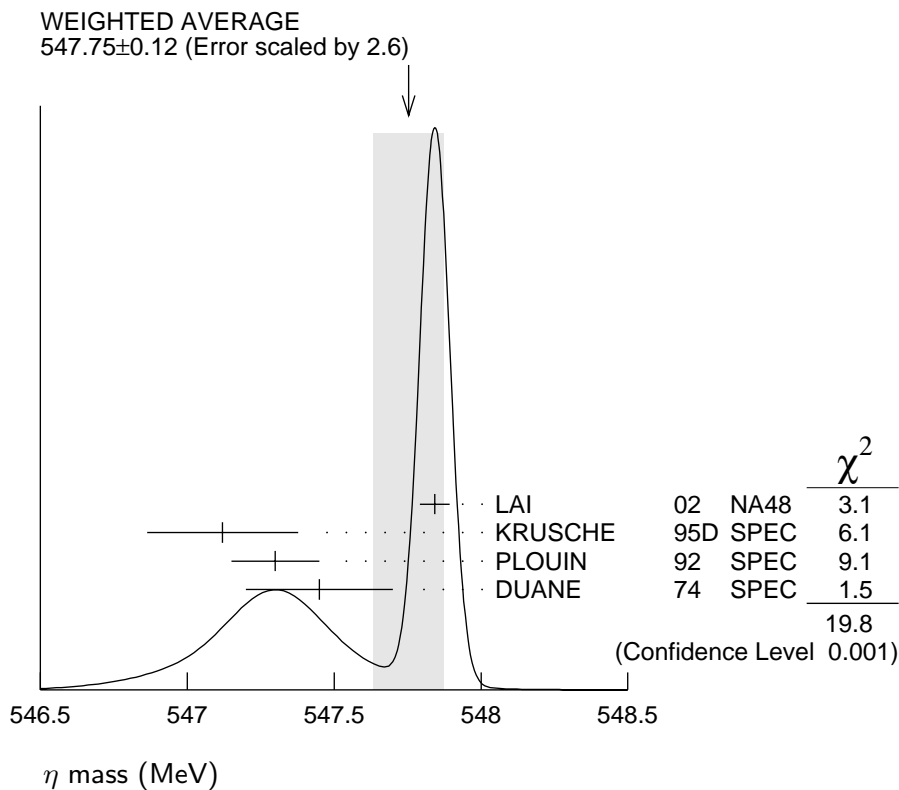$\boxed{\eta}$ $\qquad\qquad\qquad$ $I^G(J^{PC}) = 0^+(0^{-+})$

We have omitted some results that have been superseded by later experiments. The omitted results may be found in our 1988 edition Physics Letters **B204** (1988).

## η MASS

We no longer use the bubble-chamber measurements from the 1960's, which seem to have been systematically high by about 1 MeV. (However, note that the latest measurement is midway between those old values and the newer ones.) Some early results have been omitted altogether.

| VALUE (MeV) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **547.75 ±0.12 OUR AVERAGE** | | | | | Error includes scale factor of 2.6. See the ideogram below. |
| 547.843±0.030±0.041 | 1134 | LAI | 02 | NA48 | $\eta \to 3\pi^0$ |
| 547.12 ±0.06 ±0.25 | | KRUSCHE | 95D | SPEC | $\gamma p \to \eta p$, threshold |
| 547.30 ±0.15 | | PLOUIN | 92 | SPEC | $d p \to \eta\,^3$He |
| 547.45 ±0.25 | | DUANE | 74 | SPEC | $\pi^- p \to n$ neutrals |

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

| | | | | | |
|---|---|---|---|---|---|
| 548.2 ±0.65 | | FOSTER | 65C | HBC | |
| 549.0 ±0.7 | 148 | FOELSCHE | 64 | HBC | |
| 548.0 ±1.0 | 91 | ALFF-... | 62 | HBC | |
| 549.0 ±1.2 | 53 | BASTIEN | 62 | HBC | |

WEIGHTED AVERAGE
547.75±0.12 (Error scaled by 2.6)

| | | | $\chi^2$ |
|---|---|---|---|
| LAI | 02 | NA48 | 3.1 |
| KRUSCHE | 95D | SPEC | 6.1 |
| PLOUIN | 92 | SPEC | 9.1 |
| DUANE | 74 | SPEC | 1.5 |
| | | | 19.8 |

(Confidence Level 0.001)

η mass (MeV)

# $\eta$ WIDTH

This is the partial decay rate $\Gamma(\eta \to \gamma\gamma)$ divided by the fitted branching fraction for that mode. See the note at the start of the $\Gamma(2\gamma)$ data block, next below.

| VALUE (keV) | DOCUMENT ID |
|---|---|
| **1.29±0.07 OUR FIT** | |

# $\eta$ DECAY MODES

| | Mode | | Fraction ($\Gamma_i/\Gamma$) | Scale factor/ Confidence level |
|---|---|---|---|---|
| **Neutral modes** | | | | |
| $\Gamma_1$ | neutral modes | | $(72.0 \pm 0.5)\%$ | S=1.3 |
| $\Gamma_2$ | $2\gamma$ | [a] | $(39.42 \pm 0.26)\%$ | S=1.2 |
| $\Gamma_3$ | $3\pi^0$ | | $(32.56 \pm 0.28)\%$ | S=1.2 |
| $\Gamma_4$ | $\pi^0 2\gamma$ | | $(4.0 \pm 1.9) \times 10^{-4}$ | S=2.3 |
| $\Gamma_5$ | other neutral modes | | $< 2.8\%$ | CL=90% |
| **Charged modes** | | | | |
| $\Gamma_6$ | charged modes | | $(28.0 \pm 0.5)\%$ | S=1.3 |
| $\Gamma_7$ | $\pi^+\pi^-\pi^0$ | | $(22.6 \pm 0.4)\%$ | S=1.3 |
| $\Gamma_8$ | $\pi^+\pi^-\gamma$ | | $(4.68 \pm 0.11)\%$ | S=1.2 |
| $\Gamma_9$ | $e^+e^-\gamma$ | | $(6.0 \pm 0.8) \times 10^{-3}$ | S=1.4 |
| $\Gamma_{10}$ | $\mu^+\mu^-\gamma$ | | $(3.1 \pm 0.4) \times 10^{-4}$ | |
| $\Gamma_{11}$ | $e^+e^-$ | | $< 7.7 \times 10^{-5}$ | CL=90% |
| $\Gamma_{12}$ | $\mu^+\mu^-$ | | $(5.8 \pm 0.8) \times 10^{-6}$ | |
| $\Gamma_{13}$ | $e^+e^-e^+e^-$ | | $< 6.9 \times 10^{-5}$ | CL=90% |
| $\Gamma_{14}$ | $\pi^+\pi^-e^+e^-$ | | $(4.0 \, ^{+11.0}_{-2.7}) \times 10^{-4}$ | S=4.3 |
| $\Gamma_{15}$ | $\pi^+\pi^-2\gamma$ | | $< 2.0 \times 10^{-3}$ | |
| $\Gamma_{16}$ | $\pi^+\pi^-\pi^0\gamma$ | | $< 5 \times 10^{-4}$ | CL=90% |
| $\Gamma_{17}$ | $\pi^0\mu^+\mu^-\gamma$ | | $< 3 \times 10^{-6}$ | CL=90% |

