

Photoproduction of D^* Mesons and Jets with H1

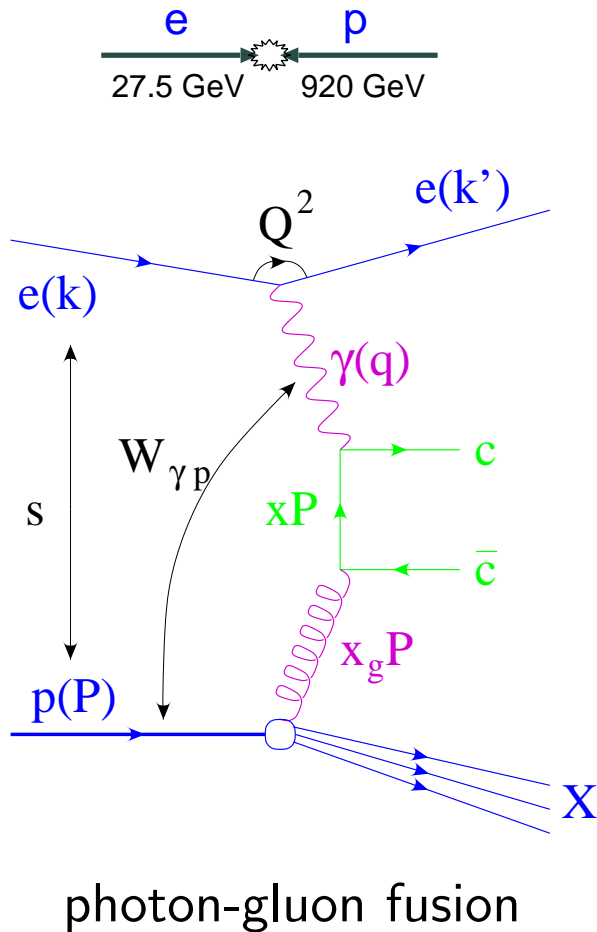


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DESY

- Charm Photoproduction at HERA
- Data Selection: $D^* + \text{Jet}$
- QCD Calculations
- Cross Sections

Charm Photoproduction at HERA



$$s = (k + P)^2 \quad \sqrt{s} \approx 320 \text{ GeV:}$$

centre-of-mass energy

$$Q^2 = -q^2 \quad \gamma \text{ virtuality}$$

$$x = \frac{Q^2}{2 \cdot q \cdot P} \quad \text{Bjorken scaling variable}$$

$$y = \frac{q \cdot P}{k \cdot P} \quad \text{inelasticity}$$

$$W_{\gamma p}^2 = (q + P)^2 \quad W_{\gamma p}: \text{ } \gamma p \text{ centre-of-mass energy}$$

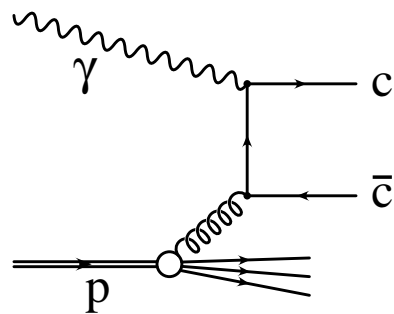
- $Q^2 < 1 \text{ GeV}^2$:
quasi real photon

\Rightarrow photoproduction

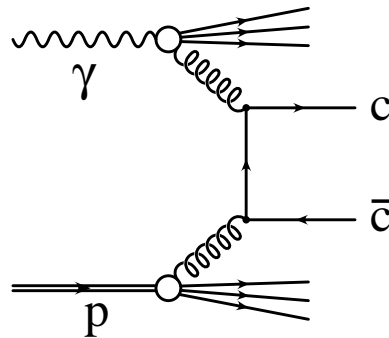
$D^* + \text{Jet}$ Photoproduction

Leading order:

