Diffraction and forward physics at HERA

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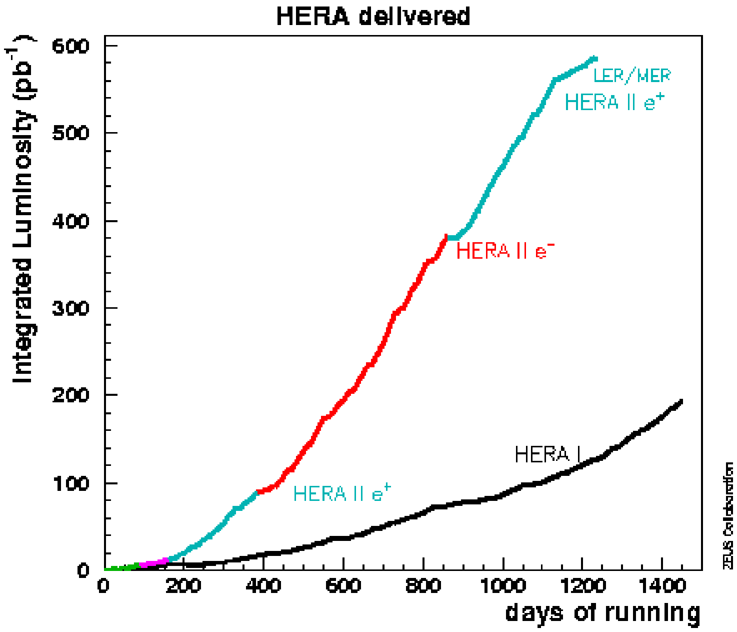
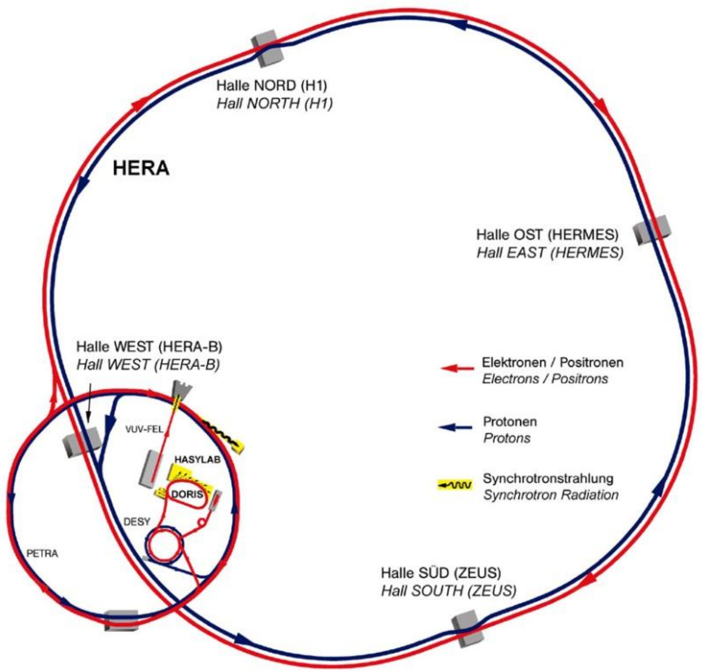
on behalf of the H1 and ZEUS collaborations

HERA 1992-2007

- The only $e^{\pm}p$ collider
  - 27.5 GeV $e \times 920$ GeV p
  - Super microscope for partons
- 0.5fb^{-1} on tape each



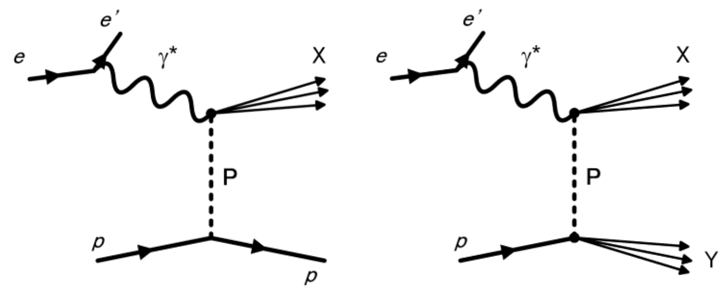


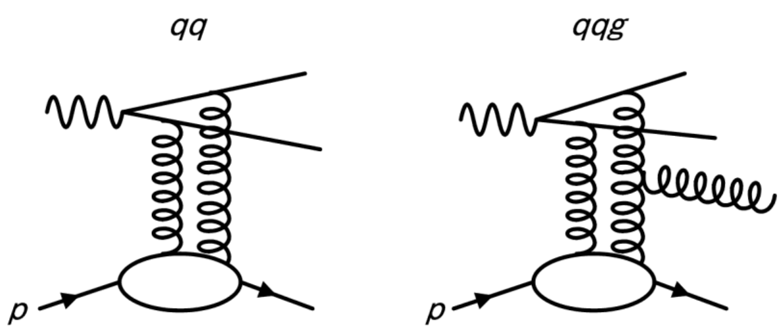
Today’s talk

- Introduction to diffractive DIS
- Recent results from diffractive DIS
  - Diffractive parton densities
  - Diffraction by forward proton tagging
  - Factorisation test
- Forward neutron production in ep scattering

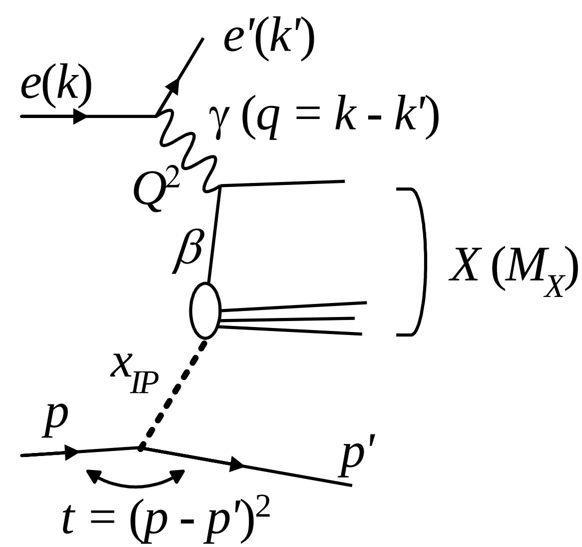
Diffraction in *ep* collisions

- Photon dissociates to system X
  Proton may stay intact or dissociates to small mass system Y
- Two major views





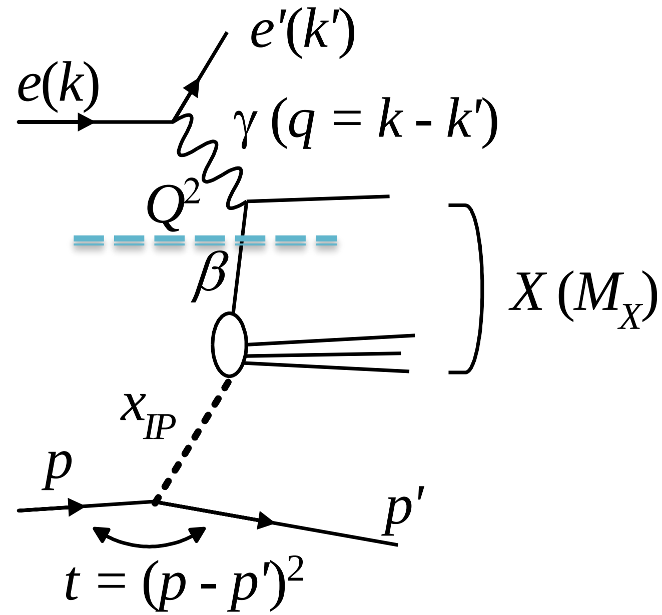
- Colourless exchange between dipole ($q\bar{q}$) and proton
  - Realised by two-gluons at the lowest order
  - Like hadron-hadron collisions



