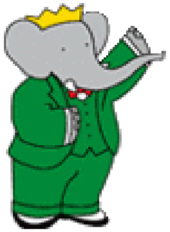
International Workshop on e^+e^- collisions from Phi to Psi

Heavy Spectroscopy

at



BaBar

Frascati, 7 – 10 Aprile 2008

Elisabetta Prencipe
On behalf of the BaBar collaboration

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE
IN2P3
INSTITUT NATIONAL DE PHYSIQUE NUCLÉAIRE ET DE PHYSIQUE DES PARTICULES
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Introduction

- Recent observations of (unexpected) new states performed.

- Several resonances do not fit theoretical predictions.

- Many subsequent interpretations of these new states and methods were suggested to analyse their structure (HQT, chiral symmetries, 4-quark models, bag model, Lattice...)

- We can classify these resonant structures in 2 main categories:

  - **Light Mesons**: f^0-*family*, $K^{*0}(1430)$, a^0-*family*

  - **Heavy Hadrons** ($c\bar{s}$ and $c\bar{c}$ mesons; baryons) → ***subject of this talk!***

Motivations

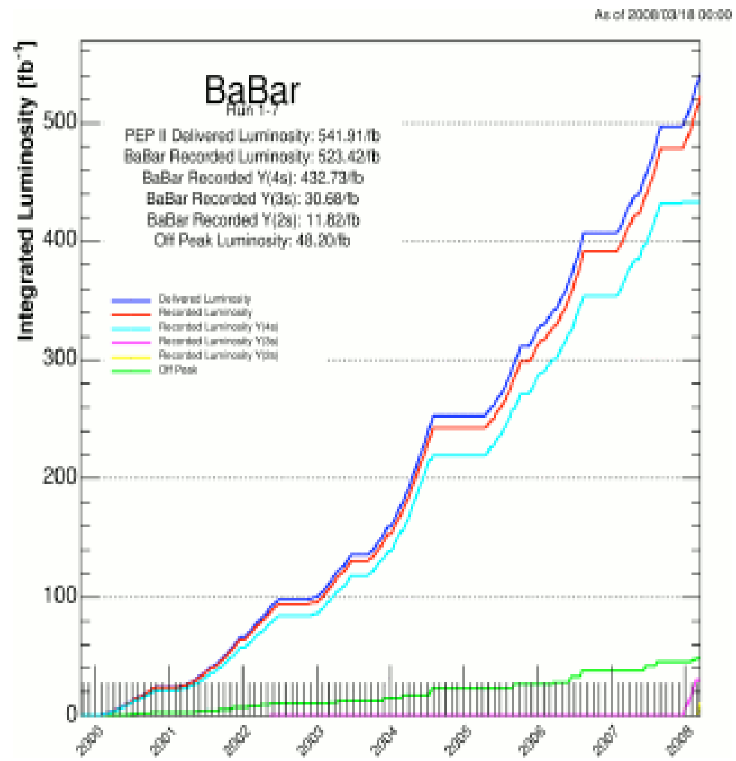
- **BaBar** is a B-factory: 1999-2007 ☞ ~ 433fb^{-1} @ Υ(4S) (on-peak data)
  end of Dec07- end of Feb08 ☞ 30fb^{-1} @ Υ(3S)
  end of Feb08-6th of April08 ☞15fb^{-1} @ Υ(2S)
  scan around Υ(4S) (25pb^{-1} every 5 MeV)

- The main goal of the BaBar Physics has been the measurement of the sides and angles of the Unitarity Triangle, and rare decays.

- B-factories have been demonstrated to be also a **huge source of $c\bar{c}$ production**.

- The spectrum of Heavy Quarkonium states is an ideal place to provide precision tests of QCD.

- Very accurate calculations are possible using Lattice techniques.
  M_c~1.5 GeV/c^2 is high enough to try to describe QCD in term of NRPM.



Heavy Spectroscopy in e^+e^- interactions @Y(4S)

BABAR

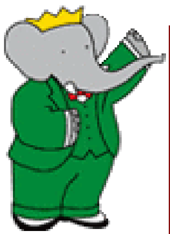
- Production in continuum:
  - $e^+e^- \rightarrow \psi \; X$ $(C_X=+)$
  - $e^+e^- \rightarrow \gamma_{ISR} X$ (only $J^{PC}=1^{--}$)
  - $\gamma\gamma \rightarrow X$ $(J_X \neq 1)$
- Production B decays:
  - $b \rightarrow c$ (color suppressed decay)
  - open-charm and charmonium
    ($c\bar{s}$ and $c\bar{c}$ meson, cqq baryons; $c\bar{c}$ +...)

charm and charmonium spectroscopy

- Transition $Y(4S) \rightarrow Y(2S)\pi^+\pi^-$, $Y(4S) \rightarrow Y(1S)\pi^+\pi^-$, $Y(4S) \rightarrow Y(1S)\eta$

bottomonium spectroscopy

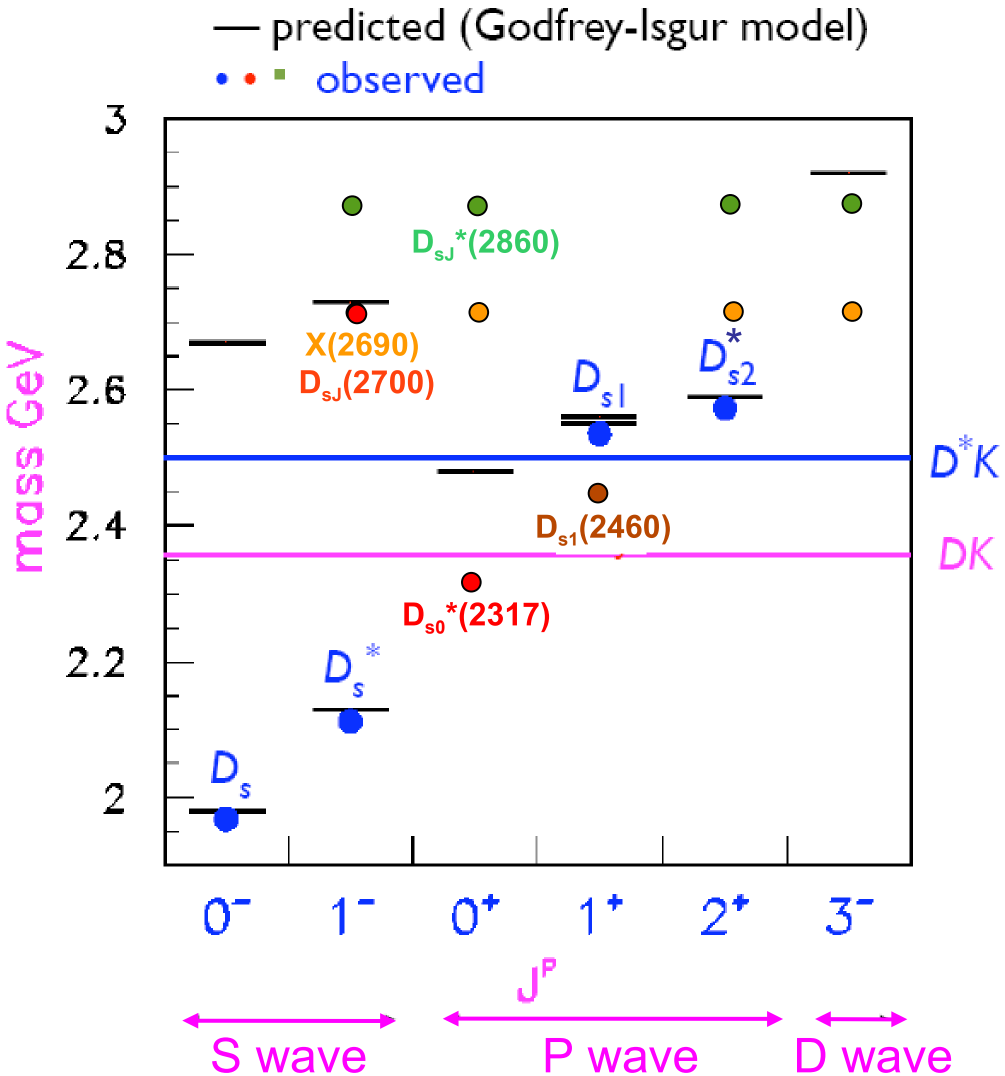
The main goal of the physics @*Y(3S)* and @*Y(2S)* will be the search of bottomonium states and light Higgs.



CHARMED MESONS

- $c\bar{s}$ mesons
  - **D_{s1}(2536)**: high precision measurements
  - **D_{s0}*(2317), D_{s1}(2460), D_{sJ}*(2860)**: charm-strange mesons
  - **X(2690)** and **D_{sJ}(2700)**: last surprise!

Overview of the recent results



- D_s*, $D_{s1}(2536)^+$, $D_{s2}(2573)^+$: well known, but J^P only **inferred** (not measured!)
- $D_{s0}*(2317)^+$ and **Ds1(2460)+** : unexpected observations of narrow resonances in **BaBar**. First two states observed at B-factories in $D_s^+\pi^0$ and $D_s^{*+}\pi^0$: they do not fit theoretical expectations . Mass, width, absolute BF fixed . Still unclear the interpretation, as more options are opened yet.
- **$D_{sJ}*(2860)^+$:** new state discovered by **BaBar**
- **$X(2690)^+$**: broad enhancement seen in **BaBar**
- **$D_{sJ}(2700)^+$**: new state discovered by Belle (is it X(2690)?)

$D_{s1}(2536)$

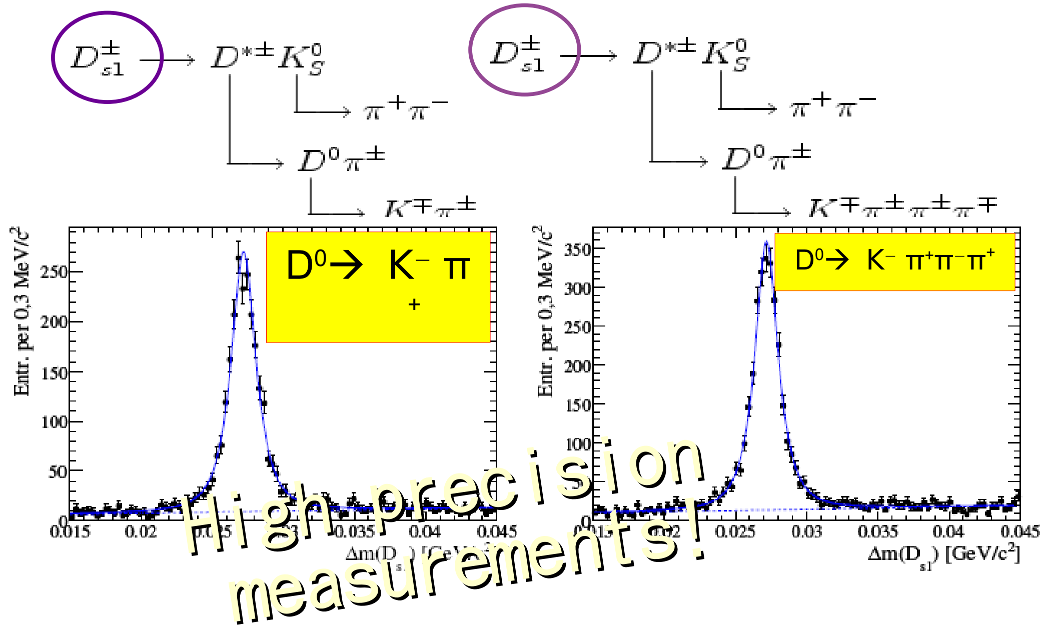
hep-ex/0607084 | 232 fb^{-1}

Study *in continuum*:

PDG07

$m(D_{s2})$ = (2535.35± 0.34±0.5)MeV/c^2
$m(D_{s1}) - m(D^*)$ = (525.3±0.6±0.1)MeV/c^2
$\Gamma(D_{s1})$ < 2.3 MeV

