$Z_b(10610)$

$I^G(J^{PC}) = 1^+(1^{+-})$

was $X(10610)$

Properties incompatible with a $q\overline{q}$ structure (exotic state). See the review on non-$q\overline{q}$ states.

Observed by BONDAR 12 in $\Upsilon(5S)$ decays to $\Upsilon(\mathrm{nS})\pi^+\pi^-$ (n = 1, 2, 3) and $h_b(\mathrm{mP})\pi^+\pi^-$ (m = 1, 2). $J^P = 1^+$ is favored from angular analyses.

$Z_b(10610)^\pm$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
10607.2±2.0	[1] BONDAR	12	BELL	$e^+e^- \to$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$10608.5 \pm 3.4^{+3.7}_{-1.4}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(1S)\pi^+\pi^-$
$10608.1 \pm 1.2^{+1.5}_{-0.2}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(2S)\pi^+\pi^-$
$10607.4 \pm 1.5^{+0.8}_{-0.2}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(3S)\pi^+\pi^-$
10611 ±4 ±3	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(1S)\pi^+\pi^-$
10609 ±2 ±3	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(2S)\pi^+\pi^-$
10608 ±2 ±3	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(3S)\pi^+\pi^-$
$10605 \pm 2 \; {}^{+3}_{-1}$	[3] BONDAR	12	BELL	$e^+e^- \to h_b(1P)\pi^+\pi^-$
$10599 \; {}^{+6}_{-3} \; {}^{+5}_{-4}$	[3] BONDAR	12	BELL	$e^+e^- \to h_b(2P)\pi^+\pi^-$

[1] Average of the BONDAR 12 measurements in separate channels.
[2] Correlated with the corresponding result from BONDAR 12.
[3] Superseded by the average measurement of BONDAR 12.

$Z_b(10610)^0$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
10609±4±4	[1] KROKOVNY	13	BELL	$e^+e^- \to \Upsilon(2S)/\Upsilon(3S)\pi^0\pi^0$

[1] From a simultaneous fit to the KROKOVNY 13 Dalitz analysis of $e^+e^- \to \Upsilon(2S)/\Upsilon(3S)\pi^0\pi^0$ decays with fixed width $\Gamma(Z_b(10610)^0) = 18.4$ MeV.

$Z_b(10610)^\pm$ WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
18.4± 2.4	[1] BONDAR	12	BELL	$e^+e^- \to$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$18.5 \pm 5.3^{+6.1}_{-2.3}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(1S)\pi^+\pi^-$
$20.8 \pm 2.5^{+0.3}_{-2.1}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(2S)\pi^+\pi^-$
$18.7 \pm 3.4^{+2.5}_{-1.3}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(3S)\pi^+\pi^-$

$22.3 \pm 7.7^{+3.0}_{-4.0}$	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(1S)\pi^+\pi^-$	
$24.2 \pm 3.1^{+2.0}_{-3.0}$	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(2S)\pi^+\pi^-$	
$17.6 \pm 3.0 \pm 3.0$	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(3S)\pi^+\pi^-$	
$11.4^{+4.5+2.1}_{-3.9-1.2}$	[3] BONDAR	12	BELL	$e^+e^- \to h_b(1P)\pi^+\pi^-$	
$13^{+10}_{-8}{}^{+9}_{-7}$	[3] BONDAR	12	BELL	$e^+e^- \to h_b(2P)\pi^+\pi^-$	

[1] Average of the BONDAR 12 measurements in separate channels.
[2] Correlated with the corresponding result from BONDAR 12.
[3] Superseded by the average measurement of BONDAR 12.

$Z_b(10610)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\Upsilon(1S)\pi^+$	$(5.4^{+1.9}_{-1.5}) \times 10^{-3}$
Γ_2	$\Upsilon(1S)\pi^0$	not seen
Γ_3	$\Upsilon(2S)\pi^+$	$(3.6^{+1.1}_{-0.8})$ %
Γ_4	$\Upsilon(2S)\pi^0$	seen
Γ_5	$\Upsilon(3S)\pi^+$	$(2.1^{+0.8}_{-0.6})$ %
Γ_6	$\Upsilon(3S)\pi^0$	seen
Γ_7	$h_b(1P)\pi^+$	$(3.5^{+1.2}_{-0.9})$ %
Γ_8	$h_b(2P)\pi^+$	$(4.7^{+1.7}_{-1.3})$ %
Γ_9	$B^+\overline{B}^0$	not seen
Γ_{10}	$B^+\overline{B}^{*0} + B^{*+}\overline{B}^0$	$(85.6^{+2.1}_{-2.9})$ %
Γ_{11}	$B^{*+}\overline{B}^{*0}$	not seen

