# $f_0(500)$

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

also known as $\sigma$; was $f_0(600)$

**See the related review(s):**

Scalar Mesons below 2 GeV

## $f_0(500)$ T-MATRIX POLE $\sqrt{s}$

Note that $\Gamma \approx 2\ \mathrm{Im}(\sqrt{s_{\mathrm{pole}}})$.

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **(400–550)−i(200–350) OUR ESTIMATE** | | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $(512 \pm 15)-i(188 \pm 12)$ | [1] ABLIKIM | 17 | BES3 | $J/\psi \to \gamma 3\pi$ |
| $(440 \pm 10)-i(238 \pm 10)$ | [2] ALBALADEJO | 12 | RVUE | Compilation |
| $(445 \pm 25)-i(278^{+22}_{-18})$ | [3,4] GARCIA-MAR... | 11 | RVUE | Compilation |
| $(457^{+14}_{-13})-i(279^{+11}_{-7})$ | [3,5] GARCIA-MAR... | 11 | RVUE | Compilation |
| $(442^{+5}_{-8})-i(274^{+6}_{-5})$ | [6] MOUSSALLAM | 11 | RVUE | Compilation |
| $(452 \pm 13)-i(259 \pm 16)$ | [7] MENNESSIER | 10 | RVUE | Compilation |
| $(448 \pm 43)-i(266 \pm 43)$ | [8] MENNESSIER | 10 | RVUE | Compilation |
| $(455 \pm 6^{+31}_{-13})-i(278 \pm 6^{+34}_{-43})$ | [9] CAPRINI | 08 | RVUE | Compilation |
| $(463 \pm 6^{+31}_{-17})-i(259 \pm 6^{+33}_{-34})$ | [10] CAPRINI | 08 | RVUE | Compilation |
| $(552^{+84}_{-106})-i(232^{+81}_{-72})$ | [11] ABLIKIM | 07A | BES2 | $\psi(2S) \to \pi^+\pi^- J/\psi$ |
| $(466 \pm 18)-i(223 \pm 28)$ | [12] BONVICINI | 07 | CLEO | $D^+ \to \pi^-\pi^+\pi^+$ |
| $(472 \pm 30)-i(271 \pm 30)$ | [13] BUGG | 07A | RVUE | Compilation |
| $(484 \pm 17)-i(255 \pm 10)$ | GARCIA-MAR... | 07 | RVUE | Compilation |
| $(430)-i(325)$ | [14] ANISOVICH | 06 | RVUE | Compilation |
| $(441^{+16}_{-8})-i(272^{+9}_{-12.5})$ | [15] CAPRINI | 06 | RVUE | $\pi\pi \to \pi\pi$ |
| $(470 \pm 50)-i(285 \pm 25)$ | [16] ZHOU | 05 | RVUE | |
| $(541 \pm 39)-i(252 \pm 42)$ | [17] ABLIKIM | 04A | BES2 | $J/\psi \to \omega\pi^+\pi^-$ |
| $(528 \pm 32)-i(207 \pm 23)$ | [18] GALLEGOS | 04 | RVUE | Compilation |
| $(533 \pm 25)-i(249 \pm 25)$ | [19] BUGG | 03 | RVUE | |
| $517 - i240$ | BLACK | 01 | RVUE | $\pi\pi \to \pi\pi$ |
| $(470 \pm 30)-i(295 \pm 20)$ | [15] COLANGELO | 01 | RVUE | $\pi\pi \to \pi\pi$ |
| $(535^{+48}_{-36})-i(155^{+76}_{-53})$ | [20] ISHIDA | 01 | | $\Upsilon(3S) \to \Upsilon\pi\pi$ |
| $610 \pm 14 - i(310 \pm 13)$ | [21] SUROVTSEV | 01 | RVUE | $\pi\pi \to \pi\pi$, $K\overline{K}$ |
| $(540^{+36}_{-29})-i(193^{+32}_{-40})$ | ISHIDA | 00B | | $p\overline{p} \to \pi^0\pi^0\pi^0$ |
| $445 - i235$ | HANNAH | 99 | RVUE | $\pi$ scalar form factor |
| $(523 \pm 12)-i(259 \pm 7)$ | KAMINSKI | 99 | RVUE | $\pi\pi \to \pi\pi$, $K\overline{K}$, $\sigma\sigma$ |
| $442 - i\ 227$ | OLLER | 99 | RVUE | $\pi\pi \to \pi\pi$, $K\overline{K}$ |
| $469 - i203$ | OLLER | 99B | RVUE | $\pi\pi \to \pi\pi$, $K\overline{K}$ |
| $445 - i221$ | OLLER | 99C | RVUE | $\pi\pi \to \pi\pi$, $K\overline{K}$, $\eta\eta$ |
| $420 - i\ 212$ | LOCHER | 98 | RVUE | $\pi\pi \to \pi\pi$ , $K\overline{K}$ |
| $440 - i245$ | [22] DOBADO | 97 | RVUE | Compilation |
| $(602 \pm 26)-i(196 \pm 27)$ | [23] ISHIDA | 97 | | $\pi\pi \to \pi\pi$ |

