Charmonium-like States at BaBar

Valentina Santoro
INFN Ferrara
Representing the BaBar Collaboration

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Outline

- Study of the $J/\psi\omega$ final state in two-photon collisions
- Search for the $Z_1(4050)^+$ and $Z_2(4250)^+$ states in $\bar{B}^0 \to \chi_{c1} K^- \pi^+$ and $B^+ \to \chi_{c1} K_S^0 \pi^+$

  PRD 85, 052003 (2012)

- Study of the reaction $e^+e^- \to J/\psi\pi^+\pi^-$ via initial state radiation

  arXiv:1204.2158

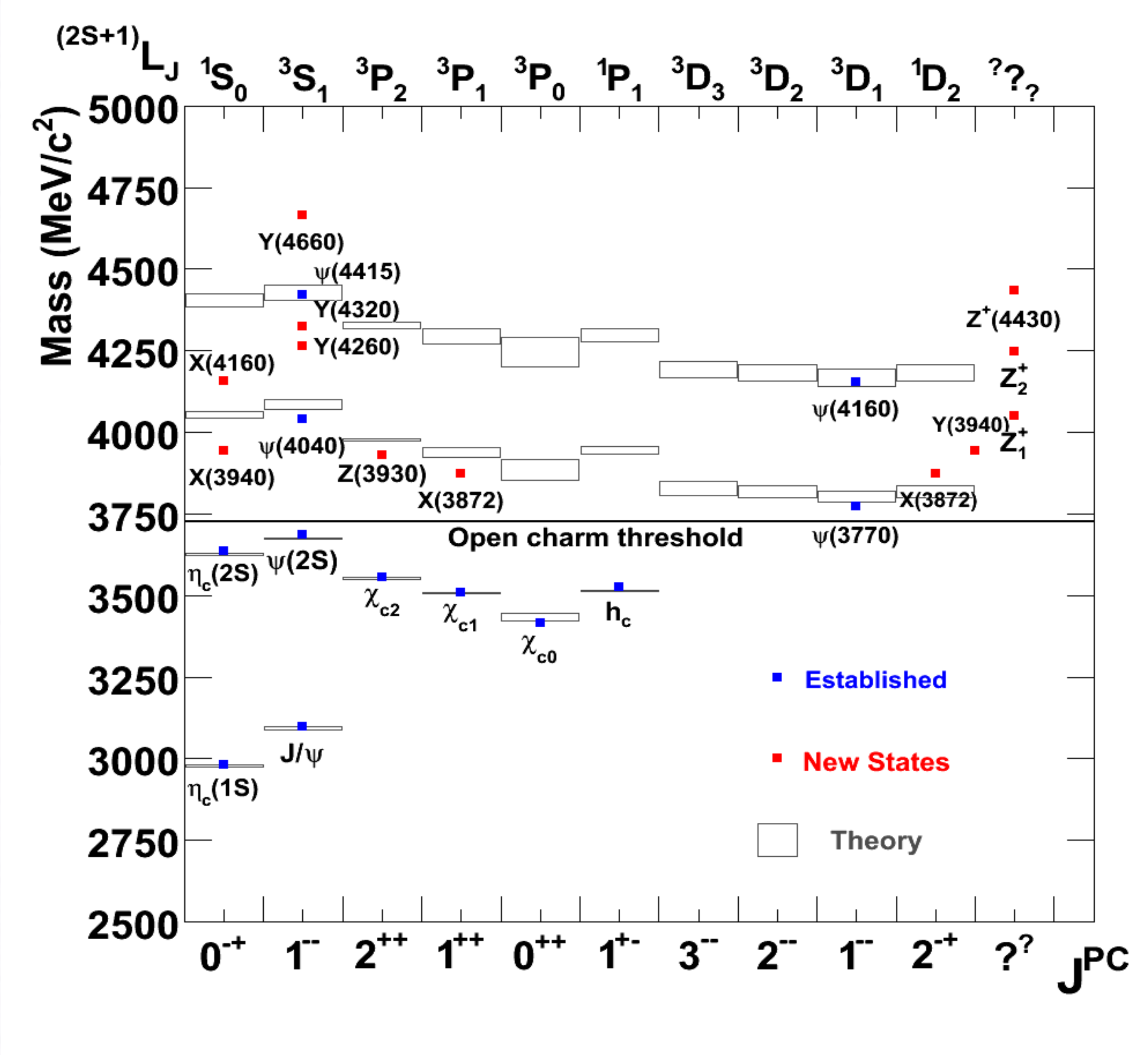
- Study of the reaction $e^+e^- \to \psi(2S)\pi^+\pi^-$ via initial state radiation

"Moses, this chapter outline is really impressive."

Charmonium spectrum

(July 2012)

Eur. Phys.J.C71, 1534 (2011)



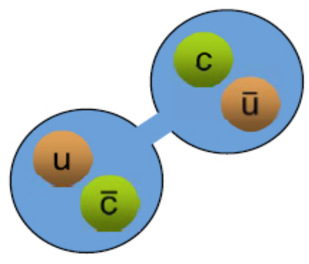
- Charmonium properties are well understood up to ψ(3770) (i.e. about the $D\bar{D}$ threshold)

Many unexpected states above the $D\bar{D}$ threshold.
Several exotic hypotheses on their nature : e.g. tetraquarks, hadronic molecules, hybrids …

To identify exotics:

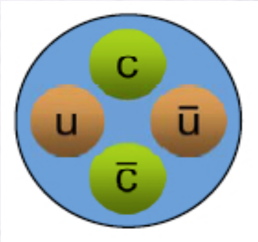
- Measure J^{PC} that is forbidden for charmonium: 0^{+-}, 1^{-+}, 2^{+-}
- Observed a narrow width above $D\bar{D}$ threshold
- Observed a $c\bar{c}$-like state with charge and/ or strangeness

Exotic charmonium-like states interpretation



Molecular state:
loosely bound state of a pair of mesons.
The dominant binding mechanism should be pion exchange. Being weakly bound, mesons tend to decay as if they were free.

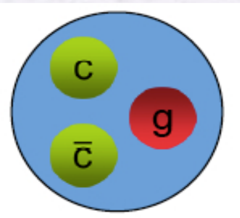
NA Tornqvist PLB 590, 209 (2004)
ES Swanson PLB 598,197 (2004)
E Braaten & T Kusunoki PRD 69 074005 (2004)
CY Wong PRC 69, 055202 (2004)
MB Voloshin PLB 579, 316 (2004)
F Close & P Page PLB 578,119 (2004) .....



Tetraquark:
Bound state of four quarks, i.e. diquark-antidiquark
Strong decays proceed via rearrangement processes.

L Maiani et al PRD 71,014028 (2005)
T-W Chiu & TH Hsieh PRD 73, 111503 (2006)
D Ebert et al PLB 634, 214 (2006)
…

Distinctive features of multi-quark picture with respect to charmonium:
- prediction of many new states
- possible existence of states with non-zero charge, strangeness or both.



Charmonium hybrids
States with an excited gluonic degree of freedom
Lattice and model predictions for the lowest lying hybrid:
m ~4200 MeV

P Lacock et al (UKQCD) **PLB 401, 308 (1997)**
SL Zhu PLB 625, 212 (2005)
FE Close, PR Page PLB 628, 215 (2005)
E Kou, O Pene PLB 631, 164 (2005)
…

Conventional charmonium

C Meng & KT Chao PRD 75, 114002 (2007)
W Dunwoodie & V Ziegler PRL 100 062006 (2008)
O Zhang, C Meng & HQ Zheng arXiv:0901.1553
…

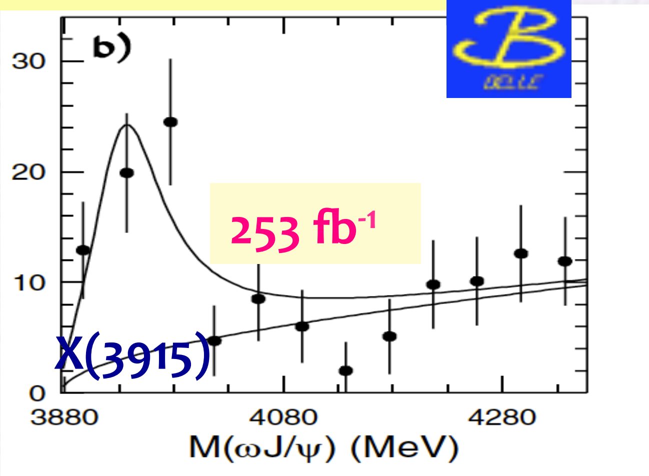
Study of the J/ψω in two-photon interactions

Phillip Island ,
Australia

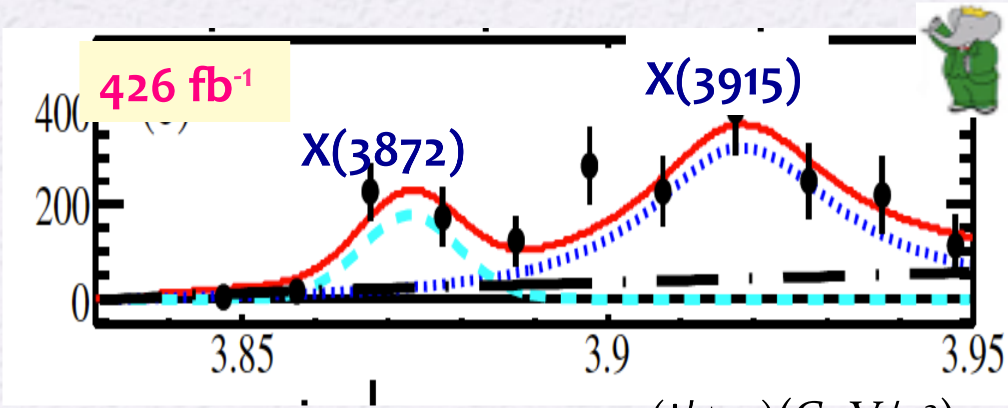
$\gamma\gamma \to J/\psi\omega$ (Analysis Motivation): look for X(3915) (1)

The X(3915) was seen by Belle and then confirmed by BaBar in $B \to X(3915)K$, with the $X(3915) \to J/\psi\omega$

PRL 94, 182002 (2005)



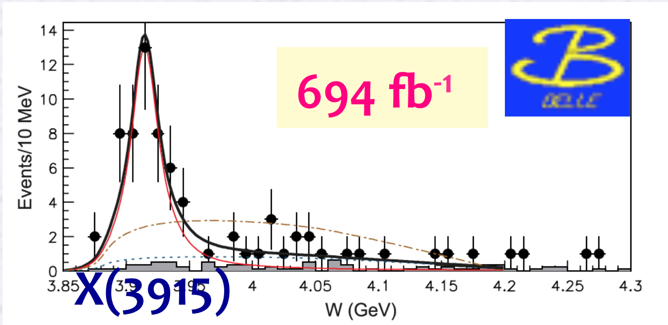
PRD 82, 011101 (R)(2010)



B decays

Belle also observed the X(3915) in the process $\gamma\gamma \to X(3915) \to J/\psi\omega$

