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Charm in Diffractive Deep Inelastic Scattering

Nikolai Vlasov
MOSCOW STATE UNIVERSITY МОСКОВСКИЙ УНИВЕРСИТЕТ
(On behalf of the ZEUS Collaboration)

O U T L I N E

Why measure open charm in diffraction

Models of diffractive exchange

Charm tagging via D^* reconstruction

Results from ZEUS

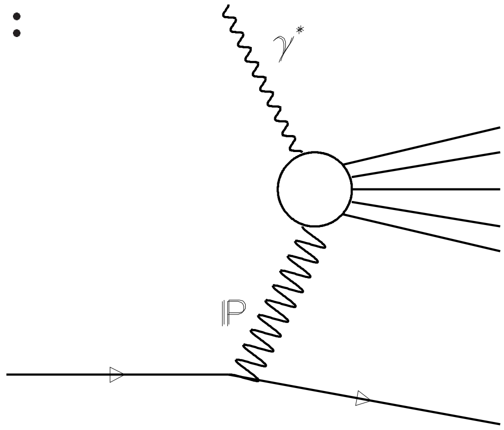
Conclusions

Why measure open charm in diffraction ?

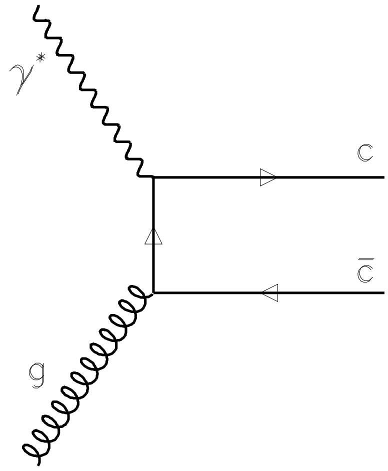
- **to test pQCD $\Lambda_{QCD} << M_C$;**
  charm mass provides a hard scale
- **to test partonic structure of diffraction ;**
  charm is sensitive to role of gluons in diffractive exchange
- **to test diffractive dynamics ;**
  variety of models for diffractive interections (resolved Pomeron, 2-gluon exchange)
- **to understand differencies between data and NLO observed for inclusive D^* in DIS (NLO is below data in forward (proton) direction)**

Models of diffractive exchange

Resolved Pomeron models :



- Based on Regge theory with Pomeron exchange
- Treat $I\!P$ as object with substructure
- Charm Production in diffractive DIS $\rightarrow$ probe gluon content of $I\!P$



- gluon-dominated $I\!P$

- Implemented in RAPGAP based on H1 QCD fits (h1 fit2)

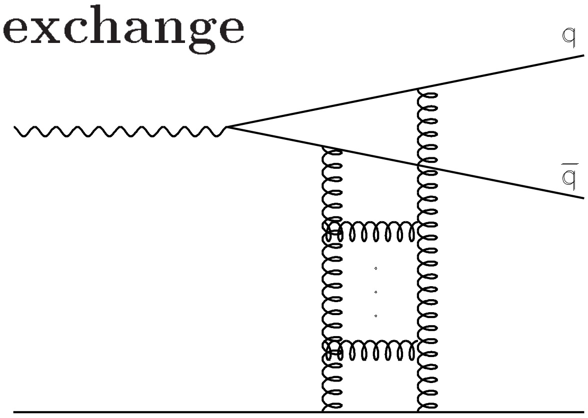
- Used by Alvero, Collins, Terron and Whitmore (ACTW) to make fits to ZEUS and H1 diffractive DIS and γp data

ACTW fit B $\rightarrow$ gluon dominated

Models of diffractive exchange

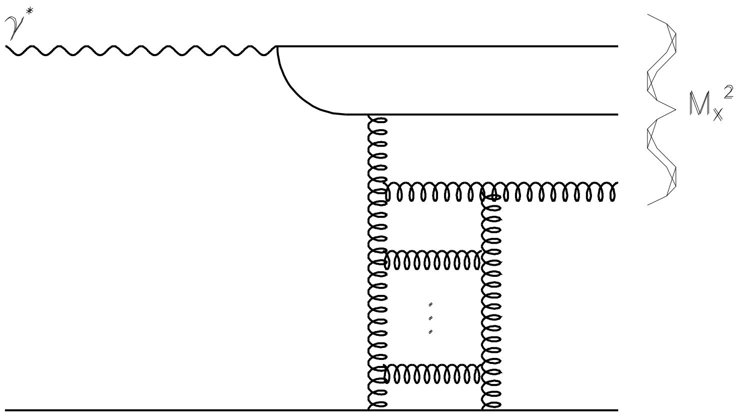
Perturbative QCD models:

- t-channel gluon ladder exchange



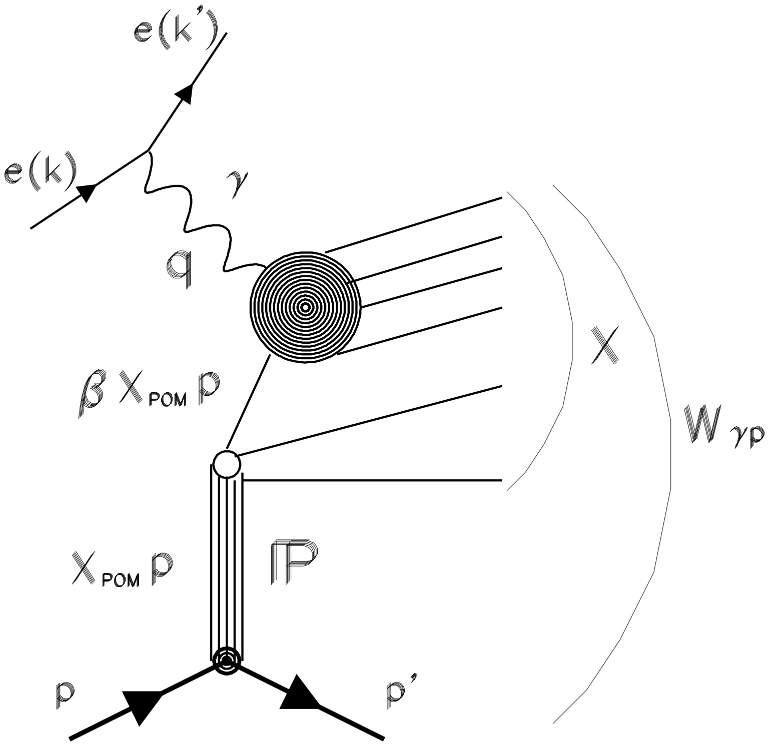
- $\sigma \propto$ (gluon density)^2

- Higher order processes $\gamma^* \to q\bar{q}g$ — cancels suppression for large masses



