Perspectives on Exclusives / Diffraction from HERA (not yet from LHC)

ATHENA Exclusive Group Meeting

24 May 2021

Paul Newman (University of Birmingham)

- Similarities and differences
- Most important observables?
- Some experimental comments / lessons

Similarities and Differences

HERA was:

- A high energy electron-proton collider with a strong exclusives / tagging programme and polarised electron/positron beams

HERA was not:

- An electron-ion collider
- A polarised target machine
- A high luminosity collider

→ useful to compare, but not necessarily to follow …

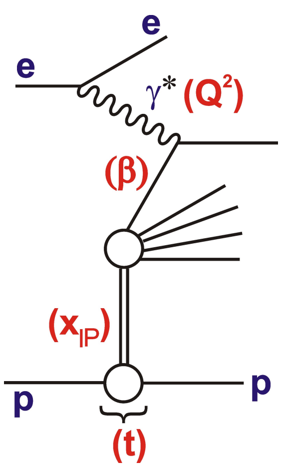
Mostly H1 is covered here:

(ZEUS similar, HERMES is a different talk entirely)

- Fairly hermetic detector
- Gap in acceptance for electrons ($0.01 < Q^2 < 1$ GeV^2)

Overview

ep collisions
at $\sqrt{s}$ ~ 300 GeV
1992-2007
~ 0.5 fb^{-1} per expt.

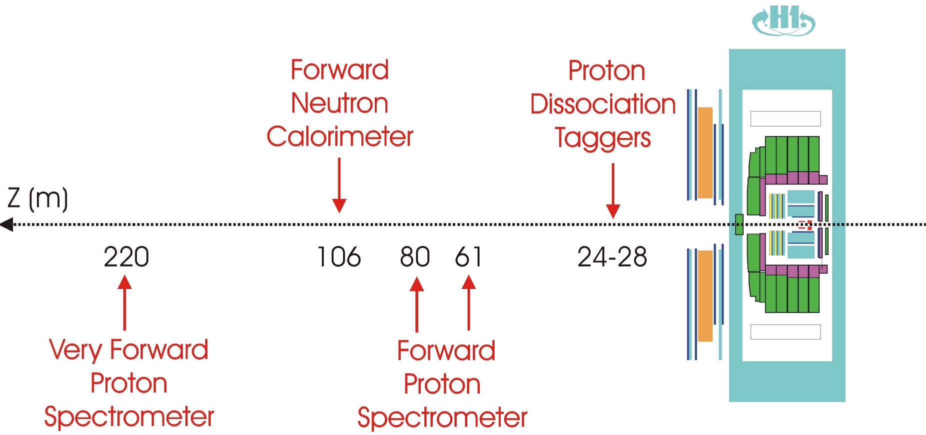


e.g. H1 publications on diffraction (similar numbers in ZEUS):

- Inclusive diffractive DIS cross sections: 15 papers
- Diffractive final states: 18 papers
- Quasi-elastic (VM, DVCS) cross sections: 22 papers
- Total photoproduction cross sections 2 papers

