Dijet Production in Diffractive Deep-Inelastic Scattering using Proton Spectrometers at HERA

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on behalf of the H1 Collaboration

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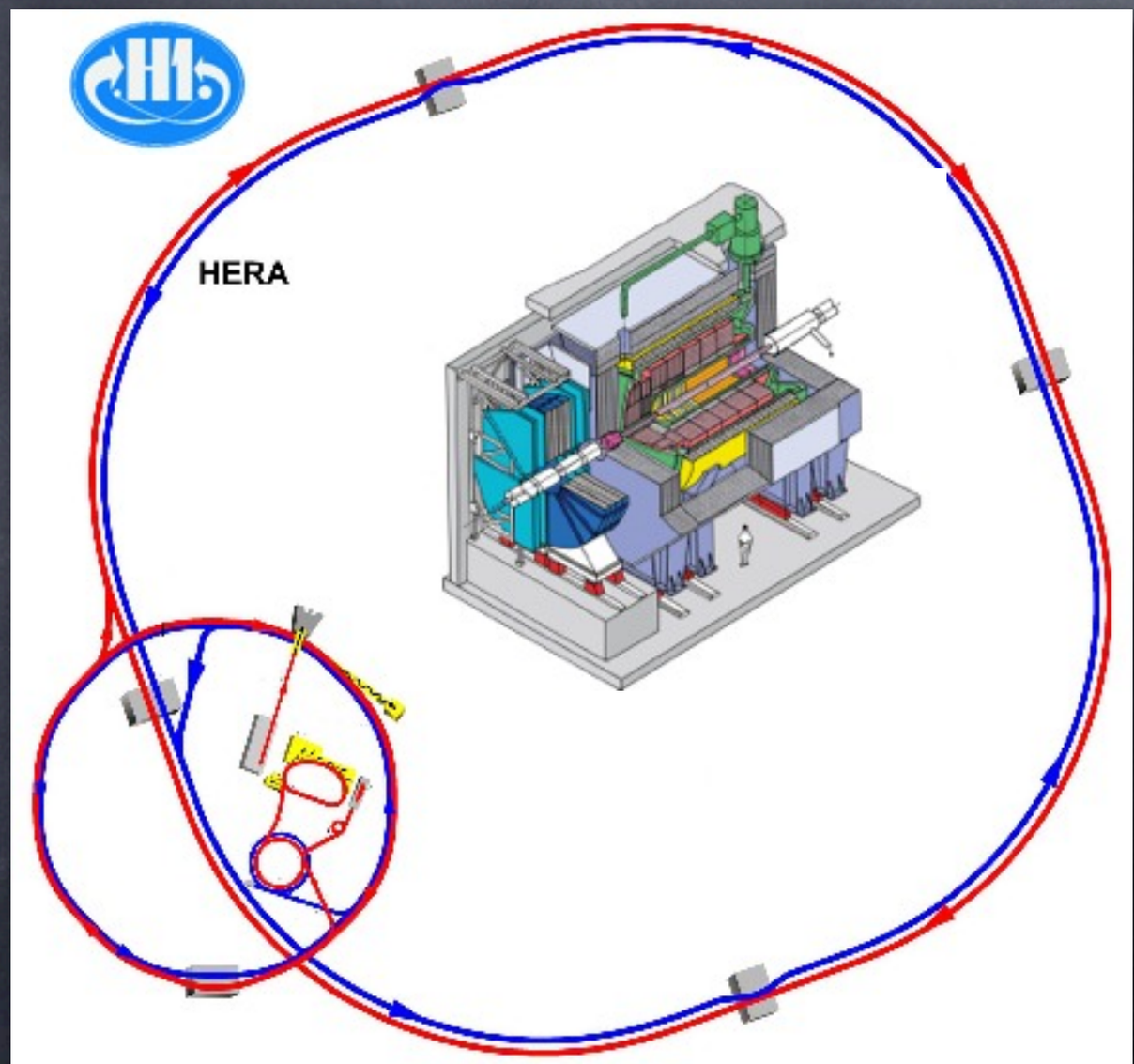
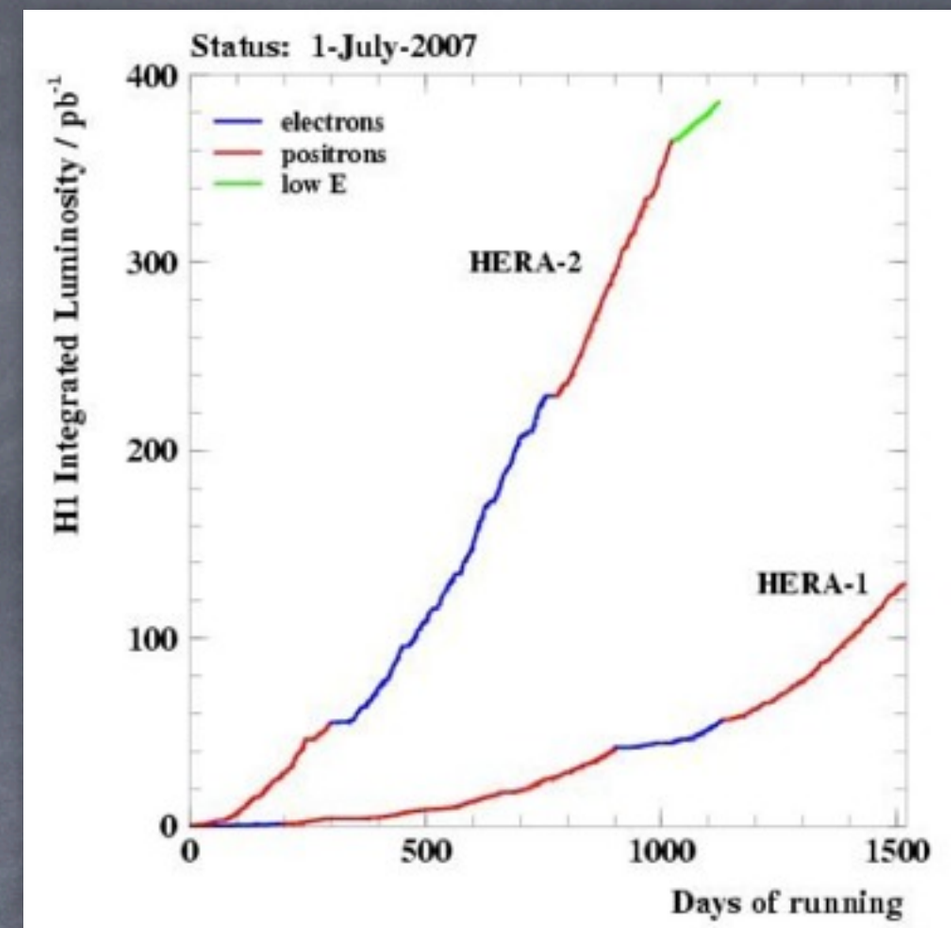
H1 @ HERA





1992 - 2007

Hadron Elektron Ring Anlage

Hamburg (Germany)

