Relative BR of $B_s \to J/\Psi \ f_0(980)$ to $B_s \to J/\Psi \ \phi$

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Introduction

- $B_s \to J/\psi \phi$
  - Golden mode to measure weak CP violating phase $\phi_s$
  - Very sensitive to new physics since $\phi_s \sim 0$ in SM
  - Current measurements have values larger than the SM, but the errors are such that the result is not yet statistically significant.
- Would like to add in other decay modes to measure $\phi_s$
  - Decays based on same tree diagram
  - $B_s \to \text{VP, PP}$ decays
    - (V: Vector, P: Pseudoscalar)
$J/\psi f_0(980)$

- $B_s \rightarrow J/\psi f_0$ ($f_0 \rightarrow K^+K^-$)
  - Same final state as $J/\psi \phi$
  - Can introduce $s$-wave $K^+K^-$ component under $\phi$ mass peak
  - Background to $J/\psi \phi$
- $B_s \rightarrow J/\psi f_0$ ($f_0 \rightarrow \pi^+\pi^-$)
  - Same tree diagram as $B_s \rightarrow J/\psi \phi$
  - CP odd eigenstate (if $\phi_s \sim 0$)
  - Sensitive to $\Delta \Gamma_s$ and $\phi_s$
- $B_s \rightarrow VP$ mode
  - No angular measurement required for measuring $\phi_s$
Predictions for Relative BR

\[
R_{\psi/\phi} = \frac{\Gamma(B_s \rightarrow J/\Psi f_0, f_0 \rightarrow \pi^+\pi^-)}{\Gamma(B_s \rightarrow J/\Psi\phi, \phi \rightarrow K^+K^-)}
\]

S. Stone and L. Zhang, PRD 79,074024

All predict sizeable event rates ~20-40%

Stone and Zhang use \(D_s^+ \rightarrow K^+K^-\pi^+\)
And \(D_s^+ \rightarrow \phi e^+\nu\) vs \(D_s^+ \rightarrow f_0 e^+\nu\)
Colangelo, de Fazio and Wang use Light Cone Sum Rules
Leitner et al., use QCD factorization
Relative BR

- Relative BR = \( \frac{N_{J/\Psi f_0} \cdot \varepsilon(J/\Psi \phi)}{N_{J/\Psi \phi} \cdot \varepsilon(J/\Psi f_0)} \)

- All is needed are relative yields and relative reconstruction efficiencies to measure relative BR.
Environment

Data from $p\bar{p}$ collisions at Tevatron $\sqrt{s} = 1.96$ TeV
Instantaneous Luminosity $\sim 3.5 \times 10^{32}$ cm$^{-2}$s$^{-1}$

Large $b\bar{b}$ production cross section
$\sim 40 \times 10^6$ $b\bar{b}$ pairs/hour

But with large backgrounds
Boosted Decision Tree

- 2 MC background samples: inclusive ($B_s \rightarrow J/\psi X$) and prompt (directly produced $J/\psi$)
- Signal sample $B_s \rightarrow J/\psi f_0(980)$
- 36 variables used to train BDT
- $f_0$ mass not a variable
Analysis cuts

• \( J/\Psi \rightarrow \mu^+\mu^- \)
  - Good quality muons
  - \# hits in silicon tracker > 0
  - \# hits in fiber tracker > 0
  - Good vertex
  - Invariant mass 2.9-3.2 GeV

• \( f_0 \rightarrow \pi^+\pi^- \)
  - \# hits in silicon tracker > 1,
  - \# hits in fiber tracker > 1
  - \# hits in silicon and fiber tracker > 7
  - Good vertex
  - Mass .91-1.05 (\( \phi \) mass : 1.01-1.03 GeV)

• Pion leading \( p_t > 1.4 \) GeV, \( B_s \) \( p_t > 5 \) GeV, \( f_0 \) \( p_t > 1.6 \) GeV,
  \( \text{BDT}_{\text{inclusive}} > 0.35 \), \( \text{BDT}_{\text{prompt}} > 0.35 \)

