Open Charm and Beauty Production at HERA

PHOTON99 *Freiburg, 26.05.1999*

On behalf of the H1 *Collaboration*

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Outline

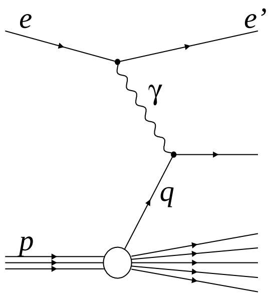
- **Motivation**
- **Open Charm Production in DIS F_2^c**
- **Charm Charm Production in γp**
- **Direct measurements of the gluon density**
- **Open Beauty Production in γp**
- **Summary**

Results from 1995 + 1996 data

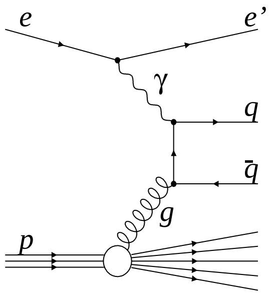
Motivation for Heavy Flavor Physics

Parton density calculations include heavy flavors

in the massless quark evolution at Q_0
Flavor Excitation (FE)

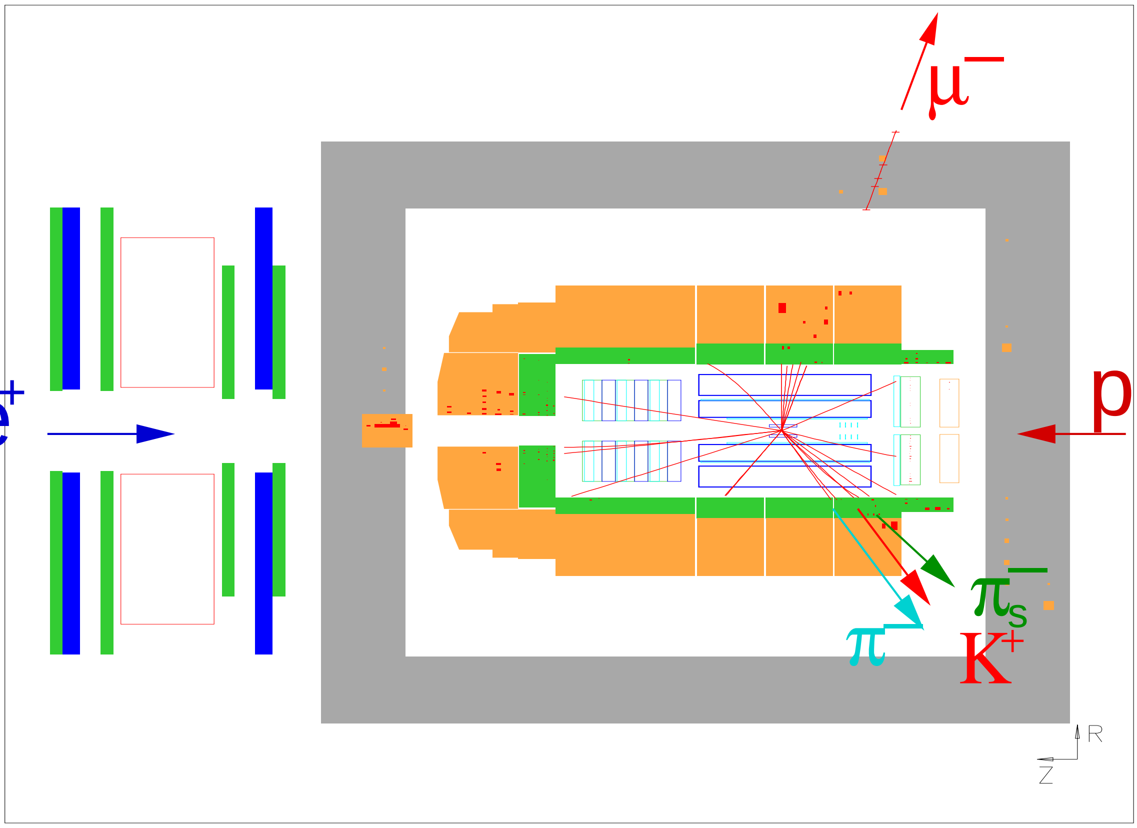


exclusively via Boson Gluon Fusion (BGF)



- **Direct access to the parton densities (HQ or gluon) in the proton or photon**
- **HQ hadron unequivocally defines the parent parton**

