The HERA/LHC Workshop

A. De Roeck/CERN
TeV4LHC workshop 17/09/04

TeV4LHC

Connection to TeV4LHC

- Introduction and Goals of the workshop
- Organization/timescale
- Activities in the working groups
  - → this talk:
    - Parton density functions
    - Diffraction

…Origin of the Workshop

CERN Workshop on
Monte Carlo tools for the LHC

July 7 – Aug 1 2003

Organizing Committee :

N. Brook, A. de Roeck, F. Gianotti, E.W.N. Glover, I. Hinchliffe, S. Jadach, F. Krauss, M. Mangano, A. Morsch, F. Paige, W. Pokorski, A. Presland, A. Ribon, P. Richardson, E. Richter–Was, P. Skands, B. Webber

Secretariat: jeanne.rostant@cern.ch
For information: michelangelo.mangano@cern.ch

http://mlm.home.cern.ch/mlm/mcwshop03/mcwshop.html

Turned out to be a good experience
After this workshop: discussion started to try to do more

Workshop in Binn, Wallis, Switzerland, 2003:

Precision Cross Section Measurements at the LHC?

October 17th - 19th, 2003

organized by the Insitute for Particle Physics, ETH Zürich

http://wwweth.cern.ch/WorkShopBinn/home.html

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 related to the above goals.
- To examine and improve theoretical and experimental tools related to the above goals.
- To increase the quantitative understanding of the implication of HERA measurements on LHC physics.

$\Rightarrow$ Five Working Groups

- Parton density functions
- Multi-jet final states
- Heavy quarks (charm and beauty)
- Diffraction
- MC-tools

Recently also thoughts on impact of searches (or findings) on LHC parameter space for New Physics

Organization

First meeting: 26-27 March CERN (~ 300-350 participants)
Intermediate meeting: 1-4 June/ DESY
Second meeting: 11-13 October CERN
Intermediate meeting: 15-19 November/ DESY
Final meeting: end of January (or a bit later) 2005/ DESY
Maybe an extra intermediate meeting before...

⇒Intermediate meetings: only WG group meetings to reduce organizational overhead

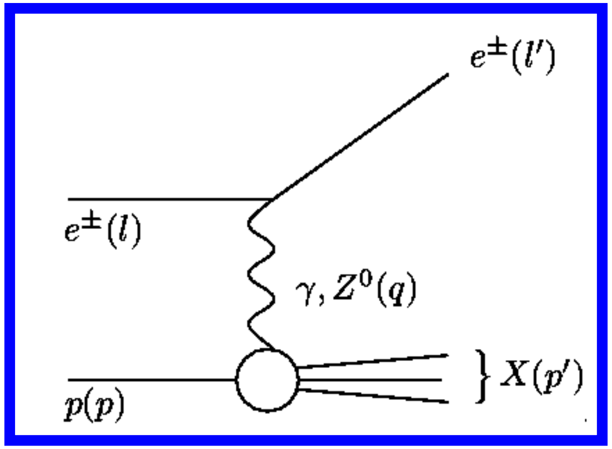
- Goals for the first meeting
  - Discuss problems
  - Set priorities/form task forces
  - Define a task list (with names)
- Long term goal
  - List of measurements to be performed at HERA
  - Quantify impact on LHC measurements
  - Development of the tools

⇒ Joint DESY/CERN Report in 2005

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

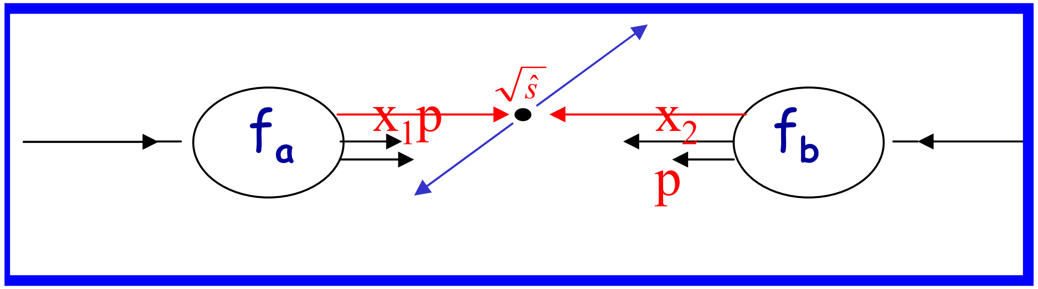
Expect a lot of results at the October meeting

ep and pp colliders



ep collisions (HERA)

*Ideal tool to study the structure of hadrons via deep inelastic scattering (structure functions/parton densities)
* Can use the photon as a pointlike or hadronic particle through its virtuality
* Main contributions are in the area of QCD: Small-x, diffraction, saturation, high densities, jets...
* Tests of new approaches/QCD



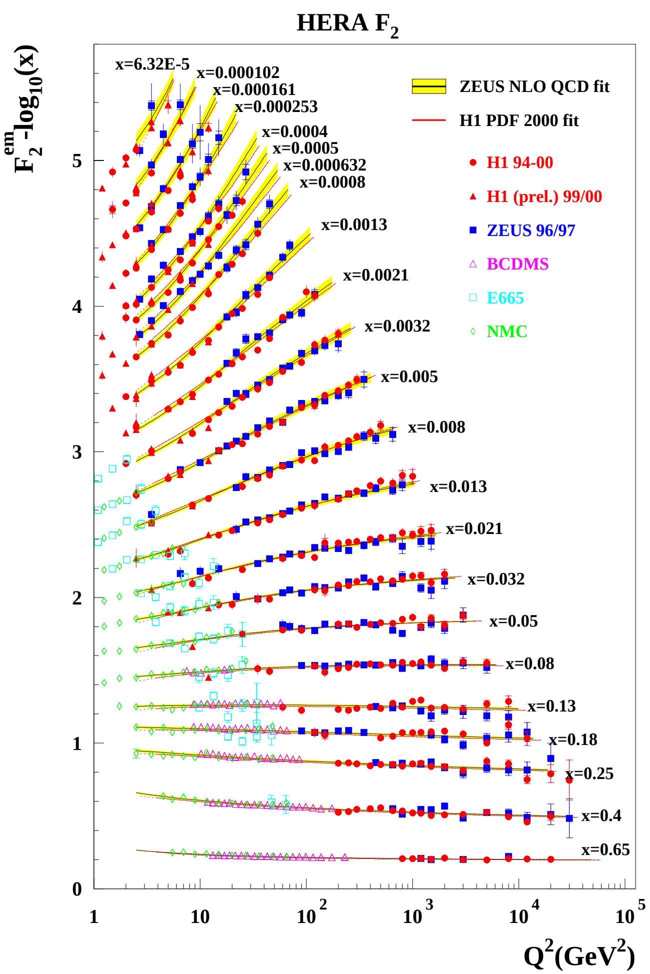
x = momentum fraction of quark in proton

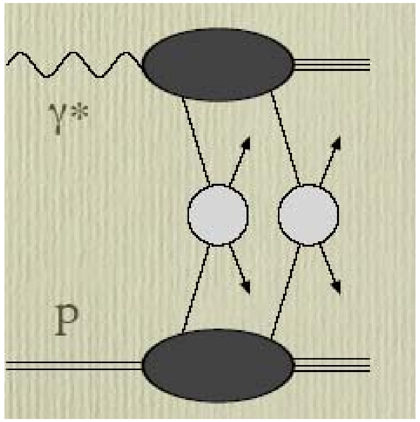
$$\sigma = \sum_{a,b} \int dx_a \, dx_b \, f_a(x_a, Q^2) \, f_b(x_b, Q^2) \, \hat{\sigma}_{ab}(x_a, x_b)$$

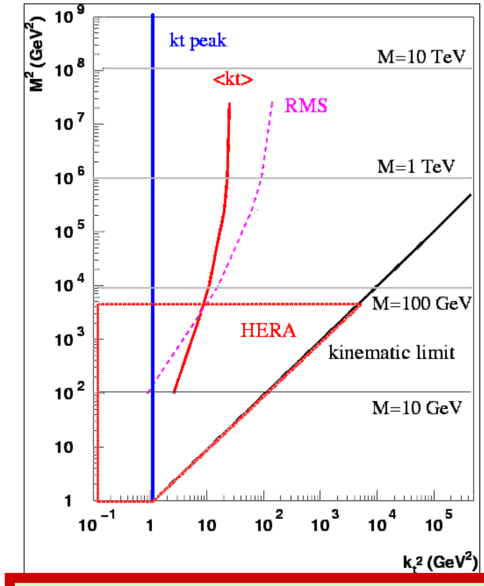
pp collisions (LHC)

* Highest energies reachable
* Can reach highest masses for new particles production
* Precision often limited by knowledge of quark/gluon structure of proton
* QCD effects need to be controlled to the best of our knowledge

Examples: HERA→ LHC





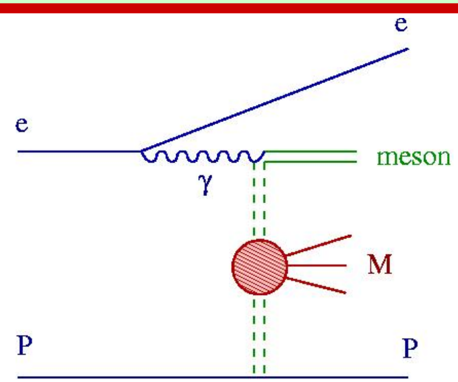


Underlying event:
tunable elementarity
of one beam particle
γp ↔γ*p collisions
LHC: event complexity

QCD: average initial K_T
does not change much
from HERA to LHC
LHC: e.g. P_T of the Higgs

Structure functions and
parton distributions
LHC: cross sections/precision

Diffraction
LHC: diffractive
scalar production



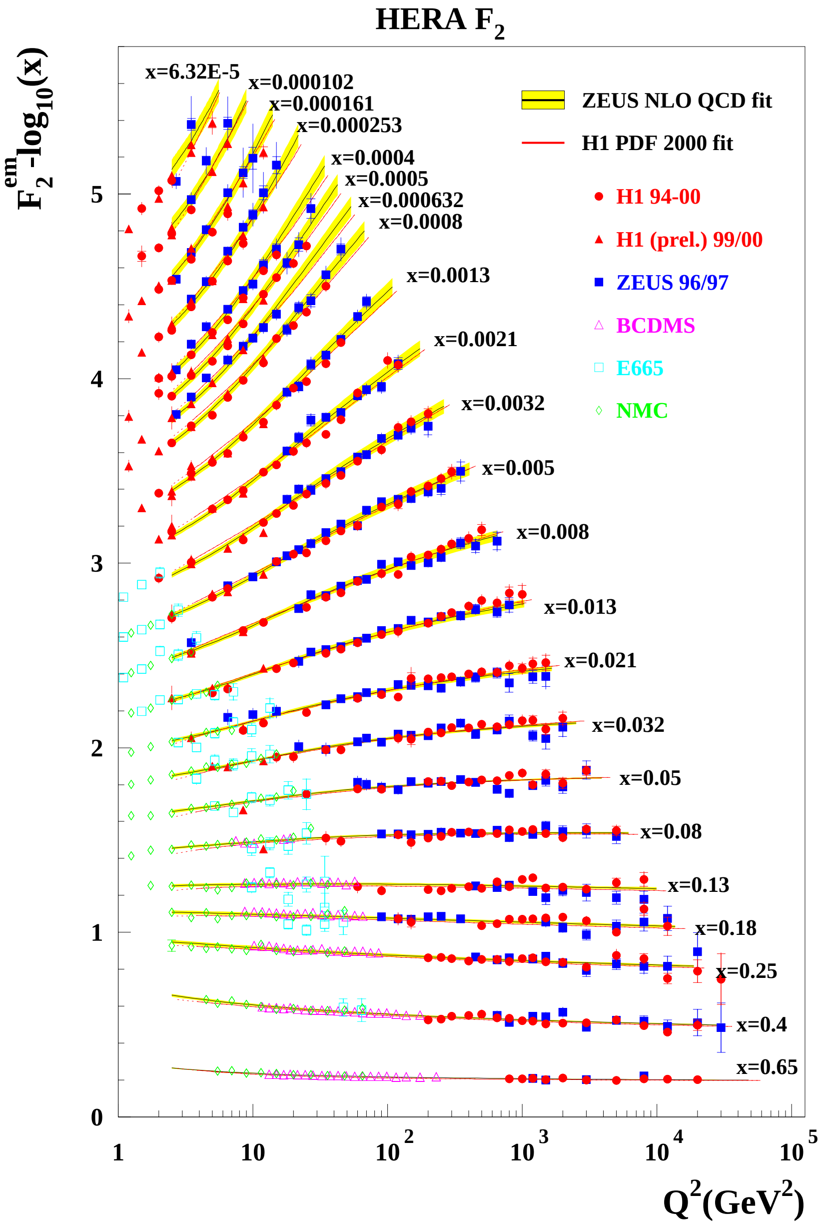
PDFs at the LHC

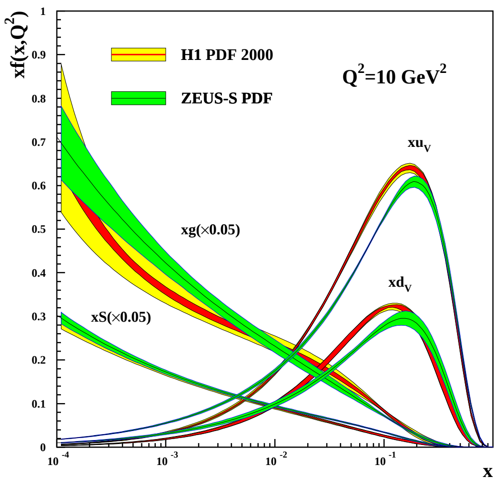
- High precision (SM and BSM) cross section predictions require precision pdfs: $\delta\sigma_{th} = \delta\sigma_{pdf} + \ldots$
- Impact of PDFs new phyiscs/Higgs discovery & measurements
- Measuring luminosities to a few % using PDFs via Z,W production
  - How well do we know the PDF uncertainties really?

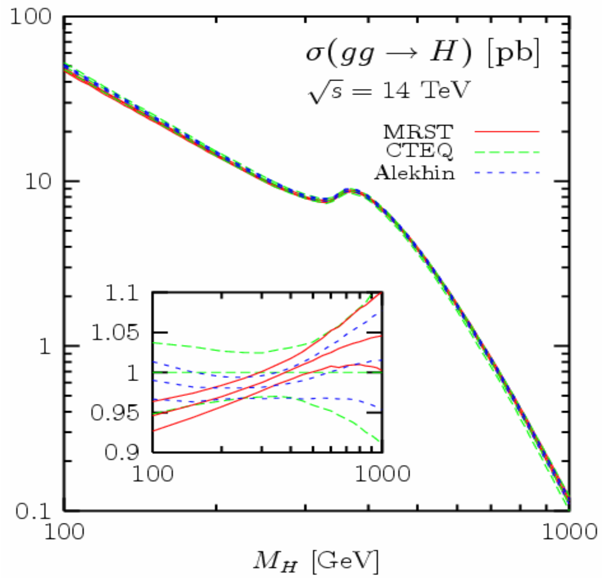
- Reference processes to study for PDF improvements (before the end of HERA)
  - high precision F_2
  - F_L as probe of gluon & non-GLAP effects
  - lower proton energy $\rightarrow$ intermediate-large x
  - deuteron running $\rightarrow$ flavor decomposition
- Learning more about pdfs from LHC measurements
  - W, Z production as luminosity monitor
  - W, Z rapidity and p_t distn. constrain PDF shape
  - W^+/W^- constrain flavor decomposition
  - use γ (W, Z) + jet to constrain the gluon (use also high mass DY?)

experience at Tevatron?

