First Observation of Open b Production at HERA

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Representing the H1 Collaboration

- **Introduction**
- **Measuring open b cross section**
  - Method I: 2-jet, 1μ $(p^{\mu}_{T,rel})$
  - Method II: like-sign dileptons
- **Conclusions, Outlook**

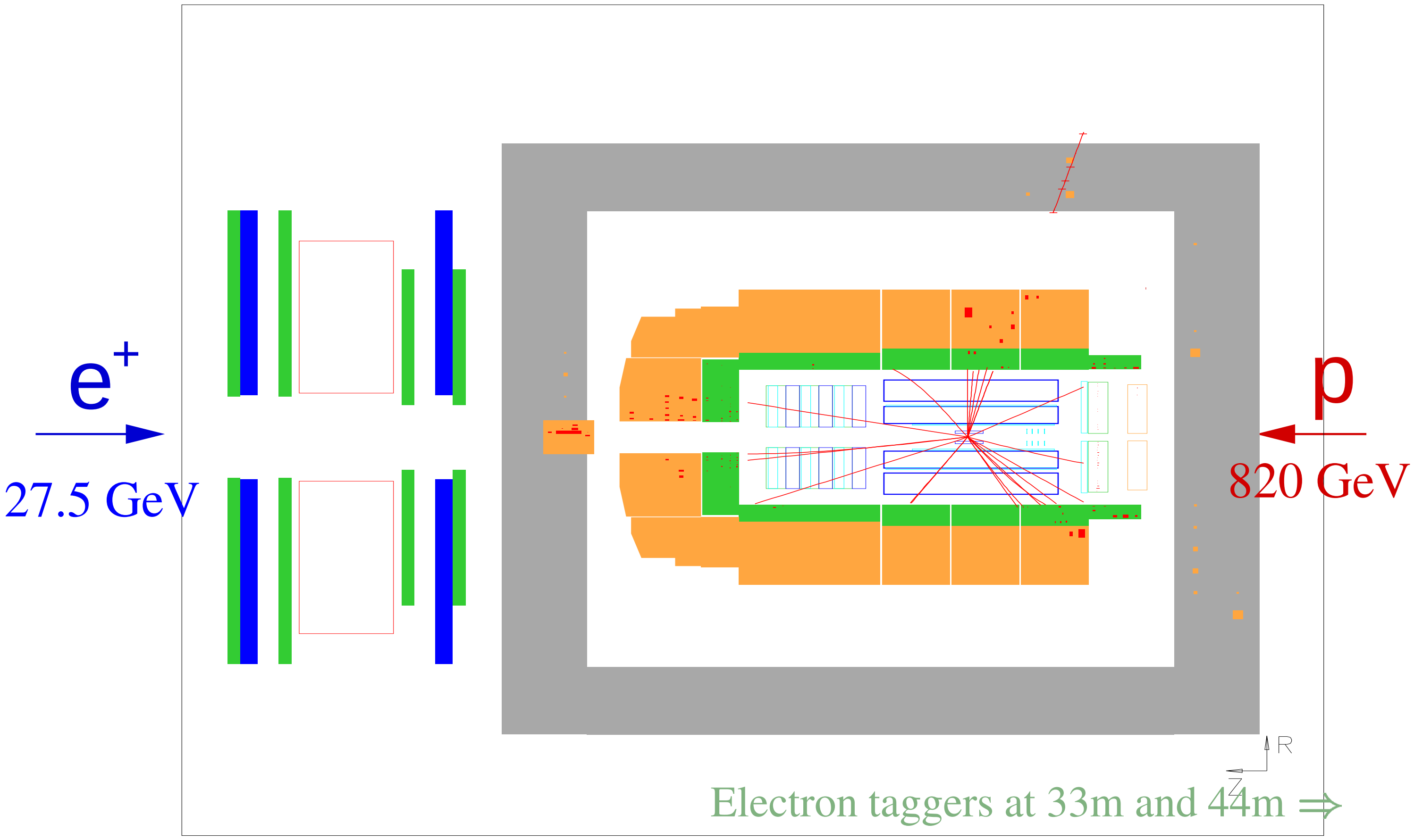
III International Conference

Hyperons, Charm and Beauty Hadrons

Genova, June 30 – July 3, 1998

Introduction

$\mathbf{27.5}\ \boldsymbol{GeV}\ \boldsymbol{e^{\pm}} \longrightarrow \sqrt{s} = \mathbf{300}\boldsymbol{GeV} \longleftarrow \boldsymbol{p}\ \mathbf{820}\ \boldsymbol{GeV}$



Electron beam ⇒ source of quasi-real photons
HERA ⇒ electron-proton and photon-proton collider !

Beauty Production at HERA

- b production cross section is predicted to be low:

Ellis and Nason	(1989)	$\mathbf{4.9 \ldots 7.1}$	nb
Smith and van Neerven	(1991)	$\mathbf{6.1 \ldots 8.8}$	nb
Frixione, *et al.*	(1994)	$\mathbf{4.7 \ldots 10.0}$	nb
LO-MC Aroma 2.2	(1996)	$\mathbf{3.8}$	nb

- Small signal-to-background ratio:

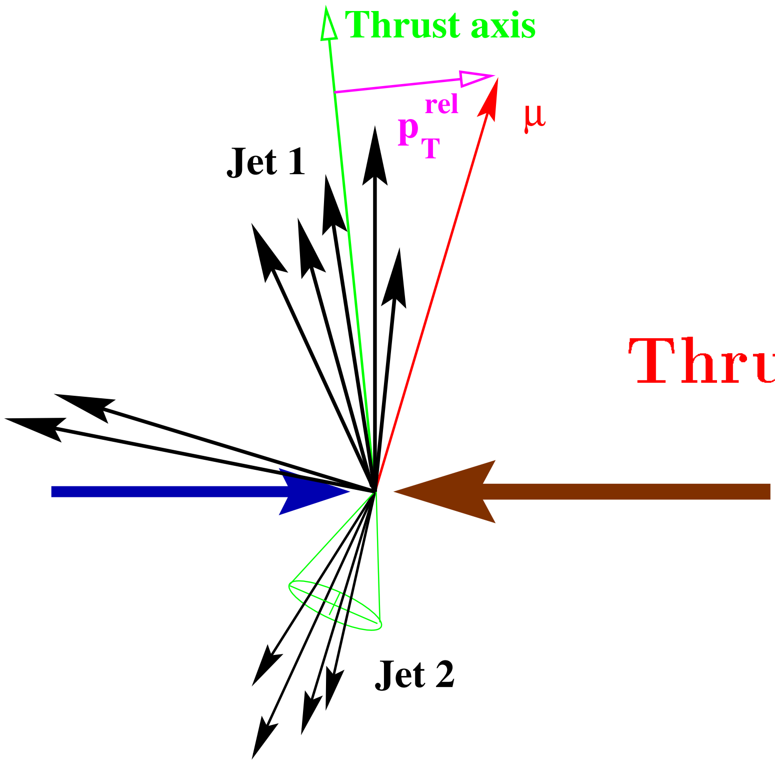
$$\boxed{\sigma_{uds} : \sigma_{charm} : \sigma_{beauty} \sim 2000 : 200 : 1}$$

