

HERA and the LHC workshop

The poster features an aerial photograph of the DESY Hamburg facility, with the HERA particle accelerator ring highlighted by a dashed orange line. The title 'HERA AND THE LHC' is in large, bold, orange letters at the top. Below it, the subtitle 'A workshop on the implications of HERA for LHC physics' is in smaller orange text. The dates 'March 2004 - Jan 2005' are prominently displayed in the center. On the left, a list of topics includes 'Parton density functions', 'Multijet final states and energy flow', 'Heavy quark', 'Diffraction', and 'Monte Carlo tools'. On the right, the meeting schedule is listed: 'Startup Meeting March 26-27 2004 CERN, Geneva', 'Midterm Meeting October 2004', and 'Final Meeting Jan 2005 DESY, Hamburg'. Logos for CERN and DESY are shown. At the bottom, the website 'www.desy.de/~heralhc' and email 'heralhc.workshop@cern.ch' are provided. A yellow diagonal banner in the bottom left corner reads 'Final Meeting March 2005 DESY, Hamburg'.

“...The mechanic, who wishes to do his work well, must first sharpen his tools ...”

—Chapter 15, “**The Analects**” attributed to Confucius, translated by James Legge.
(from X. Zu talk at DIS05)

HERA and the LHC workshop

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

Final Meeting
March 2005
DESY, Hamburg

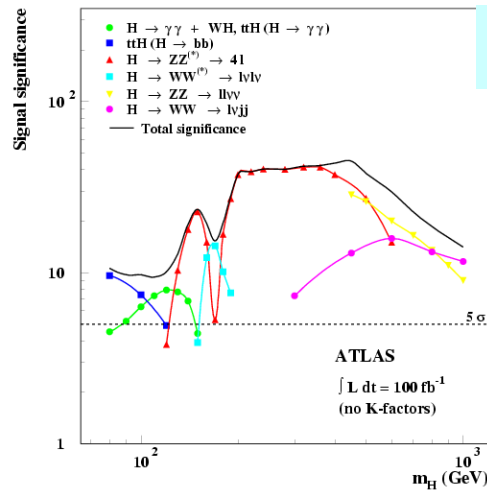
Organizing Committee:
G. Altarelli (CERN), J. Blümlein (DESY),
M. Bojars (DESY), J. Butterworth (UCL),
A. Denner (CERN) (chair), K. Eggert (CERN),
H. Jung (Lund/DESY) (chair), M. Mangano (CERN),
A. Marach (CERN), P. Newman (Birmingham),
G. Polensio (NIPN), O. Schneider (EPFL),
R. Yoshida (ANL)

Advisory Committee:
J. Badstuber (Hamburg), M. Della Negra (CERN),
J. Ellis (CERN), J. Grunberg (CERN),
G. Gustafson (Lund), G. Ingelman (Uppsala),
P. Jona-Lasinio (CERN), R. Klanner (DESY),
M. Klein (DESY), L. Malgera (BNL),
T. Matsuoka (CERN), D. Schafer (CERN),
T. Schutz (CERN), J. Schuler (CERN),
J. Sjöstrand (CERN), M. Taroni (Uppsala),
A. Wagner (DESY), R. Yoshida (ANL)

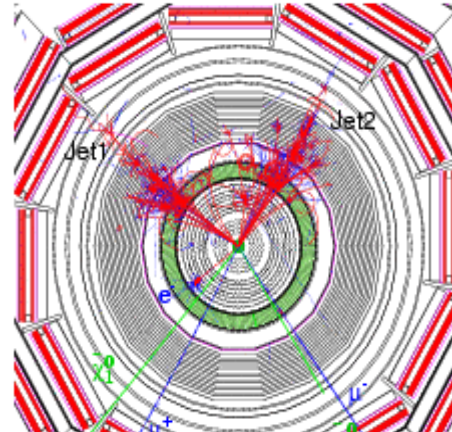
www.desy.de/~heralhc heralhc.workshop@cern.ch

- Aims of the workshop
- Outcome, results and future (highly biased.....):
 - HERA is important for the physics reach of LHC
 - further HERA measurements desirable
 - HERA experience valuable for LHC

Physics at the LHC: examples

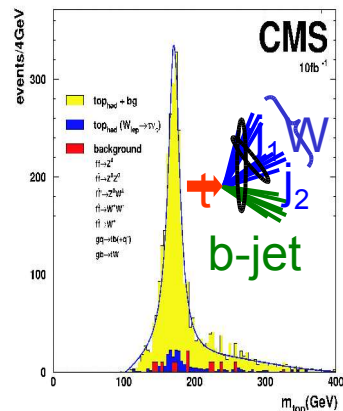
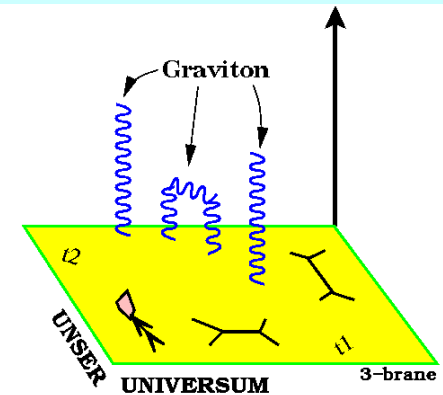


Higgs!



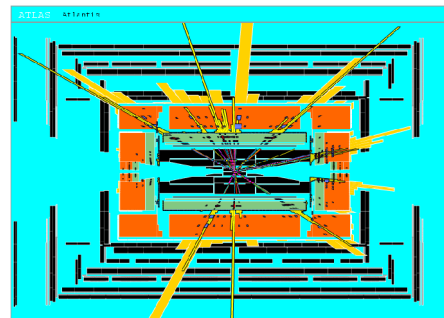
Supersymmetry?

Extra Dimensions?

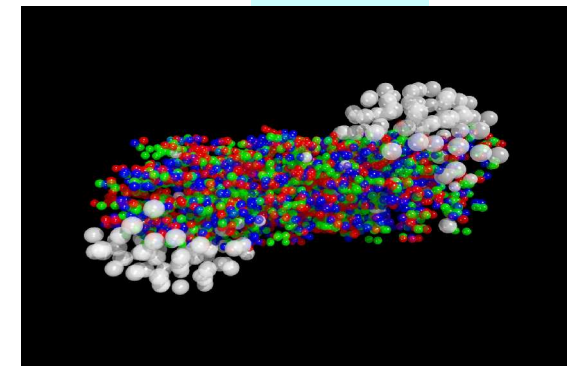


Precision measurements e.g top!

Black Holes???



QGP?



But also QCD, diffraction, b & c physics,... especially in the early phase
 These need to be understood for precision measurements, bkg understanding etc
 Important role for HERA data & HERA expertise

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.

Five Working Groups

Parton density functions (S. Forte, S. Moch M. Dittmar, A. Glazov M. Botje, J. Butterworth)

Multi-jet final states (L. Lonnblad, V. Khoze, N Tuning, C Buttar, J. Butterworth, S. Banerjee, D. Traynor)

Heavy quarks (charm and beauty) (M. Cacciari, U. Uwer, M. Smizanska, M. Corradi, A. Dainese, C. Weiser, A. Meyer)

Diffraction (J. Forshaw, M. Diehl, K. Piotrkowski, R. Orava, H. Kowalski, P. van Mechelen, M. Rijssenbeek, B. Cox)

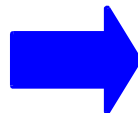
MC-tools (M. Seymour, A. Nikitenko, E. Richter-Was, P. Robbe, V. Lendermann)

Organization

First meeting:	26-27 March CERN (~ 250-300 participants)
Intermediate meeting:	1- 4 June/ DESY
Second meeting:	11-13 October CERN
Intermediate meeting:	15-19 November/ DESY
Intermediate meeting:	17-21 January 2005/ CERN
Final meeting:	21-24 March 2005/ DESY (~150 participants)

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

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



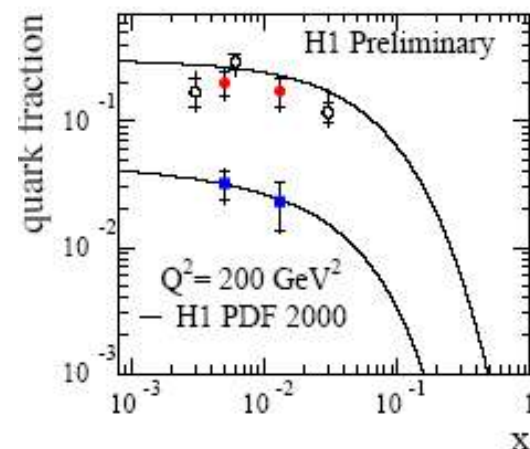
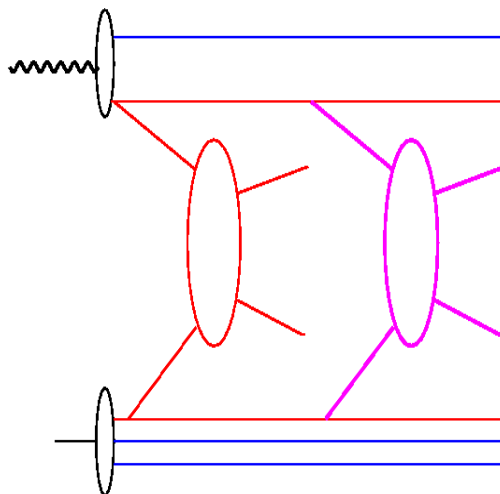
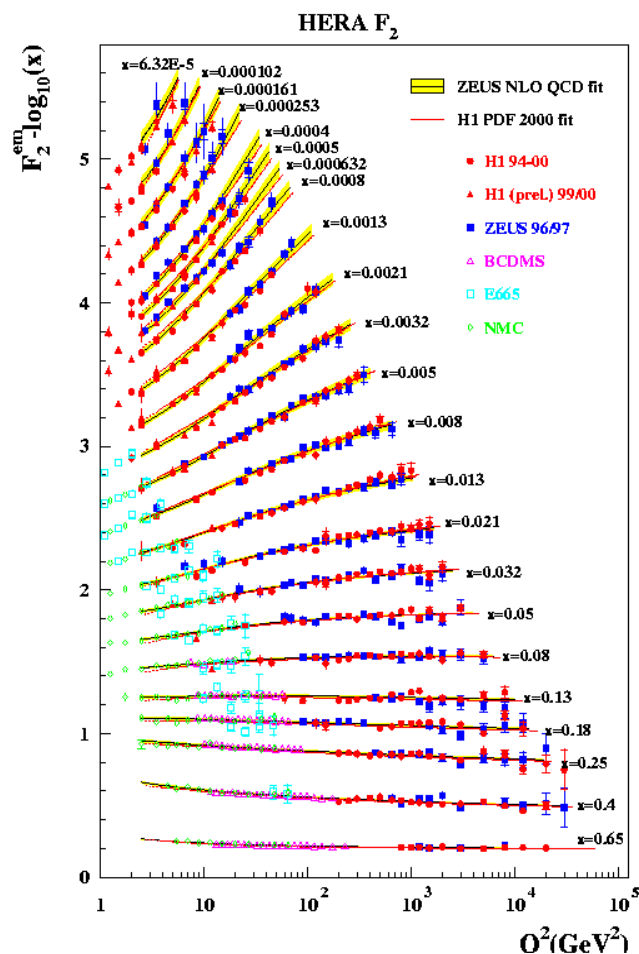
Joint DESY/CERN
Report in 2005

So, how did we do ?

HERA 2 and the LHC

**Where HERA2 investigations
will influence the physics reach
of LHC !**

Topics of the workshop

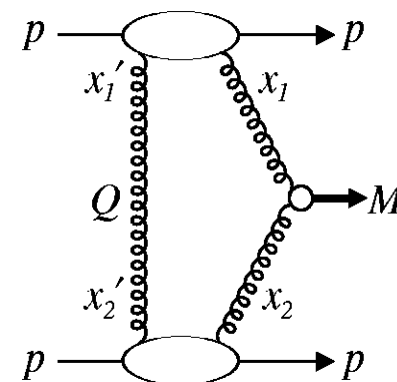


Multijets & final states
Underlying events,
un-integrated pdfs
LHC: event complexity,
jet x-section, Higgs

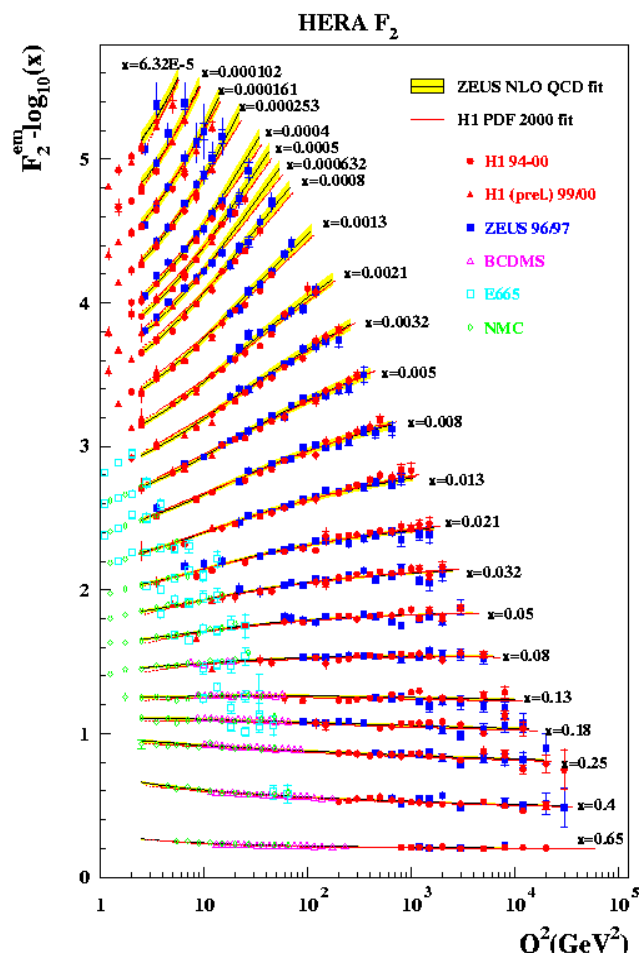
Heavy quarks:
B quark pdfs of the proton,
fragmentation fct, u-pdf
LHC: Higgs production

Structure functions and
parton distributions
LHC: cross sections/precision

Diffraction
LHC: exclusive
Higgs production



Topics of the workshop



Structure functions and
parton distributions
LHC: cross sections/precision

Potential experimental and theoretical accuracy
for various LHC processes
(DY, W, Z, WW, +jet...)

Precision measurements at LHC/luminosity
determination?

- Cross sections and distributions
- Benchmark with LHC detector simulation

Impact of PDF's on LHC measurements

- Making the most of HERA data
- Need for FL or eD scattering?
- Can we judge which PDF is "preferred"?

