Search for a J/ψ η resonance in $B^{\pm} \rightarrow J/\psi \eta K^{\pm}$ at Belle

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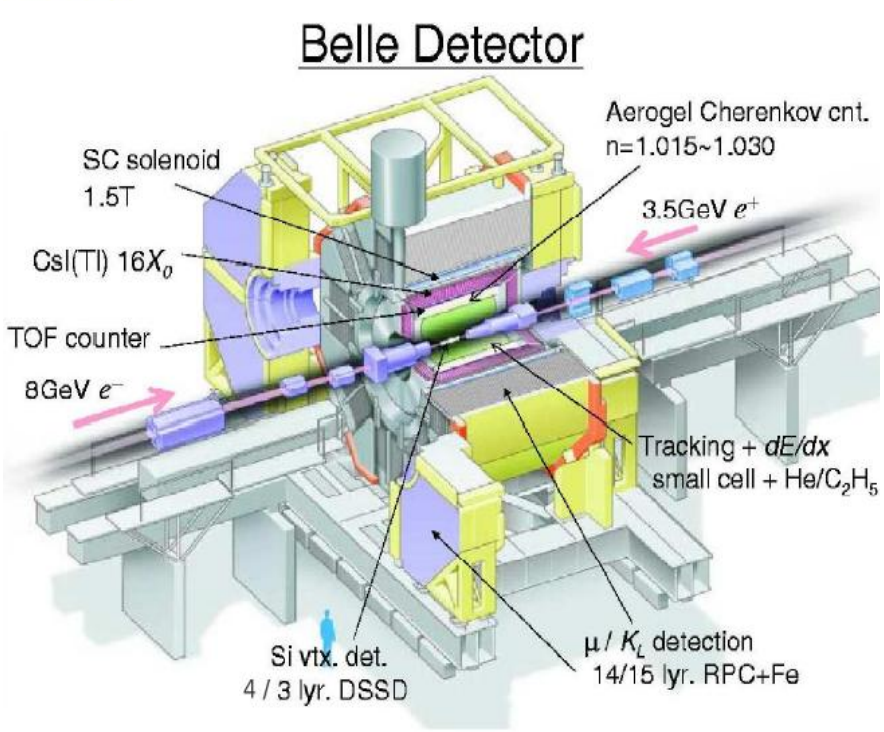
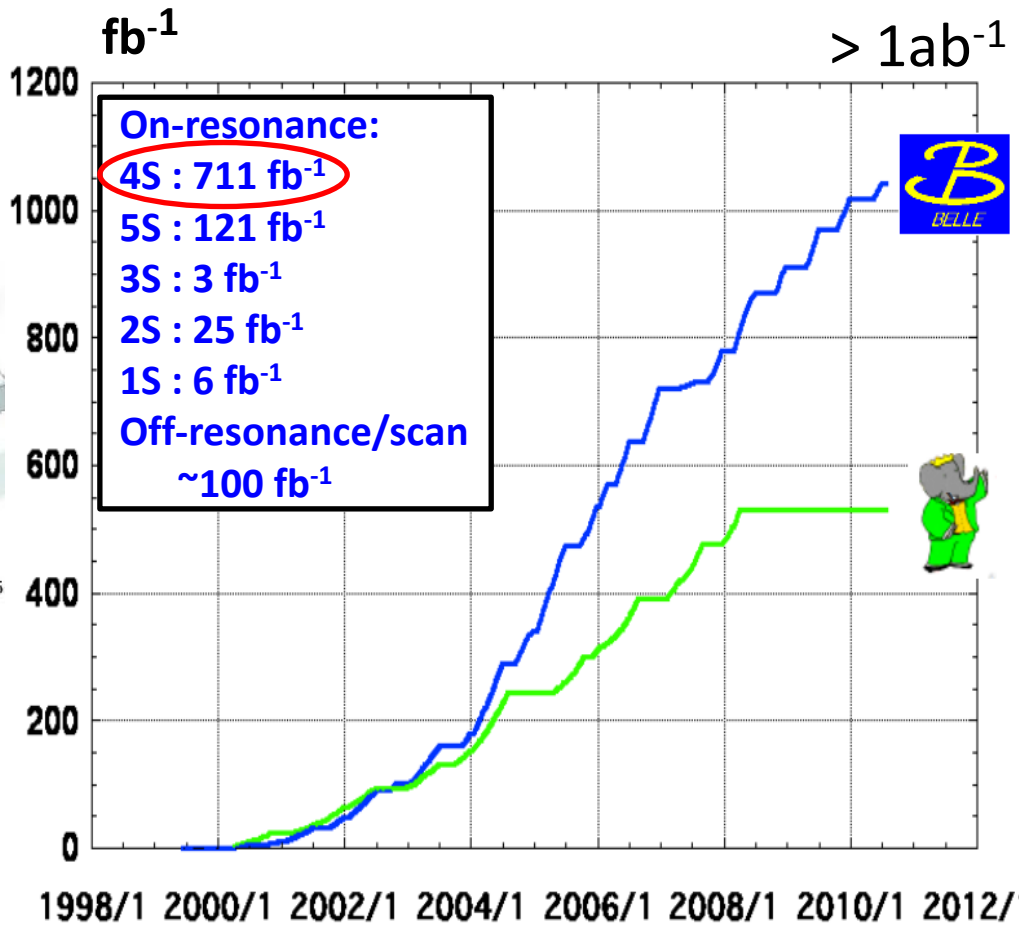
Outline

- Motivation
- B reconstruction
- Background
- Data
- Upper limit
- Summary

Belle detector





General purpose detector, build to test Standard Model mechanism for CP violation in B decays to charmonium ($B^0 \rightarrow J/\Psi, \Psi', \chi_{c1}\ K^0$).

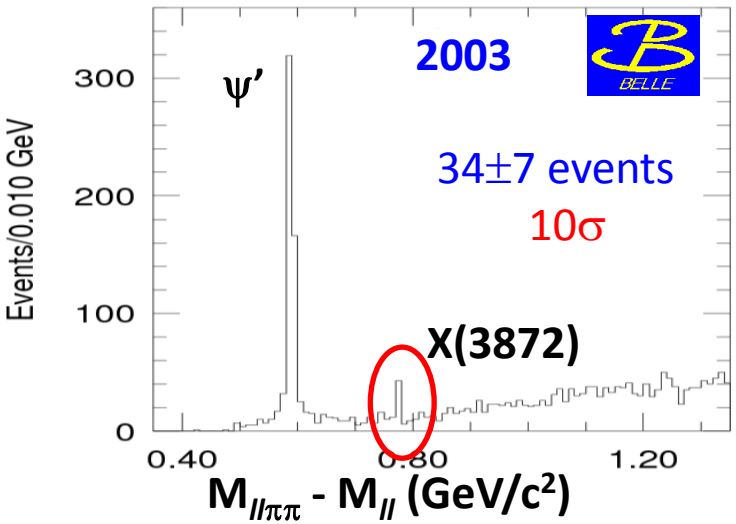
Contribution to charmonium (-like) states:

$\eta_c(2S)$, X(3872), Y(3940), Z(3930), X(3940),X(3915), Y(4260), Y(4660), $Z(4430)^+$, $Z_1(4050)^+$, $Z_2(4250)^+$ …

X(3872)

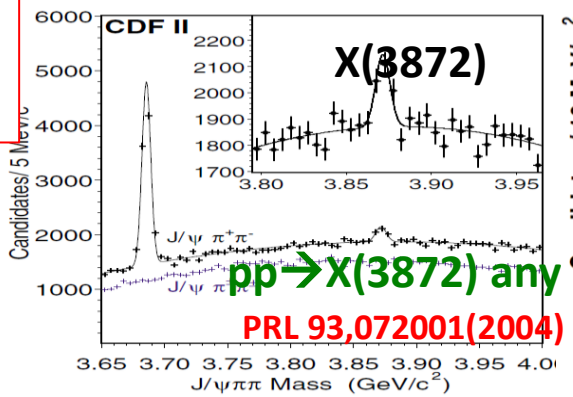
X(3872) is discovered by Belle in $J/\psi\pi^+\pi^-$ decay mode

