$Q\bar{Q}$ correlations at HERA: Measurements by H1

O. Behnke (Heidelberg)

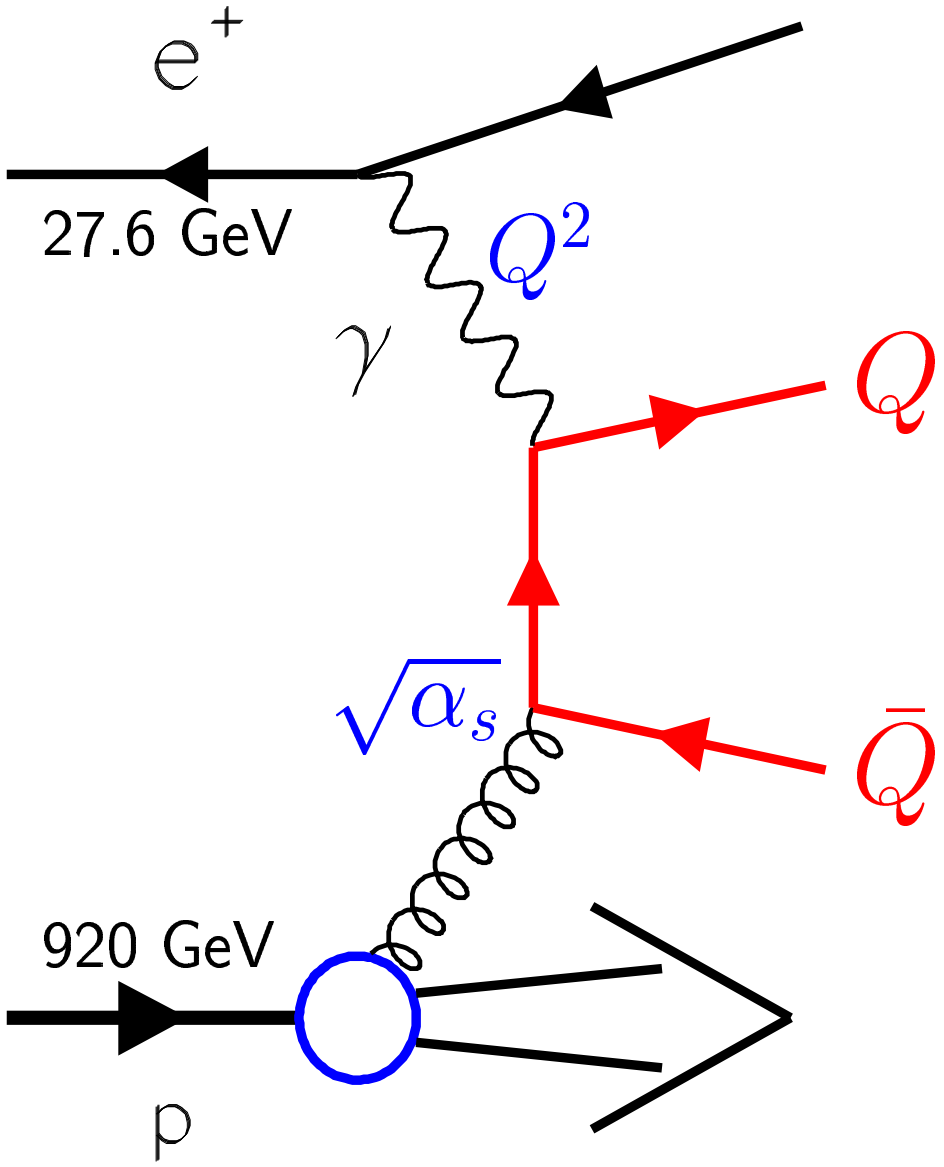
Oct 11, 2004

HERA-LHC workshop

Analysis and result foils provided by Jeannine Wagner, DESY

More information: Conference paper to EPS 2003, Aachen, Abstr. 095

(Double) tagging of heavy flavour at HERA



Q = b,c

Q-Tagging methods:

1. $D^* \to K\pi\pi_s$ (+other dec. modes)
2. Leptons (μ, e)
3. inclusive vertex tagging

Double tagging candidates:

Method	Comment
$D^* \times D^*$	Low statistics
incl. v.t. $\times$ incl. v.t..	under study
$D^* \times \mu$	Prel. results!

