

**$D_1(2420)$** 

$$I(J^P) = \frac{1}{2}(1^+)$$

 **$D_1(2420)$  MASS**

The fit includes  $D^\pm$ ,  $D^0$ ,  $D_s^\pm$ ,  $D^{*\pm}$ ,  $D^{*0}$ ,  $D_s^{*\pm}$ ,  $D_1(2420)^0$ ,  $D_2^*(2460)^0$ , and  $D_{s1}(2536)^\pm$  mass and mass difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>2422.1±0.6 OUR FIT</b>		Error includes scale factor of 1.7.			
<b>2422.1±0.8 OUR AVERAGE</b>		Error includes scale factor of 2.1. See the ideogram below.			
2424.8±0.1±0.7	79k	<sup>1</sup> AAIJ	20D LHCb	0	$B^- \rightarrow D^{*+} \pi^- \pi^-$
2427.2±1.0±1.2	4207	ABLIKIM	20P BES3	+	$e^+ e^- \rightarrow D^+ D^- \pi^+ \pi^-$
2419.6±0.1±0.7	210k	AAIJ	13CC LHCb	0	$p p \rightarrow D^{*+} \pi^- X$
2423.1±1.5 <sup>+0.4</sup> <sub>-1.0</sub>	2.7k	<sup>2</sup> ABRAMOWICZ13	ZEUS	0	$e^\pm p \rightarrow D^{(*)+} \pi^- X$
2421.9±4.7 <sup>+3.4</sup> <sub>-1.2</sub>	759	<sup>3</sup> ABRAMOWICZ13	ZEUS	+	$e^\pm p \rightarrow D^{(*)0} \pi^+ X$
2420.1±0.1±0.8	103k	DEL-AMO-SA..10P	BABR	0	$e^+ e^- \rightarrow D^{*+} \pi^- X$
2426 ±3 ±1	151	ABE	05A BELL	0	$B^- \rightarrow D^0 \pi^+ \pi^- \pi^-$
2421 ±2 ±1	124	ABE	05A BELL	+	$\bar{B}^0 \rightarrow D^+ \pi^+ \pi^- \pi^-$
2421.4±1.5±0.9		<sup>4</sup> ABE	04D BELL	0	$B^- \rightarrow D^{*+} \pi^- \pi^-$
2421 <sup>+1</sup> <sub>-2</sub> ±2	286	AVERY	94C CLE2	0	$e^+ e^- \rightarrow D^{*+} \pi^- X$
2425 ±2 ±2	146	BERGFELD	94B CLE2	+	$e^+ e^- \rightarrow D^{*0} \pi^+ X$
2422 ±2 ±2	51	FRABETTI	94B E687	0	$\gamma Be \rightarrow D^{*+} \pi^- X$
2428 ±3 ±2	279	AVERY	90 CLEO	0	$e^+ e^- \rightarrow D^{*+} \pi^- X$
2414 ±2 ±5	171	ALBRECHT	89H ARG	0	$e^+ e^- \rightarrow D^{*+} \pi^- X$
2428 ±8 ±5	171	ANJOS	89C TPS	0	$\gamma N \rightarrow D^{*+} \pi^- X$
2443 ±7 ±5	190	ANJOS	89C TPS	+	$\gamma N \rightarrow D^0 \pi^+ X^0$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
2420.5±2.1±0.9	3.1k	<sup>5</sup> CHEKANOV	09 ZEUS	0	$e^\pm p \rightarrow D^{*+} \pi^- X$
2421.7±0.7±0.6	7.5k	ABULENCIA	06A CDF	0	$1900 p \bar{p} \rightarrow D^{*+} \pi^- X$
2425 ±3	235	<sup>6</sup> ABREU	98M DLPH	0	$e^+ e^- \rightarrow D^{*+} \pi^- X$

<sup>1</sup> From a full four-body amplitude analysis of the  $B^- \rightarrow D^{*+} \pi^- \pi^-$  decay.

