# $\pi_2(1670)$

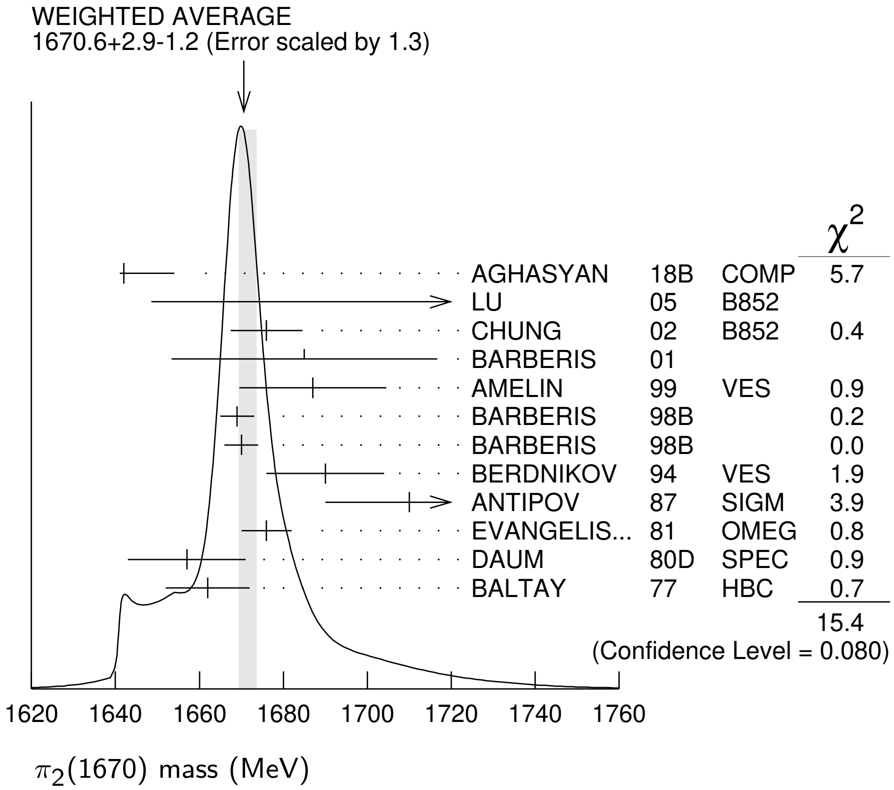
$I^G(J^{PC}) = 1^-(2^{-+})$

## $\pi_2(1670)$ MASS

| VALUE (MeV) | EVTS | DOCUMENT ID | TECN | CHG | COMMENT |
|---|---|---|---|---|---|
| **$1670.6^{+2.9}_{-1.2}$ OUR AVERAGE** | | Error includes scale factor of 1.3. See the ideogram below. | | | |
| $1642\ ^{+12}_{-1}$ | 46M | [1] AGHASYAN 18B | COMP | | 190 $\pi^- p \to \pi^-\pi^+\pi^- p$ |
| $1749 \pm 10 \pm 100$ | 145k | LU 05 | B852 | | 18 $\pi^- p \to \omega\pi^-\pi^0 p$ |
| $1676 \pm 3 \pm 8$ | | [2] CHUNG 02 | B852 | | 18.3 $\pi^- p \to \pi^+\pi^-\pi^- p$ |
| $1685 \pm 10 \pm 30$ | | BARBERIS 01 | | | 450 $pp \to p_f 3\pi^0 p_s$ |
| $1687 \pm 9 \pm 15$ | | AMELIN 99 | VES | | 37 $\pi^- A \to \omega\pi^-\pi^0 A^*$ |
| $1669 \pm 4$ | | BARBERIS 98B | | | 450 $pp \to p_f \rho\pi p_s$ |
| $1670 \pm 4$ | | BARBERIS 98B | | | 450 $pp \to p_f f_2(1270)\pi p_s$ |
| $1690 \pm 14$ | | [3] BERDNIKOV 94 | VES | | 37 $\pi^- A \to K^+K^-\pi^- A$ |
| $1710 \pm 20$ | 700 | ANTIPOV 87 | SIGM | $-$ | 50 $\pi^-$ Cu $\to \mu^+\mu^-\pi^-$ Cu |
| $1676 \pm 6$ | | [3] EVANGELIS... 81 | OMEG | $-$ | 12 $\pi^- p \to 3\pi p$ |
| $1657 \pm 14$ | | [3,4] DAUM 80D | SPEC | $-$ | 63–94 $\pi p \to 3\pi X$ |
| $1662 \pm 10$ | 2000 | [3] BALTAY 77 | HBC | $+$ | 15 $\pi^+ p \to p 3\pi$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $1658 \pm 3\ ^{+24}_{-8}$ | 420k | [5] ALEKSEEV 10 | COMP | | 190 $\pi^- Pb \to \pi^-\pi^-\pi^+ Pb'$ |
| $1730 \pm 20$ | | [6] AMELIN 95B | VES | | 36 $\pi^- A \to \pi^+\pi^-\pi^- A$ |
| $1742 \pm 31 \pm 49$ | | ANTREASYAN 90 | CBAL | | $e^+e^- \to e^+e^-\pi^0\pi^0\pi^0$ |
| $1624 \pm 21$ | | [2] BELLINI 85 | SPEC | | 40 $\pi^- A \to \pi^-\pi^+\pi^- A$ |
| $1622 \pm 35$ | | [7] BELLINI 85 | SPEC | | 40 $\pi^- A \to \pi^-\pi^+\pi^- A$ |
| $1693 \pm 28$ | | [8] BELLINI 85 | SPEC | | 40 $\pi^- A \to \pi^-\pi^+\pi^- A$ |
