

# HERA and the LHC

## 3<sup>rd</sup> workshop on the implication of HERA for LHC physics

H. Jung (DESY), A. De Roeck (CERN)

**HERA AND THE LHC**  
A workshop on the implications of HERA for LHC physics

March 2004 - Jan 2005

Parton density functions  
Multijet final states and energy flow  
Heavy quark  
Diffraction  
Monte Carlo tools

**Startup Meeting**  
March 26-27 2004  
CERN, Geneva

**Midterm Meeting**  
October 2004

**Final Meeting**  
Jan 2005  
DESY, Hamburg

**Organising Committee:**  
A. Altarelli (CERN), J. Blümlein (DESY), M. Botje (NIKHEF), J. Butterworth (UCL), A. De Roeck (CERN) (chair), K. Eggert (CERN), E. Gallo (INFN), H. Jung (DESY) (chair), M. Klein (DESY), M. Mangano (CERN), A. Morch (CERN), G. Polesello (INFN), O. Schneider (EPFL), R. Yoshida (ANL)

**Advisory Committee:**  
J. Bartels (Hamburg), M. Della Negra (CERN), J. Ellis (CERN), J. Engelen (CERN), G. Gustafson (Lund), G. Ingelman (Uppsala), P. Jenni (CERN), R. Klanner (DESY), L. McLerran (BNL), T. Nakada (CERN), D. Schlatter (CERN), F. Schrempf (DESY), J. Schukraft (CERN), J. Stirling (Durham), W.K. Tung (Michigan State), A. Wagner (DESY), R. Yazawa (NII)

[www.desy.de/~heralhc](http://www.desy.de/~heralhc) [heralhc.workshop@cern.ch](mailto:heralhc.workshop@cern.ch)

**HERA AND THE LHC**  
2nd workshop on the implications of HERA for LHC physics

6-9 June 2006  
CERN, Geneva

Parton density functions  
Multijet final states and energy flow  
Heavy quarks  
Diffraction  
Monte Carlo tools

**Organising Committee:**  
G. Altarelli (CERN), J. Blümlein (DESY), M. Botje (NIKHEF), J. Butterworth (UCL), A. De Roeck (CERN) (chair), K. Eggert (CERN), E. Gallo (INFN), H. Jung (DESY) (chair), M. Klein (DESY), M. Mangano (CERN), A. Morch (CERN), G. Polesello (INFN), O. Schneider (EPFL), R. Yoshida (ANL)

**Advisory Committee:**  
J. Bartels (Hamburg), M. Della Negra (CERN), J. Ellis (CERN), J. Engelen (CERN), G. Gustafson (Lund), G. Ingelman (Uppsala), P. Jenni (CERN), R. Klanner (DESY), L. McLerran (BNL), T. Nakada (CERN), D. Schlatter (CERN), F. Schrempf (DESY), J. Schukraft (CERN), J. Stirling (Durham), W.K. Tung (Michigan State), A. Wagner (DESY), R. Yoshida (ANL)

[www.desy.de/~heralhc](http://www.desy.de/~heralhc) [heralhc.workshop@cern.ch](mailto:heralhc.workshop@cern.ch)

**HERA AND THE LHC**  
3rd workshop on the implications of HERA for LHC physics

12-16 March 2007  
DESY Hamburg

Parton density functions  
Multijet final states and energy flow  
Heavy quarks  
Diffraction  
Monte Carlo tools

**Organising Committee:**  
G. Altarelli (CERN), J. Blümlein (DESY), M. Botje (NIKHEF), J. Butterworth (UCL), A. De Roeck (CERN) (chair), K. Eggert (CERN), E. Gallo (INFN), H. Jung (DESY) (chair), M. Klein (DESY), M. Mangano (CERN), A. Morch (CERN), G. Polesello (INFN), O. Schneider (EPFL), C. Valise (OPPM)

**Advisory Committee:**  
J. Bartels (Hamburg), M. Della Negra (CERN), J. Ellis (CERN), J. Engelen (CERN), G. Gustafson (Lund), G. Ingelman (Uppsala), P. Jenni (CERN), R. Klanner (DESY), L. McLerran (BNL), T. Nakada (CERN), D. Schlatter (CERN), F. Schrempf (DESY), J. Schukraft (CERN), J. Stirling (Durham), W.K. Tung (Michigan State), A. Wagner (DESY), R. Yoshida (ANL)

[www.desy.de/~heralhc](http://www.desy.de/~heralhc) [heralhc.workshop@cern.ch](mailto:heralhc.workshop@cern.ch)

# Workshop Aims

- To identify and prioritize those measurements to be made at HERA which have an impact on the physics reach of the LHC.
- To encourage and stimulate transfer of knowledge between the HERA and LHC communities and establish an ongoing interaction.
- To encourage and stimulate theory and phenomenological efforts.
- To examine and improve theoretical and experimental tools.
- To increase the quantitative understanding of the implication of HERA measurements on LHC physics.

<http://www.desy.de/~heralhc>

Chairs: A. De Roeck (CERN) , H. Jung (DESY)

1 <sup>st</sup> workshop	March 2004 CERN	(~ 250 participants) -
	March 2005 DESY	(~ 150 participants)
2 <sup>nd</sup> workshop	6-9 June 2006 CERN	(~ 120 participants)
3 <sup>rd</sup> workshop	NOW DESY	(> 150 participants) ....

# Proceedings of 1<sup>st</sup> Workshop

CERN-2005-014  
14 December 2005

Many thanks to all  
conveners and authors !

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE  
**CERN** EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

## HERA AND THE LHC

A workshop on the implications of HERA for LHC physics

March 2004 — March 2005

hep-ph/0601012  
hep-ph/0601013

Proceedings

Editors: A. De Roeck and H. Jung

Available on request  
from CERN/DESY libs

GENEVA  
2005

>650 pages

- Proceedings of 1<sup>st</sup> workshop were published as combined CERN - DESY report end 2005
- Are available online from workshop page and hep-ph archive
- 800 CERN yellow reports printed
- End 2006 no more printed copies available !!!!
- Reprint proceedings in 2007 at DESY
- Copies are available at DESY library !!!! and also at the registration desk ....

# From 1<sup>st</sup> to 2<sup>nd</sup> workshop ...

- To identify and prioritize those measurements to be made at HERA which have an impact on the physics reach of the LHC.
  - Measurements for parton densities
  - Measurements to understand Multiple Interactions and small  $x$
- To encourage and stimulate transfer of knowledge between the HERA and LHC communities and establish an ongoing interaction.
  - Fruitful collaboration
  - DESY joins ATLAS/CMS
- To encourage and stimulate theory and phenomenological efforts.
- To examine and improve theoretical and experimental tools.
- To increase the quantitative understanding of the implication of HERA measurements on LHC physics.

# From 1<sup>st</sup> to 2<sup>nd</sup> workshop ...

- To identify and prioritize those measurements to be made at HERA which have an impact on the physics reach of the LHC.
  - Measurements for parton densities
  - Measurements to understand Multiple Interactions and small  $x$
- To encourage and stimulate transfer of knowledge between the HERA and LHC communities and establish an ongoing interaction.
  - Fruitful collaboration
  - DESY joins ATLAS/CMS
- To encourage and stimulate theory and phenomenological efforts.
- To examine and improve theoretical and experimental tools.
- To increase the quantitative understanding of the implication of HERA measurements on LHC physics.

