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Update for the study of $\gamma\gamma \rightarrow \omega J/\psi$ at Belle and Belle II

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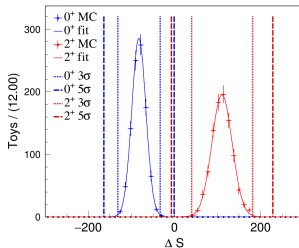
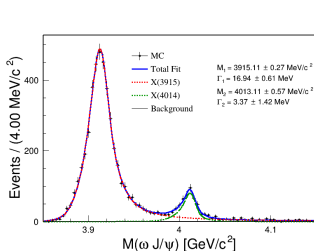
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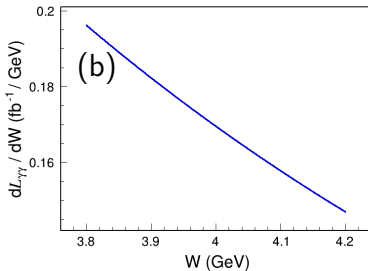
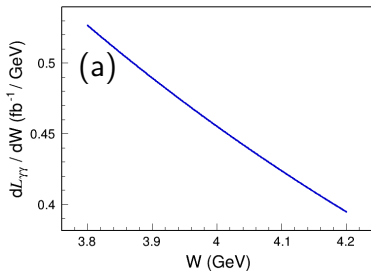
Recall

- Mass fit preliminary validated for both single- and double-resonance hypotheses with signal Toy MC.
- Amplitude analysis framework preliminary established and validated with signal Toy MC.



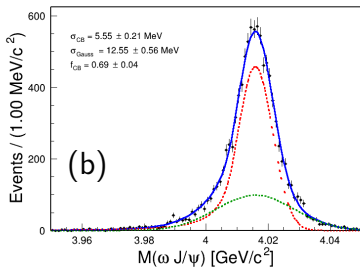
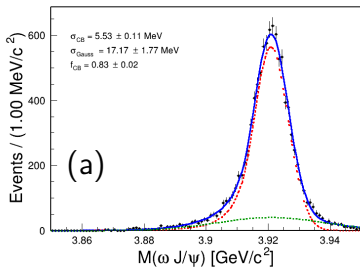
Effective Luminosity

- Calculated using the TREPS generator implemented in basf2, scaled by the integrated luminosity of Belle (a) and Belle II (b).
- Based on the Equivalent Photon Approximation (EPA) with rigorous multi-dimensional numerical integration.



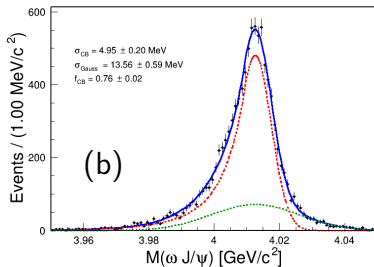
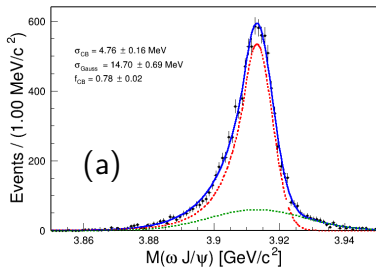
Belle Detector Resolution

- 1M zero-width Belle MCrd generated and reconstructed.
- Using Crystal Ball + Gaussian to describe.



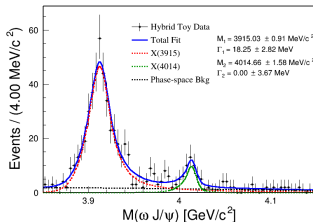
Belle II Detector Resolution

- 1M zero-width Belle II MCri generated and reconstructed.
- Using Crystal Ball + Gaussian to describe.



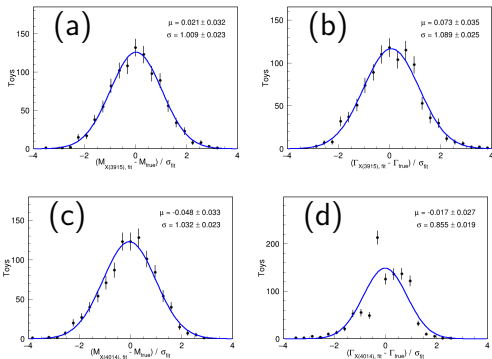
Full Model: Signal and Backgrounds

- Signal Components: Incoherent sum of two relativistic S -wave Breit-Wigner functions, each convolved with dataset-specific detector resolutions.
- Main Continuum Bkg: Parameterized by an empirical threshold function: $(M - M_{\text{th}})^{0.5} \cdot e^{-\beta_{\text{main}}(M - M_{\text{th}})}$.
- Sideband Background: Shared the same threshold functional form; shape parameters are fixed from data sidebands, while yields are constrained with Gaussian penalty terms.
- Effective Threshold: Fixed to $M_{\text{th}} = m_{J/\psi} + m_{\omega} - 5\Gamma_{\omega}$ based on the PDG nominal values.