## Charge conjugation ($C$), Parity ($P$), Charge conjugation × Parity ($CP$), or Lepton Family number ($LF$) violating modes

| | Mode | | | Fraction ($\Gamma_i/\Gamma$) | Confidence level |
|---|---|---|---|---|---|
| $\Gamma_{18}$ | $\pi^+\pi^-$ | $P,CP$ | | $< 3.3 \times 10^{-4}$ | CL=90% |
| $\Gamma_{19}$ | $\pi^0\pi^0$ | $P,CP$ | | $< 4.3 \times 10^{-4}$ | CL=90% |
| $\Gamma_{20}$ | $3\gamma$ | $C$ | | $< 1.6 \times 10^{-5}$ | CL=90% |
| $\Gamma_{21}$ | $4\pi^0$ | $P,CP$ | | $< 6.9 \times 10^{-7}$ | CL=90% |
| $\Gamma_{22}$ | $\pi^0 e^+e^-$ | $C$ | [b] | $< 4 \times 10^{-5}$ | CL=90% |
| $\Gamma_{23}$ | $\pi^0\mu^+\mu^-$ | $C$ | [b] | $< 5 \times 10^{-6}$ | CL=90% |
| $\Gamma_{24}$ | $\mu^+e^- + \mu^-e^+$ | $LF$ | | $< 6 \times 10^{-6}$ | CL=90% |

[a] Due to removing an old measurement from the average, this is 0.11 keV
larger than the width we gave in our 2002 edition, $1.18 \pm 0.11$ keV. See
the $\Gamma(2\gamma)$ data block in the Data Listings.

[b] $C$ parity forbids this to occur as a single-photon process.

## CONSTRAINED FIT INFORMATION

An overall fit to a decay rate and 19 branching ratios uses 41
measurements and one constraint to determine 9 parameters. The
overall fit has a $\chi^2 = 22.5$ for 33 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, $x_i \equiv \Gamma_i / \Gamma_{total}$. The fit constrains the $x_i$ whose labels appear in this array to sum to
one.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $x_3$ | 48 | | | | | | | |
| $x_4$ | 0 | 0 | | | | | | |
| $x_7$ | −81 | −83 | −4 | | | | | |
| $x_8$ | −64 | −67 | −3 | 67 | | | | |
| $x_9$ | −8 | −8 | 0 | −7 | −6 | | | |
| $x_{10}$ | 0 | 0 | 0 | −1 | 0 | 0 | | |
| $x_{14}$ | −5 | −6 | 0 | −13 | −10 | −1 | 0 | |
| $\Gamma$ | −13 | −6 | 0 | 10 | 8 | 1 | 0 | 1 |
| | $x_2$ | $x_3$ | $x_4$ | $x_7$ | $x_8$ | $x_9$ | $x_{10}$ | $x_{14}$ |

| | Mode | Rate (keV) | Scale factor |
|---|---|---|---|
| $\Gamma_2$ | $2\gamma$ | [a] $0.510 \pm 0.026$ | |
| $\Gamma_3$ | $3\pi^0$ | $0.422 \pm 0.022$ | |
| $\Gamma_4$ | $\pi^0 2\gamma$ | $(5.2 \pm 2.5) \times 10^{-4}$ | 2.3 |
| $\Gamma_7$ | $\pi^+ \pi^- \pi^0$ | $0.293 \pm 0.016$ | |
| $\Gamma_8$ | $\pi^+ \pi^- \gamma$ | $0.0606 \pm 0.0035$ | |
| $\Gamma_9$ | $e^+ e^- \gamma$ | $0.0078 \pm 0.0011$ | 1.3 |
| $\Gamma_{10}$ | $\mu^+ \mu^- \gamma$ | $(4.0 \pm 0.6) \times 10^{-4}$ | |
| $\Gamma_{14}$ | $\pi^+ \pi^- e^+ e^-$ | $(0.52 {}^{+1.40}_{-0.35}) \times 10^{-3}$ | 4.3 |

## $\eta$ DECAY RATES

### $\Gamma(2\gamma)$ $\qquad\qquad$ $\Gamma_2$

See the table immediately above giving the fitted decay rates. Following the advice of
NEFKENS 02, we have removed the Primakoff-effect measurement from the average.
See also the "Note on the Decay Width $\Gamma(\eta \rightarrow \gamma\gamma)$," in our 1994 edition, Phys. Rev.
**D50**, 1 August 1994, Part I, p. 1451, for a discussion of the various measurements.

| VALUE (keV) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.510±0.026 OUR FIT** | | | | | |
| **0.510±0.026 OUR AVERAGE** | | | | | |
| 0.51 ±0.12 ±0.05 | 36 | BARU | 90 | MD1 | $e^+e^- \to e^+e^-\eta$ |
| 0.490±0.010±0.048 | 2287 | ROE | 90 | ASP | $e^+e^- \to e^+e^-\eta$ |
| 0.514±0.017±0.035 | 1295 | WILLIAMS | 88 | CBAL | $e^+e^- \to e^+e^-\eta$ |
| 0.53 ±0.04 ±0.04 | | BARTEL | 85E | JADE | $e^+e^- \to e^+e^-\eta$ |

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

| | | | | | |
|---|---|---|---|---|---|
| 0.64 ±0.14 ±0.13 | | AIHARA | 86 | TPC | $e^+e^- \to e^+e^-\eta$ |
| 0.56 ±0.16 | 56 | WEINSTEIN | 83 | CBAL | $e^+e^- \to e^+e^-\eta$ |
| 0.324±0.046 | | BROWMAN | 74B | CNTR | Primakoff effect |
| 1.00 ±0.22 | | [1] BEMPORAD | 67 | CNTR | Primakoff effect |

[1] BEMPORAD 67 gives $\Gamma(2\gamma) = 1.21 \pm 0.26$ keV assuming $\Gamma(2\gamma)/\Gamma(\text{total}) = 0.314$. Bemporad private communication gives $\Gamma(2\gamma)^2/\Gamma(\text{total}) = 0.380 \pm 0.083$. We evaluate this using $\Gamma(2\gamma)/\Gamma(\text{total}) = 0.38 \pm 0.01$. Not included in average because the uncertainty resulting from the separation of the coulomb and nuclear amplitudes has apparently been underestimated.