# From 1<sup>st</sup> to 2<sup>nd</sup> workshop ...

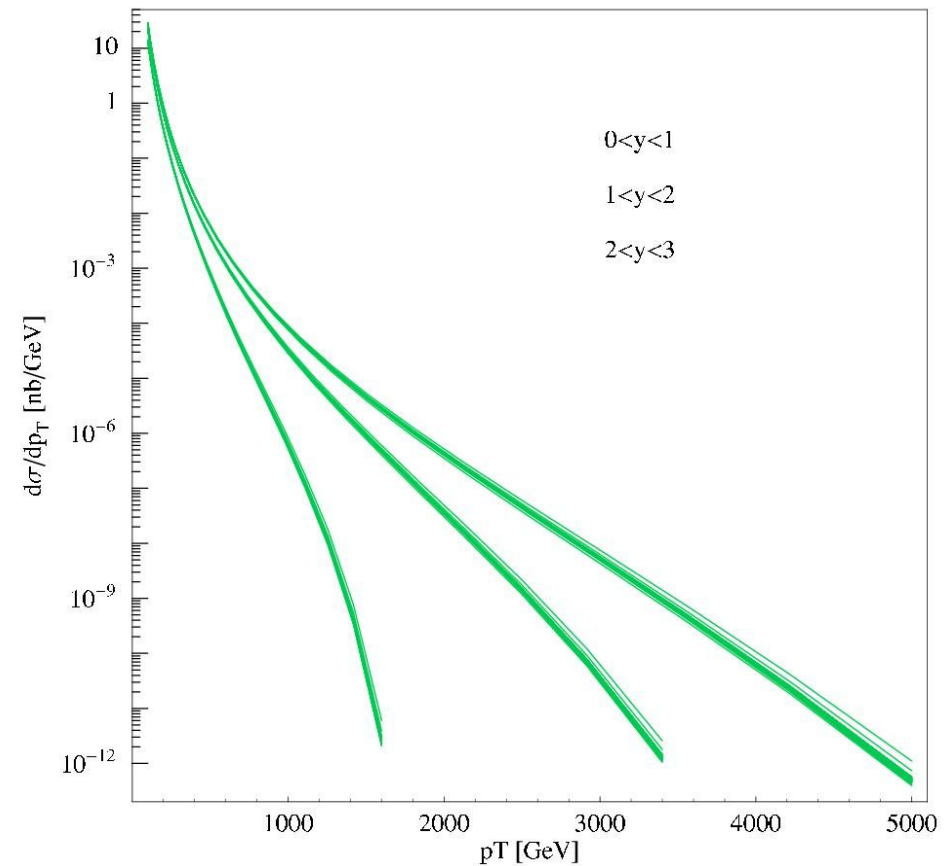
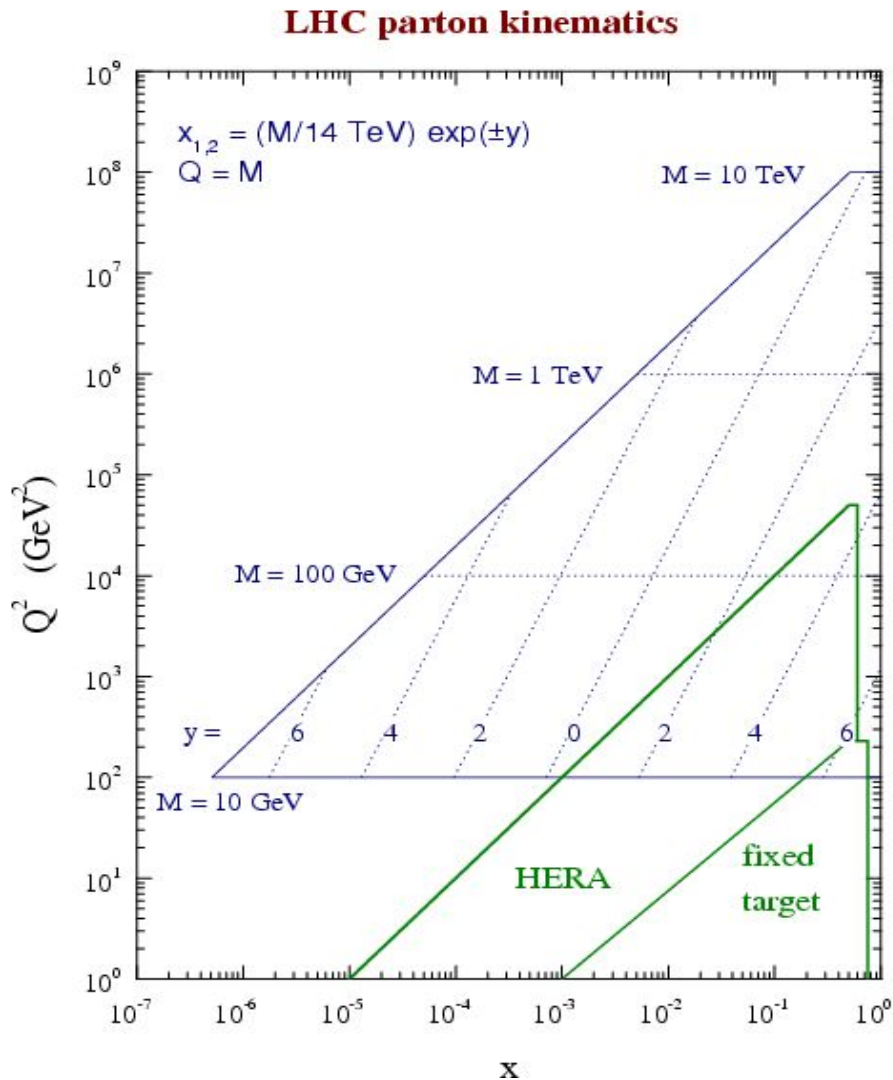
- To identify and prioritize those measurements to be made at HERA which have an impact on the physics reach of the LHC.
  - Measurements for parton densities
  - Measurements to understand Multiple Interactions and small  $x$
- To encourage and stimulate transfer of knowledge between the HERA and LHC communities and establish an ongoing interaction.
  - Fruitful collaboration
  - DESY joins ATLAS/CMS
- To encourage and stimulate theory and phenomenological efforts.
- To examine and improve theoretical and experimental tools.
- To increase the quantitative understanding of the implication of HERA measurements on LHC physics.

