Final State Correlations in Open Charm Production at HERA

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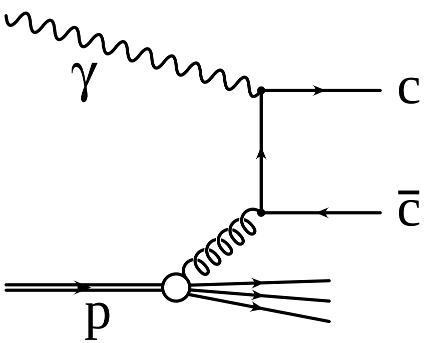
on behalf of the H1 and ZEUS collaborations

- Open Charm Production at HERA
- Jet Measurements in D^*-Tagged Events
- Jet Shape Study in μ-Tagged Events
- Summary

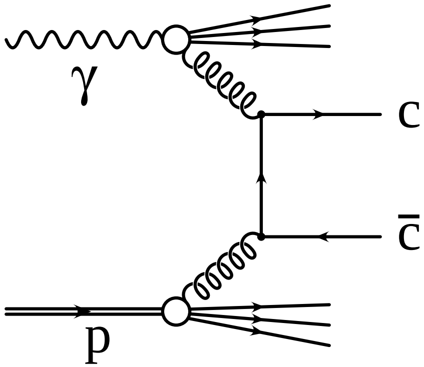
Charm Photoproduction

Leading order:

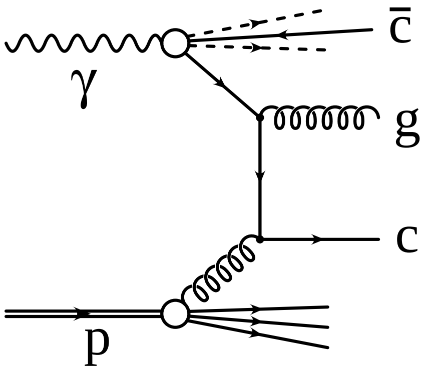
direct

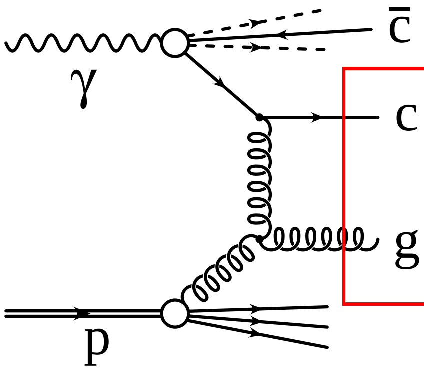


resolved



charm excitation





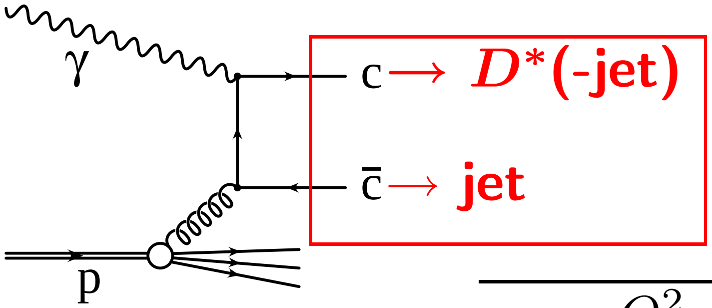
- heavy charm ($m_c \approx 1.5$ GeV) provides hard scale: test QCD in presence of more than one scale
- (Anti-)Charm quark tagged by D^* or μ
- tag second hard parton by a jet

$\Rightarrow$ correlations provide deeper insight in production process

c $\longrightarrow$ ***D^**, *D^**-jet, *μ*-jet**

g $\longrightarrow$ **jet**

D^* (Di)Jet Measurements in Photoproduction



	lower p_t			higher p_t	
Q^2	$<$	0.01 GeV^2	Q^2	$<$	1 GeV^2
$171 <$	$W_{\gamma p}$	< 256 GeV	$130 <$	$W_{\gamma p}$	< 280 GeV
$p_t(D^*)$	$>$	2.0 GeV	$p_t(D^*)$	$>$	3.0 GeV
$\|\eta(D^*)\|$	$<$	1.5	$\|\eta(D^*)\|$	$<$	1.5
$p_t(\text{jet})$	$>$	3.0 GeV	$E_t(\text{jet})$	$>$	$7.0(6.0)$ GeV
$\|\eta(\text{jet})\|$	$<$	1.5	$-1.5 < \eta(\text{jet}) < 2.4$		
D^*	$\notin$	jet	$N(\text{jet})$	$\geq$	2

