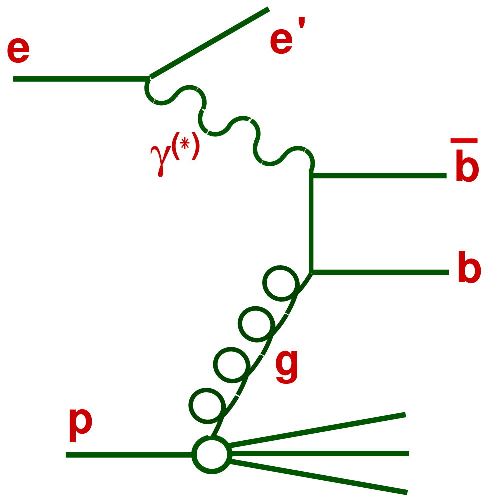
H1 Measurements of Open b Production

Paul Newman
Birmingham University, H1 Collaboration.

- Introduction
- A Measurement using Jets containing Muons
- A Measurement using Like-sign Muons
- Conclusions and Outlook

Production Rate Predictions

Open b production at HERA is believed to be dominated by the boson-gluon fusion process $\gamma^{(*)} g \to b\bar{b}$



Overall HERA cross sections are expected to be small:

$$\sigma(uds) : \sigma(c) : \sigma(b) \sim 2000 : 200 : 1$$

NLO Predictions vary with assumptions on m_b and proton parton distributions:

Ellis & Nason (1989)	$\sigma(ep \to b\bar{b}X) \sim 4.9 \ldots 7.1$ nb
Smith & van Neerven (1991)	$\sigma(ep \to b\bar{b}X) \sim 6.1 \ldots 8.8$ nb
Frixione et al. (1994)	$\sigma(ep \to b\bar{b}X) \sim 4.7 \ldots 10.0$ nb

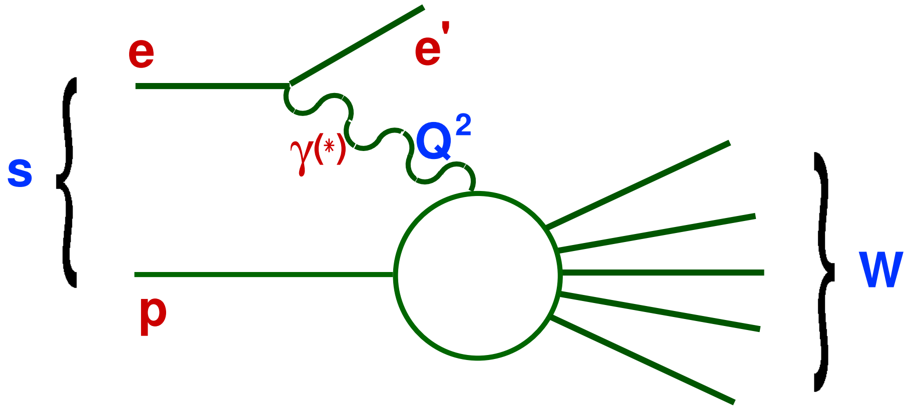
LO Predictions implemented in AROMA 2.2 Monte Carlo:

($m_b = 4.75$ GeV, MRS[G]) $\quad \sigma(ep \to b\bar{b}X) = 3.8$ nb

NLO corrections roughly at the level of a factor of 2

Data Samples and Kinematic Reconstruction

Data from 1995-1996 are used. $\mathcal{L} = 8.3\ \mathrm{pb}^{-1}$



$\sqrt{s} = 300$ GeV

To maximise statistics, make use of data in which final state electron is not observed in main calorimeters ($\theta > 177.8°$) ...
$Q^2 < 1\ \mathrm{GeV}^2$ (dominated by photoproduction $Q^2 \sim 0$)

$y \sim W^2/s$ is reconstructed using the Jacquet-Blondel method ...
$y_{\mathrm{JB}} = \frac{(E - p_z)_{\mathrm{hadrons}}}{2E_e}$

Method 1

Study events with jets containing muons; $(b \to \mu\nu_\mu X)$

Require 2 jets:

Cone algorithm with R = 1

$p_t^{\mathrm{jet}} > 6$ GeV

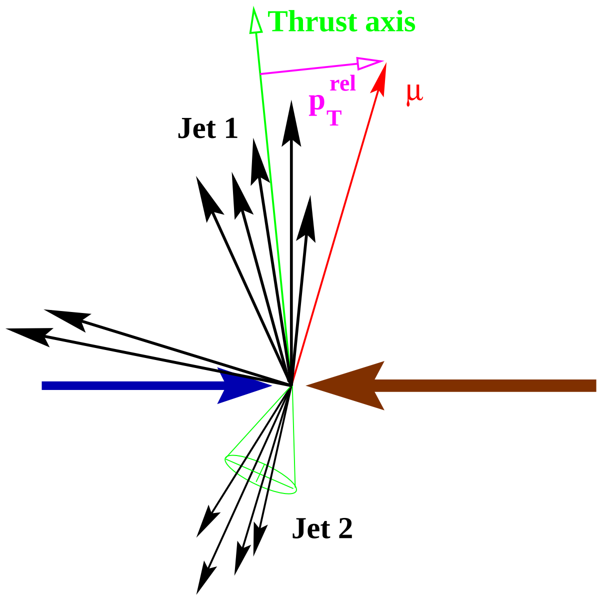
$|\eta_{\mathrm{lab}}^{\mathrm{jet}}| < 2.5$

Require ≥ 1 muon:

Inside one of the jet cones

$p_t^{\mu} > 2$ GeV

$35^\circ < \theta^\mu < 130^\circ$



This selection reduces expected $b : c$ ratio to $1 : 2$.

