Highlights of the HERA/LHC Workshop and Outlook

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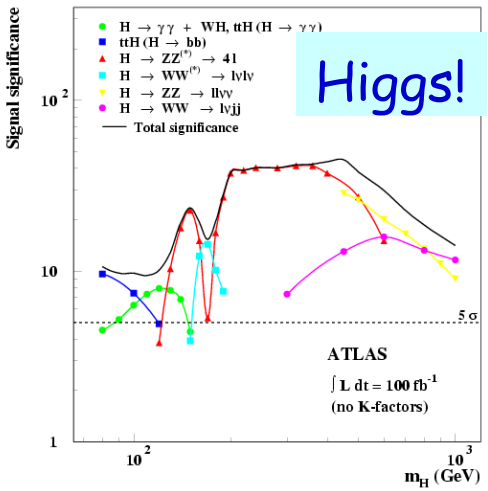
& Hannes Jung/ DESY

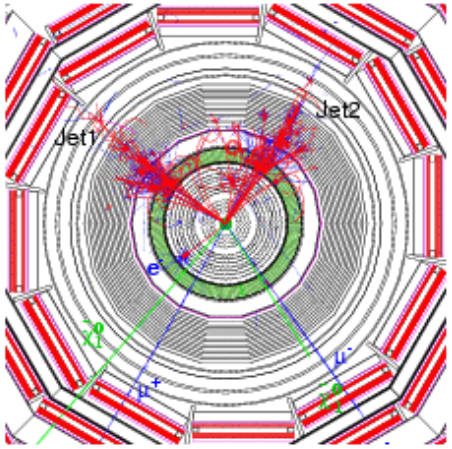
Contents

- Recall Goals of the workshop
- Some highlights
- Where do we go from here?

Physics at the LHC

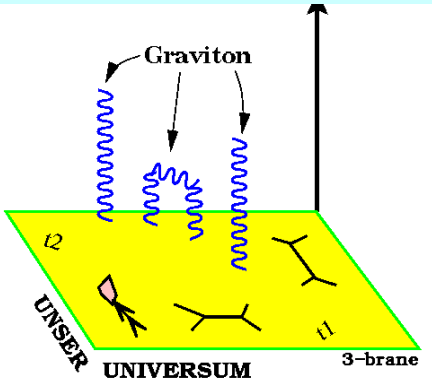


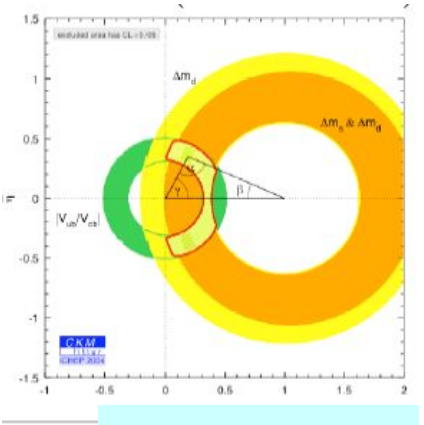
Higgs!



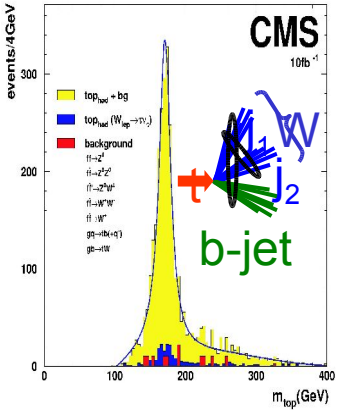
Supersymmetry?

Extra Dimensions?



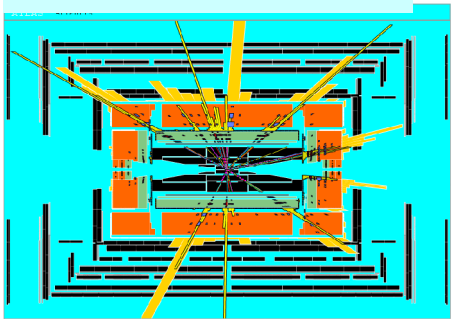


CP triangle!

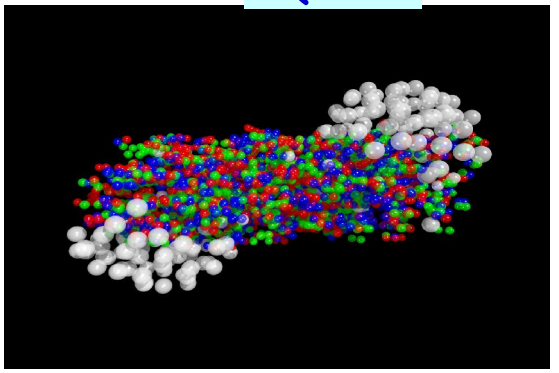


Precision measurements e.g top!

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 This workshop

Remember: The Workshop Aims

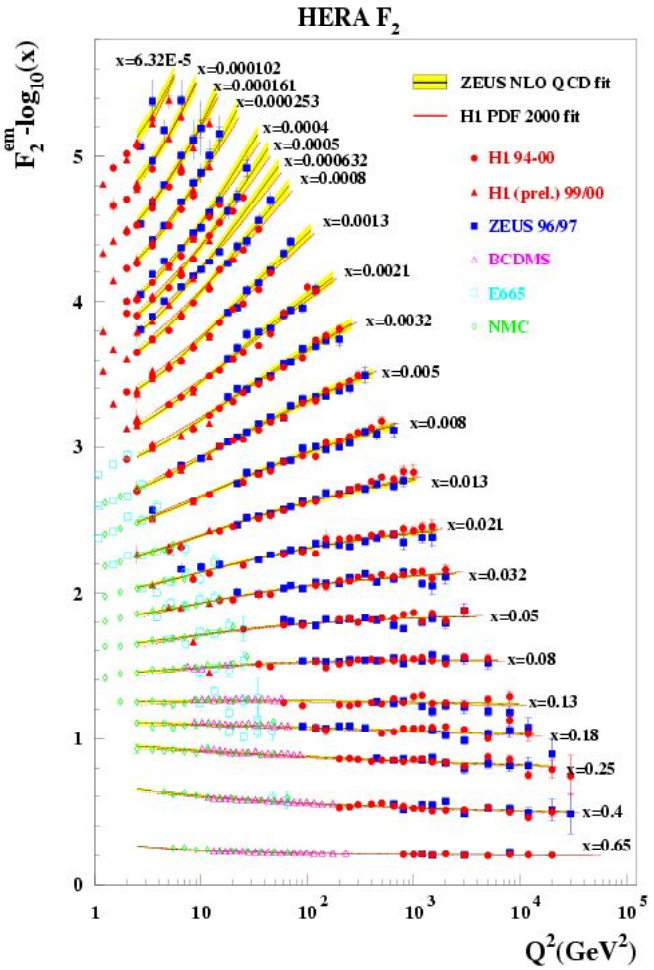
- To identify and prioritize those measurements to be made at HERA which have an impact on the physics reach of the LHC.
- To encourage and stimulate transfer of knowledge between the HERA and LHC communities and establish an ongoing interaction.
- To encourage and stimulate theory and phenomenological 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.

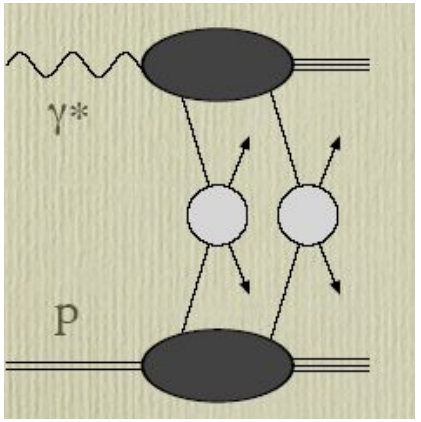
So, how well did we do?

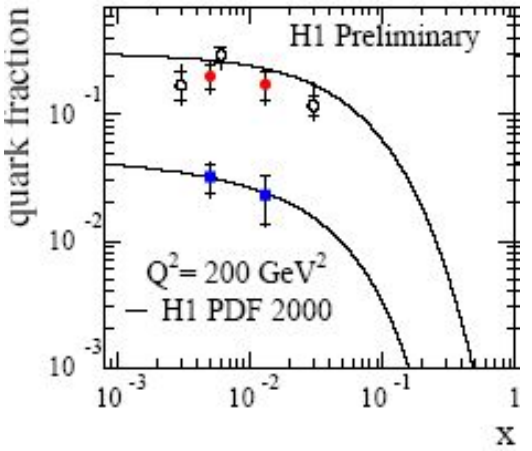
Lets look at a number of examples

WG suggestions spiced with personal flavor

Examples: HERA→LHC





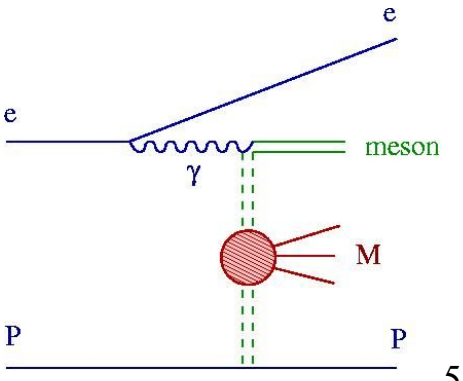


Underlying event:
tunable elementarity
of one beam particle
γp ⇔p collisions
LHC: event complexity

