Charmonia and XYZ at

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INFN TORINO

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Outline

Search for the $\eta_{c2}(1^1D_2)$ in B decays

Evidence of $\gamma\gamma^* \to X(3872)$

Search for $X(3872) \to \chi_{c1}\ \pi^0$

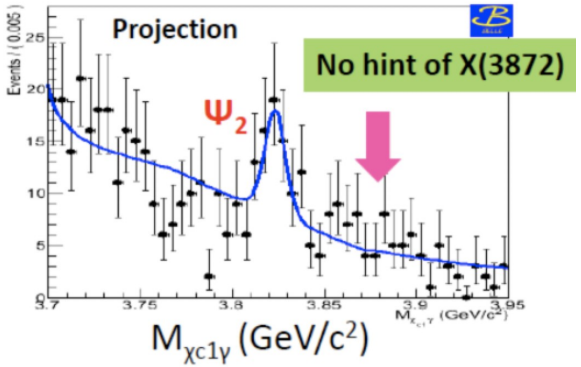
Search for $\chi_c(2P)$ states in $\gamma\gamma \to \gamma\psi'$

Y(4626) in $D_s\overline{D}_{s1}(2536)$ and $D_s\overline{D}_{s2}(2573)$

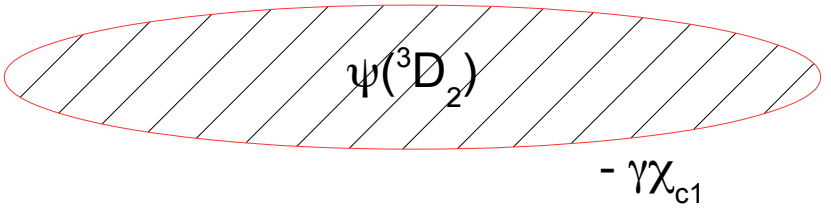
Search for doubly charged DDK

Charmonium 1D triplet: J=2

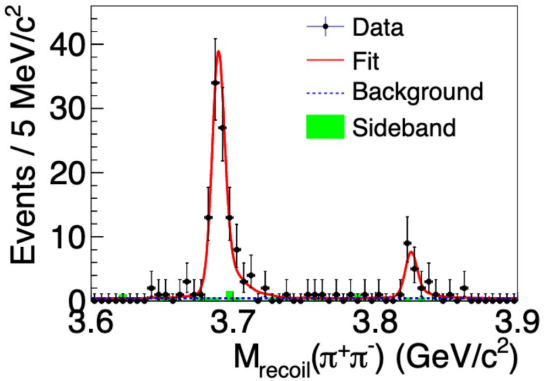
First evidence in B decays
Belle: PRL 111,032001(2013)

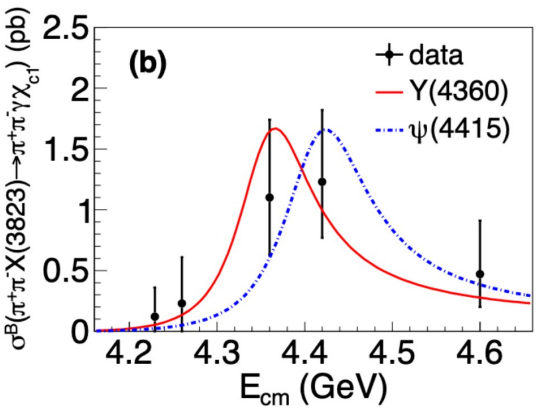


M=3822.2±1.2

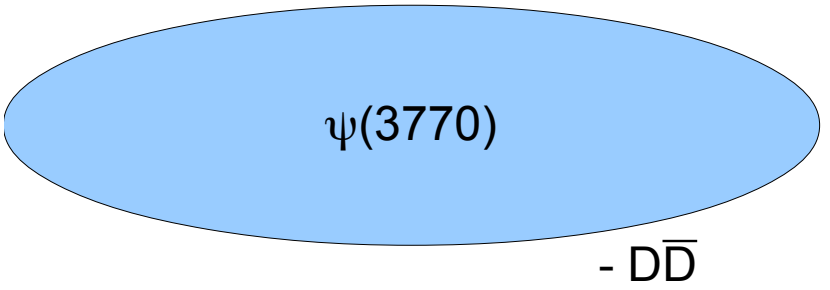


Observation in dipion transitions from ψ(4400)
BES: PRL 115,011803(2015)



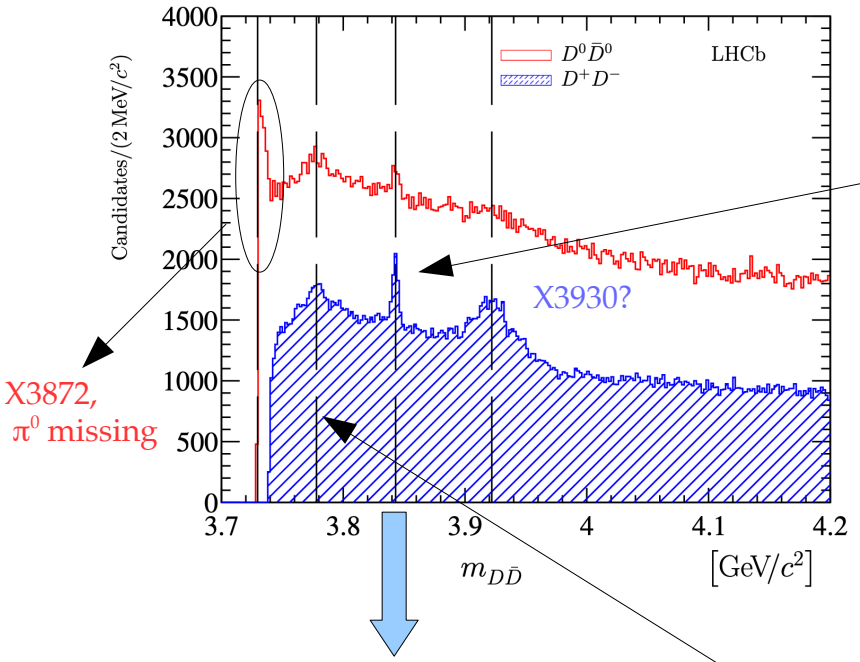


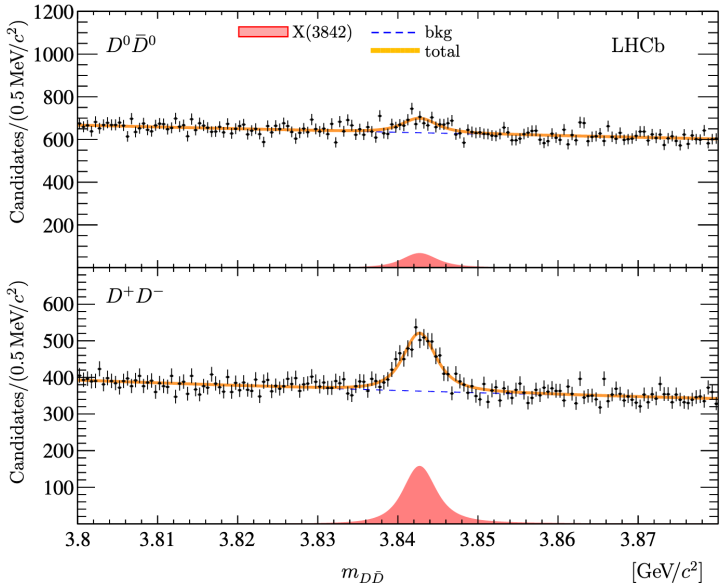
M=3773.7±0.4



Charmonium 1D triplet: J=3

Observation in pp collisions
LHCB:JHEP 07 (2019) 035





M=3842.7±0.2 $\psi(^3D_3)$

- $D\bar{D}$

M=3822.2±1.2

$\psi(^3D_2)$

- $\gamma\chi_{c1}$

M=3773.7±0.4

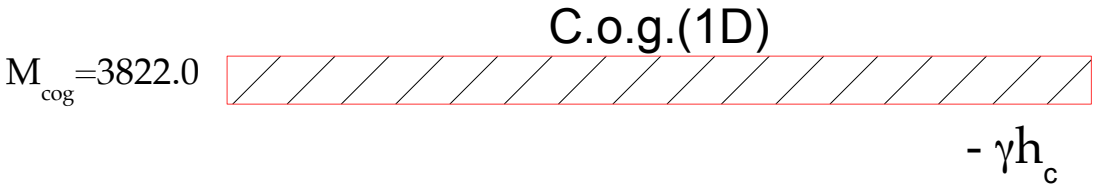
$\psi(3770)$

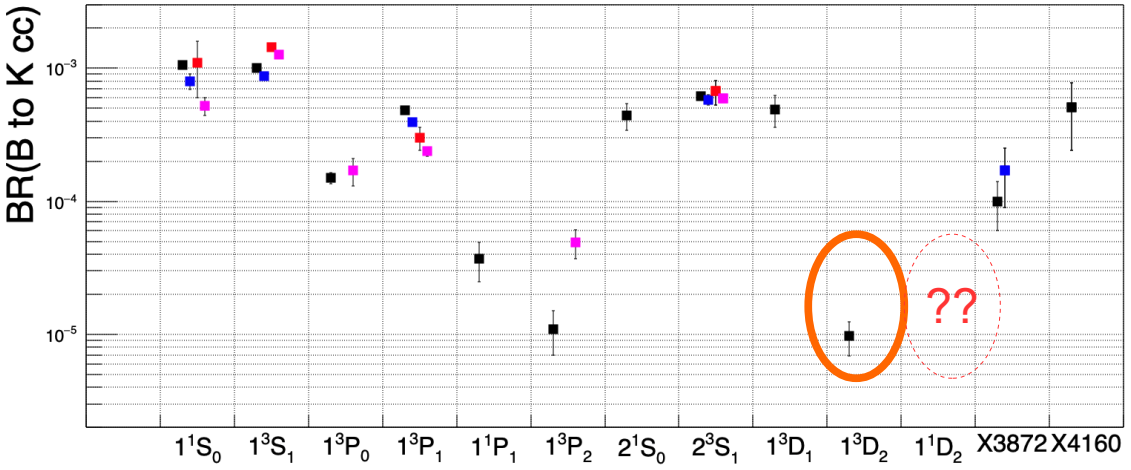
- $D\bar{D}$

Charmonium 1D singlet: search for J=2

The spin singlet 1D state $\eta_{c2}(1^1D_2)$ is expected to:

- be located at the cog of triplet D states
- decay to γh_c (can't decay to $D\bar{D}$)
- be produced in B decays at a rate comparable to the $\psi(1^3D_2)$, and the $\chi_c(1^3P_2)$





■ $B^+ \to c\bar{c}\, K^+$ ■ $B^+ \to c\bar{c}\, K^{+*}$

■ $B^0 \to c\bar{c}\, K^0$ ■ $B^0 \to c\bar{c}\, K^{0*}$

M=3842.7±0.2 $\psi(^3D_3)$

- $D\bar{D}$

M=3822.2±1.2

$\psi(^3D_2)$

- $\gamma\chi_{c1}$

M=3773.7±0.4

$\psi(3770)$

- $D\bar{D}$

Charmonium 1D singlet: search for J=2

Belle:JHEP 2005,034 (2020)

The spin singlet 1D state $\eta_{c2}(1^1D_2)$ is expected to:
- be located at the cog of triplet D states
- decay to γh_c (can't decay to $D\bar{D}$)
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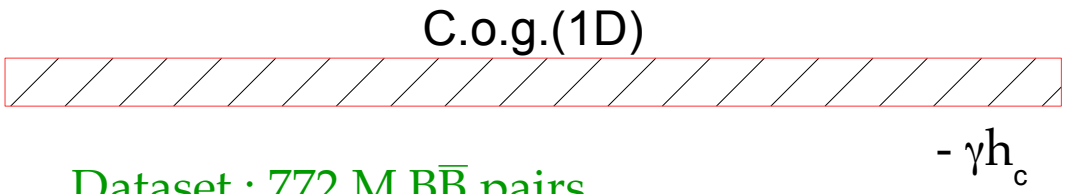


Dataset : 772 M $B\bar{B}$ pairs

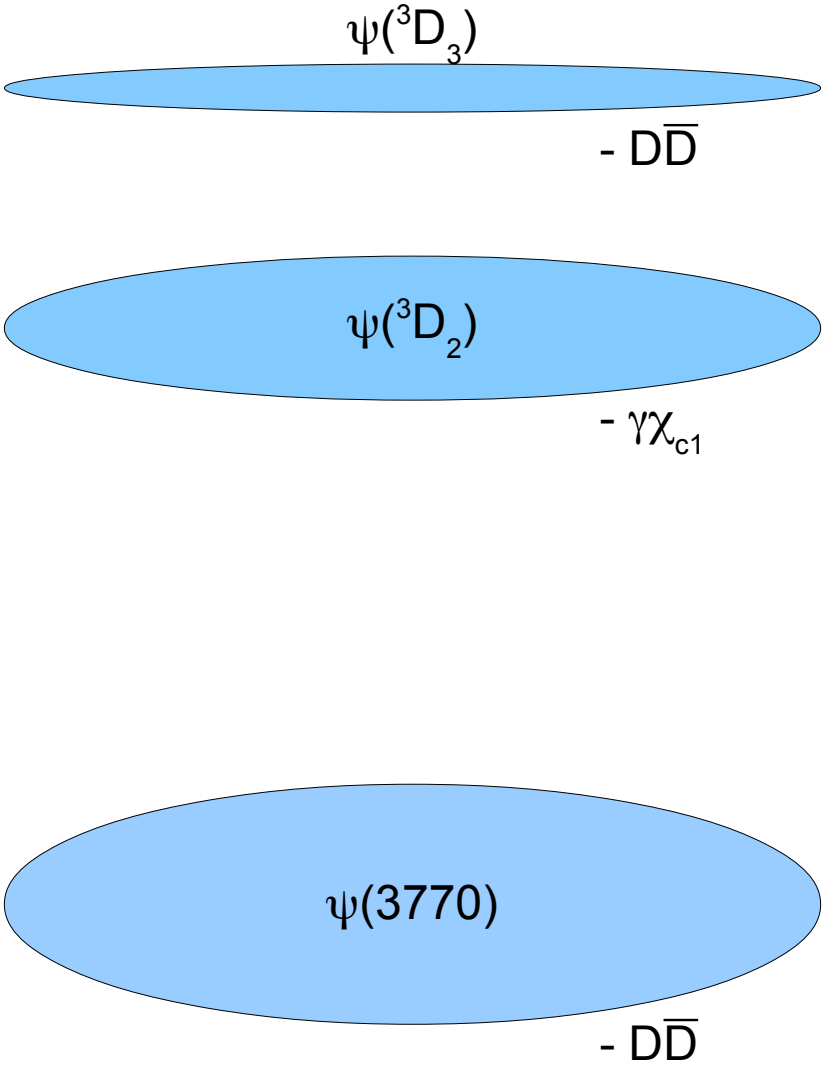
B decays to:

$B^+ \rightarrow \eta_{c2}(1D)\, K^+$, $\eta_{c2}(1D)\, \pi^+ K_s$ + c.c.