Define $p_t^{\mathrm{rel}} = p_t$ of μ relative to thrust axis of jet.

$$\ldots \text{Thrust axis maximises } T = \frac{\sum_{i \neq \mu} |p_i^{\mathrm{L}}|}{\sum_{i \neq \mu} |p_i|}$$

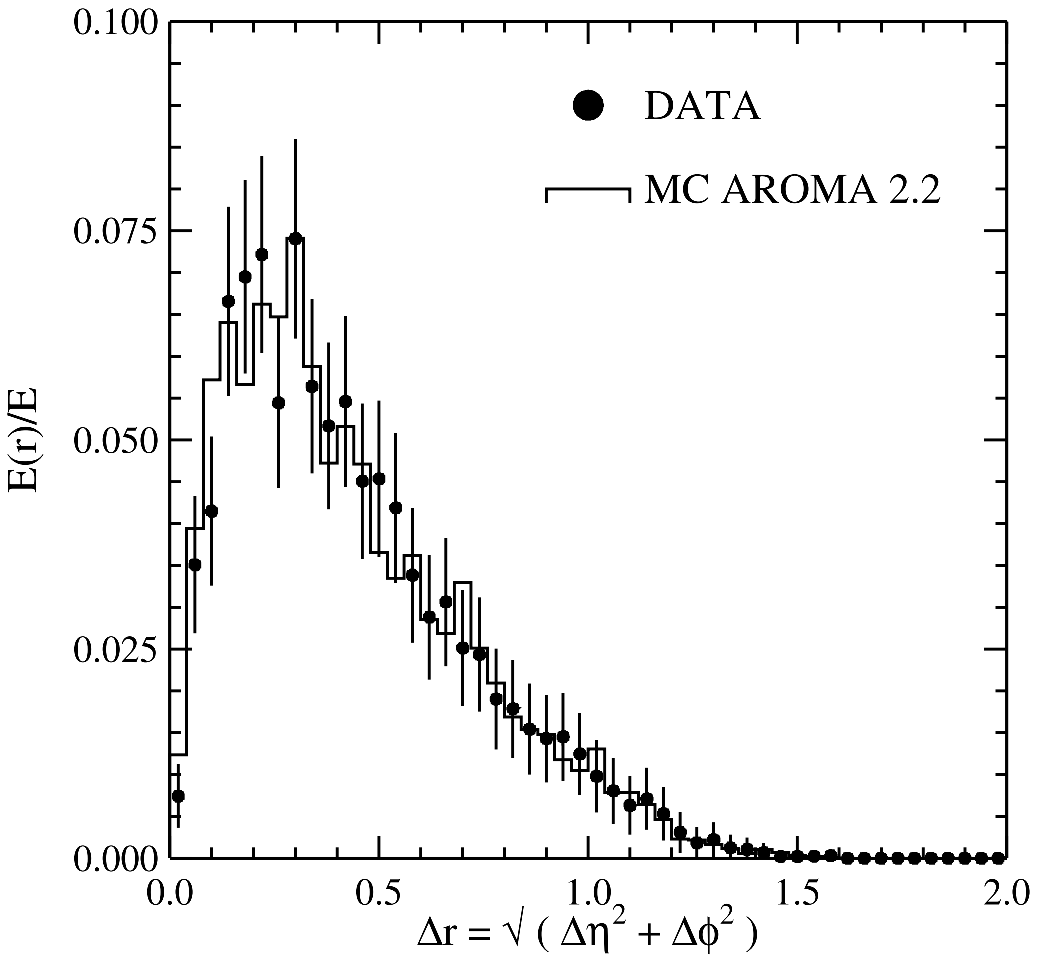
Resulting sample contains contributions from ...

