Measurement of Dijet Production in Diffractive Deep-Inelastic Scattering with a Leading Proton at HERA

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on behalf of the H1 Collaboration

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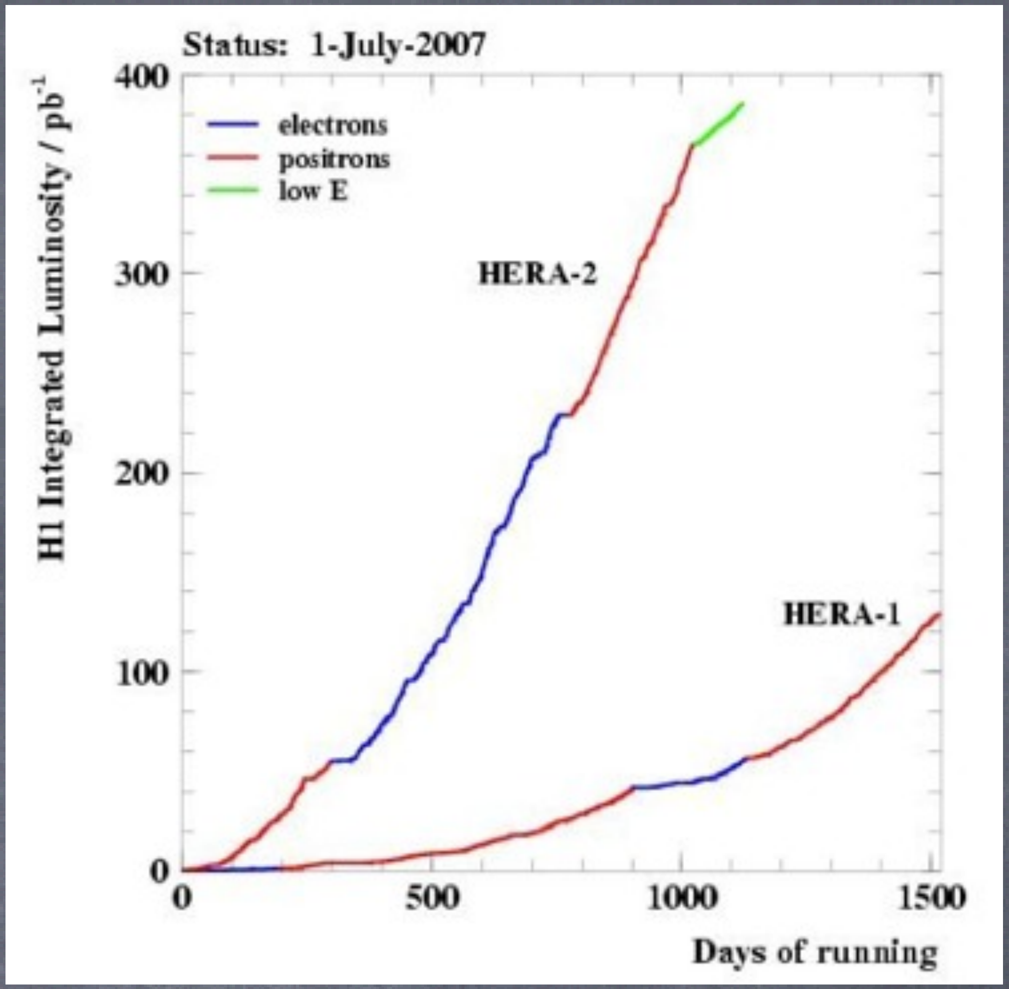
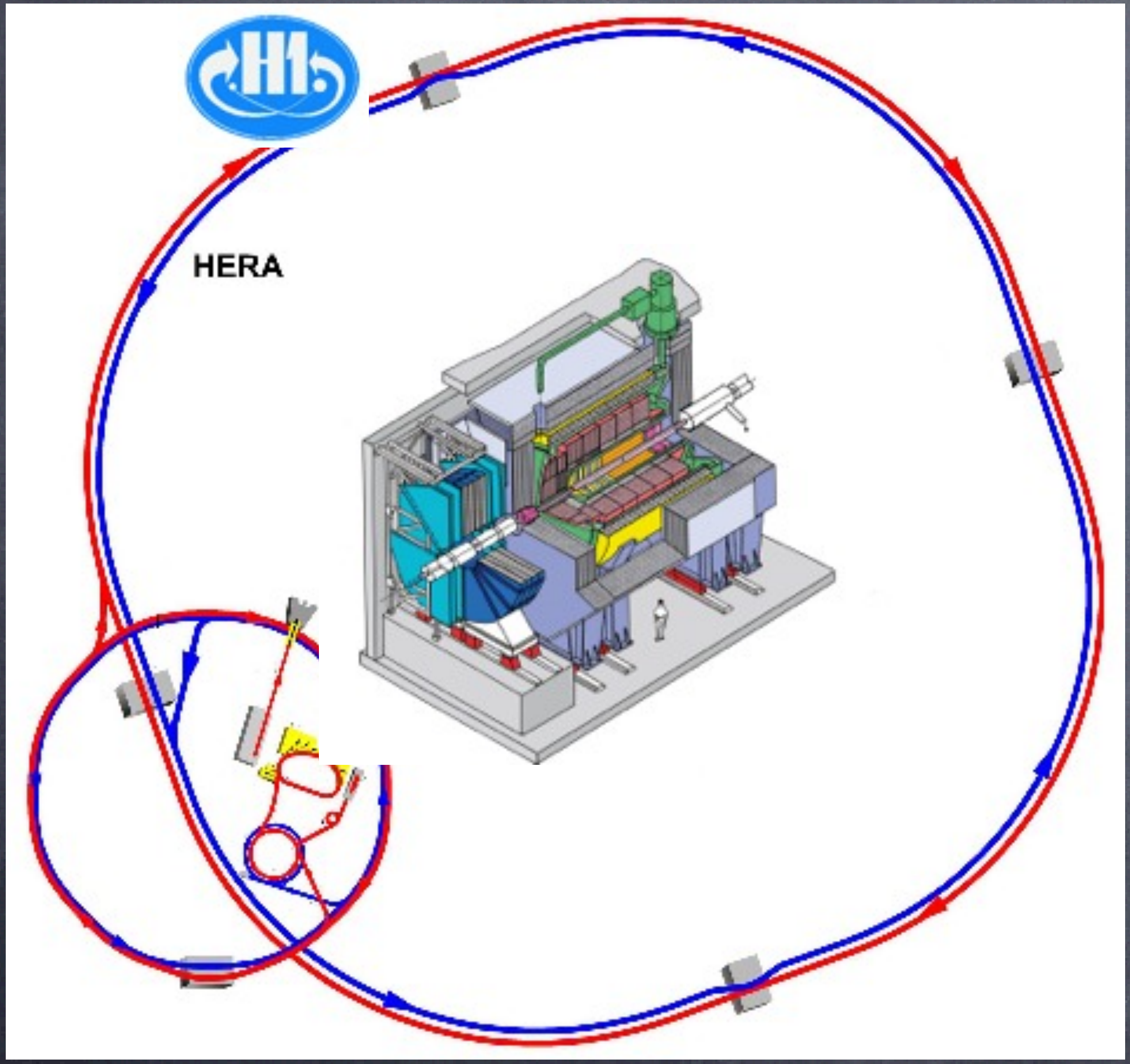
H1 @ HERA





1992 - 2007

Hadron **E**lektron **R**ing **A**nlage

Hamburg (Germany)

