D*-jet and dijet-correlations at HERA

By John Loizides

University College London

HERA - LHC

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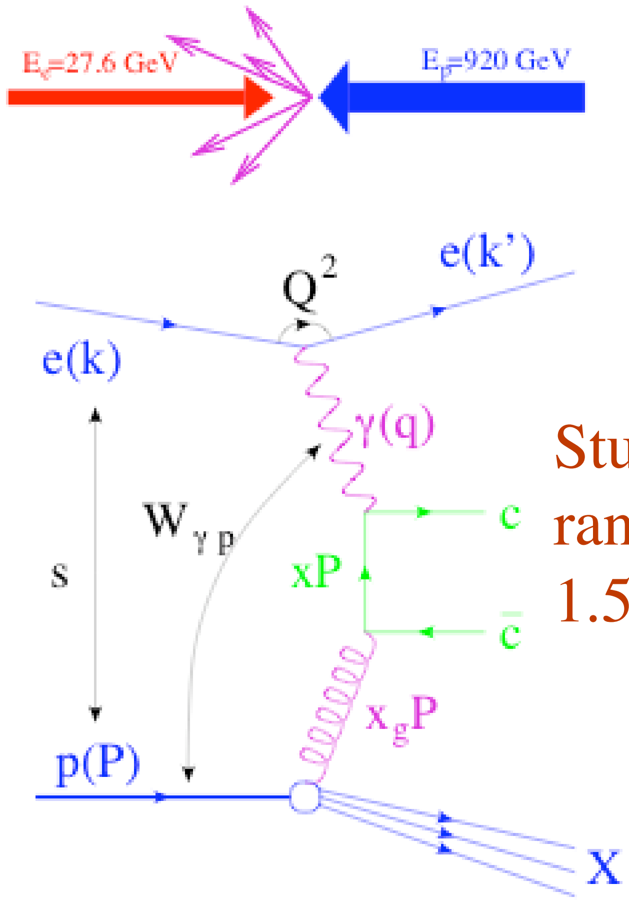
Outline of charm at HERA

- HERA and its charm
- Perturbative QCD calculations.
- D* cross sections
- D* and Jet production.
- Summary

HERA's charm production



Boson Gluon fusion

Charm directly sensitive to the proton gluon density.

Study of charm over huge kinematical ranges:
$1.5 < p_T^c < 30$ GeV, $0 < Q^2 < 1000 GeV^2$.

Photoproduction: $Q^2 \leq 1$ GeV^2

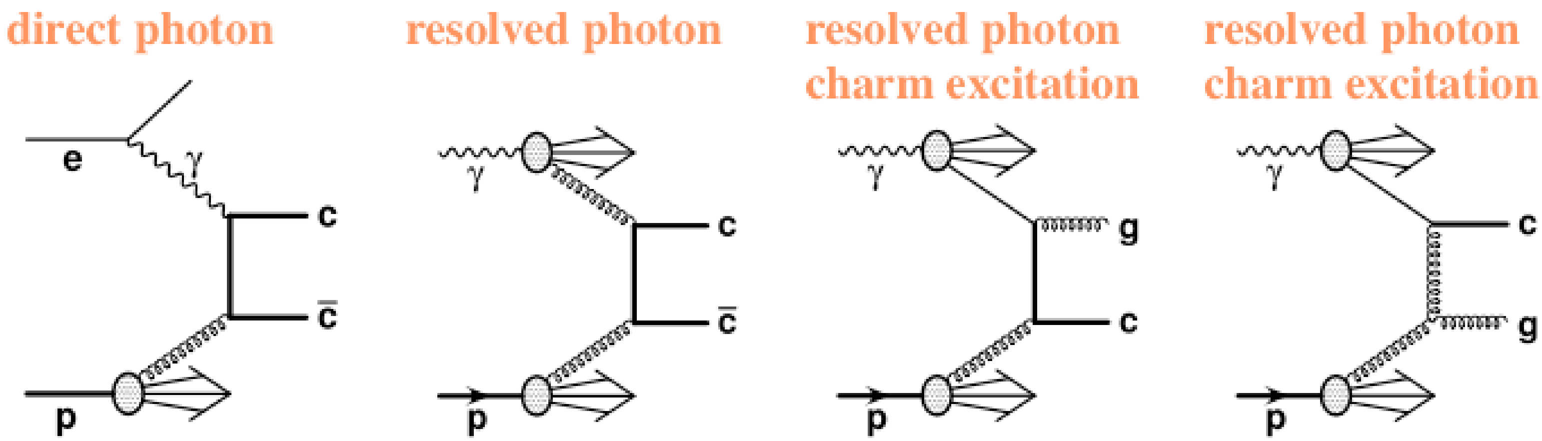
DIS: $Q^2 > 1$ GeV^2

HERA's charm production

At LO Boson Gluon Fusion (BGF) dominates -> $\gamma g \to c\bar{c}$

Direct and Resolved contributions

σ = proton PDF $\otimes$ $\sigma_{\gamma g \to QQ}$ $\otimes$ photon PDF $\otimes$ fragmentation function



Charm pQCD calculations

pQCD calculations are performed in different ways: Massive (PHP S.Fixione et al) (DIS Harris and Smith), Massless(B. Kniehl et al) and a combined method (M. Cacciari et al).

The “Massive” approach, to fixed order in α_s:

$\rightarrow m_Q \neq 0$ and the heavy quarks (c and b) are not parts of the structure functions. Heavy quarks produced dynamically in the hard interaction. $\rightarrow$ reliable at $p_T \approx m_Q$

DGLAP evolution is used to obtain the quark and gluon densities.

