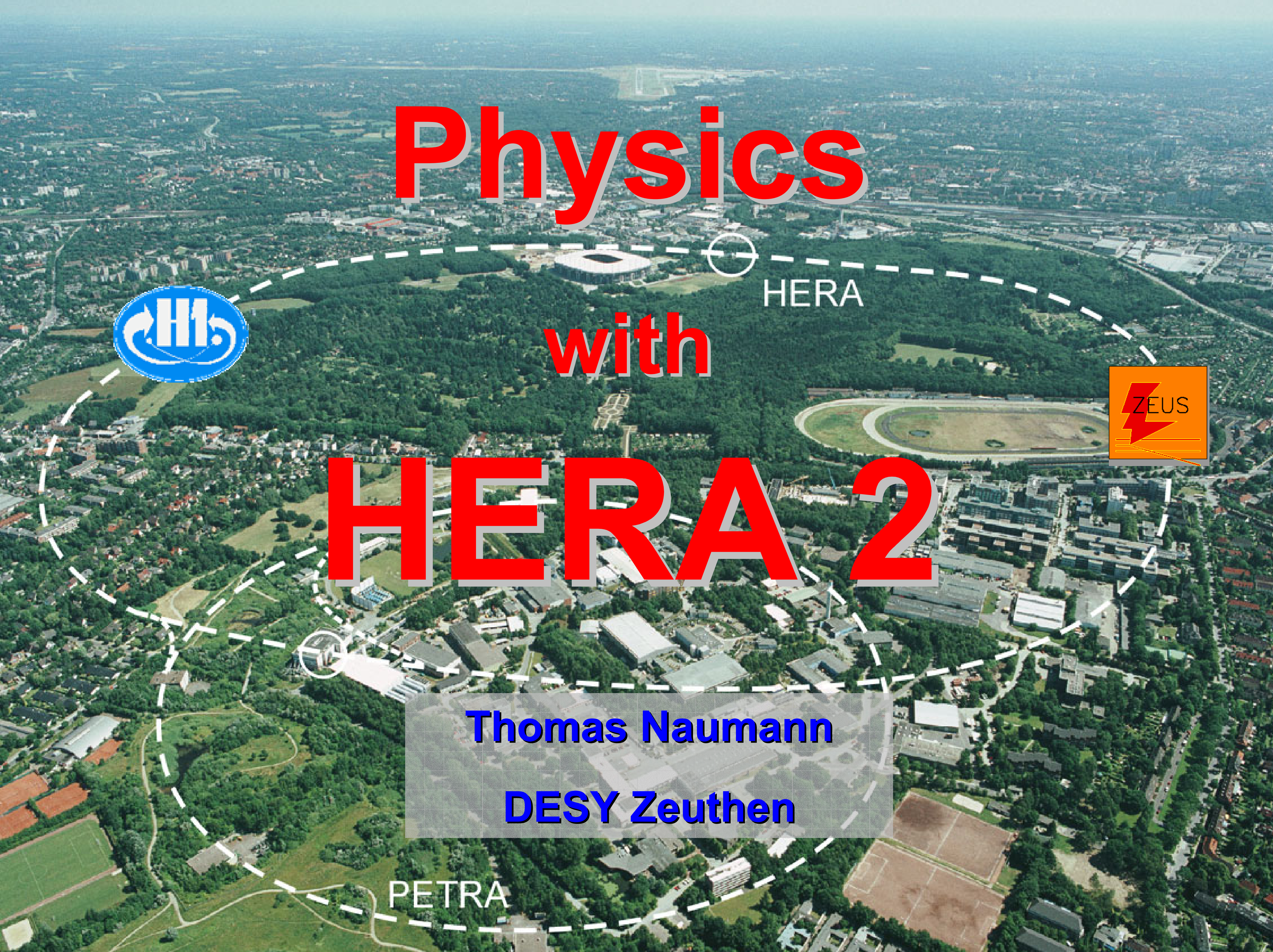
Physics with HERA 2



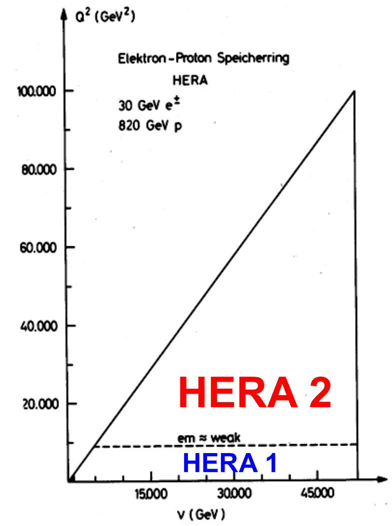
Thomas Naumann

DESY Zeuthen

Why HERA 2 ?

- **DIS:** **measure NC + CC cross sections with 2 polarizations x 2 lepton charges**
  - extract structure functions F_2, F_L, $xF_3(x,Q^2)$, …
- **QCD analyses:**
  - determine parton distribution functions $xq(x,Q^2)$
  - the gluon and α_s
- **understand production of Heavy Flavours**
- **study the nature of diffraction**
- **look beyond the Standard Model:**
  - contact interactions, leptoquarks, SUSY, …

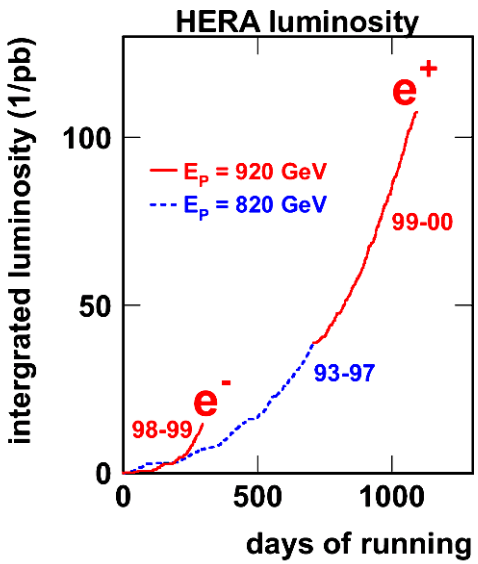
Reach original HERA goals:
HERA proposal, DESY 1981



describe upgrade of HERA and experiments

give HERA 1 results - show HERA 2 prospects

HERA Lumi Upgrade



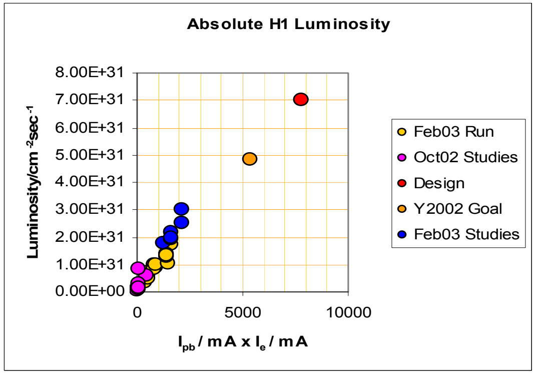
- **1993-2000:** 120 pb^{-1} e^+ , 20 pb^{-1} e^-
- mainly **low β** :
  - move proton quad's from 27 to 11 m
  - superconducting quad's inside detectors
- modest increase of beam currents
- **polarization**
- **2003-2006/7 : 'close to 1 fb^{-1} '**
- **22.10.03:** 19 mA e^+ x 52 mA p

L_{spec} = 1.6 10^{30} $cm^2 s^{-1} mA^2$ L = 1.6 10^{31} $cm^2 s^{-1}$

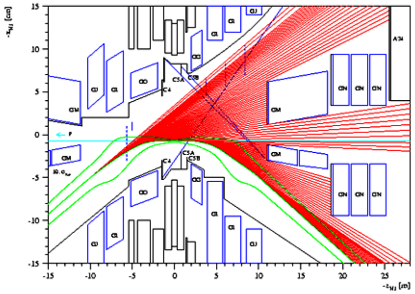
	I_e / mA	I_p / mA	β_x / m	β_y / m	L_{spec} / 10^{30} $cm^2 s^{-1} mA^2$	L / 10^{31} $cm^2 s^{-1}$	L_{int} / pb^{-1}
1993-2000 2000	50	100	7.00	0.50	0.66	< 2.0	140 67
2002-2003	< 35	< 70	< 3	< 0.25	< 1.68	< 2.7	2.5 - 12 H1 DC - HERA
2003-2007	58	140	2.45	0.18	1.82	3.7 - 7.6 2003 - design	1 000

HERA 2002 / 3

- **Luminosity:**
  - Low β and specific lumi reached, but currents limited by …



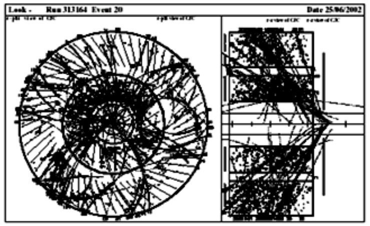
- **Background:**
  - **synchrotron radiation :**
    - better masks + collimators :
    - coating, shape (HOMs), cooling
    - lead shielding of beam pipe 2 mm

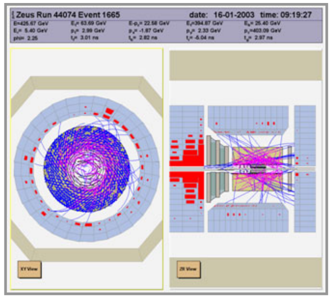


  - **p-gas :**

    only 25% of lumi with drift chambers
    - large currents

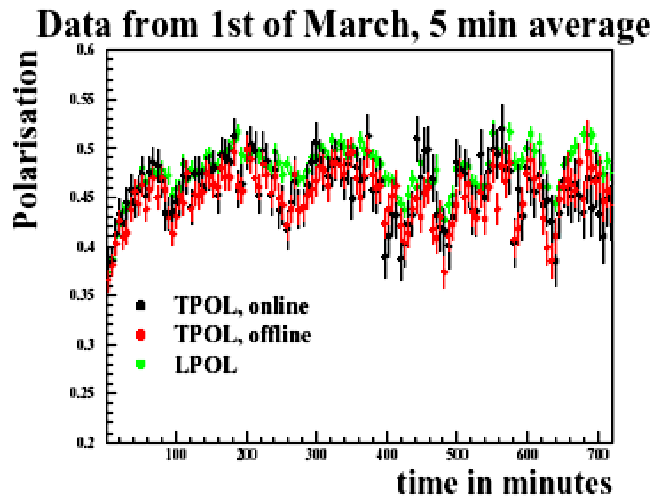
    improve vacuum
    - add ion getter pumps
    - long bake out
    - started Sept 2003

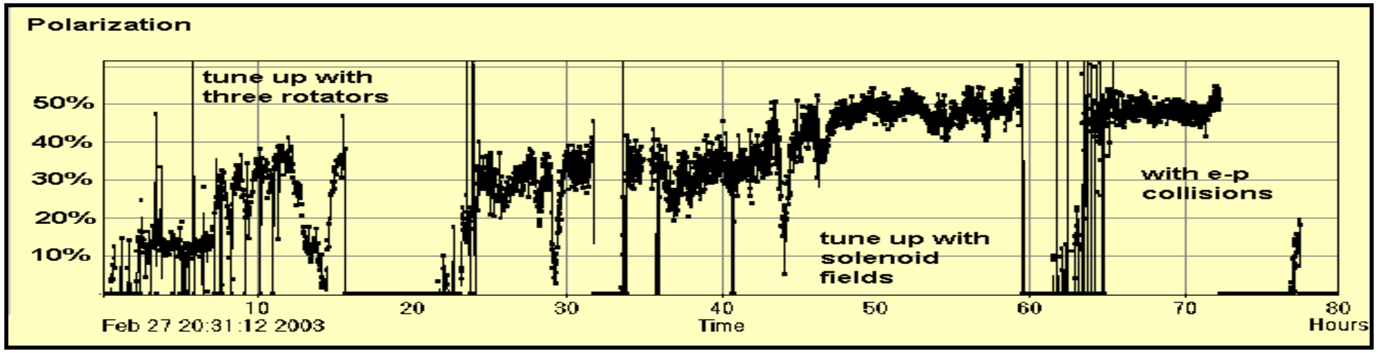




HERA Polarization

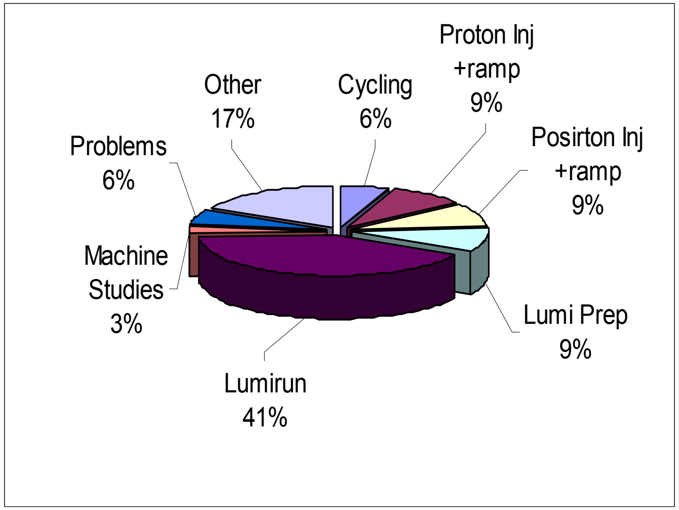
- $\sigma_{cc,pol}(e^{\pm}) = (1 \pm \lambda)\, \sigma_{cc}(e^{\pm})$
- spin rotators around H1 and ZEUS :
  λ ~ 50% reached at first try
- need **$d\lambda/\lambda$** as good as dL/L : ~1%
  precise polarimeters

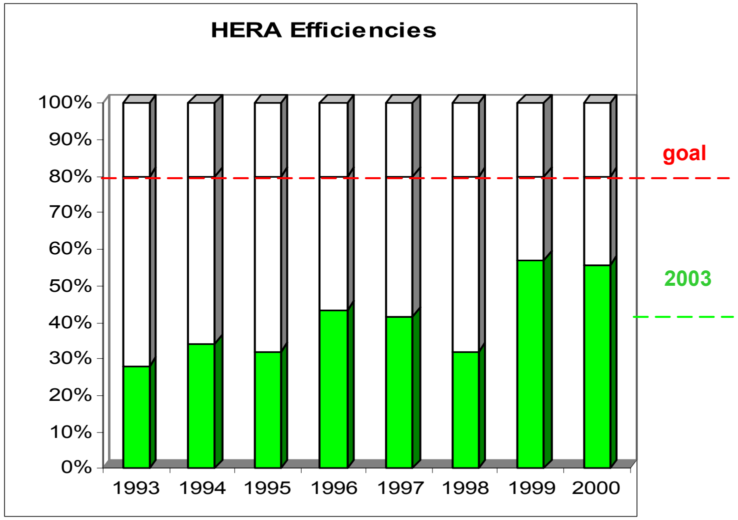




HERA 2002 / 3

- 27.5 GeV e x 920 GeV p
- 2 accelerators : efficiency ^{2}
- reliability: running efficiency Feb 2003:   41 %
  aging components





HERA Maximum Peak Luminosity

$$L = \frac{n_b \cdot I_{eb} \cdot I_{pb}}{2\pi e^2 f_0 \cdot \sigma_x \cdot \sigma_y}$$

$$I_e \cdot I_p \le I_{max}^2$$

$$L = \frac{I_{max} \cdot \sqrt{I_{eb} \cdot I_{bp}}}{2\pi e^2 f_0 \cdot \sigma_x \sigma_y}$$

I_{eb} = 0.300mA (design), 0.600mA (2 x design)

I_{pb} = 0.600 mA (Y2000 max)

$$I_p \cdot I_p \le \begin{cases} 2000\ mA^2 = I_{max}^2 \\ 1500\ mA^2 \\ 4000\ mA^2 \end{cases}$$

Can't get to maximum Luminosity with 180 bunches

Peak Luminosity Prospects 2003				
I^2_{max}/mA^2	I_{ep}/mA^2	I_{pb}/mA	n_b	$L/cm^{-2}sec^{-1}$
2000	0.3	0.6	100	3.75535E+31
1500	0.3	0.6	90	3.37982E+31
4000	0.3	0.6	140	5.2575E+31
2000	0.6	0.6	70	5.2575E+31
1500	0.6	0.6	60	4.50643E+31
4000	0.6	0.6	90	6.75964E+31

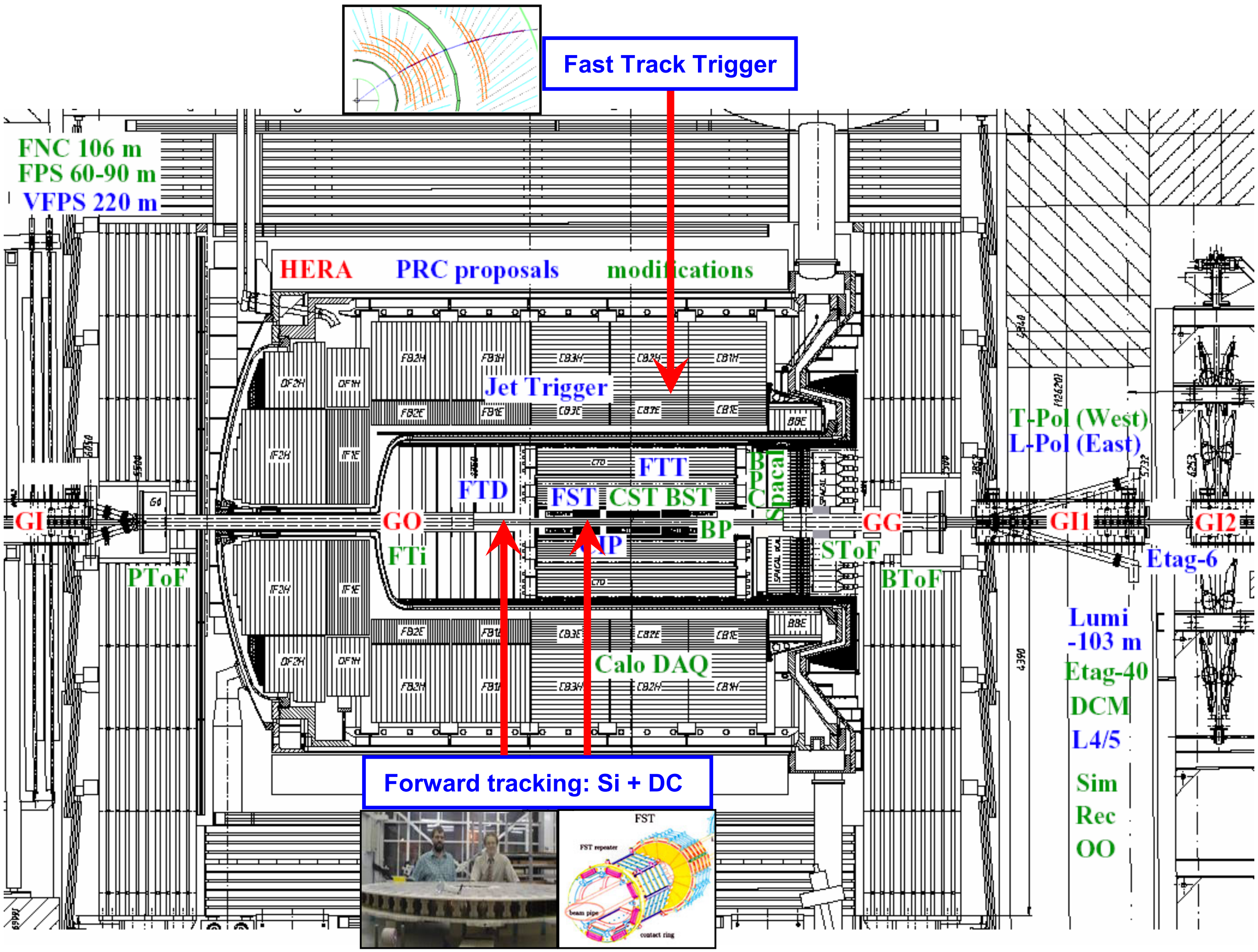
F.Willeke:

A likely scenario

H1 Upgrade

Very Forward Proton Spectro-meter
VFPS

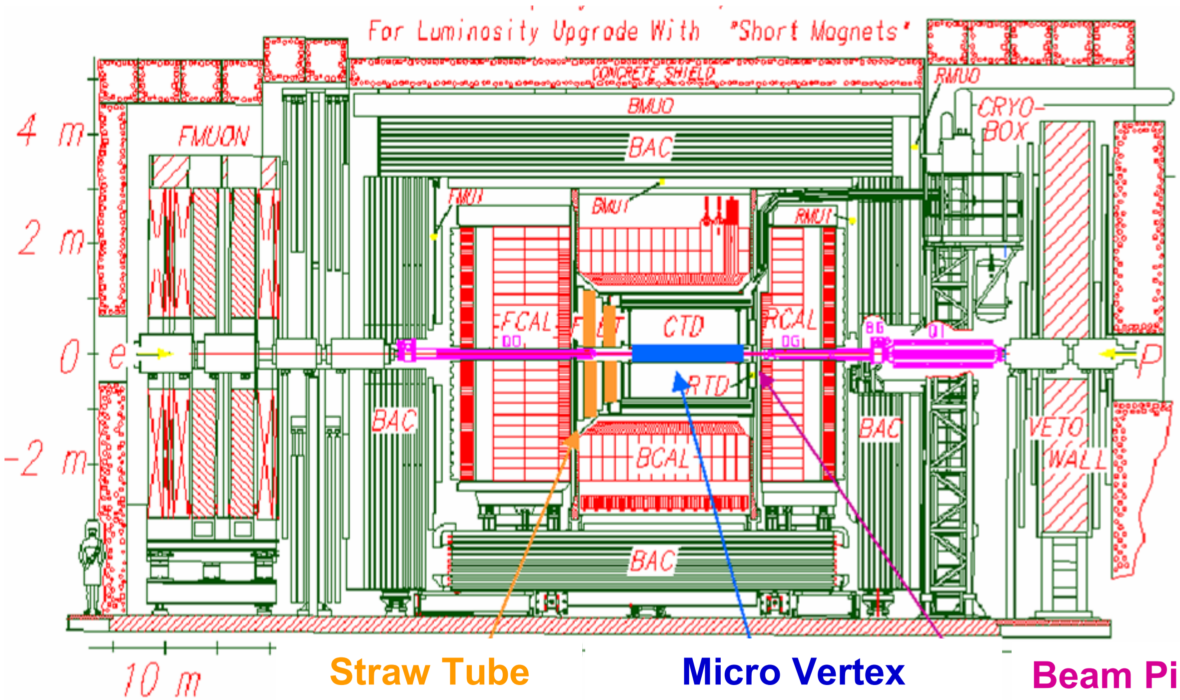
e
27.5 GeV



polarimeters

p
920 GeV

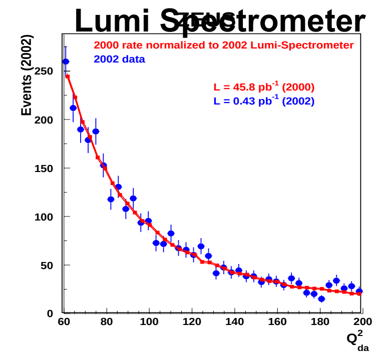
ZEUS Upgrade

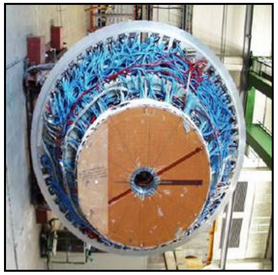


Straw Tube Forward Tracker

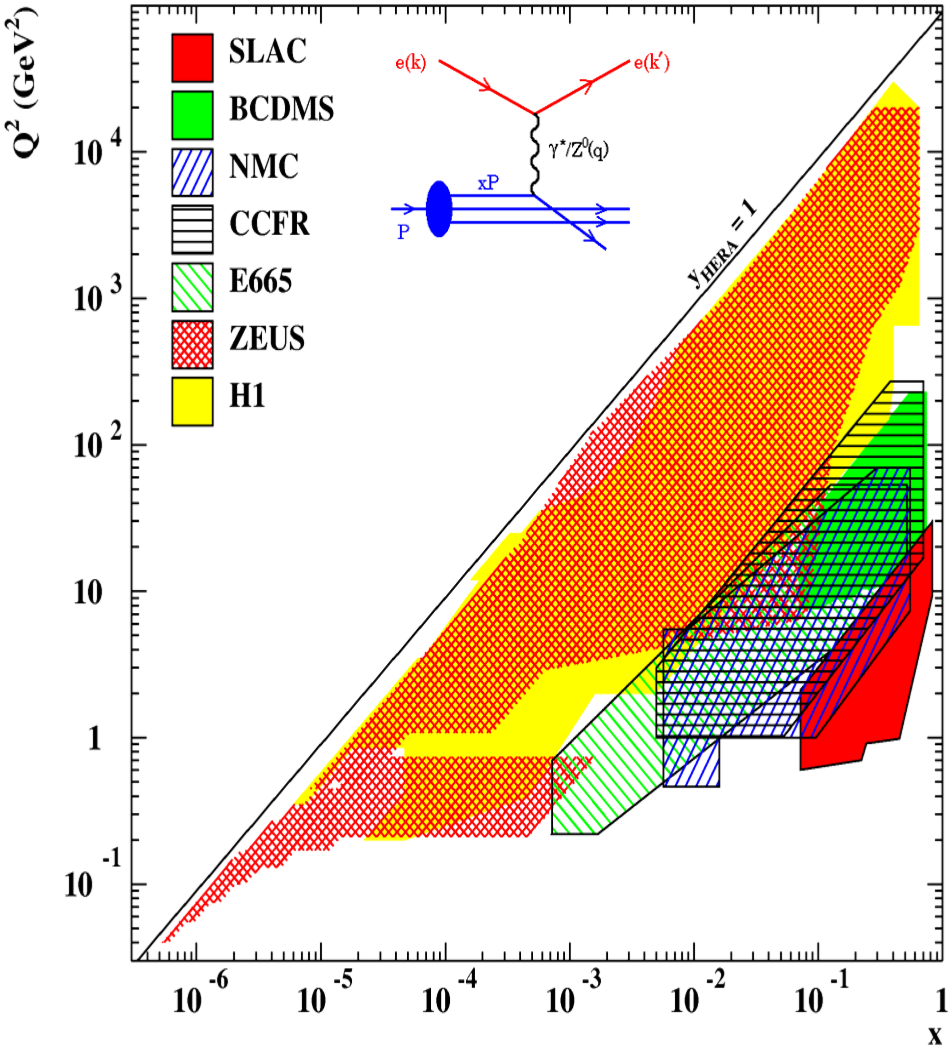
Micro Vertex Detector

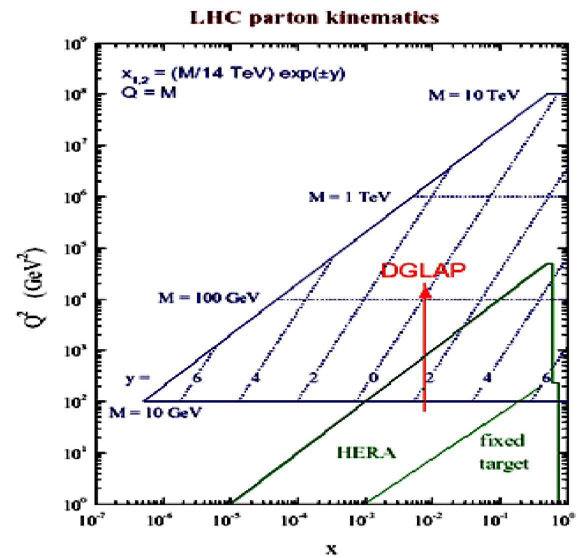
Beam Pipe Magnets





DIS Kinematics





centre-of-mass energy squared:
$s = (k + p)^2 = 4 E_e E_p$

$Q^2 = - q^2 = - (k - k')^2 = s\, x\, y$
four-momentum transfer squared

$x = Q^2 / (2P \cdot q)$ Bjorken-x
momentum fraction of struck parton

$y = (P \cdot q) / (P \cdot k)$ inelasticity
relative energy transfer to the proton

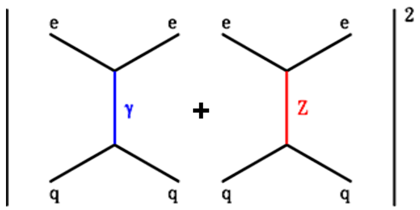
hadronic energy squared
$W^2 = (q + p)^2 = s\, y$

NC Cross Section

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

$Y_\pm = 1 \pm (1-y^2)$ helicity dependence $\tilde{\sigma}_{NC}$ = reduced cross section

Generalized Structure Functions :



$$\mathcal{F}_2 = F_2^{\gamma} + a_2\ F_2^{\gamma\text{-}Z} + b_2\ F_2^{Z}$$

$$x\mathcal{F}_3 = a_3\ xF_3^{\gamma\text{-}Z} + b_3\ xF_3^{Z}$$ parity violating

$$\mathcal{F}_L = F_L^{\gamma} + \ldots$$ (longitudinal, small at low y)

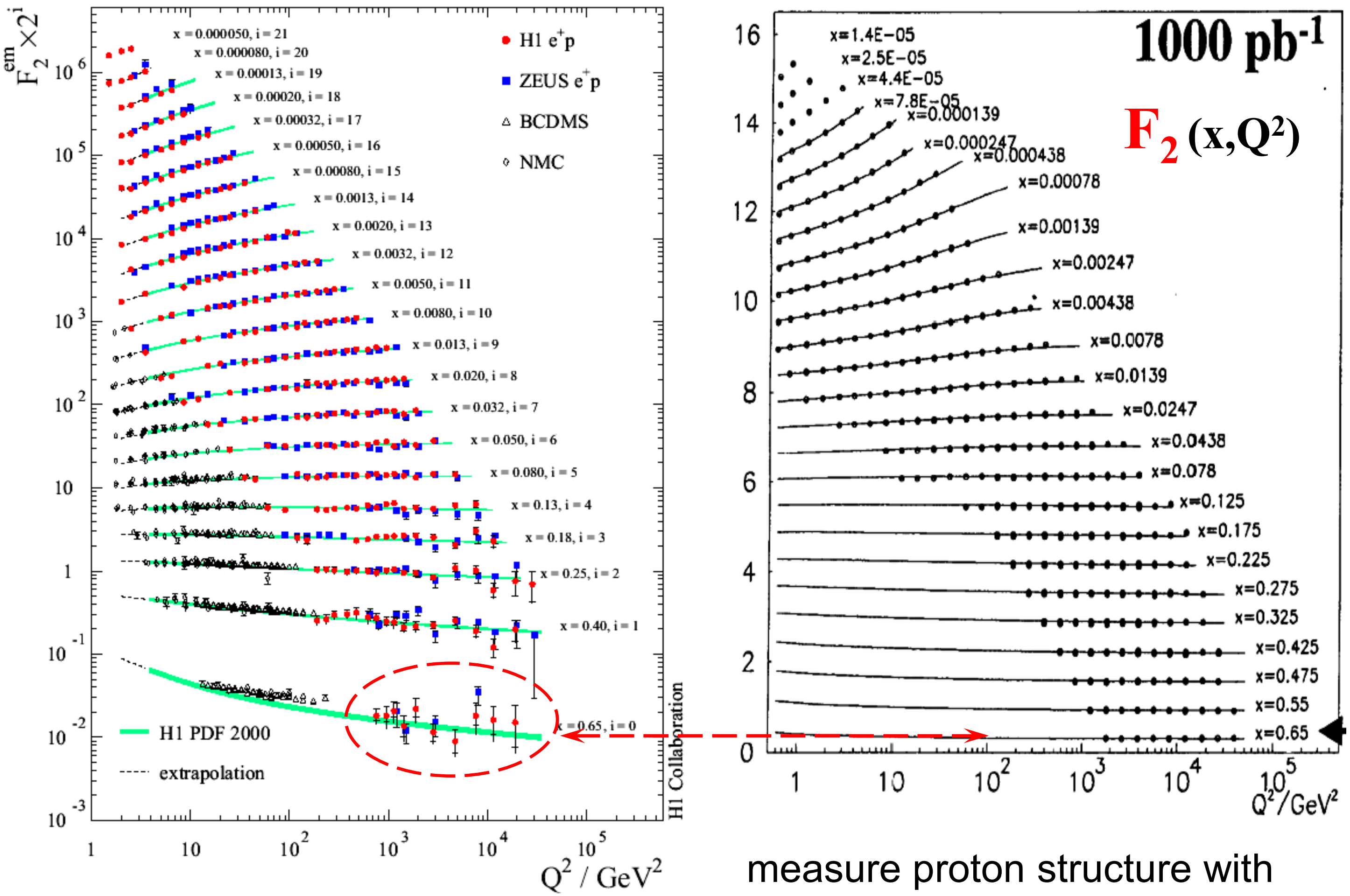
$$F_2^{\gamma,\,\gamma\text{-}Z,\,Z} = x\sum_q (e_q^2,\ 2e_q v_q,\ v_q^2+a_q^2)\ (q+\bar{q})$$

$$xF_3^{\gamma\text{-}Z,\,Z} = 2x\sum_q (\quad e_q a_q,\ v_q a_q)\quad (q-\bar{q}) = 2x\sum_{q=u,d}(e_q a_q, v_q a_q)\ q_v$$

valence quarks

F_2

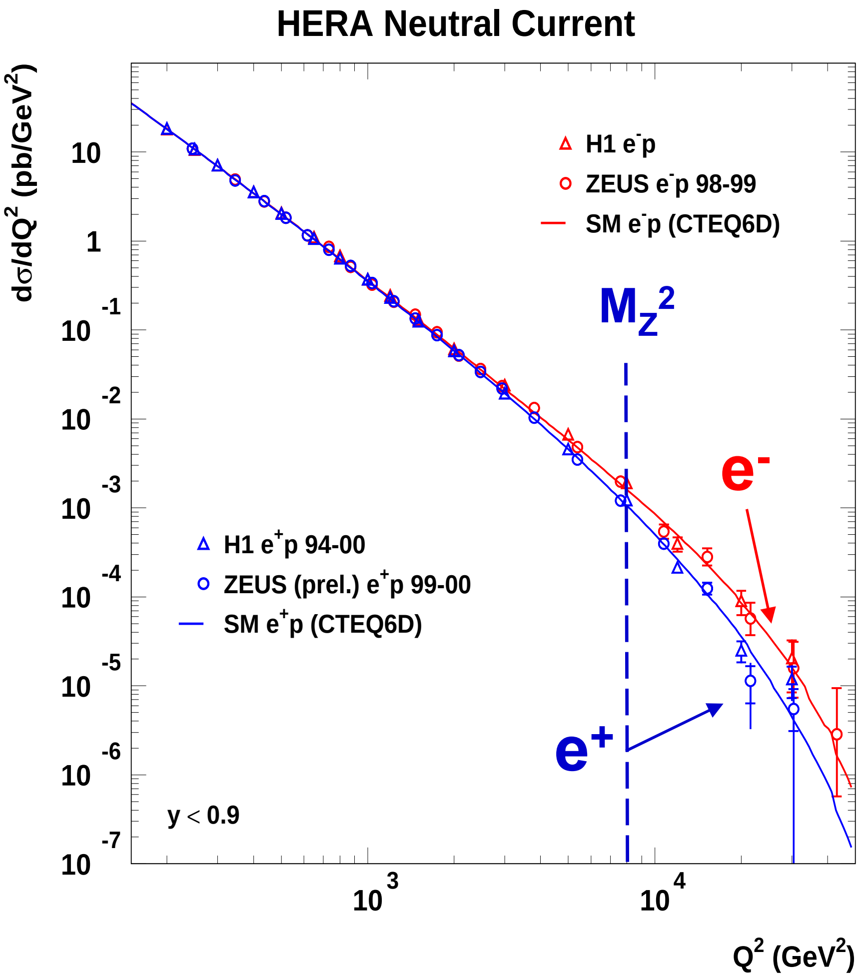
HERA 1 HERA 2



measure proton structure with

fixed target precision at high x + Q^2 !

NC cross section



Standard Model :

describes data over
6 orders of magnitude !

$Q^2 > M_Z^2$:

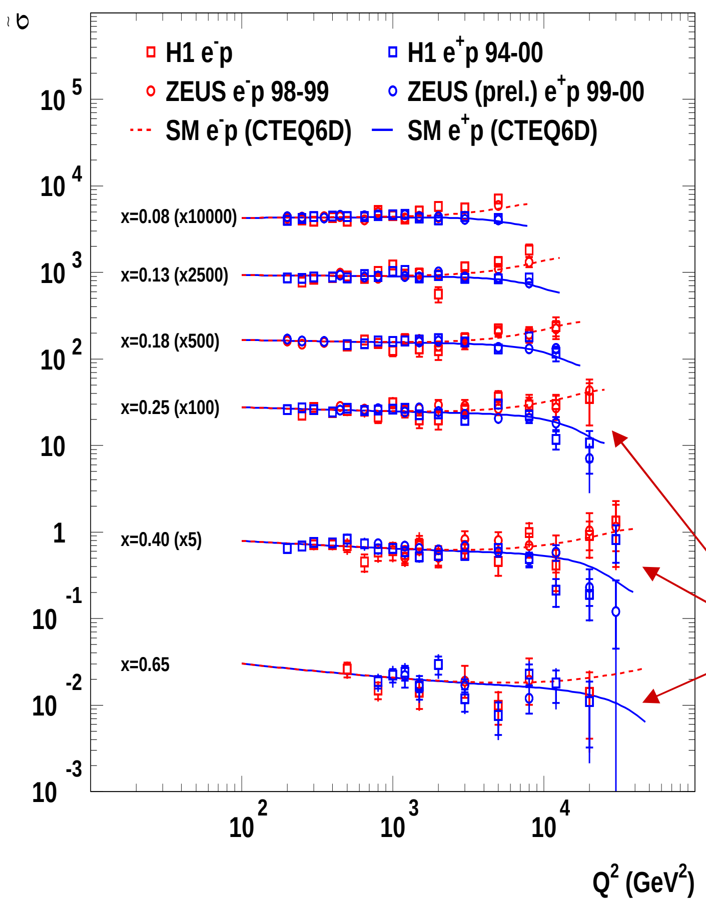
sensitivity to
electro-weak effects :

γ-Z interference:

- constructive for e^-
- destructive for e^+

NC: γ–Z interference

HERA Neutral Current at high x



Reduced cross section:

$$\tilde{\sigma} = \frac{1}{Y_+} \frac{xQ^4}{2\pi\alpha^2} \frac{d^2\sigma}{dx dQ^2}$$

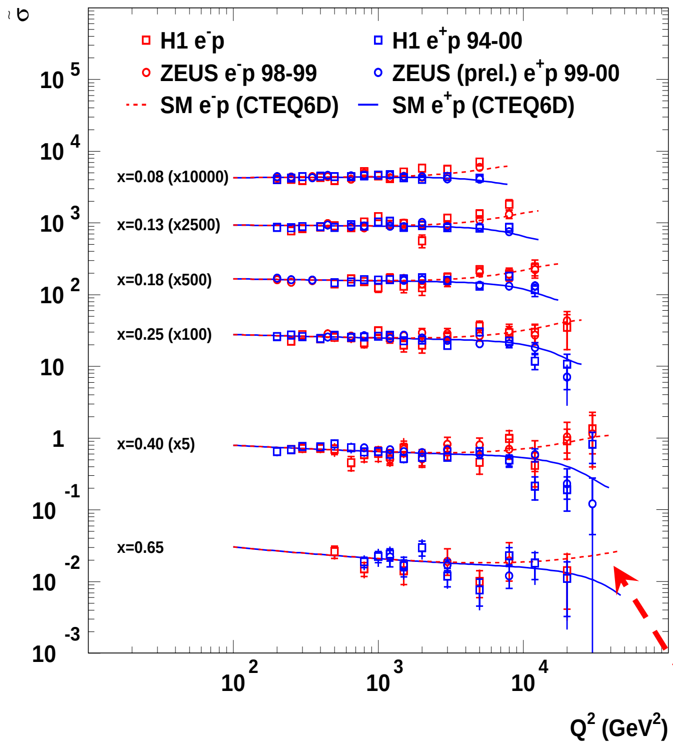
e^- constructive

effect of γ-Z interference

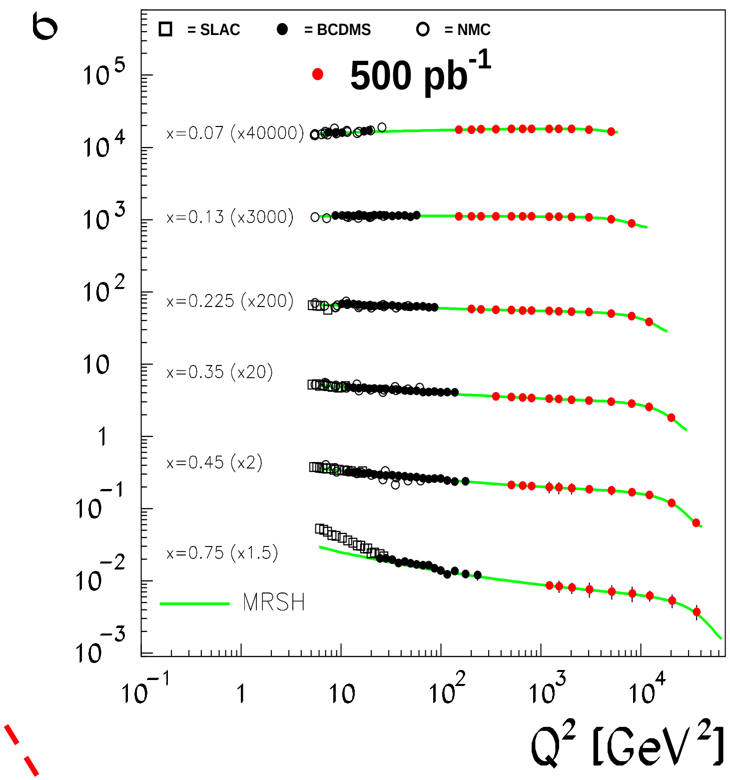
e^+ destructive

NC cross sections

HERA 1



HERA 2



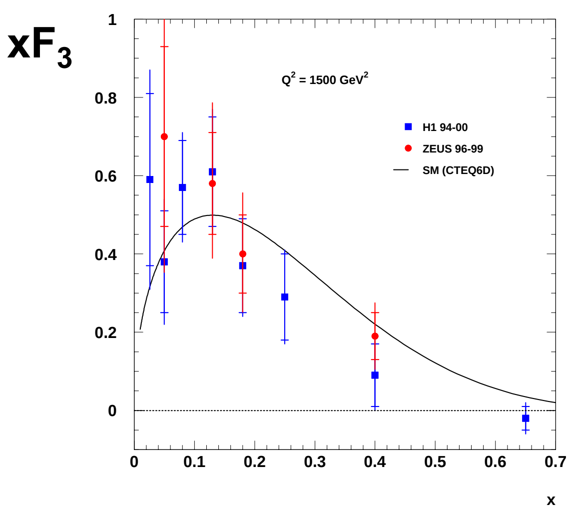
γ-Z interference: e^- constructive / e^+ destructive

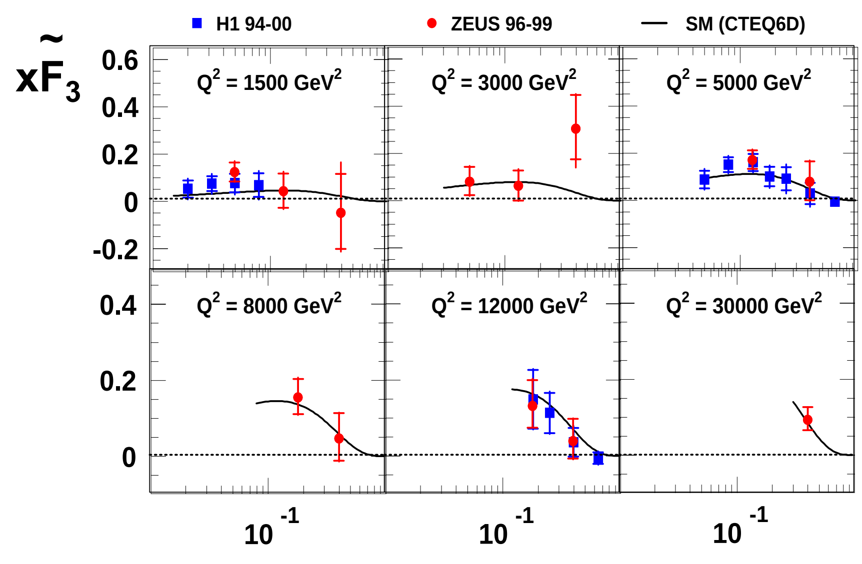
500 pb^{-1}: 10 % cross section error for Q^2 > 16.000 GeV^2

NC: xF_3

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

$$x\tilde{F}_3 = (\tilde{\sigma}^- - \tilde{\sigma}^+)_{NC}\, Y_+/2Y_- = 2x \sum_q e_q a_q\, [q - \bar{q}] \sim q_v$$





direct access to valence quark distribution ! Need lumi : HERA 2 !