Method I

$$\mathcal{L} = 8.3\ pb^{-1}$$

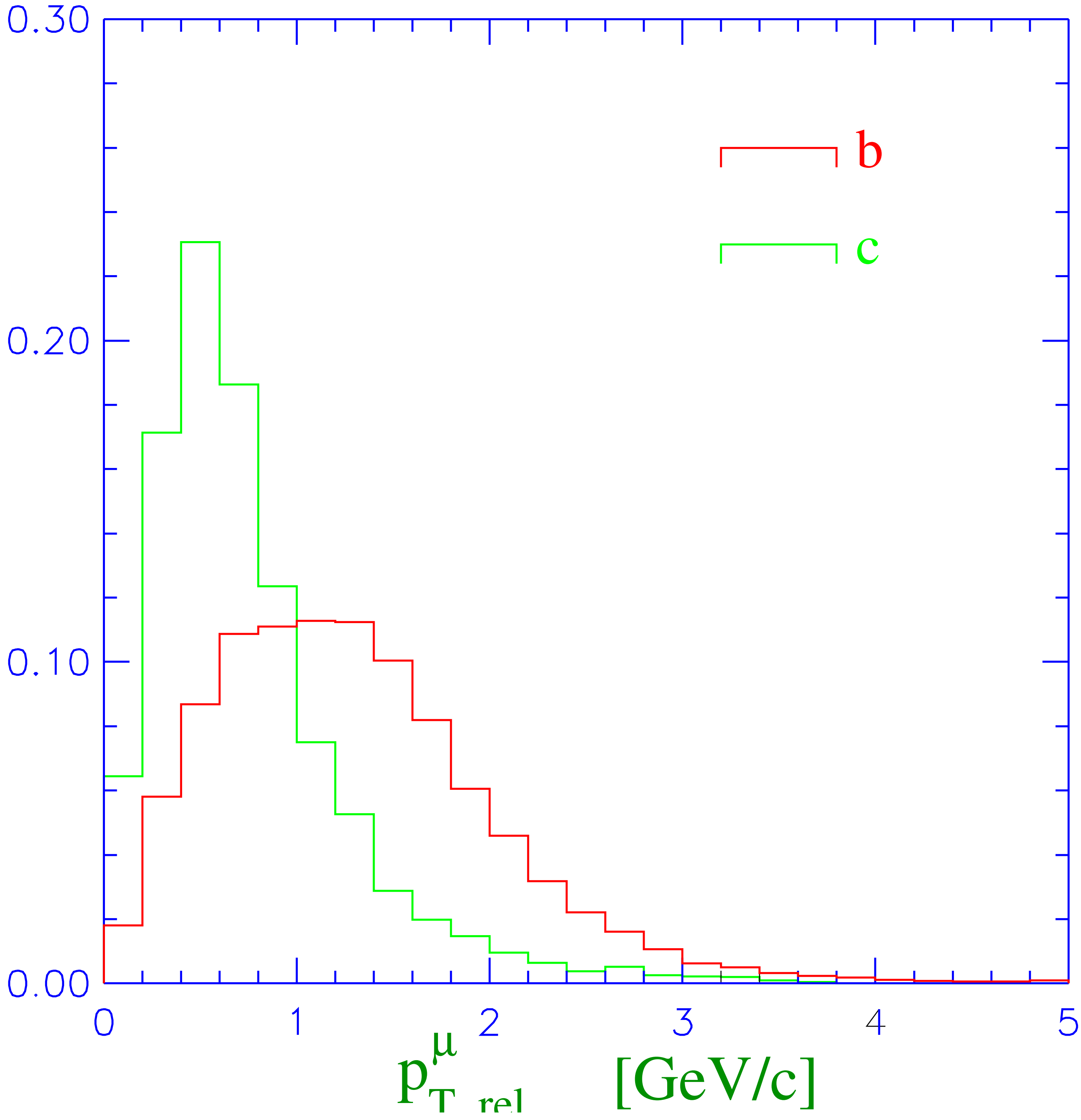
2 Jets	cone algorithm, $R = 1$
	$\|\eta\| < 2.5$
	$E_T > 6$ GeV
1 μ	$p_T^{\mu} > 2\ GeV/c$
	$35^o < \theta^{\mu} < 130^o$

- Disentangle b- and c-quarks contributions using the muon transverse momentum relative to the jet axis $p_{T,rel}^{\mu}$:



$$\text{Thrust } T = \max \frac{\Sigma\, |p_i^L|}{\Sigma\, |p_i|}$$

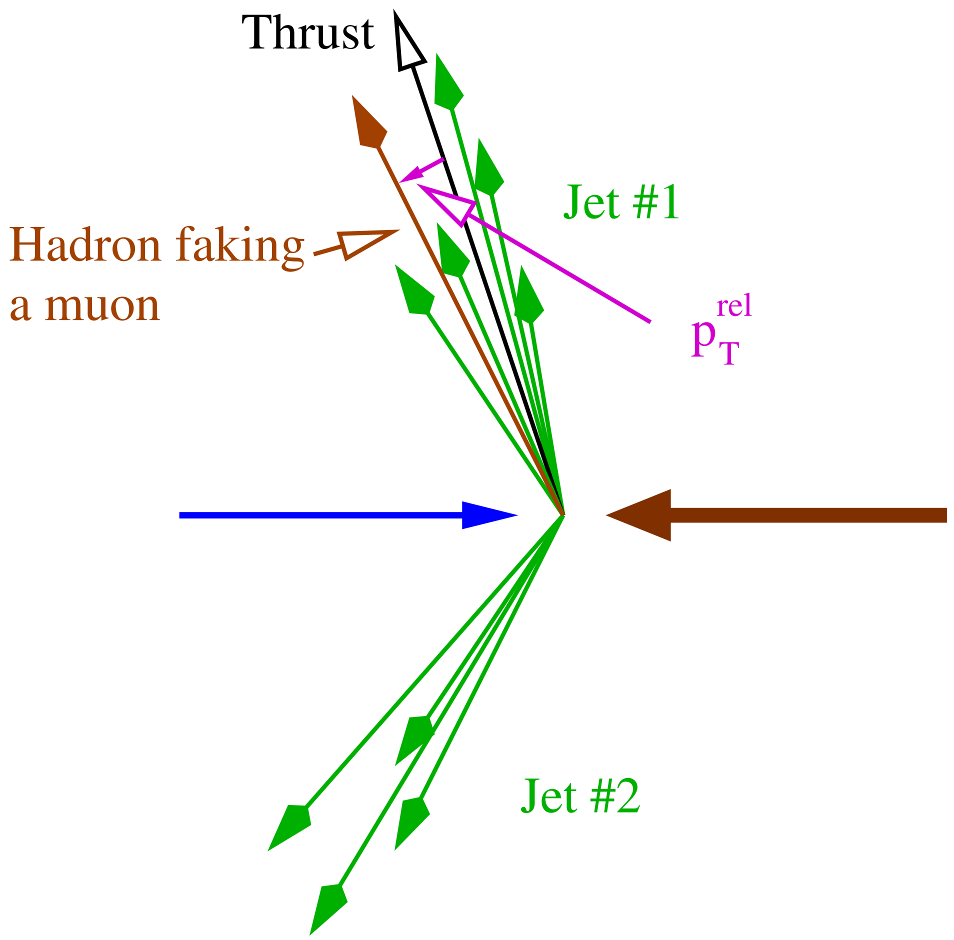
Discrimination between Charm and Beauty



What about background ?

