Prospects and status of HERA II

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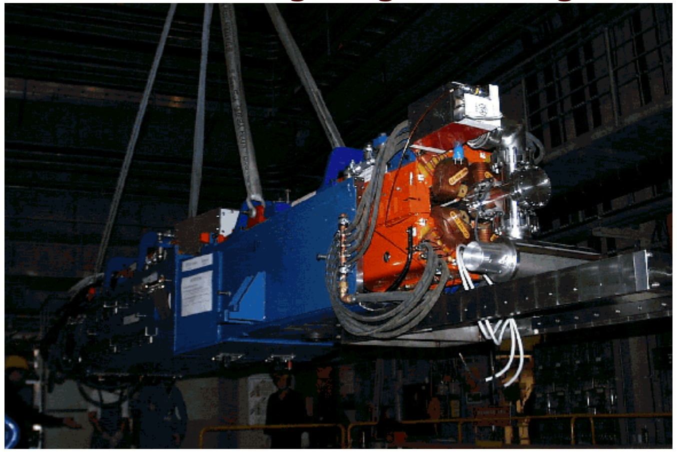
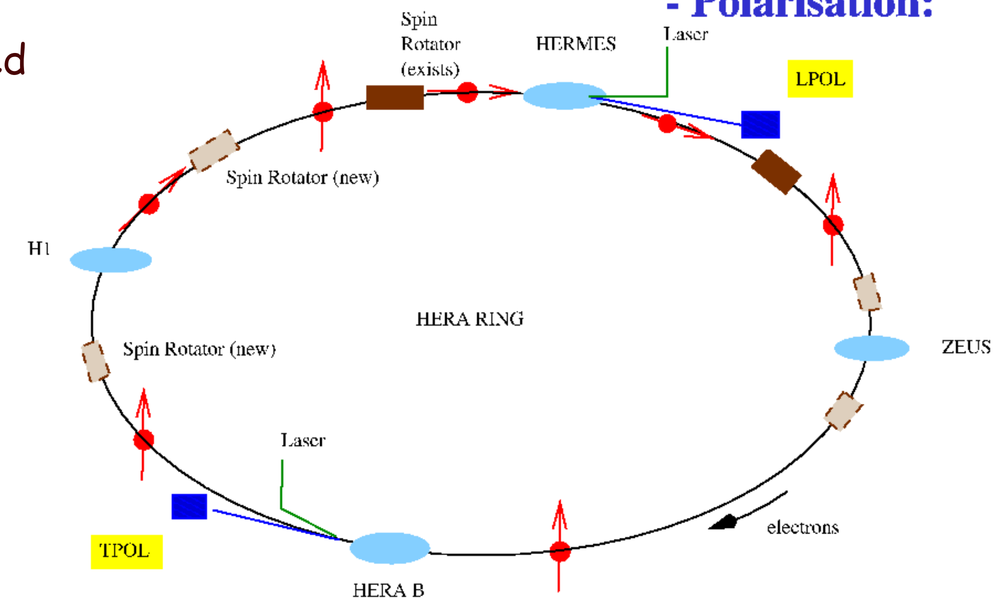
A final focusing magnet being installed

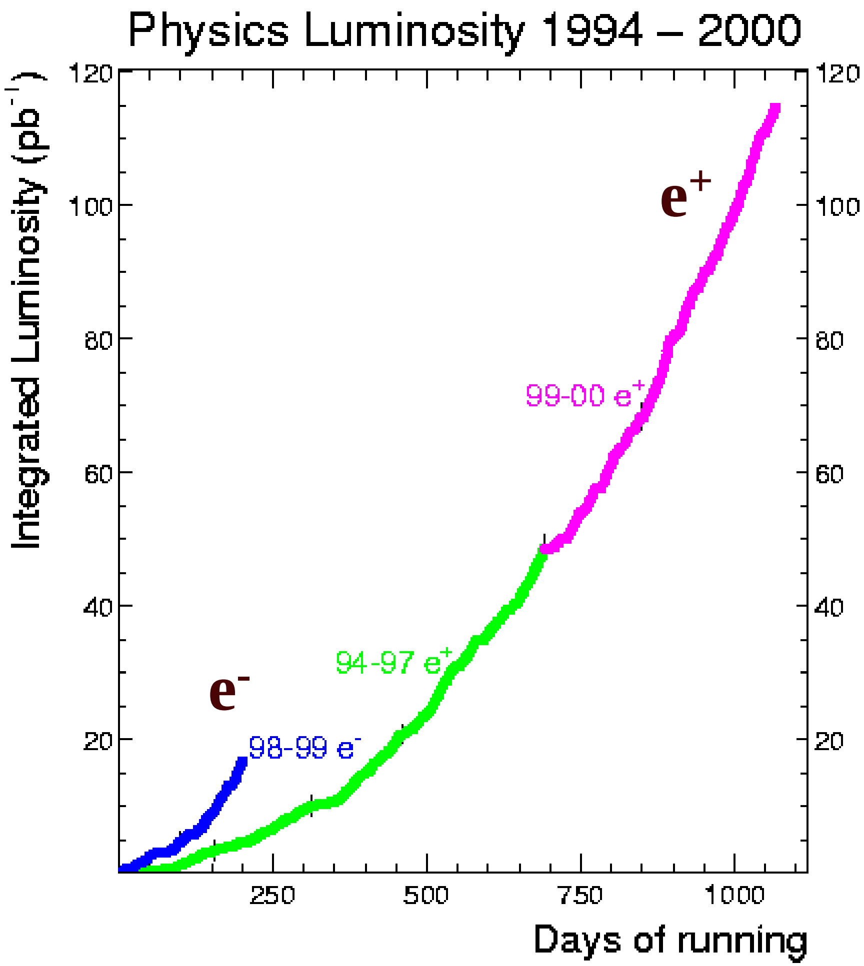


- Polarisation:



HERA I data sets:

e^+p 110 pb^{-1} e^-p 16 pb^{-1}

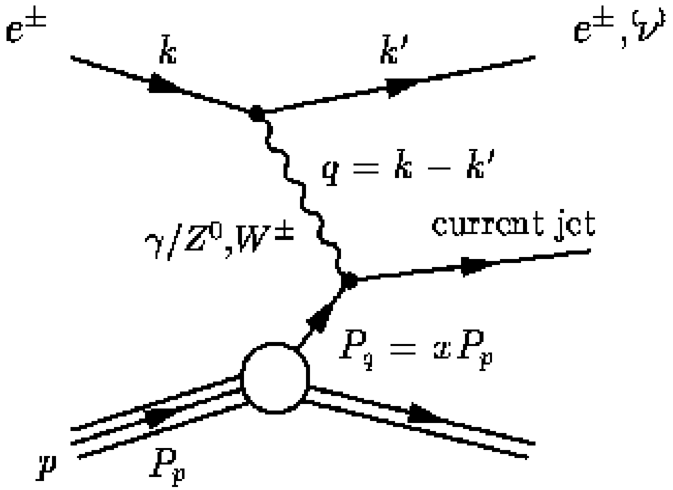


- HERA II upgrade
  - Access 1000 pb^{-1} ep physics by accelerator upgrade
    - Final focusing magnets which improve the luminosity by x5 are close to IP of H1 and ZEUS: a consequence is that forward/backward acceptance is limited
  - Access EW physics by obtaining longitudinally polarized e at H1 and ZEUS.
    - Spin rotators are installed around H1 and ZEUS.

