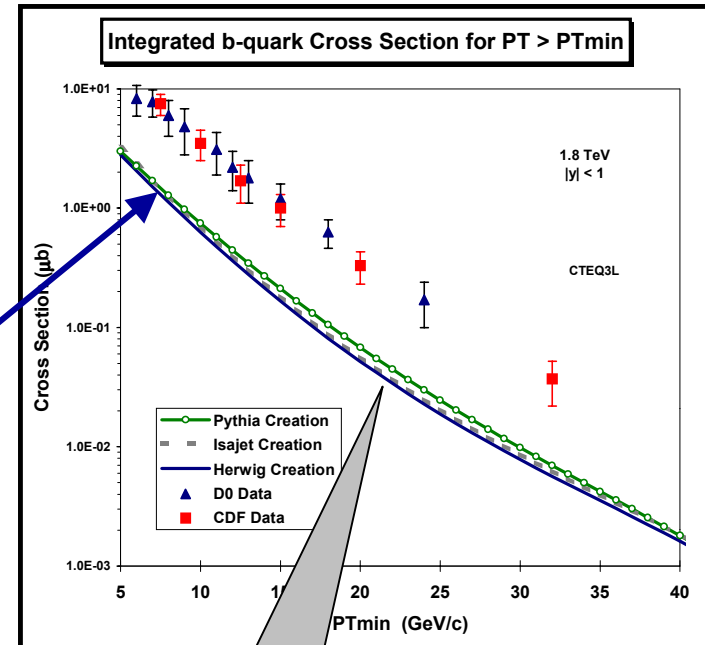




# The Sources of b-Quarks at the Tevatron



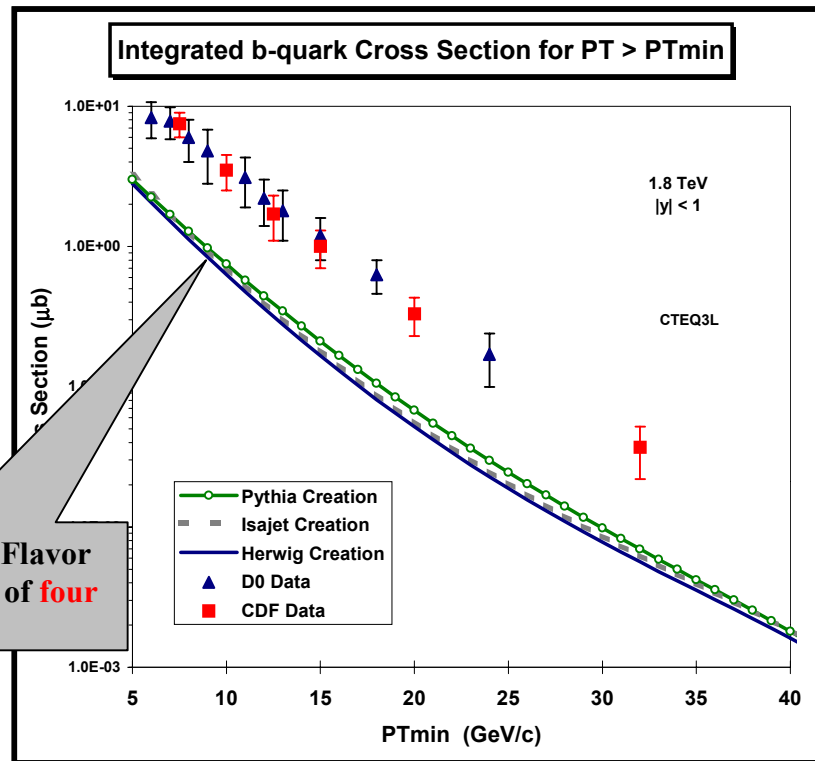
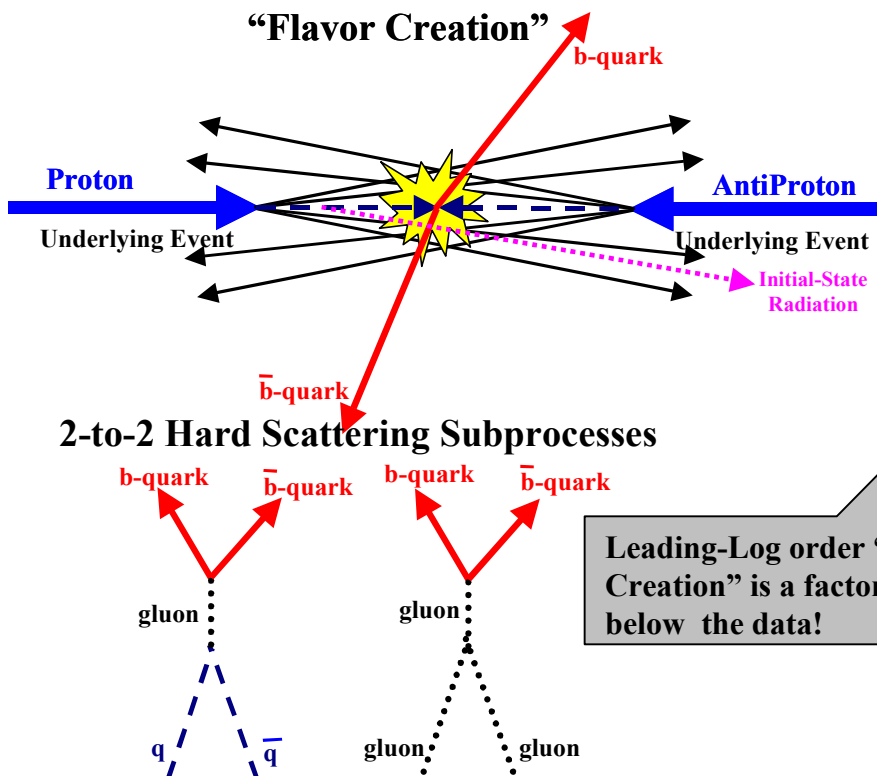
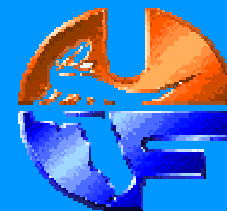
- ➔ Important to have good leading (or leading-log) order Monte-Carlo model predictions of collider observables.
- ➔ If the leading order estimates are within a factor of two of the data, higher order calculations might be expected to improve the agreement.
- ➔ On the other hand, if the leading order 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*).



QCD Monte-Carlo leading order **“Flavor Creation”** is a factor of **four** below the data!



