# Impact of future HERA data on the ZEUS PDF fit

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



Madison, Wisconsin, USA

27th April – 1st May 2005

**Claire Gwenlan** 



with the help of M. Klein (DESY),

C. Targett-Adams (UCL), R. Thorne (Cambridge), A. Tricoli (Oxford)

- **× 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

# Introduction

Besides being interesting in their own right, it is essential to know the parton density functions (PDFs) of the proton as precisely as possible in order to maximise the physics potential at both <u>current and future colliders</u> e.g. high-x gluon is dominating uncertainty in several LHC processes

HERA data are now very precise and cover a wide range in (x,Q<sup>2</sup>)

Hetermination of proton PDFs now possible within one experiment

Most recently, ZEUS have performed a NLO QCD analyses on their full set of HERA-I  $e^+$  and  $e^-$  structure function data and high precision jet data  $\rightarrow$  the **ZEUS–JETS PDF** 

With future measurements at HERA, hope to be able to do even better ...

**Presented here are the results of studies that give a first look at the potential impact of future HERA measurements on the proton PDFs:** 

- **1. within current HERA-II running scenario** 
  - increased luminosity
  - cross sections optimised for sensitivity to PDFs
- **2.** other running scenarios: low energy  $(F_L)$ , eD (sea quark asymmetry)

### **Determination of proton PDFs at HERA**





# **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 ZEUS", Juan Terron.

xf

#### <u>Data:</u>

all HER	A-I ZEUS i	ncl. NC/CC	e <sup>+</sup> /e <sup>-</sup> (94-00)
ZEUS i	nclusive jet	ts in DIS (9	6-97)
ZEUS o	lijets in ph	otoproduct	ion (96-97)

#### **Parameterisation:**

PDF	Param. at Q <sub>0</sub> <sup>2</sup> =7 GeV <sup>2</sup>
u-val. (xu <sub>v</sub> )	A <sub>uv</sub> x <sup>buv</sup> (1-x) <sup>cuv</sup> (1+d <sub>uv</sub> x)
d-val. (xd <sub>v</sub> )	A <sub>dv</sub> x <sup>b<sub>dv</sub> (1-x)<sup>c<sub>dv</sub> (1+d<sub>dv</sub>x)</sup></sup>
total sea (xS)	A <sub>s</sub> x <sup>bs</sup> (1-x) <sup>cs</sup>
gluon (xg)	A <sub>g</sub> x <sup>bg</sup> (1-x) <sup>cg</sup> (1+d <sub>g</sub> x)
dbar-ubar (x∆)	A <sub>Δ</sub> x <sup>b<sub>Δ</sub></sup> (1-x) <sup>c<sub>Δ</sub></sup>

- parameter constraints:
  - **\*** momentum and quark number sum rules
  - x low-x behaviour of  $u_v$  and  $d_v$  set equal
  - \*  $\Delta$  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...



" $\mathcal{F}$  opb<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"

# What impact will future HERA measurements have on the PDFs?

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

Valence	High Q <sup>2</sup> inclusive NC/CC e <sup>±</sup> cross sections $<\!\!<\!$	HERA-1: itatístícs límíted
Sea	Low-x from inclusive NC DIS	
	High-x ? Flavour ? (assumptions needed)	
Gluon	Low-x from HERA dF <sub>2</sub> /dlnQ <sup>2</sup>	
	Mid-to-high-x from HERA jet data	statistics limited $E_{-}$ and high- $Q^{2}$
	High-x from momentum sum rule	

### Example: high-Q<sup>2</sup> NC and CC data



HERA-II will provide greatly increased luminosity

# What impact will future HERA measurements have on the PDFs?

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

Valence	High Q <sup>2</sup> inclusive NC/CC e <sup>±</sup> cross sections $<\!\!<\!$	HERA-1: statístícs límíted
Sea	Low-x from inclusive NC DIS	
	High-x ? Flavour ? (assumptions needed)	
Gluon	Low-x from HERA dF <sub>2</sub> /dlnQ <sup>2</sup>	
	Mid-to-high-x from HERA jet data	statistics limited $E_{-}$ and high- $Q^{2}$
	High-x from momentum sum rule	

