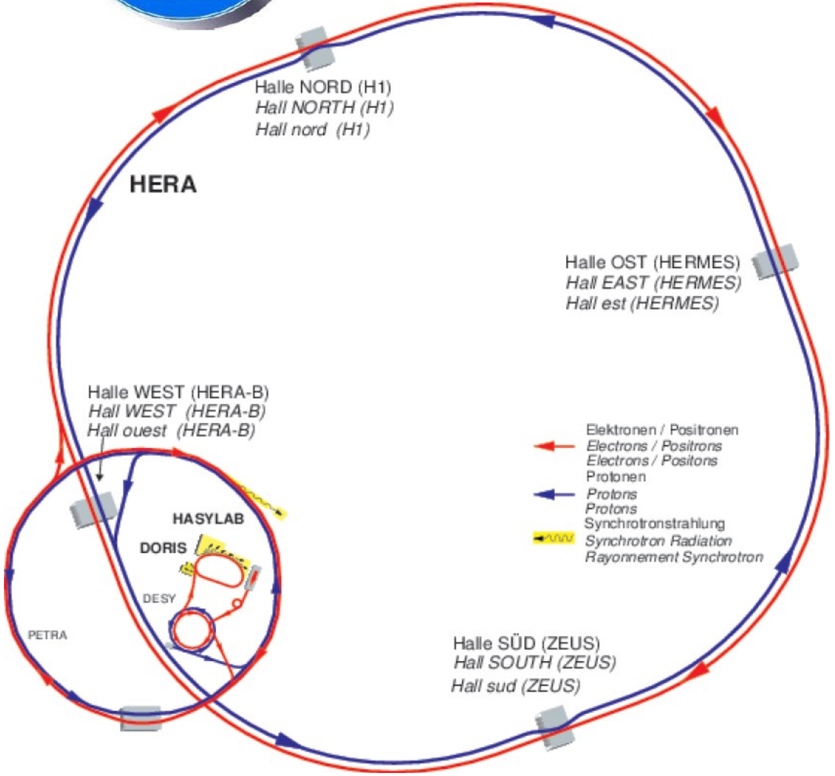
# D* production in diffractive DIS

Karel Černý
(Charles University in Prague)

on behalf of the H1 Collaboration

April the 13th 2016, DESY, Hamburg

# HERA and H1




**HERA I (1993-2000) ≈ 120 $pb^{-1}$**

**HERA II (2003-2007) ≈ 380 $pb^{-1}$**

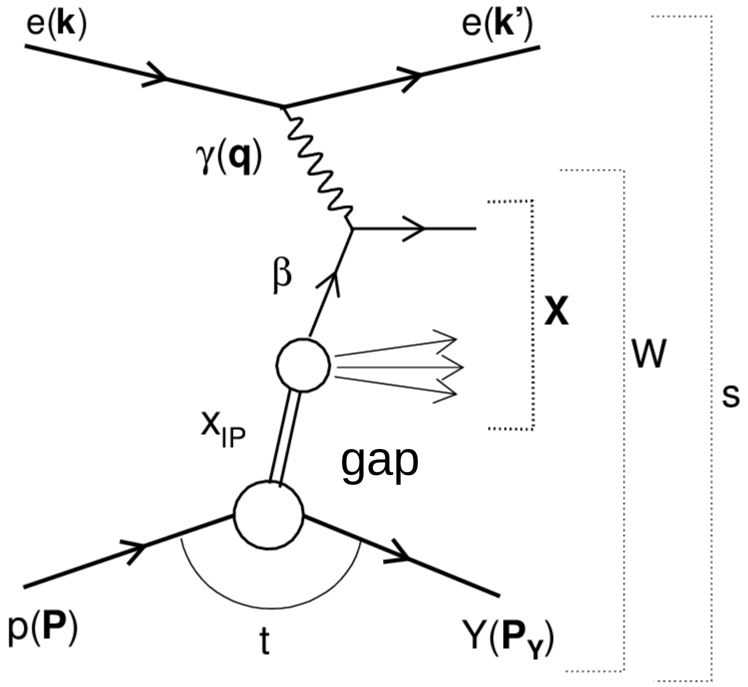
**$E_p$ = 920 GeV　　$E_{e\pm}$ = 27.5 GeV**

**$\sqrt{s}$ = 318 GeV**

# Diffractive deep inelastic scattering

**processes: ep → eXY**

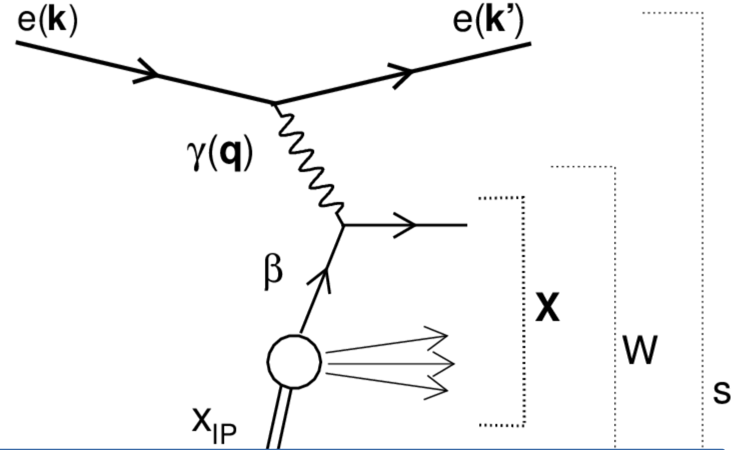
- vacuum quantum numbers exchange
- hard scale present
- rapidity gap between X and Y
  - non-exponentially-suppressed
  - intact proton (EL) or proton dissociation (PD) to Y ($M_Y$ << W)
- both gap and leading proton observation used in H1