| | | | | |
|---|---|---|---|---|
| $(537 \pm 20) - i(250 \pm 17)$ | [24] KAMINSKI | 97B | RVUE | $\pi\pi \rightarrow \pi\pi$, $K\overline{K}$, $4\pi$ |
| $470 - i250$ | [25,26] TORNQVIST | 96 | RVUE | $\pi\pi \rightarrow \pi\pi$, $K\overline{K}$, $K\pi$, $\eta\pi$ |
| $387 - i305$ | [26,27] JANSSEN | 95 | RVUE | $\pi\pi \rightarrow \pi\pi$, $K\overline{K}$ |
| $420 - i370$ | [28] ACHASOV | 94 | RVUE | $\pi\pi \rightarrow \pi\pi$ |
| $(506 \pm 10) - i(247 \pm 3)$ | KAMINSKI | 94 | RVUE | $\pi\pi \rightarrow \pi\pi$, $K\overline{K}$ |
| $370 - i356$ | [29] ZOU | 94B | RVUE | $\pi\pi \rightarrow \pi\pi$, $K\overline{K}$ |
| $408 - i342$ | [26,29] ZOU | 93 | RVUE | $\pi\pi \rightarrow \pi\pi$, $K\overline{K}$ |
| $470 - i208$ | [30] VANBEVEREN | 86 | RVUE | $\pi\pi \rightarrow \pi\pi$, $K\overline{K}$, $\eta\eta$, ... |
| $(750 \pm 50) - i(450 \pm 50)$ | [31] ESTABROOKS | 79 | RVUE | $\pi\pi \rightarrow \pi\pi$, $K\overline{K}$ |
| $(660 \pm 100) - i(320 \pm 70)$ | PROTOPOP... | 73 | HBC | $\pi\pi \rightarrow \pi\pi$, $K\overline{K}$ |
| $650 - i370$ | [32] BASDEVANT | 72 | RVUE | $\pi\pi \rightarrow \pi\pi$ |

