Diffractive Final States at H1

Frank-Peter Schilling

[DESY]

Representing the H1 Collaboration

Contents:

- Testing QCD factorization in diffraction
- NLO comparisons for diffractive jets and charm
- Jets in diffractive photoproduction

International Europhysics Conference on High Energy Physics

EPS 2003

July 17th-23rd, 2003
Aachen, Germany

Factorization in Diffraction

Proof of QCD Factorization for diffractive DIS:

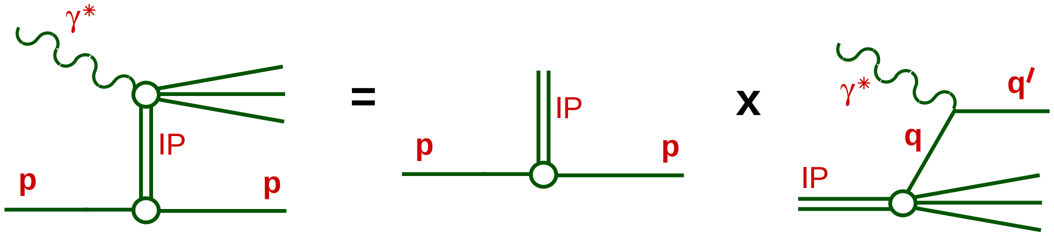
- Diffractive parton distributions (Trentadue, Veneziano, Berera, Soper, Collins, ...):

$$\frac{d^2\sigma(x,Q^2,x_{I\!P},t)^{\gamma^* p\to p' X}}{dx_{I\!P}\; dt} = \sum_i \int_x^{x_{I\!P}} d\xi \hat{\sigma}^{\gamma^* i}(x, Q^2, \xi)\; p_i^D(\xi, Q^2, x_{I\!P}, t) \quad (+\text{higher twist})$$

- $\hat{\sigma}^{\gamma^* i}$ hard scattering part, as in incl. DIS
- p_i^D diffractive pdf's in proton, conditional probabilities, valid at fixed $x_{I\!P}$, t, obey (NLO) DGLAP

Regge Factorization / 'Resolved Pomeron' model:

$x_{I\!P}, t$ dependence factorizes out (Donnachie, Landshoff, Ingelman, Schlein, ...):



- additional assumption, no proof !
- consistent with present data if sub-leading $I\!R$ included

$$F_2^D(x_{I\!P}, t, \beta, Q^2) = f_{I\!P/p}(x_{I\!P}, t)\; F_2^{I\!P}(\beta, Q^2)$$

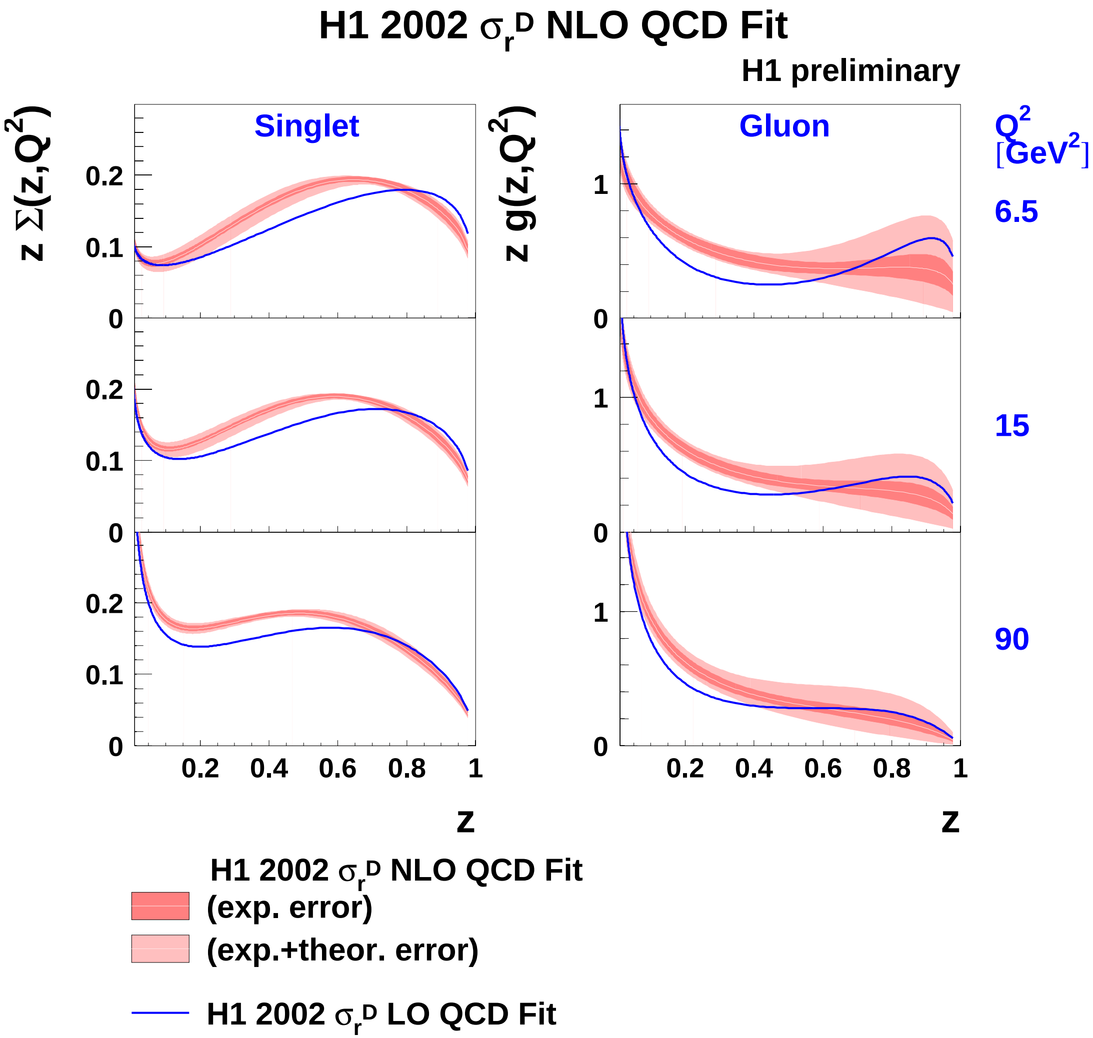
Shape of diffr. pdf's indep. of $x_{I\!P}$, t, normalization controlled by Regge flux $f_{I\!P/p}$