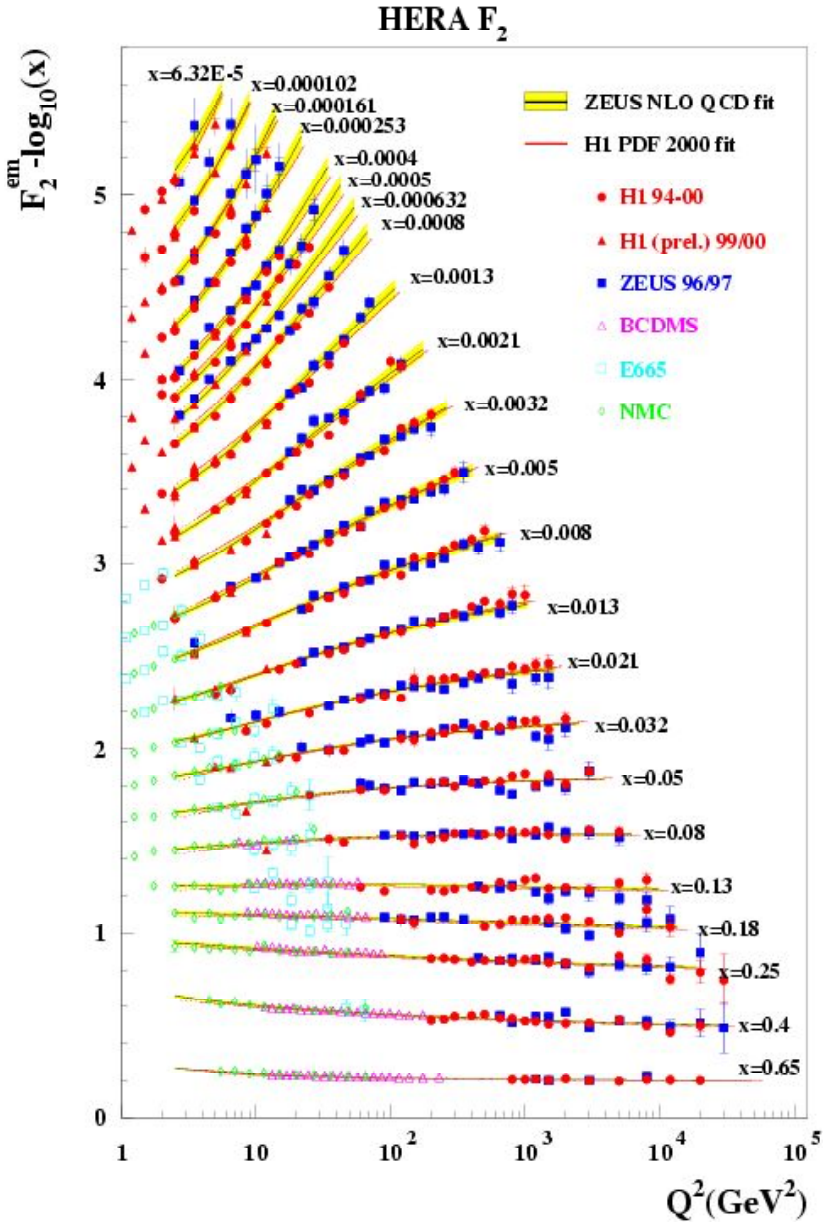
B-production: B quark
PDFs of the proton
LHC: Higgs production

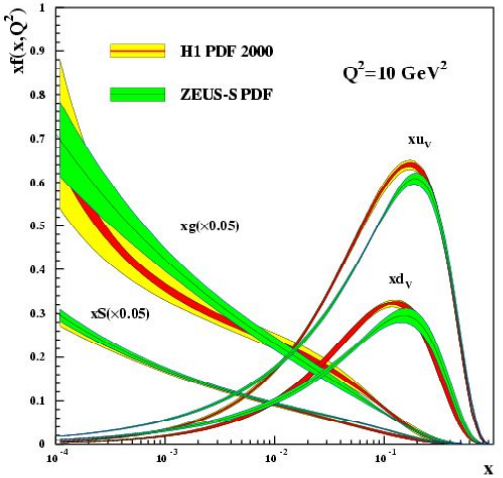
Structure functions and
parton distributions
LHC: cross sections/precision

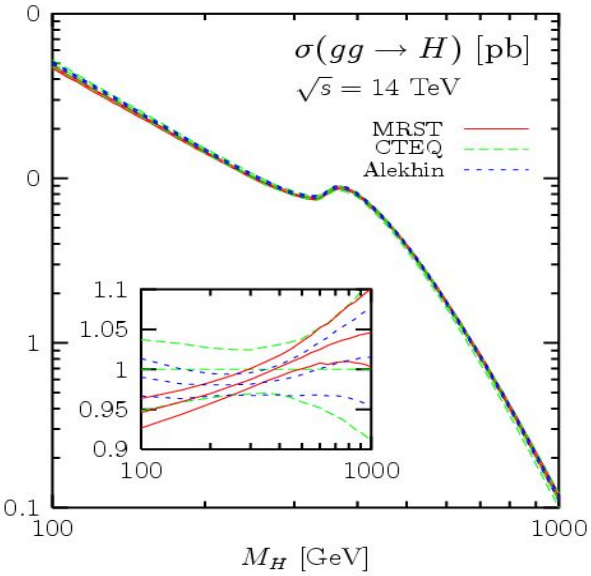
Diffraction
LHC: diffractive
scalar production



WG1: PDFs





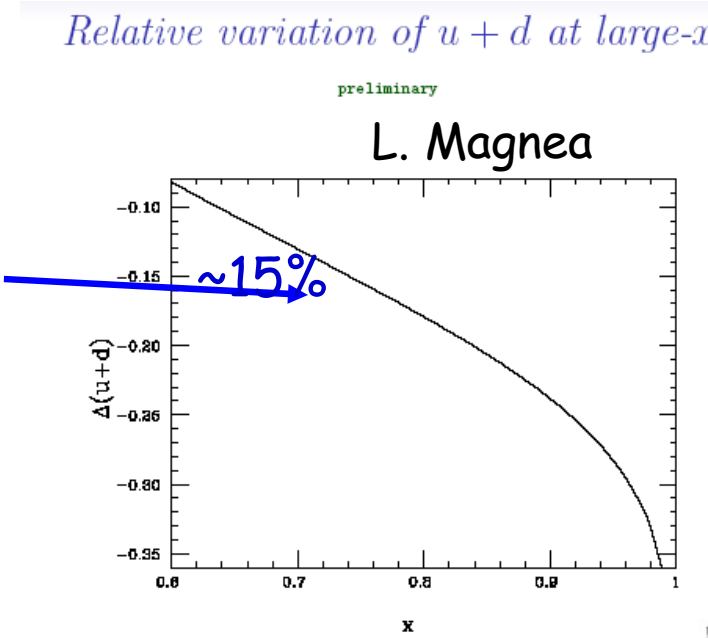


Simple spread of existing PDFs gives up to 10% uncertainty on Higgs cross section

=we have to do better than that

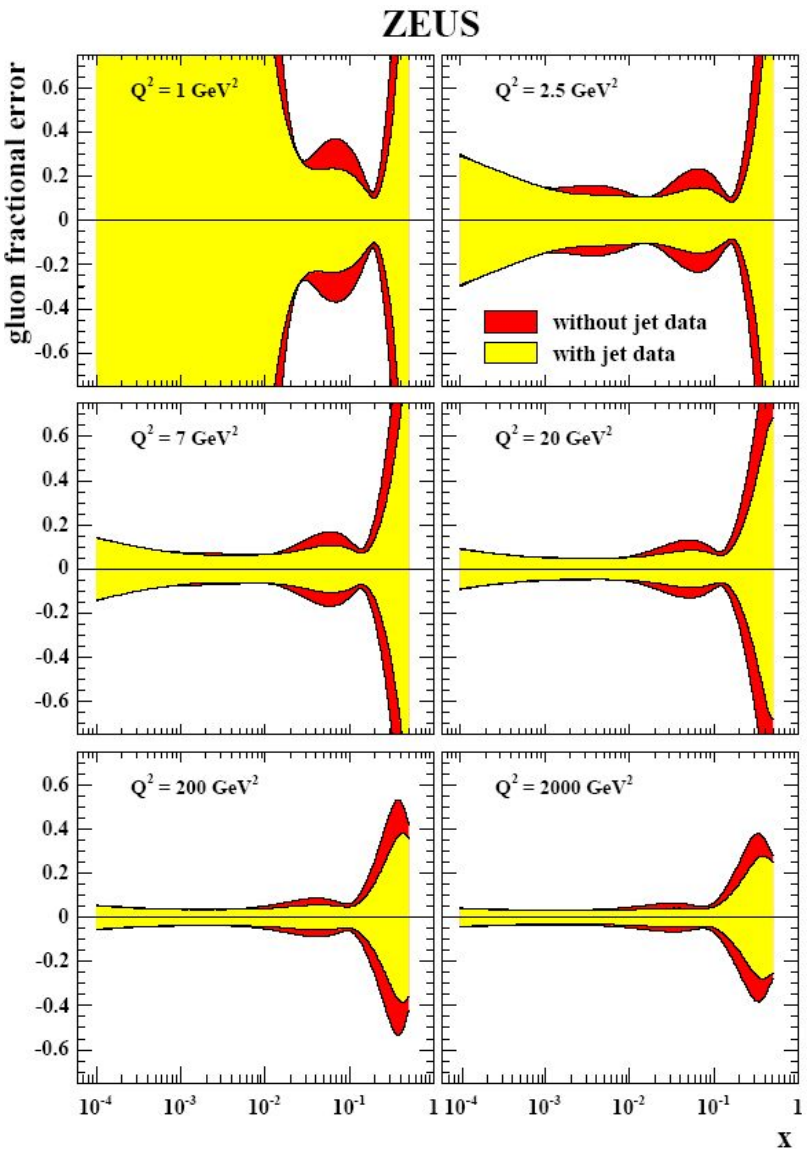
WG1: Structure Functions

- Potential experimental and theoretical accuracy for various LHC processes (DY,W,Z,WW,γ+jet…)
  - Cross sections and distributions
  - Benchmark with LHC detectorsimulation
- 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"?
- Impact of small x and large x resumations and saturation corrections on pdfs. QCD evolution validation (DGLAP,…)
  - Impact for LHC
  - Verify with HERA data.



Making the most of HERA data…

Improvement on g(x)

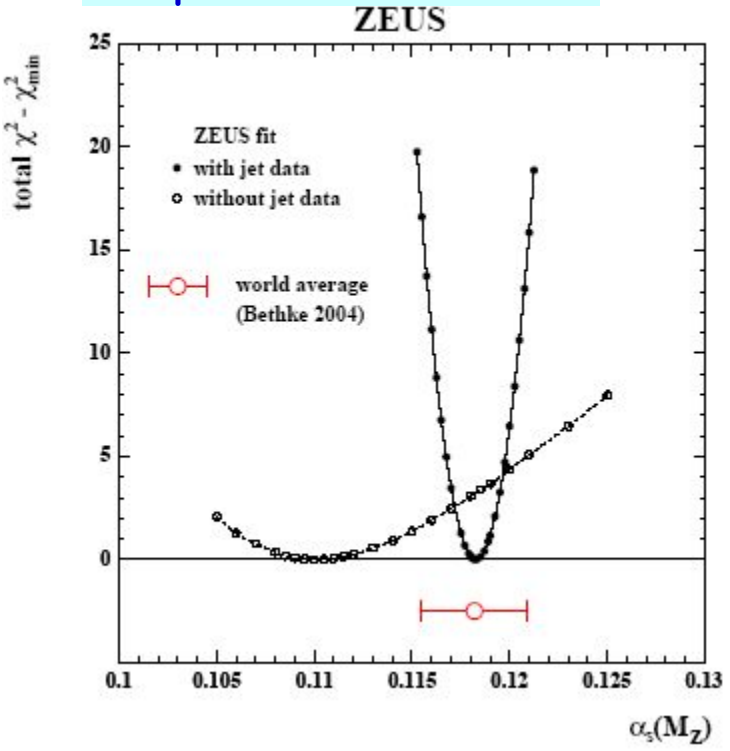


Global fits do have the problem of consistent treatment (errors) and sometimes 'tensions'

⇏ Fits of inclusive cross + jets (+..) within one "experiment"

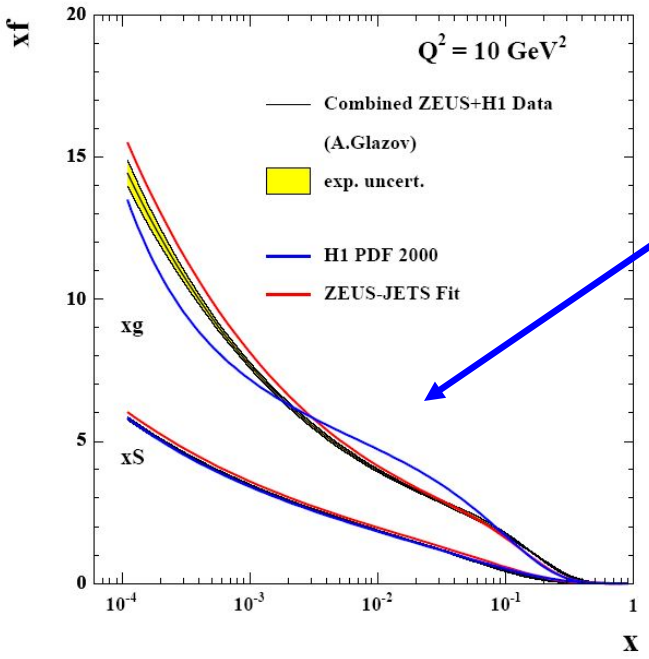
C. Gwenlan et al.