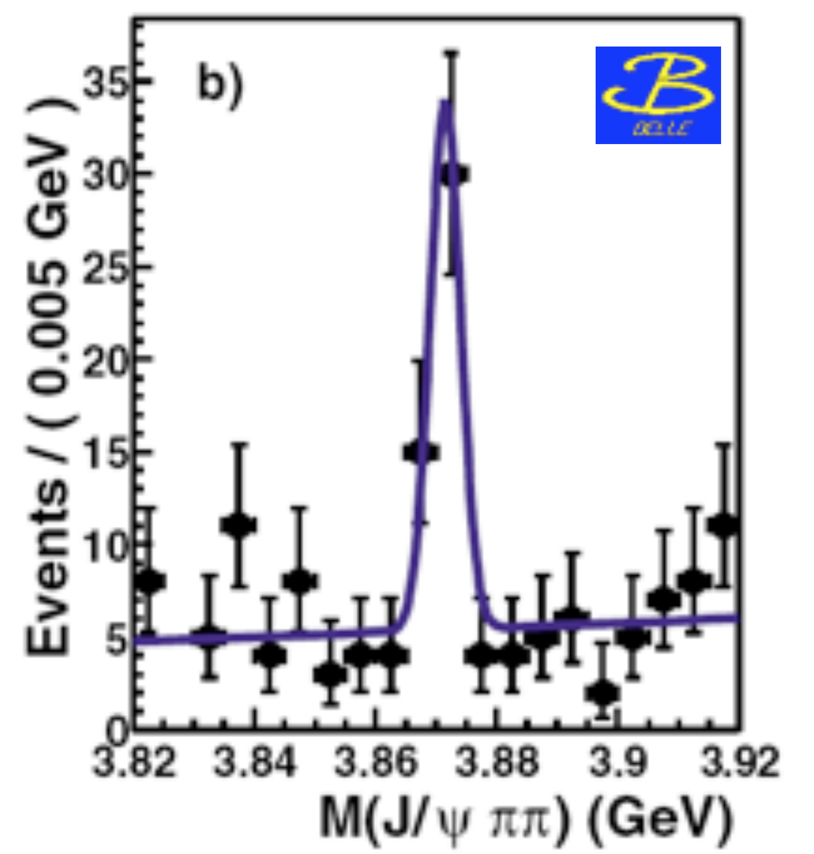
PRL 104, 092001 (2010)



$\gamma\gamma$ interactions

Interpretation of X(3915) as the χ_{c0}(2P) or χ_{c2} (2P) state has been suggested
But the $\Gamma_{\gamma\gamma}(X(3915))B(X(3915 \to J/\psi\omega)$ reported by Belle is unexpectedly large compared to other excited charmonia.

The X(3872) was seen in 2003 by Belle and soon confirmed by several experiment



PRL 91, 262001 (2003)

X(3872) interpretation

Conventional Charmonium: $\chi_{c1}(2^3P_1)$ (1^{++}) or $\eta_{c2}(1^1D_2)$ (2^{-+})

$D^0\bar{D}^{*0}$ Molecular interpretation:

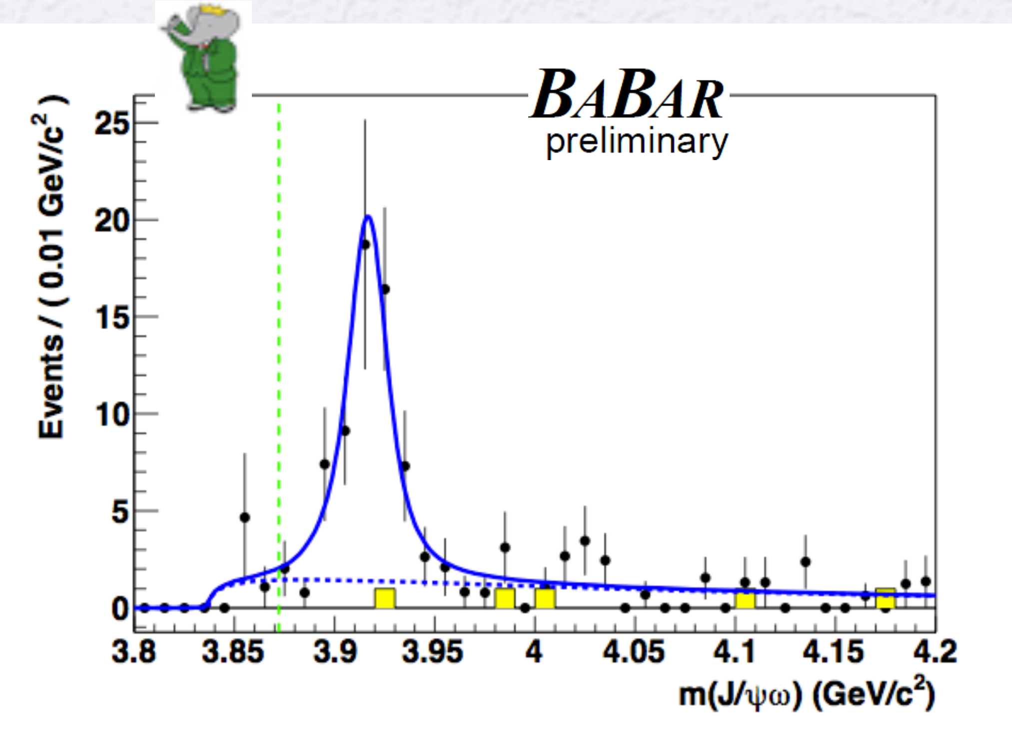
$m(D^0) + m(\bar{D}^{*0}) = 3871.73 \pm 0.29$ MeV/c^2

Compatible with $J^{PC} = 1^{++}$ assignment;

The observation of $\gamma\gamma \to X(3872)$ would imply $J^{PC}=2^{-+}$ and favor the charmonium interpretation

$\gamma\gamma \to J/\psi\omega$: new BaBar Results

BaBar with 520 fb^{-1} confirmed the evidence of the X(3915) (7.6 σ) in $\gamma\gamma \to X(3915) \to J/\psi\omega$



PRL 104, 092001 (2010)

	BABAR	Belle
Mass (MeV/c^2)	$3919.4 \pm 2.2 \pm 1.6$	$3915 \pm 3 \pm 2$
Width (MeV)	$13 \pm 6 \pm 3$	$17 \pm 10 \pm 3$
$\Gamma_{\gamma\gamma} \times \mathcal{B}$ (J=0) (eV)	$52 \pm 10 \pm 3$	$61 \pm 17 \pm 8$
$\Gamma_{\gamma\gamma} \times \mathcal{B}$ (J=2) (eV)	$10.5 \pm 1.9 \pm 0.6$	$18 \pm 5 \pm 2$

If $\Gamma_{\gamma\gamma}$=O(1 keV) (typical $c\bar{c}$) then $B(J/\psi\omega)$>(1-6)% which is relatively large compared to charmonium model predictions

No evidence of the X(3872) → limit for J=2 hypothesis

$\Gamma_{\gamma\gamma}(X(3872)) \times B(X(3872) \to J/\psi\omega)$ (J=2)<1.7 eV

Search for $Z_1(4050)^+$ and $Z_2(4250)^+$ states in $\bar{B}^0 \to \chi_{c1} K^- \pi^+$ and $B^+ \to \chi_{c1} K_S^0 \pi^+$

Z, Z_1, Z_2

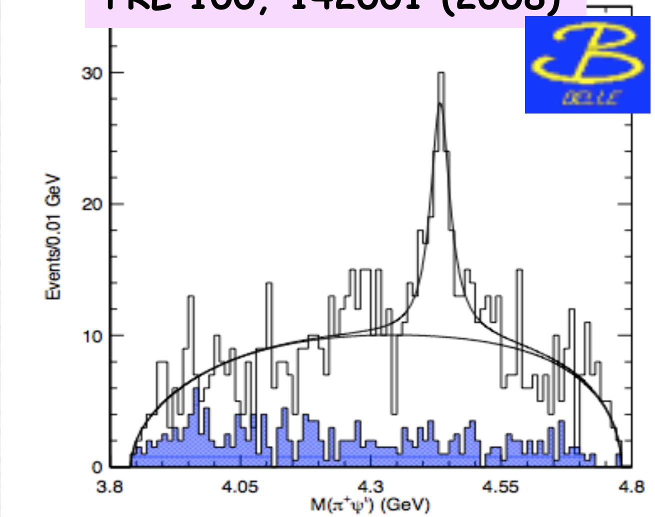
The charged Z family

- Belle observed broad, charged charmonium-like states in $(c\bar{c})K\pi$ analyses
  - $Z(4430)^+$ in $B \to \psi(2S)\pi^+K$
  - $Z_1(4050)^+$ and $Z_2(4250)^+$ in $\bar{B}^0 \to \chi_{c1}\pi^+K^-$

Maiani: arXiv: 0708.3997
Karliner & Lipkin arXiv: 0802.0649

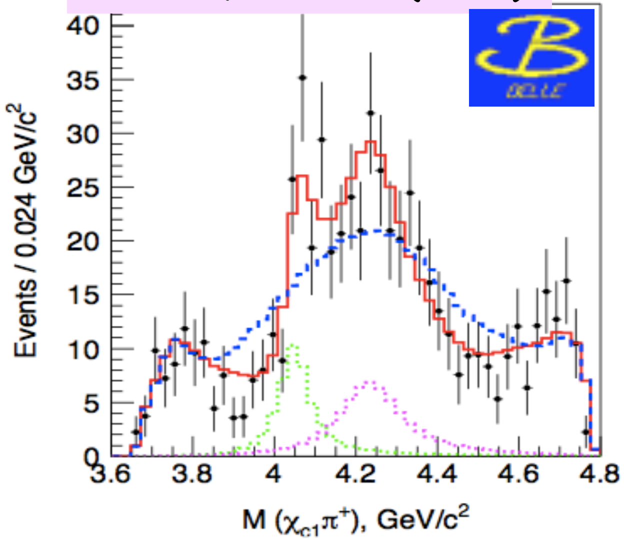
- Quark content at least $c\bar{c}u\bar{d}$: no simple $q\bar{q}$ meson

PRL 100, 142001 (2008)



$Z(4430)^+ \to \psi(2S)\pi^+$

PRD 78, 072004 (2008)



$Z_1(4050)^+ \to \chi_{c1}\pi^+$

$Z_2(4250)^+ \to \chi_{c1}\pi^+$

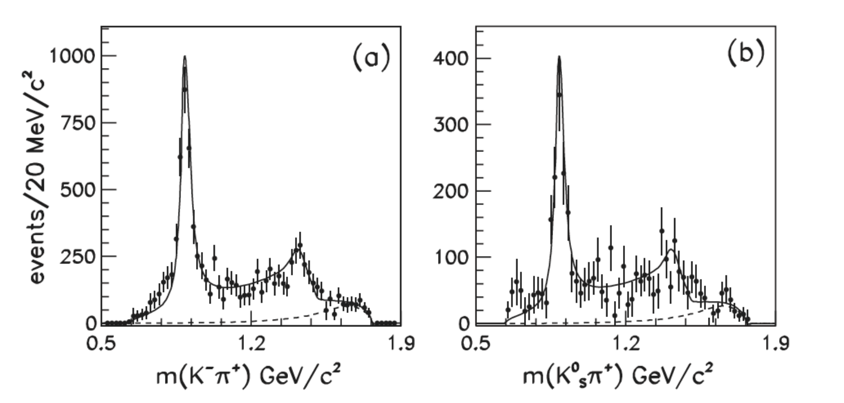
Not confirmed by BaBar experiment that studied also the $J/\psi\pi^-K^+$ and the $J/\psi\pi^-K_S^0$ channel

PRD 79, 112001 (2009)