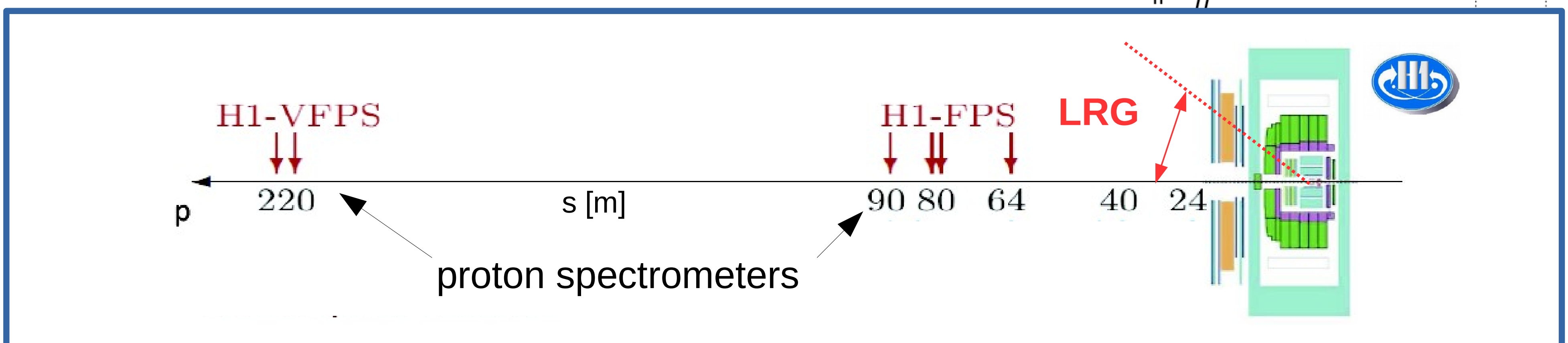

$$s=(k+P)^2$$
$$Q^2=-q^2=-(k-k')^2$$
$$W=\sqrt{(q+P)^2}$$
$$t=(P-P_Y)^2$$
$$x=x_{IP}.\beta$$
$$M_X=\sqrt{X.X}$$

# Diffractive deep inelastic scattering

## processes: ep → eXY




- vacuum quantum numbers exchange
- hard scale present




- both gap and leading proton observation used in H1

$$t=(P-P_Y)^2$$

$$x=x_{IP}.\beta$$

$$M_X=\sqrt{X.X}$$

# Diffractive deep inelastic scattering

- large data samples collected on inclusive diffractive DIS by H1
- diffractive parton distribution functions (DPDF) extracted from inclusive DDIS under assumption of:

**collinear factorization**

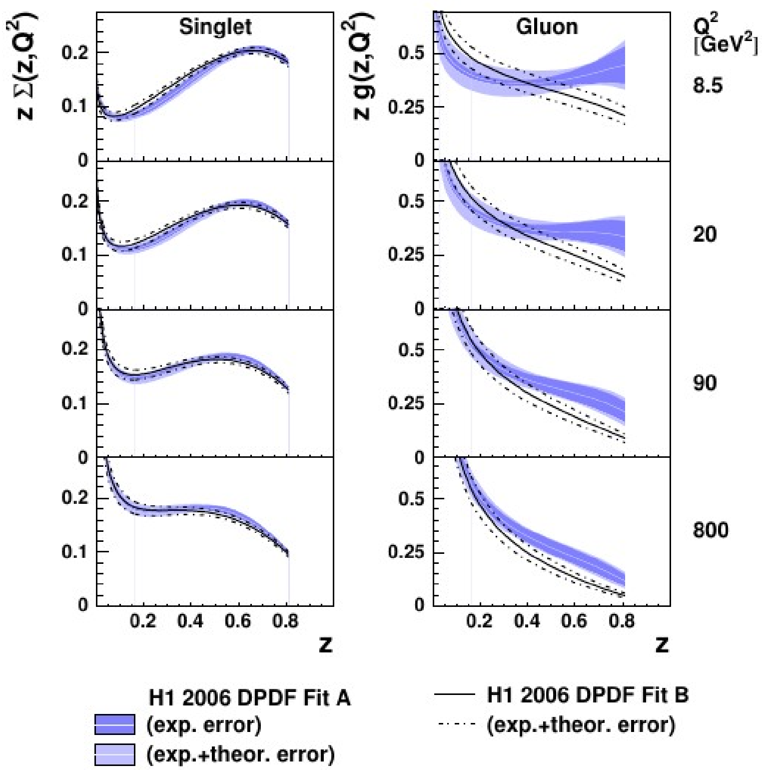
$$d\sigma^{ep\to eXY} = \sum_i f_i^D(x, Q^2, x_{IP}, t) \otimes d\hat{\sigma}^i(x, Q^2)$$

optionaly, also proton vertex factorization

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

# Diffractive deep inelastic scattering

- large data samples collected on inclusive diffractive DIS by H1
- diffractive parton distribution functions (DPDF) of:

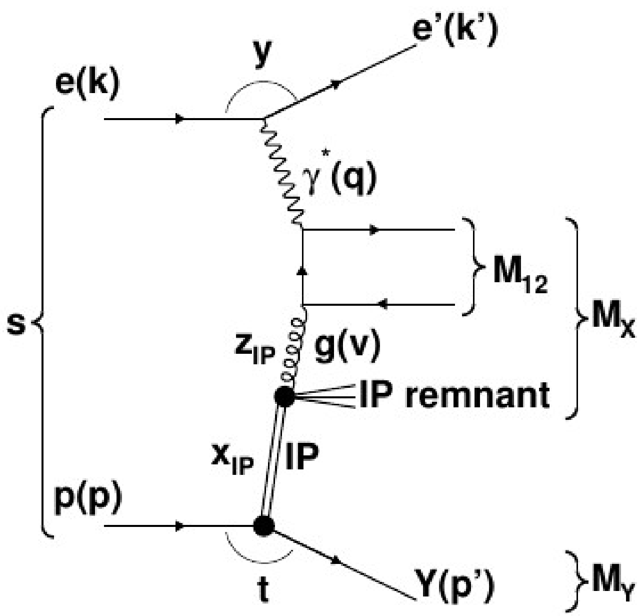



Eur.Phys.J.C48 (2006) 715-748

gluon contribution dominates

collinear factorization was tested for various final states in DIS using the DPDFs

