Study of $e^+e^- \rightarrow \gamma\omega J/\psi$ at BESIII

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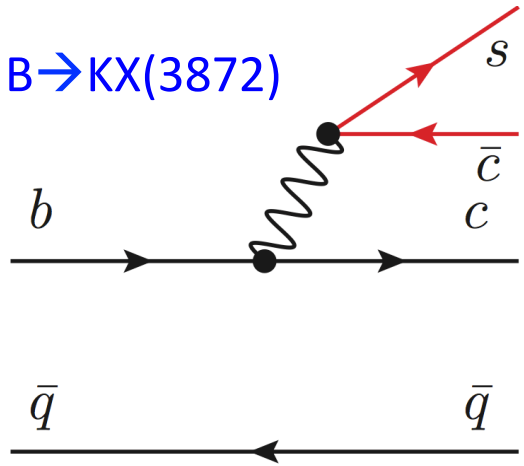
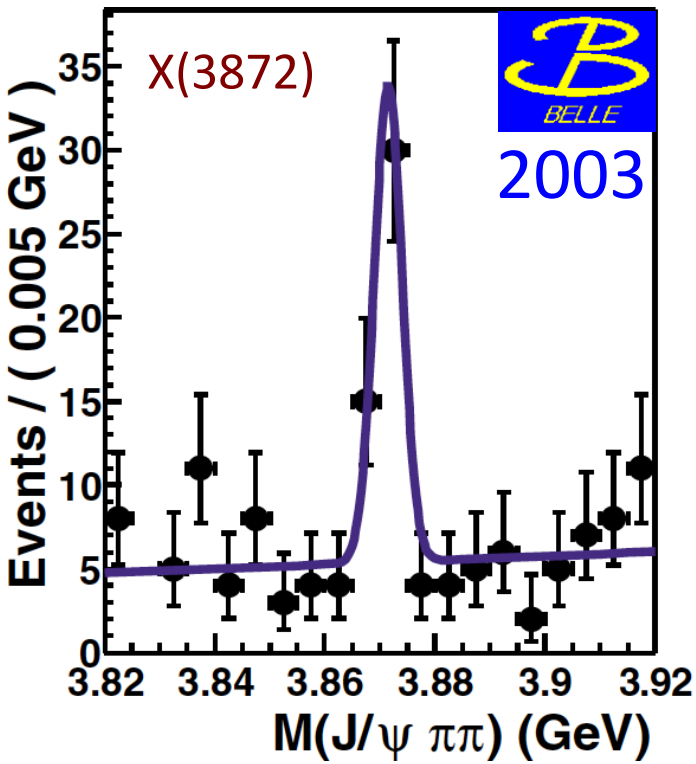
X(3872)

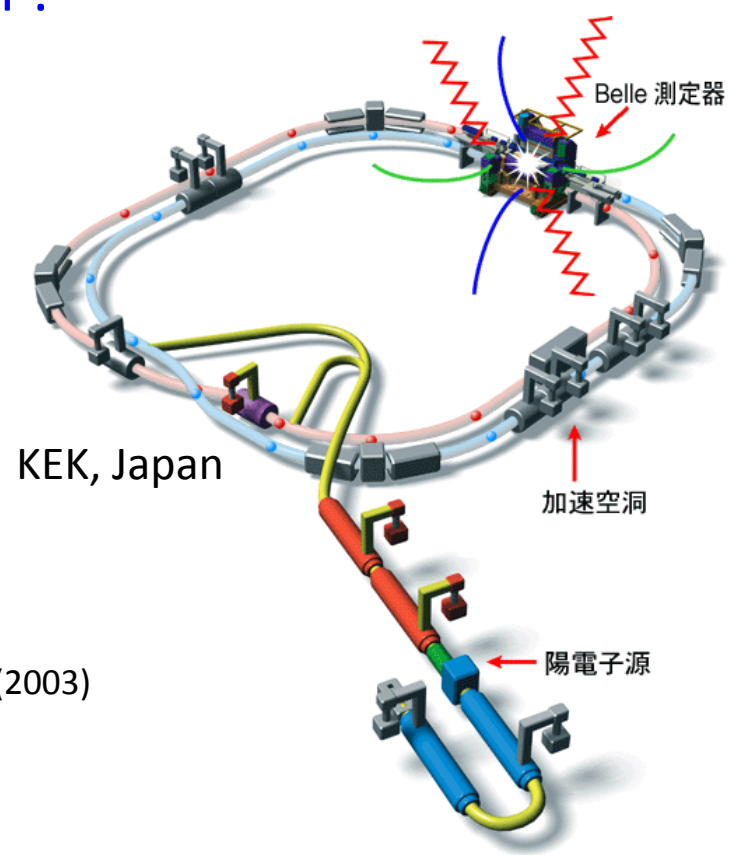


Confirmed by 7 independent experiments (Belle, BABAR, LHCb, CDF, D0, CMS, BESIII)

Solid signal !



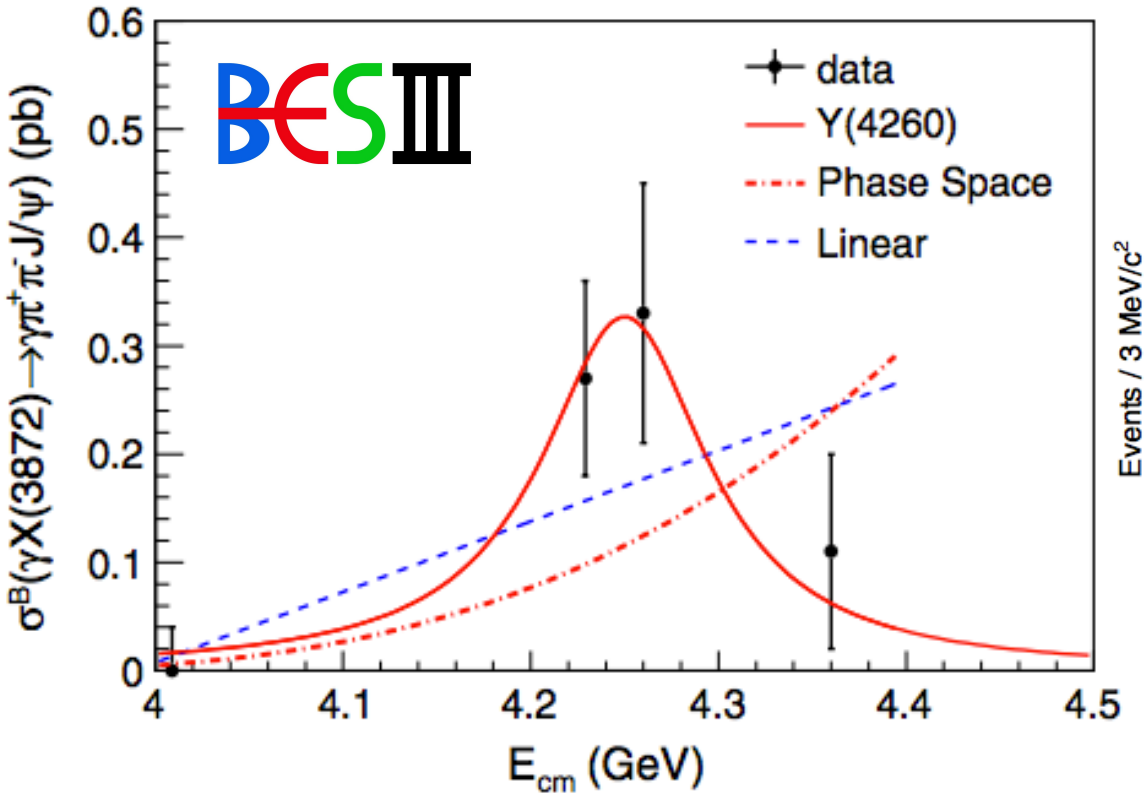
PRL 91, 262001 (2003)

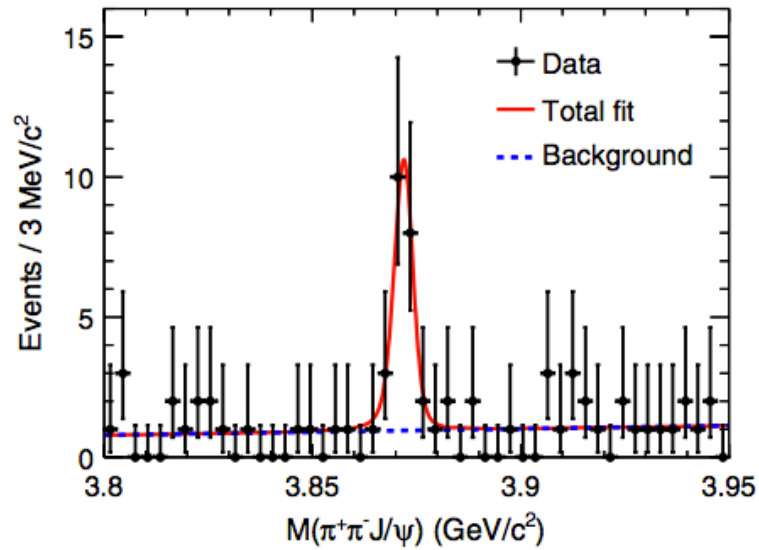


KEK, Japan

I. $X(3872) \rightarrow \pi^+\pi^- J/\psi$

e+e-→γX(3872)

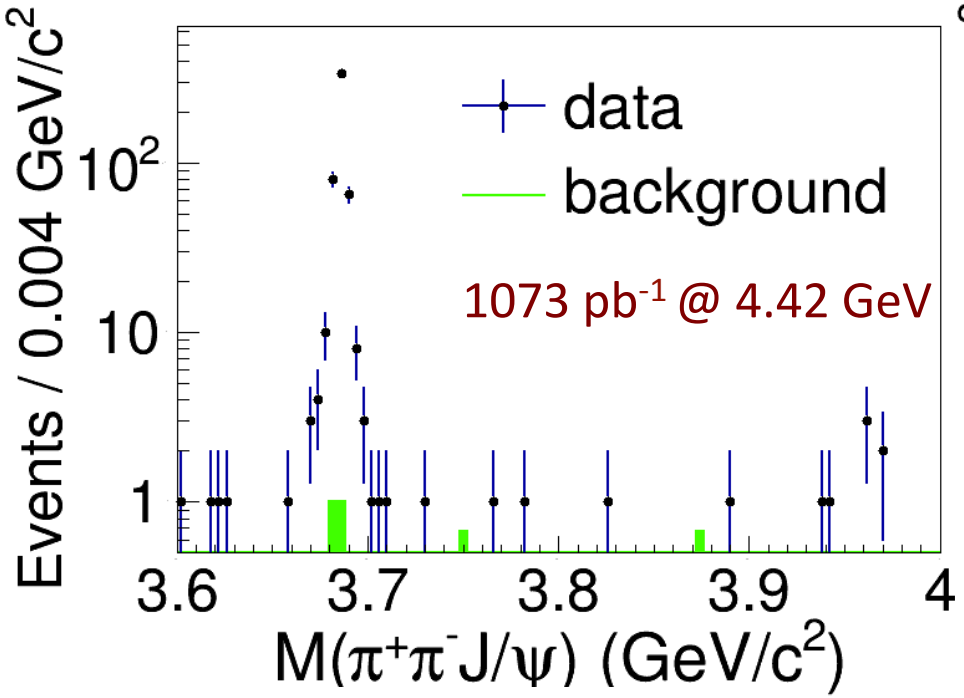


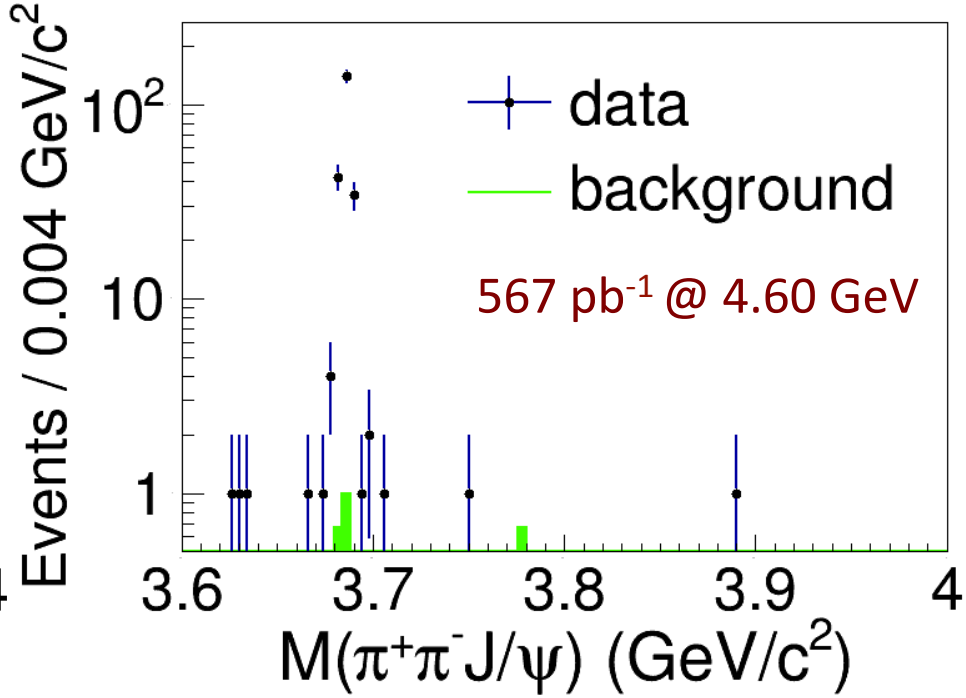


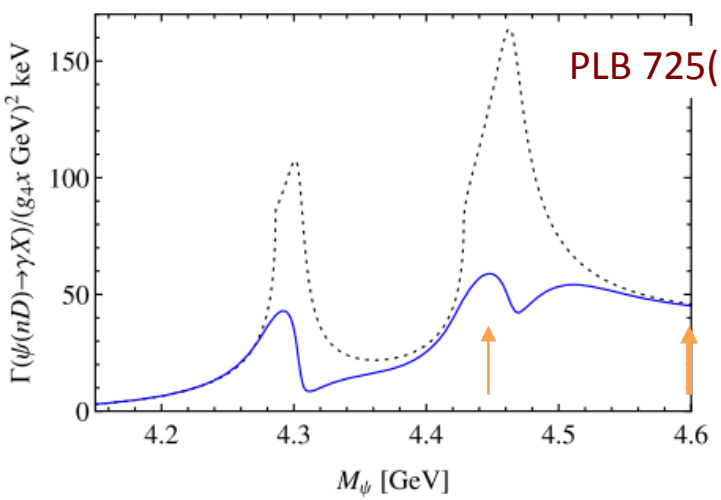
PRL 112, 092001 (2014)

$\sqrt{s}$ (GeV)	N^{obs}	N^{up}	ε (%)	$1+\delta$	$\sigma^B \cdot \mathcal{B}$ (pb)
4.009	0.0 ± 0.5	< 1.4	28.7	0.861	$0.00 \pm 0.04 \pm 0.01$
4.229	9.6 ± 3.1	$\cdots$	34.4	0.799	$0.27 \pm 0.09 \pm 0.02$
4.260	8.7 ± 3.0	$\cdots$	33.1	0.814	$0.33 \pm 0.12 \pm 0.02$
4.360	1.7 ± 1.4	< 5.1	23.2	1.023	$0.11 \pm 0.09 \pm 0.01$