PDFs







Proton structure known to a few % in a large area of x and Q^2

HERA F2 data dominate global fits

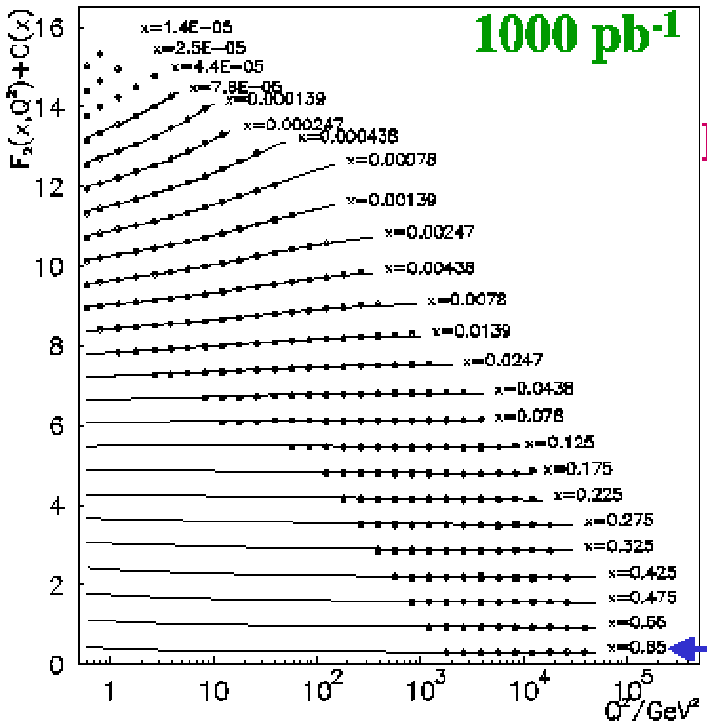
(not in all phase space corners however)

HERA-II precision

The promise... HERA-II run → 500-1000 pb^{-1}

But foreseen to end in 2007

- The Structure Function F_2



High Precision F_2

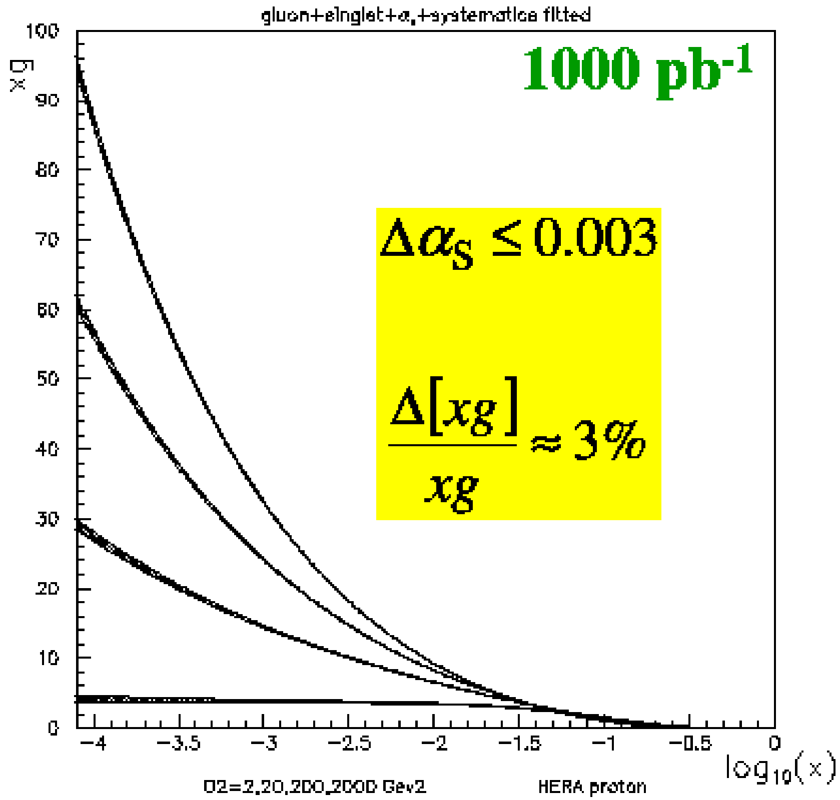
Large x,Q^2 range

→

α_S and xg

$x = 0.65$

$Q^2 = 4 \times 10^4$



High precision at large Q^2, precise determination of the gluon distribution, flavour separation (via CC), u(x)/d(x) for x→1,...

Open issues & goals for PDFs

- PDF fits, DIS data only & global fits …
  - Errors bands for PDF sets comparable but do not overlap
  - What data to include?
  - Uncertainty determinations: different methods used.
  - Correlations with α_s
  - Need of tools for error propagation
  - Limits of theoretical and experimental systematic errors?
- Are small x resummations needed?
- Saturation or non-linear effects in F_2 at small x?
- Do we need large x resummations?
- Using parton luminosities via W,Z production as luminosity monitor?
- Assess relative size of exp. and the uncertainties @ LHC
  - Where do we need further improvements
- Maximize output from HERA before shut down (high x, gluon)
- Study dependence on rapidity and p_t spectra (acceptance cuts)

PDF Working Group

Subgroups in the WG

Group 1

- List of interesting LHC reactions and assessment of their theoretical and experimental accuracy, including ratios. Document in progress

Group 2

- Study the impact of F_2 measurements on PDFs
- PDF uncertainties and impact on a selected number of LHC channels
- PDF information from future LHC data

Group 3

- Resummations at small and large x,
- Limits of resummation

Towards a list of well measurable LHC final states and their potential experimental and theoretical accuracies

contributers:

Abstract

Cross section calculations for a large number of Standard Model LHC reactions have been performed during the last 20 years. Many experimental simulations demonstrate how various final states might eventually be selected. These studies indicate how large the potential signals and backgrounds might be and the results can be found at various places in the literature. We attempt to give a comprehensive summary for these different cross sections and their potential statistical errors. Furthermore, we try to provide some consistent estimates for potential systematic errors of these future LHC measurements. Obviously, many experimental and theoretical uncertainties can only be estimated or guessed today. Nevertheless, such a list might not only become useful during the coming years, but will eventually be proven to be too pessimistic or optimistic once real measurements can be performed at the LHC.

Contact M. Dittmar

Includes Drell-Yan, Z,W production
γ-final states, di-boson event,
top quarks, multi-jet events…

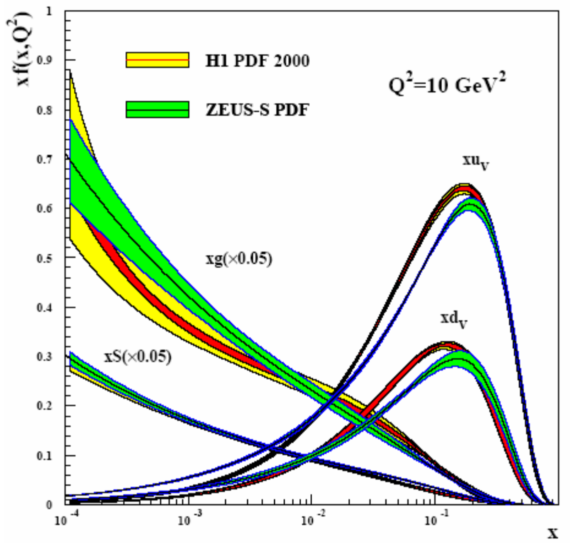
Useful also for this Workshop

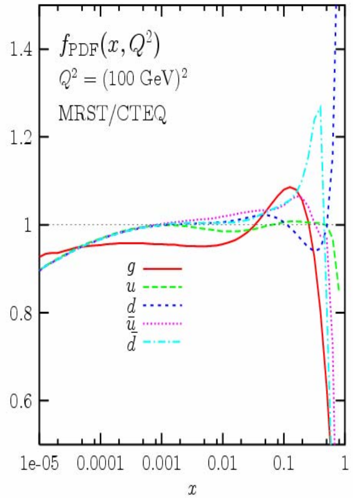
PDF Fits

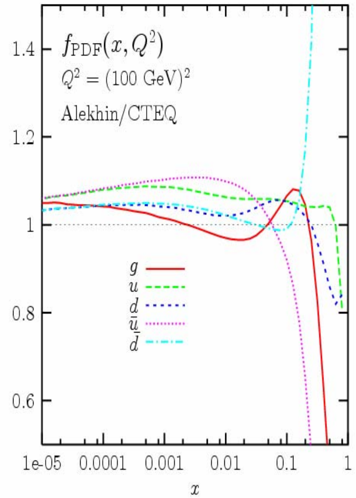
- PDFs became available with error bands : GOOD! But..

  Parton distributions do not agree (within the error bands)

- Different choices of data and (J. Stirling)
  - tolerance to define $\pm\delta f_i$ (CTEQ: $\Delta\chi^2$=100, Alekhin: $\Delta\chi^2$=1)
  - factorisation/renormalisation scheme/scale
  - Q_0^2
  - parametric form $Ax^a(1-x)^b[..]$ etc
  - α_s
  - treatment of heavy flavours
  - theoretical assumptions about $x\rightarrow 0,1$ behaviour
  - theoretical assumptions about sea flavour symmetry
  - evolution and cross section codes (removable differences)







Plan: H1 + ZEUS will combine data followed by a common fit
Issues on fits are being addressed in depth during the workshop

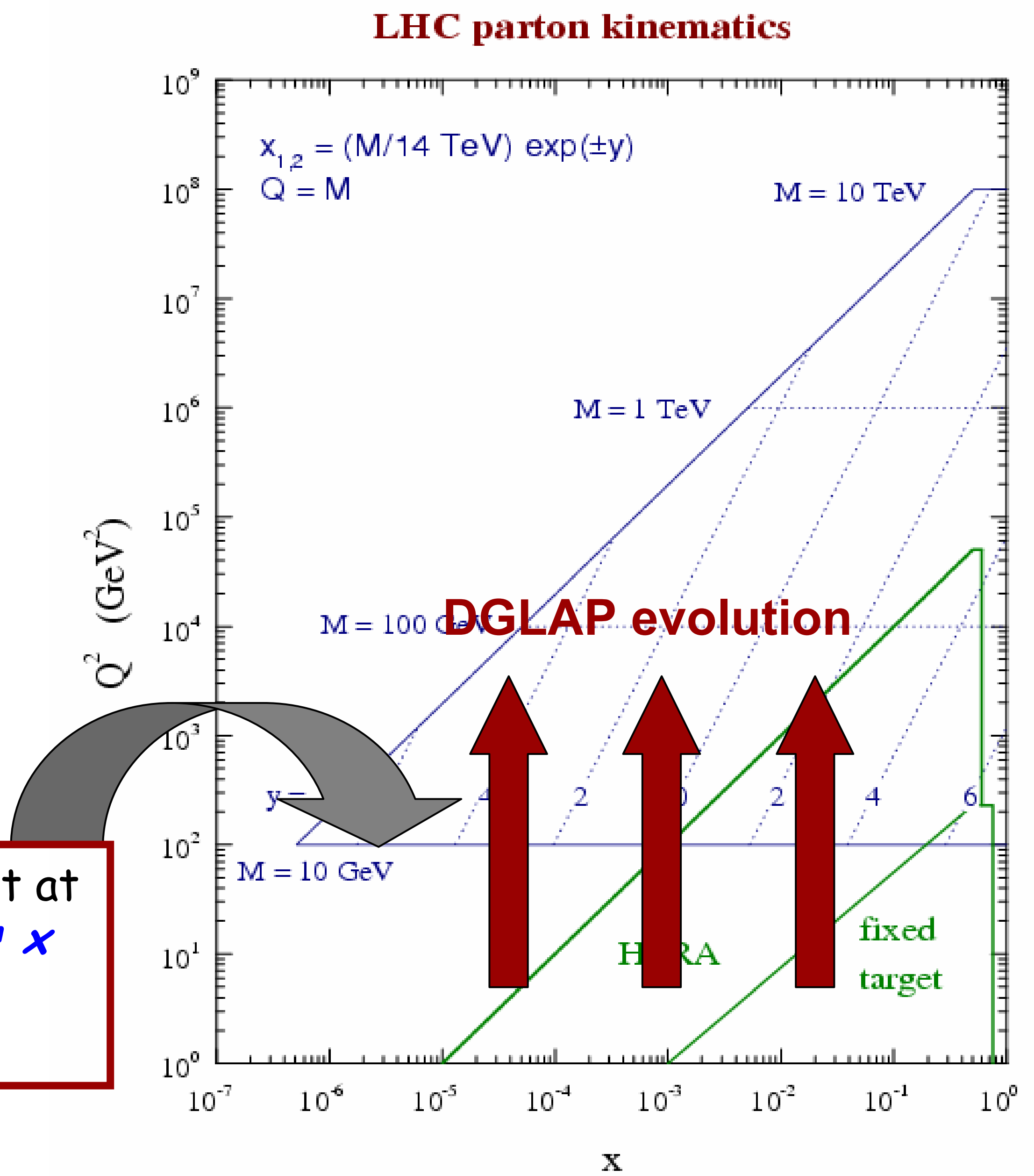
QCD Evolution of PDFs

At the LHC:
momentum fractions x_1 and x_2 determined by mass and rapidity of **X**

HERA measurements do not cover the LHC region, eg. for central Higgs production

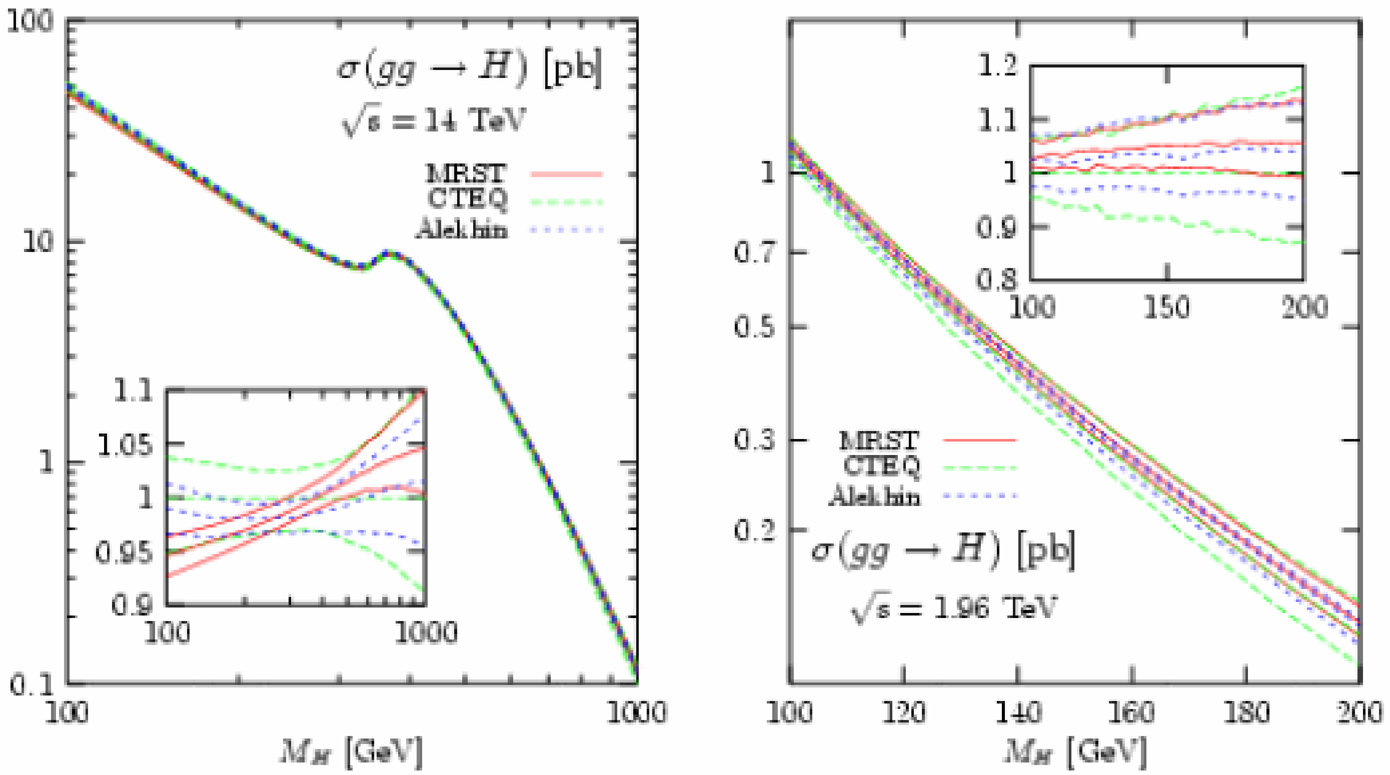
⇒ PDFs evolved via DGLAP equations from (x,Q^2_0) to (x,Q^2)

Q. is NLO (or NNLO) DGLAP sufficient at small x? Are higher-orders $\sim \alpha_S^n \log^m x$ important? CCFM? BFKL?
Non-linear effects? Saturation?



