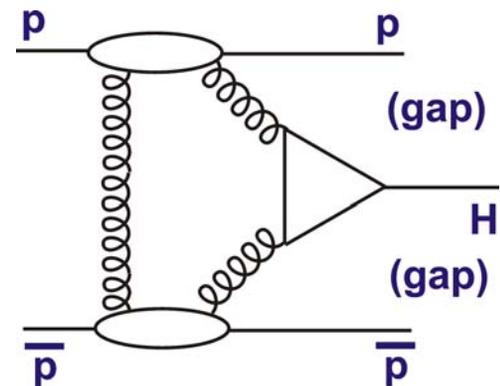
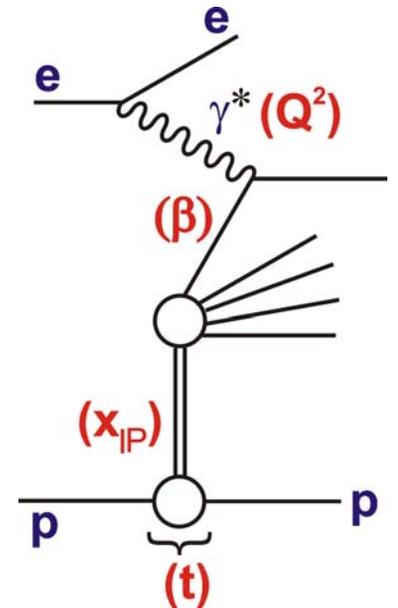


Experimental Diffraction from HERA to the LHC

P. Newman (University of Birmingham)
DIS 2008, UCL, 7 April 2008

- Forward Physics projects at the LHC
- Diffractive Parton Densities at HERA
- Diffractive Factorisation tests at HERA
- Closing in on Central Exclusive Production
(short & limited summary ... many omissions)

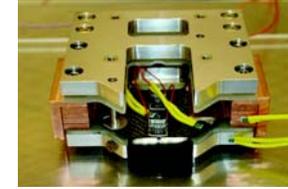
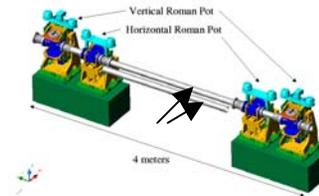
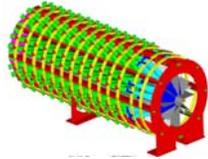
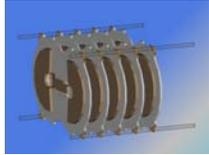
Many thanks to M. Arneodo, A. Bruni, K. Cerny, M. Diehl,
V. Khoze, M. Ruspa S. Schaetzel, P. van Mechelen ...





LHC Forward Instrumentation

IP5



TOTEM-T2

CASTOR

ZDC/FwdCal

TOTEM-RP

FP420

14m

16m

140m

147-(180)-220m

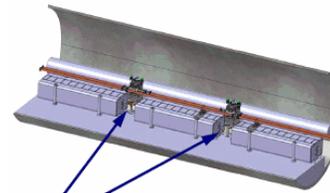
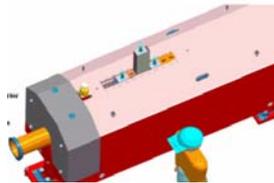
420m

LUCID

ZDC

ALFA/FP220

FP420

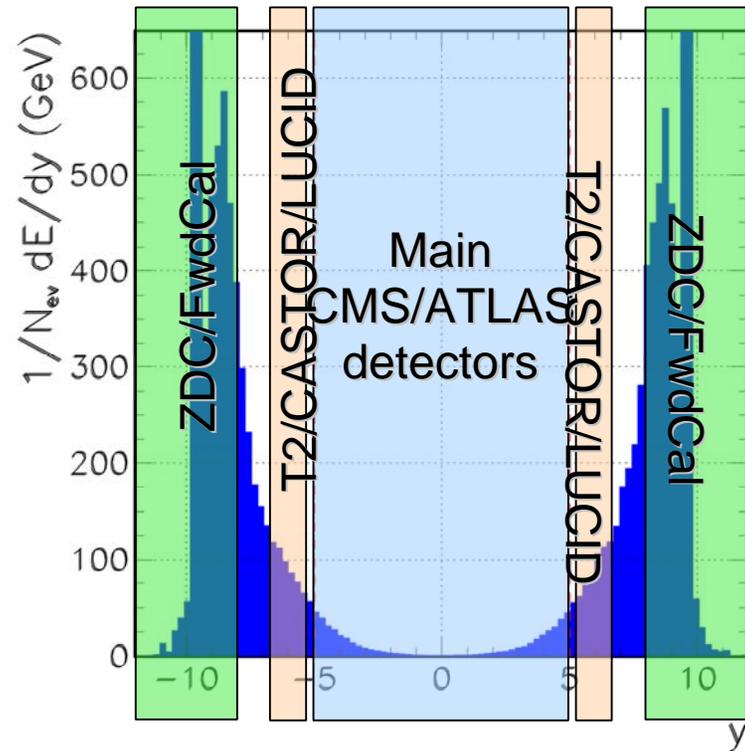
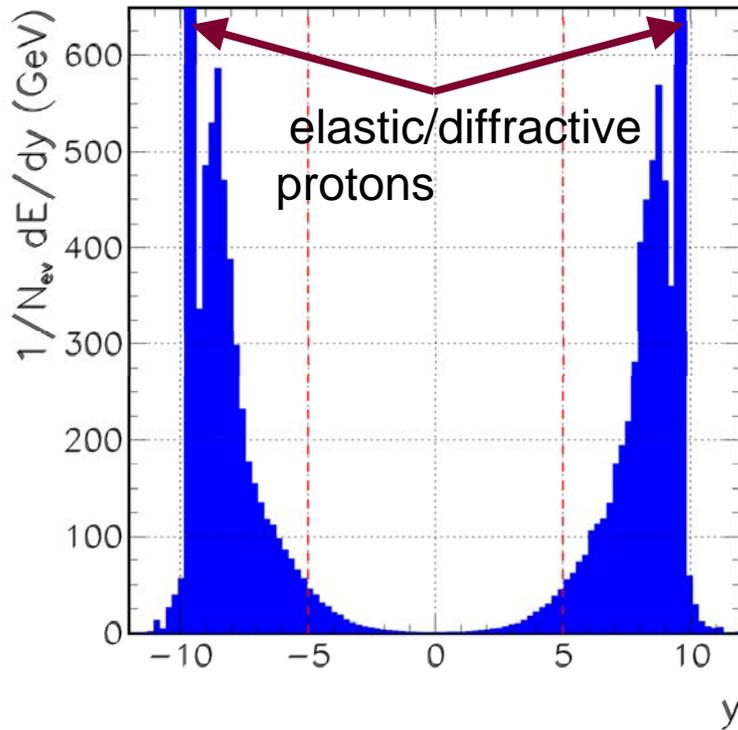


IP1

Impressive array of forward physics projects, providing high rapidity tracking / calorimetry and Roman pots for protons ...

... extreme region of QCD, only partly explored at HERA!

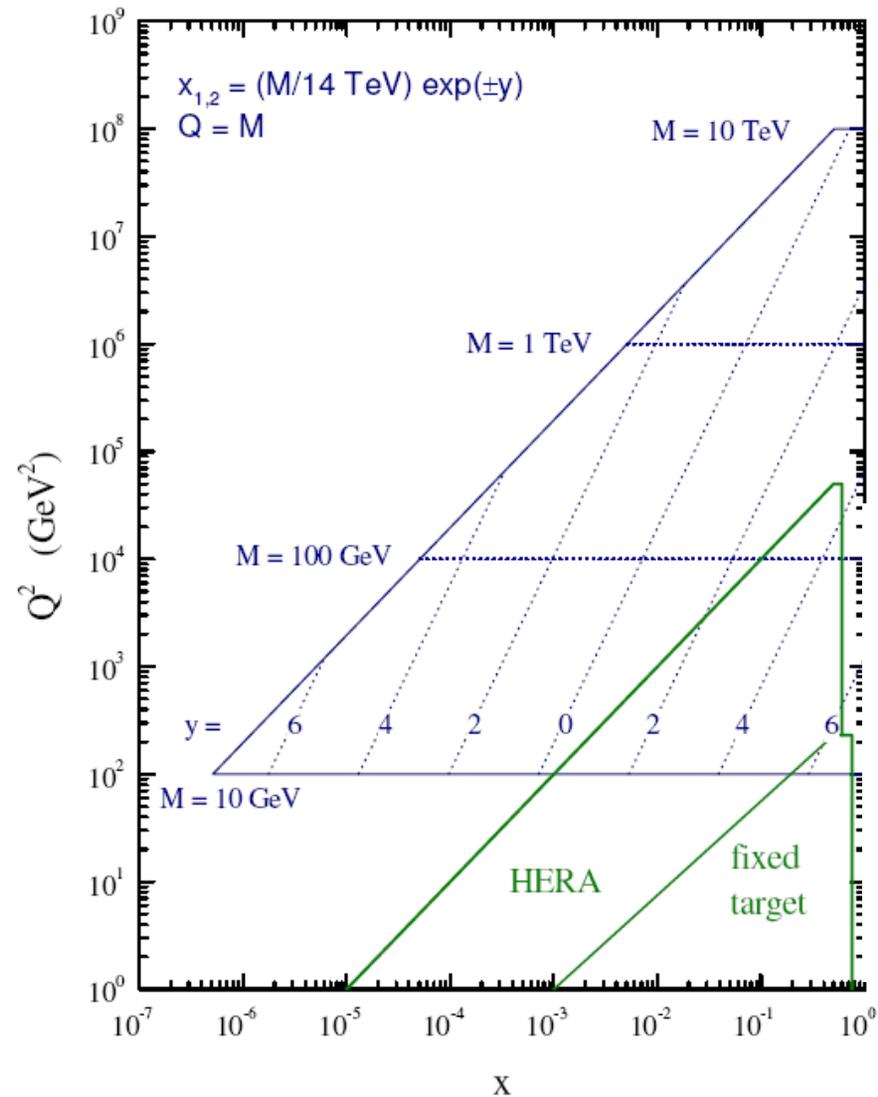
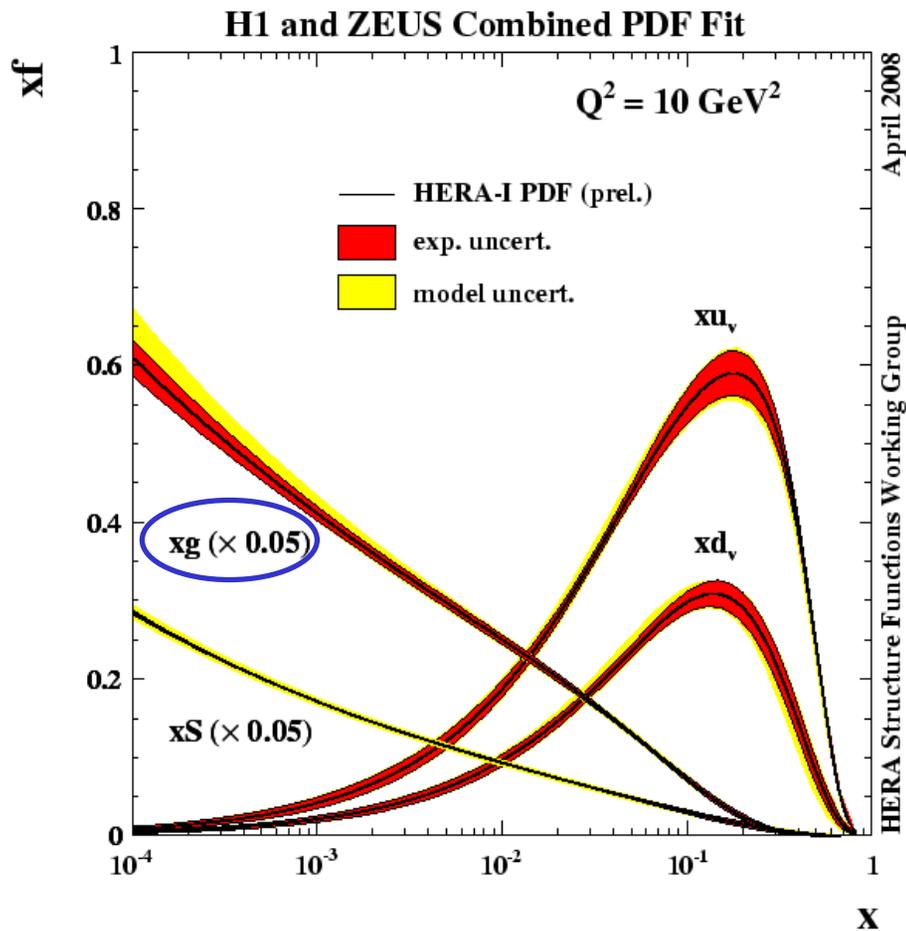
Large Rapidity and Energy Flow



LHC energy flow looks very different from particle flow!
Diffractive channels $\sim 25\%$ of total cross section
Lots of forward energy / diffractively scattered protons ...