PHYSICS of HERA II

Today, a couple of topics from a long list

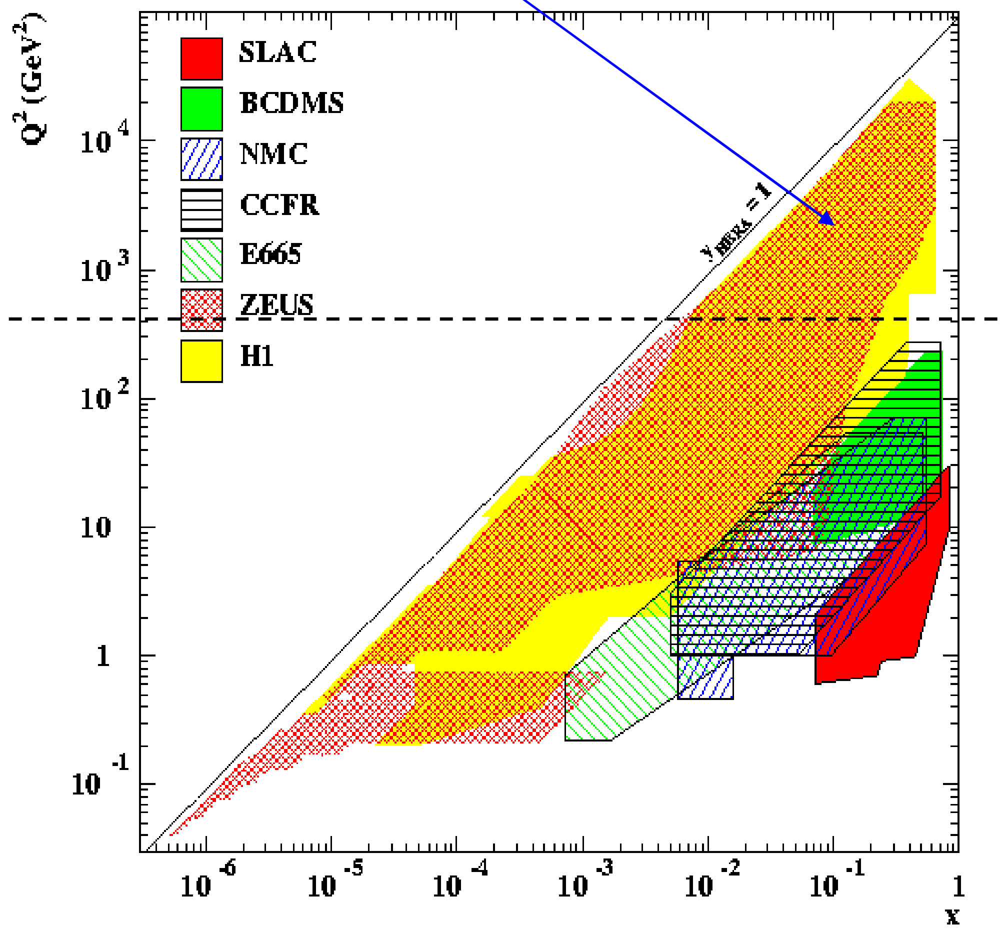
Topic		Preferred beam	Luminosity (pb^{-1})
Structure functions	σ_{NC}, F_2, xG, α_S	e^-_L	500 - 1000
	xF_3	$e^\pm_{L,R}$	500 - 1000
	G_2	$e^-_{L,R}$	500/beam
	F_2^{cc}, F_2^{bb}	e^-_L	1000
	ss from CC	e^+_R	1000
	d/u from CC	e^+_R	1000
	F_L and high-x partons	$e^\pm$ $300 < E_p < 920$	100 ($L \propto 1/E^3 \dots 1/E^2$)
Electroweak	CC versus polarisation	$e^\pm_{L,R}$	250/beam
	NC versus polarisation	$e^\pm_{L,R}$	250/beam
	G_F vs m_t (and M_W, M_H)	e^-_L	1000
	M_{W_R}	$e^-_{L,R}$	1000
QCD	Jets, c, b, α_S		1000
Searches	High-P_T leptons	e^+	1000
	R_P-violating SUSY, stop	e^+_R	1000
	LQ, CI	$e^\pm_{L,R}$	1000
	R_q, LED		1000
	Single top		1000
	e^*		1000
	ν^*	e^-_L	1000



$Q^2 = -q^2$ Virtuality of the photon,Z,W

x Mom. fraction of the struck parton.

HERA I high-x measurements
are statistic limited



HERA I results

DIS NC cross-sections at low Q^2 (< 500 GeV^2) → systematics limited. $\sigma \sim Q^{-4}$

Typical uncert. 2-3%

"Last word" for foreseeable future. (HERA III ?)

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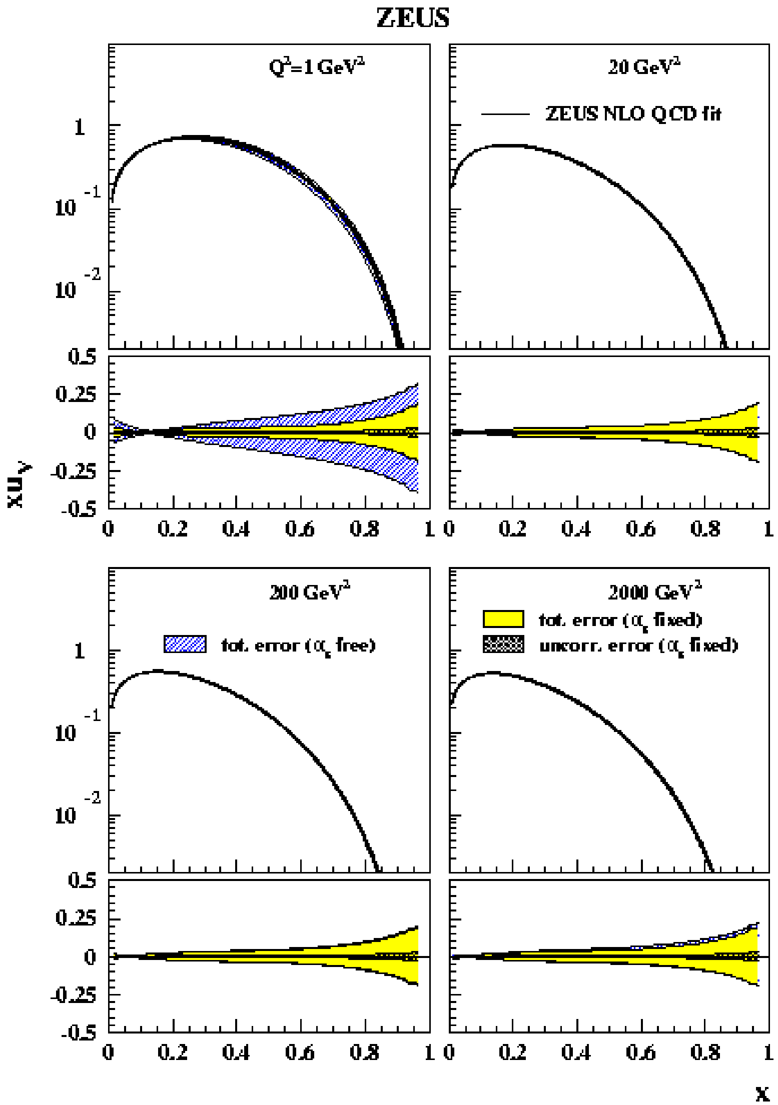
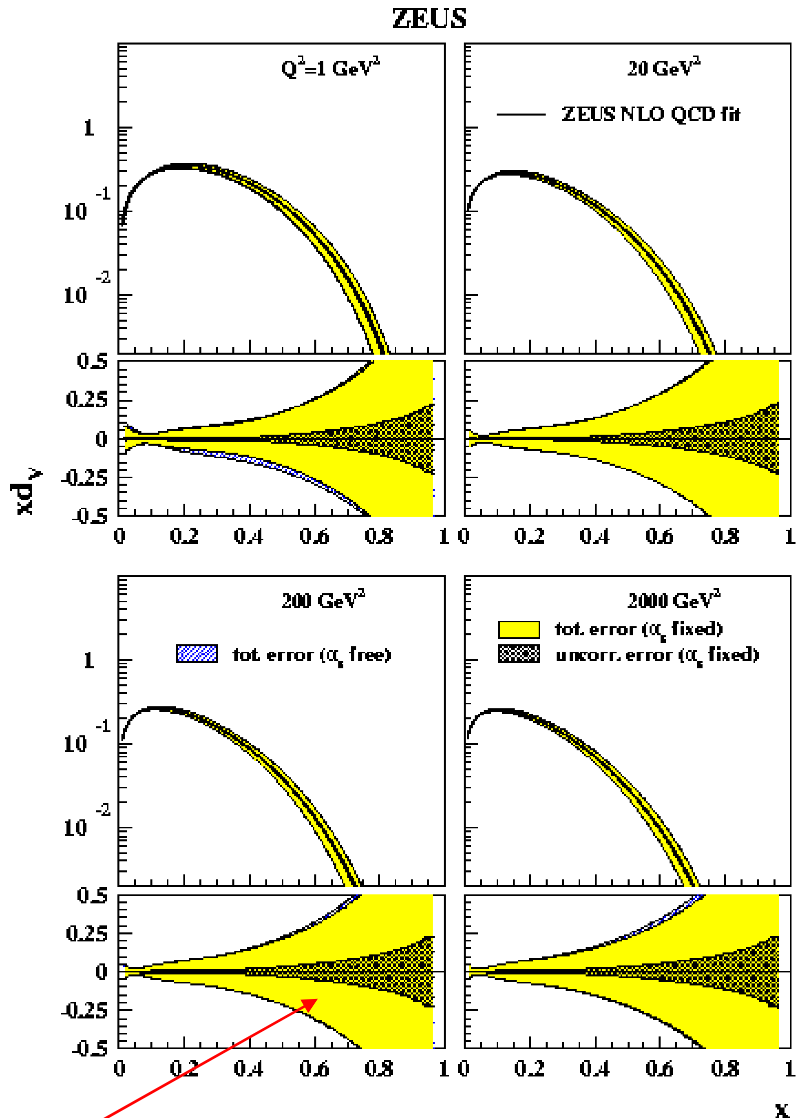
In current QCD analyses, high x partons are constrained by fixed target data.





