Diffractive Working Group Summary

M. Arneodo, V. Khoze, P.Newman, (G. Bush)

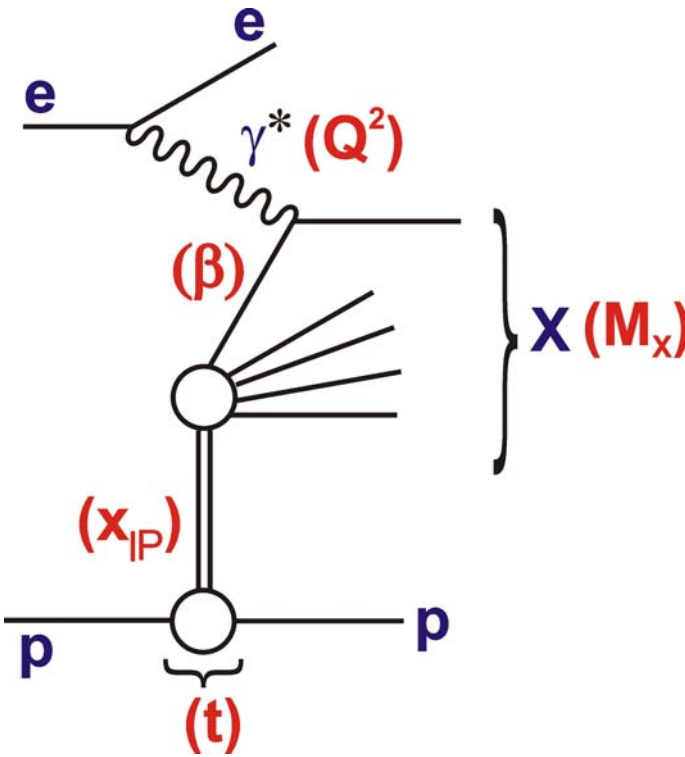
Thanks …

- to A. Bruni, B. Cox, M. Diehl, R.Orava for convening / being experiment contacts
- to all speakers for many excellent presentations
- to all participants for many lively discussions!

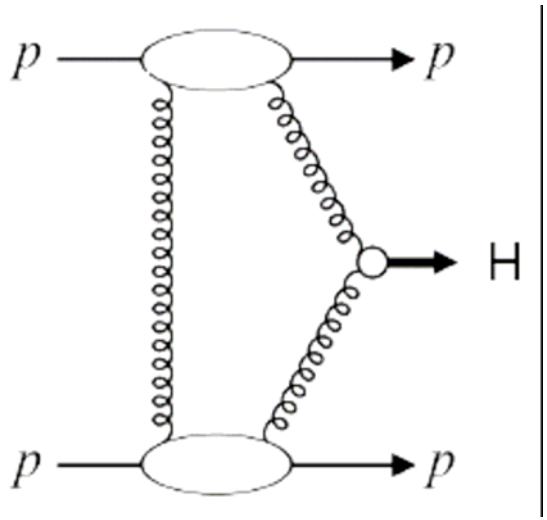
This talk …

- P. Newman `From HERA, via the Tevatron, approaching the LHC …'
- V. Khoze `… back to HERA again … and finally to the LHC'

Contents



- Diffractive Cross Sections in DIS
- Final States in DIS
- Hard Diffractive Photoproduction
- News from the Tevatron
- Experimental preparations at the LHC
- Diffraction at the LHeC



HERA Talks

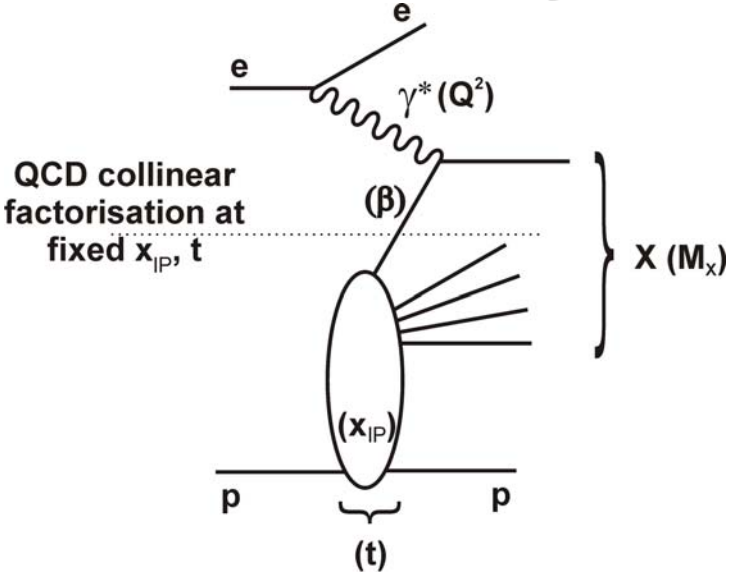
i) Diffractive DIS Cross Sections (F.Schilling, G. Watt)

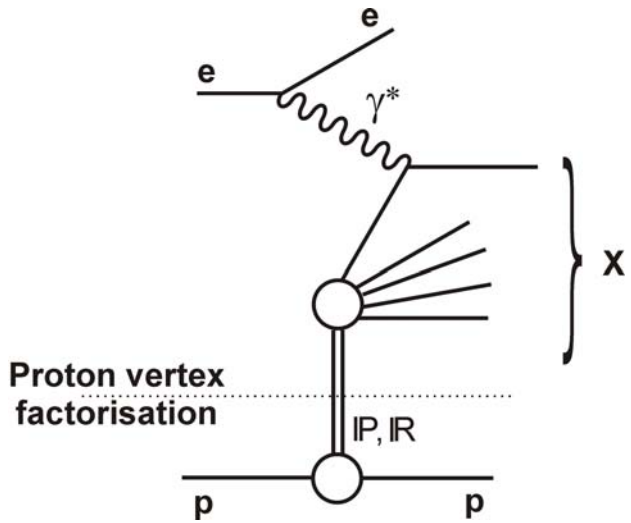
ii) Leading Neutrons (W. Schmidke, A. Martin)

iii) Dijets and Charm (R. Wolf, A. Bonato, M. Klasen)

iv) Gaps Between Jets (P. Ryan)

Two Levels of Facrorisation





QCD collinear factorisation at fixed x_{IP} and t

$$\mathrm{d}\sigma_{\text{parton } i}(ep \to eXY) = f_i^{\,D}(x, Q^2, x_{IP}, t) \otimes \mathrm{d}\hat{\sigma}^{ei}(x, Q^2)$$

`Proton vertex' factorisation (separately for IP and IR)

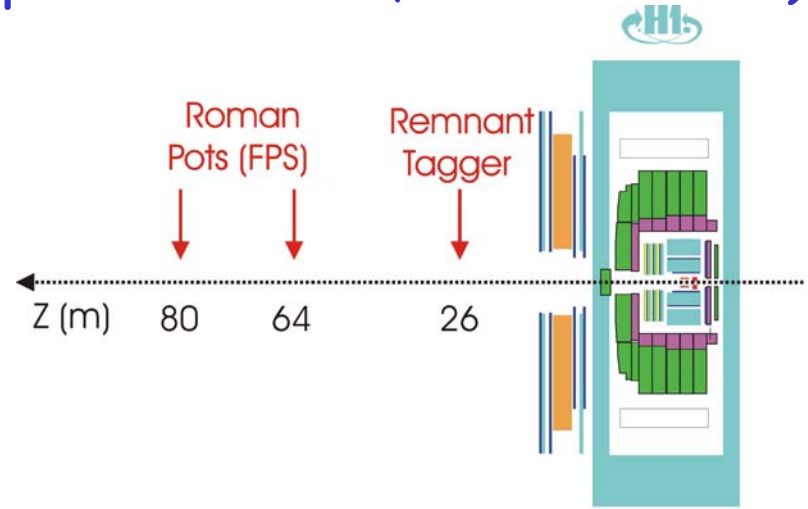
$$f_i^{\,D}(x, Q^2, x_{IP}, t) = f_{IP/p}(x_{IP}, t) \cdot f_i^{\,IP}(\beta = x / x_{IP}, Q^2)$$

- Can then predict diffractive DIS final states with diffractive parton densities (DPDFs) from inclusive DIS.
- Photoproduction and pp need extra `gap survival' factor

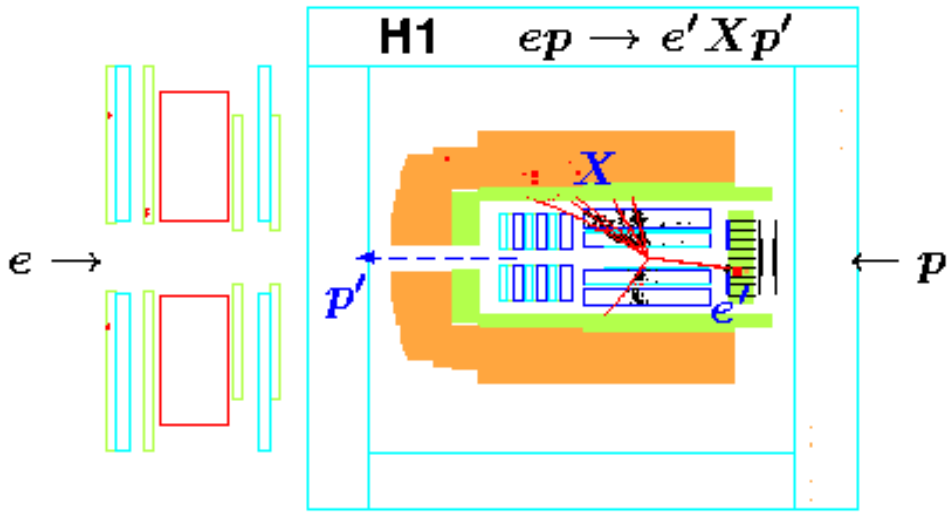
Two Different Selection Methods (H1)

Ideal selection method is to detect and measure final state proton

`Roman Pot' inserts to beampipe (`Forward Proton Spectrometer', FPS method)



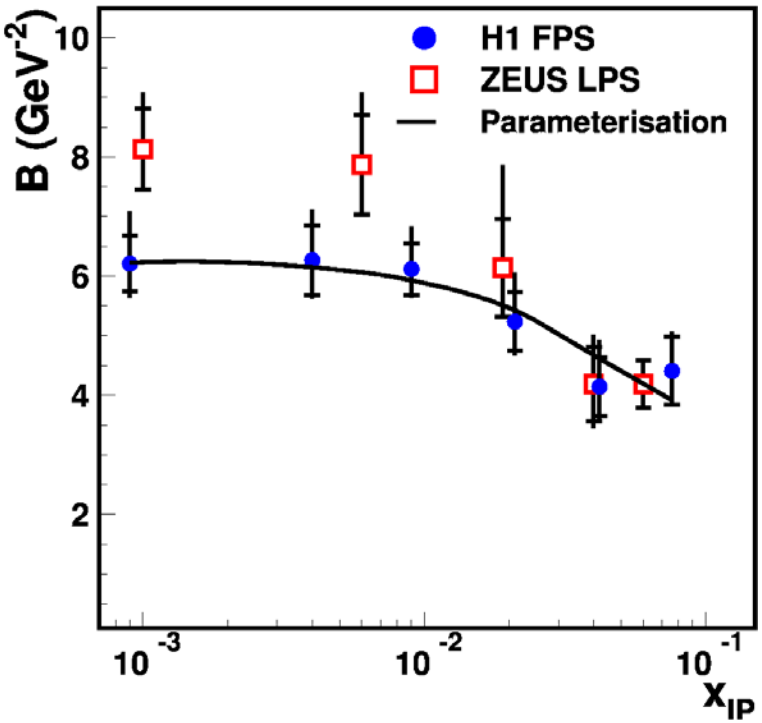
Alternative `Large Rapidity Gap' selection by requiring Absence of activity in forward part of calorimeter and forward detector components (LRG method)



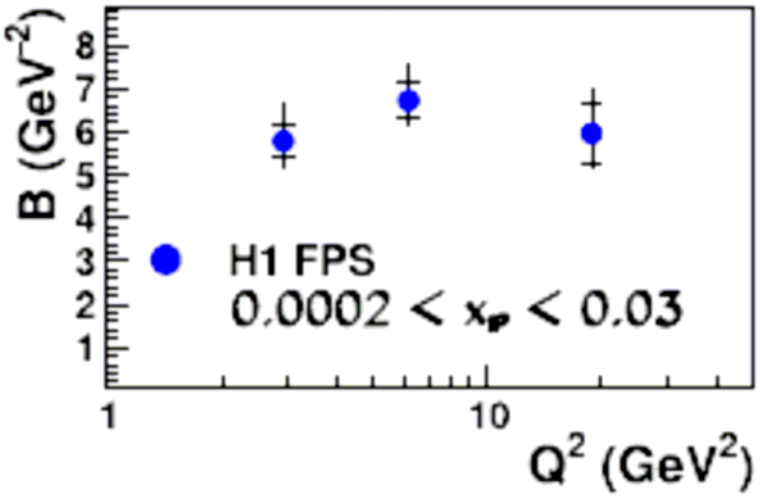
Consistency between methods and also with ZEUS LPS data

