BaBar studies of conventional and exotic quarkonium states

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Outline

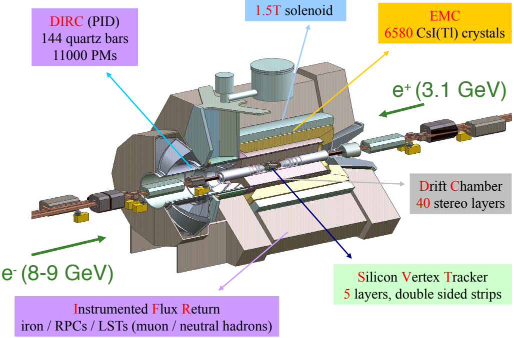
- Study of $B \to J/\psi\, K\, K\, K$ — in preparation
- Study of $\eta_c(nS) \to K^+K^-\eta$ and $\eta_c(nS) \to K^+K^-\pi^0$ in $\gamma\gamma$ reactions — arXiv:1403.7051
- Study of $X(3915) \to J/\psi\omega$ observed in $\gamma\gamma$ reactions — PRD 86, 072002 (2012)
- Measurement of anti-deuteron production in e^+e^- annihilations and $\Upsilon(nS)$ decays — arXiv:1403.4409

The *BABAR* experiment

PEP-II asymmetric e^+e^- collider operating at center of mass energies near the $\Upsilon(4S)$ (for most of the time)

$$\sqrt{s} = 10.58\,\mathrm{GeV}/c^2$$

General-purpose detector



Asymmetric:

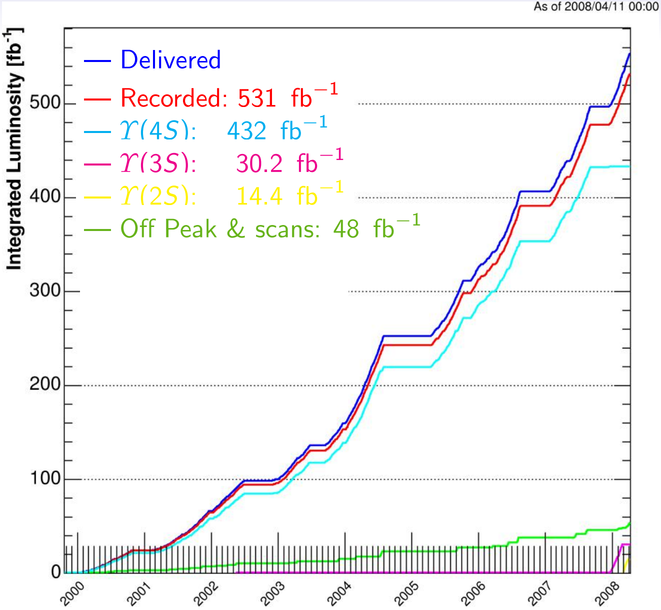
$$-0.9 < \cos\theta^* < 0.85$$

wrt electron beam

excellent performance:

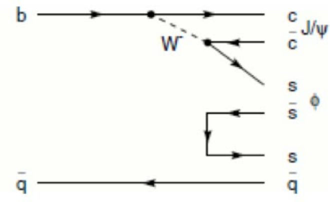
- vertexing
- tracking
- PID
- calorimeter

Data samples

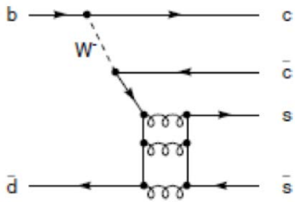


$B \to J/\psi\,\phi\,(K)$

$B \to J/\psi\,\phi\,K$



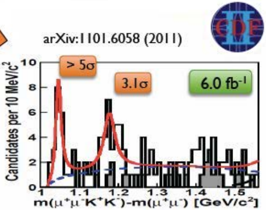
$B^0 \to J/\psi\,\phi$



Highly suppressed, gluon-rich: good place to search for gluonium/exotics

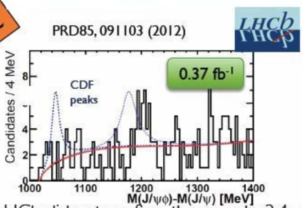
States decaying to $J/\psi\,\phi$ in $B \to J/\psi\,\phi\,K$?