# “Flavor Creation”

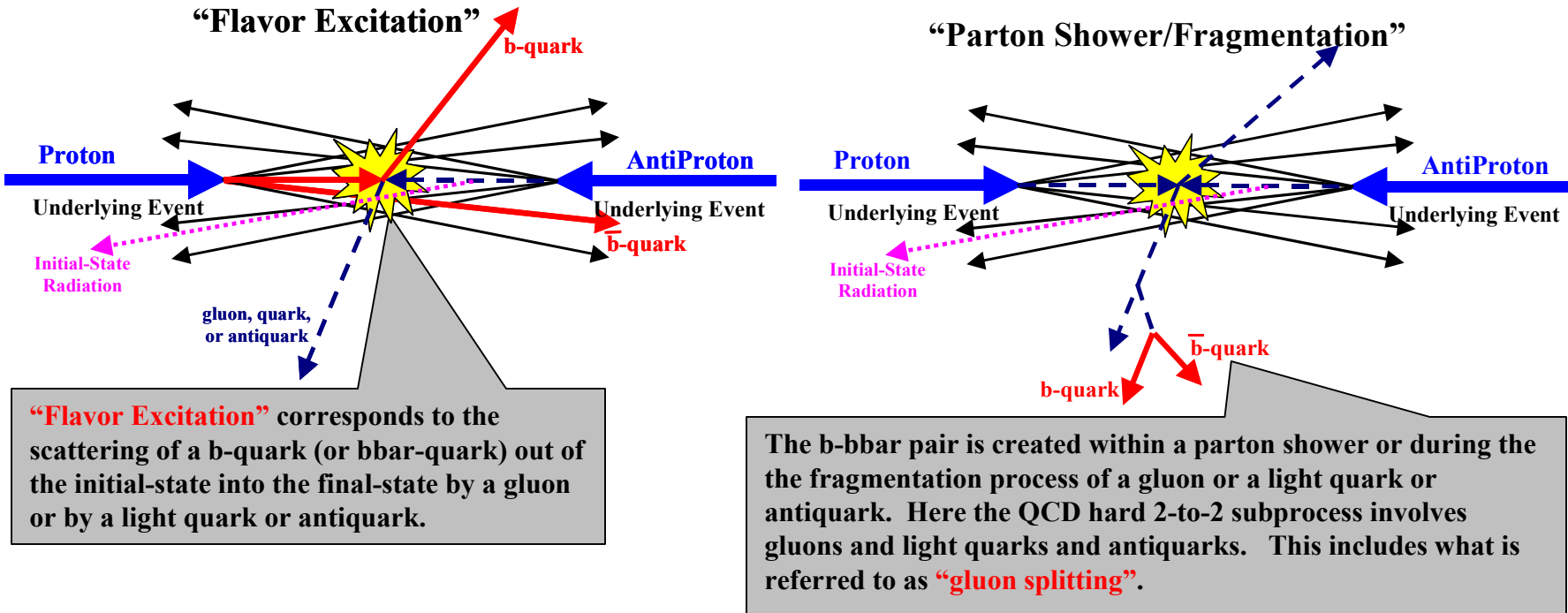


Leading-Log order “Flavor Creation” is a factor of **four** below the data!

- ➔ Data from CDF and D0 for the integrated b-quark total cross section ( $P_T > P_{Tmin}$ ,  $|y| < 1$ ) 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. .



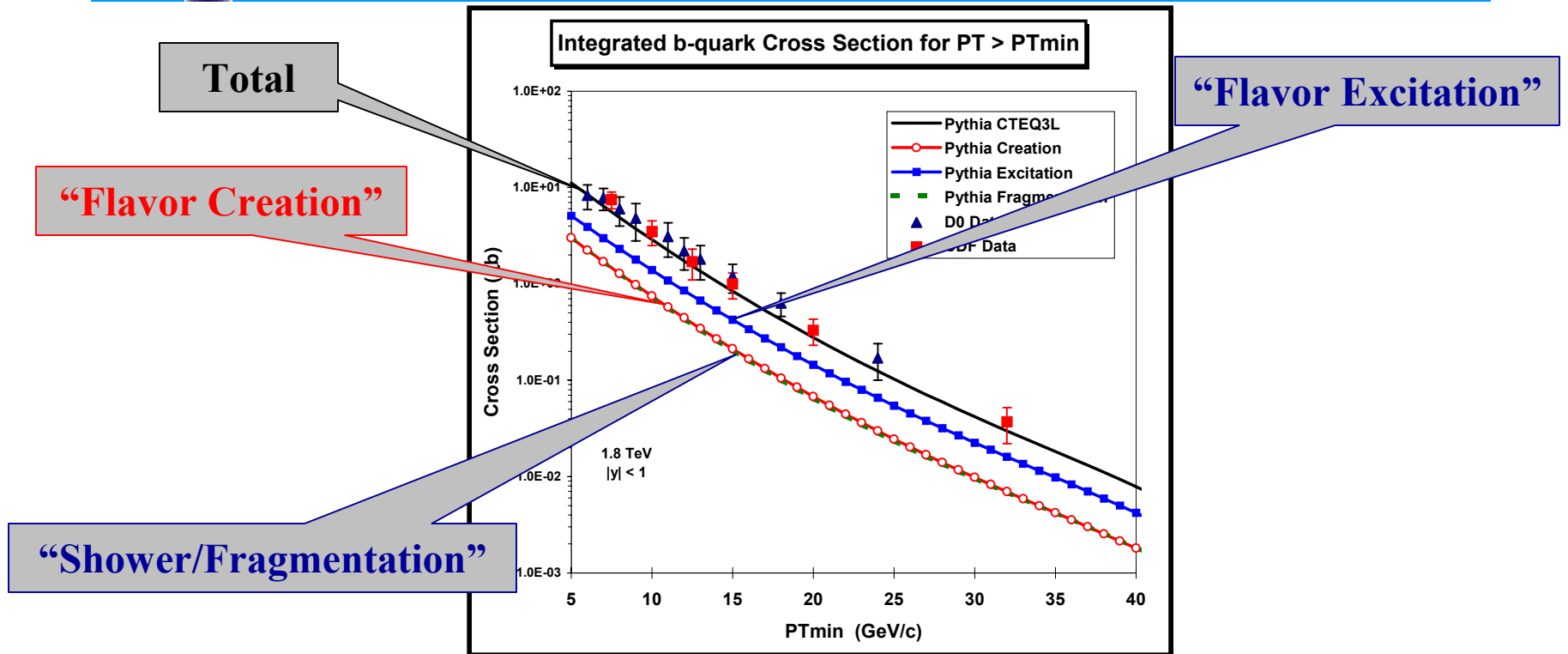
# Other Sources of b-Quarks

- ➔ **“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.