Systematics dominated

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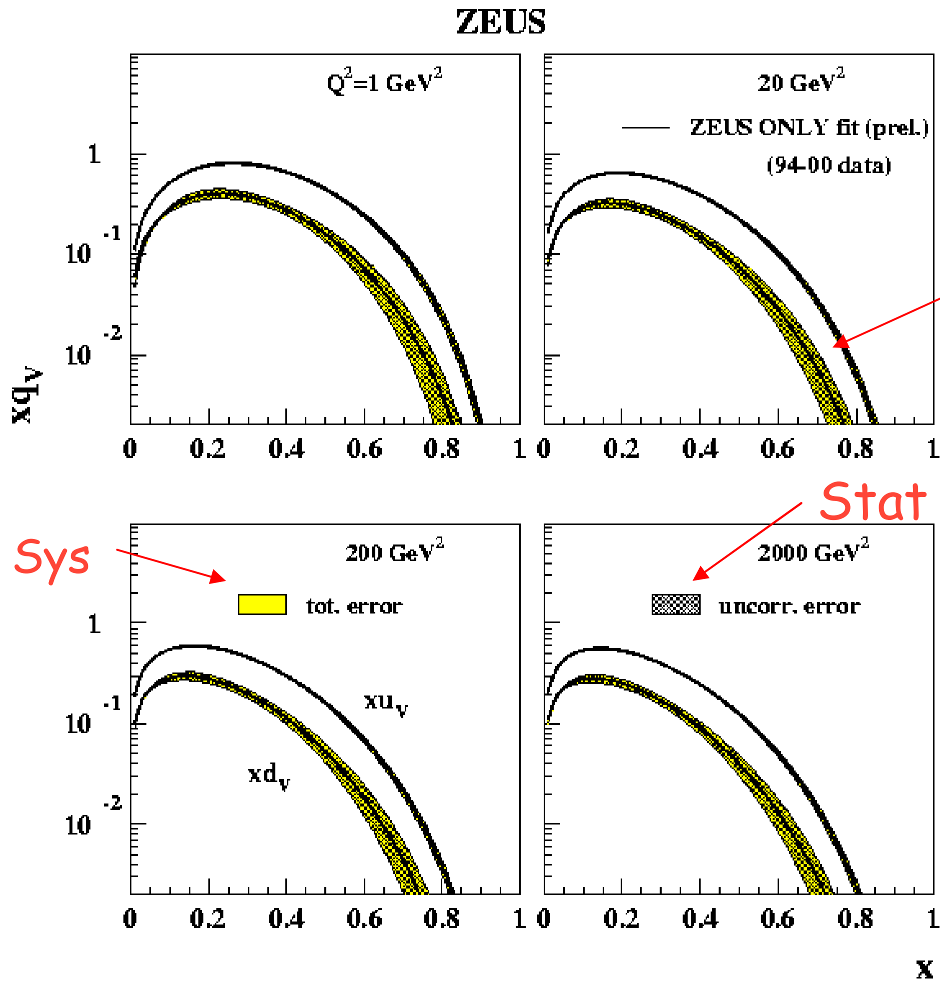
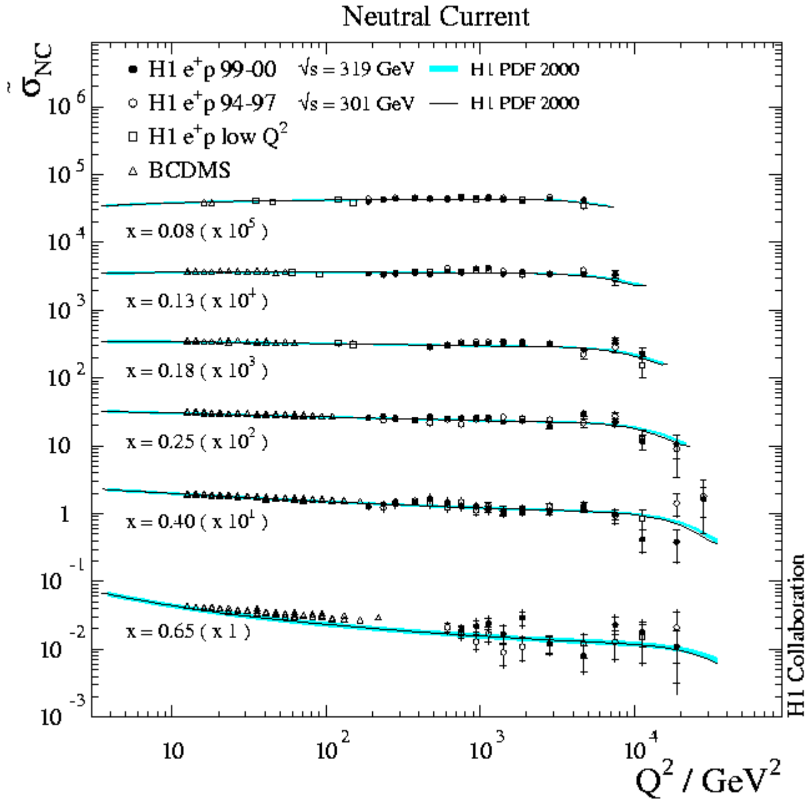
ZEUS Only :all HERA I data including charge current. (Similar results for H1)



Already good precision and dominated by statistical errors.

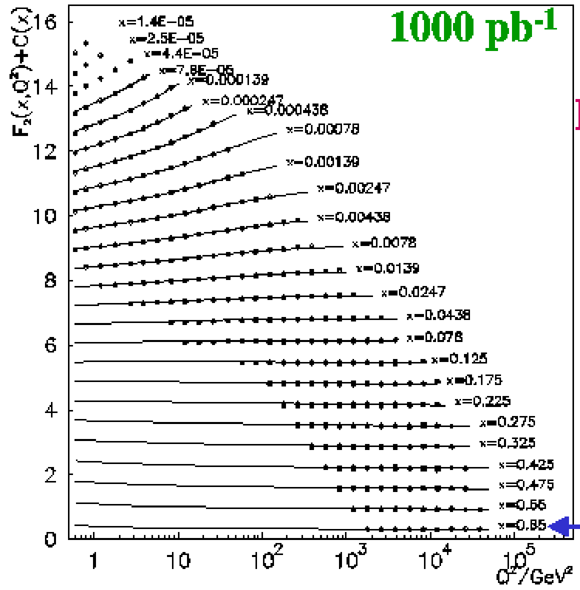
HERA II luminosity will directly translate to the precision of high x partons.