# Some Highlights from previous meetings ...

# Parton Density Functions and all that

- collinear PDFs

inclusive jet xsection

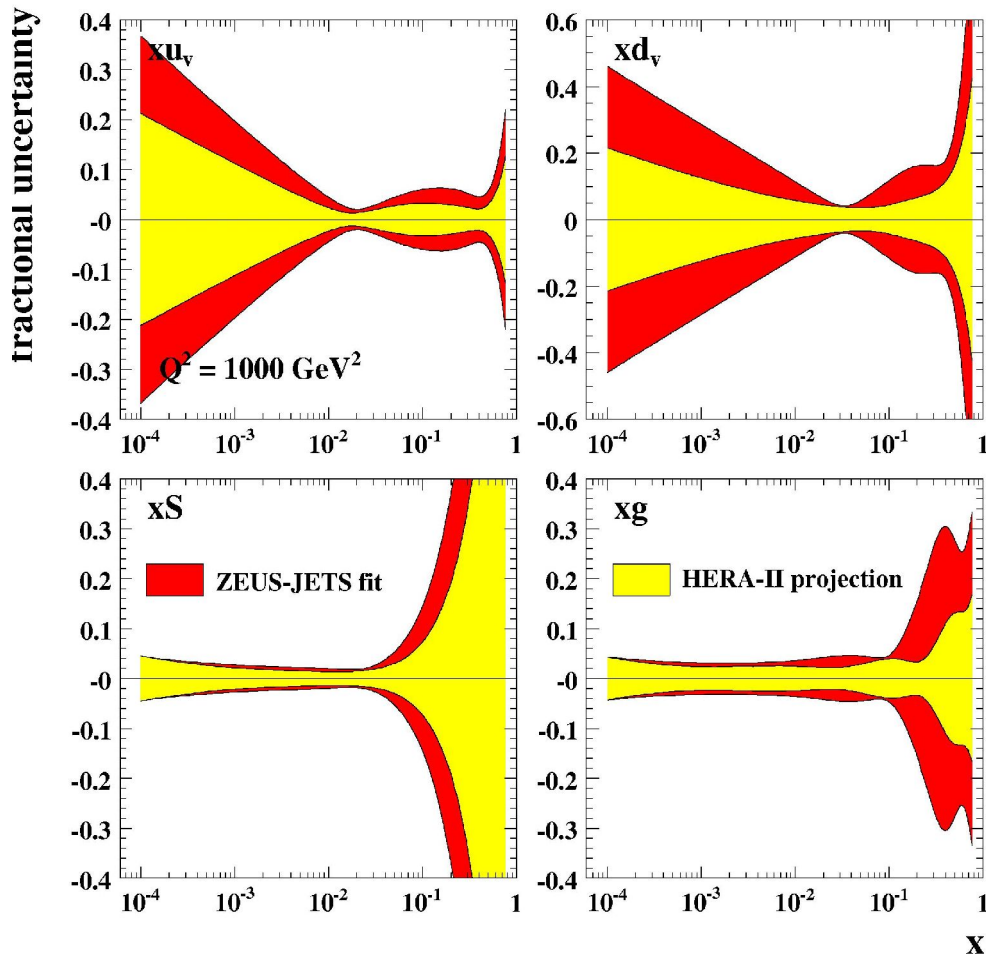




# PDF uncertainty: improvements

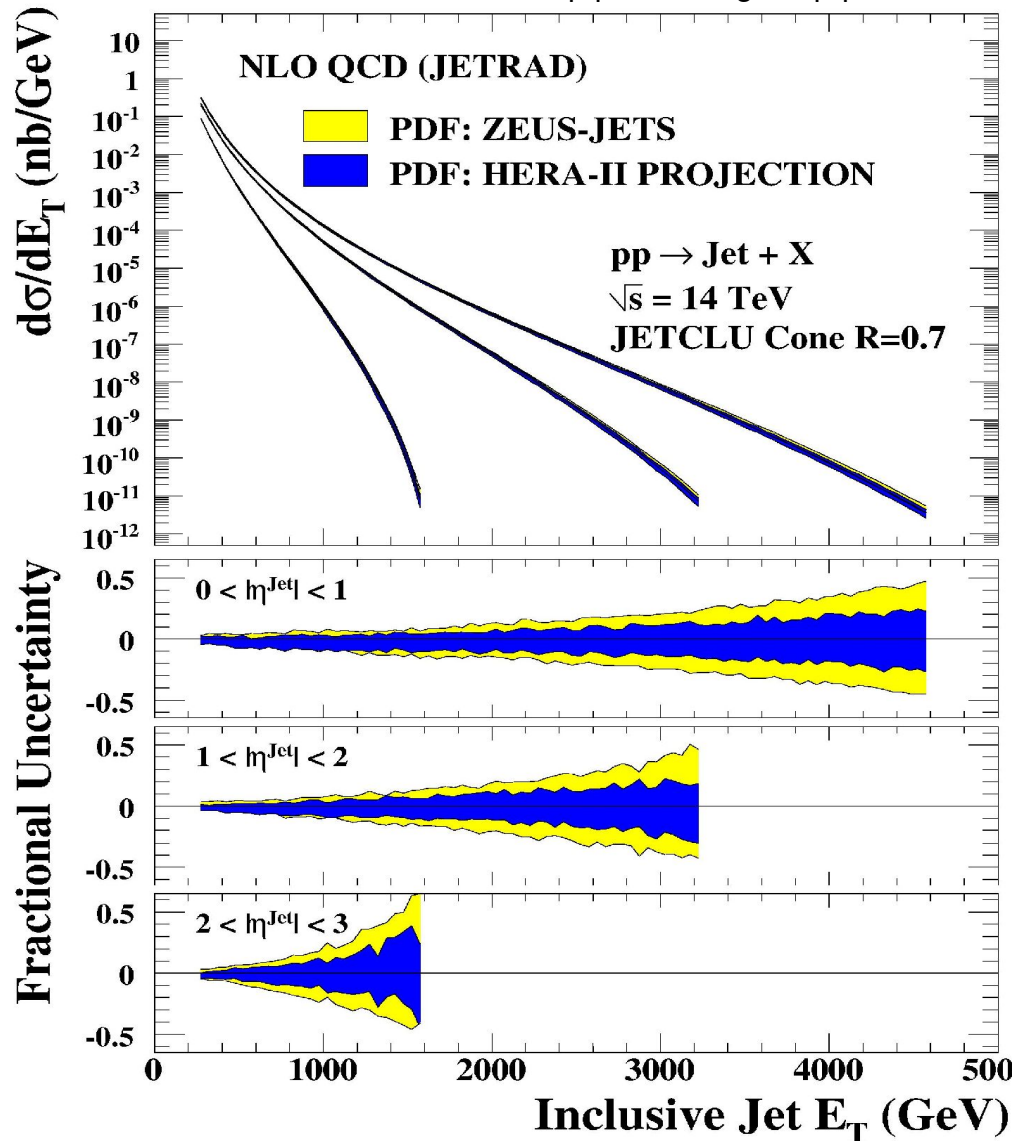
Using jets together with  $F_2$  (at large  $Q^2$ )

*quark and gluon uncertainties*



*high statistics from HERA II is important  
(assumed 700 pb<sup>-1</sup>)*

from C. Gwenlan, A. Cooper-Sarkar, C. Targett-Adams  
in HERA – LHC workshop proceedings hep-ph/0601012