$B^+ \rightarrow X(3872)\, K^+$, $X(3872) \rightarrow J/\psi\pi^+\pi^-$



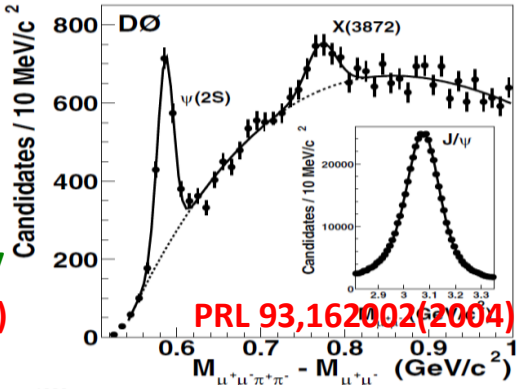
PRL 91,262001(2003)

Γ<2.5 MeV (90%CL)

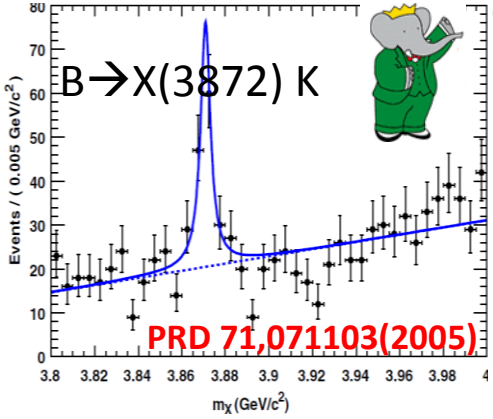


pp→X(3872) any

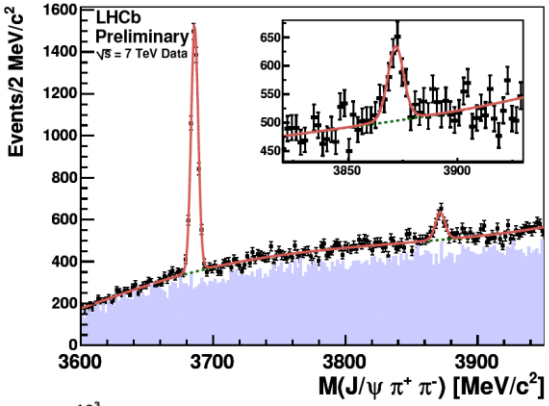
PRL 93,072001(2004)

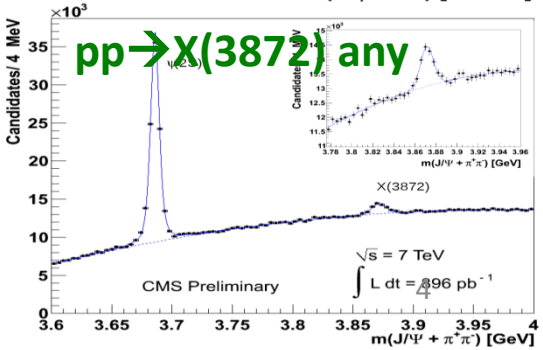


PRL 93,162002(2004)



PRD 71,071103(2005)



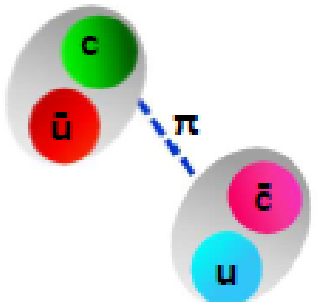


Confirmed by CDF, DO, BaBar, CMS and LHCb.

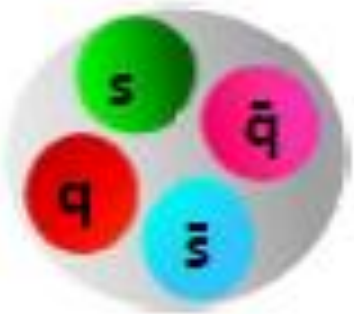
X(3872) property

No obvious charmonium candidate

- ✓ M=3871.6±0.2 MeV
  M(D^0)+M($\bar{D}^{0,*}$)=3871.7±0.2
- ✓ Γ < 1.2 MeV
- ✓ $J^{PC}=1^{++}$ or 2^{-+}
- ✓ Some theoretical models
  - Molecule model
  - Tetra-quark model
  - Hybrid meson
  - Mixing model



Molecule model



Tetra-quark model

Partners of X(3872)

Recent Belle search

Belle, PRD 85,052004 (2011)

$\Delta M(M_x(B^+)-M_x(B^0))$ = = **(-0.69±0.97±0.19) MeV**

$Br(B^0 \rightarrow X^+K^-) \cdot Br(X^+ \rightarrow \pi^+\pi^0 J/\psi) < 3.9 \times 10^{-6}$

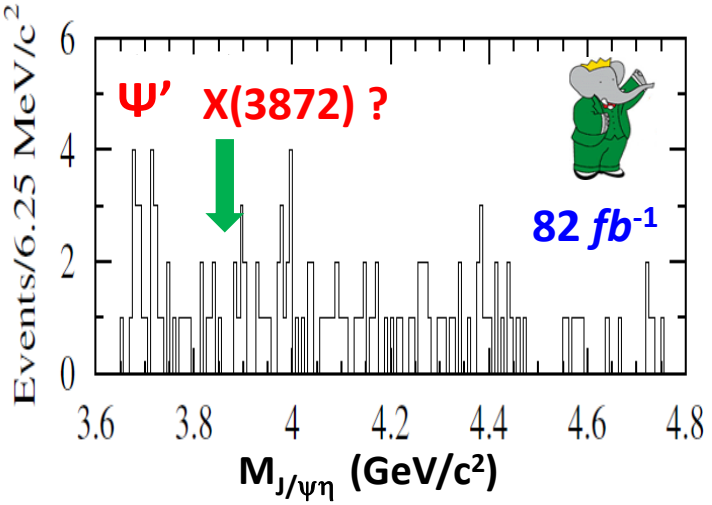
No charged partner ?

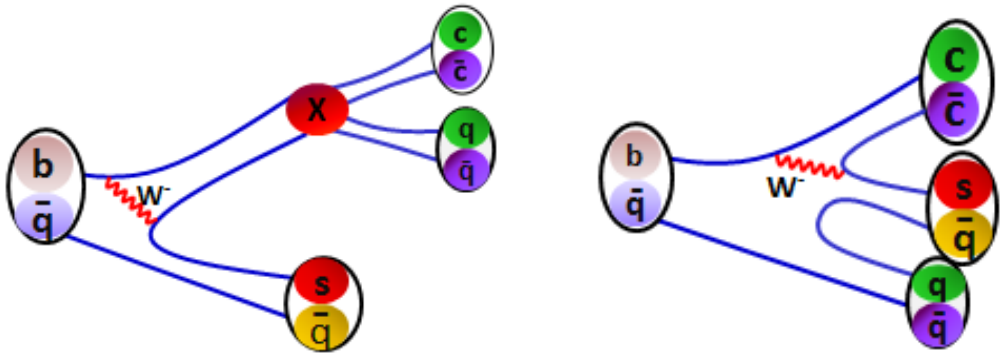
Few tetraquark models predict $X(3872)^+$ to be broad, not observed yet because of low statistics (?). K. Terasaki, Prog. Theor. Phys. 127, 577-582 (2012)

If X(3872) is tetraquark, then X(3872) has C-odd partner which can dominantly decay into $X(3872)^{C-} \rightarrow J/\psi\eta$