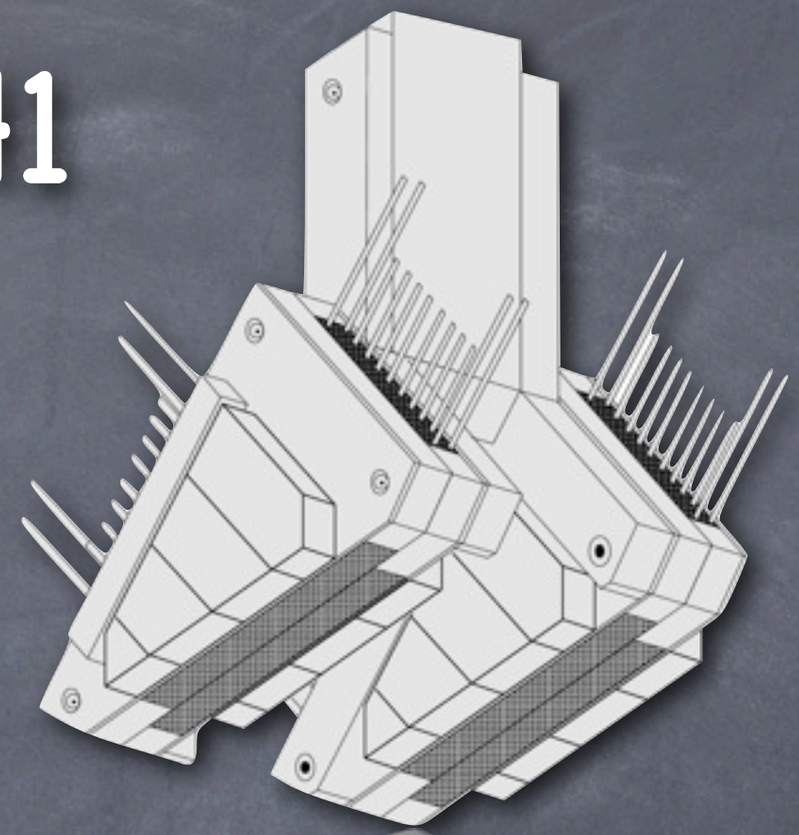
$e^{\pm}$ 27.5 GeV

p 920 GeV

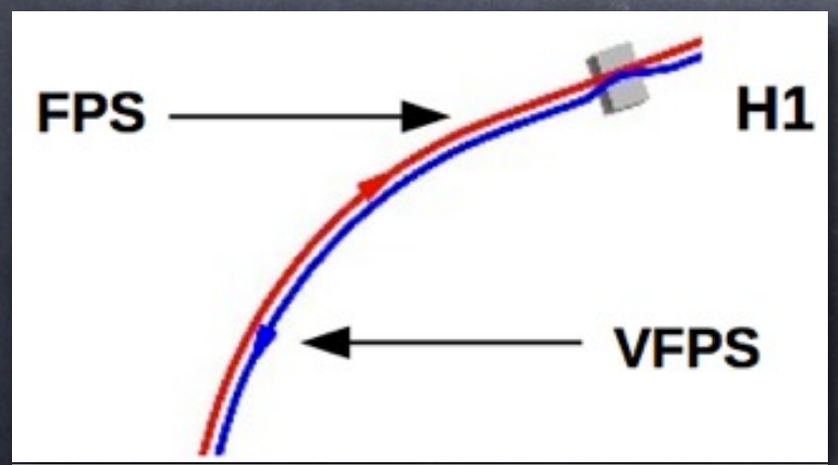
L_{int} ~0.5 fb^{-1}

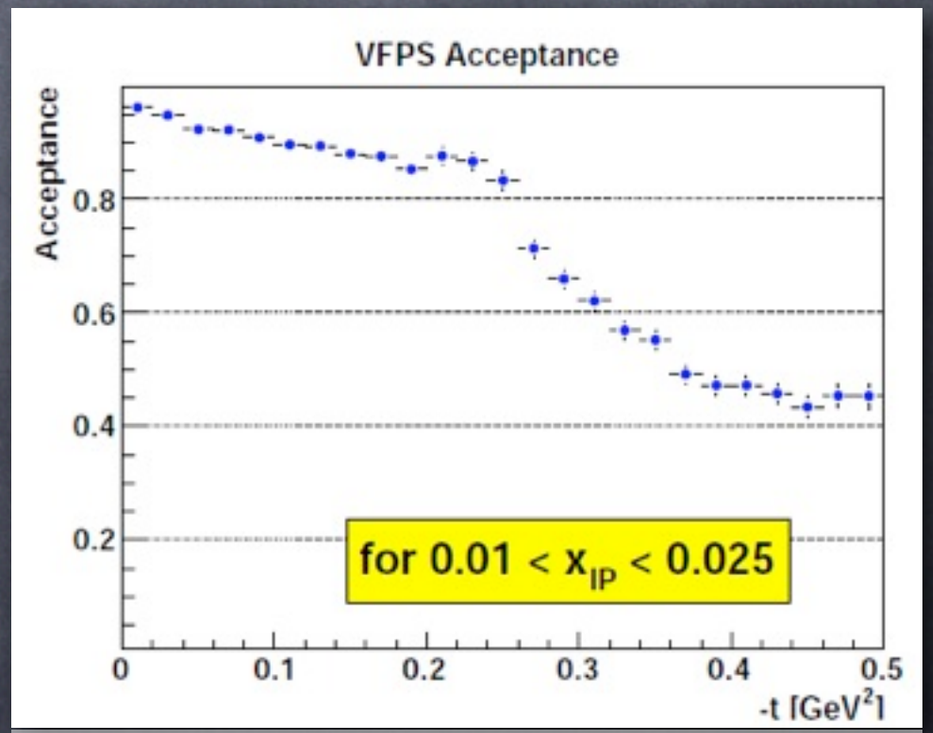
H1 & ZEUS ... 4π, asymmetric

VFPS + FPS @ H1

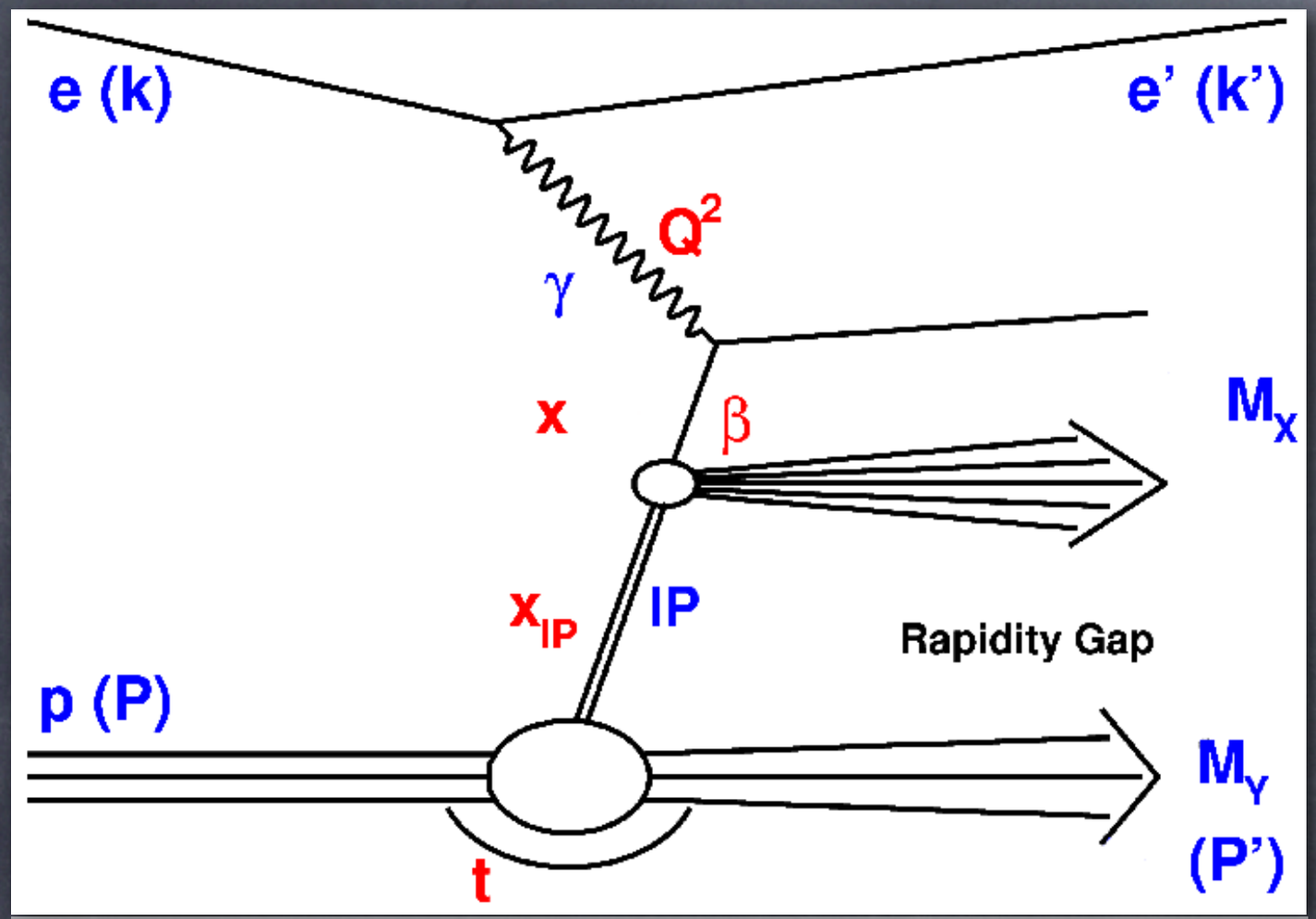


- **Very Forward Proton Spectrometer**
  - 2 stations at z=+220m, each 2 sub-detectors
  - scintillating fibres with PMTs + trigger tiles
  - very high acceptance for $0.01 < x_{IP} < 0.025$
- **Forward Proton Spectrometer:**
  - 61m and 80m horizontal stations
  - Acceptance:
    - $x_{IP} = 1 - Ep' / Ep$ 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

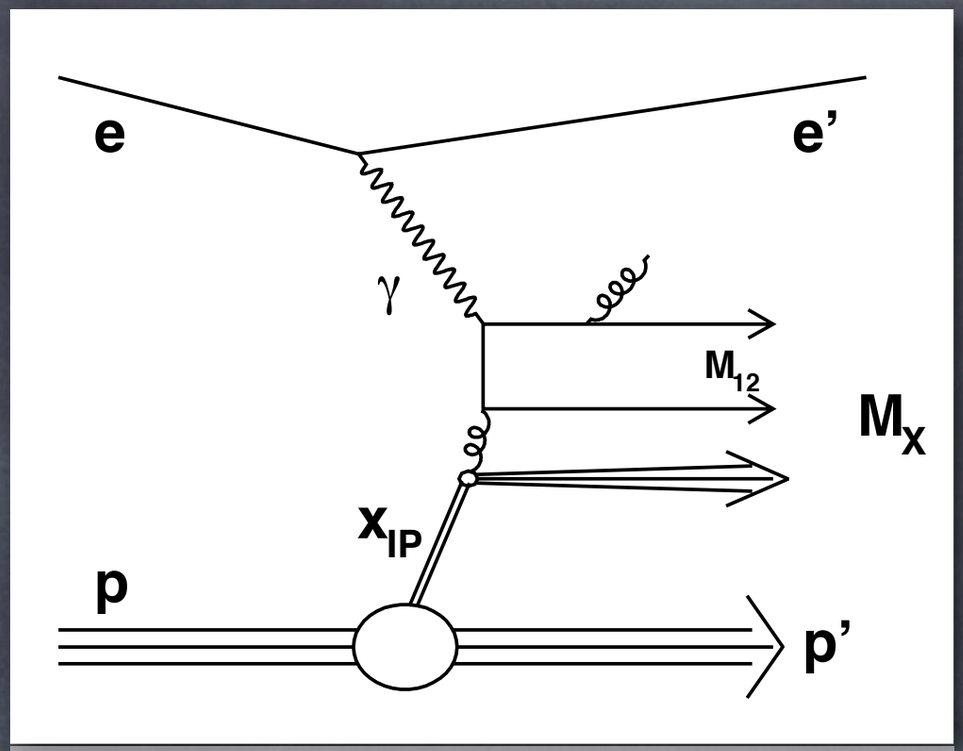
Collins factorisation, proven:

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

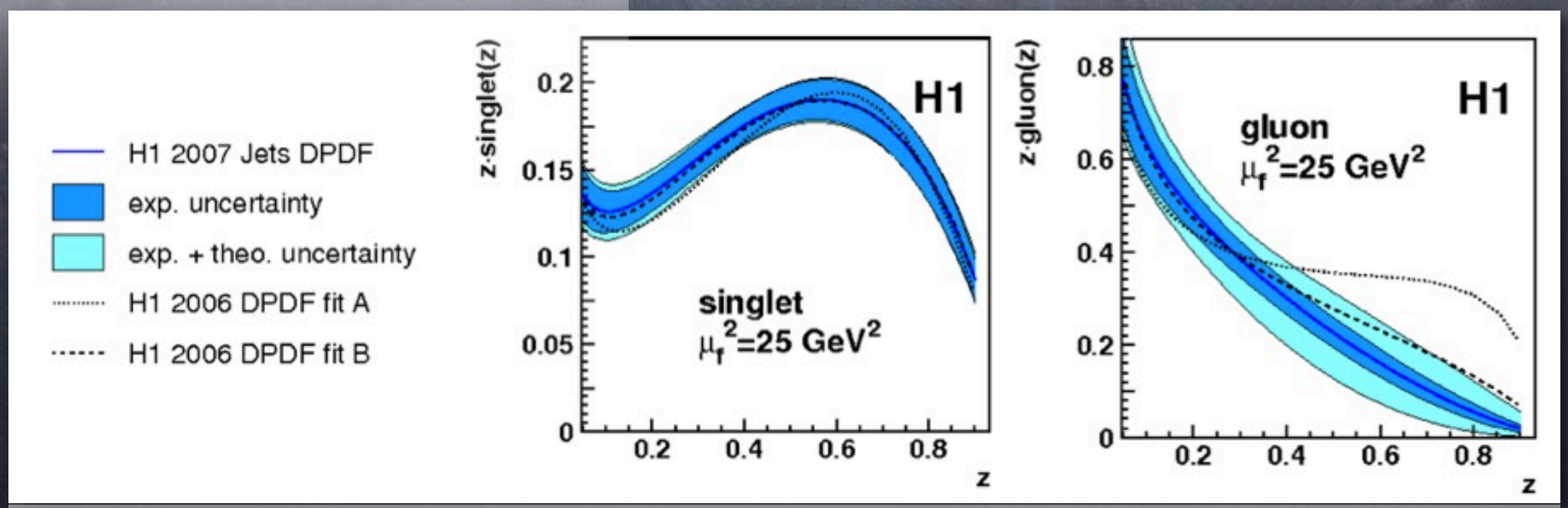
Proton Vertex Factorisation, consistent with data:

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

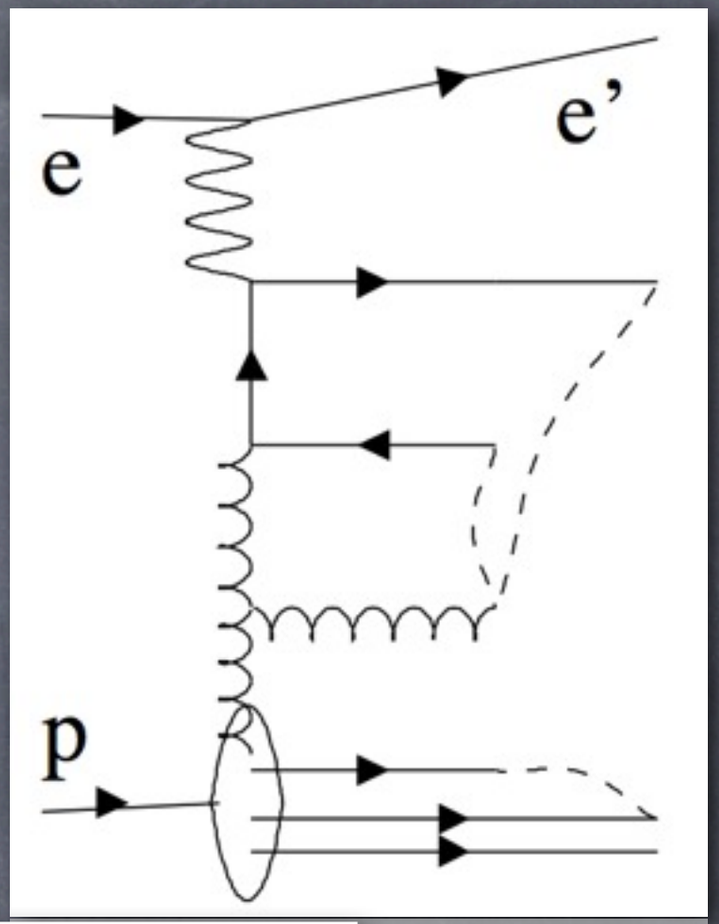
Diffractive PDFs



- DPDF extraction from inclusive measurements has large uncertainties -> 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

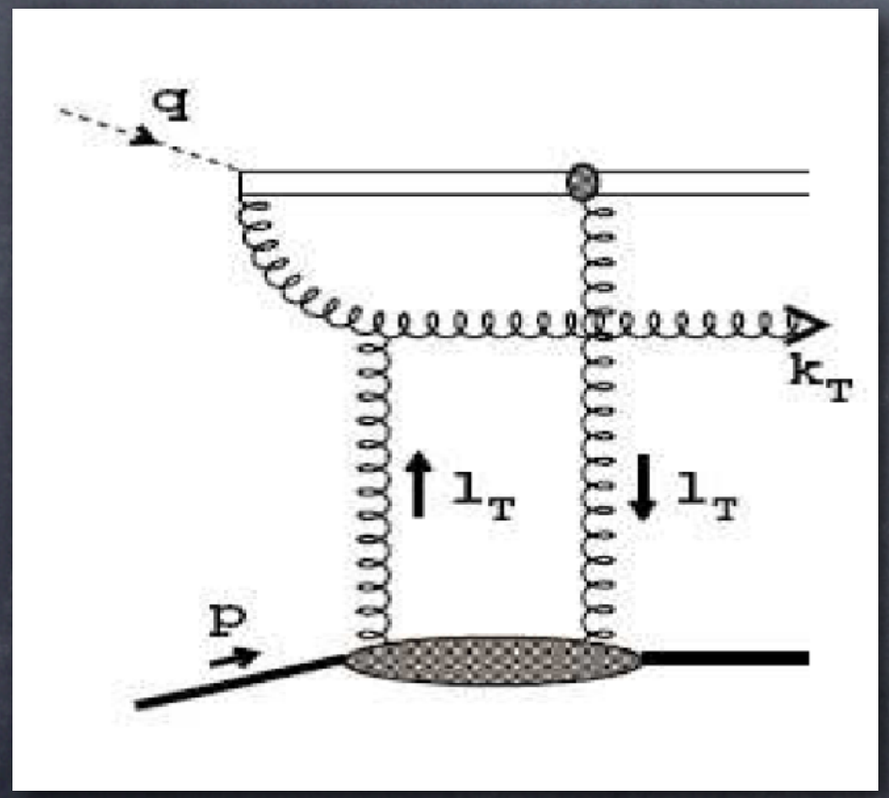


Soft Colour Interaction (SCI)

Rearrangement of colour strings in the final state

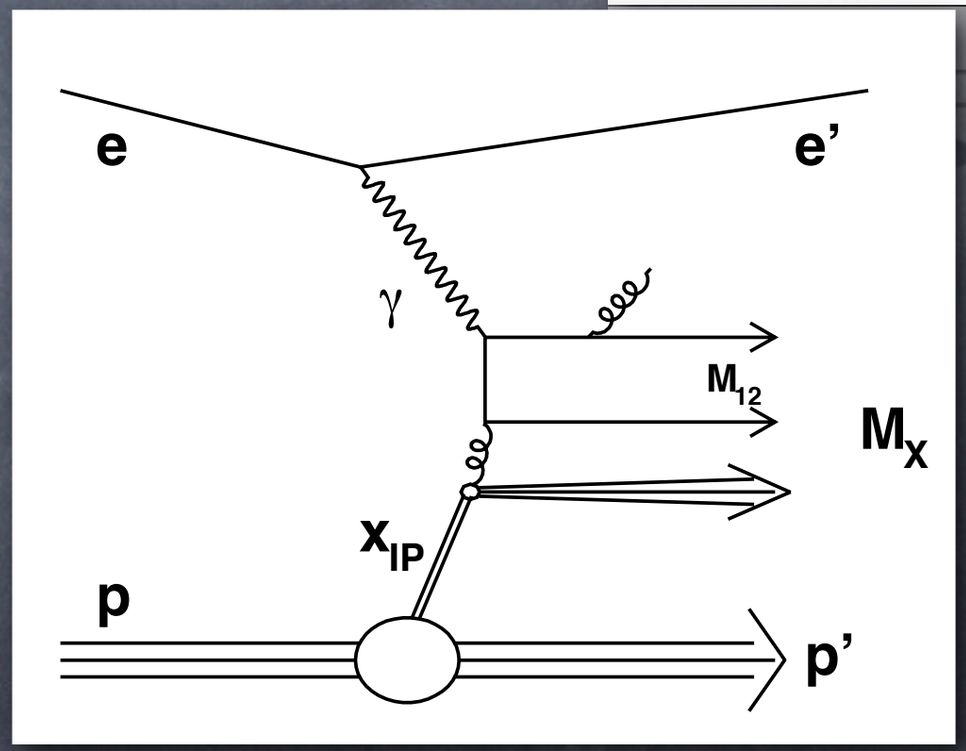
Suppression of long strings (+GAL)

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}

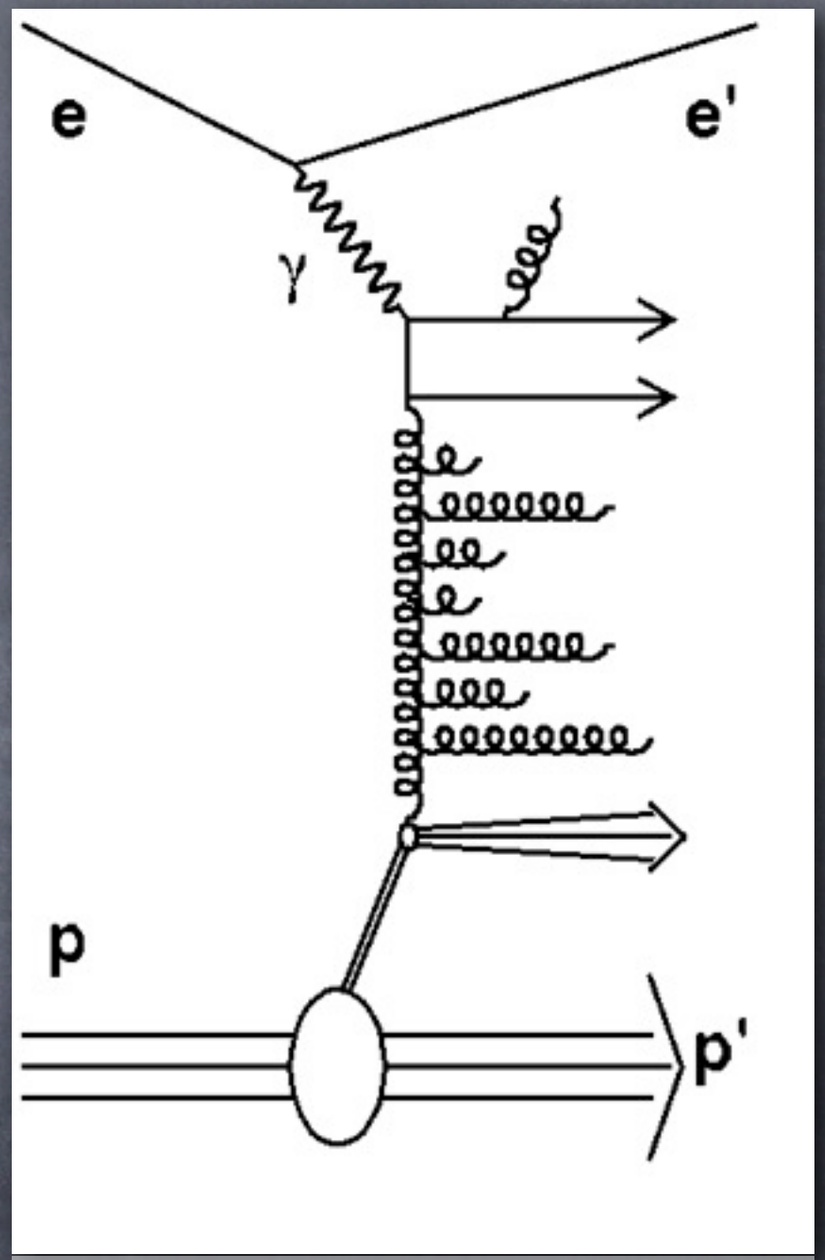


Resolved Pomeron

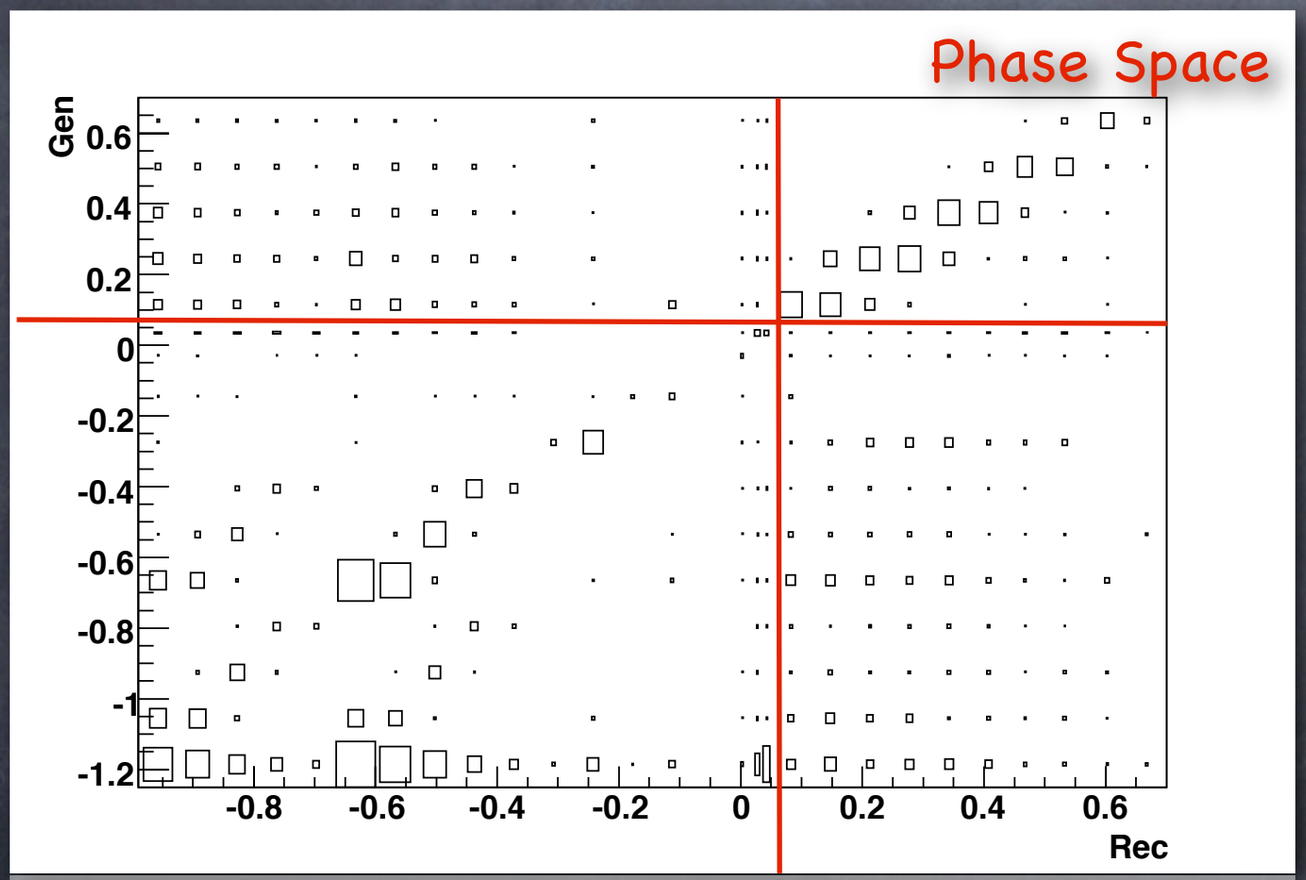
based on QCD and proton vertex factorisation

Beyond DGLAP...