# Tests of collinear factorization in diffraction in H1

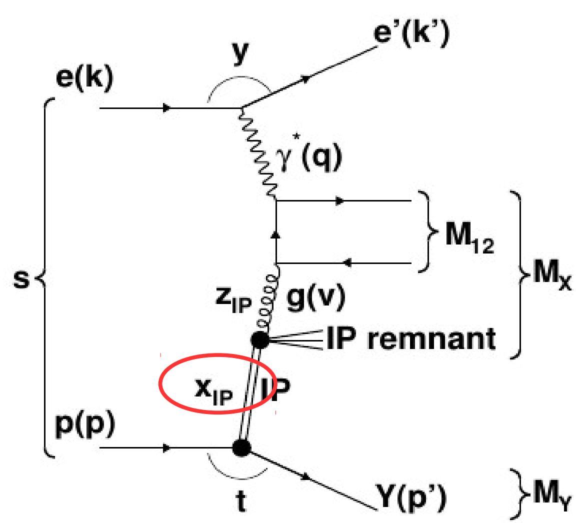


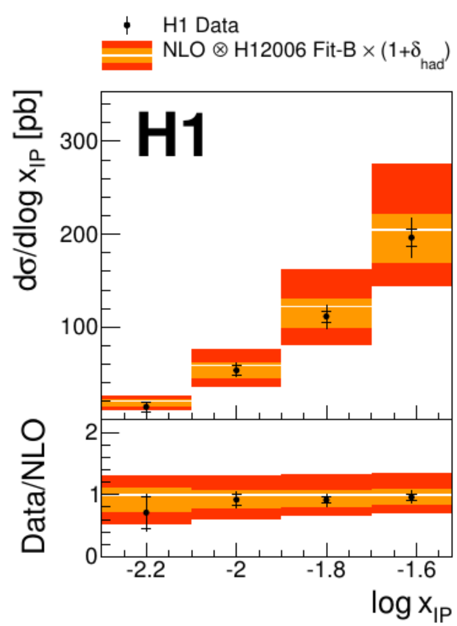

... and other, quark-initiated processes

## Dijets in diffractive DIS

- sensitive to gluon DPDF through $\gamma$-gluon fusion contribution
- $p_T$ and $Q^2$ provide hard scale
- measurement precise enough to make it to DPDF fits for further constraints on gluon

# Tests of collinear factorization in diffraction in H1




## Dijets in diffractive DIS

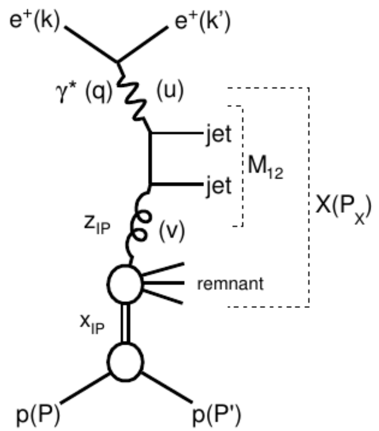
- sensitive to gluon DPDF through $\gamma$-gluon fusion contribution
- $p_T$ and $Q^2$ provide hard scale
- measurement precise enough to make it to DPDF fits for further constraints on gluon

JHEP 1503 (2015) 092

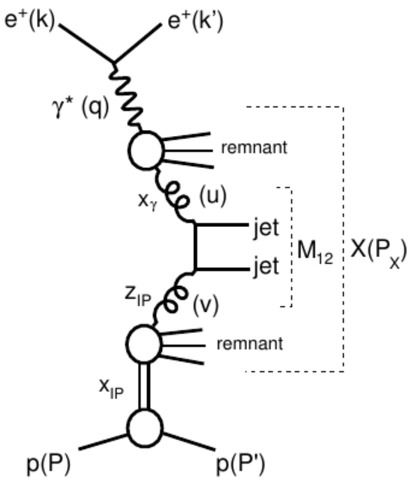
# Tests of collinear factorization in diffraction in H1

## Dijets in diffractive photoproduction

- predictions based on H1 DPDFs overestimate diffractive hadron-hadron data - gap survival ($S^2 < 1$)
- similarly expected in photoproduction regime of ep ($Q^2 \sim 0$)
- mechanism still not fully explained

