HERA and the LHC

2nd workshop on the implication of HERA for LHC physics

- **Highlights of 1st workshop !!!**

  "…The mechanic, who wishes to do his work well, must first sharpen his tools …"

—Chapter15, "**The Analects**" attributed to Confucius, translated by James Legge.
(from X. Zu at DIS05)

- **News from the 2nd workshop**
- **Future**

HERA and the LHC - workshop

Many thanks to all conveners and authors !

CERN–2005–014
14 December 2005

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

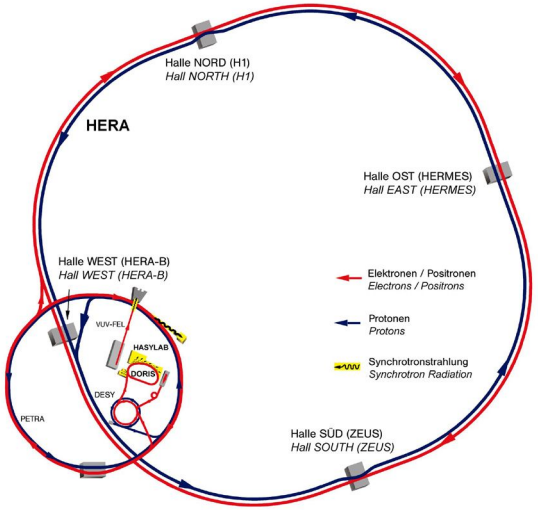
>650 pages

GENEVA
2005

Why HERA and LHC ?

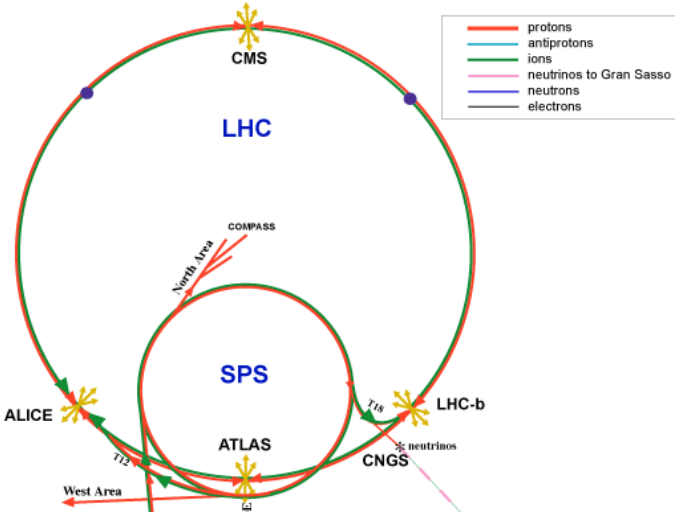
electron proton collider HERA
$\sqrt{s}$ = 320 GeV

proton proton collider LHC
$\sqrt{s}$ = 14 TeV



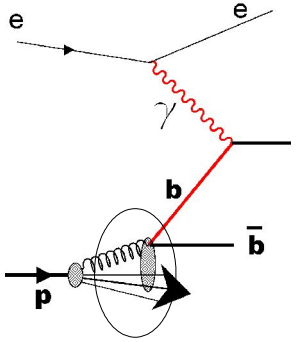
typical range

$$\sqrt{\frac{Q^2}{s}} \sim 0.01$$



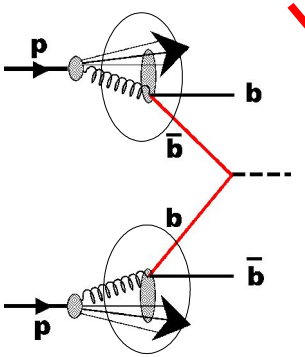
HERA: QCD
structure of the proton

LHC: Higgs, SUSY etc,
but mostly QCD...



$$\sqrt{\frac{Q^2}{s}} \sim 0.01$$

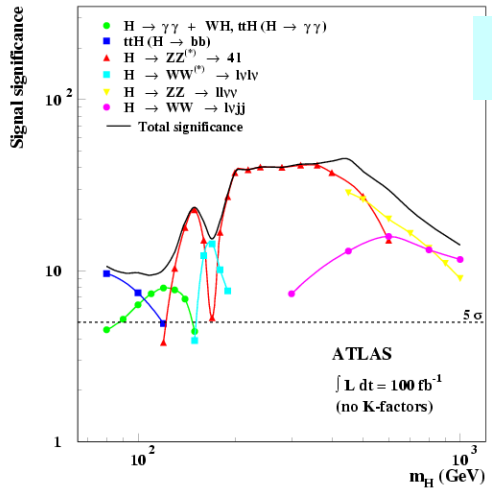
for $Q^2 \sim 10\ \mathrm{GeV}^2$



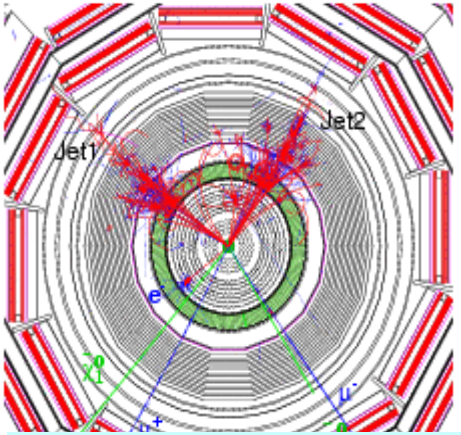
$$\sqrt{\frac{M^2}{s}} \sim 0.01$$

for $M \sim 140\ \mathrm{GeV}$

Physics at the LHC: examples

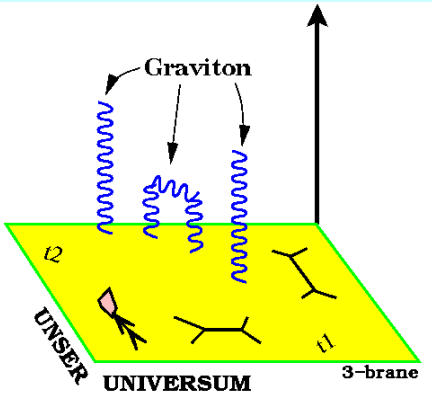


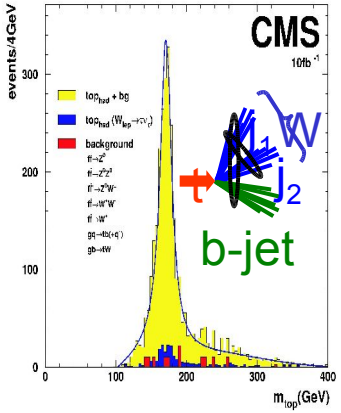
Higgs!



Supersymmetry?

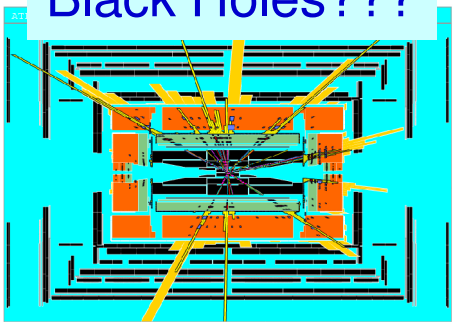
Extra Dimensions?



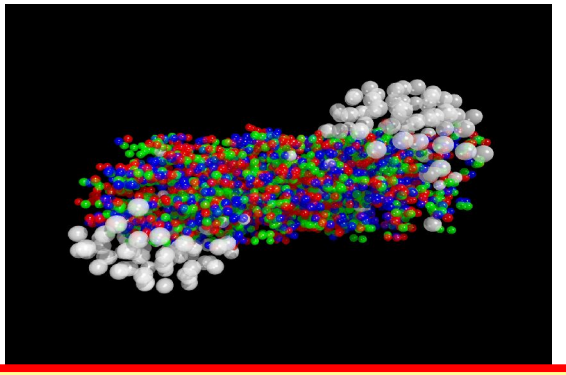


Precision measurements e.g top!

Black Holes???



QGP?



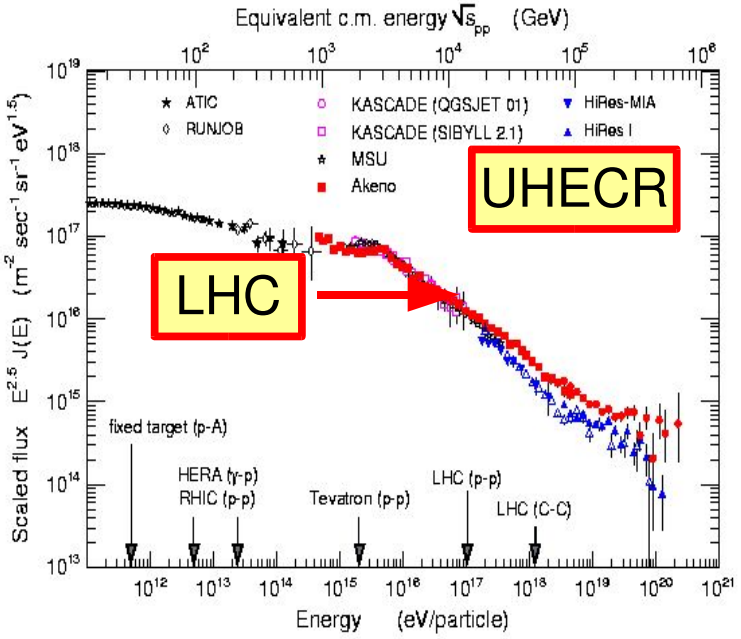
QCD is a MUST for all new physics !!!
best understanding of PDFs, jets, heavy quarks, diffraction and phenomenology is needed !!!

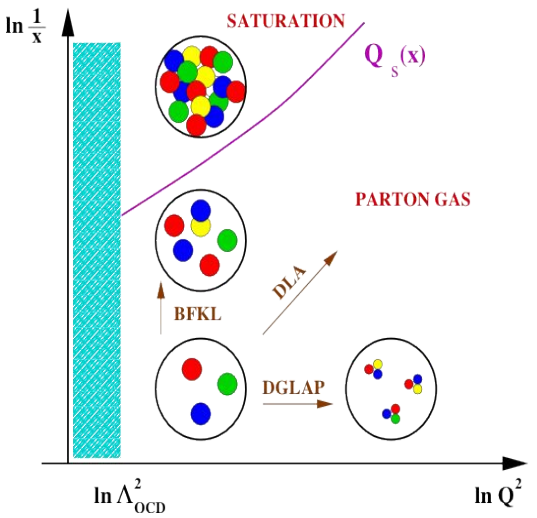
Physics at the LHC: other examples

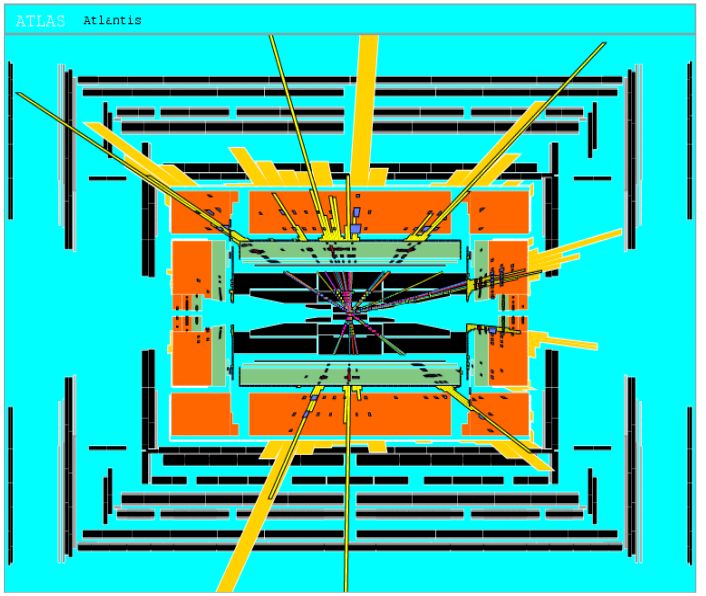
High energy hadron showers

Color glass Condensate

Multi Jet event:
Is it Multiple Interaction
or Black hole production







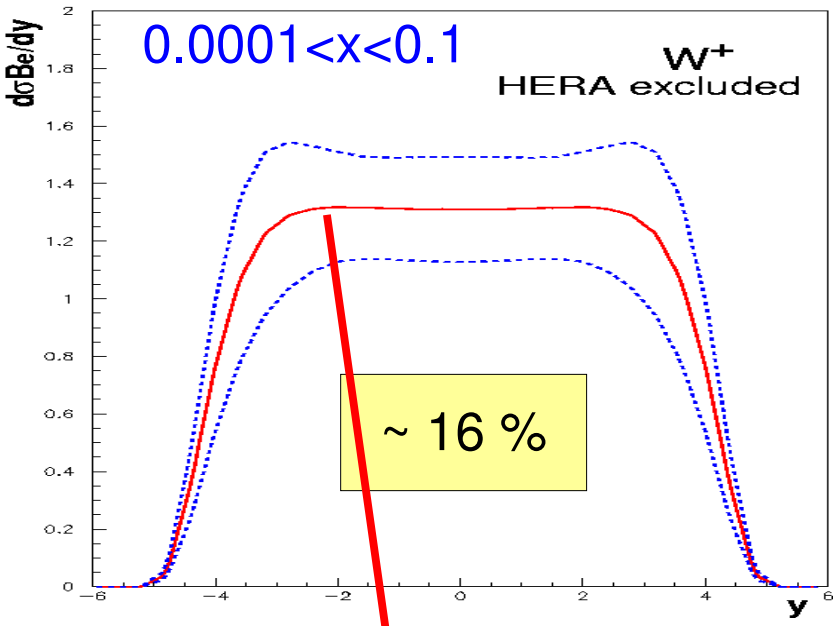
QCD @ LHC in its own!!!

High scale QCD, jets, UHECR, smallest x,

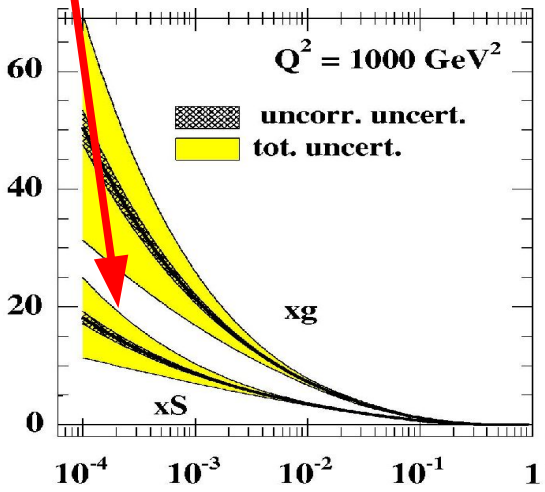
parton saturation - new phase in QCD - non-linear phenomena

Does LHC really need HERA ?

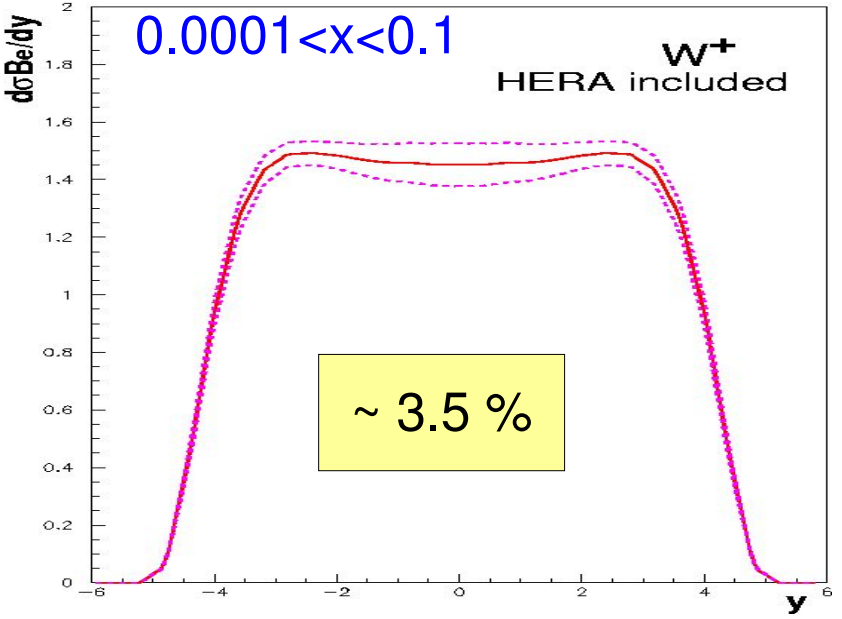
- W prod. at LHC without HERA:



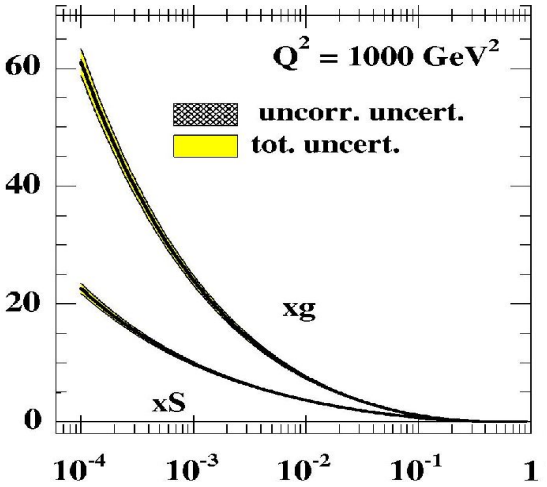
- PDFs without HERA:



- W prod. at LHC including HERA



- PDFs including HERA:



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)

1st workshop	March 2004 CERN - March 2005 DESY (~ 150 participants)
2nd workshop	6-9 June 2006 CERN (~ 120 participants)

How well did we do ?????

From 1st to 2nd 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.
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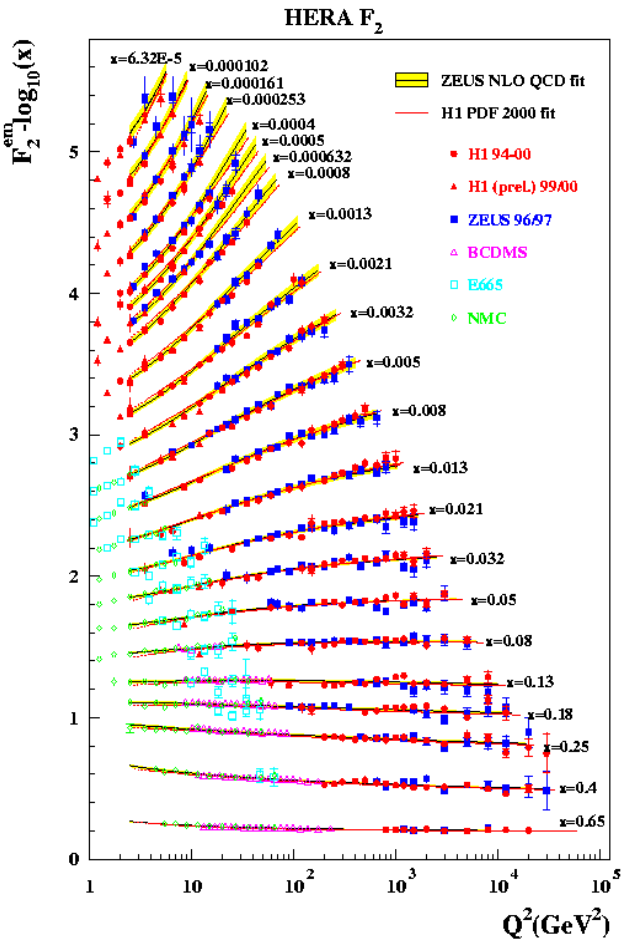
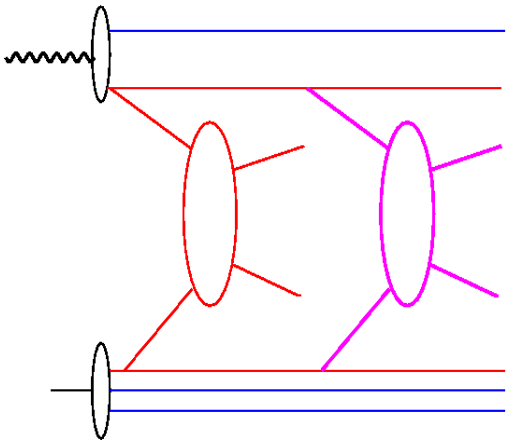
Working Groups of the workshop



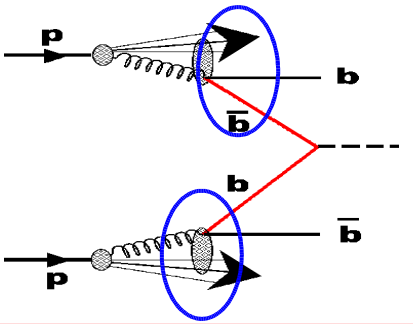
Structure functions and parton distributions

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



Multijets & final states Underlying events, un-integrated pdfs

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

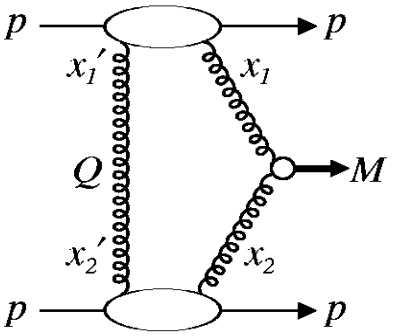


Heavy quarks: B quark pdfs of the proton, fragmentation fct, u-pdfs

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

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

Topics

Parton Density Functions and all that...