$m(D_{s1})$ = (2535.85± 0.02±0.40)MeV/c^2
$m(D_{s1}) - m(D^*)$ = (525.85±0.02±0.04)MeV/c^2
$\Gamma(D_{s1})$ = (1.03± 0.05±0.12)MeV

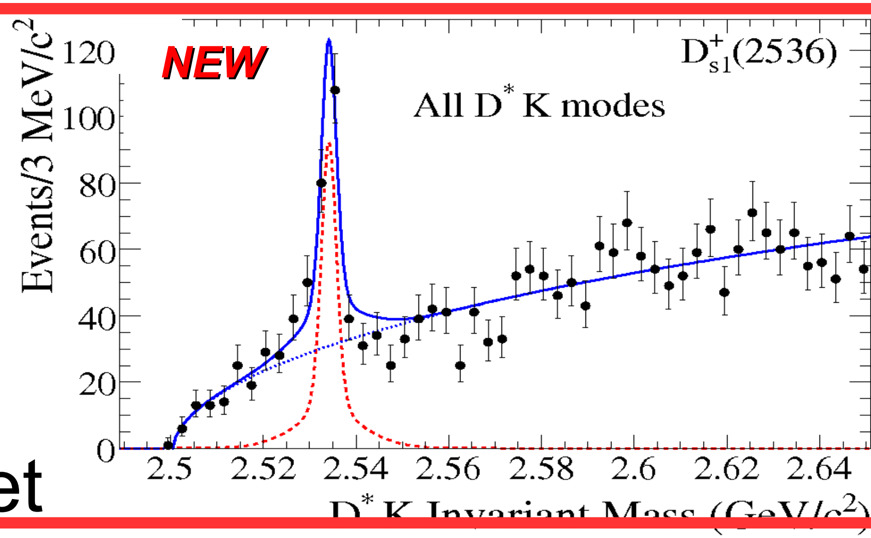


PRD97, 011102 | 347 fb^{-1}

- First observation of D_{s1} in B decays
  - B → $D^{(*)}D_{s1}$ (8 modes), D_{s1} → D*K

m = (2534.78±0.31±0.40) MeV/c^2

- J^P quantum number:
  - Statistics **too low** to conclude yet



PRL 97, 202001

PRL 97, 222001

hep-ex/0607245

hep-ex/0606139

Inclusive DK studies

- Channels under study:

$e^+e^- \rightarrow D^0K^+X;\ D^+K^0_SX$

$p^*(DK) > 3.5$ GeV/c

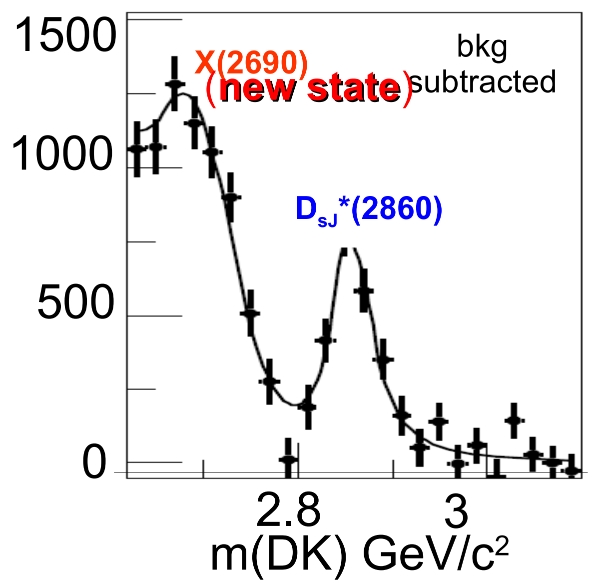
240 fb^{-1}

- Added the three modes

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

$D^+ \rightarrow K^- \pi^+ \pi^+$

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



Another new resonance at 2690 MeV/c²?

Or just a reflection?

- no signal in sidebands and $c\bar{c}$-MC
- also seen in other places...

$m(X(2690)) = 2688 \pm 4 \pm 3$ MeV/c^2

$\Gamma(X(2690)) = 112 \pm 7 \pm 36$ MeV

$m(D_{SJ}^*(2860)) = 2856.6 \pm 1.5 \pm 5.0$ MeV/c^2

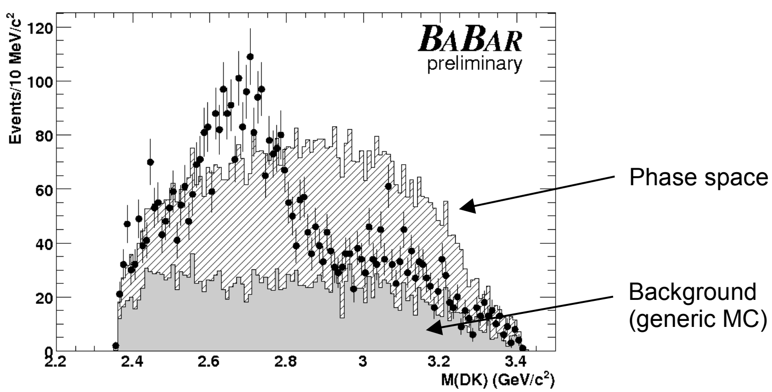
$\Gamma(D_{SJ}^*(2860)) = 47 \pm 7 \pm 10$ MeV

347 fb^{-1}

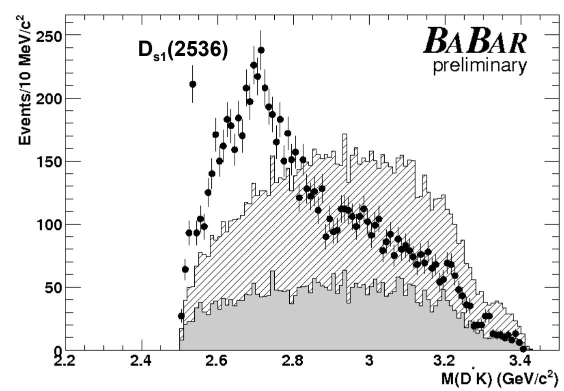
D_{sJ}(2700): another surprise?

- New resonance decaying to D^0K^+ discovered by *Belle* in $B^+ \to D^0(D^0K^+)$
  - **D_{sJ}(2700)**
- Same resonance as seen by **BaBar** in continuum, **X(2690)**?
  - **Mass** and **width** consistent, same decay mode
- Study of $B \to D^{(*)}D^{(*)}K$ decays in BaBar
  - Looking at 8 DK + 8 D*K invariant masses

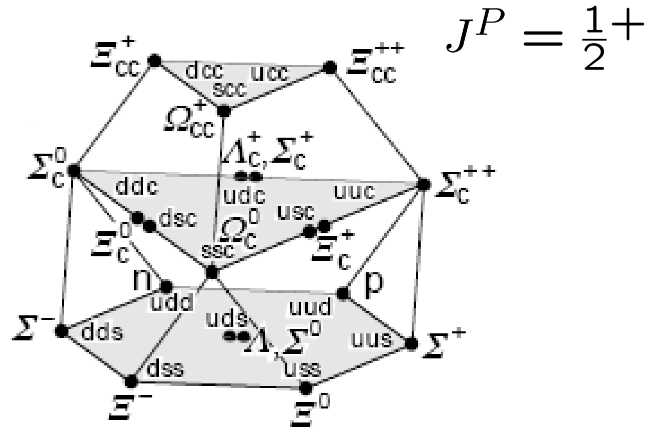
Summing all 8 DK modes

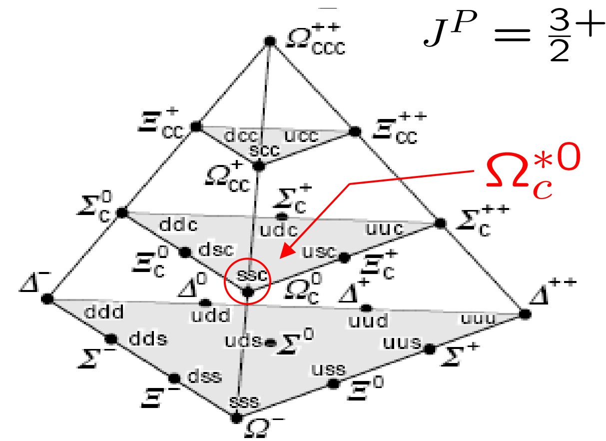


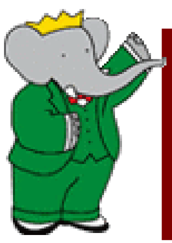
Summing all 8 D*K modes



- Enhancement observed around 2700 MeV/c^2 in DK and D*K
- Complex structure, full Dalitz plot analysis is ongoing.

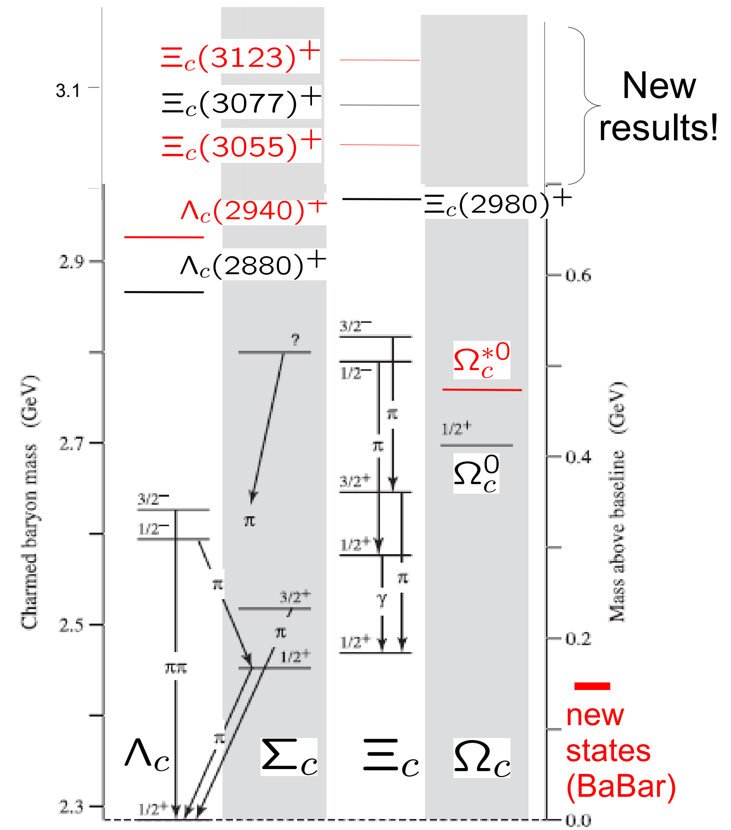






CHARMED BARYONS

- charmed baryons
  - Observation of Ω_c^0 and discovery of Ω_c^{*0}
  - Discovery of $\Lambda_c(2940)$
  - Observation of $\Xi_c(2980)^+$ and $\Xi_c(3077)^+$
  - Discovery of $\Xi_c(3055)^+$ and $\Xi_c(3123)$



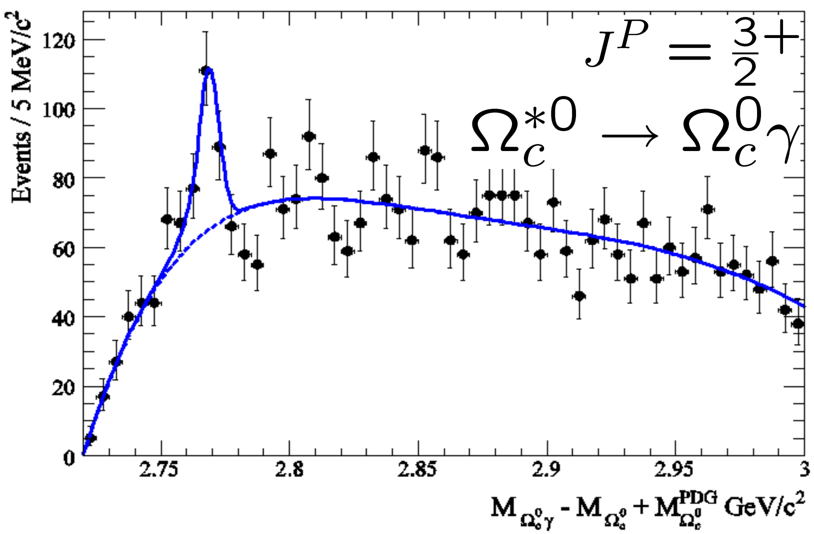
PRL 99(2007), 062001
PRL 97(2006), 232001

