

**Study of $\gamma\gamma \rightarrow \omega J/\psi$ via ISR at
Belle and Belle II**

Group meeting

2024/12/27

Data Sets

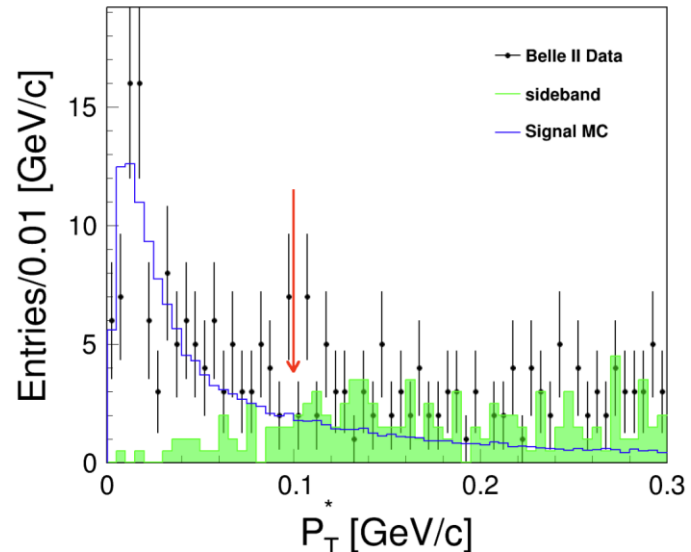
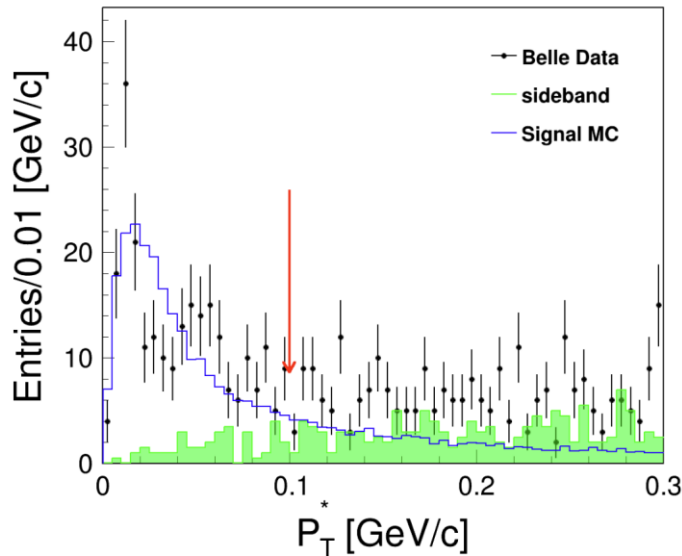
- BASF2 version: release 08-01-05
- Datasets: All Belle data ($980fb^{-1}$) and $365.29fb^{-1}$ Belle II data @ $\Upsilon(4S)$ via CharmoniumPsi Skim in Quarkonium group
- Signal MC samples : 200000 events for each channel by BASF2
 - Decay chain :
 - $\gamma\gamma \rightarrow X, X \rightarrow \omega J/\psi$ (TREPS)
 - $J/\psi \rightarrow \ell^+ \ell^-, \ell = e/\mu, \omega \rightarrow \pi^+ \pi^- \pi^0$ (EVTGEN)
 - Parameters for X : mass = **3.922/4.017** GeV , width =10 MeV.

Event selection

- Good charged tracks
 - $|dr| < 2 \text{ cm}, |dz| < 4 \text{ cm}$
 - $N_{goodtrack} = 4$
- Particle Identification
 - $muID > 0.7$ for all
 - $eID > 0.5$ for all e
 - $atcPIDBelle(2,3) > 0.6$ for all π
- Bremsstrahlung photons
 - within 0.05 radians of the original electrons
 - $E_\gamma > 20 \text{ MeV}$
- Belle π^0 selection
 - Photon divided into two categories based on $cluserE$: γ_{low} and γ_{high} .
 - $cluserE > 50 \text{ MeV}$ for other regions for γ_{low} .
 - Mass constraint fit with $\chi^2 < 20$.
 - Best candidate selection using χ^2 for $P_t < 0.2 \text{ GeV}/c \pi^0s$
- Belle II π^0 selection
 - `pi0:eff40_May2020Fit` with only best candidate selection

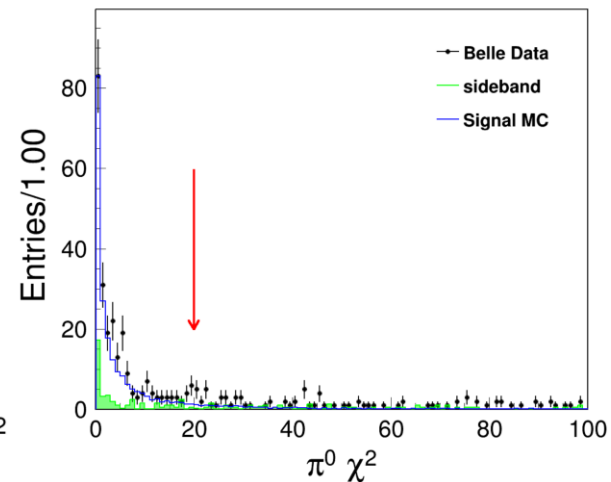
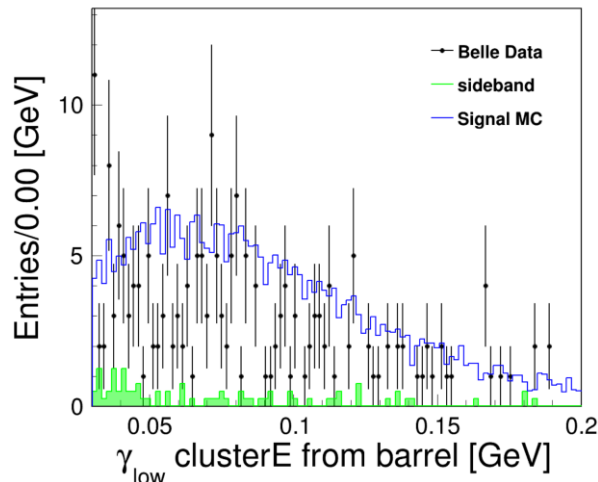
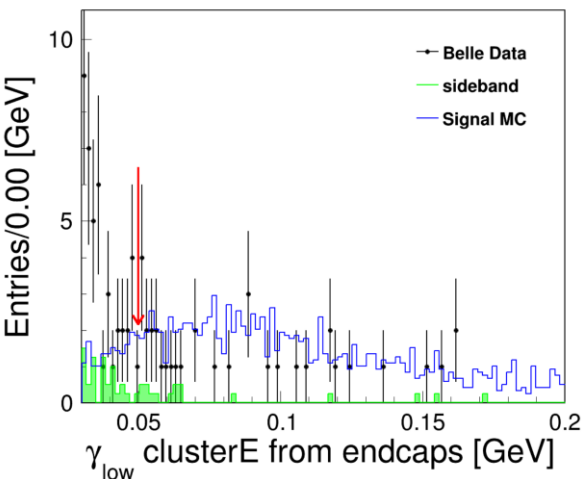
Event selection