Higher energy data



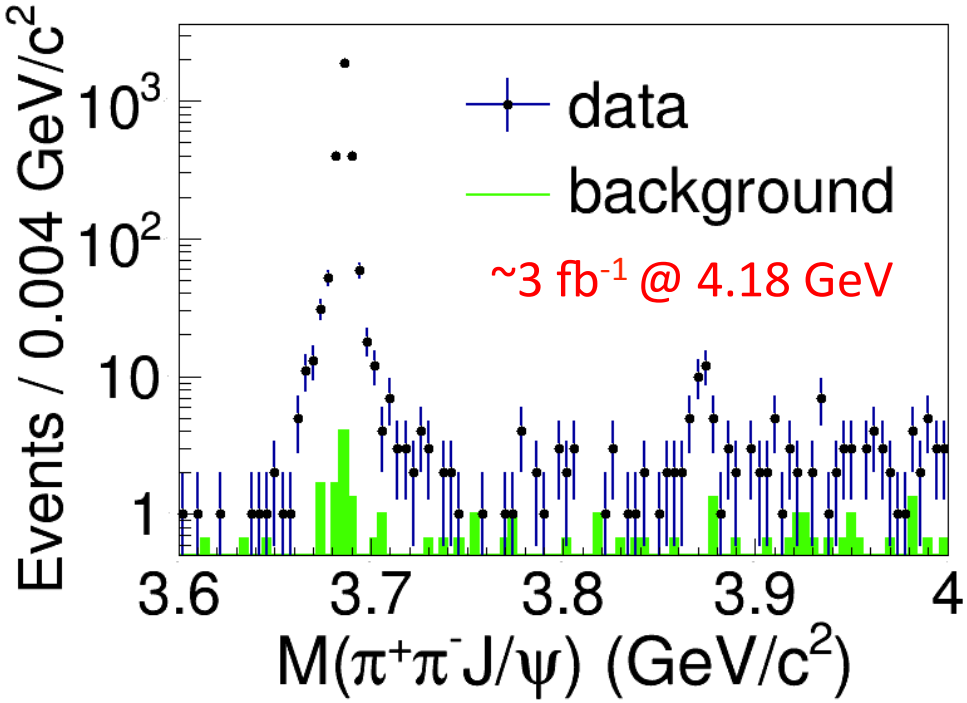


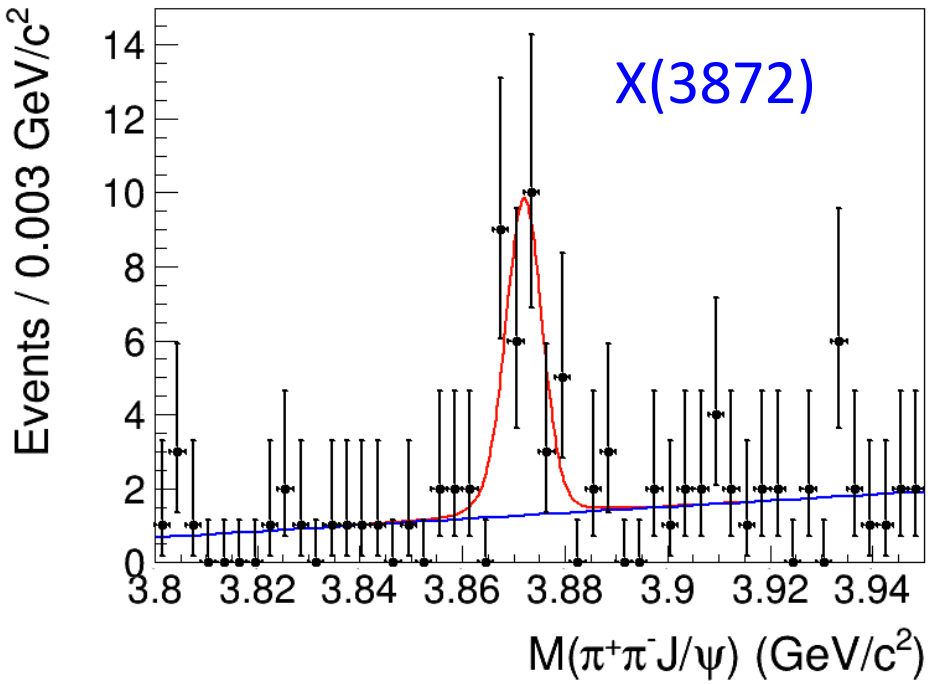


PLB 725(2013) 127-133

1. No signal at higher energies.
2. Do not agree with DD_1 molecule model prediction (C. Hanhart).

X(3872) at 4.18 GeV

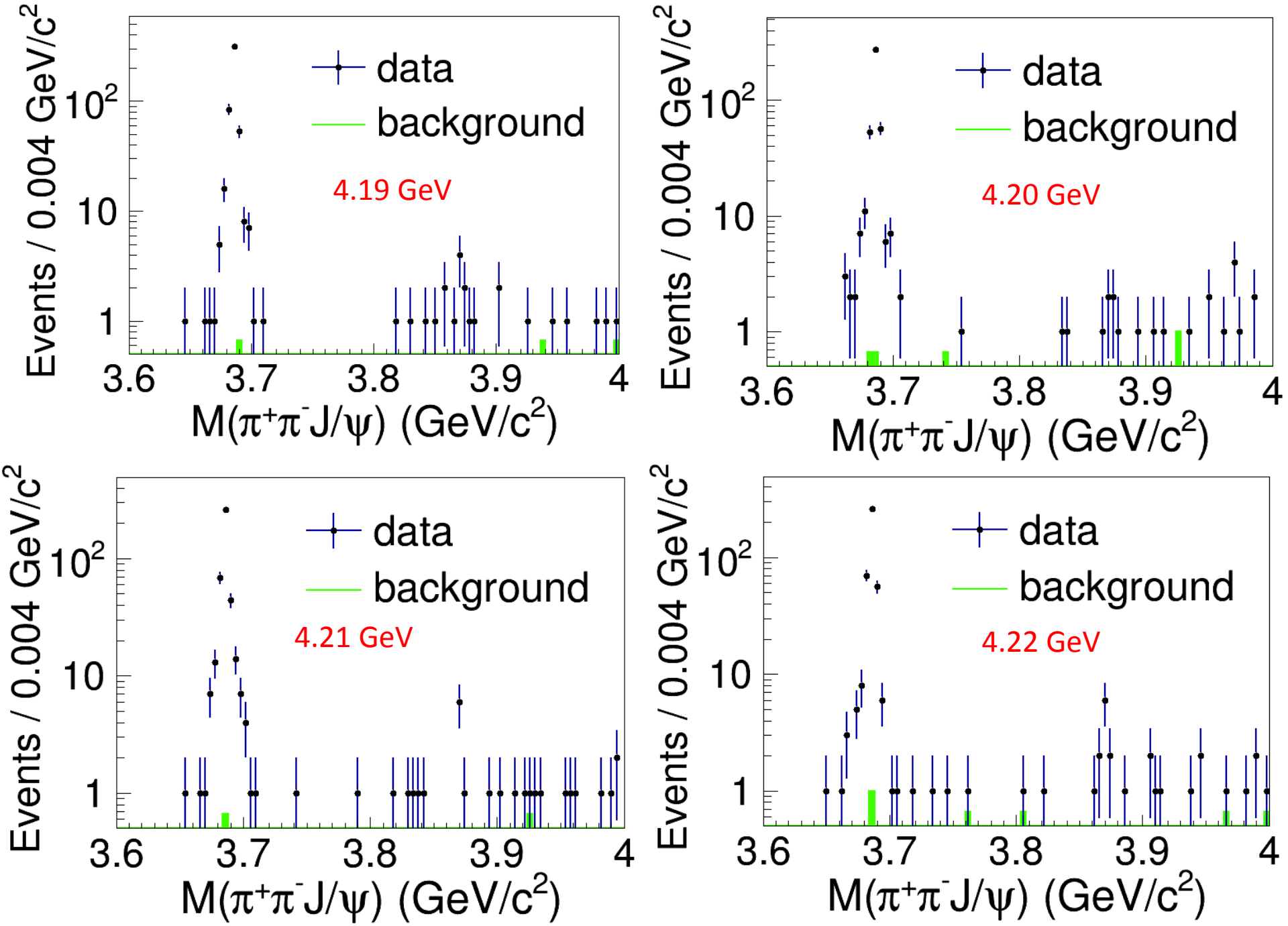


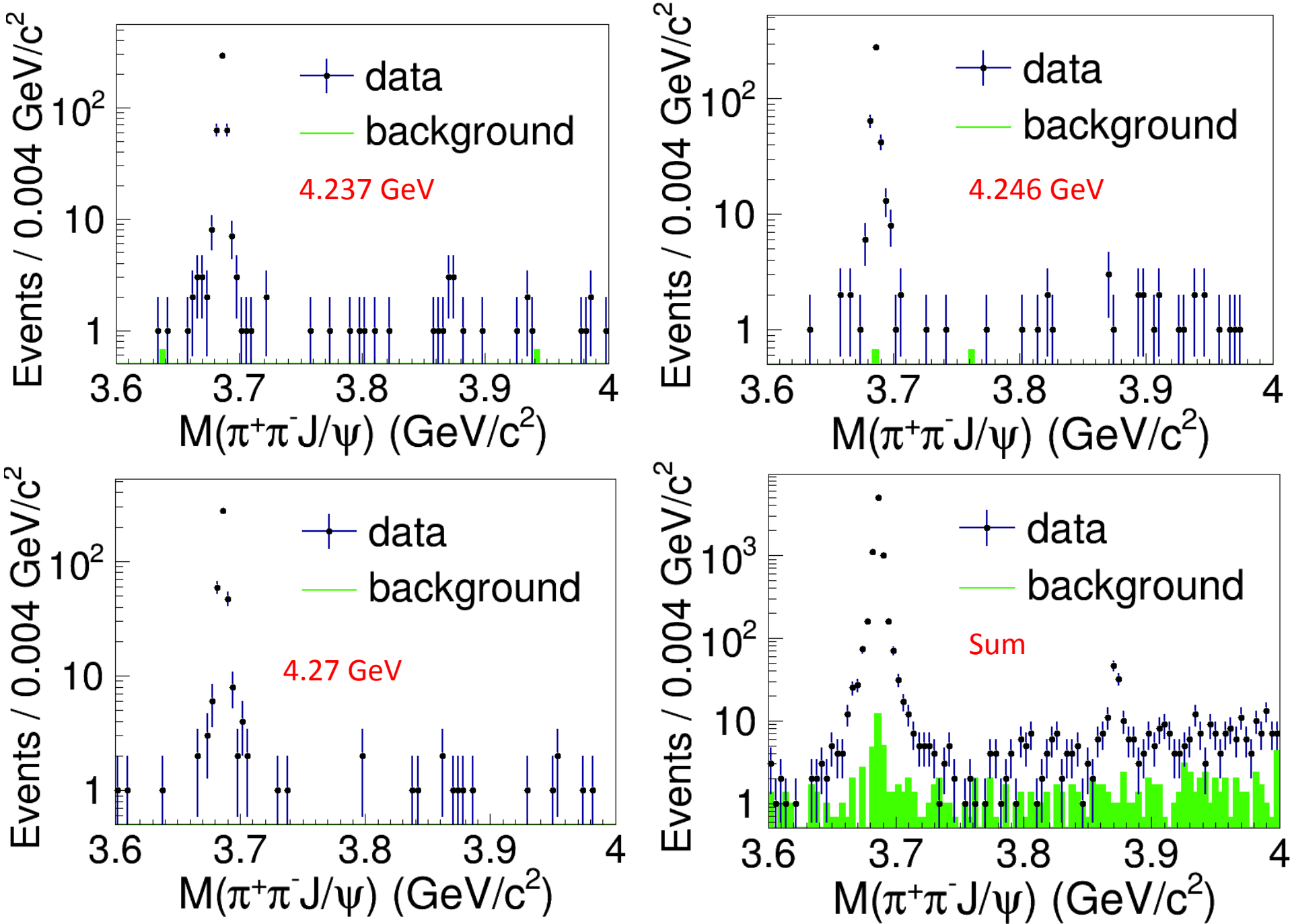


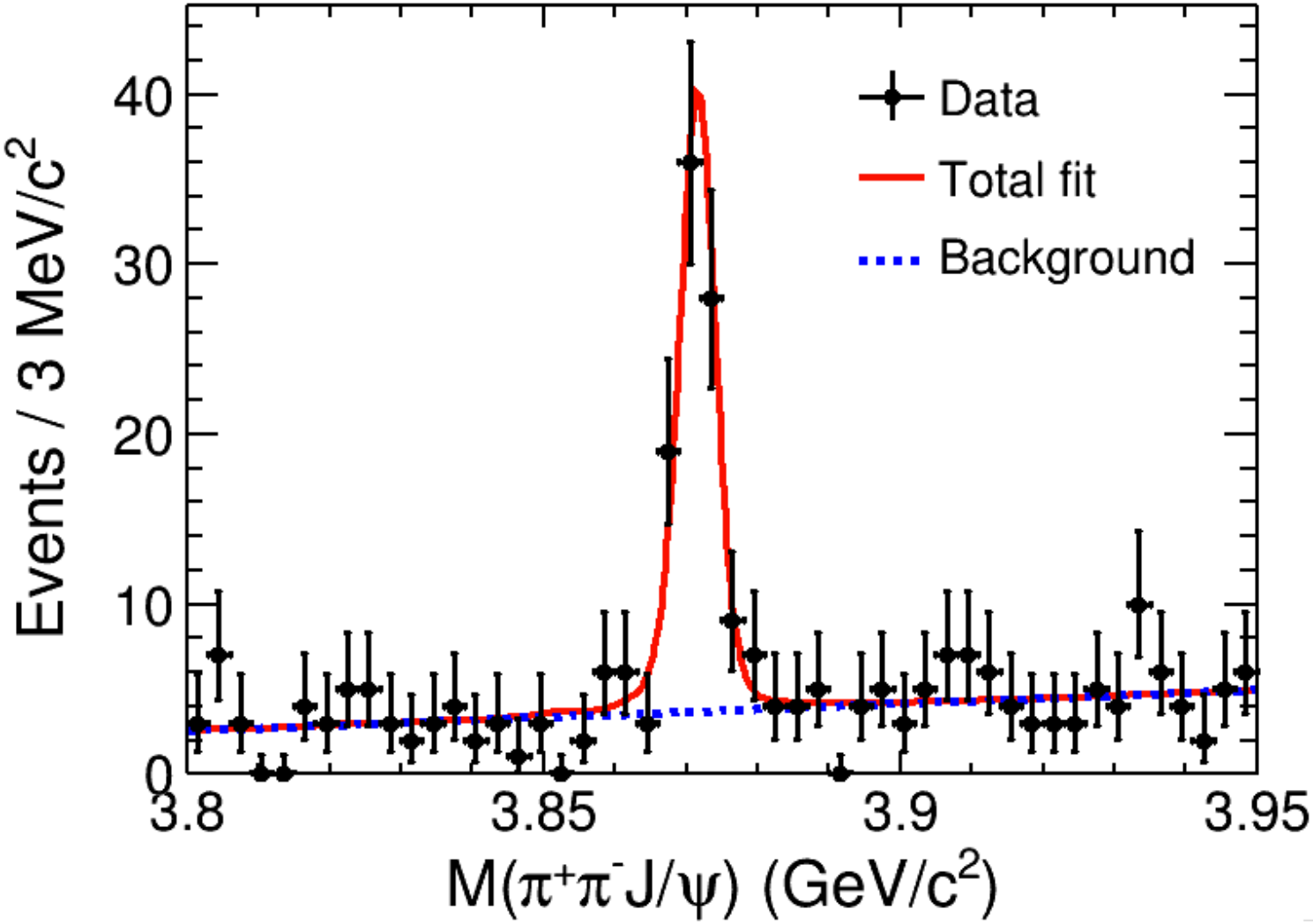
1. MC histogram $\otimes$ Gaussian + linear background

2. N^{sig}=27±6; Gaussian parameter (μ= 0.1±0.9 MeV, σ=2.8±0.9 MeV)

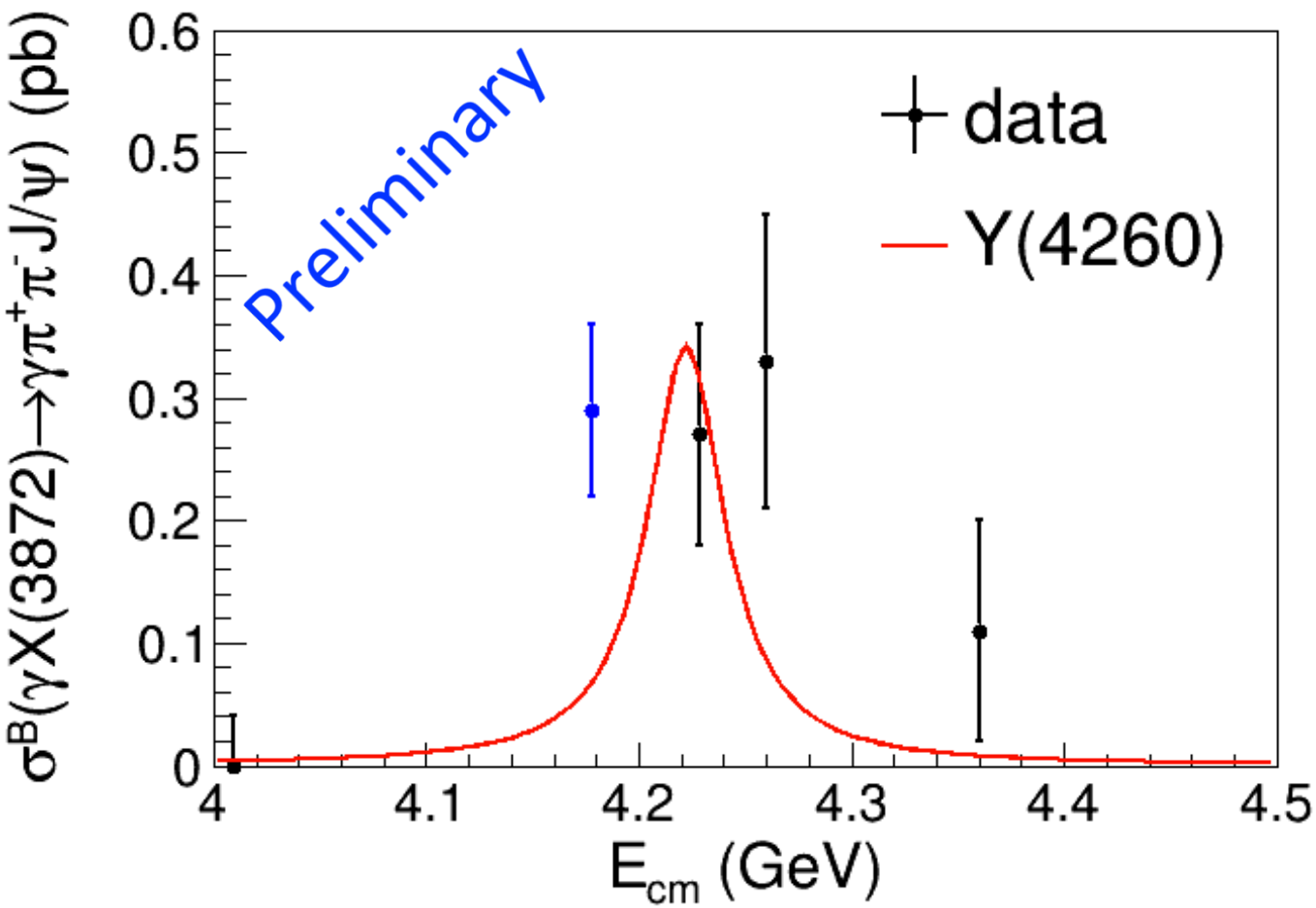
3. L=3.189 fb^{-1}, eff=27.6%; Xsec*Br[X(3872)$\rightarrow\pi^+\pi^-$J/ψ]=0.29±0.07 pb


data
background
4.19 GeV
4.20 GeV
4.21 GeV
4.22 GeV
Events / 0.004 GeV/c^2
M($\pi^+\pi^-$J/ψ) (GeV/c^2)
1
10
10^2
3.6
3.7
3.8
3.9
4


data
background
4.237 GeV
4.246 GeV
4.27 GeV
Sum
Events / 0.004 GeV/c^2
M($\pi^+\pi^-$J/ψ) (GeV/c^2)
3.6
3.7
3.8
3.9
4
1
10
10^2
10^3



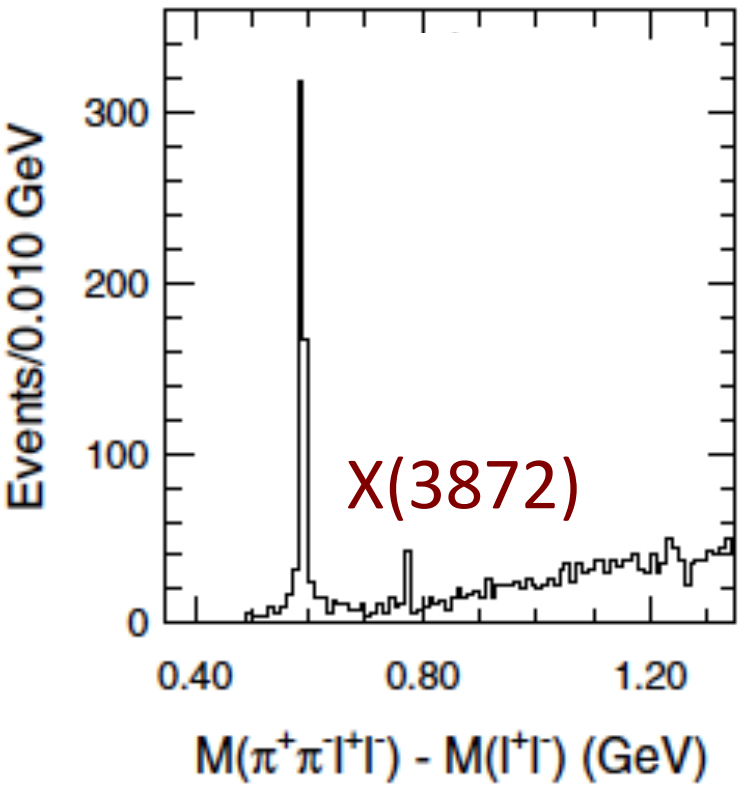
N[X(3872)]=84.0±9.3

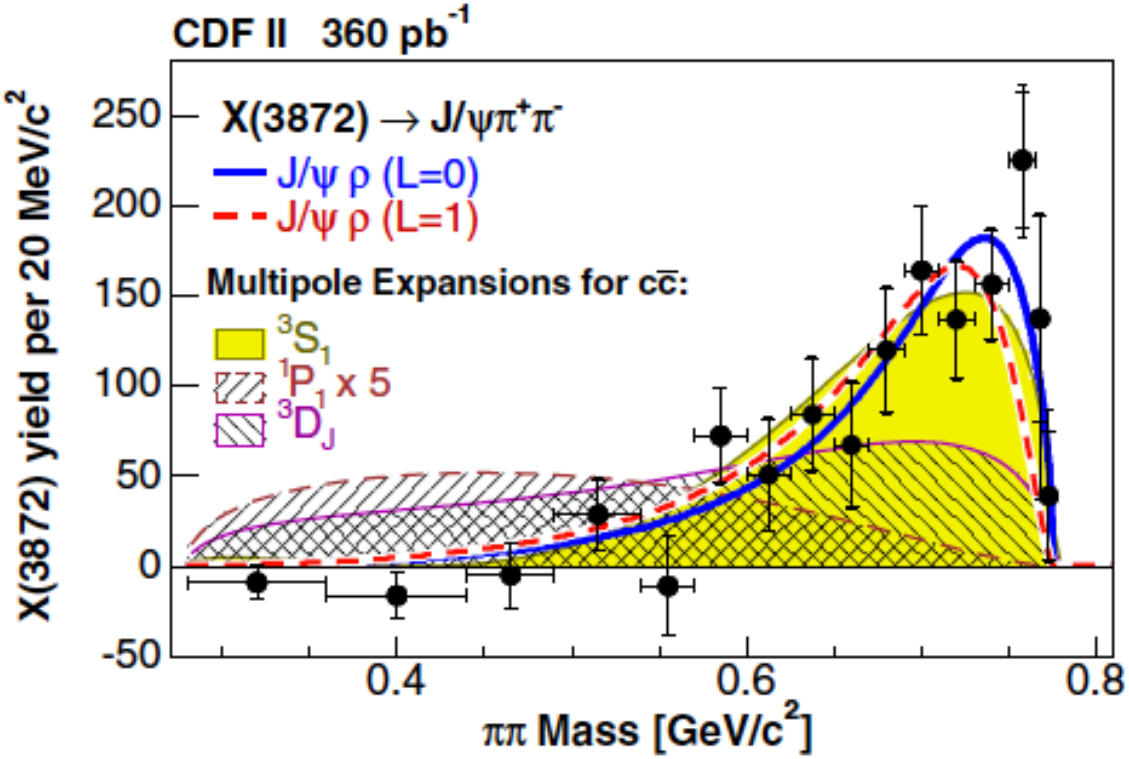


- $\gamma X(3872)$ production cross section at 4.18 GeV is comparable to 4.23(6) GeV
- Not from pure Y(4260) contribution? $\psi(4160)\to\gamma X(3872)$? …