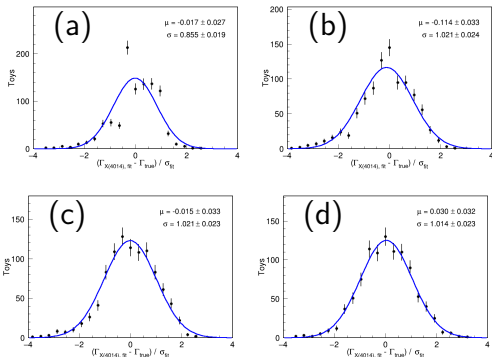
Pull distribution

- 500 Toy MC samples for Belle and Belle II generated to validate fit stability.
- Signal events:300(200) Belle (Belle II) with poisson fluctuation.
- Non-resonant events:30(20) Belle (Belle II) with poisson fluctuation.
- Sideband events:30(20) Belle (Belle II) with poisson fluctuation.



Pull distribution

- $\Gamma_{X(4014)}$ pull is not ideal (a) due to low statistics and its small true value ($\Gamma_{\text{true}} = 3 \text{ MeV}$).
- Scaled up the statistics by $2\times$ (b), $5\times$ (c), and $10\times$ (d). The pull looks normal when data size increases.
- Will fix $\Gamma_{X(4014)}$ or use a conservative estimate for its uncertainty in the real data fit.



Maximum Likelihood Fit Framework

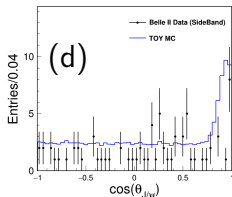
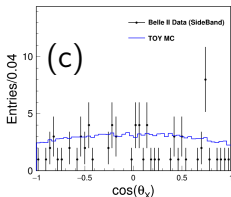
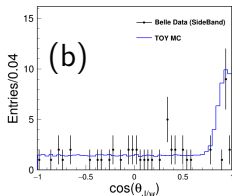
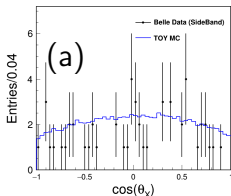
- **Total PDF:** Three-component model for each dataset k (Belle, Belle II):

$$\mathcal{P}_{\text{tot},k} = f_{\text{sig},k} \mathcal{P}_{\text{sig},k} + f_{\text{NR},k} \mathcal{P}_{\text{NR}} + f_{\text{comb},k} \mathcal{P}_{\text{comb},k}$$

- **Fractions:** Floating parameters with constraint
 $f_{\text{sig},k} + f_{\text{NR},k} + f_{\text{comb},k} = 1.$
- **Components:**
 - \mathcal{P}_{sig} : Signal helicity amplitude convolved with resolution.
 - \mathcal{P}_{NR} : Flat non-resonant background (modeled by PHSP).
 - $\mathcal{P}_{\text{comb}}$: Combinatorial background shape from data sidebands.
- **Normalization:** Evaluated numerically using high-statistics PHSP MC.
- **Minimization:** Simultaneous fit across datasets using MINUIT.

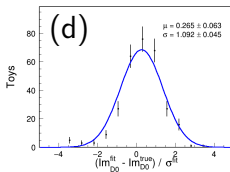
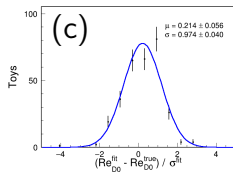
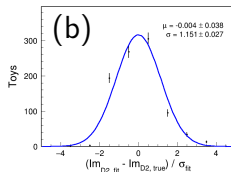
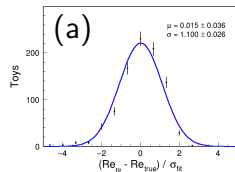
Sideband distribution

- $\cos\theta_{J/\psi}$ is sampled directly from the data sideband distribution.
- Other helicity angles are fine with PHSP MC.



Pull Distributions

- 1000 Toy MC samples generated to validate the **simultaneous fit** (both Belle and Belle II are included).
- (a) and (b) from D_2 in 0^+ MC, (c) and (d) from D_0 in 2^+ MC (worst mean among all parameters).



Summary and Outlook

■ Summary:

- Mass fit framework is validated for full model in Belle and Belle II.
- Amplitude analysis framework preliminary established and validated with full model in both Belle and Belle II.

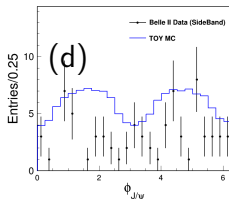
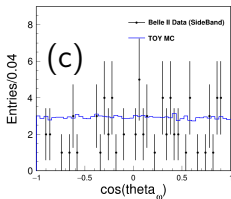
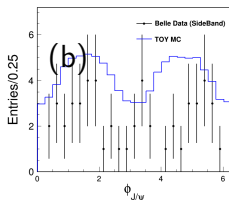
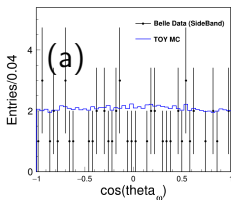
■ Next steps:

- Assess systematic uncertainties for the amplitude analysis.
- Waiting for the WG reader's comment.

Thanks!

Backup: Other Sideband Distributions

- Extra data sideband distributions used for empirical background shapes.
- (a) and (b) are for Belle; (c) and (d) are for Belle II.



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