2011



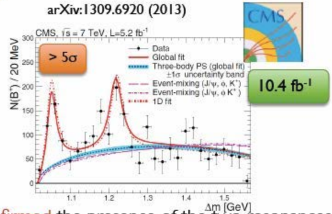
CDF reported the study of the decay mode $B^+ \to J/\psi\,\phi\,K^+$

2012



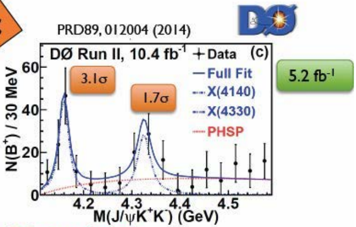
LHCb did not confirm these peaks 2.4σ disagreement with CDF

2013



CMS confirmed the presence of the two resonances

2014



D0 saw evidence for the two resonances

taken from G. Cibinetto @ DIS2014

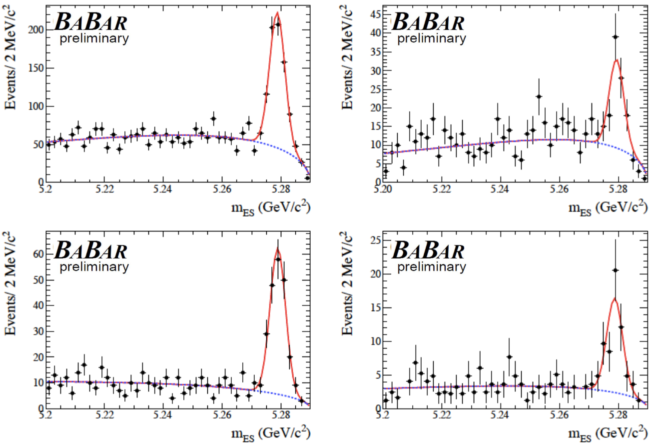
Study of $B \to J/\psi\, K\, K\, K$ at BABAR

no arXiv yet

Studied on the whole BABAR sample at the $\Upsilon(4S)$

$B^+ \to J/\psi\, K^+ K^- K^+$

$B^0 \to J/\psi\, K^+ K^- K^0_s$

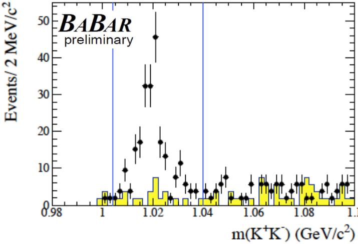


No cut on K^+K^- invariant mass

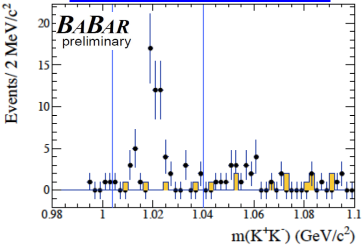
K^+K^- invariant mass in ϕ region

K^+K^- invariant mass and branching fractions

$B^+ \to J/\psi\, K^+K^-K^+$



$B^0 \to J/\psi\, K^+K^-K^0_s$



Clear $\phi \to K^+K^-$ signal – but also non resonant K^+K^-

B channel	Events yield	$\mathcal{B}$ $(\times 10^{-5})$	Efficiency (%)
$B^+ \to J/\psi K^+K^-K^+$	595^{+32}_{-31}	6.05 ± 0.33 (stat) ± 0.24 (sys)	17.96 ± 0.08
$B^+ \to J/\psi \phi K^+$	200 ± 14	4.57 ± 0.32 (stat) ± 0.13 (sys)	16.20 ± 0.03
$B^0 \to J/\psi K^-K^+K^0_S$	74 ± 12	3.55 ± 0.57 (stat) ± 0.15 (sys)	11.31 ± 0.10
$B^0 \to J/\psi \phi K^0_S$	50 ± 7	2.53 ± 0.35 (stat) ± 0.09 (sys)	10.73 ± 0.04

Values in agreement with previous *BABAR* results

- non-resonant component measured for the first time

Branching ratios

The ratios of B^0/B^+ and non-resonant/resonant components are compatible with spectator quark model expectations

$$R_+ = \frac{\mathcal{B}(B^+ \to J/\psi K^+ K^- K^+)}{\mathcal{B}(B^+ \to J/\psi \phi K^+)} = 1.32 \pm 0.12 \pm 0.07$$

$$R_0 = \frac{\mathcal{B}(B^0 \to J/\psi K^+ K^- K^0_S)}{\mathcal{B}(B^0 \to J/\psi \phi K^0_S)} = 1.40 \pm 0.30 \pm 0.08$$

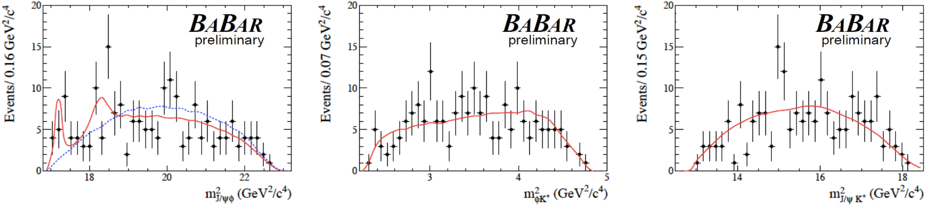
BABAR preliminary

$$R_\phi = \frac{\mathcal{B}(B^0 \to J/\psi \phi K^0_S)}{\mathcal{B}(B^+ \to J/\psi \phi K^+)} = 0.55 \pm 0.10 \pm 0.02$$

$$R_{2K} = \frac{\mathcal{B}(B^0 \to J/\psi K^+ K^- K^0_S)}{\mathcal{B}(B^+ \to J/\psi K^+ K^- K^+)} = 0.59 \pm 0.13 \pm 0.03$$