| $1710 \pm 20$ | | [9] DAUM 81B | SPEC | $-$ | 63,94 $\pi^- p$ |
| $1660 \pm 10$ | | [3] ASCOLI 73 | HBC | $-$ | 5–25 $\pi^- p \to p\pi_2$ |

[1] Statistical error negligible.
[2] From $f_2(1270)\pi$ decay.
[3] From a fit to $J^P = 2^-$ $S$-wave $f_2(1270)\pi$ partial wave.
[4] Clear phase rotation seen in $2^-S$, $2^-P$, $2^-D$ waves. We quote central value and spread of single-resonance fits to three channels.
[5] Superseded by AGHASYAN 2018B.
[6] $J^{PC}$ ambiguous.
[7] From $\rho\pi$ decay.

[8] From $\sigma\pi$ decay.
[9] From a two-resonance fit to four $2^{-}0^{+}$ waves. This should not be averaged with all the single resonance fits.




## $\pi_2(1670)$ WIDTH

| VALUE (MeV) | EVTS | DOCUMENT ID | TECN | CHG | COMMENT |
|---|---|---|---|---|---|
| **$258^{+8}_{-9}$ OUR AVERAGE** | | Error includes scale factor of 1.2. | | | |
| $311^{+12}_{-23}$ | 46M | [10] AGHASYAN | 18B | COMP | | $190\ \pi^- p \to \pi^-\pi^+\pi^- p$ |
| $408\pm 60\pm 250$ | 145k | LU | 05 | B852 | | $18\ \pi^- p \to \omega\pi^-\pi^0 p$ |
| $254\pm 3\pm 31$ | | [11] CHUNG | 02 | B852 | | $18.3\ \pi^- p \to \pi^+\pi^-\pi^- p$ |
| $265\pm 30\pm 40$ | | BARBERIS | 01 | | | $450\ pp \to p_f 3\pi^0 p_s$ |
| $168\pm 43\pm 53$ | | AMELIN | 99 | VES | | $37\ \pi^- A \to \omega\pi^-\pi^0 A^*$ |
| $268\pm 15$ | | BARBERIS | 98B | | | $450\ pp \to p_f \rho\pi p_s$ |
| $256\pm 15$ | | BARBERIS | 98B | | | $450\ pp \to p_f f_2(1270)\pi p_s$ |
| $190\pm 50$ | | [12] BERDNIKOV | 94 | VES | | $37\ \pi^- A \to K^+K^-\pi^- A$ |
| $170\pm 80$ | 700 | ANTIPOV | 87 | SIGM | $-$ | $50\ \pi^- \mathrm{Cu} \to \mu^+\mu^-\pi^- \mathrm{Cu}$ |
| $260\pm 20$ | | [12] EVANGELIS... | 81 | OMEG | $-$ | $12\ \pi^- p \to 3\pi p$ |
| $219\pm 20$ | | [12,13] DAUM | 80D | SPEC | $-$ | 63–94 $\pi p \to 3\pi X$ |
| $285\pm 60$ | 2000 | [12] BALTAY | 77 | HBC | $+$ | $15\ \pi^+ p \to p 3\pi$ |