Improvement on α_s



Combined Data Sets from HERA?

I think the World wants it (like we want one top mass etc…)
⇒HERA PDFs will be THE standard for a long time to come
An effort is starting ⇒Averaged data set… (A. Glazov et al.)



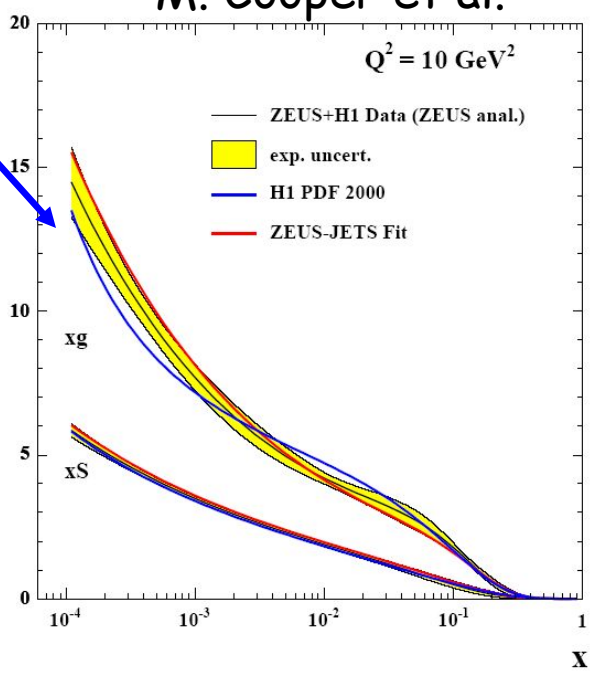
Compare PDF fit to H1+ZEUS data sets, and to the 'average data set.

Improved error?

Caution!

- Averaging procedure still very preliminary
- Some disagreements between the data set at low Q^2

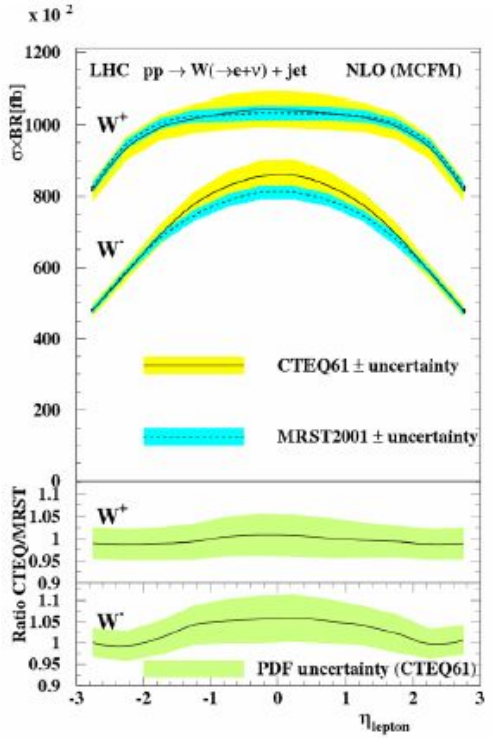
M. Cooper et al.

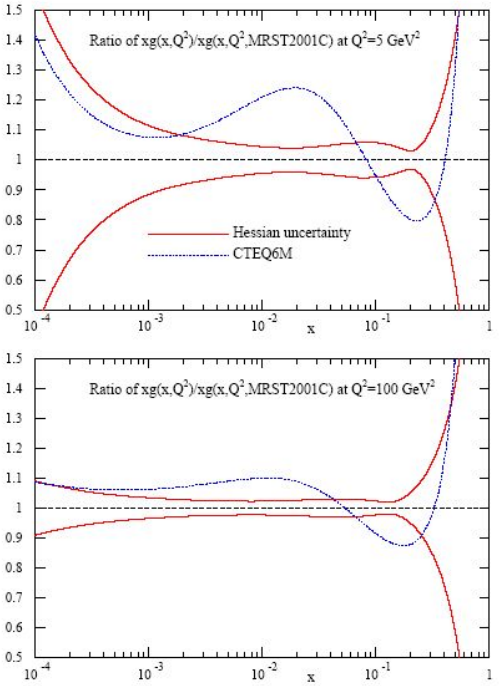


Feel encouraged to pursue this!

Need for F_L? Deuterons?

H. Stenzel





R. Thorne

F_L could referee the gluon distribution!
F_L is like F_2: little theoretical ambiguity (compared to e.g. F_2^c)

Deuterons: good for flavour separation, non-singlet SF extraction

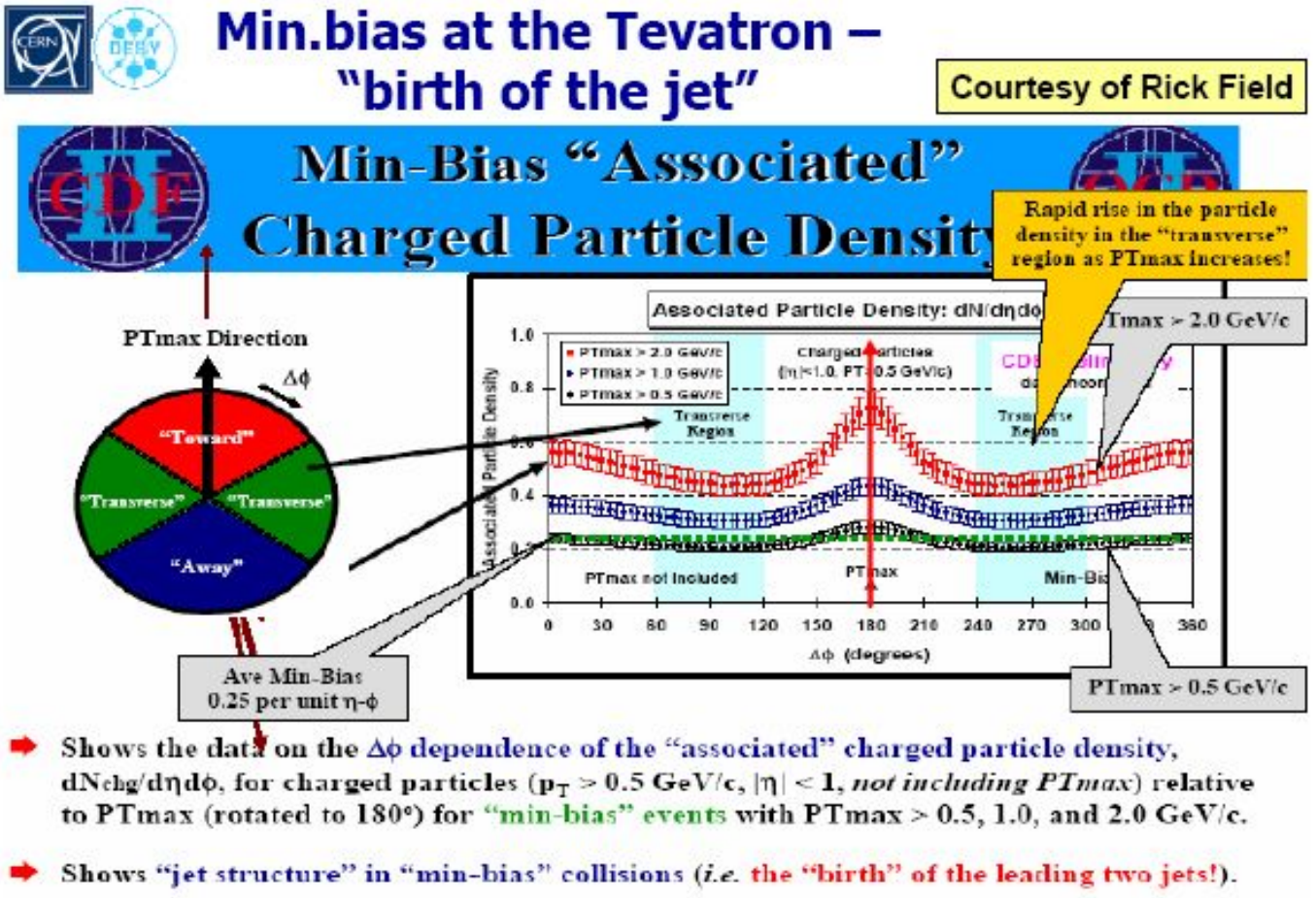
HERA is unique: looks to me that you would want to do that!!

⇒MUST make a strong quantitative argument! For Proceedings?

WG2: Multi-jet Final States & Eflows

- 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 sufficiently understood/ Consequences for the LHC
  - New measurements like effects in leading neutron spectra in ep?
- Cascade, based on CCFM (contrary to DGLAP)
  - Shows effects at the LHC at low x
- Unintegrated pdfs
- ME-PS matching
- Resummations for event shape variables
- Future parton shower developments
  - Unintegrated parton coreleation functions and QEDxQCD exponentiation

Underlying events/minimum bias

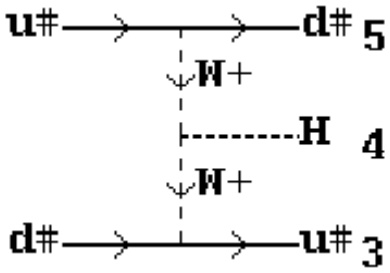


R. Field

- Shows the data on the Δφ dependence of the "associated" charged particle density, $dN_{chg}/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, *not including PTmax*) relative to PTmax (rotated to 180°) for "min-bias" events with PTmax > 0.5, 1.0, and 2.0 GeV/c.
- Shows "jet structure" in "min-bias" collisions (*i.e.* the "birth" of the leading two jets!).