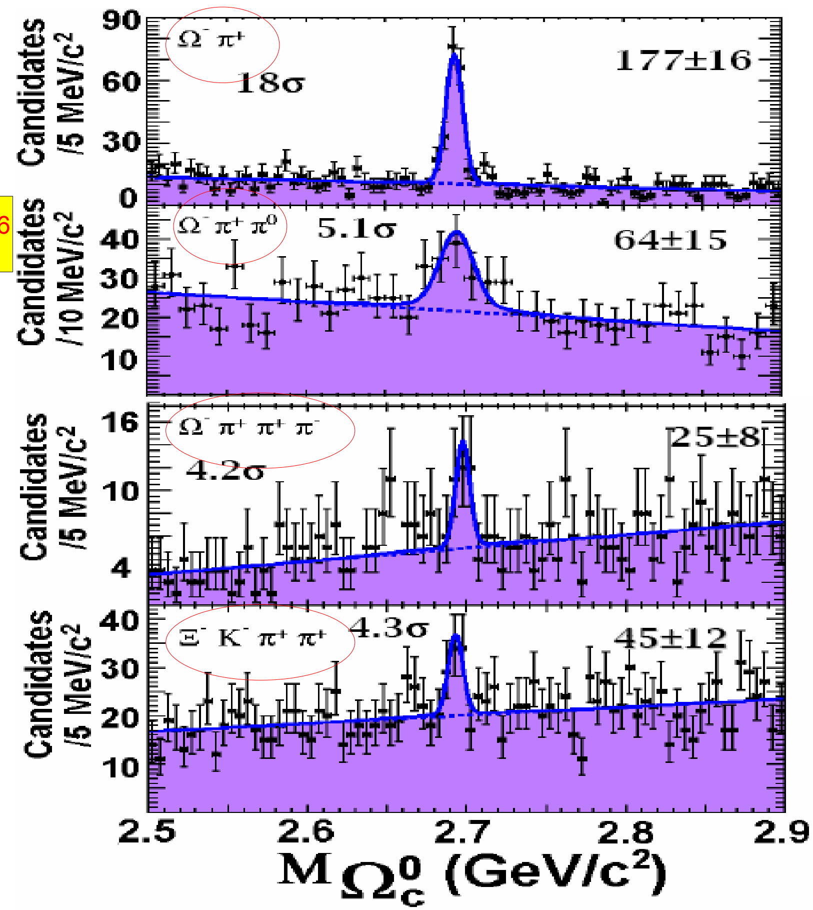
232 fb^{-1}

Study of Ω_c^0 and Ω_c^{*0}

- Ω_c^0: **css** charm baryon ground state
- Observed in 4 modes
- First observation of $B \rightarrow \Omega_c^0 X$

$B(B \rightarrow \Omega_c^0 X) \times B(\Omega_c^0 \rightarrow \Omega^- \pi^+) = (5.2 \pm 0.9 \pm 0.5) \times 10^{-6}$





Theory range Δm = 50 – 94 MeV/c^2

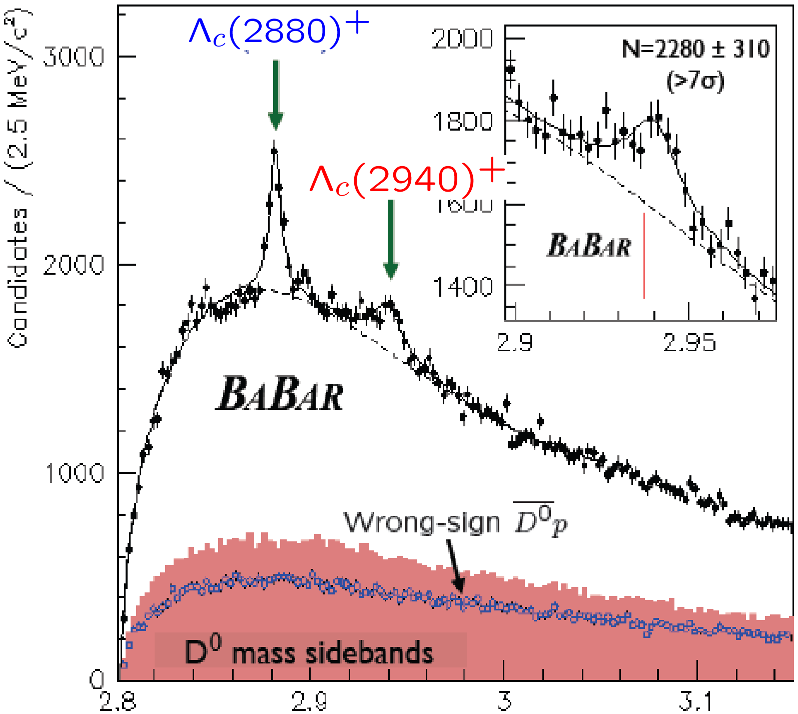
$m(\Omega_c^{*0}) - m(\Omega_c^0) = (70.8 \pm 1.0 \pm 1.1) MeV/c^2$

$$\frac{\sigma(e^+e^- \rightarrow \Omega_c^{*0})}{\sigma(e^+e^- \rightarrow \Omega_c^0)} = 1.01 \pm 0.23 \pm 0.11$$

Discovery of $\Lambda_c(2940)$

PRL 98, 012001

287 fb^{-1}



	M MeV/c^2	Γ, MeV
BaBar $\Lambda_c(2940)^+$	$2939.8 \pm 1.3 \pm 1.0$	$17.5 \pm 5.2 \pm 5.9$
Belle $\Lambda_c(2940)^+$	$2938.0 \pm 1.3^{+2.0}_{-4.0}$	13^{+8+27}_{-5-7}
CLEO $\Lambda_c(2880)^+$	$2882 \pm 1 \pm 2$	$4 \pm 2 \pm 2$
BaBar $\Lambda_c(2880)^+$	$2881.9 \pm 0.1 \pm 0.5$	$5.8 \pm 1.5 \pm 1.1$
Belle $\Lambda_c(2880)^+$	$2881.2 \pm 0.2 \pm 0.4$	$5.8 \pm 0.7 \pm 1.1$

- Decay mode: D^0p
- Known state: $\Lambda_c(2880)^+$

New decay mode;

More precise measurement of the *mass* and Γ!

- New state: $\Lambda_c(2940)^+$
- First observation of charmed baryon decay to D and light baryon

$m(\Lambda_c(2880)^+)$ =2881.9±0.1±0.5 *MeV/c*^{2}

$\Gamma(\Lambda_c(2880)^+)$ = 5.8±1.5±1.1 *MeV*

$m(\Lambda_c(2940)^+)$ =2939.8±1.3±1.0 *MeV/c*^{2}

$\Gamma(\Lambda_c(2940)^+)$ = 17.5±5.2±5.9 *MeV*

Excited charm-strange baryons

hep-ex/ 0607042
hep-ex/ 0710.5763

316 fb^{-1}

New state:

$\Xi_c(3055)^+$

m(Ξ_c^+) = 3054.2±1.2±0.5 *MeV/c*^{2}
Γ(Ξ_c^+) = 17±6±11 *MeV*
Yields = 218±53±79
significance: 6.4σ

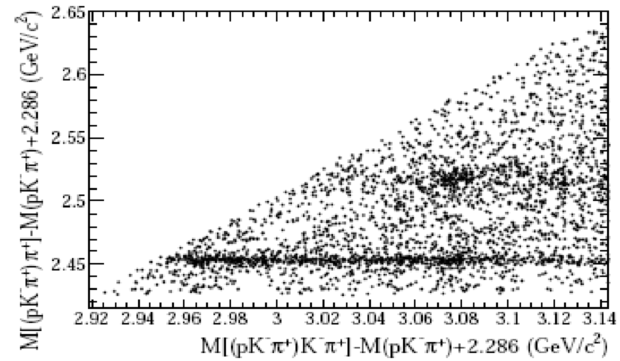
Evidence for:

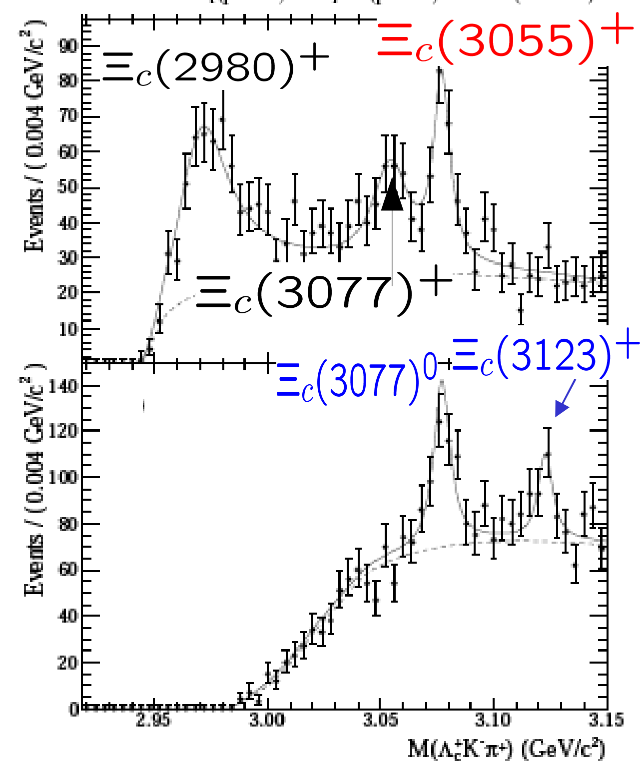
$\Xi_c(3123)^+$

m(Ξ_c^+) = 3122.9±1.3±0.3 *MeV/c*^{2}
Γ(Ξ_c^+) = 4.4±3.4±1.7 *MeV*
Yields = 101±34±9
significance: 3.6σ