An Event in H1



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

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

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

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

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

$\Delta m = 0.146$ GeV

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

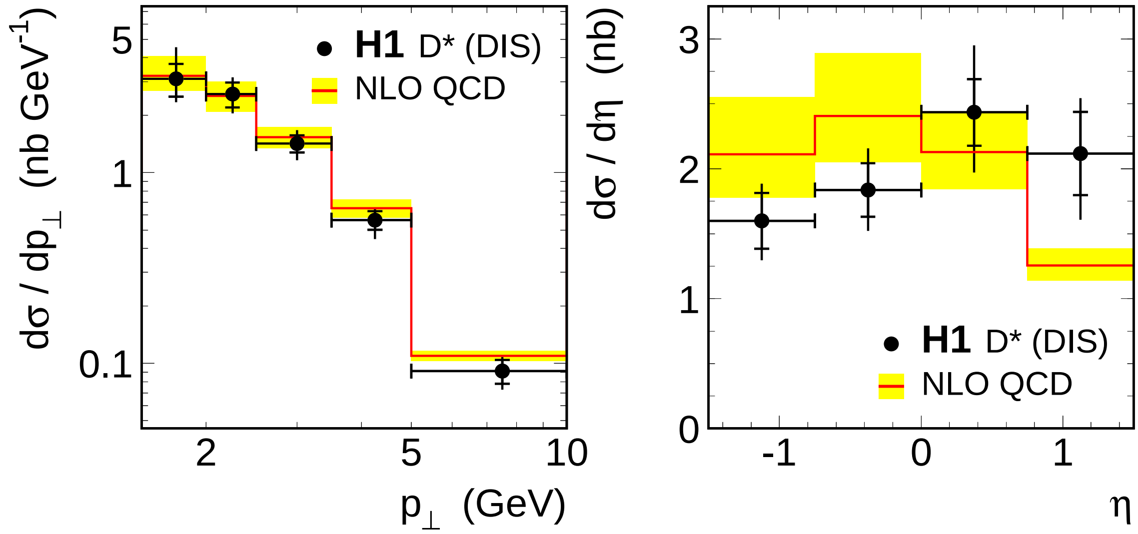
Differential D^* Cross Sections in DIS

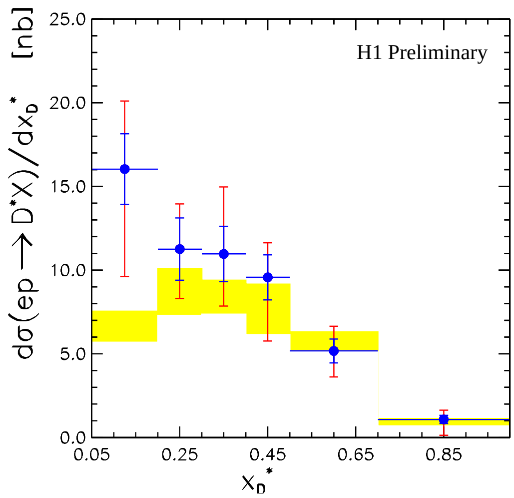
Charm tagging via reconstructed D^* Mesons

Visible range: $\mathcal{L} = 9.7\ \text{pb}^{-1}$

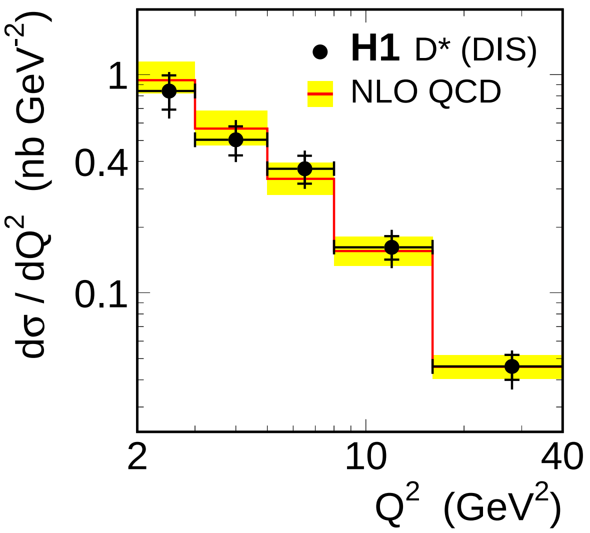
$2 < Q^2 < 100\ \text{GeV}^2$ $\qquad 0.05 < y < 0.7$

$p_{\perp,lab}(D^*) > 1.5\ \text{GeV}$ $\qquad |\eta(D^*)| < 1.5$





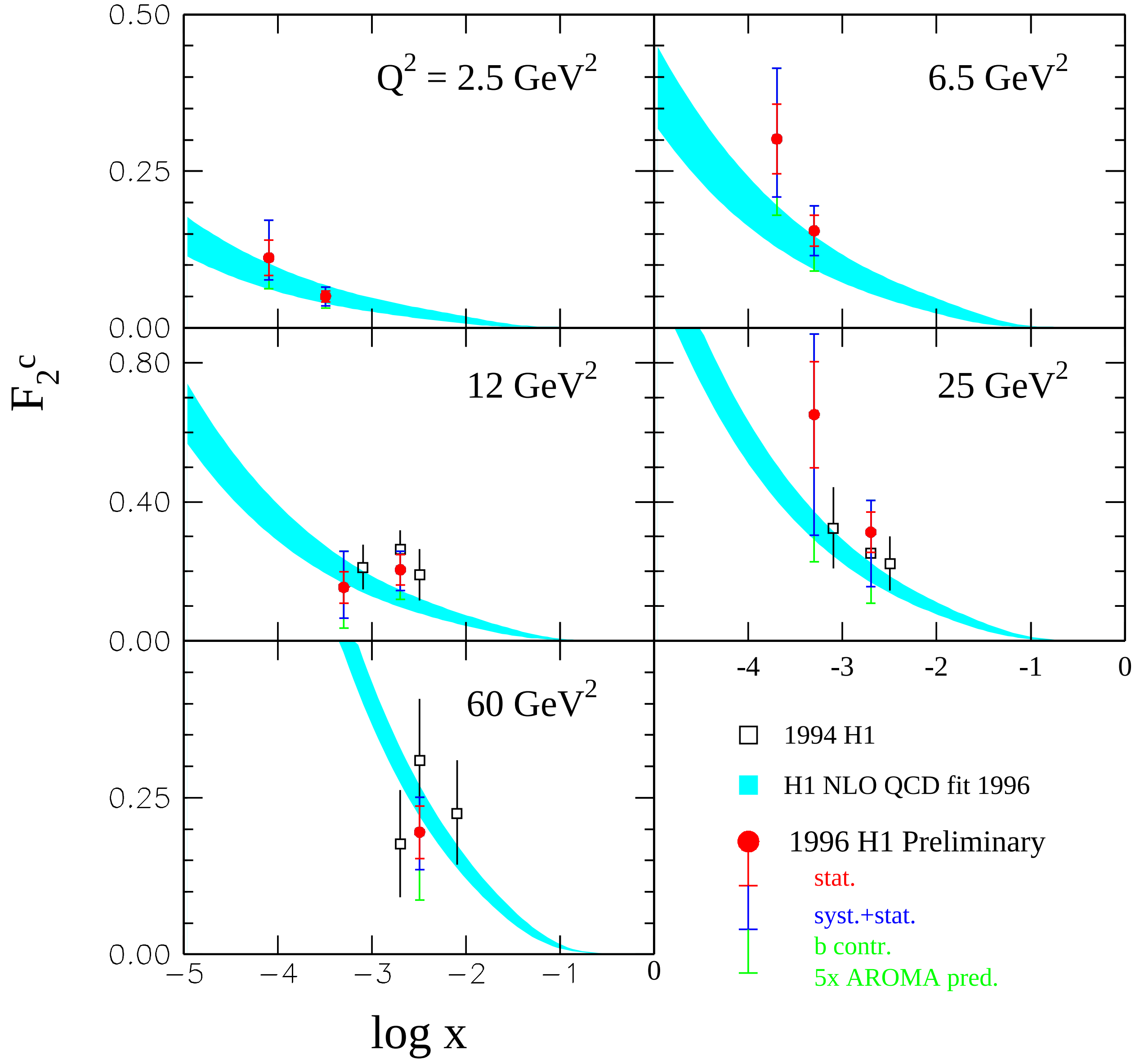
$$x_{D^*} = \frac{2|\vec{p}(D^*)^{\gamma p}|}{W}$$