Background Estimation

- "Fake muon" background : one hadron is identified as a muon



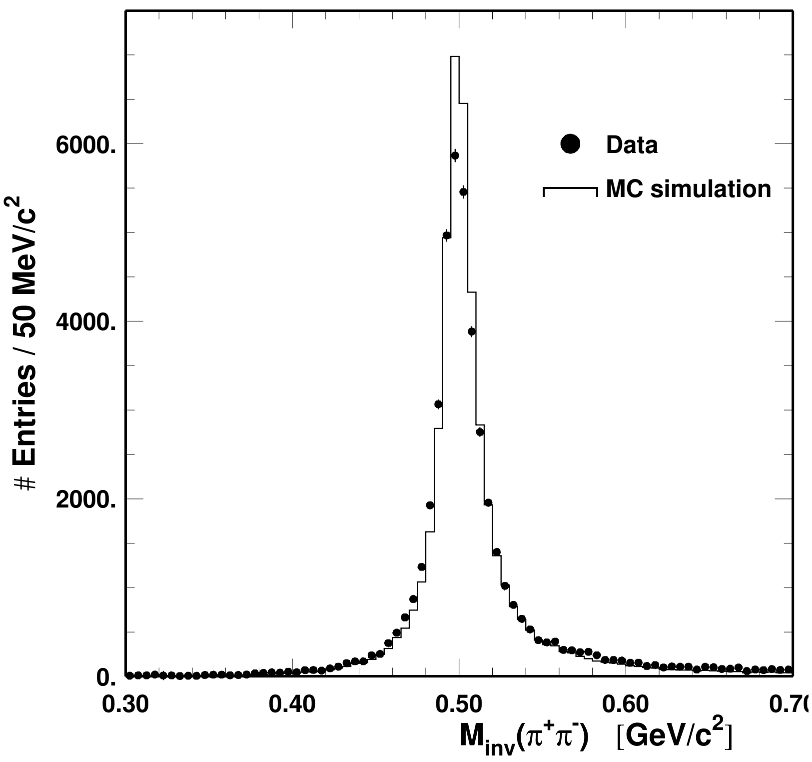
- Use data to estimate the background
- Need probability that a hadron h is identified as "muon":

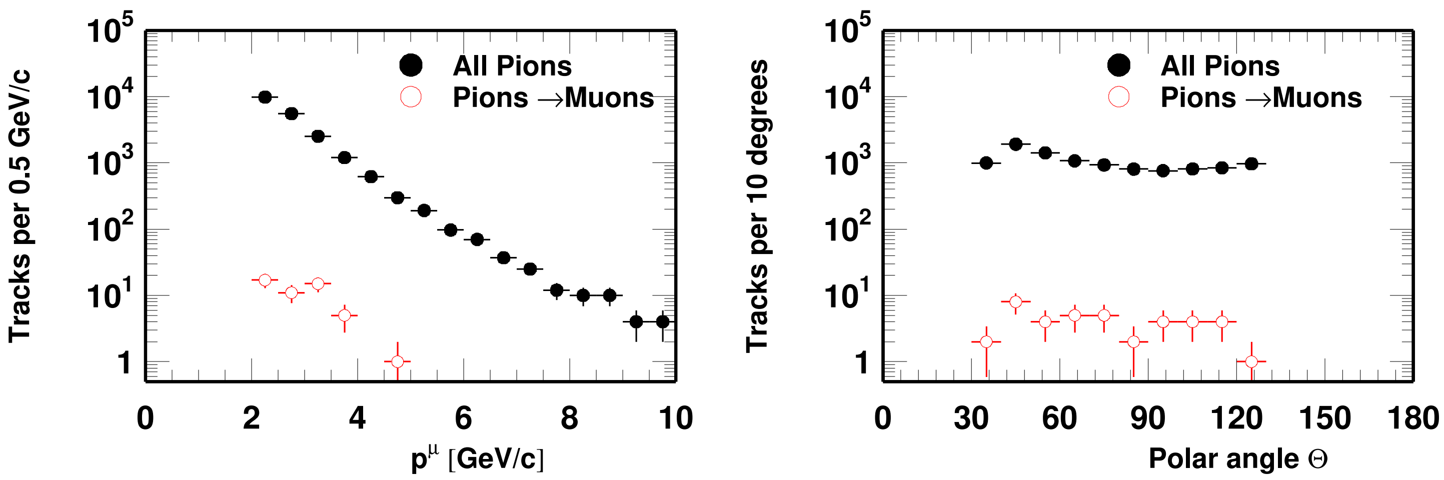
$$\mathcal{P}_h^{\mu}(p, \theta)$$

- Choose particle identity for hadron h : pions, kaons, protons
- Weight the events with the appropriate mis-identification probability, averaged over the different hadron types

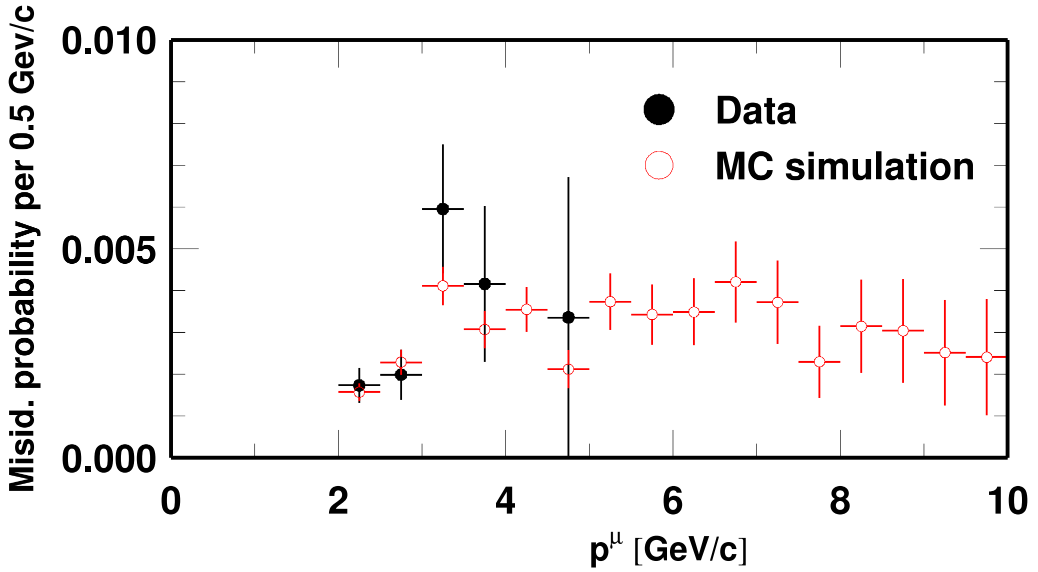
Extraction of $\mathcal{P}_h^{\mu}(p, \theta)$ from Data?

