Charm Jets In Photoproduction At ZEUS

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UCL/ANL

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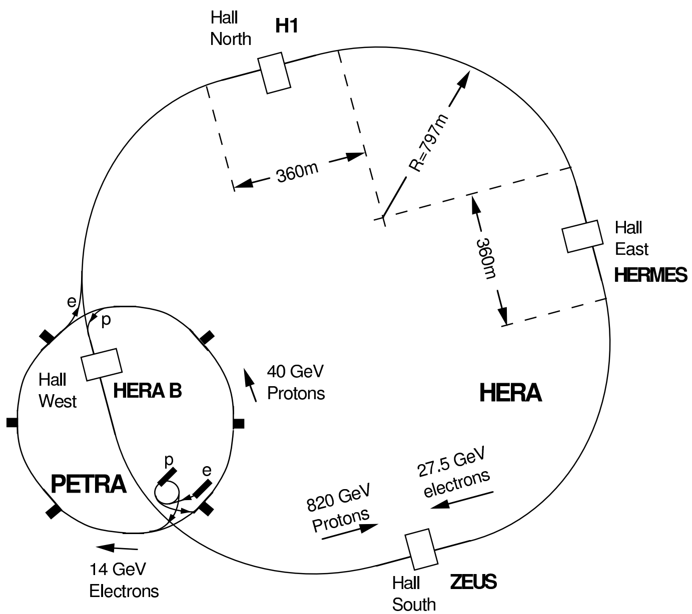
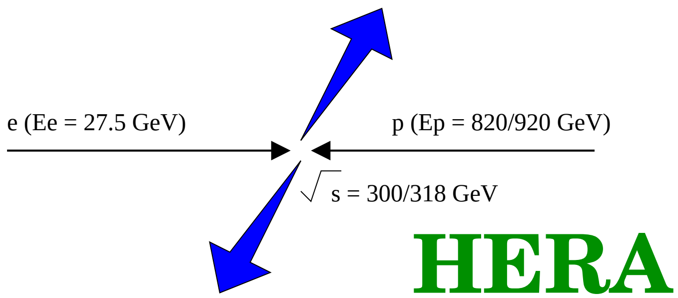




Introduction

The HERA collider provides a unique laboratory for the study of Heavy Flavour Physics

- Charm Jets can be used to test pQCD
  - $\longrightarrow$ Parton Dynamics of the Hard Scatter
  - $\longrightarrow$ Probe the photon and proton structure
- Study of the non perturbative part of QCD
  - $\longrightarrow$ Fragmentation, Hadronisation

  By studying charm production using Jets, the uncertainty from the fragmentation from the c-quark into D^* meson can be reduced.
- Jets are as close as you can get to reconstructing the parton dynamics of the event, as quarks and gluons cannot be directly observered.
- Heavy Flavour production is still an unresolved part of QCD, and requires further theoretical understanding

Kinematics of Lepton-Proton Scattering at HERA

HERA collides 27.5 GeV leptons with 820 (920) GeV protons

$\rightarrow \sqrt{s} = 300\ (318)$ GeV

- Negative four-momentum transfer squared:

$$Q^2 = -q^2 = -(k - k')^2 = sxy$$

- Photon Proton Center-of-Mass Energy:

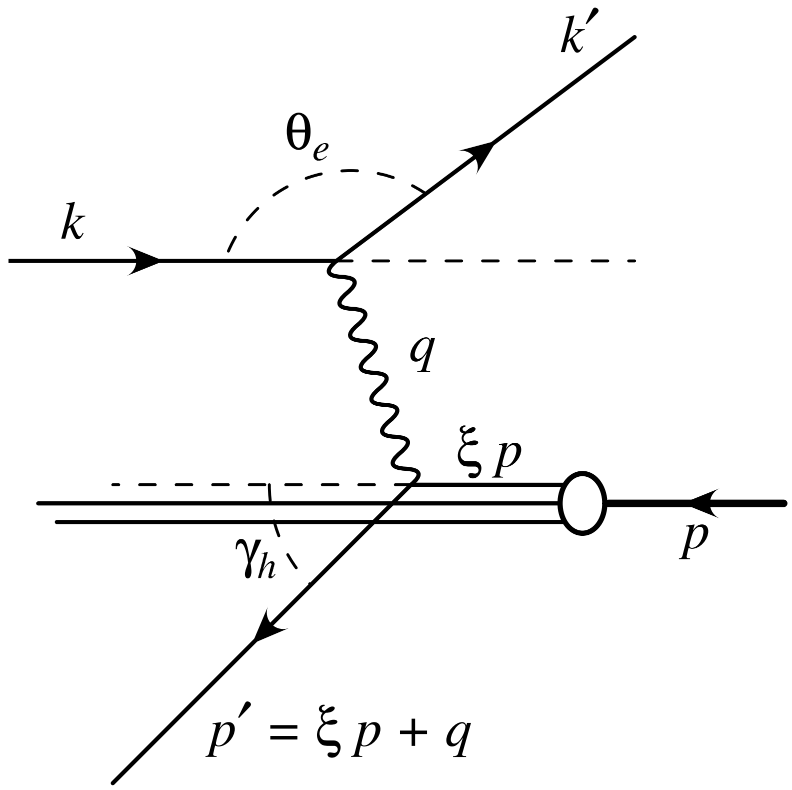
$$W^2 = (P + q)^2$$

- Bjorken scaling variable:

$$x \equiv \frac{Q^2}{2p.q}$$

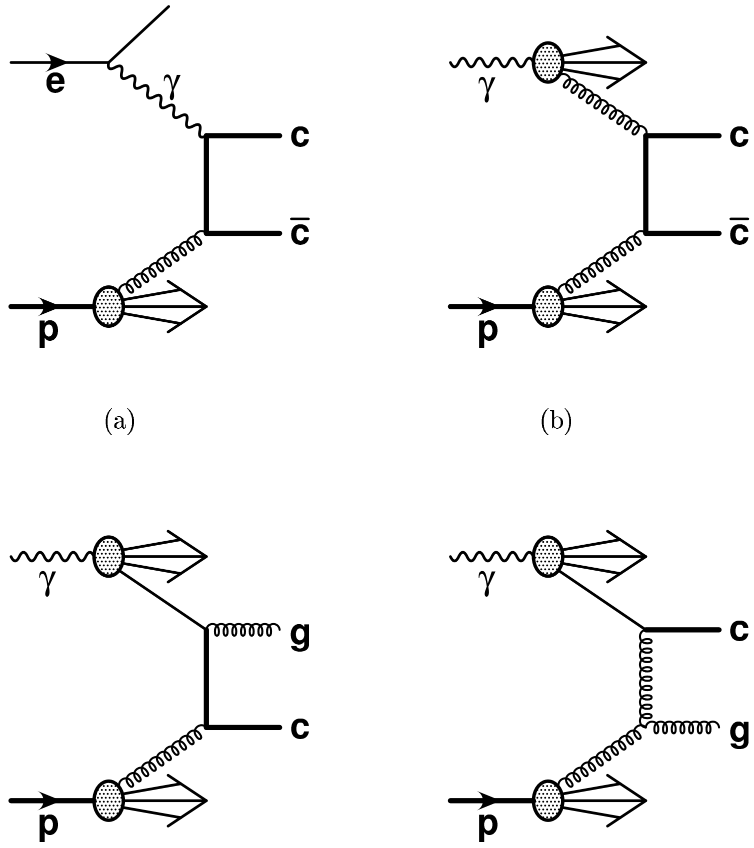
- Inelasticity:

$$y \equiv \frac{p.q}{p.k} \equiv \frac{W^2}{s}$$



Photoproduction at HERA

- In Photoproduction the electron is lost down the beam pipe.
- Photoproduction is defined as $Q^2 < 1$ GeV^2
  The main contributing processes to Heavy Flavour production (Leading Order) :
  (a) BGF (Boson Gluon Fusion)
  'Direct Process' point like photon(γ).
  The other processes have a 'Resolved-γ'
  (b) is Hadron like,(c) c-Excitation &
  q-Propagator,(d) g-Propagator.



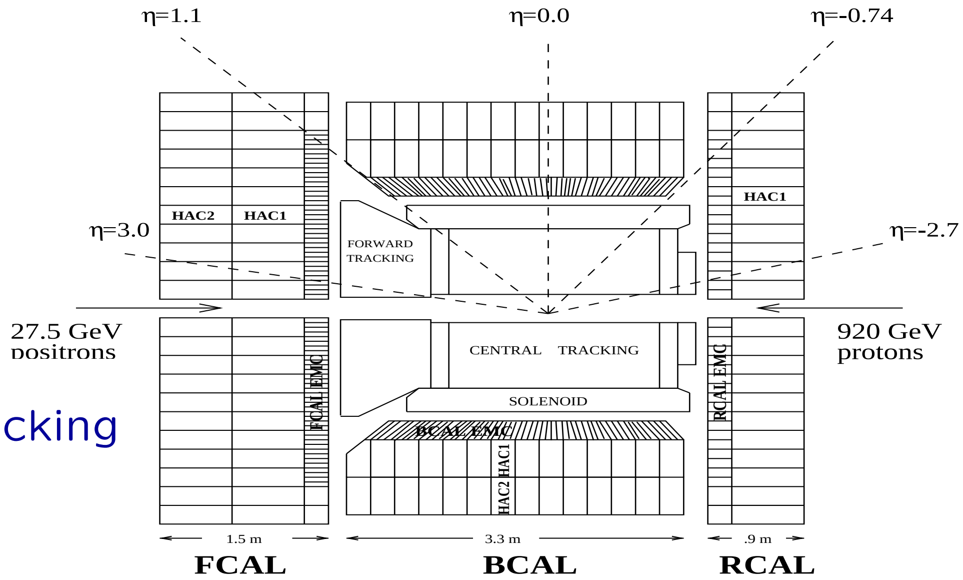
(a) (b) (c) (d)

- pQCD (Next-to-Leading-Order) calculations should give a better description of the data.

Pseudorapidity & Jet Energy loss

Pseudorapidity (η) is defined as:

$$\eta = -ln(tan\frac{\theta}{2})$$

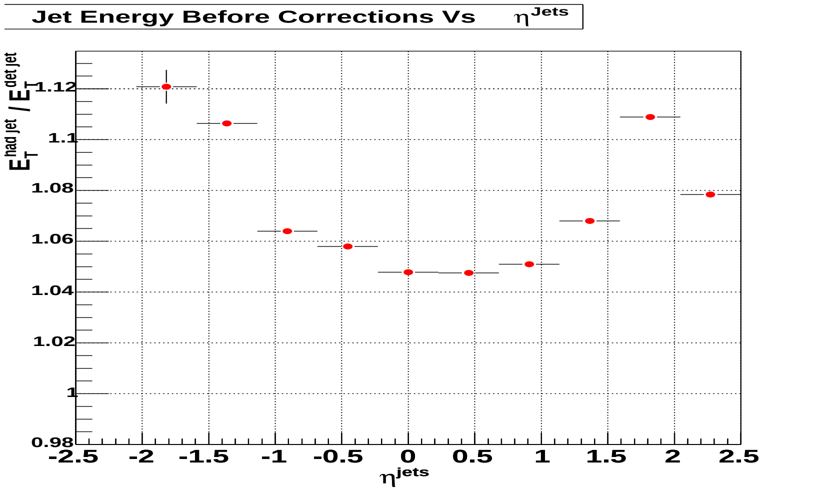


To reconstruct jets, a combination of Tracking and Calorimeter information are used (energy flow algorithm).

Jets loose the most amount of energy in the super-crack regions of the Calorimeter. and from interactions with dead material.