- J/ψ , ω reconstruction
 - $3.04 \text{ GeV}/c^2 < M_{\ell^+\ell^-} < 3.14 \text{ GeV}/c^2$
 - $2.92 \text{ GeV}/c^2 < M_{\ell^+\ell^-} < 3.02 \text{ GeV}/c^2$ & $3.16 \text{ GeV}/c^2 < M_{\ell^+\ell^-} < 3.26 \text{ GeV}/c^2$ for J/ψ sideband.
 - $0.74 \text{ GeV}/c^2 < (M_{\pi^+\pi^-\pi^0} - M_{\pi^0} + 0.1349) < 0.82 \text{ GeV}/c^2$
 - $0.86 \text{ GeV}/c^2 < (M_{\pi^+\pi^-\pi^0} - M_{\pi^0} + 0.1349) < 0.94 \text{ GeV}/c^2$ and $0.62 \text{ GeV}/c^2 < (M_{\pi^+\pi^-\pi^0} - M_{\pi^0} + 0.1349) < 0.7 \text{ GeV}/c^2$ for ω sideband.
- $M_{Rec}^2 > 10 \text{ (GeV}/c^2)^2$ for $\pi^+\pi^-\ell^+\ell^-$ to suppress ISR $\psi(2S)$ backgrounds.
- $|M_{\ell^+\ell^-} - M_{\ell^+\ell^-\pi^+\pi^-} - 0.589| > 0.01 \text{ GeV}/c^2$ suppress $\psi(2S)$ backgrounds.
- $P_t^* < 0.1 \text{ GeV}/c$ for $\omega J/\psi$ system to identify $\gamma\gamma \rightarrow \omega J/\psi$ events.



π^0 distributions @ Belle

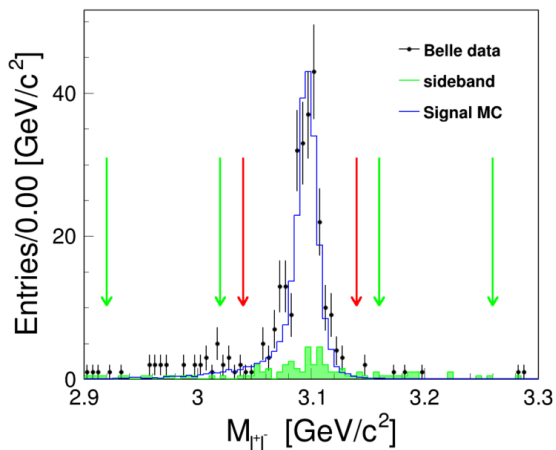
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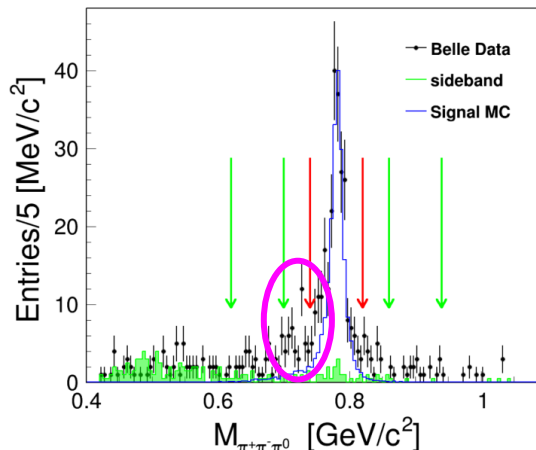
$J/\psi, \omega$ distributions

- $3.04 \text{ GeV}/c^2 < M_{\ell^+\ell^-} < 3.14 \text{ GeV}/c^2$
- $2.92 \text{ GeV}/c^2 < M_{\ell^+\ell^-} < 3.02 \text{ GeV}/c^2$ & $3.16 \text{ GeV}/c^2 < M_{\ell^+\ell^-} < 3.26 \text{ GeV}/c^2$ for J/ψ sideband.
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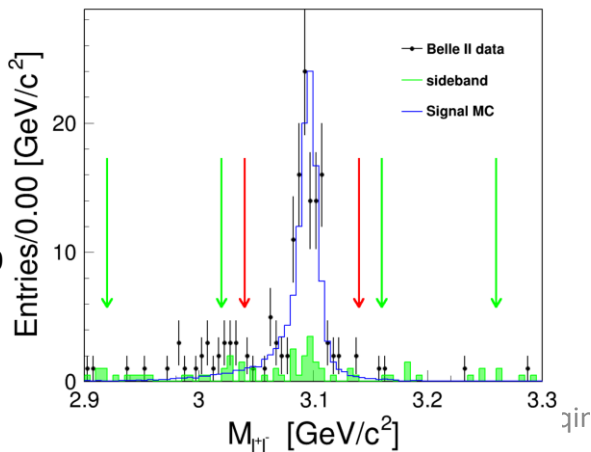
$\varepsilon_{J/\psi}$ @ Belle:
(93.8 ± 0.3)%