# What impact will future HERA measurements have on the PDFs?

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

Valence	High $Q^2$ inclusive NC/CC $e^{\pm}$ cross section	ns							
Sea	Low-x from inclusive NC DIS								
	High-x ? Flavour ? (assumptions needed)								
Gluon	Low-x from HERA dF <sub>2</sub> /dlnQ <sup>2</sup>	neasurements in							
	Mid-to-high-x from HERA jet data 🦟	kinematic regions							
	sensiti	ívíty to gluon							

# **Optimised jet cross sections**

#### Christopher Targett-Adams (UCL)

- Measure jet cross sections in kinematic regions "optimised" for sensitivity to gluon
  - ongoing ZEUS study: dijets in photoproduction ( $Q^2 < 1 \text{ GeV}^2$ )
    - data simulated using NLO QCD (Frixione-Ridolfi) and CTEQ5M1 proton PDF (500 pb<sup>-1</sup>)



# Impact of HERA-II in current running scenario:- case study

Data sample	L of HERA-I measurement (pb <sup>-1</sup> )	assumed L of HERA-II measurement (pb <sup>-1</sup> )	Central values taken from	Systematic uncertainties taken from		
Hígh-Q² NC e+	63	350	exístíng data	exístíng data		
Hígh-Q² NC e-	16	350	exístíng data	exístíng data		
Hígh-Q <sup>2</sup> CC e+	61	350	exístíng data	exístíng data		
Hígh-Q <sup>2</sup> CC e-	16	350	exístíng data	exístíng data		
Inclusive DIS jets	37	500	exístíng data	exístíng data		
Díjets ín <b>y</b> p	37	500	exístíng data	existing data		

#### 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

# Impact of HERA-II in current running scenario:- case study

Data sample	L of HERA-1 measurement (pb <sup>-1</sup> )	assumed L of HERA-II measurement (pb <sup>-1</sup> )	Central values taken from	Systematíc uncertaíntíes taken from
Hígh-Q² NC e+	63	350	exístíng data	exístíng data
Hígh-Q2 NC e-	16	350	exístíng data	exístíng data
$High-Q^2 CC e+$	61	350	exístíng data	exístíng data
Hígh-Q <sup>2</sup> CC e-	16	350	exístíng data	exístíng data
Inclusive DIS jets	37	500	exístíng data	exístíng data
Díjets ín <b>y</b> p	37	500	exístíng data	exístíng data
Optímísed díjets in <b>y</b> p	-	500	NLO QCD	NOT INCLUDED

#### 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



#### **u-valence uncertainties**



• uncertainties on u-valence distribution significantly reduced over visible x range 15

## d-valence uncertainties



• uncertainties on d-valence distribution significantly reduced over visible x range 16

## **Sea-quark uncertainties**



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

# gluon uncertainties



uncertainties on mid-to-high-x gluon significantly reduced

 $\rightarrow$  most significant improvement comes from optimised cross section

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



HERA data covers large region in  $(x,Q^2)$  $\rightarrow$  also relevant x-region for LHC

High- $p_T$  jets, new particle searches etc at LHC all depend strongly on high-x partons  $\rightarrow$  improvement to LHC cross section uncertainties after HERA-II

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

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

$$\frac{d^2\sigma_{\text{NC}}(e^{\pm}p)}{dxdQ^2} \sim Y_{+}F_2 - y^2F_L \text{ where } F_L = \alpha_s.g(x,Q^2)$$

- measured at fixed target exps. (x > 10<sup>-3</sup>)
- precision F<sub>L</sub> measurement at HERA requires low-E<sub>p</sub> running → vary y at fixed (x,Q<sup>2</sup>)

 $F_{L} contributes at O(\mathbf{\alpha}_{s}) (and HO)$ and is directly sensitive to the gluon density in the proton



$$\frac{d^2\sigma_{\text{NC}}(e^{\pm}p)}{dxdQ^2} \sim Y_{+}F_2 - y^2F_L \text{ where } F_L = \alpha_s.g(x,Q^2)$$

- precision measurement of F<sub>L</sub> at HERA-II:
  pin down gluon density at low-x
  - **\*** reduce uncertainties on gluon PDF



