

$f_4(2050)$

$$I^G(J^{PC}) = 0^+(4^{++})$$

$f_4(2050)$ MASS

| VALUE (MeV) | EVTS | DOCUMENT ID | TECN | COMMENT |
|------------------------------------|--------------------|--------------------|-------------------------------|-------------------------------------------------|
| 2025 ± 8 | OUR AVERAGE | Error | includes scale factor of 1.7. | See the ideogram below. |
| 2018 ± 6 | | ANISOVICH | 00J SPEC | |
| 1998 ± 15 | | ALDE | 98 GAM4 | 100 $\pi^- p \rightarrow \pi^0 \pi^0 n$ |
| 1970 ± 30 | | BELADIDZE | 92B VES | 36 $\pi^- p \rightarrow \omega \omega n$ |
| 2060 ± 20 | | ALDE | 90 GAM2 | 38 $\pi^- p \rightarrow \omega \omega n$ |
| 2038 ± 30 | | AUGUSTIN | 87 DM2 | $J/\psi \rightarrow \gamma \pi^+ \pi^-$ |
| 2086 ± 15 | | BALTRUSAIT.. | 87 MRK3 | $J/\psi \rightarrow \gamma \pi^+ \pi^-$ |
| 2000 ± 60 | | ALDE | 86D GAM4 | 100 $\pi^- p \rightarrow n 2\eta$ |
| 2020 ± 20 | 40k | ¹ BINON | 84B GAM2 | 38 $\pi^- p \rightarrow n 2\pi^0$ |
| 2015 ± 28 | | ² CASON | 82 STRC | 8 $\pi^+ p \rightarrow \Delta^{++} \pi^0 \pi^0$ |
| 2031 ⁺²⁵ ₋₃₆ | | ETKIN | 82B MPS | 23 $\pi^- p \rightarrow n 2K_S^0$ |
| 2020 ± 30 | 700 | APEL | 75 NICE | 40 $\pi^- p \rightarrow n 2\pi^0$ |
| 2050 ± 25 | | BLUM | 75 ASPK | 18.4 $\pi^- p \rightarrow n K^+ K^-$ |

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

| | | | |
|-----------|-----------------------|----------|-----------------------------------------|
| ~ 2000 | ³ MARTIN | 98 RVUE | $N\bar{N} \rightarrow \pi\pi$ |
| ~ 2010 | ⁴ MARTIN | 97 RVUE | $\bar{N}N \rightarrow \pi\pi$ |
| ~ 2040 | ⁵ OAKDEN | 94 RVUE | 0.36–1.55 $\bar{p}p \rightarrow \pi\pi$ |
| ~ 1990 | ⁶ OAKDEN | 94 RVUE | 0.36–1.55 $\bar{p}p \rightarrow \pi\pi$ |
| 1978 ± 5 | ⁷ ALPER | 80 CNTR | 62 $\pi^- p \rightarrow K^+ K^- n$ |
| 2040 ± 10 | ⁷ ROZANSKA | 80 SPRK | 18 $\pi^- p \rightarrow p \bar{p} n$ |
| 1935 ± 13 | ⁷ CORDEN | 79 OMEG | 12–15 $\pi^- p \rightarrow n 2\pi$ |
| 1988 ± 7 | EVANGELISTA | 79B OMEG | 10 $\pi^- p \rightarrow K^+ K^- n$ |
| 1922 ± 14 | ⁸ ANTIPOV | 77 CIBS | 25 $\pi^- p \rightarrow p 3\pi$ |

¹ From a partial-wave analysis of the data.

² From an amplitude analysis of the reaction $\pi^+ \pi^- \rightarrow 2\pi^0$.

³ Energy-dependent analysis.

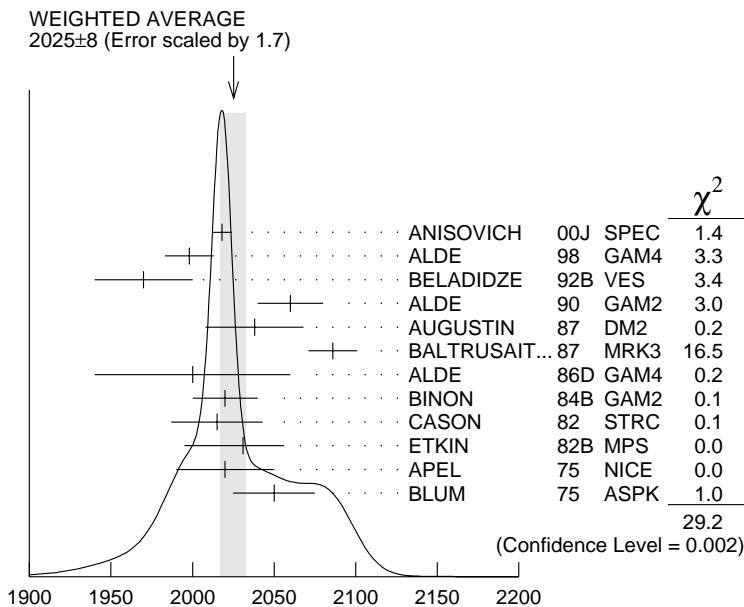
⁴ Single energy analysis.