NLO predictions in reasonable agreement with data

$F_2^c(x, Q^2)$

$$\frac{d^2\sigma^{c\bar{c}}}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left(1 + (1-y)^2\right) \cdot F_2^c(x, Q^2)$$

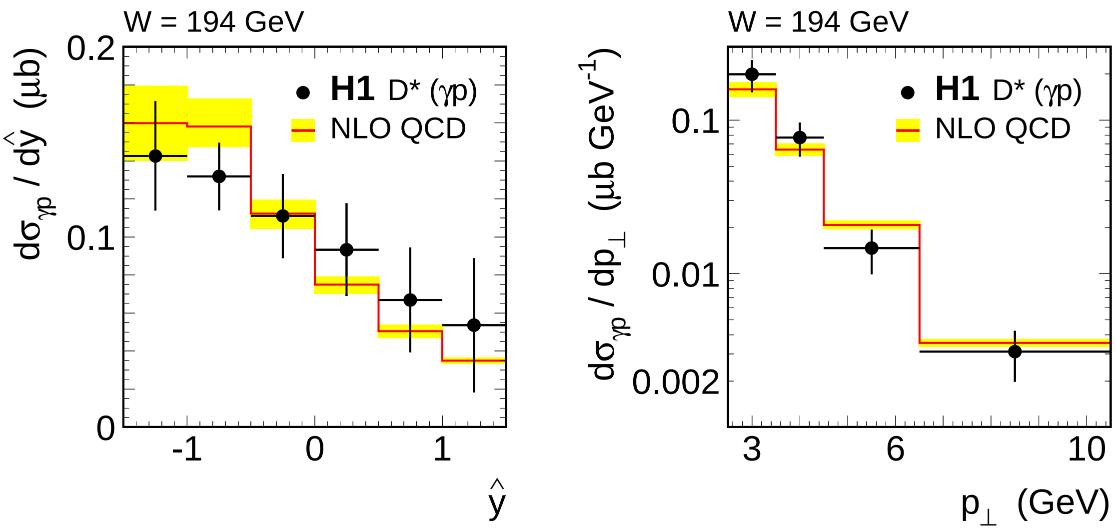


Single Differential D^* Cross Sections in γp

Positron in e-tagger ETAG-33 $\mathcal{L} = 10.7\ \text{pb}^{-1}$

$Q^2 < 0.01\ \text{GeV}^2$ $0.29 < y < 0.62$

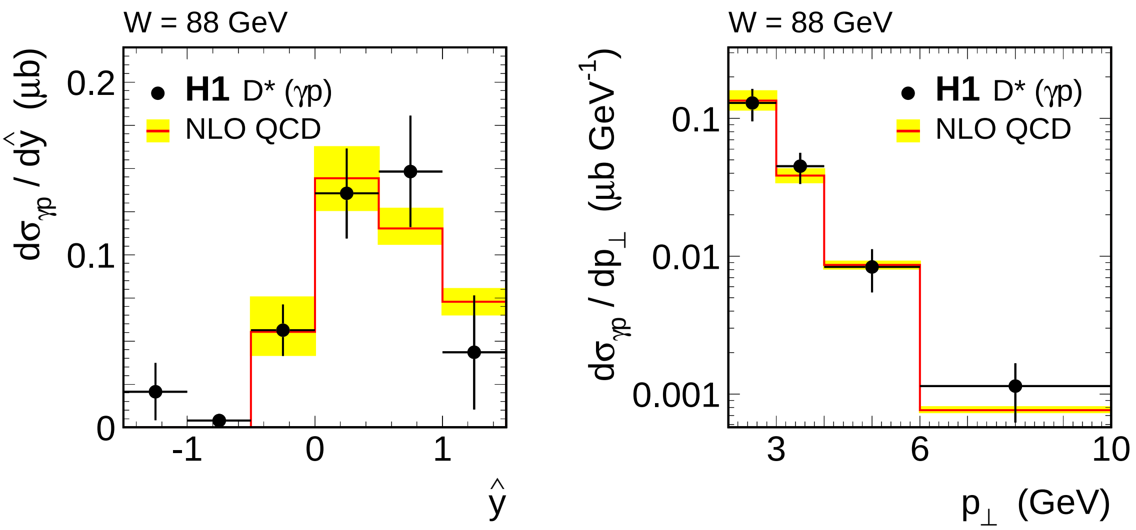
$p_{\perp,lab}(D^*) > 2.5\ \text{GeV}$ $|\eta(D^*)| < 1.5$



Positron in e-tagger ETAG-44 $\mathcal{L} = 10.2\ \text{pb}^{-1}$

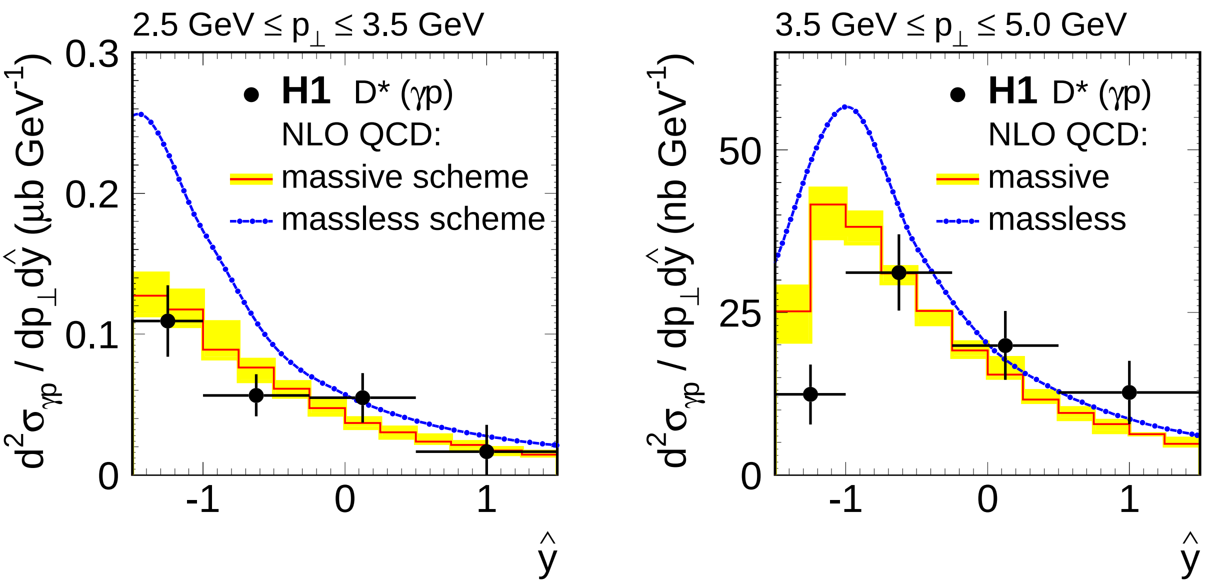
$Q^2 < 0.01\ \text{GeV}^2$ $0.02 < y < 0.32$