Most precise PDFs + errors

Impact of small x and large x resummations
and saturation corrections on pdfs. QCD
evolution validation (DGLAP,...)

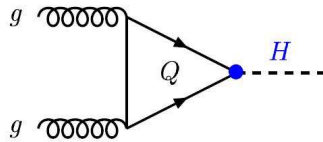
- Impact for LHC?
- Verify with HERA data.

NNLO for F_2 and F_L

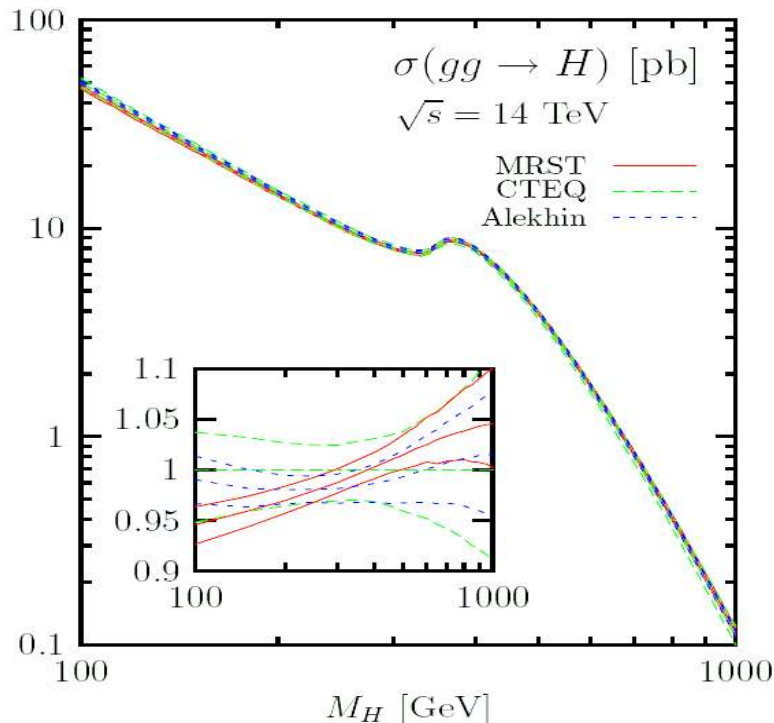
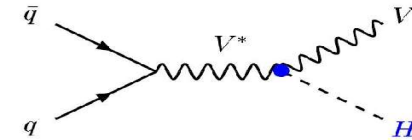
pdf uncertainty for Higgs prod.

gluon-gluon fusion

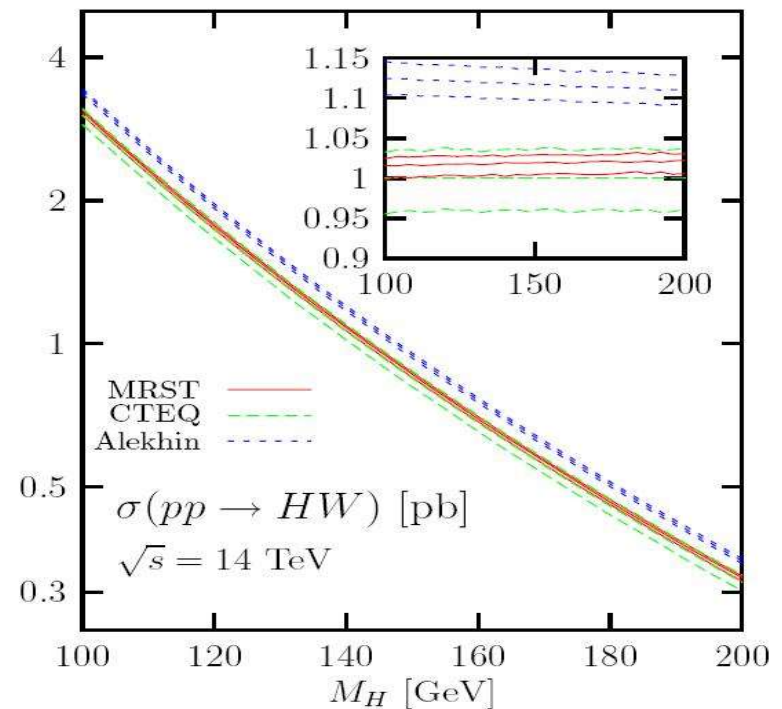
from Djouadi & Ferrag



Higgs-strahlung



Gluon induced... ~ 10 %

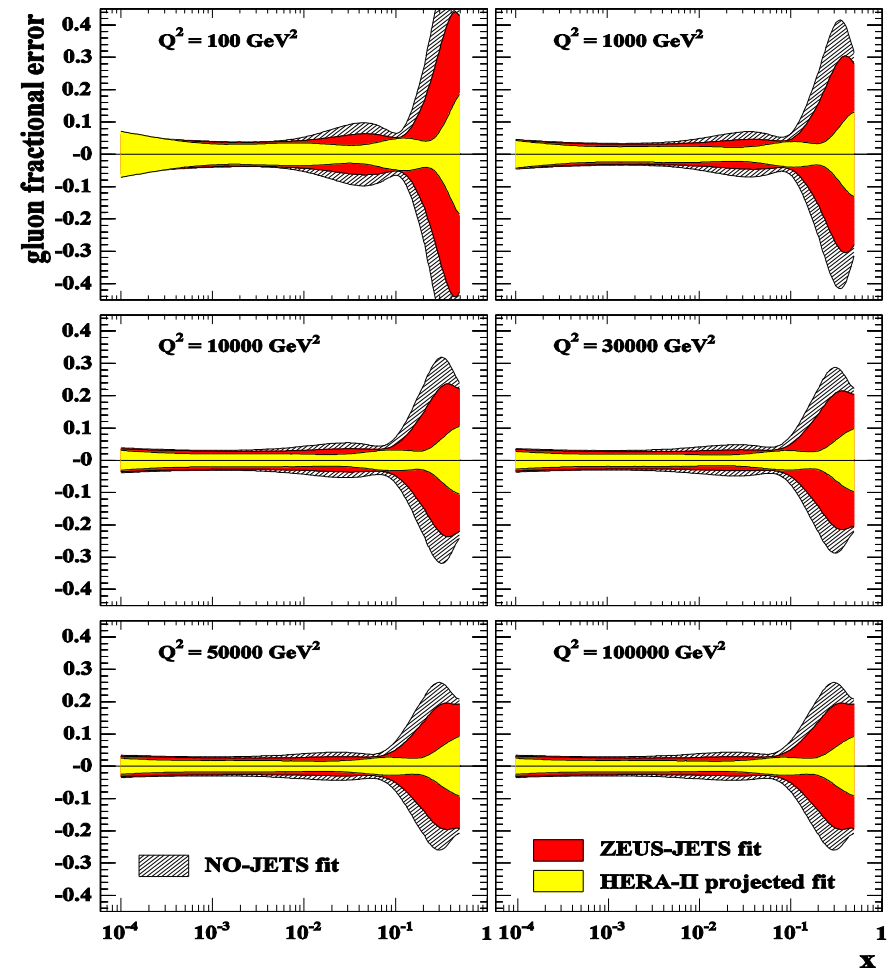
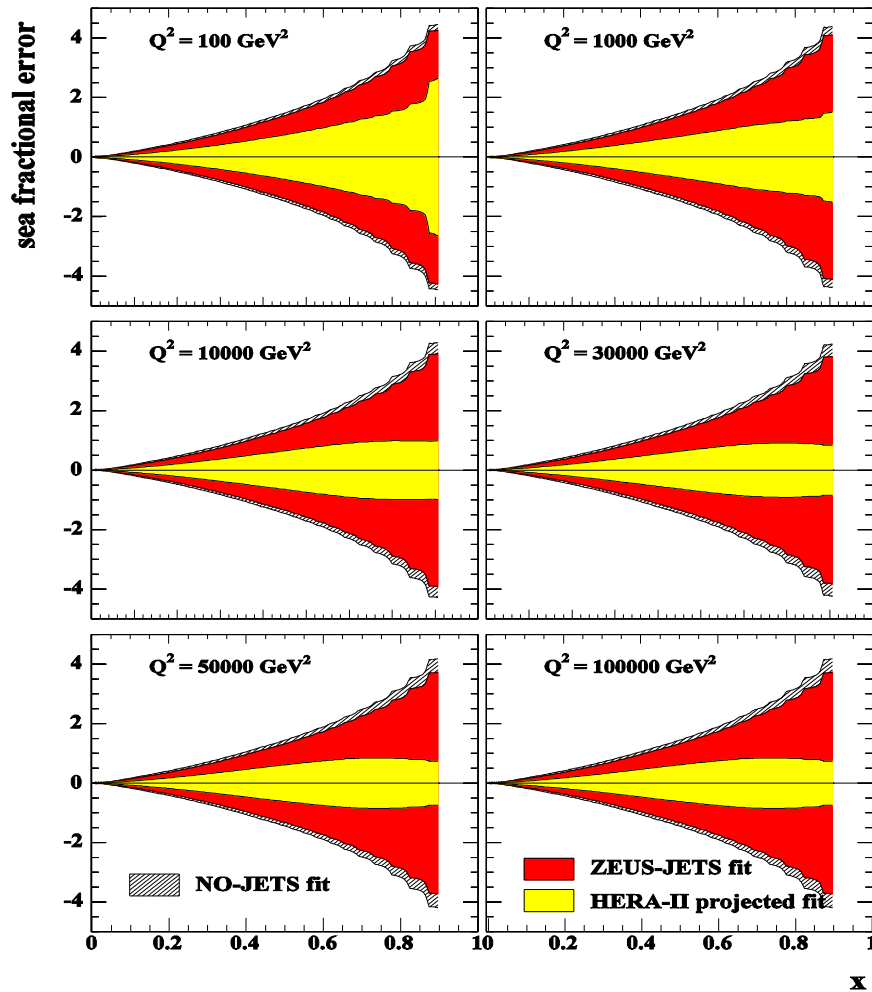


Quark induced ~ 10 % difference

pdf do not agree within respective errors (J. Stirling) !!!!

pdf uncertainty: improvements

Sea-quark uncertainties Using jets together with F_2 gluon uncertainties from C. Gwenlan



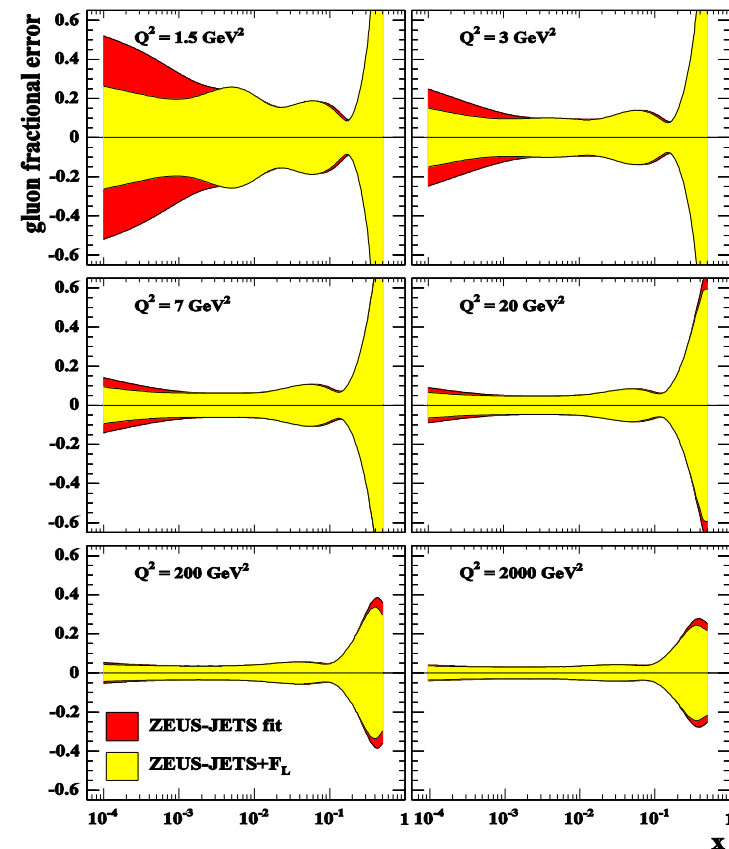
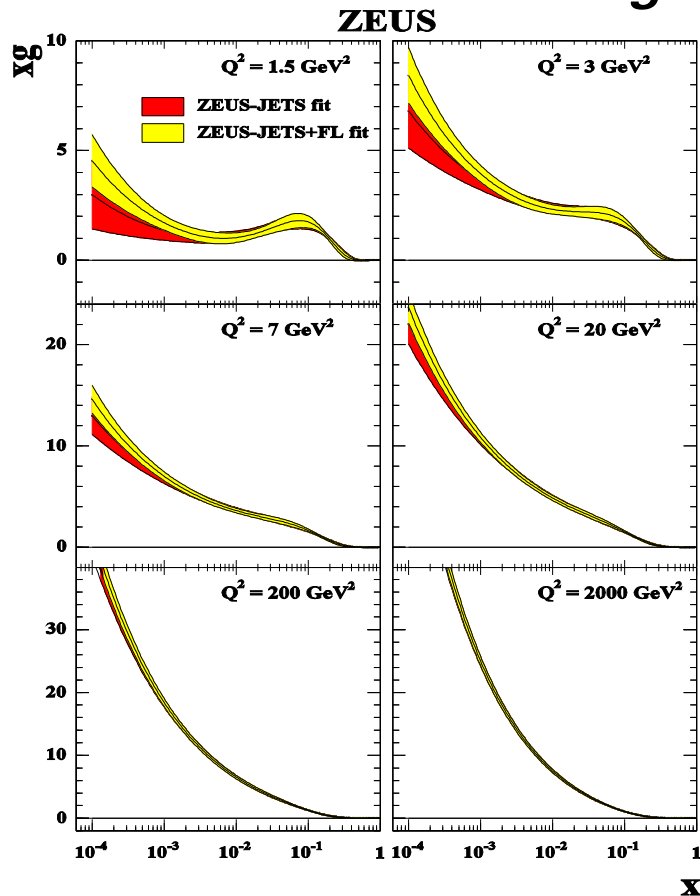
high statistics from HERA II helps
(assumed 700 pb^{-1})

optimised cross section from jets help

HERA future measurements: F_L

The gluon distribution

From C. Gwenlan, S. Glazov, M. Klein



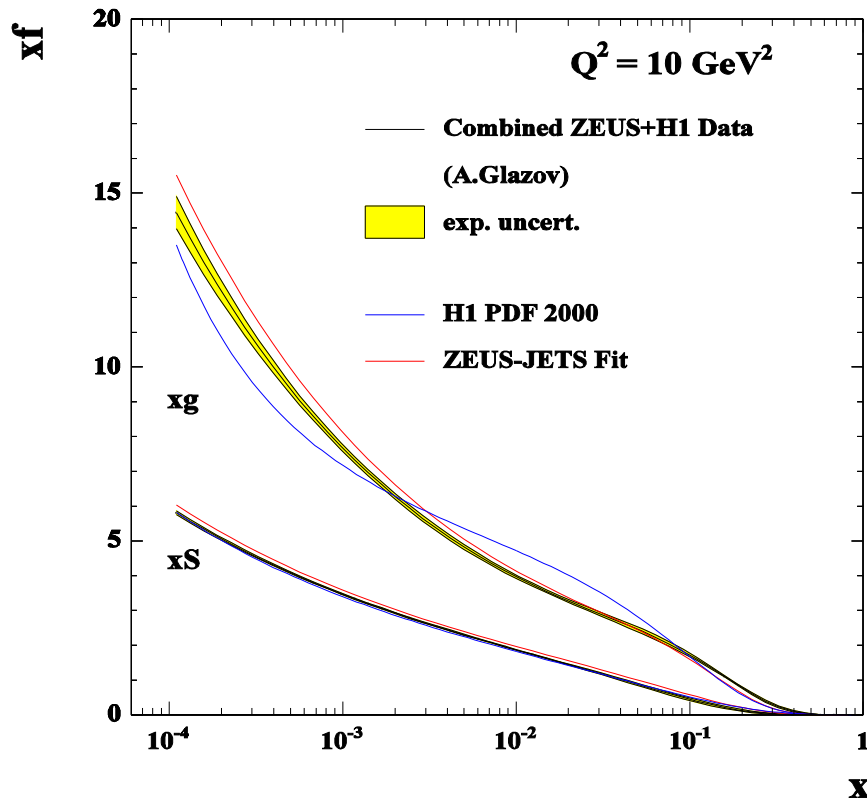
Precision measurement of F_L (3 lower p-Energies, 3-5 pb-1)

- cleanest for gluon
- provide tests of QCD at higher orders and consistency of theory
- where if not measured at HERA ?????