(assuming we have the proper theory)

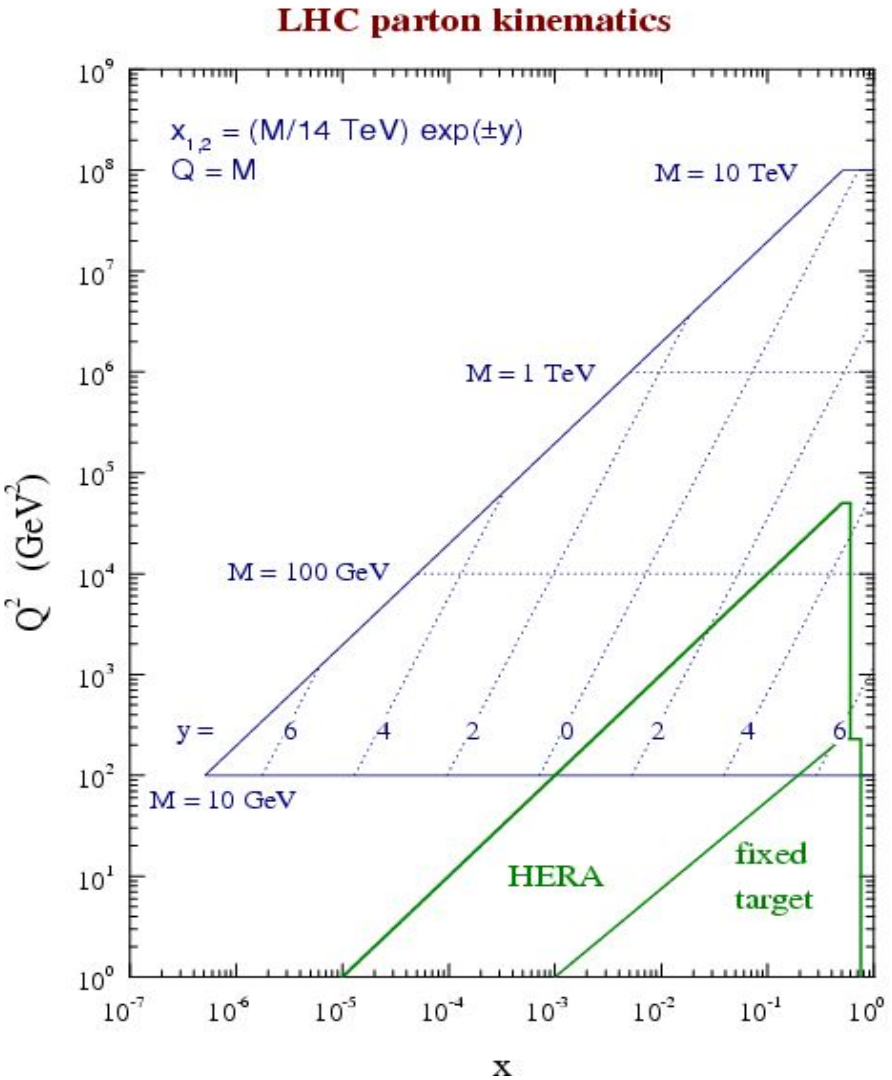
Event Topologies and all that ...

(going beyond the well known ...)

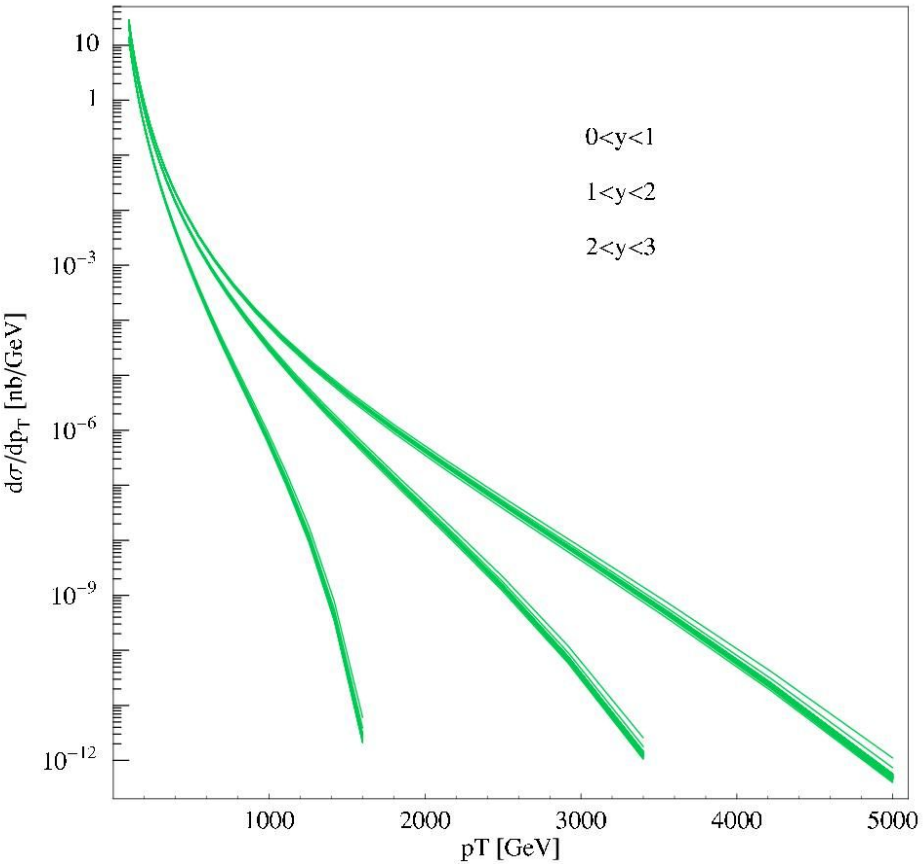
we had 17 plenary talks
80 parallel talks
cannot cover all...

Parton Density Functions and all that

- collinear PDFs



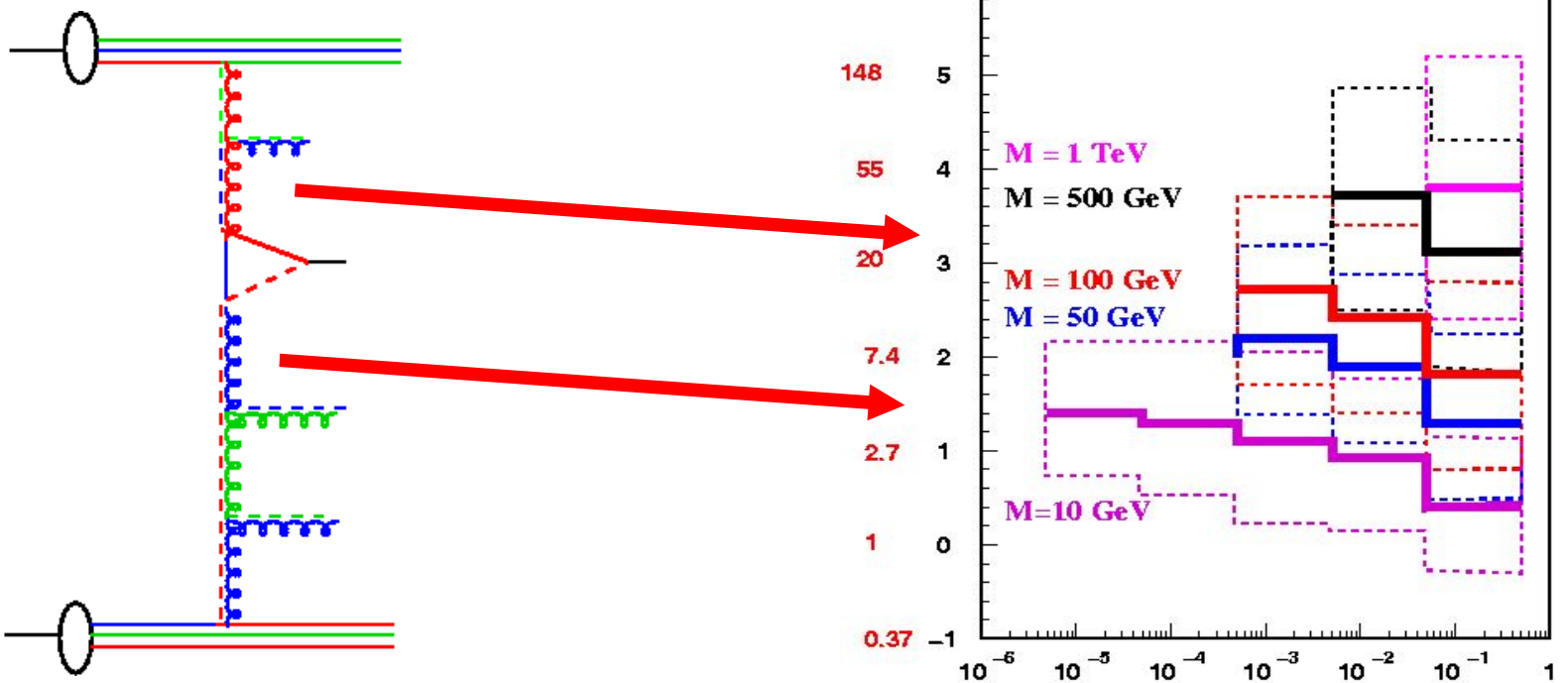
inclusive jet xsection



Parton Density Functions and all that

- collinear PDFs
- uPDFs (single and double unintegrated)

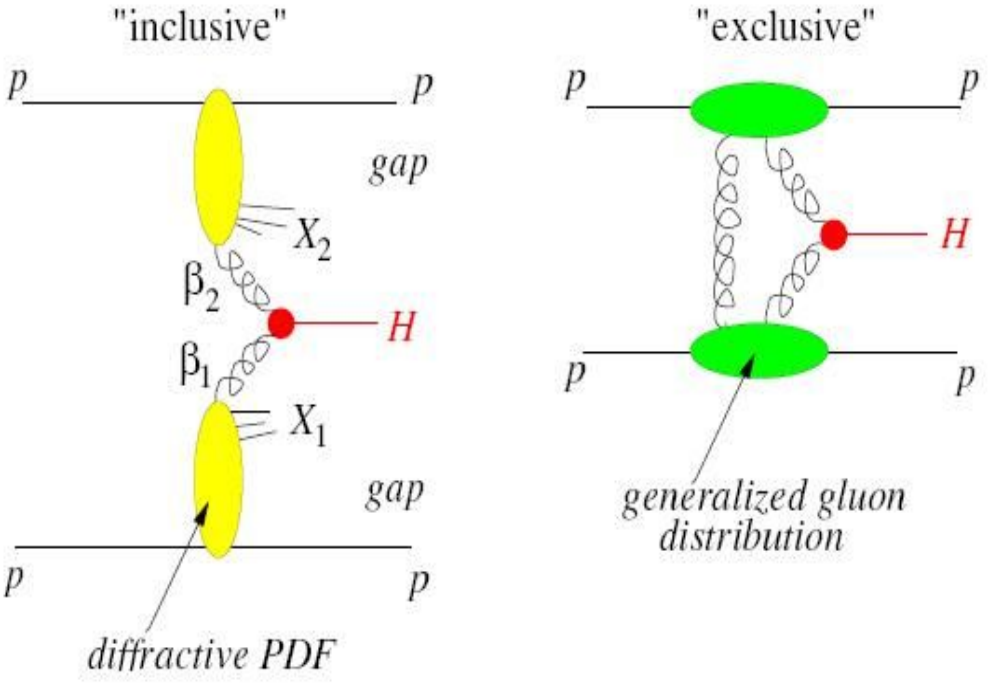
Higgs production et al



Parton Density Functions and all that

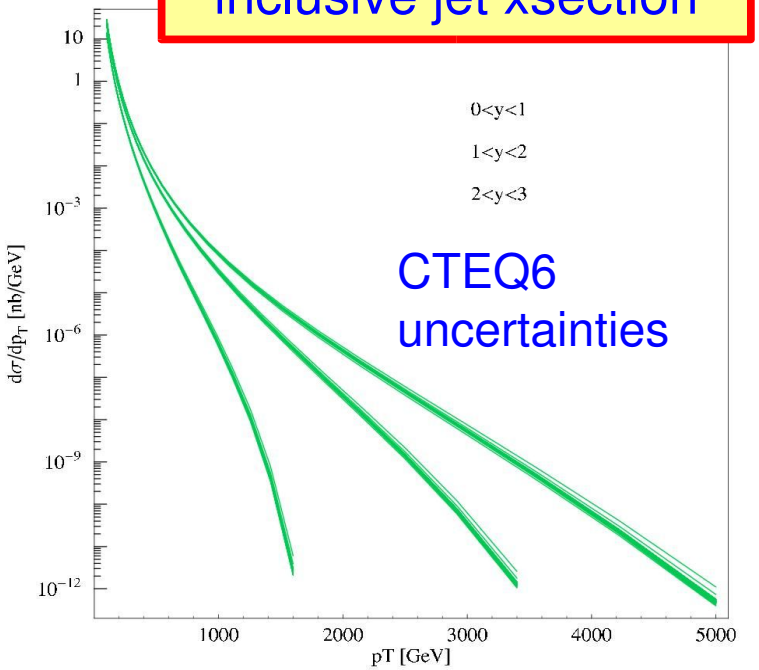
- collinear PDFs
- uPDFs (single and double unintegrated)
- diffractive and generalised PDFs

Exclusive Higgs production



Why precise PDFs for LHC

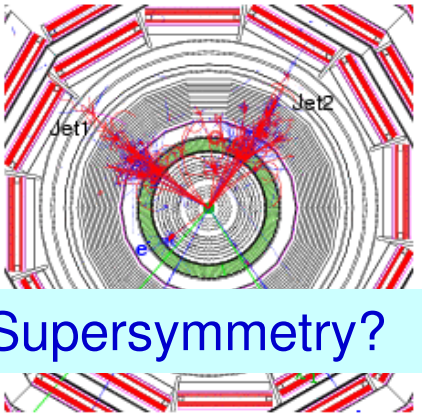
inclusive jet xsection



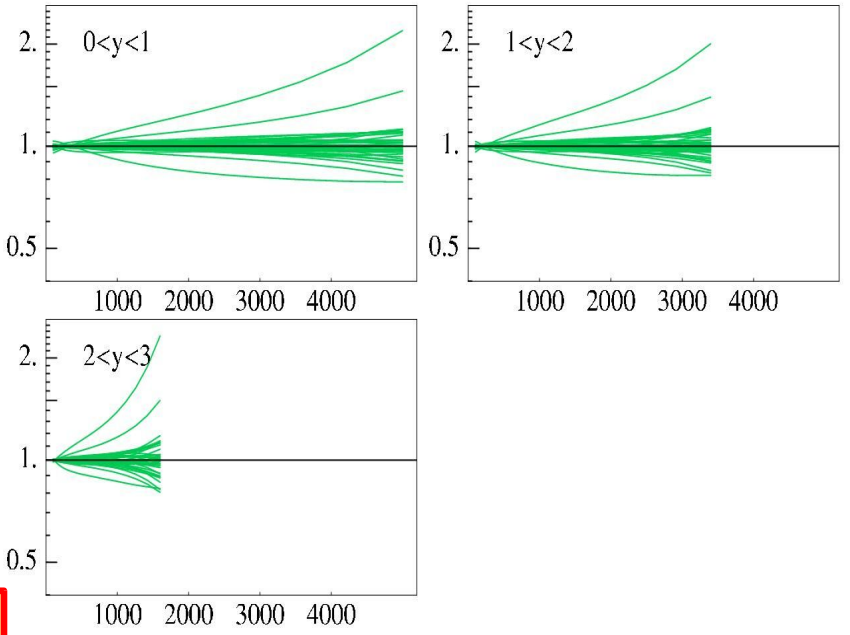
D.Stump et al hep-ph/0303013

Signature for new physics
➔ jet x-section

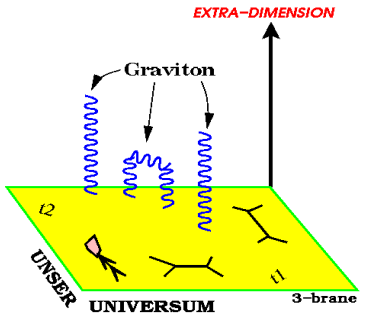
Discovery potential depends on precise PDFs



Supersymmetry?



Extra Dimensions?

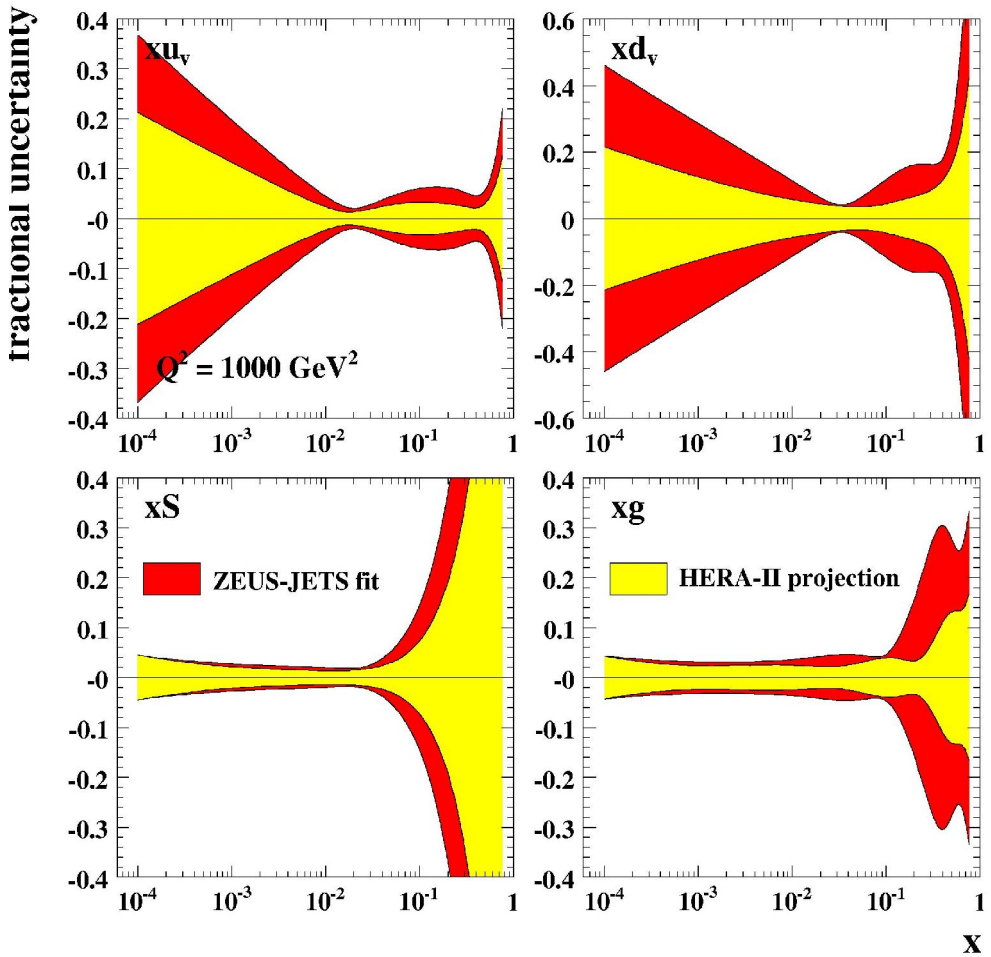


Precision determination of PDFs needed ... understanding QCD is the key to new physics

