Properties of known/expected mesons

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on behalf of the BABAR Collaboration

Outline:

A personal selection of recent and new results on heavy-"heavy" mesons

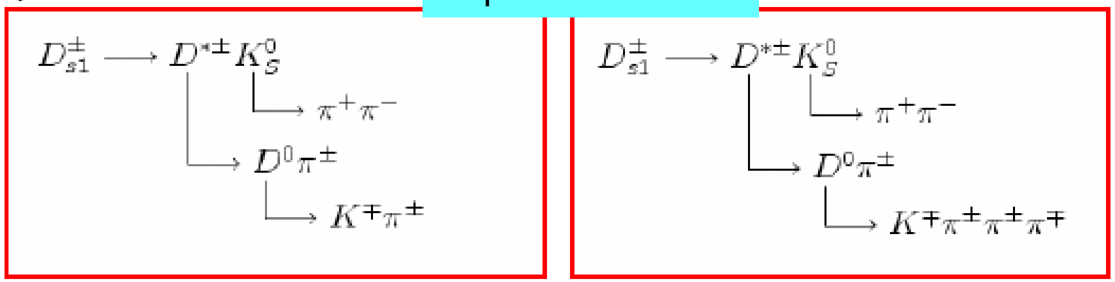
- D_{sJ} , $B_{sJ,}$ B_c and of course $c\bar{c}$ and $b\bar{b}$

"known mesons" is a rather broad field...

New measurement of $D_{s1}(2536)$ mass

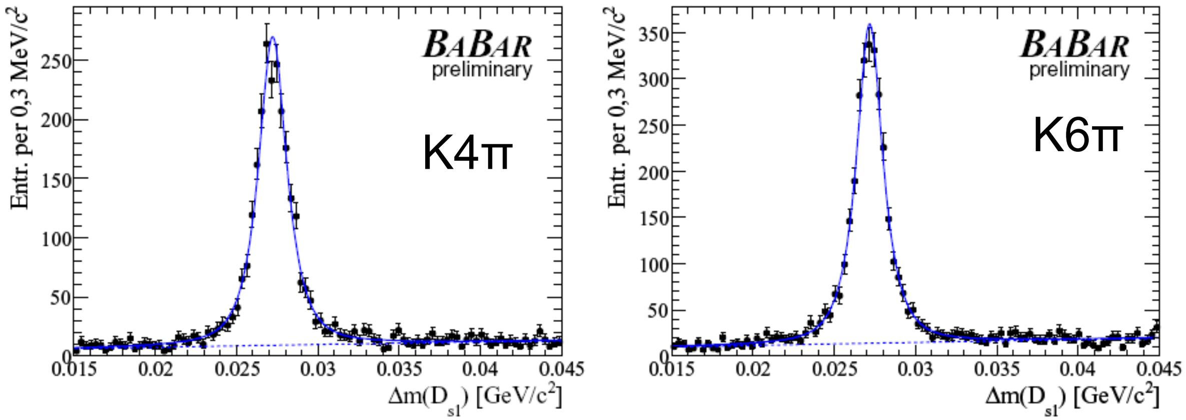
hep-ex/0607084

Study $D_{s1}(2536) \to D^{*+} K_S^0$
in continuum $e^+e^- \to c\bar{c}$
with $D^{*+} \to D^0\pi^+$ and
selecting $D^0 \to K^-\pi^+$ or
$D^0 \to K^-\pi^+\pi^-\pi^+$



Only charged tracks
→ good mass resolution

Measure
$\Delta m = M(D_{s1}^+) - m(D^{*+}) - M(K_S^0)$
to reduce systematics

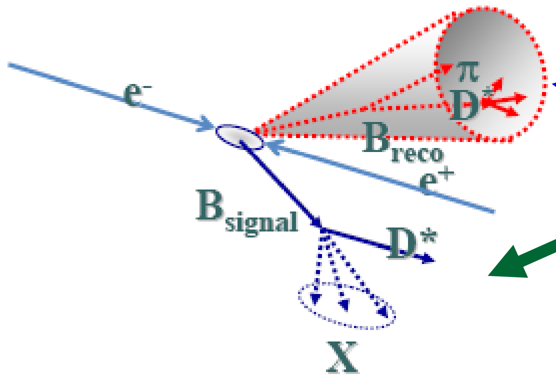


$$m(D_{s1}^+) = (\,2534.85 \pm 0.02 \pm 0.40\,)\ \mathrm{MeV}/c^2$$
$$\Gamma(D_{s1}^+) = (\,1.03 \pm 0.05 \pm 0.12\,)\ \mathrm{MeV}$$

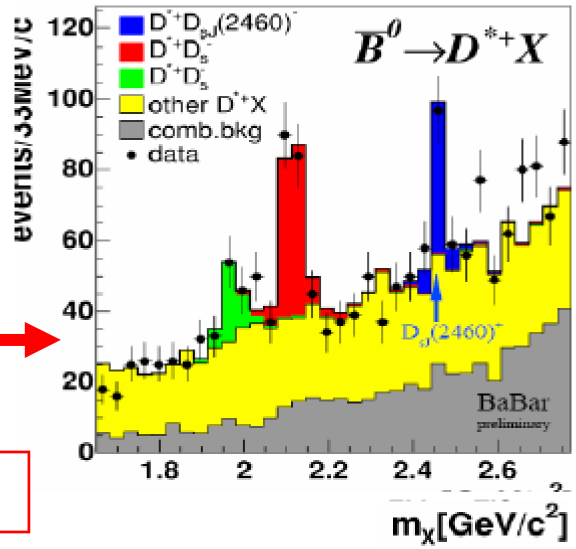
a factor 14 improvement in the splitting compared to previous PDG average:

$$m(D_{s1}^+) - m(D^{*+}) = (\,524.85 \pm 0.02 \pm 0.04\,)\ \mathrm{MeV}/c^2$$

Absolute D_{s1} (2460) Branching Fractions



Fully reconstruct one B
Partially reconstruct the other $B \to D(*)\ X$
Calculate X invariant mass .... and plot



$$\mathcal{B}(B^0 \to D^{*+} D_{s1}(2460)^-) = (0.88 \pm 0.0.2 \pm 0.14)\%$$

combine with previous BABAR measurements of fully reconstructed $B \to D^{*+} D_{s1}(2460)^-$

$$\mathcal{B}\left(D^*_{sJ}(2460)^+ \to D^*_s(2112)^+\pi^0\right) = (56 \pm 13 \pm 9)\,\%$$
$$\mathcal{B}\left(D^*_{sJ}(2460)^+ \to D^+_s\gamma\right) = (16 \pm 4 \pm 3)\,\%$$
$$\mathcal{B}\left(D^*_{sJ}(2460)^+ \to D^+_s\pi^+\pi^-\right) = (4 \pm 1)\,\%$$

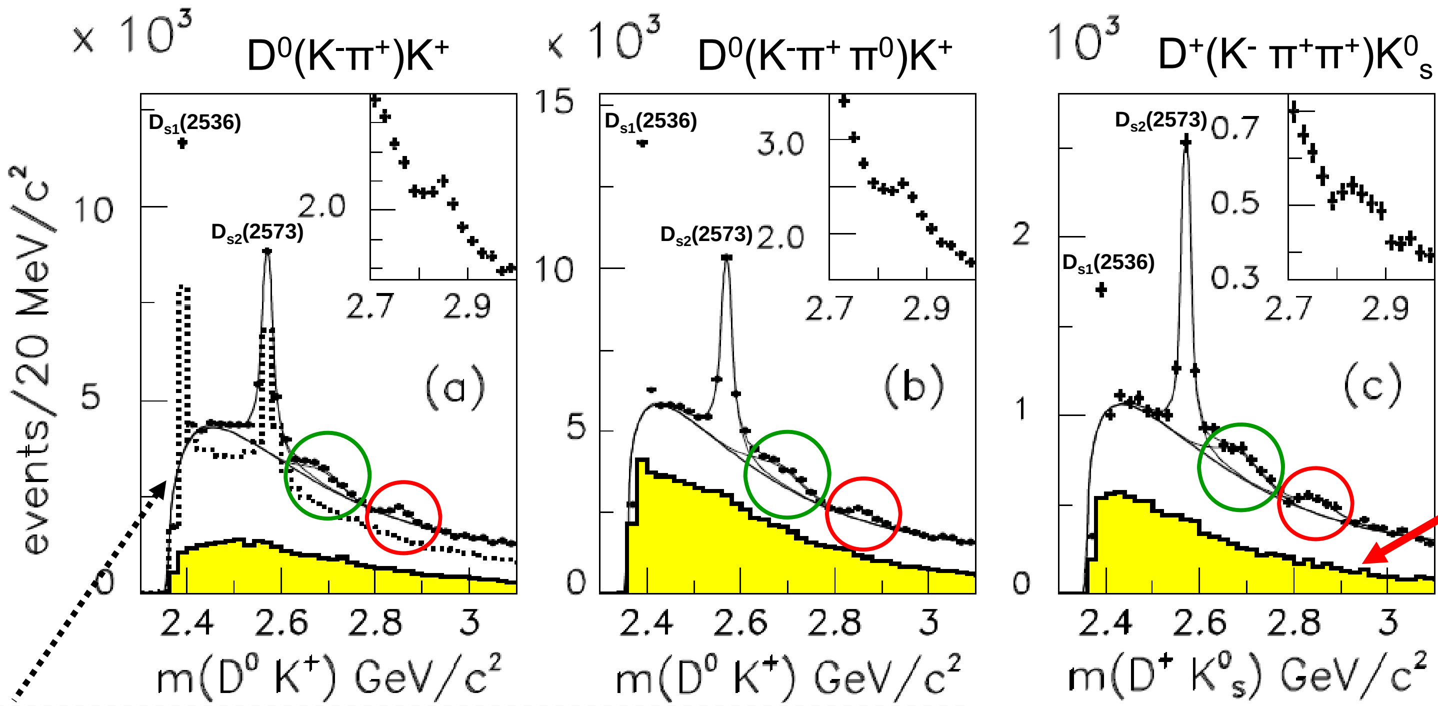
Sum of known modes: (76 ± 20)%
(assuming $\mathcal{B}(D_s^+ \to \phi\pi^+) = 4.62 \pm 0.36 \pm 0.50\%$)

BABAR: 210.5M BB
PRL 93,181801(2004)

... not really new but...

D_{sJ}*(2860): a new state!

- Looking in the $c\bar{c}$ continuum: $e^+e^- \rightarrow D^0K^+X$ and $e^+e^- \rightarrow D^+K^0_sX$



240 fb^{-1}

D "sidebands"

$c\bar{c}$ MC based on previous knowledge of c-mesons & their Br

Phys. Rev. Lett. 97 (2006) 222001

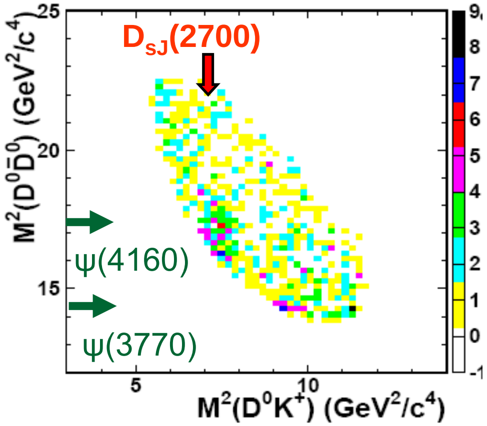
New state at 2860 MeV/c^2!