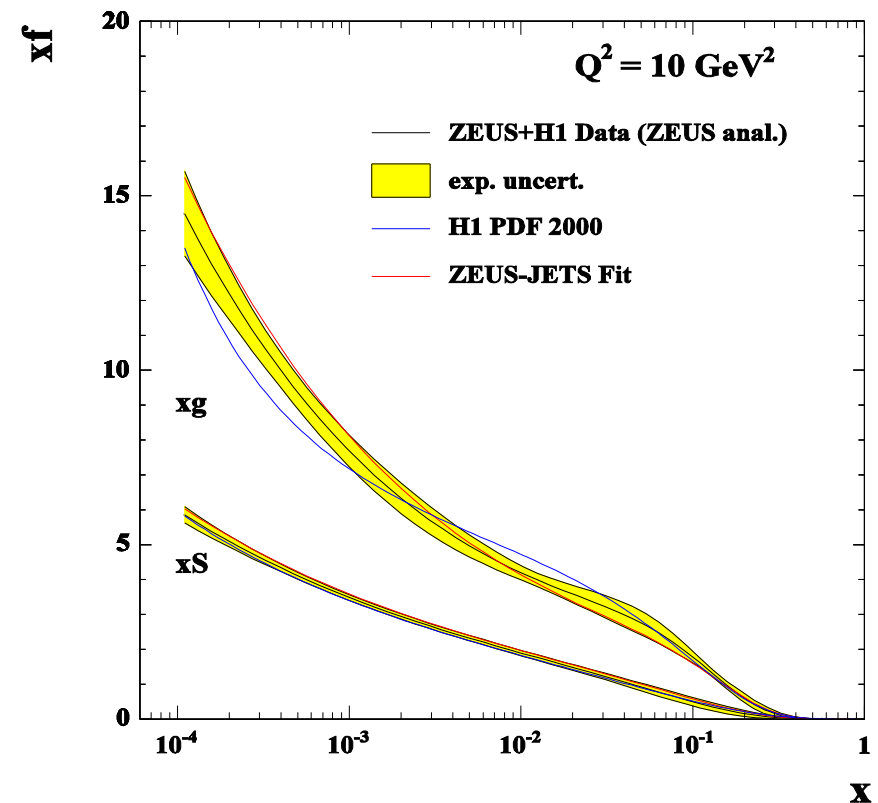
Average of HERA data

From M. Cooper-Sakar and S. Glazov

- Average H1&ZEUS data sets



- Combined PDF fit to H1 & ZEUS

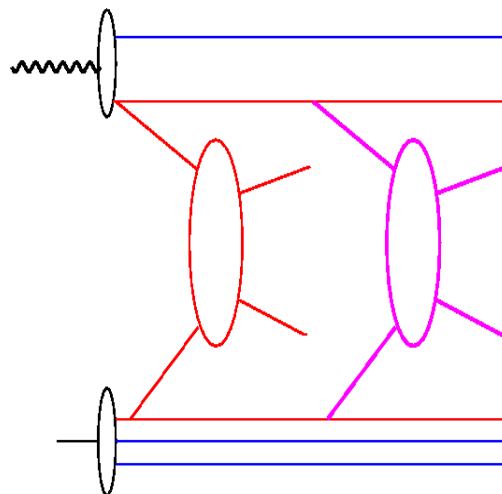
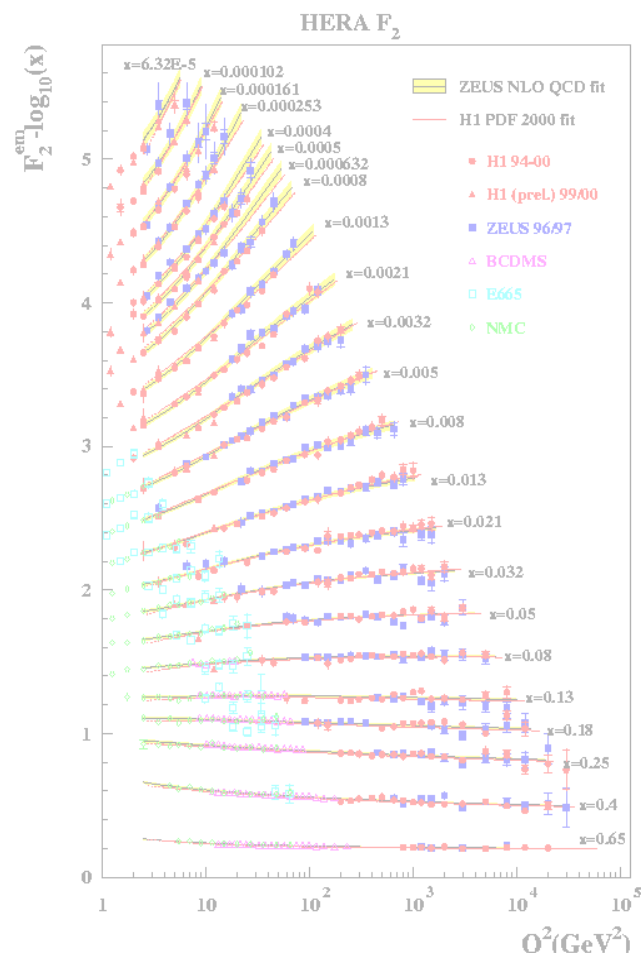


Much reduced uncertainties

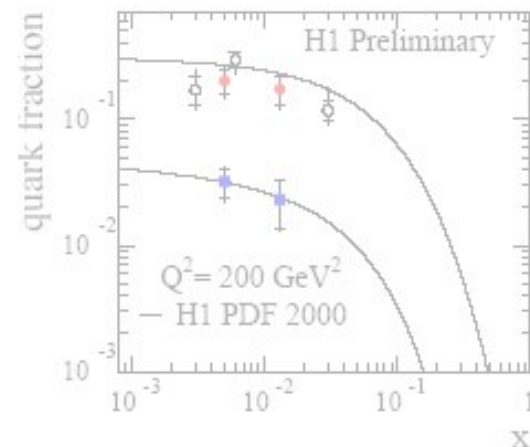
Consensus: Model independent analysis of data desirable

Joint H1 – ZEUS working group ... get HERA – pdf !!!!!

Topics of the workshop



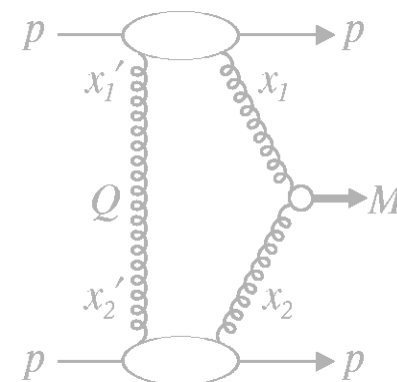
Multijets & final states
Underlying events,
un-integrated pdfs
LHC: event complexity,
jet x-section, Higgs



Heavy quarks:
B quark pdfs of the proton,
fragmentation fct, u-pdf
LHC: Higgs production

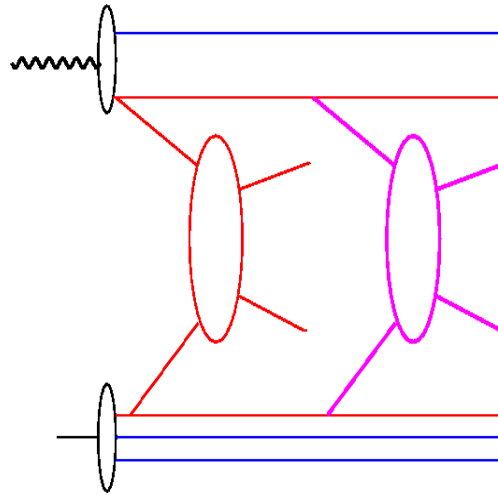
Structure functions and
parton distributions
LHC: cross sections/precision

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LHC: exclusive
Higgs production



Topics of the workshop

- inclusive x-sections **fine**
- **BUT** measurements of final states jets, heavy quarks, higgs) **more difficult**
- ➔ need full final state
- ➔ **BUT** LO/NLO parton level insufficient and **unphysical** ...
- NEW** approaches:
 - un-integrated pdfs
 - MC@NLO
 - ME + PS matching



Multijets & final states
Underlying events,
un-integrated pdfs
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Underlying event/minimum bias events

- New models appeared during the workshop
- Tunes to pp data validated
- Study similar observables in *ep* as in *pp*

Task force in action

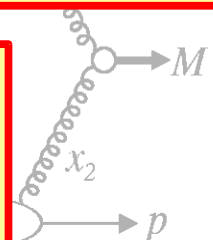
Gap survival

- Still not understood: Consequences for the LHC!
- New measurements at HERA !

1 10 10² 10³ 10⁴ 10⁵
O²(GeV²)

Structure f
parton dist
LHC: cross

- Re summations for event shape variables
- Future parton shower developments
 - Unintegrated parton correlation functions

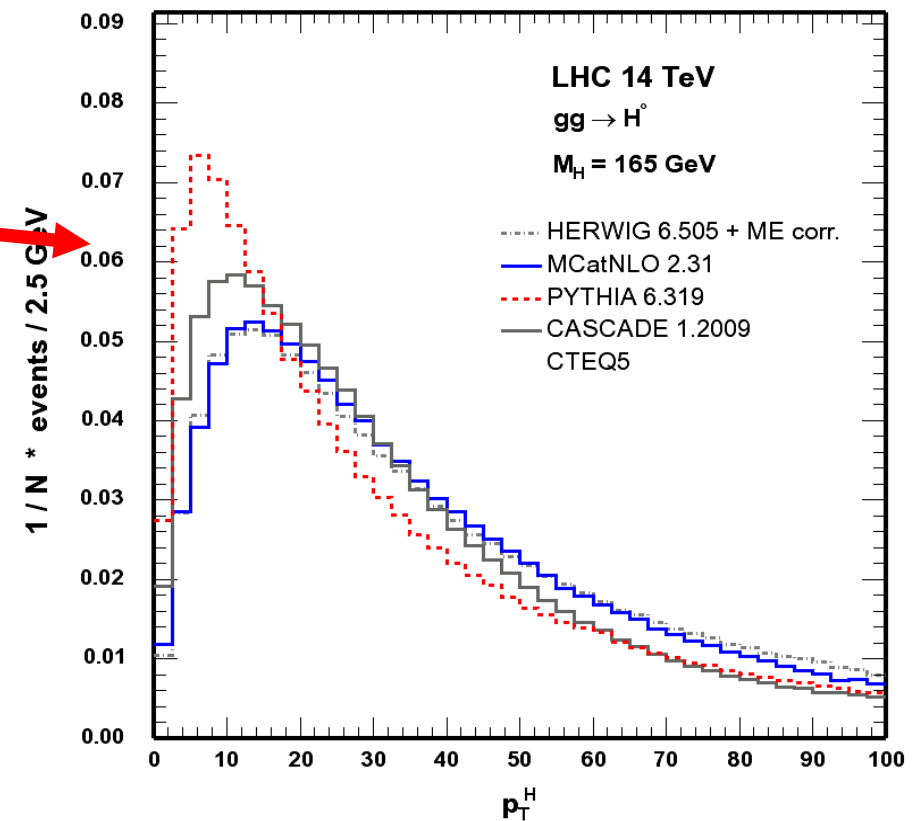
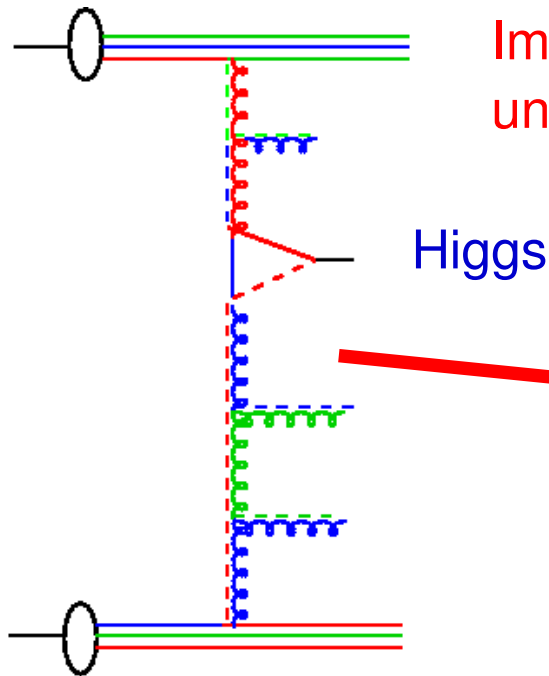


k_t effects at HERA and LHC

from G. Davatz

Do we understand the p_t spectrum of Higgs at LHC?