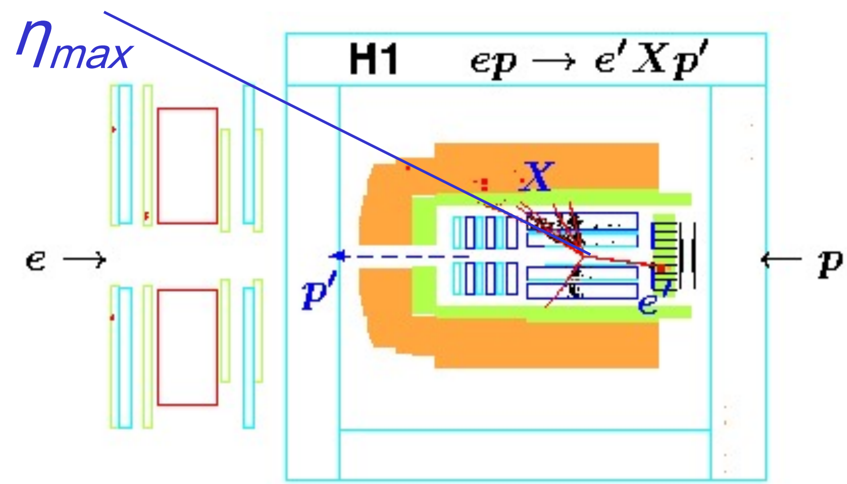
Signatures and Selection Methods

Scattered proton in Leading Proton Spectrometers **(LPS)**



Limited by statistics and p-tagging systematics

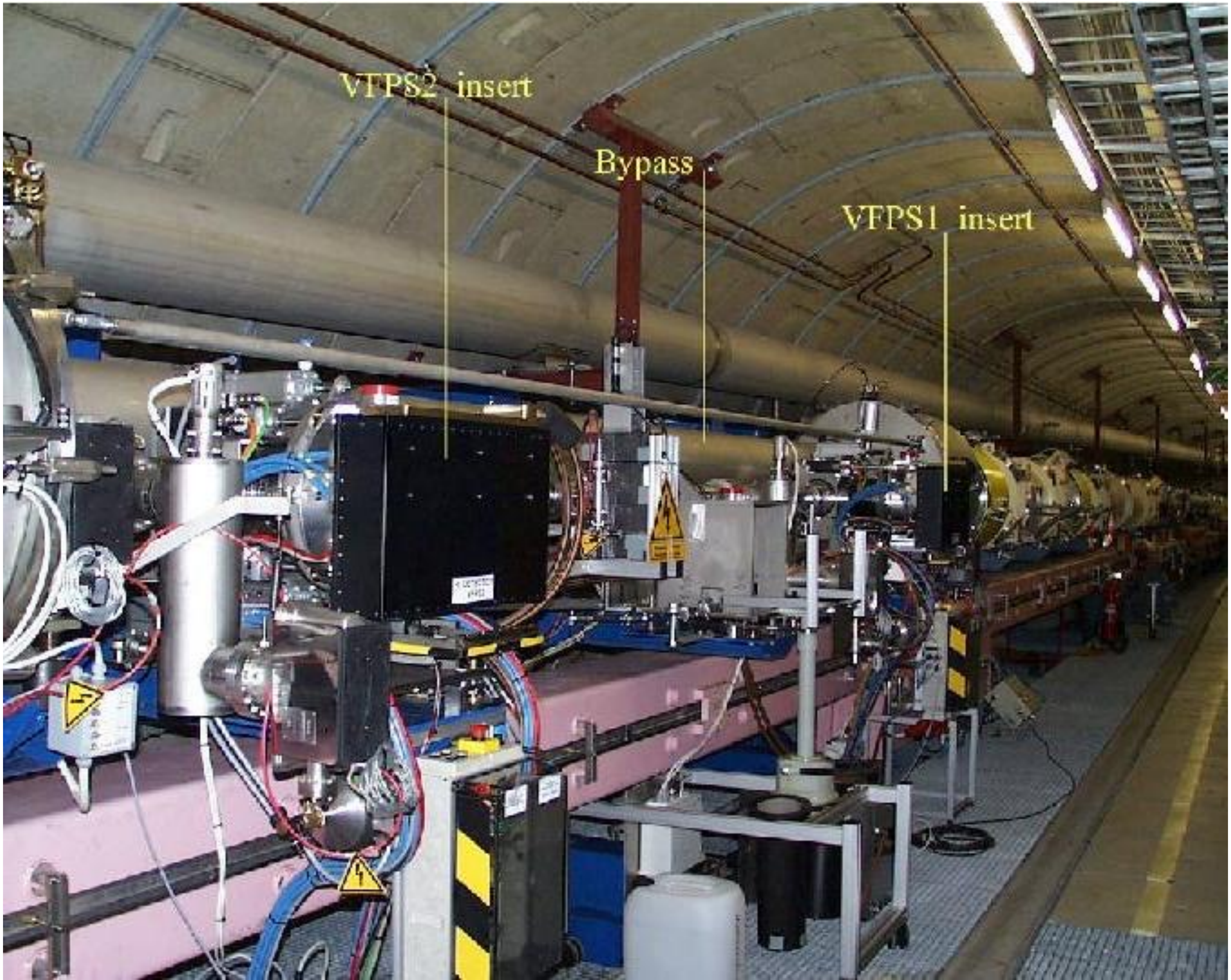
`Large Rapidity Gap' **(LRG)** adjacent to outgoing (untagged) proton



Limited by p-diss systematics

- LRG method was important at HERA because proton tagging came as an afterthought (`retro-fit') and Roman pot techniques were in their infancy.
- Proton tagging will (hopefully) dominate at EIC!
- Correlation to central detector still important at EIC for alignment, calibration, off-setting systematics
- Most measurements also involve hadronic final state in central detector

Pots may not be as simple as they look on paper!

