

# Parton Distributions from the LHeC

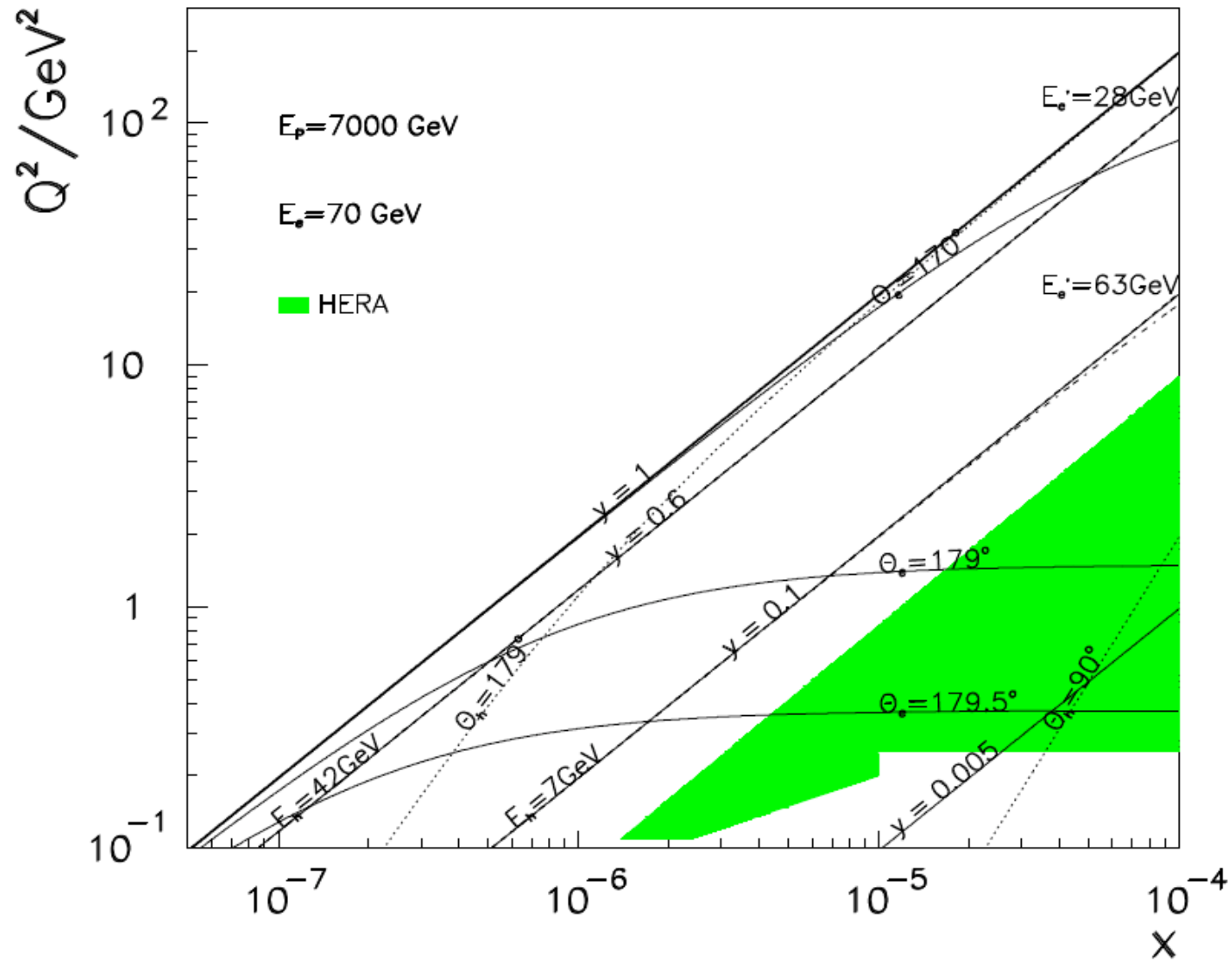
Max Klein



A simulation and study of how well we should be able to measure  $u, d, s, c, b, t$  and  $xg$  of the proton

in a new ep world of high luminosity and precision measurements in the enormous kinematic range the LHeC would open.

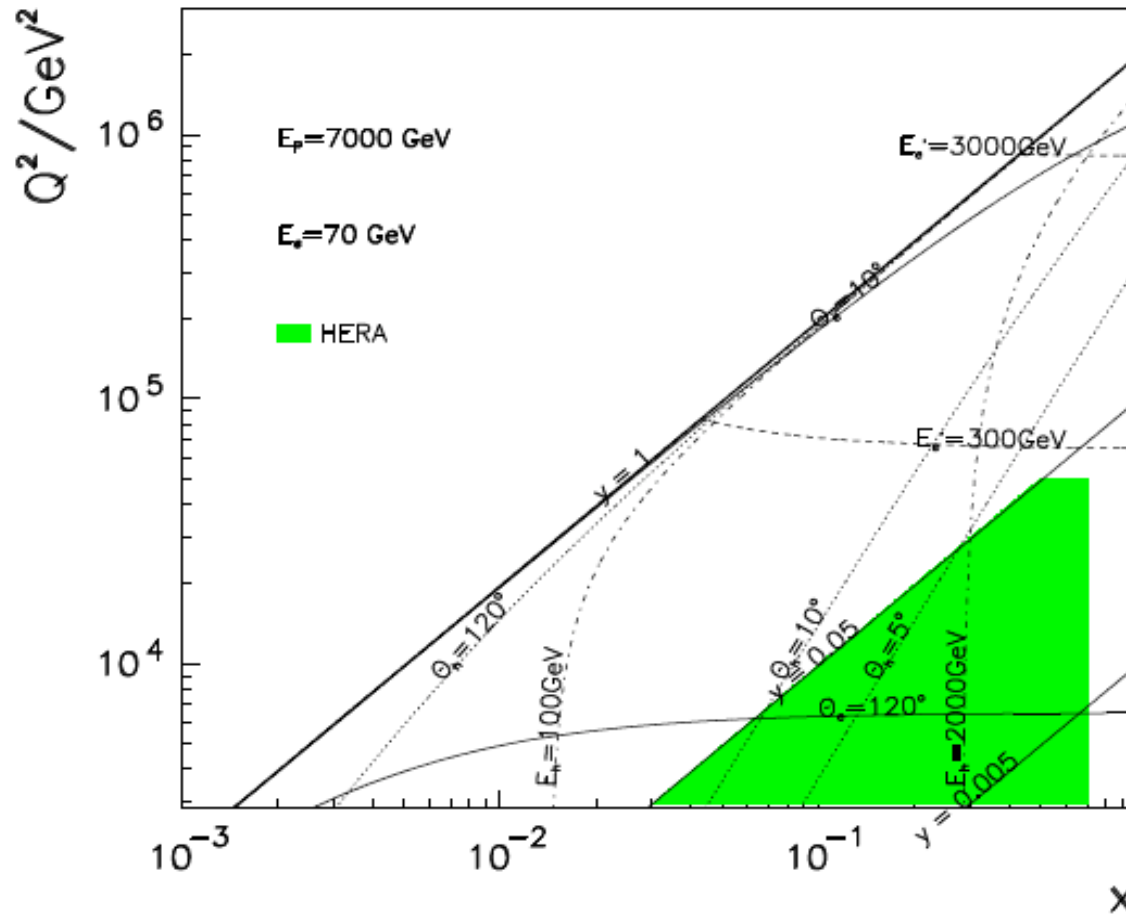
# LHeC – Low x Kinematics



$10^5$  events  
 per  $\text{pb}^{-1}$   
 for  $Q^2 > 100$   
 Lumi 'easy'

Dramatic extension of low x kinematic range

## LHeC – High $Q^2$ Kinematics



Maximum luminosity in JINST06 design achieved with focusing magnets close to IP ( $9^\circ$  cut) two detectors or detector versions required  
 Low  $x$  with  $10^{32}$ , high  $Q^2$  with  $10^{33}$ , about

# Detector requirements

High luminosity to reach high  $Q^2$  and large  $x$   
 $10^{33} - 10^{34}$  1-5  $10^{31}$