Impact of PDFs on Higgs Production

Gluon fusion



LHC: smoothly oscillating (intermediate x) and increasing (high x)

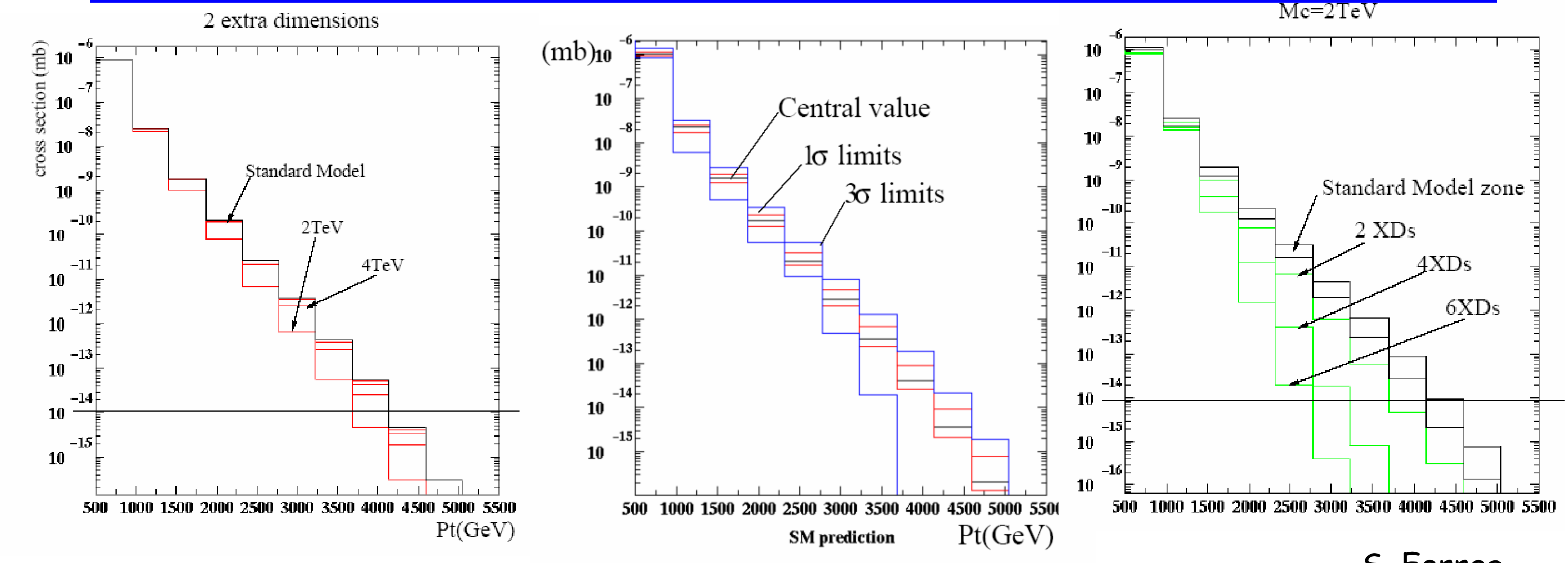
~ 4-3% to 11% (100-1000 GeV)

Tevatron: increasing (high x gluons), ~ 7% to 15% (100-200 GeV)

S. Ferrag

ADD extra dimensions: di-jet final state

Graviton exchange contributions reduce the cross section (interference)



S. Ferrag

Reduction of the sensitivity due to PDF uncertainty (CTEQ6)

	2 extra-dimensions	4 extra-dimensions	6 extra-dimensions
Theoretically	5 TeV	5 TeV	5 TeV
including PDF uncertainties	< 2 TeV	< 3 TeV	< 4 TeV

Heavy flavour production

Estimate of 2-sigma (?) uncertainties

PDFs / Scales	Tevatron	LHC
Bottom (PDFs)	±10-15%	±15-20%
Bottom (Scales)	±35%	±40%
Top (PDFs)	±5-10%	±3-6%
Top (Scales)	±5%	±12%

M. Cacciari

PDF uncertainties are getting as large as the ones from scales
The scale uncertainties will improve with HO calculations
Hence also the PDF determination will need to be improved

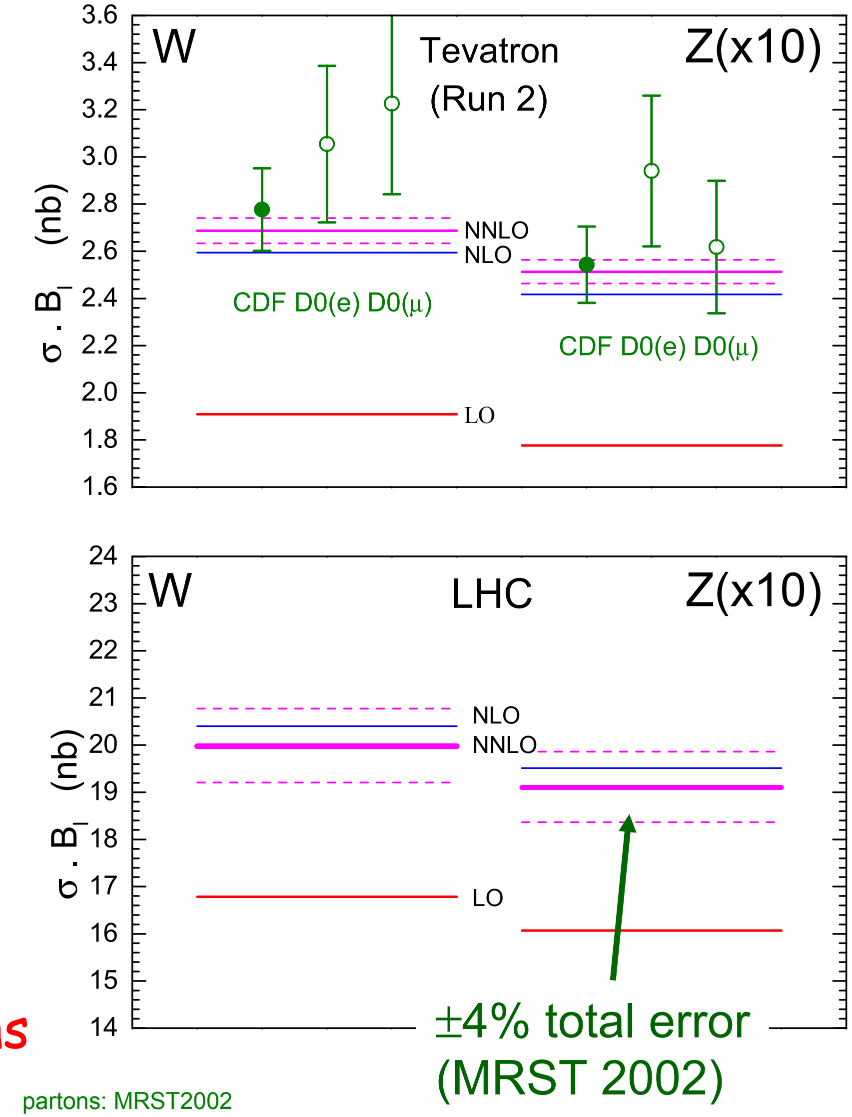
W,Z measurements at the LHC

J. Stirling

σ(W) and σ(Z) :
precision predictions
and measurements at
the LHC

LHC	$\sigma_{NLO}(W)$ (nb)
MRST2002	204 ± 4 (expt)
CTEQ6	205 ± 8 (expt)
Alekhin02	215 ± 6 (tot)

MRST2002/CTEQ6: different χ^2
Alekhin02: different partons distributions
→ Fits only DIS data

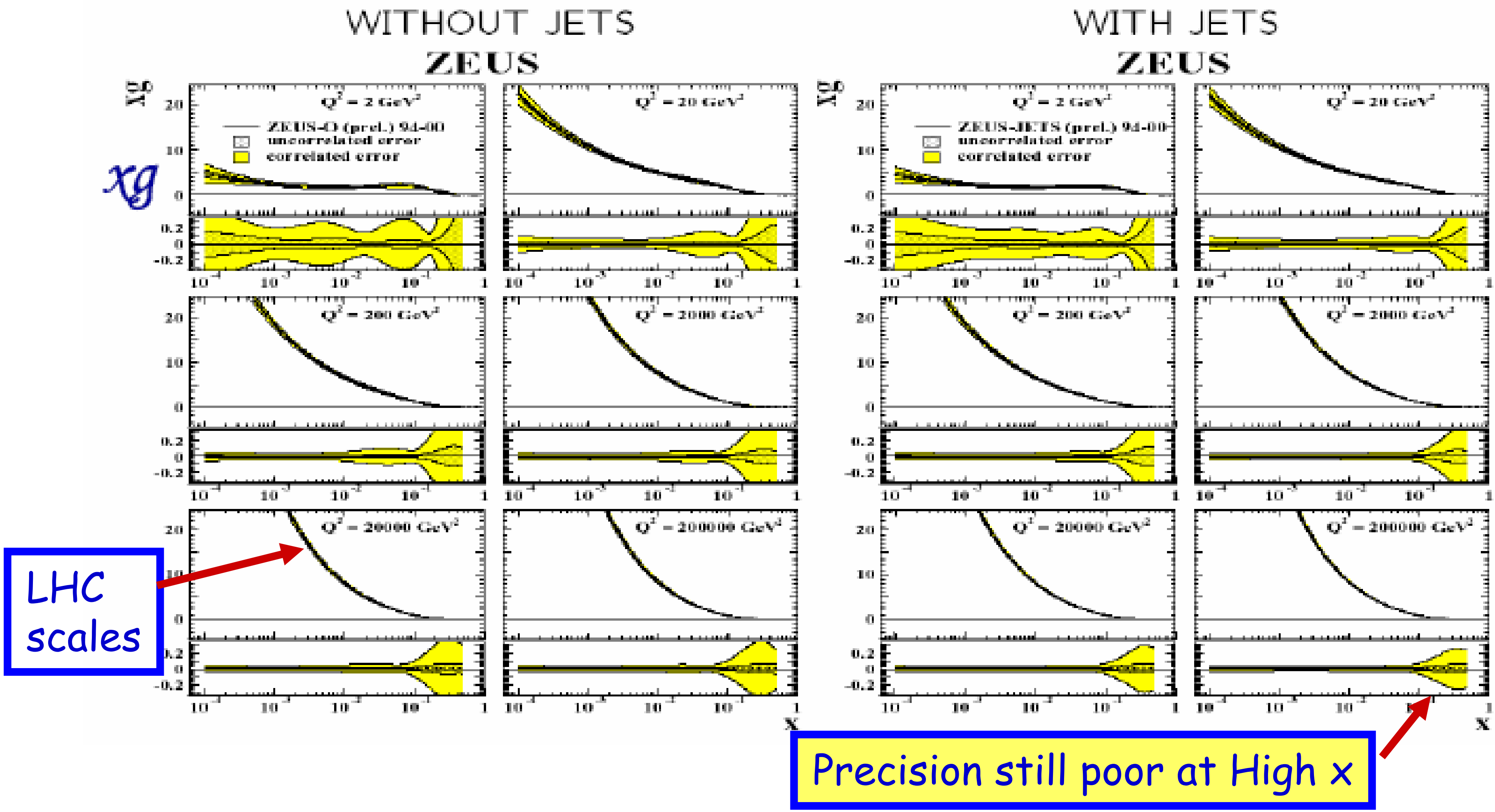


partons: MRST2002
NNLO evolution: van Neerven, Vogt approximation to Vermaseren et al. moments
NNLO W,Z corrections: van Neerven et al. with Harlander, Kilgore corrections

Constraining xg(x) by adding jet data

QCD fits to HERA F_2 + jet data

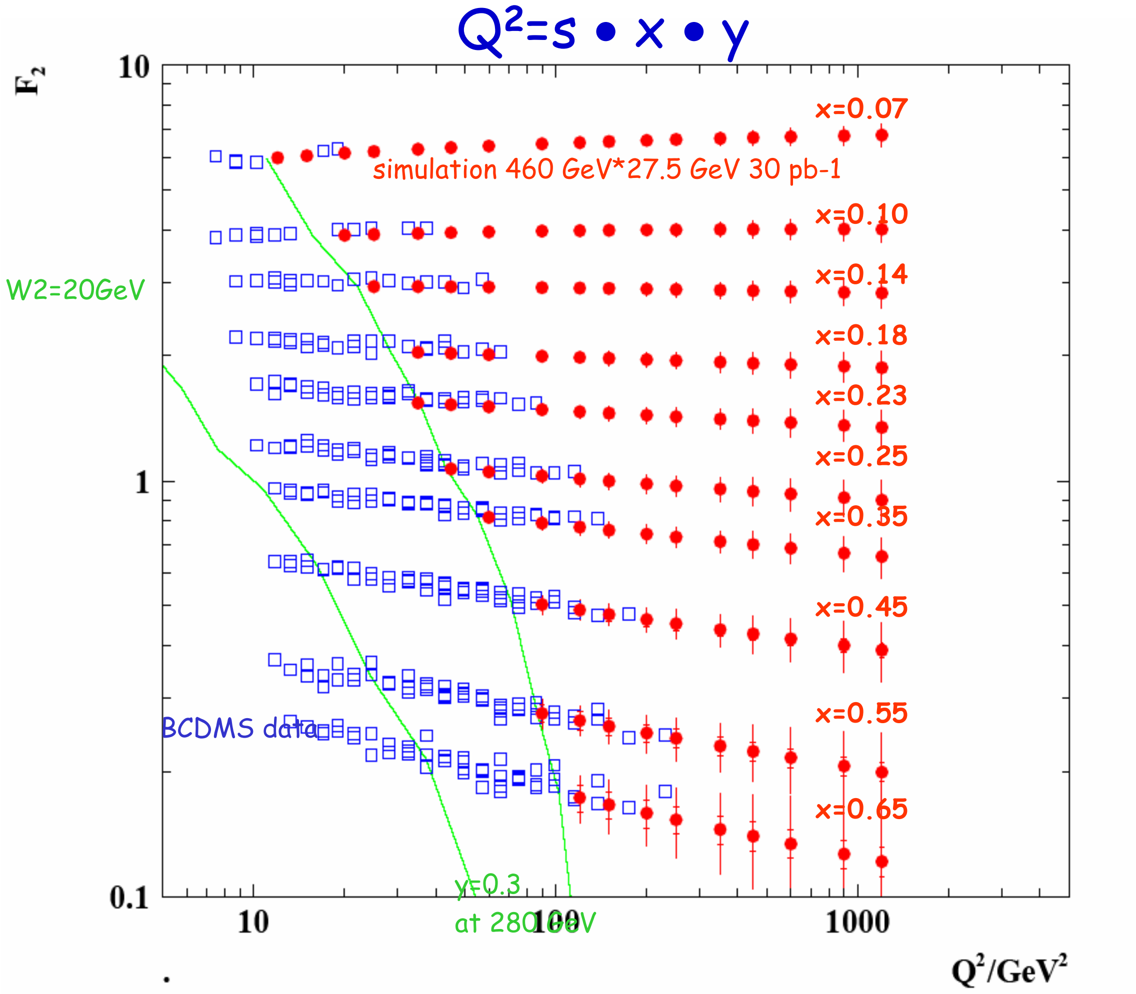
M. Cooper



+ Tevatron jet data? Carefull between "tensions" between different datasets

Access to larger x @ HERA

M. Klein



run at minimum possible proton beam energy

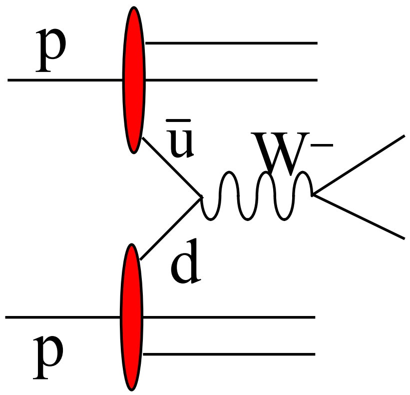
access large x at lower Q2

Technically possible but should happen before 2007

Have to quantify the gain to global fits to make the argument

Asymmetric Sea?