- DGLAP:
  - strong p_T and x ordering
- BFKL:
  - no p_T ordering, strong x ordering, hard parton at the beginning of the ladder may be emitted
- in diffractive case, no proton remnant in the forward region
- 1 central + 1 forward jet selection:
  - $p_T > 3.5$ GeV, $M_{jj} > 12$ GeV
  - $-1 < \eta_c < 2.5$, $1 < \eta_f < 2.8$, $\eta_c < \eta_f$



Unfolding

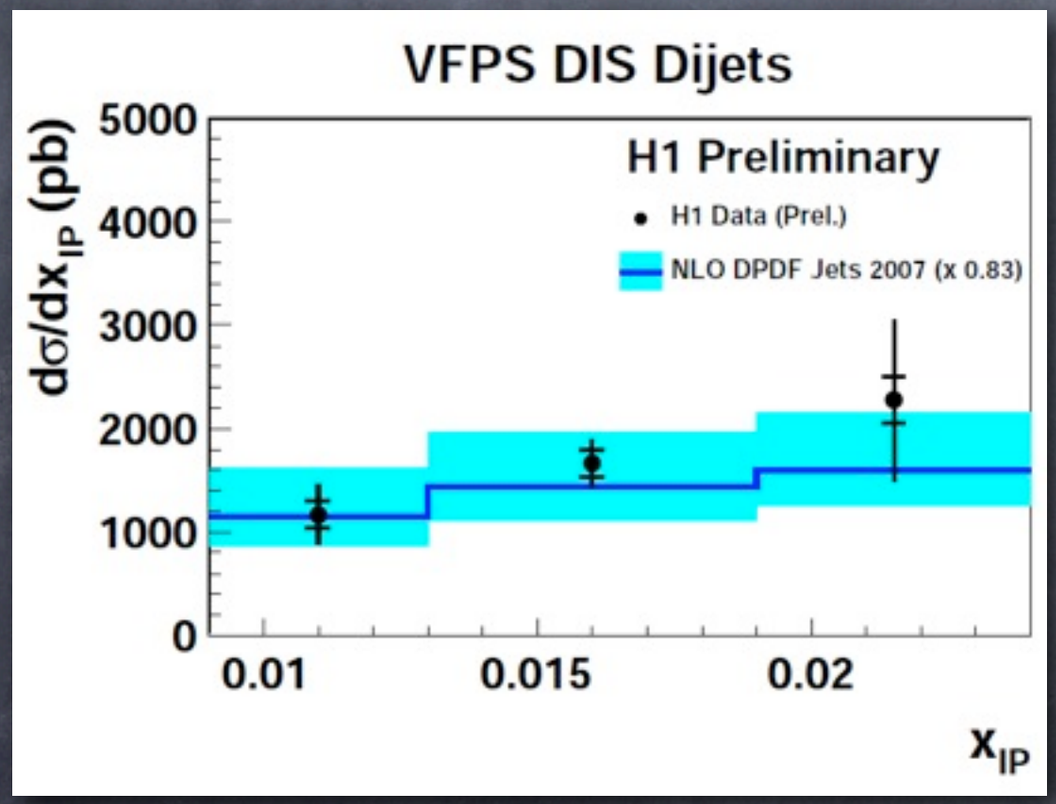


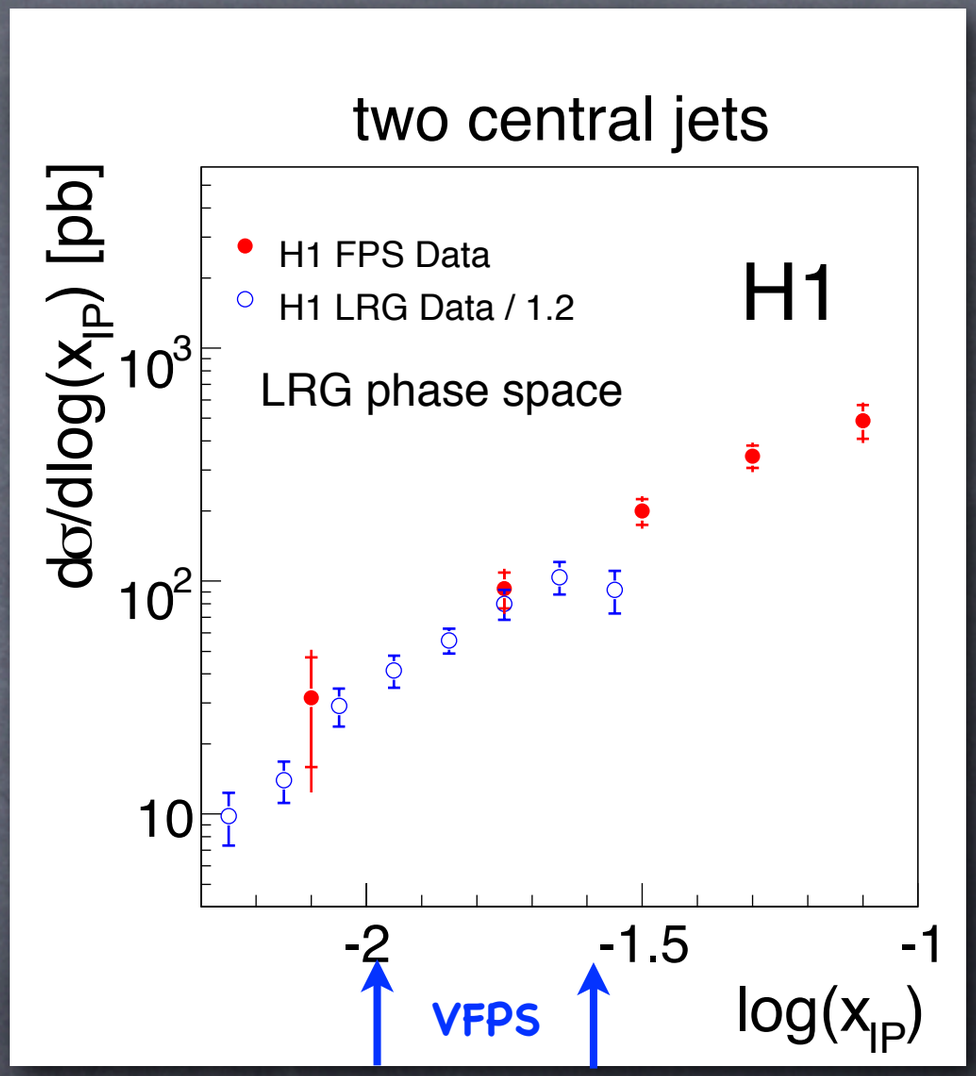
- low p_T jet measurement suffers from low purity - migrations of events from outside of phase space definition up to ~60%
- => matrix unfolding from the reconstructed to the truth level used
- TUnfold (ROOT package)
- requires measurements of "control regions" outside of the analysis phase space
- statistically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

Comparison of LRG and PS

$4\ \mathrm{GeV}^2 < Q^2 < 80\ \mathrm{GeV}^2$
$0.1 < y < 0.7$
$p_{T1}^* > 5.5$ GeV
$p_{T2}^* > 4.0$ GeV

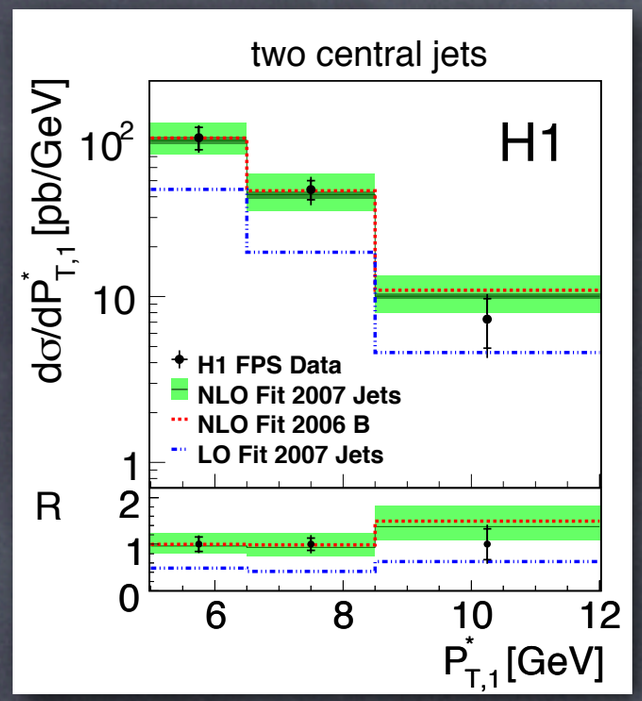
- diffractive DIS dijet analysis with LRG (JHEP 0710:042)
- LRG data are corrected for proton dissociation

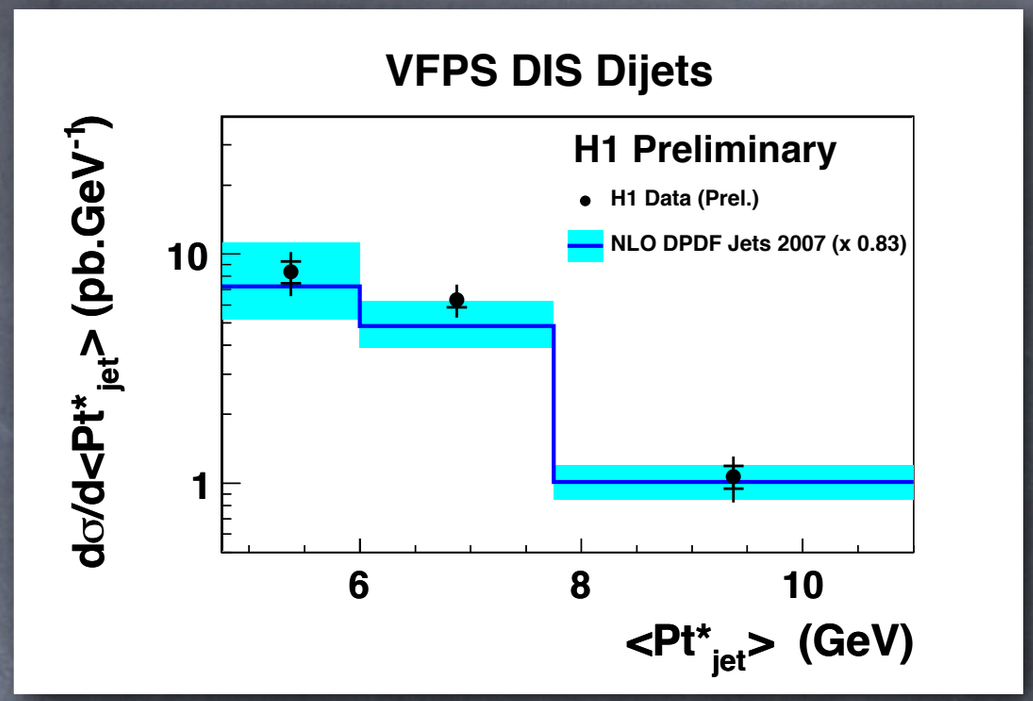




very good agreement between reconstruction methods
phase space extension by factor of 3 in x_{IP} wrt LRG
same fraction of proton dissociation as for incl. diff.

