Study of $B \to (J/\Psi\omega)K$

Sourav Patra

Rajesh Kumar Maiti

Dept of Physical Sciences

IISER Mohali

13th December

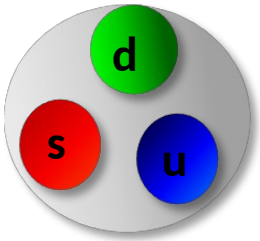
XXIII DAE-BRNS HIGH ENERGY PHYSICS SYMPOSIUM 2018

Outline

- Motivation
- Basic cuts & criteria
- Omega cut optimization
- Background study
- ΔE optimization
- $\psi'K^*$ veto and π^0 modification
- Signal extraction by $M_{J/\psi\omega}$ fitting

QCD : real particles are color singlet

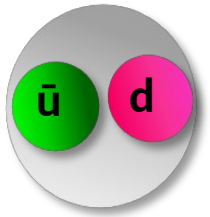
M. Gell-Mann, Phys.Lett. 8, 214 (1964)



Baryons are red-blue-green triplets

Λ=usd

Mesons are color-anticolor pairs

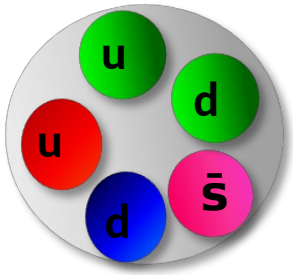


π=ūd

Other possible combinations of quarks and gluons :

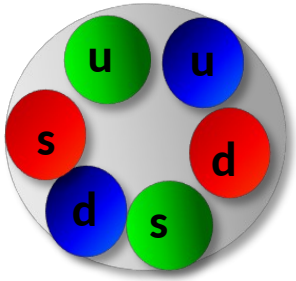
Pentaquark

S= +1 Baryon



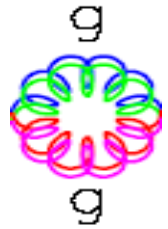
H di-Baryon

Tightly bound 6 quark state



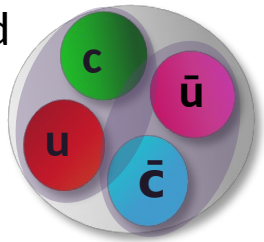
Glueball

Color-singlet multi-gluon bound state



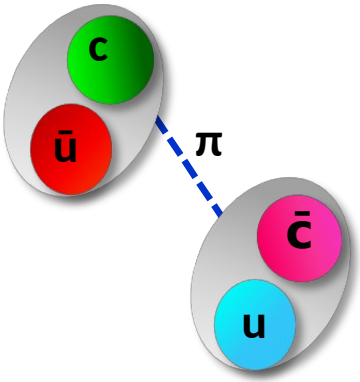
Tetraquark

Tightly bound diquark & anti-diquark

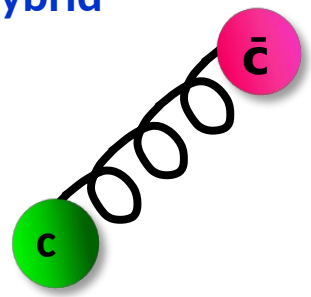


Molecule

loosely bound meson-antimeson "molecule"



qq̄ -gluon hybrid mesons



Artistic illustration

Motivation

X(3872) ws discovered by Belle Collaboration in 2003, X(3872) → J/Ψππ **PRL 91,262001(2003)**
Its mass near DD* threshold and narrow width, along with decay properties, make it difficult to assign it to conventional state.

- Belle found evidence of X(3872) → J/Ψπ⁺π⁻π⁰ in 256 fb^{-1}.

$$\frac{BR(X(3872)\to J/\Psi\pi^+\pi^-\pi^0)}{BR(X(3872)\to J/\Psi\pi^+\pi^-)} = 1.0\pm0.4\pm0.3$$

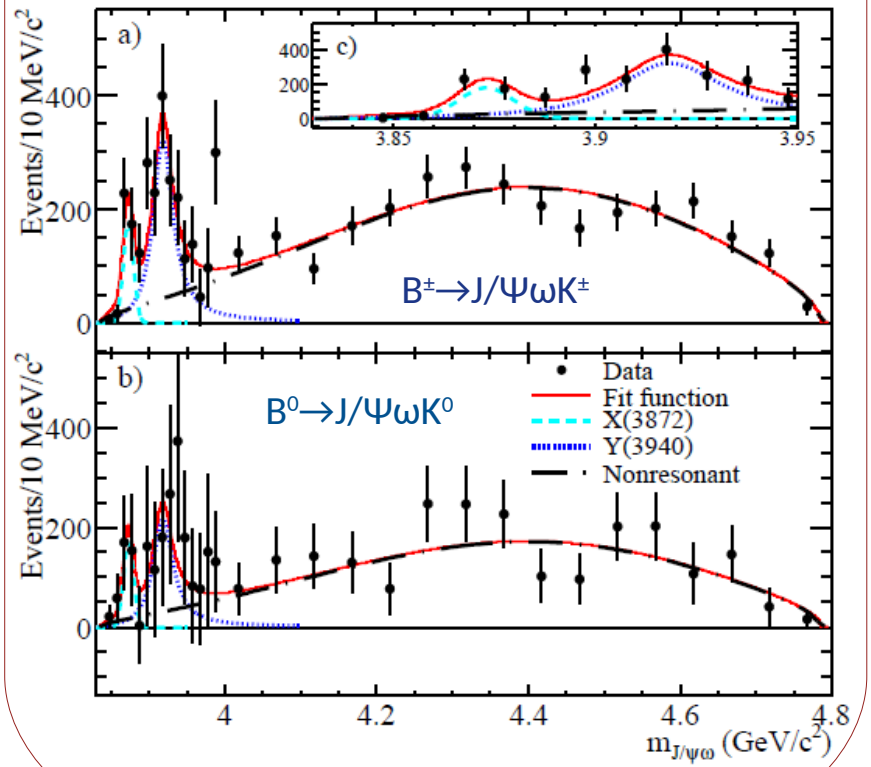
hep-ex/0505037

- Theoretically $R_{3\pi/2\pi}$ ratio has been calculated and was found to be ~30
- Large isospin violation

No one really understood why X(3872) behaves like that. Still open puzzle !

K. Terasaki, YITP-11-68

- BaBar confirms X(3872) → J/Ψω with reanalyzing 426 fb^{-1} data.
- They measured this ratio of $R_{3\pi/2\pi}$ to be 0.8 ± 0.3

