

$T_{bb1}^-(10610)$

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

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

NODE=M207

NODE=M207

$T_{bb1}^-(10610)^\pm$ MASS

NODE=M207M

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
10607.2$\pm$2.0	¹ BONDAR 12	BELL	$e^+e^- \rightarrow \text{hadrons}$
• • • 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	$e^+e^- \rightarrow \Upsilon(1S)\pi^+\pi^-$
10608.1 $\pm$ 1.2 $^{+1.5}_{-0.2}$	² GARMASH 15	BELL	$e^+e^- \rightarrow \Upsilon(2S)\pi^+\pi^-$
10607.4 $\pm$ 1.5 $^{+0.8}_{-0.2}$	² GARMASH 15	BELL	$e^+e^- \rightarrow \Upsilon(3S)\pi^+\pi^-$
10611 $\pm$ 4 $\pm$ 3	³ BONDAR 12	BELL	$e^+e^- \rightarrow \Upsilon(1S)\pi^+\pi^-$
10609 $\pm$ 2 $\pm$ 3	³ BONDAR 12	BELL	$e^+e^- \rightarrow \Upsilon(2S)\pi^+\pi^-$
10608 $\pm$ 2 $\pm$ 3	³ BONDAR 12	BELL	$e^+e^- \rightarrow \Upsilon(3S)\pi^+\pi^-$
10605 $\pm$ 2 $^{+3}_{-1}$	³ BONDAR 12	BELL	$e^+e^- \rightarrow h_b(1P)\pi^+\pi^-$
10599 $^{+6}_{-3}$ $^{+5}_{-4}$	³ BONDAR 12	BELL	$e^+e^- \rightarrow h_b(2P)\pi^+\pi^-$

NODE=M207M

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³ Superseded by the average measurement of BONDAR 12.

$T_{bb1}^-(10610)^0$ MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
10609$\pm$4$\pm$4	¹ KROKOVNY 13	BELL	$e^+e^- \rightarrow \Upsilon(2S)/\Upsilon(3S)\pi^0\pi^0$
¹ From a simultaneous fit to the KROKOVNY 13 Dalitz analysis of $e^+e^- \rightarrow \Upsilon(2S)/\Upsilon(3S)\pi^0\pi^0$ decays with fixed width $\Gamma(T_{bb1}^-(10610)^0) = 18.4$ MeV.			

NODE=M207M;LINKAGE=BO

NODE=M207M;LINKAGE=A

NODE=M207M;LINKAGE=BN

NODE=M207M0

NODE=M207M0

NODE=M207M0;LINKAGE=A

$T_{bb1}^-(10610)^\pm$ WIDTH

NODE=M207W

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
18.4$\pm$ 2.4	¹ BONDAR 12	BELL	$e^+e^- \rightarrow \text{hadrons}$
• • • 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	$e^+e^- \rightarrow \Upsilon(1S)\pi^+\pi^-$
20.8 $\pm$ 2.5 $^{+0.3}_{-2.1}$	² GARMASH 15	BELL	$e^+e^- \rightarrow \Upsilon(2S)\pi^+\pi^-$
18.7 $\pm$ 3.4 $^{+2.5}_{-1.3}$	² GARMASH 15	BELL	$e^+e^- \rightarrow \Upsilon(3S)\pi^+\pi^-$
22.3 $\pm$ 7.7 $^{+3.0}_{-4.0}$	³ BONDAR 12	BELL	$e^+e^- \rightarrow \Upsilon(1S)\pi^+\pi^-$
24.2 $\pm$ 3.1 $^{+2.0}_{-3.0}$	³ BONDAR 12	BELL	$e^+e^- \rightarrow \Upsilon(2S)\pi^+\pi^-$
17.6 $\pm$ 3.0 $\pm$ 3.0	³ BONDAR 12	BELL	$e^+e^- \rightarrow \Upsilon(3S)\pi^+\pi^-$
11.4 $^{+4.5}_{-3.9}$ $^{+2.1}_{-1.2}$	³ BONDAR 12	BELL	$e^+e^- \rightarrow h_b(1P)\pi^+\pi^-$
13 $^{+10}_{-8}$ $^{+9}_{-7}$	³ BONDAR 12	BELL	$e^+e^- \rightarrow h_b(2P)\pi^+\pi^-$

NODE=M207W

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.

NODE=M207W;LINKAGE=BO

NODE=M207W;LINKAGE=A

NODE=M207W;LINKAGE=BN

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

NODE=M207215;NODE=M207

Mode	Fraction (Γ_i/Γ)
$\Gamma_1 \quad \Upsilon(1S)\pi^+$	$(5.4^{+1.9}_{-1.5}) \times 10^{-3}$
$\Gamma_2 \quad \Upsilon(1S)\pi^0$	not seen
$\Gamma_3 \quad \Upsilon(2S)\pi^+$	$(3.6^{+1.1}_{-0.8}) \%$
$\Gamma_4 \quad \Upsilon(2S)\pi^0$	seen
$\Gamma_5 \quad \Upsilon(3S)\pi^+$	$(2.1^{+0.8}_{-0.6}) \%$
$\Gamma_6 \quad \Upsilon(3S)\pi^0$	seen
$\Gamma_7 \quad h_b(1P)\pi^+$	$(3.5^{+1.2}_{-0.9}) \%$
$\Gamma_8 \quad h_b(2P)\pi^+$	$(4.7^{+1.7}_{-1.3}) \%$
$\Gamma_9 \quad B^+\bar{B}^0$	not seen
$\Gamma_{10} \quad B^+\bar{B}^{*0} + B^{*+}\bar{B}^0$	$(85.6^{+2.1}_{-2.9}) \%$