$Z_b(10610)$ BRANCHING RATIOS

$\Gamma(\Upsilon(1S)\pi^+)/\Gamma_{total}$ Γ_1/Γ

VALUE (units 10^{-3})	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{5.4^{+1.6+1.1}_{-1.3-0.8}}$	[1] GARMASH	16	BELL	$e^+e^- \to \pi^- B^+\overline{B}^{*0}$, $\pi^-\overline{B}^0 B^{*+}$

• • • We do not use the following data for averages, fits, limits, etc. • • •

seen	GARMASH	15	BELL	$e^+e^- \to \Upsilon(1S)\pi^+\pi^-$
seen	BONDAR	12	BELL	$e^+e^- \to \Upsilon(1S)\pi^+\pi^-$

[1] Assuming the $Z_b(10610)$ decay width is saturated by the channels $\pi^+\Upsilon(1S, 2S, 3S)$, $\pi^+ h_b(1P, 2P)$, and $B^+\overline{B}^{*0} + \overline{B}^0 B^{*+}$, and using the results from BONDAR 12 and MIZUK 16.

$\Gamma(\Upsilon(1S)\pi^0)/\Gamma_{total}$ Γ_2/Γ

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
not seen	KROKOVNY	13	BELL	$e^+e^- \to \Upsilon(1S)\pi^0\pi^0$

$\Gamma(\Upsilon(2S)\pi^+)/\Gamma_{\text{total}}$ Γ_3/Γ

VALUE (units 10^{-2})	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{3.62^{+0.76+0.79}_{-0.59-0.53}}$	[1] GARMASH	16	BELL	$e^+e^- \to \pi^- B^+ \overline{B}{}^{*0}$, $\pi^- \overline{B}{}^0 B^{*+}$

• • • We do not use the following data for averages, fits, limits, etc. • • •

seen	GARMASH	15	BELL	$e^+e^- \to \Upsilon(2S)\pi^+\pi^-$
seen	BONDAR	12	BELL	$e^+e^- \to \Upsilon(2S)\pi^+\pi^-$

[1] Assuming the $Z_b(10610)$ decay width is saturated by the channels $\pi^+\Upsilon(1S,2S,3S)$, $\pi^+ h_b(1P,2P)$, and $B^+\overline{B}{}^{*0} + \overline{B}{}^0 B^{*+}$, and using the results from BONDAR 12 and MIZUK 16.

$\Gamma(\Upsilon(2S)\pi^0)/\Gamma_{\text{total}}$ Γ_4/Γ

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
seen	[1] KROKOVNY	13	BELL	$e^+e^- \to \Upsilon(2S)\pi^0\pi^0$

[1] Combined significance in $e^+e^- \to \Upsilon(2S)/\Upsilon(3S)\pi^0\pi^0$, including systematics, of 6.5σ.

$\Gamma(\Upsilon(3S)\pi^+)/\Gamma_{\text{total}}$ Γ_5/Γ

VALUE (units 10^{-2})	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{2.15^{+0.55+0.60}_{-0.42-0.43}}$	[1] GARMASH	16	BELL	$e^+e^- \to \pi^- B^+ \overline{B}{}^{*0}$, $\pi^- \overline{B}{}^0 B^{*+}$

• • • We do not use the following data for averages, fits, limits, etc. • • •

seen	GARMASH	15	BELL	$e^+e^- \to \Upsilon(3S)\pi^+\pi^-$
seen	BONDAR	12	BELL	$e^+e^- \to \Upsilon(3S)\pi^+\pi^-$

[1] Assuming the $Z_b(10610)$ decay width is saturated by the channels $\pi^+\Upsilon(1S,2S,3S)$, $\pi^+ h_b(1P,2P)$, and $B^+\overline{B}{}^{*0} + \overline{B}{}^0 B^{*+}$, and using the results from BONDAR 12 and MIZUK 16.

$\Gamma(\Upsilon(3S)\pi^0)/\Gamma_{\text{total}}$ Γ_6/Γ

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
seen	[1] KROKOVNY	13	BELL	$e^+e^- \to \Upsilon(3S)\pi^0\pi^0$

[1] Combined significance in $e^+e^- \to \Upsilon(2S)/\Upsilon(3S)\pi^0\pi^0$, including systematics, of 6.5σ.