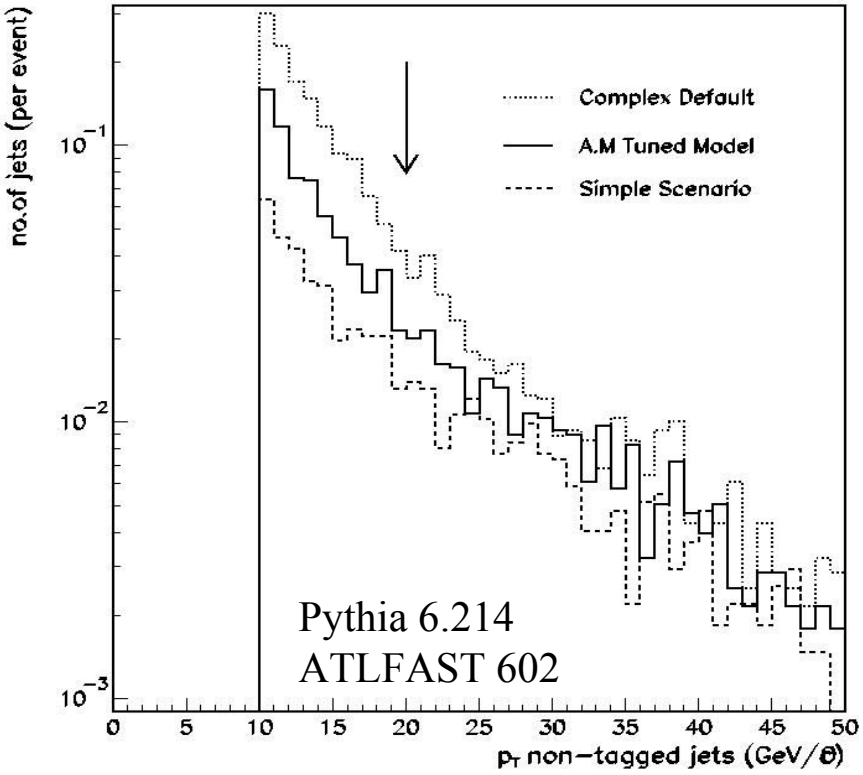
- Studies and tunes made on Tevatron/lower energy data
- These tunes should be validated on HERA data ⇒work in progress
  Similar studies should be made as for the Tevatron data
- New models on the market that should be tested (new Pythia, Jimmy, Sherpa)

Effect of underlying event on central jet veto in VBF Higgs

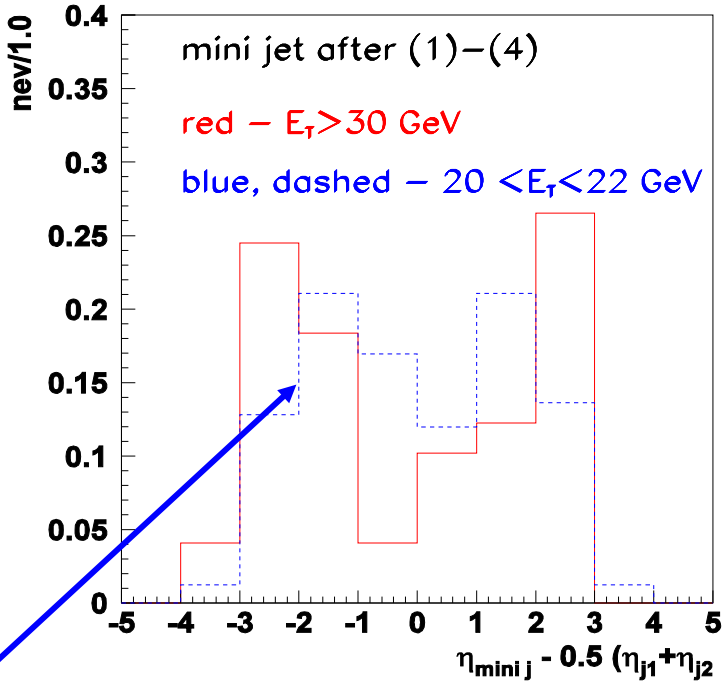


H->WW*->2l in qqH prod.

Uncertainty of the central jet veto efficiency due to UE model; ATLAS.



Rapidity of the central jet in Higgs events; CMS; full simulation, $L=2x10^{33}cm^{-2}s^{-1}$



Model	CJV efficiency	Significance
Default pythia	85%	8.2
Default DG	75%	7.7
AM tuning	79%	7.9

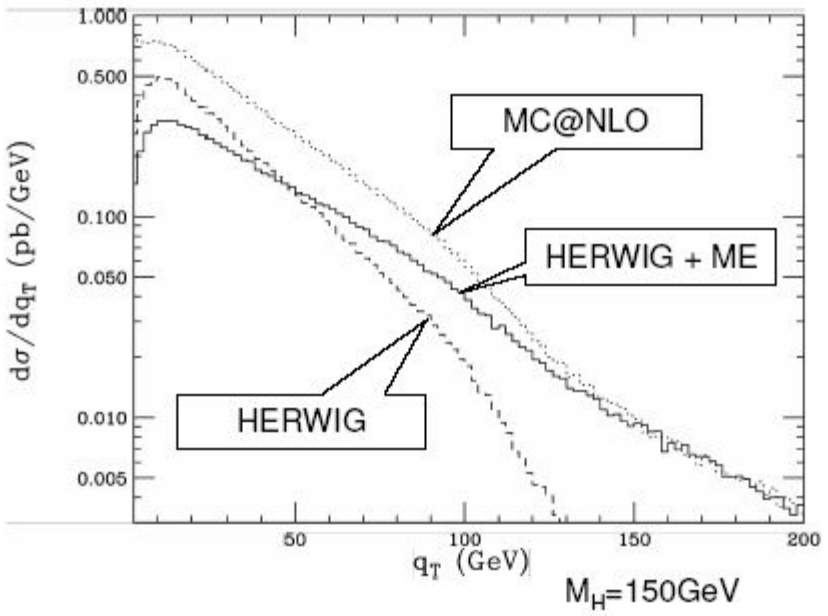
"bkg. like" behaviour for soft jets; fake jets: pile up+UE+detector

S. Nikitenko

Matrix elements and parton showers

Matrix Element Corrections to gg → Higgs

G.Corcella, S.Moretti, in progress



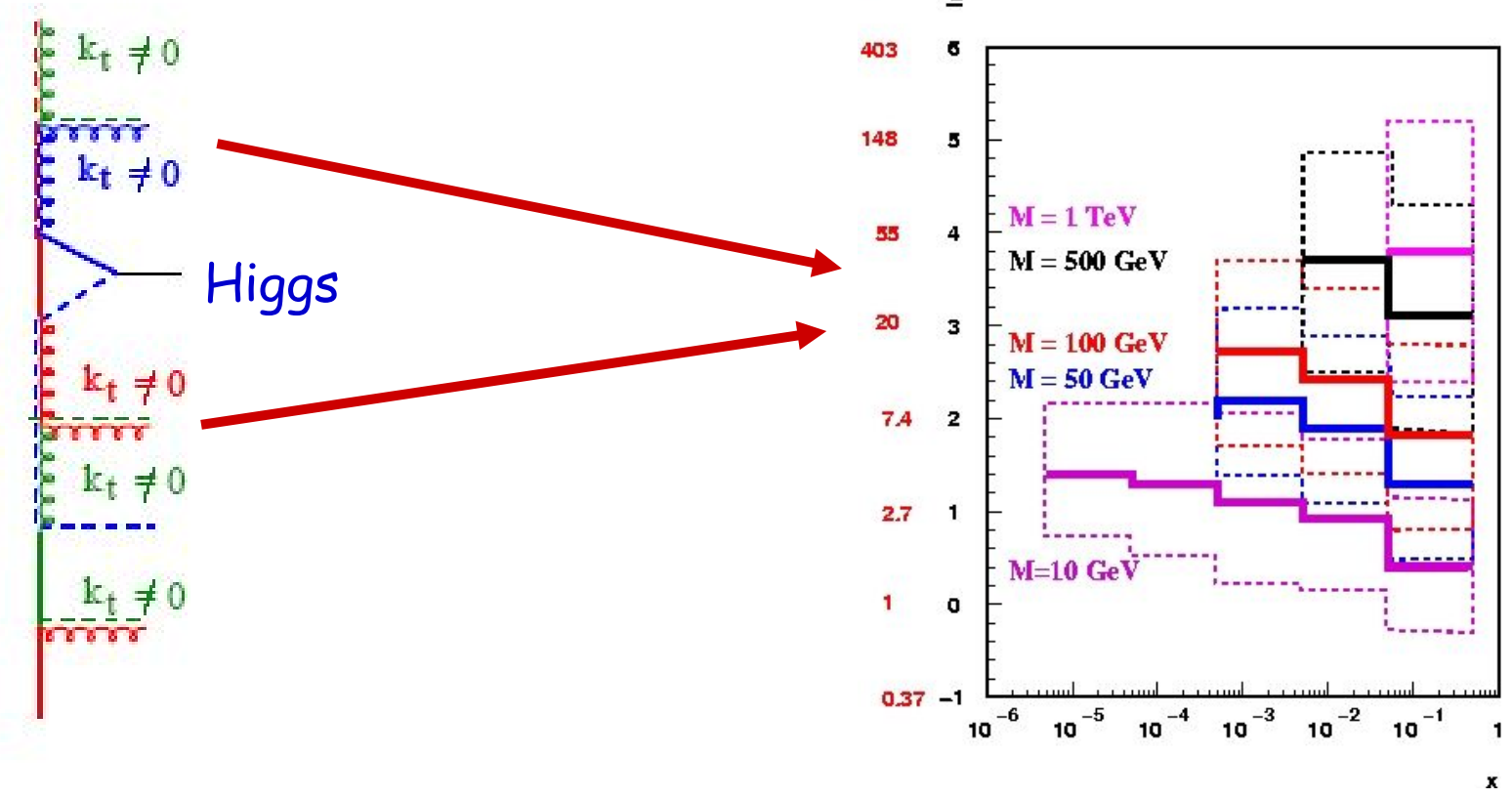
- Will be very important at the LHC
- Need to understand jet topologies of up to 8 jets (and more)
- Matching algorithms now also being implemented for ep scattering
- Can be benchmarked to HERA multi-jet data.