NC vs CC

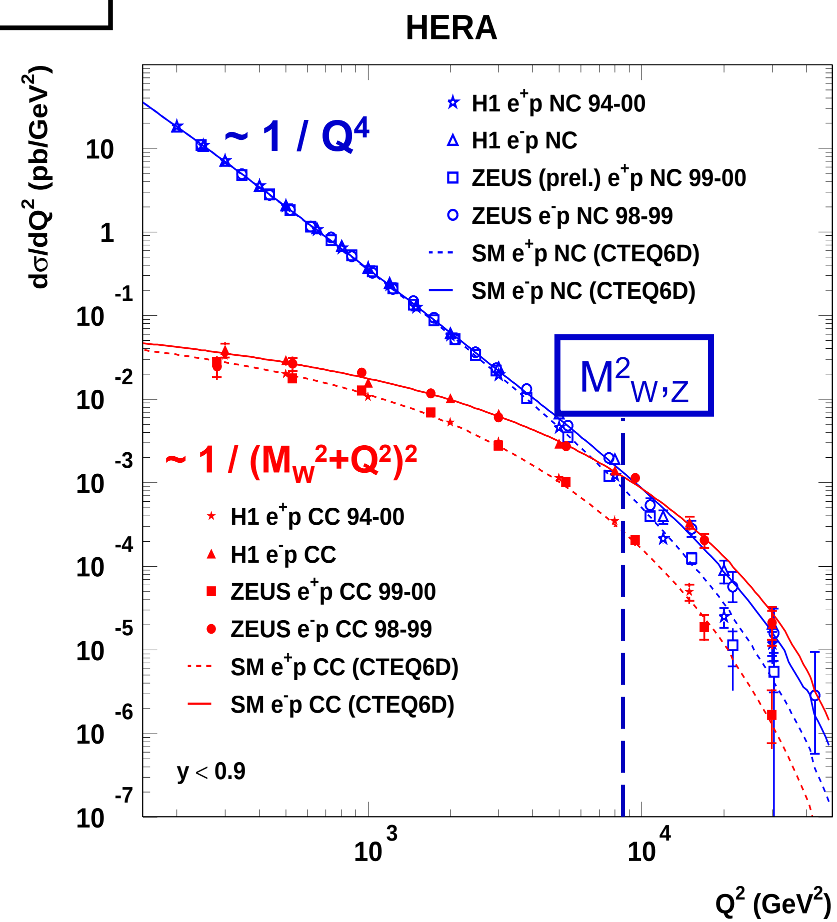
$$\frac{d^2\sigma^{CC}_{e^-p}}{dxdQ^2} = (1-\lambda)\frac{\pi\alpha^2}{8\sin^4\theta_W}\left(\frac{1}{M_W^2+Q^2}\right)^2 F_2^{CC}(x,Q^2)$$

$\lambda = \pm 1$ for left/right handed e

ignore F_L and xF_3

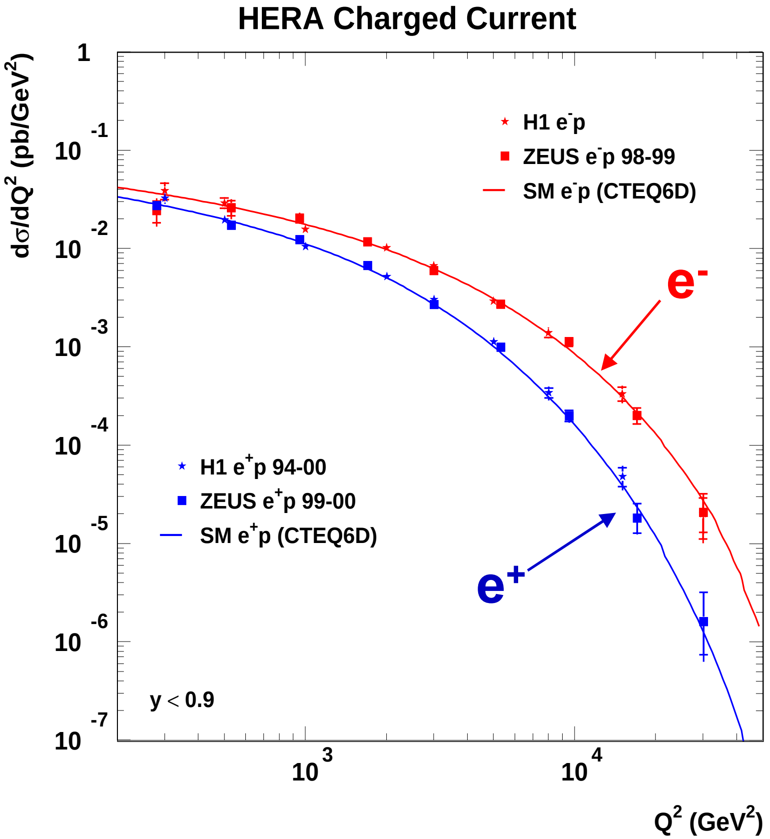
	COUPLING	PROPAGATOR
NC	$2\pi\alpha^2$	$1 / Q^4$
CC	$\pi\alpha^2 / 8 \sin^4\theta_W$	$1 / (Q^2+M_W^2)^2$
	similar since $\sin^2\theta_W \sim 1/4$	similar at $Q^2 > M_W^2$

'Unification' of elm. and weak forces



CC Cross Section

$$\frac{d^2\sigma_{CC}}{dxdQ^2}(e^\pm) = \frac{G_F^2}{4\pi x}\left[\frac{M_W^2}{M_W^2+Q^2}\right]^2 (Y_+F_2^\pm \mp Y_-xF_3^\pm - y^2F_L^\pm)$$



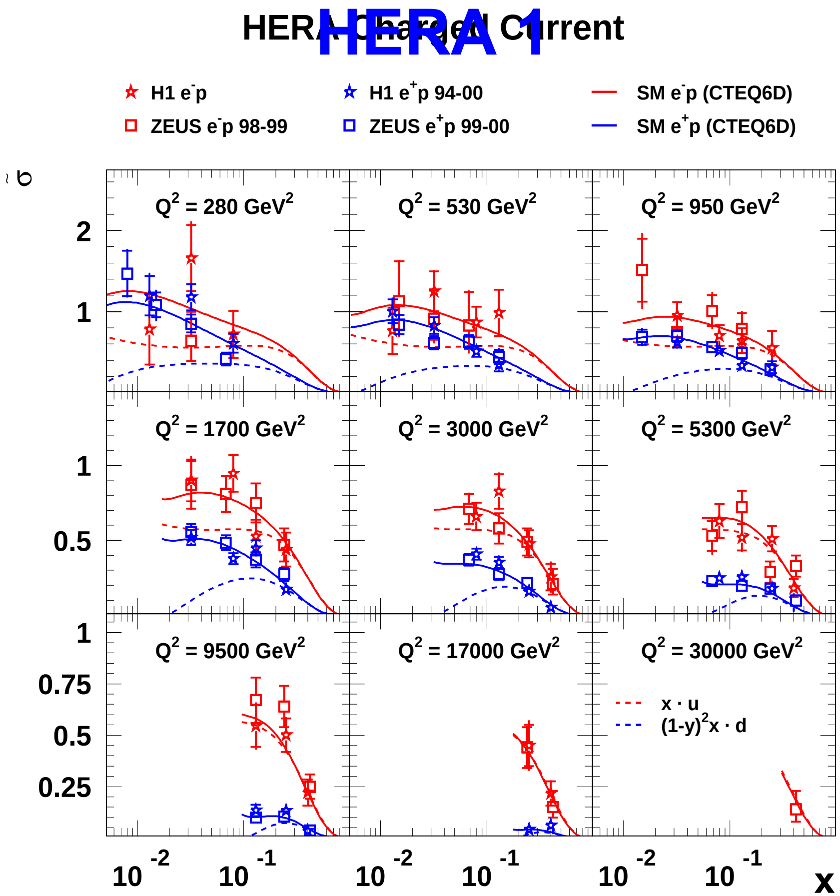
$\sigma\ (e^-p)\ >\ \sigma\ (e^+p)$

--- $\sigma\ (e^-p) \sim x\,(u+c) + (1-y^2)\ \ x\,(\bar{d}+\bar{s})$

--- $\sigma\ (e^+p) \sim x\,(\bar{u}+\bar{c}) + (1-y^2)\ \ x\,(d+s)$

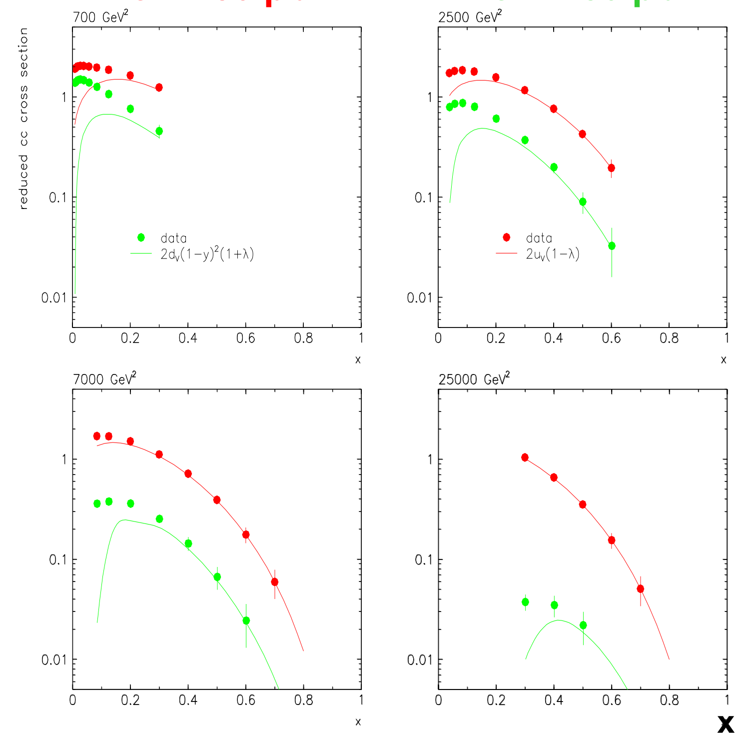
CC Cross Section

HERA 1



HERA 2

e^- 250 pb^{-1} e^+ 250 pb^{-1}



--- $\sigma(e^-p) \sim x\,(u+c) + (1-y^2)\,x\,(\overline{d}+\overline{s})$

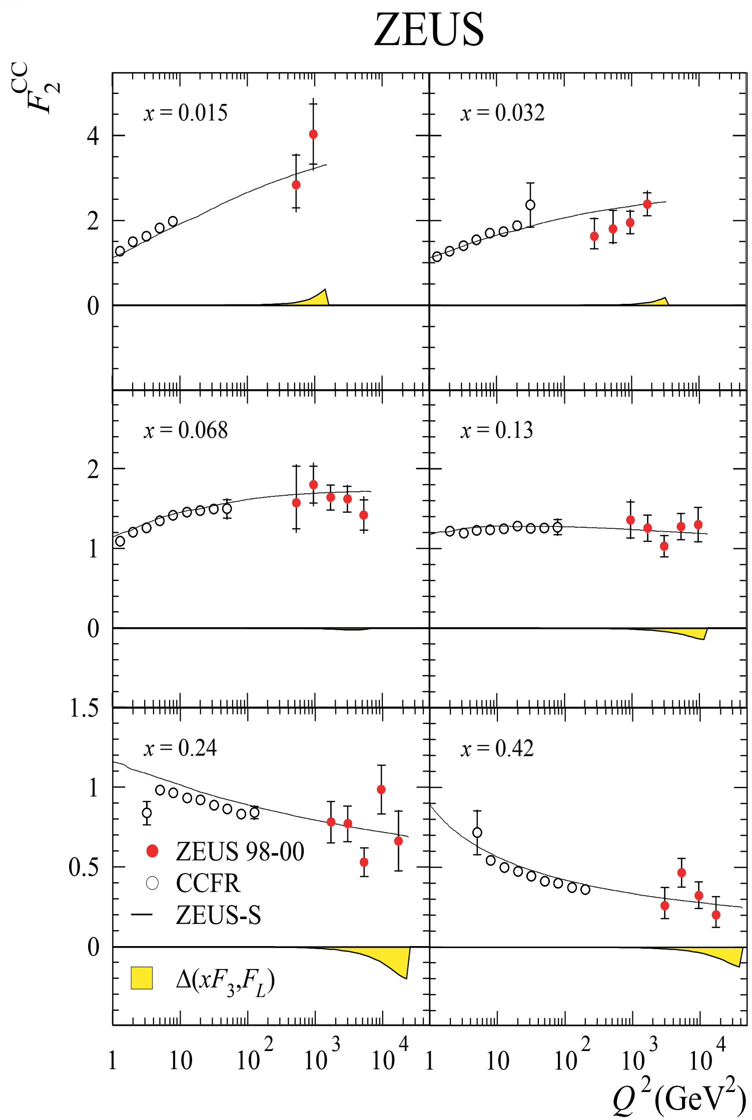
--- $\sigma(e^+p) \sim x\,(\overline{u}+\overline{c}) + (1-y^2)\,x\,(d+s)$

constrain u and d valence quark density at high x and Q^2

need more lumi

HERA 2

F_2^{cc}



CC quark singlet structure function :

$F_2^{cc} = 2 / Y_+ (\sigma^+ + \sigma^-)_{cc} + \Delta(xF_3,F_L)$

see **scaling violations in CC !**

HERA 2 :

reach precision of

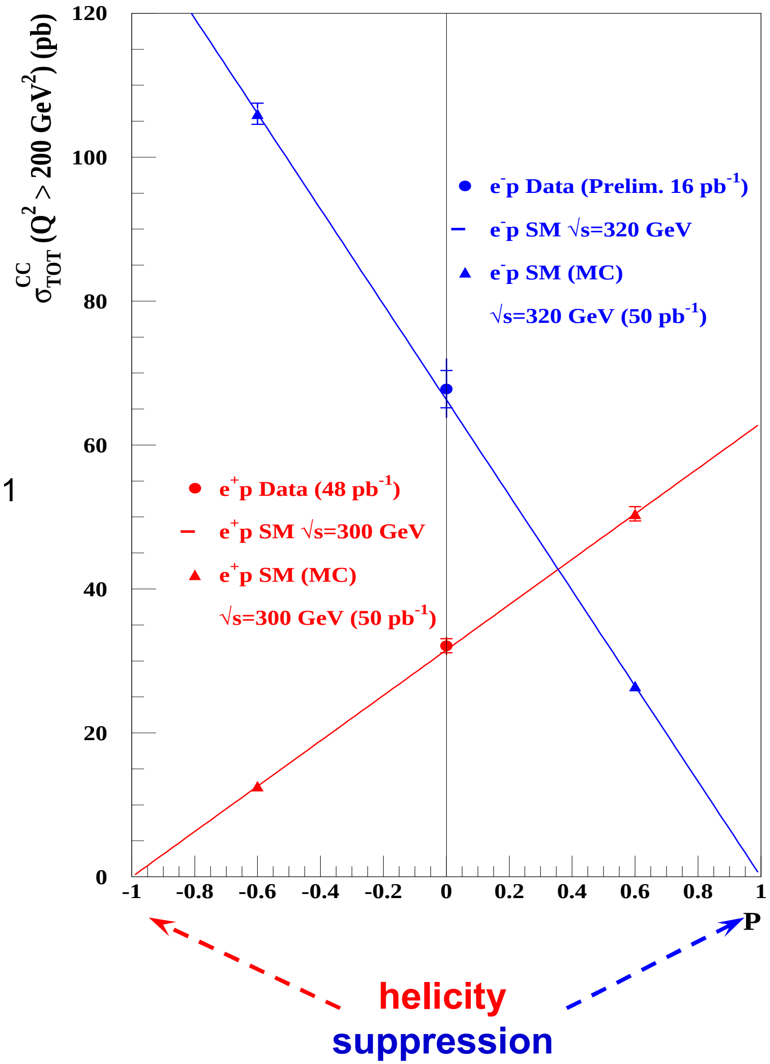
neutrino experiments !

Polarization in CC

- weak interactions violate parity :

$$\sigma_{cc}(\lambda, e^{\pm}) = (1 \pm \lambda)\, \sigma_{cc}(0, e^{\pm})$$

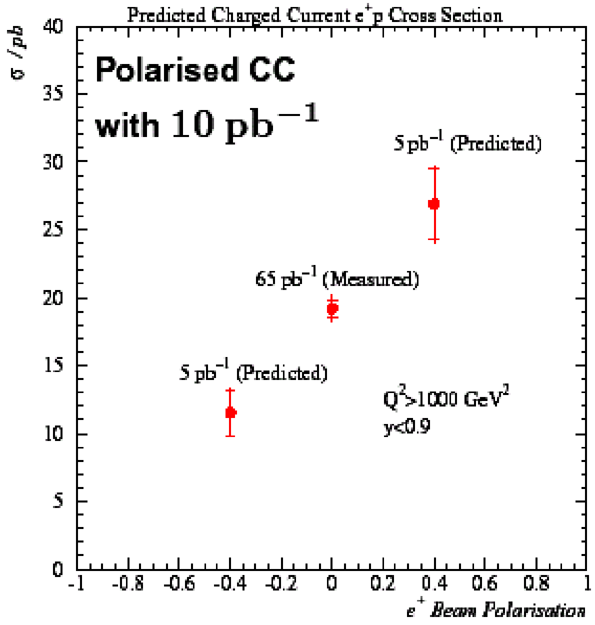
- test chiral structure of SM :
  - λ=1.0: switch CC on / off !
  - λ=0.6: simulate with 4 x 50 pb^{-1}
  - (1+0.6) / (1-0.6) = 4 ± 0.0**?**
- polarization :
  - varies in time -> syst. error
  - as precise as lumi ? 1-2% ?



Polarization

CC cross section

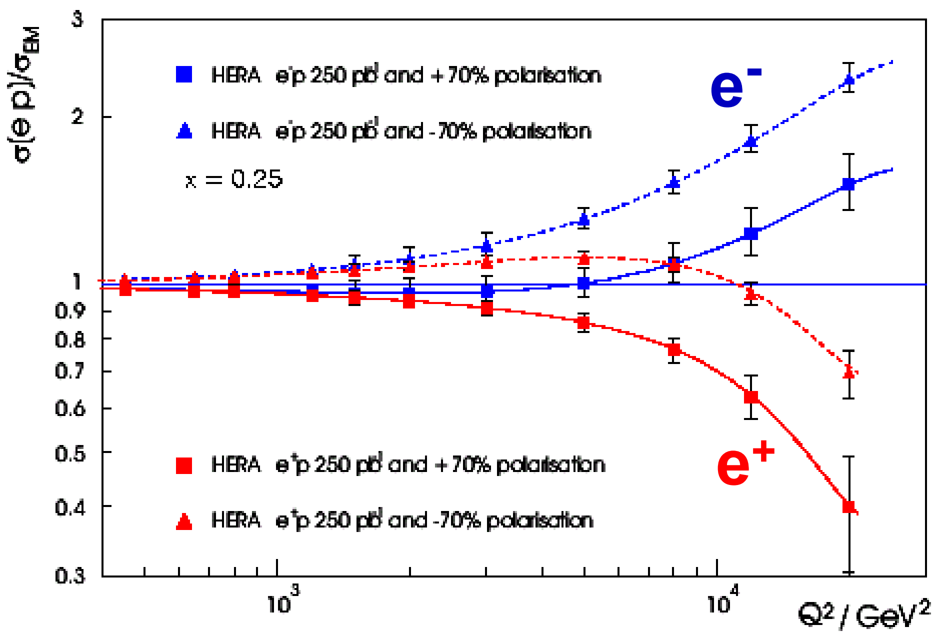
e^- 2 x 5 pb^{-1} $\lambda = \pm 0.4$



try 2003 !?