Bump at 2690 MeV/c^2?

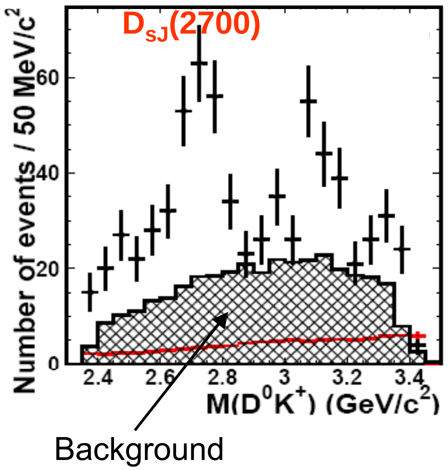
$D_{sJ}(2700)$: another one!

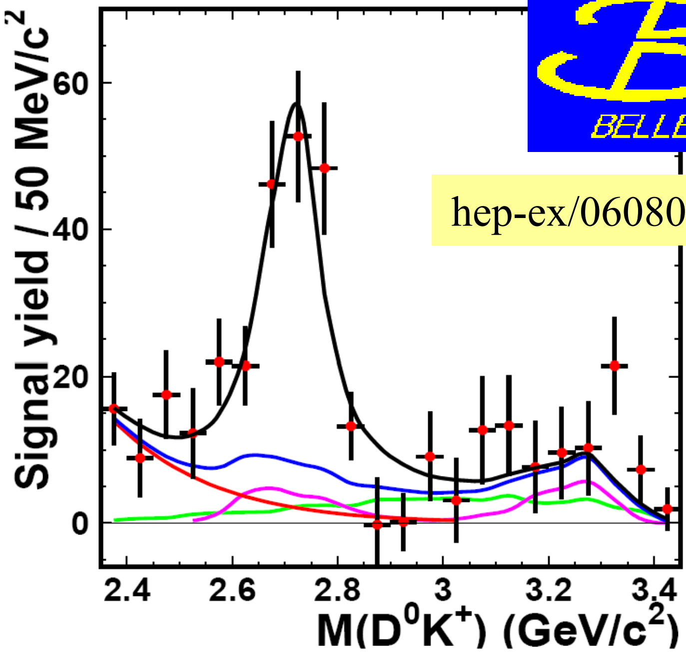
Dalitz plot study of $\boxed{B \to D^0 \overline{D}^0 K}$

Dalitz plot



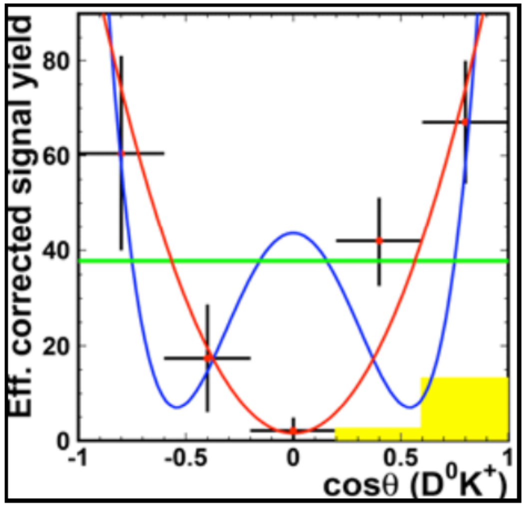
D^0K^+ projection





hep-ex/0608031

R	$D^+_{sJ}(2700)$
N_{sig}	182 ± 30
$M(MeV/c^2)$	$2715 \pm 11^{+11}_{-14}$
$\Gamma(MeV/c^2)$	$115 \pm 20^{+36}_{-32}$



J=0 χ^2/ndf=185/5

$\boxed{\text{J=1 } \chi^2\text{/ndf=7/5}}$

J=2 χ^2/ndf=250/5

$\boxed{J^P=1^-}$

$c\bar{s}(2^3S_1)$? *Expected mass 2720 (potential model)*

S. Godfrey and N. Isgur, Phys. Rev. D 32, 189 (1985)

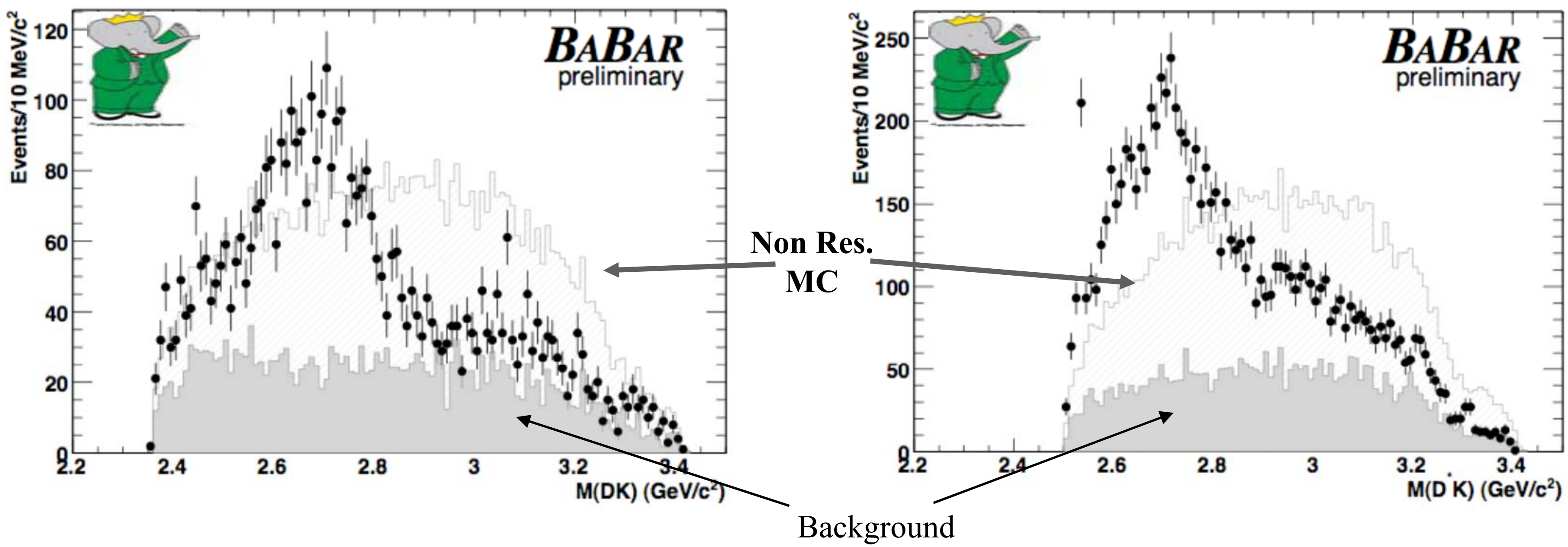
Chiral symmetry 1^+ - 1^- doublet paired with $D_{sJ}(2536)$?

M. A. Nowak, M. Rho, I. Zahed, Acta Phys.Polon. B 35, 2377 2004)

more on $D_{sJ}(2700)$

$$B \to D^{(*)}\overline{D}^{(*)}K$$ **(22 modes)**

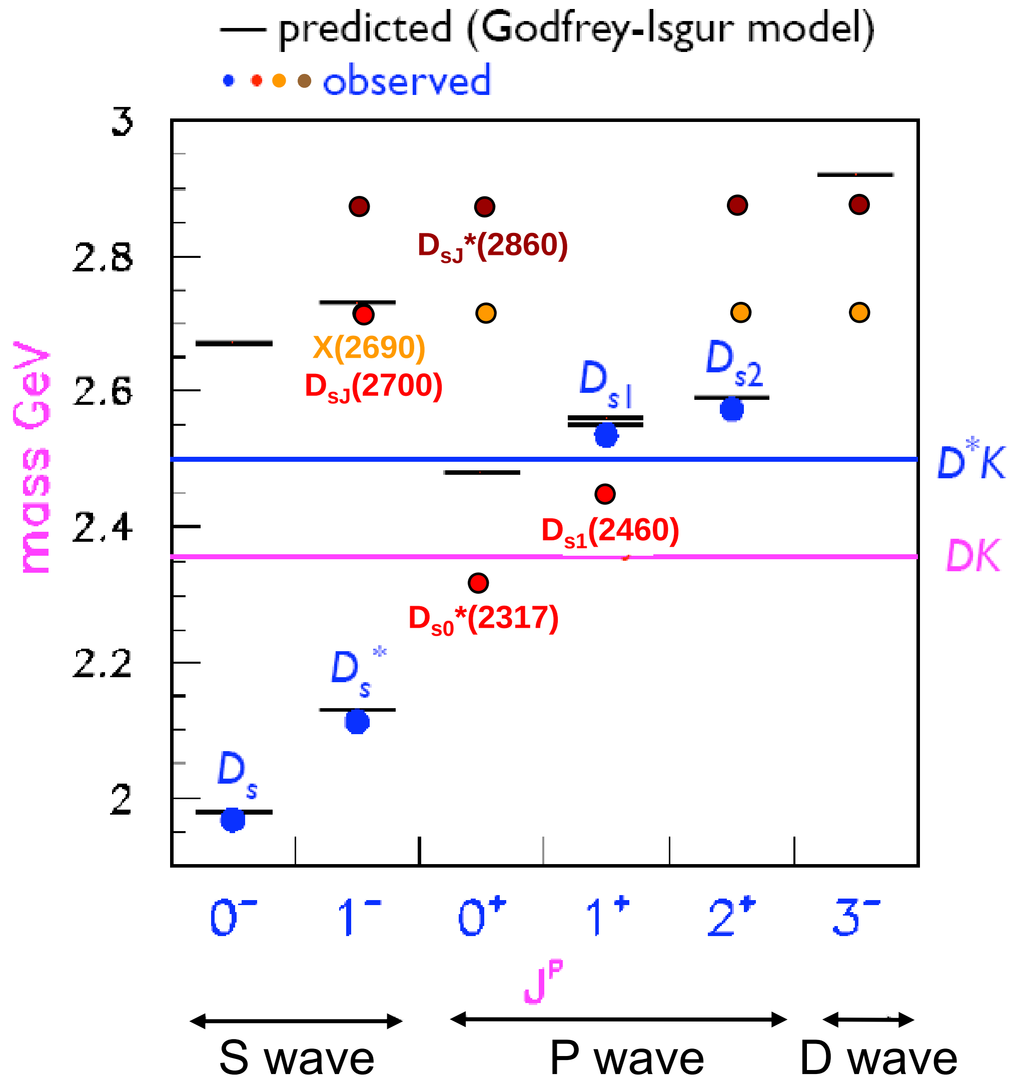
Summing all DK modes (8):   Summing all D*K modes (8):



BaBar confirms a broad enhancement near 2.7 GeV, but is it one resonance or two? Possible low-mass structure in DK.