II. X(3872)→ωJ/ψ

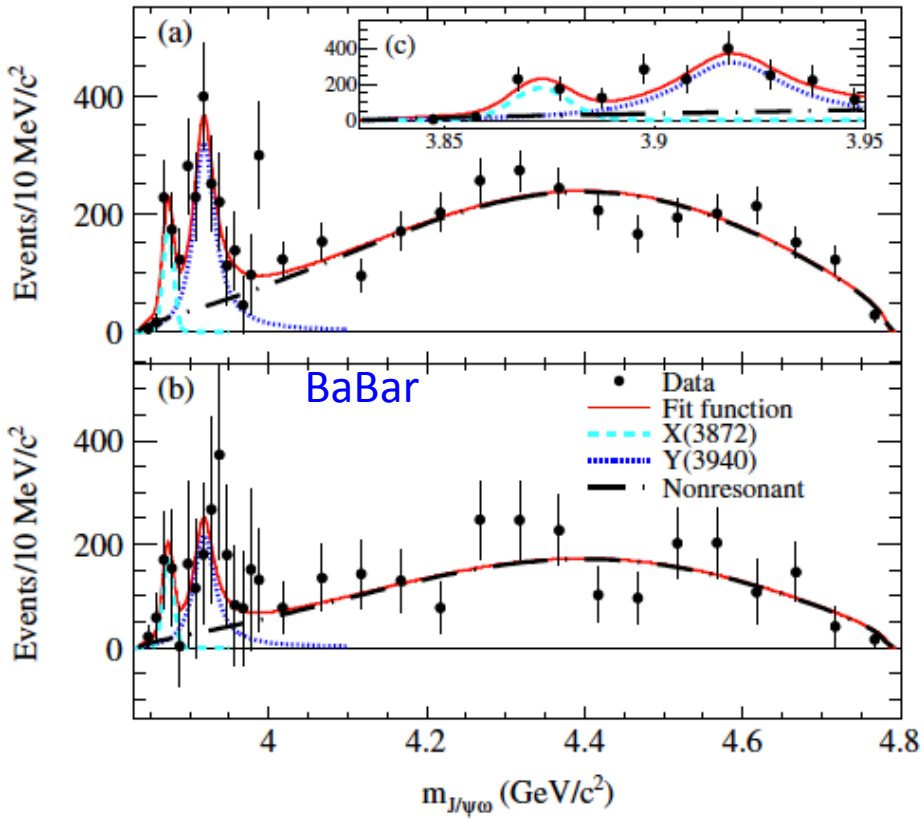
Introduction

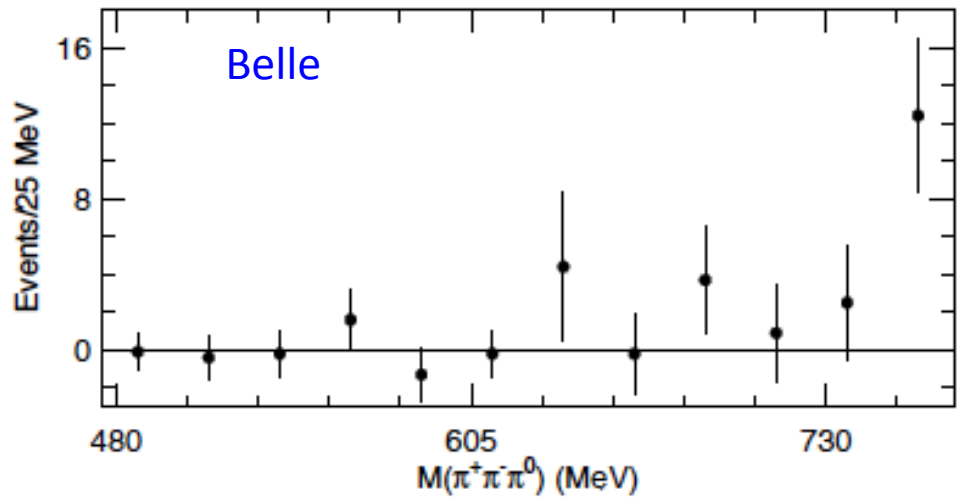




1. X(3872) was discovered by Belle in B→KππJ/ψ decay
2. CDF measure the ππ system, dominant by ρ(770)
3. X(3872) is a iso-spin 0 state (no partner found).

Introduction





Y(3940): BABAR Belle

m=3919±3.8±2 MeV; 3943±11±13 MeV

Γ=31±10±5 MeV; 87±22±26 MeV

1. BaBar and Belle observed X(3872)→ωJ/ψ decay.
2. Ratio R=[X(3872)→ωJ/ψ/X(3872)→ρJ/ψ]~(1.0±0.4±0.3) for Belle & (0.8±0.3) for BaBar.
3. X(3872) has large iso-spin violation

Data samples at BESIII

- Data:
- 3189 pb^{-1} @ 4.18 GeV → BOSS 7.0.2p01
- 1092 pb^{-1} data @ 4.23 GeV
- 827 pb^{-1} data @ 4.26 GeV
- New high luminosity scan data from 4.19 to 4.27 GeV

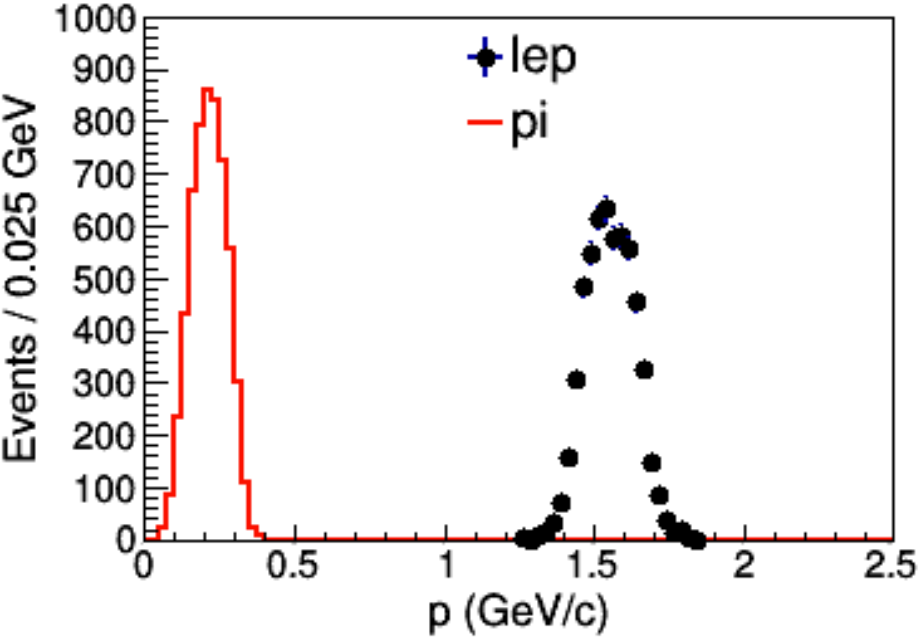
- MC:
- 500 pb^{-1} inclusive MC at 4.26 GeV
- 30,000 $\gamma X(3872) \rightarrow \gamma\omega J/\psi$
- 2000(10,000) $\omega\chi_{c0} \rightarrow \gamma\omega J/\psi$

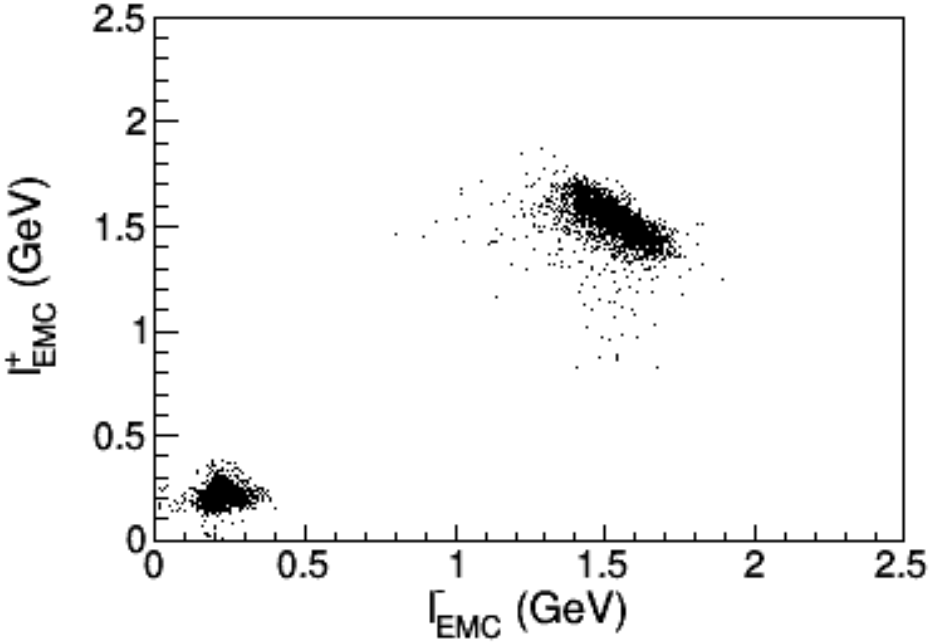
Event Selection

- Good Track:
- Vertex cut: Vr<1 cm |Vz|<10 cm.
- 4 charged track with net charge zero.
- Good photon:
- E>25 MeV Barrel and E>50 MeV Endcap.
- Time: [0,14] unit: 50 ns.
- At least 3 good photon.
- Lepton & pion:
- p>1 GeV lepton; p<1 GeV pion.
- EMC deposit energy: both muon <0.35 GeV; both electron >1.1 GeV.

Event Selection

- 5C kinematic fit:
- 4C fit + π^0 mass constraint.
- Choose the best gamma combination with least χ^2.
- $\chi^2<100$

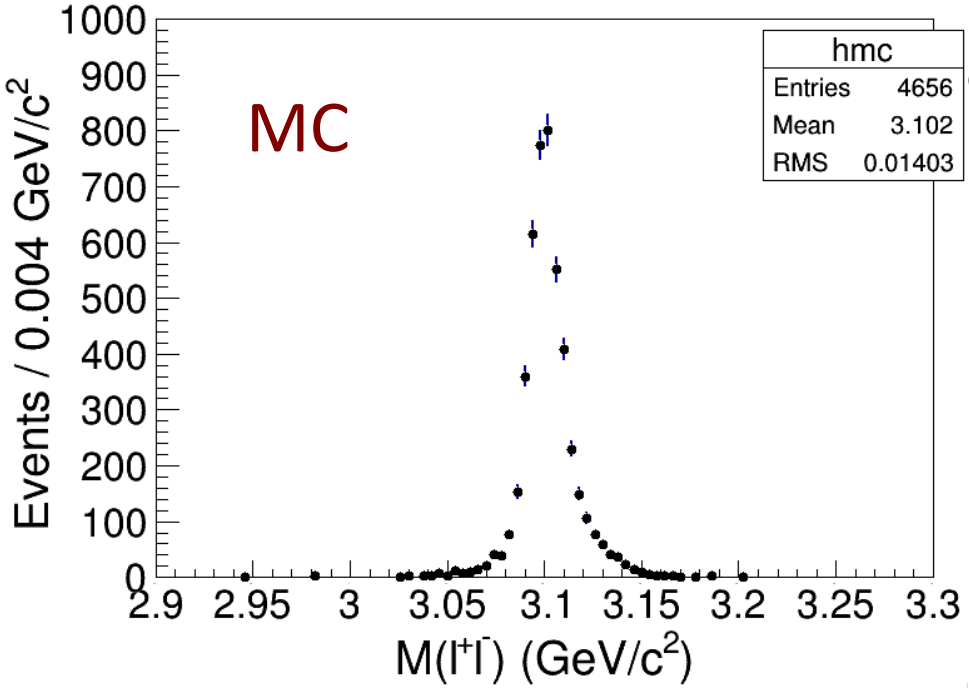


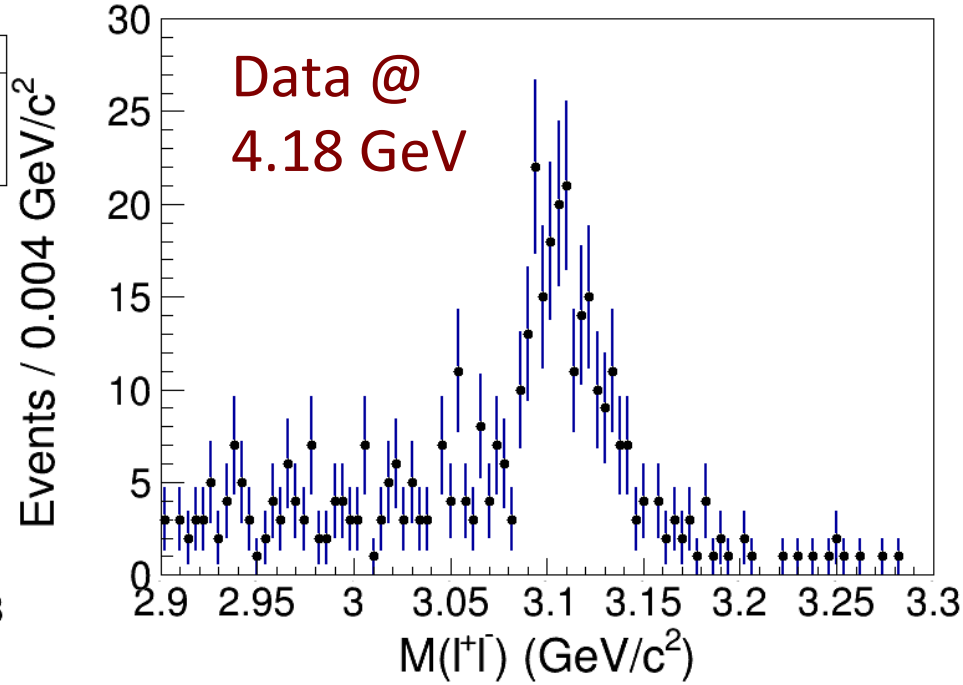


1. Signal MC simulation at 4.18 GeV

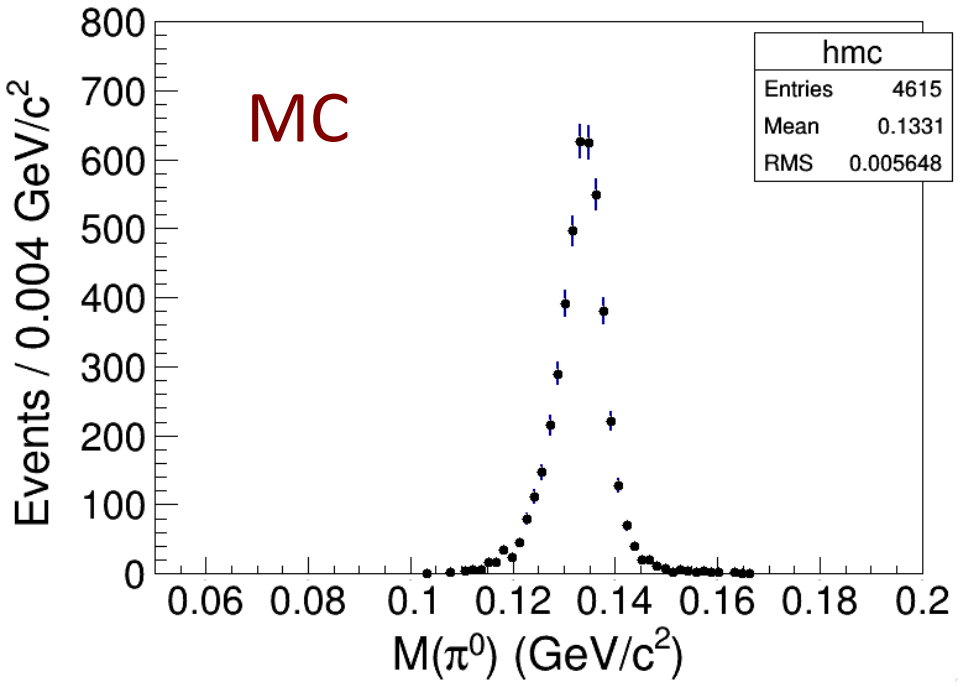
2. Lab-frame momentum: Pions < 1 GeV; leptons > 1 GeV

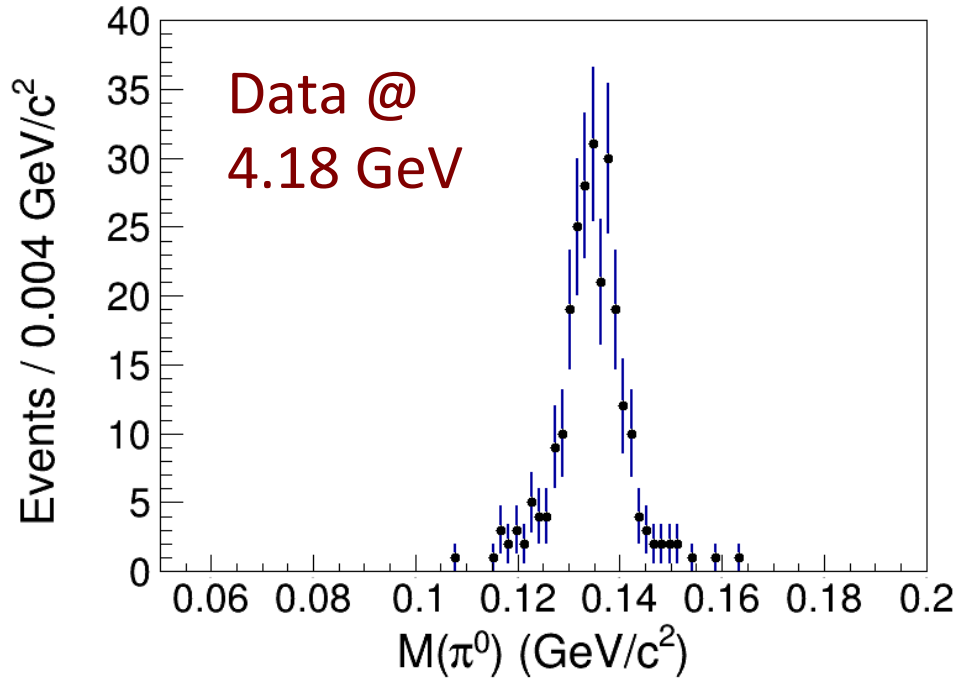
3. Both muon <0.35 GeV; both electrons >1.1 GeV