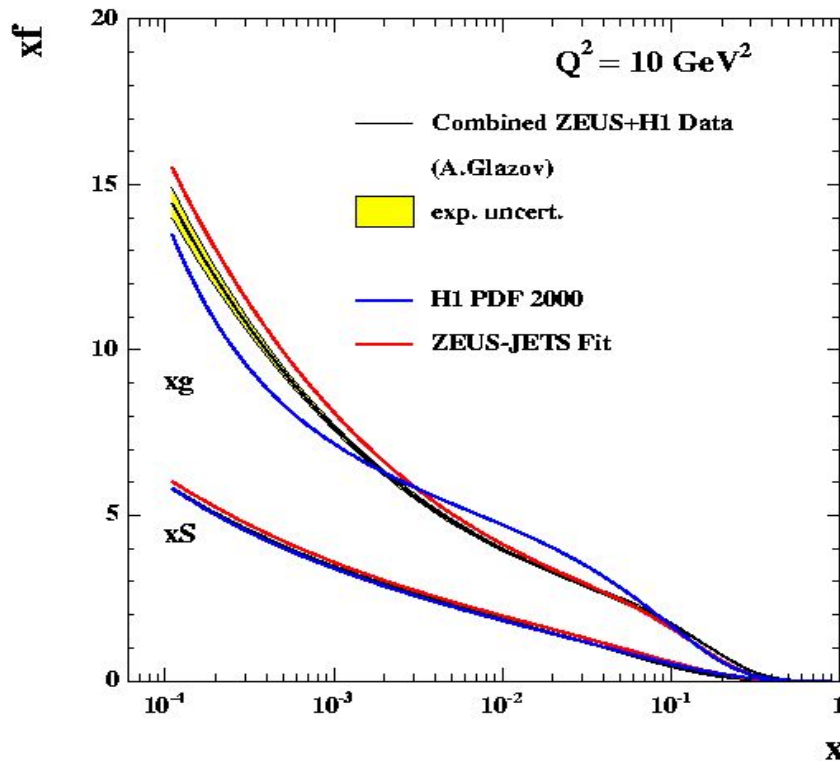


*Error on LHC jet xsection reduced !!!*

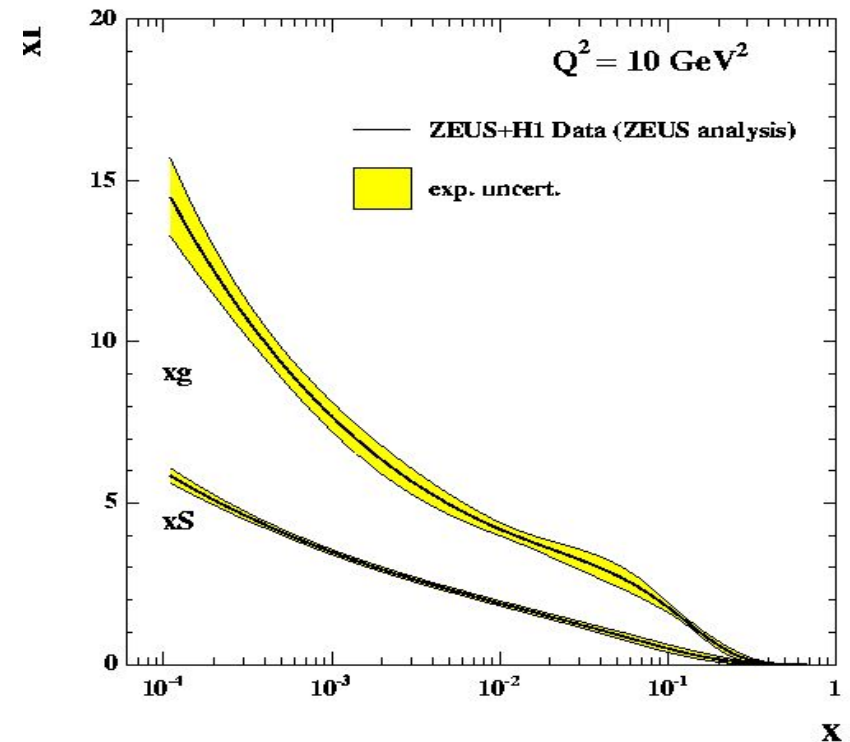
# Average of HERA data

From M. Cooper-Sakar, C. Gwenlan and S. Glazov

- Average H1&ZEUS data sets



- Combined PDF fit to H1 & ZEUS

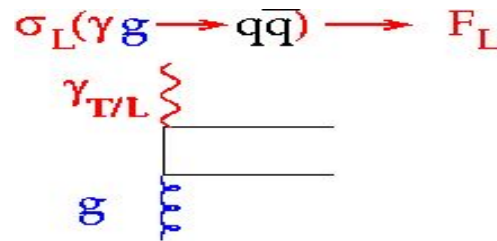
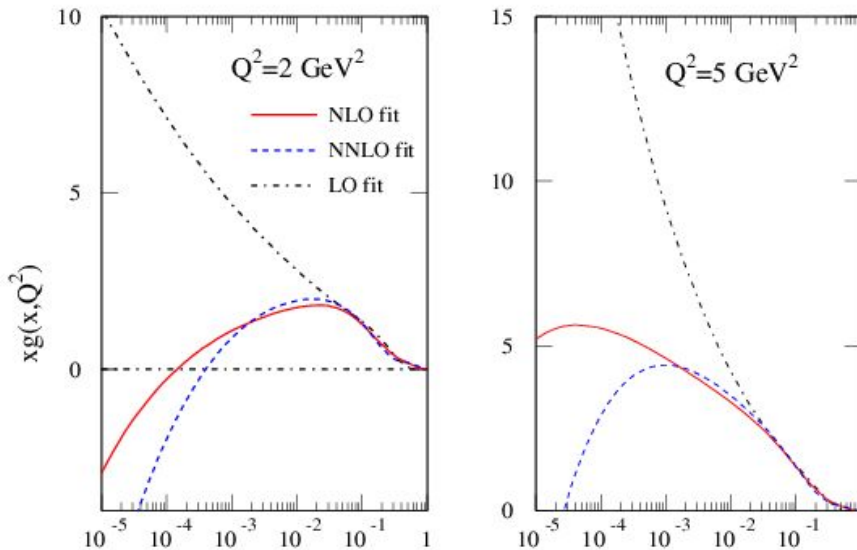


Much reduced uncertainties ....  
Model independent analysis of data desirable  
Activities started to get HERA - PDF !!!!!

# HERA measurements: $F_L$

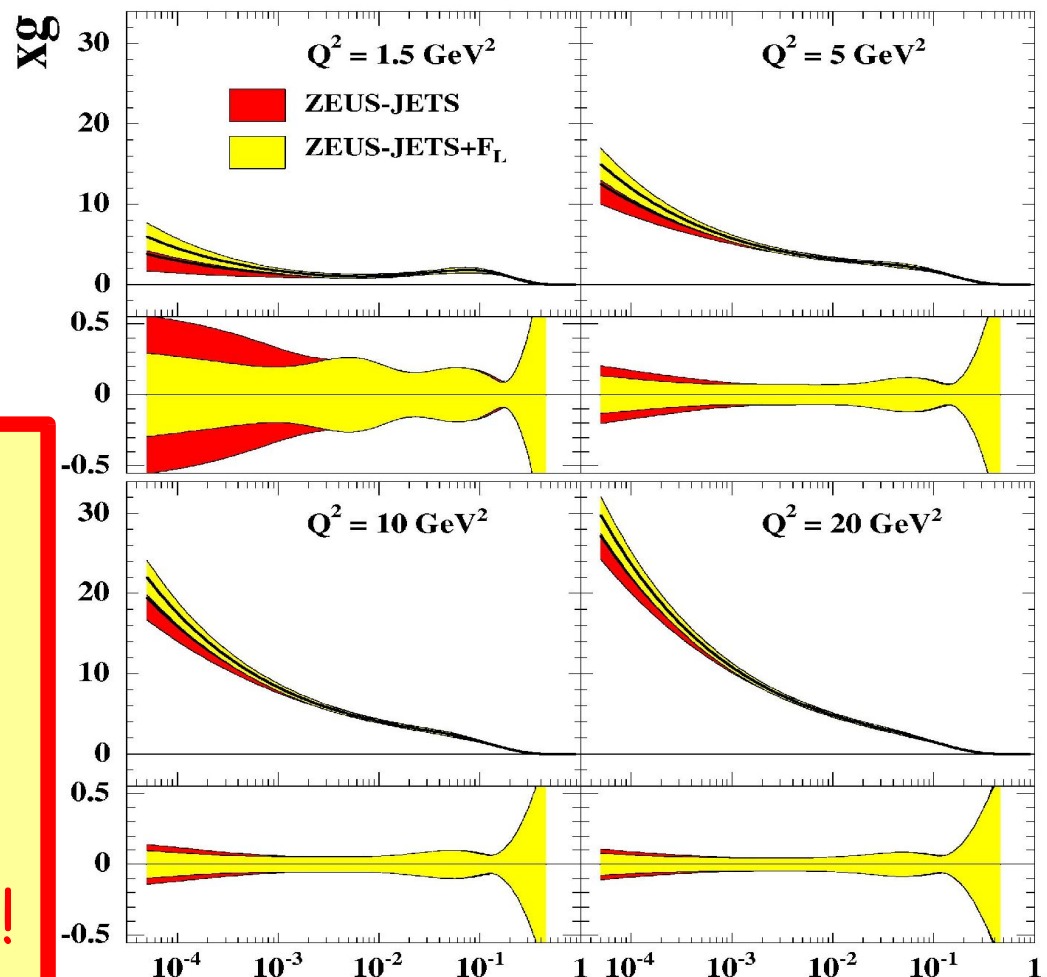
## The gluon distribution

R. Thorne, hep-ph/0511351



From J. Feltesse, C. Gwenlan, S. Glazov, M. Klein, S. Moch

$$F_L \propto \alpha_s xg(x, Q^2)$$



Precision measurement of  $F_L$  at  $E_p = 460 \text{ GeV}$  and  $5\text{-}10 \text{ pb}^{-1}$

- cleanest for gluon
  - crucial test of QCD at higher orders and consistency of theory
- Will be measured at HERA !!