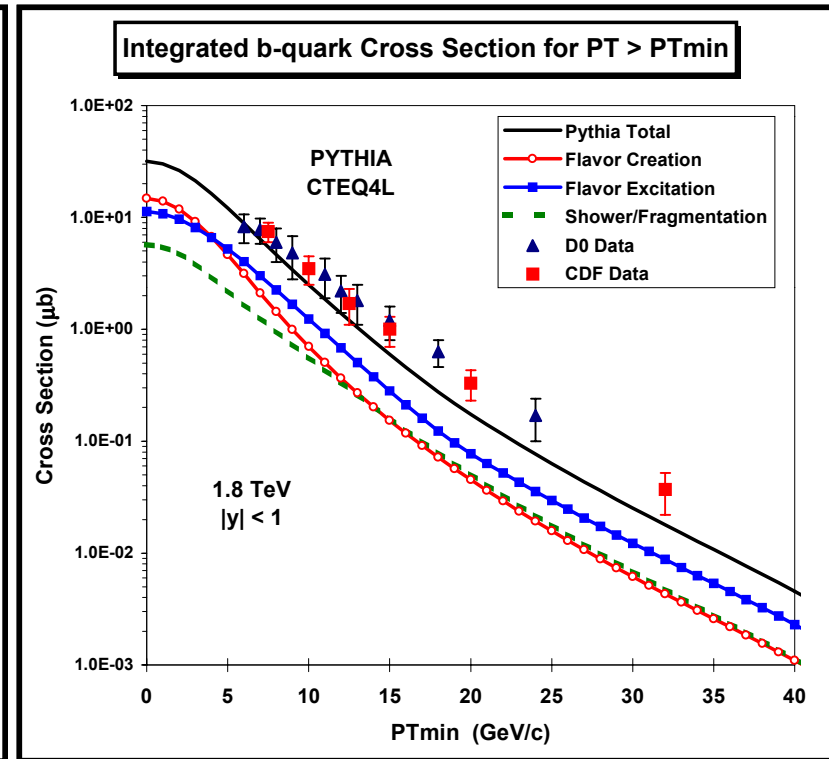
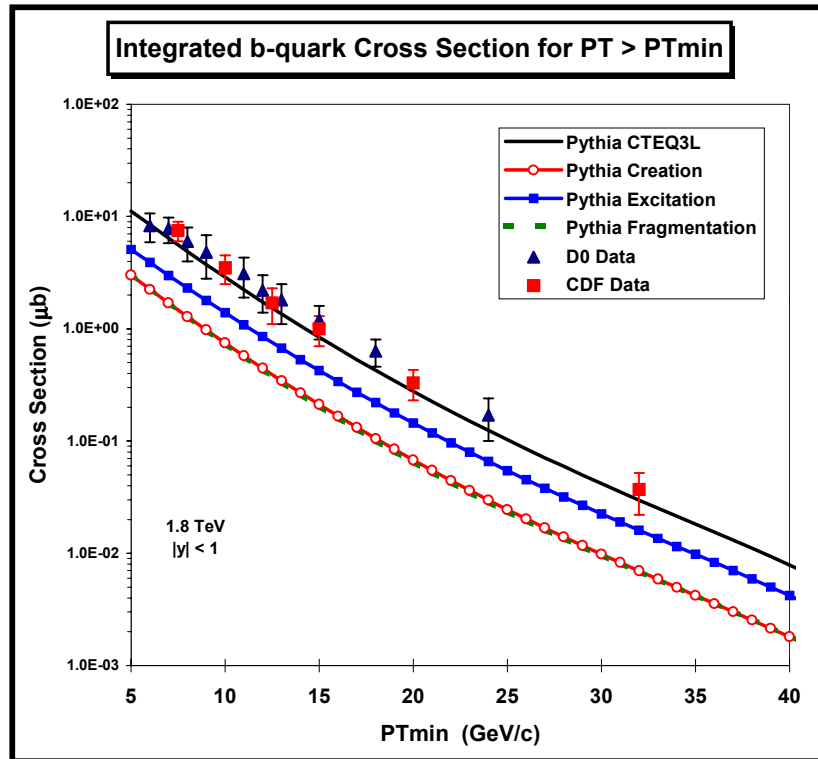
# Inclusive b-quark Cross Section



- ➔ Data on the integrated b-quark total cross section ( $P_T > P_{Tmin}$ ,  $|y| < 1$ ) 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.



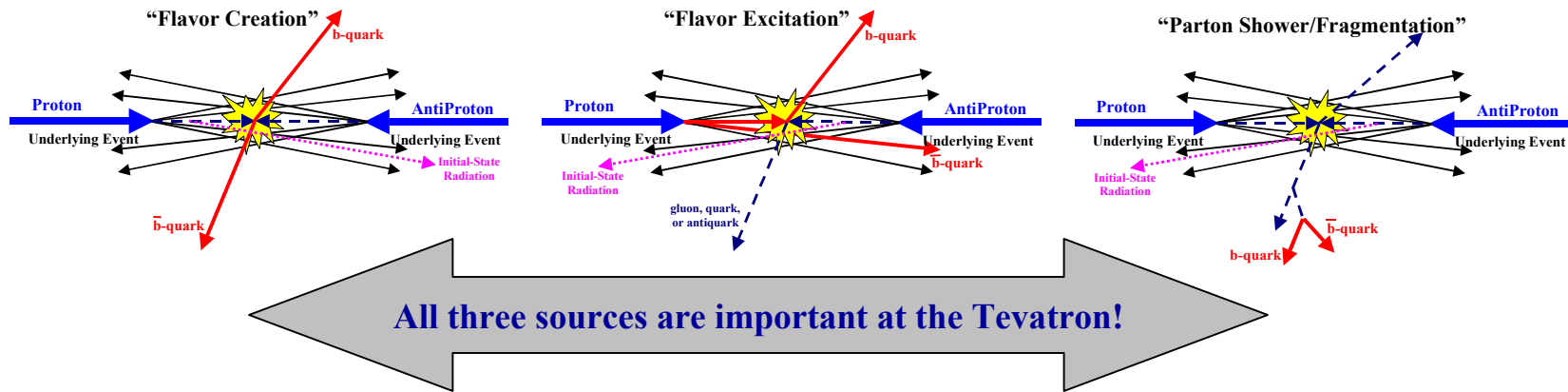
# Inclusive b-quark Cross Section



→ Data on the integrated b-quark total cross section ( $P_T > P_{Tmin}$ ,  $|y| < 1$ ) 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.