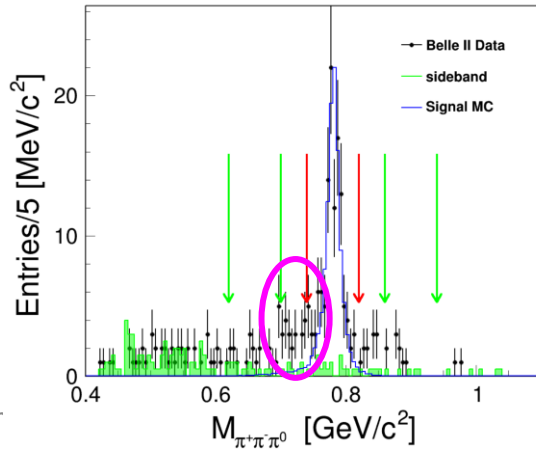
ε_ω @ Belle:
(90.5 ± 0.4)%



$\varepsilon_{J/\psi}$ @ Belle II:
(92.1 ± 0.3)%

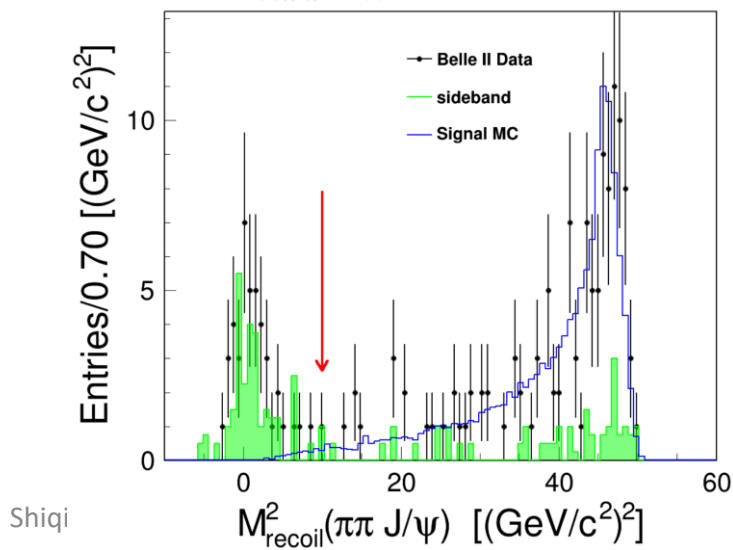
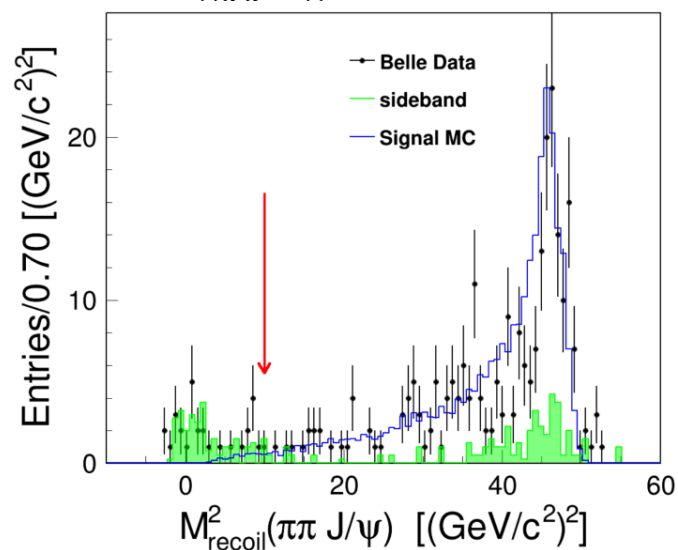
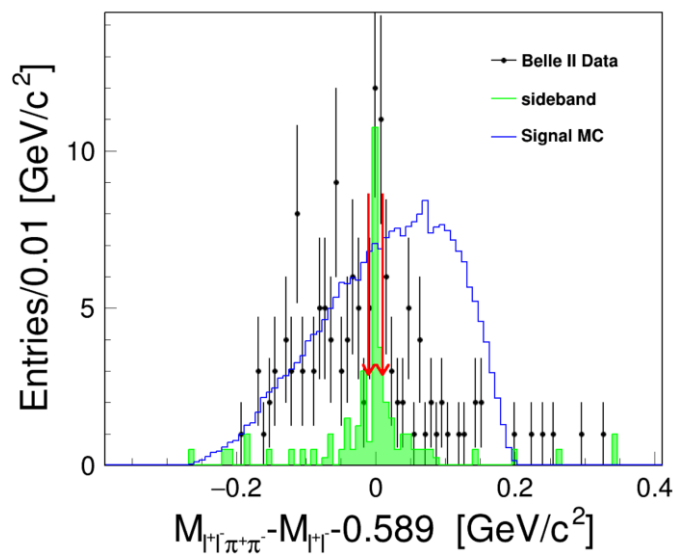
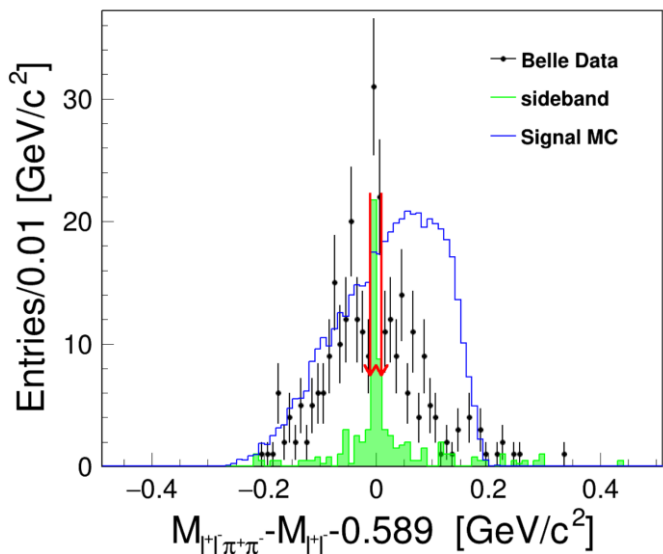


ε_ω @ Belle II:
(94.4 ± 0.3)%



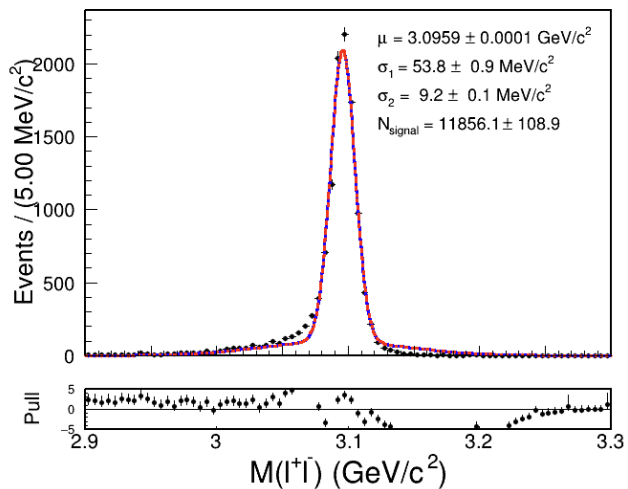
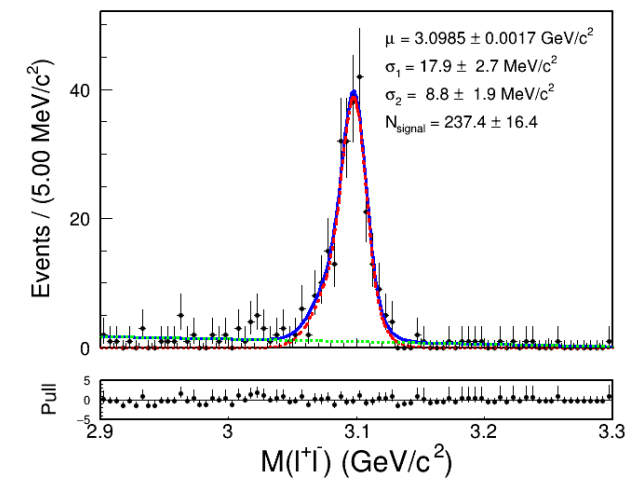
Background suppression

- $M_{Rec}^2 > 10 \text{ (GeV/c}^2\text{)}^2$ for $\pi^+\pi^-\ell^+\ell^-$ to suppress ISR $\psi(2S)$ backgrounds.
- $|M_{\ell^+\ell^-} - M_{\ell^+\ell^-\pi^+\pi^-} - 0.589| > 0.01 \text{ GeV/c}^2$ suppress $\psi(2S)$ backgrounds.

