$\eta - \eta'$ mixing analysis, status of $B^0 \to J/\psi\eta^{(\prime)}$

BHadronic WG Meeting

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Physics motivation

- LHCb results, JHEP 01 (2015) 024.
  $\mathrm{Br}(B^0 \to J/\psi\eta) = 2.0 \times 10^{-4}, 3.7\sigma$, evidence
  $\mathrm{Br}(B^0 \to J/\psi\eta') = 2.6 \times 10^{-6}, 4.7\sigma$, evidence
- Belle results, Phys. Rev. D 85 (2012) 091102.
  $\mathrm{Br}(B^0 \to J/\psi\eta) = 1.2 \times 10^{-5}, 6.3\sigma$, observation
  $\mathrm{Br}(B^0 \to J/\psi\eta') = 2.2 \times 10^{-6}, 0.4\sigma, < 7.4 \times 10^{-6}$, upper limits
- In the PDG, the results from LHCb and Belle show poor agreement. Updating the branching fraction of this channel at Belle II is crucial for comparing and discriminating between various model predictions.

Analysis settings

- Release: *light-2305-korat*
- Reconstruct signal channel
  $B^0 \to J/\psi_{\ell\ell}\eta'_{\eta\pi\pi/\rho\gamma}$

Sub-decay	branching fractions
$\mathcal{B}(\eta \to \gamma\gamma)$	39.4%
$\mathcal{B}(\eta' \to \pi\pi\eta/\rho\gamma)$	42.5/29.5%
$\mathcal{B}(J/\psi \to \ell\ell\ (\ell = e \text{ or } \mu))$	6.0%

- Data analysis with Belle II datasets.

MC Samples

Sample	Amount
Signal MC ($B^0 \to J/\psi_{\ell^+\ell^-} \eta'_{\eta\pi\pi/\rho\gamma}$)	4 M events for official generated (100 k events for private generated) MC15_rd
Generic MC ($e^+e^- \to q\bar{q}$, $\Upsilon(4S) \to B\overline{B}$)	1.4 ab^{-1}
$B \to J/\psi X$	5M events for each channel (B^0 and $B^{\pm}$) $\times$ (J/ψ_{ee} and $J/\psi_{\mu\mu}$)

Signal MC - Belle II, 100K events, selection requirements

track	$dr < 0.5$cm and $\lvert dz\rvert < 2$cm
$e^{\pm}$	pidChargedBDTScore(11,ALL)>0.9
$\mu^{\pm}$	muonID_noSVD > 0.9
$\pi^{\pm}$	pionID > 0.01
γ	`loose`
η	$0.52 < M_{\gamma\gamma} < 0.57\ \mathrm{GeV}/c^2$
	energy asymmetry < 0.85
ρ^0	$0.6 < M_{\pi^+\pi^-} < 0.95\ \mathrm{GeV}/c^2$
η'	$0.94 < M_{\pi^+\pi^-\eta} < 0.975\ \mathrm{GeV}/c^2$
η'	$0.9 < M_{\rho^0\gamma} < 1.0\ \mathrm{GeV}/c^2$
J/ψ	$2.9 < M_{\ell^+\ell^-} < 3.2\ \mathrm{GeV}/c^2$
B^0	$5.26 < \mathrm{M}_{bc} < 5.29 GeV/\mathrm{c}^2$
	$\lvert\Delta E\rvert < 0.2$ GeV
	highest `chiProb` in tree fit (BCS)

Signal efficiency at Belle II

- Assumed $\mathcal{B}(B^0 \to J/\psi\eta') = 2.2 \times 10^{-6\dagger}$

Mode	Efficiency (ϵ)	Purity	Expect
$B^0 \to J/\psi_{ee}\eta'_{\rho^0\gamma}$	17.78%	69.50%	2.4
$B^0 \to J/\psi_{\mu\mu}\eta'_{\rho^0\gamma}$	29.10%	70.48%	4.0
$B^0 \to J/\psi_{ee}\eta'_{\pi\pi\eta}$	24.87%	82.52%	1.9
$B^0 \to J/\psi_{\mu\mu}\eta'_{\pi\pi\eta}$	39.88%	82.55%	3.1
Sum	26.59%	76.77%	11.4

Table 1: Here purity is defined as $\frac{\text{number of signal candidates}}{\text{number of all candidates}}$ in signal MC. 352 M $B\bar{B}$ events in the Belle II dataset. Expect = $N_{BB} \times \epsilon \times$ sub-branching fractions

†Belle, Phys. Rev. D 85 (2012) 091102.