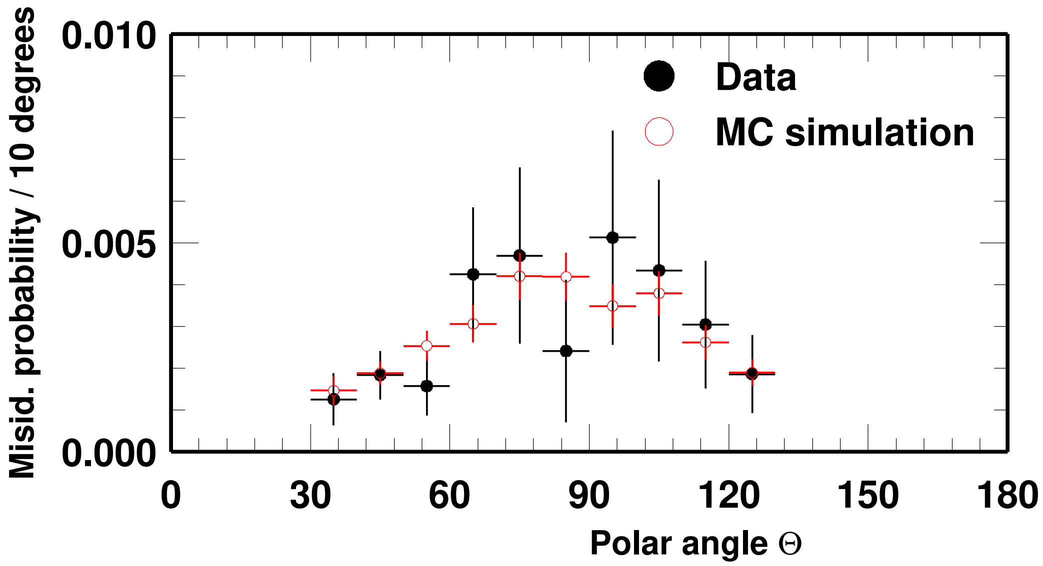
Use $\pi's$ from $K_s^0 \to \pi^+\pi^-$





Compare Data with MC

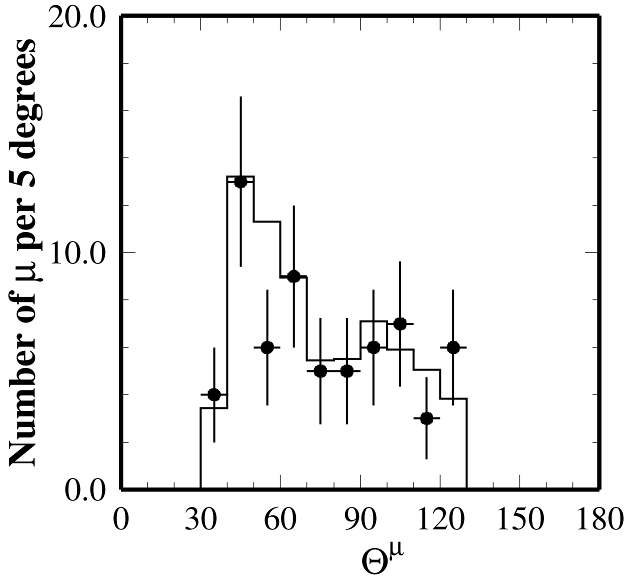


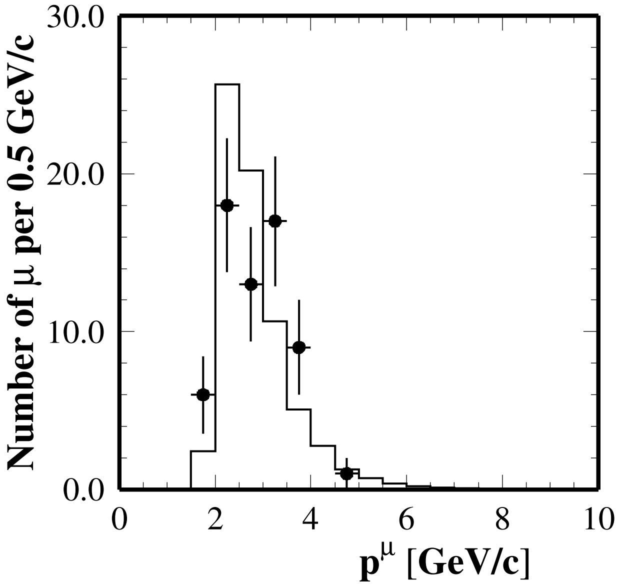


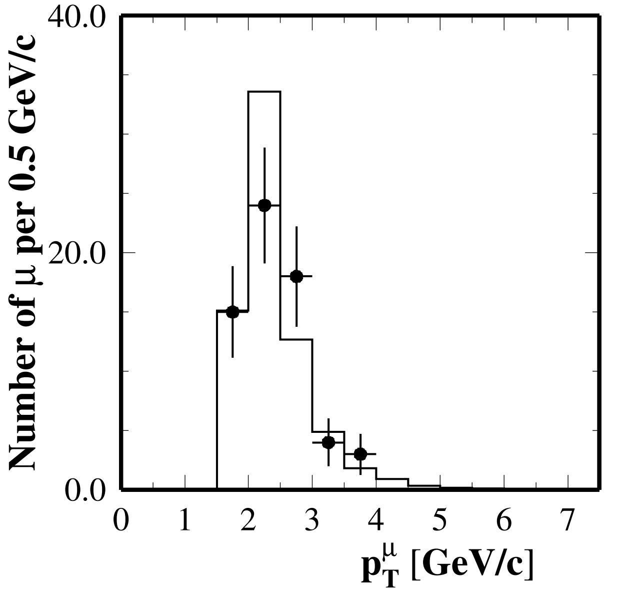
Good description of $\mathcal{P}_{\pi}^{\mu}(p,\theta)$ in MC simulation.

