Study of $e^+e^- \to \pi^+\pi^-\psi'$, $\psi' \to l^+l^-$ @ BESIII

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outline

- event selection
- $\sigma(\pi^+\pi^-\psi')$ lineshape
- background analysis
- intermediate state study
- Conclusion

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event selection

- good charged track
  $|V_{xy}|<1$, $|V_z|<10$, $|\cos(\theta)|<0.93$
  N(track) $\geqq$ 5

- particle identification
- lepton: P > 1GeV
  e: e/p > 0.7
  μ: $E_{EMC} < 0.45$GeV
  one $e^+e^-/\mu^+\mu^-$ pair

- π: P < 0.65GeV(0.8GeV)
  4 $\pi^{\pm}$ with $\sum$charge = 0 or
  3 $\pi^{\pm}$ with $\sum$charge = 1

- Kinematic fit:
  4c: $\chi^2_{4c}<60$, $\chi^2_{1c}<15$
  5c: $\sigma(\pi^+\pi^-\psi')$ measurement
  6c: intermediate state study

- J/ψ mass window:
  signal region: [3.05, 3.15] GeV

- ψ' mass window:
  signal region:[3.68, 3.693] GeV
  only one combination of $\pi^+\pi^-l^+l^-$ is in the ψ' mass window

cutflow of $e^+e^- \to \pi^+\pi^-\psi(3686)$ @ 4.26GeV

channel /cut	ee(6trk)	ee(5trk)	mm(6trk)	mm(5trk)
Ntot	100000	100000	100000	100000
track	90550	90550	90550	90550
PID	69797	69797	69797	69797
vertex fit	67627	67627	67627	67627
4C kinematic fit	58976	58976	58976	58976
χ^2_{4c}	10963	9764	15573	13593
m(J/ψ)	10962	9259	15570	13402
5C kinematic fit	10649	8330	15109	11832
6C kinematic fit	10339	7776	14649	11012
m(ψ')	7653	5638	10849	7947
Ks veto	7505	3861	10630	5490
N(γ) < 2	7505	3590	10630	5099

efficiency and RCF

Ecm(GeV)	ε(ee)	ε(μμ)	(1+δ)(ee)	(1+δ)(μμ)
4.009	0.2095	0.29316	0.90941	0.912727
4.090	0.32982	0.4669	0.79236	0.794191
4.190	0.35172	0.5031	0.833576	0.834624
4.210	0.35384	0.50852	0.839034	0.8404
4.220	0.35626	0.50698	0.842559	0.841954
4.230	0.36156	0.51376	0.844358	0.843576
4.245	0.36496	0.51526	0.846201	0.849236
4.260	0.37958	0.53882	0.850136	0.848315
4.310	0.36712	0.52204	0.857341	0.856626
4.360	0.37294	0.53464	0.862897	0.86272
4.390	0.37396	0.53578	0.865571	0.865987
4.420	0.37848	0.53988	0.868364	0.869292
4.600	0.38574	0.54766	0.882892	0.882725

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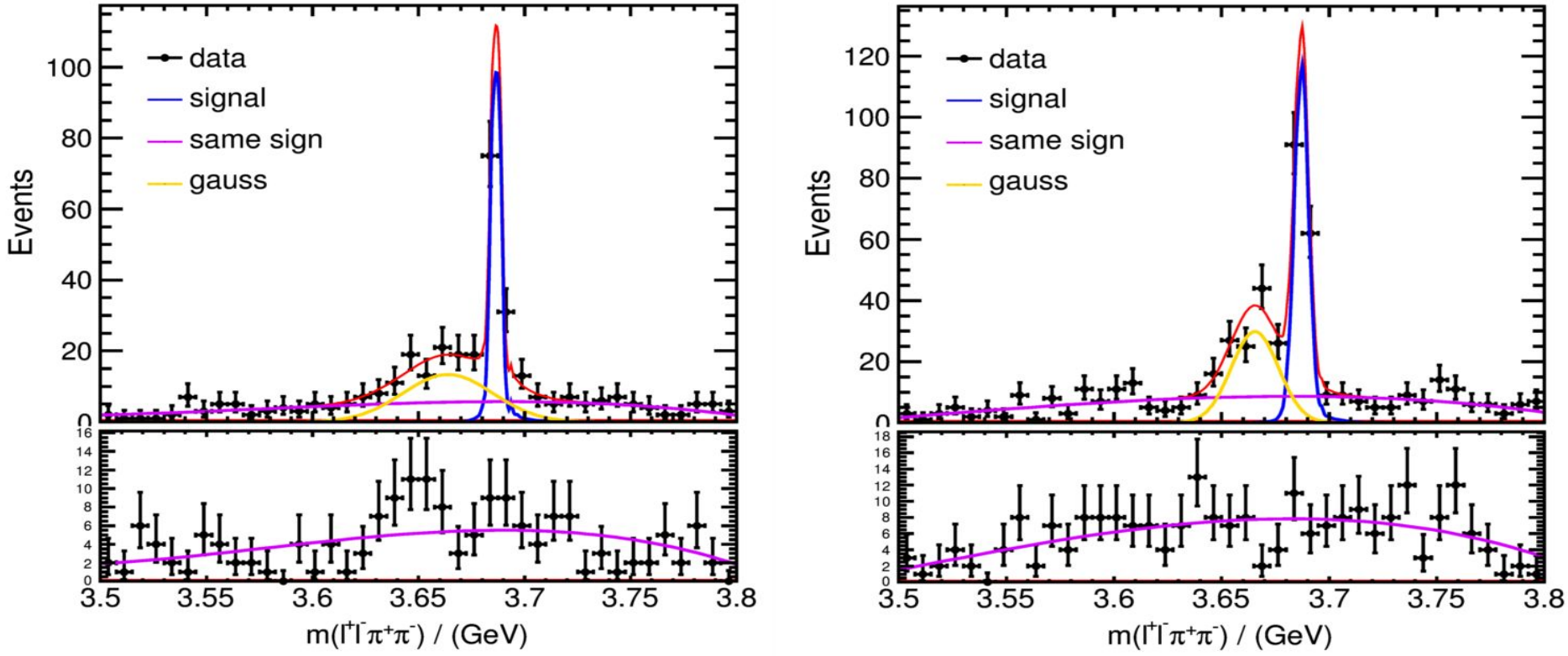
$\sigma(e^+e^-\to\pi^+\pi^-\psi')$ @ 4.26GeV