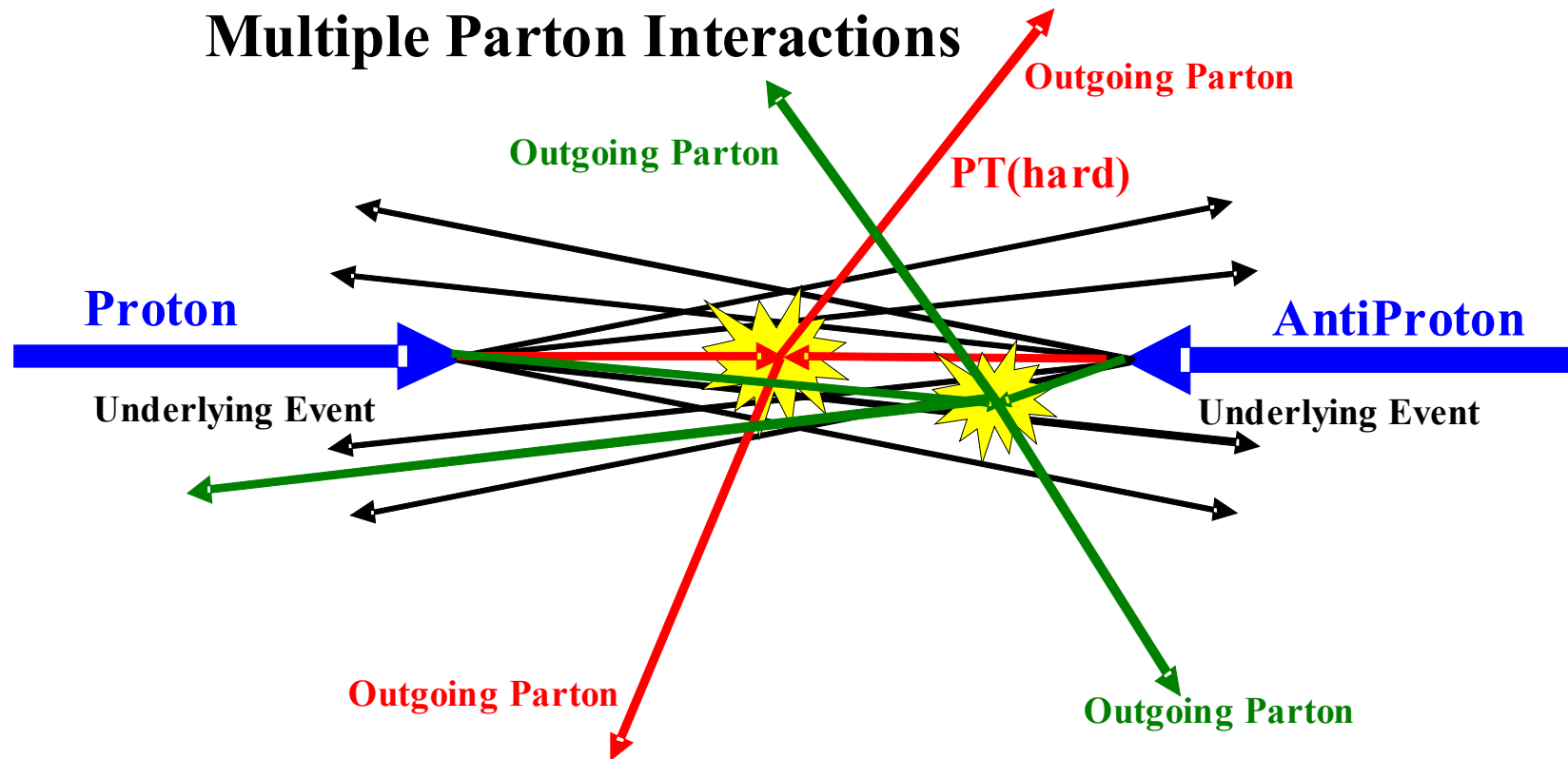
Important for the $gg \rightarrow \text{Higgs} \rightarrow WW \rightarrow \nu \nu$ to understand the jet-veto for $t\bar{t}$ suppression...



$\langle K_t \rangle$ large unintegrated parton PDFs will be needed
Need to be better constrained at HERA with final states

Multiple scatterings in pp

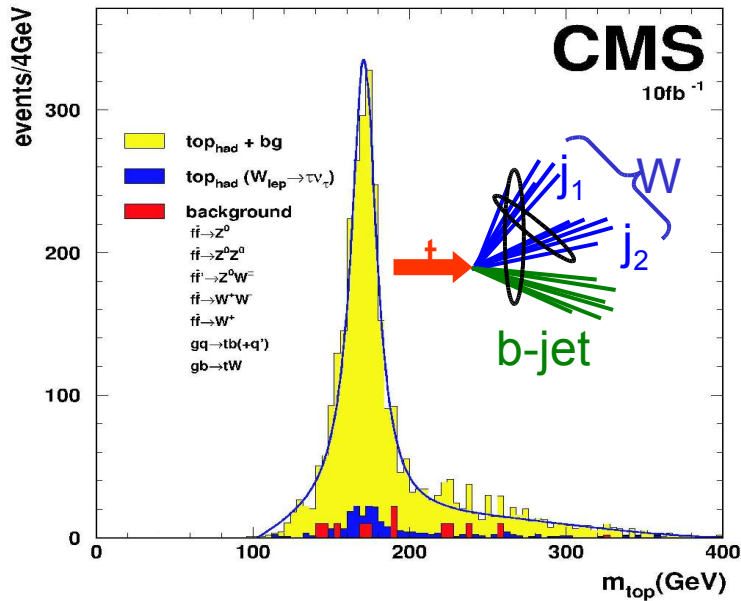
from R. Field



What is the underlying event, multiple scattering ?

- *Everything, except the LO process we're currently interested in*
- *Parton showers*
- *Additional remnant – remnant interactions*

Multiple scattering and top mass



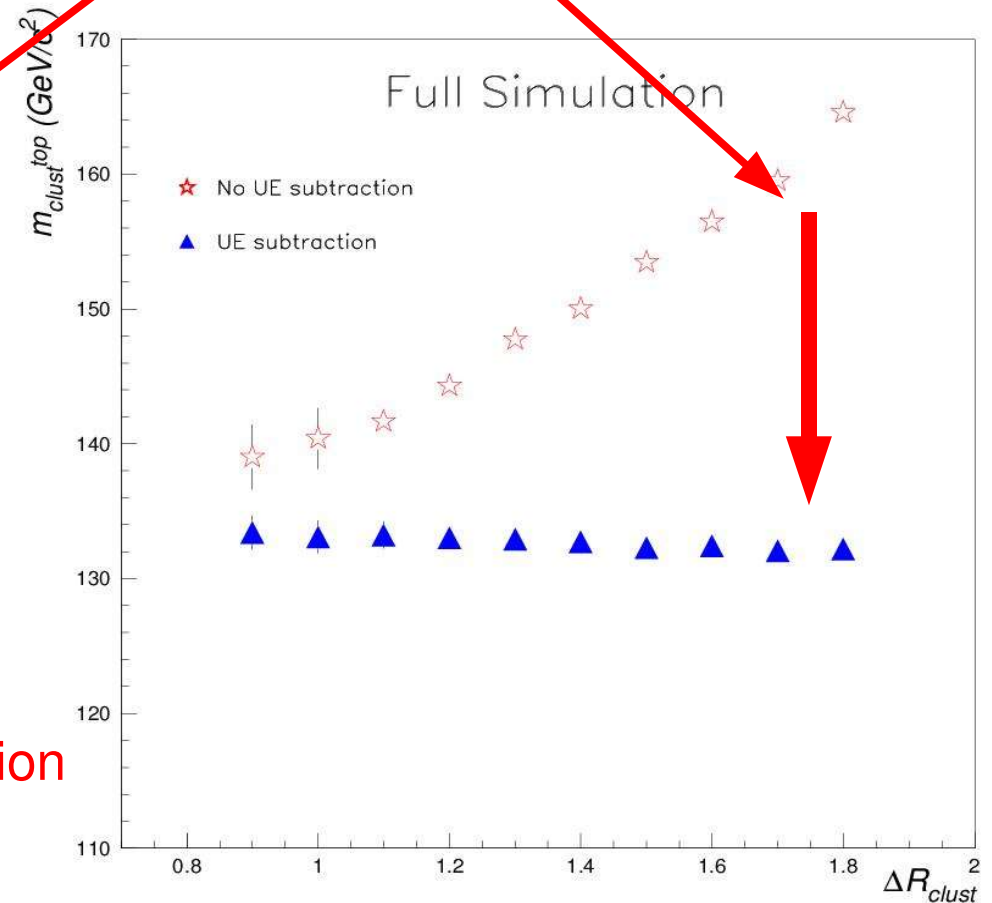
Source of error in GeV	Lepton+jets inclusive sample	Lepton+jets large clusters sample	Dilepton	All jets high pT sample
Energy scale				
Light jet energy scale	0.2	-	-	0.8
b-jet energy scale	0.7	-	0.6	0.7
Mass scale calibration	-	0.9	-	-
UE estimate	-	1.3	-	-
Physics				
Background	0.1	-	0.2	0.4
b-quark fragmentation	0.1	0.3	0.7	0.3
Initial state radiation	0.1	0.1	0.1	0.4
Final state radiation	0.5	0.1	0.6	2.8
PDF	-	-	1.2	-

from M. Mangano

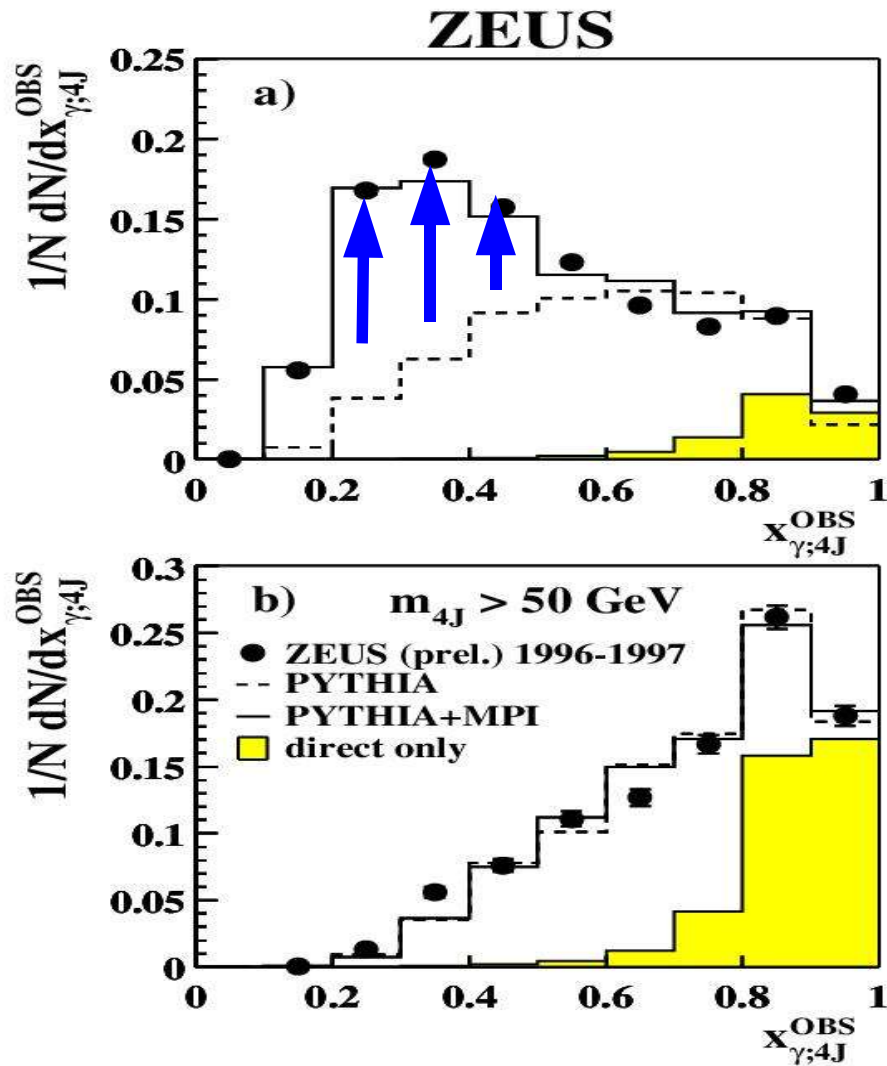
hep-ex/04003021

- Multiple scatterings
- Jet fragmentation properties, jet profiles
- Final state QCD radiation
- B-fragmentation

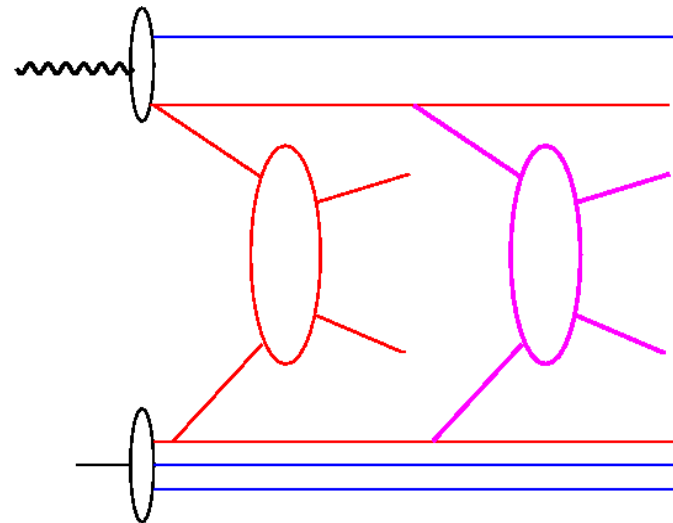
Significant effects on top mass determination
Better understand them !!!



Multiple scatterings at HERA



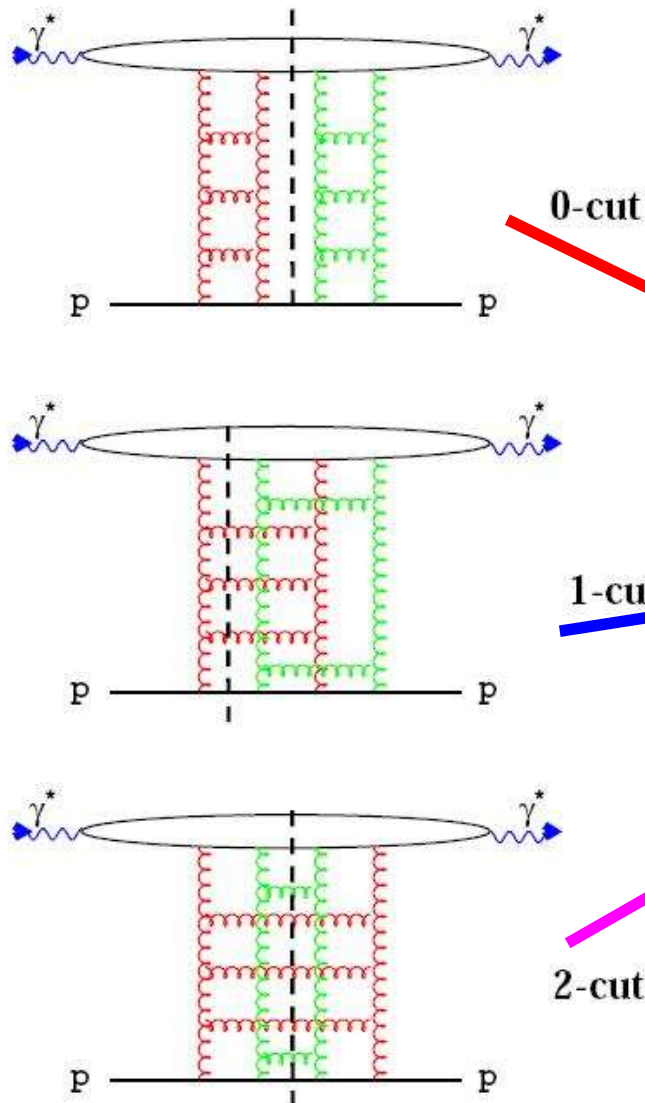
From G. Grindhammer



photoproduction is effectively hadron-hadron production...
test and understand multiple scatterings at HERA !!!