Next step: full Dalitz analysis

D_{sJ} summary



- $D_{s0}^*(2317)^+$, Apr. 2003: unexpected observation of a narrow resonance in **BaBar**
- $D_{s1}(2460)^+$, May 2003: **CLEO, BaBar** observed a new narrow resonance

  most of the $D_{s1}(2460)^+$ branching fractions are known

- $D_{sJ}^*(2860)^+$, Jul. 2006: new state discovered by **BaBar**
- $X(2690)^+$, Jul. 2006: broad enhancement seen in **BaBar**
- $D_{sJ}(2700)^+$, Jul. 2006: new state discovered by **Belle** (X(2690)?)

Observation of B_{s1} and B_{s2}^*

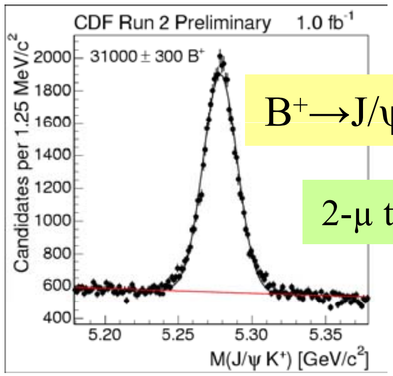
For L=1 expect

j_q	J^P	B_s^{**} state	decay mode	width
1/2	0^+	B_{s0}^*	BK	broad (S-wave)
1/2	1^+	B_{s1}	B^*K	broad (S-wave)
3/2	1^+	B_{s1}	B^*K	narrow (D-wave)
3/2	2^+	B_{s2}^*	$BK,\ B^*K$	narrow (D-wave)

Broad ☹

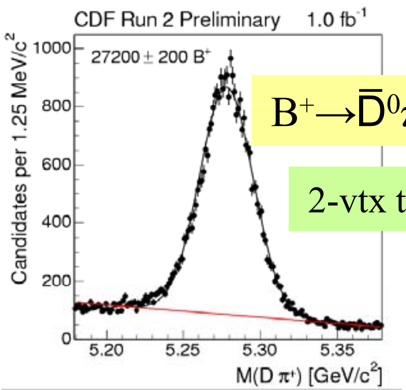
Narrow, good S/B ☺

one state observed by OPAL, DELPHI, D0 assignment not clear



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

2-μ trigger



$B^+ \to \bar{D}^0 \pi^+$

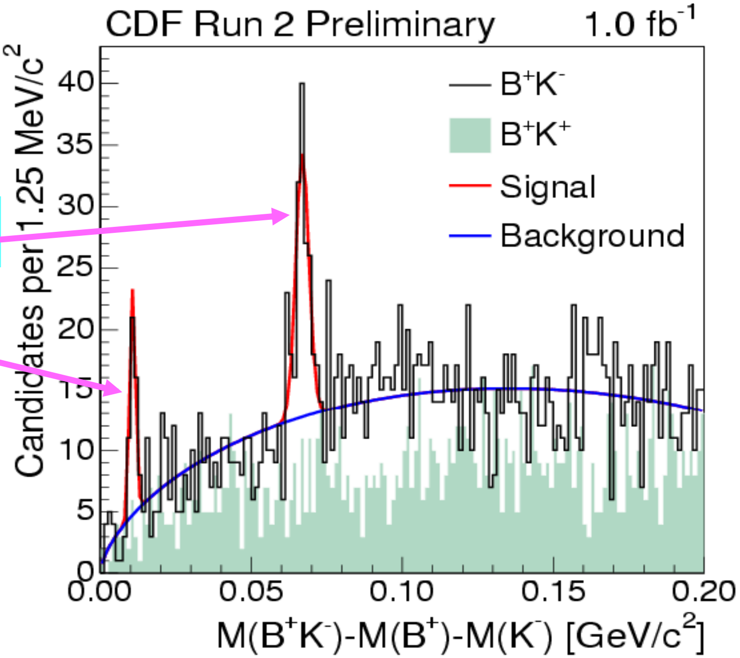
2-vtx trigger

reconstruct as $B_{sJ}^{**} \to B^+K^-$ (prompt kaon)

$N(B_{s2}^*) = 94.8 \pm 23.4$ (stat)

$N(B_{s1}) = 36.4 \pm 9.0$ (stat)

Significance of $B_{s1} > 5\sigma$



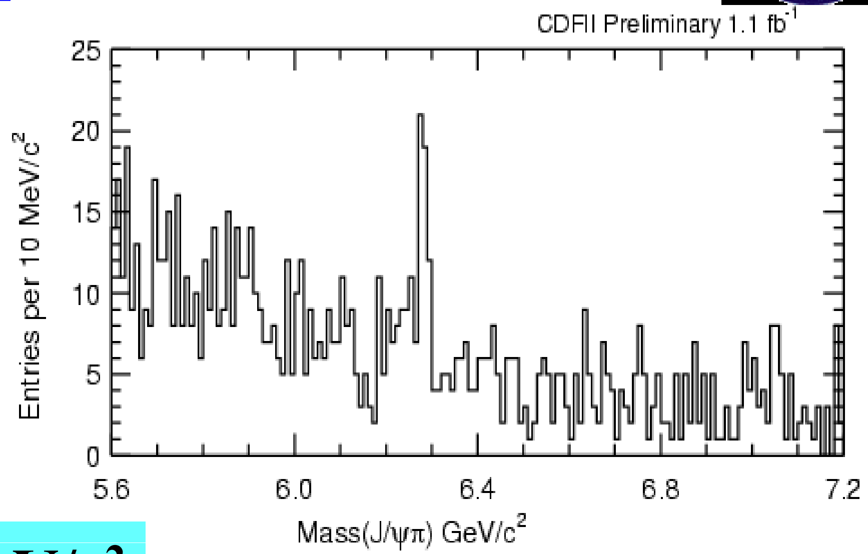
CDF Preliminary:

$$m(B_{s1}) = 5829.41 \pm 0.21\,(\text{stat}) \pm 0.14\,(\text{syst}) \pm 0.6\,(\text{PDG})\ \text{MeV}/c^2$$
$$m(B_{s2}^*) = 5839.64 \pm 0.39\,(\text{stat}) \pm 0.14\,(\text{syst}) \pm 0.5\,(\text{PDG})\ \text{MeV}/c^2$$

See Maksimovic talk at DFP06

Precision B_c mass measurement

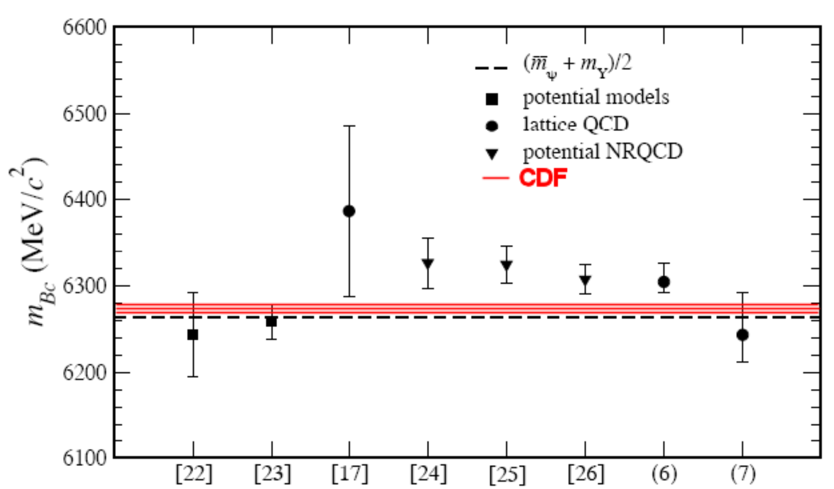
Reconstruct $B_c^+ \rightarrow J/\psi\ \pi^+$



World largest sample of fully reconstructed B_c

$M(B_c^+)=6276.5\pm4.0(\textit{stat})\pm2.7(\textit{syst})$ MeV/c^2

start to challenge theoretical predictions...



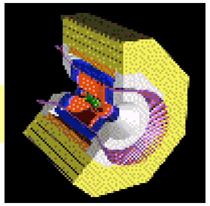
See Maksimovic talk at DFP06

$\psi(3770) \to$hadrons

long standing discrepancy: $\sigma_{\psi(3770)} \longleftrightarrow \sigma_{D\bar{D}}$

non-$D\bar{D}$?

CLEO



$$\sigma(e^+e^- \to D\bar{D}) = 6.39 \pm 0.10^{+0.17}_{-0.08}\ nb$$

PRL 95 (2005) 121801

$$\sigma(e^+e^- \to hadrons) = 6.38 \pm 0.08^{+0.41}_{-0.30}\ nb$$

PRL 96 (2006) 092002

upper limit on $\Delta\sigma \approx 10\%$

sum of observed non-DD $\approx 2\%$

BES: resonance scans

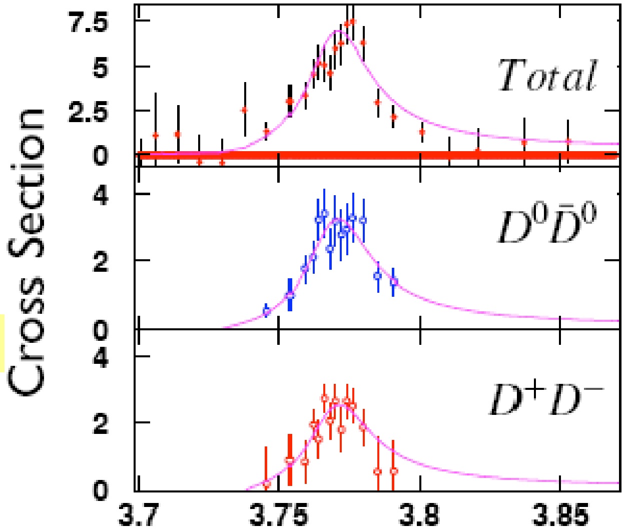
Two different methods and two different datasets

a) $BF(\psi(3770) \to non - D\bar{D}) = (16.4 \pm 7.3 \pm 4.2)\%$

PRL 97 (2006) 121801

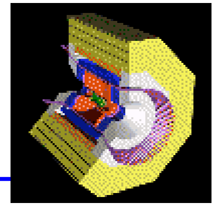
PLB 641 (2006) 145

b) $BF(\psi(3770) \to non - D\bar{D}) = (14.5 \pm 1.7 \pm 5.8)\%$

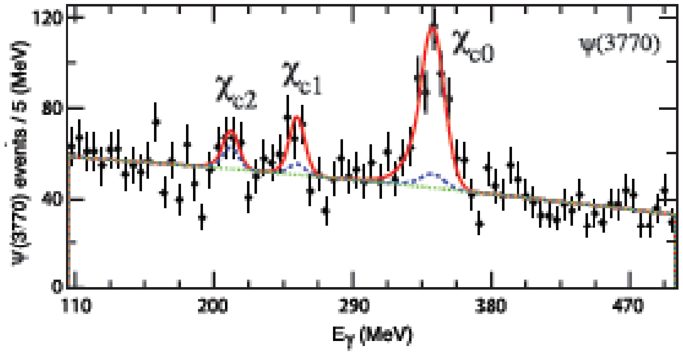


both compatible with CLEO

$\psi(3770)$ radiative transitions



PRD 74, 031106 (2006).