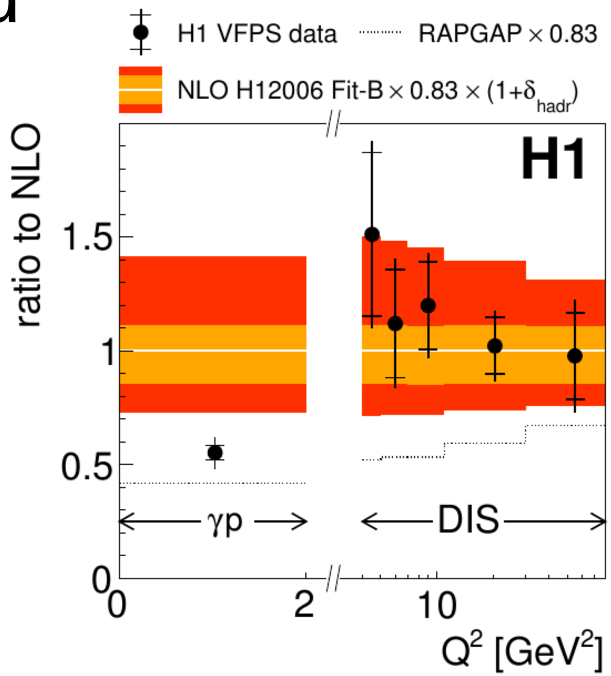



DIS
DIS-like in γp




γ-PDF in γp

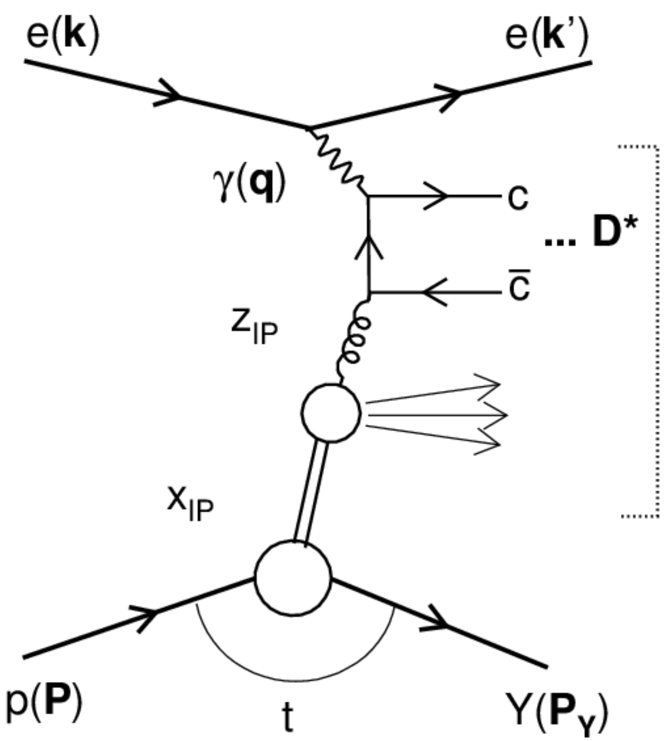
JHEP05 (2015) 056



# Tests of collinear factorization in diffraction in H1

## Open charm in diffraction

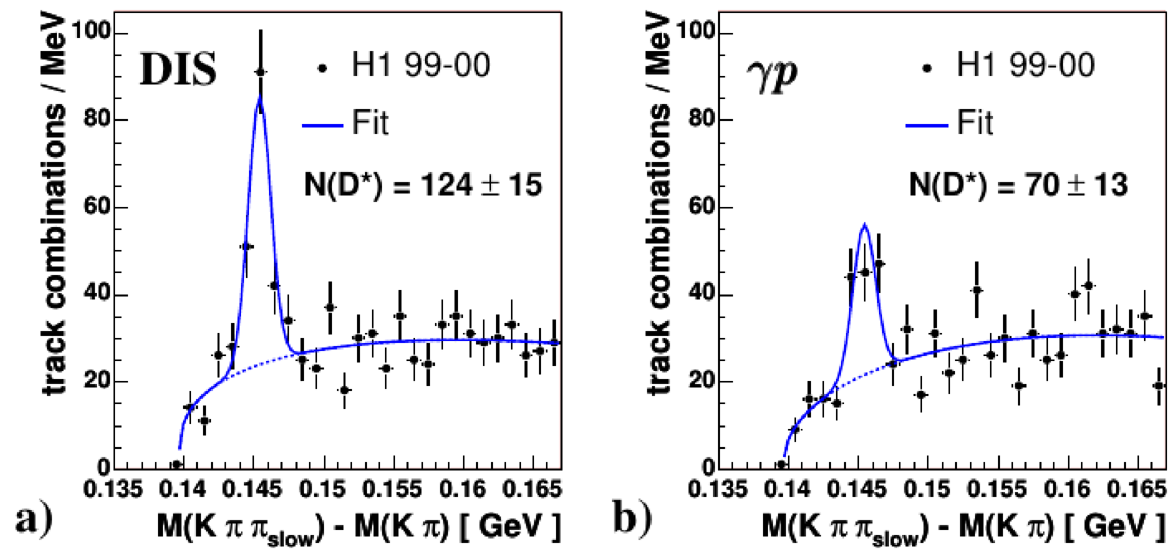
- tagged with presence of D* in the final state
- gluon initiated
- low statistics (w.r.t. dijets)




Eur.Phys.J.C50 (2007) 1

DIS: $Q^2 > 4$ GeV$^2$

γp: $Q^2 < 0.01$ GeV$^2$

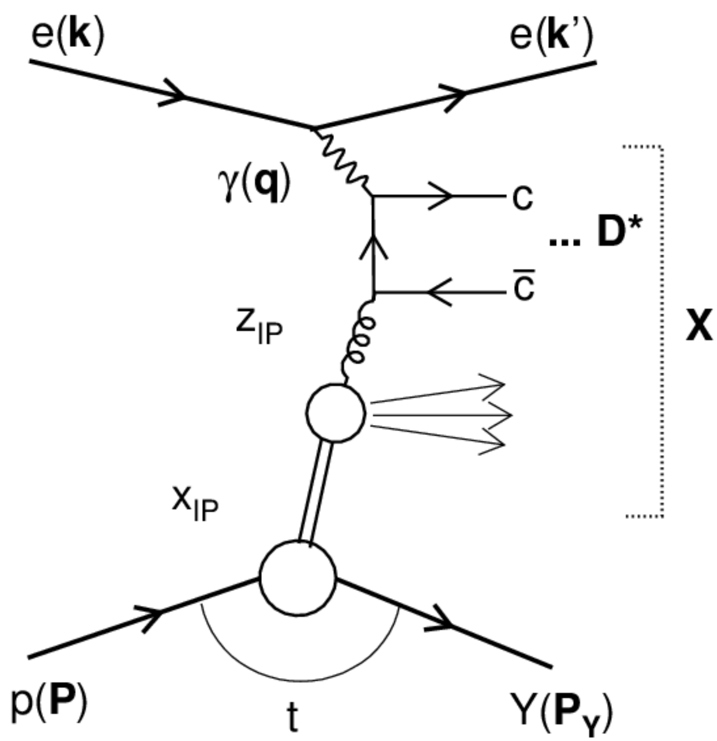



L ~ 50 pb$^{-1}$

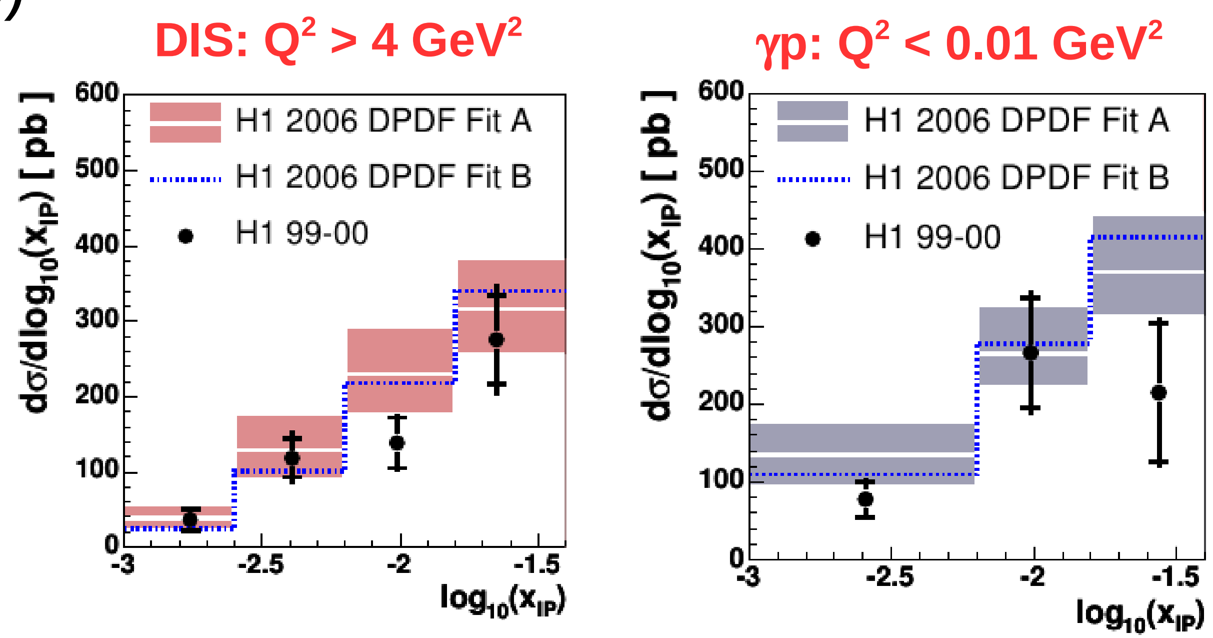
# Tests of collinear factorization in diffraction in H1

## Open charm in diffraction

- tagged with presence of D* in the final state
- gluon initiated
- low statistics (w.r.t. dijets)