HERA I: High Q^2 Neutral Current



HERA II projection

- The Structure Function F_2



High Precision F_2

Large x,Q^2 range

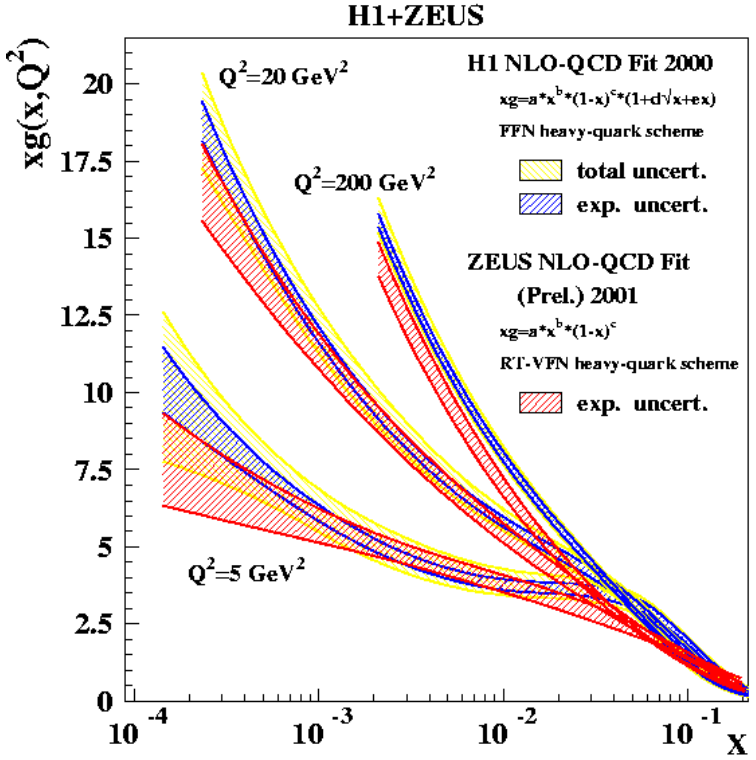
→

α_s and xg

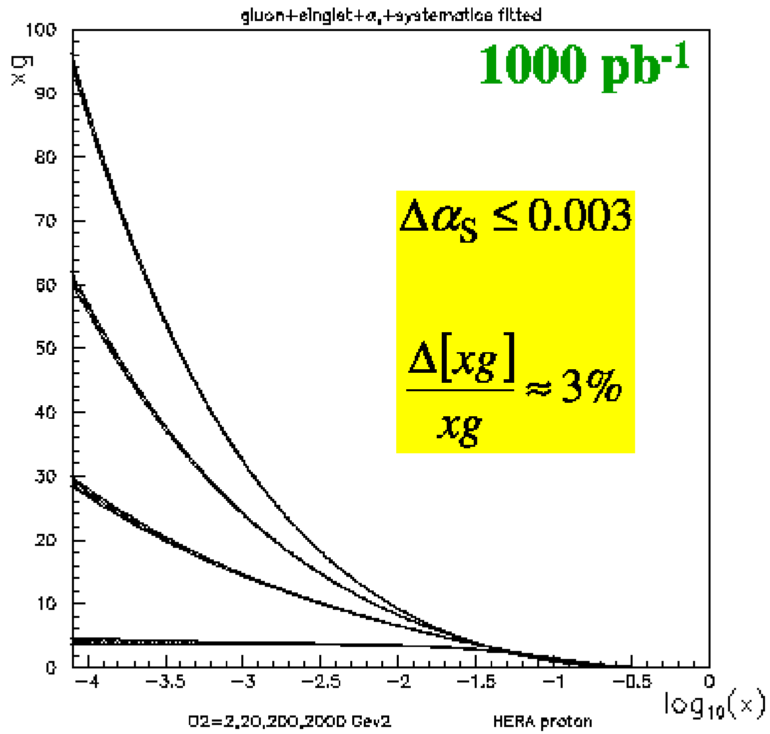
$x = 0.65$

$Q^2 = 4 \times 10^4$

HERA I: Gluon distribution



HERA II projection



What about really high x (>.65) ?

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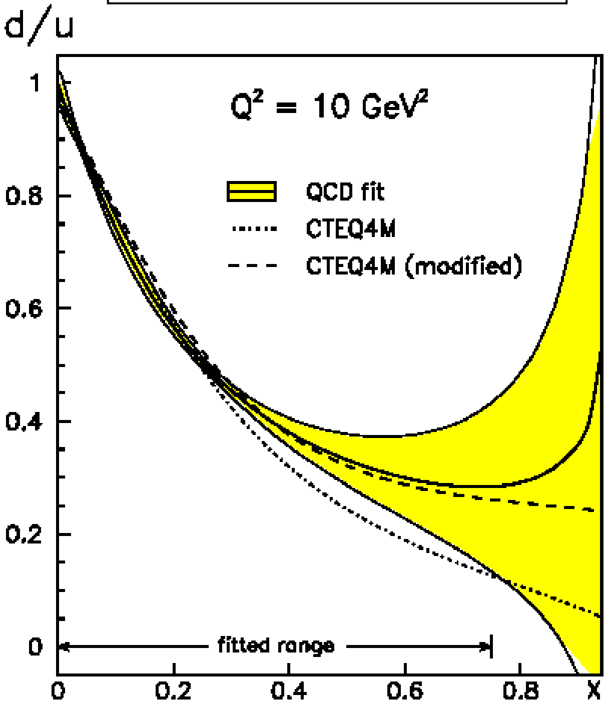
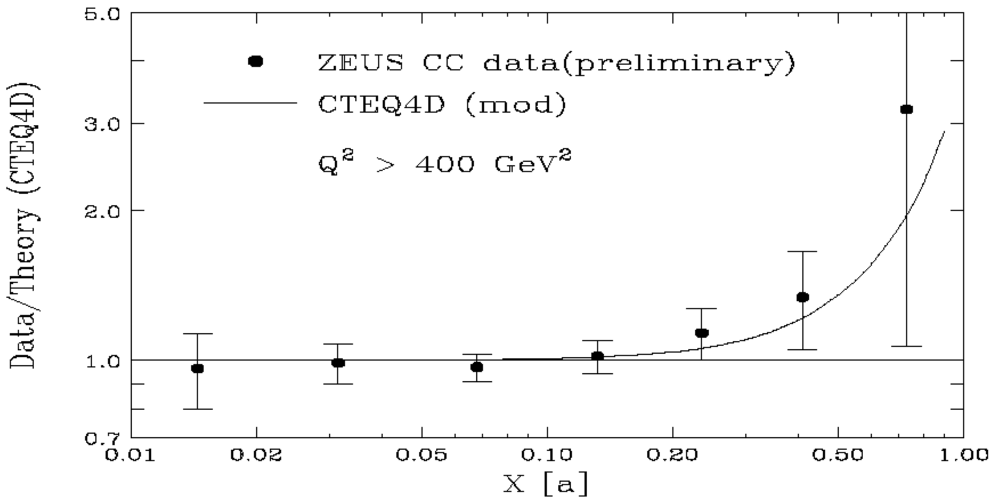
Valence distributions are not well known at very high x

Botje analysis 1999



d/u $\neq 0$ as x→1 ?

Bodek and Yang, 1998



The very highest x corresponds to highest Q2: measurements are limited by statistics. There are new ideas to use more of the data➔

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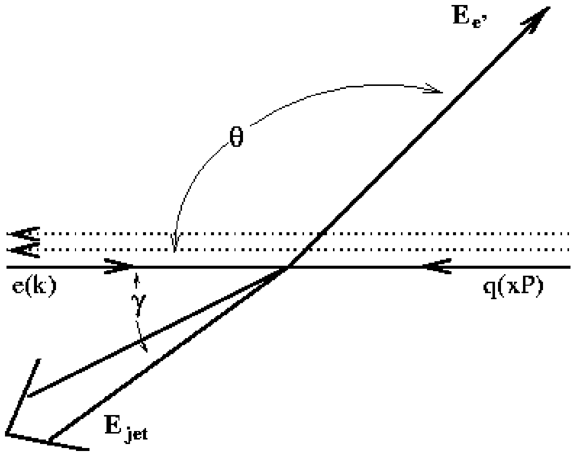
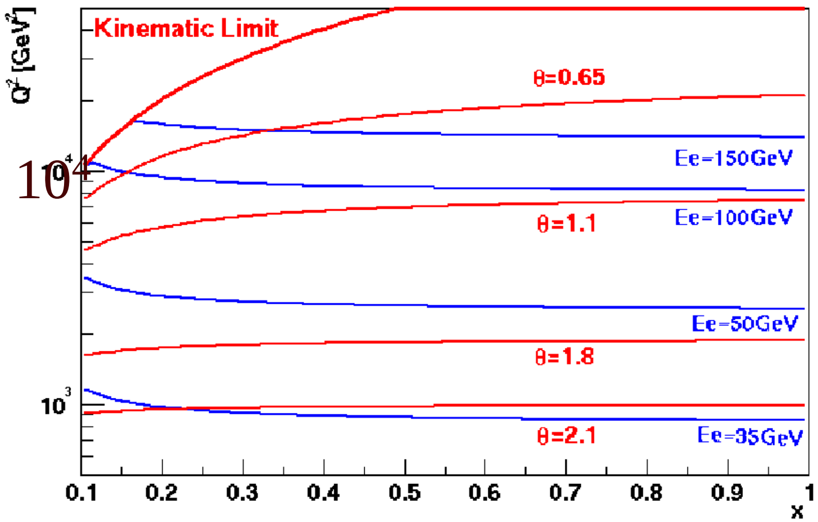


