

Weekly Report

Precision measurement of Branching fraction of the $J/\psi \rightarrow \phi\pi^0$, $\phi \rightarrow K^+K^-$,
and $\pi^0 \rightarrow \gamma\gamma$

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- Report the first observation of $J/\psi \rightarrow \phi\pi^0$ based on a sample $(1.31 \pm 0.011) \times 10^9$ J/ψ events accumulated with BESIII Detector located in BEPC, which is a double ring e^+e^- collider with a design peak luminosity of $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ at the c.m. energy of 3.773 GeV..

$$\begin{cases} e^+e^- \rightarrow J/\psi \rightarrow K^+K^-\pi^0, (\text{Signal}) \\ e^+e^- \rightarrow \gamma^* \rightarrow K^+K^-\pi^0. (\text{Background}) \end{cases}$$

- ▶ These final state already studied in DOI 10.1103/PhysicsRevD.91.112001,
 - ▶ Measured values of the branching fraction of $J/\psi \rightarrow \phi\pi^0$, $[2.94 \pm 0.16(\text{stat}) \pm 0.16(\text{sys})] \times 10^{-6}$ and $[1.24 \pm 0.33(\text{stat}) \pm 0.30(\text{sys})] \times 10^{-7}$.
- Motivation
 - ▶ To study this final state with including more statistics, and adding more backgrounds $\psi(2S) \rightarrow \pi^+\pi^- J/\psi$ (2S: state of $c\bar{c}$ quark pair).
 - ▶ Expect to get precise measurement of this branching fraction.



Data and MC samples



=> In the decay chain, $\psi(2S) \rightarrow \pi^+ \pi^- J/\psi$, $\phi \rightarrow K^+ K^-$, $\pi^0 \rightarrow \gamma \gamma$

- ▶ DST files of $\psi(3686)$ 2021, 3.4 fb^{-1} , run no {66257 – 69292} with BOSS version 709 ($\sim 2.26 \text{ B}$),
⇒ data sample : 3969408 entries.
- ▶ MC simulated data of $\psi(3686)$ 2021, 3.4 fb^{-1} , with BOSS version 709 ($\sim 2.3 \text{ B}$),
⇒ data sample : 4590369 entries.
- ▶ Generate signal sample MC,

```
*****
Decay Options:
#
Decay psi(2S)
1.0000 J/psi pi+ pi- JPIPI;
Enddecay
#
Decay J/psi
1.0000 phi pi0 HELAMP 1.0 0.0 0.0 0.0 1.0 3.1415926;
Enddecay
Decay phi
0.492 K+ K- VSS;
Enddecay
Decay pi0
0.9880 gamma gamma PHSP;
Enddecay
End
```



- Each charged particle with opposite charge (MDC):
 $|\cos\theta| < 0.93, |R_{xy}| \leq 1 \text{ cm}, |R_z| \leq 10 \text{ cm}.$
- PID: $\text{Prob}(\pi) > \text{Prob}(K),$
- Each photon

$$\begin{cases} E_{\text{emc}} \geq 0.025 \text{ GeV}, |\cos\theta| < 0.8 \text{ or,} \\ E_{\text{emc}} \geq 0.050 \text{ GeV}, 0.86 < |\cos\theta| < 0.92. \end{cases}$$

- Isolated showers: $\theta_r \geq 20^\circ.$
- a good pair of pions ($\pi^+\pi^-$):

$$\begin{cases} \cos\theta_{\pi^+\pi^-} < 0.8 \\ 3.0 \leq M_{\pi^+\pi^-}^{\text{Rec}} \leq 3.2 \text{ GeV}/c^2 \text{ where, } M_{\pi^+\pi^-}^{\text{Rec}} = \sqrt{[P_{\text{emc}} - (p_{\pi^+} + p_{\pi^-})]^2} \end{cases}$$

- Prob: $\begin{cases} \text{TkProb}(K^\pm) < 0.001 \\ \text{TkProb}(K^\pm) < \text{TkProb}(p) \\ \text{TkProb}(K^\pm) < \text{TkProb}(\pi) \end{cases}$

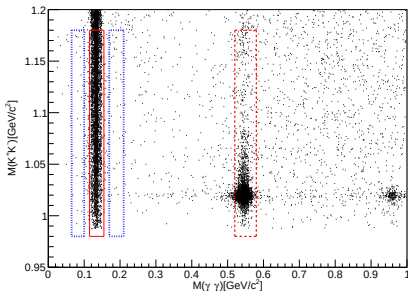
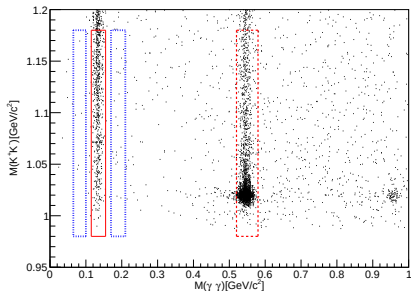