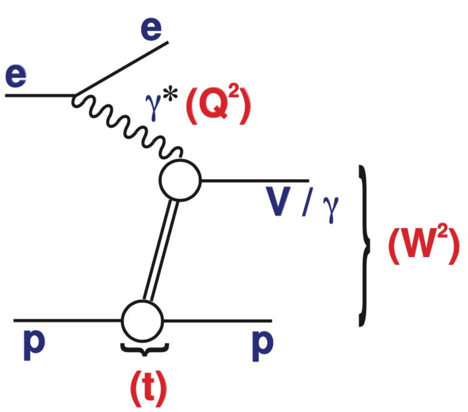


Key Observables 1: Exclusive VMs & DVCS

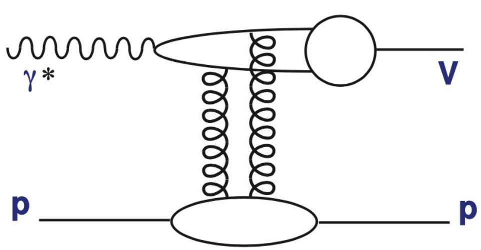
- Discussed in terms of:

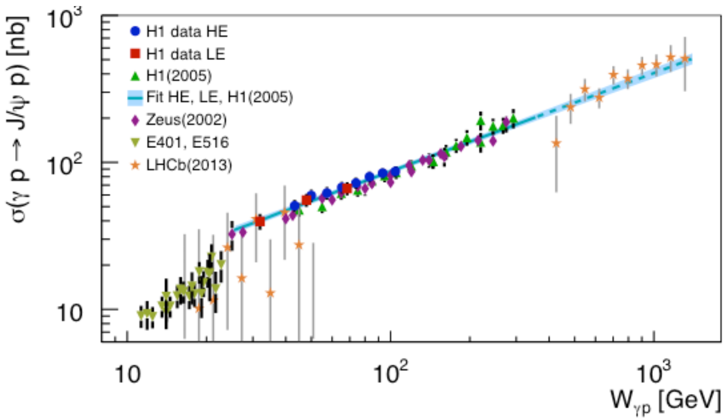
… W, t dependences (and their dependence on Q^2, M scales) → soft-hard transition (language of soft physics / Regge phenomenology)

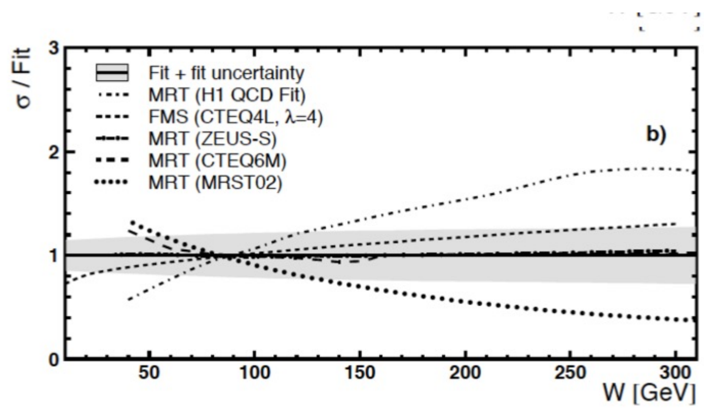
… x,Q^2 dependences (hard physics, dipole models, sensitivity to gluon density, GPDs …)

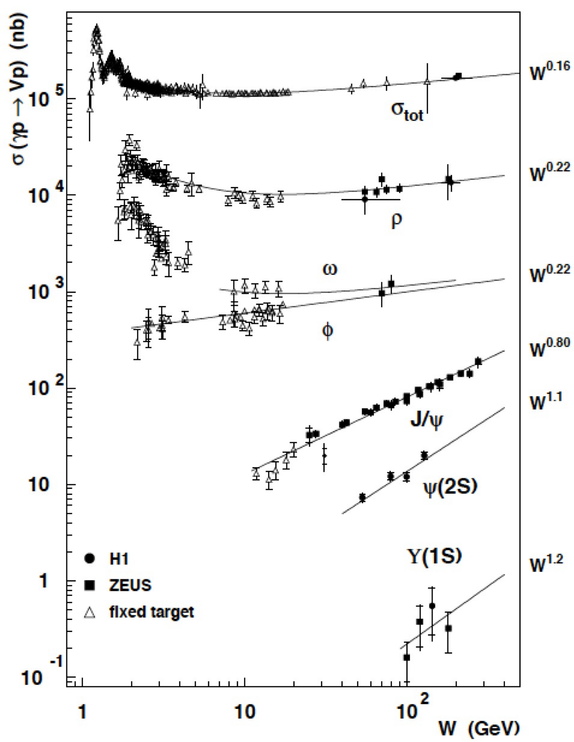


- Expect EIC to take us much further in the second category (high lumi, polarised hadrons)