 $\mathsf{F}_{\scriptscriptstyle L}$  contributes at  $\mathcal{O}(\pmb{\alpha}_{\scriptscriptstyle S})$  (and HO) and is directly sensitive to

$$\frac{d^2\sigma_{\text{NC}}(e^{\pm}p)}{dxdQ^2} \sim Y_{+}F_2 - y^2F_L \text{ where } F_L = \alpha_s g(x, Q^2)$$

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

F<sub>L</sub> contributes at O(**α**<sub>s</sub>) (and HO) and is directly sensitive to the gluon density in the proton

 $F_L$  LO , NLO, NNLO and resummed - Simulation of Low  $E_p$  H1 Data



$$\frac{d^2\sigma_{\text{NC}}(e^{\pm}p)}{dxdQ^2} \sim Y_{+}F_2 - y^2F_L \text{ where } F_L = \alpha_s.g(x,Q^2)$$

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

#### Simulation of HERA-II FL: 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	ы	3	2		

• systematic uncertainties from current H1 analysis of 99-00 data (few %)





## Impact of a HERA measurement of F<sub>1</sub>

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

- precision measurement of F<sub>1</sub> at HERA-II: \* pin down gluon density at low-x x reduce uncertainties on gluon PDF
  - \* provide tests of higher order QCD



at low-x at HERA", Max Klein, in proceedings, DIS04.

F, contributes at  $O(\alpha_{c})$  (and HO) and is directly sensitive to the gluon density in the proton

 $10 \text{ GeV}^2$ 

 $O^2 = 5 GeV^2$ 

#### Impact on gluon distribution



## Sensitivity of the NLO QCD fit

- $\bullet$   $F_L$  predictions very sensitive to underlying theory
  - $\rightarrow$  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 (Cambridge)

	PDF	QCD theory
Max. F <sub>L</sub>	MRSG95	NNLO*
Mid. F <sub>L</sub>	GRV94	NLO
Min. F <sub>L</sub>	MRST2003	NLO

- 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

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

What causes the rise of  $F_2$  at low-x?

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

 $\bar{u}=\bar{d}$  was a natural assumption for long time, until E866, HERMES found a difference at x ~ 0.1