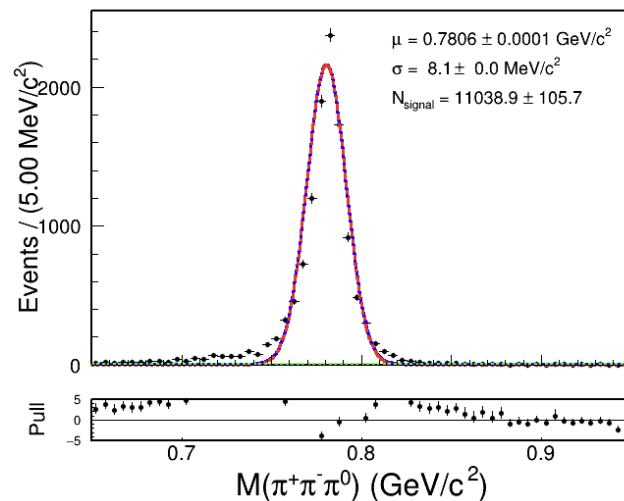
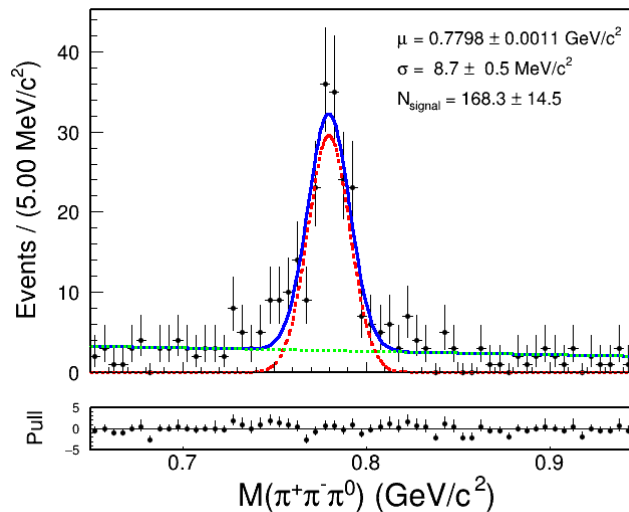


Fit for J/ψ , ω @ Belle

Double gaussian for J/ψ signal + 2nd polynomial for bkg

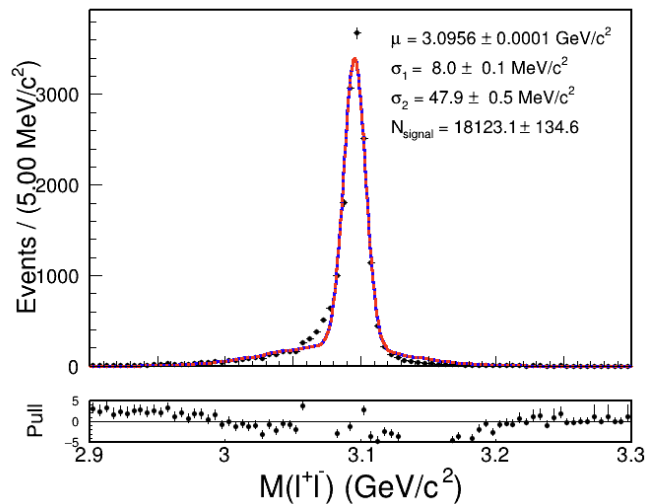
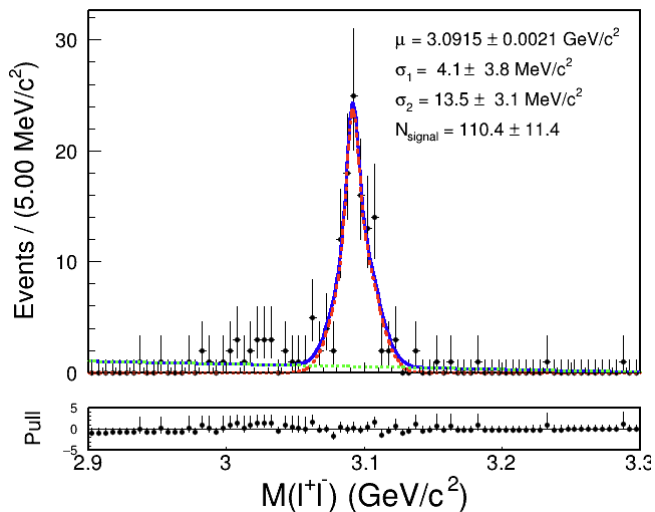


BW \otimes gauss for ω signal + polynomial for bkg (gauss σ fixed @ zero width MC σ)

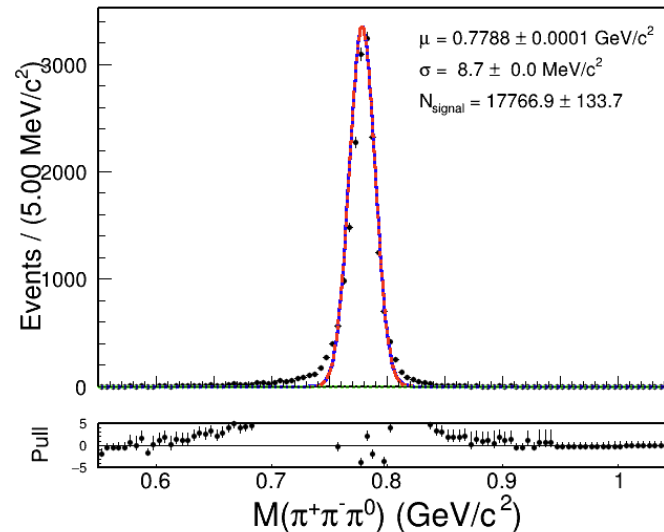
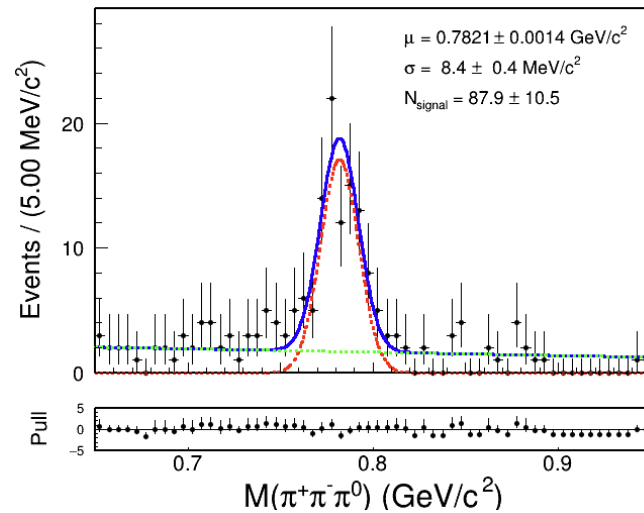