Programs for Photoproduction: FMNR (Frixione et al.) and

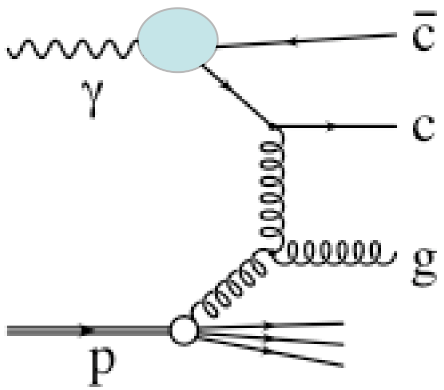
DIS: HVQDIS (Harris+Smith)

Charm pQCD calculations

"Massless" Approach: re-summation of $\alpha_s \ln(p_T^2 / m_c^2)$ at orders in α_s:

$\rightarrow M_Q = 0 \rightarrow$ the heavy quarks are an active flavour in the PDF

Heavy quarks can also be produced in flavour excitation



Relaible $p_T >> m_Q$, (B. Kniehl et al)

Charm Tagging

Charm tagging via D* meson

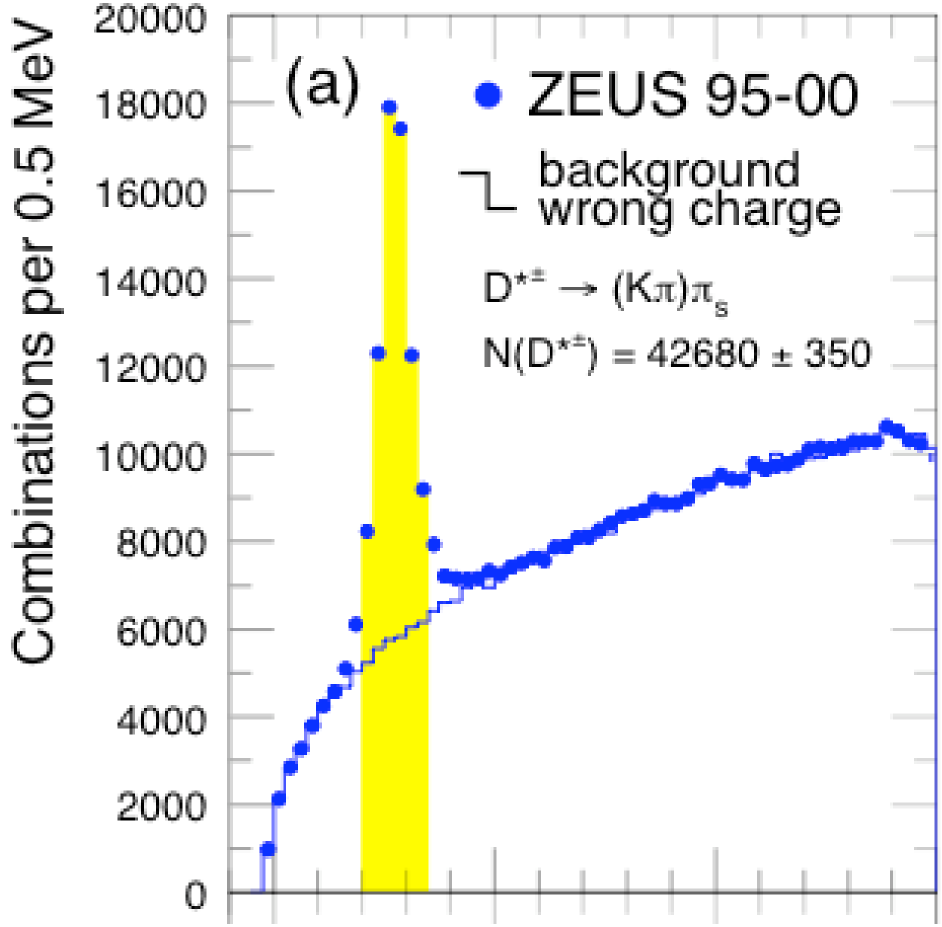
$D^* \rightarrow D^0, \pi$ Where $D^0 \rightarrow K, \pi$

HERA is a charm factory

42680 ± 350 D* mesons.

H1 & ZEUS for HERA I

50<luminosity <100 pb^{-1}.



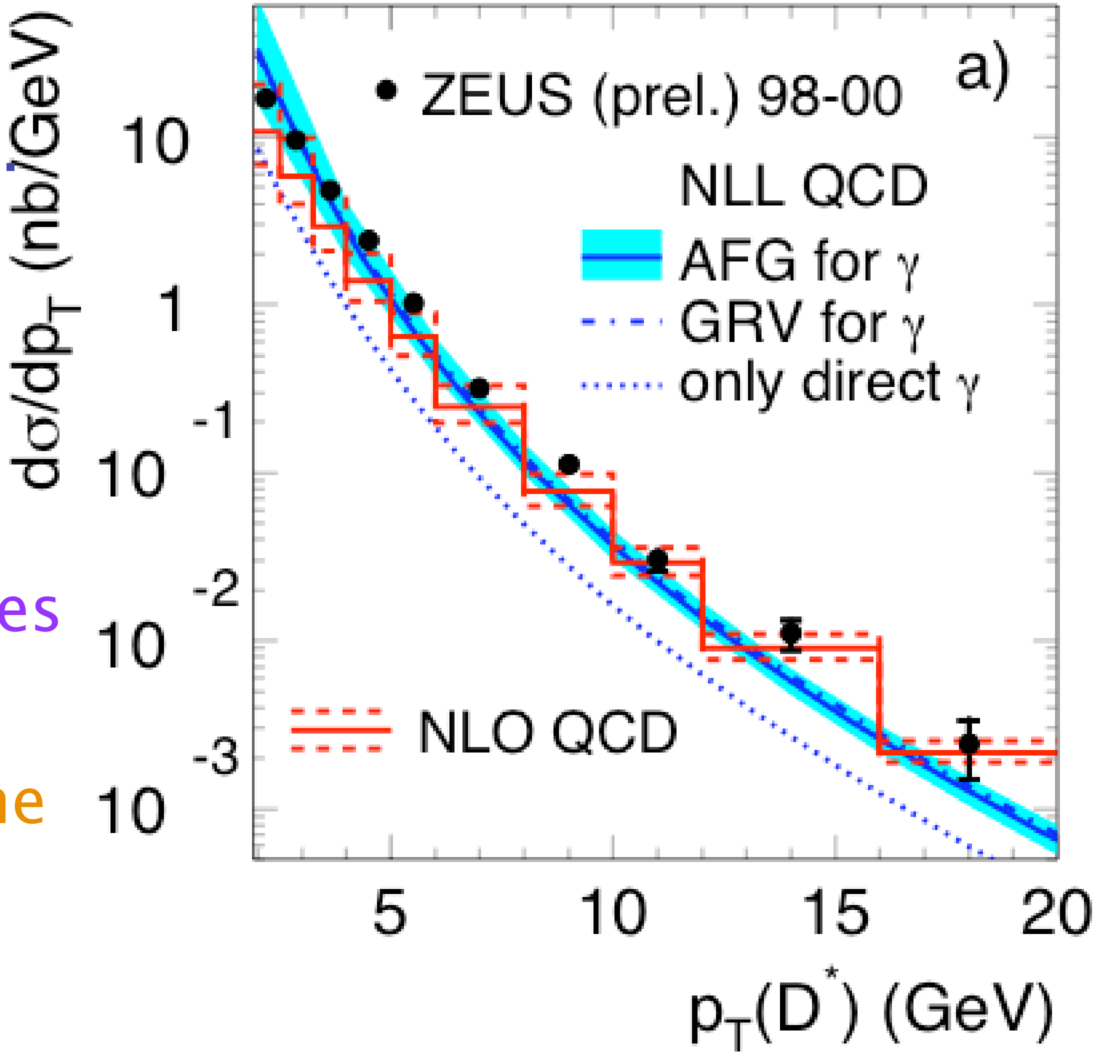
D* Photoproduction inclusive cross sections

