

$T_{c\bar{c}}(4020)$

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

was  $X(4020)$

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

Charged  $T_{c\bar{c}}(4020)$  seen by ABLIKIM 13X from  $e^+e^- \rightarrow \pi^+\pi^-h_c(1P)$  at c.m. energy from 3.90 to 4.42 GeV as a peak in the invariant mass distribution of the  $\pi^\pm h_c(1P)$  system, and by ABLIKIM 14B from  $e^+e^- \rightarrow (D^*\bar{D}^*)^\pm\pi^\mp$  events in  $(D^*\bar{D}^*)^\pm$  mass. A neutral  $T_{c\bar{c}}(4020)$  seen by ABLIKIM 14P at three c.m. energies in the same range in  $e^+e^- \rightarrow \pi^0\pi^0h_c(1P)$  as a peak in the larger of the two masses recoiling against a  $\pi^0$ . ABLIKIM 15AA observes a  $5.9\sigma$  signal in  $(D^*\bar{D}^*)^0$  in  $e^+e^- \rightarrow (D^*\bar{D}^*)^0\pi^0$  events using collisions at two c.m. energies. Production rates and mass values support grouping neutral and charged  $T_{c\bar{c}}(4020)$  together as manifestations of a single  $I = 1$  particle.

### $T_{c\bar{c}}(4020)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>4024.1 ± 1.9 OUR AVERAGE</b>					
4025.5 <sup>+2.0</sup> <sub>-4.7</sub> ± 3.1	116	<sup>1</sup> ABLIKIM 15AA	BES3	0	$e^+e^- \rightarrow (D^*\bar{D}^*)^0\pi^0$
4026.3 ± 2.6 ± 3.7	401	<sup>1</sup> ABLIKIM 14B	BES3	±	$e^+e^- \rightarrow (D^*\bar{D}^*)^\pm\pi^\mp$
4023.9 ± 2.2 ± 3.8	61	<sup>1,2</sup> ABLIKIM 14P	BES3	0	$e^+e^- \rightarrow \pi^0\pi^0h_c$
4022.9 ± 0.8 ± 2.7	253	<sup>1</sup> ABLIKIM 13X	BES3	±	$e^+e^- \rightarrow \pi^+\pi^-h_c$

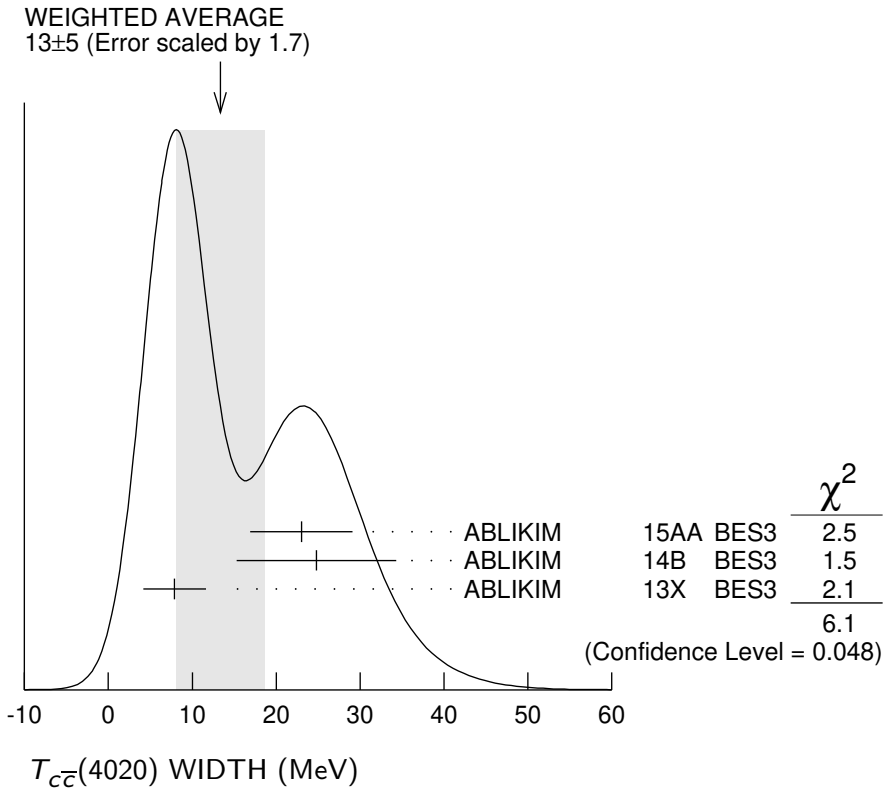
<sup>1</sup> Neglecting interference between the  $T_{c\bar{c}}(4020)$  and non-resonant continuum.

<sup>2</sup> Assuming  $J^P = 1^+$  and width of  $7.9 \pm 2.6$  MeV.