Main Peaking Background - Belle II

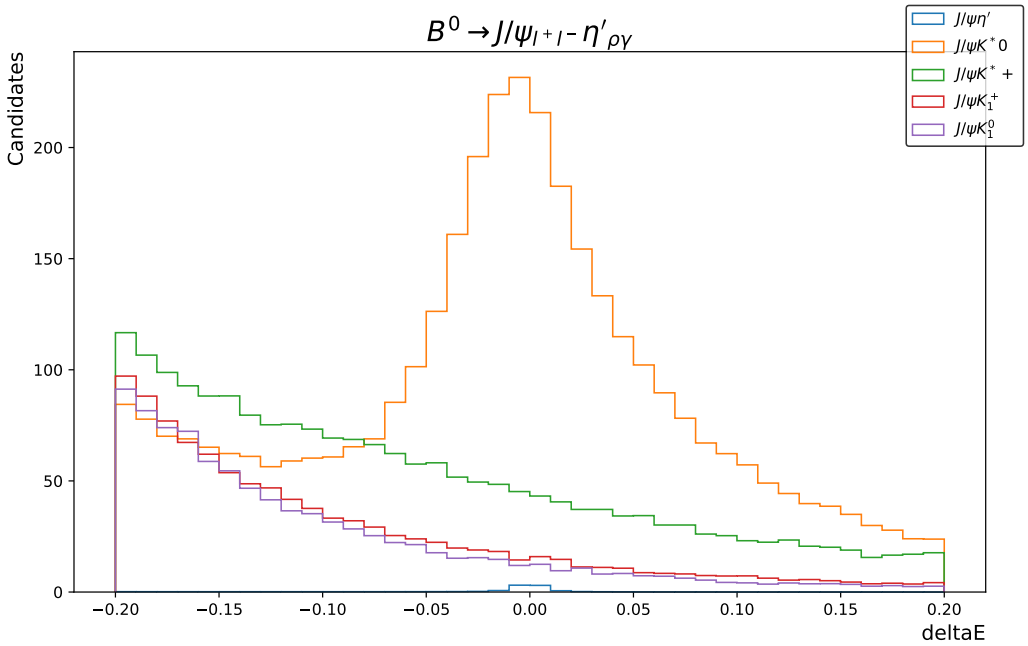
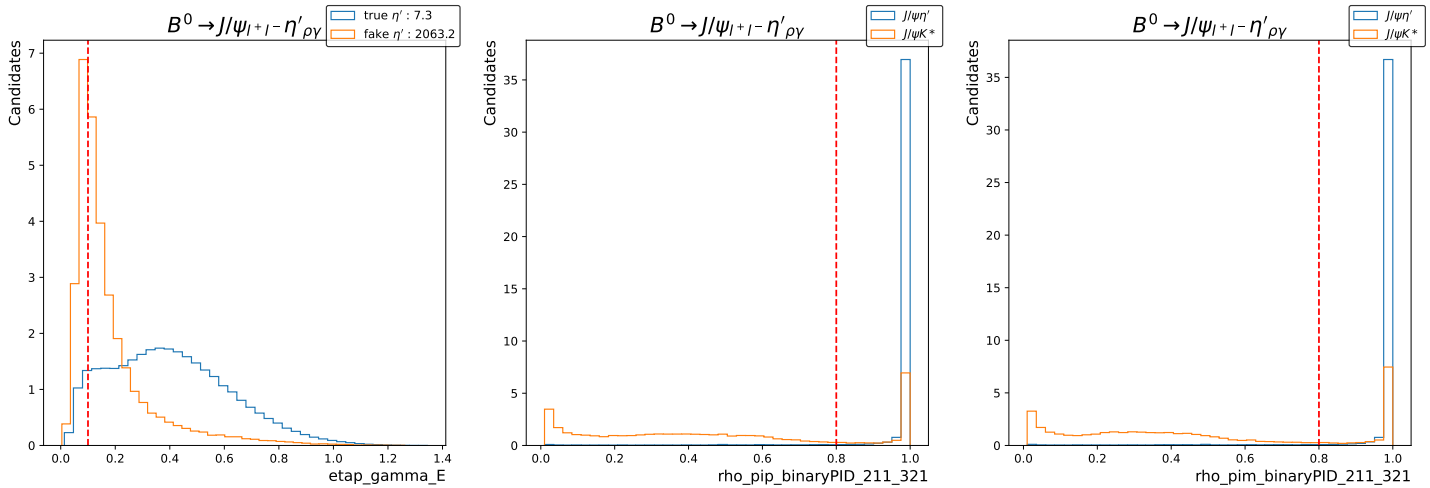