Inclusive D* production over a large lage of $p_T^{D^*}$.

At large $p_T^{D^*}$ massive calculation does better then massless.

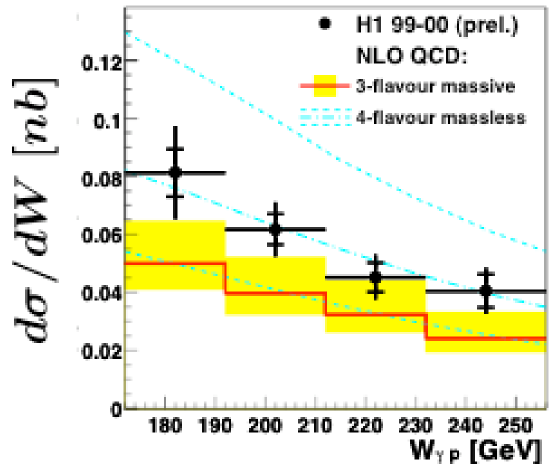
At lower values of $p_T^{D^*}$ massless calculation does better then massive.

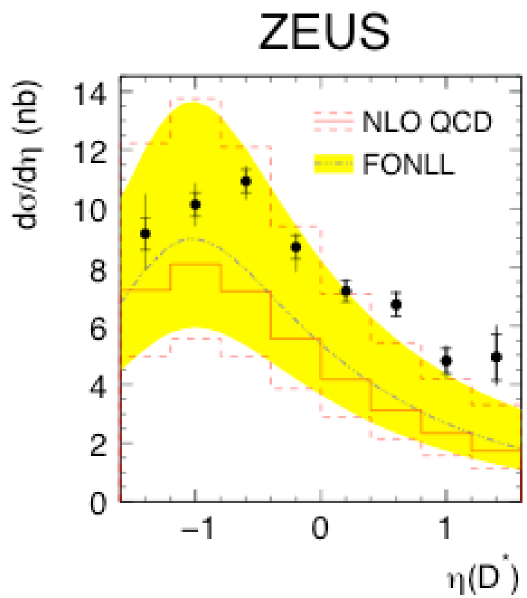
Expect scenario to be the other way round.



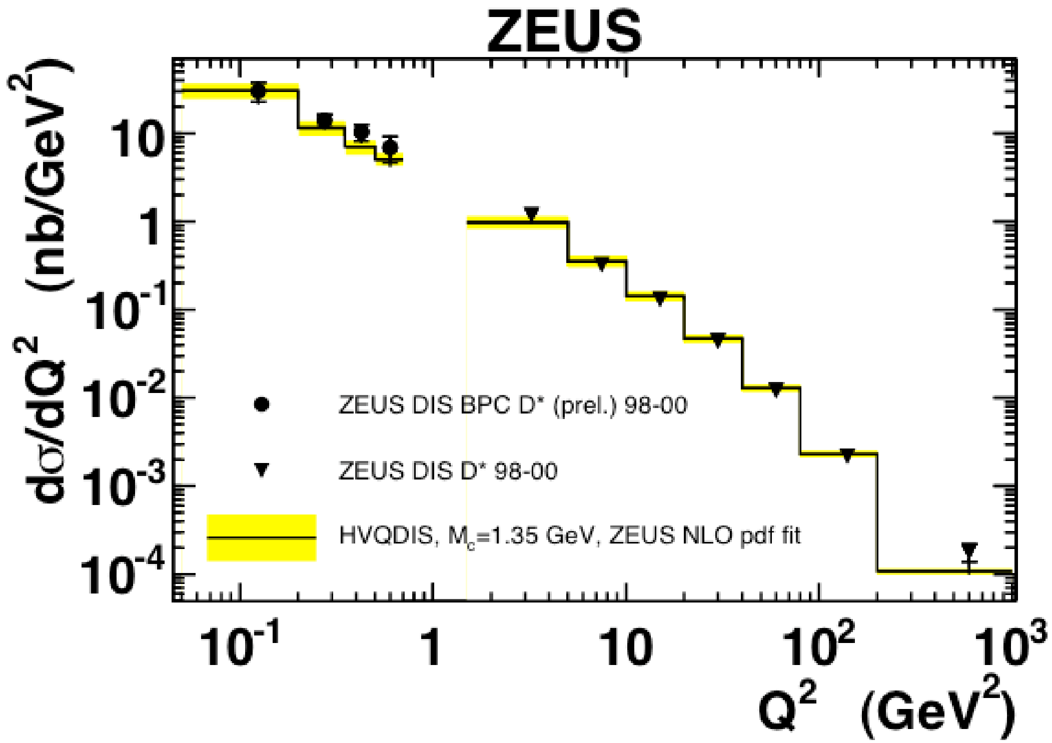
D* Photoproduction inclusive cross sections

- D* selection in photoproduction
- NLO “massive” and “massless” predictions are compared to the data.
- $d\sigma$ / dW is described well, but the shape of d σ / $d\eta(D^*)$ is not well described in shape.
- Theoretical uncertainties from charm mass and renormalisation scale are large!
- Precise data → Need for NNLO.





Charm over all Q^2



Comparison of low Q^2 data, using the beam pipe calorimeter (BPC) to tag the scattered electron.