Fit for $J/\psi, \omega$ @ Belle II

Double gaussian for J/ψ signal +2nd polynomial for bkg



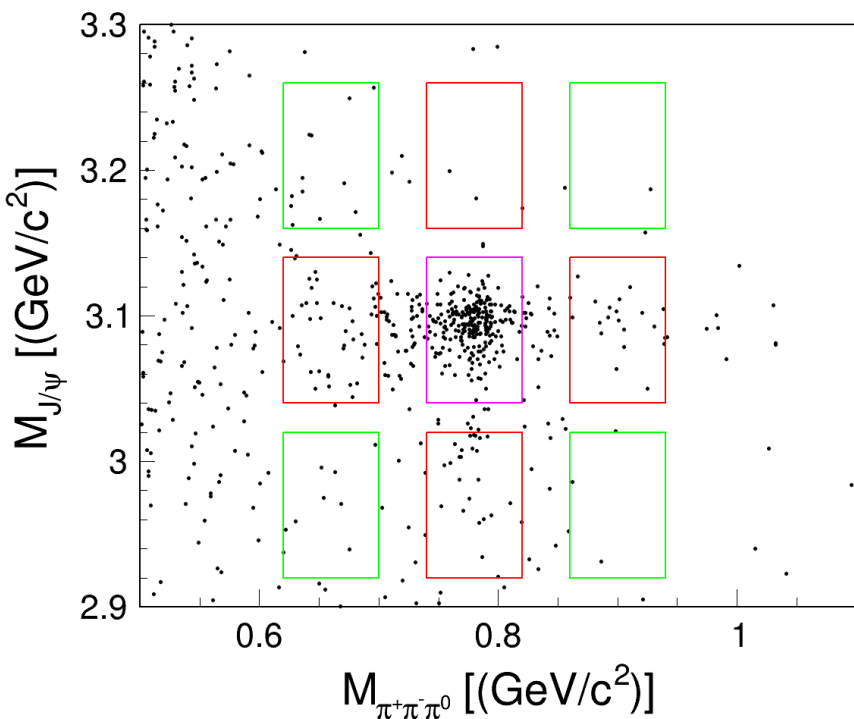
BW \otimes gauss for ω signal +polynomial for bkg (gauss σ fixed @ zero width MC σ)



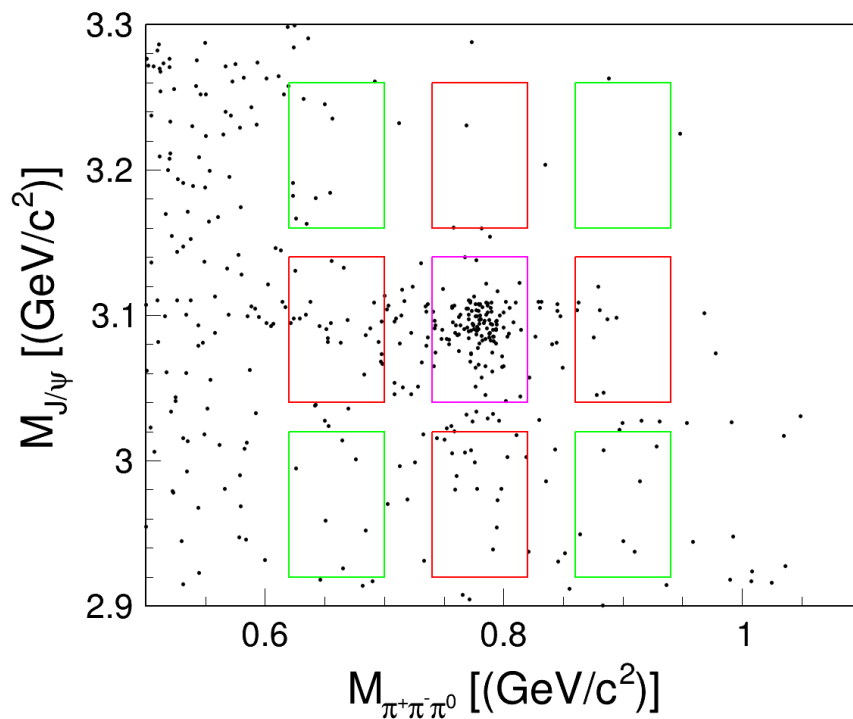
2D Sideband

Signal region (pink) , Sideband region 1 (red B1), Sideband region 2 (green B2)