- Electron scatters off partons in the colourless exchange
  - Classic view of DIS

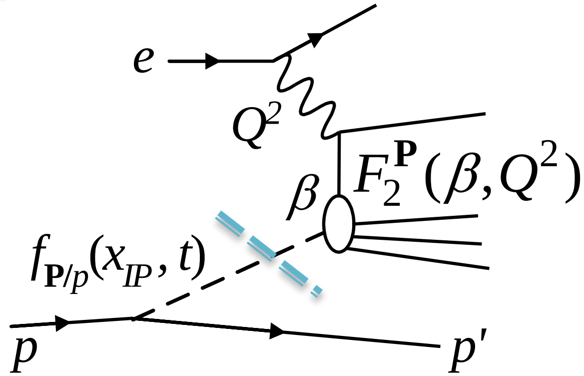
Diffractive DIS and diffractive PDFs

- Objective at HERA:
  understanding the partonic structure of diffractive exchange (Pomeron)
- What to measure first: $F_2^{D(3)}(\beta, Q^2, x_P)$
  - Structure function of diffractive process (with rapidity gap, forward proton tag …)
- Extracting diffractive PDFs (DPDFs)
  - Through scaling violation, using jets …
- If the DPDFs can be used for various processes, it is universal = factorisation
  - $\sigma = \sum_{i=q,g}(ME) \otimes (DPDF)_i$
  - Called "QCD factorisation"

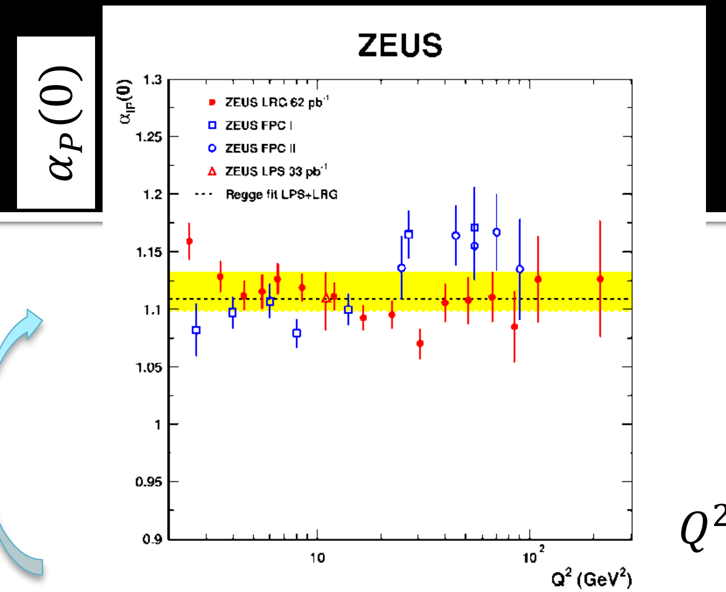


β: long. momentum fraction of the parton in the exchange
x_P : long. momentum fraction of the exchange in the proton
$Q^2 = -q^2 = -(k - k')^2$: negative of momentum transfer squared