- implemented in RIDI v2.0 generator
- Two-gluon exchange model implemented in RAPGAP v2.08/01 generator Bartels et al. (BJLW)
- Two-gluon exchange "saturation" model implemented in SATRAP generator (different treatment of the $c\bar{c}g$ final state)

Event Kinematics



$$ep \to eXp \to eD^*X'p$$

$$Q^2 = -(k-k')^2 = -q^2$$
$$W^2 = (P+q)^2$$
$$X_{I\!P} = \frac{M_X^2+Q^2}{W^2+Q^2}$$
$$\beta = \frac{Q^2}{Q^2+M_X^2} \; (for DIS)$$
$$y = \frac{Pq}{Pk}$$

$D^{*\pm}(2010)$ Reconstruction :

D^* was searched for by its decay mode:
$D^* \to D^0\pi_s \to (K\pi)\pi_s$ $\quad$ ($BR = 0.0263 \pm 0.0008$)
Both charged states $D^{*\pm}$ were detected.
$\Delta M = M(D^*) - M(D^0) = 0.14542$ **GeV** $\sim m_\pi$
$.143 < \Delta M < .148$ **GeV**, $\quad 1.81 < M(D^0) < 1.92$ **GeV**

$x(D^*) = \frac{2|\bar{P}^*(D^*)|}{W}$,
where $\bar{P}^*(D^*)$ is D^* momentum in γP system.