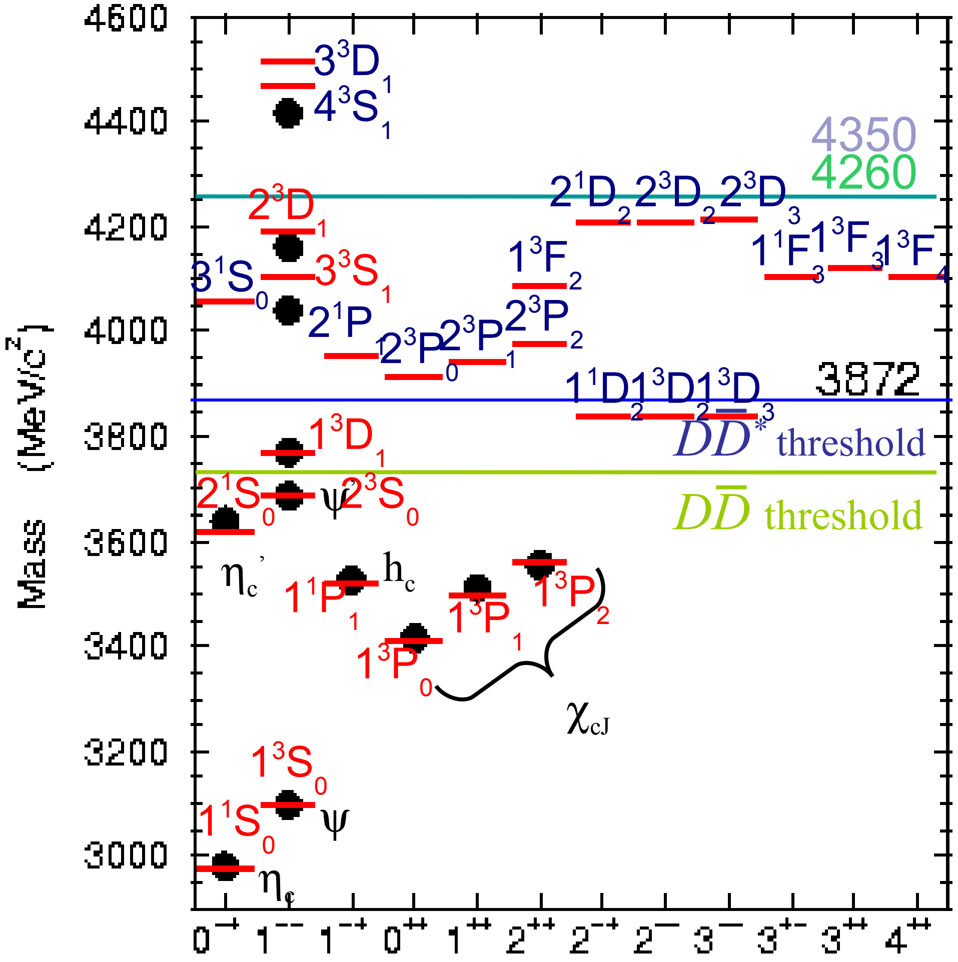
Smaller values of *m* and *Γ* due to treatment of proximity to threshold

	Mass (MeV/c^2)	Width (MeV)	Yield (Events)	Significance
BABAR $\Xi_c(2980)^+$	2967.1 ± 1.9 ± 1.0	23.6 ± 2.8 ± 1.3	284 ± 45 ± 46	7.0σ
Belle $\Xi_c(2980)^+$	2978.5 ± 2.1 ± 2.0	43.5 ± 7.5 ± 7.0	405 ± 51	6.3σ
BABAR $\Xi_c(3077)^+$	3076.4 ± 0.7 ± 0.3	6.2 ± 1.6 ± 0.5	204 ± 35 ± 12	8.6σ
Belle $\Xi_c(3077)^+$	3076.7 ± 0.9 ± 0.5	6.2 ± 1.2 ± 0.8	326 ± 40	9.7σ





CHARMONIUM SPECTROSCOPY

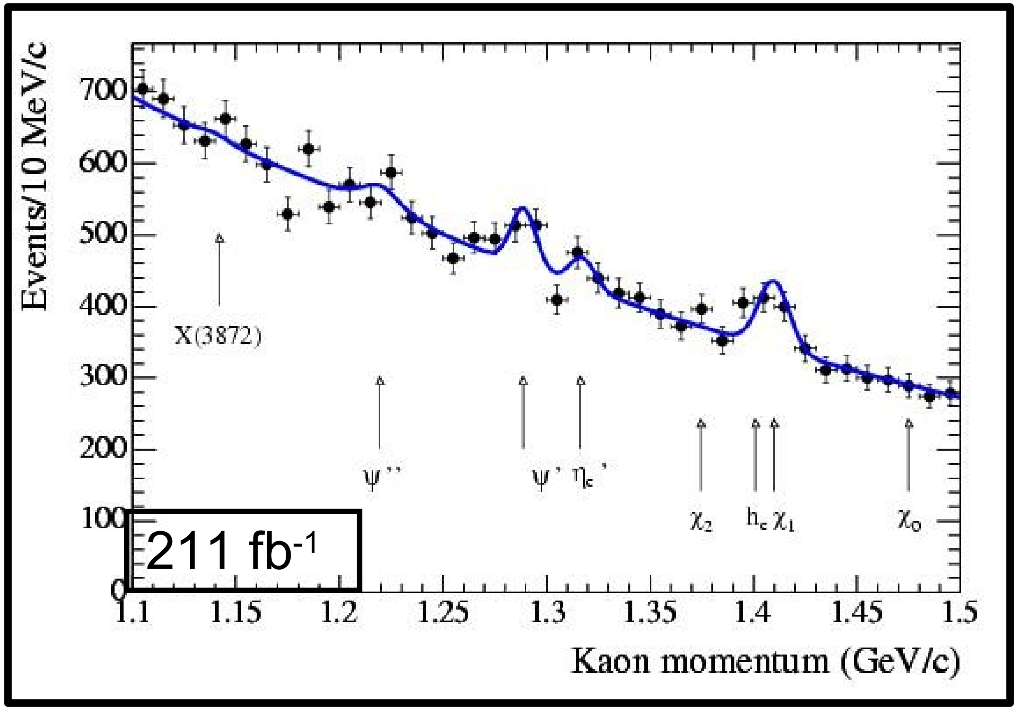


Update on:

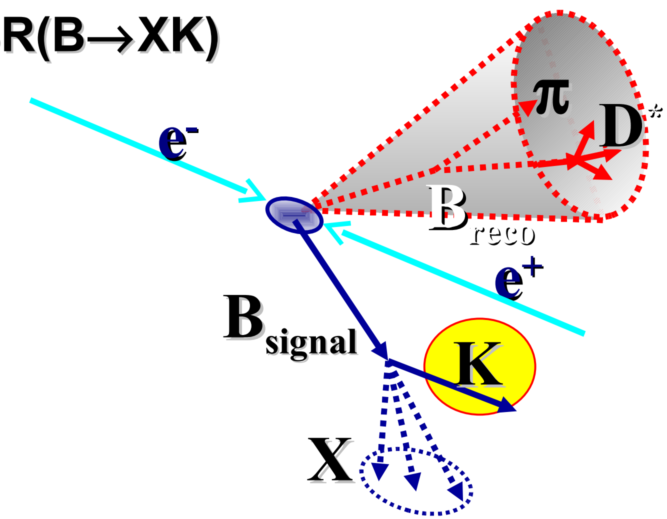
- **X(3872)**
- **Y(3940)**
- **Y(4260)**
- **Y(4350)**

PRL96, 052002

Inclusive searches @ BaBar: B→XK



- Fully reconstruct B_{reco} in hadronic modes
- The **X** mass distribution can be obtained from the momentum distribution of **$K^{\pm}$**
- Huge background due to secondary $K^{\pm}$ tracks
- Observation of X states independent from the decay mode
- **Absolute measurement of BR(B→XK)**



From BaBar-Belle average:

$BR(B^{\pm}\rightarrow X(3872)K^{\pm}, X(3872)\rightarrow J/\psi\pi^{+}\pi^{-})=$
$=(13.3\pm2.5)\cdot10^{-6}$

$BR(B^{\pm}\rightarrow X(3872)K^{\pm})<3.2\cdot10^{-4}$ at 90% CL
$BR(X(3872)\rightarrow J/\psi\pi^{+}\pi^{-})>4.2\%$ at 90% CL

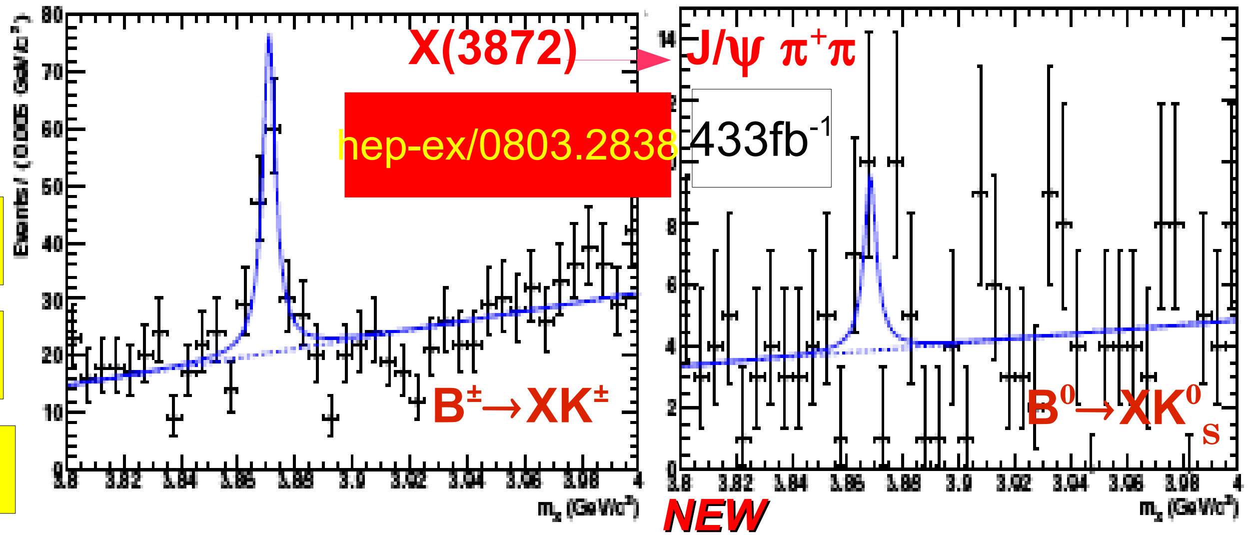
Exclusive searches @ BaBar: B→XK

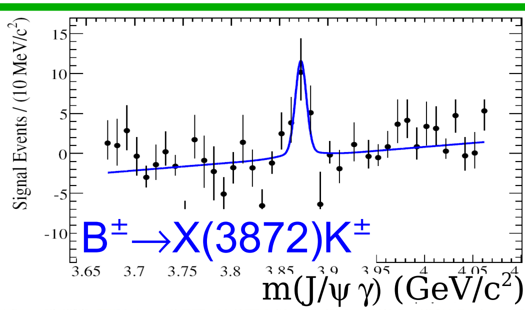
- Update on the study: B→XK, X→J/ψππ

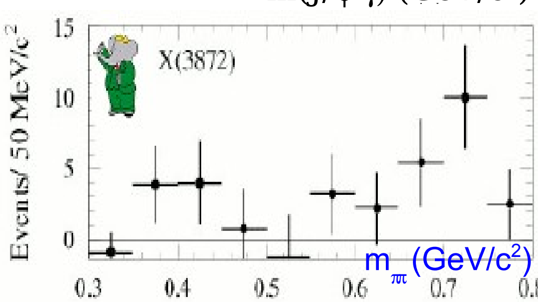
R(B^0/$B^{\pm}$) = 0.41±0.24±0.05

ΔM =(2.7±1.6±0.4) MeV/c^2

Γ < 3.3 MeV @90%CL







- $B^{\pm}$→ J/ψ γ $K^{\pm}$
  X→J/ψ γ

260 fb^{-1}

PRD74, 071101

- Invariant 2π-mass:
  S-wave J/ψρ favoured
  J^{++} favoured over J^{-+}

- **C=+** for the X(3872)
- I=1 for the (ππ) in J/ψ$\pi^+\pi^-$;
- forbidden J/ψ$\pi^0\pi^0$, J/ψπ^0, J/ψη
- **I=0** favored for X(3872);
  the J/ψ$\pi^+\pi^-$ decay is
  I-violating (small width)
- Decay X(3872)→J/ψρ against charmonium hypothesis:
  no charged partner found!