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

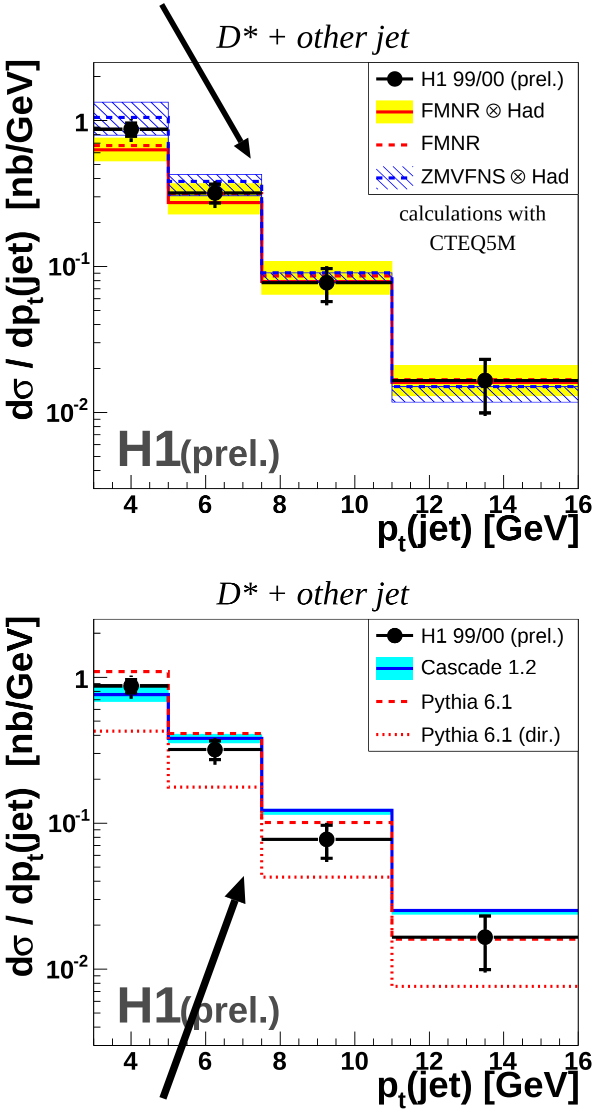
$$\Downarrow$$

$p_t(D^*) > 2$ GeV
$p_t(\text{jet}) > 3$ GeV
equivalent

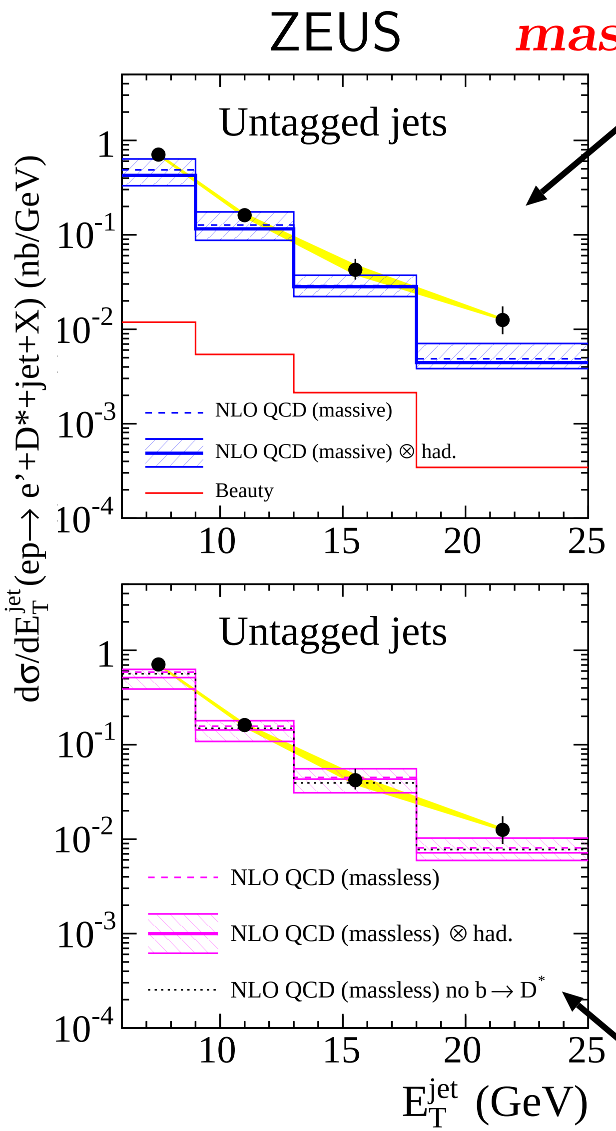
(both about 1000 events)