### $T_{c\bar{c}}(4020)$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>13 ± 5 OUR AVERAGE</b>					
Error includes scale factor of 1.7. See the ideogram below.					
23.0 ± 6.0 ± 1.0	116	<sup>1</sup> ABLIKIM 15AA	BES3	0	$e^+e^- \rightarrow (D^*\bar{D}^*)^0\pi^0$
24.8 ± 5.6 ± 7.7	401	<sup>1</sup> ABLIKIM 14B	BES3	±	$e^+e^- \rightarrow (D^*\bar{D}^*)^\pm\pi^\mp$
7.9 ± 2.7 ± 2.6	253	<sup>1</sup> ABLIKIM 13X	BES3	±	$e^+e^- \rightarrow \pi^+\pi^-h_c$

<sup>1</sup> Neglecting interference between the  $T_{c\bar{c}}(4020)$  and non-resonant continuum.



### $T_{c\bar{c}}(4020)$ DECAY MODES

Mode	Fraction ( $\Gamma_i/\Gamma$ )
$\Gamma_1$ $h_c(1P)\pi$	seen
$\Gamma_2$ $D^*\bar{D}^*$	seen
$\Gamma_3$ $D\bar{D}^* + \text{c.c.}$	not seen
$\Gamma_4$ $\eta_c \pi^+ \pi^-$	not seen
$\Gamma_5$ $\eta_c(1S)\rho(770)^\pm$	
$\Gamma_6$ $J/\psi(1S)\pi^\pm$	not seen

### $T_{c\bar{c}}(4020)$ BRANCHING RATIOS

$\Gamma(h_c(1P)\pi)/\Gamma_{\text{total}}$						$\Gamma_1/\Gamma$
VALUE	EVTS	DOCUMENT ID	TECN	CHG	COMMENT	
seen	61	ABLIKIM 14P	BES3	0	$e^+e^- \rightarrow \pi^0\pi^0 h_c$	
seen	253	ABLIKIM 13X	BES3	$\pm$	$e^+e^- \rightarrow \pi^+\pi^- h_c$	

$\Gamma(D^*\bar{D}^*)/\Gamma_{\text{total}}$						$\Gamma_2/\Gamma$
VALUE	EVTS	DOCUMENT ID	TECN	CHG	COMMENT	
seen	116	<sup>1</sup> ABLIKIM 15AA	BES3	0	$e^+e^- \rightarrow (D^*\bar{D}^*)^0 \pi^0$	
seen	401	<sup>1</sup> ABLIKIM 14B	BES3	$\pm$	$e^+e^- \rightarrow (D^*\bar{D}^*)^\pm \pi^\mp$	

<sup>1</sup> Neglecting interference between the  $T_{c\bar{c}}(4020)$  and non-resonant continuum.

$\Gamma(D\bar{D}^* + \text{c.c.})/\Gamma_{\text{total}}$   $\Gamma_3/\Gamma$ 

VALUE	DOCUMENT ID	TECN	CHG	COMMENT
<b>not seen</b>	ABLIKIM	15AC	BES3	$\pm$ $e^+e^- \rightarrow \pi^\pm(D\bar{D}^*)^\mp$

 $\Gamma(\eta_c \pi^+ \pi^-)/\Gamma_{\text{total}}$   $\Gamma_4/\Gamma$ 

VALUE	DOCUMENT ID	TECN	COMMENT
<b>not seen</b>	<sup>1</sup> VINOKUROVA 15	BELL	$B^+ \rightarrow K^+ \eta_c \pi^+ \pi^-$

<sup>1</sup> VINOKUROVA 15 reports  $B(B^+ \rightarrow K^+ T_{c\bar{c}}(4020)^0) \times B(T_{c\bar{c}} \rightarrow \eta_c \pi^+ \pi^-) < 1.6 \times 10^{-5}$  at 90% CL.

 $\Gamma(\eta_c(1S)\rho(770)^\pm)/\Gamma(h_c(1P)\pi)$   $\Gamma_5/\Gamma_1$ 

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<b>&lt;1.2</b>	90	<sup>1</sup> ABLIKIM	19BC	BES3 $e^+e^- \rightarrow \pi^+\pi^-\pi^0\eta_c(1S)$

<sup>1</sup> Using  $e^+e^- \rightarrow \pi^\mp(Z_c(4020)^\pm \rightarrow h_c(1P)\pi^\pm)$  cross section at 4.23, 4.26 and 4.36 GeV from ABLIKIM 13X.

 $\Gamma(J/\psi(1S)\pi^\pm)/\Gamma_{\text{total}}$   $\Gamma_6/\Gamma$ 

VALUE	DOCUMENT ID	TECN	COMMENT
<b>not seen</b>	<sup>1</sup> ABLIKIM	17J	BES3 $e^+e^- \rightarrow \pi^+\pi^-J/\psi$

<sup>1</sup> From Partial Wave Analysis assuming  $J^P = 1^+$ .

 **$T_{c\bar{c}}(4020)$  REFERENCES**

ABLIKIM	19BC	PR D100 111102	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	17J	PRL 119 072001	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	15AA	PRL 115 182002	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	15AC	PR D92 092006	M. Ablikim <i>et al.</i>	(BESIII Collab.)
VINOKUROVA	15	JHEP 1506 132	A. Vinokurova <i>et al.</i>	(BELLE Collab.)
Also		JHEP 1702 088 (errata.)	A. Vinokurova <i>et al.</i>	(BELLE Collab.)
ABLIKIM	14B	PRL 112 132001	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	14P	PRL 113 212002	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	13X	PRL 111 242001	M. Ablikim <i>et al.</i>	(BESIII Collab.)