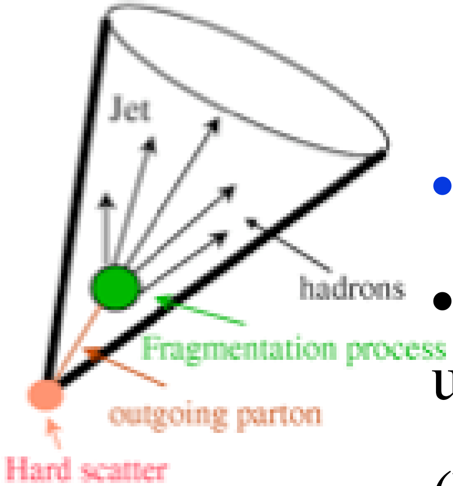
NLO charm production tested across the transition region from DIS to Photoproduction.

Low Q^2 is much smaller than charm mass.

High Q^2 is much larger than charm mass

Good agreement with massive theory.

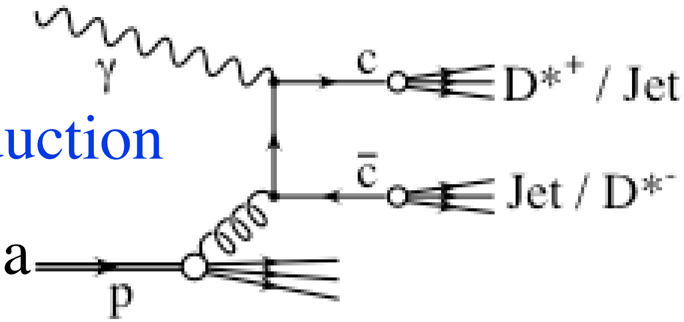
Charm Jet Production



•D* production and Jet production

•Tag second hard parton by a using a Jet.

(k_T Algorithm definition)

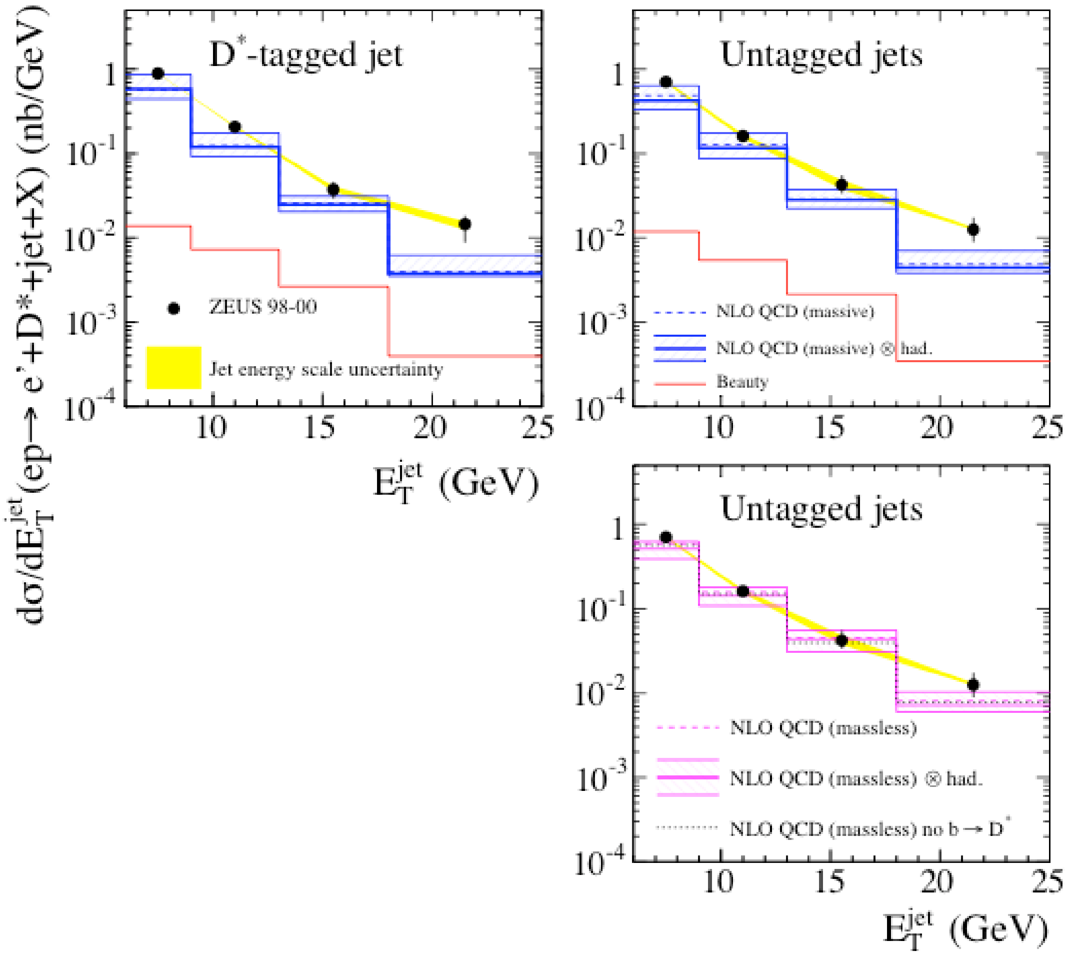


- Jet and D* correlations can be studied when the D* is NOT associated to with a Jet → angular correlations arising from higher orders.
- Jet E_T provides an extra hard scale: test QCD!

