Measurements of jets in diffraction at HERA

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On behalf of the H1 and ZEUS Collaborations

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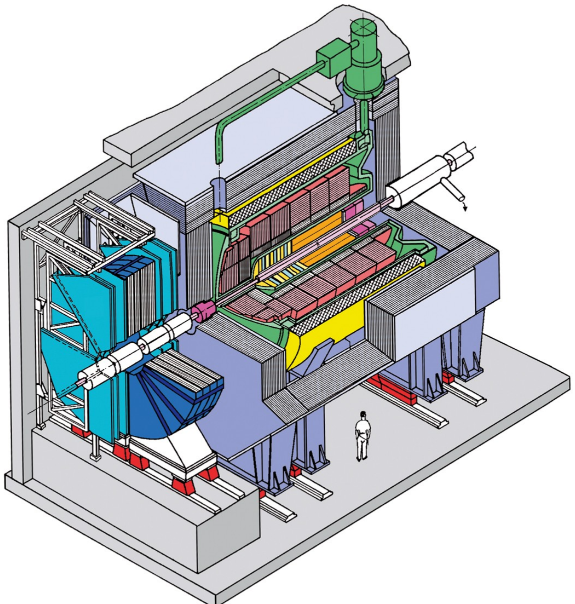
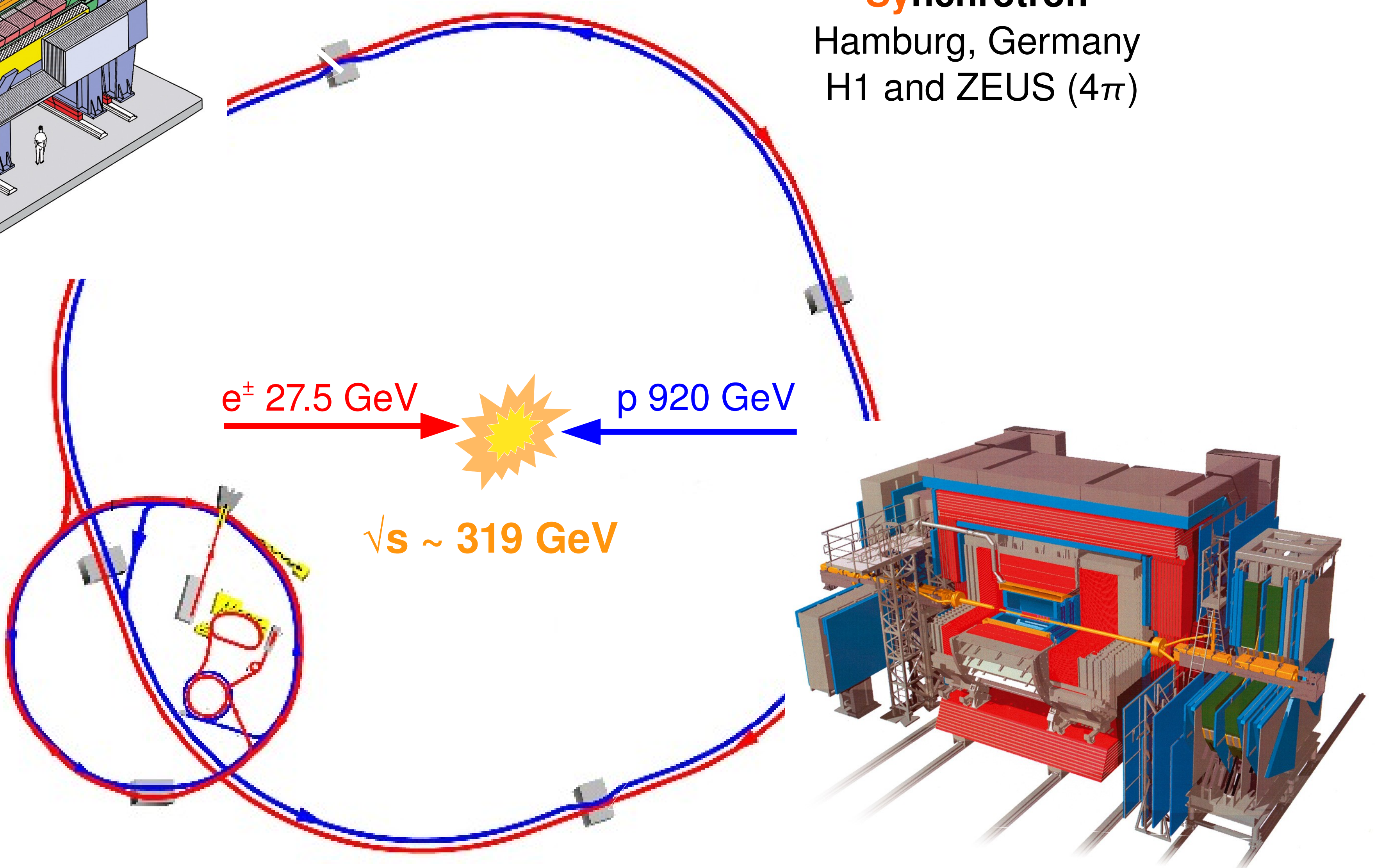
HERA

1992 – 2007
Deutsches Elektronen Synchrotron
Hamburg, Germany
H1 and ZEUS (4π)





Experimental methods

Proton Tagging:

Detection of the leading proton in forward detectors - FPS (**H1**), VFPS(**H1**), LPS (**ZEUS**)

+ direct extraction of diffractive variables, *t* dependence measured

+ free of proton dissociation background

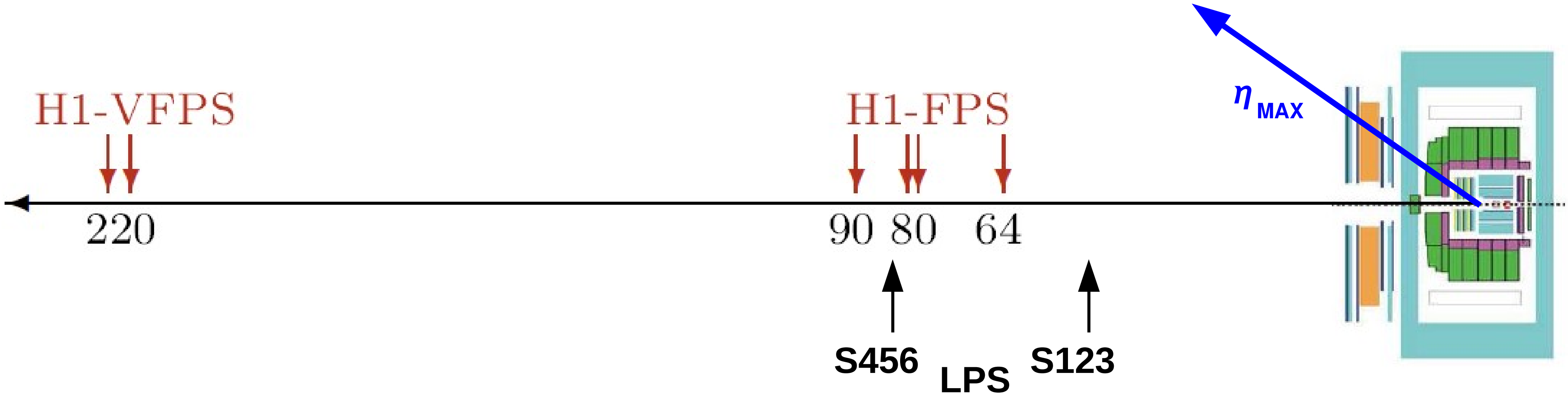
-- small acceptance → low statistics`

LRG method:

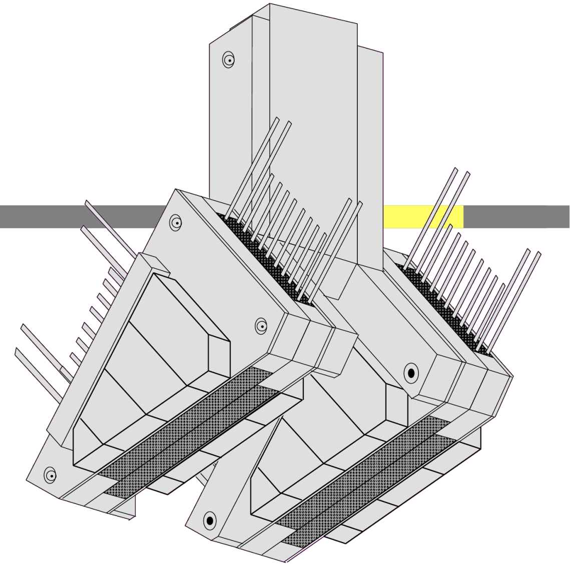
Requirement of no activity in the forward part

+ high statistics

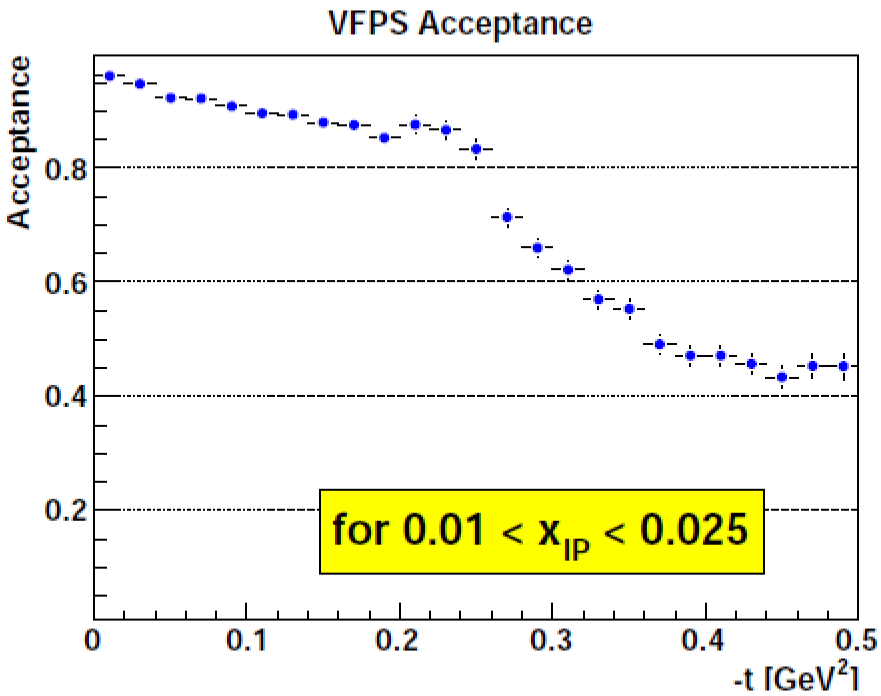
-- proton dissociative background



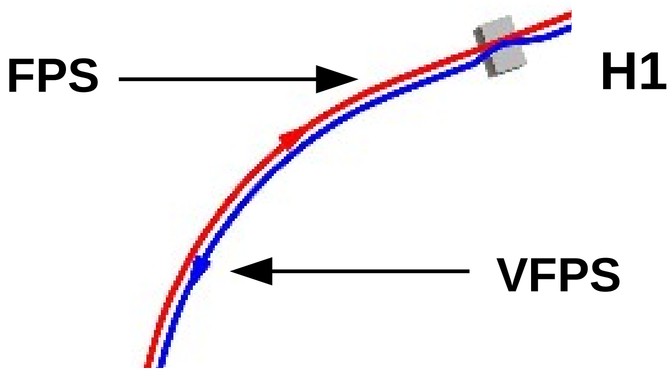
FPS & VFPS @ H1



- Very Forward Proton Spectrometer:
  - 2 stations at z = +220 m, each with 2 subdetectors
  - Scintilating fibres with PMT + trigger tiles
  - Very high acceptance for $0.01 < x_{IP} < 0.025$

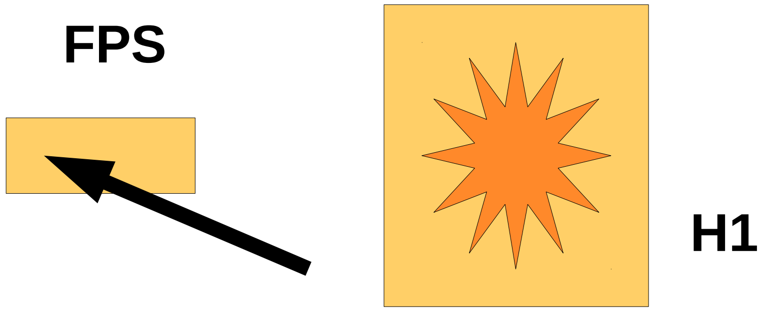


- Forward Proton Spectrometer
  - Same technology like VFPS
  - Position at 64 and 80m
  - Acceptance for $0.005 < x_{IP} < 0.1$