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

| | | | | | | |
|---|---|---|---|---|---|---|
| $271 \pm 9^{+22}_{-24}$ | 420k | [14] ALEKSEEV | 10 | COMP | | 190 $\pi^- Pb \to \pi^-\pi^-\pi^+ Pb'$ |
| $310 \pm 20$ | | [15] AMELIN | 95B | VES | | 36 $\pi^- A \to \pi^+\pi^-\pi^- A$ |
| $236 \pm 49 \pm 36$ | | ANTREASYAN | 90 | CBAL | | $e^+e^- \to e^+e^-\pi^0\pi^0\pi^0$ |
| $304 \pm 22$ | | [11] BELLINI | 85 | SPEC | | 40 $\pi^- A \to \pi^-\pi^+\pi^- A$ |
| $404 \pm 108$ | | [16] BELLINI | 85 | SPEC | | 40 $\pi^- A \to \pi^-\pi^+\pi^- A$ |
| $330 \pm 90$ | | [17] BELLINI | 85 | SPEC | | 40 $\pi^- A \to \pi^-\pi^+\pi^- A$ |
| $312 \pm 50$ | | [18] DAUM | 81B | SPEC | − | 63,94 $\pi^- p$ |
| $270 \pm 60$ | | [12] ASCOLI | 73 | HBC | − | 5–25 $\pi^- p \to p\pi_2$ |

[10] Statistical error negligible.
[11] From $f_2(1270)\pi$ decay.
[12] From a fit to $J^P = 2^-$ $f_2(1270)\pi$ partial wave.
[13] Clear phase rotation seen in $2^-S$, $2^-P$, $2^-D$ waves. We quote central value and spread of single-resonance fits to three channels.
[14] Superseded by AGHASYAN 2018B.
[15] $J^{PC}$ ambiguous.
[16] From $\rho\pi$ decay.
[17] From $\sigma\pi$ decay.
[18] From a two-resonance fit to four $2^-0^+$ waves. This should not be averaged with all the single resonance fits.

## $\pi_2$(1670) DECAY MODES

| | Mode | Fraction ($\Gamma_i/\Gamma$) | Confidence level |
|---|---|---|---|
| $\Gamma_1$ | $3\pi$ | $(95.8 \pm 1.4)$ % | |
| $\Gamma_2$ | $\pi^+\pi^-\pi^0$ | | |
| $\Gamma_3$ | $\pi^0\pi^0\pi^0$ | | |
| $\Gamma_4$ | $f_2(1270)\pi$ | $(56.3 \pm 3.2)$ % | |
| $\Gamma_5$ | $\rho\pi$ | $(31 \pm 4)$ % | |
| $\Gamma_6$ | $\sigma\pi$ | $(10 \pm 4)$ % | |
| $\Gamma_7$ | $\pi(\pi\pi)_{S\text{-wave}}$ | $(8.7 \pm 3.4)$ % | |
| $\Gamma_8$ | $\pi^\pm\pi^+\pi^-$ | $(53 \pm 4)$ % | |
| $\Gamma_9$ | $K\overline{K}^*(892)$+ c.c. | $(4.2 \pm 1.4)$ % | |
| $\Gamma_{10}$ | $\omega\rho$ | $(2.7 \pm 1.1)$ % | |
| $\Gamma_{11}$ | $\pi^\pm\gamma$ | $(7.0 \pm 1.2) \times 10^{-4}$ | |
| $\Gamma_{12}$ | $\gamma\gamma$ | $< 2.8 \times 10^{-7}$ | 90% |
| $\Gamma_{13}$ | $\eta\pi$ | $< 5$ % | |
| $\Gamma_{14}$ | $\pi^\pm 2\pi^+ 2\pi^-$ | $< 5$ % | |
| $\Gamma_{15}$ | $\rho(1450)\pi$ | $< 3.6 \times 10^{-3}$ | 97.7% |
| $\Gamma_{16}$ | $b_1(1235)\pi$ | $< 1.9 \times 10^{-3}$ | 97.7% |
| $\Gamma_{17}$ | $\eta 3\pi$ | | |
| $\Gamma_{18}$ | $f_1(1285)\pi$ | possibly seen | |
| $\Gamma_{19}$ | $a_2(1320)\pi$ | not seen | |