DESIG=1

DESIG=9

DESIG=2

DESIG=10

DESIG=3

DESIG=11

DESIG=4

DESIG=5

DESIG=8

DESIG=6

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

NODE=M207225

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

VALUE (units 10^{-3})	DOCUMENT ID	TECN	COMMENT
$5.4^{+1.6+1.1}_{-1.3-0.8}$	¹ GARMASH 16	BELL	$e^+e^- \rightarrow \pi^- B^+ \bar{B}^{*0}, \pi^- \bar{B}^0 B^{*+}$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
seen	GARMASH 15	BELL	$e^+e^- \rightarrow \Upsilon(1S)\pi^+\pi^-$
seen	BONDAR 12	BELL	$e^+e^- \rightarrow \Upsilon(1S)\pi^+\pi^-$

NODE=M207R01
NODE=M207R01

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

NODE=M207R01;LINKAGE=A

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

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

NODE=M207R09
NODE=M207R09 **$\Gamma(\Upsilon(2S)\pi^+)/\Gamma_{\text{total}}$** **$\Gamma_3/\Gamma$**

VALUE (units 10^{-2})	DOCUMENT ID	TECN	COMMENT
$3.62^{+0.76+0.79}_{-0.59-0.53}$	¹ GARMASH 16	BELL	$e^+e^- \rightarrow \pi^- B^+ \bar{B}^{*0}, \pi^- \bar{B}^0 B^{*+}$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
seen	GARMASH 15	BELL	$e^+e^- \rightarrow \Upsilon(2S)\pi^+\pi^-$
seen	BONDAR 12	BELL	$e^+e^- \rightarrow \Upsilon(2S)\pi^+\pi^-$

NODE=M207R02
NODE=M207R02

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

NODE=M207R02;LINKAGE=A

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

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

NODE=M207R10
NODE=M207R10

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

NODE=M207R10;LINKAGE=A

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

NODE=M207R03
NODE=M207R03

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

NODE=M207R03;LINKAGE=A

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

VALUE	DOCUMENT ID	TECN	COMMENT
seen	¹ KROKOVNY 13	BELL	$e^+e^- \rightarrow \Upsilon(3S)\pi^0\pi^0$
¹ Combined significance in $e^+e^- \rightarrow \Upsilon(2S)/\Upsilon(3S)\pi^0\pi^0$, including systematics, of 6.5σ .			

NODE=M207R11
 NODE=M207R11

NODE=M207R11;LINKAGE=A

 $\Gamma(h_b(1P)\pi^+)/\Gamma_{\text{total}}$ 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	$e^+e^- \rightarrow \pi^- B^+ \bar{B}^{*0}, \pi^- \bar{B}^0 B^{*+}$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
possibly seen	² MIZUK 16	BELL	$e^+e^- \rightarrow h_b(1P)\pi^+\pi^-$
seen	³ BONDAR 12	BELL	$e^+e^- \rightarrow h_b(1P)\pi^+\pi^-$

NODE=M207R04
 NODE=M207R04

NODE=M207R04;LINKAGE=C

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

NODE=M207R04;LINKAGE=A

NODE=M207R04;LINKAGE=B

 $\Gamma(h_b(2P)\pi^+)/\Gamma_{\text{total}}$ 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	$e^+e^- \rightarrow \pi^- B^+ \bar{B}^{*0}, \pi^- \bar{B}^0 B^{*+}$
• • • 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	$e^+e^- \rightarrow h_b(2P)\pi^+\pi^-$

NODE=M207R05
 NODE=M207R05

NODE=M207R05;LINKAGE=C

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

NODE=M207R05;LINKAGE=A

NODE=M207R05;LINKAGE=B

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

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

NODE=M207R08
 NODE=M207R08

 $[\Gamma(B^+ \bar{B}^{*0}) + \Gamma(B^{*+} \bar{B}^0)]/\Gamma_{\text{total}}$ 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	$e^+e^- \rightarrow \pi^- B^+ \bar{B}^{*0}, \pi^- B^{*+} \bar{B}^0$

NODE=M207R00
 NODE=M207R00

NODE=M207R00;LINKAGE=A

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 $B^+ \bar{B}^{*0} + B^{*+} \bar{B}^0$, and using the results from BONDAR 12 and MIZUK 16. Using the mass and width of the $T_{b\bar{b}1}(10610)$ from BONDAR 12.

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

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. • • •

$5.93^{+0.99+1.01}_{-0.69-0.73}$	357	¹ GARMASH 16	BELL	$e^+e^- \rightarrow \pi^- B^+ \bar{B}^{*0}, \pi^- \bar{B}^0 B^{*+}$
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NODE=M207R07
 NODE=M207R07

NODE=M207R07;LINKAGE=A

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

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

NODE=M207

GARMASH 16	PRL 116 212001	A. Garmash <i>et al.</i>	(BELLE Collab.)	REFID=57446
MIZUK 16	PRL 117 142001	R. Mizuk <i>et al.</i>	(BELLE Collab.)	REFID=57465
GARMASH 15	PR D91 072003	A. Garmash <i>et al.</i>	(BELLE Collab.)	REFID=56811
KROKOVNY 13	PR D88 052016	P. Krokovny <i>et al.</i>	(BELLE Collab.)	REFID=55588
BONDAR 12	PRL 108 122001	A. Bondar <i>et al.</i>	(BELLE Collab.)	REFID=53963