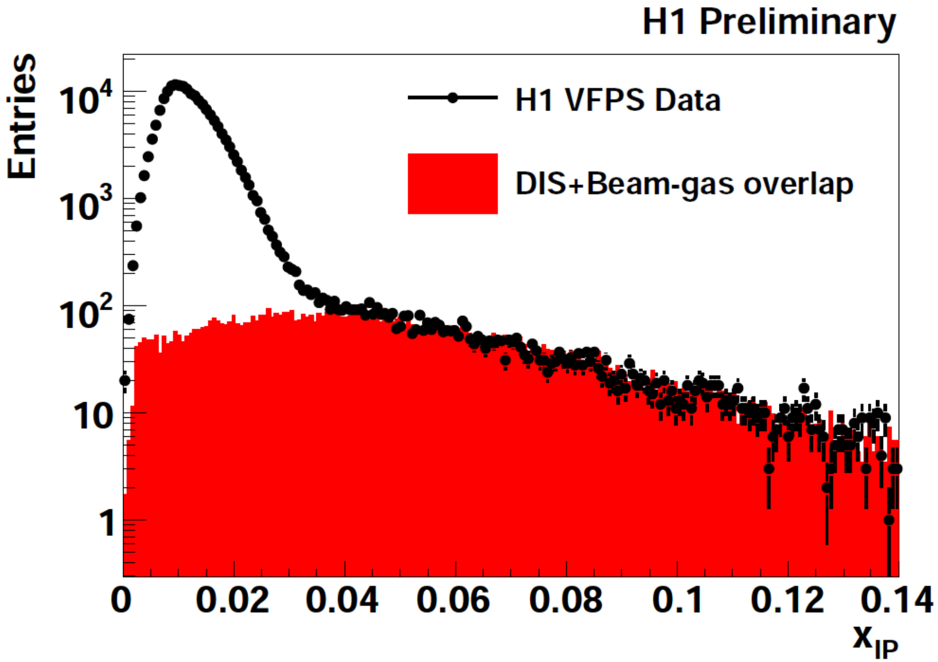


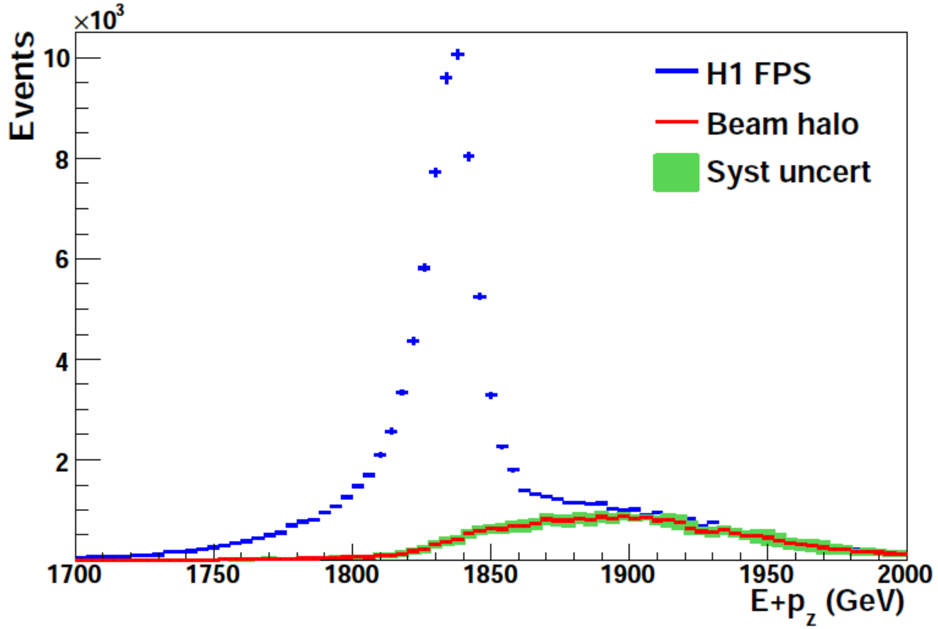
Beam Halo Background

- Coincidence of beam halo protons in (V)FPS and DIS event in H1

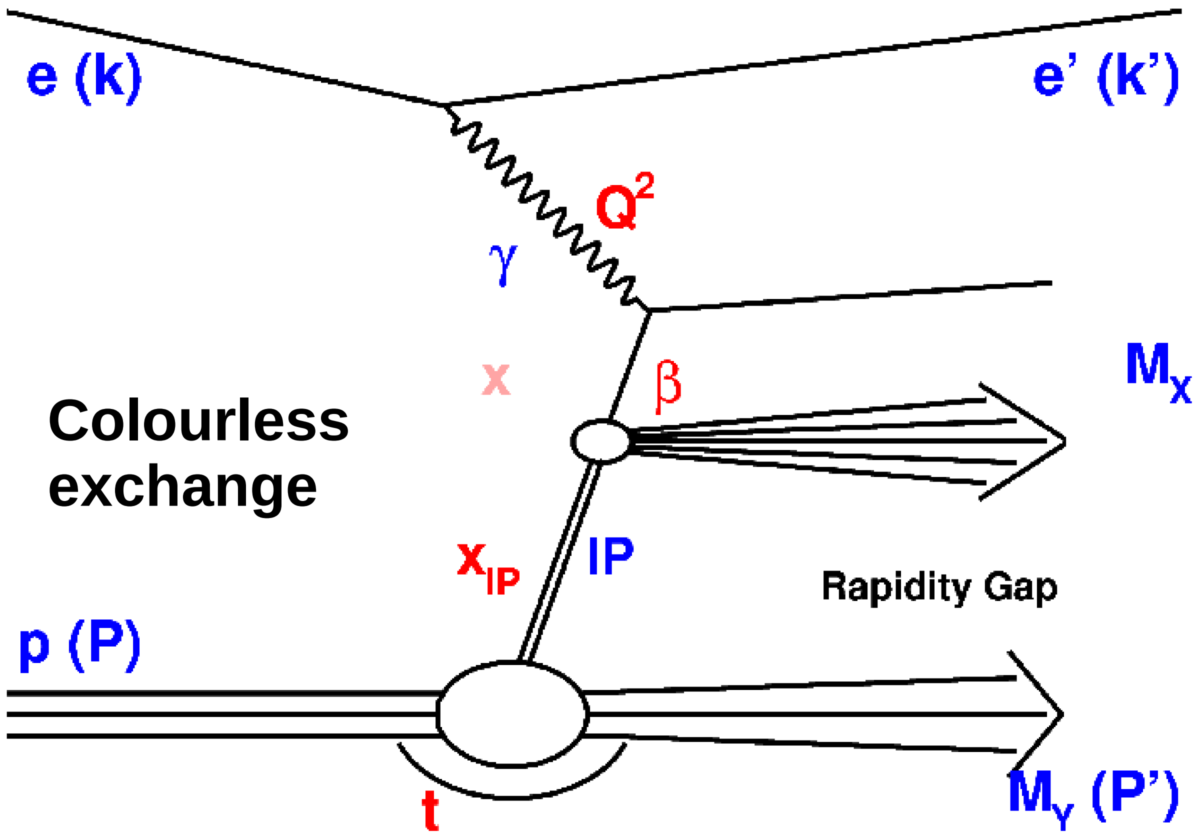


- Data driven Background estimation





Diffractive kinematics



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

$x \;= Q^2/2Pq$

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

$\quad = 1 - E_p/E'_p$

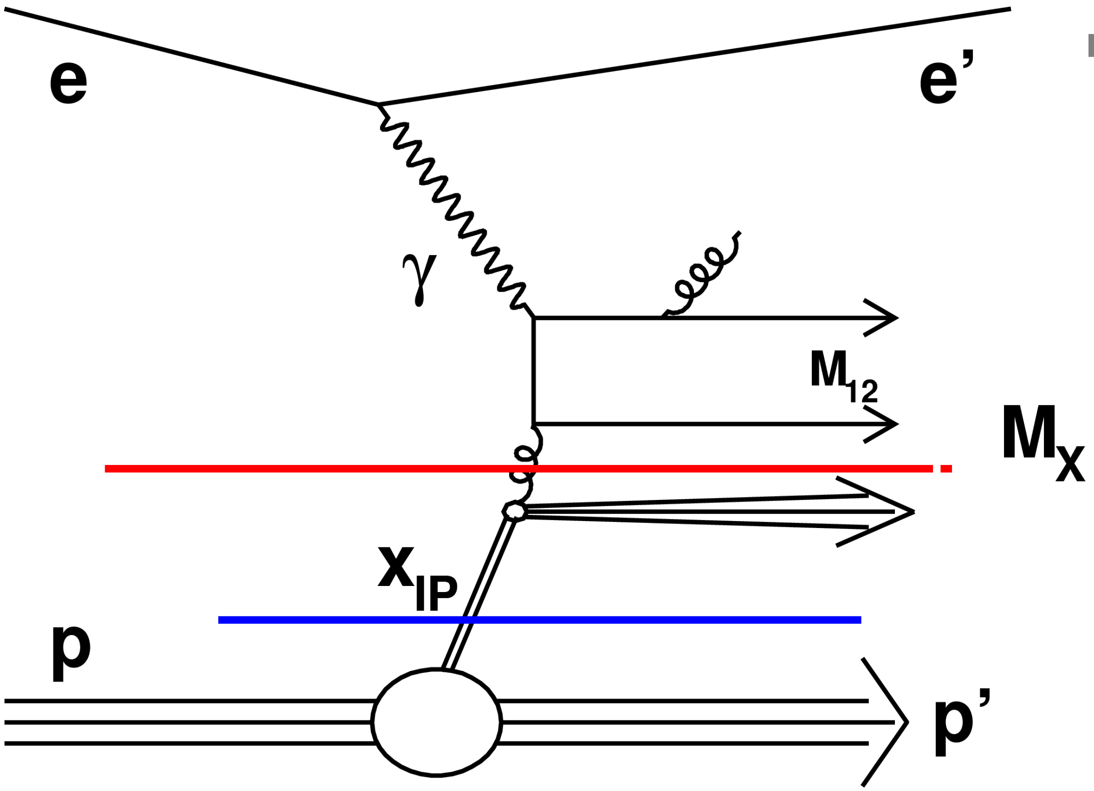
$\beta \;= x/x_{IP}$

$t \;= (P' - P)^2$

$M_Y = m_p$ intact proton