Largest possible acceptance  
1-179° 7-177°

High resolution tracking  
0.1 mrad 0.2-1 mrad

Precision electromagnetic calorimetry  
0.1% 0.2-0.5%

Precision hadronic calorimetry  
0.5% 1%

High precision luminosity measurement  
0.5% 1%

LHeC

HERA

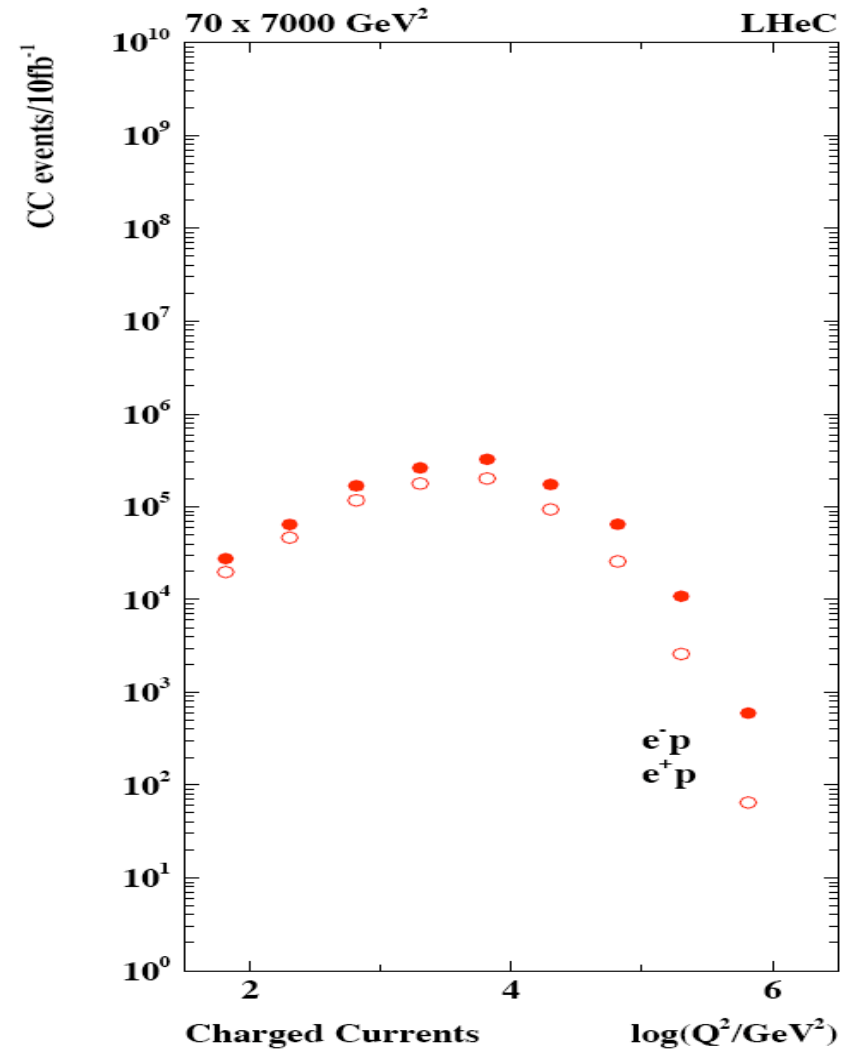
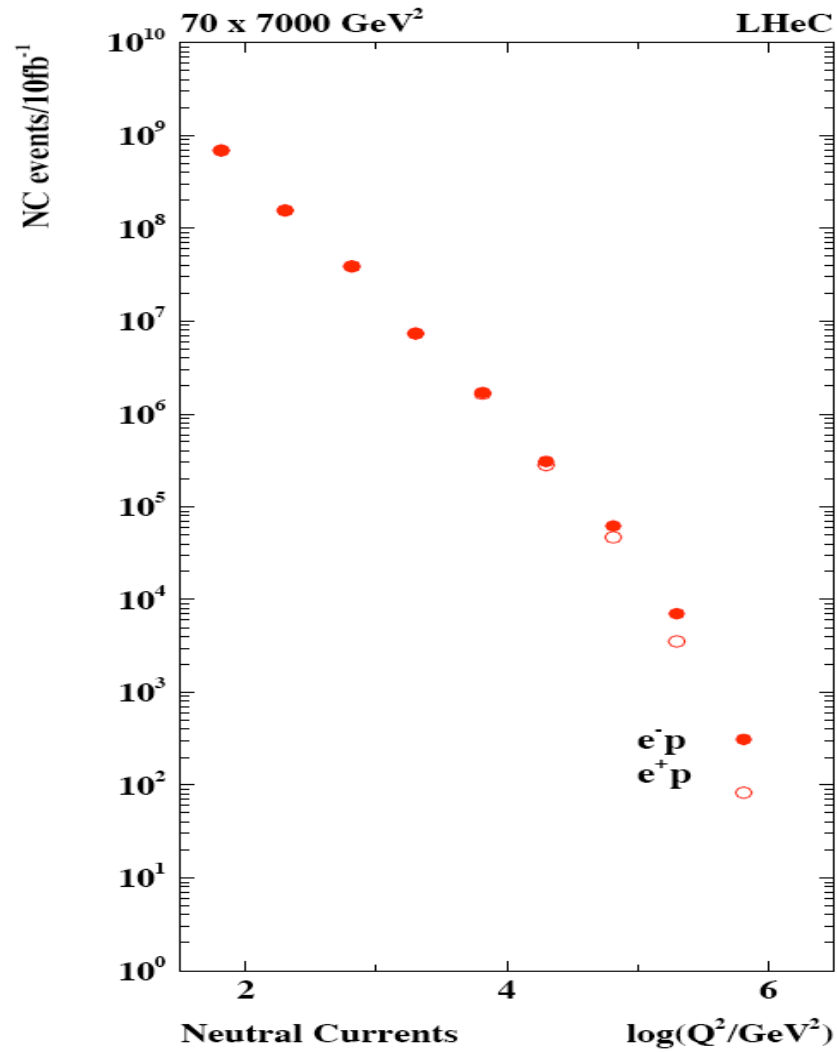
The new detector (L1)

has to be at least  
2 times better than the  
good old H1

Detector parameters  
were put in simulation of  
NC and CC (LO) cross  
sections with analytic  
calculation of systematic  
uncertainties.

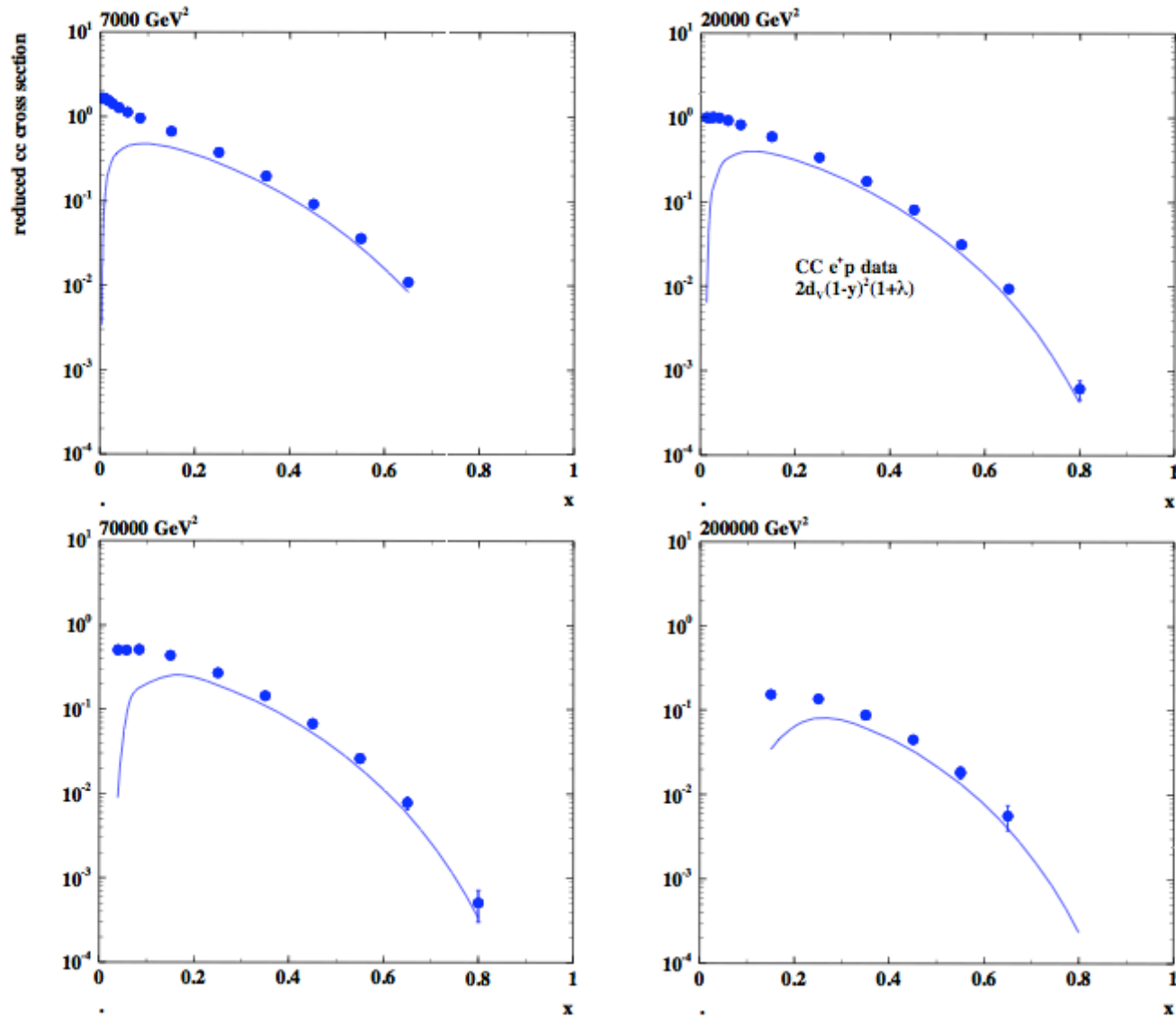
NLO QCD fits to these  
'data' were performed,  
on pdfs by Emmanuelle  
Perez and on alphas by  
Thomas Kluge.

# Rates

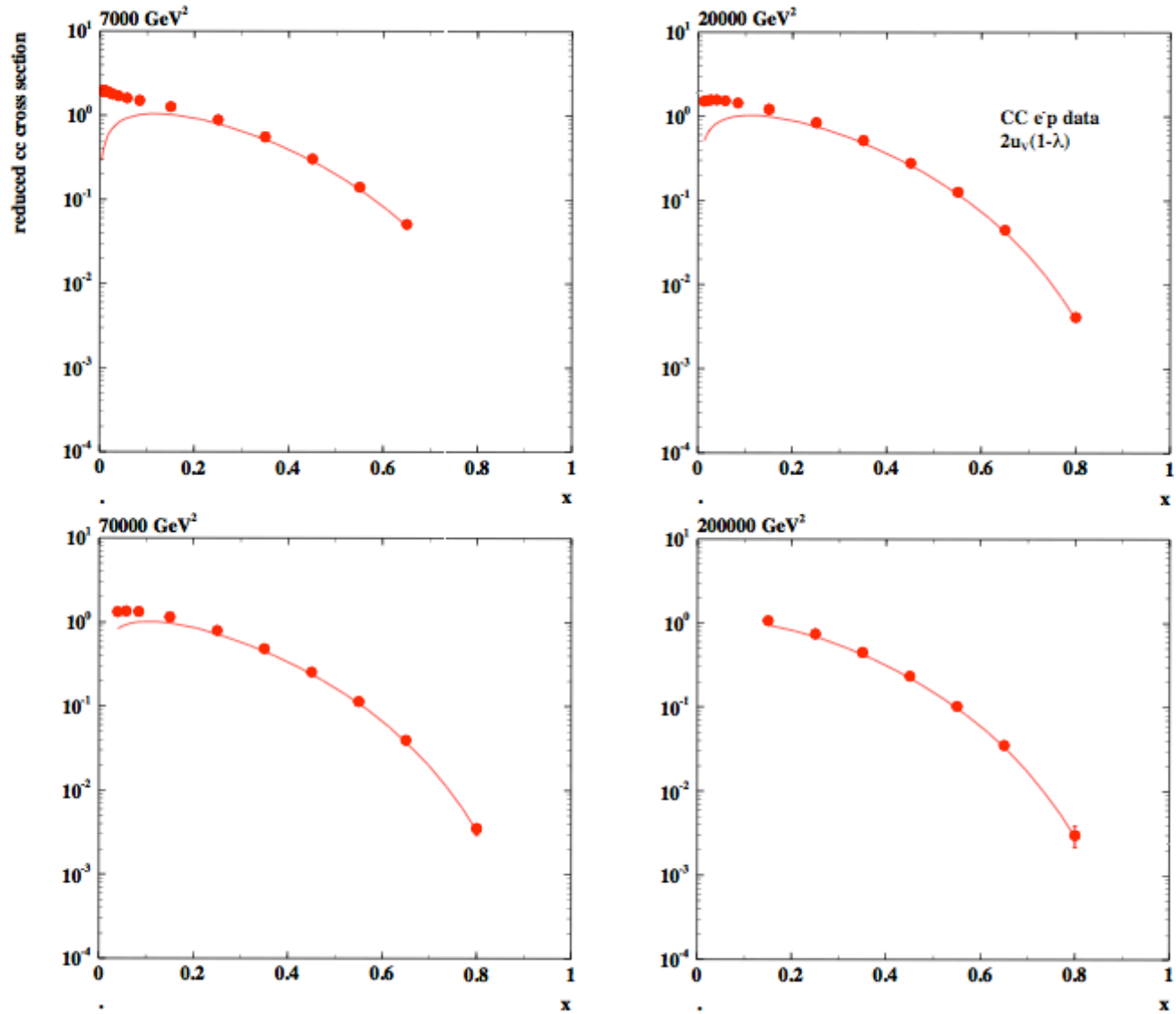


Simulations done for 10fb<sup>-1</sup> and statistical error limited to 0.1% at low Q<sup>2</sup>