## $\eta$ BRANCHING RATIOS

### ——— Neutral modes ———

### $\Gamma(\text{neutral modes})/\Gamma_{\text{total}}$ $\qquad\qquad \Gamma_1/\Gamma = (\Gamma_2+\Gamma_3+\Gamma_4)/\Gamma$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.720±0.005 OUR FIT** Error includes scale factor of 1.3. | | | | | |
| **0.705±0.008** | 16k | BASILE | 71D | CNTR | MM spectrometer |

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

| | | | | | |
|---|---|---|---|---|---|
| 0.79 ±0.08 | | BUNIATOV | 67 | OSPK | |

### $\Gamma(2\gamma)/\Gamma_{\text{total}}$ $\qquad\qquad\qquad\qquad\qquad\qquad\qquad \Gamma_2/\Gamma$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.3942±0.0026 OUR FIT** Error includes scale factor of 1.2. | | | | | |
| **0.3949±0.0017±0.0030** | 65k | ABEGG | 96 | SPEC | $pd \to {}^3\text{He}\eta$ |

### $\Gamma(2\gamma)/\Gamma(\text{neutral modes})$ $\qquad\qquad \Gamma_2/\Gamma_1 = \Gamma_2/(\Gamma_2+\Gamma_3+\Gamma_4)$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.5474±0.0020 OUR FIT** | | | | | |
| **0.548 ±0.023 OUR AVERAGE** Error includes scale factor of 1.5. | | | | | |
| 0.535 ±0.018 | | BUTTRAM | 70 | OSPK | |
| 0.59 ±0.033 | | BUNIATOV | 67 | OSPK | |

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

| | | | | | |
|---|---|---|---|---|---|
| 0.52 ±0.09 | 88 | ABROSIMOV | 80 | HLBC | |
| 0.60 ±0.14 | 113 | KENDALL | 74 | OSPK | |
| 0.57 ±0.09 | | STRUGALSKI | 71 | HLBC | |
| 0.579 ±0.052 | | FELDMAN | 67 | OSPK | |
| 0.416 ±0.044 | | DIGIUGNO | 66 | CNTR | Error doubled |
| 0.44 ±0.07 | | GRUNHAUS | 66 | OSPK | |
| 0.39 ±0.06 | | [2] JONES | 66 | CNTR | |

[2] This result from combining cross sections from two different experiments.

## $\Gamma(3\pi^0)/\Gamma(\text{neutral modes})$ $\qquad$ $\Gamma_3/\Gamma_1 = \Gamma_3/(\Gamma_2+\Gamma_3+\Gamma_4)$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.4521±0.0020 OUR FIT** | | | | | |
| **0.439 ±0.024** | | BUTTRAM | 70 | OSPK | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.44 ±0.08 | 75 | ABROSIMOV | 80 | HLBC | |
| 0.32 ±0.09 | | STRUGALSKI | 71 | HLBC | |
| 0.41 ±0.033 | | BUNIATOV | 67 | OSPK | Not indep. of $\Gamma(2\gamma)/$ $\Gamma(\text{neutral modes})$ |
| 0.177 ±0.035 | | FELDMAN | 67 | OSPK | |
| 0.209 ±0.054 | | DIGIUGNO | 66 | CNTR | Error doubled |
| 0.29 ±0.10 | | GRUNHAUS | 66 | OSPK | |

## $\Gamma(3\pi^0)/\Gamma(2\gamma)$ $\qquad$ $\Gamma_3/\Gamma_2$

| VALUE | DOCUMENT ID | | TECN | CHG | COMMENT |
|---|---|---|---|---|---|
| **0.826±0.007 OUR FIT** | | | | | |
| **0.826±0.007 OUR AVERAGE** | | | | | |
| 0.826±0.024 | ACHASOV | 00D | SND | | $e^+e^- \to \phi \to$ $\eta\gamma$ |
| 0.832±0.005±0.012 | KRUSCHE | 95D | SPEC | | $\gamma p \to \eta p$, threshold |
| 0.841±0.034 | AMSLER | 93 | CBAR | | $\overline{p}p \to \pi^+\pi^-\eta$ at rest |
| 0.822±0.009 | ALDE | 84 | GAM2 | 0 | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.796±0.016±0.016 | ACHASOV | 00 | SND | | See ACHASOV 00D |
| 0.91 ±0.14 | COX | 70B | HBC | | |
| 0.75 ±0.09 | DEVONS | 70 | OSPK | | |
| 0.88 ±0.16 | BALTAY | 67D | DBC | | |
| 1.1 ±0.2 | CENCE | 67 | OSPK | | |
| 1.25 ±0.39 | BACCI | 63 | CNTR | | Inverse BR reported |

## $\Gamma(\pi^0 2\gamma)/\Gamma(2\gamma)$ $\qquad$ $\Gamma_4/\Gamma_2$

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN | CHG | COMMENT |
|---|---|---|---|---|---|---|
| **1.0±0.5 OUR FIT** Error includes scale factor of 2.3. | | | | | | |
| **1.8±0.4** | | [3] ALDE | 84 | GAM2 | 0 | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| 2.5±0.6 | 70 | BINON | 82 | GAM2 | | See ALDE 84 |

[3] The measurement of $\Gamma_4/\Gamma_3$ by KNECHT 04 implies a lower value of $\Gamma_4$ than the result from ALDE 84.

## $\Gamma(\pi^0 2\gamma)/\Gamma_{\text{total}}$ $\qquad$ $\Gamma_4/\Gamma$

Early results are summarized in the review by LANDSBERG 85.

| VALUE (units $10^{-4}$) | CL% | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **4.0±1.9 OUR FIT** Error includes scale factor of 2.3. | | | | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| < 8.4 | 90 | 7 | ACHASOV | 01D | SND | $e^+e^- \to \phi \to \eta\gamma$ |
| <30 | 90 | 0 | DAVYDOV | 81 | GAM2 | $\pi^- p \to \eta n$ |

## $\Gamma(\pi^0 2\gamma)/\Gamma(3\pi^0)$ $\qquad$ $\Gamma_4/\Gamma_3$

| VALUE (units $10^{-4}$) | DOCUMENT ID | TECN | COMMENT |
|---|---|---|---|
| **12 ±6 OUR FIT** Error includes scale factor of 2.3. | | | |
| **8.3±2.8±1.4** | [4] KNECHT 04 | CRYB | $\pi^- p \to n\eta$ |

[4] The value of $\Gamma_4$ implied by KNECHT 04 is lower than the one obtained by ALDE 84 from $\Gamma_4/\Gamma_2$.