Comparison with NLO





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

$0.1 < y < 0.65$

$0.009 < x_{IP} < 0.024$

$p_{T1}^* > 5.5$ GeV

$p_{T2}^* > 4.0$ GeV

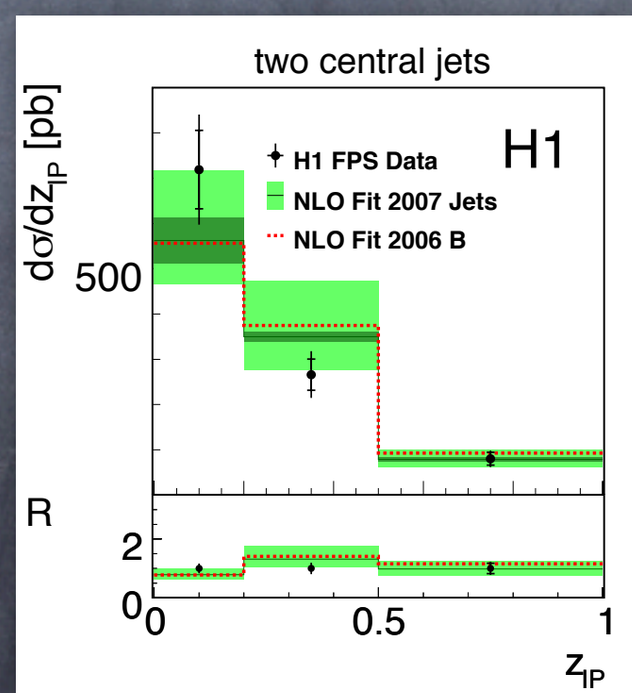
$4\ \mathrm{GeV}^2 < Q^2 < 110\ \mathrm{GeV}^2$

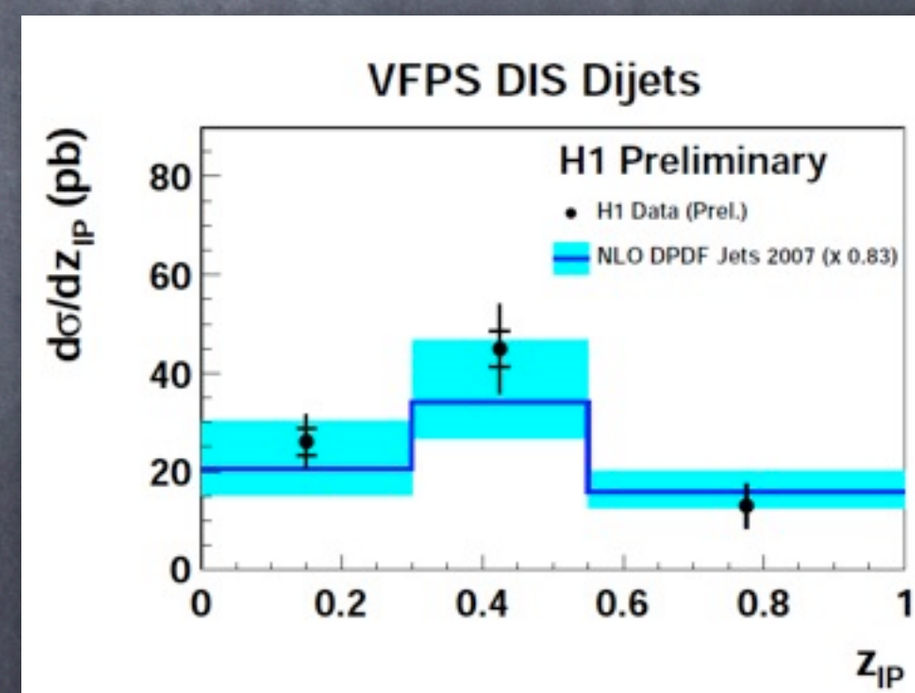
$0.1 < y < 0.7$

$0.003 < x_{IP} < 0.1$

$p_{T1}^* > 5.0$ GeV

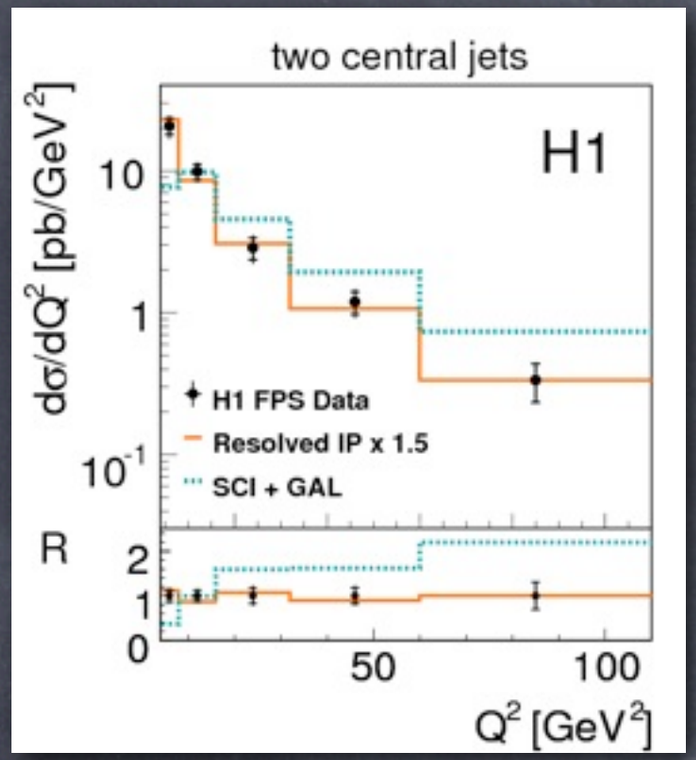
$p_{T2}^* > 4.0$ GeV





Data are well described by the NLO predictions

Comparison with LO MC



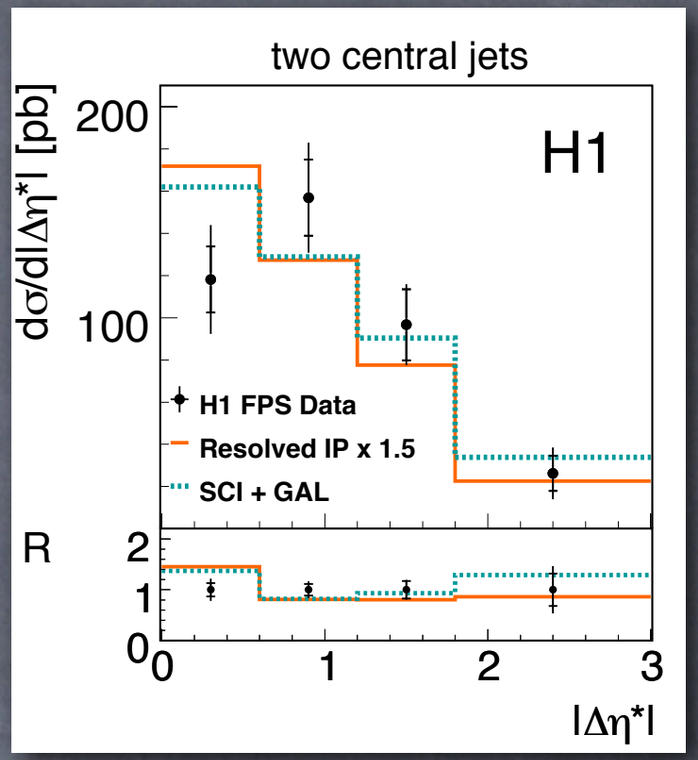
$4\ \mathrm{GeV}^2 < Q^2 < 110\ \mathrm{GeV}^2$