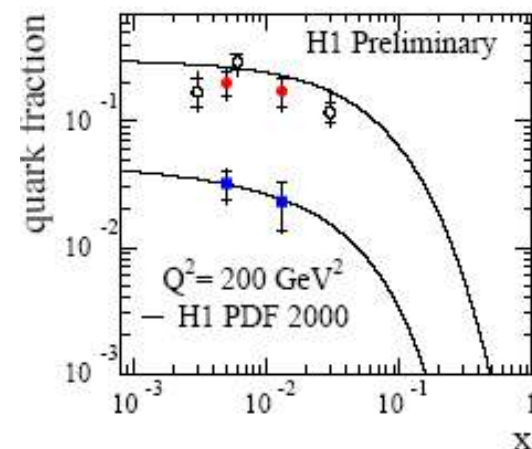
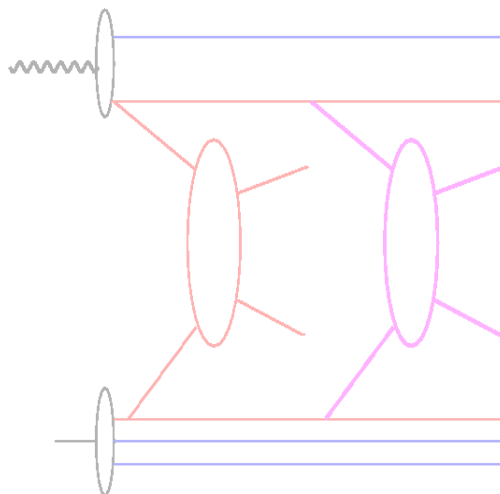
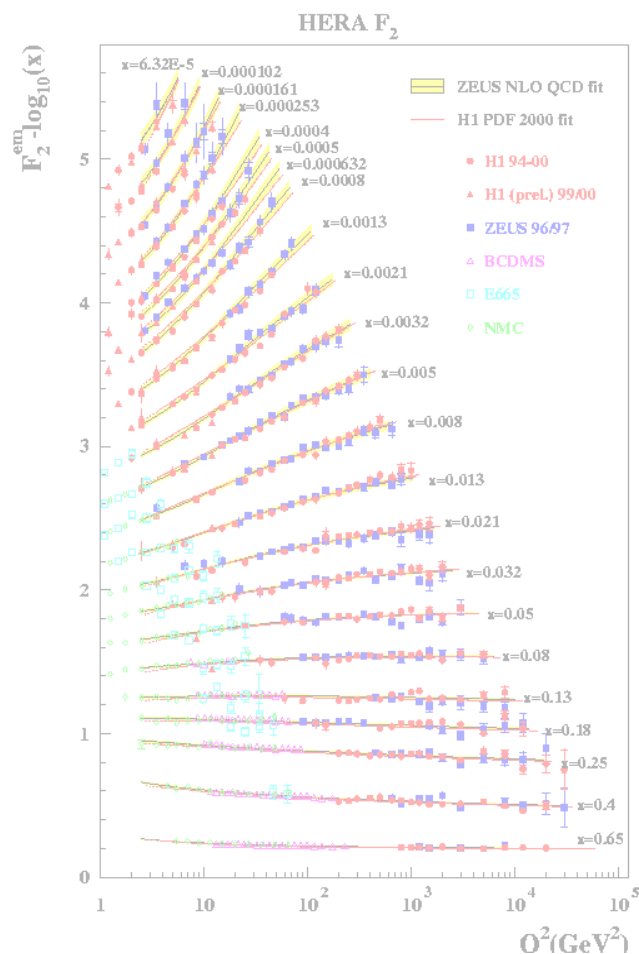
Towards understanding of MI

Bartels, Kowalski, Sabio-Vera



- Cutting rules (AGK) extended to QCD
- Relate diffraction, multiple scatterings and saturation
- All from the same amplitude, but different factors:
 - +1 Diffraction
 - - 4 Saturation
 - +2 Multiple Scatterings
- Extended now also to pp !!!!
- Much further work needed ...
- Towards the descriptions of *“everything”* !!!!!

Topics of the workshop

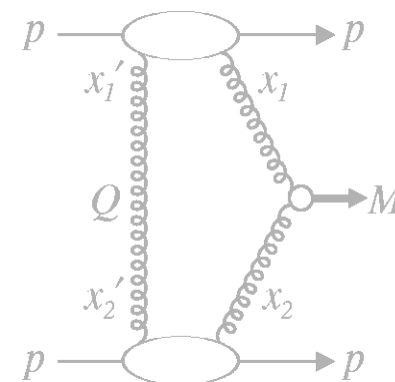


Multijets & final states
Underlying events,
un-integrated pdfs
LHC: event complexity,
jet x-section, Higgs

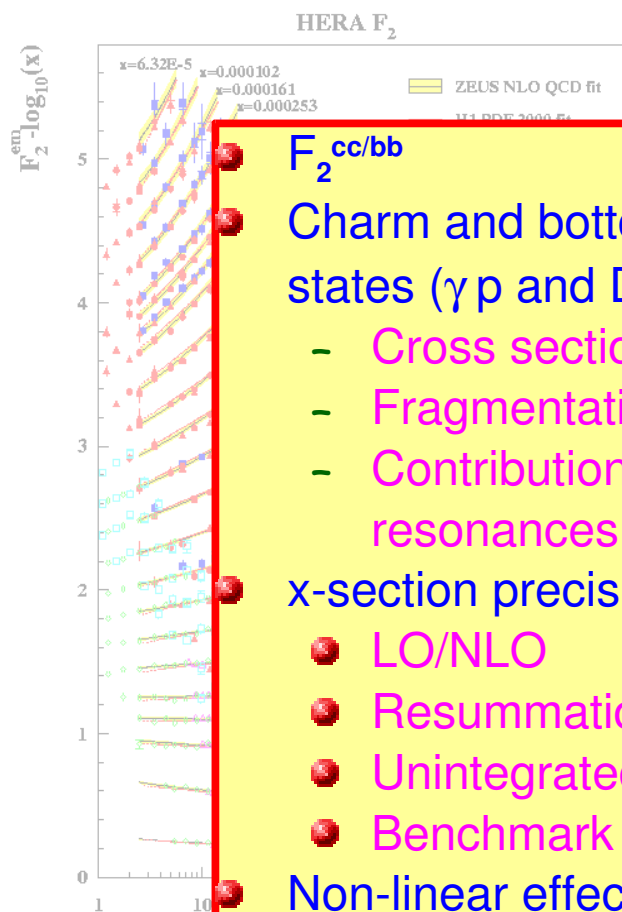
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Diffraction
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$F_2^{\text{cc/bb}}$

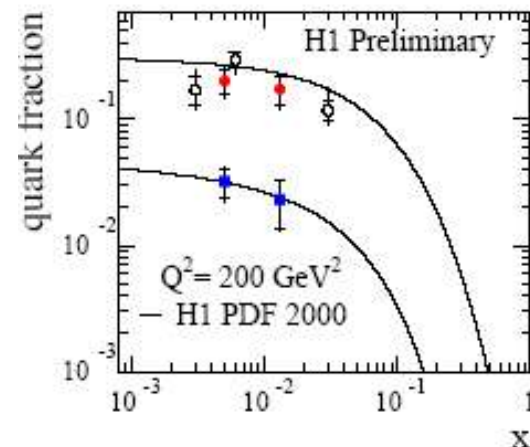
Charm and bottom exclusive final states (γp and DIS)

- Cross sections
- Fragmentation universality
- Contribution from higher charm resonances

x-section precision

- LO/NLO
- Resummation
- Unintegrated pdfs
- Benchmark x-section

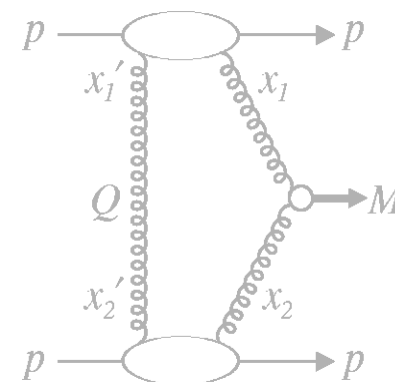
Non-linear effects/saturation



Heavy quarks:
 B quark pdfs of the proton,
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 LHC: Higgs production

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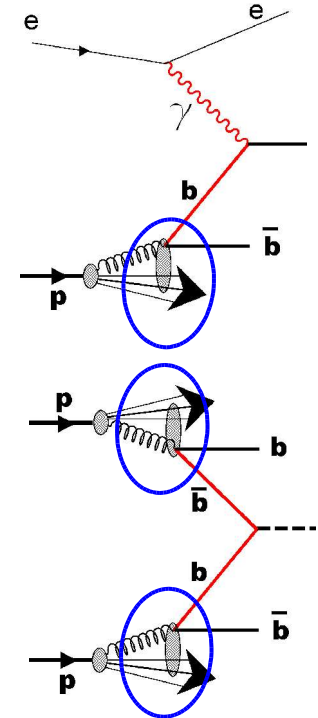
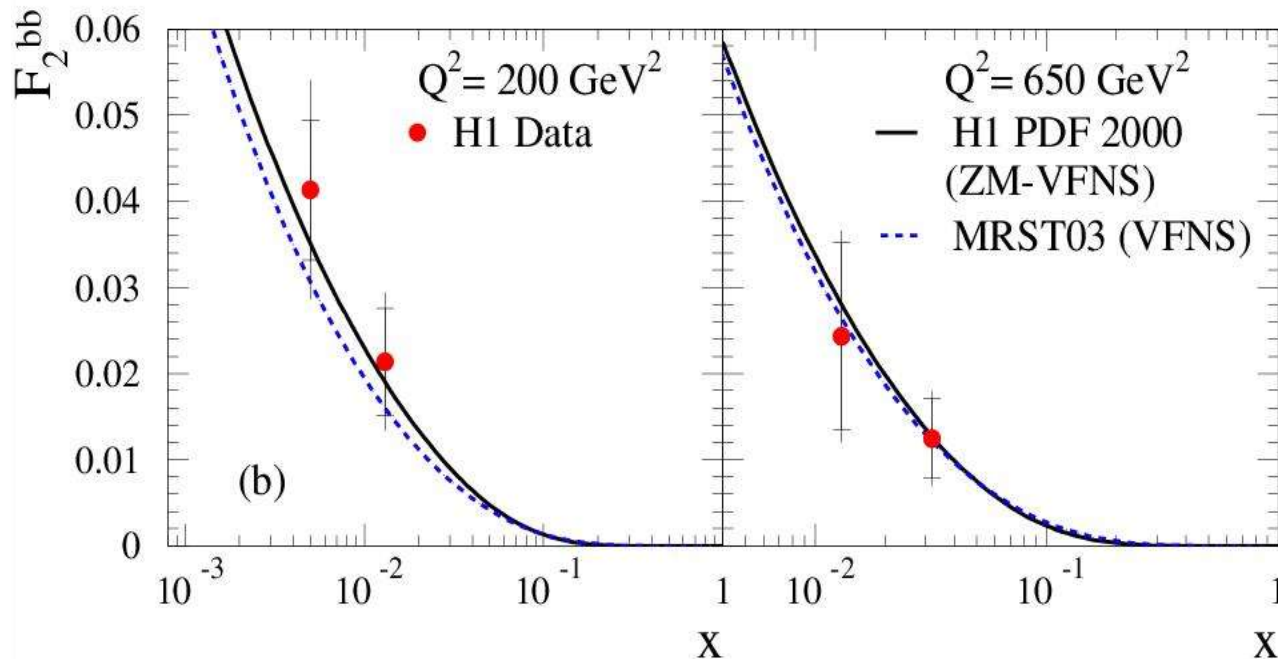
Diffraction
 LHC: exclusive
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F_2^b at large Q^2

From P.Thompson, A. Geiser

- Current H1 (HERA I) analysis: first measurement



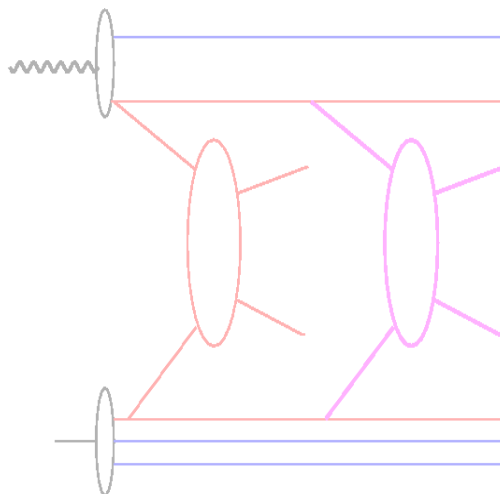
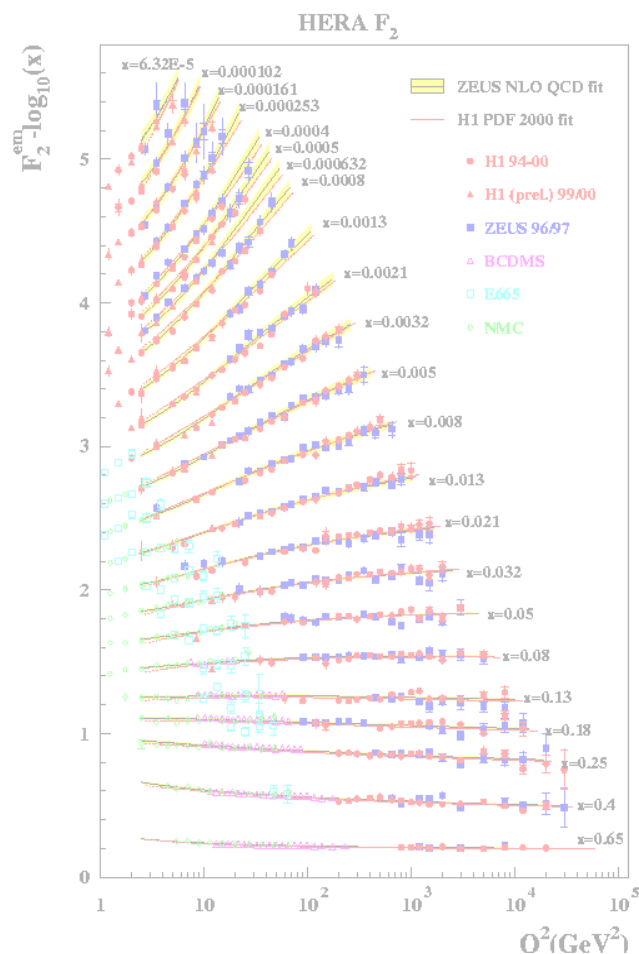
- HERA II analysis (expected)

- more statistics (> factor 10), larger kinematic range, two experiments

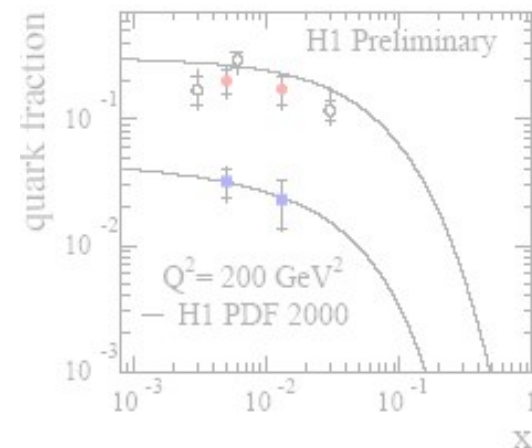
-> test „b content of proton“ (at $Q^2 \gg m_b^2$) much more precisely
relevant for many LHC processes!