Still some surprises: $B \to (D\bar{D})_X K$

PRD77, 011102

347 fb^{-1}

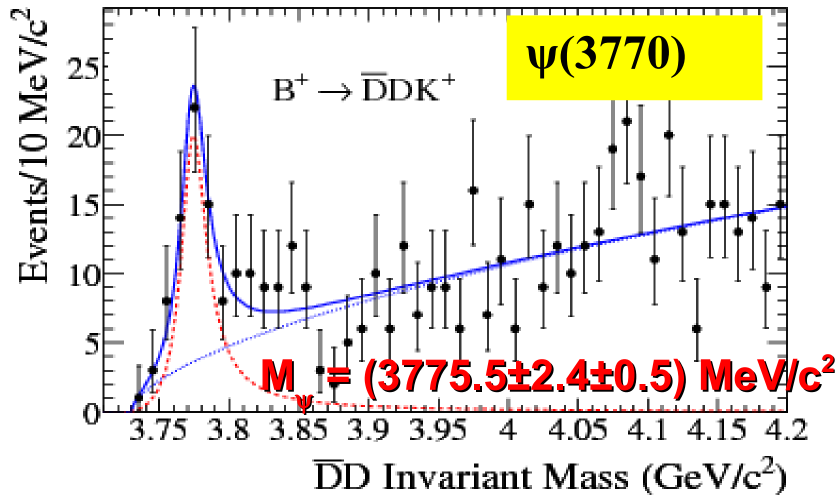
- BaBar studied the channels:

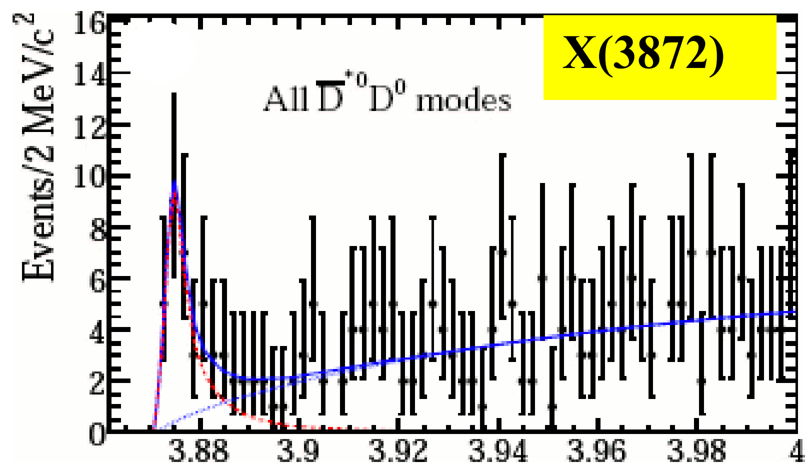
$B^+ \to D^0\bar{D}^{*0}K^+ + D^{*0}\bar{D}^0K^+$
$B^0 \to D^0\bar{D}^{*0}K^0 + D^{*0}\bar{D}^0K^0$

$D^{*0} \to D^0\gamma$ and $D^0\pi$

- Measurements:
  - $\Delta M = (0.2 \pm 1.6) MeV/c^2$
  - $R(B^0/B^\pm) = (1.33 \pm 0.69 \pm 0.43)\ MeV/c^2$
  - $R \left(\frac{X(3872) \to D^0\bar{D}^0\pi^0}{X(3872) \to D^0\bar{D}^0\gamma} \right) = 1.37 \pm 0.56$

experiment	Mass (MeV/c^2)
BABAR	$3875.2^{+0.7}_{-0.5} \pm 0.5$
BELLE	$3875.2 \pm 0.7^{+0.3}_{-1.6} \pm 0.8$





M is ~4.5σ away from the world average in $J/\psi\pi$

R Expected: 1.3 for a state proceeding only via D^0D^{0*}

Even more: $B\to YK$, $Y\to J/\psi\omega$, $\to \pi^+\pi^-\pi^0$

$$M(Y) = (3914.6^{+3.8}_{-3.4}(stat)^{+1.9}_{-1.9}(syst))\ \mathrm{MeV}/c^2$$
$$\Gamma(Y) = (33^{+12}_{-8}(stat)^{+5}_{-5}(syst))\ \mathrm{MeV}$$

$B \to Y K$

$$\mathcal{B}(B^+) = (4.9^{+1.0}_{-1.0}(stat)^{+0.5}_{-0.5}(syst)) \times 10^{-5}$$
$$\mathcal{B}(B^0) = (1.5^{+1.4}_{-1.2}(stat)^{+0.2}_{-0.2}(syst)) \times 10^{-5}$$

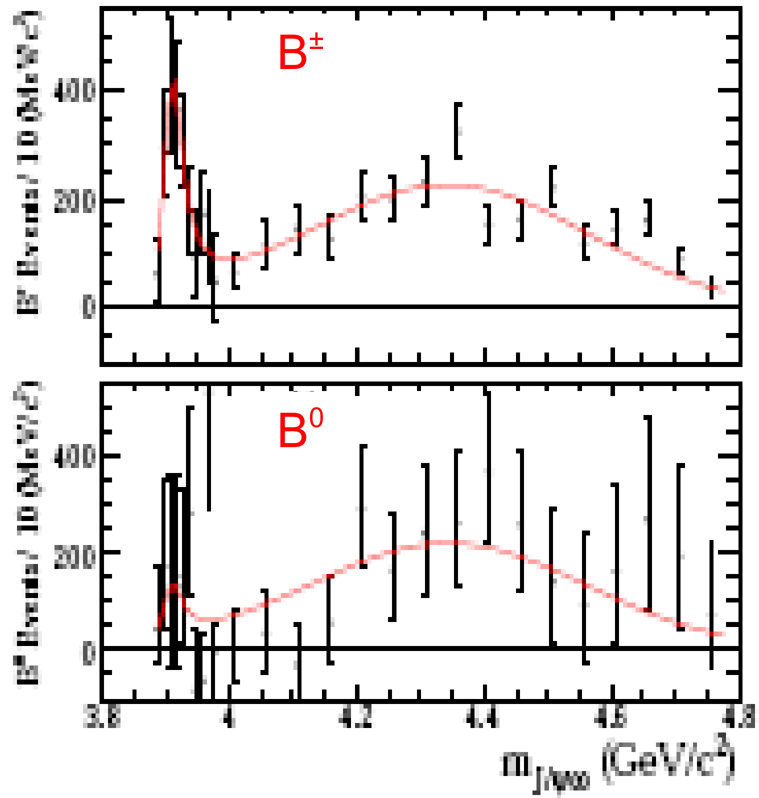
$B \to J/\psi\omega\ K$

$$\mathcal{B}(B^+_{tot}) = (3.5^{+0.2}_{-0.2}(stat)^{+0.4}_{-0.4}(syst)) \times 10^{-4}$$
$$\mathcal{B}(B^0_{tot}) = (3.0^{+0.6}_{-0.6}(stat)^{+0.3}_{-0.3}(syst)) \times 10^{-4}$$

$R_1(B^0/B^+) = 0.30^{+0.29}_{-0.24}(stat)^{+0.04}_{-0.01}(syst)$ signal region

$R_2(B^0/B^+) = 0.94^{+0.23}_{-0.21}(stat)^{+0.03}_{-0.02}(syst)$ non resonant contribution

- The measured values are corrected for efficiency and resolution effects



hep-ex/0711.2047 | 347 fb^{-1}

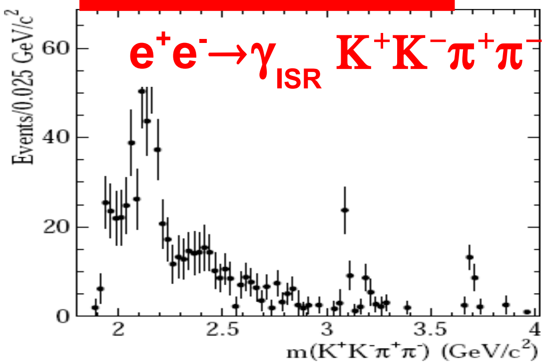
Study in ISR production

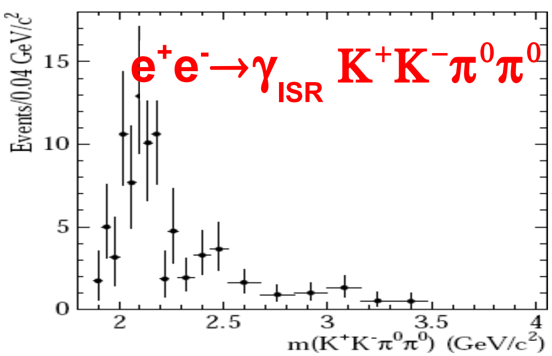
- What are these new structures?

First observed at BaBar $J^{PC}=1^{--}$

232 fb^{-1}

PRD74,091103



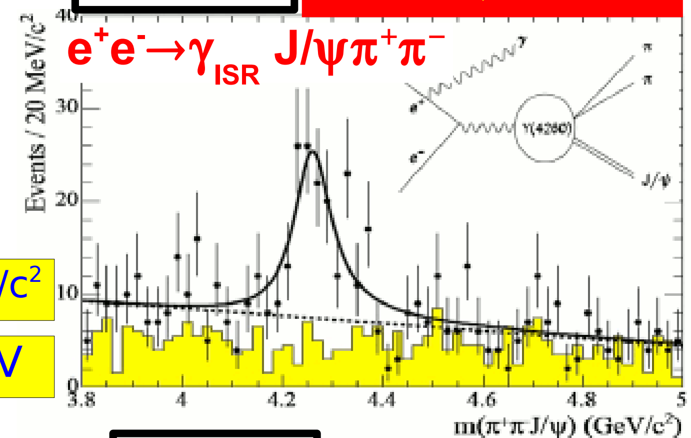


$M = (2175\pm10\pm15)$ MeV/c^2

$\Gamma = (58\pm16\pm20)$ MeV

233 fb^{-1}

PRL95, 142001

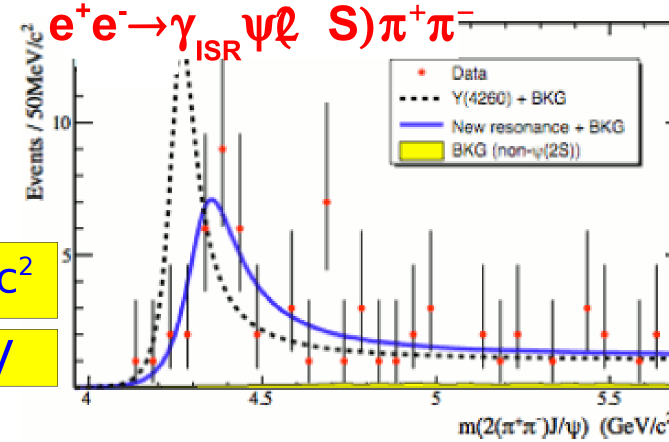


$M_Y = 4259\pm8^{+2}_{-6}$ MeV/c^2

$\Gamma_Y = 88\pm23^{+6}_{-4}$ MeV

298 fb^{-1}

PRL98,212001



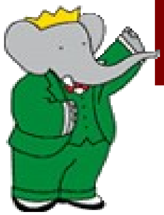
$M = (4324\pm24)$ MeV/c^2

$\Gamma = (172\pm33)$ MeV

See the A. Denig's talk!