CLEO:

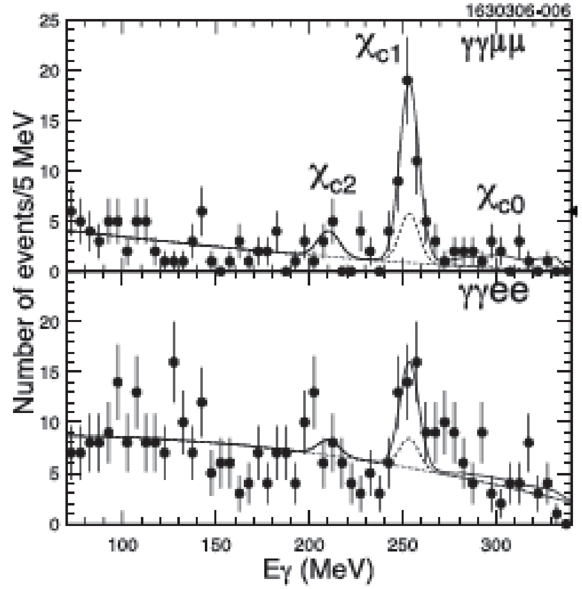
Two independent analyses:

1. $\psi(3770) \to \gamma\chi_{cJ}$ with $\chi_{cJ} \to \gamma J/\psi(l^+l^-)$

2. $\psi(3770) \to \gamma\chi_{cJ}$ with $\chi_{cJ} \to (2K, 2K2\pi, 4\pi, 6\pi)$

using $\psi(2S)$ decays as normalization.

PRL 96, 182002 (2006).

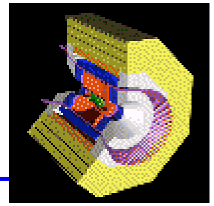


Combining the two CLEO results

	$\psi(3770) \to \gamma\chi_{cJ}$ $J=0$	$J=1$	$J=2$
$\mathcal{B}$ (%)	0.73 ± 0.09	0.29 ± 0.06	< 0.09
Γ (keV)	172 ± 30	70 ± 17	< 21
	Theory Γ predictions		
Rosner non-relativistic	523 ± 12	73 ± 9	24 ± 4
Ding-Qin-Chao			
non-relativistic	312	95	3.6
relativistic	199	72	3.0
Eichten-Lane-Quigg			
non-relativistic	254	183	3.2
coupled-channel	225	59	3.9
Barnes-Godfrey-Swanson			
non-relativistic	403	125	4.9
relativistic	213	77	3.3

The observed radiative transition reinforce the interpretation of the $\psi(3770)$ as the 1^3D_1 level of charmonium

$\chi_{c1}(1P)\to h^+h^-h^0$ CLEO



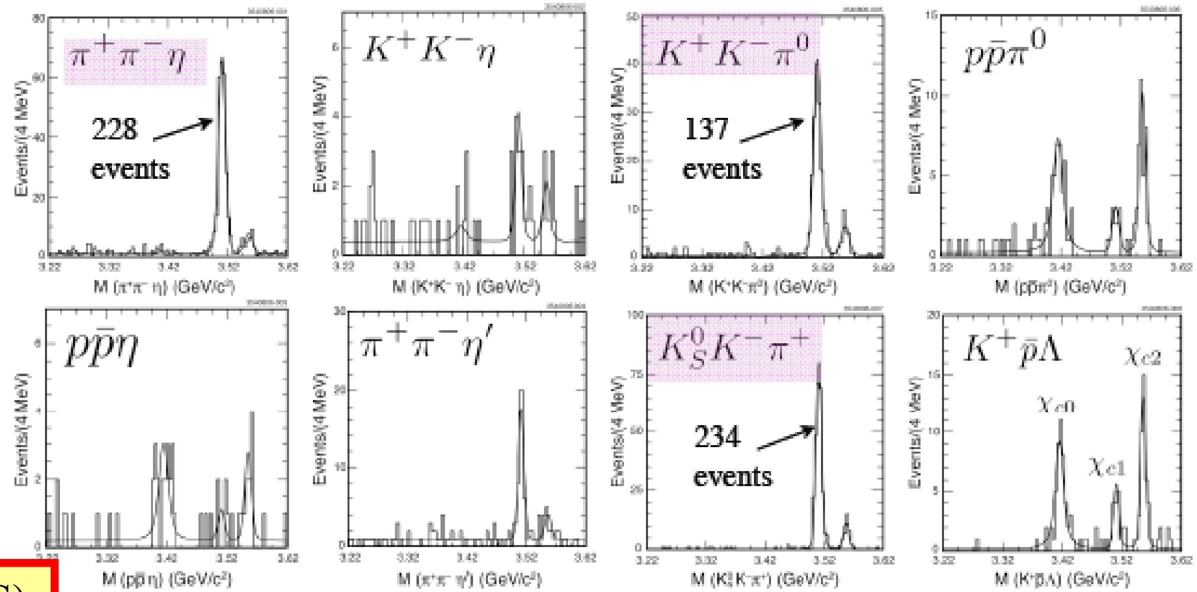
PRD 75, 032002 (2007)

A selection of 3-body decays based on $\boxed{3M\ \psi(2S)}$.

Many first observations.

$\chi_{c1}\to\pi^+\pi^-\eta$, $K^+K^-\pi^0$, and $K_SK^-\pi^+$ have sufficient statistics for a substructure analysis.

but they are already analyzing 29M $\psi(2S)$



Mode	χ_{c0}	χ_{c1}	χ_{c2}
$\eta\pi^+\pi^-$	< 0.021	$0.52 \pm .03 \pm .03 \pm .03$	$0.051 \pm .011 \pm .004 \pm .003$
ηK^+K^-	< 0.024	$0.034 \pm .010 \pm .003 \pm .002$	< 0.033
$\eta p\bar{p}$	$0.038 \pm .010 \pm .003 \pm .02$	< 0.015	$0.019 \pm .007 \pm .002 \pm .002$
$\eta'\pi^+\pi^-$	< 0.038	$0.24 \pm .03 \pm .02 \pm .02$	< 0.053
$\pi^0K^+K^-$	< 0.006	$0.200 \pm .015 \pm .018 \pm .014$	$0.032 \pm .007 \pm .002 \pm .002$
$\pi^0p\bar{p}$	$0.059 \pm .010 \pm .006 \pm .004$	$0.014 \pm .005 \pm .001 \pm .001$	$0.045 \pm .007 \pm .004 \pm .003$
$\overline{K}^0K^+\pi^-$*	< 0.010	$0.84 \pm .05 \pm .06 \pm .05$	$0.15 \pm .02 \pm .01 \pm .01$
$\Lambda K^+\bar{p}$*	$0.114 \pm .016 \pm .009 \pm .007$	$0.034 \pm .009 \pm .003 \pm .002$	$0.088 \pm .014 \pm .007 \pm .006$

* includes charge conjugate

$\chi_{cJ}(1P) \rightarrow$ hadrons (exclusive modes)

many new results from BES

large samples, PWA for substructure analysis

$\chi_{cJ} \rightarrow \phi\phi, \phi K^+K^-, K^+K^-K^+K^-$	PLB642,197(2006)
$\chi_{cJ} \rightarrow \Xi^-\bar{\Xi}^+, \Lambda\bar{\Lambda}\pi^+\pi^- K_S^0K_S^0 p\bar{p}$	PRD73,052006(2006)
$\chi_{cJ} \rightarrow K_S^0K^+\pi^- + c.c.$	PRD74,072001(2006)
$\chi_{cJ} \rightarrow \eta\pi^+\pi^-, a_0(890)\pi, \eta f_2(1270)$	PRD74,072001(2006)

$\chi_{cJ} \rightarrow K^+K^-K^+K^-$

Channel	$2(K^+K^-)(\times 10^{-3})$		$\phi K^+K^-(\times 10^{-3})$	$\phi\phi(\times 10^{-3})$	
	BES-II	PDG	BES-II	BES-II	PDG
χ_{c0}	$3.47 \pm 0.22 \pm 0.48$	2.3 ± 0.5	$1.02 \pm 0.22 \pm 0.15$	$0.94 \pm 0.21 \pm 0.14$	1.0 ± 0.6
χ_{c1}	$0.68 \pm 0.13 \pm 0.10$	0.42 ± 0.19	$0.44 \pm 0.14 \pm 0.07$	–	–
χ_{c2}	$1.88 \pm 0.18 \pm 0.28$	1.8 ± 0.5	$1.46 \pm 0.21 \pm 0.22$	$1.48 \pm 0.26 \pm 0.23$	2.4 ± 0.9

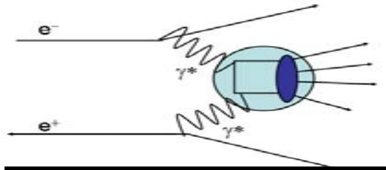
$\chi_{cJ} \rightarrow \pi^+\pi^-\pi^+\pi^- p\bar{p}$

Decay modes	Branching ratios
$\chi_{c0} \rightarrow \Xi^-\bar{\Xi}^+$	$(5.3 \pm 2.7 \pm 0.9) \times 10^{-4}$ or $<10.3 \times 10^{-4}$ (90% C.L.)
$\chi_{c1} \rightarrow \Xi^-\bar{\Xi}^+$	$<3.4 \times 10^{-4}$ (90% C.L.)
$\chi_{c2} \rightarrow \Xi^-\bar{\Xi}^+$	$<3.7 \times 10^{-4}$ (90% C.L.)
$\chi_{c0} \rightarrow \Lambda\bar{\Lambda}\pi^+\pi^-$	$(2.0 \pm 1.1 \pm 0.4) \times 10^{-3}$ (2.5σ) or $<4.0 \times 10^{-3}$ (90% C.L.)
$\chi_{c1} \rightarrow \Lambda\bar{\Lambda}\pi^+\pi^-$	$<1.5 \times 10^{-3}$ (90% C.L.)
$\chi_{c2} \rightarrow \Lambda\bar{\Lambda}\pi^+\pi^-$	$(1.8 \pm 1.0 \pm 0.3) \times 10^{-3}$ (2.5σ) or $<3.5 \times 10^{-3}$(90% C.L.)
$\chi_{c0} \rightarrow K_S^0K_S^0 p\bar{p}$	$<8.8 \times 10^{-4}$ (90% C.L.)
$\chi_{c1} \rightarrow K_S^0K_S^0 p\bar{p}$	$<4.5 \times 10^{-4}$ (90% C.L.)
$\chi_{c2} \rightarrow K_S^0K_S^0 p\bar{p}$	$<7.9 \times 10^{-4}$ (90% C.L.)