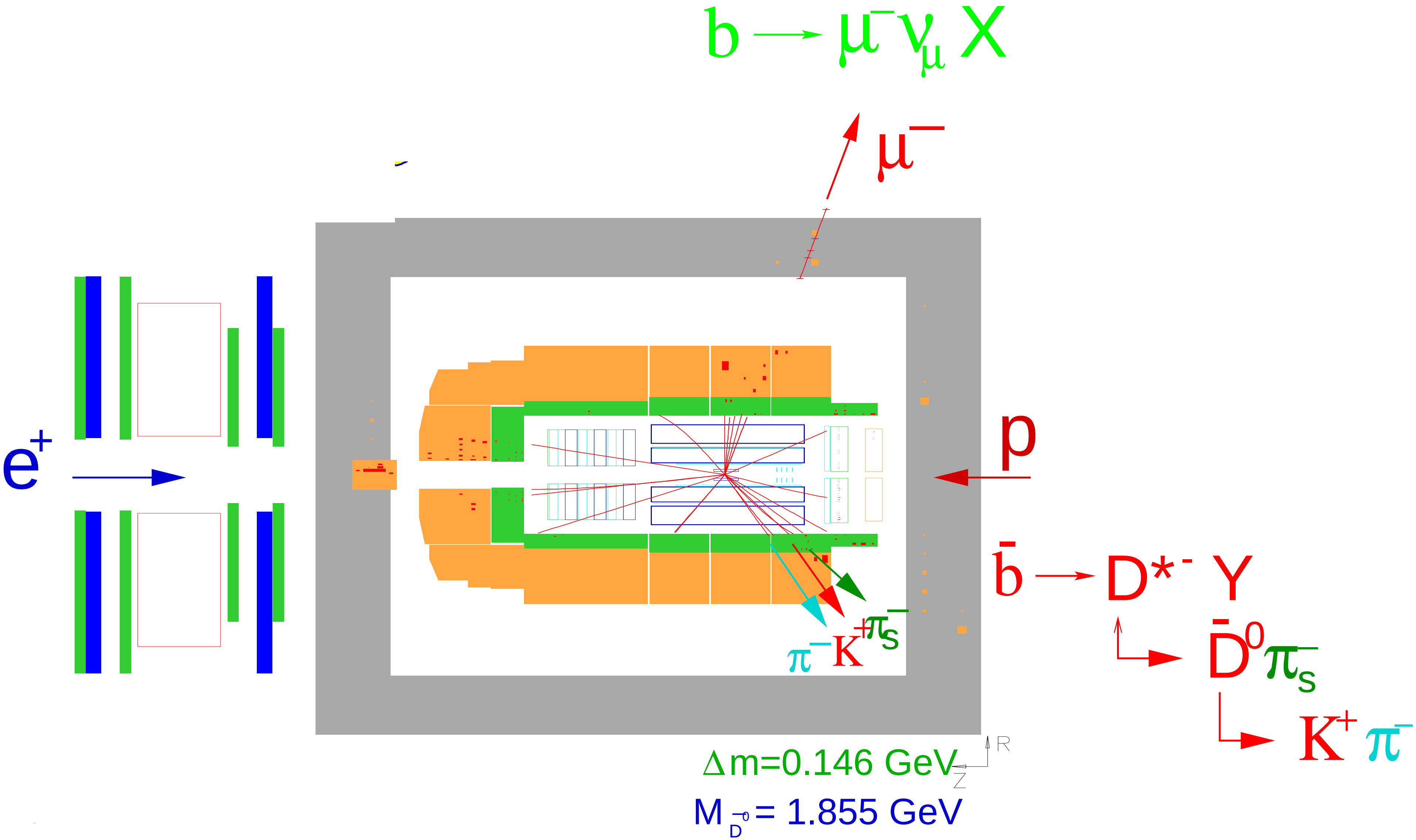
- $b \to \mu\nu_\mu X$; $b \to c \to \mu\nu_\mu X$
- $c \to \mu\nu_\mu X$
- Normal dijet events with hadron misidentified as muon.

Check of Simulated Energy Flow inside Jet

A data sample is selected containing at least one D^* candidate and at least one jet.
Energy flow inside the jet is compared to a MC model of D^* production.

Fractional energy flow within jets

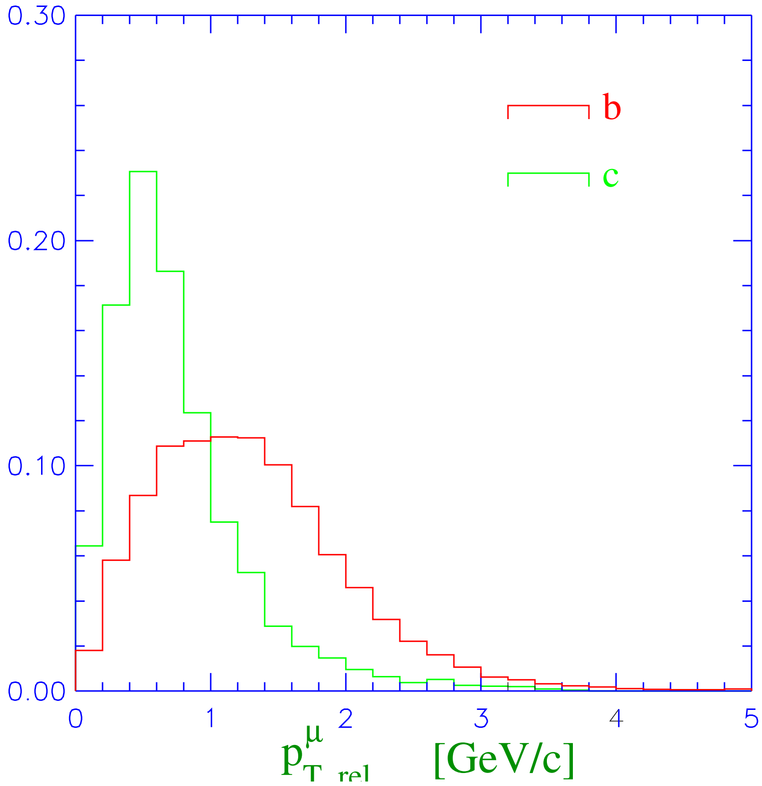




$b \rightarrow \mu^- \nu_\mu X$
μ^-
e^+
p
$\bar{b} \rightarrow D^{*-} Y$
$\bar{D}^0 \pi_s^-$
$K^+ \pi^-$
$\pi^- K^+ \pi_s^-$
Δm=0.146 GeV
$M_{\bar{D}^0}$ = 1.855 GeV
R
Z