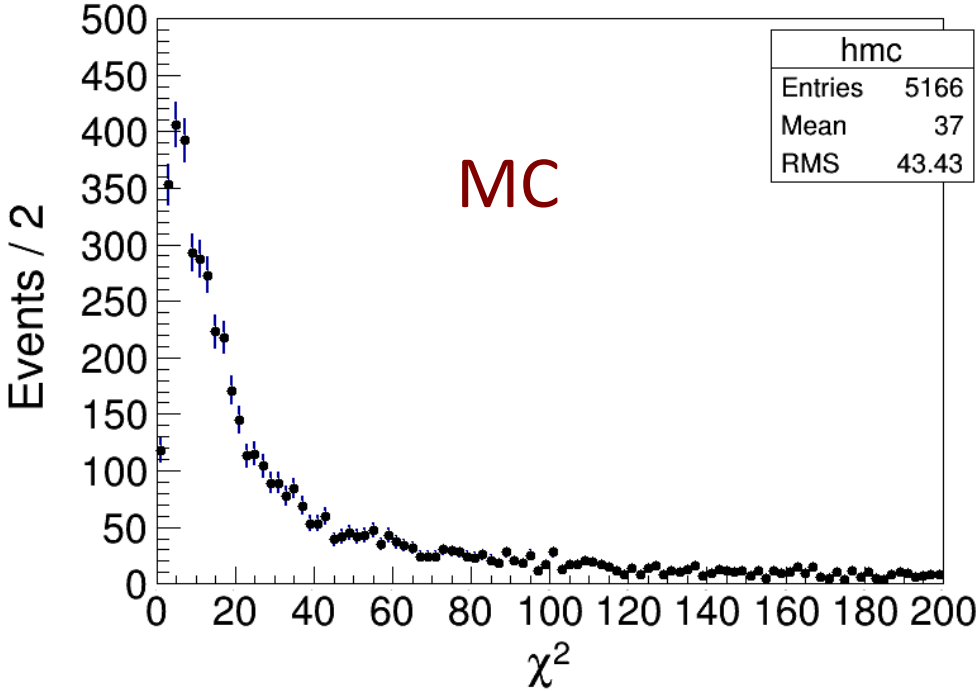


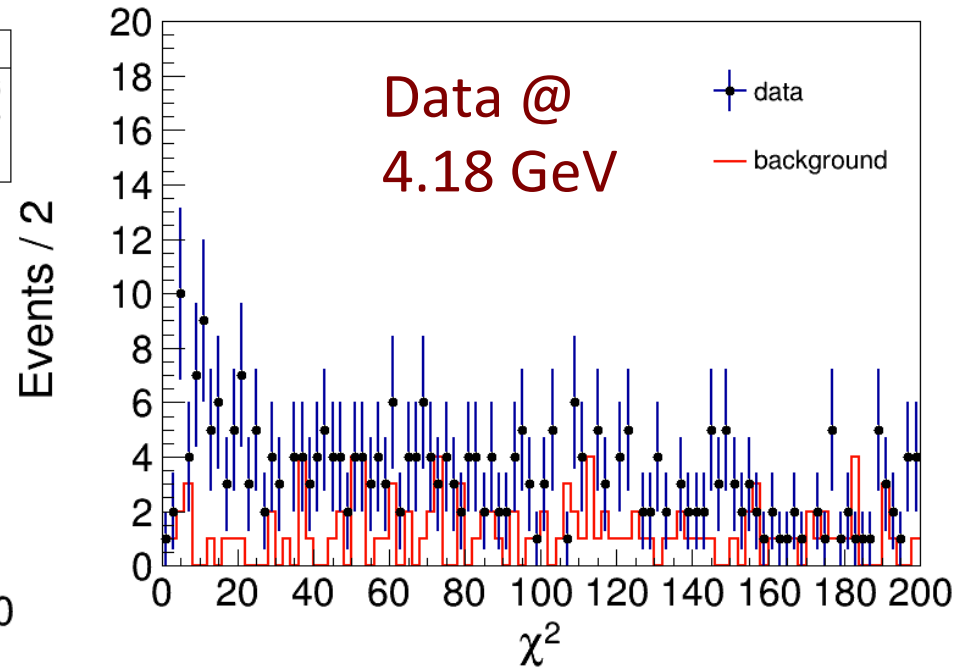
1. Lepton pair invariant mass distribution.
2. Mass window: [3.07, 3.15] GeV.





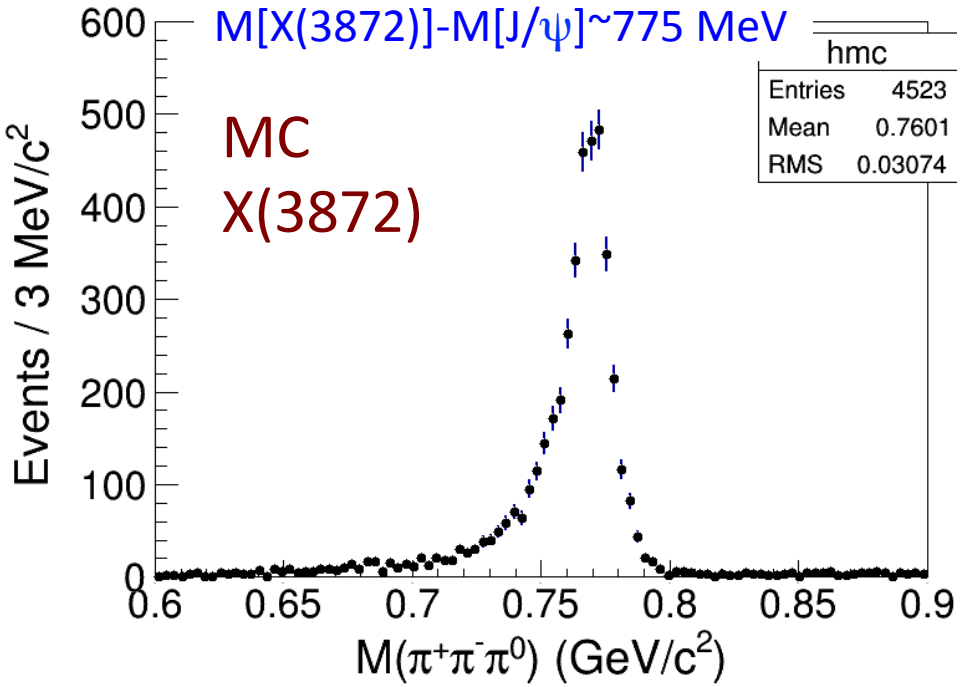
π^0 mass distribution after 4C kinematic fit
(Left) Signal MC simulation; (Right) Data distribution

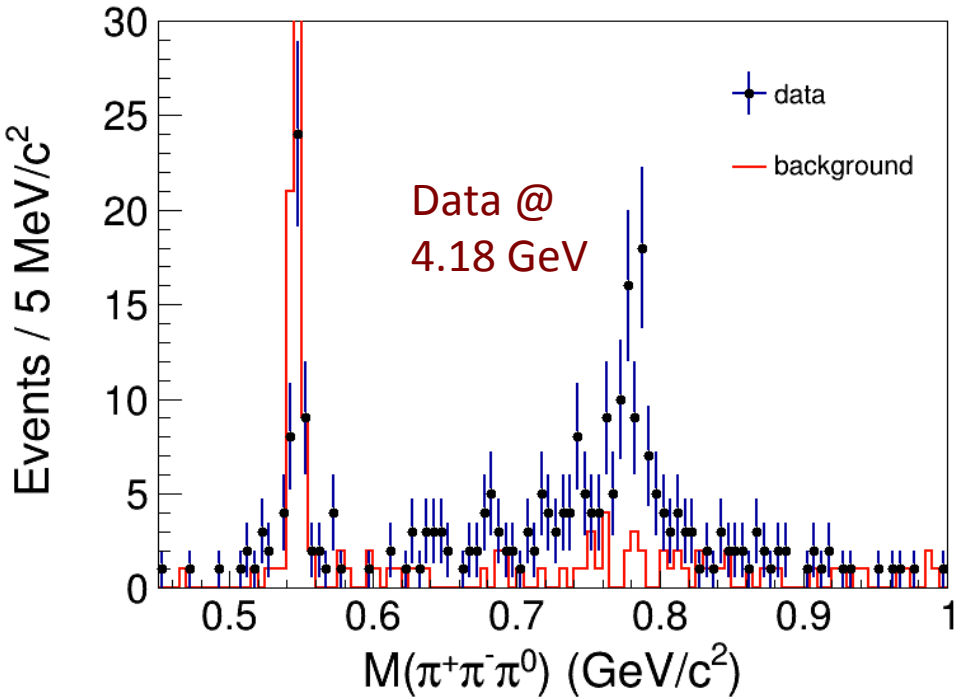


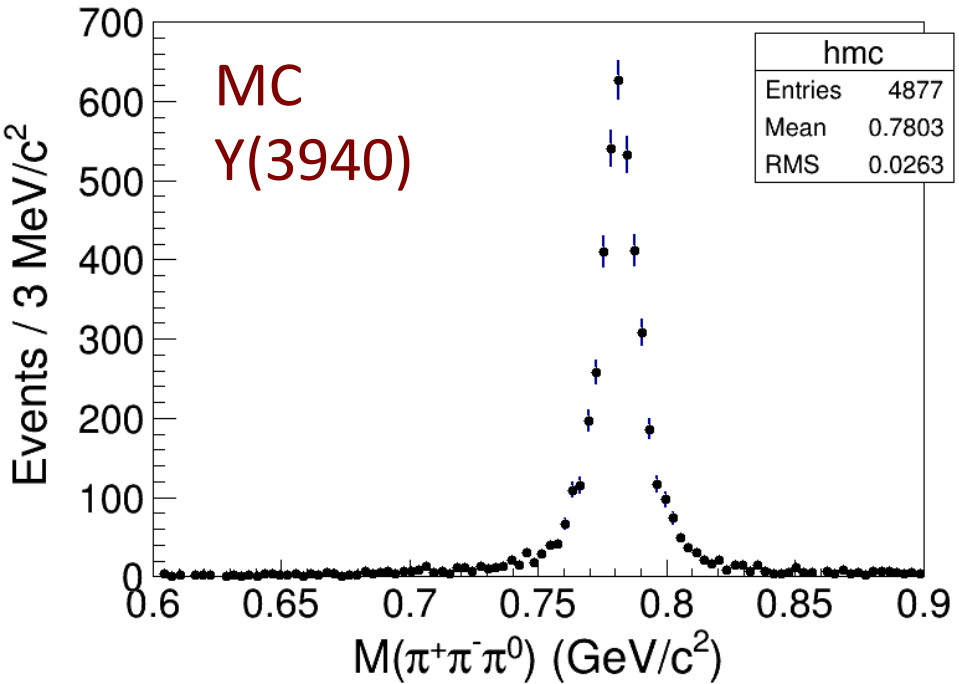


1. 5C kinematic fit χ^2 distribution.

2. $\chi^2<100$

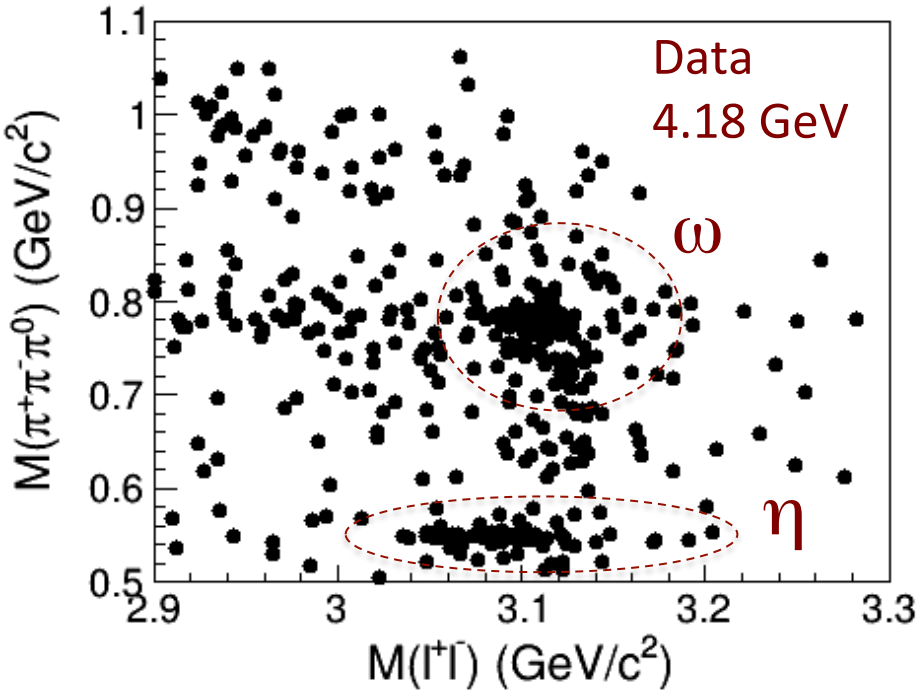


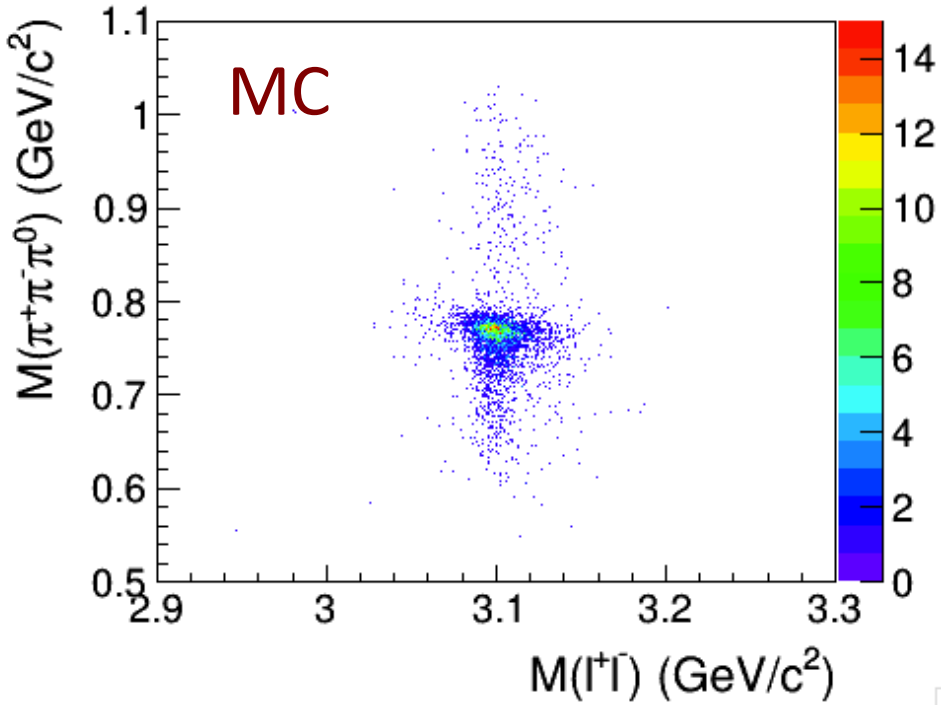




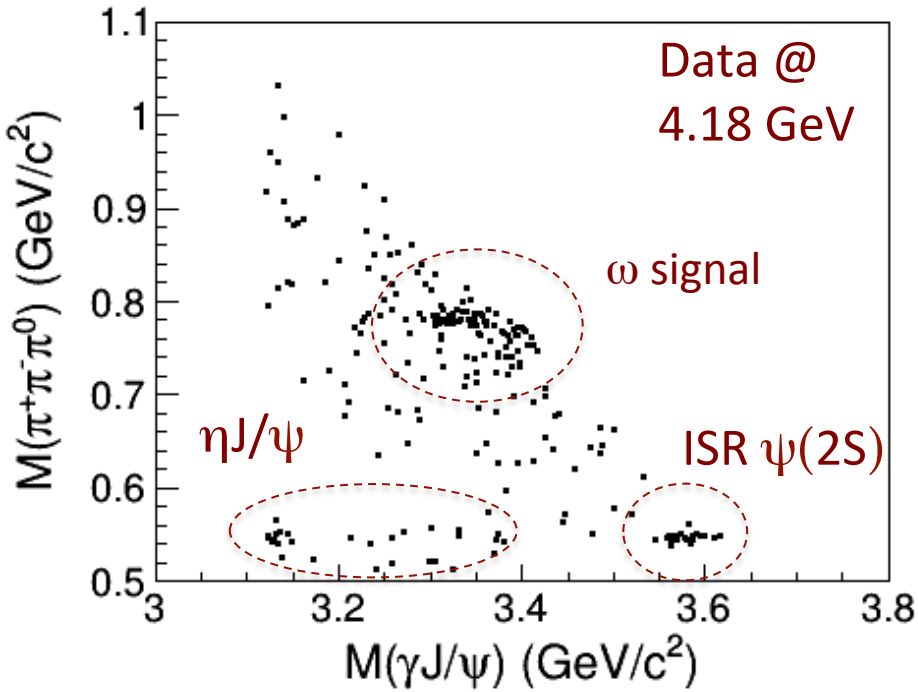
1. $M(\pi^+\pi^-\pi^0)$ invariant mass distribution.
2. Very clear η, ω peak in data.

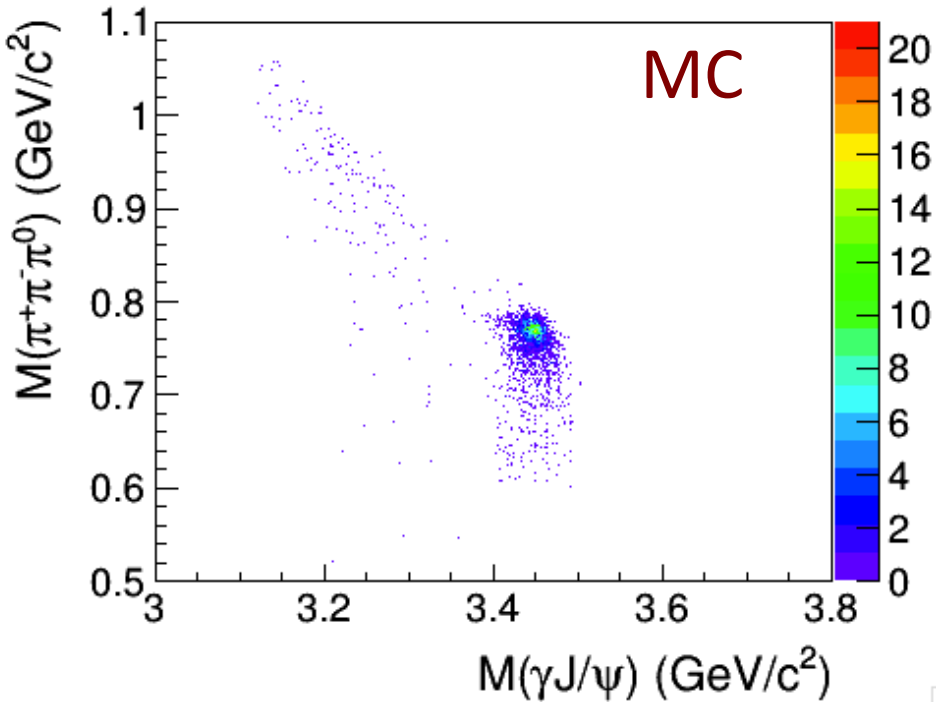
3. ω signal region: [0.72, 0.81] GeV.
4. Sideband: [0.61, 0.70] & [0.83, 0.92] GeV.