- Understand b-production mechanism (...remember b-puzzle at the TeVatron...)

Topics of the workshop



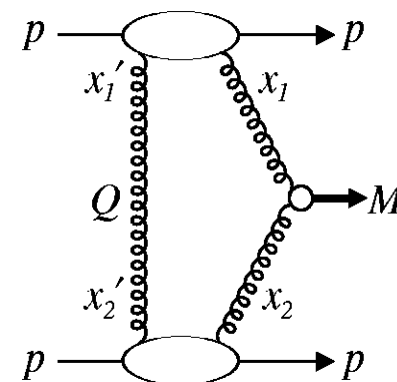
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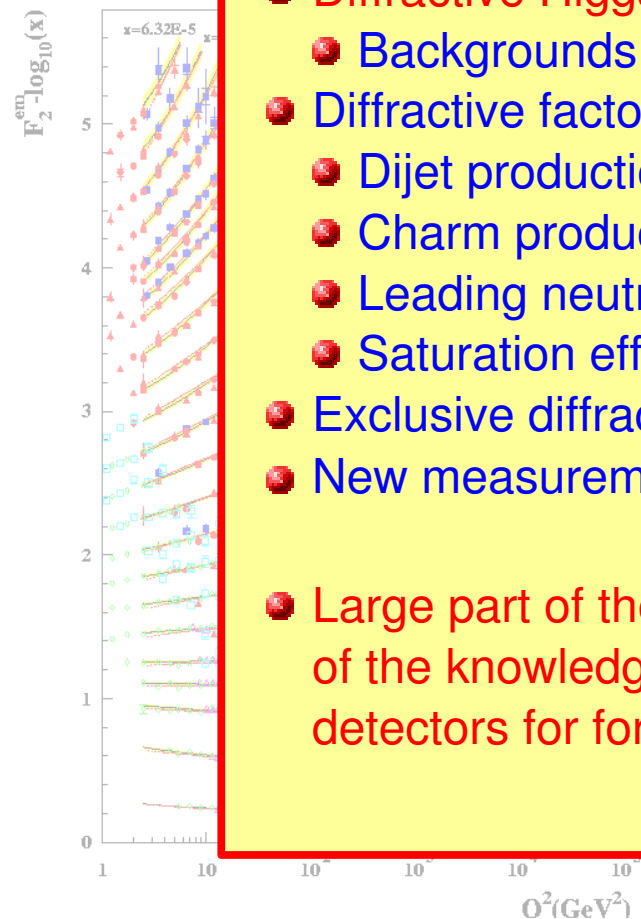
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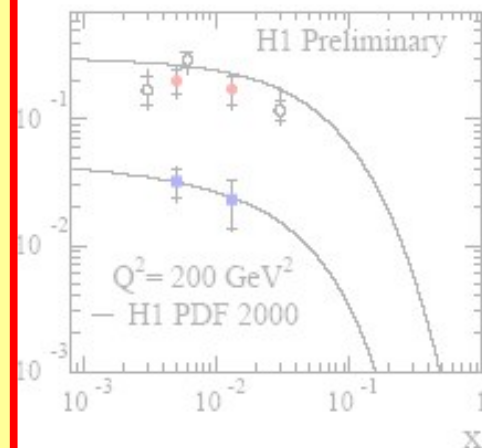
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Topics of the workshop



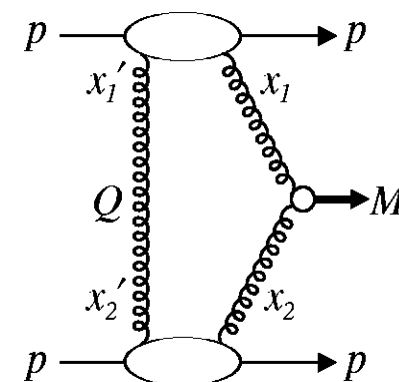
- Diffractive Higgs production
- Backgrounds to diffractive Higgs
- Diffractive factorization breaking
- Dijet production
- Charm production
- Leading neutrons
- Saturation effects and relation to MI/gap survival
- Exclusive diffractive dijets
- New measurements e.g F_L^D
- Large part of the activities was transfer of experience of the knowledge and design and operation of detectors for forward physics from HERA to the LHC



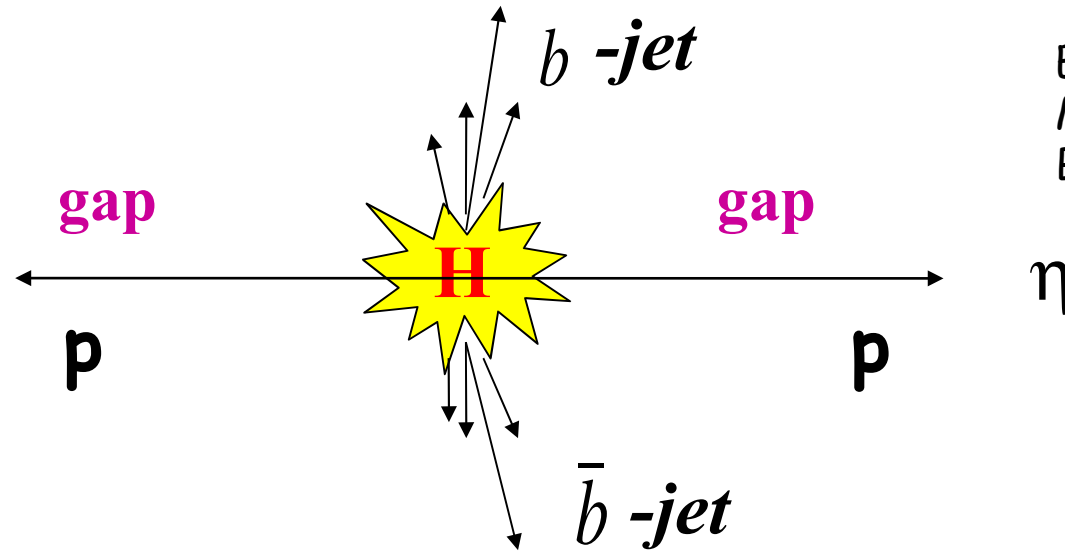
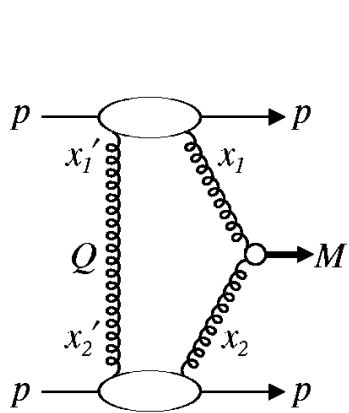
y quarks:
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Higgs production

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LHC: exclusive
Higgs production



Diffractive Higgs Production



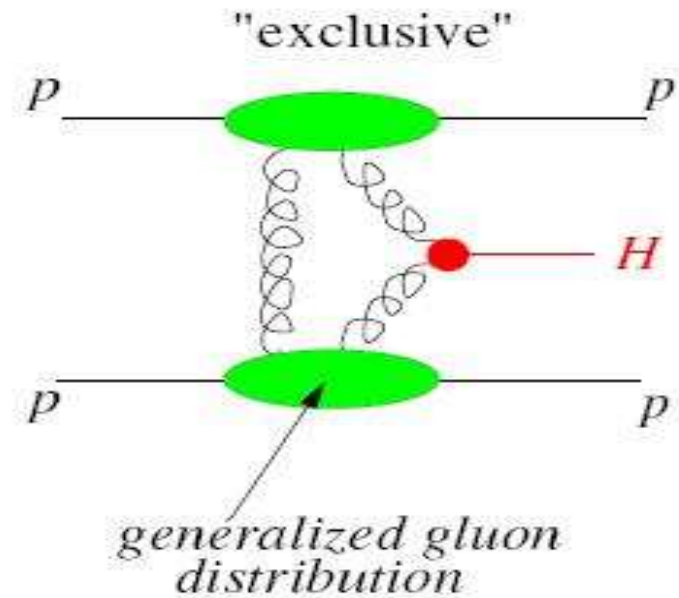
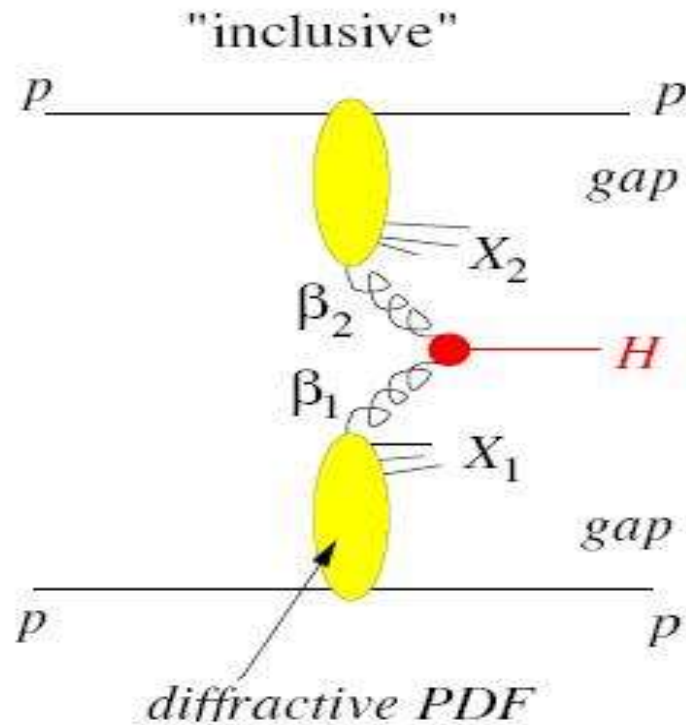
E.g. V. Khoze et al
M. Boonekamp et al.
B. Cox et al. ...

$$M_H^2 = (p + \bar{p} - p' - \bar{p}')^2$$

- Exclusive diffractive Higgs production $pp \rightarrow p H p$: 2-10 fb
- Inclusive diffractive Higgs production $pp \rightarrow p+X+H+Y+p$: $O(100)$ fb
- Advantages: Mass resolution
- Sensitive to un-integrated pdfs

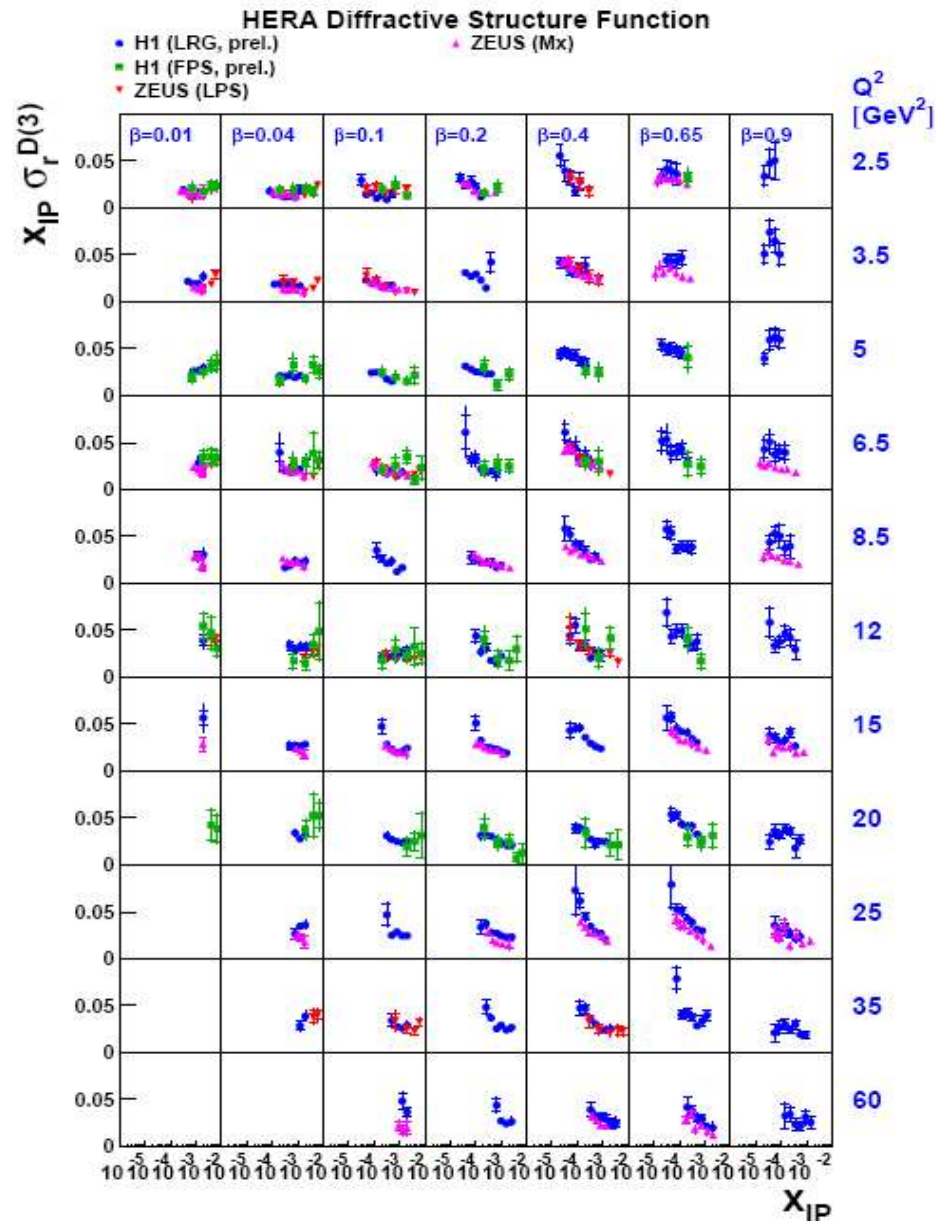
Exclusive Higgs and diff. at HERA

from M. Diehl



- Inclusive diff. events become background to exclusive one, when remnant systems X become soft...
- relevant region for diff. Pdfs:
 $\beta \rightarrow 1$ and $Q^2 \sim M_h^2$
- measure diff pdf at highest Q^2 and highest β

Grand F_2^D summary at HERA



From FP Schilling, P. Newman

F_2^D is crucial for understanding CSE in hadronic interactions:

At this workshop 1st step was made towards final, combined F_2^D from HERA!