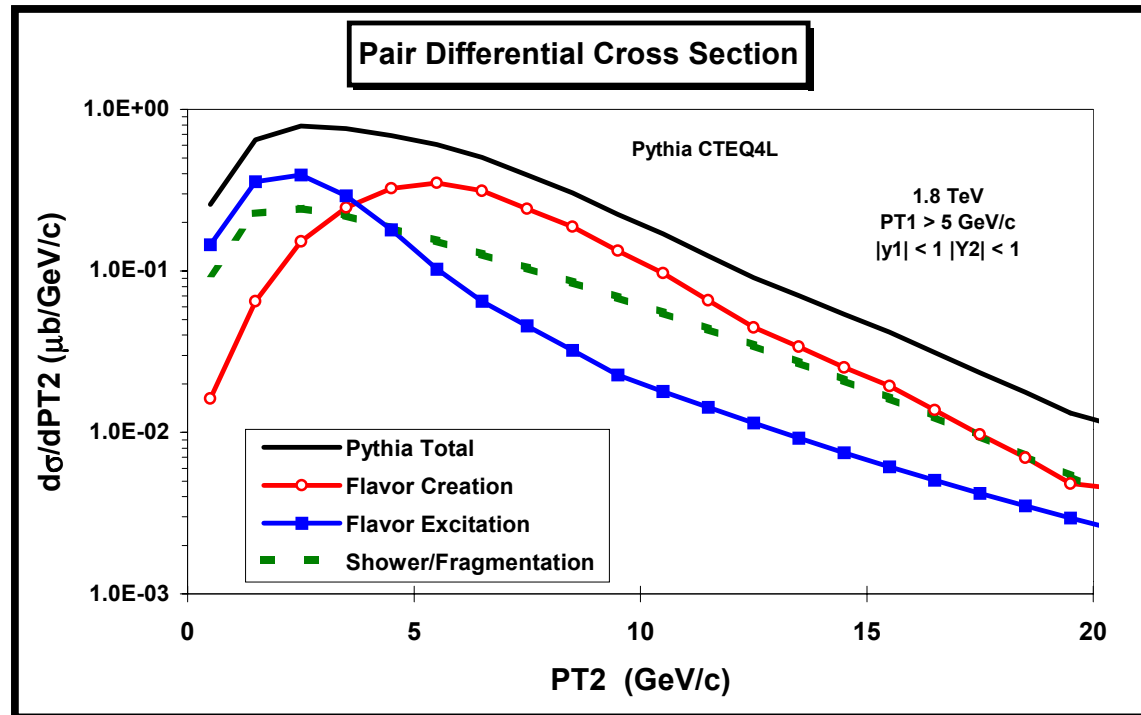
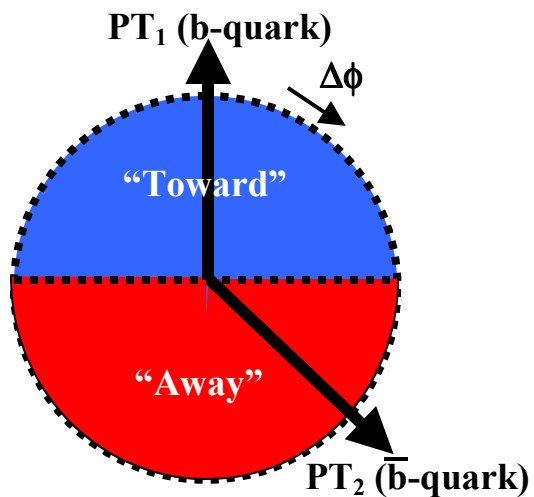
# Preliminary Conclusions



- ➔ 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  $b$ - $\bar{b}$  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.



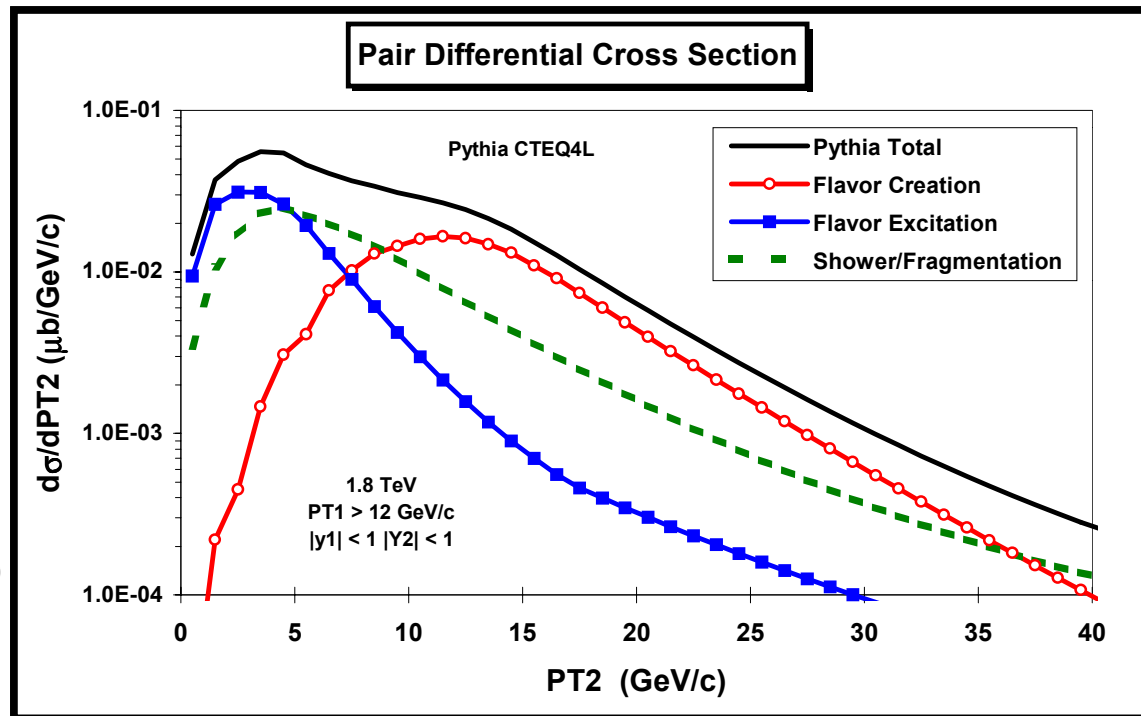
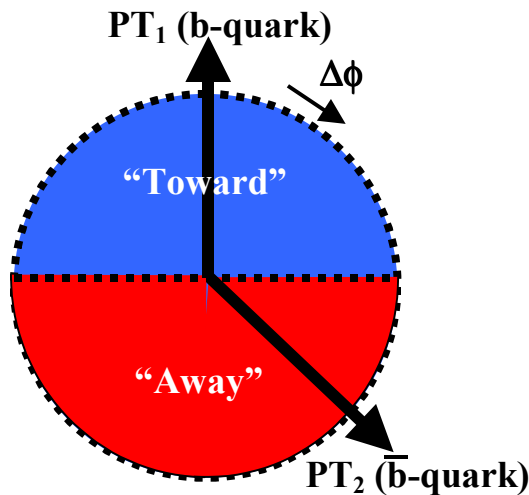
# Pair Differential Cross Section

- ➔ Prediction of PYTHIA 6.158 (CTEQ4L,  $PT(\text{hard}) > 0$  GeV/c) for the transverse momentum,  $PT_2$ , of a  $\bar{b}$ -quark with  $|y_2| < 1.0$  for events with a b-quark with  $PT_1 > 5$  GeV/c and  $|y_1| < 1$  in proton-antiproton collisions at 1.8 TeV. The curves correspond to  $d\sigma/dPT_2$  ( $\mu\text{b}/\text{GeV}/c$ ) for **flavor creation**, **flavor excitation**, **shower/fragmentation**, and the resulting total.