PDF uncertainty: improvements

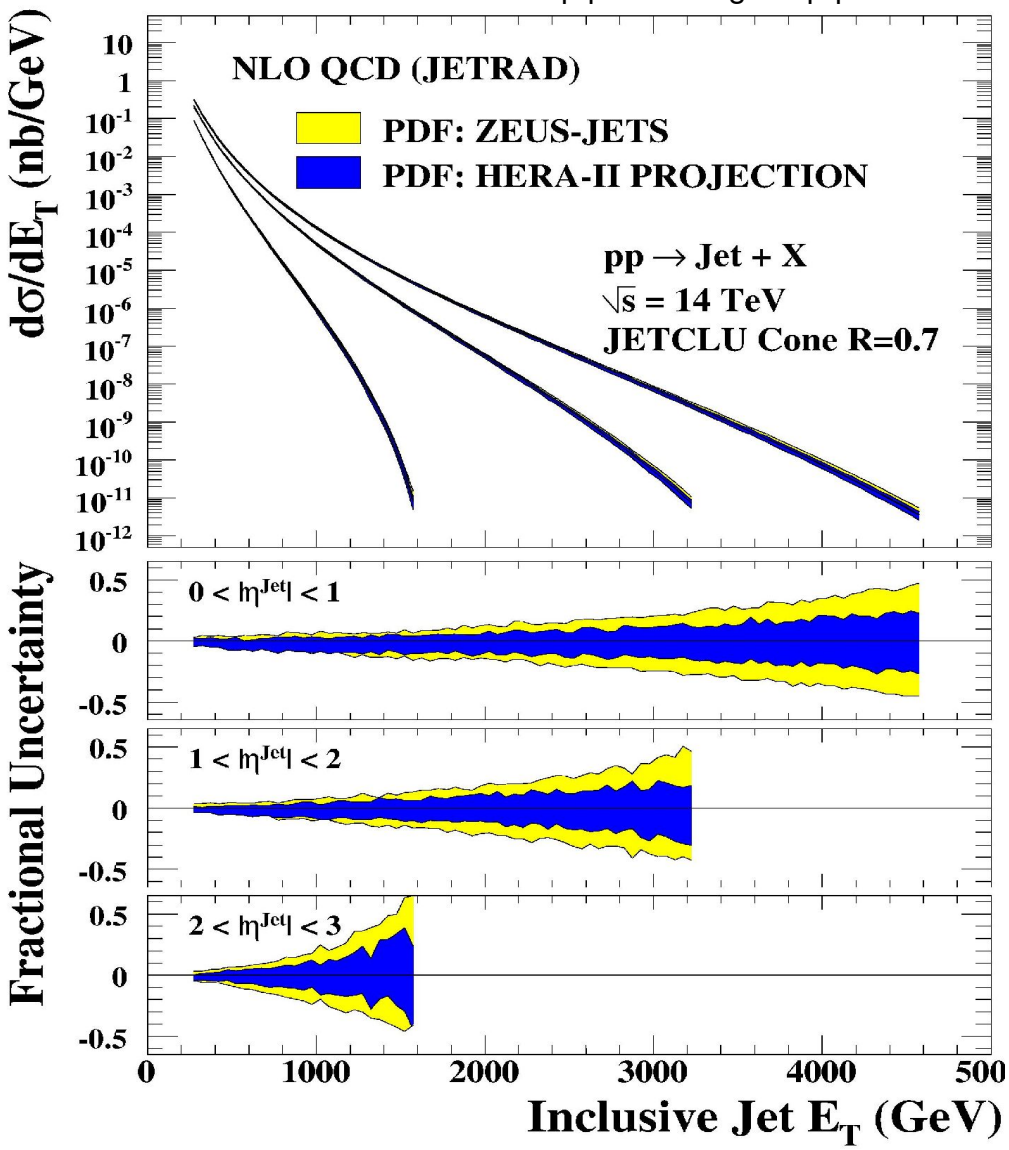
Using jets together with F_2 (at large Q^2)

quark and gluon uncertainties



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

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

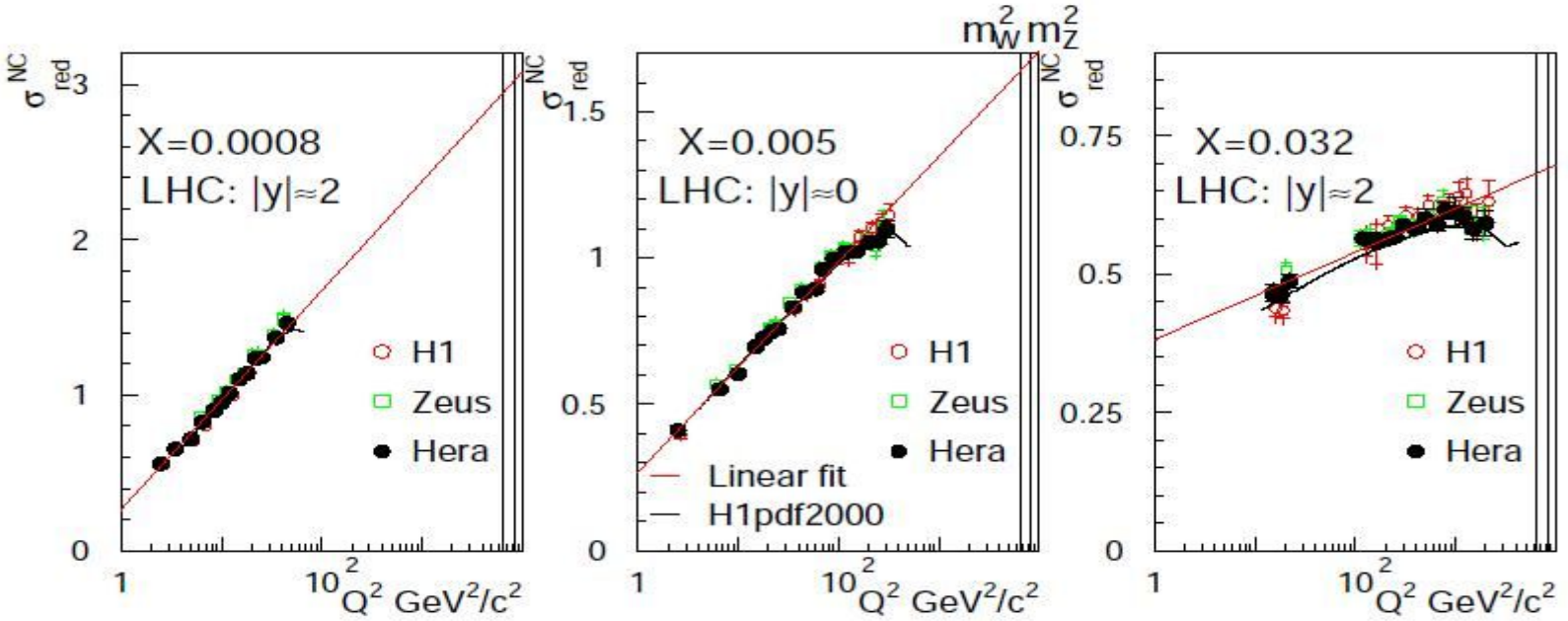


Error on LHC jet xsection reduced !!!

PDF from HERA to LHC

S. Glazov

F_2 extrapolation to W, Z mass



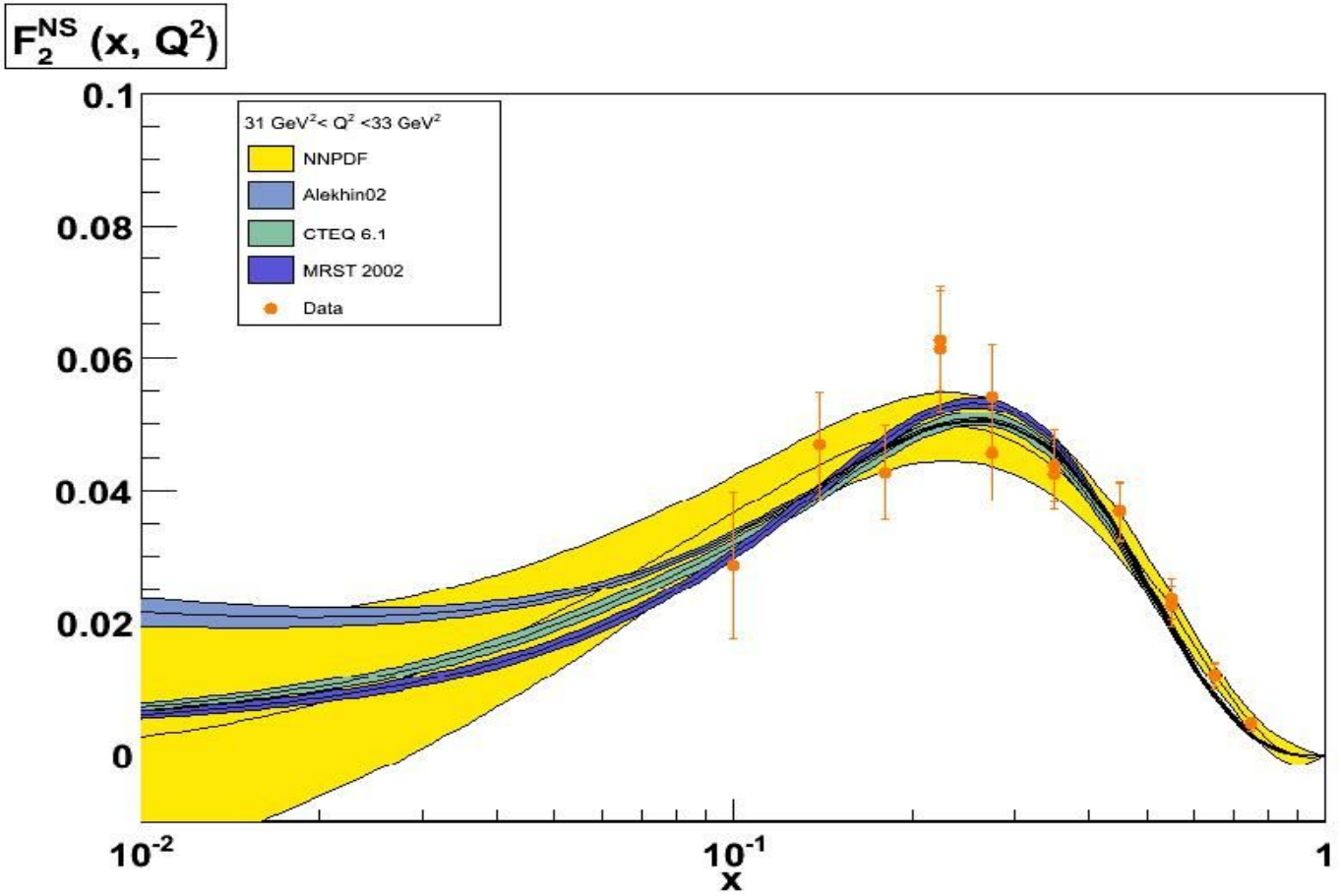
HERA data covers complete central rapidity range of LHC for W, Z production. "Leading order" predictions can be read directly from HERA data + linear extrapolation.

- Linear extrapolation to LHC ... nothing NEW in between ?

PDF fits

A. Piccione, S. Forte et al

- PDF fits using Neural Networks at NLO including errors



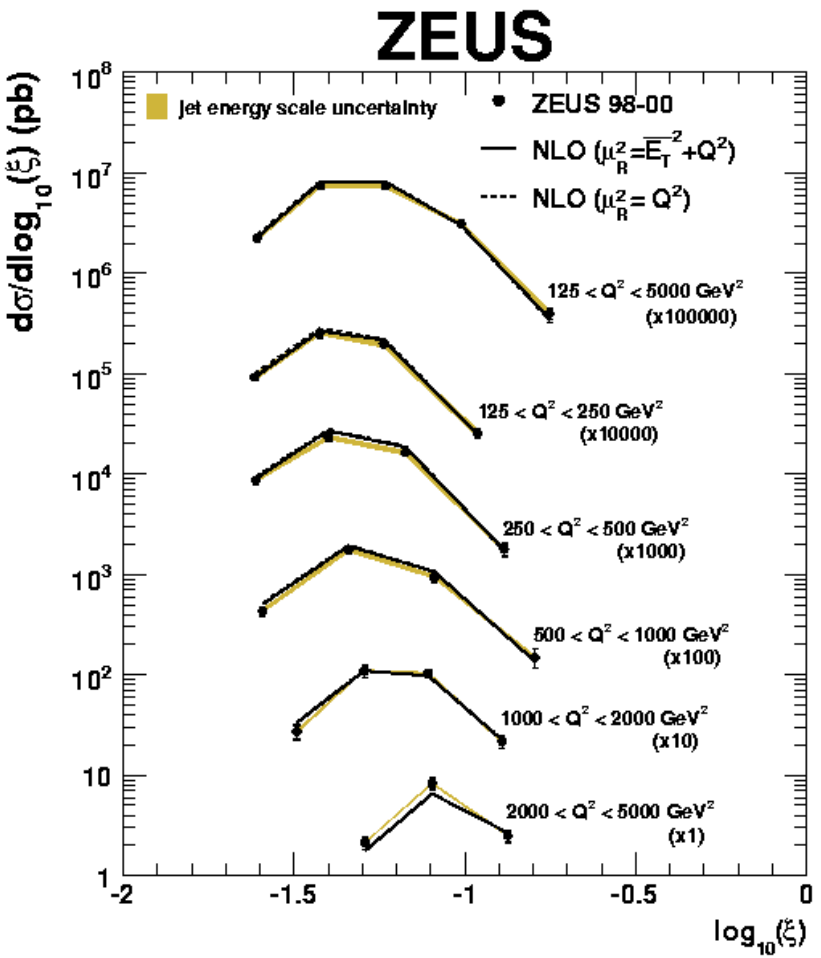
similar claims
also from V. Blobel
- uncertainties are larger !!!!

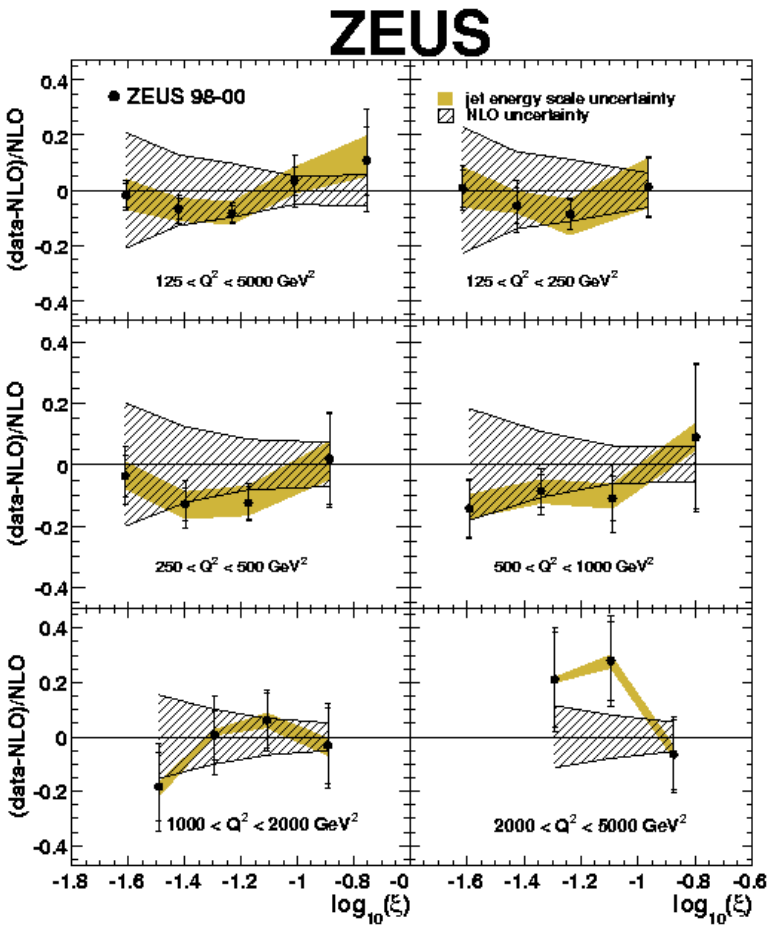
- provides faithful combination of experimental errors
- allows faithful propagation of errors on computed observables
- Aim: singlet set from DIS data until Dec 2007, singlet set from DI+DY April 2007

Dijets and PDFs

T. Schoerner-Sadenius

- ZEUS dijets at large $Q^2 > 125\ GeV^2$: $\log(\xi)$ in Q^2 bins





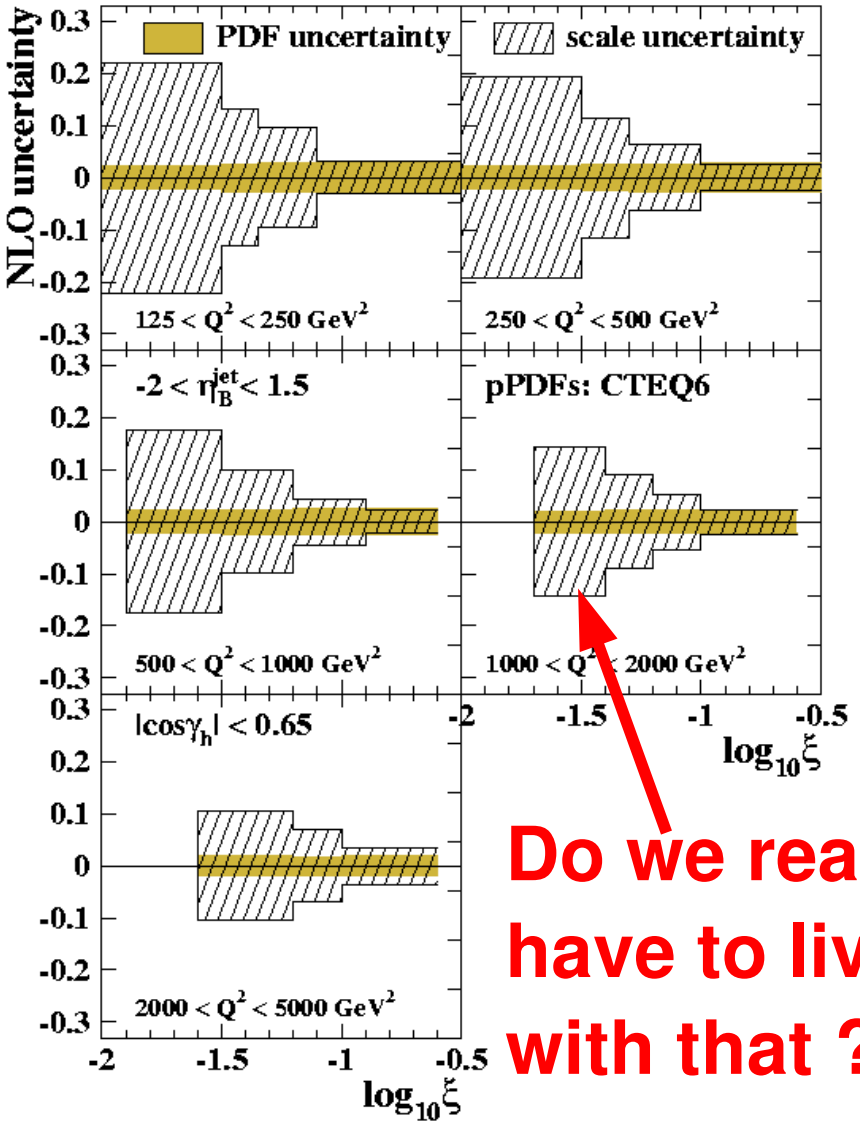
¶ Also double-differential data well described by NLO.

¶ Still large theoretical uncertainties; at high Q^2 statistics getting low.

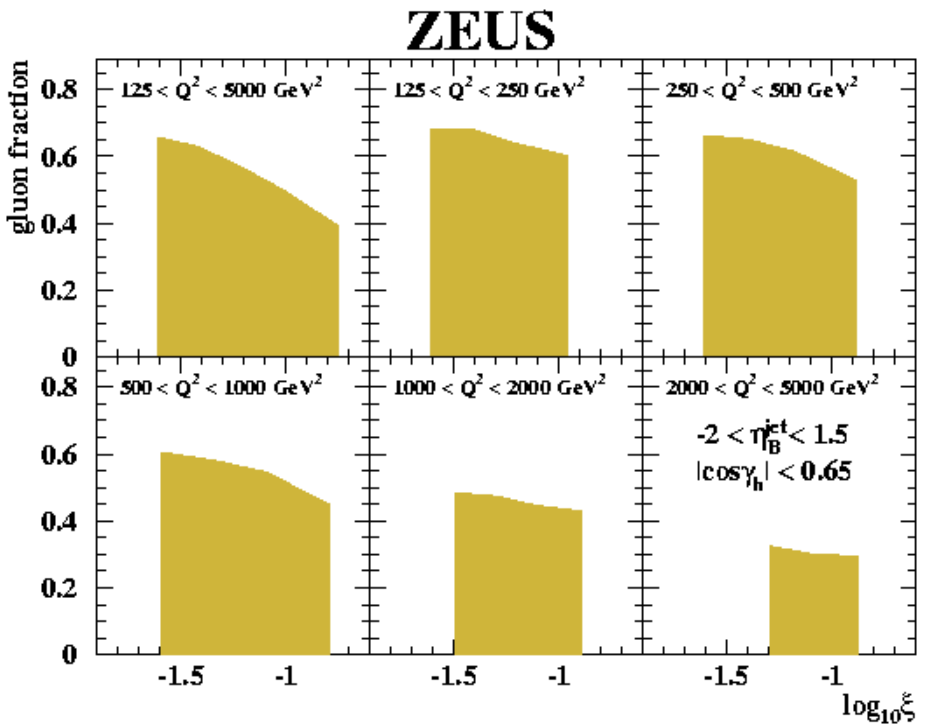
DIJETS: theory uncertainty and gluon fraction

T. Schoerner-Sadenius

– scale uncertainty 5-20%, large at small ξ.
– PDF uncertainty ≤3%, significant at high ξ.