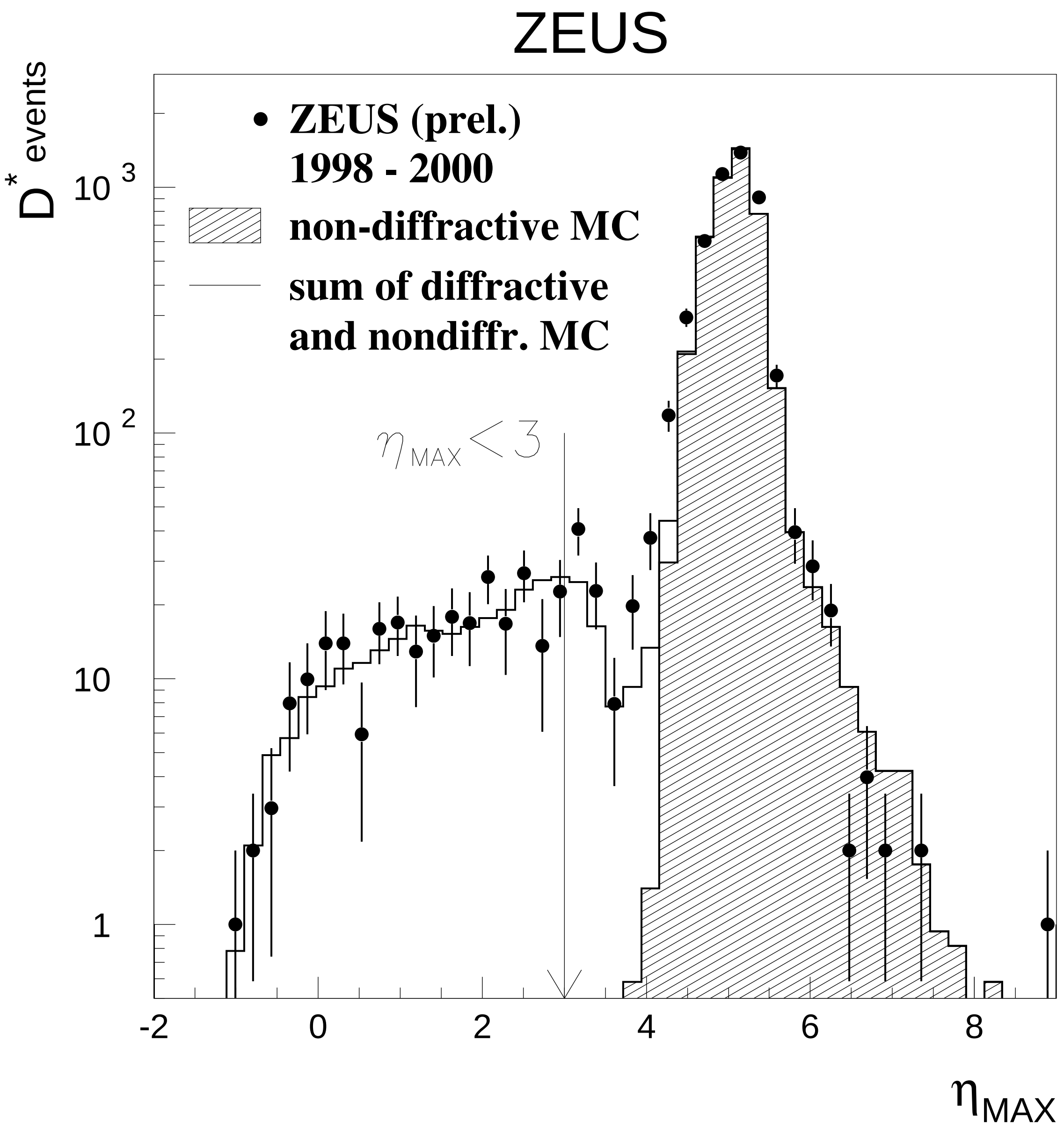
Diffractive reconstruction

Diffractive event $\rightarrow$ LRG event

η_{MAX} **method: most forward particle**

$\rightarrow \eta_{MAX} < \eta_0$

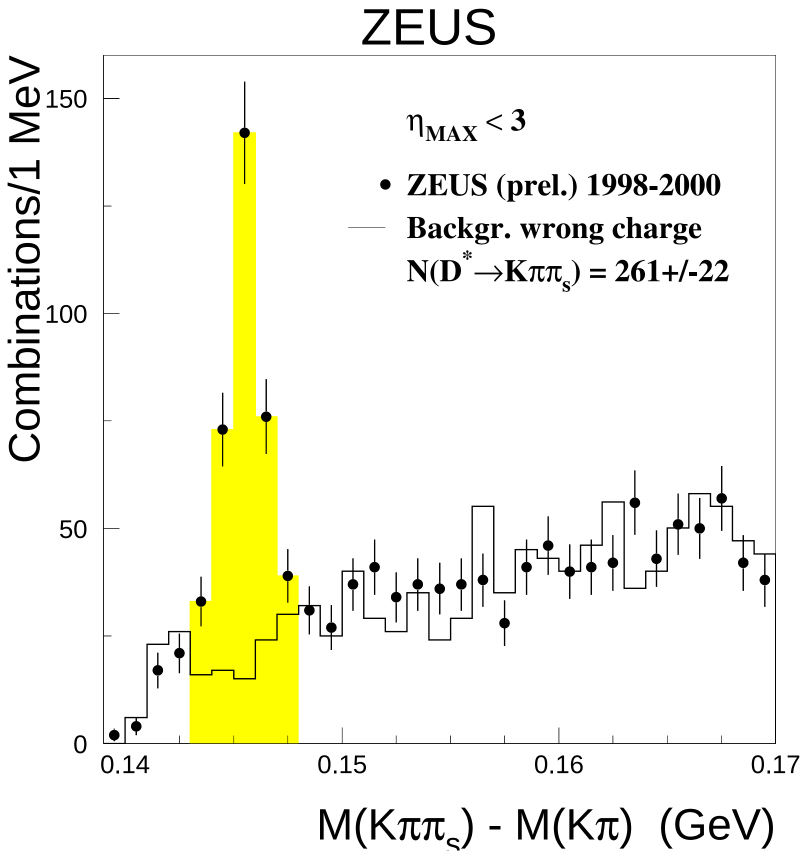
$\rightarrow$ **restricts the range** $x_{I\!P} < 0.035$



$\eta_{MAX} < \eta_0 \,:\, ep \rightarrow e' X N^*$

proton dissociative hadronic system N^* **may fit the cut. Its estimated contribution of** 17 ± 3 % **subtracted from all measured cross sections.**

Diffractive D^* Results ($L = 82\ pb^{-1}$)



$$1.5 < p_\perp(D^*) < 10.\ GeV, \quad -1.5 < \eta(D^*) < 1.5,$$
$$0.02 < y < 0.7, \quad 1.5 < Q^2 < 200.\ GeV^2,$$
$$X_{I\!P} < 0.035, \quad \beta < 0.8$$

$$\sigma^{DIF}_{ep \to D^* X p} = 505 \pm 43\ (stat)^{+30}_{-61}\ (syst)^{+21}_{-21}\ (p.dis.)\ pb$$

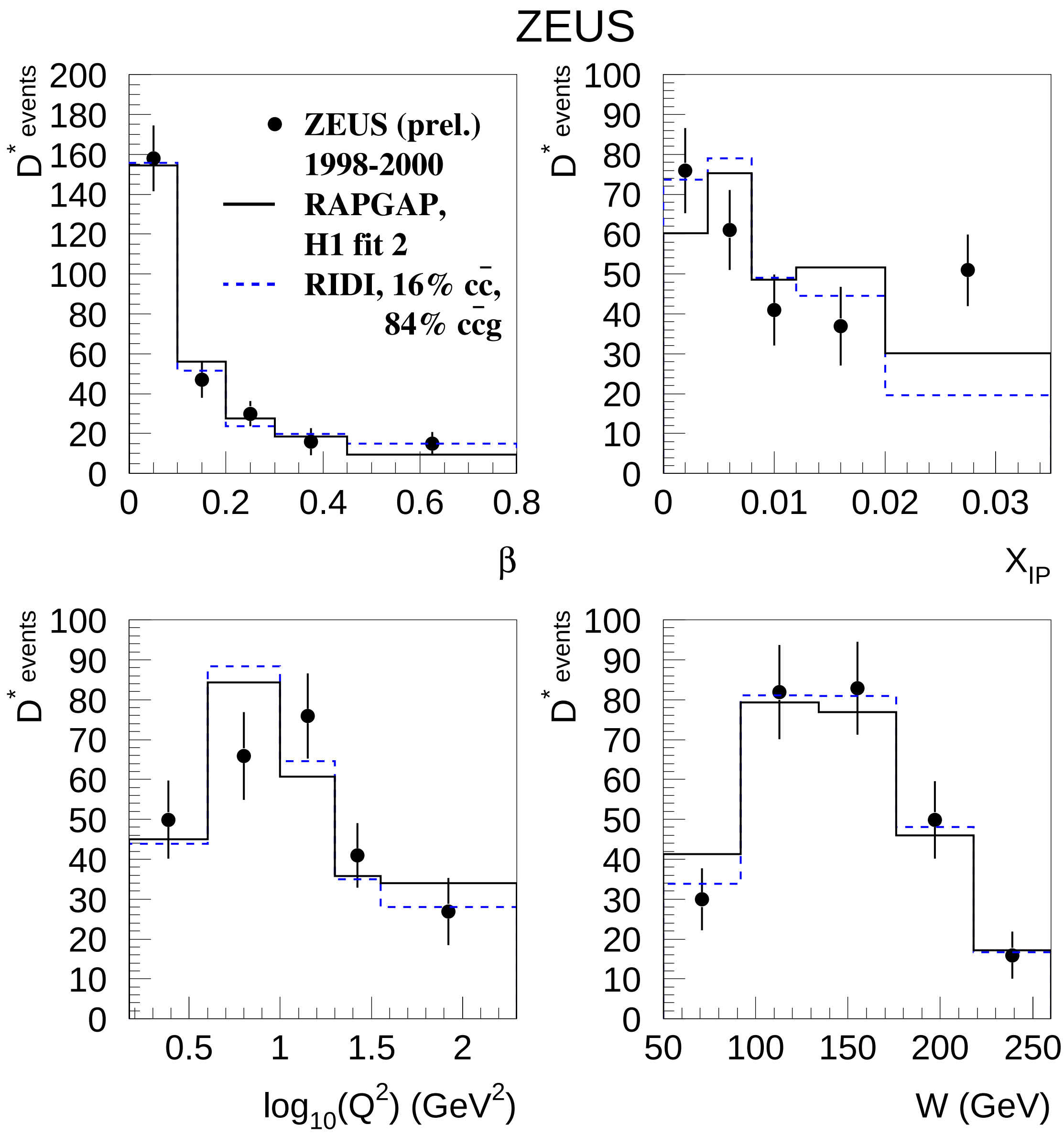
$$R_D = \frac{\sigma^{DIF}}{\sigma^{INC}} = 6.3 \pm 0.6\ (stat)^{+0.3}_{-0.7}\ (syst)^{+0.3}_{-0.3}\ (p.dis.)\ \%$$

