QQ Validation

John Paul Chou
Harvard University

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- Introduction
- B Quark Fragmentation
- Branching Fractions
- Lifetimes
- SecVtx Efficiency

Introduction

Validation of QQ by measuring branching fractions, lifetimes, and hadronization rates

- Do b quarks hadronize as we expect?
- Do b hadrons decay as expected?
- Might differences have an effect on SecVtx Efficiency and Scale Factor?
- See note 7453 (update to include new results/changes forthcoming)

Top Group is using old decay table to in MC

- Not maintained since Run I
- Newer, better table exists (need to quantify how much “newer” and “better”)

Methodology

- Generate two $t\bar{t}$ MC samples (ttopti) with new and old decay tables
- Reconstruct B decay tree bottom-up with HEPG banks
- Use OBSP information to validate lifetimes
- Requirement of $P_T > 0.5$ and $|\eta| < 2.0$ removed to better compare with PDG

b quark Hadronization

Relative Abundance of B hadrons in Pythia (ttopel) and Herwig (ttopti) $t\bar{t}$ MC

- Hadronization properly responsibility of generator, not QQ
- Two MC samples are comparable to PDG, although not each other
- Different decay files do not affect fragmentation rates

Fragmentation	ttopel	ttopti	PDG
$\bar{b} \rightarrow B^0$	$(39.08 \pm 0.15)\%$	$(38.64 \pm 0.22)\%$	$(39.7 \pm 1.0)\%$
$\bar{b} \rightarrow B^\pm$	$(39.23 \pm 0.15)\%$	$(38.90 \pm 0.22)\%$	$(39.7 \pm 1.0)\%$
$\bar{b} \rightarrow B_s$	$(11.59 \pm 0.10)\%$	$(10.71 \pm 0.14)\%$	$(10.7 \pm 1.1)\%$
$\bar{b} \rightarrow B_c$	$(0.023 \pm 0.005)\%$	$(0.004^{+0.004}_{-0.003})\%$	—
$\bar{b} \rightarrow$ baryon	$(10.07 \pm 0.09)\%$	$(11.74 \pm 0.15)\%$	$(9.9 \pm 1.7)\%$

Table 1: Production fraction of B^0, $B^\pm$, B_s, B_c, $B-$baryon admixture (energies above $\Upsilon(4S)$).

Inclusive Branching Fractions

Branching Fractions of B admixture have statistical deviations from PDG

- Both new and old decay tables are not consistent with PDG (although newer one is usually better)

	Decay Mode	Old ttopti BF	New ttopti BF	PDG BF
$\times$	$D^0\ X$	$(0.351^{+0.052}_{-0.47})\%$	$(5.49 \pm 0.06)\%$	—
$\surd$	$\overline{D}^0\ X$	$(50.91 \pm 0.41)\%$	$(53.73 \pm 0.13)\%$	$(61.0 \pm 3.2)\%$
$\times$	$D^+\ X$	$(0.529 \pm 0.059)\%$	$(2.58 \pm 0.04)\%$	—
$\surd$	$D^-\ X$	$(21.43 \pm 0.33)\%$	$(21.78 \pm 0.11)\%$	$(23.1 \pm 2.2)\%$
$\times$	$D^\star(2010)^+\ X$	$(0.285^{+0.049}_{-0.044})\%$	$(2.58 \pm 0.04)\%$	—
$\surd$	$D^\star(2010)^-\ X$	$(21.67 \pm 0.34)\%$	$(22.32 \pm 0.11)\%$	$(17.3 \pm 2.0)\%$
$\surd$	$D_s^+\ X$	$(8.66 \pm 0.23)\%$	$(9.53 \pm 0.08)\%$	$(10.1 \pm 3.1)\%$
$\times$	$D_s^-\ X$	$(8.19 \pm 0.22)\%$	$(4.23 \pm 0.05)\%$	$(18 \pm 5)\%$
$\surd$	$J/\psi\ X$	$(1.145 \pm 0.087)\%$	$(1.052 \pm 0.028)\%$	$(1.16 \pm 0.10)\%$
$\surd$	$K^\pm\ X$	$(57.69 \pm 0.40)\%$	$(66.99 \pm 0.13)\%$	$(74 \pm 6)\%$
$\surd$	$K_s^0\ X$	$(25.17 \pm 0.35)\%$	$(30.99 \pm 0.13)\%$	$(29.0 \pm 2.9)\%$
$\surd$	$\pi^\pm\ X$	$(395.4 \pm 3.6)\%$	$(376.3 \pm 1.1)\%$	$(397 \pm 21)\%$
$\surd$	$\pi^0\ X$	$(230.9 \pm 2.2)\%$	$(225.5 \pm 0.7)\%$	$(278 \pm 60)\%$
$\times$	$\phi\ X$	$(4.818 \pm 0.17)\%$	$(4.02 \pm 0.05)\%$	$(2.8 \pm 0.23)\%$