$D^*\mu$ analysis

Detection of **both** **heavy quarks** of the BGF by their decay and fragmentation products:

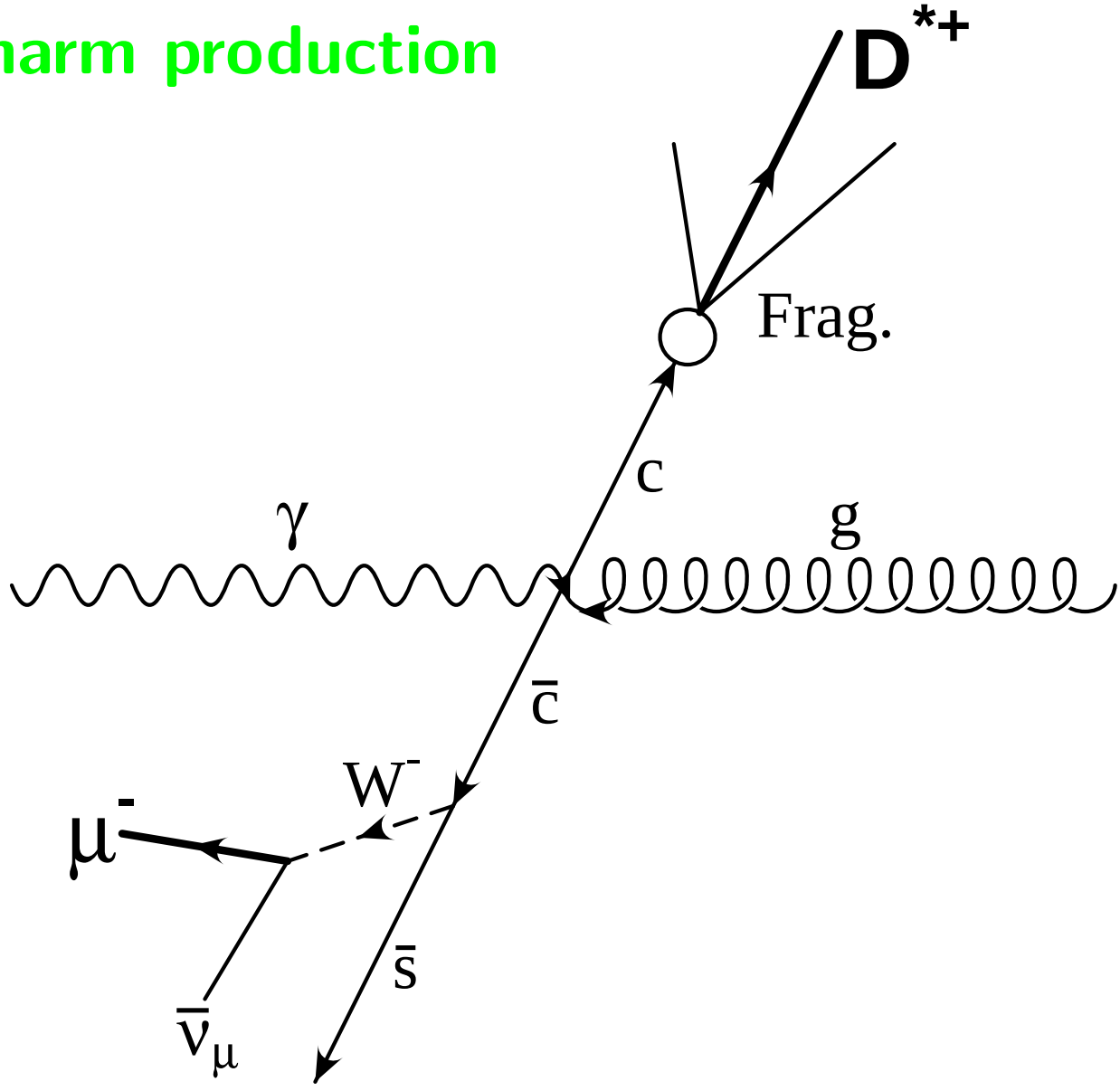
$$Q \longrightarrow D^* \rightarrow D^0\pi_s \rightarrow K\pi\pi_s$$

$$\bar{Q} \longrightarrow \mu$$

- **separation** of charm and beauty possible due to charge and angle correlations of the D^* and the muon
- almost complete reconstruction of the $Q\bar{Q}$ final state
  - ◇ measurement of the gluon density
  - ◇ sensitivity to higher orders

