IMPROVED BRANCHING FRACTION MEASUREMENT FOR $B^0 \rightarrow J/\Psi \pi^+ \pi^-$ DECAY MODE

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OUTLINE

- Motivation
- Event Selection
- Reconstruction
- Selection Variable
- Conclusion
**Motivation**

- $B^0 \rightarrow J/\psi \pi^+ \pi^-$ is flavor non-specific final state and is Cabibbo-suppressed decay.
- Tree and penguin amplitudes which contribute to $b \rightarrow c \bar{c}d$ are of same order in the sine of Cabibbo angle.

![Diagram](image)

- So far, other experiments have provided limited knowledge about $B^0 \rightarrow J/\psi \pi^+ \pi^-$ because of their limited statistics.
- By observation of di-pion invariant mass spectrum, sources of pion pair can be resolved into resonant and non-resonant contributions.

- The components contributing to di-pion are also provide important information to understand strong interaction effects in $B$ decays.
**RECONSTRUCTION/SELECTION**

- **Reconstruction mechanism:**
  
  - $B^0 \rightarrow J/\psi \pi^+\pi^-$
  
  - $e^+ e^- \rightarrow \mu^+ \mu^-$

- **$J/\psi$ and $\pi^+\pi^-$ Reconstruction:**
  Standard Charmonium group selection criteria

- **MC Sample:**
  
  - 100,000 signal MC events are generated using EvtGen, where detector response is simulated using GEANT4.
  
  - Large inclusive $J/\psi$ MC sample to study background etc.

- **Event Selection:**
  
  - Events which are skimmed as psiskim are used in analysis.
  
  - Ratio of second to zeroth Fox-Wolfram moments $R_2 < 0.5$
  
  - $|dz| < 5$ cm and $|dr| < 0.5$ cm
  
  - $0.4$ rad $< \theta < 2.43$ rad
**$J/\psi$ Reconstruction**

- $J/\psi$ reconstruction is performed using its leptonic decays
  
  $J/\psi \rightarrow e^+e^-$ or $\mu^+\mu^-$

- $\mu$ selection: $\text{muon.Likelihood} > 0.1$

- $e$ selection: $\text{eid.prob()} > 0.01$

- Invariant mass window for $\mu^+\mu^-(e^+e^-)$ channel:
  
  $-0.06$ (-0.15) GeV/$c^2 \leq M_{\mu^+\mu^-} - M_{J/\psi} \leq 0.036$ GeV/$c^2$
**$B^0$ Reconstruction**

- $\Upsilon(4S)(10.58 \text{ GeV}/c^2) \rightarrow B^0/B^0$; both $B_s$ are produced almost at rest in CMS of $\Upsilon(4S)$; $M_B=5.29 \text{ GeV}/c^2$

- Kinematics variables $M_{bc}$ and $\Delta E$ are used to separate the signal from the background.
  - $M_{bc} = \sqrt{(E_{\text{beam}})^2 - (p_B)^2}$
  - $\Delta E = E_B - E_{\text{beam}}$; ($E_{\text{beam}} = \sqrt{s}/2 = 5.29$ GeV)

- Signal region:
  - $-0.04 \text{ GeV} < \Delta E < 0.04 \text{ GeV}$
  - $5.27 \text{ GeV}/c^2 < M_{bc} < 5.29 \text{ GeV}/c^2$

- Optimized by calculating FOM

- Charged pions selection:
  - $R_{\pi/K} = L_\pi/(L_\pi + L_K) > 0.6$
  - $\text{eid.prob}(3,-1,5) < 0.1$
  - $\muon\_likelihood() < 0.9$

- To reduce $B^0 \rightarrow J/\Psi K_s (K_s \rightarrow \pi^+\pi^-)$ & backgrounds due to accidently formed pion pairs $\rightarrow$ (distance between reconstructed vertices of $J/\Psi$ and $\pi^+\pi^-$ pair) $< 3 \text{ mm}$

- If more than one $J/\Psi \pi^+\pi^-$ event satisfy $-0.2 \text{ GeV} < \Delta E < 0.2 \text{ GeV}$ and $M_{bc} > 5.20 \text{ GeV}/c^2$ $\rightarrow$ pion pair with least $\chi^2$ is selected
Several sources of di-pion system in $B^0 \rightarrow J/\psi \pi^+\pi^-$ final state: $B^0 \rightarrow J/\psi \rho^0$ contribute predominantly.

