Diffraction in ep - LHeC prospects

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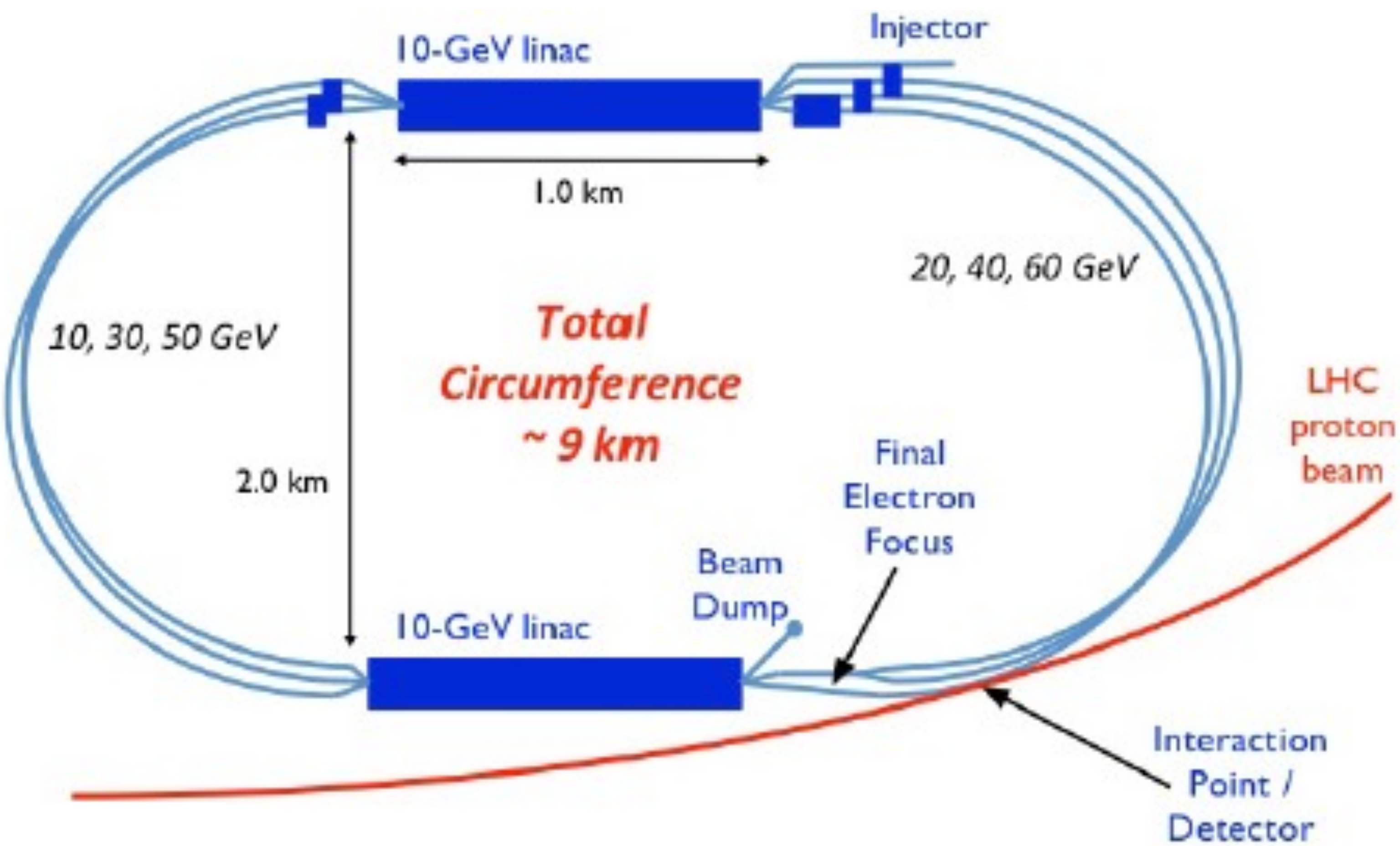
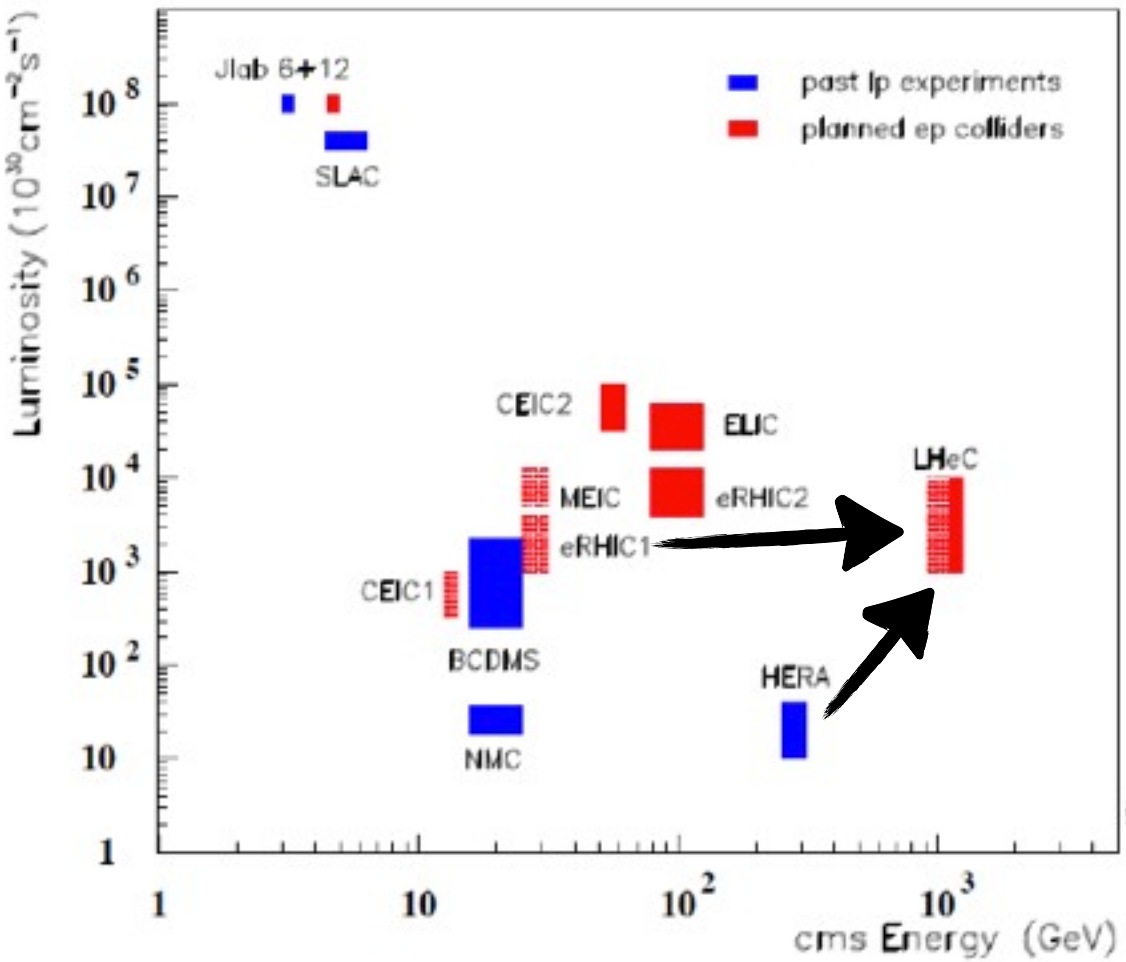
LHeC @ HL-LHC