Initial k_t at HERA and LHC

Initial K_t in the hard scattering

Jung

Cascade calculation



$\langle K_t \rangle$ large ⇒ unintegrated parton PDFs will be needed

Measure unintegrated PDFs at HERA via final states

WG3: Heavy Flavours

List of measurements of measurements to be made at LHC (need > 400 pb^{-1})

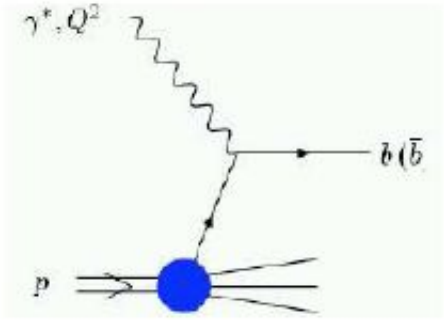
- $F_2^{cc/bb}$
- Charm exclusive final states (γp and DIS)
  - Cross sections
  - Fragmentation universality
  - Contribution from higher charm resonances
- Charm exclusive final states with jets (γp and DIS)
- Beauty exclusive final states (γp and DIS)
- Double quark tag
- Charm and beauty in charged current events
- Quarkonia
- Diffraction

Several of these have direct impact on the LHC

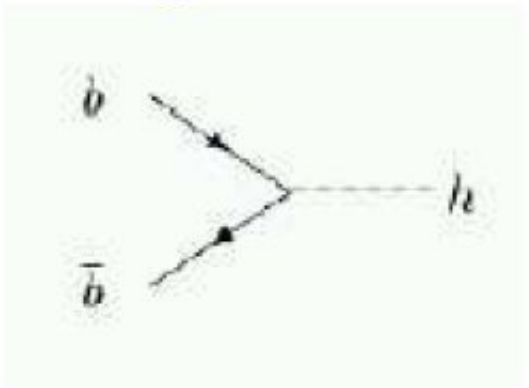
F2b at large Q2

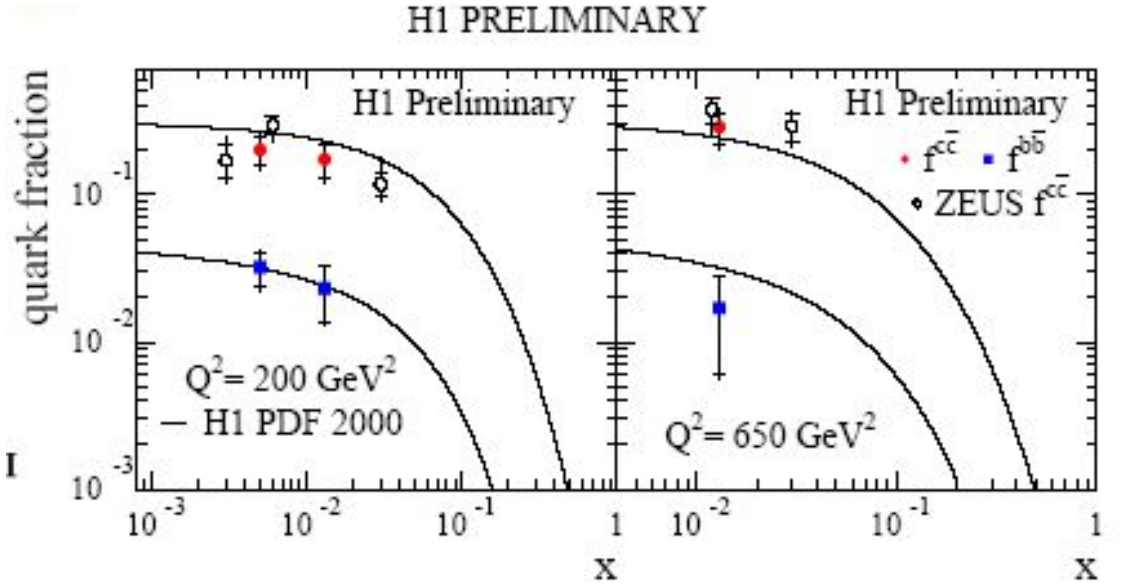
b-pdf at HERA goes to LHC

Beauty at HERA



Higgs at LHC



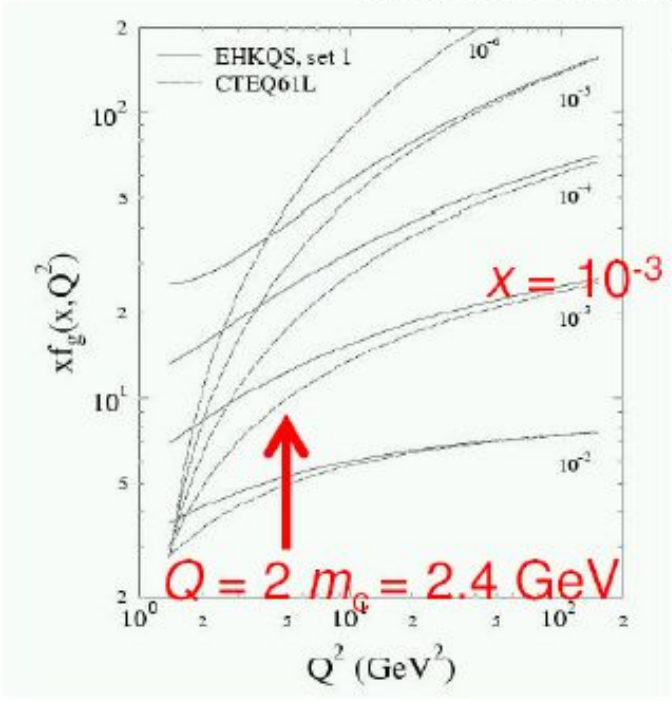


Need to measure the F_2^b at the same scale as ~$M_H/2$

Possibly reduce error by a factor of 4 at HERA-II

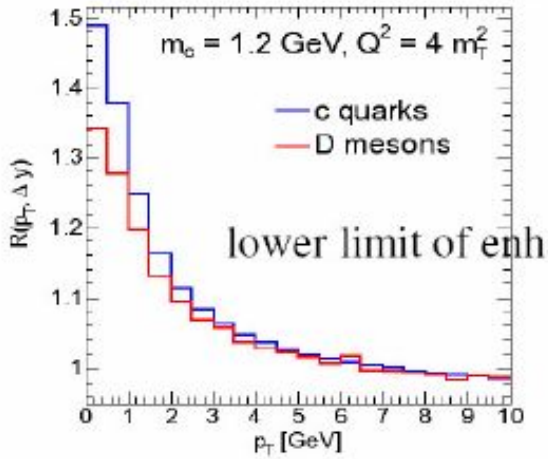
Charm production

Charm enhancement at LHC due to nonlinear gluon evolution



- Fits to HERA F_2 data at small x, small Q^2 improved by adding nonlinear terms (nonDGLAP) to gluon evol. [hep-ph/0211239]
- At LO, implies higher xf_g in x region probed by LHC

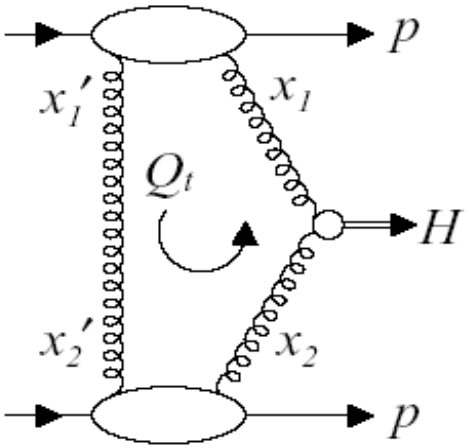
→ more charm at low p_T [hep-ph/0310111]



- ALICE can reconstruct D mesons down to $p_T \approx 0$ and look for the effect [hep-ph/0403098]

WG4: Diffraction

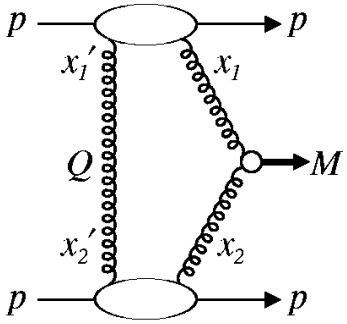
- Diffractive Higgs production
- Backgrounds to diffractive Higgs
- Diffractive factorization breaking
  - Dijet production
  - Charm production
  - Leading neutrons
- Rapidity gap survival (with WG2)
- Exclusive diffractive dijets

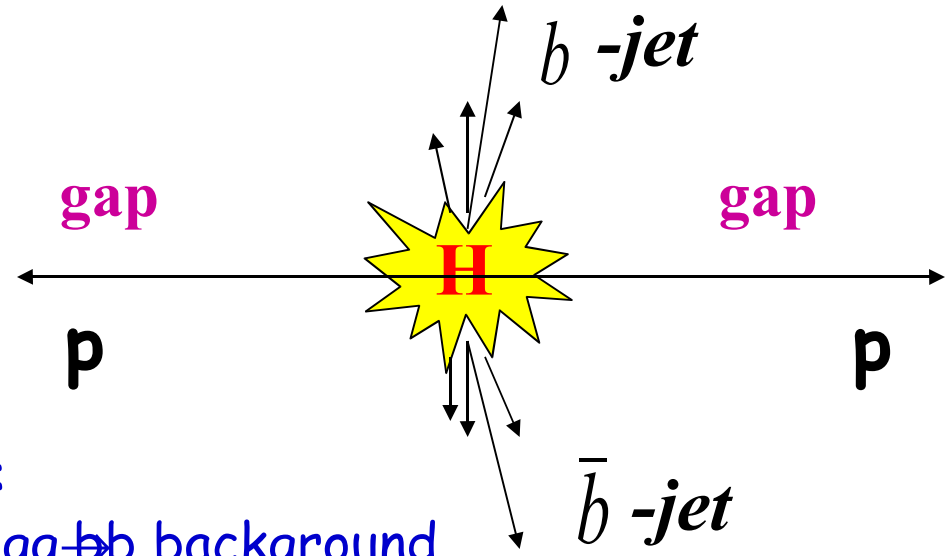


- Large part of the activities was transfer of experience of the knowledge and design and operation of detectors for forward physics from HERA to the LHC

Diffractive Higgs Production

Exclusive diffractive Higgs production pp→p H p : 2-10 fb
Inclusive diffractive Higgs production pp →p+X+H+Y+p : O(100) fb