Transverse Momentum Measurements

NLO



LO+PS

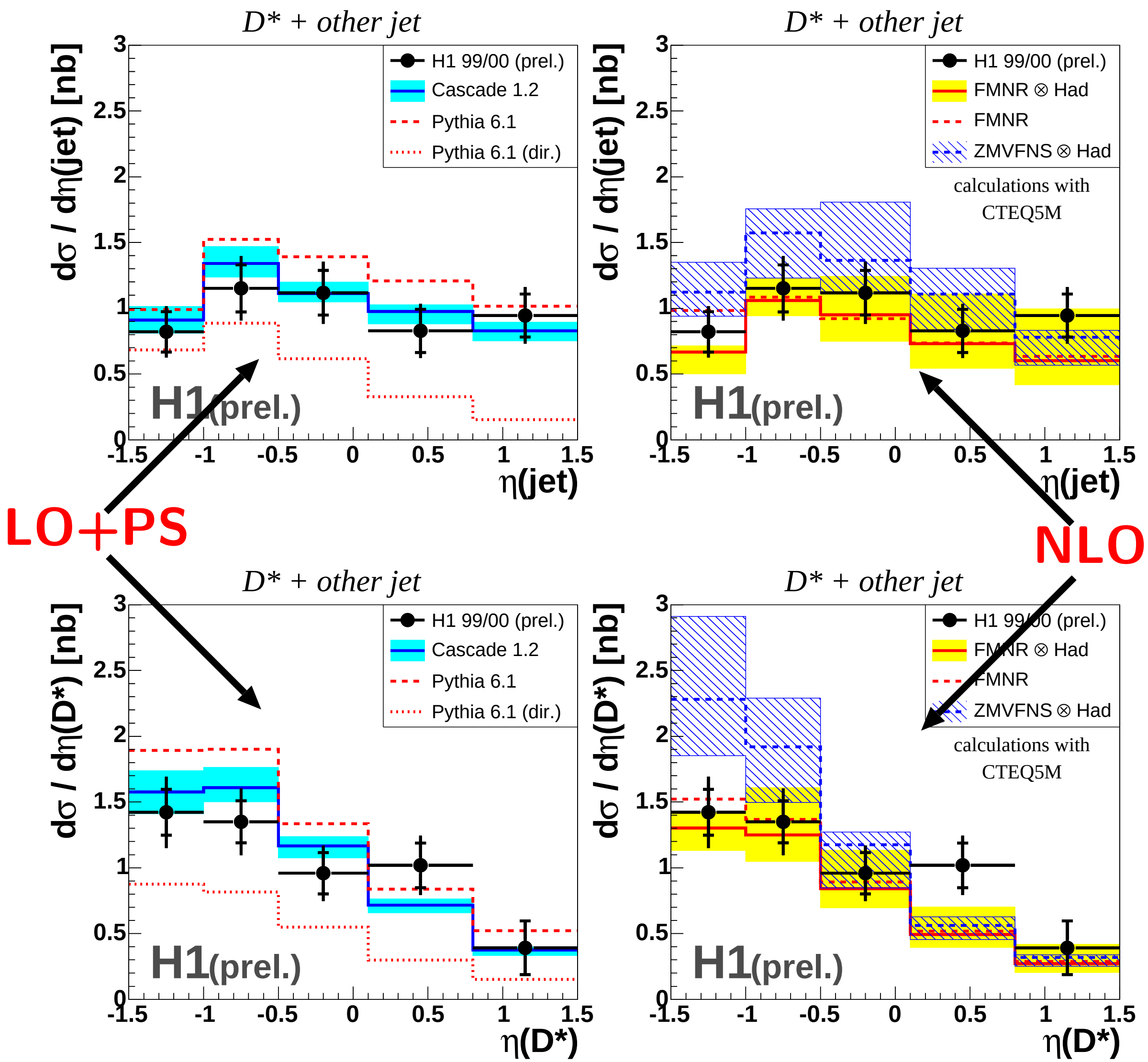


***massive* NLO**

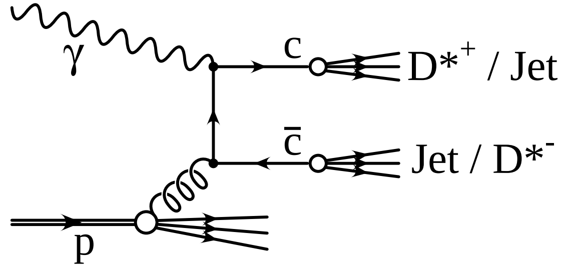
***massless* NLO**

- uncertainties of the calculations: vary scales (μ_r, μ_f) and charm mass (m_c)
- various calculations all fit within uncertainties
  - k_t factorising CASCADE predicts slightly harder p_t spectrum (sensitive to unintegrated gluon density?)