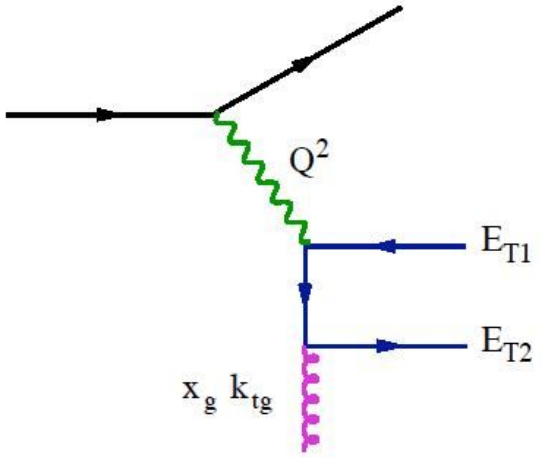
Do we really have to live with that ?

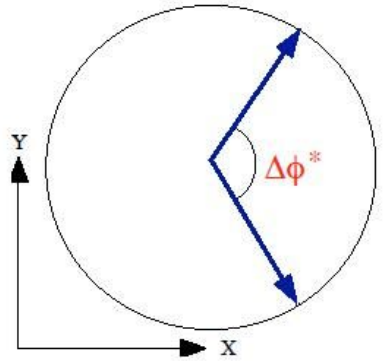


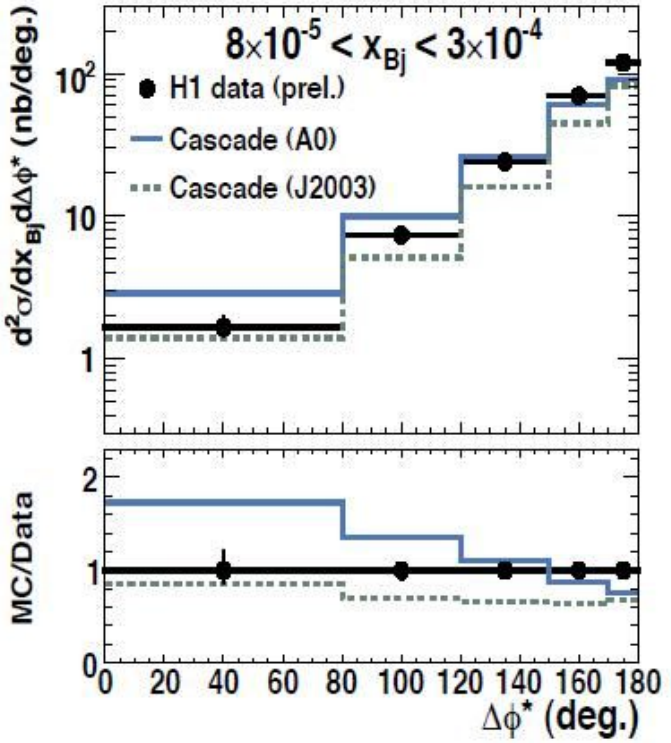
- gluon fraction decreases with increasing ξ and Q^2.
- still substantial gluon contribution
- **use it in NLO QCD fits of PDFs.**

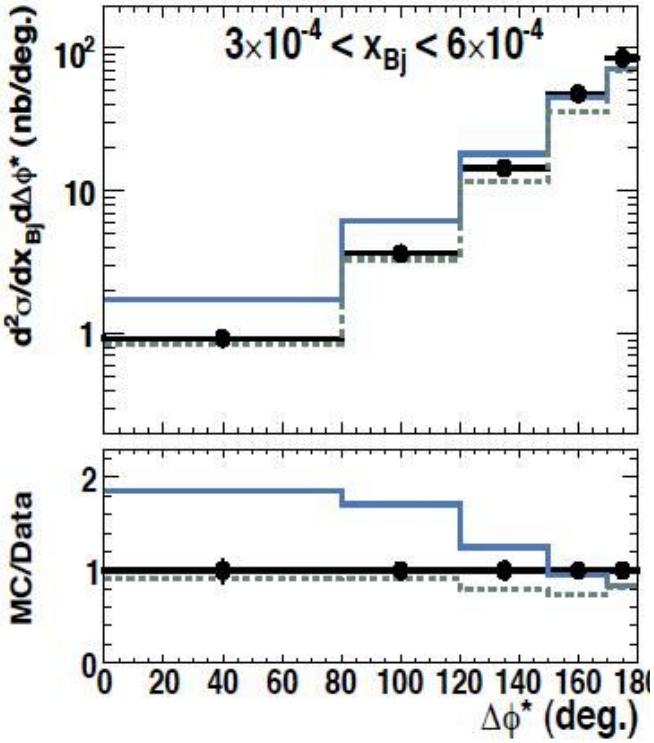
Dijets and PDFs: azimuthal correlations

D. Traynor









- Sensitive to higher order contributions $\mathcal{O}(\alpha_s^3)$ and higher ????

➔ check calculations, resummations needed ?

- Sensitivity to unintegrated gluon density (uPDFs)

➔ use it in fits to uPDFs

Sensitivity of HERA D* measurement

P. Thompson

- Effective x range increase with mass

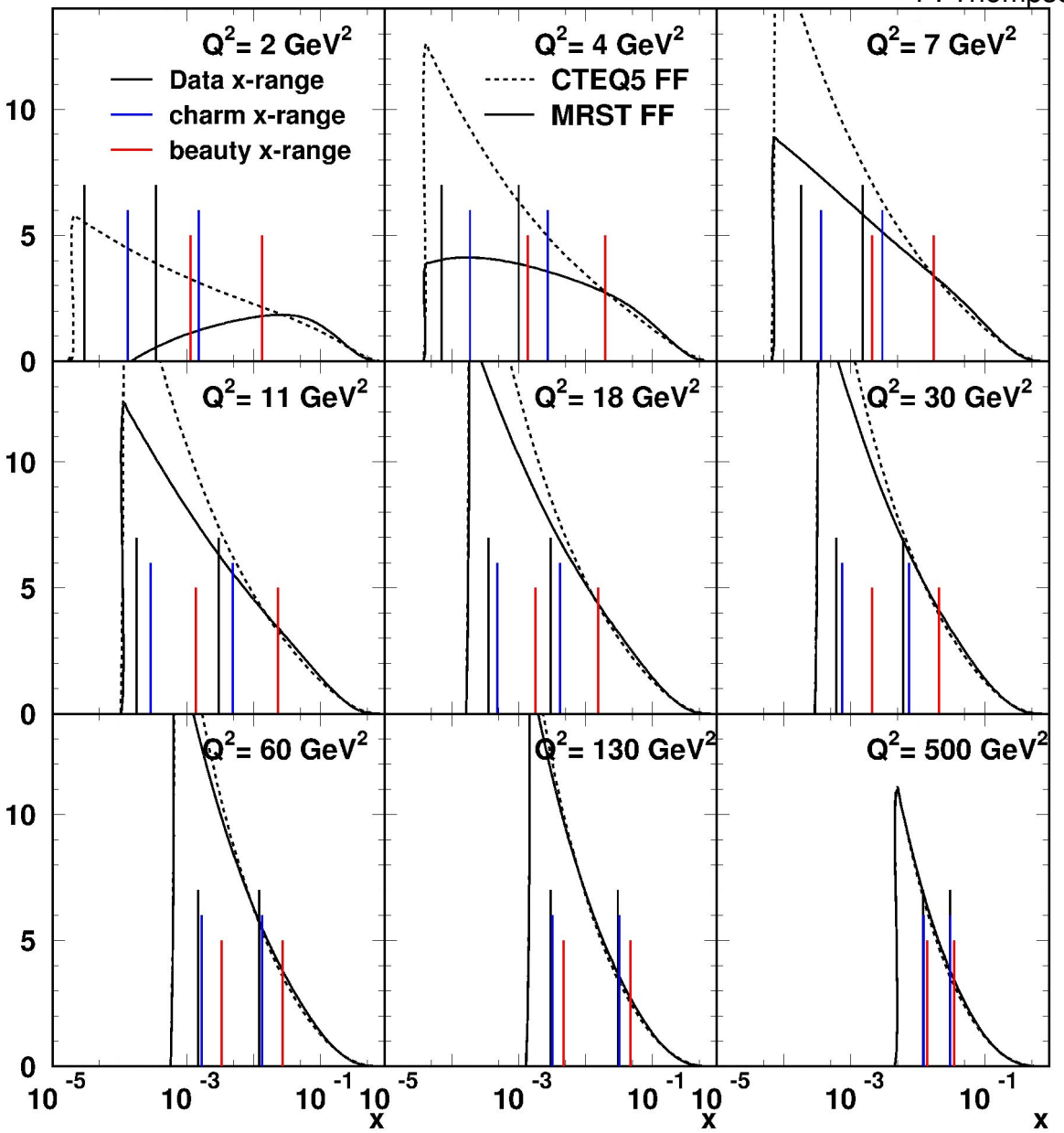
$$x' = x\frac{Q^2 + M^2}{Q^2}$$

- vertical lines show
  black - HERA charm data
  blue – effective charm x
  red – effective bottom x

- large range at small Q^2

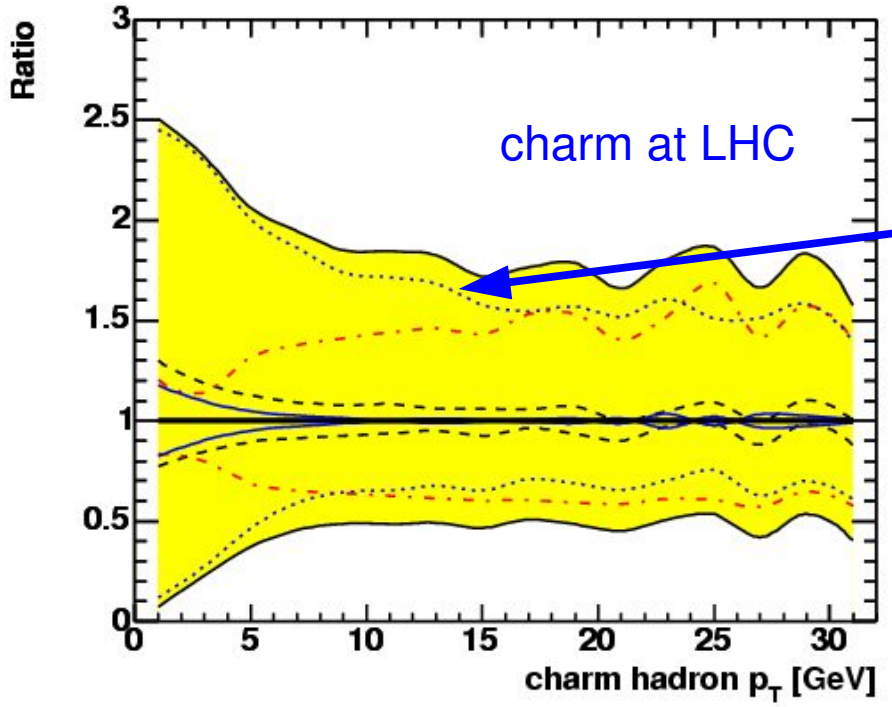
- Note that HQ x-section is a convolution of ME with gluon density

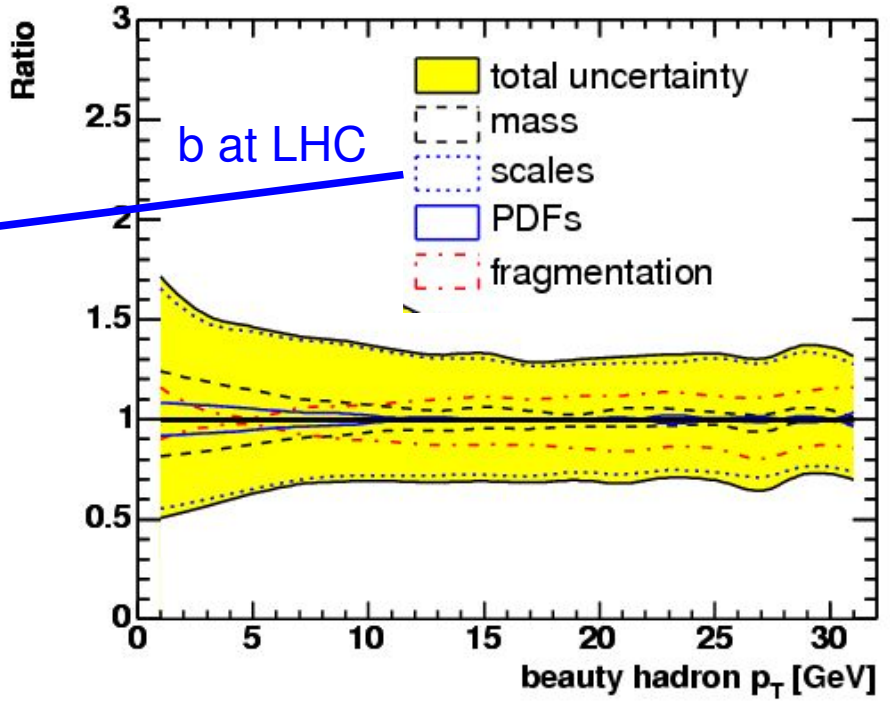
- **use it for PDF fits**



Uncertainties in HQ production

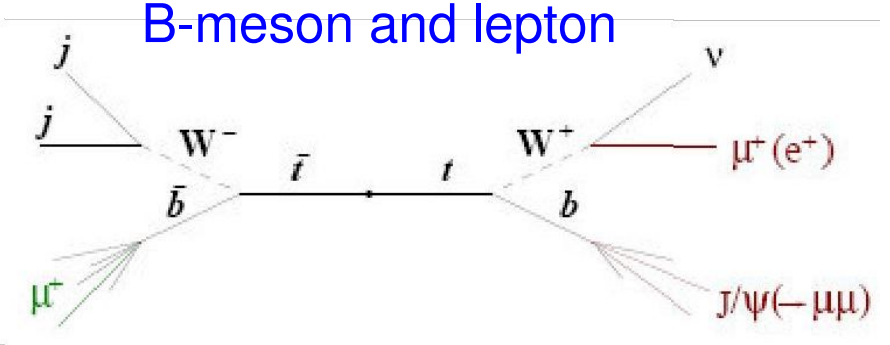
A. Mitov





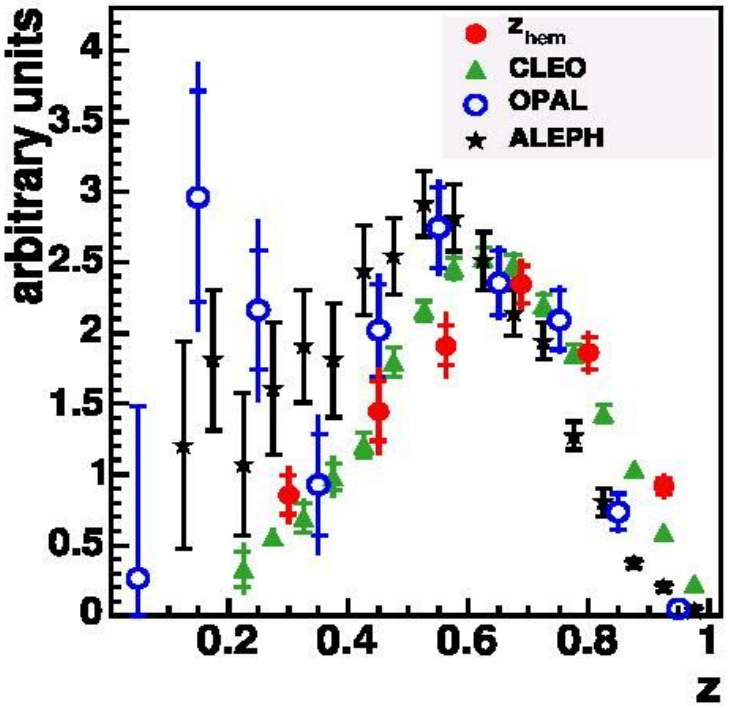
- Leading uncertainties are:
  - ➔ scales & fragmentation
- Can these uncertainties be reduced ?
  - ➔ pert. corr. known to NLO. NNLO is hard, but feasible (work started...)
  - ➔ fragmentation is presently refined at NLL level

- Important also for top mass measure:
  B-meson and lepton



Fragmentation Functions (Exp)

- for complicated final states: interface FMNR x PYTHIA (A.-E. Nuncio-Quiroz)
- experimental determination of Fragmentation Functions Z. Rurikova



H1 hemisphere method
$<\sqrt{\hat{s}}> \approx 8$ GeV,
$z = \frac{(E+p_L)_{D^*}}{\sum_{hem}(E+p)}$

CLEO $\sqrt{s} = 10.6$ GeV,
$z = p_{D^*}/p_{max}$

OPAL $\sqrt{s} = 91.2$ GeV,
$z = 2E_{D^*}/\sqrt{s}$

ALEPH $\sqrt{s} = 91.2$ GeV,
$z = 2E_{D^*}/\sqrt{s}$

- ▷ different observable definitions
- ▷ different center of mass energies, thus different pert. components as well

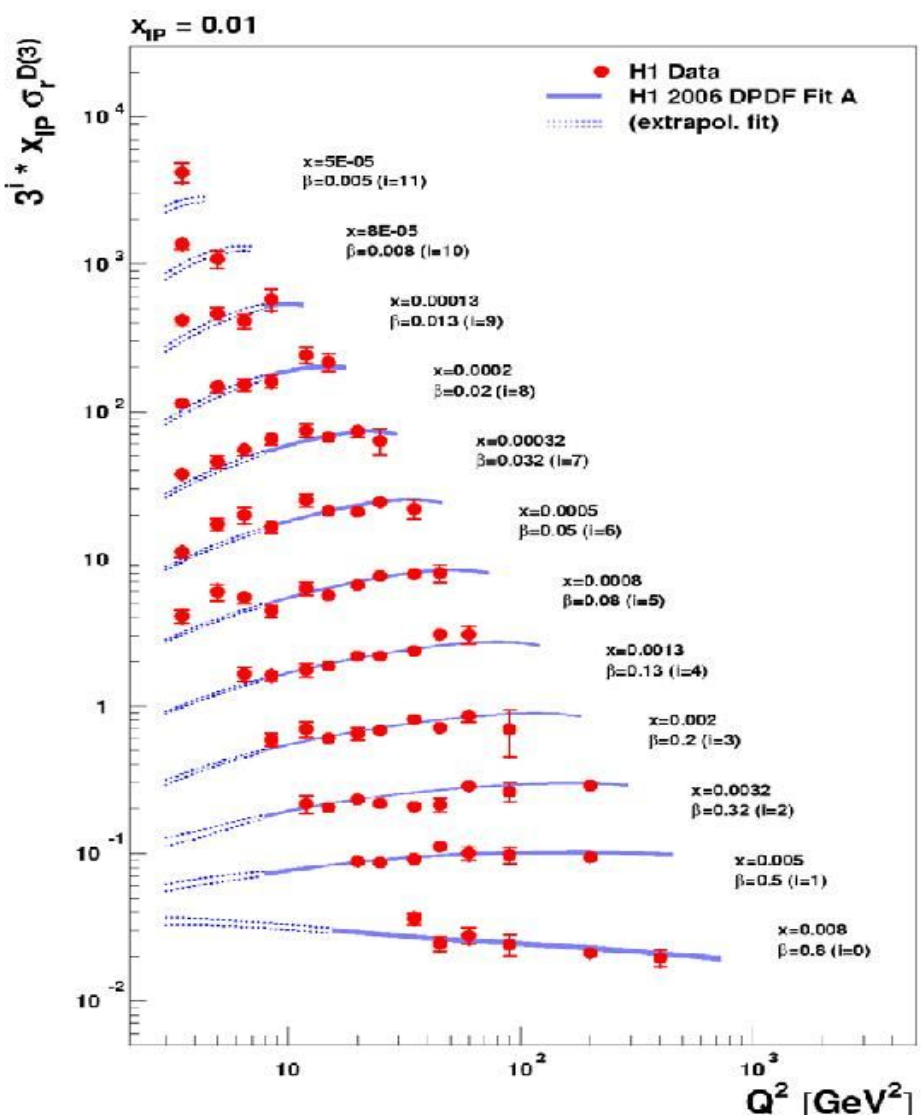
$\Longrightarrow$ **Direct shape comparison impossible!**

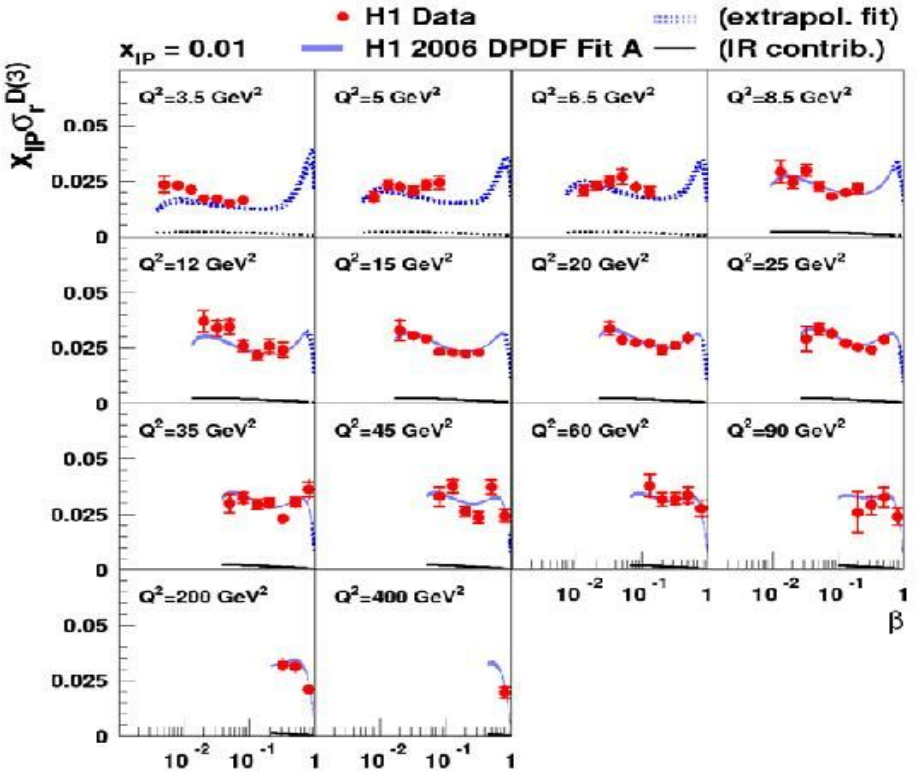
- will provide valuable input for NEW upcoming NLL calculations

Diffractive PDFs

P. Newman

LRG Data at e.g. x_{IP}=0.01 (a diffractive F_2!)