... the best instrumented forward beam lines ever...

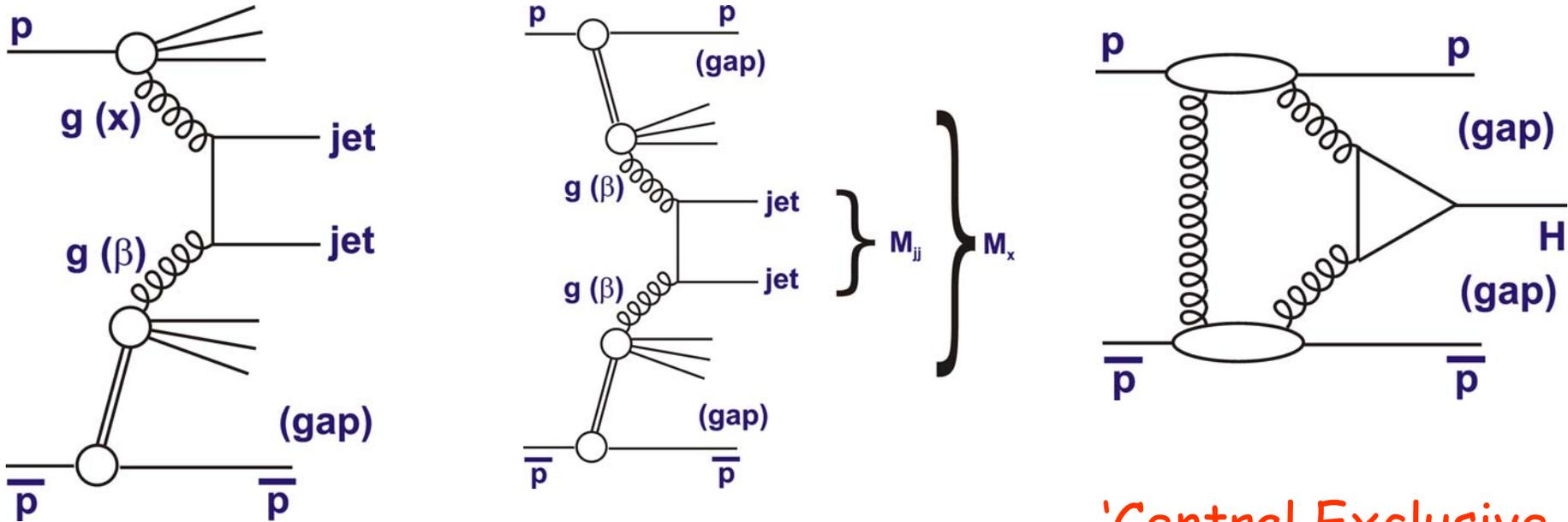
Parton Saturation?



e.g. TOTEM acceptance to $|\eta|=6.5$ corresponds to $x \sim 10^{-6}$ at $Q^2 = 100 \text{ GeV}^2$ and 10^{-7} at $Q^2 = 1 \text{ GeV}^2$

... Unconstrained by HERA ... Virgin territory!!!

Hard Diffraction at the LHC



Opportunity to study single and double dissociation without and with hard scales (jet, heavy flavours, W, Z).

→ Depend on DPDFs from HERA

→ Also on gap survival factors!

'Central Exclusive Production'

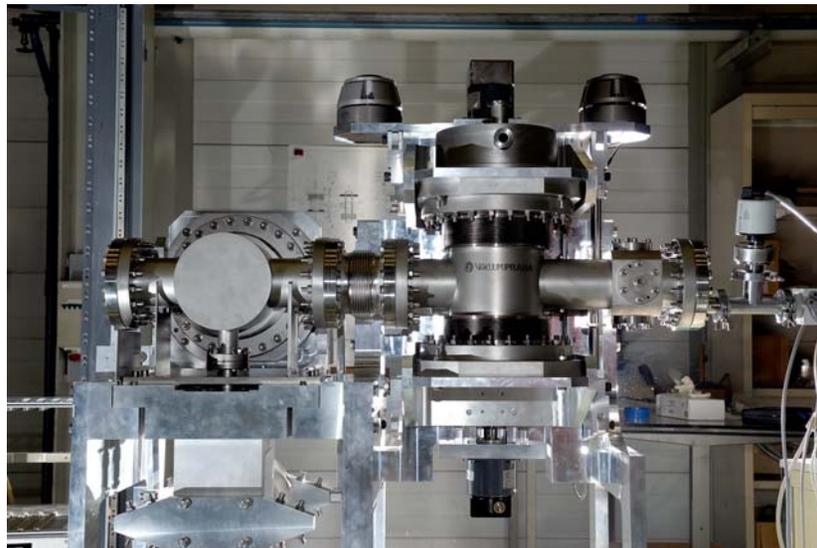
... No DPDFs ...

... but unintegrated gluon / GPDs

... and gap survival

Clearly lots of possible input from HERA!

LHC Roman Pots



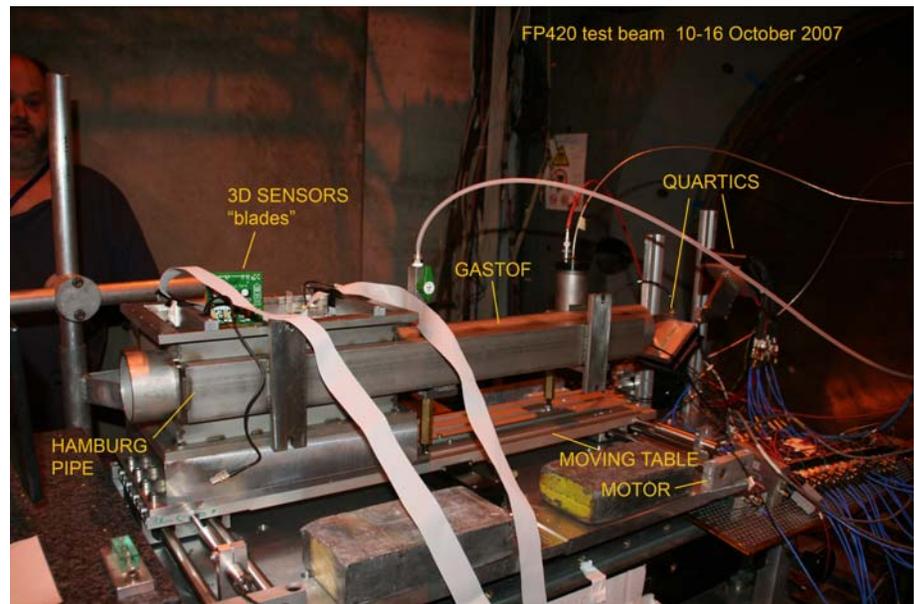
Pots up to 220m

CMS / TOTEM pots at 150m and 220m in place for start-up

FP220 proposed for installation in ATLAS >2009.

Pots at 420m

FP420 R&D project near its end ... available for ATLAS or CMS (installation >2009)

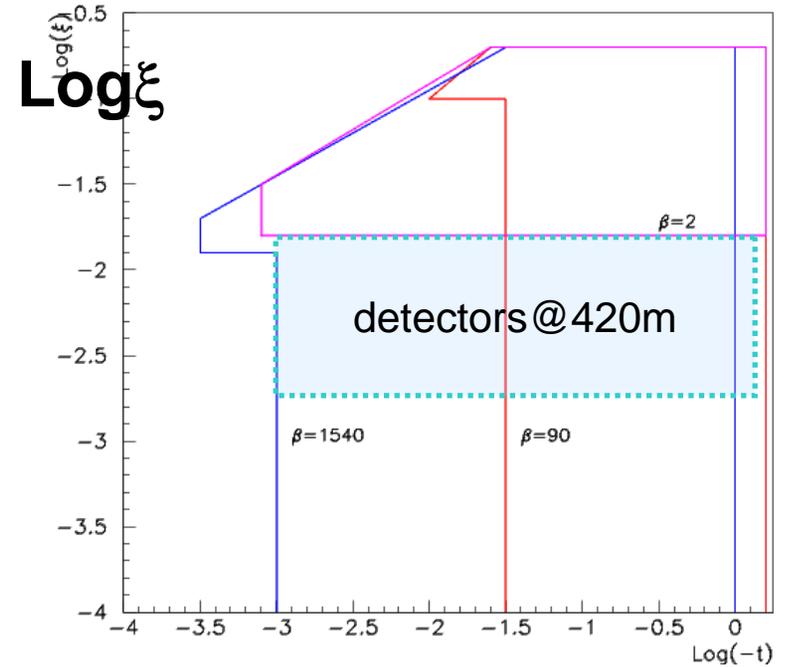
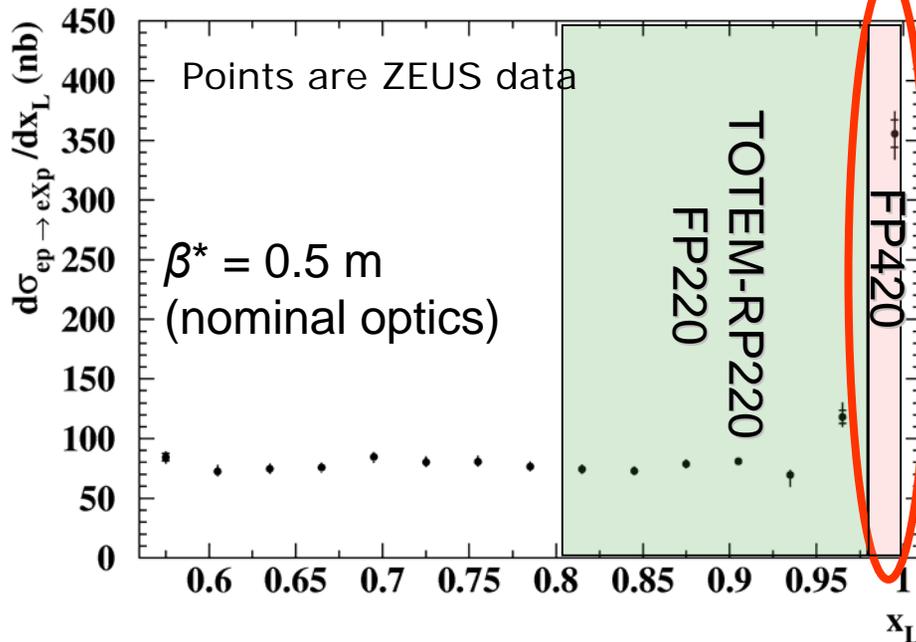


Proton Acceptance

150m + 220m Pots

$0.02 < \xi < 0.2$ at $\beta^* = 0.5\text{m}$
(high lumi optics)

Reaches lower ξ at
 $\beta^* = 90$ or 1540 m (lower lumi)