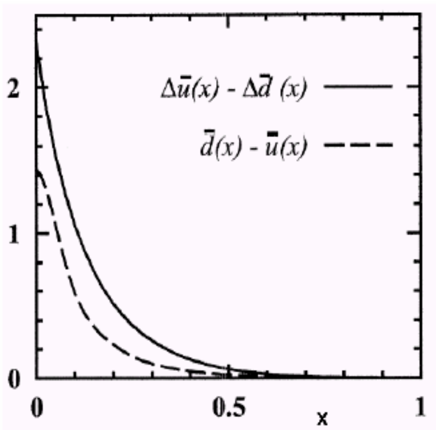
Global fits assume $\bar{u}=\bar{d}$ at small x

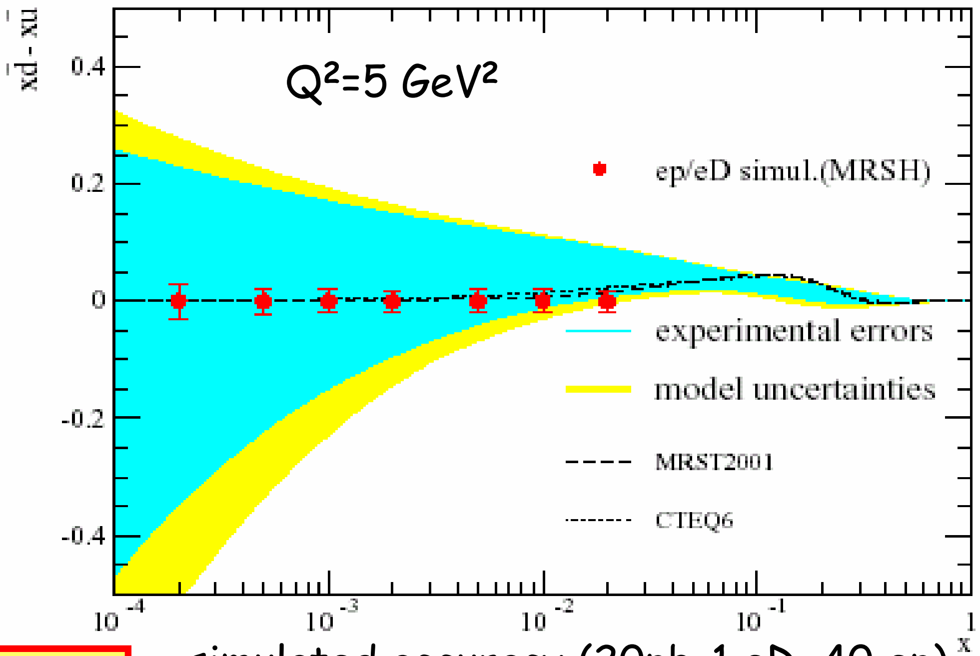


$$\tfrac{1}{2}\left(F_2^p + F_2^n\right) - F_2^p$$
$$= x\left(\tfrac{1}{6}d_v - \tfrac{1}{6}u_v + \tfrac{1}{3}\bar{d} - \tfrac{1}{3}\bar{u}\right)$$
$$\approx \tfrac{1}{3}x\left(\bar{d} - \bar{u}\right) \text{ at low x.}$$

Needs electron-Deuteron runs

Eg. Chiral Soliton model





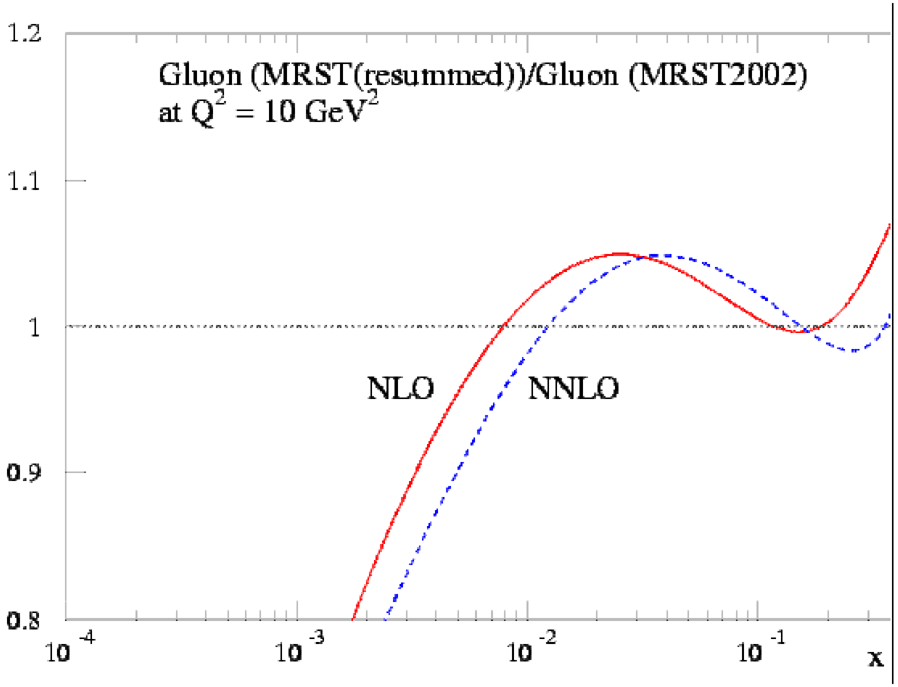
simulated accuracy (20pb-1 eD, 40 ep)

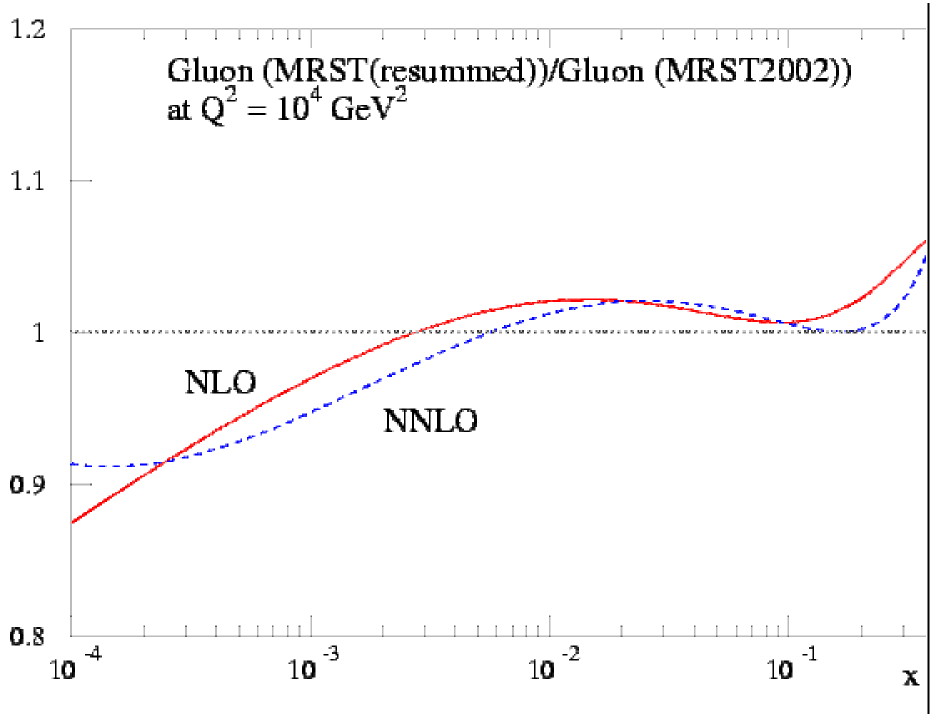
Parton luminosity problem at the LHC?

Low-x Resummation

Global fits: effects of including low x resummation (R.Thorne)

Differences can be larger than 20% at x ~ 10^{-3}, low Q^2





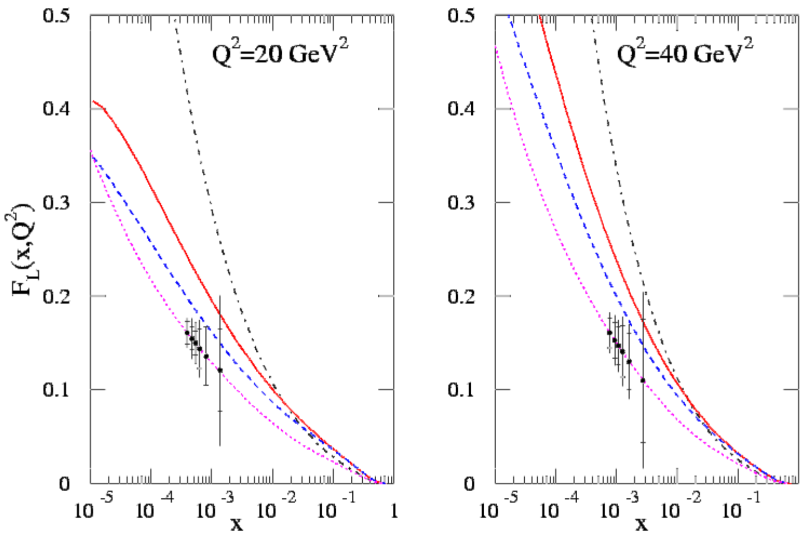
Need for other methods to extract the gluon or verify the QCD evolution/corrections

The Measurement of F_L

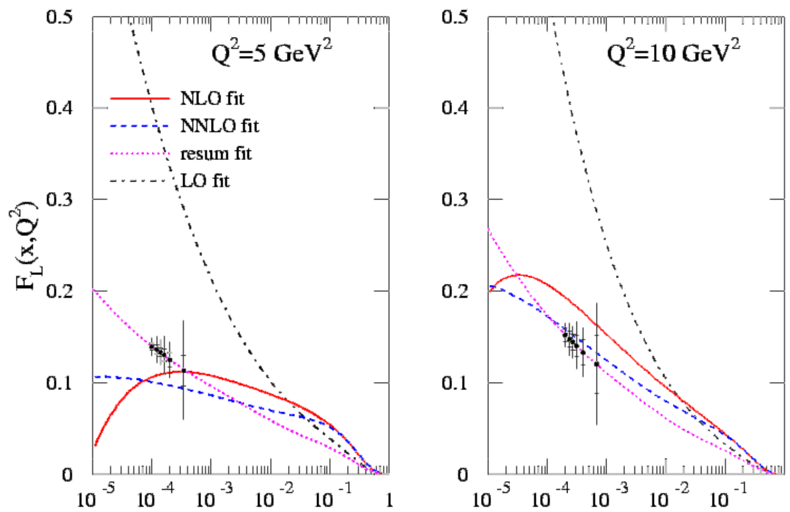
$$\sigma_r = F_2 - y^2/[1+(1-y)^2]\cdot F_L = F_2(x,Q^2) - f(y)\cdot F_L(x,Q^2)$$

Thorne, Klein

- F_L: longitudinal structure function
- Measure F_L to distinguish!
- Accurate F_L data at low x and Q2 allows to test HO QCD and allows to pin down xG(x,Q2)
- For this to happen HERA will need to run at lower energies. Here we assume that the proton energy is lowered from 920 GeV to 400, 465 and 575 GeV, for 1/2 year.
- This is presently NOT planned



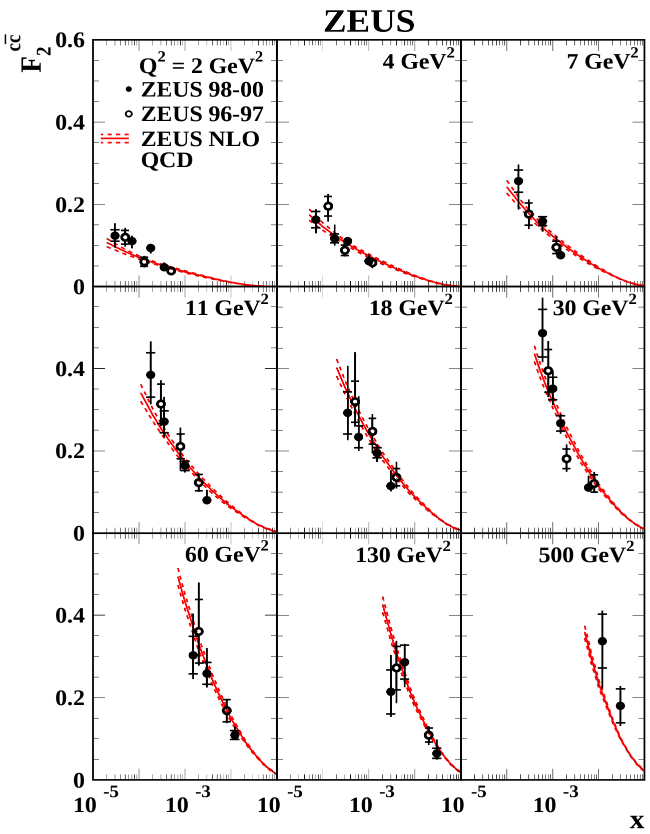
F_L LO , NLO, NNLO and resummed - Simulation of Low Ep H1 Data

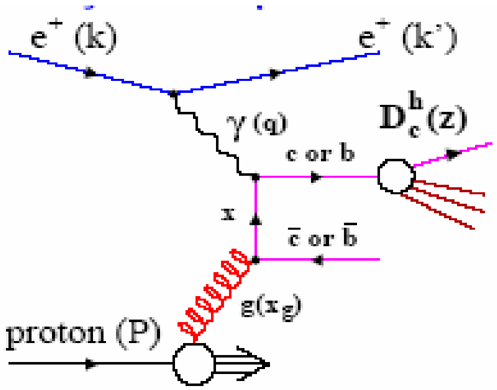


F_2^c and F_2^b measurements

Heavy flavor production is a good test of gluon density and NLO QCD

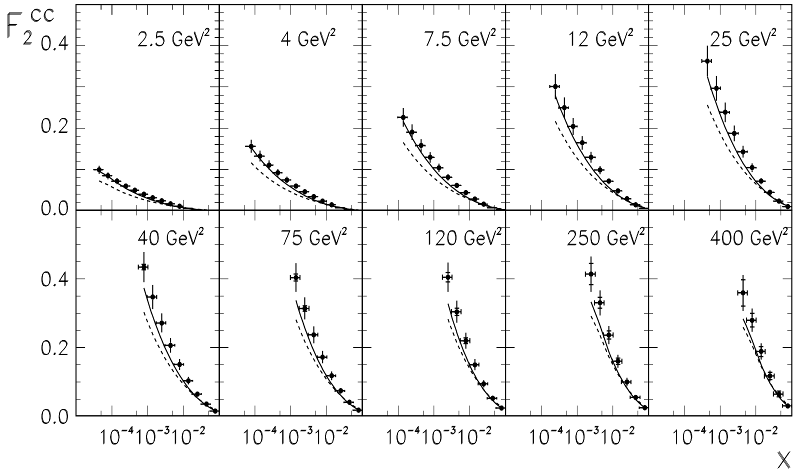
HERA I



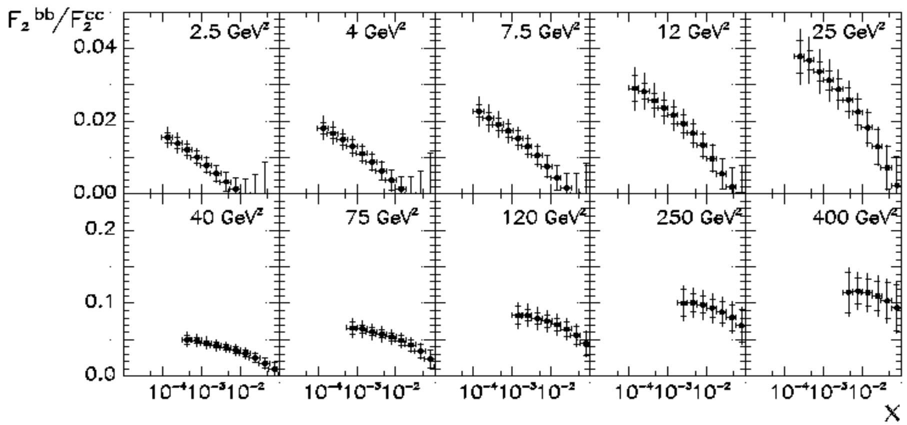


Charm significant part of F_2. Will be systematics/theory limited over most of kinematic range.

HERA II – 200 pb^{-1}

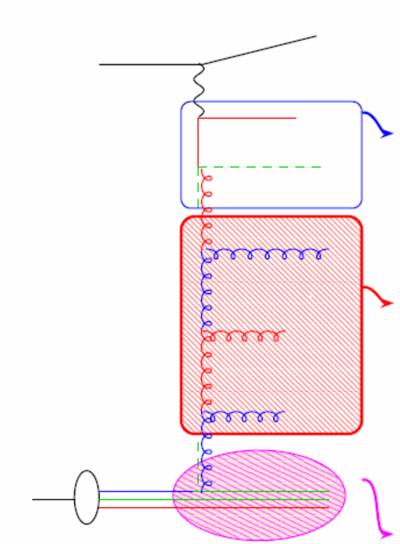


F_2^b/F_2^c with 500 pb^{-1}



Study of QCD evolution via final states

H. Jung

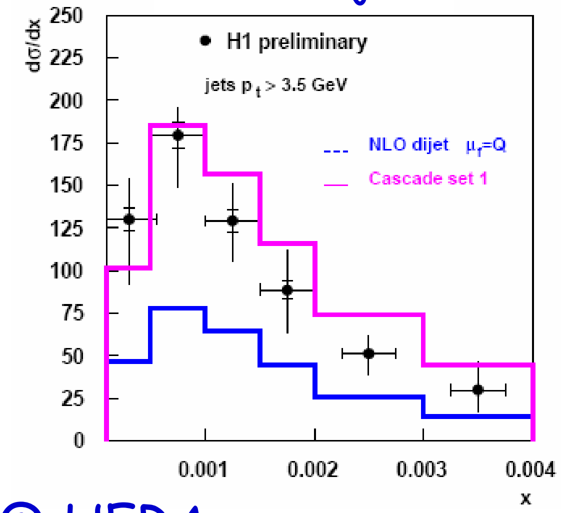


EG k_t factorization/CCFM

evolution of parton cascade with CCFM splitting fct.