Eur.Phys.J.C50 (2007) 1




L ~ 50 pb$^{-1}$

# D* production in diffractive DIS

**new H1 measurement - preliminary**

**ep → e Y X(D*)**

- H1-HERA 2 data

  **$L_{int}$ ~ 280 $pb^{-1}$**

- D* reconstructed fully in:

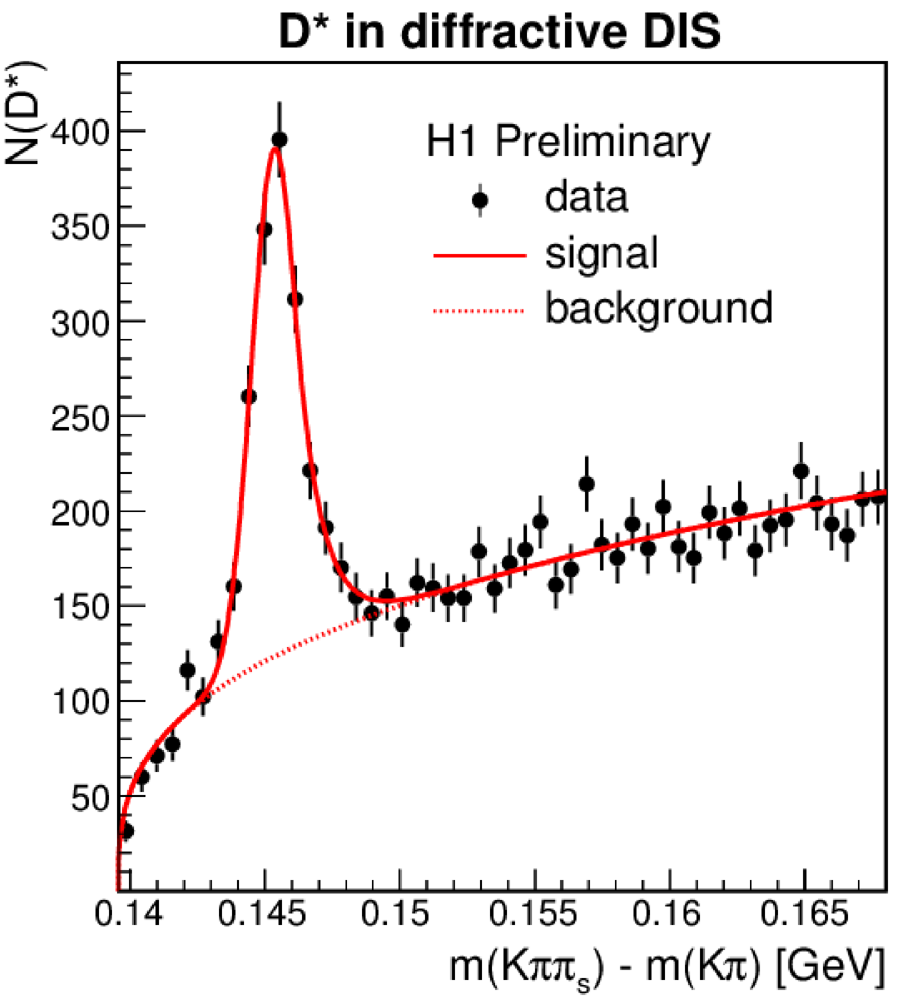
$$D^{*+} \rightarrow D^0 \pi^+_{slow} \rightarrow (K^- \pi^+) \pi^+_{slow} + C.C.$$

(BR ~ 2.6 %)

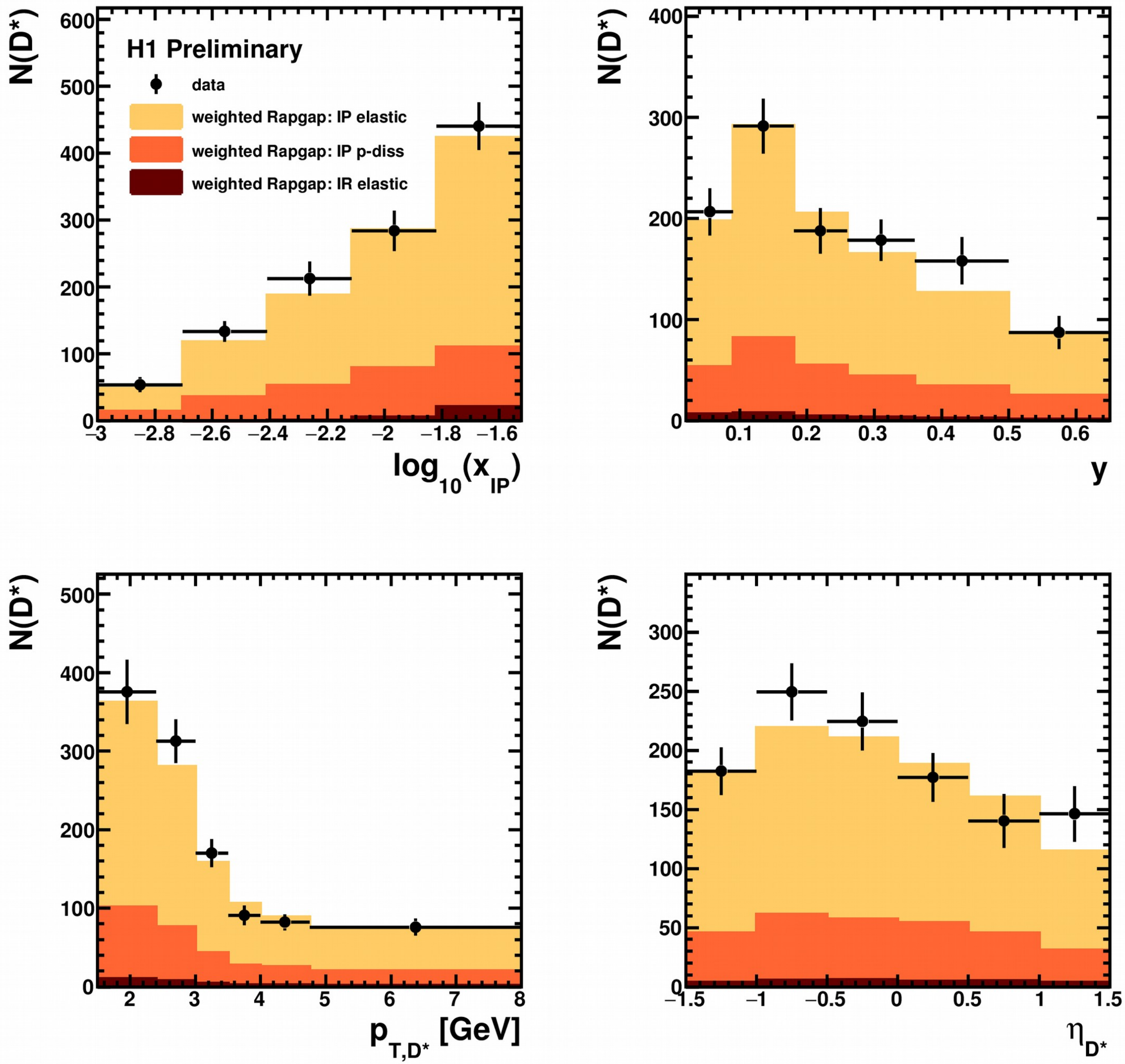
- fits of $\Delta m = m(D^*_{cand}) - m(D^0_{cand})$