## $\Gamma(\text{neutral modes})/\left[\Gamma(\pi^+\pi^-\pi^0) + \Gamma(\pi^+\pi^-\gamma) + \Gamma(e^+e^-\gamma)\right]$
### $\Gamma_1/(\Gamma_7+\Gamma_8+\Gamma_9) = (\Gamma_2+\Gamma_3+\Gamma_4)/(\Gamma_7+\Gamma_8+\Gamma_9)$

| VALUE | EVTS | DOCUMENT ID | TECN |
|---|---|---|---|
| **2.58±0.06 OUR FIT** Error includes scale factor of 1.3. | | | |
| **2.64±0.23** | | BALTAY 67B | DBC |

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

| | | | |
|---|---|---|---|
| 4.5 ±1.0 | 280 | [5] JAMES 66 | HBC |
| 3.20±1.26 | 53 | [5] BASTIEN 62 | HBC |
| 2.5 ±1.0 | 10 | [5] PICKUP 62 | HBC |

[5] These experiments are not used in the averages as they do not separate clearly $\eta \to \pi^+\pi^-\pi^0$ and $\eta \to \pi^+\pi^-\gamma$ from each other. The reported values thus probably contain some unknown fraction of $\eta \to \pi^+\pi^-\gamma$.

## $\Gamma(\text{neutral modes})/\Gamma(\pi^+\pi^-\pi^0)$ $\qquad$ $\Gamma_1/\Gamma_7 = (\Gamma_2+\Gamma_3+\Gamma_4)/\Gamma_7$

| VALUE | EVTS | DOCUMENT ID | TECN |
|---|---|---|---|
| **3.18±0.08 OUR FIT** Error includes scale factor of 1.3. | | | |
| **3.26±0.30 OUR AVERAGE** | | | |
| 2.54±1.89 | 74 | KENDALL 74 | OSPK |
| 3.4 ±1.1 | 29 | AGUILAR-... 72B | HBC |
| 2.83±0.80 | 70 | [6] BLOODWO... 72B | HBC |
| 3.6 ±0.6 | 244 | FLATTE 67B | HBC |
| 2.89±0.56 | | ALFF-... 66 | HBC |
| 3.6 ±0.8 | 50 | KRAEMER 64 | DBC |
| 3.8 ±1.1 | | PAULI 64 | DBC |

[6] Error increased from published value 0.5 by Bloodworth (private communication).

## $\Gamma(2\gamma)/\left[\Gamma(\pi^+\pi^-\pi^0) + \Gamma(\pi^+\pi^-\gamma) + \Gamma(e^+e^-\gamma)\right]$ $\qquad$ $\Gamma_2/(\Gamma_7+\Gamma_8+\Gamma_9)$

| VALUE | EVTS | DOCUMENT ID | TECN |
|---|---|---|---|
| **1.412±0.033 OUR FIT** Error includes scale factor of 1.3. | | | |
| **1.1 ±0.4 OUR AVERAGE** | | | |
| 1.51 ±0.93 | 75 | KENDALL 74 | OSPK |
| 0.99 ±0.48 | | CRAWFORD 63 | HBC |

## $\Gamma(2\gamma)/\Gamma(\pi^+\pi^-\pi^0)$ $\qquad$ $\Gamma_2/\Gamma_7$

| VALUE | EVTS | DOCUMENT ID | TECN | COMMENT |
|---|---|---|---|---|
| **1.74±0.04 OUR FIT** Error includes scale factor of 1.3. | | | | |
| **1.75±0.13 OUR AVERAGE** | | | | |
| 1.78±0.10±0.13 | 1077 | AMSLER 95 | CBAR | $\overline{p}p \to \pi^+\pi^-\eta$ at rest |
| 1.72±0.25 | 401 | BAGLIN 69 | HLBC | |
| 1.61±0.39 | | FOSTER 65 | HBC | |

## $\Gamma(3\pi^0)/\Gamma(\pi^+\pi^-\pi^0)$  $\Gamma_3/\Gamma_7$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **1.44±0.04 OUR FIT** | Error includes scale factor of 1.3. | | | | |
| **1.49±0.06 OUR AVERAGE** | | | | | |
| 1.52±0.04±0.08 | 23k | [7] AKHMETSHIN | 01B | CMD2 | $e^+e^- \to \phi \to \eta\gamma$ |
| 1.44±0.09±0.10 | 1627 | AMSLER | 95 | CBAR | $\overline{p}p \to \pi^+\pi^-\eta$ at rest |
| $1.50^{+0.15}_{-0.29}$ | 199 | BAGLIN | 69 | HLBC | |
| $1.47^{+0.20}_{-0.17}$ | | BULLOCK | 68 | HLBC | |

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

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| 1.3 ±0.4 | | BAGLIN | 67B | HLBC | |
| 0.90±0.24 | | FOSTER | 65 | HBC | |
| 2.0 ±1.0 | | FOELSCHE | 64 | HBC | |
| 0.83±0.32 | | CRAWFORD | 63 | HBC | |

[7] AKHMETSHIN 01B uses results from AKHMETSHIN 99F.

## $\Gamma(\text{other neutral modes})/\Gamma_{\text{total}}$  $\Gamma_5/\Gamma$

These are neutral modes other than $\gamma\gamma$, $3\pi^0$, and $\pi^0\gamma\gamma$. Nearly any such mode one can think of would violate $P$, or $C$, or both.

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<0.028** | 90 | ABEGG | 96 | SPEC | $pd \to {}^3\text{He}\eta$ |

—————— **Charged modes** ——————

## $\Gamma(\pi^+\pi^-\pi^0)/[\Gamma(2\gamma)+\Gamma(3\pi^0)]$  $\Gamma_7/(\Gamma_2+\Gamma_3)$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.314 ±0.007 OUR FIT** | Error includes scale factor of 1.3. | | | |
| **0.304 ±0.012** | ACHASOV | 00D | SND | $e^+e^- \to \phi \to \eta\gamma$ |

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

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| 0.3141±0.0081±0.0058 | ACHASOV | 00B | SND | See ACHASOV 00D |

## $\Gamma(\pi^+\pi^-\gamma)/\Gamma(\pi^+\pi^-\pi^0)$  $\Gamma_8/\Gamma_7$

| VALUE | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **0.207±0.004 OUR FIT** | Error includes scale factor of 1.1. | | | |
| **0.207±0.004 OUR AVERAGE** | Error includes scale factor of 1.1. | | | |
| 0.209±0.004 | 18k | THALER | 73 | ASPK |
| 0.201±0.006 | 7250 | GORMLEY | 70 | ASPK |

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

| VALUE | DOCUMENT ID | | TECN |
|---|---|---|---|
| 0.28 ±0.04 | BALTAY | 67B | DBC |
| 0.25 ±0.035 | LITCHFIELD | 67 | DBC |
| 0.30 ±0.06 | CRAWFORD | 66 | HBC |
| 0.196±0.041 | FOSTER | 65C | HBC |