Discrimination between Charm and Bottom

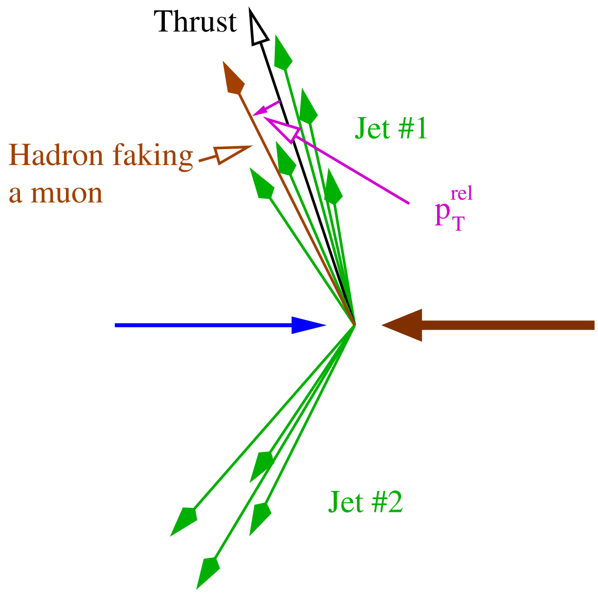
AROMA MC model: Larger mass of b yields harder p_t^{rel} distribution.



But what about backgrounds?

Background from Hadrons Faking Muons

Probabilities $\mathcal{P}_h^\mu(p,\theta)$ that $h = \pi$, K, p give fake signals in μ detectors are obtained from large samples of simulated particles, after checking that the detector simulation describes the data very well.



Obtain . . .

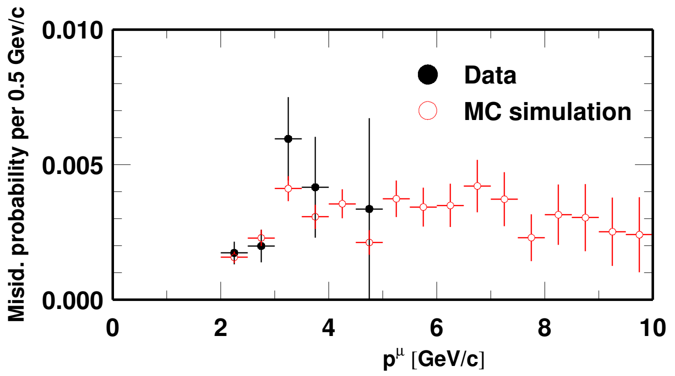
$$\mathcal{P}_\pi^\mu(p,\theta) < 6.0 \times 10^{-3}$$
$$\mathcal{P}_K^\mu(p,\theta) < 2.0 \times 10^{-2}$$
$$\mathcal{P}_p^\mu(p,\theta) < 2.0 \times 10^{-3}$$

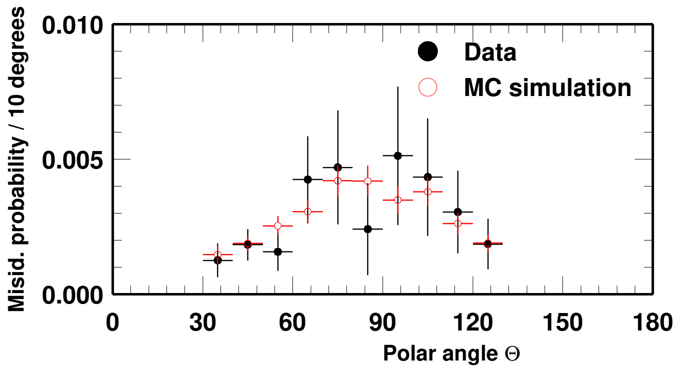
. . . for all p, θ.

Use JETSET to model $\pi : K : p$ ratios in data.

Probabilities $\mathcal{P}_h^\mu(p,\theta)$ are then used to estimate background directly from data.

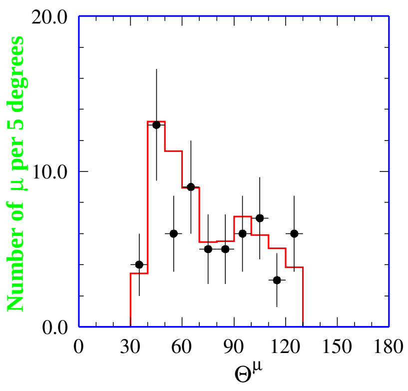
Checks of $\mathcal{P}_h^\mu(p,\theta)$ in the Data

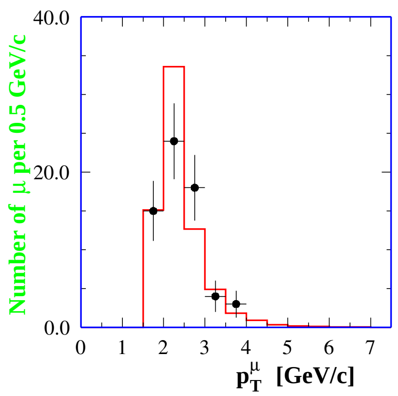




Clean $\pi^\pm$ sample obtained by selecting $K_s^0 \to \pi^+\pi^-$ decays.