⁵ From solution A of amplitude analysis of data on $\bar{p}p \rightarrow \pi\pi$. See however KLOET 96 who fit $\pi^+ \pi^-$ only and find waves only up to $J = 3$ to be important but not significantly resonant.

⁶ From solution B of amplitude analysis of data on $\bar{p}p \rightarrow \pi\pi$. See however KLOET 96 who fit $\pi^+ \pi^-$ only and find waves only up to $J = 3$ to be important but not significantly resonant.

⁷ $I(J^P) = 0(4^+)$ from amplitude analysis assuming one-pion exchange.

⁸ Width errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.



$f_4(2050)$ mass (MeV)

$f_4(2050)$ WIDTH

| VALUE (MeV) | EVTS | DOCUMENT ID | TECN | COMMENT |
|------------------------------------|------|-------------------------------------|------|-------------------------------------------------|
| 194± 13 OUR AVERAGE | | Error includes scale factor of 2.2. | | See the ideogram below. |
| 182± 7 | | ANISOVICH 00J | SPEC | |
| 395± 40 | | ALDE 98 | GAM4 | 100 $\pi^- p \rightarrow \pi^0 \pi^0 n$ |
| 300± 50 | | BELADIDZE 92B | VES | 36 $\pi^- p \rightarrow \omega \omega n$ |
| 170± 60 | | ALDE 90 | GAM2 | 38 $\pi^- p \rightarrow \omega \omega n$ |
| 304± 60 | | AUGUSTIN 87 | DM2 | $J/\psi \rightarrow \gamma \pi^+ \pi^-$ |
| 210± 63 | | BALTRUSAIT..87 | MRK3 | $J/\psi \rightarrow \gamma \pi^+ \pi^-$ |
| 400±100 | | ALDE 86D | GAM4 | 100 $\pi^- p \rightarrow n 2\eta$ |
| 240± 40 | 40k | ⁹ BINON 84B | GAM2 | 38 $\pi^- p \rightarrow n 2\pi^0$ |
| 190± 14 | | DENNEY 83 | LASS | 10 $\pi^+ n/\pi^+ p$ |
| 186 ⁺¹⁰³ ₋₅₈ | | ¹⁰ CASON 82 | STRC | 8 $\pi^+ p \rightarrow \Delta^{++} \pi^0 \pi^0$ |
| 305 ⁺³⁶ ₋₁₁₉ | | ETKIN 82B | MPS | 23 $\pi^- p \rightarrow n 2K_S^0$ |
| 180± 60 | 700 | APEL 75 | NICE | 40 $\pi^- p \rightarrow n 2\pi^0$ |
| 225 ⁺¹²⁰ ₋₇₀ | | BLUM 75 | ASPK | 18.4 $\pi^- p \rightarrow n K^+ K^-$ |

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

| | | | |
|---------|-------------------------|------|-----------------------------------------|
| ~ 170 | ¹¹ MARTIN 98 | RVUE | $N\bar{N} \rightarrow \pi\pi$ |
| ~ 200 | ¹² MARTIN 97 | RVUE | $\bar{N}N \rightarrow \pi\pi$ |
| ~ 60 | ¹³ OAKDEN 94 | RVUE | 0.36–1.55 $\bar{p}p \rightarrow \pi\pi$ |
| ~ 80 | ¹⁴ OAKDEN 94 | RVUE | 0.36–1.55 $\bar{p}p \rightarrow \pi\pi$ |
| 243± 16 | ¹⁵ ALPER 80 | CNTR | 62 $\pi^- p \rightarrow K^+ K^- n$ |

- | | | | |
|----------|-----------------|---------|--------------------------------------|
| 140 ± 15 | 15 ROZANSKA | 80 SPRK | 18 $\pi^- p \rightarrow p \bar{p} n$ |
| 263 ± 57 | 15 CORDEN | 79 OMEG | 12-15 $\pi^- p \rightarrow n 2\pi$ |
| 100 ± 28 | EVANGELISTA 79B | | 10 $\pi^- p \rightarrow K^+ K^- n$ |
| 107 ± 56 | 16 ANTIPOV | 77 CIBS | 25 $\pi^- p \rightarrow p 3\pi$ |

⁹ From a partial-wave analysis of the data.