~2025-2035
CERN, Geneva
simultaneously with ATLAS & CMS





Ep = 14 TeV x Ee = 60 GeV

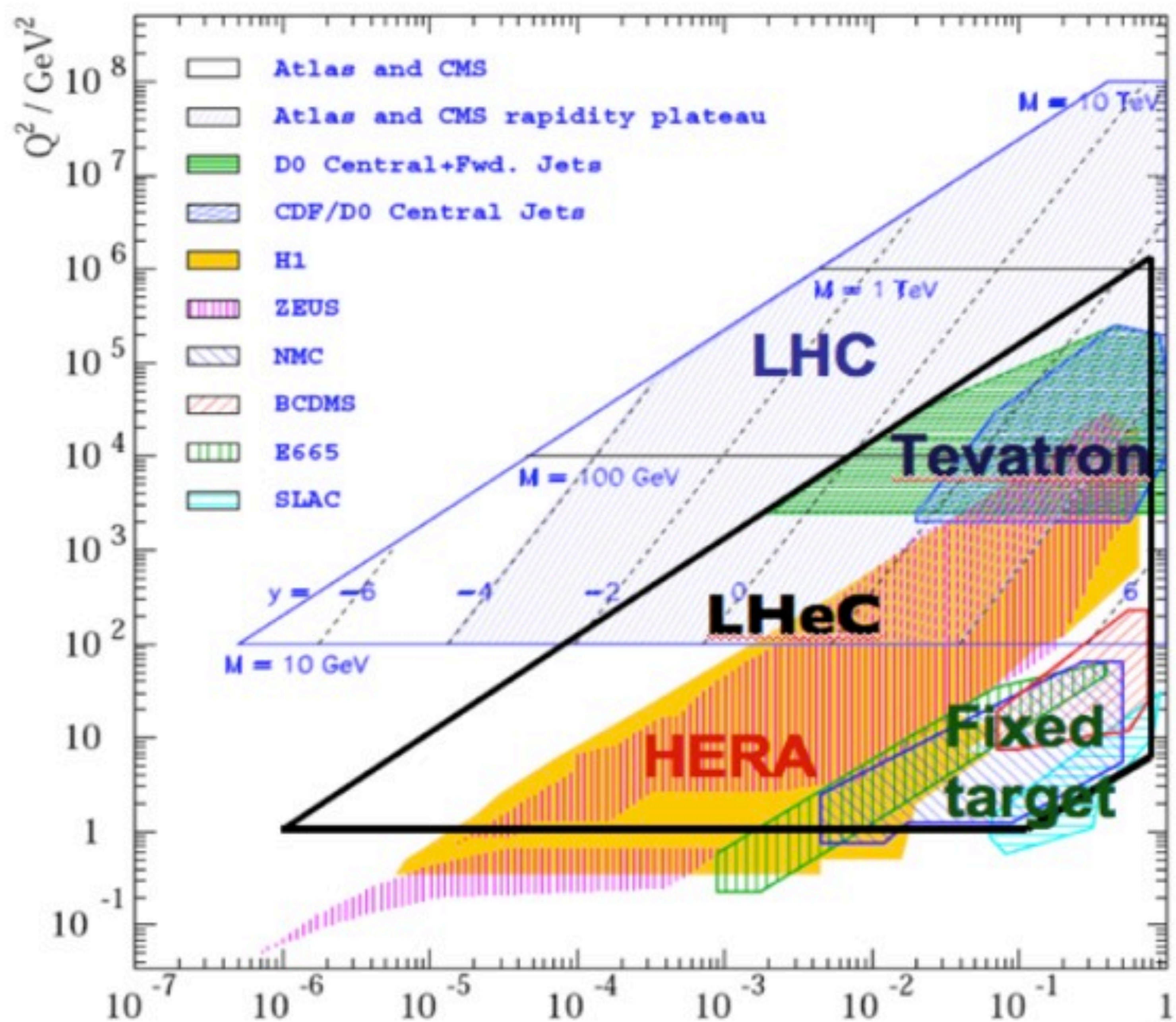
√s ~1.8 TeV

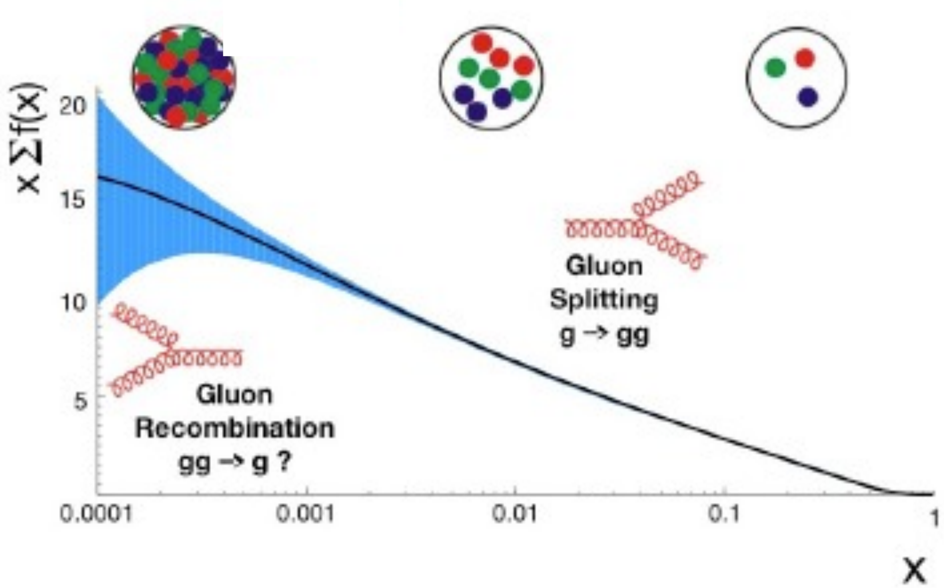
Lint = 100 - 1000 fb^{-1}

eD and eA collisions foreseen as well

Extending the x-Q^2 plane

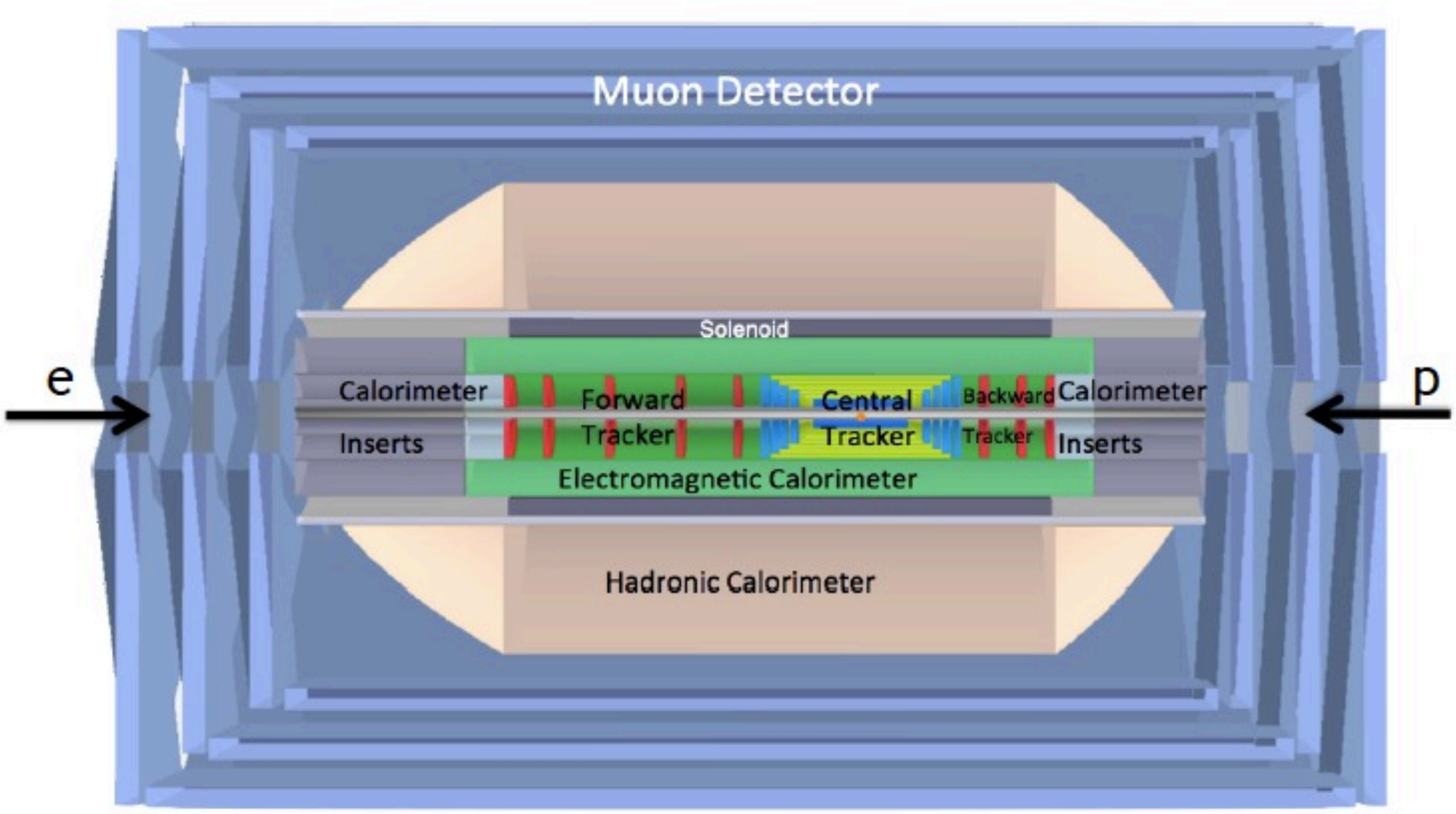
- covering unique phase space
- newly opened low x-Q^2 area allows to study high density matter
  - non-linear evolution dynamics
  - saturation effects
  - study of confinement and hadronic mass generation