• All bad runs removed, events that only fired an IP trigger removed.
Data yields (8 fb$^{-1}$)

$B_s \rightarrow J/\psi f_0$

$B_s \rightarrow J/\psi \phi$

$498 \pm 74$

$2863 \pm 61$
Potential Physics Background

Want to avoid known resonances

\[ B \to J/\psi \, K^*(K^* \to K\pi) \]

\[ B \to \rho \, X \, (\rho \to \pi\pi) \]

So choose 0.8-0.9 GeV

No evidence of any \( \pi\pi \) non-resonant bkg
Efficiencies

• Generated MC samples for both J/ψ φ and J/ψ f₀
• Ran analysis code over samples to determine reconstruction efficiencies.
• Samples have a 0.4 GeV pion/kaon preselection cut during generation so also need to determine efficiency of preselection cut on both samples
• Preselection cut efficiencies
  – J/ψ φ : 0.795 ± 0.011
  – J/ψ f₀ : 0.594 ± 0.010

• Relative efficiencies
  – RunIIa: 1.21 ± 0.03
  – RunIIb1: 1.31 ± 0.04
  – RunIIb2: 1.20 ± 0.05

Data collected in 4 periods with different average instantaneous luminosities
RunIIa (1.4 fb⁻¹)
RunIIb1(1.4 fb⁻¹)
RunIIb2(3.3 fb⁻¹)
RunIIb3(2.1 fb⁻¹)
8 fb$^{-1}$ Systematics

- Vary cuts around nominal to see effects

<table>
<thead>
<tr>
<th>cut</th>
<th>Affect on R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bdt inclusive &gt; 0.3</td>
<td>.958</td>
</tr>
<tr>
<td>Bdt prompt &gt;0.3</td>
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<tr>
<td>Bdt inclusive &gt; 0.4</td>
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<td>Bdt prompt &gt; 0.4</td>
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<td>K leading pt &gt; 1.8</td>
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<td>Decay length sig &gt;4</td>
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<td>Decay length sig &gt;5</td>
<td>1.02</td>
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</table>
Systematics: fitting choices

<table>
<thead>
<tr>
<th>Nominal Fit</th>
<th>498 ± 74</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd degree bkg function</td>
<td>446 ± 72</td>
</tr>
<tr>
<td>Exponential bkg function</td>
<td>423 ± 67</td>
</tr>
<tr>
<td>Fit range 5.1-5.6</td>
<td>437 ± 78</td>
</tr>
<tr>
<td>Fit range 5.15-5.8</td>
<td>427 ± 63</td>
</tr>
<tr>
<td>Fit range 5.05-5.8</td>
<td>449 ± 71</td>
</tr>
</tbody>
</table>

Fairly large variation with fitting choices

Biggest Systematic

Black: opp sign pions
Red: same sign pions
Preliminary Result

\[ R_{f/\phi} \frac{\Gamma(B_s \to J/\Psi f_0, f_0 \to \pi^+ \pi^-)}{\Gamma(B_s \to J/\Psi \phi, \phi \to K^+ K^-)} = 0.210 \pm 0.032 \text{(stat)} \pm 0.036 \text{(syst.)} \]
Conclusions

• Results consistent with previous measurements and theoretical predictions.
• Large relative branching ratio make this mode promising for measuring $\Delta \Gamma_s$ and $\phi_s$
• Currently working on extracting $\Delta \Gamma_s$ and $\phi_s$ from data.
BACKUP
Detector

Good muon ID with wide acceptance $|\eta|<2$

Improved vertex detector with Layer 0 inserted in 2006

Very good data taking efficiency
Selective triggers to deal with high instantaneous luminosity
Measuring $\phi_s$ (eventually)

Lifetime $\sim e^{-\Gamma t}\{\cosh \Delta \Gamma t/2 + \cos(\phi_s)\sinh \Delta \Gamma t/2 \pm \sin(\phi_s)\sin(\Delta m_s t)\}$

+ sign $\bar{B}_s$
- sign $B_s$

Toy MC

Red- background
Blue dotted -signal
Blue solid - signal+bkg

Flavor tagging required