$$\mathcal{P}_{\pi}^{\mu}(p,\theta) < 5 \cdot 10^{-3}$$

Check $\mathcal{P}_{\pi}^{\mu}(p,\theta)$ with Data





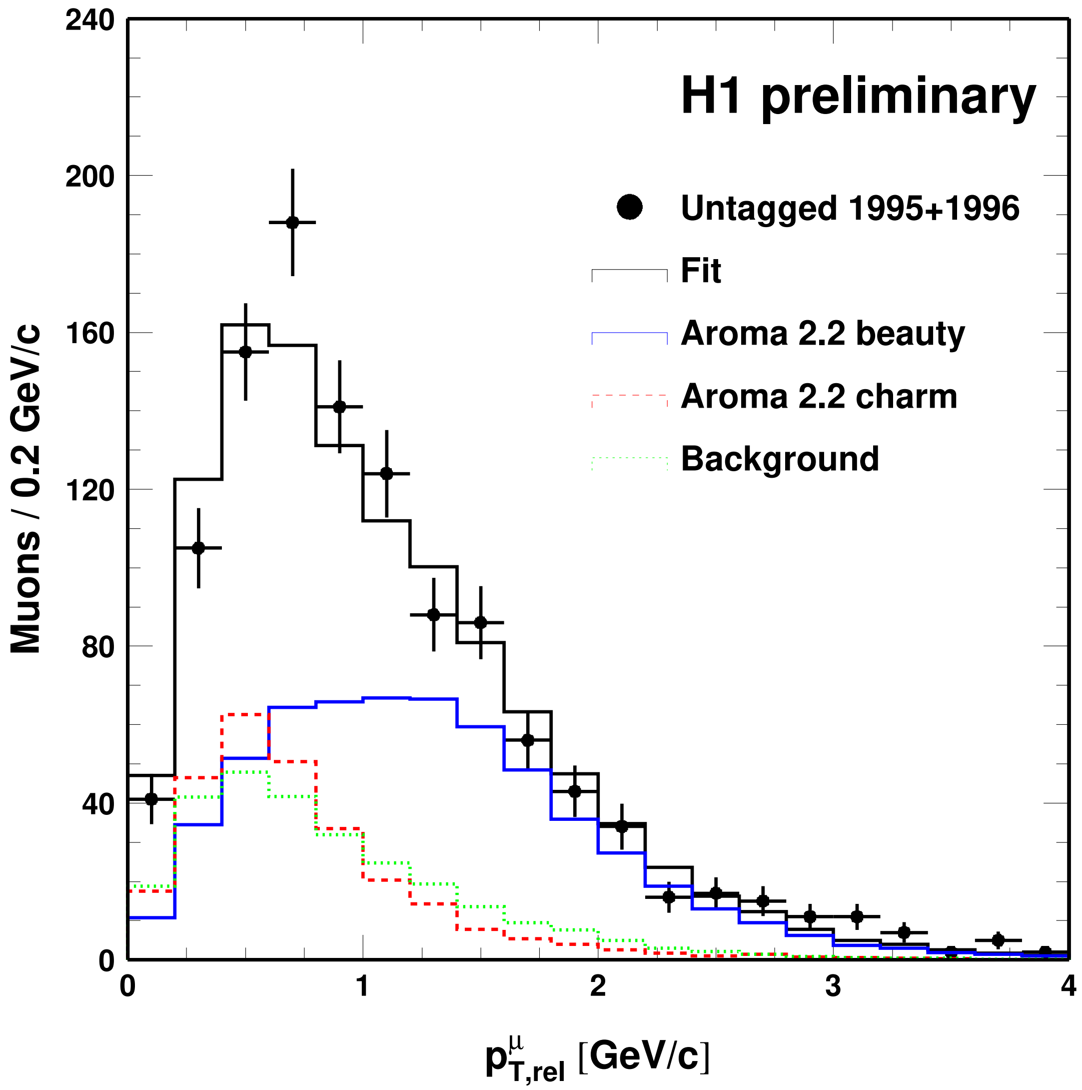


Measured: **64.0**

Predicted: **69.8**

$$\mathcal{P}_{\pi}^{\mu}(p,\theta) < 5 \cdot 10^{-3}$$
$$\mathcal{P}_{K}^{\mu}(p,\theta) < 2 \cdot 10^{-2}$$
$$\mathcal{P}_{p}^{\mu}(p,\theta) < 10^{-3}$$

Fit the Data



Beauty : 51.4%

Charm : 23.5%

Background : 23.5%

Visible b Production Cross Section

- Visible range:

$$Q^2 < 1\ \mathrm{GeV}^2 \qquad p_T^\mu > 2.0\ \mathrm{GeV/c}$$
$$0.1 < y_{JB} < 0.8 \qquad 35^o < \theta^\mu < 130^o$$

- Visible b production cross section

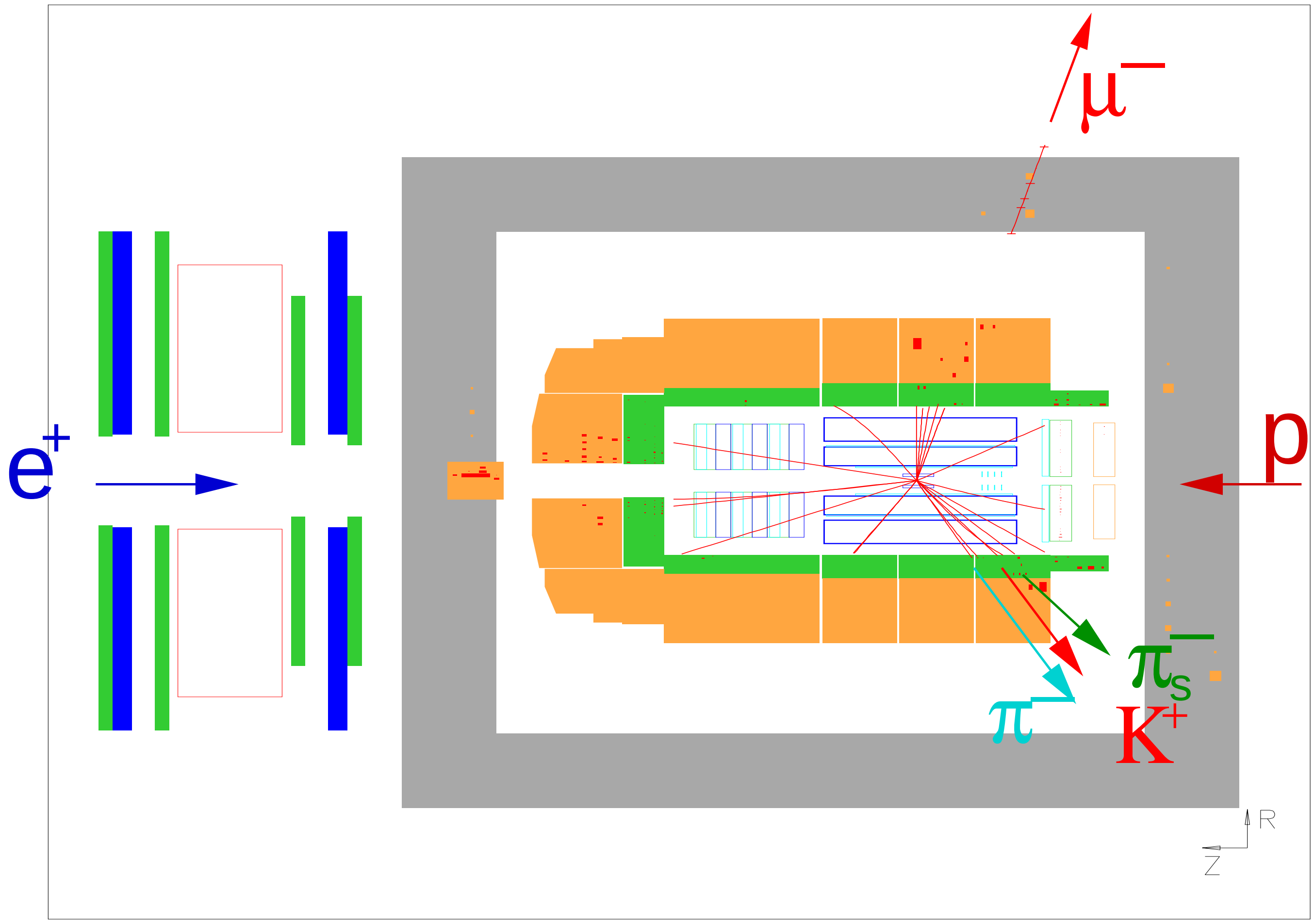
$$\boxed{\sigma_{b\bar{b}}^{vis} = 0.93 \pm 0.08^{+0.17}_{-0.07}\ nb\ \ \text{(H1 prelim.)}}$$

- $\sigma_{c\bar{c}}$ consistent with D^* measurements.