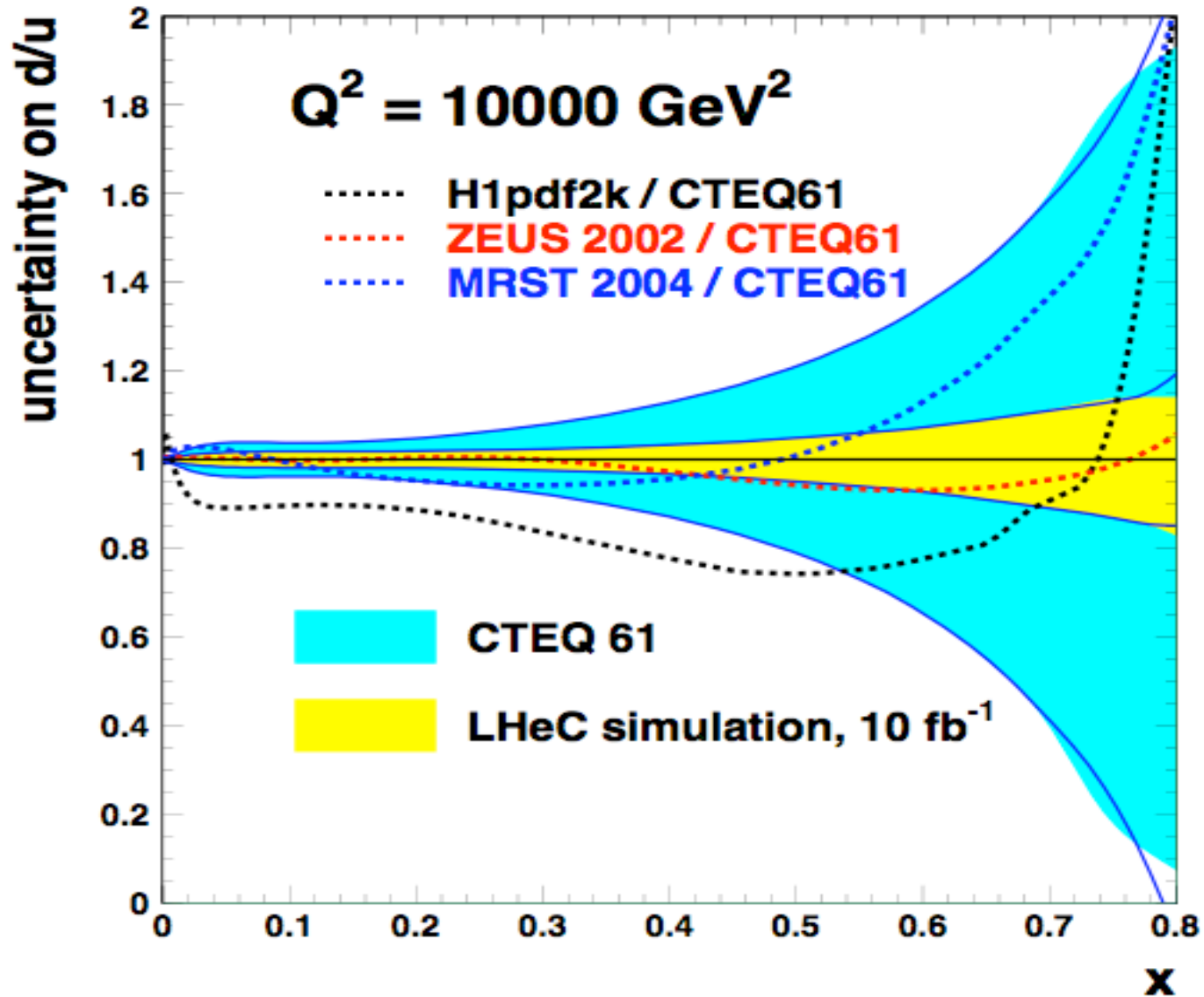
# Charged currents (e+)