- Q^2 and x (= β x_{IP}) dependence at fixed x_{IP} … QCD structure
- Precision in best regions … 5% (stat.), 5% (syst) 6% (norm)

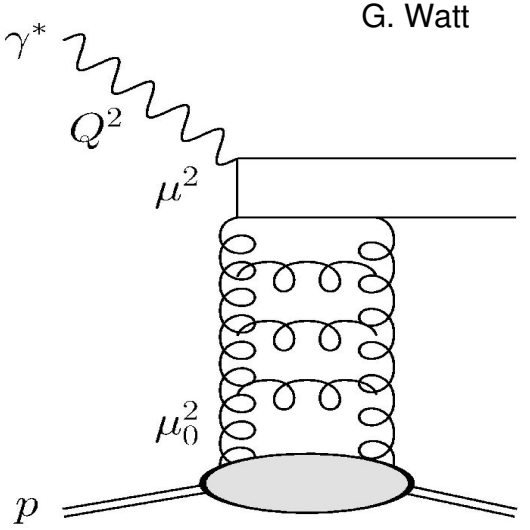
A more complete approach

- Include direct ("hard perturbative") contribution in addition to factorizing component
- leads to additional inhomogeneous term in evolution

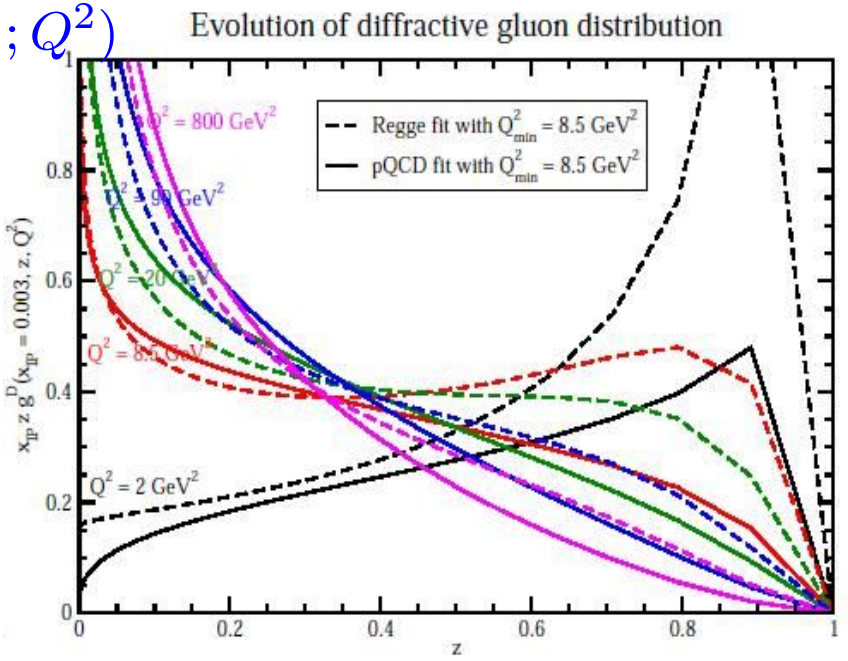
$$F_2^{\mathrm{D}(3)} = \underbrace{\sum_{a=q,g} C_{2,a} \otimes a^{\mathrm{D}}}_{\text{Resolved Pomeron}} + \underbrace{C_{2,I\!P}}_{\text{Direct Pomeron}}$$

$$\frac{\partial a^{\mathrm{D}}}{\partial \ln Q^2} = \sum_{a'=q,g} P_{aa'} \otimes a'^{\mathrm{D}} + P_{aI\!P}(z)\, f_{I\!P}(x_{I\!P}; Q^2)$$

G. Watt



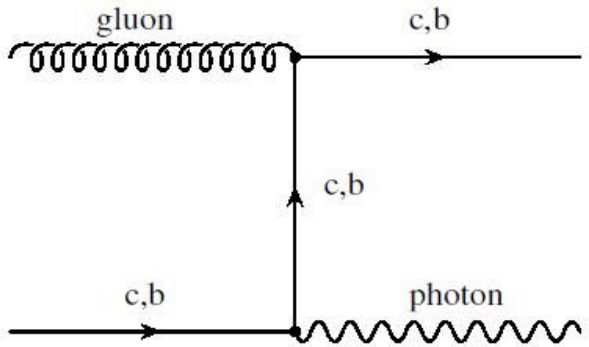
- Adding direct Pomeron component influences gluon at large z !!!
- **find a direct signal for direct component in data at HERA ?**

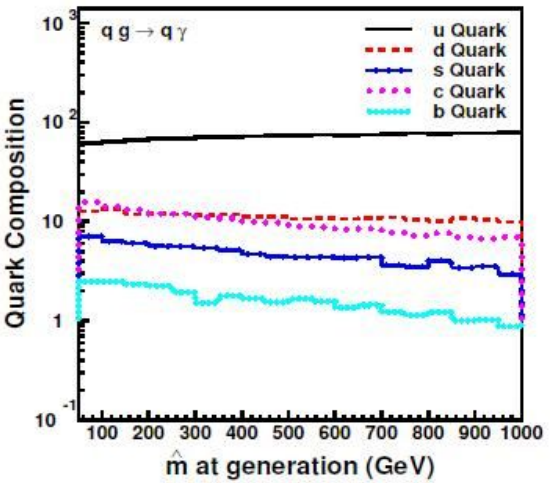


PDF determination at LHC

K. Mazumdar et al

- charm quark PDF



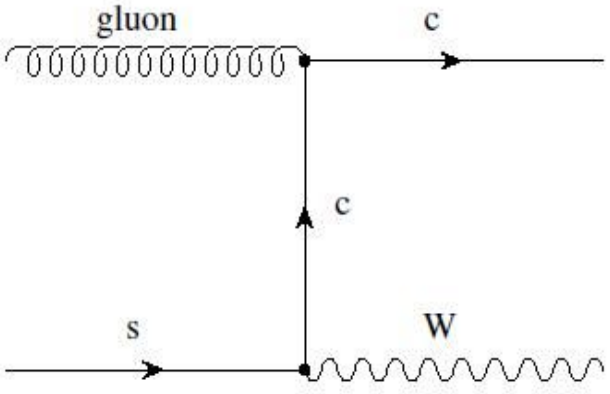


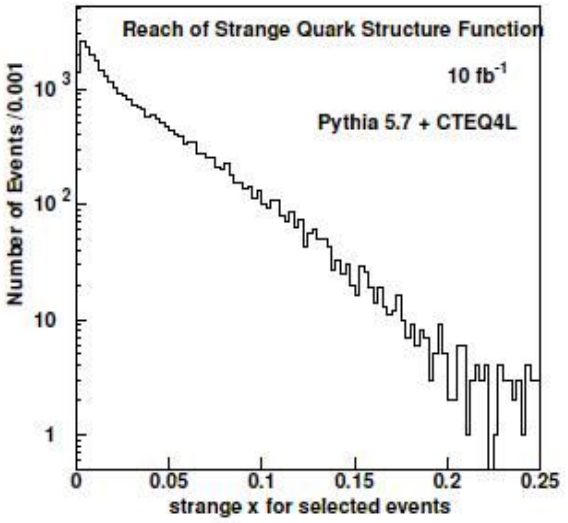
➔ ~ 10^5 c+b events in 10 fb^{-1} with p_t^{muon} >10 GeV

➔ x_c,x_b probed in $0.05<x_c,x_b<0.1$ with 10% stat.accuracy

- ∼ 20% of these γ+jet events are from $gc/b \to \gamma c/b$.
- Select semileptonic decays of heavy mesons in γ+jet events

- strange quark PDF





➔ x_s ~0.1 for 10 fb^{-1} with 10% stat. accuracy

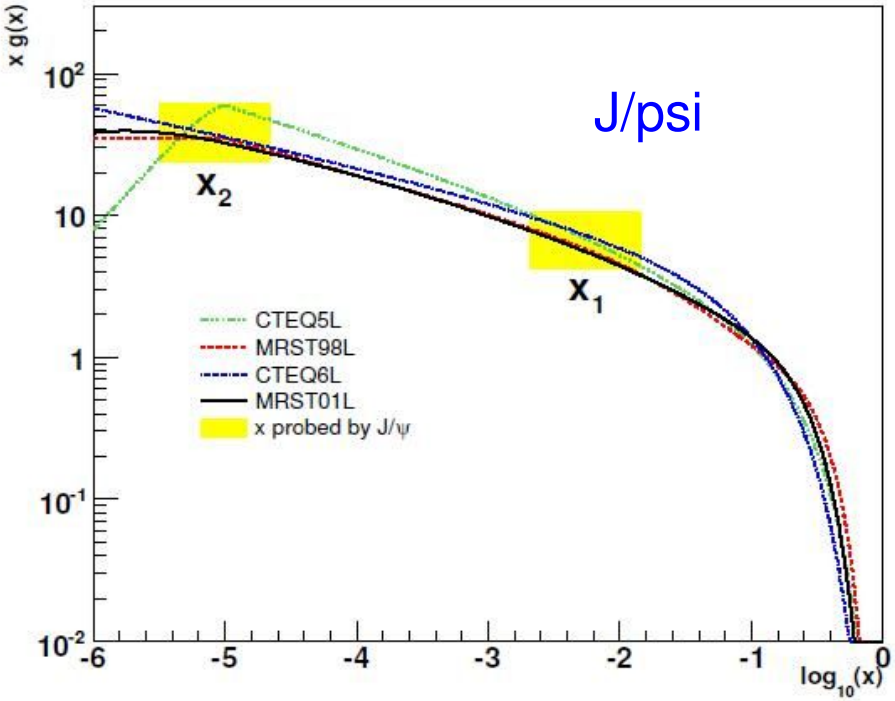
- need u,d uncertainties
- simulation of final state including frag.fct and PS

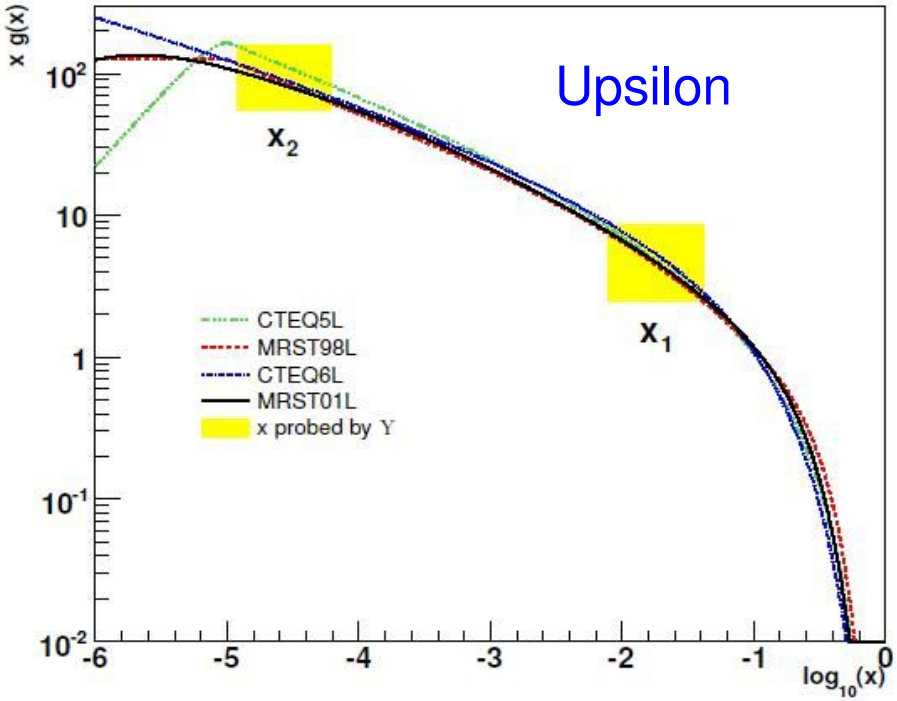
PDFs from quarkonia at ALICE

D. Stocco

study done for ALICE $J/\psi \Longleftarrow$ Region explored by $(2.5 < y < 4)$ $\Longrightarrow \Upsilon$

Here using ColorEvapoartionModel....
What about the other approaches (NRQCD, kt-factorization) ?

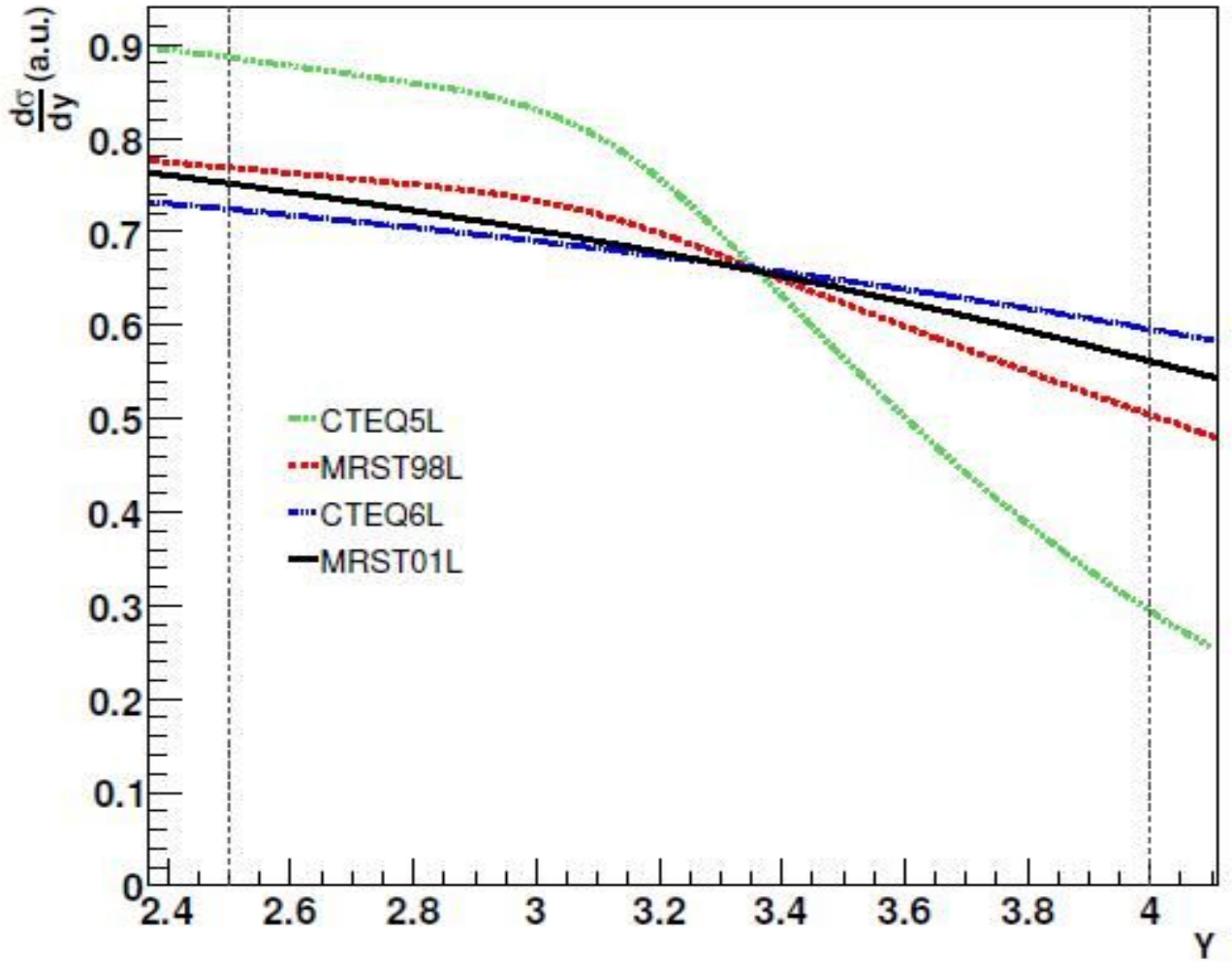




- the shape of the rapidity distribution depends on the PDFs
- compare different PDFs...

PDFs from quarkonia at ALICE

D. Stocco



- the shape of the rapidity distribution depends on the PDFs
- compare different PDFs...
- check also for other experiments (CMS,ATLAS)

Lumi measurement

M. Ferro-Luzzi, T. Lastovicka

Luminosity via the beam profiles

- Set $v_1 = v_2 = c$ and crossing angle ϕ :

$$L = f\, N_1\, N_2\, 2c\, \cos^2(\phi/2) \int_{4-\text{fold}} \rho_1(\mathbf{x},t)\, \rho_2(\mathbf{x},t)\, d^3x\, dt$$

Measured by AB-BI

Measured by the experiments

Accelerators and Beams", section "Beam diagnostics and Instrumentation"

- Proposed method:
  - Inject tiny bit of gas into the vtx detector region
  - Reconstruct bunch-gas interaction vertices
    - get beam angles, profiles & relative positions
    - calculate overlap integral
  - Simult., reconstruct bunch-bunch interaction vertices
    - calibrate 'reference' cross-section

Typical rates:

N=5x10^{10}, β*=34 m

10^{-7} mbar Xe

***p*-Xe** ~ 15 Hz per bunch per 20 cm z-bin

***pp*(7TeV)** ~ 1 kHz per bunch pair

- beam-gas vertex reconstruction to image the two beam profiles
- accuracy of ~ 1 % for overlap integrals
- accurary of Lumi: 5% quite certain, 1% quite challenging !!!!
- Absolute Lumi determination !!! complementary to W/Z !!!