$m_p \leq M_Y \leq 1.6$ GeV intact proton or proton dissociation (incl. nucleon resonances)

Factorisation



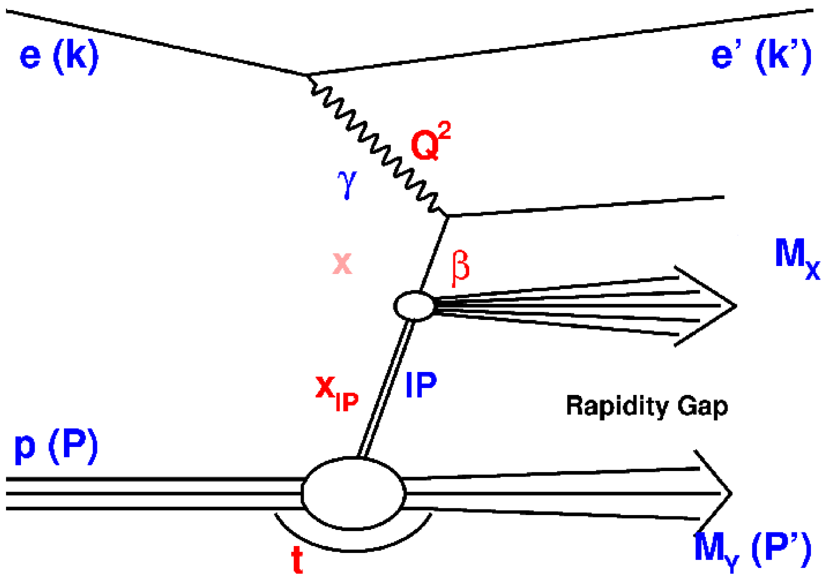
QCD collinear factorisation (Collins)

Proton vertex factorisation

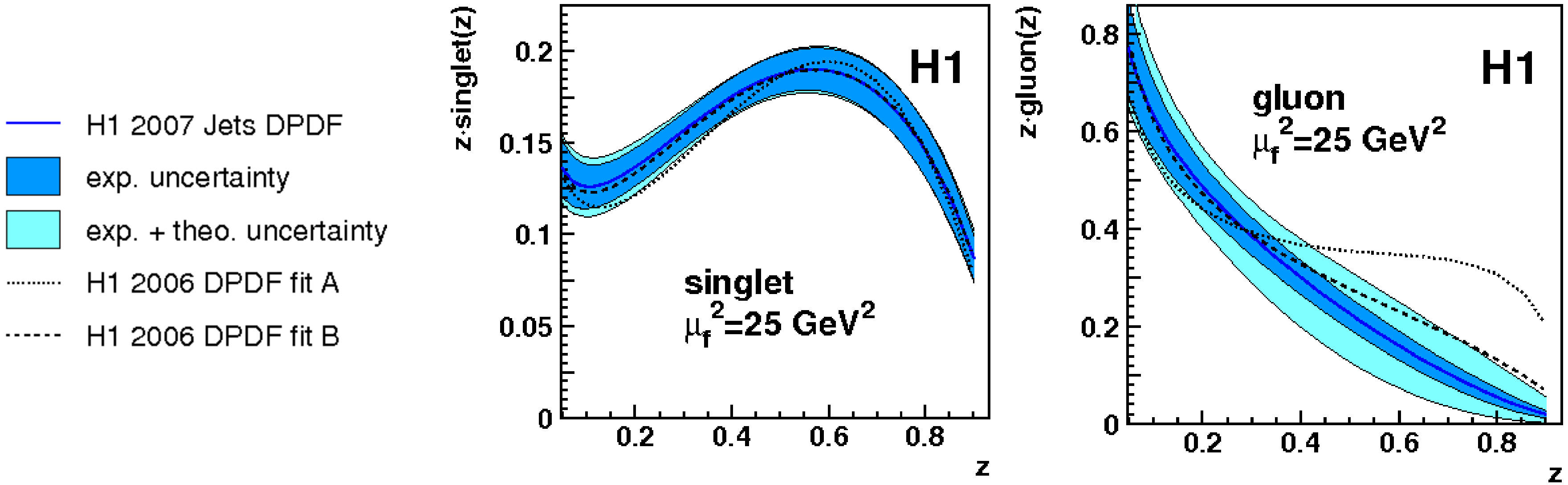
$$d\sigma^{ep\to eXp}(\beta,Q^2,x_{IP},t)=\sum_i f_i^D(\beta,Q^2,x_{IP},t)\cdot d\hat{\sigma}^{ei}(\beta,Q^2)$$

$$f_i^D(\beta,Q^2,x_{IP},t)=f_{IP/p}(x_{IP},t)\cdot f_i(\beta,Q^2) \qquad f_{IP/p}(x_{IP},t)=A_{IP}\frac{e^{B_{IP}t}}{x_{IP}^{2\alpha(t)-1}}$$