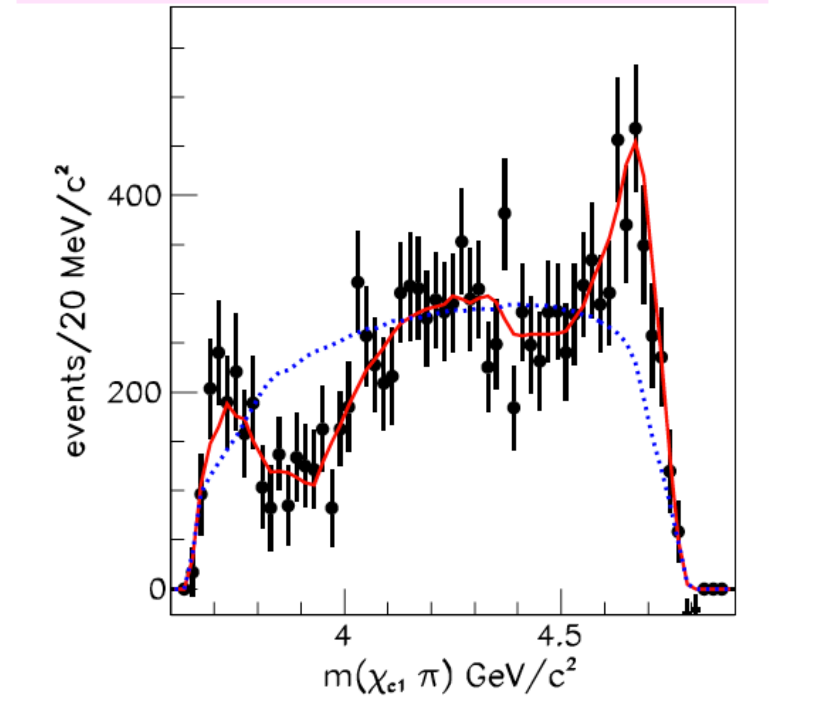
Search for Z1 and Z2 @ BaBar (1)

PRD 85, 052003 (2012)

- BaBar studied $B^+ \to \chi_{c1} K^0_S \pi^+$ and $\bar{B}^0 \to \chi_{c1} K^- \pi^+$ to search for Z_1 and Z_2 found by Belle ($\chi_{c1} \to J/\psi\gamma$)
- Binned χ^2 fits to the background-subtracted and efficiency-corrected $K\pi$ mass spectra in terms of S, P and D wave amplitudes



Black dots: data
Red curve: MC simulation with L_{MAX}=5 (angular weights)
Dotted blue curve: Results of the simulation with no angular weights



- To represent the angular structure we compute the efficiency-corrected Legendre polynomial moments $<Y_L^0>$ in each $K\pi$ mass interval
- Using the information from the $K\pi$ system a description of the $\chi_{c1}\pi$ mass distribution is studied. A MC simulation for $B \to \chi_{c1} K\pi$ has been performed.
- The best χ^2/NDF obtained is for L_{MAX}=5 (L is the order of the Legendre polynomial moments) ; the result of the simulation with L_{MAX}=5 is superimposed on the data (red curve).
- The excellent description of the data indicated that the angular information from the $K\pi$ is able to account for the structures observed in the $\chi_{c1}K\pi$ projection.

This indicates the absence of significant structure in the exotic $\chi_{c1}\pi^+$ channel

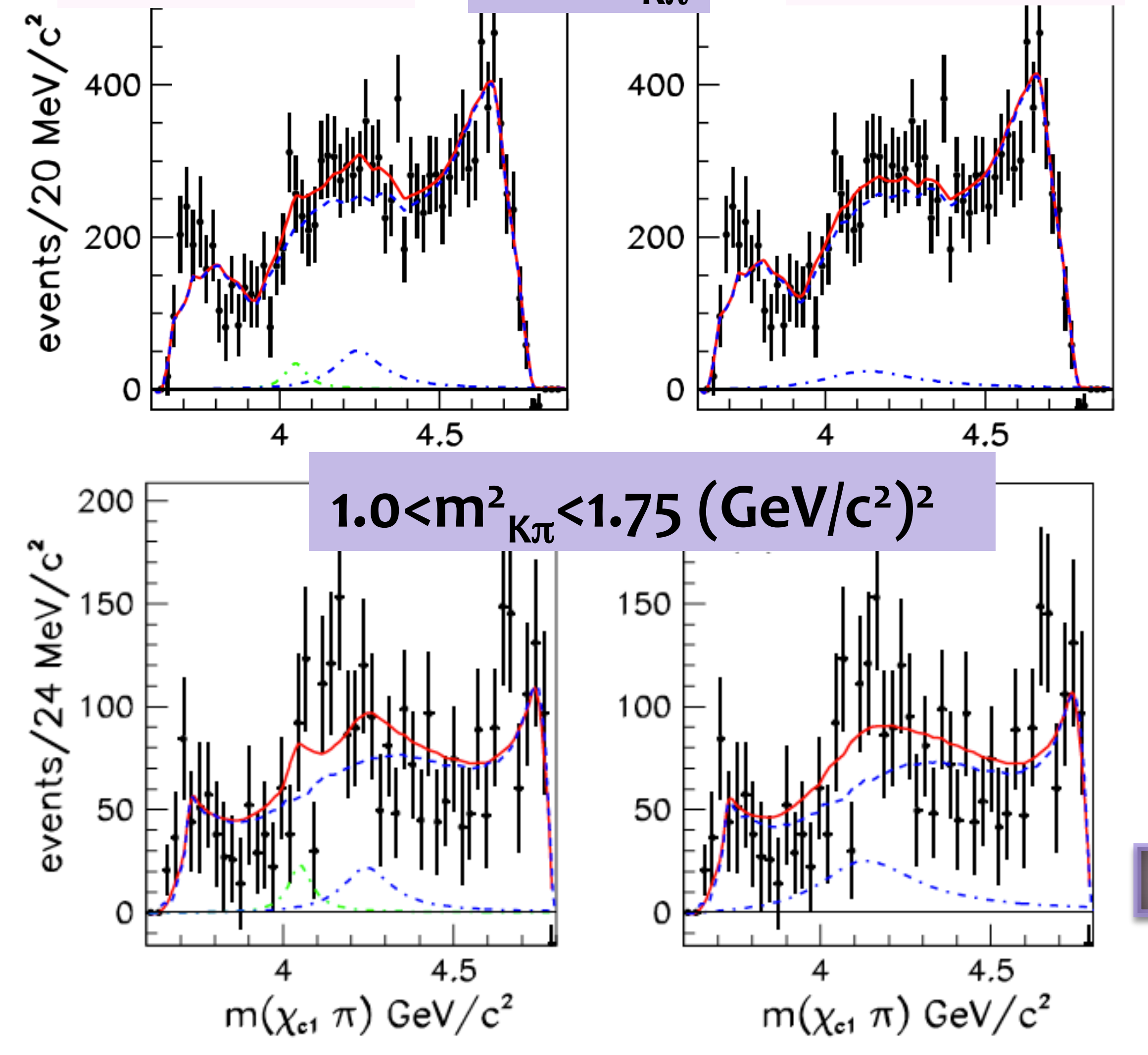
Search for Z1 and Z2 @ BaBar (Results)

PRD 85, 052003 (2012)

429 fb^{-1}

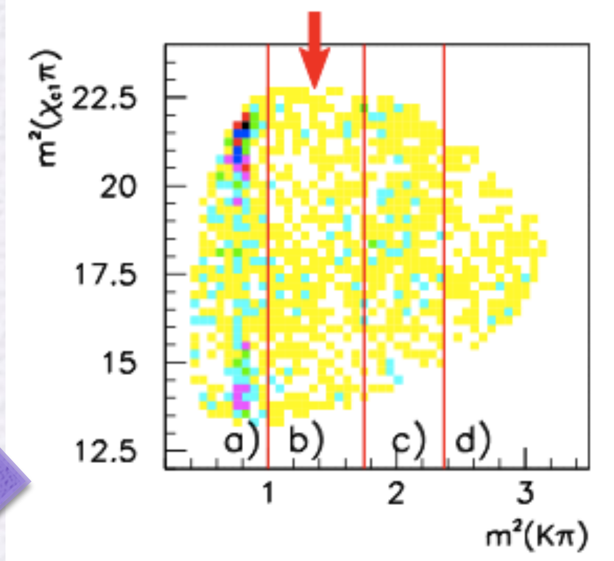
Fit the $\chi_{c1}\pi$ mass spectrum using two scalar Breit-Wigners with parameters fixed to the Belle measurement

2 resonances fit | **all $m^2_{K\pi}$** | **1 resonance fit**



$1.0<m^2_{K\pi}<1.75$ (GeV/c^2)^2

Belle: maximal resonant activity in window $1.0 < m^2_{K\pi} < 1.75$ (GeV/c^2)^2



For two resonances fit

$$B(\bar{B}^0 \to Z_1^+ K^-) \times B(Z_1^+ \to \chi_{c1}\pi^+) < 1.8\times10^{-5} \text{ @ } 90\% C.L.$$

$$B(\bar{B}^0 \to Z_2^+ K^-) \times B(Z_2^+ \to \chi_{c1}\pi^+) < 4.0\times10^{-5} \text{ @ } 90\% C.L.$$

For a single resonance fit

$$B(\bar{B}^0 \to Z^+ K^-) \times B(Z^+ \to \chi_{c1}\pi^+) < 4.7\times10^{-5} \text{ @ } 90\% C.L.$$

In all cases we obtained very low (<2σ) statistical significances

Study of the reaction $e^+e^- \rightarrow J/\psi\pi^+\pi^-$ via initial-state radiation

Great Ocean Road, Australia

$e^+e^- \to \gamma_{ISR} J/\psi\pi^+\pi^-$ analysis motivation

The Y(4260)

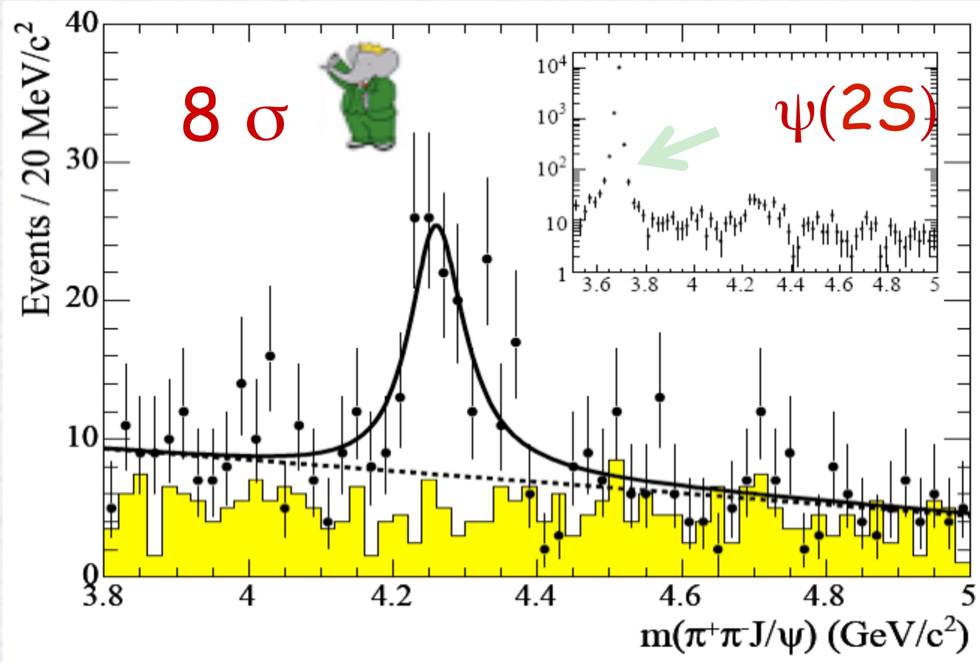
$J^{PC} = 1^{--}$

Discovered at BaBar in ISR-production of $J/\psi\pi^+\pi^-$ events in 2005 (233 fb^{-1})

Phys. Rev. Lett. 95 (2005) 142001

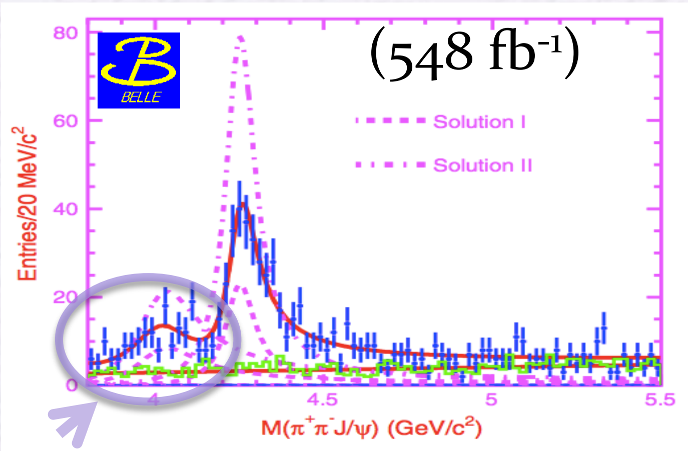
$$m_Y = (4259 \pm 8^{+2}_{-6})\ \mathrm{MeV}/c^2$$

$$\Gamma_Y = (88 \pm 23^{+6}_{-4})\ \mathrm{MeV}$$



Confirmations by CLEO-c, CLEO-III and Belle with some spread in the resonance parameters.