$\mathcal{P}_\pi^\mu(p,\theta)$ extracted directly from data well described by simulation used for actual measurment.





● Fake μ from K_s^0 decay found in data (64).

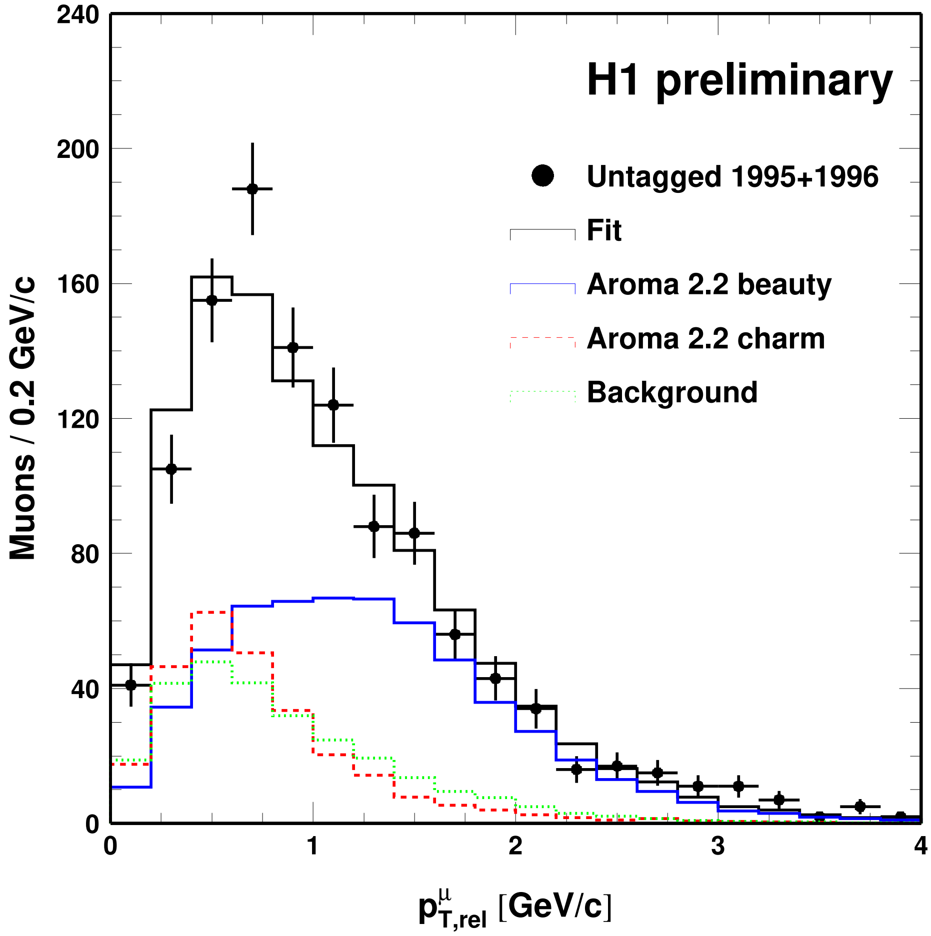
— Fake μ from all K_s^0 decays $\otimes$ $\mathcal{P}_\pi^\mu(p,\theta)$ (69.8)

Similar test performed for $\phi \to K^+K^-$ decays.
6.0 fake μ observed. Prediction using $\mathcal{P}_K^\mu(p,\theta)$ is 7.2.

Fit to p_t^{rel} Distribution in Data

Contribution from hadrons faking muons fixed to that extracted from data.

Fit p_t^{rel} distribution to unfold b, c contributions, assuming shapes as predicted by AROMA.