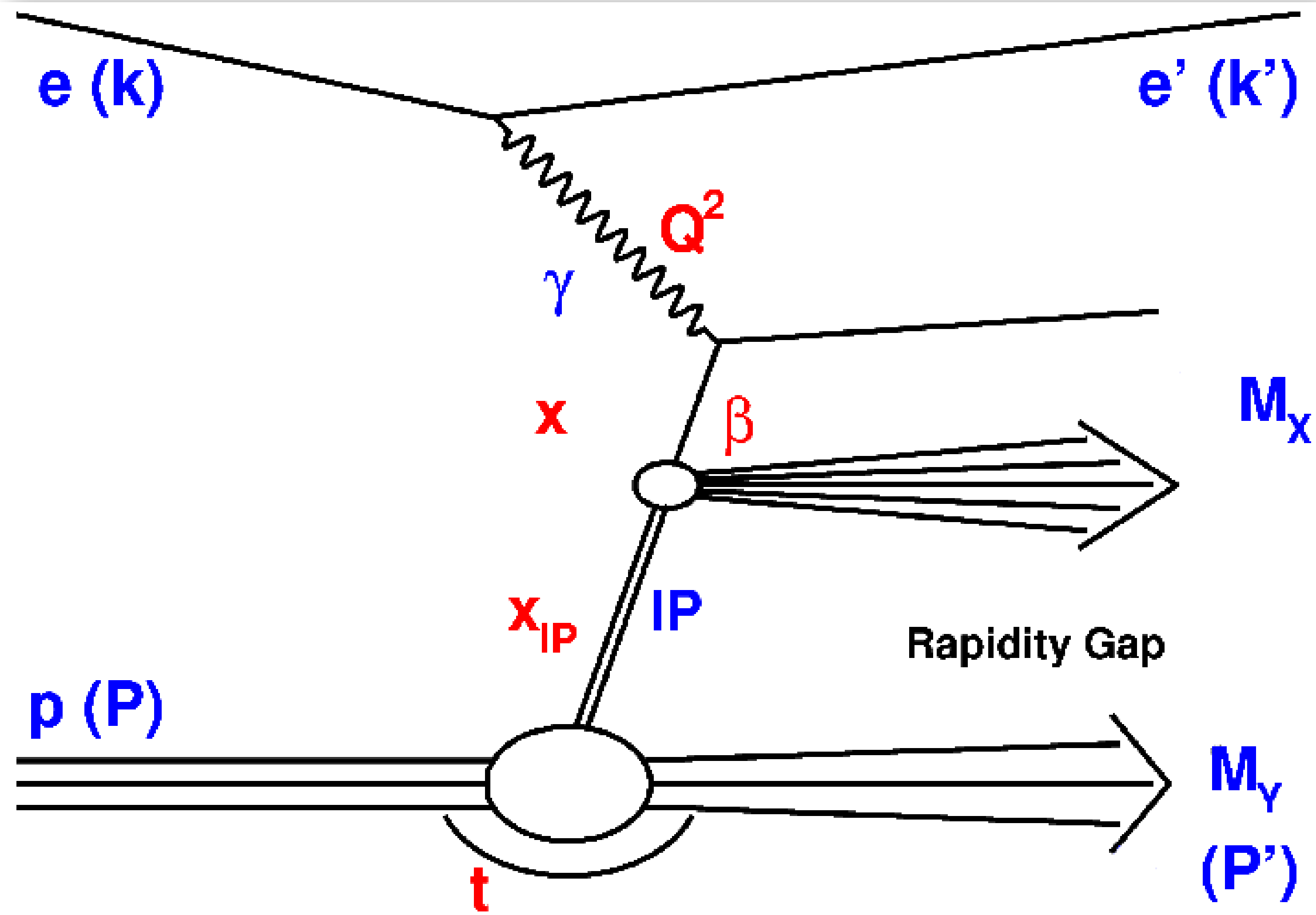
connected with experimental challenges…

the L1 detector concept



- 4π but asymmetric -> "forward" in direction of outgoing proton
- in order to reach Q^2 ~1 GeV^2 @ x ~$5x10^{-7}$, precise scattered electron detection at 179° necessary

Diffraction



- exchange of a **colorless** object between the proton and the boson ($\gamma^{(*)}$,Z,W)
  - rapidity gap effect
- $Q^2 = -q^2 = (k-k')^2$
- $x = Q^2/2Pq$
- x_{IP} ("ξ") $=q(P-P')/qP = 1 - Ep'/Ep$
- $\beta=x/x_{IP}$
- $M_Y = mp$ .. intact proton
- $M_Y > mp$ .. proton dissociation

Collins factorisation, proven:

$$d\sigma^{ep\rightarrow eXp}(\beta,Q^2,x_{IP},t)=\sum_i f_i^D(\beta,Q^2,x_{IP},t)\cdot d\sigma^{ei}(\beta,Q^2)$$

Proton Vertex Factorisation, consistent with data:

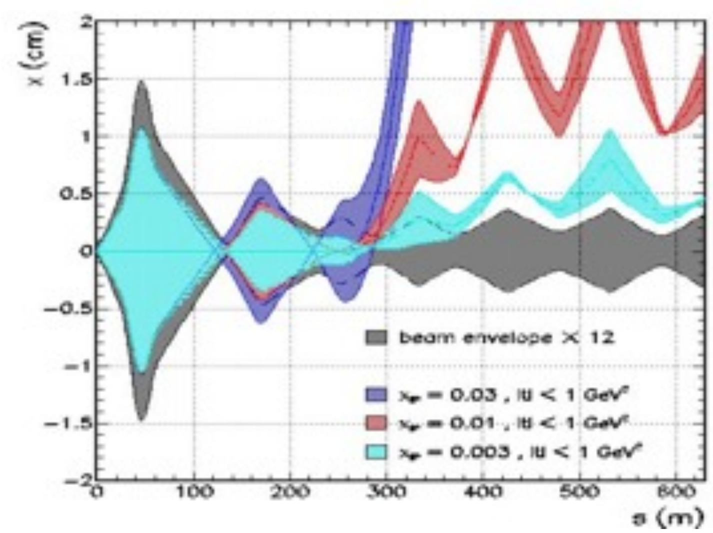
$$f_i^D(\beta,Q^2,x_{IP},t)=f_{IP/p}(x_{IP},t)\cdot f_i(\beta,Q^2)$$

4

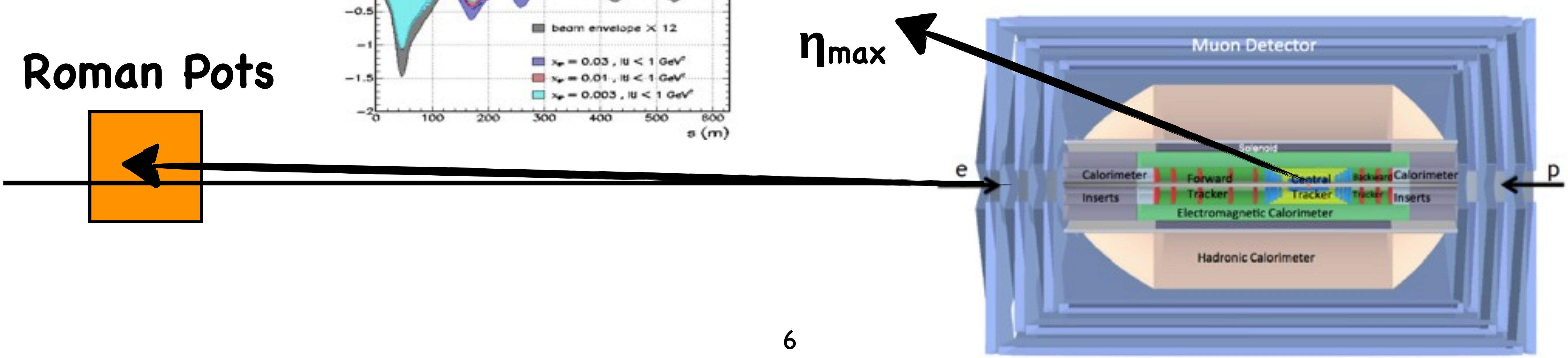
concept of diffractive parton distribution functions (DPDFs)

Experimental methods

- forward proton detection
  - AFP-like project @ ~400m
  - full reconstruction of the proton kinematics
  - scintillator spectrometers approaching the beam to 12σ (250μm)



- leading neutron calorimeter (ZDC) @ ~100m from IP
- Large Rapidity Gap method (LRG)
  - requirement of "empty" calorimeter in the forward region
  - typically large statistics



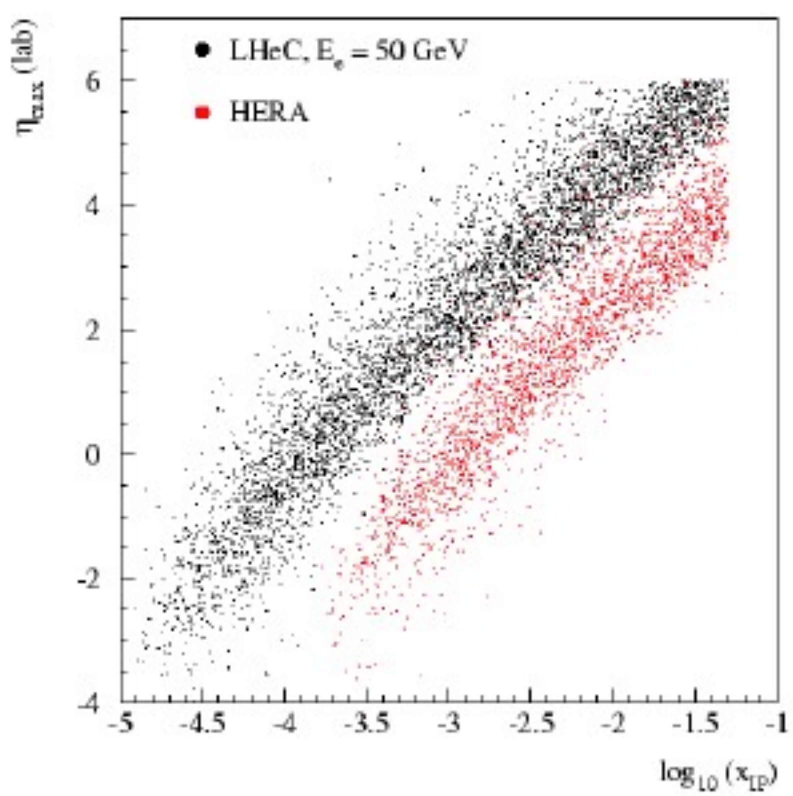
Experimental methods (2)