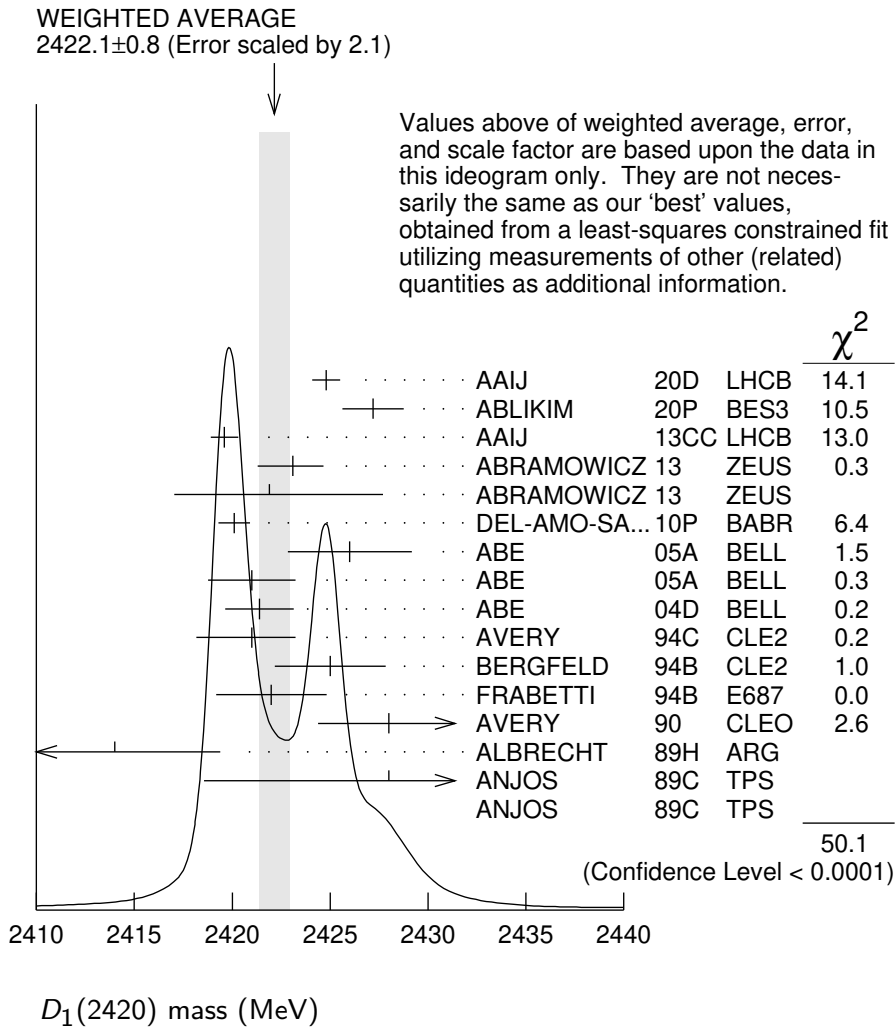
<sup>2</sup> From the combined fit of the  $M(D^+ \pi^-)$  and  $M(D^{*+} \pi^-)$  distributions. and  $A_{D_2}$  fixed to the theoretical prediction of  $-1$ .

<sup>3</sup> From the fit of the  $M(D^0 \pi^+)$  distribution. The widths of the  $D_1^+$  and  $D_2^{*+}$  are fixed to 25 MeV and 37 MeV, and  $A_{D_1}$  and  $A_{D_2}$  are fixed to the theoretical predictions of 3 and  $-1$ , respectively.

<sup>4</sup> Fit includes the contribution from  $D_1^*(2430)^0$ .

<sup>5</sup> Calculated using the mass difference  $m(D_1^0) - m(D^{*+})_{PDG}$  reported below and  $m(D^{*+})_{PDG} = 2010.27 \pm 0.17$  MeV. The 0.17 MeV uncertainty of the PDG mass value should be added to the experimental uncertainty of 0.9 MeV.

<sup>6</sup> No systematic error given.



**$m_{D_1(2420)^0} - m_{D^{*+}}$**

The fit includes  $D^\pm, D^0, D_s^\pm, D^{*\pm}, D^{*0}, D_s^{*\pm}, D_1(2420)^0, D_2^*(2460)^0,$  and  $D_{s1}(2536)^\pm$  mass and mass difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
<b>411.8±0.6 OUR FIT</b>	Error includes scale factor of 1.7.			
<b>411.5±0.8 OUR AVERAGE</b>				
410.2±2.1±0.9	3.1k	CHEKANOV 09	ZEUS	$e^\pm p \rightarrow D^{*+} \pi^- X$
411.7±0.7±0.4	7.5k	ABULENCIA 06A	CDF	1900 $p\bar{p} \rightarrow D^{*+} \pi^- X$

