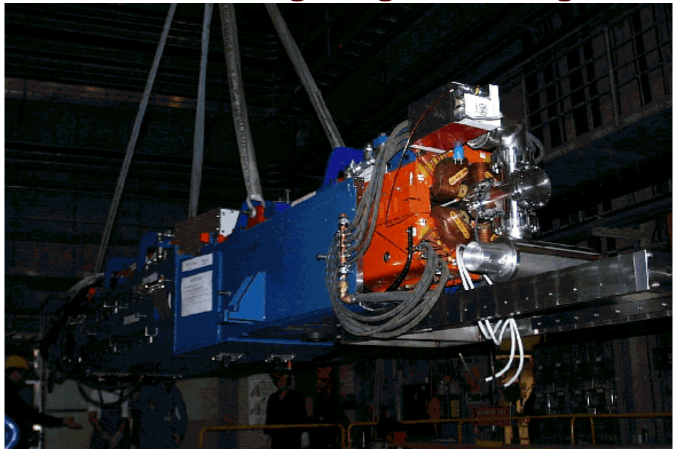
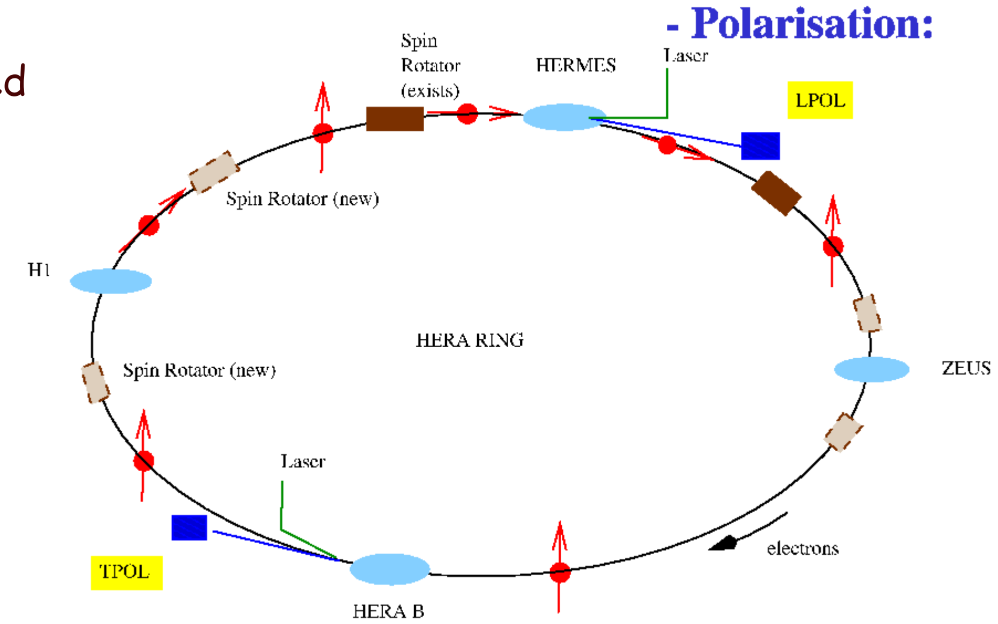
Prospects and status of ZEUS at HERA II

R. Yoshida
Argonne National Laboratory, USA

Ringberg 2003

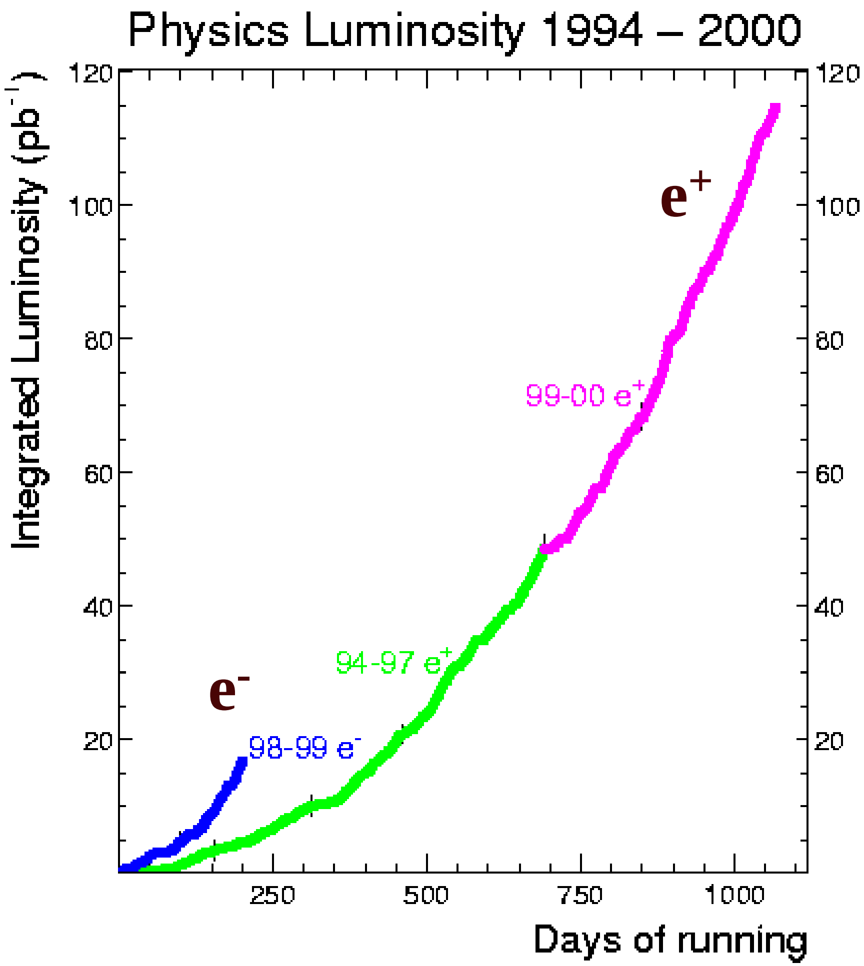
A final focusing magnet being installed





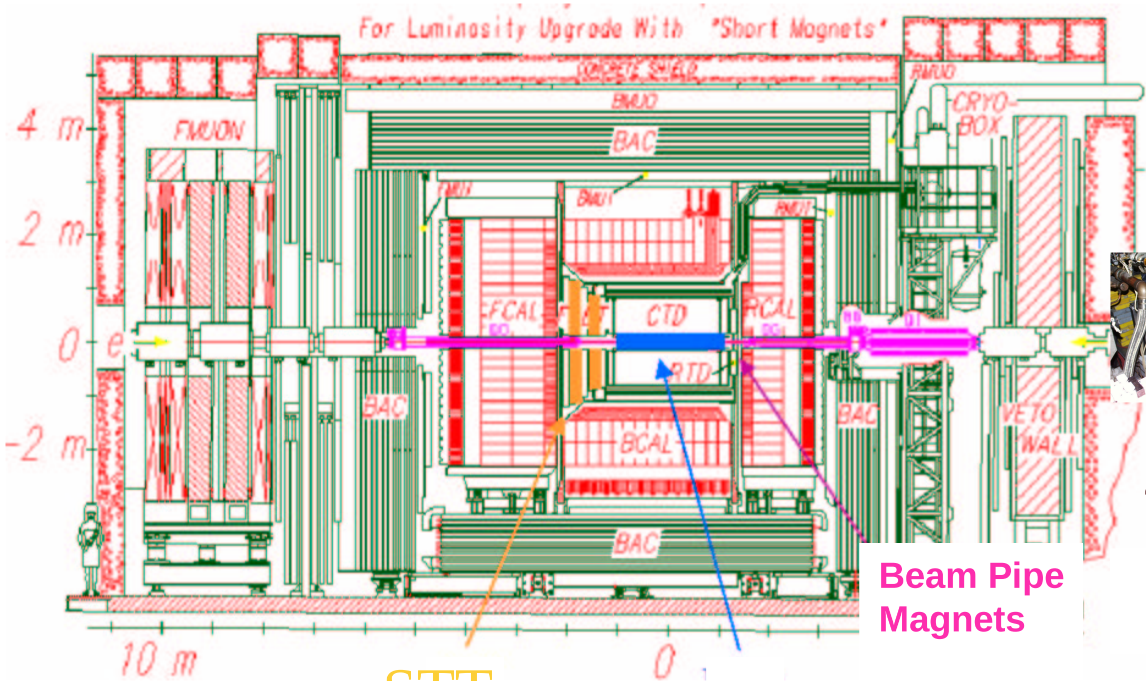
HERA I data sets:

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

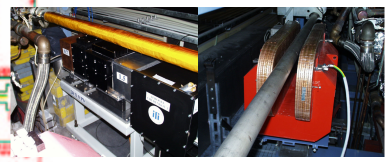


- HERA II upgrade
  - Access 1000 pb^{-1} ep physics by accelerator upgrade
    - Final focusing magnets which improve the luminosity by x5 are close to IP of H1 and ZEUS: a consequence is that forward/backward acceptance is limited
  - Access EW physics by obtaining longitudinally polarized e at H1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