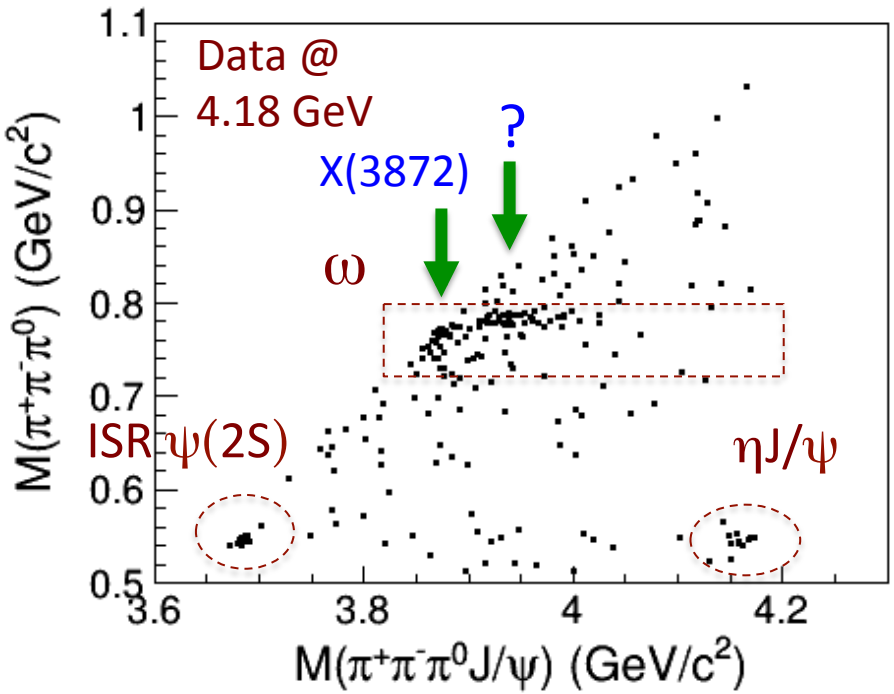


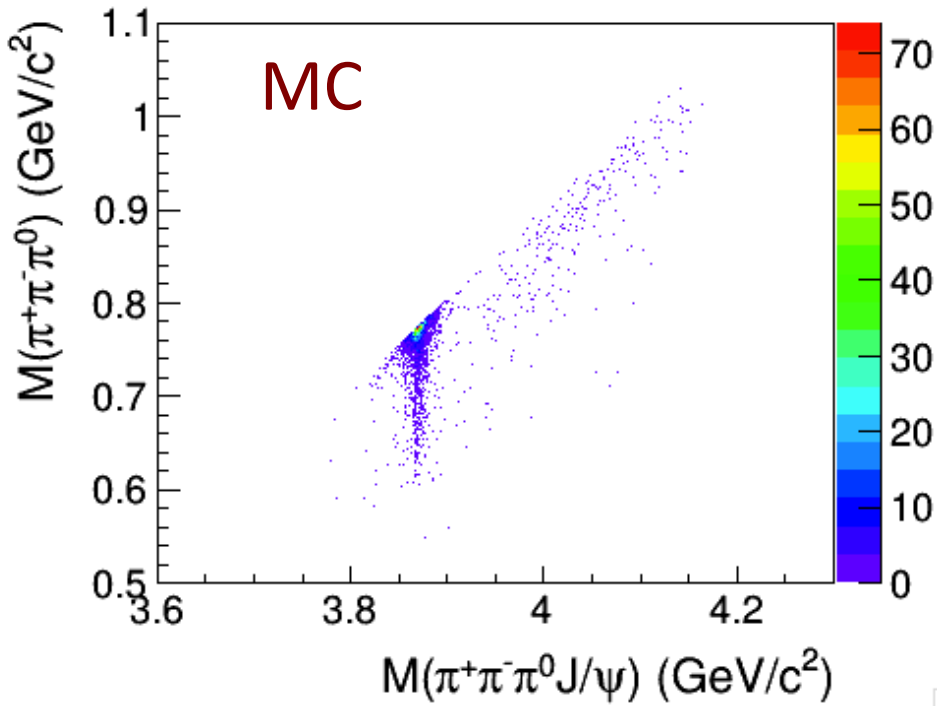
1. Scatter plot of $M(\pi^+\pi^-\pi^0)$ vs. M(ll)
2. $\eta J/\psi$ and $\omega J/\psi$ event is obvious



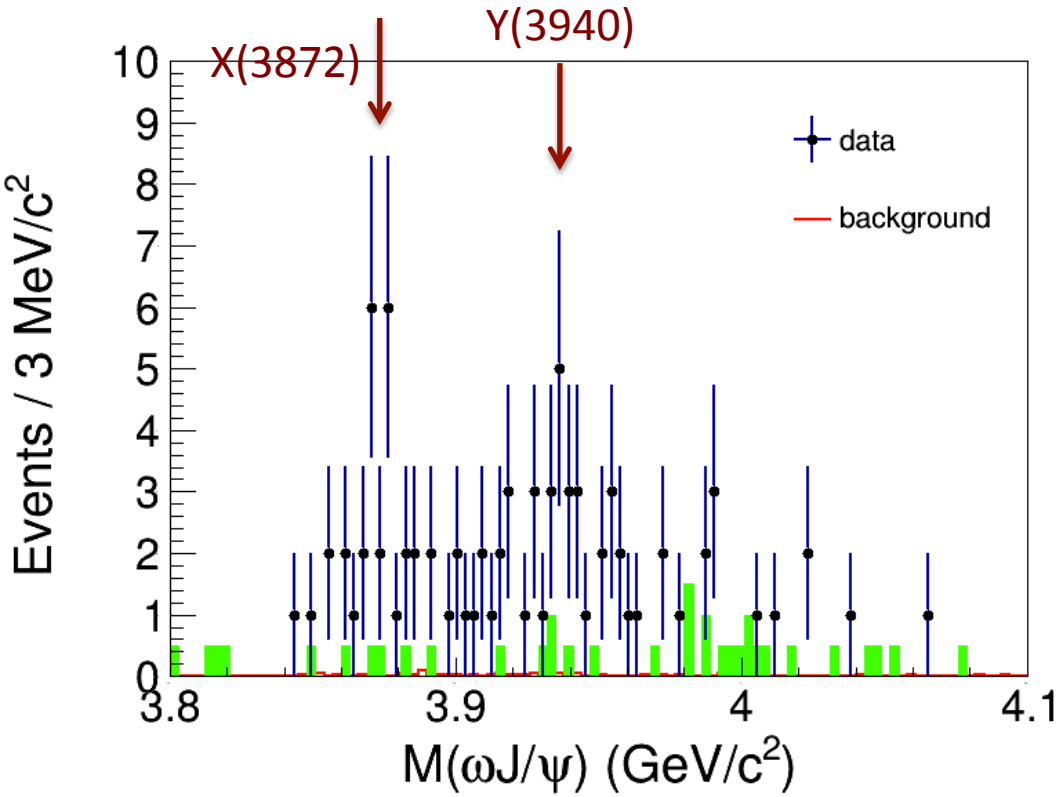


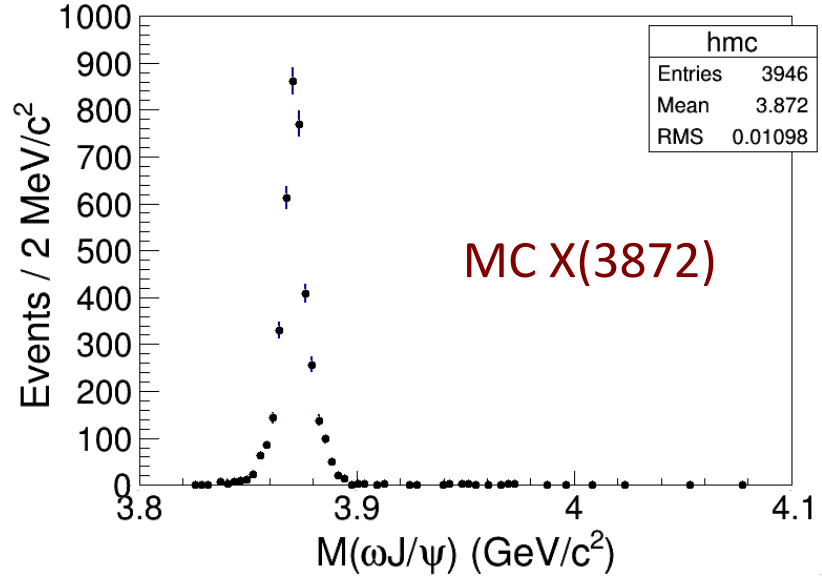
1. Scatter plot of $M(\pi^+\pi^-\pi^0)$ vs. $M(\gamma J/\psi)$
2. ISR $\psi(2S) \rightarrow \eta J/\psi$ & $e^+e^- \rightarrow \eta J/\psi$ events is obvious
3. $\gamma(\pi^+\pi^-\pi^0)J/\psi$ backgound & ~~$\omega\chi_{c0}$ background~~

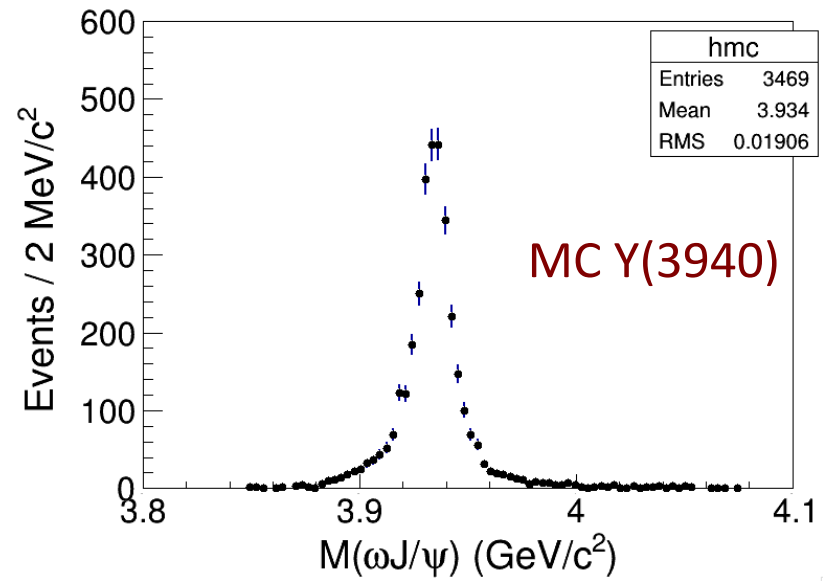




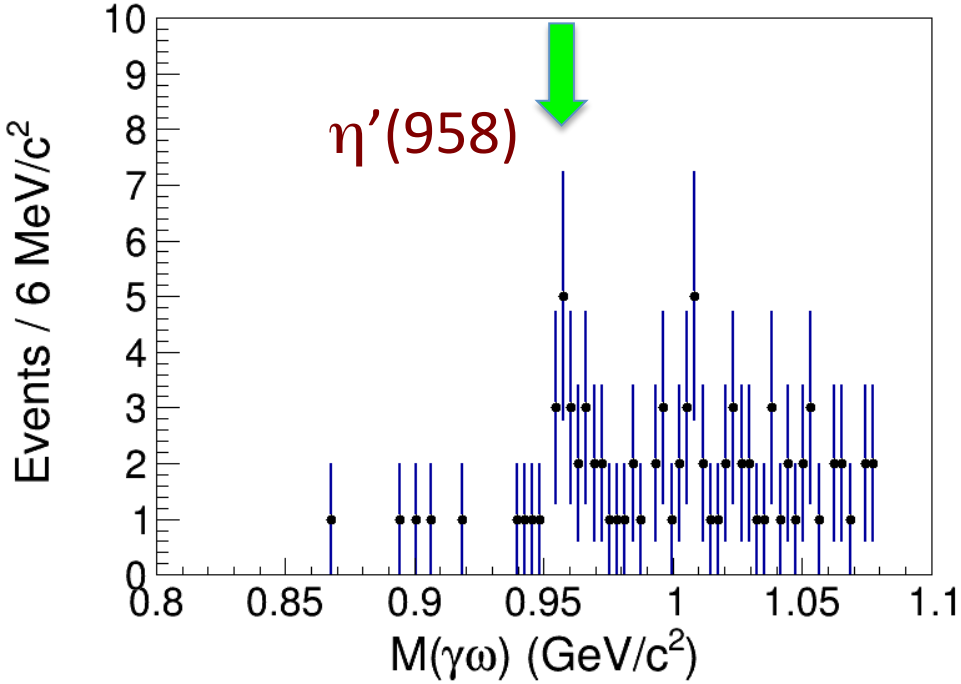
1. Scatter plot of $M(\pi^+\pi^-\pi^0)$ vs. $M(\pi^+\pi^-\pi^0 J/\psi)$
2. ISR $\psi(2S) \rightarrow \eta J/\psi$ & $e^+e^- \rightarrow \eta J/\psi$ events is obvious
3. $X(3872) \rightarrow \omega J/\psi$ signal is evident; new structure ~3.94 GeV?

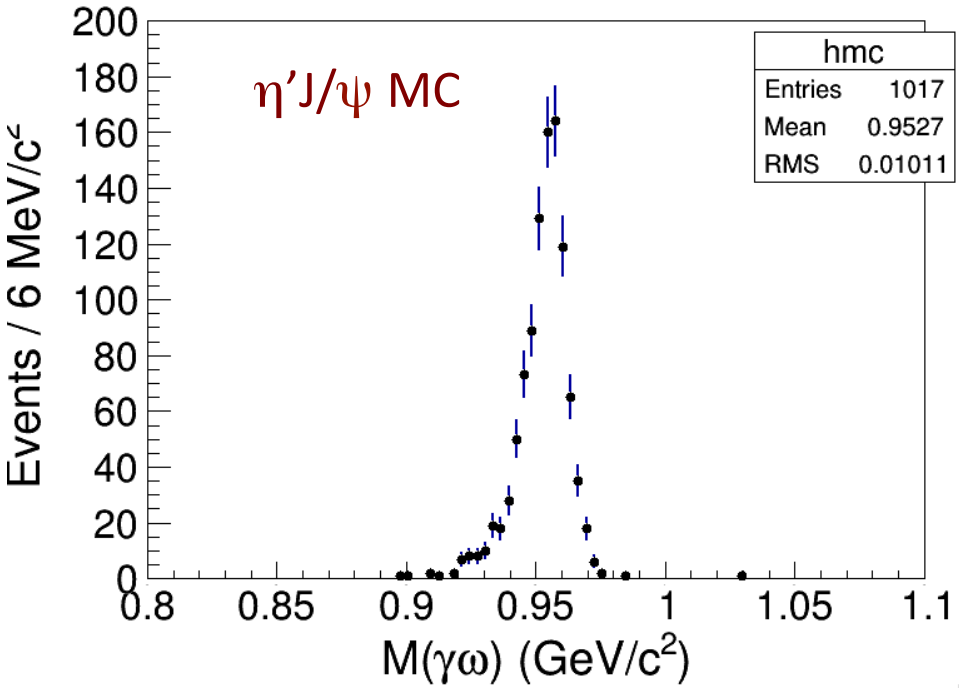




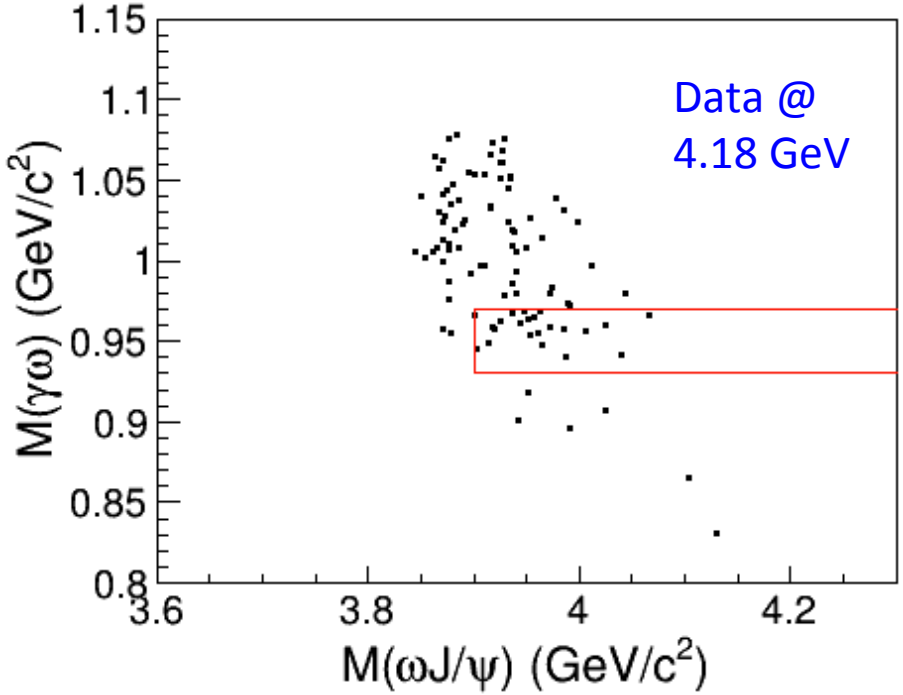


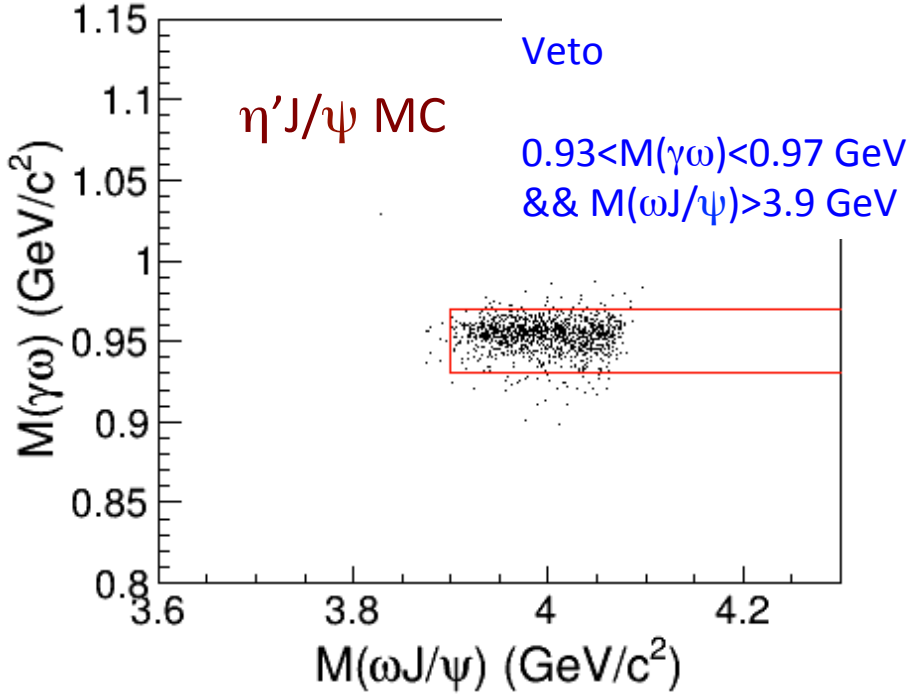
- Event in the ω signal region.
- Two peaks are evident in the ωJ/ψ mass distribution.
- e+e-→η'J/ψ→γωJ/ψ background.

