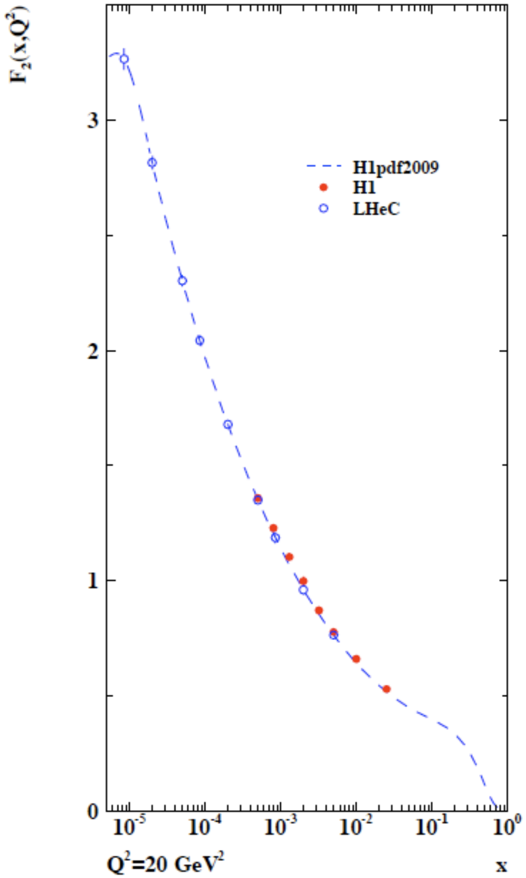
The Unfolding of Proton's Structure with the LHeC



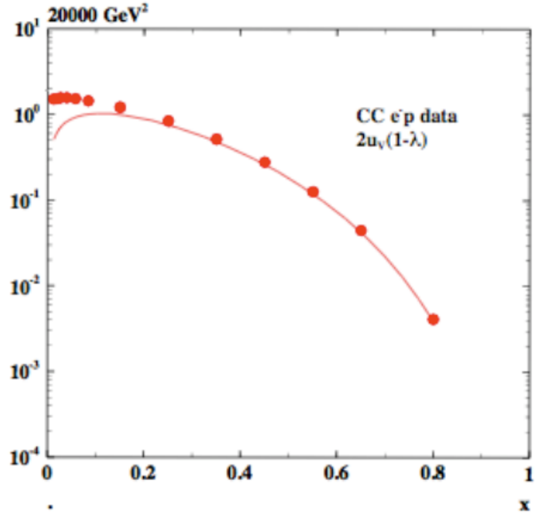
High precision

Very low X

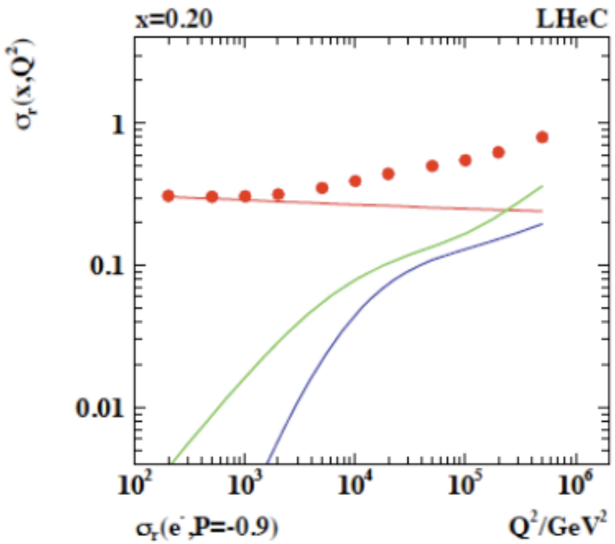
Max Klein

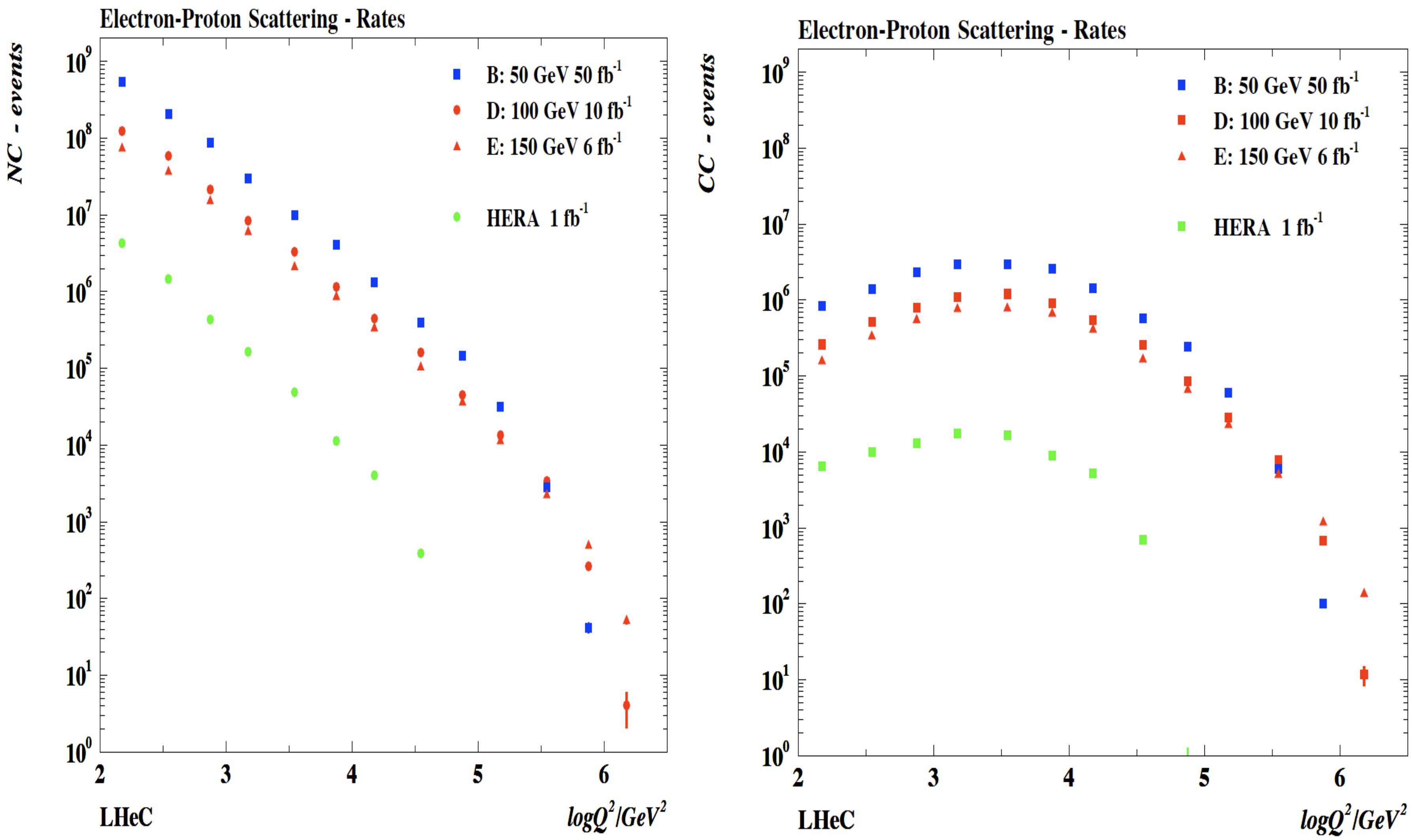
Parton Distributions at the LHC
Cambridge, 3. June 2009

Don't discuss diffraction or GPDs

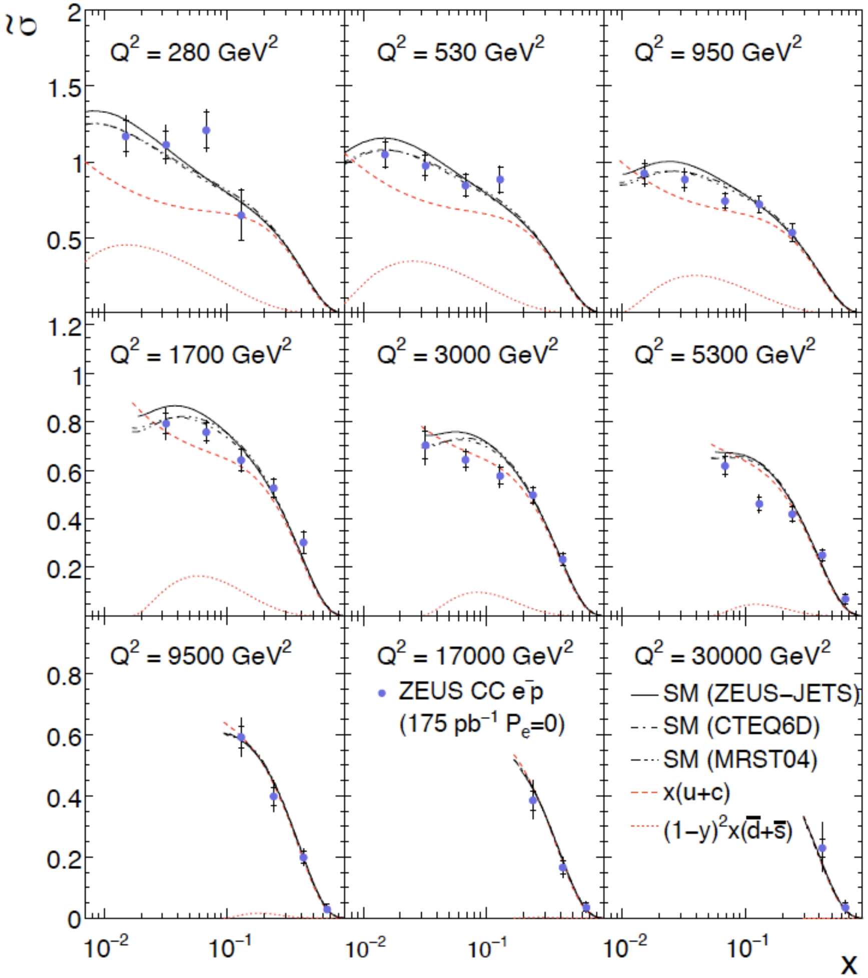


High Q^2, very large x



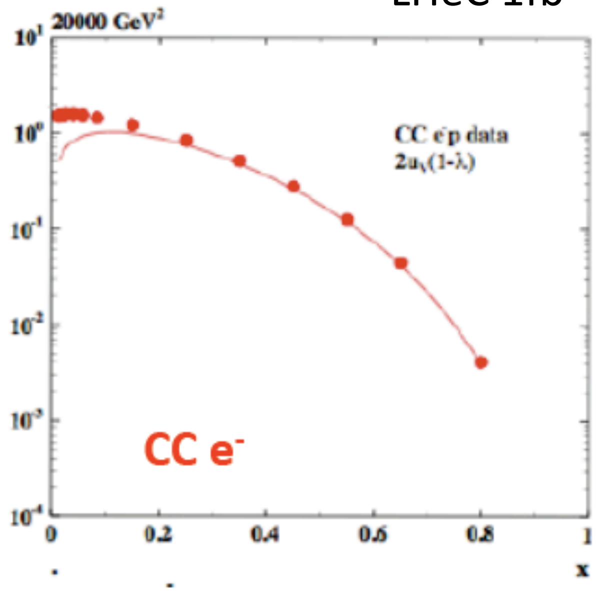

Electron-Proton Scattering - Rates
NC - events
B: 50 GeV 50 fb-1
D: 100 GeV 10 fb-1
E: 150 GeV 6 fb-1
HERA 1 fb-1
LHeC
logQ2/GeV2
Electron-Proton Scattering - Rates
CC - events
B: 50 GeV 50 fb-1
D: 100 GeV 10 fb-1
E: 150 GeV 6 fb-1
HERA 1 fb-1
LHeC
logQ2/GeV2