ZEUS upgrades



Lumi detector upgrades



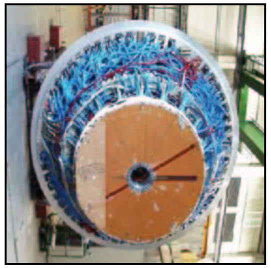
+ beam counters, γ tagger

Beam Pipe Magnets

Straw Tube Forward Tracker

STT

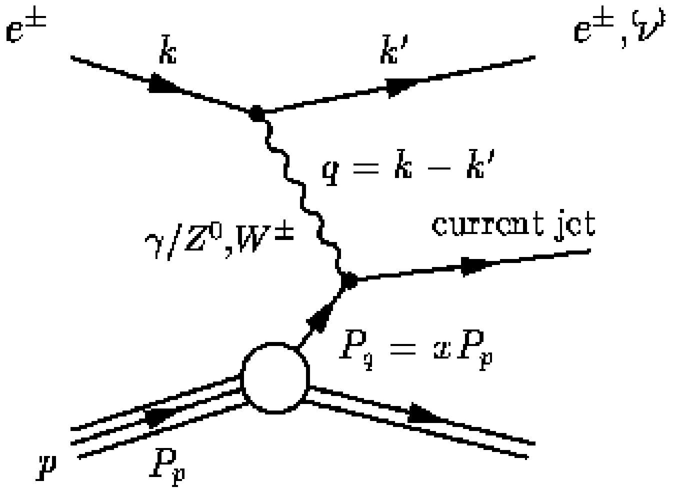
MVD



Micro Vertex Detector

Outline

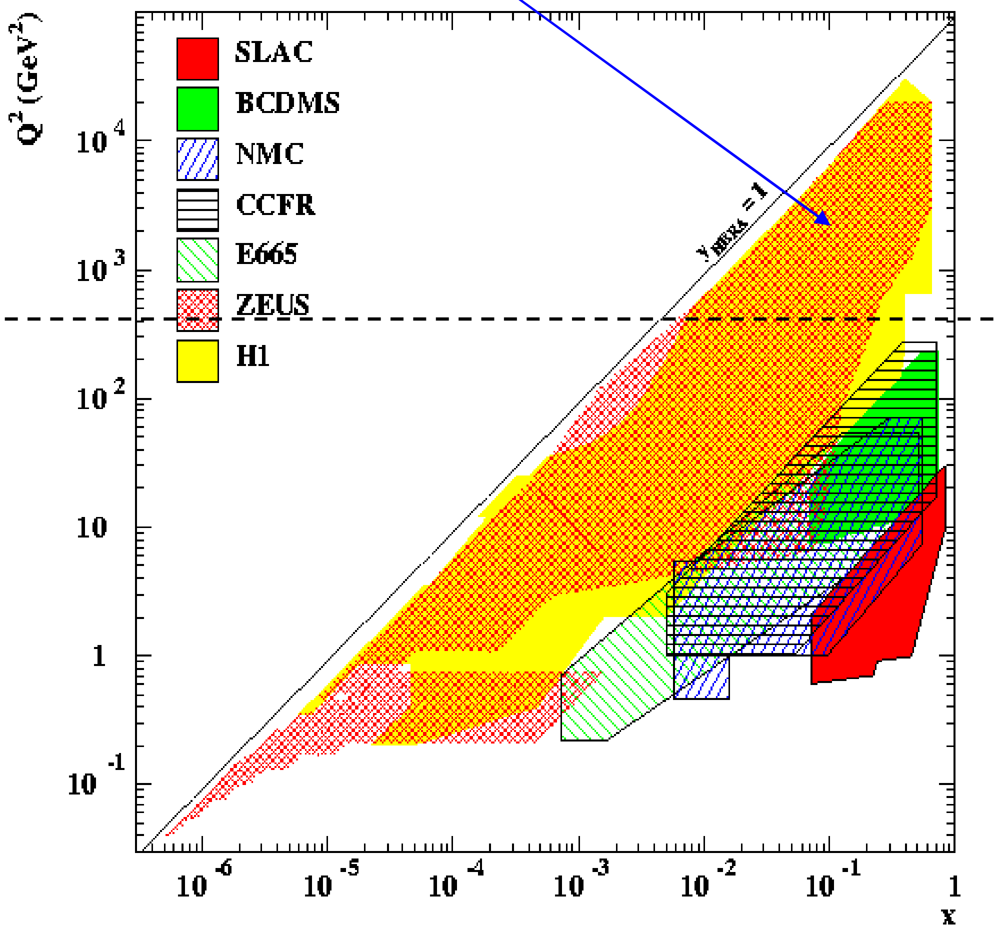
- Physics of HERA II (try to be orthogonal to Max)
  - structure functions
  - electroweak
  - exotics and anomalies
- Prospects for data, status of background
- Luminosity requirements and constraints



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

x Mom. fraction of the struck parton.

HERA I high-x measurements are statistic limited



HERA I results

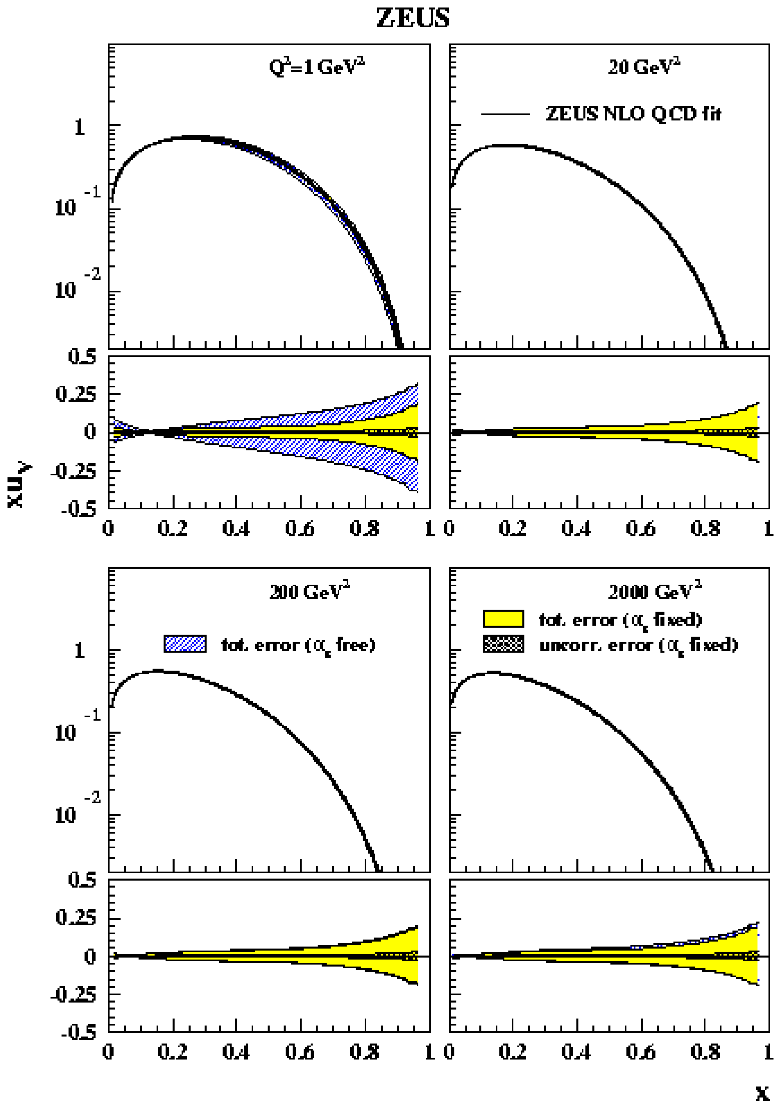
DIS NC cross-sections at low Q^2 (< 500 GeV^2) → systematics limited. $\sigma \sim Q^{-4}$