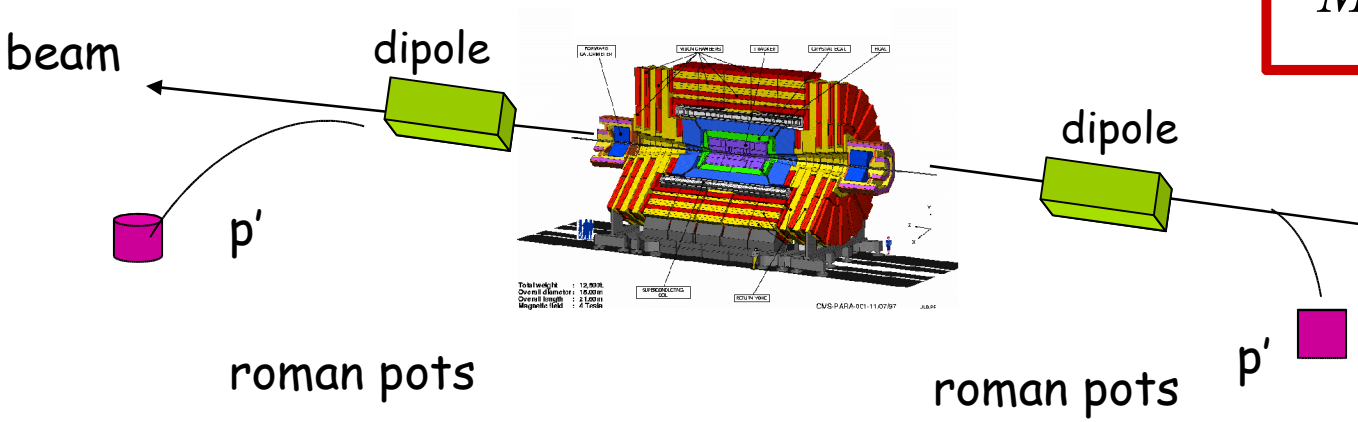


E.g. V. Khoze et al
M. Boonekamp et al.
B. Cox et al. …

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

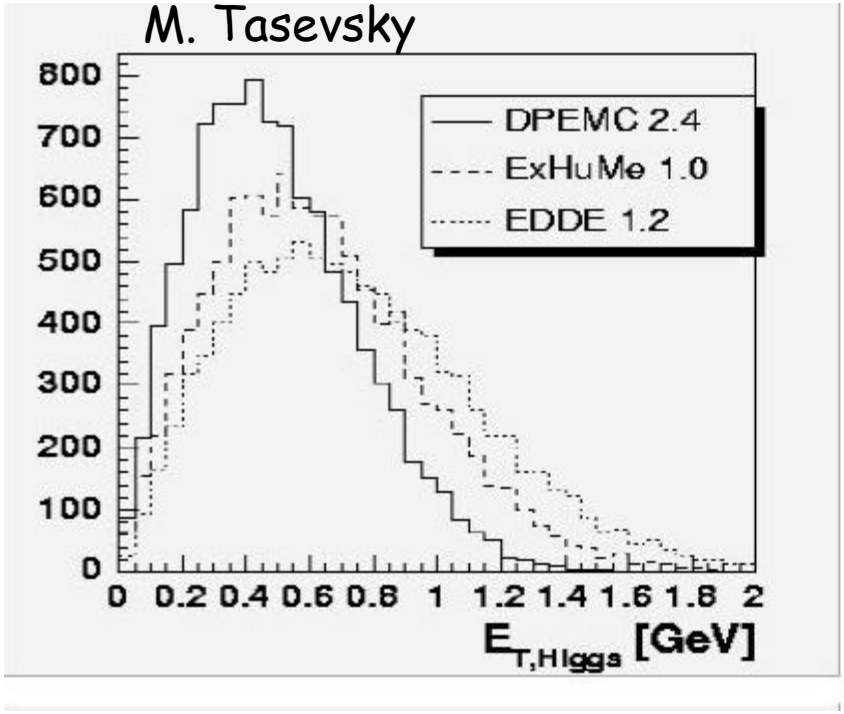


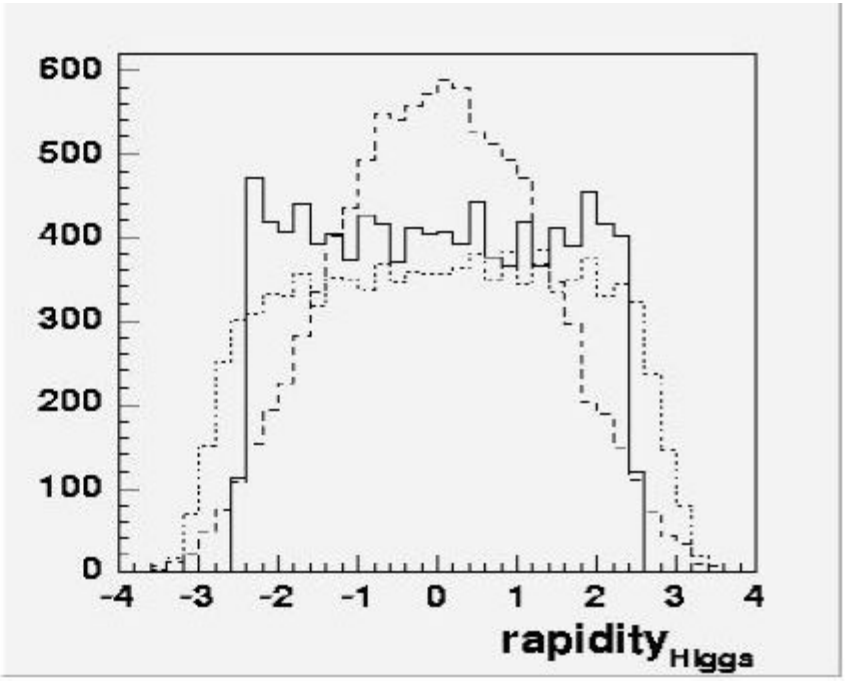
P. Landshoff not convinced that the cross sec. is small

Diffractive Higgs production

A lot of useful and necessary discussion during this workshop on

- Different models
- Realism of such measurement

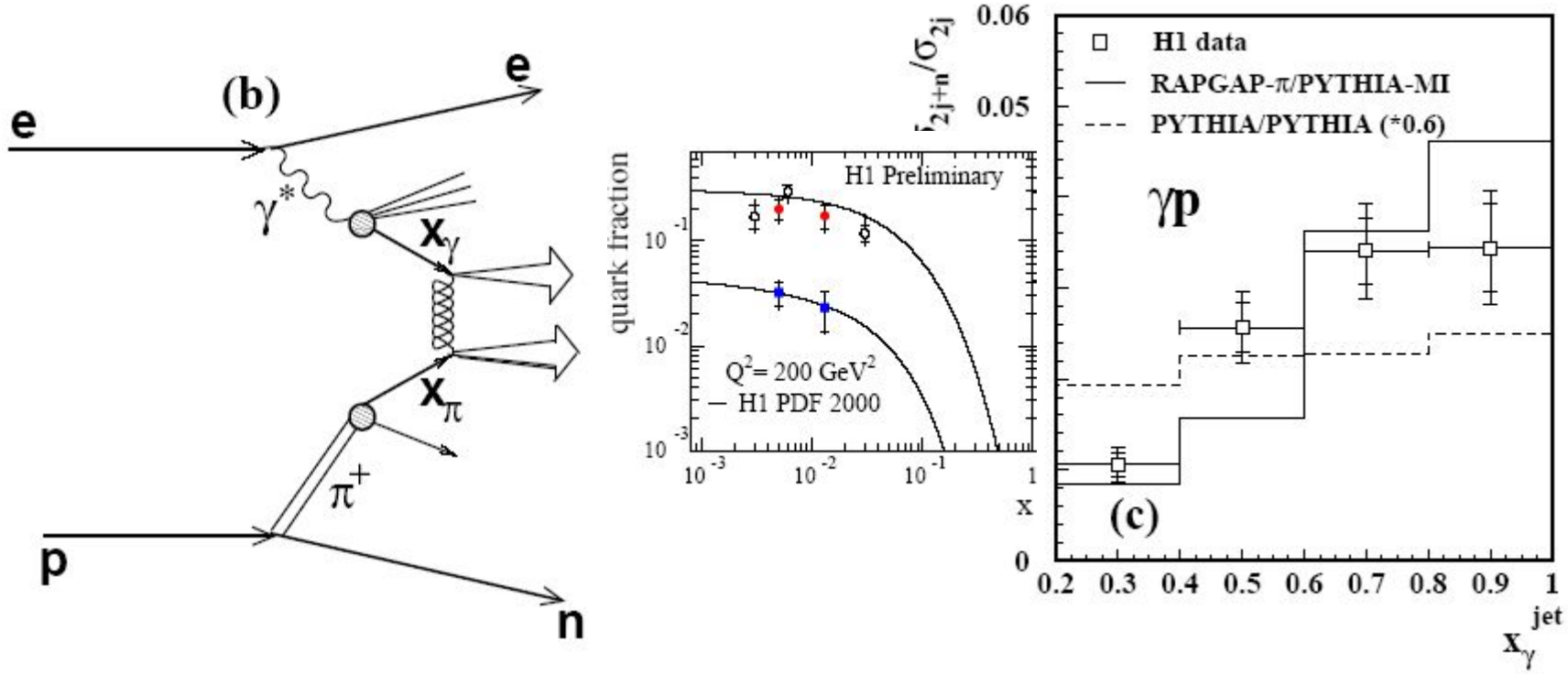




- Differences understood (Sudakov factors, parton distributions…)
- Exhume gives the more natural expected ηbehavior
- Khoze-Martin-Ryskin calculations checked by independent group ⇒ok

Understanding the Gap Survival

A complementary way to study rescattering effects in collisions
⇒ look at events with a leading neutron



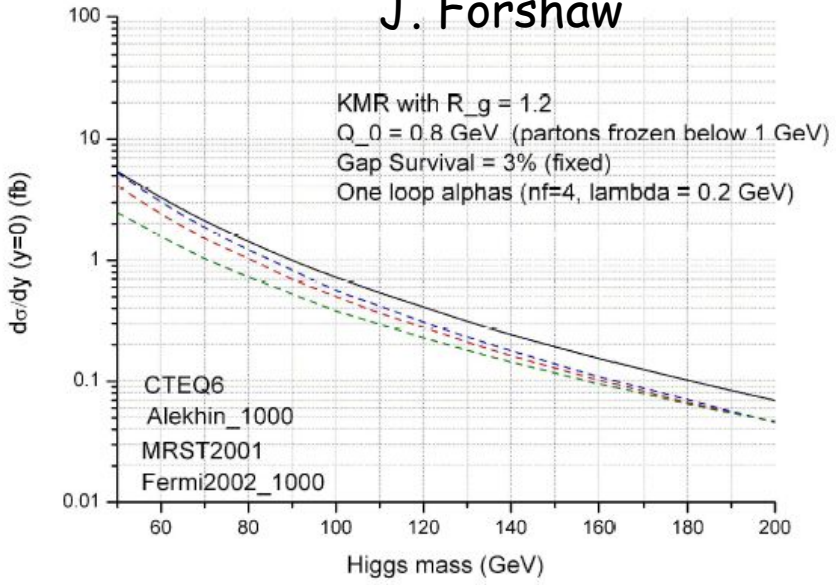
- Can be an ideal laboratory to study the dynamics of gap survival probability
- Effects can be calculated, x-pt correlations etc. (A. Kadialov et al. to appear)
- More measurements like the one shown here will be very usefull