Search for substructures in $B \to J/\psi\phi K$

Unbinned maximum likelihood fit with phase-space model with or without the resonances reported by CDF



Fit function weighted by the 2-D efficiency map determined over the Dalitz plot

- fit without resonances (phase space):

$$\chi^2/\text{ndof} = 24.0/15$$

Acceptable fit in both cases

- fit with two resonances (parameters fixed to CDF)

$$\chi^2/\text{ndof} = 17.2/13$$

Upper limits

No evidence for new resonances

The 90%CL upper limits on the the fit fractions of the two resonances

- $f_{X(4140)} < 12.1\%$ @90%CL
- $f_{X(4270)} < 16.4\%$ @90%CL

BABAR preliminary

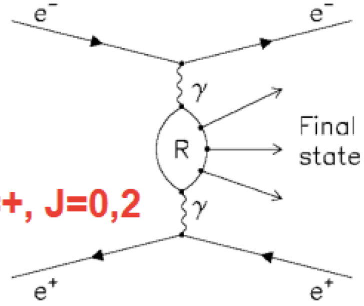
are not incompatible with any of the previous measurements

Experiment	[ref]	$M_{X(4140)}$ [MeV/c^2]	$\Gamma_{X(4140)}$ [MeV]	$f_{X(4140)}$ [%]
CDF	PRL102.242002(2009)	$4143.2 \pm 2.9 \pm 1.2$	$11.7^{+8.3}_{-5.0} \pm 3.7$	-
CDF	arXiv:1101.6058	$4143.6^{+2.9}_{-3.0} \pm 0.6$	$15.3^{+10.4}_{-6.1} \pm 2.5$	$14.9 \pm 2.9 \pm 2.4$
LHCb	PRD85,091103(2012)	-	-	< 7
CMS	arXiv:1309.6920	$4148.2 \pm 2.4 \pm 6.3$	$28^{+15}_{-11} \pm 19$	13.4 ± 3.0 (*)
D0	PRD89,012004(2014)	$4159.0 \pm 4.3 \pm 6.6$	$19.9 \pm 12.6^{+1.0}_{-8.0}$	$19 \pm 7 \pm 4$
		$M_{X(4270)}$ [MeV/c^2]	$\Gamma_{X(4270)}$ [MeV]	$f_{X(4270)}$ [%]
CDF	arXiv:1101.6058	$4274.6^{+8.4}_{-6.7} \pm 1.9$	$32.3^{+21.1}_{-15.3} \pm 7.6$	-
LHCb	PRD85,091103(2012)	-	-	< 8
CMS	arXiv:1309.6920	$4314.0 \pm 5.3 \pm 7.3$	$38^{+30}_{-15} \pm 16$	18.0 ± 7.3 (*)
D0	PRD89,012004(2014)	≈ 4360	30(*fixed*)	-

(*) estimated from the number of signal events quoted

$\gamma\gamma$ reactions

Electron and positron beams emit (quasi-real) photons which interact and may form resonances



C=+, J=0,2

- Final state $e^{\pm}$ emitted along beam direction undetected
- allowed $J^{PC} = 0^{\pm+}, 2^{\pm+}$ (and $4^{\pm+}, 3^{++}, 5^{++}, ...$)
- low p_t with respect to beam axis

$\eta_c(1S)$ and $\eta_c(2S)$ studies in $\gamma\gamma$

Ongoing program in *BABAR* to study exclusive $\eta_c(nS)$ decays in $\gamma\gamma$ reactions

- $\eta_c(nS)$ decays not well known:

$$\sum \mathcal{B}(\eta_c(1S)) \approx 20\%; \qquad \sum \mathcal{B}(\eta_c(2S)) \approx 5\%$$

- large event yield, proportional to $\Gamma_{\gamma\gamma} \times \mathcal{B}_{fin}$
- excellent S/B: non resonant hadronic cross section small

$\eta_c(nS) \to K^+K^-\pi^0$ and $\eta_c(nS) \to K^+K^-\eta$

- $\mathcal{B}$'s not well measured:

  BESIII studied $\psi(2S) \to \pi^0 h_c \to \pi^0\gamma\eta_c$ decays
  - 6.7 ± 3.2 events for $\eta_c(nS) \to K^+K^-\eta$
  - 54.9 ± 9.2 events for $\eta_c(nS) \to K^+K^-\pi^0$