$$\text{Total sideband} = (2 * N_{B1} - N_{B2})/4$$



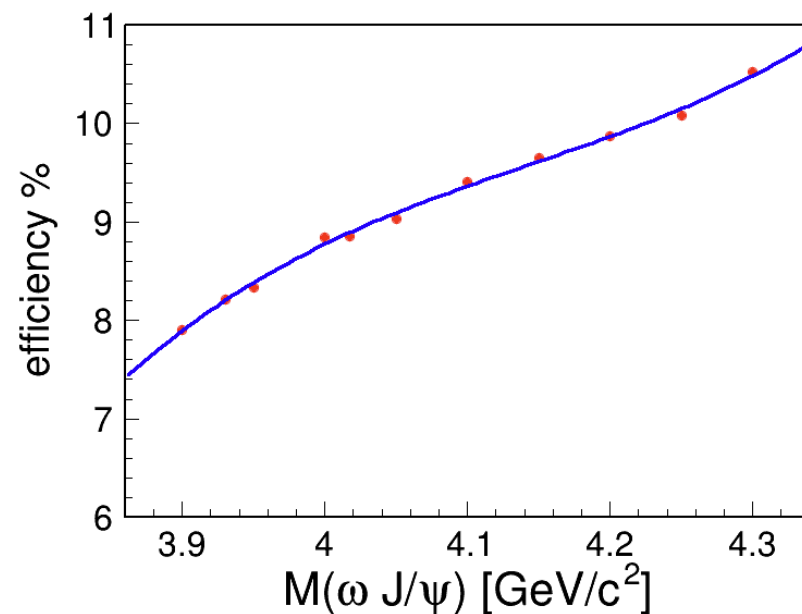
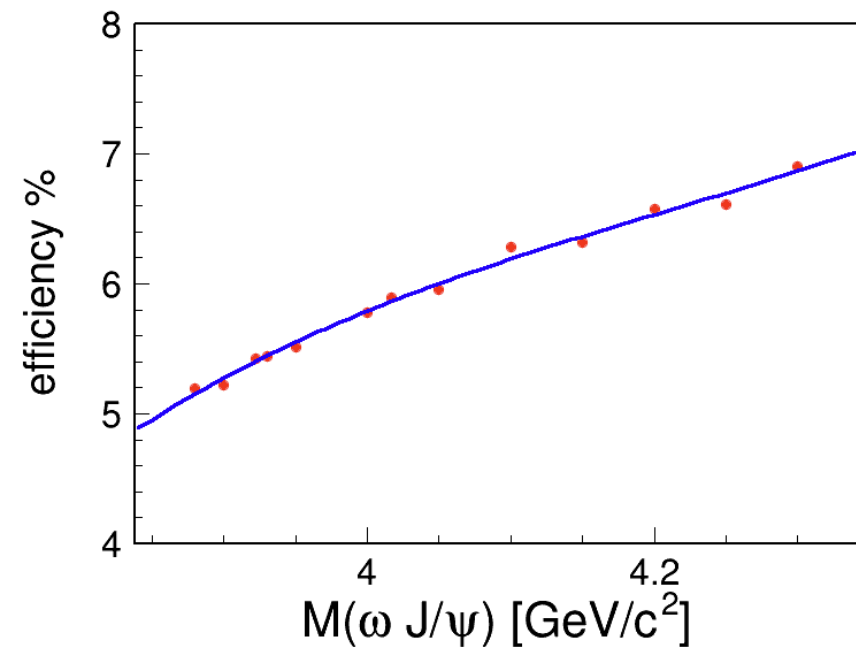
245 signals with 39.25 sideband
@Belle



120 signals with 20.25 sideband
@Belle II

Eff curve

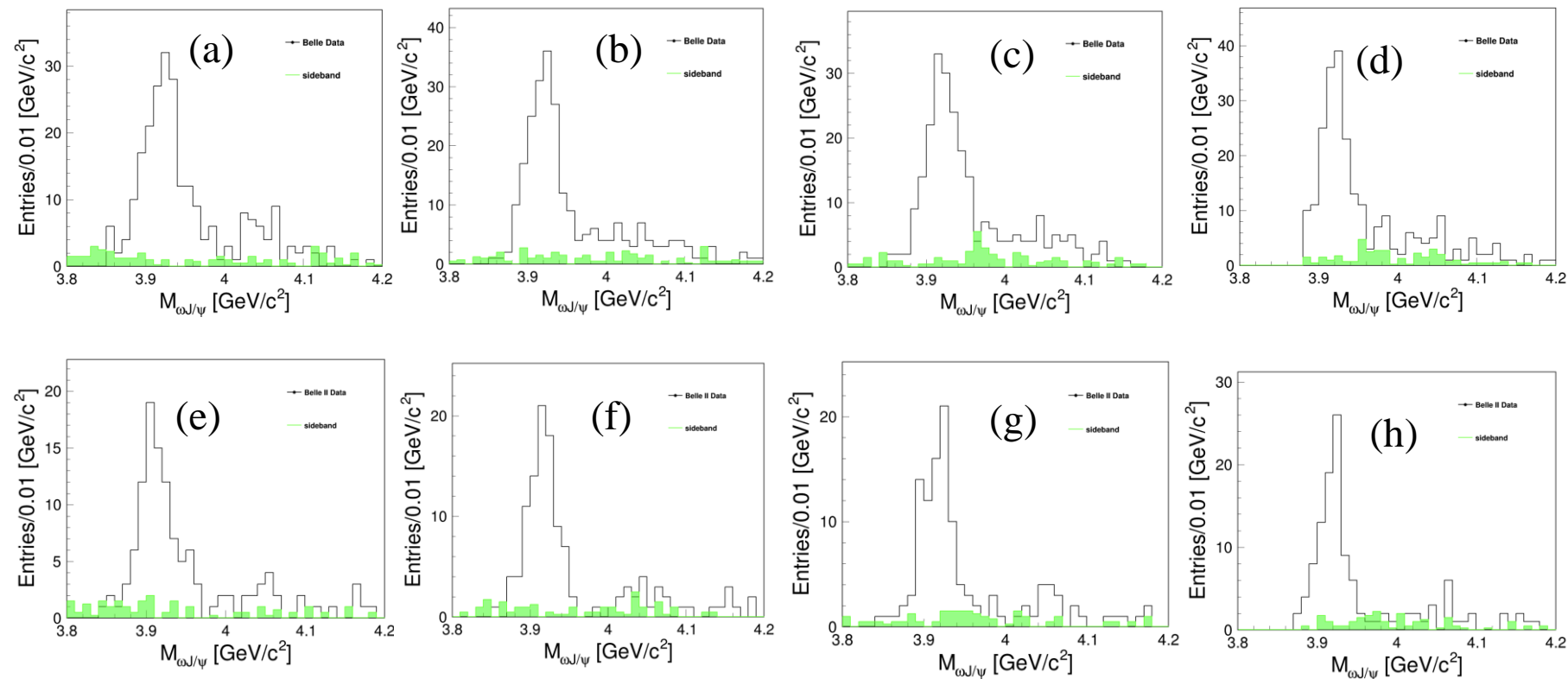
200,000 MC for each energy point. Left for Belle, Right for Belle II. Corrected with PID (Belle 91.4% Belle II 100.1%)