# Charged currents (e-)



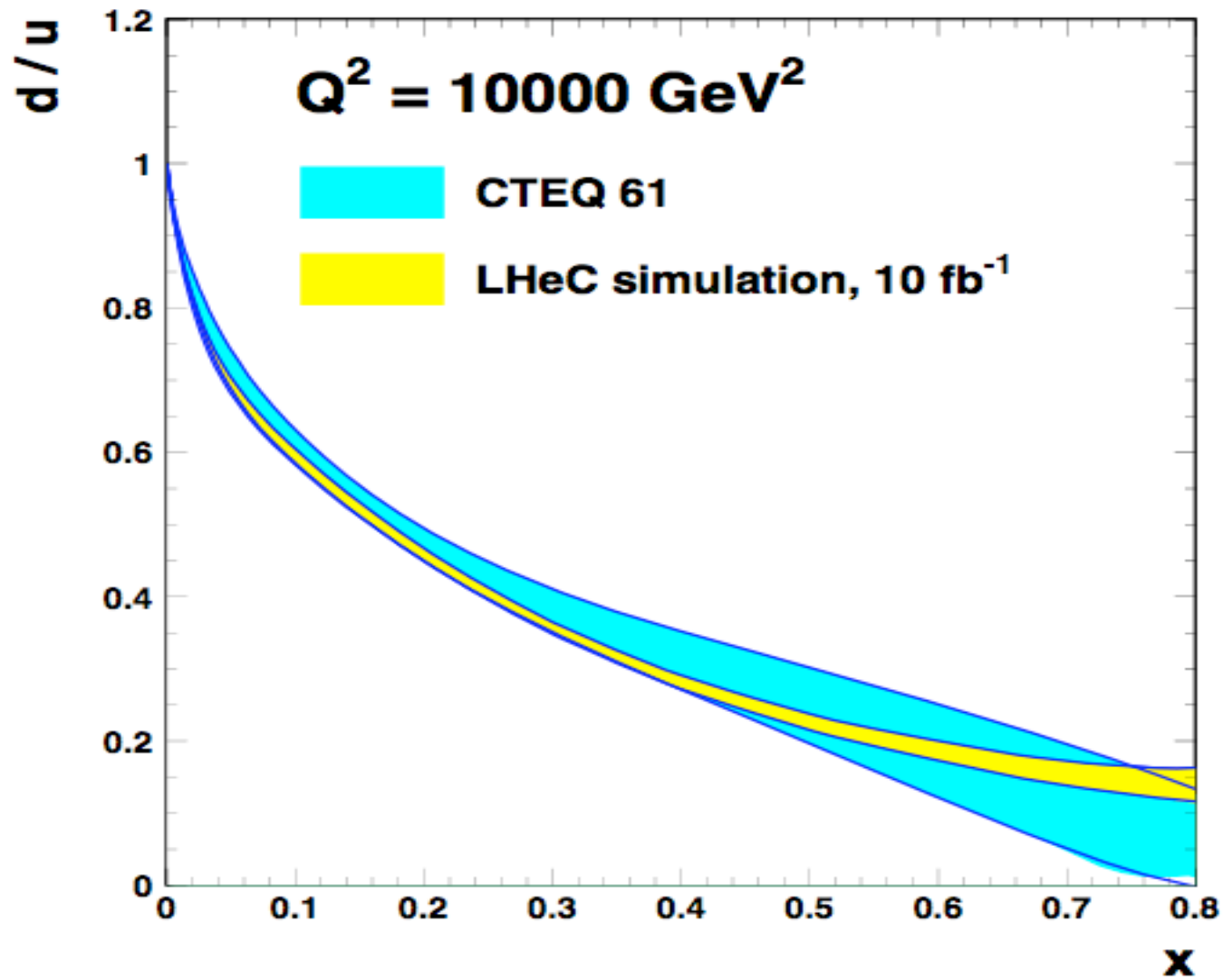
# d/u at large x



E.Perez

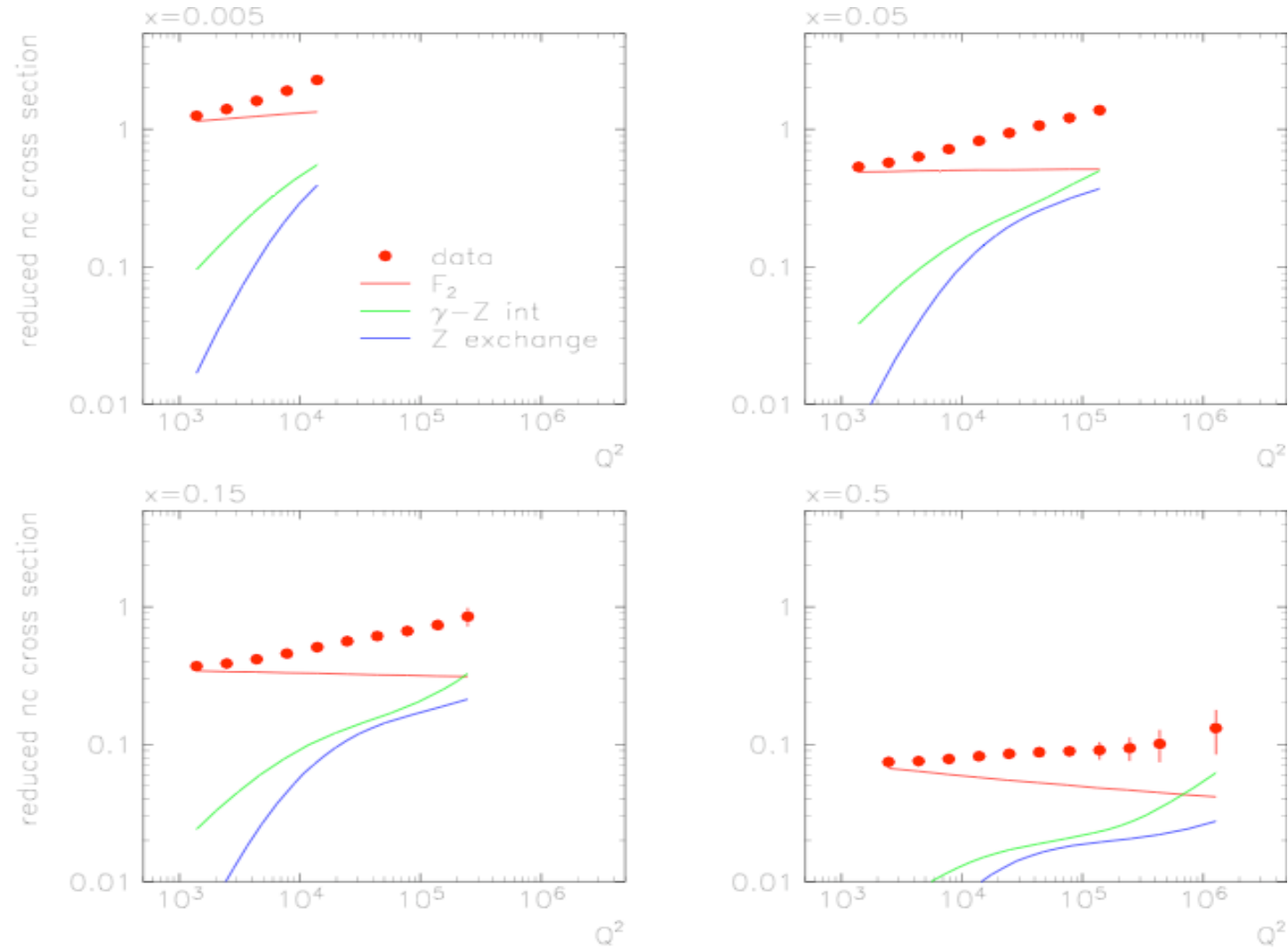


# d/u at large x

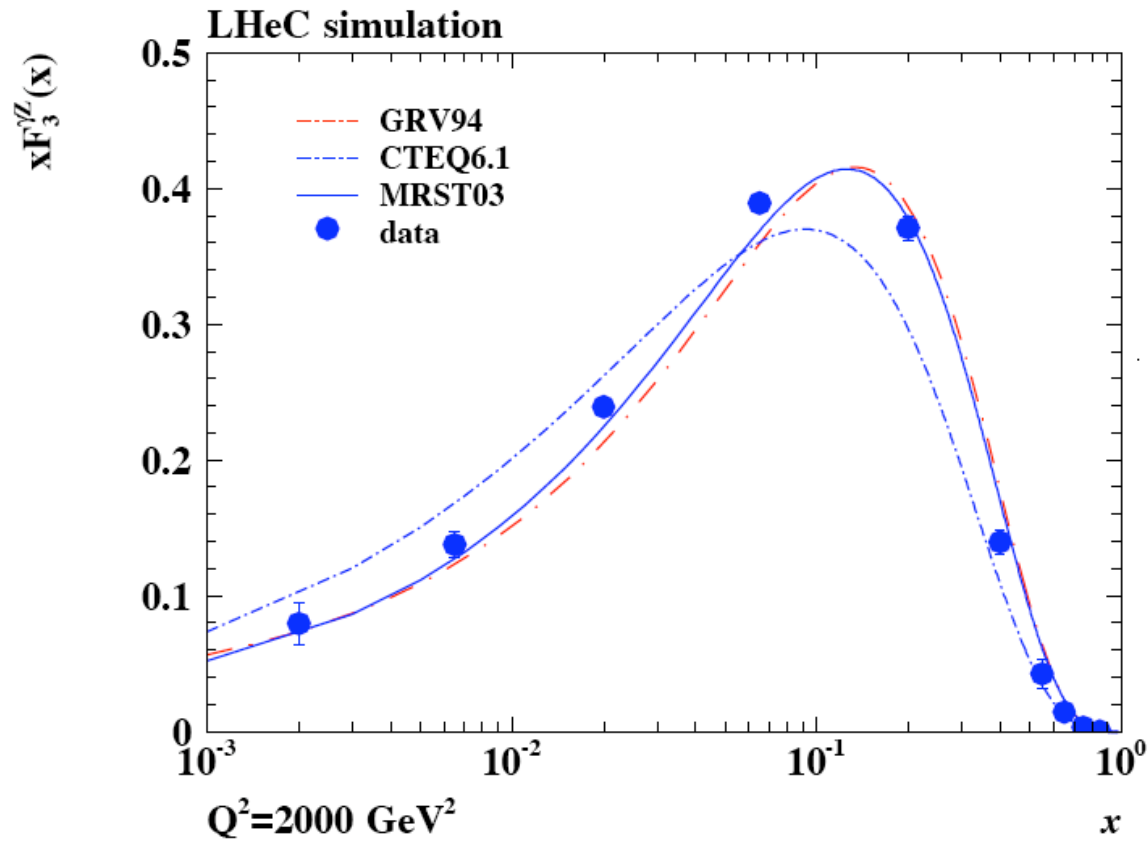


E.Perez

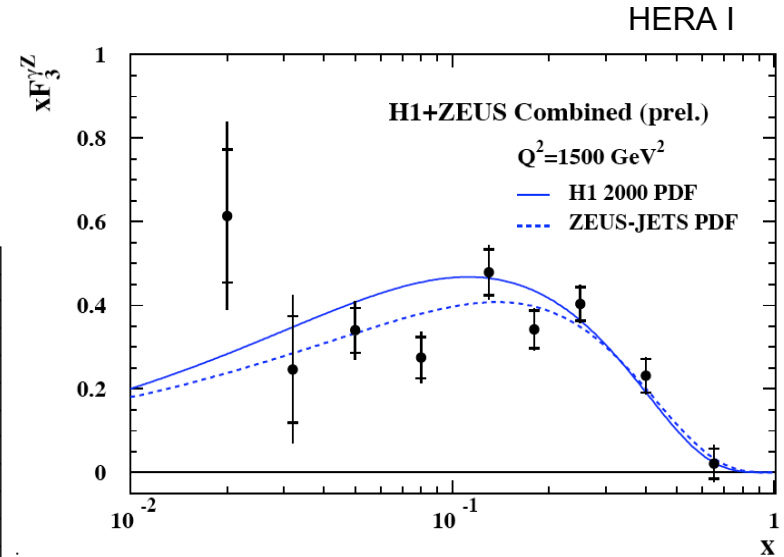
# The LHeC is an electroweak machine



$x F_3^{\gamma Z}$



$$x F_3^{\gamma Z} = 2x [e_u a_u (u_v + \Delta_u) + e_d a_d (d_v + \Delta_d)]$$



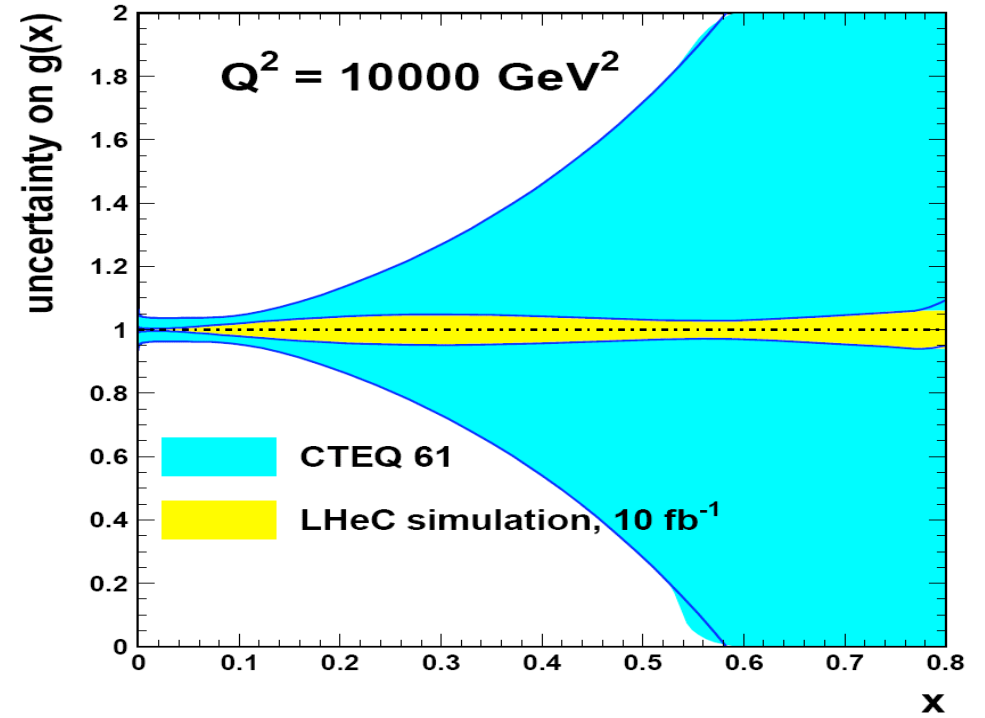
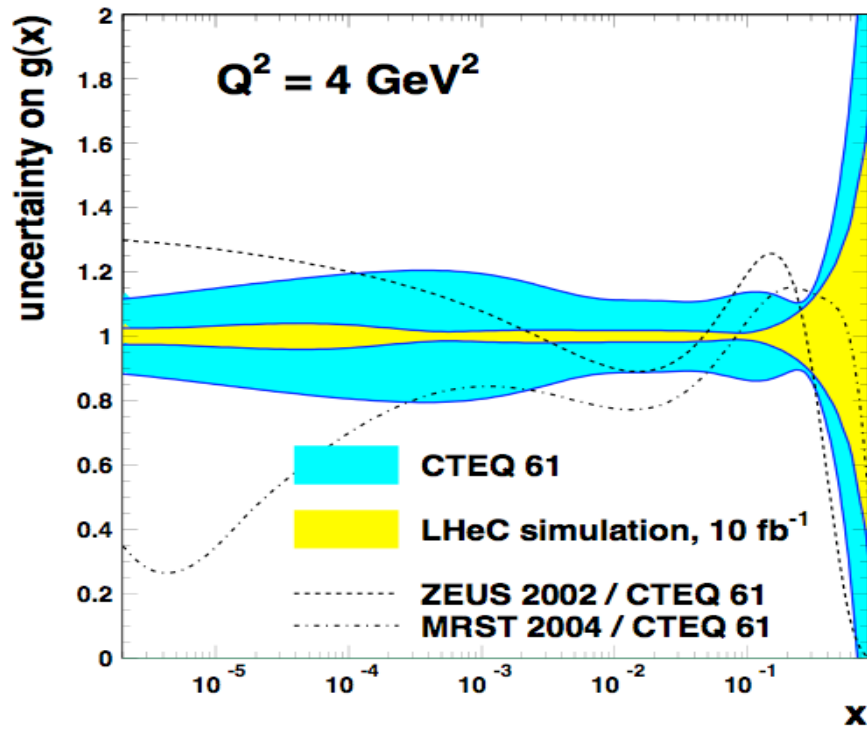
Valence quarks at low x  
 or/and unexpected sea  
 asymmetries