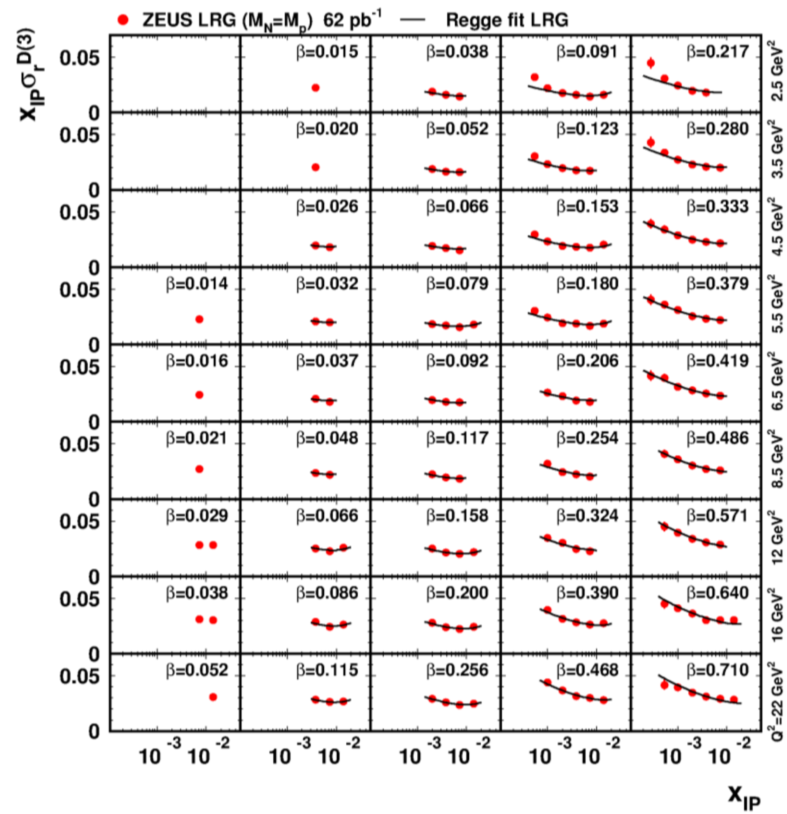
Regge factorisation



Fit by $\dfrac{1}{x_P^{2\overline{\alpha}_P - 1}}$

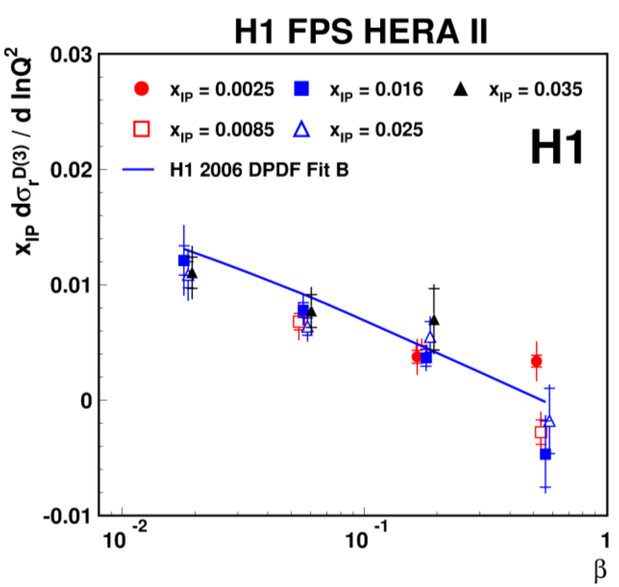


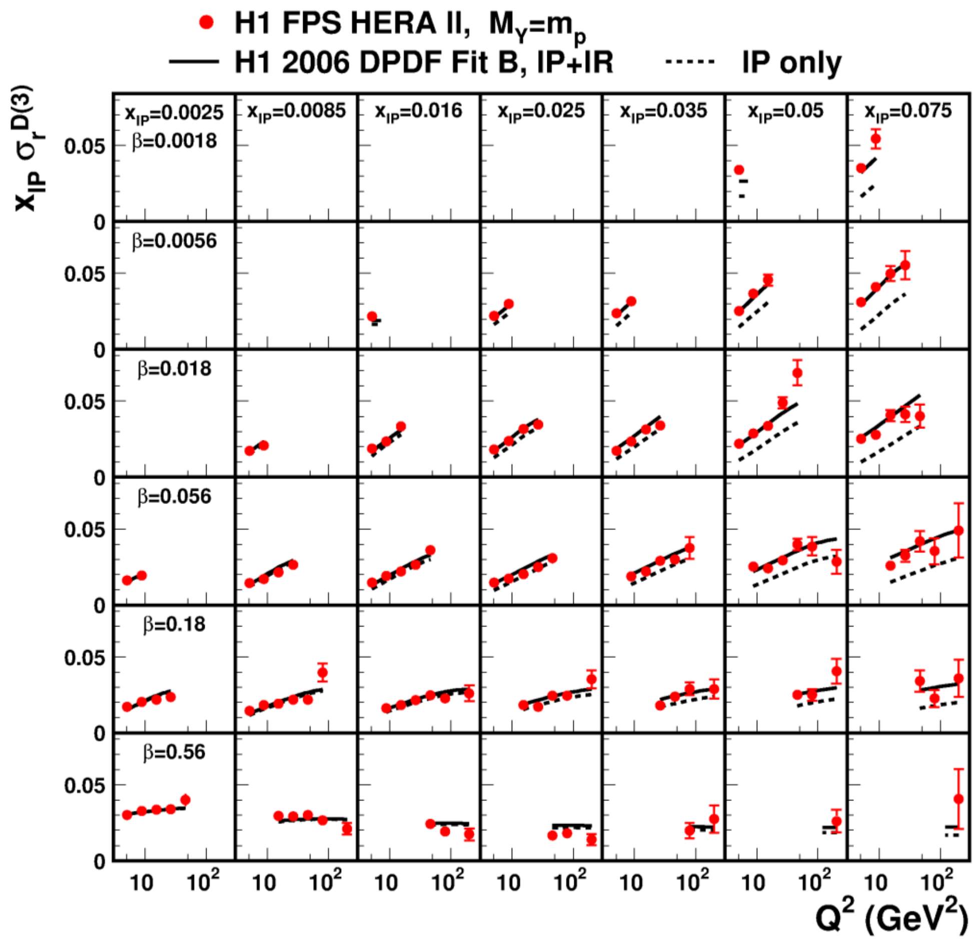
- Assuming that the exchanged object is a particle (Pomeron)
  - The probability to emit the Pomeron is universal i.e. Pomeron flux is process independent
- This hypothesis holds pretty well
  - Once we include sub-leading exchange
  - Cross section shape in x_P independent of β and Q^2



Scaling violation and extraction of gluons

- Positive scaling violation in almost all β values
  - Quarks dynamically produced through gluons 
  - Slope independent of x_P after sub-leading exchange included

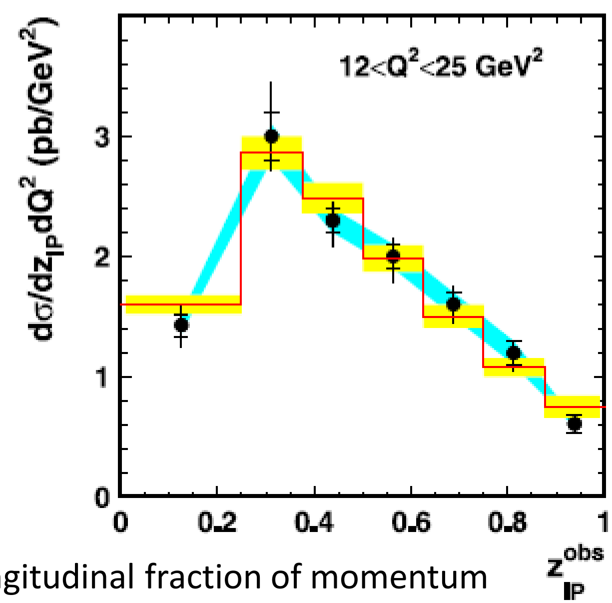




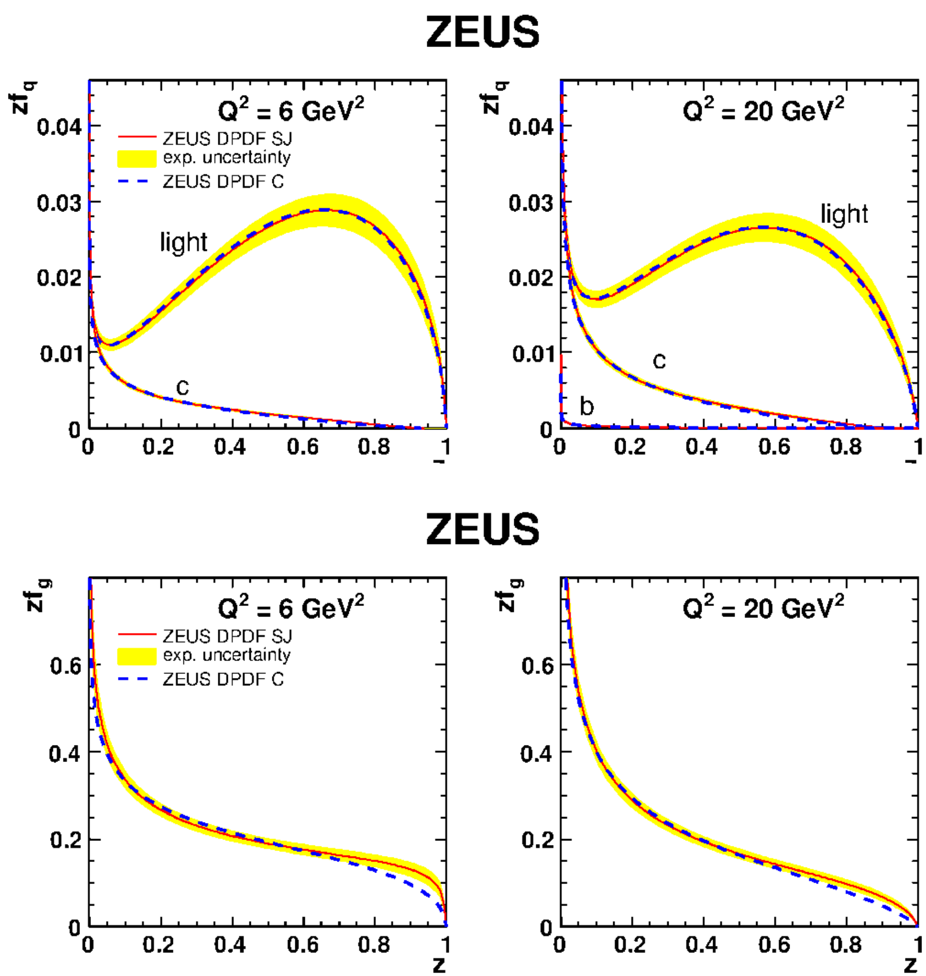
Extracted diffractive parton densities

- Diffractive exchange is gluon rich
  - But gluons are not strongly constrained in diffractive DIS
  - Jet cross sections are used to constrain gluons