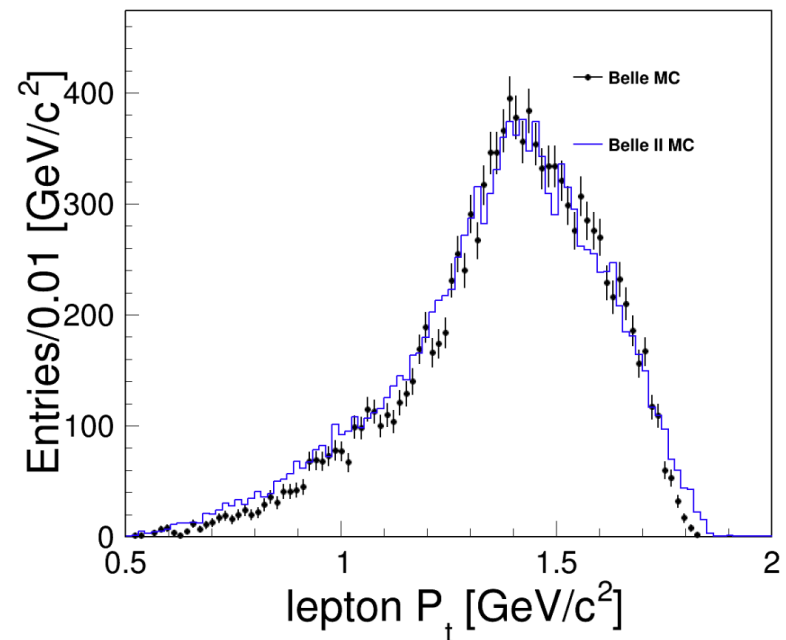
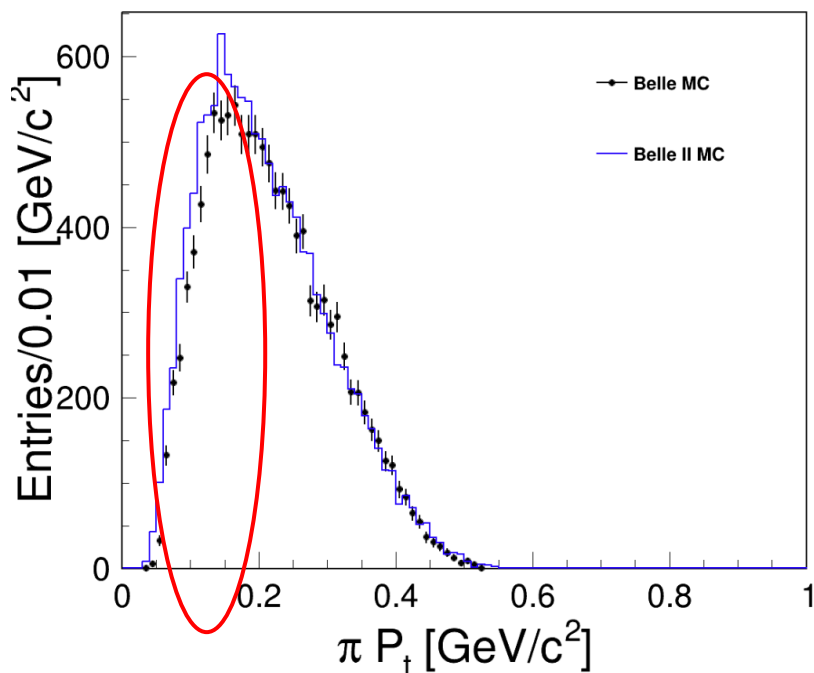
$\omega J/\psi$ distribution

(a) with no cut for resolution, (b) cut J/ψ res, (c) cut ω res, (d) cut $\omega J/\psi$ res.

(e)~(h) using Belle II data with same method.



Low pt track checking



$P_t < 0.15$ GeV 占比 @ pi:

Belle : 26%

Belle II : 30%

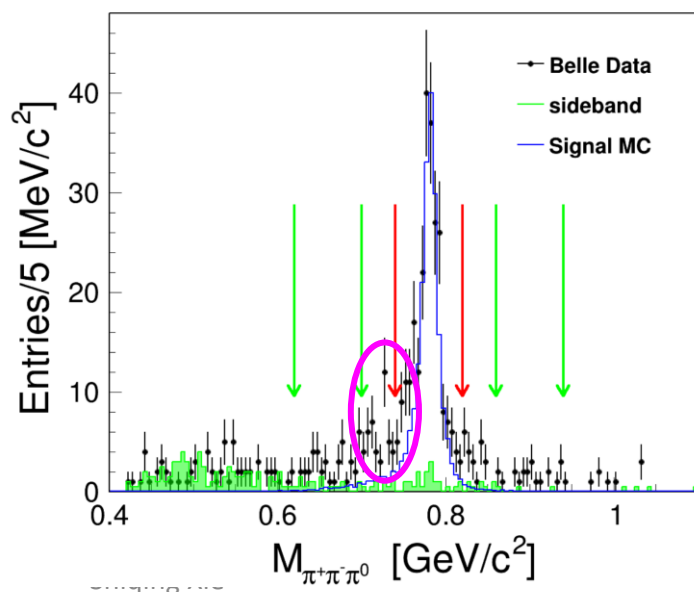
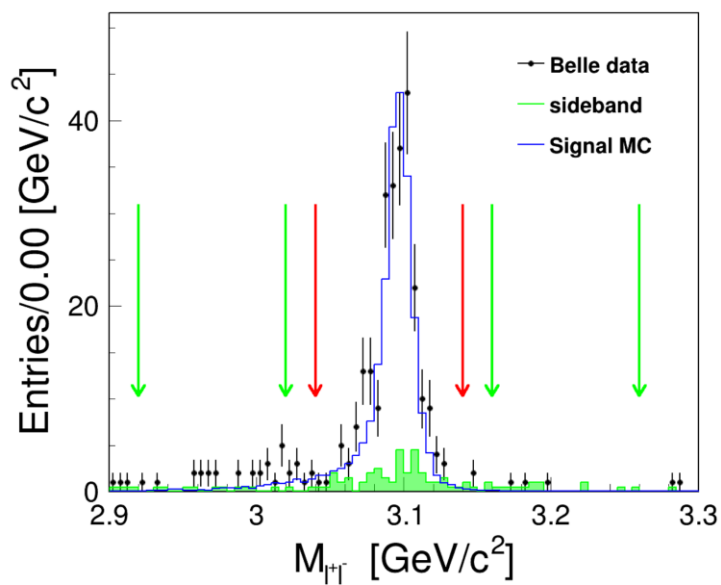
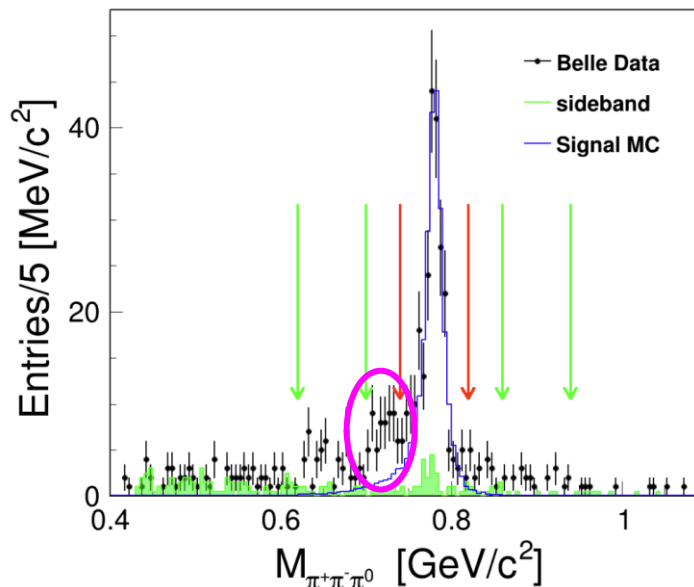
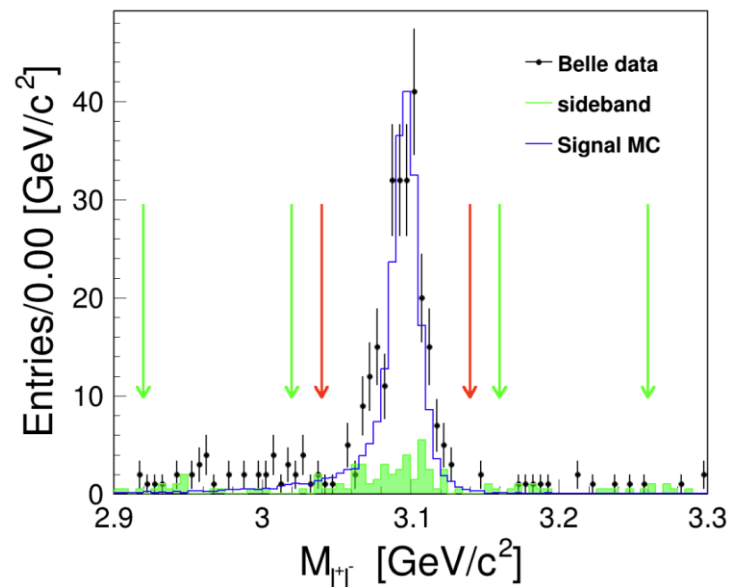
差值百分比(估计): Belle II =1.15 Belle for single low pt track @ pi。

