$T_{b\bar{b}1}(10650)$

$I^G(J^{PC}) = 1^+(1^{+-})$
I, G, C need confirmation.

was $Z_b(10650)$, $X(10650)^{\pm}$

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.

$T_{b\bar{b}1}(10650)^+$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
10652.2±1.5	[1] BONDAR	12	BELL	$e^+e^- \to$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$10656.7 \pm 5.0^{+1.1}_{-3.1}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(1S)\pi^+\pi^-$
$10650.7 \pm 1.5^{+0.5}_{-0.2}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(2S)\pi^+\pi^-$
$10651.2 \pm 1.0^{+0.4}_{-0.3}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(3S)\pi^+\pi^-$
10657 ±6 ±3	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(1S)\pi^+\pi^-$
10651 ±2 ±3	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(2S)\pi^+\pi^-$
10652 ±1 ±2	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(3S)\pi^+\pi^-$
$10654 \pm 3 \ {}^{+1}_{-2}$	[3] BONDAR	12	BELL	$e^+e^- \to h_b(1P)\pi^+\pi^-$
$10651 \ {}^{+2}_{-3} \ {}^{+3}_{-2}$	[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[3] Superseded by the average measurement of BONDAR 12.

$T_{b\bar{b}1}(10650)^+$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
11.5± 2.2	[1] BONDAR	12	BELL	$e^+e^- \to$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$12.1 \ {}^{+11.3+}_{-4.8-} \ {}^{2.7}_{0.6}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(1S)\pi^+\pi^-$
$14.2 \pm 3.7 \ {}^{+0.9}_{-0.4}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(2S)\pi^+\pi^-$
$9.3 \pm 2.2 \ {}^{+0.3}_{-0.5}$	[2] GARMASH	15	BELL	$e^+e^- \to \Upsilon(3S)\pi^+\pi^-$
$16.3 \pm 9.8 \ {}^{+6.0}_{-2.0}$	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(1S)\pi^+\pi^-$
$13.3 \pm 3.3 \ {}^{+4.0}_{-3.0}$	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(2S)\pi^+\pi^-$
8.4± 2.0± 2.0	[3] BONDAR	12	BELL	$e^+e^- \to \Upsilon(3S)\pi^+\pi^-$
$20.9 \ {}^{+5.4+}_{-4.7-} \ {}^{2.1}_{5.7}$	[3] BONDAR	12	BELL	$e^+e^- \to h_b(1P)\pi^+\pi^-$
$19 \pm 7 \ {}^{+11}_{-7}$	[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[3] Superseded by the average measurement of BONDAR 12.

$T_{b\bar{b}1}(10650)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\Upsilon(1S)\pi^+$	$(\ 1.7^{+0.8}_{-0.6}) \times 10^{-3}$
Γ_2	$\Upsilon(2S)\pi^+$	$(\ 1.4^{+0.6}_{-0.4})$ %
Γ_3	$\Upsilon(3S)\pi^+$	$(\ 1.6^{+0.7}_{-0.5})$ %
Γ_4	$h_b(1P)\pi^+$	$(\ 8.4^{+2.9}_{-2.4})$ %
Γ_5	$h_b(2P)\pi^+$	(15 ± 4) %
Γ_6	$B^+\overline{B}^0$	not seen
Γ_7	$B^+\overline{B}^{*0}\ +\ B^{*+}\overline{B}^0$	not seen
Γ_8	$B^{*+}\overline{B}^{*0}$	(74 $^{+4}_{-6}$) %

$T_{b\bar{b}1}(10650)$ BRANCHING RATIOS

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

VALUE (units 10^{-3})	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{1.7^{+0.7+0.3}_{-0.6-0.2}}$	[1] GARMASH	16	BELL	$e^+e^- \to \pi^- B^{*+}\overline{B}^{*0}$
• • • 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 $T_{b\bar{b}1}(10650)$ decay width is saturated by the channels $\pi^+\,\Upsilon(1S, 2S, 3S)$, $\pi^+ h_b(1P, 2P)$, and $B^{*+}\overline{B}^{*0}$, and using the results from BONDAR 12 and MIZUK 16.