[1] S-matrix pole; 8595 events.
[2] Applying the chiral unitary approach at NLO to the $K_{e4}$ data of BATLEY 10 and $\pi N \rightarrow \pi\pi N$ data of HYAMS 73, GRAYER 74, and PROTOPOPESCU 73.
[3] Uses the $K_{e4}$ data of BATLEY 10C and the $\pi N \rightarrow \pi\pi N$ data of HYAMS 73, GRAYER 74, and PROTOPOPESCU 73.
[4] Analytic continuation using Roy equations.
[5] Analytic continuation using GKPY equations.
[6] Using Roy equations.
[7] Average of three variants of the analytic K-matrix model. Uses the $K_{e4}$ data of BATLEY 08A and the $\pi N \rightarrow \pi\pi N$ data of HYAMS 73 and GRAYER 74.
[8] Average of the analyses of three data sets in the K-matrix model. Uses the data of BATLEY 08A, HYAMS 73, and GRAYER 74, partially of COHEN 80 or ETKIN 82B.
[9] From the $K_{e4}$ data of BATLEY 08A and $\pi N \rightarrow \pi\pi N$ data of HYAMS 73.
[10] From the $K_{e4}$ data of BATLEY 08A and $\pi N \rightarrow \pi\pi N$ data of PROTOPOPESCU 73, GRAYER 74, and ESTABROOKS 74.
[11] From a mean of three different $f_0(500)$ parametrizations. Uses 40k events.
[12] From an isobar model using 2.6k events.
[13] Reanalysis of ABLIKIM 04A, PISLAK 01, and HYAMS 73 data.
[14] Using the N/D method.
[15] From the solution of the Roy equation (ROY 71) for the isoscalar S-wave and using a phase-shift analysis of HYAMS 73 and PROTOPOPESCU 73 data.
[16] Reanalysis of the data from PROTOPOPESCU 73, ESTABROOKS 74, GRAYER 74, ROSSELET 77, PISLAK 03, and AKHMETSHIN 04.
[17] From a mean of six different analyses and $f_0(500)$ parameterizations.
[18] Using data on $\psi(2S) \rightarrow J/\psi\pi\pi$ from BAI 00E and on $\Upsilon(\mathrm{nS}) \rightarrow \Upsilon(\mathrm{mS})\pi\pi$ from BUTLER 94B and ALEXANDER 98.
[19] From a combined analysis of HYAMS 73, AUGUSTIN 89, AITALA 01B, and PISLAK 01.
[20] A similar analysis (KOMADA 01) finds $(580^{+79}_{-30}) - i(190^{+107}_{-49})$ MeV.
[21] Coupled channel reanalysis of BATON 70, BENSINGER 71, BAILLON 72, HYAMS 73, HYAMS 75, ROSSELET 77, COHEN 80, and ETKIN 82B using the uniformizing variable.
[22] Using the inverse amplitude method and data of ESTABROOKS 73, GRAYER 74, and PROTOPOPESCU 73.
[23] Reanalysis of data from HYAMS 73, GRAYER 74, SRINIVASAN 75, and ROSSELET 77 using the interfering amplitude method.
[24] Average and spread of 4 variants ("up" and "down") of KAMINSKI 97B 3-channel model.
[25] Uses data from BEIER 72B, OCHS 73, HYAMS 73, GRAYER 74, ROSSELET 77, CASON 83, ASTON 88, and ARMSTRONG 91B. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems.
[26] Demonstrates explicitly that $f_0(500)$ and $f_0(1370)$ are two different poles.
[27] Analysis of data from FALVARD 88.
[28] Analysis of data from OCHS 73, ESTABROOKS 75, ROSSELET 77, and MUKHIN 80.

[29] Analysis of data from OCHS 73, GRAYER 74, and ROSSELET 77.
[30] Coupled-channel analysis using data from PROTOPOPESCU 73, HYAMS 73, HYAMS 75, GRAYER 74, ESTABROOKS 74, ESTABROOKS 75, FROGGATT 77, CORDEN 79, BISWAS 81.
[31] Analysis of data from APEL 72C, GRAYER 74, CASON 76, PAWLICKI 77. Includes spread and errors of 4 solutions.
[32] Analysis of data from BATON 70, BENSINGER 71, COLTON 71, BAILLON 72,PROTOPOPESCU 73, and WALKER 67.

## $f_0(500)$ BREIT-WIGNER MASS

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **400 to 800 OUR ESTIMATE** | | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $513 \pm 32$ | [33] MURAMATSU | 02 | CLEO | $e^+ e^- \approx$ 10 GeV |
| $478^{+24}_{-23} \pm 17$ | AITALA | 01B | E791 | $D^+ \to \pi^- \pi^+ \pi^+$ |
| $563^{+58}_{-29}$ | [34] ISHIDA | 01 | | $\Upsilon(3S) \to \Upsilon \pi\pi$ |
| 555 | [35] ASNER | 00 | CLE2 | $\tau^- \to \pi^- \pi^0 \pi^0 \nu_\tau$ |
| $540 \pm 36$ | ISHIDA | 00B | | $p\overline{p} \to \pi^0 \pi^0 \pi^0$ |
| $750 \pm 4$ | ALEKSEEV | 99 | SPEC | $1.78\ \pi^- p_{\text{polar}} \to \pi^- \pi^+ n$ |
| $744 \pm 5$ | ALEKSEEV | 98 | SPEC | $1.78\ \pi^- p_{\text{polar}} \to \pi^- \pi^+ n$ |
| $759 \pm 5$ | [36] TROYAN | 98 | | $5.2\ np \to np \pi^+ \pi^-$ |
| $780 \pm 30$ | ALDE | 97 | GAM2 | $450\ pp \to pp \pi^0 \pi^0$ |
| $585 \pm 20$ | [37] ISHIDA | 97 | | $\pi\pi \to \pi\pi$ |
| $761 \pm 12$ | [38] SVEC | 96 | RVUE | 6–17 $\pi N_{\text{polar}} \to \pi^+ \pi^- N$ |
| $\sim$ 860 | [39,40] TORNQVIST | 96 | RVUE | $\pi\pi \to \pi\pi$, $K\overline{K}$, $K\pi$, $\eta\pi$ |
| $1165 \pm 50$ | [41,42] ANISOVICH | 95 | RVUE | $\pi^- p \to \pi^0 \pi^0 n$, $\overline{p}p \to \pi^0 \pi^0 \pi^0$, $\pi^0 \pi^0 \eta$, $\pi^0 \eta\eta$ |
| $414 \pm 20$ | [38] AUGUSTIN | 89 | DM2 | |