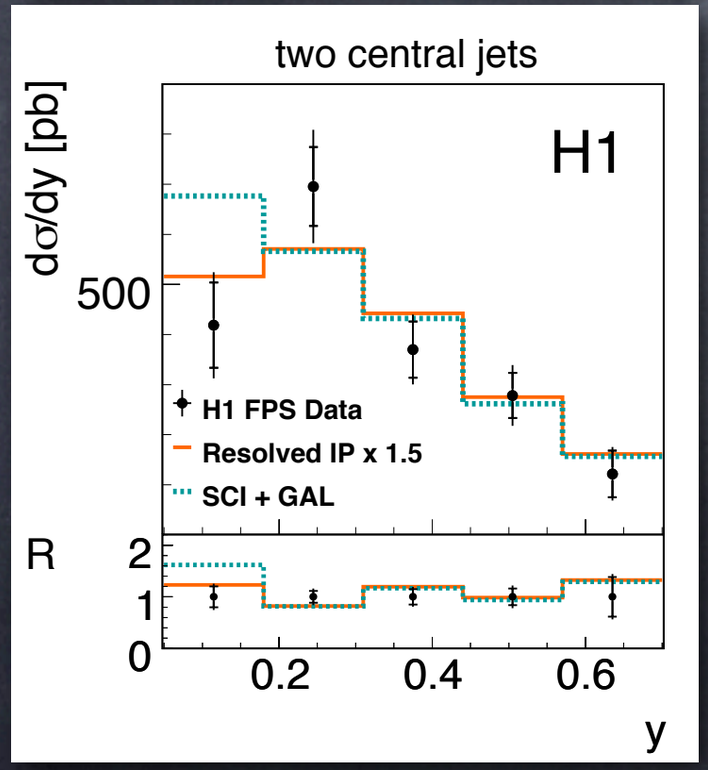
$0.1 < y < 0.7$

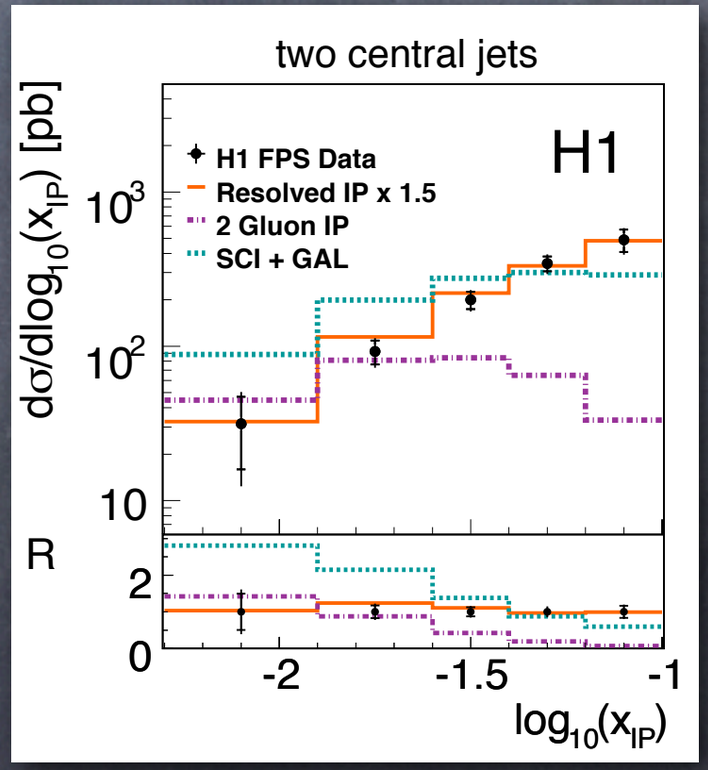
$0.003 < x_{IP} < 0.1$

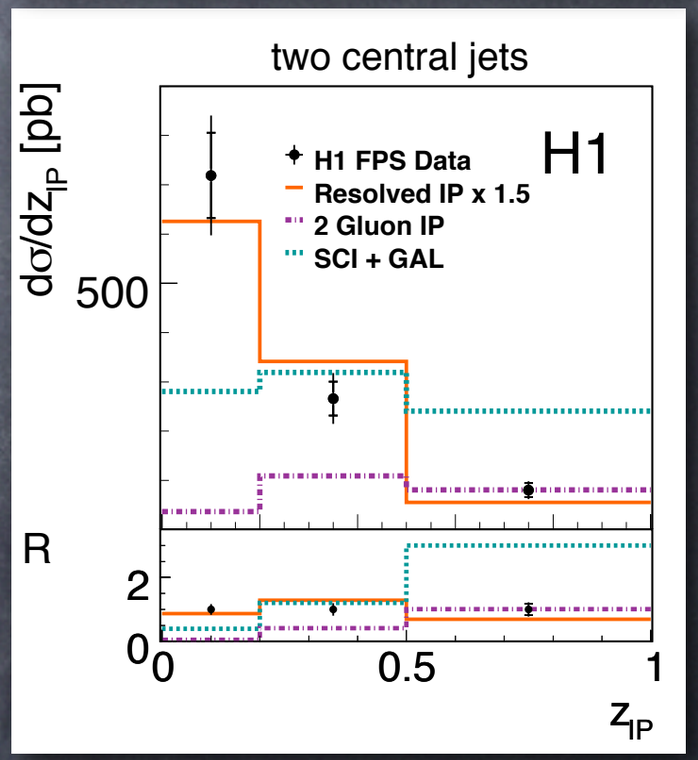
$p_{T1}^* > 5.0$ GeV

$p_{T2}^* > 4.0$ GeV







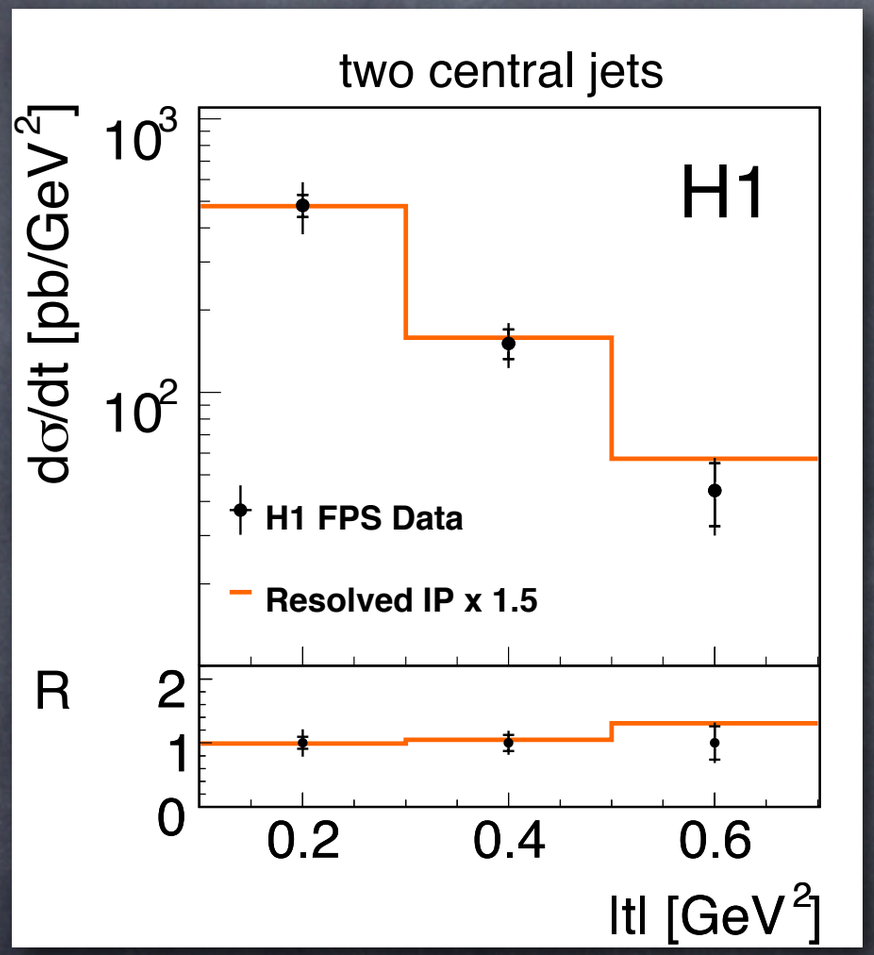


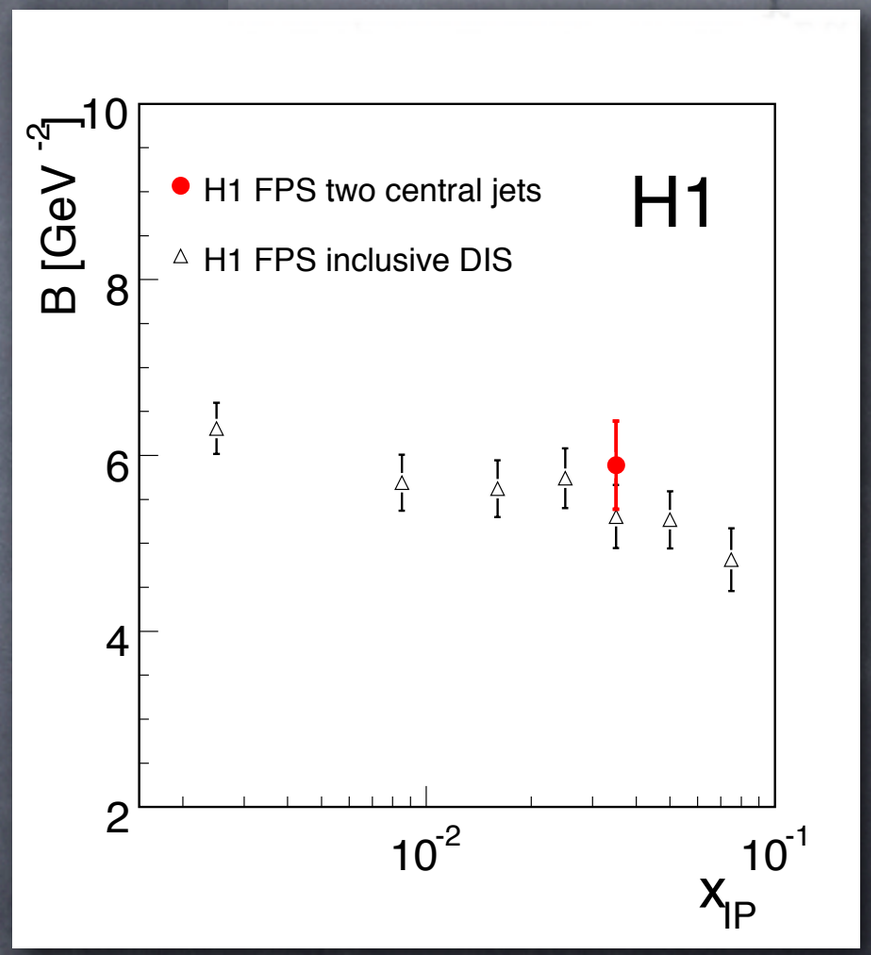
none of MC models describes the data in all aspects