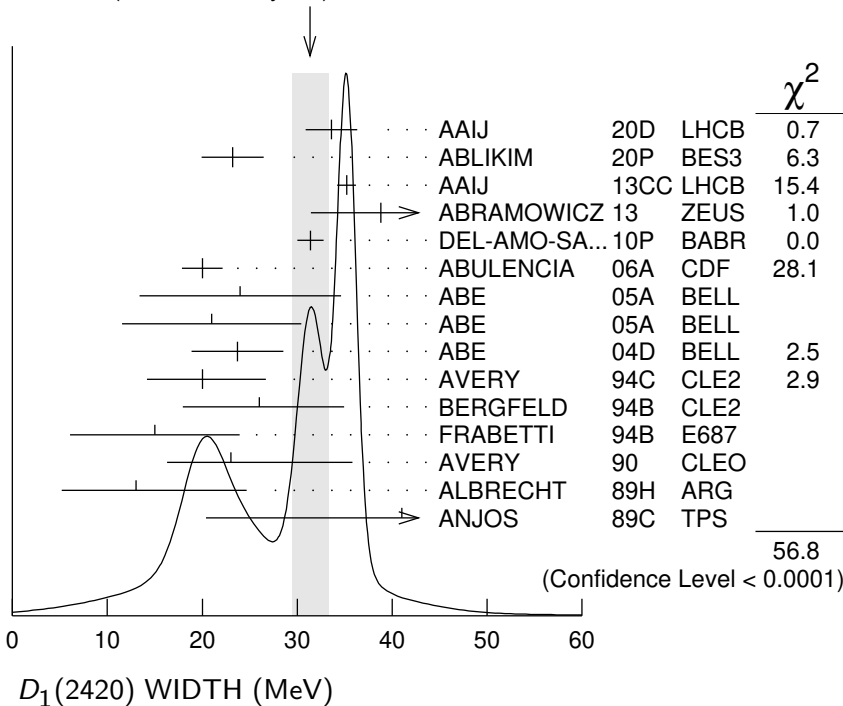
**$m_{D_1(2420)^\pm} - m_{D_1(2420)^0}$**

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b><math>4^{+2}_{-3} \pm 3</math></b>	BERGFELD 94B	CLE2	$e^+ e^- \rightarrow \text{hadrons}$

## $D_1(2420)$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>31.3 ± 1.9 OUR AVERAGE</b>		Error includes scale factor of 2.8. See the ideogram below.			
33.6 ± 0.3 ± 2.7	79k	<sup>1</sup> AAIJ	20D	LHCB	0 $B^- \rightarrow D^{*+} \pi^- \pi^-$
23.2 ± 2.3 ± 2.3	4207	ABLIKIM	20P	BES3	+ $e^+ e^- \rightarrow D^+ D^- \pi^+ \pi^-$
35.2 ± 0.4 ± 0.9	210k	AAIJ	13CC	LHCB	0 $pp \rightarrow D^{*+} \pi^- X$
38.8 ± 5.0 <sup>+</sup> <sub>-5.4</sub>	2.7k	<sup>2</sup> ABRAMOWICZ13	ZEUS	0	$e^\pm p \rightarrow D^{(*)+} \pi^- X$
31.4 ± 0.5 ± 1.3	103k	DEL-AMO-SA...10P	BABR	0	$e^+ e^- \rightarrow D^{*+} \pi^- X$
20.0 ± 1.7 ± 1.3	7.5k	ABULENCIA	06A	CDF	0 $1900 p\bar{p} \rightarrow D^{*+} \pi^- X$
24 ± 7 ± 8	151	ABE	05A	BELL	0 $B^- \rightarrow D^0 \pi^+ \pi^- \pi^-$
21 ± 5 ± 8	124	ABE	05A	BELL	+ $\bar{B}^0 \rightarrow D^+ \pi^+ \pi^- \pi^-$
23.7 ± 2.7 ± 4.0		<sup>3</sup> ABE	04D	BELL	0 $B^- \rightarrow D^{*+} \pi^- \pi^-$
20 <sup>+</sup> <sub>-5</sub> ± 6 ± 3	286	AVERY	94C	CLE2	0 $e^+ e^- \rightarrow D^{*+} \pi^- X$
26 <sup>+</sup> <sub>-7</sub> ± 8 ± 4	146	BERGFELD	94B	CLE2	+ $e^+ e^- \rightarrow D^{*0} \pi^+ X$
15 ± 8 ± 4	51	FRABETTI	94B	E687	0 $\gamma Be \rightarrow D^{*+} \pi^- X$
23 <sup>+</sup> <sub>-6</sub> ± 8 ± 10	279	AVERY	90	CLEO	0 $e^+ e^- \rightarrow D^{*+} \pi^- X$
13 ± 6 ± 10	171	ALBRECHT	89H	ARG	0 $e^+ e^- \rightarrow D^{*+} \pi^- X$
41 ± 19 ± 8	190	ANJOS	89C	TPS	+ $\gamma N \rightarrow D^0 \pi^+ X^0$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
53.2 ± 7.2 <sup>+</sup> <sub>-4.9</sub>	3.1k	CHEKANOV	09	ZEUS	0 $e^\pm p \rightarrow D^{*+} \pi^- X$
58 ± 14 ± 10	171	ANJOS	89C	TPS	0 $\gamma N \rightarrow D^{*+} \pi^- X$