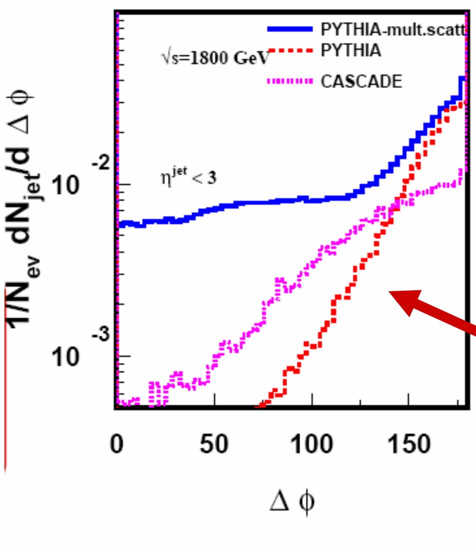
$$\tilde{P} = \bar{\alpha}_s \left(\frac{1}{1-z} + \frac{1}{z} \Delta \text{ns} \right)$$

Forward jets

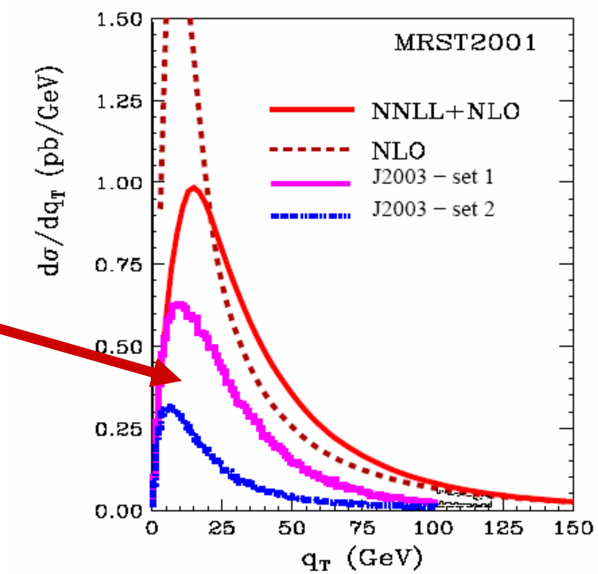


Describes F_2... and forward jets@ HERA

Cascade program



CCFM evolution instead of DGLAP affects Higgs P_t and the shape of underlying events at LHC

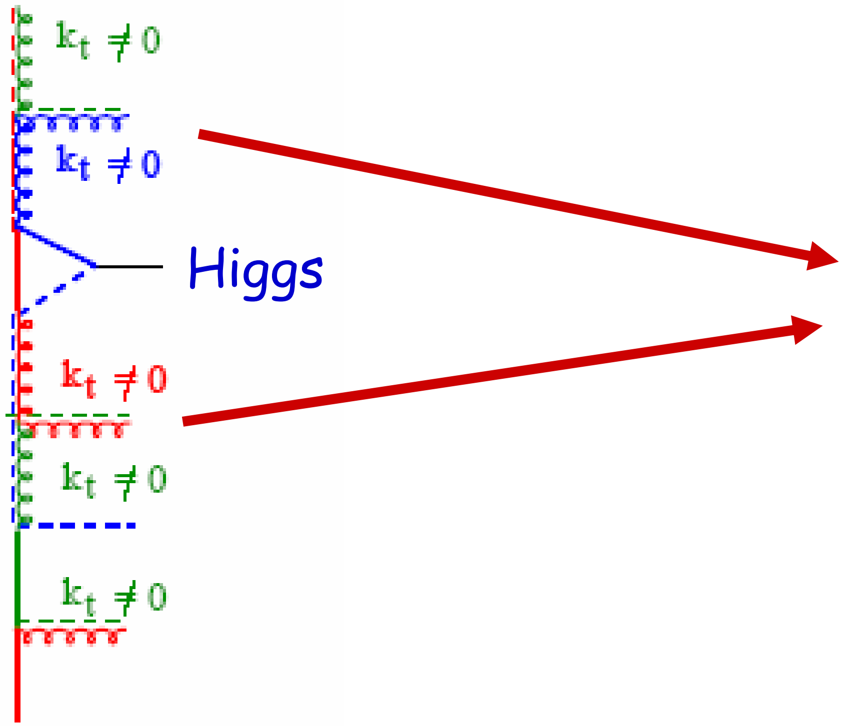


Check in hadronic final states at the Tevatron?

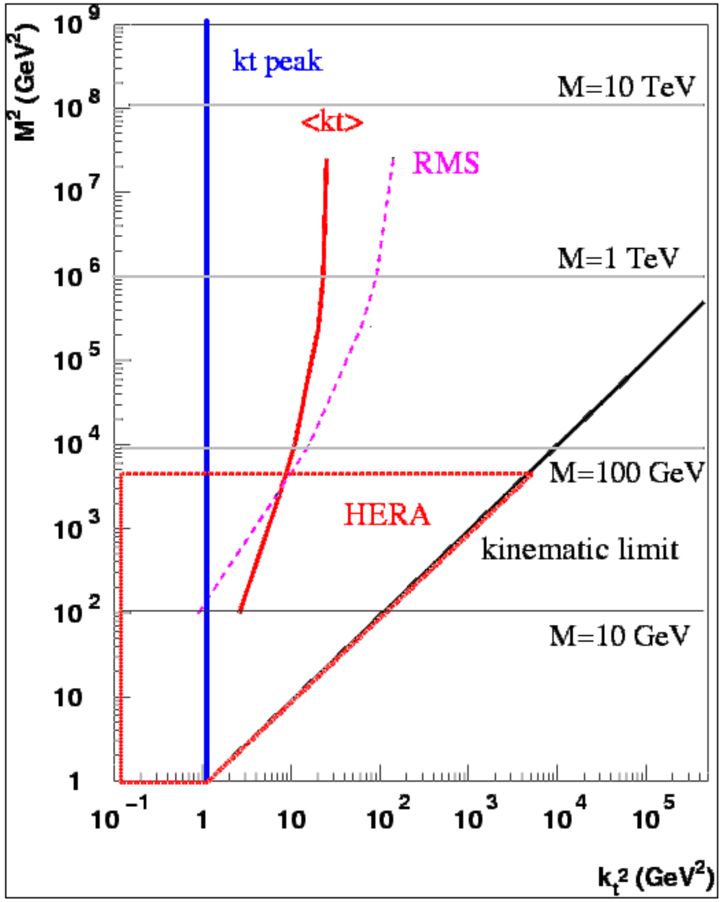
Initial k_t at HERA and LHC

Jung

Initial K_t in the hard scattering



Pythia calculation



$\langle K_t \rangle$ similar for HERA and LHC
$\Rightarrow$ K_t understanding at HERA relevant for the LHC

Near Future: from NLO→NNLO

LO and NLO singlet splitting functions

$$
\begin{aligned}
P^{(0)}_{\mathrm{ps}}(x) &= 0 \\
P^{(0)}_{\mathrm{qg}}(x) &= 2n_f\, p_{\mathrm{qg}}(x) \\
P^{(0)}_{\mathrm{gq}}(x) &= 2C_F\, p_{\mathrm{gq}}(x) \\
P^{(0)}_{\mathrm{gg}}(x) &= C_A\Big(4p_{\mathrm{gg}}(x) + \frac{11}{3}\delta(1-x)\Big) - \frac{2}{3}n_f\,\delta(1-x)
\end{aligned}
$$

$$
P^{(1)}_{\mathrm{ps}}(x) = 4C_F n_f\Big(\frac{20}{9}\frac{1}{x} - 2 + 6x - 4\mathrm{H}_0 + x^2\Big[\frac{8}{3}\mathrm{H}_0 - \frac{56}{9}\Big] + (1+x)\Big[5\mathrm{H}_0 - 2\mathrm{H}_{0,0}\Big]\Big)
$$

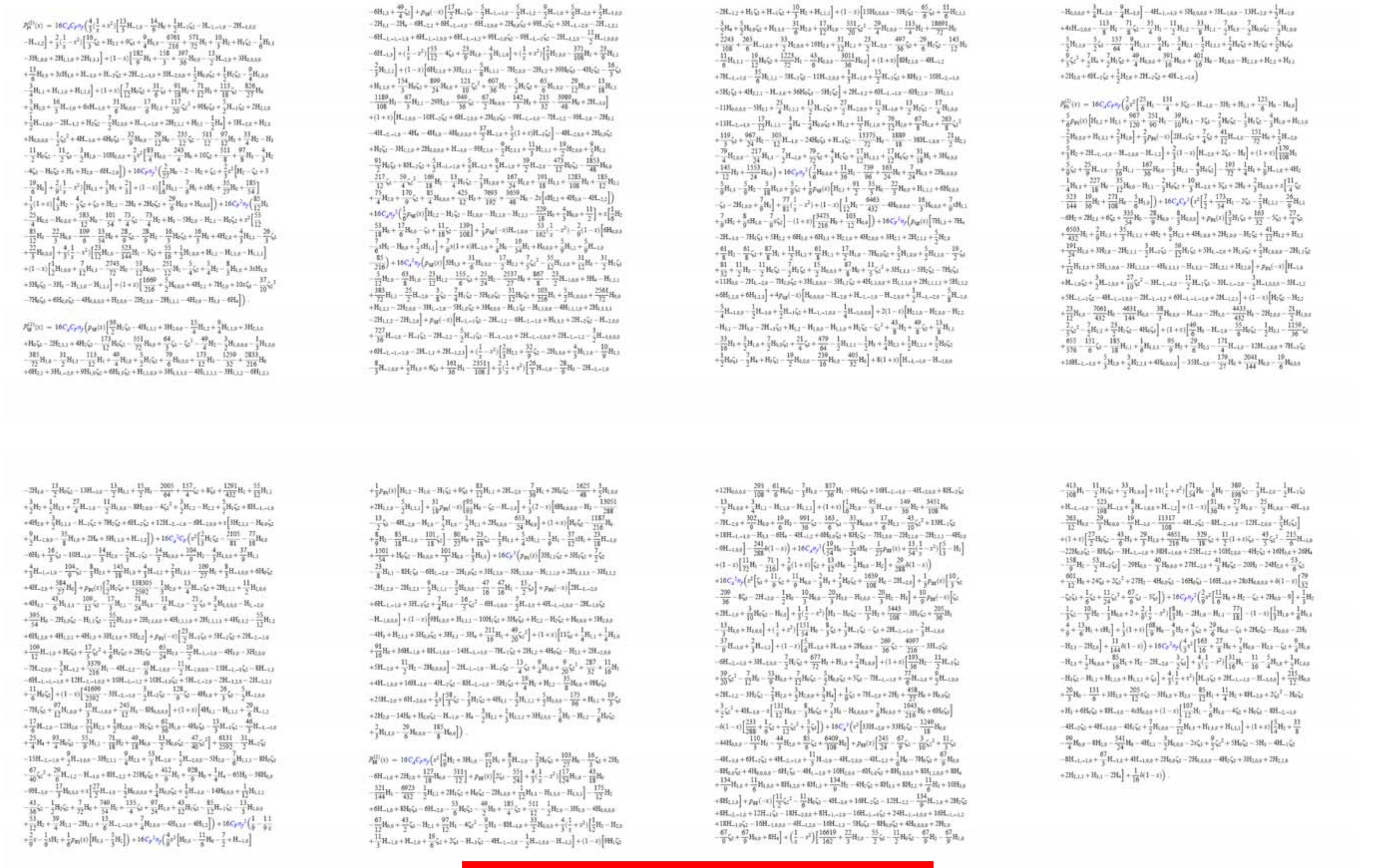
$$
\begin{aligned}
P^{(1)}_{\mathrm{qg}}(x) &= 4C_A n_f\Big(\frac{20}{9}\frac{1}{x} - 2 + 25x - 2p_{\mathrm{qg}}(-x)\mathrm{H}_{-1,0} - 2p_{\mathrm{qg}}(x)\mathrm{H}_{1,1} + x^2\Big[\frac{44}{3}\mathrm{H}_0 - \frac{218}{9}\Big] \\
&+4(1-x)\Big[\mathrm{H}_{0,0} - 2\mathrm{H}_0 + x\mathrm{H}_1\Big] - 4\zeta_2 x - 6\mathrm{H}_{0,0} + 9\mathrm{H}_0\Big) + 4C_F n_f\Big(2p_{\mathrm{qg}}(x)\Big[\mathrm{H}_{1,0} + \mathrm{H}_{1,1} + \mathrm{H}_2 \\
&-\zeta_2\Big] + 4x^2\Big[\mathrm{H}_0 + \mathrm{H}_{0,0} + \frac{5}{2}\Big] + 2(1-x)\Big[\mathrm{H}_0 + \mathrm{H}_{0,0} - 2x\mathrm{H}_1 + \frac{29}{4}\Big] - \frac{15}{2} - \mathrm{H}_{0,0} - \frac{1}{2}\mathrm{H}_0\Big)
\end{aligned}
$$

$$
\begin{aligned}
P^{(1)}_{\mathrm{gq}}(x) &= 4C_A C_F\Big(\frac{1}{x} + 2p_{\mathrm{gq}}(x)\Big[\mathrm{H}_{1,0} + \mathrm{H}_{1,1} + \mathrm{H}_2 - \frac{11}{6}\mathrm{H}_1\Big] - x^2\Big[\frac{8}{3}\mathrm{H}_0 - \frac{44}{9}\Big] + 4\zeta_2 - 2 \\
&-7\mathrm{H}_0 + 2\mathrm{H}_{0,0} - 2\mathrm{H}_1 x + (1+x)\Big[2\mathrm{H}_{0,0} - 5\mathrm{H}_0 + \frac{37}{9}\Big] - 2p_{\mathrm{gq}}(-x)\mathrm{H}_{-1,0}\Big) - 4C_F n_f\Big(\frac{2}{3}x \\
&-p_{\mathrm{gq}}(x)\Big[\frac{2}{3}\mathrm{H}_1 - \frac{10}{9}\Big]\Big) + 4C_F^{\,2}\Big(p_{\mathrm{gq}}(x)\Big[3\mathrm{H}_1 - 2\mathrm{H}_{1,1}\Big] + (1+x)\Big[\mathrm{H}_{0,0} - \frac{7}{2} + \frac{7}{2}\mathrm{H}_0\Big] - 3\mathrm{H}_{0,0} \\
&+1 - \frac{3}{2}\mathrm{H}_0 + 2\mathrm{H}_1 x\Big)
\end{aligned}
$$

$$
\begin{aligned}
P^{(1)}_{\mathrm{gg}}(x) &= 4C_A n_f\Big(1 - x - \frac{10}{9}p_{\mathrm{gg}}(x) - \frac{13}{9}\Big(\frac{1}{x} - x^2\Big) - \frac{2}{3}(1+x)\mathrm{H}_0 - \frac{2}{3}\delta(1-x)\Big) + 4C_A^{\,2}\Big(27 \\
&+(1+x)\Big[\frac{11}{3}\mathrm{H}_0 + 8\mathrm{H}_{0,0} - \frac{27}{2}\Big] + 2p_{\mathrm{gg}}(-x)\Big[\mathrm{H}_{0,0} - 2\mathrm{H}_{-1,0} - \zeta_2\Big] - \frac{67}{9}\Big(\frac{1}{x} - x^2\Big) - 12\mathrm{H}_0 \\
&-\frac{44}{3}x^2\mathrm{H}_0 + 2p_{\mathrm{gg}}(x)\Big[\frac{67}{18} - \zeta_2 + \mathrm{H}_{0,0} + 2\mathrm{H}_{1,0} + 2\mathrm{H}_2\Big] + \delta(1-x)\Big[\frac{8}{3} + 3\zeta_3\Big]\Big) + 4C_F n_f\Big(2\mathrm{H}_0 \\
&+\frac{2}{3}\frac{1}{x} + \frac{10}{3}x^2 - 12 + (1+x)\Big[4 - 5\mathrm{H}_0 - 2\mathrm{H}_{0,0}\Big] - \frac{1}{2}\delta(1-x)\Big)\,.
\end{aligned}
$$

NNLO splitting functions have arrived…

S. Moch et al.



→ NNLO fits to come

Diffraction: WG program

Rapidity gaps and/or leading protons

- Study key processes at the LHC (Higgs & Co, spectroscopy)
- Understand different theory approaches to rapidity gaps and/or leading baryons.
- How much do we know from QCD, where do models have to be used?
- Understand/study gap survival/factorization breaking: compare γp with ep
- Need to analyse hard subprocesses at NLO vs LO?
- Physics accessible with leading protons vs rapidity gap?
- Which processes are well described by theory (HERA,Tevatron). Extrapolate to LHC?
- Identify useful measurements at the LHC.
- Nonforward parton distributions
- Improve longit. and trans. momentum spectra of leading protons in MCsimulations.
- Physics opportunities with rapidity gaps originating from photon or W exchange
- Diffractive processes using nuclear beams at LHC

Low-x dynamics, saturation, high-density QCD

- Compare theory approaches for small x: BFKL, k_T factorization,
- To which processes/obervables can these approaches be applied?
- In which processes at LHC does one expect saturation to be relevant?
- Prospects to "see" and study saturation at HERA?