Valence Quarks at Large x - CC

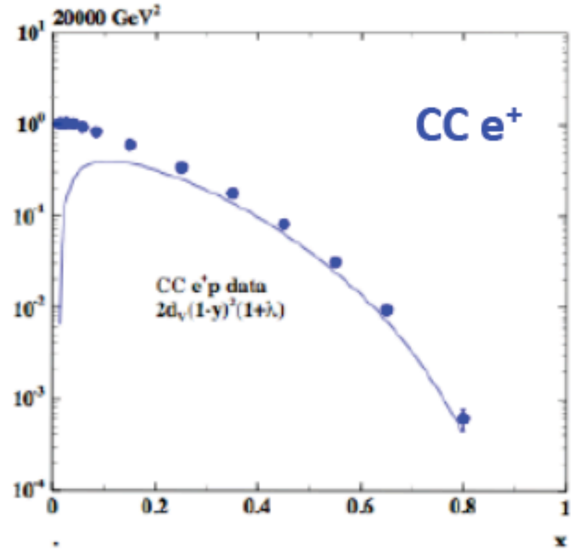


DESY 08-177, submitted
HERA II, 175 pb^{-1}

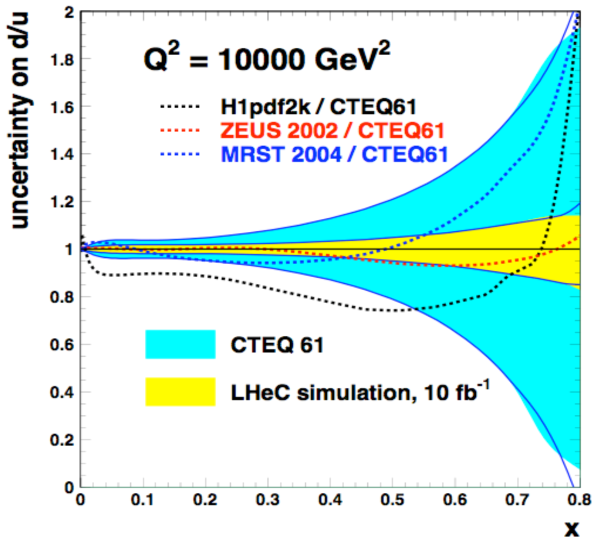
LHeC 1fb^{-1}

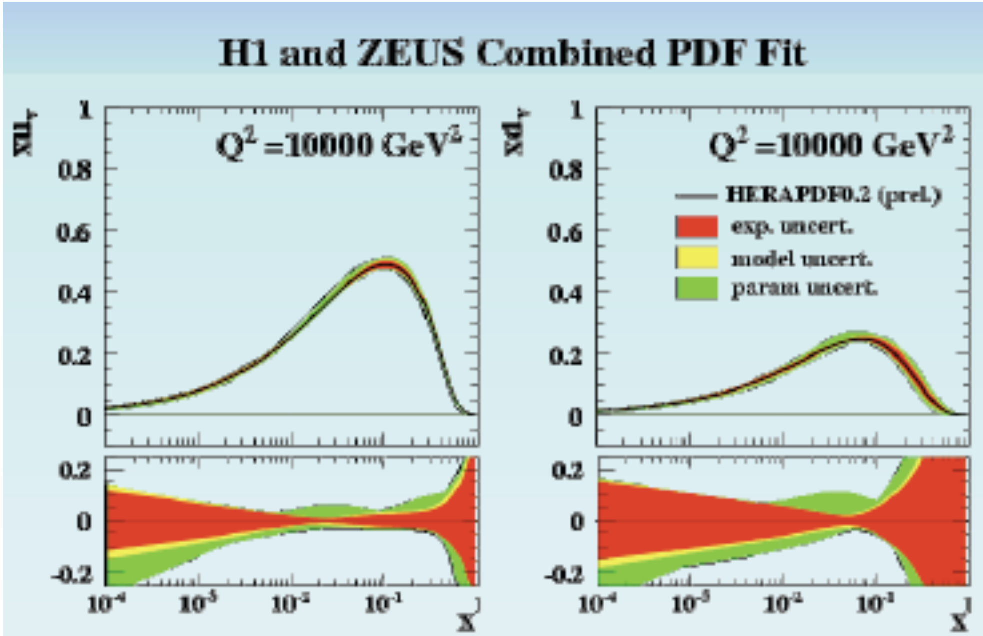


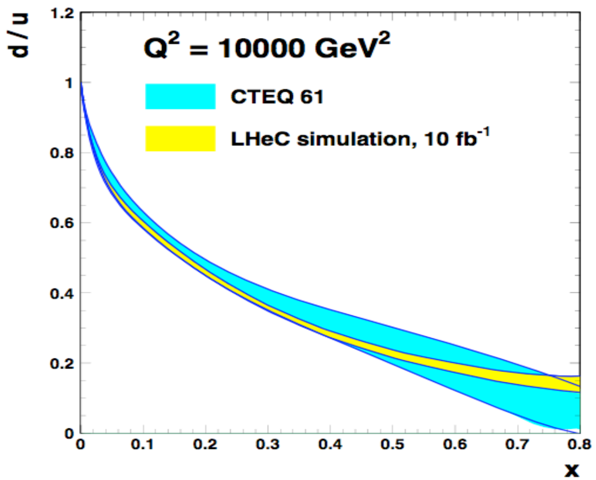
Flavour separation to highest x

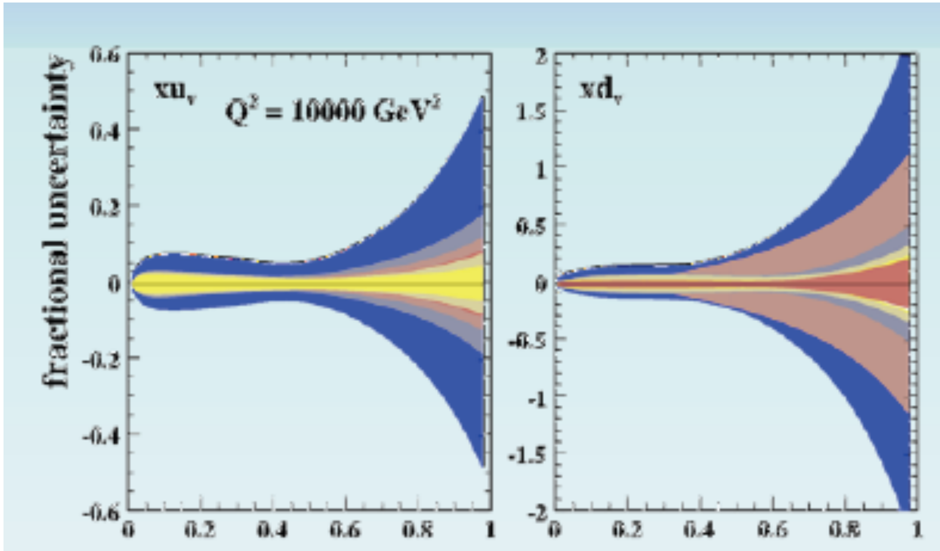


d / u at Large x









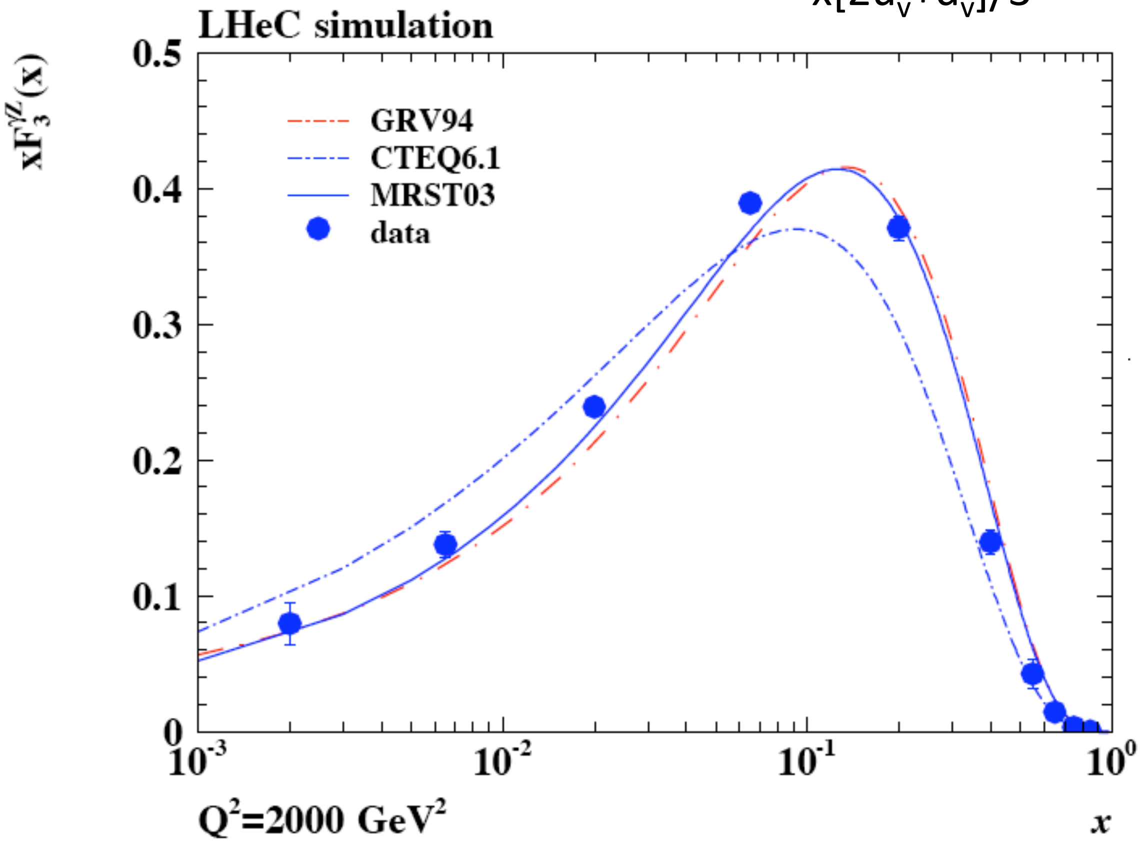
E.Perez

C.Gwenlan

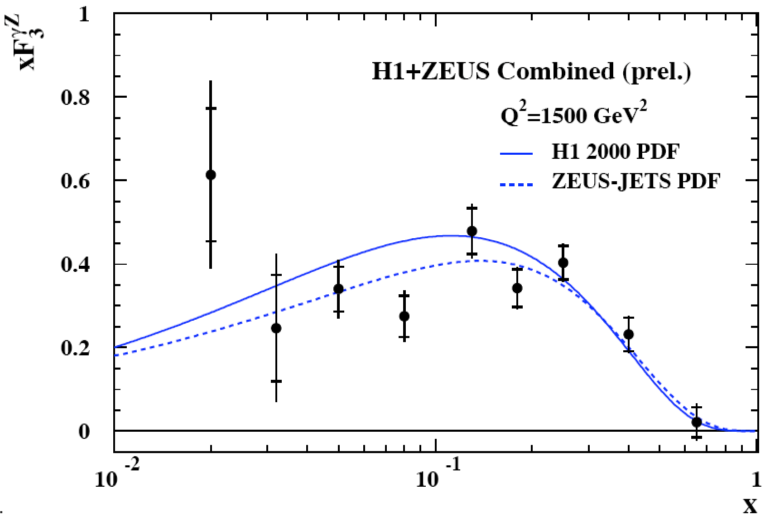
Valence Quarks at Low x

$xF_3^{\gamma Z}$

x[2u$_v$+d$_v$]/3