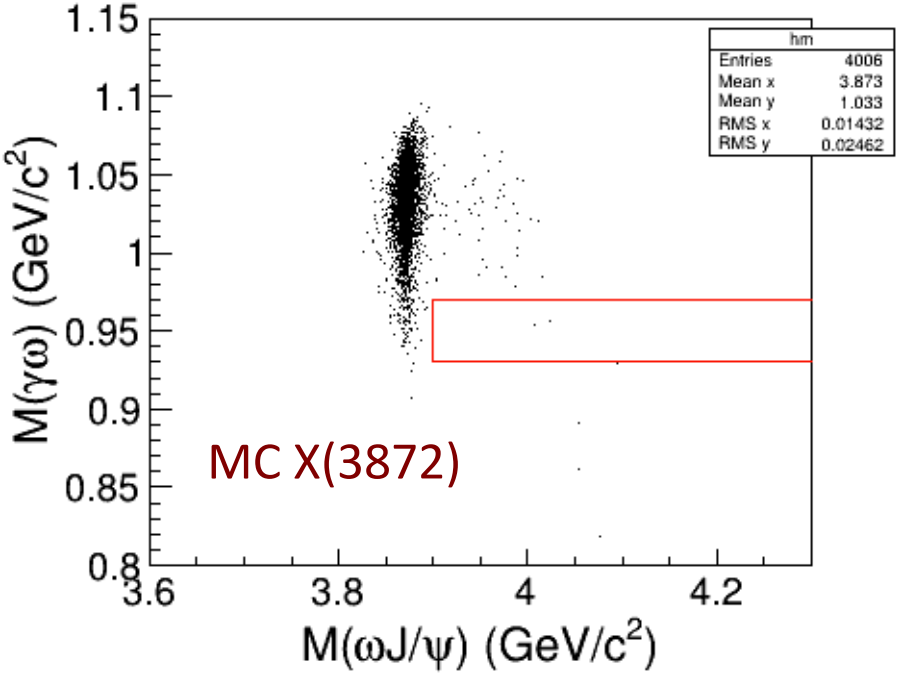


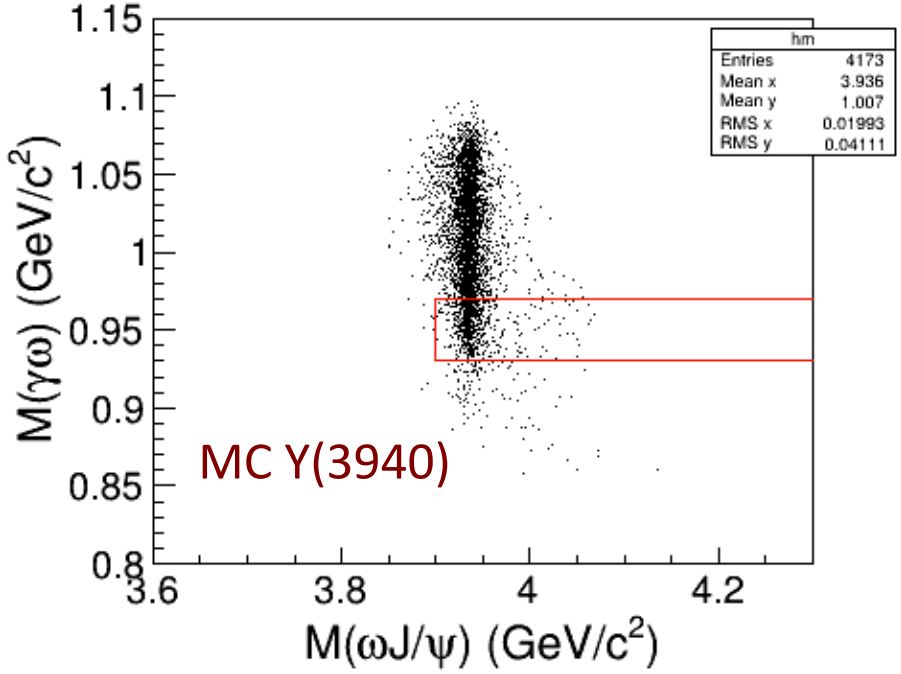


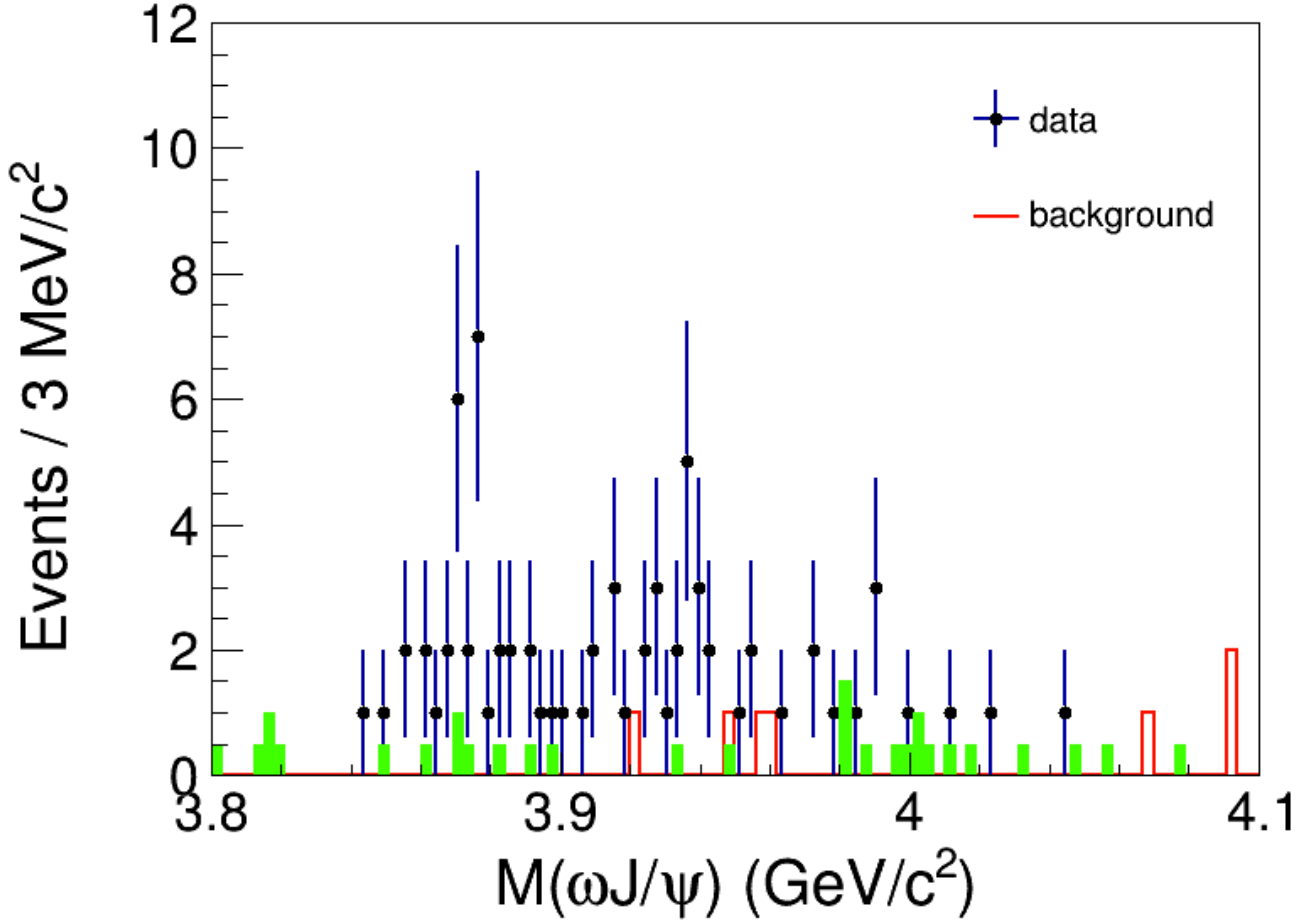
- Event in the ω signal region.
- Evident e+e- →η'J/ψ→γωJ/ψ background events
- Br[η'→γω=2.75%]


Data @
4.18 GeV
M(γω) (GeV/c²)
M(ωJ/ψ) (GeV/c²)

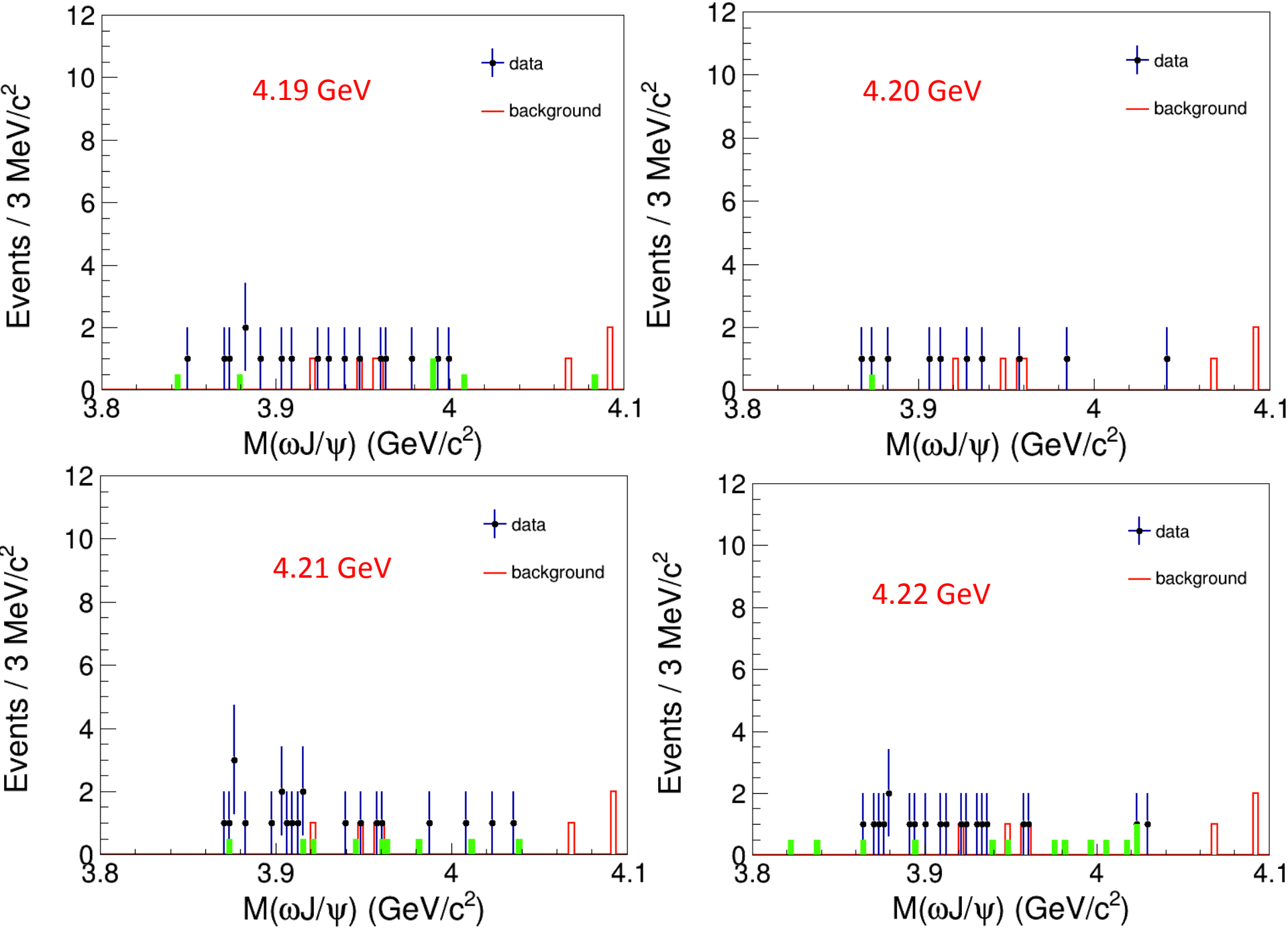

Veto
η'J/ψ MC
0.93<M(γω)<0.97 GeV
&& M(ωJ/ψ)>3.9 GeV
M(γω) (GeV/c²)
M(ωJ/ψ) (GeV/c²)

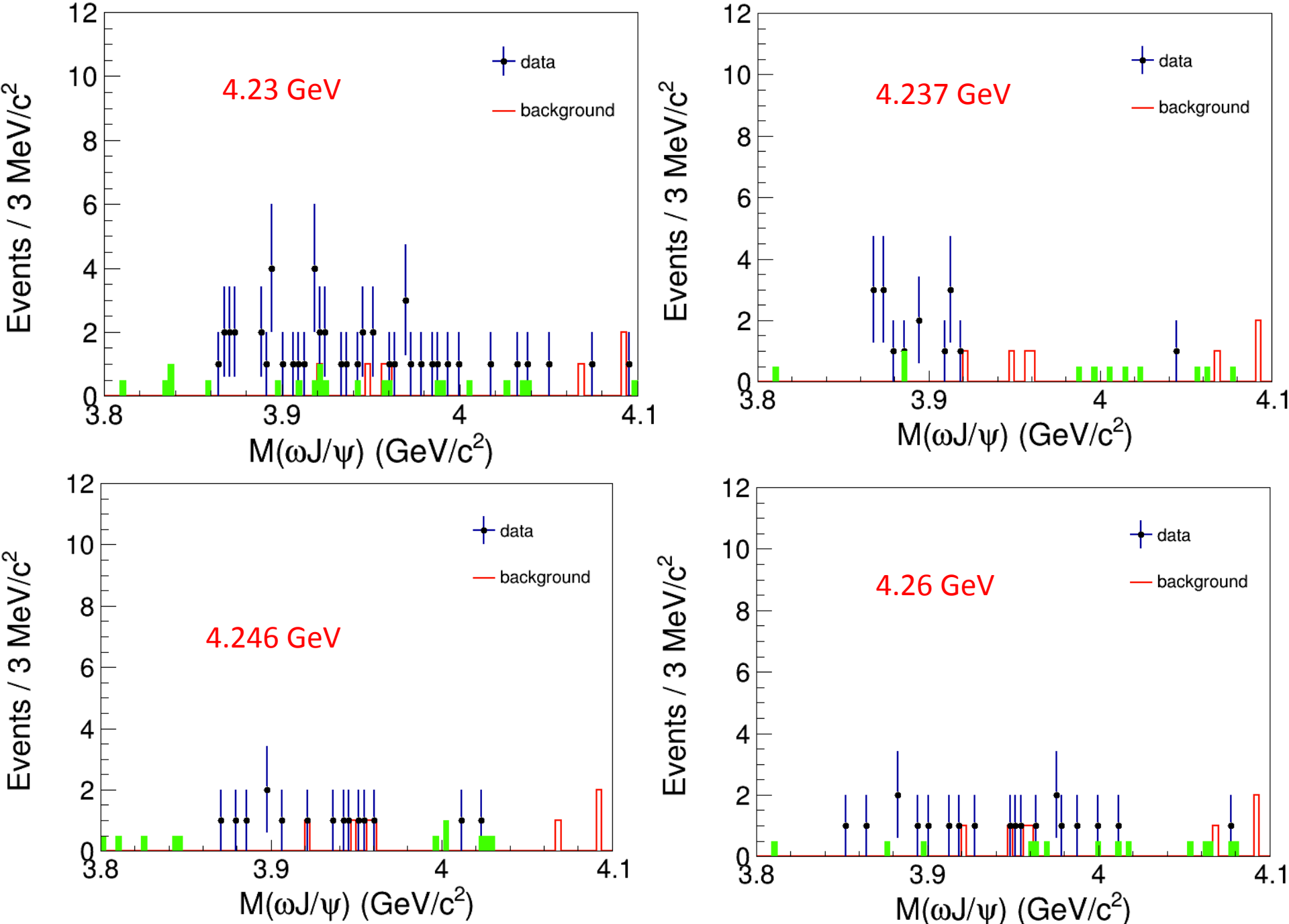

hm
Entries 4006
Mean x 3.873
Mean y 1.033
RMS x 0.01432
RMS y 0.02462
MC X(3872)
M(γω) (GeV/c²)
M(ωJ/ψ) (GeV/c²)

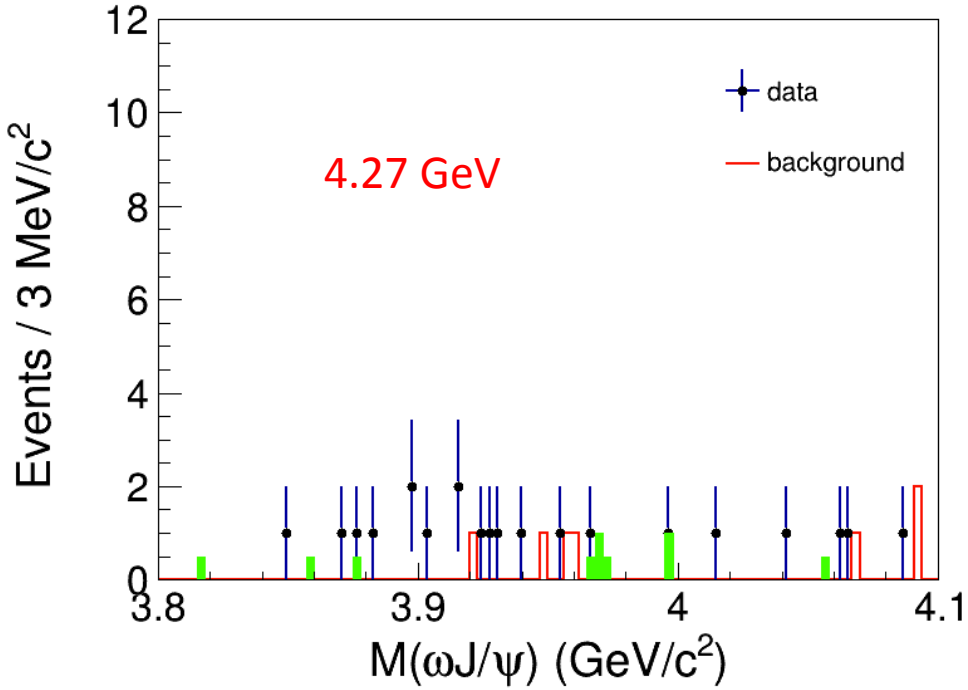

hm
Entries 4173
Mean x 3.936
Mean y 1.007
RMS x 0.01993
RMS y 0.04111
MC Y(3940)
M(γω) (GeV/c²)
M(ωJ/ψ) (GeV/c²)

