Charm Fragmentation and Dijet Angular distributions

Sanjay Padhi
McGill University

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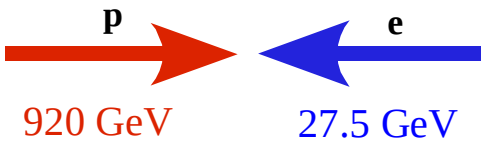
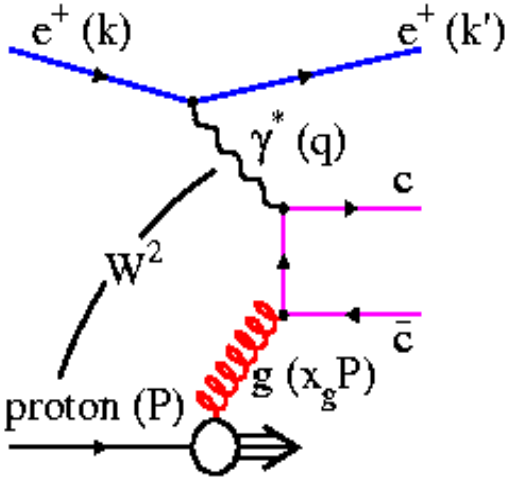
Outline:

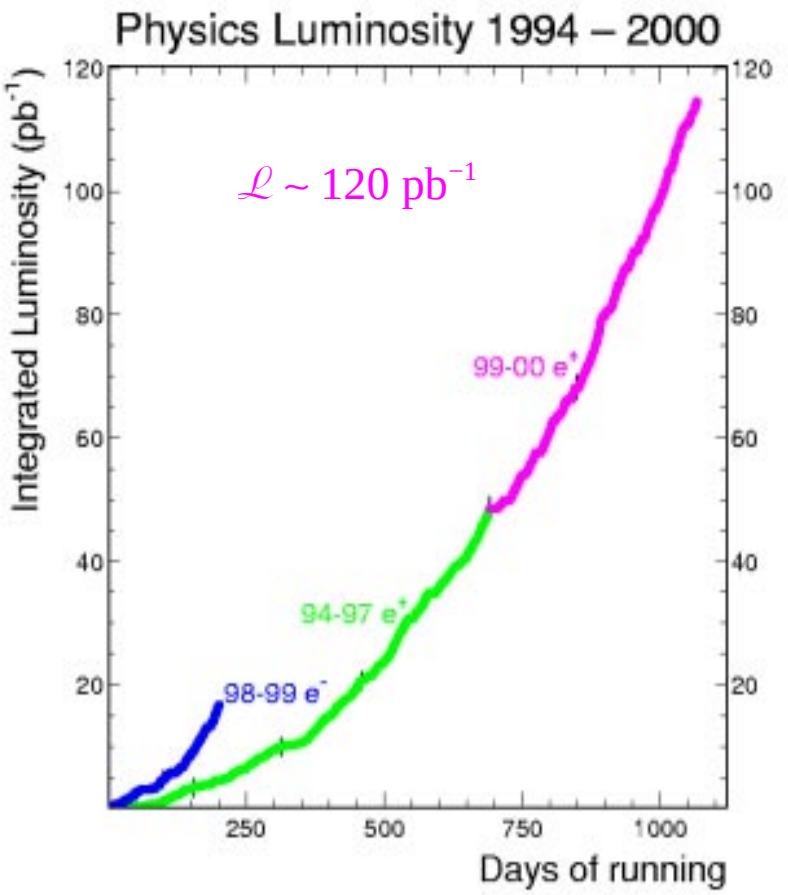
- Introduction
- Charm production & fragmentation
- Universality of charm fragmentation
- Dijet angular distributions in D^* photoproduction
- Summary and outlook

Introduction

$\sqrt{s} \sim 320$ GeV







Kinematic Variables

- 4−momentum transfer : $Q^2 = -q^2 = -(k-k')^2$
- Bjorken−x scaling variable : $x = Q^2/2P.q$
- γp CMS energy square : $W^2 = (P + q)^2$
- Fraction of energy transfer : $y = P.q/P.k \cong W^2/s$

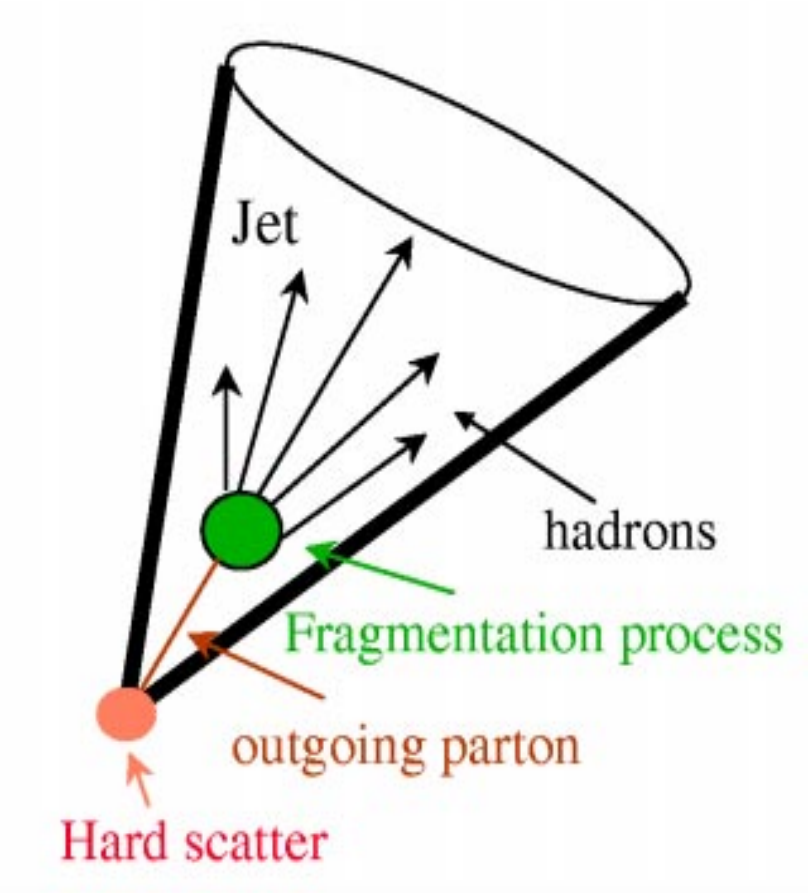
Photoproduction Regime:

- No scattered electrons
- $Q^2 \leq 1$ GeV^2
- $130 < W < 280$ GeV

Charm Production and Fragmentation

Heavy Flavour (charm) Production :

- Production of $q\ \bar{q}$
- Development of Parton shower
- Transition of partons to hadrons (Hadronisation)
- Unstable hadrons decay (according to BR)



Experimentally ($c \rightarrow$ D) Meson:

- Fragmentation Fraction

  $f(c \rightarrow D^{*+}) = 0.235 \pm 0.007$ (LEP)
- Fragmentation Functions

(e.g Peterson Fragmentation Function, Lund, Collins & Spiller ...)

Are these fragmentation fractions universal ?

Charm Production and Fragmentation

Charmed Mesons:

Vector State (V) $D^{*\pm}$ $\rightarrow$ spin 1

Pseudoscalar (PS) D^0 $\rightarrow$ spin 0

$P_v = V/(V + PS)$

Simple spin counting : $P_v = 0.75$

The relative production of these two states is sensitive to non−perturbative effects in the hadronisation process, thus cannot be calculated exactly.

However there are several models

K. Cheung hep−ph/9505365 (1995) $P_v = 0.68$

E. Braaten et. al. Phys.Rev.D51(1995) 4819 $0.5 < P_v < 0.75$

Y. Q. Chen. Phys. Rev. D48 (1993) 5181 $P_v = 0.6$

Yi−Jin Pei, Z. Phys. C 72, 39 (1996) $P_v = 0.56$

Universality of Charm Fragmentation

Direct Production rates from charm fragmentation :

$$P_v = \sigma_{dir}(D^{*\pm})/(\sigma_{dir}(D^{*\pm}) + \sigma_{dir}(D^0))$$

Assuming :

a) $\sigma(D^{*0}) = \sigma(D^{*\pm})$

b) No sizable distortions from excited D mesons

Decay Modes:

$D^0 \rightarrow K^- \pi^+$ (+c.c)

$D^{*+} \rightarrow (K^- \pi^+) \pi_s^+$ (+c.c)