Phys. Rev. Lett. 99, 182004 (2007)



Y(4008)

The Belle result suggested the existence of another broad structure the Y(4008)

$M_{Y4008} = 4008 \pm 40\ ^{+114}_{-28}$

$\Gamma_{Y4008} = 226 \pm 44 \pm 87$

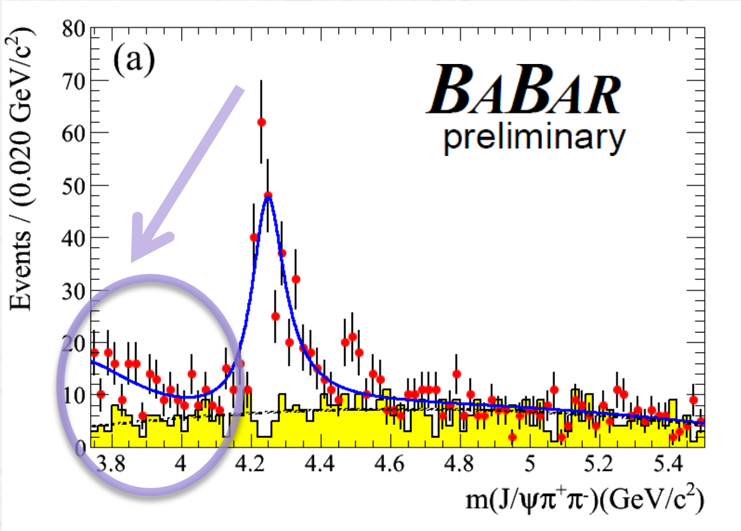
All the 1^{--} slots in the charmonium spectrum were already filled

$e^+e^- \to \gamma_{ISR} J/\psi\pi^+\pi^-$: New BaBar Analysis

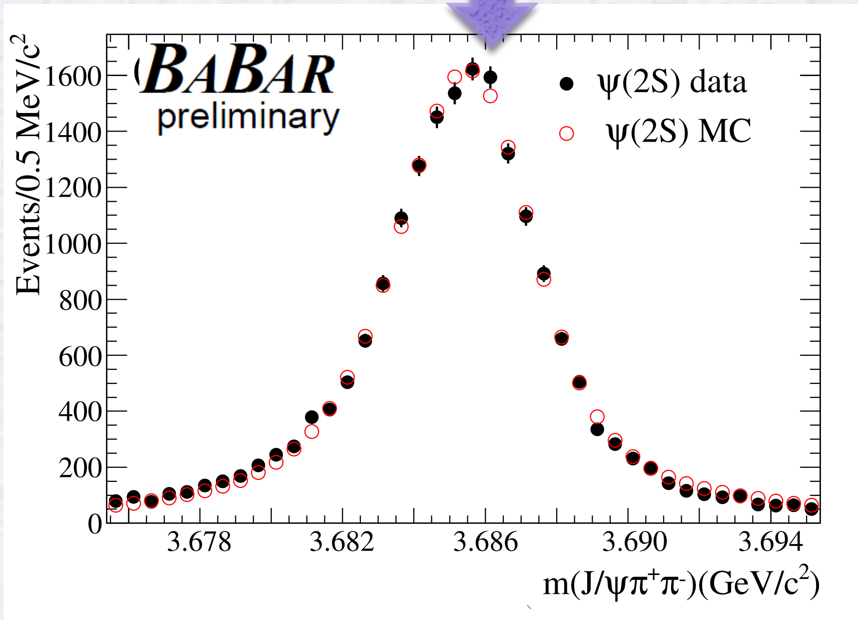
arXiv:1204.2158

The ψ(2S) region (3.5-4 GeV/c²)

The excess of events above 3.74 GeV/c² can be attributed to different sources such as ψ(2S) tail, $J/\psi\pi^+\pi^-$ continuum or ψ(3770) decay to $J/\psi\pi^+\pi^-$, since BES (PLB 605, 63(2005)) and CLEO (PRL 96, 082004 (2006)) reported such decay mode for the ψ(3770)



In order to understand the possible contribution coming from the ψ(2S) tail a detailed study of the ψ(2S) lineshape has been performed



$$\sigma(e^+e^- \to \gamma\psi(2S)) = 14.5 \pm 0.7\, pb$$

$$\Gamma(\psi(2S) \to e^+e^-) = 2.29 \pm 0.05 keV$$

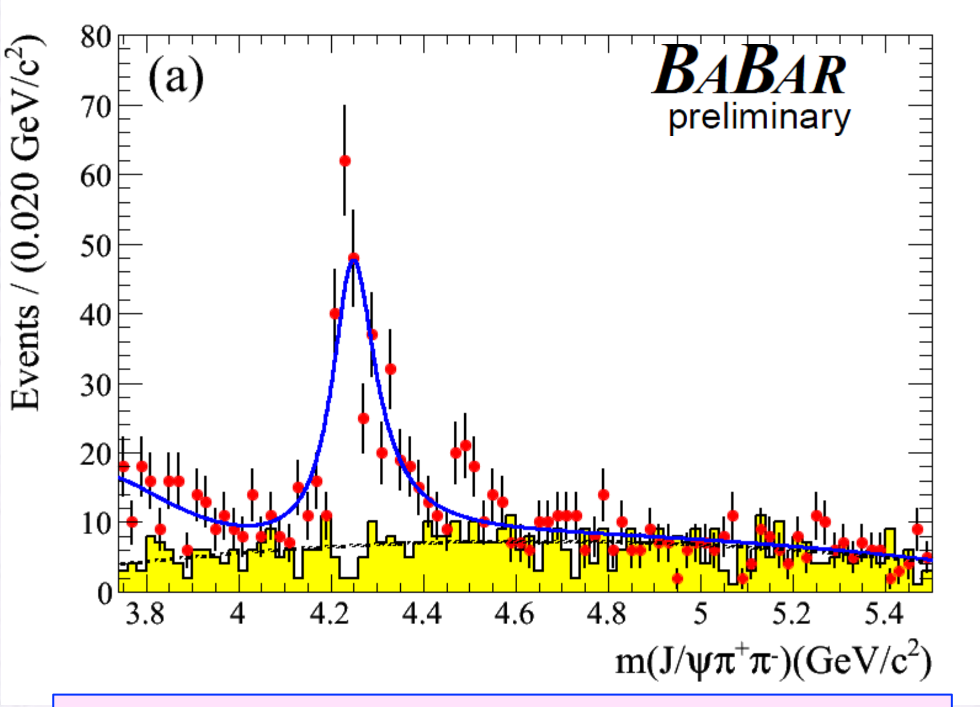
The conclusion is that we cannot discount the possibility of a contribution from $e^+e^- \to J/\psi\pi^+\pi^-$ continuum cross section in this region

The Y(4260) region (up to 5.5 GeV/c²)

We performed an extended-maximum-likelihood fit to the signal region **$J/\psi\pi^+\pi^-$** distribution and simultaneously to the background distribution

The fit is corrected for efficiency and luminosity

arXiv:1204.2158
SUBMITTED TO PRD(RC)

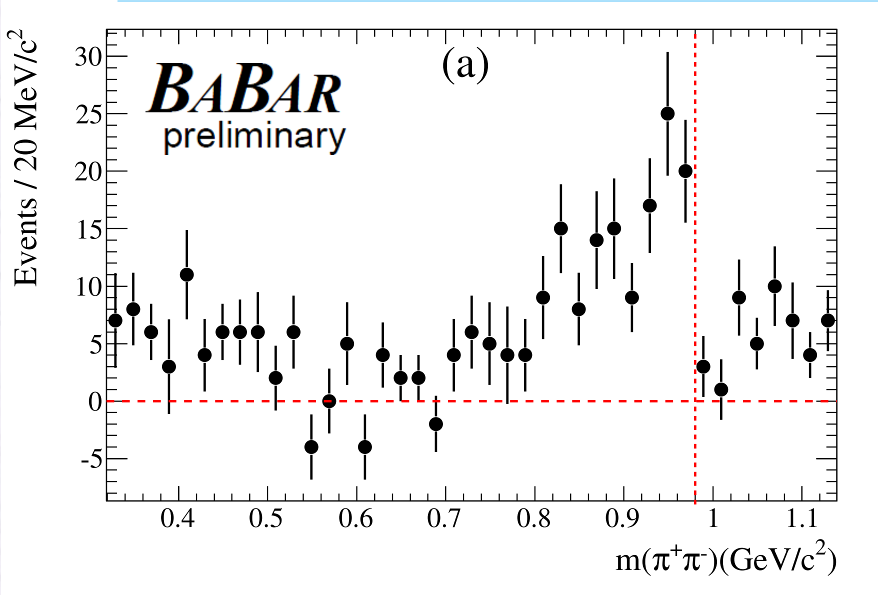


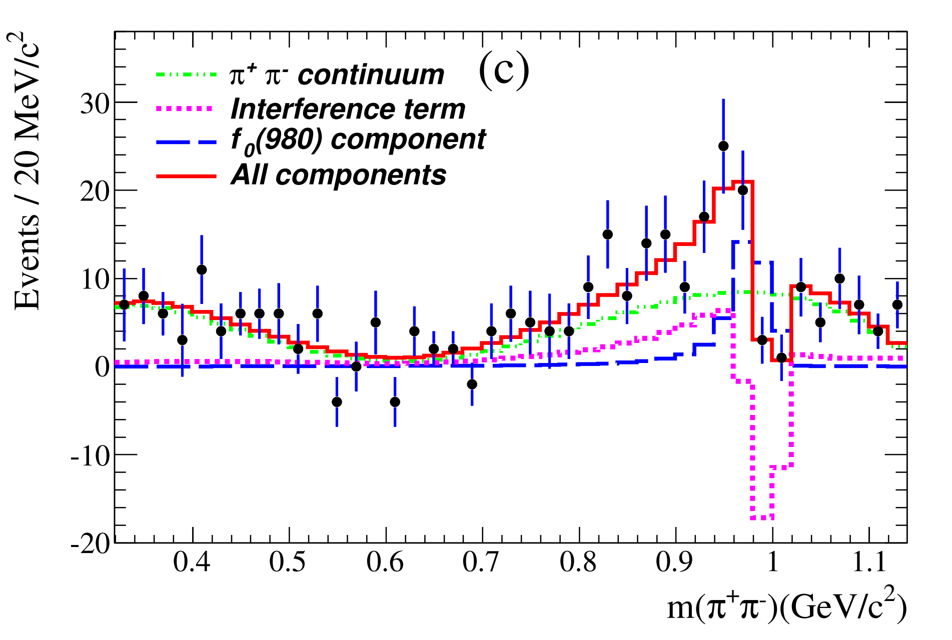
$m(Y(4260)) = 4244 \pm 5 \pm 4$ MeV/c²
$\Gamma(Y(4260)) = 114^{+16}_{-15} \pm 7$ MeV
$\Gamma_{e+e-} \times B(J/\psi\pi^+\pi^-) = 9.2 \pm 0.8 \pm 0.7$ eV