(from D^* $\sigma(ep \to c\bar{c}) = 941 \pm 160^{+142}_{-120}$ Nucl.Phys.B472(1996)32)

- Aroma 2.2 predicts $\sigma_{b\bar{b}}^{vis} = 0.19\ nb$.

A $b\bar{b}$ event



$e^+ p \rightarrow \bar{b}\, b$ + remnant

$b \rightarrow \mu^- \nu_\mu X$

$\bar{b} \rightarrow D^{*-}\, Y$

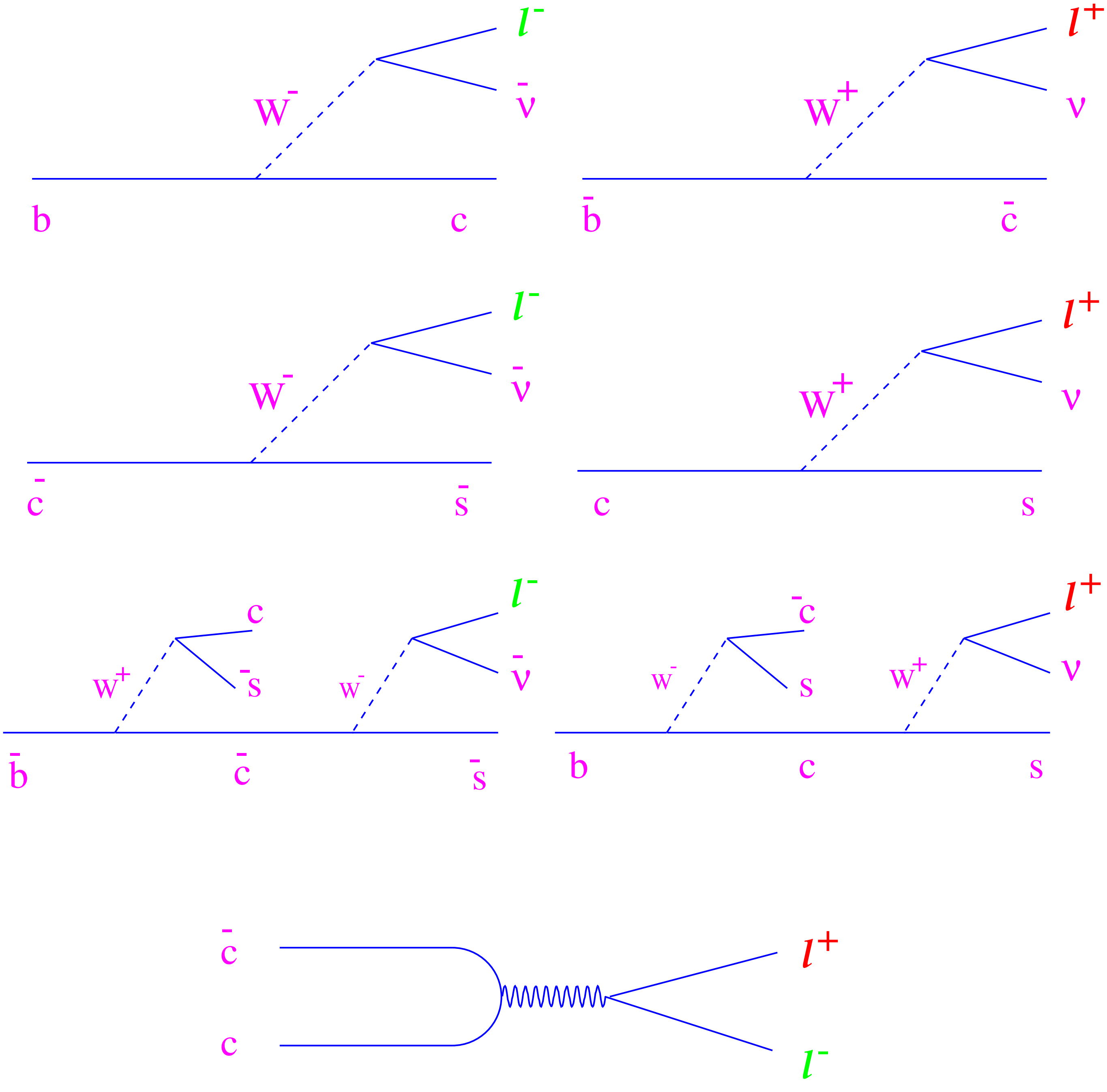
$D^{*-} \rightarrow \bar{D}^0 \pi_s^-$

$\bar{D}^0 \rightarrow K^+ \pi^-$

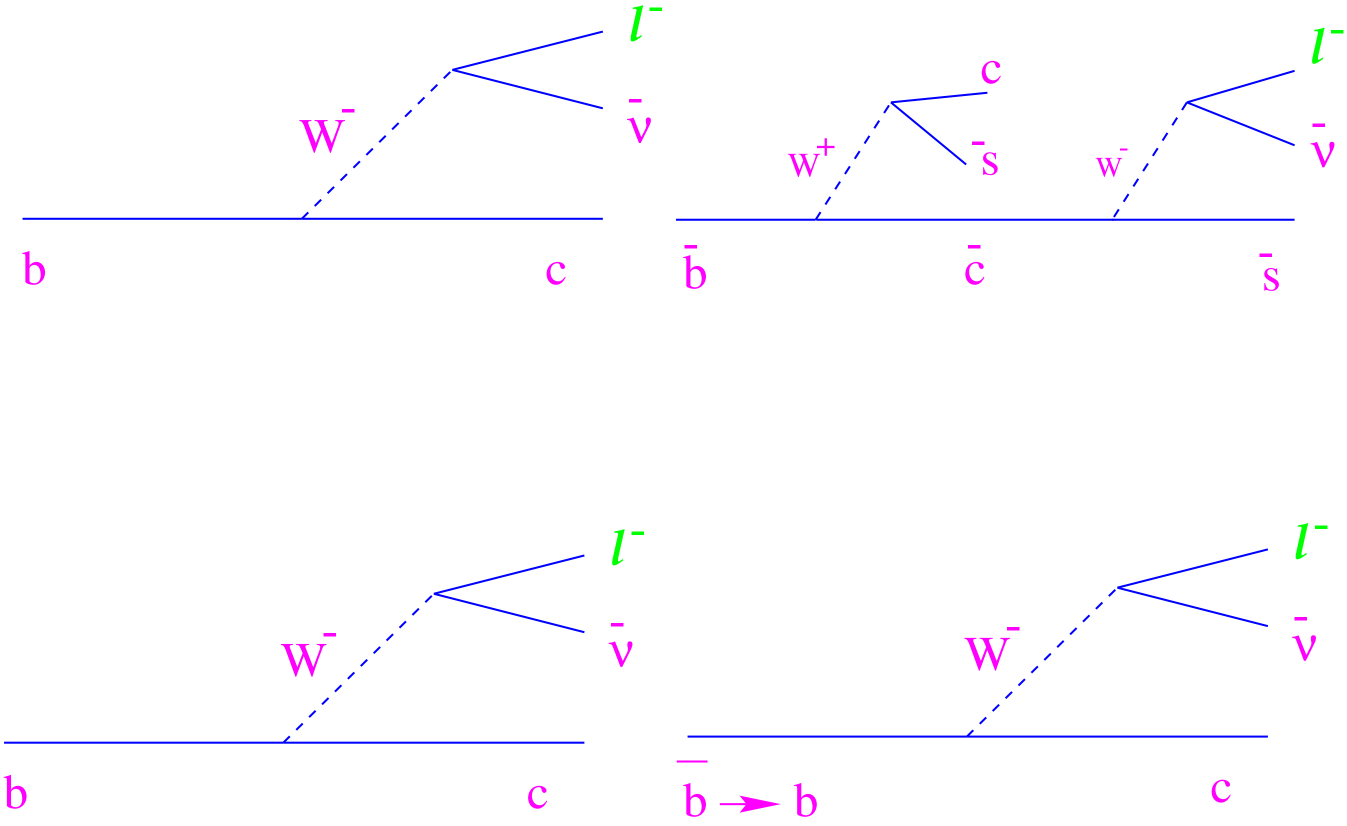
$\Delta m = 0.146$ GeV

$M_{\bar{D}^0} = 1.855$ GeV

Method II: Dileptons



Method II: Dileptons



Like sign dileptons accessible only from b-events

$$
\begin{aligned}
N_{\pm\pm} &= N_{bb} + N_{bf} + N_{cf} + N_{ff} \\
&\rightarrow N_{bb} + (N_b + N_c + N_f) \otimes N_f \\
&\rightarrow N_{bb} + \textit{single lepton evts} \otimes N_f
\end{aligned}
$$