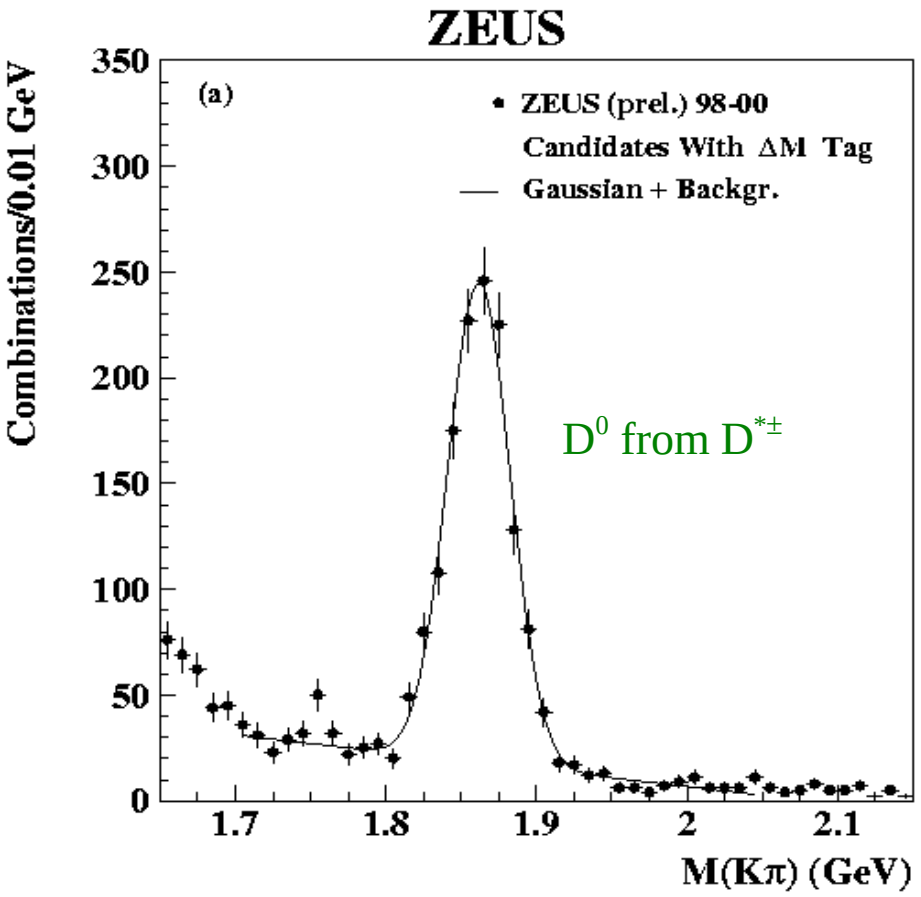
; π_s is a soft pion with low momentum

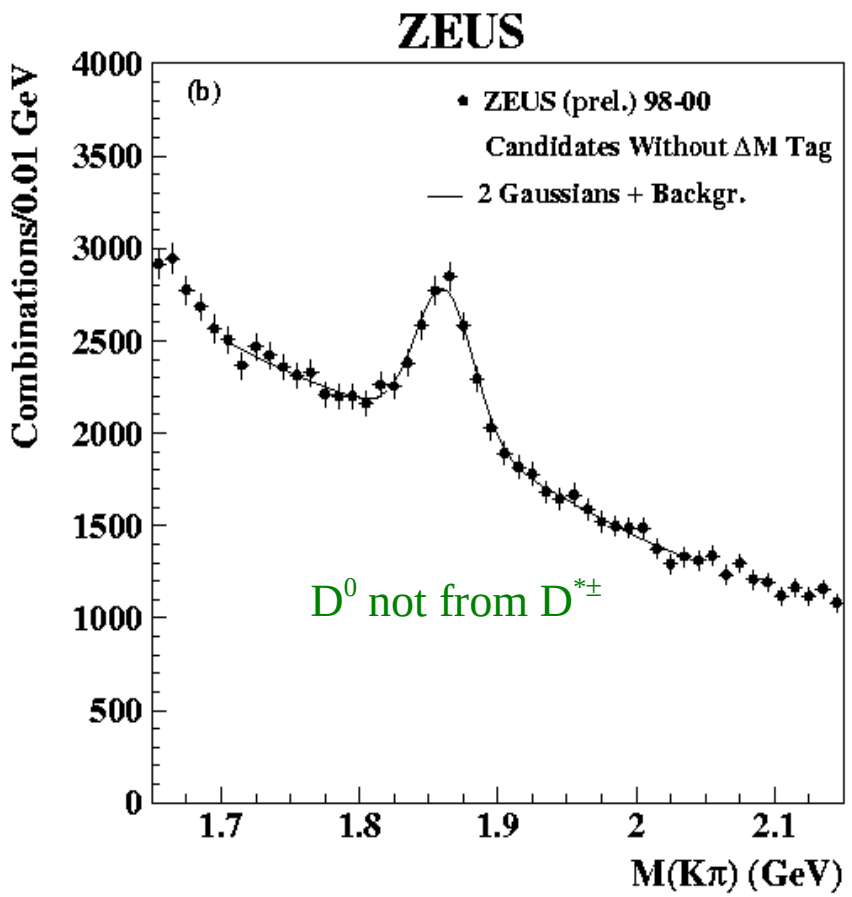
$$\sigma_{dir}(D^0) = \sigma_{tot}(D^0) - \sigma_{tot}(D^{*\pm})\,(1 + BR(D^{*\pm} \rightarrow D^0\pi^{\pm}))$$

$$P_v = \frac{1}{(\sigma_{tot}(D^0)/\sigma(D^{*\pm}) - BR(D^{*\pm} \rightarrow D^0\pi^{\pm}))}$$

P_v measured from ZEUS data for D^* and D^0 mesons

Universality of Charm Fragmentation ?





$P_V = 0.546 \pm 0.045$ (stat.) ± 0.028 (syst.)

Using : $N(D^0) = 5223 \pm 185$

$N(D^{*\pm}) = 1180 \pm 39$

OPAL : $P_V = 0.57 \pm 0.05$

ALEPH : $P_V = 0.595 \pm 0.045$

Results consistent with universality of charm fragmentation fraction

Dijet in charm Photoproduction

QCD predicts that the angular distribution of the outgoing partons in resolved processes will be enhanced at high $|\cos\theta^*|$ with respect to direct photon processes.
(Phys. Rev D40 (1989) 2844)

ZEUS Coll., Phys. Lett. B 384(1996) 401

ZEUS 1994

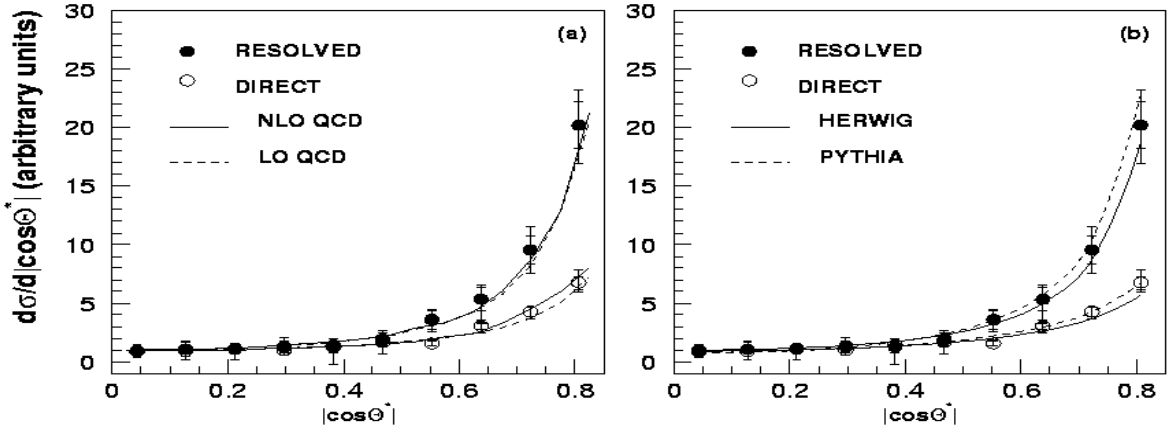
Direct photon LO is q−exchange

⇒ *Cross section rises mildly with* $|\cos\theta^*|$

Resolved photon LO is g−exchange

$qg \rightarrow qg$, $gg \rightarrow gg$, $qq \rightarrow qq$

⇒ *Cross section rises steeply with* $|\cos\theta^*|$

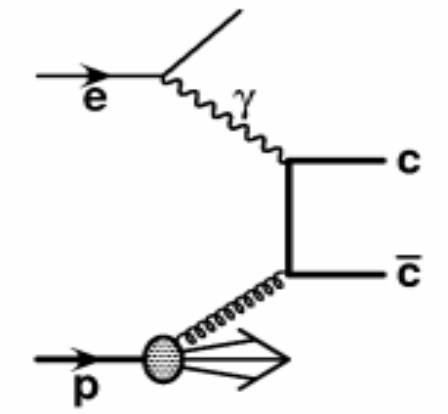


Is it true in case of charm ?