[33] Statistical uncertainty only.
[34] A similar analysis (KOMADA 01) finds $526^{+48}_{-37}$ MeV.
[35] From the best fit of the Dalitz plot.
[36] $6\sigma$ effect, no PWA.
[37] Reanalysis of data from HYAMS 73, GRAYER 74, SRINIVASAN 75, and ROSSELET 77 using the interfering amplitude method.
[38] Breit-Wigner fit to S-wave intensity measured in $\pi N \to \pi^- \pi^+ N$ on polarized targets. The fit does not include $f_0(980)$.
[39] Uses data from ASTON 88, OCHS 73, HYAMS 73, ARMSTRONG 91B, GRAYER 74, CASON 83, ROSSELET 77, and BEIER 72B. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems.
[40] Also observed by ASNER 00 in $\tau^- \to \pi^- \pi^0 \pi^0 \nu_\tau$ decays.
[41] Uses $\pi^0 \pi^0$ data from ANISOVICH 94, AMSLER 94D, and ALDE 95B, $\pi^+ \pi^-$ data from OCHS 73, GRAYER 74 and ROSSELET 77, and $\eta\eta$ data from ANISOVICH 94.
[42] The pole is on Sheet III. Demonstrates explicitly that $f_0(500)$ and $f_0(1370)$ are two different poles.

## $f_0(500)$ BREIT-WIGNER WIDTH

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **100 to 800 OUR ESTIMATE** | | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $335\pm 67$ | [43] MURAMATSU | 02 | CLEO | $e^+e^- \approx$ 10 GeV |
| $324^{+42}_{-40}\pm21$ | AITALA | 01B | E791 | $D^+ \to \pi^-\pi^+\pi^+$ |
| $372^{+229}_{-95}$ | [44] ISHIDA | 01 | | $\Upsilon(3S) \to \Upsilon\pi\pi$ |
| 540 | [45] ASNER | 00 | CLE2 | $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$ |
| $372\pm 80$ | ISHIDA | 00B | | $p\overline{p} \to \pi^0\pi^0\pi^0$ |
| $119\pm 13$ | ALEKSEEV | 99 | SPEC | $1.78\ \pi^- p_{\mathrm{polar}} \to \pi^-\pi^+ n$ |
| $77\pm 22$ | ALEKSEEV | 98 | SPEC | $1.78\ \pi^- p_{\mathrm{polar}} \to \pi^-\pi^+ n$ |
| $35\pm 12$ | [46] TROYAN | 98 | | $5.2\ np \to np\pi^+\pi^-$ |
| $780\pm 60$ | ALDE | 97 | GAM2 | $450\ pp \to pp\pi^0\pi^0$ |
| $385\pm 70$ | [47] ISHIDA | 97 | | $\pi\pi \to \pi\pi$ |
| $290\pm 54$ | [48] SVEC | 96 | RVUE | 6–17 $\pi N_{\mathrm{polar}} \to \pi^+\pi^- N$ |
| $\sim 880$ | [49,50] TORNQVIST | 96 | RVUE | $\pi\pi \to \pi\pi$, $K\overline{K}$, $K\pi$, $\eta\pi$ |
| $460\pm 40$ | [51,52] ANISOVICH | 95 | RVUE | $\pi^- p \to \pi^0\pi^0 n$, $\overline{p}p \to \pi^0\pi^0\pi^0$, $\pi^0\pi^0\eta$, $\pi^0\eta\eta$ |
| $494\pm 58$ | [48] AUGUSTIN | 89 | DM2 | |

[43] Statistical uncertainty only.

[44] A similar analysis (KOMADA 01) finds $301^{+145}_{-100}$ MeV.

[45] From the best fit of the Dalitz plot.

[46] $6\sigma$ effect, no PWA.

[47] Reanalysis of data from HYAMS 73, GRAYER 74, SRINIVASAN 75, and ROSSELET 77 using the interfering amplitude method.