$J/\psi\eta$ search important to identify X(3872) nature

B→J/ψηK decay





BaBar observed $B^+ \rightarrow J/\Psi\eta K^+$ and provided

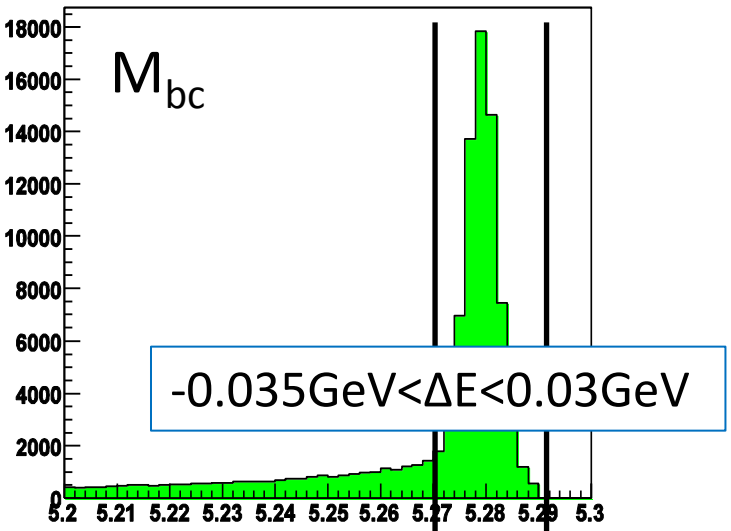
$Br(B^+ \rightarrow J/\psi\eta\, K^+) = (10.8 \pm 2.3 \pm 2.4) \times 10^{-5}$

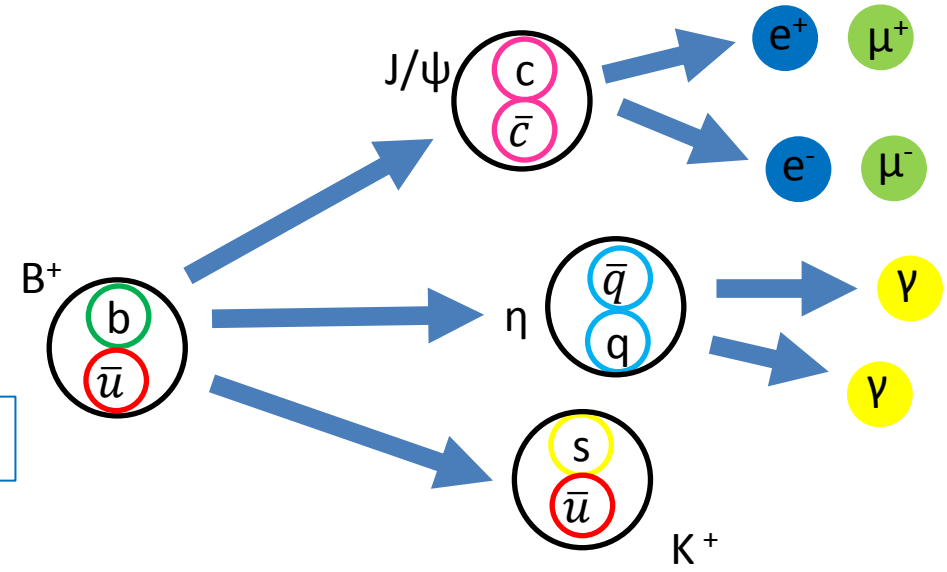
$Br(B^+ \rightarrow X(3872)K^+) \cdot Br(X(3872) \rightarrow J/\psi\eta) < 7.7 \times 10^{-6}$ (90% CL)

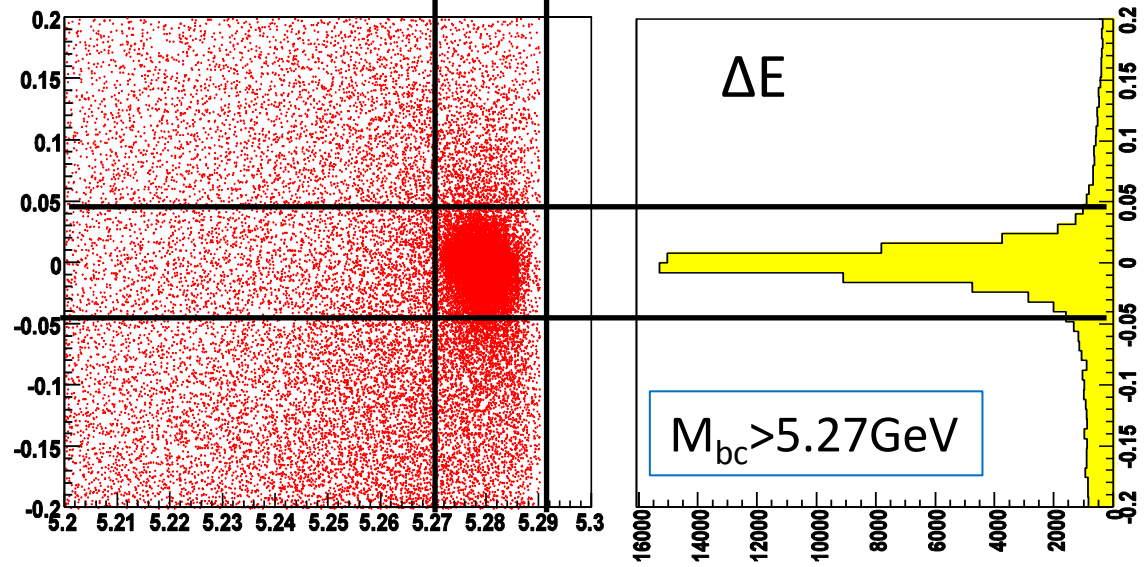
BaBar,PRL 93, 041801 (2004)

With more data (9x), Belle may find or can rule out the $X(3872)^{C-}$ partner.