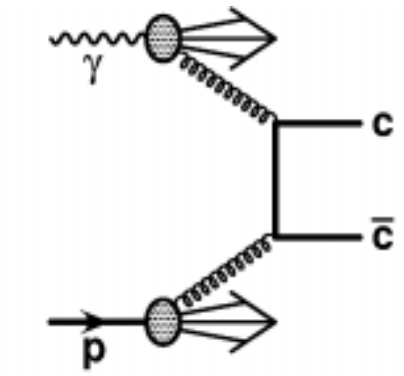
ZEUS Coll., "*Dijet Angular Distribution in D* Photoproduction at HERA*". Paper 499, EPS HEP01, Budapest, Hungary, July 12−18, 2001.

What can we learn from this ??

Dijet in charm Photoproduction



Direct−γ: γ–g fusion



Resolved−γ: g g → c $\bar{c}$

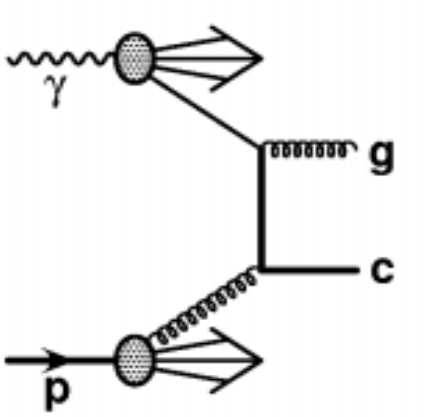
Define: direct photon $x_\gamma^{obs} > 0.75$

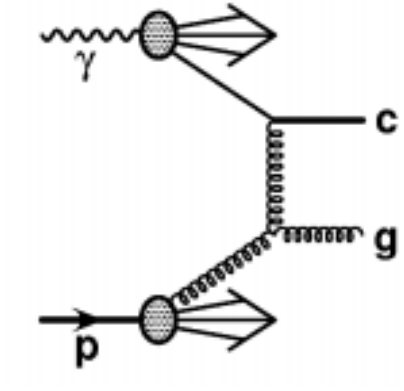
resolved photon $x_\gamma^{obs} < 0.75$

q−exchange $d\sigma/d|\cos\theta^*| \sim (1 - |\cos\theta^*|)^{-1}$

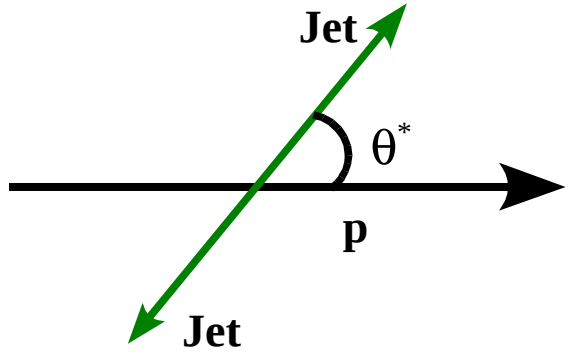
g−exchange $d\sigma/d|\cos\theta^*| \sim (1 - |\cos\theta^*|)^{-2}$

(Rutherford scattering)





Resolved−γ: c excitation



θ^* = center of mass scattering angle

q−exchange

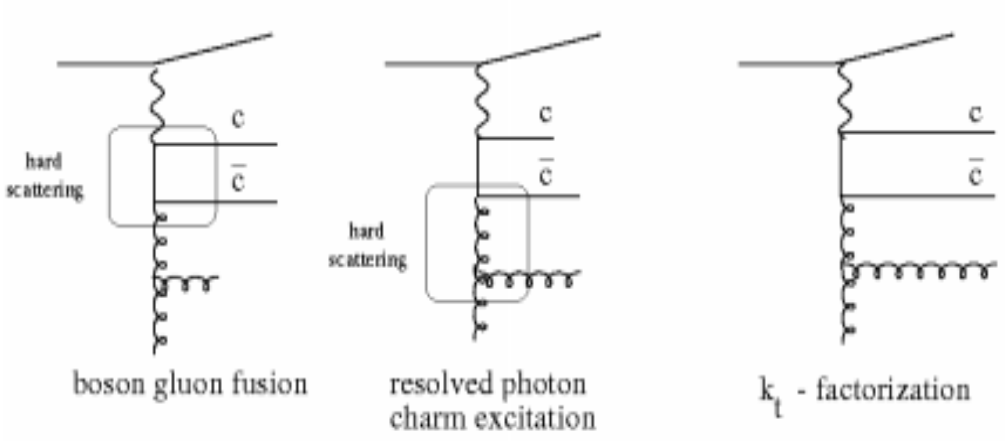
g−exchange

Expected dominant resolved photon processes are via g−exchange

Monte Carlo generators

- PYTHIA, HERWIG (ISR, ME, FSR), DGLAP
- CASCADE

[ISR(CCFM) + BGF + FSR(From PYTHIA)]



Dijet in charm Photoproduction

D* dijet events enable study of photon structure in particular its charm content.