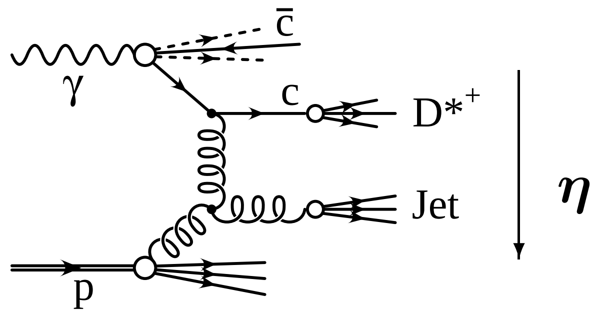
Pseudorapidity Distributions: Charm Tagged vs Untagged



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



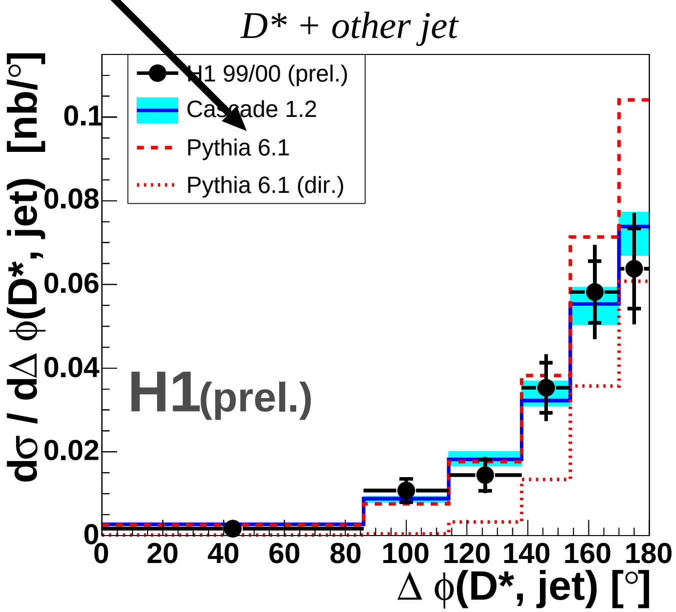
- "forward" $(\eta > 0)$: more jets

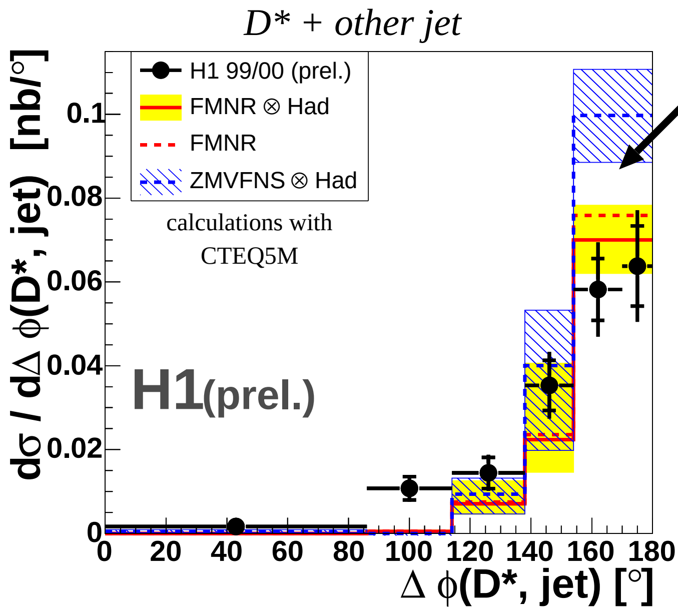


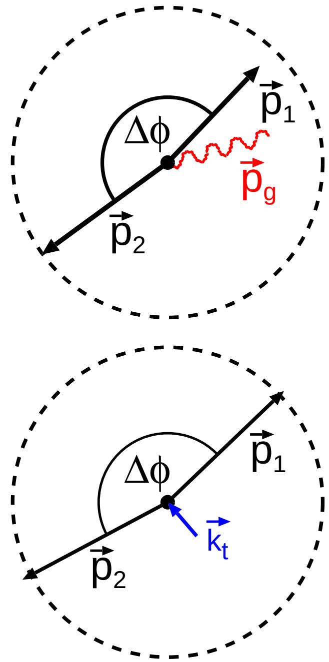
⇒ jet at $\eta > 0$ often caused by gluon (or light quark)

