### Impact of future HERA data on the ZEUS PDF fit

13<sup>th</sup> International Workshop on Deep Inelastic Scattering (DIS05)



Madison, Wisconsin, USA

27<sup>th</sup> April – 1<sup>st</sup> May 2005 Claire Gwenlan



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with the help of M. Klein (DESY),

#### × Introduction

- × The ZEUS-JETS QCD fit: an overview
- × Impact of future HERA data on the proton PDFS
  - within current HERA-II running scenario
- additional studies (F<sub>L</sub>, sea-quark asymmetry)
  - **×** Conclusions



ZEUS-JETS NLO QCD fit

For more details on the ZEUS-JETS fit (hep-ph/05030274), and the data included, see cont. to this workshop, "Proton PDFs using Structure Functions and Jet Data from

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#### **Parameterisation:**

Param. at Q <sub>0</sub> <sup>2</sup> =7 GeV <sup>2</sup>	A <sub>uv</sub> x <sup>buv</sup> (1-x) <sup>cuv</sup> (1+d <sub>uv</sub> x)	A <sub>dv</sub> x <sup>bdv</sup> (1-x) <sup>cdv</sup> (1+d <sub>dv</sub> x)	A <sub>S</sub> x <sup>bs</sup> (1-x) <sup>cs</sup>	A <sub>g</sub> x <sup>bg</sup> (1-x) <sup>cg</sup> (1+d <sub>g</sub> x)	$\mathbf{A}_{\Delta} \ \mathbf{x}^{\mathbf{b}\Delta}$ (1-x) $^{\mathbf{c}\Delta}$
PDF	u-val. (xu <sub>v</sub> )	d-val. (xd <sub>v</sub> )	total sea (xS)	gluon (xg)	dbar-ubar (x∆)

#### parameter constraints:

- x momentum and quark number sum rules
- × low-x behaviour of  $u_v$  and  $d_v$  set equal
- $\boldsymbol{x} \ \Delta$  set consistent with Gottfried sum and Drell-Yan

#### ▶ 11 free parameters in total

- heavy quarks treated in variable flavour number scheme of Thorne and Roberts
  - uncertainties evaluated using Offset Method



×

#### PART I:

#### Impact of future **HERA** measurements on the ZEUS PDF fit: within current **HERA-II running scenario**

**Current HERA-II running scenario** 

HERA-II is running efficiently...



" 700pb<sup>-1</sup> integrated luminosity, equally divided between e<sup>+</sup>/e<sup>-</sup>, expected by the end of HERA-II running in mid-2007 "



Where does the information come from in a HERA-Only fit ?

High Q <sup>2</sup> inclusive NC/CC	Low-x from inclusive NC	High-x ? Flavour ? (assur	Low-x from HERA dF <sub>2</sub> /dIr	Mid-to-high-x from HERA	High-x from momentum :
e <sup>±</sup> cross sections	DIS	nptions needed)	Q <sup>2</sup>	jet data <u>HERA-I: st</u> athich-F	sum rule
HERA-I: atistics limited				atistics limited	







Where does the information come from in a HERA-Only fit ?

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HERA-I: stics limite stics limite nd high-Q

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mpact will future HERA rements have on the PD	the information come from in a HERA-Only fit ?	High Q <sup>2</sup> inclusive NC/CC e <sup>±</sup> cross sections	Low-x from inclusive NC DIS High-x ? Flavour ? (assumptions needed)	Low-x from HERA dF <sub>2</sub> /dInQ <sup>2</sup> Mid-to-high-x from HERA jet data only cer Potent High-x from momentum sum rule se
What i measu	Where does	Valence	Sea	Gluon

nsitivity to gluon DF (500 pb <sup>-1</sup> )	nced: x <sup>oвs</sup> >0.75	E <sub>1</sub> <sup>jet1,2</sup> >30,25 GeV 1 <nj<sup>st1,ŋ<sup>st2</sup>&lt;2</nj<sup>	5
<b>S Sections</b> ions "optimised" for se stion (Q <sup>2</sup> < 1 GeV <sup>2</sup> ) i) and CTEQ5M1 proton PE	direct-photon enha	E <sub>1<sup>61,1</sup></sub> >20,15 GeV 1<η <sup>61</sup> <2, 2<η <sup>612</sup> <3	E <sup>µer1,2</sup> >35,30 GeV -1<η <sup>let1</sup> ,η <sup>let2</sup> <2.5
<b>id jet CrOS:</b> <b>t-Adams (UCL)</b> sections in kinematic reg dy: dijets in photoproduc ng NLO QCD (Frixione-Ridolf	nhanced: x <sub>y</sub> <sup>obs</sup> <0.75	dc/dx <sup>p</sup> about the first of th	<ul> <li>ZEUS Simulated Data (500 pb<sup>-1</sup>)</li> <li>NLO (ZEUS-S)</li> <li>Gluon PDF error (ZEUS-S)</li> <li>Gluon component (ZEUS-S)</li> <li>Up Valence component (ZEUS-S)</li> <li>Down Valence component (ZEUS-S)</li> </ul>
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Impact of HERA-II in current running scenario:- case study