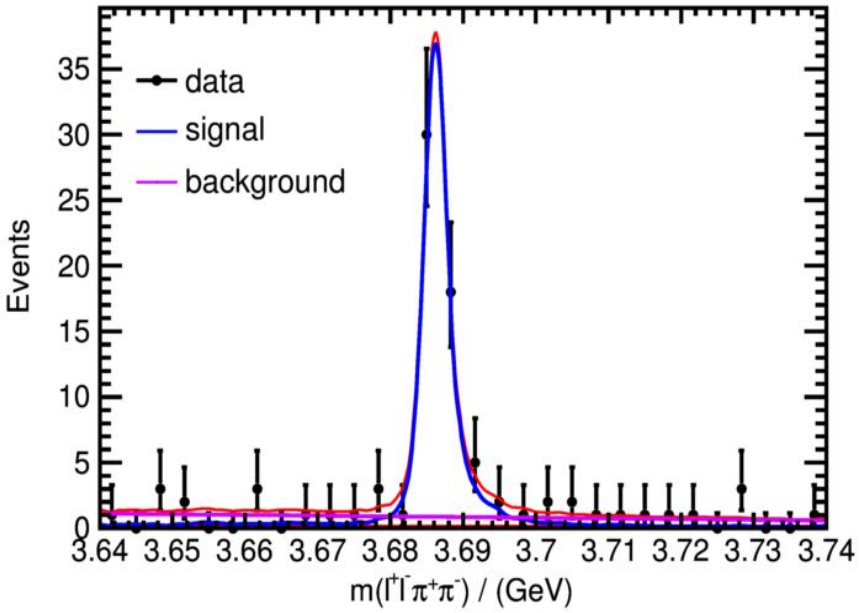
- the data fitted includes 4 kinds of $\pi^+\pi^-J/\psi$ combinations

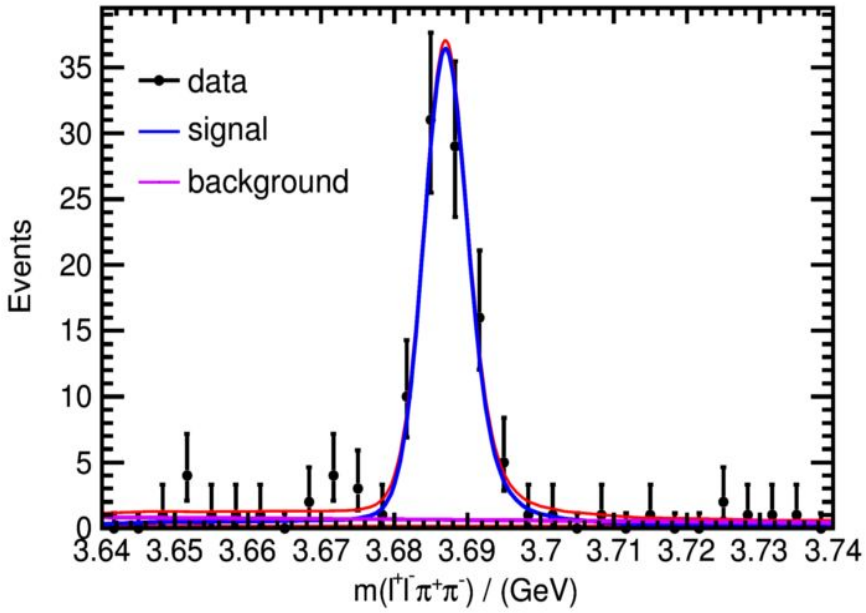
  MC_shape×Gauss + Wide_Gauss + Polynominal

- $\sigma(Y(4260)\to\pi^+\pi^-\psi')$ is measured to be:

  σ_{ee} = 16.25±2.17 pb; $\sigma_{\mu\mu}$ = 17.24±1.96 pb;

cross check of $\sigma(e^+e^-\to\pi^+\pi^-\psi')$ @ 4.26GeV





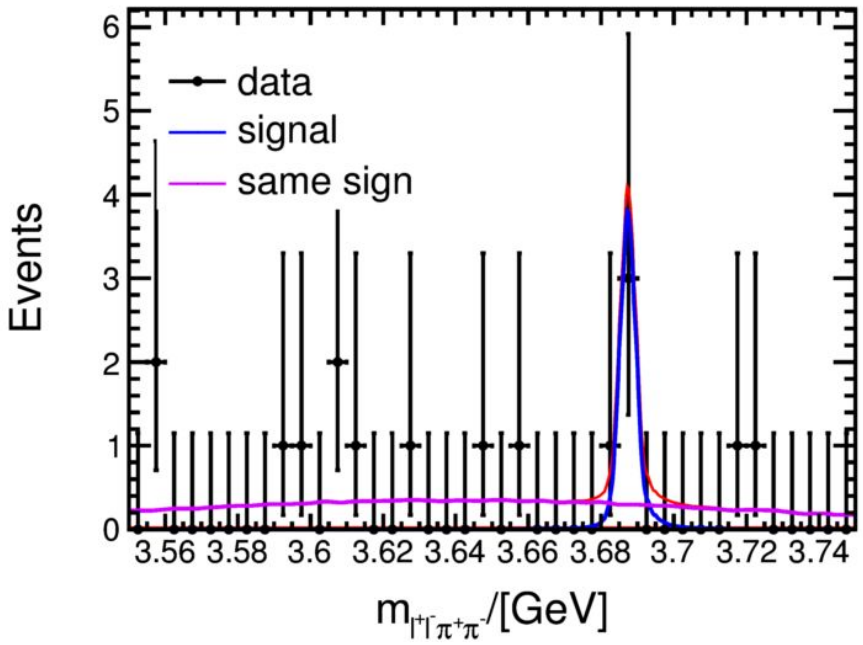
- the data include the events with no more than one $\pi^+\pi^-J/\psi$ combination in $\psi(3686)$ mass window