## The H1 NLO QCD fit

	6 68 9008 900				11000000			2 1002 1002 1 5 55 1										6 6 6 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9							68 YOG YOG YOG F 6 Y
	1122120			1001 1001 1001	2 8 28 28 <b>2</b> 8 <b>2</b> 8			2 102 102 2 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	See 139 139 14	2 20 20 20		200.2200.250	201 201 201 2				1001100110011		101919181102		2011/2011/2017		89111233	2012/2012/2012 201	to have have have been
4 68 YO	6 6 <b>1 1 1 1 1 1 1</b> 1 1 1 1 1	1000 TO 0 1 5 68 1	221008100816	2 104 104 104	11000000	1041144-041		3 - 2 G 10 G 1 S G 1	0.0000000000000000000000000000000000000	12 10 2 10 2 10 2	G1100033	00000031668		0444400		a	1000 1000 1000 I	6 68 YO G TO B	104111440.000		102103103	1668-008-008-1	08110001	0081008100811	48 1008 1008 1008 1 6 4
		And Distances	1000 1000 2 8	1228 122 228	22 102 12			3 19 19 3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5		April 101 1	7 and 17	1000	2028 2028 2028	122222		AF	10 10 10 1	W	ALC: U.S. 12	***********	10 10 10 10		11 C 14 C	228 1228 1228 1	** 1278 1278 1278 * 5 *
2 28 LT/28	100 610	10.00		1000 1000	1000					THE LOCK LOCK LT	1 2 22 17 17 19		Local Division in the local division of the			ALC: NOTE OF	* * *******		1000		110 110 110		100 B 88 1108	1000	
919509 Hannes	to be area	1 may 1997 1	100 100 100 10	1012 1012 1012	12 1091	109111	10.0	9-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0-0		19 10/9 10 10	2323507	******	10 10 10 10 10 10	10000	100923285	1100	the second	1 1 1 1 1 1 1	1091 191	9100910091119	10 101 10	111111111111	1000010-0000	1000000000	12 12 12 12 12 12 12 12 12 12 12 12 12 1
1212102	100000	1000	187 11481	102100	22 5325	202222 22	313 11 11 11 1	4 4 1 2 2 2 3 3 4 3 4	1222 22	100 1 10	1000	1000118	100000000000000000000000000000000000000	037 ALC:	100 0021285	10, 107, 11	200 201005	1 W A	ST 18 1	1001002728	10 102 12	12121 (2104)	- 10 C	A A 44	4 Y Y X X X X X X X X X X X X X X X X X
1 - 10 - 10 - 10 - 10 - 10 - 10 - 10 -	E anos anos	been block was at \$1		and the second second			in how he was		se asia ber da	to another the last	in he see also be	Street Hills	COLUMN TOTAL	5 <b>1</b> 1 1 1 1 1	n ment blöt hit bilde	COLUMN TWO IS NOT	abor more abore a	a it was bid b	boundary of		101101101		State in some lit	en mer han har	and some states
	6 68 YOG YOG				1111000000			2 10 2 10 2 10 2 10 2 10 10 10 10 10 10 10 10 10 10 10 10 10								0.000.000.000		F 6 68 1008 1008 1	100211442100						18110610081008161
	1122120				2 8 28 28 <b>2</b> 8 <b>2</b> 8			2 102 102 2 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5											101919181102						to have have have been
																									11 004 004 004 111
12111201120112011						198313201980			5815815811		10112 Decision			100112010			0-50-50-50		1988 1989 199			112010401040		5 DE 5 DE 5 DE 13	1010010010011
2 5013 5013 5013 5 <u>0</u> 13	2 5013 5013 5	215 5215 52 52 52 521	5 5015 5015 50 51	5013 5013 5013 5	1 1 1 1013 1013 10	na 52 5 2 5 50na 50n	5 5015 52 5 8 5015	5113 5113 51 5 8 5 8 51	13 Str3 Str3 St 51	2 5013 5013 5013	152 5 2 5015 501	3 5013 51 5 8 5	173 <b>5</b> 173 <b>5</b> 173 <b>5</b> 17	15 St 1 & St 15	5013 5013 50 18 50 5013	5013 5013 50 50 50	5015 5015 5015 50	22 5013 5013 50	ris 52 5 8 90ris 5	5015 5015 50 5 8 5	175 <b>5</b> 175 <b>5</b> 175 <b>5</b> 8	2 2 5013 5013 50	5 5 1 1 5 5 5 5 5 5 C	5 5015 5015 50 51	2 5013 5013 5013 52 2 2
	a pure pure a			THE REAL PROPERTY IN		CONTRACTOR OF A DECK									State of the state	PULL PULL BUILD BU		1 1 PC 2 PC 2 PC				a second period per			
12/12/12/12/12	12:12	a life attac	12 Acres 12	2022	1000 122	12212121	12/12/2010 12:2	2012/121121	9 19 20 21	1	2012/07/20	*****	*****	9811899	방영 방영 방법 방영	******	******	112012-022	C2 21 20	112112112112	1 march 1 m	ALC: N	2 A A A A A A A A A A A A A A A A A A A	12:15	120.002202311
120-50-50	120.00	- 10 A 11 A 11	68 6866 B	1000	10000000000	668 BB 188	2016 B 1 2 1 5	Distance of the local sectors	2 W		and property			100112010			0-50-50-50	112030	10 10 10 10	Distance 1922	1 mar 12	2 80 5 80 S	689 BT 8	920 A 52	0 5 0 5 0 5 0 5 0 F 3
12/22/00/0001	1 2019 1 2 2		5 5 5 5 5 5 <b>5</b> 5		10,000,000	12 2 2 2 2 2 2	C12 28 1 1012	50 BC 5 50 BC		C 12 C 18	181 1813 1811	22022228282		12 22 28 28 19 19	*******	20202311	******	112020 220	2 2 2 201	122200	10 March 10	1 2012 2013	222 M R	77 A 184	100000000000000000000000000000000000000
120-50-50	930.69	ar 16 mar -	18 SEC. 13	100.000	1000	168 P. 8 P. 80	A10.001 010	2 P 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2		8 6 67	B. DOGEC	1011001112		100112010	Brodrod 11200	Brodrod 111	0-50-50-50	1120103	66 B 2 2 6	Distance 1922	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1000 100 100	680 AN AN		100000000000000000000000000000000000000
10000000000	1000000	CC 4 CC	0.0000000000000000000000000000000000000	6161614	100000000000000000000000000000000000000	2010 B 1000	0.00000000000		2020203	Total Controls	1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	220223352		2215202	2022233520	2222335		112122-022	12 13 2010		Reception of the	10.10.10	101100000	202223	*****
241541541541	141 541 54	1 5 81 5 81 1 4 81		4154154154	11140.560.560	584128-581	101200110012	61 S 61 S 61 1 4 61	5815815811	441 5 61 5 61 1	821241541	241241144	541541541	2011012	AT 5 AT 5 AT 1 AT 5	81 5 81 5 84 F #1	1.251.251.251	1141 541 541	581144151	61 S 61 S 64 1 4 6	56156156	1141541541	101110-011-0-01	581 581 581 1	4
		0.3 20.3 24 14 20.	3 20 3 20 3 24 1	20.3 20.3 20.3 2	11 20 3 20 3 20	3 24 1 4 20 3 20 1	3 20.3 26 1 6 20.3	20.3 20.3 24 14 20	3 20 3 20 3 24 1	1 90 3 90 3 90 s	24 14 20 3 20	3 20.3 26 1 6 2	3 20 3 20 3 20	3 24 14 20.3	20.3 20.3 24 14 20.3	20.3 20.3 26 1 5	0.3 20.3 20.3 20	11 20 3 20 3 20	3 24 1 4 20 3 1	20.3 20.3 24 14 2	3 20 3 20 3 20	11 20.3 20.3 20	3 24 14 20 3 20	3 20.3 20.3 26 1	1 10 3 20 3 20 3 20 1