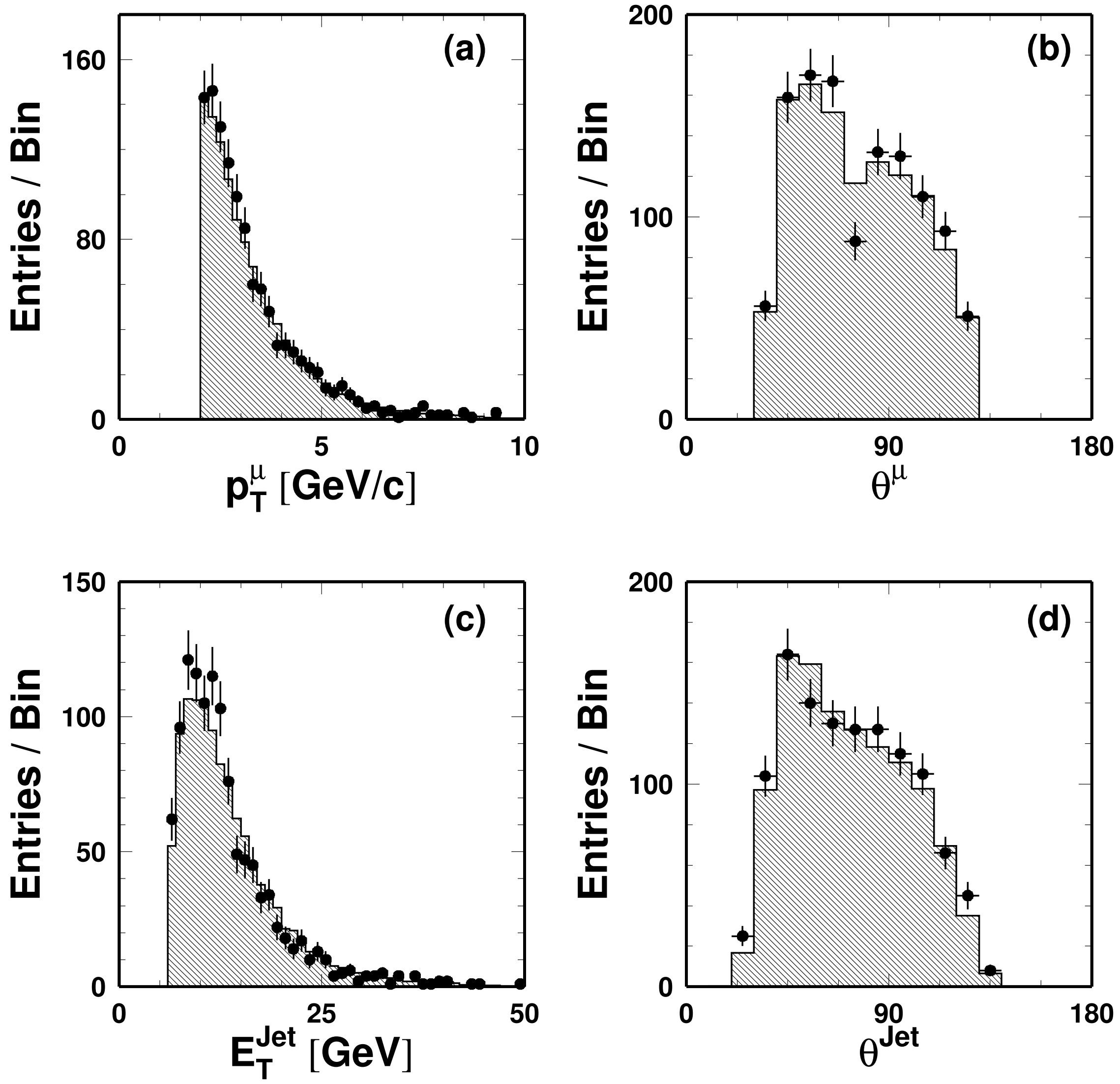


Bottom:	51.4 ± 4.4 %
Charm:	23.5 ± 4.3 %
Background:	23.5 %

Control Distributions

$\mu+$ jets sample compared to sum of background estimate and MC model of b and c contributions.

Ratio of $b:c$ fixed to results of fits to $p_t^{\rm rel}$ distribution.



Extraction of b Production Cross Section

b, c contributions from $p_t^{\rm rel}$ distribution are used to extract total cross sections for the visible region ...

$Q^2 < 1\ {\rm GeV}^2$	$0.1 < y_{\rm JB} < 0.8$
$p^{\mu}_{t({\rm lab})} > 2.0\ {\rm GeV}$	$35^\circ < \theta^\mu < 130^\circ$

Extracted result for $\sigma^{\rm vis}(ep \to c\bar{c}X)$ is consistent with that extracted directly from D^* measurements
[H1, Nucl. Phys. **B472** (1996) 32.]

H1 Preliminary b Cross Section

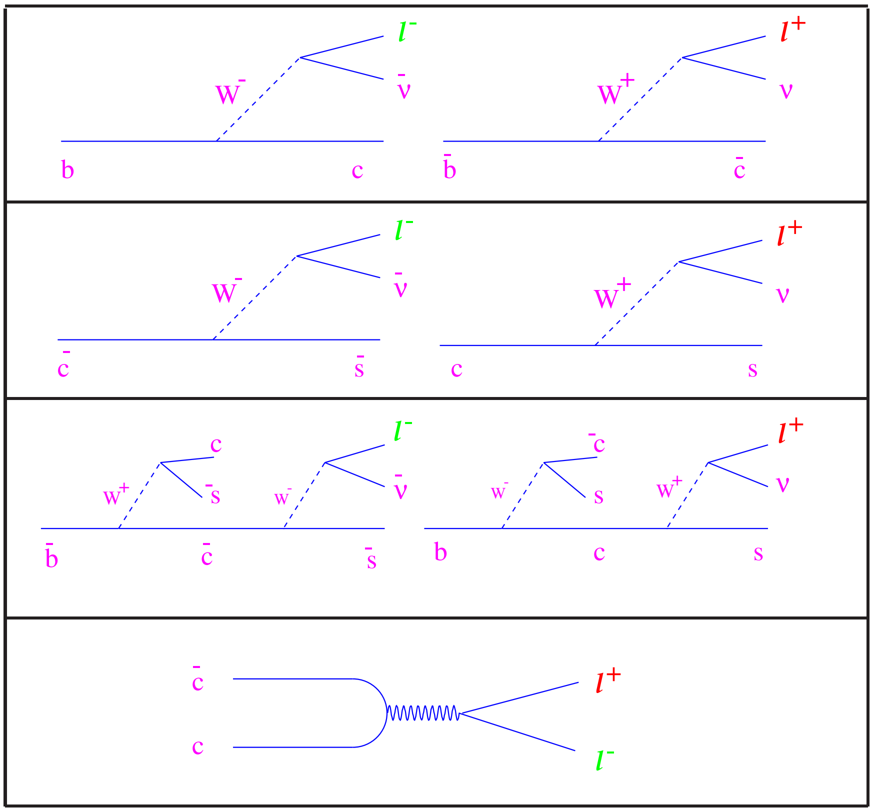
$$\sigma^{\rm vis}(ep \to b\bar{b}X) = 0.93 \pm 0.08\ ({\rm stat.})\ {}^{+0.21}_{-0.12}\ ({\rm syst.})\ {\rm nb}$$

AROMA 2.2 LO Prediction (MRSG, $m_b = 4.75$ GeV ...)