B reconstruction







Two variable at Y(4S) center mass frame

$$M_{bc} = \sqrt{E_{beam}{}^2 - P_B{}^2}$$

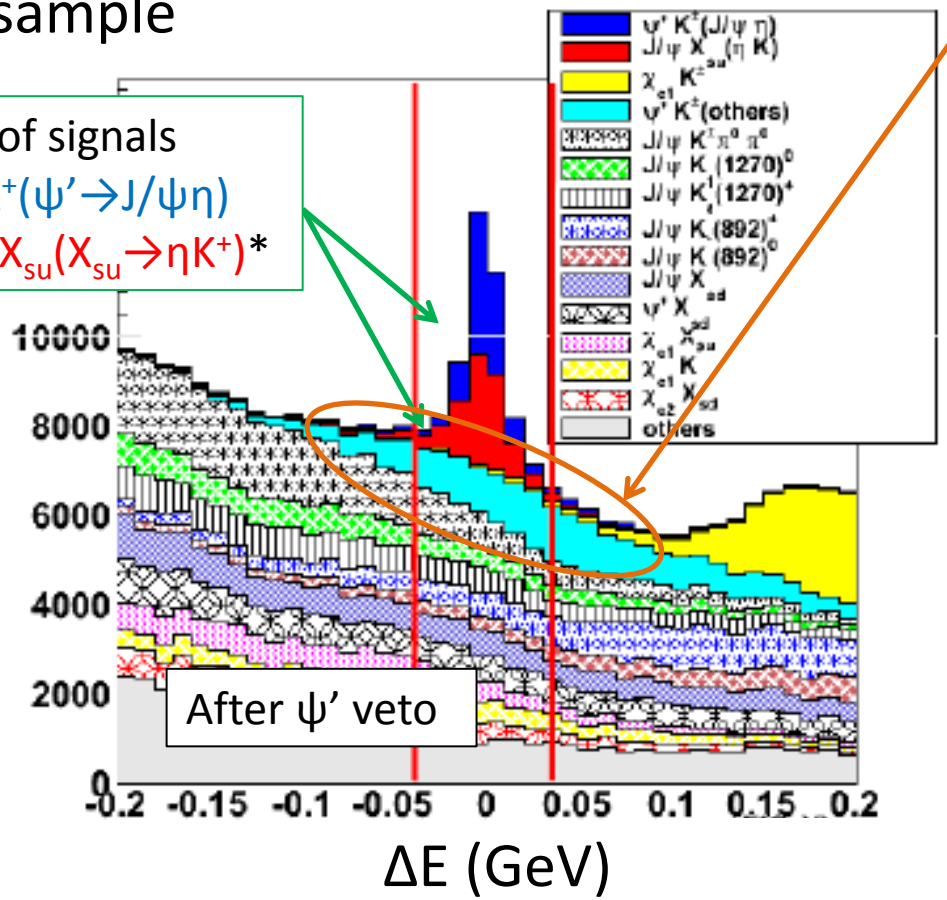
$$\Delta E = E_B - E_{beam}$$

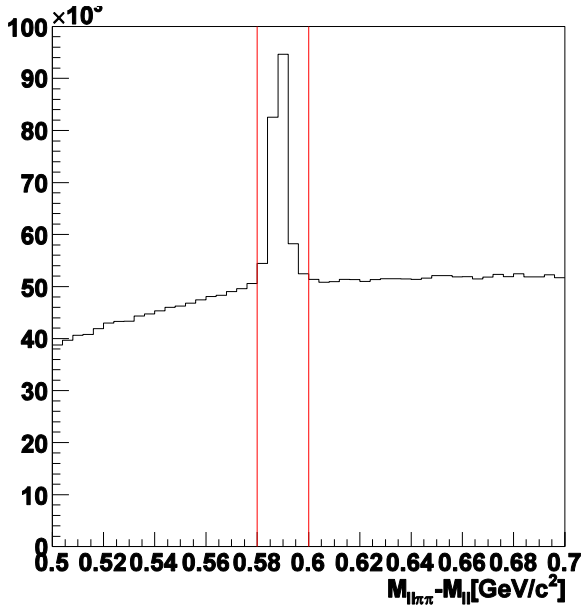
Background

B→J/ψ**X** MC
100 times data sample

We applied ψ' veto to reduce background

Part of signals
- ψ'K⁺(ψ'→J/ψη)
- $J/\psi X_{su}(X_{su}\rightarrow \eta K^+)$*



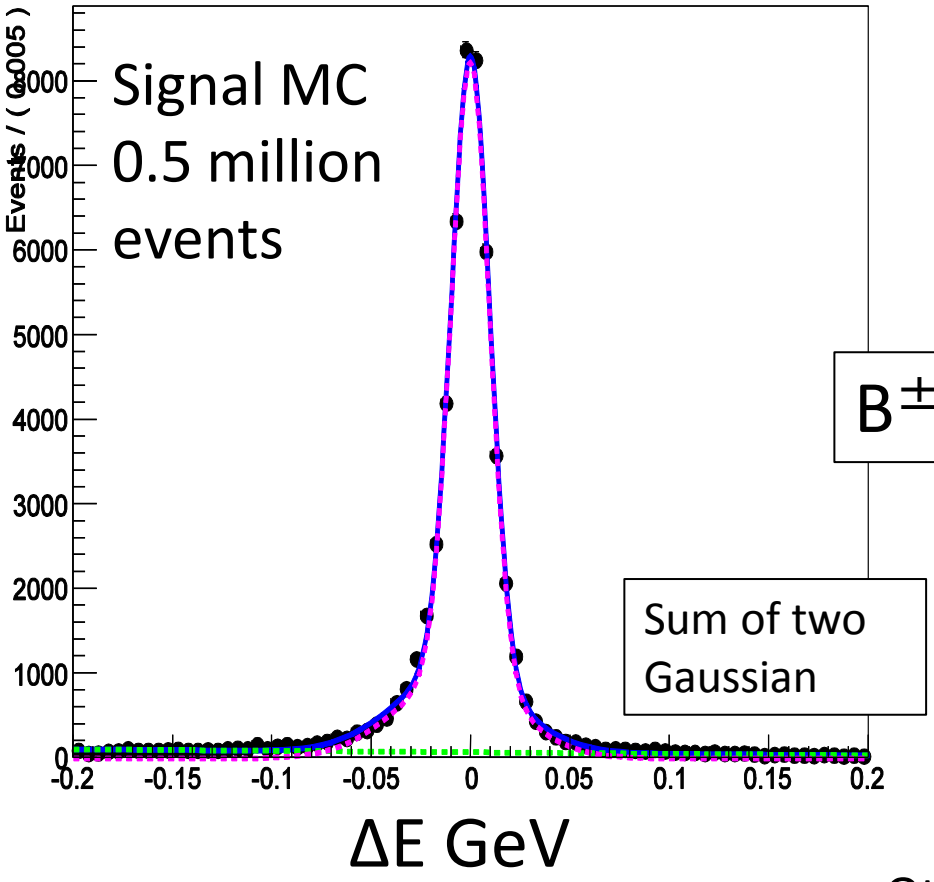


$0.58\text{GeV}/c^2 < M_{J/\psi\pi\pi} - M_{J/\psi} < 0.60\text{GeV}/c^2$ for ψ'K veto

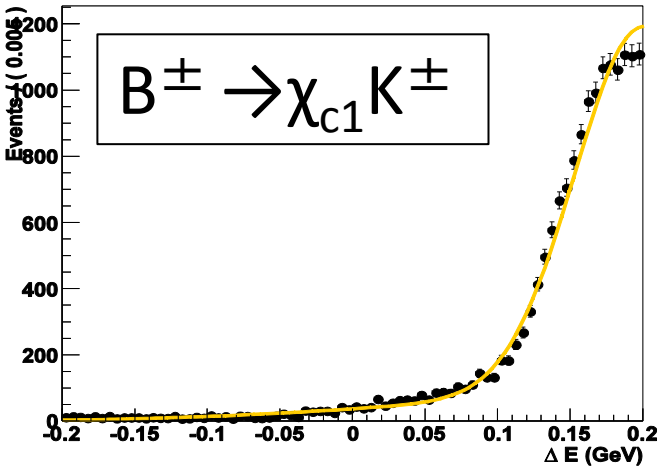
* X_{su} is the JETSET/PYTHIA fragmentation and hadronization object.