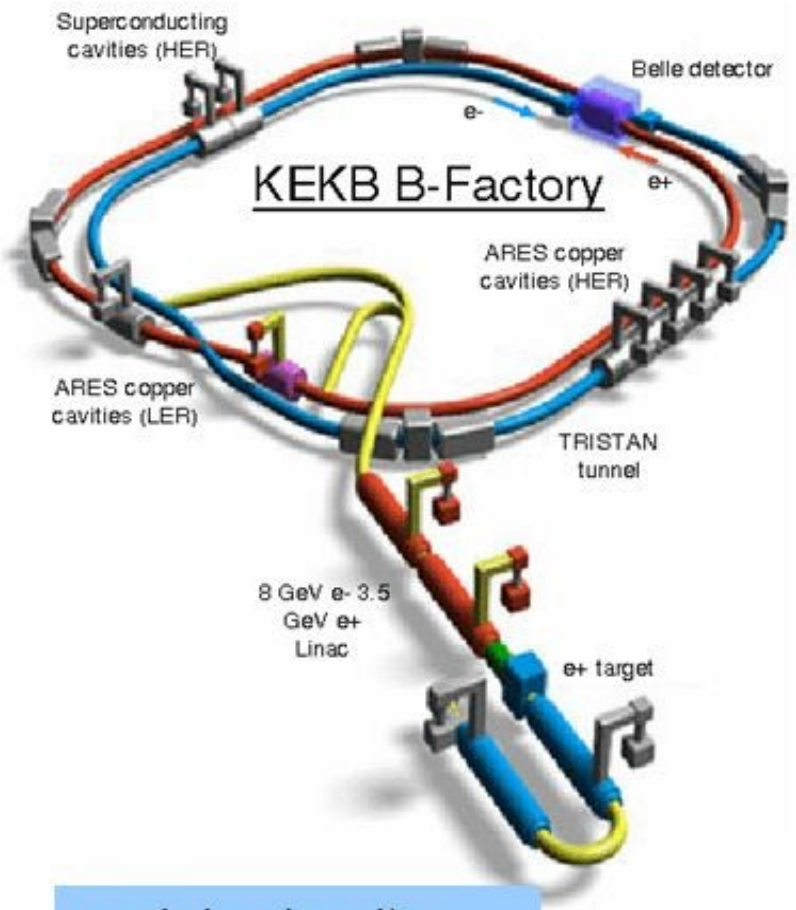


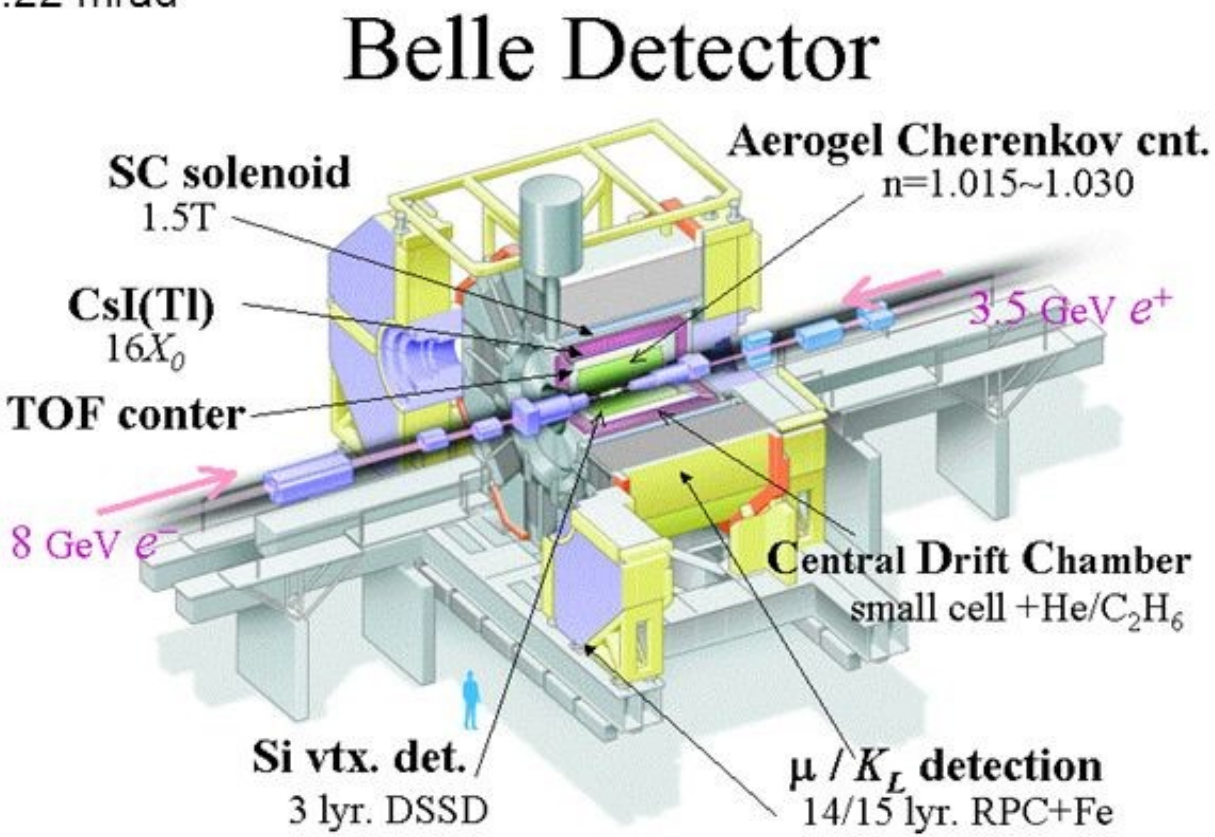
BaBar, PRD 82 011101 (R)

With full data set of Belle, one can measure this ratio more precisely !

Belle Experiment

Beam crossing angle :22 mrad





peak luminosity:
1.71×10^{34} cm^{-2} s^{-1}
world record

1.3 million B $\bar{B}$ pairs / day

Total ~770 × 10^6 B $\bar{B}$ pairs

e-(HER) → 10.58 GeV ← e+(LER) +Z →

MC Generation and Reconstruction

We generated and simulated signal MC for the following decay modes

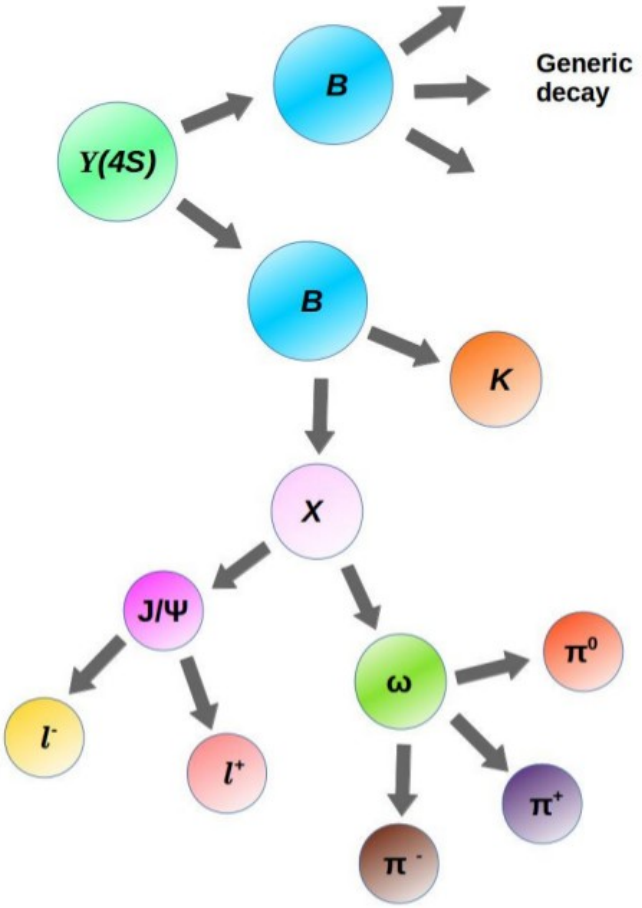
Neutral Events

- $B^0 \rightarrow J/\Psi\omega K_s$
- $B^0 \rightarrow X(3872)K_s$
- $B^0 \rightarrow X(3915)K_s$

Charged Events

- $B^+ \rightarrow J/\Psi\omega K^+$
- $B^+ \rightarrow X(3872)K^+$
- $B^+ \rightarrow X(3915)K^+$

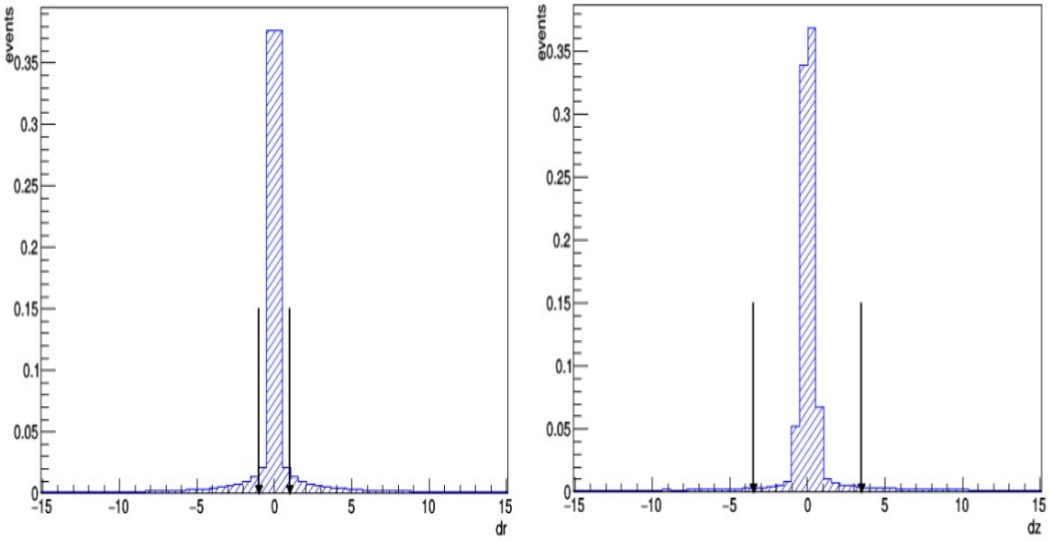
We detect the final states particles in detector
Therefore, we reconstruct our *B* decay from the final states particles as shown in the pictorial diagram.