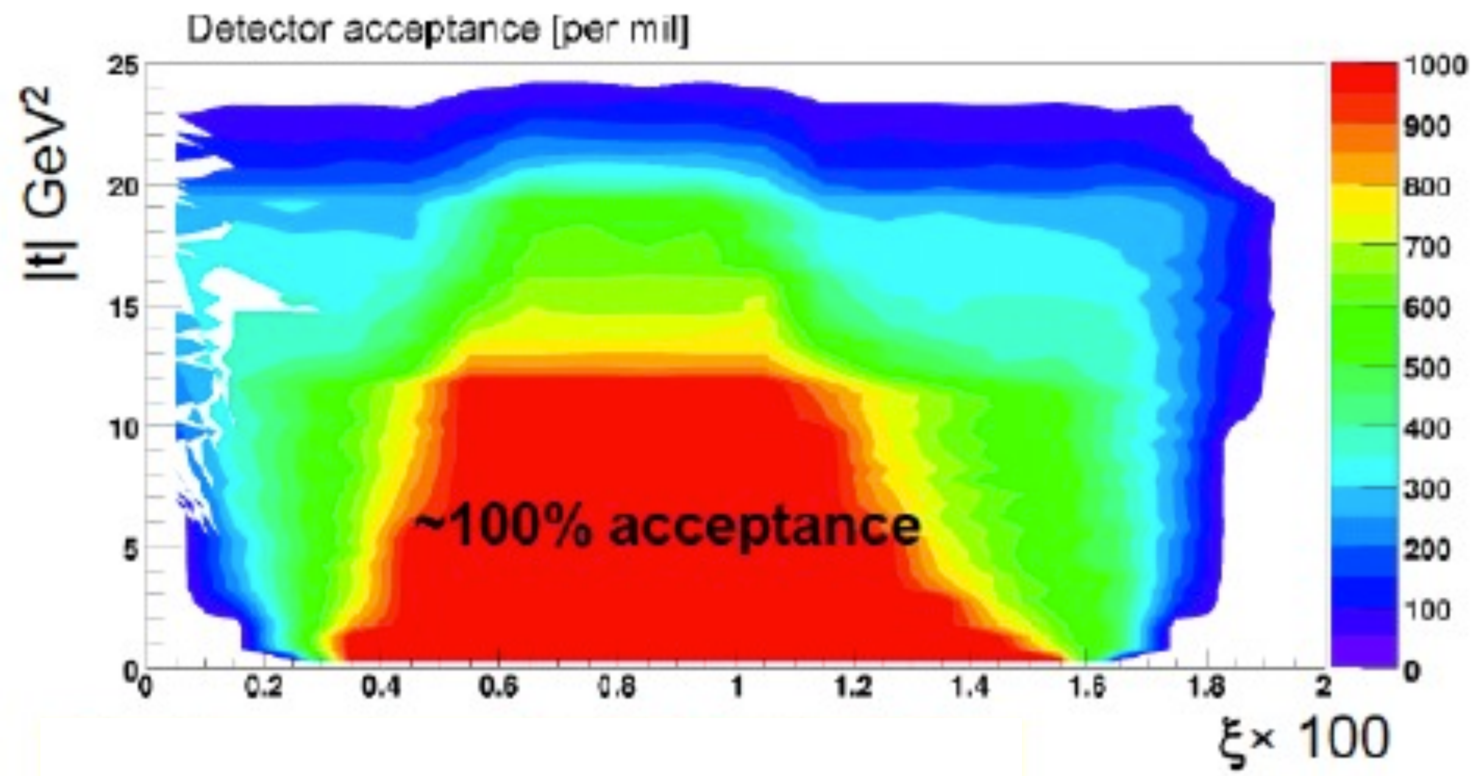
- wider range in η_{max}-x_{IP} coverable by the LRG method

- ~100% acceptance for the roman pots for $0.002 < x_{IP} < 0.013$

- both methods are complementary, overlap regions of phase space are cross calibrating each other -> very important

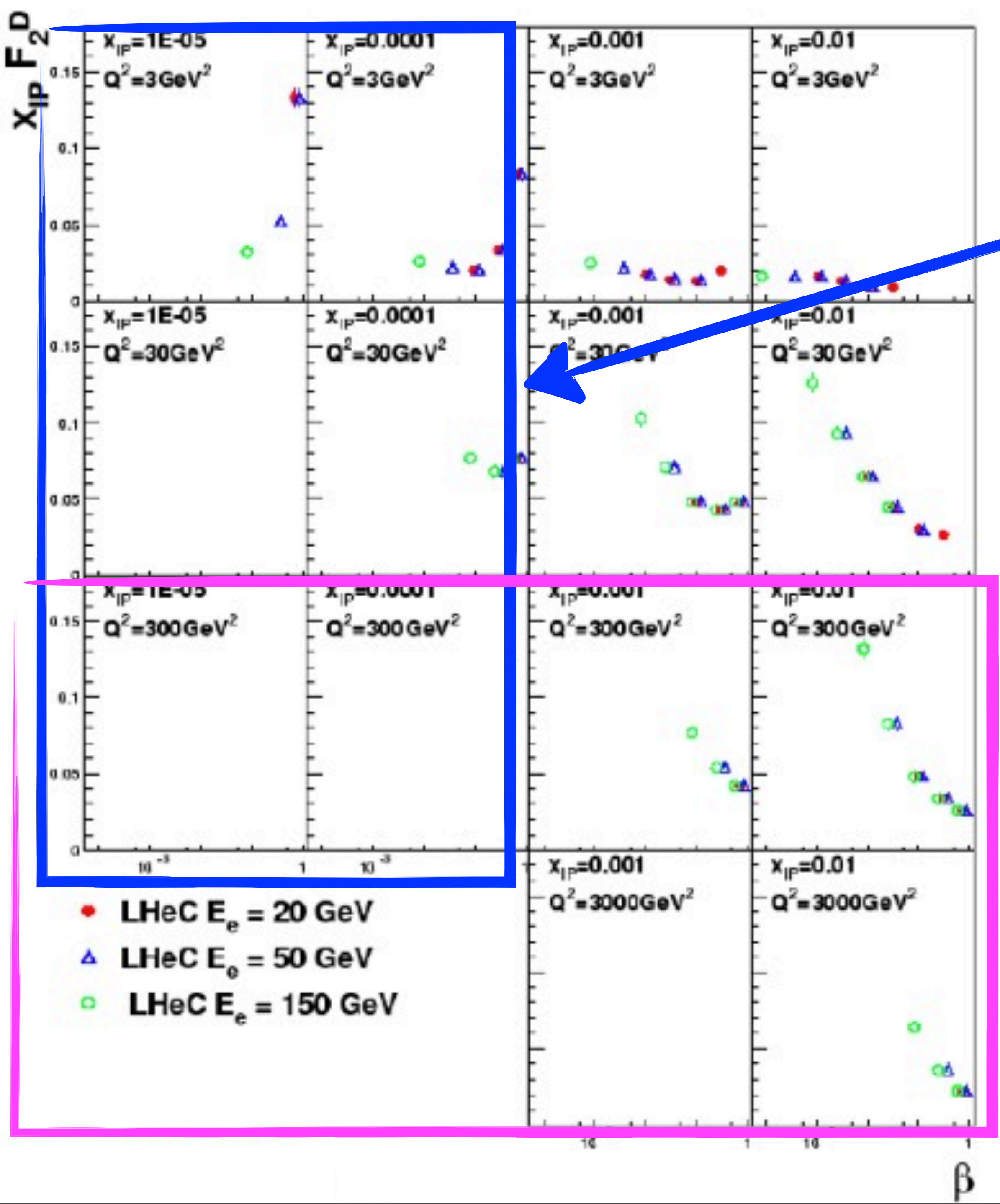
  - worked at HERA in accessible phase space

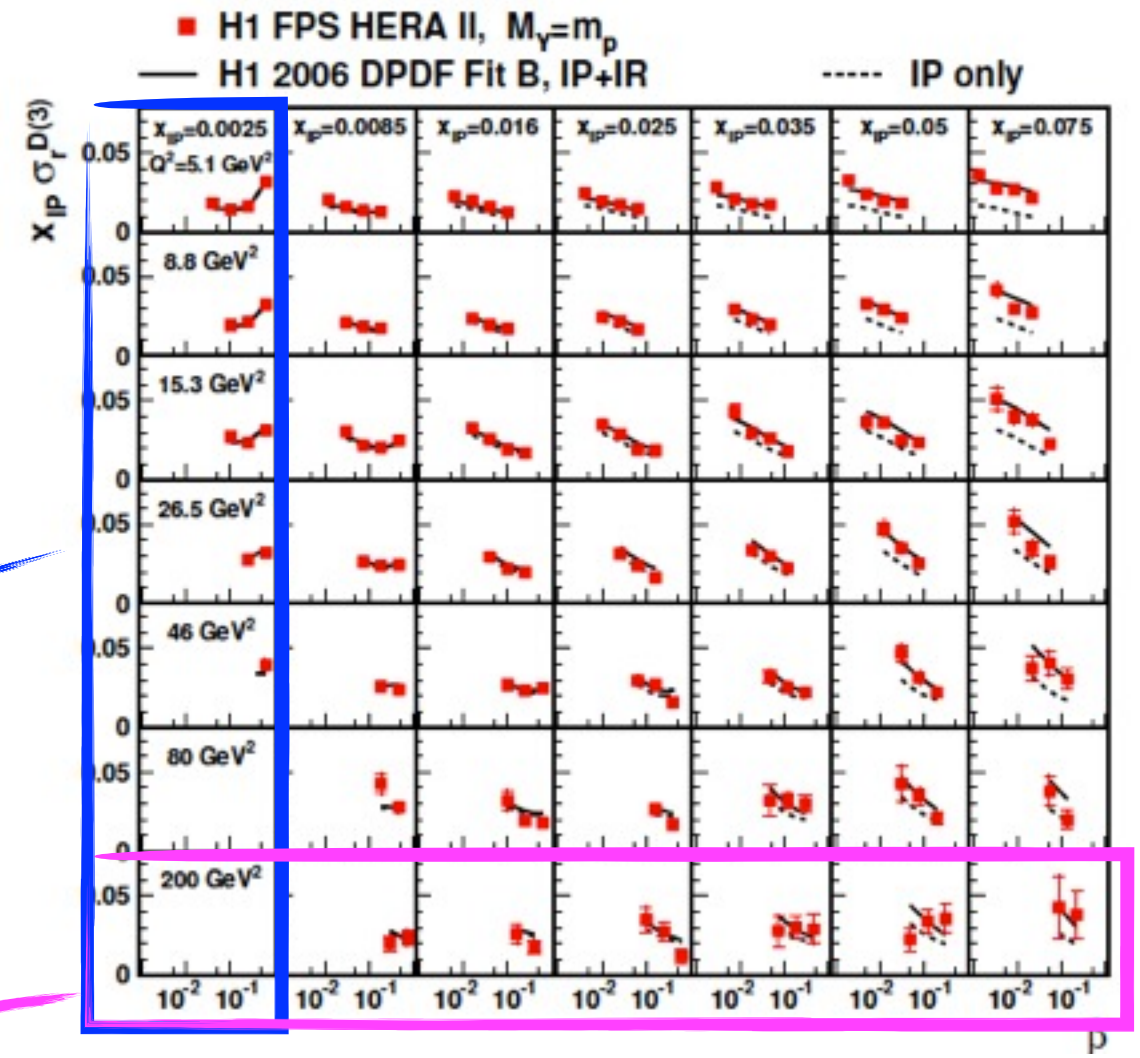




Inclusive diffraction -> DPDFs

- extension of phase space down in x_{IP} and up in Q^2
  - -> important for DPDFs