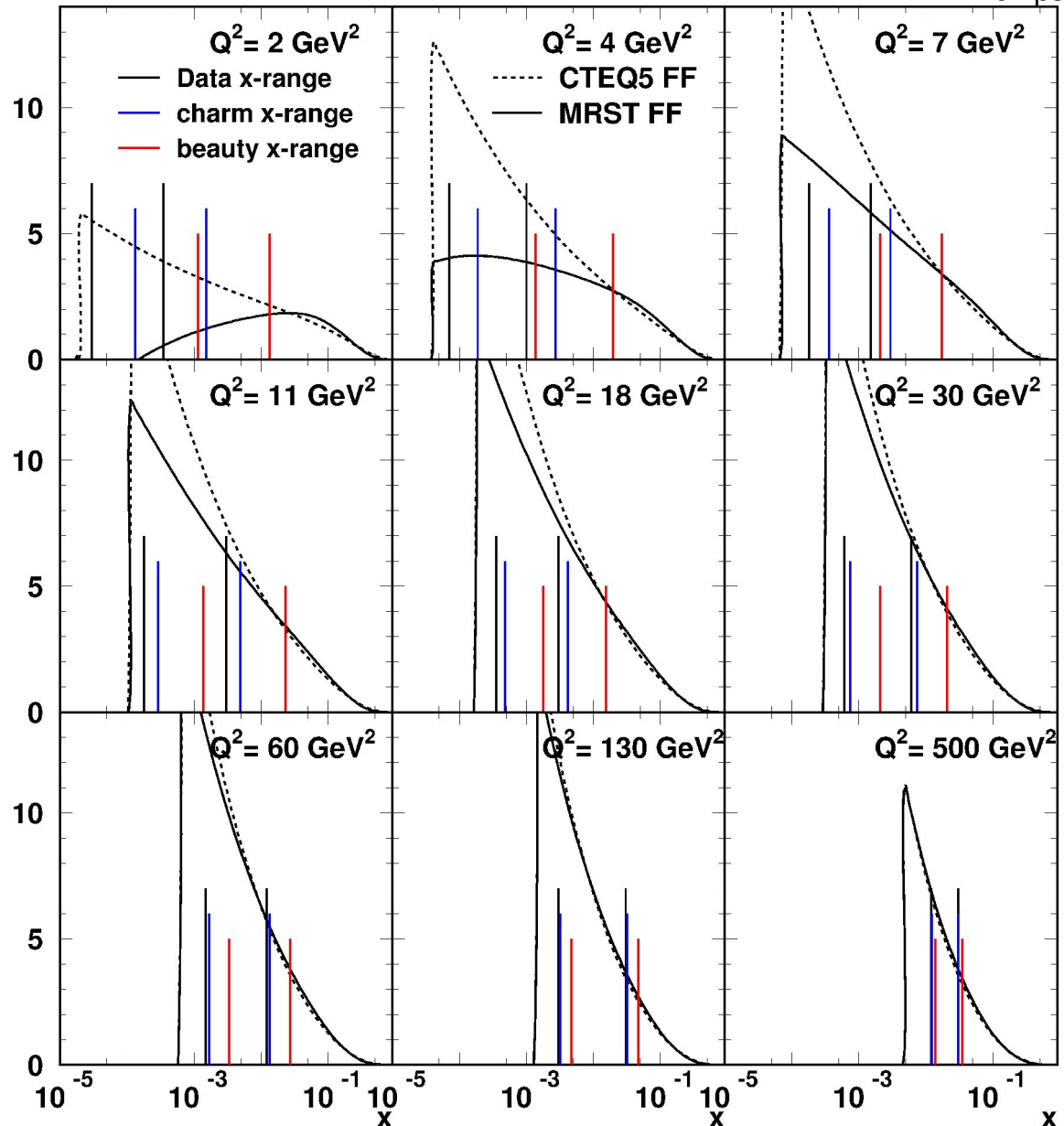
# Sensitivity of HERA $F_2^c$ measurement

- Effective  $x$  increases with mass

$$x' = x \frac{Q^2 + M^2}{Q^2}$$

- vertical lines show
  - black - HERA charm data
  - blue - effective charm  $x$
  - red - effective bottom  $x$
- large range at small  $Q^2$
- Note that HQ x-section is a convolution of ME with gluon density
- use it for PDF fits**

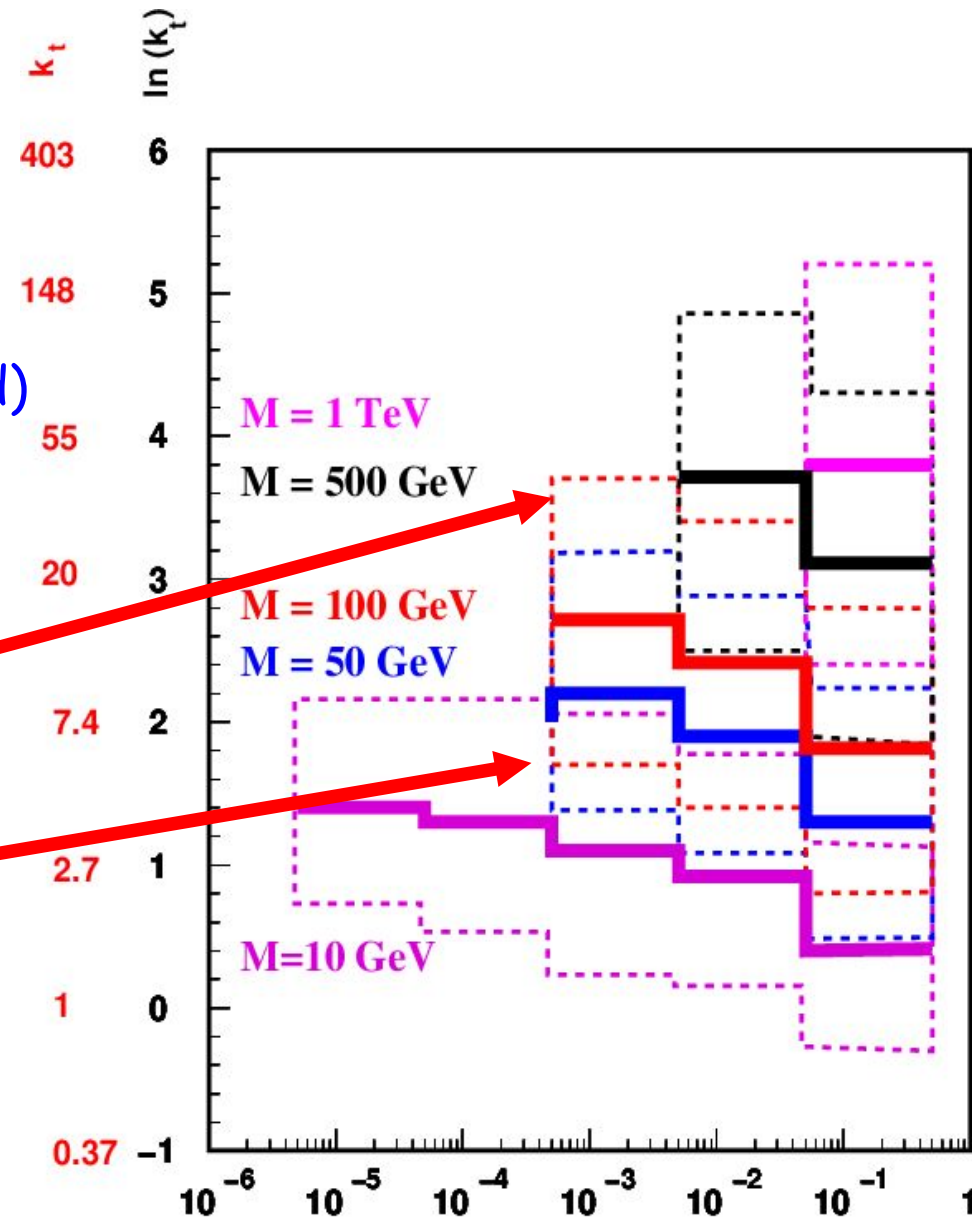
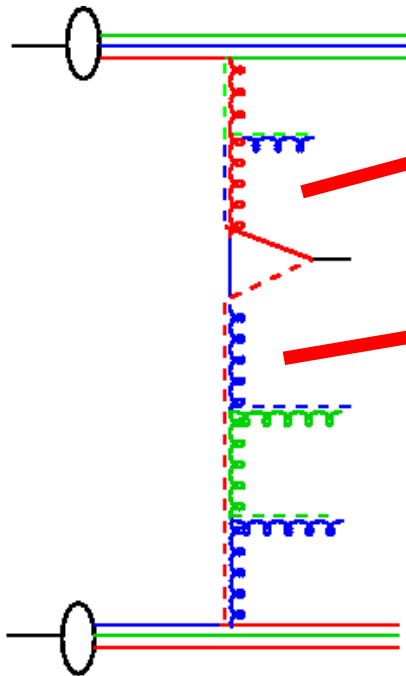
P. Thompson