ZEUS dijet cross section and DPDF SJ

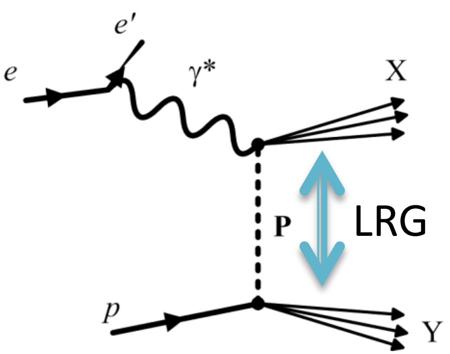


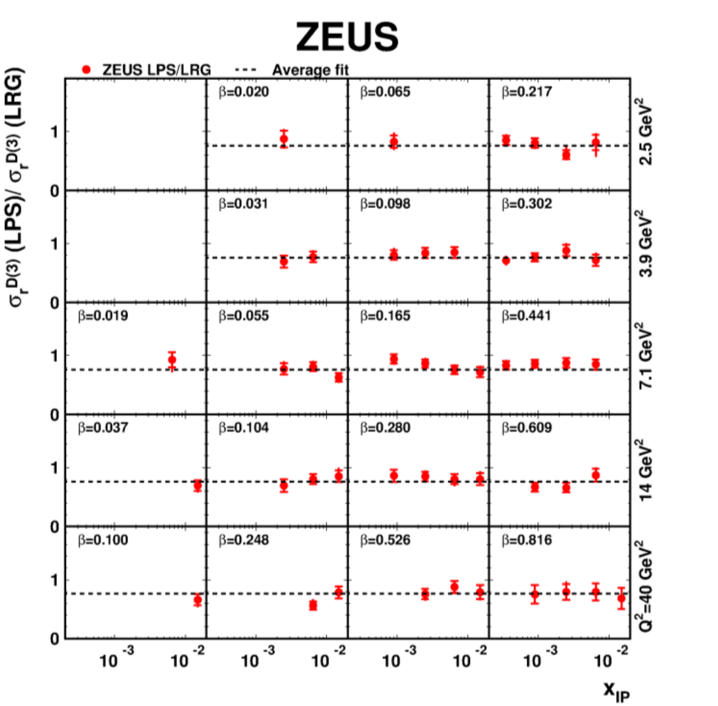
Longitudinal fraction of momentum carreid by the dijet system, wrt Pomeron

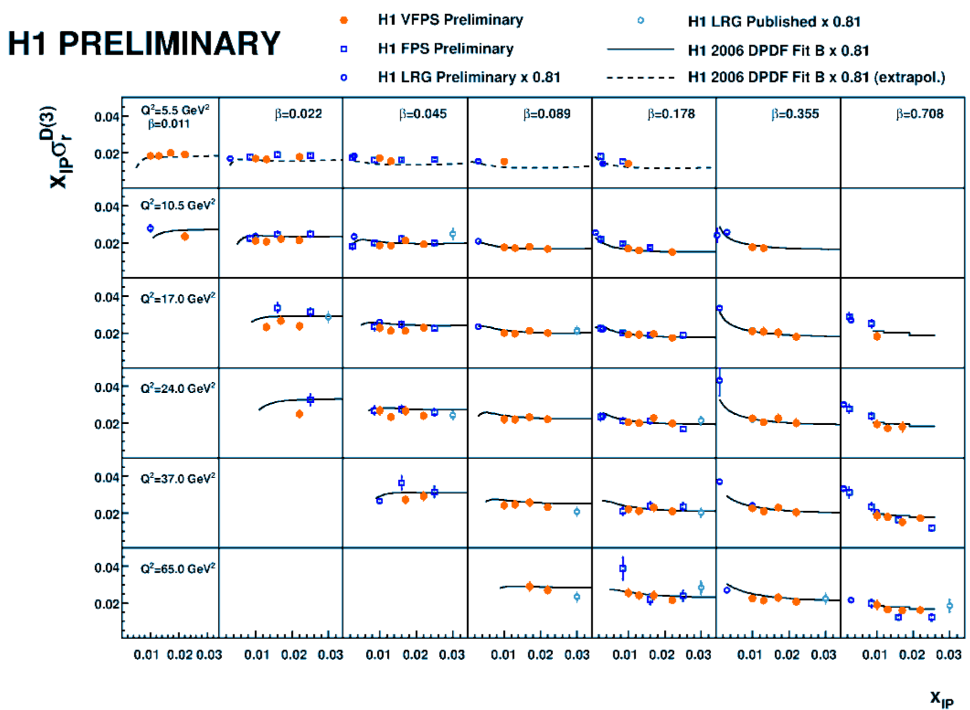


Results from forward proton spectrometer

- Rapidity gap (LRG) method contains proton dissociation
  - Fraction of pdissoc measured by taking ratio $\sigma_{LRG}/\sigma_{tag}$
  - No dependence in kinematical variable observed
- Access to high-x_P region by new H1 VFPS
  - Providing info on sub-leading exhcange