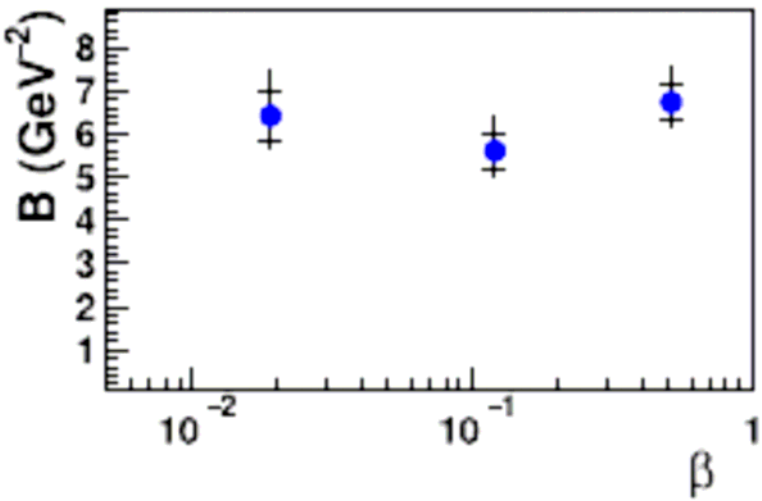
t Dependence from FPS Measurements

Fit to exp(Bt) in bins of x_{IP}, β, Q^2



$$\alpha'_{IP} = 0.06^{+0.19}_{-0.06}\ \text{GeV}^{-2}$$

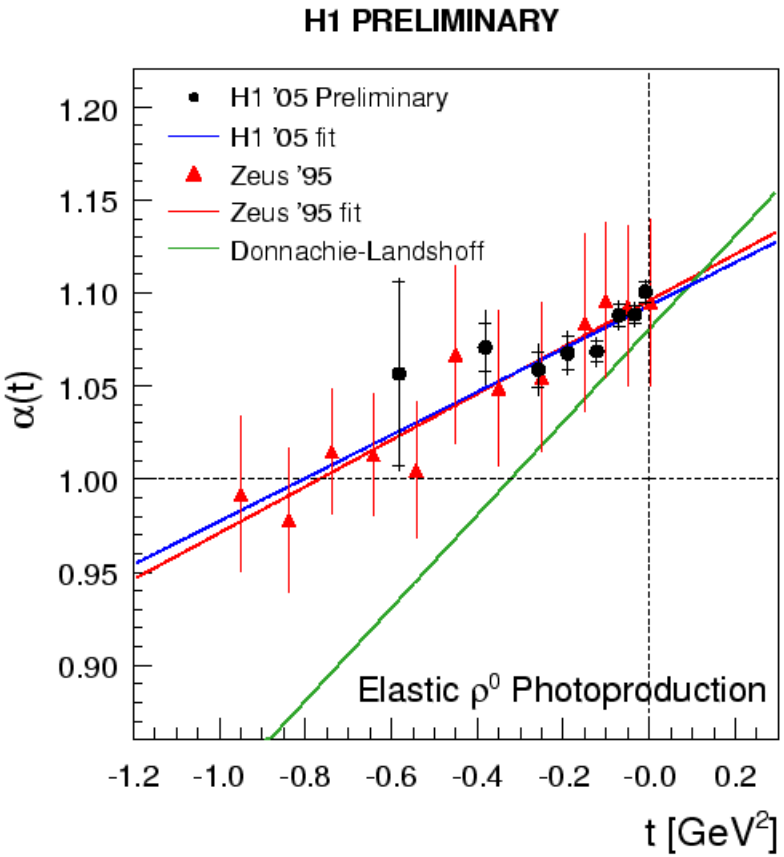




$B(x_{IP})$ data yield value for slope of pomeron trajectory

Proton vertex factorises

Aside: What is a soft pomeron anyway?



The `soft' pomeron in photoproduction at HERA is not as soft as we expected from pp

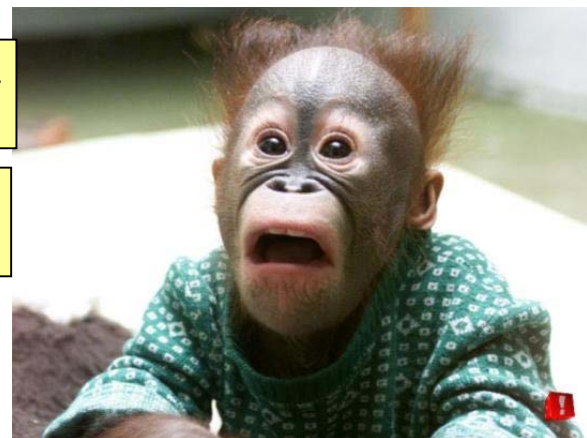
New result from $\gamma p \to \rho^0 p$

(ZEUS ϕ similar)

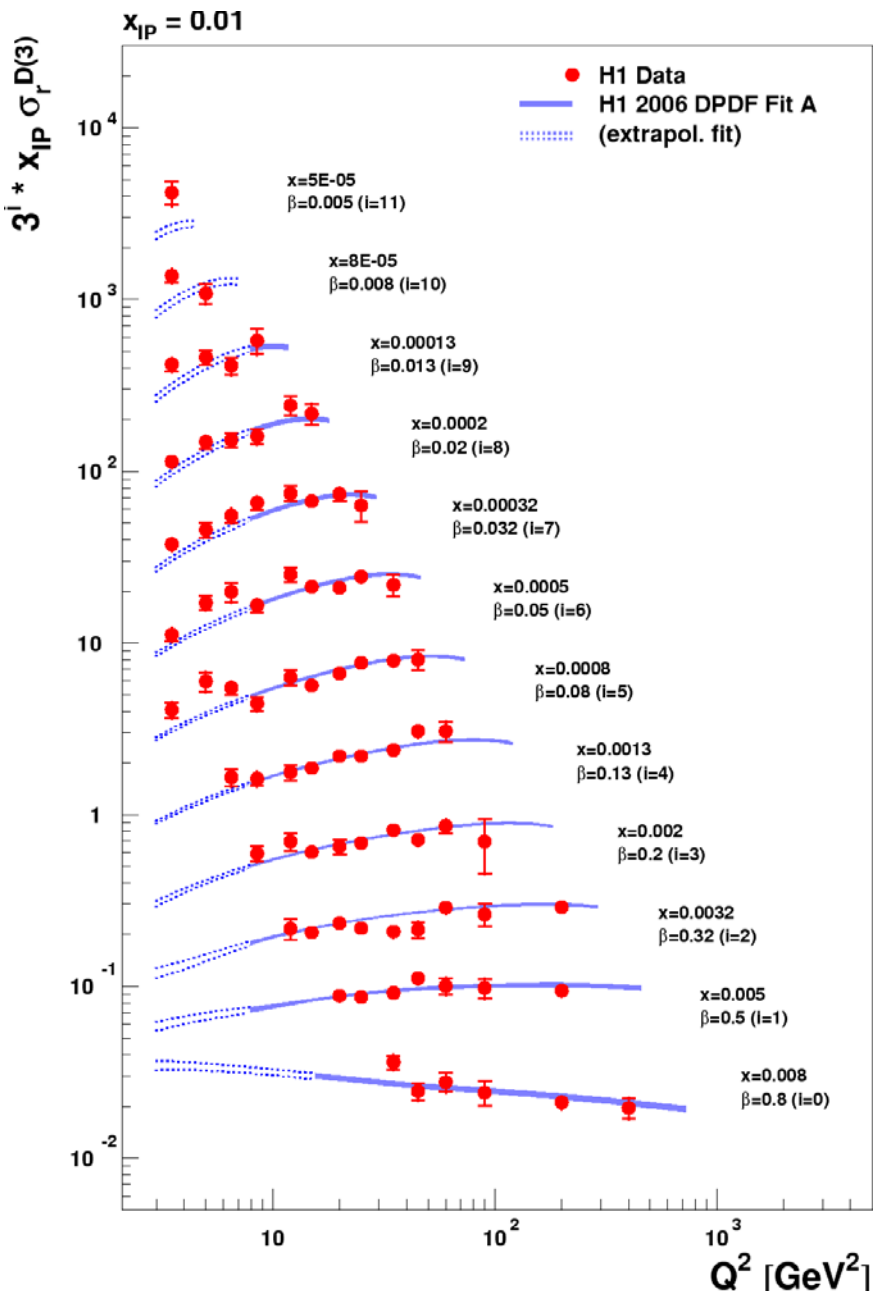
H1 $\alpha_{IP}(t) = [1.093 \pm 0.008] + [0.116 \pm 0.049]t$

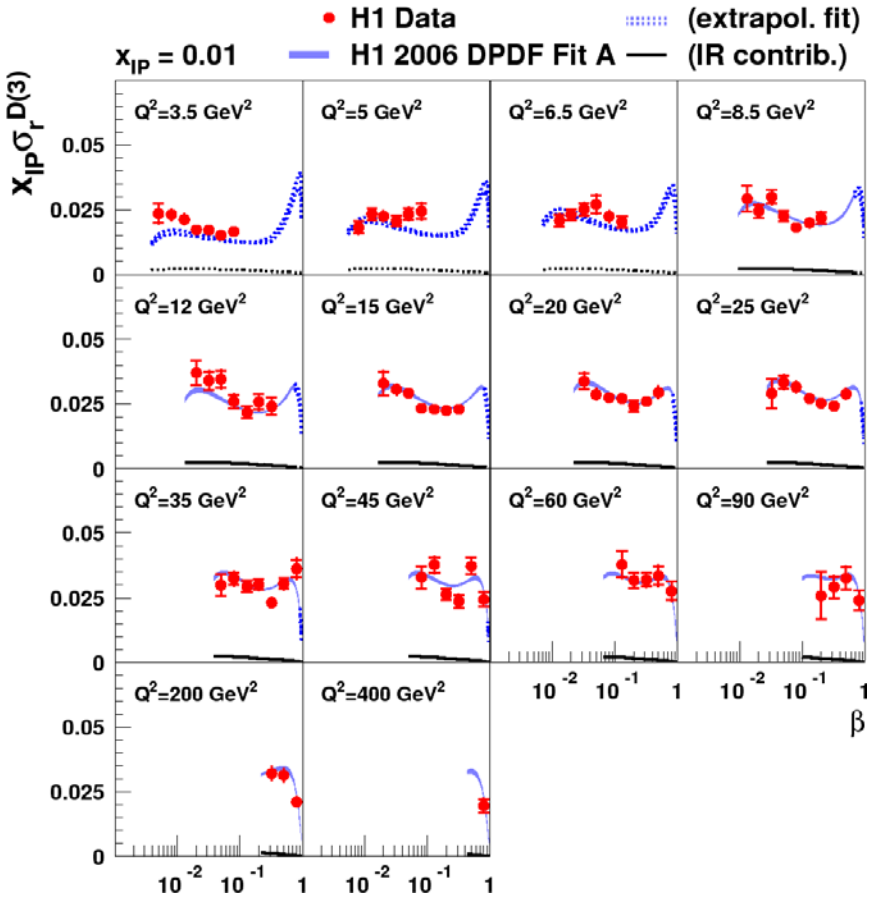
ZEUS $\alpha_{IP}(t) = [1.096 \pm 0.021] + [0.125 \pm 0.038]t$