Diffractive Parton Distributions and Factorization Tests

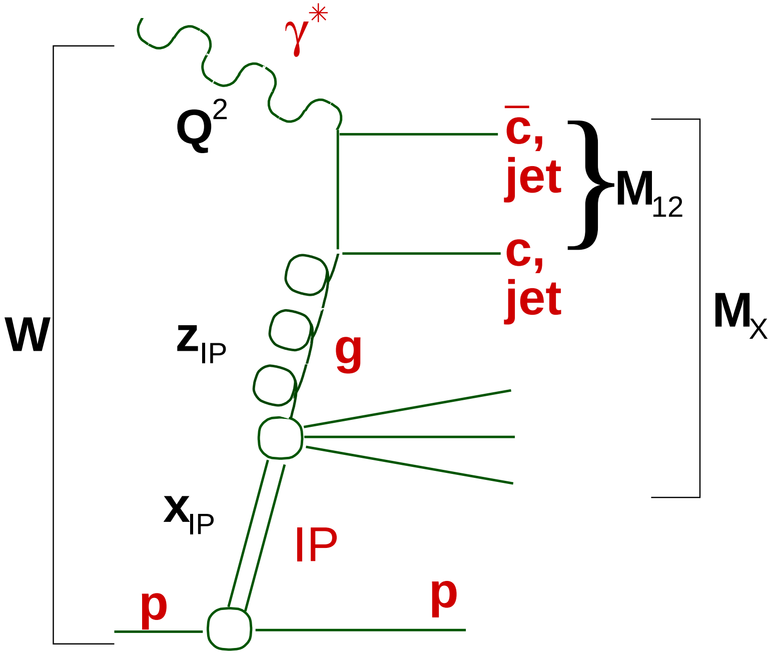
- New NLO (and LO) diffractive parton distributions from H1
- Extracted from DGLAP QCD fit to H1 diffractive DIS data (see previous talk)
- Gluon dominated
- Factorizing in $x_{I\!P}$
- Gluon uncertainty large for $z > 0.5$

If QCD factorization works, these pdf's can be used to predict final state cross sections (jets, heavy quarks)!

pdf's of diffractive exchange



Jet and Heavy Flavour Production in Diffractive DIS



Q^2: Photon virtuality
W: $\gamma^* p$ CMS energy

M_X: mass of diffractively produced system

$M_{12} = \sqrt{\hat{s}}$: mass of two jets / $c\bar{c}$ pair

$$x_{I\!P} = \frac{Q^2 + M_X^2}{Q^2 + W^2}$$

momentum fraction of diffractive exchange w.r.t. proton

$$z_{I\!P} = \frac{Q^2 + M_{12}^2}{Q^2 + M_X^2}$$

momentum fraction of diffractive exchange entering hard process

→ High sensitivity to diffractive gluon distribution!

- high p_T jet production
- $c \rightarrow D^*$ Meson production

NLO Calculations for Diffractive Final States

- So far mostly LO Monte Carlo programs with parton showers used
- QCD factorization: Hard scattering cross section same as for normal DIS
- NLO important to describe non-diffractive Jet production

$\longrightarrow$ use standard NLO programs for jets and heavy quarks in DIS ($\mathcal{O}(\alpha_s^2)$)

Diffractive DIS Jets:

Use DISENT (Seymour)
c.f. Hautmann [JHEP 0210 (2002) 025]

Calculate NLO cross section at fixed $x_{I\!P}$ by running with reduced $E_p = x_{I\!P} E_{p,nom.}$

Use diffractive pdf $p_{i/I\!P}(z, \mu^2)$

Mul. w/ flux $f_{I\!P}(x_{I\!P}) = \int \mathrm{d}t f_{I\!P}(x_{I\!P}, t)$

Data integrated over $x_{I\!P}$:
"$x_{I\!P}$ slicing"

Diffractive DIS D^*:

Diffractive version of HVQDIS (Harris, Smith) by Alvero, Collins, Whitmore [hep-ph/9806340]

$x_{I\!P}$, t integration numerically

NLO Calculation in massive scheme

Peterson fragmentation

Both Interfaced to H1 diffractive pdf's

NLO Comparisons with Diffractive DIS Jets

Data:

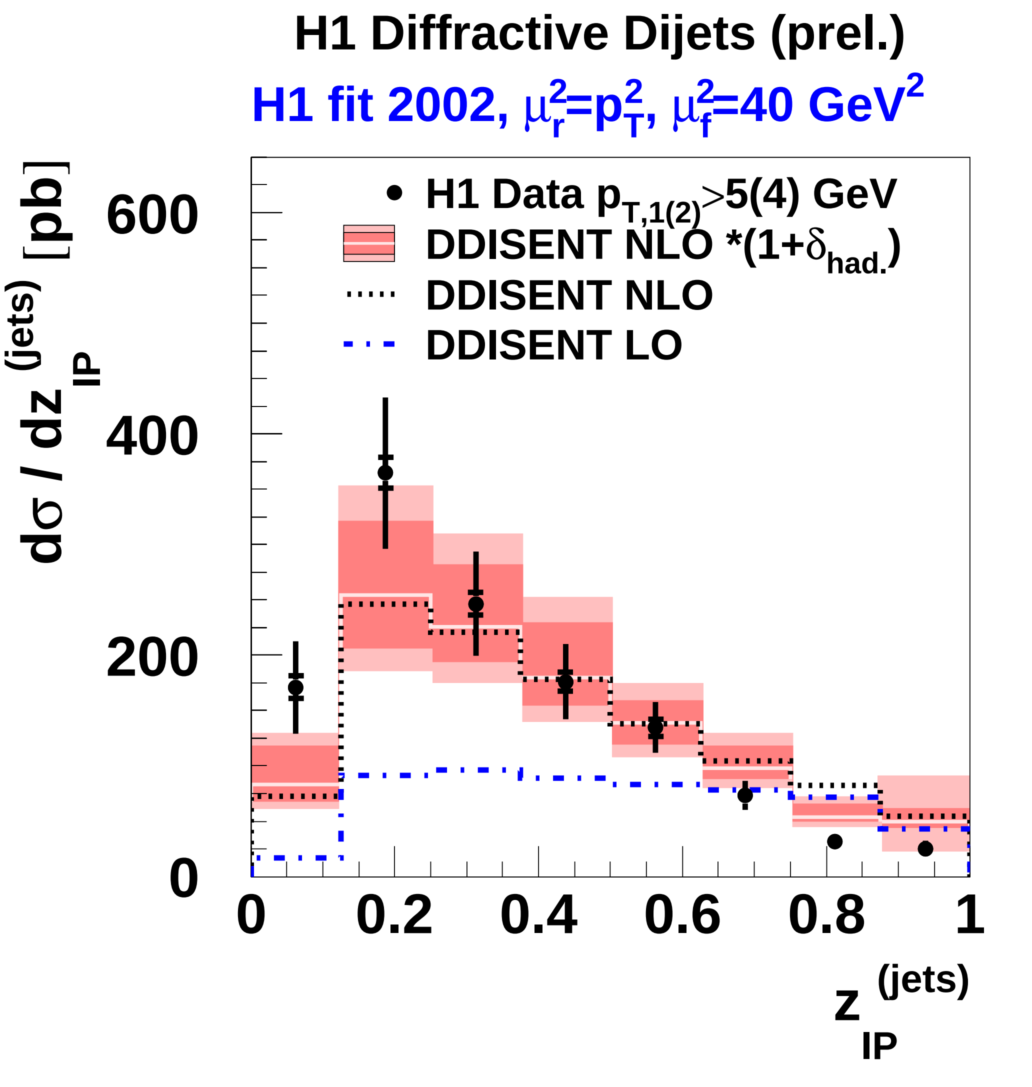
Published H1 data:
[Eur. Phys. J. **C20** (2001) 29]
$4 < Q^2 < 80\ \mathrm{GeV}^2, 0.1 < y < 0.7,$
$x_{I\!P} < 0.05$
Jets: CDF cone, $p_{T,jet} > 4$ GeV

But: NLO unstable if $p_{T,1} \sim p_{T,2}$
$\longrightarrow$ Data corrected to $p_{T,1(2)} > 5(4)$ GeV

NLO Calculations with DISENT:

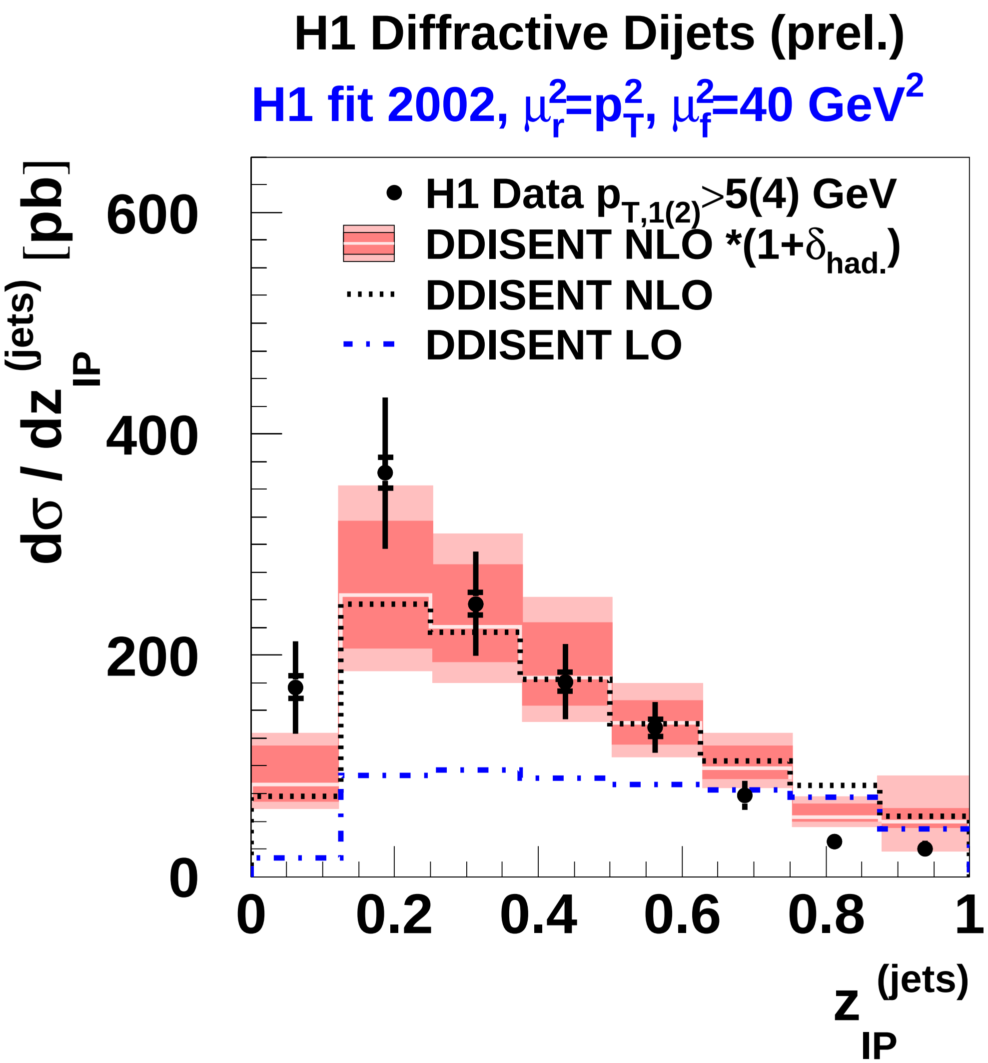
$\mu_r^2 = p_T^2, \mu_f^2 = 40\ \mathrm{GeV}^2$
$\Lambda^4_{QCD} = 0.2$ GeV (as in QCD fit)
Hadronization corrections applied

Inner band: $0.25\mu_r^2 \ldots 4\mu_r^2$
Outer band includes unc. in hadr. corr.



NLO Comparisons with Diffractive DIS Jets

- Cross section differential in $z_{\mathbb{P}}$
- LO Calculation too low, shape of data not reproduced (note: w/o parton showers!)
- Size of NLO correction on average factor ~ 2 (due to low jet p_T)
- NLO, corrected for hadronization: reasonable description in shape and normalization
- Renormalization scale unc. $\sim 20\%$
- Not shown: pdf uncertainty (gluon at high $z_{\mathbb{P}}$)

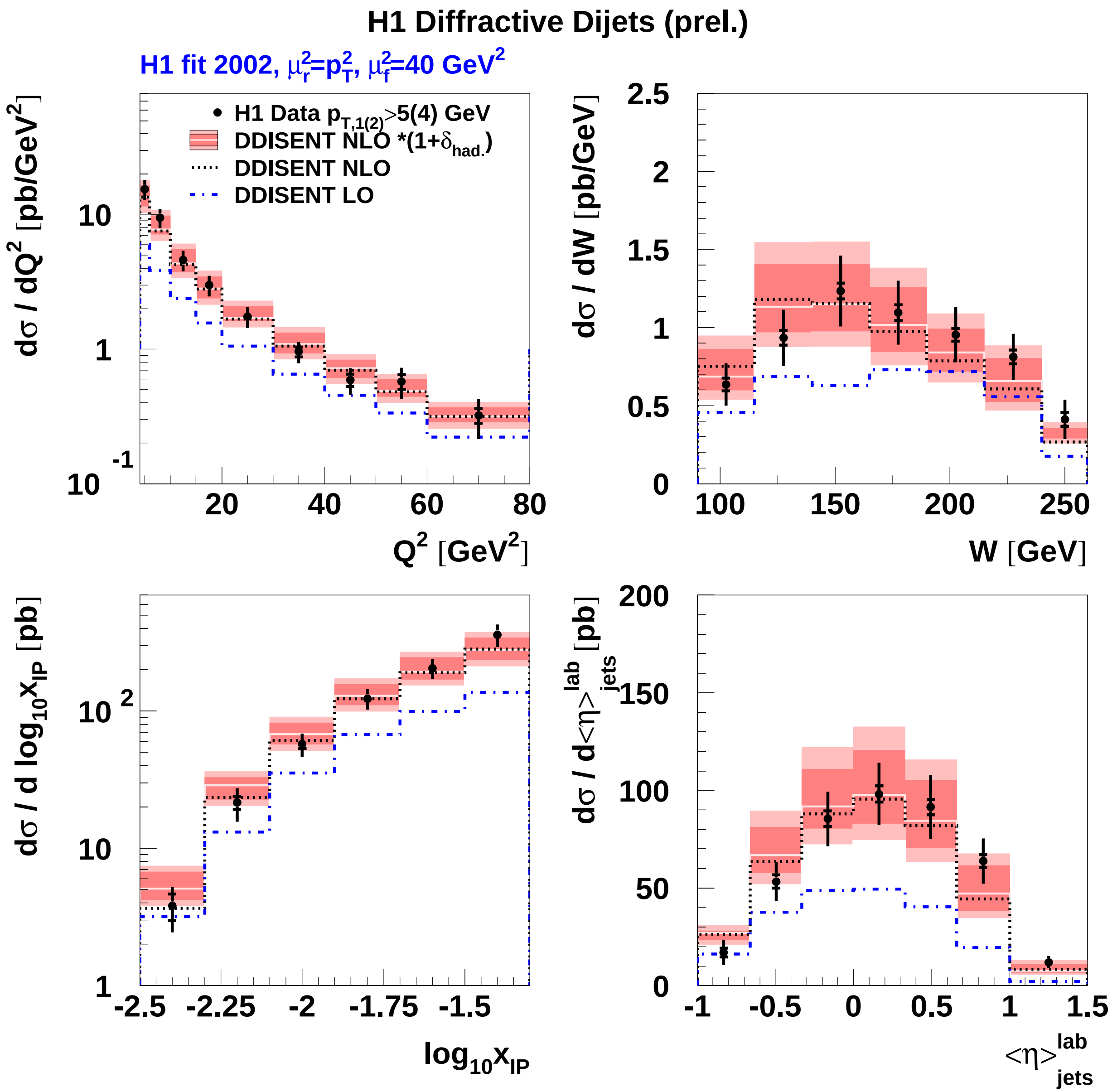


NLO Comparisons with Diffractive DIS Jets

- Further Cross sections:

- Size of NLO Corrections decreasing with Q^2 (and p_T ,not shown)

- Reasonable agreement with NLO calculation

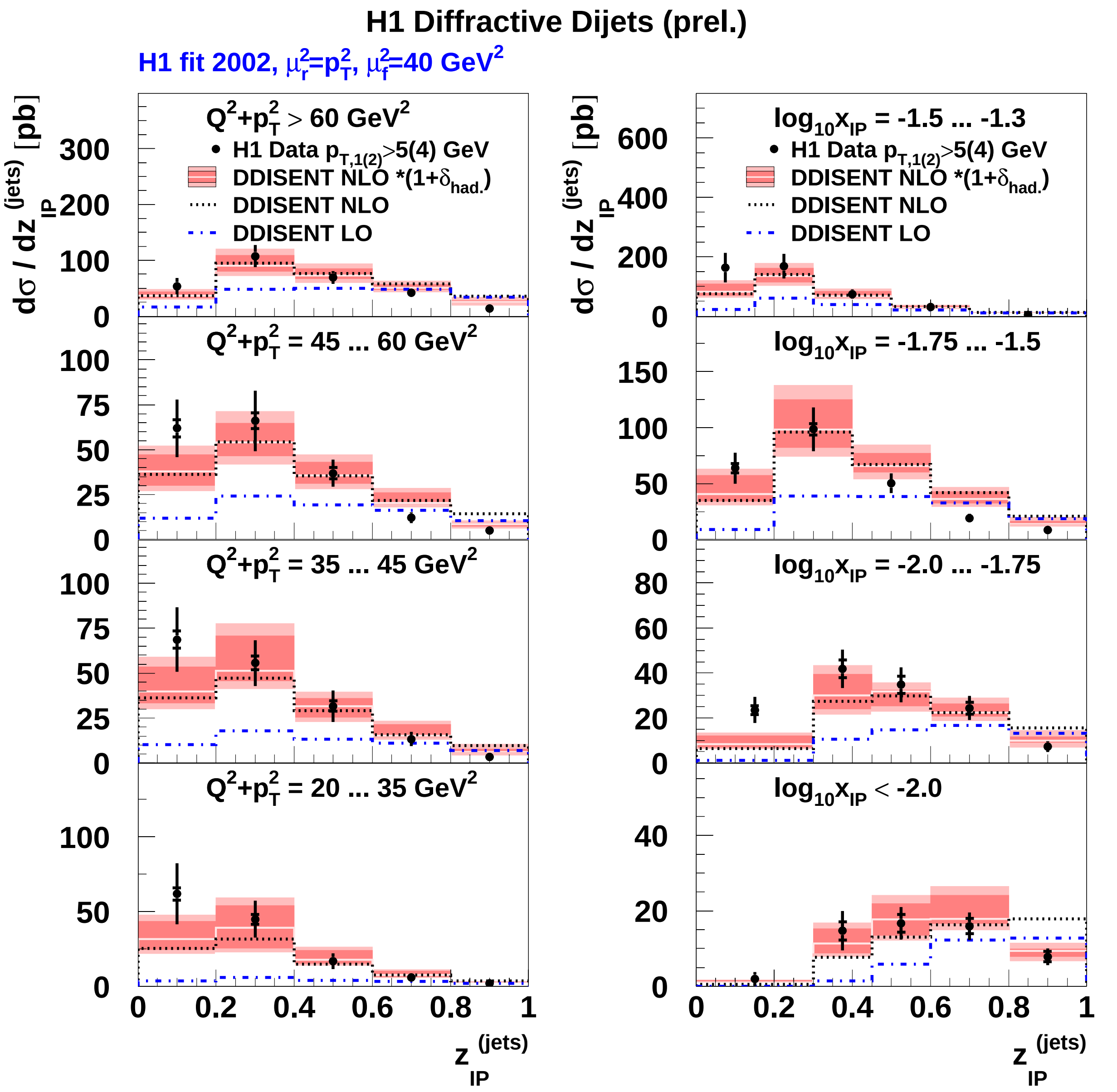


NLO Comparisons with Diffractive DIS Jets

- Double differential cross sections:

  – $z_{I\!P}$ in bins of $Q^2 + p_T^2$
  – $z_{I\!P}$ in bins of $x_{I\!P}$

- Reasonable agreement with NLO calculation



NLO Comparisons with Diffractive DIS D^*

Data:

Published H1 data:
[Phys. Lett. **B520** (2001) 191]
$2 < Q^2 < 100\ \mathrm{GeV}^2, 0.05 < y < 0.7,$
$x_{I\!P} < 0.04$

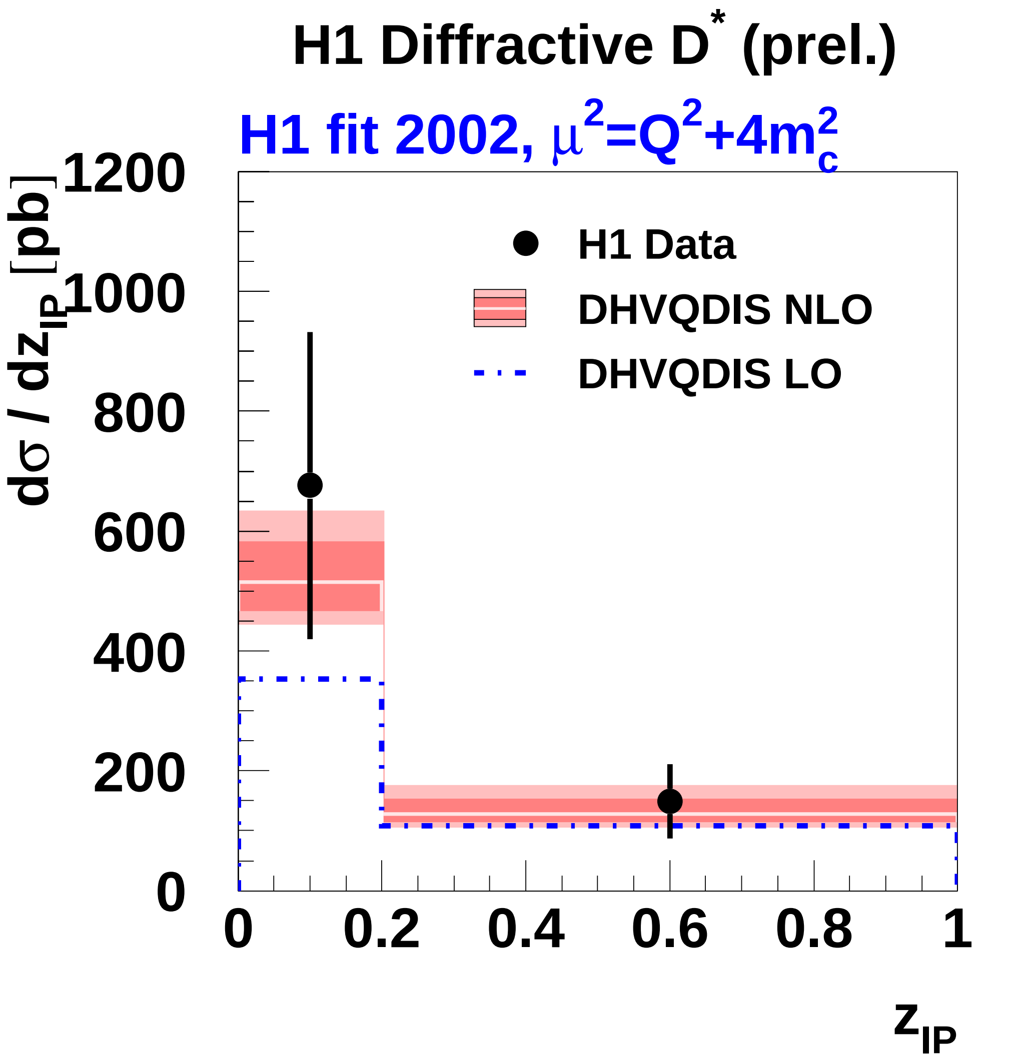
$D^* \to K\pi\pi$
$p^*_{T,D^*} > 2\ \mathrm{GeV}, |\eta_{D^*}| < 1.5$