HERA I



$$xF_3^{\gamma Z} = 2x[e_u a_u(u_v + \Delta_u) + e_d a_d(d_v + \Delta_d)]$$

Valence quarks at low x

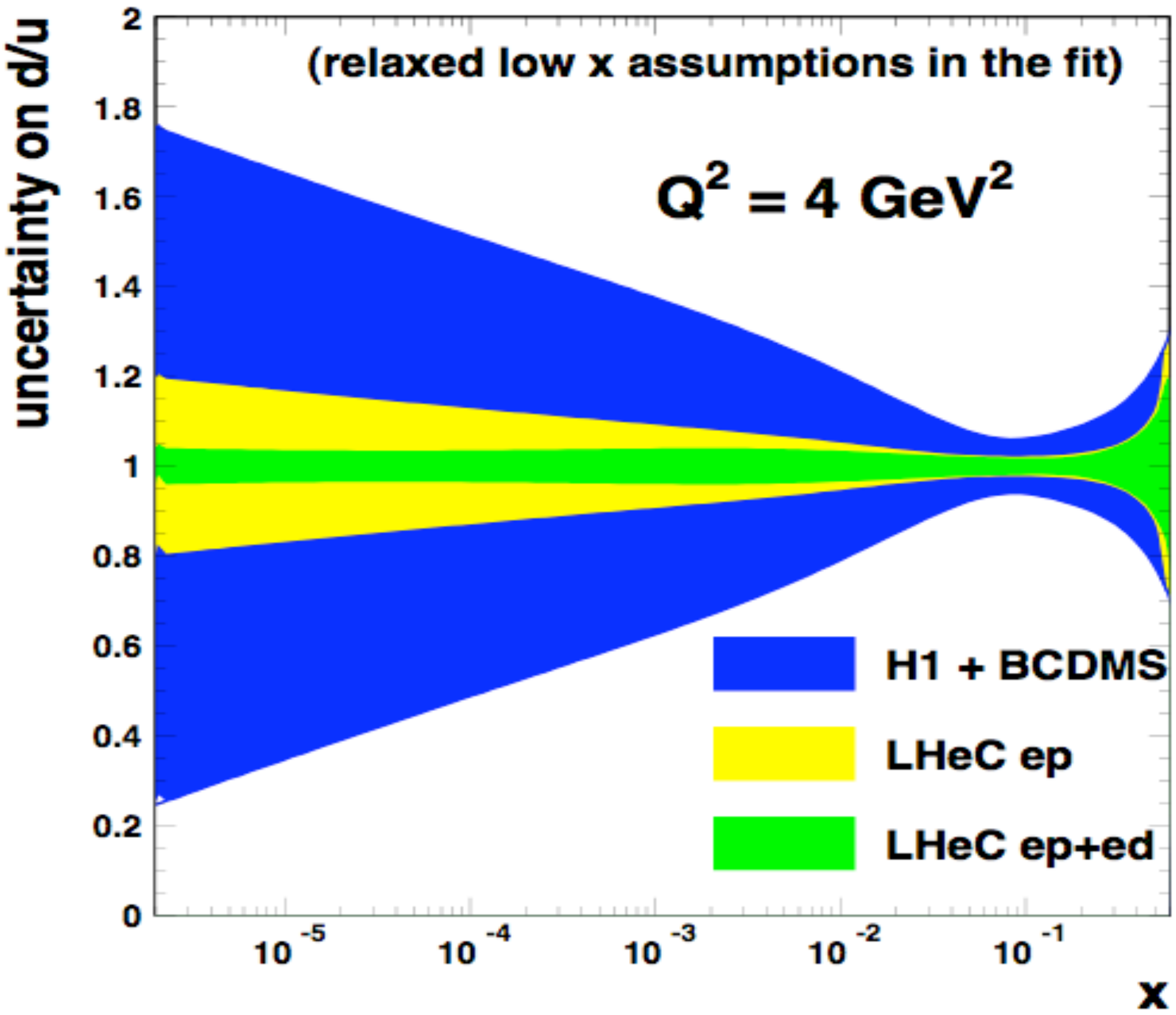
or/and unexpected sea

asymmetries

$$\Delta_u = (u_{sea} - \overline{u} + c - \overline{c})$$
$$\Delta_d = (d_{sea} - \overline{d} + s - \overline{s})$$

from γZ interference

d/u at Low x from ep+ed

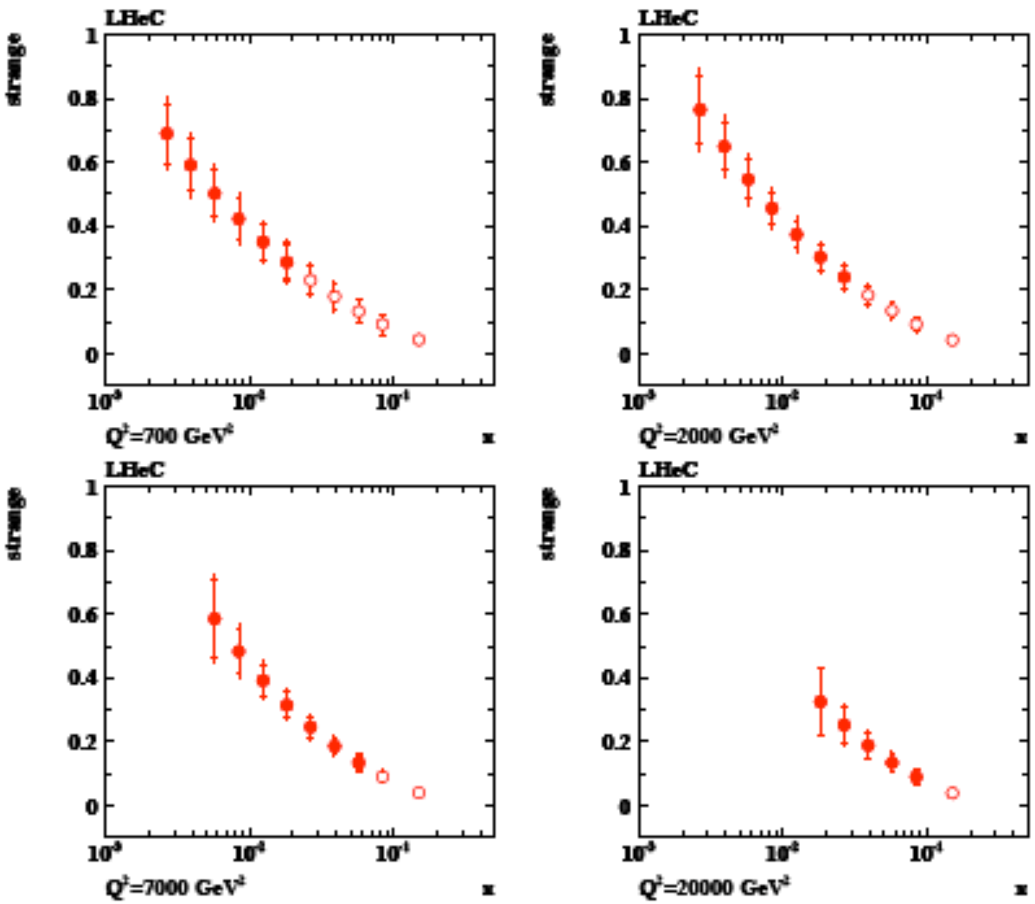


Note
all QCD fits
assume
u=d
at low x

No constraint
from HERA

E.Perez

Strange Quark Distribution [CC, e^+, c tag]