$e^{\pm}$ 27.5 GeV

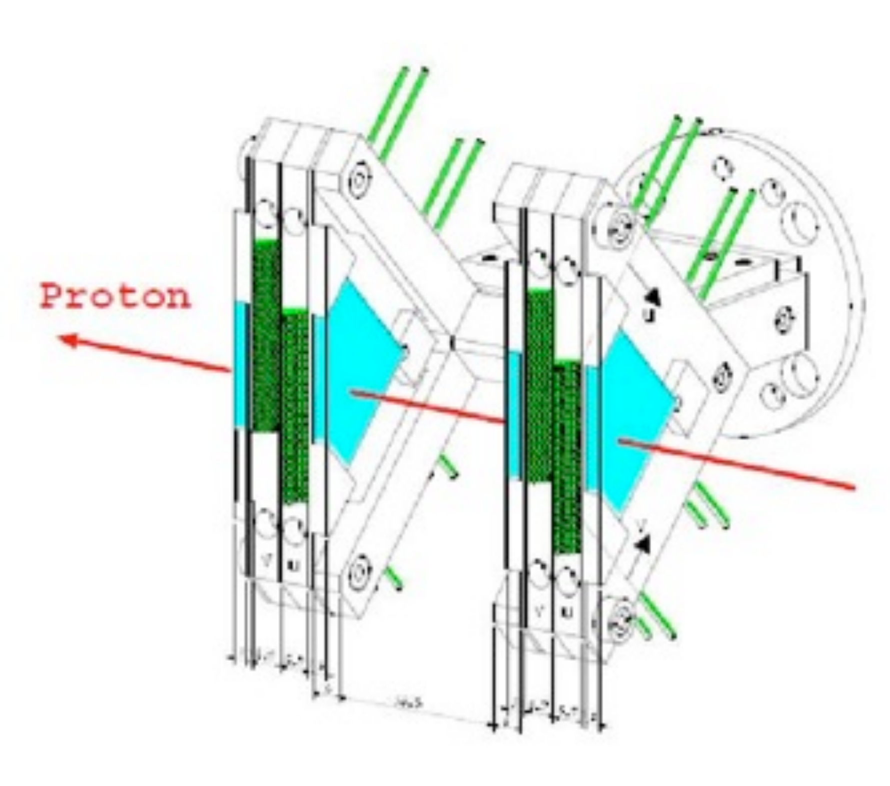
p 920 GeV

L_{int} ~0.5 fb^{-1}

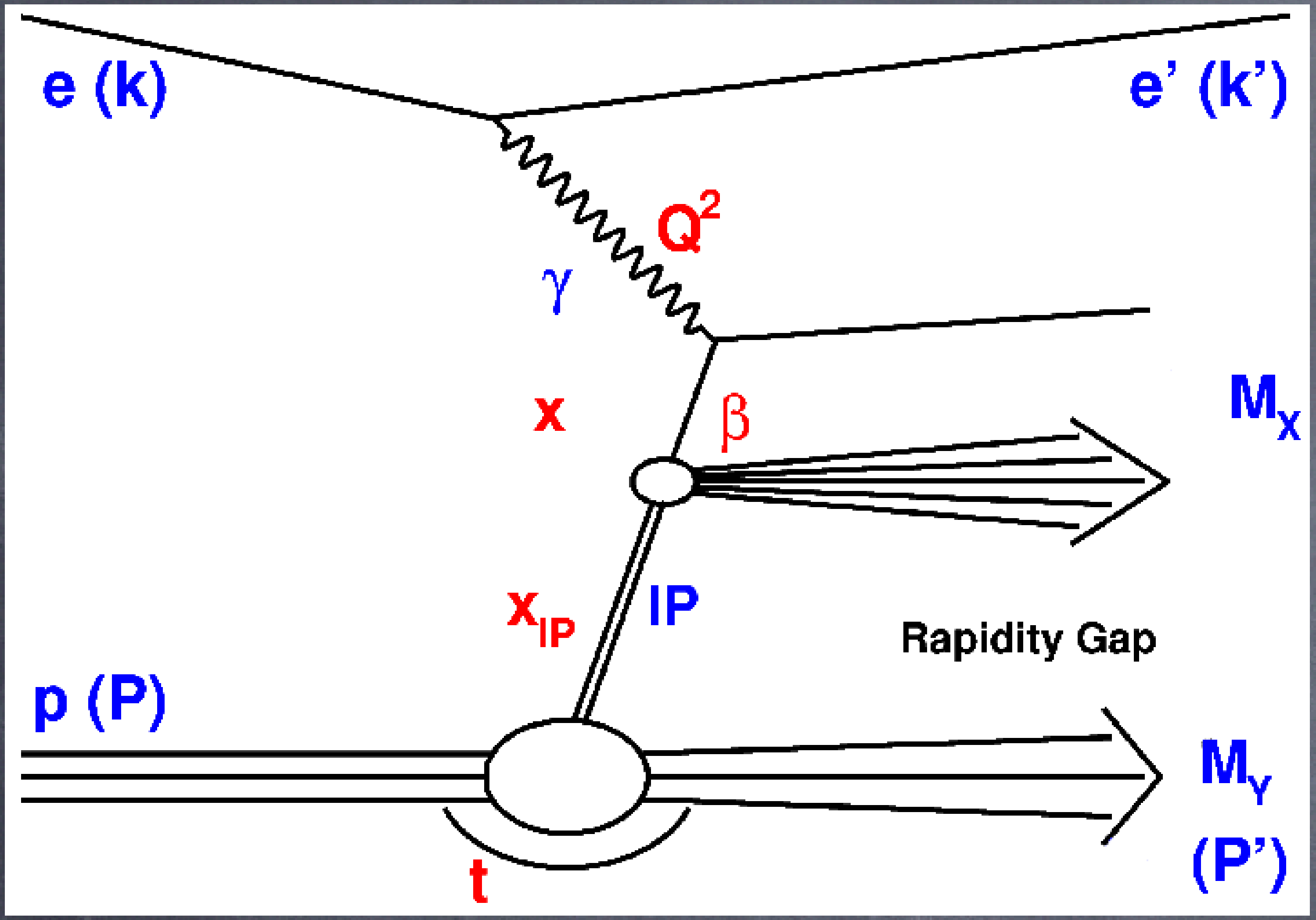
H1 & ZEUS … 4π, asymmetric

FPS @ H1

- **Forward Proton Spectrometer:**
  - 61m and 80m horizontal stations
  - each station estimates independently x and y position, measurement from both stations allows
    to measure angle of the proton
  - scintillating fibres with PMTs
  - Acceptance:
    - $x_{IP} = 1 - Ep' / Ep$ up to 0.1
    - $0.1\ GeV^2 < |t| < 0.7\ GeV^2$



Diffractive kinematics



$Q^2 = -q^2 = (k' - k)^2$

$x = Q^2 / 2Pq$

$x_{IP} = q(P' - P)/qP$

$= 1 - E'p/Ep$

$\beta = x/x_{IP}$

$z_{IP} = (Q^2 + M_{jj}^2)/x_{IP}ys$

$M_Y = mp$ .... intact proton

$mp \leq M_Y \leq 1.6$ GeV .... intact proton or proton dissociation

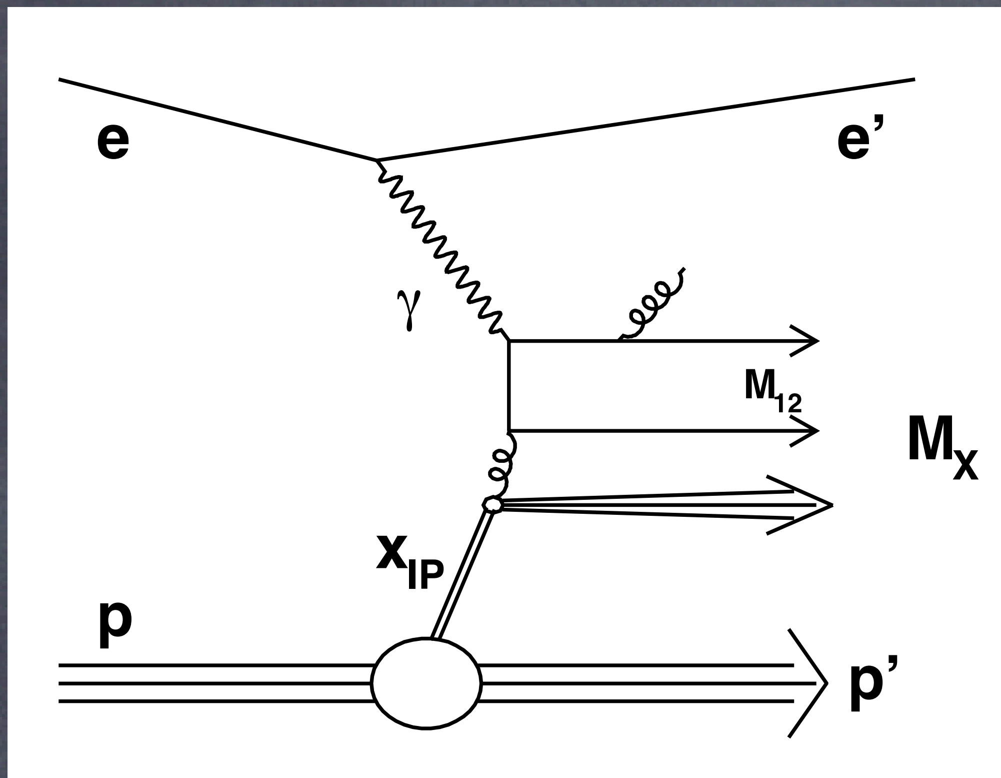
Collins factorisation, proven:

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

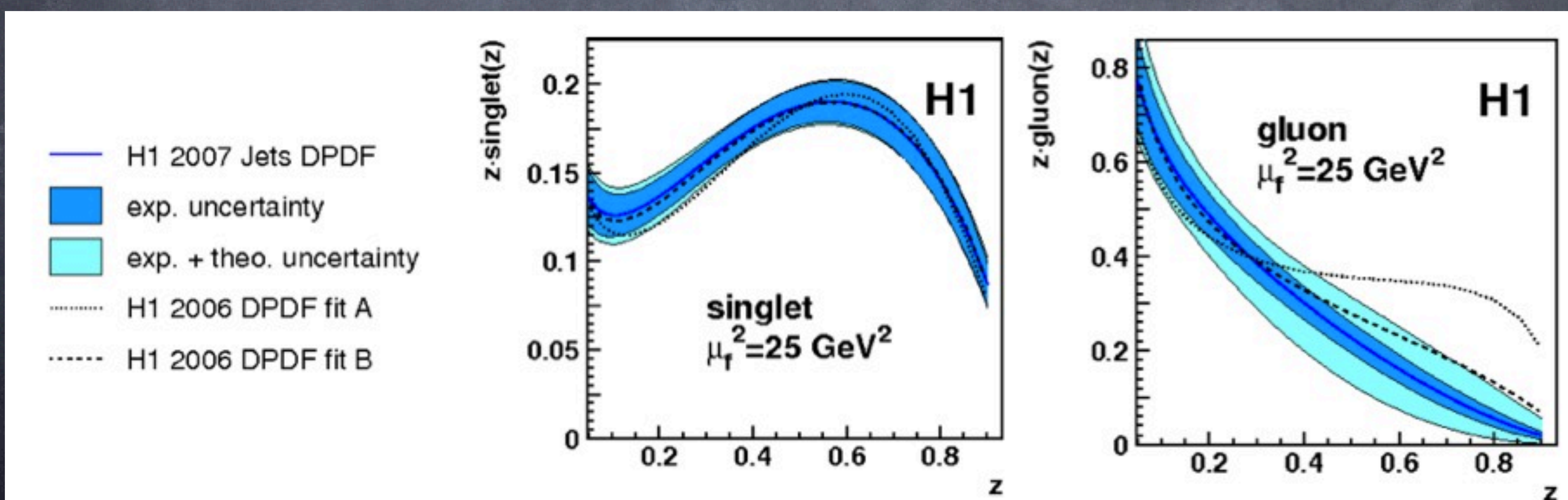
Proton Vertex Factorisation, consistent with data:

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

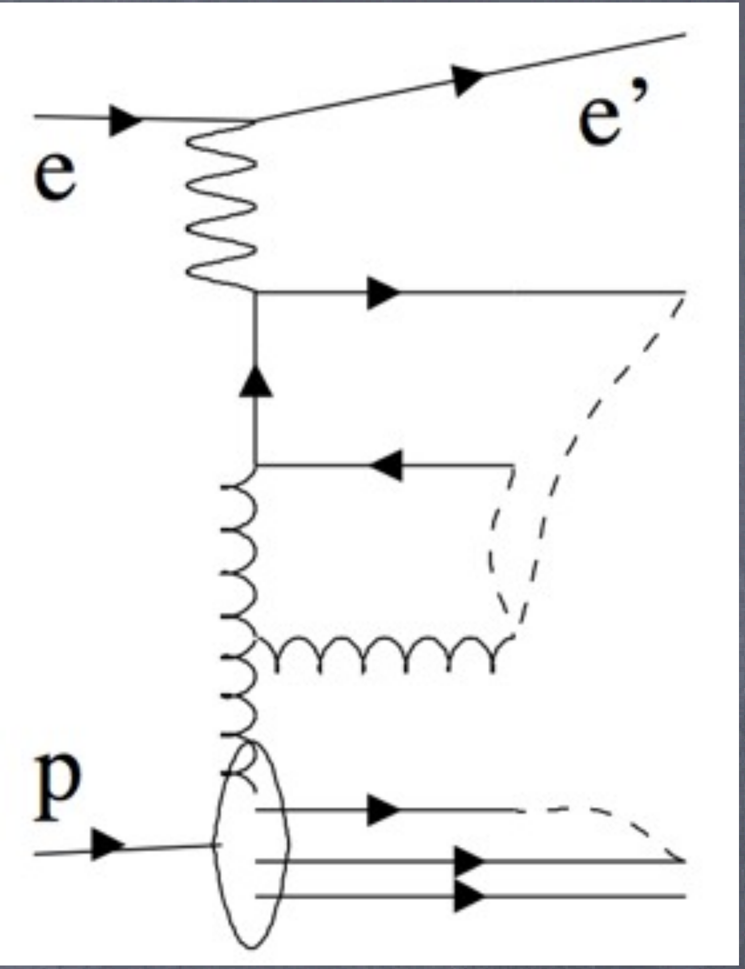
Diffractive PDFs



- DPDF extraction from inclusive measurements gives 2 solutions -> jets
- diffractive jets constrain the gluon part of DPDFs, sensitive to high z_{IP}
- jet pT provides an additional hard scale - possible to calculate pQCD (NLOJET++ 4.1 modified for diffraction)
- search for physics beyond DGLAP parton evolution



Diffractive final states

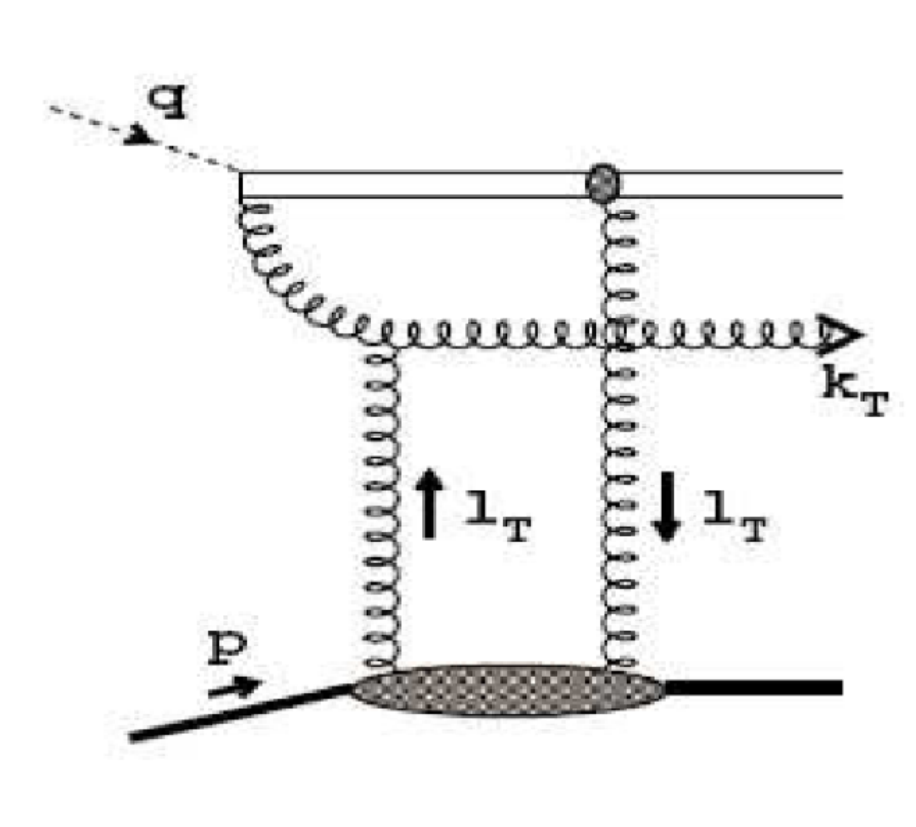


Soft Colour Interaction (SCI)