Resolved $I\!P$ model predictions for ACTW:

- gluon dominated parametrization fit B
$(\alpha(0) = 1.14, \alpha' = 0.25)$ **:** $\sigma^{DIF}_{ep \to e D^* X p} \sim 530\ pb$

- quark dominated parametrization fits A,C underestimates cross section by factor of $\sim$ 100

Shape Comparison I

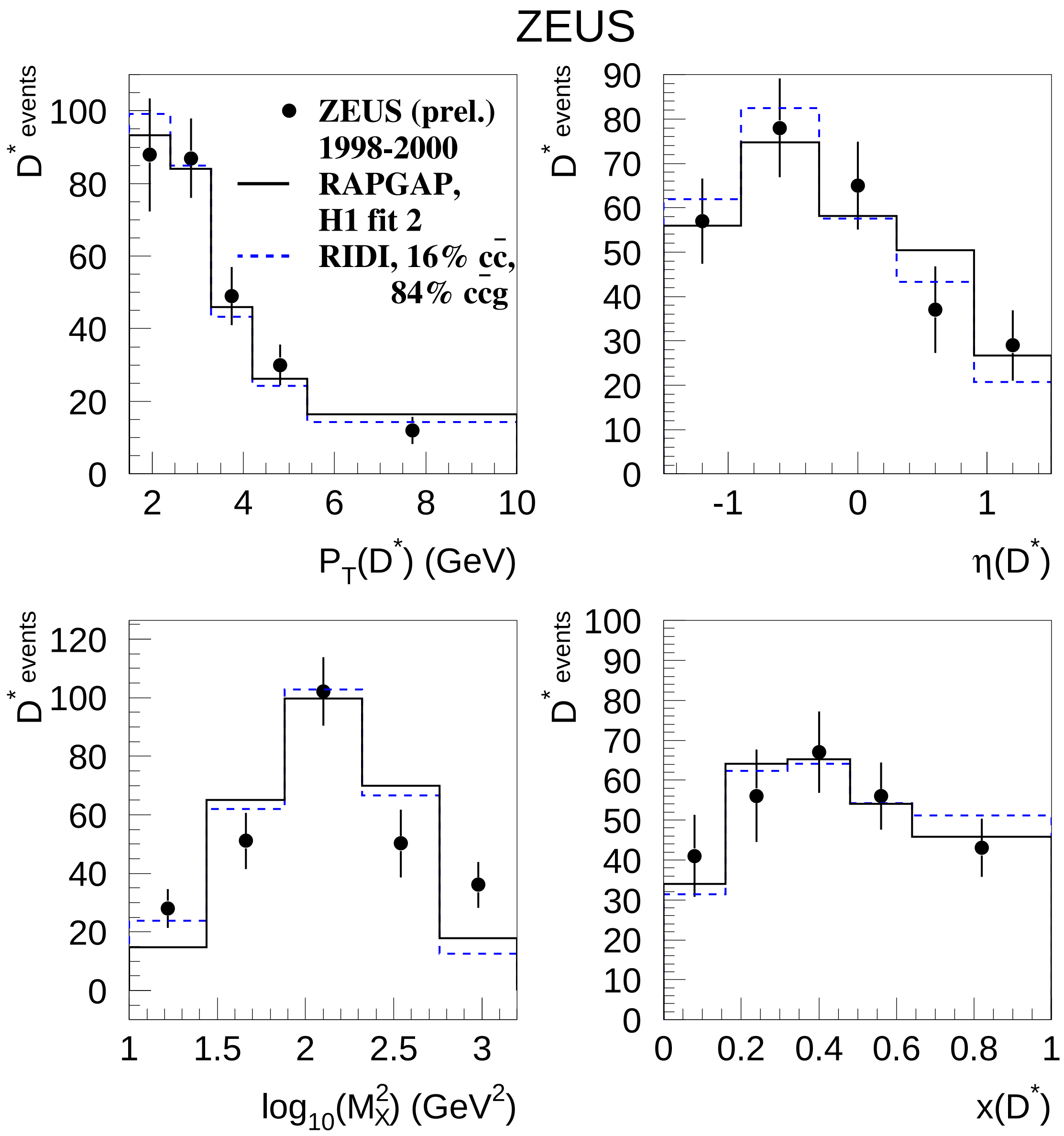


MC distributions are area normalized to data

RIDI (2-gluon exchange model):

to describe data $c\bar{c}$ and $c\bar{c}g$ components are added in proportion 16:84