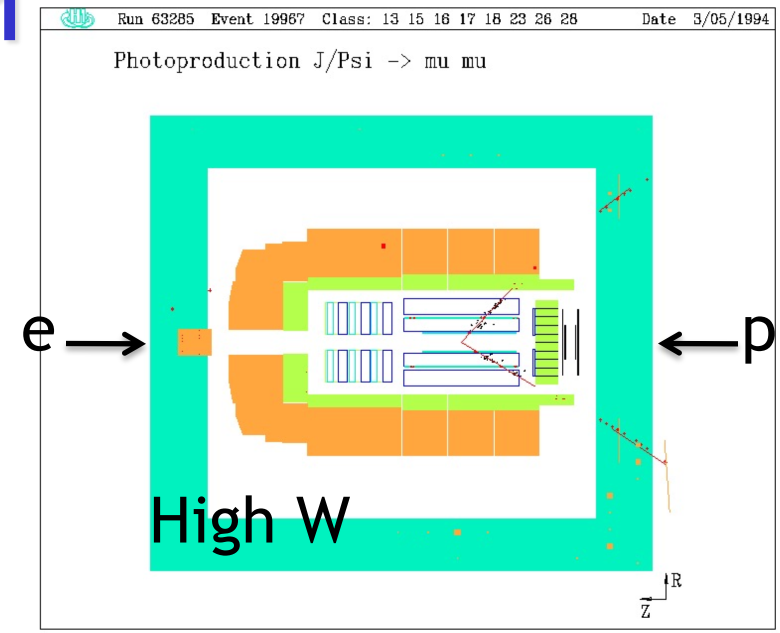


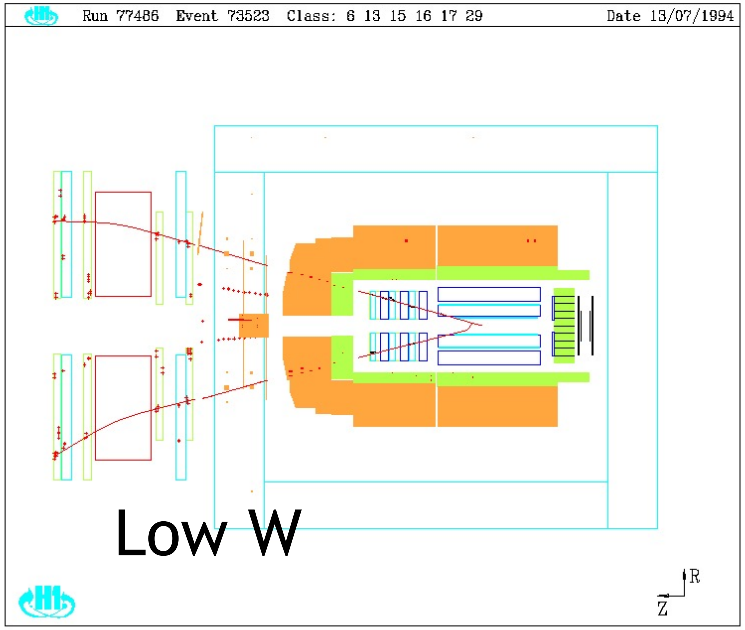
Experimental Comments 1

- 2-prong decays with large cross sections (ρ, J/Ψ) are by far the most productive

- t and W precisely measured from VM decay products (Roman pots were less precise, but would have helped to separate proton-dissociation background)