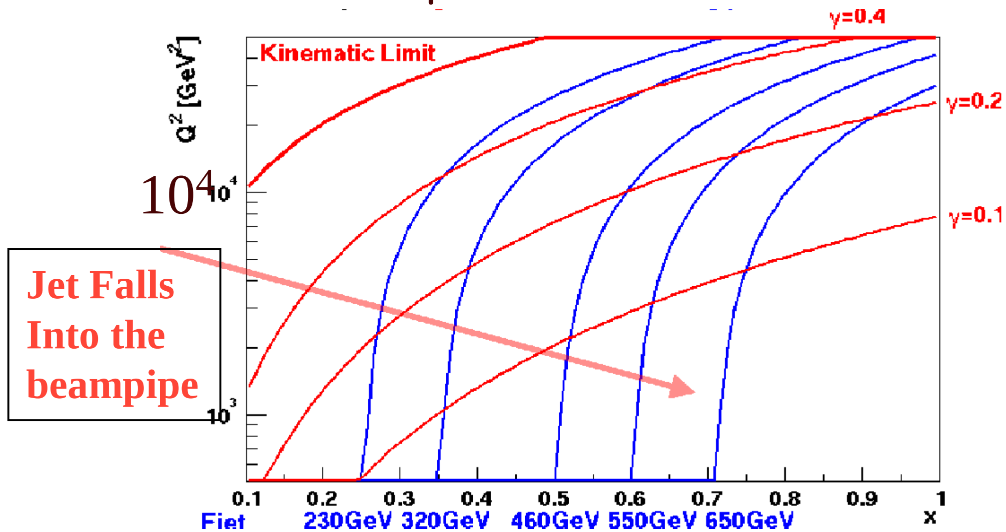
Energies and angles of the electron and the jet: 4 variables measured

Need to reconstruct 2 kinematic variables: x and Q^2.

Acceptance for electrons, but no resolution in x.



Jet has resolution in x but no acceptance



However, not seeing a jet is a good measurement of x

(Helbich and Caldwell, 2002)

(Helbich and Caldwell 2002)

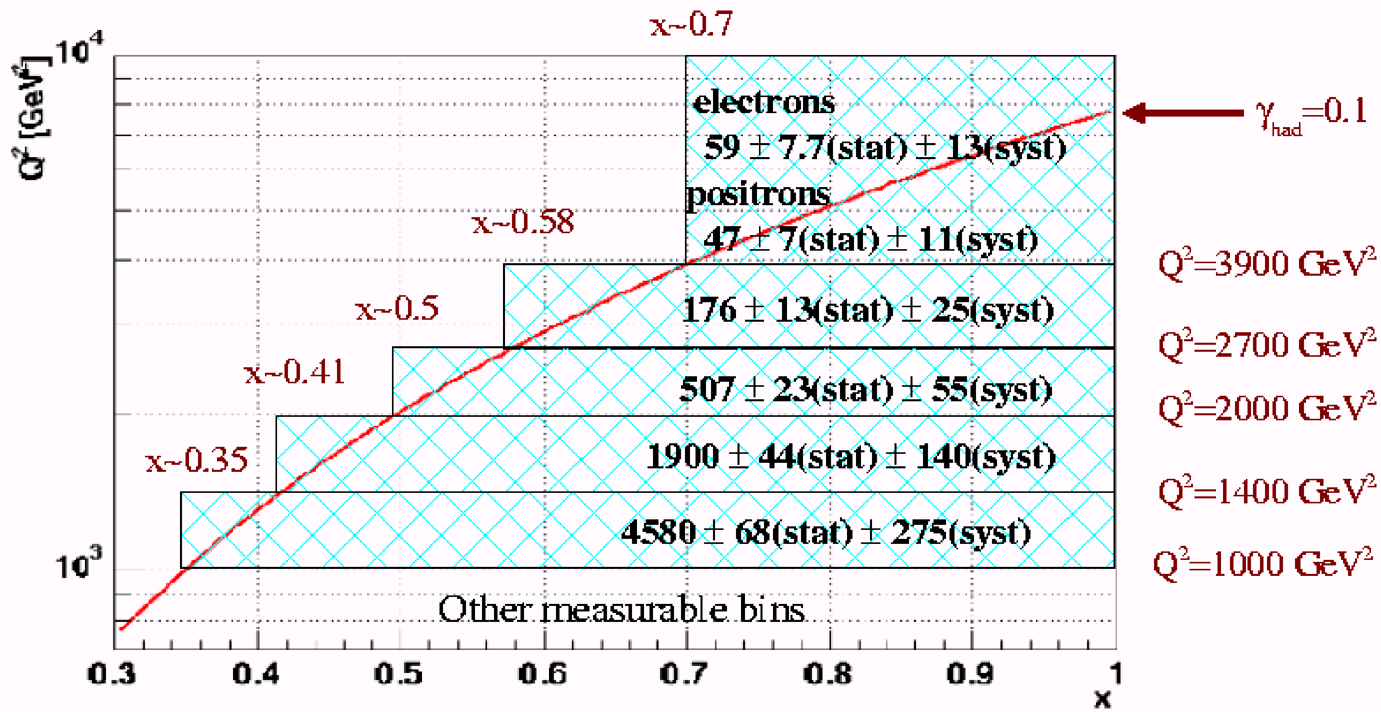
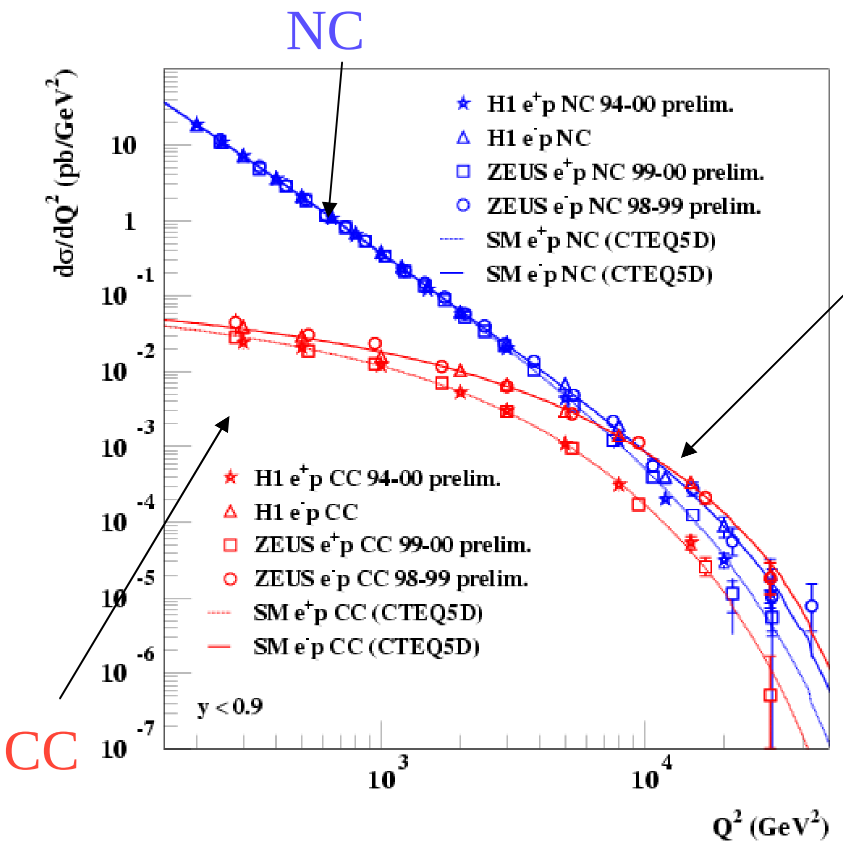


Fig. 1. Expected number of measured events for $1 fb^{-1}$ of data with Ep=920GeV

20 % (ish) measurement at x ≃0.8 possible: better if systematic uncertainties (hadronic energy deposit) can be brought under better control.

Charged Current cross-sections:



EM and Weak have similar cross-sections.