[48] Breit-Wigner fit to S-wave intensity measured in $\pi N \to \pi^-\pi^+ N$ on polarized targets. The fit does not include $f_0(980)$.

[49] Uses data from ASTON 88, OCHS 73, HYAMS 73, ARMSTRONG 91B, GRAYER 74, CASON 83, ROSSELET 77, and BEIER 72B. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems.

[50] Also observed by ASNER 00 in $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$ decays.

[51] Uses $\pi^0\pi^0$ data from ANISOVICH 94, AMSLER 94D, and ALDE 95B, $\pi^+\pi^-$ data from OCHS 73, GRAYER 74 and ROSSELET 77, and $\eta\eta$ data from ANISOVICH 94.

[52] The pole is on Sheet III. Demonstrates explicitly that $f_0(500)$ and $f_0(1370)$ are two different poles.

## $f_0(500)$ DECAY MODES

| | Mode | Fraction ($\Gamma_i/\Gamma$) |
|---|---|---|
| $\Gamma_1$ | $\pi\pi$ | seen |
| $\Gamma_2$ | $\gamma\gamma$ | seen |

# $f_0(500)$ PARTIAL WIDTHS

## $\Gamma(\gamma\gamma)$ $\Gamma_2$

| VALUE (keV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $2.05\pm0.21$ | [53] DAI | 14A | RVUE | Compilation |
| $1.7\pm0.4$ | [54] HOFERICHT... | 11 | RVUE | Compilation |
| $3.08\pm0.82$ | [55] MENNESSIER | 11 | RVUE | Compilation |
| $2.08\pm0.2\ {}^{+0.07}_{-0.04}$ | [56] MOUSSALLAM | 11 | RVUE | Compilation |
| 2.08 | [57] MAO | 09 | RVUE | Compilation |
| $1.2\pm0.4$ | [58] BERNABEU | 08 | RVUE | |
| $3.9\pm0.6$ | [55] MENNESSIER | 08 | RVUE | $\gamma\gamma \to \pi^+\pi^-$, $\pi^0\pi^0$ |
| $1.8\pm0.4$ | [59] OLLER | 08 | RVUE | Compilation |
| $1.68\pm0.15$ | [59,60] OLLER | 08A | RVUE | Compilation |
| $3.1\pm0.5$ | [61,62] PENNINGTON | 08 | RVUE | Compilation |
| $2.4\pm0.4$ | [62,63] PENNINGTON | 08 | RVUE | Compilation |
| $4.1\pm0.3$ | [64] PENNINGTON | 06 | RVUE | $\gamma\gamma \to \pi^0\pi^0$ |
| $3.8\pm1.5$ | [65,66] BOGLIONE | 99 | RVUE | $\gamma\gamma \to \pi^+\pi^-$, $\pi^0\pi^0$ |
| $5.4\pm2.3$ | [65] MORGAN | 90 | RVUE | $\gamma\gamma \to \pi^+\pi^-$, $\pi^0\pi^0$ |
| $10\pm6$ | COURAU | 86 | DM1 | $e^+e^- \to \pi^+\pi^-e^+e^-$ |

[53] Using dispersive analysis with phases from GARCIA-MARTIN 11A and BUETTIKER 04 as input.

[54] Using Roy-Steiner equations with $\pi\pi$ phase shifts from an update of COLANGELO 01 and from GARCIA-MARTIN 11A.

[55] Using an analytic K-matrix model.

[56] Using dispersion integral with phase input from Roy equations and data from MARSISKE 90, BOYER 90, BEHREND 92, UEHARA 08A, and MORI 07.

[57] Used dispersion theory. The value quoted used the $f_0(500)$ pole position of $457 - i276$ MeV.

[58] Using $p$, $n$ polarizabilities from PDG 06 and fitting to $\pi\pi$ phase motion from GARCIA-MARTIN 07 and $\sigma$-poles from GARCIA-MARTIN 07 and CAPRINI 06.

[59] Using twice-subtracted dispersion integrals.

[60] Supersedes OLLER 08.

[61] Solution A (preferred solution based on $\chi^2$-analysis).

[62] Dispersion theory based amplitude analysis of BOYER 90, MARSISKE 90, BEHREND 92, and MORI 07.

[63] Solution B (worse than solution A; still acceptable when systematic uncertainties are included).