Shapes Comparison II

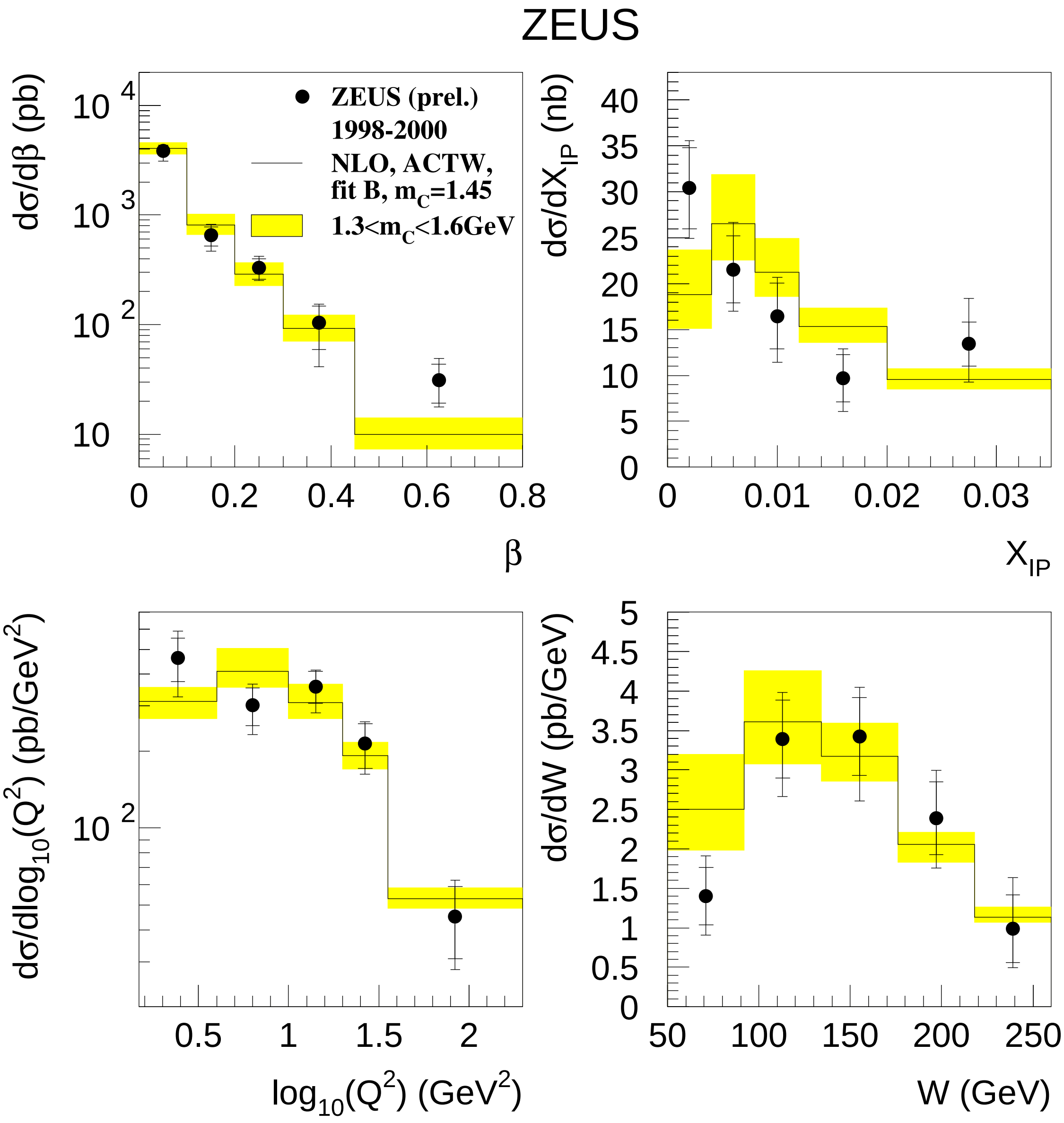


MC distributions are area normalized to data

RAPGAP with H1 fit 2 (resolved Pomeron model) describes shapes reasonably well

Resolved Pomeron Model Comparison I

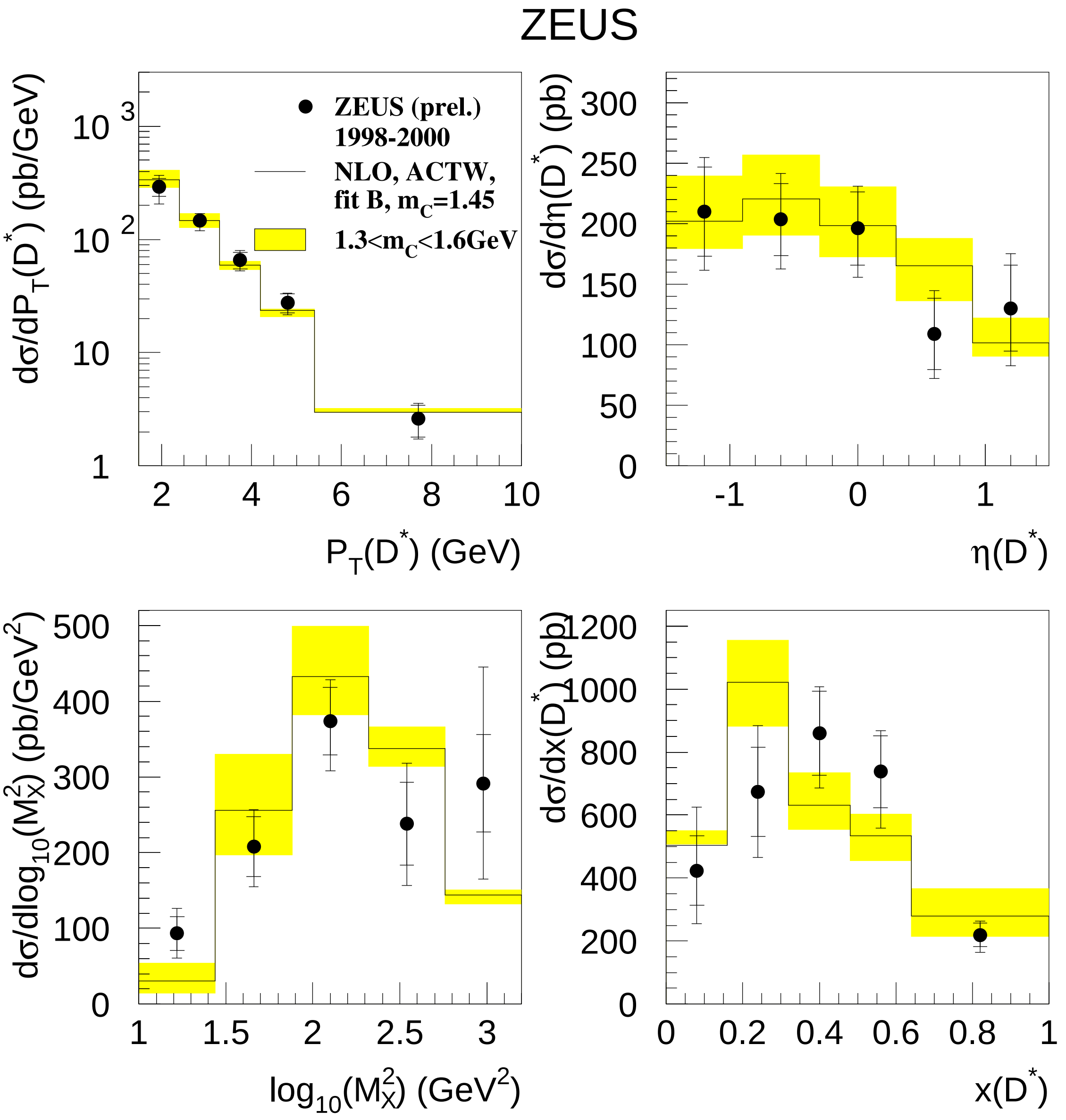
$\sigma^{DIF}_{ep\to eD^*Xp}$ $\quad 1.5 < p_\perp(D^*) < 10\ GeV$ $\quad |\eta(D^*)| < 1.5$