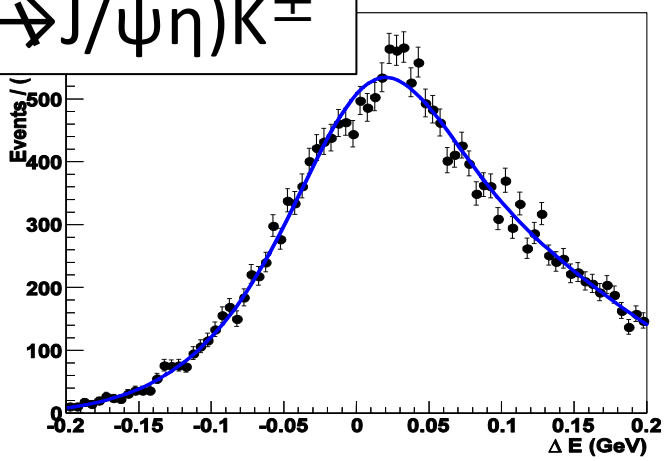
PDFs

Signal MC of $B^{\pm} \to J/\psi \eta K^{\pm}$ phase space (PHSP) decay



$B \to J/\psi X$ MC
100 times data sample

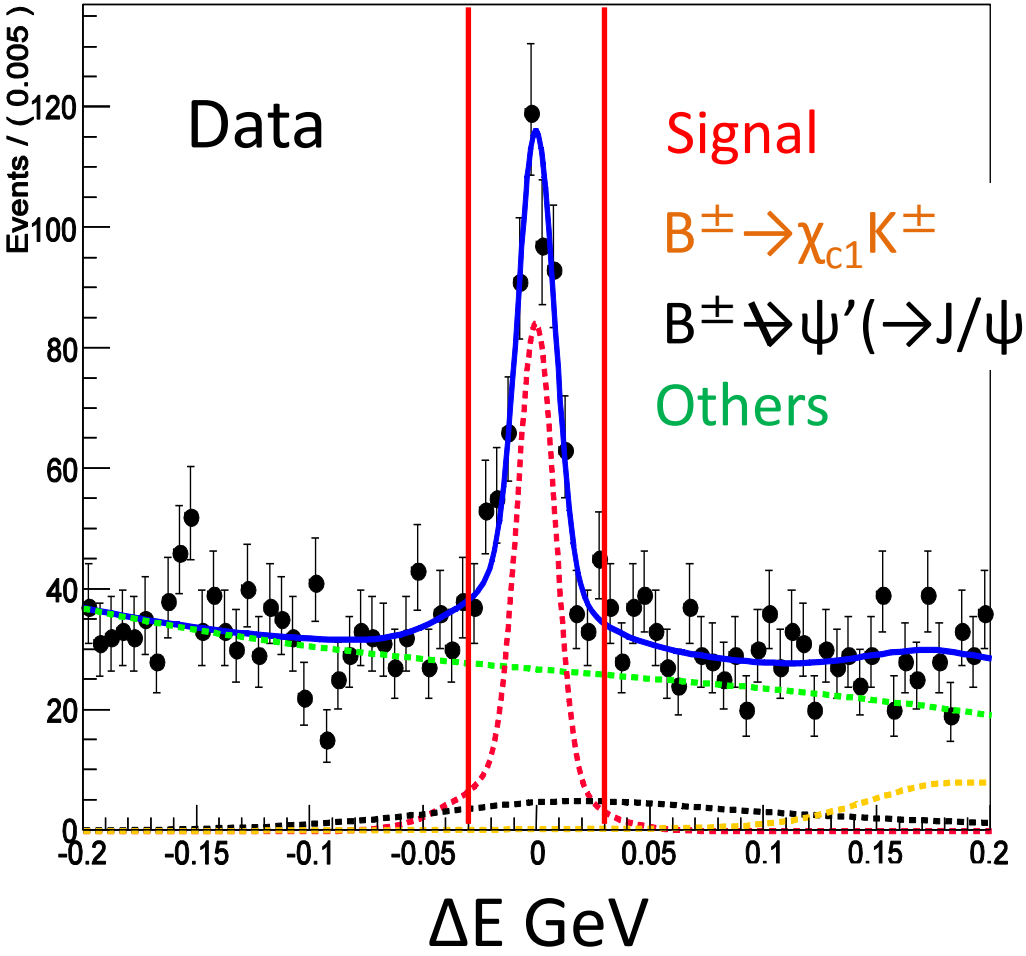




Other backgrounds are smooth polynomial

No bias is observed in fitter using Geant simulation study and Toy MC study

B decay signal extraction



We look at the data ΔE distribution.

Signal yield is 428±37 events.

Signal ΔE peak shift
1.15±0.83MeV

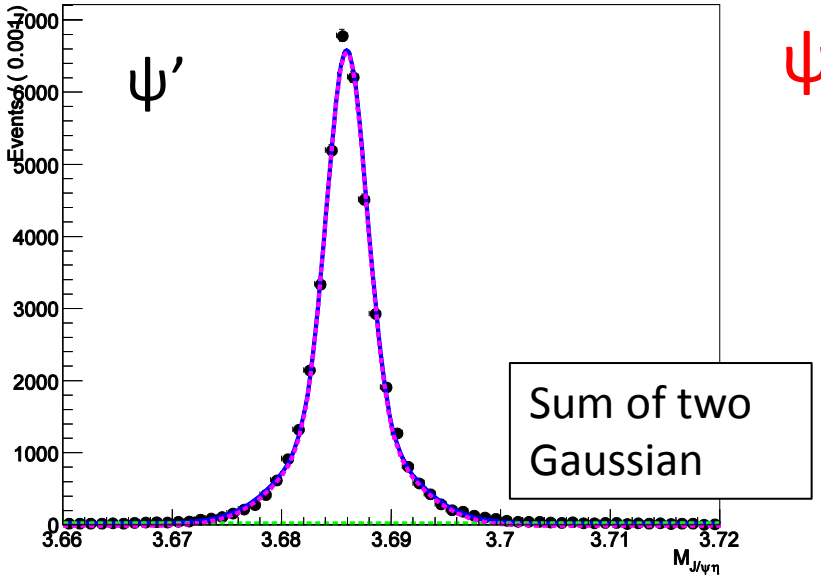
Signal ΔE resolution ratio
1.11±0.13
(Between data and MC)

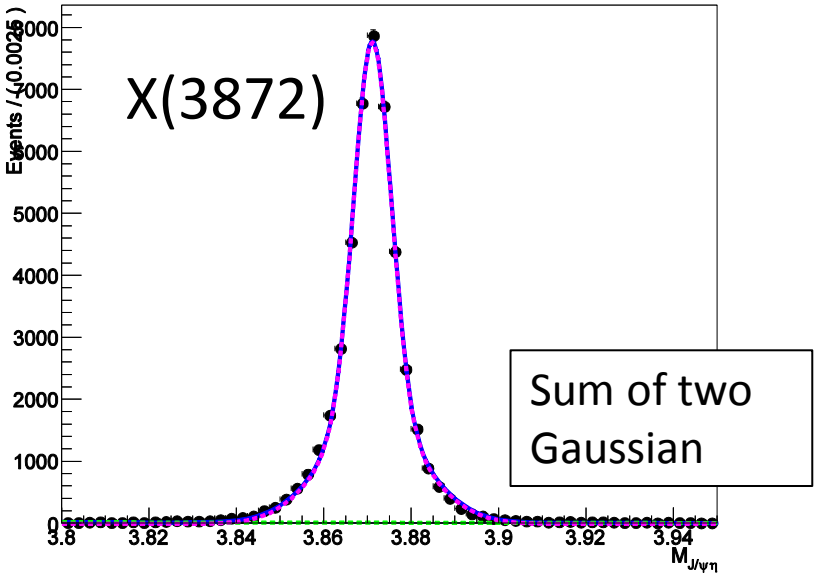
Efficiency is 9.9% at
-0.2GeV<ΔE<0.2GeV

$M_{J/\psi\eta}$ PDFs

Signal MC

0.5 million events

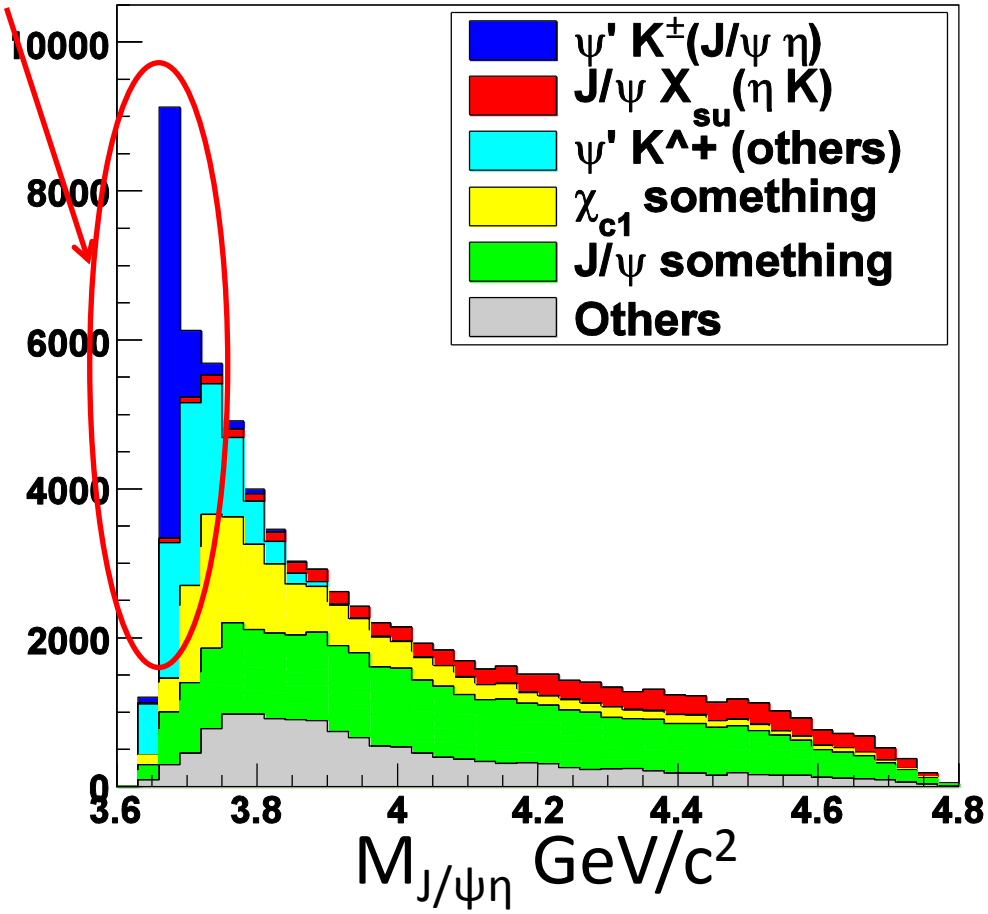




ψ'

