$T_{b\bar{b}1}(10610)$

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

was $Z_b(10610)$, $X(10610)$

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 $\Upsilon(nS)\pi^+\pi^-$ (n = 1, 2, 3) and $h_b(mP)\pi^+\pi^-$ (m = 1, 2). $J^P = 1^+$ is favored from angular analyses.

$T_{b\bar{b}1}(10610)^{\pm}$ 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. • • •				
$10608.5\pm3.4^{+3.7}_{-1.4}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(1S)\pi^+\pi^-$
$10608.1\pm1.2^{+1.5}_{-0.2}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(2S)\pi^+\pi^-$
$10607.4\pm1.5^{+0.8}_{-0.2}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(3S)\pi^+\pi^-$
$10611 \pm4 \pm3$	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(1S)\pi^+\pi^-$
$10609 \pm2 \pm3$	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(2S)\pi^+\pi^-$
$10608 \pm2 \pm3$	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(3S)\pi^+\pi^-$
$10605 \pm2 ^{+3}_{-1}$	[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[3] Superseded by the average measurement of BONDAR 12.

$T_{b\bar{b}1}(10610)^0$ 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 $\Gamma(T_{b\bar{b}1}(10610)^0) = 18.4$ MeV.

$T_{b\bar{b}1}(10610)^{\pm}$ 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	$e^+e^- \to \ \Upsilon(2S)\pi^+\pi^-$
$17.6\pm\ 3.0\pm3.0$	[3] BONDAR	12	BELL	$e^+e^- \to \ \Upsilon(3S)\pi^+\pi^-$
$11.4^{+\ 4.5}_{-\ 3.9}{}^{+2.1}_{-1.2}$	[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.

$T_{b\overline{b}1}(10610)$ 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}	$B^+\overline{B}^{*0} +\ B^{*+}\overline{B}^0$	$(85.6^{+2.1}_{-2.9})\ \%$

$T_{b\overline{b}1}(10610)$ 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	$e^+e^- \to\ \pi^-B^+\overline{B}^{*0},$ $\pi^-\overline{B}^0B^{*+}$

• • • 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 $T_{b\overline{b}1}(10610)$ decay width is saturated by the channels $\pi^+\Upsilon(1S, 2S, 3S)$, $\pi^+ h_b(1P, 2P)$, and $B^+\overline{B}^{*0} +\ \overline{B}^0B^{*+}$, 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	$e^+e^- \to\ \Upsilon(1S)\pi^0\pi^0$

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

VALUE (units 10^{-2})	DOCUMENT ID		TECN	COMMENT
$3.62^{+0.76+0.79}_{-0.59-0.53}$	[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 $T_{b\overline{b}1}(10610)$ 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.

$\Gamma\big(\Upsilon(2S)\pi^0\big)/\Gamma_{total}$ $\qquad\qquad$ 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.

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

VALUE (units 10^{-2})	DOCUMENT ID		TECN	COMMENT
$2.15^{+0.55+0.60}_{-0.42-0.43}$	[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 $T_{b\overline{b}1}(10610)$ 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.

$\Gamma\big(\Upsilon(3S)\pi^0\big)/\Gamma_{total}$ $\qquad\qquad$ 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.

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

VALUE (units 10^{-2})	DOCUMENT ID		TECN	COMMENT
$3.45^{+0.87+0.86}_{-0.71-0.63}$	[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 $T_{b\overline{b}1}(10610)$ 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 $\Upsilon(10860)$.

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

VALUE (units 10^{-2})	DOCUMENT ID		TECN	COMMENT
$4.67^{+1.24+1.18}_{-1.00-0.89}$	[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 $T_{b\overline{b}1}(10610)$ 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 $\Upsilon(10860)$.

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

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

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

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

[1] Assuming the $T_{b\overline{b}1}(10610)$ 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 $T_{b\overline{b}1}(10610)$ from BONDAR 12.

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

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 $T_{b\overline{b}1}(10610)$ branching fractions to $\pi^+\Upsilon(1S, 2S, 3S)$, $\pi^+ h_b(1P, 2P)$, and $B^+\overline{B}{}^{*0} + \overline{B}{}^0 B^{*+}$.

$T_{b\overline{b}1}(10610)$ 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.)