Basic Cuts & Criteria

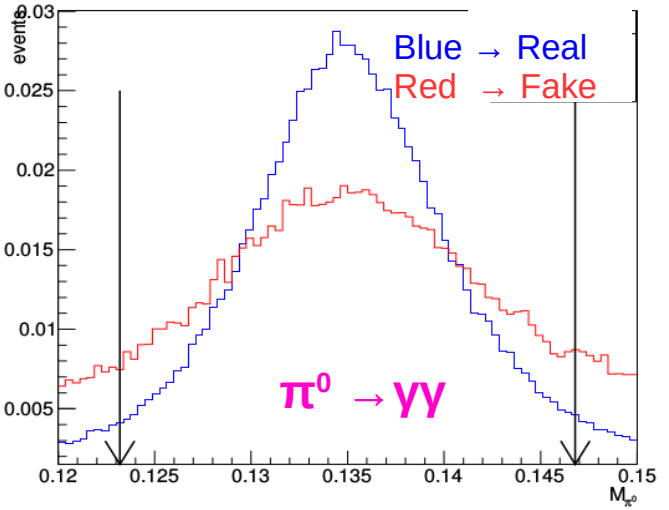
Distance of closest approach

|dr|<1cm **|dz| < 3.5 cm**

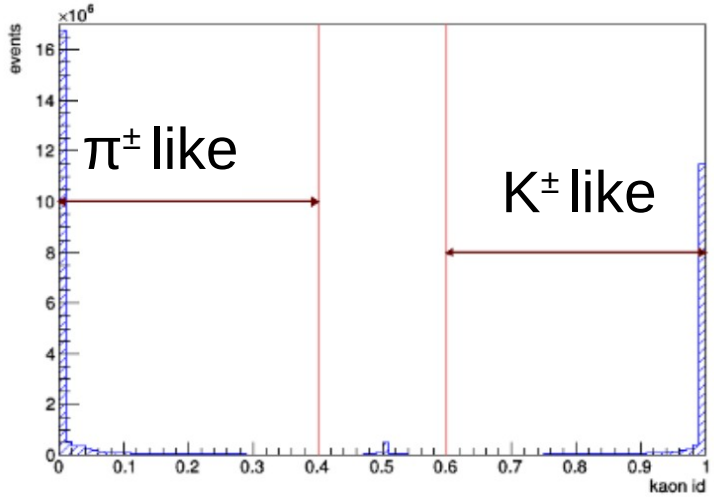


π^0 selection

$M_{\pi 0}$ [123 ↔ 147] MeV/c²

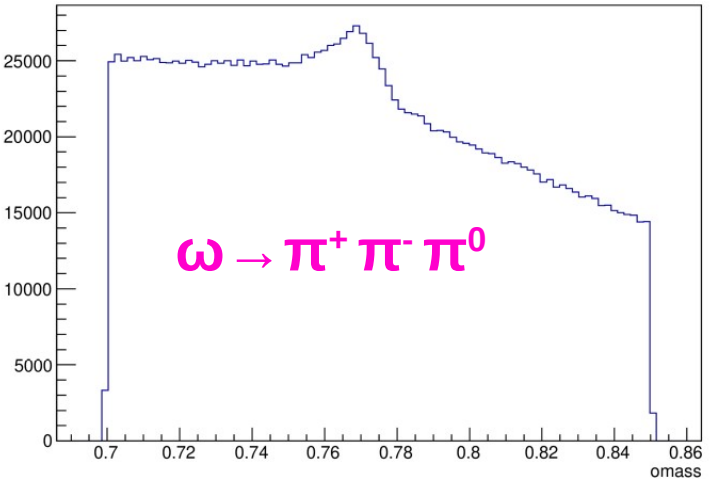


Charged π vs K selection



$$R_{K(\pi)} = \frac{L_{K(\pi)}}{L_K + L_\pi}$$

Omega reconstraction



700 < M_ω < 850 MeV/c²

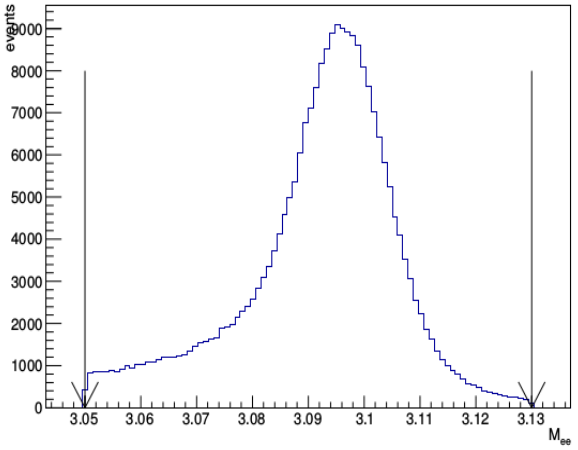
Reconstruction

J/Ψ reconstruction

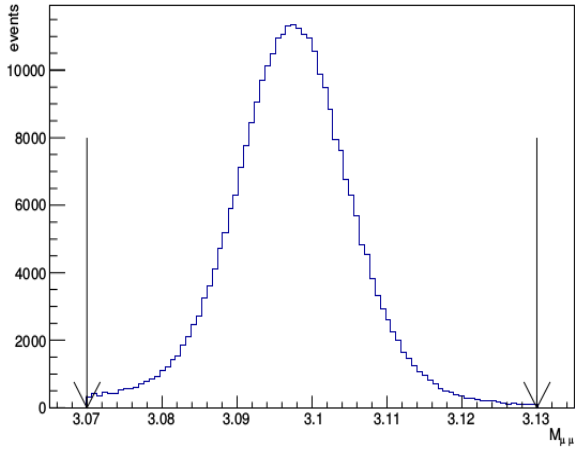
$J/\Psi \rightarrow \mu^+\mu^-$ / $e^+ e^-$

We add gammas within 50 mrad of $e^{\pm}$ direction to account for brehmstraglung.

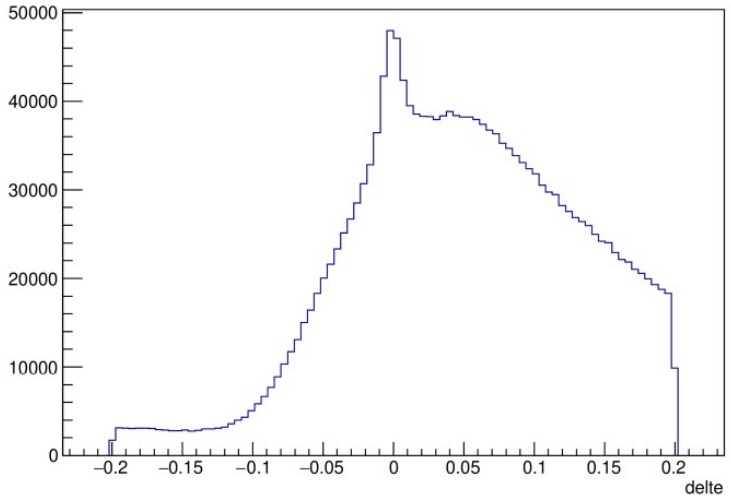
$3.05 < M_{e+e-} < 3.13$ GeV/c^2



$3.07 < M_{\mu+\mu-} < 3.13$ GeV/c^2



Delta E

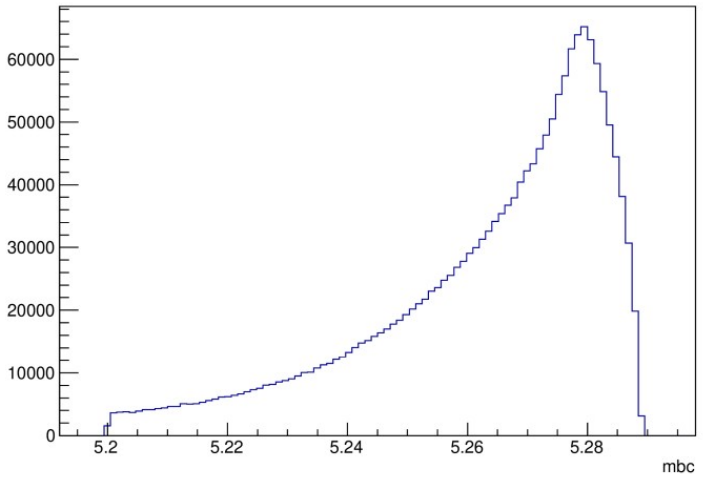


$-0.2 < \Delta E < 0.2$ GeV

$$\Delta E = E_{beam} - E^*_B$$

$$M_{bc} = \sqrt{(E_{beam} - p^*_B)}$$

Beam Constrained Mass(M_{bc})