Figure 1: Main distribution of peaking background is $B^0 \to J/\psi K^{*0}$

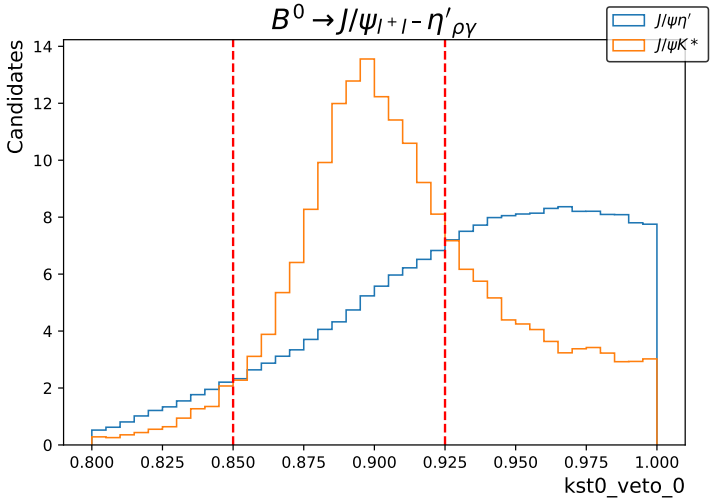
Further suppress the backgrounds - Belle II

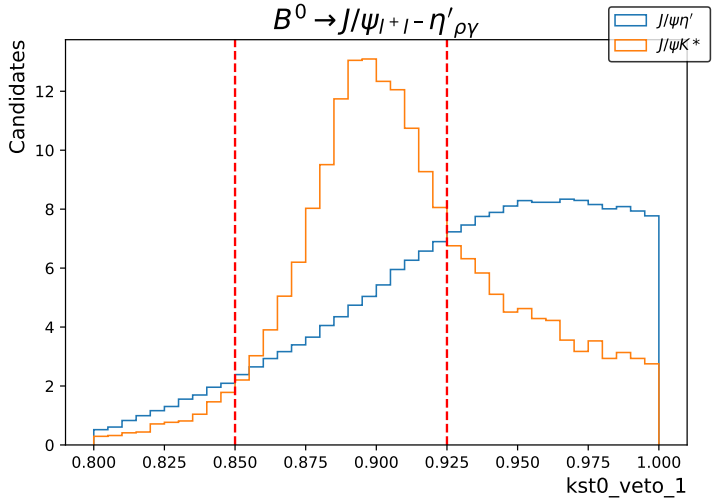
- $\gamma_{\eta'}$ energy >0.1 GeV (left)
- π_ρ^+ binaryPID >0.8 (center)
- π_ρ^- binaryPID > 0.8(right)



Further suppress the backgrounds - Belle II

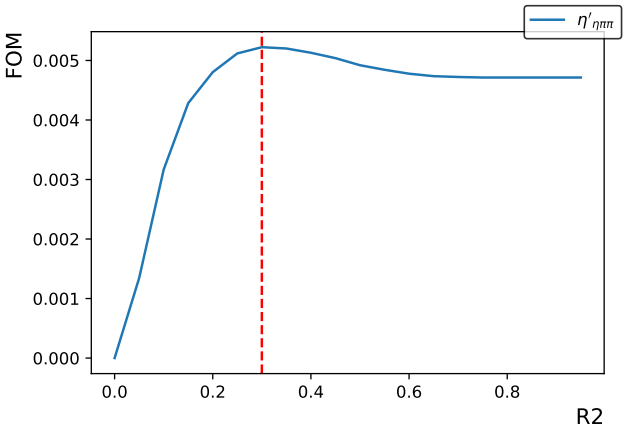
- Majority of peaking background is from $K^{*0} \to K\pi$ fake to $\rho \to \pi\pi$. To suppress such background, we perform a veto assuming one of ρ^0 daughters is a K and re-calculate the invariant mass and place a veto mass window as the figures below.
- The veto mass window is $0.85 < M_{K^{*0}} < 0.925 GeV/c^2$