## $\Gamma(e^+e^-\gamma)/\Gamma_{\text{total}}$  $\Gamma_9/\Gamma$

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **6.0 ±0.8 OUR FIT** | Error includes scale factor of 1.4. | | | | |
| **6.3 ±1.0 OUR AVERAGE** | Error includes scale factor of 1.6. | | | | |
| 5.15±0.62±0.74 | 283 | ACHASOV | 01B | SND | $e^+e^- \to \phi \to \eta\gamma$ |
| 7.10±0.64±0.46 | 323 | AKHMETSHIN | 01 | CMD2 | $e^+e^- \to \phi \to \eta\gamma$ |

## $\Gamma(e^+ e^- \gamma)/\Gamma(\pi^+ \pi^- \pi^0)$ $\qquad$ $\Gamma_9/\Gamma_7$

| VALUE (units $10^{-2}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **2.65±0.35 OUR FIT** | Error includes scale factor of 1.5. | | | | |
| **2.1 ±0.5** | 80 | JANE | 75B | OSPK | See the erratum |

## $\Gamma(\mu^+ \mu^- \gamma)/\Gamma_{\text{total}}$ $\qquad$ $\Gamma_{10}/\Gamma$

| VALUE (units $10^{-4}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **3.1±0.4 OUR FIT** | | | | | |
| **3.1±0.4** | 600 | DZHELYADIN | 80 | SPEC | $\pi^- p \to \eta n$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 1.5±0.75 | 100 | BUSHNIN | 78 | SPEC | See DZHELYADIN 80 |

## $\Gamma(e^+ e^-)/\Gamma_{\text{total}}$ $\qquad$ $\Gamma_{11}/\Gamma$

| VALUE (units $10^{-4}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<0.77** | 90 | BROWDER | 97B | CLE2 | $e^+ e^- \simeq$ 10.5 GeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <2 | 90 | WHITE | 96 | SPEC | $pd \to \eta ^3\text{He}$ |
| <3 | 90 | DAVIES | 74 | RVUE | Uses ESTEN 67 |

## $\Gamma(\mu^+ \mu^-)/\Gamma_{\text{total}}$ $\qquad$ $\Gamma_{12}/\Gamma$

| VALUE (units $10^{-6}$) | CL% | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **5.8±0.8 OUR AVERAGE** | | | | | | |
| 5.7±0.7±0.5 | | 114 | ABEGG | 94 | SPEC | $pd \to \eta ^3\text{He}$ |
| 6.5±2.1 | | 27 | DZHELYADIN | 80B | SPEC | $\pi^- p \to \eta n$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| $5.6^{+0.6}_{-0.7}$±0.5 | | 100 | KESSLER | 93 | SPEC | See ABEGG 94 |
| <20 | 95 | 0 | WEHMANN | 68 | OSPK | |

## $\Gamma(\mu^+ \mu^-)/\Gamma(2\gamma)$ $\qquad$ $\Gamma_{12}/\Gamma_2$

| VALUE (units $10^{-5}$) | DOCUMENT ID | | TECN |
|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | |
| 5.9±2.2 | HYAMS | 69 | OSPK |

## $\Gamma(e^+ e^- e^+ e^-)/\Gamma_{\text{total}}$ $\qquad$ $\Gamma_{13}/\Gamma$

| VALUE (units $10^{-5}$) | CL% | DOCUMENT ID | TECN | COMMENT |
|---|---|---|---|---|
| **<6.9** | 90 | AKHMETSHIN 01 | CMD2 | $e^+ e^- \to \phi \to \eta \gamma$ |

## $\Gamma(\pi^+ \pi^- e^+ e^-)/\Gamma(\pi^+ \pi^- \gamma)$ $\qquad$ $\Gamma_{14}/\Gamma_8$

| VALUE (units $10^{-2}$) | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **$0.9^{+2.3}_{-0.6}$ OUR FIT** | Error includes scale factor of 4.4. | | | |
| **2.6±2.6** | 1 | GROSSMAN | 66 | HBC |

## $\Gamma(\pi^+\pi^- e^+ e^-)/\Gamma_{total}$ $\qquad$ $\Gamma_{14}/\Gamma$

| VALUE (units $10^{-4}$) | EVTS | DOCUMENT ID | TECN | COMMENT |
|---|---|---|---|---|
| $4.0^{+11.0}_{-2.7}$ **OUR FIT** | Error includes scale factor of 4.3. | | | |
| $3.7^{+2.5}_{-1.8}\pm0.3$ | 4 | AKHMETSHIN 01 | CMD2 | $e^+e^- \to \phi \to \eta\gamma$ |

## $\Gamma(\pi^+\pi^- 2\gamma)/\Gamma(\pi^+\pi^- \pi^0)$ $\qquad$ $\Gamma_{15}/\Gamma_7$

| VALUE | CL% | DOCUMENT ID | TECN |
|---|---|---|---|
| **<0.009** | | PRICE | 67 HBC |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | |
| <0.016 | 95 | BALTAY | 67B DBC |

## $\Gamma(\pi^+\pi^- \pi^0\gamma)/\Gamma(\pi^+\pi^- \pi^0)$ $\qquad$ $\Gamma_{16}/\Gamma_7$

| VALUE (units $10^{-2}$) | CL% | EVTS | DOCUMENT ID | TECN |
|---|---|---|---|---|
| **<0.24** | 90 | 0 | THALER | 73 ASPK |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| <1.7 | 90 | | ARNOLD | 68 HLBC |
| <1.6 | 95 | | BALTAY | 67B DBC |
| <7.0 | | | FLATTE | 67 HBC |
| <0.9 | | | PRICE | 67 HBC |

## $\Gamma(\pi^0\mu^+\mu^-\gamma)/\Gamma_{total}$ $\qquad$ $\Gamma_{17}/\Gamma$

| VALUE (units $10^{-6}$) | CL% | DOCUMENT ID | TECN | COMMENT |
|---|---|---|---|---|
| **<3** | 90 | DZHELYADIN 81 | SPEC | $\pi^- p \to \eta n$ |

——————— **Rare or forbidden modes** ———————

## $\Gamma(\pi^+\pi^-)/\Gamma_{total}$ $\qquad$ $\Gamma_{18}/\Gamma$

Forbidden by $P$ and $CP$ invariance.

| VALUE (units $10^{-4}$) | CL% | EVTS | DOCUMENT ID | TECN | COMMENT |
|---|---|---|---|---|---|
| **< 3.3** | 90 | | AKHMETSHIN 99B | CMD2 | $e^+e^- \to \phi \to \eta\gamma$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| < 9 | 90 | | AKHMETSHIN 97C | CMD2 | See AKHMETSHIN 99B |
| <15 | | 0 | THALER | 73 ASPK | |

## $\Gamma(\pi^0\pi^0)/\Gamma_{total}$ $\qquad$ $\Gamma_{19}/\Gamma$

Forbidden by $P$ and $CP$ invariance.

| VALUE (units $10^{-4}$) | CL% | DOCUMENT ID | TECN | COMMENT |
|---|---|---|---|---|
| **<4.3** | 90 | AKHMETSHIN 99C | CMD2 | $e^+e^- \to \phi \to \eta\gamma$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| <6 | 90 | [8] ACHASOV | 98 SND | $e^+e^- \to \phi \to \eta\gamma$ |

[8] ACHASOV 98 observes one event in a $\pm3\sigma$ region around the $\eta$ mass, while a Monte Carlo calculation gives $10 \pm 5$ events. The limit here is the Poisson upper limit for one observed event and no background.