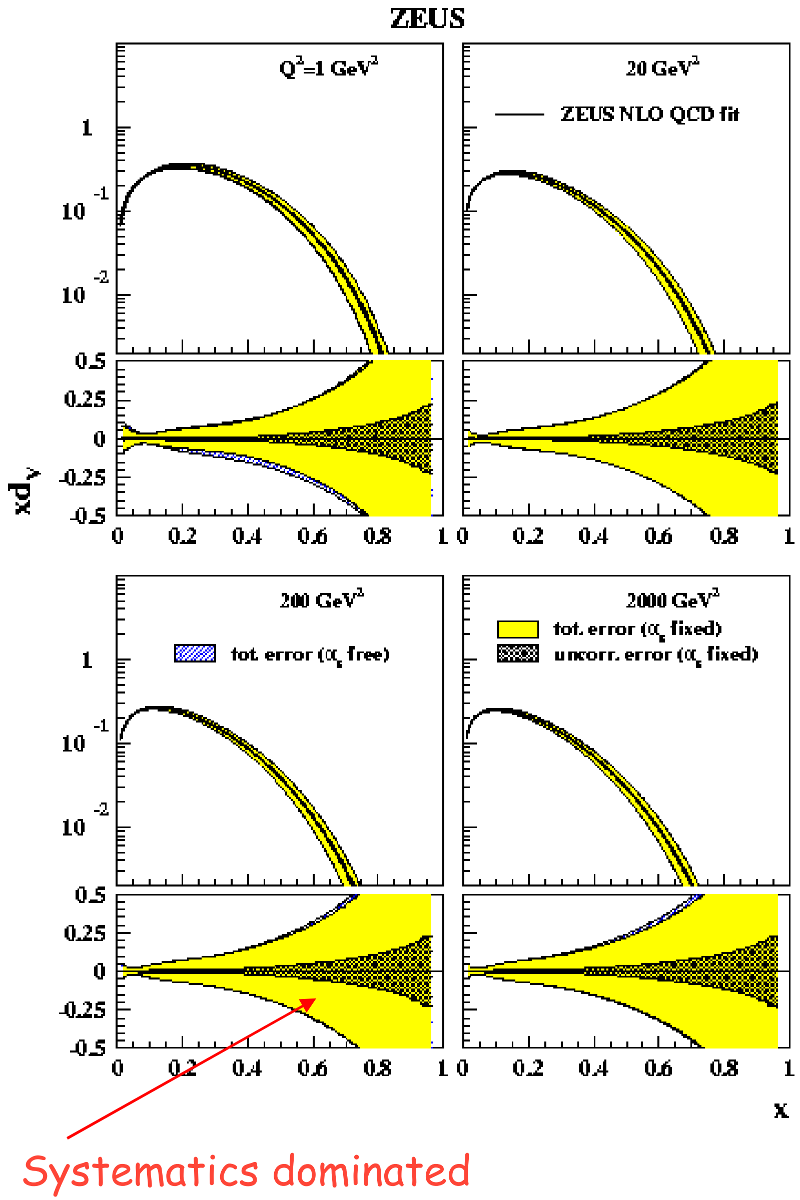
Typical uncert. 2-3%

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

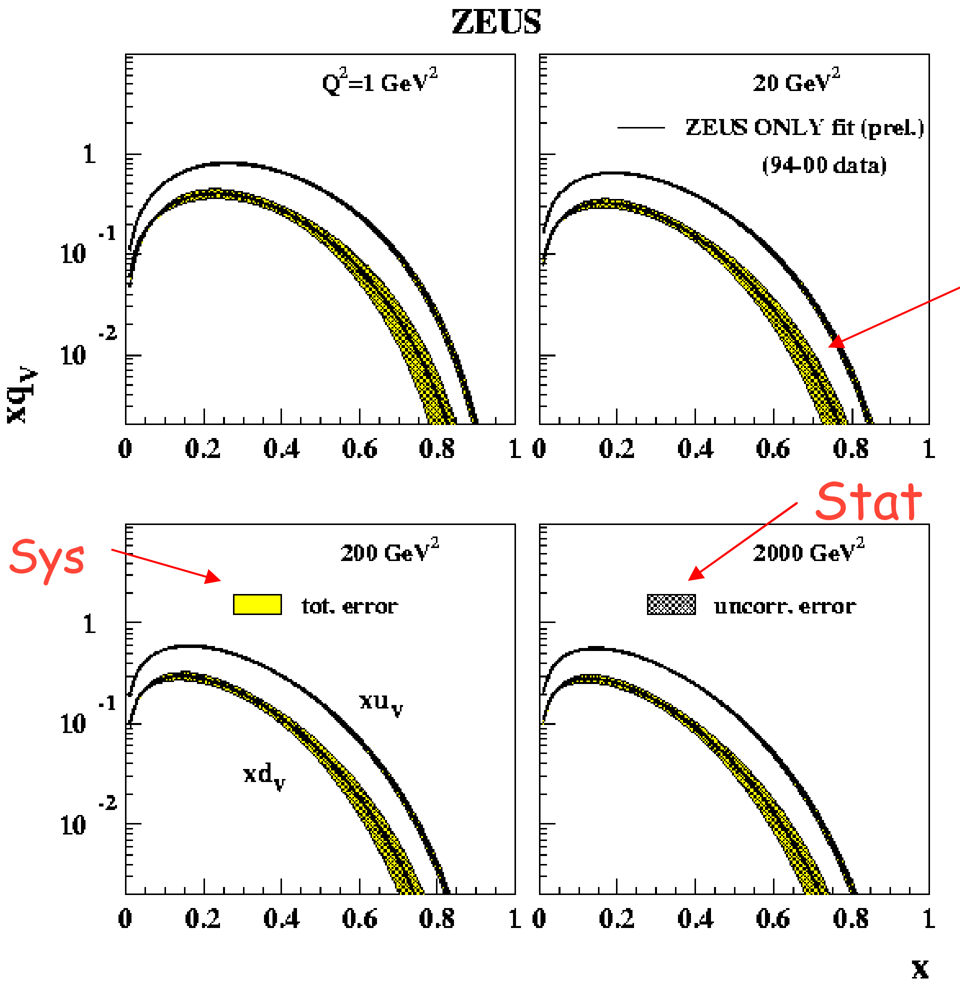
R. Yoshida, 2 Oct 2003

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





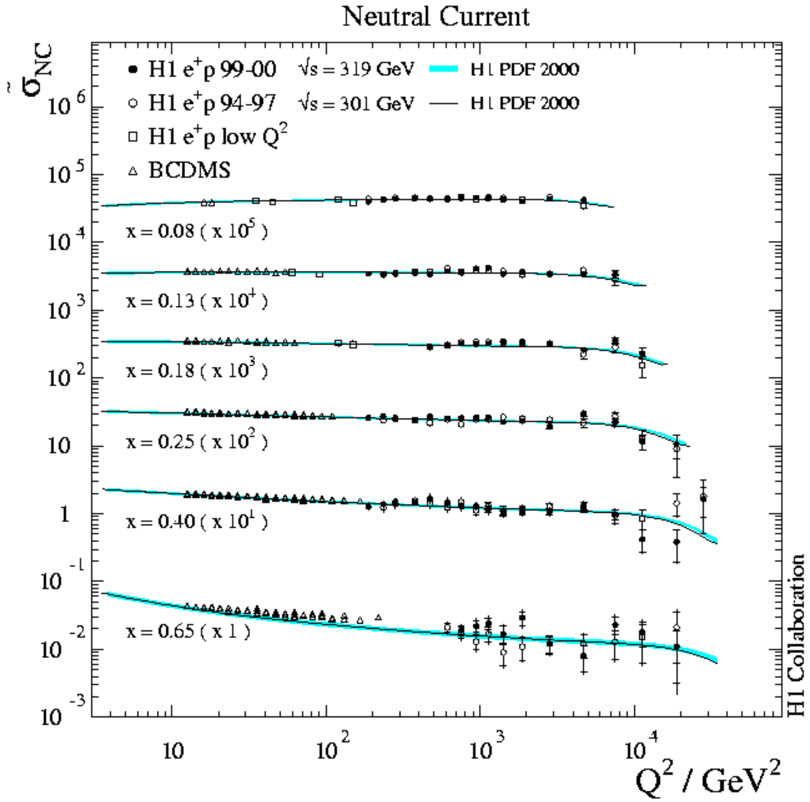
ZEUS Only :all HERA I data including charge current. (Similar results for H1)



Already good precision and dominated by statistical errors.

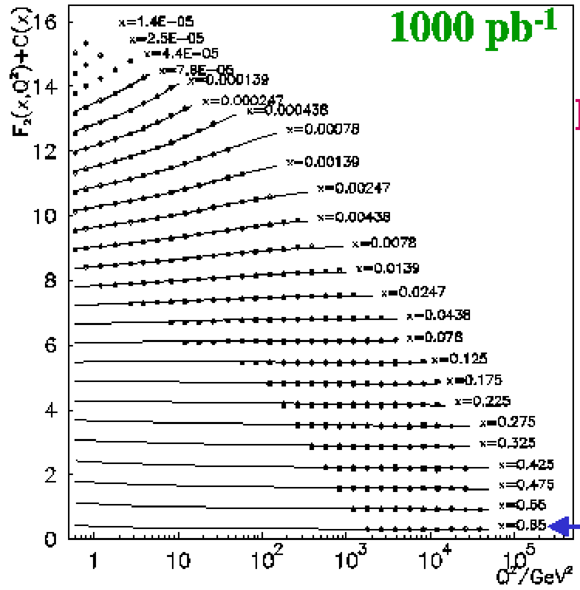
HERA II luminosity will directly translate to the precision of high x partons.

HERA I: High Q^2 Neutral Current



HERA II projection

- The Structure Function F_2



High Precision F_2

Large x, Q^2 range

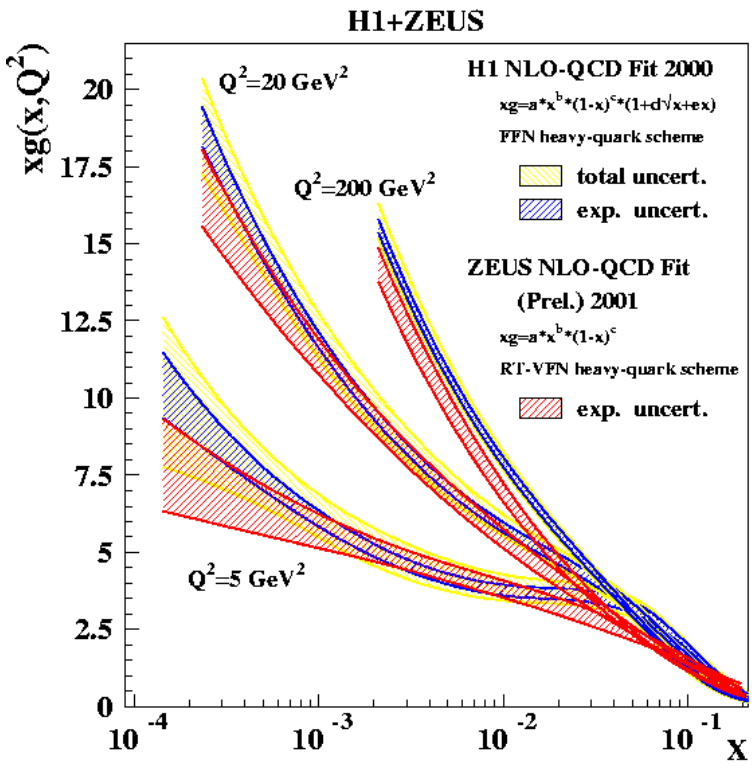
→

α_S and xg

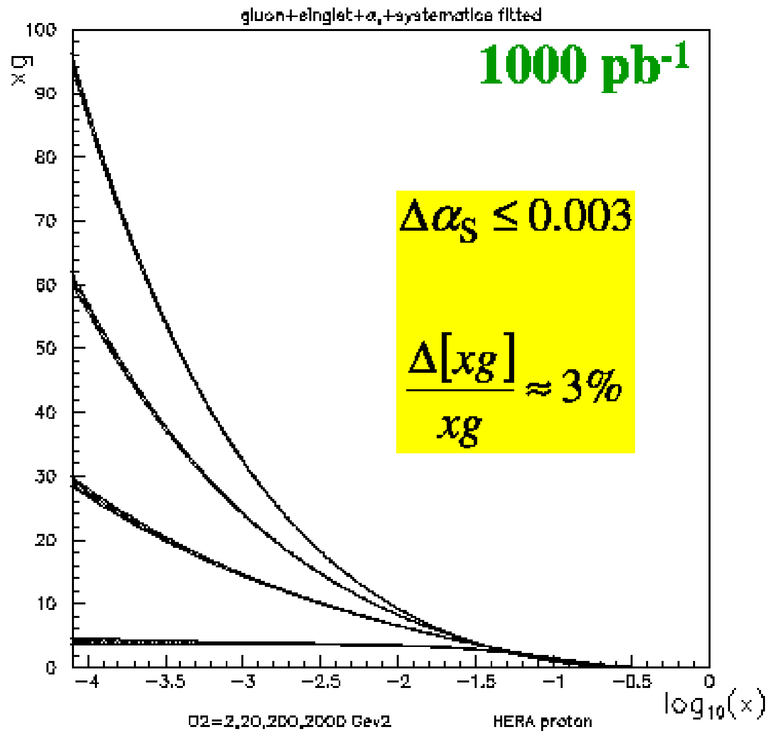
$x = 0.65$

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

HERA I: Gluon distribution



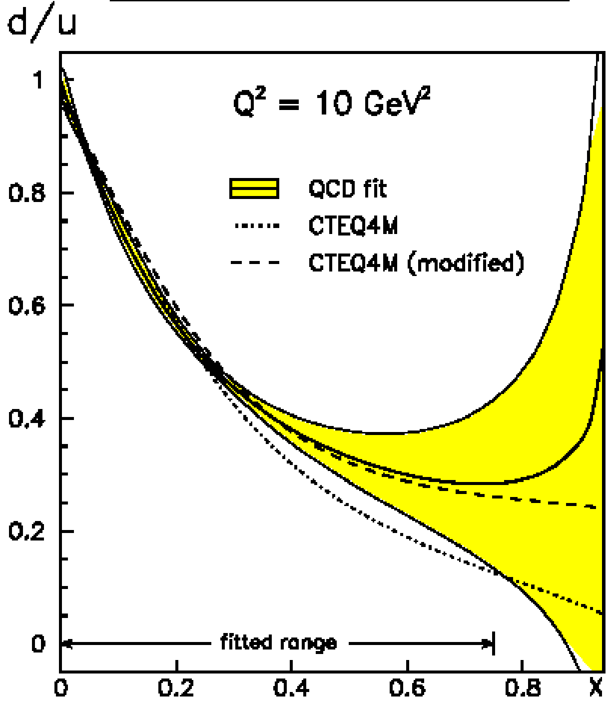
HERA II projection



What about really high x (>.65) ?

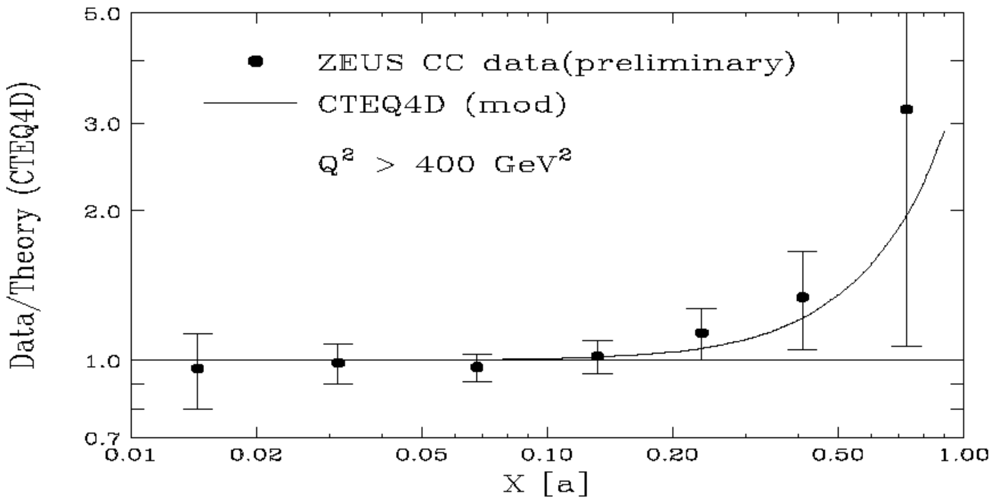
Valence distributions are not well known at very high x

Botje analysis 1999

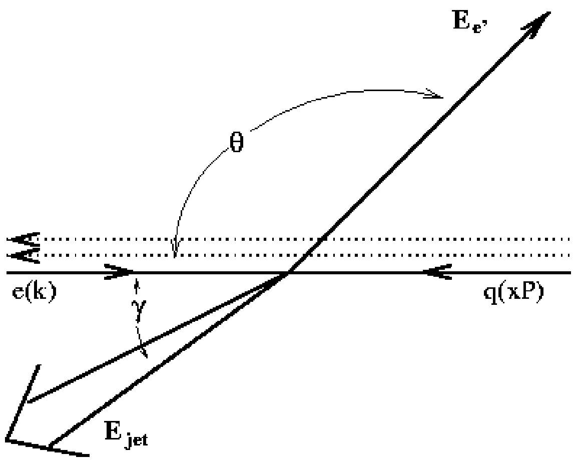


d/u $\neq 0$ as x→1 ?