$W^+ s \rightarrow c$

$1 fb^{-1}$

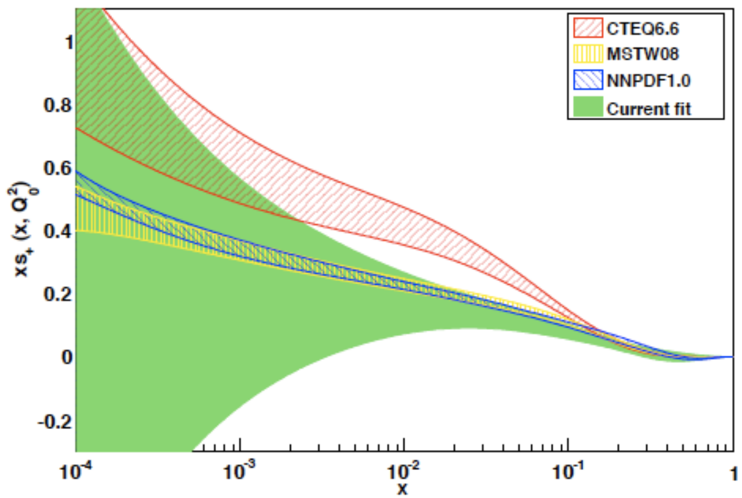
$\varepsilon_c = 0.1$

$\varepsilon_q = 0.01$

$\delta_{syst} = 0.1$

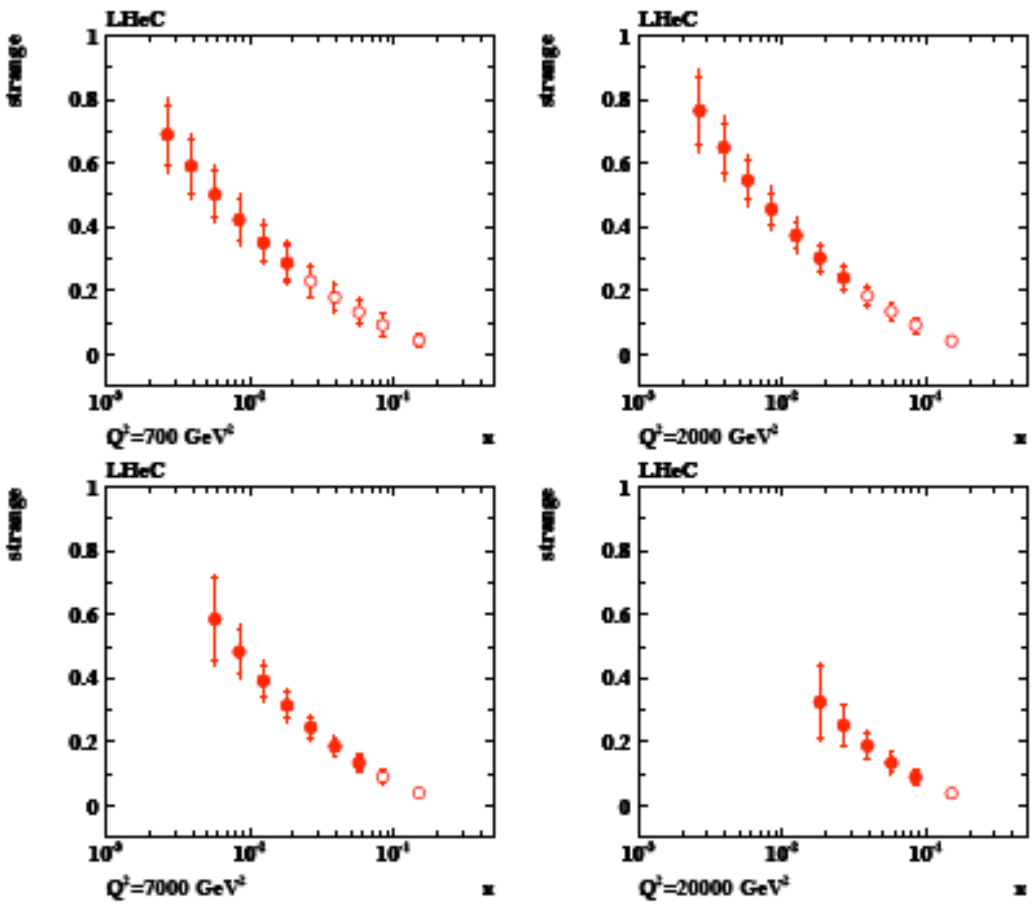
$\circ - \vartheta_h \geq 1^o$

$\bullet - \vartheta_h \geq 10^o$



J.Rojo, DIS09. s^+, Q^2=20GeV^2

Anti-Strange Quark Distribution [CC e^-, c tag]



$W^- sbar \rightarrow cbar$

$1 fb^{-1}$

$\varepsilon_c = 0.1$

$\varepsilon_q = 0.01$

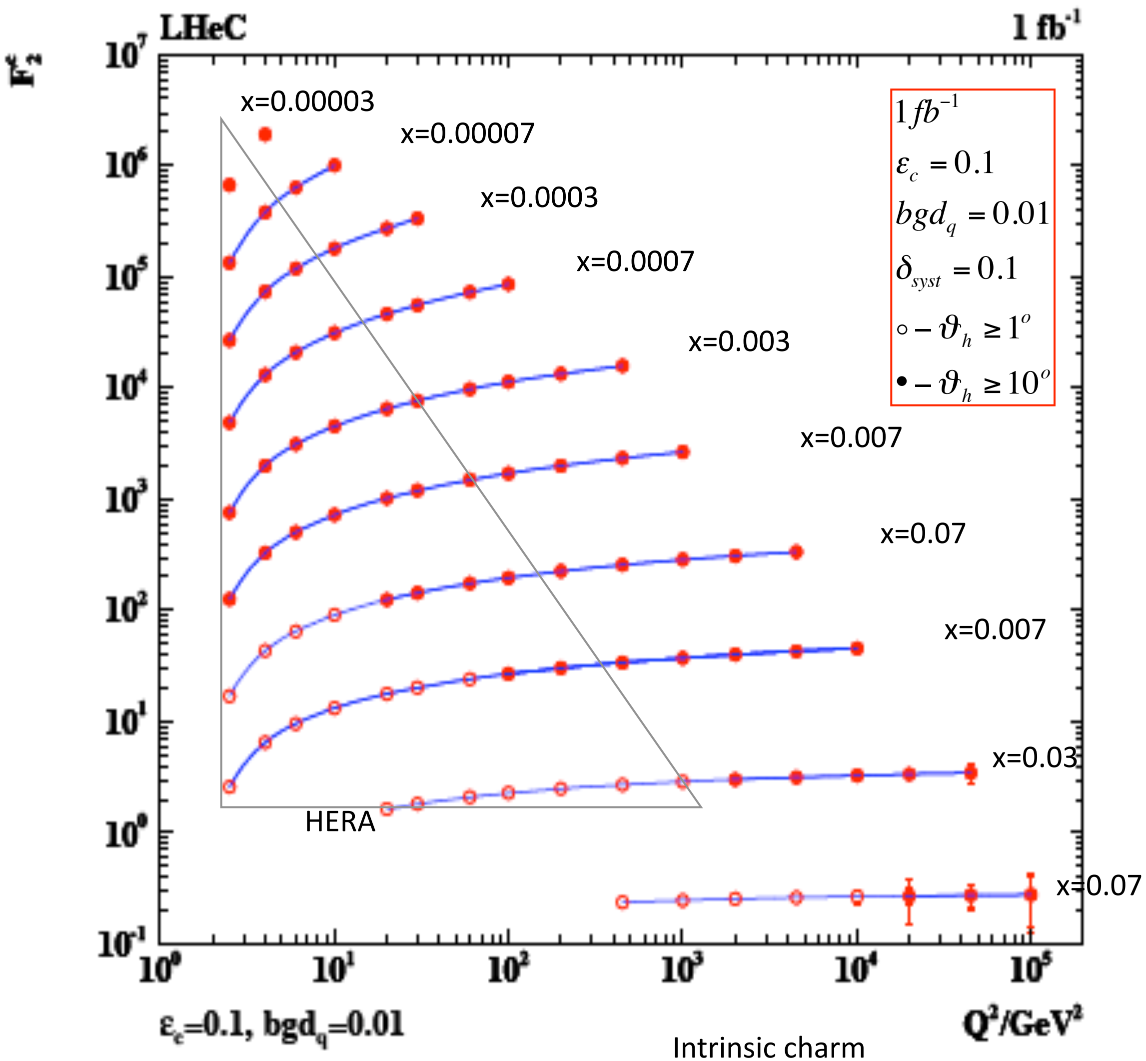
$\delta_{syst} = 0.1$

$\circ - \vartheta_h \geq 1^o$

$\bullet - \vartheta_h \geq 10^o$

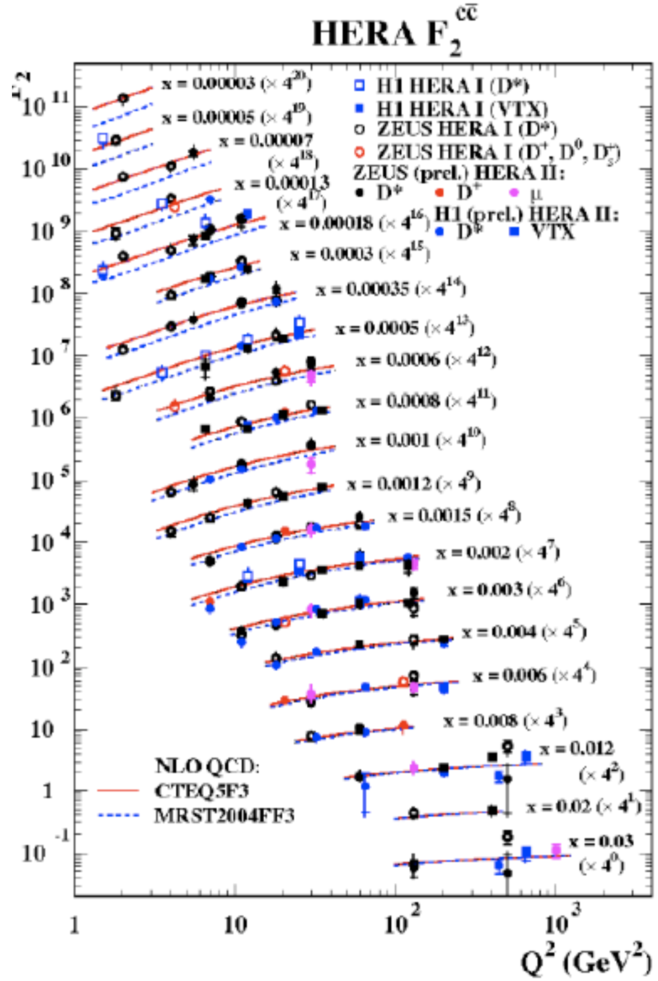
Measurement of s^+ and s^- over large range of x and Q^2 from CC $e^{\pm}$ data

Charm Quark Distribution [NC, tagged]