Results

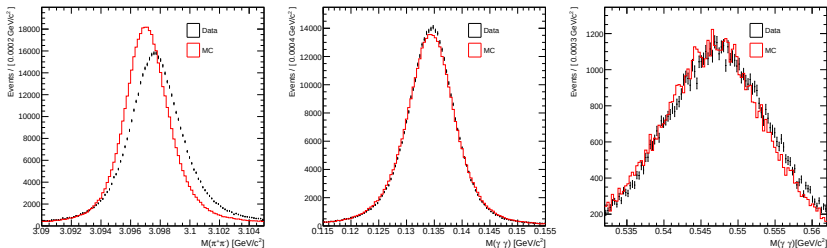
MC vs Data (Distribution)



- $\psi' \rightarrow K^+ K^- \pi^+ \pi^- (\pi^0 \rightarrow \gamma\gamma \text{ or } \eta \rightarrow \gamma\gamma)$
 - For $J/\psi \rightarrow \phi \pi^0 \rightarrow K^+ K^- \gamma\gamma$, $\chi^2_{4C} < 30$.



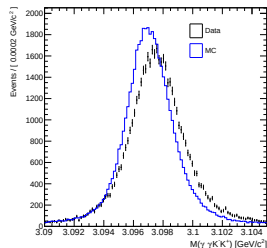
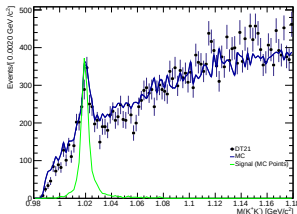
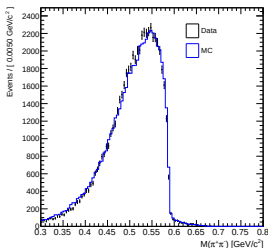
Data vs MC comparison



• These plots : $\psi(2S) \rightarrow K^+ K^- \pi^+ \pi^- \gamma \gamma$,

- ▶ Data (black) and MC (red) curves,
- ▶ Left: invariant mass of $\pi^+ \pi^-$, $3.0 \leq M_{\pi^+ \pi^-}^{\text{Rec}} \leq 3.2 \text{ GeV}/c^2$
 where, $M_{\pi^+ \pi^-}^{\text{Rec}} = \sqrt{[P_{\text{ecm}} - (p_{\pi^+} + p_{\pi^-})]^2}$
- ▶ Middle: the invariant mass of $\gamma \gamma$, ($\pi^0 \rightarrow \gamma \gamma$) where, $0.115 \leq M_{\gamma \gamma} \leq 0.155 \text{ GeV}/c^2$
- ▶ Right: the invariant mass of $\gamma \gamma$, ($\eta \rightarrow \gamma \gamma$) where, $0.532 \leq M_{\gamma \gamma} \leq 0.567 \text{ GeV}/c^2$

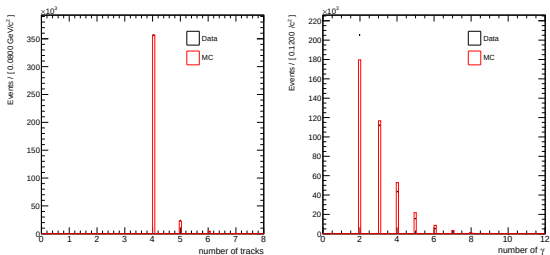
Data vs MC distribution



- Data (black) and MC (blue) curves,
- Left: invariant mass of a good pair of $\pi^+\pi^0$, $0.3 \leq M_{\pi^+\pi^-}^{\text{Inv}} \leq 0.6 \text{ GeV}/c^2$
- Middle: the invariant mass of K^+K^- where, $M_{K^+K^-} \leq 1.2 \text{ GeV}/c^2$
- Right: the invariant mass of $K^+K^-\gamma\gamma$, $3.09 \leq M_{K^+K^-\gamma\gamma} \leq 3.105 \text{ GeV}/c^2$,



Data vs MC distribution



- Recoil mass of gamma gamma ($\gamma\gamma$) (done)
- Invariant mass of gamma gamma ($\gamma\gamma$) (done)
- Invariant mass of gamma gamma ($K^+K^-\gamma\gamma$) (done)
- Plots $M(\gamma\gamma)$ (GeV/c^2) invariant mass - number of events (y-axis) for $J/\psi \rightarrow \gamma\gamma K^+K^-$ (done)
- Plot invariant mass of $M(K^+K^-)$ (GeV/c^2) (GeV)
- Photon energy, Kaon momentum, pion momentum () and their cosine theta and phi (underprogressing)
- select $J/\psi \rightarrow K^+K^-\pi^0$ final states with using reasonable cuts , (under progressing)
- select $J/\psi \rightarrow K^+K^-\eta$, (under progress)



=> Work is still in progress,

- ▶ Generated MC Samples,
- ▶ Encrease data sample from to get more accuracy and efficiency results needed.
- ▶ Looked in to different kinematic distribution for $\psi \rightarrow \pi^+\pi^- J/\psi$ decays selection.
- ▶ Applied some cuts to get most validated results needed.

=> Outcomes and next plans

- ▶ Improve measurements of $B(J/\psi \rightarrow \phi\pi^0)$ based on this selected events.