## CONSTRAINED FIT INFORMATION

An overall fit to 4 branching ratios uses 6 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2 =$ 1.9 for 3 degrees of freedom.

The following *off-diagonal* array elements are the correlation coefficients $\left\langle \delta x_i \delta x_j \right\rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\text{total}}$. The fit constrains the $x_i$ whose labels appear in this array to sum to one.

| | | | |
|---|---|---|---|
| $x_5$ | −53 | | |
| $x_7$ | −29 | −59 | |
| $x_9$ | −8 | −21 | −9 |
| | $x_4$ | $x_5$ | $x_7$ |

## $\pi_2(1670)$ PARTIAL WIDTHS

### $\Gamma(\pi^\pm\gamma)$ — $\Gamma_{11}$

| VALUE (keV) | DOCUMENT ID | | TECN | CHG | COMMENT |
|---|---|---|---|---|---|
| **181±11±27** | [19] ADOLPH | 14 | COMP | − | 190 $\pi^- \text{Pb} \to \pi^+\pi^-\pi^- \text{Pb}'$ |

[19] Primakoff reaction. Assumes incoherent $f_2(1270)\pi$ contribution to $3\pi$ final state and uses B($\pi_2(1670) \to f_2\pi$) = 56%.

### $\Gamma(\gamma\gamma)$ — $\Gamma_{12}$

| VALUE (keV) | CL% | DOCUMENT ID | | TECN | CHG | COMMENT |
|---|---|---|---|---|---|---|
| **<0.072** | 90 | [20] ACCIARRI | 97T | L3 | | $e^+e^- \to e^+e^-\pi^+\pi^-\pi^0$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| <0.19 | 90 | [20] ALBRECHT | 97B | ARG | | $e^+e^- \to e^+e^-\pi^+\pi^-\pi^0$ |
| 1.41 ±0.23±0.28 | | ANTREASYAN | 90 | CBAL | 0 | $e^+e^- \to e^+e^-\pi^0\pi^0\pi^0$ |
| 0.8 ±0.3 ±0.12 | | [21] BEHREND | 90C | CELL | 0 | $e^+e^- \to e^+e^-\pi^+\pi^-\pi^0$ |
| 1.3 ±0.3 ±0.2 | | [22] BEHREND | 90C | CELL | 0 | $e^+e^- \to e^+e^-\pi^+\pi^-\pi^0$ |

[20] Decaying into $f_2(1270)\pi$ and $\rho\pi$.
[21] Constructive interference between $f_2(1270)\pi$,$\rho\pi$ and background.
[22] Incoherent Ansatz.

## $\pi_2(1670)$ $\Gamma(i)\Gamma(\gamma\gamma)/\Gamma(\text{total})$

### $\Gamma(\pi^+\pi^-\pi^0) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ — $\Gamma_2\Gamma_{12}/\Gamma$

| VALUE (keV) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<0.1** | 95 | [23] SCHEGELSKY | 06 | RVUE | $\gamma\gamma \to \pi^+\pi^-\pi^0$ |

[23] From analysis of L3 data at 183–209 GeV.