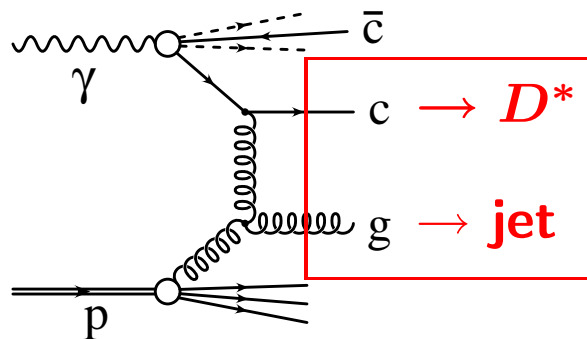
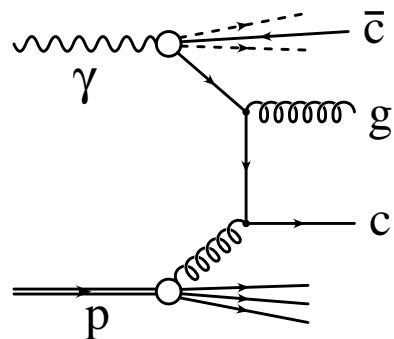
direct



resolved



charm excitation

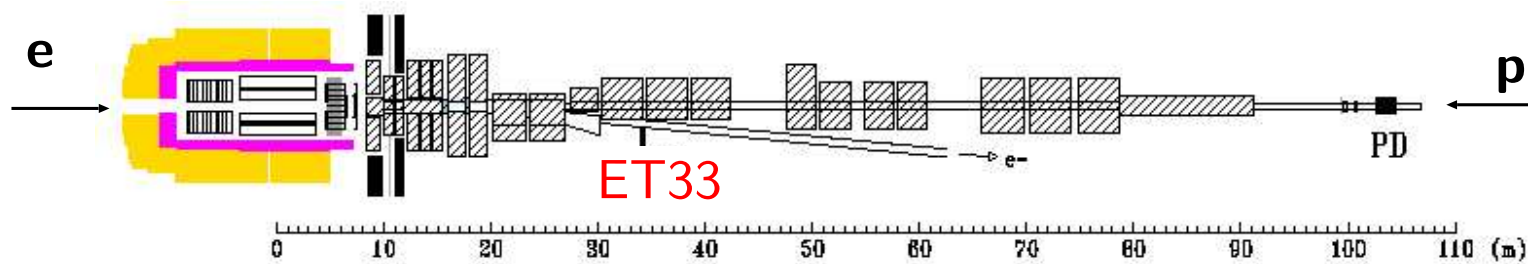


- heavy charm ($m_c \approx 1.5 \text{ GeV}$) provides hard scale: test QCD
 - (Anti-)Charm quark tagged by $c \rightarrow D^* \rightarrow D^0 \pi_s \rightarrow K \pi \pi_s$
 - tag second hard parton by a jet
- ▷ $D^* + \text{jet}$ where jet does not contain D^* meson:

deeper insight in production process

(Tagged) Photoproduction

$Q^2 < 1 \text{ GeV}^2 \Rightarrow$ no scattered electron in main detector



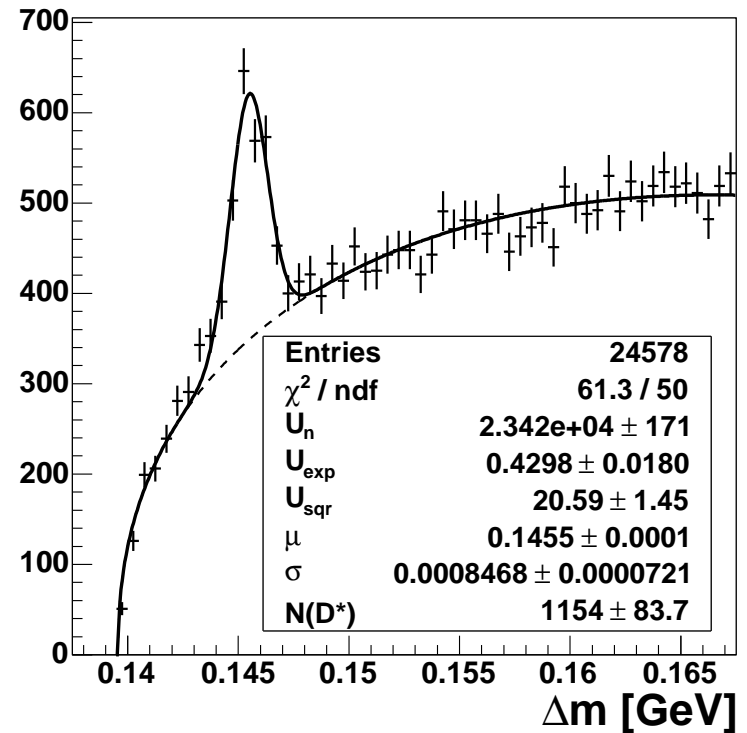
detection in
electron tagger (calorimeter)
 at small angle ($< 5 \text{ mrad}$)
 outside H1