Vivid illustration of cross-section suppression due to the W mass

$$\sigma_{cc}(e^+p) \sim G_F^2\left(\frac{M_W^2}{M_W^2+Q^2}\right)^2[(1-y)^2(d+s)+(\bar{u}+\bar{c})]$$

$$\sigma_{nc}^{\pm} \sim \frac{\alpha^2}{Q^4}[Y_+\sum e_q^2(q+\bar{q}) \mp Y_-\sum B(Q^2)(q-\bar{q})]$$

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 → $(v_e^2 + a_e^2)$

v_e =~-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 → $2a_ev_e$

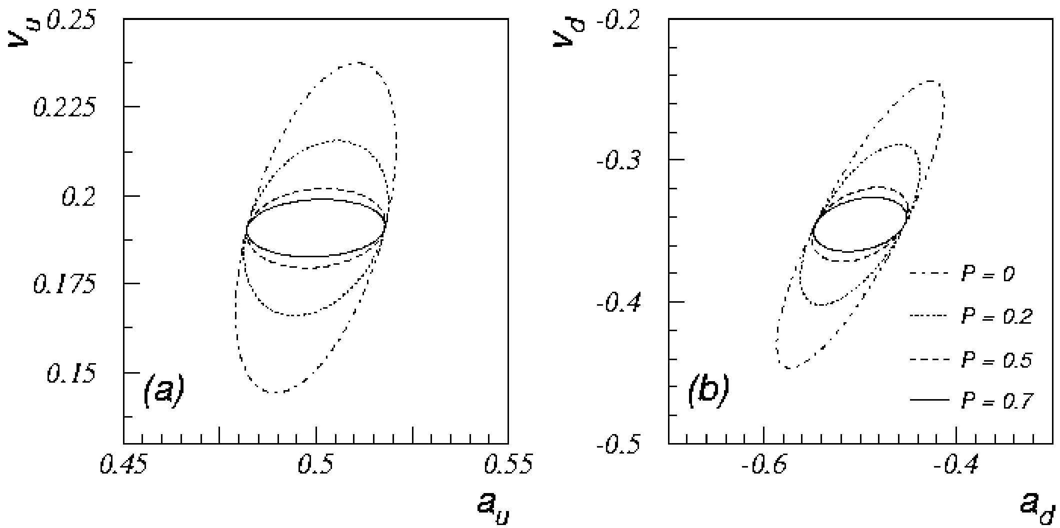
Sensitivity to a_q already in unpolarized xF3

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.



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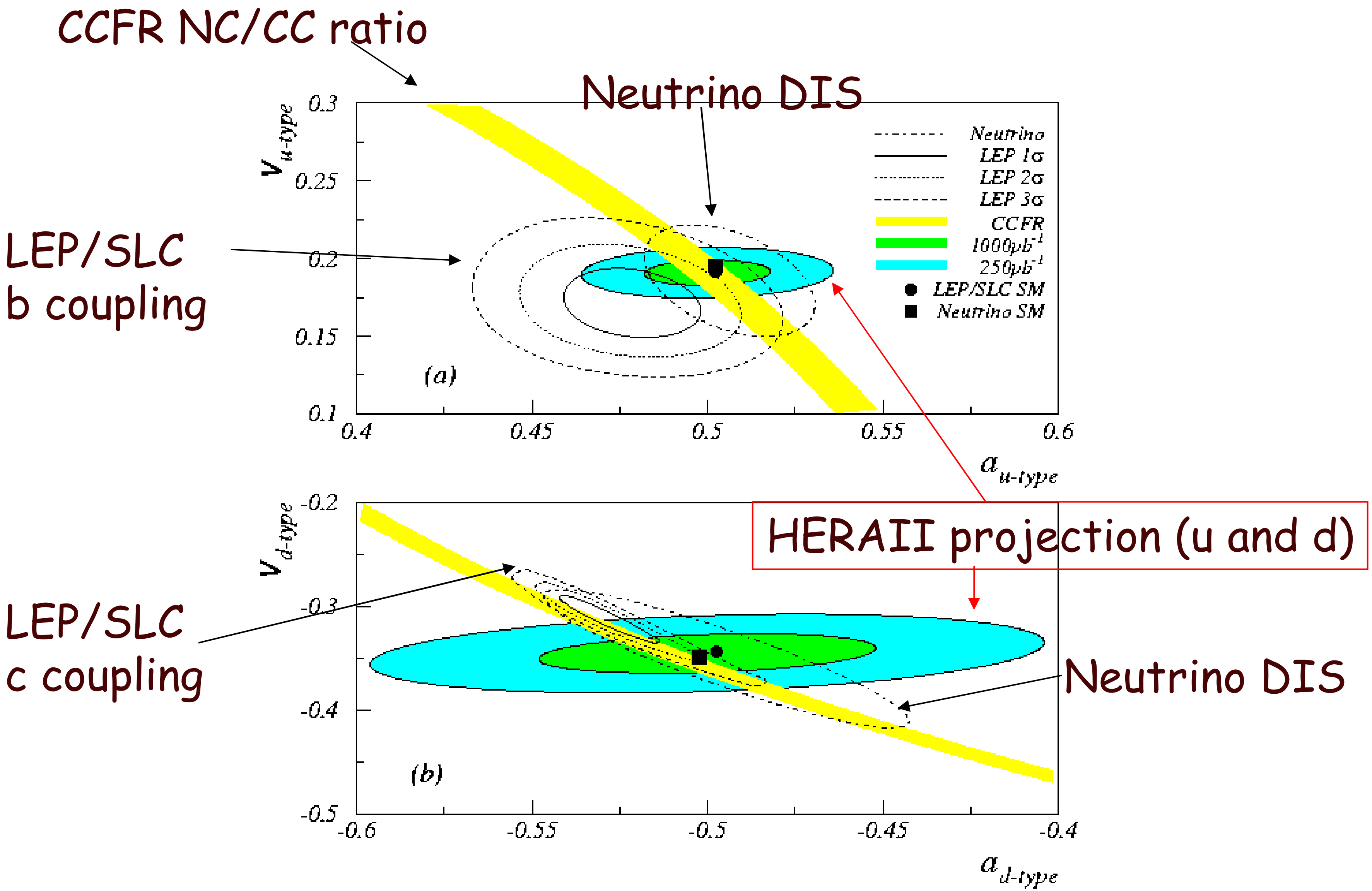


High precision: complimentary measurement.

Sensitivity to top and Higgs mass:

$$G_F = \frac{\pi\alpha}{\sqrt{2}} \frac{M_Z^2}{(M_Z^2 - M_W^2)\, M_W^2} \frac{1}{1-\Delta r}$$

Higher order corrections: relates fermion masses and coupling constants

Running alpha

$$\Delta r \sim \Delta r_0 - \rho_t / \tan^2\theta_W$$

$$\rho_t = 3G_F m_t^2 / 8\sqrt{2}\pi^2 = 0.00952 (m_t / 174.3 \text{ GeV})^2$$

Quadratic dependence on top mass

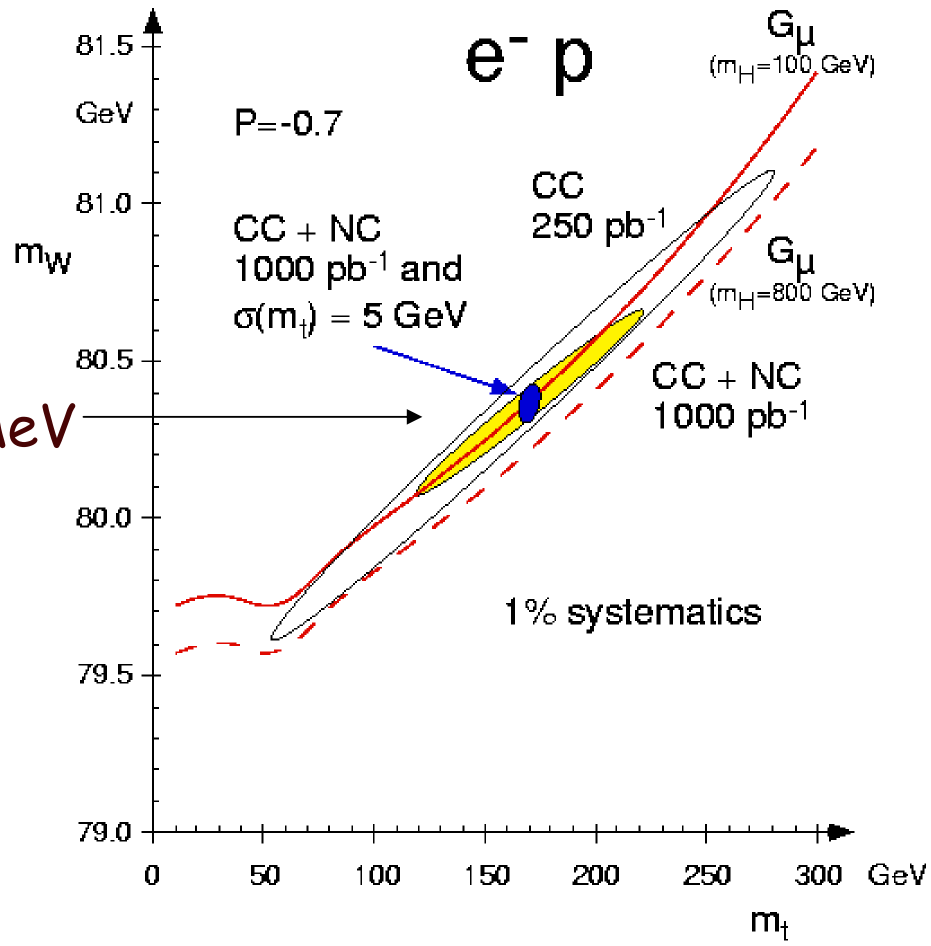
--also has logarithmic dependence on Higgs mass.