Rearrangement of colour strings in the final state

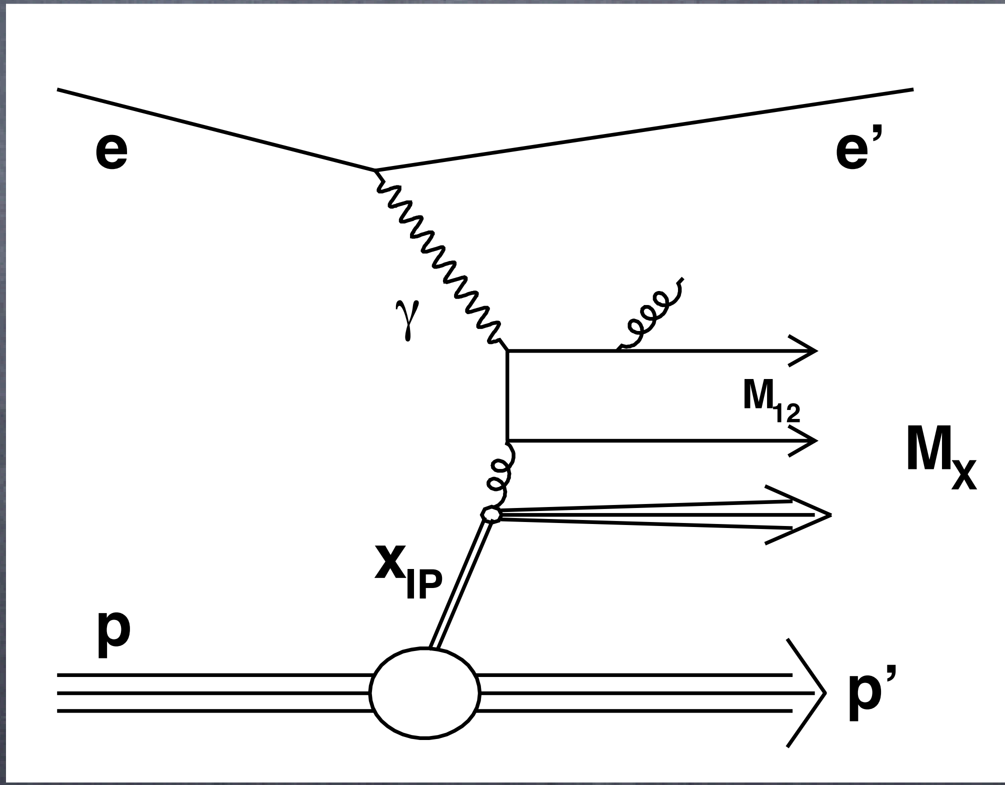
Suppression of long strings (+GAL)

Probability of having SCI parameter **R** tuned to 0.3 to describe the total dijet cross section



2 Gluon Pomeron

pomeron modeled in pQCD as colourless combination of gluons valid for low x_{IP}

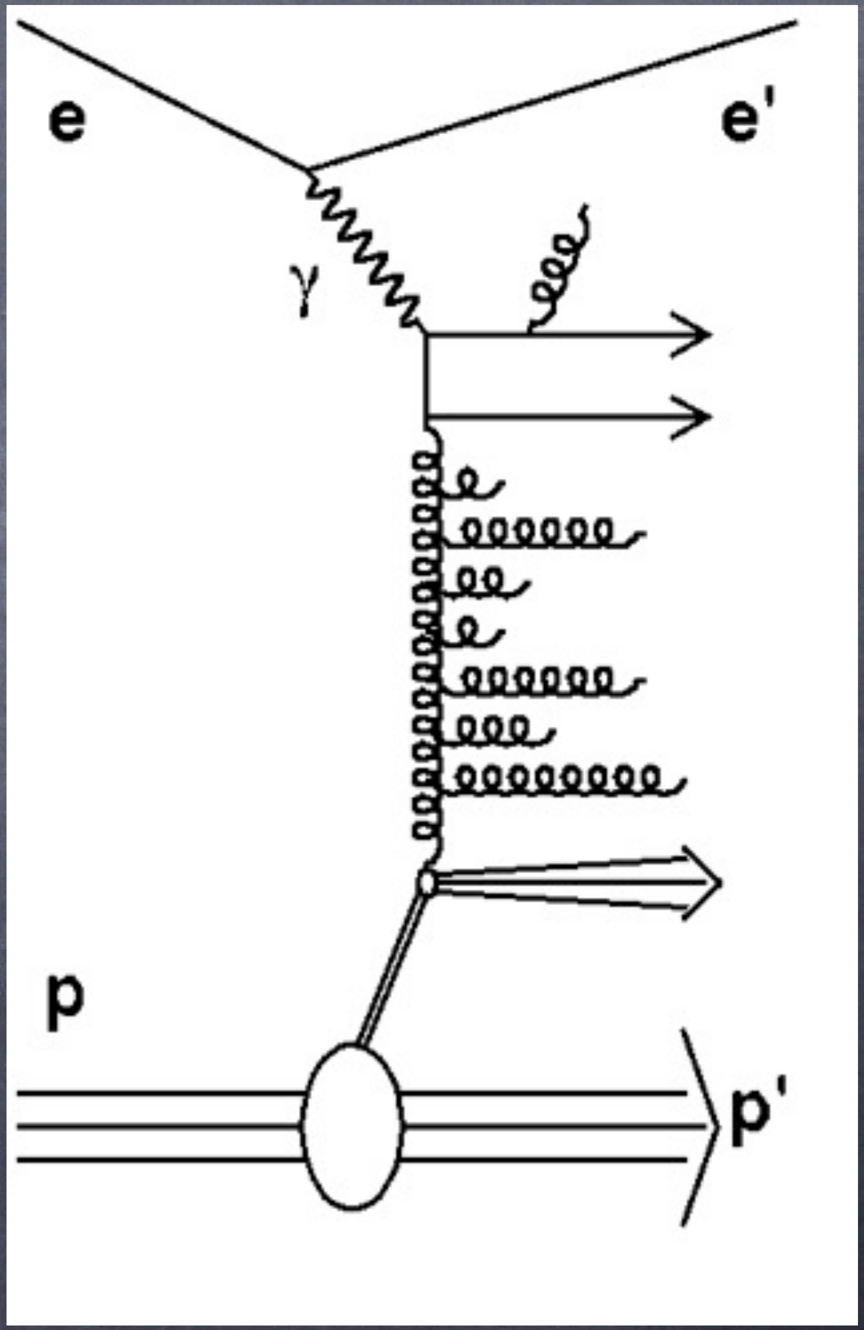


Resolved Pomeron

based on QCD and proton vertex factorisation

Beyond DGLAP...