# $\pi_2(1670)$ BRANCHING RATIOS

### $\Gamma(3\pi)/\Gamma_{\rm total}$ $\qquad\Gamma_1/\Gamma = (\Gamma_4+\Gamma_5+\Gamma_7)/\Gamma$

| VALUE | DOCUMENT ID |
|---|---|
| **0.958±0.014 OUR FIT** | |

### $\Gamma(\pi^0\pi^0\pi^0)/\Gamma(\pi^+\pi^-\pi^0)$ $\qquad\Gamma_3/\Gamma_2$

| VALUE | DOCUMENT ID | | COMMENT |
|---|---|---|---|
| **0.29±0.03±0.05** | BARBERIS | 01 | 450 $p p \rightarrow p_f 3\pi^0 p_s$ |

### $\Gamma(\rho\pi)/0.565\Gamma(f_2(1270)\pi)$ $\qquad\Gamma_5/0.565\Gamma_4$

(With $f_2(1270) \rightarrow \pi^+\pi^-$.)

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.97±0.09 OUR AVERAGE** | Error includes scale factor of 1.9. | | | |
| 0.76±0.07±0.10 | CHUNG | 02 | B852 | 18.3 $\pi^- p \rightarrow \pi^+\pi^-\pi^- p$ |
| 1.01±0.05 | BARBERIS | 98B | | 450 $p p \rightarrow p_f \pi^+\pi^-\pi^0 p_s$ |

### $\Gamma(\sigma\pi)/\Gamma(f_2(1270)\pi)$ $\qquad\Gamma_6/\Gamma_4$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.17±0.02±0.07** | CHUNG | 02 | B852 | 18.3 $\pi^- p \rightarrow \pi^+\pi^-\pi^- p$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.24±0.10 | [24,25] BAKER | 99 | SPEC | 1.94 $\overline{p} p \rightarrow 4\pi^0$ |

### $\frac{1}{2}\Gamma(\rho\pi)/\Gamma(\pi^\pm\pi^+\pi^-)$ $\qquad\frac{1}{2}\Gamma_5/\Gamma_8 = \frac{1}{2}\Gamma_5/(0.565\Gamma_4+\frac{1}{2}\Gamma_5+0.624\Gamma_7)$

| VALUE | DOCUMENT ID | | TECN | CHG | COMMENT |
|---|---|---|---|---|---|
| **0.29±0.04 OUR FIT** | | | | | |
| **0.29±0.05** | [26] DAUM | 81B | SPEC | | 63,94 $\pi^- p$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <0.3 | BARTSCH | 68 | HBC | + | 8 $\pi^+ p \rightarrow 3\pi p$ |

### $0.565\Gamma(f_2(1270)\pi)/\Gamma(\pi^\pm\pi^+\pi^-)$ $\qquad 0.565\Gamma_4/\Gamma_8 = 0.565\Gamma_4/(0.565\Gamma_4+\frac{1}{2}\Gamma_5+0.624\Gamma_7)$

(With $f_2(1270) \rightarrow \pi^+\pi^-$.)

| VALUE | DOCUMENT ID | | TECN | CHG | COMMENT |
|---|---|---|---|---|---|
| **0.604±0.035 OUR FIT** | | | | | |
| **0.60 ±0.05 OUR AVERAGE** | Error includes scale factor of 1.3. | | | | |
| 0.61 ±0.04 | [26] DAUM | 81B | SPEC | | 63,94 $\pi^- p$ |
| 0.76 $^{+0.24}_{-0.34}$ | ARMENISE | 69 | DBC | + | 5.1 $\pi^+ d \rightarrow d 3\pi$ |
| 0.35 ±0.20 | BALTAY | 68 | HBC | + | 7–8.5 $\pi^+ p$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.59 | BARTSCH | 68 | HBC | + | 8 $\pi^+ p \rightarrow 3\pi p$ |

### $0.624\Gamma(\pi(\pi\pi)_{S\text{-wave}})/\Gamma(\pi^\pm\pi^+\pi^-)$ $\qquad 0.624\Gamma_7/\Gamma_8 = 0.624\Gamma_7/(0.565\Gamma_4+\frac{1}{2}\Gamma_5+0.624\Gamma_7)$

(With $(\pi\pi)_{S\text{-wave}} \rightarrow \pi^+\pi^-$.)