$$\Delta_u = (u_{sea} - \bar{u} + c - \bar{c})$$

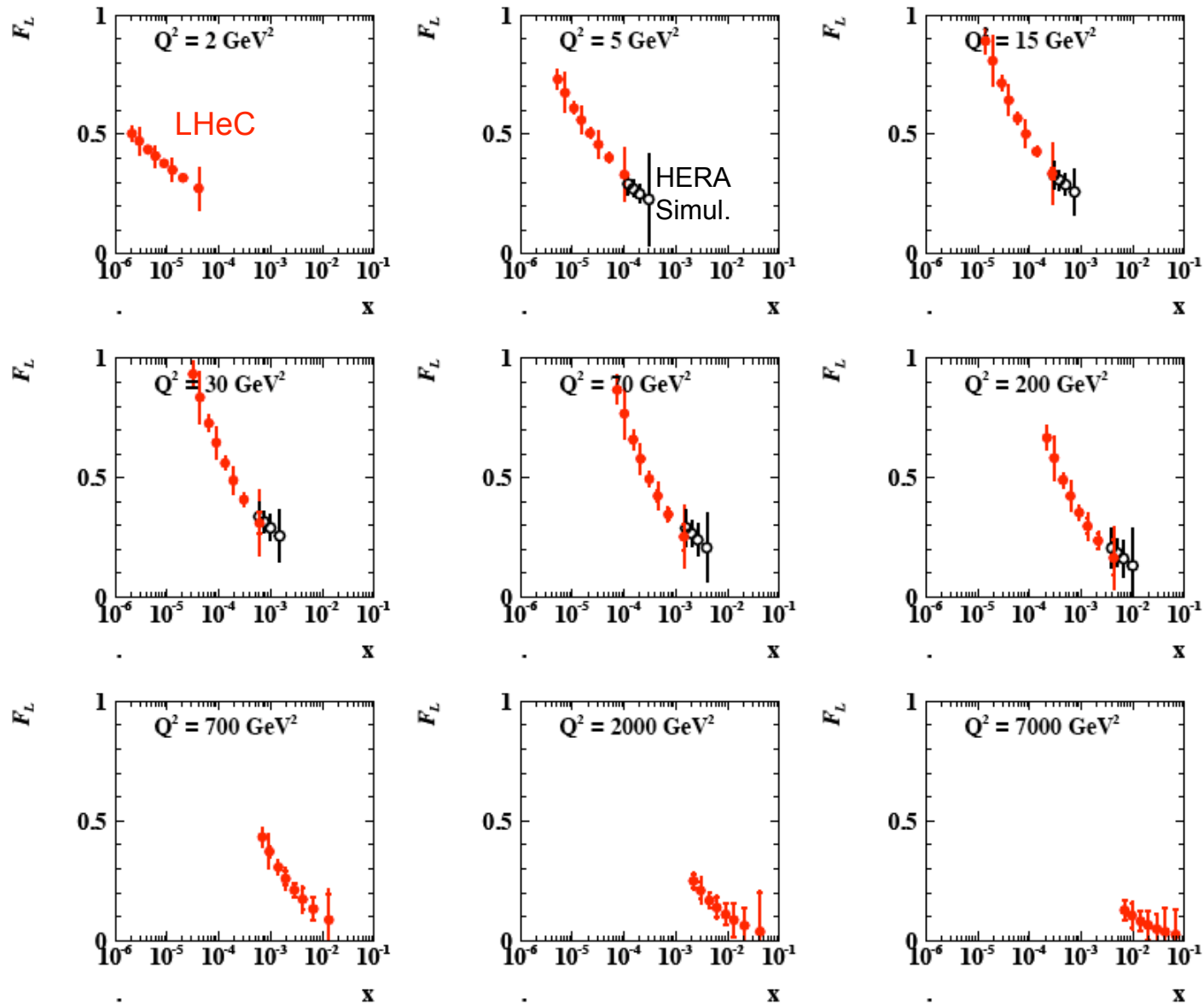
$$\Delta_d = (d_{sea} - \bar{d} + s - \bar{s})$$

from  $\gamma Z$  interference

# Gluon Distribution



E.Perez



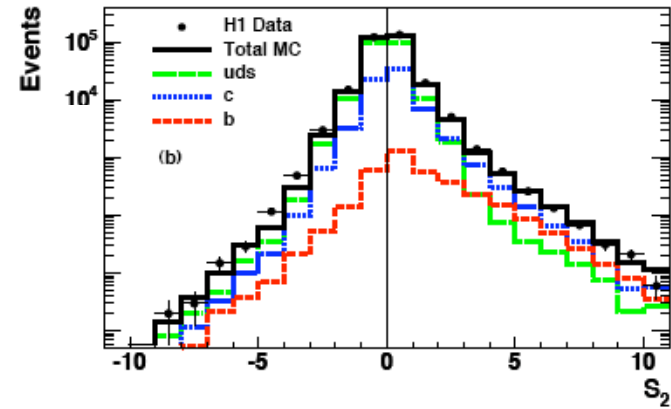
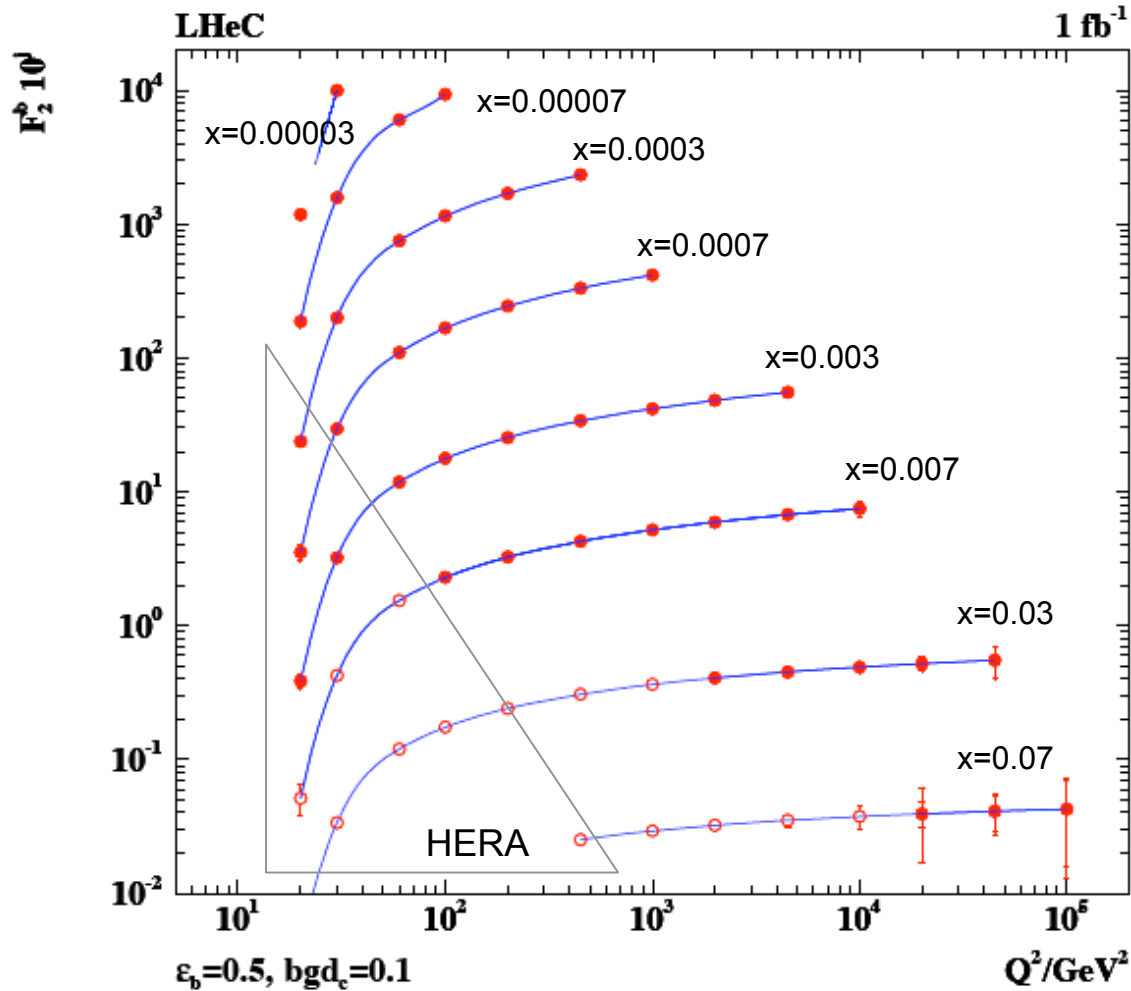
**DIS08**  
**J.Forshaw**  
**et al.**

May not be able to simultaneously fit the two proton structure functions  $F_2$  and  $F_L$  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)...**

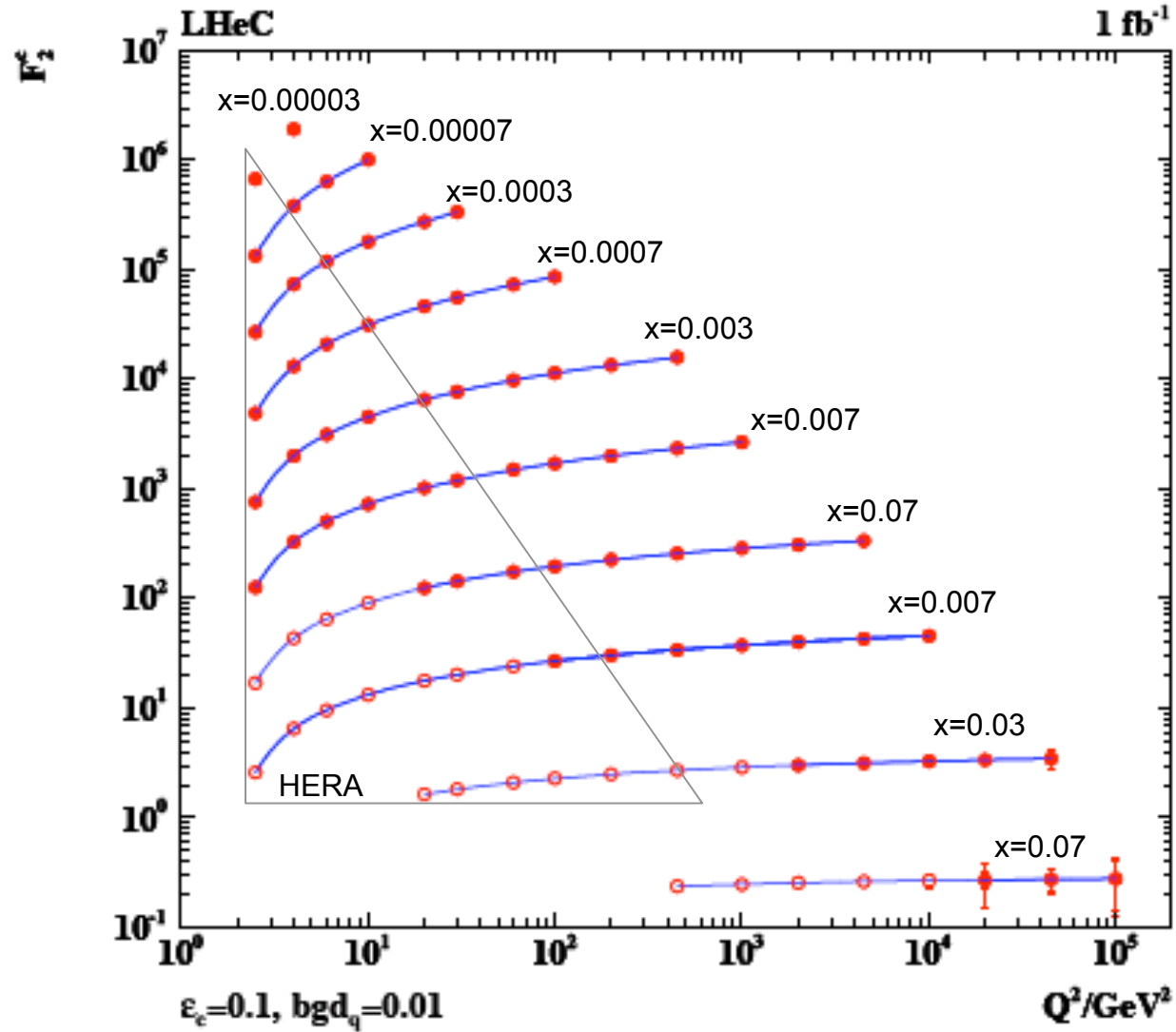
# Beauty quark distribution



$1 fb^{-1}$   
 $\epsilon_b = 0.5$   
 $bgd_c = 0.1$   
 $\delta_{syst} = 0.1$   
 $\circ - \vartheta_h \geq 1^\circ$   
 $\bullet - \vartheta_h \geq 10^\circ$