NC cross section

$e^\pm$ 4 x 250 pb^{-1} $\lambda = \pm 0.7$



NC: xG_2

- "F_2" of γ-Z interference: parity violating

$$\frac{\sigma(\lambda)-\sigma(-\lambda)}{\sigma(\lambda)+\sigma(-\lambda)} \sim \pm\lambda\kappa_Z a_e \frac{G_2}{F_2} \sim \pm\lambda\kappa_Z \frac{1+d/u}{4+d/u}$$

for **NC $e^{\pm}$**

- simulation of 2 x 200 pb^{-1} with $\lambda = \pm\, 0.5$:

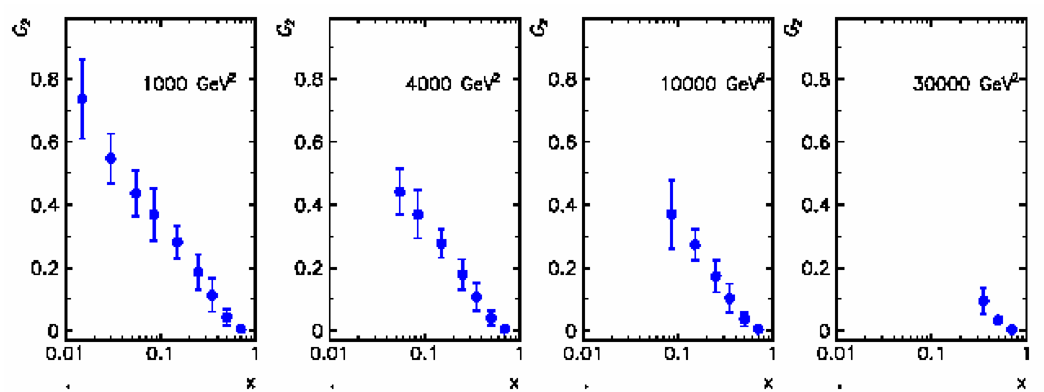
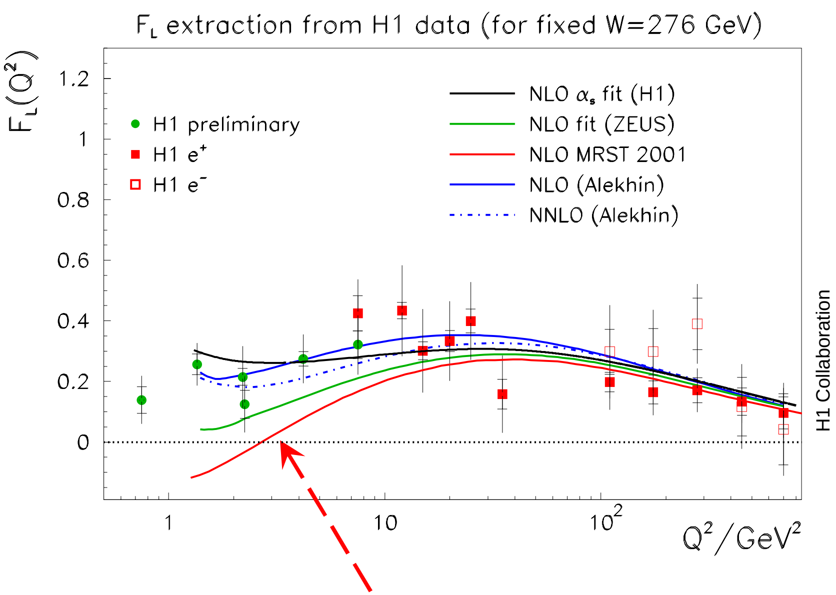


Figure 4: Expected statistical accuracy of the γZ interference structure function G_2 for $P = \pm 0.5$ and 200 pb^{-1} for each polarization. From M. Klein, Proceedings DIS Bologna

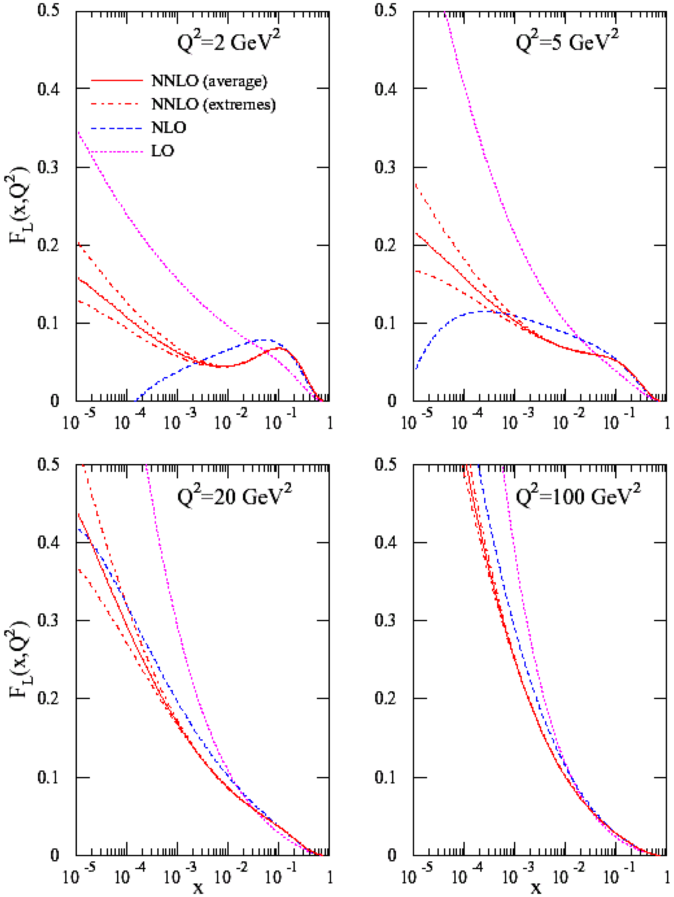
F_L

F_L sensitive to gluon and to theory.

Important measurement + consistency test of QCD !



F_L in LO - NLO - NNLO

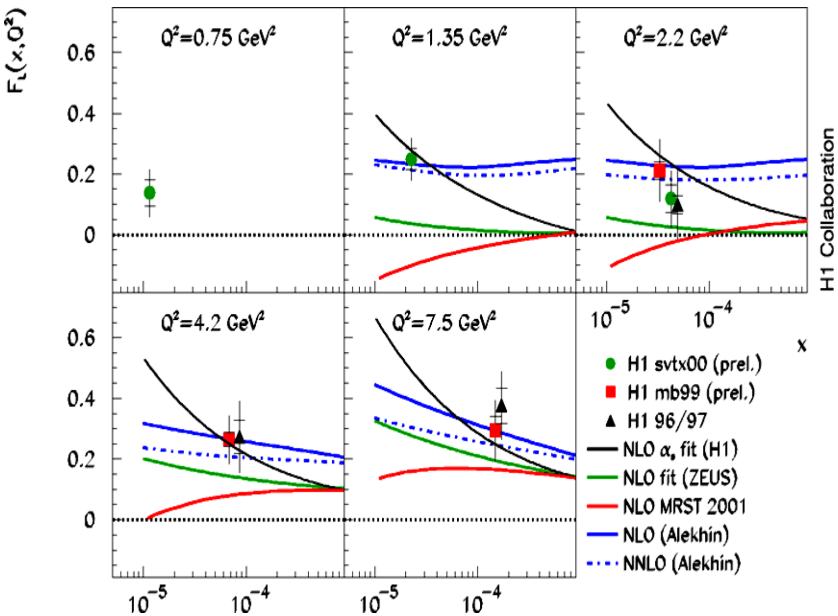


R. Thorne, Lepton-Photon, FNAL 2003

F_L

$$\frac{d^2\sigma}{dxdQ^2} = \frac{4\pi\alpha^2}{xQ^4}(1+(1-y)^2)F_2(x,Q^2) - y^2 F_L(x,Q^2))$$

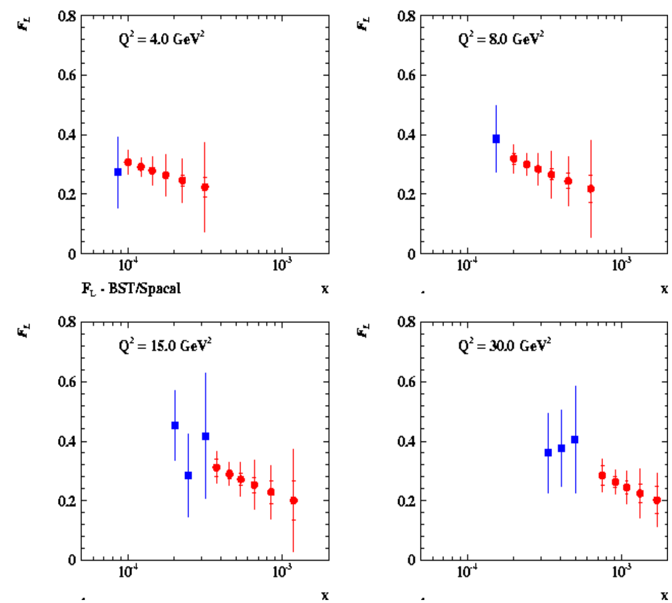
HERA 1: **determine F_L with extrapolation method**



T.Lastovicka, EPS 2003 Aachen

HERA 2: **vary y by varying E_p**

E_p = 300, 350, 465, 920 GeV 10 pb^{-1} each



L.Bauerdick, A.Glazov, M.Klein, HERA Workshop 1996

HERA low energy

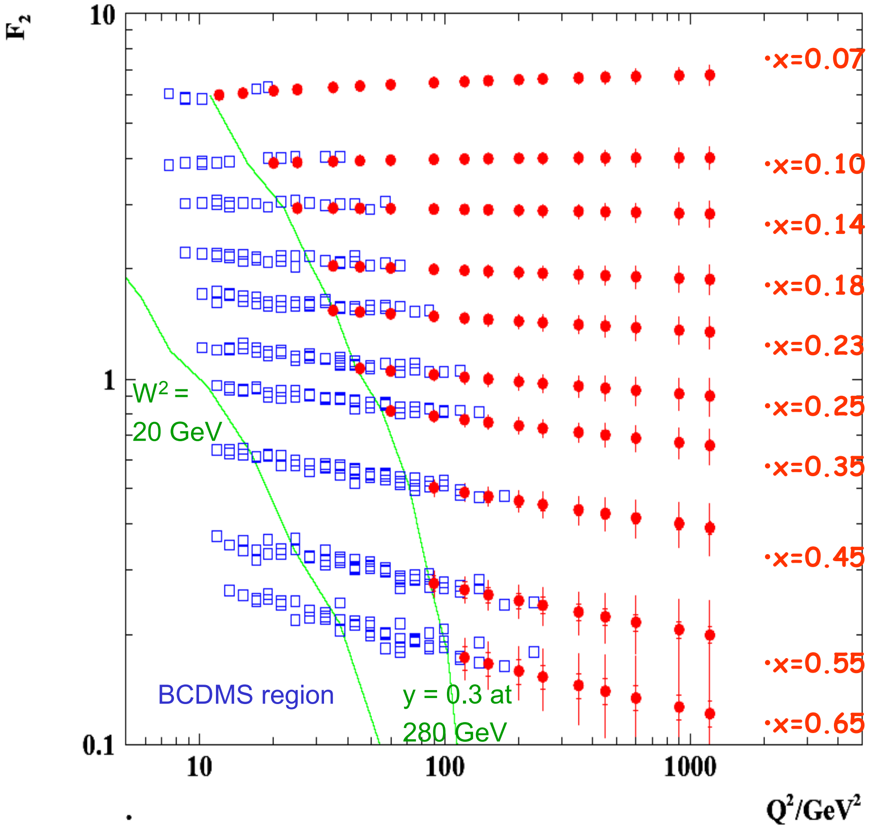
- minimum possible proton energy:

  extend kinematics

  access large x
  at lower Q^2
  overlap with BCDMS

  α_s from one expt. ?

simulation 460 GeV x 27.5 GeV 30 pb^{-1}



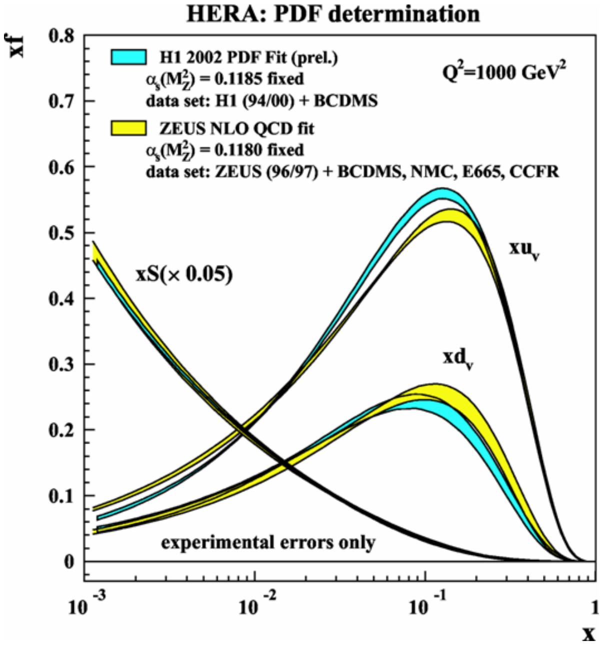
Parton Distribution Functions

DGLAP equations:

$$\frac{dq_i(x,Q^2)}{d\ln Q^2} = \frac{\alpha_S(Q^2)}{2\pi}\int_x^1 \frac{dz}{z}\left[q_i(z,Q^2)P_{qq}\left(\frac{x}{z}\right) + g(z,Q^2)P_{qg}\left(\frac{x}{z}\right)\right]$$

$$\frac{dg(x,Q^2)}{d\ln Q^2} = \frac{\alpha_S(Q^2)}{2\pi}\int_x^1 \frac{dz}{z}\left[\sum_i (q_i(z,Q^2)+\overline{q_i}(z,Q^2))P_{gq}\left(\frac{x}{z}\right)+g(z,Q^2)P_{gg}\left(\frac{x}{z}\right)\right]$$

- needed to understand new physics !
- valence quarks : % precision
- problem: **gluon** !



Parton Distribution Functions

needed to **understand new physics, e.g. at LHC !**

QCD fits to structure functions :

$F_2 \sim 4/9\,(U+\bar{U}) + 1/9\,(D+\bar{D})$

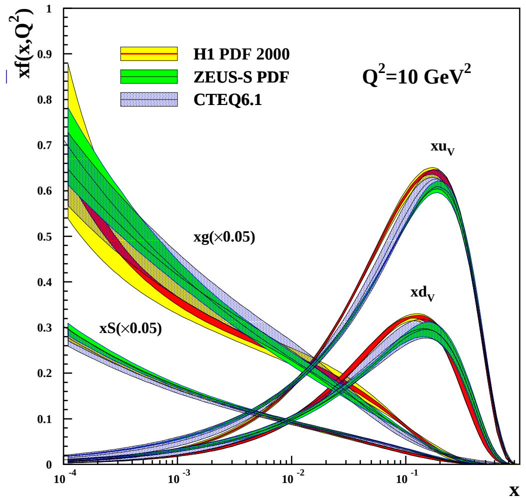
with

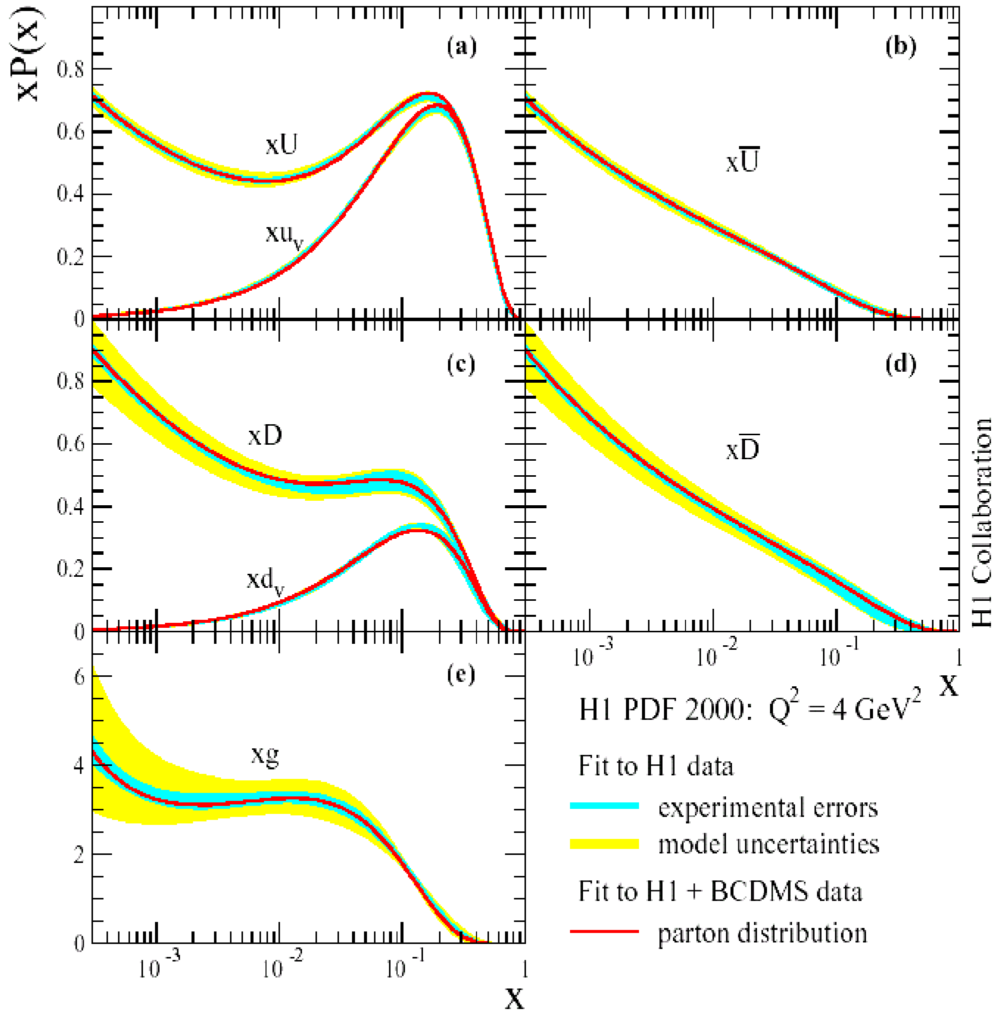
$xF_3 \sim \quad 2\,(U-\bar{U}) + \quad (D-\bar{D})$

$\bar{D} = \bar{d}+\bar{s} \qquad \bar{U} = \bar{u}+\bar{c}$

$U = u+c \qquad D = d+s$

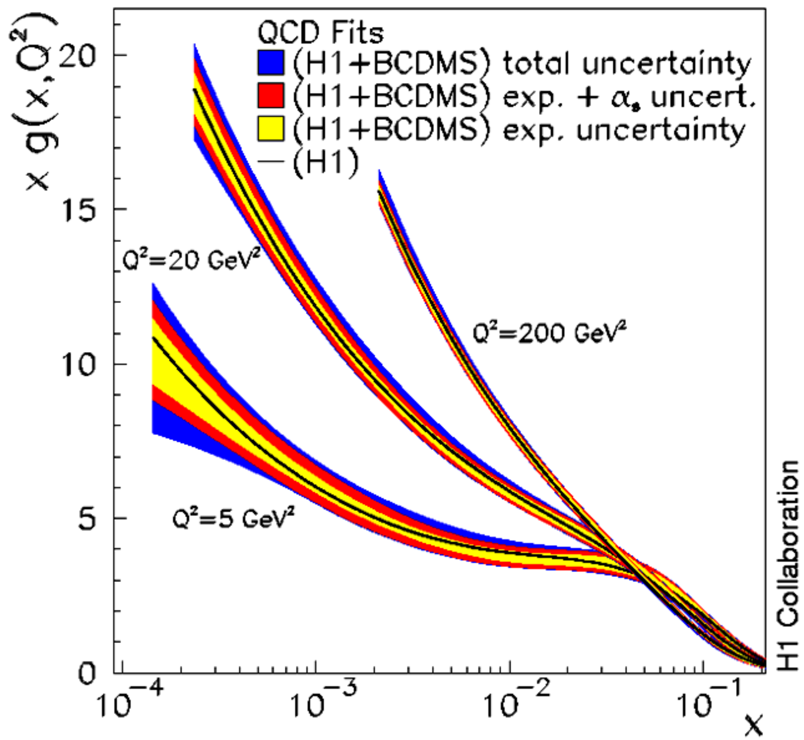
% precision except for **gluon :**



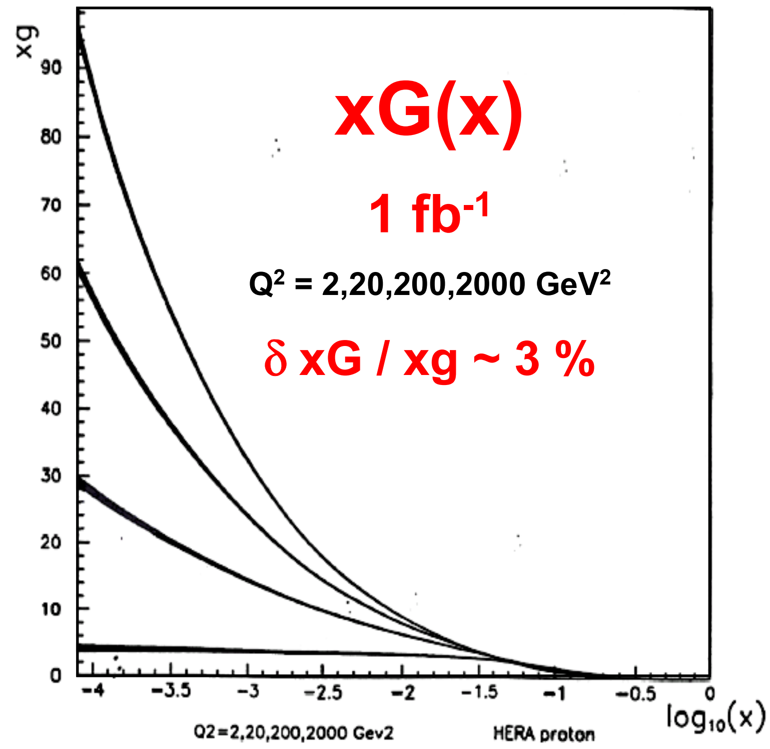


Gluon

HERA 1



HERA 2



systematics fitted

M.Botje, M.Klein, C.Pascaud, HERA Workshop 1995

$\alpha_s\,(Q^2)$

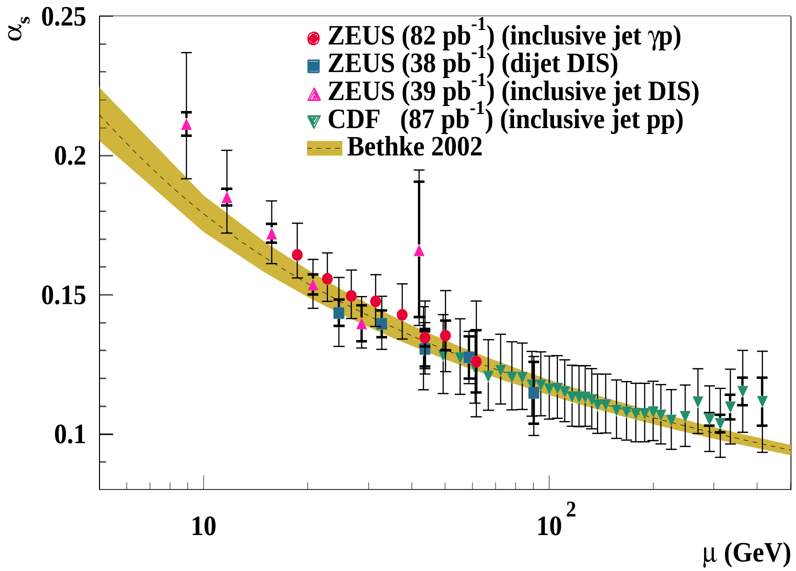
- QCD fit of F_2 scaling violations :