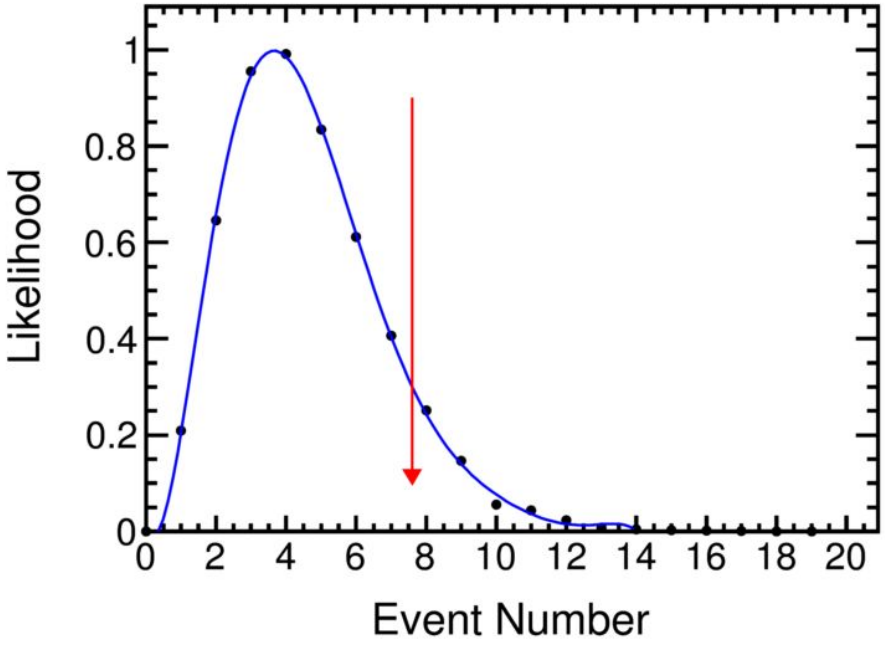
  MC_shape×Gauss + Polynominal

- $\sigma(Y(4260)\to\pi^+\pi^-\psi')$ is measured to be:

  σ_{ee} = 13.18±1.92 pb; $\sigma_{\mu\mu}$ = 15.66±1.75 pb;

upper limit of $\sigma(e^+e^-\to\pi^+\pi^-\psi')$ @ 4.19GeV





- the data fitted includes 4 kinds of $\pi^+\pi^-J/\psi$ combinations

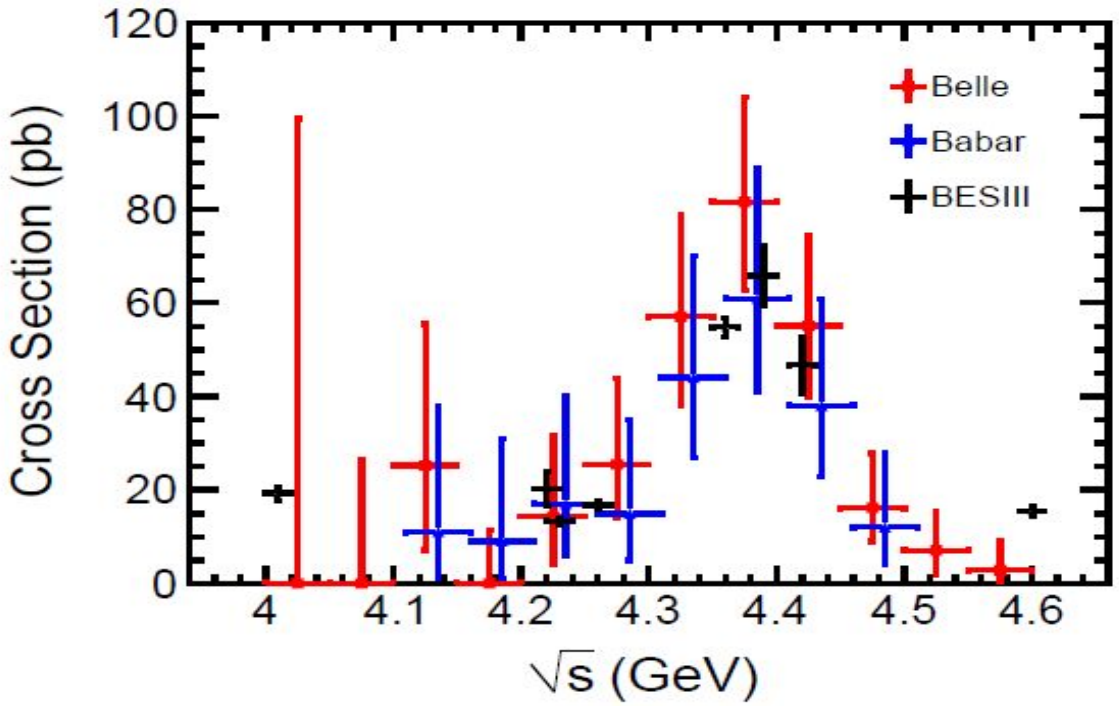
  MC_shape×Gauss + Wide_Gauss + Polynominal

- $\sigma(e^+e^-\to\pi^+\pi^-\psi')$ is measured to be:

  $\sigma < 12.28$ pb @ 90% C.L.

$\sigma(e^+e^-\to\pi^+\pi^-\psi')$ lineshape

- $\sigma(e^+e^-\to\pi^+\pi^-\psi')$ lineshape:



- I only show the nominal results with its statistic error, which is very similar to Babar(blue) measurements at all the energy ponits, and it is generally consistent with the measurement from Belle(red) within statistic errors.