$B^0 \rightarrow \eta_{c2}(1D)\, K_s$, $\eta_{c2}(1D)\, \pi^+ K^-$ + c.c.

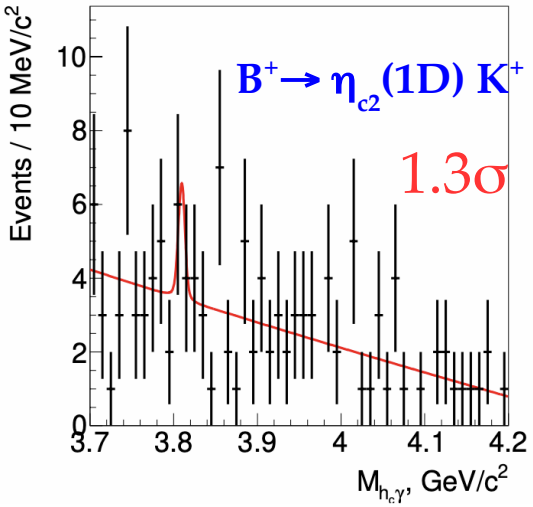
With $\eta_{c2}(1D) \rightarrow \gamma\gamma\eta_c(1S)$ decays via h_c
and $\eta_c(1S)$ reconstructed in 10 decay modes: $K^+K^-\pi^0$, $K^+K_s\pi^-$, $K_sK_s\pi^0$, $K^+K^-\eta$, $K^+K^-K^+K^-$, $\eta'\pi^+\pi^-$, $p\bar{p}$, $p\bar{p}\pi^0$, $p\bar{p}\pi^+\pi^-$, $\Lambda\bar{\Lambda}$

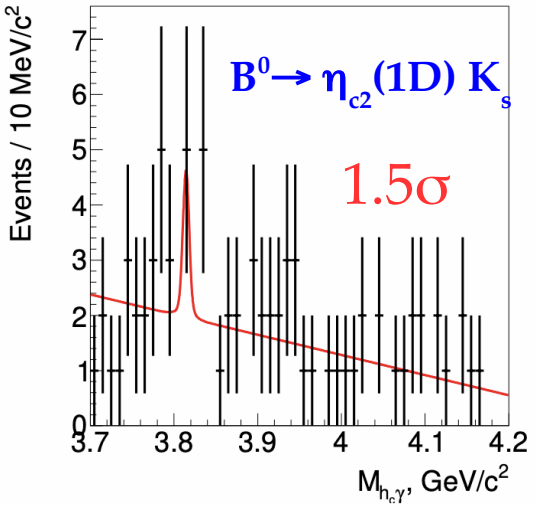
- MVA using a multilayer perceptron NN
- Global optimization performed

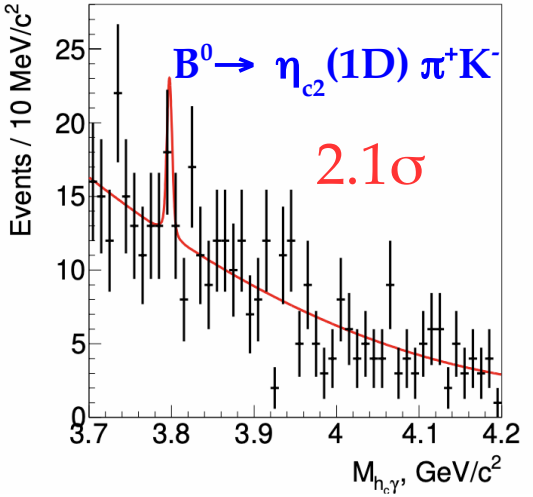


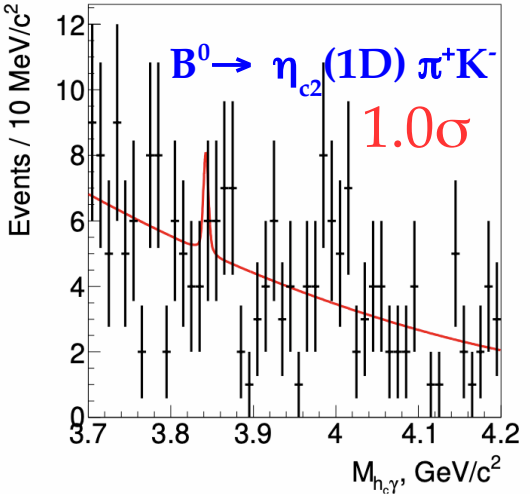
Charmonium 1D singlet: search for J=2

BELLE
Fit results







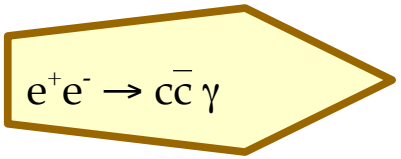


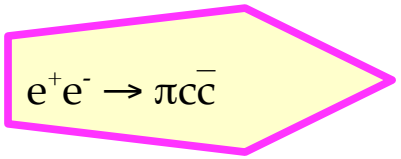
JHEP 2005,034 (2020)

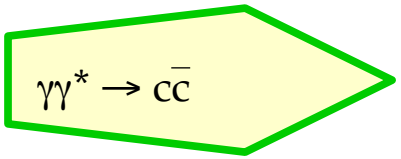
90% UL:

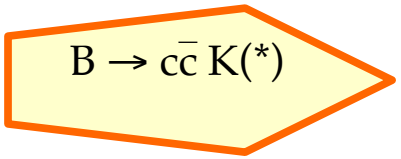
$\mathcal{B}(B^+ \to \eta_{c2}(1D)K^+)\mathcal{B}(\eta_{c2}(1D) \to h_c\gamma)$	3.7×10^{-5}	$\mathcal{B}(B^0 \to \eta_{c2}(1D)K_S^0)\mathcal{B}(\eta_{c2}(1D) \to h_c\gamma)$	3.5×10^{-5}
$\mathcal{B}(B^0 \to \eta_{c2}(1D)\pi^-K^+)\mathcal{B}(\eta_{c2}(1D) \to h_c\gamma)$	1.0×10^{-4}	$\mathcal{B}(B^+ \to \eta_{c2}(1D)\pi^+K_S^0)\mathcal{B}(\eta_{c2}(1D) \to h_c\gamma)$	1.1×10^{-4}

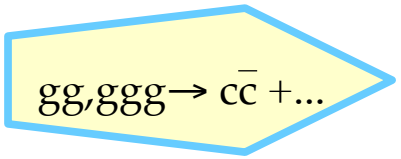
Charmonium 2P states: the 3850-3950 MeV jungle