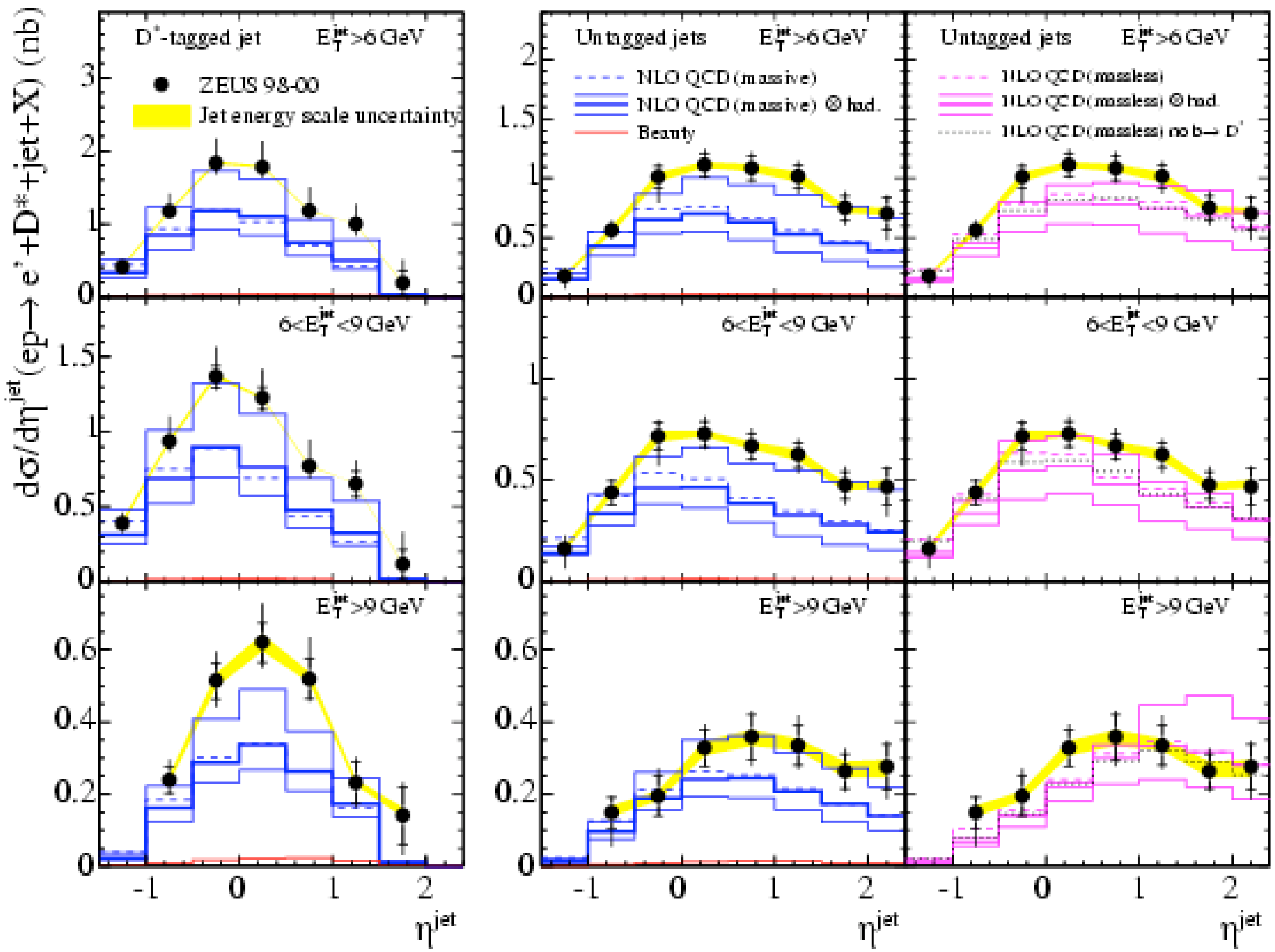
Charm Jet Production

- D* photoproduction and Jet selection.
- "massive" and "massless" pQCD predictions give reasonable descriptions of the data.
- Data lie on upper bound of NLO → lower charm mass and renormalisation scale changed simultaneously.

→ Large theoretical uncertainties.



Charm Jet Production



- “massive” and “massless” pQCD predictions give reasonable descriptions of the data.
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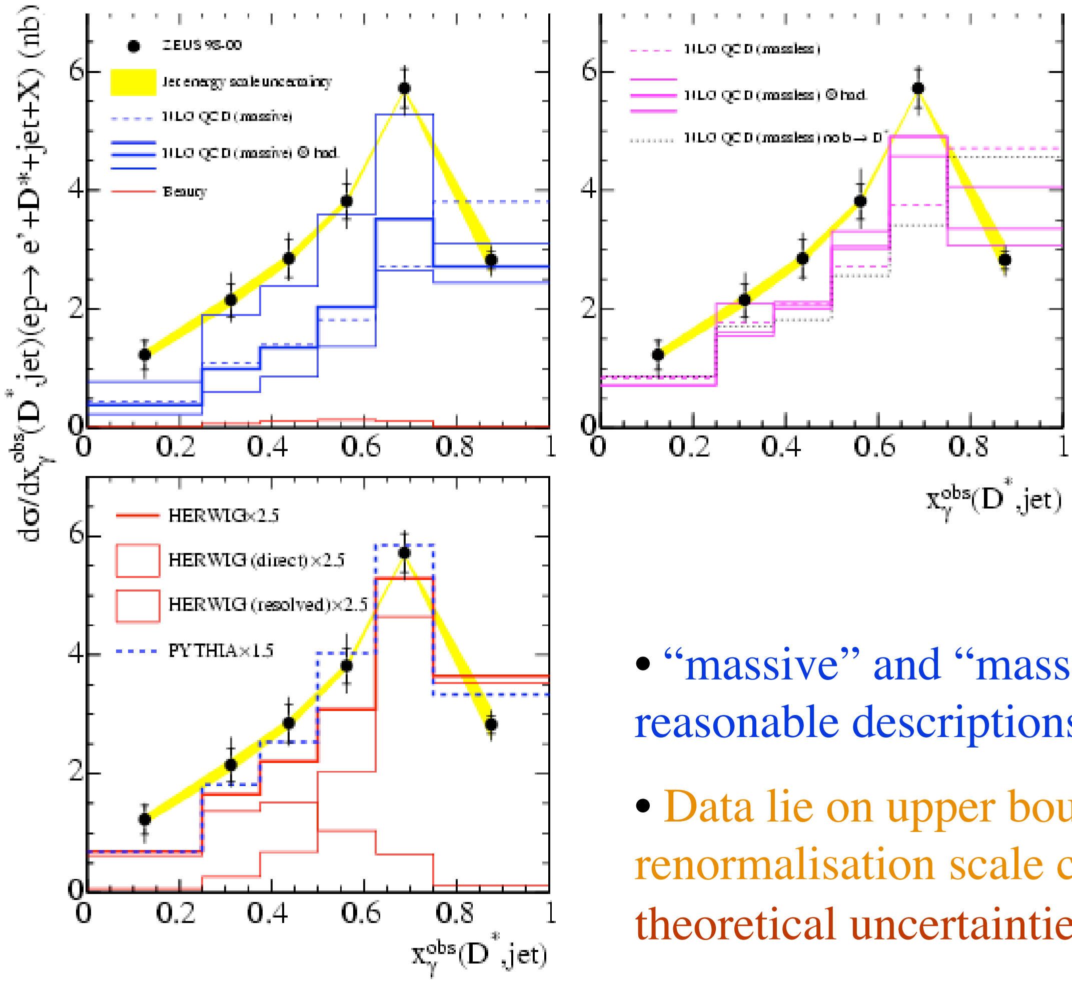
Charm Jet Production

$$x_\gamma^{\text{obs}}(D^*, \text{untagged jet}) = \frac{p_T^{D^*} e^{-\eta^{D^*}} + E_T^{(\text{untagged jet})} e^{-\eta^{(\text{untagged jet})}}}{2yE_e}$$