Fix coupling to SM parameters: use Mz, alpha measurements

Check consistency of SM by fitting for Mt and Mw: →

Fixing alpha and Mz :

M_w to 55 MeV



Precision check of EW theory when combined with precise top mass measurement from Tevatron, LHC.

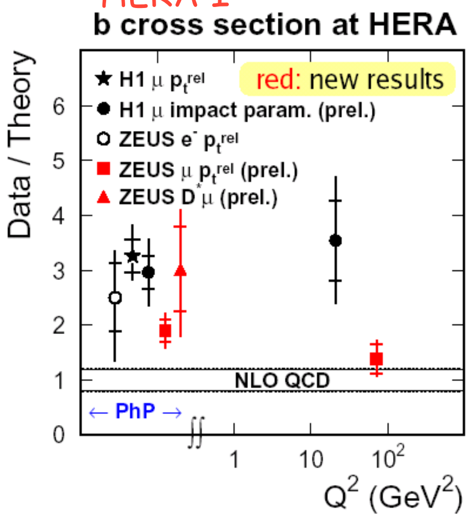
HERA II Physics Summary

1 fb^{-1} of data → high statistics at high Q^2 and Et.

Access to high-x partons at high Q^2
Jets at high Et and Q^2

→pQCD studies (PDF's, jet cross-sections) at higher scales.
Further improve understanding of QCD.

HERA I



Not covered: heavy quarks → new tracking detectors —new era in HERA heavy flavor studies

Polarization (combined with large statistics)
→ Sensitivity to electroweak effects:
a new regime of physics for HERA.

HERA II: Will continue to be a superb QCD machine + provide sensitive tests of the Standard Model

Recent history of HERA

Main focus of experiments and accelerator in last 8 months

- 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.
- February 2003: HERA record luminosity: 2.7×10^{31} $cm^{-2}s^{-1}$ (more on this later)
- Shutdown in progress to improve background conditions (and some upgrades, repairs)
- HERA restart: July 2003,
Data taking restart: end August, early September 2003.

Background at HERA II

Up to now, H1 and ZEUS could not effectively take data due to background: too much current drawn in the central tracking detectors

Three sources of background at HERA II

- Backscattered synchrotron radiation: worse at ZEUS than at H1—reduce through redesigning masks and coating absorbers (factor 10 reduction at ZEUS).
- Electron-gas background: reduce thickness of collimators, and improve vacuum. (factor 2 reduction).
- Proton-gas background: dominant background after above fixes—improved vacuum system, better vacuum conditioning, collimators redesigned to reduce heating… (aim for factor 2 reduction).

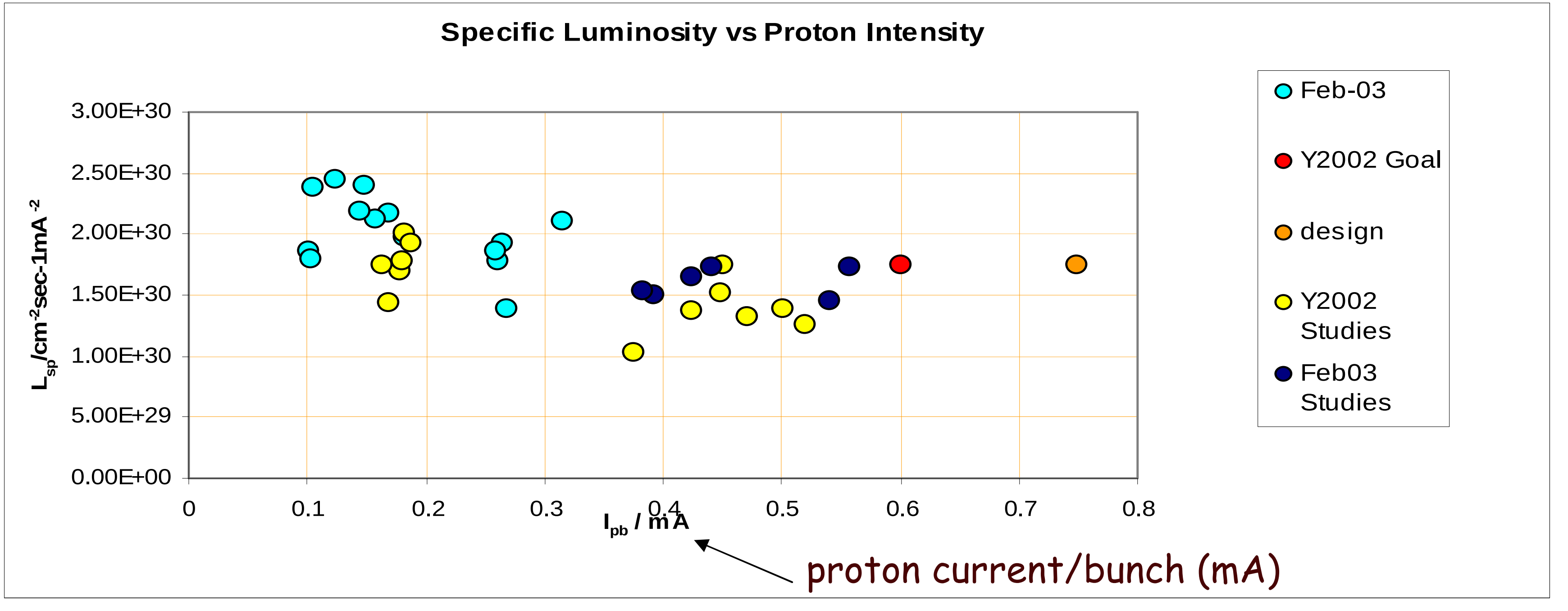
Quantitatively understood

"Dynamic" vacuum problem; i.e. when electron is in machine.

Harder to quantify: however, improvement over time (x1.7 from Oct-Jan) seen. Higher current in machine after shutdown will help