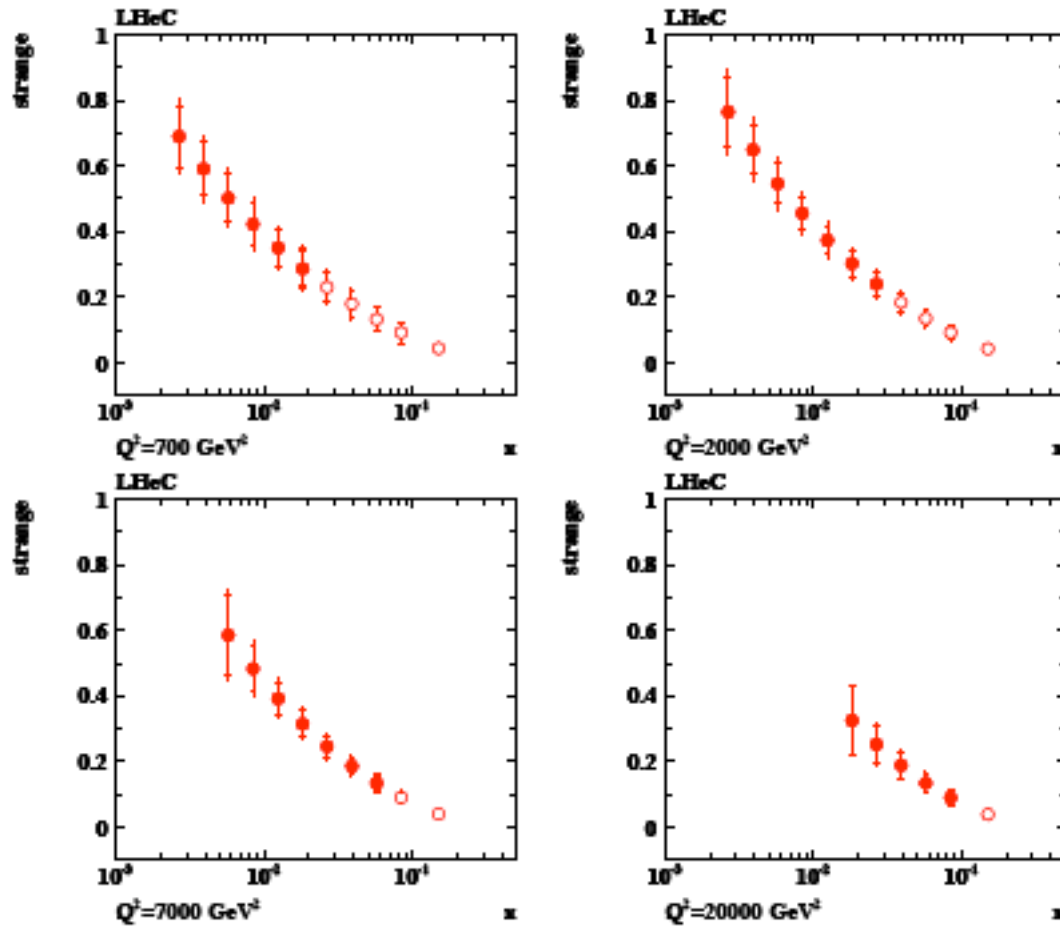
Impact parameter tagging  
 At LHeC may also tag  
 decays with dedicated  
 vertex detector  
 beam spot  $35 \times 15 \mu m^2$

# Charm quark distribution



$1 \text{ fb}^{-1}$   
 $\epsilon_c = 0.1$   
 $\text{bgd}_q = 0.01$   
 $\delta_{\text{syst}} = 0.1$   
 $\circ - \vartheta_h \geq 1^\circ$   
 $\bullet - \vartheta_h \geq 10^\circ$

# Strange quark distribution



$$W^+ s \rightarrow c$$

$$1 \text{ fb}^{-1}$$

$$\varepsilon_c = 0.1$$

$$\varepsilon_q = 0.01$$

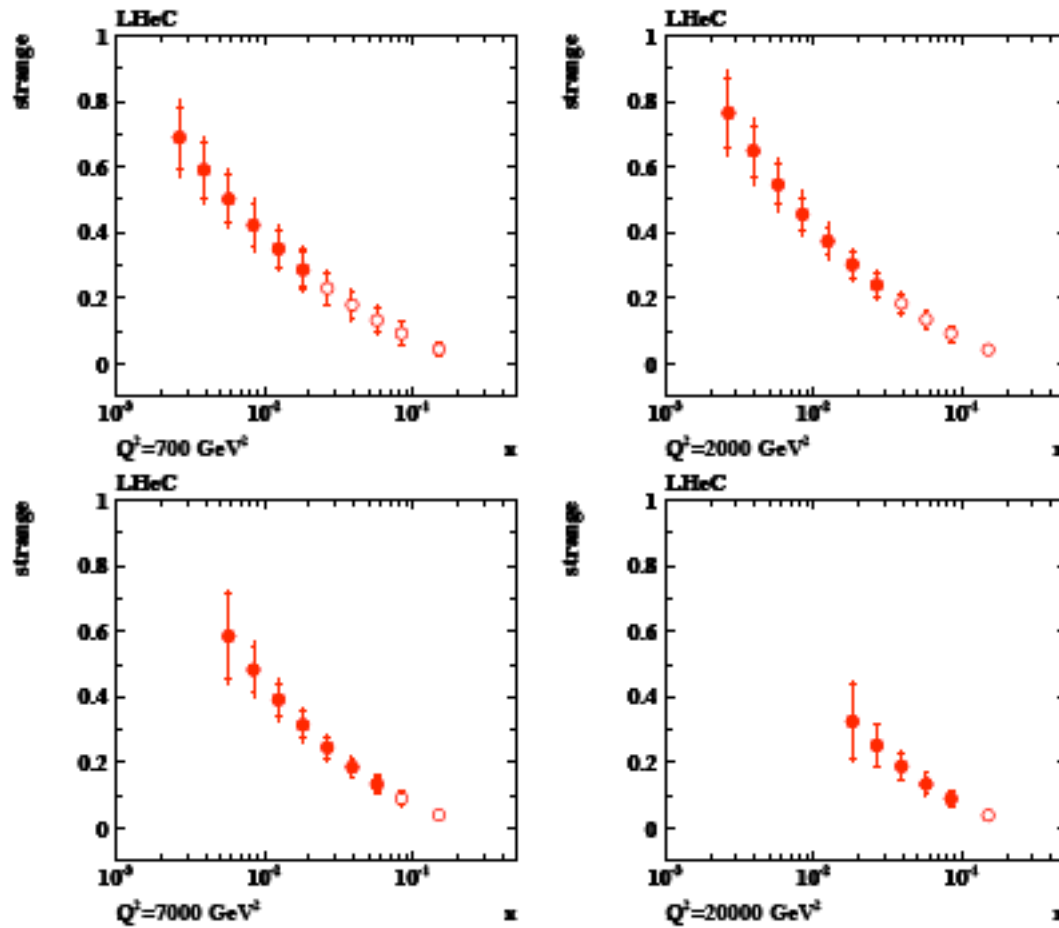
$$\delta_{\text{sys}} = 0.1$$

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

$$\bullet - \vartheta_h \leq 10^\circ$$



# Anti-Strange quark distribution



$W^- s\bar{b}ar \rightarrow c\bar{b}ar$

$1 fb^{-1}$

$\epsilon_c = 0.1$

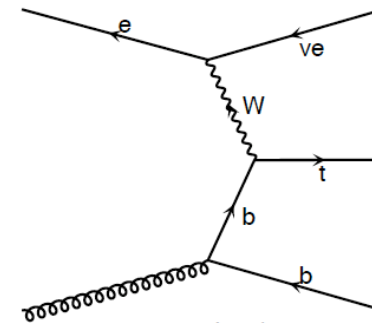
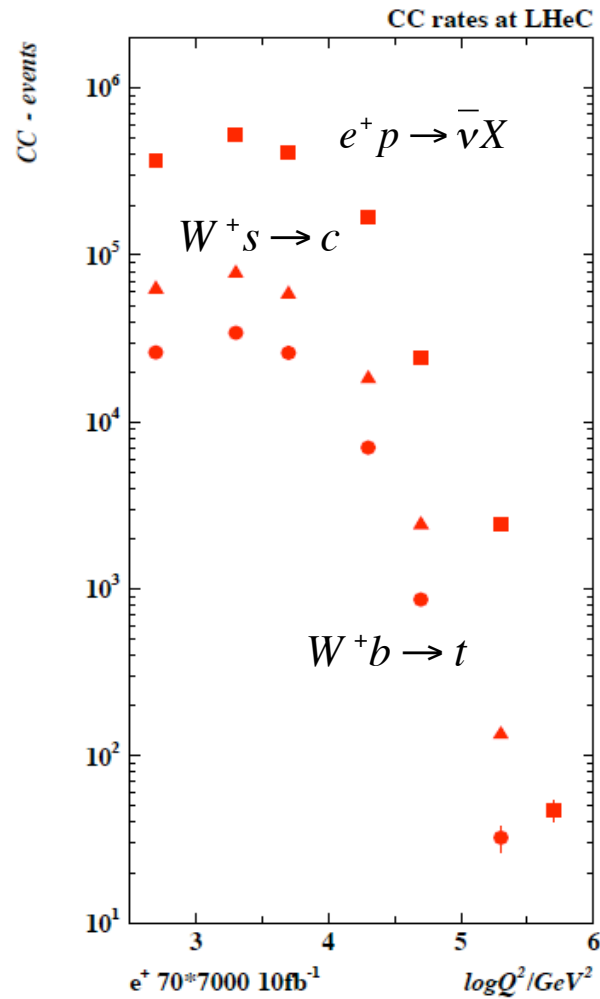
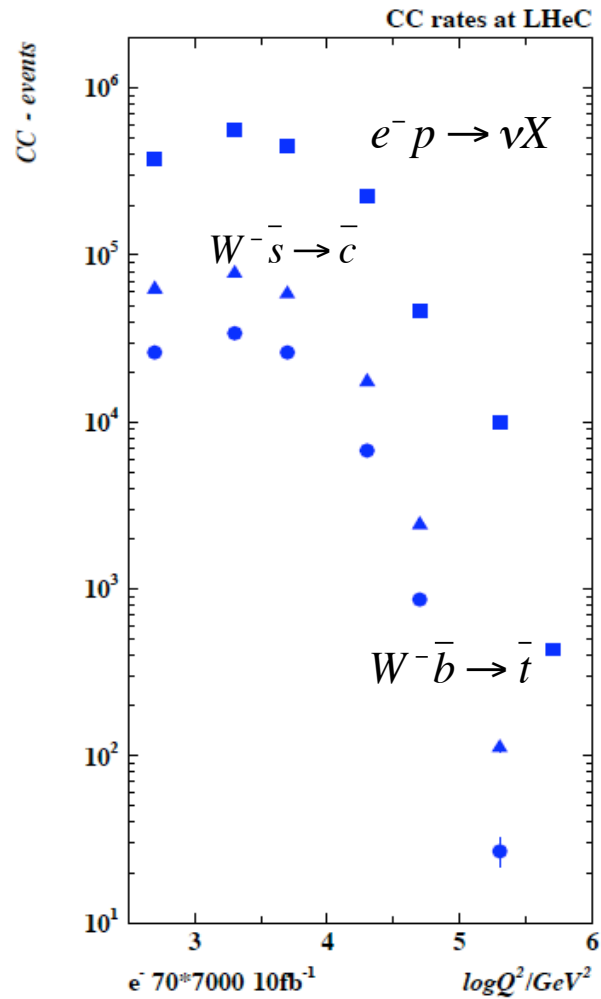
$\epsilon_q = 0.01$