$p_{\perp,lab}(D^*) > 2.0\ \text{GeV}$ $|\eta(D^*)| < 1.5$



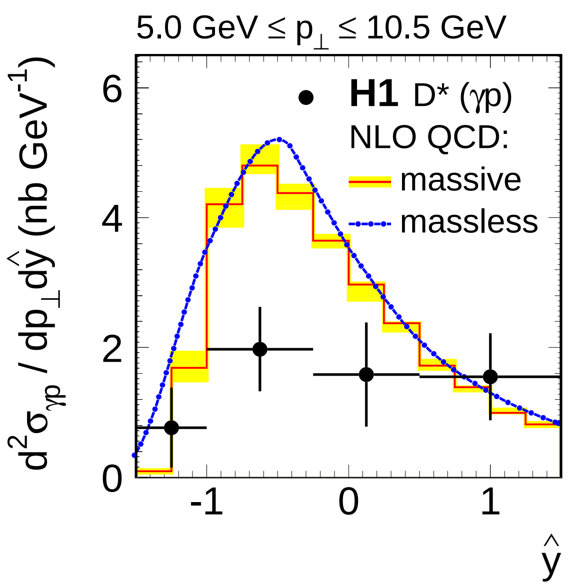
Double Differential D^* Cross Sections in γp

$W = 194$ GeV



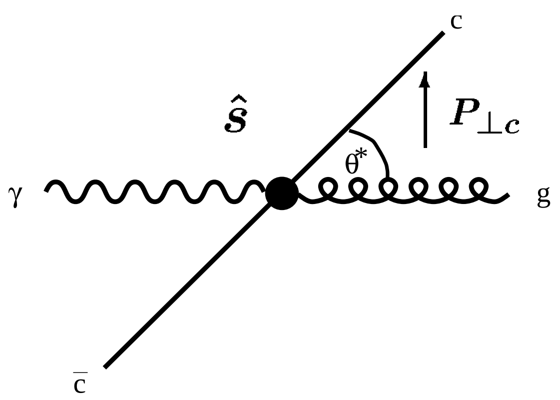
Massive calculation reproduce data for $p_\perp < 5$ GeV

Massless approach does not describe data



How to get the Gluon Density

- Reconstruct x_g^{obs} from kinematics in the γg system (LO)

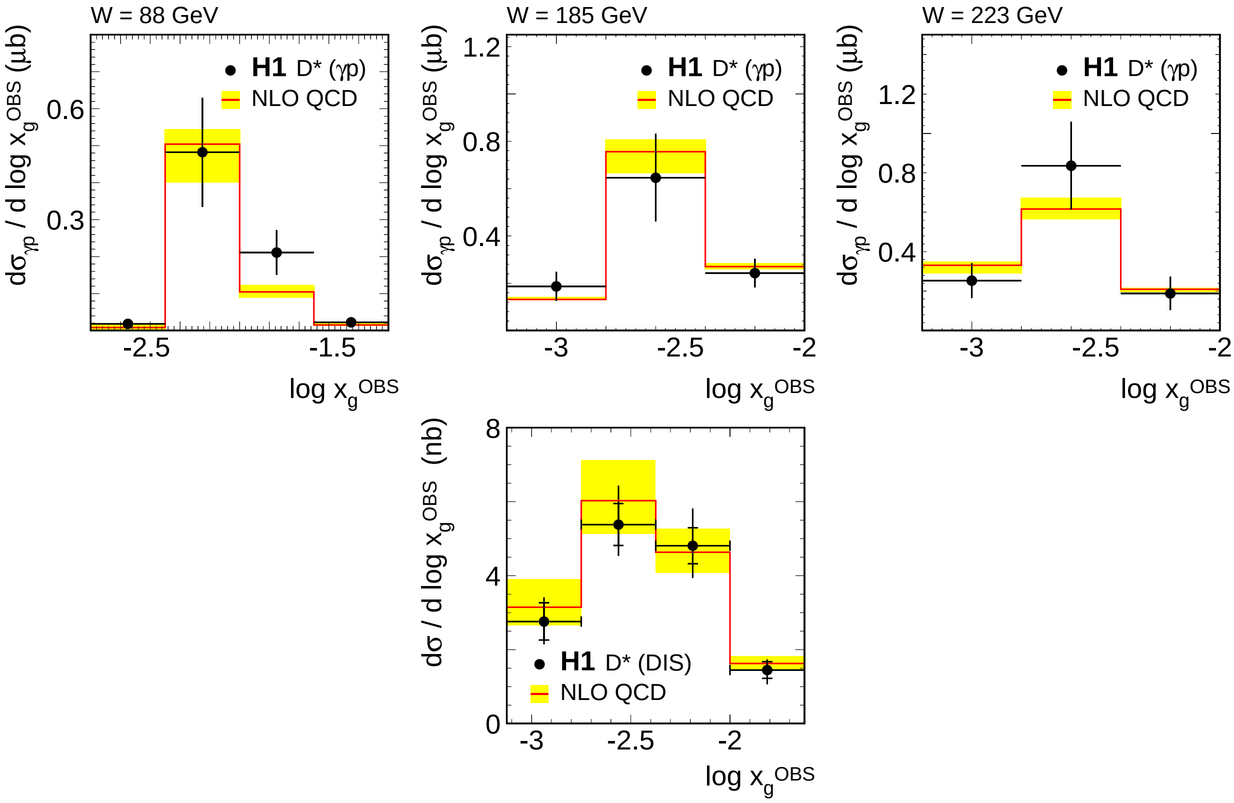


$$x_g = \frac{\hat{s}+Q^2}{y \cdot s} \qquad \hat{s} = \frac{m_c^2 + p_{\perp c}^{*\,2}}{z(1-z)}$$