- large rapidity gap selection

- 5 < $Q^2$ < 100 $GeV^2$ 0.02 < y < 0.65
  $p_{T,D^*}$ > 1.5 GeV $|\eta_{D^*}|$ < 1.5 … both in laboratory frame
  $x_{IP}$ < 0.03



# D* in diffractive DIS




**detector level control distributions**

- correction of the data for detector effects relies on adequate description with simulation
- fits performed in each bin for data and MC contribution
- proton dissociation contribution ($M_Y > m_p$)
- non-diffractive background negligible
- weighting applied to correct shape and normalization agreement

## cross sections compared with

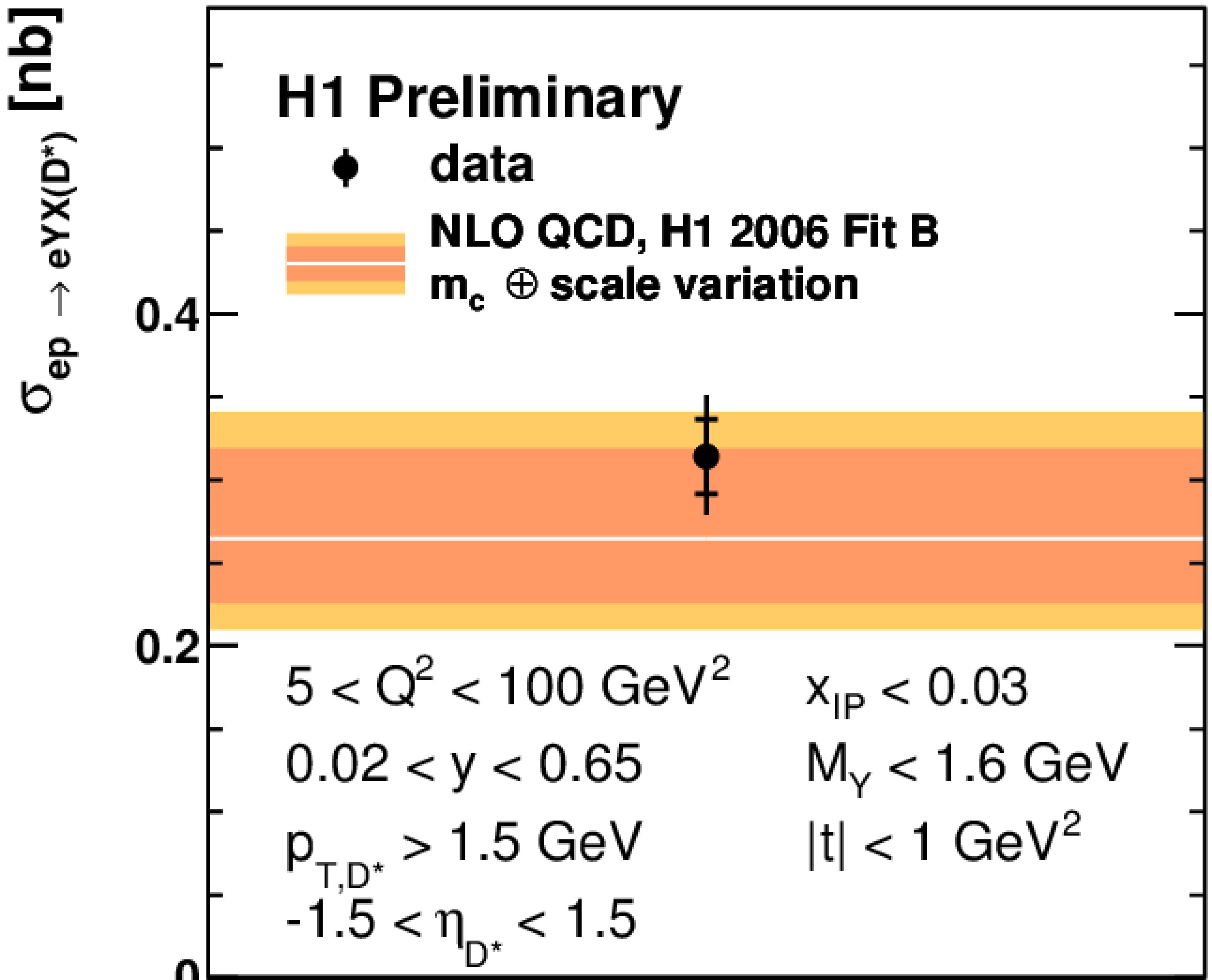
## NLO QCD by HVQDIS in FFNS

- adapted for diffraction, using H1 2006 DPDF Fit B Eur.Phys.J.C73 (2013) 2311
- $\mu^2_r = \mu^2_f = m^2_c + 4\,Q^2$
- charm mass $m_c$ = 1.5 GeV
- Kartvelishvili fragmentation used
  - according to H1 measurement, Eur.Phys.J.C71 (2011) 1769