# Pair Differential Cross Section



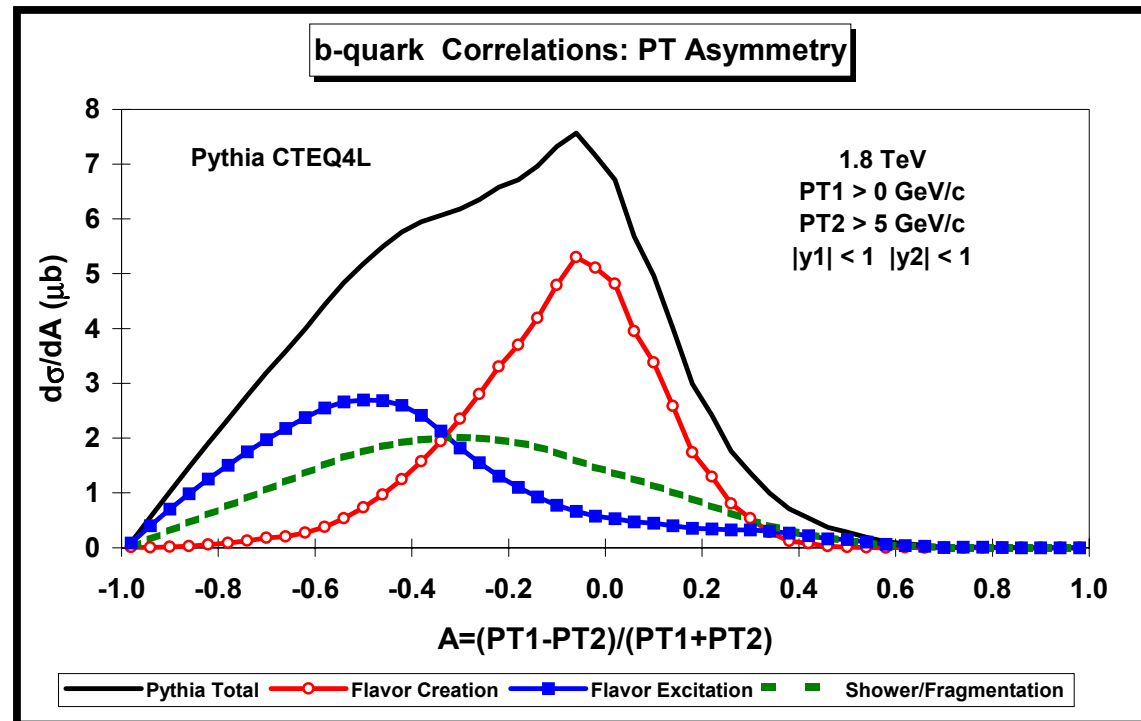
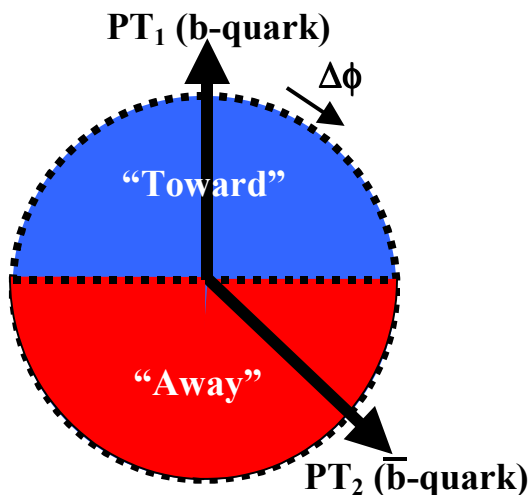
- ➔ Prediction of PYTHIA 6.158 (CTEQ4L, PT(hard) > 0 GeV/c) for the transverse momentum, PT<sub>2</sub>, of a  $\bar{b}$ -quark with  $|y_2| < 1.0$  for events with a b-quark with PT<sub>1</sub> > 12 GeV/c and  $|y_1| < 1$  in proton-antiproton collisions at 1.8 TeV. The curves correspond to  $d\sigma/dPT_2$  ( $\mu\text{b}/\text{GeV}/c$ ) for **flavor creation**, **flavor excitation**, **shower/fragmentation**, and the resulting total.



# PT Asymmetry



$$A = (PT_1 - PT_2) / (PT_1 + PT_2)$$



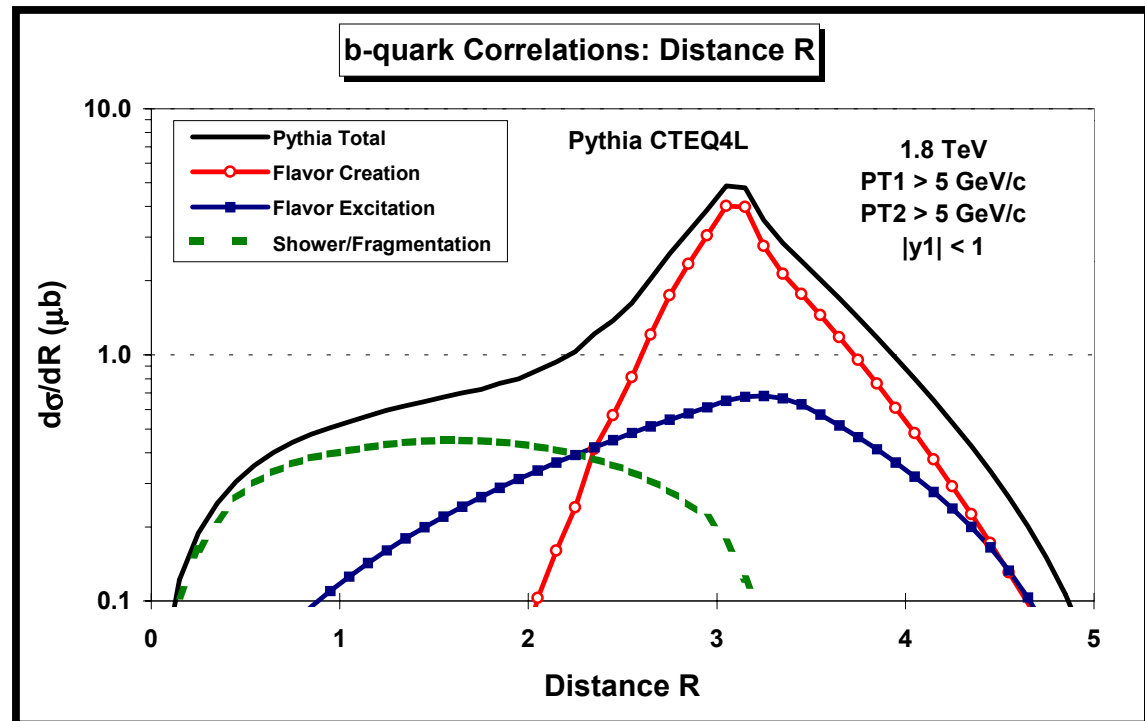
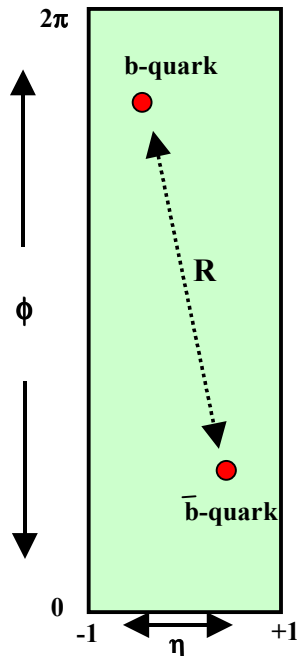
- ➔ Prediction of PYTHIA 6.158 (CTEQ4L, PT(hard) > 0) for the asymmetry  $A = (PT_1 - PT_2) / (PT_1 + PT_2)$  for events with a b-quark with  $PT_1 > 0$  GeV/c and  $|y_1| < 1.0$  and a  $\bar{b}$  quark with  $PT_2 > 5$  GeV/c and  $|y_2| < 1.0$  in proton-antiproton collisions at 1.8 TeV. The curves correspond to  $d\sigma/dA$  ( $\mu\text{b}$ ) for **flavor creation**, **flavor excitation**, **shower/fragmentation**, and the resulting total.