  PRD86, 010001 (2012)

- no published Dalitz plot study of η_c decays to 3 pseudoscalars
  - can study poorly known scalar states
  - search for new gluonic states, so far searched in $J/\psi \to \gamma$ *hadrons*

$\eta_c(nS) \to K^+K^-\pi^0$ and $\eta_c(nS) \to K^+K^-\eta$ samples

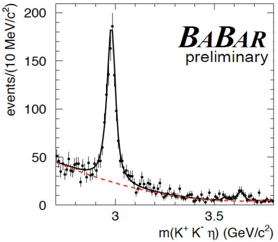
Clear signals in both modes

- $\eta_c(1S) \to K^+K^-\eta$: 1145 events
  First observation
- $\eta_c(2S) \to K^+K^-\eta$: 47 events
  First evidence
- $\eta_c(1S) \to K^+K^-\pi^0$: 4518 events
- $\eta_c(2S) \to K^+K^-\pi^0$: 178 events

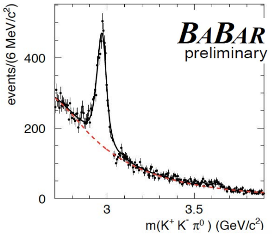
Resonance	Mass (MeV/c^2)	Γ (MeV)
$\eta_c \to K^+K^-\eta$	$2984.1 \pm 1.1 \pm 2.1$	$34.8 \pm 3.1 \pm 4.0$
$\eta_c \to K^+K^-\pi^0$	$2979.8 \pm 0.8 \pm 3.5$	$25.2 \pm 2.6 \pm 2.4$
$\eta_c(2S) \to K^+K^-\eta$	$3635.1 \pm 5.8 \pm 2.1$	11.3 (fixed)
$\eta_c(2S) \to K^+K^-\pi^0$	$3637.0 \pm 5.7 \pm 3.4$	11.3 (fixed)

arXiv:1403.7051

$K^+K^-\eta$



$K^+K^-\pi^0$



Branching fraction measurements

arXiv:1403.7051

Channel	Event yield	Weights	$\mathcal{R}$	Significance
$\eta_c \to K^+K^-\pi^0$	$4518 \pm 131 \pm 50$	17.0 ± 0.7		$32\ \sigma$
$\eta_c \to K^+K^-\eta\ (\eta \to \gamma\gamma)$	$853 \pm 38 \pm 11$	21.3 ± 0.6		$21\ \sigma$
$\mathcal{B}(\eta_c \to K^+K^-\eta)/\mathcal{B}(\eta_c \to K^+K^-\pi^0)$			$0.602 \pm 0.032 \pm 0.065$	
$\eta_c \to K^+K^-\eta\ (\eta \to \pi^+\pi^-\pi^0)$	$292 \pm 20 \pm 7$	31.2 ± 2.1		$14\ \sigma$
$\mathcal{B}(\eta_c \to K^+K^-\eta)/\mathcal{B}(\eta_c \to K^+K^-\pi^0)$			$0.523 \pm 0.040 \pm 0.083$	
$\eta_c(2S) \to K^+K^-\pi^0$	$178 \pm 29 \pm 39$	14.3 ± 1.3		$3.7\ \sigma$
$\eta_c(2S) \to K^+K^-\eta$	$47 \pm 9 \pm 3$	17.4 ± 0.4		$4.9\ \sigma$
$\mathcal{B}(\eta_c(2S) \to K^+K^-\eta)/\mathcal{B}(\eta_c(2S) \to K^+K^-\pi^0)$			$0.82 \pm 0.21 \pm 0.27$	
$\chi_{c2} \to K^+K^-\pi^0$	$88 \pm 27 \pm 23$			$2.5\ \sigma$
$\chi_{c2} \to K^+K^-\eta$	$2 \pm 5 \pm 2$			$0.0\ \sigma$

Weighted mean of the two $K^+K^-\eta$ decay modes:

$\eta_c(1S)$:

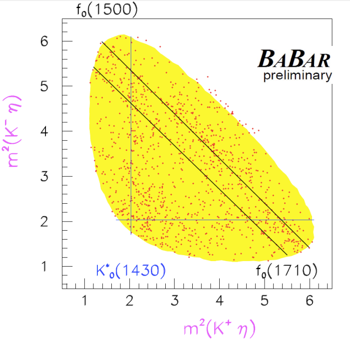
$$\mathcal{R}(\eta_c) = \frac{\mathcal{B}(\eta_c \to K^+K^-\eta)}{\mathcal{B}(\eta_c \to K^+K^-\pi^0)} = 0.571 \pm 0.025 \pm 0.051$$

BESIII: 0.46 ± 0.24 PRD86, 010001 (2012)