PDFs from F_2 , Jets and HQs

- Howto fit jet data to NLO PDFs ?
  - very slow to evaluate cross section for each parameter settings of the PDF
  - ➔ discretized and pre-tabulate NLO partonic cross section
- NLOGRID (D. Clements et al)
  - ➔ uses log(1/x) + a(1-x)
- fastNLO (Th. Kluge et al)
  - ➔ uses $(\log(1/x))^{1/2}$

fastNLO

http://hepforge.cedar.ac.uk/fastnlo

- full simulation using MC's (HJU et al)
  - ➔ pre-tabulate (u-)PDF, use full simulation as MC@NLO or CASCADE
- First steps done to include Jets and F_2
- **Next go for including HQs in DIS and photoproduction !!!**

Conclusion PDFs

M. Dittmar

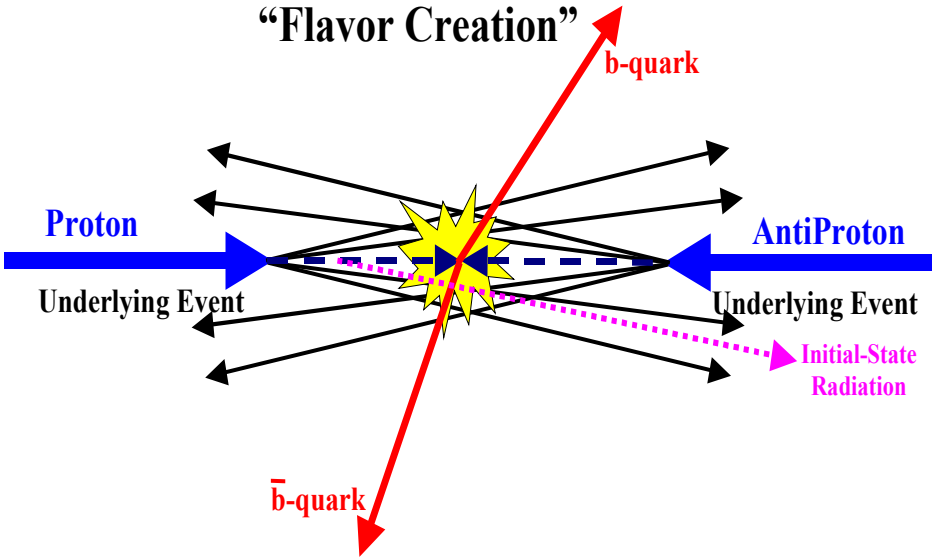
- A good preparation for the LHC start needs also to include:

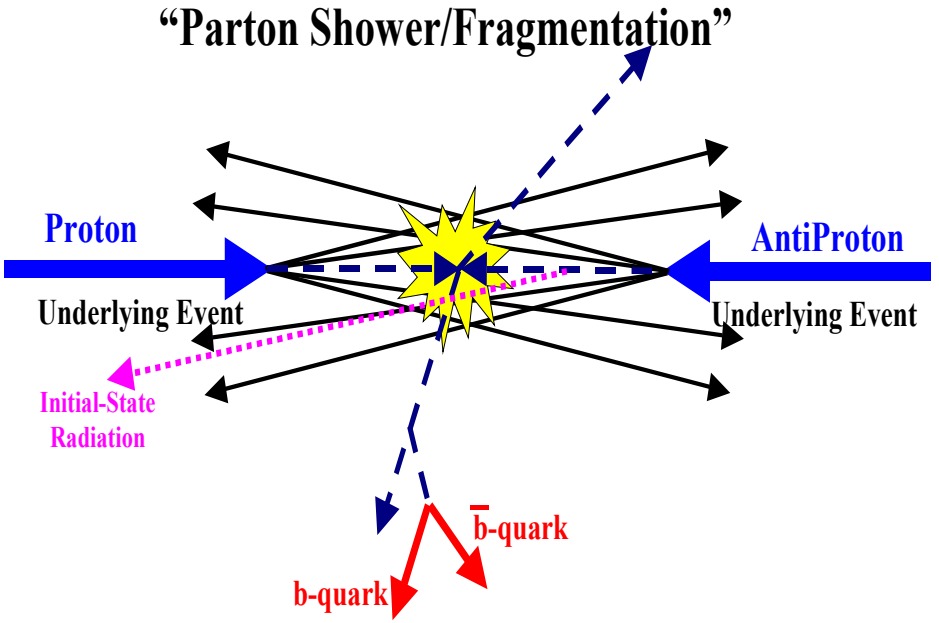
➔ realistic simulations to optimize data analysis and data interpretations

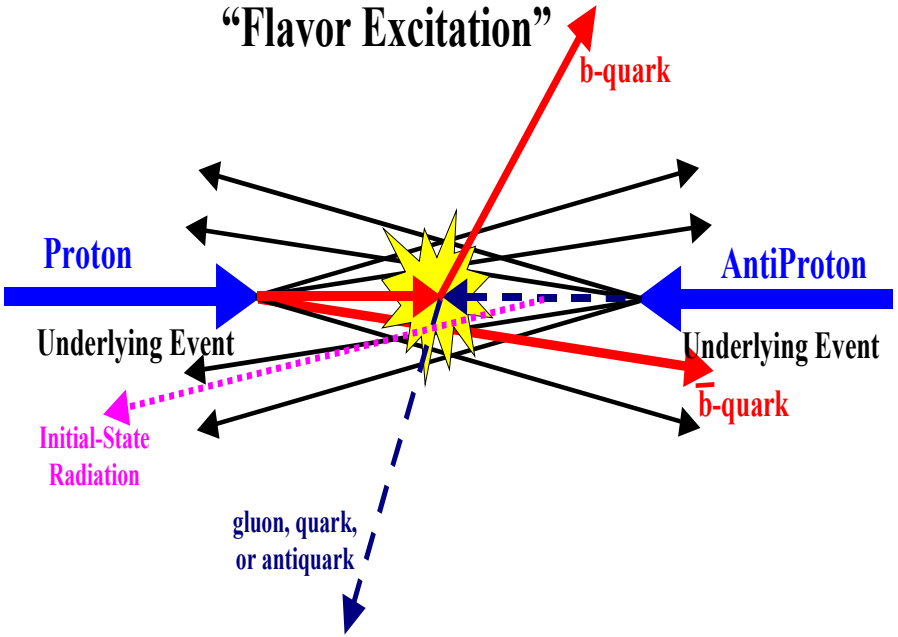
➔ need to investigate and identify final states where accurate x-section measurements/calculations can be made

- Find a realistic interactive (HERA-LHC) strategy to constrain PDF's
- Experimentalists and theorists have to “learn” how to measure and calculate the same things !
- **What about HERA PDF: H1 – ZEUS combined ?**
- **Should form a “group” from ATLAS, CMS, LHCb, ALICE, H1, ZEUS and theoretical PDF experts**

Event Topologies: example



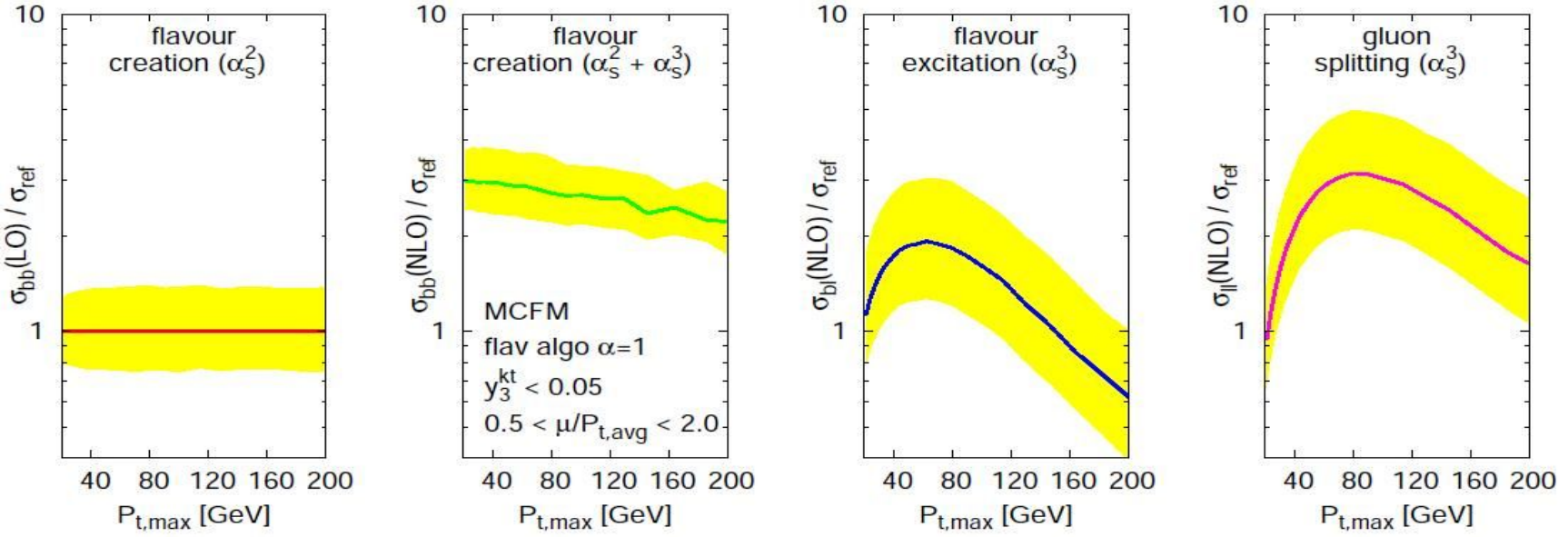




NLO uncertainties of HQ production

- Tevatron RunII $\sqrt{s} = 1.96\text{TeV}$
- Dijet events with $P_{t,\max} > 30\text{GeV}$ and $|\eta_{\text{jet}}| < 1$
- NLO predictions obtained with MCFM

A. Banfi, G. Zanderighi, G. Salam

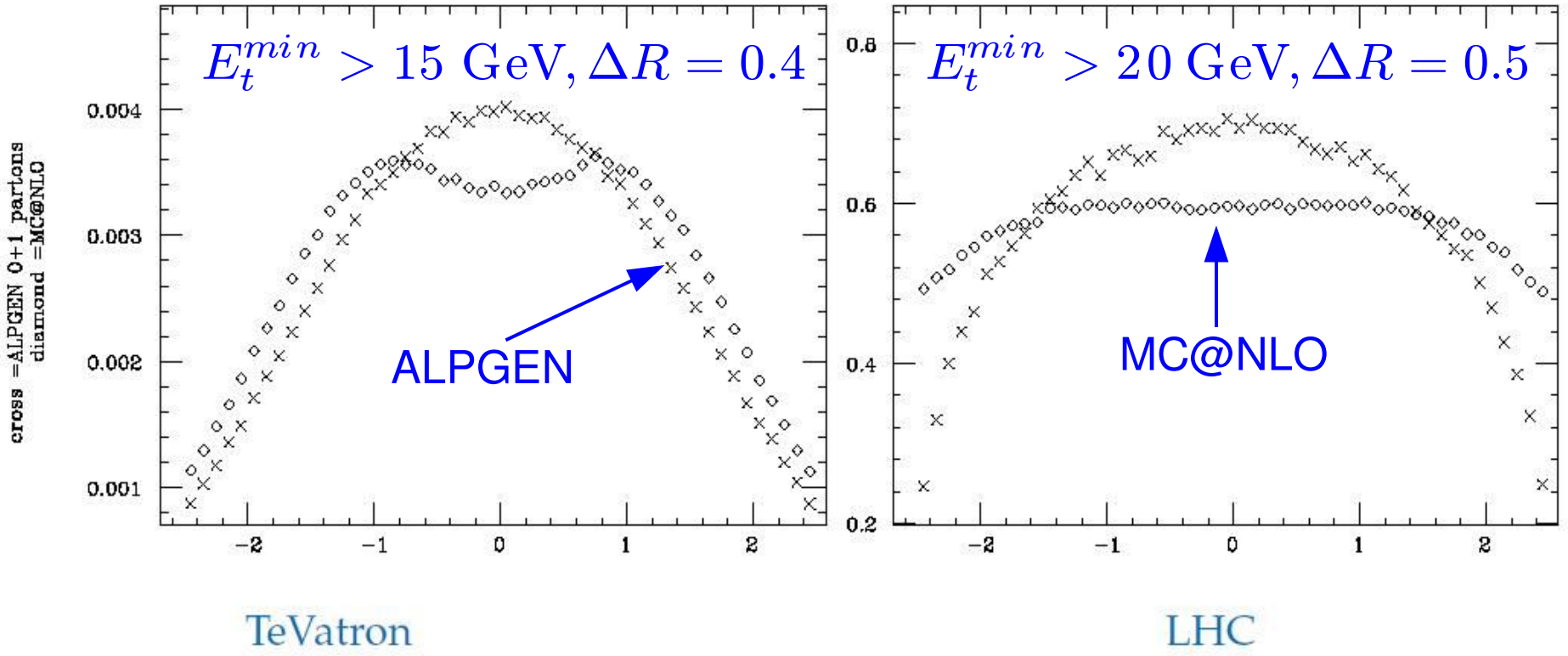


- Flavor creation $\alpha_s^2 + \alpha_s^3$ → well described by NLO
- Flavor excitation $\alpha_s^2 \times \alpha_s \log E_T/m_b$ → $\alpha_s^n \log^n E_T/m_b$ in *b-pdf*
- Gluon Splitting $\alpha_s^2 \times \alpha_s \log E_T/m_b$ → all order $\alpha_s^n \log^{2n-1} E_T/m_b$
- Do proper resummation !

expect uncertainty to decrease from 40-50% to ~ 20 %

Fixed order vrs resummed calcs

- study ttbar + 1 jet production with ALPGEN (n-parton MC) and MC@NLO
- inclusive top xsections agree, but extra radiation is problematic



- depletion coming from PS in MC@NLO
- which one is correct ?

Progress on parton showers and NLO

Z. Nagy

We use an evolution variable e.g.:

$$\log\frac{Q^2}{\hat{p}_1\cdot\hat{p}_2}=t\in[0,\infty]$$

The evolution is given by a linear operator

$$|A(t))=U(t,t_0)|A(t_0))$$

Group decomposation

$$U(t_3,t_2)\,U(t_2,t_1)=U(t_3,t_1)$$

Preserves the normalization

$$(1|A(t_0))=1 \quad\Rightarrow\quad (1|U(t,t_0)|A(t_0))=1$$

Parton Shower at NLO

Let us calculate the N-jet cross section. The matrix element improved cross section is

$$(F_N|\sigma_\Delta(t_f))=\int_{t_2}^{t_f}dt_N\,(F_N|N(t_f,t_N)W_\Delta(t_f,t_N,t_2)|\sigma_N)+\int_{t_2}^{t_f}dt_{N+1}\,(F_N|U(t_f,t_{N+1})W_\Delta(t_f,t_{N+1},t_2)|\sigma_{N+1})$$

Expanding it in α_s then we have

"Error term" from $1/N_c^2$ approx. : $E=E^{(0)}+\frac{\alpha_s}{2\pi}E^{(1)}=\mathcal{O}\left(\frac{1}{N_c^2}\right)$

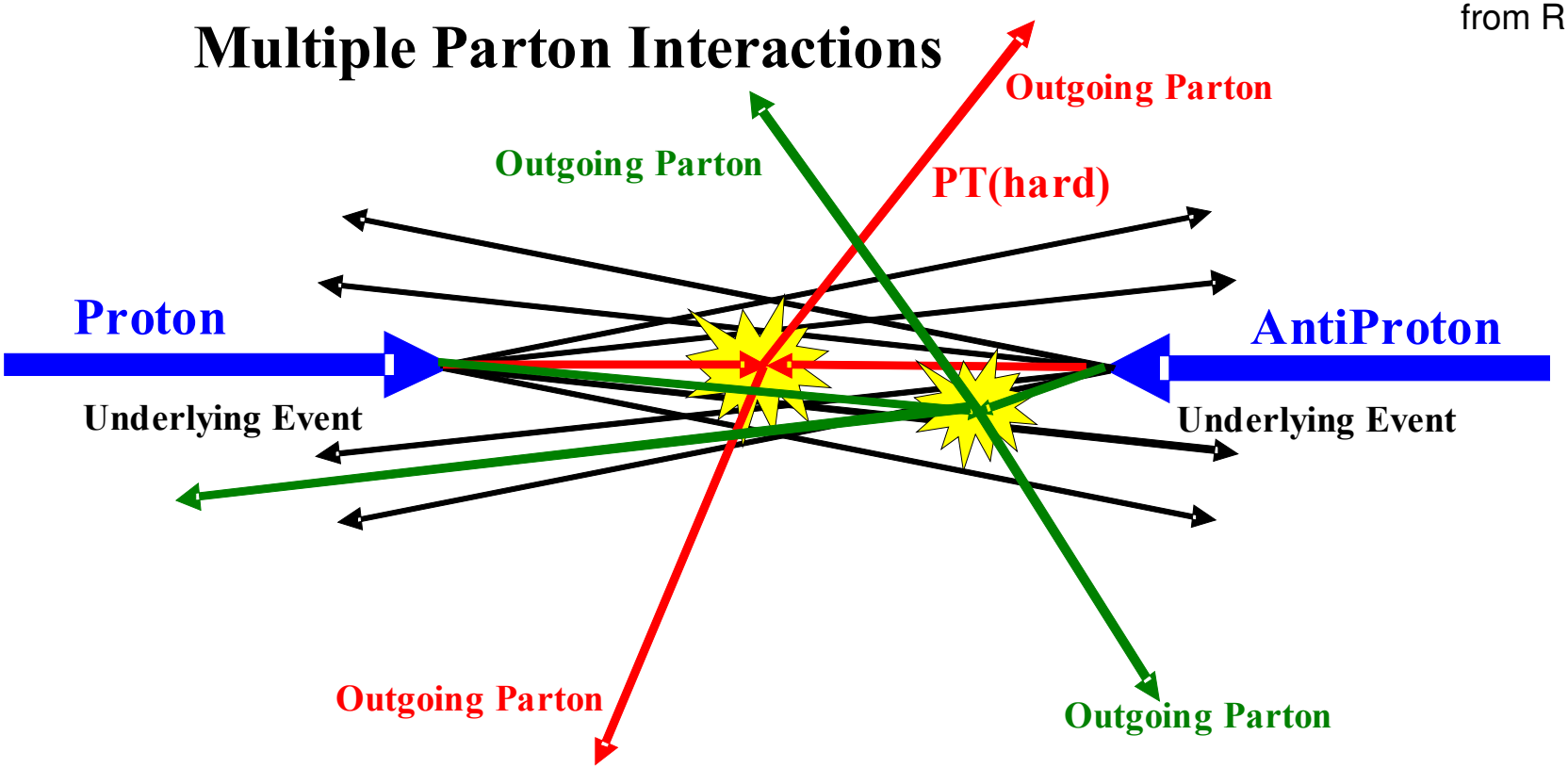
$$(F_N|\sigma_\Delta)=\int_N d\sigma^B\left(1+E+\frac{\alpha_s}{2\pi}W_\Delta^{(1)}\right)+\int_{N+1}\left[d\sigma^R-d\sigma^A\right]+\mathcal{O}(\alpha_s^2)$$

Born term; "Quasi virtual"; Real - Dipoles

- Formulation of Parton Shower approach in a formal way... some theorists like that ....
- evolution variable and splitting function in terms of dipole-subtraction a la Catani/Seymour
- PS matches closely subtraction terms

Event Topologies

from R. Field



What is the underlying event (UE)?

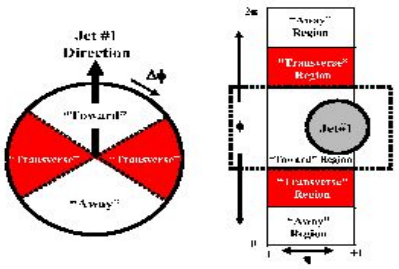
➔ *Everything, except the LO process we're currently interested in*

- *parton showers*
- *additional remnant – remnant interactions*

✗ NOT pile-up events (luminosity dependent)

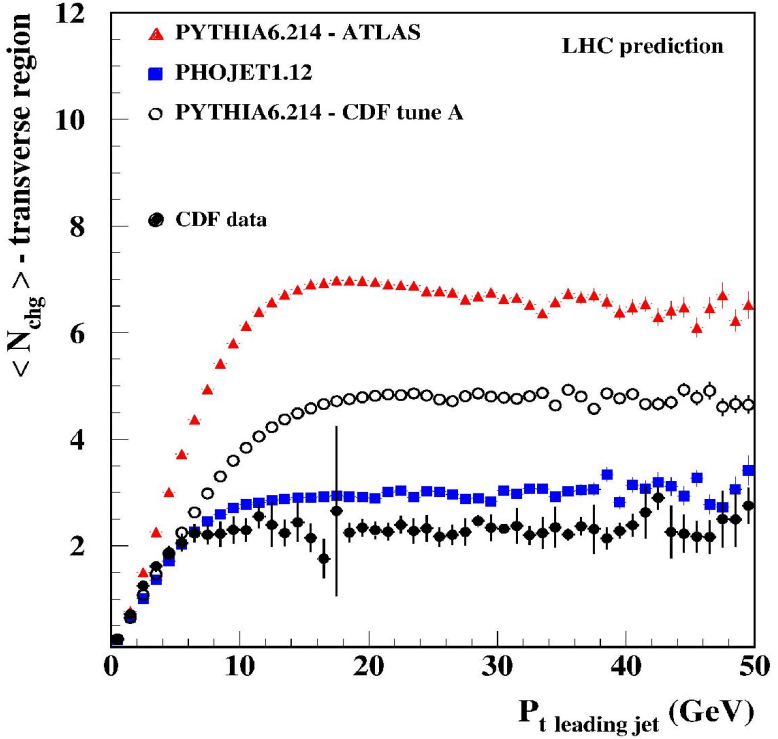
Multiple Interactions at LHC

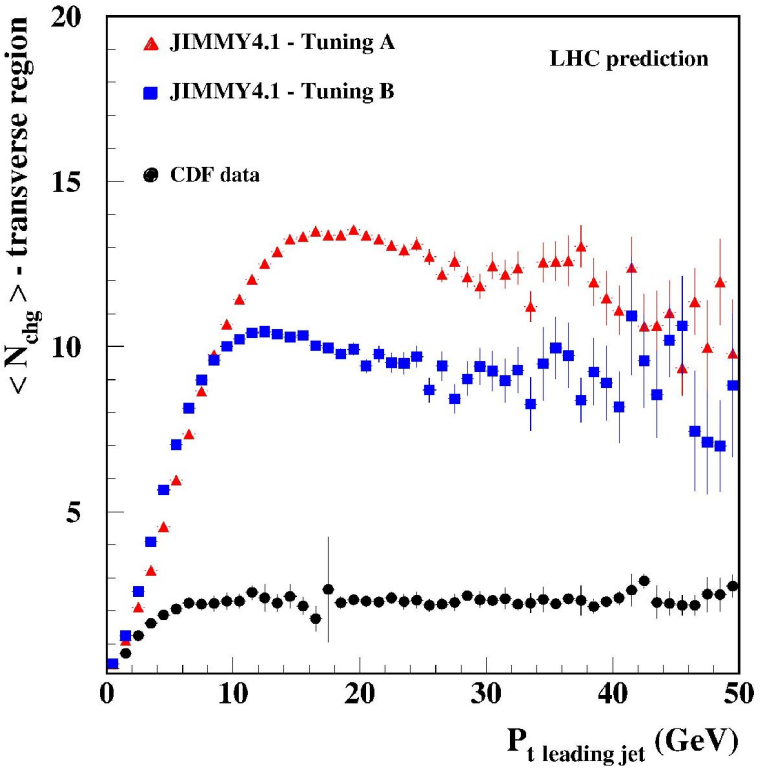
C. Buttar et al in HERA – LHC workshop proceedings hep-ph/0601012