## $\Gamma(4\pi^0)/\Gamma_{total}$  $\Gamma_{21}/\Gamma$

Forbidden by $P$ and $CP$ invariance.

| VALUE (units $10^{-7}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<6.9** | 90 | PRAKHOV | 00 | CRYB | $\pi^- p \to n\eta$, 720 MeV/$c$ |

## $\Gamma(3\gamma)/\Gamma(2\gamma)$  $\Gamma_{20}/\Gamma_2$

| VALUE (units $10^{-3}$) | CL% | DOCUMENT ID | | TECN | CHG |
|---|---|---|---|---|---|
| <1.2 | 95 | ALDE | 84 | GAM2 | 0 |

## $\Gamma(3\gamma)/\Gamma(3\pi^0)$  $\Gamma_{20}/\Gamma_3$

| VALUE (units $10^{-5}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<4.9** | 90 | ALOISIO | 04 | KLOE | $\phi \to \eta\gamma$ |

## $\Gamma(\pi^0 e^+ e^-)/\Gamma(\pi^+\pi^-\pi^0)$  $\Gamma_{22}/\Gamma_7$

$C$ parity forbids this to occur as a single-photon process.

| VALUE (units $10^{-4}$) | CL% | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|
| **< 1.9** | 90 | | JANE | 75 | OSPK |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| < 42 | 90 | | BAGLIN | 67 | HLBC |
| < 16 | 90 | 0 | BILLING | 67 | HLBC |
| < 77 | | 0 | FOSTER | 65B | HBC |
| <110 | | | PRICE | 65 | HBC |

## $\Gamma(\pi^0 e^+ e^-)/\Gamma_{total}$  $\Gamma_{22}/\Gamma$

$C$ parity forbids this to occur as a single-photon process.

| VALUE (units $10^{-2}$) | CL% | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <0.016 | 90 | 0 | MARTYNOV | 76 | HLBC |
| <0.084 | 90 | | BAZIN | 68 | DBC |
| <0.7 | | | RITTENBERG | 65 | HBC |

## $\Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_{total}$  $\Gamma_{23}/\Gamma$

$C$ parity forbids this to occur as a single-photon process.

| VALUE (units $10^{-4}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<0.05** | 90 | DZHELYADIN | 81 | SPEC | $\pi^- p \to \eta n$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <5 | | WEHMANN | 68 | OSPK | |

## $\left[\Gamma(\mu^+ e^-) + \Gamma(\mu^- e^+)\right]/\Gamma_{total}$  $\Gamma_{24}/\Gamma$

Forbidden by lepton family number conservation.

| VALUE (units $10^{-6}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<6** | 90 | WHITE | 96 | SPEC | $pd \to \eta\,^3$He |

# $\eta$ C-NONCONSERVING DECAY PARAMETERS

## $\pi^+\pi^-\pi^0$ LEFT-RIGHT ASYMMETRY PARAMETER

Measurements with an error $> 1.0 \times 10^{-2}$ have been omitted.

| VALUE (units $10^{-2}$) | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **0.09±0.17 OUR AVERAGE** | | | | |
| 0.28±0.26 | 165k | JANE | 74 | OSPK |
| −0.05±0.22 | 220k | LAYTER | 72 | ASPK |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 1.5 ±0.5 | 37k | [9] GORMLEY | 68C | ASPK |

[9] The GORMLEY 68C asymmetry is probably due to unmeasured ($\mathbf{E} \times \mathbf{B}$) spark chamber effects. New experiments with ($\mathbf{E} \times \mathbf{B}$) controls don't observe an asymmetry.

## $\pi^+\pi^-\pi^0$ SEXTANT ASYMMETRY PARAMETER

Measurements with an error $> 2.0 \times 10^{-2}$ have been omitted.

| VALUE (units $10^{-2}$) | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **0.18±0.16 OUR AVERAGE** | | | | |
| 0.20±0.25 | 165k | JANE | 74 | OSPK |
| 0.10±0.22 | 220k | LAYTER | 72 | ASPK |
| 0.5 ±0.5 | 37k | GORMLEY | 68C | WIRE |

## $\pi^+\pi^-\pi^0$ QUADRANT ASYMMETRY PARAMETER

| VALUE (units $10^{-2}$) | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **−0.17±0.17 OUR AVERAGE** | | | | |
| −0.30±0.25 | 165k | JANE | 74 | OSPK |
| −0.07±0.22 | 220k | LAYTER | 72 | ASPK |

## $\pi^+\pi^-\gamma$ LEFT-RIGHT ASYMMETRY PARAMETER

Measurements with an error $> 2.0 \times 10^{-2}$ have been omitted.

| VALUE (units $10^{-2}$) | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **0.9 ±0.4 OUR AVERAGE** | | | | |
| 1.2 ±0.6 | 35k | JANE | 74B | OSPK |
| 0.5 ±0.6 | 36k | THALER | 72 | ASPK |
| 1.22±1.56 | 7257 | GORMLEY | 70 | ASPK |

## $\pi^+\pi^-\gamma$ PARAMETER $\beta$ (D-wave)

Sensitive to a D-wave contribution: $dN/d\cos\theta = \sin^2\theta \ (1 + \beta \ \cos^2\theta)$.

| VALUE | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **−0.02 ±0.07 OUR AVERAGE** Error includes scale factor of 1.3. | | | | |
| 0.11 ±0.11 | 35k | JANE | 74B | OSPK |
| −0.060±0.065 | 7250 | GORMLEY | 70 | WIRE |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.12 ±0.06 | | [10] THALER | 72 | ASPK |

[10] The authors don't believe this indicates D-wave because the dependence of $\beta$ on the $\gamma$ energy is inconsistent with the theoretical prediction. A $\cos^2\theta$ dependence can also come from P- and F-wave interference.

# ENERGY DEPENDENCE OF $\eta \to 3\pi$ DALITZ PLOTS

## PARAMETERS FOR $\eta \to \pi^+\pi^-\pi^0$

See the "Note on $\eta$ Decay Parameters" in our 1994 edition, Phys. Rev. **D50**, 1 August 1994, Part I, p. 1454. The following experiments fit to one or more of the coefficients $a$, $b$, $c$, $d$, or $e$ for $|\text{matrix element}|^2 = 1 + ay + by^2 + cx + dx^2 + exy$.