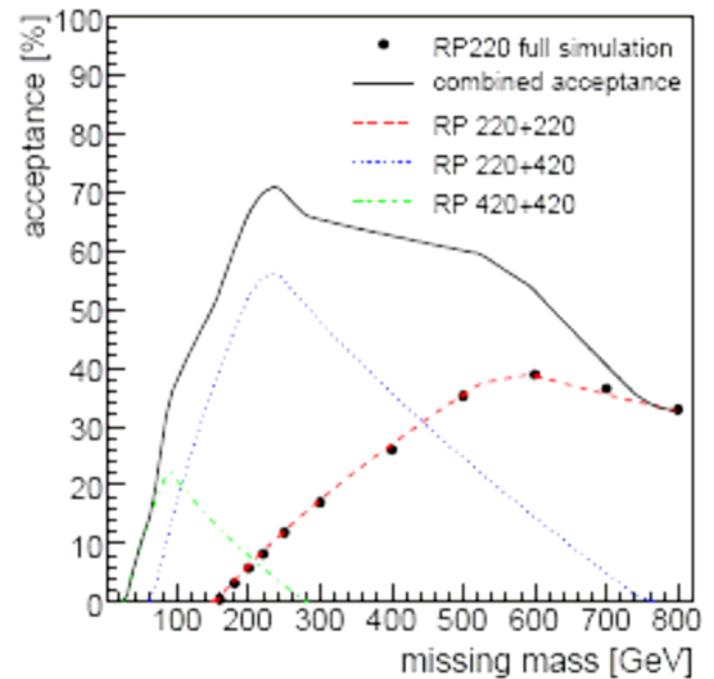
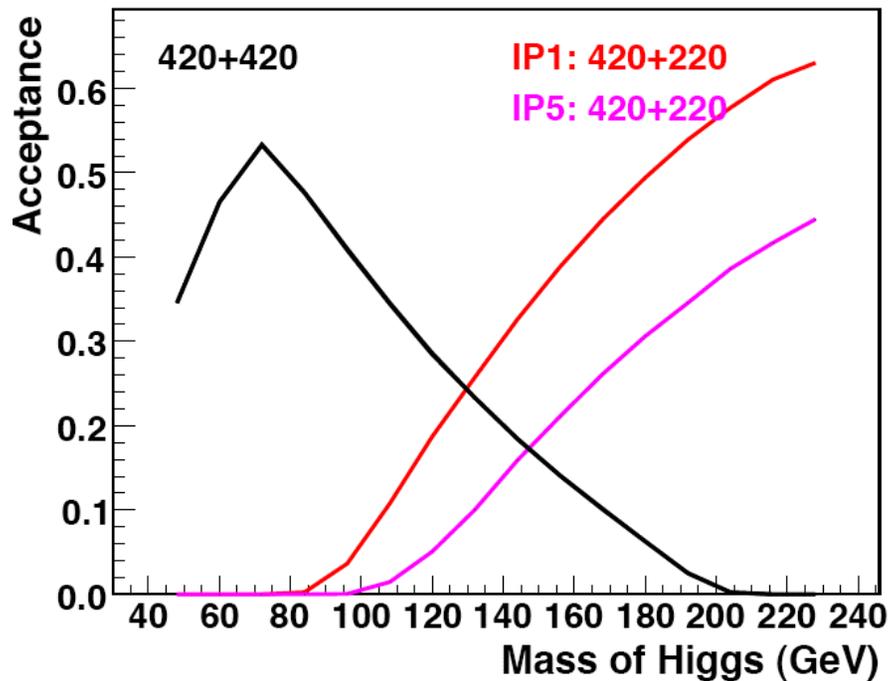
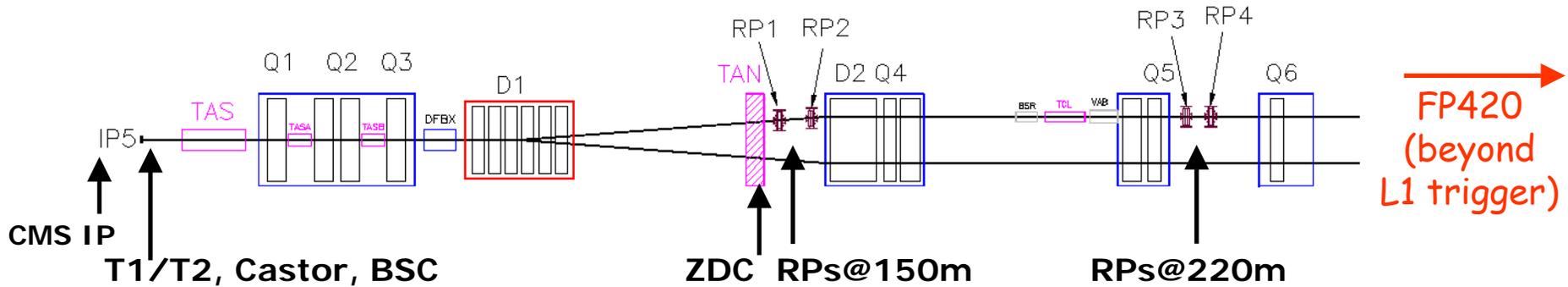


Log(-t)

420m Pots

$0.002 < \xi < 0.02$
(high lumi optics)

Higgs / 0^+ Resonance Acceptance



Comprehensive coverage with 220m, 420m combined ...

Example Strategy: CMS + Totem + FP420

“Prospects for **diffractive** and **forward** physics at the LHC”

CERN/LHCC 2006-039/G-124, CMS Note 2007/002, TOTEM Note 06-5, Dec 2006

Low lumi: Large rapidity gap selection possible
Proton tagging optional

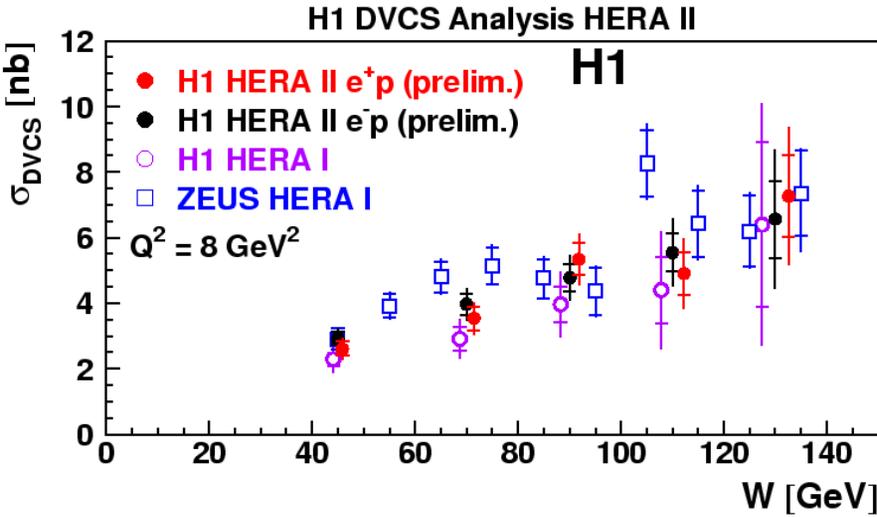
- ... Soft diffraction
- ... Hard diffraction / DPDFs
- ... Understanding pile-up
- ... $\gamma\gamma$ physics

High lumi: Pile-up ruins rapidity gap selection
Proton tagging essential (220 & 420 m)

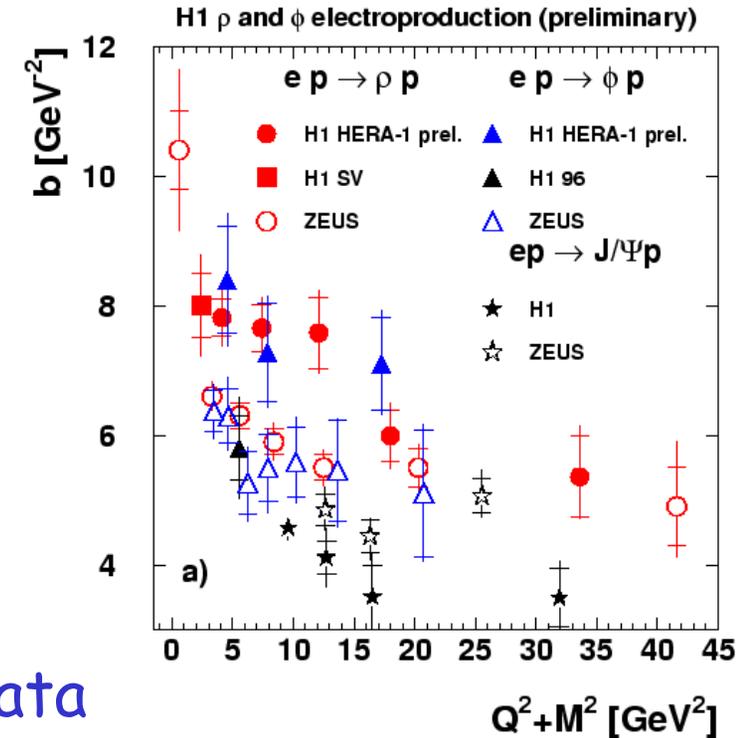
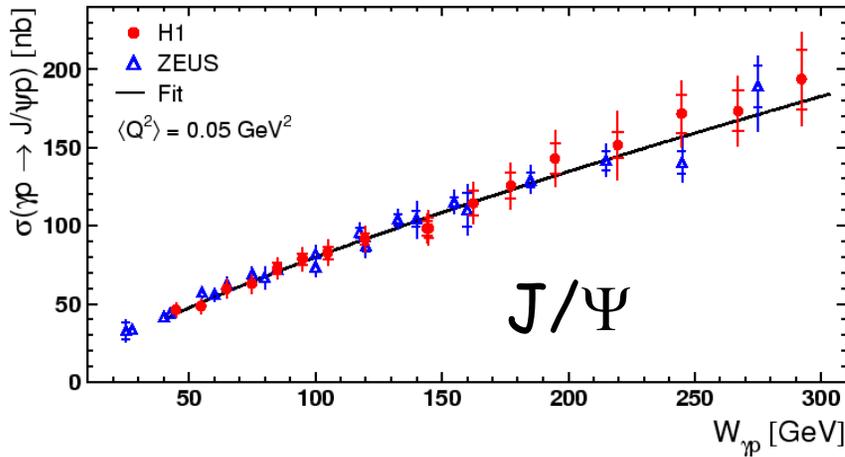
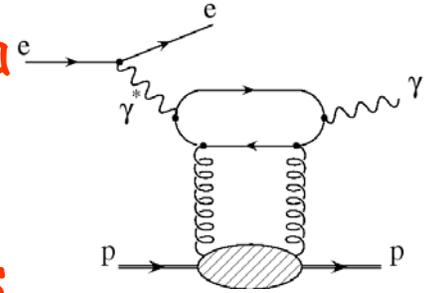
- ... Diffractive Higgs and other exotica
- ... More hard diffraction / DPDFs
- ... $\gamma\gamma$ physics

Triggering and understanding / overcoming pile-up are major experimental challenges: lots of presentations