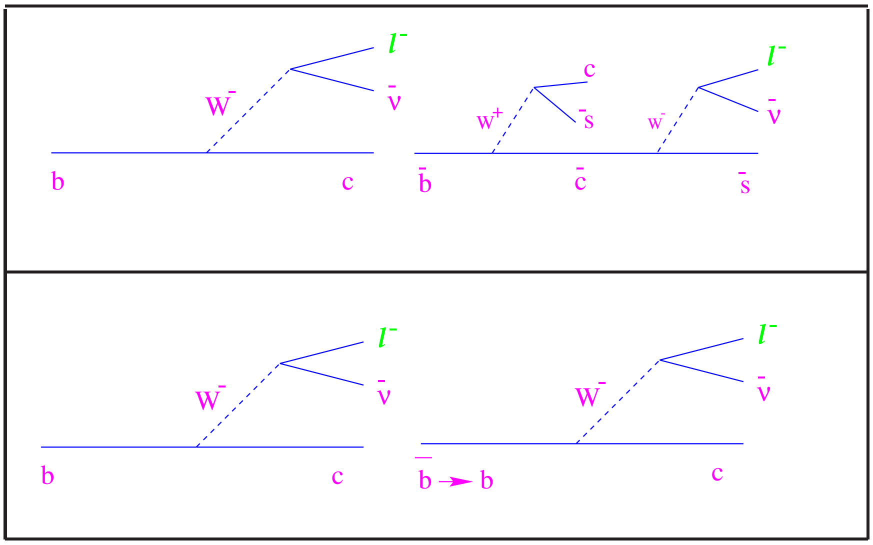
$$\sigma^{\rm vis}(ep \to b\bar{b}X) = 0.19\ {\rm nb}$$