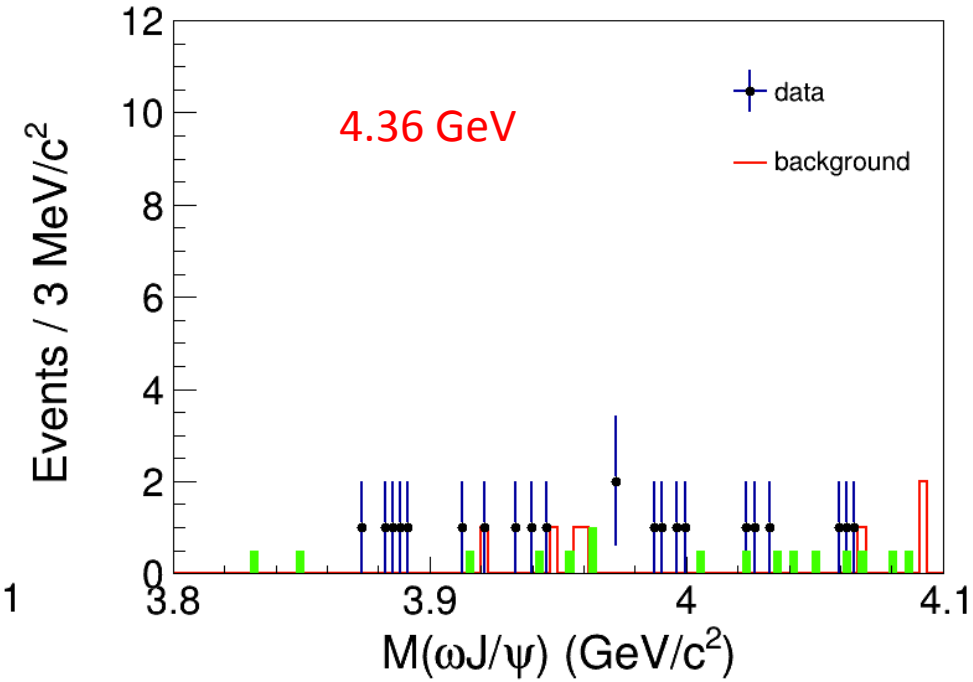


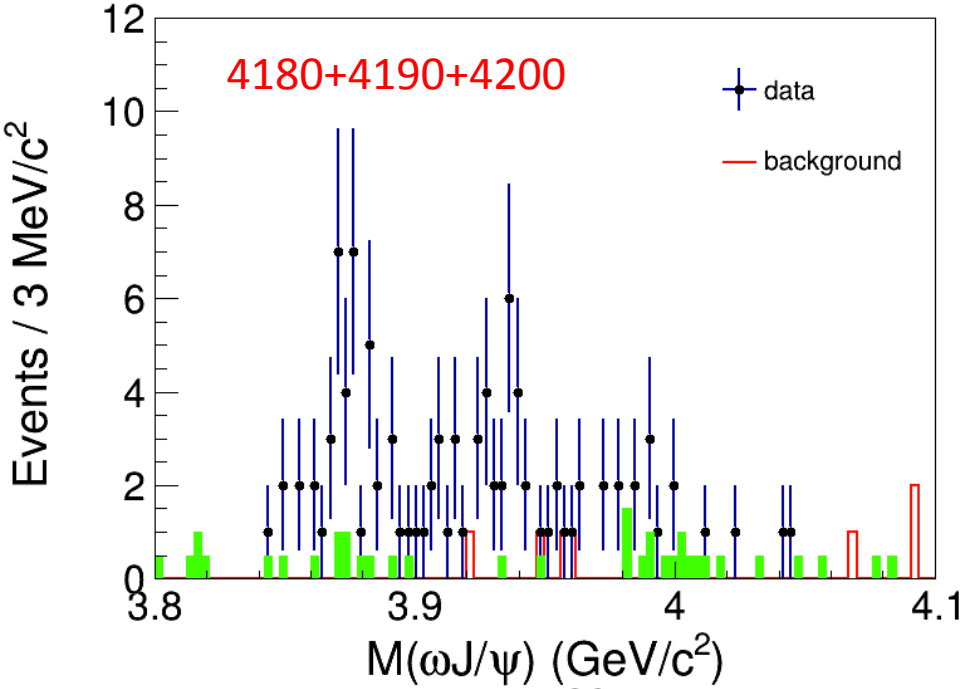
- Final obtained M(ωJ/ψ) invariant mass distribution
- Two distinct peaks are evident: X(3872) & Y(3940)
- Selection efficiency: X(3872)→13.3%; Y(3940)→11.4%

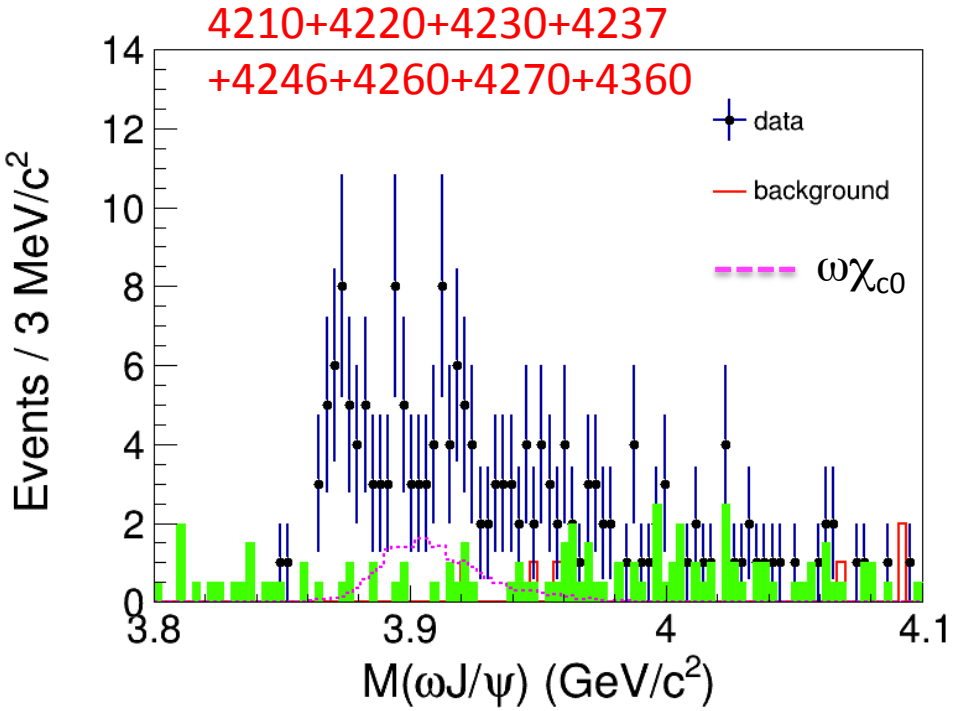

4.19 GeV
4.20 GeV
4.21 GeV
4.22 GeV
data
background
Events / 3 MeV/c^2
M(ωJ/ψ) (GeV/c^2)
0
2
4
6
8
10
12
3.8
3.9
4
4.1

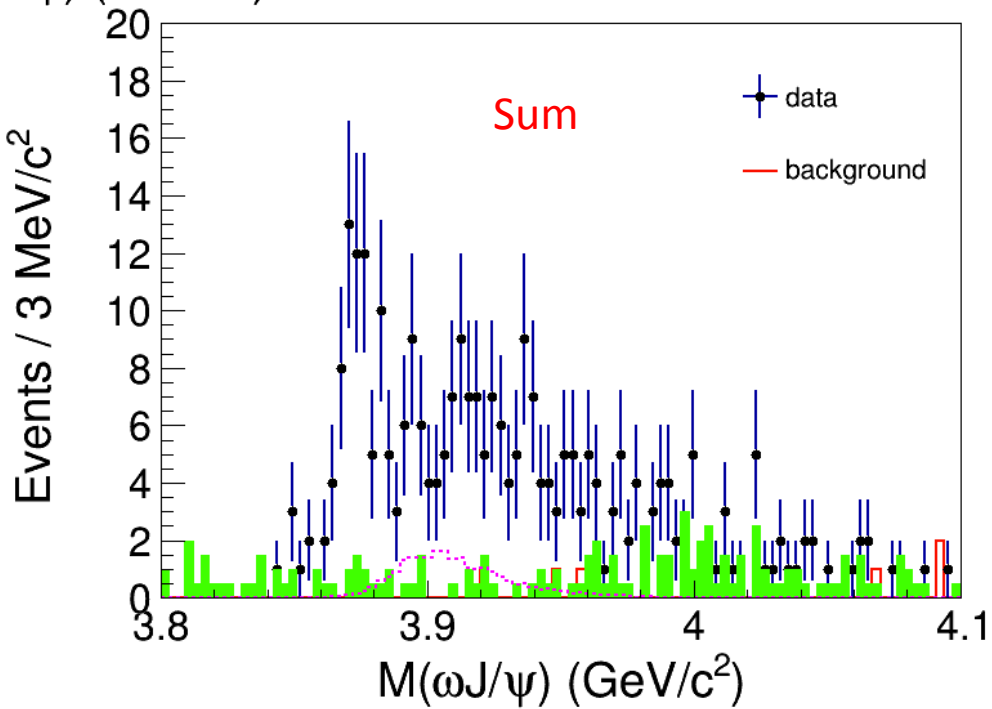

4.23 GeV
4.237 GeV
4.246 GeV
4.26 GeV
data
background
Events / 3 MeV/c²
M(ωJ/ψ) (GeV/c²)
0
2
4
6
8
10
12
3.8
3.9
4
4.1

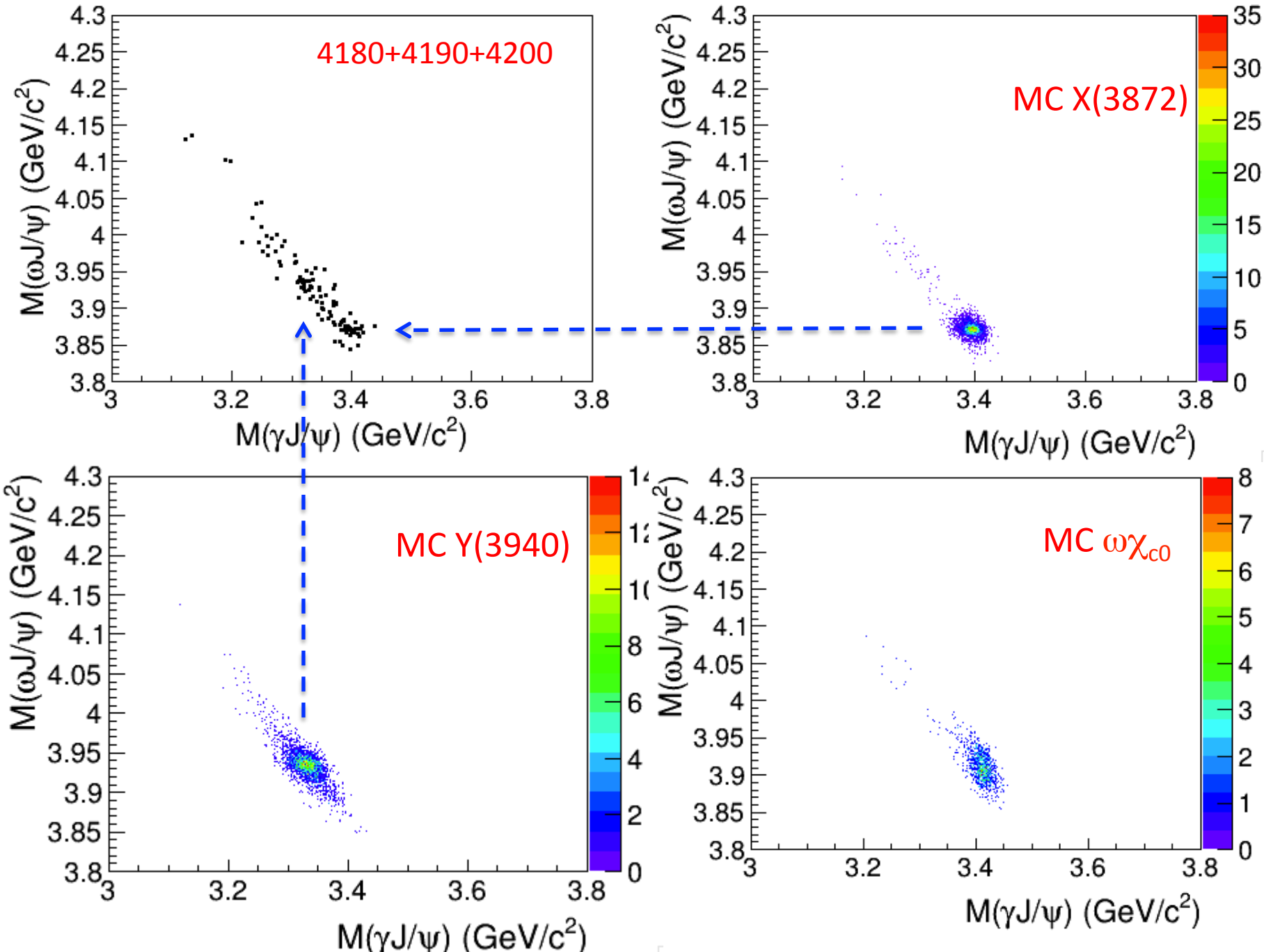

4.27 GeV
data
background
Events / 3 MeV/c^2
M(ωJ/ψ) (GeV/c^2)
0
2
4
6
8
10
12
3.8
3.9
4
4.1

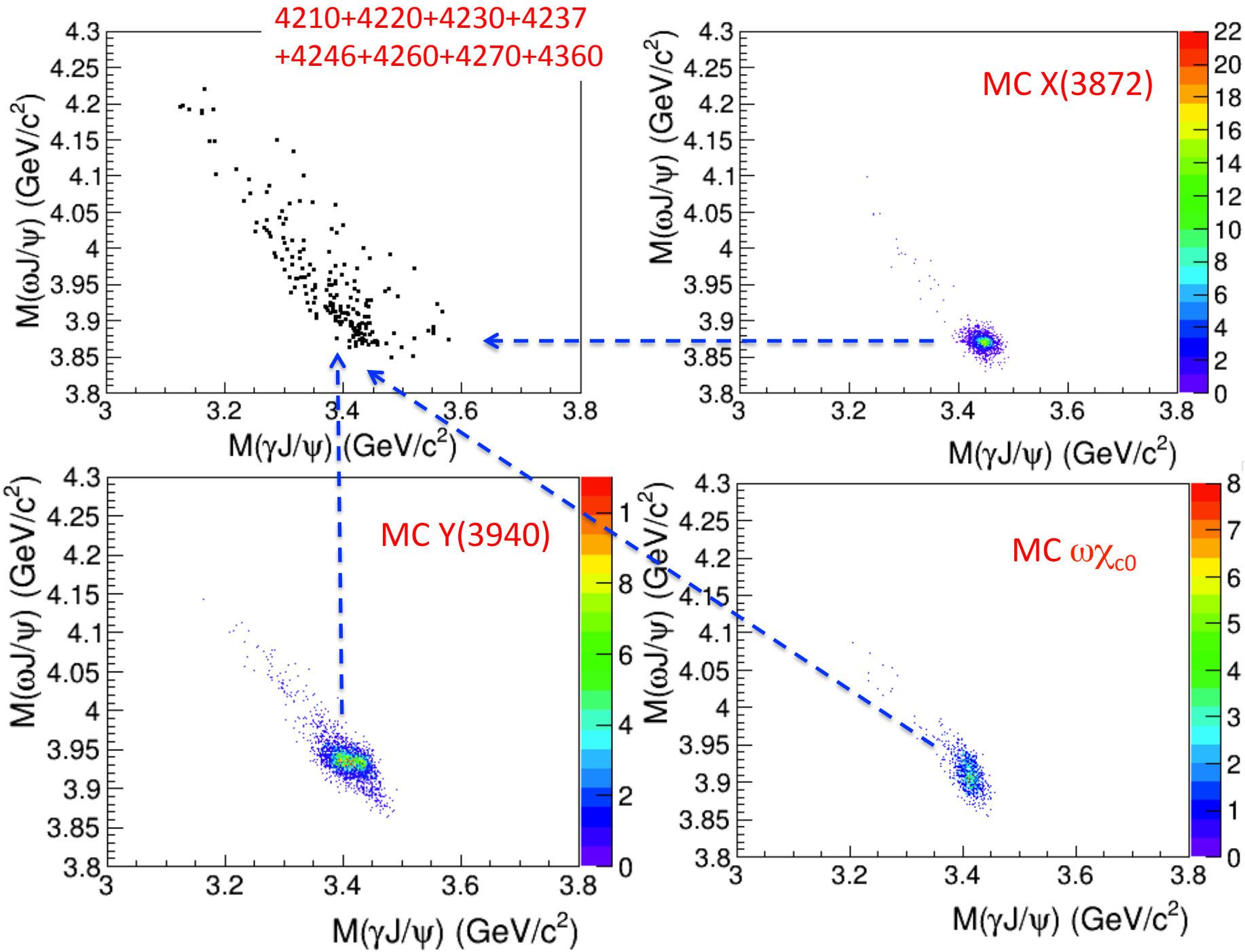

4.36 GeV
data
background
Events / 3 MeV/c^2
M(ωJ/ψ) (GeV/c^2)
0
2
4
6
8
10
12
3.8
3.9
4
4.1


4180+4190+4200
data
background
Events / 3 MeV/c^2
M(ωJ/ψ) (GeV/c^2)


4210+4220+4230+4237
+4246+4260+4270+4360
data
background
$\omega\chi_{c0}$
Events / 3 MeV/c^2
M(ωJ/ψ) (GeV/c^2)


Sum
data
background
Events / 3 MeV/c^2
M(ωJ/ψ) (GeV/c^2)

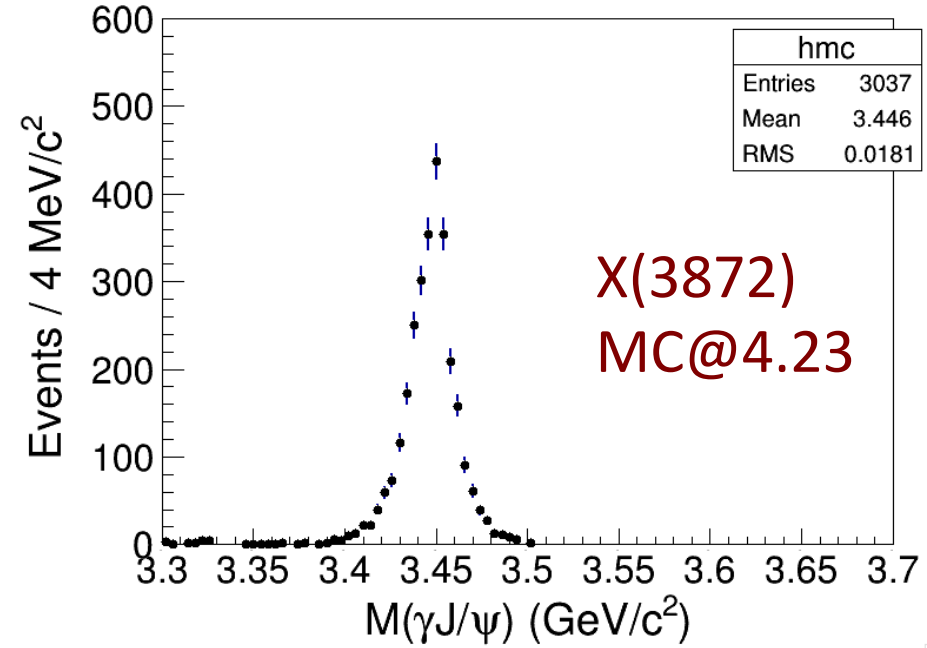

4180+4190+4200
MC X(3872)
MC Y(3940)
MC ωχc0
M(ωJ/ψ) (GeV/c²)
M(γJ/ψ) (GeV/c²)

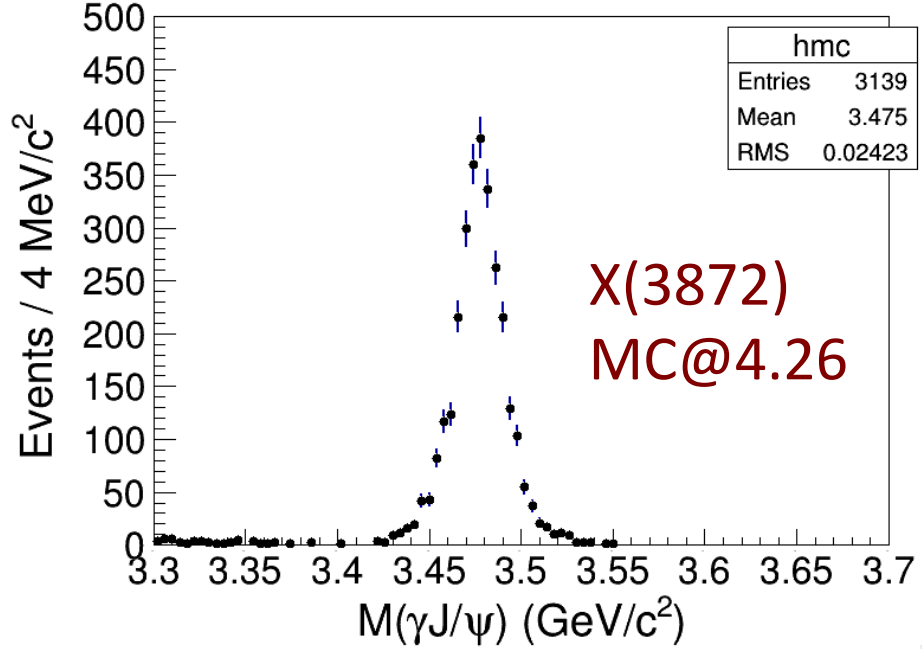

4210+4220+4230+4237
+4246+4260+4270+4360
MC X(3872)
MC Y(3940)
MC ωχc0
M(ωJ/ψ) (GeV/c²)
M(γJ/ψ) (GeV/c²)