$\chi_{cJ} \rightarrow \pi^+\pi^-\pi^+K^\pm$, $\pi^+\pi^-\gamma\gamma$

Mode	$\mathrm{Br}(\times 10^{-3})$	$\mathrm{Br}(\times 10^{-3})$(CLEO-c)
$\chi_{c1} \rightarrow K_S K^+\pi^- + c.c.$	$4.1 \pm 0.3 \pm 0.7$	$\bar{K}^0K^+\pi^-$: $8.4 \pm 0.5 \pm 0.6 \pm 0.5$
$\chi_{c2} \rightarrow K_S K^+\pi^- + c.c.$	$0.8 \pm 0.3 \pm 0.2$	$\bar{K}^0K^+\pi^-$: $1.5 \pm 0.2 \pm 0.1 \pm 0.1$
$\chi_{c1} \rightarrow \eta\pi\pi$	$6.1 \pm 0.8 \pm 1.0$	$5.2 \pm 0.3 \pm 0.3 \pm 0.3$
$\chi_{c1} \rightarrow a_0^+\pi^- \rightarrow \eta\pi^+\pi^-$	$2.0 \pm 0.5 \pm 0.5$	
$\chi_{c1} \rightarrow f_2(1270)\eta$	$2.1 \pm 0.5 \pm 0.4$	

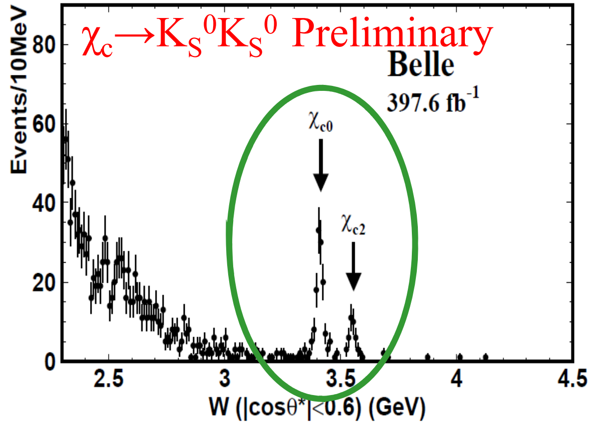
$\gamma\gamma \to \chi_{cJ}$



C = + resonances: $\chi_{c0}(nP)$, $\chi_{c2}(nP)$, $\eta_c(nS)$
quasi-real photons ($|q2|<0.001\,GeV^2$, with no-tag condition) → p_t balance

process	$\chi_{c0} \to K_S^0 K_S^0$	$\chi_{c2} \to K_S^0 K_S^0$
$\Gamma_{\gamma\gamma} Br(K_S^0 K_S^0)$ (eV)	7.00 ± 0.65 ±0.71	0.31 ± 0.05 ±0.03
$Br(K_S^0 K_S^0)$ / $Br(K^+K^-)$	0.49 ± 0.07 ±0.08	0.70 ± 0.21 ±0.12

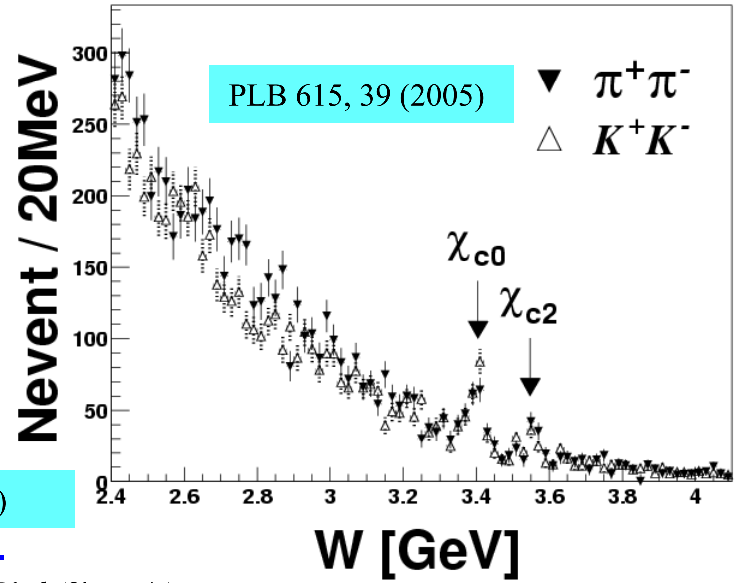
Consistent with I-spin ratio R=0.5



Previous two-photon measurements from Belle:
$\Gamma_{\gamma\gamma} \times Br(\chi cJ(1P))$ (eV)

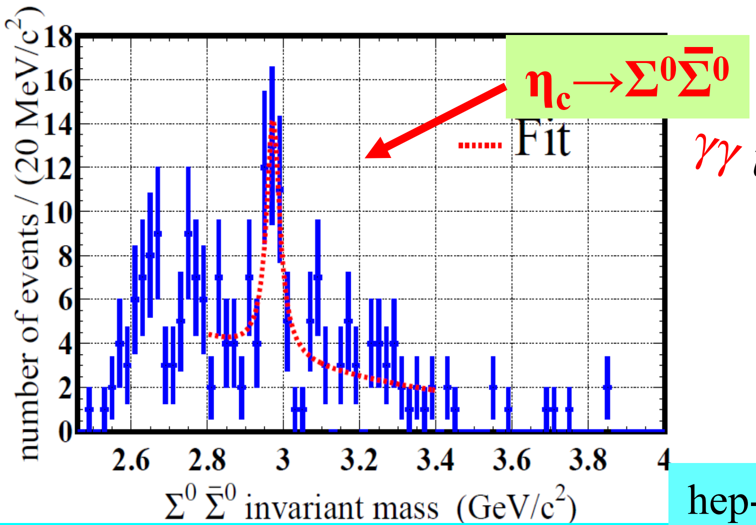
$\Gamma_{\gamma\gamma} Br(\chi_{c0} \to \pi^+\pi^-) = 15.1 \pm 2.1 \pm 2.3$
$\Gamma_{\gamma\gamma} Br(\chi_{c0} \to K^+K^-) = 14.3 \pm 1.6 \pm 2.3$
$\Gamma_{\gamma\gamma} Br(\chi_{c2} \to \pi^+\pi^-) = 0.76 \pm 0.14 \pm 0.11$
$\Gamma_{\gamma\gamma} Br(\chi_{c2} \to K^+K^-) = 0.44 \pm 0.76 \pm 0.14$
$\Gamma_{\gamma\gamma} Br(\chi_{c2} \to \gamma J/\psi) = 114 \pm 11 \pm 9 \pm 2$

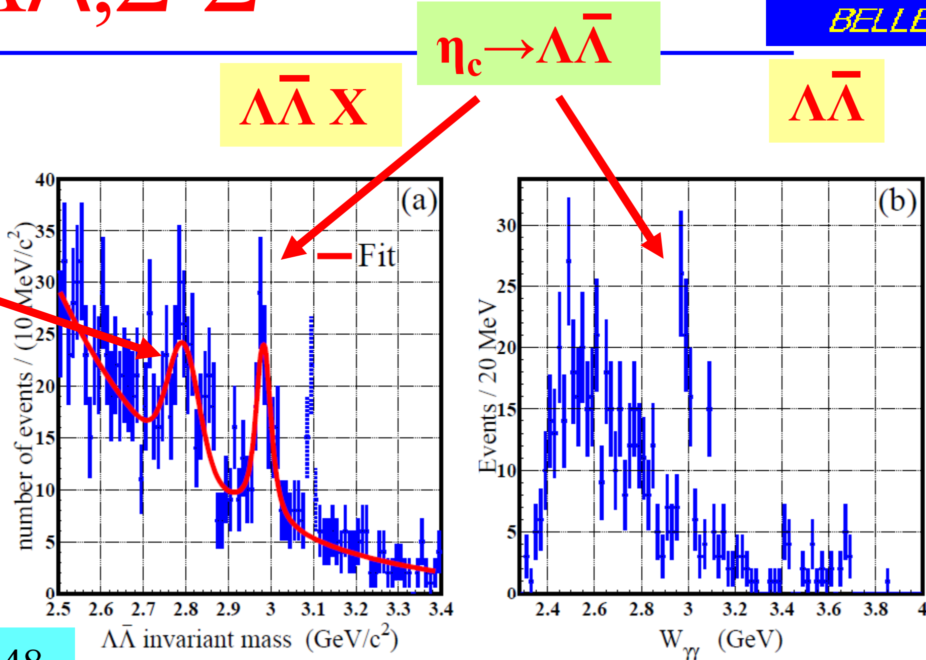
PLB 540, 33 (2002)



$\gamma\gamma \to \Lambda\bar{\Lambda}, \Sigma^0\bar{\Sigma}^0$

Select $\Lambda\bar{\Lambda}$ X, with $\Lambda \to p\pi^-$; $\Sigma^0 \to \Lambda\gamma$





hep-ex/0609048

$\eta_c \to x\bar{x}$	N	$\Gamma_{\gamma\gamma} Br(x\bar{x})[eV]$	$Br(x\bar{x}) \times 10^3$
$\Lambda\bar{\Lambda}$	$101.2 \pm 16.4^{+1.2}_{-3.0}$	$6.21 \pm 1.01^{+0.49}_{-0.52}$	$0.89 \pm 0.14^{+0.07+0.13}_{-0.07-0.11}$
$\Sigma^0\bar{\Sigma}^0$	$36.1 \pm 9.2^{+0.0}_{-1.2}$	$9.80 \pm 2.50^{+0.98}_{-1.03}$	$1.40 \pm 0.36^{+0.14+0.20}_{-0.15-0.18}$
$p\bar{p}$ (PLB 621,41(2005))			$7.20 \pm 1.53 \pm 0.67$

$Br(\Lambda\bar{\Lambda}) / Br(p\bar{p}) \approx 0.86 \pm 0.26$

$Br(\Sigma^0\bar{\Sigma}^0) / Br(p\bar{p}) \approx 1.36 \pm 0.49$

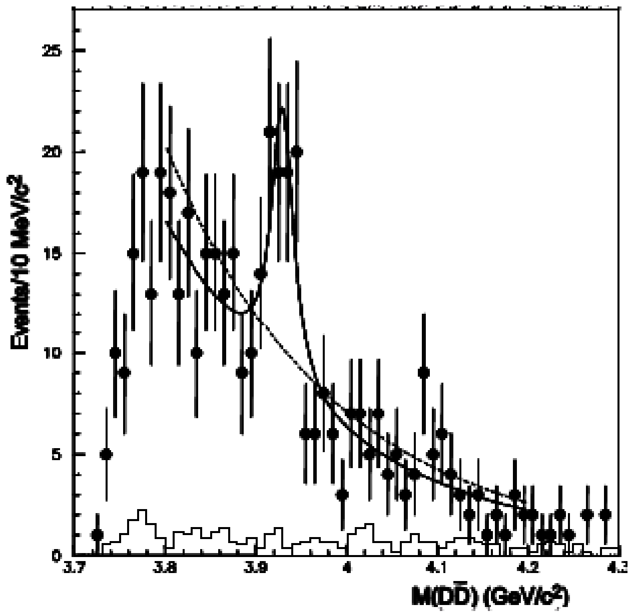
somehow larger than di-quark prediction

$Br(\Lambda\bar{\Lambda}) / Br(p\bar{p}) \approx 0.5$

$Br(\Sigma^0\bar{\Sigma}^0) / Br(p\bar{p}) \approx 0.3 - 0.4$

PRD 38, 3516 (1988)