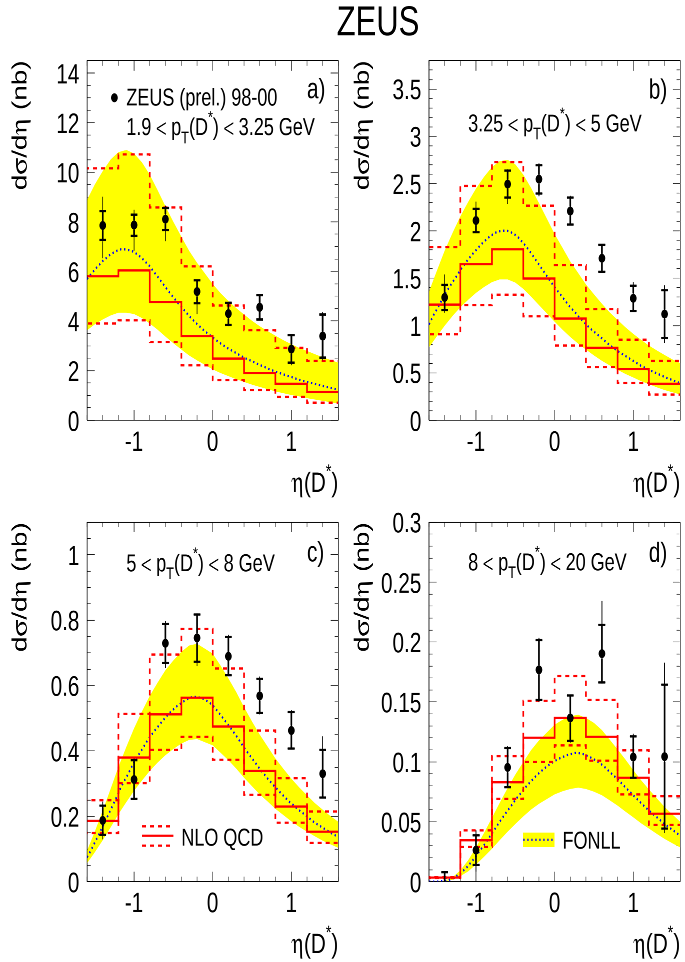
$\rightarrow$ Jet energies corrected for.

The C++ Kt Algorithm is used with massless objects.



$D^{*\pm}$ Photoproduction at HERA Overview

- Charm is tagged at ZEUS most efficiently with the reconstruction of a D^* meson,in the decay channel $D^{*\pm} \rightarrow K^{\mp} \pi^{\pm} \pi_s^{\pm}$.
- The plot shows the differential cross-section dσ/dη,for inclusive $D^{*\pm}$ photoproduction These data are compared with NLO calculations (upper and lower bounds show NLO uncertainties).
- These data are not described by the NLO predictions. Charm with the addition requirement of a jet could help understanding and reduce theoretical uncertinties. Another hard scale is included reducing the dependence of non-perturbative parts.



Event and Trigger Selection

- ZEUS has a three level trigger system.
- Photoproduction selection:

  No electron candidate, $|Z_{vertex}| < 50$ cm

  $130 < W_{JB} < 280$ GeV
- $D^{*\pm}$ selection:

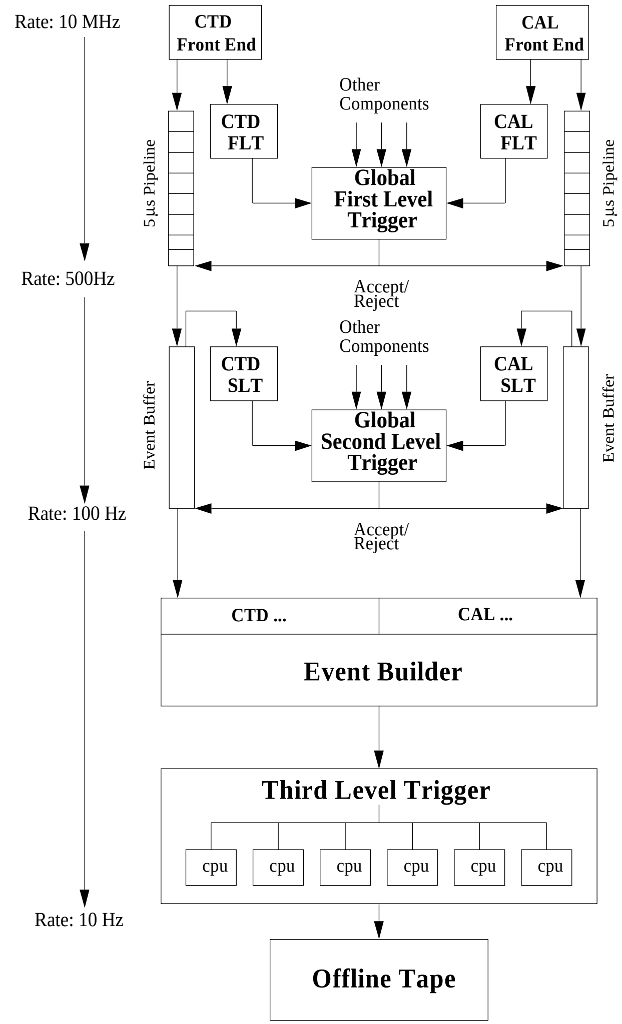
  $P_{T,\pi_s} > 0.12$ GeV , $P_{T,\pi K} > 0.4$ GeV, $|\eta_{track}| < 1.75$

  $P_{T,D^*} > 3.0$ GeV , $|\eta_{D^*}| < 1.5$

  $1.80 < m(D^0) < 1.92$ GeV

  $0.143 < \Delta M \, (M(D^*) - M(D^0)) < 0.148$ GeV
- Jet Selection one or more

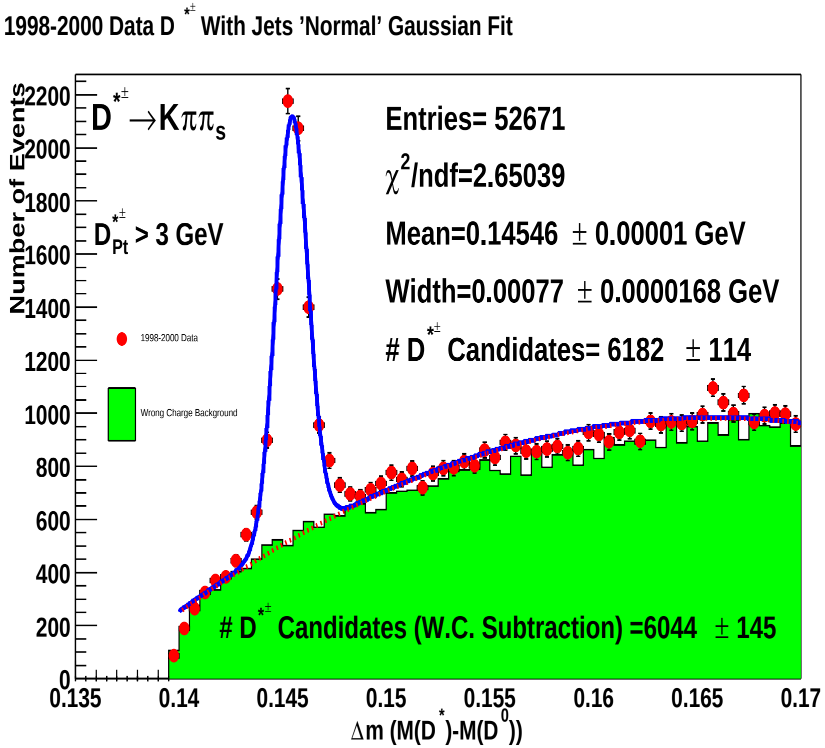
  $E_{T,jet} > 6$ GeV,$|\eta_{jet}| < 2.4$
- Luminosity used: 1998-2000 Data $\rightarrow$ $82pb^{-1}$