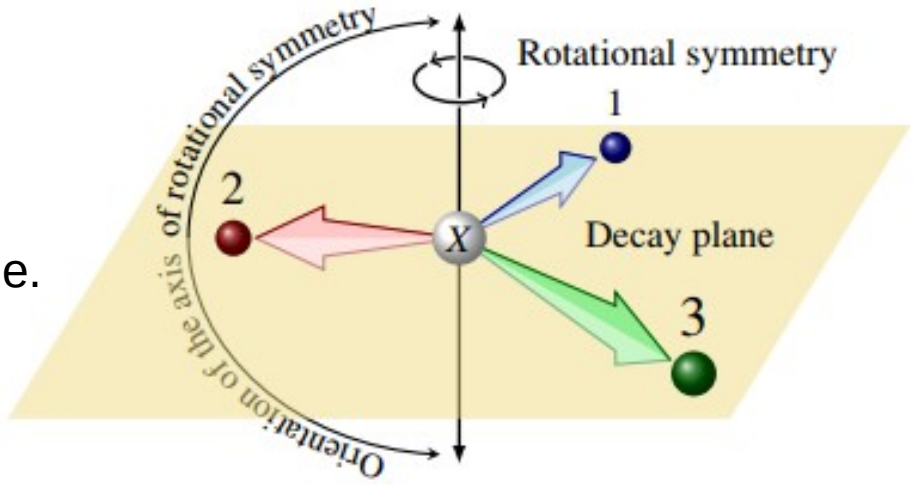


$M_{bc} > 5.2$ GeV/c^2

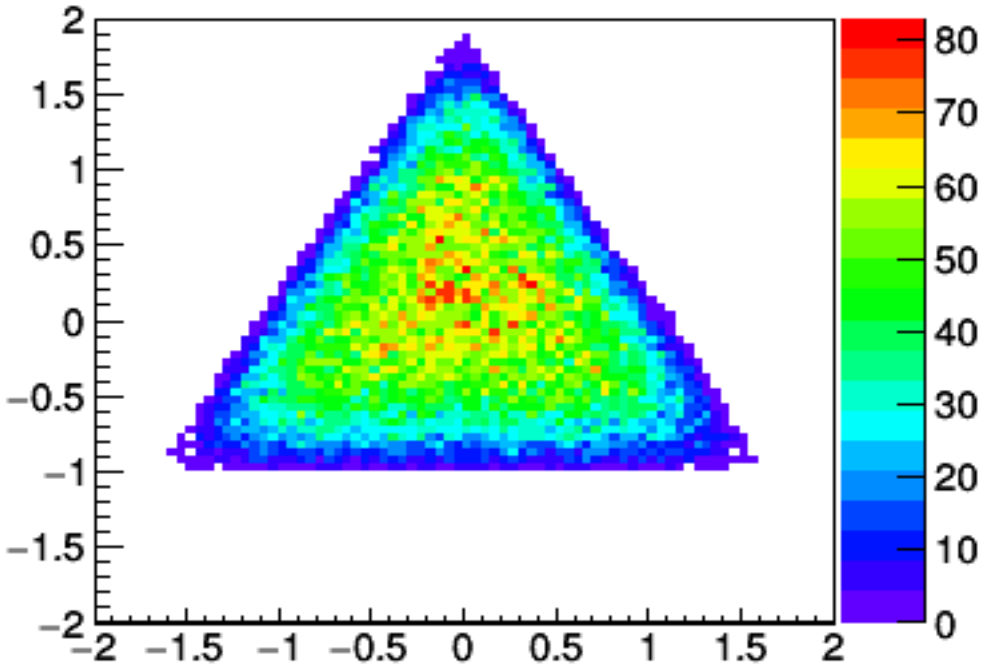
Omega Cut Optimization

$$X = \frac{\sqrt{3}(T_{\pi+} - T_{\pi-})}{Q} \qquad Y = \frac{2T_{\pi0} - (T_{\pi+} + T_{\pi-})}{Q}$$

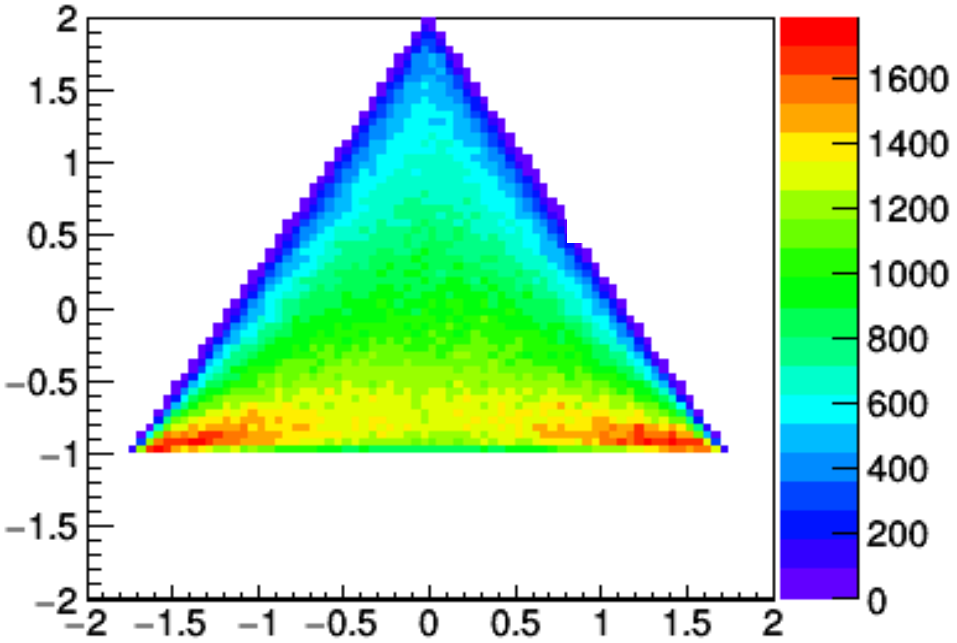
T is the kinatic energy of the corresponding particle.



If J^P of $\pi^+\pi^-\pi^0$ is -1, then events of ω enhanced at center

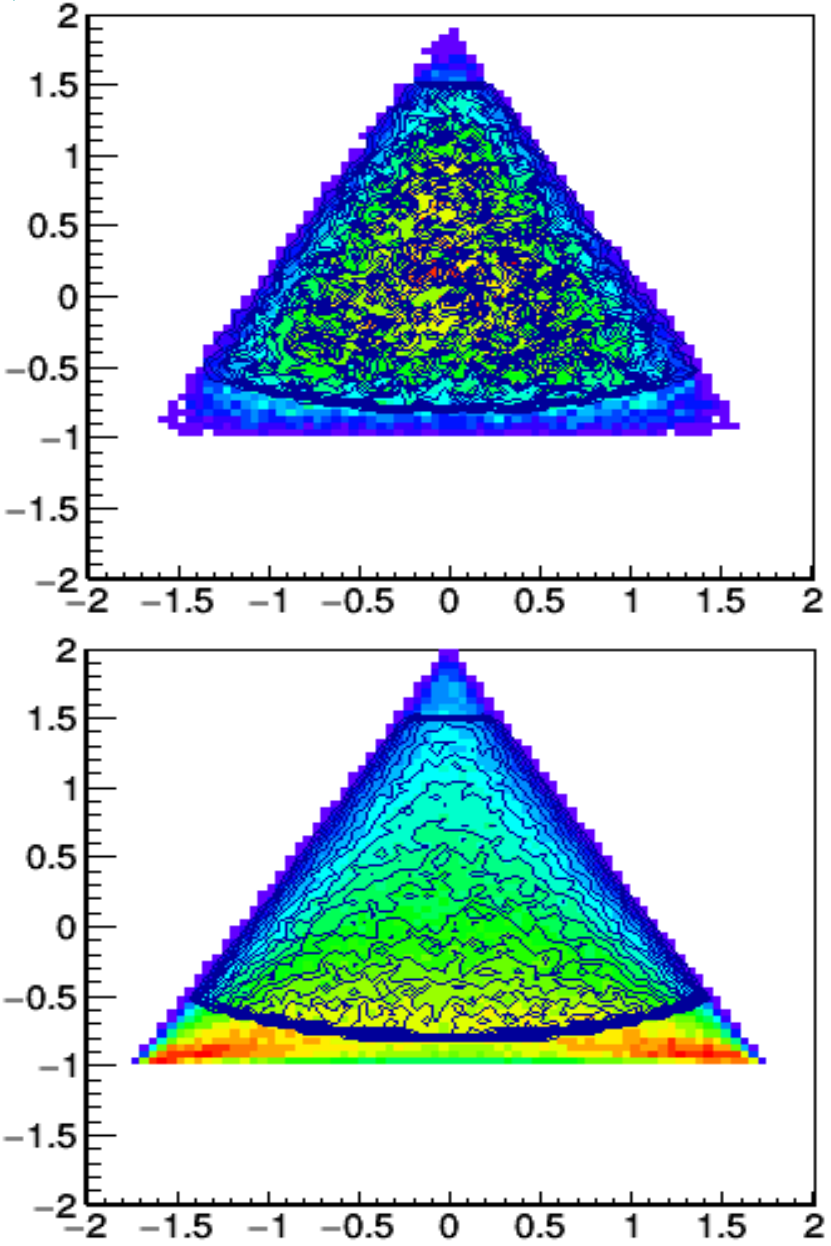


Fake ω



Omega Cut Optimization for $B \rightarrow X(3872)K$

- Use two concentric circular cut for selecting best Omega candidates.
- Select the region within two concentric cercular cuts 1.5 and 3.8 centered at (0,3).
- Signal rejected 7% and fake events rejected 29%.
- Selected events (represented with the contour) are projected on the signal and background saperately.



