International Conference for High Energy Physics, 4-12 July 2012, Melbourne

New particle spectroscopy update

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Spectroscopy results @ ICHEP2012 (1)

BESIII Precise measurement of η_c , η_c' , h_c parameters — Shan Jin
New decay modes of J/ψ , ψ' , χ_{cJ} , η_c
PWA $J/\psi \to \gamma$ pp
PWA $J/\psi \to \gamma\, \omega\varphi$
PWA $J/\psi \to \gamma\, \eta\eta$
Confirmation of X(1835) in $J/\psi \to \gamma\, \pi^+\pi^-\eta'$, +two new
First observation of isospin violating mode $\eta(1405) \to f_0(980)\pi^0$
First observation of $\psi' \to \eta_c'\, \gamma$

KEDR Precise measurement of $\psi(2S)$ and $\psi(3770)$ parameters — Todyshev

BaBar Study of $\gamma\gamma \to \eta_c(1S)\, \pi^+\pi^-$ — Santoro
Update on Y(4260) using $e^+e^- \to J/\psi\pi^+\pi^-$
Confirmation of Y(4660) using e+e- $\to \psi(2S)\pi^+\pi^-$
Confirmation of $\gamma\gamma \to$ X(3915) $\to J/\psi\omega$
Search for charged Z^+ states in B $\to \chi_{c1}$ Kπ
Precise measurement of D* width

Spectroscopy results @ ICHEP2012 (2)

BELLE

Evidence for resonant structures in $\gamma\gamma \to \omega\omega$, $\omega\varphi$, $\varphi\varphi$	Nakazawa
Study of $\gamma\gamma \to \eta'\pi^+\pi^-$	
First evidence for ψ_2	Yabsley
Search for $X(3872)^{C-}$ in $B \to (J/\psi\eta)\, K$ decays	
Study of $e^+e^- \to J/\psi\eta$	
Amplitude analysis of $B \to J/\psi K\pi$	
Measurement of BF[$\Upsilon(2S) \to \Upsilon(1S)\, \eta$]	Barrett
First observation of $\Upsilon(1S,2S) \to$ light hadrons	
Search for $\Upsilon(2S) \to$ baryon pairs	
Search for $\chi_{bJ} \to$ double charmonium	
Search for Ξ_5^{--} pentaquark and H dibaryon in $\Upsilon(1S,2S)$ decays	
R_b scan	Bondar
First evidence for $\eta_b(2S)$	
Observation of $Z_b(10610) \to BB^*$ and $Z_b(10650) \to B^*B^*$	
Evidence for Z_b^0	
Observation of $\Upsilon(5S) \to \Upsilon(1S,2S)\, \eta$ and $\Upsilon(5S) \to \Upsilon(1D)\, \pi^+\pi^-$	

Spectroscopy results @ ICHEP2012 (3)

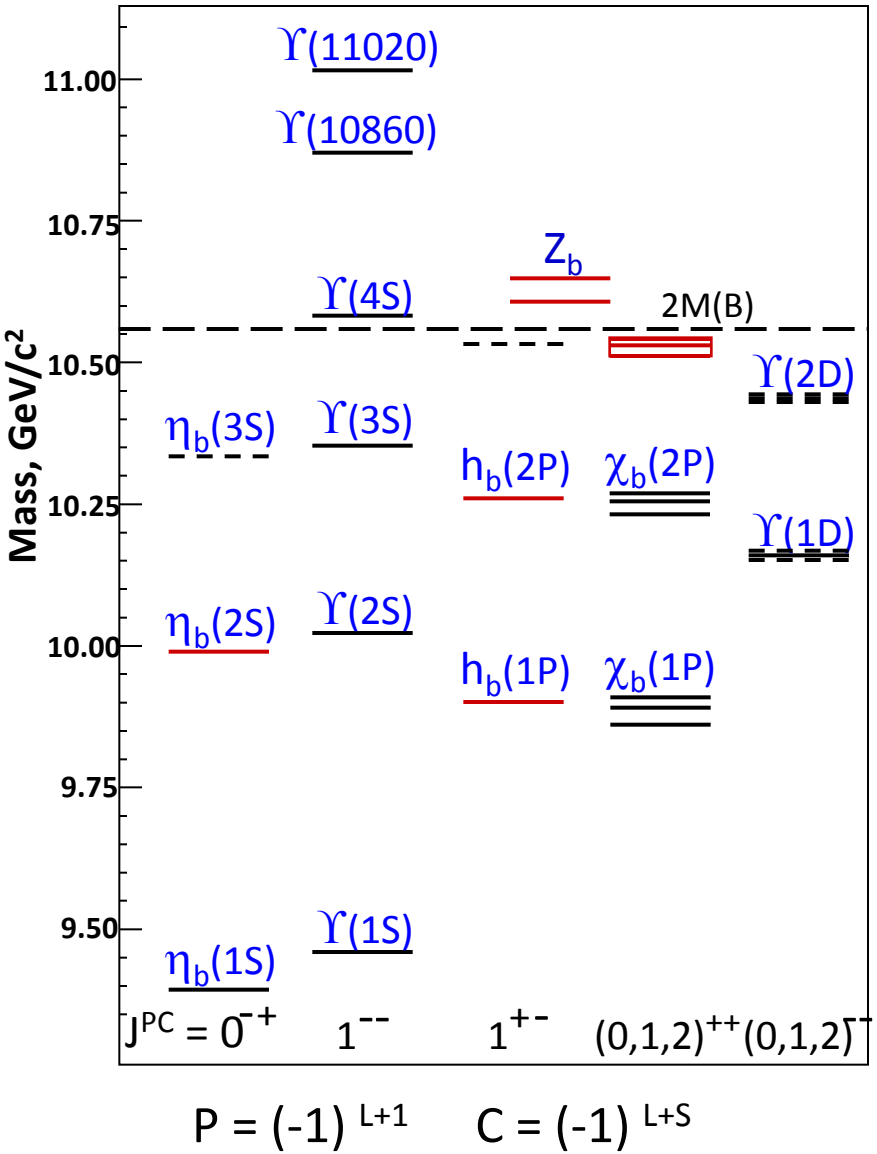
CDF	Observation of Ξ_b^0 Evidence for P-wave Λ_b^* resonance	Gorelov
D0	Observation of $X_b \to \Upsilon(1S)\gamma$	Buszello
ATLAS	First observation of $\chi_b(3P)$ Masses and life-times of b-hadrons	Toms
CMS	First observation of Ξ_b^* baryon χ_{c2}/χ_{c1} cross-section ratio, $\Upsilon(nS)$ cross-section	Kai Yi
LHCb	First observation of P-wave excited Λ_b^* resonances b-baryons mass measurements Study of D_{sJ}	Märki

My talk: Heavy quarkonium (-like) states
New baryons

Apologies: time is limited so I cannot cover all results

Introduction

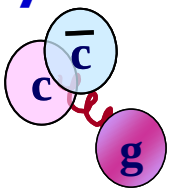
Charmonium & bottomonium played important role in establishing QCD as theory of strong interactions



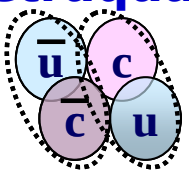
Quark Model successfully describes
+ spectrum
+ annihilation widths
+ radiation widths

Breakdown for high excitations
– new dynamics ?
– exotic states? (not $q\bar{q}$ or qqq)

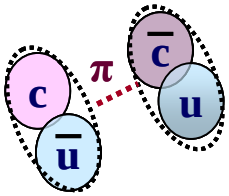
hybrid



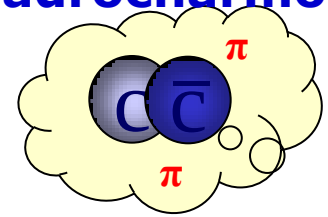
tetraquark



molecule



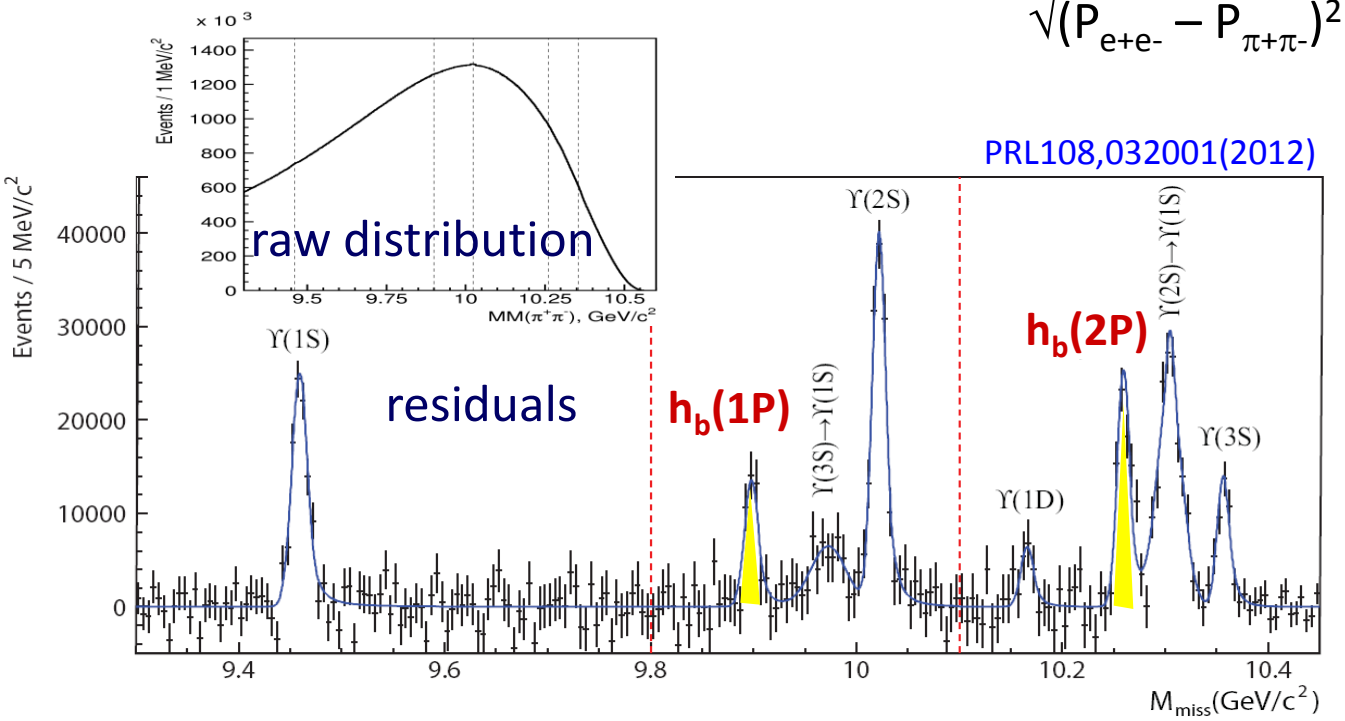
hadrocharmonium



Observation of $h_b(1P,2P)$

$e^+e^- \to \Upsilon(5S) \to h_b(nP)\pi^+\pi^-$ ← reconstructed, use $\mathbf{M_{miss}(\pi^+\pi^-)}$

$$\sqrt{(P_{e+e-} - P_{\pi+\pi-})^2}$$



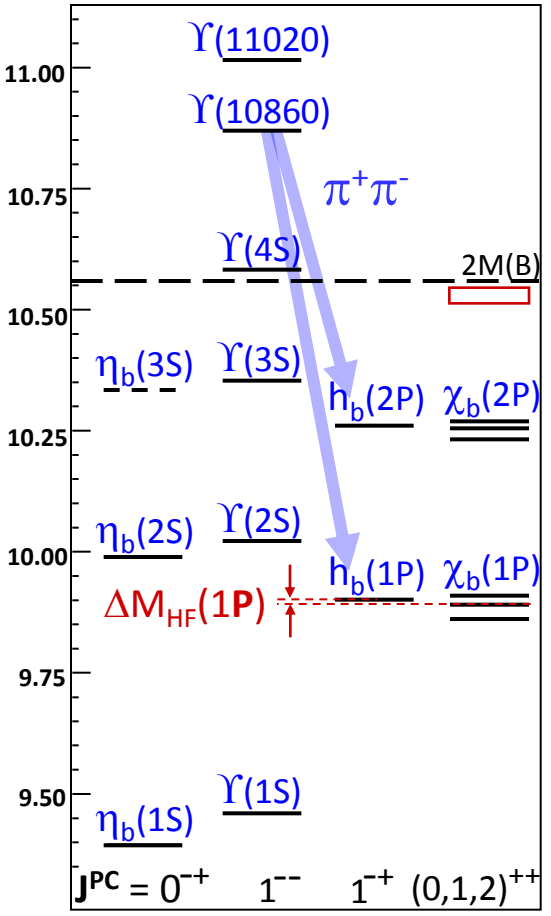
PRL108,032001(2012)

Belle arxiv:1205.6351

$\Delta M_{HF}(\mathbf{1P}) = +0.8 \pm 1.1$ MeV

$\Delta M_{HF}(\mathbf{2P}) = +0.5 \pm 1.2$ MeV

consistent with zero, as expected



Large $h_b(1,2P)$ production rates

c.f. CLEO $e^+e^- \to \psi(4170) \to h_c\,\pi^+\pi^-$

Observation of $h_b(1P,2P)$

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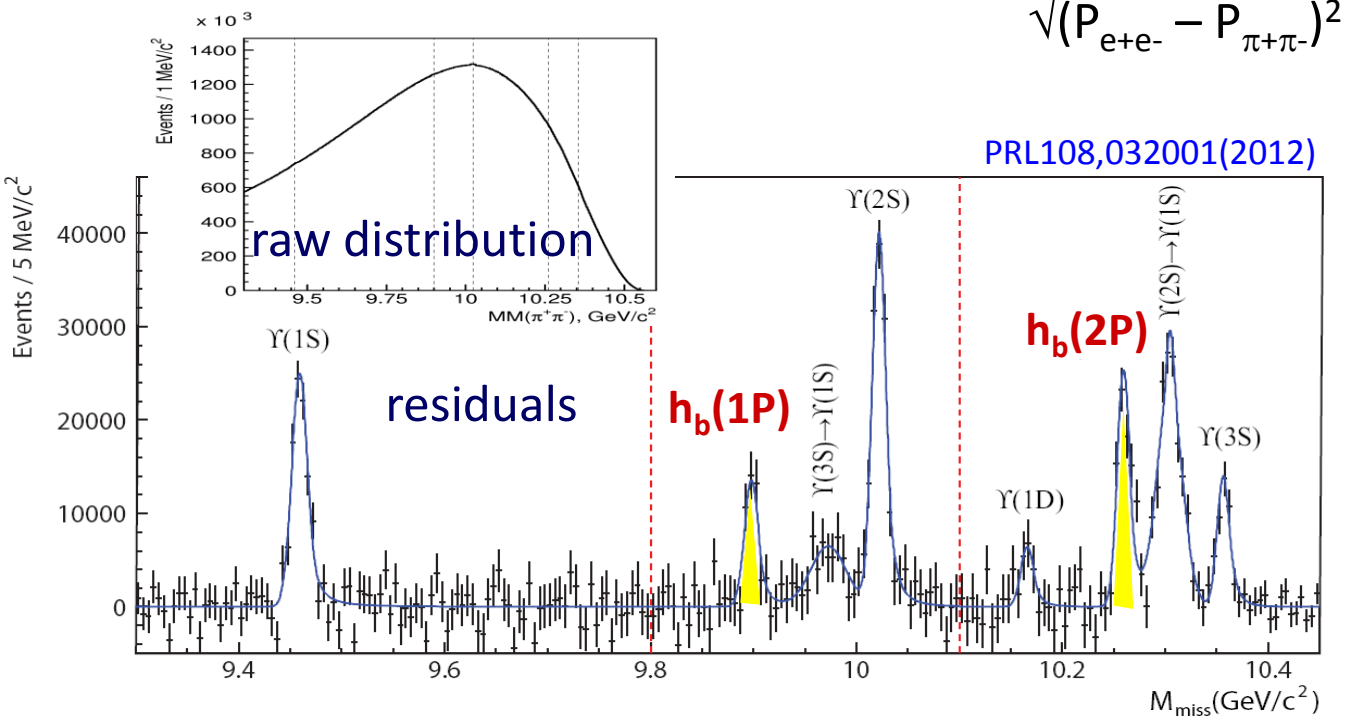