Extracting DPDFs

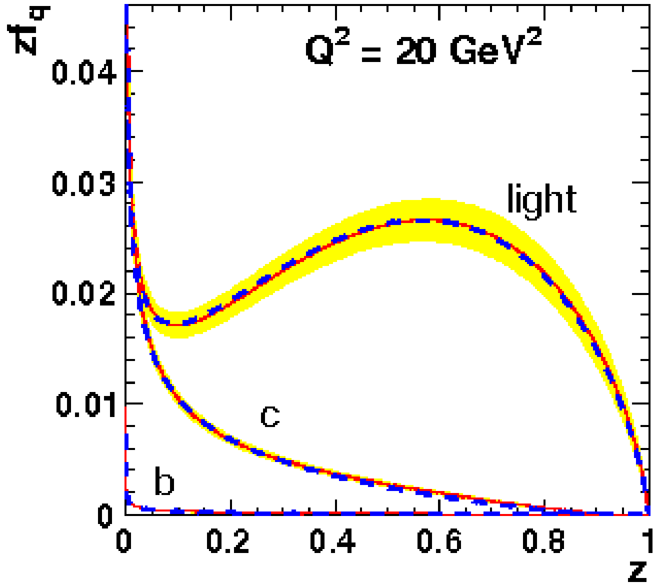


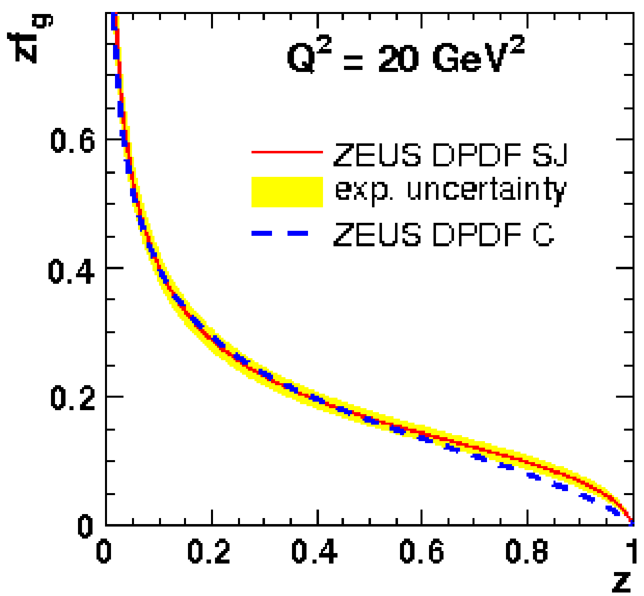
- Fit β and Q^2 dependence at fixed x_{IP}
- Parametrise at starting scale Q_0^2 and evolve using NLO DGLAP
- PVF allows to combine DPDFs with pomeron flux Ansatz
- Diffractive Jets constrain gluon part of DPDFs

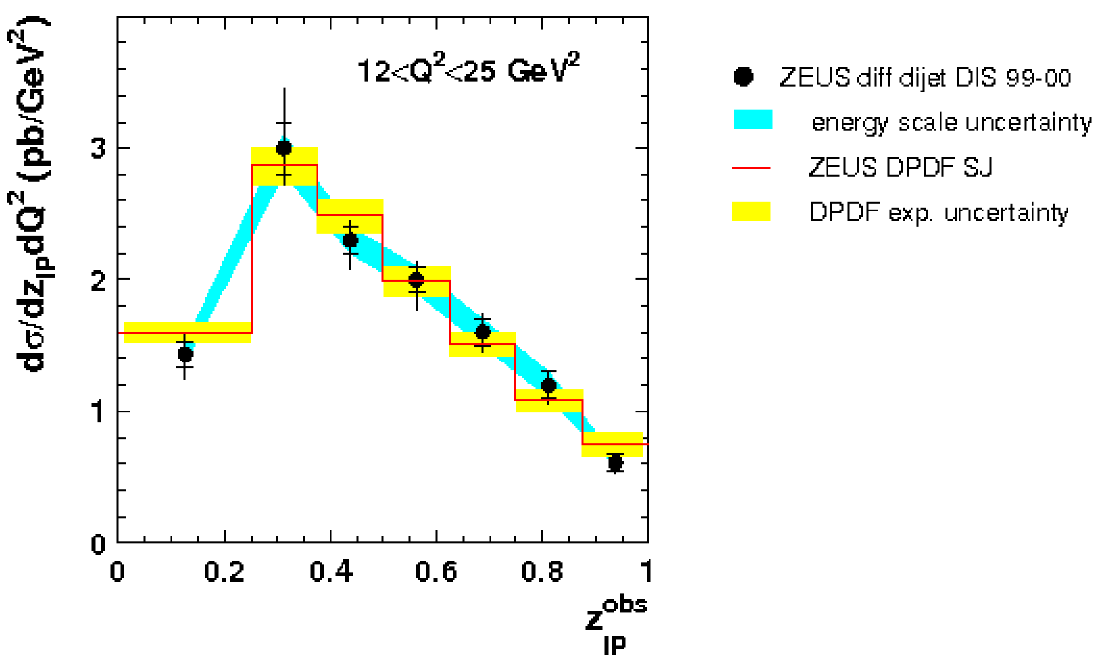


DPDFs

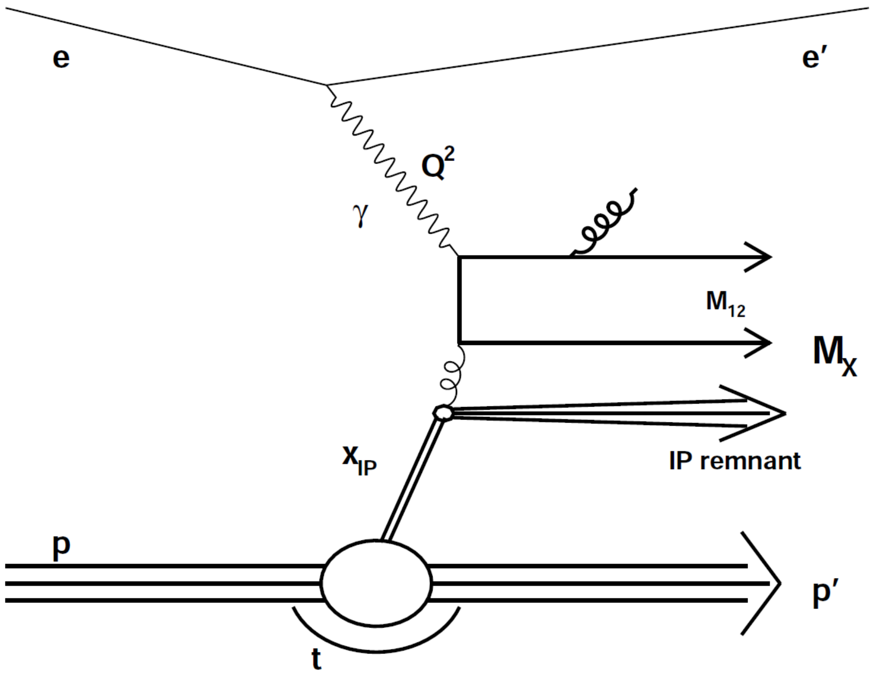
- Recent ZEUS fits to LRG and LPS inclusive and dijet data
- Improved heavy flavour treatment
- Good agreement with H1 up to normalisation uncertainty
- **Excellent** description of dijet data