Best Candidate Selection

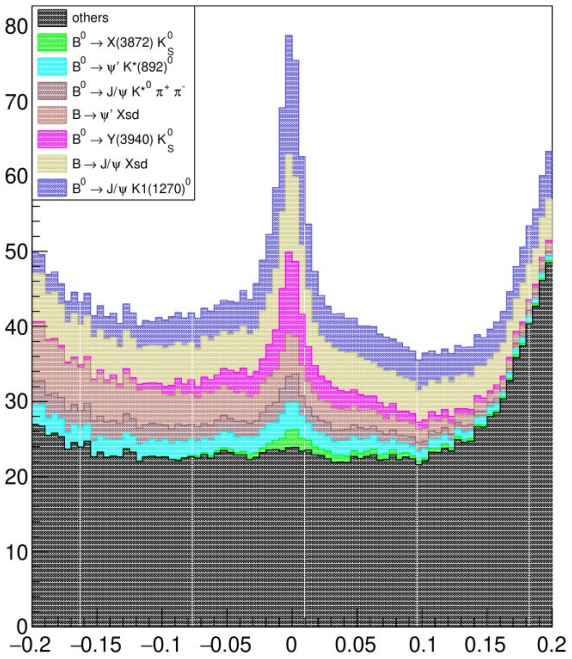
$$\chi^2 = \chi^2_V + \left(\frac{\delta E}{\sigma_{\delta E}}\right)^2 + \left(\frac{M_{ll} - m_{J/\psi}}{\sigma_{J/\psi}}\right)^2 + \left(\frac{M_{3\pi} - m_{\omega}}{\sigma_{\omega}}\right)^2 + \left(\frac{M_{\gamma\gamma} - m_{\pi_0}}{\sigma_{\pi_0}}\right)^2 + \left(\frac{M_{\pi\pi} - m_{K_S}}{\sigma_{K_S}}\right)^2$$

- For best candidate selection χ^2 minimization method is used.
- With this, we lost 21% of the true candidates while rejecting 83% of the fake candidates for charge *B* reconstruction.

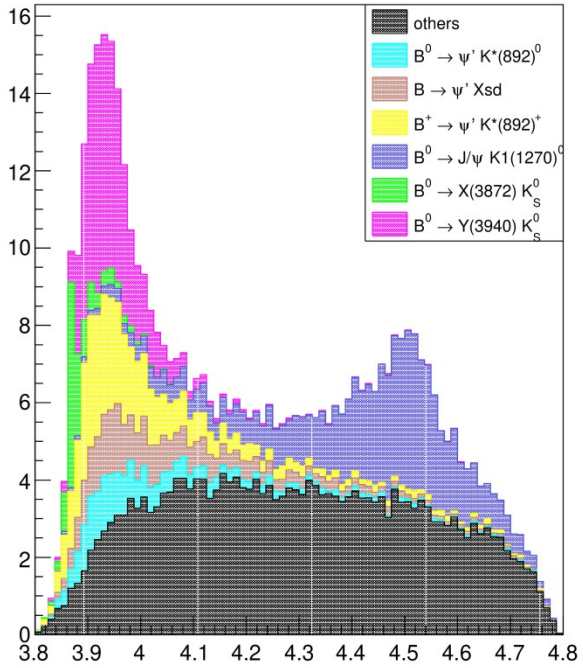
Signal	Multiplicity	BCS efficiency	Signal Efficiency
$X(3872)K^{\pm}$	35 %	69 %	9.1 %
$X(3872)K^0_S$	35 %	58 %	6.5 %

Background study for $B^0 \to (J/\psi\omega)K^0$

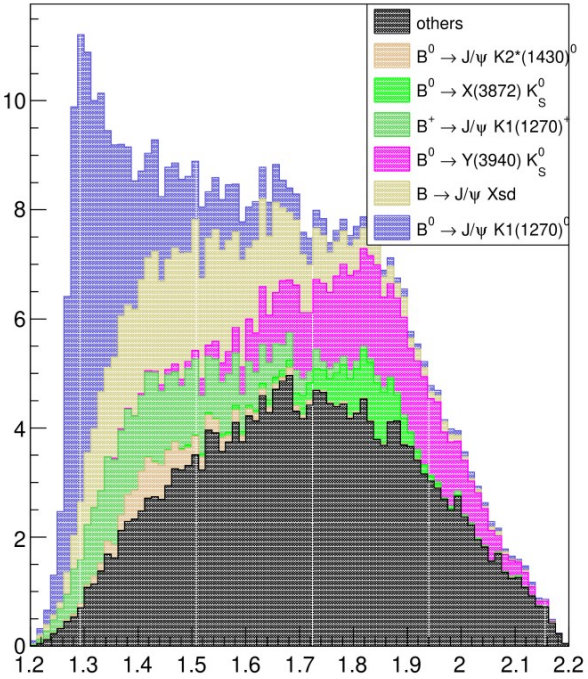
- We expect most of the background to come from *B* decays having *J/Ψ* in the final state.
- In order to study possible background, large (100 times data) set of MC simulation of $B \to J/\Psi X$ inclusive decays was used.



ΔE (GeV)



M(Jψω) (GeV/c²)



M(Kω) (GeV/c²)

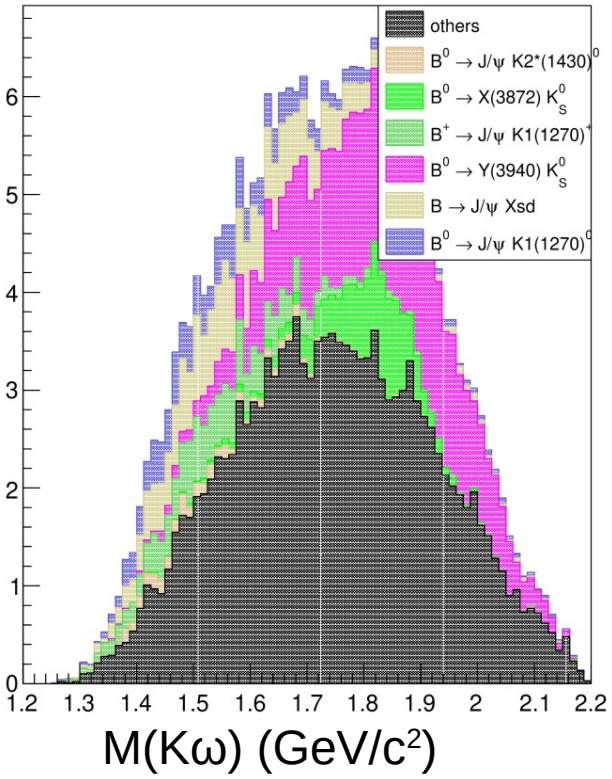
-20 < ΔE < 20 MeV

B → J/ψ X inclusive MC(scaled to data)

Background study for $B^0 \to (J/\psi\omega)K^0$

We are more interested in X(3872), X(3915) region.

$-0.02 < \Delta E < 0.02$ GeV
$3.81\ \text{GeV}/c^2 < M_{J/\psi\omega} < 4.2\ \text{GeV}/c^2$



In order to clean M(J/ψω), we apply cut at M(Kω)> 1.4 GeV/c^2.

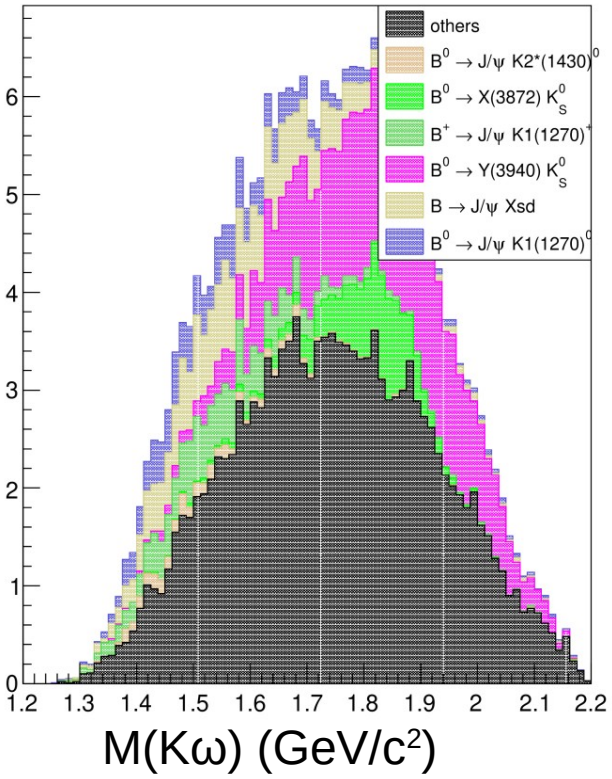
B → J/ψ X inclusive MC(scaled to data)

Background study for $B^0 \to (J/\psi\omega)K^0$

We are more interested in X(3872), X(3915) region.