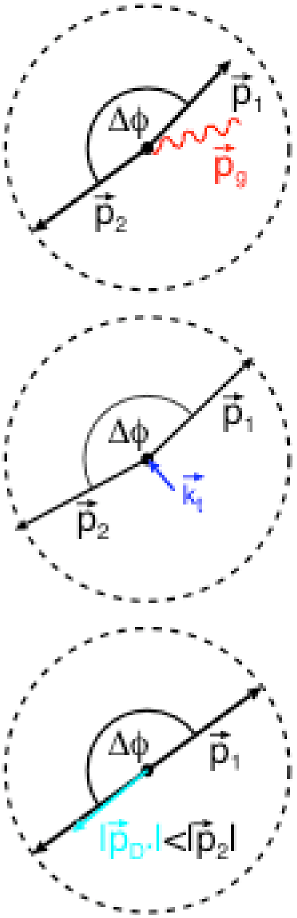


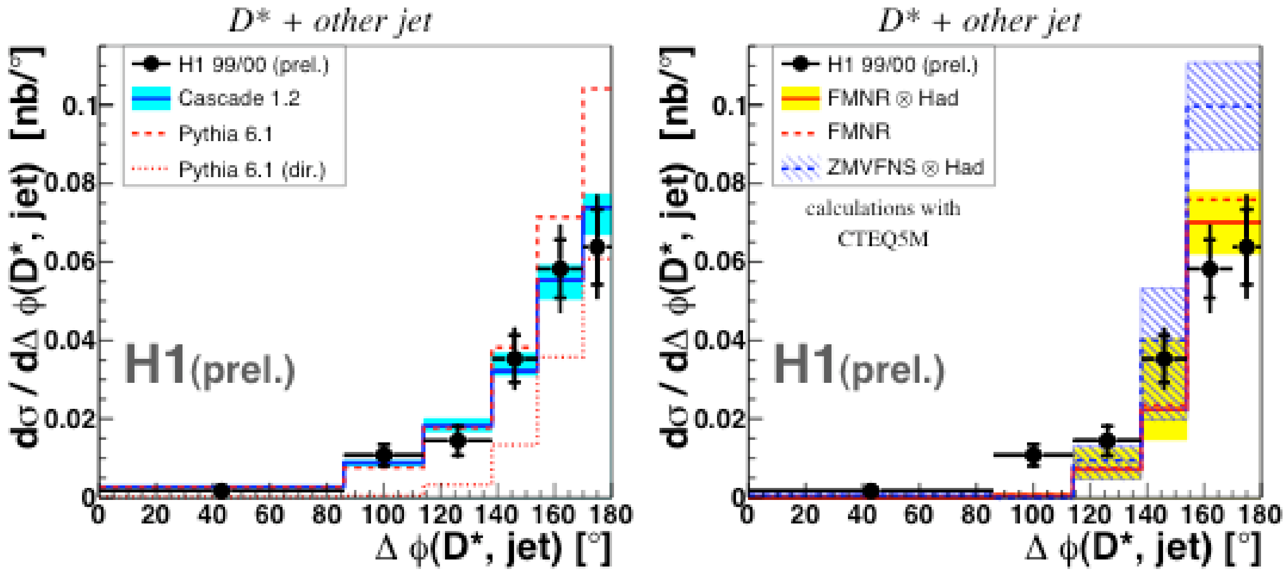
- Similar ability to separate between direct and resolved diagrams as the traditional x_γ^{obs}.
- P_T^{D*} can go lower then the E_T^{JET}.

  → more statistical precision.
- Also can compare to both 'massive and 'massless' predictions.

- "massive" and "massless" pQCD predictions give reasonable descriptions of the data.
- Data lie on upper bound of NLO → lower charm mass and renormalisation scale changed simultaneously. → Large theoretical uncertainties.
- Large hardonisation uncertainties.

Charm Jet Production





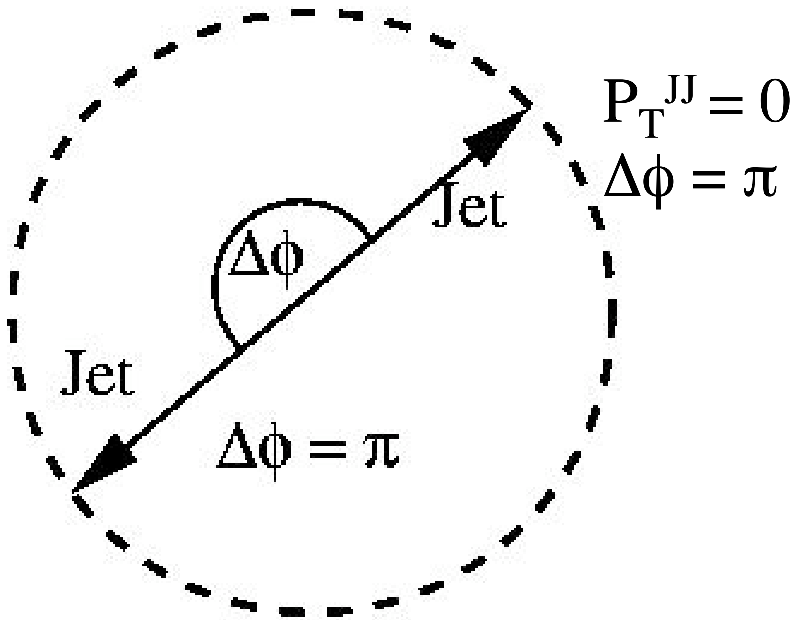
- D* + Jet selection in photoproduction. Different Kinematic region from ZEUS, lower E_T^{Jet}.
- Comparison to pQCD and LO+PS models. → CASCADE and PYTHIA describe data. pQCD does not.
- Only one parton radiation from NLO not sufficient to describe the data.