# Distance R in $\eta$ - $\phi$ Space



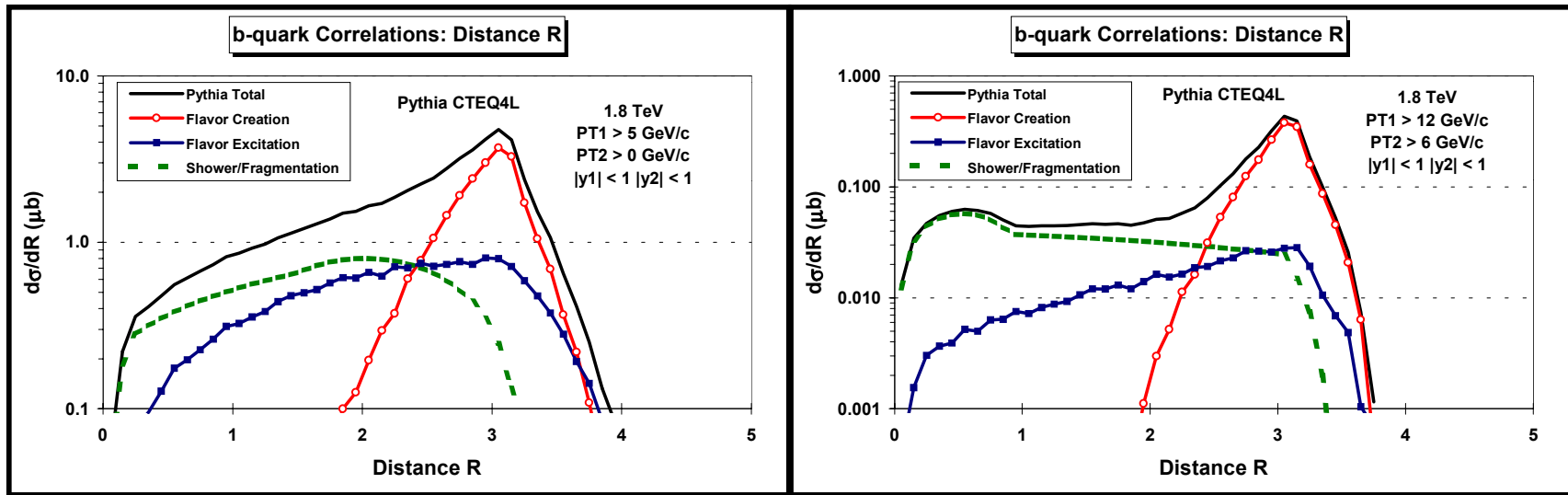
$\eta$ - $\phi$  Space



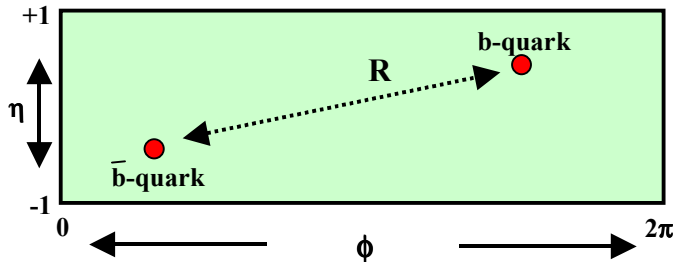
- ➔ Prediction of PYTHIA 6.158 (CTEQ4L, PT(hard) > 0) for the distance, R, in  $\eta$ - $\phi$  space between the b and bbar-quark with PT<sub>1</sub> > 5 GeV/c, PT<sub>2</sub> > 5 GeV/c, and |y<sub>1</sub>| < 1 in proton-antiproton collisions at 1.8 TeV. The curves correspond to  $d\sigma/dR$  ( $\mu\text{b}$ ) for **flavor creation**, **flavor excitation**, **shower/fragmentation**, and the resulting total.



# Distance R in $\eta$ - $\phi$ Space



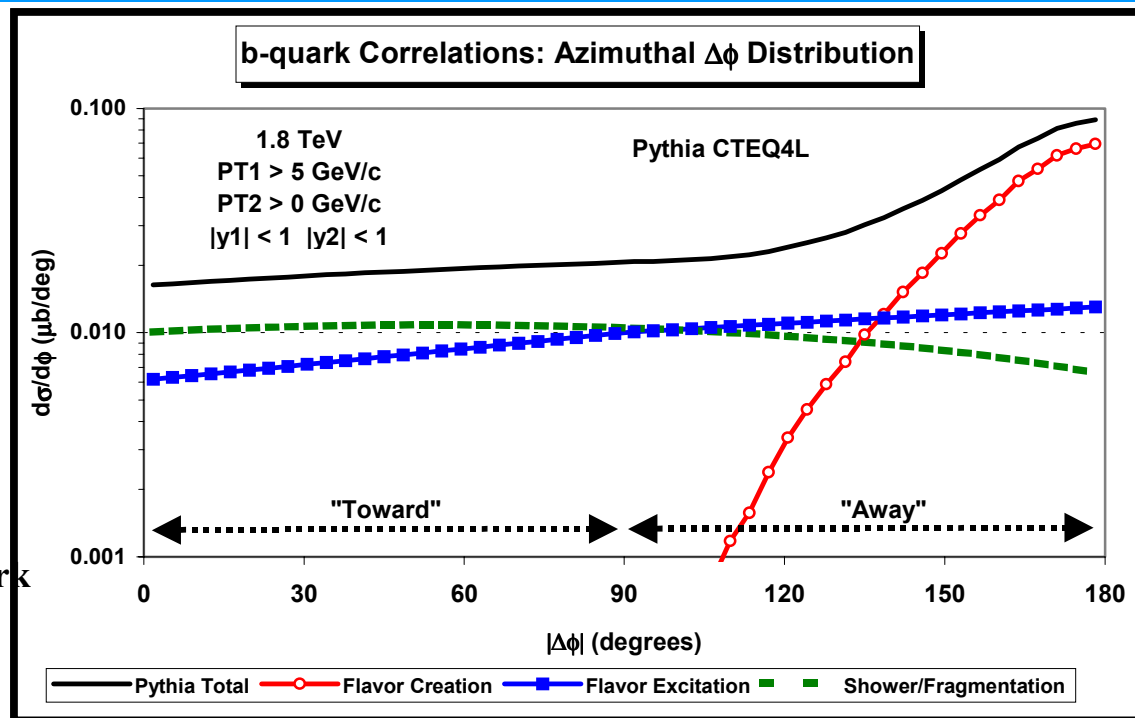
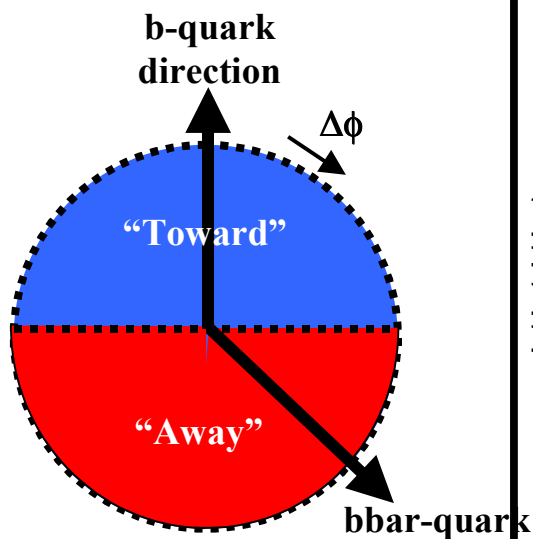
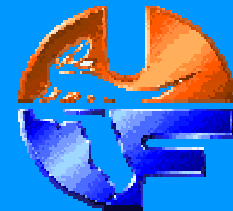
## $\eta$ - $\phi$ Space