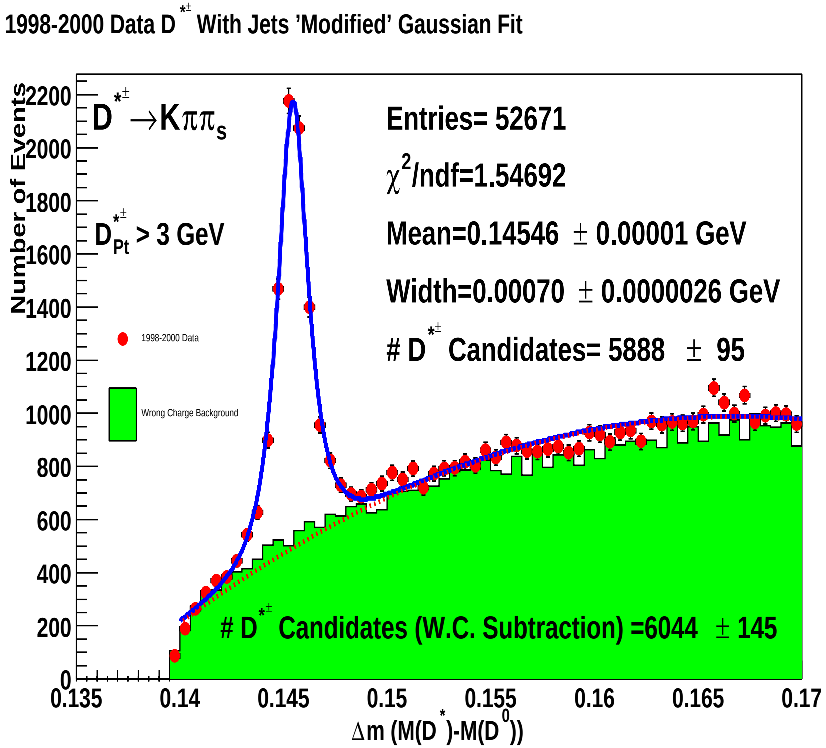


$D^{*\pm} \rightarrow K^{\mp}\ \pi^{\pm}\ \pi_s^{\pm}$ Fitting

$$\text{Normal Gaussian: } \sim \exp^{(-0.5.x^2)} \text{ where } x = \frac{\mathrm{x} - \mathrm{a}}{\sigma}$$

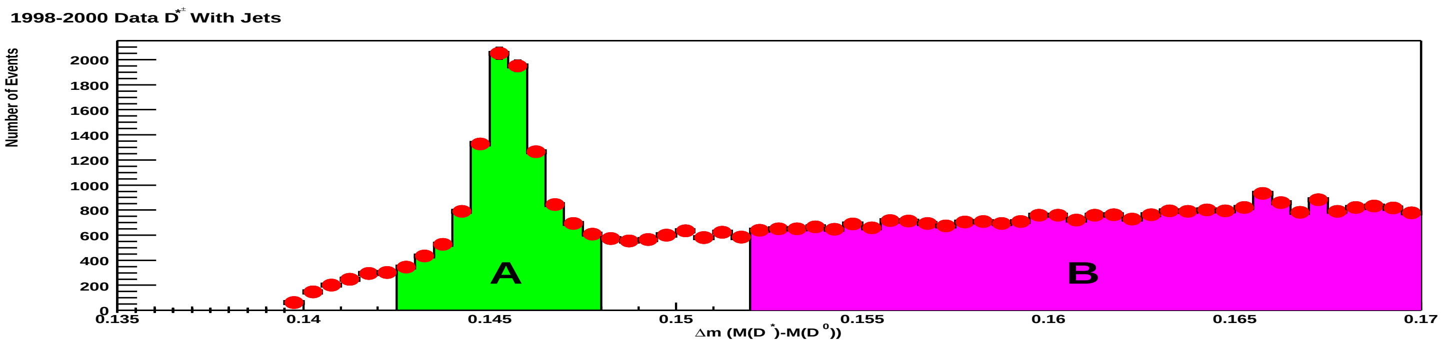
$$\text{Modified Gaussian: } \sim \exp^{(-0.5.x^{(1 + \frac{1}{1 + 0.5.x})})} \text{ where, } x = \left|\frac{\mathrm{x} - \mathrm{a}}{\sigma}\right|$$

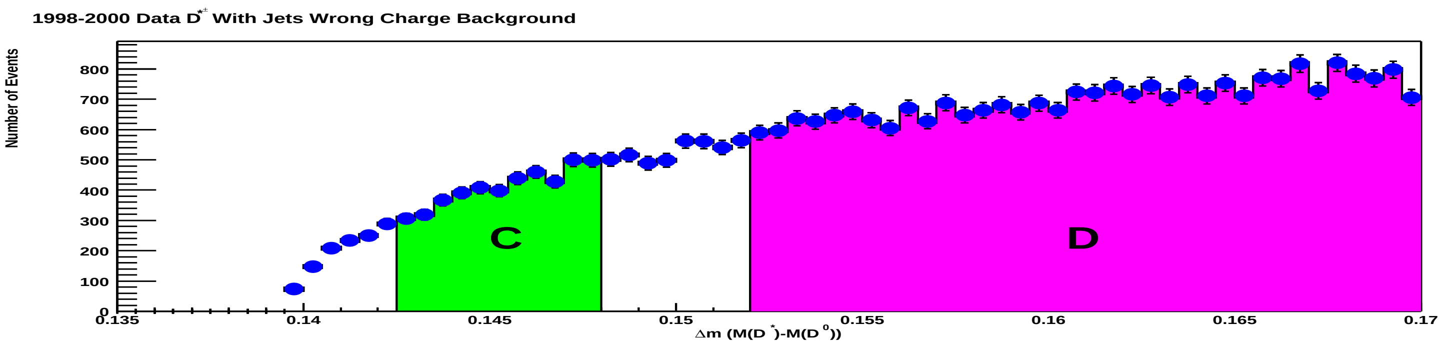




→ 'Modified' Gaussian gives a better fit; 'Modified' Gaussian will be used for all fits.