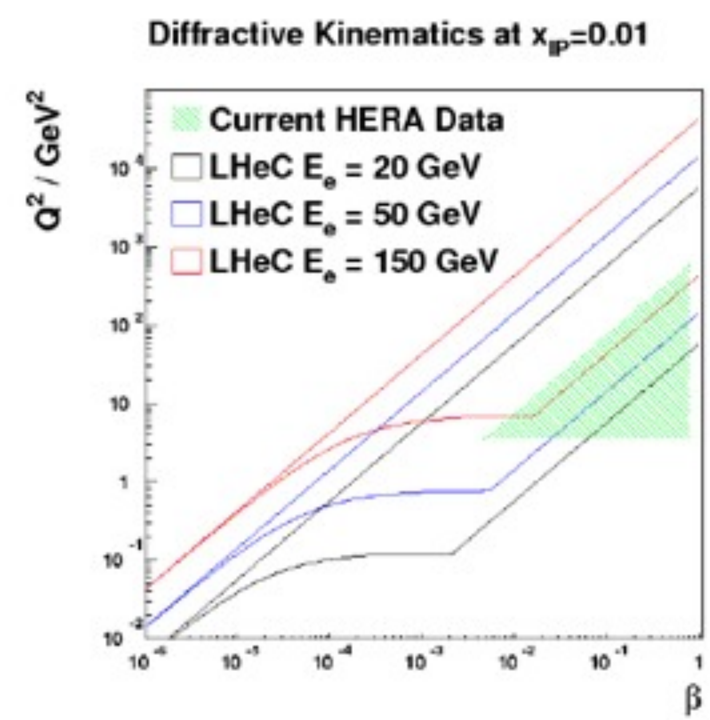




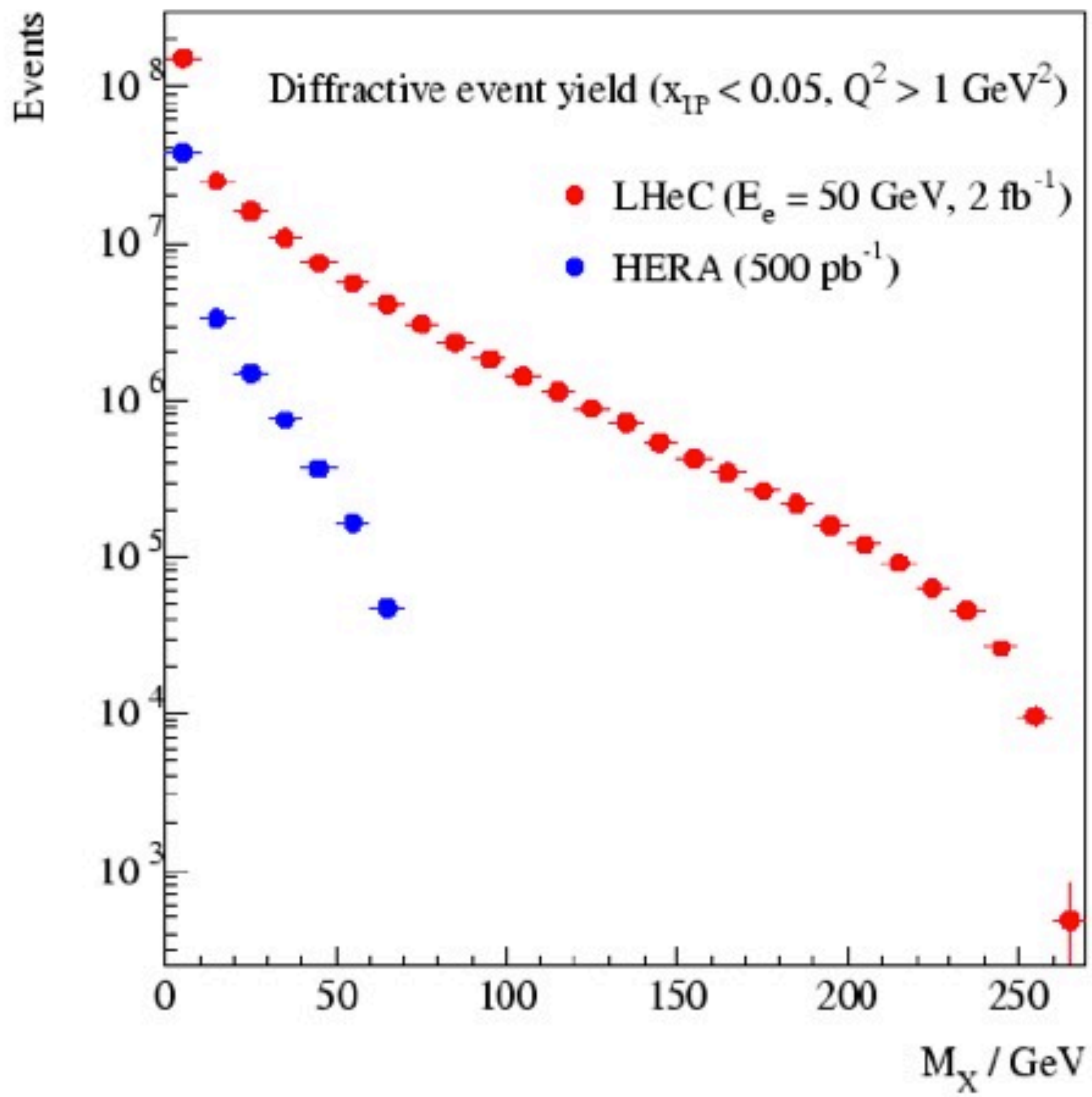
low x_{IP} ... cleanly separates diffraction

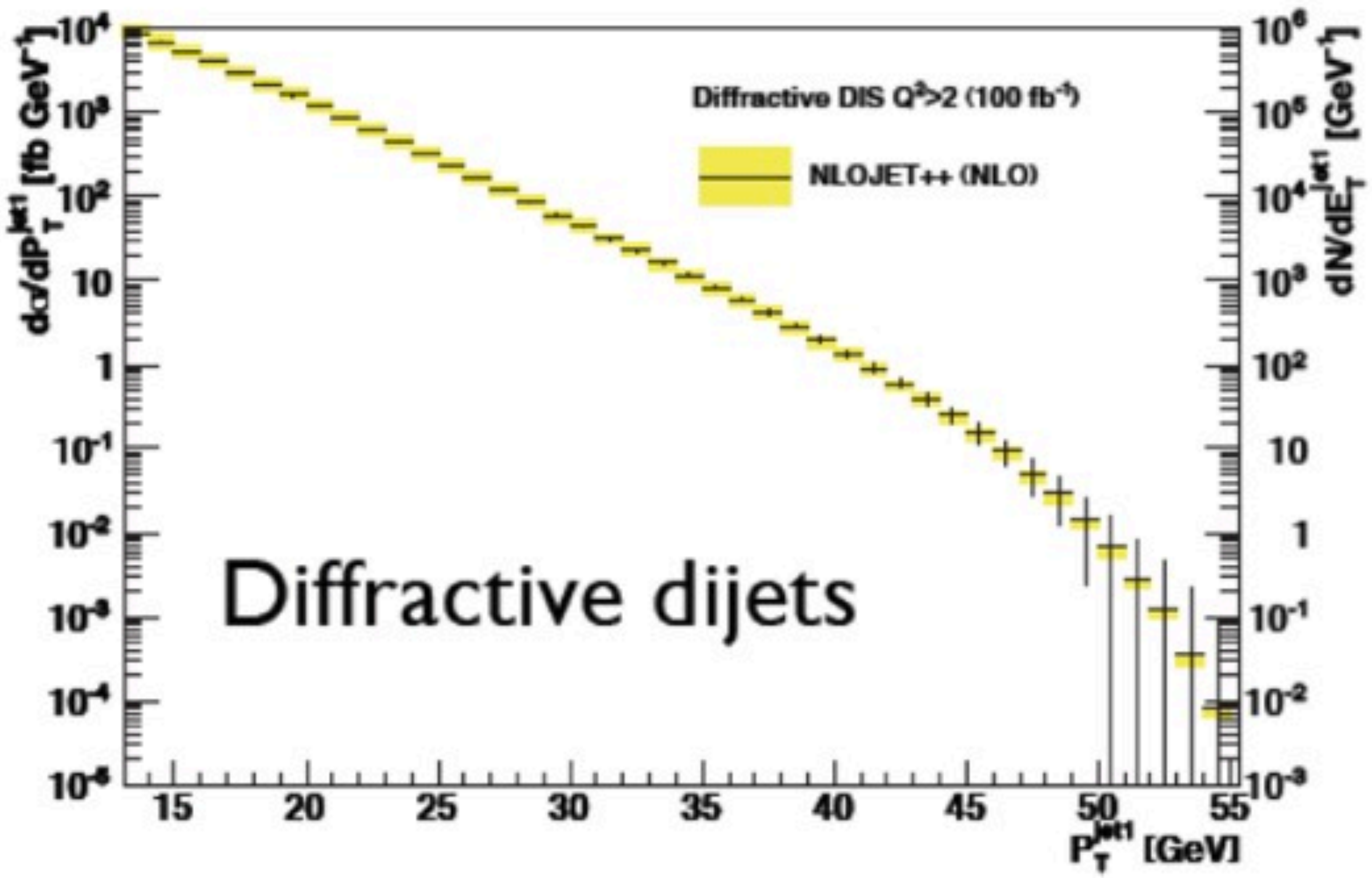
low β ... non-linear dynamics?