- No evidence of the additional state claimed by Belle ~4 GeV/c²
- Excess of events above 3.74 GeV/c² might result from the ψ(2S) tail and a possible $J/\psi\pi^+\pi^-$ continuum contribution
- Very clear signal for the Y(4260)
- The small excess of events ~ 4.5 GeV/c² attributed to statistical fluctuation

$\pi^+\pi^-$ invariant mass distribution in the Y(4260) decay

4.15<m(J/ψπ⁺π⁻)<4.45 GeV/c²





- The distribution seems to peak around the $f_0(980)$ mass; however the peak is displaced ~ 940 MeV/c²
- This fact suggests a possible interference between the $f_0(980)$ and $m(\pi^+\pi^-)$ continuum
- To test this possibility the $f_0(980)$ line shape is taken from the BaBar analysis $D_s^+ \to \pi^+\pi^-\pi^+$ (PRD 79, 032003 (2009)) and used in the following model

$$|\sqrt{pol} + e^{i\phi} F_{f0(980)}|^2$$

- where ***pol*** is a polynomial function used to describe the $m(\pi^+\pi^-)$ continuum and $F_{f0(980)}$ is the line shape from the D_s analysis ; ϕ allows for a phase difference between these amplitudes
- The result indicates that there is a real $f_0(980)$ contribution to the decay of the Y(4260) to $J/\psi\pi^+\pi^-$ but its contribution is not dominant

$$\frac{\mathcal{B}(Y_{4260} \to J/\psi f_0(980),\ f_0(980) \to \pi^+\pi^-)}{\mathcal{B}(Y_{4260} \to J/\psi\pi^+\pi^-)} = (17 \pm 13)\%$$

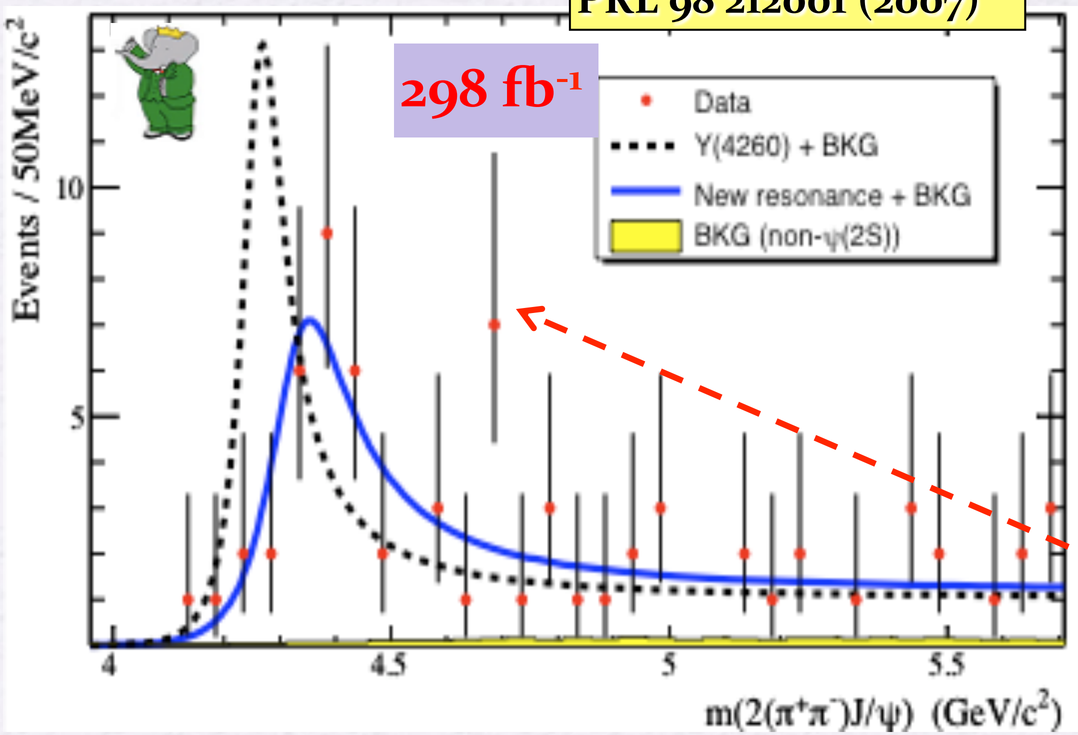
Study of the reaction $e^+e^- \to \psi(2S)\pi^+\pi^-$ via initial-state radiation

Yarra Valley, Australia

Y(4350) and Y(4660) →$\pi^+\pi^-\psi(2S)$ (Motivation)

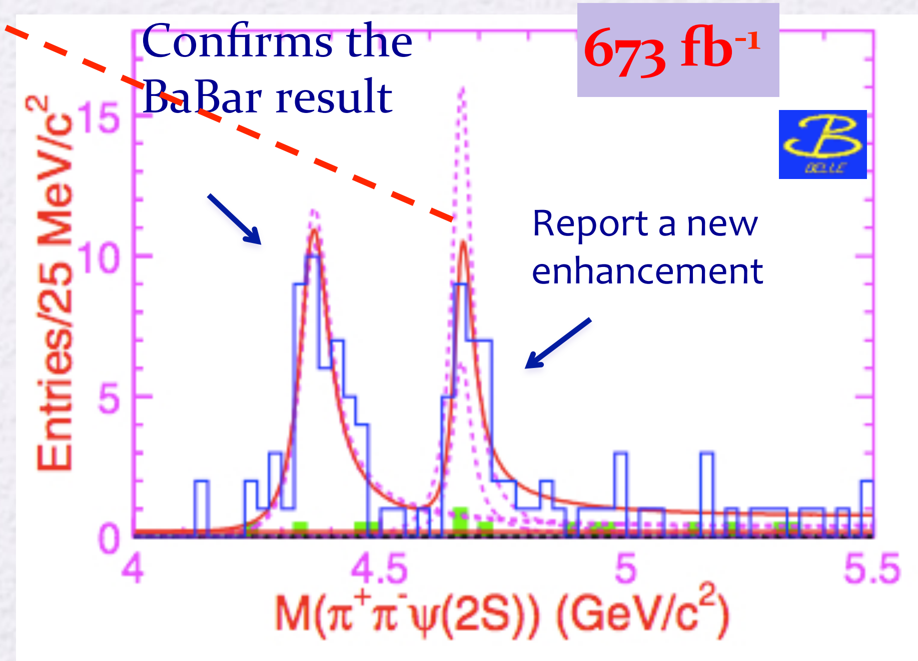
Y(4260) discovered in ISR $\pi^+\pi^- J/\psi$. How about $\pi^+\pi^-\psi(2S)$ in ISR?

PRL 98 212001 (2007)



In $\psi(2S)\pi^+\pi^-$ BaBar observed the Y(4350)
Single resonance fit =>
m=(4324±24) MeV/c², Γ=(172±33) MeV
Incompatible with ψ(4415);
Poorly described by Y(4260)

PRL 99, 142002 (2007)

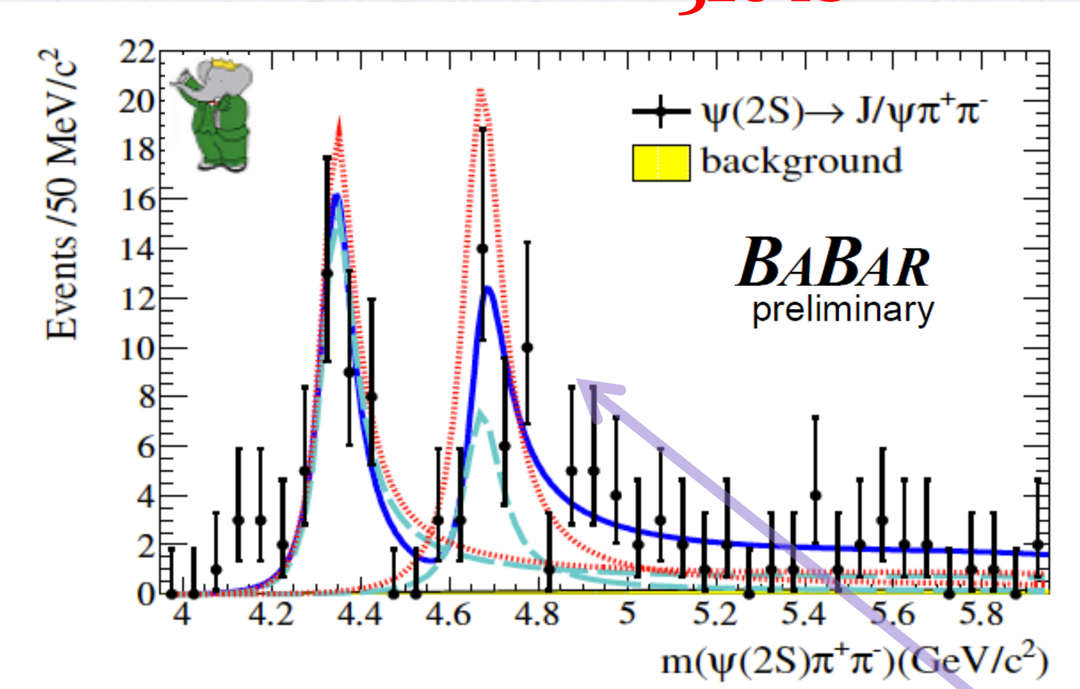


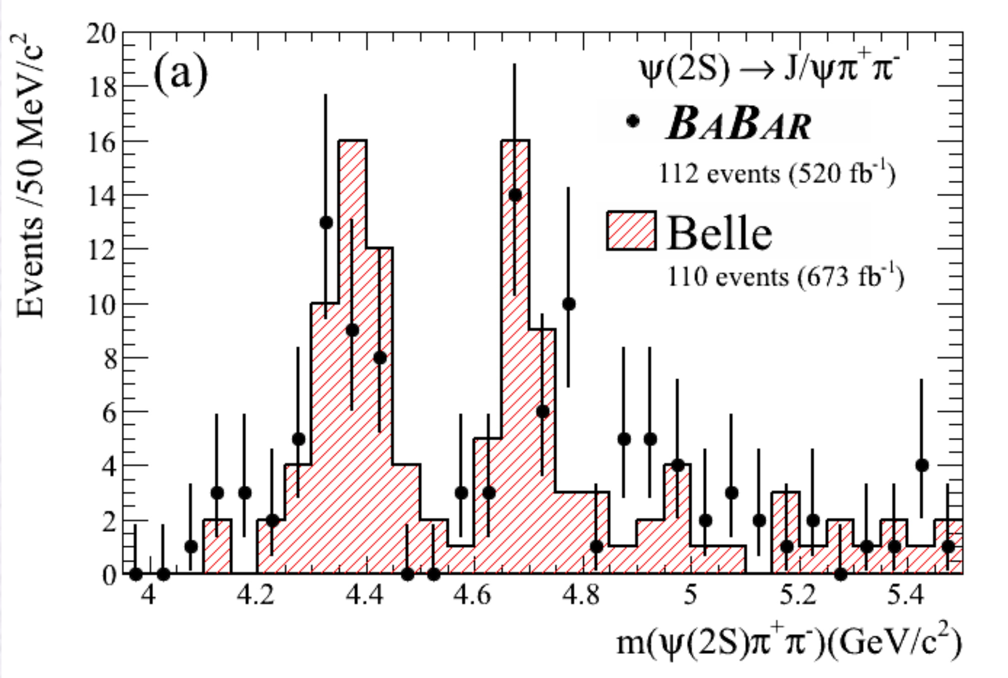
	State	M, MeV/c²	Γ_{tot}, MeV
	Y(4325)	4324 ± 24	172 ± 33
	Y(4325)	4361 ± 9 ± 9	74 ± 15 ± 10
	Y(4660)	4664 ± 11 ± 5	48 ± 15 ± 3