$D^{*\pm} \rightarrow K^{\mp}\pi^{\pm}\pi^{\pm}$ Wrong Charge Subtratction Method



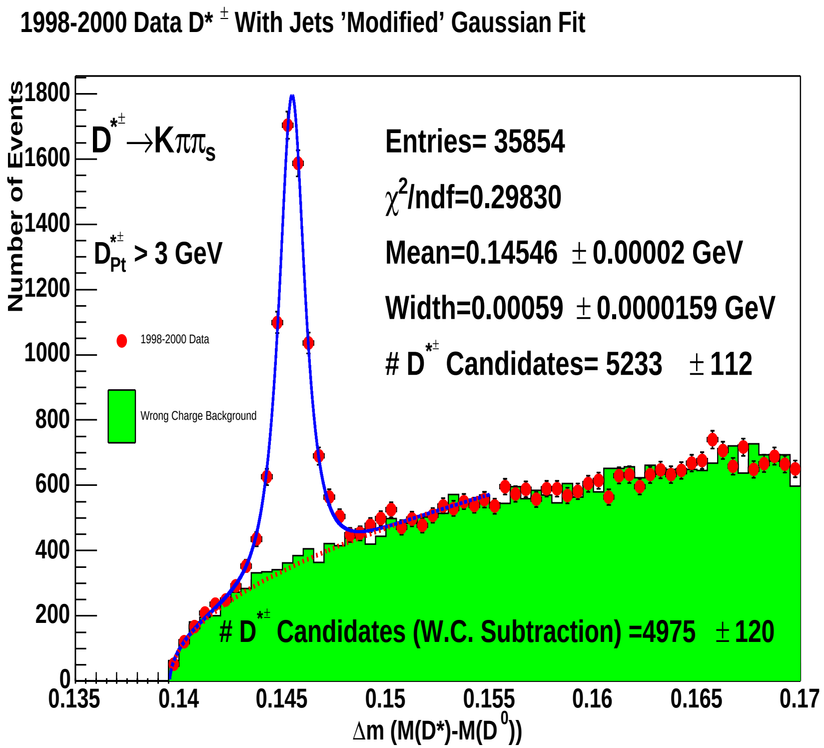


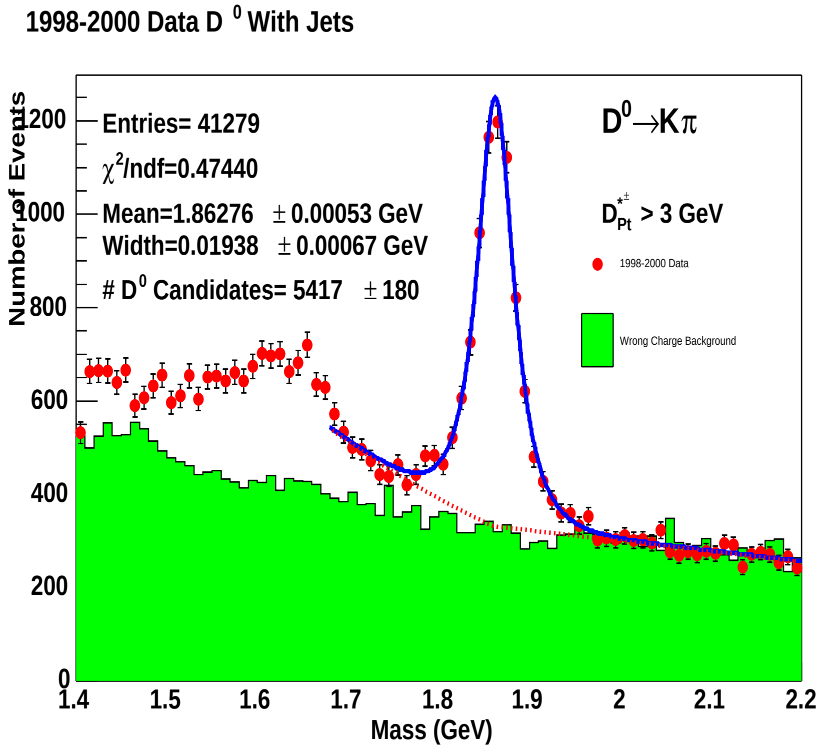
Wrong charge background subtraction method:

$$\text{Number of Events} = N(A) - N(C).\frac{N(B)}{N(D)}$$

$$\text{Error} = \sqrt{(N(A) + N(C).N(B).\frac{N(C) + N(B) + N(C).\frac{N(B)}{N(D)}}{N(D)^2})}$$

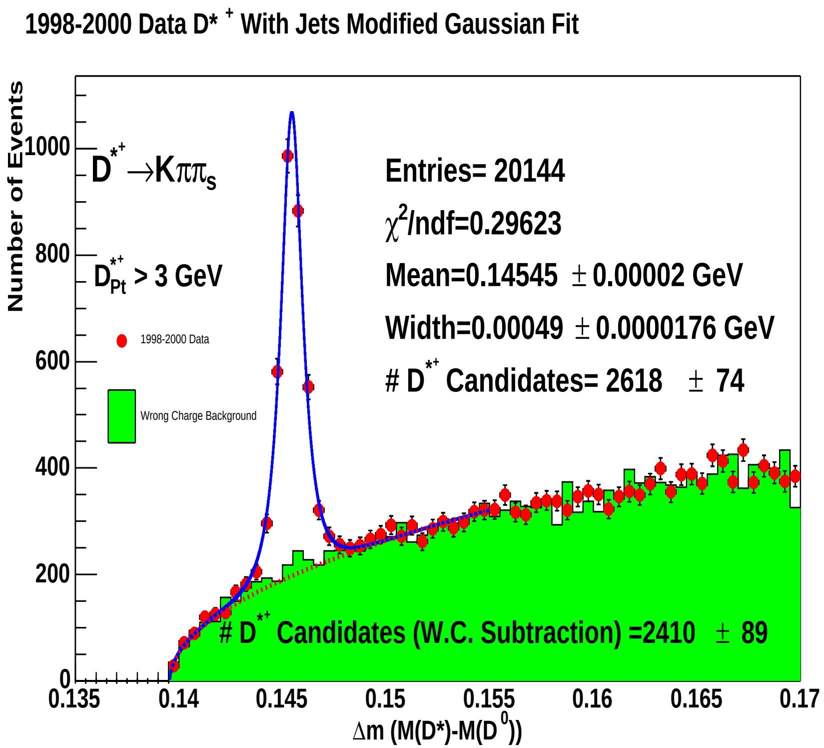
$D^{*\pm} \rightarrow K^{\mp}\ \pi^{\pm}\ \pi_s^{\pm}$ & Jets