NLO Calculations with diffr. HVQDIS:

$\mu_r^2 = \mu_f^2 = Q^2 + 4m_c^2$
$\Lambda^4_{QCD} = 0.2\ \mathrm{GeV}$ (as in QCD fit)

Peterson Fragmentation: $\epsilon = 0.078$

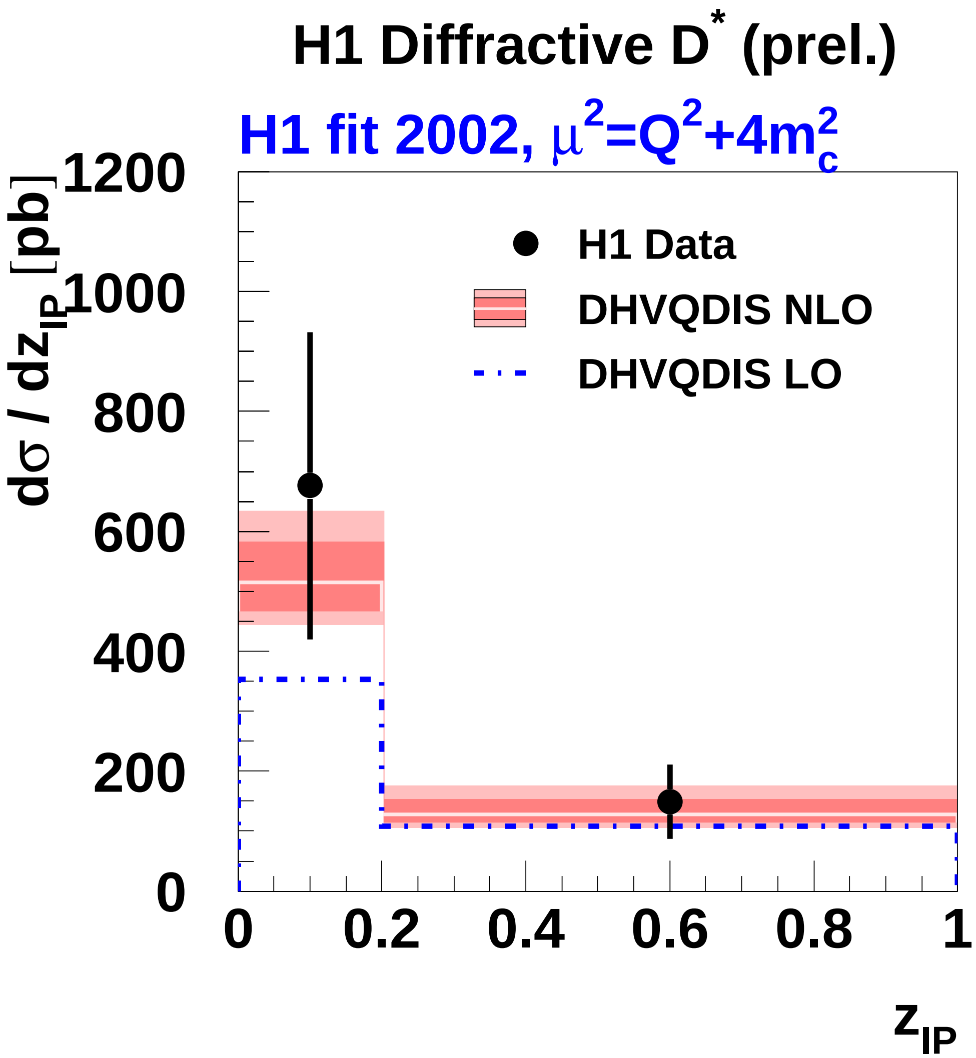
$m_c = 1.5\ \mathrm{GeV}, f(c \to D^*) = 0.233$



NLO Comparisons with Diffractive DIS D^*

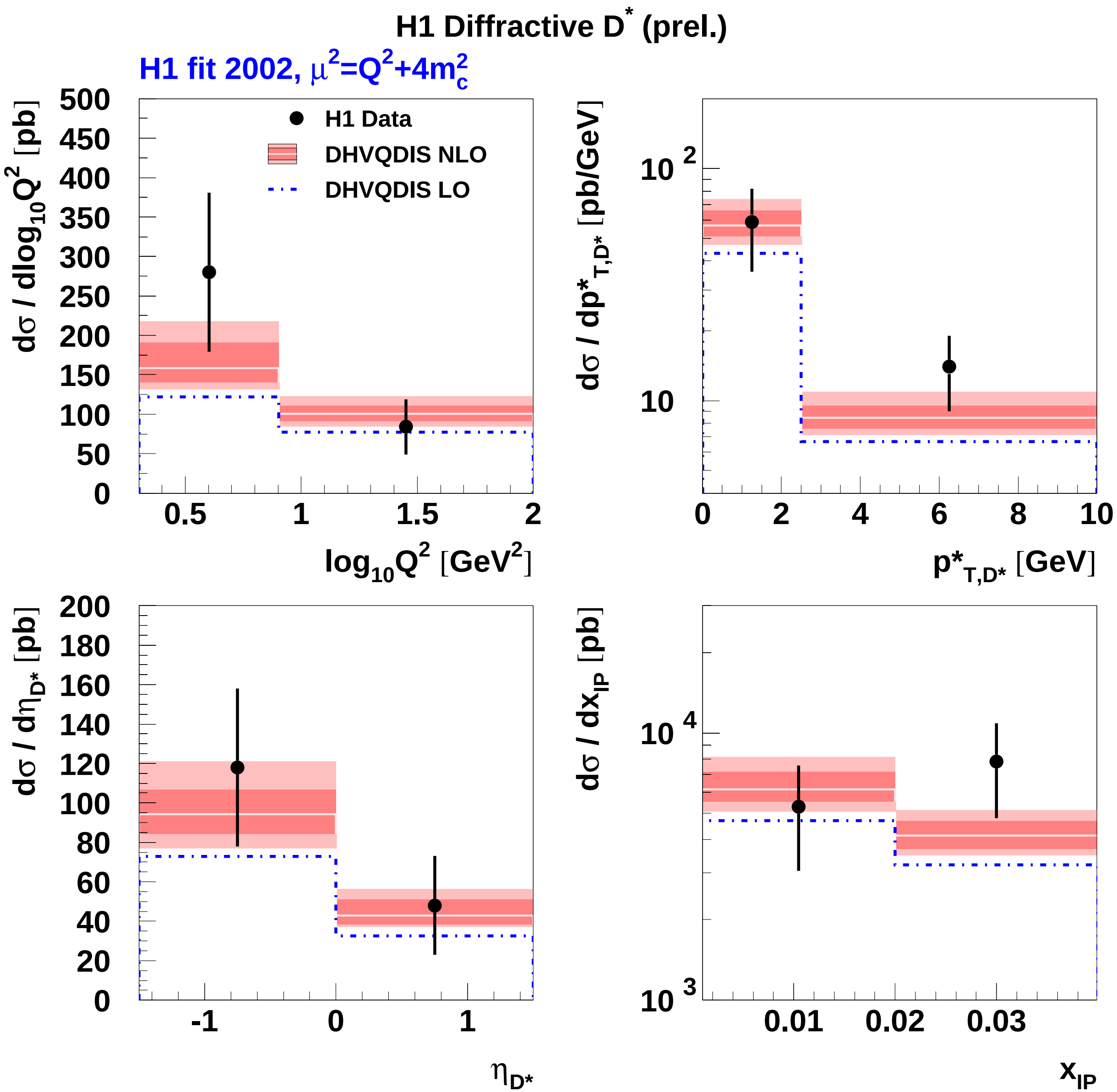
Inner NLO error band: $0.25\mu_r^2 \ldots 4\mu_r^2$
Outer band also includes
– $1.35 < m_c < 1.65$ GeV ($\pm 12\%$)
– $0.035 < \epsilon < 0.100$ ($+21/-7\%$)