ISR $\pi^+\pi^-\psi(2S)$: New BaBar Result

- BaBar update using the full dataset, including the Υ(2S) and Υ(3S) data
- $\psi(2S) \to J/\psi\pi^+\pi^-$

520 fb^{-1}





Parameters	First Solution [constructive interference]	Second Solution [destructive interference]
Mass Y(4360)(MeV/c^2)	$4340 \pm 16 \pm 9$	
Width Y(4360)(MeV)	$94 \pm 32 \pm 13$	
$\mathcal{B} \times \Gamma_{ee}(Y(4360))$(eV)	$6.0 \pm 1.0 \pm 0.5$	$7.2 \pm 1.0 \pm 0.6$
Mass Y(4660)(MeV/c^2)	$4669 \pm 21 \pm 3$	
Width Y(4660)(MeV)	$104 \pm 48 \pm 10$	
$\mathcal{B} \times \Gamma_{ee}(Y(4660))$(eV)	$2.7 \pm 1.3 \pm 0.5$	$7.5 \pm 1.7 \pm 0.7$
$\phi(^\circ)$	$12 \pm 27 \pm 4$	$-78 \pm 12 \pm 3$

Confirm the BELLE enhancement ~ 4.6 GeV/c²
The obtained parameters for the Y(4360) and Y(4660) are consistent with the Belle results

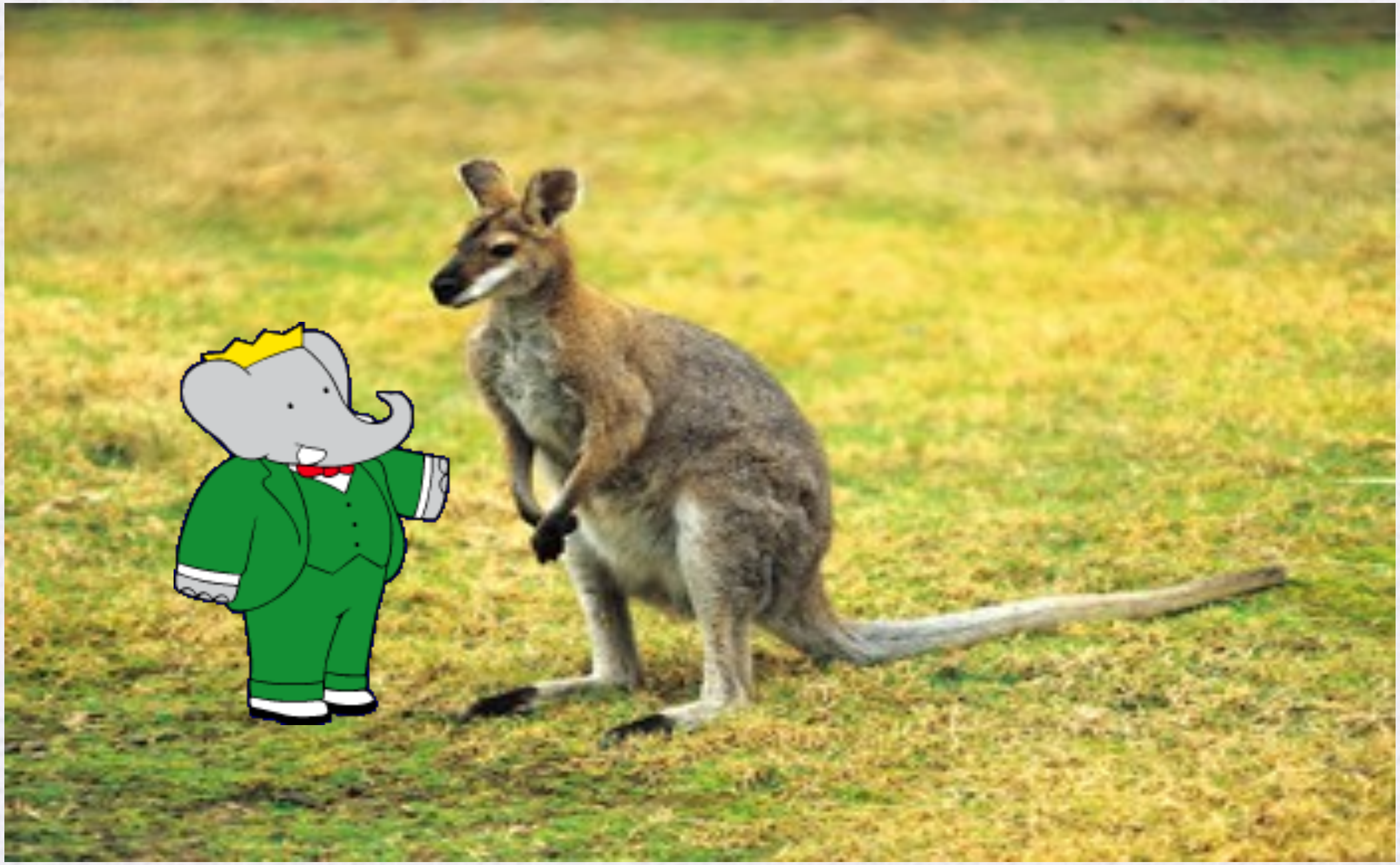
Conclusions

- ✓ Charmonium spectroscopy has been revitalized by the discovery of many new states above the open charm threshold. A review of some of these new states has been presented

- ✓ Many experimental results have been shown, with just enough data to whet the appetite, but at a statistical level which does not permit a clear understanding of the observed signals

- ✓ More data are required, possibly from LHCb, but also from the SuperB or BELLE-II projects

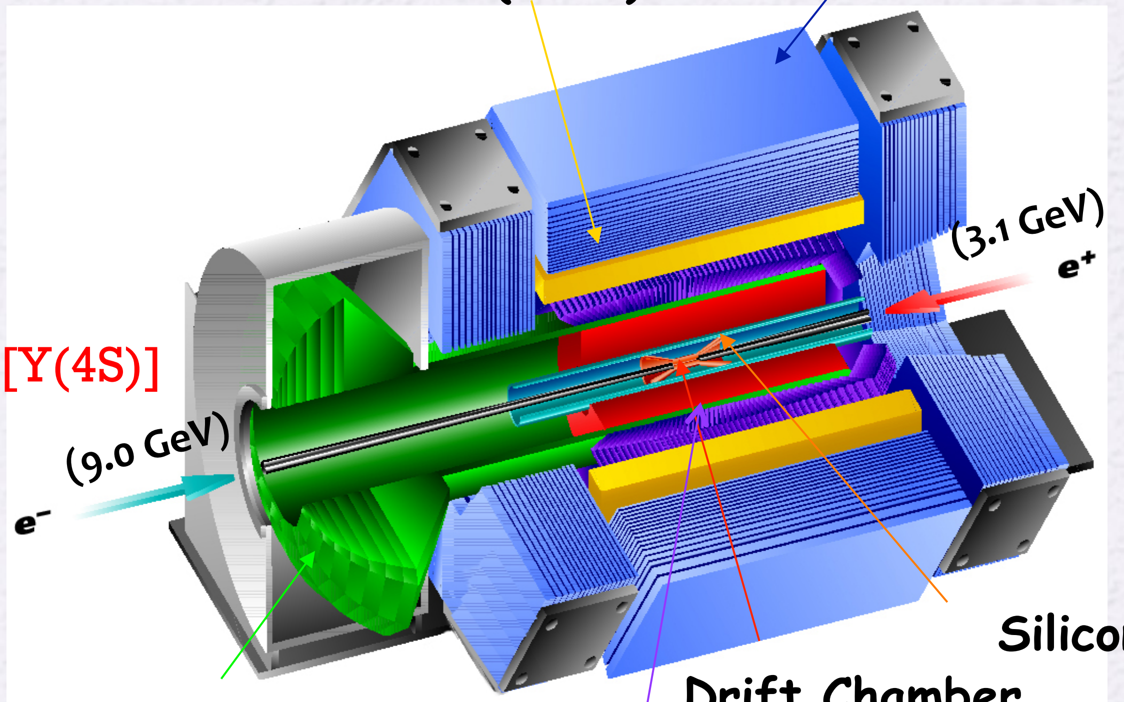
BACK-UP SLIDES



The BaBar detector and data sample

BaBar is a powerful *b* factory: 467 million $B\bar{B}$ pairs in the total data sample

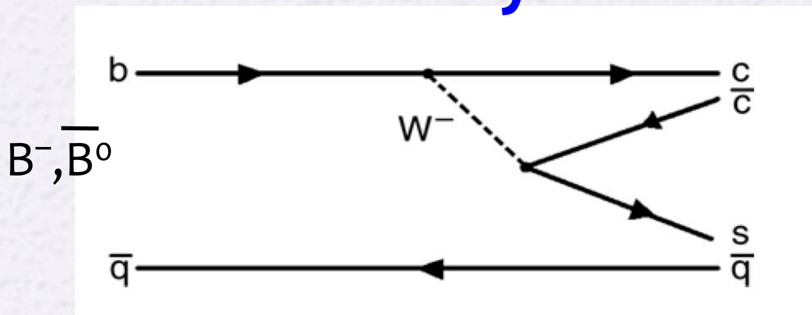
BaBar is also a *c* factory: 1.3 million Charm events per fb^{-1}



Offpeak (10.54GeV) + Scan above Υ(4S): 53.9 fb^{-1}

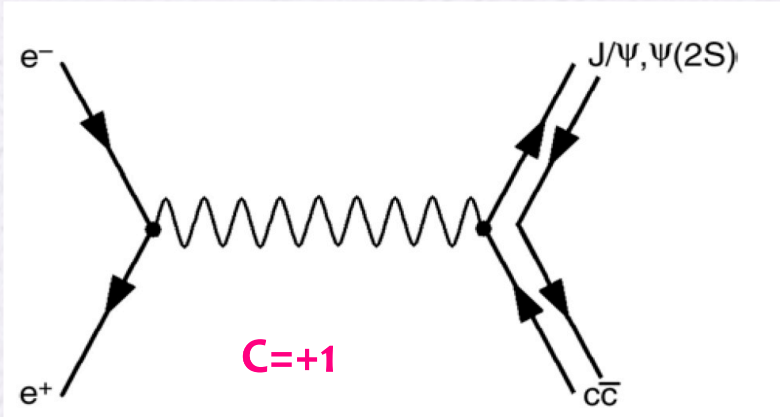
Υ(4S): 432 fb^{-1}
Υ(3S): 30.2 fb^{-1}
Υ(2S): 14.5 fb^{-1}