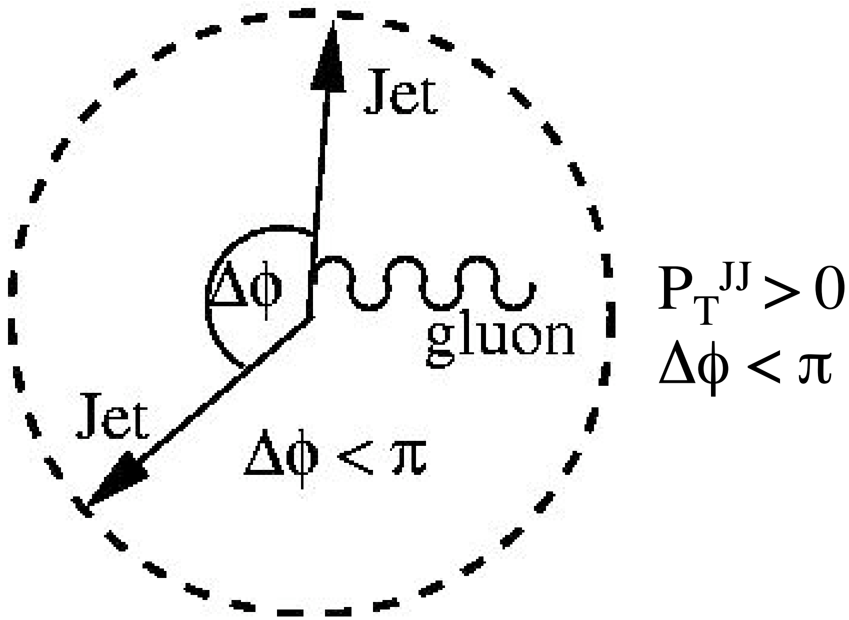
Charm Dijet Production

• D* Dijet photoproduction.

•Jet variables and D* correlations → sensitive to angular correlations arising from higher orders.

$(P_T^{JJ})^2 = (p_x^{Jet1} + p_x^{jet2})^2 + (p_y^{jet1} + p_y^{jet2})^2$ $\Delta\phi = | \phi^{jet1} - \phi^{jet2} |$

