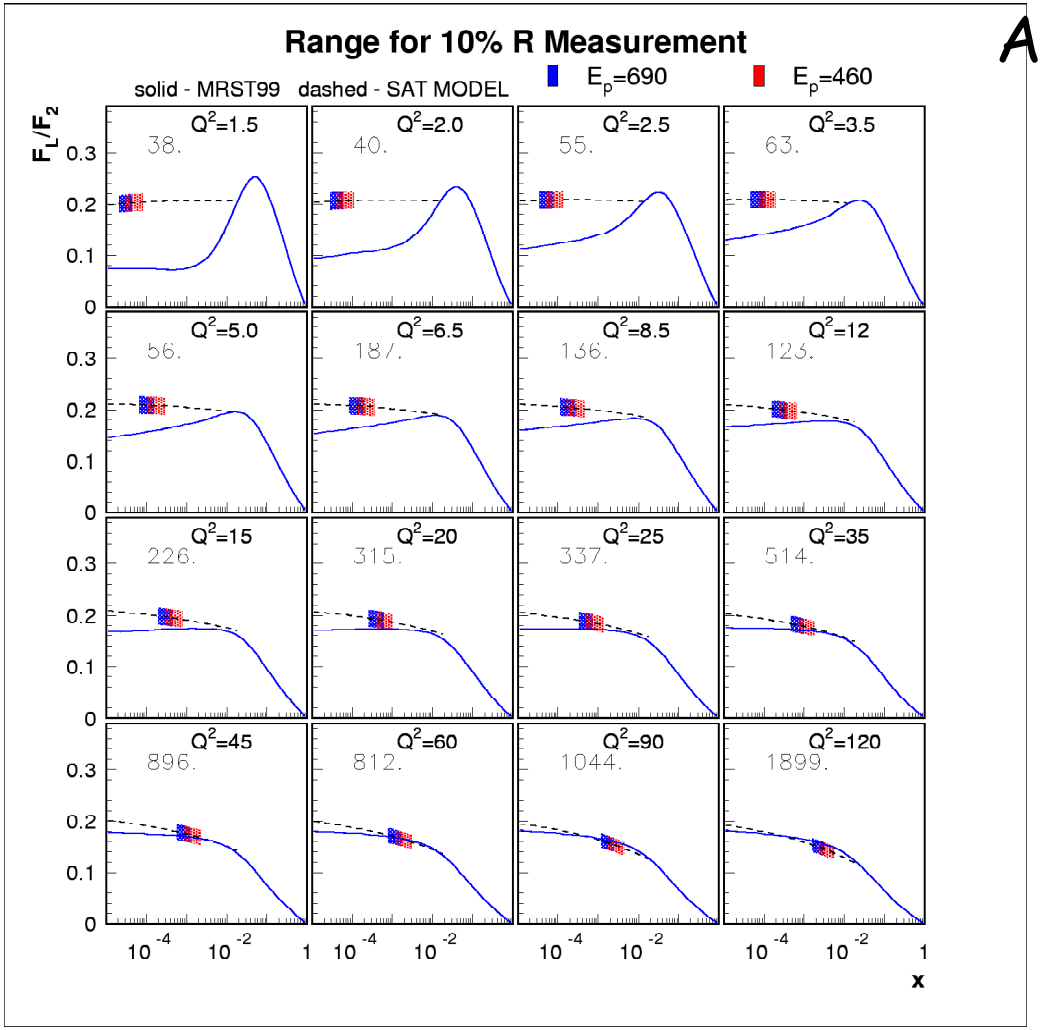
C. Gwenlan



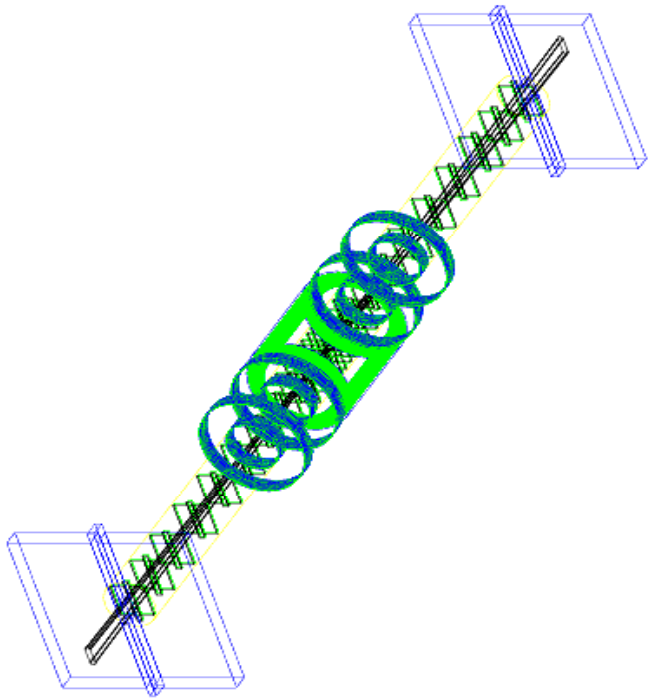


Precision of F_L in HERA II will not give strong constraints to gluons in a conventional NLO analysis.