# Parton Density Functions and all that

- collinear PDFs
- uPDFs (single and double unintegrated)

Higgs production et al

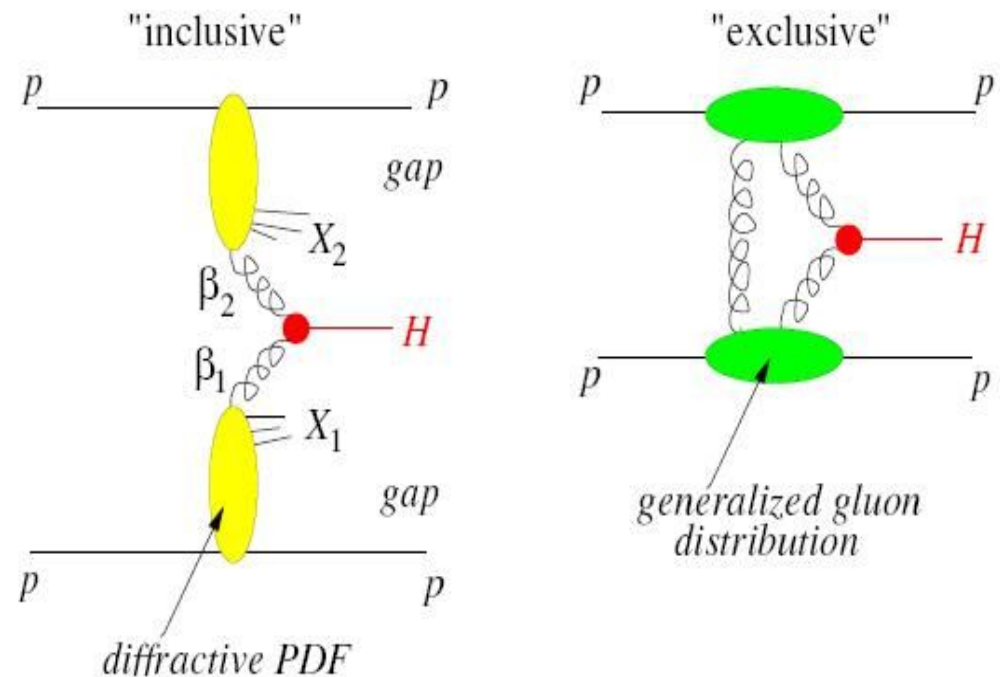


# Parton Density Functions and all that

- collinear PDFs
- uPDFs (single and double unintegrated)

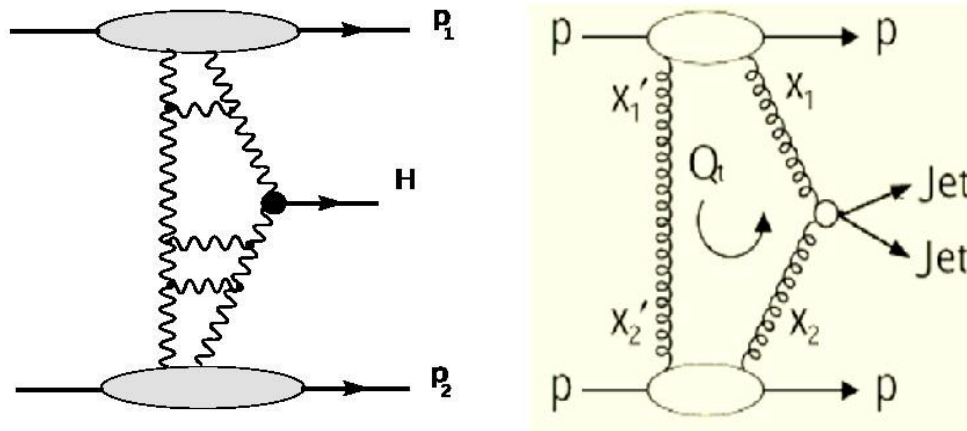
## Exclusive Higgs production

- diffractive and generalized PDFs



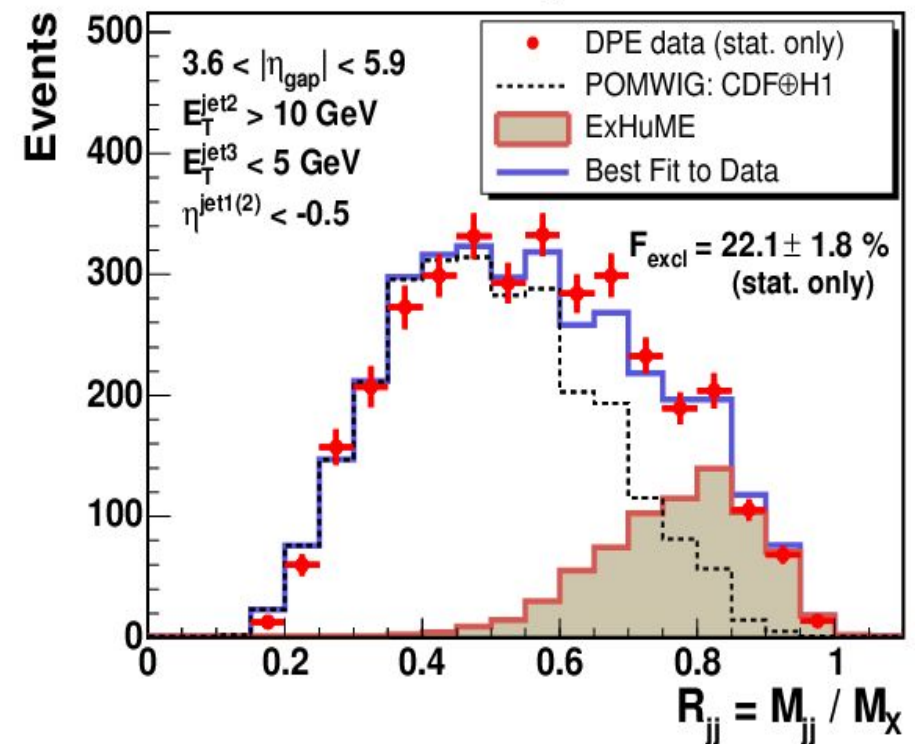
# Exclusive Higgs production, again...

- Numerous papers by V. Khoze, A. Martin, M. Ryskin, A. Kaidalov, J. Stirling:



- Test mechanism with **exclusive dijet production at Tevatron**

CDF Run II Preliminary



- Are CDF data proof of correctness of calculation ?
- Are rescattering effect really small ?
- gap survival prob well understood ?
- do we understand exclusive production well ?
- Where are exclusive dijets from HERA ?

# PDFs and all that ...

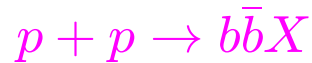
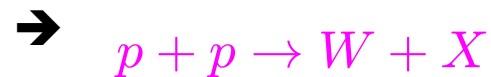
- Conclusion of PDF WG in 2006 (M. Dittmar):
  - A good preparation for the LHC start needs also to include:
    - realistic simulations to optimize data analysis
  - Find a realistic interactive (HERA-LHC) strategy to constrain PDF's
- Need for HERA PDF: H1 - ZEUS combined
- Should form a "group" from ATLAS, CMS, LHCb, ALICE, H1, ZEUS and theory experts !
- **NOW** we should make it happen !!!