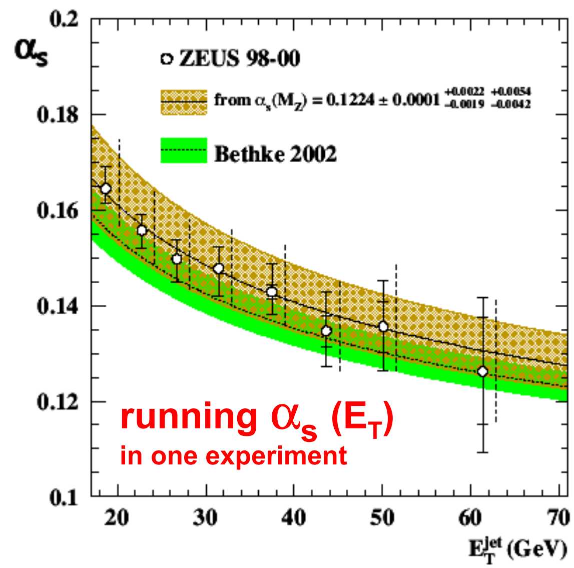
  $\alpha_s = 0.1150 \pm 0.0019$ (expt+fit) ± 0.0050 (scale) **H1**

  $\alpha_s = 0.1166 \pm 0.0052$ (expt+fit) ± 0.0040 (scale) **ZEUS**

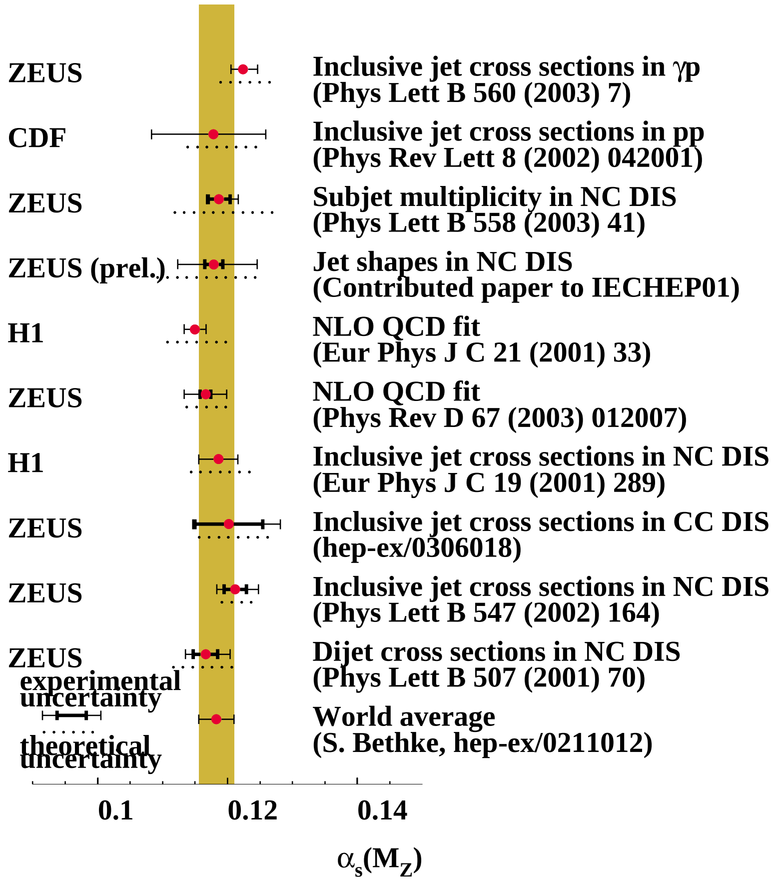
- Jet cross sections: 1, 2, 3 jets

  $\alpha_s = 0.1224 \pm 0.002$ (exp) ± 0.004-5 (theory)





α_s at HERA

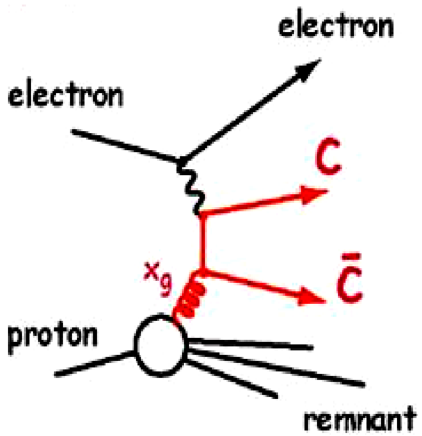


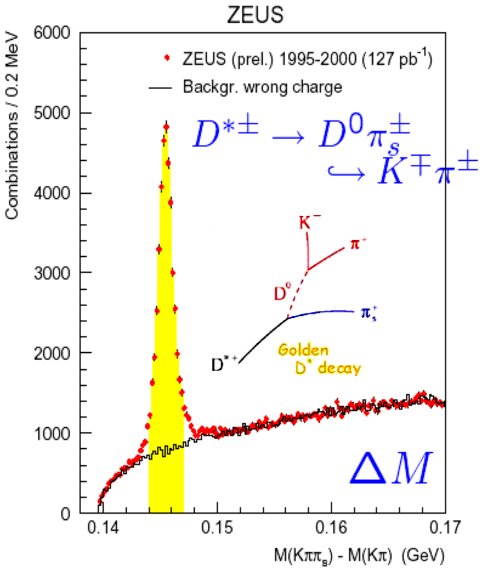
$\delta\ \alpha_s$	HERA 1	HERA 2
experiment	0.002	0.001
theory	0.005	0.00**?**

precision limited by **theory :**

NNLO non-singlet expected for 2003
NNLO singlet + gluon 2004

HERA's Charm and Beauty





F_2^c / F_2

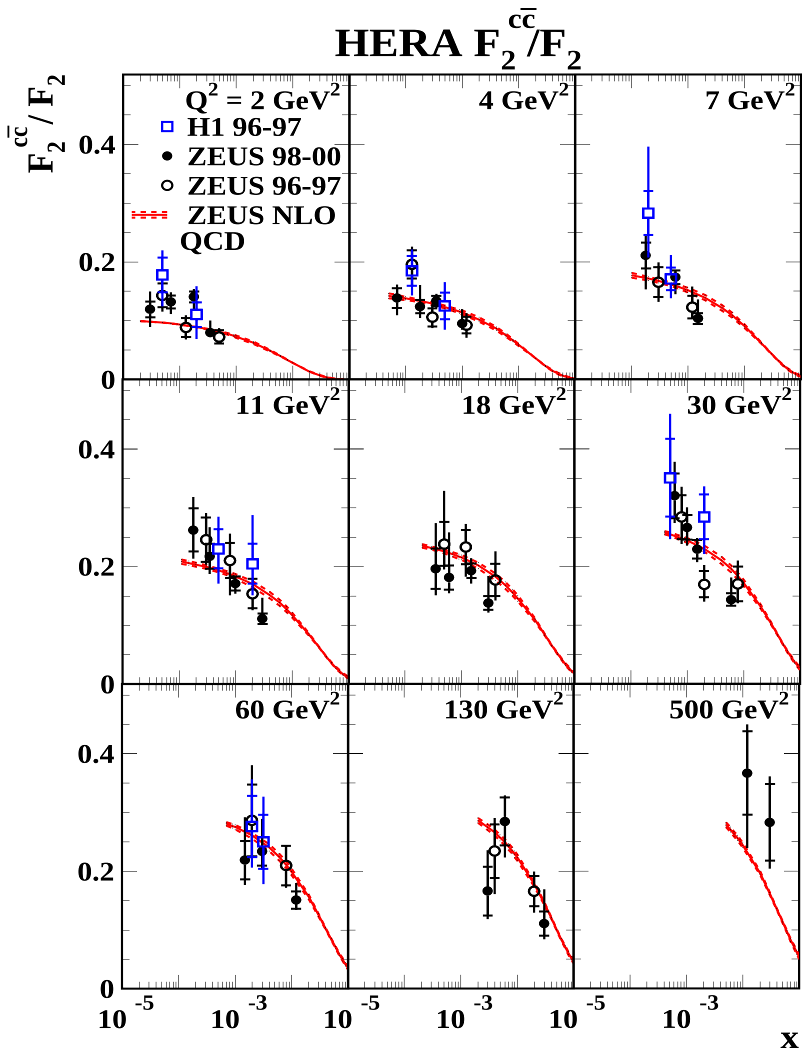
charm fraction

in the proton

F_2^c / F_2

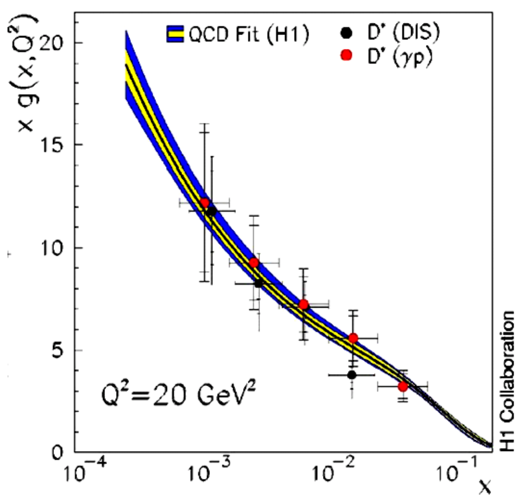
at high Q^2

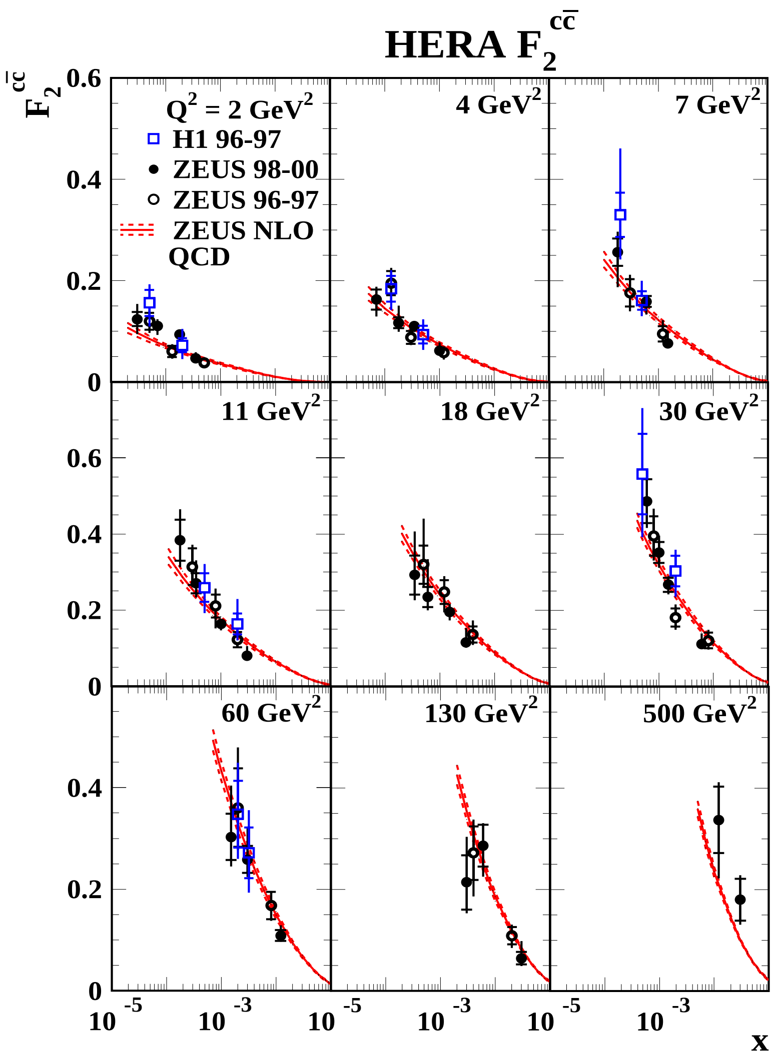
reaches 30-40% :



F_2^c

- use **D*→D** π to tag charm
- **F_2^c** agrees with prediction based on xg(x) from F_2 QCD fits
- and vice versa :

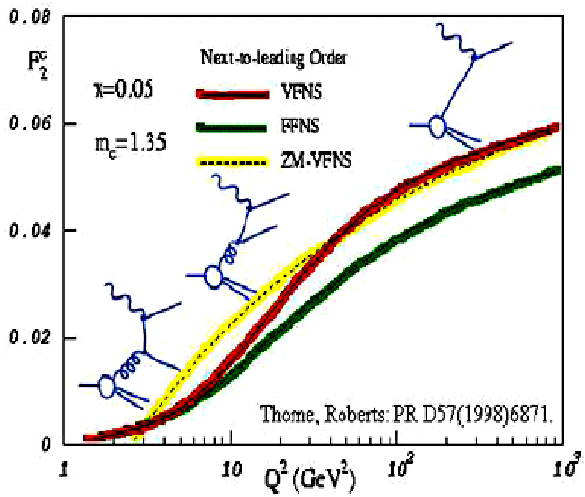




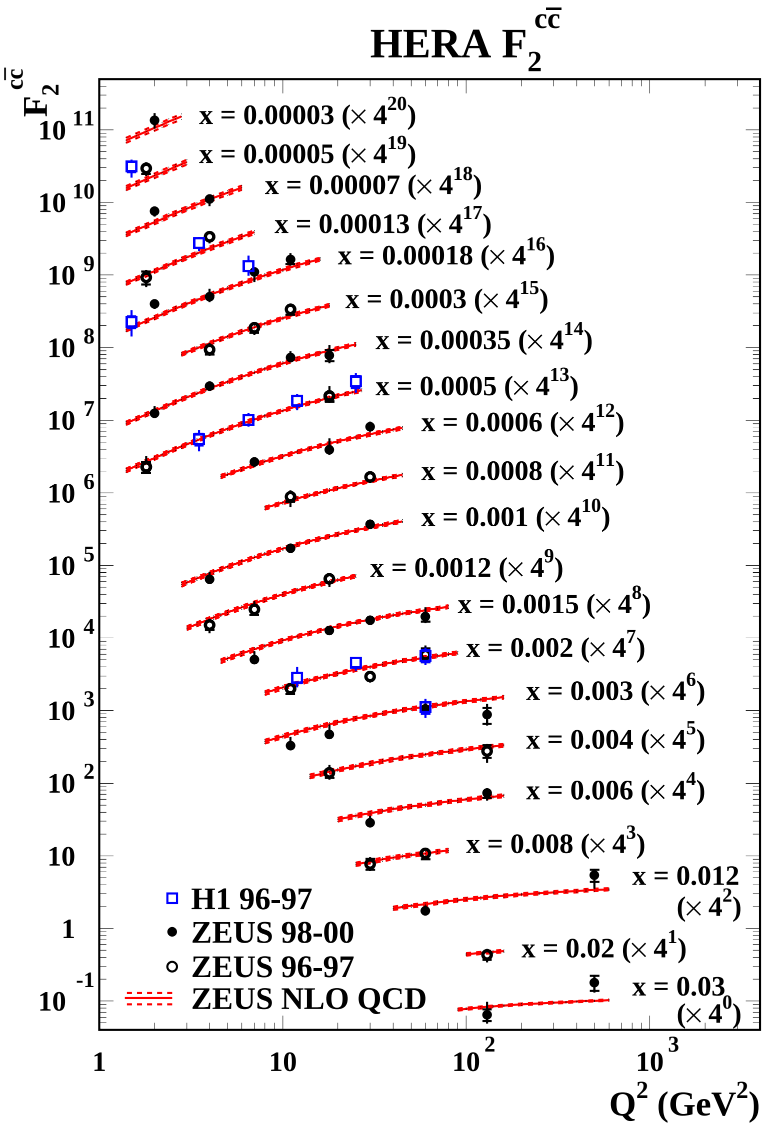
- important consistency check
- improve statistics + systematics

$F_2^c(Q^2)$

do we understand
how to pass the
charm threshold in NLO :



match fixed order scheme
at $p_T \leq m_Q$ with massless
NLL resummations (Frixione, …)



HERA 2 : F_2^c

HERA 1 :

- measure in limited phase space :

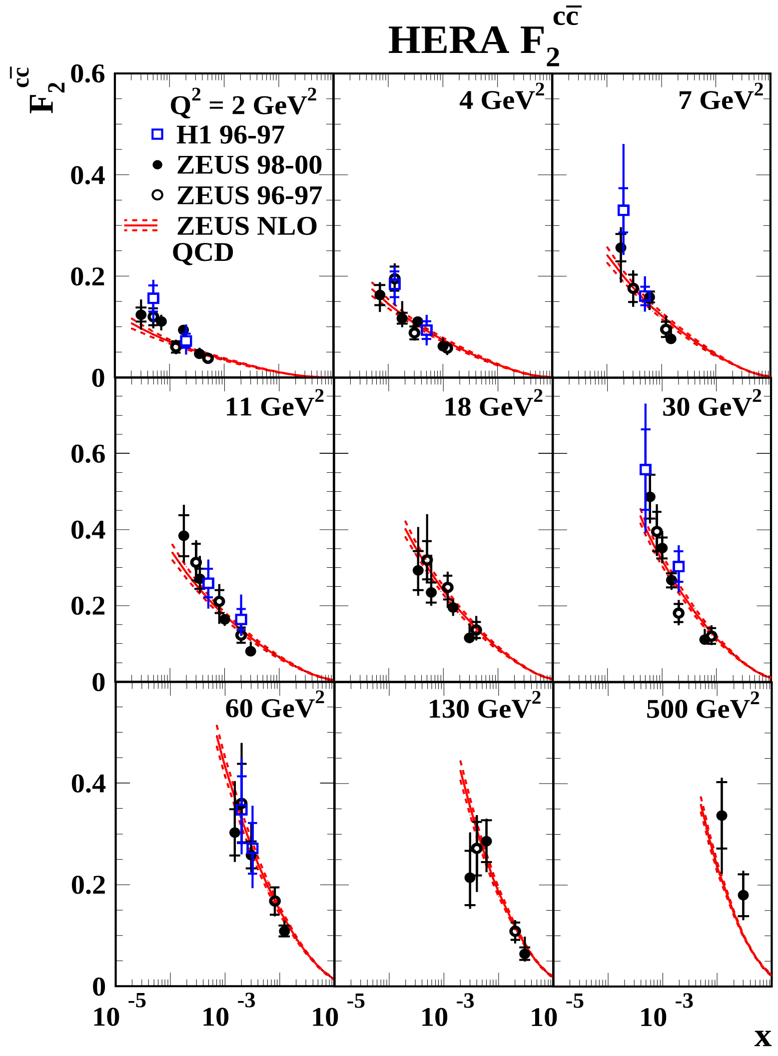
  $1.5 < p_T(D^*) < 15$ GeV

  $|\eta(D^*)| < 1.5$

HERA 2 : H1 + ZEUS

new Si detectors + forward trackers

- kinematic range extended by ±1 unit in η
- open new decay channels
- and more lumi …



