

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

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

I, G, C need confirmation.

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

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

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

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
10652.2 ± 1.5	¹ BONDAR	12	BELL $e^+e^- \rightarrow$ 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 $e^+e^- \rightarrow \Upsilon(1S)\pi^+\pi^-$
$10650.7 \pm 1.5^{+0.5}_{-0.2}$	² GARMASH	15	BELL $e^+e^- \rightarrow \Upsilon(2S)\pi^+\pi^-$
$10651.2 \pm 1.0^{+0.4}_{-0.3}$	² GARMASH	15	BELL $e^+e^- \rightarrow \Upsilon(3S)\pi^+\pi^-$
$10657 \pm 6 \pm 3$	³ BONDAR	12	BELL $e^+e^- \rightarrow \Upsilon(1S)\pi^+\pi^-$
$10651 \pm 2 \pm 3$	³ BONDAR	12	BELL $e^+e^- \rightarrow \Upsilon(2S)\pi^+\pi^-$
$10652 \pm 1 \pm 2$	³ BONDAR	12	BELL $e^+e^- \rightarrow \Upsilon(3S)\pi^+\pi^-$
$10654 \pm 3 \pm 1_{-2}$	³ BONDAR	12	BELL $e^+e^- \rightarrow h_b(1P)\pi^+\pi^-$
$10651 \pm 2_{-3} \pm 3_{-2}$	³ BONDAR	12	BELL $e^+e^- \rightarrow h_b(2P)\pi^+\pi^-$

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³ Superseded by the average measurement of BONDAR 12.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

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

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** $T_{b\bar{b}1}(10650)^-$ decay modes are charge conjugates of the modes below.

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 $h_b(2P)\pi^+$	$(15 \pm 4) \%$
Γ_6 $B^+\bar{B}^0$	not seen
Γ_7 $B^+\bar{B}^{*0} + B^{*+}\bar{B}^0$	not seen
Γ_8 $B^{*+}\bar{B}^{*0}$	$(74^{+4}_{-6}) \%$

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

$\Gamma(\Upsilon(1S)\pi^+)/\Gamma_{\text{total}}$				Γ_1/Γ
VALUE (units 10^{-3})	DOCUMENT ID	TECN	COMMENT	

$1.7^{+0.7+0.3}_{-0.6-0.2}$	¹ GARMASH	16	BELL	$e^+e^- \rightarrow \pi^- B^{*+}\bar{B}^{*0}$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

seen	GARMASH	15	BELL	$e^+e^- \rightarrow \Upsilon(1S)\pi^+\pi^-$
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seen	BONDAR	12	BELL	$e^+e^- \rightarrow \Upsilon(1S)\pi^+\pi^-$
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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 $B^{*+}\bar{B}^{*0}$, 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	

$1.39^{+0.48+0.34}_{-0.38-0.23}$	¹ GARMASH	16		$e^+e^- \rightarrow \pi^- B^{*+}\bar{B}^{*0}$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

seen	GARMASH	15	BELL	$e^+e^- \rightarrow \Upsilon(2S)\pi^+\pi^-$
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seen	BONDAR	12	BELL	$e^+e^- \rightarrow \Upsilon(2S)\pi^+\pi^-$
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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 $B^{*+}\bar{B}^{*0}$, and using the results from BONDAR 12 and MIZUK 16.

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

<u>VALUE (units 10^{-2})</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$1.63^{+0.53+0.39}_{-0.42-0.28}$	¹ GARMASH	16	BELL $e^+e^- \rightarrow \pi^- B^{*+} \bar{B}^{*0}$

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

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

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 $B^{*+}\bar{B}^{*0}$, and using the results from BONDAR 12 and MIZUK 16.

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

<u>VALUE (units 10^{-2})</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$8.41^{+2.43+1.49}_{-2.12-1.06}$	¹ GARMASH	16	BELL $e^+e^- \rightarrow \pi^- B^{*+} \bar{B}^{*0}$

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

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

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 $B^{*+}\bar{B}^{*0}$, 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

<u>VALUE (units 10^{-2})</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$14.7^{+3.2+2.8}_{-2.8-2.3}$	¹ GARMASH	16	BELL $e^+e^- \rightarrow \pi^- B^{*+} \bar{B}^{*0}$

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

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

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 $B^{*+}\bar{B}^{*0}$, 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 $\Upsilon(10860)$.

 $\Gamma(B^+\bar{B}^0)/\Gamma_{\text{total}}$ Γ_6/Γ

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
not seen	GARMASH	16	BELL $e^+e^- \rightarrow \pi^- B^+ \bar{B}^0$

 $[\Gamma(B^+\bar{B}^{*0}) + \Gamma(B^{*+}\bar{B}^0)]/\Gamma_{\text{total}}$ Γ_7/Γ

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
not seen	GARMASH	16	BELL $e^+e^- \rightarrow \pi^- B^+ \bar{B}^{*0}, \pi^- \bar{B}^0 B^{*+}$

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

<u>VALUE (units 10^{-2})</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$73.7^{+3.4+2.7}_{-4.4-3.5}$	161	¹ GARMASH	16	BELL $e^+e^- \rightarrow \pi^- B^{*+} \bar{B}^{*0}$

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 $B^{*+} \bar{B}^{*0}$, 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.

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

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
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• • • 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	BELLE $e^+ e^- \rightarrow \pi^- B^{*+} \bar{B}^{*0}$
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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 $B^{*+} \bar{B}^{*0}$.

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

GARMASH	16	PRL 116 212001	A. Garmash <i>et al.</i>	(BELLE Collab.)
MIZUK	16	PRL 117 142001	R. Mizuk <i>et al.</i>	(BELLE Collab.)
GARMASH	15	PR D91 072003	A. Garmash <i>et al.</i>	(BELLE Collab.)
BONDAR	12	PRL 108 122001	A. Bondar <i>et al.</i>	(BELLE Collab.)