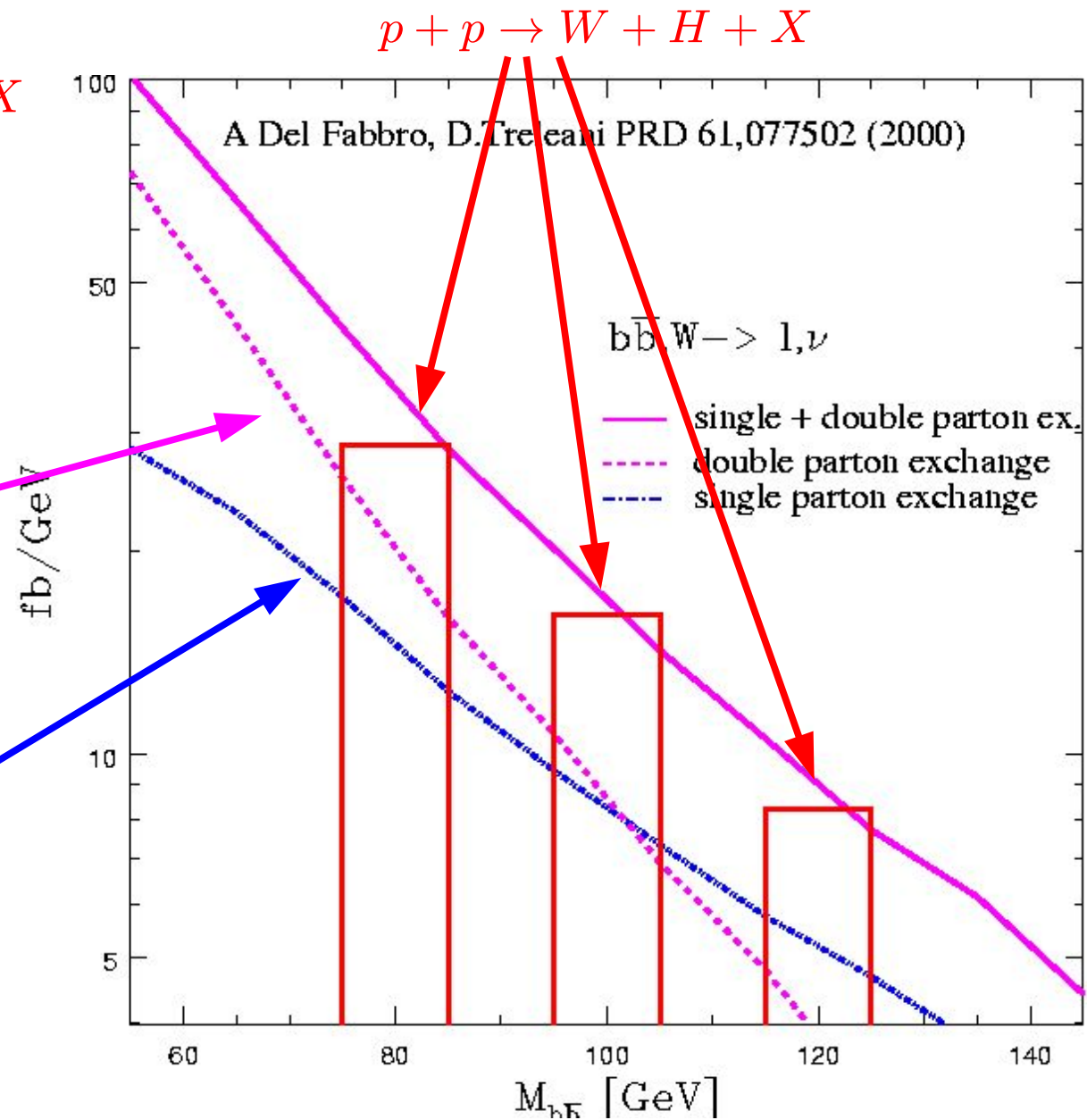
# Multi-Parton Interactions at LHC

- Higgs:  $p + p \rightarrow W + H + X$   
with  $W \rightarrow l\nu$ ,  $H \rightarrow b\bar{b}$

- Double parton scattering:



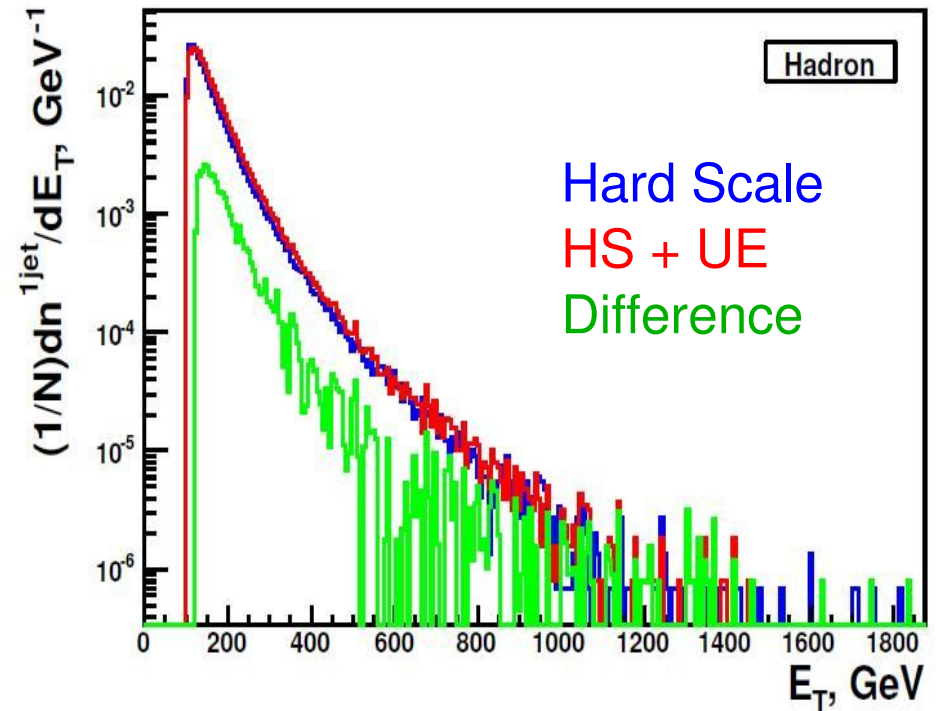
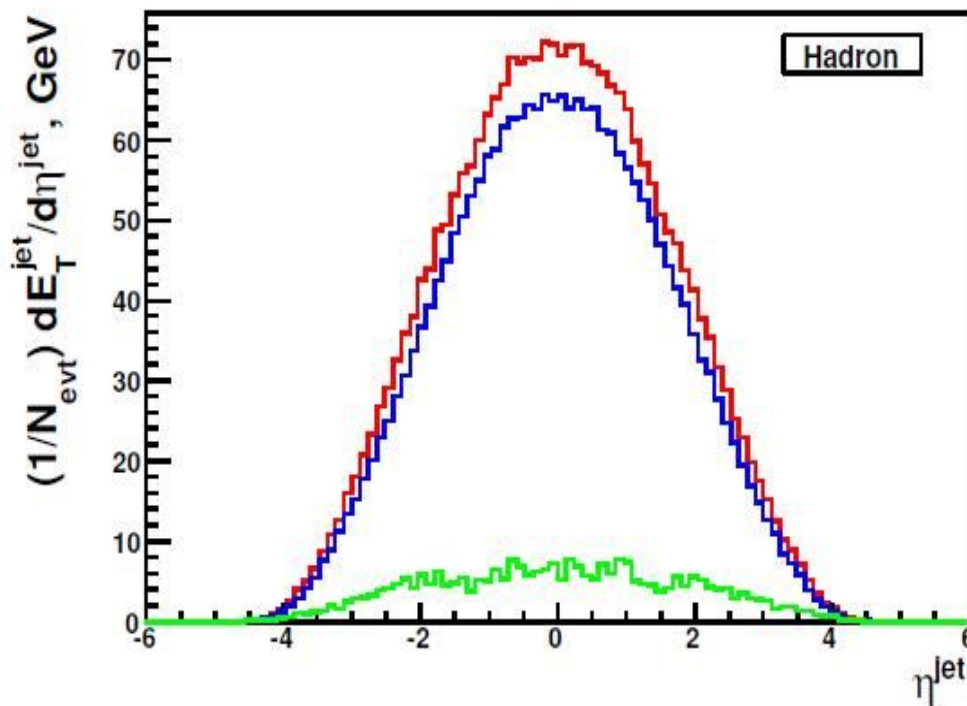
- compared to single parton scattering



# Underlying event and jets

P. Starovoitov, T. Carli

- SHERPA:  $E_T > 100 \text{ GeV}, |\eta| < 5$



- UE contributes  $\sim 10\%$  to Jets, even at large  $E_T$  !!!!
- need reliable model, to be tuned with 2st LHC data, for subtraction !!??!!!