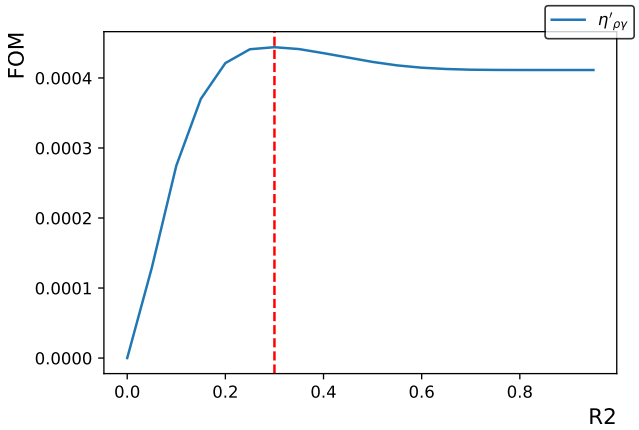


Further suppress the backgrounds- Belle II

- Use FOM to optimize the R_2 cut value.
- The FOM (Punzi formula = $\frac{\epsilon_s}{a/2+\sqrt{N_B}}$, where a=3)



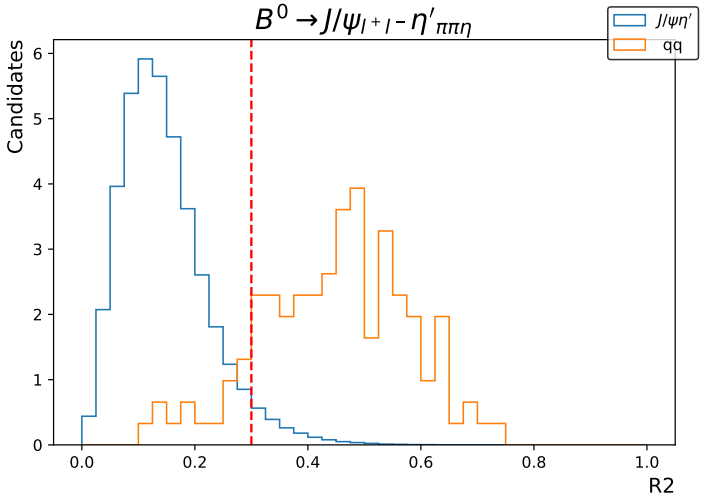
((a)) $\eta'_{\eta\pi\pi}$

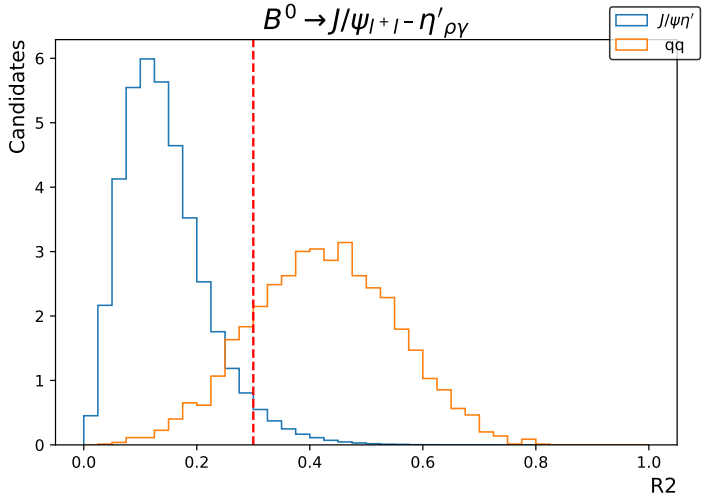


((b)) $\eta'_{\rho\gamma}$

ContinuumMC - Belle II

- The maximum FOM value is $R_2 < 0.3$.





Summary

- MC study for $B^0 \to J/\psi\eta'$ is ongoing.
  - $\to$ Signal selections have been completed.
  - $\to$ Background study is currently in progress.
    - $R_2 > 0.3$ has been studied.
    - MVA will be utilized for the suppression of continuum events.

Backup