- DGLAP evolution equations assume strong increasing ordering in transverse momenta of emerging partons and decrease in fractional energy along the gluon ladder
- BFKL doesn't require pT ordering, hard parton at the beginning of the ladder may be emitted
- in diffractive case, no proton remnant in the forward region

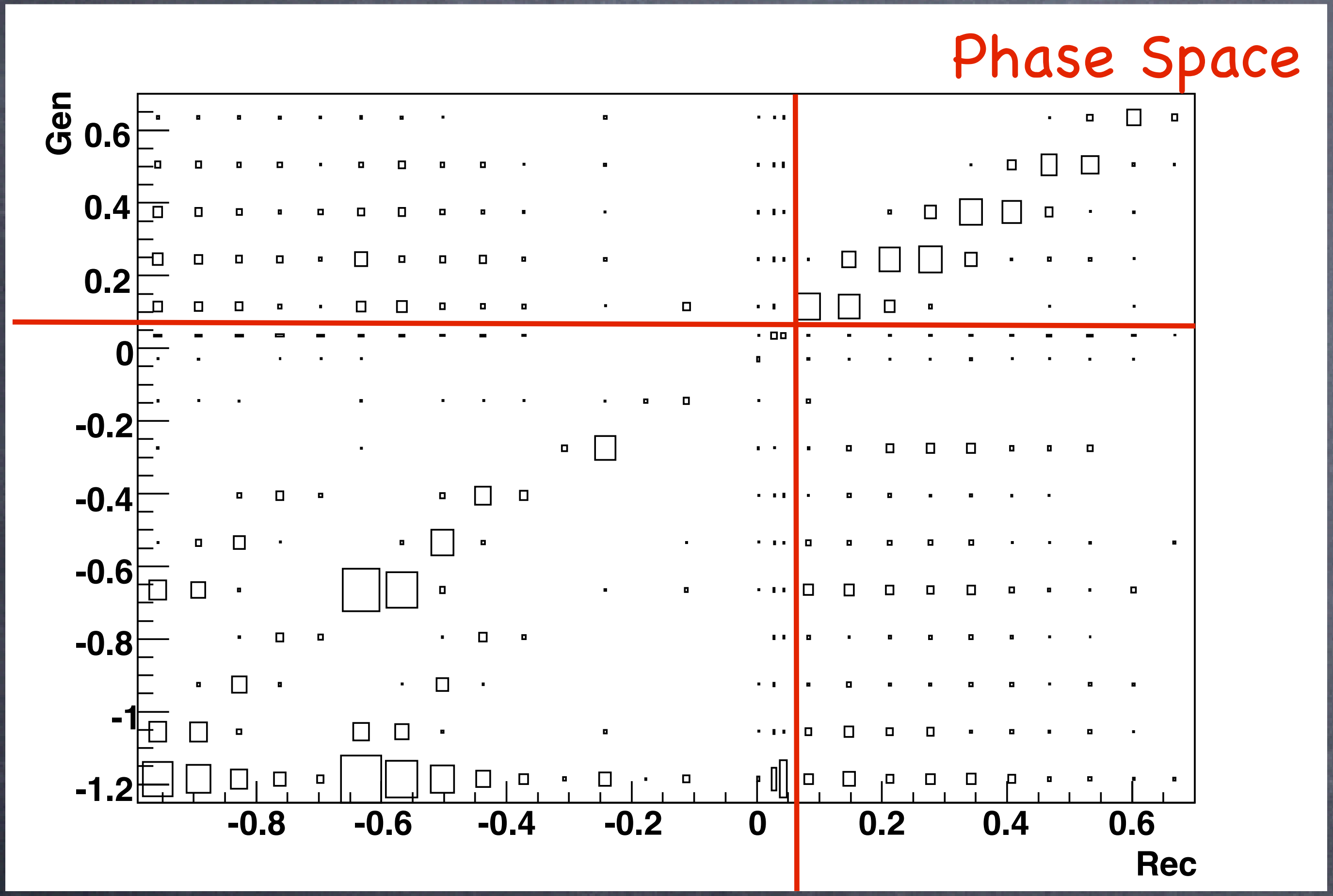


Jet topologies

Selection	two central jets	one central + one forward jet
DIS	$4 < Q^2 < 110\ \mathrm{GeV}^2$ $0.05 < y < 0.7$	
Leading Proton	$x_{I\!P} < 0.1$ $\|t\| < 1\ \mathrm{GeV}^2$	
Jets	$P^*_{T,1} > 5$ GeV $P^*_{T,2} > 4$ GeV $-1 < \eta_{1,2} < 2.5$	$P^*_{T,c}, P^*_{T,f} > 3.5$ GeV $M_{jj} > 12$ GeV $-1 < \eta_c < 2.5$ $1 < \eta_f < 2.8, \eta_f > \eta_c$

	two central jets σ [pb]	one central + one forward jet σ [pb]
Data	254 ± 20 (stat.) ± 27 (syst.)	150 ± 19 (stat.) ± 26 (syst.)

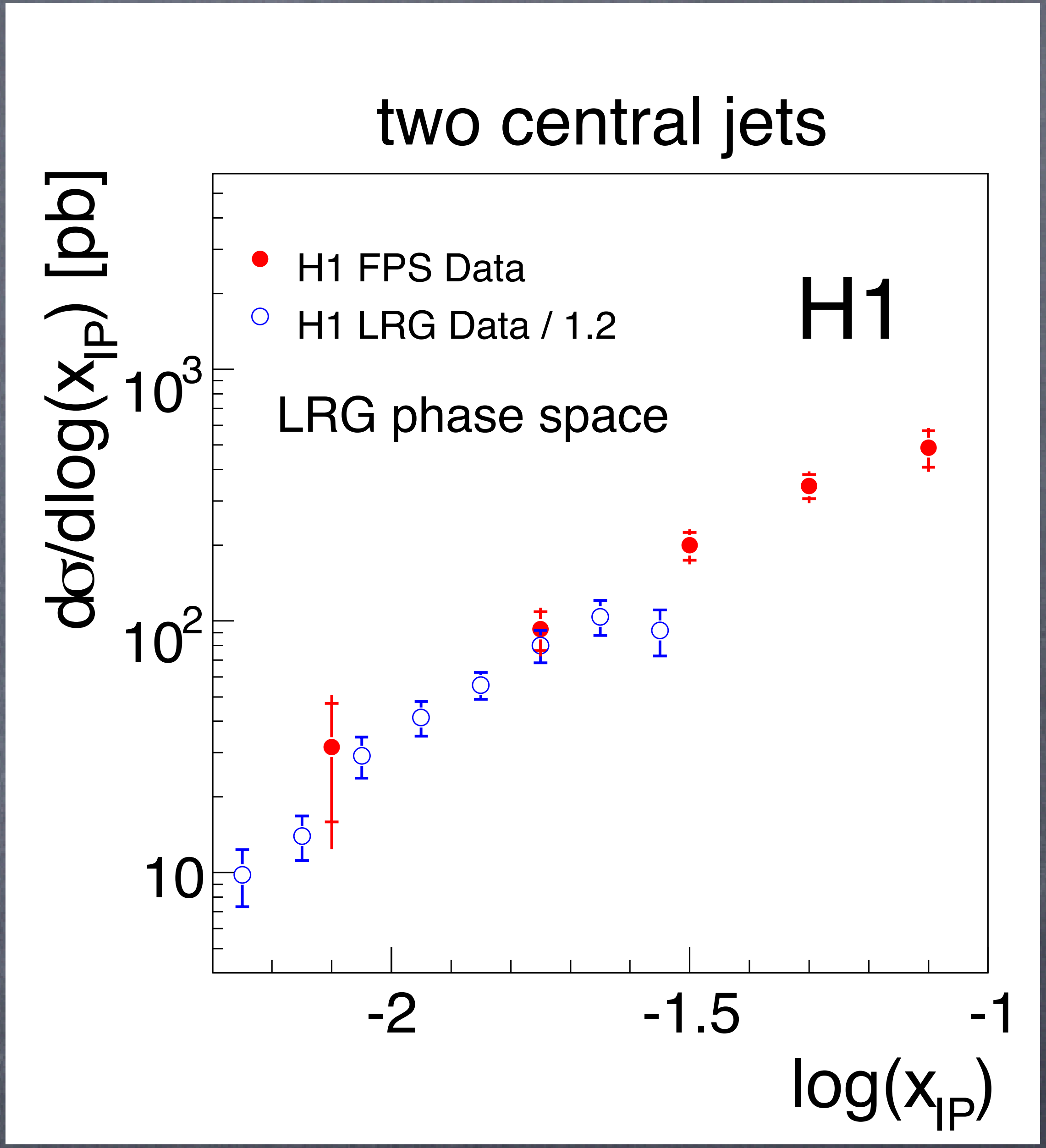
Unfolding



- low pT jet measurement suffers from low purity - migrations of events from outside of phase space definition up to ~60%
- => matrix unfolding from the reconstructed to the truth level used
- TUnfold (ROOT package)
- requires measurements of "control regions" outside of the analysis phase space
- statistically correct treatment of correlations between the cross section bins