Forward Physics@LHC (CMS/TOTEM)

ADR

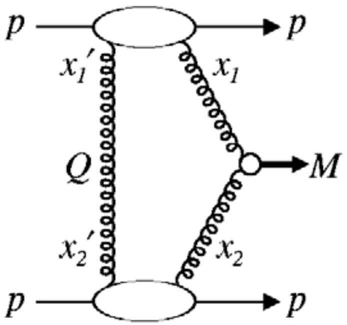
- Soft & Hard diffraction
  - Total cross section and elastic scattering (TOTEM)
  - Gap survival dynamics, multi-gap events, proton light cone ($pp \rightarrow 3jets+p$)
  - Diffractive structure: Production of jets, W, J/ψ, b, t, hard photons
  - Double Pomeron exchange events as a gluon factory (anomalous W,Z production?)
  - Diffractive Higgs production, (diffractive Radion production?)
  - SUSY & other (low mass) exotics & exclusive processes
- Low-x Dynamics
  - Parton saturation, BFKL/CCFM dynamics, proton structure, multi-parton scattering…
- New Forward Physics phenomena
  - New phenomena such as DCCs, incoherent pion emission, Centauro's
- Strong interest from cosmic rays community
  - Forward energy and particle flows/minimum bias event structure
- Two-photon interactions and peripheral collisions
- Forward physics in pA and AA collisions
- Use QED processes to determine the luminosity to 1% ($pp \rightarrow ppee$, $pp \rightarrow pp\mu\mu$)

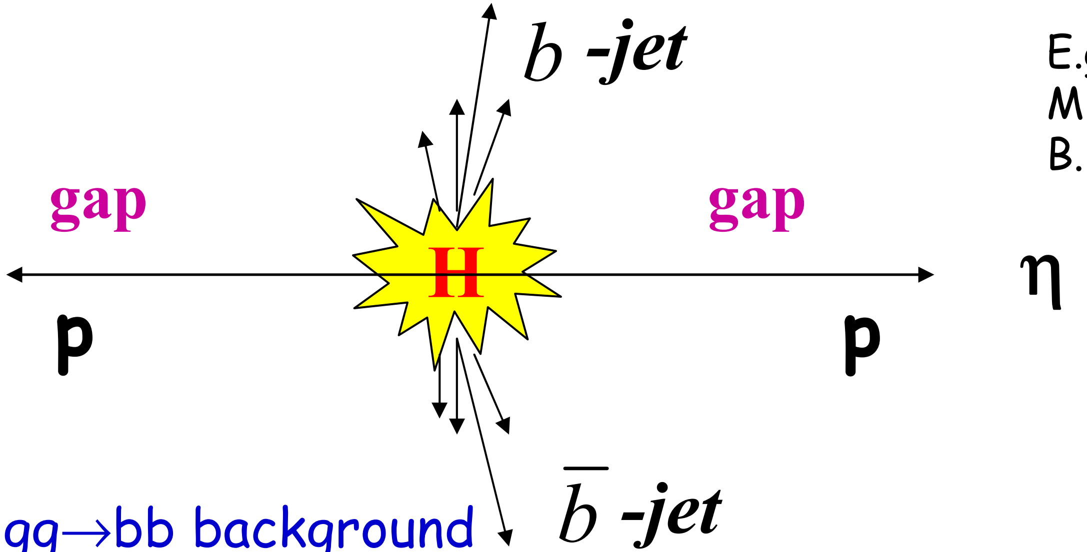
Many of these studies can be done best with L ~10^{33} (or lower)

Diffractive Higgs Production

Exclusive diffractive Higgs production pp→ p H p : 3-10 fb
Inclusive diffractive Higgs production pp → p+X+H+Y+p : 50-200 fb

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



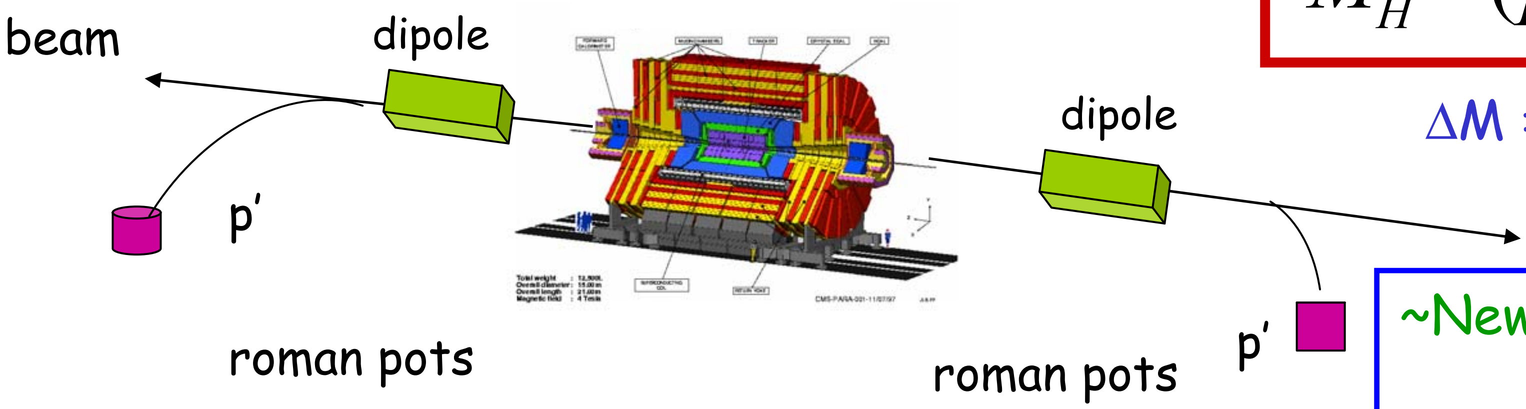


Advantages Exclusive:

- Jz=0 suppression of gg→bb background
- Mass measurement via missing mass

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

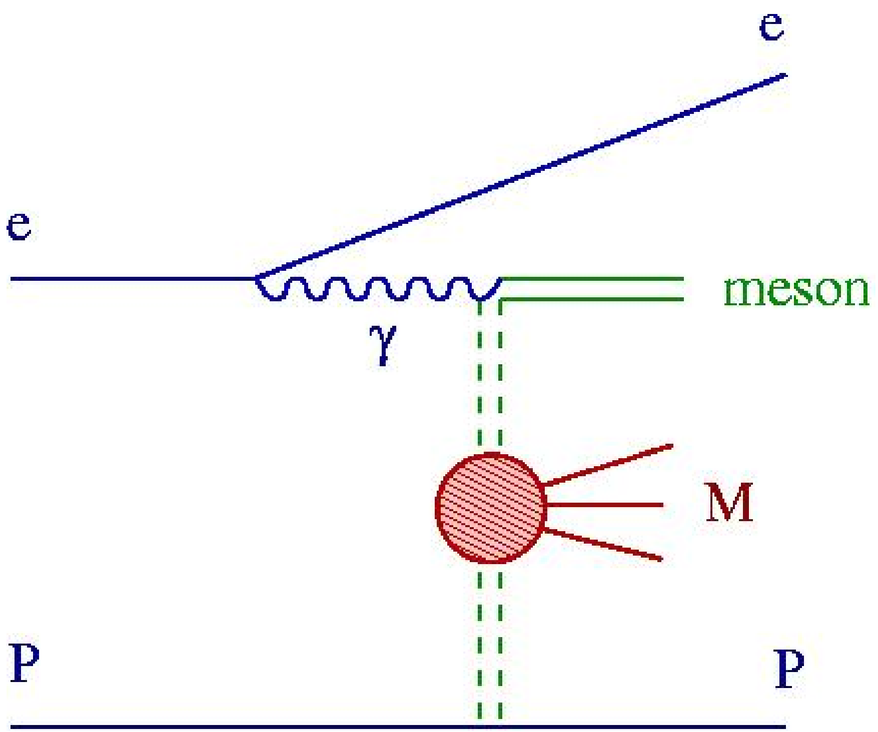
ΔM = O(1.0 - 2.0) GeV



~New: Under study by many groups

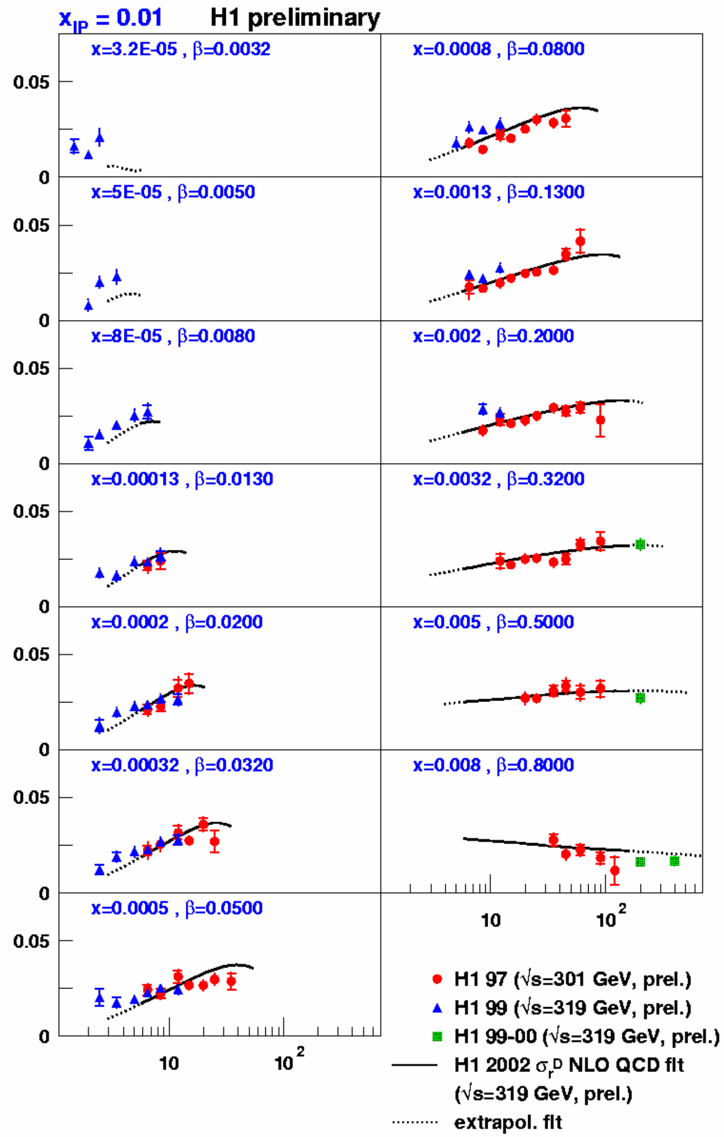
Information from HERA

Study the process of $\gamma p \rightarrow$ VM+ X+ p



Double pomeron exchange @ HERA

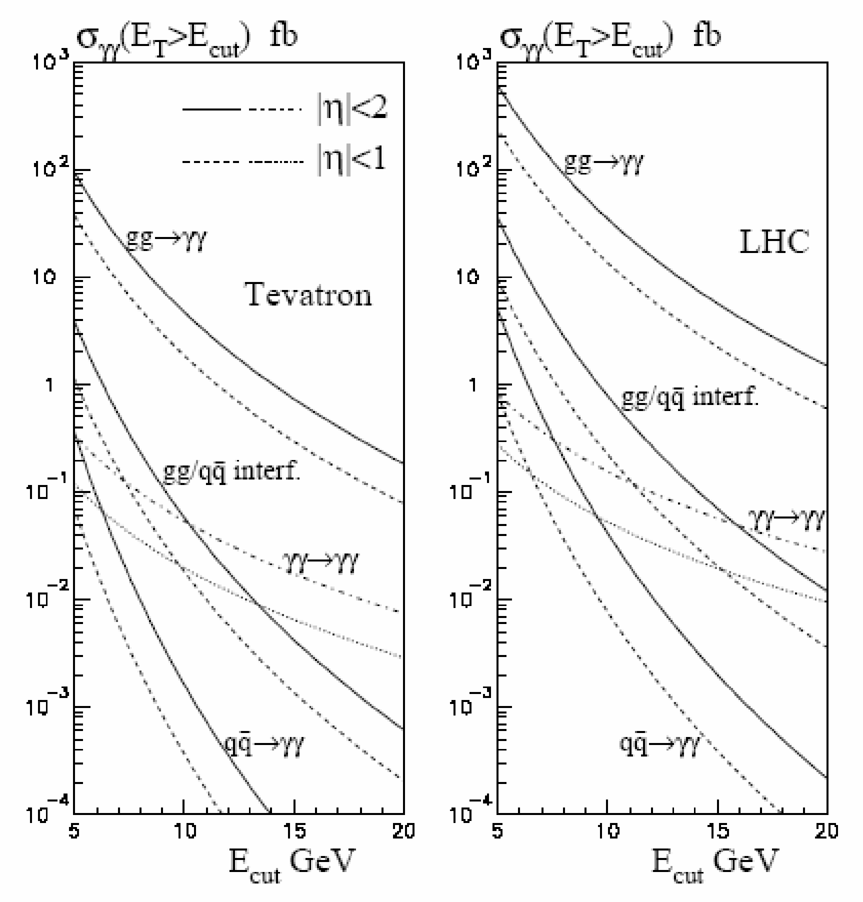
Diffractive structure functions



Information from Tevatron!