➔ Prediction of PYTHIA 6.158 (CTEQ4L,  $PT(\text{hard}) > 0$ ) for the distance,  $R$ , in  $\eta$ - $\phi$  space between the  $b$  and  $b$ -quark with  $|y_1| < 1$  and  $|y_2| < 1$  in proton-antiproton collisions at 1.8 TeV. The curves correspond to  $d\sigma/dR$  ( $\mu\text{b}$ ) for **flavor creation**, **flavor excitation**, **shower/fragmentation**, and the resulting total.



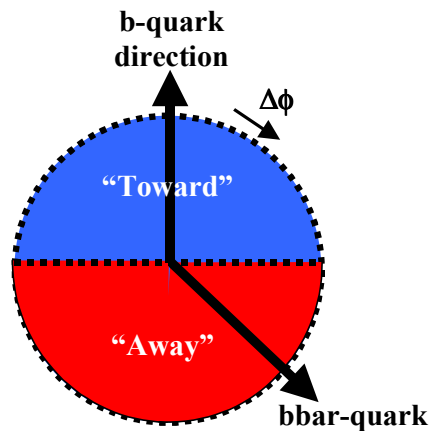
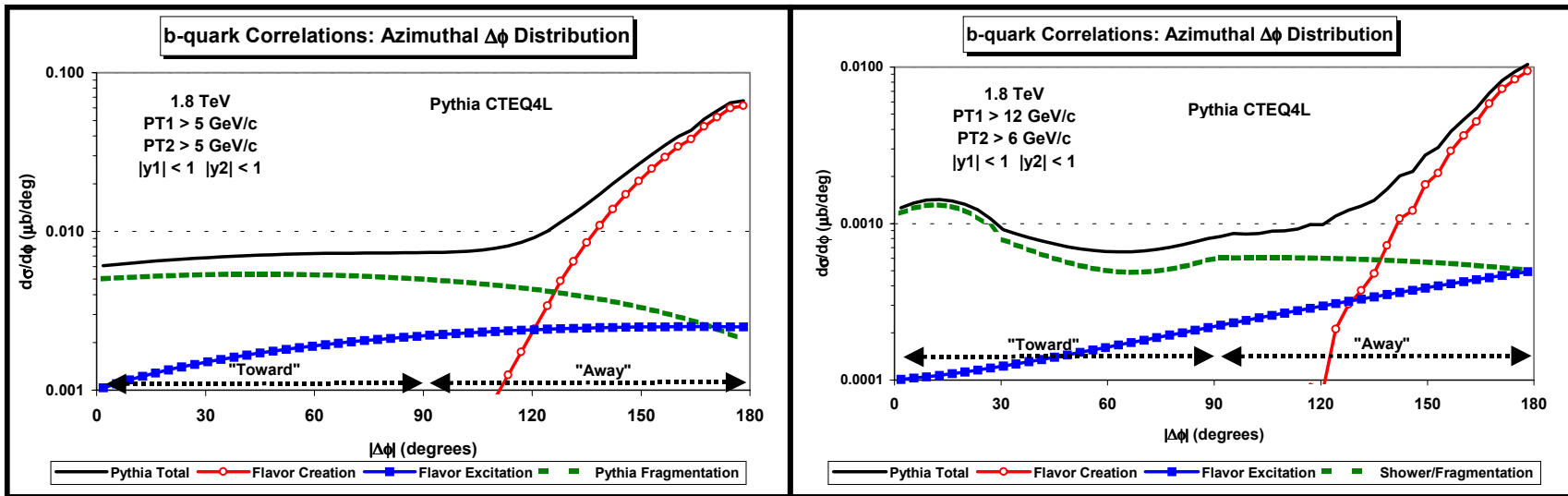
# Azimuthal Correlations



- ➔ Predictions of PYTHIA 6.158 (CTEQ4L,  $PT(\text{hard}) > 0 \text{ GeV}/c$ ) for the azimuthal angle,  $\Delta\phi$ , between a b-quark with  $PT_1 > 5 \text{ GeV}/c$  and  $|y_1| < 1$  and a bbar-quark with  $PT_2 > 0 \text{ GeV}/c$  and  $|y_2| < 1$  in proton-antiproton collisions at 1.8 TeV. The curves correspond to  $d\sigma/d\Delta\phi$  ( $\mu\text{b}/^\circ$ ) for **flavor creation**, **flavor excitation**, **shower/fragmentation**, and the resulting total.



# Azimuthal Correlations



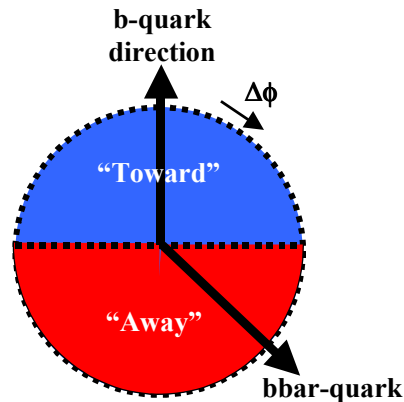
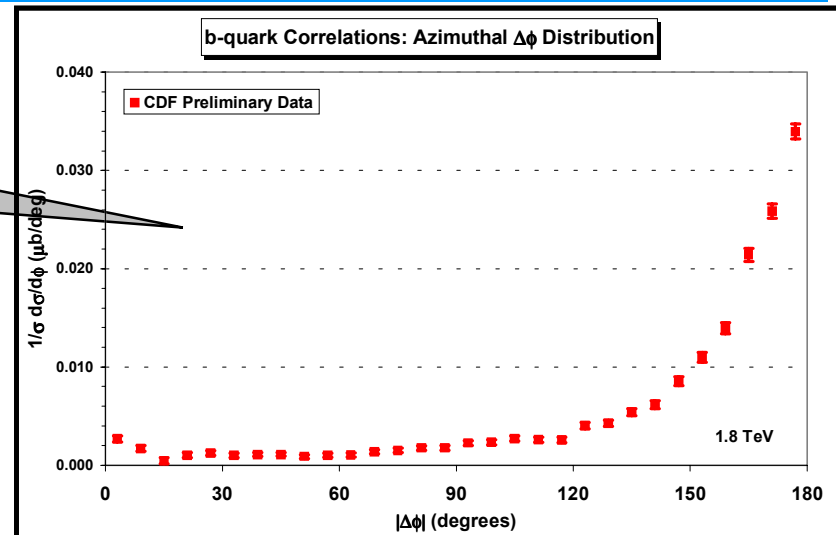
➔ Predictions of PYTHIA 6.158 (CTEQ4L,  $PT(\text{hard}) > 0$  GeV/c) for the azimuthal angle,  $\Delta\phi$ , between a b-quark and  $b\bar{b}$ -quark with  $|y_1| < 1$  and  $|y_2| < 1$  in proton-antiproton collisions at 1.8 TeV. The curves correspond to  $d\sigma/d\Delta\phi$  ( $\mu\text{b}/^\circ$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



