Too much beauty....

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Introduction: b and c facts in $\gamma \gamma$ (L3) and $\gamma g, gg$

Analysis tools: PYTHIA LO description & NLO computation

Treatment of heavy quarks: a multi-scale problem
  A toy model for $\gamma$ pdfs
  Missing components

Conclusions
Charm and beauty production

γγ L3 facts

D* tagging used for extracting the open charm cross section

Muon and electron semi-leptonic decays: a global fit gives open c and b cross sections
Charm and beauty production

$\gamma\gamma$ facts shared by the LEP community

$$\sigma^{e^+e^-\rightarrow e^+e^-c\bar{c}X} \simeq 1000 \text{ pb (± 10%)}$$

$$\sigma^{e^+e^-\rightarrow e^+e^-b\bar{b}X} \simeq 13 \text{ pb (± 30%)}$$

With stat $\simeq$ syst
Charm and beauty production

Difficult for c quarks
to mimic the b contribution

Even without a signed impact parameter

2 distinct kinematical regions

\[ p_T \text{ of the } \mu \text{ candidate with respect to the closest jet} \]

\[ \frac{m_c}{2} \lesssim \frac{m_b}{2} \]
Charm and beauty production

\[ \gamma g \quad gg \]

**b cross section at HERA**

- Star: H1 \( p_t^{\text{rel}} \)
- Black circle: H1 \( p_t^{\text{rel}} \) impact param. (prel.)
- Open circle: ZEUS e+ \( p_t^{\text{rel}} \)
- Red square: ZEUS \( p_t^{\text{rel}} \) (prel.)
- Red triangle: ZEUS D \( p_t^{\text{rel}} \) (prel.)

**Graphical Data / Theory**

- **NLO QCD**
  - Left: \( Q^2 \) vs. Data / Theory
  - Right: \( p_t^B \) vs. Data / Theory

**Theoretical Models**

- Dashed: \( \mu_R = \mu_F = \mu_0 = \sqrt{(m_b^2 + p_t^2)} \)
- Solid: \( \mu_0/2 < \mu_R, \mu_F < 2\mu_0 \)

**CTEQ5M1**

- \( m_b = 4.75 \text{ GeV} \)
- \( f(b \rightarrow B) = 0.375 \)

**Dotted: Peterson, \( \epsilon = 0.0006 \)**

**Theory: FONLL with N=2 fit**

With recent theoretical improvements
The experimentalist toolkit

- $\gamma \gamma$ Physics with PYTHIA
  - SaS parameterizations (à la FKP)
  - Phase Space slicing at the LO
  - Massless vs massive quarks
  - Takes into account all scales
  - Acceptance corrections
  - Effective fragmentation
  - Simulation of the signal

- The old Drees, Kramer, Zunft, Zerwas computation
A toy model

Different scales at LO with PS slicing with a “gluon” density $P(y, p_T^2) = \frac{\alpha}{2\pi} a y^{\lambda} \ln \frac{p_T^2}{p_{T0}^2}$

$$\sigma(\gamma\gamma \rightarrow q\bar{q}) \approx \frac{4\pi\alpha^2}{W^2} (3e_q^4) \ln \frac{W^2}{s_0}$$

$$\sigma_{\text{direct}}^{e^+e^- \rightarrow e^+e^- q\bar{q}} \approx 3e_q^4 \left( \frac{\alpha}{\pi} \ln \frac{s}{m_c^2} \right)^2 \frac{4\pi\alpha^2}{s_0} \ln \frac{s}{s_0}$$

$$\sigma_{\text{direct}}^{e^+e^- \rightarrow e^+e^- q\bar{q}} \approx 3e_q^2 (\frac{\alpha}{\pi} \ln \frac{s}{m_c^2})^2 (6a \frac{\alpha}{b}) \frac{4\pi\alpha^2}{s_0}$$

$$\sigma_{\text{res}}^{e^+e^- \rightarrow e^+e^- q\bar{q}X} \approx 3e_q^2 (\frac{\alpha}{\pi} \ln \frac{s}{m_c^2})^2 (6a \frac{\alpha}{b}) \frac{4\pi\alpha^2}{s_0}$$

$$\left\{ \frac{1}{\lambda^2 (1-\lambda)^2} \left( \frac{s}{s_0} \right)^{\lambda-1} - 1 \right\} + \left[ \frac{-1}{\lambda - 1} - \frac{s_0}{\lambda s} \right] \ln \frac{s}{s_0} + \frac{2\lambda + 1}{\lambda^2} \left[ 1 - \frac{s_0}{s} \right]$$

$\sigma$ (pb)

$\lambda=1.9$

$\lambda=1.6$

$\lambda=1.75$

$\lambda=1.9$

$\lambda=1.6$

$\lambda=1.75$

Direct c

Direct b

0.6 GeV

$s_0 = 4 (m_q^2 + p_T^2)$

Running masses?

$M_c = 1.55$ GeV

$M_b = 4.9$ GeV

Use $a=0.05$, $b = 33 - 2N_f$

Mimics LEPII DKZZ GRV LO

A naive increase of beauty gives an excess of charm
Hints towards a solution?

Play with fragmentation functions (you can also do that within PYTHIA)

Fit pdfs to LEP and HERA data

Improve QCD calculations with masses and different scales

Recent theoretical computations are getting closer:

(... many good reviews at International Conferences)
The $\gamma \gamma \rightarrow gg$ through the box diagram (cf B. De Tollis...)

All the physics is in the box.

The $\gamma \gamma \rightarrow 4$ quarks connection (cf Jiri Chyla ...)

In a more general way 2 lepton QED corrections to the total $\gamma \gamma$ cross section.
Conclusions

A new measurement of open beauty production with real photon collisions is needed ... maybe soon at SLAC with the LEPC.

And wait a bit for an open top cross section measurement at the PLC.