Charged multiplicities in transverse region

- Models tuned to TeVatron data
- ➔ give **HUGE** differences at LHC ...
- ➔ **better understand multiple interactions ...**
  - ➔ photo-production of jets at HERA T. Namsoo

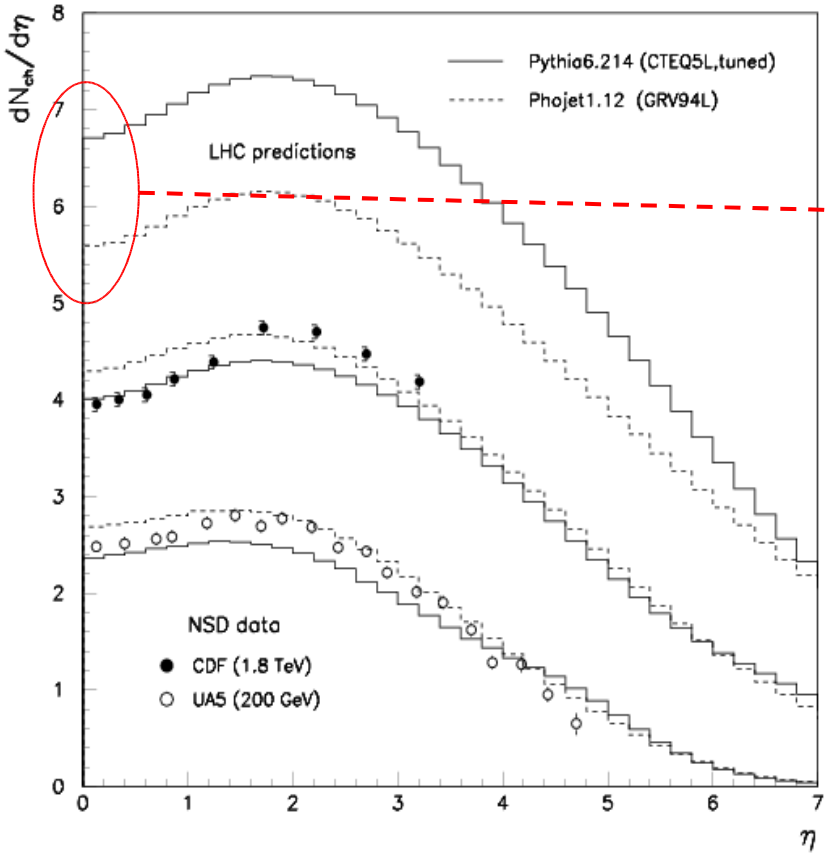


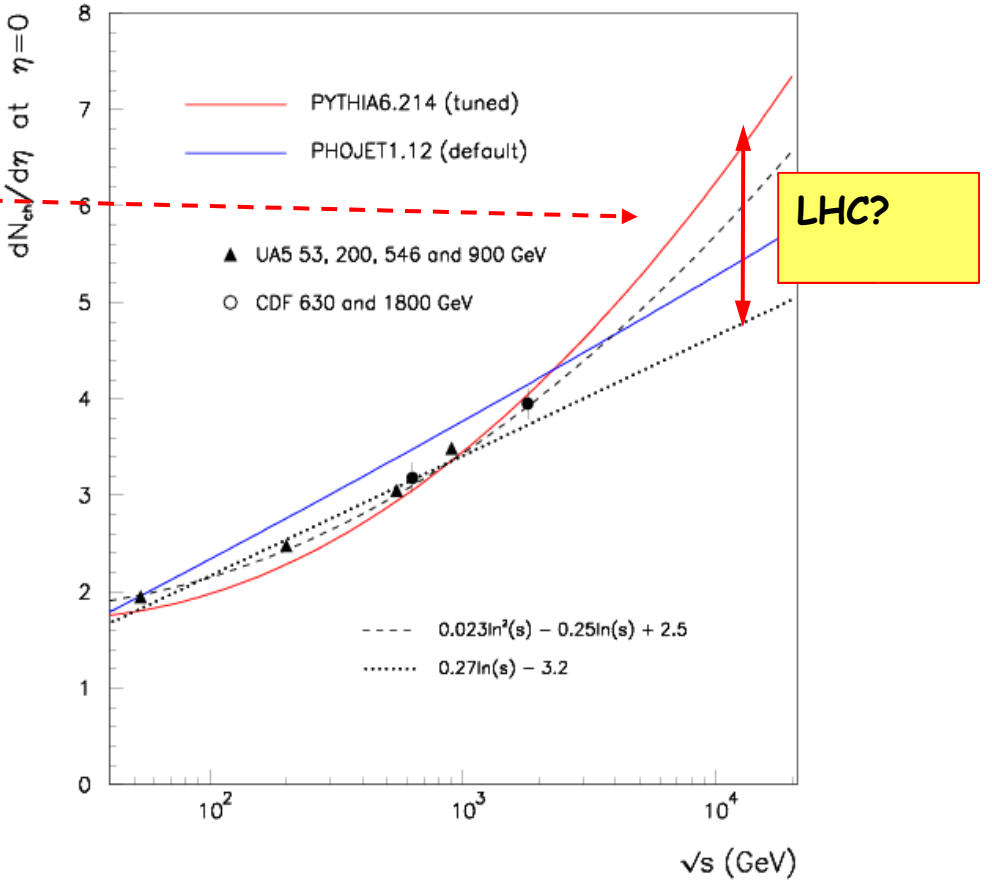


Underlying events and MI

L. Fano

- Underlying event studies at LHC: charged particle multiplicity and spectra





Different energy behavior:

PHOJET (DPM) -> ln(s)

PYTHIA (MPI) -> ln²(s)

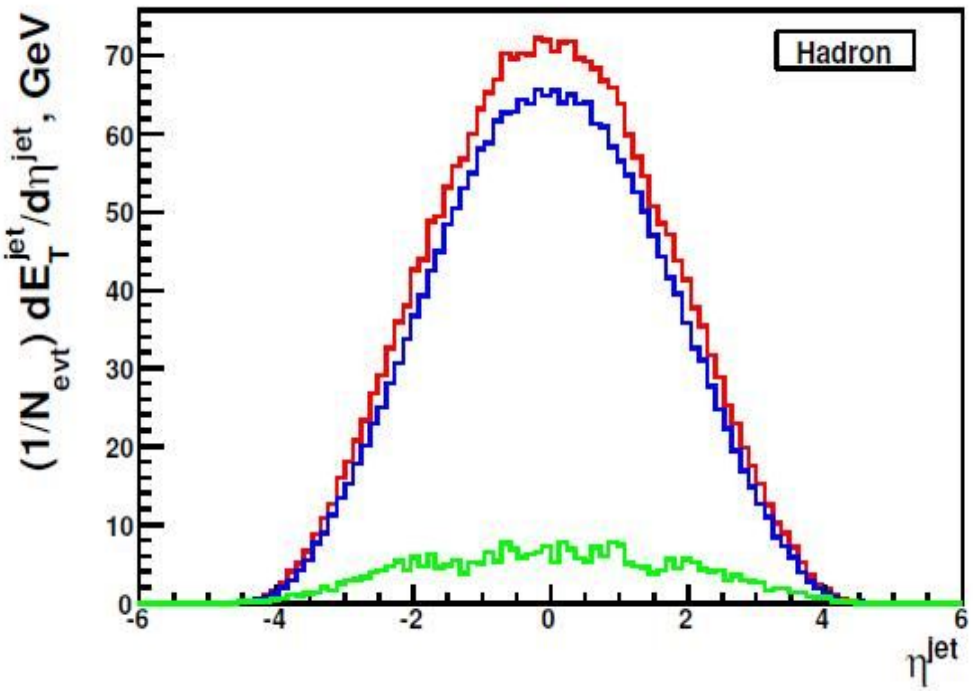
- frist tasks to measure at LHC:

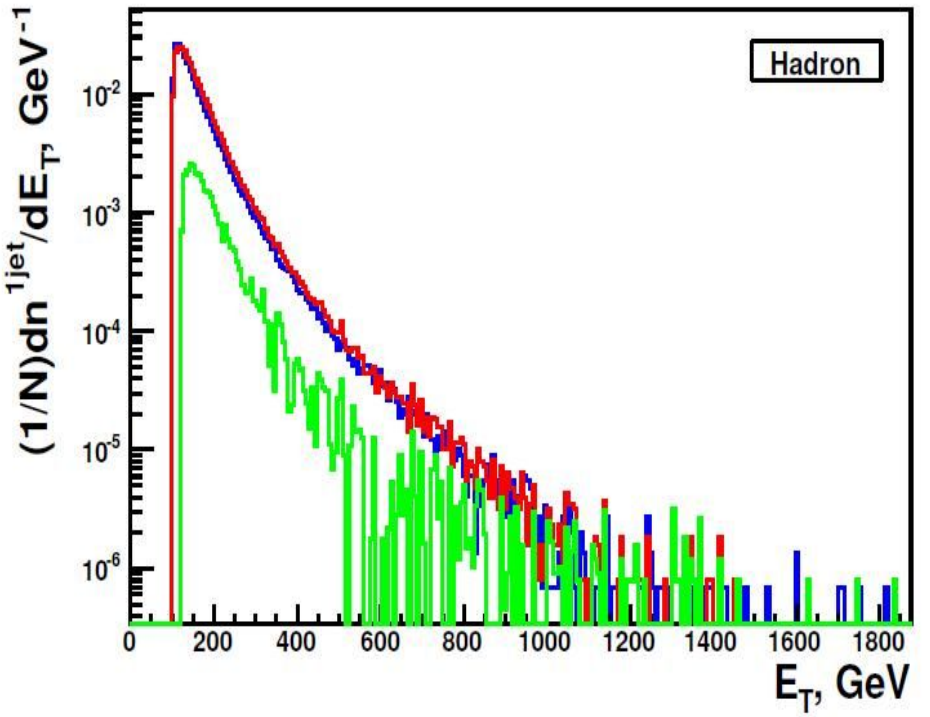
$dN_{ch}/d\eta$; dN_{ch}/dp_T

Underlying event and jets

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

P. Starovoitov, T. Carli





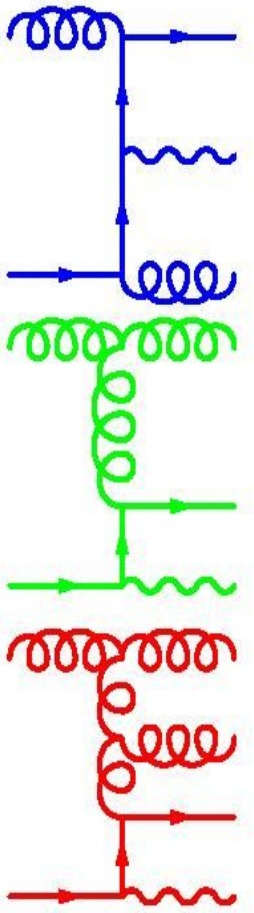
Hard Scale HS+UE Difference

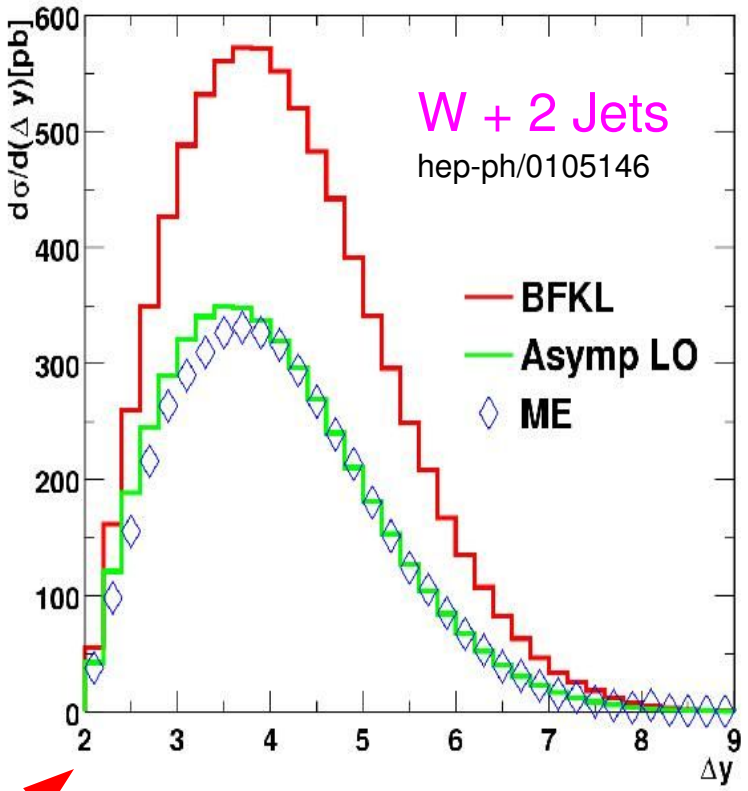
- UE contributes ~ 10 % to Jets, even at large Et !!!!
- UE contribution is eta dependent !!!!
- **need reliable model for subtraction !!??!!!**

W + n-Jets

J. Andersen

Example: *W*+n-jet production at the LHC





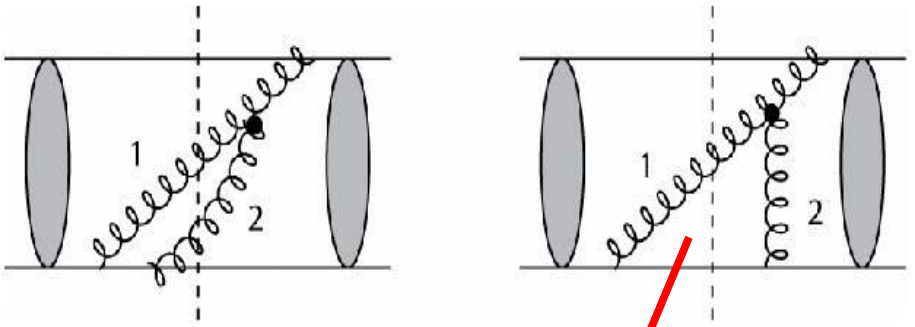
$$\Delta y = y_{j_2} - y_{j_1}, y_W, y_{j_2} \geq 1, y_{j_1} \leq -1$$

rapidity difference of 2 jets

- W+n jets complicated: in in fixed order: W+5 jets in MadGraph is the limit..., W+1(2) jets in NLO
- for n>5 jets only BFKL calculation available
- work started to extend LO BFKL calc to NLL (quark contribution is ready...)
- Program for analysis of W+n-jet is available:
  http://www.hep.phy.cam.ac.uk/~andersen/BFKL

$p + p \rightarrow jet + gap + jet$

qq→ qq: Secondary gluons



Non-cancellation if g_1 is outside and g_2 is inside gap

- Jets with $p_t = Q$
- no real gluons between Jets with $Q_0 < p_{tg} < Q$
- collinear gluons from outside the gap can emit virtual gluons inside the gap
- ➔ NO cancellation

- appearance of Super Leading Logs (SLL):

$$\sigma = \alpha_s^2 (c_1 \alpha_s L + c_2 \alpha_s^2 L^2 + c_3 \alpha_s^3 L^3 + c_4 \alpha_s^4 L^5 + \cdots)$$

- Consequences for CollinsSoperSterman resummation of soft collinear gluons.... used for example for pt spectrum of Higgs
- Consequences for kt spectra etc ...
- Consequences for factorization in general ?

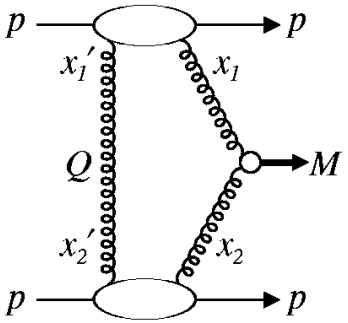
Diffraction

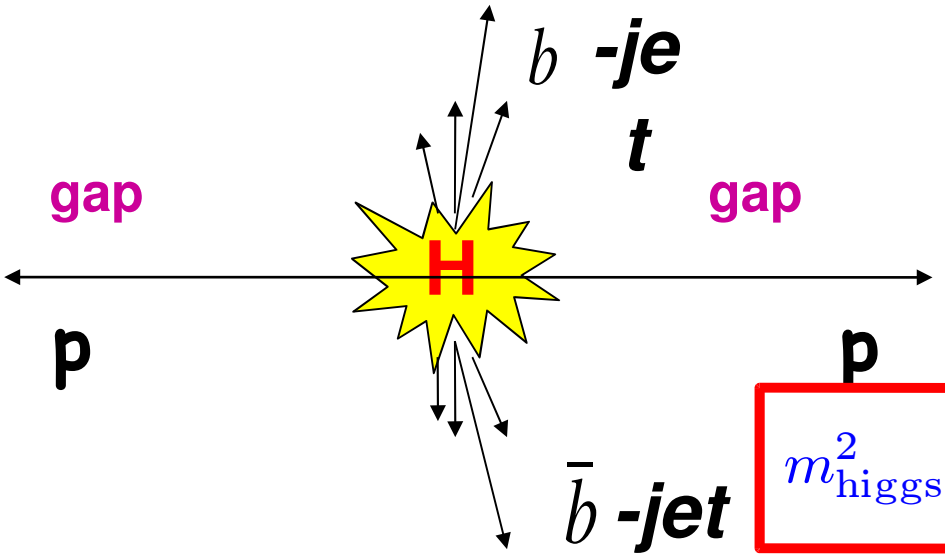
Since last year's workshop:

- From HERA: new F2D measurements (new dPDFs)
  new leading neutron measurements
  new measurements of semi-inclusive final states
  (validity of hard diffractive factorization ?)
- From Tevatron exclusive diffractive dijets
  exclusive 2-gamma events
- From LHC: more studies of potential for diffraction of Atlas, CMS, Totem and Fp420
- Several theoretical developments

Here only few of them are covered !!!

Diffractive Higgs Production





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

$$m^2_{\text{higgs}} = (p + \bar{p} - p' - \bar{p}')$$

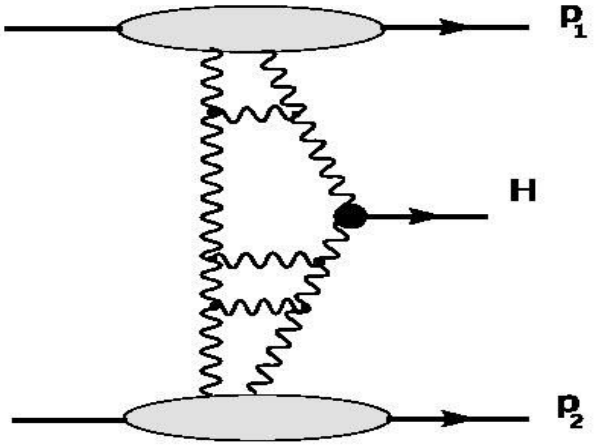
- Exclusive diffractive Higgs production $p + p \to p + H + p$ 2-10 fb
- Inclusive diffractive Higgs production $pp \to p + X + H + Y + p$ O(100) fb

- Advantages:
  - Mass resolution
    from energy of protons determine mass,precise mass determination
  - Quantum numbers
    central system produced in $J_z=0$, *C* and *P* even state
- Sensitive to unintegrated PDFs

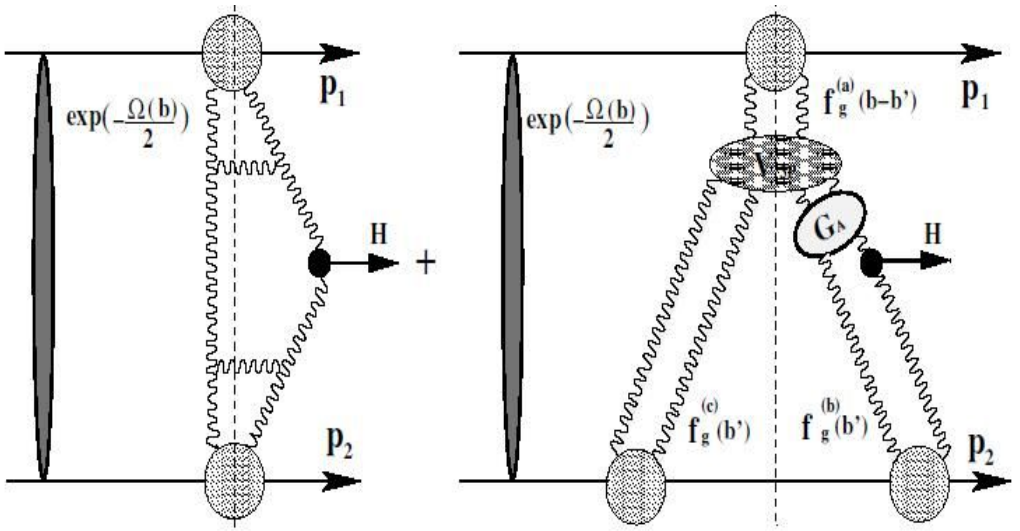
Exclusve Higgs production, again...