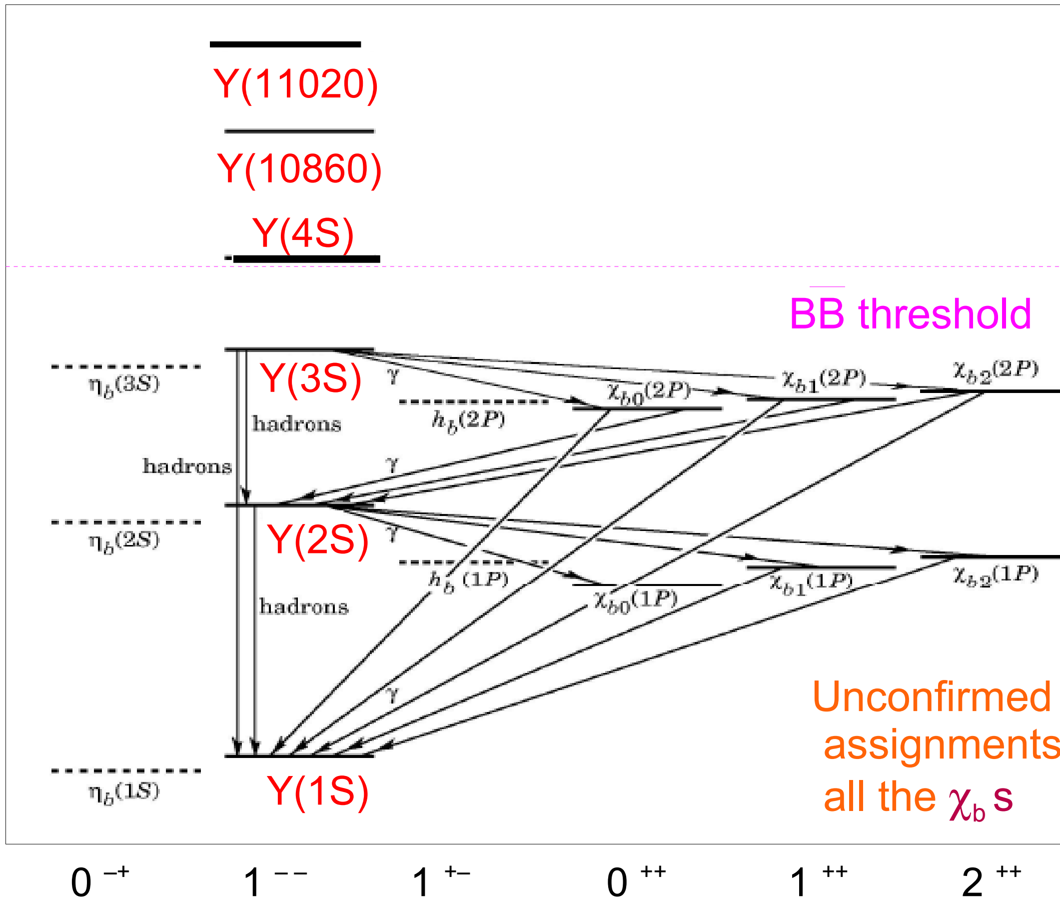
- **Incompatible** with Y(4260)
- **Incompatible** with ψ(4415)
- **Compatible** with Y(4295) *Belle*

BOTTOMONIUM SPECTROSCOPY



2 h_b and 3 D wave states are narrow but not observed

η_b completely missing



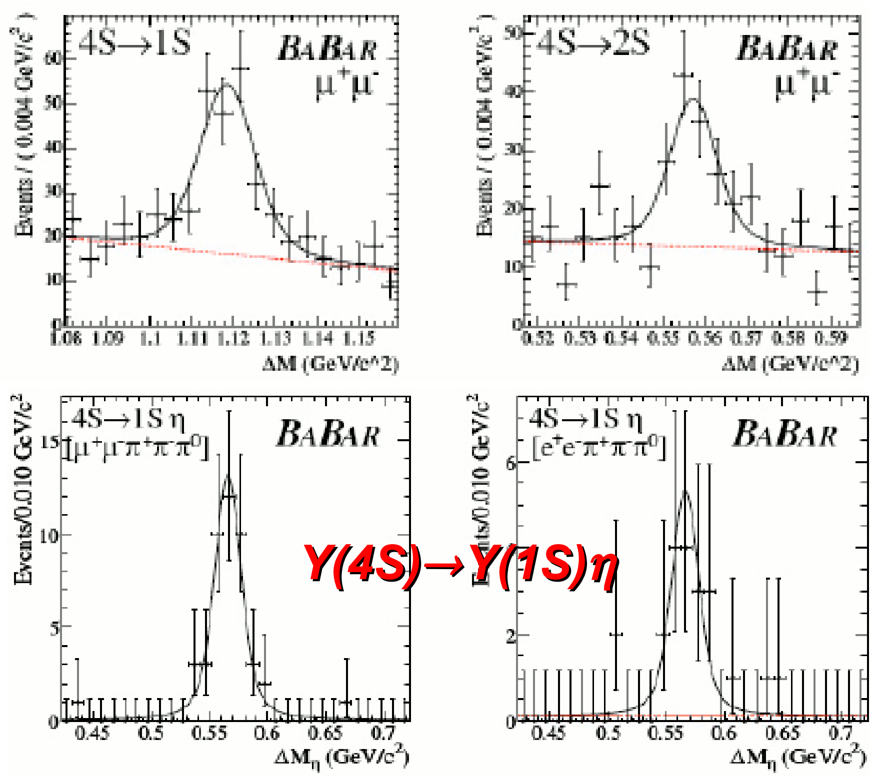
PRL96, 232001

230 M Υ(4S)

Bottomonium @ Υ(4S)

BABAR

- Non $B\bar{B}$ decays
- Transitions: **$\Upsilon(4S) \to \Upsilon(2S)\pi^+\pi^-$**
  $\Upsilon(4S) \to \Upsilon(1S)\pi^+\pi^-$



$\Upsilon(4S) \to \Upsilon(1S)\eta$

$B_{4S\to 1S\eta} = (1.96\pm0.060.09)\times10^{-4}$

$B_{4S\to 2S} = (1.29\pm0.32)\times10^{-4}$
$\Gamma_{4S\to 2S} = (2.7\pm0.8)$ keV

$B_{4S\to 1S} = (0.90\pm0.15)\times10^{-4}$
$\Gamma_{4S\to 1S} = (1.8\pm0.4)$ keV

Unexpected result:

$$\frac{\Gamma_{4S\to 1S\eta}}{\Gamma_{4S\to 1S\pi\pi}} = 2.41\pm0.40\pm0.12$$

E1M2/
E1E1

Summary

What is in the  *zoo?*

EXP	STATE	MASS (MeV/c²)	Γ (MeV)	J^{PC}	DECAY MODE	PRODUCTION MECHANISM
Belle CDF, D0 BaBar	X(3872)	3871.2±0.5	< 2.3	1^{++}	$\pi^+\pi^- J/\psi$ $\pi^+\pi^-\pi^0 J/\psi$	B decays, $p\bar{p}$
Belle BaBar		$3875.4 \pm 0.7^{+1.2}_{-2.0}$ $3875.1^{+0.7}_{-0.5} \pm 0.5$	$3.0^{+1.9}_{-1.4} \pm 0.9$	$(2^{++}$?)	$D^0 D^0 \pi^0$ DD^*	B decays
Belle	Z(3930)	3929±5±2	29±10±2	2^{++}	$D^0 D^0$, $D^+ D^-$	$e^+e^- \to J/\psi X$
Belle BaBar	Y(3940)	3943±1.1±1.3 $3914.6^{+3.8}_{-3.4} \pm 1.9$	87±22±26 $33^{+12}_{-8} \pm 5$	$?^{??}$	$\omega J/\psi$	B decays
Belle	X(3940)	$3942^{+7}_{-6} \pm 6$	$37^{+25}_{-15} \pm 8$	$?^{?+}$	DD^*	γ
Belle	Y(4008)	$4008 \pm 40^{+72}_{-28}$	$226 \pm 44^{+87}_{-79}$	1^{--}	$\pi^+\pi^- J/\psi$	B decays
Belle	Y(4160)	$4156^{+15}_{-20} \pm 15$	$139^{+111}_{-61} \pm 21$	$?^{?+}$	$D^* D^*$	$e^+e^- \to J/\psi X$
BaBar	Y(4175)	2175±10±15	58±16±20	1^{--}	$K^+K^-\pi\pi$	ISR
Babar CLEO Belle	Y(4260)	$4259 \pm 8^{+8}_{-6}$ $4284^{+17}_{-16} \pm 4$ $4247 \pm 12^{+17}_{-32}$	$88 \pm 23^{+6}_{-4}$ $73^{+39}_{-25} \pm 5$ 108±19±10	1^{--}	$\pi^+\pi^- J/\psi$ $\pi^0\pi^0 J/\psi$ $K^+K^- J/\psi$	ISR
Babar Belle	Y(4350)	4324±24 4361±9±9	172±33 74±15±10	1^{--}	$\pi^+\pi^-\psi(2S)$	ISR
Belle	Z(4430)	4433±4±1	$44^{+17}_{-13}{}^{+30}_{-11}$	$?^{??}$	$\pi^+\psi(2S)$	B decays
Belle	Y(4620)	4466±11±5	48±15±3	1^{--}	$\pi^+\pi^-\psi(2S)$	ISR

confirmed now also from BES → (Y(4175))

Theory still not clear.

Significant contribution from **BaBar** in these 9 years.

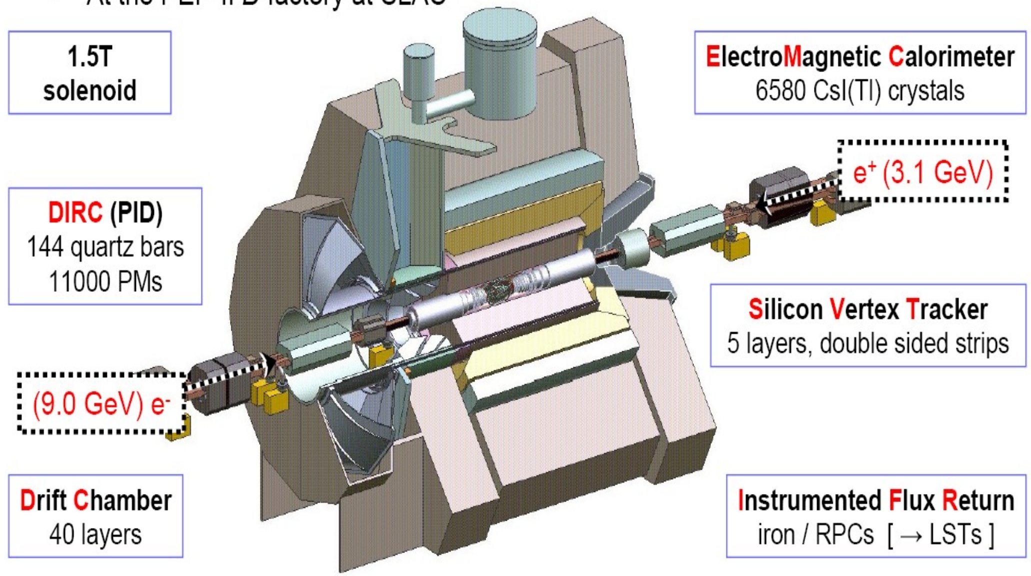
Important analyses are ongoing...

Backup slides

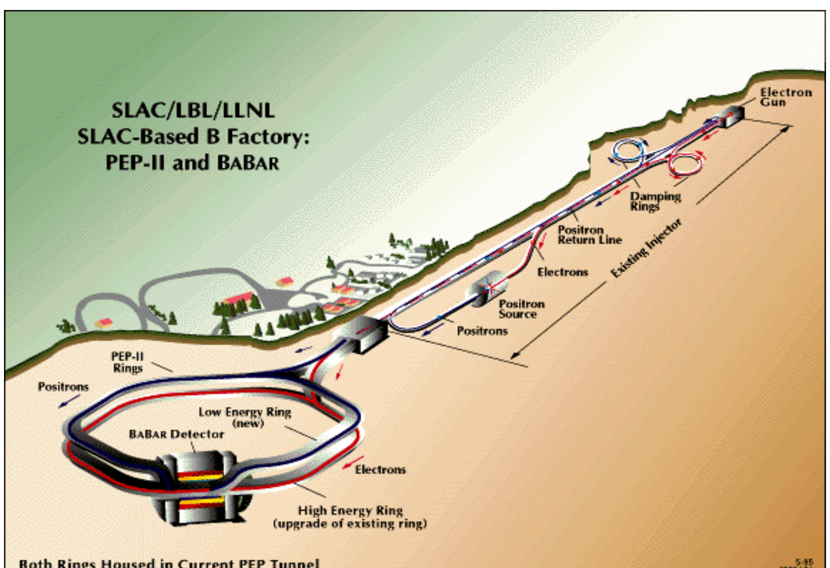
BaBar: Who? Where? What?