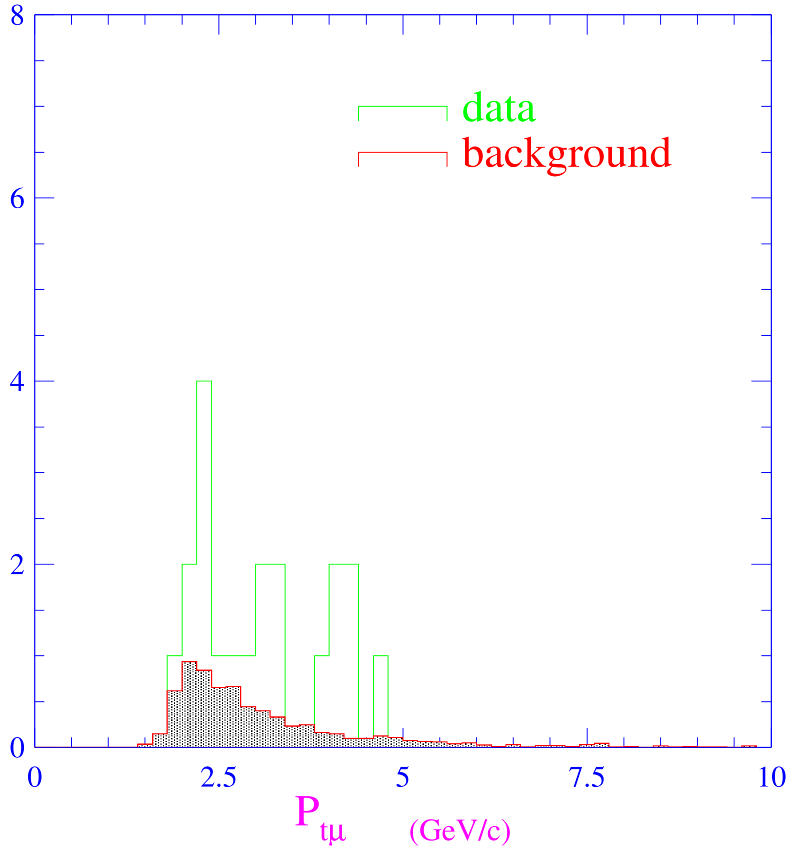
Dilepton Data

$$\mathcal{L} = 8.3 pb^{-1}$$

$2\mu \quad p_T^{\mu} > 2.0$ GeV/c

$35^o < \theta^{\mu} < 130^o$

$9\ events\ N_{\pm\pm}$ $\quad 3 \pm 0.15\ background\ evts\ expected$

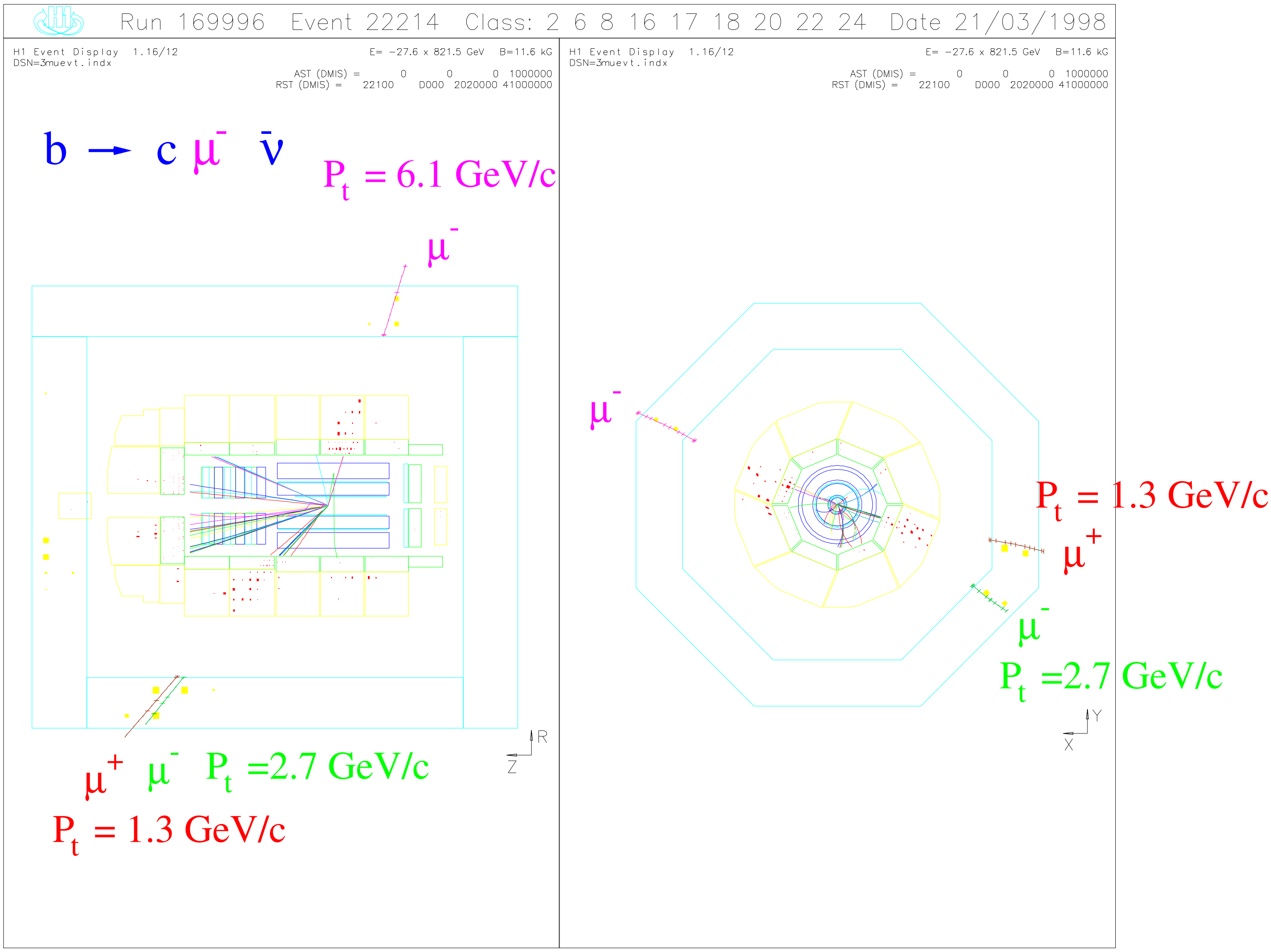


$$\boxed{\sigma_{bb}^{vis} = 55 \pm 30 \pm 7\ pb \ \text{(H1 prelim.)}}$$

- Aroma 2.2 predicts $\sigma_{bb}^{vis} = 17\ pb$.

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

A $b\bar{b}$ event



$\bar{b} \rightarrow \bar{c}\ \mu^+\ \nu$
$\quad\quad \hookrightarrow s\ \mu^-\ \bar{\nu}$

$\bar{b} \leftrightarrow b \rightarrow c\ \mu^-\ \bar{\nu}$