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| | 3230 | [11] ABELE | 98D | CBAR | $\overline{p}p \to \pi^0\pi^0\eta$ at rest |
| | 1077 | [12] AMSLER | 95 | CBAR | $\overline{p}p \to \pi^+\pi^-\eta$ at rest |
| | 81k | LAYTER | 73 | ASPK | |
| | 220k | LAYTER | 72 | ASPK | |
| | 1138 | CARPENTER | 70 | HBC | |
| | 349 | DANBURG | 70 | DBC | |
| | 7250 | GORMLEY | 70 | WIRE | |
| | 526 | BAGLIN | 69 | HLBC | |
| | 7170 | CNOPS | 68 | OSPK | |
| | 37k | GORMLEY | 68C | WIRE | |
| | 1300 | CLPWY | 66 | HBC | |
| | 705 | LARRIBE | 66 | HBC | |

[11] ABELE 98D obtains $a = -1.22 \pm 0.07$ and $b = 0.22 \pm 0.11$ when $c$ (our $d$) is fixed at 0.06.

[12] AMSLER 95 fits to $(1+ay+by^2)$ and obtains $a=-0.94 \pm 0.15$ and $b=0.11 \pm 0.27$.

## $\alpha$ PARAMETER FOR $\eta \to 3\pi^0$

See the "Note on $\eta$ Decay Parameters" in our 1994 edition, Phys. Rev. **D50**, 1 August 1994, Part I, p. 1454. The value here is of $\alpha$ in $|\text{matrix element}|^2 = 1 + 2\alpha z$.

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **−0.031±0.004 OUR AVERAGE** | | Error includes scale factor of 1.1. | | | |
| −0.010±0.021±0.010 | 12k | ACHASOV | 01C | SND | $e^+e^- \to \phi \to \eta\gamma$ |
| −0.031±0.004 | 1M | TIPPENS | 01 | CRYB | $\pi^-p \to n\eta$, 720 MeV/$c$ |
| −0.052±0.017±0.010 | 98k | ABELE | 98C | CBAR | $\overline{p}p \to 5\pi^0$ |
| −0.022±0.023 | 50k | ALDE | 84 | GAM2 | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| −0.32 ±0.37 | 192 | BAGLIN | 70 | HLBC | |

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## $\eta$ REFERENCES

| | | | | |
|---|---|---|---|---|
| ALOISIO | 04 | PL B591 49 | A. Aloisio *et al.* | (KLOE Collab.) |
| KNECHT | 04 | PL B589 14 | N. Knecht *et al.* | |
| LAI | 02 | PL B533 196 | A. Lai *et al.* | (CERN NA48 Collab.) |
| NEFKENS | 02 | PS T99 114 | B.M.K. Nefkens, J.W. Price | (UCLA) |
| ACHASOV | 01B | PL B504 275 | M.N. Achasov *et al.* | (Novosibirsk SND Collab.) |
| ACHASOV | 01C | JETPL 73 451 | M.N. Achasov *et al.* | (Novosibirsk SND Collab.) |
| | | Translated from ZETFP 73 511. | | |
| ACHASOV | 01D | NP B600 3 | M.N. Achasov *et al.* | (Novosibirsk SND Collab.) |
| AKHMETSHIN | 01 | PL B501 191 | R.R. Akhmetshin *et al.* | (Novosibirsk CMD-2 Collab.) |
| AKHMETSHIN | 01B | PL B509 217 | R.R. Akhmetshin *et al.* | (Novosibirsk CMD-2 Collab.) |
| TIPPENS | 01 | PRL 87 192001 | W.B. Tippens *et al.* | (BNL Crystal Ball Collab.) |
| ACHASOV | 00 | EPJ C12 25 | M.N. Achasov *et al.* | (Novosibirsk SND Collab.) |
| ACHASOV | 00B | JETP 90 17 | M.N. Achasov *et al.* | (Novosibirsk SND Collab.) |
| | | Translated from ZETF 117 22. | | |
| ACHASOV | 00D | JETPL 72 282 | M.N. Achasov *et al.* | (Novosibirsk SND Collab.) |
| | | Translated from ZETFP 72 411. | | |