Table 2: Inclusive branching fractions for $\overline{b}$ admixture. $\surd$ indicates both results are within 3 σ of the PDG, whereas $\times$ indicates otherwise.

Inclusive BF (continued...)

- Double D decays are low compared to PDG
- Proton BF because Λ^0 does not decay in QQ (material interactions)

	Decay Mode	Old ttopti BF	New ttopti BF	PDG BF
×	$p/\overline{p}\ X$	$(6.73 \pm 0.20)\%$	$(6.05 \pm 0.64)\%$	$(13.1 \pm 1.1)\%$
√	$\Lambda_c\ X$	$(13.14 \pm 0.27)\%$	$(12.89 \pm 0.09)\%$	$(9.7 \pm 2.9)\%$
√	$e^+\nu_e\ X$	$(10.72 \pm 0.25)\%$	$(10.78 \pm 0.08)\%$	$(10.86 \pm 0.35)\%$
√	$\mu^+\nu_\mu\ X$	$(10.28 \pm 0.25)\%$	$(10.75 \pm 0.08)\%$	$(10.95^{+0.29}_{-0.25})\%$
√	$\tau^+\nu_\tau\ X$	$(2.24 \pm 0.12\%$	$(2.40 \pm 0.04)\%$	$(2.48 \pm 0.26)\%$
√	$D^-\ell^+\nu_\ell\ X$	$(1.81 \pm 0.11)\%$	$(1.75 \pm 0.04)\%$	$(2.3 \pm 0.4)\%$
×	$D^-\pi^-\ell^+\nu_\ell\ X$	$< 0.0086\%$	$< 9.4 \times 10^{-6}$	$(2.6 \pm 1.6) \times 10^{-3}$
√	$D^-\pi^+\ell^+\nu_\ell\ X$	$(0.285^{+0.049}_{-0.044})\%$	$(0.236 \pm 0.014)\%$	$(0.49 \pm 0.19)\%$
×	$D^0\overline{D}^0\ X$	$< 0.0086\%$	$(0.193 \pm 0.012)\%$	$(5.1^{+2.0}_{-1.8})\%$
×	$D^0 D^\pm\ X$	$(0.079^{+0.028}_{-0.021})\%$	$(0.535 \pm 0.020)\%$	$(2.7^{+1.8}_{-1.6})\%$
×	$D^0 D^\star \pm\ X$	$(0.043^{+0.022}_{-0.018})\%$	$(0.812 \pm 0.024)\%$	$(3.0^{+1.1}_{-0.9})\%$
×	$D^0 D_s^\pm\ X$	$(1.38 \pm 0.095)\%$	$(1.506 \pm 0.033)\%$	$(9.1^{+3.9}_{-2.8})\%$

Table 3: Inclusive branching fractions for $\overline{b}$ admixture (continued from Table 2).