Correlations in the γg-CMS (I)

Charm production

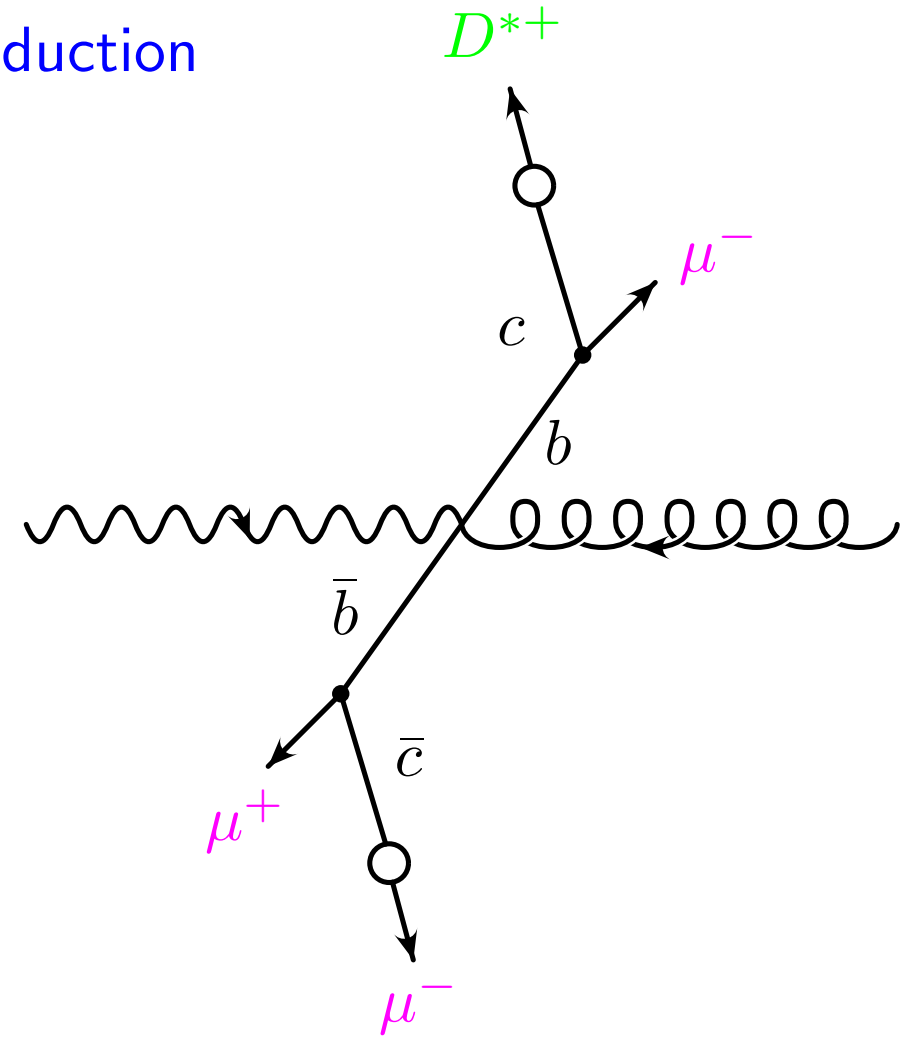


$$\Delta\Phi \approx 180^\circ$$

$$Q(D^*) \neq Q(\mu)$$

Correlations in the γg-CMS (II)

Beauty production



For beauty production three correlations are possible:

- $\mathbf{\Delta\Phi \approx 180^\circ}$ and $\mathbf{Q(D^*) \neq Q(\mu)}$
- $\mathbf{\Delta\Phi \approx 180^\circ}$ and $\mathbf{Q(D^*) = Q(\mu)}$
- $\mathbf{\Delta\Phi \approx 0^\circ}$ and $\mathbf{Q(D^*) \neq Q(\mu)}$