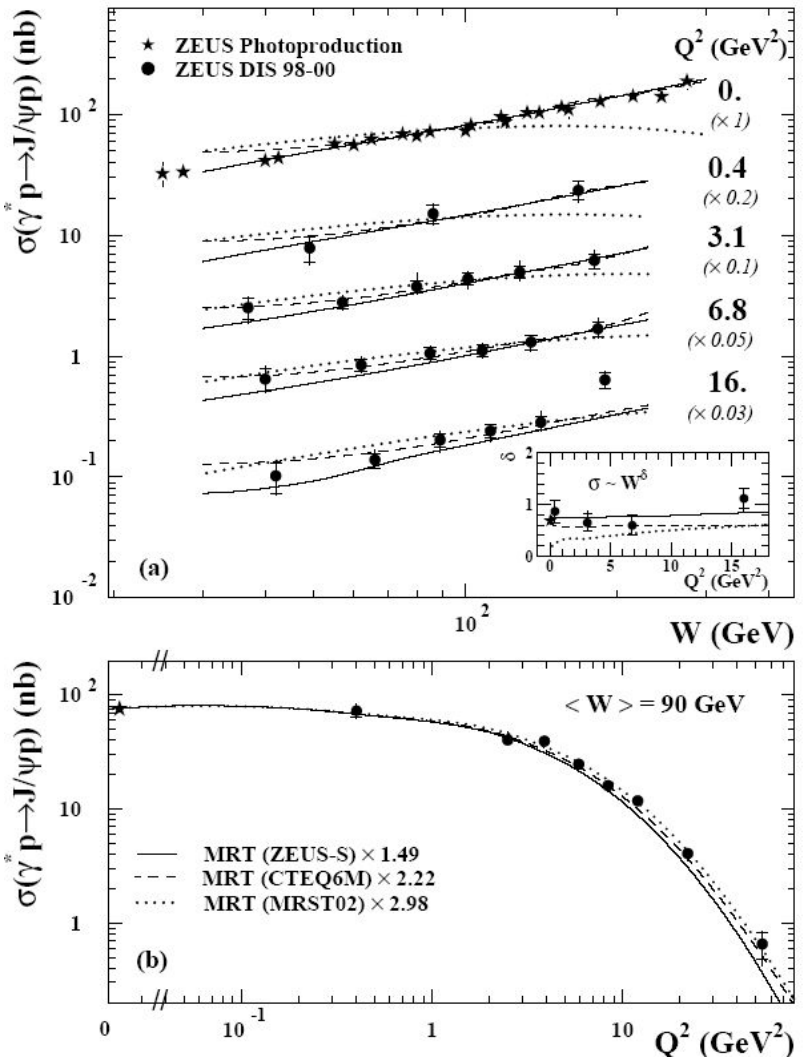
Generalized Parton Distributions

Generalized parton distributions affect the predictions for diffractive Higgs production

Can be measured at HERA eg. in exclusive J/ψproduction

J. Forshaw

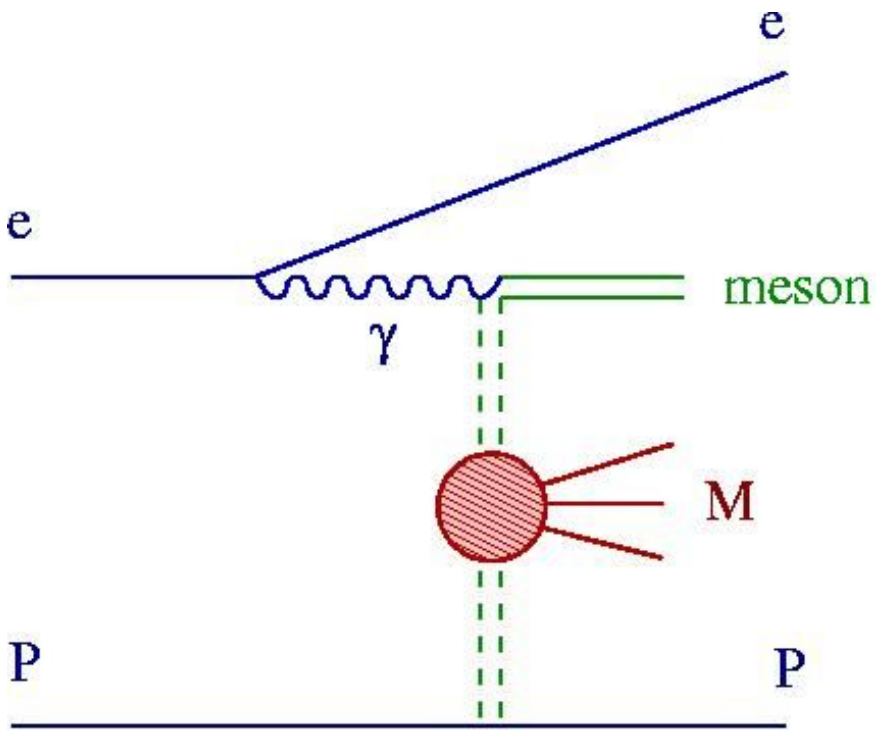




Upsilon production measurement would be even better!

Information from HERA

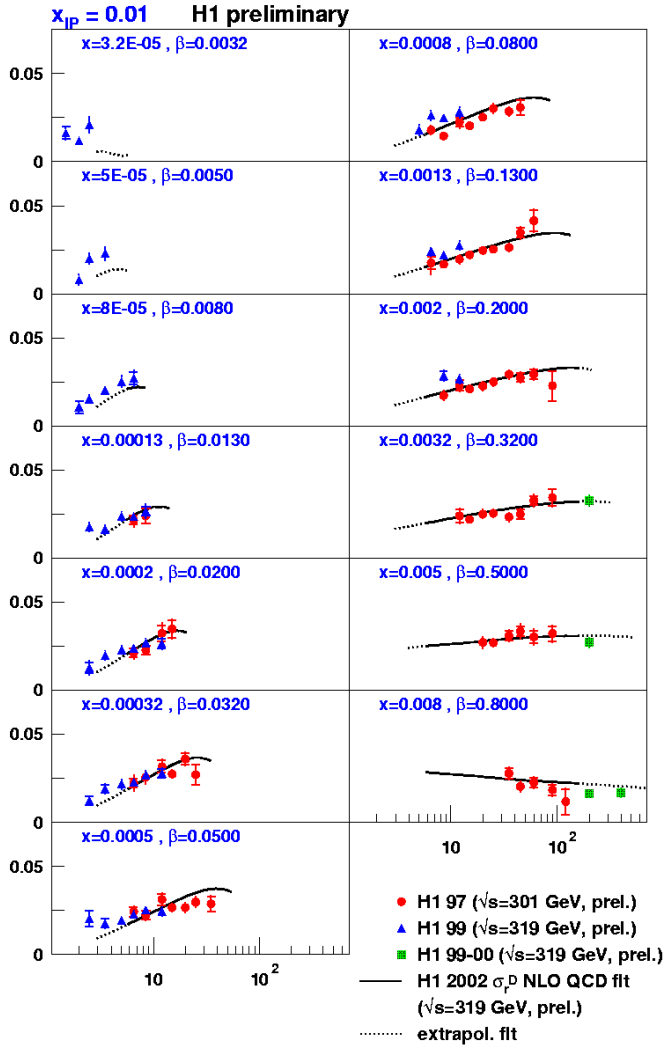
Study the process of $\gamma p \rightarrow VM + X + p$



Double pomeron exchange @ HERA

B. Cox et al.

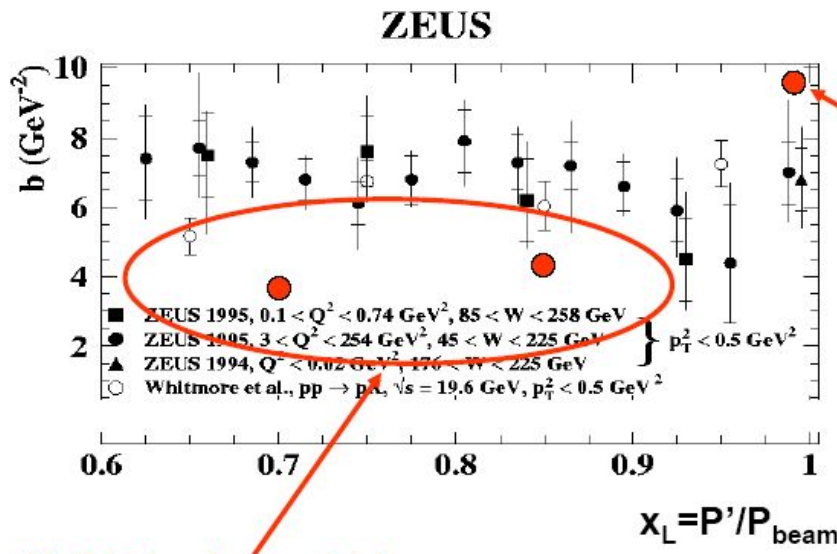
Diffractive structure functions



Leading proton spectra in generators

M. Ruspa

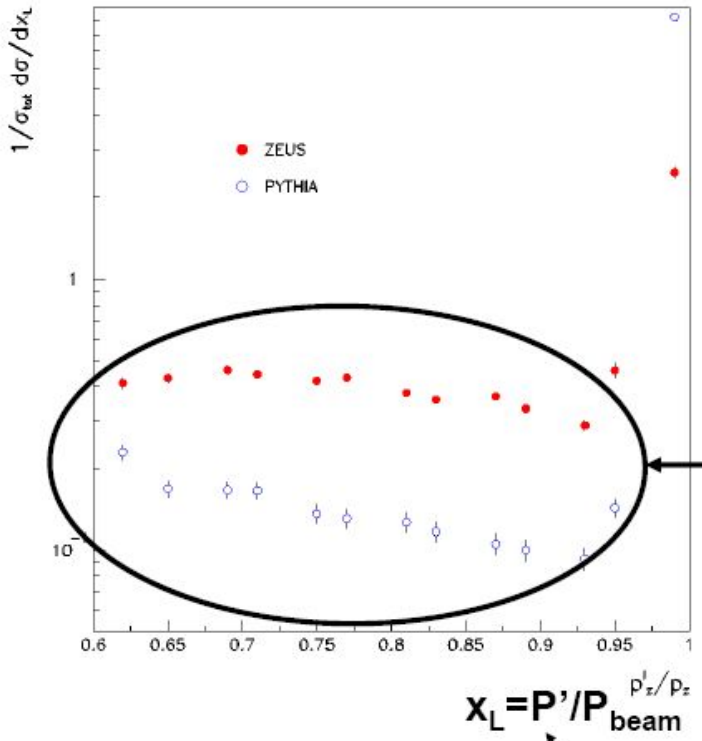
Pythia used for pile-up background studies at LHC
How good is it when compared to data, e.g. from HERA??