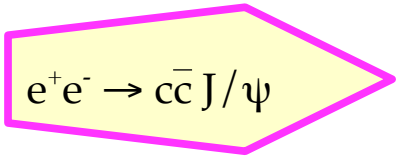


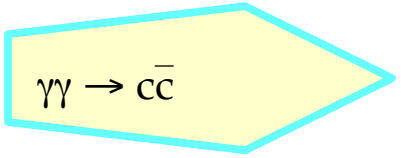


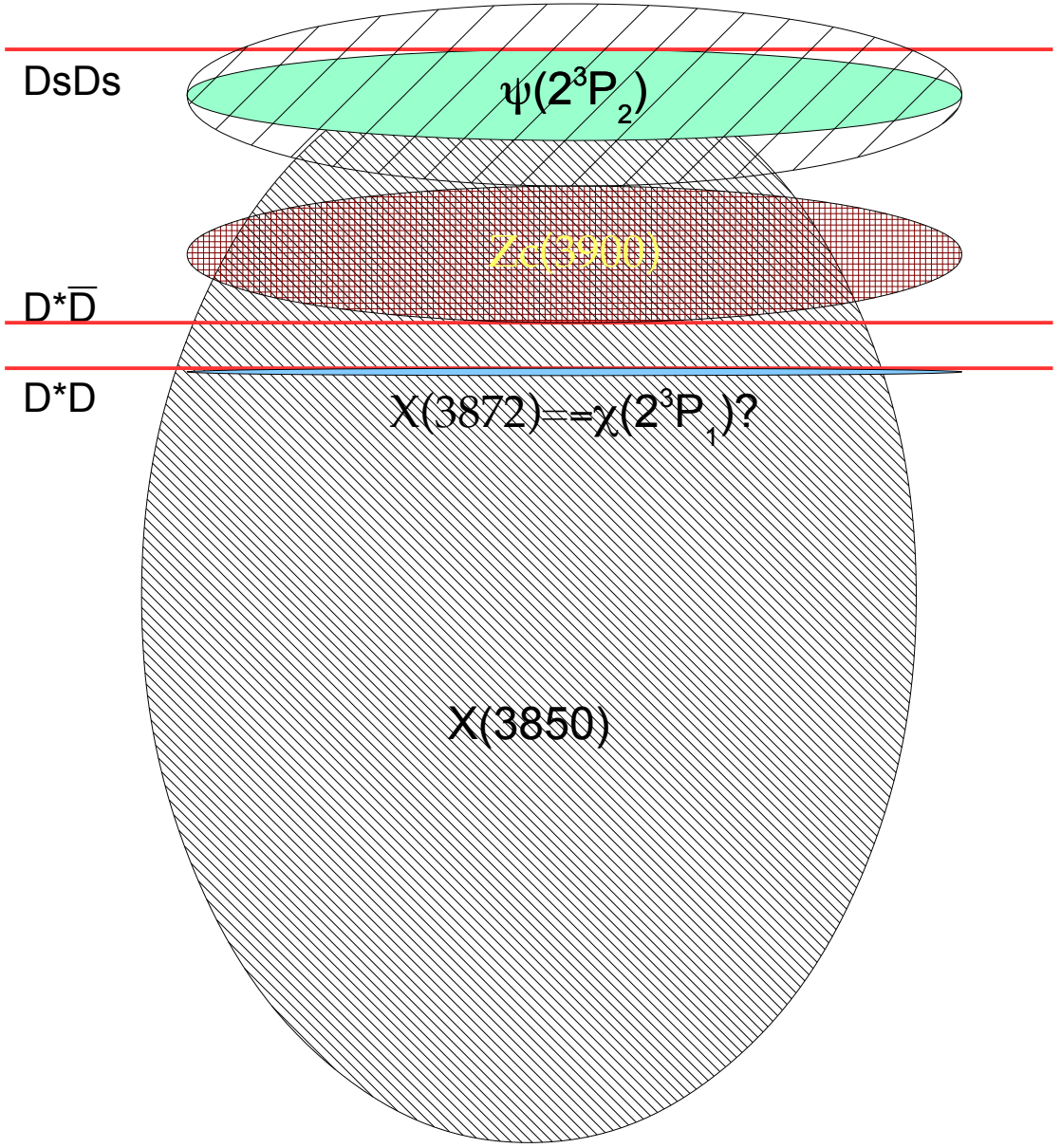


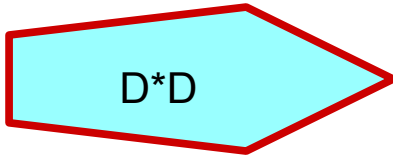


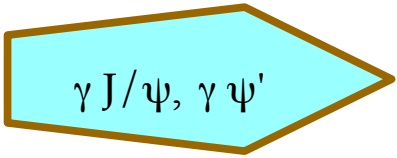


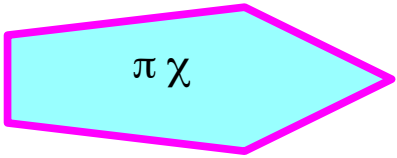


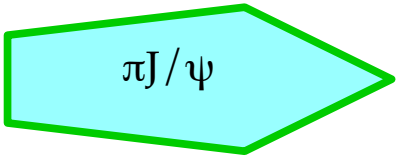


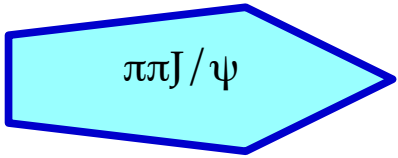


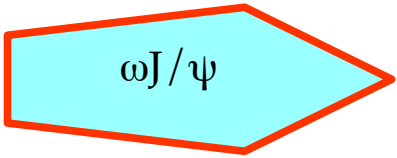








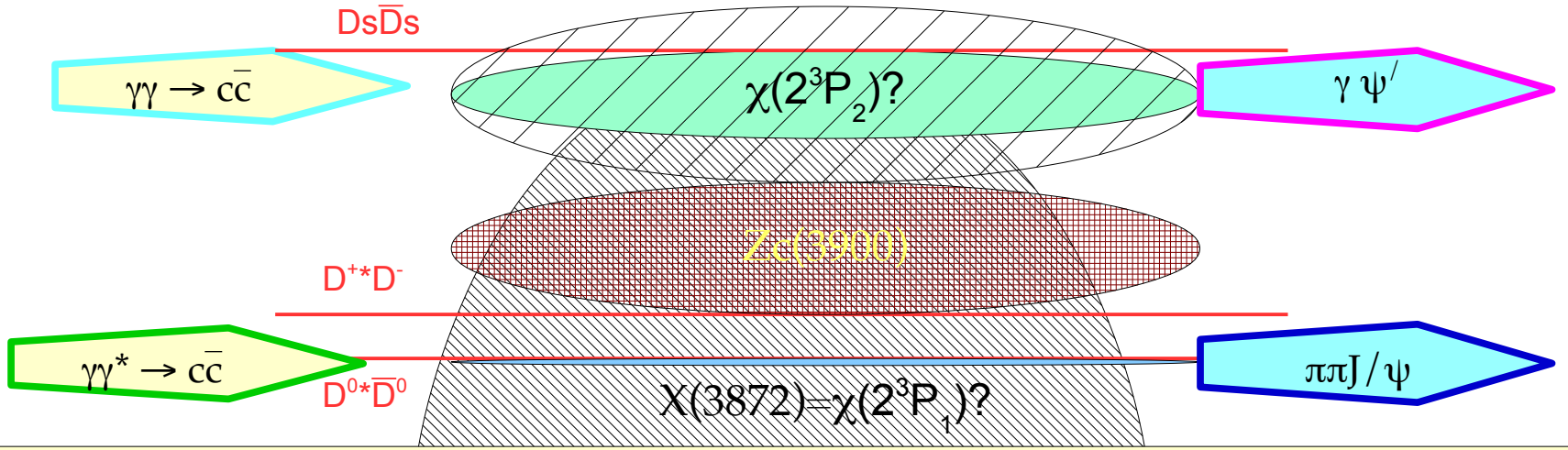




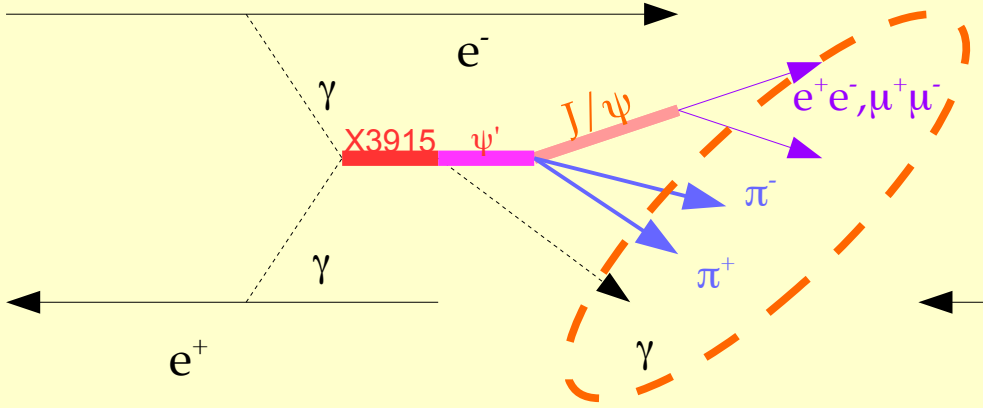
Huge variety of input channels

..... and decay modes

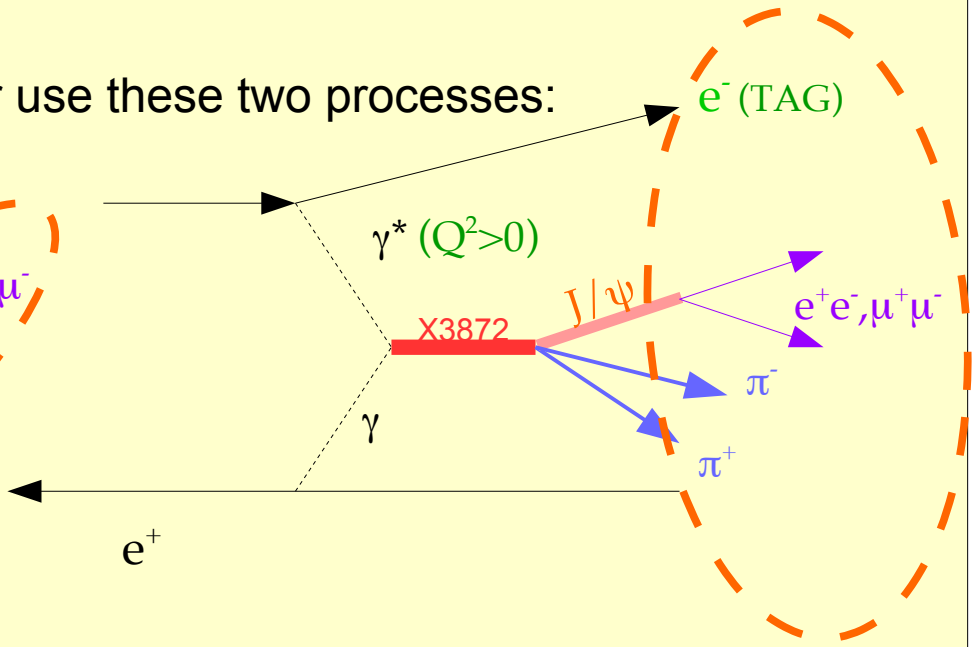
Charmonium 2P states: the 3850-3950 MeV jungle



Most recent Belle publications in the 2P sector use these two processes:



ArXiV:2105.06605



PRL126 (2020) 122001

Charmonia from γγ in the 3.7-4.2 GeV range

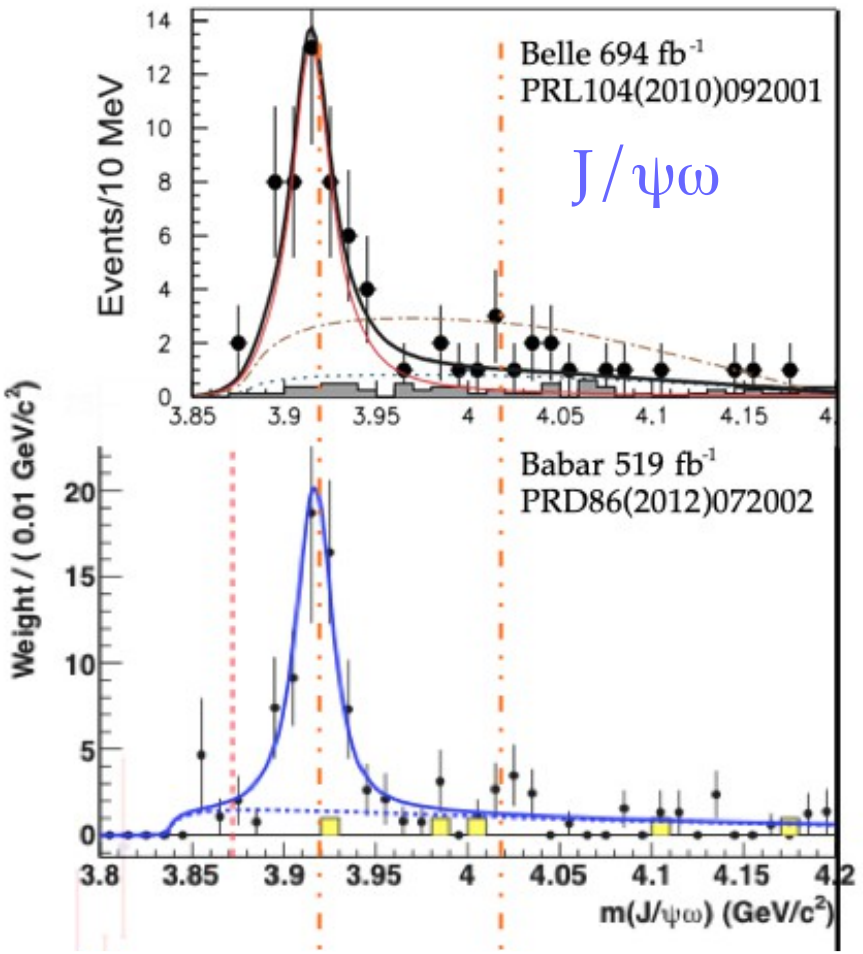
The production of X(3915) in γγ, with decay to ψω, was observed by both Belle and Babar.
PDG: $\Gamma\gamma\gamma \times BR(X(3915) \rightarrow \psi\omega) = 54\pm9$ eV (assuming JP=0+)
Angular analyses disfavor 2+ and 0-.

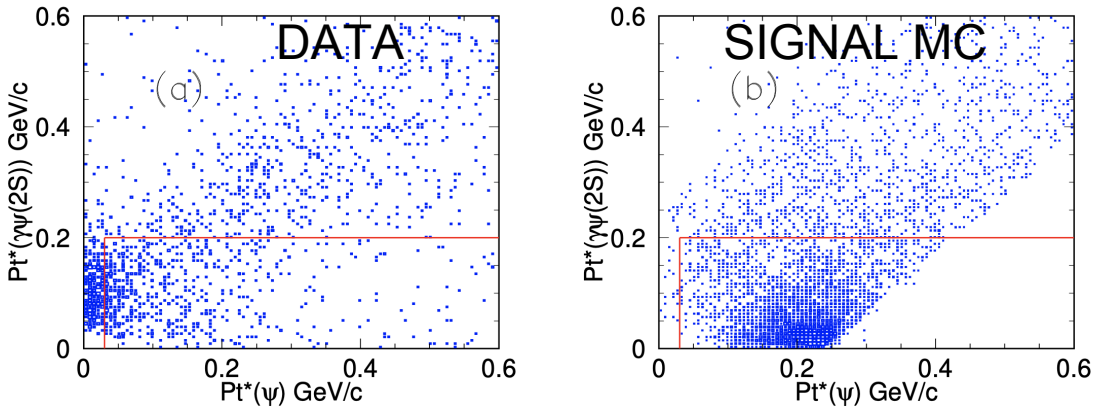
But … helicity 2 amplitude is dominant on helicity 0, for **pure** $c\bar{c}$ states …

As $\Gamma(\chi_{c2}(2P) \rightarrow \gamma\psi')$ is expected ~300 keV,
Γ~20 MeV implies BR ~1.5% for this transition

Belle searched for $\psi' \rightarrow \pi\pi J/\psi$,
with $J/\psi \rightarrow e^+e^-, \mu^+\mu^-$