`Soft' $\alpha_{IP}(t) = [1.085] + [0.25]t$



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





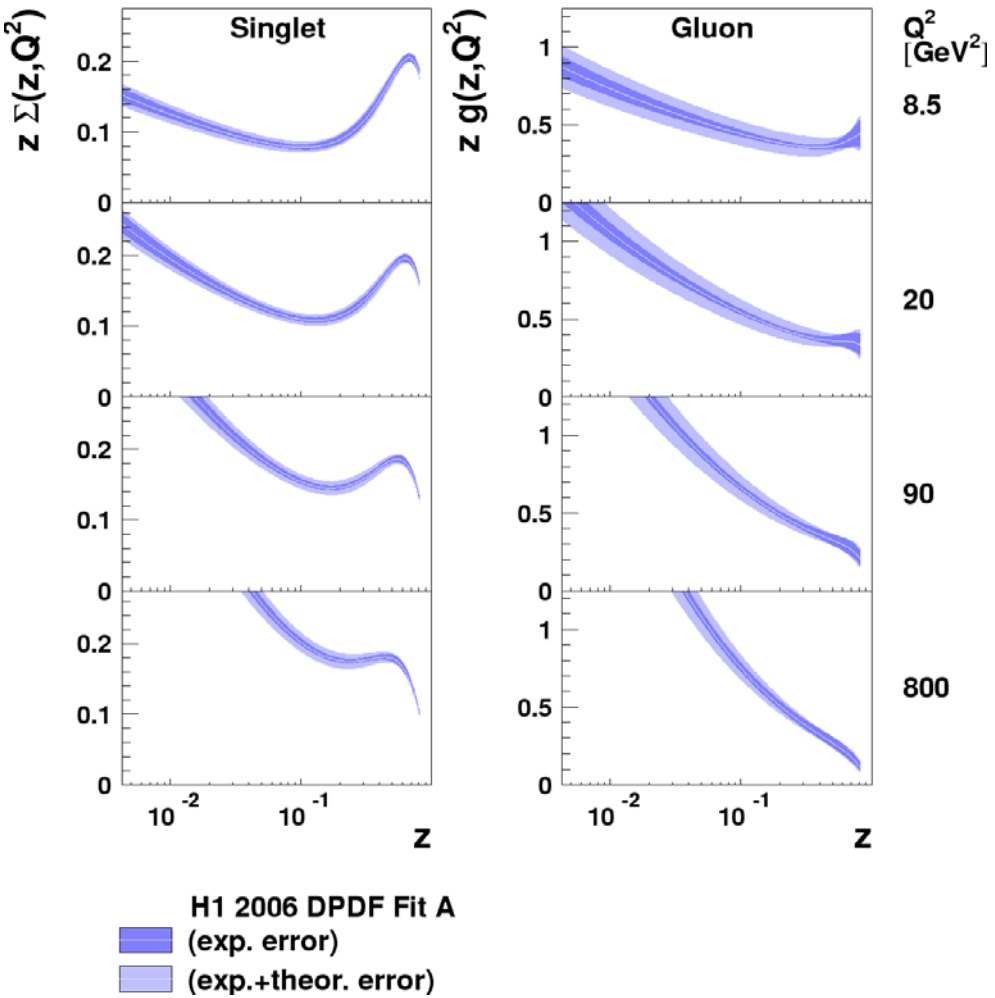
- Q^2 and x (= β x_{IP}) dependence at fixed x_{IP} … QCD structure
- Precision in best regions … 5% (stat.), 5% (syst) 6% (norm)

H1 2006 DPDF Fit Results (log z scale)

- As in inclusive case, F2D gives quark density and its Q^2 dependence gives gluon.

- Extracted through fit to data. Experimental and theoretical uncertainties evaluated.

- Singlet constrained to ~5%, gluon to ~15% at low z, growing considerably at high z

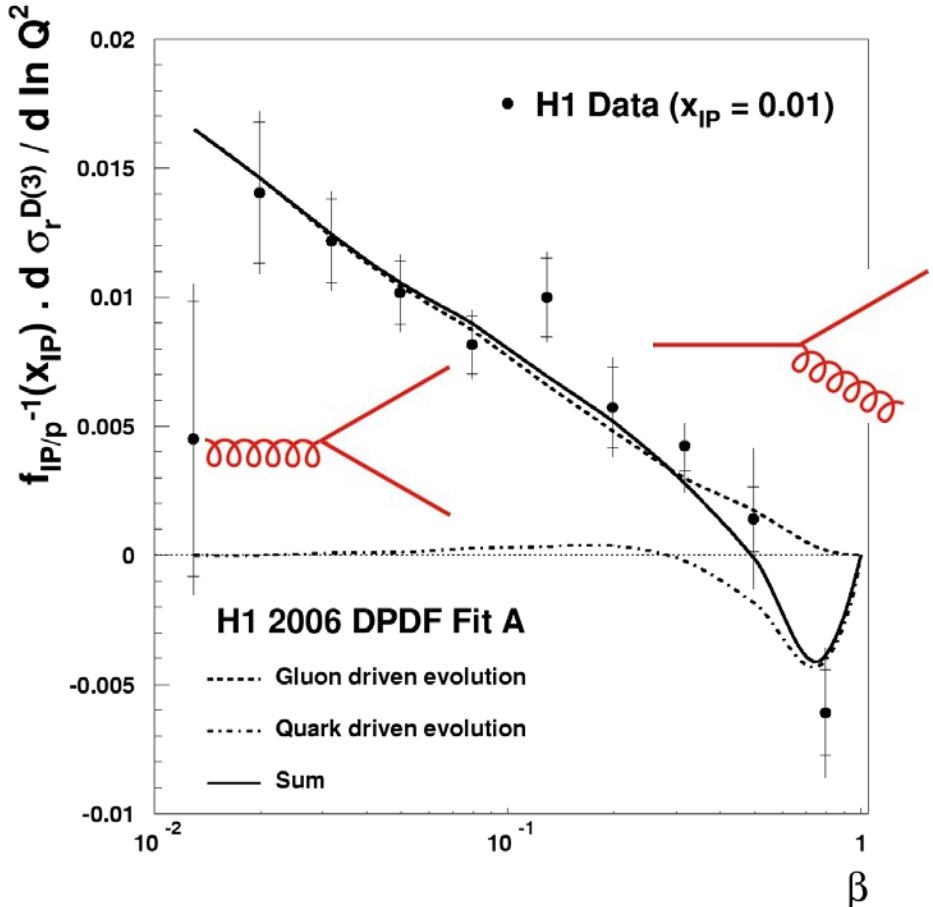


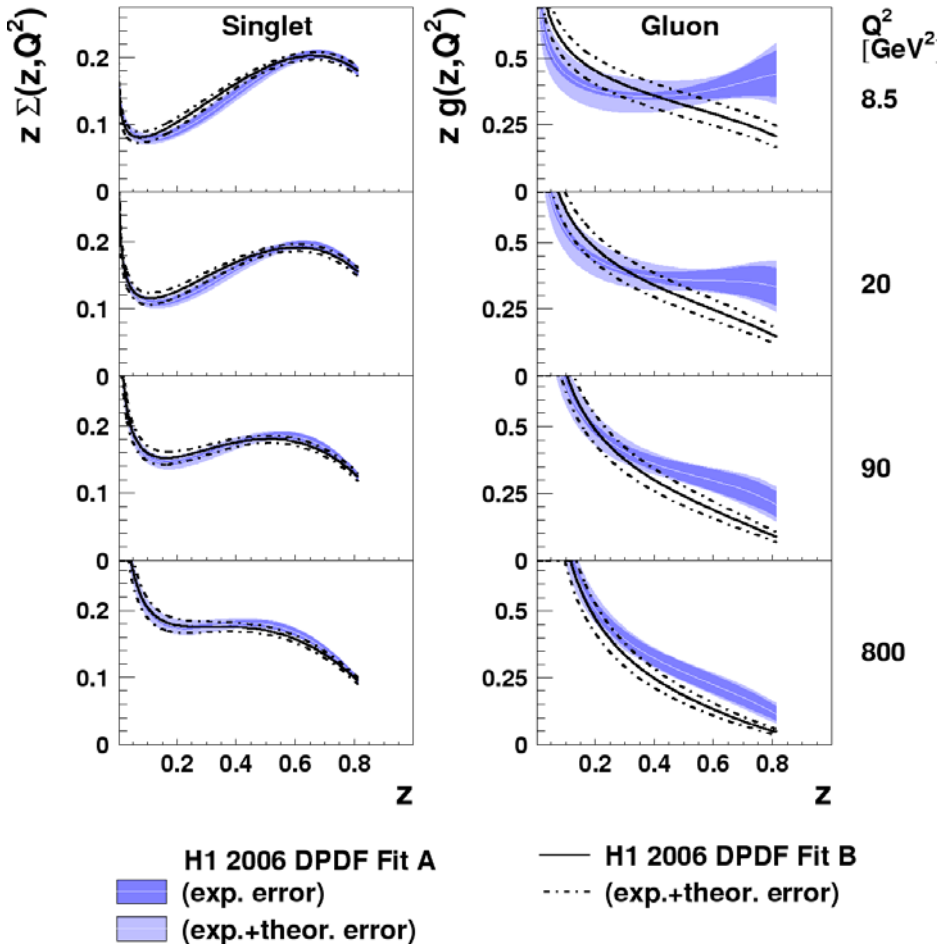
~70% gluons
Integrated over z

A Closer Look at the High z Region

With only singlet quarks, DGLAP equation for F_2^D ...

$$\frac{dF_2^D}{d\ln Q^2} \sim \frac{\alpha_s}{2\pi}\left[P_{qg}\otimes g + P_{qq}\otimes \Sigma\right]$$





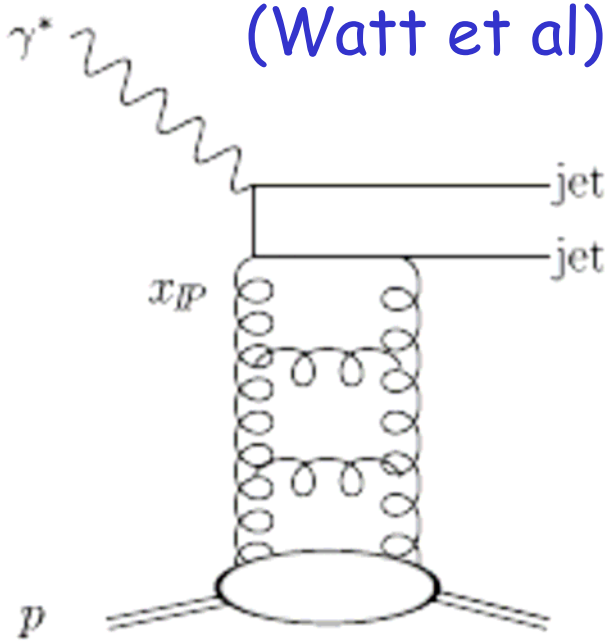
Very different high z gluon but similar χ^2 with modified parameterisation

A more complete approach to DPDF Fits

• Include direct (`hard, perturbative') pomeron contribution in addition to `proton vertex factorising' non-perturbative contribution.

Leads to additional inhomogeneous term in evolution equations, analogous to direct component in photon structure

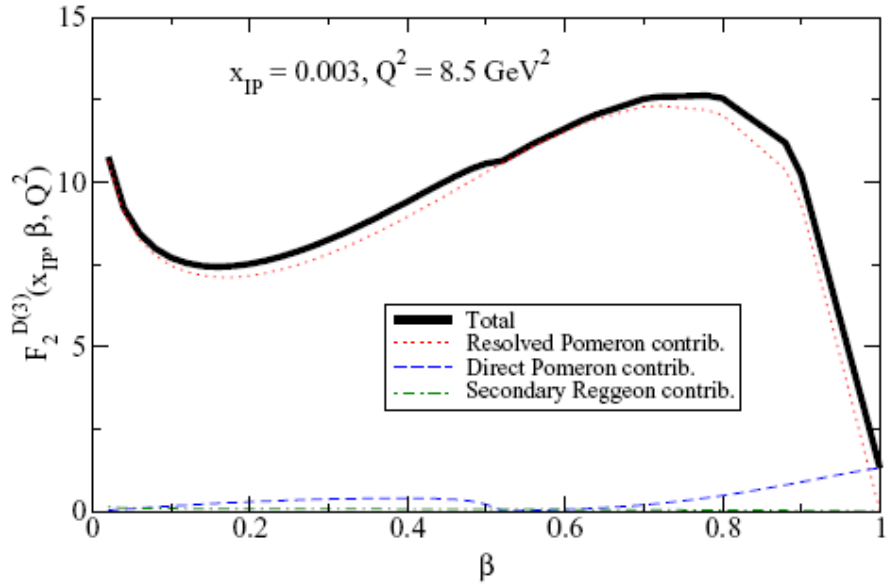
(Watt et al)