Comparison of LRG and FPS

- diffractive DIS dijet analysis with LRG (JHEP 0710:042)
- LRG data are corrected for proton dissociation



$4\ \mathrm{GeV}^2 < Q^2 < 80\ \mathrm{GeV}^2$

$0.1 < y < 0.7$

$p_{T1}^* > 5.5$ GeV

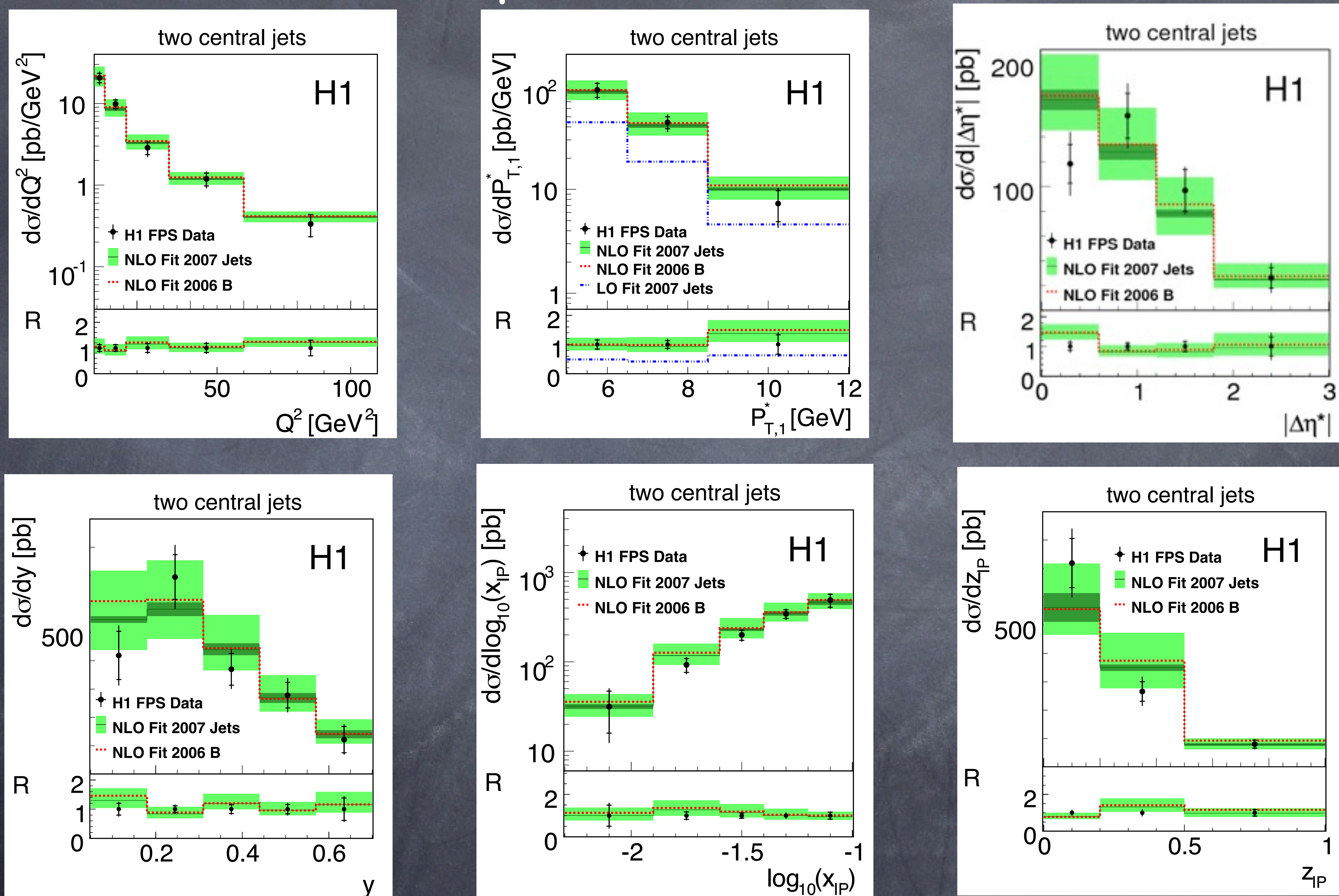
$p_{T2}^* > 4.0$ GeV

very good agreement

phase space extension by factor of 3 in x_{IP}

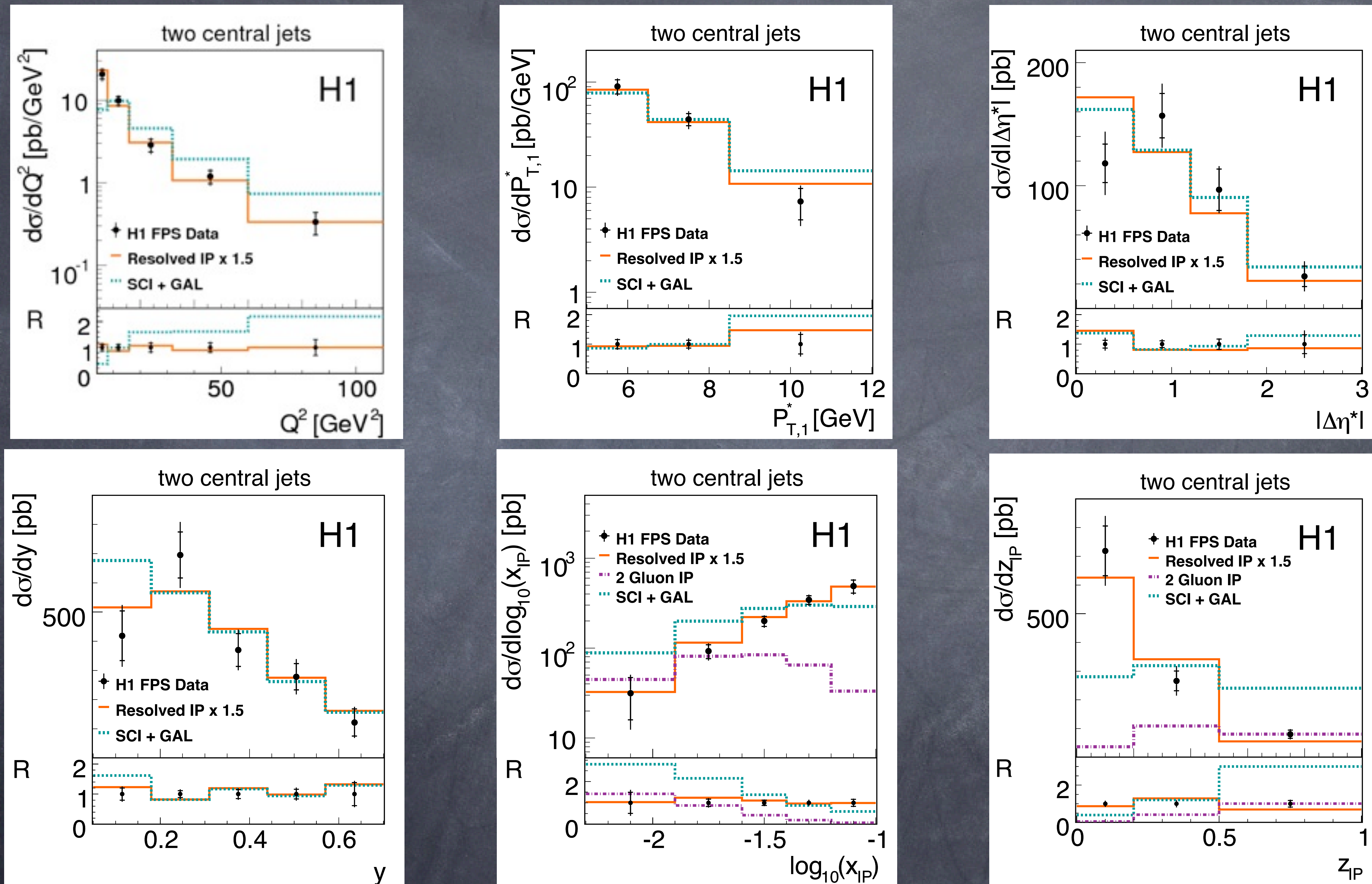
same fraction of proton dissociation as for incl. diff.