B→J/ψ**X** MC

100 times data sample

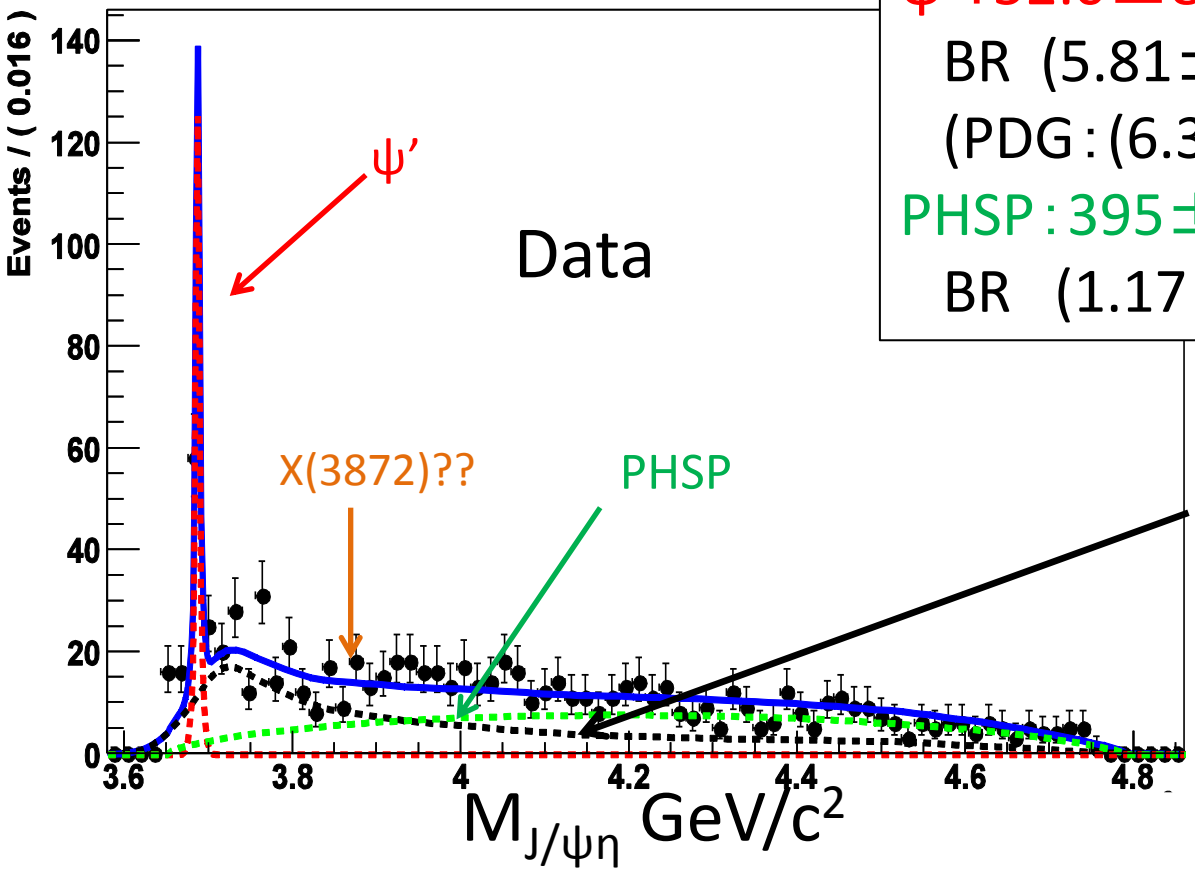


Background estimated from this distribution.

$M_{J/\psi\eta}$ distribution

We can find ψ' signal.

Other signals distribute phase space like.



ψ' : 52.0 ± 8.2event

BR $(5.81 \pm 0.92 \pm 0.44) \times 10^{-4}$

(PDG : $(6.39 \pm 0.33) \times 10^{-4}$)

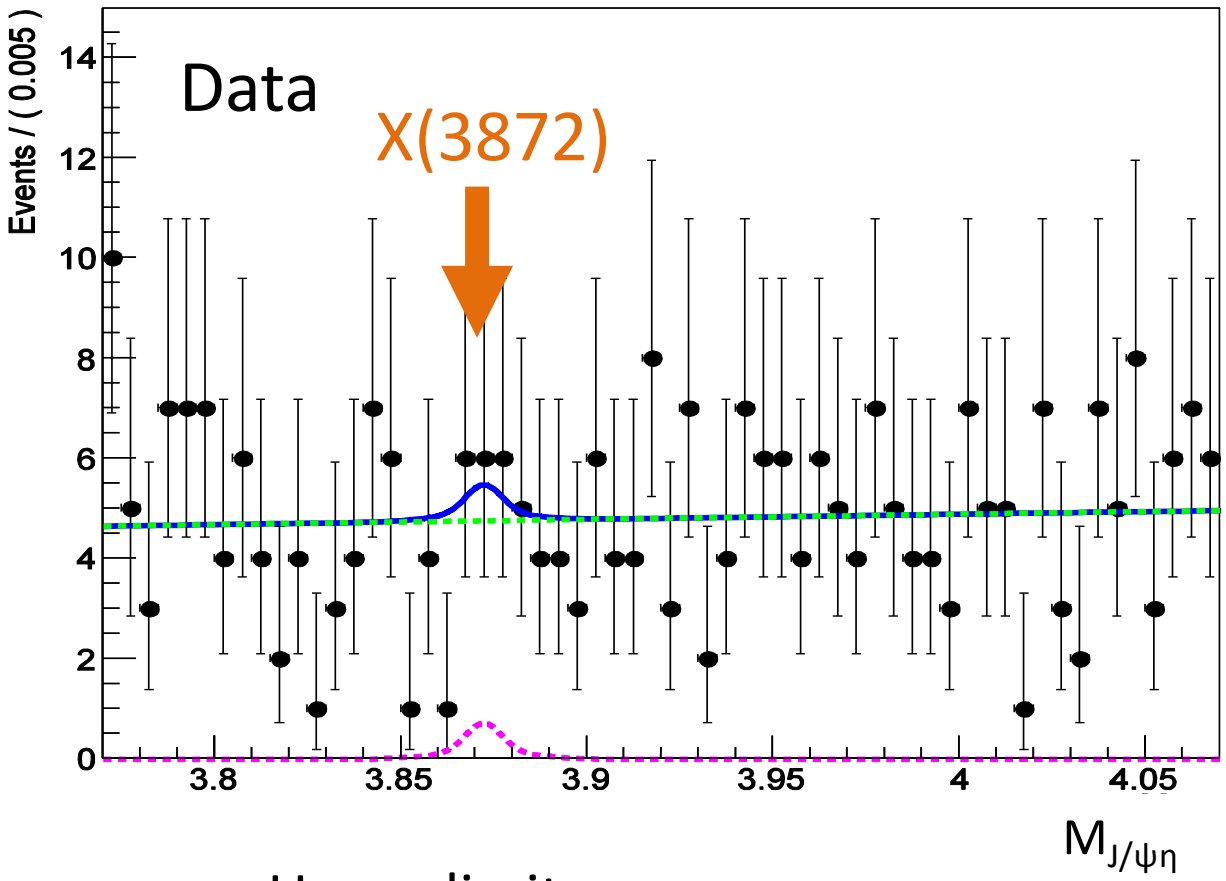
PHSP : 395 ± 26event

BR $(1.17 \pm 0.07 \pm 0.11) \times 10^{-4}$

Background is estimated from $M_{J/\psi\eta}$ distribution using B→J/ψ**X** MC

We can't find any peak above 3.9 GeV

At X(3872) region



Upper limit

$Br(B \to X(3872)K) \cdot Br(X(3872) \to J/\psi\eta)$

$< 3.8 \times 10^{-6}$ @ 90% C.L.