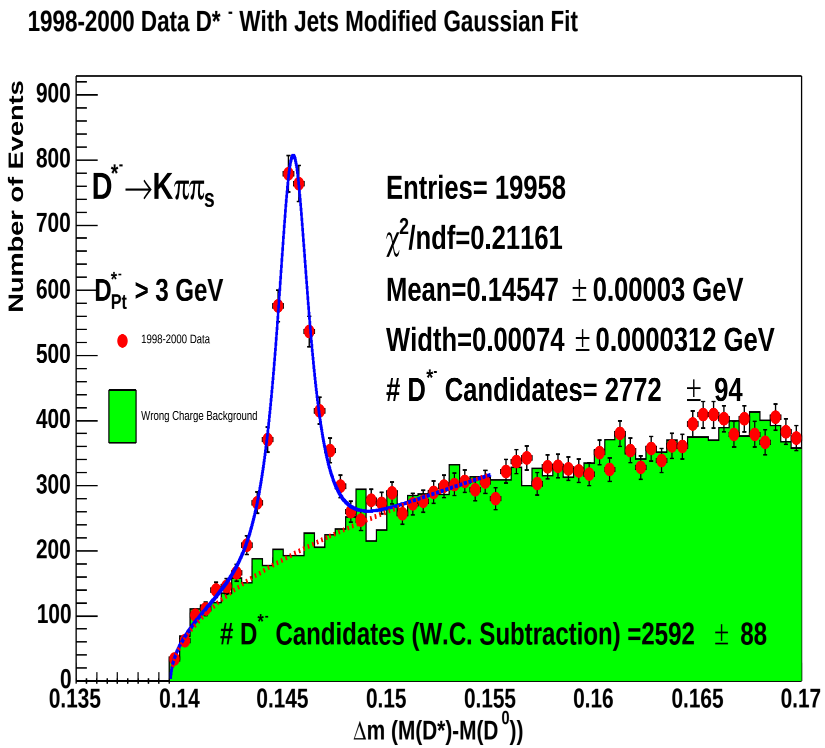




→ Plentiful data to be able to make some differential distibutions.

D^{*+}, D^{*-} & Jets





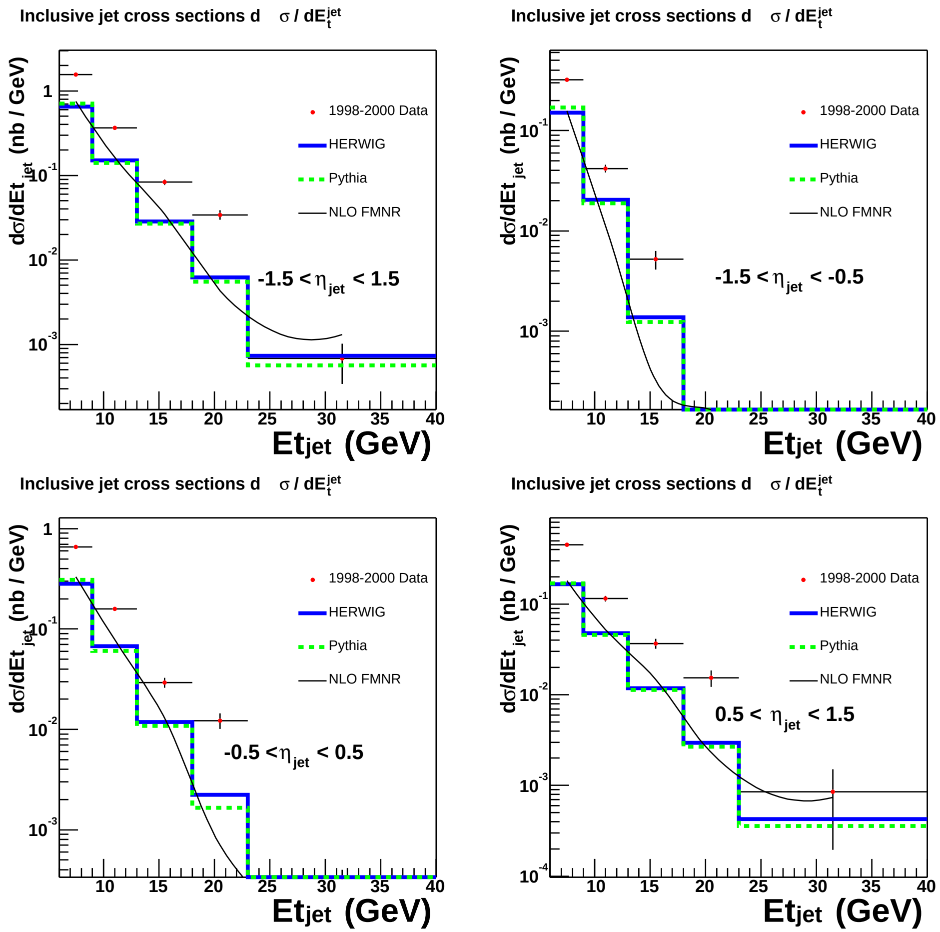
→ D^{*+} & D^{*-} widths are different. This is due to the CTD reconstruction difference of positive and negative tracks at lower P_t.

$D^{*\pm}$ Photoproduction Inclusive jet cross sections $d\sigma/dE_t^{jet}$

- Kinematic region:

  $Q^2 < 1$ GeV^2, $130 < W_{JB} < 280$ GeV,

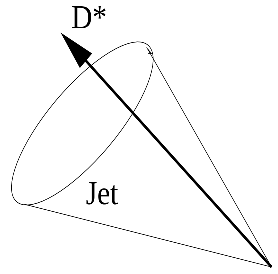
  $P_{T,D^*} > 3.0$ GeV, $|\eta_{D^*}| < 1.5$
- The plot shows all jets within $|\eta_{jet}| < 1.5$ &, $E_t^{jet} > 6$ for the whole η_{jet} range,backwards,central & forward regions.
- These data are compared to LO & NLO. Mass of the charm is fixed to 1.5 GeV,light flavours are massless.
- Poor description by both Herwig(LO), Pythia(LO) & FMNR(NLO)
- Discrepency seems to be large when requiring a jet.