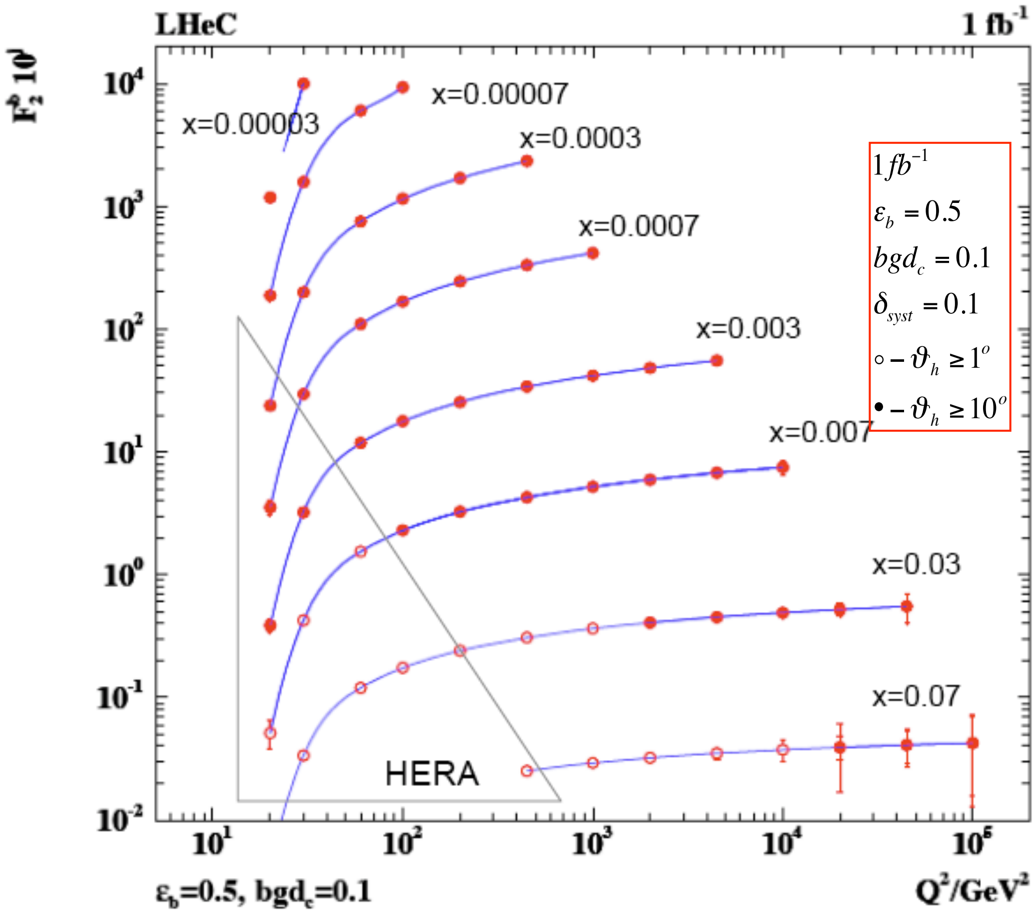


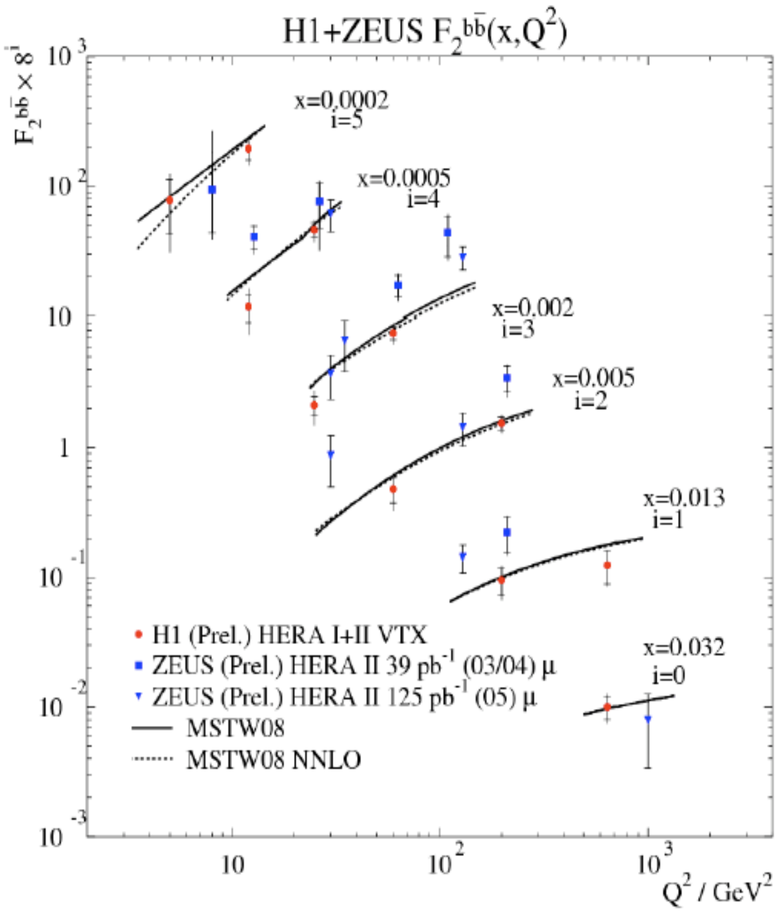
$$\delta_{stat} = \frac{1}{\varepsilon_c N_c} \cdot \sqrt{\varepsilon_c N_c + bgd_{LQ} N_{NC}}$$

Intrinsic charm
(i.e. larger x) requires dedicated
forward tagging and low E_p .



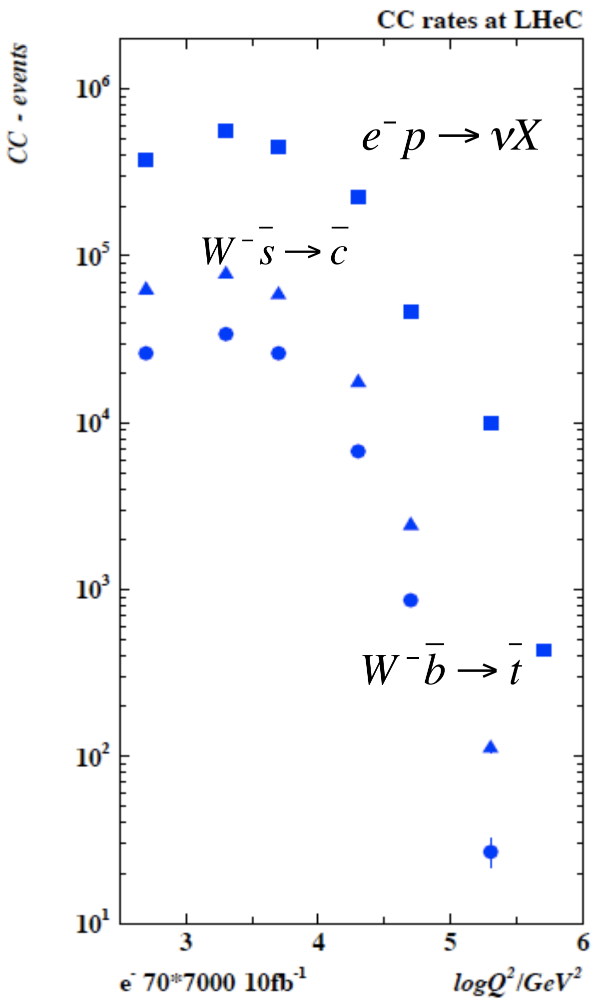
Beauty quark distribution [NC, tagged]

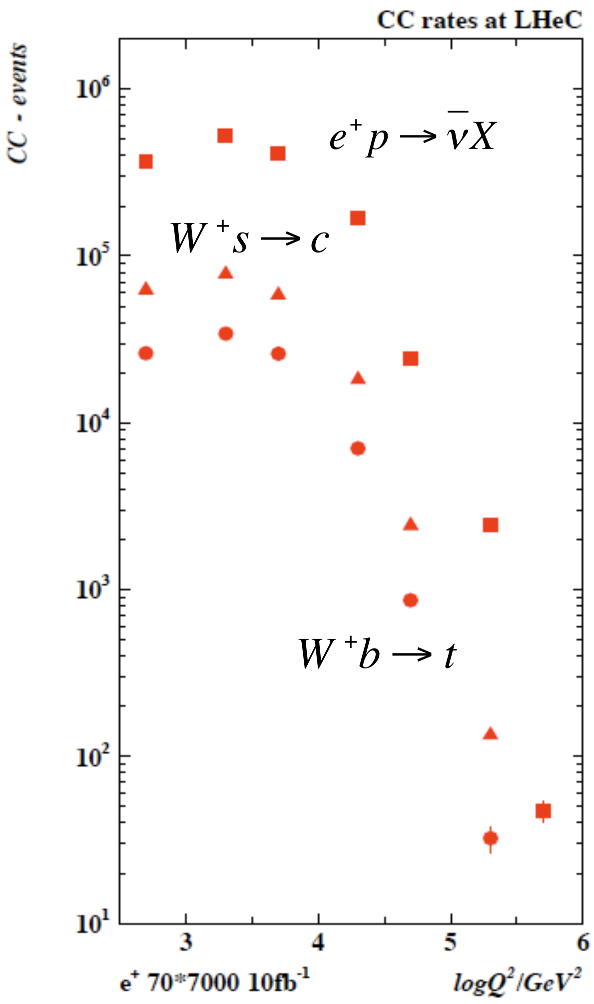


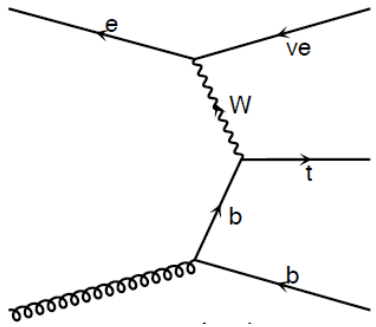


bb→ A in MSSM for larger tan β

$\overline{\text{Top}}$ and Top Production at the LHeC [CC]







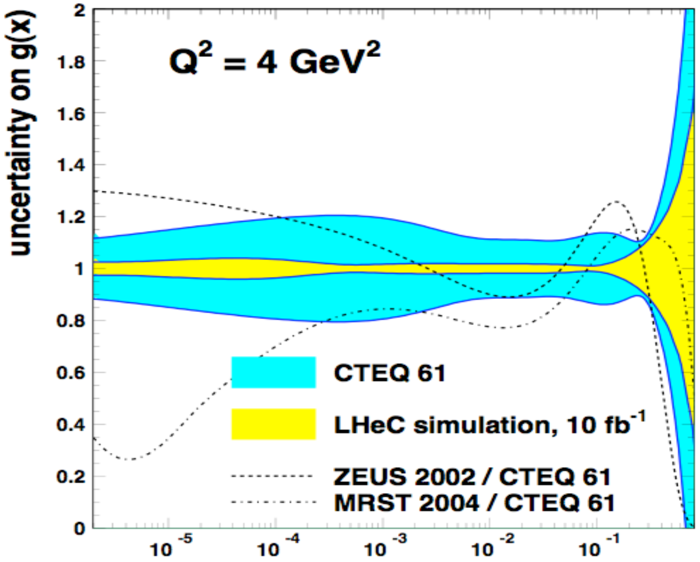
LHeC is a single top and anti-top quark factory

with a CC cross section of O(10)pb

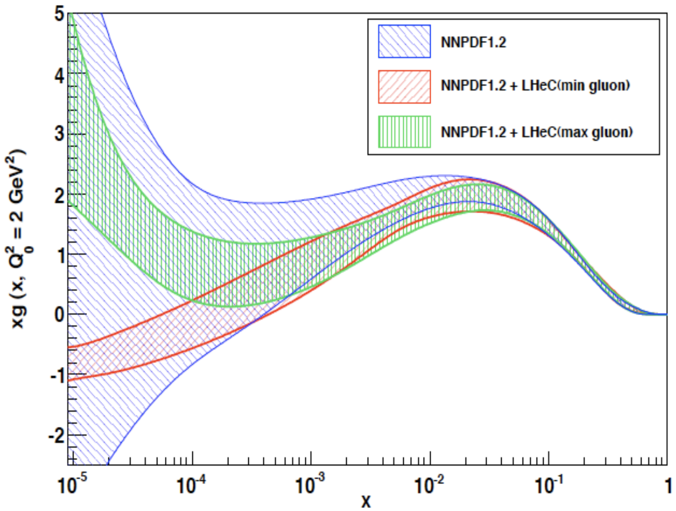
Top at HERA essentially impossible to study. Single top at Tevatron barely seen and at LHC very challenging