$D^*\mu$-events

H1 data: 97-00 $\mathcal{L} = 91.2$ pb^{-1}

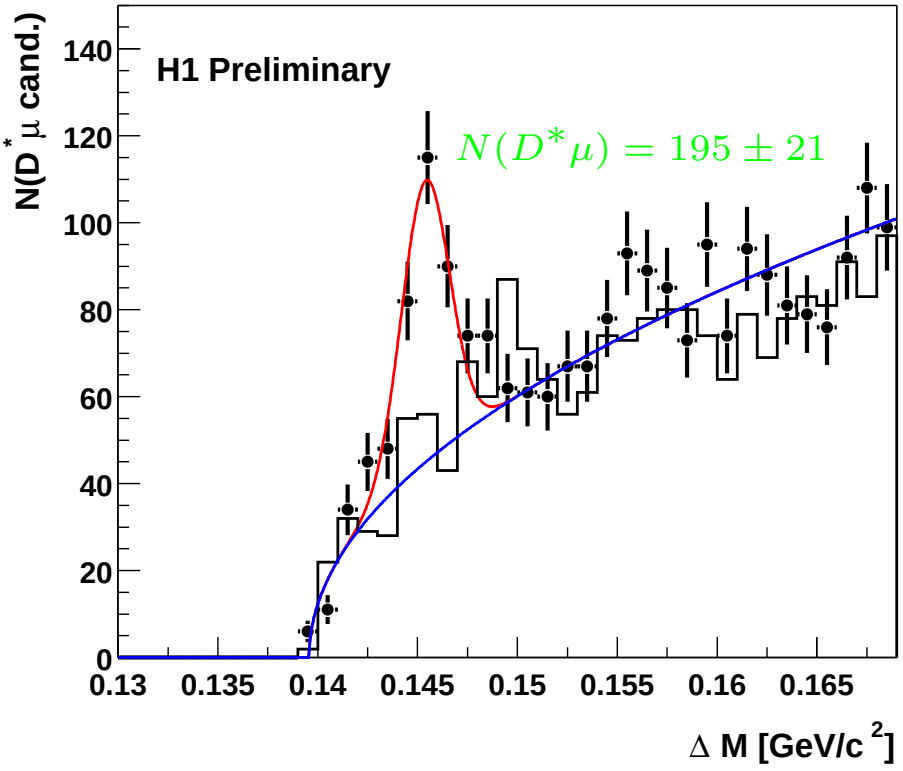
visible range:

- $p_T(D^*) > 1.5$ GeV/c ; $|\eta_{D^*}| < 1.5$
- $p_T(\mu) > 1.0$ GeV/c ; $20^\circ \leq \theta_\mu \leq 160^\circ$
- $0.05 < y < 0.75$; no cut on Q^2

$\Rightarrow$ resolved photon contribution suppressed

Reconstruction of D^{*+}: $D^{*+} \rightarrow D^0\pi_s^+ \rightarrow K^-\pi^+\pi_s^+$

simultaneous fit of right $(K^-\pi^+\pi_s^+)$ and wrong $(K^+\pi^+\pi_s^-)$ charge combinations



Correlation in the lab frame

DIS $\Longrightarrow$ transform into γp system ($\Delta\Phi \rightarrow \Delta\Phi^*$)

Smearing by:

$\star$ perturbative effects (**gluon radiation**)

$\star$ non perturbative effects (**fragmentation**)

$\Longrightarrow$ angle between the D^* and the muon $\Delta\Phi^*$ can differ substantially from 180° or 0° respectively

$\longrightarrow$ distinction only between $\Delta\Phi^* \geq 90^\circ$ and $\Delta\Phi^* \leq 90^\circ$

	$\boldsymbol{\Delta\Phi^* \leq 90^\circ}$	$\boldsymbol{\Delta\Phi^* \geq 90^\circ}$
$Q(\mu) = Q(D^*)$	1 **no charm** **few beauty**	2 **no charm** **beauty**
$Q(\mu) \neq Q(D^*)$	3 **few charm** **beauty**	4 **charm** **beauty**

2 dim. Log-Likelihood-Fit

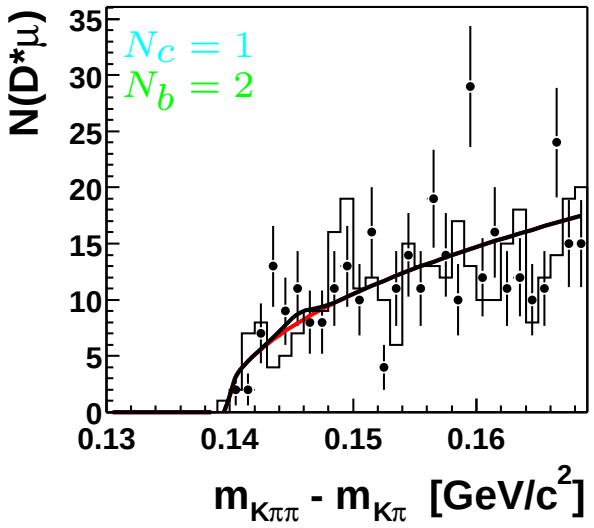
using a 2dim.Log-Likelihood-Fit to separate c and b