Present status: In unified analysis of measured cross-sections reasonable global agreement between H1 & ZEUS is found, and regions of significant discrepancies identified.

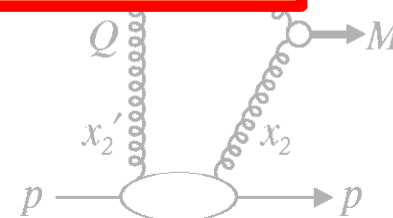
Topics of the workshop

MC&Tools WG (V. Lendermann)

- Parton distribution library:
 - LHAPDF now official carrier of the PDFs
 - HERA pdfs have been added
 - Pion and photon added, particularly for HERA. F2D next?
- NLOLIB framework for NLO QCD programs
 - Uniform user interface/interface to HZTOOL
 - e+e-/ep included, pp can be added (but not done yet?)
- HZTOOL/JetWeb/RunMC/Cedar(?) for tuning
 - all HERA results included, important ones from pp
- JetWeb/RunMC graphical interface to MC generators
- NEW MC developments
- Continuation of the MC@LHC workshop, concerning validation

Structure functions and
parton distributions
LHC: cross sections/precision

Diffraction
LHC: exclusive
Higgs production



RunMC session...

from S. Chekanov

The screenshot displays the JRunMC software interface, which is used for Monte Carlo simulations. The main window, JRunMC, shows the 'MC model' tab with 'CASCADE' selected. The 'Events No.' is set to 10000, and the 'Project name' is 'hztoolv3'. The 'run' button is visible. Below this, a status bar indicates 'current run was finished'.

The 'Variables and Histogram editor' window shows a list of variables and their corresponding histograms. The 'Histograms' window displays a list of histograms, including 'h301;1', 'h302;1', 'h303;1', 'h304;1', 'h_1201;1', 'h_1202;1', 'h_1203;1', 'h_1204;1', and 'h_1205;1'.

The 'RunMC' window shows two histograms: 'PTtot' and 'N(tot)'. The 'PTtot' histogram has a peak around 15, and the 'N(tot)' histogram has a peak around 40. The 'PTtot' histogram has a mean of 17.7 and an RMS of 5.291. The 'N(tot)' histogram has a mean of 43.86 and an RMS of 12.32.

The 'oolv3.log' window shows the output of the simulation, including the model name 'CASCADE', the number of events '10000', and the project name 'hztoolv3'. It also displays the energy of the particles, 'e+(27.0 GeV)' and 'p(920.0 GeV)'. The log file contains detailed information about the simulation parameters and results.

The 'hzxxxx.inc' window shows the initialization and calculation steps of the simulation, including the generation of the 'CAS' model and the calculation of the 'N(tot)' histogram.

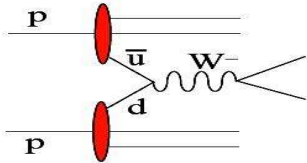
The 'unmchztool.f' window shows the initialization and calculation steps of the simulation, including the generation of the 'CAS' model and the calculation of the 'N(tot)' histogram.

HERA and the LHC

**Where further measurements at
HERA are desirable for the
physics reach of LHC !**

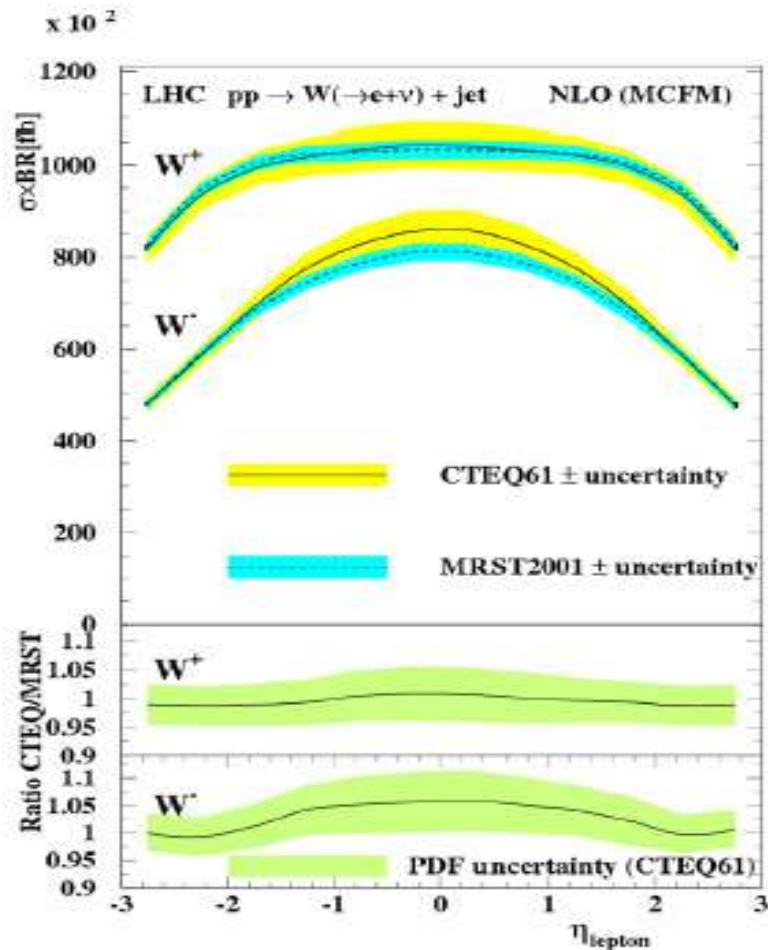
HERA future measurement: deuteron

W xsection at LHC



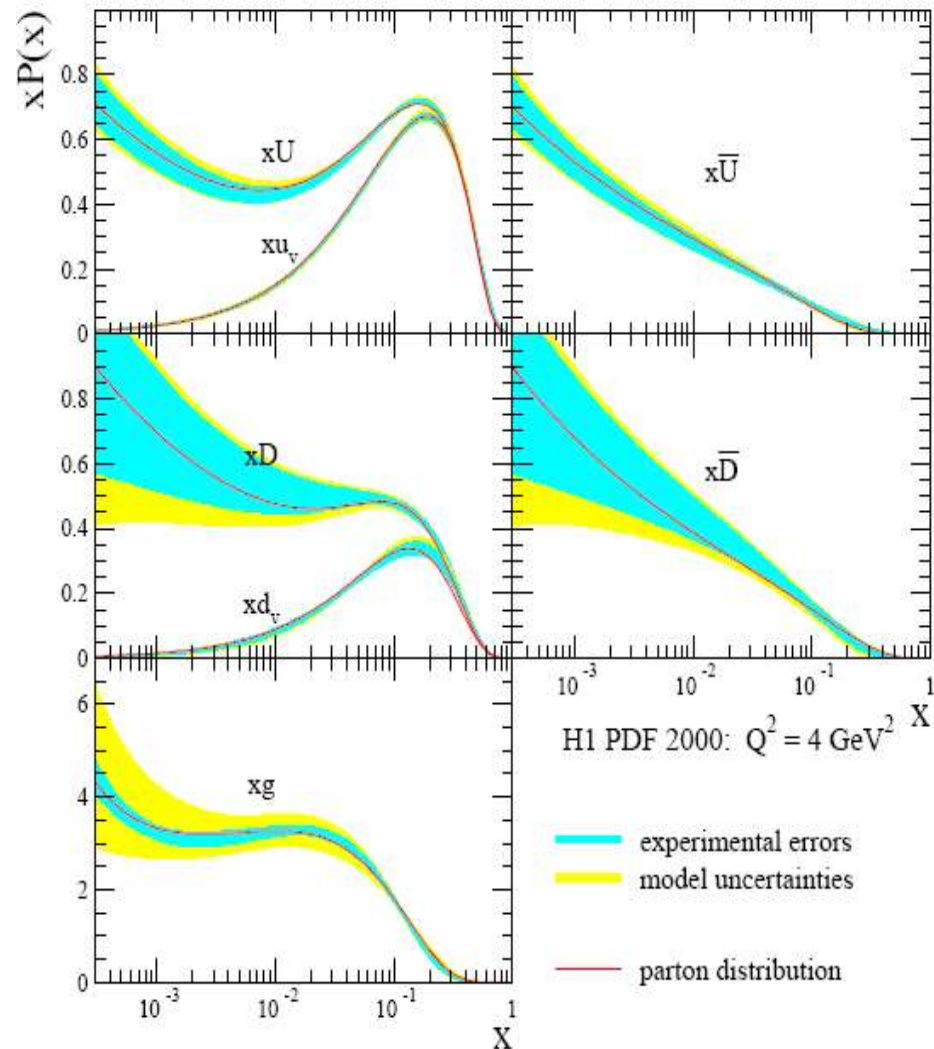
Global fits assume $u=d$ at small x

from M. Klein



H. Stenzel

H1 + BCDMS fit (no constraint on A, b)



Future HERA measurement: deuteron

from M. Klein

The light sea quark asymmetry is expected and has been assumed to vanish at low x . However, F_2 rises strongly towards low x which deserves to be studied.

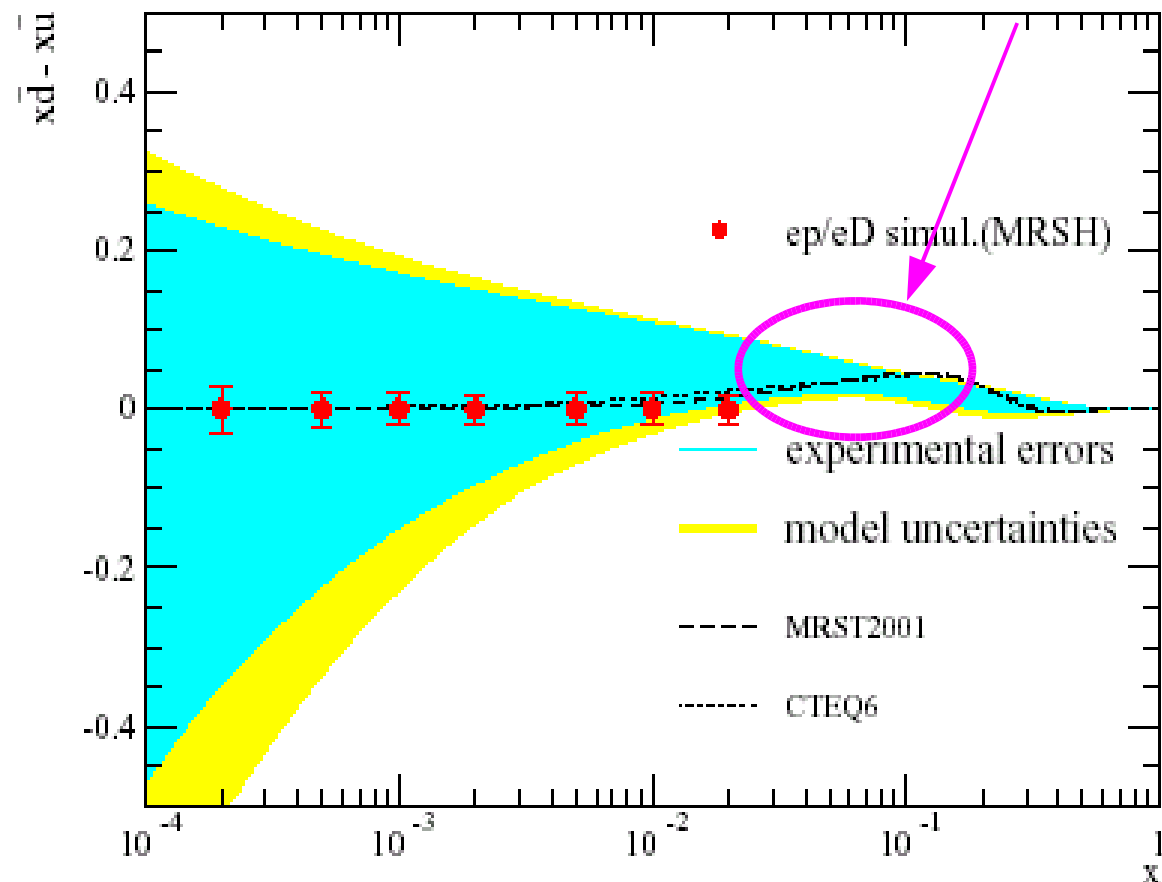
Tevatron with W

$$\frac{1}{2}(F_2^p + F_2^n) - F_2^p$$

$$\approx x \left(\frac{1}{6} d_v - \frac{1}{6} u_v + \frac{1}{3} \bar{d} - \frac{1}{3} \bar{u} \right)$$

$$\gg \frac{1}{3} x (\bar{d} - \bar{u}) \text{ at low } x$$

simulated accuracy:
(20 pb⁻¹ eD, 40 pb⁻¹ ep)



Can obtain important information for LHC ...

HERA and the LHC

**Where HERA experience is
valuable for the LHC !!!**

HERA experience

- experience in QCD analyses:
pdfs, jet-physics, heavy quarks
- experience in QCD phenomenology:
parton level calculations and Monte Carlo event generators.... which are now also used for LHC studies....
- What LEP was for the electro weak sector, HERA is for QCD
Only that QCD is more complicated but also much richer....