visible range	
Q^2	$< 0.01 \text{ GeV}^2$
y	$0.29 < y < 0.65$
$W_{\gamma p}$	$171 < W_{\gamma p} < 256 \text{ GeV}$

$$W_{\gamma p} = \sqrt{y \cdot s}$$

D^* Selection

- H1 data 1999 & 2000 (e^+p)
 $\Rightarrow \mathcal{L} = 51.1 \text{ pb}^{-1}$
- $D^{*\pm} \rightarrow D^0 \pi_s^\pm \rightarrow K^\mp \pi^\pm \pi_s^\pm$
 - ◇ $p_t(D^*) > 2.0 \text{ GeV}$
 - ◇ $|\eta(D^*)| < 1.5$
- $N(D^*)$ from fit in
 $\Delta m = m(K\pi) - m(K\pi\pi_s)$:
gaussian signal + background

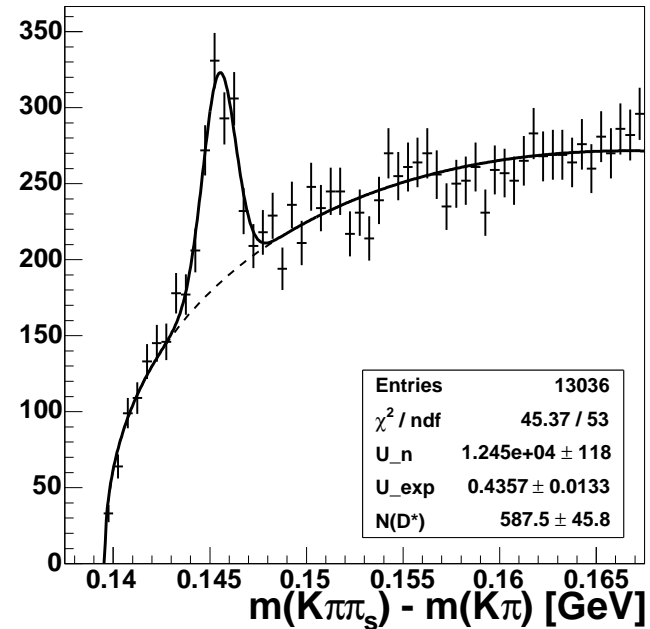


Jet Selection

jet *not* containing D^* :

- inclusive k_t -jet algorithm
(p_t -weighted scheme)
- charged and neutral particles
- D^* meson replaces its K, π, π_s

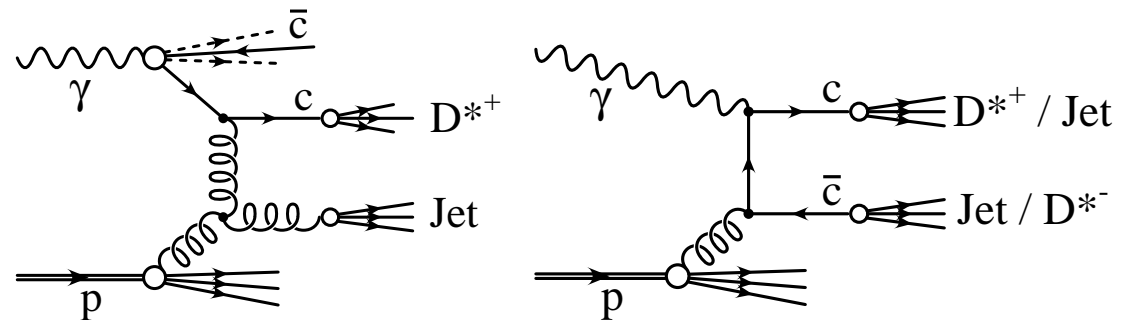
$$\begin{aligned}
 p_t(\text{jet}) &> 3.0 \text{ GeV} \\
 |\eta(\text{jet})| &< 1.5 \\
 D^* &\notin \text{jet} \\
 &\text{highest } p_t \text{ jet}
 \end{aligned}$$