$$z = \frac{(E-p_z)_c^{\mathrm{lab}}}{2E_e y}$$

$c \approx D^*$

- Measure $\sigma(x_g^{obs})$ in restricted p_T and η

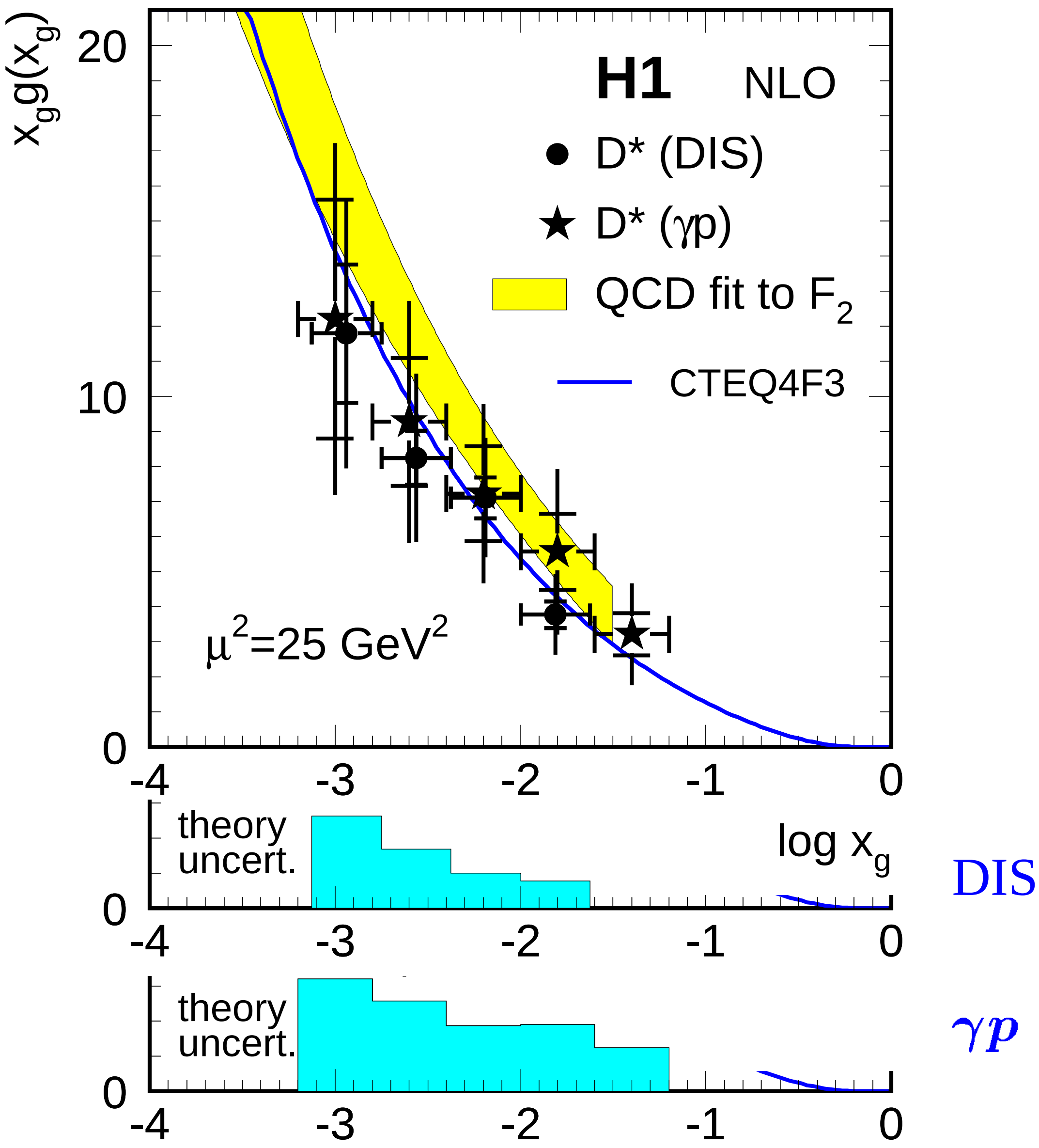


- Get correlation $x_g \Leftrightarrow x_g^{obs}$ from NLO calculations
- Unfold iteratively to determine $\sigma(x_g)$

Gluon Density from Charm Production

$$\sigma(x_{g,i})^{exp} = g(x_{g,i}, \langle\mu_i^2\rangle)^{exp} \cdot \hat{\sigma}_{\gamma g}(x_{g,i})$$

$$g(x_{g,i}, \langle\mu^2\rangle)^{exp} = g(x_{g,i}, \langle\mu^2\rangle)^{th} \cdot \frac{\sigma(x_{g,i})^{exp}}{\sigma(x_{g,i})^{th}}$$