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background analysis

- Remaining backgrounds

No.	decay chain	nEvt	nTot
0	$Y_{4260} \to \pi^-\pi^+\psi',\ \psi' \to \pi^-\pi^+ J/\psi,\ J/\psi \to \mu^-\mu^+$	146	146
1	$Y_{4260} \to \pi^-\pi^+\psi',\ \psi' \to \pi^-\pi^+ J/\psi,\ J/\psi \to e^-e^+$	92	238
2	$Y_{4260} \to K_S K_S J/\psi,\ K_S \to \pi^-\pi^+,\ K_S \to \pi^-\pi^+,\ J/\psi \to \mu^-\mu^+$	4	242
3	$Y_{4260} \to K_S K_S J/\psi,\ K_S \to \pi^-\pi^+,\ K_S \to \pi^-\pi^+,\ J/\psi \to e^-e^+$	2	244
4	$Y_{4260} \to \pi^0\pi^0\psi',\ \psi' \to \pi^-\pi^+ J/\psi,\ J/\psi \to \mu^-\mu^+$	1	245
5	$Y_{4260} \to \eta\psi',\ \eta \to \gamma\gamma,\ \psi' \to \pi^-\pi^+ J/\psi,\ J/\psi \to \mu^-\mu^+$	2	247
6	$Y_{4260} \to \pi^-\pi^0\pi^+ J/\psi,\ J/\psi \to e^-e^+$	1	248
7	$Y_{4260} \to \eta J/\psi,\ \eta \to \pi^-\pi^0\pi^+,\ J/\psi \to \mu^-\mu^+$	1	249

- ※ ksksJ/ψ background could contaminate the signal both in channels with 5 tracks and in those with 6 tracks:

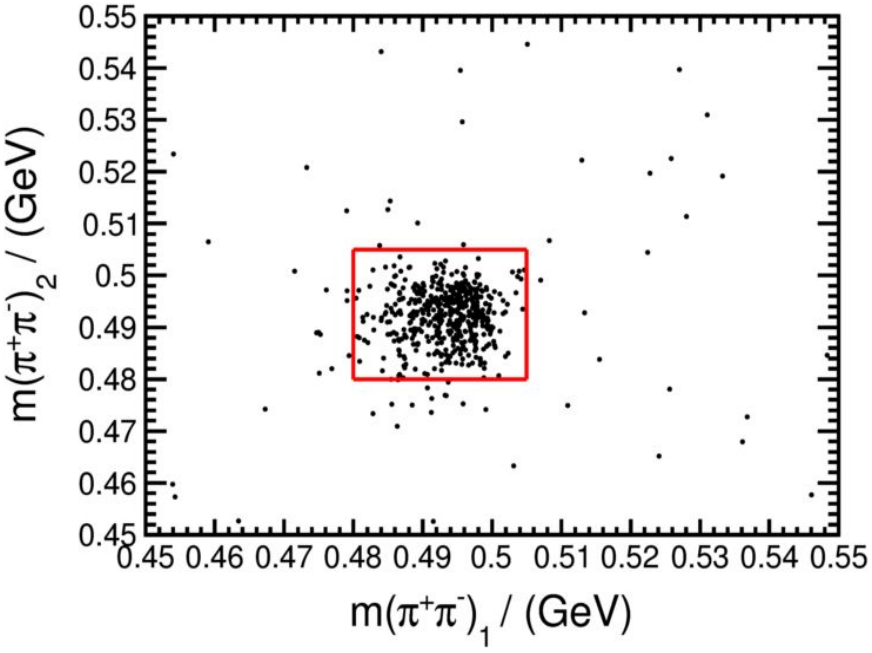
  6 track: events with 2 pairs of $\pi^+\pi^-$ in ks mass region are removed

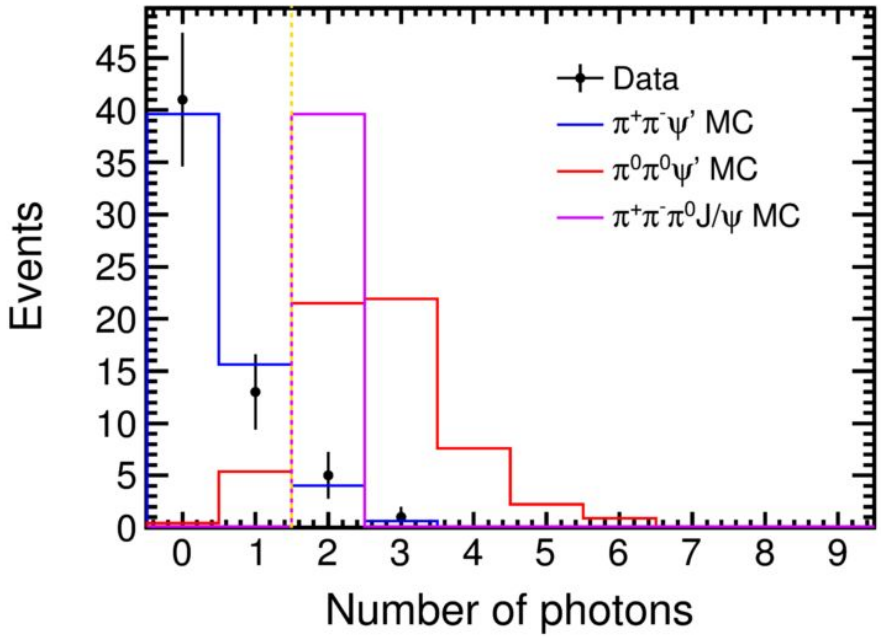
  5 track: events with 1 pair of $\pi^+\pi^-$ in ks mass region are removed

- ※ $\pi^0\pi^0\psi'$ and $\pi^+\pi^-\pi^0 J/\psi$ backgrounds contain more photons than the signal and only contaminates the channels with 5 tracks:

  N(neutral tracks) < 2 in channels with 5 tracks

background analysis





Consider the two backgrounds left in Zc(3900) signal region, assuming

Br(Y(4260)→KsKsJ/ψ)=Br(Y(4260)→$\pi^0\pi^0\psi'$)=Br(Y(4260)→$\pi^+\pi^-\psi'$)