588 ± 46 D^* +jet combinations

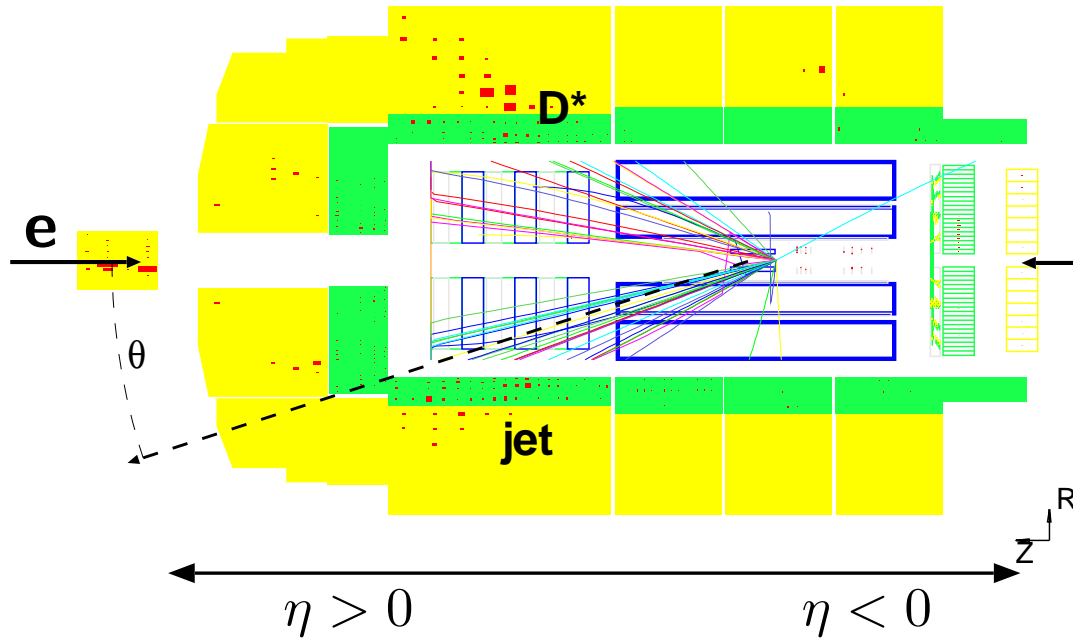
fragmentation: $\left\langle \frac{p_t(D^*)}{p_t(c)} \right\rangle \approx 0.7$

\Rightarrow $\left. \begin{aligned} p_t(D^*) &> 2 \text{ GeV} \\ p_t(\text{jet}) &> 3 \text{ GeV} \end{aligned} \right\} \text{equivalent}$