Beauty Tagging - I

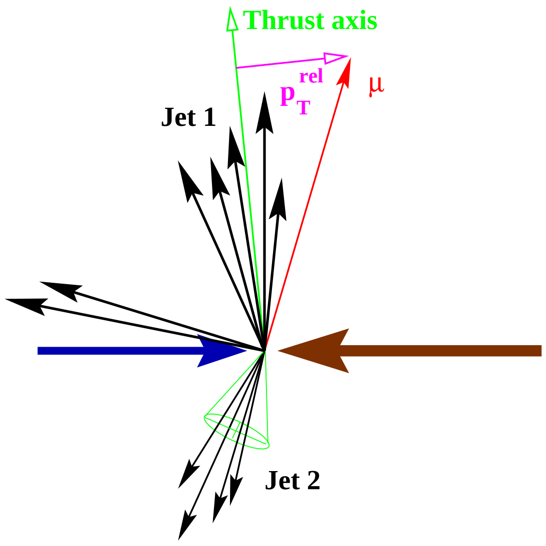
Semi-leptonic B-decays

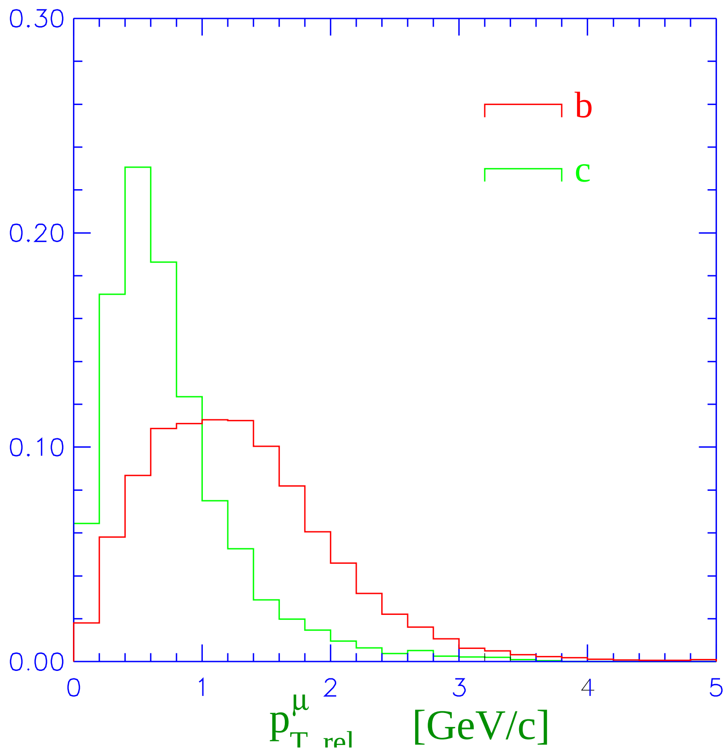
2-Jet events Cone algorithm $R = 1$

$$|\eta^{jet}| < 2.5 \quad E_{\perp}^{jet} > 6 \text{ GeV}$$

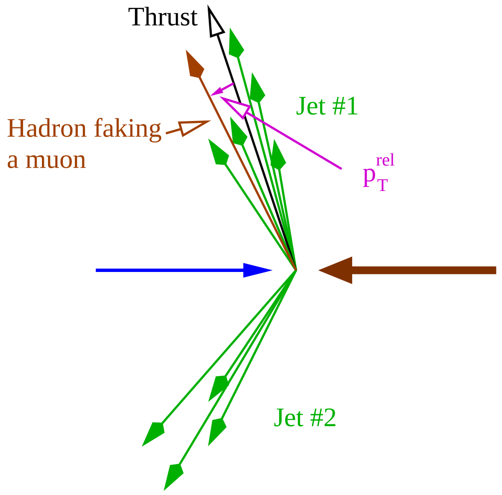
+ 1 muon

$$p_{\perp,lab}^{\mu} > 2.0 \text{ GeV} \quad 35^{\circ} < \Theta^{\mu} < 130^{\circ}$$





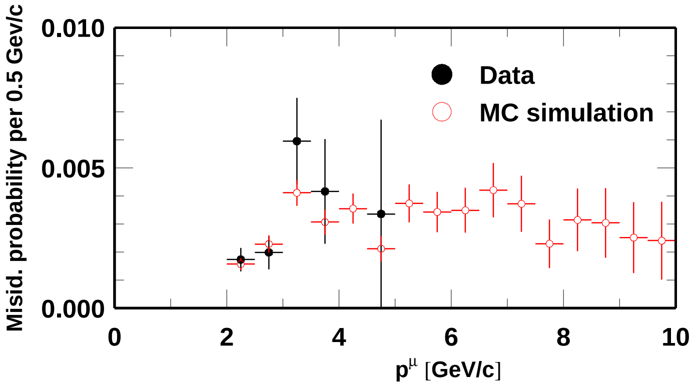
Background Estimate from Data

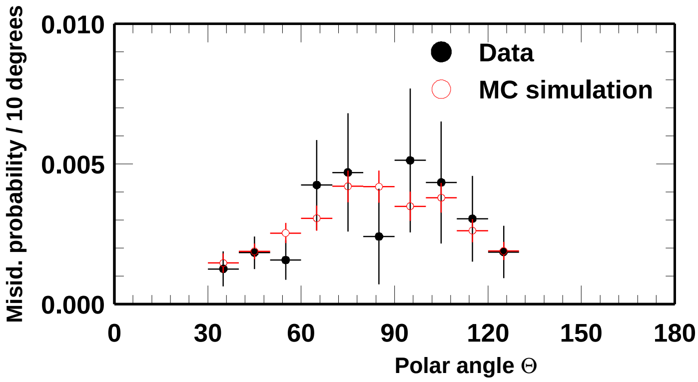


μ-fake probabilities of hadrons:

K_s^0	data	$\Rightarrow$	$P_\pi^\mu(p,\Theta)$
ϕ	data	$\Rightarrow$	$P_K^\mu(p,\Theta)$
Λ	data	$\Rightarrow$	$P_p^\mu(p,\Theta)$

$$P_\pi^\mu(p,\Theta)$$





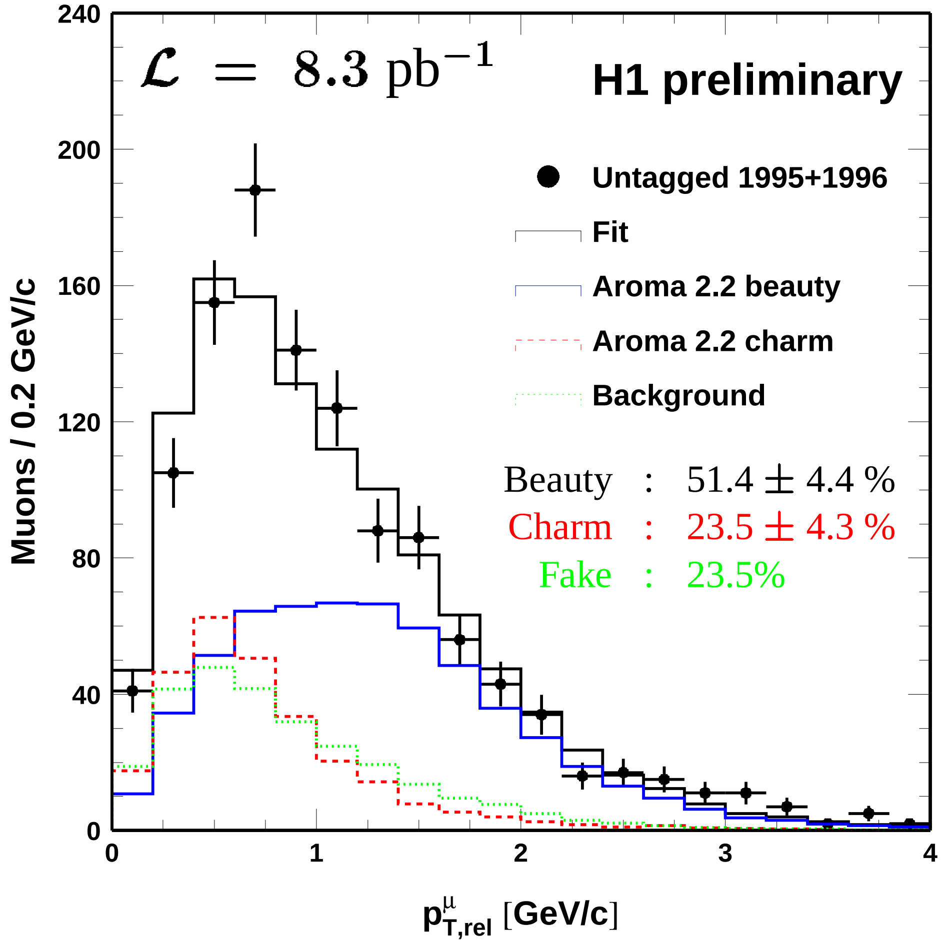
$$P_\pi^\mu(p,\Theta) < 5.0\cdot 10^{-3}$$
$$P_K^\mu(p,\Theta) < 2.0\cdot 10^{-2}$$
$$P_p^\mu(p,\Theta) < 10^{-3}$$