Study of diffractive exclusive processes

V. Khoze et al., hep-ph/0409037



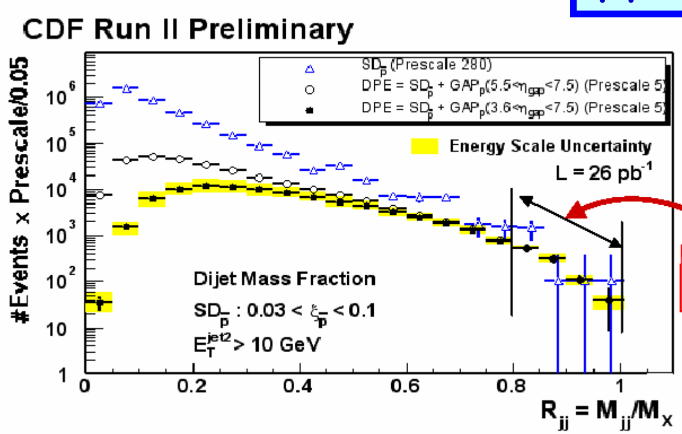
pp →p + γγ +p

V. Khoze et al., hep-ph/0403218

	Tevatron $\sqrt{s}=2$ TeV χ_c	χ_b	LHC $\sqrt{s}=14$ TeV χ_c	χ_b
$d\sigma_{\rm excl}/dy\|_{y=0}$	130	0.2	340	0.6
$\sigma_{\rm excl}$	650	0.5	3000	4
$d\sigma_{\rm incl}/dy\|_{y=0}$	13	0.06	30	0.2
$\sigma_{\rm incl}$	70	0.3	200	2

pp →p + χ_c +p

pp →p + dijets+p

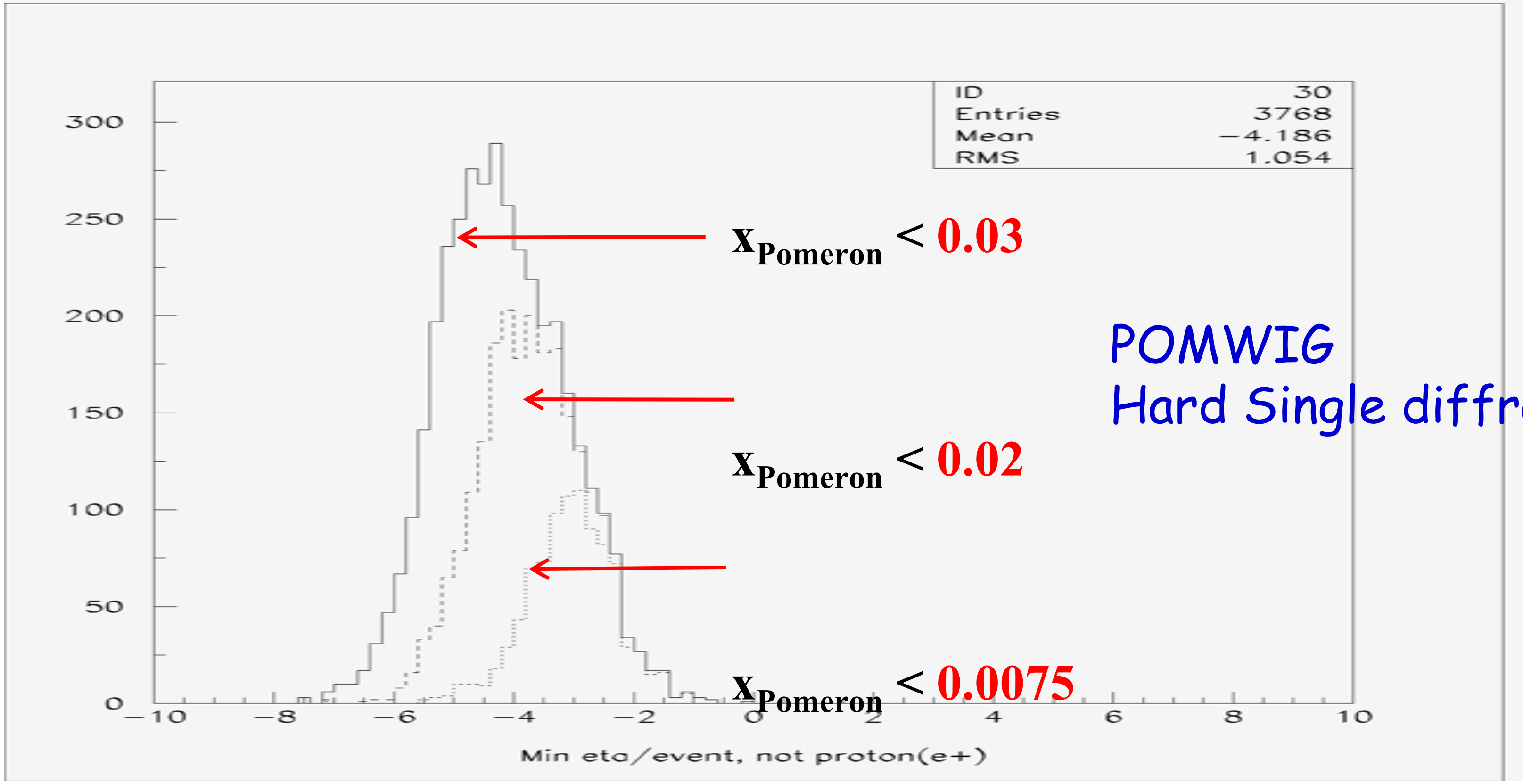


D. Goulianos

$|\eta_{jet1,2}|<2.5$, $0.03<\xi_{\bar p}<0.1$, $3.6<\eta_{gap}<7.5$, $R = 0.7$

Minimum E_T^{jet1}	Cross Section : $\sigma_{DPE}^{excl.\ jj}(R_{jj}>0.8)$
10 GeV	970 ± 65(stat) ± 272(syst) pb
25 GeV	34 ± 5(stat) ± 10(syst) pb

Gap moves farther from outgoing proton for smaller x_{POM}



POMWIG
Hard Single diffraction

η of **minimum-η** particle per event

rapidity gap trigger study

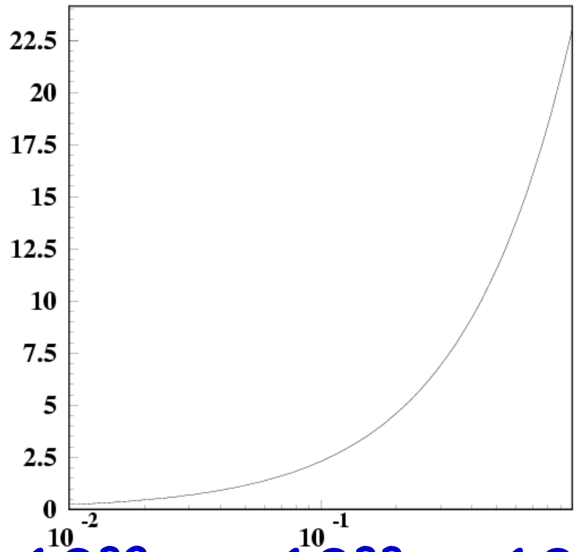
G. Snow

Rapidity Gaps at LHC

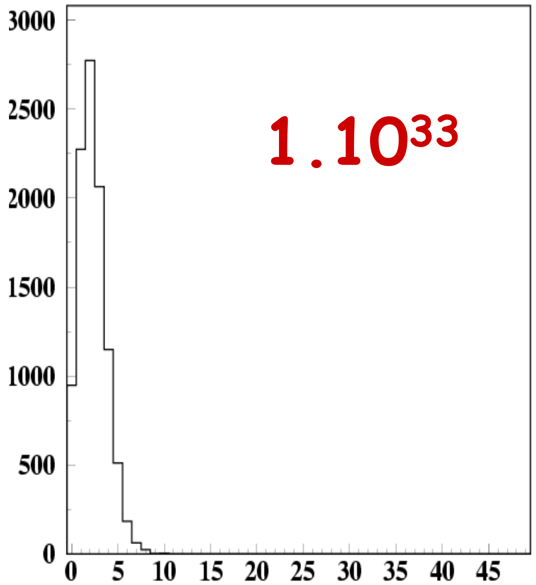
Number of overlap events versus LHC luminosity

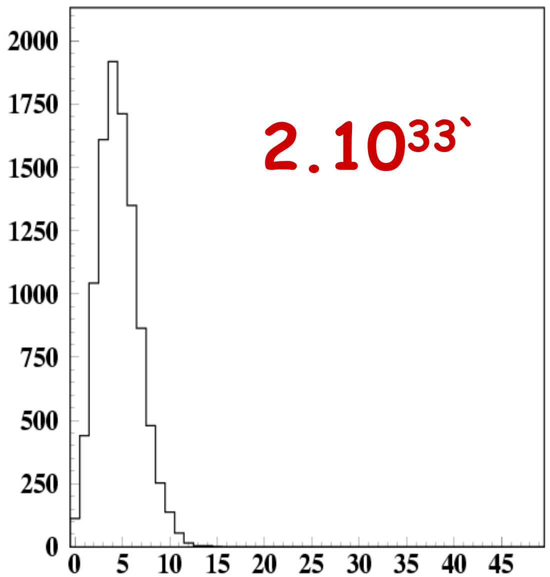
distribution of number of interactions

Doable at startup luminosity!



10^{32} 10^{33} 10^{34}

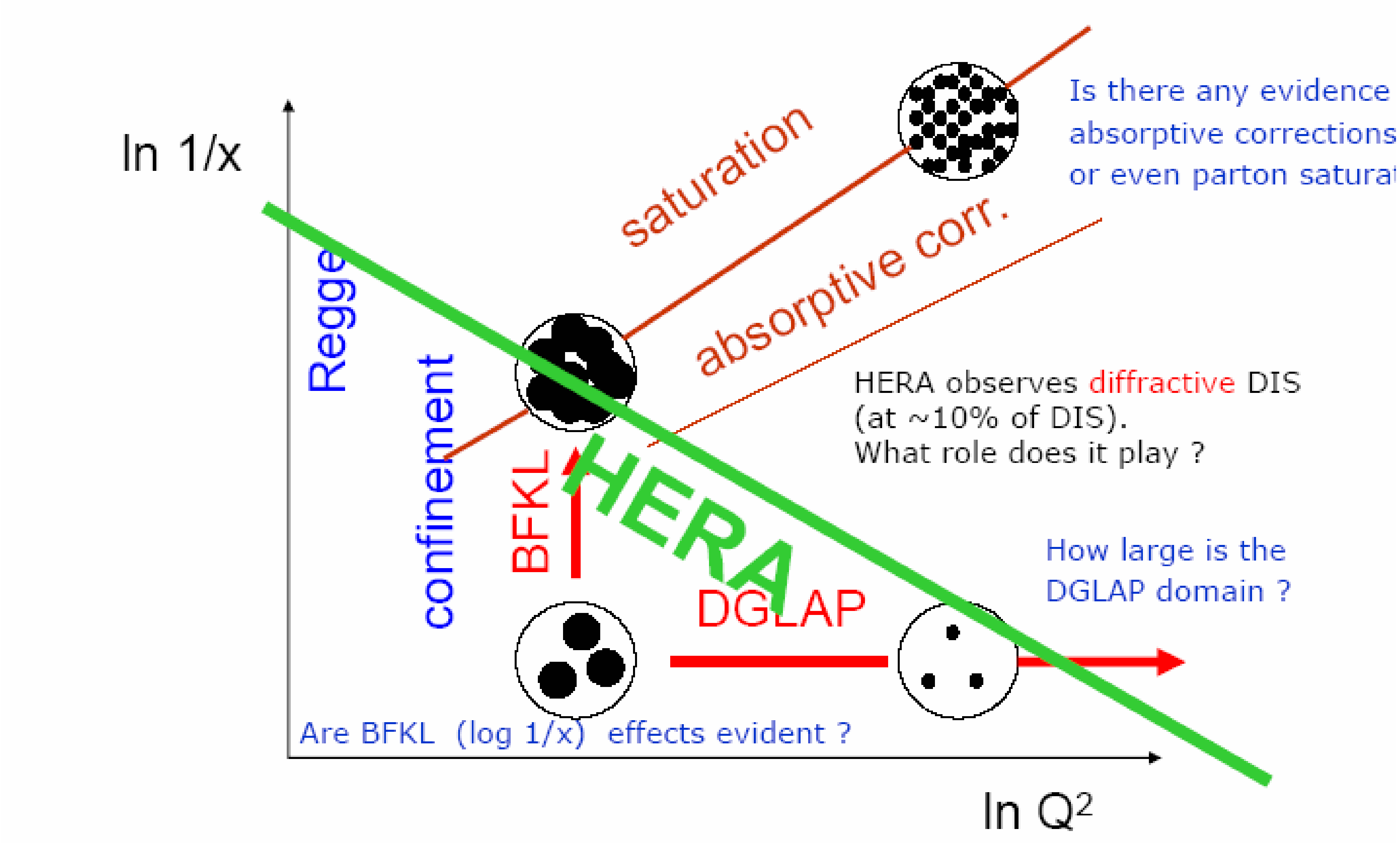




1 int. 22% **4%**

Benefit from experience of HERA/Tevatron experiments !!

Saturation Effects



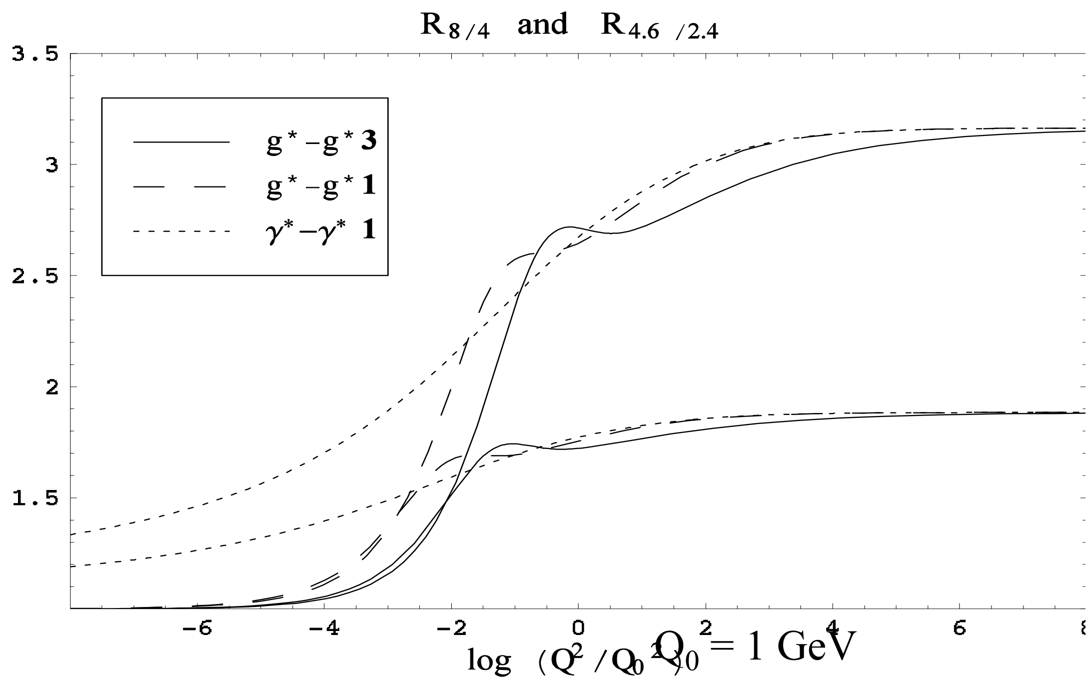
Saturation: any sign in the HERA data?
Effect on the LHC predictions? Can LHC discover saturation in pp data?

Saturation Effects at the LHC

Peschanski, marquet

$$R_{i/j} \equiv \frac{\sigma(Q_1, Q_2, \Delta\eta_i)}{\sigma(Q_1, Q_2, \Delta\eta_j)}$$

- The value of R goes down from the transparency limit towards the saturation regime where R→1
- One can observe a sharper transition in the case of the gluon-initiated process
- The values of Q at the transition are weak for jet cuts at the Tevatron
- Along with BFKL studies, the signal deserves to be studied at the LHC
- Alternatives to bypass the small-Q problem?



Transition is at low scales

◊ Heavy vector mesons J/Ψ or Y?

◊ D mesons or B mesons?

◊ medium p_t particles?

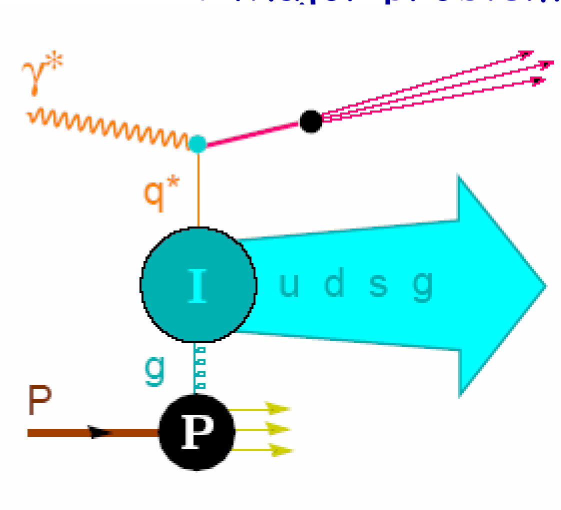
$R_{4.6/2.4}$: ratio studied at the Tevatron

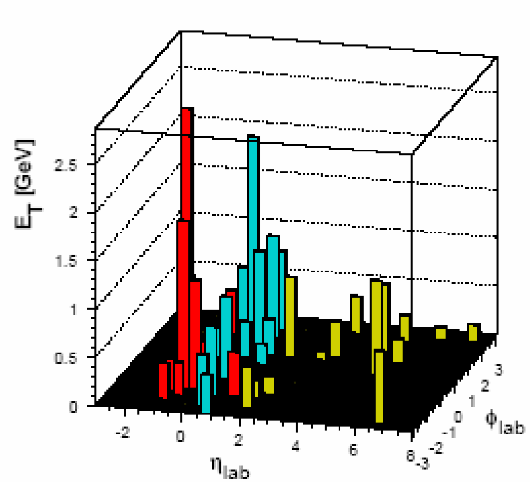
$R_{8/4}$: ratio realistic for the LHC

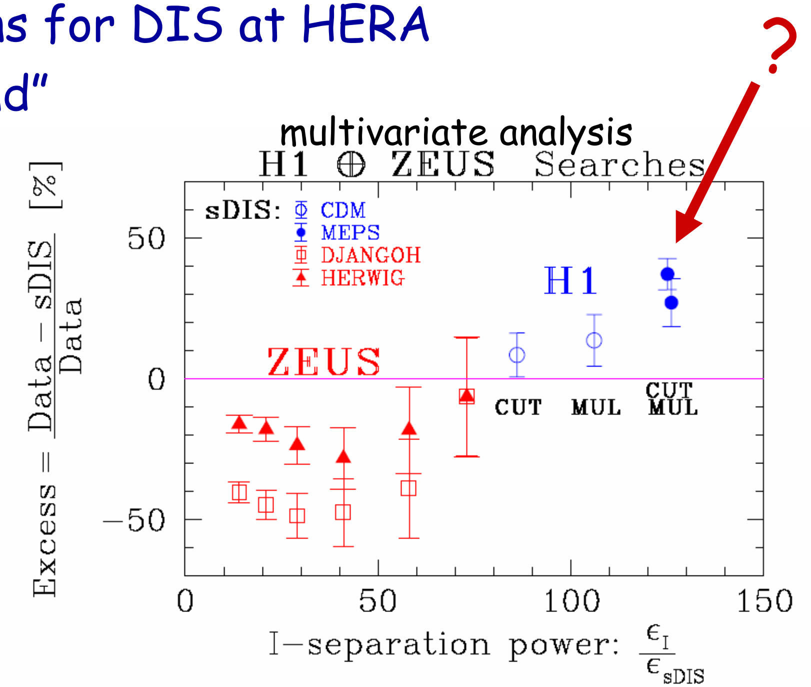
Try out at the Tevatron?