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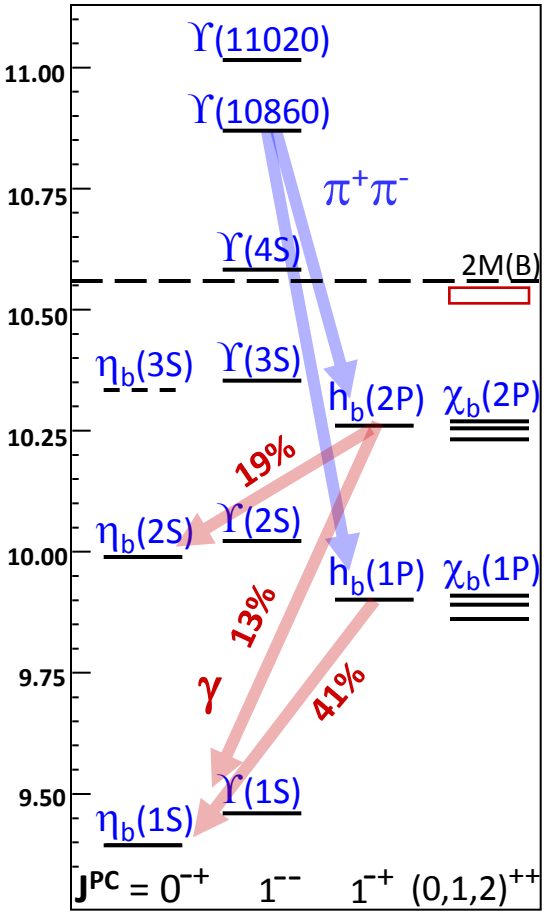


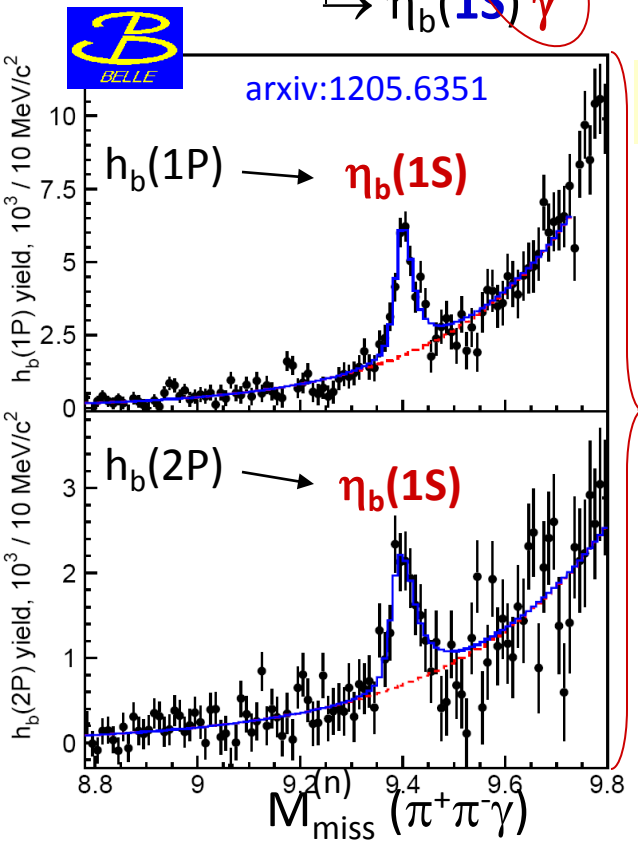
Large $h_b(1,2P)$ production rates

c.f. CLEO $e^+e^- \to \psi(4170) \to h_c\,\pi^+\pi^-$

$h_b(nP)$ decays are a source of $\eta_b(mS)$

Observation of $h_b(1P,2P) \to \eta_b(1S)\,\gamma$

$e^+e^- \to \Upsilon(5S) \to h_b(\mathbf{nP})\,\pi^+\pi^-$ reconstruct
$\hookrightarrow \eta_b(\mathbf{1S})\,\gamma$

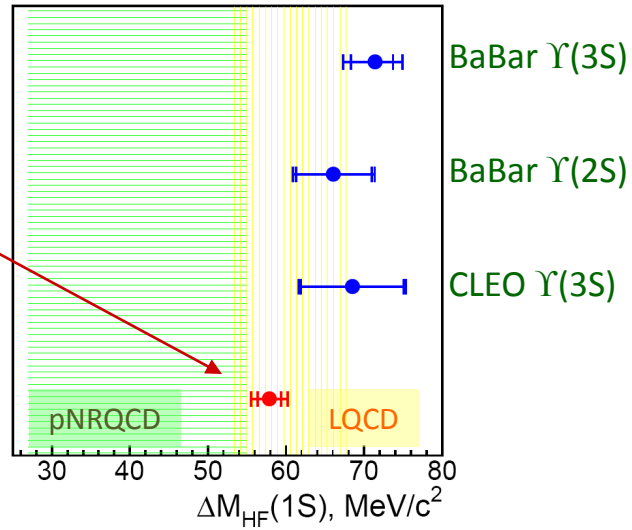


$\Delta M_{HF}(\mathbf{1S})$

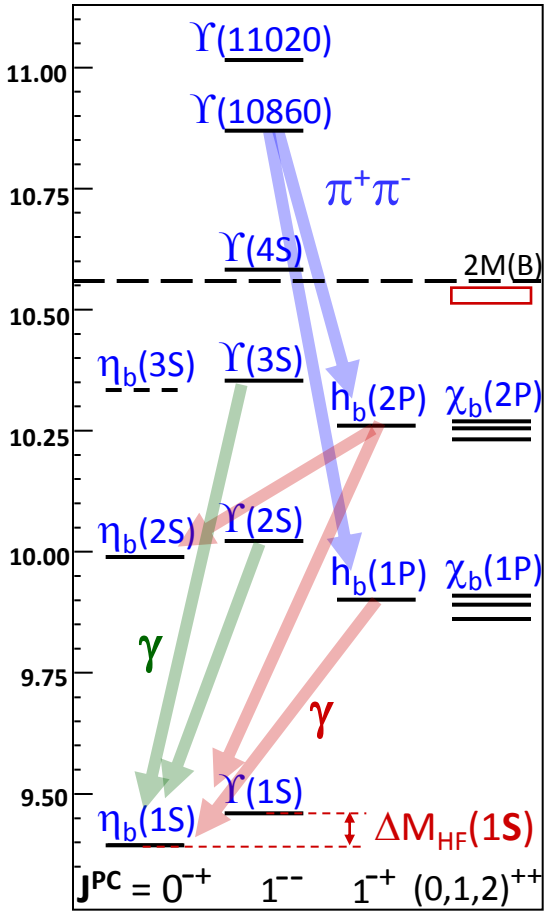
Belle : 57.9 ± 2.3 MeV

PDG'12 : 69.3 ± 2.8 MeV

3σ



Kniehl et al, PRL92,242001(2004)
Meinel, PRD82,114502(2010)



Belle result decreases tension with theory

First measurement $\Gamma = 10.8\ ^{+4.0}_{-3.7}\ ^{+4.5}_{-2.0}$ MeV

as expected

Observation of $h_b(1P,2P) \to \eta_b(1S)\,\gamma$

$e^+e^- \to \Upsilon(5S) \to h_b(\mathbf{nP})\,\pi^+\pi^-$ reconstruct
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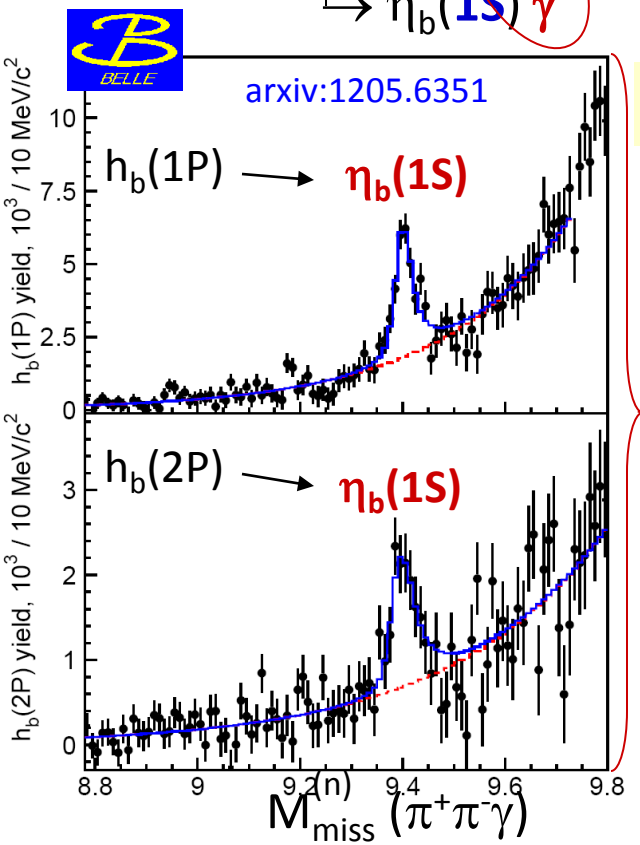

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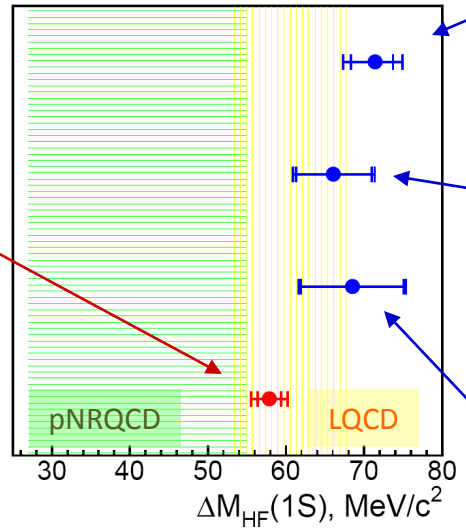

Kniehl et al, PRL92,242001(2004)
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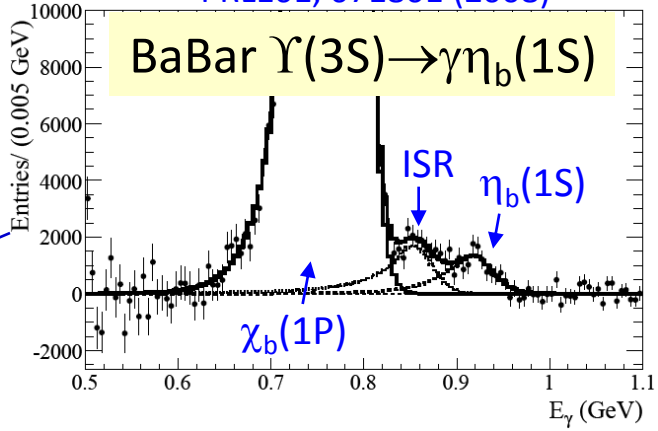
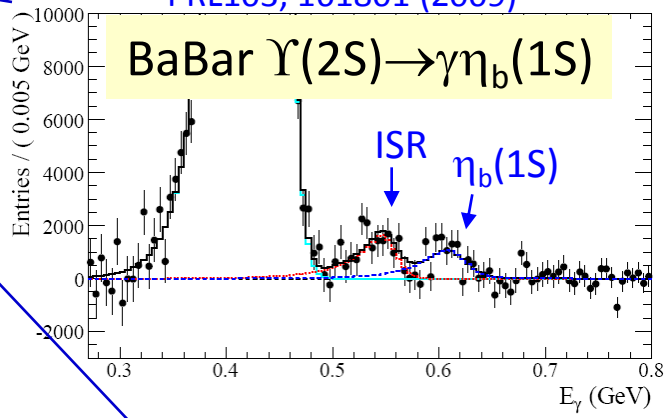
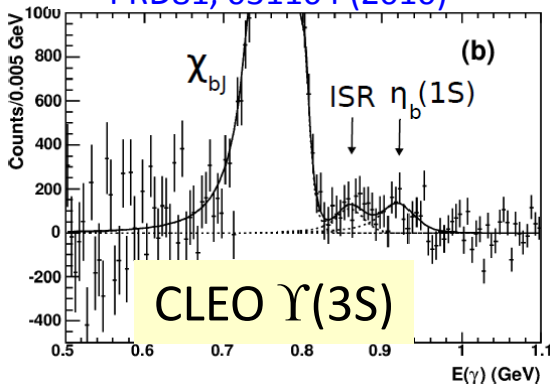
PRL101, 071801 (2008)



PRL103, 161801 (2009)



PRD81, 031104 (2010)



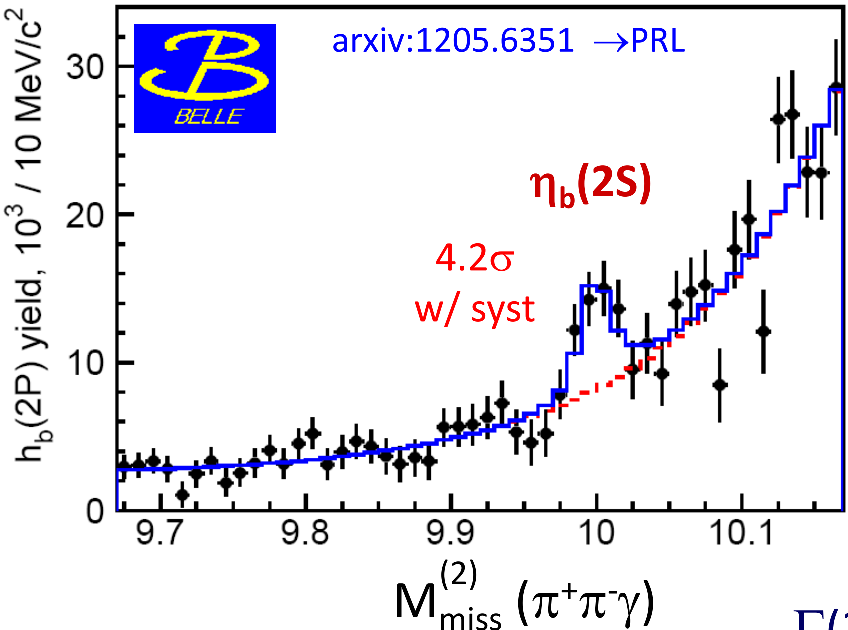
Belle result decreases tension with theory

First measurement $\Gamma = 10.8\ ^{+4.0}_{-3.7}\ ^{+4.5}_{-2.0}$ MeV

as expected

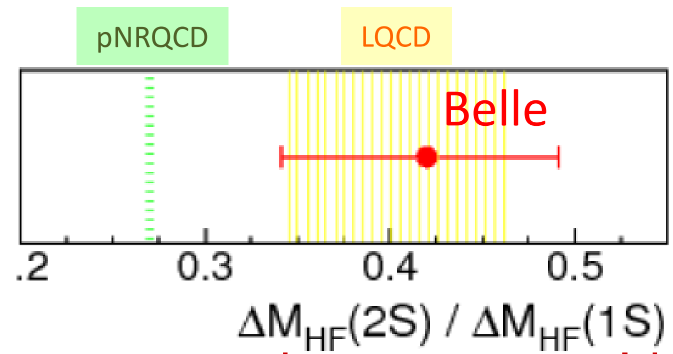
First evidence for $\eta_b(2S)$

$e^+e^- \to \Upsilon(5S) \to h_b(\mathbf{2P})\, \pi^+\pi^-$
$\quad \hookrightarrow \eta_b(\mathbf{2S})\, \gamma$



$\Delta M_{HF}(\mathbf{2S}) = 24.3\ ^{+4.0}_{-4.5}$ MeV

First measurement



In agreement with theory

$\Gamma(2S) = 4 \pm 8$ MeV, < 24MeV @ 90% C.L.
expect ~4MeV

Branching fractions

	Expectations
$BF[h_b(1P) \to \eta_b(1S)\,\gamma] = 49.2 \pm 5.7^{+5.6}_{-3.3}$ %	41%
$BF[h_b(2P) \to \eta_b(1S)\,\gamma] = 22.3 \pm 3.8^{+3.1}_{-3.3}$ %	13%
$BF[h_b(2P) \to \eta_b(2S)\,\gamma] = 47.5 \pm 10.5^{+6.8}_{-7.7}$ %	19%