Proton vertex factorisation

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

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

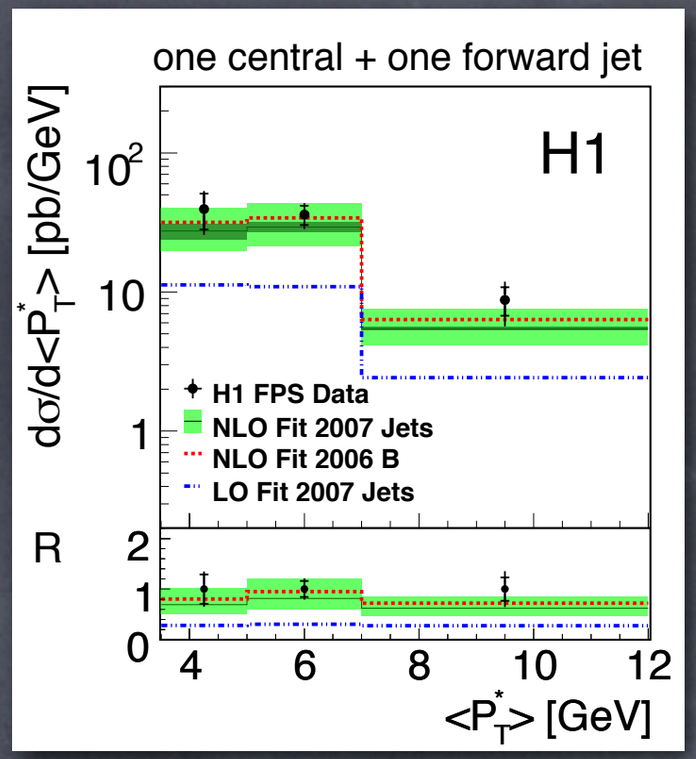


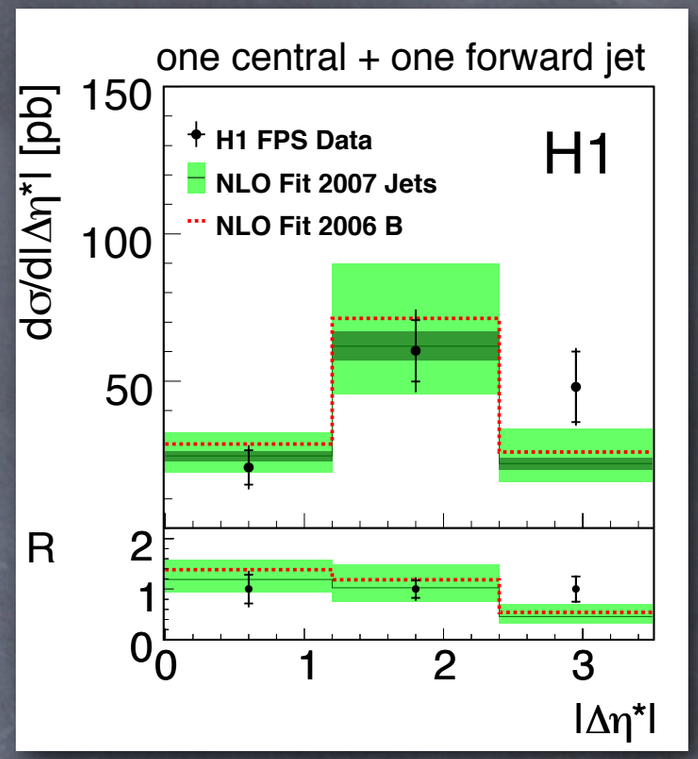


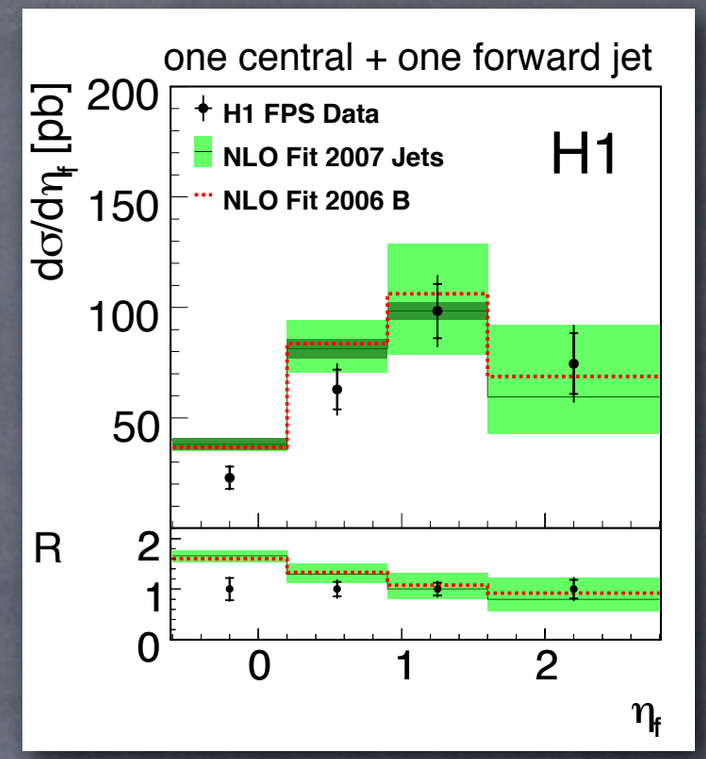
$B = 5.89 \pm 0.50\ \mathrm{GeV}^{-2}$

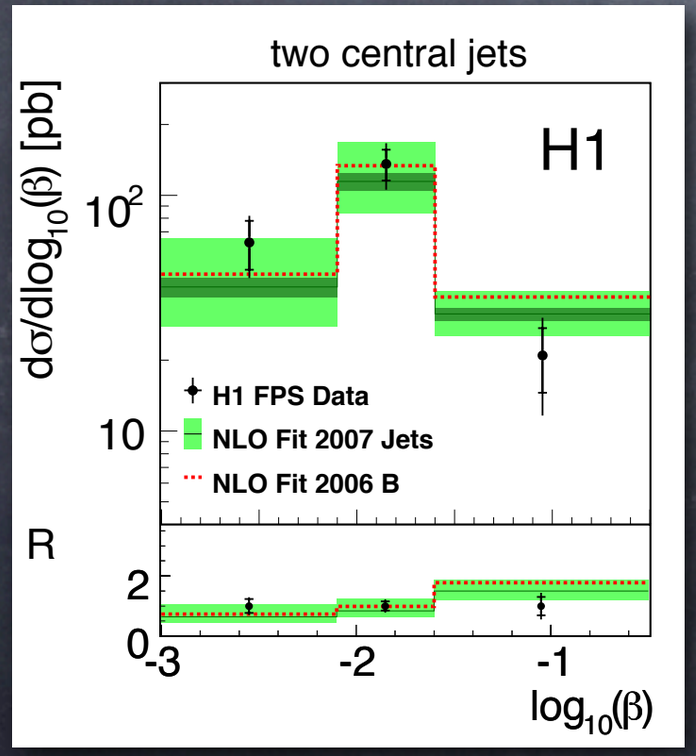
consistent with inclusive measurement

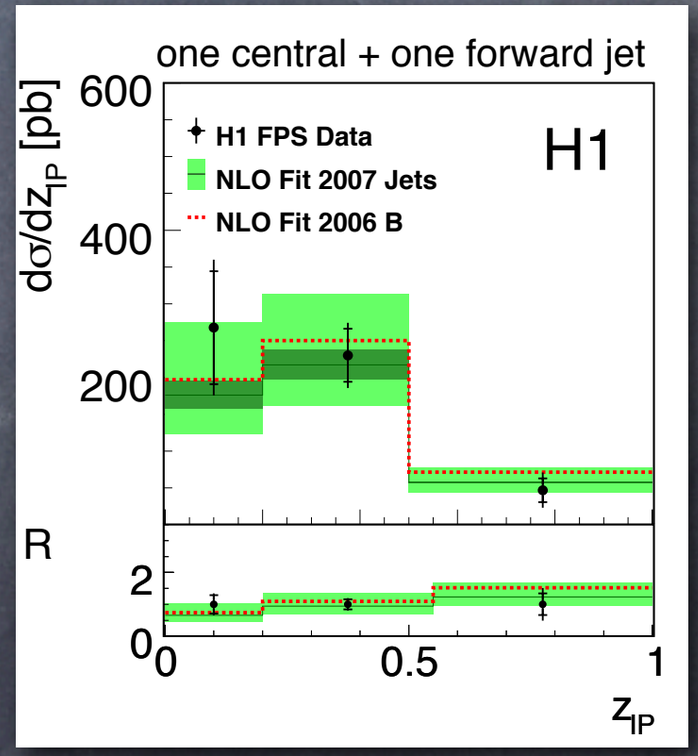
Comparison with DGLAP NLO - 1 central + 1 forward jet