Visible Beauty Production Cross Section

Visible range:

$Q^2 < 1\ \mathrm{GeV}^2$ $\quad 0.1 < y_{JB} < 0.8$

$p^{\mu}_{\perp,lab} > 2.0\ \mathrm{GeV}$ $\quad 35° < \Theta^{\mu} < 130°$



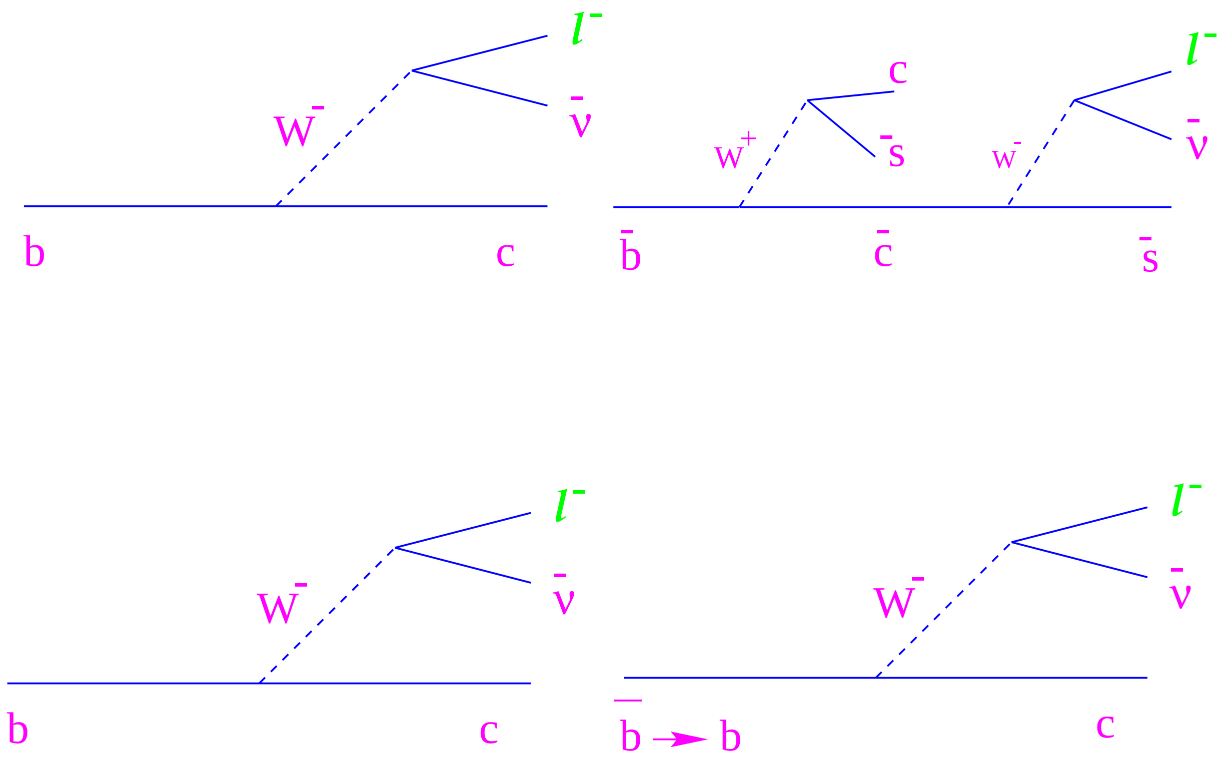
$$\sigma^{vis}_{b\bar{b}} = 0.93 \pm 0.08\ ^{+0.21}_{-0.12}\ \mathrm{nb}$$ (H1 prel.)

AROMA 2.2 (MRSG, $m_b = 4.75$ GeV) : $\sigma^{vis}_{b\bar{b}} = 0.19$ nb

$\sigma_{c\bar{c}}$ consistent with D^* measurement (NPB472 (1996) 32)