$\eta_c(2S)$:

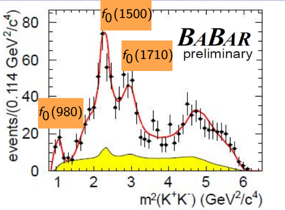
$$\mathcal{R}(\eta_c(2S)) = \frac{\mathcal{B}(\eta_c(2S) \to K^+K^-\eta)}{\mathcal{B}(\eta_c(2S) \to K^+K^-\pi^0)} = 0.82 \pm 0.21 \pm 0.27$$

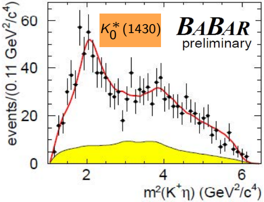
Dalitz plot for $\eta_c(1S) \to K^+K^-\eta$



Unbinned ML fit taking into account background from η_c sidebands (yellow histogram)

K^+K^- amplitudes: I=0

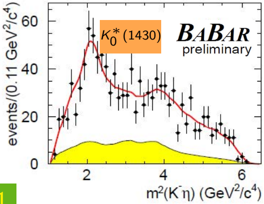




First evidence of $K_0^*(1430)^\pm \to K^\pm\eta$ seen as a peak

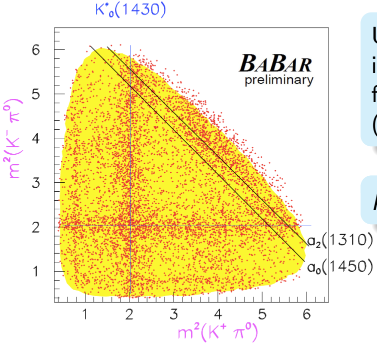
Final state	Fraction %	Phase (radians)
$f_0(1500)\eta$	$23.7 \pm 7.0 \pm 1.8$	0.
$f_0(1710)\eta$	$8.9 \pm 3.2 \pm 0.4$	$2.2 \pm 0.3 \pm 0.1$
$K_0^*(1430)^+K^-$	$16.4 \pm 4.2 \pm 1.0$	$2.3 \pm 0.2 \pm 0.1$
$f_0(2200)\eta$	$11.2 \pm 2.8 \pm 0.5$	$2.1 \pm 0.3 \pm 0.1$
$K_0^*(1950)^+K^-$	$2.1 \pm 1.3 \pm 0.2$	$-0.2 \pm 0.4 \pm 0.1$
$f_2'(1525)\eta$	$7.3 \pm 3.8 \pm 0.4$	$1.0 \pm 0.1 \pm 0.1$
$f_0(1350)\eta$	$5.0 \pm 3.7 \pm 0.5$	$0.9 \pm 0.2 \pm 0.1$
$f_0(980)\eta$	$10.4 \pm 3.0 \pm 0.5$	$-0.3 \pm 0.3 \pm 0.1$
NR	$15.5 \pm 6.9 \pm 1.0$	$-1.2 \pm 0.4 \pm 0.1$
Sum	$100.0 \pm 11.2 \pm 2.5$	
χ^2/ν	87/65	

$f_0(1500)$ and $f_0(1710)$ gluonium candidates



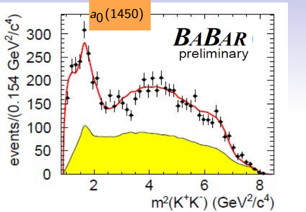
arXiv:1403.7051

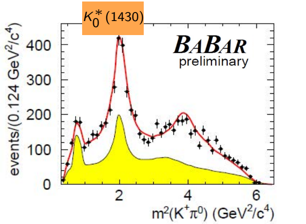
Dalitz plot for $\eta_c(1S) \to K^+K^-\pi^0$

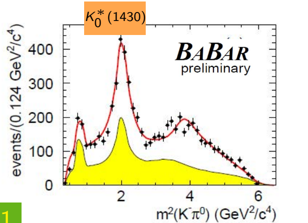


Unbinned ML fit taking into account background from η_c sidebands (yellow histogram)