Cut on Pt to suppress ISR





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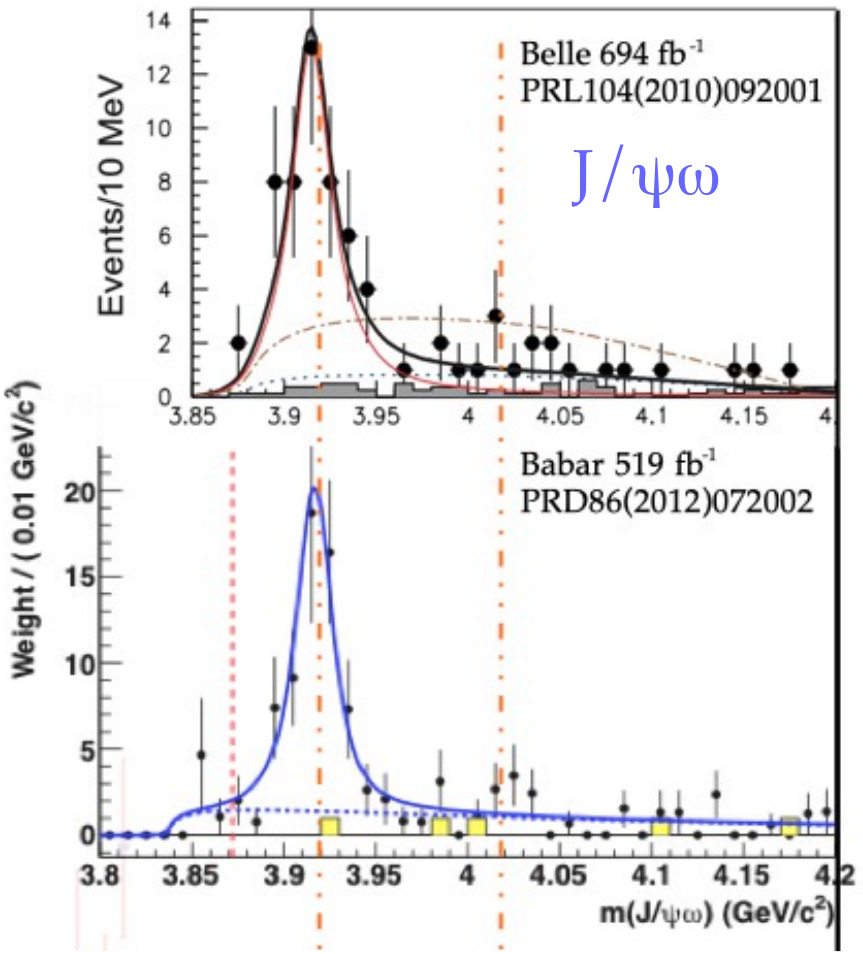
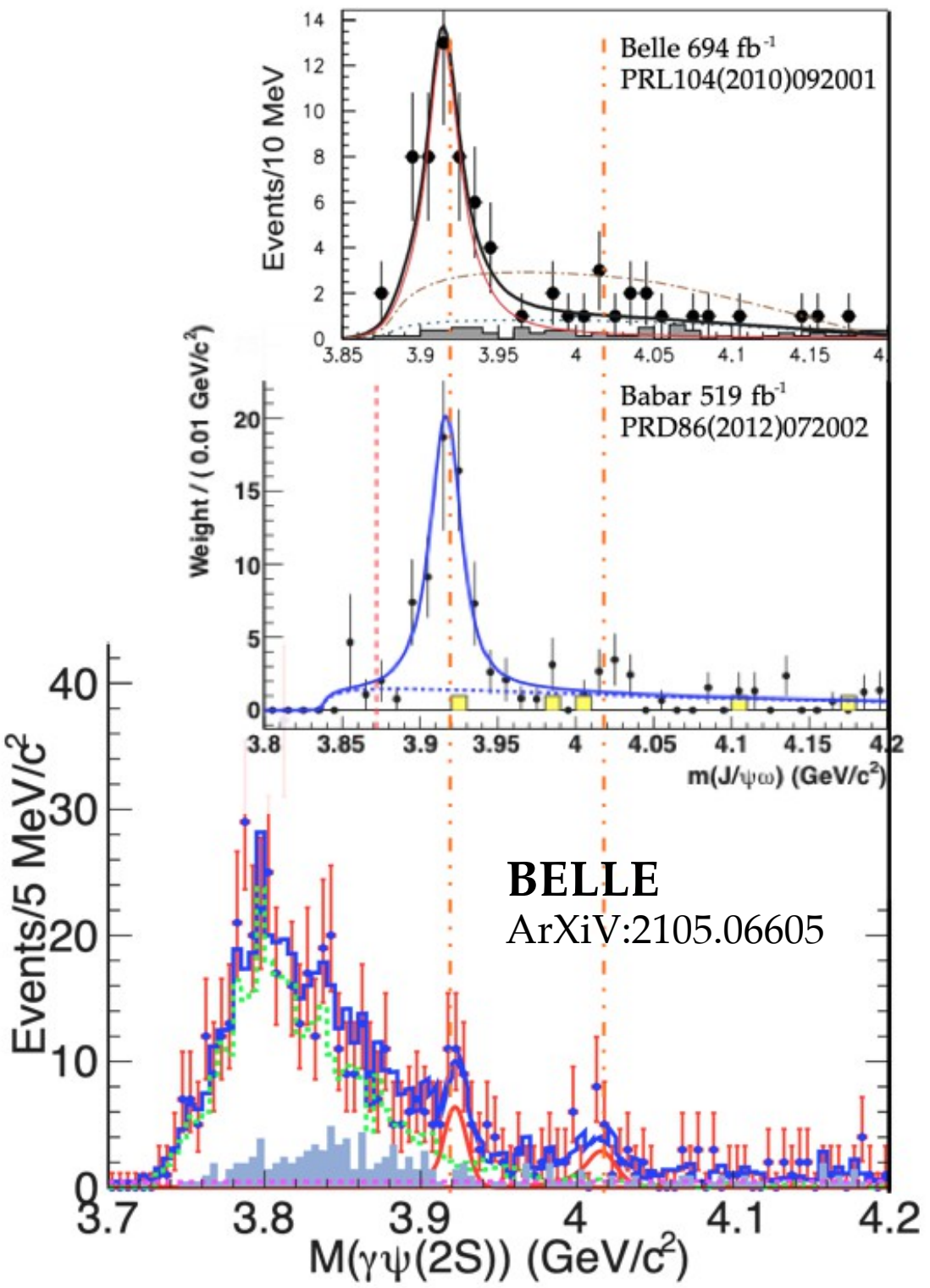
Let's look for radiative transitions to ψ'



Charmonia from γγ in the 3.7-4.2 GeV range

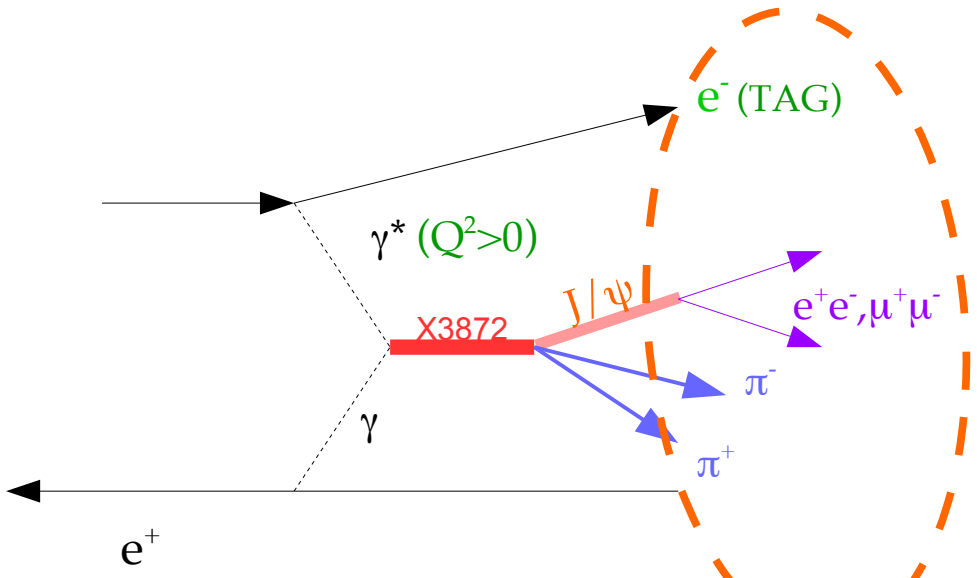
Resonant parameters	$J=0$	$J=2$
M_1	$3921.3 \pm 2.4 \pm 1.6$	
Γ_1	$0.0 \pm 5.3 \pm 2.0$	
$\Gamma_1^{\rm UL}$	11.5	
$\Gamma_{\gamma\gamma}\mathcal{B}(R_1 \to \gamma\psi(2S))$	$8.2 \pm 2.3 \pm 0.9$	$1.6 \pm 0.5 \pm 0.2$
M_2	$4014.4 \pm 4.1 \pm 0.5$	
Γ_2	$6 \pm 16 \pm 12$	
$\Gamma_2^{\rm UL}$	39.3	
$\Gamma_{\gamma\gamma}\mathcal{B}(R_2 \to \gamma\psi(2S))$	$5.3 \pm 2.7 \pm 2.5$	$1.1 \pm 0.5 \pm 0.5$
$\Gamma_{\gamma\gamma}^{\rm UL}\mathcal{B}(R_2 \to \gamma\psi(2S))$	12.8	2.6
$M_{X(3915)}$	3918.4 (fixed)	
$\Gamma_{X(3915)}$	20 (fixed)	
$\Gamma_{\gamma\gamma}\mathcal{B}(X(3915) \to \gamma\psi(2S))$	$10.9 \pm 3.1 \pm 1.2$	$2.2 \pm 0.6 \pm 0.2$
$M_{Z(3930)}$	—	3922.2 (fixed)
$\Gamma_{Z(3930)}$	—	35 (fixed)
$\Gamma_{\gamma\gamma}\mathcal{B}(Z(3930) \to \gamma\psi(2S))$	—	$2.4 \pm 0.7 \pm 0.4$

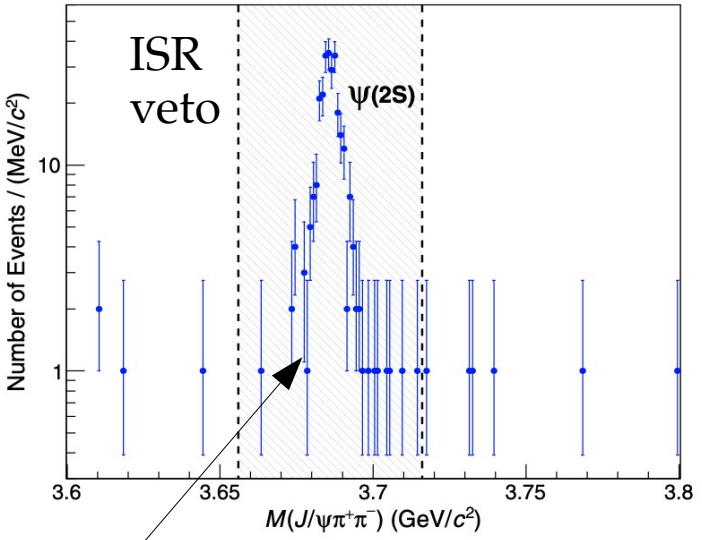


Evidence of X(3872) in γγ*

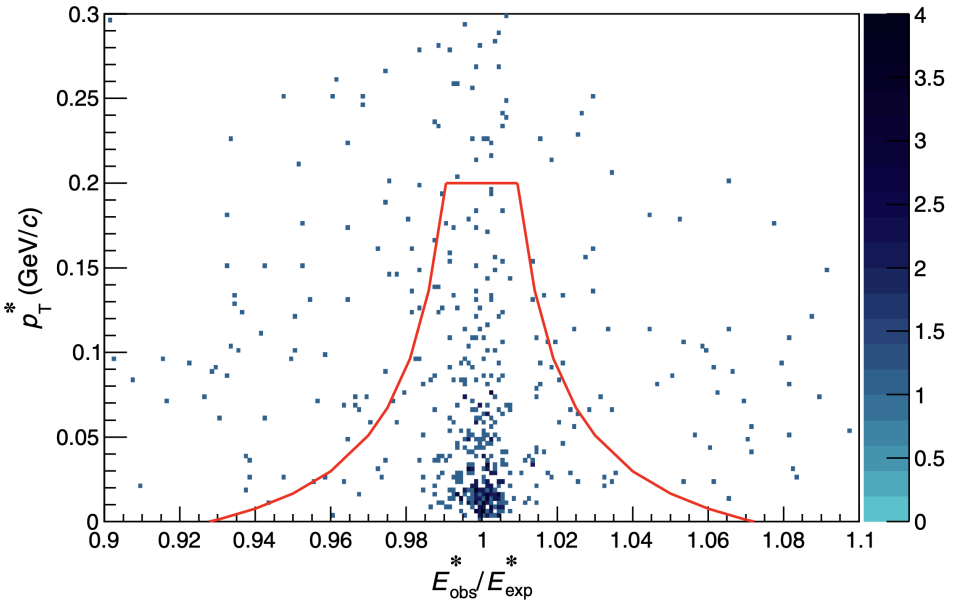
PRL 126, 122001 (2021)

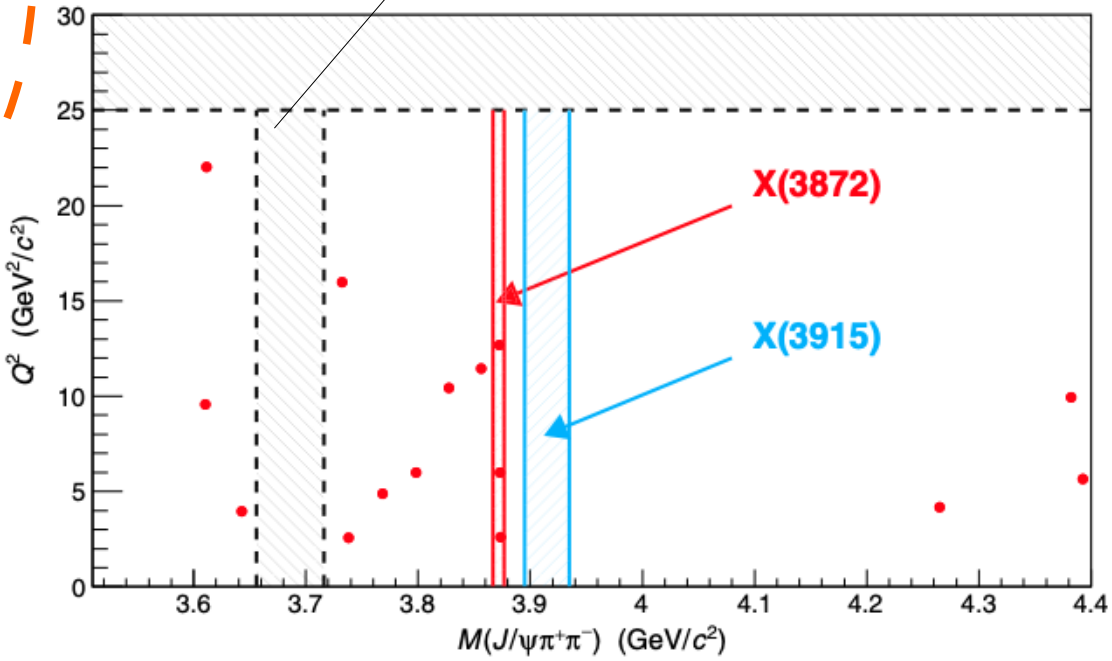
Dataset: 825 fb^{-1}





Kinematics cuts:





3 events survive in the X3872 band
Significance : 3.2 sigma
0 events in the X3915 band

Evidence of X(3872) in γγ*

PRL 126, 122001 (2021)

- Dataset: 825 fb^{-1}
- **3 events survive in the X3872 band**
- Significance : 3.2 sigma .
- The Partial width extraction from the number of observed events is model dependent (assumes that the X8342 is a qq axial vector meson)

$$\frac{\mathrm{d}\sigma_{ee}(X)}{\mathrm{d}Q^2} = \tilde{\Gamma}_{\gamma\gamma} F(M, Q^2, \epsilon) \left.\frac{\mathrm{d}^2 L_{\gamma^*\gamma}}{\mathrm{d}W \mathrm{d}Q^2}\right|_{W=M}$$

where

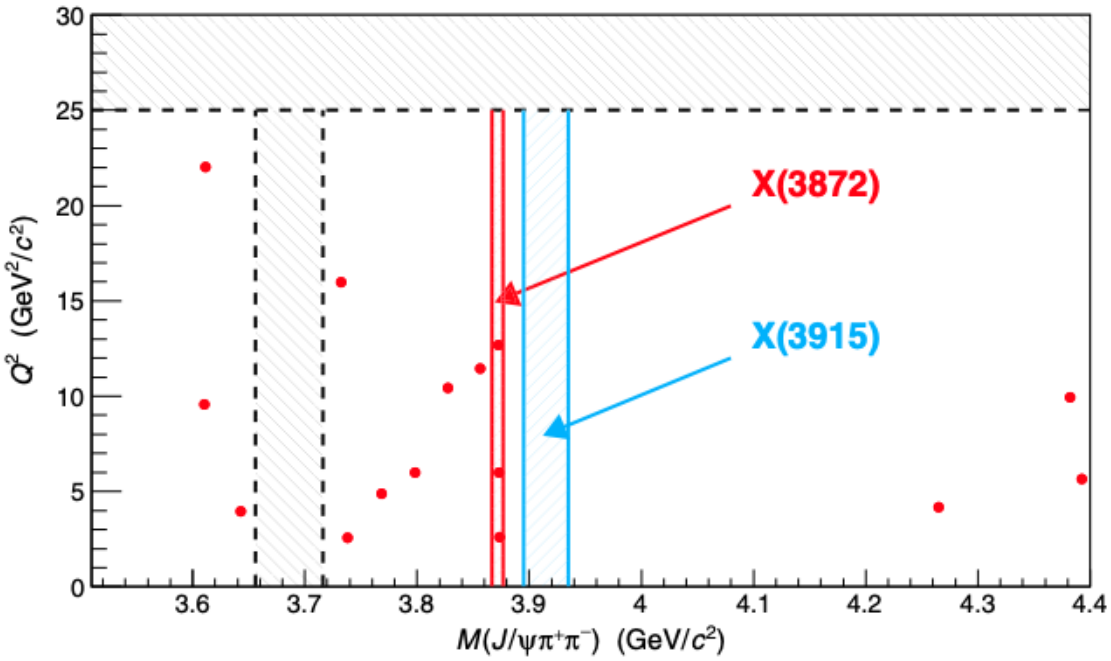
$$F(M, Q^2, \epsilon) = \frac{48\pi^2}{M^2} \frac{\frac{Q^2}{2M^2} + \epsilon}{\left(1 + \frac{Q^2}{M^2}\right)^3} \frac{Q^2}{M^2}$$

We then get

$$N_{\mathrm{sig}} = L_{\mathrm{int}} \mathcal{B}(X \to J/\psi\pi^+\pi^-) \mathcal{B}(J/\psi \to \ell^+\ell^-) \times \tilde{\Gamma}_{\gamma\gamma} \int_{Q^2_{\mathrm{min}}}^{Q^2_{\mathrm{max}}} \mathrm{d}Q^2 F(M, Q^2, \epsilon) \varepsilon_{\mathrm{eff}}(Q^2) \left.\frac{\mathrm{d}^2 L_{\gamma^*\gamma}}{\mathrm{d}W \mathrm{d}Q^2}\right|_{W=M}$$

And integrating Q^2 in the range [1.5,25] GeV$^2/c^2$, we obtain:

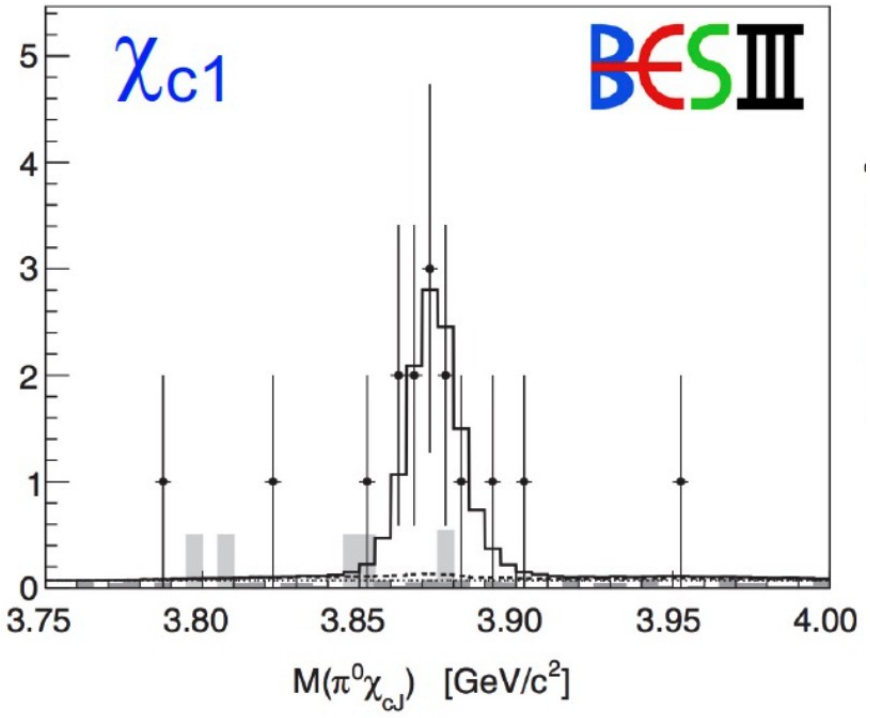
$$\tilde{\Gamma}_{\gamma\gamma} \mathcal{B}(X(3872) \to J/\psi\pi^+\pi^-) = (1.88 \pm 0.24)\ \mathrm{eV} \times N_{\mathrm{sig}}$$



$$\tilde{\Gamma}_{\gamma\gamma} \mathcal{B}(X \to J/\psi\pi^+\pi^-) = 5.5^{+4.1}_{-3.8}\ (\mathrm{stat.}) \pm 0.7\ (\mathrm{syst.})\ \mathrm{eV}$$

Search for X3872,X3915 → $\chi_{c1}(1P)\pi^0$

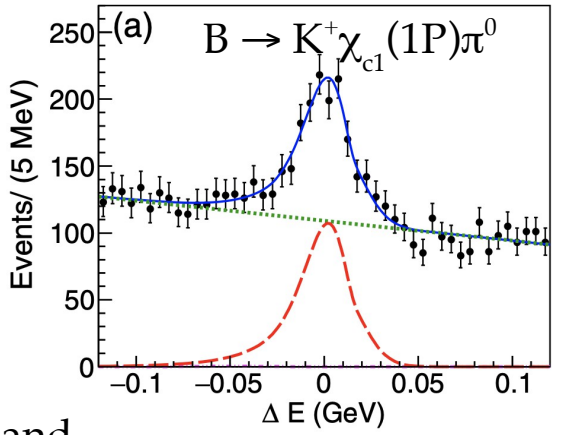
BES-III PRL122(2019)22001
X(3872) observed in e^+e^- → γX(3872)
in the region 4.15 < Ecm < 4.30 GeV



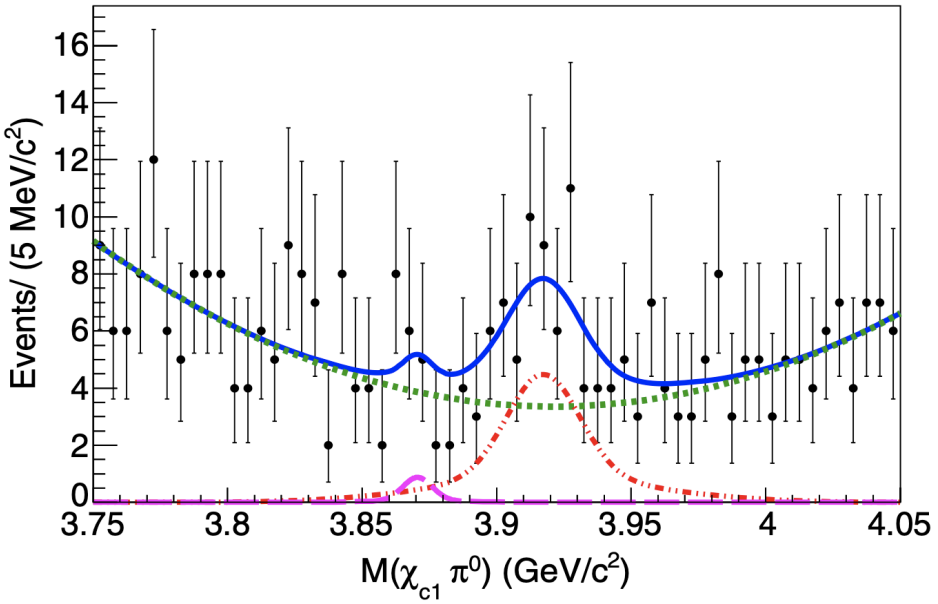
BR comparable with $\psi\pi^+\pi^-$:

$$R^X_{\chi_{c1}/\psi} \equiv \frac{\mathcal{B}(X(3872) \to \chi_{c1}\pi^0)}{\mathcal{B}(X(3872) \to J/\psi\pi^+\pi^-)} = 0.88^{+0.33}_{-0.27} \pm 0.10$$

Belle (772M $B\bar{B}$ decays at Y(4S))
PRD 99 (2019) 111101



$BR(B^+ \to K^+\chi_{c1}\pi^0) = 3.3\text{x}10\text{-}4$
mostly dominated by the K* band
K* veto: $791.8 < M(K^+\pi^0) < 991.8\ \mathrm{MeV}/c^2$



Belle obtains these 90% upper limits:

$$\mathcal{B}(B^+ \to X(3872)K^+) \times \mathcal{B}(X(3872) \to \chi_{c1}\pi^0) < 8.1 \times 10^{-6}$$

$$\mathcal{B}(B^+ \to X(3915)K^+) \times \mathcal{B}(X(3915) \to \chi_{c1}\pi^0) < 3.8 \times 10^{-5}$$

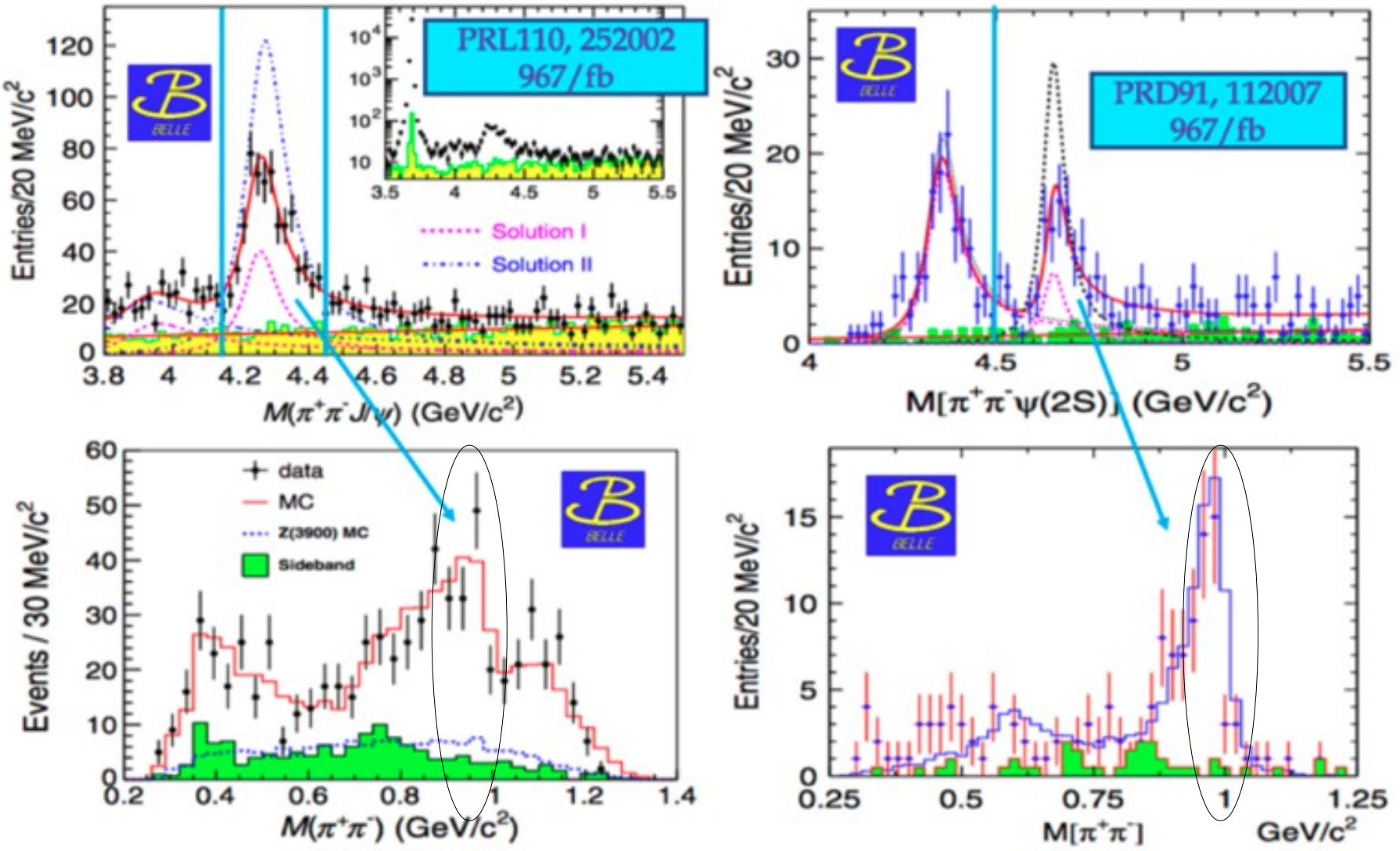
$$R^X_{\chi_{c1}/\psi} < 0.97\ (90\%\ \mathrm{CL})$$

Does not contradict BES-III measurement

More statistics needed

$Y(4626): e^+e^- \to D^+D_{s1}^-(2536)/D_{s1}^-(2573)$ +c.c.