Jets in Diffraction



$$z_{IP} = \frac{Q^2 + M_{12}^2}{x_{IP}\, y s}$$

- Presence of an additional hard scale – p_T, possible to compare with NLO QCD calculations
- Direct sensitivity of the gluon part of the DPDF
- Better constraint of DPDFs at high $\beta(z_{IP})$
- Search for physics beyond DGLAP parton evolution
- Comparison of different methods for selecting diffraction

$d\sigma/dx_{IP}$

VFPS

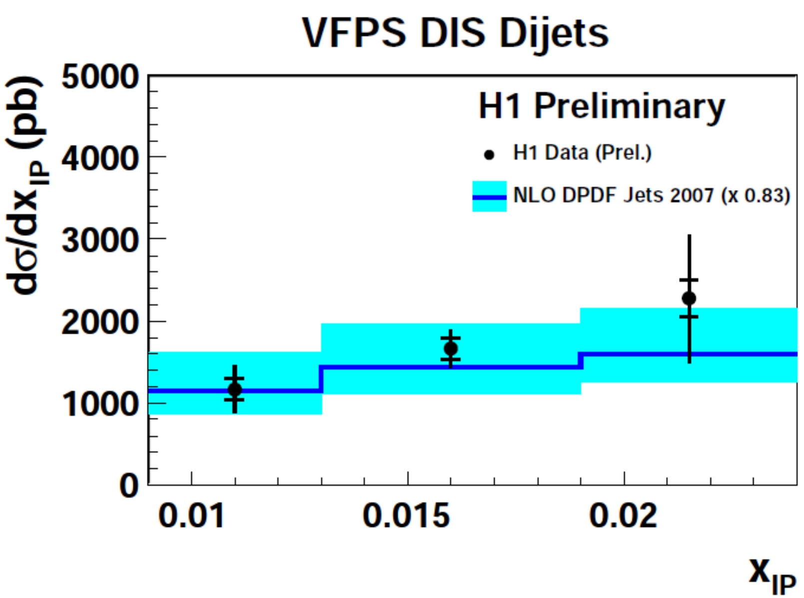
$5 < Q^2 < 80$ GeV^2
$0.1 < y < 0.65$
$0.009 < x_{IP} < 0.024$

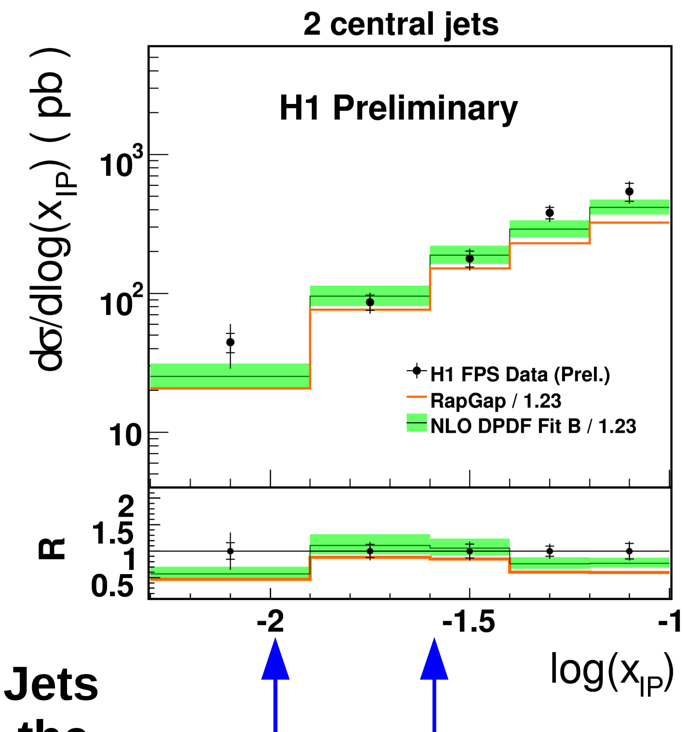
$p_{T1}^* > 5.5$ GeV
$p_{T2}^* > 4$ GeV
$-3 < \eta^* < 0$

FPS

$4 < Q^2 < 110$ GeV^2
$0.05 < y < 0.7$
$0.005 < x_{IP} < 0.1$

$p_{T1}^* > 5$ GeV
$p_{T2}^* > 4$ GeV
$-1 < \eta < 2.5$





NLO QCD predictions based on DPDFs H1 2007 Jets and H1 2006 B provide a good description within the errors

VFPS

dσ/dy

VFPS

$5 < Q^2 < 80$ GeV^2 $0.1 < y < 0.65$ $0.009 < x_{IP} < 0.024$	$p_{T1}^* > 5.5$ GeV $p_{T2}^* > 4$ GeV $-3 < \eta^* < 0$

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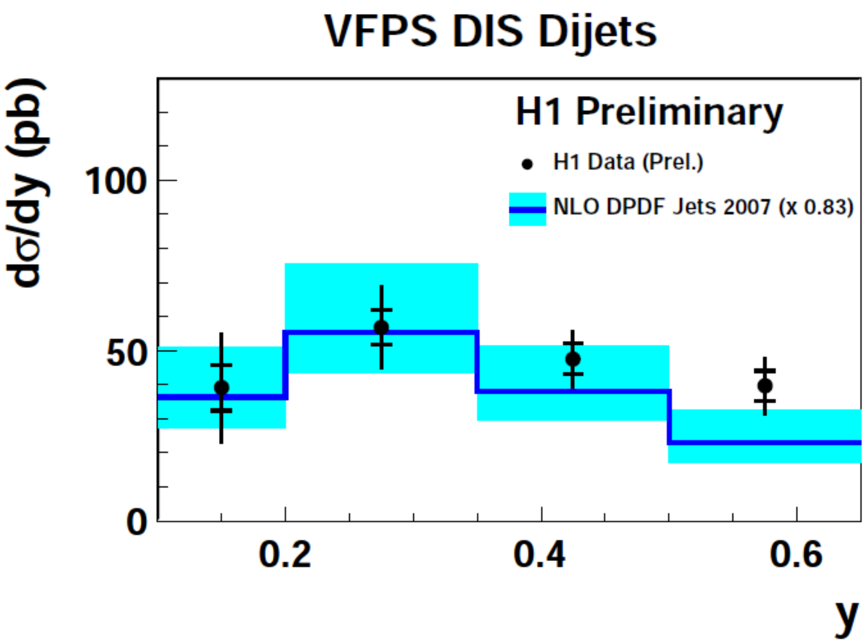