Generalised Gluon and t Dependence @ HERA



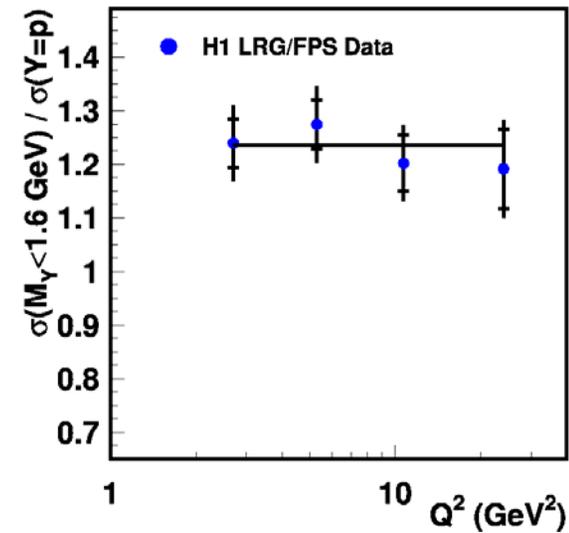
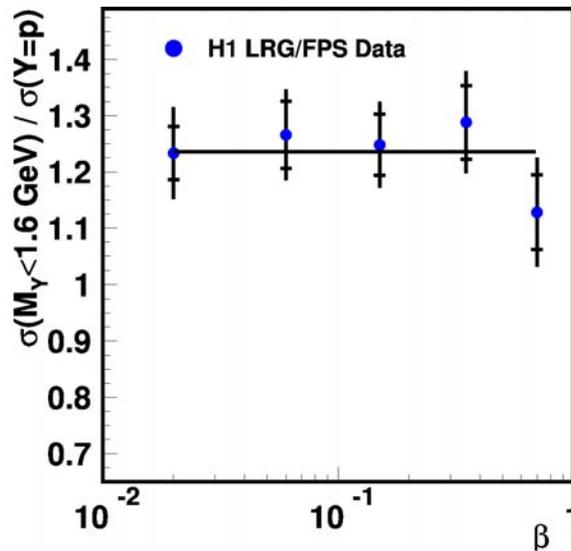
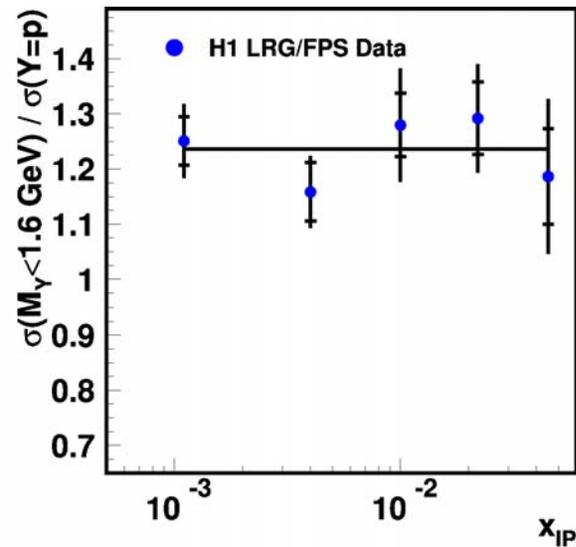
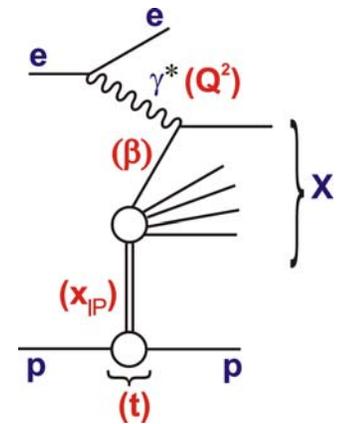
HERA DVCS data now include charge and poln asymmetries ... full HERA-II stats needed! ... J/Ψ is better known ...



Lots of VM and other data on t dependences, often statistics limited ... every reason to analyse full HERA data

Inclusive ep Diffraction

Lots of work converging to a final HERA diffractive F_2^D ... H1 v ZEUS? LPS v LRG? ...



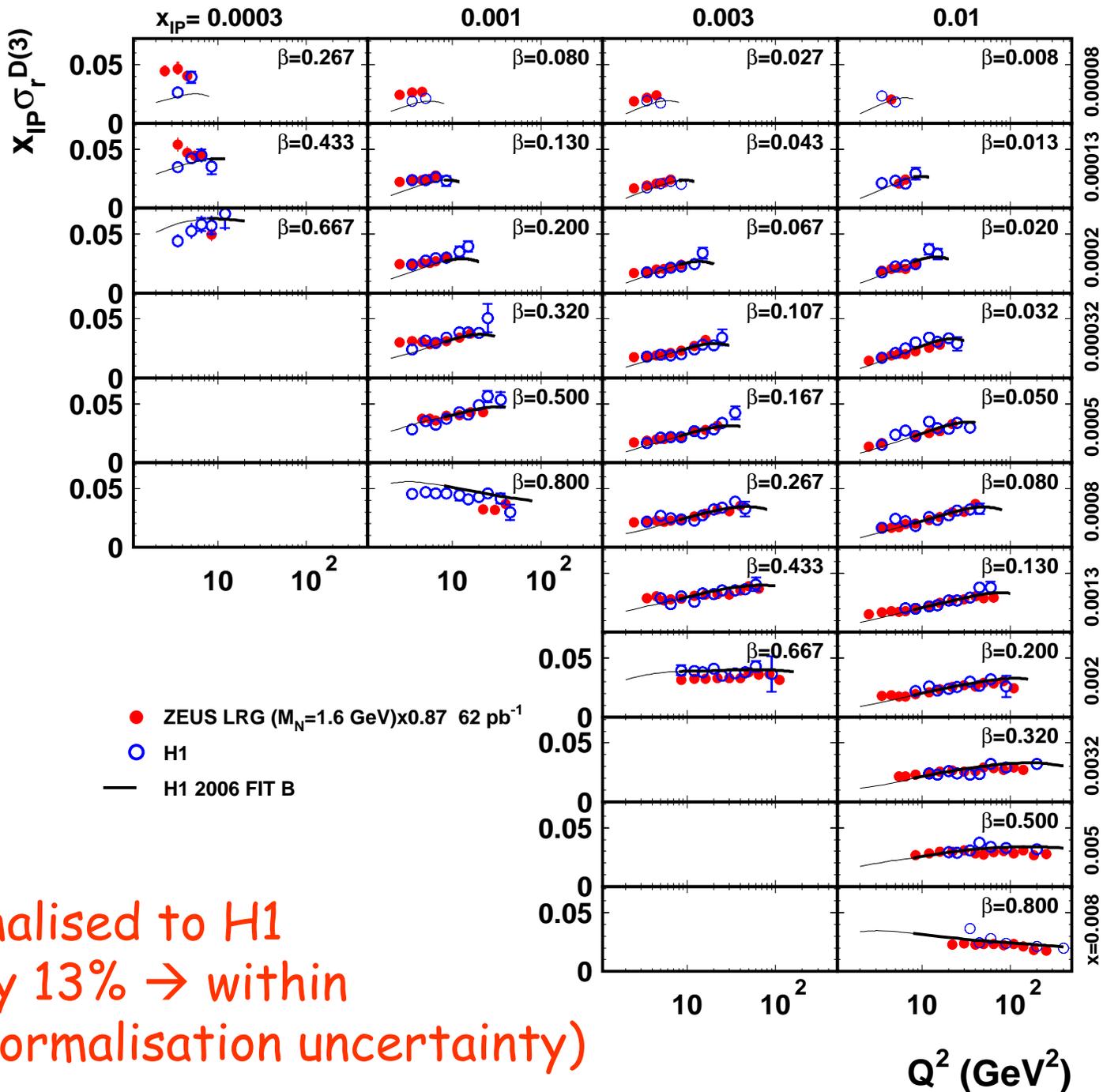
- Good agreement between Rapidity gap and Proton tag selection methods with very different systematics!
- Similar numbers from H1 and ZEUS on proton dissociation contributions in LRG samples

ZEUS v H1 LRG

[See
Marta
Ruspa's
talk]

Basically
agree ...

ZEUS normalised to H1
(reduced by 13% → within
combined normalisation uncertainty)

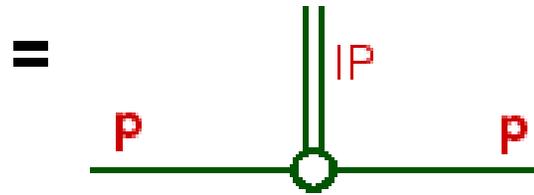
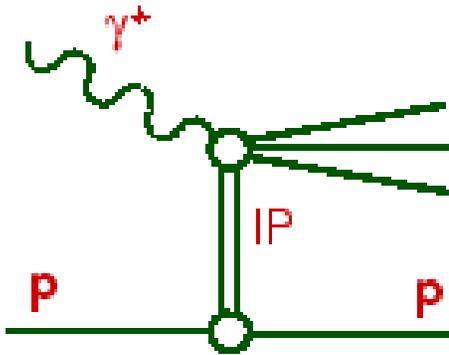


Questions in Diffractive Parton Densities ...

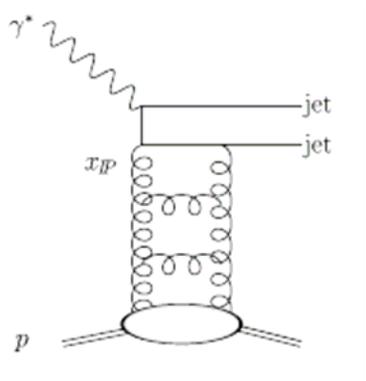
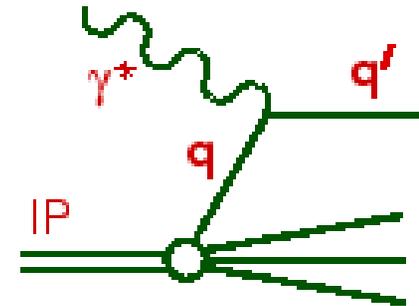
Q^2 , β , x_{IP} and t dependent diffractive parton densities (DPDFs) exist, DGLAP evolving with Q^2 as for inclusive PDFs

'Proton vertex' factorisation valid? (empirically motivated)

Regge FLUX (x_{IP}, t) \times STRUCTURE (β, Q^2)



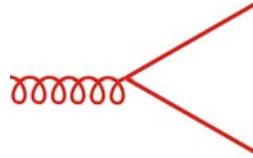
\times



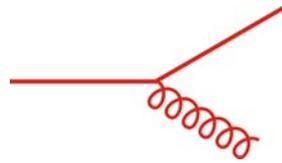
Martin, Ryskin & Watt include direct ('hard, perturbative') pomeron contribution in addition to proton vertex factorising non-perturbative piece

e.g. H1 DPDF Fit Results (linear z scale)

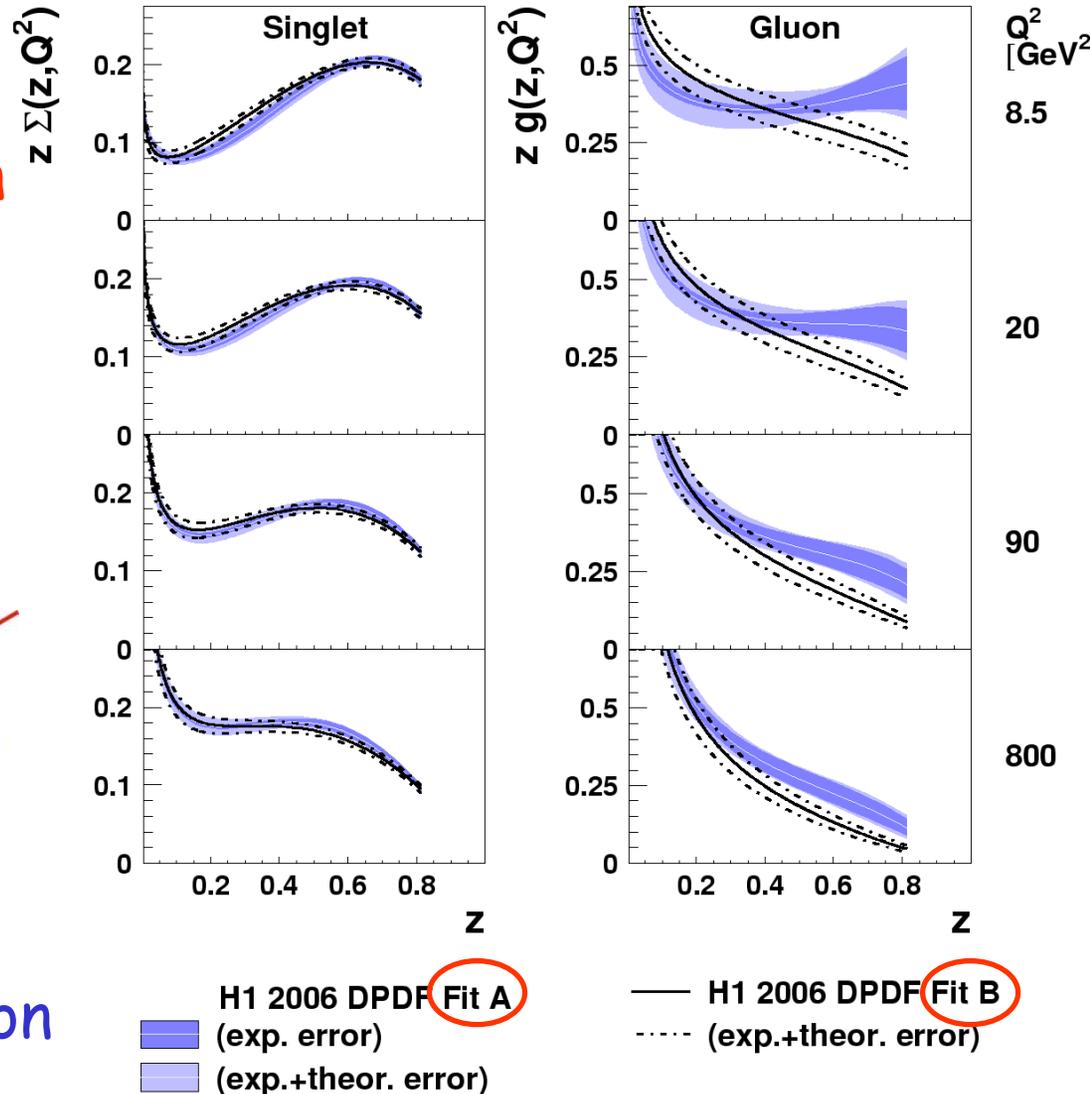
- σ_r^D gives quark density
... singlet to $\sim 5\%$,
- $d\sigma_r^D / d \ln Q^2$ gives gluon
at low z
... gluon to
 $\sim 15\%$ at low z
... 70% contribution!