Bodek and Yang, 1998



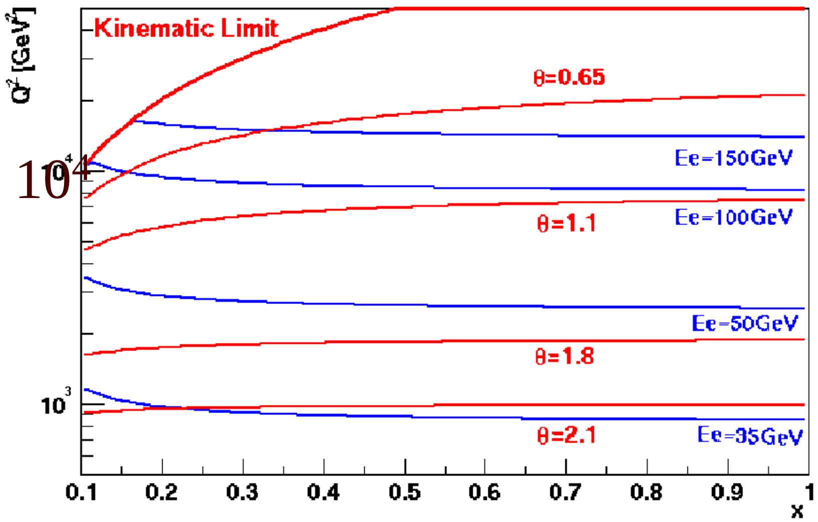
The very highest x corresponds to highest Q2: measurements are limited by statistics. There are new ideas to use more of the data→



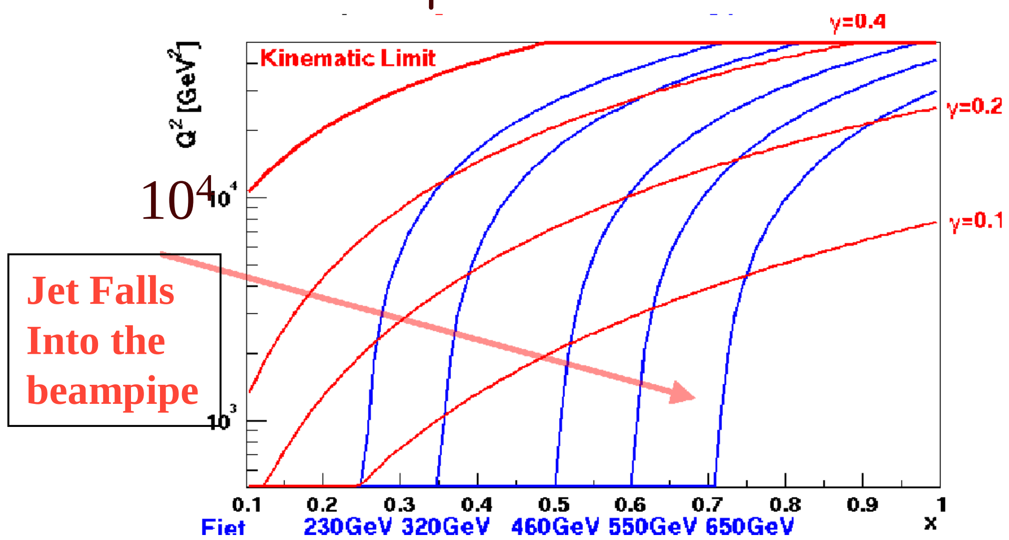
Energies and angles of the electron and the jet: 4 variables measured

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)

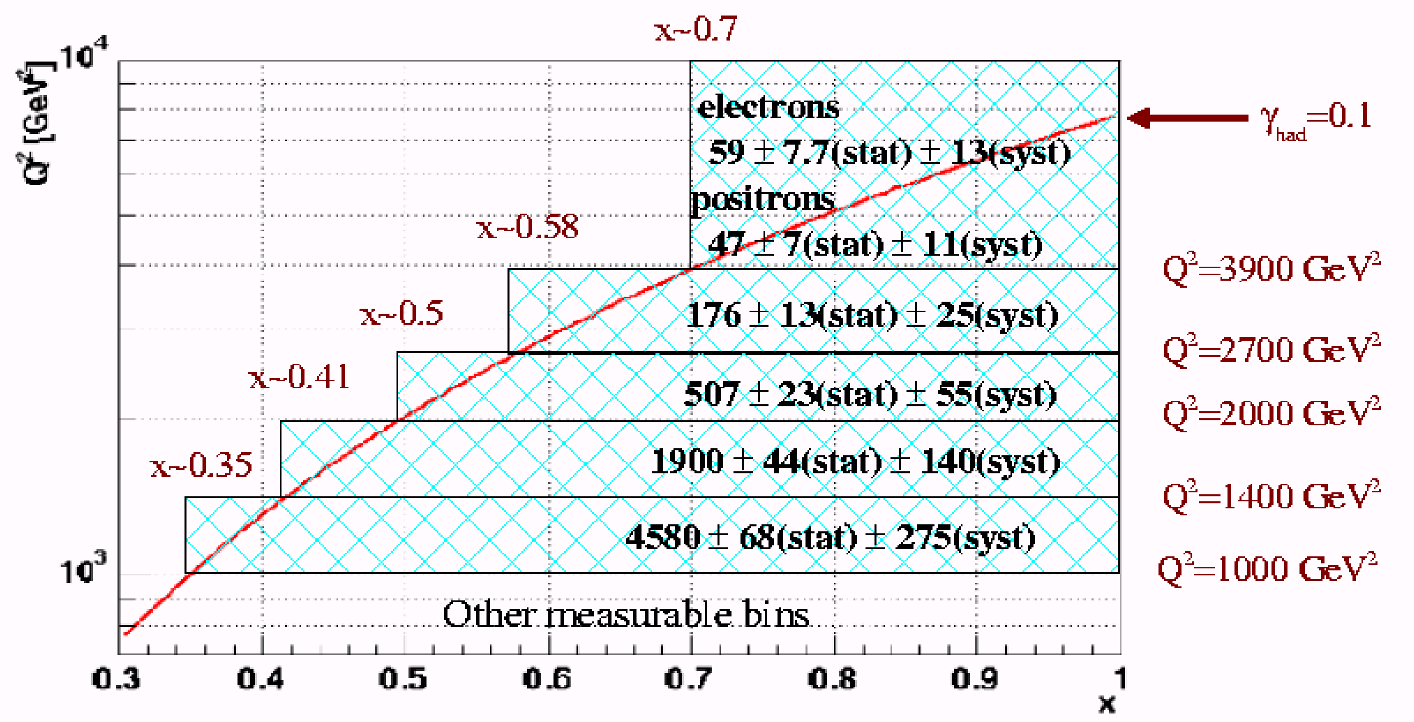
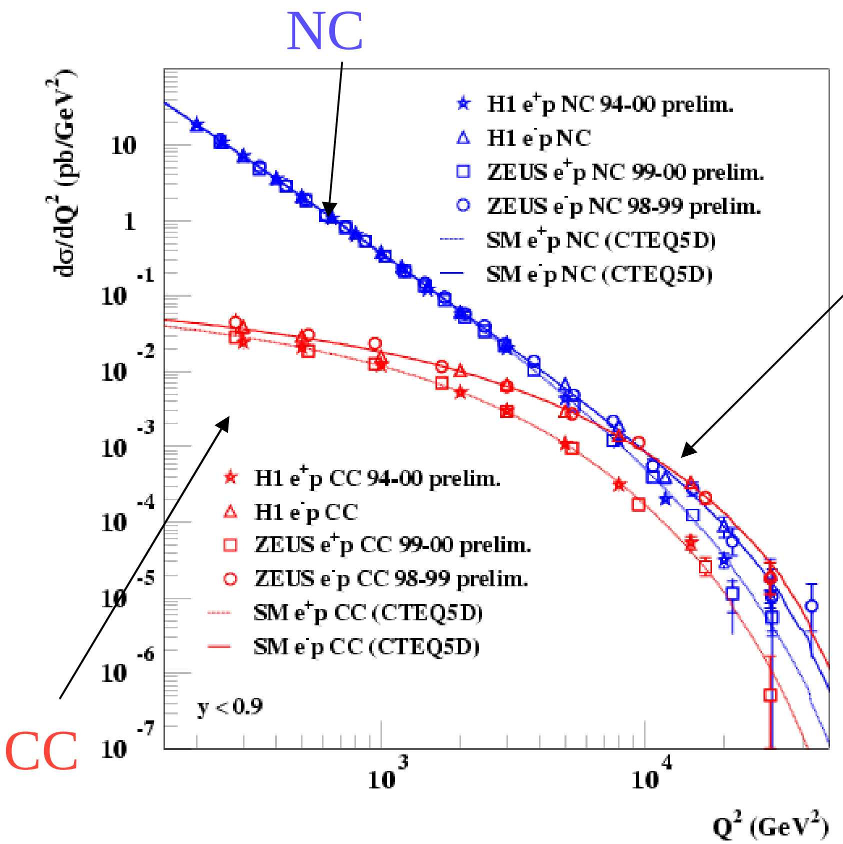


Fig. 1. Expected number of measured events for $1 fb^{-1}$ of data with Ep=920GeV

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)

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

=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 → $2a_ev_e$

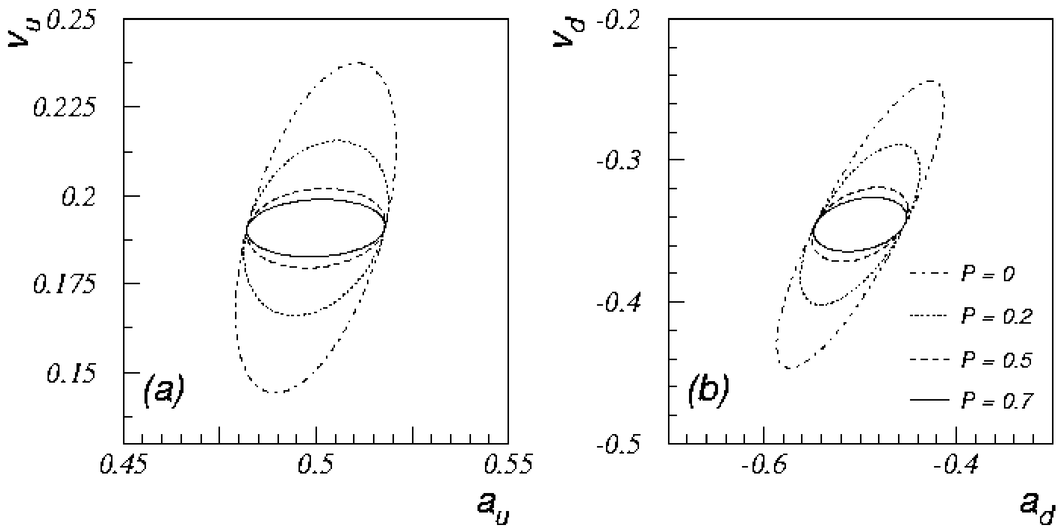
Sensitivity to a_q already in unpolarized xF3