Gluon Distribution

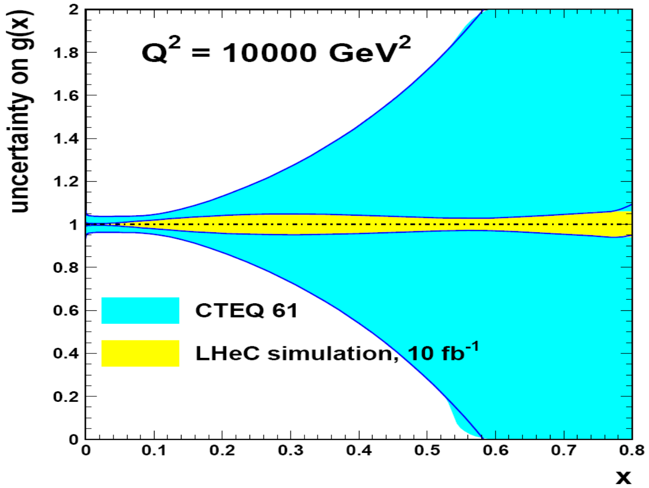
E.Perez



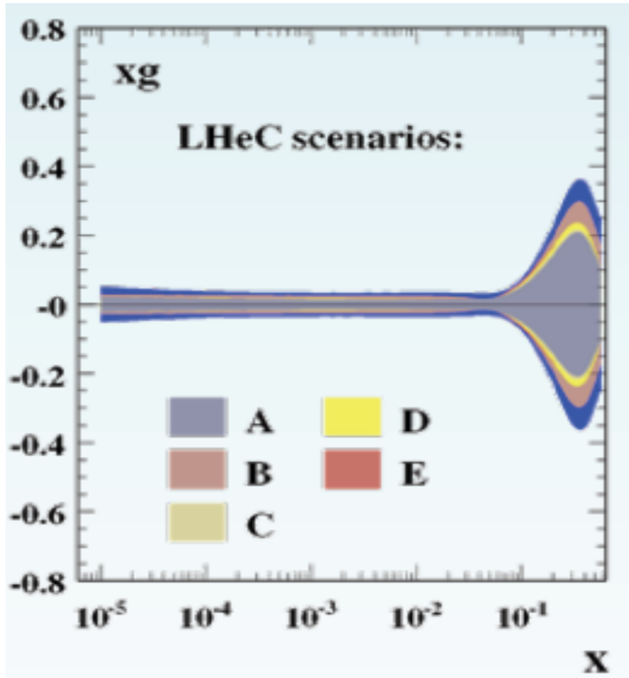
J.Rojo



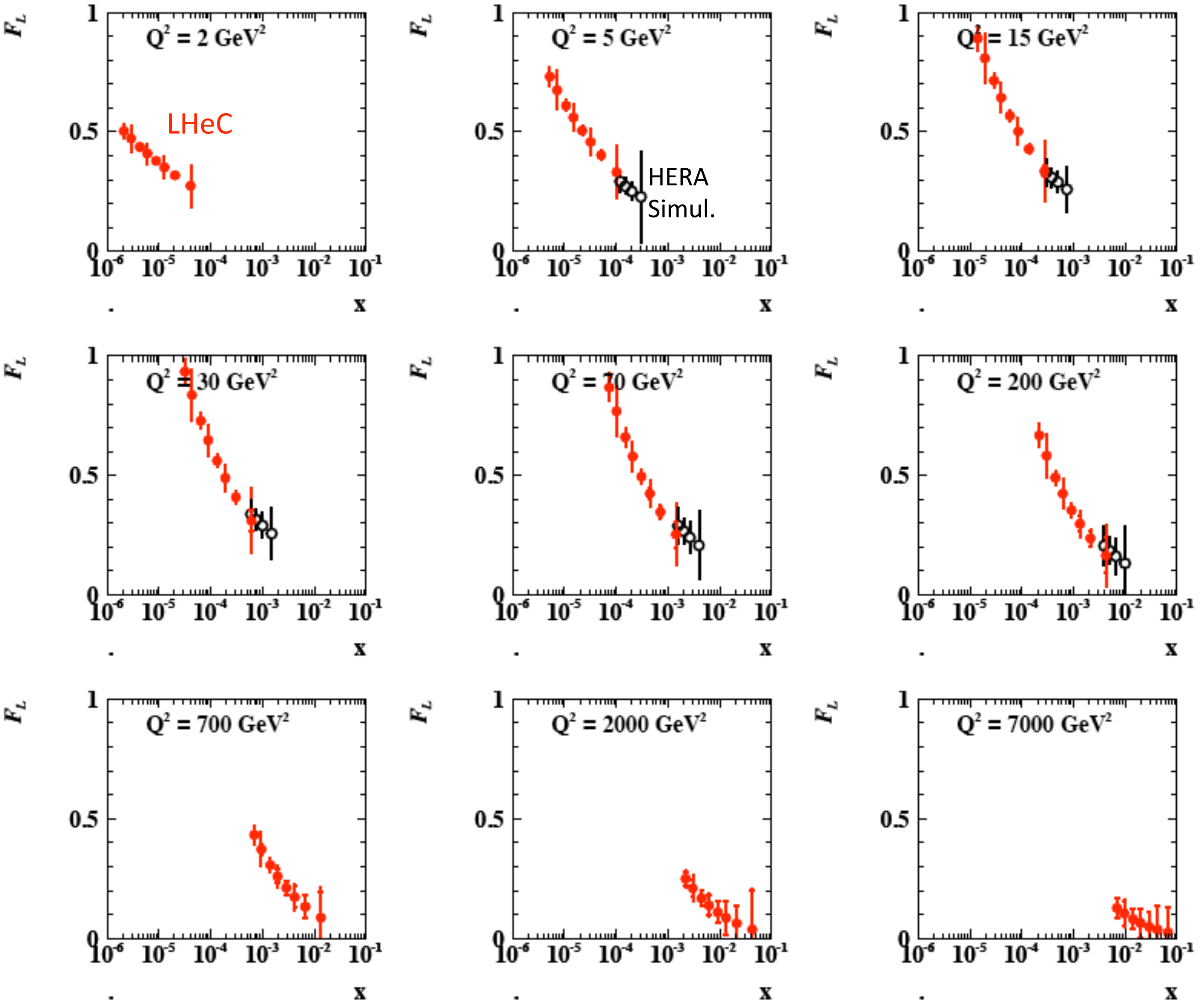
Greatly improved precision at low and hi x



C. Gwenlan



CG-EP: different input + error treatment..



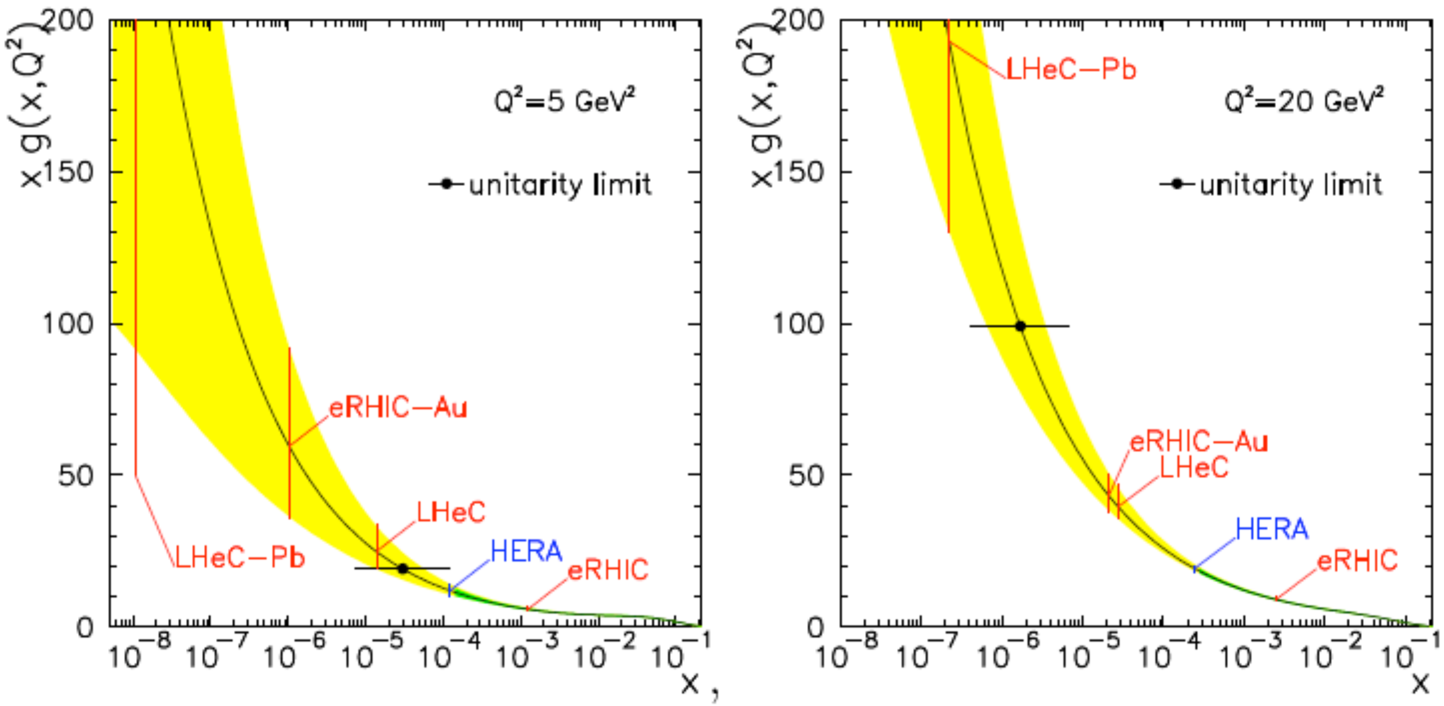
DIS08
J.Forshaw et al.
DIS09
J.Rojo

May not be able to simultaneously fit the two proton structure functions F2 and FL when these represent a saturation CDM

With enlarged energy, saturation scale moves into DIS region and DGLAP may truly be shown to fail when confronted with very low x data.