- $d\sigma_r^D / d \ln Q^2$
lacks gluon
sensitivity at high z

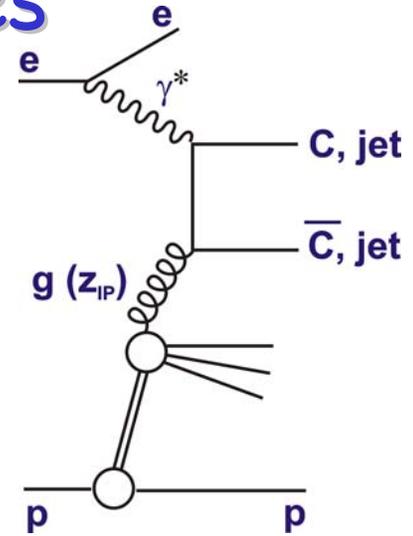


... yet high z important for
Central Exclusive Production
background!

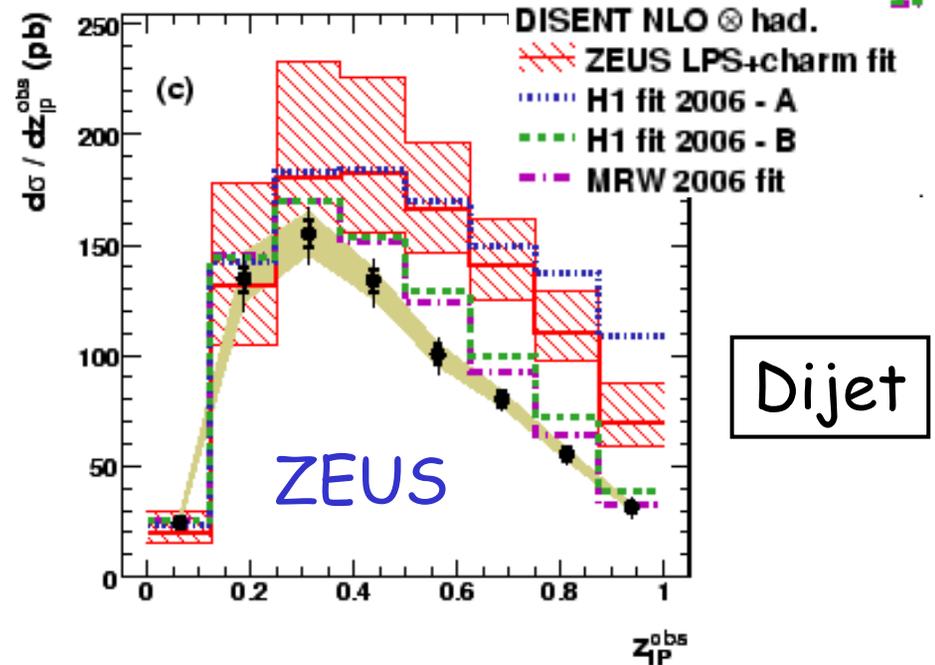
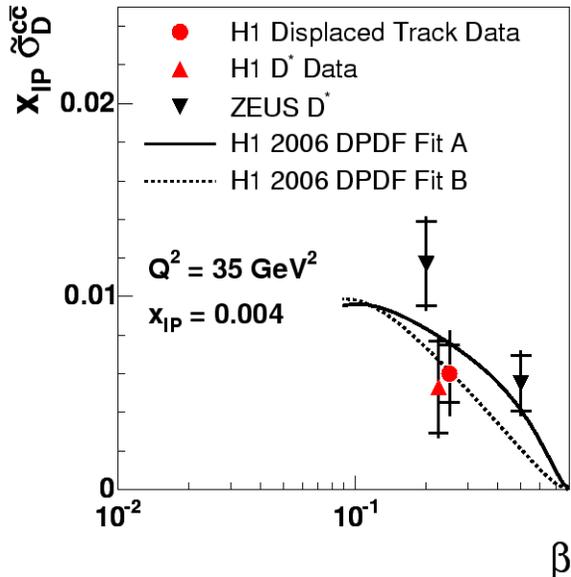
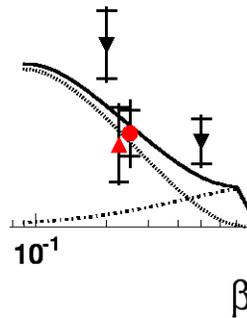
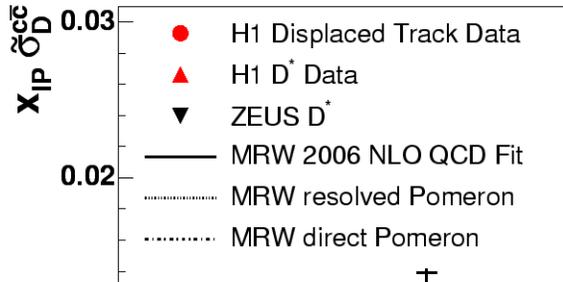


Testing Factorisⁿ in DIS Final States

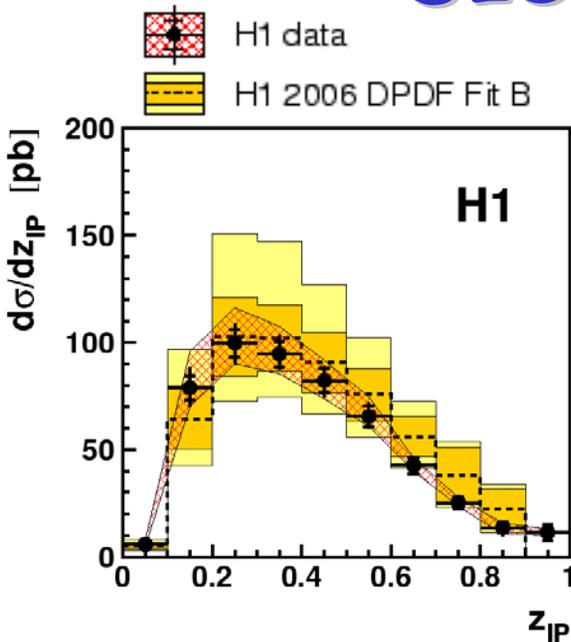
- Gluon DPDF known only indirectly from σ_r^D
- Test using processes driven by $\gamma^*g \rightarrow qq\bar{c}$
e.g. diffr charm & jets in DIS
- Good agreement (... H1 fit B, MRW are best)



Charm

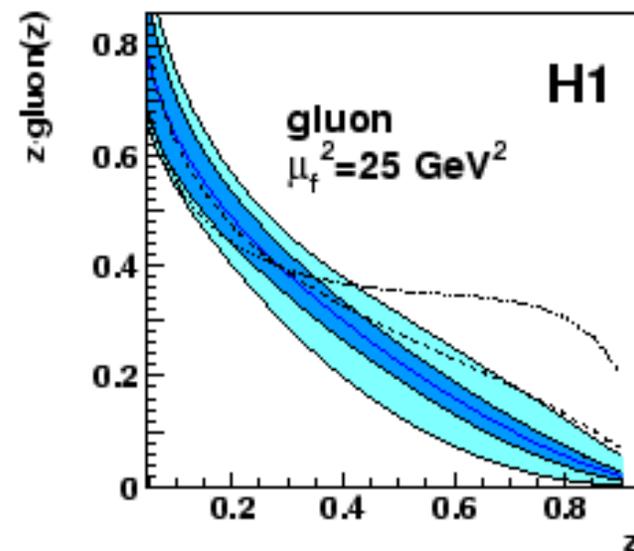
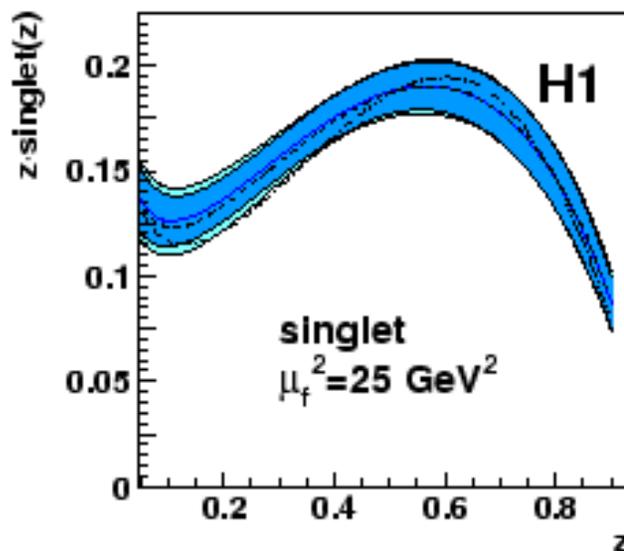
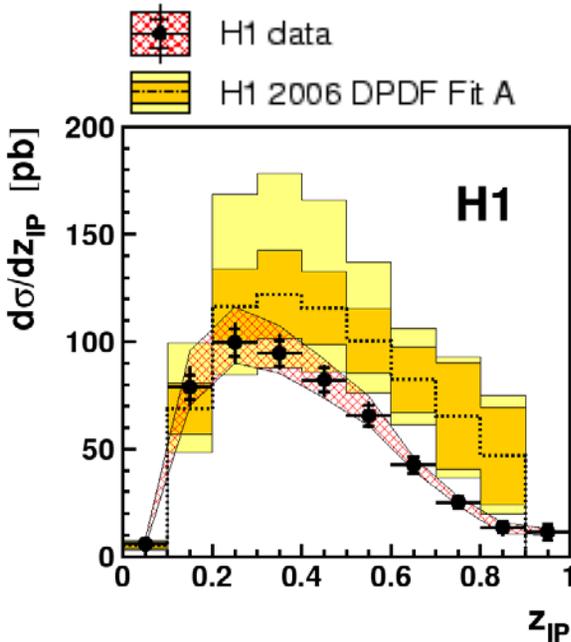
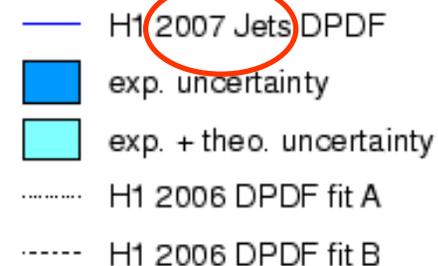
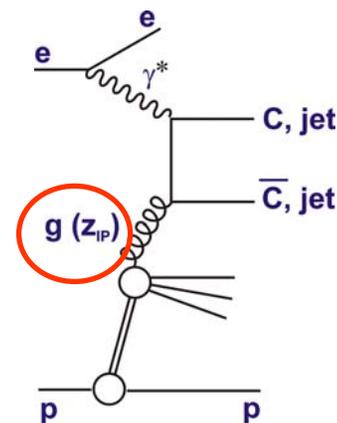