NLO QCD with ACTW fit B Pomeron s.f.
- compare shapes and normalisation
Peterson fragmentation with $\epsilon = 0.035$
$f(c \to D^*) = 23.5\ \%$
scales $\mu^2 = Q^2 + 4m_C^2$
The model do not has Reggeon contribution

Resolved Pomeron Model Comparison II

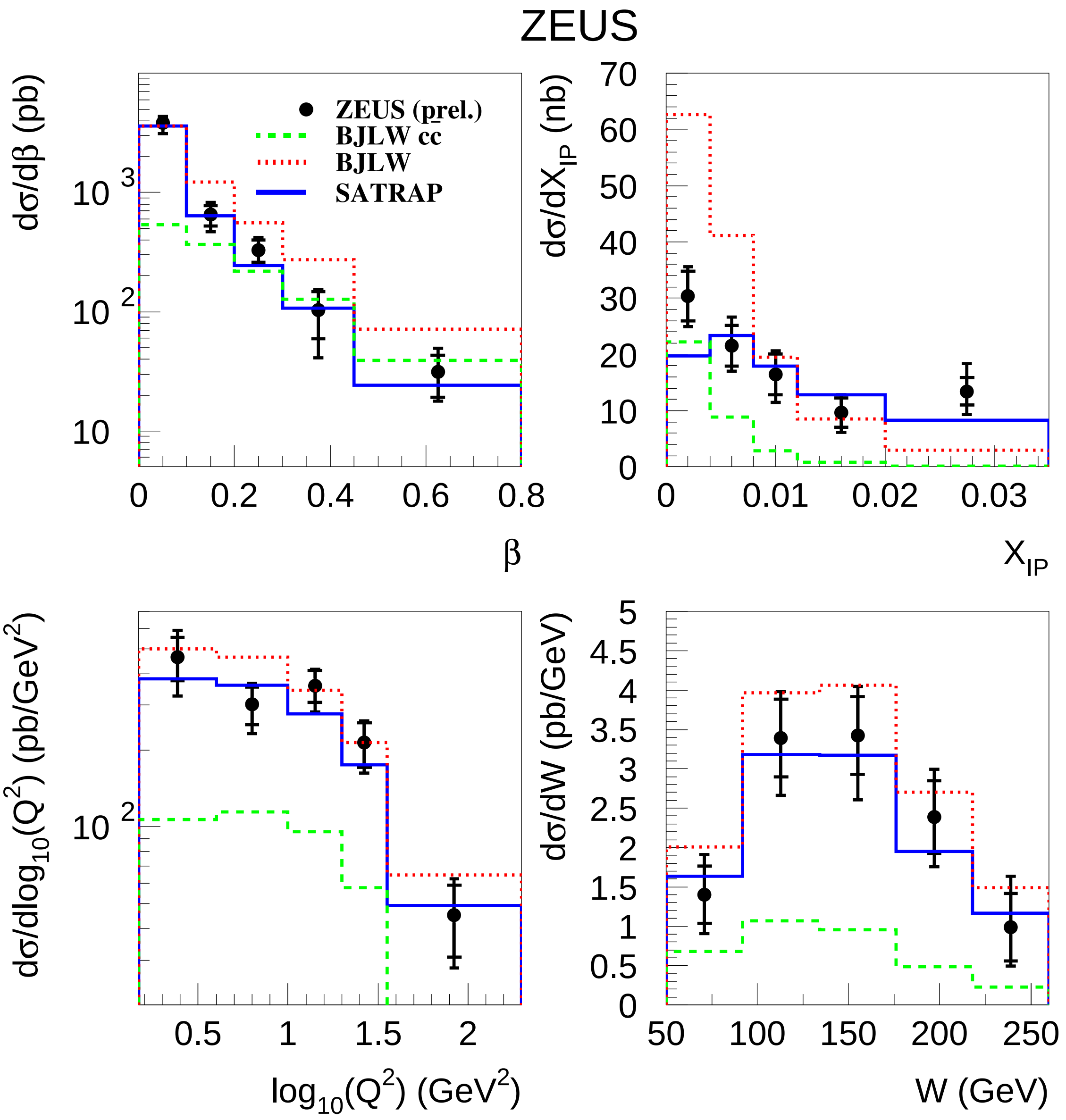
$\sigma^{DIF}_{ep \to e D^* X' p}$ $\quad 1.5 < p_\perp(D^*) < 10\ GeV$ $\quad |\eta(D^*)| < 1.5$