★ Quantities: correlation region, ΔM

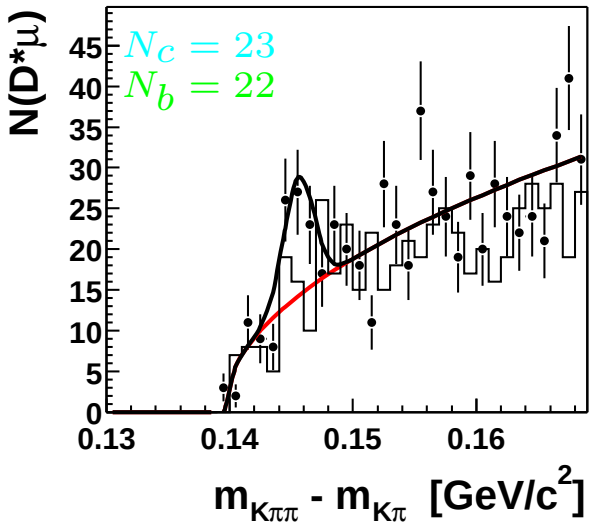
★ simultaneous fit of right and wrong charge combinations

H1 Preliminary

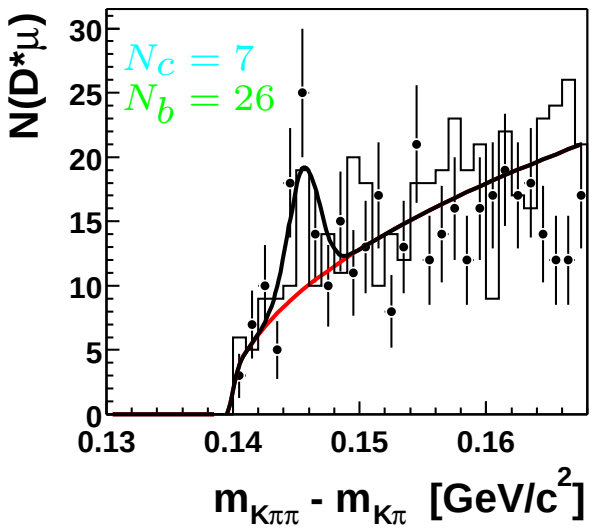
$Q(D^*)=Q(\mu)$, $\Delta\Phi^*<90^\circ$



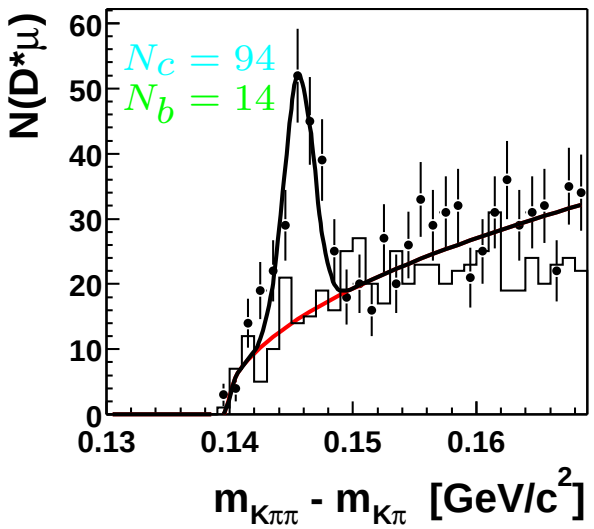
$Q(D^*)=Q(\mu)$, $\Delta\Phi^*>90^\circ$