$\Gamma(h_b(1P)\pi^+)/\Gamma_{\text{total}}$ Γ_7/Γ

VALUE (units 10^{-2})	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{3.45^{+0.87+0.86}_{-0.71-0.63}}$	[1] GARMASH	16	BELL	$e^+e^- \to \pi^- B^+ \overline{B}{}^{*0}$, $\pi^- \overline{B}{}^0 B^{*+}$

• • • We do not use the following data for averages, fits, limits, etc. • • •

possibly seen	[2] MIZUK	16	BELL	$e^+e^- \to h_b(1P)\pi^+\pi^-$
seen	[3] BONDAR	12	BELL	$e^+e^- \to h_b(1P)\pi^+\pi^-$

[1] Assuming the $Z_b(10610)$ decay width is saturated by the channels $\pi^+\Upsilon(1S,2S,3S)$, $\pi^+ h_b(1P,2P)$, and $B^+\overline{B}{}^{*0} + \overline{B}{}^0 B^{*+}$, and using the results from BONDAR 12 and MIZUK 16.
[2] Using e^+e^- energies near the $\Upsilon(11020)$.
[3] Using e^+e^- energies near the $\Upsilon(10860)$.

$\Gamma(h_b(2P)\pi^+)/\Gamma_{total}$ Γ_8/Γ

VALUE (units 10^{-2})	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{4.67^{+1.24+1.18}_{-1.00-0.89}}$	[1] GARMASH	16	BELL	$e^+e^- \to \pi^- B^+ \overline{B}^{*0}$, $\pi^- \overline{B}^0 B^{*+}$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
possibly seen	[2] MIZUK	16	BELL	$e^+e^- \to h_b(2P)\pi^+\pi^-$
seen	[3] BONDAR	12	BELL	$e^+e^- \to h_b(2P)\pi^+\pi^-$

[1] Assuming the $Z_b(10610)$ decay width is saturated by the channels $\pi^+\Upsilon(1S,2S,3S)$, $\pi^+ h_b(1P,2P)$, and $B^+\overline{B}^{*0} + \overline{B}^0 B^{*+}$, and using the results from BONDAR 12 and MIZUK 16.
[2] Using e^+e^- energies near the $\Upsilon(11020)$.
[3] Using e^+e^- energies near the $\Upsilon(10860)$.

$\Gamma(B^+\overline{B}^0)/\Gamma_{total}$ Γ_9/Γ

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
not seen	GARMASH	16	BELL	$e^+e^- \to \pi^- B^+ \overline{B}^0$

$[\Gamma(B^+\overline{B}^{*0}) + \Gamma(B^{*+}\overline{B}^0)]/\Gamma_{total}$ Γ_{10}/Γ

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{85.6^{+1.5+1.5}_{-2.0-2.1}}$	357	[1] GARMASH	16	BELL	$e^+e^- \to \pi^- B^+ \overline{B}^{*0}$, $\pi^- B^{*+} \overline{B}^0$

[1] Assuming the $Z_b(10610)$ decay width is saturated by the channels $\pi^+\Upsilon(1S,2S,3S)$, $\pi^+ h_b(1P,2P)$, and $B^+\overline{B}^{*0} + B^{*+}\overline{B}^0$, and using the results from BONDAR 12 and MIZUK 16. Using the mass and width of the $Z_b(10610)$ from BONDAR 12.

$\Gamma(B^{*+}\overline{B}^{*0})/\Gamma_{total}$ Γ_{11}/Γ

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
not seen	GARMASH	16	BELL	$e^+e^- \to \pi^- B^{*+} \overline{B}^{*0}$

$[\Gamma(B^+\overline{B}^{*0}) + \Gamma(B^{*+}\overline{B}^0)]/[\Gamma(\Upsilon(1S)\pi^+) + \Gamma(\Upsilon(2S)\pi^+) + \Gamma(\Upsilon(3S)\pi^+) + \Gamma(h_b(1P)\pi^+) + \Gamma(h_b(2P)\pi^+)]$ $\Gamma_{10}/(\Gamma_1+\Gamma_3+\Gamma_5+\Gamma_7+\Gamma_8)$

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$5.93^{+0.99+1.01}_{-0.69-0.73}$	357	[1] GARMASH	16	BELL	$e^+e^- \to \pi^- B^+ \overline{B}^{*0}$, $\pi^- \overline{B}^0 B^{*+}$

[1] Combined with the results of BONDAR 12 and MIZUK 16. Not independent from $Z_b(10610)$ branching fractions to $\pi^+\Upsilon(1S,2S,3S)$, $\pi^+ h_b(1P,2P)$, and $B^+\overline{B}^{*0} + \overline{B}^0 B^{*+}$.

$Z_b(10610)$ REFERENCES

GARMASH	16	PRL 116 212001	A. Garmash *et al.*	(BELLE Collab.)
MIZUK	16	PRL 117 142001	R. Mizuk *et al.*	(BELLE Collab.)
GARMASH	15	PR D91 072003	A. Garmash *et al.*	(BELLE Collab.)
KROKOVNY	13	PR D88 052016	P. Krokovny *et al.*	(BELLE Collab.)
BONDAR	12	PRL 108 122001	A. Bondar *et al.*	(BELLE Collab.)