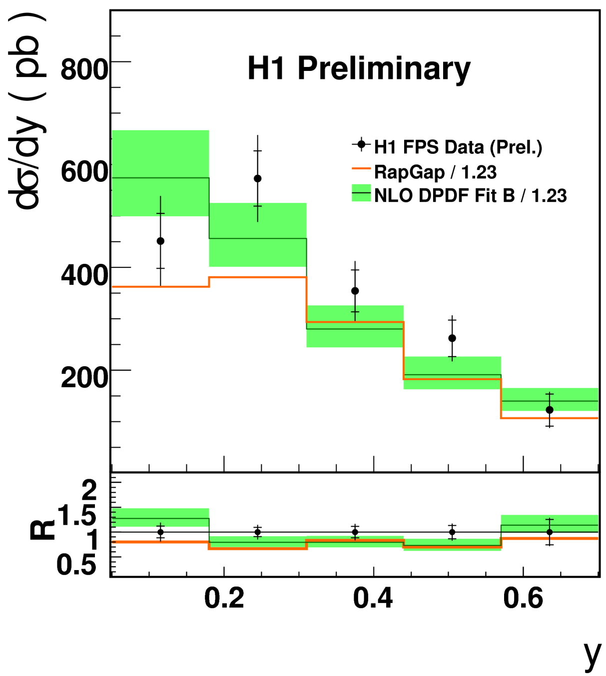

NLO QCD predictions based on DPDFs H1 2007 Jets and H1 2006 B provide a good description within the errors

$d\sigma/dz_{IP}$

VFPS

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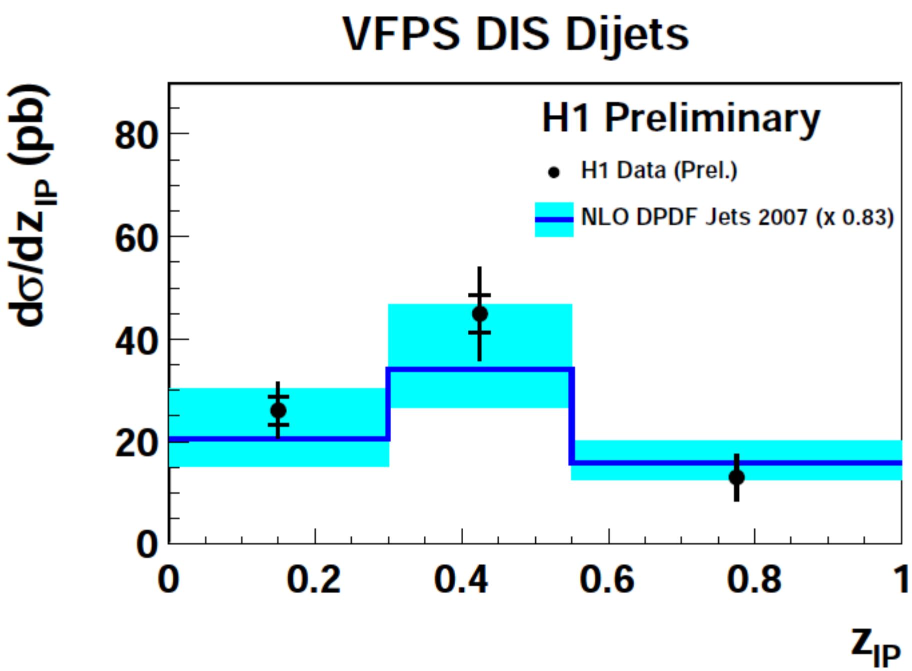
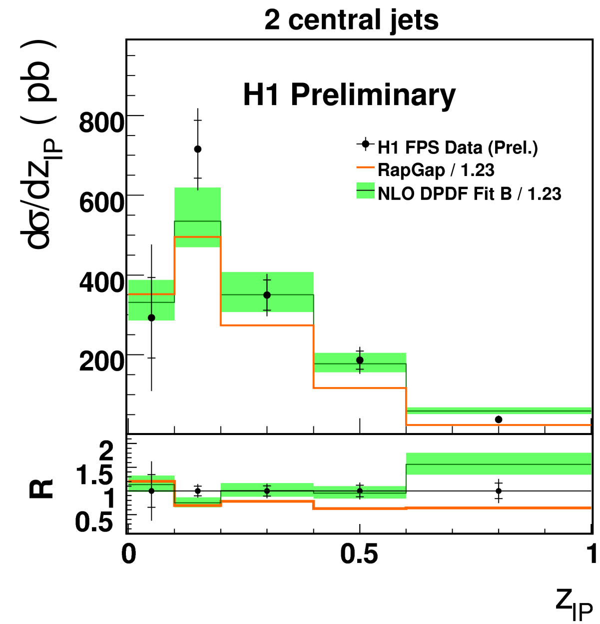




NLO QCD predictions based on DPDFs H1 2007 Jets and H1 2006 B provide a good description within the errors

Comparison of FPS and LRG

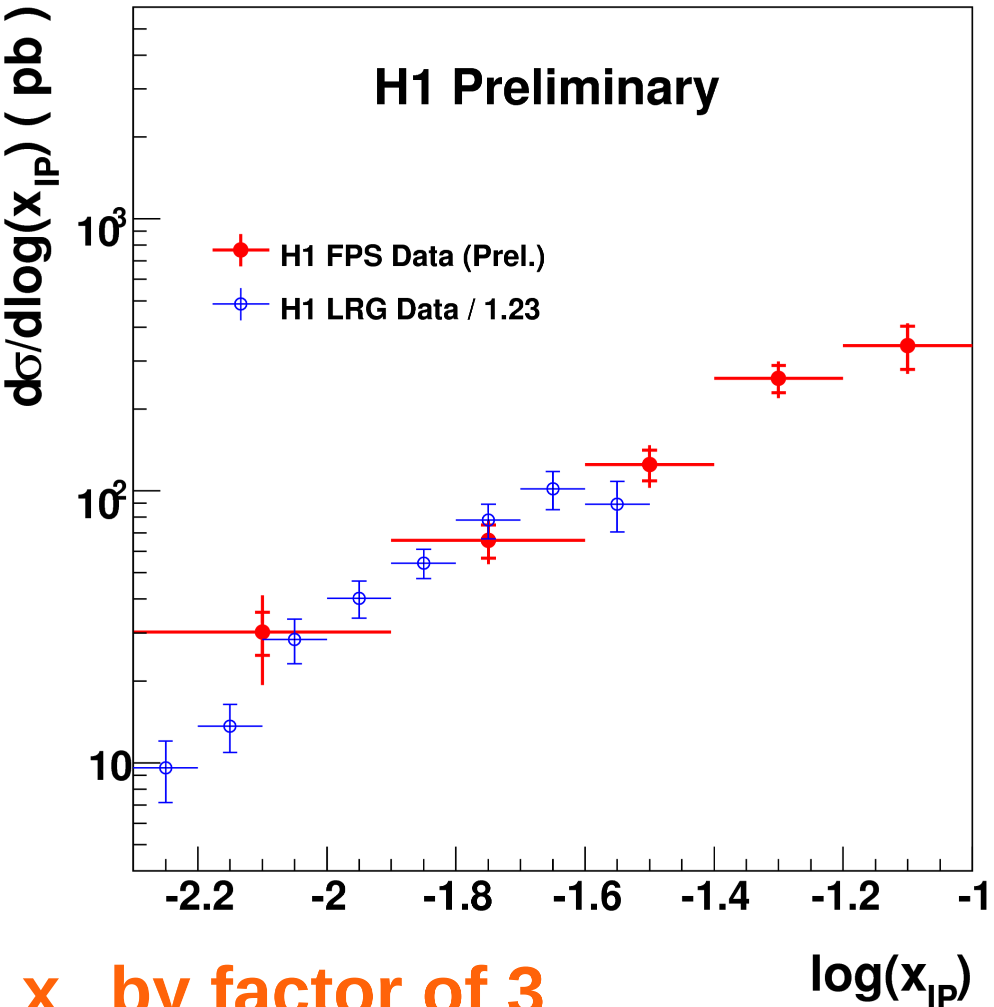
- Diffractive DIS dijet analysis with LRG (JHEP 0710:042)
- Published data corrected for proton dissociation