$Q(D^*)\neq Q(\mu)$, $\Delta\Phi^*<90^\circ$

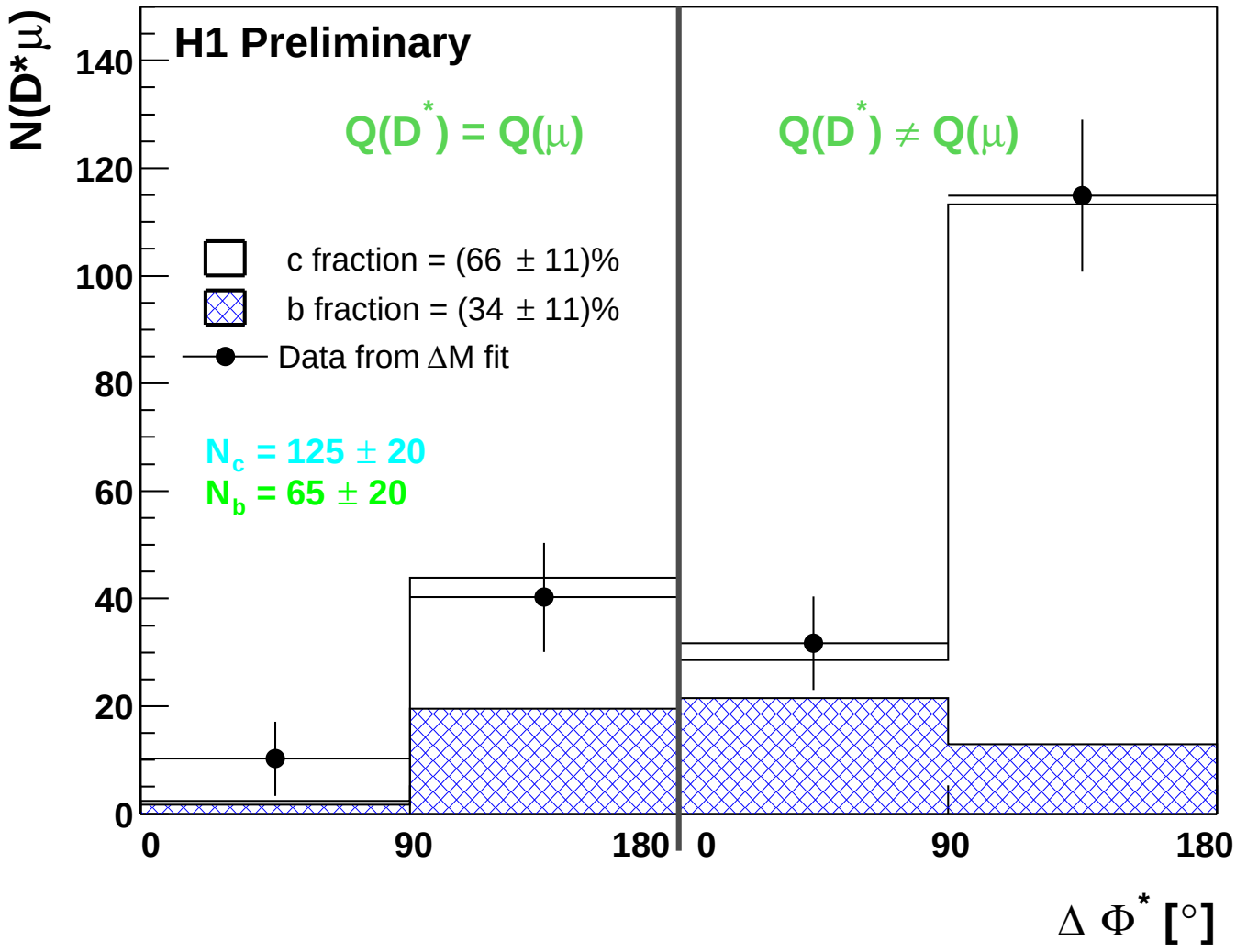


$Q(D^*)\neq Q(\mu)$, $\Delta\Phi^*>90^\circ$



2 dim. Log-Likelihood-Fit

(correlation regions)



Subtract background due to wrongly identified muons (c: $\approx 30\%$, b: $\approx 5\%$):

$N_c = 88 \pm 14 \Longrightarrow$ c contribution: 59%

$N_b = 62 \pm 19 \Longrightarrow$ b contribution: 41%

Total c and b cross sections

Visible range:

$p_T(D^*) > 1.5$ GeV/c ; $|\eta(D^*)| < 1.5$

$p_T(\mu) > 1.0$ GeV/c ; $20^\circ < \theta_\mu < 160^\circ$

$0.05 < y < 0.75$

$$\boldsymbol{\sigma^c_{vis}(ep \to e' D^* \mu X)} = \boldsymbol{(720 \pm 115 \pm 245)} \text{ pb}$$

$$\boldsymbol{\sigma^b_{vis}(ep \to e' D^* \mu X)} = \boldsymbol{(380 \pm 120 \pm 130)} \text{ pb}$$

Comparison with LO direct prediction (AROMA):

	$\sigma^{dir.}_{LO}(ep \to e' D^* \mu X)$ [pb]
charm	≈ 400
beauty	≈ 100

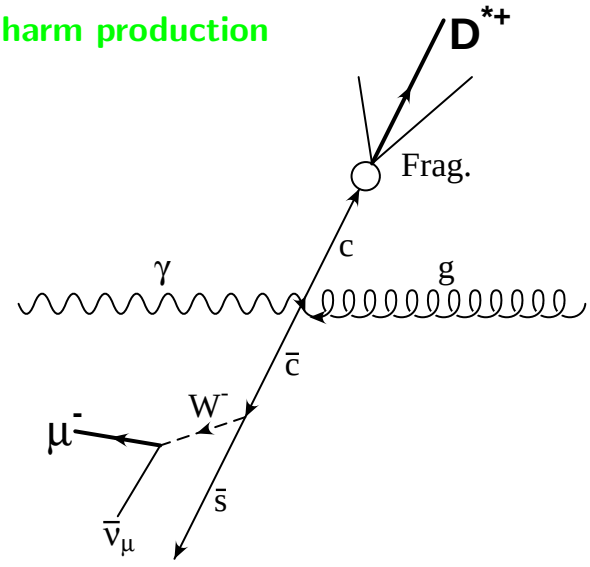
Double tagging with $D^*\mu$ correlations

- $D^*\mu$ quantities are taken as an approximation of $Q\bar{Q}$ quantities
- Characteristic quantities:

  $p_T(D^*\mu)$: transverse momentum of $D^*\mu$ pair
  $M(D^*\mu)$: invariant mass of $D^*\mu$ pair
  $\hat{y}(D^*\mu)$: rapidity of $D^*\mu$ pair
  $\Delta\Phi$: azimuthal angle difference of the D^* and the μ

Leading order (LO):