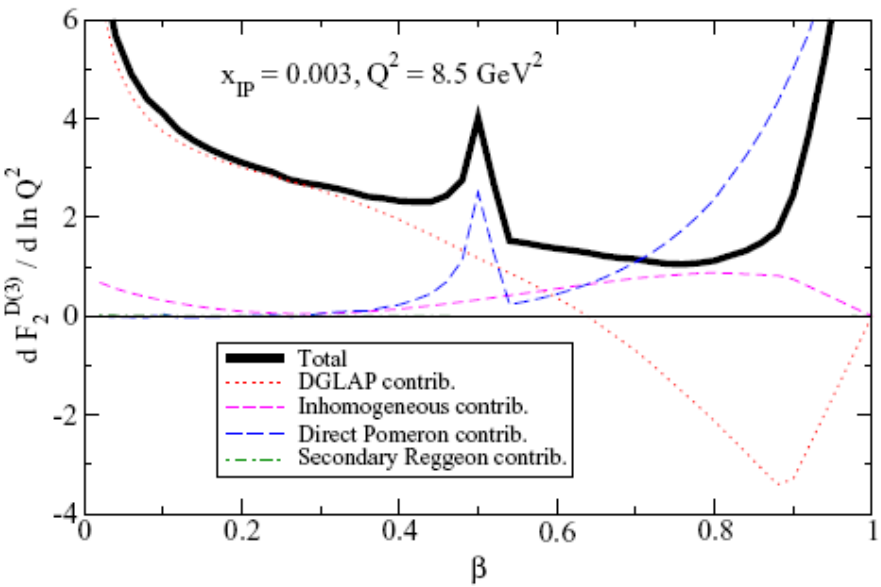


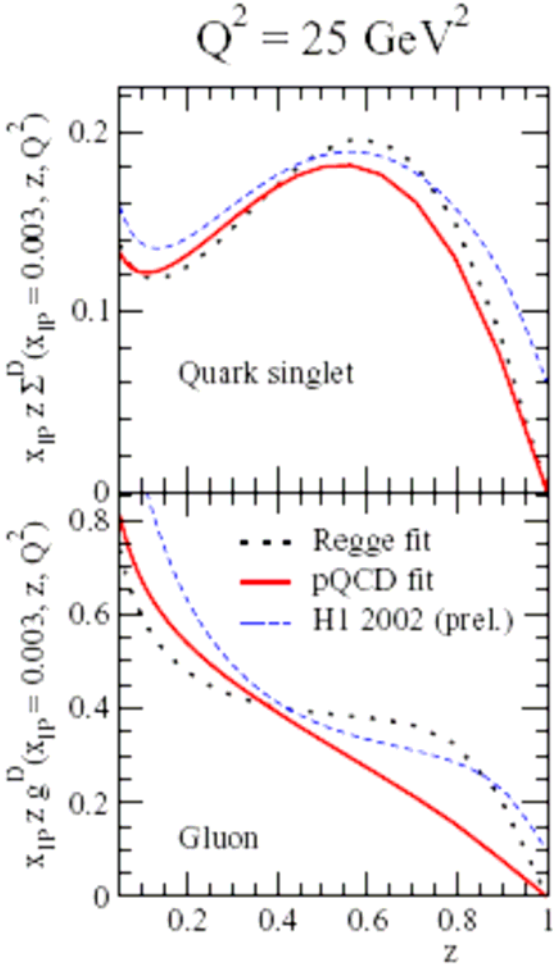
$$F_2^{D(3)}(x_{I\!P}, \beta, Q^2) = \underbrace{\sum_{a=q,g} C_{2,a} \otimes a^D}_{\text{Resolved Pomeron}} + \underbrace{C_{2,I\!P}}_{\text{Direct Pomeron}}$$

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

Fits to H1 Data





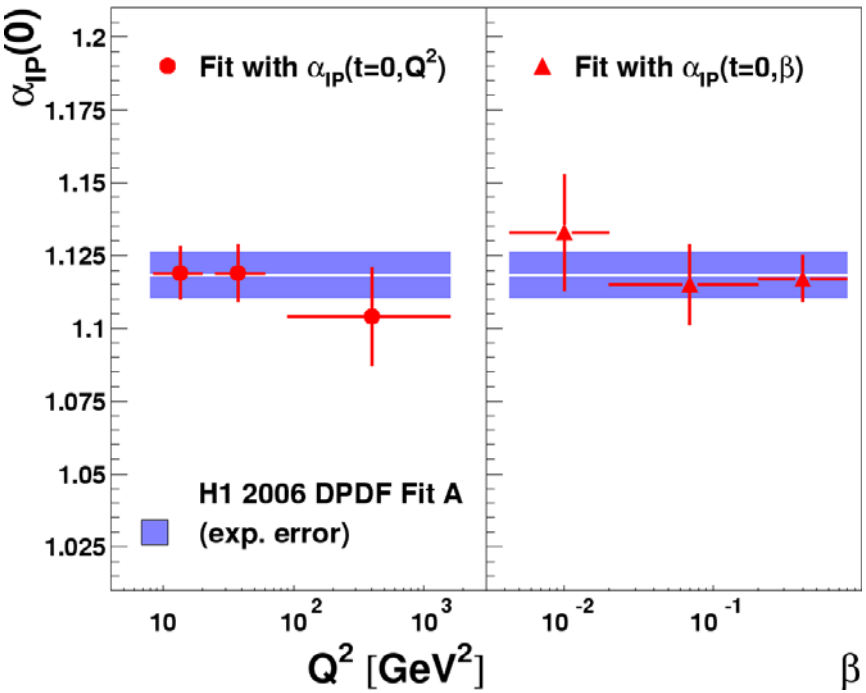


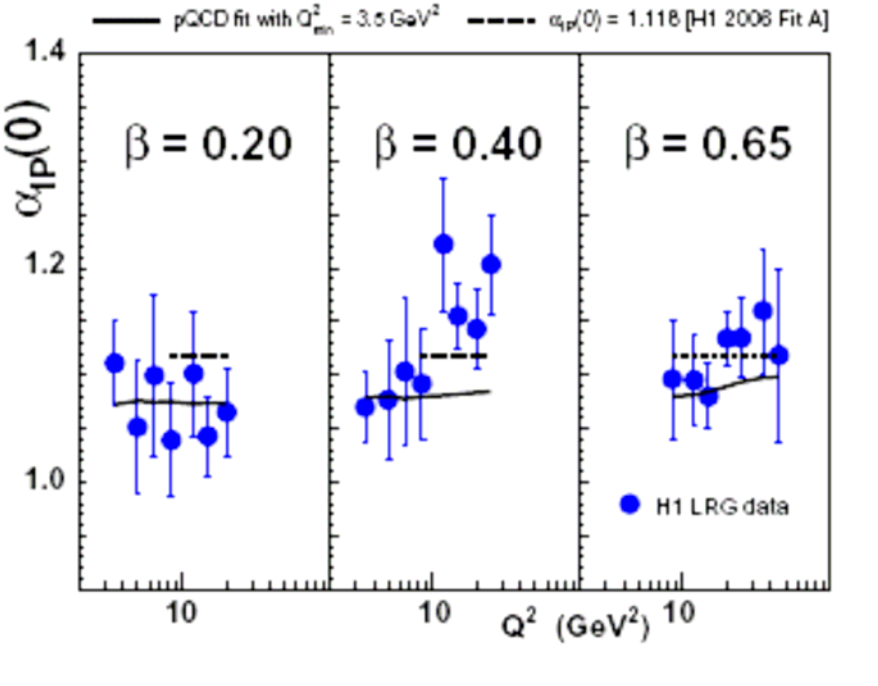
- Main features of H1 `Regge' fit reproduced as cross check
- Adding direct pomeron influences gluon at high z
- Look directly for this in e.g exclusive dijets

Pomeron Intercept from Fits

H1 LRG $\alpha_{IP}(0) = 1.118 \pm 0.008\ (\text{exp.})\ ^{+0.029}_{-0.010}\ (\text{theory})$

H1 FPS $\alpha_{IP}(0) = 1.114 \pm 0.018\ (\text{stat.}) \pm 0.012\ (\text{syst.})\ ^{+0.040}_{-0.020}\ (\text{theory})$

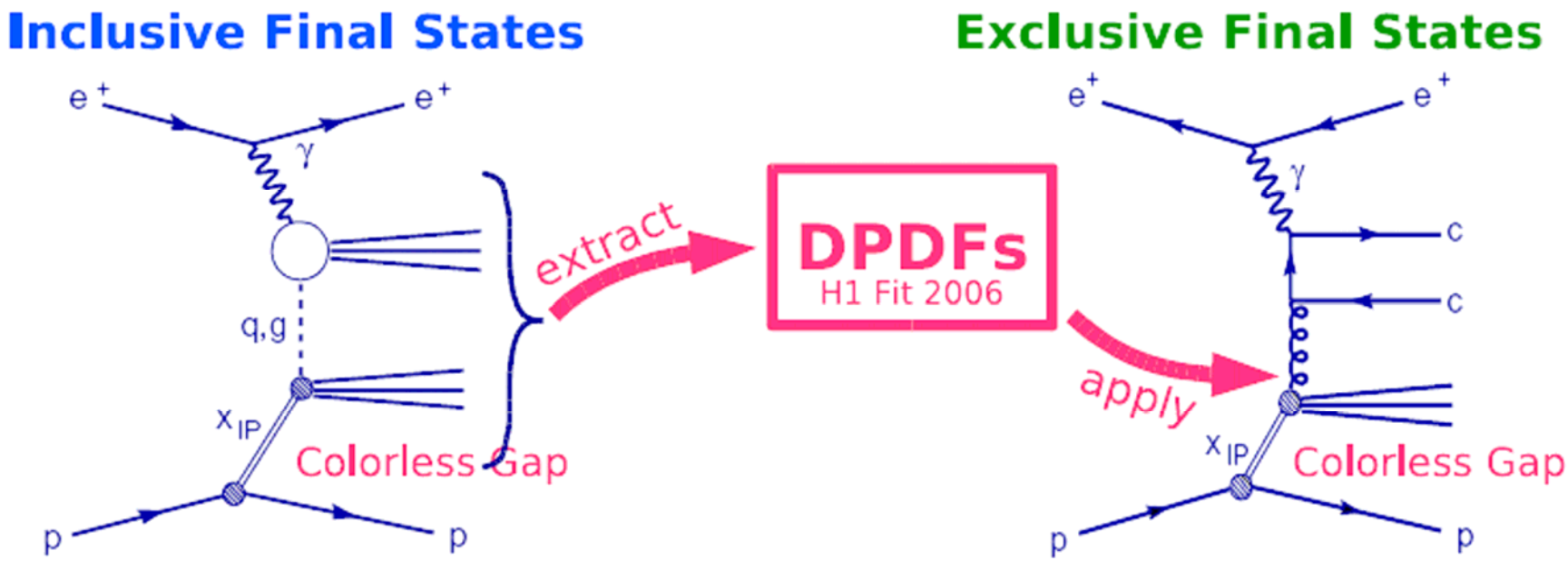




H1 "No evidence for dependence on β or Q^2 … p-vertex factorisation"

Watt et al: "Looking more differentially, maybe Q^2 dependence at high β? … factorisation breaking?"

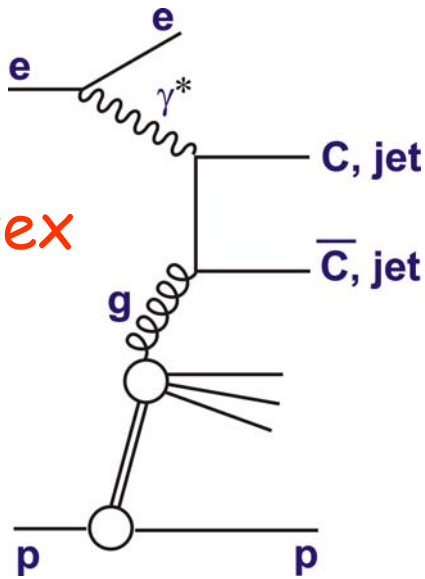
Tests with the Hadronic Final State at HERA