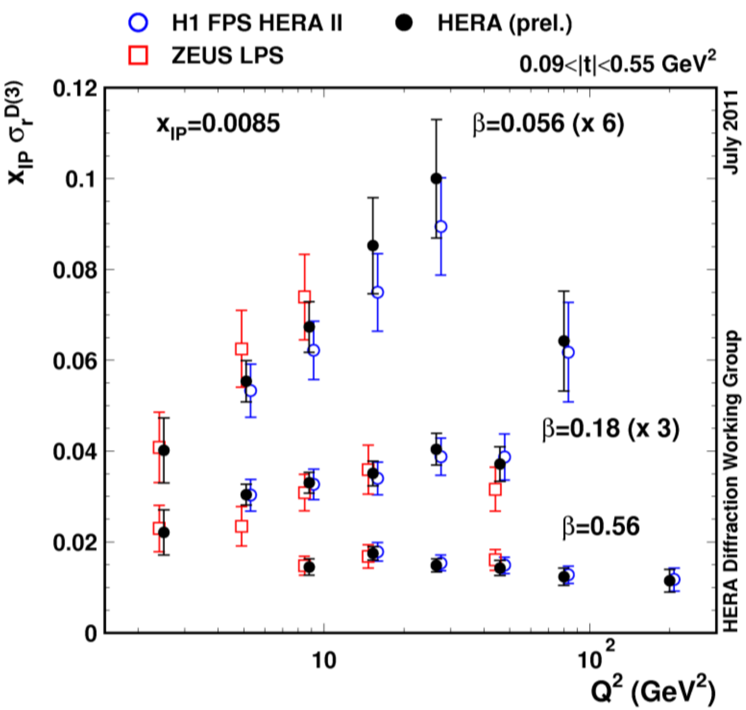


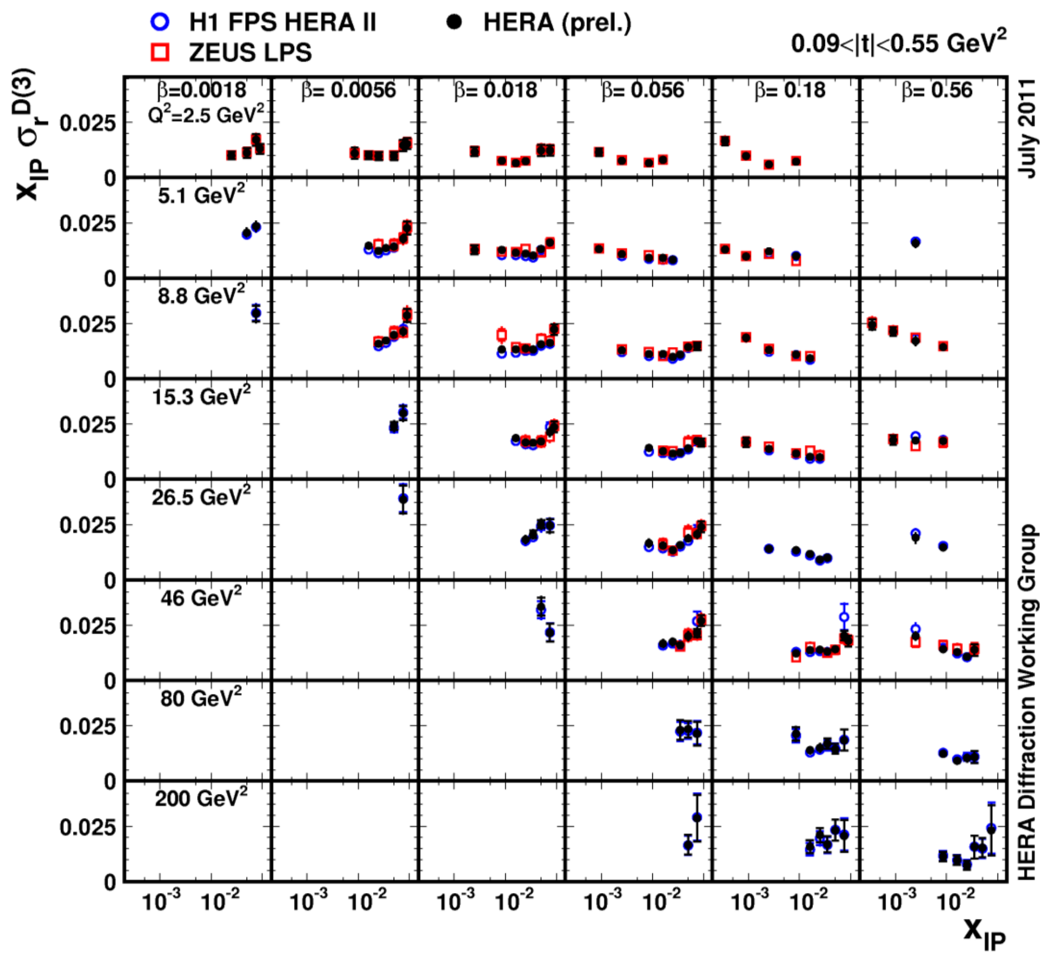




Combination of data H1 and ZEUS

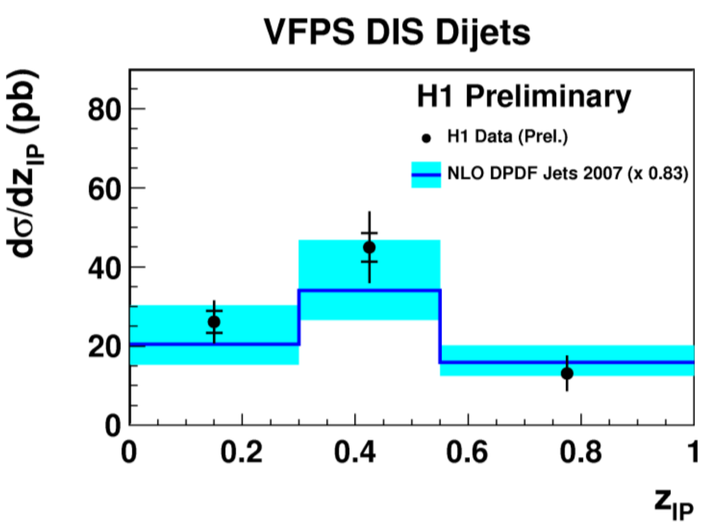
- Forward proton results: statistically limited
- Also cross-calibrating systematics errors



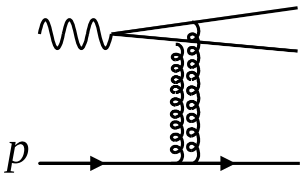


Checking gluon densities: QCD factorisation

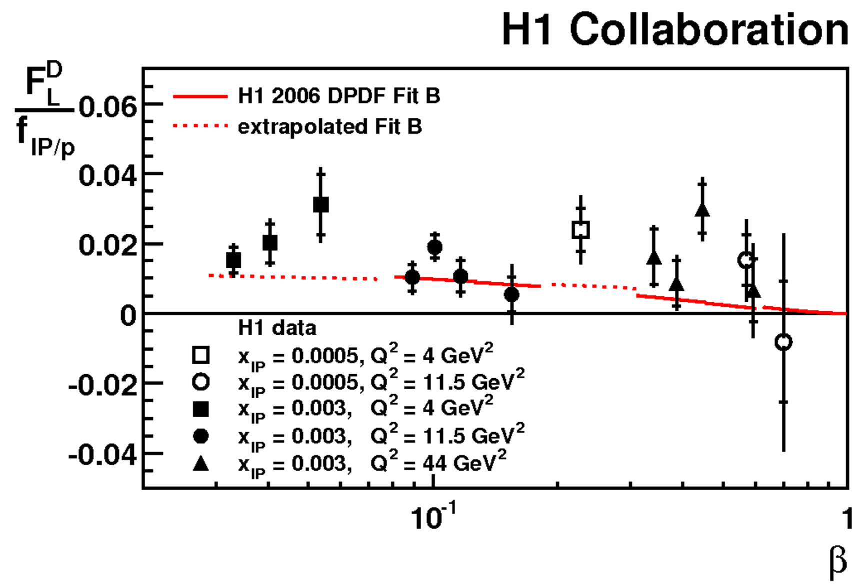
- New: dijets with VFPS
  - Acceptance at high-x_P Checking gluons there
- Good agreement with the prediction using extracted DPDFs



- Longitudinal diffractive SF F_L^D
  - Proportional to gluon density
  - Dipole model predicts presence of both σ_L and σ_T in $\gamma \to q\bar{q}$ component at high β