2 pi : $1.15^2 = 1.33$ 。

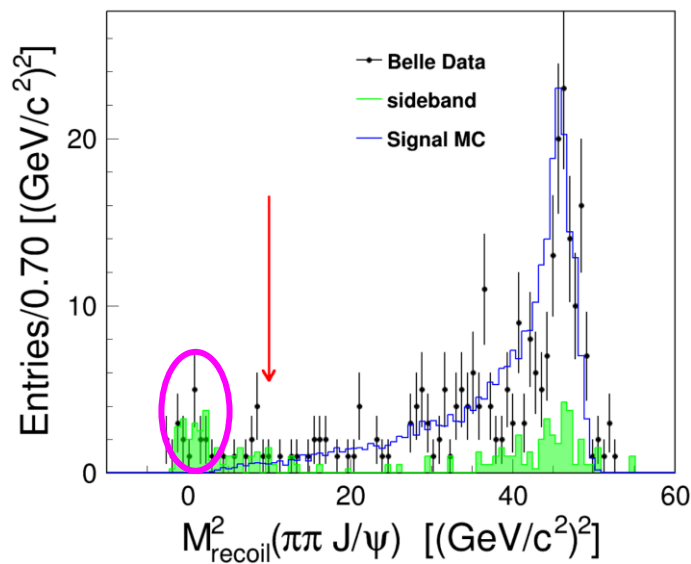
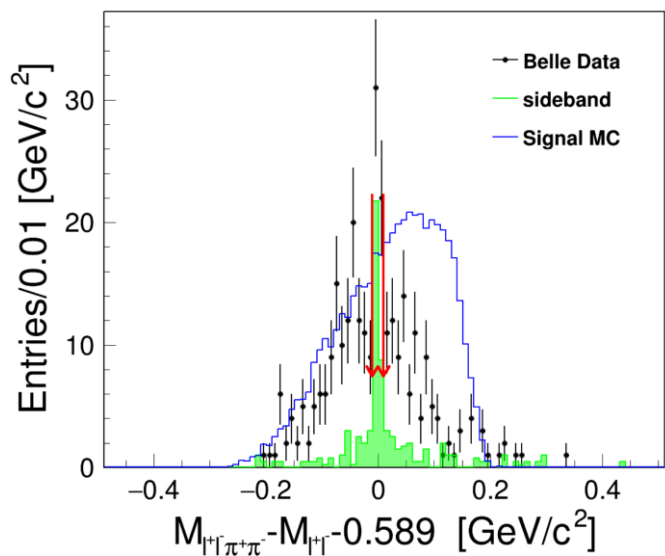
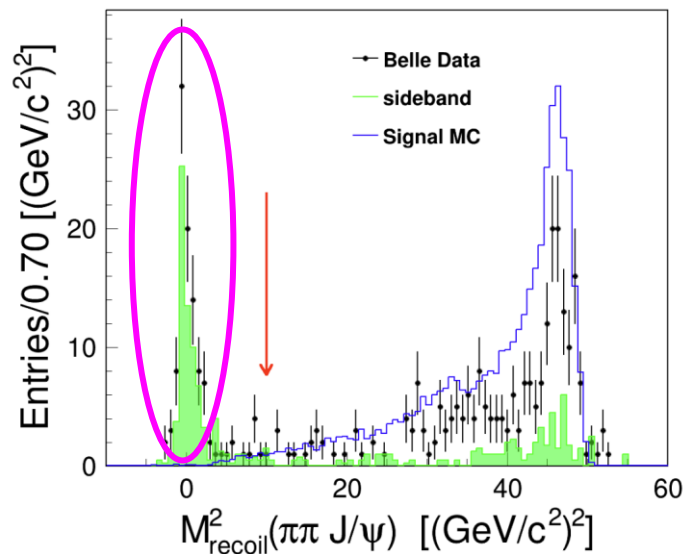
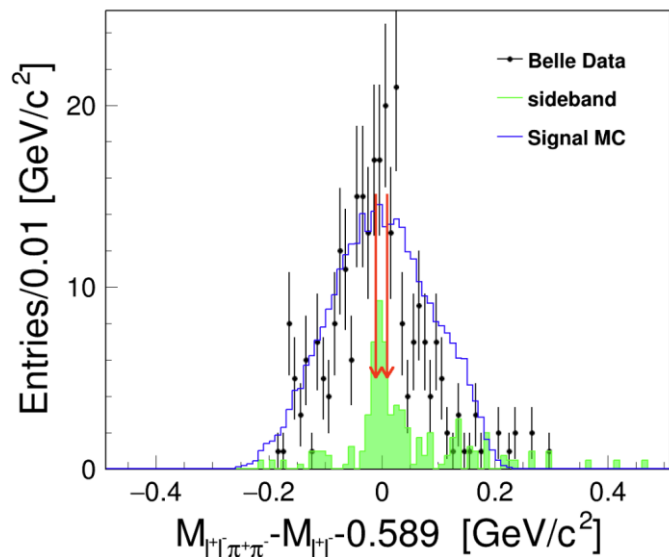
PID修正前效率: Belle II / Belle = 9.05%/6.4%=1.41 。

低动量track以及总体track效率的详细情况准备查一下相关的note

Mass fit checking result (first row)



Mass fit checking result (first row)



Mass fit checking result (first row)