Additional possible contributions:
- $B^0 \rightarrow J/\psi f_2$
- non-resonant $B^0 \rightarrow J/\psi \pi^+\pi^-$

Monte Carlo samples for these decay modes are prepared.

<table>
<thead>
<tr>
<th>B$^0$ Decay Mode</th>
<th># of Events</th>
<th>Decay Model</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^0 \rightarrow J/\psi \rho^0$</td>
<td>100,000</td>
<td>SVV</td>
<td>0.24 ± 0.007</td>
</tr>
<tr>
<td>$B^0 \rightarrow J/\psi f_2$</td>
<td>100,000</td>
<td>PHSP &amp; TSS</td>
<td>0.27 ± 0.007</td>
</tr>
<tr>
<td>$B^0 \rightarrow J/\psi \pi^+\pi^-$</td>
<td>100,000</td>
<td>PHSP</td>
<td>0.28 ± 0.007</td>
</tr>
</tbody>
</table>
**Signal MC Events**

$M_{bc} - \Delta E$ 2D distribution

$\Delta E$ projection in $5.27 < M_{bc} < 5.29 \text{ GeV/c}^2$

$M_{bc}$ projection in $-0.04 < \Delta E < 0.04 \text{ GeV}$
**EXPERIMENTAL DATA**

$M_{bc} - \Delta E$ 2D distribution

$\Delta E$ projection in $5.27 < M_{bc} < 5.29$ GeV/$c^2$

$M_{bc}$ projection in $-0.04 < \Delta E < 0.04$ GeV
**Background Study: MC**

- Major source of background is $B$ decays having a $J/\Psi$ candidate in final state.
- Background estimation is carried out by large inclusive $J/\Psi$ MC sample of size $\sim 3.88 \times 10^{10}$
- Peaking background in $B^0 \rightarrow J/\Psi \pi^+ \pi^-$ decay mode is due to decay modes whose event kinematics is quite similar to the signal mode, few most probable are:
  
  $B^0 \rightarrow J/\Psi K_s^0$
  
  $B^0 \rightarrow J/\Psi K^{*0}$
  
  $B^0 \rightarrow J/\Psi K^0*(1430)^0$
  
  $B^0 \rightarrow J/\Psi K_{2}^{*}(1430)^0$
  
  $B^\pm \rightarrow J/\Psi K^\pm$
  
  $B^\pm \rightarrow J/\Psi \pi^\pm$
**ΔE Distribution**

- Experimental ΔE distribution superimposed with background expectations obtained from inclusive $J/\psi$ MC sample.
- $B^0 \rightarrow J/\psi K_s^0$ forms a peaking structure in the signal region → *can be subtracted by using $M_{\pi^+\pi^-}$ distribution*
**Fit to \(\Delta E\) Distribution**

- Signal shape being modeled by Gaussian
- Decays \(B^0 \rightarrow J/\psi K^*\), \(B^0 \rightarrow J/\psi K^0(1430)^0\), \(B^0 \rightarrow J/\psi K_2^*(1430)^0\), \(B^\pm \rightarrow J/\psi K^\pm\), \(B^\pm \rightarrow J/\psi \pi^\pm\) are expressed by smoothed histograms
- Remaining backgrounds are expressed by a 1\(^{st}\) order polynomial

\[ \text{N}_{\text{events}} = 435 \pm 29 \]
$M_{\pi+\pi^-}$ DISTRIBUTION

- $B^0 \rightarrow J/\Psi K_s^0$ subtraction is done by studying the $M_{\pi+\pi^-}$ distribution to obtain the net $B^0 \rightarrow J/\Psi \pi^+ \pi^-$ signal yield
- Fitting $\rightarrow$ Double Gaussian (shape is fixed to MC)

Net $B^0 \rightarrow J/\Psi \pi^+ \pi^-$ events = $334 \pm 40$
Next Plan

- To perform the fit to the pion pair invariant mass spectrum in order to resolve the contributions of the decays in $B^0 \to J/\psi \pi^+ \pi^-$ final state
- Following contributions will be taken into account:
  - $B^0 \to J/\psi \rho^0$
  - $B^0 \to J/\psi f_2$
  - non resonant $B^0 \to J/\psi \pi^+ \pi^-$
- PDFs are finalized for these decay modes and their contributions will be determined
- Belle Note writing process is underway