- Asymmetric e^+e^- beam @ PEPII
- Peak luminosity: $1.2\times10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- >500M $B\bar{B}$ produced (2007)

- At the PEP-II *B*-factory at SLAC

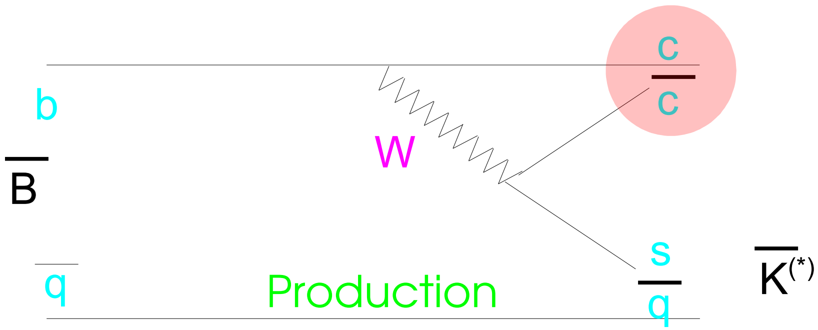


- *BABAR* collaboration consists 11 countries and 630 physicists!

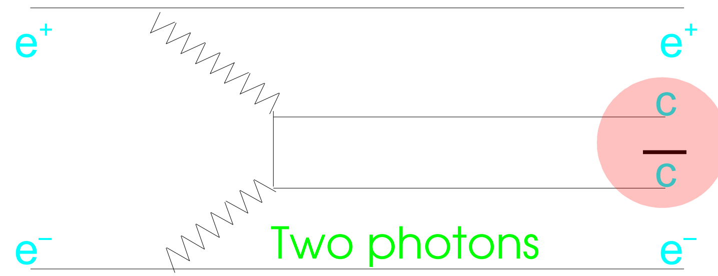


$\sqrt{s}$ = 10.58 GeV

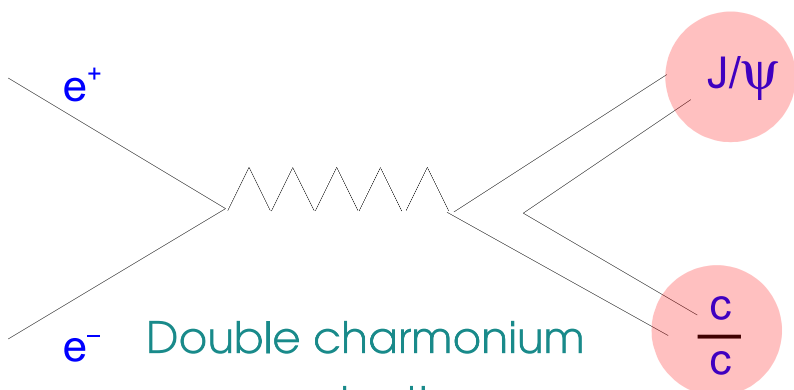
B-factory: charmonium production processes



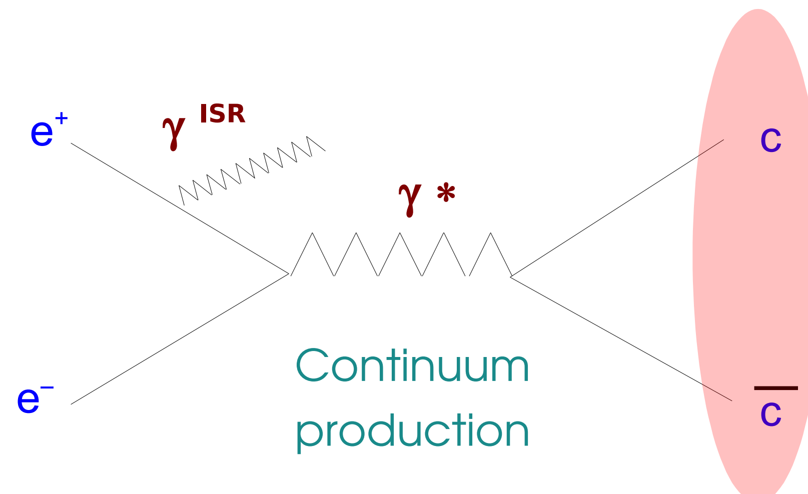
Production in B decays (color suppressed)



Two photons production



Double charmonium production



Continuum production

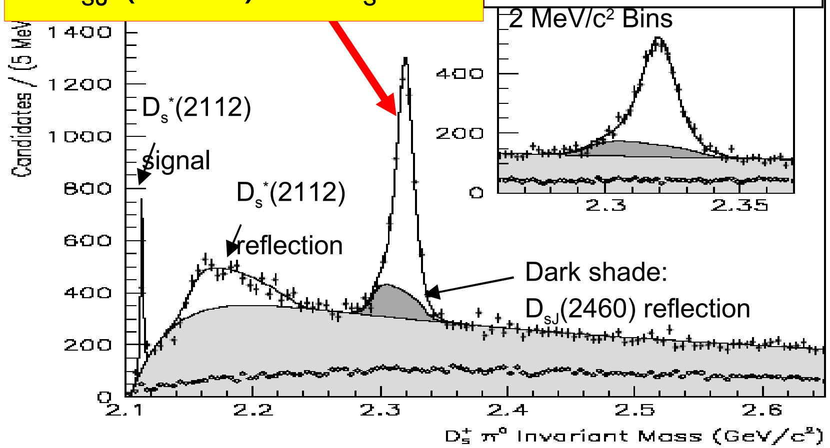
$D_{s0}^*(2317)$ and $D_{s1}(2460)$

- Discovered 4 years ago in $e^+e^- \to c\bar{c}$ events; subsequently observed in B decays
- $D_{s0}^*(2317)$ and $D_{s1}(2460)$ very well established and known experimentally
  - **Masses** and tight upper limits on **widths**
  - **J^P**: 0^+ for $D_{s0}^*(2317)$ and 1^+ for $D_{s1}(2460)$
  - **decay modes** and **absolute branching fractions**
- Interpretation of these new states still unclear!
  - One possibility: identify these 2 states as the **0^+ and 1^+ $c\bar{s}$ states**
  - Strong difficulties within the potential model
  - **Other** possible interpretations under examination

PRD 74,032007 | 232 fb^{-1}

Some additional plots

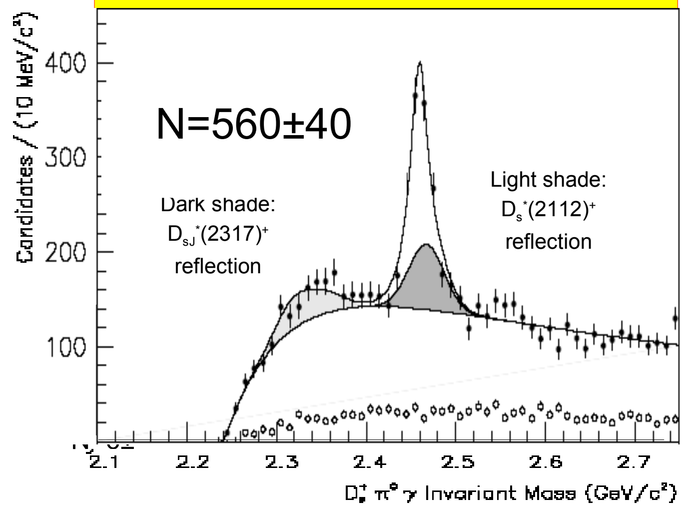
$D_{sJ}^{*}(2317)^{+} \rightarrow D_s^{+}\pi^0$ N=3180±80



$m = (2319.6 \pm 0.2 \pm 1.4)\ MeV/c^2$

$\Gamma < 3.8$ MeV @ 95% CL

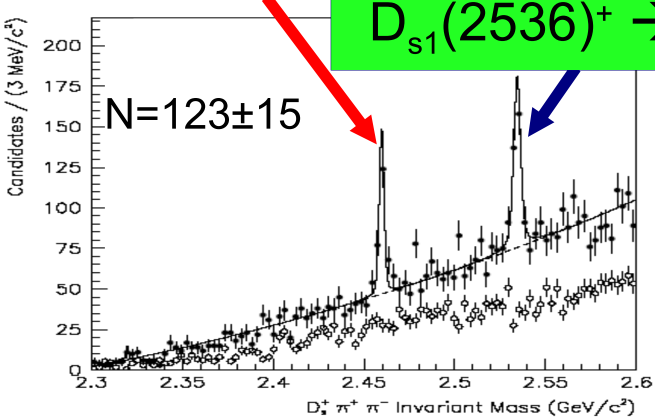
$D_{sJ}(2460)^{+} \rightarrow D_s^{+}\pi^0\gamma$



J^P of both states established from B decay processes

$D_{sJ}(2460)^{+} \rightarrow D_s^{+}\pi^{+}\pi^{-}$

$D_{s1}(2536)^{+} \rightarrow D_s^{+}\pi^{+}\pi^{-}$

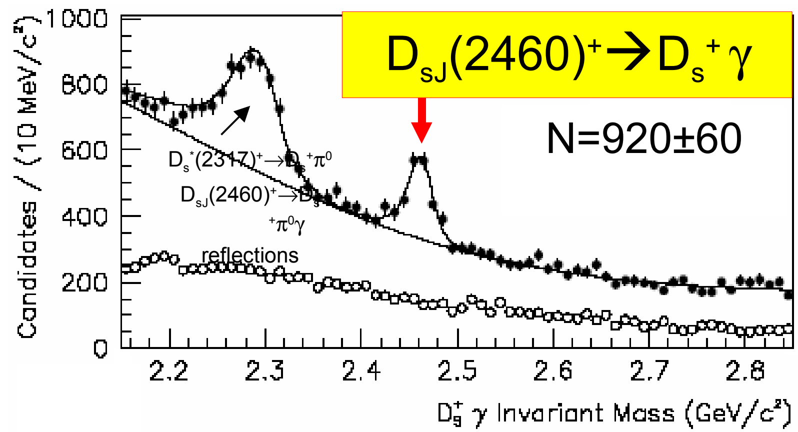


$m = (2460.2 \pm 0.2 \pm 0.8)\ MeV/c^2$ $\quad$ $m = (2534.6 \pm 0.3 \pm 0.7)\ MeV/c^2$

$\Gamma < 3.5$ MeV @ 95% CL $\quad$ $\Gamma < 2.5$ MeV @ 95% CL

$$\frac{B(D_{sJ}(2460)^{+} \rightarrow D_s^{+}\pi^{+}\pi^{-})}{B(D_{sJ}(2460)^{+} \rightarrow D_s^{+}\pi^{0}\gamma)} = 0.077 \pm 0.013 \pm 0.008$$