HERA 2 : F_2^c

HERA 2 : H1+ZEUS

new Si detectors + forward trackers

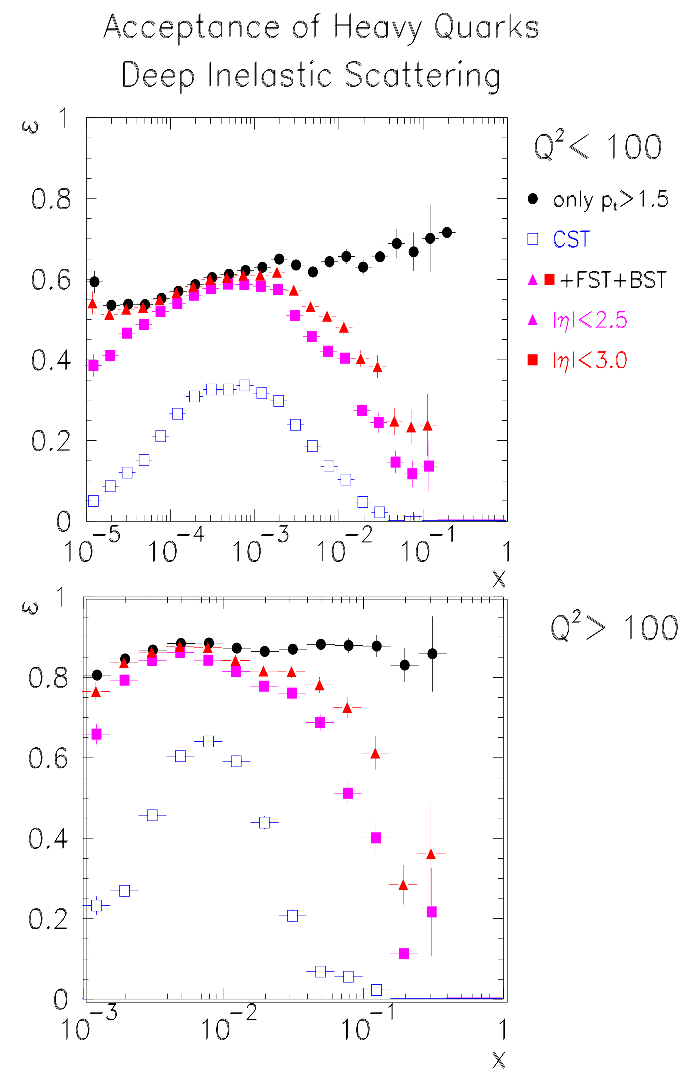
- extend kinematic range

  by ±1 unit in η :

  smaller extrapolation errors

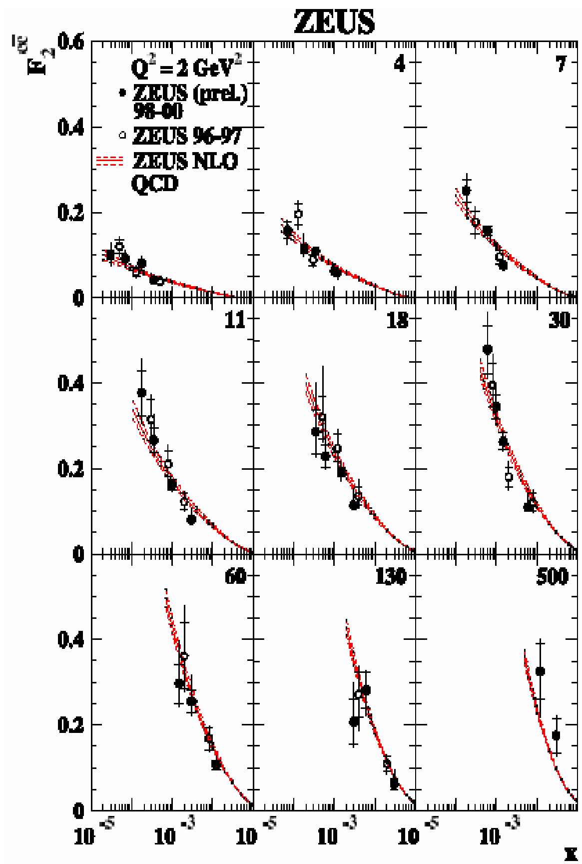
  less model dependence

- open new decay channels

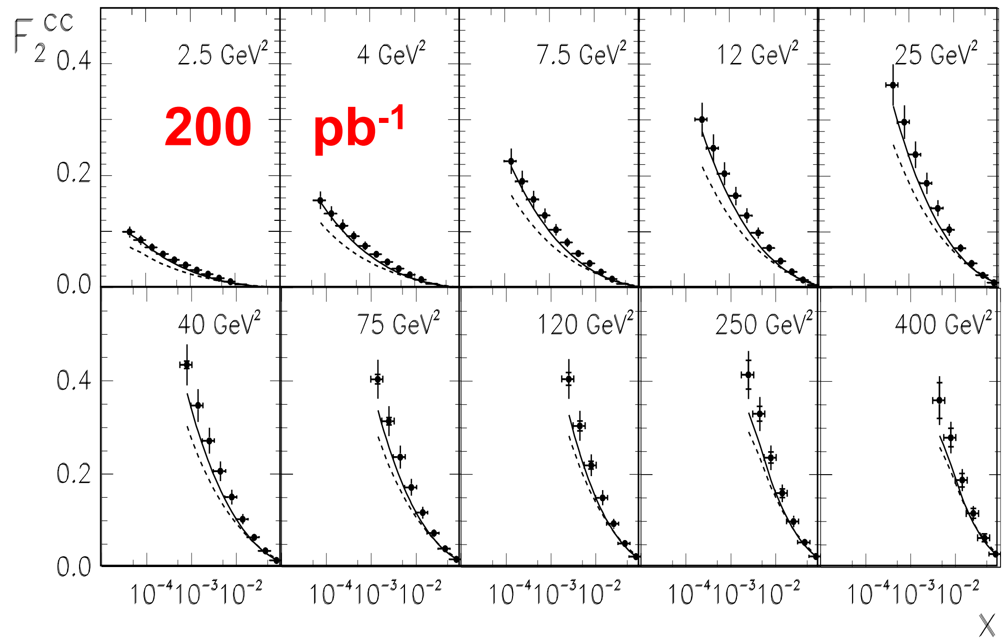


HERA 2 : F_2^c

HERA 1

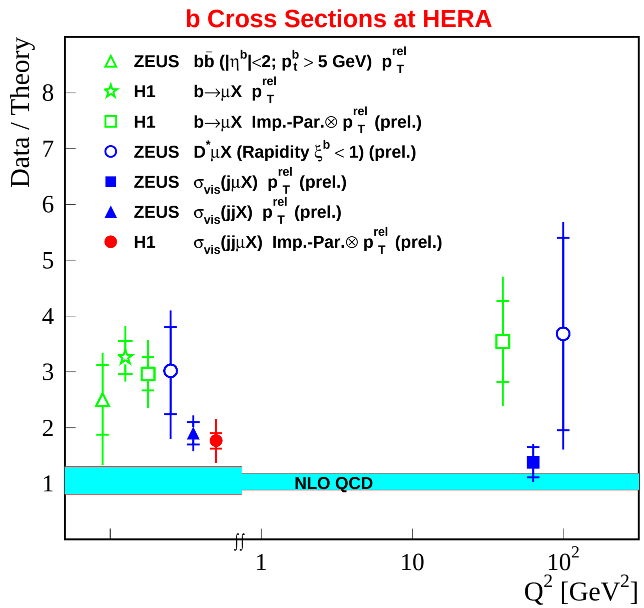


HERA 2



K.Daum, hep-ex/9708009

Beauty cross section

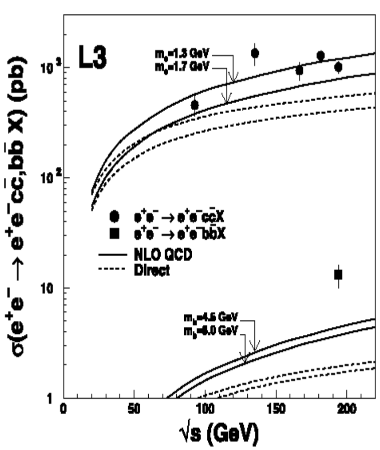


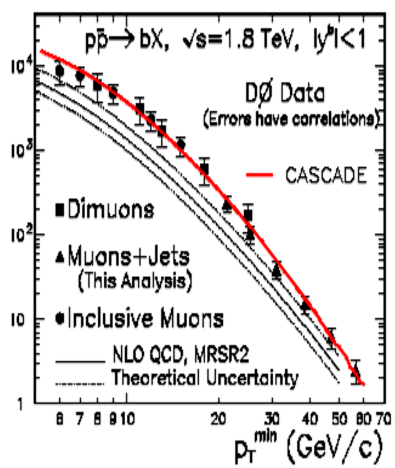
HERA 1 :

- b excess seen in all experiments
- c excess also at high pt
- still large errors

HERA 2 :

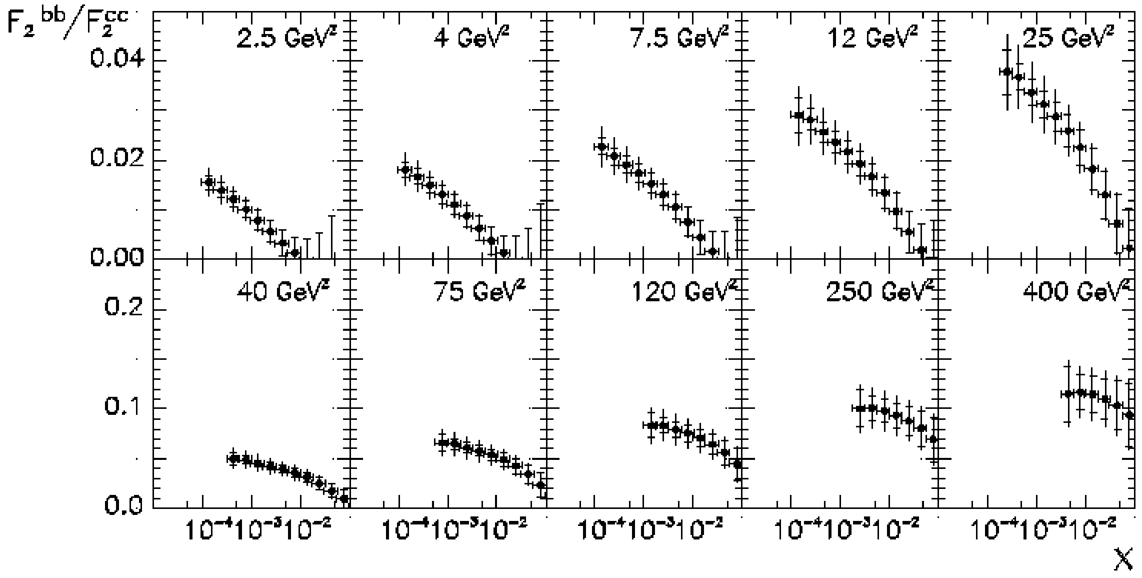
- high lumi
- vertex tagging over larger kine. range
  smaller extrapolation errors
- theory: need full NLO
  heavy flavor Monte Carlo's
  fragmentation treatment





F_2^b / F_2^c

HERA 2 : simulate F_2^b / F_2^c with 500 pb^{-1}

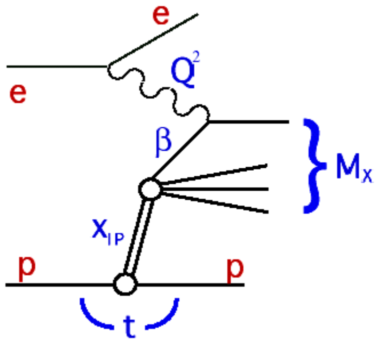


K.Daum, hep-ex/9708009

b/c ~ 10% at Q^2 = 400 GeV^2 b/c → 25% at $Q^2 >> m_b^2$

DIS Diffraction

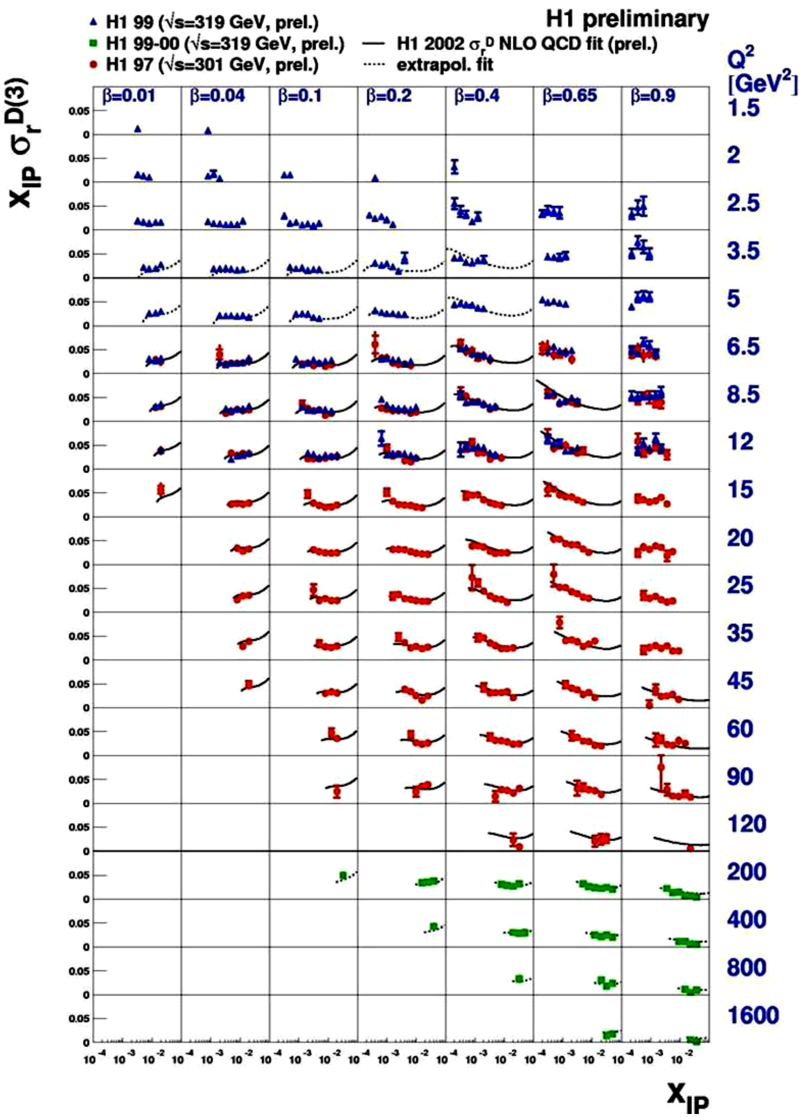
get parton structure of diffractive exchange :



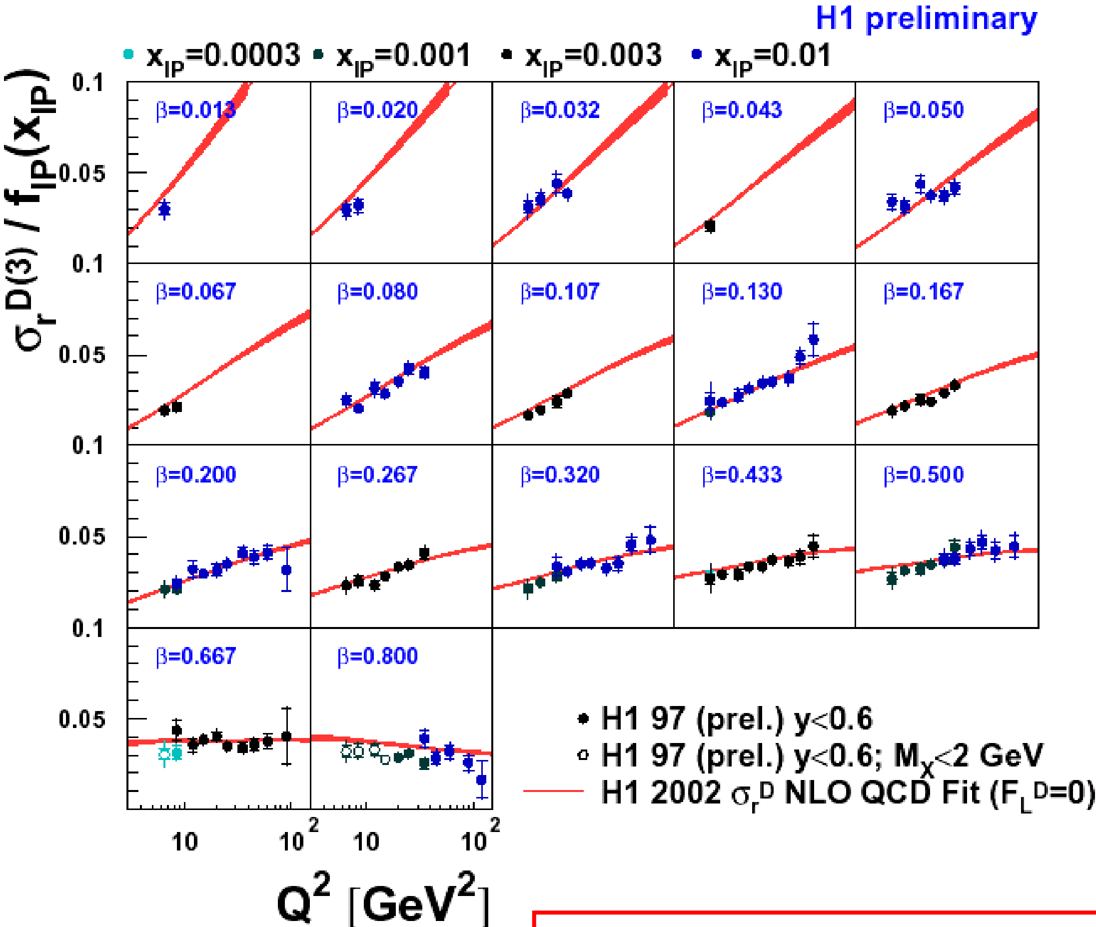
$F_2^D(t, \beta, x_{IP}, Q^2)$

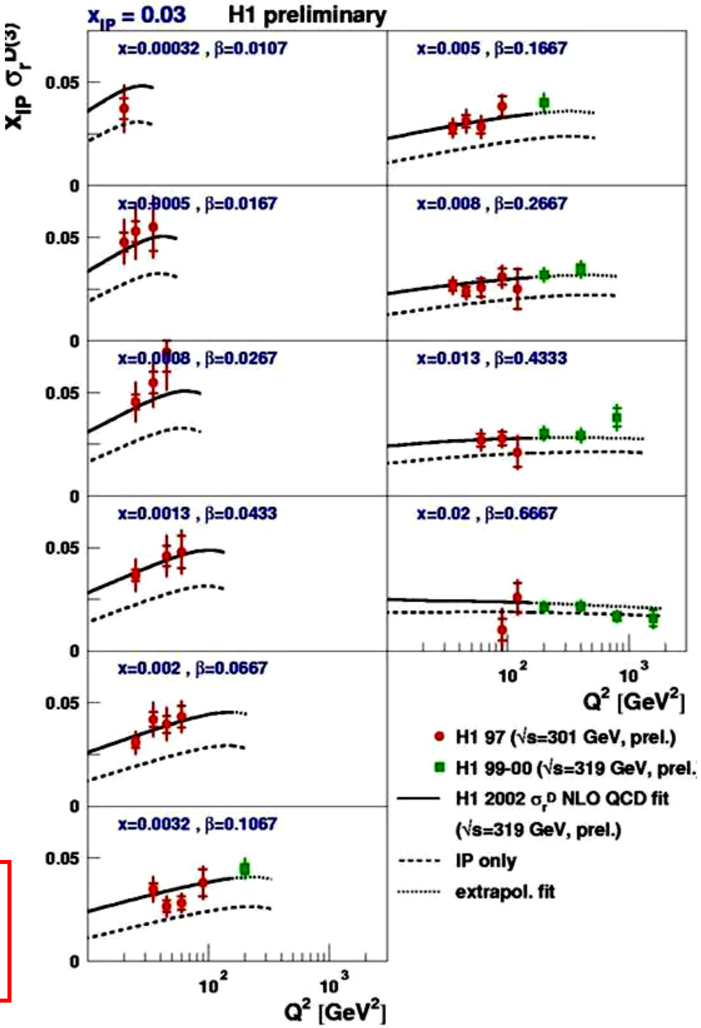
$F_2^{D(3)}$ now covers 4 orders of magnitude in Q^2

QCD fit for diffractive parton densities describes data well



DIS Diffraction





positive scaling violations
up to large β

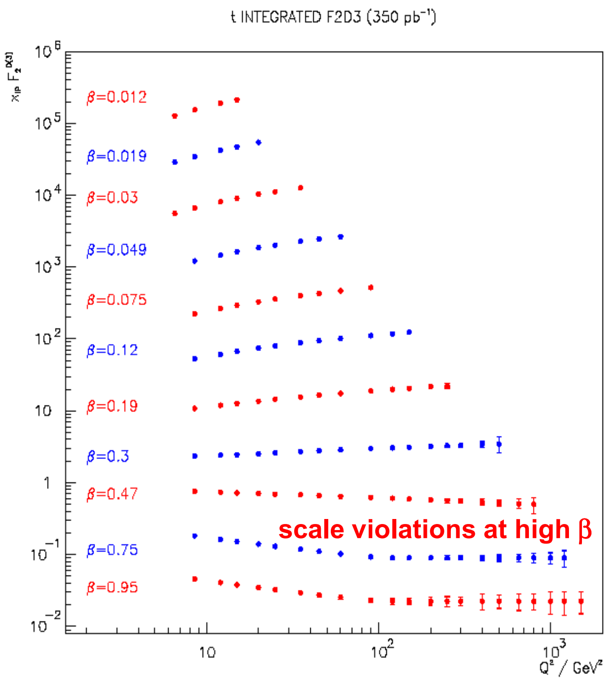
Diffraction: H1 VFPS

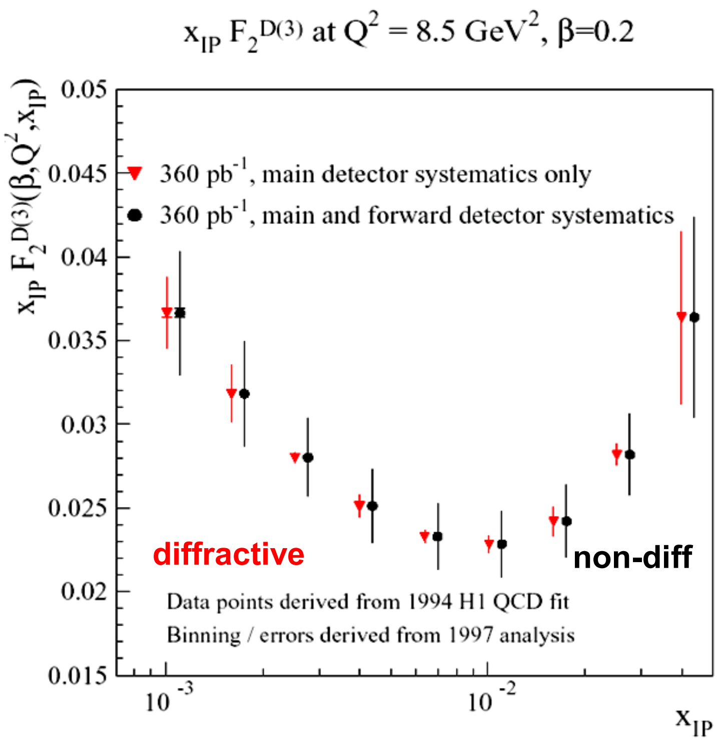
HERA 2

H1 VFPS at z = 220 m

simulation for 350 pb^{-1}

- increase acceptance hor. FPS→VFPS 1%→50%
- σ^D for x_{IP}=0.017 integrated over |t|< 0.8 GeV^2
- measure x = β x_{IP} and Q^2 in central detector