## Theoretical uncertainties considered at the moment

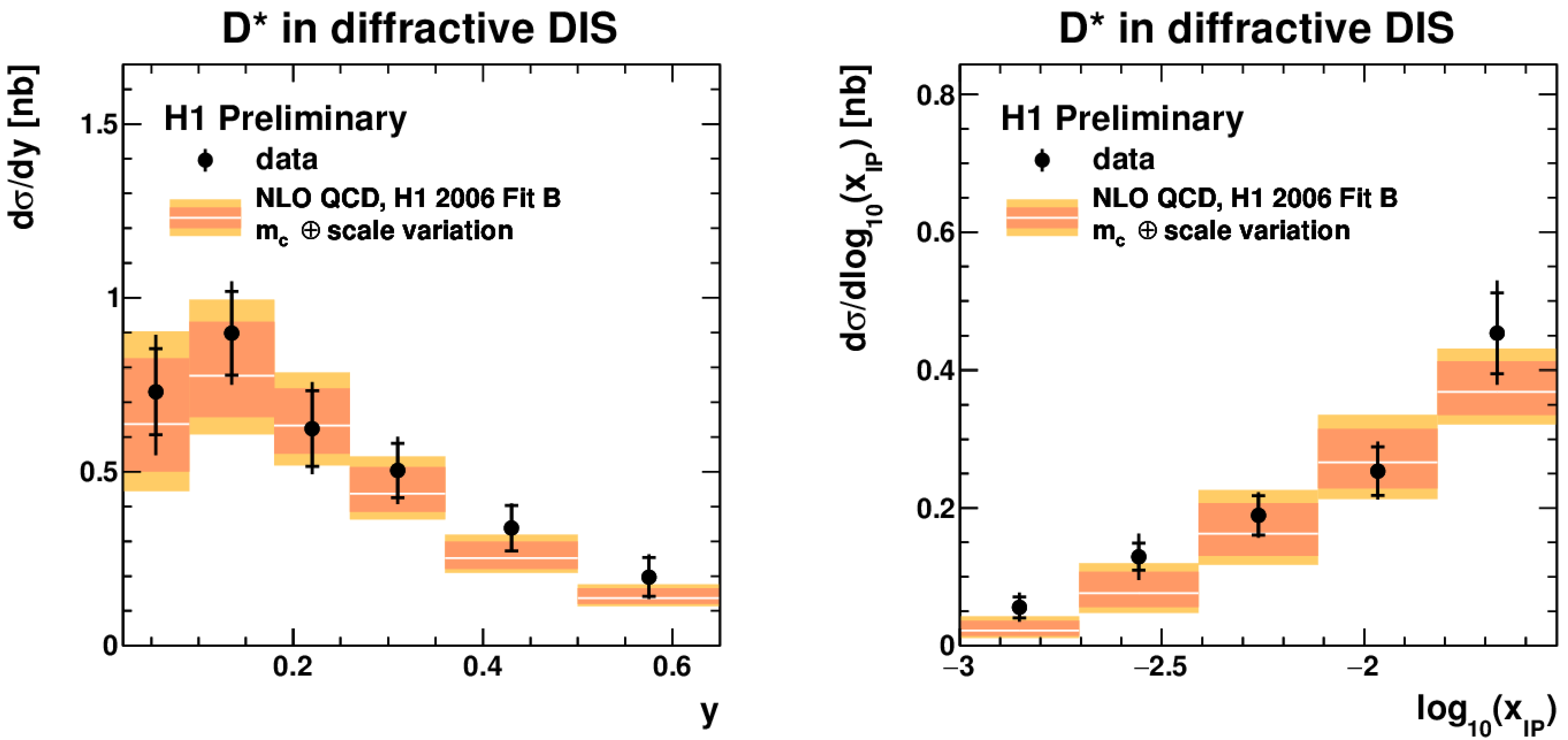
- $\mu_r$ , $\mu_f$ varied by 0.5 and 2 simultaneously for th. uncertainty
- $1.3 < m_c < 1.7$ GeV