¹⁰ From an amplitude analysis of the reaction $\pi^+ \pi^- \rightarrow 2\pi^0$.

¹¹ Energy-dependent analysis.

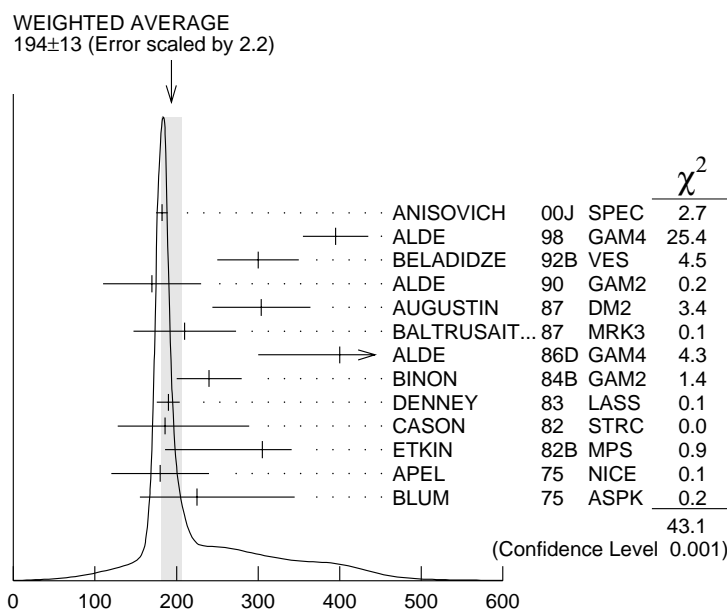
¹² Single energy analysis.

¹³ From solution A of amplitude analysis of data on $\bar{p} p \rightarrow \pi \pi$. See however KLOET 96 who fit $\pi^+ \pi^-$ only and find waves only up to $J = 3$ to be important but not significantly resonant.

¹⁴ From solution B of amplitude analysis of data on $\bar{p} p \rightarrow \pi \pi$. See however KLOET 96 who fit $\pi^+ \pi^-$ only and find waves only up to $J = 3$ to be important but not significantly resonant.

¹⁵ $I(J^P) = 0(4^+)$ from amplitude analysis assuming one-pion exchange.

¹⁶ Width errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.



$f_4(2050)$ WIDTH

$f_4(2050)$ DECAY MODES

| Mode | Fraction (Γ_i/Γ) |
|---------------------------|--------------------------------------|
| Γ_1 $\omega\omega$ | not seen |
| Γ_2 $\pi\pi$ | $(17.0 \pm 1.5) \%$ |
| Γ_3 $K\bar{K}$ | $(6.8^{+3.4}_{-1.8}) \times 10^{-3}$ |

| | | |
|------------|----------------|--------------------------------|
| Γ_4 | $\eta\eta$ | $(2.1 \pm 0.8) \times 10^{-3}$ |
| Γ_5 | $4\pi^0$ | < 1.2 % |
| Γ_6 | $\gamma\gamma$ | |
| Γ_7 | $a_2(1320)\pi$ | seen |

$f_4(2050) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(\text{total})$

$\Gamma(K\bar{K}) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_3\Gamma_6/\Gamma$

| <u>VALUE (keV)</u> | <u>CL%</u> | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u> |
|--------------------|------------|--------------------|-------------|----------------|
|--------------------|------------|--------------------|-------------|----------------|

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

| | | | | |
|----------|----|---------|----------|----------------------------------------|
| < 0.29 | 95 | ALTHOFF | 85B TASS | $\gamma\gamma \rightarrow K\bar{K}\pi$ |
|----------|----|---------|----------|----------------------------------------|

$\Gamma(\pi\pi) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_2\Gamma_6/\Gamma$

| <u>VALUE (keV)</u> | <u>CL%</u> | <u>EVTS</u> | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u> |
|--------------------|------------|-------------|--------------------|-------------|----------------|
|--------------------|------------|-------------|--------------------|-------------|----------------|

| | | | | | |
|---------|----|------------|------|---------|---------------------------------------|
| < 1.1 | 95 | 13 ± 4 | OEST | 90 JADE | $e^+e^- \rightarrow e^+e^-\pi^0\pi^0$ |
|---------|----|------------|------|---------|---------------------------------------|