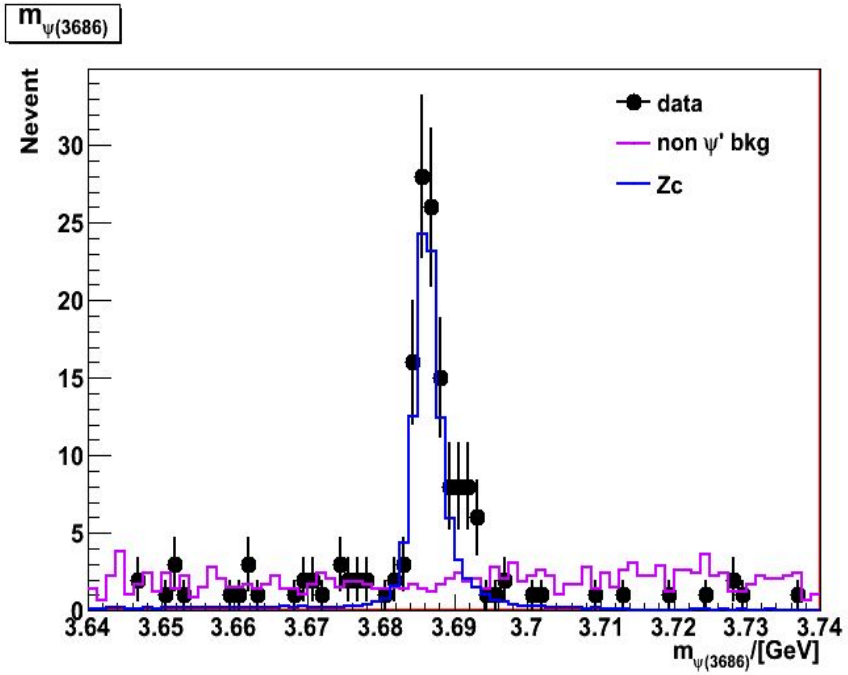
N(data) = 96, ε(KsKsJ/ψ) =1.72E-3 , ε($\pi^0\pi^0\psi'$)=1.8E-4;

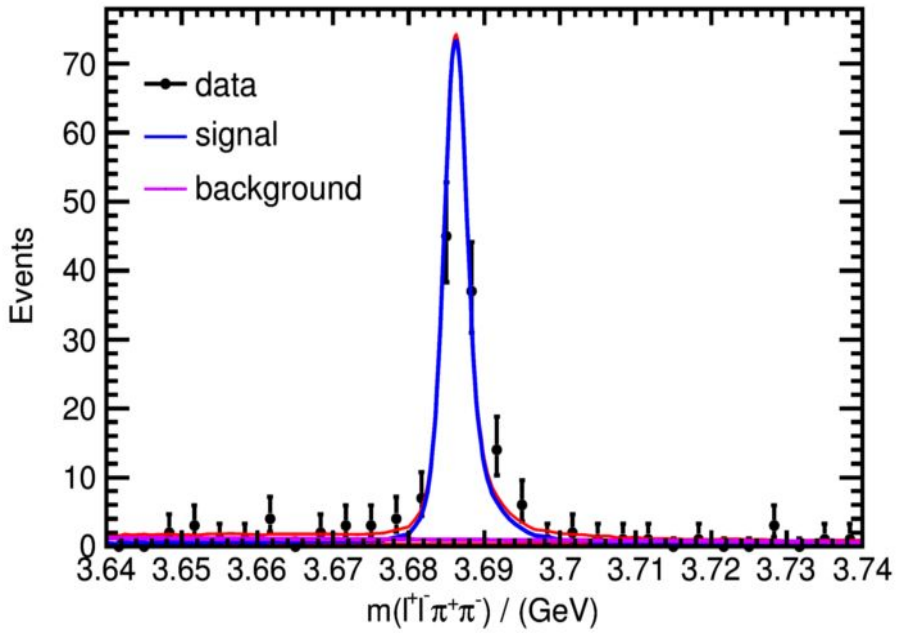
We could estimate:

N(KsKsJ/ψ) = 1.03

N($\pi^0\pi^0\psi'$) = 0.075

non ψ' background in Zc measurement





The ψ' spectrum contains all kinds of $\pi^+\pi^-$J/ψ combination with no more than one combination in ψ' mass window, the non ψ' background gives a flat distribution, so we estimate, in the signal region:

$$N(\text{non } \psi') = 27.96*0.013/0.1 * 0.96 = 3.49$$

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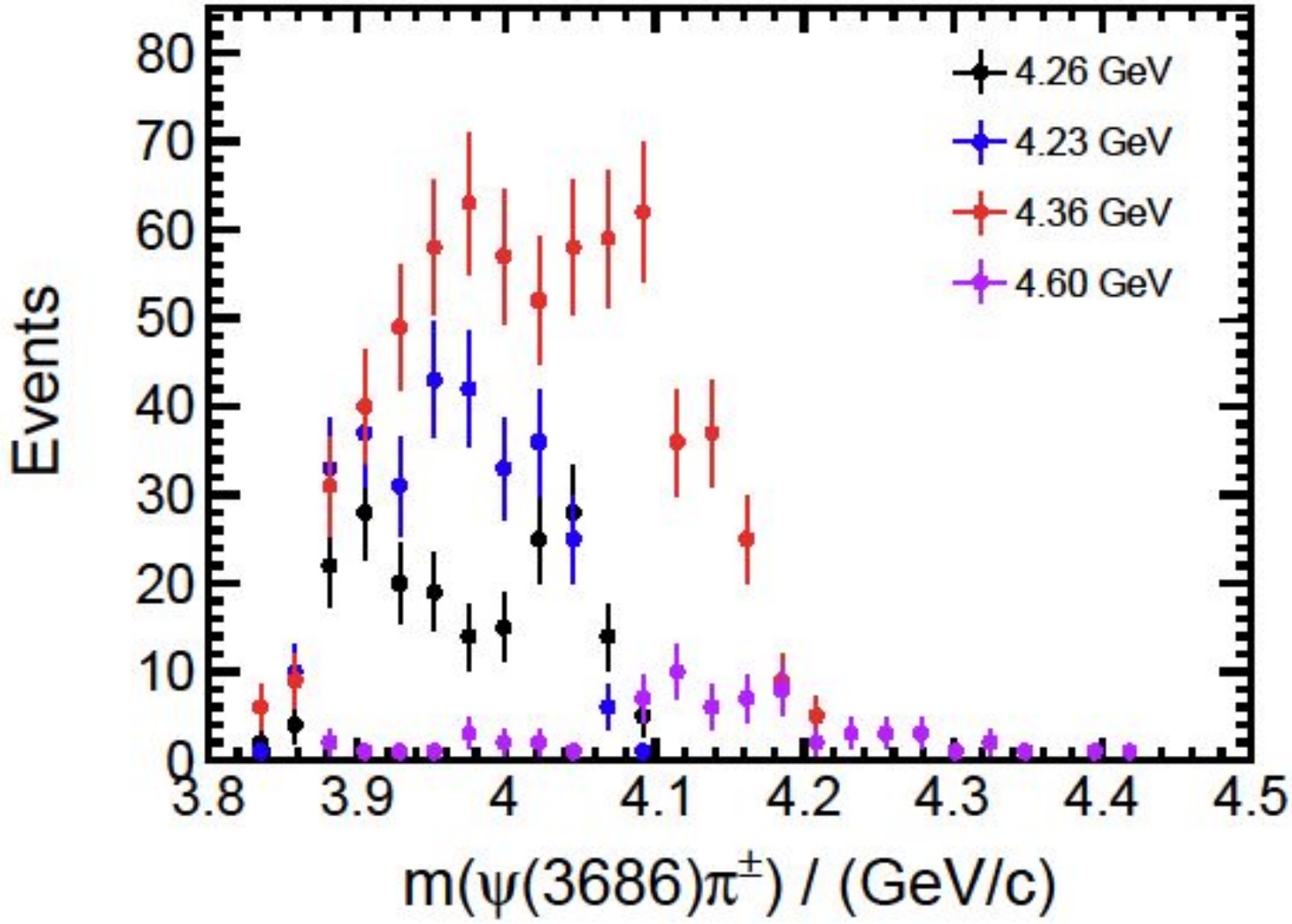
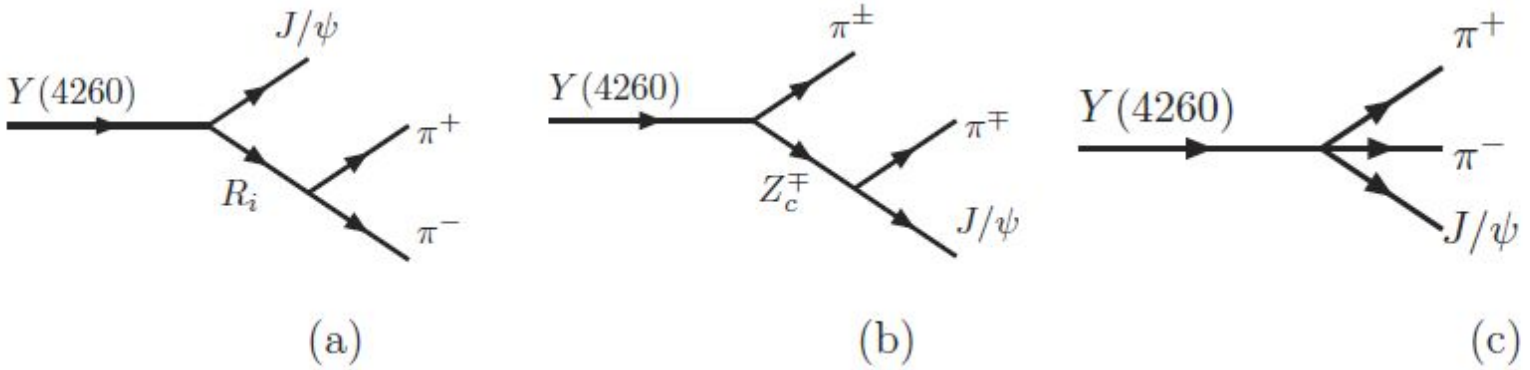
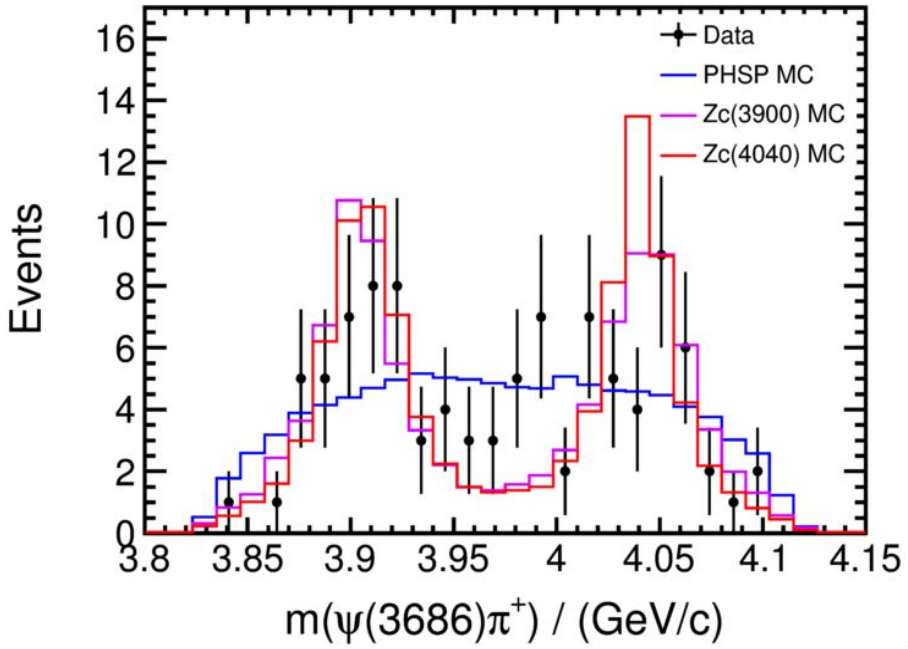
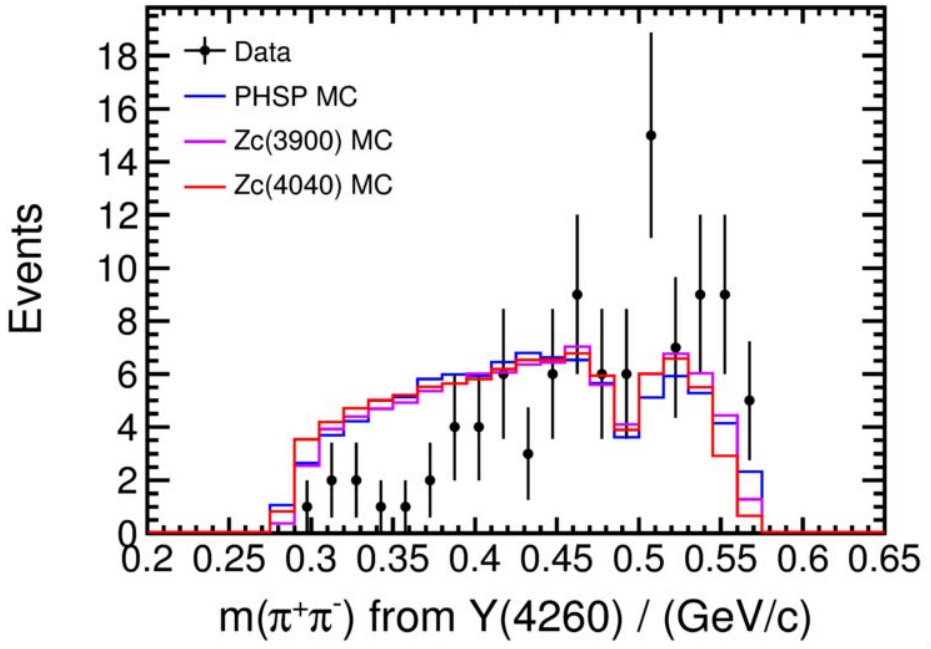
$M(\pi^{\pm}\psi')$ spectrum @ 4.23, 4.26, 4.36, 4.6GeV