high Q^2 ... lever arm for gluon



Large diffractive masses - jets

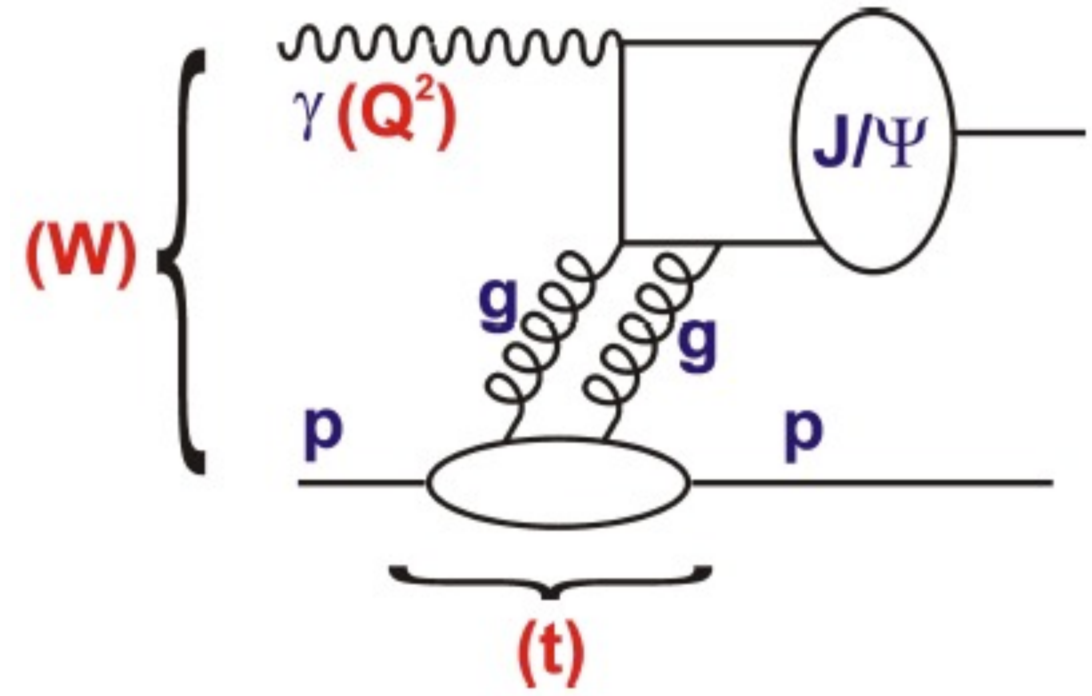




- large x_{IP} correlated with large M_X
- proper diffractive QCD (large E_T) with jets and charm
- new diffractive channels - beauty, W/Z bosons...

Exclusive production - elastic J/Ψ γp

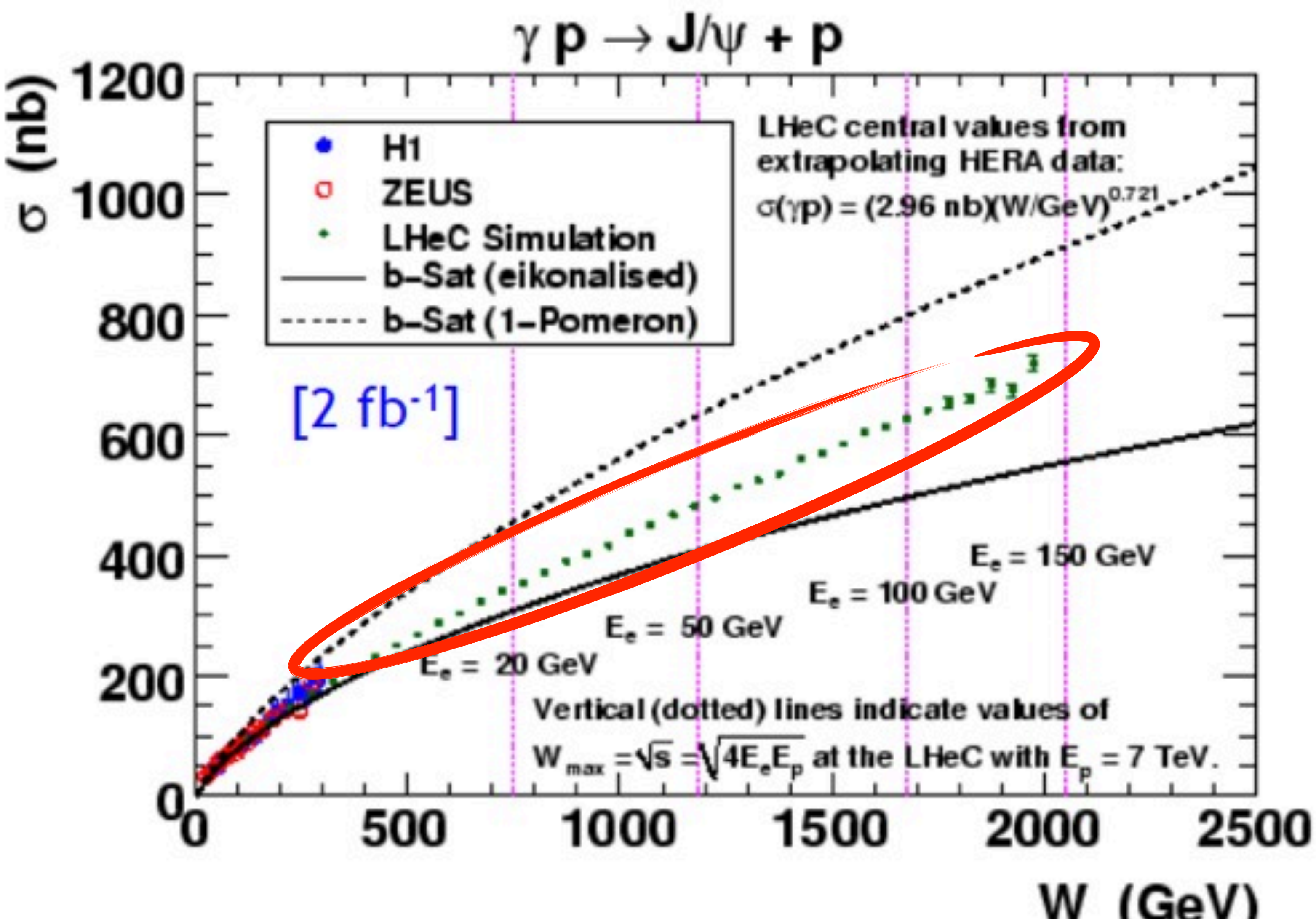
- interpreted as hard two-gluon-exchange coupling to a qqbar dipole
- c and cbar share energy equally, simplifying the wavefunction
- very clean experimentally - l^+l^- at correct mass
- LHeC extends to
  - $x_g \sim (Q^2+M_V^2)/(Q^2+W^2) \sim 5\times10^{-6}$
  - Q2 ~ $(Q^2+M_V^2)/4 \sim 3$ GeV2

