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

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

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

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

$T_{b\bar{b}1}(10610)^{\pm}$ 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. • • •				
$10608.5 \pm 3.4^{+3.7}_{-1.4}$	[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[3] Superseded by the average measurement of BONDAR 12.

$T_{b\bar{b}1}(10610)^0$ 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	$e^+e^- \to \Upsilon(2S)\pi^+\pi^-$	
$17.6 \pm 3.0 \pm 3.0$	[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+9}_{-8-7}	[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.

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

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

$\Gamma(\Upsilon(1S)\pi^+)/\Gamma_{\text{total}}$ 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 $T_{b\overline{b}1}(10610)$ 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.

$\Gamma(\Upsilon(1S)\pi^0)/\Gamma_{\text{total}}$ 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	$e^+e^-\to\ \pi^-B^+\overline{B}^{*0}$, $\pi^-\overline{B}^0B^{*+}$

• • • 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.

$\Gamma(\Upsilon(2S)\pi^0)/\Gamma_{\text{total}}$ 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	$e^+e^-\to\ \pi^-B^+\overline{B}^{*0}$, $\pi^-\overline{B}^0B^{*+}$

• • • 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.

$\Gamma(\Upsilon(3S)\pi^0)/\Gamma_{\text{total}}$ 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	$e^+e^-\to\ \pi^-B^+\overline{B}^{*0}$, $\pi^-\overline{B}^0B^{*+}$

• • • 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 $T_{b\bar{b}1}(10610)$ 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 $\Upsilon(10860)$.

$\Gamma(h_b(2P)\pi^+)/\Gamma_{\text{total}}$ 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 $T_{b\bar{b}1}(10610)$ 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 $\Upsilon(10860)$.

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

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

$\left[\Gamma(B^+\overline{B}^{*0}) + \Gamma(B^{*+}\overline{B}^0)\right]/\Gamma_{\text{total}}$ 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 $T_{b\bar{b}1}(10610)$ 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 $T_{b\bar{b}1}(10610)$ from BONDAR 12.

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

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

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