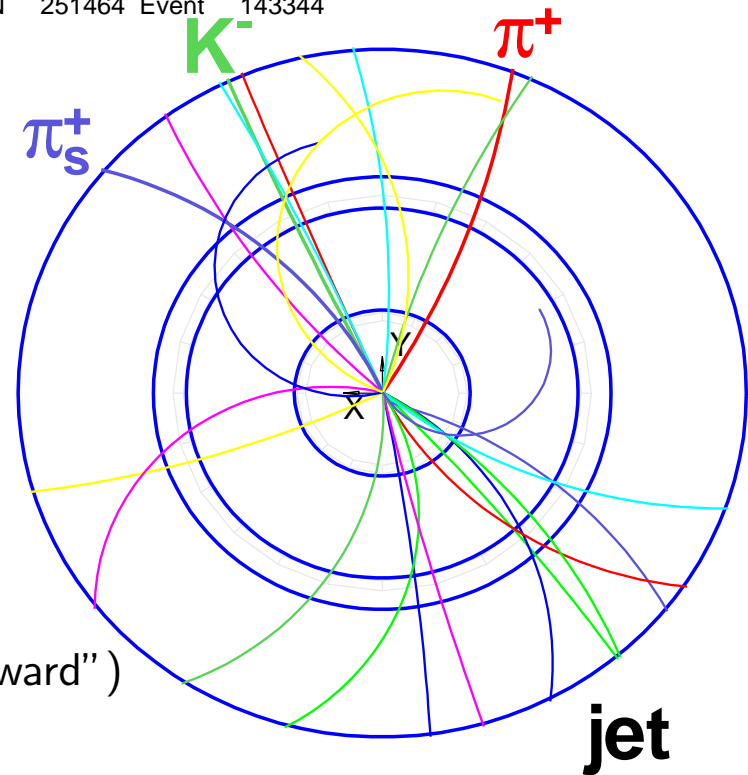


A D^*+Jet Event in the H1 Detector

RUN 251464 Event 143344



RUN 251464 Event 143344



pseudorapidity:

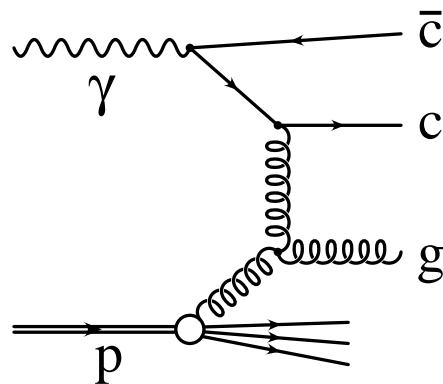
$$\eta = -\ln\left(\tan\left(\frac{\theta}{2}\right)\right), \theta \text{ polar angle}$$

$\eta > 0$: proton direction ("forward")

$\eta < 0$: electron / photon direction ("backward")

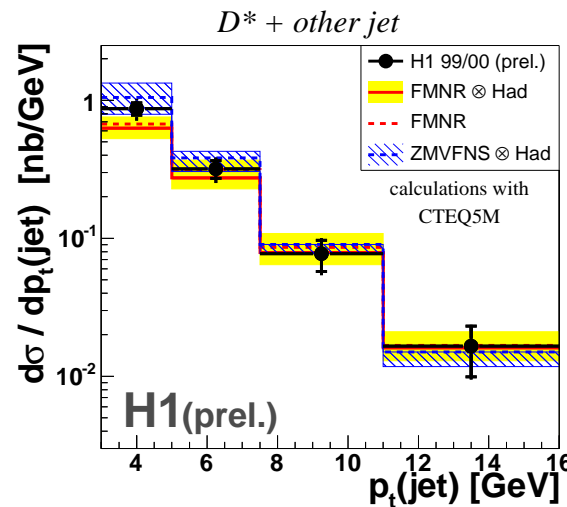
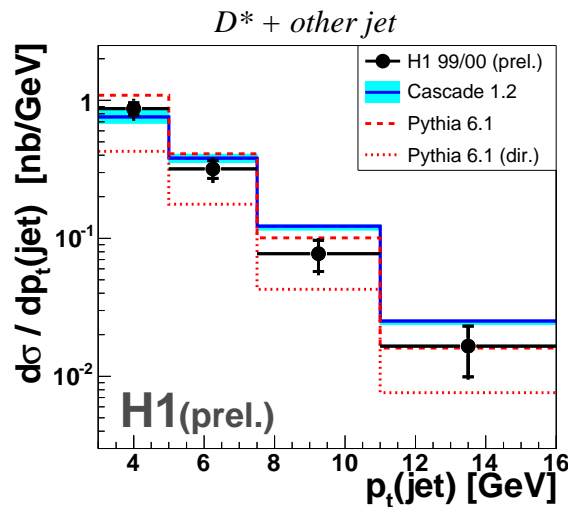
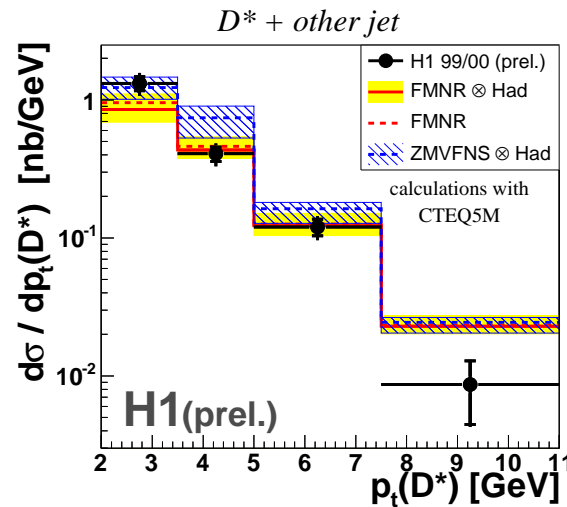
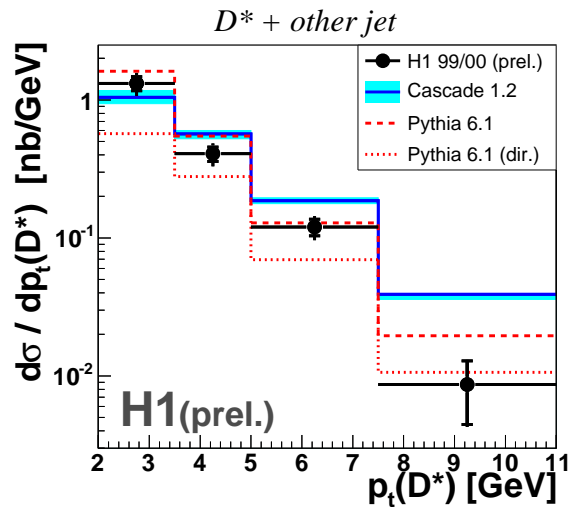
QCD Calculations