# CDF Run I Analysis Azimuthal Correlations



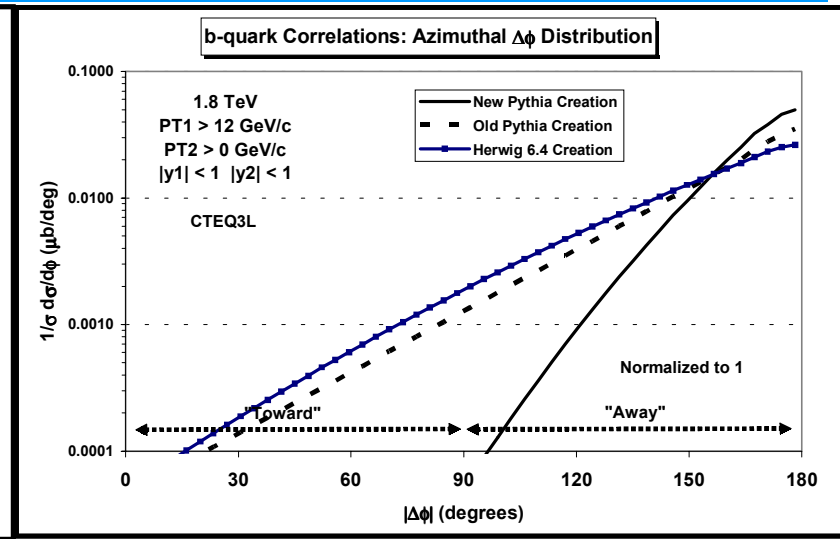
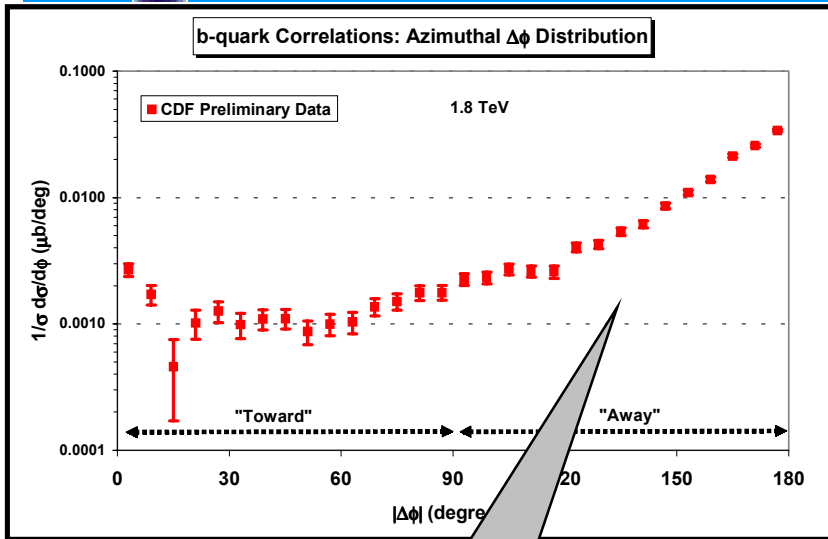
See the talk by **Kevin Lannon**  
(UI/CDF) DPF2002 QCD  
Session VIII!



➔ **CDF Run I data** for the azimuthal angle,  $\Delta\phi$ , between a b-quark and bbar-quark in proton-antiproton collisions at 1.8 TeV. The points correspond to  $1/\sigma \frac{d\sigma}{d\Delta\phi}$  ( $1^\circ$ ) (normalized to 1).



# Azimuthal Correlations



➔ 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 bbar-quark with  $PT_1 > 12$  GeV/c,  $|y_1| < 1$  and  $PT_2 > 0$ ,  $|y_2| < 1$  proton-antiproton collisions at 1.8 TeV. The curves correspond to  $1/\sigma \frac{d\sigma}{d\Delta\phi}$  ( $1^\circ$ ) normalized to 1 for flavor creation only.

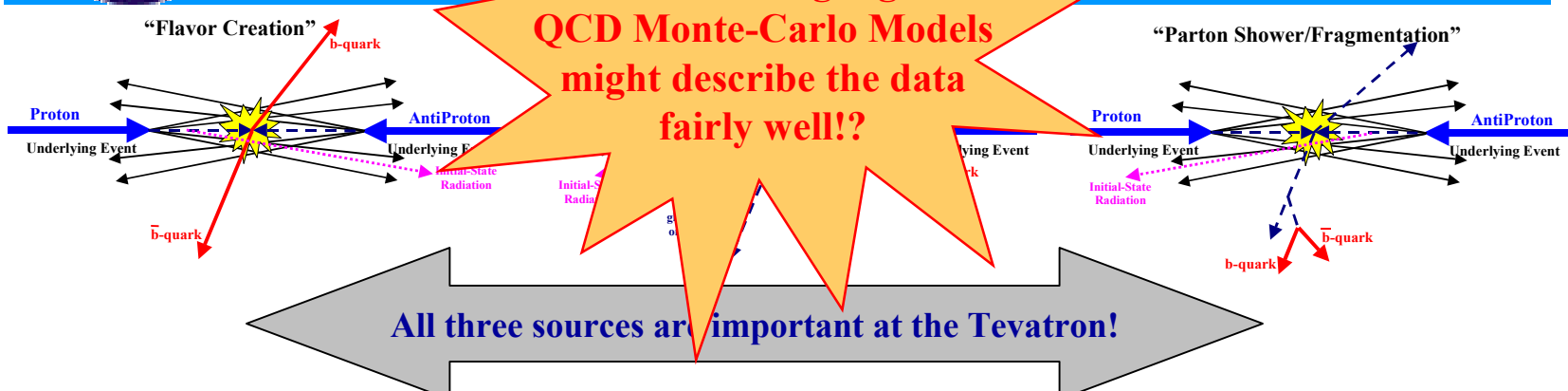
➔ Old Pythia (<6.138) has PARP(67) = 4. New Pythia (>6.138) including 6.206 has PARP(67) = 1. PARP(67) is a scale factor that governs the amount of large angle initial-state radiation. Larger values of PARP(67) results in more large angle initial-state radiation! Does this represent an uncertainty?

See my DPF2002 QCD Session IV talk!

See the talk by Kevin Lannon (UI/CDF) DPF2002 QCD Session VIII!



# Summary & Conclusions

- ➔ 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 bbar-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-bbar pairs with  $R < 1$ , where R is the distance between the b and bbar-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-bbar correlations in detail.