Beauty Tagging - II

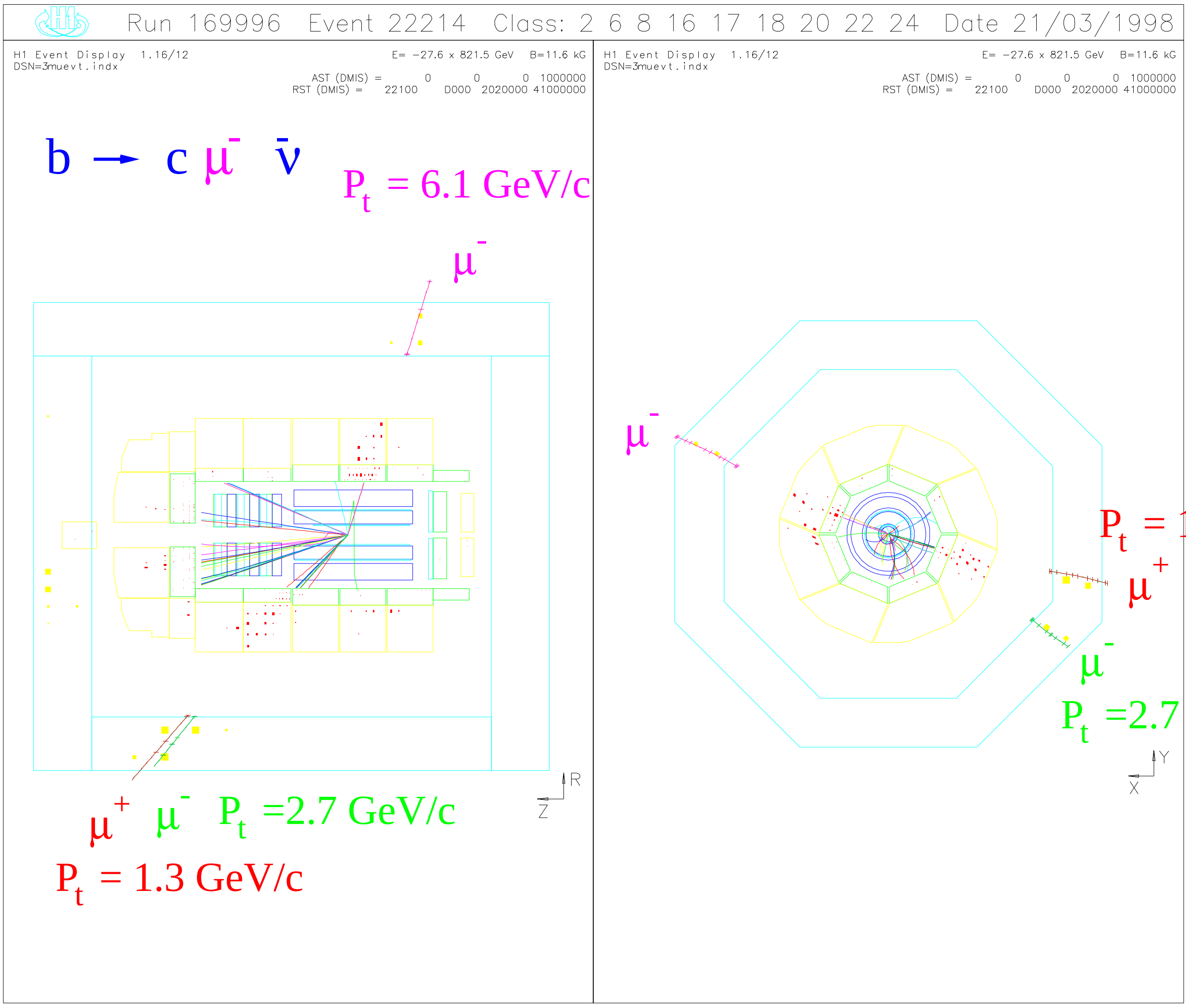
Like sign Dimouns



Like sign dileptons only from beauty events

$$
\begin{aligned}
N_{\pm\pm} &= N_{bb} + N_{bf} + N_{cf} + N_{ff} \\
&\rightarrow N_{bb} + (N_b + N_c + N_f) \otimes N_f \\
&\rightarrow N_{bb} + single\ lepton\ evts \otimes P_h^{\mu}(p, \Theta)
\end{aligned}
$$

A Candidate for $B^0 - \overline{B}^0$ - Mixing



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

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

Visible Beauty Like-sign Dimuon Cross Section

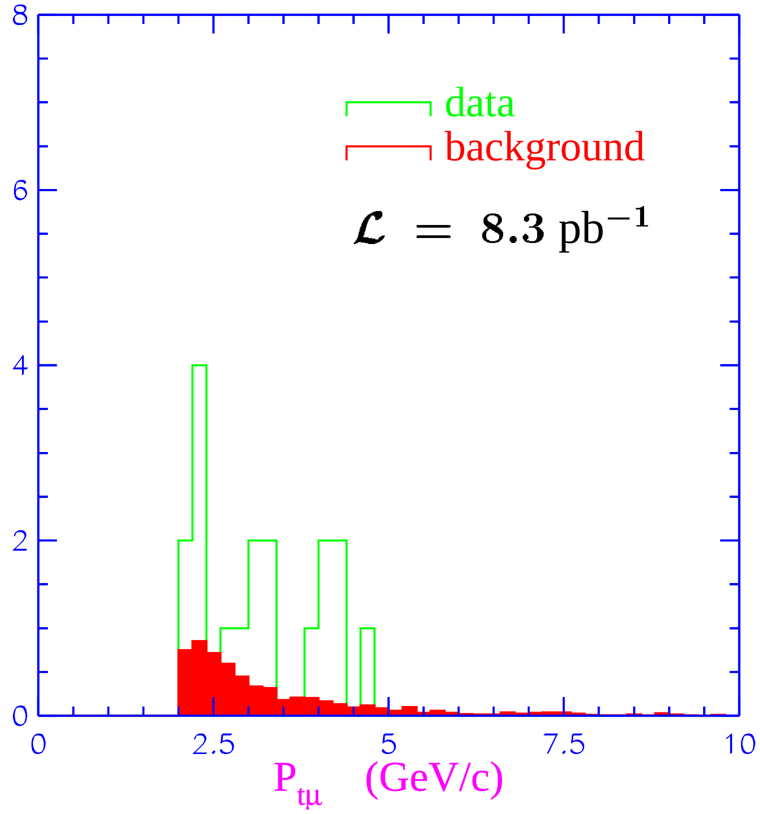
Visible range:

$Q^2 < 1\ \mathrm{GeV}^2 \qquad 0.1 < y_{JB} < 0.8$

$p^{\mu}_{\perp,lab} > 2.0\ \mathrm{GeV} \qquad 35^\circ < \Theta^{\mu} < 130^\circ$

9 like-sign 2-μ events in data

3.0 ± 0.3 background events from fake muons



$$\sigma^{vis}_{b\bar{b}} = 55 \pm 30 \pm 7\ \mathrm{pb} \quad \text{(H1 prel.)}$$

AROMA 2.2 (MRSG, $m_b = 4.75$ GeV) : $\sigma^{vis}_{b\bar{b}} = 17$ pb

Summary

- Massive NLO calculations are found to agree with Charm data in DIS and in γp

- Charm contributes significantly (25 %) to F_2 at HERA
  Measurement of F_2^c in agreement with NLO fit to F_2

- The extracted gluon density from Charm data agrees with the determination from the NLO fit to the F_2 data from H1

- The cross section of Beauty production in γp is found to be about five times larger than the LO expectation
  The like-sign di-muon analysis shows the same tendency as the single muon analysis