The Sources of b-quarks at the Tevatron

- Important to have good leading (or leading-log) order predictions of collider observables.
- If the leading order estimates are within a factor of two of the data, higher order calculations might be expected to improve the agreement.
- On the other hand, if the leading order estimates are not within roughly a factor of two of the data, one cannot expect higher order calculations to improve the situation.
- If a leading order estimate is off by more than a factor of two, it usually means that one has overlooked something.
- “Something is goofy” (Rick Field, CDF B Group Talk, December 3, 1999).
- http://www.phys.ufl.edu/~rfield/cdf/

Integrated b-quark Cross Section for PT > PTmin

Leading order “Flavor Creation” is a factor of four below the data!

NLO/LO “Flavor Creation” is roughly a factor of two.

Today’s talk available at my WEBsite.
Data from CDF and D0 for the integrated $b$-quark total cross section ($P_T > P_{T\text{min}}$, $|y| < 1$) for proton-antiproton collisions at 1.8 TeV compared with the QCD Monte-Carlo model predictions of HERWIG, PYTHIA, and ISAJET for the “flavor creation” subprocesses. The parton distribution functions CTEQ3L have been used for all three Monte-Carlo models.

→ Data from CDF and D0 for the integrated $b$-quark total cross section ($P_T > P_{T\text{min}}$, $|y| < 1$) for proton-antiproton collisions at 1.8 TeV compared with the QCD Monte-Carlo model predictions of HERWIG, PYTHIA, and ISAJET for the “flavor creation” subprocesses. The parton distribution functions CTEQ3L have been used for all three Monte-Carlo models.
“Flavor Excitation” corresponds to the scattering of a b-quark (or b-bar-quark) out of the initial-state into the final-state by a gluon or by a light quark or antiquark.

“Flavor excitation” is, of course, very sensitive to the number of b-quarks within the proton \((i.e.\) the structure functions).

The Monte-Carlo models predictions for the “shower/fragmentation” contribution differ considerably. This is not surprising since ISAJET uses independent fragmentation, while HERWIG and PYTHIA do not; and HERWIG and PYTHIA modify the leading-log picture of parton showers to include “color coherence effects”, while ISAJET does not.
Data on the integrated b-quark total cross section ($P_T > PT_{\text{min}}$, $|y| < 1$) for proton-antiproton collisions at 1.8 TeV compared with the QCD Monte-Carlo model predictions of PYTHIA (CTEQ3L) and PYTHIA (GRV94L). The four curves correspond to the contribution from flavor creation, flavor excitation, shower/fragmentation, and the resulting total.
Data on the integrated b-quark total cross section \((P_T > P_{T_{\text{min}}}, \ |y| < 1)\) for proton-antiproton collisions at 1.8 TeV compared with the QCD Monte-Carlo model predictions of ISAJET (CTEQ3L) and HERWIG (CTEQ3L). The four curves correspond to the contribution from flavor creation, flavor excitation, shower/fragmentation, and the resulting total.
Predictions of HERWIG, PYTHIA, and ISAJET for the integrated b-quark total cross section \( (P_T > P_{T\text{min}}, |y| < 1) \) for proton-antiproton collisions at 1.8 TeV resulting from “flavor excitation” and “shower/fragmentation”. The parton distribution functions CTEQ3L have been used for all three Monte-Carlo models.
Predictions of ISAJET (CTEQ3L), HERWIG (CTEQ3L), PYTHIA (CTEQ3L), HERWIG (DO1.1), and PYTHIA (GRV94L) for the integrated b-quark total cross section \( (P_T > 5 \text{ GeV/c}, |y| < 1) \) for proton-antiproton collisions at 1.8 TeV. The contributions from flavor creation, flavor excitation, and shower/fragmentation are shown together with the resulting sum (overall height of box).

The differences in the flavor excitation contribution are due to the different ways the models handle the b-quark mass in this subprocess. However, it seems likely that at the Tevatron the flavor excitation contribution to the b-quark cross section is comparable to or greater than the contribution from flavor creation.

The QCD Monte-Carlo predictions differ considerably for the “shower/fragmentation” contribution. However, at the Tevatron the fragmentation contribution to the b-quark cross section might be comparable to the contribution from flavor creation.
Predictions of PYTHIA (CTEQ3L), and HERWIG (CTEQ3L) for the b-quark rapidity distribution ($P_T > 5$ GeV/c) for proton-antiproton collisions at 1.8 TeV. The four curves correspond to the contribution from flavor creation, flavor excitation, shower/fragmentation, and the resulting total.
Predictions of PYTHIA (CTEQ3L) for the probability of finding a bbar-quark with $P_T > 5$ GeV/c and $|y|<1$ for proton-antiproton collisions at 1.8 TeV. The contribution from the “toward” ($|\Delta \phi|<90^\circ$) and the “away” ($|\Delta \phi|>90^\circ$) region of the b-quark are shown for flavor creation, flavor excitation, and shower/fragmentation.

For events with a b-quark ($P_T > 5$ GeV/c $|y|<1$), probability of observing a bbar-quark ($P_T > 5$ GeV/c $|y|<1$).
Simple Correlations

- Predictions of HERWIG (CTEQ3L) and ISAJET (CTEQ3L) for the probability of finding a b-quark with $P_T > 5$ GeV/c and $|y|<1$ for events with a b-quark with $P_T > 5$ GeV/c and $|y|<1$ for proton-antiproton collisions at 1.8 TeV. The contribution from the “toward” ($|\Delta\phi|<90^\circ$) and the “away” ($|\Delta\phi|>90^\circ$) region of the b-quark are shown for flavor creation, flavor excitation, and shower/fragmentation.
Data from CDF on the single b-quark inclusive cross section and the b-bbar pair cross section at 1.8 TeV.

Divide the pair cross section $\sigma_2$ by the single inclusive cross section $\sigma_1$. 
Data from CDF on the $b$-$b\bar{b}$ pair cross section and the $b$-$b\bar{b}$ probability at 1.8 TeV compared with the QCD Monte-Carlo predictions of PYTHIA (CTEQ3L). The four curves correspond to the contribution from flavor creation, flavor excitation, shower/fragmentation, and the resulting total.
QCD Monte-Carlo predictions of PYTHIA (CTEQ3L) for the b-bbar pair azimuthal cross section $d\sigma/d\phi$ for $|y|<1$. The four curves correspond to the contribution from flavor creation, flavor excitation, shower/fragmentation, and the resulting total at 1.8 TeV.
Data from CDF on the single b-quark inclusive cross section and the b-bbar pair cross section at 1.8 TeV compared with the QCD Monte-Carlo predictions of PYTHIA (CTEQ3L) where the flavor creation term has been multiplied by a factor of 2 to take into account higher order corrections.
One should not take the QCD Monte-Carlo model estimates of “flavor excitation” and “shower/fragmentation” too seriously. The contributions from these subprocesses are very uncertain and more work needs to be done. There are many subtleties!

However, it seems likely that all three sources are important at the Tevatron.

In Run II we should be able experimentally to isolate the individual contributions to b-quark production by studying b-stand correlations in detail.

All three sources are important at the Tevatron!