[64] Using unitarity and the $\sigma$ pole position from CAPRINI 06.

[65] This width could equally well be assigned to the $f_0(1370)$. The authors analyse data from BOYER 90 and MARSISKE 90 and report strong correlation with $\gamma\gamma$ width of $f_2(1270)$.

[66] Supersedes MORGAN 90.

# $f_0(500)$ REFERENCES


| | | | | |
|---|---|---|---|---|
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| ALBALADEJO | 12 | PR D86 034003 | M. Albaladejo, J.A. Oller | (MURC) |
| GARCIA-MAR... | 11 | PRL 107 072001 | R. Garcia-Martin *et al.* | (MADR, CRAC) |
| GARCIA-MAR... | 11A | PR D83 074004 | R. Garcia-Martin *et al.* | (MADR, CRAC) |
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| MENNESSIER | 11 | PL B696 40 | G. Mennessier, S. Narison, X.-G. Wang | |
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| BATLEY | 08A | EPJ C54 411 | J.R. Batley *et al.* | (CERN NA48/2 Collab.) |
| BERNABEU | 08 | PRL 100 241804 | J. Bernabeu, J. Prades | (IFIC, GRAN) |
| CAPRINI | 08 | PR D77 114019 | I. Caprini | |
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| BONVICINI | 07 | PR D76 012001 | G. Bonvicini *et al.* | (CLEO Collab.) |
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| PISLAK | 03 | PR D67 072004 | S. Pislak *et al.* | (BNL E865 Collab.) |
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| OLLER | 99B | NP A652 407 (erratum) | J.A. Oller, E. Oset | |
| OLLER | 99C | PR D60 074023 | J.A. Oller, E. Oset | |
| ALEKSEEV | 98 | PAN 61 174 | I.G. Alekseev *et al.* | |
| ALEXANDER | 98 | PR D58 052004 | J.P. Alexander *et al.* | (CLEO Collab.) |
| LOCHER | 98 | EPJ C4 317 | M.P. Locher *et al.* | (PSI) |
| TROYAN | 98 | JINRRC 5-91 33 | Yu. Troyan *et al.* | |
| ALDE | 97 | PL B397 350 | D.M. Alde *et al.* | (GAMS Collab.) |
| DOBADO | 97 | PR D56 3057 | A. Dobado, J.R. Pelaez | |
| ISHIDA | 97 | PTP 98 1005 | S. Ishida *et al.* | (TOKY, MIYA, KEK) |
| KAMINSKI | 97B | PL B413 130 | R. Kaminski, L. Lesniak, B. Loiseau | (CRAC, IPN) |
| Also | | PTP 95 745 | S. Ishida *et al.* | (TOKY, MIYA, KEK) |
| SVEC | 96 | PR D53 2343 | M. Svec | (MCGI) |