- Maximising kinematic coverage requires maximum η range for central tracking



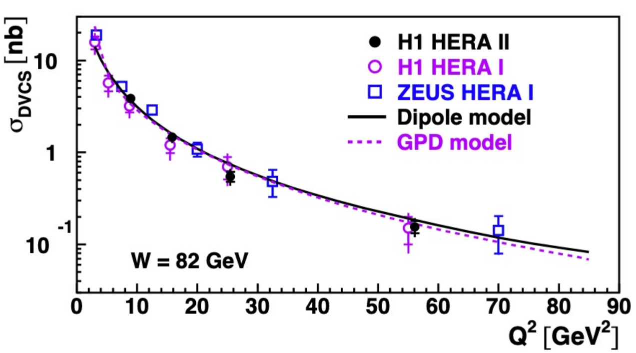


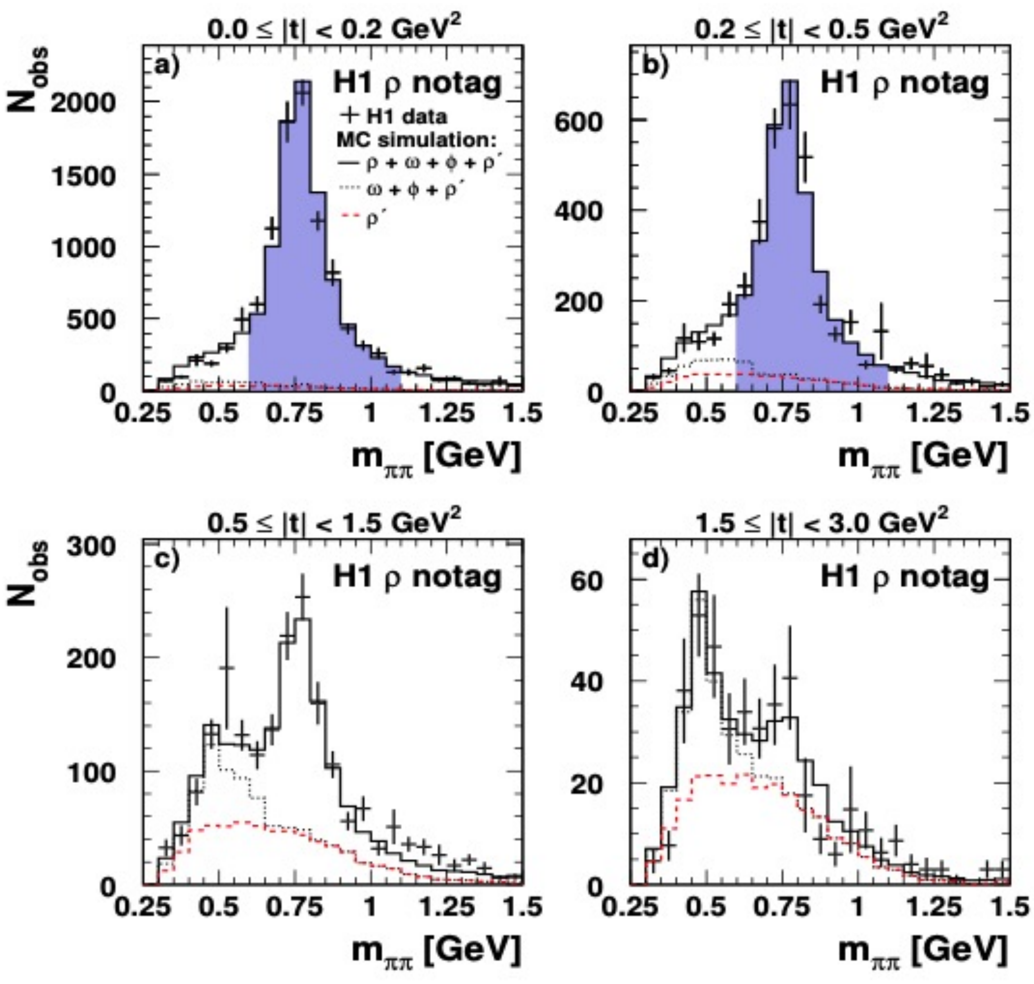
Experimental Comments 2

(example from ρ electroproduction)

- Background from other diffractive processes was sometimes large
→ little PID,
→ unreconstructed particles)

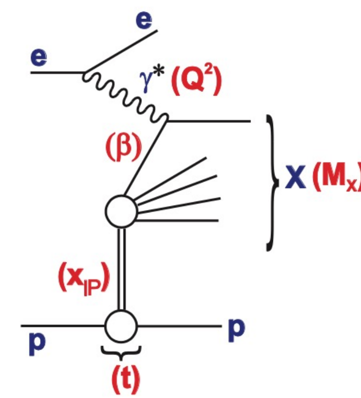
- DVCS came only late due to smaller cross sections.
… will certainly feature much more strongly at EIC