- Cross section differentially in $z_{I\!P}$
- Good agreement in shape and normalization within uncertainties
- Size of NLO correction smaller than for dijets



NLO Comparisons with Diffractive DIS D^*

- Further cross sections
- Good agreement within uncertainties
- Variation of Λ_{QCD} by ± 30 MeV: $\pm 5\%$ effect

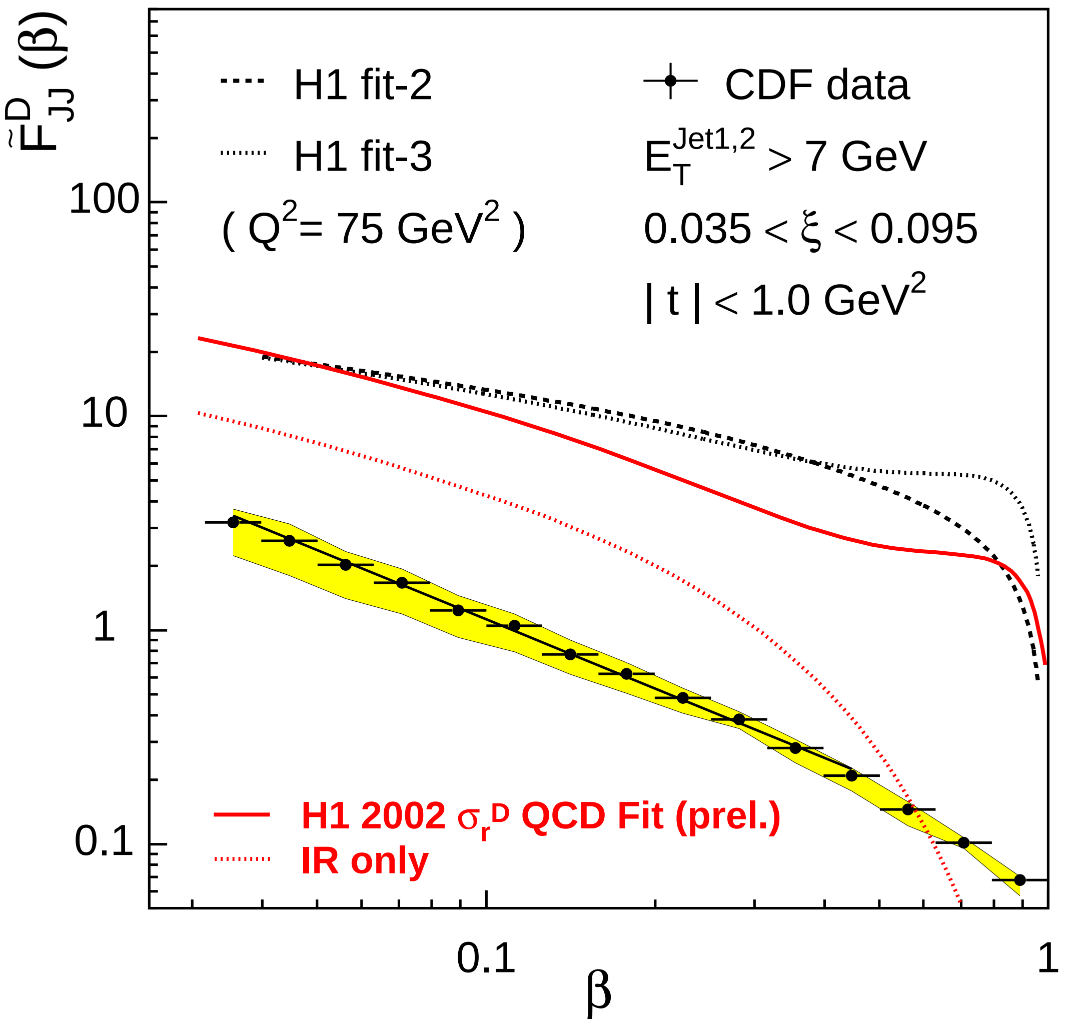


Summary for DIS jets and D^*:

Consistent with QCD factorization in diffractive DIS, tested to NLO

But what if the photon is real ($Q^2 \sim 0$) ?

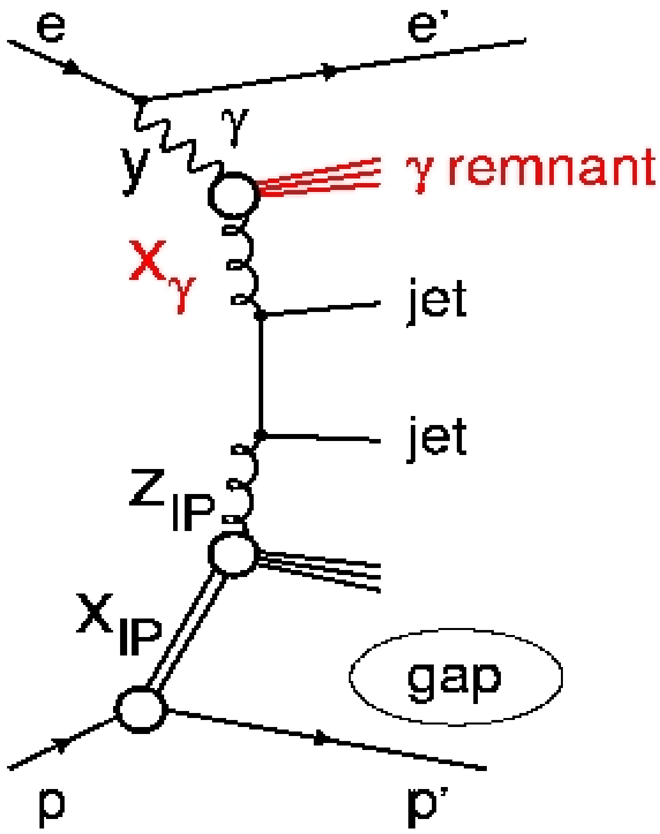
Dijets with tagged $\overline{p}$ at CDF



- Serious breakdown of factorization observed if HERA pdf's transported to TEVATRON:
- Prediction based on H1 pdf's one order of magnitude above CDF data
- Due to presence of second hadron in initial state?