Method 2

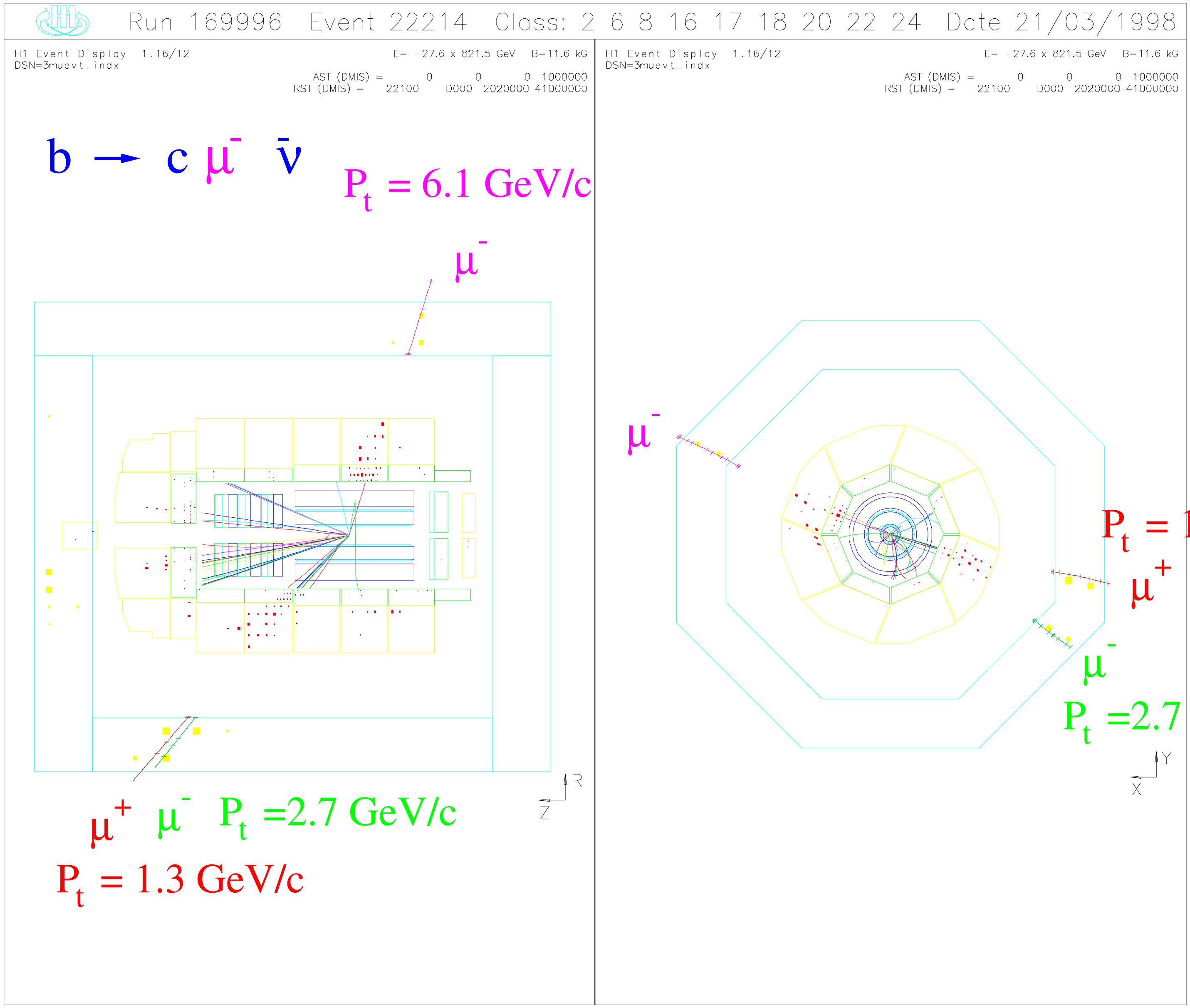
Study events with like-sign muon pairs



There are many ways to produce unlike-sign muon pairs in heavy flavour phyics at HERA



At low orders of QCD unlike-sign muon pairs are produced only in $b\bar{b}$ events.



$\bar{b} \rightarrow \bar{c}\,\mu^+\,\nu$

$\quad\hookrightarrow \bar{s}\,\mu^-\,\bar{\nu}$

$\bar{b} \leftrightarrow b \rightarrow c\,\mu^-\,\bar{\nu}$

$\quad\hookrightarrow s\,\mu^+\,\nu$

Dimuon Measurement

Events are Selected with two like-sign μ in the region ...

$$p_t^\mu > 2.0 \text{ GeV} \qquad\qquad 35^\circ < \theta^\mu < 130^\circ$$

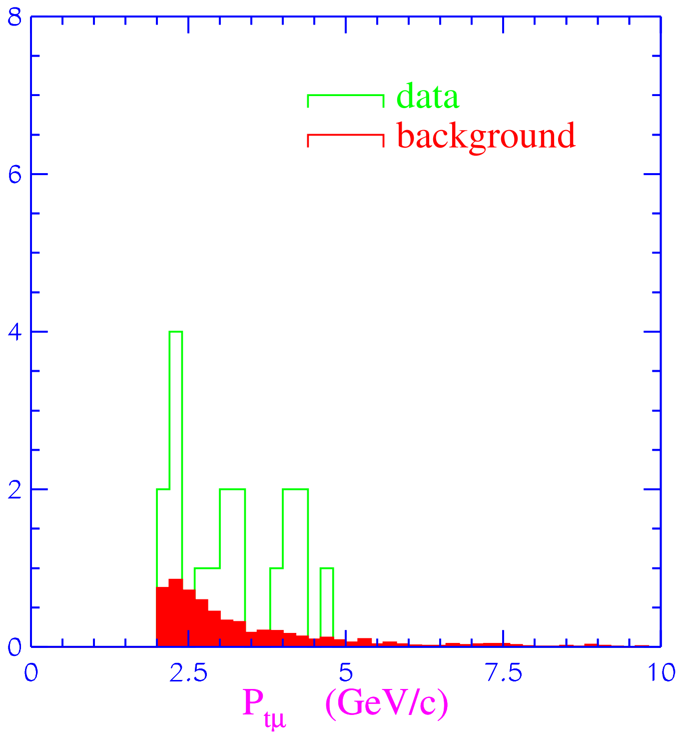
Principle background to b production in the like-sign μ sample again arises from hadrons misidentified as muons. The probabilities $\mathcal{P}_h^\mu(p, \theta)$ are used to estimate this background.

$$\begin{aligned} N_{\text{like}} &= N_{b\bar{b}} + N_{bf} + N_{cf} + N_{ff} \\ &= N_{b\bar{b}} + (N_b + N_c + N_f) \otimes N_f \\ &= N_{b\bar{b}} + \text{all single } \mu \text{ evts} \otimes \mathcal{P}_h^\mu(p, \theta) \end{aligned}$$

Dilepton Data

9 like-sign μ events are observed.

3.0 ± 0.2 background events are expected from fake muons.



Correcting to . . .

$Q^2 < 1\ \mathrm{GeV}^2$ $\qquad$ $0.1 < y_{\mathrm{JB}} < 0.9$

$p^{\mu}_{t(\mathrm{lab})} > 2.0\ \mathrm{GeV}$ $\qquad$ $35^\circ < \theta^\mu < 130^\circ$

H1 Preliminary b Cross Section

$$\sigma^{\mathrm{vis}}(ep \rightarrow b\bar{b}X) = 55 \pm 30\ (\mathrm{stat.})\ \pm 7\ (\mathrm{syst.})\ \mathrm{pb}$$

AROMA 2.2 LO Prediction (MRSG, $m_b = 4.75$ GeV . . .)

$$\sigma^{\mathrm{vis}}(ep \rightarrow b\bar{b}X) = 17\ \mathrm{nb}$$

Summary

- Open b Production observed in two different H1 Measurements.
- Measured cross sections approximately a factor of 5 larger than LO predictions.
- NLO Corrections are Expected to Increase Predictions by Approximately a factor of 2.

Outlook

- Good Prospects for More Precise Measurements in the Future.
- Several times more statistics are available for analysis from 1997 data and beyond.
- Silicon Vertex Detectors can be used.
- HERA Luminosity Upgrade will increase Statistics Further from 2001.