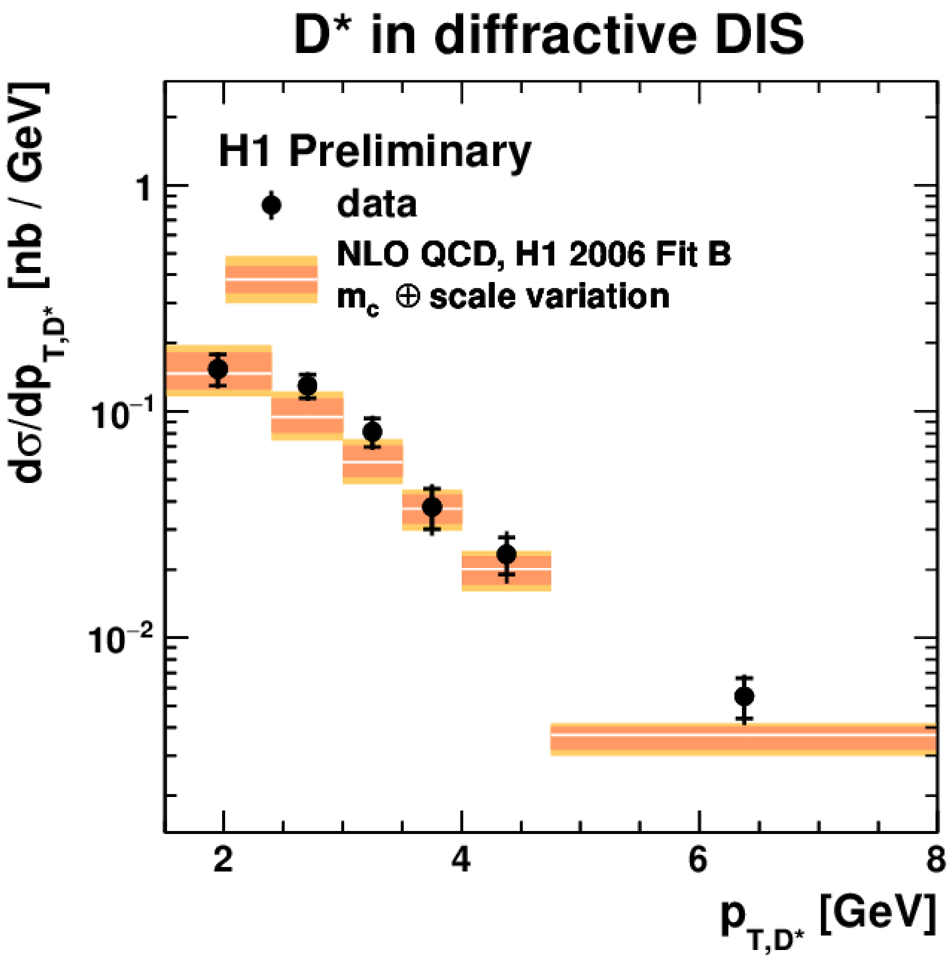
# D* in diffractive DIS

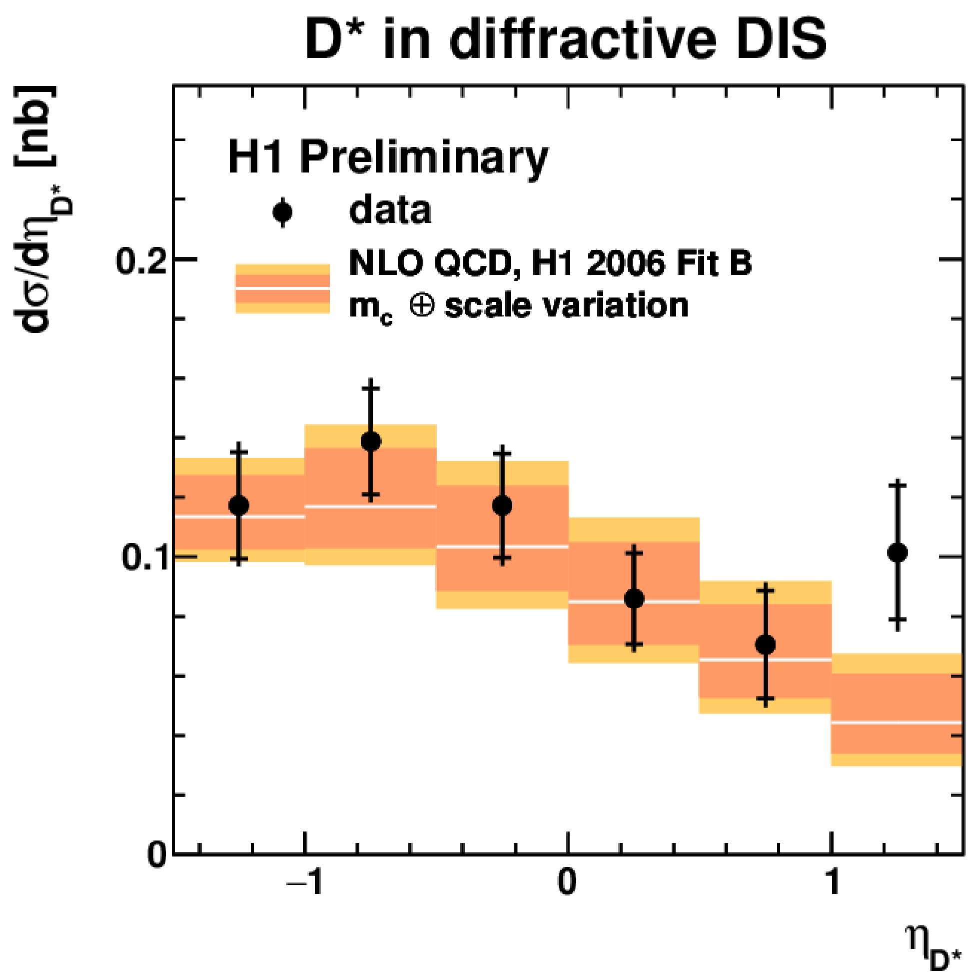



$$\sigma_{ep\rightarrow eYX(D^*)} = 0.314 \pm 0.022\,(\mathrm{stat.}) \pm 0.028\,(\mathrm{syst.})\ [\mathrm{nb}]$$

dominant sources of syst. error: gap selection
proton dissociation contribution


D* in diffractive DIS
H1 Preliminary
data
NLO QCD, H1 2006 Fit B
m_c ⊕ scale variation
dσ/dy [nb]
1.5
1
0.5
0
0.2
0.4
0.6
y
D* in diffractive DIS
H1 Preliminary
data
NLO QCD, H1 2006 Fit B
m_c ⊕ scale variation
dσ/dlog10(x_IP) [nb]
0.8
0.6
0.4
0.2
0
−3
−2.5
−2
log10(x_IP)


D* in diffractive DIS
H1 Preliminary
data
NLO QCD, H1 2006 Fit B
m_c ⊕ scale variation
dσ/dp_T,D* [nb / GeV]
p_T,D* [GeV]


D* in diffractive DIS
H1 Preliminary
data
NLO QCD, H1 2006 Fit B
m_c ⊕ scale variation
dσ/dη_D* [nb]
η_D*

# Conclusions

**new preliminary H1 measurement**

**(1)** New measurement of open charm production in diffractive DIS with larger dataset.

**(2)** NLO QCD prediction (in FFNS) based on DPDFs measured from inclusive H1 data, agree well within errors with measured cross sections - new test of collinear factorization validity.

**(3)** Charm fragmentation function with Kartvelishvili parameterization determined in previous H1 (non-diffractive) analysis, supports universality of fragmentation.

**(4)** Final measurement of cross sections might serve as an input to DPDF fits.

# Backup

# Measurement of $D^{*\pm}$ Meson Production and Determination of $F_2^{c\bar{c}}$ at low $Q^2$ in Deep-Inelastic Scattering at HERA

Eur.Phys.J.C71 (2011) 1769

| RAPGAP | | |
|---|---|---|
| Parameter name | Central value | Variation |
| Charm mass | $m_c = 1.5$ GeV | |
| Renormalisation scale | $\mu_r = \sqrt{Q^2 + 4m_c^2 + (p_T^*)^2}$ | |
| Factorisation scale | $\mu_f = \sqrt{Q^2 + 4m_c^2 + (p_T^*)^2}$ | |
| Fragmentation | $\alpha = 10.3$ for $\hat{s} < \hat{s}_{threshold}$<br>$\alpha = 4.4$ for $\hat{s} > \hat{s}_{threshold}$<br>$\hat{s}_{threshold} = 70$ GeV$^2$ | $8.7 < \alpha < 12.2$<br>$3.9 < \alpha < 5.0$<br>$50 < \hat{s}_{threshold} < 90$ GeV$^2$ |
| PDF | CTEQ6.6M | CTEQ6LL |

| HVQDIS | | |
|---|---|---|
| Parameter name | Central value | Variation |
| Charm mass | $m_c = 1.5$ GeV | $1.3 < m_c < 1.7$ GeV |
| Renormalisation scale | $\mu_{r,0} = \sqrt{Q^2 + 4m_c^2}$ | $1/2 < \mu_r/\mu_{r,0} < 2$ |
| Factorisation scale | $\mu_{f,0} = \sqrt{Q^2 + 4m_c^2}$ | $1/2 < \mu_f/\mu_{f,0} < 2$ |
| Fragmentation | $\alpha = 6.1$ for $\hat{s} < \hat{s}_{threshold}$<br>$\alpha = 3.3$ for $\hat{s} > \hat{s}_{threshold}$<br>$\hat{s}_{threshold} = 70$ GeV$^2$ | $5.3 < \alpha < 7.0$<br>$2.9 < \alpha < 3.7$<br>$50 < \hat{s}_{threshold} < 90$ GeV$^2$ |
| PDF | CT10f3 | MSTW2008f3 |
| Fragmentation fraction | $f(c \to D^*) = 23.8 \pm 0.8\%$ [37] | |