L. Motyka

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



- New investigation of rescattering effects by L. Motyka, J. Bartels, S. Bondarenko, K. Kutak



L. Motyka:

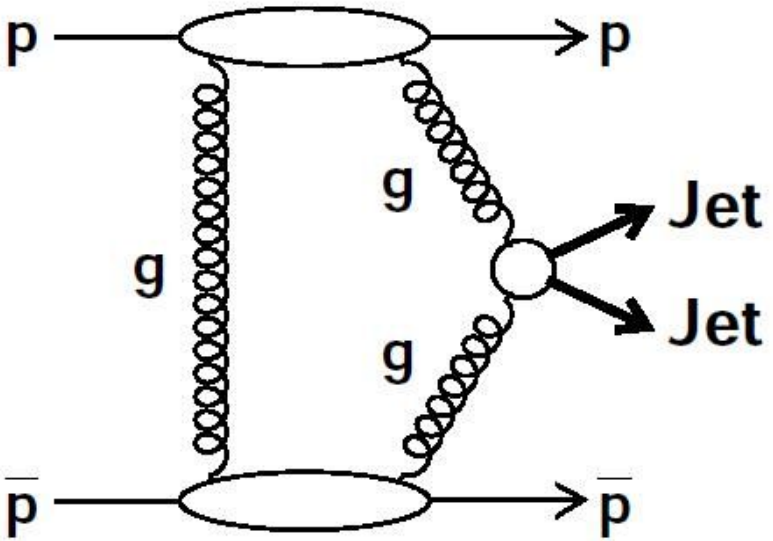
- First correction due to hard rescattering are large, and negative
- need to perform resummation
- Durham assumption of factorization of hard production and soft rescattering does not hold, unless special cancellations occur

➔ Needs further clarification

Tevatron search for exclusive production

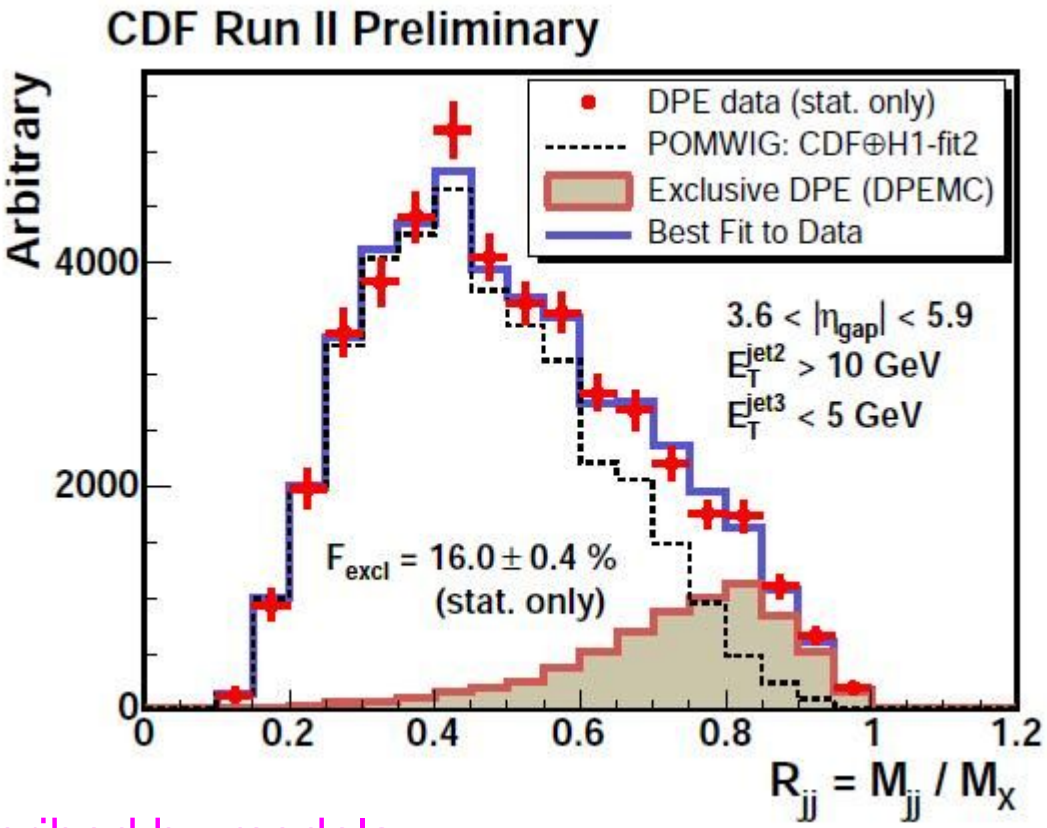
K. Terashi

- Observation of exclusive dijets/diphotons/di-heavy-quarks is a proof of principle for the Higgs diagram and constrains gap survival probablility



$gg \rightarrow gg, q\bar{q}g, \ldots$

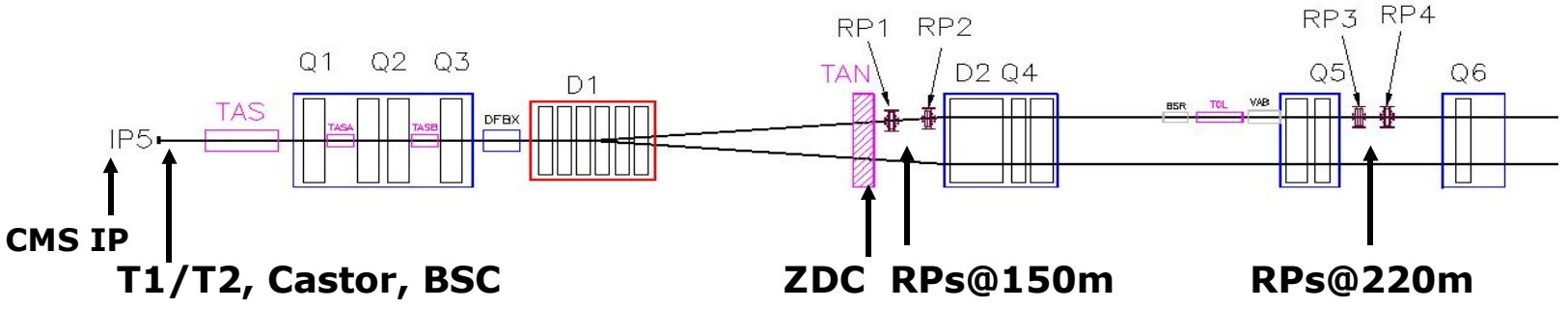
$gg \rightarrow q\bar{q}$ $J_z=0$ suppressed

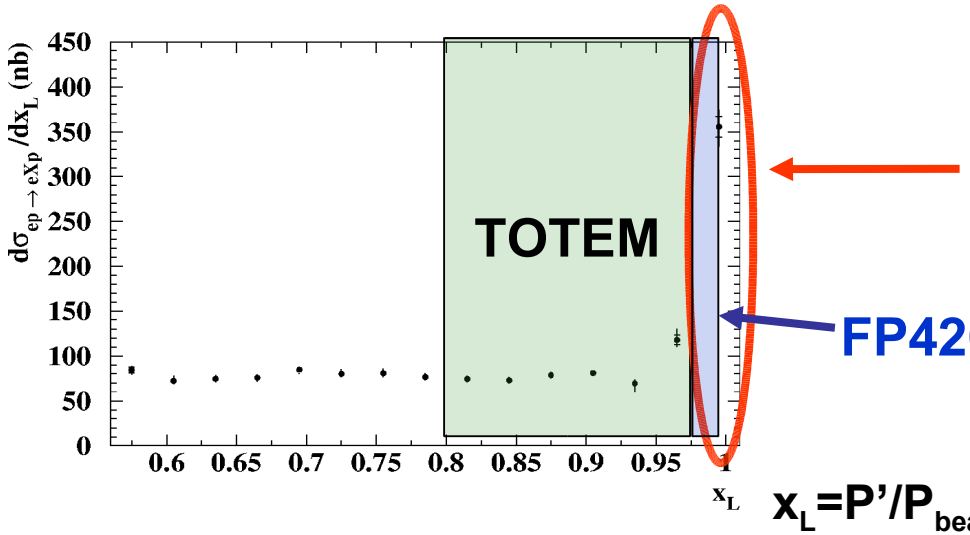


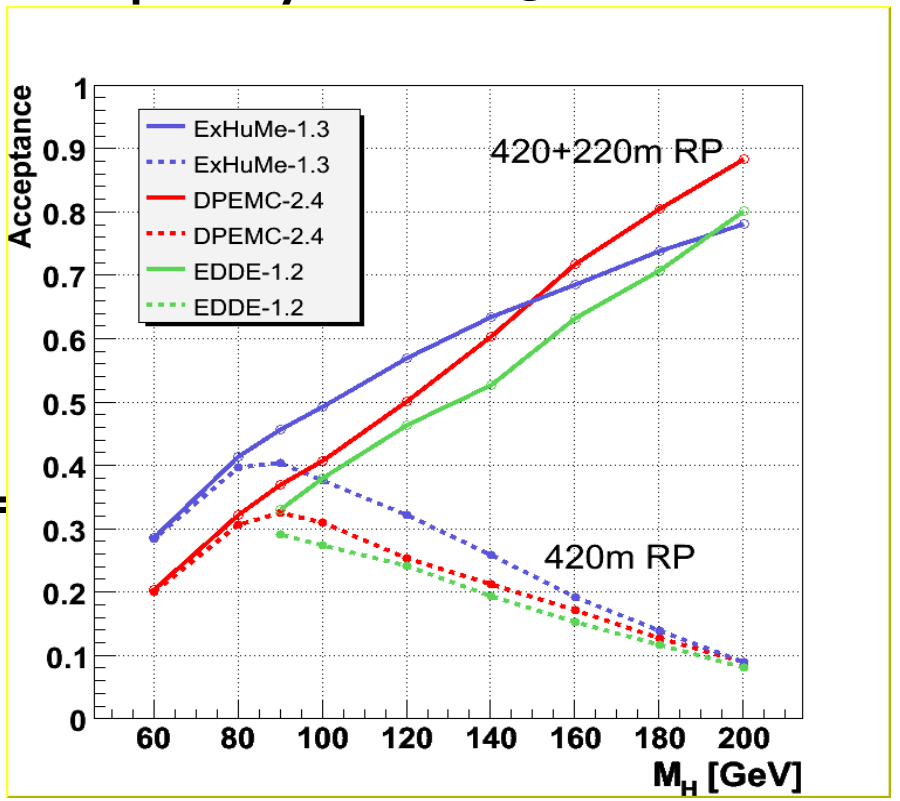
- The excess at high R_{jj} is well described by models....
- BUT hard to tell difference from inclusive dijets with DPDFs: resolution etc...
- **What is HERA saying to that ?**

FP420

M. Grothe







Nominal LHC beam optics, $\beta^* = 0.5$m:

TOTEM: $0.02 < \xi < 0.2$

FP420: $0.002 < \xi < 0.02$

FP220 and FP420 program also in ATLAS !!!

CMS + Totem + FP420

M. Grothe

Low lumi
Rapidity gap selection possible
HF, Castor, BSCs, T1, T2
Proton tag selection optional
RPs at 220m and 420 m

Diffraction is about 1/4 of σ_{tot}
High cross section processes
"Soft" diffraction
Interesting for start-up running
Important for understanding pile-up

Low lumi | High lumi

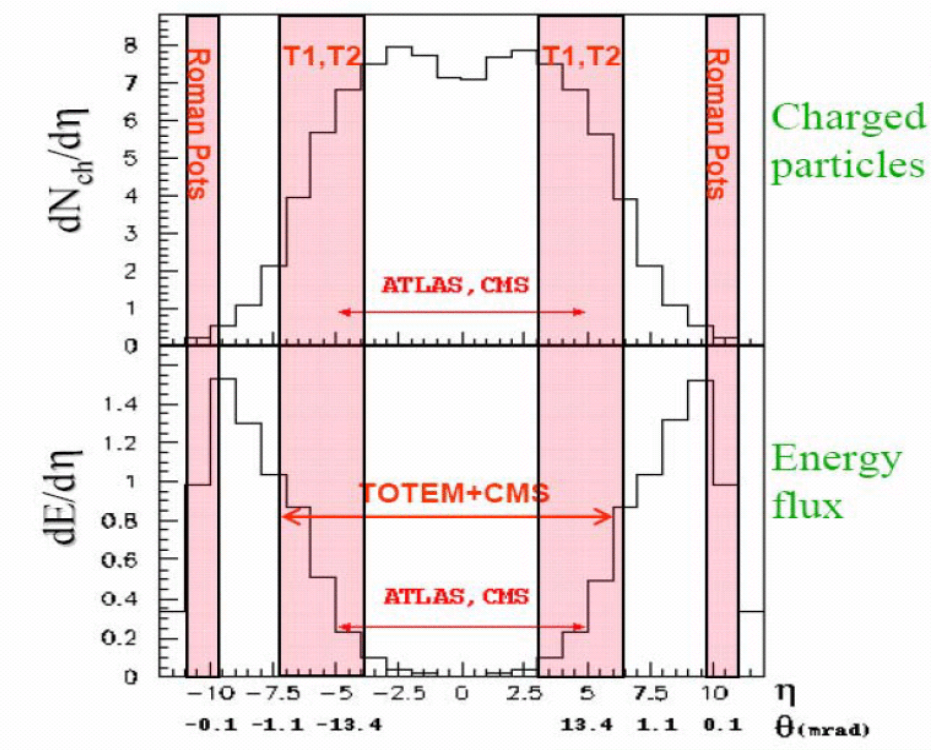
High lumi
No Rapidity gap selection possible
Proton tag selection indispensable
RPs at 220m and 420 m

Central exclusive production
Discovery physics:
Light SM Higgs
MSSM Higgs
Extra dimensions

Gamma-gamma and gamma-proton interactions (QED)
Forward energy flow - input to cosmics shower simulation
QCD: Diffraction in presence of hard scale
Low-x structure of the proton
High-density regime (Color glass condensate)
Diff PDFs and generalized PDFs
Diffractive Drell-Yan

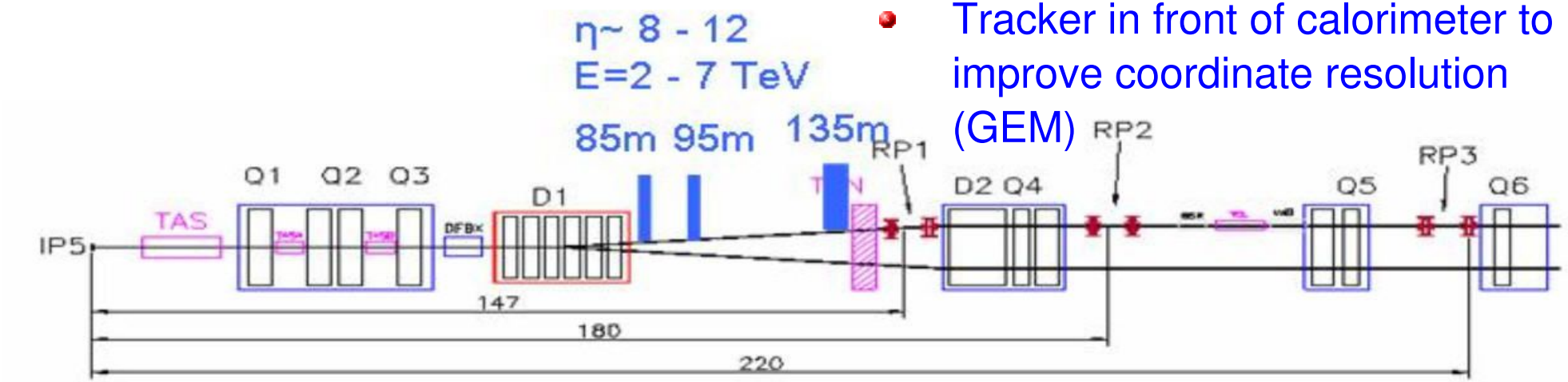
Monika Grothe, CMS diffractive and forward physics program, June 2006

Towards a full rapidity coverage



V.Andreev, A.Bunyatyan, K.Borras, HJU, M.Kapishin, L.Lytkin

- Idea to fill gap in rapidity with calorimeter at 135 m in front of TAN (E ~ 2.0 - 5.5 TeV and pseudorapidity range 8 – 12)
- Beamline simulation performed
- Pseudorapidity resolution ~ 0.25-0.5 (depends on the selected energy rapidity range)
- Radiation level near the calorimeter at 135 m is reasonable (from studies of ZDC)
- Tracker in front of calorimeter to improve coordinate resolution (GEM)



Monte Carlo and Tools

C. Risler, J Butterworth

HZtool

- calculate and compare predictions with measurements

➔ MC generators, NLOlib, MC@NLO

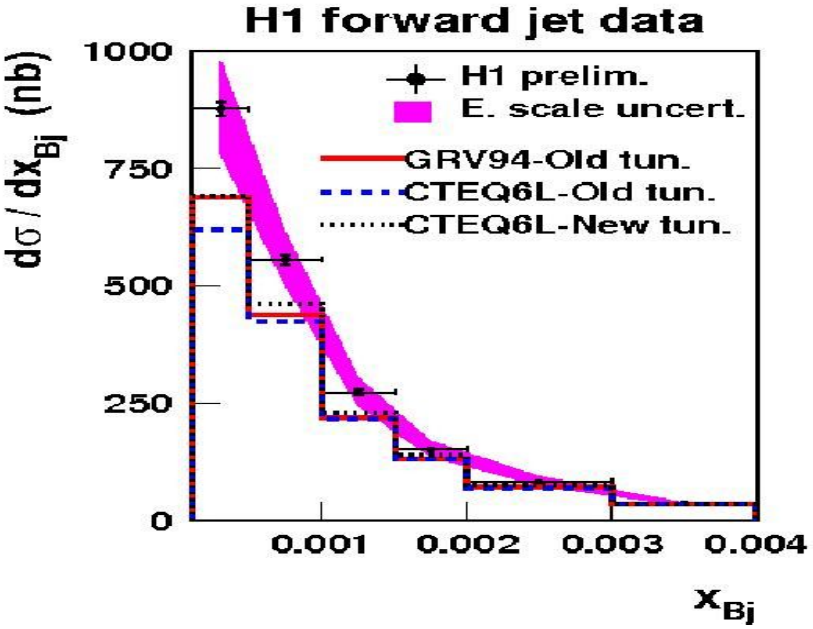
➔ useful for tuning of parameters

➔ useful for PDF fits with final states

  - ➔ includes HERA, LEP, TeVatron data
  - ➔ will be coupled to HEPDATA
  - ➔ will develop into RIVET (Robust Independent Validation of Experiment and Theory) a C++ version of HZTool. Work started !
  - ➔ MC/NLO validation
  - ➔ compare to very different measurements

- Request by HERA & TeVatron & LHC:
  - ➔ include all available infos for benchmarking, validation and tuning

- example for tuning: ARIADNE parameters with new PDFs
- compare to fwd jet xsection (not used in tuning) (A. Knutsson, L. Joensson)



- Include also LEP data
- **Provide tuning including HERA, LEP and TeVatron data !!!**

From 1st to 2nd 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.***

What LHC needs for start in 2007 ?

- PDF determination:
  - collinear integrated PDFs
  - uPDFs
  - diffractive PDFs, generalised PDFs
- Event topologies:
  - Multiple Interactions
  - Underlying Events
  - Higher Order Corrections
- Reliable Simulations/ Theory/Models
  - tuning of free parameters to many different measurements
  - improved calculations
  - alternative approaches

Keywords: tools, phenomenological progress, and quantitative estimate for the impact of HERA on LHC measurements

.... this not the end

- **Next HERA-LHC workshop**
  (before LHC starts)
  Spring 2007 at DESY
  (exact dates still to be decided)
- informal meetings/working group weeks
  fall 2006 and/or Jan 2007
- Proceedings after 2007 meeting
  - contributed papers for 2006 are still accepted and electronically published
- 2008 meeting at CERN with first results from LHC
- ***Contributions are still possible and welcome !***

HERA and the LHC

This is the beginning of a beautiful friendship !