(PDG $< 7.7 \times 10^{-6}$)

Systematic uncertainties

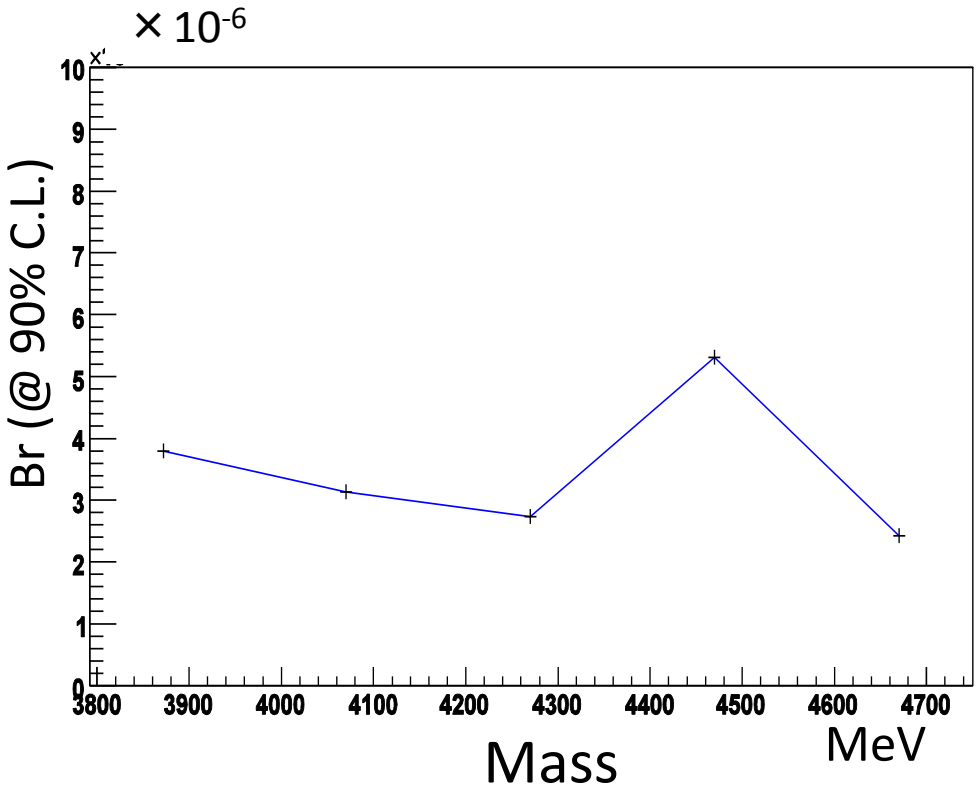
Source	Uncertainty (%)
Tracking	1.6
Kaon ID	0.97
Electron ID	0.9
Muon ID	3.93
η	4.0
Signal MC statistics	$0.48_{(B\pm\to\psi' K\pm\cdot\psi'\to J/\psi\eta)}$*
Number of $B\bar{B}$	1.4
B.R.s	$2.4_{(B\pm\to\psi' K\pm\cdot\psi'\to J/\psi\eta)}$, $1.1_{(B\pm\to J/\psi\eta K\pm)}$
PDF syst.	$3.9_{(B\pm\to\psi' K\pm\cdot\psi'\to J/\psi\eta)}$, $7.3_{(B\pm\to J/\psi\eta K\pm)}$
Total	**$7.7_{(B\pm\to\psi' K\pm\cdot\psi'\to J/\psi\eta)}$, $9.6_{(B\pm\to J/\psi\eta K\pm)}$**

* Depend by mode

Upper limit for narrow resonances

$Br(B \to \mathbf{X}K) \times Br(\mathbf{X} \to J/\psi\eta)$

X	U.L. ($\times 10^{-6}$) Include systematics
X(3872)	3.8
4070	3.1
4270	2.7
4470	5.3
4670	2.4



UL (@90% CL) is also provided at different masses (using 0-width states).

Summary

- We measure B→J/ψηK decay using Belle's full data sample, 772 M$B\bar{B}$ pair.
  - ψ' yield as expected 52.0 ± 8.2 events

    $Br(B\to\psi' K)=(5.81\pm0.92\pm0.44)\times10^{-4}$
  - PHSP yield is obtained to be 395±26 events

    $Br(B\to J/\psi\eta K) = (1.17\pm0.07\pm0.11)\times10^{-4}$
- In $M_{J/\psi\eta}$ distribution
  - No other peak, rest is well explained with phase space distribution
  - Stringent limit on narrow resonances

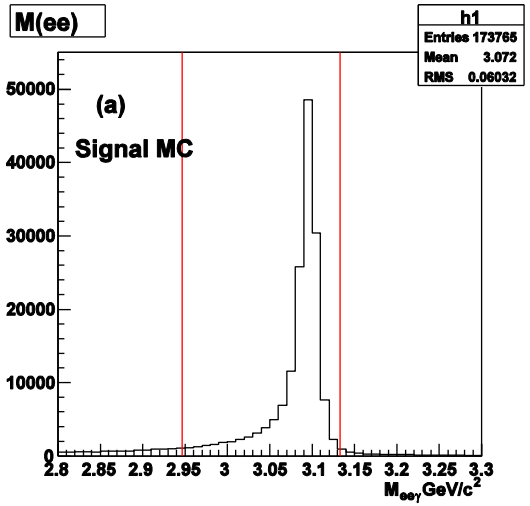
    Ex.) $Br(B\to X(3872)K)\cdot Br(X(3872)\to J/\psi\eta) < 3.8\times10^{-6}$

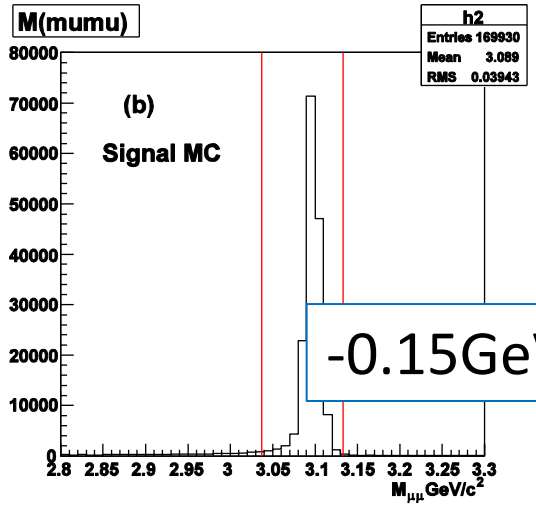
    @90% C.L.

BACK UP

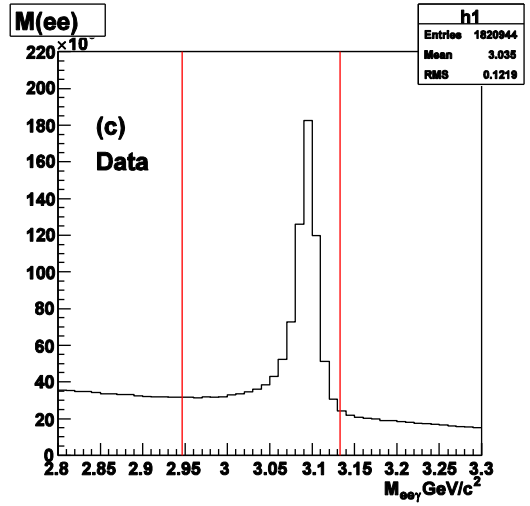
J/ψ reconstruction

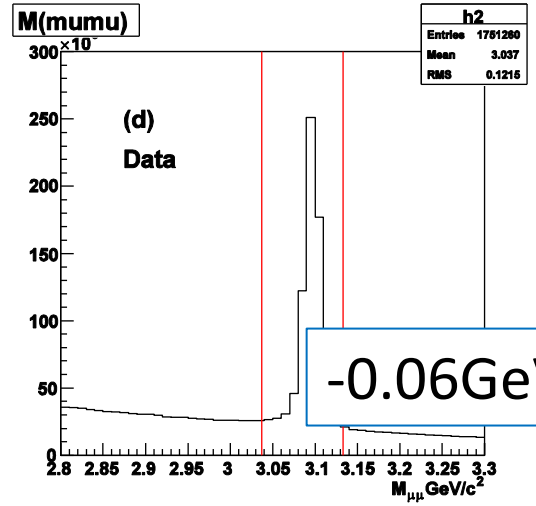
J/ψ is reconstructed from lepton pair (e^-e^+,$\mu^-\mu^+$)