  (spectator interactions break up $\overline{p}$, "rapidity gap survival probability")

Dijets in Diffractive Photoproduction



Real photon may develop hadronic structure
$\longrightarrow$ similar to hadron-hadron interactions

x_γ: Momentum fraction of photon entering the hard process

- $x_\gamma = 1$: Direct interaction, similar to DIS
- $x_\gamma < 1$: Resolved interaction, similar to hadron-hadron scattering

- Does QCD factorization also work in diffractive photoproduction (although not proven)?
- Is there a dependence on x_γ?
- Can factorization breaking w.r.t. Tevatron be understood?

Dijets in Diffractive Photoproduction

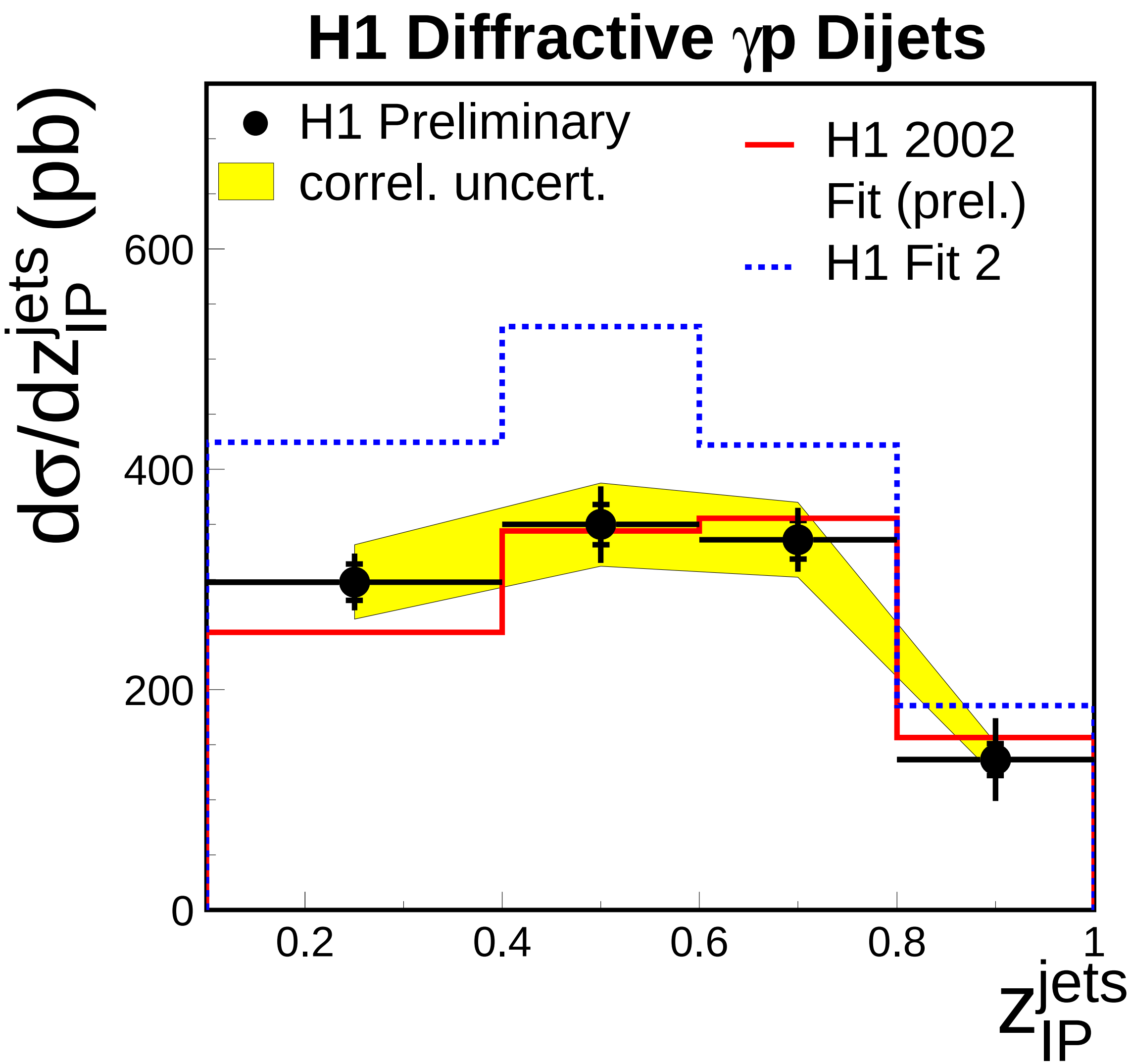
H1 data:

$Q^2 < 0.01\ \mathrm{GeV}^2, 0.3 < y < 0.65$
$x_{\mathbb{P}} < 0.03$
Jets: incl. k_T algo.
$p_{T,1(2)} > 5(4)\ \mathrm{GeV}$

Monte Carlo comparisons:
LO ME + parton showers: RAPGAP

$\mu_r^2 = p_T^2$

- New 2002 LO fit describes data very well
- Old "H1 fit 2" too high, but large uncertainties



[Wrong (too high) α_s value used in previous version of plot, corrected, Data unchanged]