$-0.02 < \Delta E < 0.02$

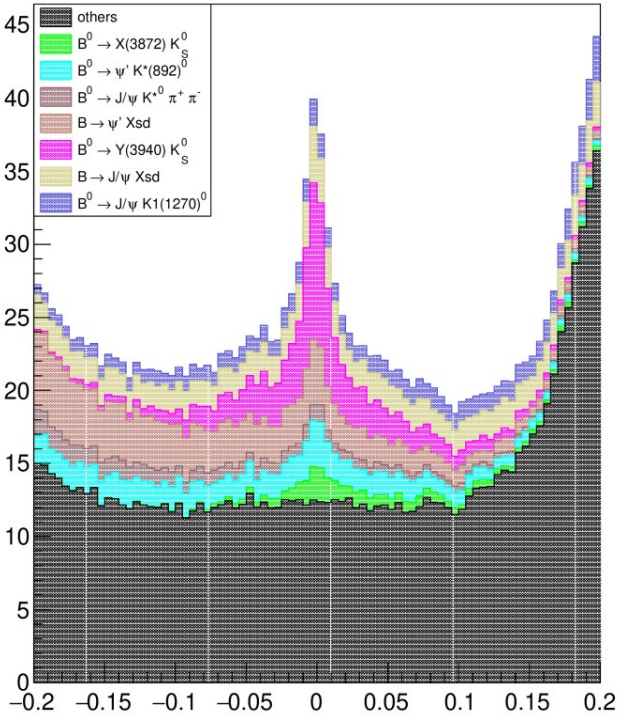
$3.81\ GeV/c^2 < M_{J/\Psi\omega} < 4.2\ GeV/c^2$



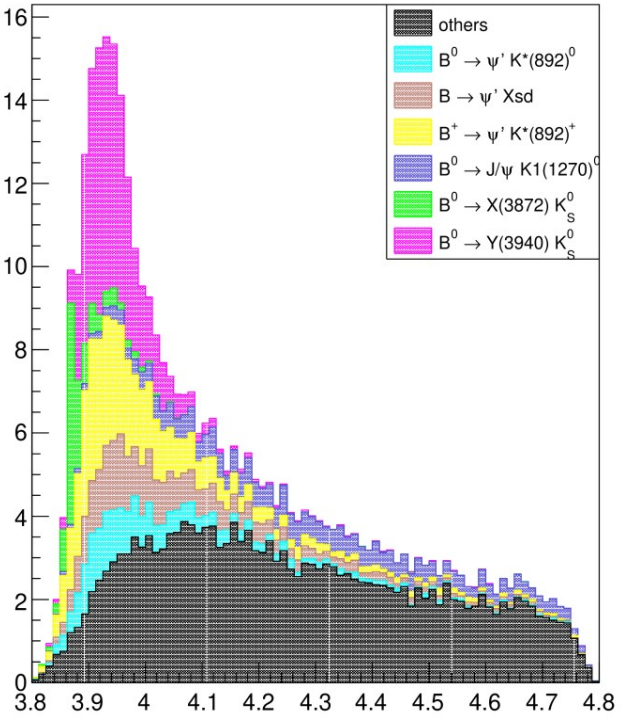
In order to clean M(J/ψω), we apply cut at M(Kω)> 1.4 GeV/c².

M(Kω)> 1.4 GeV/c²

$3.81\ GeV/c^2 < M_{J/\Psi\omega} < 4.2\ GeV/c^2$



$-0.02 < \Delta E < 0.02$



$B \to J/\psi$ X inclusive MC(scaled to data)

ΔE optimization

In order to optimize the ΔE window, we used figure of merit study

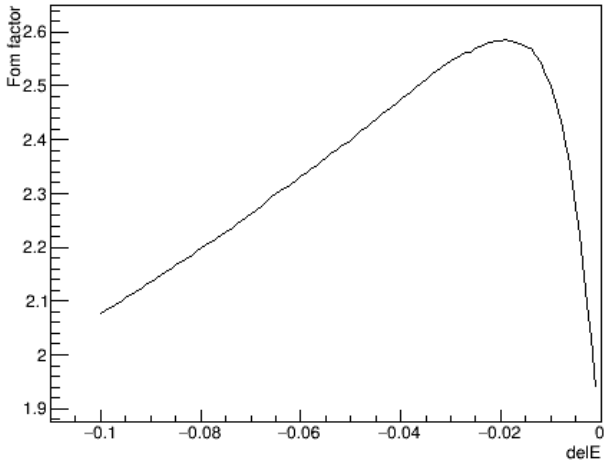
$$FOM = \frac{S}{\sqrt{(S+B)}}$$

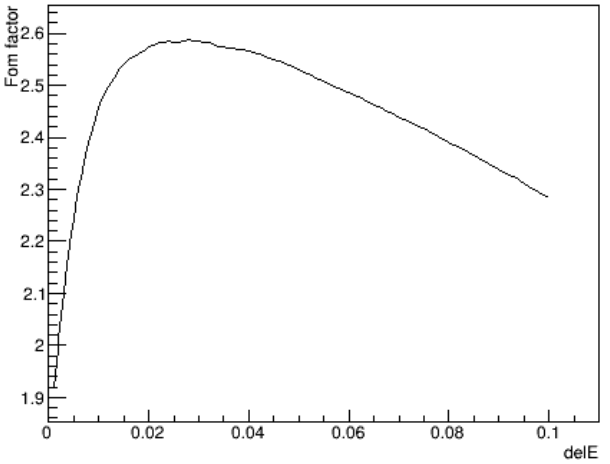
- For signal yield, BF from BaBar study was used.
- While background was estimated from B → J/ΨX inclusive study.

We set the Δ*E* signal window as

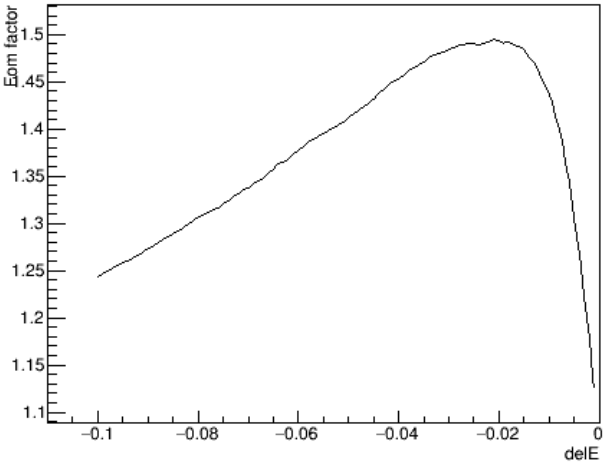
-0.02 < ΔE < 0.02 GeV

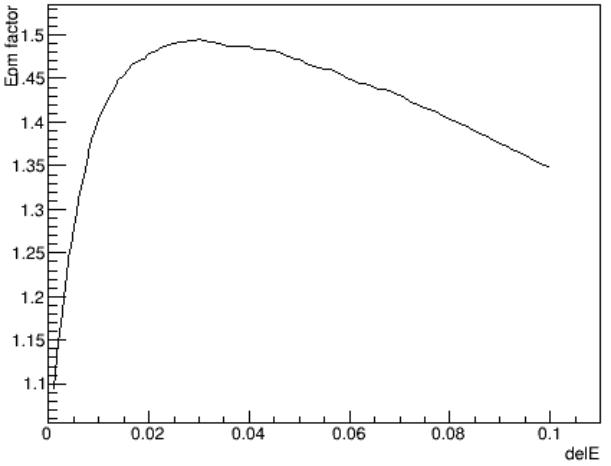
$B^+ \rightarrow X(3872)(J/\psi\omega)K^+$





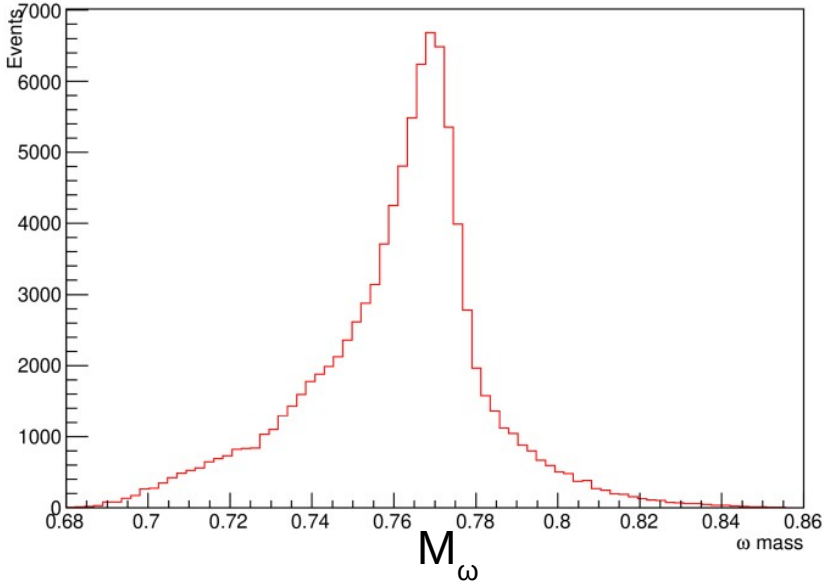
$B^0 \rightarrow X(3872)(J/\psi\omega)K^0$