DIS Dijets and the high z Gluon

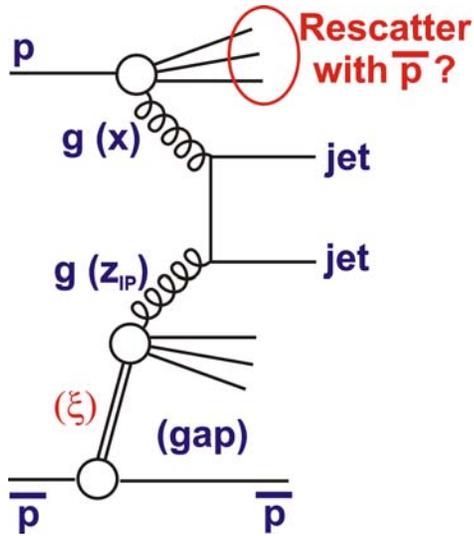


• Including jet data in fit lowers high z gluon a little
 → 'H1 2007 Jets' DPDF

• See also 'ZEUS LPS+charm fit'



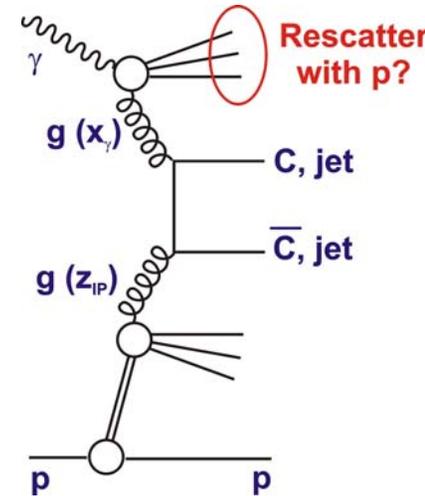
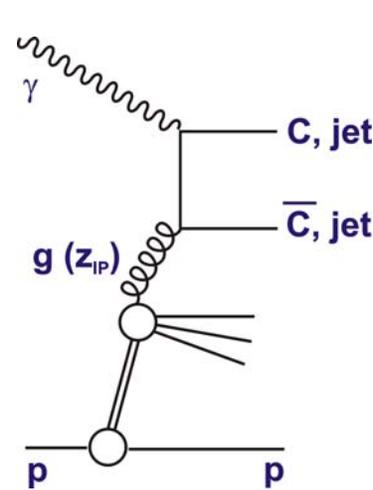
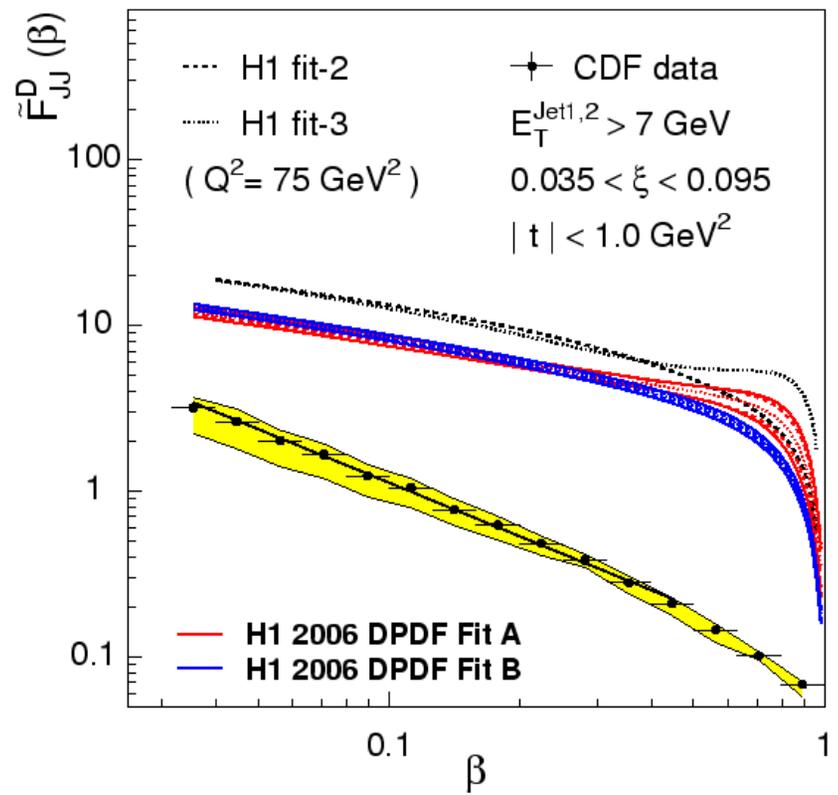
Meanwhile in pp(bar) ...



- 'Gap survival' factor ~ 10

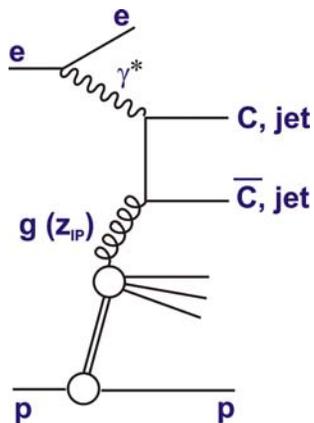
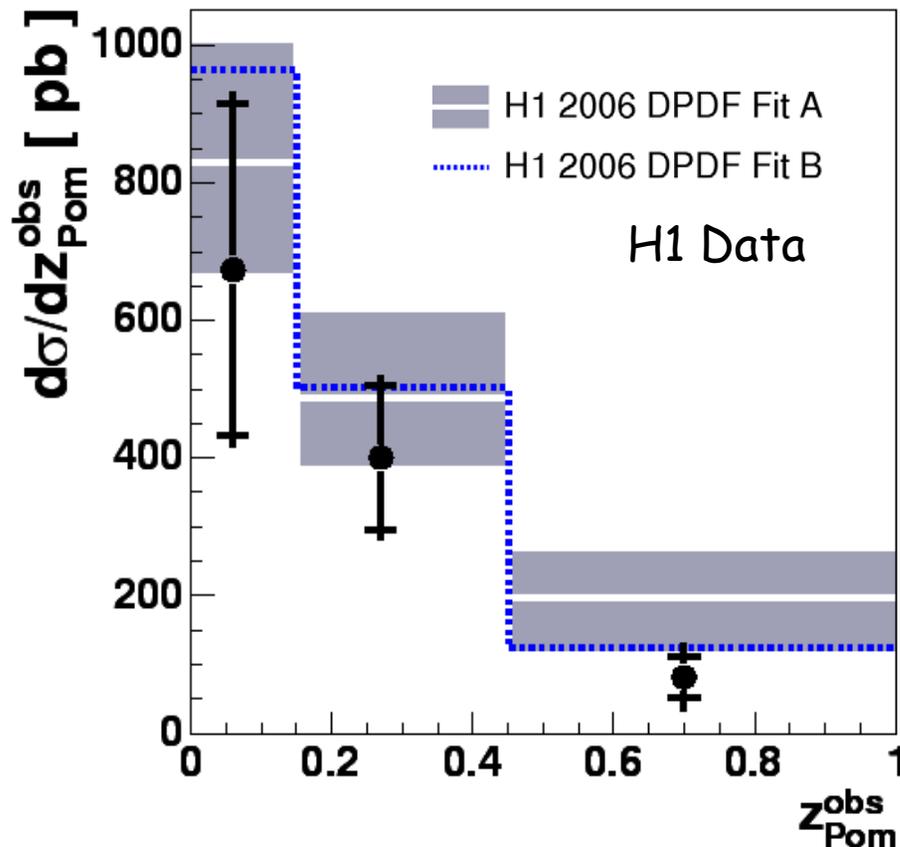
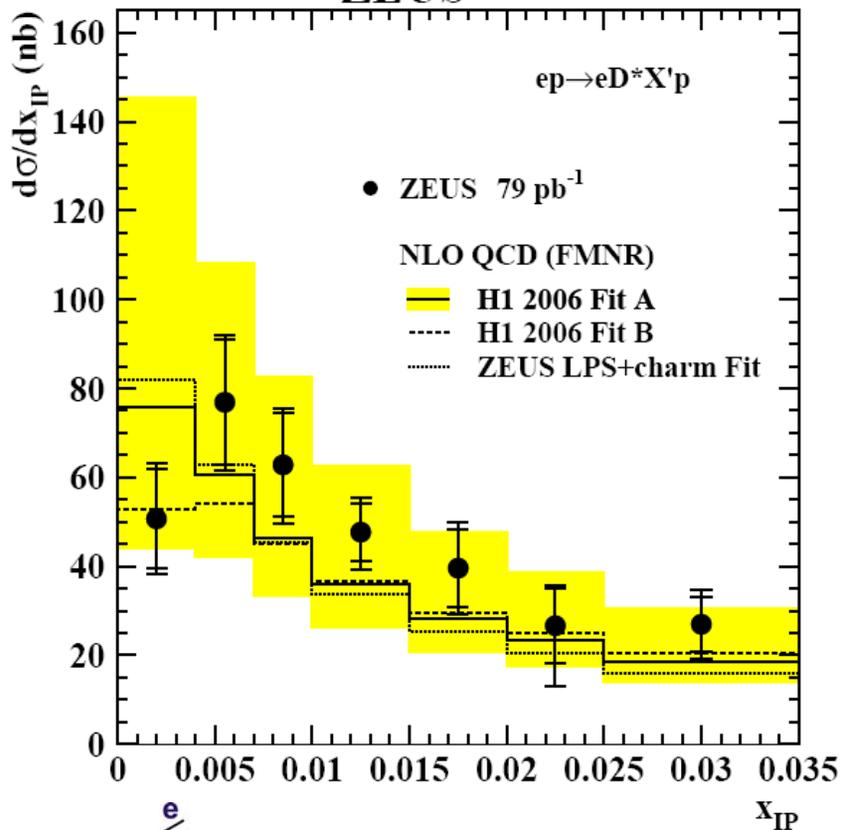
... γp as a Control Expt?