Dijets in Diffractive Photoproduction

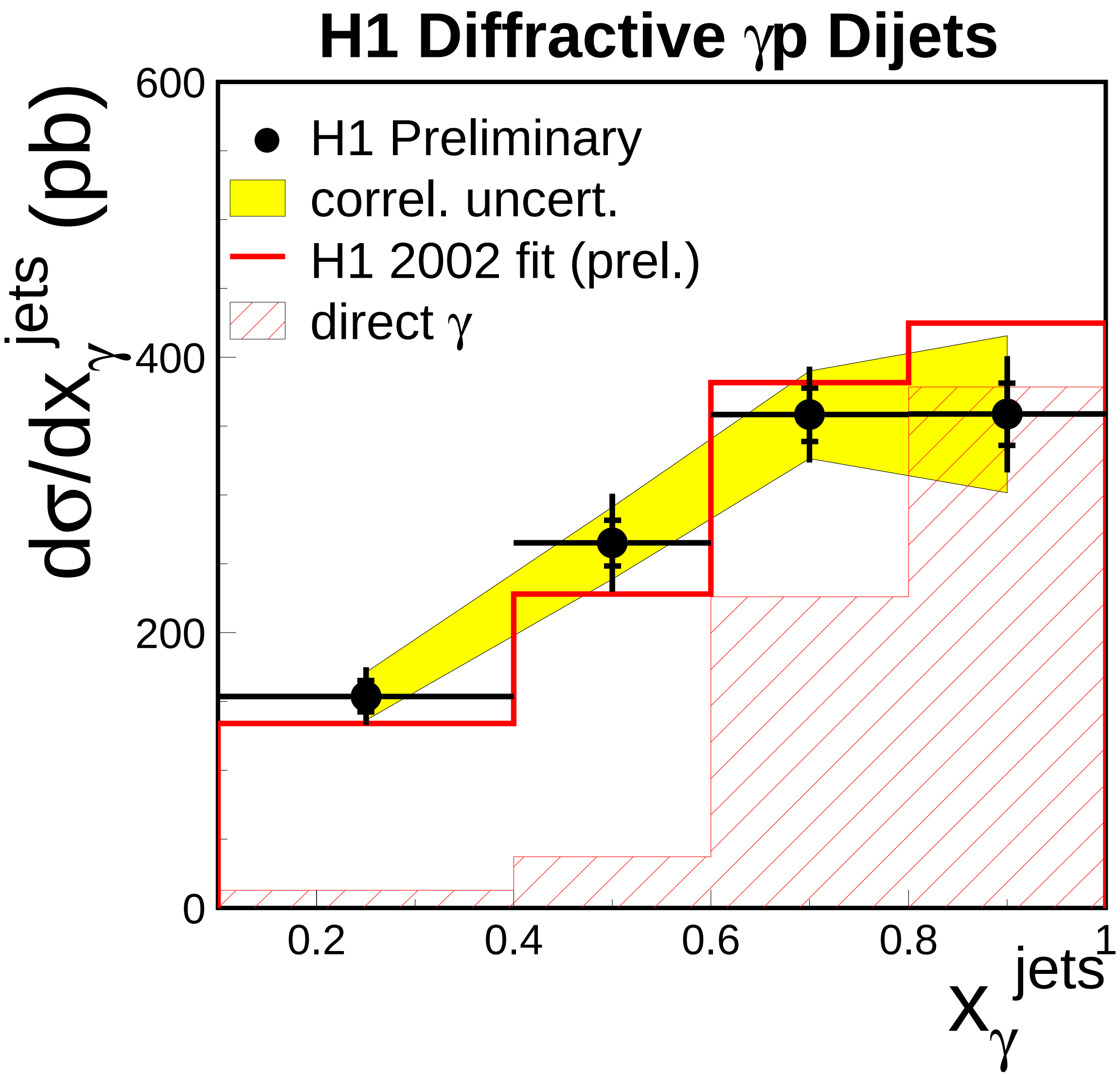
- Cross section as a function of x_γ
- New 2002 fit describes direct and resolved contribution

Direct comparison DIS vs γp:

$$\frac{\left(\frac{Model}{Data}\right)_{\gamma p}}{\left(\frac{Model}{Data}\right)_{DIS}} = 1.25 \pm 0.30(\text{exp.})$$

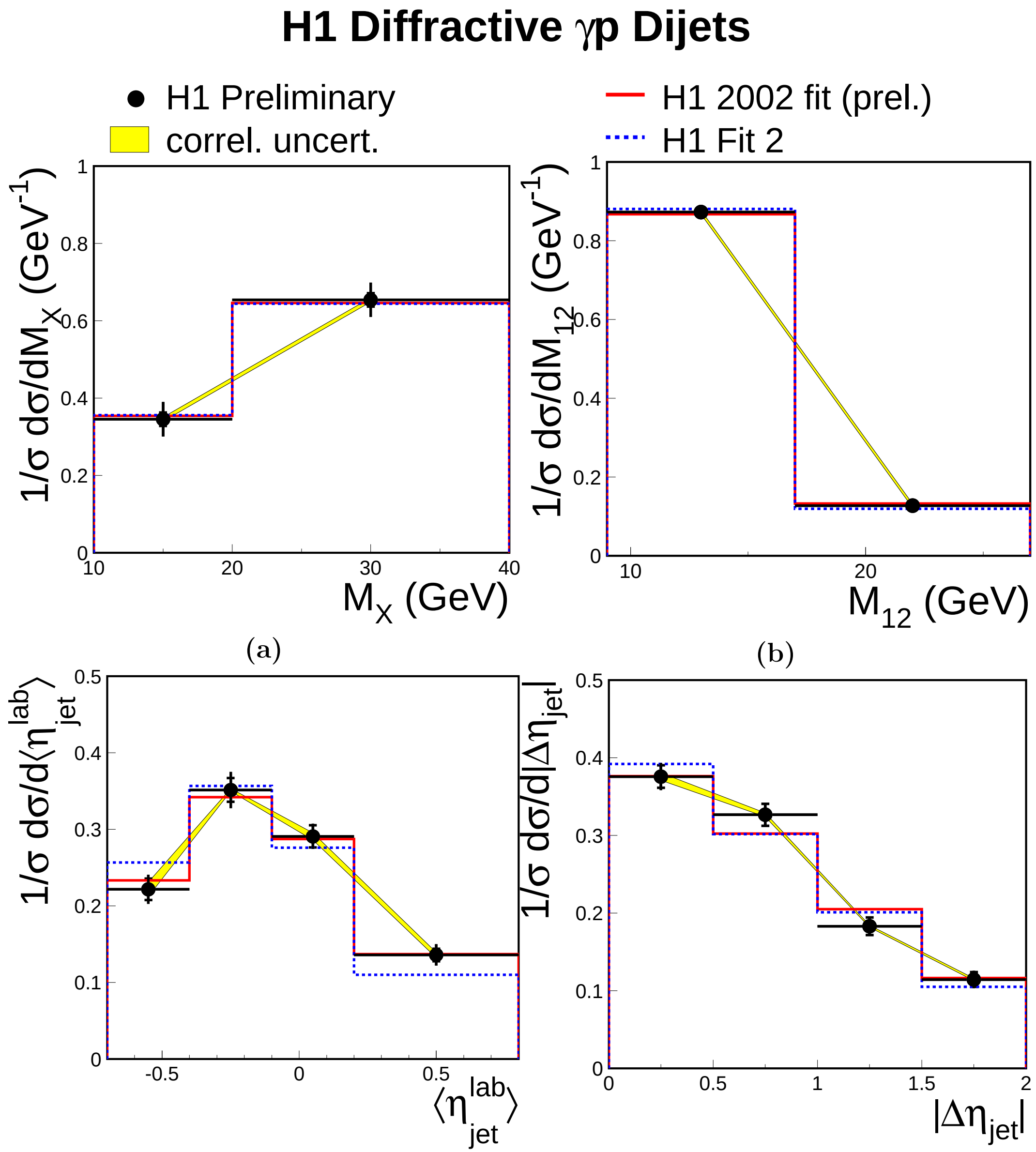
Within uncertainties no suppression of γp w.r.t. DIS diffractive jets

Independent of fit



Dijets in Diffractive Photoproduction

- Normalized Cross sections: Compare shapes
- Well described



(a) (b) (c) (d)

Conclusions

Diffractive DIS Jets and D^*:

- Using 2002 NLO QCD fit to F_2^D ...
- For the first time, NLO predictions for diffractive DIS jets
- NLO Comparisons also for diffractive D^*

- Reasonable agreement observed in shape and normalization
- NLO Corrections large for jets at low p_T
- Still large scale uncertainties (20%), even at NLO
- Consistent with QCD factorization

Diffractive Photoproduction Jets:

- Well described in shape and normalization by new 2002 LO fit (LO ME+PS)
- No significant suppression w.r.t DIS: 1.25 ± 0.30
- Factorization even works in (resolved) photoproduction?!

Backup: Correction of DIS Data to asymmetric jet cuts