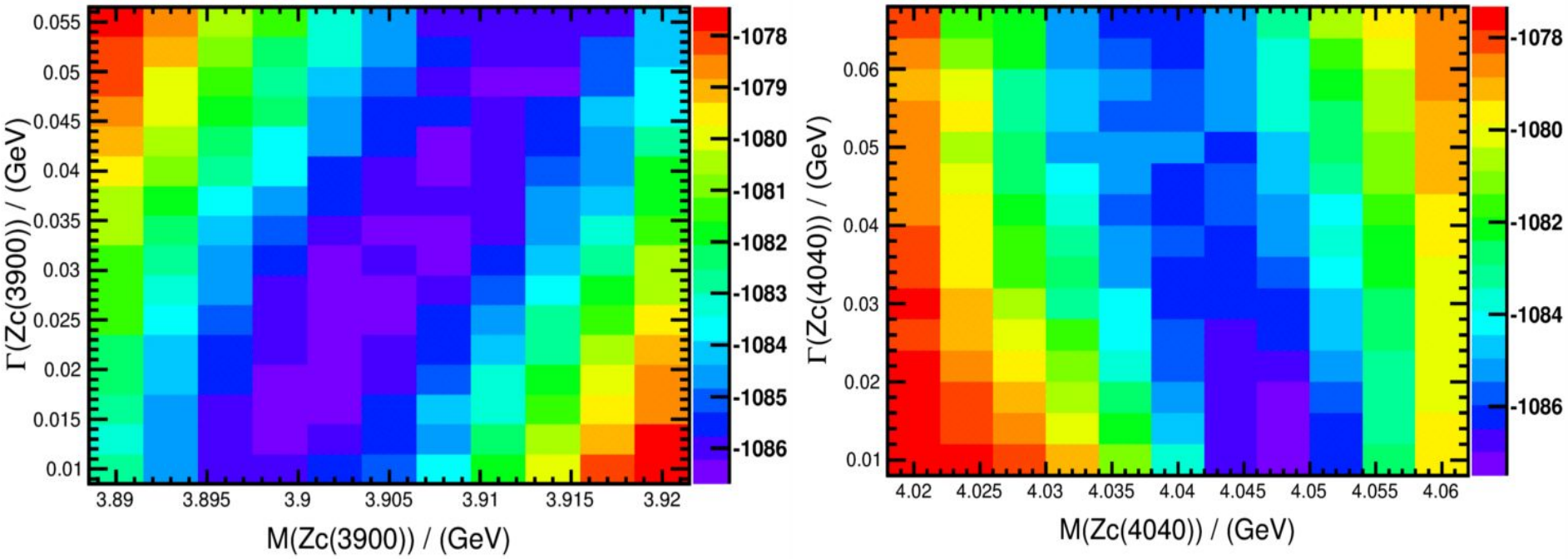
intermediate state study @ 4.26GeV







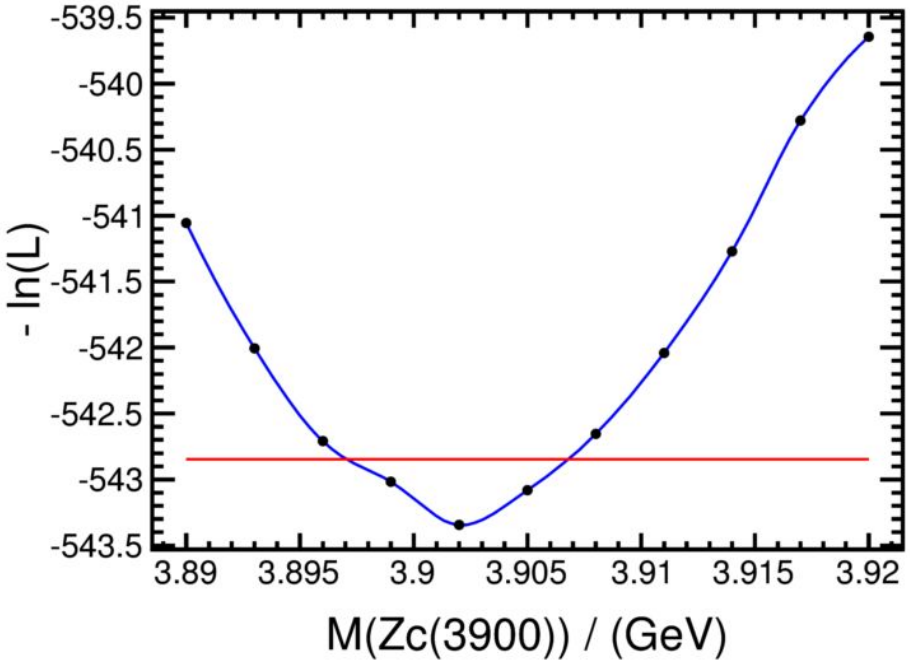
mass and width scan of Zc(3900)/Zc(4040)