Exclusive Modes

Selected Exclusive Decay Modes for B Mesons

Decay Mode	Old ttopti BF	New ttopti BF	PDG BF
$B^0 \to D^{(\star)-}\ell^+\nu_\ell$	$(4.81 \pm 0.22)\%$	$(5.06 \pm 0.20)\%$	$(5.44 \pm 0.23)\%$
$B^0 \to \overline{D}^{(\star)0}\rho^+\pi^+\pi^-\pi^-$	$(2.39 \pm 0.20)\%$	$(1.54 \pm 0.16)\%$	—
$B^0 \to D^-\ell^+\nu_\ell$	$(1.73 \pm 0.14)\%$	$(1.65 \pm 0.13)\%$	$(2.14 \pm 0.20)\%$
$B^0 \to D^{(\star)-}D_s^{(\star)+}$	$(1.68 \pm 0.17)\%$	$(2.11 \pm 0.19)\%$	$(1.9 \pm 0.5)\%$
$B^0 \to D^{(\star)-}D^{(\star)0}K^+$	$< 1.4 \times 10^{-4}$	$(1.38 \pm 0.15)\%$	$(1.18 \pm 0.20)\%$
$B^0 \to D^{(\star)-}D^{(\star)+}K^0$	$< 1.4 \times 10^{-4}$	$(1.38 \pm 0.15)\%$	$(8.8 \pm 1.9) \times 10^{-3}$
$B^+ \to \overline{D}^{(\star)0}\ell^+\nu_\ell$	$(4.74 \pm 0.23)\%$	$(5.04 \pm 0.23)\%$	$(6.5 \pm 0.5)\%$
$B^+ \to D^{(\star)-}\rho^+\pi^+\pi^+\pi^-$	$(2.26 \pm 0.19)\%$	$(1.74 \pm 0.17)\%$	—
$B^+ \to \overline{D}^{(\star)0}a_1^+$	$(1.91 \pm 0.18)\%$	$(1.67 \pm 0.17)\%$	$(1.9 \pm 0.5)\%$
$B^+ \to \overline{D}^0\ell^+\nu_\ell$	$(1.84 \pm 0.12)\%$	$(1.88 \pm 0.12)\%$	$(2.15 \pm 0.22)\%$
$B^+ \to \overline{D}^{(\star)0}D_s^{(\star)+}$	$(1.65 \pm 0.17)\%$	$(2.90 \pm 0.22)\%$	$(2.7 \pm 1.0)\%$
$B^+ \to \overline{D}^{(\star)0}\rho^+$	$(1.67 \pm 0.17)\%$	$(1.38 \pm 0.15)\%$	$(9.8 \pm 1.7) \times 10^{-3}$
$B^+ \to \overline{D}^{(\star)0}D^{(\star)+}K^0$	$< 1.4 \times 10^{-4}$	$(1.42 \pm 0.15)\%$	$(7.8 \pm 2.6) \times 10^{-3}$
$B_s \to D_s^{(\star)+}D_s^{(\star)-}$	$(1.01 \pm 0.25)\%$	$(2.31 \pm 0.38)\%$	$(23^{+21}_{-13})\%$

Table 4: Some 20% of the B^0 and B^+ branching fractions in the new decay table are accounted for here.