$\gamma\gamma \to D\bar{D}$

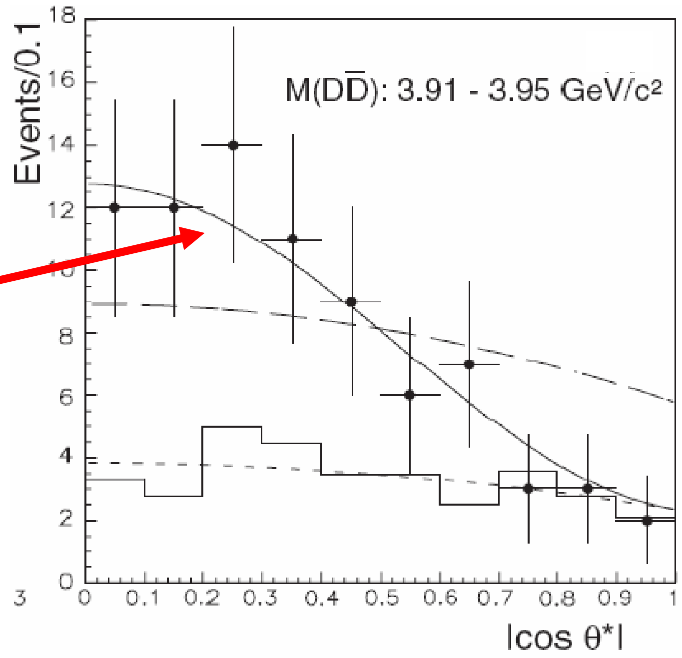


Observation of a new charmonium **Z(3930)**

N(ev)	64±18
M [MeV/c^2]	3929±5±2
Γ [MeV]	29±10±2
$\Gamma_{\gamma\gamma}\times Br$ [keV]	0.18±0.05±0.03

(5.3σ)

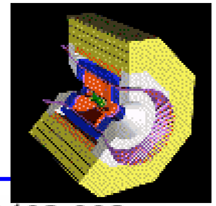
PRL 96, 082003 (2006)

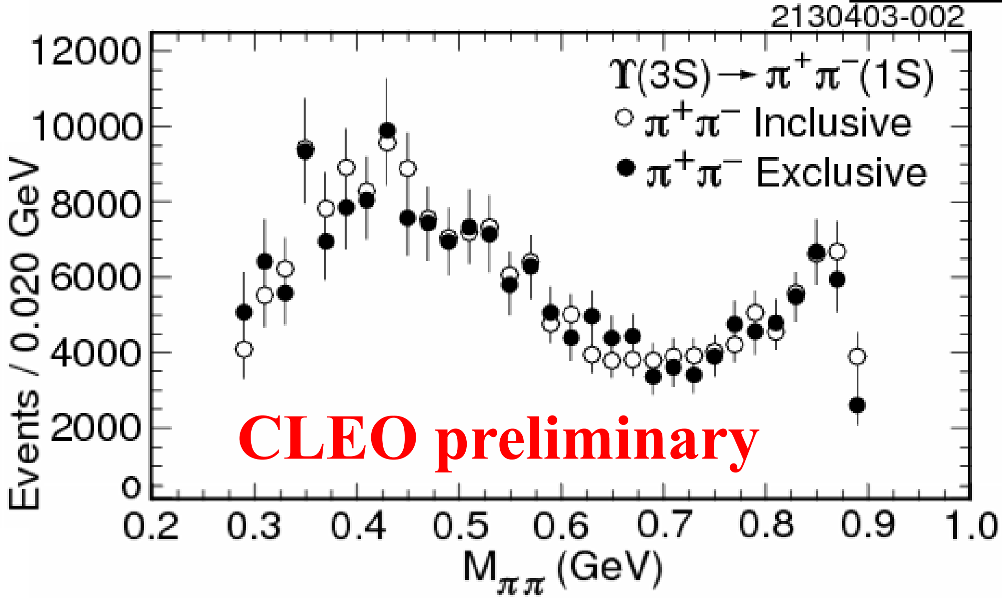


χ_{c2}(2P) candidate

J=2 (helicity 2)

$\Upsilon(3S)\to\Upsilon(1S)\pi\pi$





Long standing puzzle:

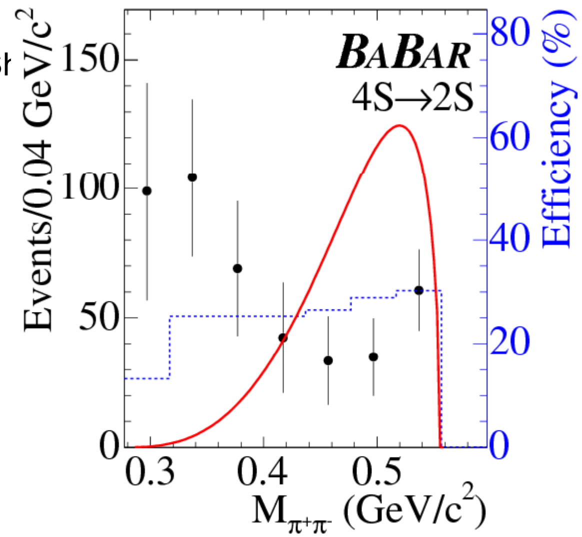
double bump structure of $M(\pi\pi)$ distribution in $\Upsilon(3S)\to\Upsilon(1S)\pi\pi$

different from all other similar known di-pion transitions until recently

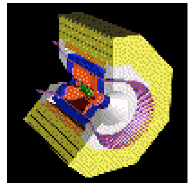
Over the years many different proposals:

- Large final state interactions [Belanger,DeGrand,Moxhay,PR,D39,257(89);Chakravarty,Kim,Ko,PR,D50,389(94)]
- σ-meson in ππ system [Komada,Ishida,Ishida,PL,B508,31(01);PL,B518,47(01);Uehara Prog.Theor.Phys.109,265(03)]
- Exotic Υπ resonance [Voloshin,JTEP Lett.,37,69(83); Belanger et al ,PR,D39,257(89); Anisovich,Bugg,Sarantsev,Zhou,PR,D51,4619(95); Guo,Sh
- Ad hoc constant term in amplitude [Moxhay,PR,D39,3497(89)]
- Coupled channel effects [Lipkin,Thuan,PL,B206,349(88); Zhou,Kuang,PR,D44,756(91)]
- 3^3S_1-n^3D_1 mixing [Chakravarty,Kim,Ko,PR,D48,1212(93)]
- Relativistic corrections [Voloshin,PR,D74,054022(06)]

a new puzzle: $\Upsilon(4S)\to\Upsilon(2S)\pi\pi$



Matrix elements in $\Upsilon(nS)\to\Upsilon(mS)\pi\pi$



Matrix element (chiral symmetry for soft pions) as sum of three terms: [Brown,Cahn PRL, 35, 1 (75)]

$$M = \mathrm{A}(\varepsilon'\cdot\varepsilon)(q^2-2m_\pi{}^2)+\mathrm{B}(\varepsilon'\cdot\varepsilon)E_1E_2+\mathrm{C}\left[(\varepsilon'\cdot q_1)(\varepsilon\cdot q_2)+(\varepsilon'\cdot q_2)(\varepsilon\cdot q_1)\right]$$

see extra slides for definitions

no $\cos\theta_X$ dep.

depends on $\cos\theta_X$ and q^2

couples pions to Υ polarization (spin-flip in ME)

C ≈ 0 [Yan PR,D22,1652 (80)]

M(ππ) distribution calculated in non-relativistic QCD-inspired calculation of E1*E1 transition has form similar to the 1st term

A » B [Voloshin,Zakharov,PRL,45,688(80); Novikov, Shifman, ZP,C8,43(81)]

Fit simultaneously the $\cos\theta_X$ vs $M_{\pi\pi}$ Dalitz plot of $\pi^+\pi^-$ and $\pi^0\pi^0$ samples

all three distributions well described by chiral-symmetry matrix element with constant (complex) factors

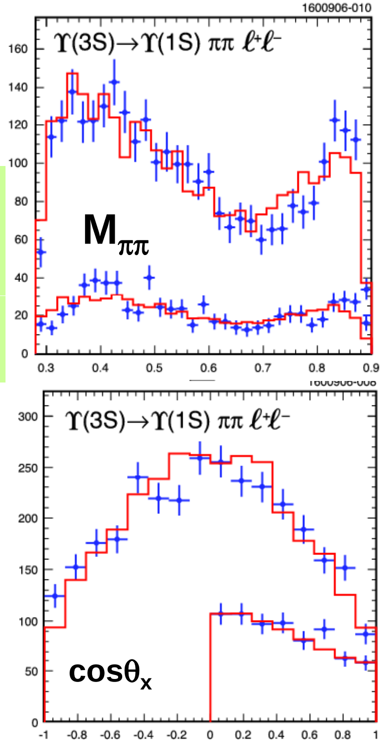
C not needed	|C/A|	|B/A|
$\Upsilon(3S)\to\Upsilon(1S)\pi\pi$	0.45±0.40	2.89±0.25

CLEO preliminary

3S→1S anomaly explained just by large **\|B/A\| and** non-trivial phase??

assume C=0	Re(B/A)	Im(B/A)	|B/A|	Arg(B/A)
$\Upsilon(3S)\to\Upsilon(1S)\pi\pi$	-2.52±0.04	1.19±0.07	2.79±0.05	155±2°
$\Upsilon(2S)\to\Upsilon(1S)\pi\pi$	-0.75±0.15	0.00±0.11	0.75±0.15	180±9°
$\Upsilon(3S)\to\Upsilon(2S)\pi\pi$	-0.39±0.33	0.0±1.1	0.4±1.1	---

Projections



Skwarnicki talk at DPF06

Conclusions

- many results on ordinary mesons in past years
  $\longrightarrow$ B-factories are indeed τ-charm(+bottom) factories
- Precision measurement are now tackling long standing puzzles:
  $\psi(3770) \rightarrow D\bar{D}$, $\Upsilon(3S) \rightarrow \Upsilon(1S)\,\pi\pi$, “rho-pi” puzzle…

No time to discuss that unfortunately…
Many new exclusive modes measured by BES and CLEO