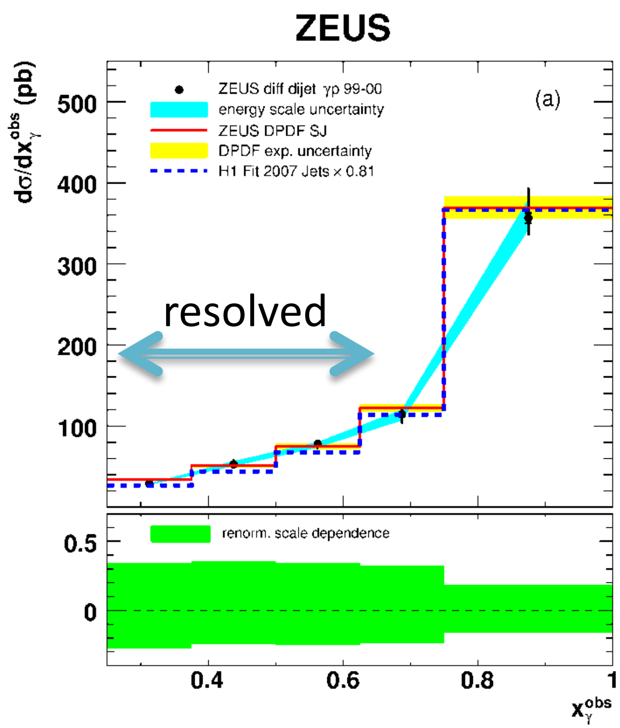


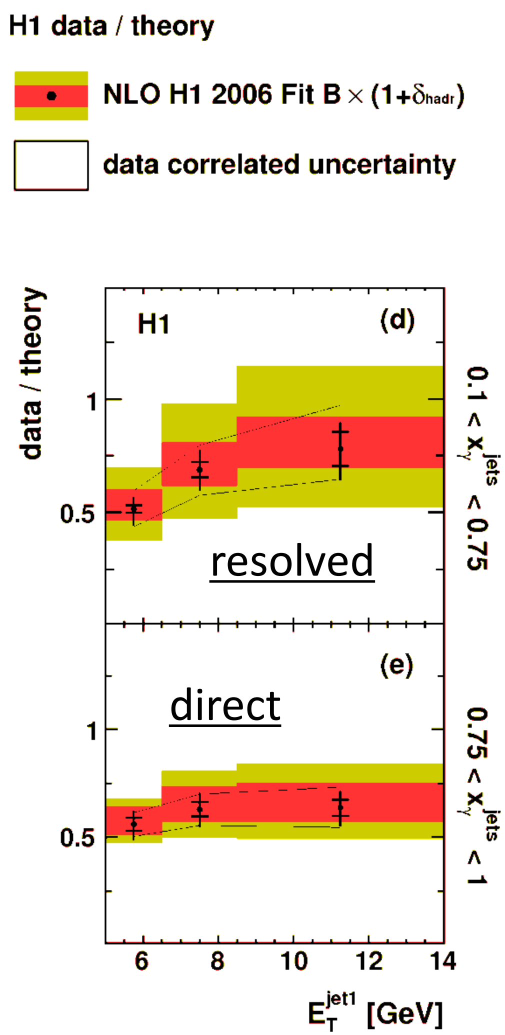
- Result: consistent with prediction using extracted DPDF
  - Tend to be higher, though



Further factorisation test in PHP

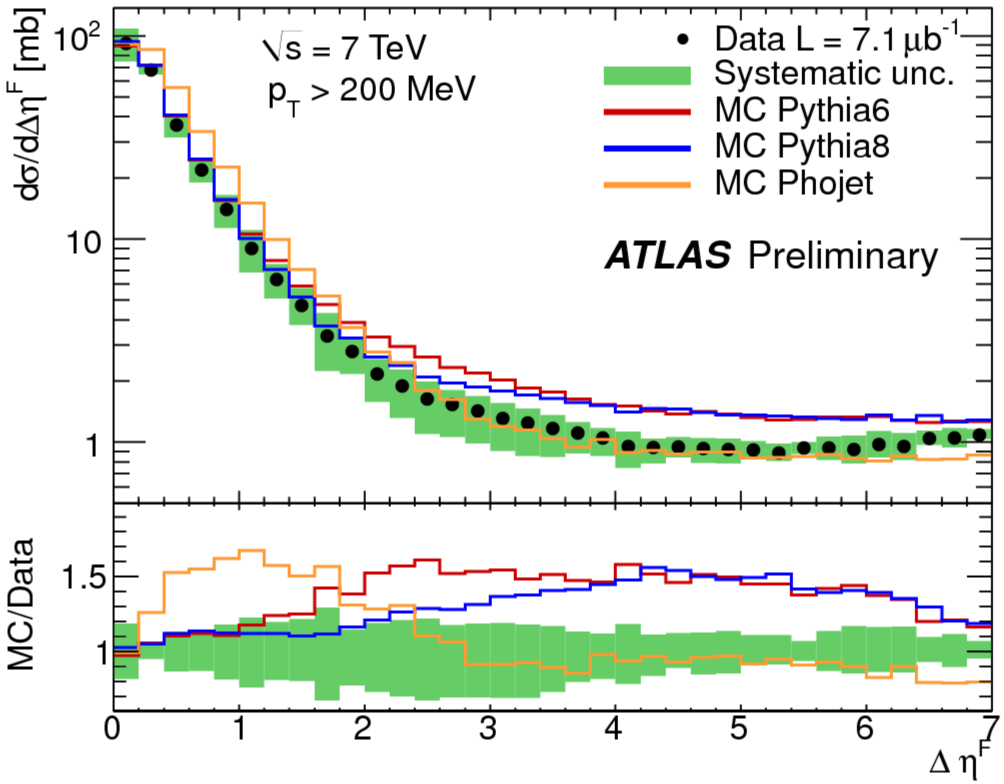
- Famous suppression of hard diffraction at the Tevatron
  - Attributed to multi-parton exchange: does resolved photon (≈ hadron) show suppression?
- No firm conclusion at HERA drawn
  - H1 sees it but both in direct and resolved
  - ZEUS not





Factorisation breaking at the LHC?

- First results for soft diffraction
  - Models adequately describe the magnitude of cross sections
- Eager to wait for the hard diffraction result