B decays

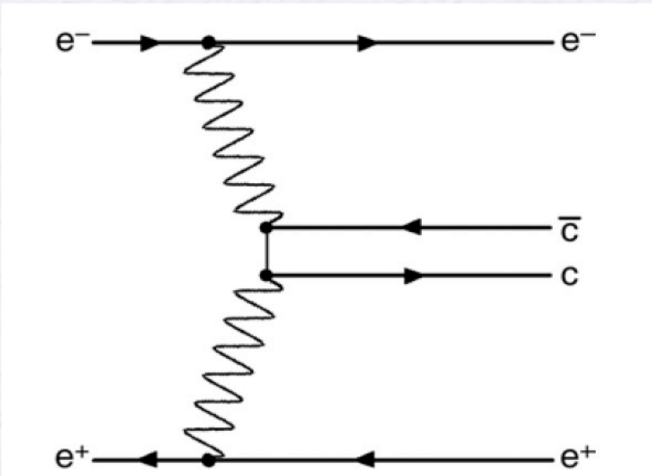


States of any quantum numbers can be formed

Double charmonium production

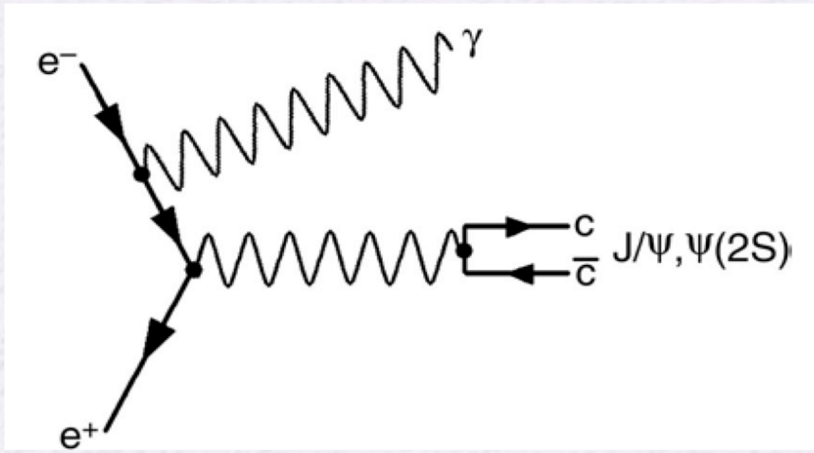


2 γ production



$J^{PC}=0^{\pm+}, 2^{\pm+}...$

Initial State Radiation (ISR)



$J^{PC}=1^{--}$

Charmonium-like States

Over 16 new resonances only 5 have been seen by more than one experiment

OK = confirmed by different experiments
N.C. =Seen by only one experiment not by other
N.Y.C= Not yet confirmed

NEW Results from BaBar

State	$m(MeV/c^2)$	Γ(MeV)	J^{PC}	Process (mode)	Experiment	Year	Status
X(3823)	3823.5 ± 2.8	4 ± 6	$?/2^{--}$	$B \to K(\chi_{c1}\gamma)$	Belle	2012	N.Y.C
X(3872)	3871.52 ± 0.20	1.3 ± 0.6	$1^{++}/2^{++}$	$B \to K(\pi^+\pi^- J/\psi)$	Belle, BABAR, LHCb	2003	OK
				$p\bar{p} \to (\pi^+\pi^- J/\psi) + \ldots$	CDF, DØ, CMS		
				$B \to K(J/\psi\omega)$	Belle, BABAR		
				$B \to K(D^{*0}\bar{D}^0)$	Belle, BABAR		
				$B \to K(J/\psi\gamma)$	Belle, BABAR		
				$B \to K(\psi(2S)\gamma)$	BABAR		N.C.
X(3915)	3915.6 ± 3.1	28 ± 10	$0/2^{?+}$	$B \to K(J/\psi\omega)$	Belle, BABAR	2004	OK
				$e^+e^- \to e^+e^-(J/\psi\omega)$	Belle, BABAR		
X(3940)	3942^{+9}_{-8}	37^{+27}_{-17}	$?^{?+}$	$e^+e^- \to J/\psi(D\bar{D}^*)$	Belle	2007	N.Y.C.
Y(4008)	4008^{+121}_{-49}	226 ± 97	1^{--}	$e^+e^- \to \gamma J/\psi\pi^+\pi^-$	Belle	2007	N.C.
$Z_1(4050)^+$	4051^{+24}_{-43}	82^{+51}_{-55}	?	$B \to K(\pi^+\chi_{c1}(1P))$	Belle	2008	N.C.
Y(4140)	4143 ± 3.0	15^{+11}_{-7}	$?^{?+}$	$B \to K(\phi J/\psi)$	CDF	2009	N.C.
X(4160)	4156^{+29}_{-25}	139^{+113}_{-65}	$?^{?+}$	$e^+e^- \to J/\psi(D\bar{D}^*)$	Belle	2007	N.Y.C.
$Z_2(4250)^+$	4248^{+185}_{-45}	177^{+321}_{-72}	?	$B \to K(\pi^+\chi_{c1}(1P))$	Belle	2008	N.C.
Y(4260)	4263 ± 5	108 ± 14	1^{--}	$e^+e^- \to \gamma J/\psi\pi^+\pi^-$	BABAR, CLEO, Belle	2005	OK
				$e^+e^- \to J/\psi\pi^0\pi^0$	CLEO		
Y(4274)	$4274.4^{+8.4}_{-6.7}$	32^{+22}_{-15}	$?^{?+}$	$B \to K(\phi J/\psi)$	CDF	2010	N.C.
X(4350)	$4350.6^{+4.6}_{-5.1}$	$13.3^{+18.4}_{-10.0}$	$0, 2^{++}$	$e^+e^- \to e^+e^-(\phi J/\psi)$	Belle	2009	N.Y.C.
Y(4360)	4353 ± 11	96 ± 42	1^{--}	$e^+e^- \to \gamma\psi(2S)\pi^+\pi^-$	BABAR, Belle	2007	OK
$Z(4430)^+$	4443^{+24}_{-18}	107^{+113}_{-71}	?	$B \to K(\pi^+\psi(2S))$	Belle	2007	N.C.
X(4360)	4634 ± 12	92^{+41}_{-32}	1^{--}	$e^+e^- \to \gamma\Lambda_c^+\Lambda_c^-$	Belle	2007	N.Y.C.
Y(4660)	4664 ± 12	48 ± 15	1^{--}	$e^+e^- \to \gamma\psi(2S)\pi^+\pi^-$	Belle, BABAR	2007	OK

$\gamma\gamma \rightarrow \eta_c\pi^+\pi^-$ (Motivation)

arXiv:1206.2008

- BaBar using 474 fb^{-1} studied the process $\gamma\gamma \rightarrow X \rightarrow \eta_c(1S)\pi^+\pi^-$ where X stands for one of the resonances $\chi_{c2}(1P)$, $\eta_{c2}(2S)$, X(3872), X(3915) or $\chi_{c2}(2P)$; the $\eta_c(1S)$ is reconstructed using the decay $\eta_c(1S) \rightarrow K_s^0 K^- \pi^+$; $K_s^0 \rightarrow \pi^+\pi^-$

- Predictions for $B(\eta_{c2}(2S) \rightarrow \eta_{c2}(1S)\,\pi^+\pi^-) \sim 2.2\%$ obtained from $\Gamma(\eta_{c2}(2S) \rightarrow \eta_c(1S)\pi^+\pi^-)/\Gamma(\psi(2S) \rightarrow J/\psi\,\pi^+\pi^-) \sim 2.9$

  M.B.Voloshin Mod. Phys. Lett A 17:1533-1538, (2002)

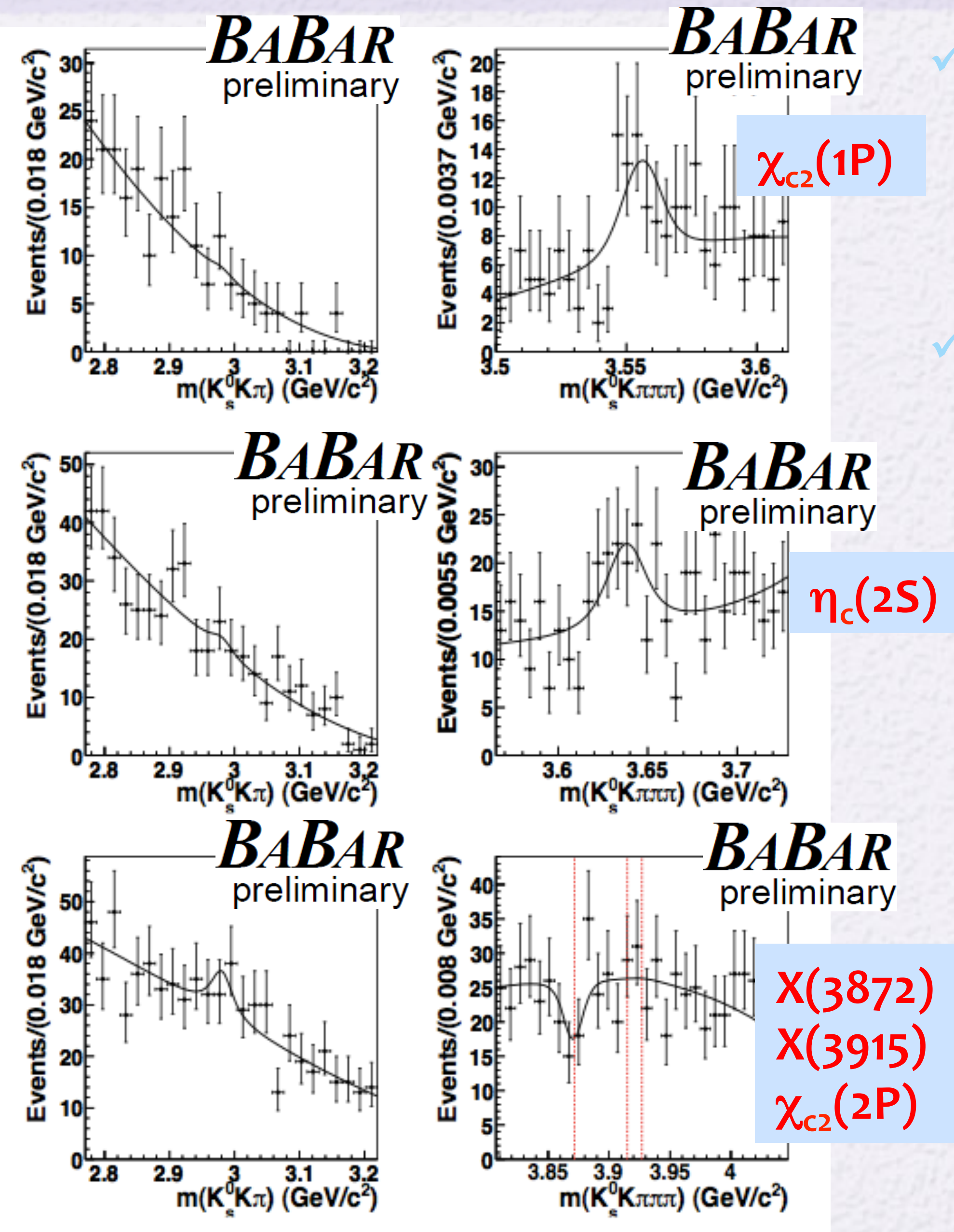
- If the X(3872) is the 1^1D_2 state η_{c2} the branching fraction $B(X(3872)) \rightarrow \eta_c\pi^+\pi^-)$ could be significantly larger than $B(X(3872)) \rightarrow J/\psi\pi^+\pi^-)$

  S.L. Olsen (Belle Collaboration) Int. J. Mod, Phys, A497 20, 240 (2005)

- The quantum numbers $J^{PC}=2^{-+}$ of the η_{c2} are consistent with the angular analysis of CDF for the X(3872) and would allow production of the X(3872) in two-photon fusion

  PRL 98, 132002 (2007)

$\gamma\gamma \rightarrow \eta_c \pi^+ \pi^-$ BaBar Result



Signal Extraction in two steps

- We extract the value of $m(K_s^o K^\pm \pi^\mp)$ distribution parameters of the combinatoric background from a one-dimensional fit to $m(K_s^o K^\pm \pi^\mp)$, without any restriction on $m(K_s^o K^+ \pi^- \pi^+ \pi^-)$
- To extract the signal yield for each X resonance we perform a two-dimensional fit in $m(K_s^o K^\pm \pi^\mp)$ and $m(K_s^o K^\pm \pi^\mp \pi^+ \pi^-)$