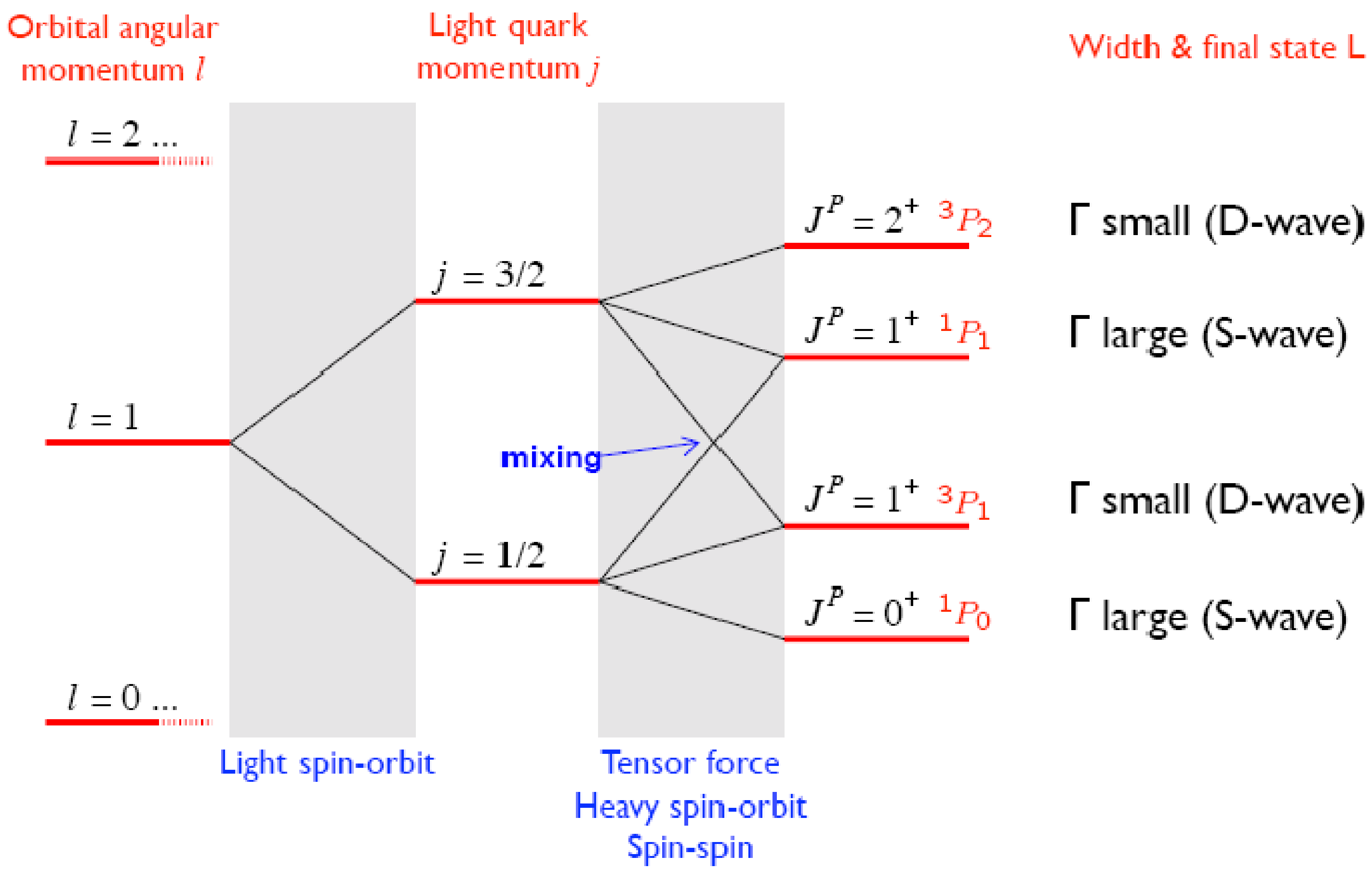
- ... but new puzzles continue to keep us busy...

- CLEO analyses published on 3M $\psi(2S)$, they now have 29M
- BES-III will start operation soon
- and later PANDA …

it will be fun!

Extra slides

D_{sJ}: what we expect



Pattern of D_{sJ} decay modes

Decay Mode	Central Value	Limit	
$\mathcal{B}(D^*_{sJ}(2317)^+ \to X)/\boxed{\mathcal{B}(D^*_{sJ}(2317)^+ \to D_s^+\pi^0)}$			Only mode observed
$D_s^+\gamma$	$-0.02 \pm 0.02 \pm 0.08$	< 0.14	Forbidden
$D_s^+\pi^0\pi^0$	$0.08 \pm 0.06 \pm 0.04$	< 0.25	Forbidden
$D_s^+\gamma\gamma$	$0.06 \pm 0.04 \pm 0.02$	< 0.18	Allowed
$D_s^*(2112)^+\gamma$	$0.00 \pm 0.03 \pm 0.07$	< 0.16	Allowed
$D_s^+\pi^+\pi^-$	$0.0023 \pm 0.0013 \pm 0.0002$	< 0.0050	Forbidden
$\mathcal{B}(D_{sJ}(2460)^+ \to X)/\mathcal{B}(D_{sJ}(2460)^+ \to D_s^+\pi^0\gamma)$			
$D_s^+\pi^0$	$-0.023 \pm 0.032 \pm 0.005$	< 0.042	Forbidden
$D_s^+\gamma$	$\boxed{0.337 \pm 0.036 \pm 0.038}$	—	Seen
$D_s^*(2112)^+\pi^0$	$\boxed{0.97 \pm 0.09 \pm 0.05}$	> 0.75	Seen
$D^*_{sJ}(2317)^+\gamma$	$0.03 \pm 0.09 \pm 0.05$	< 0.25	
$D_s^+\pi^0\pi^0$	$0.13 \pm 0.13 \pm 0.06$	< 0.68	Allowed
$D_s^+\gamma\gamma$	$0.08 \pm 0.10 \pm 0.04$	< 0.33	Allowed
$D_s^*(2112)^+\gamma$	$-0.02 \pm 0.08 \pm 0.10$	< 0.24	Allowed
$D_s^+\pi^+\pi^-$	$\boxed{0.077 \pm 0.013 \pm 0.008}$	—	Seen

Assumes 0^+ hypothesis

Assumes 1^+ hypothesis

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

- Discovered 4 years ago in $e^+e^- \rightarrow c\bar{c}$ events

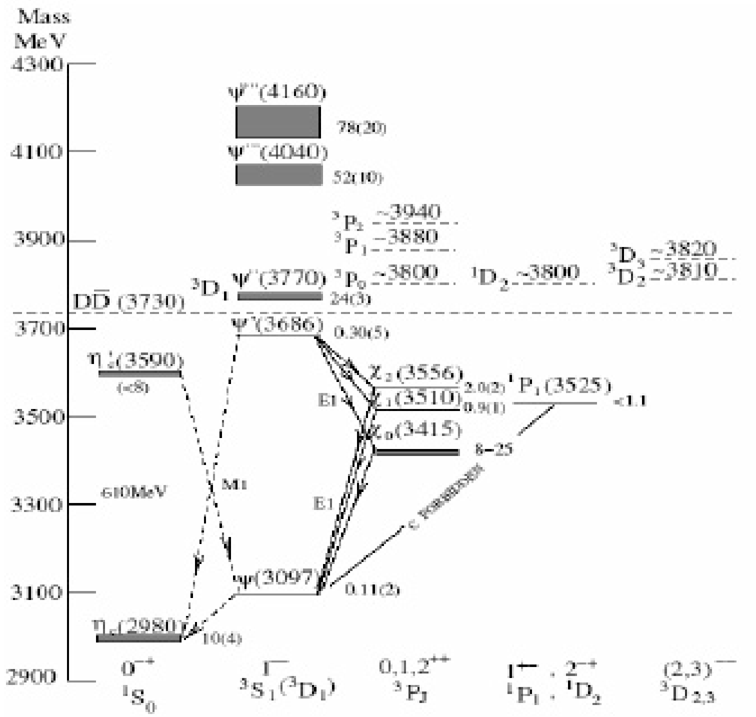
  Also observed in B decays
- $D_{s0}^*(2317)$ and $D_{s1}(2460)$ very well established and known experimentally
  - ✓ **decay modes** and **branching fractions**
  - ✓ Natural $\mathbf{J^P}$: 0^+ for $D_{s0}^*(2317)$ and 1^+ for $D_{s1}(2460)$
  - ✓ **Masses** and **widths**

- Interpretation of these new states still unclear!
  - ➢ One possibility: identify these 2 states as the **0^+ and 1^+ $c\bar{s}$ states**

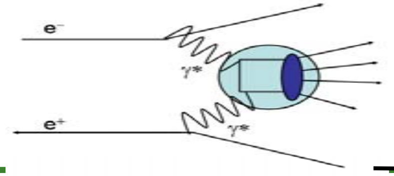
    However strong difficulties within the potential model
  - ➢ **Other** possibilities

    4 quark states? DK molecule? Dπ atom? Chiral symmetry?

$c\bar{c}$ spectrum



$c\bar{c}$ mesons in two photon reactions



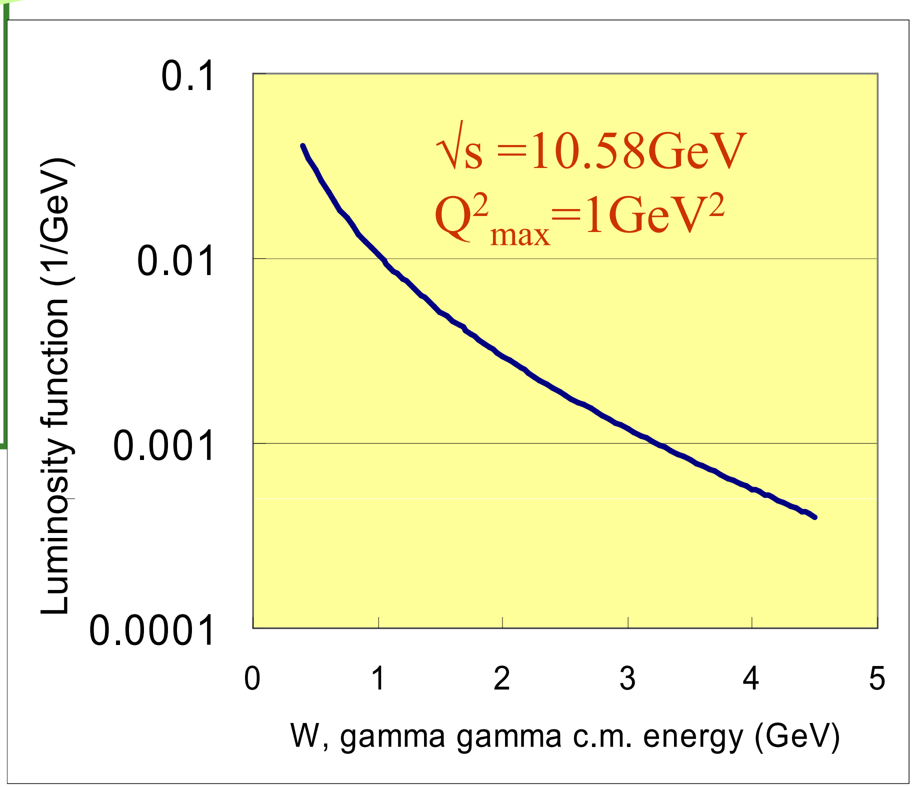
C = + resonances: $\chi_{c0}(nP)$, $\chi_{c2}(nP)$, $\eta_c(nS)$
quasi-real photons ($|q2|<0.001\text{GeV}^2$, with no-tag condition) → p_t balance

similar in Babar

The cross sections at Belle

$e^+e^-\to Y(4S)\to B\bar{B}$ --- 1.1 nb
$e^+e^-\to q\bar{q}$ (uds) --- 2.1 nb
$e^+e^-\to c\bar{c}$ --- 1.2 nb
$e^+e^-\to \tau^+\tau^-$ --- 0.9 nb
$\gamma\gamma \to$ hadrons ($W_{\gamma\gamma}$>0.8GeV) --- ~1 nb
(within the acceptance)

Luminosity Function
for quasi-real $\gamma\gamma$ collisions
$d\sigma_{ee} = \sigma_{\gamma\gamma}\, L_{\gamma\gamma}(W)\, dW$