	k_t factorisation	collinear factorisation	
	leading order (with parton shower)	leading order (with parton shower)	next-to-leading order
massive (no $\alpha_s \ln\left(\frac{p_t}{m_c}\right)$)	CASCADE	PYTHIA <ul style="list-style-type: none"> ● direct ● resolved 	FMNR
massless (no $\alpha_s \ln\left(\frac{m_c}{p_t}\right)$)		<ul style="list-style-type: none"> ● c excitation 	ZMVFNS



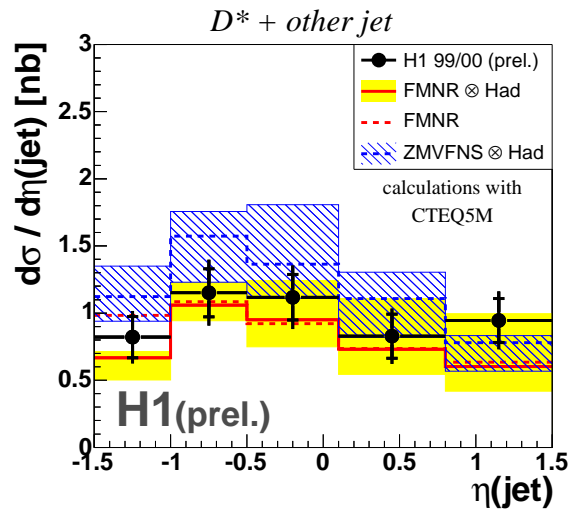
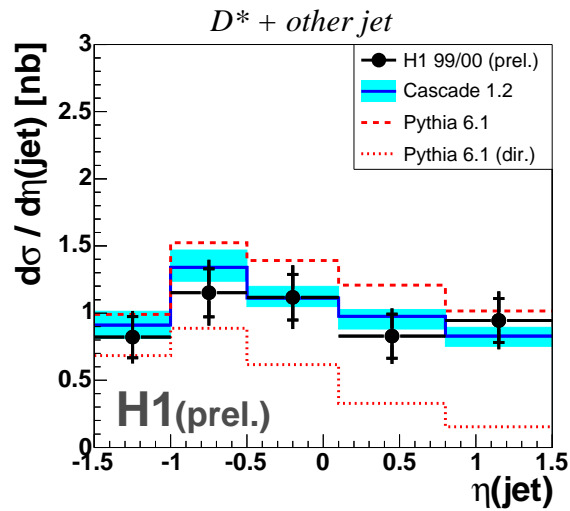
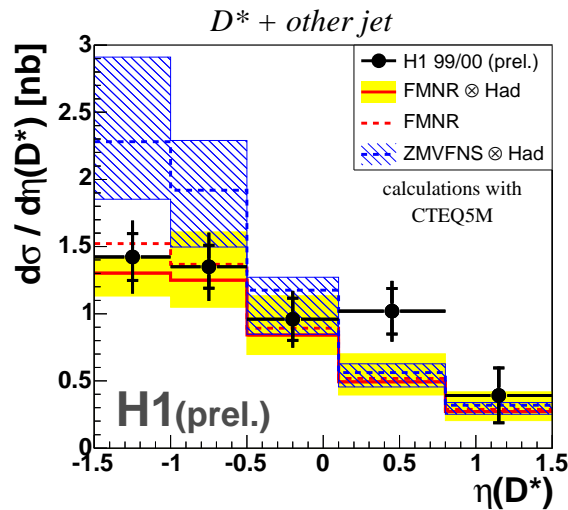
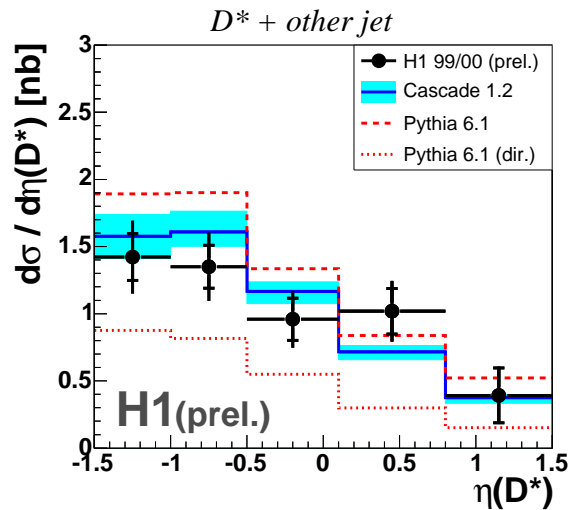
← included in all calculations