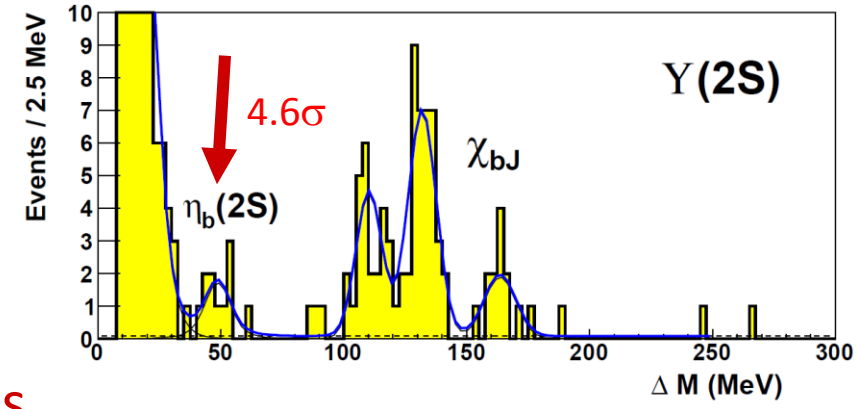
Godfrey Rosner PRD66,014012(2002)

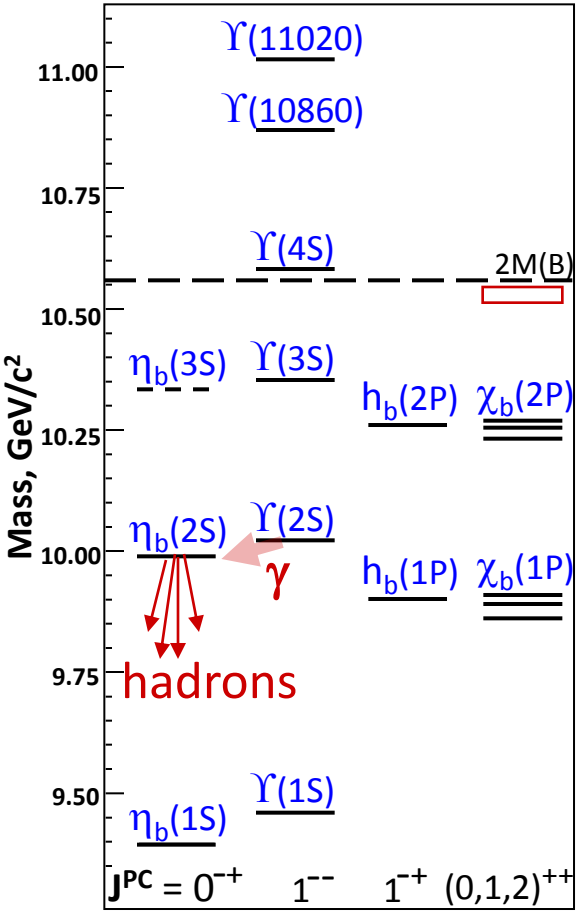
c.f. BESIII $BF[h_c(1P) \to \eta_c(1S)\,\gamma] = 54.3 \pm 8.5$ % — 39%

"Signal" of exclusively reconstructed $\eta_b(2S)$

Dobbs, Metreveli, Seth, Tomaradze, Xiao, arxiv:1204.4205 **CLEO data**

$e^+e^- \to \Upsilon(2S) \to \eta_b(2S)\,\gamma$, $\eta_b(2S) \to$ 4,6,8,10 $\pi^\pm$, $K^\pm$, $p/\bar{p}$ (26 channels)





Issues

Bg from final state radiation can mimic signal
e.g. $\Upsilon(2S) \to K^+K^-\, n(\pi^+\pi^-)\, \gamma_{FSR}$ not discussed
power law tail instead of exponential

Large production rate: N $\eta_b(2S)$ ~ 0.2 N χ_{b1} ↔ factor 30
c.f. $\Gamma(\psi' \to \eta_c(2S)\gamma) = 0.007\, \Gamma(\psi' \to \chi_{c1}\gamma)$
BESIII arxiv:1205.5103 →PRL

Large $\Delta M_{HF}(2S)$ CLEO 48.7 ± 2.7 MeV ← strong disagreement with theory ↔ 5σ
Belle $24.3\ ^{+4.0}_{-4.5}$ MeV ← agrees with theory

Reported excess is unlikely to be the $\eta_b(2S)$ signal

Observation of $\chi_b(3P)$

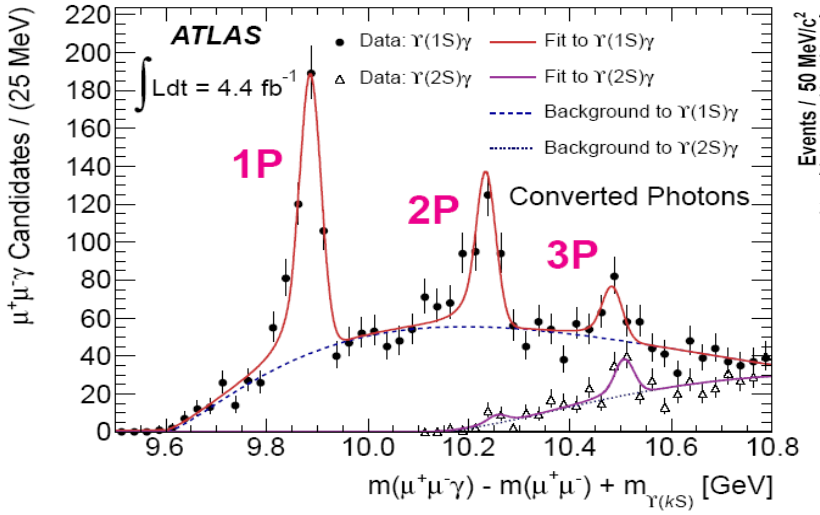
$\chi_b(3P) \to \Upsilon(1,2S)\,\gamma \to \mu^+\mu^-\,\gamma$

[Buszello]

γ conversion to e^+e^-

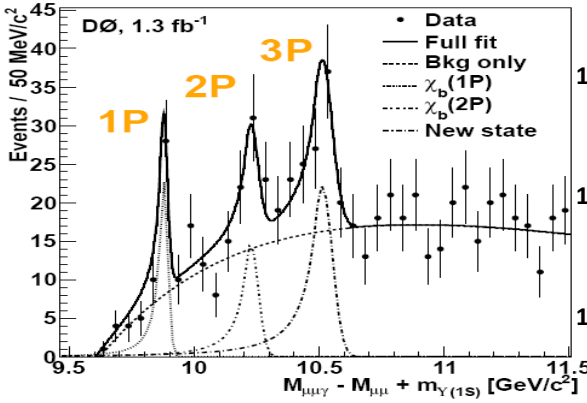
Observed by ATLAS

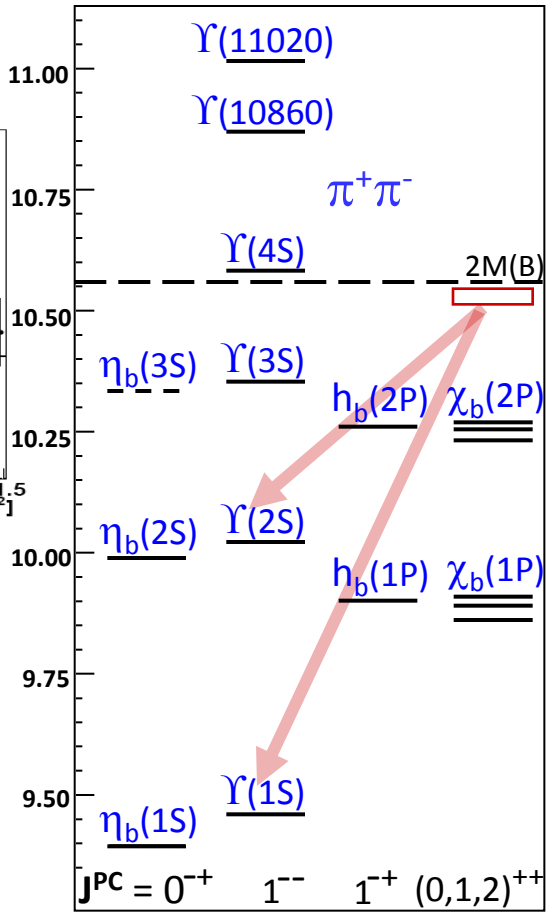
[ATLAS PRL108,152001(2012)]



confirmed by D0

[D0 arXiv:1203.6034]





Spin-averaged M[$\chi_b(3P)$]

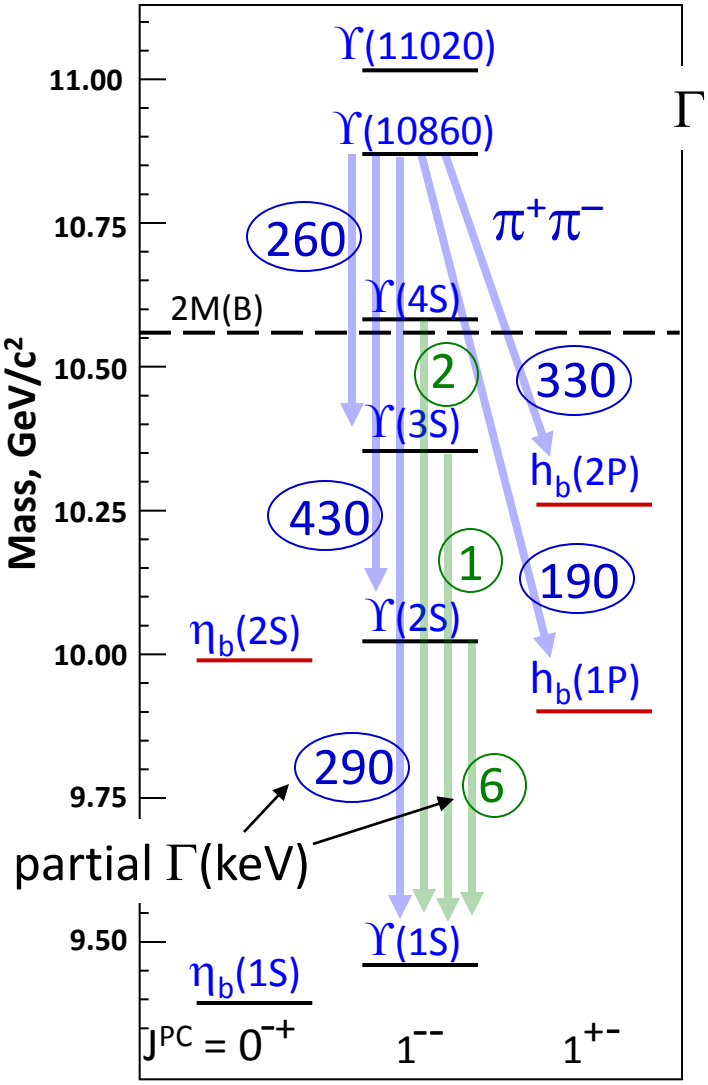
ATLAS	$10530 \pm 9 \pm 5$ MeV
D0	$10551 \pm 14 \pm 17$ MeV
theory	10525

In agreement with theoretical expectations

Charged bottomonium-like states

Anomalies in $\Upsilon(5S) \to (b\bar{b})\ \pi^+\pi^-$ transitions

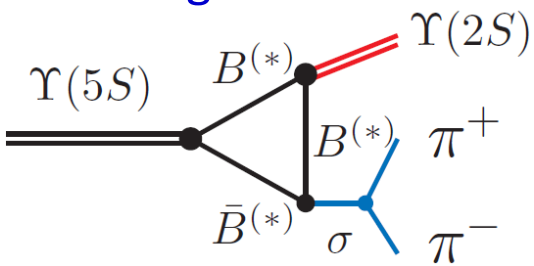
[Bondar]



Belle PRL100,112001(2008)

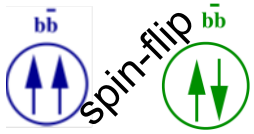
$\Gamma[\Upsilon(\mathbf{5S}) \to \Upsilon(1,2,3S)\ \pi^+\pi^-] \gg \Gamma[\Upsilon(\mathbf{4,3,2S}) \to \Upsilon(1S)\ \pi^+\pi^-]$ (~100)

⇐ Rescattering of on-shell $B^{(*)}\bar{B}^{(*)}$?



Belle PRL108,032001(2012)

$\Upsilon(5S) \to \mathbf{h_b}(1,2P)\ \pi^+\pi^-$ are **not suppressed**

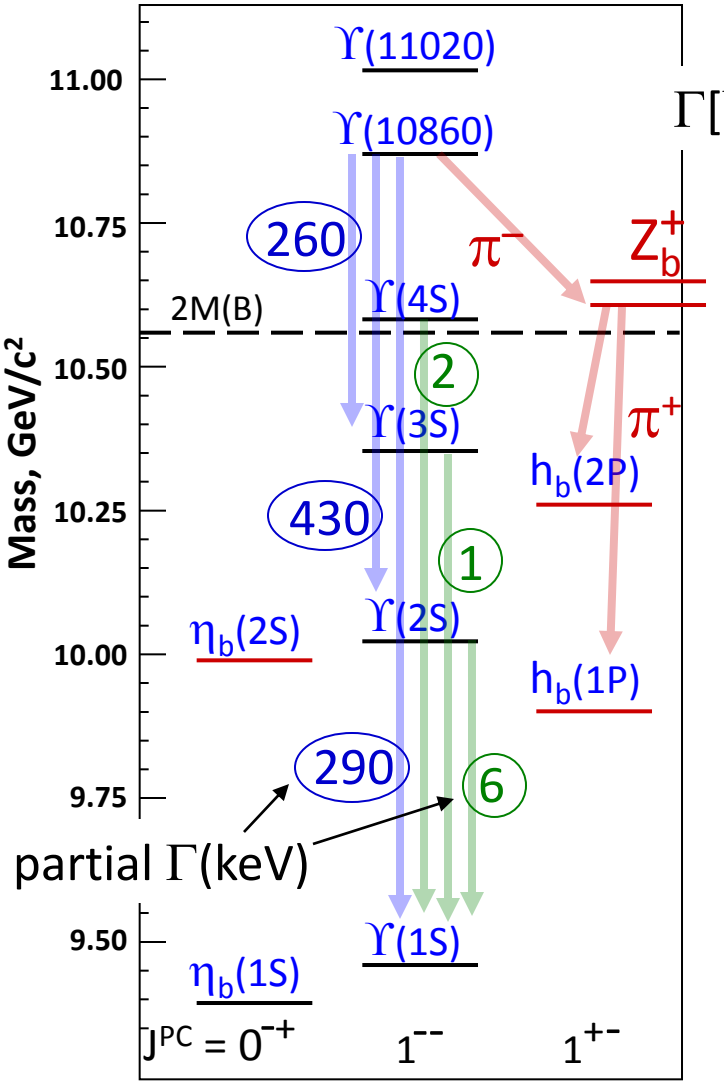


expect suppression $\sim\Lambda_{QCD}/m_b$

~~Heavy Quark Symmetry~~

Anomalies in $\Upsilon(5S) \to (b\bar{b})\ \pi^+\pi^-$ transitions

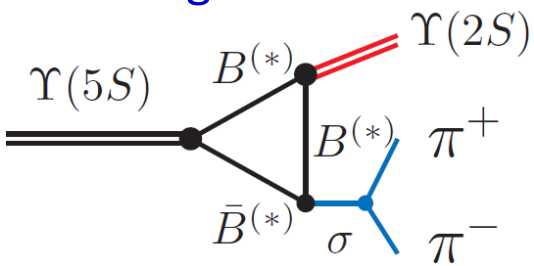
[Bondar]



Belle PRL100,112001(2008)

$\Gamma[\Upsilon(\mathbf{5S}) \to \Upsilon(1,2,3S)\ \pi^+\pi^-]$ >> $\Gamma[\Upsilon(\mathbf{4,3,2S}) \to \Upsilon(1S)\ \pi^+\pi^-]$ ~100

⇐ Rescattering of on-shell $B^{(*)}\bar{B}^{(*)}$?