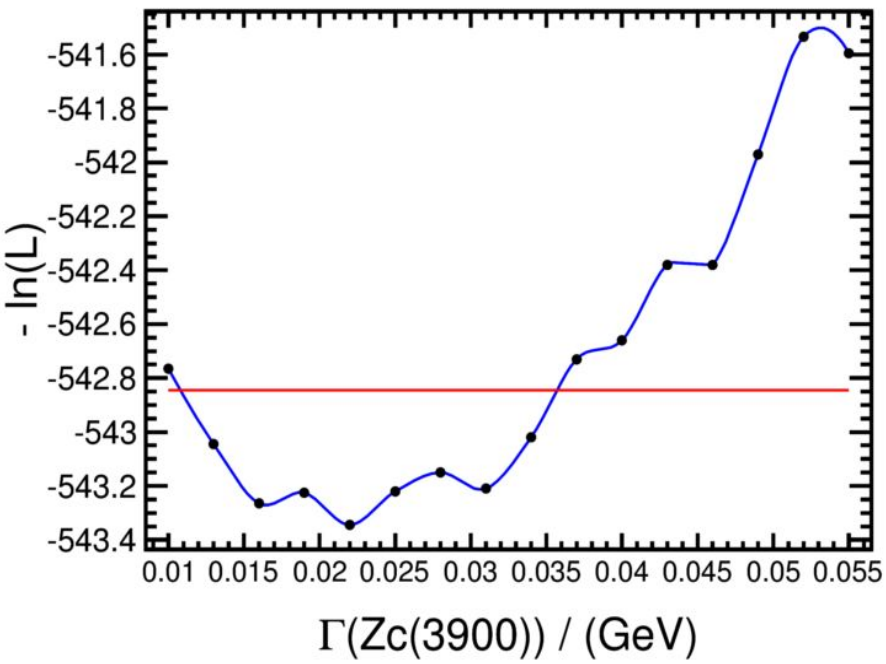


fitting results with maximum likelihood value:

Zc(3900): M=3.902GeV, Γ=22MeV, significance=3.1σ
Zc(4040): M=4.048GeV, Γ=10MeV, significance=3.2σ

mass and width scan of Zc(3900)





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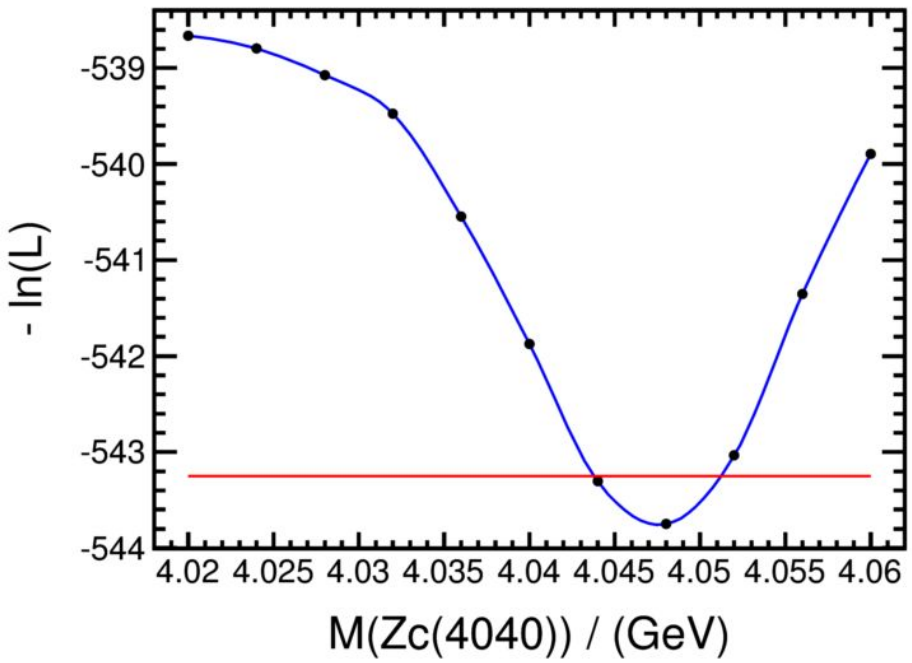
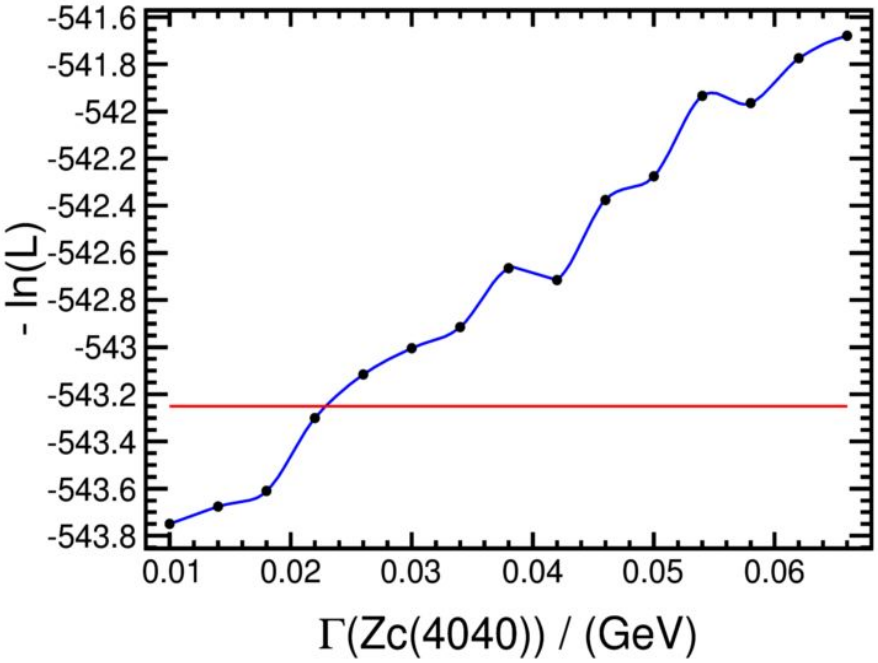
mass and width scan of Zc(4040)





fitting results with maximum likelihood value:

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Conclusion

- $\sigma(\pi^+\pi^-\psi')$ lineshape is measured with BESIII data, which is consistent with Belle and Babar measurement within statistic errors.
- an exotic state with significance around 3.1σ has been observed in $\pi^{\pm}\psi'$ mass spectrum at 4.26GeV, it could be a state at 3.902GeV with 22MeV width, or a state at 4.048GeV with 10MeV width.
- Systematic error analysis is still ongoing.
- We expect consistent measurement of the lineshape and observation of the charged charmonium structure in neutral channels. Further combination between charge and neutral channels is still ongoing.

Back Up