- similar at higher p_t (ZEUS)

The Azimuthal Difference $\Delta\phi$





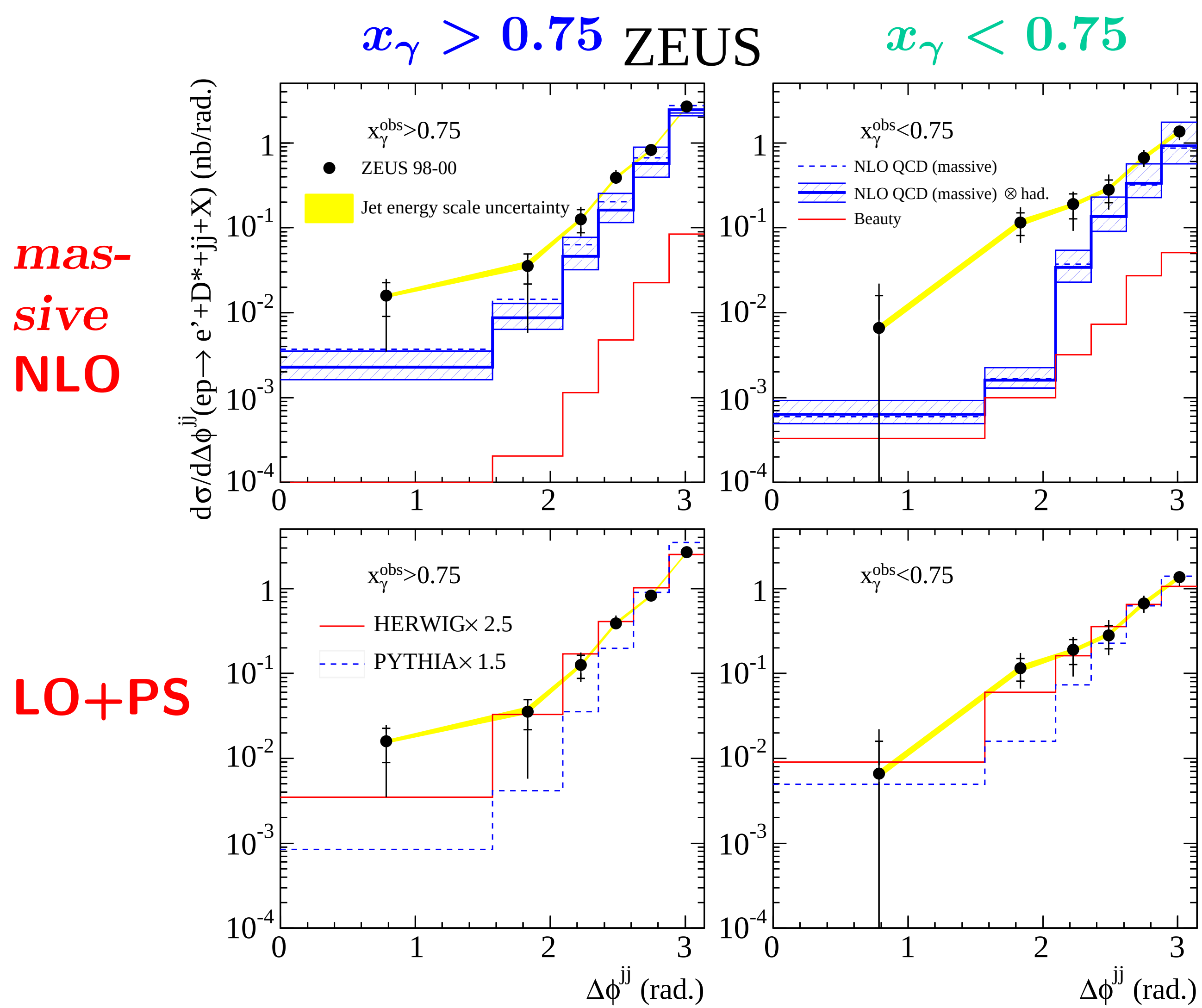


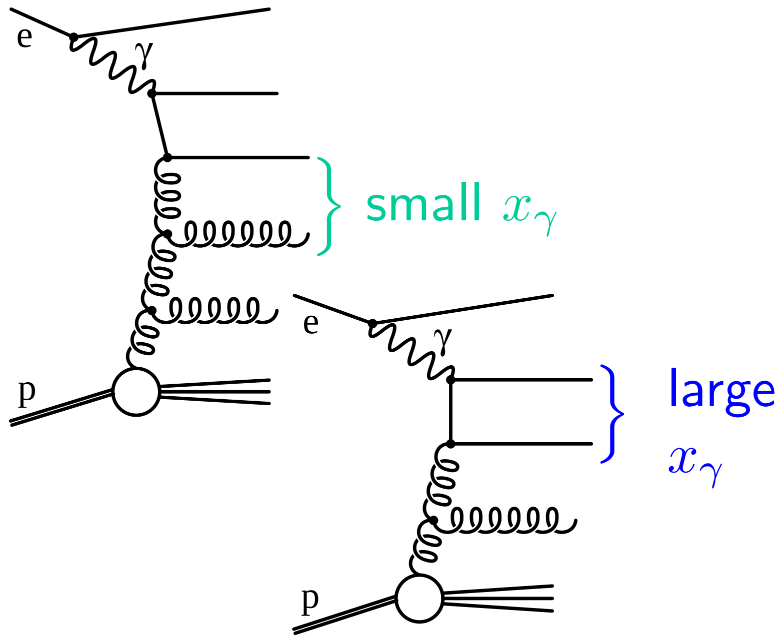
- only small fraction is back-to-back (= LO, $\gamma p \to c\bar{c}$)
- CASCADE (k_t fact.) and charm excitation in PYTHIA (parton shower) describe small $\Delta\phi$

☐ infrared sensitivity ⇒ merging highest bins for NLO

☐ one parton radiation from NLO (effectively LO) seems not sufficient

$x_\gamma < 0.75$: Increased Sensitivity to Higher Orders





- small x_γ ⇔ higher orders

⇒ NLO discrepancy highest for small x_γ