Lifetimes

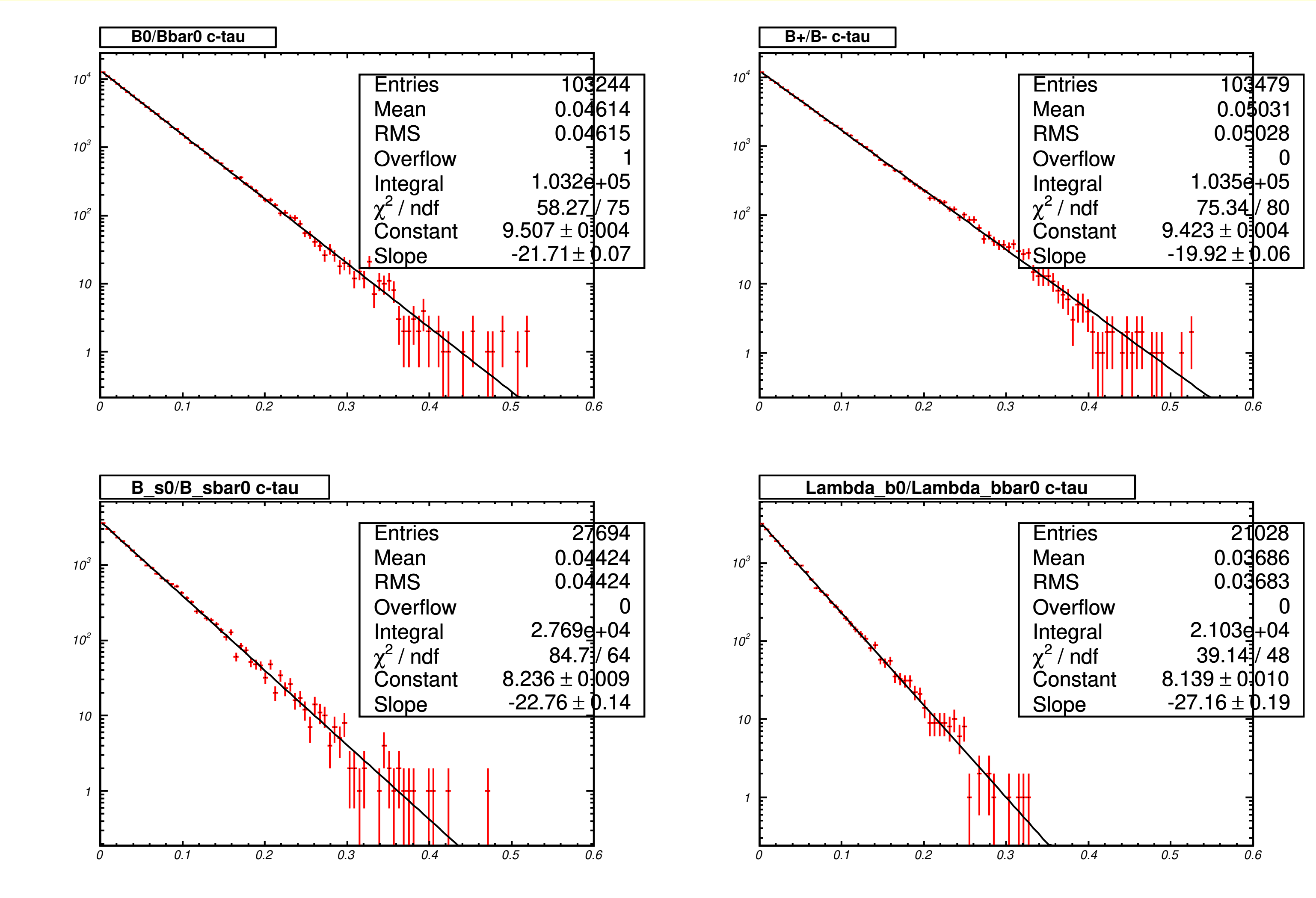

Figure 1: $c\tau$ measurements of $B^0/\overline{B}^0$, B^+/B^-, $B_s/\overline{B}_s$, and $\Lambda_b^0/\overline{\Lambda}_b^0$ from ttopti with new decay table.

Lifetimes (continued)

Central values of important lifetimes changing from old to new decay table:

- B^0 $c\tau = 486$ μm$\rightarrow$ 462 μm (-5%)
- $B^\pm$ $c\tau = 493$ μm$\rightarrow$ 502 μm $(+2\%)$
- B_s^0 $c\tau = 465$ μm$\rightarrow$ 438 μm (-6%)
- Λ_b^0 $c\tau = 387$ μm$\rightarrow$ 368 μm (-5%)

Will this send the SECVTX efficiency down?

Meson	Measured cτ in MC	Stated MC cτ	PDG Value
$B^0/\overline{B}^0$	(460.6 ± 1.4) μm	462 μm	(462.6 ± 4.8) μm
B^+/B^-	(502.0 ± 1.6) μm	502 μm	(502.2 ± 5.4) μm
$B_s/\overline{B}_s$	(439.3 ± 2.6) μm	438 μm	(438 ± 17) μm
$\Lambda_b^0/\overline{\Lambda}_b^0$	(368.2 ± 2.6) μm	368 μm	(369 ± 24) μm

Table 5: Summary of Lifetime Plots (shown in Figure 1). We compare the lifetime measured in MC, the value given in the decay file, and the PDG value for B hadrons.

SecVtx *Efficiency by Decay Table*

Isolate effect of lifetimes by generating MC with old table but with new lifetimes