- $p_T(Q\bar{Q}) \approx 0$
- $\Delta\Phi \approx 180°$



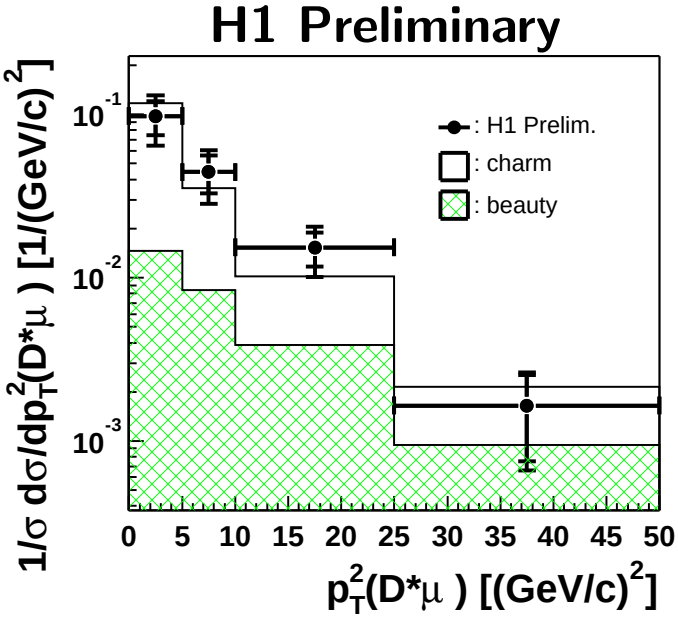
LO modified: Smearing

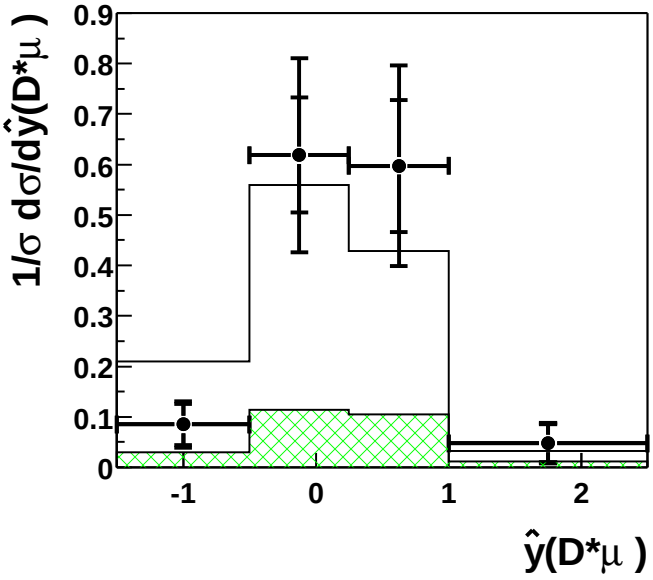
- parton shower (PS)
- fragmentation
- non-zero k_T of initial partons

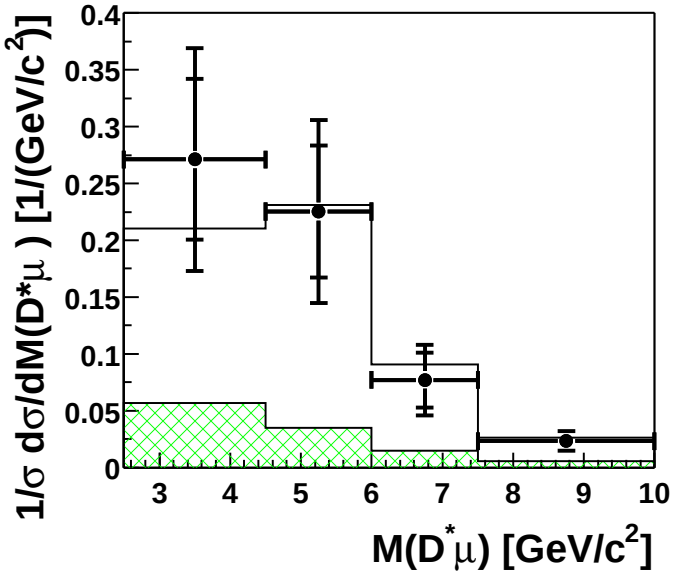
$p_T(Q\bar{Q})$,$\Delta\Phi$ and $\hat{y}(Q\bar{Q})$ used to study non pert. effects.

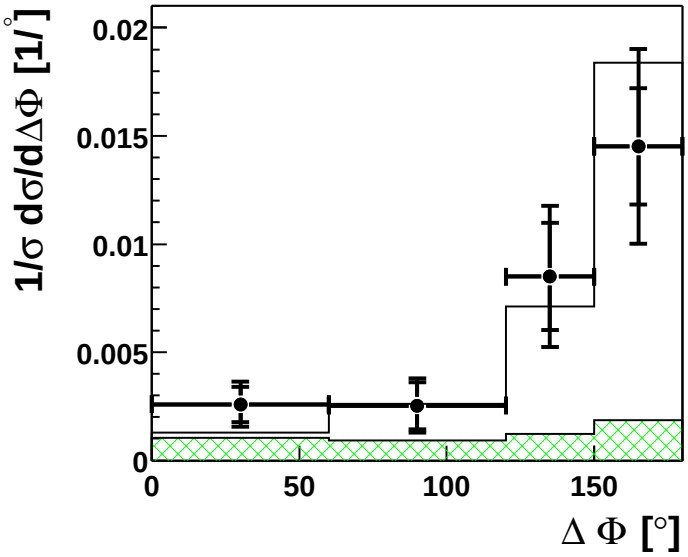
$M(Q\bar{Q})$ and $\hat{y}(Q\bar{Q})$: needed to determine the gluon density

Normalized differential cross sections









⇒ LO + PS prediction describes the shape of the data.

Conclusions

◇ First **double tagging** measurement at HERA:

$$Q \longrightarrow D^* \rightarrow D^0\pi_s \rightarrow K\pi\pi_s$$

$$\bar{Q} \longrightarrow \mu$$

◇ **separation** of charm and beauty with the aid of charge and angle correlations

◇ charm and beauty **cross sections** are compatible with previous results

◇ LO+PS model describes the **shape** of the $D^*\mu$ variables