PDF	Param. at Q <sub>0</sub> <sup>2</sup> =4 GeV <sup>2</sup>
xU=x(u+c)	A <sub>U</sub> x <sup>bu</sup> (1-x) <sup>cu</sup> (1+d <sub>U</sub> x+e <sub>U</sub> x <sup>3</sup> )
xUbar	A <sub>Ubar</sub> x <sup>b∪bar</sup> (1-x) <sup>c∪bar</sup>
xD=x(d+s)	A <sub>D</sub> x <sup>bD</sup> (1-x) <sup>cD</sup> (1+d <sub>D</sub> x)
xDbar	A <sub>Dbar</sub> x <sup>bDbar</sup> (1-x) <sup>cDbar</sup>
xg	A <sub>g</sub> x <sup>bg</sup> (1-x) <sup>cg</sup> (1+d <sub>g</sub> x)

- No information on sea flavour composition
- only one measurement at low-x:
  - $F_2 = 4/9 x(U+\bar{U}) + 1/9 x(D+\bar{D})$
- Assume quark and anti-quark distributions are equal at low-x and u=d
  - $\mathbf{b}_{\mathbf{U}} = \mathbf{b}_{\mathbf{D}} = \mathbf{b}_{\overline{\mathbf{U}}} = \mathbf{b}_{\overline{\mathbf{D}}} \equiv \mathbf{b}_{\mathbf{q}}$
  - $A_{\overline{u}} = A_{\overline{D}} \cdot (1 f_s) / (1 f_c)$ , which means that  $\overline{d} / \overline{u} \to 1$  as  $x \to 0$



#### **Releasing the dbar-ubar constraint**



#### **Releasing the dbar-ubar constraint**



#### **Releasing the dbar-ubar constraint**



33

## Summary

Potential impact of future HERA data on proton PDFs has been investigated:

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

## Summary (cont.)

- 3. <u>Deuteron running and the sea-quark asymmetry:</u> (Max Klein, Burkard Reisert):
- So far HERA has not resolved the light sea quarks at low x
  - **\*** relaxing assumption that  $\bar{u}=\bar{d}$ ,  $u=\bar{u}$  and  $d=\bar{d}$  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 ....

#### **Example: high-Q<sup>2</sup>/high-E<sub>T</sub> jet data**



HERA-II will provide greatly increased luminosity

# **Comparison with global fit (u-val.)**



• Uncertainties with full HERA-II inclusive data-set comparable to global fits 38

# **Comparison with global fit (d-val.)**



• Uncertainties comparable to or better than current global fit

39

### Impact on sea/gluon uncertainties



• blue band: ZEUS-JETS fit + 120 pb<sup>-1</sup> (HERA-I) optimised jet cross sections only

- already at HERA-I, optimised jet cross sections would have significant impact on high-x gluon 40