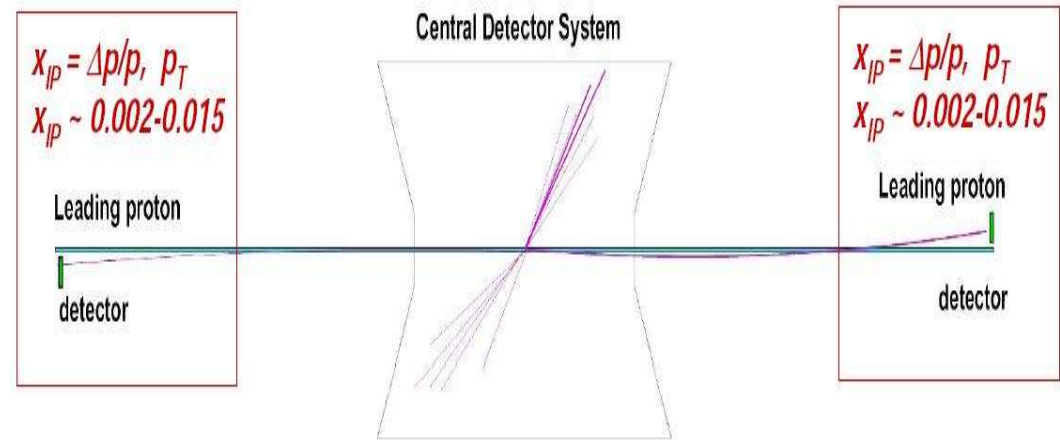
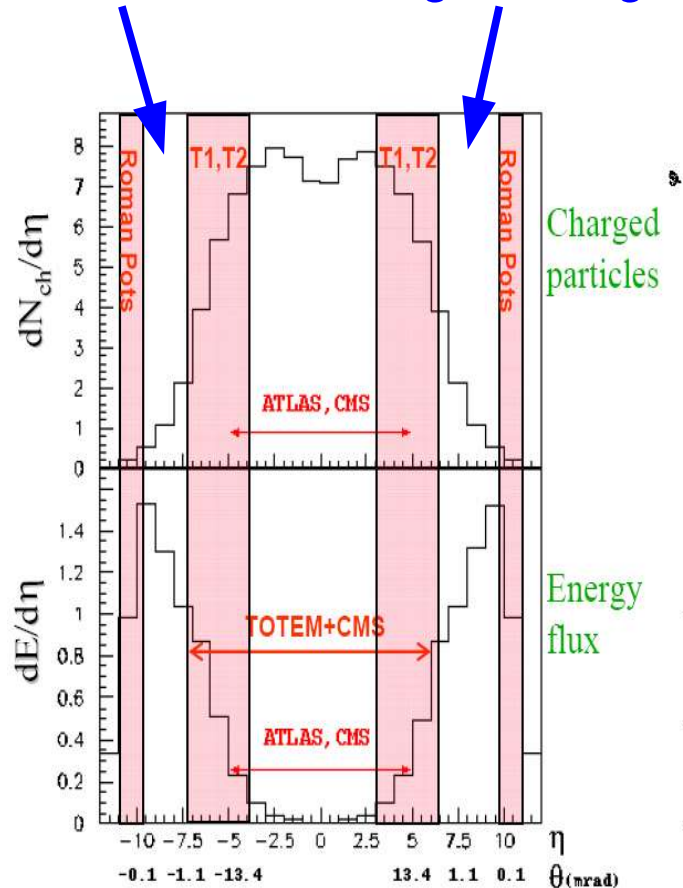
But also...

HERA experience in forward physics.....

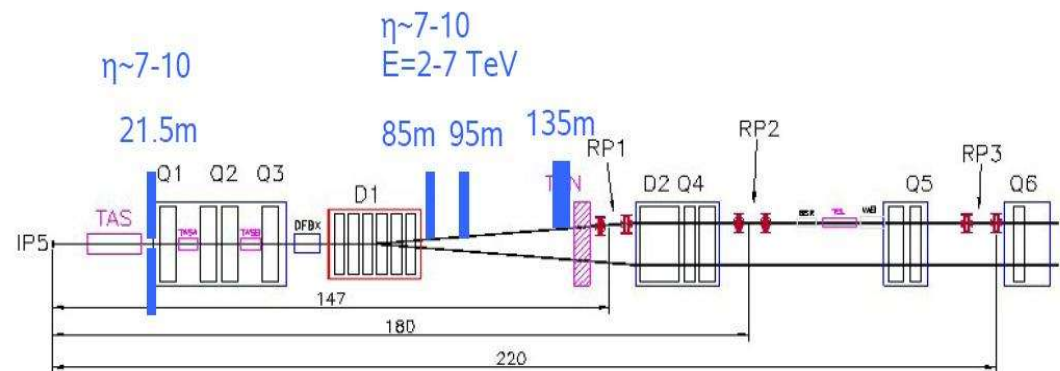
Ideas for upgrading forward region

from H. Kowalski

Here is something missing



from V. Andreev, A. Buniatian, L. Lytkine, M. Kapishin, H.J.



Wait.... this is not the end



- Phase I of this workshop is over and will be concluded with the proceedings
- However an important link between communities has been established.
- We should not just let it fade away, but strongly exploit it, to the benefit of both communities.

Therefore this is not THE END

- Keep momentum with one plenary HERA/LHC meeting per year

March 2006	CERN
March 2007	DESY
March 2008	CERN... (first physics @ LHC!?!)

- Keep also good contacts with TeV4LHC (a common meeting some time?)

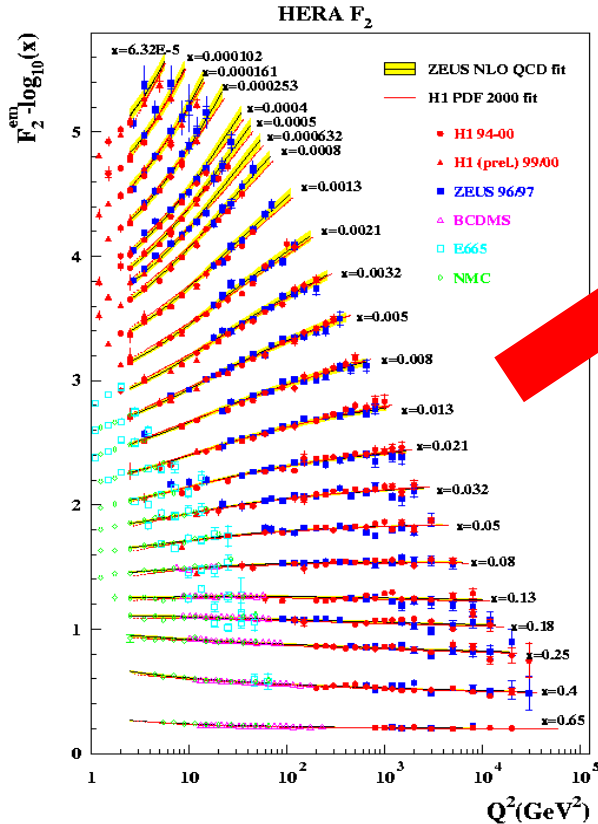
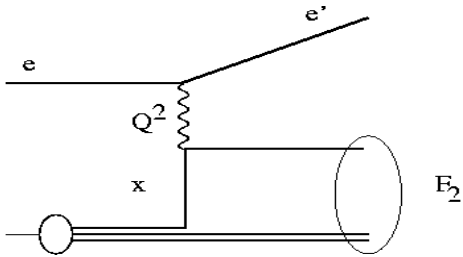


HERA and the LHC

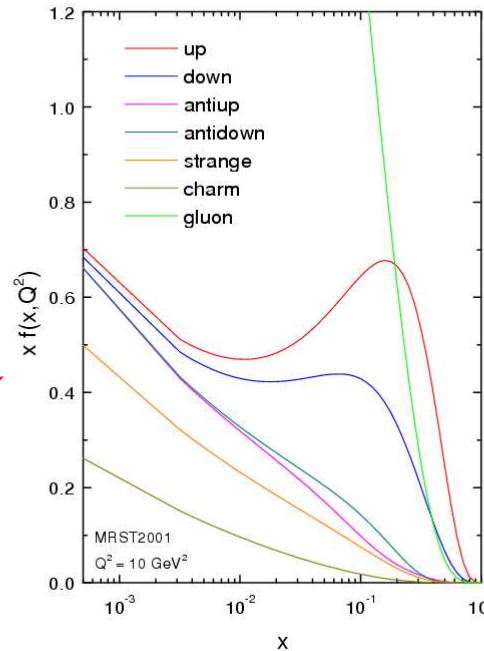


**This will be the beginning of a
beautiful friendship !**

From HERA F_2 to Higgs at LHC



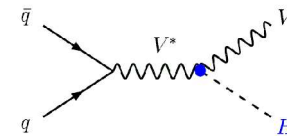
total x-section, F_2



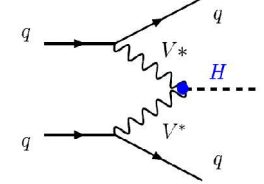
extract parton densities

from J. Stirling

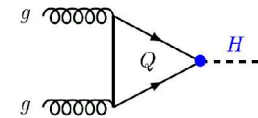
Higgs-strahlung



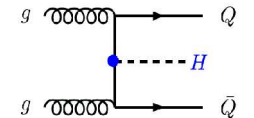
Vector boson fusion



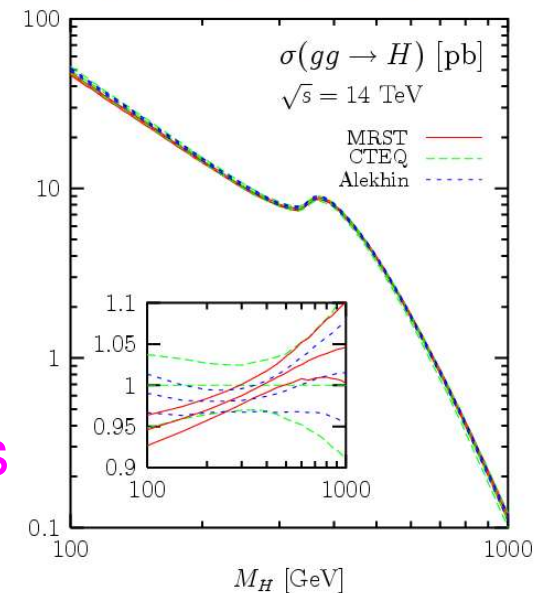
gluon-gluon fusion



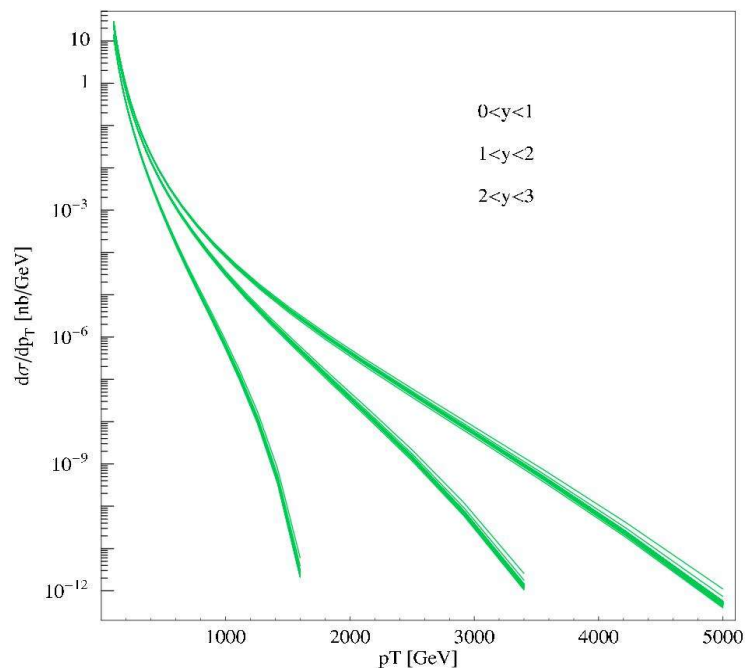
in associated with $Q\bar{Q}$



calculate Higgs prod

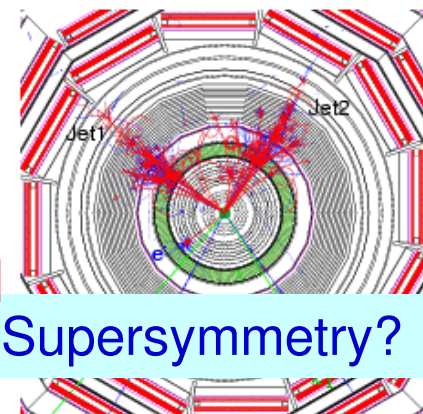


Why precise pdfs for LHC

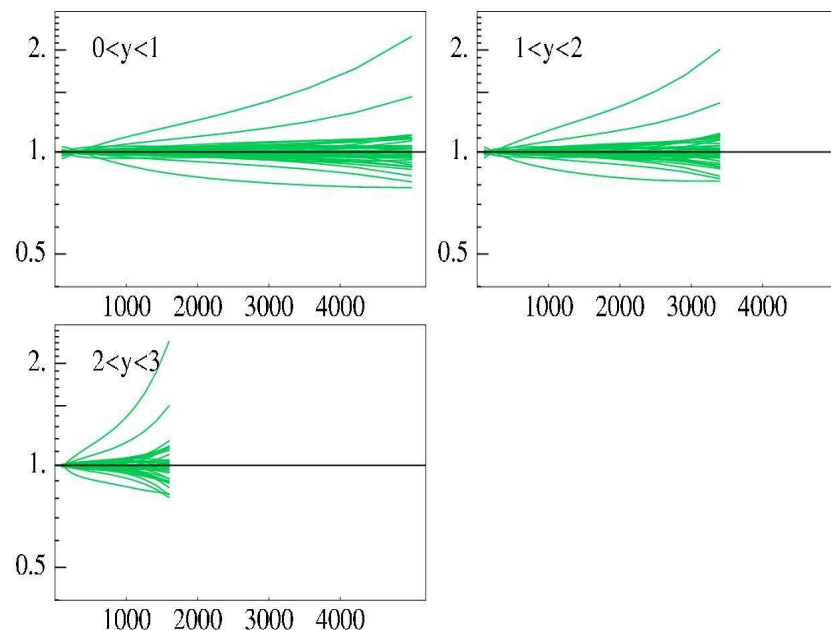
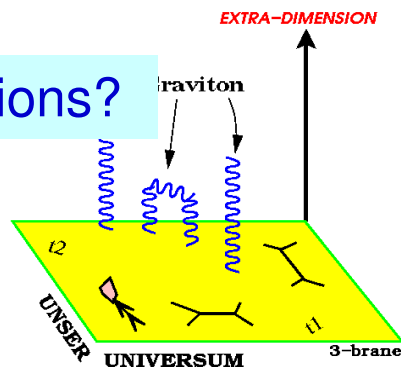


Signature for new physics
jet x-section

Discovery potential depend
on precise pdfs



Extra Dimensions?



Precision determination of pdfs needed ...
understanding QCD is the key to new physics

Is DGLAP all ??????

from J. Stirling

Can we just assume DGLAP is ok also at highest energies ?

- remember surprises from HERA
- Is factorisation valid ?
- What about kt-factorisation ?
- What about non-linear effects ?

Is NLO (or NNLO) DGLAP sufficient at small x ?
Are higher orders important ?

LHC parton kinematics