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|---|---|---|---|---|---|
| TORNQVIST | 96 | PRL 76 1575 | N.A. Tornqvist, M. Roos | (HELS) | |
| ALDE | 95B | ZPHY C66 375 | D.M. Alde *et al.* | (GAMS Collab.) | |
| ANISOVICH | 95 | PL B355 363 | V.V. Anisovich *et al.* | (PNPI, SERP) | |
| JANSSEN | 95 | PR D52 2690 | G. Janssen *et al.* | (STON, ADLD, JULI) | |
| ACHASOV | 94 | PR D49 5779 | N.N. Achasov, G.N. Shestakov | (NOVM) | |
| AMSLER | 94D | PL B333 277 | C. Amsler *et al.* | (Crystal Barrel Collab.) | |
| ANISOVICH | 94 | PL B323 233 | V.V. Anisovich *et al.* | (Crystal Barrel Collab.) | |
| BUTLER | 94B | PR D49 40 | F. Butler *et al.* | (CLEO Collab.) | |
| KAMINSKI | 94 | PR D50 3145 | R. Kaminski, L. Lesniak, J.P. Maillet | (CRAC+) | |
| ZOU | 94B | PR D50 591 | B.S. Zou, D.V. Bugg | (LOQM) | |
| ZOU | 93 | PR D48 3948 | B.S. Zou, D.V. Bugg | (LOQM) | |
| BEHREND | 92 | ZPHY C56 381 | H.J. Behrend | (CELLO Collab.) | |
| ARMSTRONG | 91B | ZPHY C52 389 | T.A. Armstrong *et al.* | (ATHU, BARI, BIRM+) | |
| BOYER | 90 | PR D42 1350 | J. Boyer *et al.* | (Mark II Collab.) | |
| MARSISKE | 90 | PR D41 3324 | H. Marsiske *et al.* | (Crystal Ball Collab.) | |
| MORGAN | 90 | ZPHY C48 623 | D. Morgan, M.R. Pennington | (RAL, DURH) | |
| AUGUSTIN | 89 | NP B320 1 | J.E. Augustin, G. Cosme | (DM2 Collab.) | |
| ASTON | 88 | NP B296 493 | D. Aston *et al.* | (SLAC, NAGO, CINC, INUS) | |
| FALVARD | 88 | PR D38 2706 | A. Falvard *et al.* | (CLER, FRAS, LALO+) | |
| COURAU | 86 | NP B271 1 | A. Courau *et al.* | (CLER, LALO) | |
| VANBEVEREN | 86 | ZPHY C30 615 | E. van Beveren *et al.* | (NIJM, BIEL) | |
| CASON | 83 | PR D28 1586 | N.M. Cason *et al.* | (NDAM, ANL) | |
| ETKIN | 82B | PR D25 1786 | A. Etkin *et al.* | (BNL, CUNY, TUFTS, VAND) | |
| BISWAS | 81 | PRL 47 1378 | N.N. Biswas *et al.* | (NDAM, ANL) | |
| COHEN | 80 | PR D22 2595 | D. Cohen *et al.* | (ANL) | IJP |
| MUKHIN | 80 | JETPL 32 601 | K.N. Mukhin *et al.* | (KIAE) | |
| | | Translated from ZETFP 32 616. | | | |
| CORDEN | 79 | NP B157 250 | M.J. Corden *et al.* | (BIRM, RHEL, TELA+) | JP |
| ESTABROOKS | 79 | PR D19 2678 | P. Estabrooks | (CARL) | |
| FROGGATT | 77 | NP B129 89 | C.D. Froggatt, J.L. Petersen | (GLAS, NORD) | |
| PAWLICKI | 77 | PR D15 3196 | A.J. Pawlicki *et al.* | (ANL) | IJ |
| ROSSELET | 77 | PR D15 574 | L. Rosselet *et al.* | (GEVA, SACL) | |
| CASON | 76 | PRL 36 1485 | N.M. Cason *et al.* | (NDAM, ANL) | IJ |
| ESTABROOKS | 75 | NP B95 322 | P.G. Estabrooks, A.D. Martin | (DURH) | |
| HYAMS | 75 | NP B100 205 | B.D. Hyams *et al.* | (CERN, MPIM) | |
| SRINIVASAN | 75 | PR D12 681 | V. Srinivasan *et al.* | (NDAM, ANL) | |
| ESTABROOKS | 74 | NP B79 301 | P.G. Estabrooks, A.D. Martin | (DURH) | |
| GRAYER | 74 | NP B75 189 | G. Grayer *et al.* | (CERN, MPIM) | |
| ESTABROOKS | 73 | Tallahassee | P.G. Estabrooks *et al.* | (CERN, MPIM) | |
| HYAMS | 73 | NP B64 134 | B.D. Hyams *et al.* | (CERN, MPIM) | |
| OCHS | 73 | Thesis | W. Ochs | (MPIM, MUNI) | |
| PROTOPOP... | 73 | PR D7 1279 | S.D. Protopopescu *et al.* | (LBL) | |
| APEL | 72C | PL 41B 542 | W.D. Apel *et al.* | (KARLK, KARLE, PISA) | |
| BAILLON | 72 | PL 38B 555 | P.H. Baillon *et al.* | (SLAC) | |
| BASDEVANT | 72 | PL 41B 178 | J.L. Basdevant, C.D. Froggatt, J.L. Petersen | (CERN) | |
| BEIER | 72B | PRL 29 511 | E.W. Beier *et al.* | (PENN) | |
| BENSINGER | 71 | PL 36B 134 | J.R. Bensinger *et al.* | (WISC) | |
| COLTON | 71 | PR D3 2028 | E.P. Colton *et al.* | (LBL, FNAL, UCLA+) | |
| ROY | 71 | PL 36B 353 | S.M. Roy | | |
| BATON | 70 | PL 33B 528 | J.P. Baton, G. Laurens, J. Reignier | (SACL) | |
| WALKER | 67 | RMP 39 695 | W.D. Walker | (WISC) | |