Most models predict gap survival probability = 1 (direct) < 1 (resolved ... e.g. Kaidalov et al. predict 0.34)



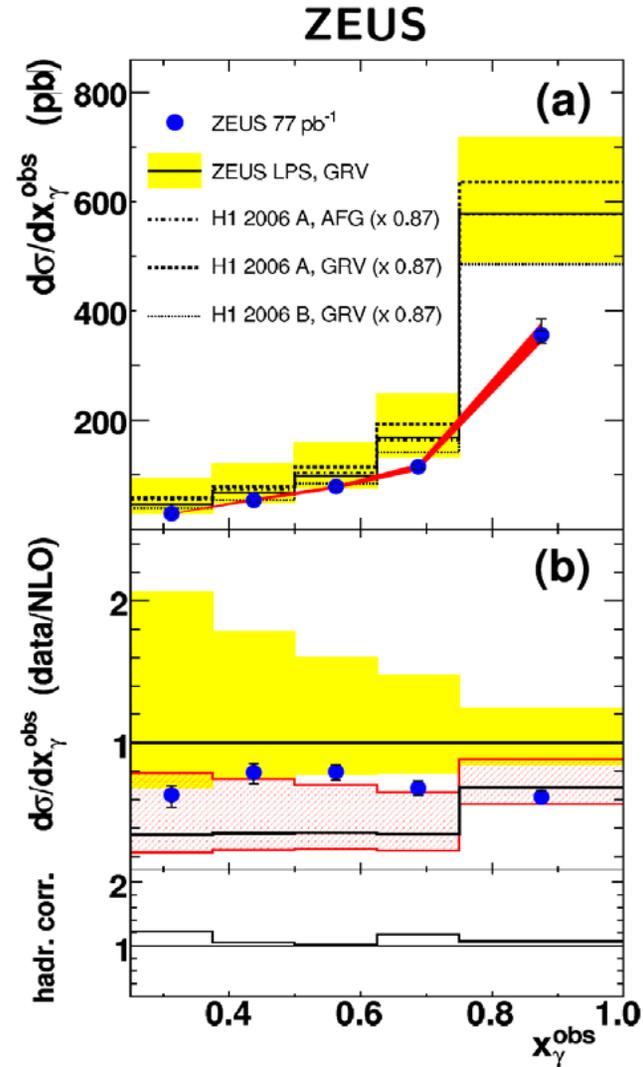
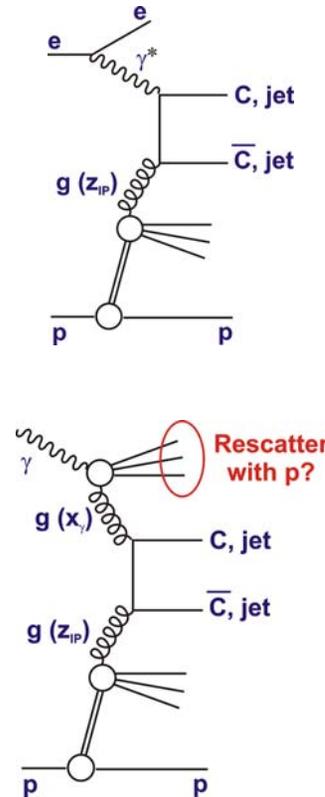
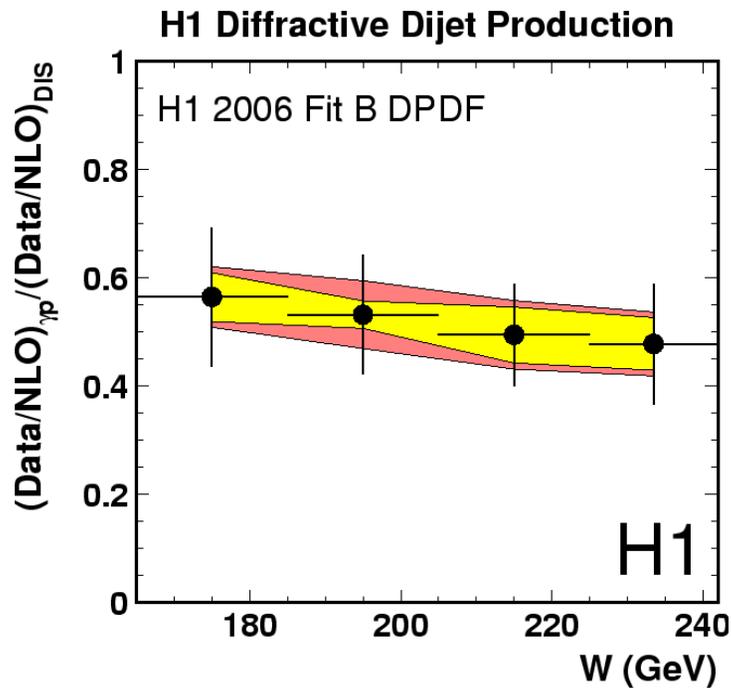
Charm (D^*) Photoproduction: Direct Photons

ZEUS



- Charm γp dominated by direct photons
- ... well described by DPDFs from F_2^D fits
- Large scale uncertainties on theory due to low scales accessed.

Dijet Photoproduction



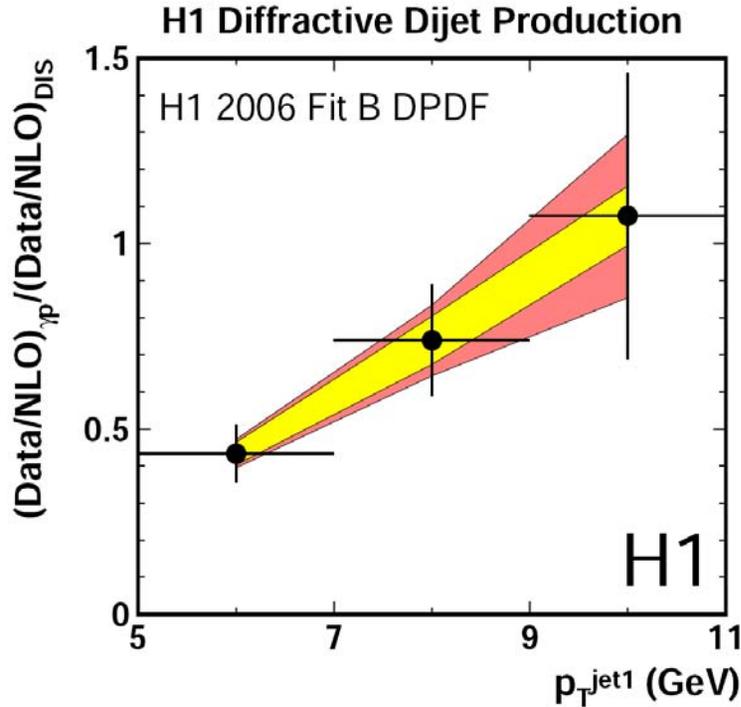
- H1 97: $E_{\text{jet}1} > 5 \text{ GeV}$
 "Suppression by factor ~ 2 "

- ZEUS 99-00: $E_{\text{jet}1} > 7.5 \text{ GeV}$
 "Weaker suppression"

- Neither collaboration sees difference between resolved and direct regions, in contrast to theoretical expectations

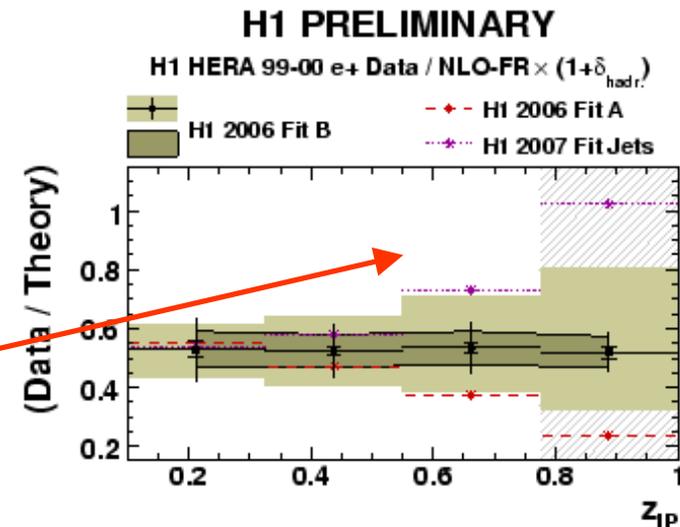
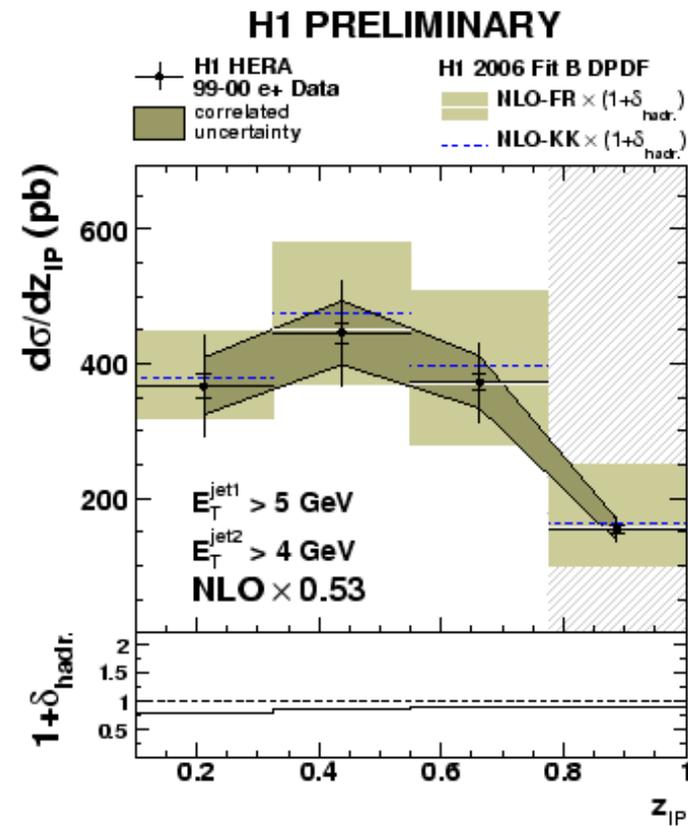
Two Recent Developments

"H1 - ZEUS difference due to different E_T ?" (DIS07, ZEUS)



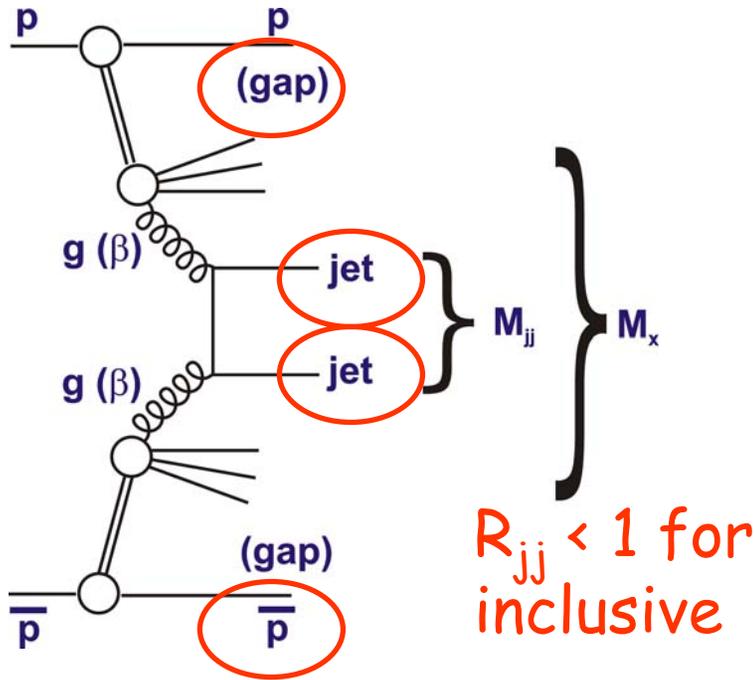
Similar E_T dependence observed in ZEUS 99-00, H1 97, H1 99-00 ...

Poorly constrained DPDFs give Very large uncertainties at high z !

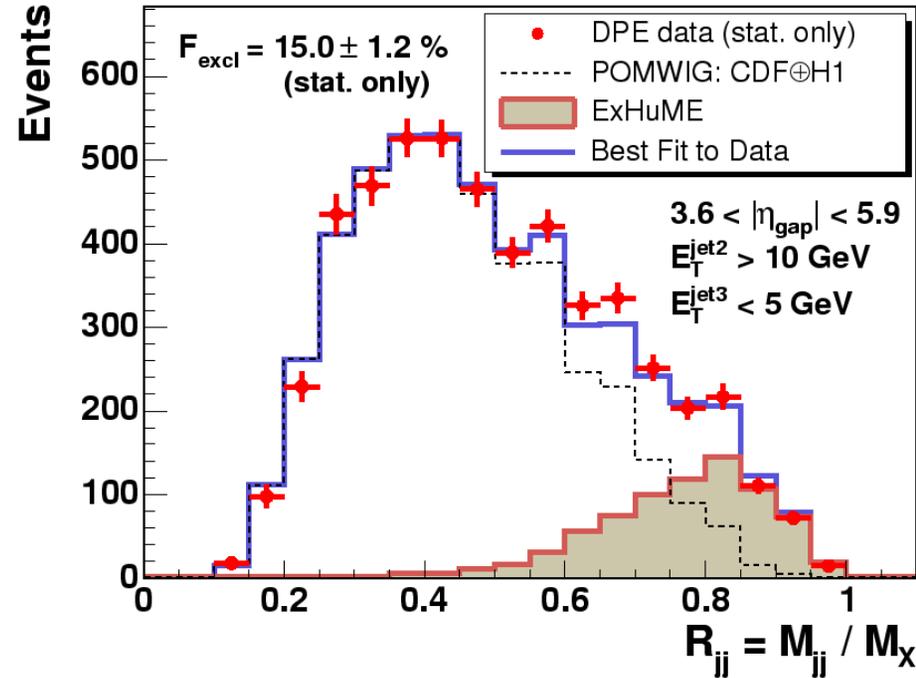


Exclusive Dijet Production at the Tevatron?