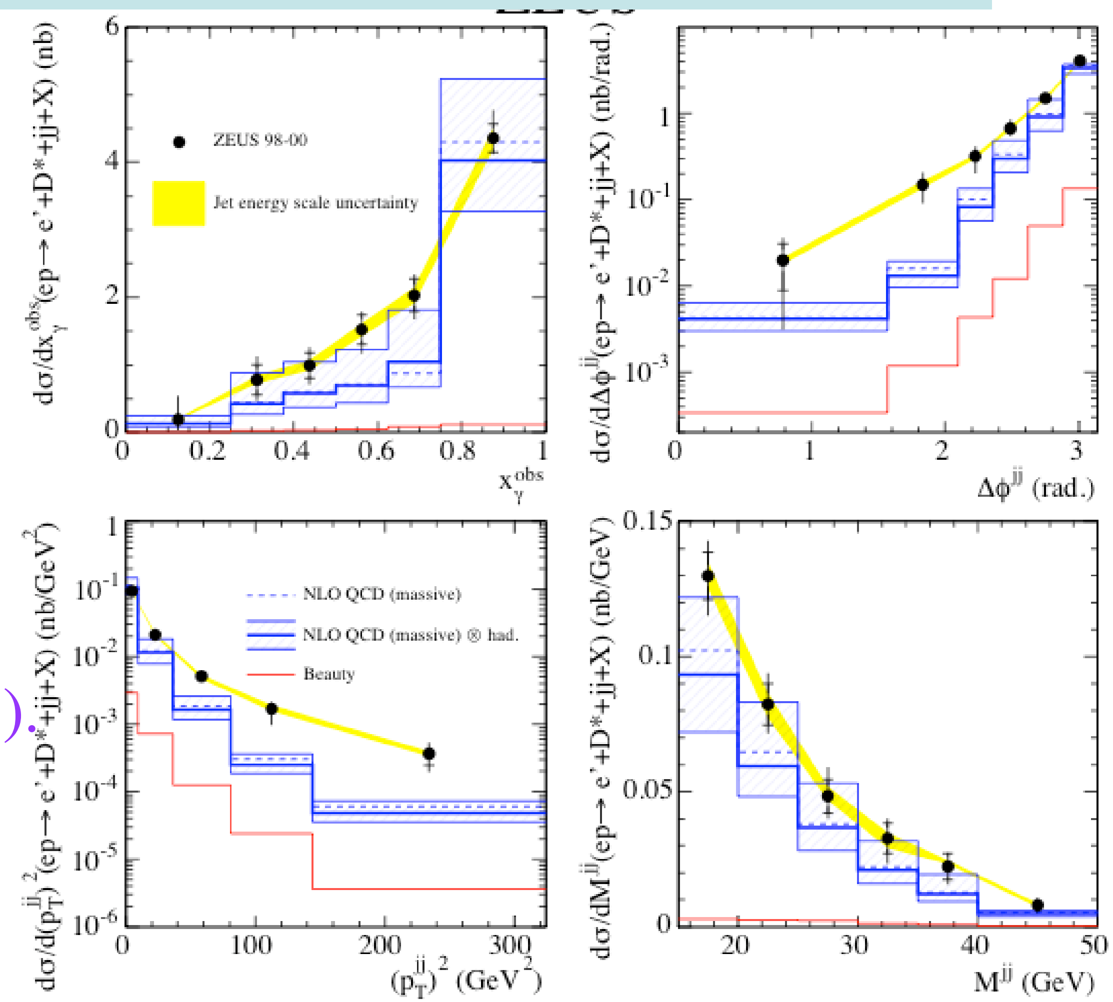




Charm Dijet Production

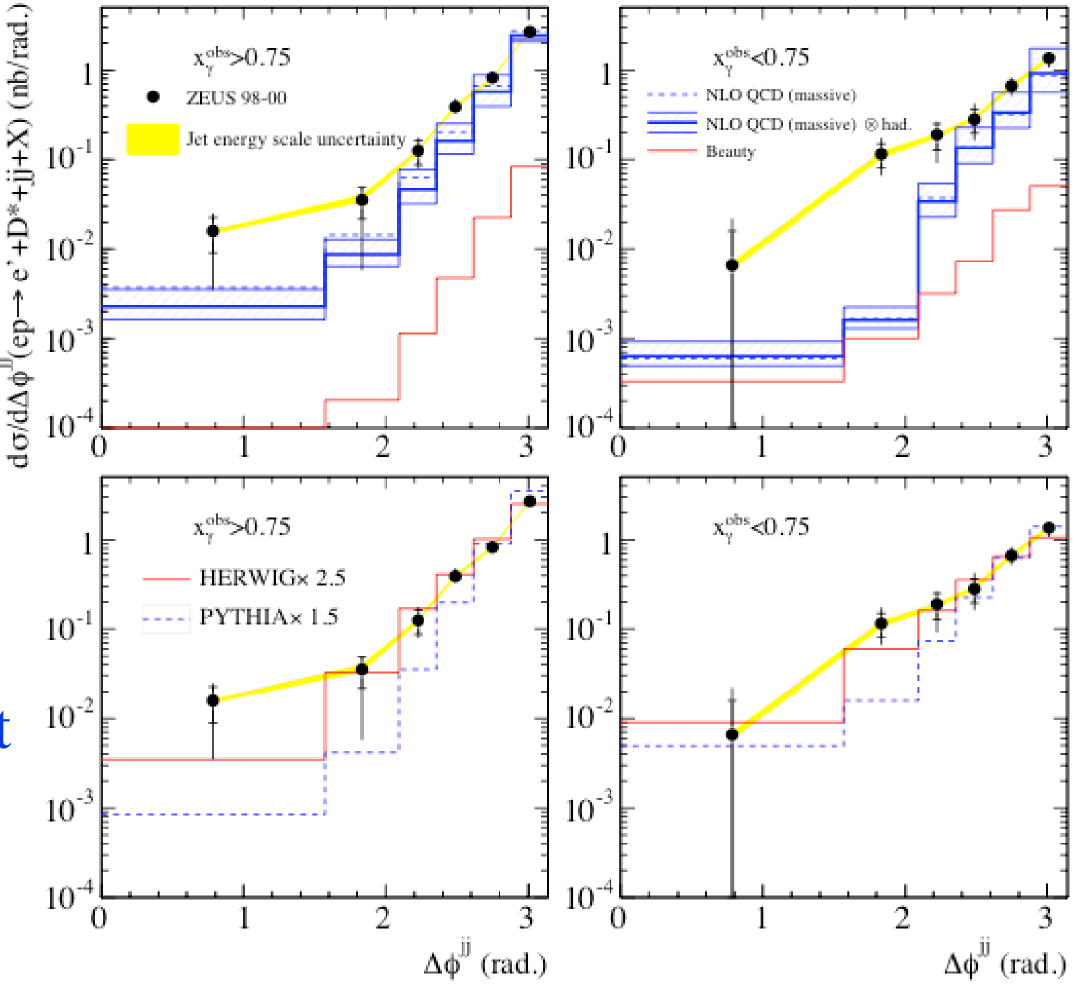
- D* Dijet photoproduction.
- M^{JJ} and x_γ^{obs} well described.
- Angular correlations $(p_T^{JJ})^2$ and $\Delta\phi^{JJ}$ are not described.
- Split sample:
  direct-enriched ($x_\gamma^{obs} > 0.75$),
  resolved-enriched($x_\gamma^{obs} < 0.75$).

Does one sample contribute more then other to the discrepancy?



Charm Dijet Production

- D* Dijet photoproduction.
- Split sample direct-enriched ($x_\gamma^{obs} > 0.75$) resolved-enriched($x_\gamma^{obs} < 0.75$).
- Discrepancies between pQCD and resolved-enriched ($x_\gamma^{obs} < 0.75$).
- LO+PS can describe shape but not normalisation.
- → need for higher order calculations e.g. NLO +PS

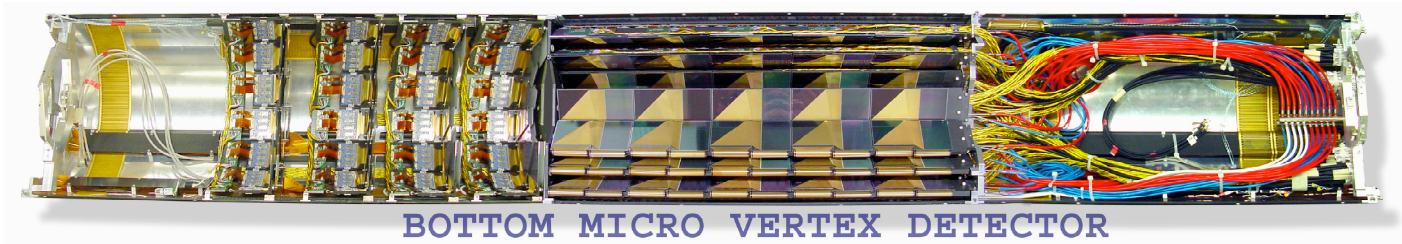


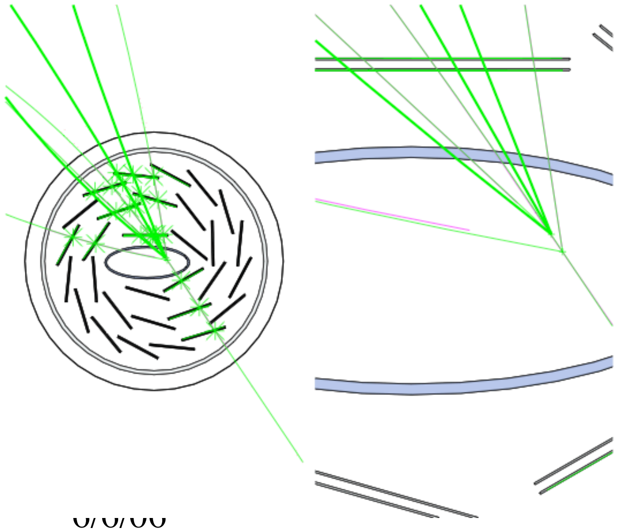
Summary

- Charm results in reasonable agreement with pQCD.

•Areas of disagreement can be selected(e.g. D* + dijets) indicating the need for higher order corrections e.g. MC@NLO.

•HERA errors small compared to theoretical uncertainties.





Future charm prospects:

- Extend phase space to the forward region and p_T.

•Use new theory (hopefully coming soon) to compare to existing data and new HERA II data.

•Impact of charm data on PDF fits.