Diffraction

- exclusive final states **statistics** limited
- get high statistics for all proton **elastics**:

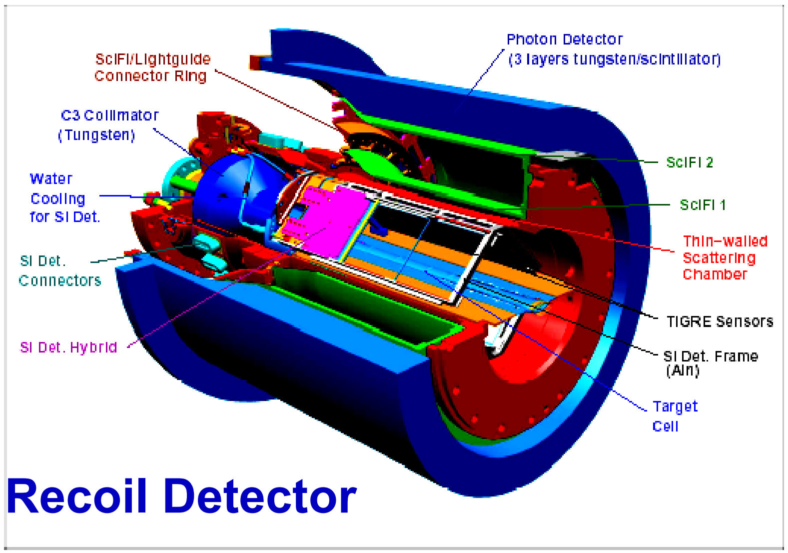
PROCESS	HERA-1 ($100\,\mathrm{pb}^{-1}$)	HERA-2 ($1\,\mathrm{fb}^{-1}$)
Elastic ρ^0 ($Q^2 > 20\,\mathrm{GeV}^2$)	1000	10000
Elastic ϕ ($Q^2 > 20\,\mathrm{GeV}^2$)	125	1250
Elastic J/ψ ($Q^2 > 20\,\mathrm{GeV}^2$)	140	1400
Elastic Υ (all Q^2)	50	500
Diffractive D^* ($Q^2 > 10\,\mathrm{GeV}^2$)	100 (H1)	1000

HERMES

$$\underbrace{\frac{1}{2} = \overbrace{\frac{1}{2}\left(\Delta u_v + \Delta d_v + \Delta q_s\right)}_{\text{HERA 1}} + L_q}^{J_q} + \overbrace{(\Delta G + L_g)}^{J_g}$$

disentangle proton spin : $\frac{1}{2} = \overbrace{\frac{1}{2}\underbrace{\left(\Delta u_v + \Delta d_v + \Delta q_s\right)}_{\text{HERA 1}} + L_q}^{J_q} + \overbrace{(\Delta G + L_g)}^{J_g}$

$\frac{\Delta G}{G} = 0.41 \pm 0.18 \pm 0.03$

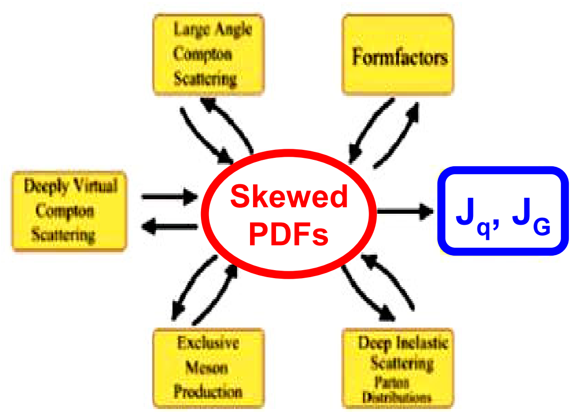


build by DESY, Erlangen, Ferrara, Frascati, Gent, Giessen, Glasgow and PNPI

HERA 2 : HERMES recoil

hard exclusive reactions:
VM + pseudo scalars + DVCS

Generalized PDF's
access orbital momentum of quarks

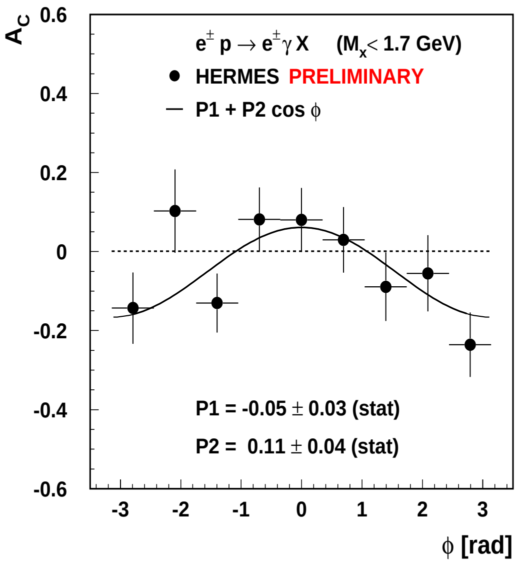


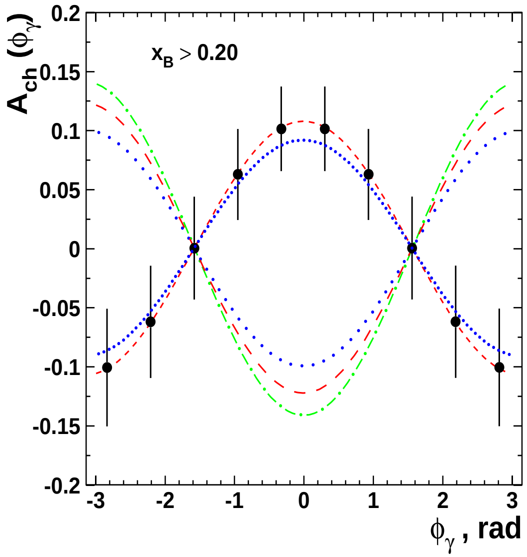
HERMES DVCS

Interference DVCS – Bethe-Heitler $I_{DVCS\text{-}BH}$
Lepton charge asymmetry, unpolarized beam + target

$$A_{ch} \sim d\sigma(e^+p) - d\sigma(e^-p) \sim \cos(\Phi_{\gamma\gamma}) \times \mathrm{Re}\, I_{DVCS\text{-}BH}$$

HERA 1 **HERA 2** ($x_B > 0.2$)





HERMES transversity

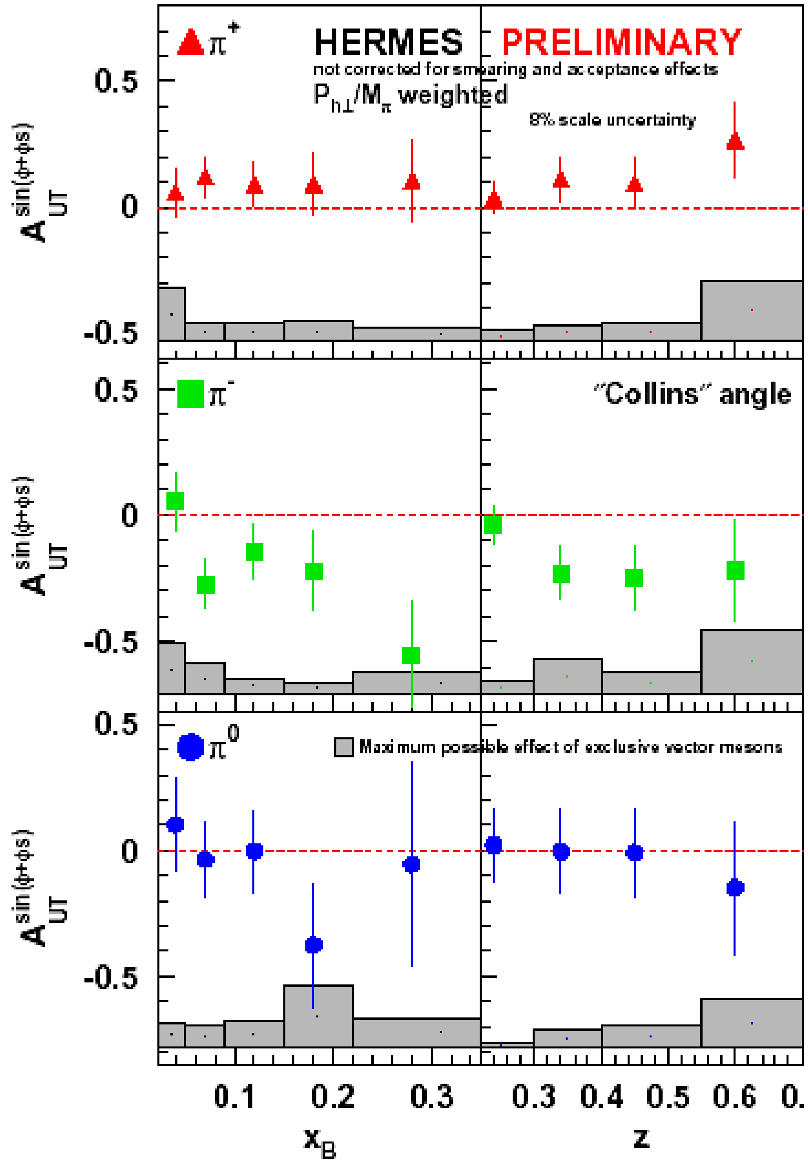
$e\, p\!\uparrow\, \rightarrow e\, p\, \pi\, X$

First Result from HERA II

- only 1/7 of finally needed statistics
- $\pi^+ : A_{UT}^{\sin\Phi} > 0 \Longrightarrow \frac{\delta u}{u} > 0$
- $\pi^- : A_{UT}^{\sin\Phi} < 0 \Longrightarrow \frac{\delta d}{d} < 0$

BUT

- need more statistics to disentangle CollinsFragmentation effects from quark polarizations

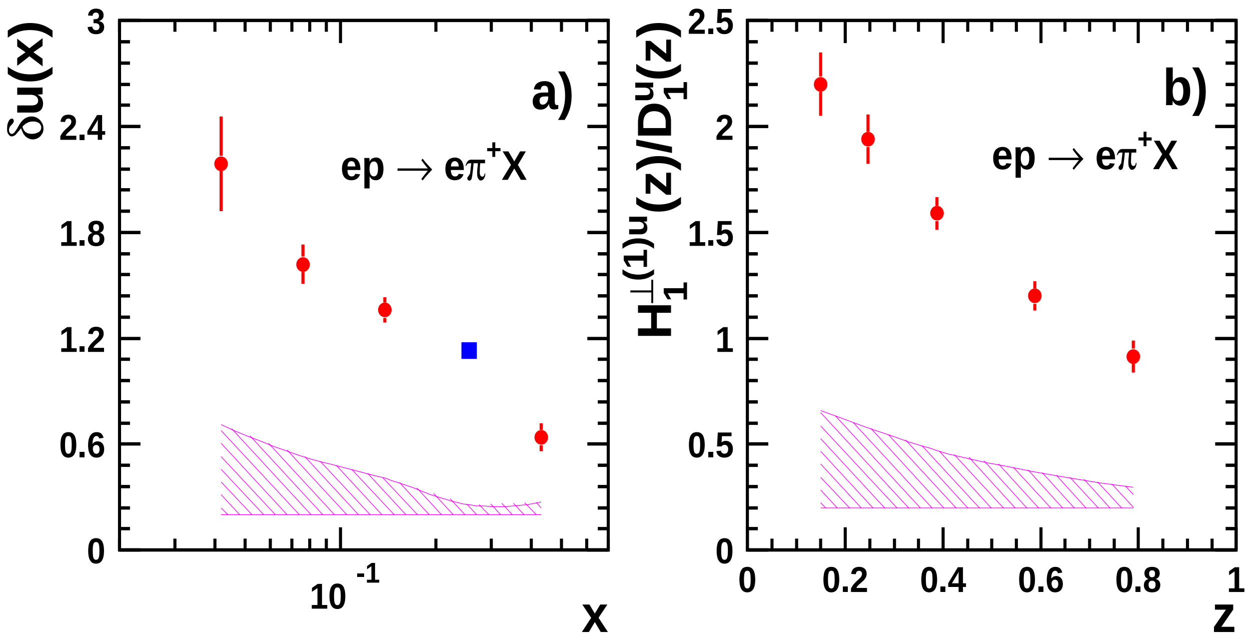


HERMES transversity

transverse spin structure of the nucleon :
last missing peace in the leading spin structure of the nucleon

$e\,p\uparrow \longrightarrow e\,p\,X$ Collins fragmentation. Predictions for

$\delta u(x)$ and $H_1^u(z)/\,D_1^u(z)$

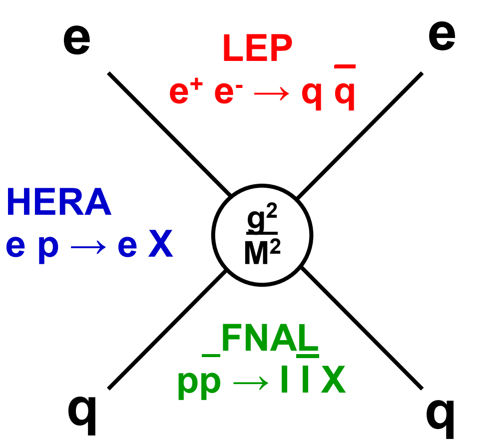


Beyond the Standard Model

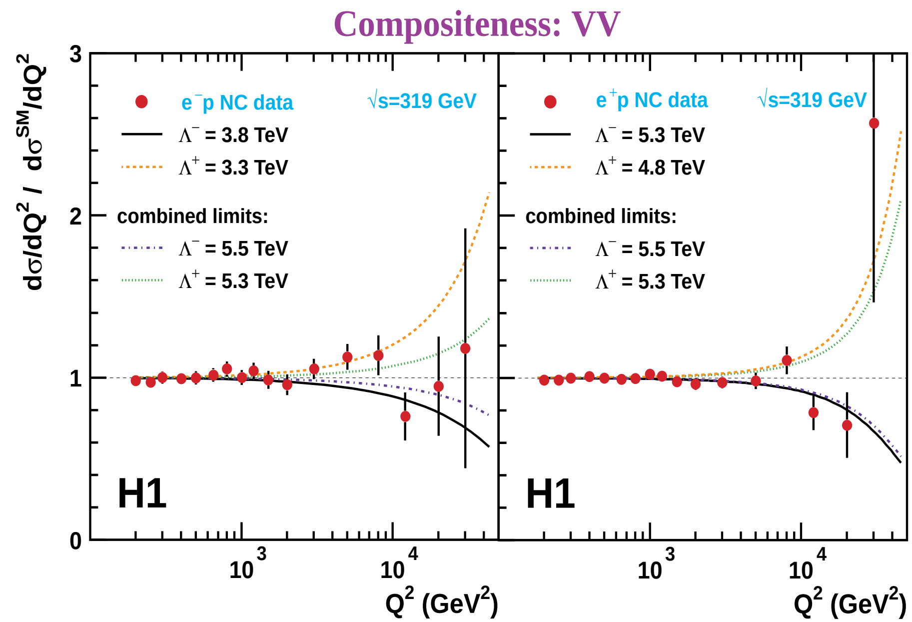
- contact interactions
- R_p-violating SUSY
- leptoquarks
- large extra dimensions

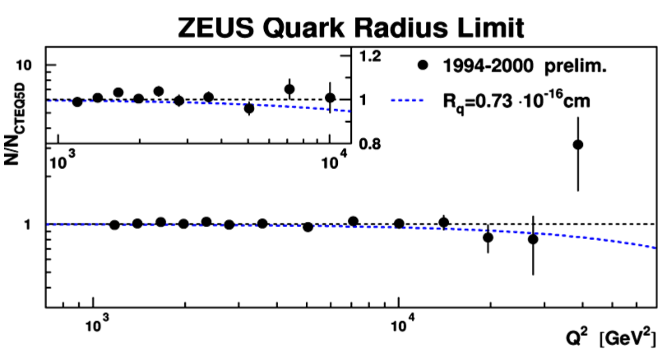
BSM : contact interactions

complementarity :



new physics enters
4 fermion contact term



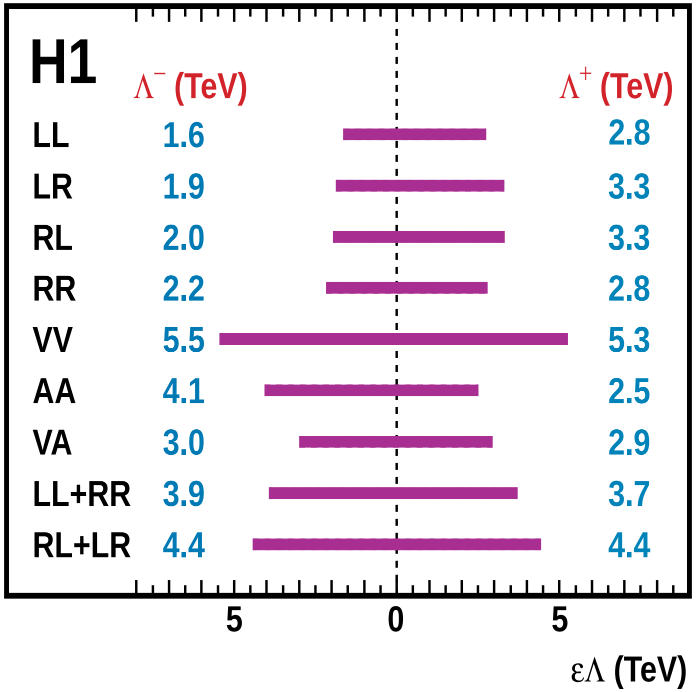


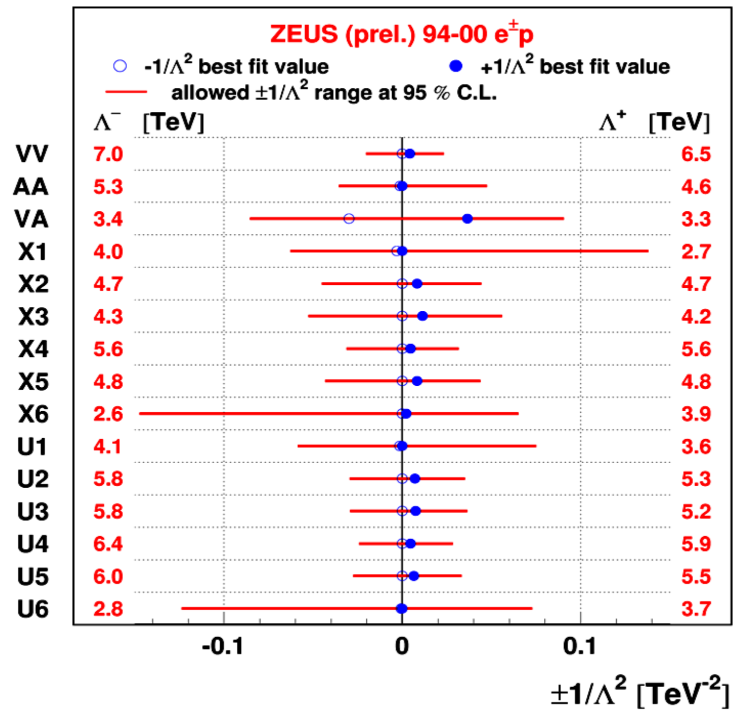
HERA 1 : cross sections agree with Standard Model up to highest Q^2

quark radius
constrained to $R_q < 10^{-18}$ m

HERA 2 : with 500 pb^{-1} 5 σ discovery
if deviation data / SM > 1.5

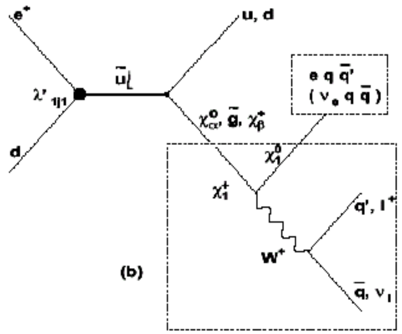
BSM : contact interactions

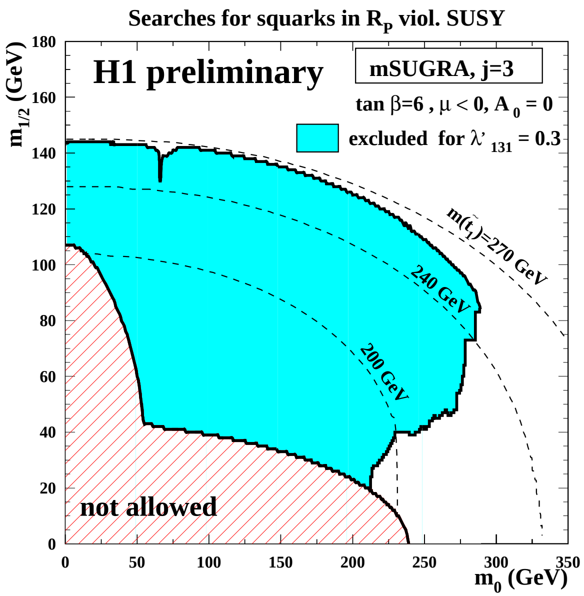




HERA, LEP, FNAL : all have similar 95% CL limits in the TeV range

BSM : R_p violating SUSY





SUSY-Top

may be lightest squark !