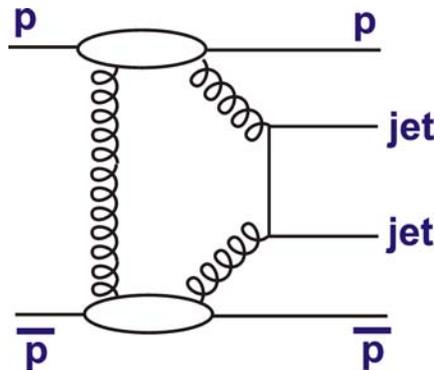
"DPE" dijets, plot $R_{jj} = M_{jj} / M_x$



CDF Run II |



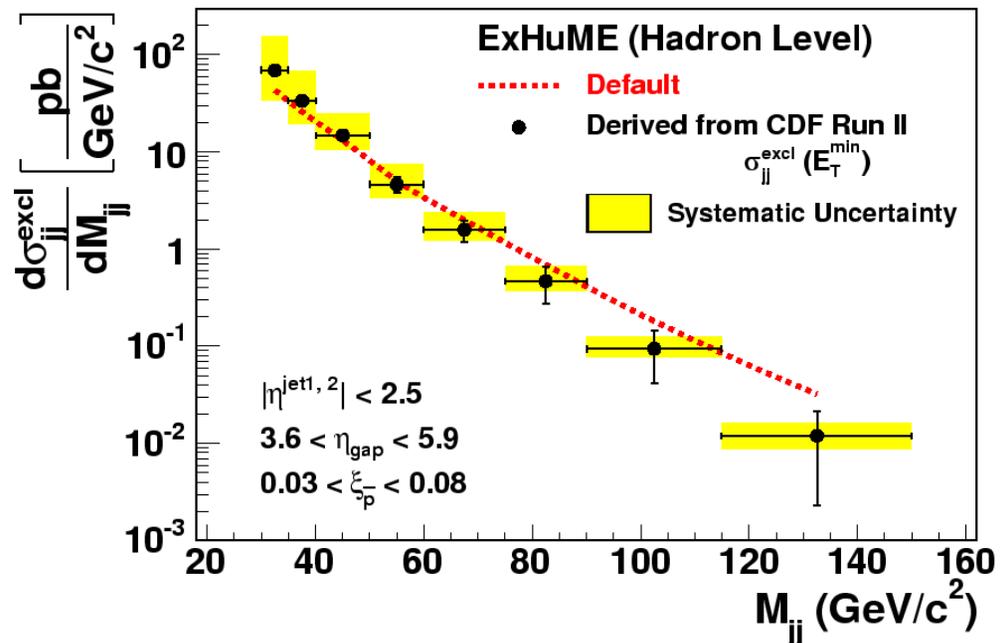
$R_{jj} \rightarrow 1$ for exclusive
(complicated by hadronisⁿ,
higher order QCD ...)



Many comparisons with varying MC modelling and DPDFs ...
...hard to get rid of signal!
Fit with free normalisation of inclusive, exclusive models to quantify exclusive part ...

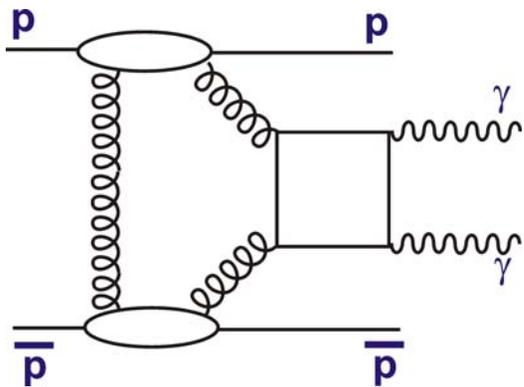
CDF Exclusive Dijet Cross Section

- ExHuME model based on KMR calculation ...
 - 4.5% gap survival prob
 - "Uncertainty factor 2.5"



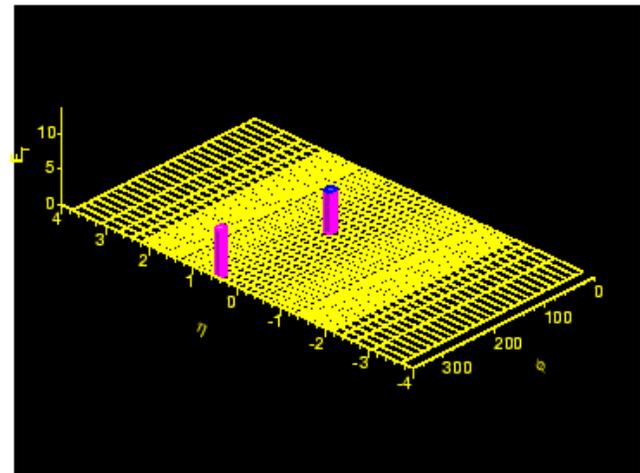
- Expressed in terms of M_{jj} , signal extends into possible Higgs discovery mass region!

CDF Exclusive Di-photons



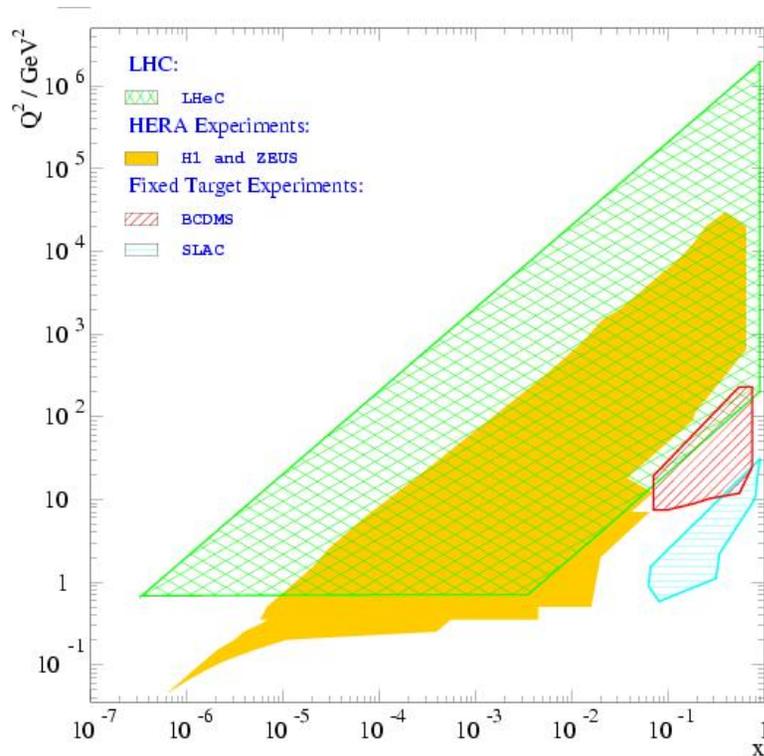
3 candidates with bkgrd 0.09 +/- 0.04

KMR predicts 0.8 events (big uncty.)

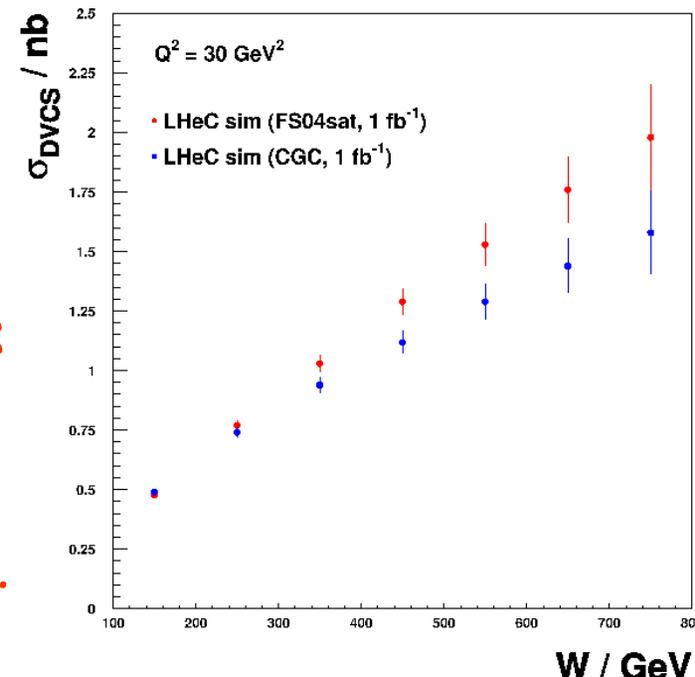
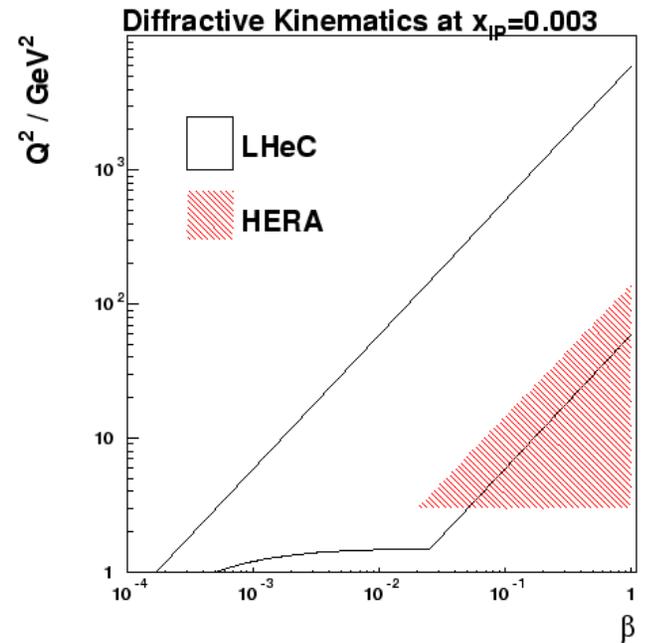


Longer term ep?...

Diffraction and LHeC



- TeV scale, very high lumi, ep physics: another new world for low x / diff'n!...
- 2008 ECFA/CERN LHeC Workshop ...



HERA AND THE LHC

4th workshop on the implications of HERA for LHC physics

26-30 May 2008
CERN

Organising Committee:

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W.K. Tung (Michigan State), A. Wagner (DESY),
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Parton density functions

Multijet final states
and energy flow

Heavy quarks

Diffraction

Monte Carlo tools

www.desy.de/~heralhc

heralhc.workshop@cern.ch

HERA-LHC Meeting

Diffractive sessions
under construction ...

- F_2^D and DPDFs at HERA
- Dijets at HERA
- DVCS, VMs and GPDs
- Leading baryons at HERA
- Tevatron data and theory
- LHC plans: CMS, Totem, ATLAS, ALICE, FP420, Alfa
- Central Exclusive Production
- Gap Survival
- Establishing saturation

Contact convenors for more
information

[M. Arneodo, M. Diehl, V. Khoze, P. Newman]

Experimental summary / shopping list

Well advanced forward physics plans at LHC ...

- Programme of single and double diffraction and C.E.P.
- Trigger and pile-up studies are critical
- FP420 etc now need impetus from inside ATLAS / CMS
- Tevatron data are bench-marking theory predictions

Emerging From HERA over timescale of workshop so far...

- Clarity between experiments on F_2^D and DPDFs
- Clarity between experiments on factorisation tests
- Vector meson precision, t slopes, leading neutron data

Biggest things still to wish for ...

- Understanding of photoproduction dijets?!?!
- Systematic search for `exclusive dijets' (pure pQCD)
- Optimised data on t slopes and GPDs (VM / DVCS / pots)
- & many more to be explored further at the workshop