Differential Cross Sections: $d\sigma/dp_t(D^*)$, $d\sigma/dp_t(\text{Jet})$

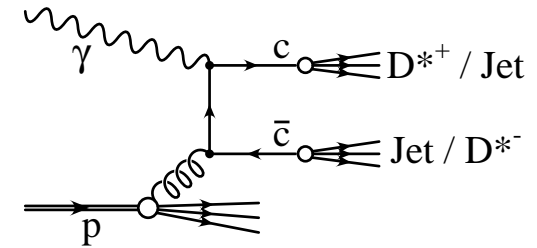


- uncertainty of the calculations:
scale (μ_r, μ_f) and
charm mass (m_c) variations
- all calculations fit within
uncertainties
- CASCADE predicts
slightly harder p_t spectra

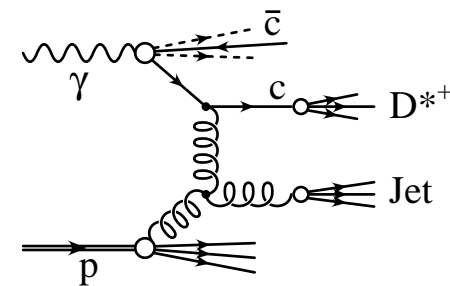
Differential Cross Sections: $d\sigma/d\eta(D^*)$, $d\sigma/d\eta(\text{Jet})$