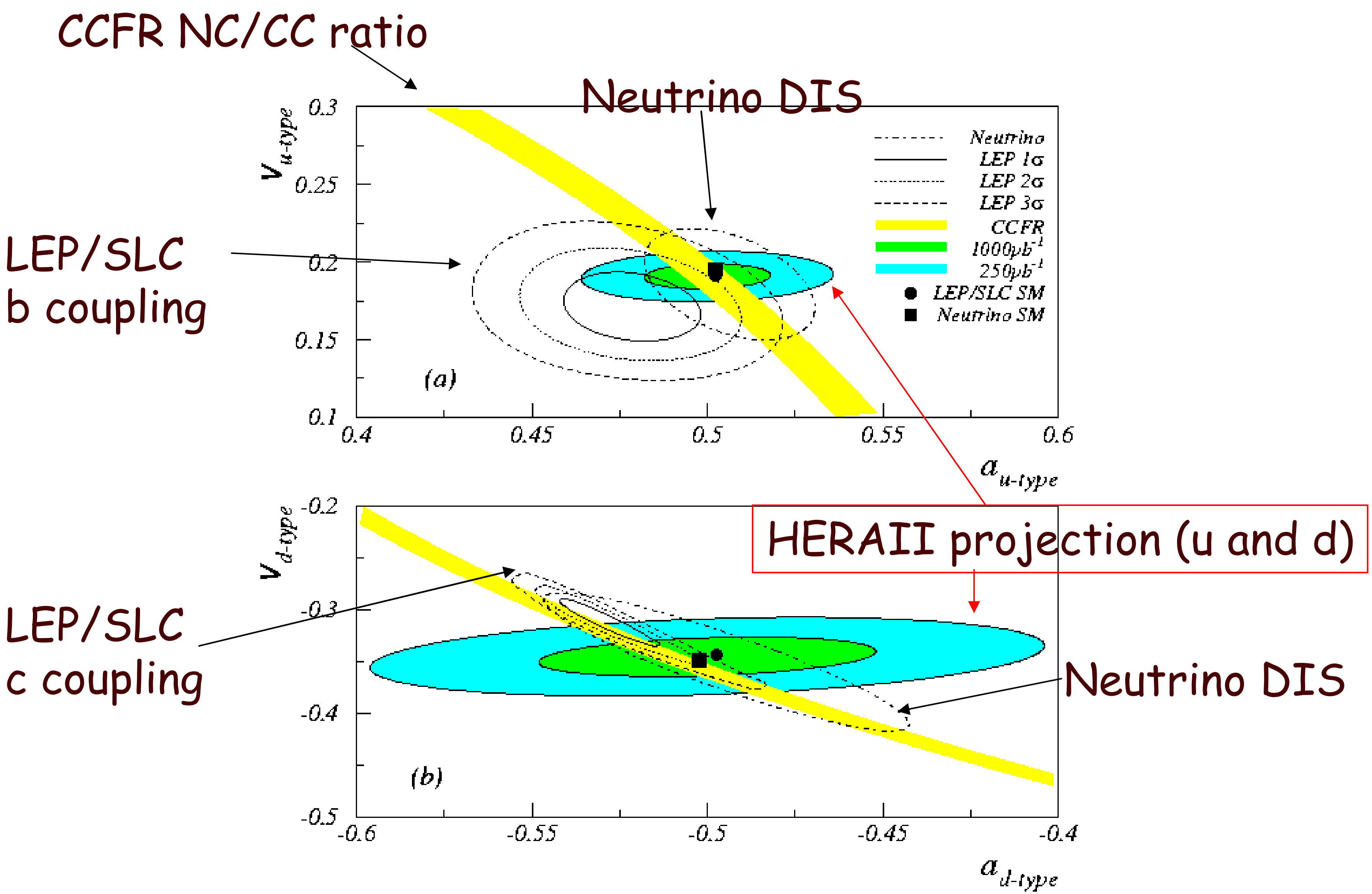
Vector and Axial-vector coupling of light quarks:

$Q^2 = 10^4\ \mathrm{GeV}^2$	$v_q = 0,\ a_q = a_q^{SM}$	$v_q = v_q^{SM},\ a_q = 0$
$1 - \frac{F_2^0(x,Q^2;v_q,a_q)}{F_2^0(x,Q^2)}$	~ 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. →





High precision: complimentary measurement.

R. Yoshida, 2 Oct 2003

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

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

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

Quadratic dependence on top mass

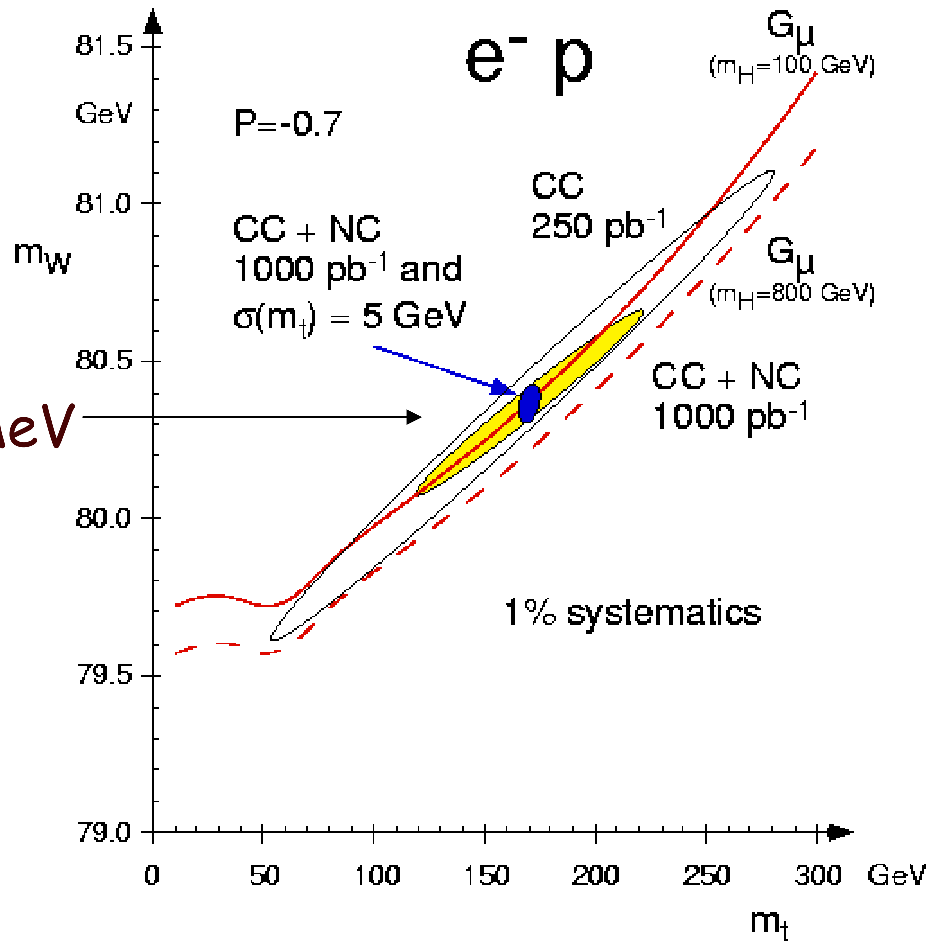
--also has logarithmic dependence on Higgs mass.

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.

A. Caldwell: report to Feltese committee

Exotics & Anomalies

Motivation:

- There are unresolved anomalies from HERA I
- HERA competitive for some new physics (R_P violating SUSY, LQ, …)

Requirements:

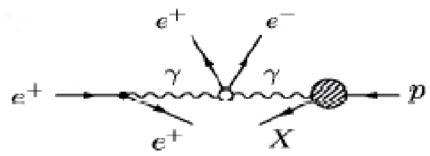
- 200 pb^{-1} to confirm/rule out anomalies, max possible to study new physics if there
- Lepton sign, polarization important for understanding new physics

E. Perez (LP03)

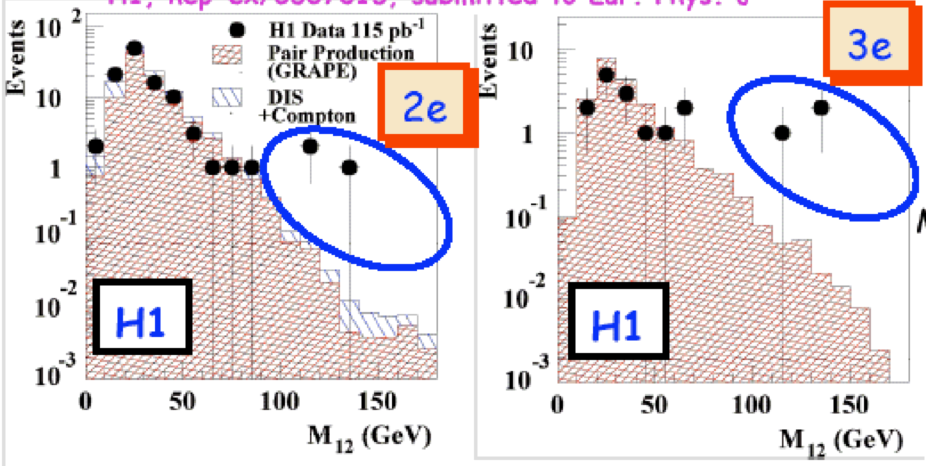
HERA multilepton events

Search for events with several leptons in final state

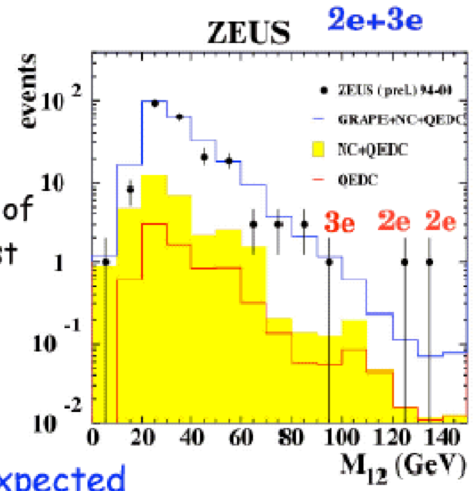
Mainly produced via $\gamma\gamma$ collisions

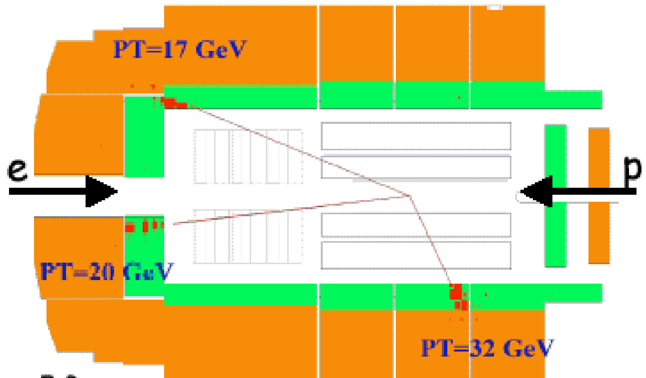


H1, hep-ex/0307015, submitted to Eur. Phys. J



M_{12} = mass of two highest P_T e





observed / expected

selection \ expt	H1 (115 pb^{-1})	ZEUS (130 pb^{-1})
2e, M > 100 GeV	3 / 0.30 ± 0.04	2 / 0.77 ± 0.08
3e, M > 100 GeV	3 / 0.23 ± 0.04	0 / 0.37 ± 0.04

(different angular ranges in H1 / ZEUS analyses)