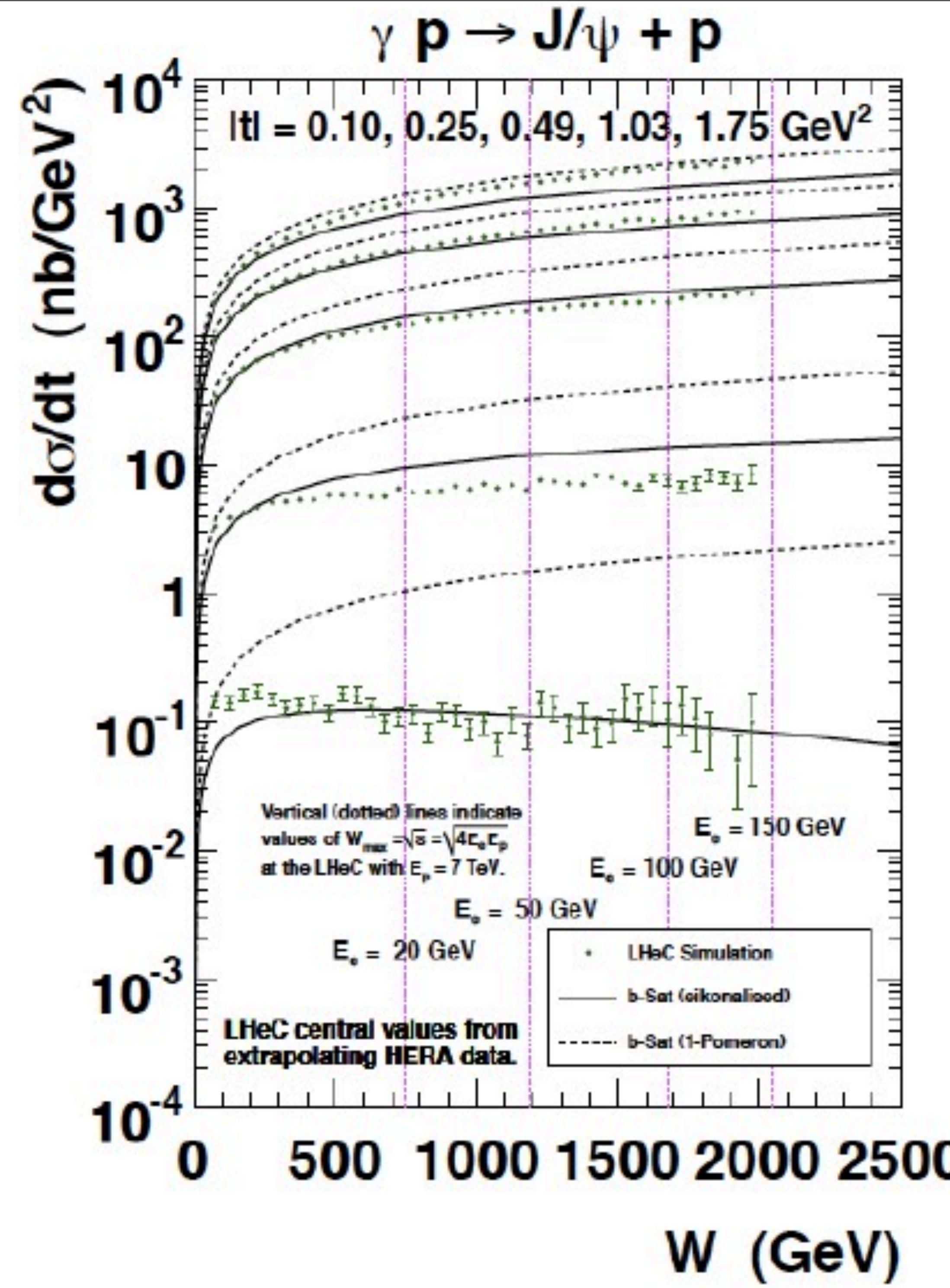


DIFFVM simulations of untagged photoproduction in $\mu\mu$ final state (1° acceptance)

elastic J/Ψ γp (2)

- saturated dipole models
  - "eikonalised" .. with impact parameter dependent simulation
  - "1 Pomeron" .. non-saturating
- significant non-linear effects expected at LHeC, with eA and also t-dependence, it becomes a powerful probe



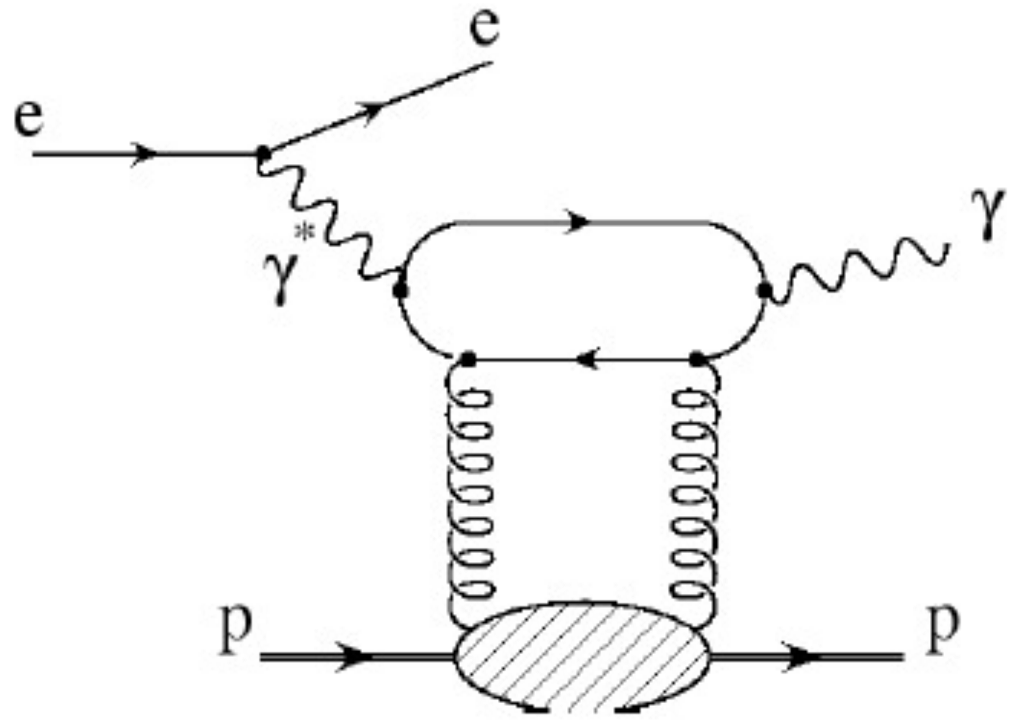


- precise t measurement of μ tracks over wide W range extends to ~2 GeV² and enhances sensitivity to saturation

- possible in W, t and even Q²

Deeply virtual Compton Scattering (DVCS)

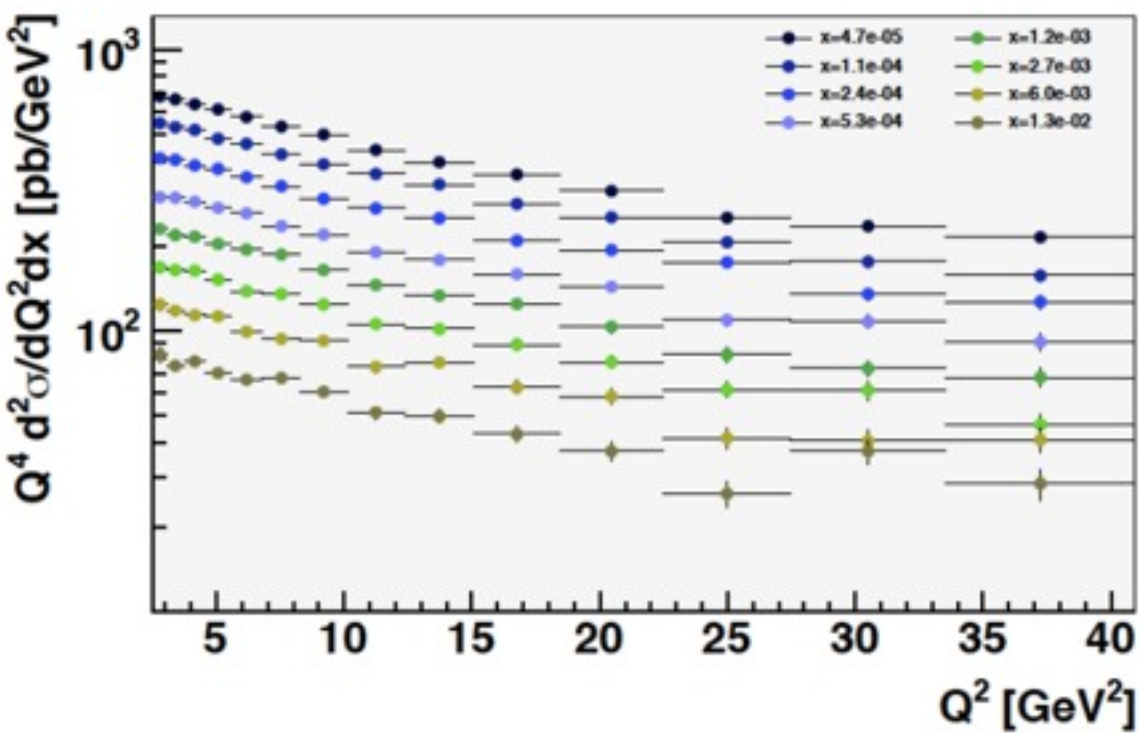
- way to GPDs (generalized PDFs)
  - longitudinal and transverse information
- no problems with VM wavefunctions
- cross section suppressed by photon coupling
  - limited precision at HERA
  - would benefit mostly from the **high luminosity** LHC