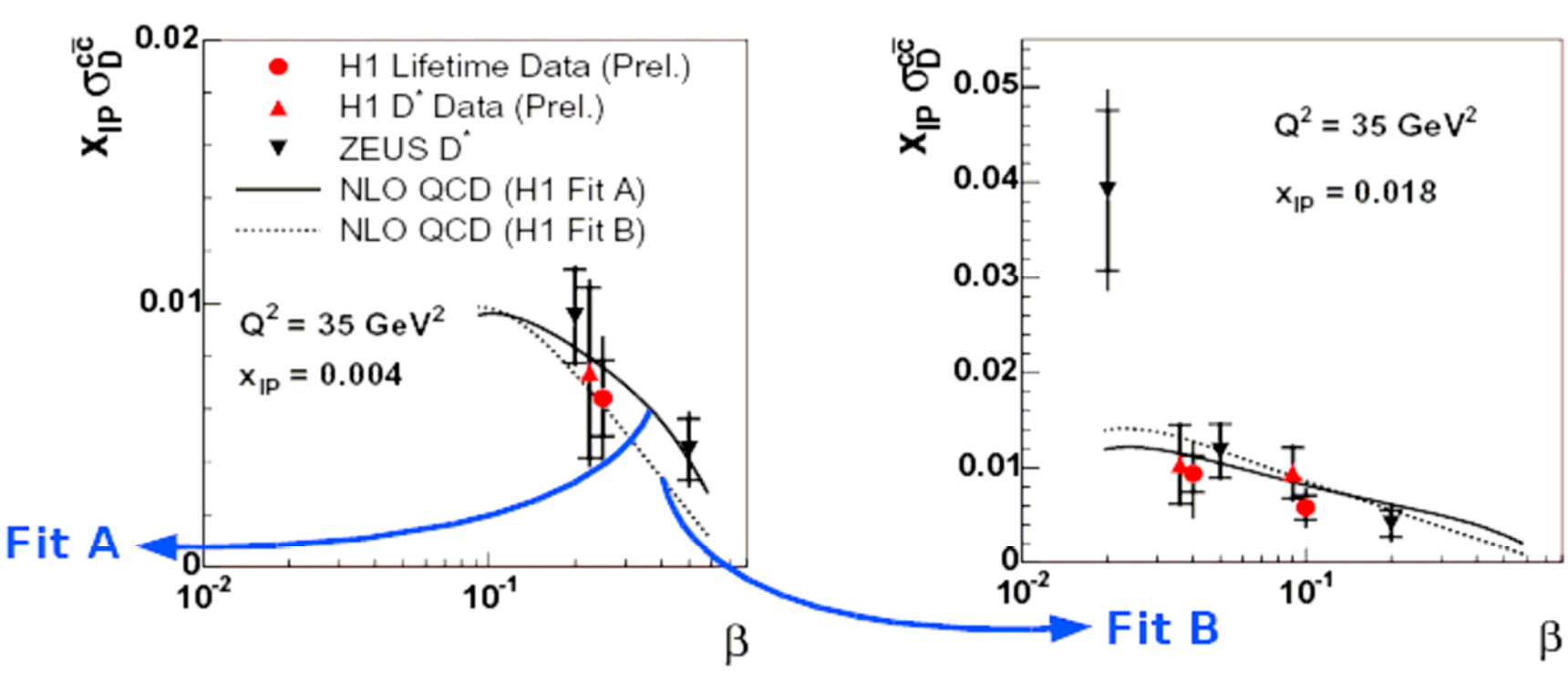
- If factorisation holds, gluon density from QCD fits to inclusive data should predict final states.
- Expect this to work in DIS and `direct' photoproduction and to fail in resolved photoproduction

- ZEUS and H1 both have charm and dijet data in DIS and γp

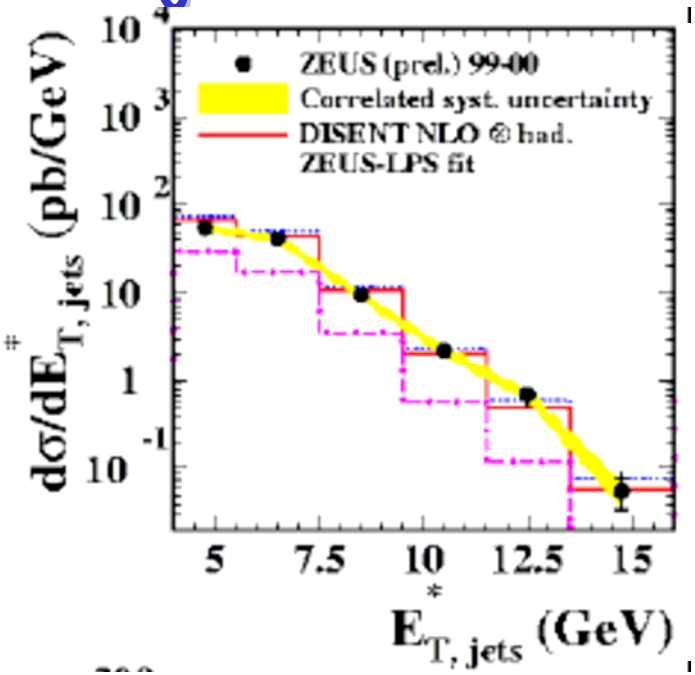
Testing DPDFs with Charm in DIS

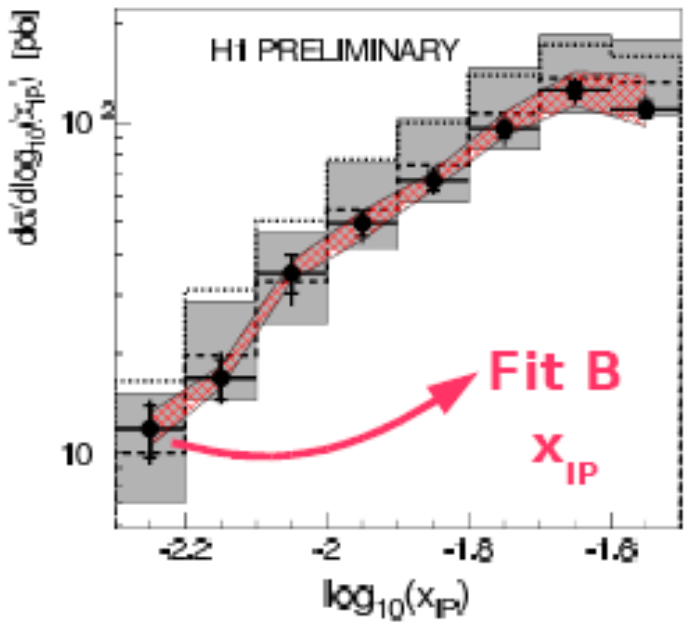


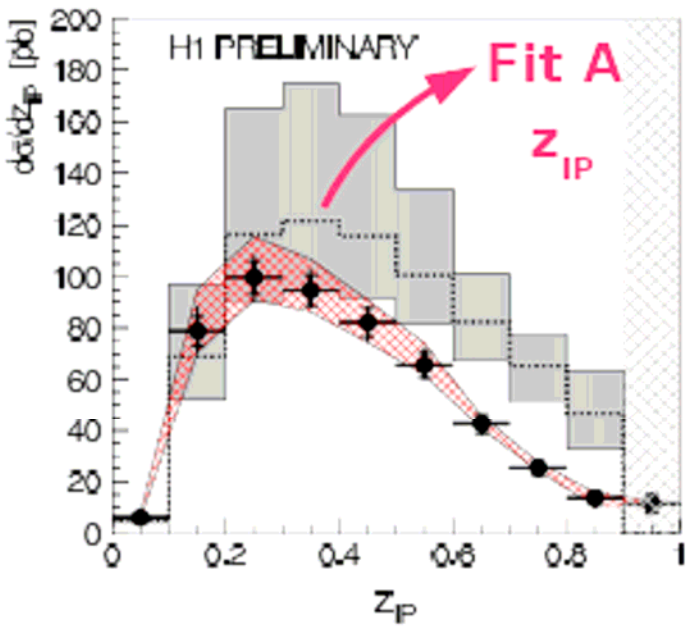
- New H1 charm data based on secondary vertex analysis agree with D* data and with predictions from fits.
- Kinematically restricted to fairly high z

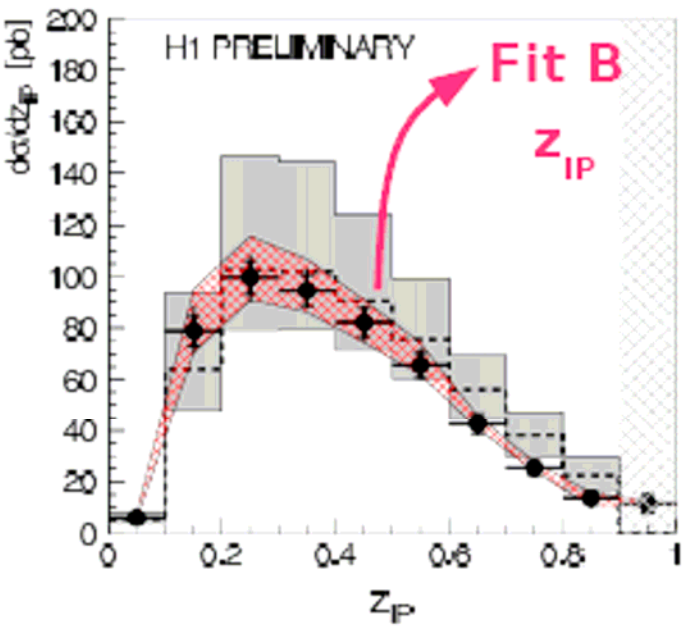


Dijets in DIS: Resolving the high z gluon







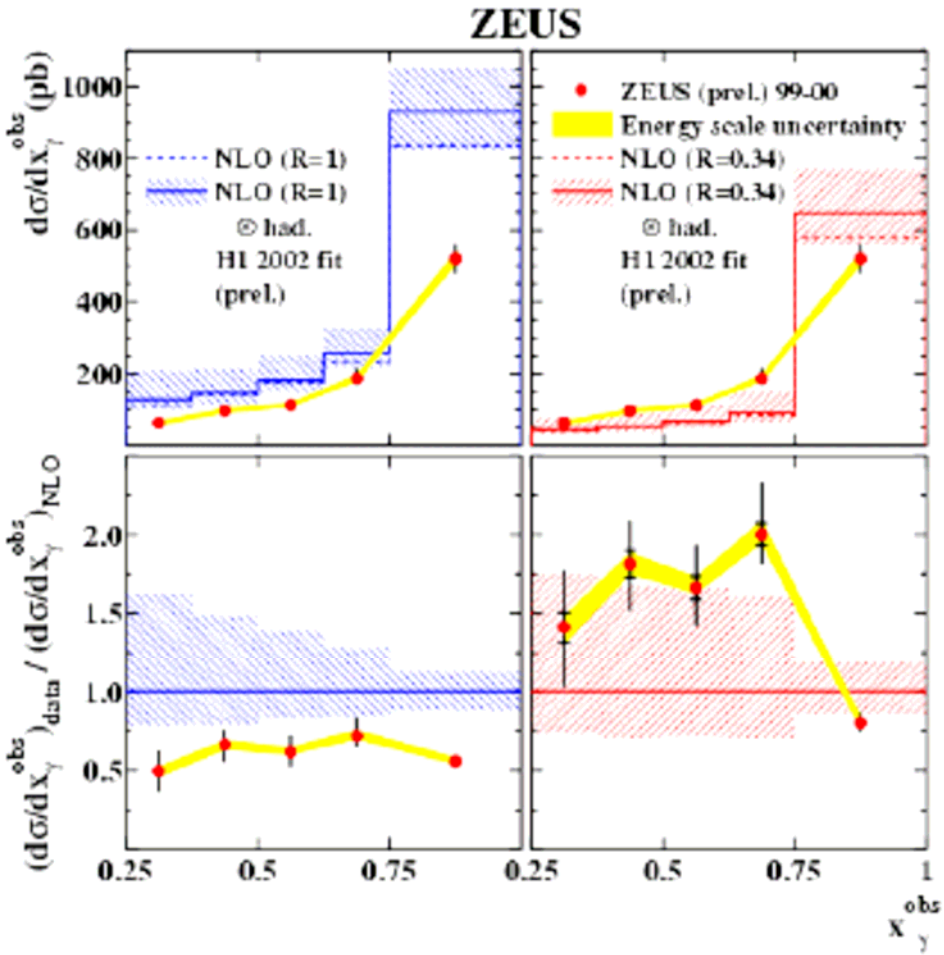


Description not bad, but kinematically restricted to high z … exactly the region where inclusive data don't constrain gluon well.

… H1 joint fit to inclusive and jet data … the way forward?