Data sample	L of HERA-I measurement (pb <sup>-</sup> ¹)	assumed L of HERA- II measurement (pb <sup>-</sup> ¹)	Central values taken from	Systematic uncertainties taken from
High-Q <sup>2</sup> NC e+	63	350	existing	existing data
High-Q <sup>2</sup> NC e-	16	350	exdatag	existing data
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#### statistically limited data-sets

- scale statistical uncerts. on existing data assuming max. 700 pb<sup>-1</sup> (equally between e+/e-)
- systematic uncertainties taken from existing data

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#### statistically limited data-sets

- scale statistical uncerts. on existing data assuming max. 700 pb<sup>-1</sup> (equally between e+/e-)
- systematic uncertainties taken from existing data

#### optimised jet cross sections

- include simulated data-points from NLO QCD, statistical uncertainties assume 500 pb<sup>-1</sup>
- no systematics included

### **HERA-II** projected fit

 Impact of the projected HERA-II measurements has been studied in context of the ZEUS-JETS fit



















 uncertainties on sea-quark distribution significantly reduced at high-x ightarrow most significant improvement from increased statistics at HERA-II

### gluon uncertainties



ightarrow most significant improvement comes from optimised cross section uncertainties on mid-to-high-x gluon significantly reduced

## HERA Kinematic (x,Q<sup>2</sup>) Range



HERA data covers large region in (x,Q²) → also relevant x-region for LHC

High-p<sub>T</sub> jets, new particle searches etc at LHC all depend strongly on high-x partons → improvement to LHC cross section uncertainties after HERA-II

Impact of HERA-II projected PDF on LHC cross sections under study

#### PART II: Alternative I

**Alternative HERA running scenarios:** low energy running and a precision measurement of F<sub>L</sub>



# Impact of a HERA measurement of $F_L$

$$\frac{d^{2}\sigma_{Nc}(e^{\pm}p)}{dxdQ^{2}} \sim Y_{+}F_{2} - y^{2}F_{L} \text{ where } F_{L} = \alpha_{s}.g(x,Q^{2})$$

- precision measurement of  $F_L$  at HERA-II:
  - x pin down gluon density at low-x

 $\mathbf{E}^{\mathbf{r}}$ 

x reduce uncertainties on gluon PDF





 $\mathbf{E}^{\mathbf{r}}$ 



$$\frac{d^{2}\sigma_{NC}(e^{\pm}p)}{dxdQ^{2}} \sim Y_{\pm}F_{2} - y^{2}F_{L} \text{ where } F_{L} = \alpha_{s}.g(x,Q^{2})$$

- precision measurement of F<sub>L</sub> at HERA-II:
  - \* pin down gluon density at low-x
- x reduce uncertainties on gluon PDF
- x provide tests of higher order QCD
- x test the need for extensions to DGLAP at low-x







 $\frac{d^{2}\sigma_{Nc}(e^{\pm}p)}{dxdQ^{2}} \sim Y_{+}F_{2} - y^{2}F_{L} \text{ where } F_{L} = \alpha_{s}.g(x,Q^{2})$ 

- precision measurement of F<sub>L</sub> at HERA-II:
  - × pin down gluon density at low-x
- × reduce uncertainties on gluon PDF
- x provide tests of higher order QCD
- x test the need for extensions to DGLAP at low-x

Simulation of HERA-II F<sub>L</sub>: Max Klein (DESY)

- F<sub>L</sub> simulated using GRV94 NLO PDF
- statistical uncertainties correspond to:

E <sub>p</sub> (GeV)	920	575	465	400
L (pb <sup>-1</sup> )	10	5	3	2

 systematic uncertainties from current H1 analysis of 99-00 data (few %) For further details, see "On the future measurement of F<sub>L</sub> at low-x at HERA", Max Klein, in measurement DISAA













## Sensitivity of the NLO QCD fit

- ullet  $F_L$  predictions very sensitive to underlying theory
- ightarrow choice of PDF, order of QCD calculation ..
- how sensitive is the NLO QCD fit to inclusion of "extreme" sets of simulated F<sub>L</sub> data?