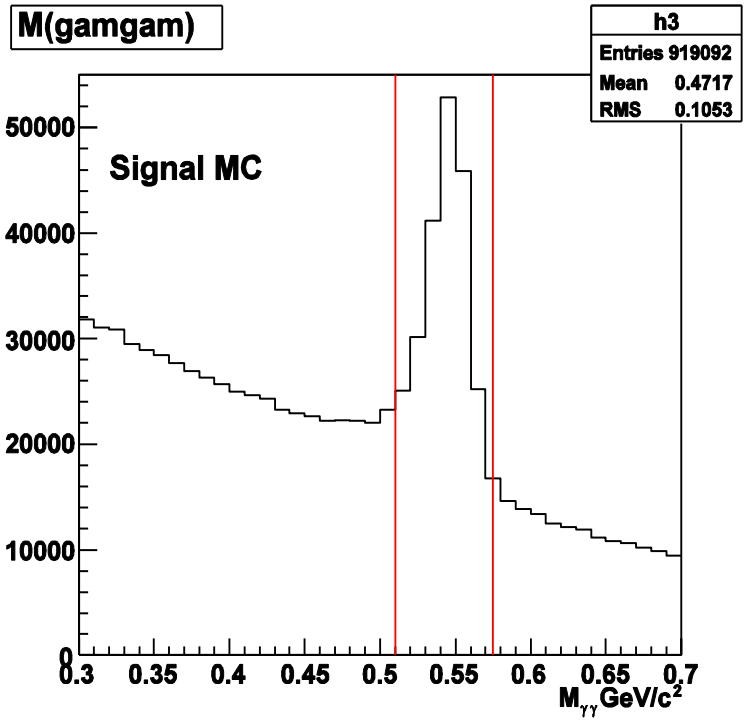
$-0.15\text{GeV}/c^2 < M_{J/\psi} - M_{ee} < 0.036\text{GeV}/c^2$

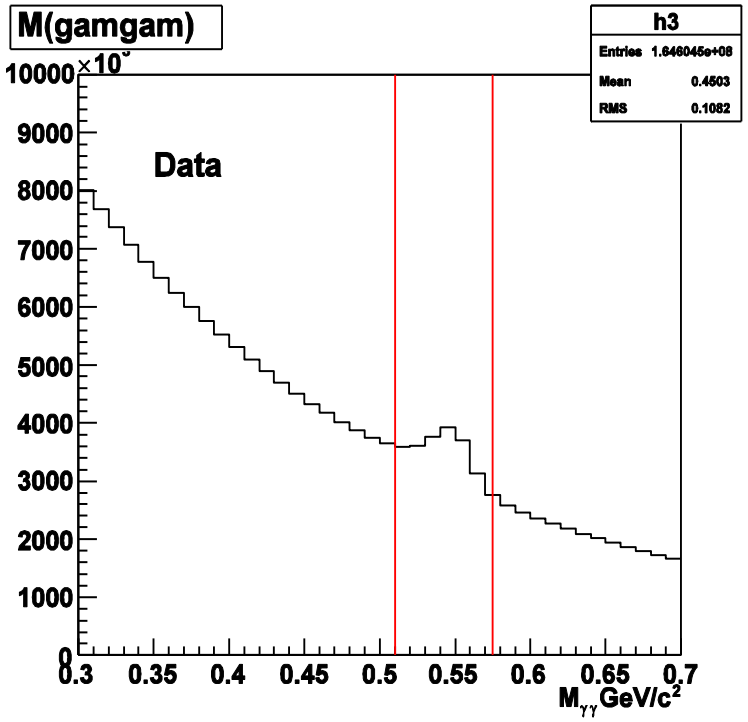




$-0.06\text{GeV}/c^2 < M_{J/\psi} - M_{\mu\mu} < 0.036\text{GeV}/c^2$

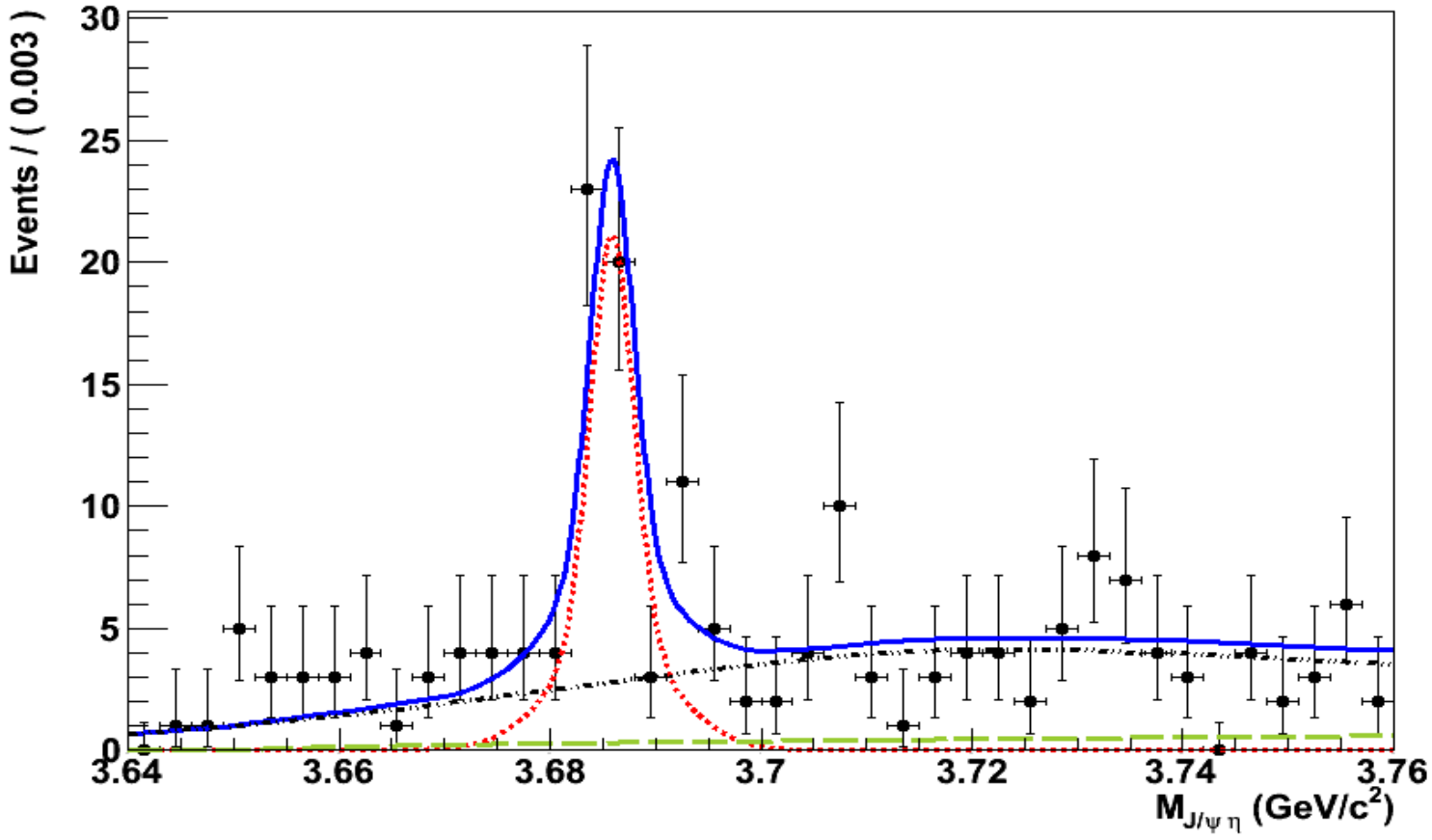
η reconstruction





η is reconstructed from γγ

- Energy balance $A_E=\frac{|E_1-E_2|}{E_1+E_2}$<0.8, Energy threshold=100MeV
- 0.51GeV/c^2<$M_{\gamma\gamma}$<0.575GeV/c^2
  (For π^0 veto 0.125GeV/c^2<$M_{\gamma\gamma}$<0.140GeV/c^2 was removed)


Events / (0.003)
30
25
20
15
10
5
0
3.64
3.66
3.68
3.7
3.72
3.74
3.76
$M_{J/\psi\,\eta}$ (GeV/c^2)