Base idea:



The dipion pair in both Y(4260) and Y(4660) peaks resonates at the mass of the $f_0(980)$, which has also a $s\bar{s}$ component.

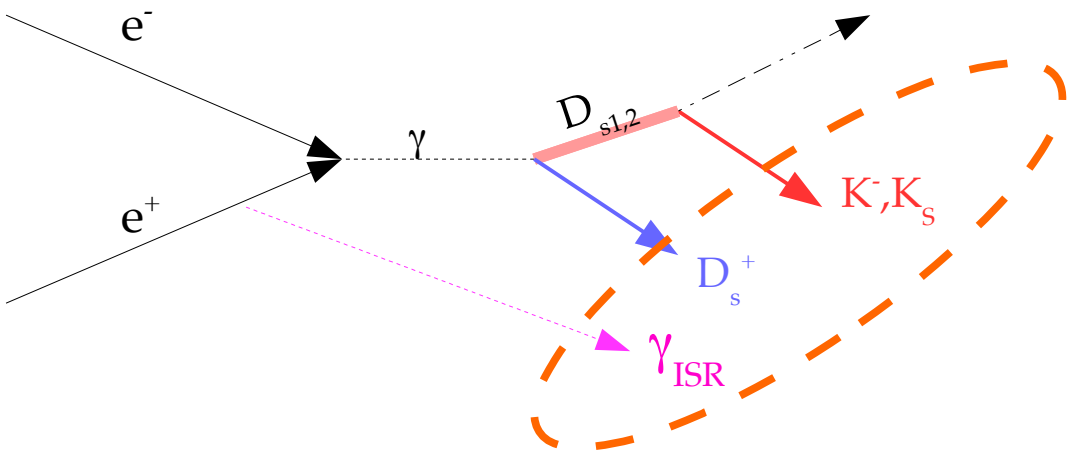
Y(4626): $e^+e^- \to D_s^+ D_{s1}^-(2536)/D_{s1}^-(2573)$ +c.c.

Datasets: 89.5+711+121= 921.9 fb-1 (@ $\sqrt{s}$=10.52,10.58,10.86GeV)

Analysis strategy:

$D_{s1}^-(2536) \to D^{*0}K^-$ | $D^{*-}K_S$; $D_{s2}^-(2573) \to D^0K^-$ | D^-K_S

D_s^+ reconstruction in 8 final states: $\phi\pi^+$, $\overline{K}^{*0}K^+$, K_SK^+, $K^+K^-\pi^+\pi^0$, $K^{*+}K_S$, $\eta\pi^+$, $\eta'\pi^+$



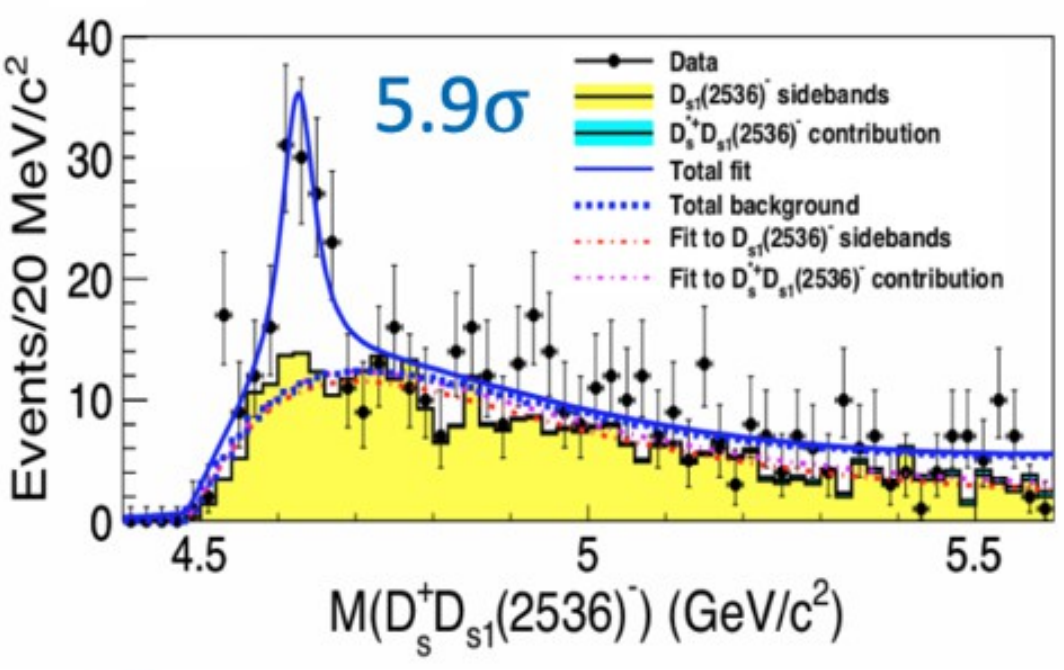
Signal :

- D^{*0}/D^{*-} in the $M_{rec}(\gamma_{ISR}, D_s, K^-/K_S)$ distribution for $D_{s1}(2536)$
- D^0/D^- in the $M_{rec}(\gamma_{ISR}, D_s, K^-/K_S)$ distribution for $D_{s1}(2573)$

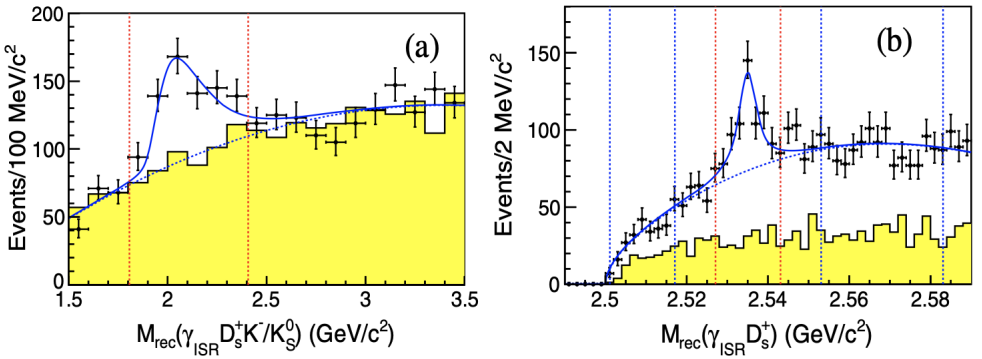
An unbinned simultaneous likelihood fit:

- Signal: a *BW* convolved with a Gaussian function, then multiplied by an efficiency function
- A non-resonant contribution: a two-body phase space form
- $D_{s1}(2536)^-$ mass sidebands: a threshold function
- $e^+e^- \to D_s^{*+}D_{s1}(2536)^-$ background contribution: a threshold function

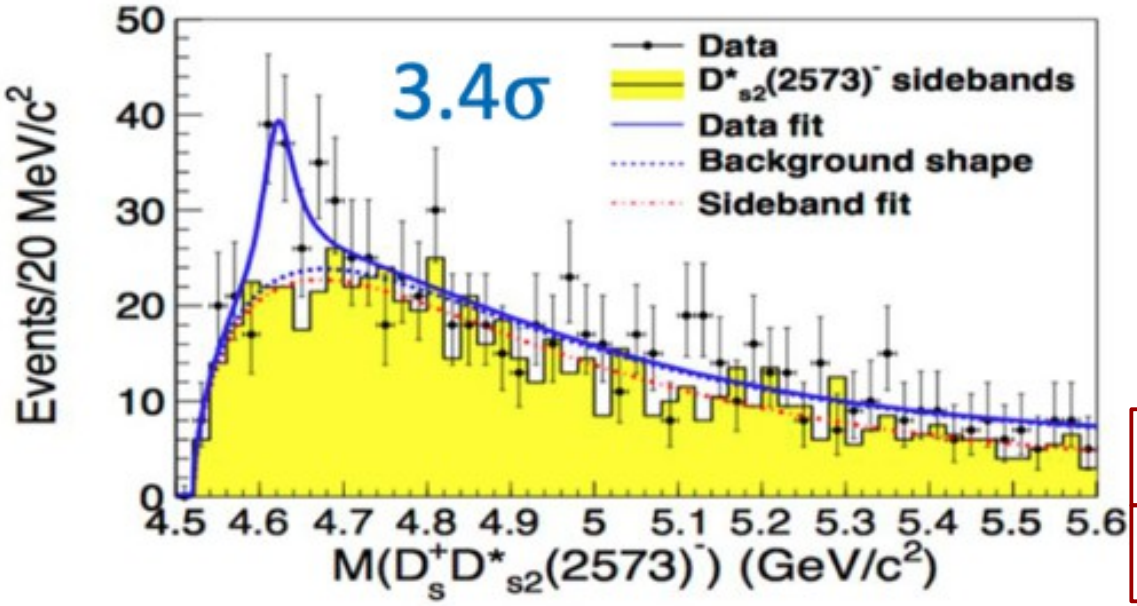
Y(4626): $e^+e^- \to D_s^+ D_{s1}^-(2536)/D_{s1}^-(2573)$ +c.c.



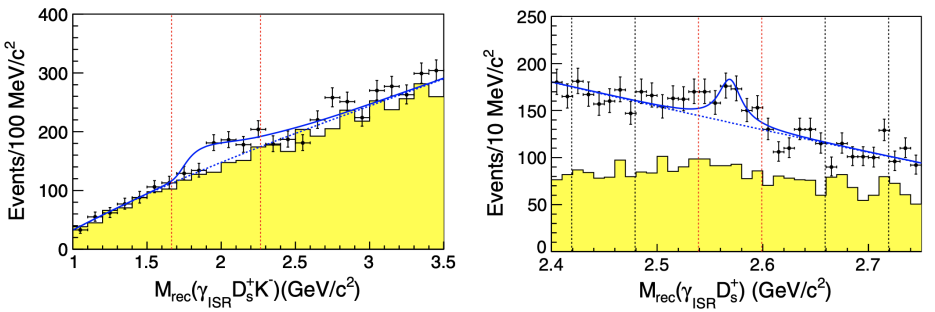
PRD 100 (2019) 111103(R)



M	$(4625.9^{+6.2}_{-6.0}(\text{stat})\pm0.4(\text{syst}))\,\text{MeV}/c^2$
Γ	$(49.8^{+13.9}_{-11.5}(\text{stat})\pm4.0(\text{syst}))\,\text{MeV}$



PRD 101 (2020) 091101



M	$(4619.8^{+8.9}_{-8.0}(\text{stat.})\pm2.3(\text{syst.}))\ \text{MeV}/c^2$
Γ	$(47.0^{+31.3}_{-14.8}(\text{stat.})\pm4.6(\text{syst.}))\ \text{MeV}$

Inclusive search for a $cc\bar{d}\bar{s}$ bound state

Following the LHCB discovery of doubly charmed baryons , a plethora of papers suggested the search for doubly heavy same-sign bound states, initiated by Karliner, Rosner PRL119 (2017) 20, 202001, and Eichten,Quigg PRL 119 (2017) 20, 202002

State	J^P	$m(Q_iQ_j\bar{q}_k\bar{q}_l)$	Decay Channel	$\mathcal{Q}$ [MeV]
$\{cc\}[\bar{u}\bar{d}]$	1^+	3978	D^+D^{*0} 3876	102
$\{cc\}[\bar{q}_k\bar{s}]$	1^+	4156	$D^+D_s^{*+}$ 3977	179
$\{cc\}\{\bar{q}_k\bar{q}_l\}$	$0^+, 1^+, 2^+$	4146, 4167, 4210	D^+D^0, D^+D^{*0} 3734, 3876	412, 292, 476
$[bc][\bar{u}\bar{d}]$	0^+	7229	B^-D^+/B^0D^0 7146	83
$[bc][\bar{q}_k\bar{s}]$	0^+	7406	B_sD 7236	170
$[bc]\{\bar{q}_k\bar{q}_l\}$	1^+	7439	B^*D/BD^* 7190/7290	249
$\{bc\}[\bar{u}\bar{d}]$	1^+	7272	B^*D/BD^* 7190/7290	82
$\{bc\}[\bar{q}_k\bar{s}]$	1^+	7445	DB_s^* 7282	163
$\{bc\}\{\bar{q}_k\bar{q}_l\}$	$0^+, 1^+, 2^+$	7461, 7472, 7493	BD/B^*D 7146/7190	317, 282, 349
$\{bb\}[\bar{u}\bar{d}]$	1^+	10482	$B^-\bar{B}^{*0}$ 10603	**−121**
$\{bb\}[\bar{q}_k\bar{s}]$	1^+	10643	$\bar{B}\bar{B}_s^*/\bar{B}_s\bar{B}^*$ 10695/10691	**−48**
$\{bb\}\{\bar{q}_k\bar{q}_l\}$	$0^+, 1^+, 2^+$	10674, 10681, 10695	B^-B^0, B^-B^{*0} 10559, 10603	115, 78, 136