WEIGHTED AVERAGE  
31.3 ± 1.9 (Error scaled by 2.8)



<sup>1</sup> From a full four-body amplitude analysis of the  $B^- \rightarrow D^{*+} \pi^- \pi^-$  decay.

<sup>2</sup> From the combined fit of the  $M(D^+ \pi^-)$  and  $M(D^{*+} \pi^-)$  distributions. and  $A_{D_2}$  fixed to the theoretical prediction of  $-1$ .

<sup>3</sup> Fit includes the contribution from  $D_1^*(2430)^0$ .

## $D_1(2420)$ DECAY MODES

$\bar{D}_1(2420)$  modes are charge conjugates of modes below.

Mode	Fraction ( $\Gamma_i/\Gamma$ )
$\Gamma_1$ $D^*(2007)^0 \pi$	seen
$\Gamma_2$ $D \pi^+ \pi^-$	
$\Gamma_3$ $D \rho^0$	
$\Gamma_4$ $D f_0(500)$	
$\Gamma_5$ $D_0^*(2300)^0 \pi$	
$\Gamma_6$ $D^0 \pi$	
$\Gamma_7$ $D^* \pi^+ \pi^-$	

## $D_1(2420)$ BRANCHING RATIOS

$\Gamma(D^*(2007)^0 \pi)/\Gamma_{\text{total}}$	$\Gamma_1/\Gamma$
<u>VALUE</u>	<u>DOCUMENT ID</u> <u>TECN</u> <u>CHG</u> <u>COMMENT</u>
seen	ACKERSTAFF 97W OPAL 0 $e^+ e^- \rightarrow D^{*+} \pi^- X$
seen	AVERY 90 CLEO 0 $e^+ e^- \rightarrow D^{*+} \pi^- X$
seen	ALBRECHT 89H ARG 0 $e^+ e^- \rightarrow D^* \pi^- X$
<b>seen</b>	ANJOS 89C TPS 0 $\gamma N \rightarrow D^{*+} \pi^- X$
<b>seen</b>	ANJOS 89C TPS + $\gamma N \rightarrow D^0 \pi^+ X^0$

$\Gamma(D^0 \pi)/\Gamma(D^*(2007)^0 \pi)$	$\Gamma_6/\Gamma_1$
<u>VALUE</u>	<u>CL%</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>CHG</u> <u>COMMENT</u>
<b>&lt;0.18</b>	90 BERGFELD 94B CLE2 + $e^+ e^- \rightarrow \text{hadrons}$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●	
<0.24	90 AVERY 90 CLEO 0 $e^+ e^- \rightarrow D^+ \pi^- X$

## $D_1(2420)$ POLARIZATION AMPLITUDE $A_{D_1}$

A polarization amplitude  $A_{D_1}$  is a parameter that depends on the initial polarization of the  $D_1$  and is sensitive to a possible  $S$ -wave contribution to its decay. For  $D_1$  decays the helicity angle,  $\theta_h$ , distribution varies like  $1 + A_{D_1} \cos^2 \theta_h$ , where  $\theta_h$  is the angle in the  $D^*$  rest frame between the two pions emitted by the  $D_1 \rightarrow D^* \pi$  and the  $D^* \rightarrow D \pi$ .

Unpolarized  $D_1$  decaying purely via  $D$ -wave is predicted to give  $A_{D_1} = 3$ .