$D_{sJ}(2460)^{+} \rightarrow D_s^{+}\gamma$



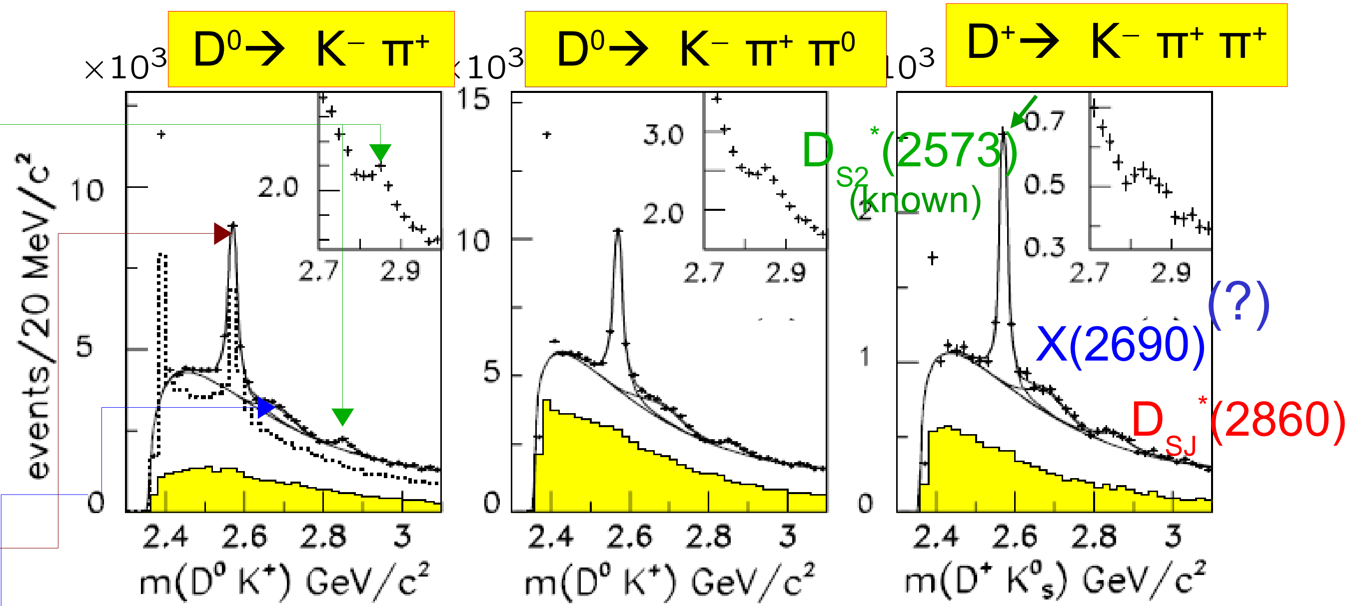
$m = (2460.2 \pm 0.2 \pm 0.8)\ MeV/c^2$

$\Gamma < 3.5$ MeV @ 95% CL

Inclusive DK studies : more details

PRL 97, 222001
hep-ex/0606110
hep-ex/0607245
hep-ex/0606139

240 fb^{-1}



$m(X(2690)) = 2688 \pm 4 \pm 3$ MeV/c²
$\Gamma(X(2690)) = 112 \pm 7 \pm 36$ MeV

$m(D_{S2}^*(2573)) = 2572.2 \pm 0.3 \pm 1.0$ MeV/c²
$\Gamma(D_{S2}^*(2573)) = 27.1 \pm 0.6 \pm 5.6$ MeV

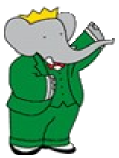
$m(D_{SJ}^*(2860)) = 2856.6 \pm 1.5 \pm 5.0$ MeV/c²
$\Gamma(D_{SJ}^*(2860)) = 47 \pm 7 \pm 10$ MeV

$e^+e^- \to D^0K^+X/D^+K^0_SX$

p(DK)* > 3.5 GeV/c

X(3872): Discovery

Belle: PRL 91 (2003) 262003
BaBar: PRD71 (2005) 071103
BaBar: PRD73 (2006) 011101
BaBar: PRD74 (2006) 071101
CDF: PRL93 (2004) 072001
D0: PRL93 (2004) 162002



Discovered by Belle:

M_X=(3871.2±0.5) MeV

old value

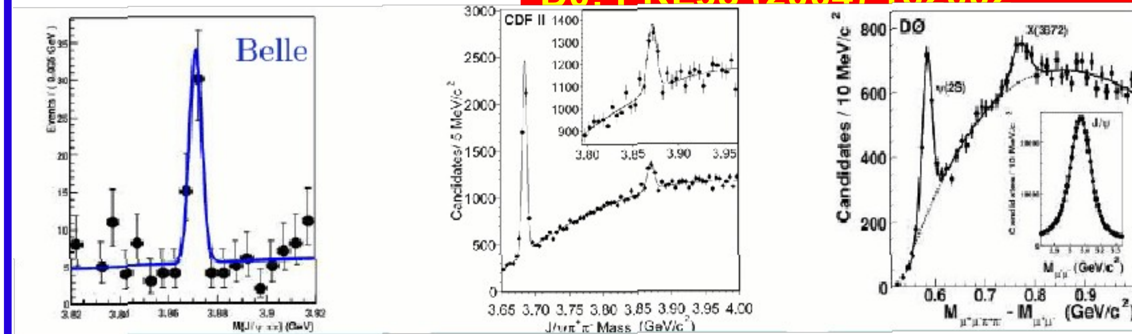
Confirmed by:

- BABAR
- CDF
- D0

M=3871.4 ± 0.6 MeV/c^2

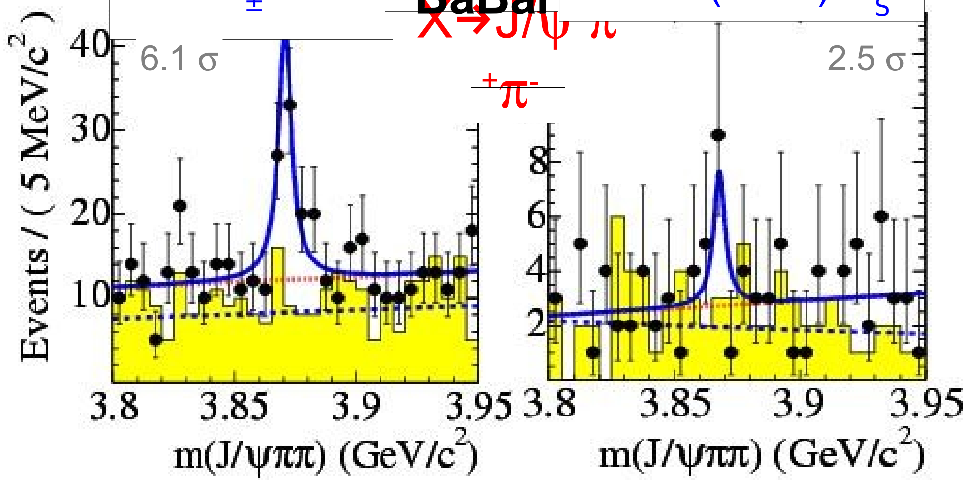
Γ < 2.3 MeV @90% CL

Combined results



$B^+ \rightarrow X(3872)K^+$

$\rightarrow J/\psi\ \pi^+\pi^-$



Search for X(3872) charged partners

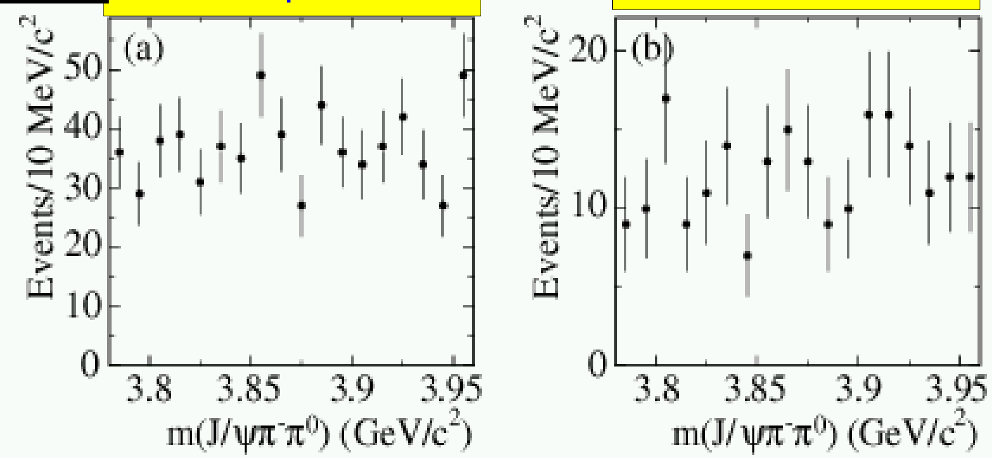
- Decay $X(3872) \to J/\psi\rho$ against charmonium hypothesis
- If X(3872) is not charmonium it could be isospin multiplet
- $BR(B \to X^- K) \sim 2\, BR(B \to X^0 K)$

PRD 71, 031501 (2005)

212 fb^{-1}

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

$B^- \to J/\psi\pi^-\pi^0K_s$

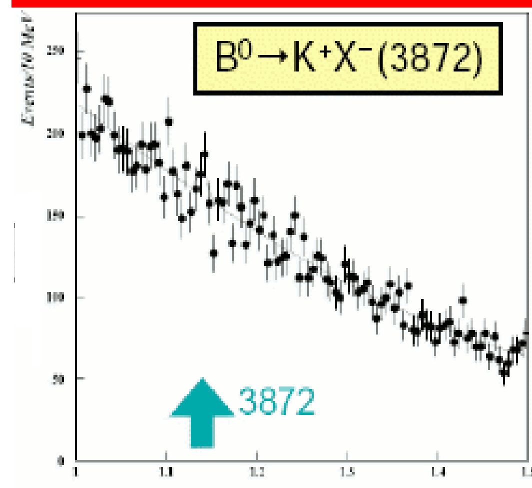


No charged partner observed

No evidence found!

I = 0 favored for X(3872)

PRL 96, 052002 (2006)



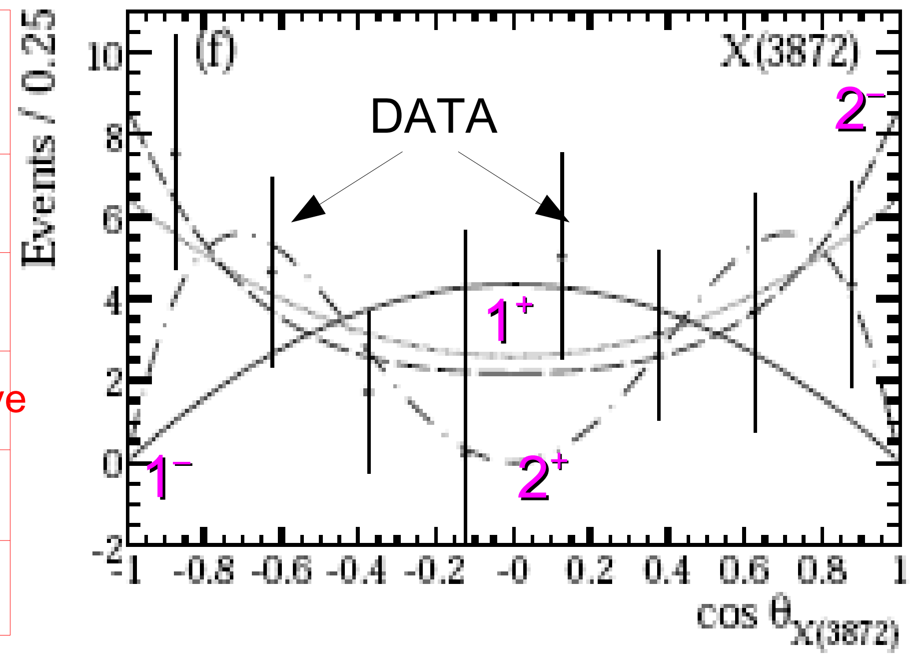
$BR(B^0 \to X^- K^+) \cdot BR(X^- \to J/\psi\pi^-\pi^0) < 5.4 \cdot 10^{-6}$ at 90% CL

$BR(B^- \to X^- K^0) \cdot BR(X^- \to J/\psi\pi^-\pi^0) < 22 \cdot 10^{-6}$ at 90% CL

Additional info on $X \to D\bar{D}$ analysis

$J^P = +$

J^P	$\chi^2/n.d.f$
1^-	9.8/7 S-wave
1^+	3.9/7 S-wave
1^+	2.5/6 S+D-wave
2^+	5.9/7
2^-	2.7/6



Comparison for X(3872) @ Babar

	ΔM (MeV/c^2)	R(R^0/B^+)
$B \to XK$	(2.7±1.6±0.4)	0.41±0.24±0.05
$B \to D\bar{D}^* K$	(0.2±1.6)	1.33±0.68±0.24

J= 1++ or J= 2++?
The molecular hypothesis is favored!!!

Is it a molecular state?

PRD71 (2005) 074005

Is it a 4-quark state?

PRD71 (2005) 014028

...what else?