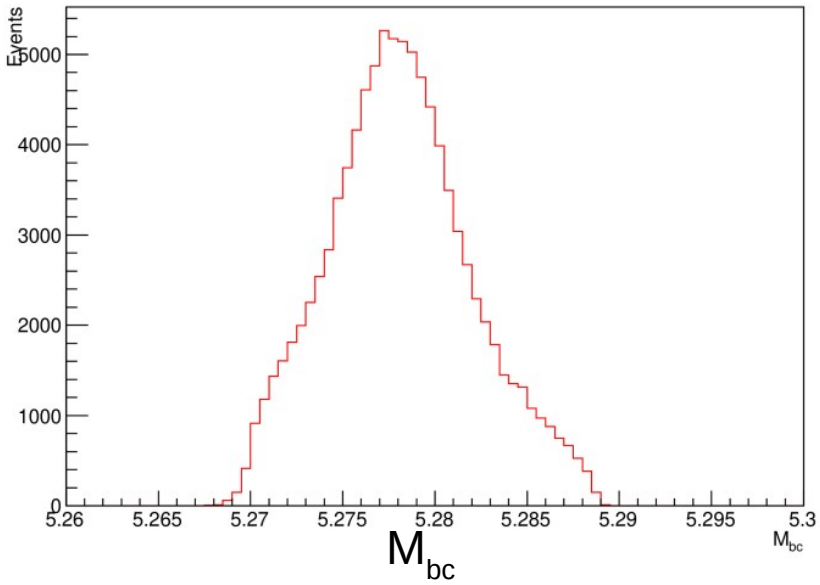




Modification of π^0 Momentum

To improve the resolution of M(J/ψω), we modify the π^0 momentum.





We assume that the ΔE resolution is bad due to π^0 resolution

- Energy of π^0 is scaled such a way that it forces ΔE to be zero (ideal scenario).

$$s = \frac{E_{beam} - \left(E_{J/\psi} + E_K + E_\pi + E_\pi\right)}{E_{\pi^0}}$$

- In order to keep the π^0 mass invariant, we also scaled the momentum of the π^0.

$$\alpha = \sqrt{\left(1 - \left(1 - s^2\right)\frac{E_{\pi^0}^2}{P_{\pi^0}^2}\right)}$$

Modified π^0 was then used for ω reconstruction.

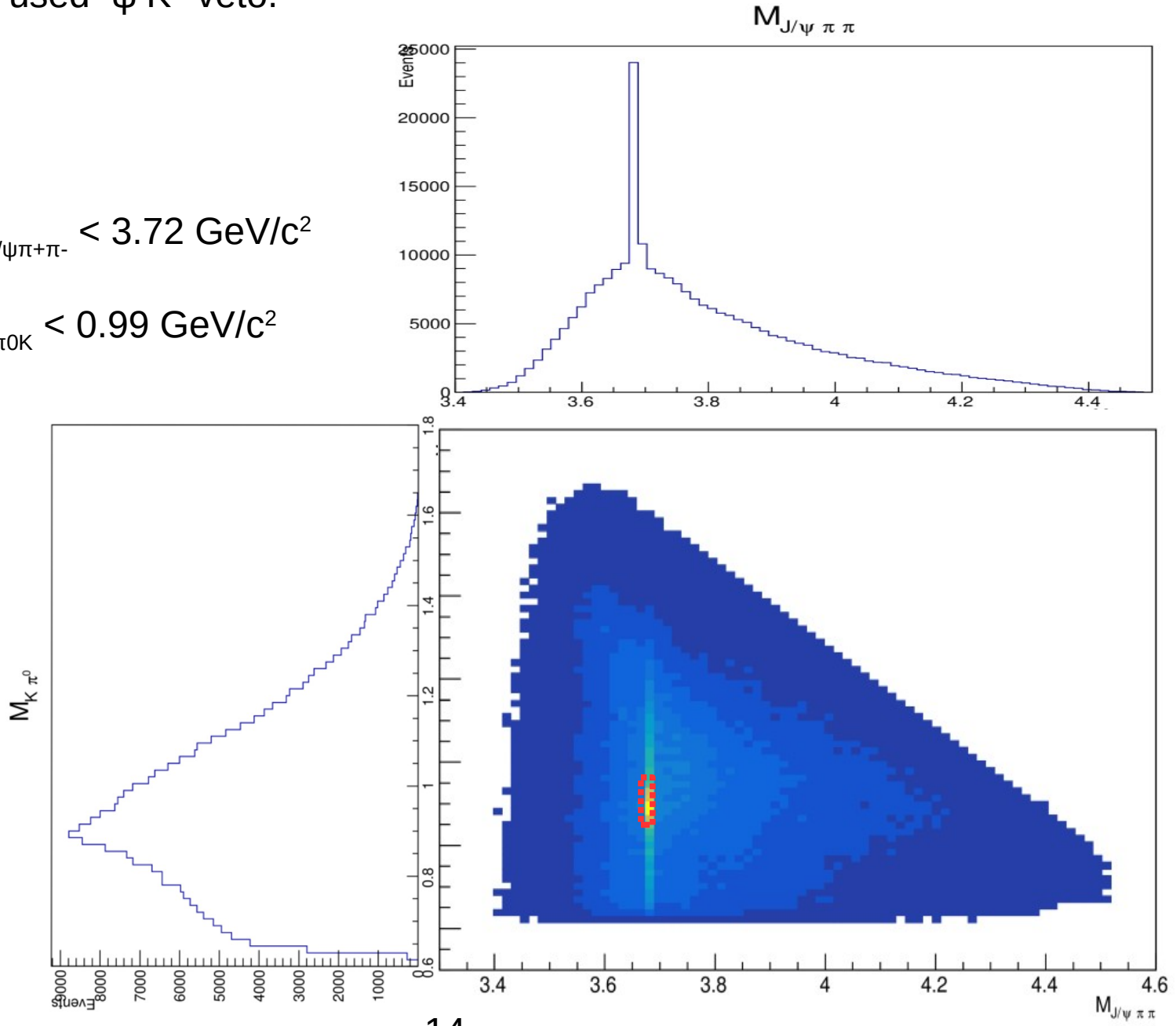
B→Ψ′ K* Veto

$B \to \psi'(\to J/\psi\pi^+\pi^-)K^{*+}(\to K^+\pi^0)$ decay mode has same final state and is peaking background. To remove it, we used ψ'K* veto.