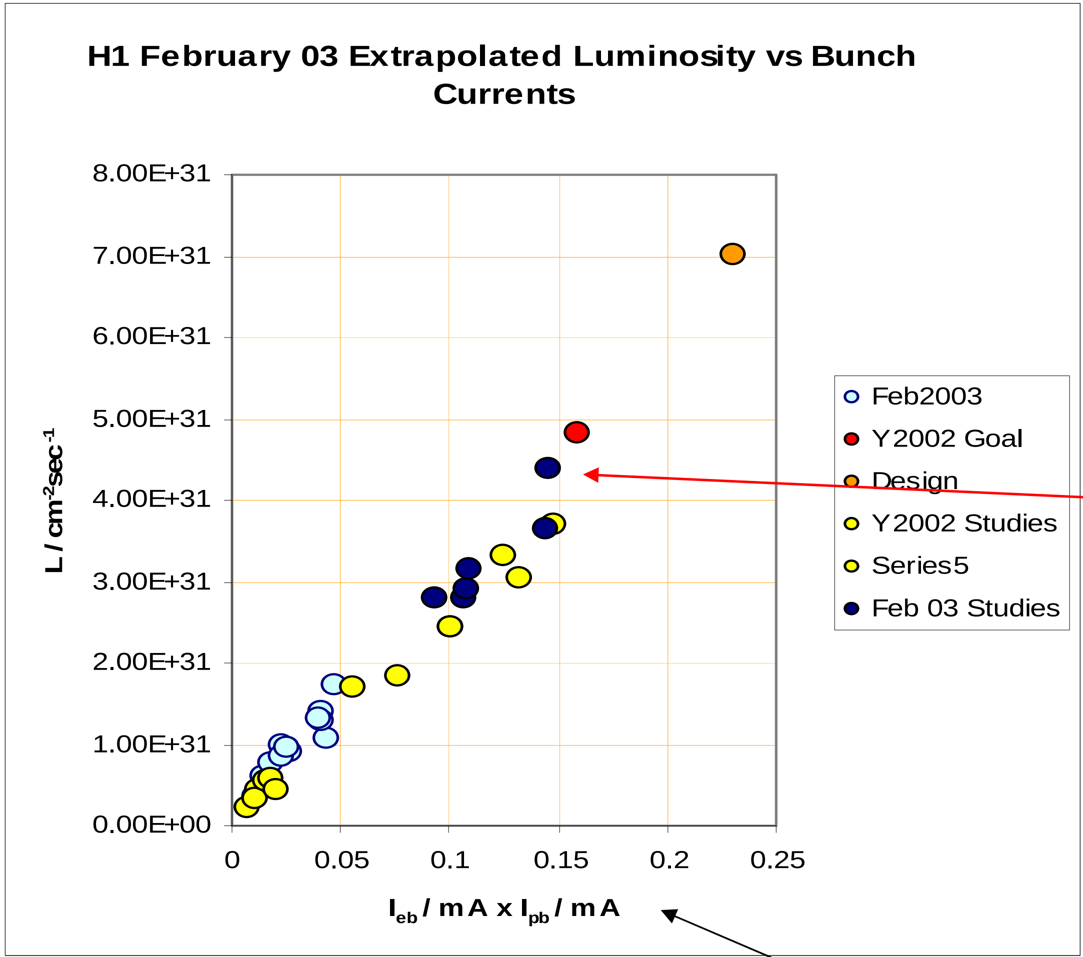
After shutdown, H1 and ZEUS should be able to run at close to design luminosities. The conditions are expected improve steadily over time.

The machine is ready to deliver high luminosity and polarization:



Specific luminosity design goals have been achieved.

HERA II accelerator status

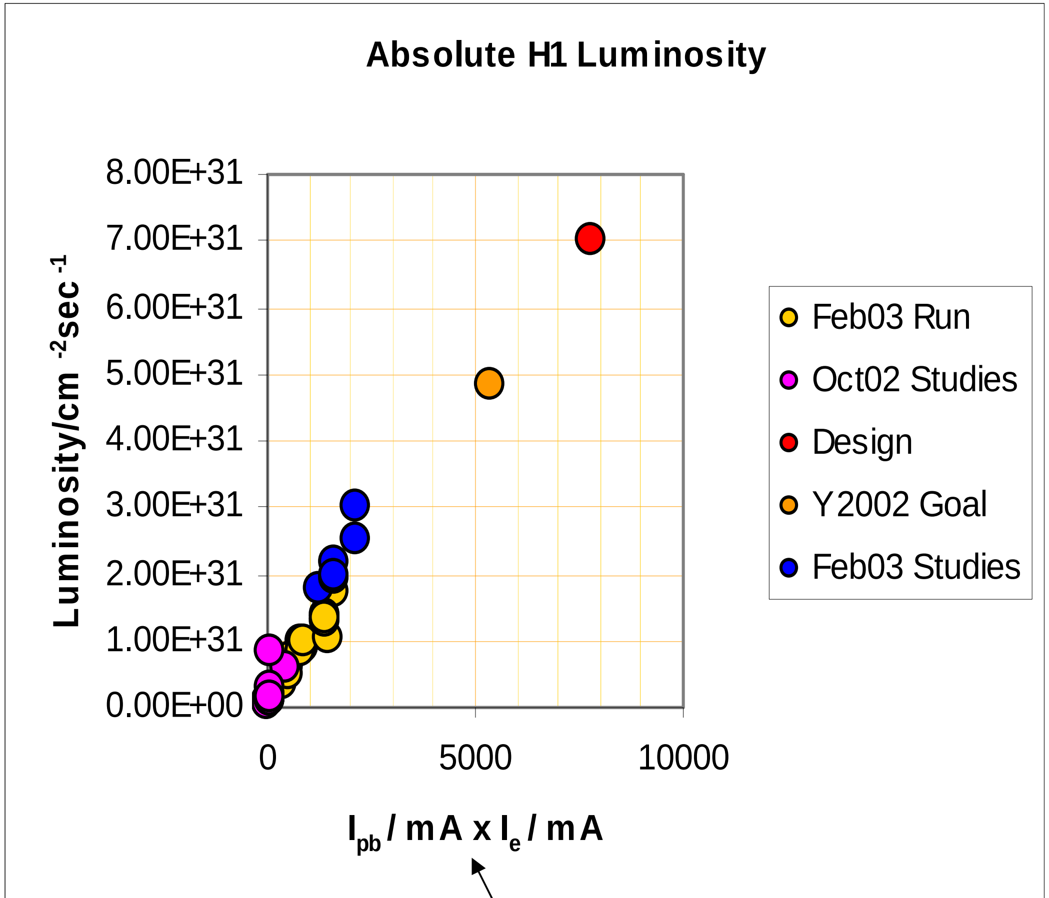


Per bunch luminosity goals for Y2002 has been achieved.

Feb 2003

Product of proton and electron per-bunch-current.

HERA II accelerator status



120 Bunches design (180 bunches)

I_p < 70 mA design (140 mA)

I_e < 35 mA design (60 mA)

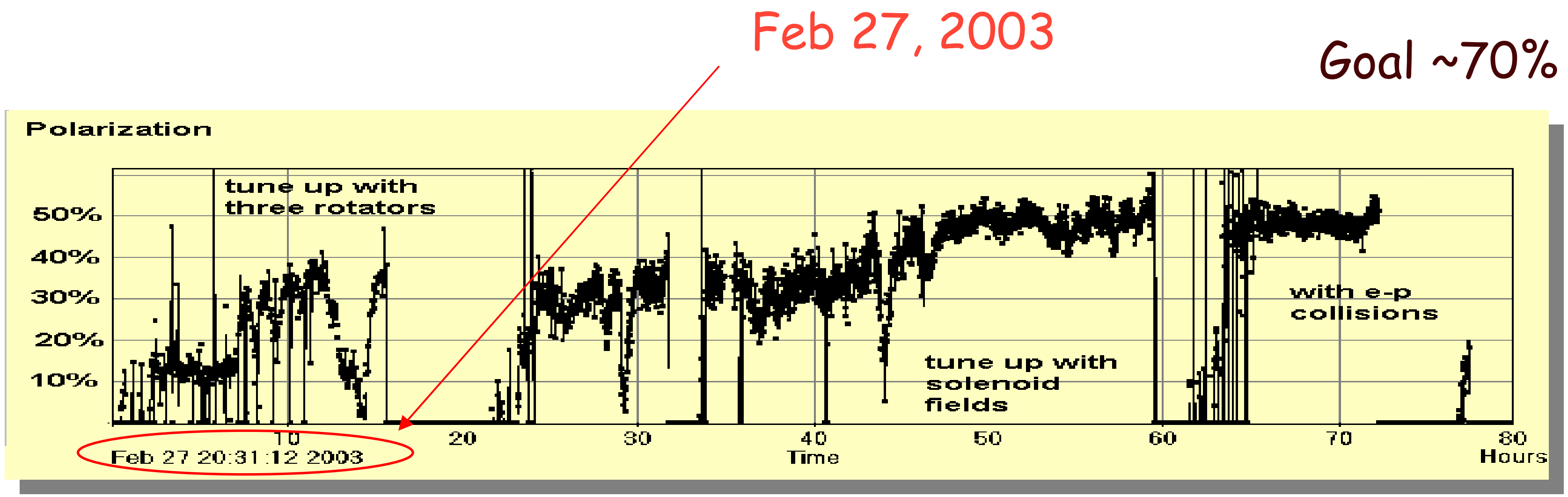
L_{peak} < 2.7×10^{31} $cm^{-2}s^{-1}$

HERA record luminosity: Feb. 2003

~40% design luminosity achieved.

Product of electron and proton currents

Status of Polarization



Good polarization at 3 interaction points were achieved within a few days of rotator turn- on.

R. Yoshida, 20 May 2003

Final remarks

- Many exciting physics accessible at HERA II. I covered only a few of these today.
- Long and frustrating period of bad background conditions at HERA II is coming to an end.
- We're all looking forward to resuming data taking later this year.