$f_4(2050)$ BRANCHING RATIOS

$\Gamma(\omega\omega)/\Gamma_{\text{total}}$ Γ_1/Γ

| <u>VALUE</u> | <u>DOCUMENT ID</u> | <u>COMMENT</u> |
|--------------|--------------------|----------------|
|--------------|--------------------|----------------|

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

| | | |
|----------|----------|-------------------------------------------------|
| not seen | BARBERIS | 00F 450 $p p \rightarrow p_f \omega \omega p_s$ |
|----------|----------|-------------------------------------------------|

$\Gamma(\omega\omega)/\Gamma(\pi\pi)$ Γ_1/Γ_2

| <u>VALUE</u> | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u> |
|--------------|--------------------|-------------|----------------|
|--------------|--------------------|-------------|----------------|

| | | | |
|---------------|------|---------|------------------------------------------|
| 1.5 ± 0.3 | ALDE | 90 GAM2 | $38 \pi^- p \rightarrow \omega \omega n$ |
|---------------|------|---------|------------------------------------------|

$\Gamma(\pi\pi)/\Gamma_{\text{total}}$ Γ_2/Γ

| <u>VALUE</u> | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u> |
|--------------|--------------------|-------------|----------------|
|--------------|--------------------|-------------|----------------|

0.170 ± 0.015 OUR AVERAGE

| | | | |
|-----------------|----------------------|----------|-------------------------------------------------|
| 0.18 ± 0.03 | ¹⁷ BINON | 83C GAM2 | $38 \pi^- p \rightarrow n 4\gamma$ |
| 0.16 ± 0.03 | ¹⁷ CASON | 82 STRC | $8 \pi^+ p \rightarrow \Delta^{++} \pi^0 \pi^0$ |
| 0.17 ± 0.02 | ¹⁷ CORDEN | 79 OMEG | $12-15 \pi^- p \rightarrow n 2\pi$ |

¹⁷ Assuming one pion exchange.

$\Gamma(K\bar{K})/\Gamma(\pi\pi)$ Γ_3/Γ_2

| <u>VALUE</u> | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u> |
|--------------|--------------------|-------------|----------------|
|--------------|--------------------|-------------|----------------|

| | | | |
|-------------------------------------------------------------|-------|---------|-----------------------------------|
| $0.04 \begin{smallmatrix} +0.02 \\ -0.01 \end{smallmatrix}$ | ETKIN | 82B MPS | $23 \pi^- p \rightarrow n 2K_S^0$ |
|-------------------------------------------------------------|-------|---------|-----------------------------------|

$\Gamma(\eta\eta)/\Gamma_{\text{total}}$ Γ_4/Γ

| <u>VALUE (units 10^{-3})</u> | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u> |
|-------------------------------------------|--------------------|-------------|----------------|
|-------------------------------------------|--------------------|-------------|----------------|

| | | | |
|---------------|------|----------|-------------------------------------|
| 2.1 ± 0.8 | ALDE | 86D GAM4 | $100 \pi^- p \rightarrow n 4\gamma$ |
|---------------|------|----------|-------------------------------------|

$\Gamma(4\pi^0)/\Gamma_{\text{total}}$ Γ_5/Γ

| <u>VALUE</u> | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u> |
|--------------|--------------------|-------------|----------------|
|--------------|--------------------|-------------|----------------|

| | | | |
|-----------|------|---------|------------------------------------|
| < 0.012 | ALDE | 87 GAM4 | $100 \pi^- p \rightarrow 4\pi^0 n$ |
|-----------|------|---------|------------------------------------|

$\Gamma(a_2(1320)\pi)/\Gamma_{\text{total}}$ Γ_7/Γ

| VALUE | DOCUMENT ID | TECN | COMMENT |
|-------|-------------------------------------------------------------------------|--------|---------------------------------------------|
| • • • | We do not use the following data for averages, fits, limits, etc. • • • | | |
| seen | AMELIN | 00 VES | 37 $\pi^- p \rightarrow \eta \pi^+ \pi^- n$ |