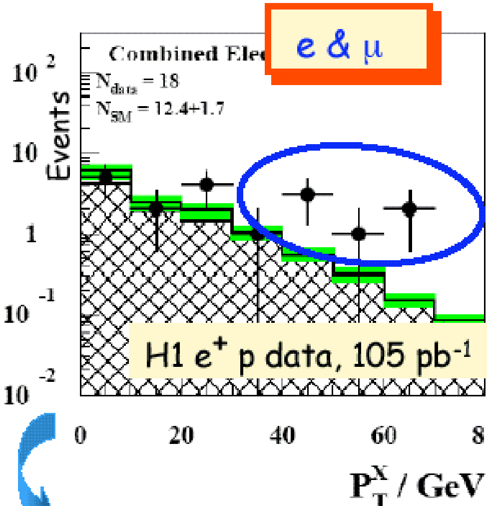
No excess in ep → $\mu\mu X$

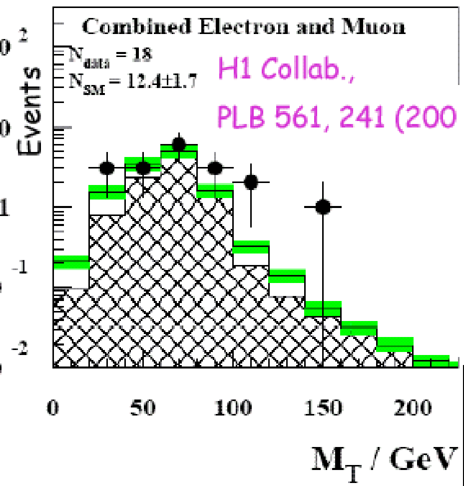
E. Perez 8 LP ' 03, 08 / 11 / 03

R. Yoshida, 2 Oct 2003

E. Perez (LP03)

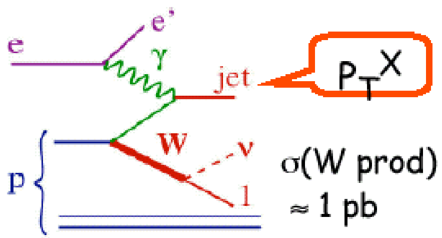
HERA events with isolated lepton + $P_{T,miss}$





$e\,p \rightarrow l + jet + P_{T,miss}$

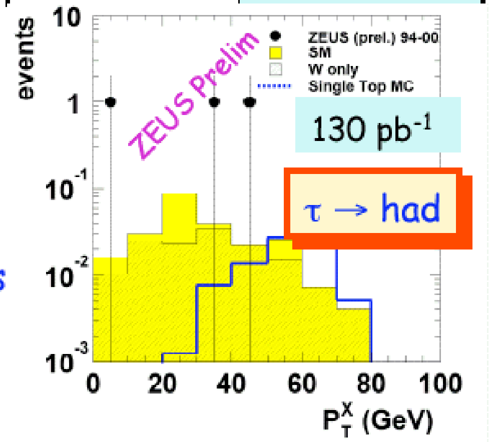
Main SM contribution :



observed / expected

H1 $e^+ p$ data	e channel	μ channel	Combined e & μ
$P_T^X > 25$ GeV	4 / 1.48 ± 0.25	6 / 1.44 ± 0.25	10 / 2.92 ± 0.49
$P_T^X > 40$ GeV	3 / 0.54 ± 0.11	3 / 0.55 ± 0.12	6 / 1.08 ± 0.22

ZEUS $e^{\pm}$ p data	τ channel
$P_T^X > 25$ GeV	2 / 0.12 ± 0.02
$P_T^X > 40$ GeV	1 / 0.06 ± 0.01



- No excess in H1 e^- p data
- No excess in ZEUS data in e & μ channels, τ candidates
- Agreement in the had. channel (but large bckgd)
- W prod : full NLO corrections included (recently available)

E. Perez 9

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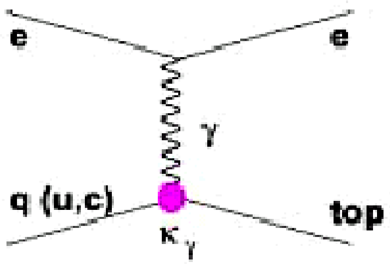
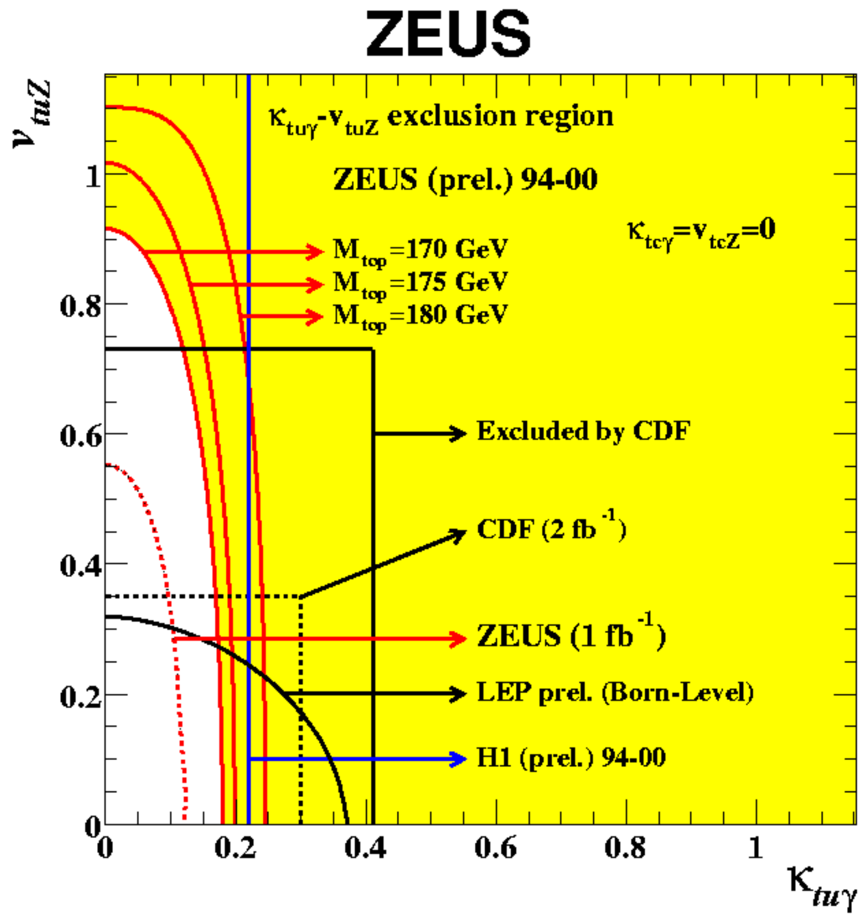
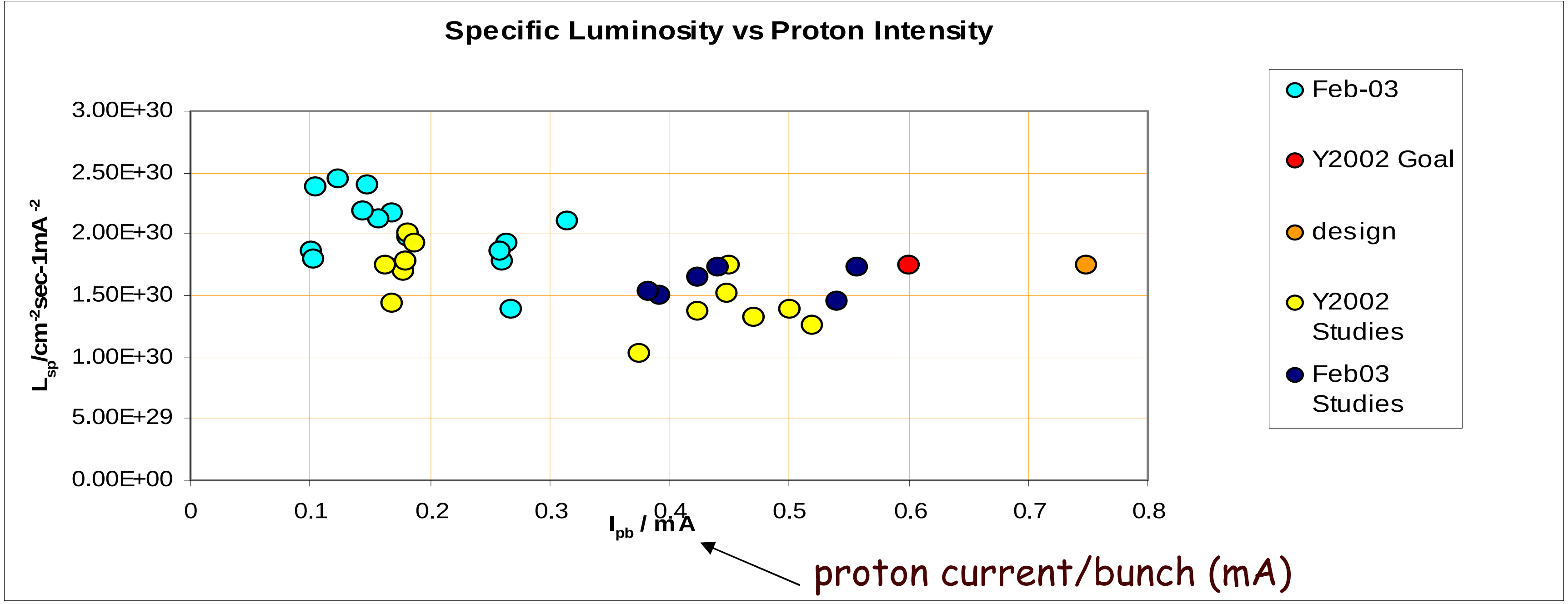
Exotics

Example of new physics – anomalous top coupling. HERA will continue to be very competitive.





The machine is ready to deliver high luminosity and polarization:



Specific luminosity design goals have been achieved.

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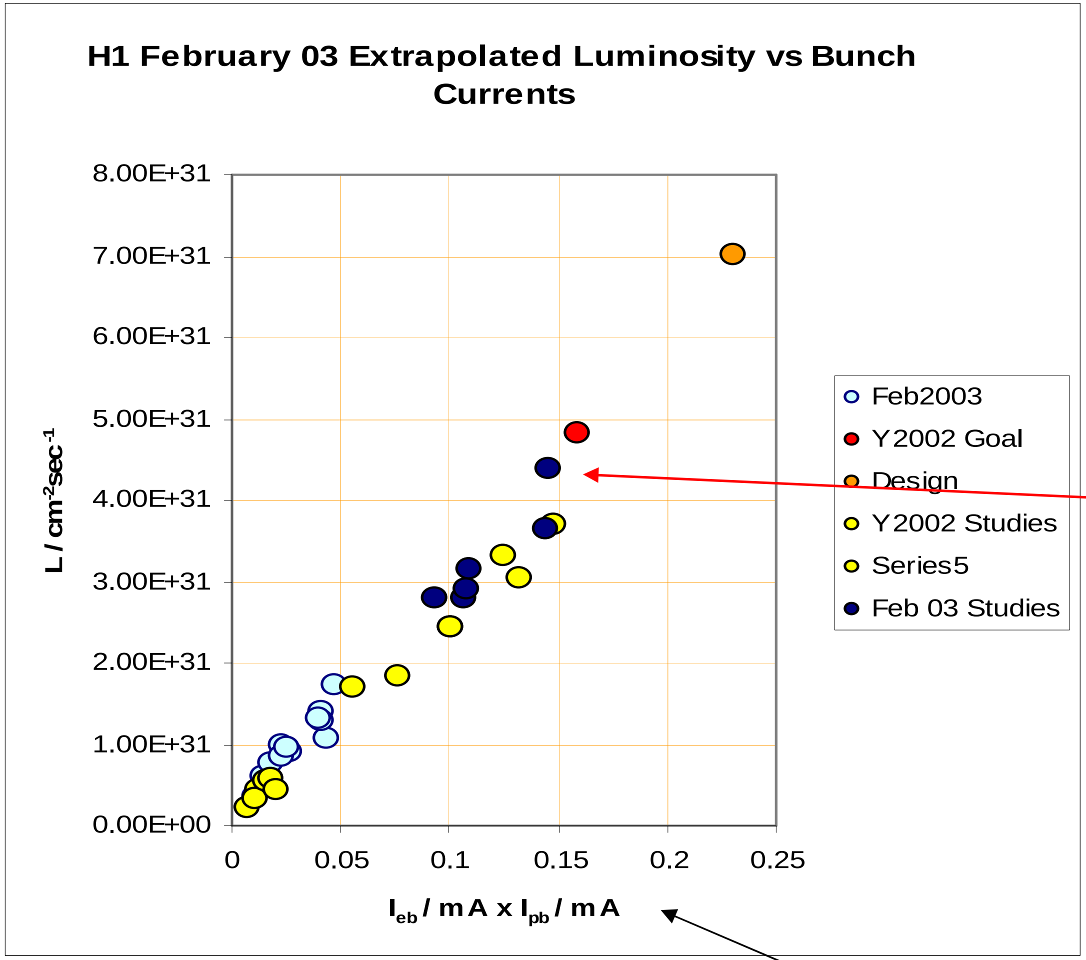
HERA II accelerator status