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.10±0.04 OUR FIT** | | | | |
| **0.10±0.05** | [26] DAUM | 81B | SPEC | 63,94 $\pi^- p$ |

### $\Gamma(K\overline{K}^*(892)+\text{c.c.})/\Gamma(f_2(1270)\pi)$ — $\Gamma_9/\Gamma_4$

| VALUE | DOCUMENT ID | | TECN | CHG | COMMENT |
|---|---|---|---|---|---|
| **0.075±0.025 OUR FIT** | | | | | |
| **0.075±0.025** | [27] ARMSTRONG | 82B | OMEG | − | 16 $\pi^- p \rightarrow K^+ K^- \pi^- p$ |

### $\Gamma(\omega\rho)/\Gamma_{\text{total}}$ — $\Gamma_{10}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.027±0.004±0.010** | [28] AMELIN | 99 | VES | 37 $\pi^- A \rightarrow \omega\pi^-\pi^0 A^*$ |

### $\Gamma(\eta\pi)/\Gamma(\pi^\pm\pi^+\pi^-)$ — $\Gamma_{13}/\Gamma_8 = \Gamma_{13}/(0.565\Gamma_4+\frac{1}{2}\Gamma_5+0.624\Gamma_7)$

(All $\eta$ decays.)

| VALUE | DOCUMENT ID | | TECN | CHG | COMMENT |
|---|---|---|---|---|---|
| **<0.09** | BALTAY | 68 | HBC | + | 7–8.5 $\pi^+ p$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <0.10 | CRENNELL | 70 | HBC | − | 6 $\pi^- p \rightarrow f_2\pi^- N$ |

### $\Gamma(\pi^\pm 2\pi^+ 2\pi^-)/\Gamma(\pi^\pm\pi^+\pi^-)$ — $\Gamma_{14}/\Gamma_8 = \Gamma_{14}/(0.565\Gamma_4+\frac{1}{2}\Gamma_5+0.624\Gamma_7)$

| VALUE | DOCUMENT ID | | TECN | CHG | COMMENT |
|---|---|---|---|---|---|
| **<0.10** | CRENNELL | 70 | HBC | − | 6 $\pi^- p \rightarrow f_2\pi^- N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <0.1 | BALTAY | 68 | HBC | + | 7,8.5 $\pi^+ p$ |

### $\Gamma(\rho(1450)\pi)/\Gamma_{\text{total}}$ — $\Gamma_{15}/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<0.0036** | 97.7 | AMELIN | 99 | VES | 37 $\pi^- A \rightarrow \omega\pi^-\pi^0 A^*$ |

### $\Gamma(b_1(1235)\pi)/\Gamma_{\text{total}}$ — $\Gamma_{16}/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<0.0019** | 97.7 | AMELIN | 99 | VES | 37 $\pi^- A \rightarrow \omega\pi^-\pi^0 A^*$ |

### $\Gamma(f_1(1285)\pi)/\Gamma_{\text{total}}$ — $\Gamma_{18}/\Gamma$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **possibly seen** | 69k | KUHN | 04 | B852 | 18 $\pi^- p \rightarrow \eta\pi^+\pi^-\pi^- p$ |

### $\Gamma(a_2(1320)\pi)/\Gamma_{\text{total}}$ — $\Gamma_{19}/\Gamma$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **not seen** | 69k | KUHN | 04 | B852 | 18 $\pi^- p \rightarrow \eta\pi^+\pi^-\pi^- p$ |

### D-wave/S-wave RATIO FOR $\pi_2(1670) \rightarrow f_2(1270)\pi$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **−0.18±0.06** | [24] BAKER | 99 | SPEC | 1.94 $\overline{p}p \rightarrow 4\pi^0$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.22±0.10 | [26] DAUM | 81B | SPEC | 63,94 $\pi^- p$ |

### *F*-wave/*P*-wave RATIO FOR $\pi_2(1670) \to \rho\pi$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **−0.72±0.07±0.14** | CHUNG | 02 | B852 | 18.3 $\pi^- p \to \pi^+ \pi^- \pi^- p$ |

[24] Using preliminary CBAR data.
[25] With the $\sigma\pi$ in $L$=2 and the $f_2(1270)\pi$ in $L$=0.
[26] From a two-resonance fit to four $2^-0^+$ waves.
[27] From a partial-wave analysis of $K^+ K^- \pi^-$ system.
[28] Normalized to the B($\pi_2(1670) \to f_2\pi$).

## $\pi_2$(1670) REFERENCES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