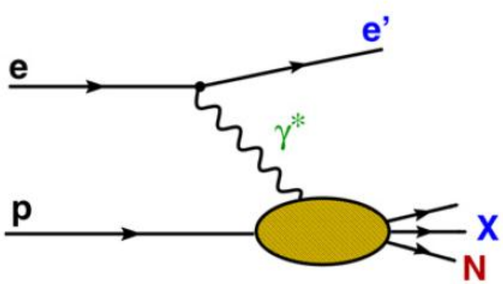


Leading neutron produciton in ep collisions

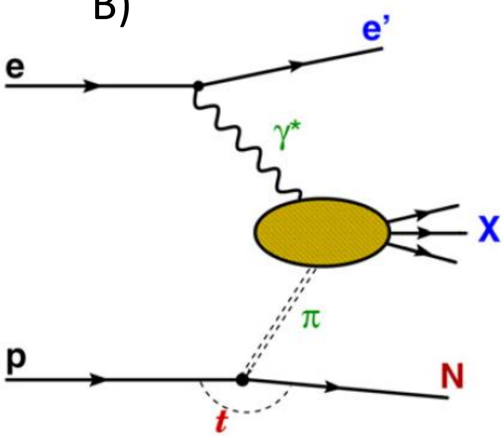
Leading newtron: introduction

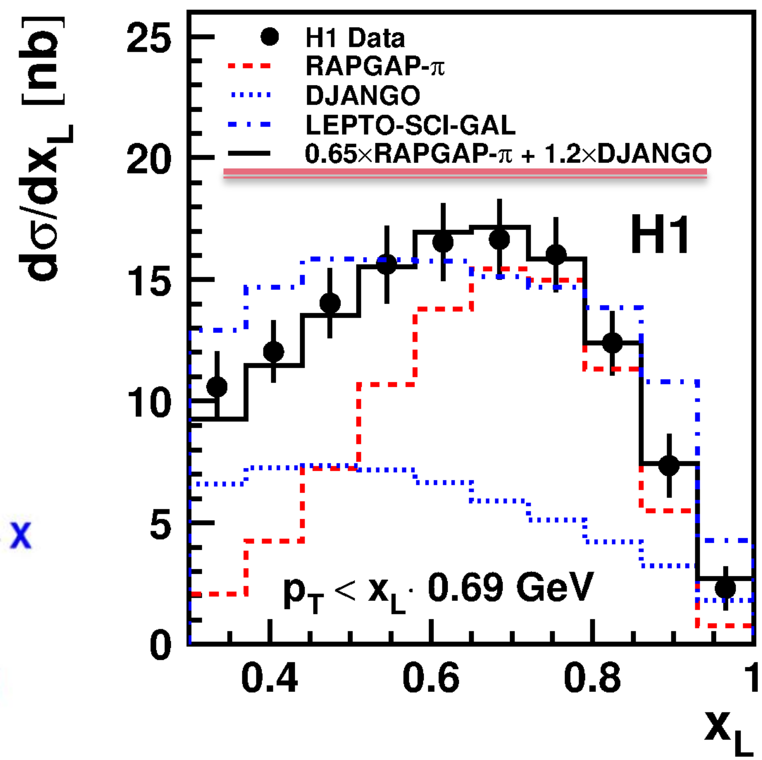
- Large longitudinal momentum fraction (x_L) and small p_T
- Production mechanism
  - A) Generic fragmentation of proton remnant
  - B) One Pion Exchange (OPE) charge exchange $p \to n$
- Data show fragmentation insufficient, need OPE

A)

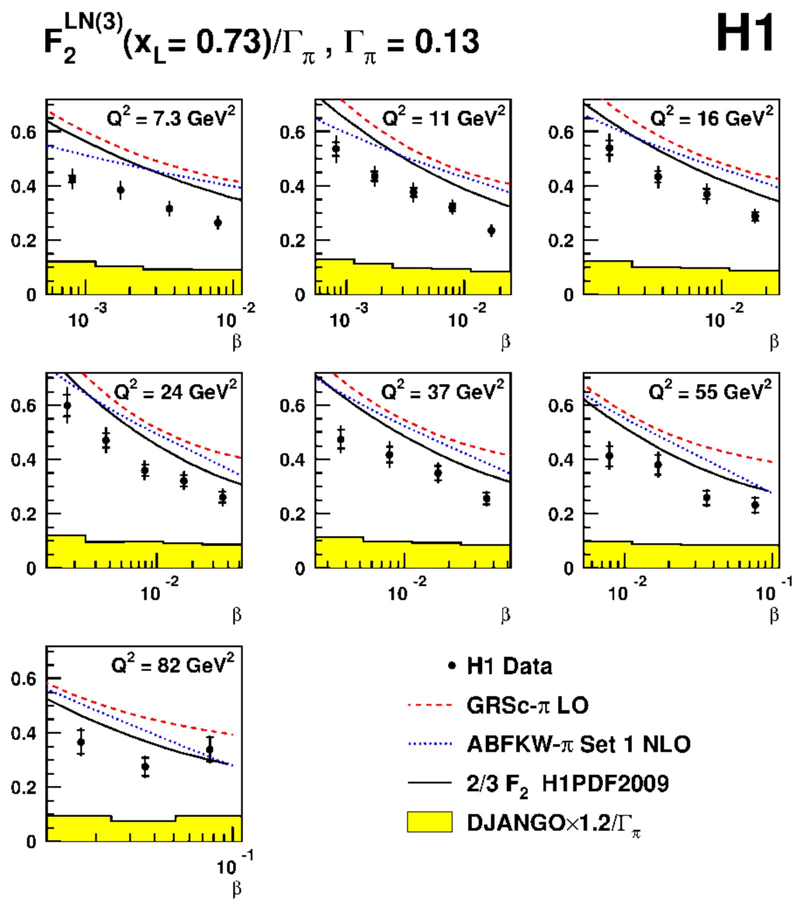


B)

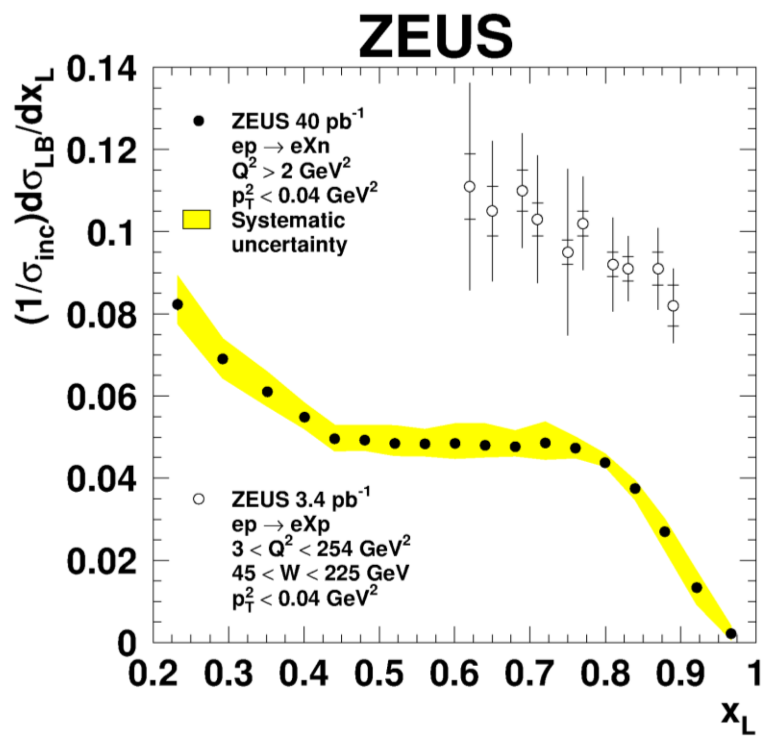




Neutron yield in DIS

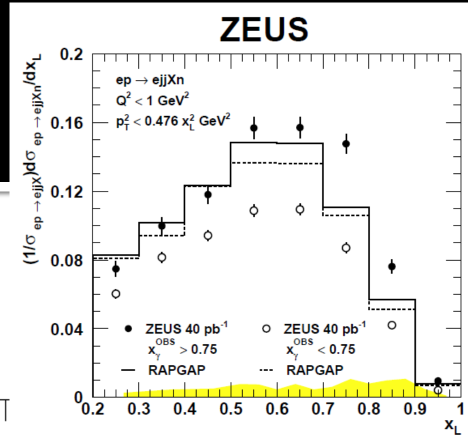


- Neutron yield is 20-30% fewer than naïve prediction of 2/3 expected from isovector exchange