Comparison with NLO



Data are well described by the NLO predictions

Comparison with LO MC

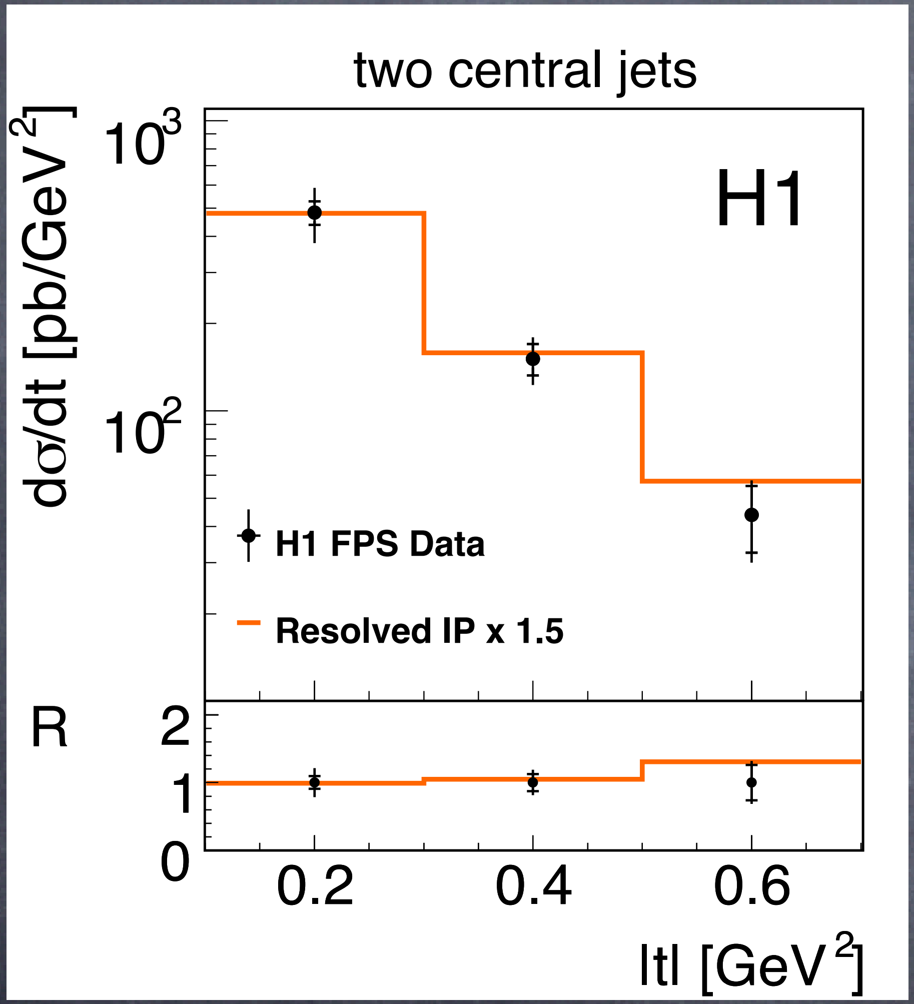


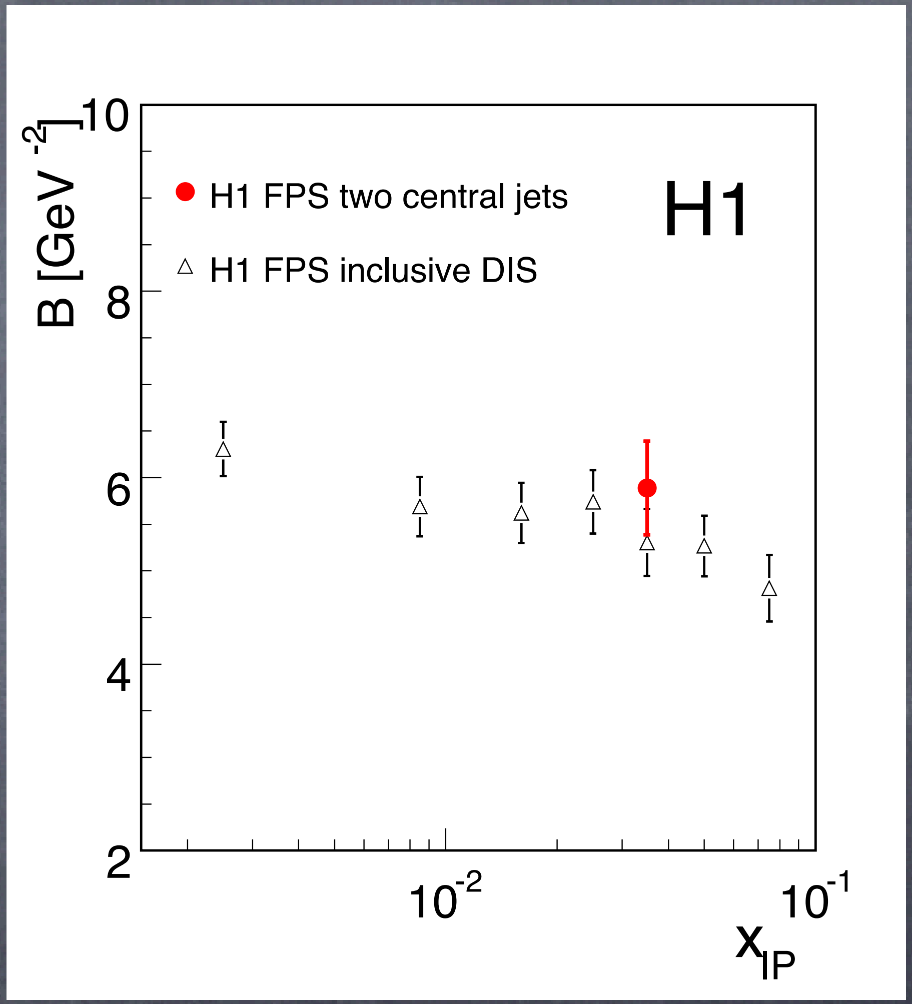
none of MC models describes the data in all aspects