$\Gamma(\Upsilon(2S)\pi^+)/\Gamma_{\text{total}}$ Γ_2/Γ

VALUE (units 10^{-2})	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{1.39^{+0.48+0.34}_{-0.38-0.23}}$	[1] GARMASH	16		$e^+e^- \to \pi^- B^{*+}\overline{B}^{*0}$
• • • 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 $T_{b\bar{b}1}(10650)$ decay width is saturated by the channels $\pi^+\,\Upsilon(1S, 2S, 3S)$, $\pi^+ h_b(1P, 2P)$, and $B^{*+}\overline{B}^{*0}$, and using the results from BONDAR 12 and MIZUK 16.

$\Gamma(\Upsilon(3S)\pi^+)/\Gamma_{\text{total}}$ Γ_3/Γ

VALUE (units 10^{-2})	DOCUMENT ID		TECN	COMMENT
$\mathbf{1.63^{+0.53+0.39}_{-0.42-0.28}}$	[1] GARMASH	16	BELL	$e^+e^- \to \pi^- B^{*+}\overline{B}^{*0}$

• • • 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 $T_{b\overline{b}1}(10650)$ decay width is saturated by the channels $\pi^+\Upsilon(1S,2S,3S)$, $\pi^+ h_b(1P,2P)$, and $B^{*+}\overline{B}^{*0}$, and using the results from BONDAR 12 and MIZUK 16.

$\Gamma(h_b(1P)\pi^+)/\Gamma_{\text{total}}$ Γ_4/Γ

VALUE (units 10^{-2})	DOCUMENT ID		TECN	COMMENT
$\mathbf{8.41^{+2.43+1.49}_{-2.12-1.06}}$	[1] GARMASH	16	BELL	$e^+e^- \to \pi^- B^{*+}\overline{B}^{*0}$

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

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 $T_{b\overline{b}1}(10650)$ decay width is saturated by the channels $\pi^+\Upsilon(1S,2S,3S)$, $\pi^+ h_b(1P,2P)$, and $B^{*+}\overline{B}^{*0}$, 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_5/Γ

VALUE (units 10^{-2})	DOCUMENT ID		TECN	COMMENT
$\mathbf{14.7^{+3.2+2.8}_{-2.8-2.3}}$	[1] GARMASH	16	BELL	$e^+e^- \to \pi^- B^{*+}\overline{B}^{*0}$

• • • 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 $T_{b\overline{b}1}(10650)$ decay width is saturated by the channels $\pi^+\Upsilon(1S,2S,3S)$, $\pi^+ h_b(1P,2P)$, and $B^{*+}\overline{B}^{*0}$, 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_6/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_7/Γ

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

$\Gamma(B^{*+}\overline{B}^{*0})/\Gamma_{\text{total}}$ Γ_8/Γ

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{73.7^{+3.4+2.7}_{-4.4-3.5}}$	161	[1] GARMASH	16	BELL	$e^+e^- \to \pi^- B^{*+}\overline{B}^{*0}$

[1] Assuming the $T_{b\bar{b}1}(10650)$ decay width is saturated by the channels $\pi^+\,\Upsilon(1S,2S,3S)$, $\pi^+ h_b(1P,2P)$, and $B^{*+}\overline{B}^{*0}$, and using the results from BONDAR 12 and MIZUK 16. Using the mass and width of the $T_{b\bar{b}1}(10650)$ from BONDAR 12.

$\Gamma(B^{*+}\overline{B}^{*0})/\left[\Gamma(\Upsilon(1S)\pi^+)+\Gamma(\Upsilon(2S)\pi^+)+\Gamma(\Upsilon(3S)\pi^+)+\Gamma(h_b(1P)\pi^+)+\Gamma(h_b(2P)\pi^+)\right]$ $\Gamma_8/(\Gamma_1+\Gamma_2+\Gamma_3+\Gamma_4+\Gamma_5)$

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$2.80^{+0.69+0.54}_{-0.40-0.36}$	161	[1] GARMASH	16	BELL	$e^+e^- \to \pi^- B^{*+}\overline{B}^{*0}$

[1] Combined with the results of BONDAR 12 and MIZUK 16. Not independent from $T_{b\bar{b}1}(10650)$ branching fractions to $\pi^+\,\Upsilon(1S,2S,3S)$, $\pi^+ h_b(1P,2P)$, and $B^{*+}\overline{B}^{*0}$.

$T_{b\bar{b}1}(10650)$ 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.)
BONDAR	12	PRL 108 122001	A. Bondar *et al.*	(BELLE Collab.)