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b><math>5.73 \pm 0.25</math> OUR AVERAGE</b>					
7.8 $^{+6.7}_{-2.7}$ $^{+4.6}_{-1.8}$	2.7k	<sup>1</sup> ABRAMOWICZ13	ZEUS	0	$e^\pm p \rightarrow D^{(*)+} \pi^- X$
$5.72 \pm 0.25$	103k	DEL-AMO-SA..10P	BABR	0	$e^+ e^- \rightarrow D^{*+} \pi^- X$

5.9	$\begin{matrix} +3.0 & +2.4 \\ -1.7 & -1.0 \end{matrix}$	CHEKANOV	09	ZEUS	0	$e^\pm p \rightarrow D^{*+} \pi^- X$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
3.30	$\pm 0.48$	210k	<sup>2</sup> AAIJ	13CC	LHCB	0 $pp \rightarrow D^{*+} \pi^- X$
3.8	$\pm 0.6 \pm 0.8$		<sup>3</sup> AUBERT	09Y	BABR	0 $B^+ \rightarrow D_1^0 \ell^+ \nu_\ell$
3.8	$\pm 0.6 \pm 0.8$		<sup>3</sup> AUBERT	09Y	BABR	+ $B^0 \rightarrow D_1^- \ell^+ \nu_\ell$
2.74	$\begin{matrix} +1.40 \\ -0.93 \end{matrix}$		<sup>4</sup> AVERY	94C	CLE2	0 $e^+ e^- \rightarrow D^{*+} \pi^- X$

<sup>1</sup> From the combined fit of the  $M(D^+ \pi^-)$  and  $M(D^{*+} \pi^-)$  distributions. and  $A_{D_2}$  fixed to the theoretical prediction of  $-1$ . A pure  $D$ -wave not excluded although some  $S$ -wave mixing possible.

<sup>2</sup> Systematic uncertainty not estimated. Resonance parameters fixed.

<sup>3</sup> Assuming  $\Gamma(\Upsilon(4S) \rightarrow B^+ B^-) / \Gamma(\Upsilon(4S) \rightarrow B^0 \bar{B}^0) = 1.065 \pm 0.026$  and equal partial widths and helicity angle distributions for charged and neutral  $D_1$  mesons.

<sup>4</sup> Systematic uncertainties not estimated.

## **$D_1(2420)$ REFERENCES**

AAIJ	20D	PR D101 032005	R. Aaij <i>et al.</i>	(LHCb Collab.)
ABLIKIM	20P	PL B804 135395	M. Ablikim <i>et al.</i>	(BESIII Collab.)
AAIJ	13CC	JHEP 1309 145	R. Aaij <i>et al.</i>	(LHCb Collab.)
ABRAMOWICZ	13	NP B866 229	H. Abramowicz <i>et al.</i>	(ZEUS Collab.)
DEL-AMO-SA...	10P	PR D82 111101	P. del Amo Sanchez <i>et al.</i>	(BABAR Collab.)
AUBERT	09Y	PRL 103 051803	B. Aubert <i>et al.</i>	(BABAR Collab.)
CHEKANOV	09	EPJ C60 25	S. Chekanov <i>et al.</i>	(ZEUS Collab.)
ABULENCIA	06A	PR D73 051104	A. Abulencia <i>et al.</i>	(CDF Collab.)
ABE	05A	PRL 94 221805	K. Abe <i>et al.</i>	(BELLE Collab.)
ABE	04D	PR D69 112002	K. Abe <i>et al.</i>	(BELLE Collab.)
ABREU	98M	PL B426 231	P. Abreu <i>et al.</i>	(DELPHI Collab.)
ACKERSTAFF	97W	ZPHY C76 425	K. Ackerstaff <i>et al.</i>	(OPAL Collab.)
AVERY	94C	PL B331 236	P. Avery <i>et al.</i>	(CLEO Collab.)
BERGFELD	94B	PL B340 194	T. Bergfeld <i>et al.</i>	(CLEO Collab.)
FRABETTI	94B	PRL 72 324	P.L. Frabetti <i>et al.</i>	(FNAL E687 Collab.)
AVERY	90	PR D41 774	P. Avery, D. Besson	(CLEO Collab.)
ALBRECHT	89H	PL B232 398	H. Albrecht <i>et al.</i>	(ARGUS Collab.) JP
ANJOS	89C	PRL 62 1717	J.C. Anjos <i>et al.</i>	(FNAL E691 Collab.)