Proton vertex factorisation

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

$$f_{IP/p}(x_{IP}, t) = A_{IP} \frac{e^{B_{IP} t}}{x_{IP}^{2\alpha(t)-1}}$$

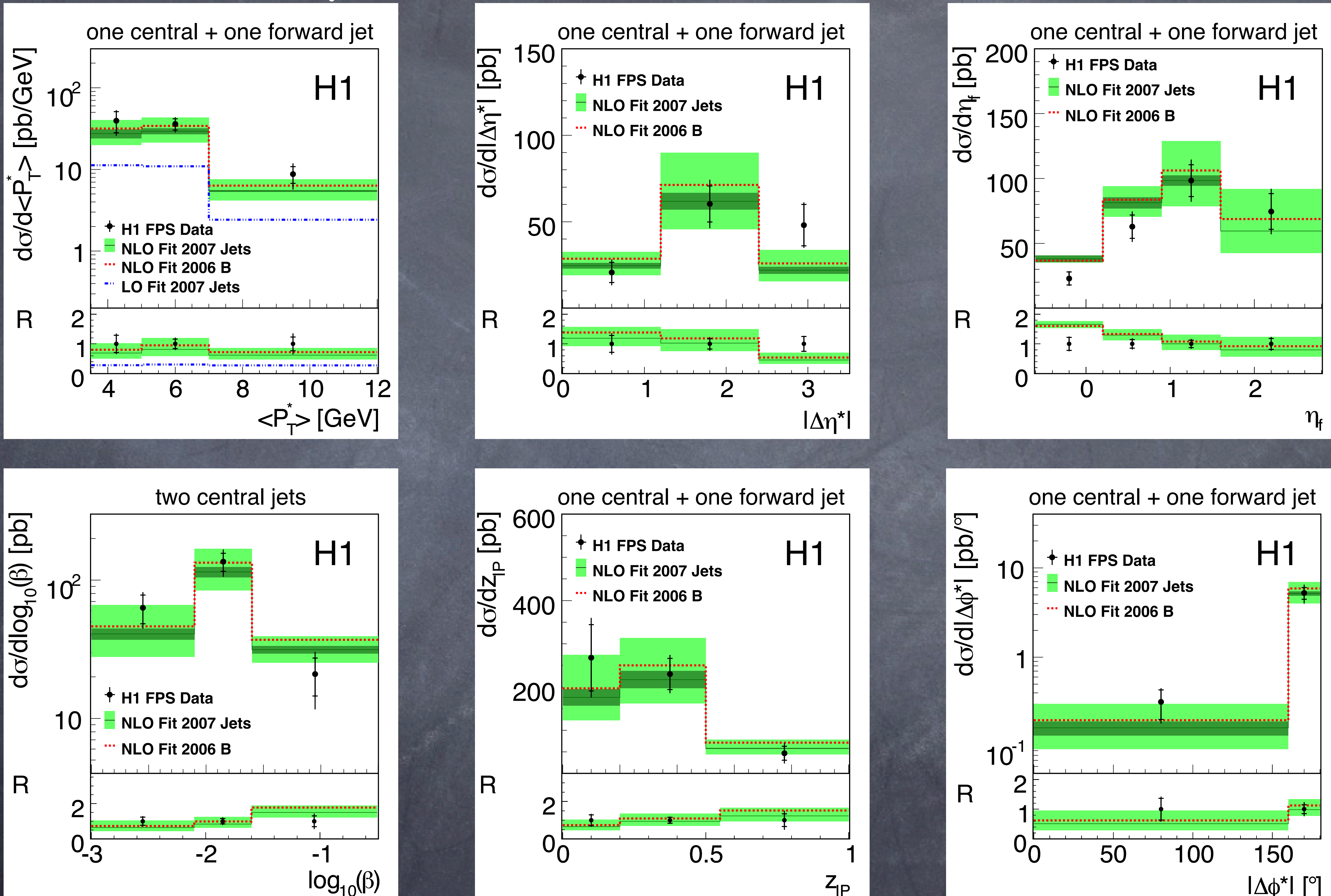




$B = 5.89 \pm 0.50 \text{ GeV}^{-2}$

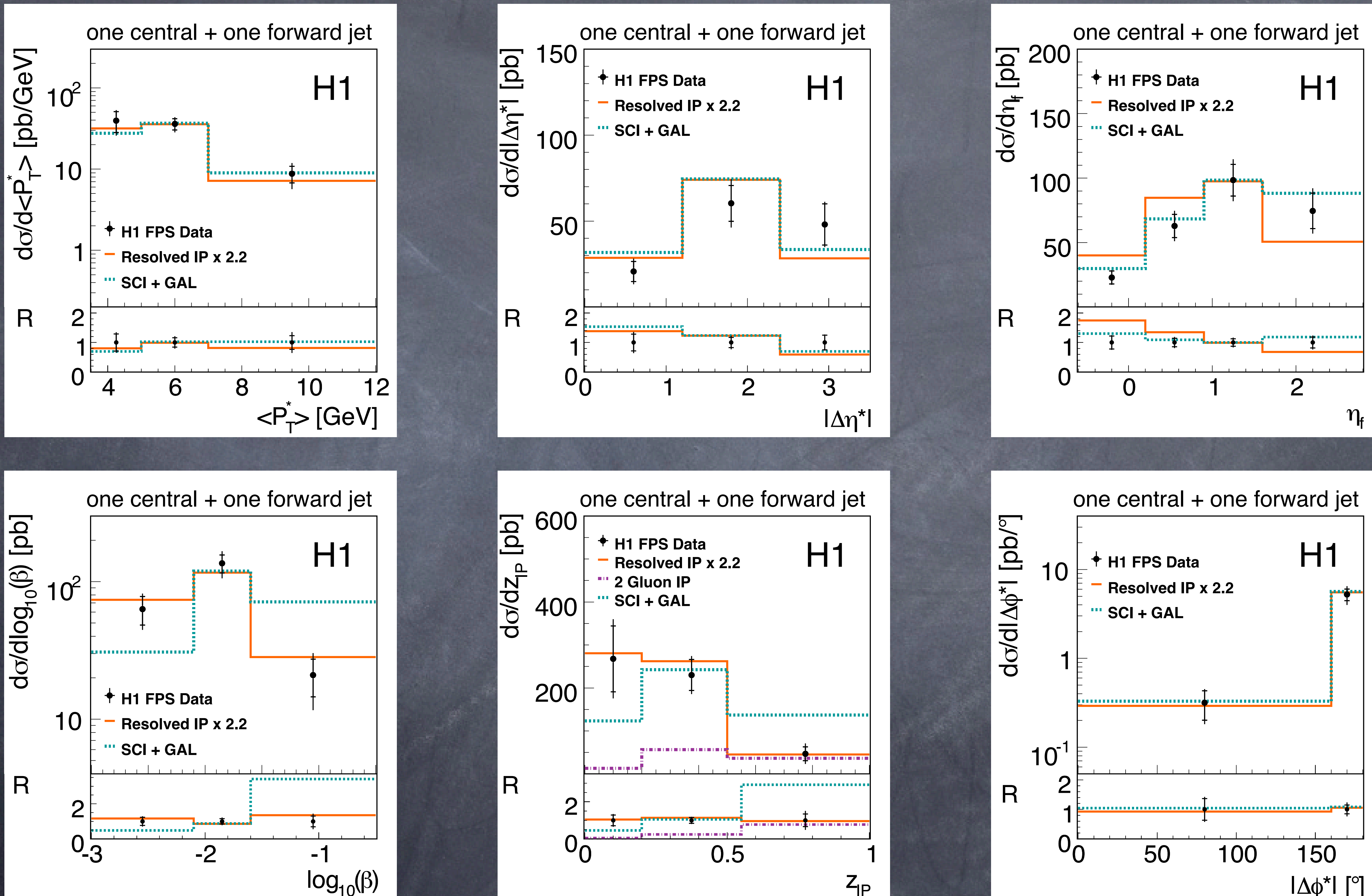
consistent with inclusive measurement

Comparison with DGLAP NLO



No significant devations from DGLAP NLO QCD

Comparison with LO MC



none of MC models describes the data in all aspects

Summary

- Diffractive dijet measurement with a tagged leading proton performed for the first time
- Data agree well with a previous measurement using the LRG method
- amount of proton dissociation in dijet events is same as in inclusive events
- NLO predictions based on DPDF H1 2007 Jets describe the data within errors
- LO MC models do not describe the data satisfactorily
- measured data are consistent with the proton vertex factorisation assumption
- no hints of physics beyond DGLAP observed in the accessible phase space

Backup

Beam halo background

- protons not emerging from interaction can trigger a signal in FPS
- data driven method
- $E+Pz = En\ (HFS + Ep') + Pz\ (HFS + Ep') < 2*Ep$