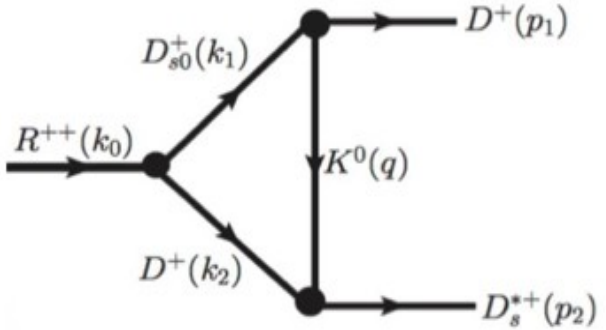
C.Quigg, Beauty 2019

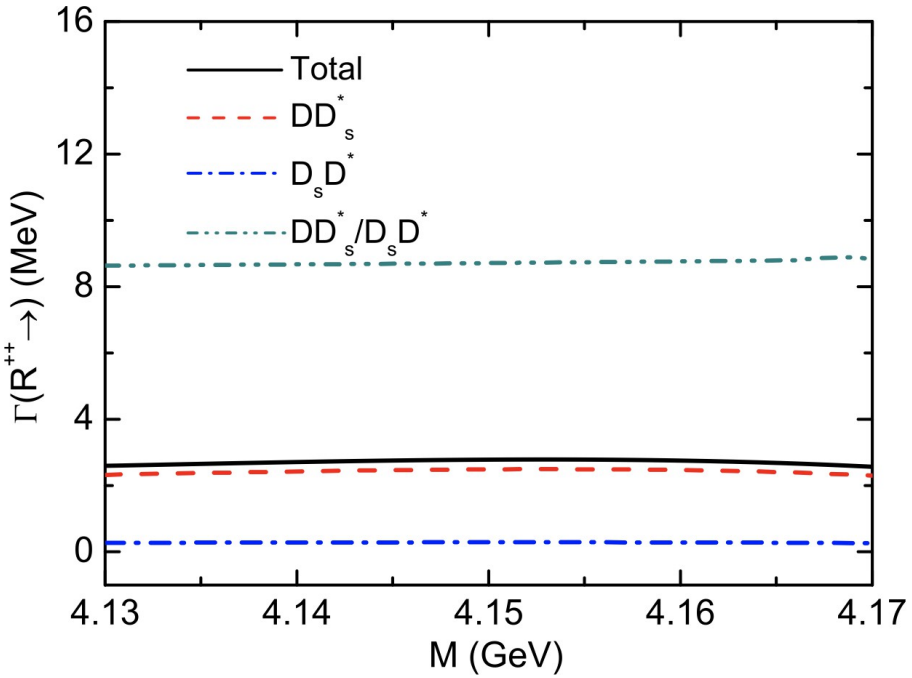
Inclusive search for a $cc\bar{d}\bar{s}$ bound state

Following the LHCB discovery of doubly charmed baryons , a plethora of papers suggested the search for doubly heavy same-sign tetraquarks, initiated by Karliner, Rosner PRL119 (2017) 20, 202001, and Eichten,Quigg PRL 119 (2017) 20, 202002

State	J^P	$m(Q_iQ_j\bar{q}_k\bar{q}_l)$	Decay Channel	$\mathcal{Q}$ [MeV]
$\{cc\}[\bar{u}\bar{d}]$	1^+	3978	D^+D^{*0} 3876	102
➡ $\{cc\}[\bar{q}_k\bar{s}]$	1^+	4156	$D^+D_s^{*+}$ 3977	179
$\{cc\}\{\bar{q}_k\bar{q}_l\}$	$0^+, 1^+, 2^+$	4146, 4167, 4210	D^+D^0, D^+D^{*0} 3734, 3876	412, 292, 476

A narrow DDK state (total width ~2.5 MeV) is predicted between 4.13 and 4.17 GeV
Huang et al, PRD 101 (2020) 014022





Belle searched for peaks in inclusive $\mathbf{D^+D_s^{*+}}$ reconstructed in these modes:

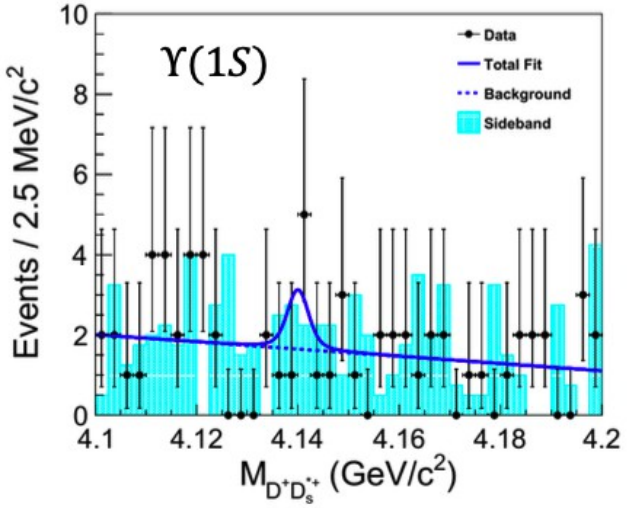
- $D^+ \to K^-\pi^+\pi^-/K_S^0(\to \pi^+\pi^-)\pi^+$
- $D_s^{*+} \to D_s^+\gamma$
- $D_s^+ \to \phi\pi^+/\bar{K}^{*0}K^-$

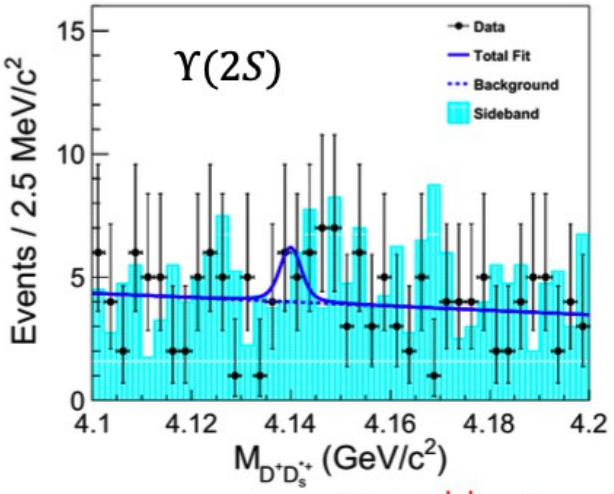
Datasets: 952.5 fb^{-1}
Y(1,2,4,5S) and 10.52 GeV

Inclusive search for a $c\bar{c}ds$ bound state

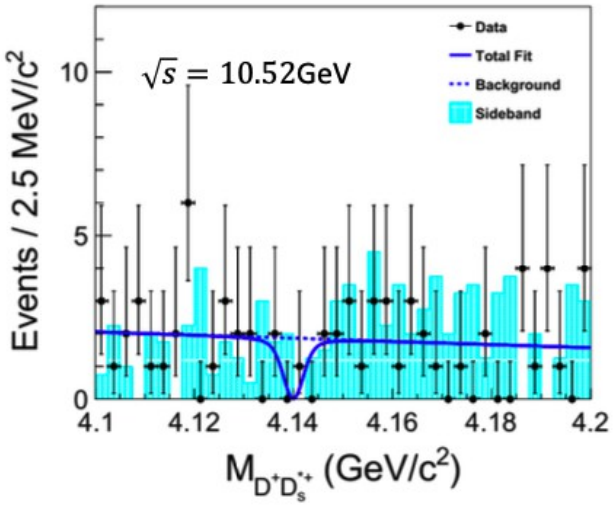
PRD 102, 112001 (2020)

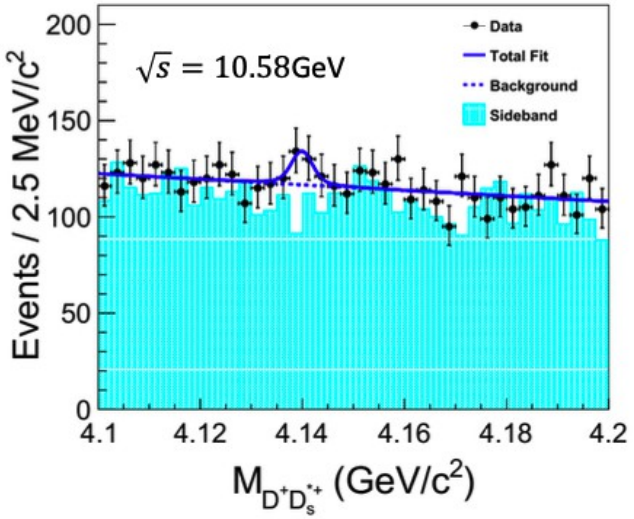
Belle results

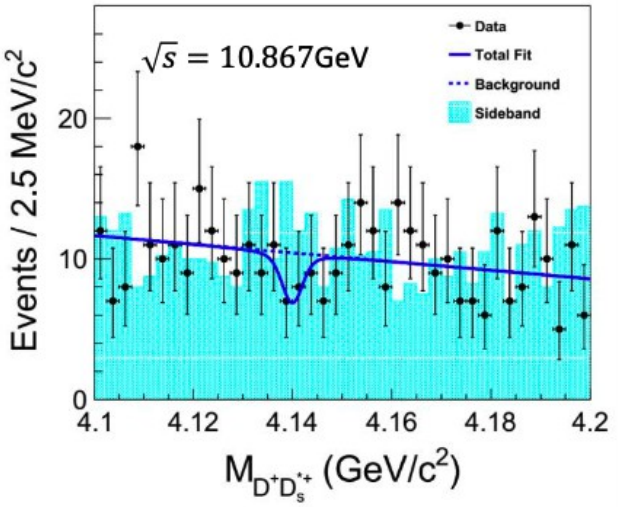




No R^{++} signals are observed.





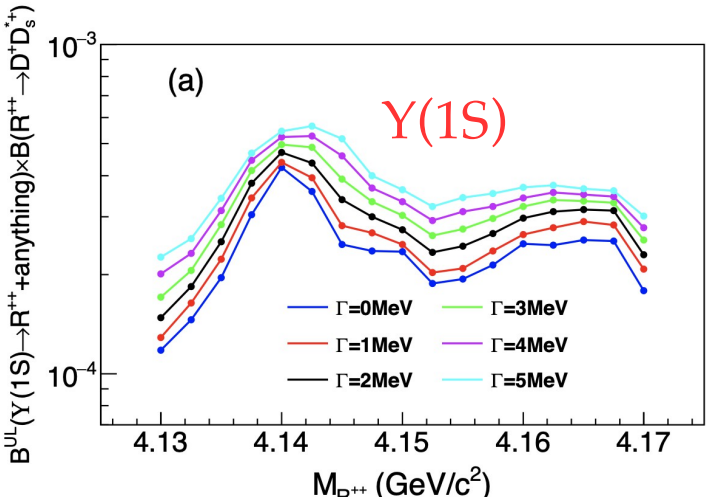


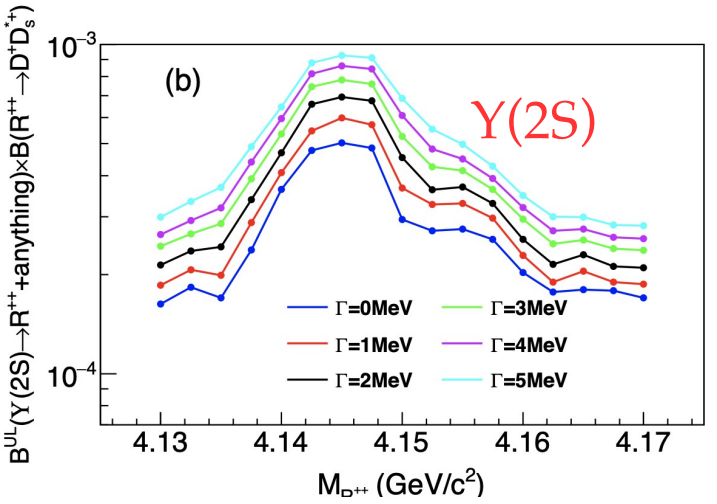
Fits assuming mass M=4.14 GeV/c2 and width Γ=2 MeV

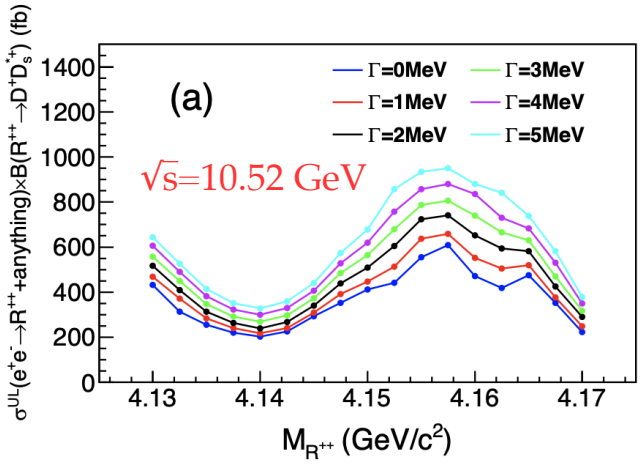
Inclusive search for a $c\bar{c}d\bar{s}$ bound state