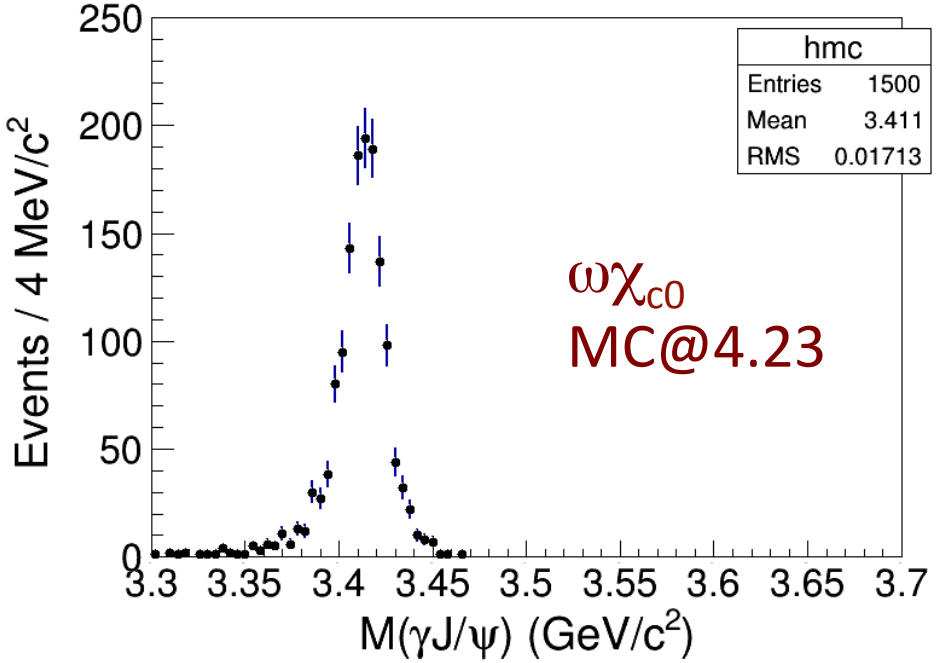
Summary

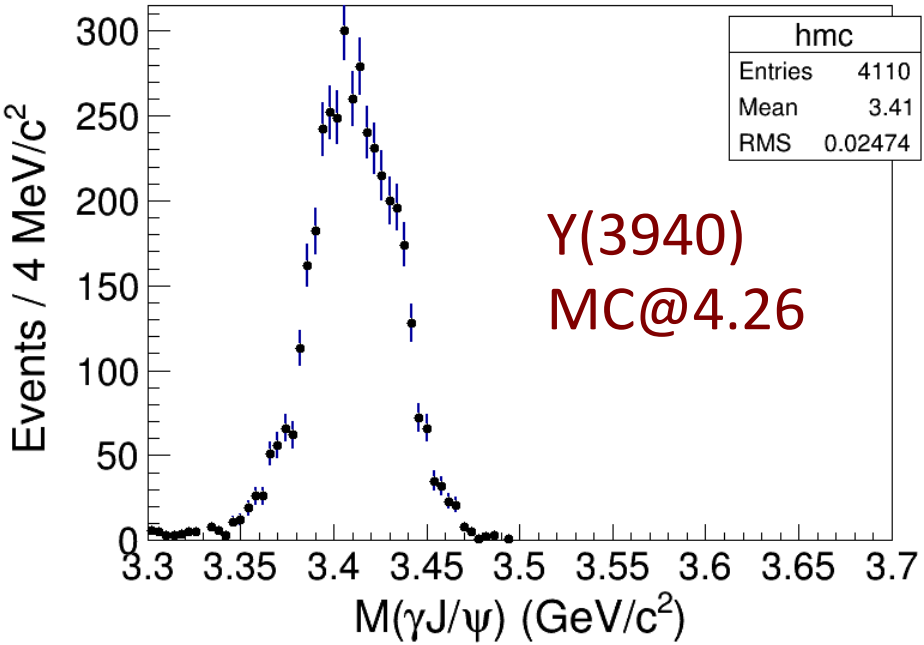
- Two distinct peaks are evident in the $\omega J/\psi$ system: X(3872) and Y(3940)?
- Understand the background sources carefully.
- Potential to measure the Ratio $R=Br[X(3872)\rightarrow\omega J/\psi]/Br[X(3872)\rightarrow\pi^+\pi^- J/\psi]$ better than BABAR & Belle.
- Update all the analysis with final calibrated data sets.

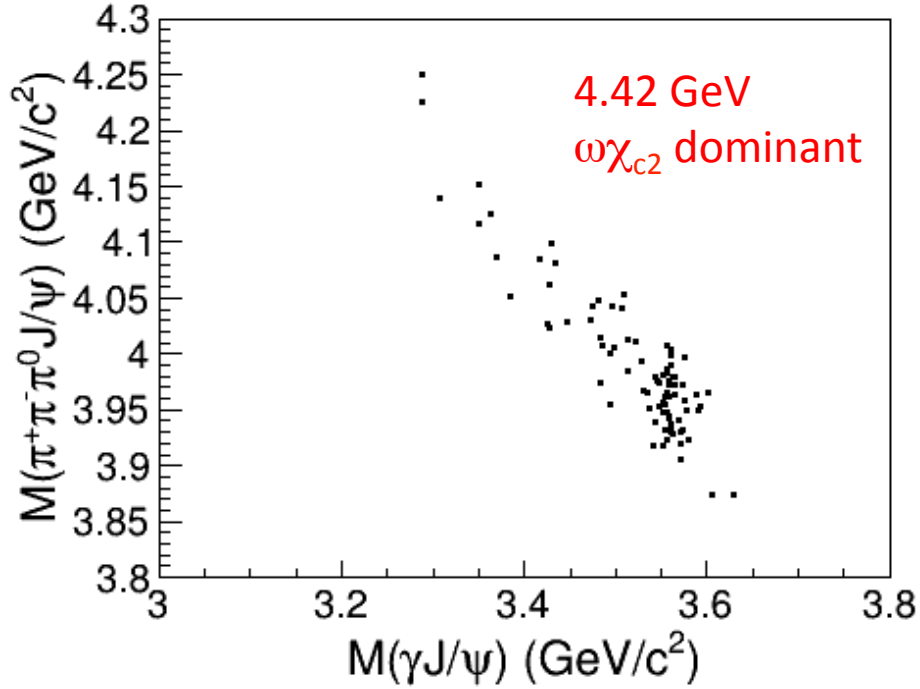
Thank you !

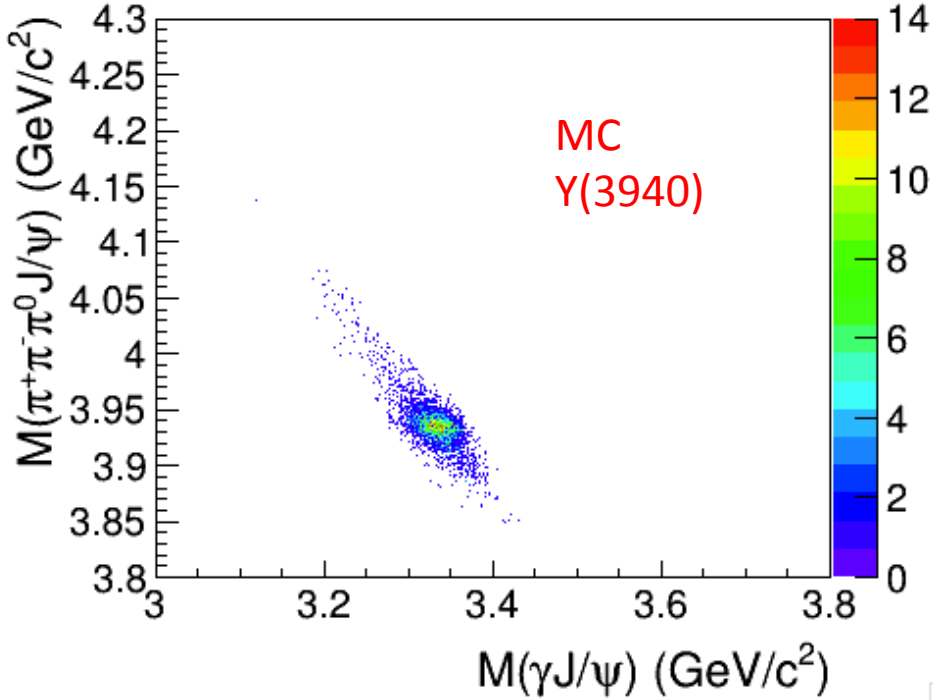

hmc
Entries 3037
Mean 3.446
RMS 0.0181
X(3872)
MC@4.23
Events / 4 MeV/c^2
M(γJ/ψ) (GeV/c^2)

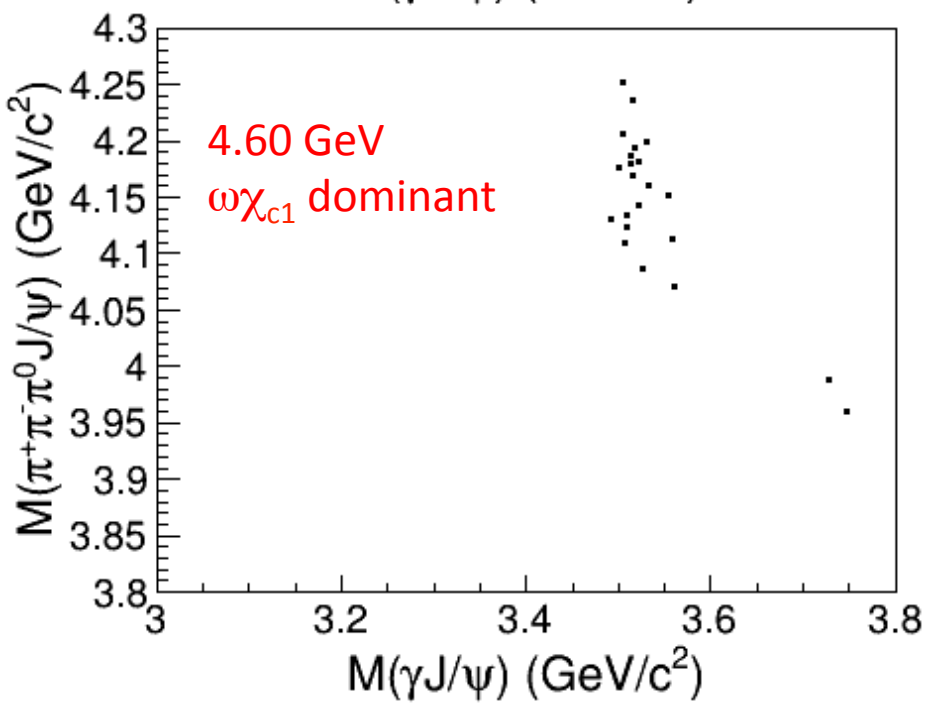

hmc
Entries 3139
Mean 3.475
RMS 0.02423
X(3872)
MC@4.26
Events / 4 MeV/c^2
M(γJ/ψ) (GeV/c^2)

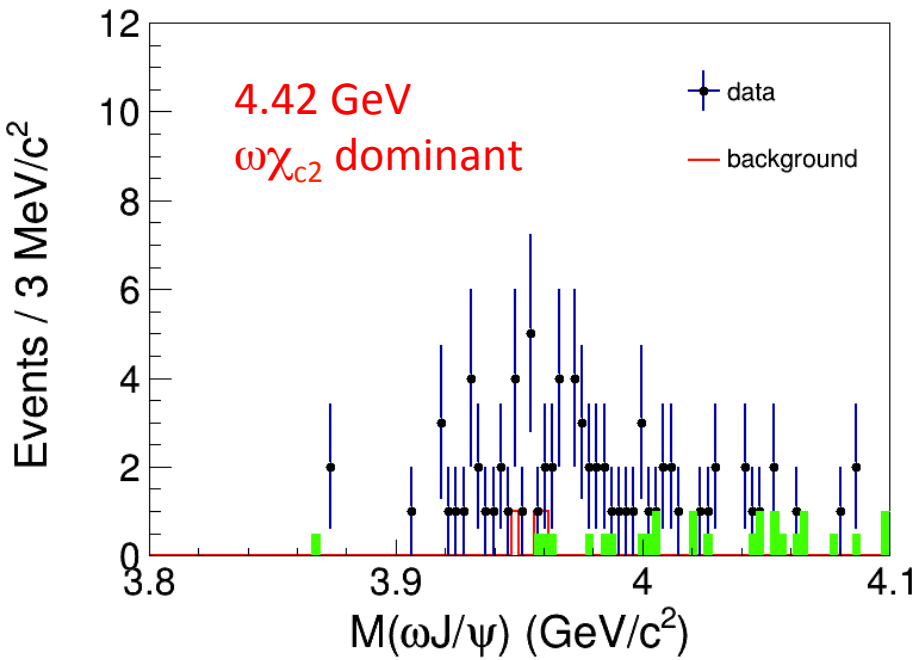

hmc
Entries 1500
Mean 3.411
RMS 0.01713
$\omega\chi_{c0}$
MC@4.23
Events / 4 MeV/c^2
M(γJ/ψ) (GeV/c^2)

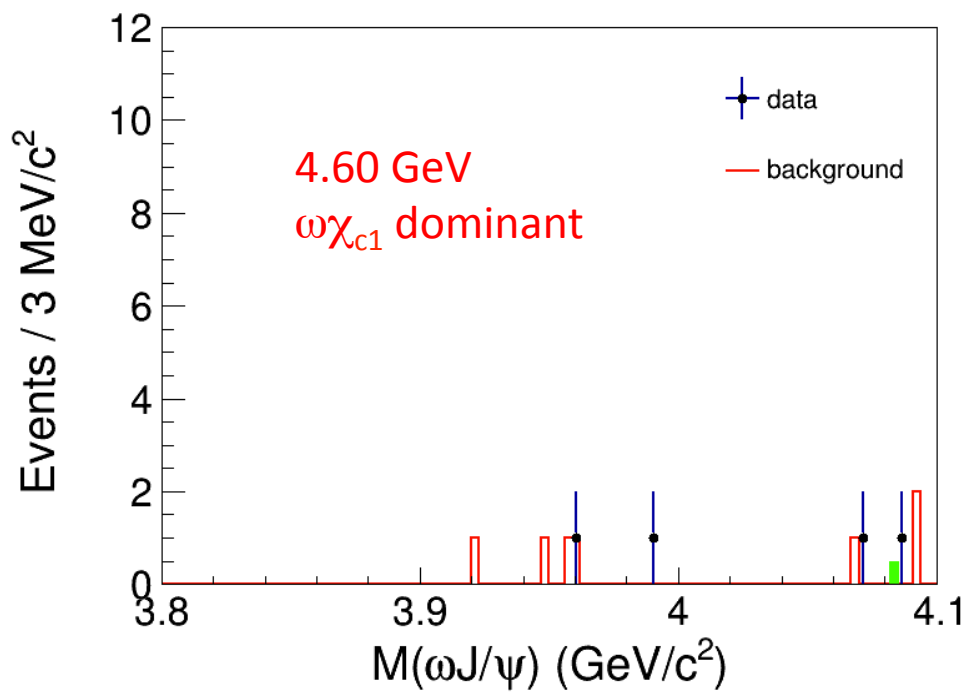

hmc
Entries 4110
Mean 3.41
RMS 0.02474
Y(3940)
MC@4.26
Events / 4 MeV/c^2
M(γJ/ψ) (GeV/c^2)


4.42 GeV
ωχc2 dominant
M(π+π-π0J/ψ) (GeV/c2)
M(γJ/ψ) (GeV/c2)


MC
Y(3940)
M(π+π-π0J/ψ) (GeV/c2)
M(γJ/ψ) (GeV/c2)

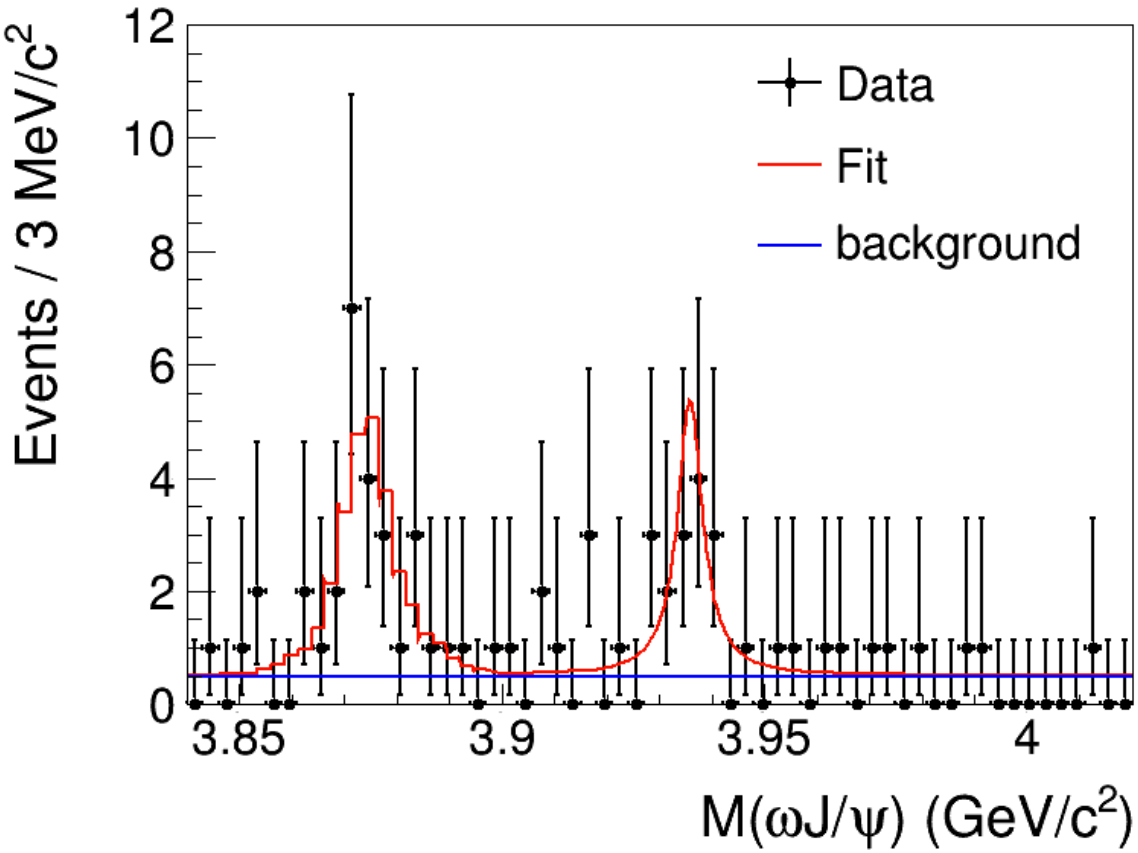

4.60 GeV
ωχc1 dominant
M(π+π-π0J/ψ) (GeV/c2)
M(γJ/ψ) (GeV/c2)





BESIII Collaboration
PRD93,011102(2016)

Statistical significance



X(3872) MC histogram ⊗ Gaussian + BW + linear bkg

X(3872):
μ=(3.1±0.5) MeV
N^{sig}[X3872]=20.4±5.4
Significance: 4.8σ

Y(3940):
M=3935.8±1.1 MeV
Γ=5.8±4.5 MeV
N^{sig}[X(3935)]=14.5±5.9
Significance: 4.0σ

$Br[X(3872)\rightarrow\pi^+\pi^-\pi^0 J/\psi]/Br[X(3872)\rightarrow\pi^+\pi^- J/\psi]=$
$N^{3\pi}/N^{2\pi}*eff^{2\pi}/eff^{3\pi}$ = 1.6±0.6