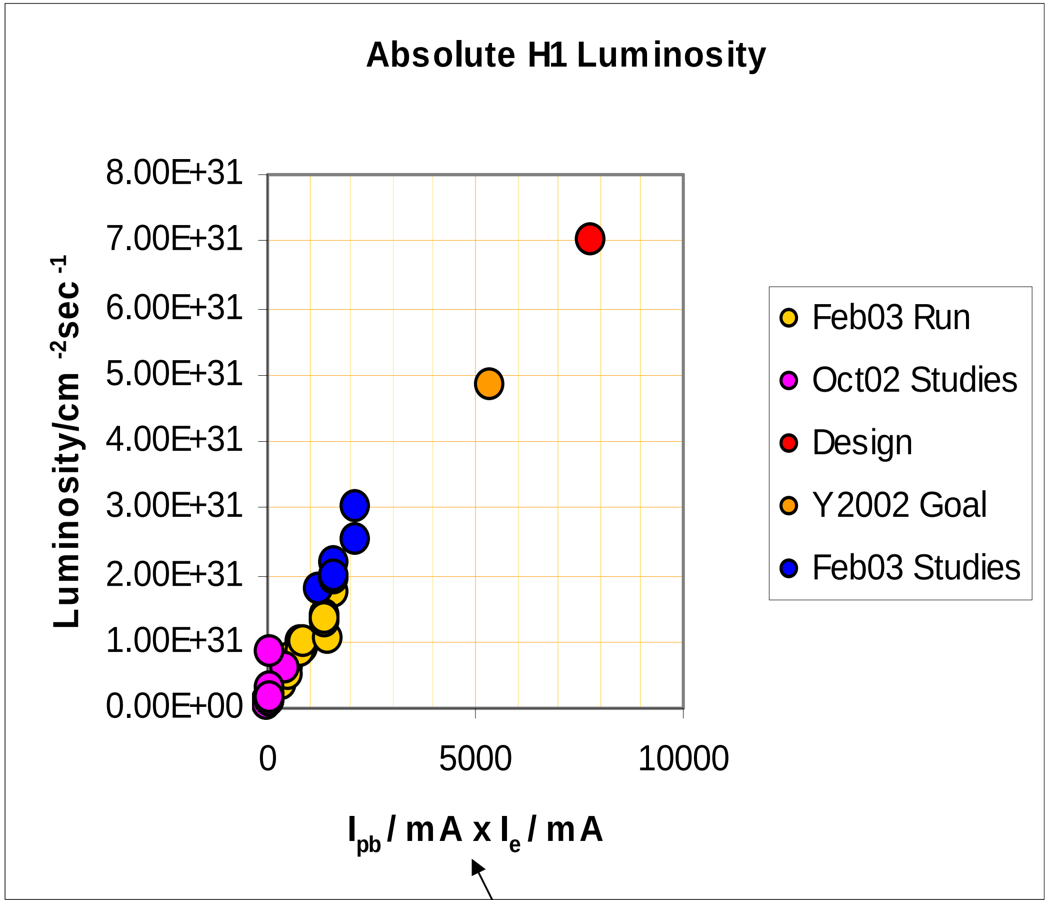


Per bunch luminosity goals for Y2002 has been achieved.

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 x 10^{31} $cm^{-2}s^{-1}$

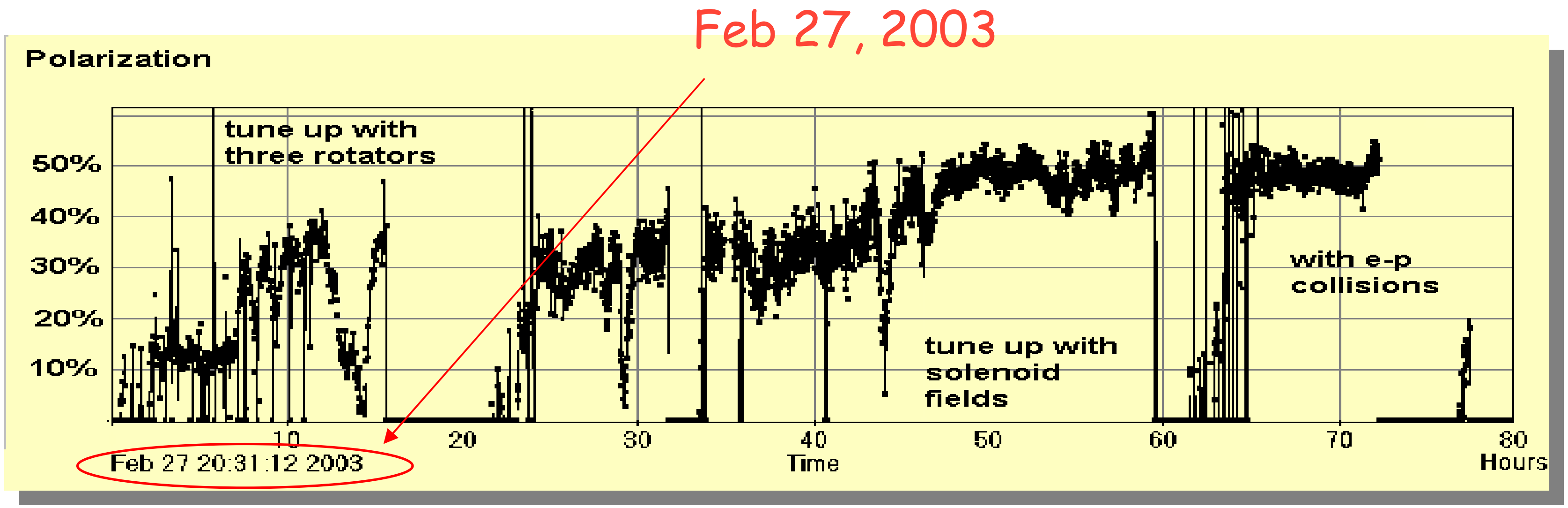
HERA record luminosity: Feb. 2003

~40% design luminosity achieved.