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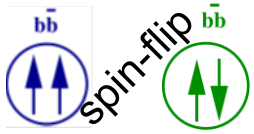


expect suppression ~Λ_{QCD}/m_b

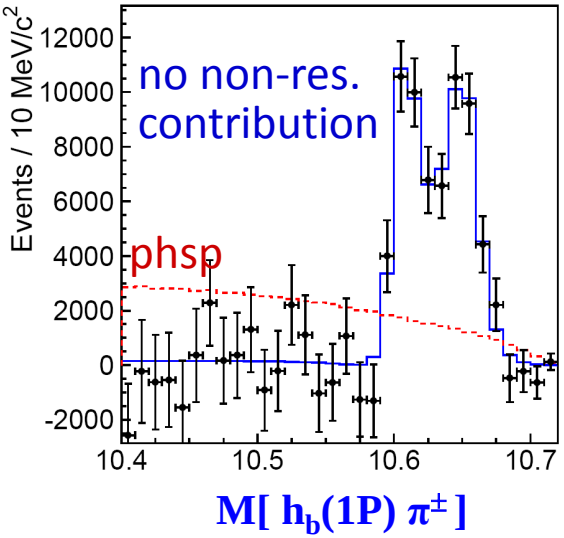
~~Heavy Quark Symmetry~~

h_b production mechanism? ⇒ Study resonant structure in $h_b(mP)\ \pi^+\pi^-$

Resonant structure of $\Upsilon(5S) \to (b\bar{b})\,\pi^+\pi^-$

Belle PRL108,122001(2012)

$\Upsilon(5S) \to h_b(1P)\pi^+\pi^-$



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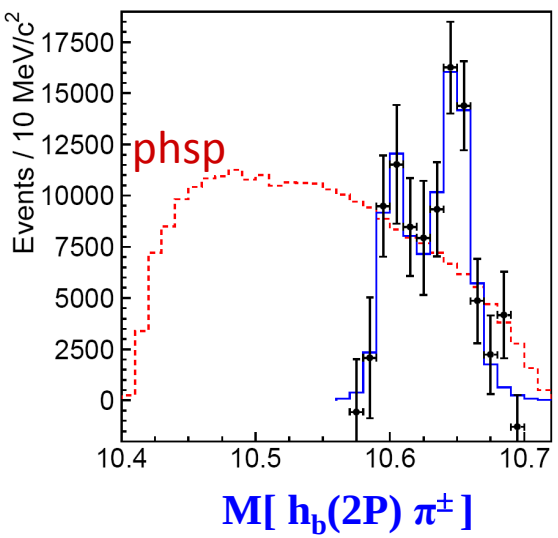


Two peaks in all modes

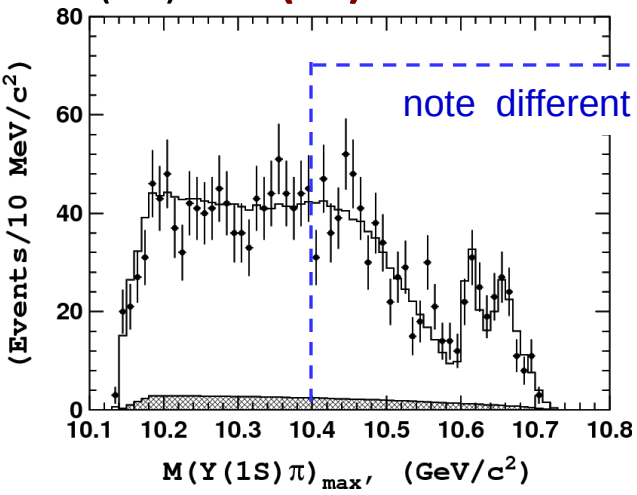
Minimal quark content

$|\, b\bar{b}u\bar{d}\,\rangle$

flavor-exotic states

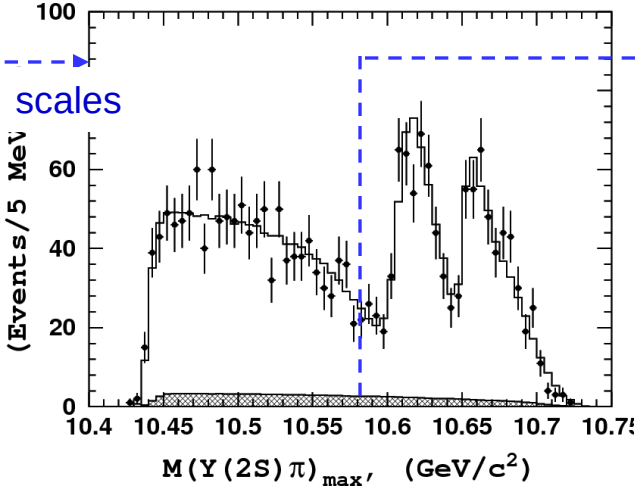
Dalitz plot analysis

$\Upsilon(5S) \to \Upsilon(1S)\pi^+\pi^-$

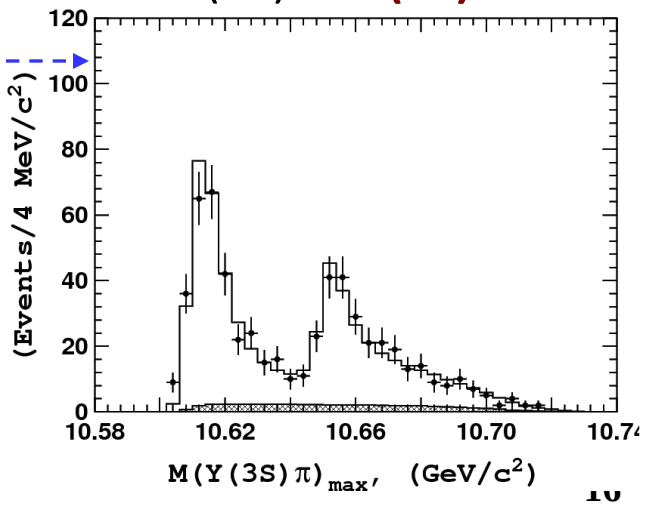


note different scales

$\Upsilon(5S) \to \Upsilon(2S)\pi^+\pi^-$



$\Upsilon(5S) \to \Upsilon(3S)\pi^+\pi^-$



Fit results

Average over 5 channels

$M_1 = 10607.2 \pm 2.0$ MeV

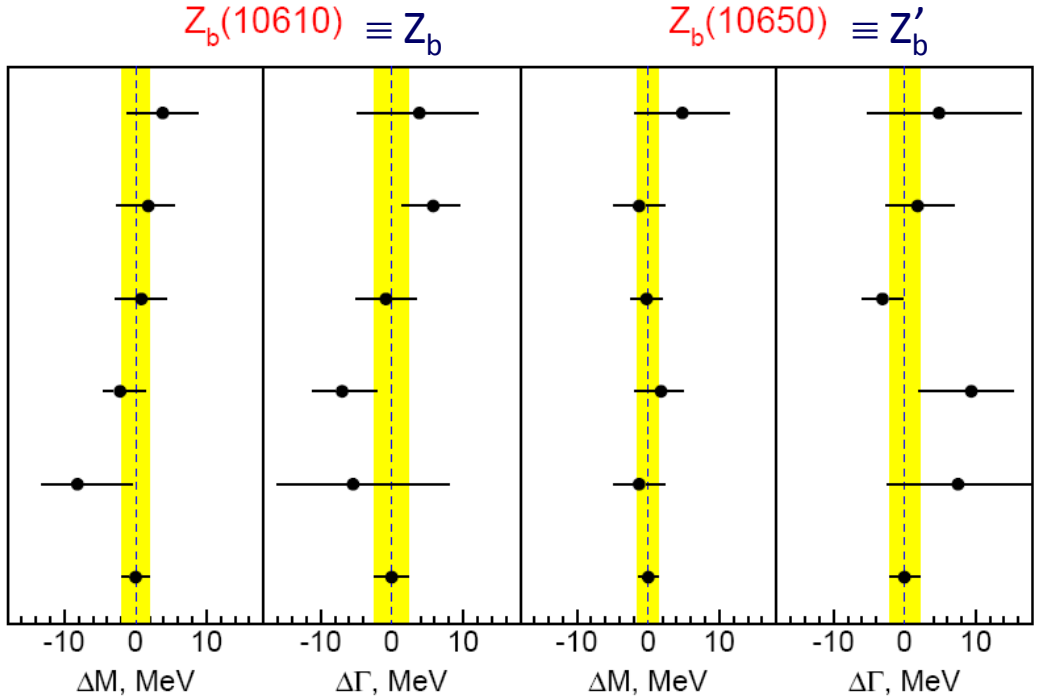
$\Gamma_1 = 18.4 \pm 2.4$ MeV

$M_{Zb} - (M_B + M_{B^*}) = +2.6 \pm 2.1$ MeV

$M_2 = 10652.2 \pm 1.5$ MeV

$\Gamma_2 = 11.5 \pm 2.2$ MeV

$M_{Zb'} - 2M_{B^*} = +1.8 \pm 1.7$ MeV

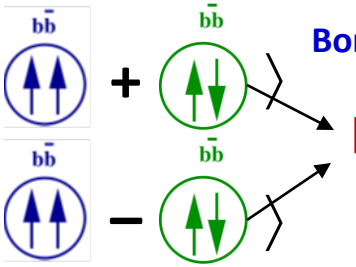


Angular analysis ⇒ both states are $J^P = 1^+$ Decays ⇒ $I^G = 1^+$ (C= –)

Proximity to thresholds favors molecule over tetraquark

$Z_b \sim |\, B\ B^* \,\rangle = |$ + S-wave

$Z_b' \sim |\, B^* B^* \,\rangle = |$ –



$h_b(mP)\pi$ not suppressed

Bondar et al, PRD84,054010(2011)

Phase btw Z_b and Z_b' amplitudes is **~0°** for $\Upsilon(nS)\pi\pi$ and **~180°** for $h_b(mP)\pi\pi$

Fit results

Average over 5 channels

$M_1 = 10607.2 \pm 2.0$ MeV

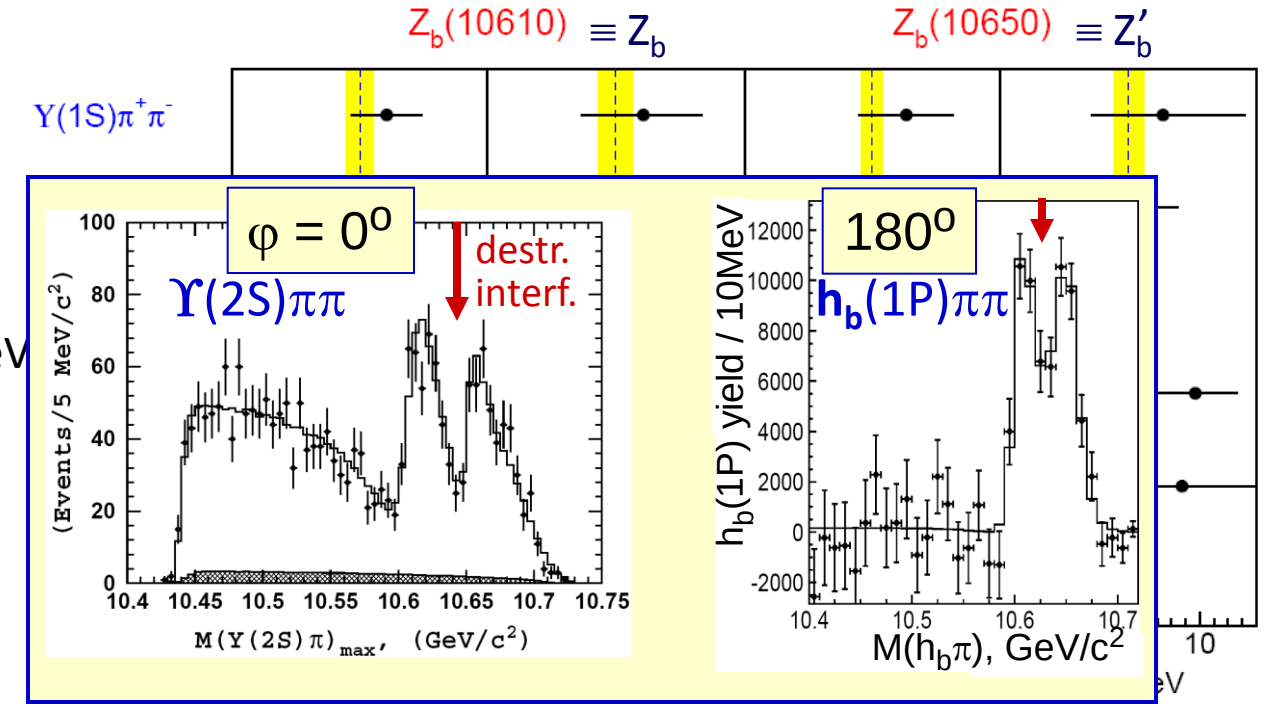
$\Gamma_1 = 18.4 \pm 2.4$ MeV

$M_{Zb} - (M_B + M_{B^*}) = +2.6 \pm 2.1$ MeV

$M_2 = 10652.2 \pm 1.5$ MeV

$\Gamma_2 = 11.5 \pm 2.2$ MeV

$M_{Zb'} - 2M_{B^*} = +1.8 \pm 1.7$ MeV

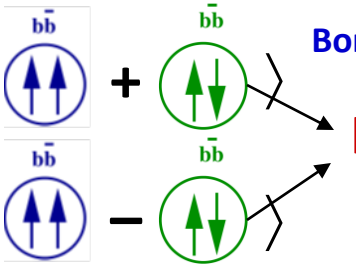


Angular analysis $\Rightarrow$ both states are $J^P = 1^+$ Decays $\Rightarrow$ $I^G = 1^+$ (C= –)

Proximity to thresholds favors molecule over tetraquark

$Z_b \sim |\, B\ B^* \,\rangle = |$ + S-wave

$Z_b' \sim |\, B^*B^* \,\rangle = |$ –



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Resonant behavior of Z_b amplitudes (intensity & phase).

Properties of Z_b states are consistent with molecular structure.

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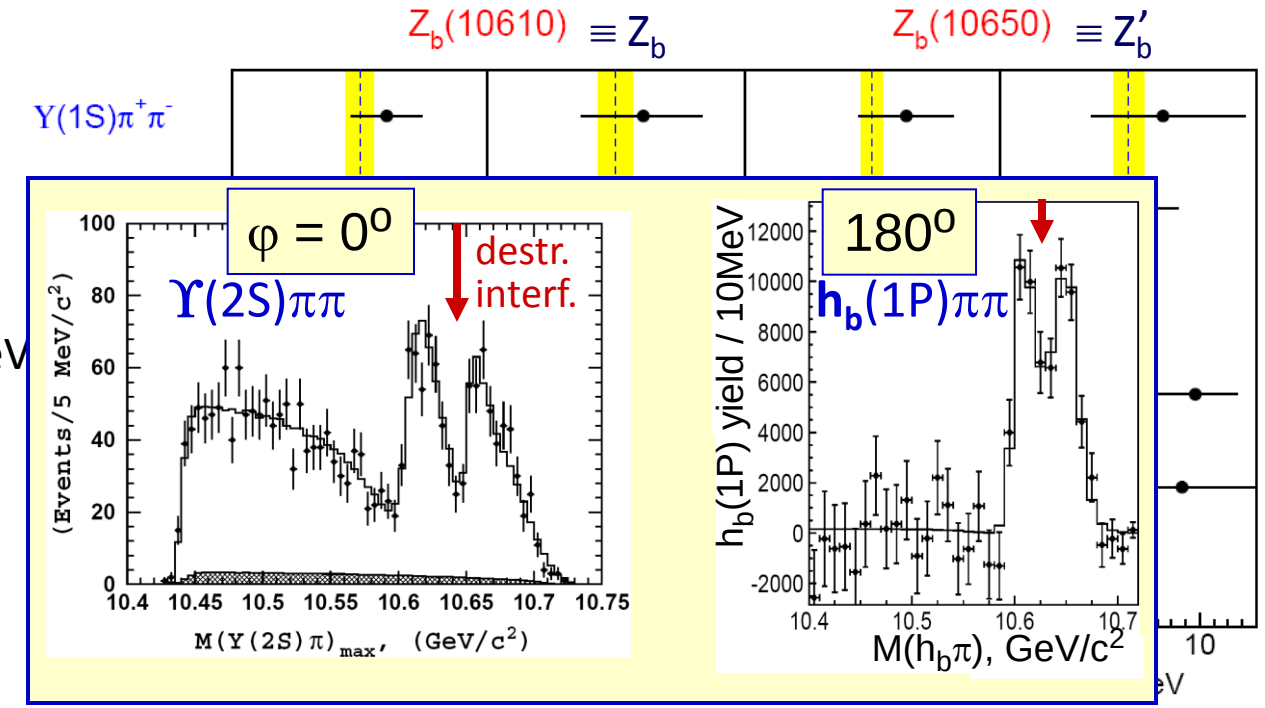


Angular analysis $\Rightarrow$ both stat

Proximity to thresholds favors molecule over tetraquark

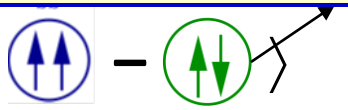
Mass above threshold ?