#### Simulated F<sub>L</sub> data

extremes provided by Robert Thorne

QCD theory	*ONNO	NLO	NLO
) PDF	MRSG95	GRV94	<b>MRST2003</b>
(Cambridge	Max. F <sub>L</sub>	Mid. F <sub>L</sub>	Min. F <sub>L</sub>

- ZEUS fit relatively stable to inclusion of extreme F<sub>L</sub> data-sets
- an F<sub>L</sub> measurement of this precision should have power to discriminate between theoretical models



#### **Bonus Extra:**

#### **Alternative HERA running scenarios:** deuteron running and the sea quark asymmetry

a study by Max Klein and Burkard Reisert (in the context of the H1 fit) sea quark asymmetry

What causes the rise of F<sub>2</sub> at low-x?

 $F_2$  of the proton measures  $4\bar{u}+\bar{d}$  but  $\bar{u}$ and  $\bar{d}$  are unknown at low  $x \rightarrow would$  be accessible via deuteron (eD) running at HERA-II

ū=đ was a natural assumption for long time, until E866, HERMES found a difference at x ~ 0.1

are up and down quarks equal at low x are sea quarks and anti-quarks equal ?



### The H1 NLO QCD fit

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Param. at Q <sub>0</sub> <sup>2</sup> =4 GeV <sup>2</sup>	A <sub>u</sub> x <sup>bu</sup> (1-x) <sup>cu</sup> (1+d <sub>u</sub> x+e <sub>u</sub> x³)	A <sub>Ubar</sub> x <sup>bUbar</sup> (1-x) <sup>cUbar</sup>	A <sub>D</sub> x <sup>bD</sup> (1-x) <sup>cD</sup> (1+d <sub>D</sub> x)	A <sub>Dbar</sub> X <sup>bDbar</sup> (1-x) <sup>cDbar</sup>	A <sub>g</sub> x <sup>bg</sup> (1-x) <sup>cg</sup> (1+d <sub>g</sub> x)
ЪDF	xU=x(u+c)	xUbar	(s+p)x=Qx	xDbar	хg

- No information on sea flavour composition
- only one measurement at low-x: 5

 Assume quark and anti-quark distributions are equal at low-x and u=d

$$b_{u} = b_{b} = b_{\overline{u}} = b_{\overline{b}} \equiv b_{q}$$

$$A_{\overline{u}} = A_{\overline{b}} \cdot (1 - f_{s}) / (1 - f_{c}), \text{ which means that } \overline{d} / \overline{u} \rightarrow 1 \text{ as } x \rightarrow 0$$



# **Releasing the dbar-ubar constraint**



# **Releasing the dbar-ubar constraint**



**Releasing the dbar-ubar constraint** 



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simulated accuracy (20 pb<sup>-1</sup> eD, 40 pb<sup>-1</sup> ep)

Potential impact of future HERA data on proton PDFs has been investigated:
1. <u>Impact on PDFs of current HERA-II running scenario:</u>
<ul> <li>increased luminosity of HERA-II will provide</li> </ul>
ightarrow significantly improved precision on statistically limited data-sets
• high-Q <sup>2</sup> NC/CC data $ ightarrow$ significant improvement to <u>valence distributions</u>
<ul> <li>high-Q<sup>2</sup> and high-E<sub>T</sub> jet data → improvement to high-x sea and gluon</li> </ul>
<ul> <li>measurements of jet cross sections <u>optimised</u> for sensitivity to gluon</li> </ul>
<ul> <li>significant improvement to <u>high-x gluon</u></li> </ul>
impact of projected HERA-II PDFs on LHC cross sections under study
2. <u>Low energy running scenario:</u>
<ul> <li>precise measurement of F<sub>L</sub> at low-x possible with low-E<sub>p</sub> running</li> </ul>
<ul> <li>inclusion of simulated F<sub>L</sub> data in NLO QCD fit indicates:</li> </ul>
<ul> <li>improvement in gluon uncertainties at low-x and low-Q<sup>2</sup></li> </ul>
- ability of precision HERA F <sub>L</sub> to discriminate between theoretical models

Summary

### Summary (cont.)

### 3. Deuteron running and the sea-quark asymmetry:

(Max Klein, Burkard Reisert):

## So far HERA has not resolved the light sea quarks at low x

- x relaxing assumption that u=d, u=u and d=d at low-x leads to large uncertainties
- deuteron data from fixed target experiments (e.g. BCDMS) help but cannot

solve the problem since the data lie at higher-x

## would need deuteron running at HERA to resolve this issue

#### Extras ...



CLOSS

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HERA-II will provide greatly increased luminosity





#### **HERA-II Projected PDF**



# Uncertainties with full HERA-II inclusive data-set comparable to global fits

# Comparison with global fit (d-val.)



#### **HERA-II Projected PDF**



## Uncertainties comparable to or better than current global fit

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# mpact on sea/gluon uncertainties



40 - already at HERA-I, optimised jet cross sections would have significant impact on high-x gluon blue band: ZEUS-JETS fit + 120 pb<sup>-1</sup> (HERA-I) optimised jet cross sections only