Sample Used : Photoproduction with a reconstructed D* and at least 2 hadron jets

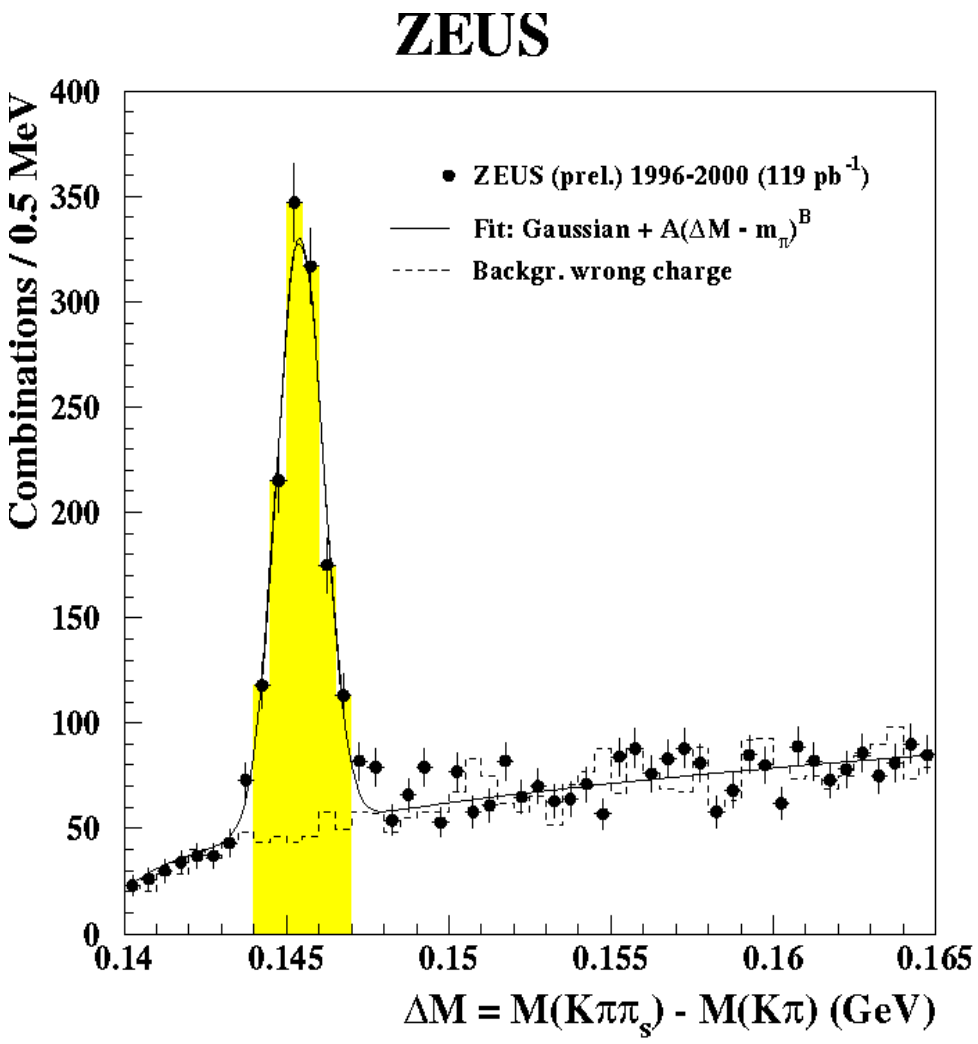
- Require D* with $p_T^{D*} > 3.0$ GeV, $|\eta^{D*}| < 1.5$
- Dijets $E_t^{jet} > 5$ GeV, $|\eta^{jet}| < 2.4$, $M_{jj} > 18$ GeV

  [EPS 2001 PAPER 499]

Kinematic region :