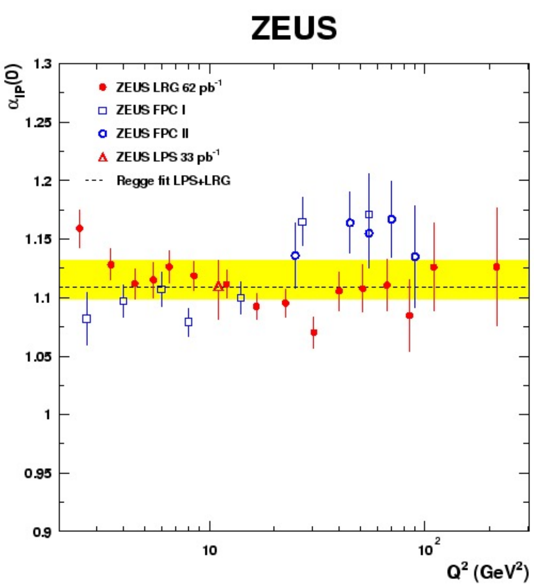


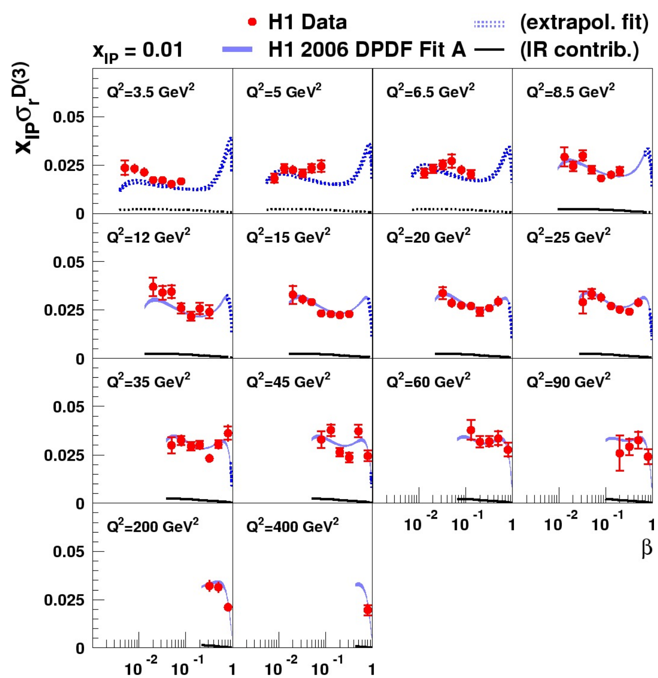
Inclusive Diffractive DIS

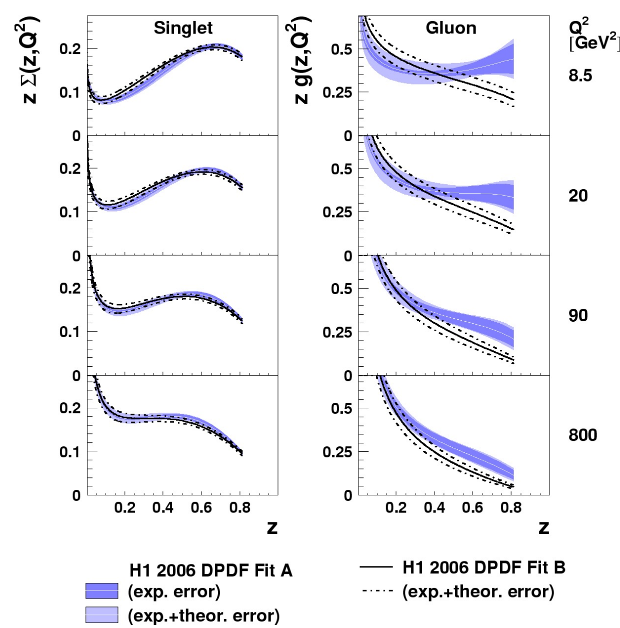
- Leading twist diffractive process!
- 10% of total DIS cross section → influenced inclusive measurements and interpretation



- Discussed in terms of:
  - Mx, W and t dependences (soft physics, interpretation of exchange)
  - β, Q^2 dependences (diffractive parton densities)
  - Is there an exclusive contribution beyond VMs (eg exclusive dijets)?