Calculated with equivalent-photon approximation

Production in continuum $s^{1/2} \leq 10.58$ GeV

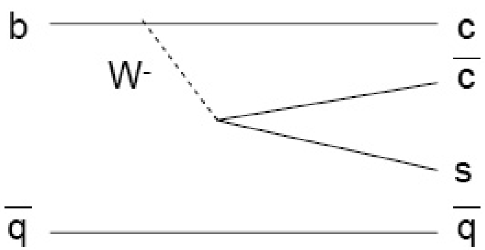
- Two photons production
- Double charmonium production
- Initial State radiation

Production in B decay $s^{1/2} \approx 5.28$ GeV

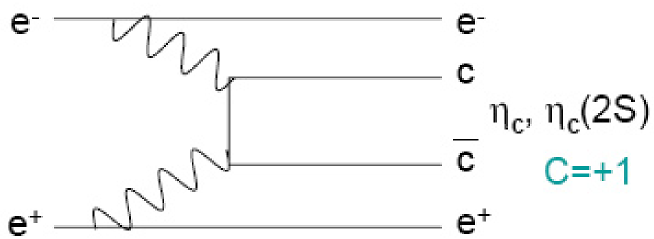
b c color suppressed transition

charmonium and open-charm

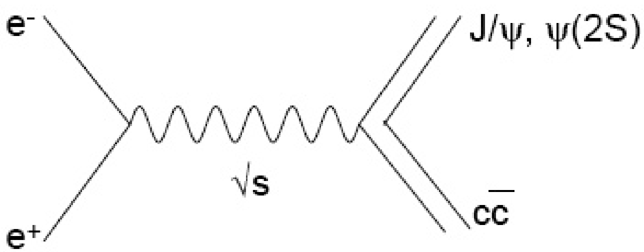
Color suppressed B decays



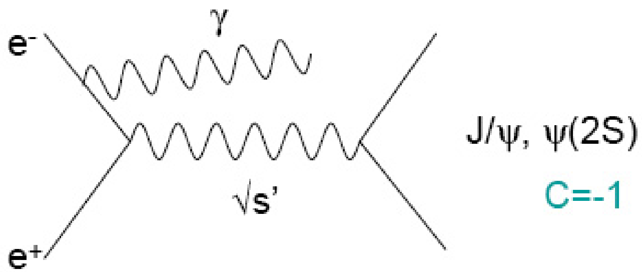
Two photons production



Double charmonium production

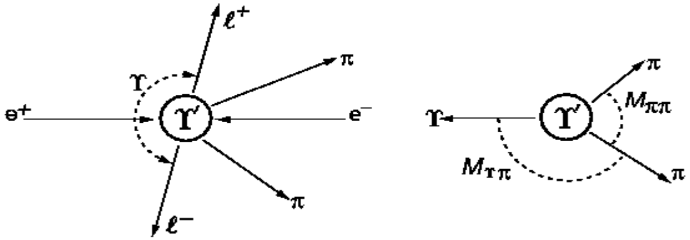


Initial state radiation



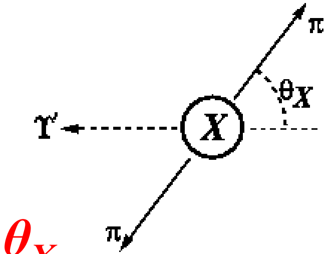
Matrix element in di-pion transitions

Three-body decay Υ'→Υππ (or ψ′→J/ψ ππ)



$q^2 = M_{\pi\pi}{}^2$

$r^2 = M_{\Upsilon\pi}{}^2$ or equivalently $\cos\theta_X$



pions in these transitions are soft. Matrix element structure constrained from **chiral symmetry** (PCAC) in non-relativistic limit:

[Brown,Cahn PRL, 35, 1 (75)]

$$M = A(\varepsilon'\cdot\varepsilon)(q^2 - 2m_\pi{}^2) + B(\varepsilon'\cdot\varepsilon)\,E_1E_2 + C\left[(\varepsilon'\cdot q_1)(\varepsilon\cdot q_2) + (\varepsilon'\cdot q_2)(\varepsilon\cdot q_1)\right]$$

$\varepsilon', \varepsilon$ – Polarization vectors of parent and daughter Υ states

q_1, q_2 – Four-vectors of pions, E_1, E_2 – their energies in parent Υ rest frame

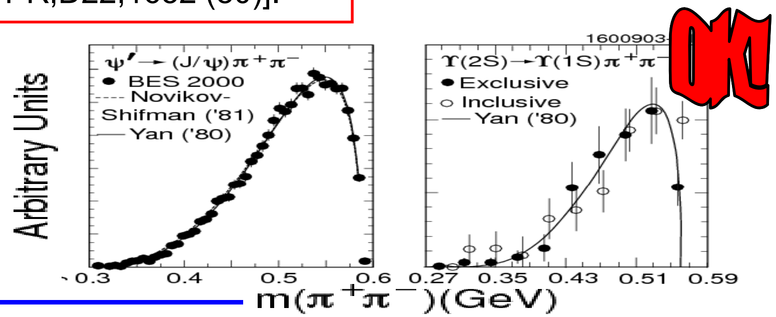
$q^2 = (q_1 + q_2)^2 \equiv M_{\pi\pi}{}^2$ A,B,C expected approximately constant (real in the chiral limit)

|A|»|B| S-wave expected to dominate E1*E1
[Voloshin,Zakharov,PRL,45,688(80);
Novikov, Shifman, ZP,C8,43(81)]

C≈0
QCD multipole expansion
[Yan PR,D22,1652 (80)].

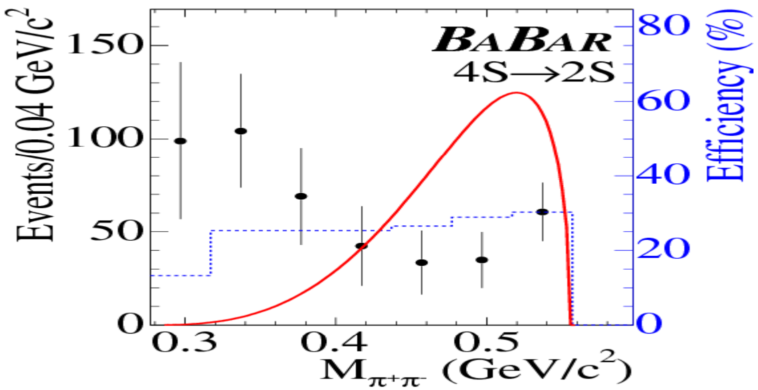
ψ(2S)→J/ψ(1S)ππ distribution
reproduced assuming B=C=0

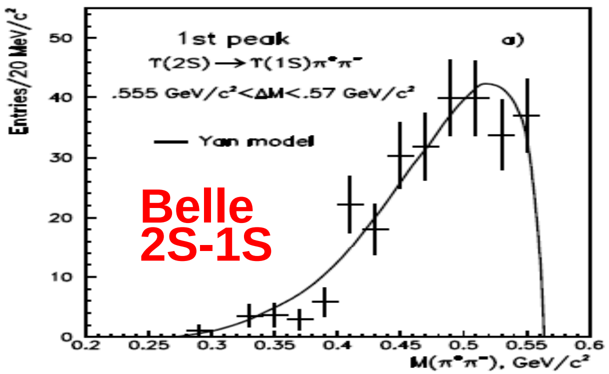
Similar ππ invariant mass for Υ'→Υππ

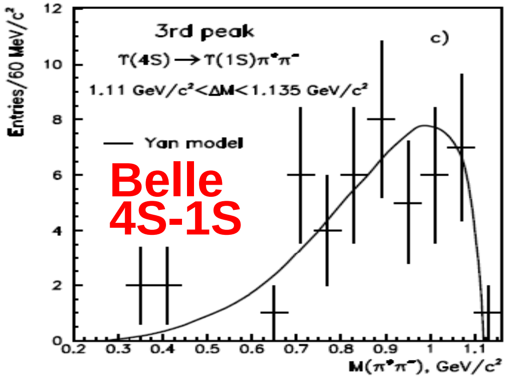


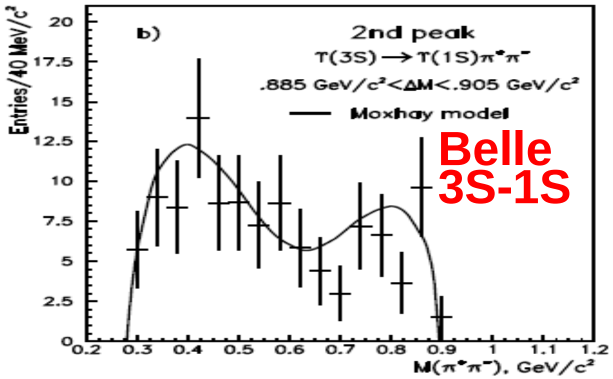
Dipion transitions in the Υ sector

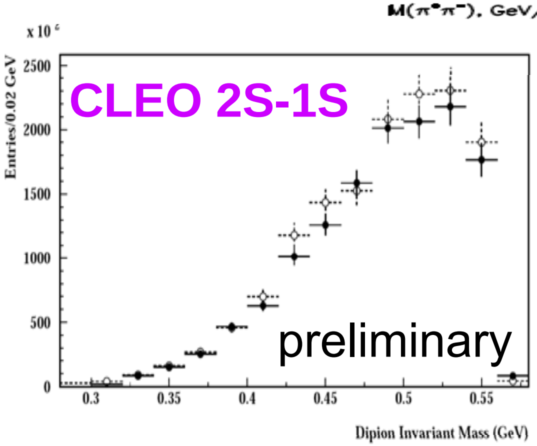
- Something special when Δn=2??

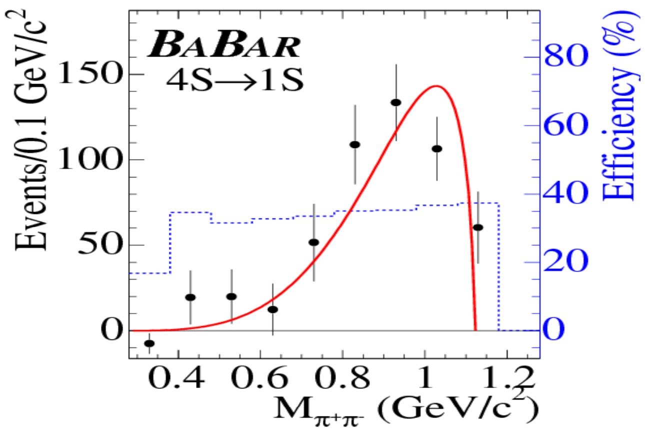


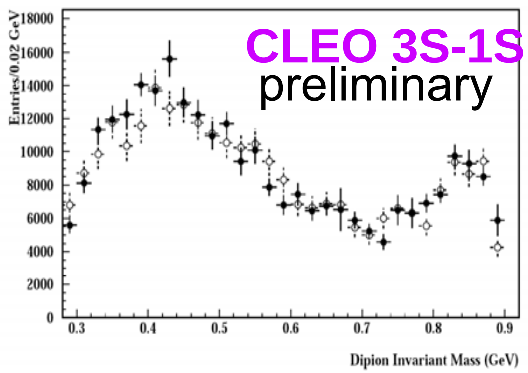












Δn=1

Δn=2