$Q^2 < 1$ GeV^2

$130 < W_{\gamma p} < 280$ GeV

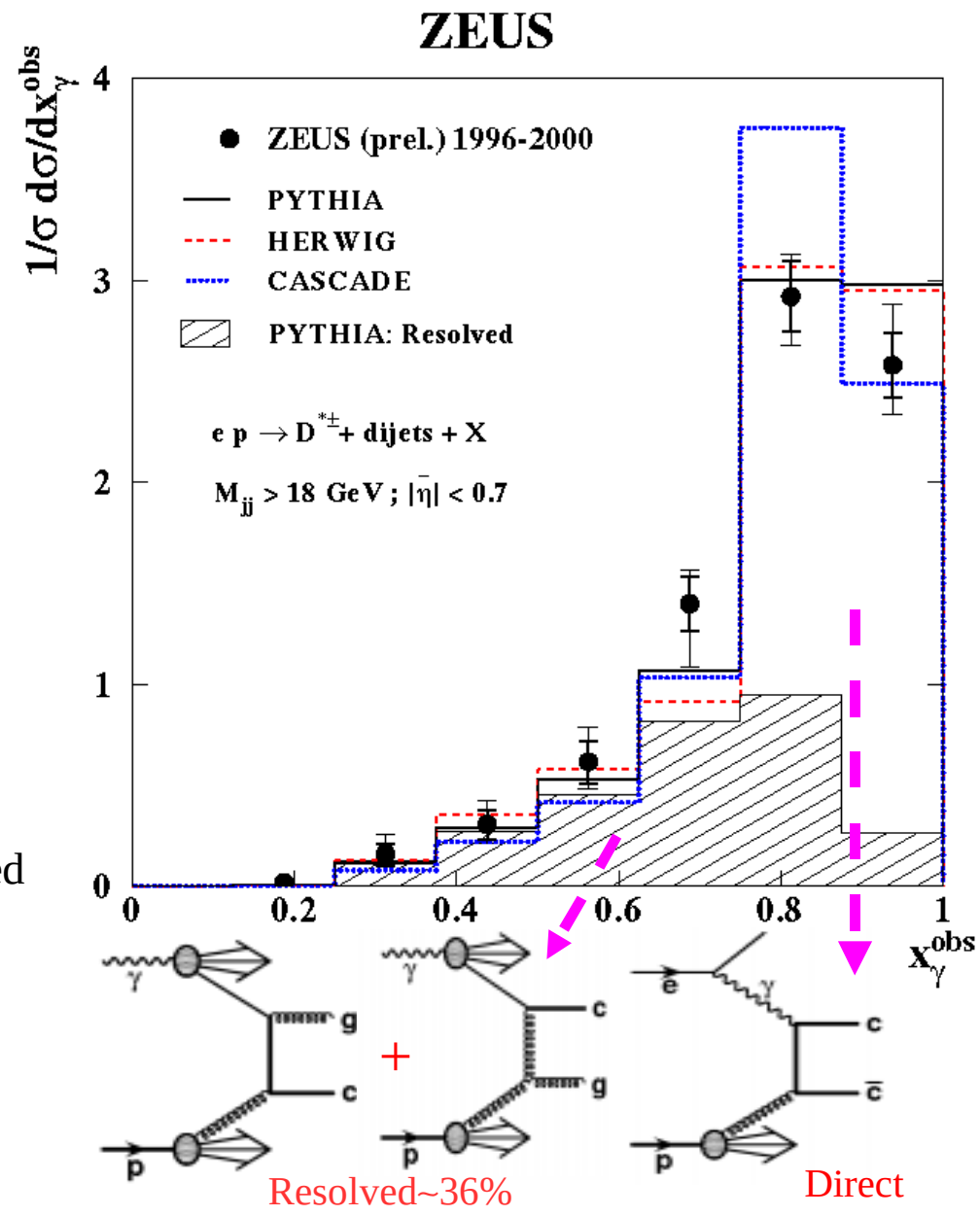


Dijet in charm Photoproduction

- 1) First indication of charm content of photon can be obtained by studying ...

Fraction of photon energy contributing to the production of two highest E_t^{jet} jets.

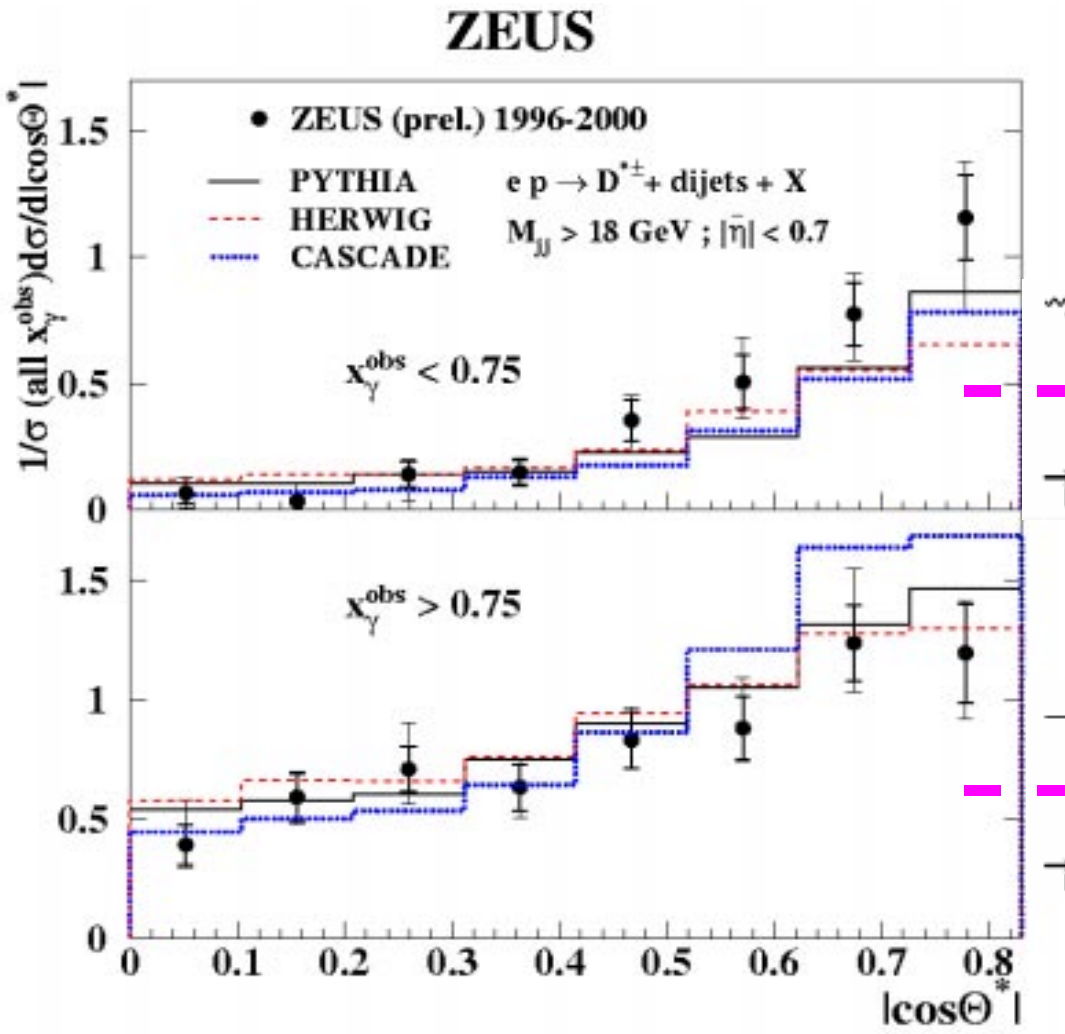
$$x_\gamma^{obs} = \frac{\Sigma_{jets} E_T e^{-\eta}}{2yE_e}$$

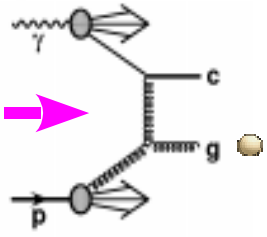


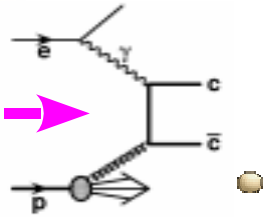
- Both direct and resolved fractions are significant
- Dominant part of the resolved is from "charm content of the photon" c−excitation.
- Significant reduction of Resolved events observed due to Hard Cuts $M_{jj} > 18$ GeV, $|\bar{\eta}| < 0.7$
- PYTHIA, HERWIG and CASCADE in general can reproduce the shape

Dijet angular distributions

- 2) Observation of g−propagator in resolved events.