$\delta_{syst} = 0.1$

○ -  $\vartheta_h \geq 1^\circ$

● -  $\vartheta_h \geq 10^\circ$

# Top and Top Production at the LHeC (cc)

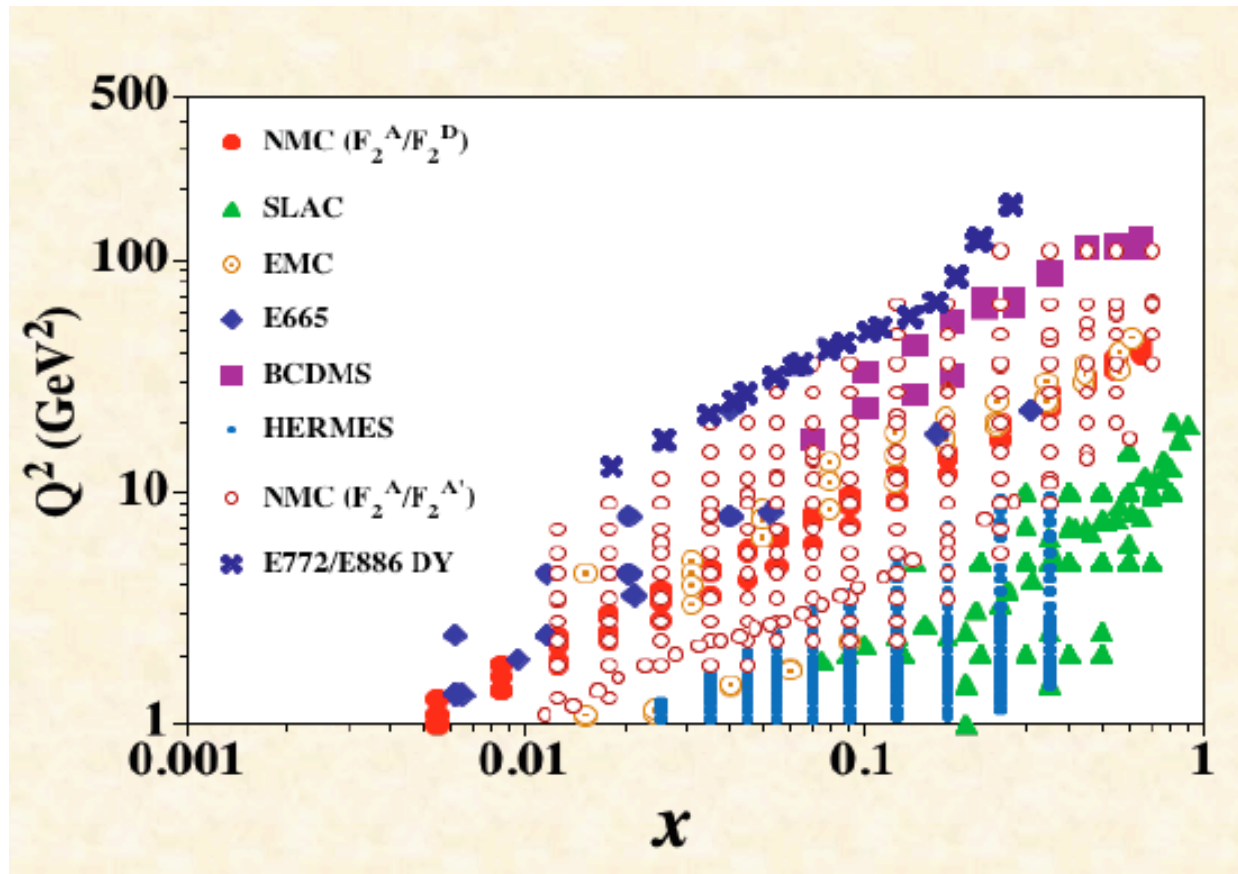


**LHeC is a single top and tbar quark factory**

**with a CC cross section of O(10)pb - worth studying further**

**Cross section to be Checked (pdf's)**

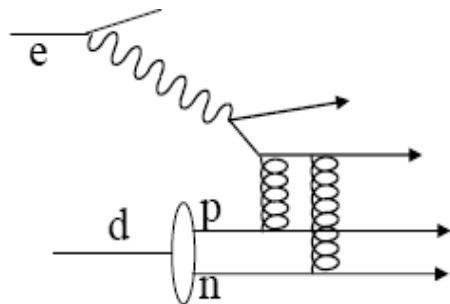
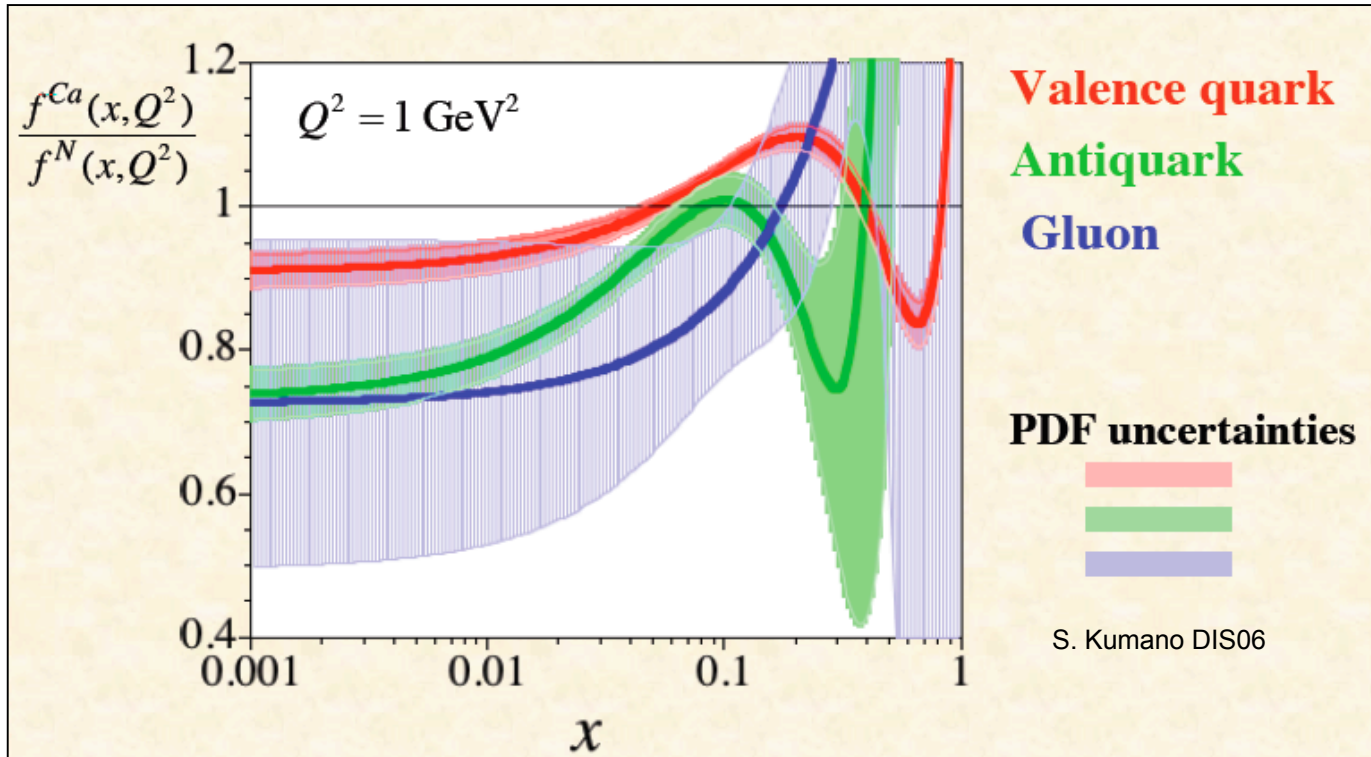
# Available data on $F_2$ in nuclei



Limited information on quarks and nearly none on gluons

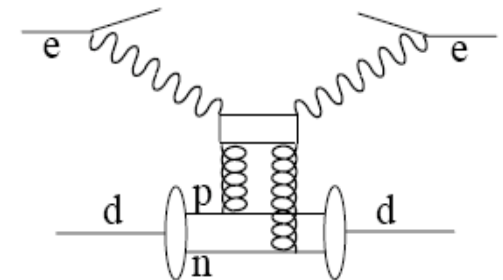
The LHeC extends the eA kinematic range by 4 orders of magnitude

# Determination of nPDF's

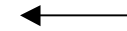
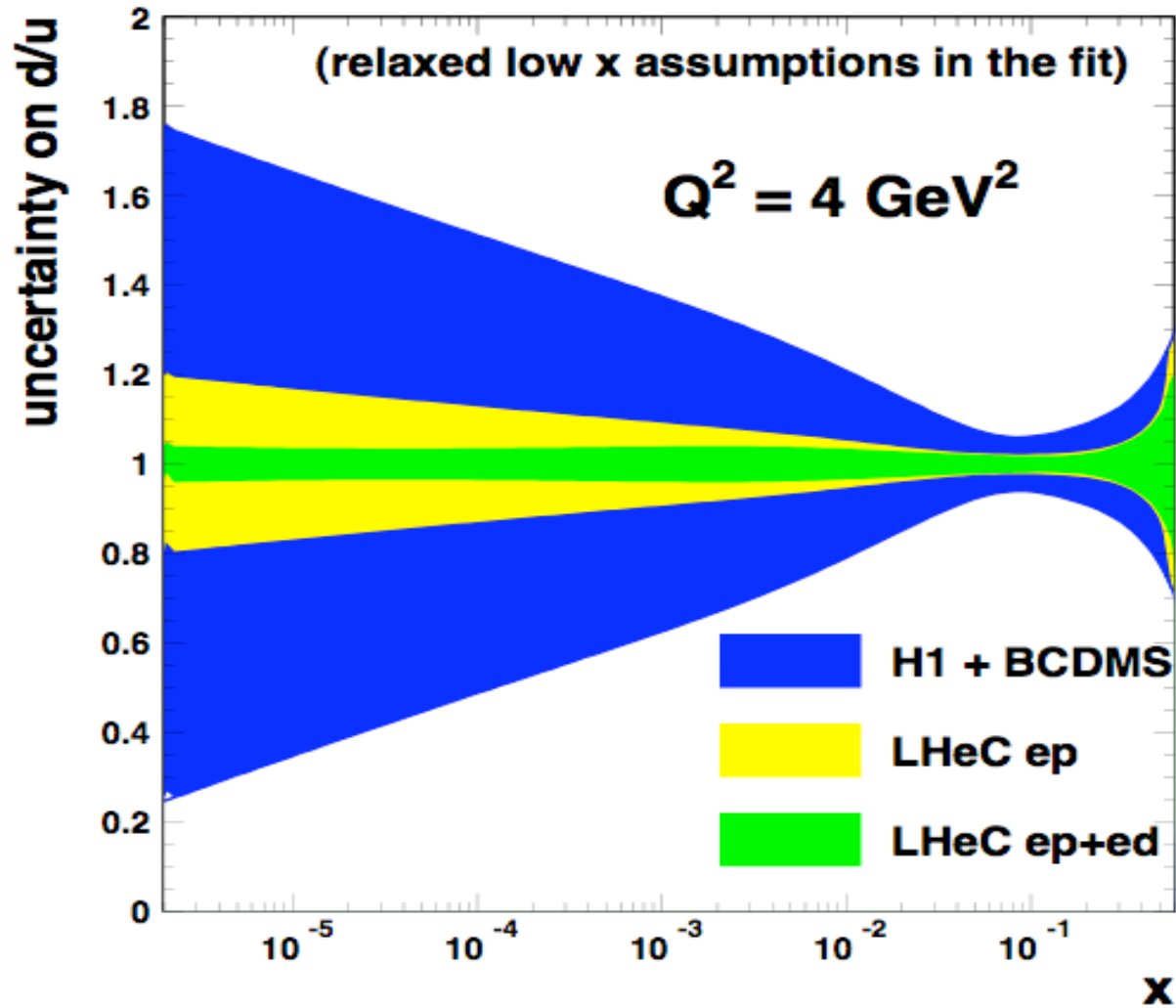