Dijets in Photoproduction

Similar results from ZEUS and H1

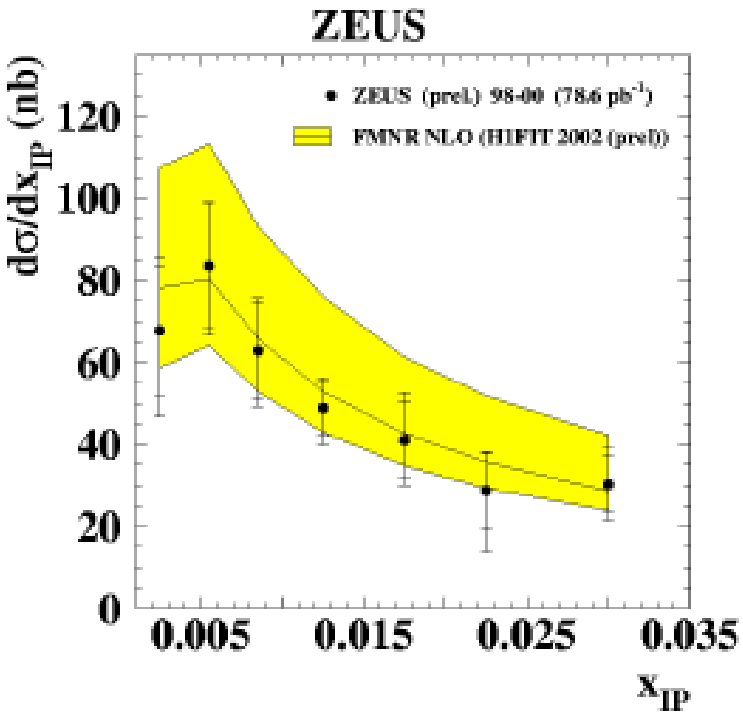


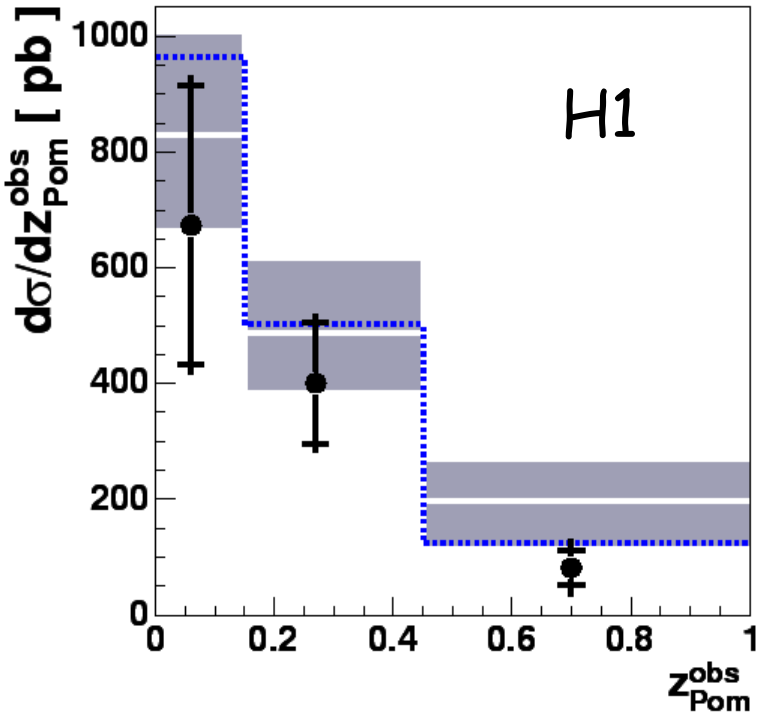
- Factorisation broken as expected for resolved …
… but also for direct!?!?

Survival factor ~0.6 larger than expected from eikonal models (0.34)

See Valery's talk … possible explanation (M Klasen)?

Charm Photoproduction





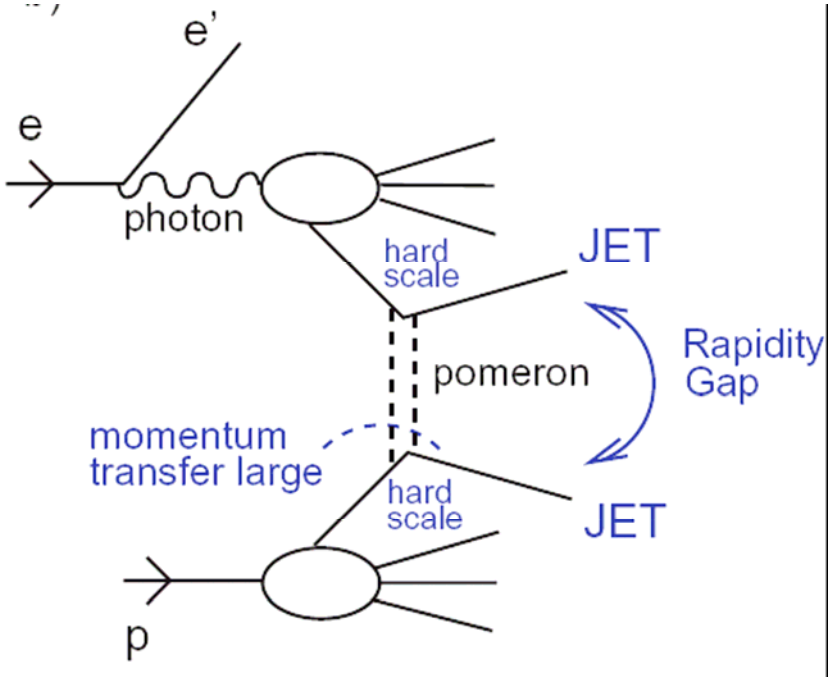
Charm γp data consistent with no suppression, but also with factor 0.6 as for dijets.

… dominated by direct processes.

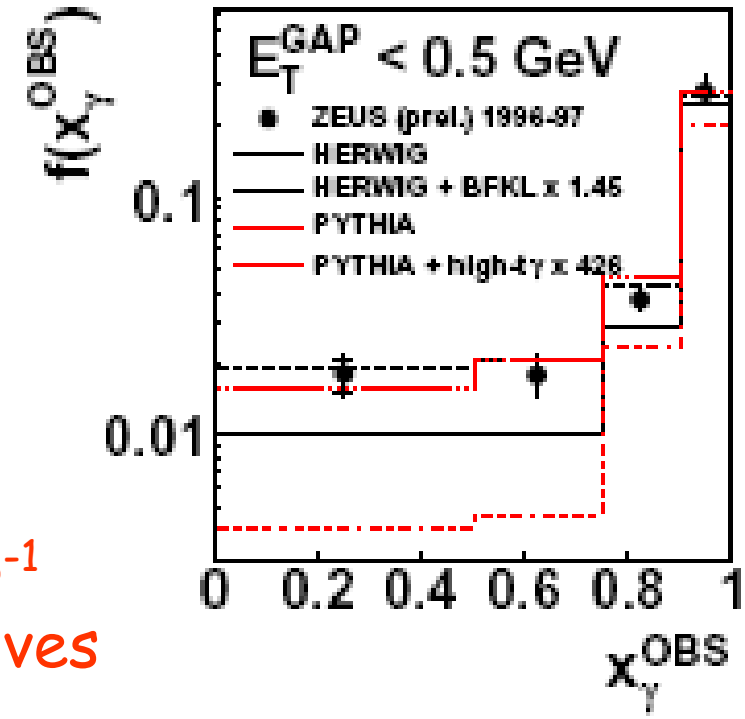
QCD Factorization:

	DIS	γp
charm	+	+
Dijets	+	-

Gaps Between Jets in Photoproduction



Fraction of dijet events with gap between jets



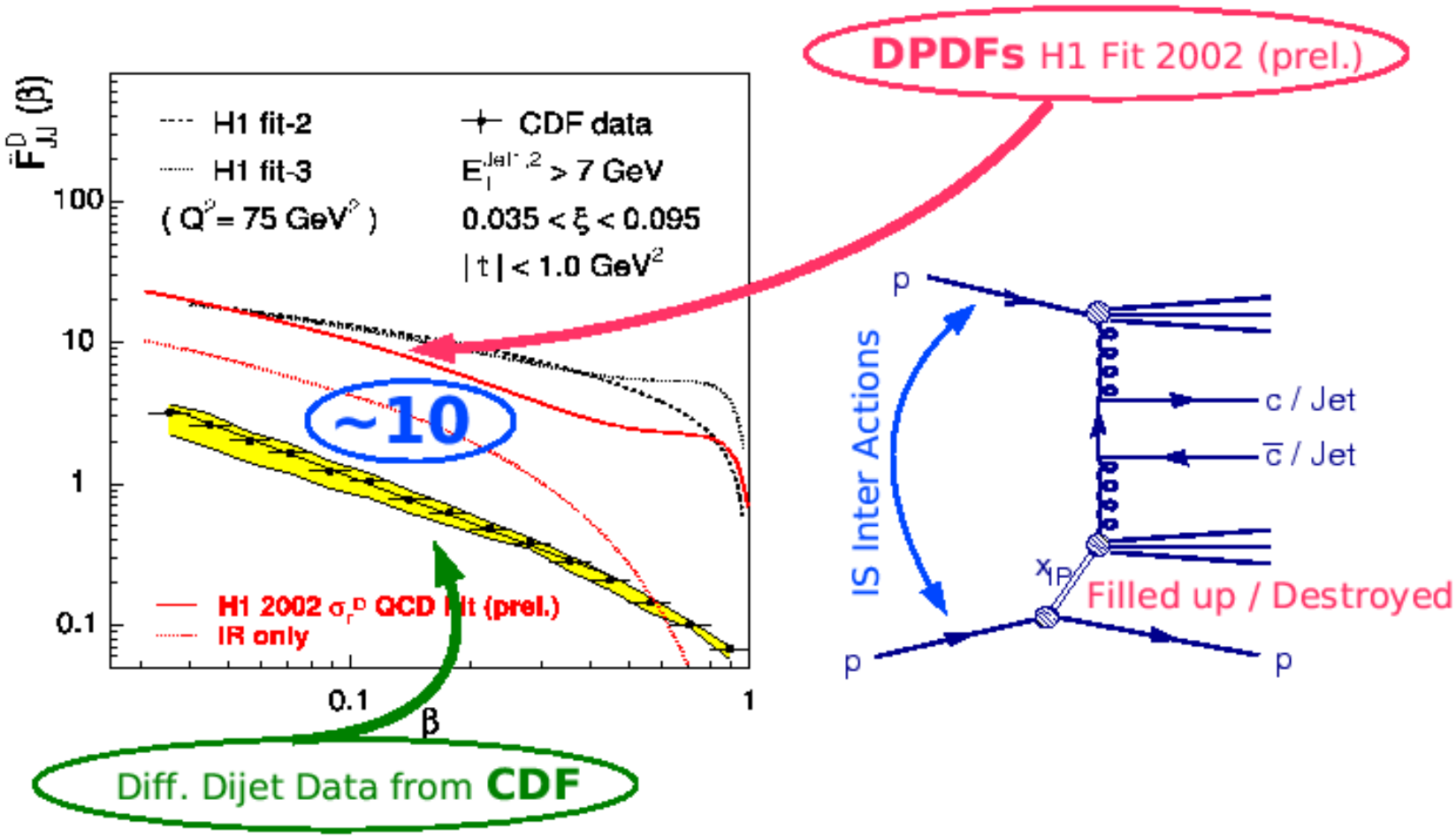
New ZEUS result based on 38 pb^{-1} confirms previous data and improves precision.

Sensitive to hard pomeron cross section and gap survival probabilities … challenge to describe phenomenologically

What about the Tevatron

(K. Terashi)

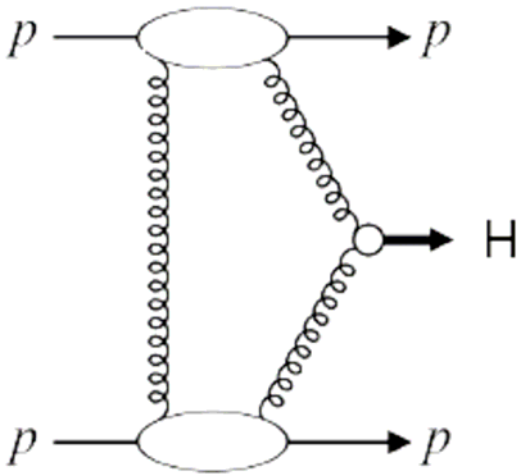
Rapidity gap survival known to play an important role

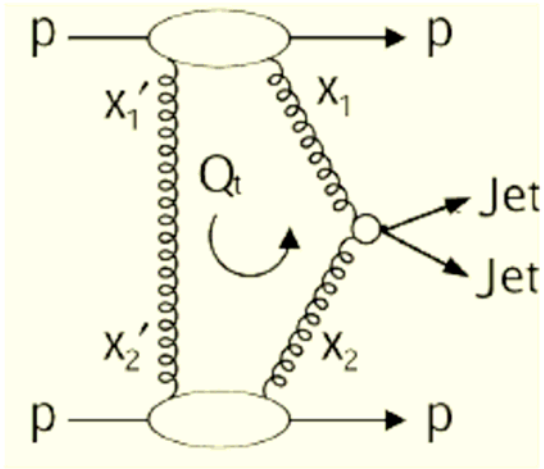


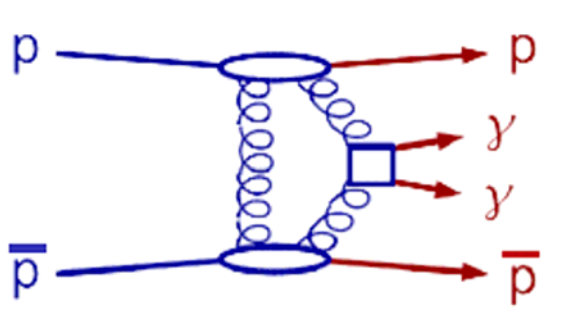
Many new results on such processes shown here

Tevatron Search for Exclusive Production

Observation of exclusive dijets / di-photons is a proof of principle for the Higgs diagram and constrains poorly known aspects such as gap survival probability