$D^{*\pm}$ and non-$D^{*\pm}$ jet cross sections $d\sigma/dE_t^{jet}$

$D^{*\pm}$ selected by ΔR cut:

$$\Delta R = \sqrt{(\Phi_{jet} - \Phi_{D^*})^2 + (\eta_{jet} - \eta_{D^*})^2}$$



Matched Jets $\Delta R < 0.6$, Measurements have jets & D^* associated according to the Kt algorithm

Kinematic region:

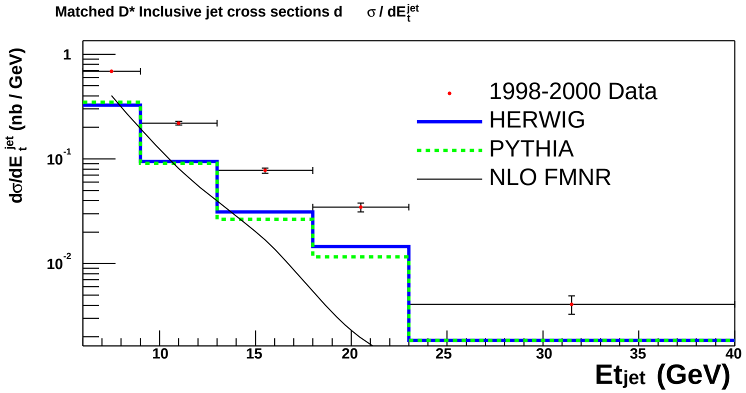
$Q^2 < 1$ GeV^2, 130 $<$ W$_{\mathrm{JB}}$ $<$ 280 GeV,

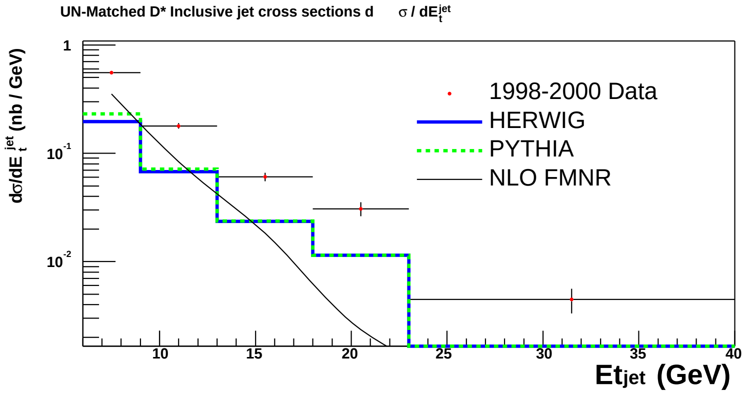
$P_{T,D^*} > 3.0$ GeV, $|\eta_{D^*}| < 1.5$

$|\eta_{jet}| < 2.4$ &,$E_t^{jet} > 6$ GeV

These data are corrected back to true jets clustered with the D^*

Poor description by FMNR(NLO), Herwig(LO) & Pythia(LO), underestimated these data by a factor 2-3, shape is good.





$D^{*\pm}$ Photoproduction Inclusive jet cross sections $d\sigma/d\eta_{jet}$

- Kinematic cuts:

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  $P_{T,D^*} > 3.0$ GeV, $|\eta_{D^*}| < 1.5$, $|\eta_{jet}| < 2.4$

- The top plot shows $d\sigma/d\eta_{jet}$,$E_t^{jet} > 6$GeV

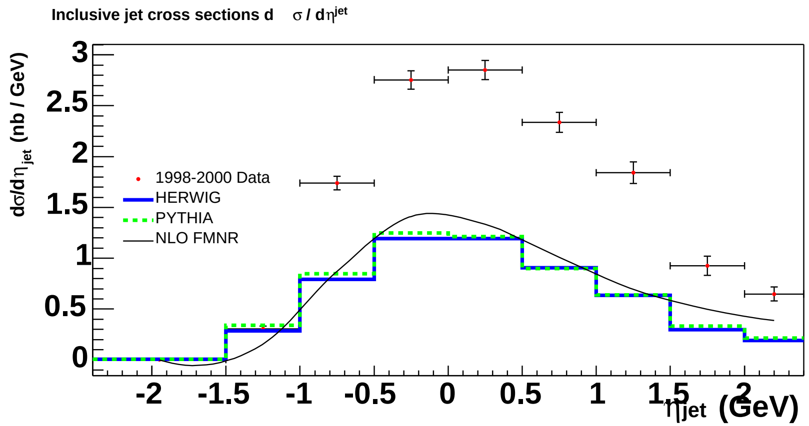
  The bottom plot shows $d\sigma/d\eta_{jet}$, $E_t^{jet} > 8$GeV

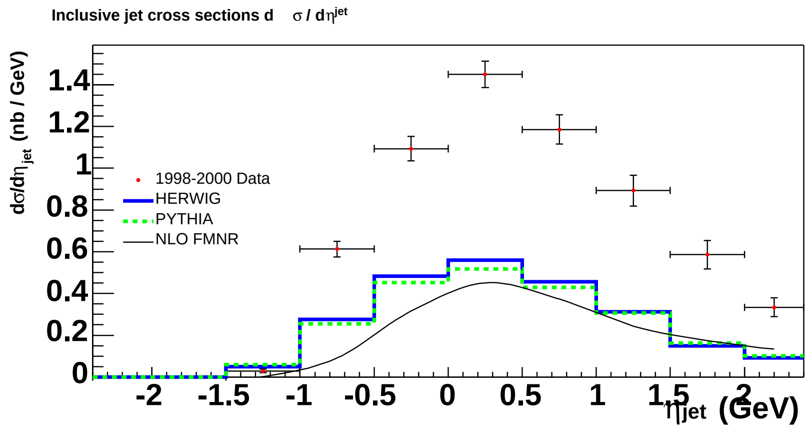
- These data are compared to FMNR NLO.

  Mass of the charm is fixed to 1.5 GeV,light flavours are massless.

- Poor description by FMNR(NLO), Herwig(LO) & Pythia(LO) in all regions of η_{jet}.

  Shape is good but normalisation is wrong.