# Monte Carlo and Tools

C. Risler, J Butterworth

## HZtool

- calculate and compare predictions with measurements
  - MC generators, NLOlib, MC@NLO
  - useful for tuning of parameters
  - useful for PDF fits with final states
    - includes HERA, LEP, TeVatron data
    - develops into RIVET (Robust Independent Validation of Experiment and Theory) a C++ version of HZTool.  
Work progressing - report this week ...
- Request for HERA & TeVatron & LHC:
  - include all available measurements for benchmarking, validation and tuning
- Provide tuning including HERA, LEP and TeVatron data !!!
- Will hear about VISTA later today...
- For LHC experiments it's important to have well tuned MC files at startup !!!!!

# From 2<sup>nd</sup> to 3<sup>rd</sup> workshop ...

- To identify and prioritize those measurements to be made at HERA which have an impact on the physics reach of the LHC.
  - Measurements for parton densities
  - Measurements to understand Multiple Interactions and small  $x$
- To encourage and stimulate transfer of knowledge between the HERA and LHC communities and establish an ongoing interaction.
  - Fruitful collaboration
  - DESY joins ATLAS/CMS
- To encourage and stimulate theory and phenomenological efforts.
- To examine and improve theoretical and experimental tools.
- To increase the quantitative understanding of the implication of HERA measurements on LHC physics.

? Do we have all necessary feedback from HERA?  
for the first Data Analysis at LHC ?

# What LHC needs in 2007/2008 ?

- LHC will have first data at 900 GeV end of this year ..
  - First 14 TeV data in summer 2008
    - LHC experiments are preparing Monte Carlo data for 14 TeV analysis now... so need to fix parameters now
    - Examples:
      - Which PDFs to use ...
        - HERA ?, LO/NLO ? Which scheme ?
      - Underlying event/multiple interaction parameters need to be fixed soon ...
- Need feedback from HERA now ....

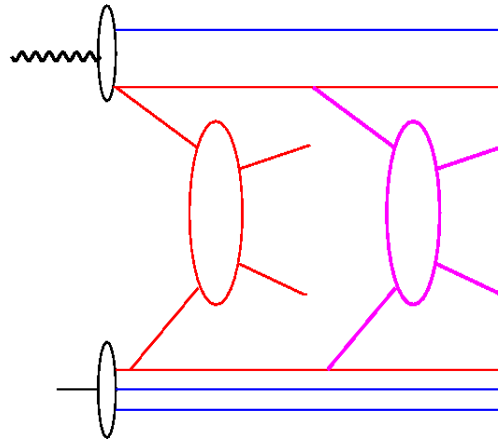
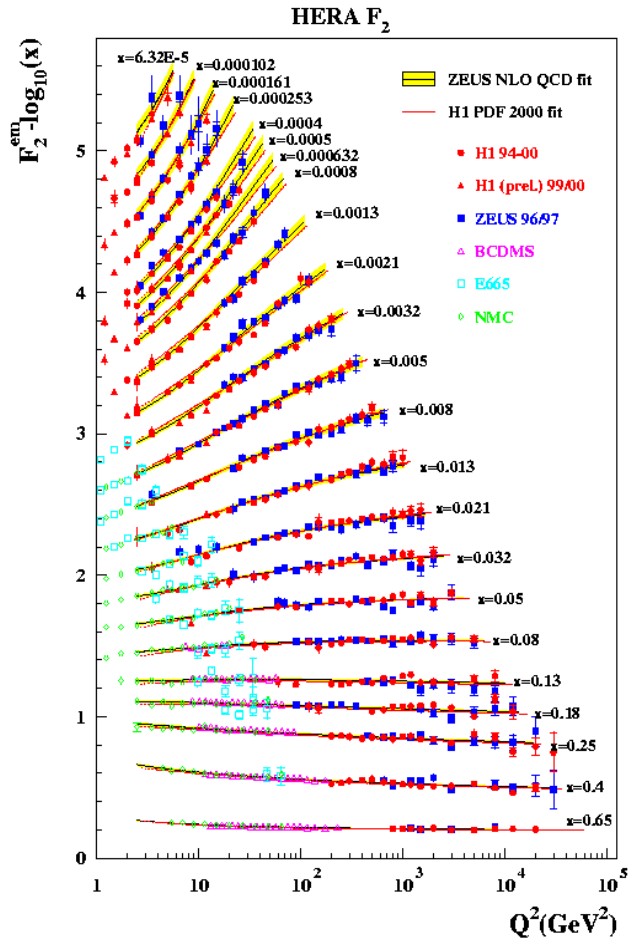
# What is still left to do - a few examples ....

- what is the present and expected precision of the **parton densities** obtained using HERA data and what are the resulting **theoretical uncertainties** for benchmark cross section measurements in the first days
  - Fit group of experts from HERA, LHC & theory
- do we have the tools to understand the **underlying event and multiple parton interactions** ?
  - Is PYTHIA MI/Jimmy the final answer to MI and underlying events ?
  - Do we understand MI enough to just tune MCs ?
  - Are further investigations also from HERA needed ?
- do we have the necessary measurements and informations to obtain **best tuned Monte Carlo event generators**
  - Tuning of MCs. Are data available in computer usable form (Hztool, Rivet) ?
  - Which pdfs to use in MC generators (LO,NLO, Msbar, DIS, ... uPDFs) ?

What is still left to do ?

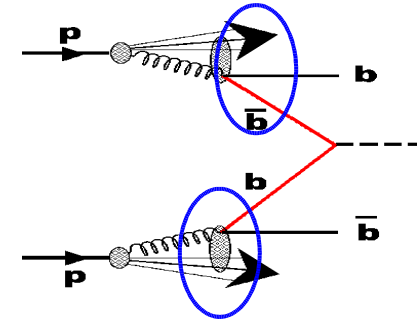
There are many more areas ...  
join the working groups !!!

# Working Groups of the workshop



Multijets & final states  
Underlying events,  
un-integrated pdfs

L. Lonnblad, G. Zanderighi,  
C. Gwenlan, N. Tuning,  
S. Banerjee, D. Traynor



Heavy quarks:  
B quark pdfs of the proton,  
fragmentation fct, u-pdfs

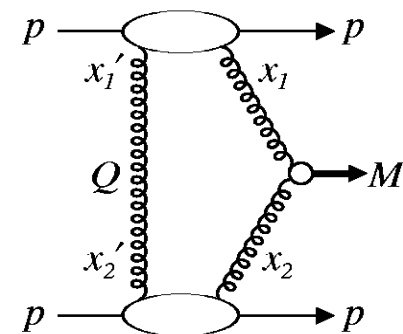
M. Cacciari, H. Spiesberger,  
A. Dainese, A. Geiser,  
K. Lipka, U. Uwer

Structure functions and  
parton distributions

S. Forte, S. Moch,  
M. Dittmar, A. Glazov  
M. Botje

MC - Tools

S. Gieseke, F. Krauss,  
T. Kluge, P. Bartalini,  
P. Robbe, S. Chekanov



Diffraction

M. Diehl, V. Khoze  
M. Arneodo, P. Newman,  
A. Bruni, B. Cox, R. Orava



# Organizational issues

- **Schedule:**
  - Tuesday morning plenary,
  - Thursday afternoon, Friday morning plenary
  - **parallel sessions:** coffee always at 10:00 and 15:00 in sem area !  
still time left for informal discussions... if you need a room, contact us !!
- **Proceedings**
  - printed copies from 1<sup>st</sup> workshop are again available ..
  - No proceedings for this meeting, plan for proceedings after next meeting at CERN
- **Conference Dinner** ( 5 Euro, thanks to DESY for sponsoring)
- **Visit to H1 experiment and HERA** on Friday afternoon
  - Sign up at the registration desk

Enjoy the Workshop