Important to have good leading (or leading-log) order Monte-Carlo model 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).
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” 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 \((P_T > P_{\text{Tmin}}, |y| < 1)\) for proton-antiproton collisions at 1.8 TeV compared with the QCD Monte-Carlo model predictions of PYTHIA 6.115 (CTEQ3L). 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 PYTHIA 6.115 (CTEQ3L) and PYTHIA 6.158 (CTEQ4L). The four curves correspond to the contribution from flavor creation, flavor excitation, shower/fragmentation, and the resulting total.
Preliminary Conclusions

All three sources are important at the Tevatron!

- 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.
- “Nothing is goofy” (*Rick Field, CDF B Group Talk, March 9, 2001*).
- Next step is to study b-bbar correlations and compare the predictions of Herwig, Isajet, and Pythia in order to understand how precise the predictions are!
- Want to know what the leading-log QCD Monte-Carlo Models predict and how they compare with data.
Prediction of PYTHIA 6.158 (CTEQ4L, PT(hard) > 0 GeV/c) for the transverse momentum, $\text{PT}_2$, of a $b\bar{b}$-quark with $|y_2| < 1.0$ for events with a $b$-quark with $\text{PT}_1 > 5$ GeV/c and $|y_1| < 1$ in proton-antiproton collisions at 1.8 TeV. The curves correspond to $d\sigma/d\text{PT}_2$ (µb/GeV/c) for flavor creation, flavor excitation, shower/fragmentation, and the resulting total.
Prediction of PYTHIA 6.158 (CTEQ4L, PT(hard) > 0 GeV/c) for the transverse momentum, PT$_2$, of a $b\bar{b}$-quark with |$y_2$| < 1.0 for events with a $b$-quark with PT$_1$ > 12 GeV/c and |$y_1$| < 1 in proton-antiproton collisions at 1.8 TeV. The curves correspond to d$\sigma$/dPT$_2$ (µb/GeV/c) for flavor creation, flavor excitation, shower/fragmentation, and the resulting total.
Prediction of PYTHIA 6.158 (CTEQ4L, PT(hard) > 0) for the asymmetry $A = (PT_1 - PT_2)/(PT_1 + PT_2)$ for events with a $b$-quark with $PT_1 > 0$ GeV/c and $|y_1| < 1.0$ and a $b\bar{b}$ quark with $PT_2 > 5$ GeV/c and $|y_2| < 1.0$ in proton-antiproton collisions at 1.8 TeV. The curves correspond to $d\sigma/dA$ (µb) for flavor creation, flavor excitation, shower/fragmentation, and the resulting total.
Prediction of PYTHIA 6.158 (CTEQ4L, PT(hard) > 0) for the distance, R, in $\eta$-$\phi$ space between the $b$ and $\bar{b}$-quark with $PT_1 > 5$ GeV/c, $PT_2 > 5$ GeV/c, and $|y_1| < 1$ in proton-antiproton collisions at 1.8 TeV. The curves correspond to $d\sigma/dR \ (\mu b)$ for flavor creation, flavor excitation, shower/fragmentation, and the resulting total.
Prediction of PYTHIA 6.158 (CTEQ4L, PT(hard) > 0) for the distance, R, in \( \eta - \phi \) space between the b and bbar-quark with \(|y_1| < 1\) and \(|y_2| < 1\) in proton-antiproton collisions at 1.8 TeV. The curves correspond to \(d\sigma/dR(\mu b)\) for flavor creation, flavor excitation, shower/fragmentation, and the resulting total.
Predictions of PYTHIA 6.158 (CTEQ4L, PT(hard) > 0 GeV/c) for the azimuthal angle, Δφ, between a b-quark with PT₁ > 5 GeV/c and |y₁| < 1 and a bbar-quark with PT₂ > 0 GeV/c and |y₂| < 1 in proton-antiproton collisions at 1.8 TeV. The curves correspond to dσ/dΔφ (μb/°) for flavor creation, flavor excitation, shower/fragmentation, and the resulting total.
Azimuthal Correlations

Predictions of PYTHIA 6.158 (CTEQ4L, PT(hard) > 0 GeV/c) for the azimuthal angle, $\Delta \phi$, between a b-quark and bbar-quark with $|y_1| < 1$ and $|y_2|<1$ in proton-antiproton collisions at 1.8 TeV. The curves correspond to $d\sigma/d\Delta \phi (\mu b/°)$ for flavor creation, flavor excitation, shower/fragmentation, and the resulting total.
CDF Run I data for the azimuthal angle, $\Delta \phi$, between a $b$-quark and $b\bar{b}$-quark in proton-antiproton collisions at 1.8 TeV. The points correspond to $1/\sigma \, d\sigma/d\Delta \phi$ (1/$^\circ$) (normalized to 1).

See the talk by Kevin Lannon (UI/CDF) DPF2002 QCD Session VIII!
Predictions of PYTHIA 6.115 (old Pythia), PYTHIA 6.158 (new Pythia), and HERWIG 6.4 for the azimuthal angle, $\Delta \phi$, between a $b$-quark and $b\bar{b}$-quark with $P_{T1} > 12$ GeV/c, $|y_1| < 1$ and $P_{T2} > 0$, $|y_2| < 1$ proton-antiproton collisions at 1.8 TeV. The curves correspond to $1/\sigma d\sigma/d\Delta \phi (1/\mu b/deg)$ normalized to 1 for flavor creation only.

Old Pythia (<6.138) has PARP(67) = 4. New Pythia (>6.138) including 6.206 has PARP(67) = 1. PARP(67) is a scale factor that governs the amount of large angle initial-state radiation. Larger values of PARP(67) results in more large angle initial-state radiation! Does this represent an uncertainty?
All three sources are important at the Tevatron!

- A measurement of the “toward-side” azimuthal, $\Delta \phi$, correlations should easily establish the importance of the flavor excitation and shower/fragmentation components.

- The flavor excitation terms have, on the average, a large PT asymmetry between the $b$ and $\bar{b}$-quark. Asymmetries with a magnitude greater than 60% isolate the flavor excitation contribution.

- The parton shower/fragmentation contribution can be isolated by looking for $b$-$\bar{b}$ pairs with $R < 1$, where $R$ is the distance between the $b$ and $\bar{b}$-quark in $\eta$-$\phi$ space.

- In Run II (and Run I) we should be able experimentally to isolate the individual contributions to $b$-quark production by studying $b$-$\bar{b}$ correlations in detail.