$4 < Q^2 < 80$ GeV^2

$0.1 < y < 0.7$

$p_{T1}^* > 5.5$ GeV

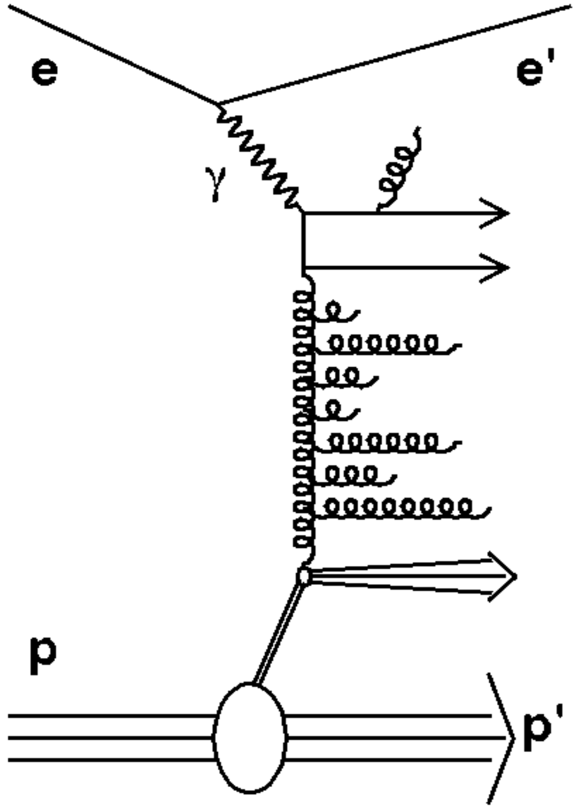
$p_{T2}^* > 4$ GeV



- **Very good agreement**
- **Phase space extension in x_{IP} by factor of 3**
- **Same fraction of proton dissociation as for incl. diff.**

Diffractive Forward Jets

- DGLAP evolution equations assume strong k_T ordering and neglect terms ~1/x
- Forward jets with leading proton in DDIS – search for physics beyond DGLAP
  - Possible in leading proton measurement
  - Possibility to investigate jets close to the proton direction
  - Low x region

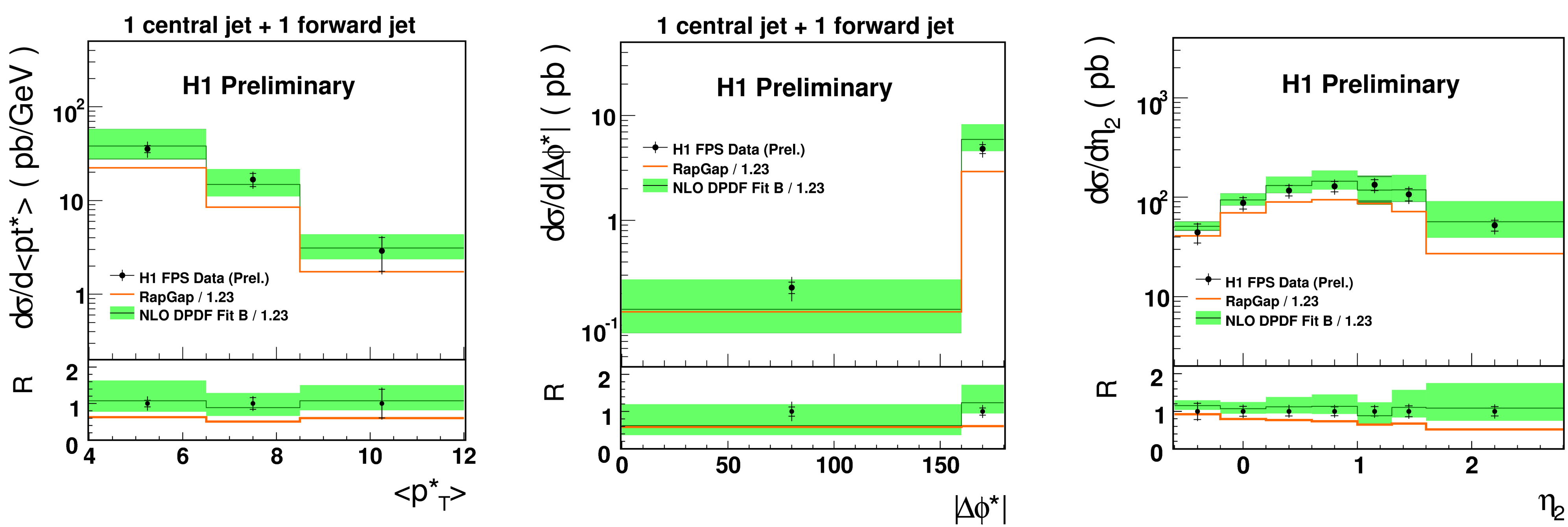


- Selection of **1 central + 1 forward jet** suppressing DGLAP phase space
- Calculable in NLO (NLOJET++ with DPDF H1 2006 Fit B)

Diffractive Forward Jets

$4 < Q^2 < 110$ GeV^2
$0.05 < y < 0.7$
$X_{IP} < 0.1$

$p^*_{T,forward} > 4.5$ GeV, $p^*_{T,central} > 3.5$ GeV
$1 < \eta_{forward} < 2.8$, $-1 < \eta_{central} < 2.5$
$\eta_{central} < \eta_{forward}$



Good description by NLO QCD DGLAP predicions

Summary

- Measurements of diffractive dijets with different experimental techniques presented
- Good agreement with NLO QCD predictions based on DPDFs
- Very good agreement of FPS and LRG measurement within errors, fraction of proton dissociation is consistent for inclusive and jet final states
- NLO QCD DGLAP calculations describe the diffractive forward jets successfully