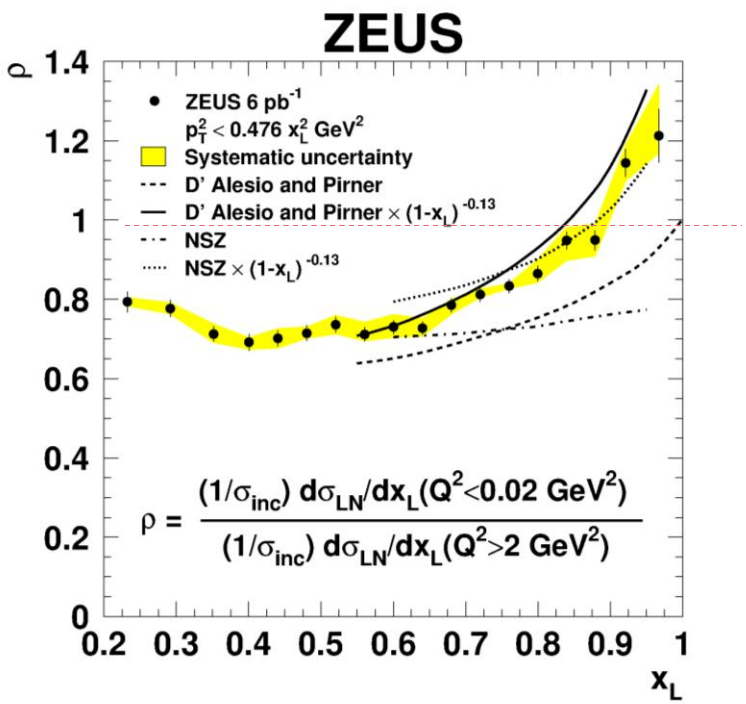


- Protons are produced more than neutron
  - At least in very forward region $p_T < 0.04$ GeV^2

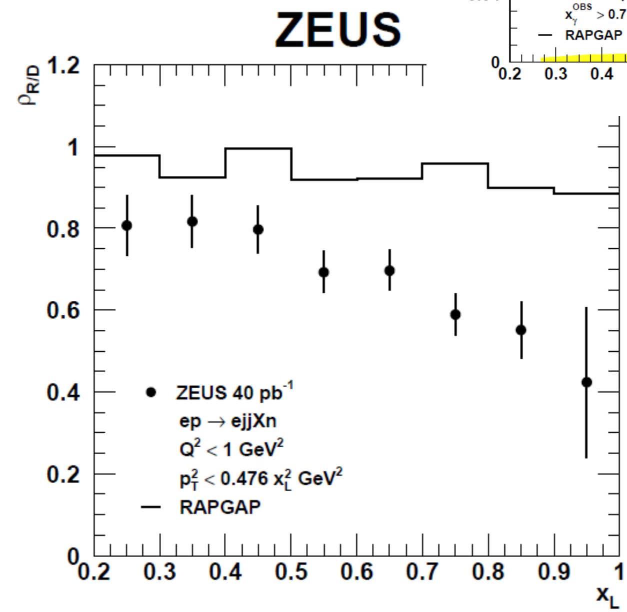
Neutron yield for various processes



Ratio PHP/DIS



Ratio resolved/direct



- Ratio Photoproduction/DIS
- Phoproduction suppressed
  - “large photon” – more rescattering
- Neutron with PHP dijet
- Resolved = “larger photon” is suppressed w.r.t. direct
  - Suppression larger than RAPGAP, which simulates kinematical constraint

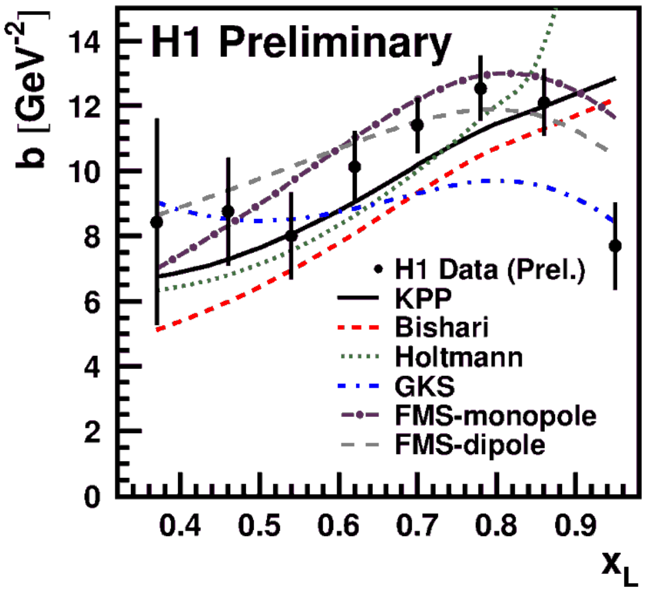
Leading neutron suppressed in photoproduction

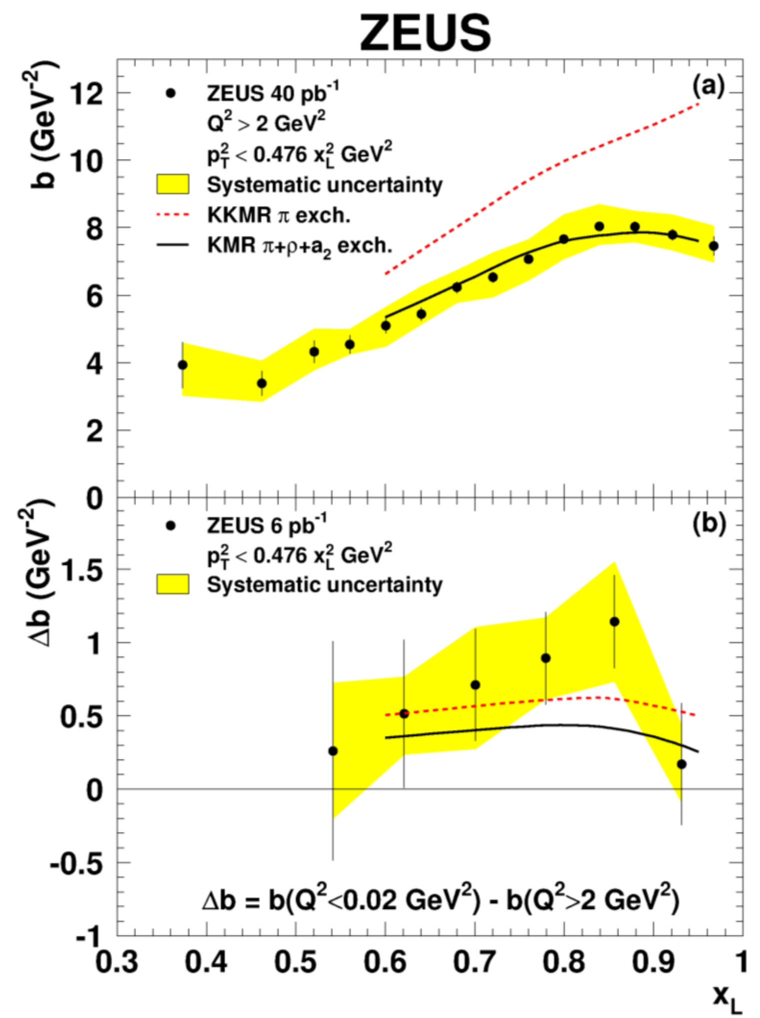
Conclusion

- More diffractive data with leading proton tag
  - Precise data from proton-tagged diffraction
  - Confirming LRG data
- Photoproduction: QCD factorisation or not ?
  - No conclusion at HERA for diffraction
  - Leading neutrons show small suppression in photoproduction w.r.t. DIS
  - LHC result of hard diffraction?

- Smaller yield of neutron than naïve counting
- OPE necessary to describe longitudinal spectrum
  - Interesting to compare with LHCf / ZDC results etc. from the LHC

p_T distribution $\propto e^{-bp_T^2}$





- Discriminating between models
- b-slope(PHP-DIS): PHP is larger
  - Rescattering removes high-p_T neutrons
    More chance to see $\gamma^{(*)}$ twice,
    if p_T is high i.e. central collision