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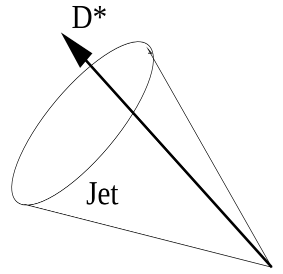

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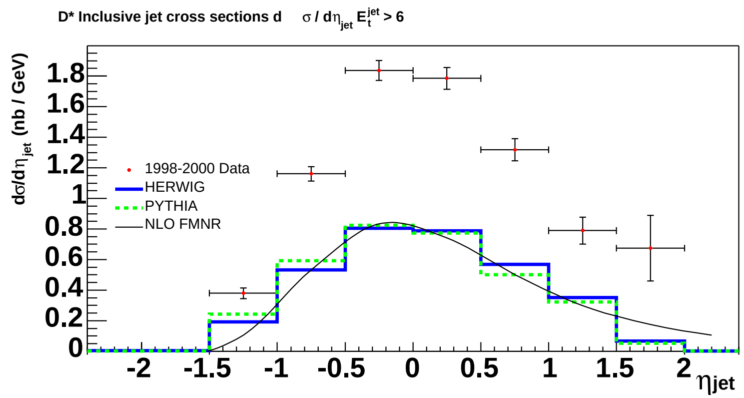

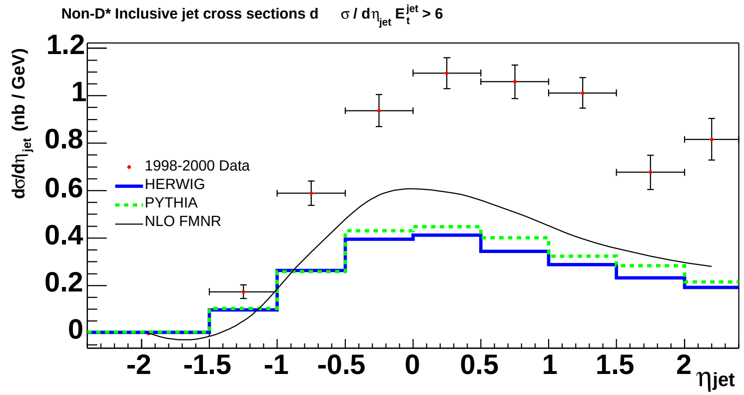

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Possible Extension To The Analysis

Measure 3 jet events to study the effect of the dead cone, $cos(\theta) = \sum_{jet=1}^{n} \frac{\vec{P_{D^*}} \cdot \vec{P_{jet}}}{|P_{D^*}| \cdot |P_{jet}|}$.

Kinematic region:

$Q^2 < 1$ GeV^2, 130 $<$ W$_{JB}$ $<$ 280 GeV,

$P_{T,D^*} > 3.0$ GeV, $|\eta_{D^*}| < 1.5$

$|\eta_{jet}| < 2.4$ &,$E_t^{jet1} > 6$ GeV,

$E_t^{jet2} > 5$ GeV, $E_t^{jet3} > 5$ GeV

The Angular distribution of gluon radiation differs from light quarks and charm quarks.

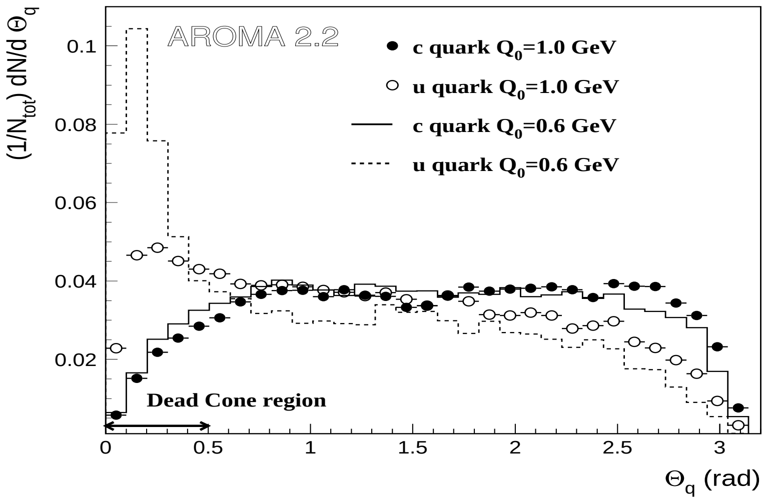
$\rightarrow$ measurment of charm mass.

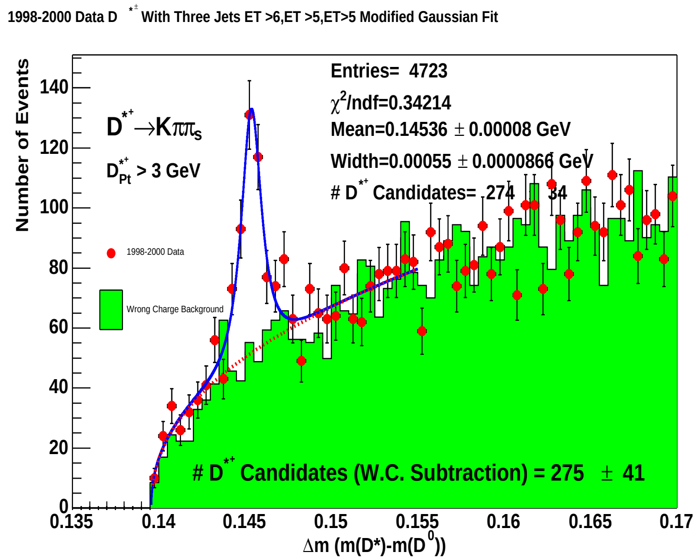
S.V. Chekanov, Phys. Lett. B484(2000) 51-57

Yu.L. Dokshitzer, V.A Khose, S.I. Troyan,

J. Phys. G 17 (1991) 1481, 1602

275 events for 3 jets with charm.





Summary and Outlook

- HERA has produced a wealth of charm jet data in photoproduction
- These data have been analysed & compared to LO & NLO pQCD predictions.

  → There are still big differences between these theories & data.

  → Differences bigger in charm & jets then in inclusive charm production.
- Parton dynamics of charm physics need more understanding at HERA. pQCD is not able to reproduce cross sections in fundamental quantities such as E_t and η, normalisation off shape approximately o.k.
- Work in progress, systematic errors need to be calculated, more Monte Carlo Models to be compared.

  → new theoretical developments, and NNLO calculations needed!
- Experimental precision and coverage of data is now good, & can only get better with HERA II and the use of the MVD.