If Z_b can decay to $B^{(*)}\bar{B}^*$ its lineshape is asymmetric

this can shift the mass to slightly below threshold

Cleven et al, EPJA47,120(2011)

(2011)

$Z_b' \sim |B^*B^*\rangle = |$  $\rangle$

not suppressed

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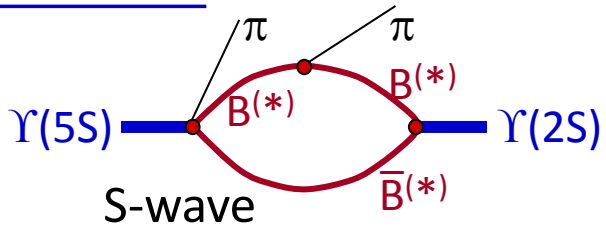
Resonant behavior of Z_b amplitudes (intensity & phase).

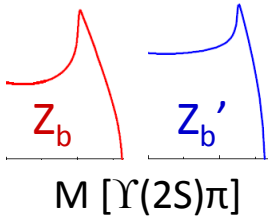
Properties of Z_b states are consistent with molecular structure.

Origin of structure at threshold

1. Threshold effect



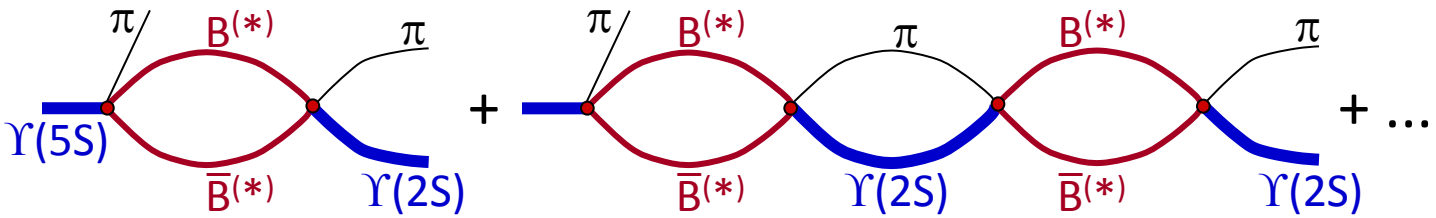
Chen Liu PRD84,094003(2011)

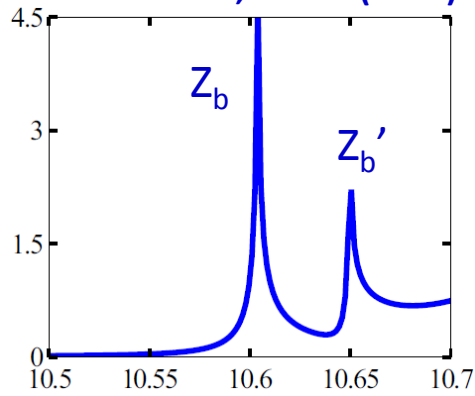


Pronounced structures and fast change of phase are not typical ?

Danilkin Orlovsky Simonov PRD85,034012(2012)

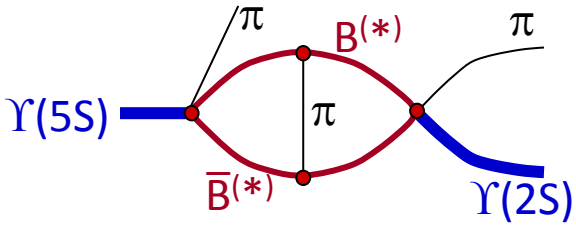
2. Coupled-channel resonance multiple re-scatterings ⇒ pole





3. Deuteron-like molecule

π,ρ,ω,σ exchange



Ohkoda et al arxiv:1111.2921

Fit data to various predictions

Study $e^+e^- \to \Upsilon(5S) \to B^{(*)}\bar{B}^{(*)}\pi$

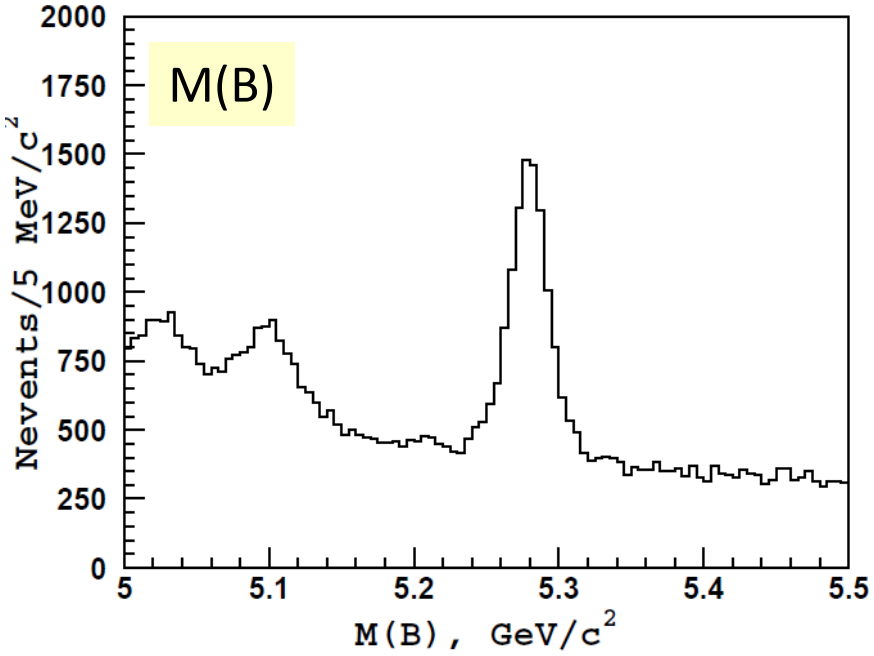
[Bondar]

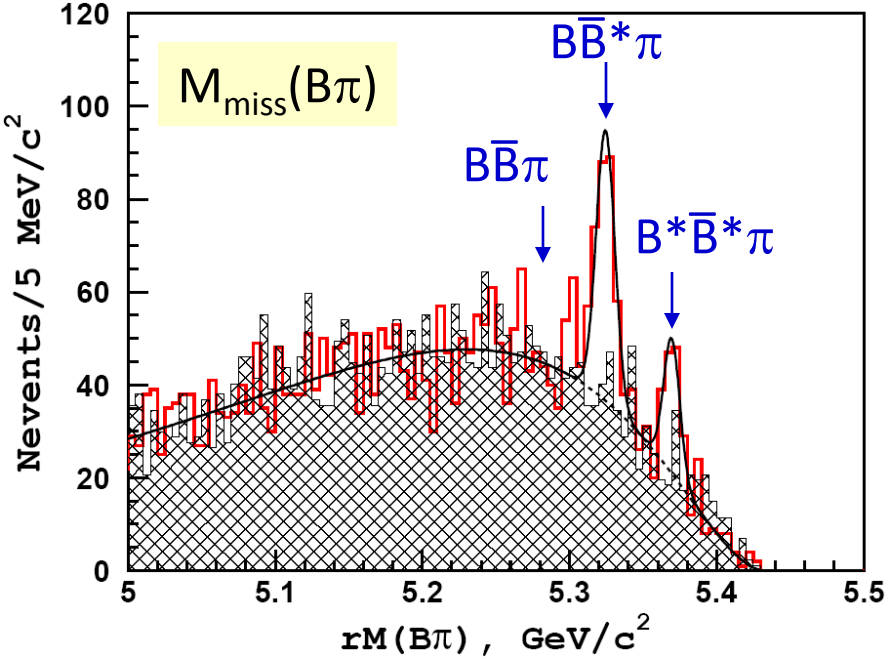
NEW!

preliminary

Search for $Z_b \to B\bar{B}^*$ and $B^*\bar{B}^*$

Full reconstruction of one B





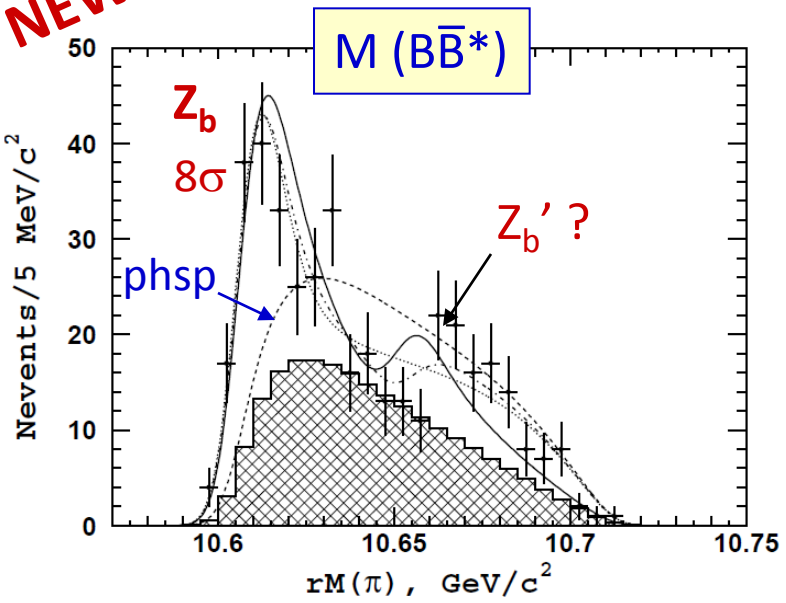
$BF[\ \Upsilon(5S) \to B^{(*)}\bar{B}^{(*)}\pi\ ]$	preliminary Belle 121.4 fb^{-1}	significance	PRD81,112003(2010) Belle 23.6 fb^{-1}
$B\bar{B}$	<0.60 % at 90% C.L.		(0 ± 1.2) %
$B\bar{B}^* + B\bar{B}^*$	$(4.25 \pm 0.44 \pm 0.69)$ %	9.3σ	(7.3 ± 2.3) %
$B^*\bar{B}^*$	$(2.12 \pm 0.29 \pm 0.36)$ %	5.7σ	(1.0 ± 1.4) %

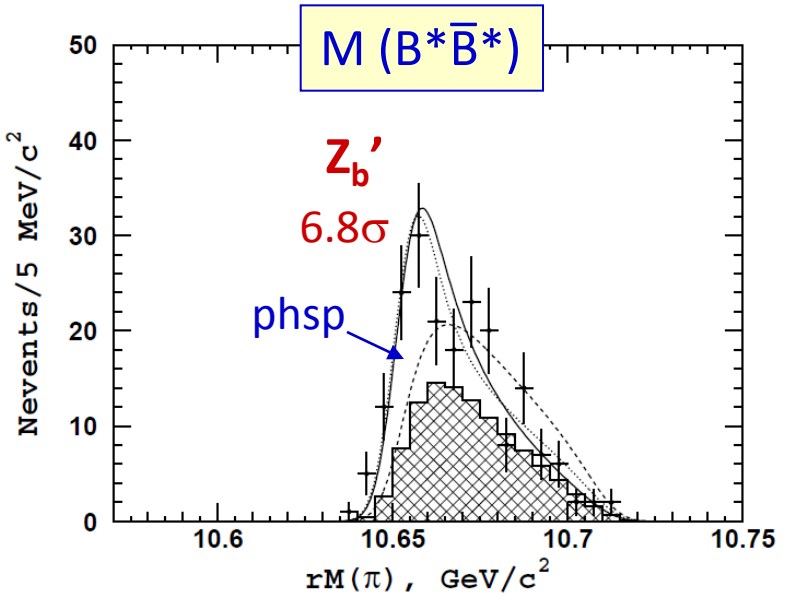
BFs are consistent with previous measurement

Observation of $Z_b \to B\bar{B}^*$ and $Z_b' \to B^*\bar{B}^*$ [Bondar]

preliminary

NEW!





$Z_b' \to B\bar{B}^*$ is suppressed w.r.t. $B^*\bar{B}^*$ despite larger PHSP

Challenging for tetraquark

Molecule $\Rightarrow$ admixture of $B\bar{B}^*$ in Z_b' is small

Channel	Fraction, %	
	$Z_b(10610)$	$Z_b(10650)$
$\Upsilon(1S)\pi^+$	0.32 ± 0.09	0.24 ± 0.07
$\Upsilon(2S)\pi^+$	4.38 ± 1.21	2.40 ± 0.63
$\Upsilon(3S)\pi^+$	2.15 ± 0.56	1.64 ± 0.40
$h_b(1P)\pi^+$	2.81 ± 1.10	7.43 ± 2.70
$h_b(2P)\pi^+$	4.34 ± 2.07	14.8 ± 6.22
$B^+\bar{B}^{*0} + \bar{B}^0 B^{*+}$	86.0 ± 3.6	–
$B^{*+}\bar{B}^{*0}$	–	73.4 ± 7.0

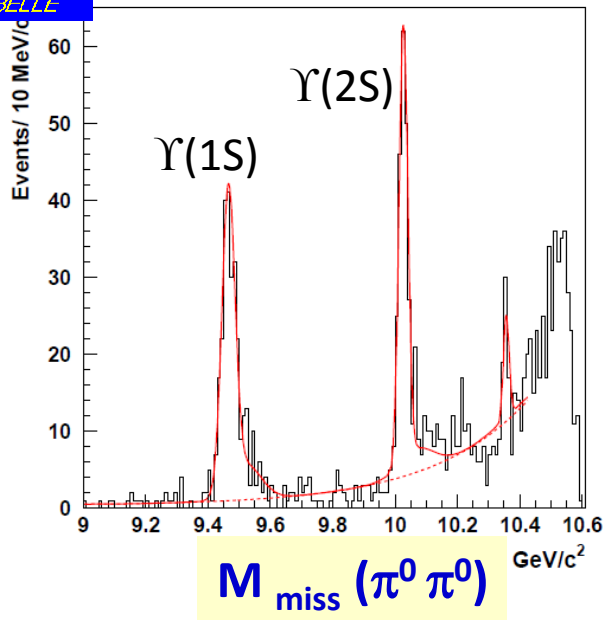
Crucial input for the models

Evidence for a neutral Z_b partner

[Bondar]

preliminary

NEW!