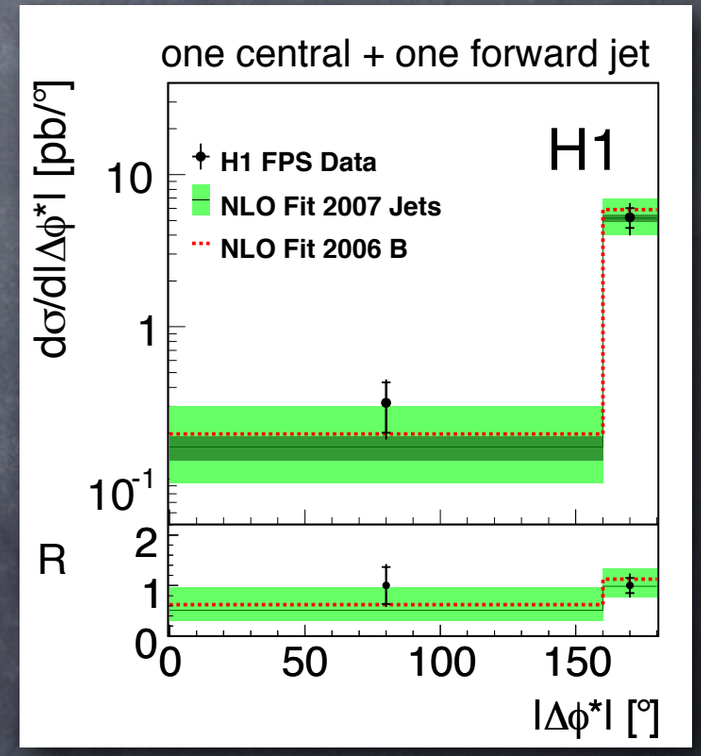






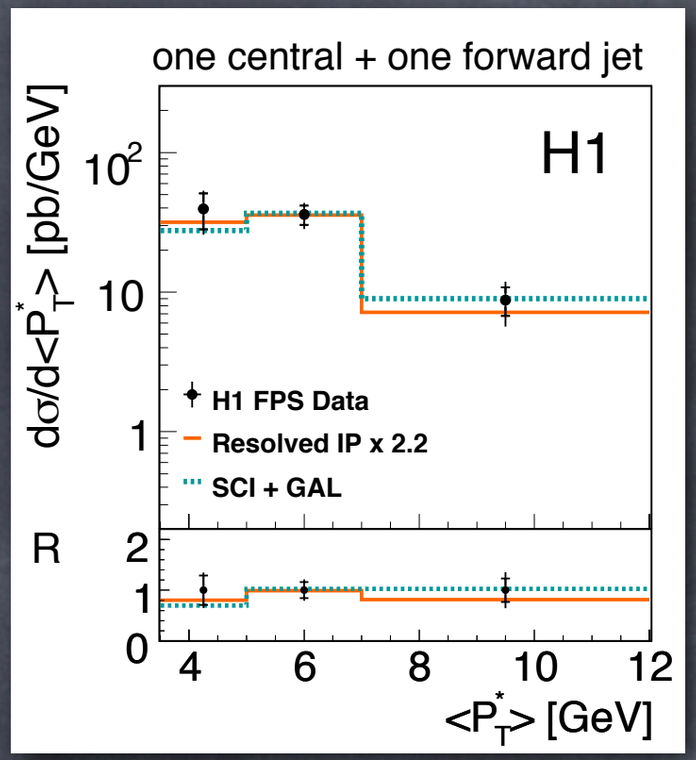


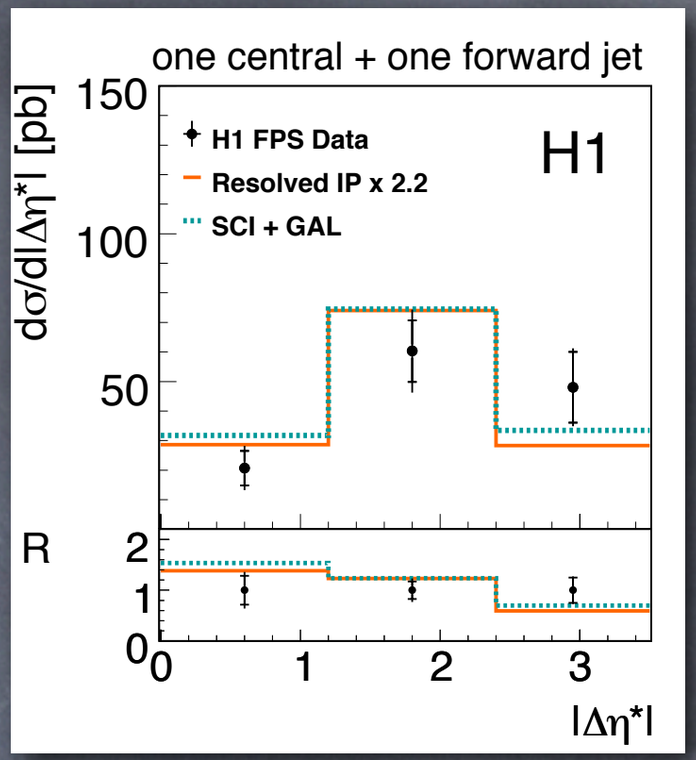


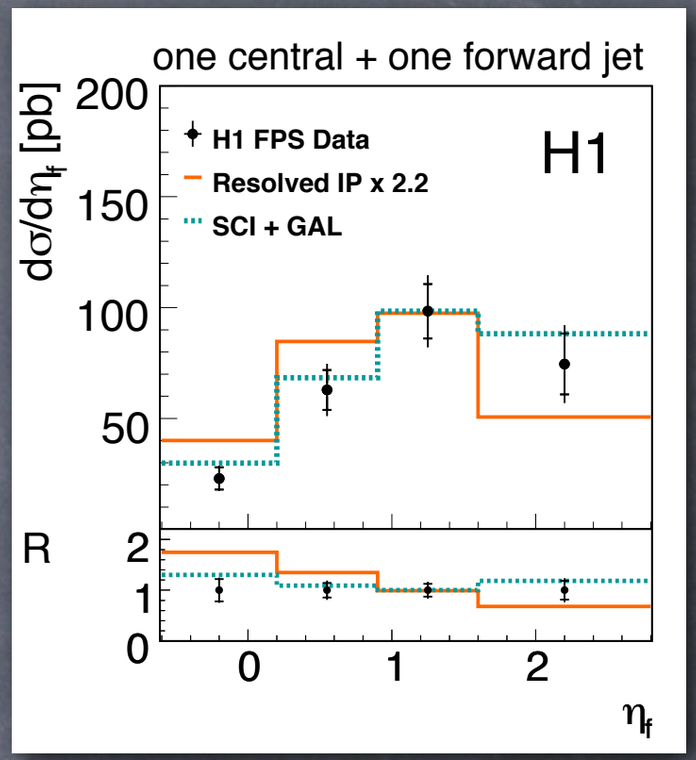


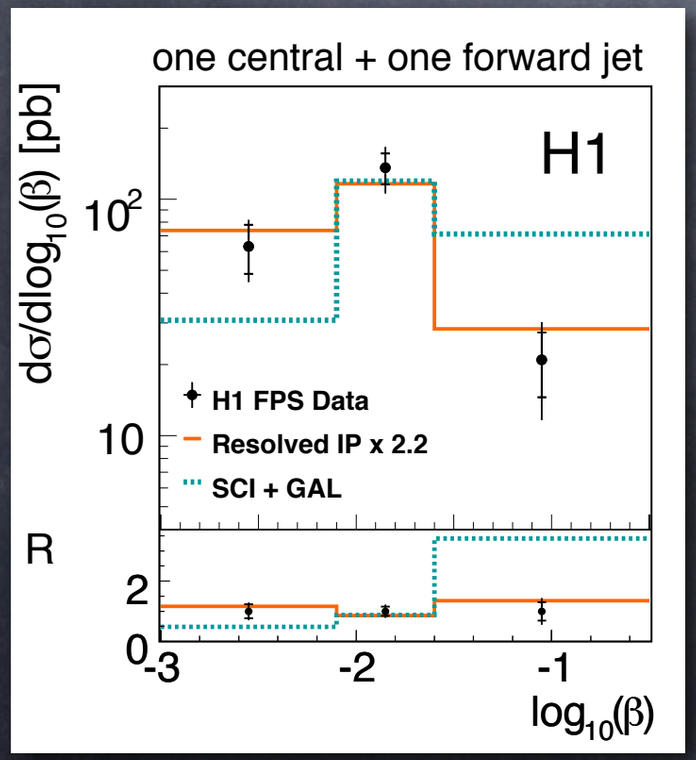
No significant devations from DGLAP NLO QCD

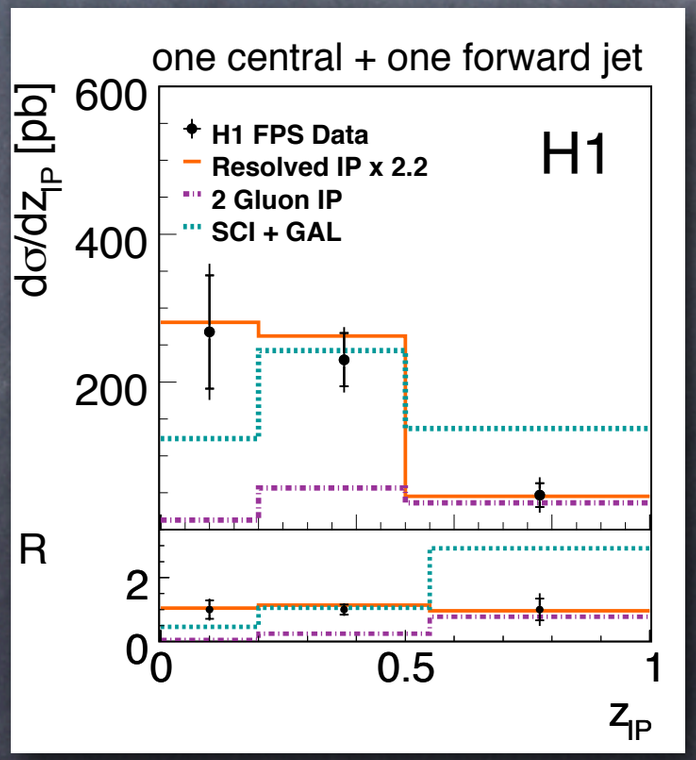
Comparison with LO MC - 1 central + 1 forward jet

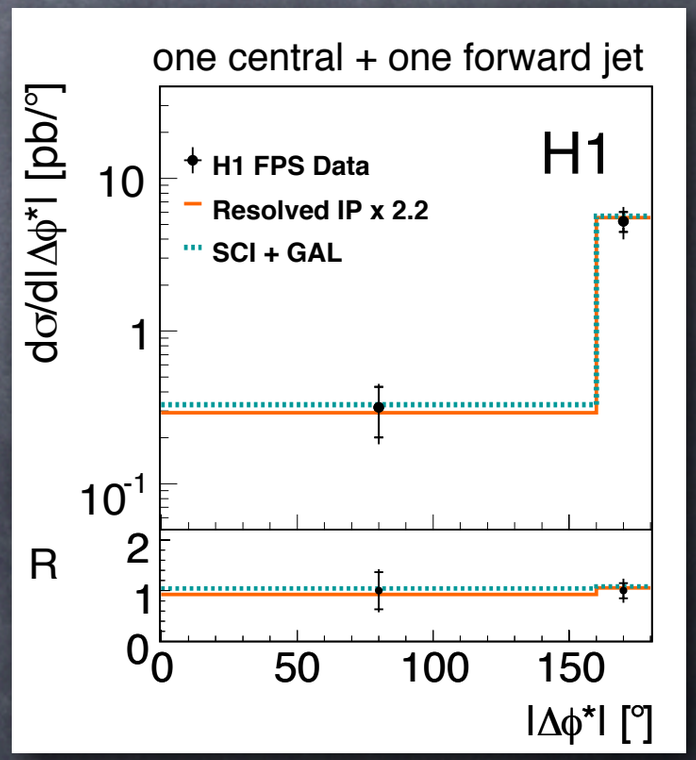










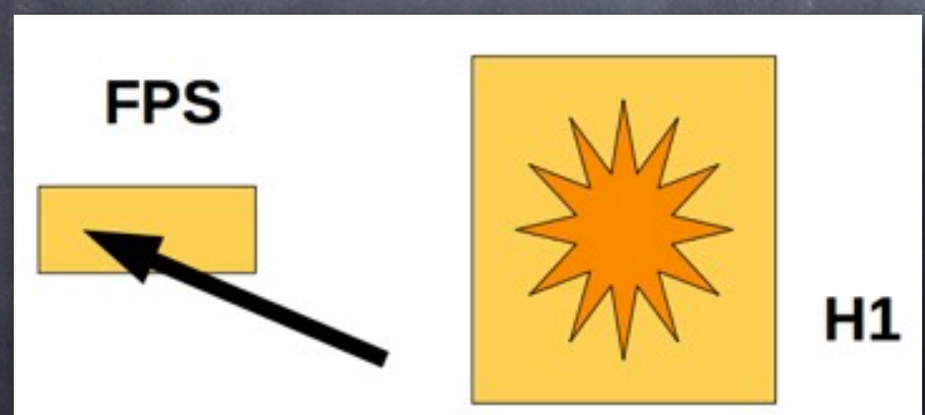
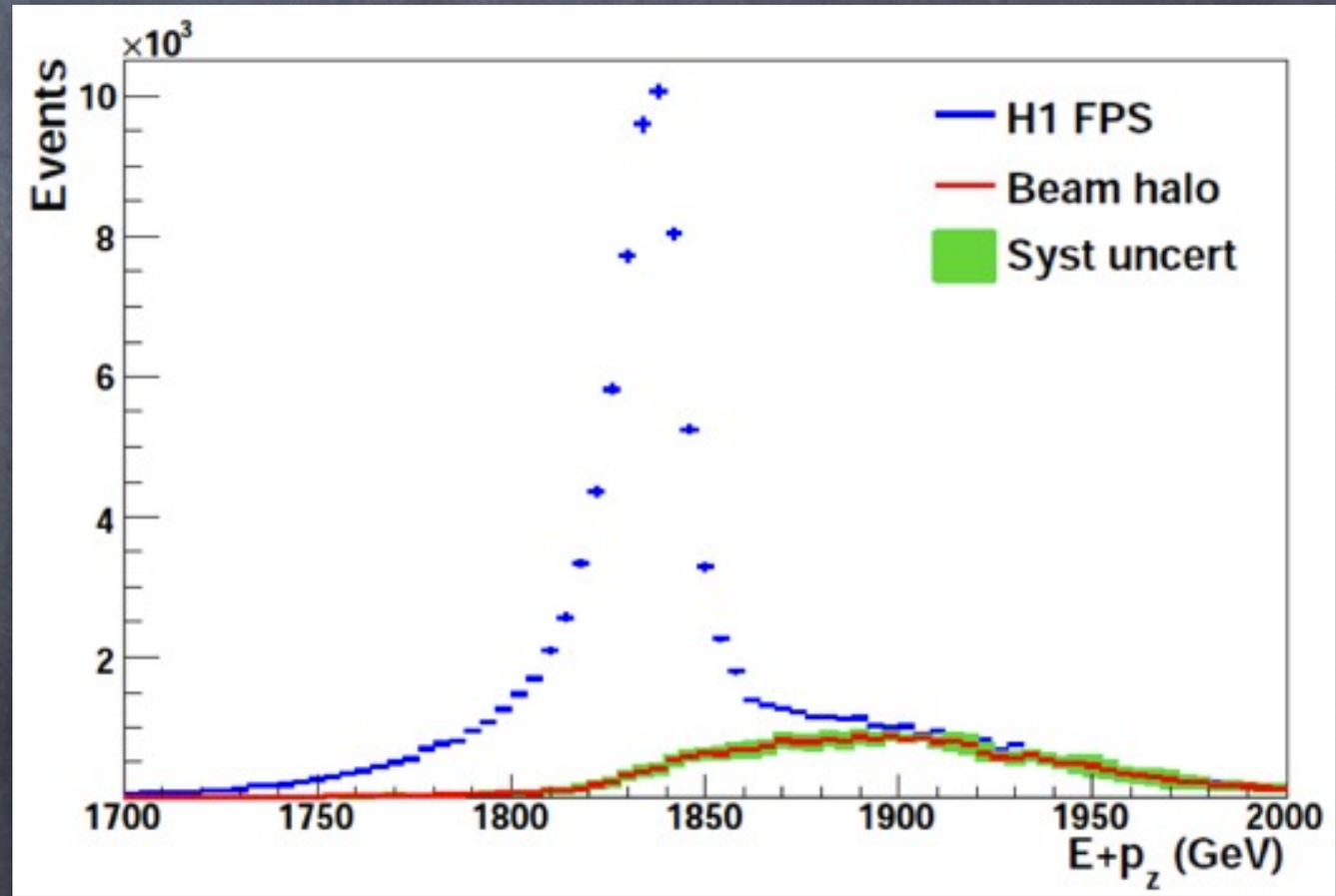


none of MC models describes the data in all aspects

Summary

- Diffractive dijet measurement with a tagged leading proton performed for the first time with the VFPS and FPS spectrometers
- Data agree well with a previous measurement using the LRG method
- amount of proton dissociation in dijet events is same as in inclusive events (LRG/FPS ~1.2)
- 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