$\cos\theta^* = \tanh(0.5(\eta^{jet1} - \eta^{jet2}))$

θ^* = angle between jet−jet axis and beam direction in dijet rest frame

- Resolved distribution rises strongly at high $|\cos\theta^*|$, signature of g−exchange
- Direct distribution shows a shallower rise, consistent with q−exchange
- General trend by all the three MC to reproduce the DATA shape

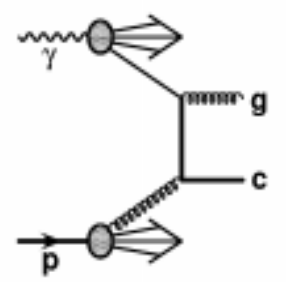
q−exchange $d\sigma/d|\cos\theta^*| \sim (1 - |\cos\theta^*|)^{-1}$

g−exchange $d\sigma/d|\cos\theta^*| \sim (1 - |\cos\theta^*|)^{-2}$

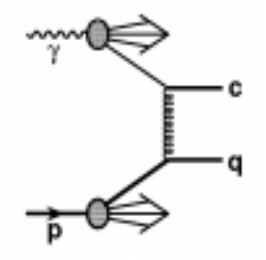
A clear signature of g−exchange

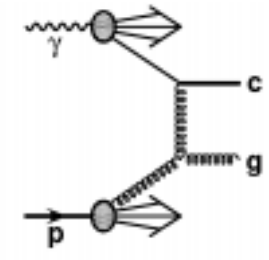
Dijet angular distributions

3) Study of various sub−processes with charm



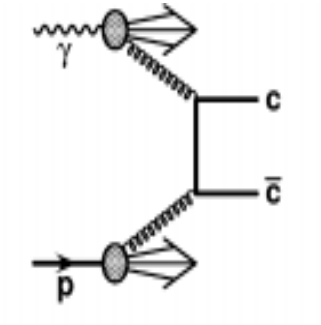
q−exchange



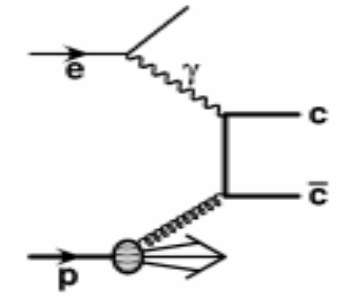


g−exchange

Resolved−γ (pythia) : c excitation ~35%

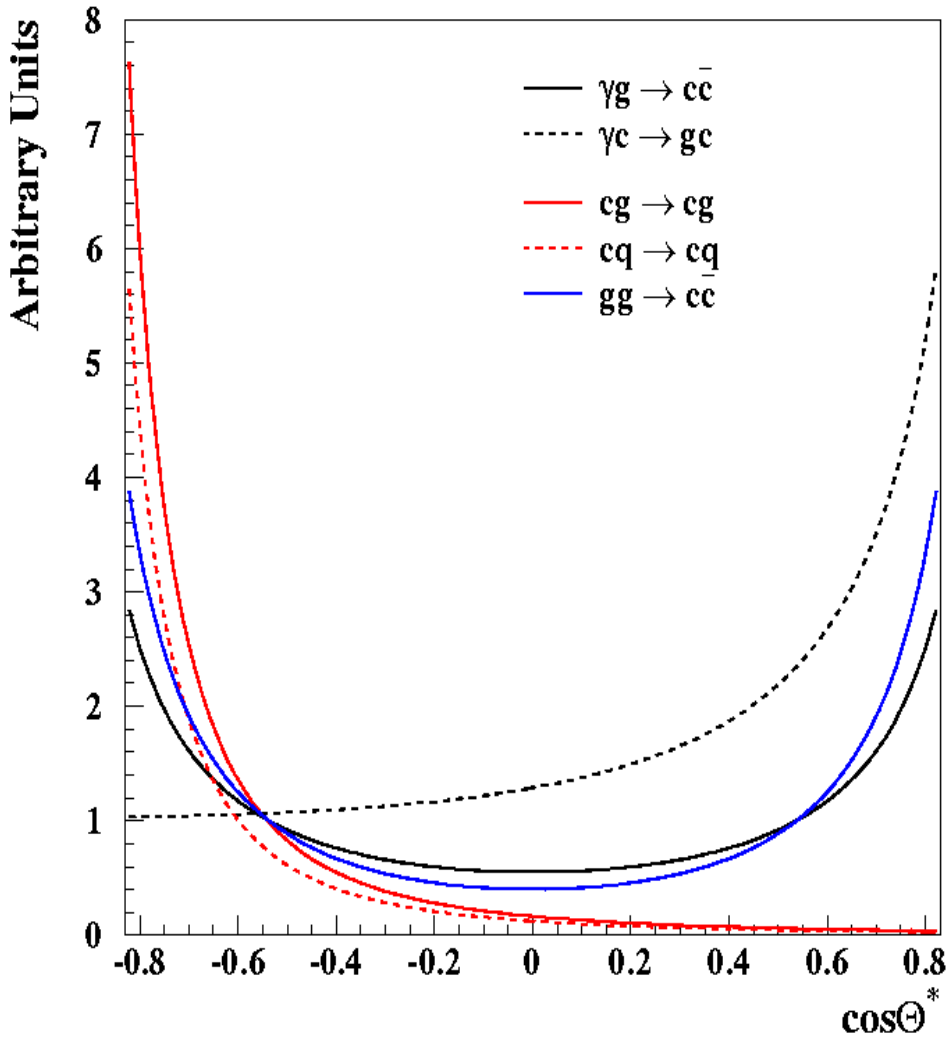


⇐ Resolved−γ: g g → c $\bar{c}$ ~ 0.46%

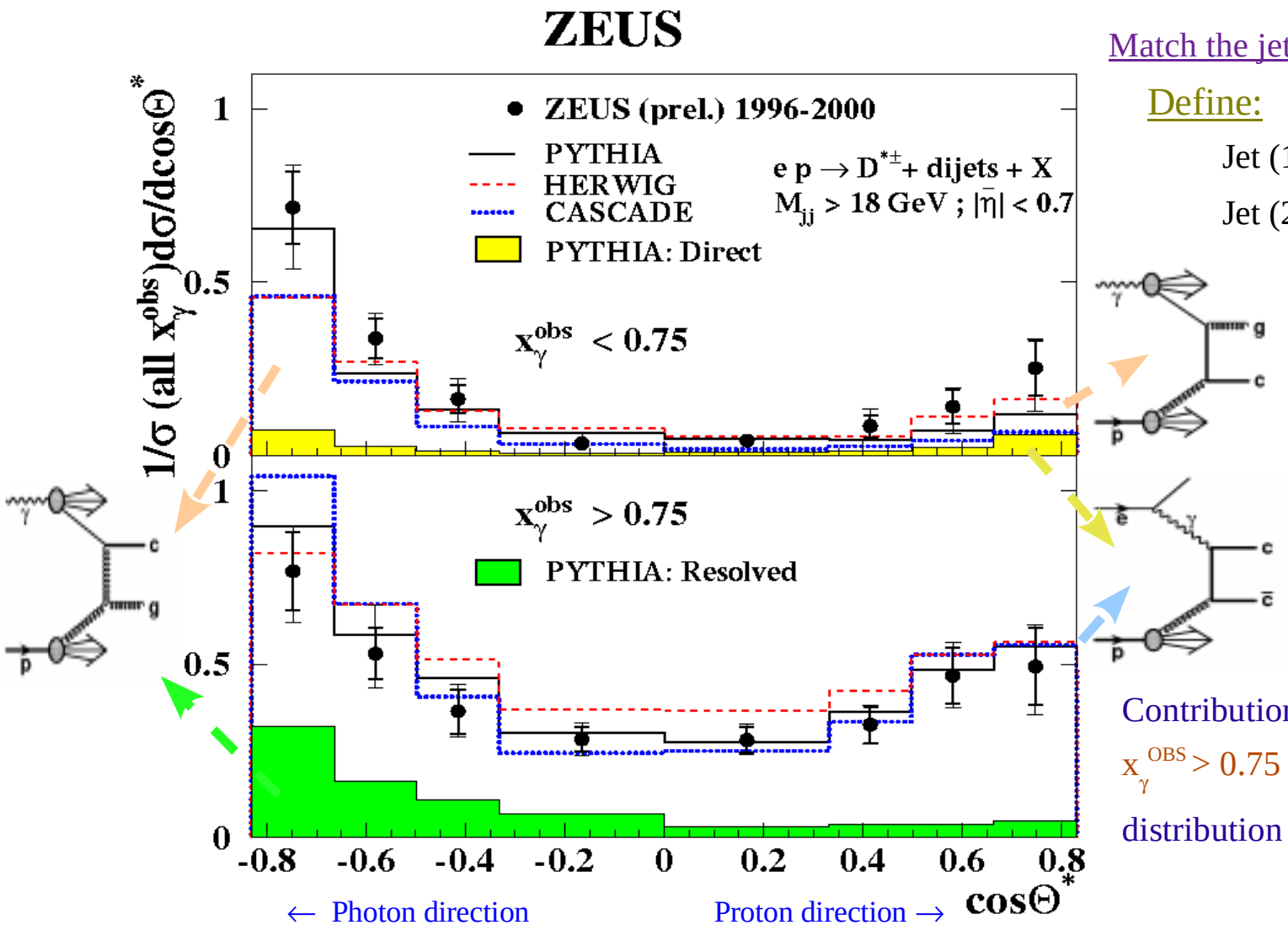


⇐ Direct−γ: γ–g fusion ~ 61%

Just from Matrix elements



Dijet angular distributions



Match the jet with a D* in (η−φ) space

Define:

Jet (1) = D* Jet

Jet (2) = other Jet

Contribution of LO resolved to $x_\gamma^{OBS} > 0.75$ explains the asymmetric distribution in $\cos\theta^*$

Clear evidence of charm content of the photon

Summary and Outlook

- HERA provides wide spectrum of charm flavoured jet measurements
- Measurement of P_V is consistent with Universality of charm fragmentation.
- Angular distribution of direct and resolved photon events are significantly different, reflecting different spin of q/g propagator.
- Steep rise towards high $|\cos\theta^*|$ of resolved events $\Rightarrow$ signature of gluon exchange
- Mild rise of $x_\gamma^{OBS} > 0.75$ is consistent with q−exchange as predicted by QCD
- Measurement of unfolded $\cos\theta^*$, with a D* tagged to a jet, gives a clear peak in the PHOTON direction (clear evidence of charm in photon).

A lot of interesting measurements related to charm fragmentation and charm content of the photon is going to come soon from HERA.