$M_{miss}(\pi^0\pi^0)$

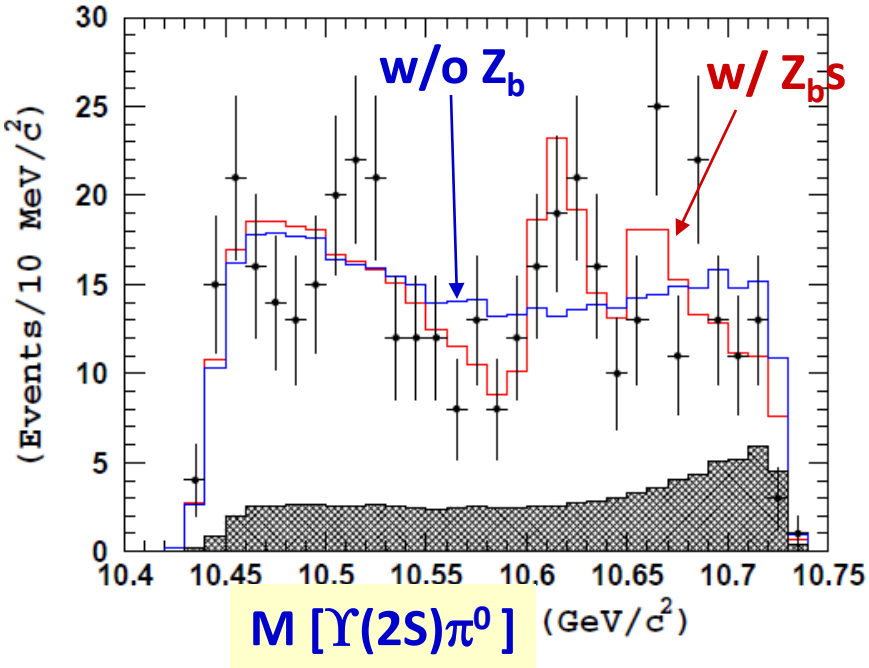
$e^+e^- \to \Upsilon(5S) \to \Upsilon(nS)\pi^0\pi^0$

$BF[\Upsilon(5S)\to\Upsilon(1S)\pi^0\pi^0] = (2.25\pm0.11\pm0.20)\ 10^{-3}$

$BF[\Upsilon(5S)\to\Upsilon(2S)\pi^0\pi^0] = (3.79\pm0.24\pm0.49)\ 10^{-3}$

in agreement with isospin relations

Dalitz plot analysis of $\Upsilon(1S,2S)\pi^0\pi^0 \Rightarrow$



$\Upsilon(2S)\ \pi^0\pi^0$: $Z_b(10610)^0$ 5.3σ (4.9σ w/ syst.)
$Z_b(10650)^0$ $\sim 2\sigma$

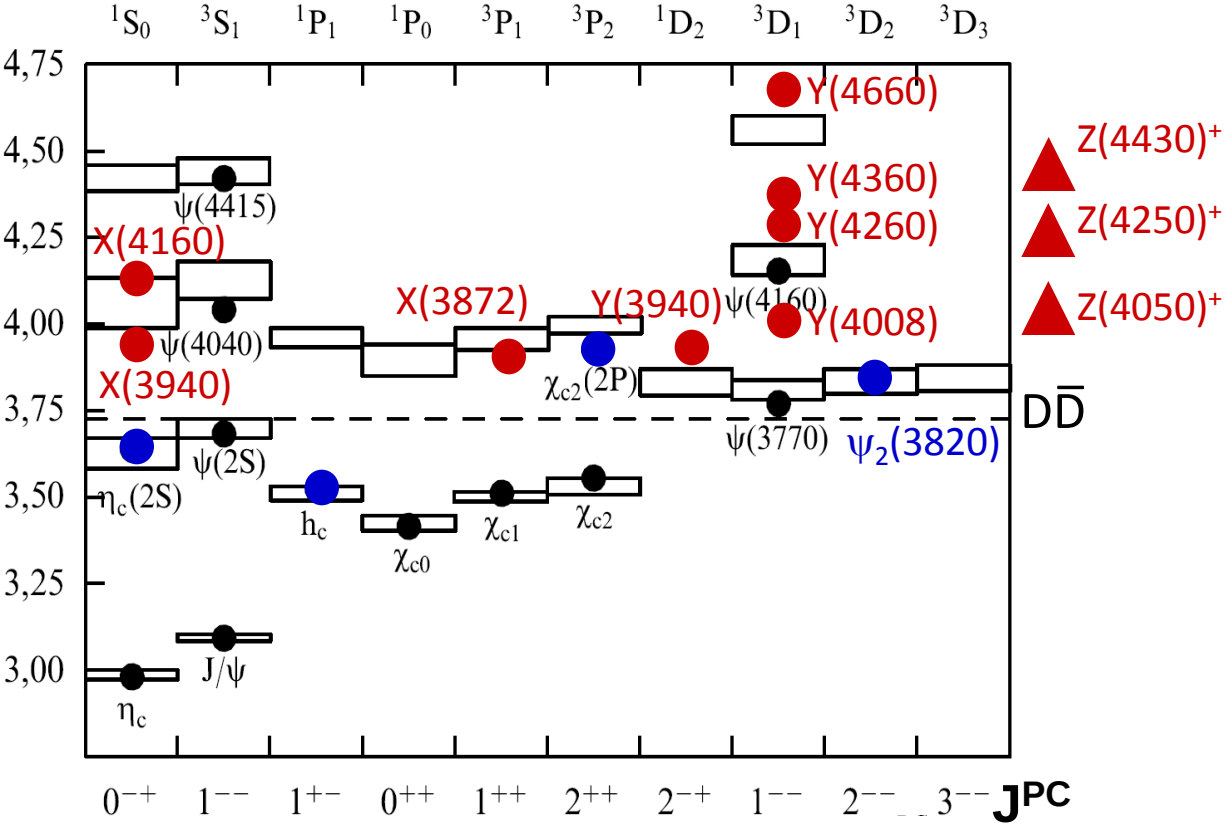
$\Upsilon(1S)\ \pi^0\pi^0$: Z_b signals not significant

Yields agree with isospin expectations

$\Rightarrow$ Confirmation that Z_b is an isotriplet

Charmonium (-like) states

Charmonium table



●● (Recently observed) Charmonia with conventional properties

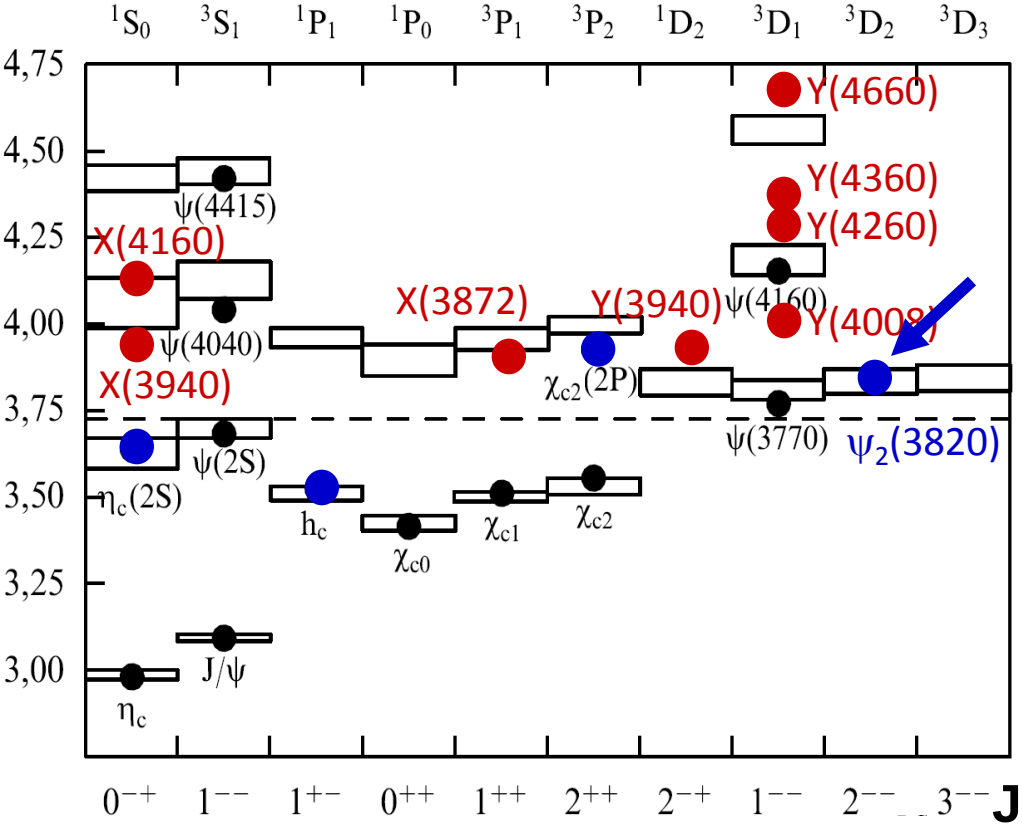
all states below $D\bar{D}$ threshold are observed

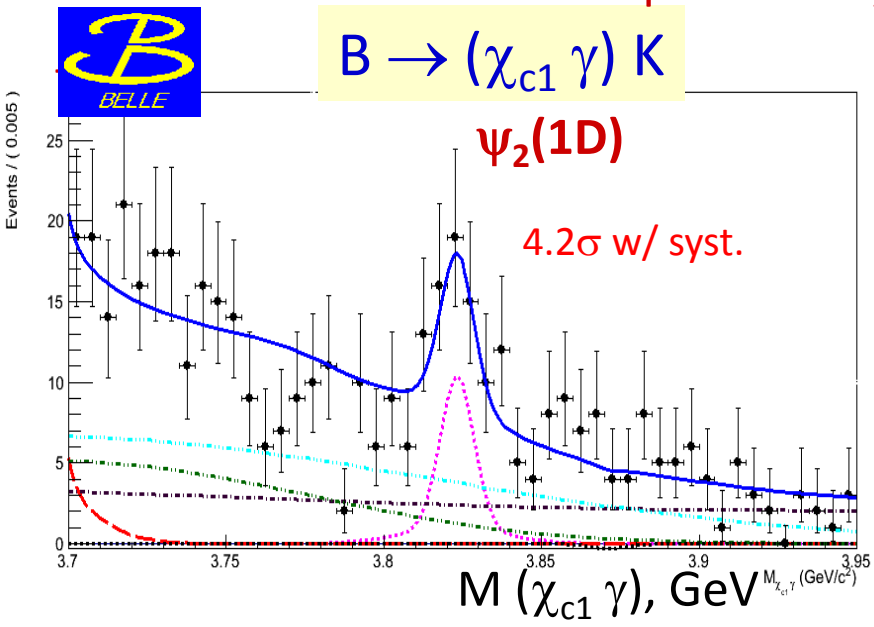
● XYZ states with anomalous properties

Evidence for new charmonium state

[Yabsley]

preliminary





M = 3823.5 ± 2.8 MeV

Γ = 4 ± 6 MeV

C = –

Expectations

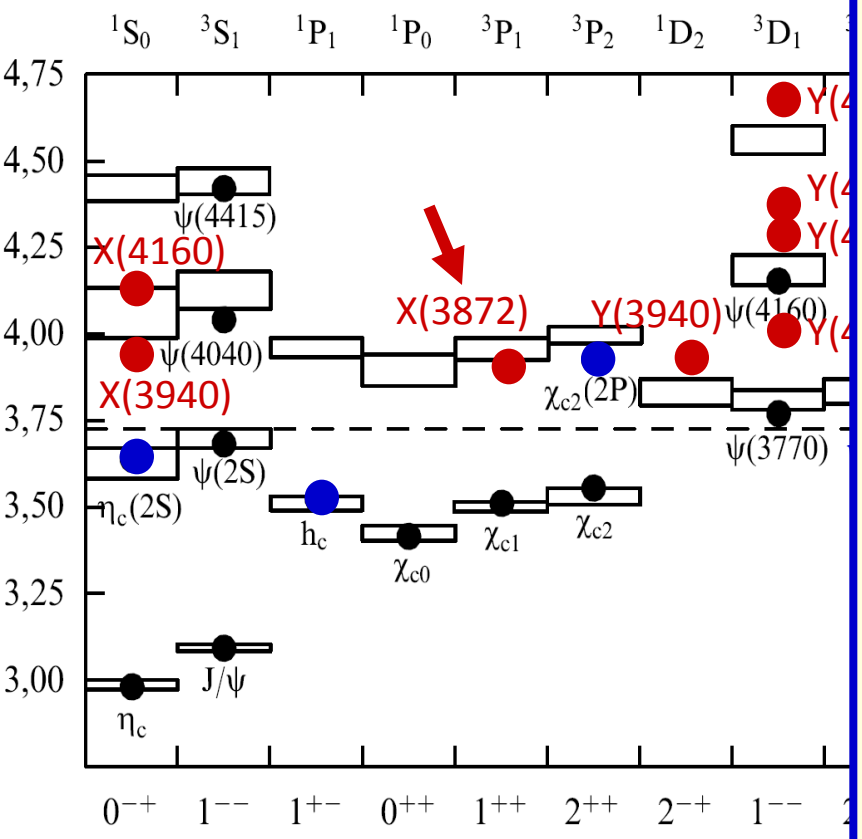
Radiative decay is seen ⇒ Γ~O(10keV)

2^{--}
→ $D\bar{D}$ is forbidden (unnatural spin-parity) ⇒ small Γ
→ $\chi_{c1}\gamma$ is prominent (E1)

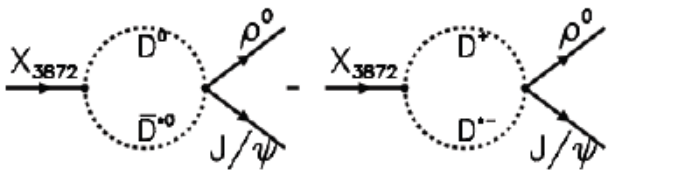
3^{--}
→ $D\bar{D}$ is allowed ⇒ Γ~O(10MeV)
→ $\chi_{c1}\gamma$ is suppressed (E2)
→ $\chi_{c2}\gamma$ is allowed (E1) , but small – not found

Evidence for $\psi_2(1D)$ candidate

L=2 S=1



Isospin Violation in X(3872) decay:



≈on mass shell ≈8 MeV off mass shell

X(3872) Discovery by Belle 2003

Studied also by CDF,D0, BaBar,LHCb,CMS

PDG'12

$M_{X(3872)} - (M_{D^0} + M_{\bar{D}^{*0}}) = -0.16 \pm 0.32$ MeV

	Relative BF	
$J/\psi\,\rho$	1	isospin violation
$J/\psi\,\omega$	0.8 ± 0.3	
$J/\psi\,\gamma$	0.21 ± 0.06	$\Rightarrow \Gamma$ is O(10keV)
$D^0\bar{D}^{*0}$	~10	

Most likely interpretation:

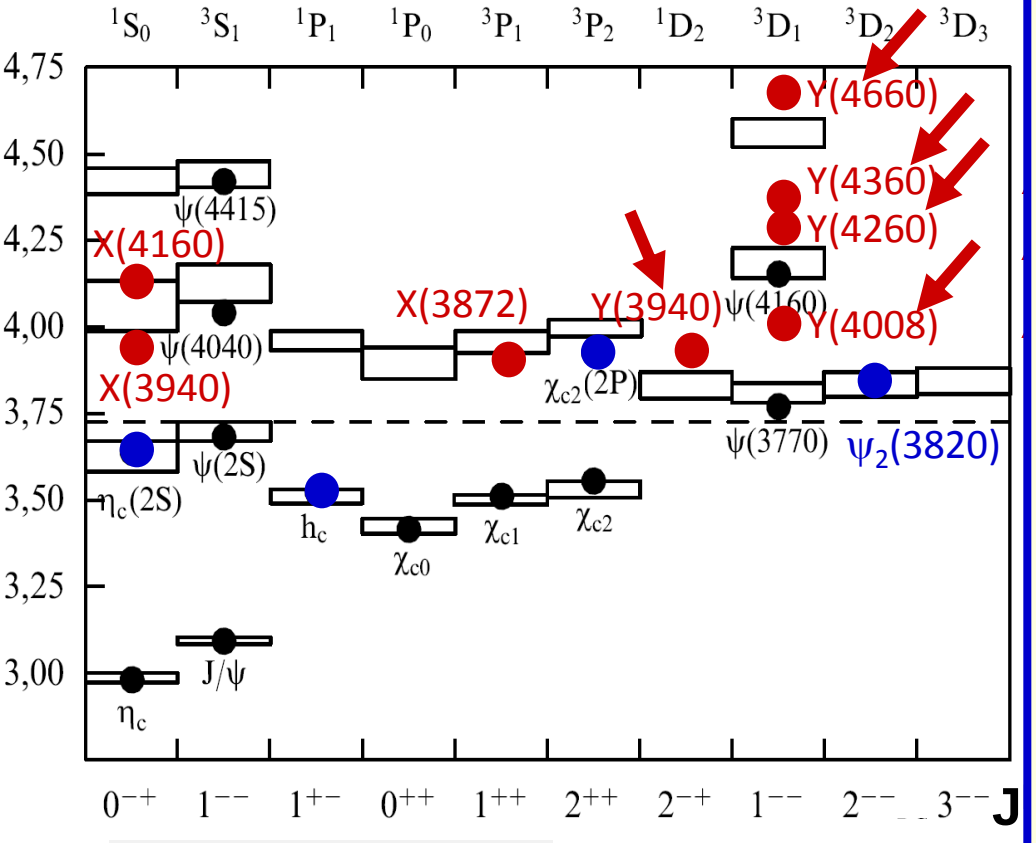
DD* molecule with admixture of $\chi_{c1}(2P)$

isospin violation

production at high energy

Urgent issues : $J^{PC} = 1^{++}$ or 2^{-+} ?