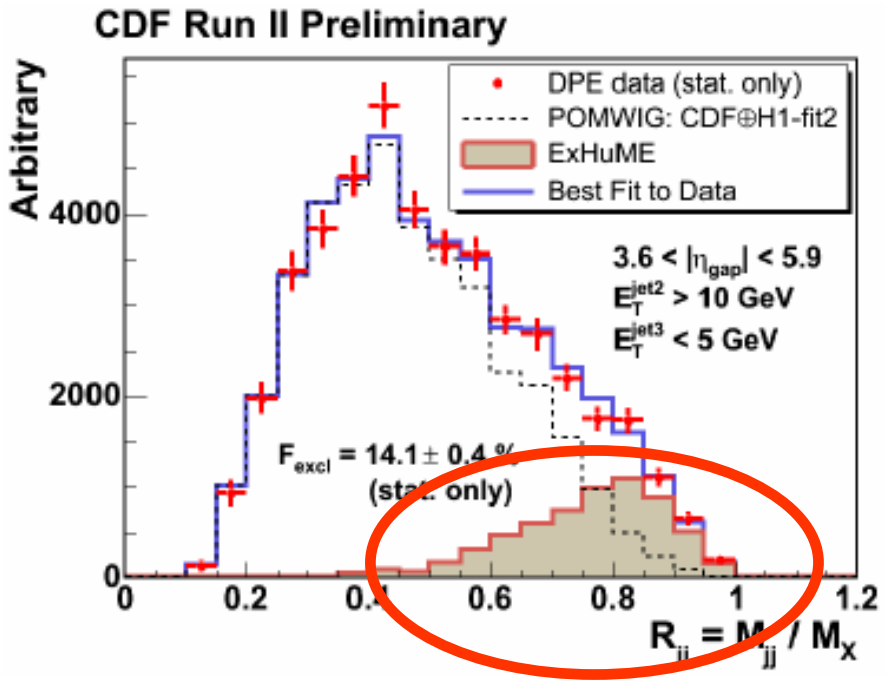


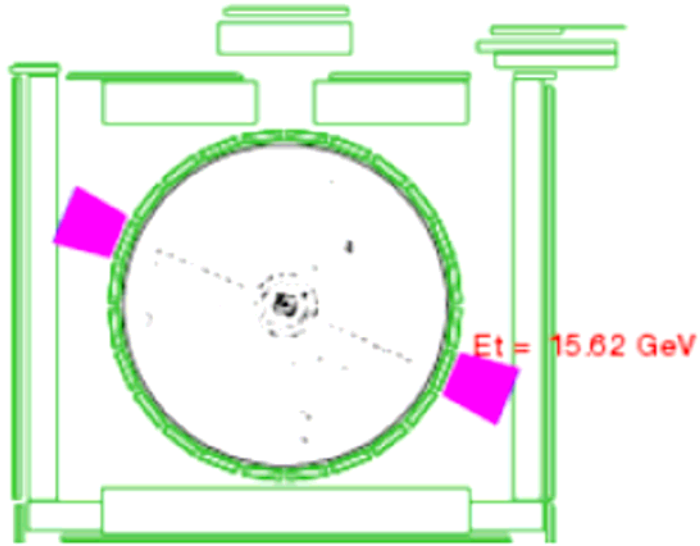


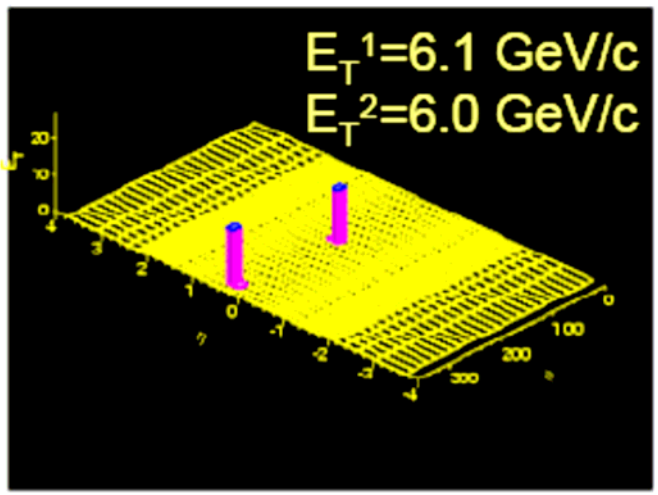


Difficult task to separate exclusive dijets from inclusive dijets produced via DPDFs

Tevatron evidence for Exclusive Production







- Mounting evidence for exclusive dijets … need full assessment of uncertainties and corrected cross sections!!!
- 3 di-photon events observed, expect $0.0^{+0.3}_{-0.0}$

Diffraction at the LHC: Experimental Talks

i) CMS + TOTEM + FP420 (M. Grothe)

ii) ATLAS (H. Stenzel)

iii) TOTEM (R. Orava, see plenary presentation)

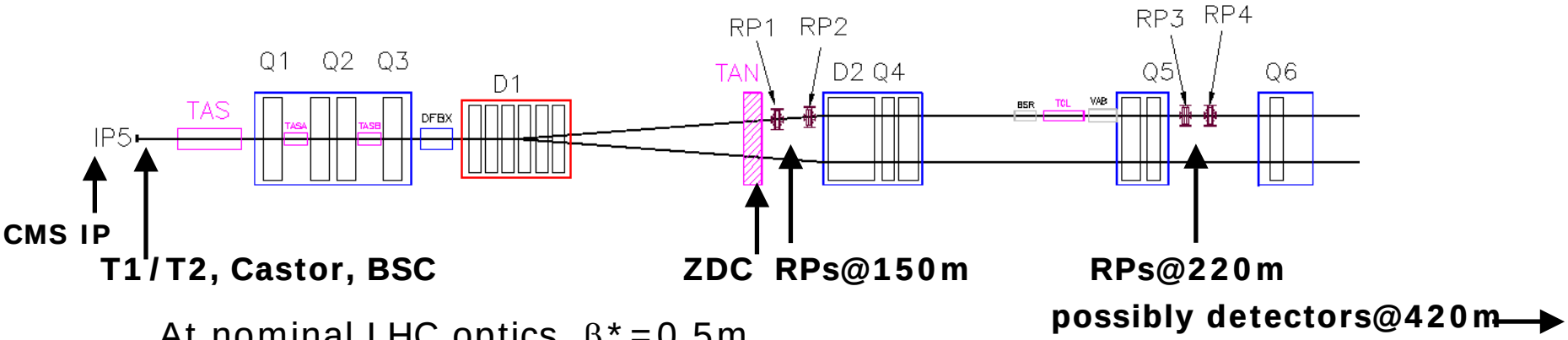
iv) FP420 (B. Cox, see plenary presentation)

v) More Forward Calorimetry (V. Andreev)

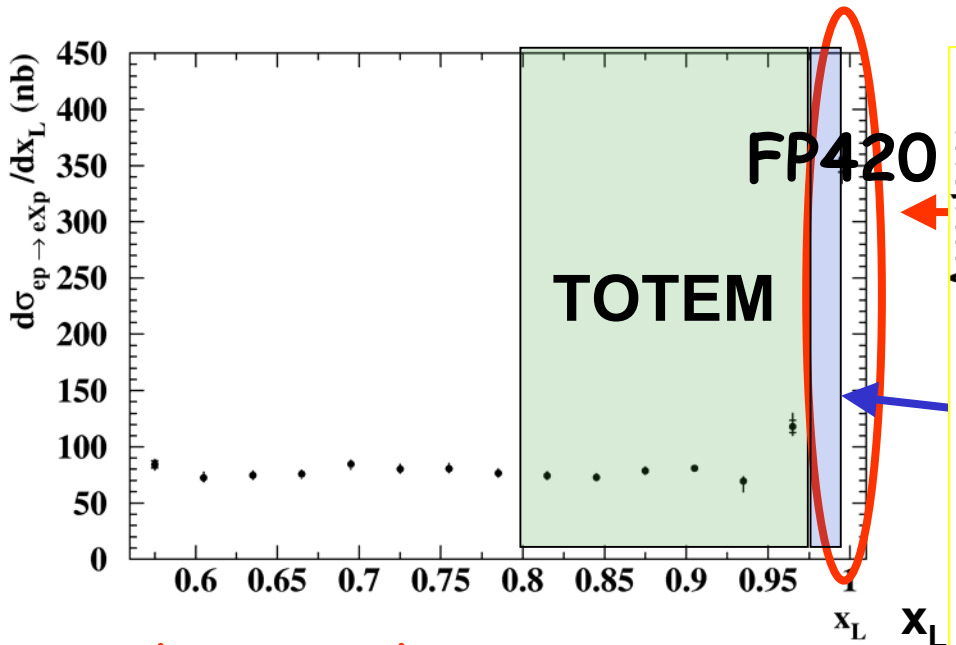
Also:

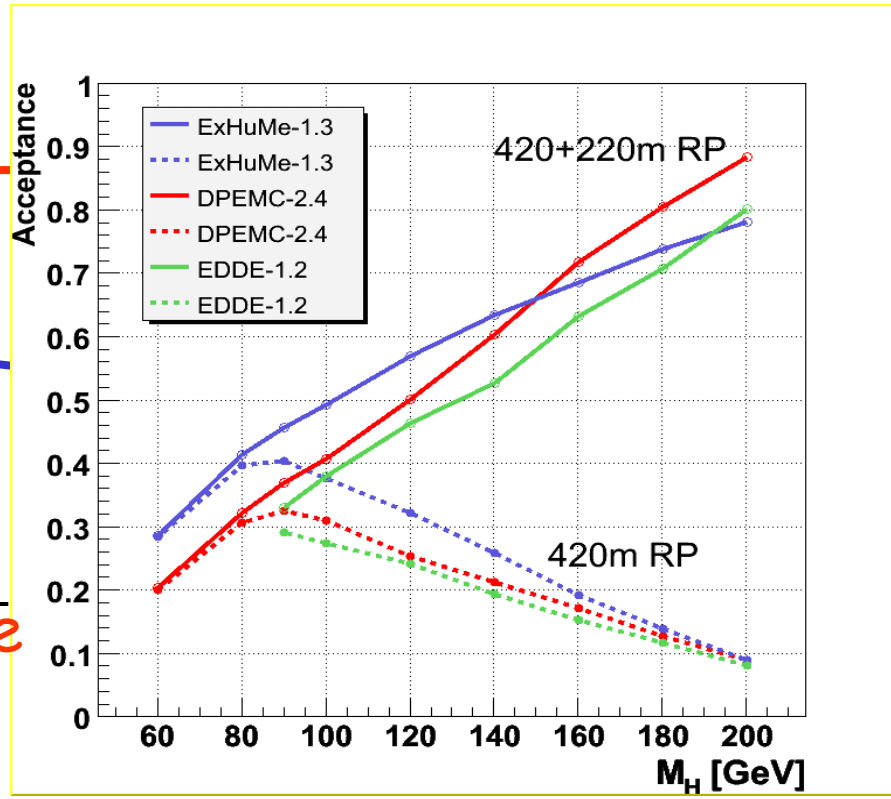
MC, pile-up studies etc (A. Pilkington, M. Tasevsky)

CMS + Totem + FP420



At nominal LHC optics, $\beta^* = 0.5$m





Comprehensive kinematic coverage

Difficulties at high lumi: trigger, pile-up … detailed studies ongoing

CMS + Totem + FP420: Overall Programme

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

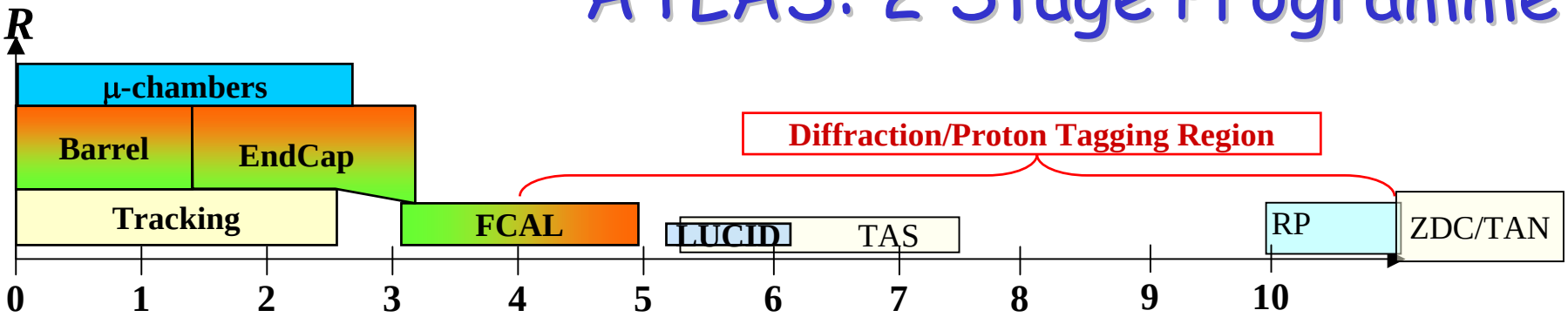
Central exclusive production
Discovery physics:
Light SM Higgs
MSSM Higgs
Extra dimensions