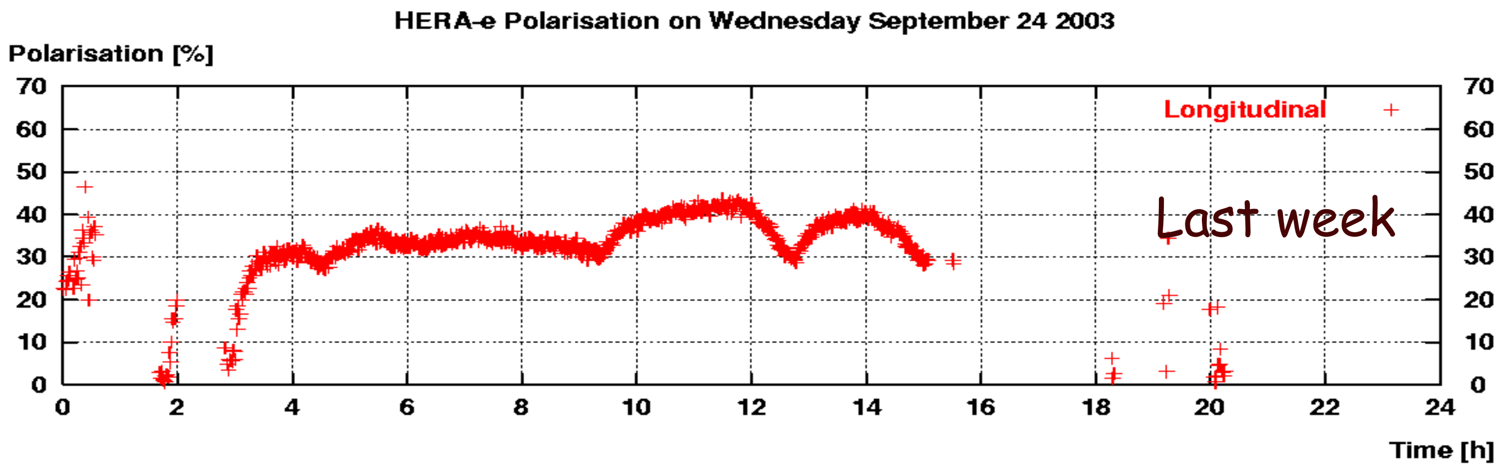
Product of electron and proton currents

Status of Polarization

Goal ~70%



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



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

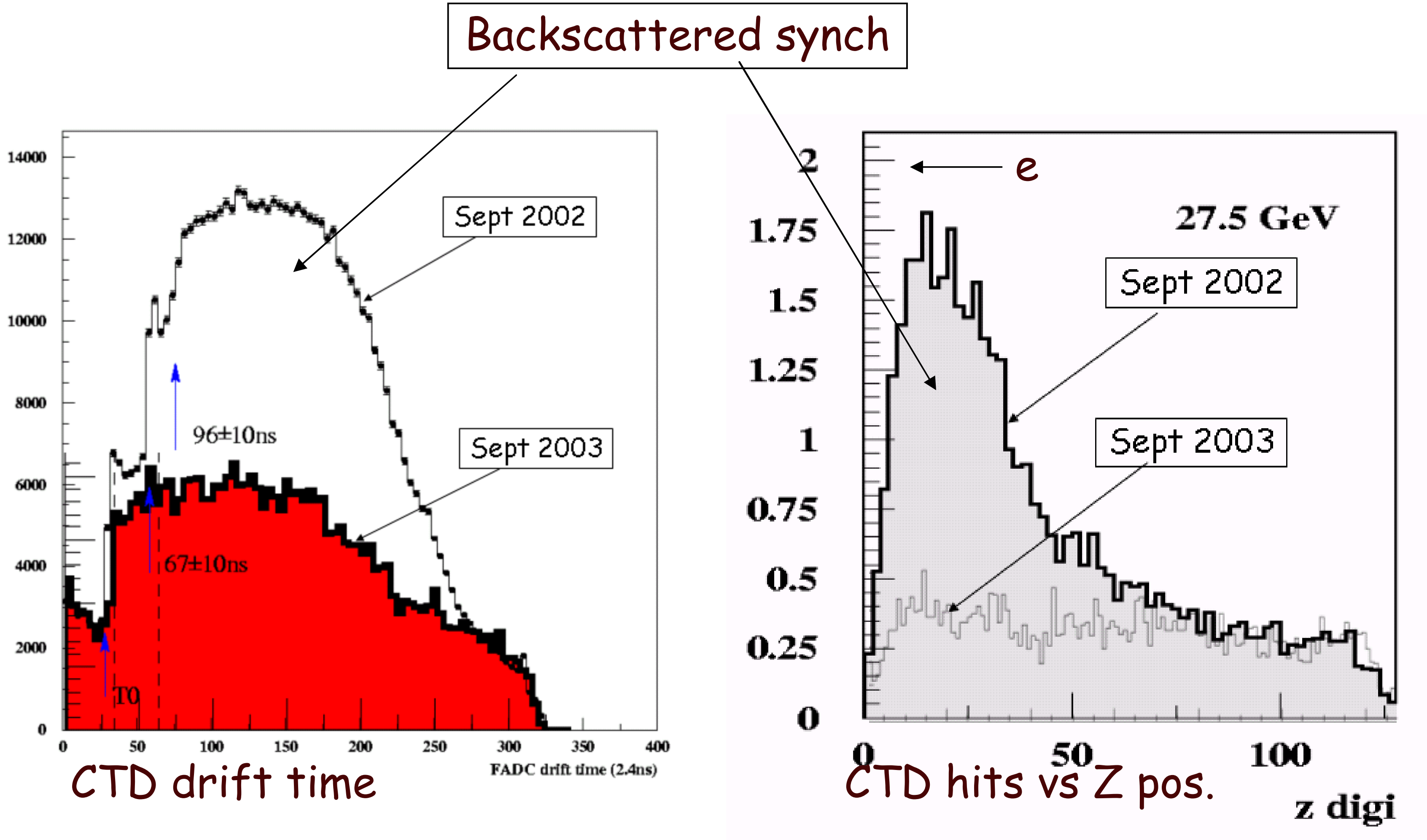
- Backscattered synchrotron radiation: worse at ZEUS than at H1—reduce through redesigning masks and coating absorbers (factor 10 reduction at ZEUS).
- Electron-gas background: reduce thickness of collimators, and improve vacuum. (factor 2 reduction).
- Proton-gas background: dominant background after 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.

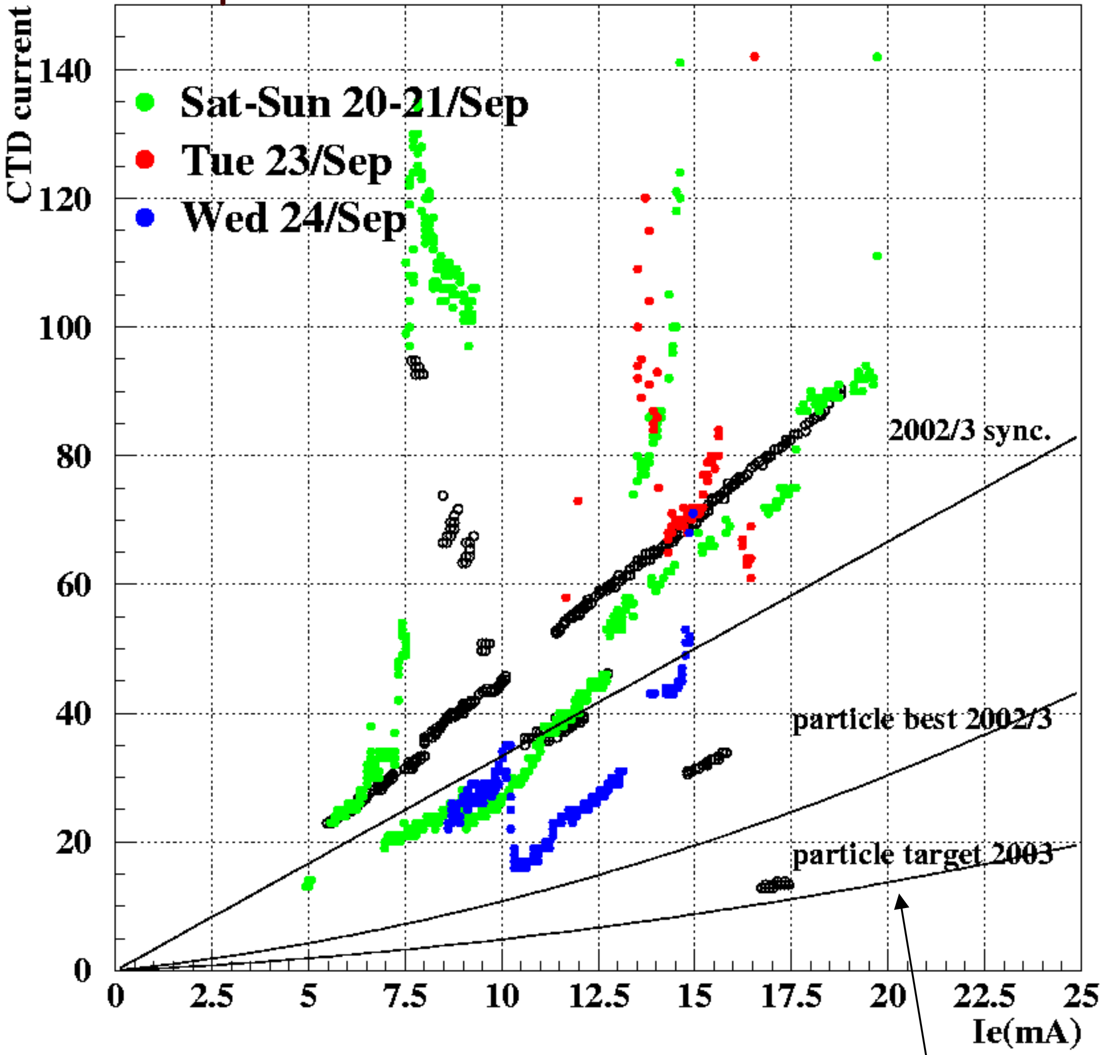
Harder to quantify: however, improvement over time (x1.7 from Oct-Jan) seen. Higher current in machine after shutdown will help

First indications of background after the shutdown:



Synch. bg at ZEUS largely gone!

September 2003



Where we want to be

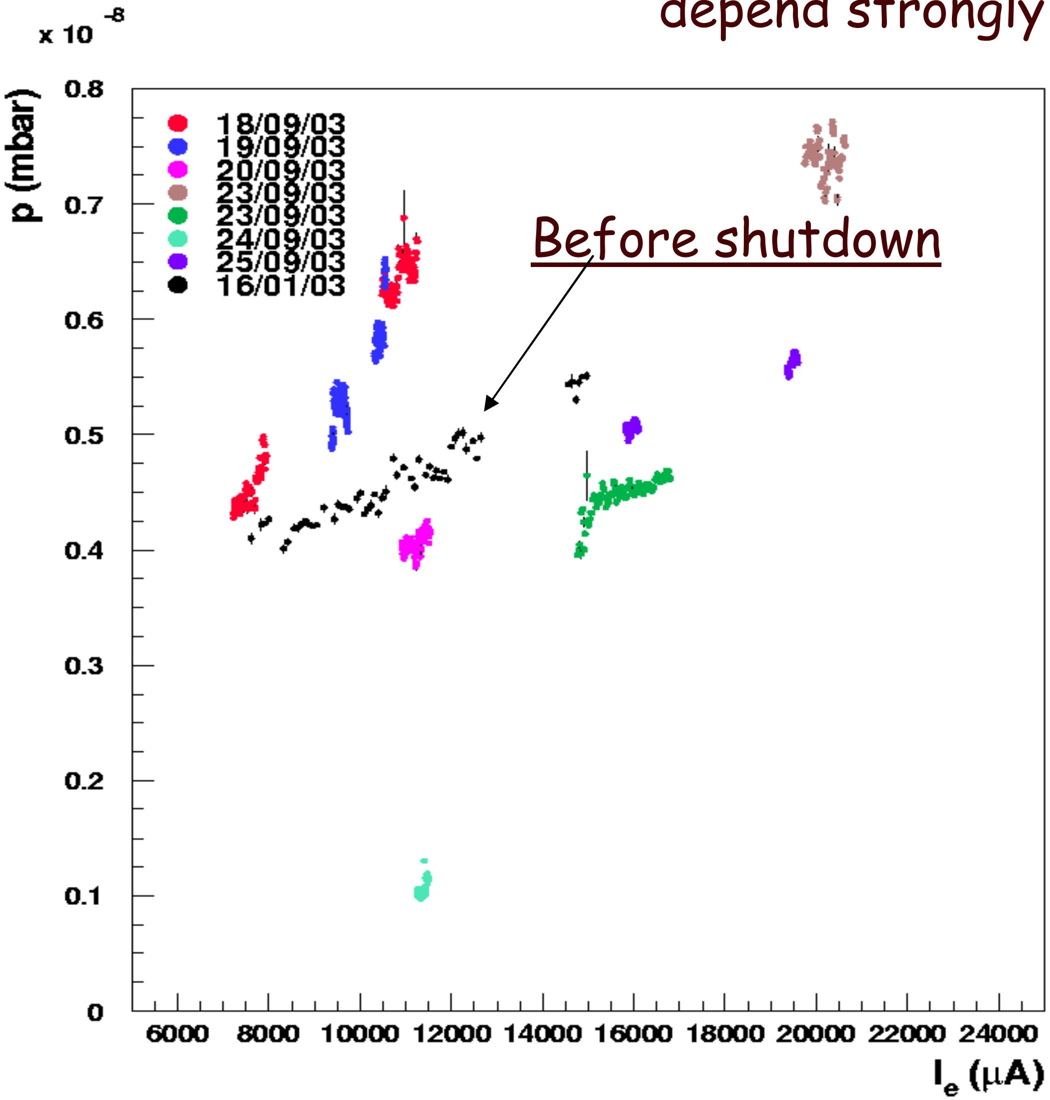
So far e only in machine: CTD current is a measure of "e-gas (particle)" background.

Steady improvement seen over a few days.

Unfortunately vacuum leak on 26 Sep. means we have to start over (to some extent).

P-gas background?

No sizable proton current yet in HERA, however p-gas background is known to depend strongly on IP area vacuum.



IP vacuum can be measured by the Luminosity monitor that measures the bremsstrahlung rate from the IP area.

Improvement over several days of positron running.

Already better than before shutdown?

(All before vacuum leak 26 Sep)

- HERA currently recovering from a small set-back. (Vacuum leak near ZEUS)
- However, in general, outlook for both the machine and experimental background seems to be good.
- I believe it is still too early to make a realistic planning based on expected HERA performance. however…
- Ferdi's estimate made for the Feltese committee (which convened earlier this week) was:
  - ~700 pb-1 total for period now-mid 2007
  - of which ~180 pb-1 comes in 2004
  - This assumes no low-energy running.

Luminosity needs for HERA II physics:

(Allen's) Summary

Baseline

some compromises with baseline necessary

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		

Lower p energy: when?

Final remarks

- Lots of extremely interesting topics in HERA II
- Performance of machine, background situation after shutdown—are cause for optimism
- Still probably not enough luminosity to do all we want to do, comfortably.
- I believe it is still a little too early to discuss running scenarios in a concrete way—however obviously…
- Important strategic choices are:
  - When do we switch to electrons?
  - When (if?) do we lower the proton energy?
- All of us have the same aim: maximizing the physics output of HERA II. I'm hopeful that—later on this year—we can reach a consensus about how to proceed.