Minimum Supergravity +
R_P violation :

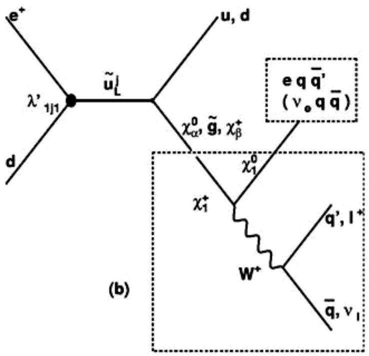
sensitivity to R_p violating stop:

HERA 1: ~ 270 GeV

Tevatron Run 2: 200-250 GeV

HERA 2 : discovery potential !

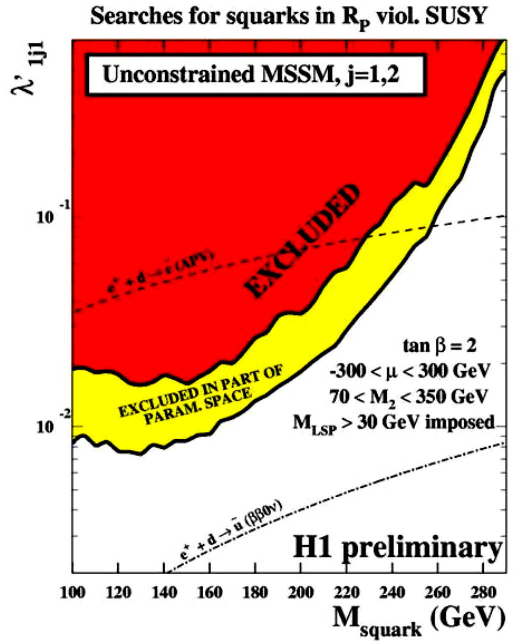
BSM : R_p violating SUSY

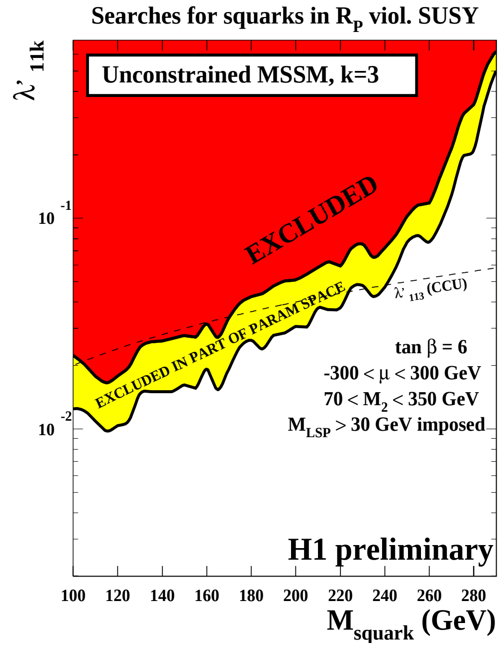


Search for $\tilde{q}$ in $\not{R}_p$ Supersymmetry

e.g. $e^+ d \rightarrow \tilde{u}_L \ldots$

e.g. $e^- u \rightarrow \tilde{d}_R \ldots$





Study several

leptons + jets channels

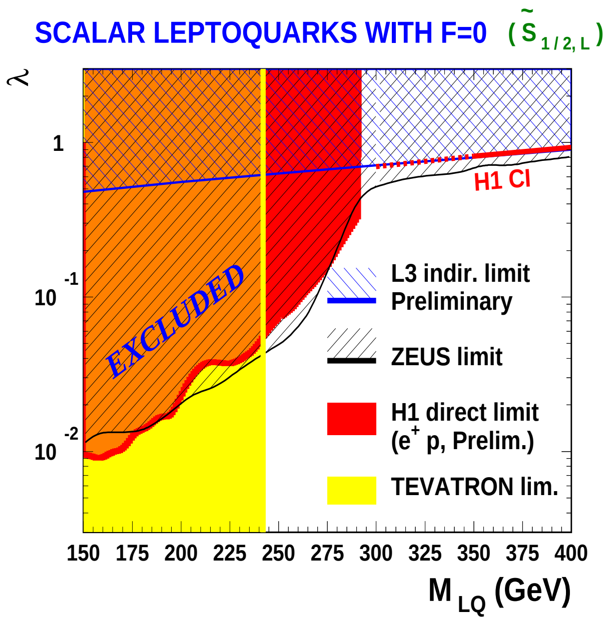
No significant

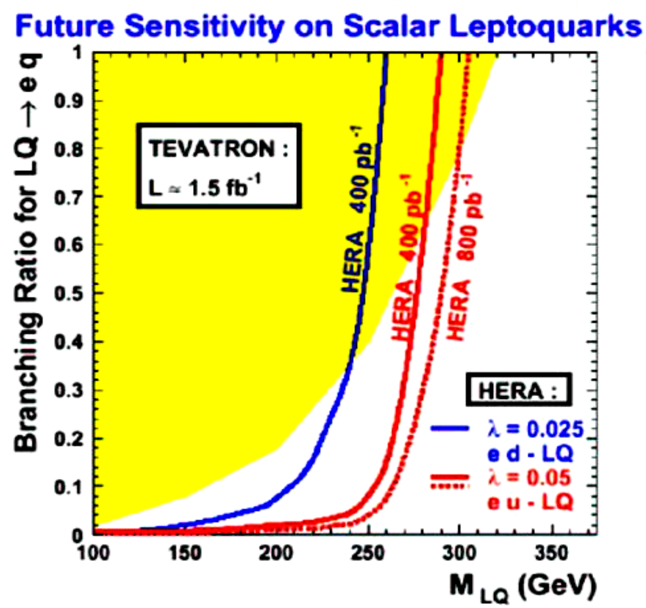
deviations from

expectations

$m_{\tilde{q}} < 275$ GeV excluded in large part of parameter space for λ' of electromagnetic strength

BSM : Leptoquarks





LQ (RPV q)	H1 M_{LQ}	LEP GeV/g
S_0L	710	2150
S_0R	640	1700
$\check{S}_0R$	330	660
$S_{1/2}$ L	850	590
$S_{1/2}$ R	370	770
$\check{S}_{1/2}$ L	430	-
S_1L	490	1190
V_0L	730	3030
V_0R	580	540
$V\sim_0R$	990	1610
$V_{1/2}L$	420	1000
$V_{1/2}R$	950	750
$V\sim_{1/2}L$	1020	580
V_1L	1360	2170

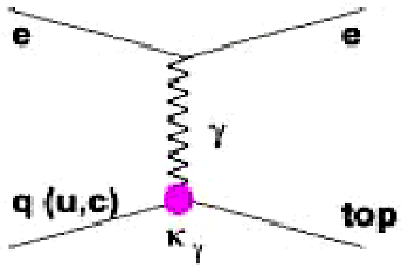
A.Zarnecki, EPS 2003, Aachen

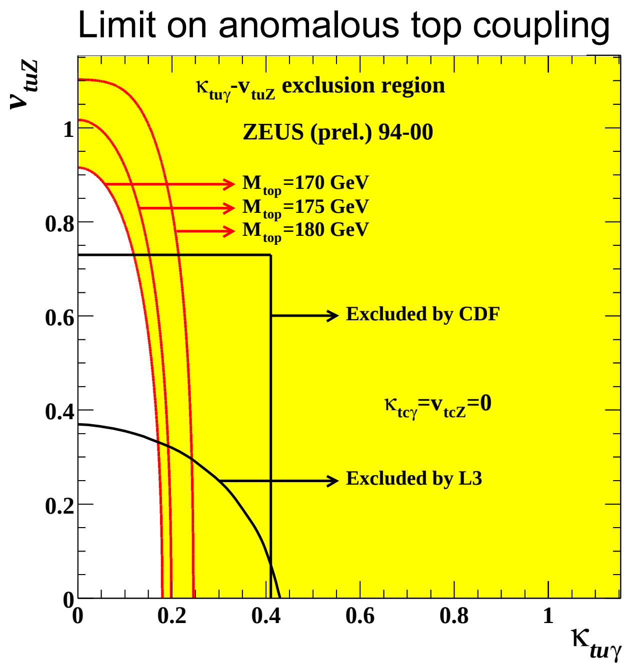
HERA competitive for small branching ratios:

HERA 1 limits compete with LEP and Tevatron Run 1

HERA 2 limits compete with Tevatron Run 2

BSM : anomalous couplings



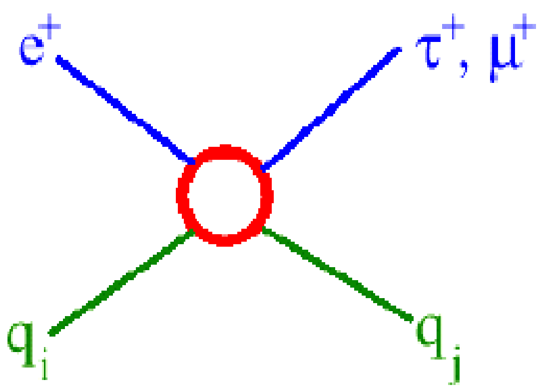


Flavor Changing Neutral Currents:

single top production

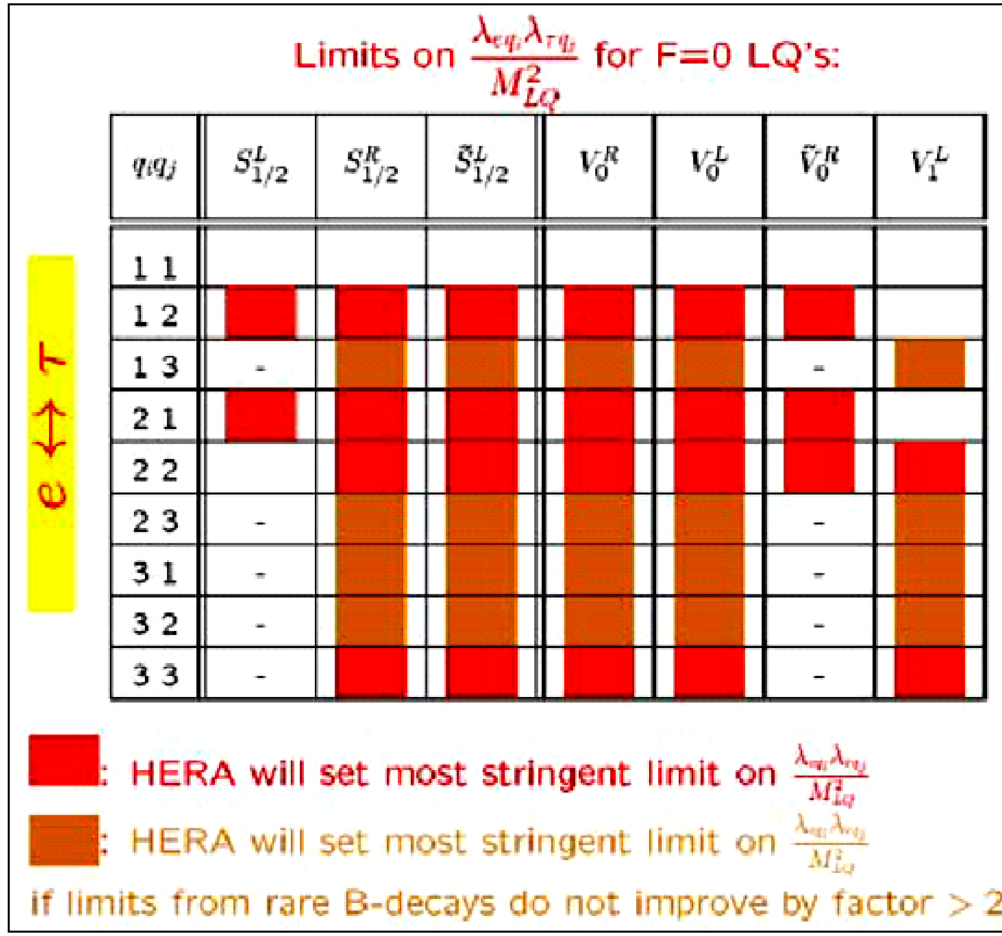
HERA has exclusion potential !

BSM : Lepton flavor violation

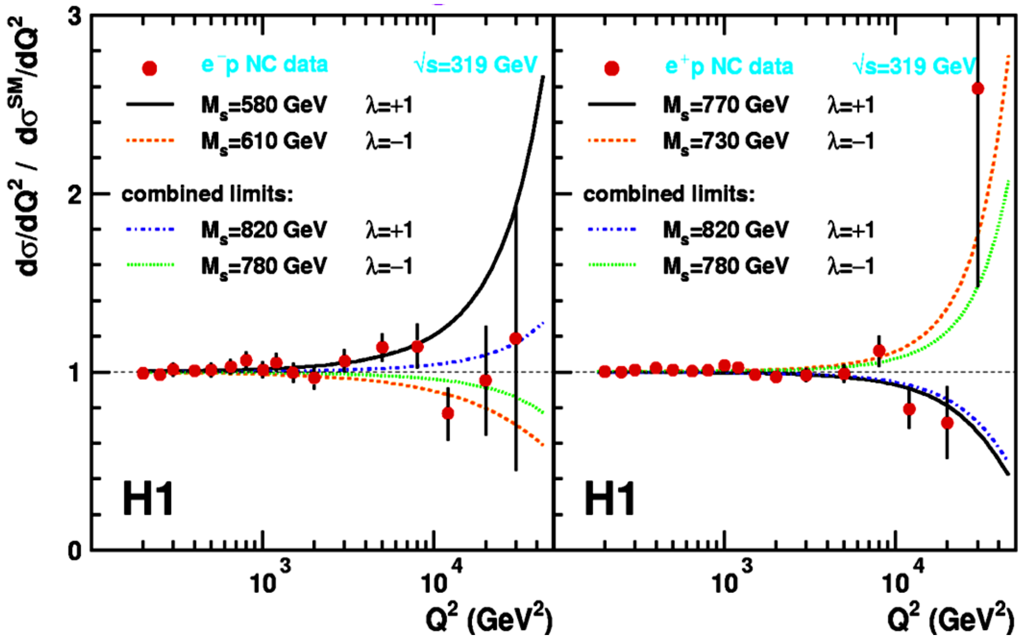


HERA 2 :

high discovery potential
in many channels :



Extra Dimensions



TeV	M_s^-	M_s^+
LEP (Hewett)	1.2	1.
H1 (GRW)	0.780	0.820
D0 Run I+II	1.37	
HERA 2	~ 1	

M.Sanders, EPS 2003, Aachen

BSM : Search Strategy

model	beam charge	best polarization left	best polarization right
right handed currents (CC)	e^-	- -	$e^-_R \to \nu_R$ (W_R)
SUSY R_P Violating	e^+		$e^+_R \to$ $\tilde{u}_L, \tilde{c}_L, \tilde{t}_L$
	e^-	$e^-_L \to$ $\tilde{d}_R, \tilde{s}_R, \tilde{b}_R$	
anomalous top	$e^\pm$	$t_{L,R}$	

$F=0$ Leptoquarks	e^+	$S_{1/2}, V_0$	
		$e^+_L \to \overline{\tilde{V}^R_0}$	$e^+_R \to \overline{V^L_1}$ $e^+_R \to \overline{\tilde{S}^L_{1/2}}$
$F=2$ Leptoquarks	e^-	$S_0, V_{1/2}$	
		$e^-_L \to S^L_1$ $e^-_L \to \tilde{V}^L_{1/2}$	$e^-_R \to \tilde{S}^R_0$
Contact Interaction	$e^\pm$	various	
Quark Radius	$e^\pm$	any	
Large Extra Dimens.	$e^\pm$	any	
Excited Fermions	$e^\pm$	$e^-_L \to f^*_R$	$e^+_R \to f^*_L$
Excited Neutrinos	e^-	$e^-_L \to \nu^*_R$	

HERA2 :

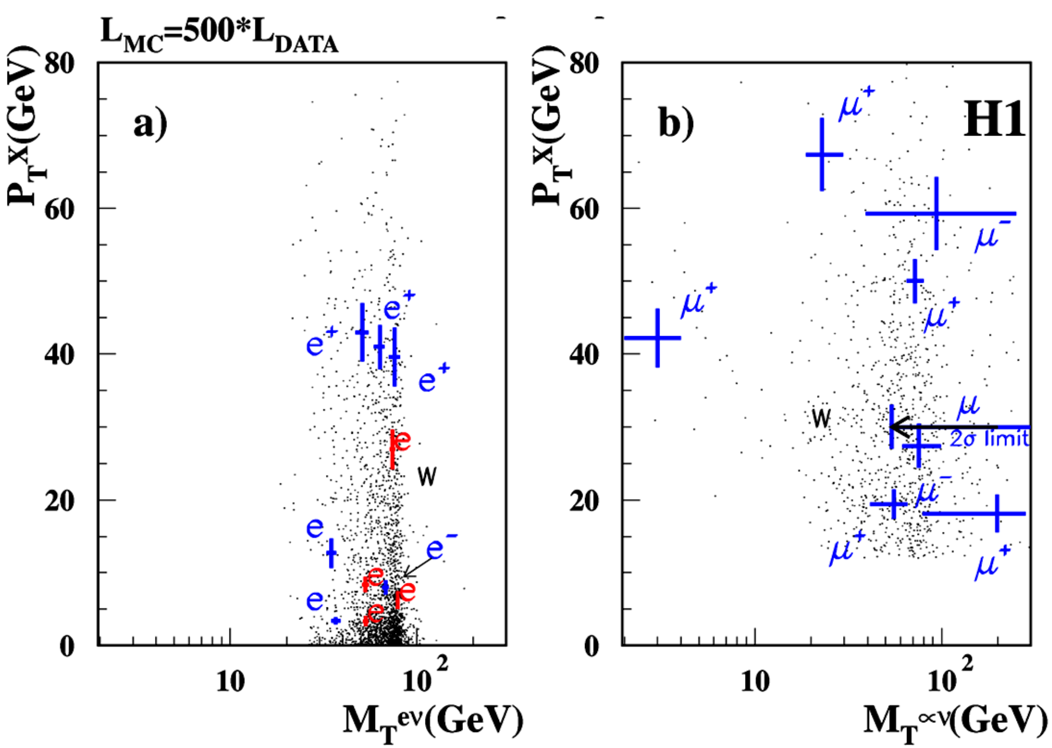
Polarization + Lumi
will help to sharpen limits

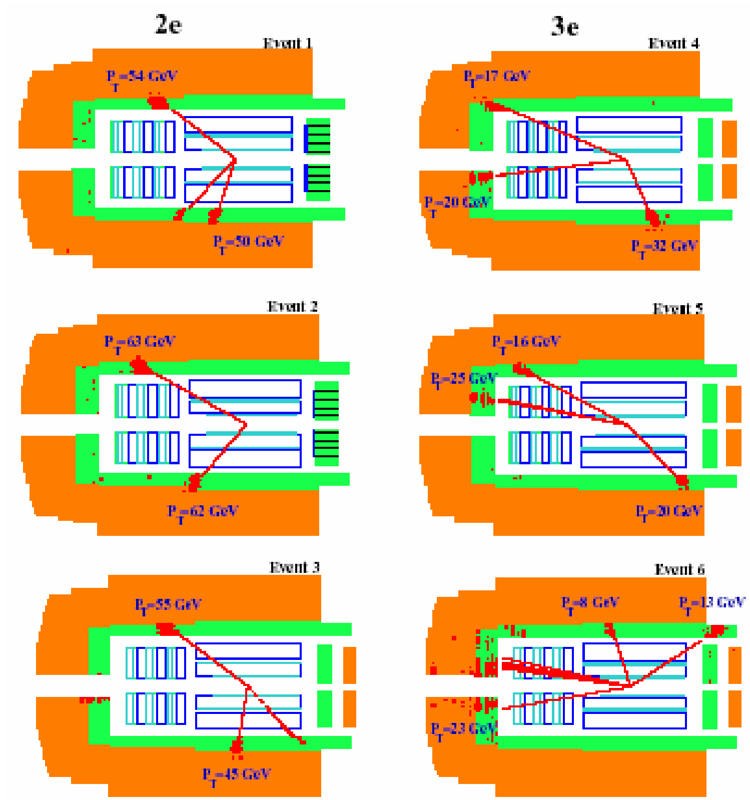
Use maximum possible energy

HERA 2 : Discoveries

HERA 1 100 pb^{-1} e^+: **H1** 10 high p_t multileptons for 3 expected

HERA 2 1000 pb^{-1} **?**





HERA 2 Summary

HERA 2: take up to **1 fb^{-1}** with **$e^{\pm}$ and $\pm\lambda$** till 2007

high precision NC and CC data up to highest possible x and Q^2

- measure **$F_2(x,Q^2)$, $xF_3(x,Q^2)$, $\sigma_{cc}^{\pm}(x,Q^2)$, …**
- disentangle flavor content of proton
- further constrain PDFs
- gluon: $\delta g / g < 3\%$ at $x \sim 10^{-2}$
- get α_s to < 2%
- understand heavy flavor production

- directly measure $F_L(x,Q^2)$ to test QCD
  with ~10 pb^{-1} at 3-4 proton energies

- need **theory**: NNLO !

- **Look beyond the standard model**
  for :
  - leptoquarks
  - SUSY
  - contact interactions
  - single top production
  - excited fermions
  - extra dimensions
  - …
  - the **unexpected** !

HERA 2 Temple

in Paestum, Italy

before and **after**

UPGRADE