F_L takes long (1986-2008)…

Gluon density - amplification?

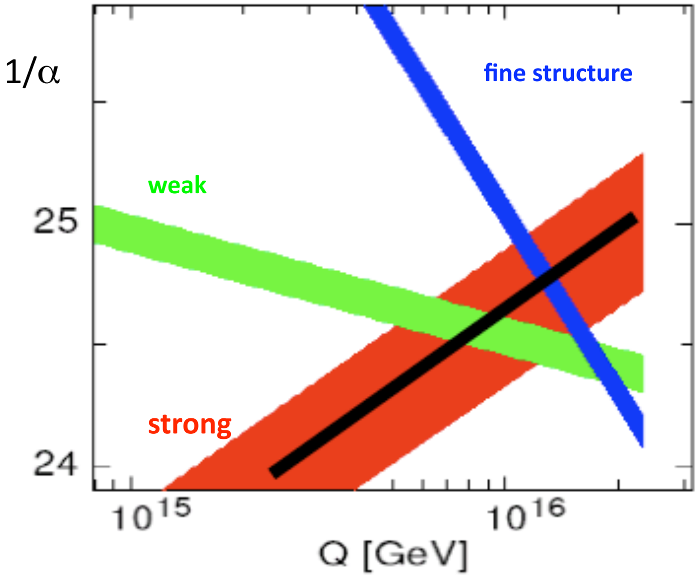


High density $$\frac{g_A/\pi r_A^2}{g_p/\pi r_p^2} = A^{1/3}\frac{g_A}{A g_p}$$

Unitarity $$xg(x,Q^2) \le \frac{1}{\pi N_c \alpha_s(Q^2)} Q^2 R^2 \simeq \frac{Q^2}{\alpha_s}$$

α_s **High Precision** el.weak

Simulation of α_s measurement at LHeC

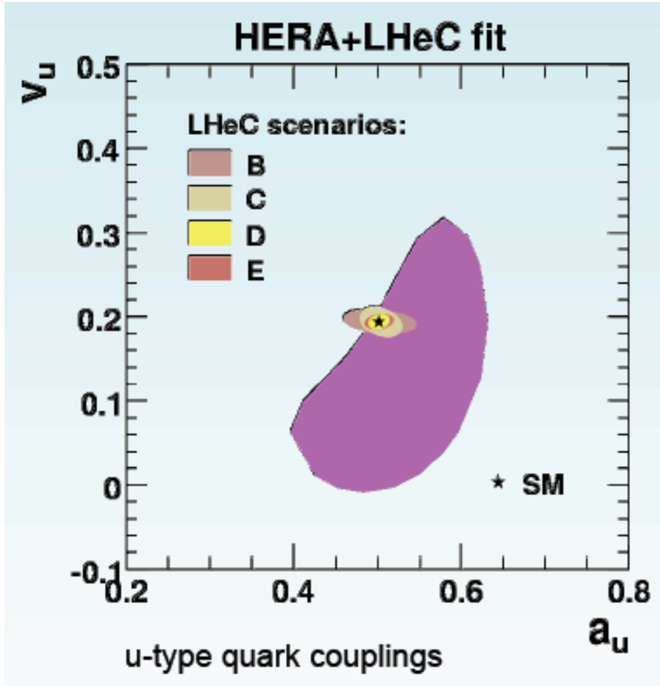


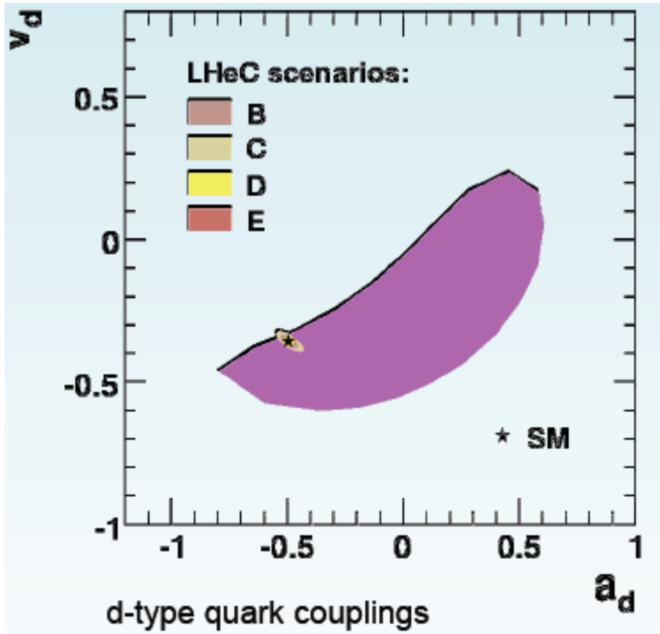
MSSM - B.Allnach et al, hep-ex/0403133

DATA	exp. error on α_s
NC e⁺ only	0.48%
NC	0.41%
NC & CC	**0.23% :=⁽¹⁾**
(1) γ_h>5°	0.36% :=⁽²⁾
(1) +BCDMS	0.22%
(2) +BCDMS	0.22%
(1) stat. *= 2	0.35%

independent of BCDMS

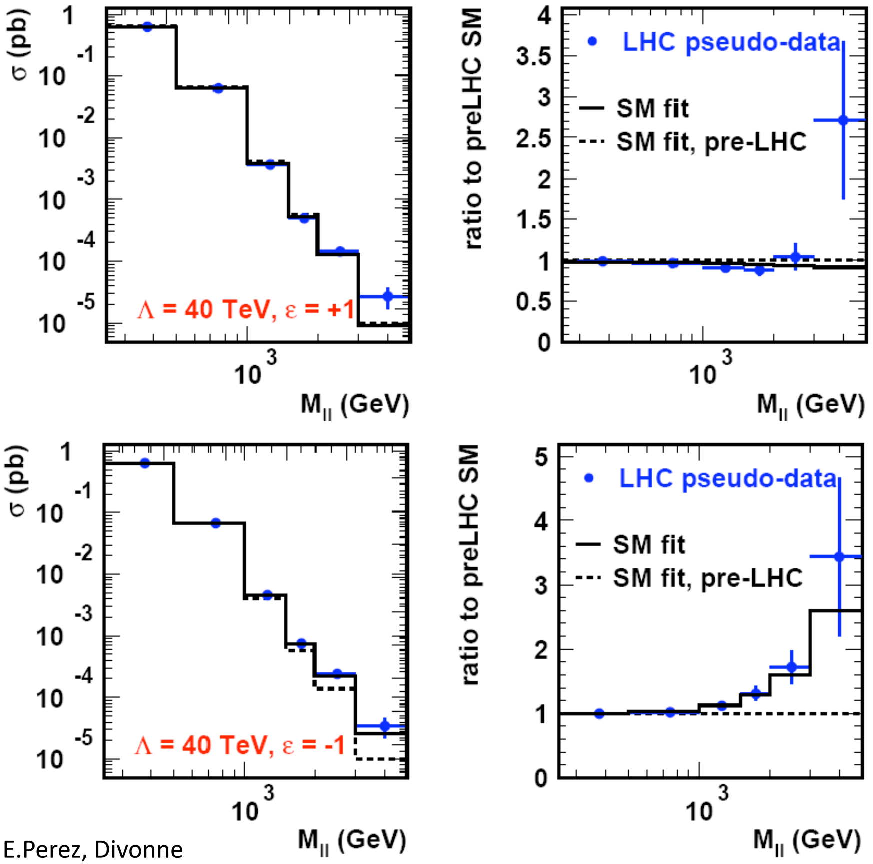
DIS08, T.Kluge





DIS09, C.Gwenlan

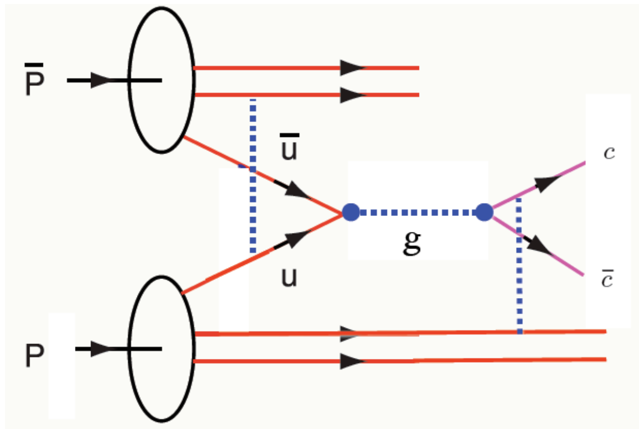
pdf's and New Physics at the LHC



E.Perez, Divonne

NP may be accommodated by HERA/BCDMS DGLAP fit. It can not by the fit to also LHeC.

(recall high E_T excess at the Tevatron which disappeared when xg became modified)



Factorisation is violated in production of high p_T particles (IS and FS i.a.s).

Important, perhaps crucial, to measure pdf's in the kinematic range of the LHC. cf also ED limits vs pdf's.

John Collins, Jian-Wei Qiu . ANL-HEP-PR-07-25, May 2007.

e-Print: **arXiv:0705.2141** [hep-ph]

Summary:

The LHeC has the potential to completely unfold the partonic content of the proton, u,d, c,s, t,b, for the first time and in an unprecedent kinematic range. This is based on inclusive NC, CC cross sections, complemented by heavy quark identification.

Puzzles as u/d at large x or a strange-antistrange asymmetry can be expected to be solved.

Precision measurements are possible of xg (up to large x) and the beauty density which are of particular relevance for the LHC.

The precision measurement of all quark distributions [largely independent of QCD and parameterisations] may be crucial for the interpretation of new physics at the LHC.

There is a huge potential for electroweak physics in accurate data LHeC (couplings, $F_2^{\gamma Z}$, ..) which has only started to be evaluated. α_s may be measured to permill.

Low x physics will be lead to a new area with the extension of the kinematic range beyond unitarity in DIS and high precision measurements, as of F_2 and also F_L.

Neutron distributions will become measurable in deuteron runs with p,n,d tagging. Diffraction is predicted to constrain shadowing.