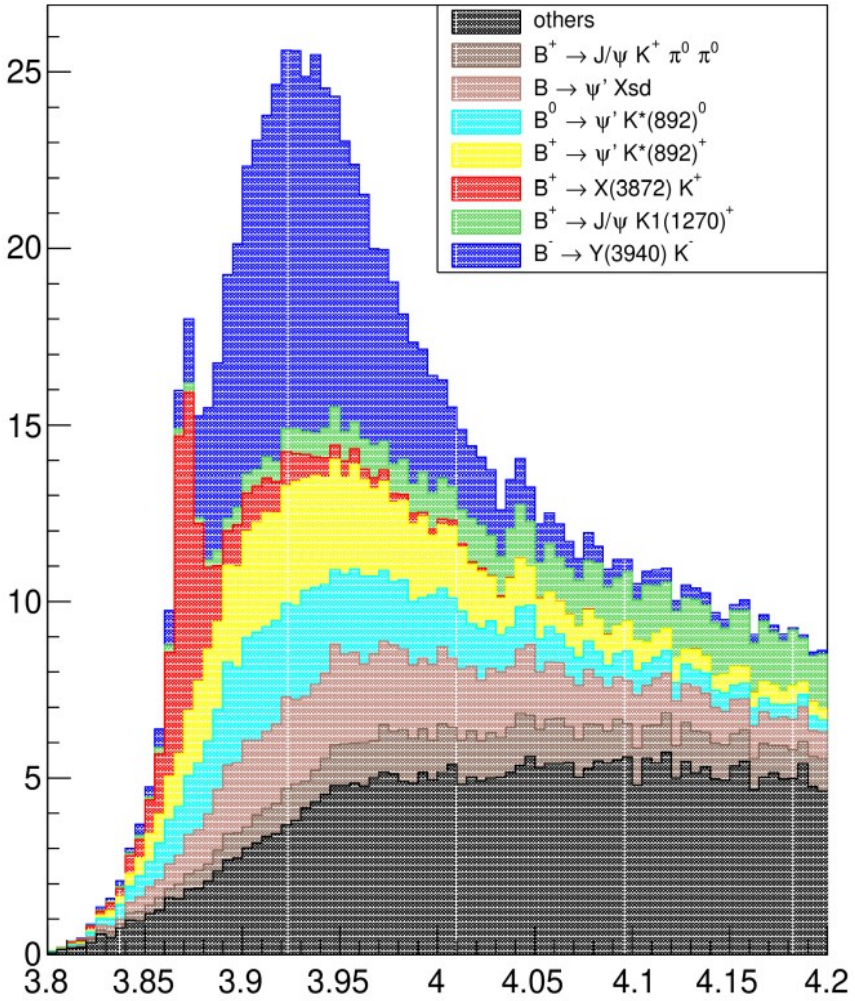
<u>Rejected Windows</u>

i) 3.67 MeV/c^2 < $M_{J/\psi\pi+\pi-}$ < 3.72 GeV/c^2

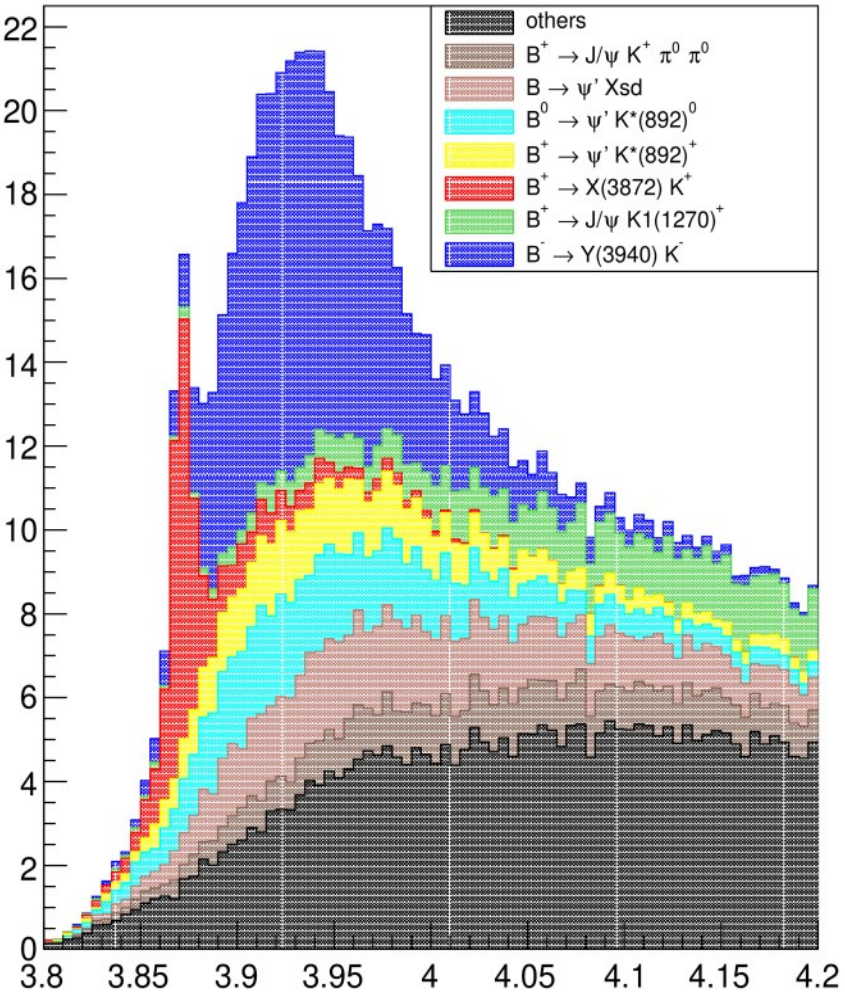
ii) 0.79 GeV/c^2 < $M_{\pi 0K}$ < 0.99 GeV/c^2



Improvement in background for $B \to (J/\psi\omega)K$



Unmodified

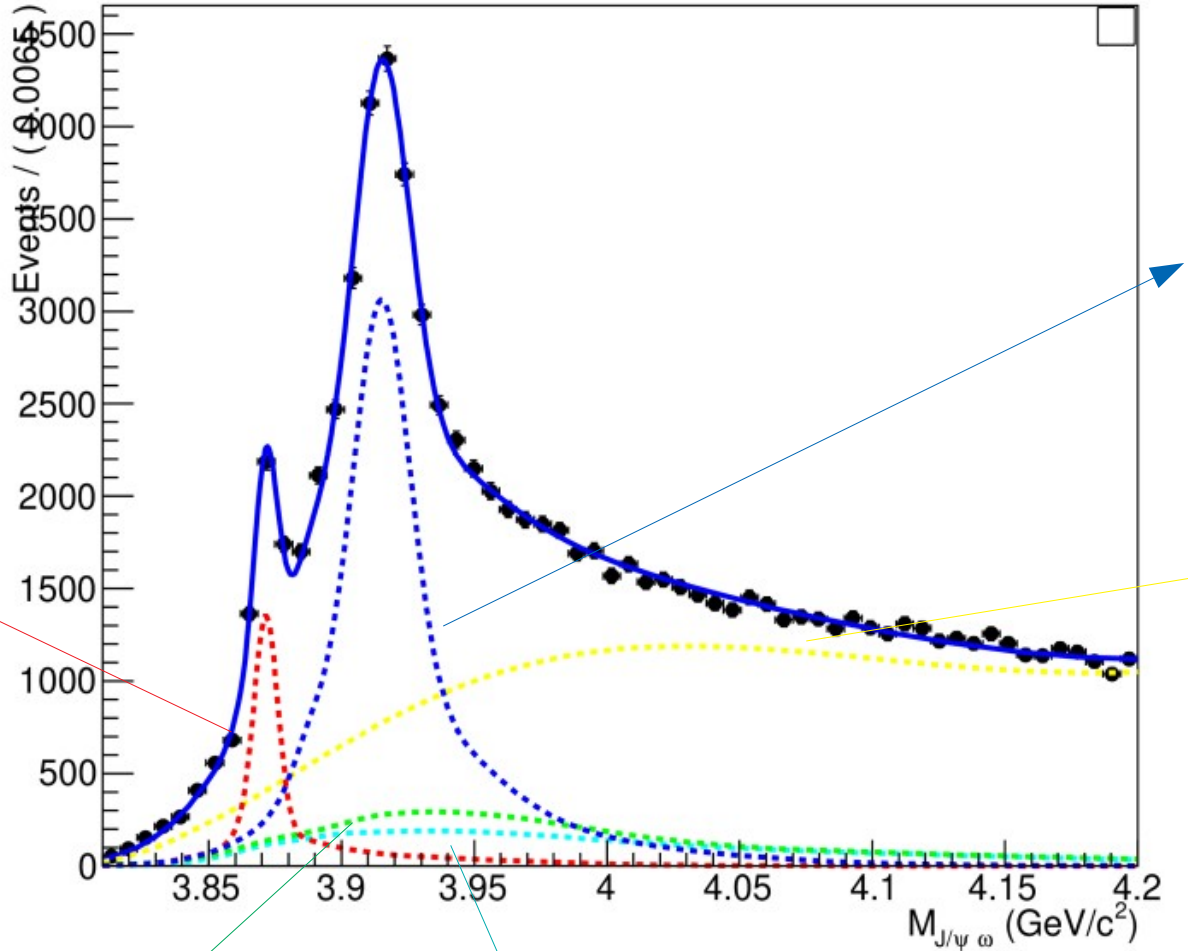


Modified

$B \to J/\psi$ X inclusive MC(scaled to data)

$M_{J/\psi\omega}$ fit for signal extraction

1D UML fit to M(J/ψω) to extract X(3872) and X(3915) component.



$B \to X(3915)K$

$B \to X(3872)K$

Combinatorial background

$B \to \Psi' K^{*+}$

$B \to \Psi' K^{*0}$

B→J/ψ X inclusive MC(100 times data)

Summary

Done:

- Signal MC study for $B \rightarrow (J/\psi\omega)K$ has been done.
- In case of multiple candidates, we select the best candidate using minimum χ^2.
- ω cleanup done.
- Potential backgrounds have been identified using $B \rightarrow J/\psi X$ inclusive MC (x100 data) and reduced.
- Signal resolution is improved using π^0 scaling method.
- Fitter has been prepared for the signal extraction.

Future tasks:

- Fit bias to be studied.
- Unblind the data and measure X(3872) and X(3915) component.

Thank You