Good agreement with resolved Pomeron model using NLO QCD calculation with ACTW fit B

Two-gluon Model Comparison I

$\sigma^{DIF}_{ep \to eD^* X' p}$ $\quad 1.5 < p_\perp(D^*) < 10\ GeV \quad |\eta(D^*)| < 1.5$



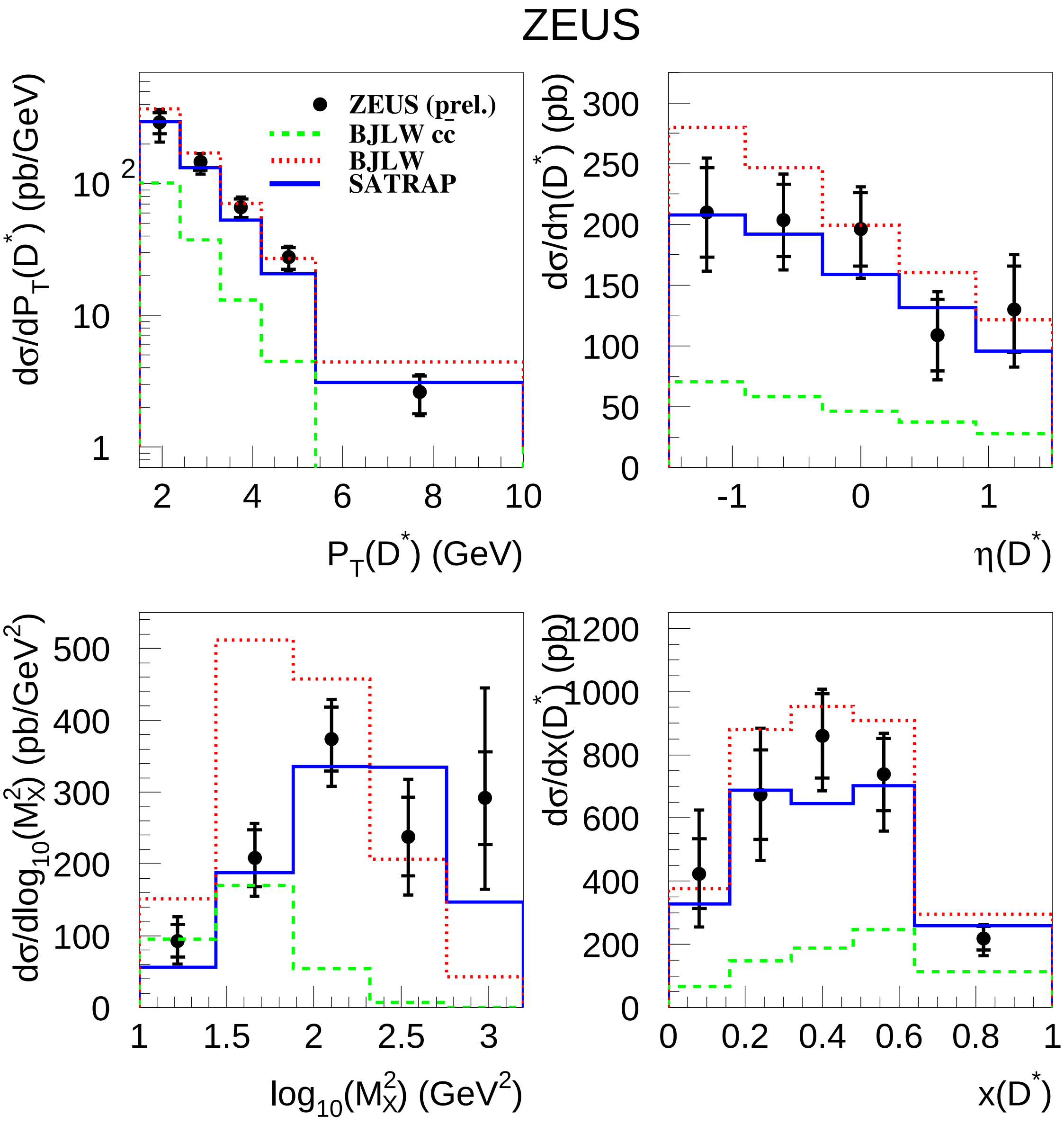
Peterson fr. with $\epsilon = 0.035$, $f(c \to D^*) = 23.5\ \%$
scales $\mu^2 = p_\perp^2 + m_C^2$, **proton s.f. GRV-94 HO**

Cross sections for $x_{I\!P} < 0.01$ $\rightarrow$
(where no Reggion contribution is expected)

Data: $\sigma^{DIF}_{ep \to eD^* X' p} = 240 \pm 25\ (stat)^{+14}_{-23}\ (syst)^{+10}_{-10}\ (p.dis.)\ pb$
BJLW $c\bar{c}$ **:** $\sim 160\ pb$, **BJLW :** $\sim 570\ pb$
SATRAP : $\sim 250\ pb$