K^+K^- amplitudes: I=1







$K^\pm\pi^0$ dominated by $K_0^*(1430)$

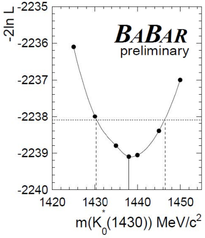
Final state	Fraction %	Phase (radians)
$K_0^*(1430)^+K^-$	33.8 ± 1.9 ± 0.4	0.
$K_0^*(1950)^+K^-$	6.7 ± 1.0 ± 0.3	-0.67 ± 0.07 ± 0.03
$a_0(980)\pi^0$	1.9 ± 0.1 ± 0.2	0.38 ± 0.24 ± 0.02
$a_0(1450)\pi^0$	10.0 ± 2.4 ± 0.8	-2.4 ± 0.05 ± 0.03
$a_2(1320)\pi^0$	2.1 ± 0.1 ± 0.2	0.77 ± 0.20 ± 0.04
$K_2^*(1430)^+K^-$	6.8 ± 1.4 ± 0.3	-1.67 ± 0.07 ± 0.03
NR	24.4 ± 2.5 ± 0.6	1.49 ± 0.07 ± 0.03
Sum	85.8 ± 3.6 ± 1.2	
χ^2/ν	212/130	

arXiv:1403.7051

$K_0^*(1430)$ properties

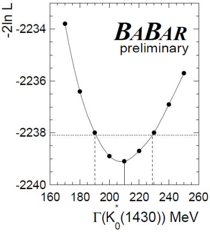
arXiv:1403.7051

Likelihood scan for $K_0^*(1430)$ parameters in $\eta_c \to K^+K^-\pi^0$ Dalitz plot fit



- $M = 1438 \pm 8 \pm 4\ \mathrm{MeV}/c^2$
  in agreement with LASS

Nucl.Phys.B 296,493(1988)



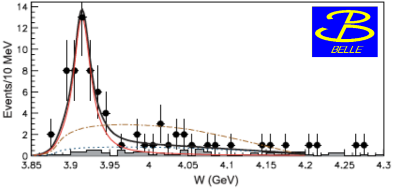
- $\Gamma = 210 \pm 20 \pm 12\ \mathrm{MeV}$
  $\approx 3\sigma$ smaller than LASS result

$$\frac{\mathcal{B}(K_0^* \to \eta K)}{\mathcal{B}(K_0^* \to \pi K)} = 0.092 \pm 0.025^{+0.010}_{-0.025}$$

$\gamma\gamma \to J/\psi\omega$

$X(3915)$ decaying to $J/\psi\omega$ observed by Belle in $\gamma\gamma$ PRL 104, 092001 (2010)

$$M = 3915 \pm 3 \pm 2 \text{ MeV}/c^2$$
$$\Gamma = 17 \pm 10 \pm 3 \text{ MeV}$$
$$\Gamma_{\gamma\gamma} \cdot \mathcal{B}(J\psi\omega) = 61 \pm 17 \pm 8 \text{ eV} \quad (J = 0)$$
$$\Gamma_{\gamma\gamma} \cdot \mathcal{B}(J\psi\omega) = 18 \pm 5 \pm 2 \text{ eV} \quad (J = 2)$$



but there are other resonances in the same final state or mass range

- $Y(3940)$ decaying to $J/\psi\omega$ has been observed in B decays

  PRL 94, 182002 (2005) PRL 101, 082001 (2008) PRD 82, 011101 (2010)

- $Z(3930)$ decaying to $D\bar{D}$ observed in $\gamma\gamma$

  PRL 96, 082003 (2006) PRD 81, 092003 (2010)

  angular distribution supports $J = 2$, identified with $\chi_{c2}(2P)$

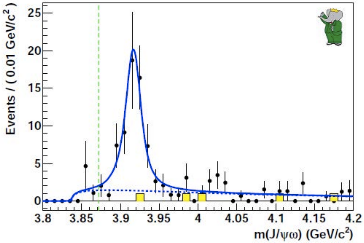
Are they all the same or not?

Study of $X(3915) \to J/\psi\omega$ in $\gamma\gamma$ reactions at *BABAR*

$X(3915)$ confirmed by *BABAR*: PRD 86, 072002 (2012)

Resonance parameters in agreement with Belle:

$$M = 3919.4 \pm 2.2 \pm 1.6 \ \mathrm{MeV}/c^2$$
$$\Gamma = 13 \pm 6 \pm 3 \ \mathrm{MeV}$$
$$\Gamma_{\gamma\gamma} \cdot \mathcal{B}(J\psi\omega) = 52 \pm 10 \pm 3 \ \mathrm{eV} \qquad (J = 0)$$
$$\Gamma_{\gamma\gamma} \cdot \mathcal{B}(J\psi\omega) = 10.5 \pm 1.9 \pm 0.6 \ \mathrm{eV} \qquad (J = 2)$$



If $\Gamma_{\gamma\gamma} = \mathcal{O}(1 \ \mathrm{keV})$ (typical $c\bar{c}$), then $\mathcal{B}(J/\psi\omega) > (1-6)\%$

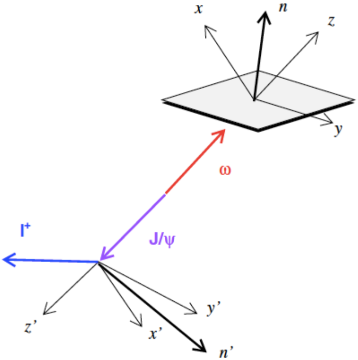
Angular distribution for $\gamma\gamma \to J/\psi\omega$

Angular analysis follows J. L. Rosner, PRD 70, 094023 (2004)

Since events have low p_t the $\gamma\gamma$ collision axis is approximately along the beam axis.