Max Klein LHeC pdf Divonne 2.9.08

In eA at the collider, test Gribovs relation between shadowing and diffraction, control nuclear effects at low Bjorken  $x$  to high accuracy



# d/u at low x from deuterons

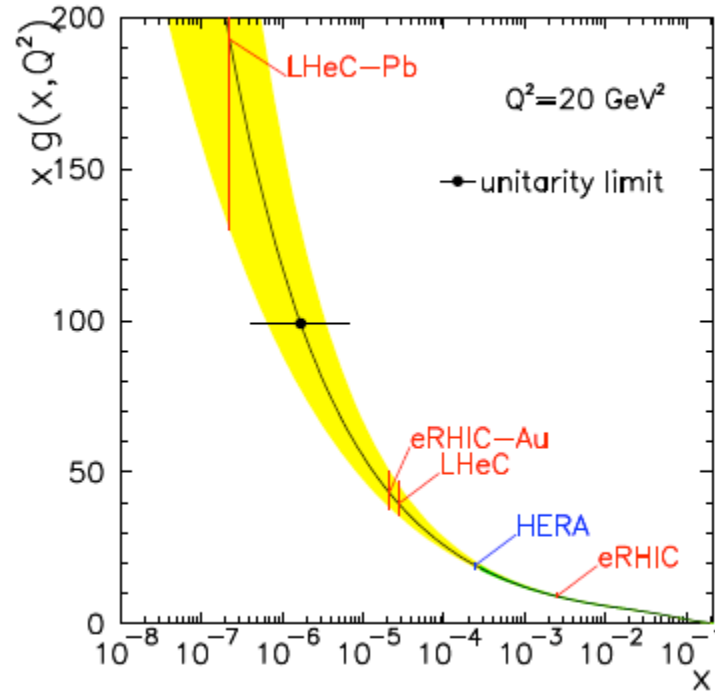
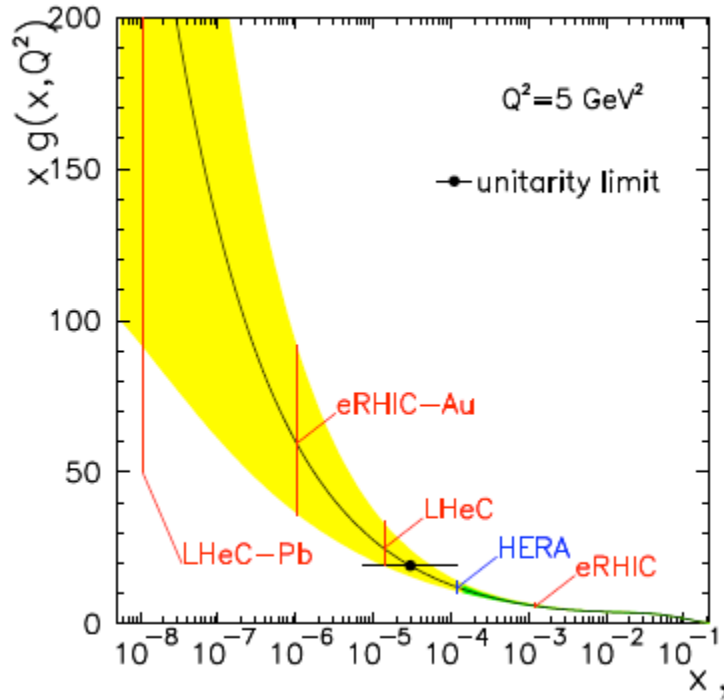


Note  
all QCD fits  
assume  
 $u=d$   
at low  $x$

No constraint  
from HERA

[W asymmetry]

# 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

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

# 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 unprecedented 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 will 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 whole p structure which the LHC assumes to know will become accurately known.

There is a huge potential for electroweak physics in these accurate data (couplings,  $G_2$ , ..) not yet studied.

Low x physics will lead to a new area with the extension of the kinematic range and high precision measurements, as of F2 and also FL.

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

Not much done on nuclear pdfs, apart from a visualisation of the  $A^{1/3}$  amplification of the gluon density, though here the impact of the LHeC is most striking (extension by 4 orders of magnitude!)

# Backup slides



hep-ex/0306016

## Deep inelastic electron-nucleon scattering at the LHC

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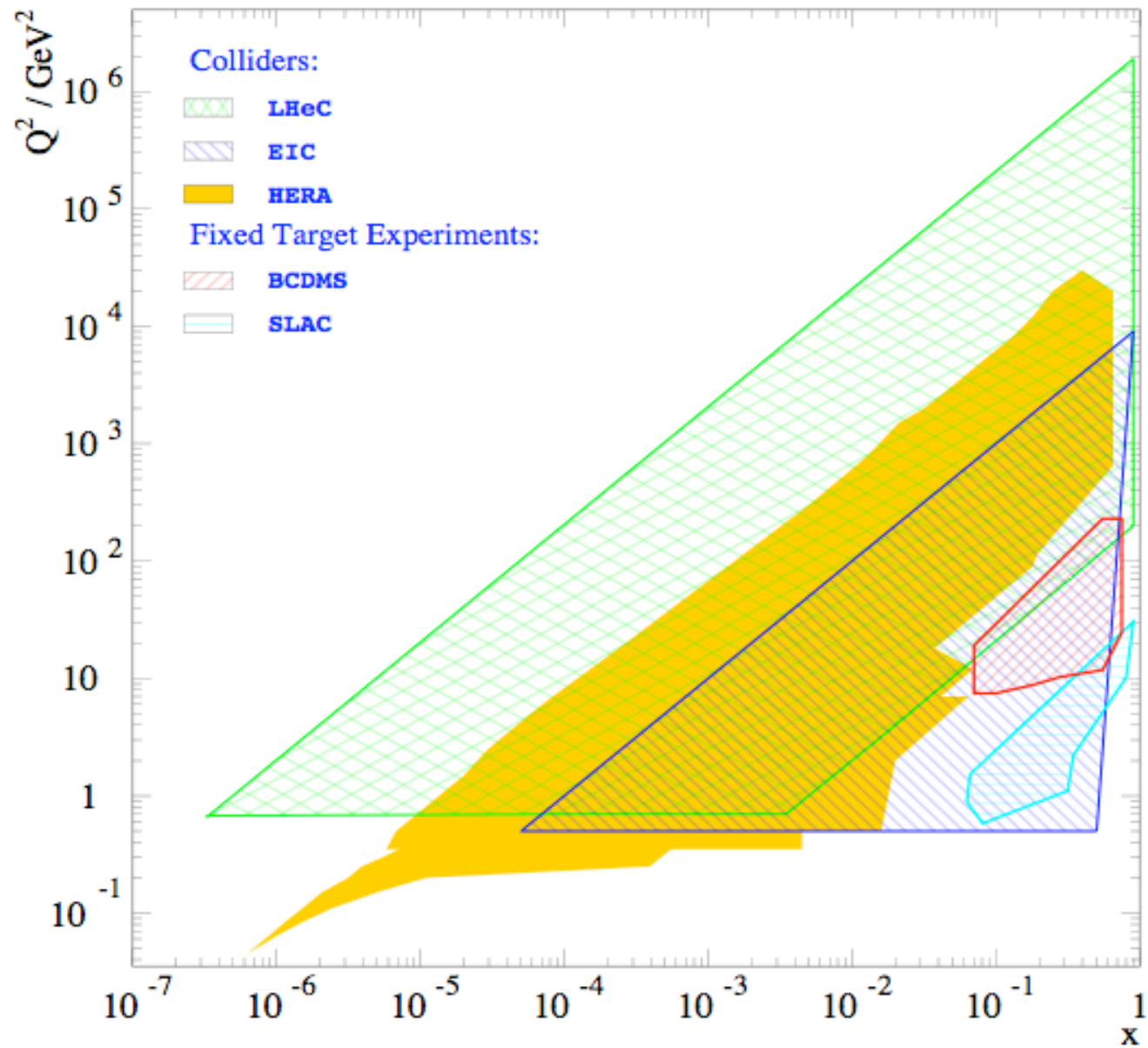
*E-mail: klein@ifh.de*

**ABSTRACT:** The physics, and a design, of a Large Hadron Electron Collider (LHeC) are sketched. With high luminosity,  $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ , and high energy,  $\sqrt{s} = 1.4 \text{ TeV}$ , such a collider can be built in which a 70 GeV electron (positron) beam in the LHC tunnel is in collision with one of the LHC hadron beams and which operates simultaneously with the LHC. The LHeC makes possible deep-inelastic lepton-hadron ( $ep$ ,  $eD$  and  $eA$ ) scattering for momentum transfers  $Q^2$  beyond  $10^6 \text{ GeV}^2$  and for Bjorken  $x$  down to the  $10^{-6}$ . New sensitivity to the existence of new states of matter, primarily in the lepton-quark sector and in dense partonic systems, is achieved. The precision possible with an electron-hadron experiment brings in addition crucial accuracy in the determination of hadron structure, as described in Quantum Chromodynamics, and of parton dynamics at the TeV energy scale. The LHeC thus complements the proton-proton and ion programmes, adds substantial new discovery potential to them, and is important for a full understanding of physics in the LHC energy range.

**KEYWORDS:** Accelerator modelling and simulations (multi-particle dynamics; single-particle dynamics); Large detector systems for particle and astroparticle physics.

2006 JINST 1 P10001

# LHeC, HERA and EIC



title