⇒ LO+PS better than NLO: MC@NLO needed?

- similar for $(p_t^{jj})^2$

Jet Shape Study

So far:

- $\Delta\phi \Rightarrow$ we need higher orders
- $\eta(c\text{-tagged})$ and $\eta(\text{other jet})$
  $\Rightarrow$ 'no tag' sometimes not charm
- What does the untagged jet stem from ?

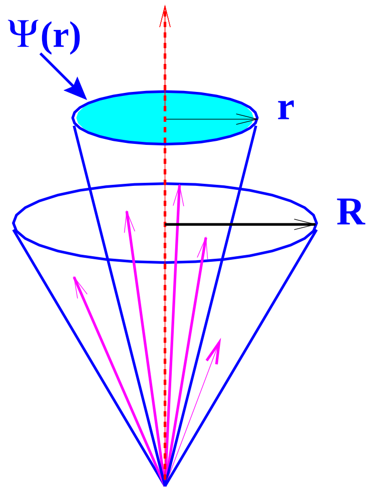
Analysis:

- photoproduction dijet sample:
  $p_t^j > 7(6)$ GeV, $|\eta^j| < 1.7$
- tag charm jet via muon:
  $p_t^\mu > 2.5$ GeV, $35° < \theta^\mu < 130°$
- study integrated jet shape $\Psi(r)$ of untagged jet

We know:

- (light) quark jets are narrow
- gluon jets are broad

$$\Psi(r) = \frac{p_t^{jet}(r)}{p_t^{jet}(R)}$$

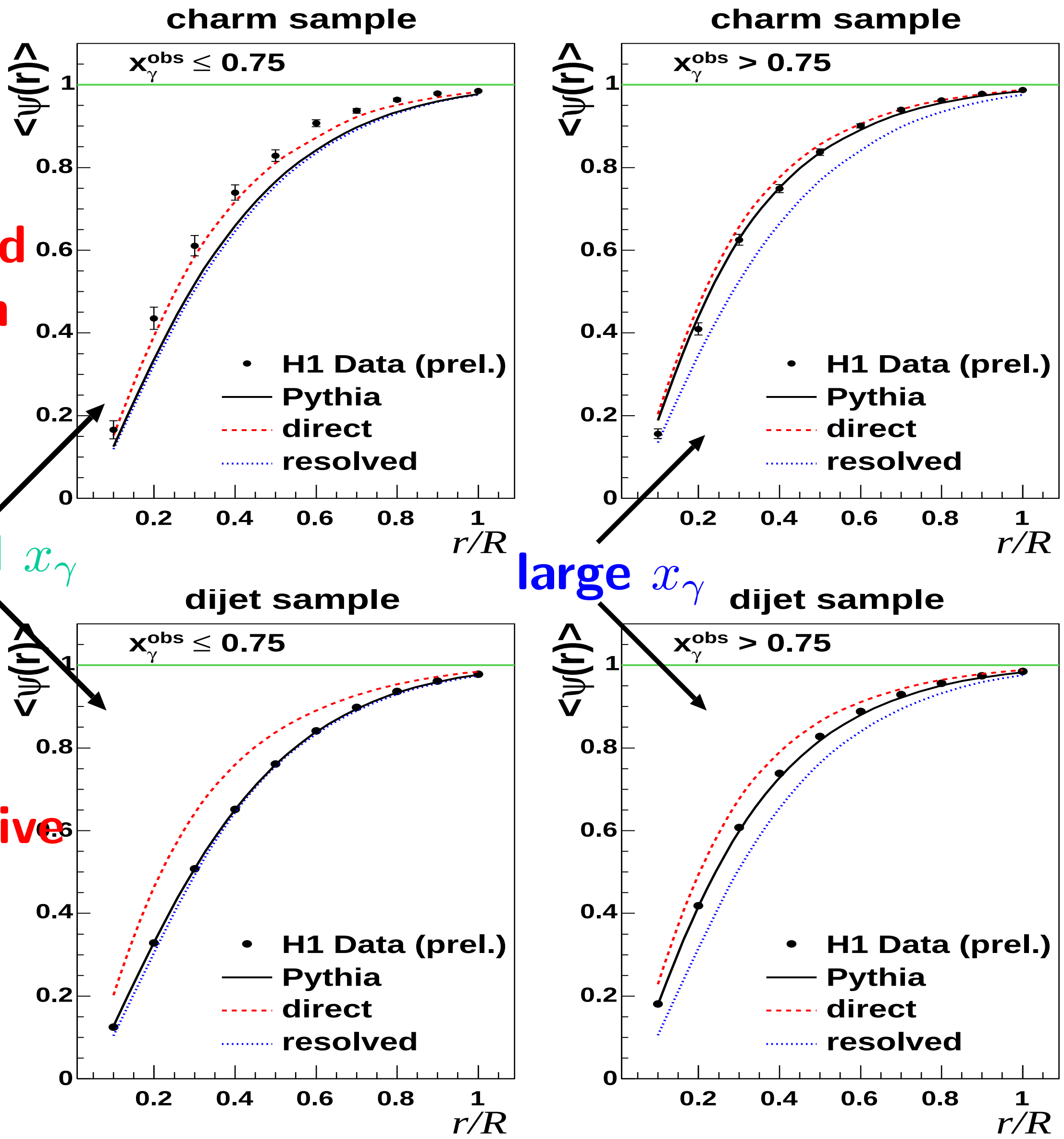


Jet Shape

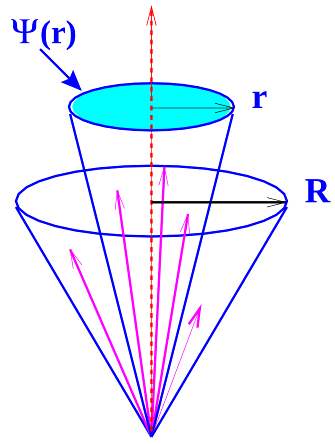
un-tagged charm jet

small x_γ **large x_γ**

inclusive dijets

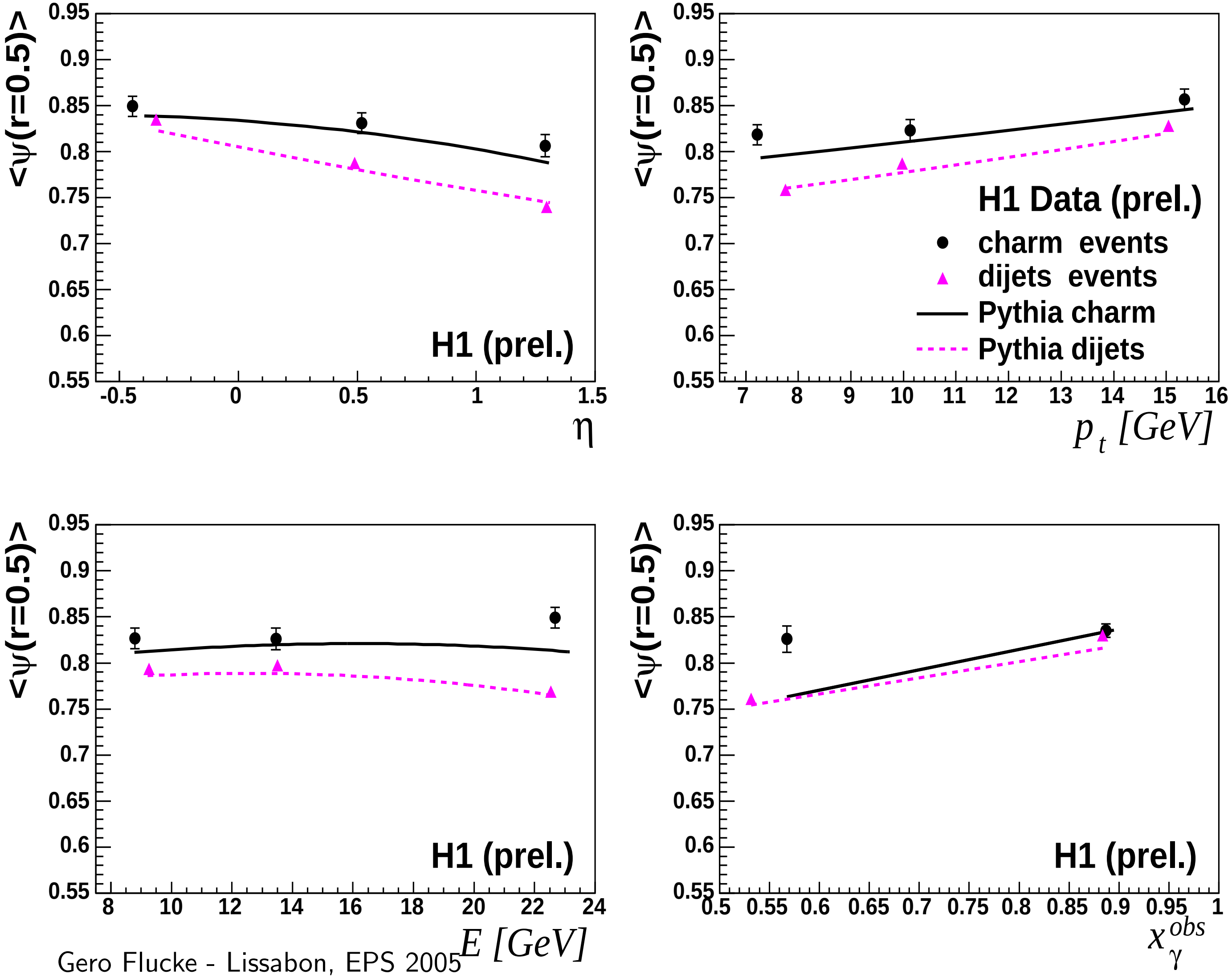


$$\Psi(r) = \frac{p_t^{jet}(r)}{p_t^{jet}(R)}$$



- charm, large x_γ:
  enhance $\gamma g \to c\bar{c}$ (direct)
  $\Rightarrow$ charm quark dominated,
  well described
- charm, small x_γ:
  expect broad gluon jets
  (e.g. $cg \to cg$)
  $\Rightarrow$ jets still narrow,
  not described
- cross check:
  light quark dominated dijet
  sample shows expected features

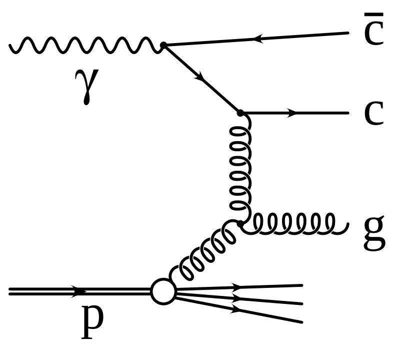
Dependence of Jet Shape



- $\Psi(r)$ at $r = 0.5$
- inclusive dijets: well described
- untagged charm jet predictions: deviations where contributions from small x_γ expected

$\Rightarrow$ narrower than g-jets

$\Rightarrow$ contradicts large $cg \to cg$ contribution



Summary

- H1 and ZEUS D^* (di)jet measurements shown
- inclusive p_t, η well described by various QCD approaches
- azimuthal $\Delta\phi$ distributions need higher orders (e.g. parton showers)
- we observe non-charm jet contribution:
  $\Rightarrow$ QCD predictions suggest $cg \rightarrow cg$
- However, H1 jet shape study (charm event tag by μ):
  un-tagged jet not described at low x_γ,
  narrower than gluon jet dominated prediction

$\Rightarrow$ Details of open charm production still a challenge for theory.