The impact of the LHeC on nuclear pdf's is most striking (extension by 4 orders of magnitude!)

backup

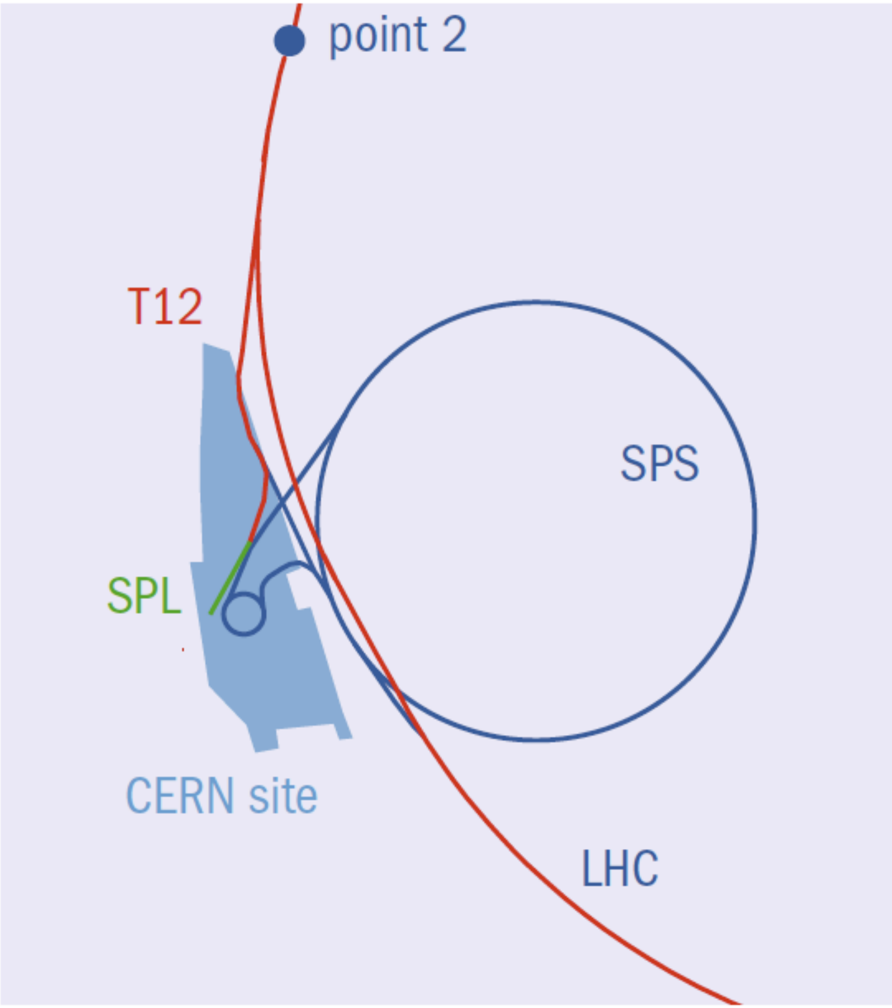


Fig. 4. Sketch of a possible layout to inject an electron beam into the LHC ring, using the SPL and the TI2 connection to the LHC tunnel.

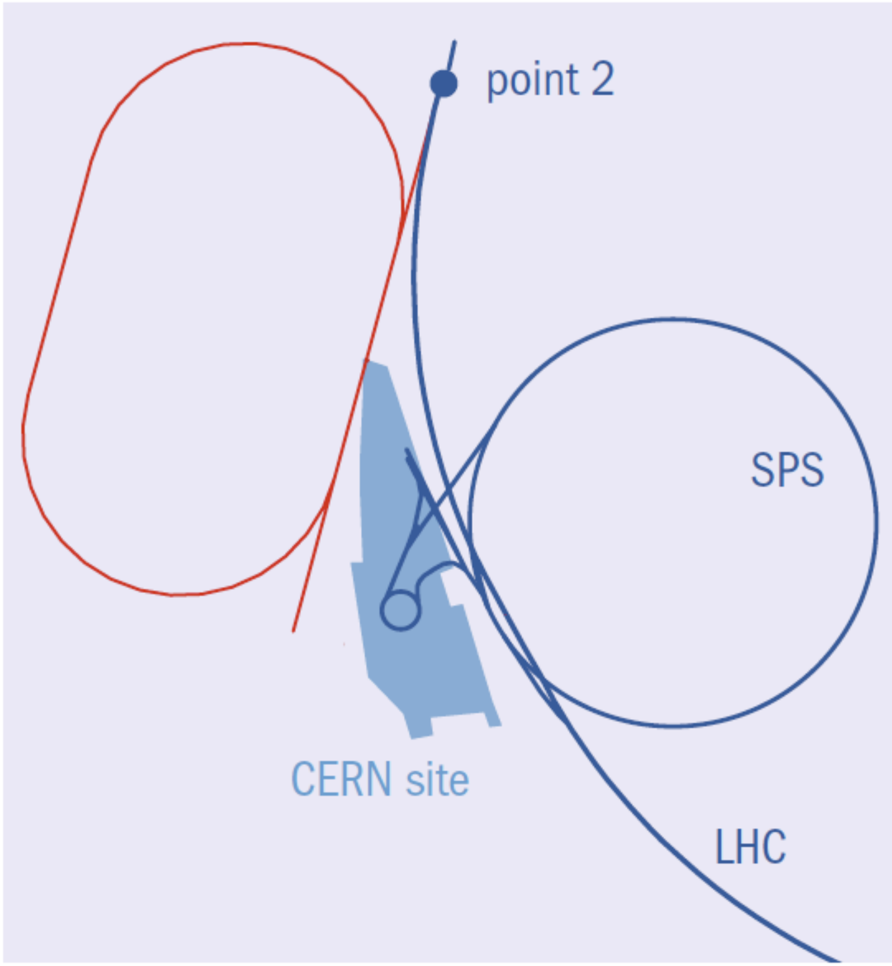


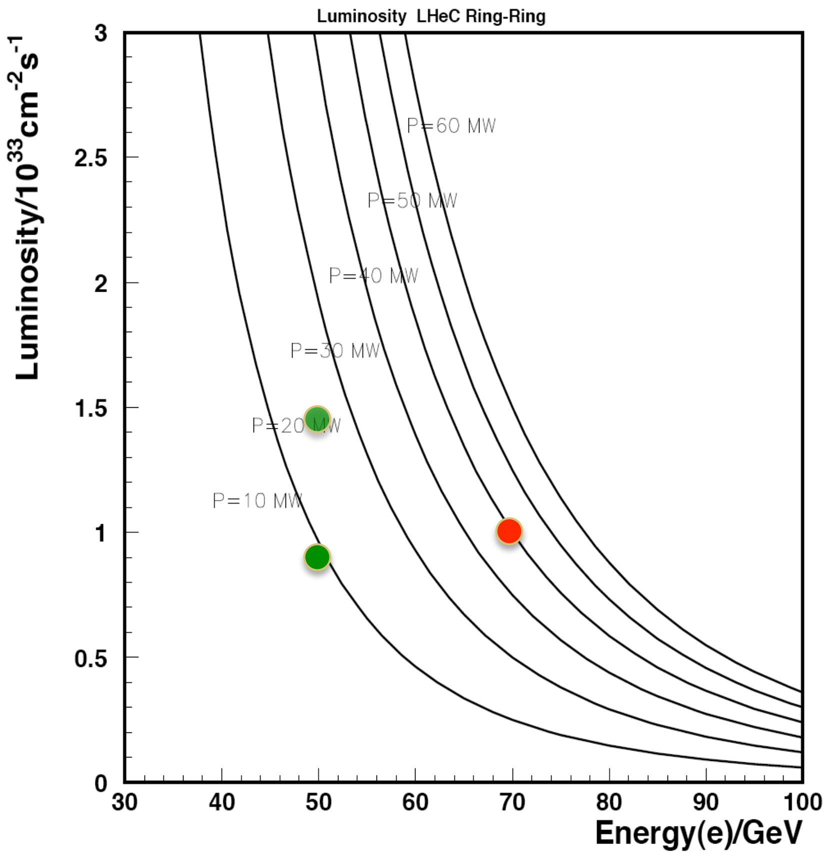
Fig. 5. A possible layout in which an electron linac arrives tangentially to the LHC, after multiple passes around a "racetrack" that makes full use of the linac accelerating structures.

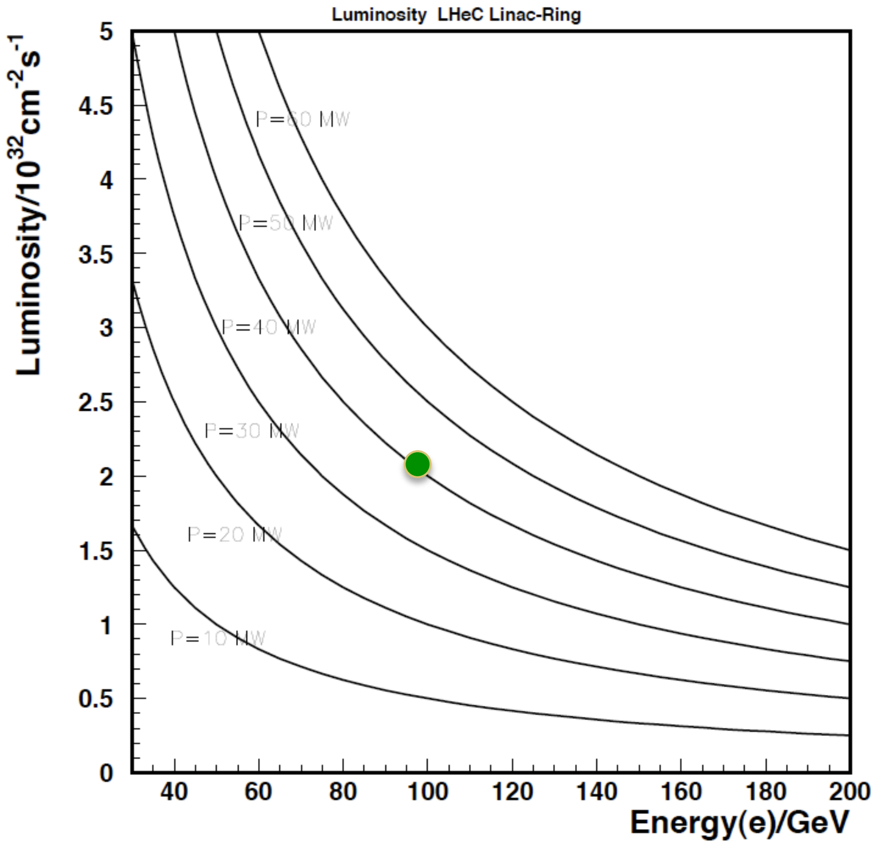
CERN Courier 4/09 PN,MK

Luminosity Estimates

Ring-Ring: L ~P/E^4

LINAC-Ring: L~P/E





F.Willeke, 70GeV * 7TeV, 50MW [JINST 2006]

B.Holzer, A.Kling et al, Divonne08,ECFA08

Scale BH to 50MW: 5 10^{33} at 50 GeV

F.Zimmermann, ECFA08

Scale 100 GeV to 50 GeV: 5 10^{32} cm^{-2}s^{-1}

HIgh energy recovery LINAC?