Pythia approx OK in diffractive Peak, after taking shrinkage ($b = b_0 + 4\alpha' \ln s$) into account

Pythia too low outside diffractive peak

b-slope

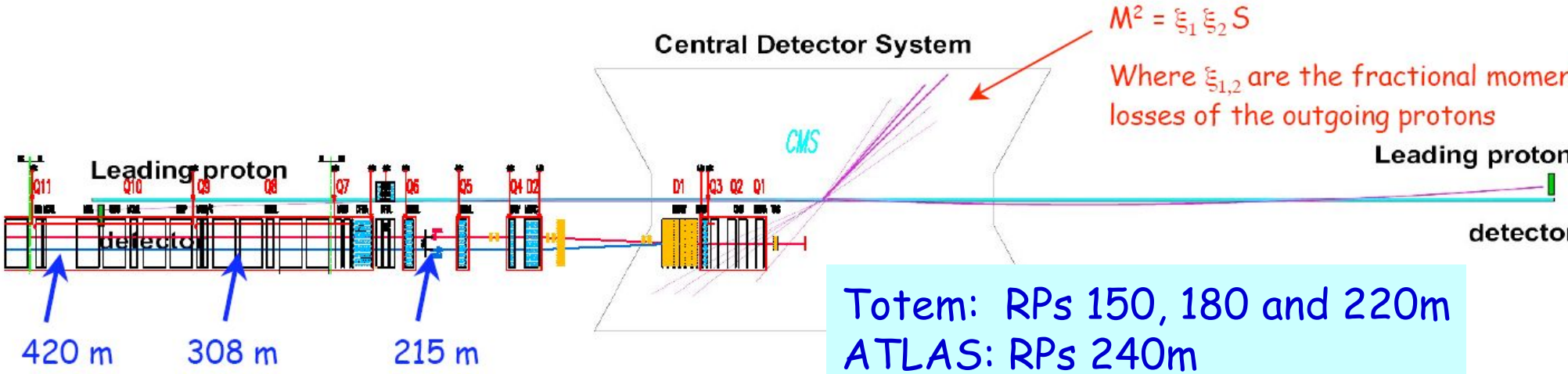


Pythia wrong in shape and normalisation outside diffractive peak (approx factor 2-3)

Fastest proton in the event

Leading proton spectra

Forward Detectors



Totem: RPs 150, 180 and 220m
ATLAS: RPs 240m

High β^* (1540m): Lumi 10^{28}-10^{31}cm^{-2}s^{-1}
>90% of all diffractive protons are seen in the Totem Roman Pots.

Low β^*: (0.5m): Lumi 10^{33}-10^{34}cm^{-2}s^{-1}
220m: $0.02 < \xi < 0.2$
300/400m: $0.002 < \xi < 0.2$ →Diffractive Higgs

R&D effort for detectors at 420m FP420 started in earnest
If you are interested it is time to join

See B. Cox

TOTEM/CMS Forward Detectors

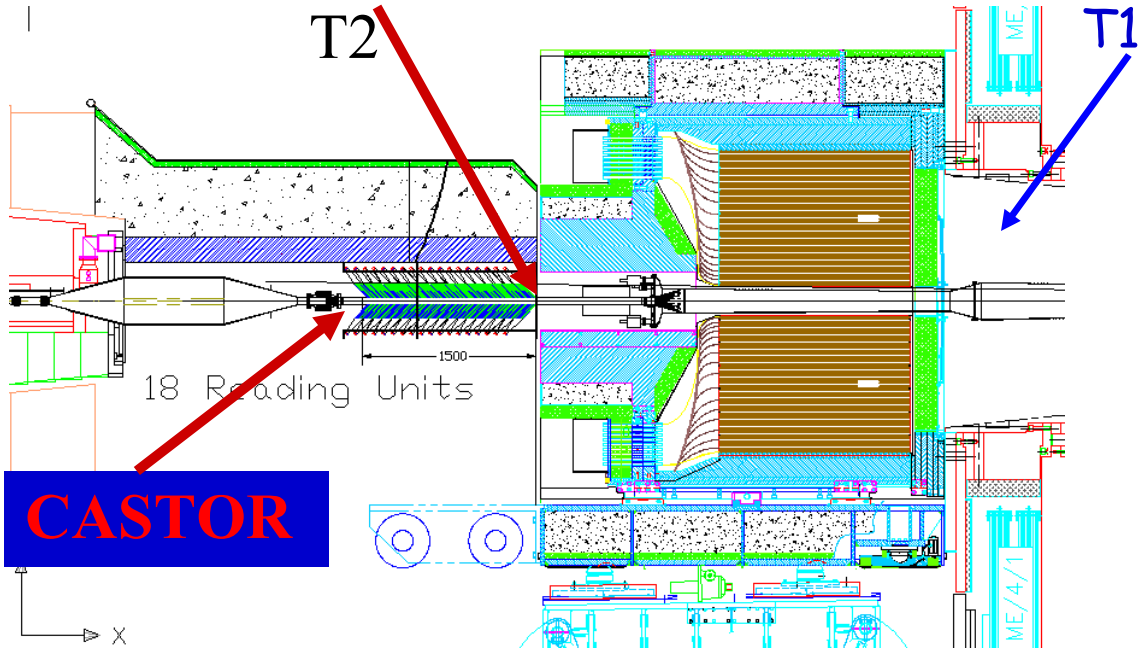
T1/T2 inelastic event taggers
- T1 CSC/RPC tracker ('99 LOI)
- T2 GEM or Silicon tracker (TOTEM/New)
- CASTOR Calorimeter (CMS/New)
- ZDC Calorimeter (CMS/New)
- More detectors under study

T1 $3.1 < \eta < 4.7$
T2 $5.3 < \eta < 6.7$
Castor $5.25 < \eta < 6.5$

Diffraction/Low-x is part of the LHC physics program (EOI)

CMS/TOTEM work on common LOI for diffraction+

ATLAS starting…



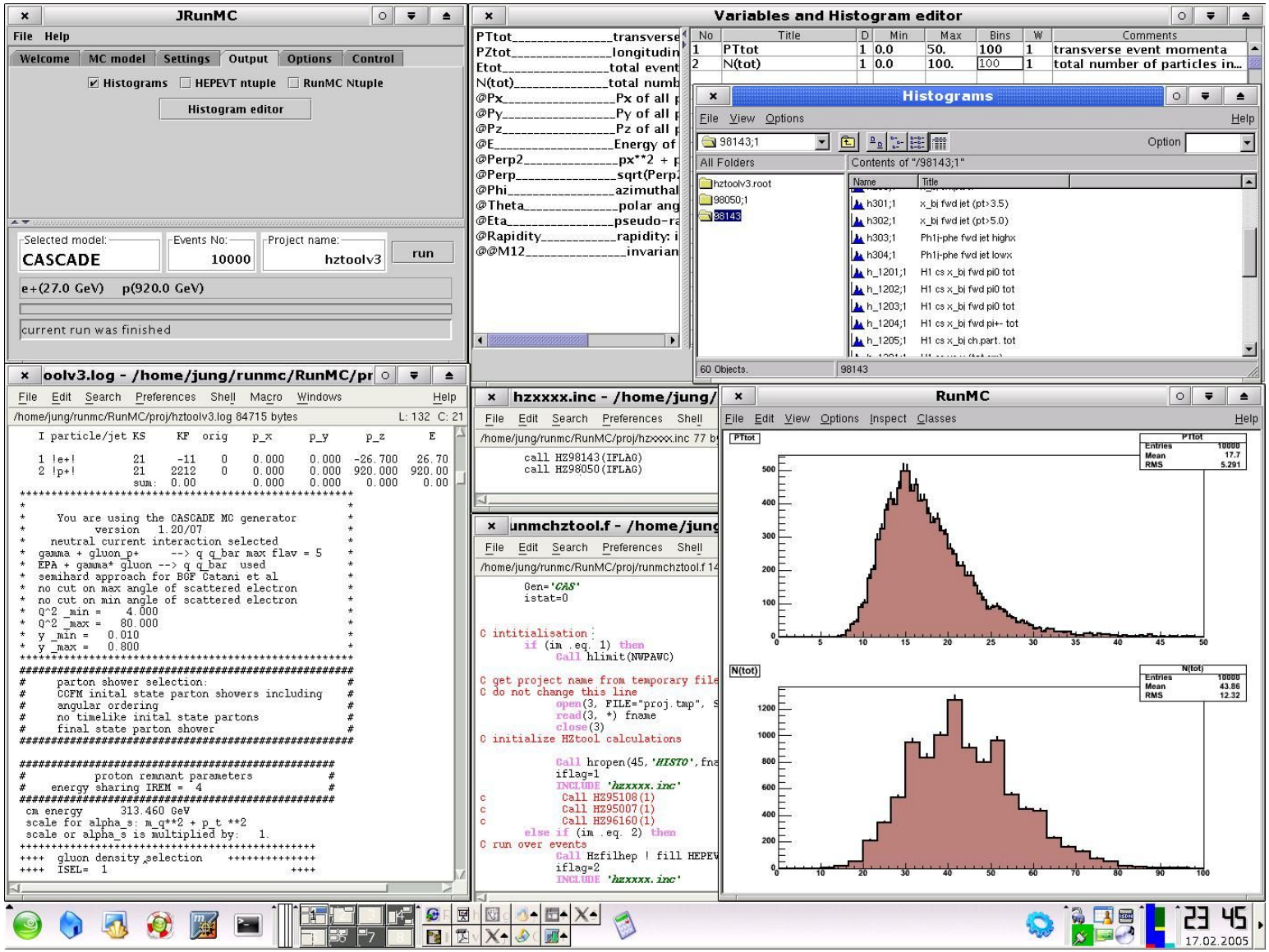
Opportunities for new groups to contribute to the LOI !!

WG5: Tools

- Parton distribution library:
  - LHAPDF now official carrier of the PDFs
  - Used by LHC experiments in generators
  - HERA pdfs have been added
  - Allows error uncertainty estimates
  - Pion and photon added, particulalry 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 tunning
  - All HERA results to be included, some e+e-. Include more pp?
- RAPGAP, Cascade Monte Carlos for inclusive and diffractive pp
- Plenty of exchange on other MC tools, leading to other MC tools and comparisons with ep where possible
- Continuation of the MC@LHC workshop, concerning validation

Screen shot of RUNMC session

S. Chekanov



The Verdict

- 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.

Many studies still ongoing ⇒ for Proceedings and Beyond

I think we are not doing so bad!

Wait… did he say "beyond"?

Next steps

- Proceedings
  - Deadline first of August! Plan your summer conference/holiday carefully!
  - WGS may organize a WG meeting to get their "act" together
- Beyond the workshop
  - Plenary meetings of this workshop end now (in 5 min)
  - 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 (as R. Heuer(*) anticipated)
  - Keep momentum with one plenary HERA/LHC meeting per year
    - Eg. Fall 2005 CERN (or early 2006)
    - 2006 DESY
    - 2007 CERN… (Lyn promised collisions @ LHC!!)
  - Keep also good contacts with Tev4LHC (a common meeting some time?)

(*) Guess he is ready to 'support' it

Final words

- Important: have established contacts and good working relations between the HERA and LHC communities
- Several projects are established and ongoing.

Good!

- To all participants in general and the WG convenors in particular

Thank you!

But keep the work going!