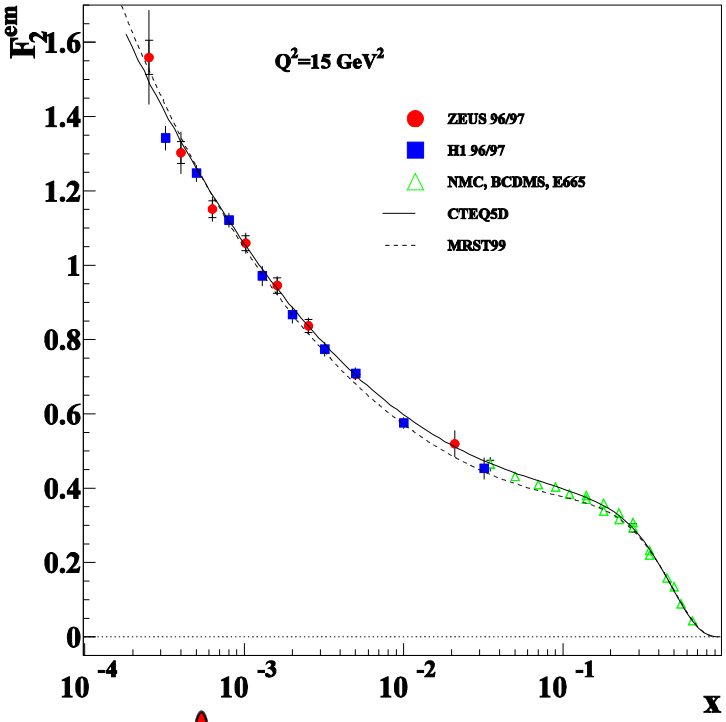
A precise (10%) measurement of FL will require a new dedicated detector in HERA: no plans to do this exist

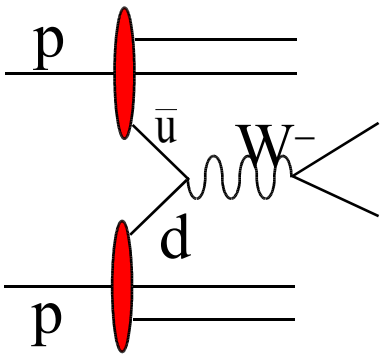


A. Caldwell



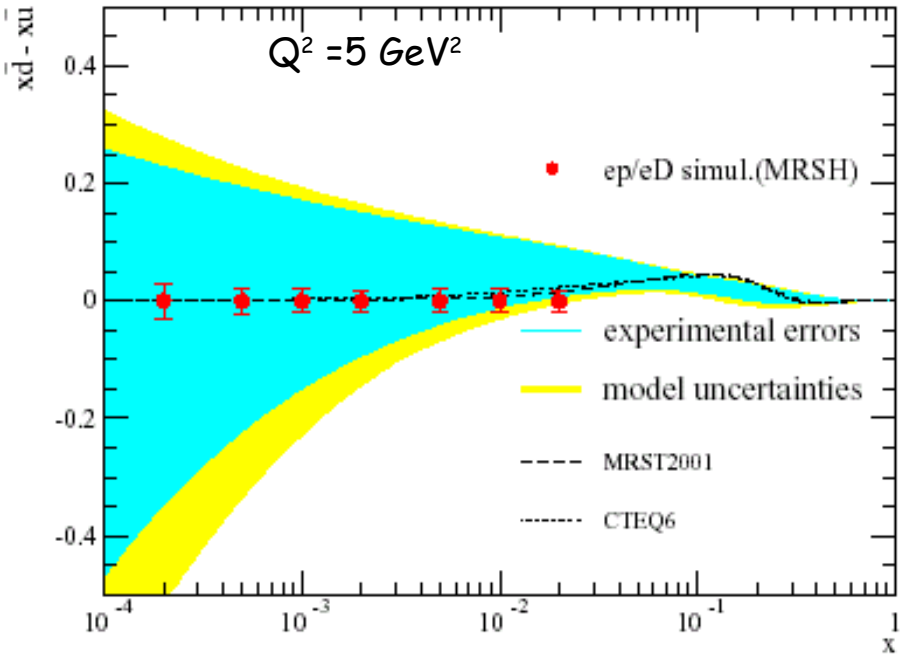
Likewise, D in HERA will provide ubar dbar at low-x:
Also no plans to do this exist.





Exploration of the rising F2(x,Q2)

$$\frac{1}{2}\left(F_2^p + F_2^n\right) \quad F_2^p$$
$$= x\left(\frac{1}{6}d_v \quad \frac{1}{6}u_v \quad \frac{1}{3}\bar{d} \quad \frac{1}{3}\bar{u}\right)$$
$$\approx \frac{1}{3}x\left(\bar{d} \quad \bar{u}\right) \text{ at low } x.$$



simulated accuracy (20pb^{-1} eD, 40 ep)

Affects parton luminosity at the LHC
Want 2% accuracy for δm_t = 2 GeV

Conclusions

- HERA II, after a slow startup, is running well.
- 700 pb^{-1} (possibly more) of physics data, shared equally in e+, e-, polarization, by end of HERA II (mid-2007) appears feasible.
- We are on track to accumulate x10 e-p data by the next summer shutdown.
- The goals of the high luminosity running (EW, structure functions, alpha_s, searches, heavy quarks) appears achievable.
- Within the remaining time for HERA, there is no room to do more than that.