- $\eta(D^*)$ and $\eta(\text{jet})$ differ
- PYTHIA direct: similar

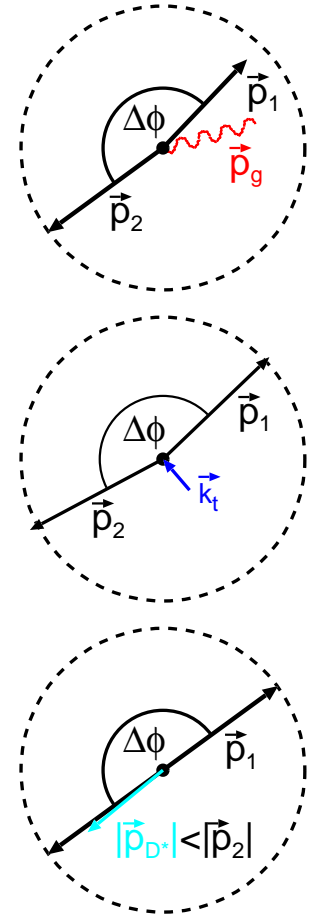
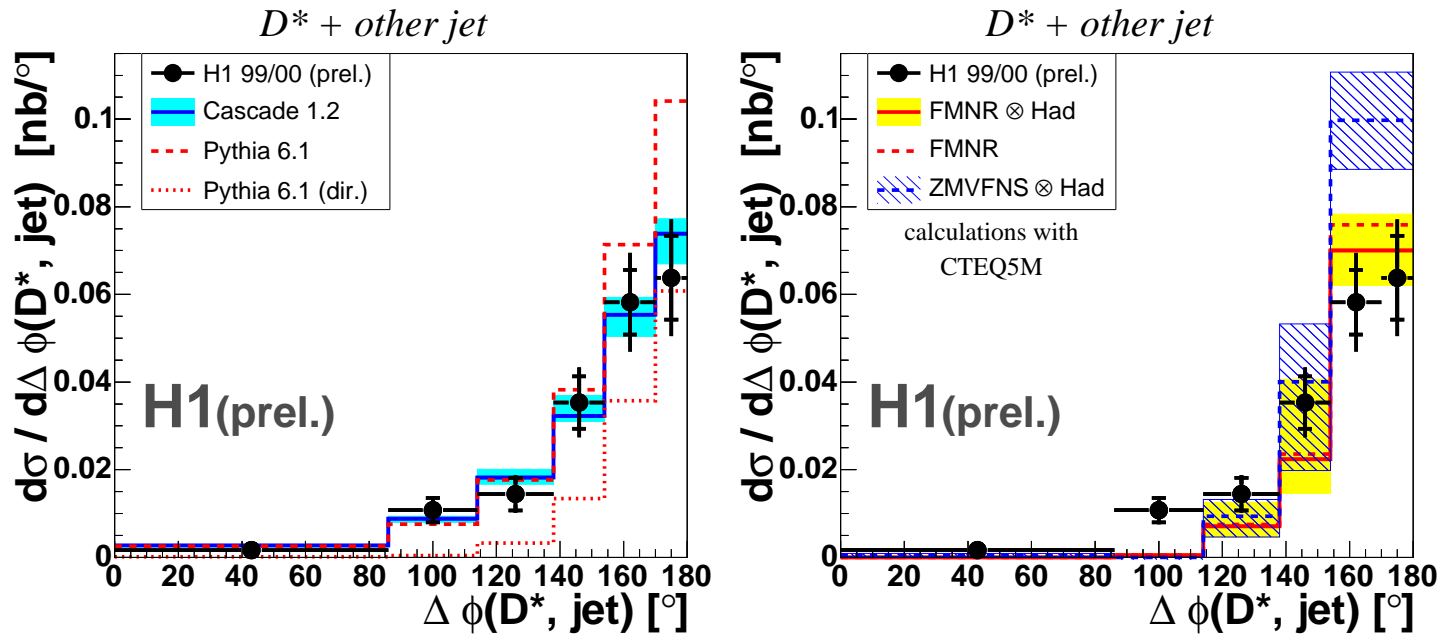


- “forward” ($\eta > 0$): more jets



⇒ jet at $\eta > 0$ often caused by gluon (or light quark)

Differential Cross Section: $d\sigma/d\Delta\phi(D^*, \text{Jet})$



- only $\sim 1/4$ is back to back (= LO, $\gamma p \rightarrow c\bar{c}$)
- CASCADE (k_t fact.) and charm excitation in PYTHIA (parton shower) describe $\Delta\phi(D^*, \text{jet}) \approx 100^\circ$
- infrared sensitivity \Rightarrow merging highest bins for NLO
- one parton radiation from NLO (effectively LO) seems not sufficient

Summary

- D^* +jet photoproduction with H1:
testing QCD at low transverse momenta
 - comparing data with various QCD calculations
 - data reasonably described by quite different theoretical approaches
 - “forward” ($\eta > 0$) jets often seem to be *not* caused by charm
 - $\Delta\phi(D^*, \text{jet})$ tends to need more than “just NLO”
- ⇒ higher order radiation seems relevant in charm photoproduction