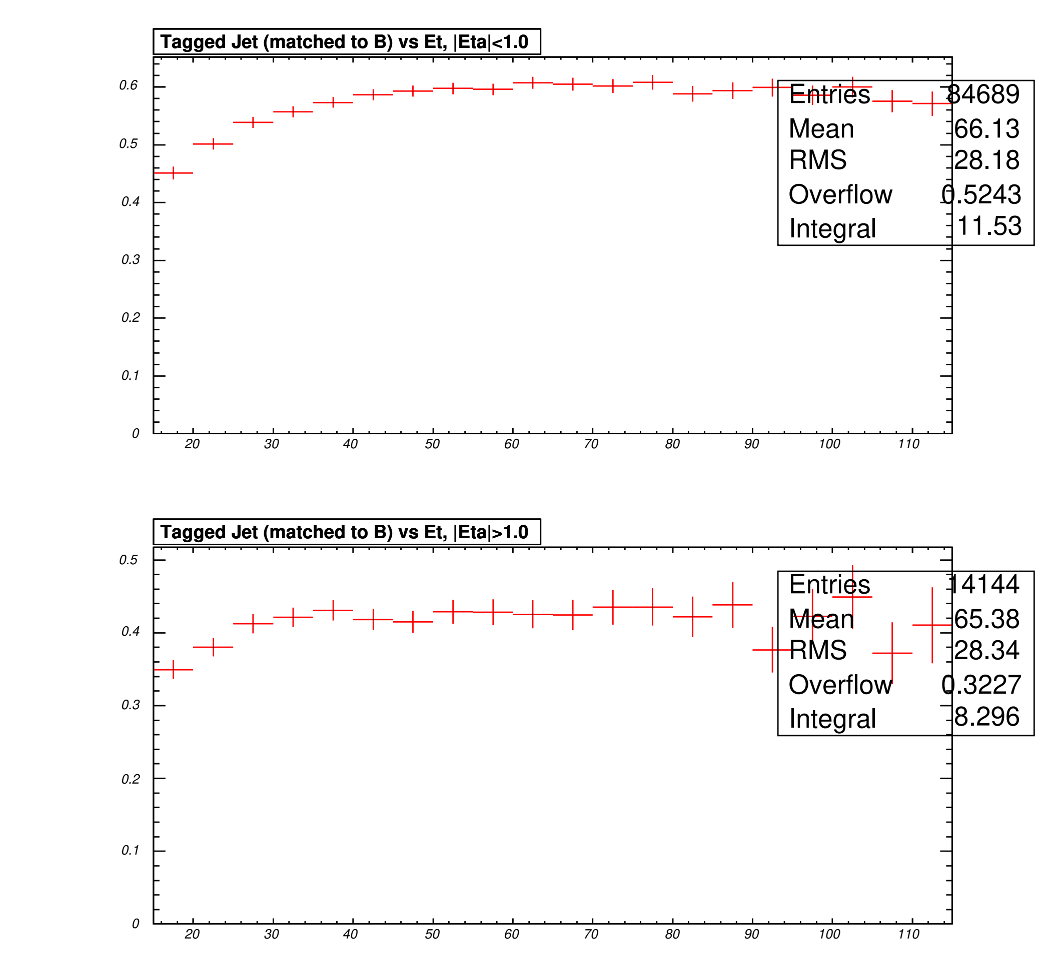

Figure 2: SecVtx Efficiency for B-jets $|\eta| < 1.0$ (above) and $|\eta| > 1.0$ (below).

SECVTX *Efficiency by Decay Mode*

SECVTX tagging rates vary widely by decay mode!

- Matched Taggable Jet to B ($\Delta R < 0.4$)
- Taggable $\equiv E_T > 15.0$ GeV, $|\eta| < 2.0$, # Good Trks ≥ 2
- Reminder: double D decays not well represented in either decay table!

Decay Mode	SECVTX Tagging Efficiency	Avg. # Good Tracks
All $\bar{b}$ modes	$(54.21 \pm 0.12)\%$	6.5
$\bar{b} \rightarrow e^+\nu_e\ X$	$(43.94 \pm 0.35)\%$	5.7
$\bar{b} \rightarrow \mu^+\nu_\mu\ X$	$(46.86 \pm 0.37)\%$	5.9
$\bar{b} \rightarrow \tau^+\nu_\tau\ X$	$(48.60 \pm 0.77)\%$	5.9
$\bar{b} \rightarrow D^-\ell^+\nu_\ell\ X$	$(41.3 \pm 0.9)\%$	5.5
$\bar{b} \rightarrow D^-\pi^-\ell^+\nu_\ell\ X$	Not enough statistics	—
$\bar{b} \rightarrow D^-\pi^+\ell^+\nu_\ell\ X$	$(54.7 \pm 2.4)\%$	6.1
$\bar{b} \rightarrow D^0\overline{D}^0\ X$	$(65.3 \pm 2.5)\%$	6.7
$\bar{b} \rightarrow D^0 D^\pm\ X$	$(59.1 \pm 1.6)\%$	6.6
$\bar{b} \rightarrow D^0 D^\star(2010)^\pm\ X$	$(60.2 \pm 1.2)\%$	6.9
$\bar{b} \rightarrow D^0 D_s^\pm\ X$	$(58.2 \pm 0.9)\%$	6.6

Table 6: SECVTX efficiencies are sum of both stated mode and its charge conjugate.

Still Need to look into 8 GeV Electron Sample

Conclusions

- I'm getting there...