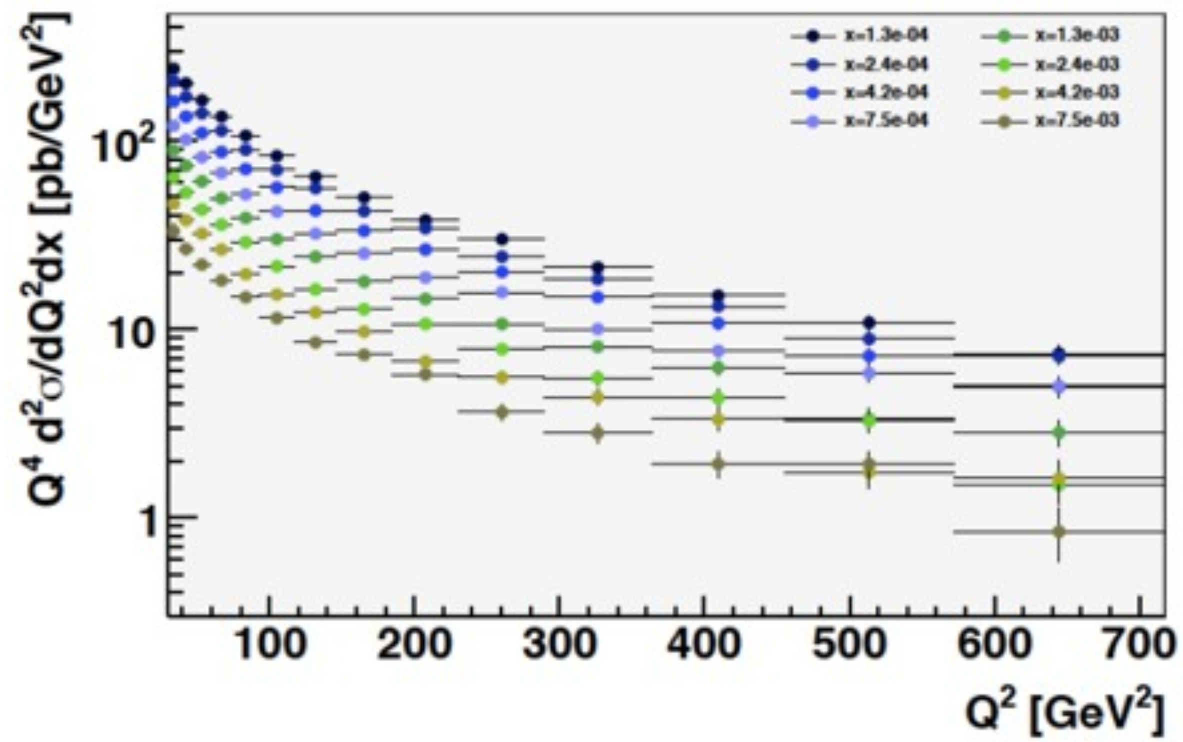
- Simulations based on FFS model in the MILOU generator
  - double differential in x, Q^2 with 1° and 10° working points for the scattered electron
  - kinematical range determined by p_T^γ cut
    - ECAL performance important

DVCS (2)

1 fb^{-1}, E_e = 50 GeV, 1° acceptance, p_T^γ > 2 GeV



100 fb^{-1}, E_e = 50 GeV, 10° acceptance, p_T^γ > 5 GeV

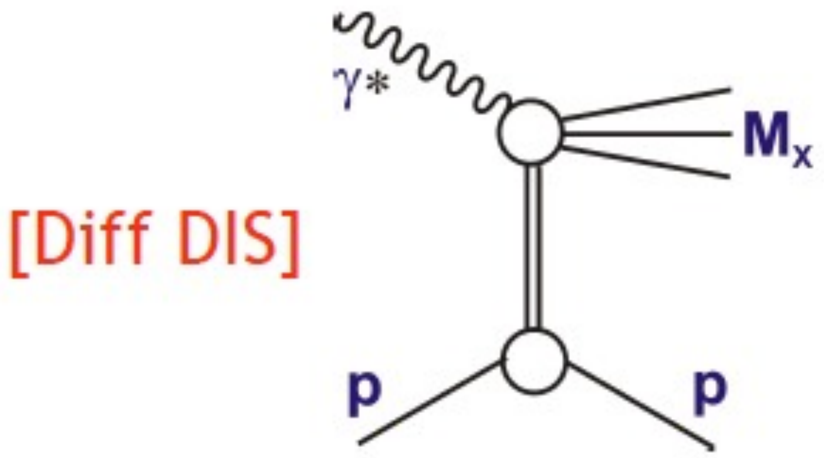


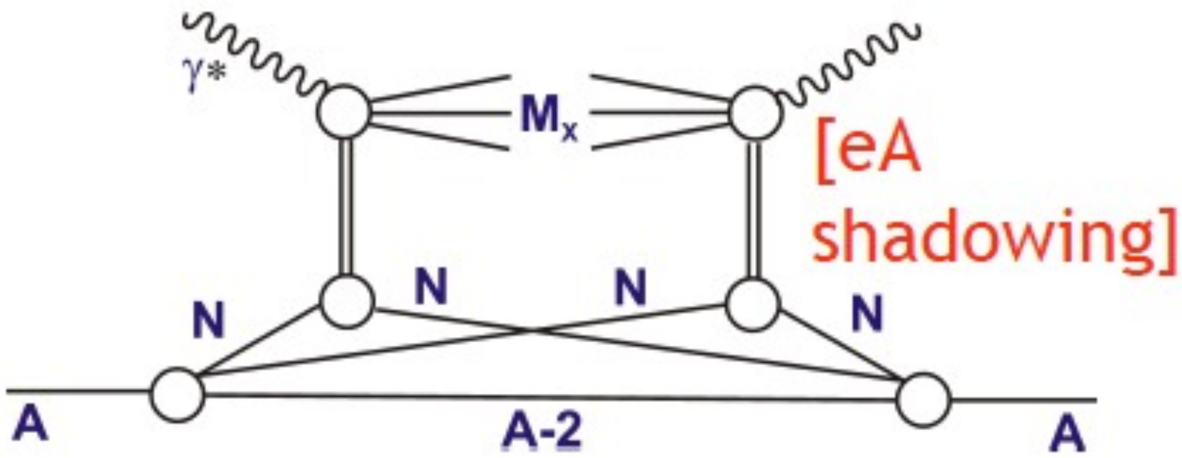
- precise double differential data in low Q^2 region
- stat. precision deteriorates for Q^2 > 25 GeV^2
- W acceptance to ~1 TeV (5x HERA)

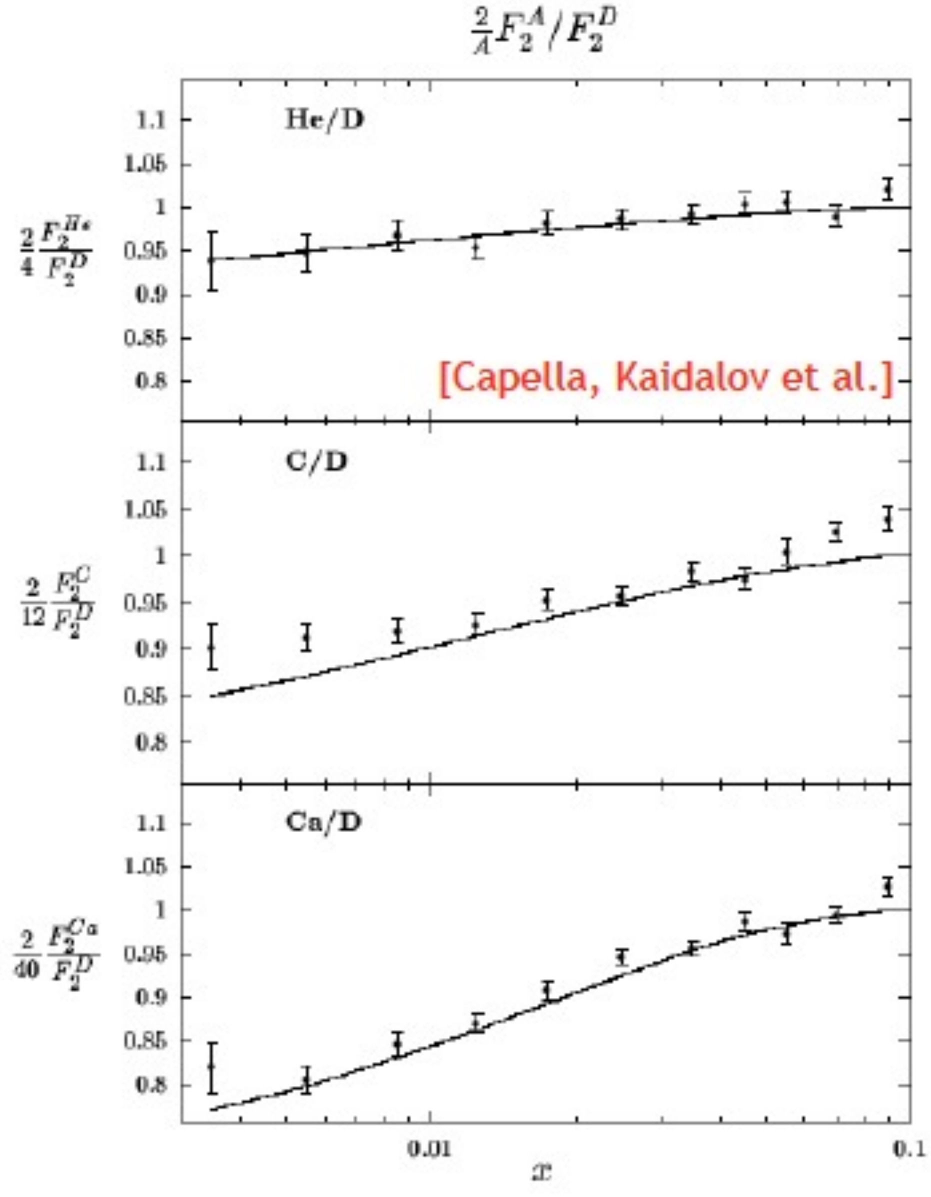
- high lumi gives precision data to Q2 of several hundreds of GeV^2
  - completely new region

F_2^D and nuclear shadowing

- nuclear shadowing can be described (Gribov-Glauber) as multiple interactions starting from ep DPDFs







starting point for extending precision LHeC studies into eA collisions

Summary

- **low x physics is important** - discovery potential for the strong force
  - dense partonic systems - correlations / interactions
- **diffractions plays an important role**
  - enhances / complements inclusive data in saturation search
  - parton correlations, impact parameter dependence
  - extension of phase space and DPDFs, possible to observe new final states
- **still lot of work ahead**
  - recently started work on impact of LHeC on DPDF fits with pseudo-data - stay tuned
- more on **http://lhec.web.cern.ch**