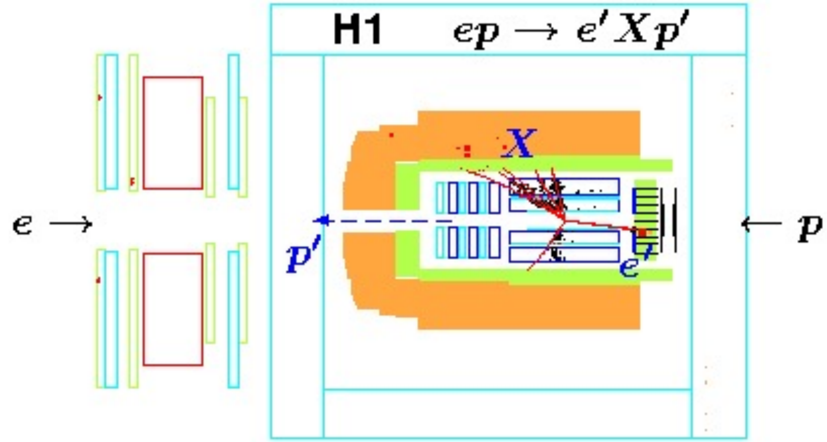






Experimental Comments

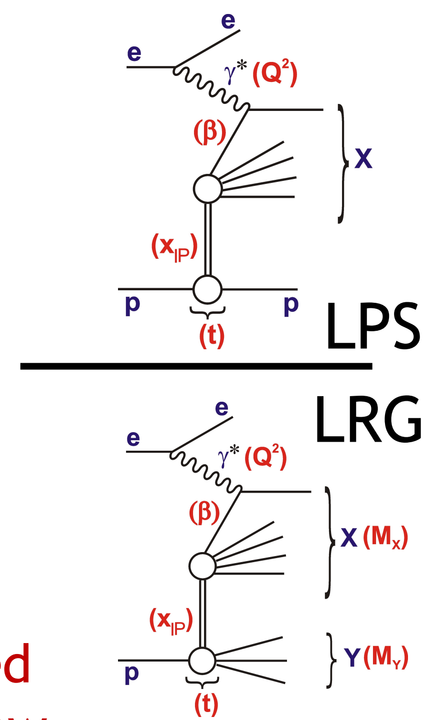
- Proton dissociation in LRG method was biggest complication … may still be important to establish techniques at EIC… eg to calibrate Roman pot ξ (x_{IP}) measurement

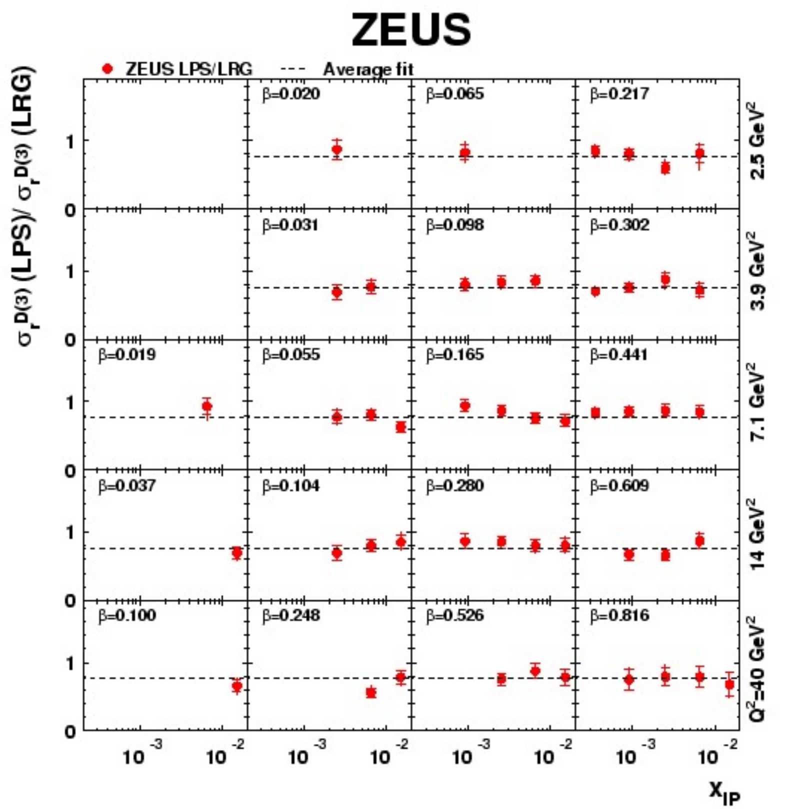


- Reconstruction of hadronic final state X (low mass, based on soft particles in central detector) important for hadronic final state studies and maybe also for basic kinematic reconstruction …