 $f_4(2050)$ REFERENCES

| | | | | |
|---------------|-----|------------------------|---------------------------------|--------------------------------|
| AMELIN | 00 | NP A668 83 | D. Amelin <i>et al.</i> | (VES Collab.) |
| ANISOVICH | 00J | PL B491 47 | A.V. Anisovich <i>et al.</i> | |
| BARBERIS | 00F | PL B484 198 | D. Barberis <i>et al.</i> | (WA 102 Collab.) |
| ALDE | 98 | EPJ A3 361 | D. Alde <i>et al.</i> | (GAM4 Collab.) |
| Also | 99 | PAN 62 405 | D. Alde <i>et al.</i> | (GAMS Collab.) |
| | | Translated from YAF 62 | 446. | |
| MARTIN | 98 | PR C57 3492 | B.R. Martin <i>et al.</i> | |
| MARTIN | 97 | PR C56 1114 | B.R. Martin, G.C. Oades | (LOUC, AARH) |
| KLOET | 96 | PR D53 6120 | W.M. Kloet, F. Myhrer | (RUTG, NORD) |
| OAKDEN | 94 | NP A574 731 | M.N. Oakden, M.R. Pennington | (DURH) |
| BELADIDZE | 92B | ZPHY C54 367 | G.M. Beladidze <i>et al.</i> | (VES Collab.) |
| ALDE | 90 | PL B241 600 | D.M. Alde <i>et al.</i> | (SERP, BELG, LANL, LAPP+) |
| OEST | 90 | ZPHY C47 343 | T. Oest <i>et al.</i> | (JADE Collab.) |
| ALDE | 87 | PL B198 286 | D.M. Alde <i>et al.</i> | (LANL, BRUX, SERP, LAPP) |
| AUGUSTIN | 87 | ZPHY C36 369 | J.E. Augustin <i>et al.</i> | (LALO, CLER, FRAS+) |
| BALTRUSAIT... | 87 | PR D35 2077 | R.M. Baltrusaitis <i>et al.</i> | (Mark III Collab.) |
| ALDE | 86D | NP B269 485 | D.M. Alde <i>et al.</i> | (BELG, LAPP, SERP, CERN+) |
| ALTHOFF | 85B | ZPHY C29 189 | M. Althoff <i>et al.</i> | (TASSO Collab.) |
| BINON | 84B | LNC 39 41 | F.G. Binon <i>et al.</i> | (SERP, BELG, LAPP) |
| BINON | 83C | SJNP 38 723 | F.G. Binon <i>et al.</i> | (SERP, BRUX+) |
| | | Translated from YAF 38 | 1199. | |
| DENNEY | 83 | PR D28 2726 | D.L. Denney <i>et al.</i> | (IOWA, MICH) |
| CASON | 82 | PRL 48 1316 | N.M. Cason <i>et al.</i> | (NDAM, ANL) |
| ETKIN | 82B | PR D25 1786 | A. Etkin <i>et al.</i> | (BNL, CUNY, TUFTS, VAND) |
| ALPER | 80 | PL 94B 422 | B. Alper <i>et al.</i> | (AMST, CERN, CRAC, MPIM+) |
| ROZANSKA | 80 | NP B162 505 | M. Rozanska <i>et al.</i> | (MPIM, CERN) |
| CORDEN | 79 | NP B157 250 | M.J. Corden <i>et al.</i> | (BIRM, RHEL, TELA+ JP) |
| EVANGELISTA | 79B | NP B154 381 | C. Evangelista <i>et al.</i> | (BARI, BONN, CERN+) |
| ANTIPOV | 77 | NP B119 45 | Y.M. Antipov <i>et al.</i> | (SERP, GEVA) |
| APEL | 75 | PL 57B 398 | W.D. Apel <i>et al.</i> | (KARLK, KARLE, PISA, SERP+ JP) |
| BLUM | 75 | PL 57B 403 | W. Blum <i>et al.</i> | (CERN, MPIM) JP |

OTHER RELATED PAPERS

| | | | | |
|--------------|-----|--------------------------|-------------------------------|---------------------|
| ANISOVICH | 99D | PL B452 180 | A.V. Anisovich <i>et al.</i> | |
| Also | 99F | NP A651 253 | A.V. Anisovich <i>et al.</i> | |
| ANISOVICH | 99F | NP A651 253 | A.V. Anisovich <i>et al.</i> | |
| PROKOSHKIN | 97 | SPD 42 117 | Y.D. Prokoshkin <i>et al.</i> | (SERP) |
| | | Translated from DANS 353 | 323. | |
| CASON | 83 | PR D28 1586 | N.M. Cason <i>et al.</i> | (NDAM, ANL) |
| GOTTESMAN | 80 | PR D22 1503 | S.R. Gottesman <i>et al.</i> | (SYRA, BRAN, BNL+) |
| EISENHAND... | 75 | NP B96 109 | E. Eisenhandler <i>et al.</i> | (LOQM, LIVP, DARE+) |
| WAGNER | 74 | London Conf. 2 27 | F. Wagner | (MPIM) |