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

CMS alone

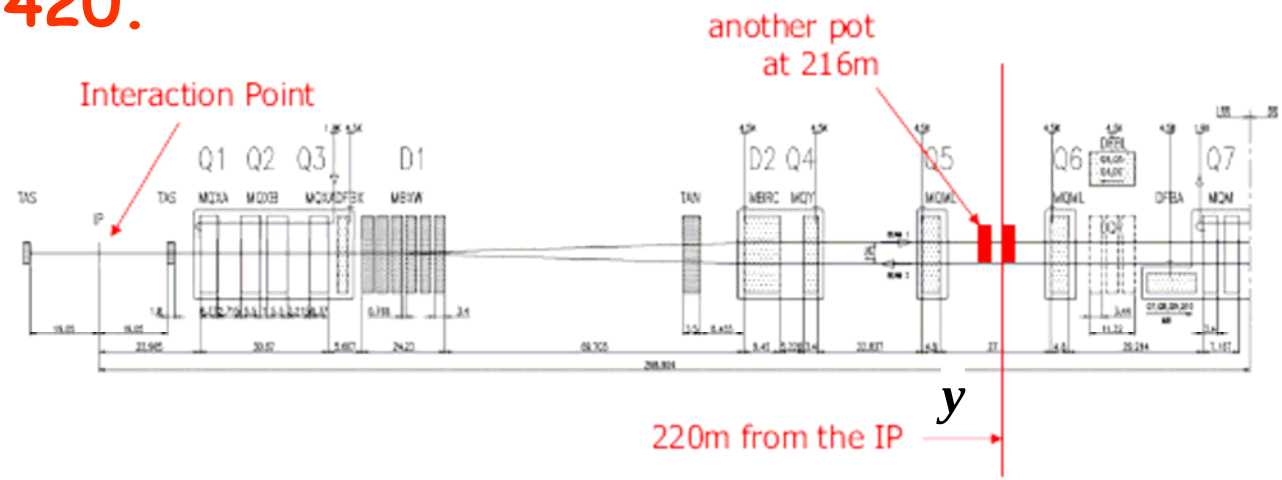
CMS with Totem and/or FP420

ATLAS: 2 Stage Programme

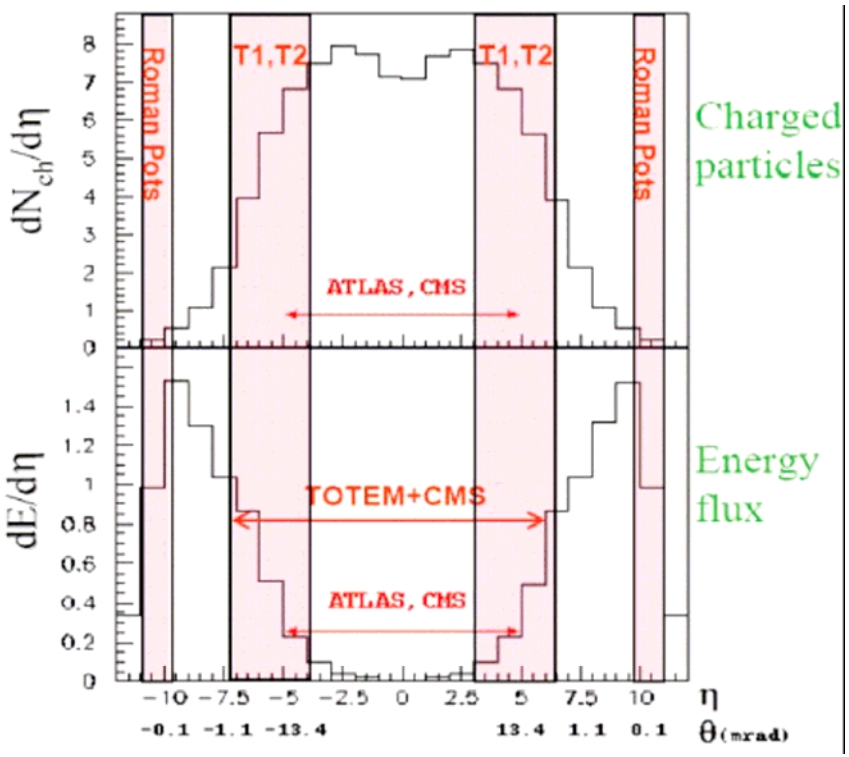


1: Luminosity calibration of forward Cerenkov detector, LUCID using 220m Roman Pots at high β*, based on elastic scattering in the Coulomb region.

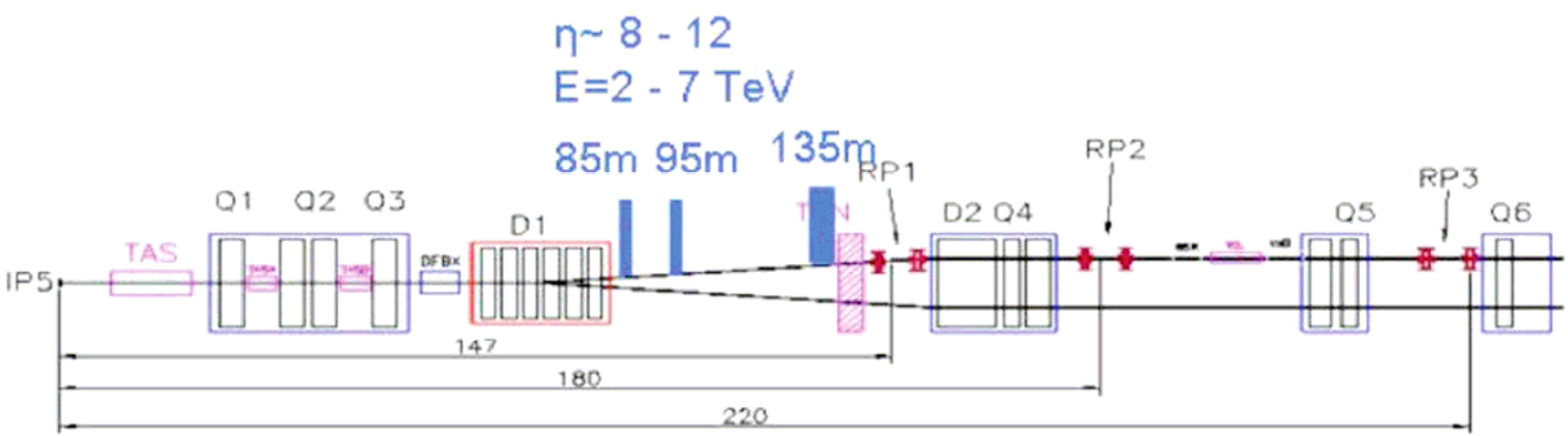
2: Hard diffractive physics at high luminosity, using new radiation hard Roman pots at 220m (under development) complementing FP420.



More Calorimetry at High Rapidities?

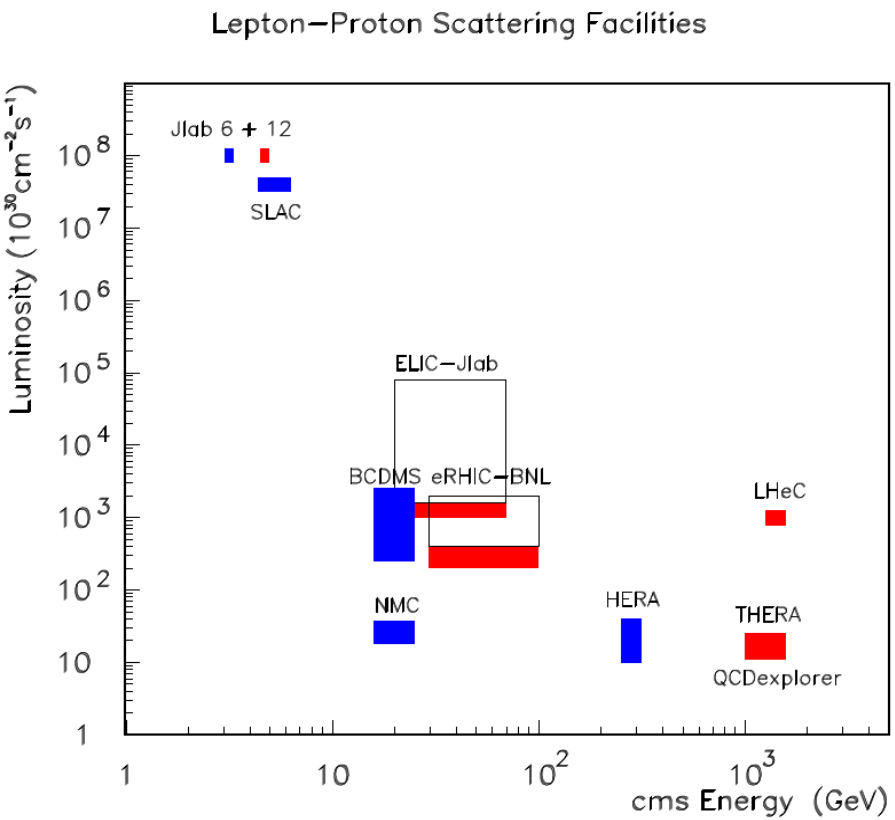


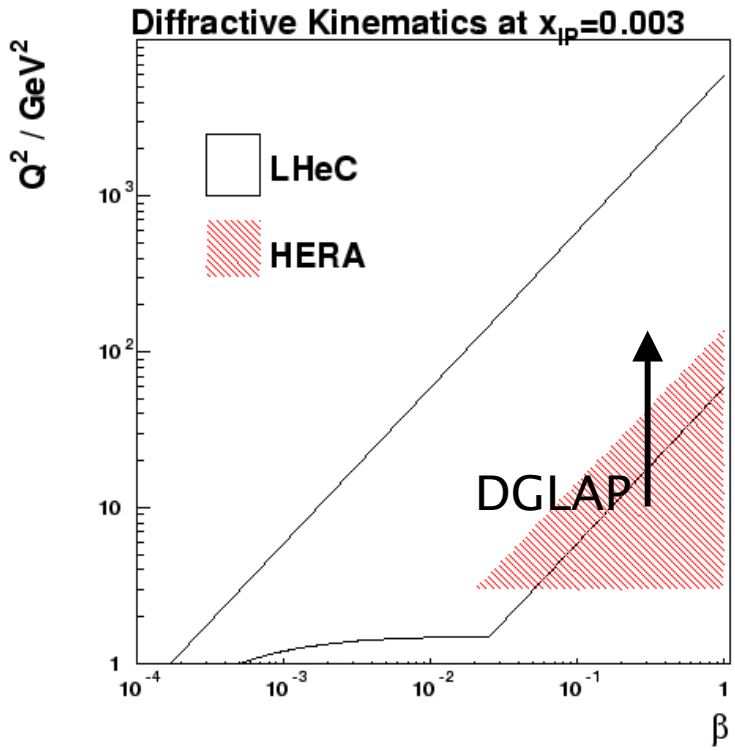
- Idea to partially fill gap in rapidity coverage with a hadron calorimeter at 135m.
- Radiation tolerable (cf ZDC)
- Sandwich lead + quartz / Si diodes, GEM tracker in front?
- … Under study



The Longer term: Diffraction and LHeC

(PRN)



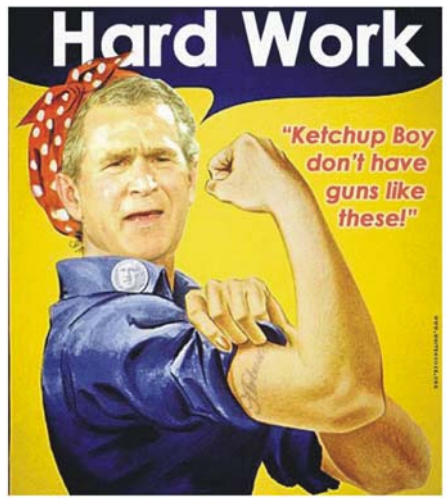


- Using LHC is natural next step for ep!.. Fantastic for low x!
- First thoughts on diffractive DIS at 70 GeV x 7 TeV
- Large extensions to kinematic coverage for DPDFs, novel QCD effects, diffractive Z, understanding new 1^{--} states …

Interim Summary – experimental shopping list

From HERA …

- Clarity on DPDFs – a single set from H1 and ZEUS, using all available DIS information: inclusive data, jets, charm
- Systematic search for `exclusive dijets' in γp and DIS
- Better data on t slopes from all processes (pots)
- Multi-differential (x, Q^2, x_L, t) and more precise leading neutron data (simple Regge decomposition)
- More diff / incl ratios (eg for dijets)
- Proton dissociation measurements for hard processes … eg J/Ψ (constrain 3pom vertex)



From LHC …

- Use up-to-date HERA input (DPDFs etc)
- Finalise feasibility studies (trigs, pile-up …)