The angles are defined in three different center of mass frames: $J/\psi\omega$, J/ψ, and ω.

The normal to the ω decay plane defines the axis orientation



No background subtraction:

assume that all events in $3890 < M(J\psi\omega) < 3950\ \mathrm{MeV}/c^2$ are from $X(3915)$ decay

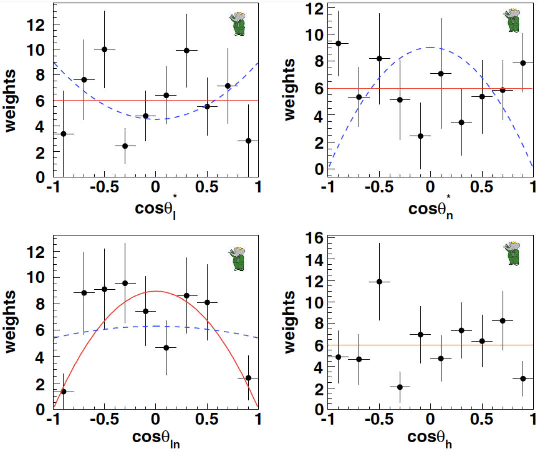
PRD 86, 072002 (2012)

$X(3915)$: J=0 or J=2?

The efficiency corrected distributions for events in the $X(3915)$ signal region in each of the three discriminating angles favors $J = 0$ over $J = 2$

Angle	$J^P = 0^{\pm}$	$J^P = 2^{+}$
θ_l^*	1	$1 + \cos^2\theta_l^*$
χ^2	11.2	16.9
θ_n^*	1	$\sin^2\theta_n^*$
χ^2	6.9	65.9
θ_{ln}	$\sin^2\theta_{ln}$	$7 - \cos^2\theta_{ln}$
χ^2	12.5	18.0
θ_h	1	
χ^2	12.2	

(NDOF=9)

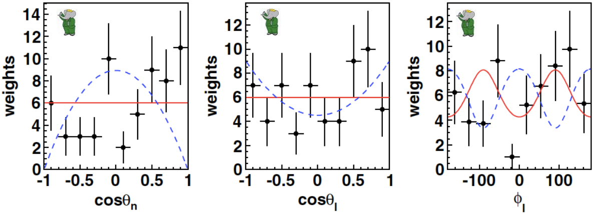


Overall J=0 strongly preferred over J=2

PRD 86, 072002 (2012)

$X(3915)$: 0^- or 0^+?

The efficiency corrected distributions for events in the $X(3915)$ signal region in three discriminating angles favors 0^+ over 0^-



Angle	$J^P = 0^-$	$J^P = 0^+$
θ_n	$\sin^2\theta_n$	1
χ^2	77.6	16.3
θ_l	$1 + \cos^2\theta_l$	1
χ^2	8.7	8.3
ϕ_l	$2 - \cos(2\cos\phi_l)$	$2 + \cos(2\cos\phi_l)$
χ^2	21.7	9.6

(NDOF=9)

$\chi_{c0}(2P)$ **candidate?**

PRD 86, 072002 (2012)

Inclusive anti-deuteron production in $\Upsilon(nS)$ decays

Excess of anti-nuclei in cosmic rays can indirectly probe Dark Matter annihilation Cui,Mason,Randall JHEP 1011,017(2010) Dal,Kachelriess PRD 86, 103536(2012) Vittino,Fornengo,Maccione arXiv:1308.4848

- colored partons hadronization into nuclei
  $\Longrightarrow$ processes involving 6-quarks in close proximity

e^+e^- annihilations offer a clean environment, both in continuum and in $\Upsilon(nS)$ decays

previous measurements from

- ARGUS PLB 236,102(1990), CLEO PRD 75,012009(2007) at $\Upsilon(1S)$ and $\Upsilon(2S)$
- Aleph PLB 639,192(2006) for e^+e^- at $E_{CM} = 91.2$ GeV