$\quad\quad\quad\quad \hookrightarrow \bar{s}\ \mu^+\ \nu$

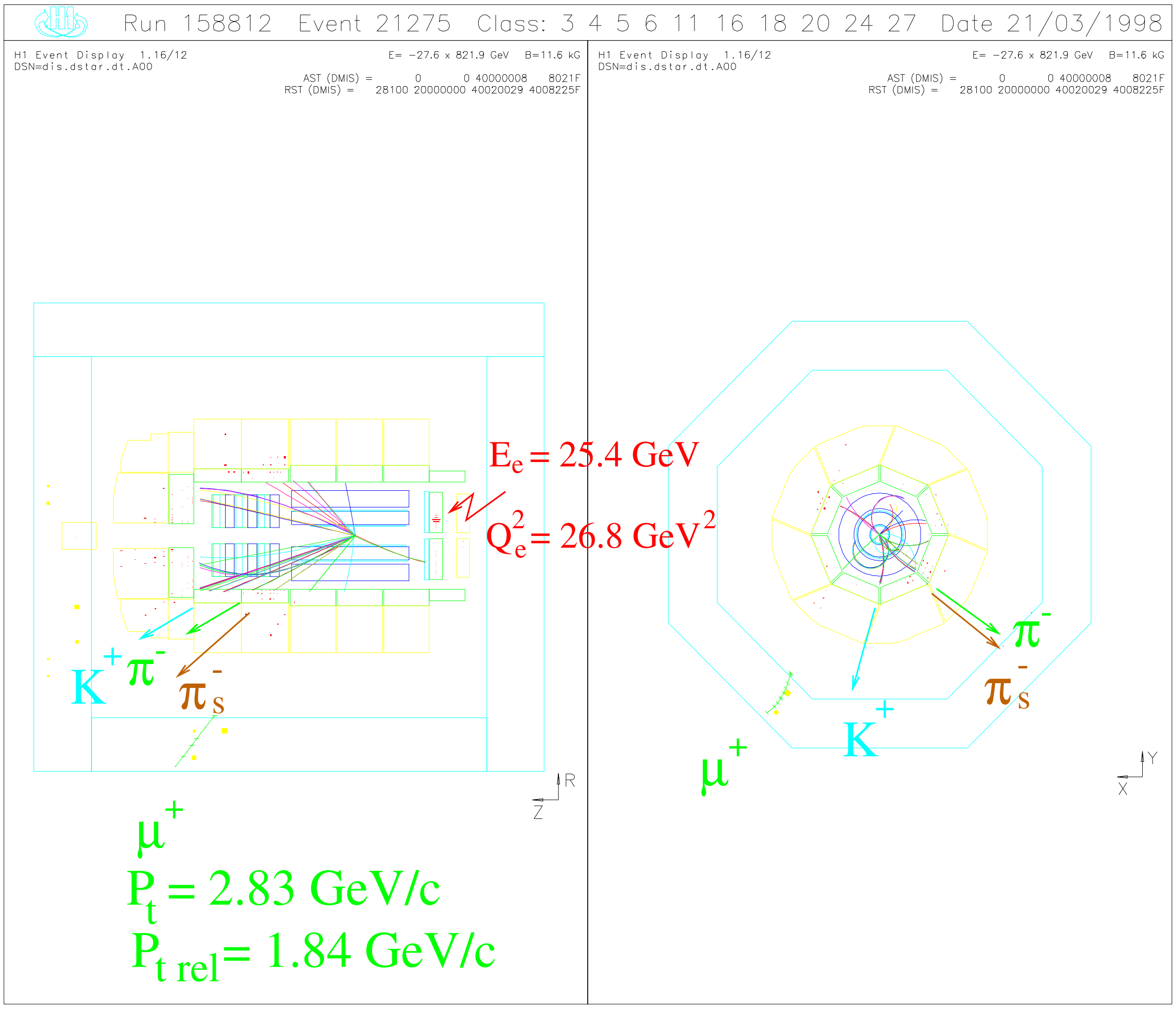
Conclusions & Outlook

- First observation of open b production at HERA
- The measured b cross section is higher than the LO QCD expectation by a factor $\sim \mathbf{5}$

- What's next ?
  - ▷ b cross section with cut on p_T^b instead of p_T^μ
  - ▷ b production in DIS
  - ▷ Use Si-vtx detectors
  - ▷ High lumi upgrade of HERA at 2000 ....

A $b\bar{b}$ event in DIS

$$B^0 \rightarrow D^{*-} \mu^+ \nu$$



$$M_{D^0} = 1.902\ \text{GeV}/c^2$$

$$\Delta M = 0.1457\ \text{GeV}/c^2$$