Two-gluon Model Comparison II

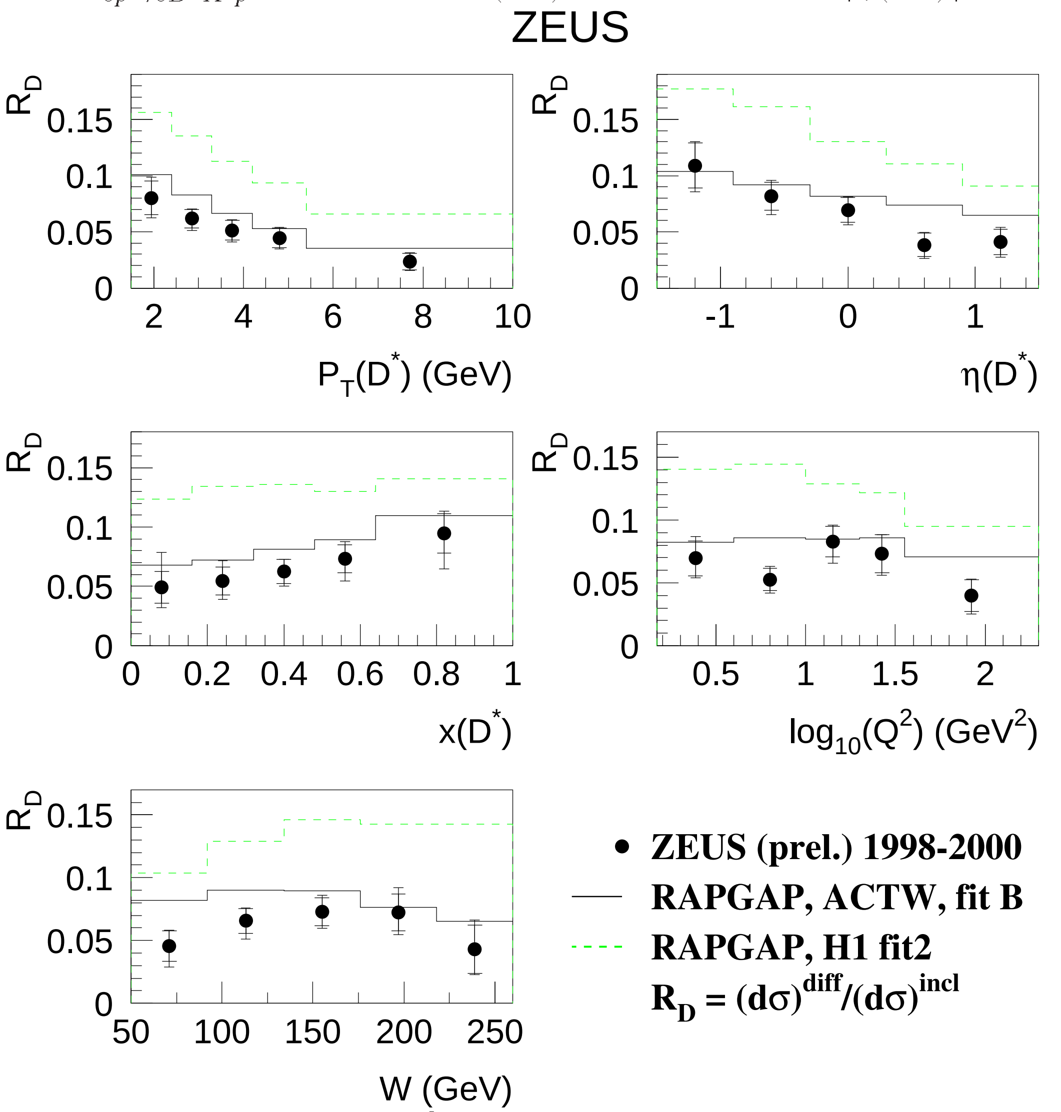
$\sigma^{DIF}_{ep \to eD^* X' p}$ $\quad 1.5 < p_\perp(D^*) < 10\ GeV \quad |\eta(D^*)| < 1.5$



- BJLW $c\bar{c}$ component can not describe the data by itself
- BJLW $c\bar{c} + c\bar{c}g$ is above the data
- SATRAP gives a reasonable description of all distributions

Ratio of Diffractive $D^{*\pm}$ to Total $D^{*\pm}$ Production

$\sigma^{DIF}_{ep\to eD^*X'p}$ $\quad 1.5 < p_\perp(D^*) < 10\ GeV \quad |\eta(D^*)| < 1.5$



- No significant Q^2 or W dependance observed
- Diffractive relative contribution is larger at small $p_\perp(D^*)$ and negative $\eta(D^*)$
- Looks like diffractive production cannot be responsible for a disagreement in forward $(\eta(D^*) > 0)$ direction for inclusive D^* in DIS
- ACTW reasonably describes both shapes and absolute values of R_D. H1 fit2 overestimates absolute values of R_D

Summary

1. **Diffractive cross section in the kinematic range:**
   $1.5 < p_\perp(D^*) < 10.$ **GeV**; $-1.5 < \eta(D^*) < 1.5$
   $0.02 < y < 0.7, \quad 1.5 < Q^2 < 200. \quad GeV^2$
   $X_{I\!P} < 0.035, \quad \beta < 0.8$
   $\sigma^{DIF} = 505 \pm 43\ (stat)^{+30}_{-61}\ (syst)^{+21}_{-21}\ (p.dis.)\ pb$

2. **Resolved Pomeron model:**
   NLO QCD calculation with ACTW fit B Pomeron parametrization describes both normalization and shapes of the measured cross sections within the errors, regarding gluon dominated Pomeron structure

3. **Two-gluon exchange models:**
   - BJLW with $c\bar{c}$ only predicts too small cross sections
   - BJLW with $c\bar{c}$ and $c\bar{c}g$ components overestimates data in $\sim$ 2 times
   - SATRAP reproduces data distributions

4. **Relative contribution of diffractive mechanism to inclusive D^* in DIS production is:**
   $R_D = 6.3 \pm 0.6\ (stat)^{+0.3}_{-0.7}\ (syst)^{+0.3}_{-0.3}\ (p.dis.)\ \%$

5. **Diffractive relative contribution is larger at small $p_\perp(D^*)$ and negative $\eta(D^*)$. Leading order calculations reproduce the trends**