BABAR search in both resonant and continuum samples: arXiv:1403.4409

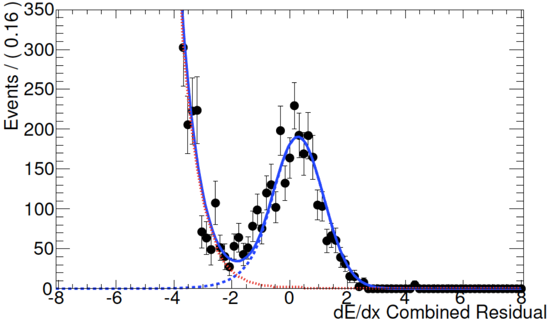
Resonance	Onpeak	# of Υ Decays	Offpeak
$\Upsilon(4S)$	$429\,\mathrm{fb}^{-1}$	463×10^6	$44.8\,\mathrm{fb}^{-1}$
$\Upsilon(3S)$	$28.5\,\mathrm{fb}^{-1}$	116×10^6	$2.63\,\mathrm{fb}^{-1}$
$\Upsilon(2S)$	$14.4\,\mathrm{fb}^{-1}$	98.3×10^6	$1.50\,\mathrm{fb}^{-1}$

also: $\Upsilon(1S)$ sample from $\Upsilon(2S) \to \pi^+\pi^- X$

Anti-deuteron yield

Most deuterons produced in interactions of particles with detector material: restrict analysis to anti-deuterons

- (anti)-deuterons heavy: highly ionizing, no (or little) Čerenkov light

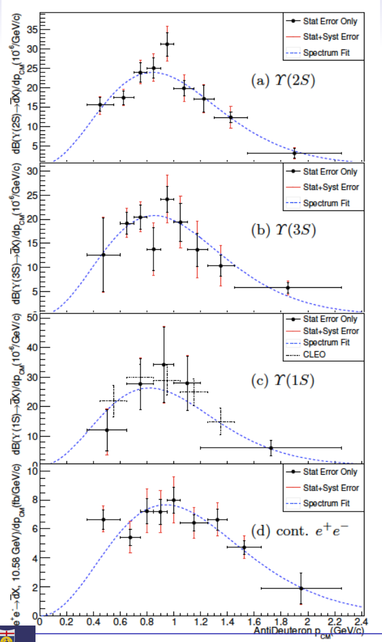


The number of events with an anti-deuteron is determined – in each bin of CM momentum – from a fit to the residual of the expected dE/dx

arXiv:1403.4409

Branching fractions

arXiv:1403.4409



- $\Upsilon(1S)$ and $\Upsilon(2S)$ branching fractions compatible with previous measurements
- significant improvement in $\Upsilon(2S)$ branching fraction
- $\Upsilon(3S)$ branching fraction measured for the first time
- measurement of continuum cross section at $\sqrt{s} \approx 10.58$ GeV

Process	Rate
$\mathcal{B}(\Upsilon(3S) \to \bar{d}X)$	$(2.33 \pm 0.15^{+0.31}_{-0.28}) \times 10^{-5}$
$\mathcal{B}(\Upsilon(2S) \to \bar{d}X)$	$(2.64 \pm 0.11^{+0.26}_{-0.21}) \times 10^{-5}$
$\mathcal{B}(\Upsilon(1S) \to \bar{d}X)$	$(2.81 \pm 0.49^{+0.20}_{-0.24}) \times 10^{-5}$
$\sigma(e^+e^- \to \bar{d}X)$ $[\sqrt{s} \approx 10.58\,\mathrm{GeV}]$	$(9.63 \pm 0.41^{+1.17}_{-1.01})$ fb
$\frac{\sigma(e^+e^- \to \bar{d}X)}{\sigma(e^+e^- \to \mathrm{Hadrons})}$	$(3.01 \pm 0.13^{+0.37}_{-0.31}) \times 10^{-6}$

$\bar{d}$ production suppressed by one order of magnitude in quark-dominated $e^+e^- \to q\bar{q}$ with respect to gluon-dominated $\Upsilon(nS)$ decays

Conclusions

- Study of $B \to J/\psi K K (K)$
  - Branching fractions and ratios measured
  - X(4140) and X(4270): no evidence
- $\eta_c(nS) \to K^+ K^- \eta$ and $\eta_c(nS) \to K^+ K^- \pi^0$ in $\gamma\gamma$ reactions
  - First observation of $\eta_c(1S) \to K^+ K^- \eta$ and first evidence for $\eta_c(2S) \to K^+ K^- \eta$
  - first Dalitz plot analysis of these modes
    - Decay dominated by pseudoscalar-scalar two-body
    - large contribution from $\eta_c(1S) \to \eta f_0(1500)$
  - First observation of $K_0^*(1430) \to K^\pm \eta$
    new measurement of $K_0^*(1430)$ parameters
- Study of $X(3915) \to J/\psi \omega$ observed in $\gamma\gamma$ reactions
  - Confirm the state observed by Belle
  - Study of angular distribution suggests 0^{++} $\chi_{c0}(2P)$**??**
- Measurement of anti-deuteron production in $e^+ e^-$ annihilations and $\Upsilon(nS)$ decays

many new results also from ISR:
$\Longrightarrow$ see E. Solodov talk this afternoon (parallel session B)