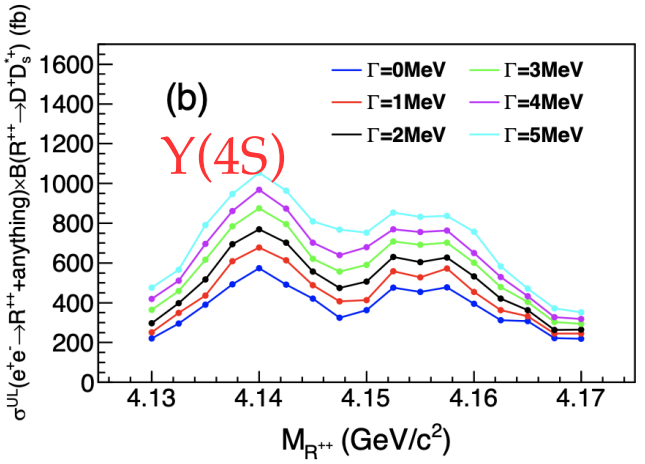
PRD 102, 112001 (2020)

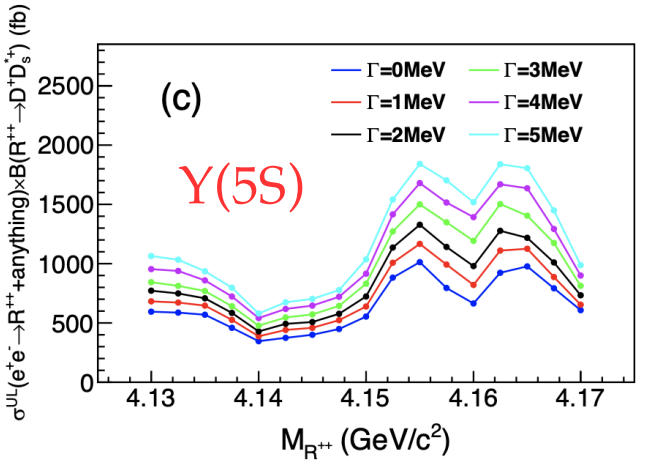
Belle 90% upper limits:











$$\mathcal{B}(\Upsilon(1S)\to R^{++}+\text{anything})\mathcal{B}(R^{++}\to D^{+}D_s^{*+}) < (1.18-5.65)\times 10^{-4}$$

$$\mathcal{B}(\Upsilon(2S)\to R^{++}+\text{anything})\mathcal{B}(R^{++}\to D^{+}D_s^{*+}) < (1.63-9.27)\times 10^{-4}$$

$$\sigma(e^{+}e^{-}\to R^{++}+\text{anything})\mathcal{B}(R^{++}\to D^{+}D_s^{*+}) < (202.8-950.6)\ \text{fb at}\ \sqrt{s}=10.52\ \text{GeV}$$

$$\sigma(e^{+}e^{-}\to R^{++}+\text{anything})\mathcal{B}(R^{++}\to D^{+}D_s^{*+}) < (218.9-1054.0)\ \text{fb at}\ \sqrt{s}=10.58\ \text{GeV}$$

$$\sigma(e^{+}e^{-}\to R^{++}+\text{anything})\mathcal{B}(R^{++}\to D^{+}D_s^{*+}) < (346.6-1841.7)\ \text{fb at}\ \sqrt{s}=10.867\ \text{GeV}$$

In conclusion …

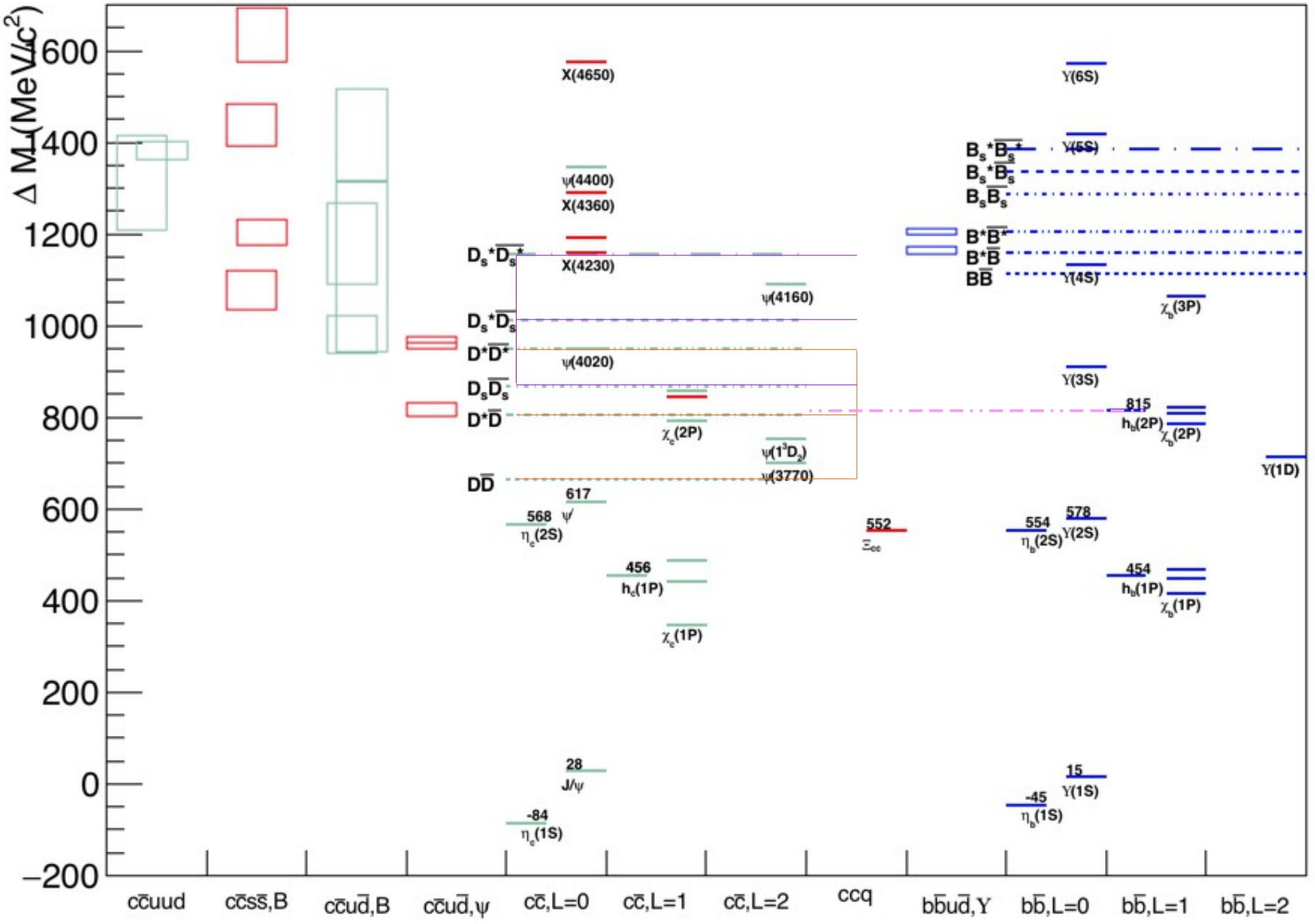
11 years after the end of data taking BELLE is still actively contributing to the understanding of the jungle of states discovered in the first decade of the 3rd millenium.
Getting ready for the large datasets from BELLE-II, we keep analysing our rich dataset to react to the new discoveries done by BES-III and LHC experiments.

In conventional charmonium, the last years have seen the completion of 1D wave triplet. Upper limits from the first search for the 1D wave singlet in B decays were given.

Searching for X3872 decay to $\pi^0\chi_{c1}$,BELLE unexpectedly find more coupling to X3915: more statistics is needed , again

The radiative decays to ψ' from the 2P jungle region are explored for the first time, hinting for signals from X(3915) and 4.02 GeV

LHCB discovery of double charm baryons and double J/ψ has suggested new ideas for further explorations on our old datasets: *more results to come!*


Δ M (MeV/c²)
600
400
1200
1000
800
600
400
200
0
−200
X(4650)
ψ(4400)
X(4360)
X(4230)
ψ(4160)
ψ(4020)
χc(2P)
ψ(1³D2)
ψ(3770)
617
568 ψ'
ηc(2S)
456
hc(1P)
χc(1P)
28
J/ψ
-84
ηc(1S)
552
Ξcc
Υ(6S)
Υ(5S)
Υ(4S)
χb(3P)
Υ(3S)
815
hb(2P)
χb(2P)
Υ(1D)
554
ηb(2S)
578
Υ(2S)
454
hb(1P)
χb(1P)
15
Υ(1S)
-45
ηb(1S)
cc̄uud
cc̄ss̄,B
cc̄ud̄,B
cc̄ud̄,ψ
cc̄,L=0
cc̄,L=1
cc̄,L=2
ccq
bb̄ud̄,Υ
bb̄,L=0
bb̄,L=1
bb̄,L=2

Still many results from Belle on charmonia and XYZ

The study of $\gamma\gamma \to \gamma\psi(2S)$ at Belle X.L. Wang, B.S. Gao, W.J. Zhu, et al. (Belle Collaboration), submitted to PRD Belle preprint 2021-08, KEK Preprint 2021-4, arXiv:2105.06605 [hep-ex]

Evidence for $X(3872) \to J/\psi\pi^+\pi^-$ produced in single-tag two-photon interactions Y.Teramoto, et al. (Belle Collaboration), published in PRL 126, 122001 (2021 March 23)
Belle preprint 2020-08, KEK Preprint 2020-7, arXiv:2007.05696 [hep-ex]

Search for a doubly-charged DDK bound state in $\Upsilon(1S,2S)$ inclusive decays and via direct production in e^+e^- collisions at $\sqrt{s}$ = 10.520, 10.580, and 10.867 GeV Y.Li, S.Jia, C.P.Shen, et al. (Belle Collaboration), published in PRD 102, 112001 (2020 December 1)
Belle preprint 2020-10, KEK Preprint 2020-11, arXiv:2008.13341 [hep-ex]

Evidence for a vector charmonium-like state in $e^+e^- \to D_s^+D_{s2}(2573)^-$ + c.c. S.Jia, et al. (Belle Collaboration), published in PRD 101, 091101(R) (2020 May 12)
Belle preprint 2020-05, KEK Preprint 2020-1, arXiv:2004.02404 [hep-ex]

First search for the $\eta_{c2}(1D)$ in B decays at Belle K.Chilikin, et al. (Belle Collaboration), published in JHEP 2005, 034 (2020 May 08)
Belle preprint 2020-02, KEK Preprint 2019-58, arXiv:2003.08335 [hep-ex]

Observation of a vector charmonium-like state in $e^+e^- \to D_sD_{s1}(2536)$ + c.c.
S.Jia, C.P.Shen, et al. (Belle Collaboration), published in
PRD 100, 111103(R) (2019 December 31)
Belle preprint 2019-20, KEK Preprint 2019-42, arXiv:1911.00671 [hep-ex]

Still many results from Belle on charmonia and XYZ

Search for $B^0 \to X(3872)\,\gamma$
PC.Chou, et al. (Belle Collaboration), published in PRD 100, 012002 (2019 July 19)
Belle preprint 2019-08, KEK Preprint 2019-6, arXiv:1905.11718 [hep-ex]

Search for X(3872) and X(3915) decay into $\chi_{c1}\pi^0$ in B decays at Belle
V.Bhardwaj, S.Jia, et al. (Belle Collaboration), published in PRD 99, 111101 (R) (2019 June 12)
Belle preprint 2019-07, KEK Preprint 2019-5, arXiv:1904.07015 [hep-ex]

Search for the $B \to Y(4260)\,K$, $Y(4260) \to J/\psi\pi^+\pi^-$ decays
R.Garg, et al. (Belle Collaboration), published in PRD 99, 071102 (R) (2019 April 12)
Belle preprint 2019-01, KEK Preprint 2018-86, arXiv:1901.06470 [hep-ex]

Observation of $e^+e^- \to \gamma\chi_{c1}$ and search for $e^+e^- \to \gamma\chi_{c0}$, $\gamma\chi_{c2}$, and $\gamma\eta_c$ at $\sqrt{s}$ near 10.6 GeV at Belle
S.Jia, X.L.Wang, C.P.Shen, C.Z.Yuan, et al. (Belle Collaboration), published in
PRD98, 092015 (2018 November 30)
Belle preprint 2018-22, KEK Preprint 2018-55, arXiv:1810.10291 [hep-ex]

Search for $\Upsilon(1S,2S) \to Z_c^+Z_c^{(\prime)-}$ and $e^+e^- \to Z_c^+Z_c^{(\prime)-}$ at $\sqrt{s}$ = 10.52, 10.58, and 10.867 GeV
S.Jia, C.P.Shen, C.Z.Yuan, et al. (Belle Collaboration), published in PRD97, 112004 (2018 June 14)
Belle preprint 2018-02, KEK Preprint 2017-65, arXiv:1805.02308 [hep-ex]

Measurement of $\eta_c(1S)$, $\eta_c(2S)$ and non-resonant eta'$\pi^+\pi^-$ production via two-photon collisions
Q.N.Xu, et al. (Belle Collaboration), published in PRD98, 072001 (2018 October 3)
Belle preprint 2018-06, KEK Preprint 2017-71, arXiv:1805.03044 [hep-ex]