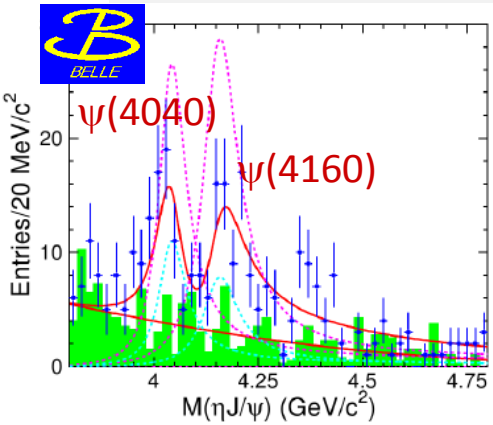
absolute BF, lineshape, ...



$e^+e^- \to \gamma_{ISR}\eta\psi$

[Yabsley]

preliminary



$\Gamma \sim O(1MeV)$

Large for convenrional charmonium state!

States with anomalous decay rates to lower quarkonia :

Y(4008) → J/ψ $\pi^+\pi^-$

Y(4260) → J/ψ $\pi^+\pi^-$

Y(4360) → ψ(2S) $\pi^+\pi^-$

Y(4660) → ψ(2S) $\pi^+\pi^-$

Y(3940) → J/ψ ω

from ISR

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

typical $\Gamma >\sim 1MeV$

c.f. $\Gamma(\psi'' \to J/\psi\pi\pi) \approx 50keV$

recall $\Upsilon(5S) \to \Upsilon(nS)\ \pi^+\pi^-$

$\varphi(2170) \to \varphi\ \pi^+\pi^-$

BaBar PRD74,091103R(2006)

1^{--} supernumerary states

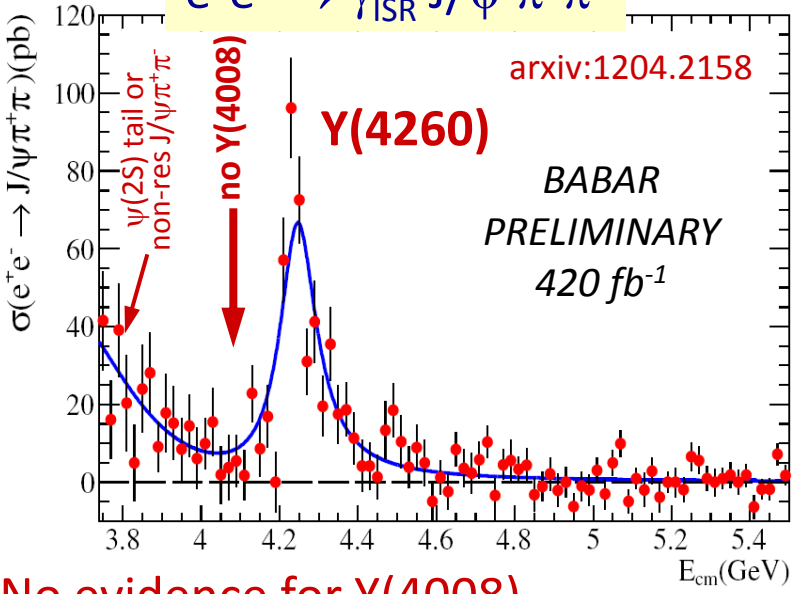
hybrids ?

hadrocharmonia ?

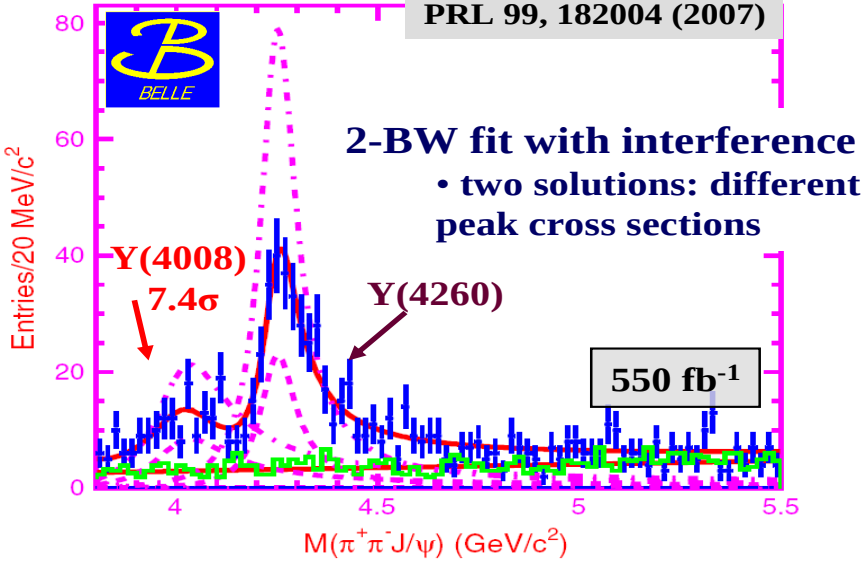
States with anomalous $\Gamma(J/\psi\pi\pi, \psi'\pi\pi, J/\psi\omega)$

[Santoro]

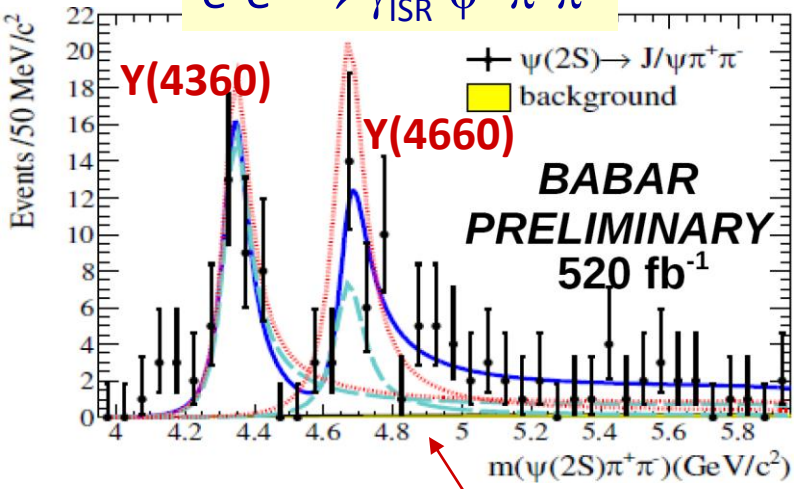
$e^+e^- \to \gamma_{ISR}\, J/\psi\, \pi^+\pi^-$



No evidence for Y(4008)
(reported by Belle)

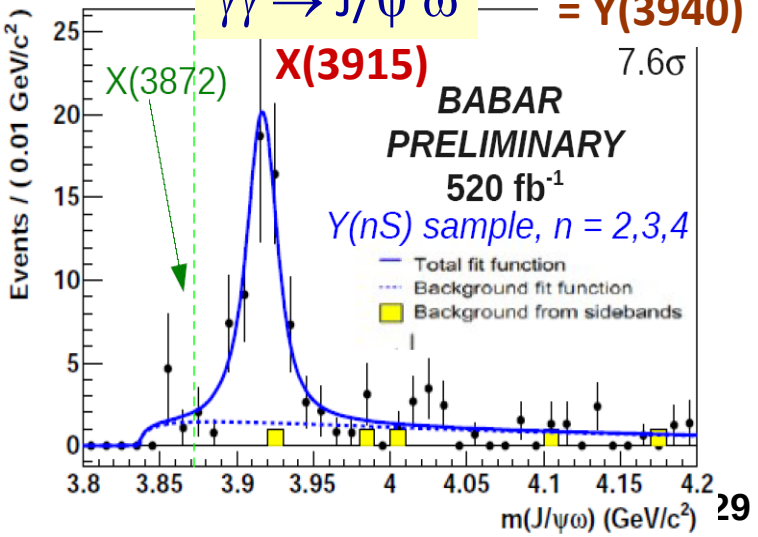


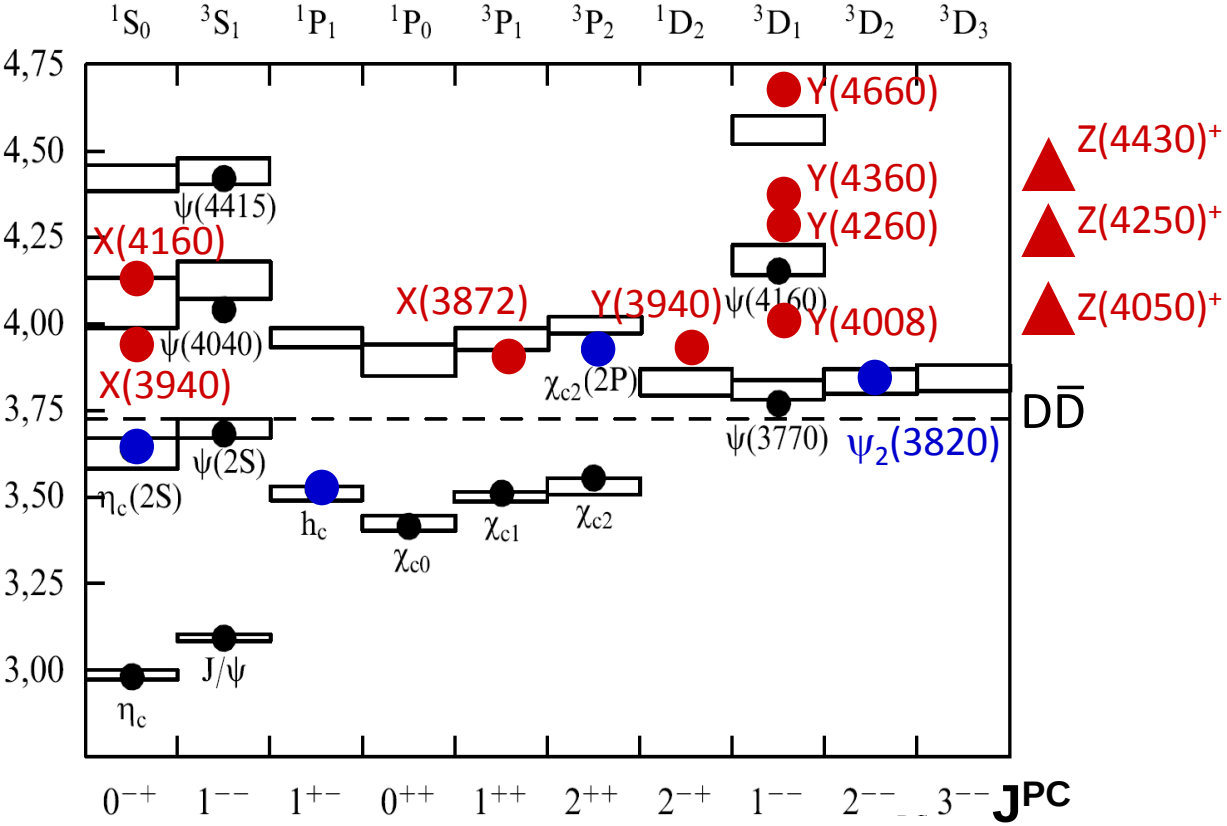
$e^+e^- \to \gamma_{ISR}\, \psi'\, \pi^+\pi^-$



Confirmations of Y(4660) & X(3915)
(observed by Belle)

$\gamma\gamma \to J/\psi\, \omega$ — = Y(3940)





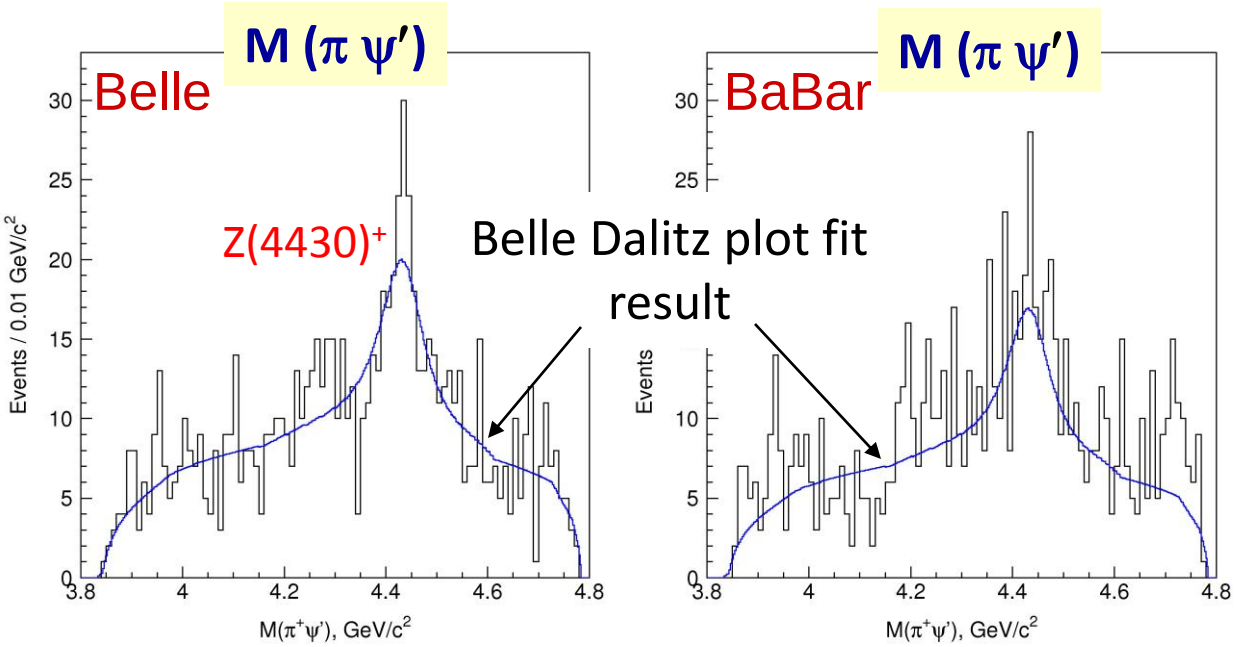
Charged charmonium like states – multiquark candidates

Belle: **Z(4430)** → ψ(2S) π^+ and **Z(4050)** **Z(4250)** → χ_{c1} π^+ but no signal in J/ψ π^+

produced in B → Z K decays

BaBar: no significant signals

Study of $\bar{B} \to \psi'\pi^+K^-$ at Belle & BaBar



Belle and BaBar data look very similar

Conclusions are different:

Belle : observation of Z(4430) – resonance in ($\psi'\pi$) channel

BaBar : structure is due to contributions of ($K\pi$) waves

Different conclusions are due to different approaches :

Belle : Dalitz analysis using isobar model (Breit-Wigner amplitudes, helicity formalizm)

description of amplitudes is model-dependent

BaBar : fit $K\pi$ helicity angle distribution in M($K\pi$) bins (no 2D fit)

unphysical behaviour of amplitude is possible

High statistics data from LHC can help to clarify

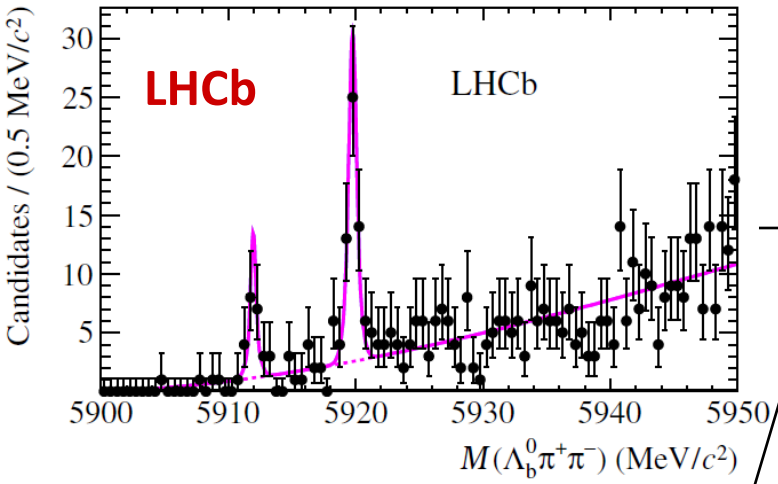
New results on baryons

Beauty baryons

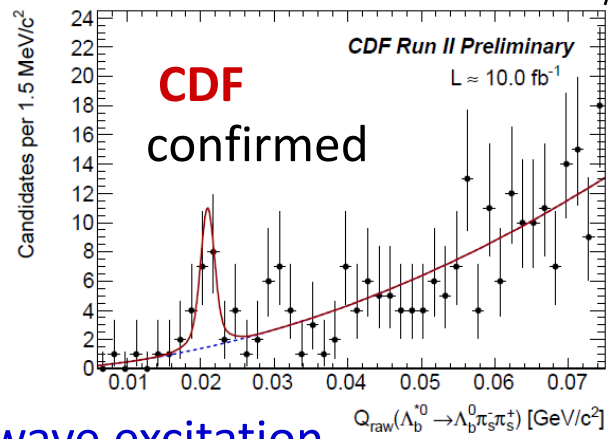
[Märki, Gorelov]