No resonant signal observed
Observed contribution from non-resonant
$\gamma\gamma \rightarrow X \rightarrow K_S^o K^\pm \pi^\mp \pi^+ \pi^-$

Resonance	$\Gamma_{\gamma\gamma}\mathcal{B}$(eV) Central value	UL
$\chi_{c2}(1P)$	$7.2^{+5.5}_{-4.4} \pm 2.9$	15.7
$\eta_c(2S)$	$65^{+47}_{-44} \pm 18$	133
$X(3872)$	$-4.5^{+7.7}_{-6.7} \pm 2.9$	11.1
$X(3915)$	$-13^{+12}_{-12} \pm 8$	16
$\chi_{c2}(2P)$	$-16^{+15}_{-14} \pm 6$	19

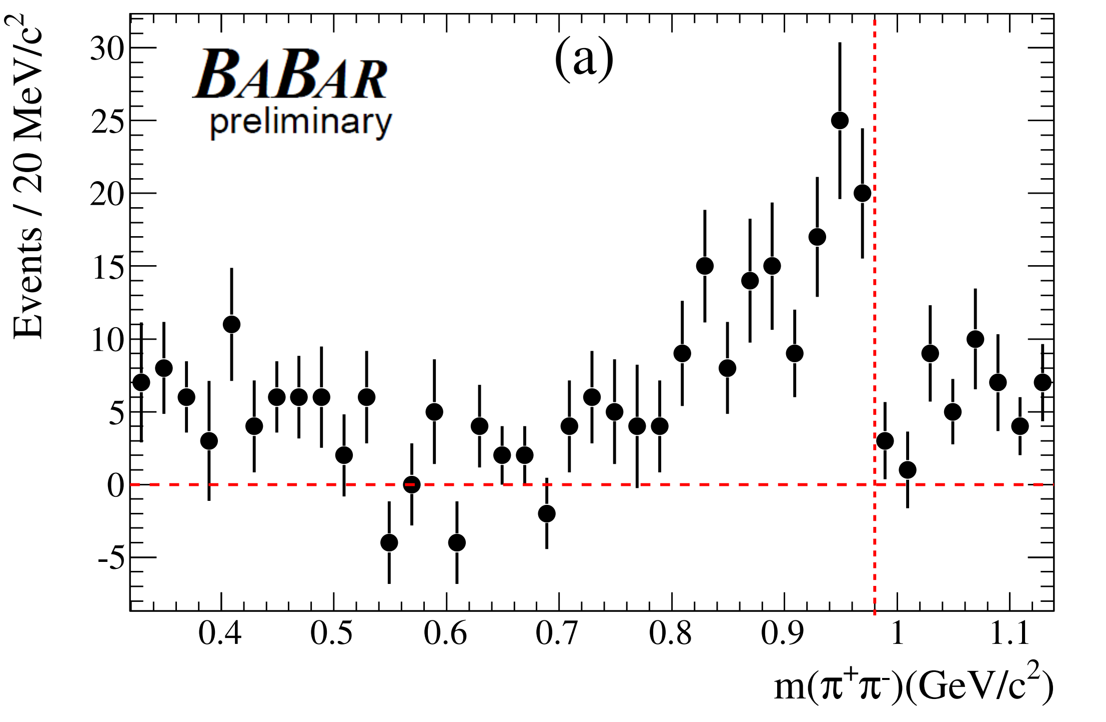
Using $B(\chi_{c2}(1P) \rightarrow K_S^o K^\pm \pi^\mp)$ and $B(\eta_c(2S) \rightarrow K_S^o K^\pm \pi^\mp)$ we obtain:

$B(\chi_{c2}(1P) \rightarrow \eta_c(1S)\pi\pi) < 2.2$ % @ 90%CL
$B(\eta_{c2}(2S) \rightarrow \eta_c(1S)\pi\pi) < 7.4$ % @ 90%CL

First Measurement

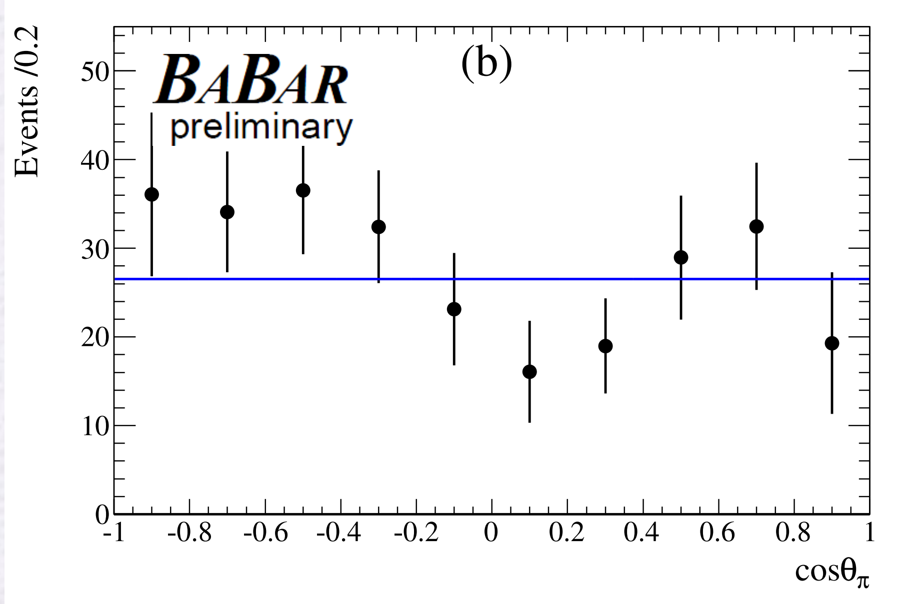
$\pi^+\pi^-$ invariant mass distribution in the Y(4260) decay (1)

$4.15 < m(J/\psi\pi^+\pi^-) < 4.45$ GeV/c²



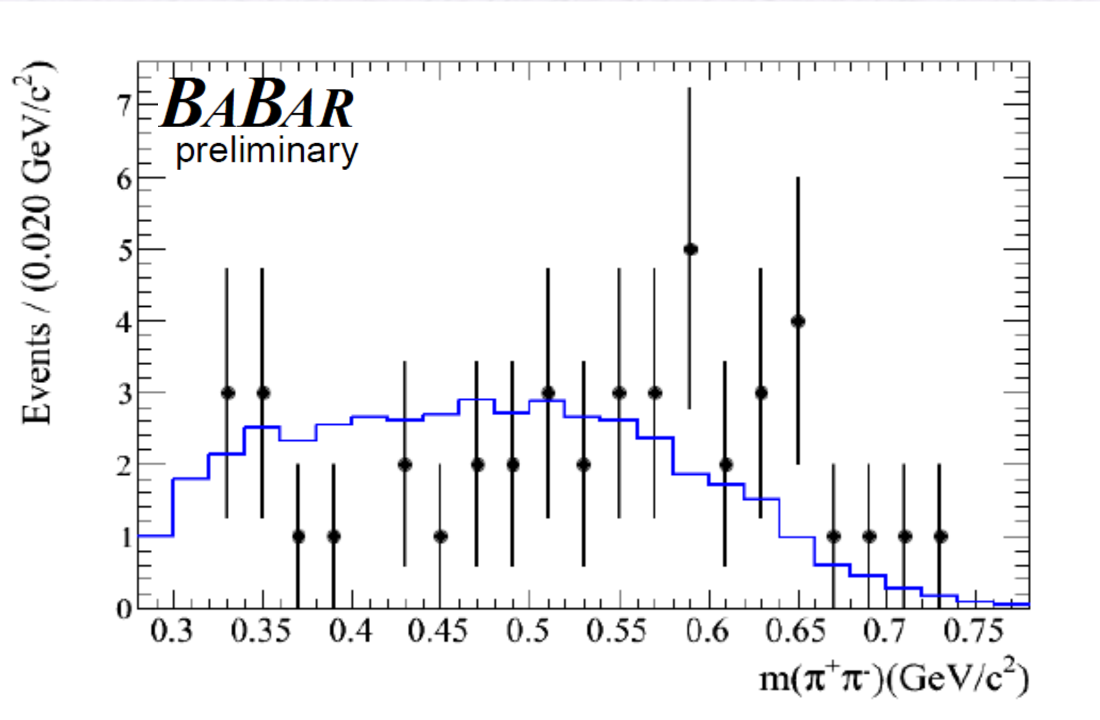
- The distribution seems to peak around the $f_0(980)$ mass; however the peak is displaced since it is around 940 MeV/c²
- The fact that the peak is displaced and the particular shape of the $m(\pi^+\pi^-)$ mass distribution seems to suggest a possible interference between the $f_0(980)$ and $m(\pi^+\pi^-)$ continuum

- We define θ_π as the angle between the π^+ direction and that of the recoil J/ψ both in the dipion rest frame
- The distribution is consistent with the *S*-wave behaviour (χ^2/NDF=12.3/9; Probability =19.7%)

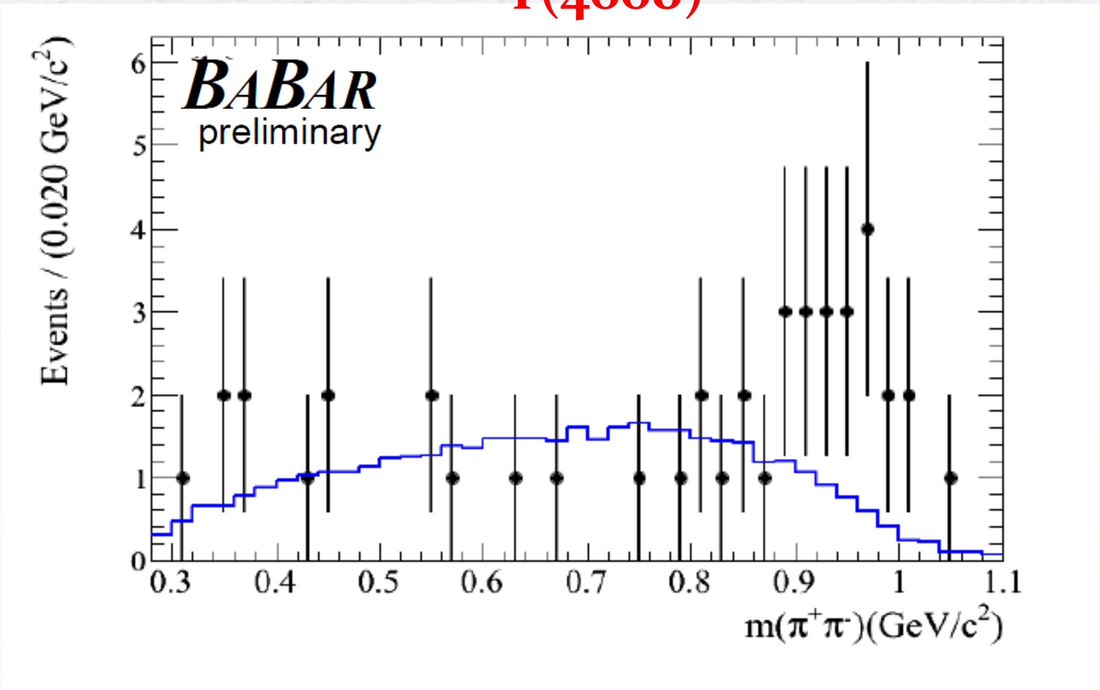


ISR $\pi^+\pi^-\psi(2S)$

Y(4360)



Y(4660)



Statistics too low to draw conclusions