$$\beta = \frac{Q^2}{Q^2 + M_X^2} \quad ; \quad x_{IP} = \frac{x}{\beta} .$$

… high performance mixed calo / tracker particle flow algorithms were important



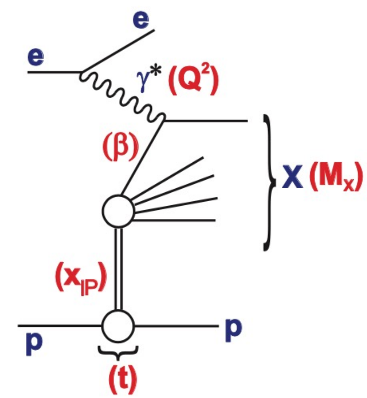


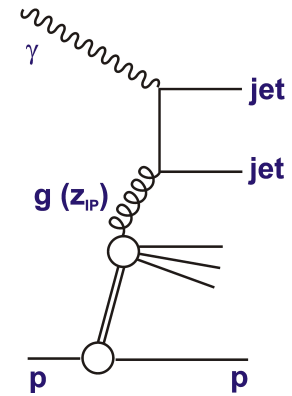
Diffractive Final States

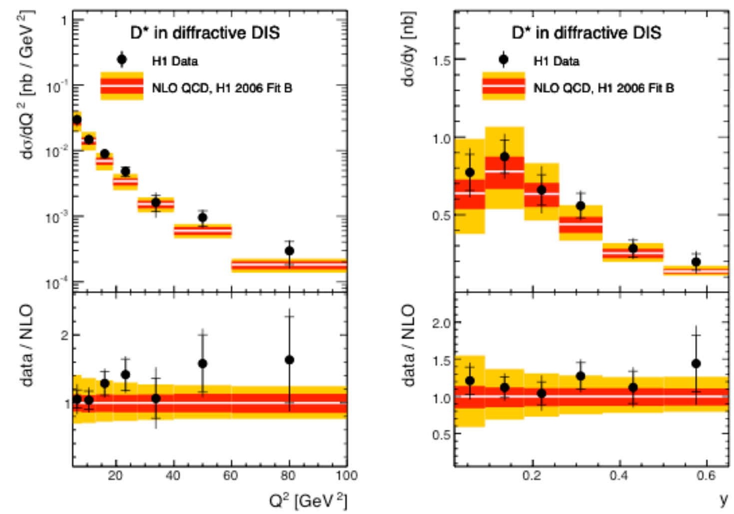
Testing diffractive parton densities and factorisation properties and understanding basic structure of process

→ Diffactive jets (not enough energy at EIC)
→ Diffractive charm
→ Energy flow and charged particle spectra
→ 2 particle (and higher) correlations

Factorisation is complicated and remains far from understood! (works at high Q^2, but not in photoproduction, nor in pp – 'gap survival probabilities'







Experimental Comment

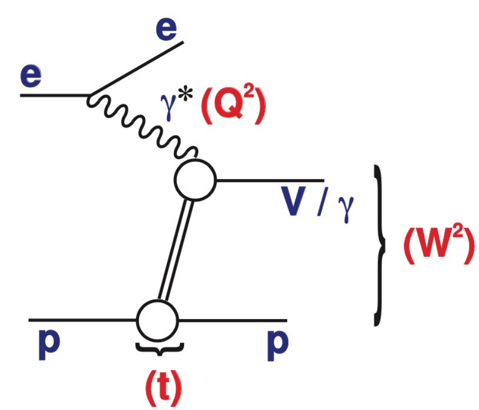
Through final state measurements, diffractive physics is connected to (a subset of) most other aspects of EIC physics

Summary / Things I didn't cover

- We can learn from HERA, but EIC is also different in physics focus (and physics moved on 15 years) so we certainly should not be bound to its ideas!

- Importance of incorporating proton tagging with maximum possible acceptance in detector design from outset ✓

- Alignment and calibration of Roman pots needs to be built into thinking from outset (eg ρ production, Comparing proton to π+π- system) … essential to have overlap in kinematic coverage



- x, Q^2 reconstruction can be 'inherited' from inclusive group, but is not always the same (known and well measured hadronic final state → methods involving E_h, θ_h (eg double angle) can have enhanced performance compared with non-diffractive processes

- Leading neutrons → eg pion structure from charge exchange

- Diffraction in eA …