$\Lambda_b^* \to \Lambda_b \pi^+ \pi^-$
$\quad \hookrightarrow \Lambda_c^+ \pi^-$
$\quad\quad \hookrightarrow pK\pi$

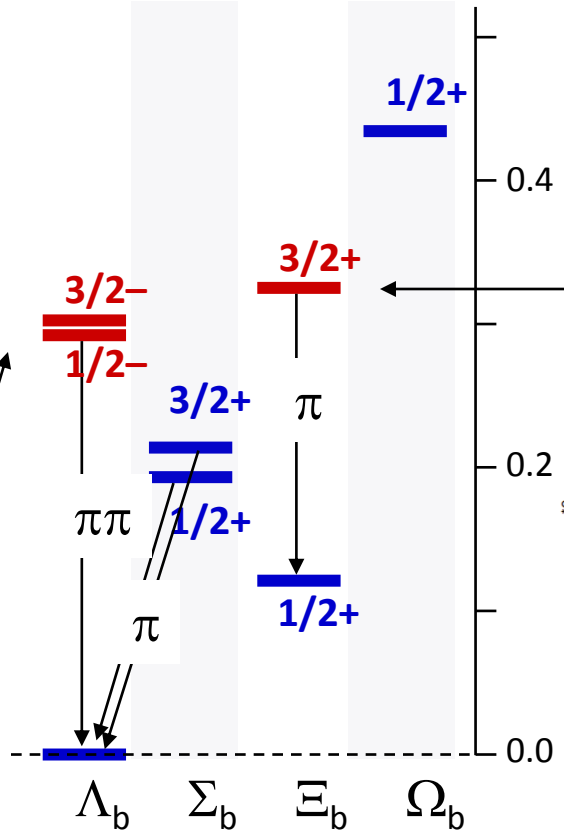
arxiv:1205.3452



NEW!

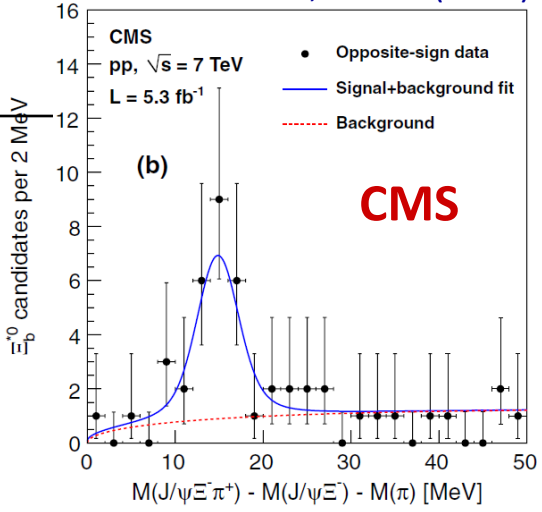


P-wave excitation



$\Xi_b^* \to \Xi_b \pi^+$
$\quad \hookrightarrow J/\psi \Xi^-$
$\quad\quad \hookrightarrow \Lambda\pi^-$

PRL108,252002(2012)



spin-excitation

Ground states ⇐ CDF, D0

First P-wave excitation and Ξ_b spin-excitation

Masses are in agreement w/ expectations

Summary

Many new results from hadronic machines and B- and c-factories

Exotics: two charged Z_b^+ bottomonium-like states in 5 decay modes:

$\Upsilon(1S)\pi^+$, $\Upsilon(2S)\pi^+$, $\Upsilon(3S)\pi^+$, $h_b(1P)\pi^+$, $h_b(2P)\pi^+$

NEW: $Z_b \to BB^*$, $Z_b' \to B^*B^*$, neutral member of isotriplet

Quarkonia: ψ_2 , $\eta_b(2S)$, $h_b(1P)$, $h_b(2P)$, $\chi_b(3P)$

Baryons: spin excitation Ξ_b^*, P-wave Λ_b baryons, NEW: two N*

Ground states & low excitations – no surprises

High excitations – progress in clarifying experimental situation, pattern :

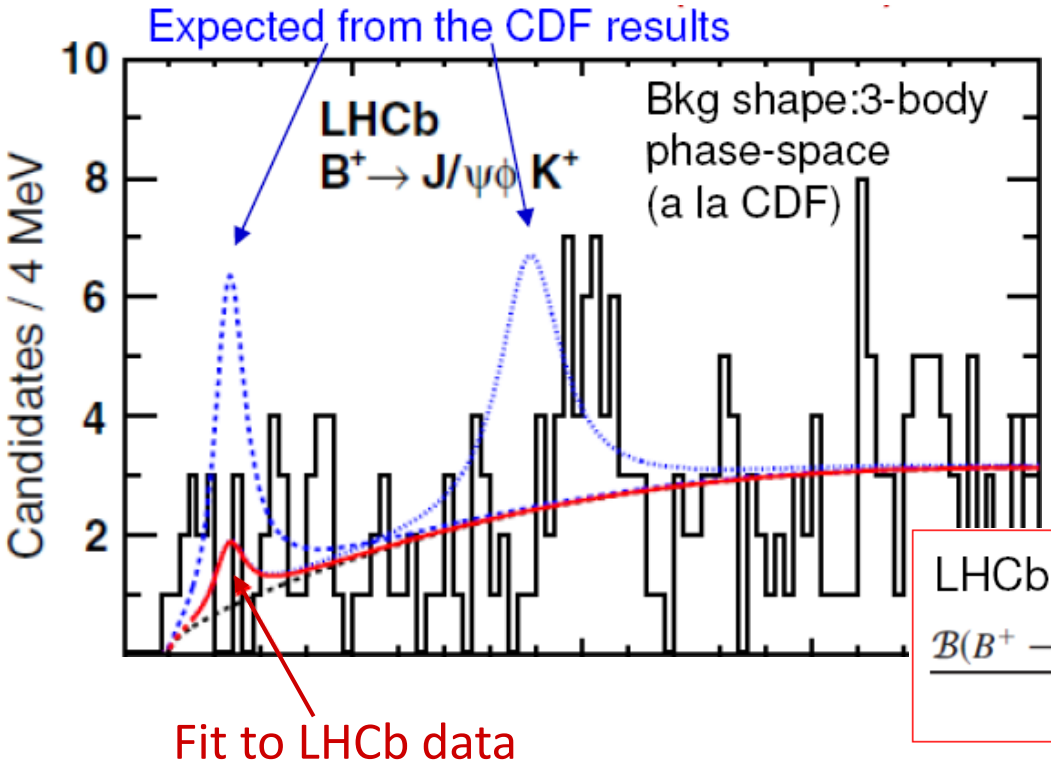
1. States close to thresholds w/ molecular structure: X(3872), $Z_b(10610)$, $Z_b(10650)$
2. States w/ anomalous partial Γ to lower quarkonia:
   $\varphi(2170)$, Y(4260), Y(4360), Y(4660), $\Upsilon(5S)$, charged Z ?
3. States w/ "wrong" masses: X(3940), X(4160)

Similar phenomena in $s\bar{s}$, $c\bar{c}$ and $b\bar{b}$ sectors. Some/many of these states cannot be conventional quarkonia. However, the exact interpretation is still unclear.

Input from high-statistics measurements is important: LHC, Super B-factories.

Back-up

Search for X(4140) in LHCb



LHCb (90% CL):

$$\frac{\mathcal{B}(B^+ \to X(4140)K^+) \times \mathcal{B}(X(4140) \to J/\psi\phi)}{\mathcal{B}(B^+ \to J/\psi\phi K^+)} < 0.07$$

vs CDF: $0.149 \pm 0.039 \pm 0.024.$

2.4σ disagreement

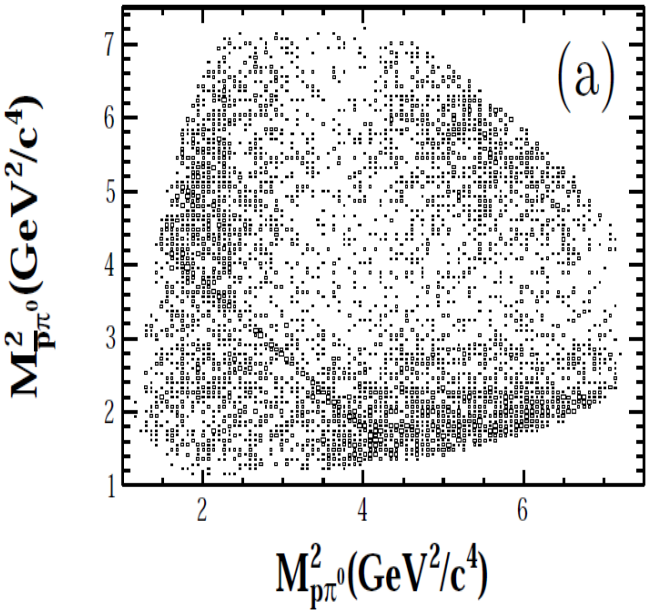
- The most sensitive measurement to date
- Don't find evidence for this state in 2.4σ disagreement with the CDF

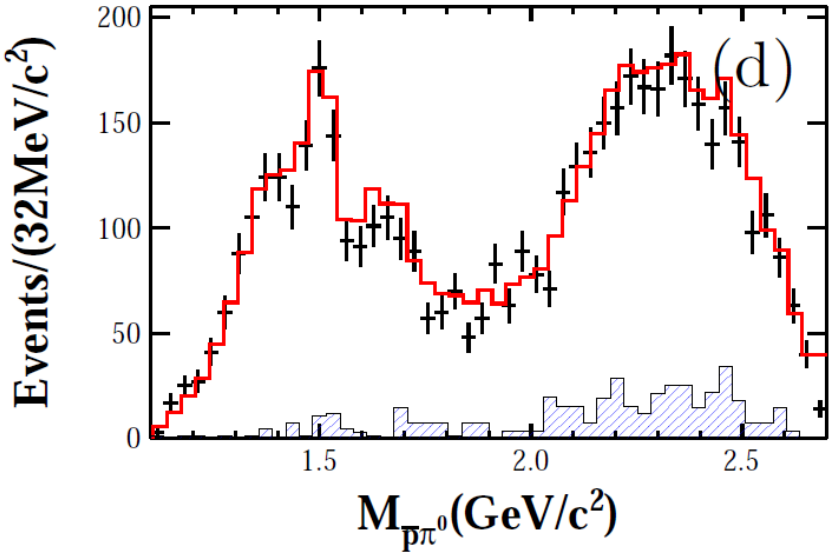
NEW!

Observation of two new N*

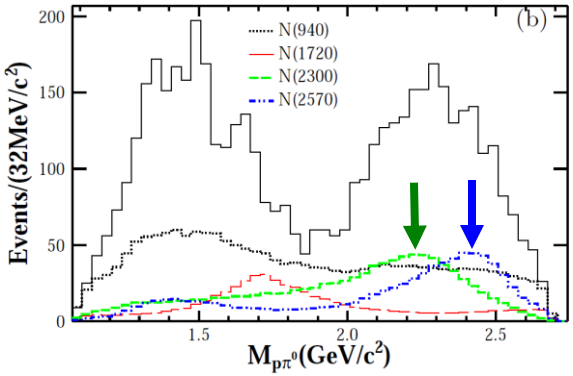
preliminary

BESIII PWA of $\psi(2S) \to p\bar{p}\,\pi^0$





	$M(\mathrm{MeV}/c^2)$	$\Gamma(\mathrm{MeV}/c^2)$
$N(2300)$	$2300^{+40+109}_{-30-0}$	$340^{+30+110}_{-30-58}$
$N(2570)$	2570^{+19+34}_{-10-10}	250^{+14+69}_{-24-21}



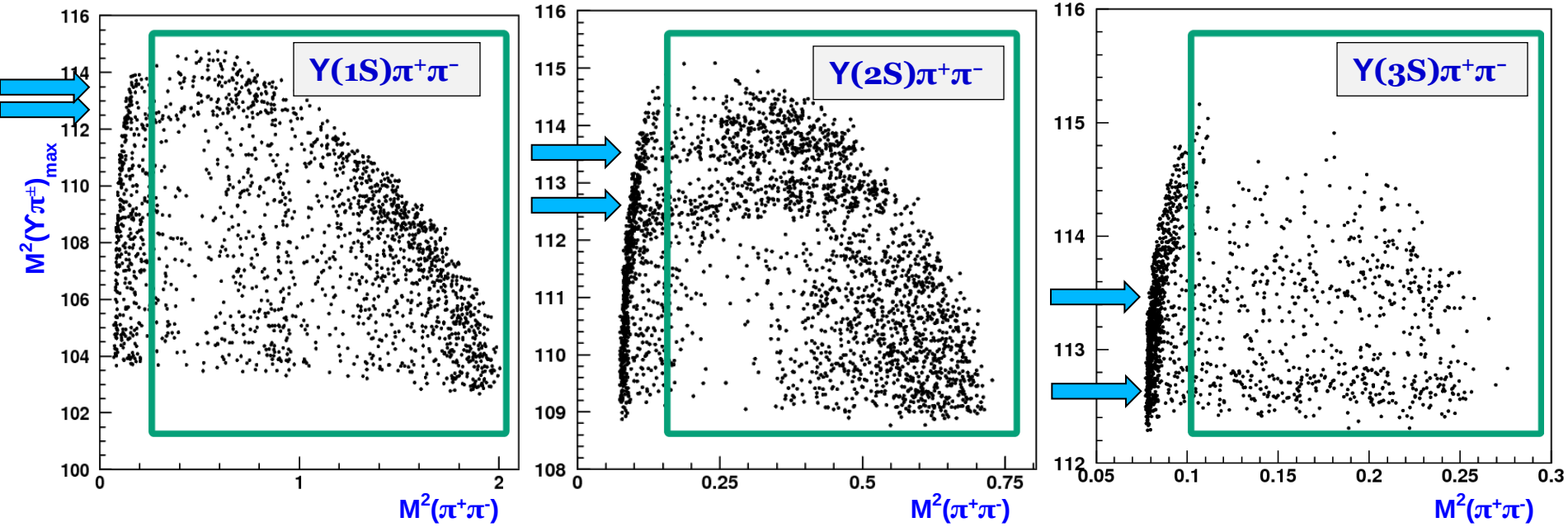
First PWA for baryon spectroscopy from BESIII data

Look at Υ(5S)→Υ(nS) $\pi^+\pi^-$

Dalitz distributions for events in Υ(nS) signal regions.

$$A(Z_{b1}^+) + A(Z_{b2}^+) + A(f_0(980)) + A(f_2(1270)) + A(\mathbf{NR})$$

9.43 GeV <MM($\pi^+\pi^-$) < 9.48 GeV **10.05 GeV <MM($\pi^+\pi^-$) < 10.10 GeV** **10.33 GeV <MM($\pi^+\pi^-$) < 10.38 GeV**



To exclude contamination from gamma conversions we require:

$M^2(\pi^+\pi^-) > 0.20\ GeV^2$ **$M^2(\pi^+\pi^-) > 0.16\ GeV^2$** **$M^2(\pi^+\pi^-) > 0.10\ GeV^2$**

Belle PRL 108, 122001