Instantons

- A basic aspect of QCD: Non-perturbative fluctuations of gluon fields with typical size ~0.5 fm, associated with non-trivial topology of the QCD vacuum
- Induce hard chirality violating processes, forbidden in usual perturbative QCD, connections to saturation.
- Instanton perturbation theory → predictions for DIS at HERA
  ⇒ Major problem "standard QCD background"







"fireball disintegration": Large E_t, large multiplicity, flavour democracy

Project: Study of the discovery potential at the LHC: (F. Schrempp et al.)
Single out & calculate optimal I-subprocess (with W/γ?), trigger/selection,
⇒ Use years of experience at HERA (test at Tevatron?)

Conclusions

HERA-LHC workshop well under way

- Many communalities with TeV4LHC: close contact/collaboration mandatory
  - Tevatron people have been invited & participating in both meetings we had so far.
- PDFs important issue for the LHC. Needs good effort to get best possible understanding by 2007(6).
  - LHC experiments use LHAPDF as standard PDF library
- Diffraction and related subjects part of the LHC physics program
  - Can learn a lot here from the techniques used at HERA and Tevatron

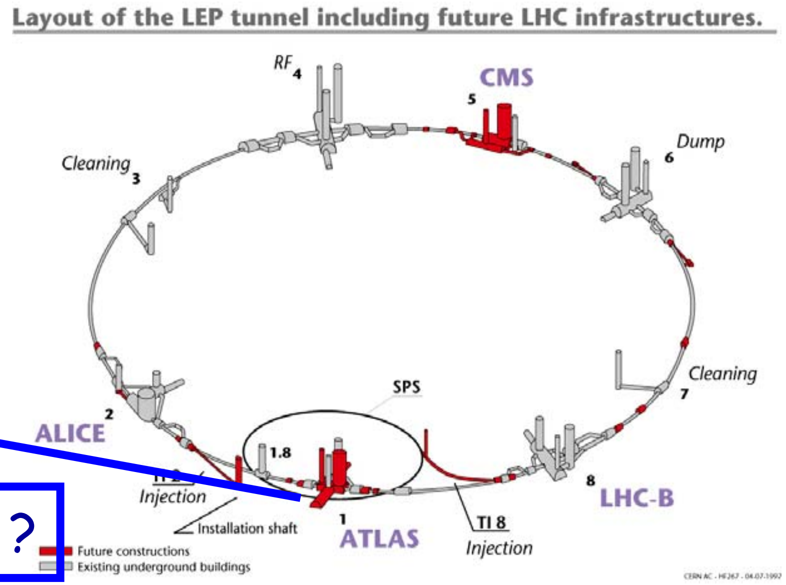
A lot of work (and fun) to quantify these topics

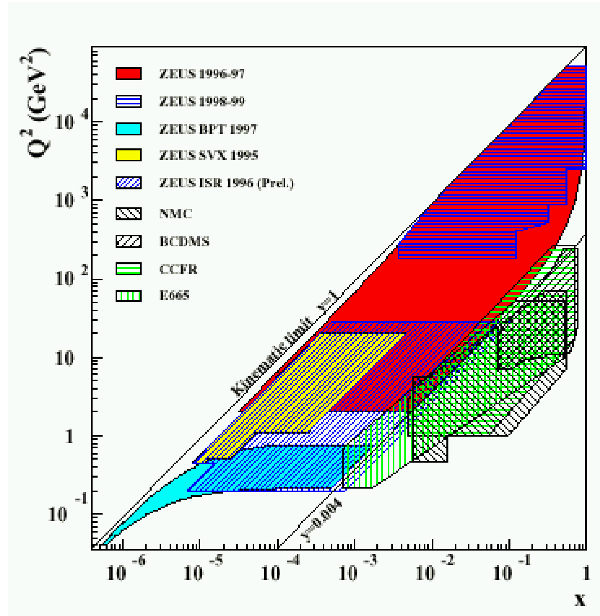
Where can be the ep IP?

More ep scattering required ?

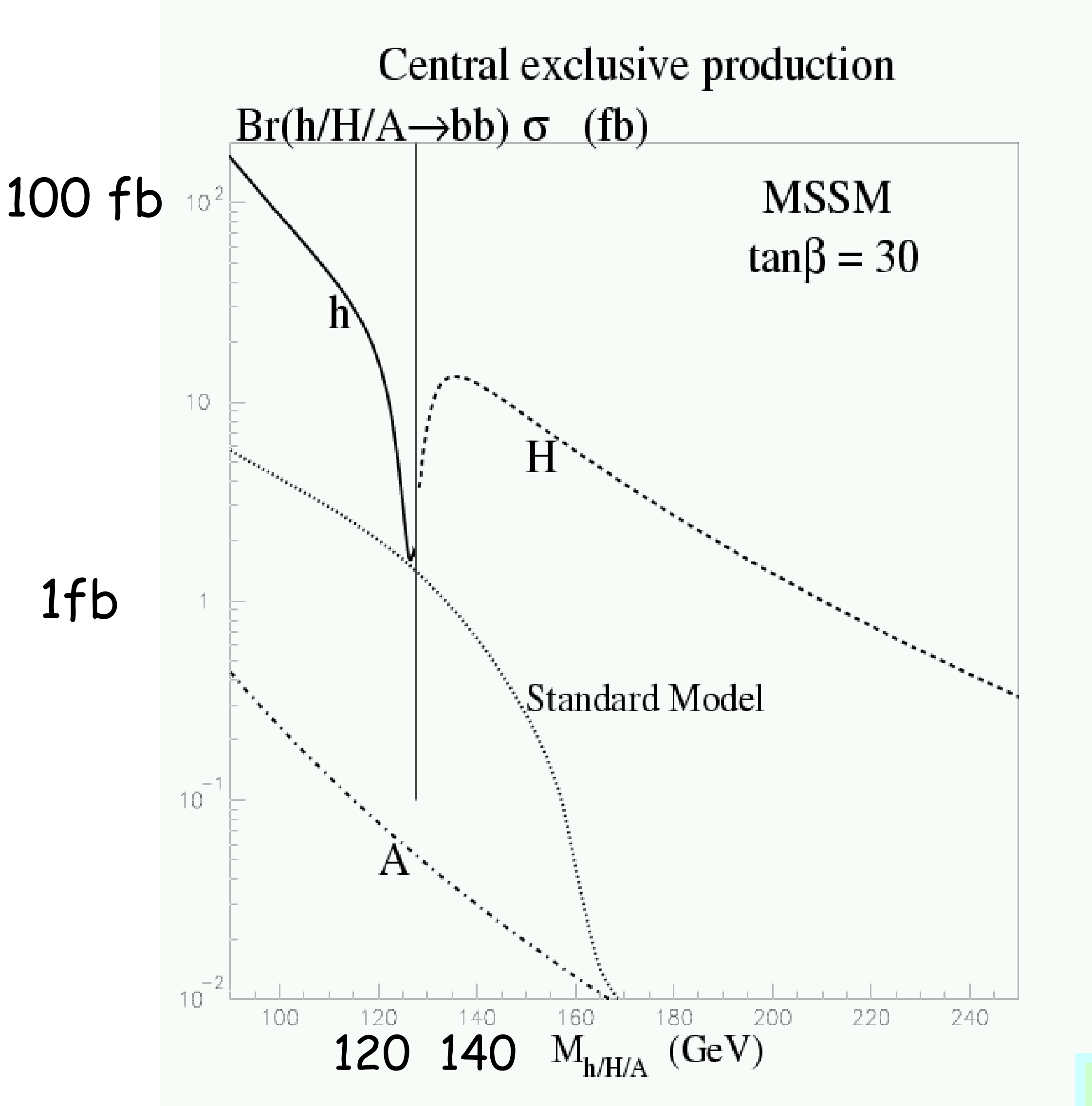
HERA-II precision?
HERA at lower energies (FL)
HERA-III (ed scattering)
Beyond HERA? (>2015)
Higher energy
Electron and or proton beams
e.g. LC on Tevatron,
CLICI (70 GeV)on LHC
→ kinematic range factor 10 larger

CLIC1 ?





MSSM Higgs



SM Higgs: ($30fb^{-1}$)
11 signal events
O(10) background events
See C. Royon

Cross section factor
~ 10-20 larger in MSSM
(high tanβ)

Kaidalov et al.,
hep-ph/0307064

⇒Study correlations between the outgoing protons to analyse the spin-parity structure of the produced boson

A way to get information on the spin of the Higgs

Beyond Standard Model

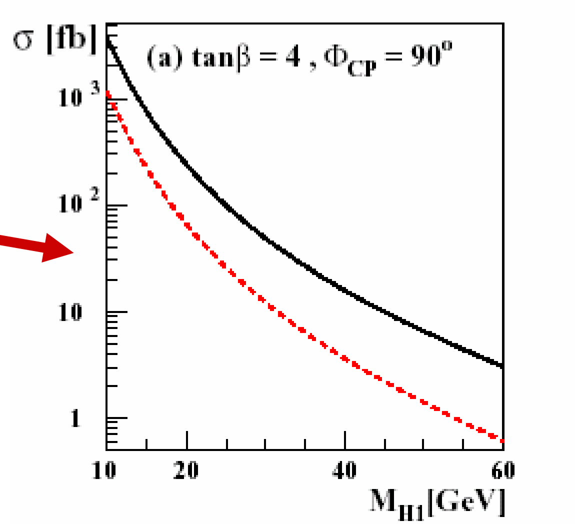
Diffractive production of new heavy states pp→ p + M + p

Particularly if produced in gluon gluon (or γγ) fusion processes

Examples:

Light CP violating Higgs Boson $M_H < 70$ GeV

B. Cox et al.



Light MSSM Higgs h→bb at large tan β

Light H,A (M<150 GeV) in MSSM with

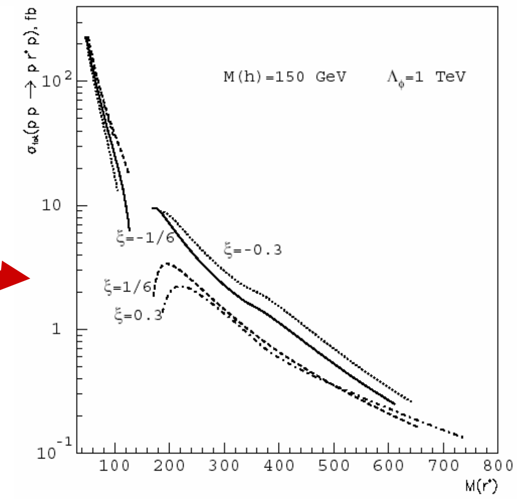
large tan β (~ 30) → S/B > 10

Medium H,A (M=150-200 GeV) medium tan β?

V. Khoze et al.

Radion production - couples strongly to gluons

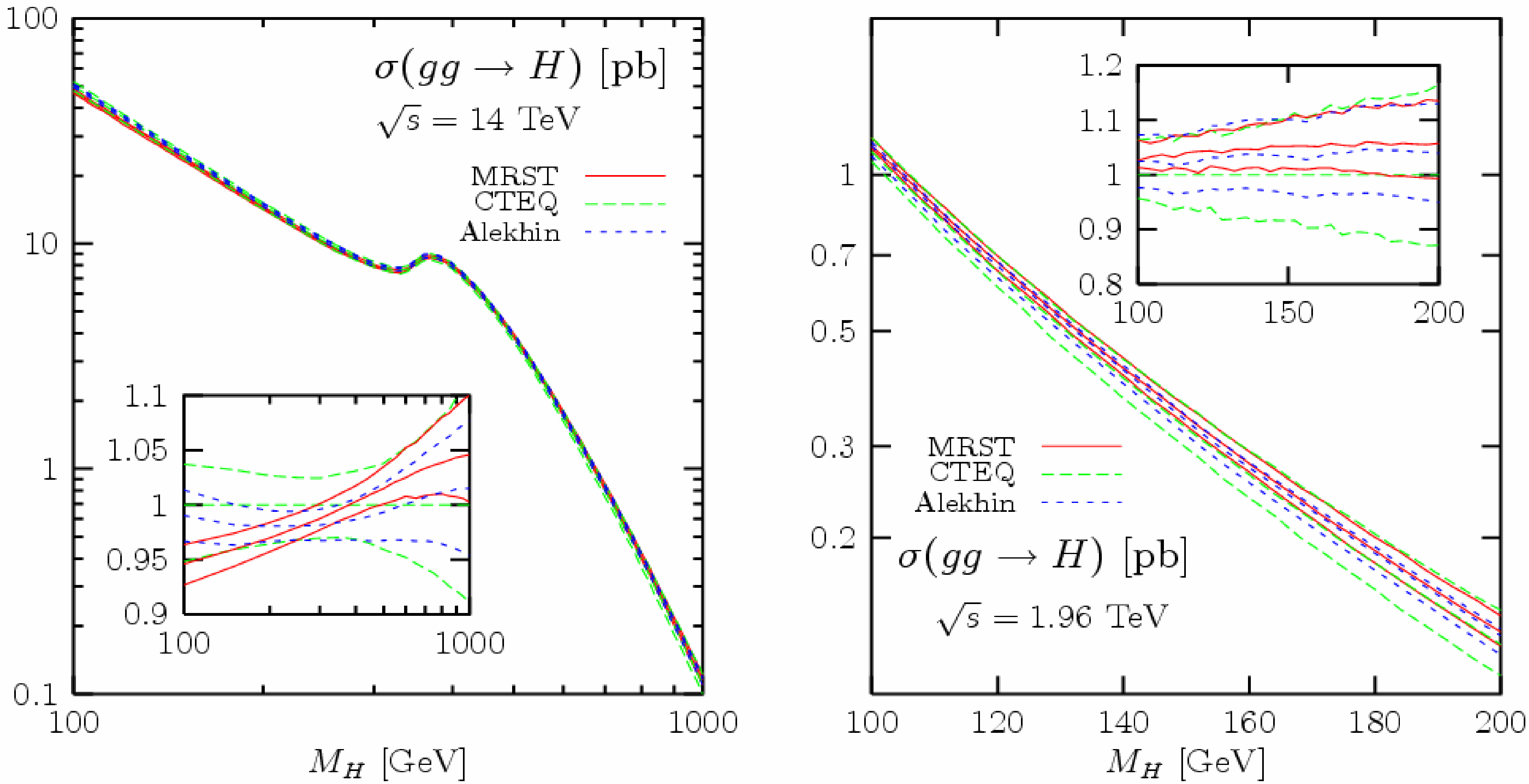
Ryutin, Petrov



Exclusive gluino-gluino production?

Only possible if gluino is light (< 200-250 GeV)

V. Khoze et al.



Djouadi & Ferrag, hep-ph/0310209