| PRAKHOV | 00 | PRL 84 4802 | S. Prakhov *et al.* | (BNL Crystal Ball Collab.) |
|---|---|---|---|---|
| AKHMETSHIN | 99B | PL B462 371 | R.R. Akhmetshin *et al.* | (Novosibirsk CMD-2 Collab.) |
| AKHMETSHIN | 99C | PL B462 380 | R.R. Akhmetshin *et al.* | (Novosibirsk CMD-2 Collab.) |
| AKHMETSHIN | 99F | PL B460 242 | R.R. Akhmetshin *et al.* | (Novosibirsk CMD-2 Collab.) |
| ABELE | 98C | PL B417 193 | A. Abele *et al.* | (Crystal Barrel Collab.) |
| ABELE | 98D | PL B417 197 | A. Abele *et al.* | (Crystal Barrel Collab.) |
| ACHASOV | 98 | PL B425 388 | M.N. Achasov *et al.* | (Novosibirsk SND Collab.) |
| AKHMETSHIN | 97C | PL B415 452 | R.R. Akhmetshin *et al.* | (Novosibirsk CMD-2 Collab.) |
| BROWDER | 97B | PR D56 5359 | T.E. Browder *et al.* | (CLEO Collab.) |
| ABEGG | 96 | PR D53 11 | R. Abegg *et al.* | (Saturne SPES2 Collab.) |
| WHITE | 96 | PR D53 6658 | D.B. White *et al.* | (Saturne SPES2 Collab.) |
| AMSLER | 95 | PL B346 203 | C. Amsler *et al.* | (Crystal Barrel Collab.) |
| KRUSCHE | 95D | ZPHY A351 237 | B. Krusche *et al.* | (TAPS + A2 Collab.) |
| ABEGG | 94 | PR D50 92 | R. Abegg *et al.* | (Saturne SPES2 Collab.) |
| AMSLER | 93 | ZPHY C58 175 | C. Amsler *et al.* | (Crystal Barrel Collab.) |
| KESSLER | 93 | PRL 70 892 | R.S. Kessler *et al.* | (Saturne SPES2 Collab.) |
| PLOUIN | 92 | PL B276 526 | F. Plouin *et al.* | (Saturne SPES4 Collab.) |
| BARU | 90 | ZPHY C48 581 | S.E. Baru *et al.* | (MD-1 Collab.) |
| ROE | 90 | PR D41 17 | N.A. Roe *et al.* | (ASP Collab.) |
| WILLIAMS | 88 | PR D38 1365 | D.A. Williams *et al.* | (Crystal Ball Collab.) |
| AIHARA | 86 | PR D33 844 | H. Aihara *et al.* | (TPC-2$\gamma$ Collab.) |
| BARTEL | 85E | PL 160B 421 | W. Bartel *et al.* | (JADE Collab.) |
| LANDSBERG | 85 | PRPL 128 310 | L.G. Landsberg | (SERP) |
| ALDE | 84 | ZPHY C25 225 | D.M. Alde *et al.* | (SERP, BELG, LAPP) |
| Also | 84B | SJNP 40 918 | D.M. Alde *et al.* | (SERP, BELG, LAPP) |
| | | Translated from YAF 40 1447. | | |
| WEINSTEIN | 83 | PR D28 2896 | A.J. Weinstein *et al.* | (Crystal Ball Collab.) |
| BINON | 82 | SJNP 36 391 | F.G. Binon *et al.* | (SERP, BELG, LAPP+) |
| | | Translated from YAF 36 670. | | |
| Also | 82B | NC 71A 497 | F.G. Binon *et al.* | (SERP, BELG, LAPP+) |
| DAVYDOV | 81 | LNC 32 45 | V.A. Davydov *et al.* | (SERP, BELG, LAPP+) |
| Also | 81B | SJNP 33 825 | V.A. Davydov *et al.* | (SERP, BELG, LAPP+) |
| | | Translated from YAF 33 1534. | | |
| DZHELYADIN | 81 | PL 105B 239 | R.I. Dzhelyadin *et al.* | (SERP) |
| Also | 81C | SJNP 33 822 | R.I. Dzhelyadin *et al.* | (SERP) |
| | | Translated from YAF 33 1529. | | |
| ABROSIMOV | 80 | SJNP 31 195 | A.T. Abrosimov *et al.* | (JINR) |
| | | Translated from YAF 31 371. | | |
| DZHELYADIN | 80 | PL 94B 548 | R.I. Dzhelyadin *et al.* | (SERP) |
| Also | 80C | SJNP 32 516 | R.I. Dzhelyadin *et al.* | (SERP) |
| | | Translated from YAF 32 998. | | |
| DZHELYADIN | 80B | PL 97B 471 | R.I. Dzhelyadin *et al.* | (SERP) |
| Also | 80D | SJNP 32 518 | R.I. Dzhelyadin *et al.* | (SERP) |
| | | Translated from YAF 32 1002. | | |
| BUSHNIN | 78 | PL 79B 147 | Y.B. Bushnin *et al.* | (SERP) |
| Also | 78B | SJNP 28 775 | Y.B. Bushnin *et al.* | (SERP) |
| | | Translated from YAF 28 1507. | | |
| MARTYNOV | 76 | SJNP 23 48 | A.S. Martynov *et al.* | (JINR) |
| | | Translated from YAF 23 93. | | |
| JANE | 75 | PL 59B 99 | M.R. Jane *et al.* | (RHEL, LOWC) |
| JANE | 75B | PL 59B 103 | M.R. Jane *et al.* | (RHEL, LOWC) |
| Also | 78B | PL 73B 503 | M.R. Jane | |
| | | Erratum in private communication. | | |
| BROWMAN | 74B | PRL 32 1067 | A. Browman *et al.* | (CORN, BING) |
| DAVIES | 74 | NC 24A 324 | J.D. Davies, J.G. Guy, R.K.P. Zia | (BIRM, RHEL+) |
| DUANE | 74 | PRL 32 425 | A. Duane *et al.* | (LOIC, SHMP) |
| JANE | 74 | PL 48B 260 | M.R. Jane *et al.* | (RHEL, LOWC, SUSS) |
| JANE | 74B | PL 48B 265 | M.R. Jane *et al.* | (RHEL, LOWC, SUSS) |
| KENDALL | 74 | NC 21A 387 | B.N. Kendall *et al.* | (BROW, BARI, MIT) |
| LAYTER | 73 | PR D7 2565 | J.G. Layter *et al.* | (COLU) |
| THALER | 73 | PR D7 2569 | J.J. Thaler *et al.* | (COLU) |
| AGUILAR-... | 72B | PR D6 29 | M. Aguilar-Benitez *et al.* | (BNL) |
| BLOODWO... | 72B | NP B39 525 | I.J. Bloodworth *et al.* | (TNTO) |
| LAYTER | 72 | PRL 29 316 | J.G. Layter *et al.* | (COLU) |
| THALER | 72 | PRL 29 313 | J.J. Thaler *et al.* | (COLU) |
| BASILE | 71D | NC 3A 796 | M. Basile *et al.* | (CERN, BGNA, STRB) |
| STRUGALSKI | 71 | NP B27 429 | Z.S. Strugalski *et al.* | (JINR) |
| BAGLIN | 70 | NP B22 66 | C. Baglin *et al.* | (EPOL, MADR, STRB) |
| BUTTRAM | 70 | PRL 25 1358 | M.T. Buttram, M.N. Kreisler, R.E. Mischke | (PRIN) |
| CARPENTER | 70 | PR D1 1303 | D.W. Carpenter *et al.* | (DUKE) |
| COX | 70B | PRL 24 534 | B. Cox, L. Fortney, J.P. Golson | (DUKE) |
| DANBURG | 70 | PR D2 2564 | J.S. Danburg *et al.* | (LRL) |

| | | | | |
|---|---|---|---|---|
| DEVONS | 70 | PR D1 1936 | S. Devons *et al.* | (COLU, SYRA) |
| GORMLEY | 70 | PR D2 501 | M. Gormley *et al.* | (COLU, BNL) |
| Also | 70B | Thesis Nevis 181 | M. Gormley | (COLU) |
| BAGLIN | 69 | PL 29B 445 | C. Baglin *et al.* | (EPOL, UCB, MADR, STRB) |
| Also | 70 | NP B22 66 | C. Baglin *et al.* | (EPOL, MADR, STRB) |
| HYAMS | 69 | PL 29B 128 | B.D. Hyams *et al.* | (CERN, MPIM) |
| ARNOLD | 68 | PL 27B 466 | R.G. Arnold *et al.* | (STRB, MADR, EPOL+) |
| BAZIN | 68 | PRL 20 895 | M.J. Bazin *et al.* | (PRIN, QUKI) |
| BULLOCK | 68 | PL 27B 402 | F.W. Bullock *et al.* | (LOUC) |
| CNOPS | 68 | PRL 21 1609 | A.M. Cnops *et al.* | (BNL, ORNL, UCND+) |
| GORMLEY | 68C | PRL 21 402 | M. Gormley *et al.* | (COLU, BNL) |
| WEHMANN | 68 | PRL 20 748 | A.W. Wehmann *et al.* | (HARV, CASE, SLAC+) |
| BAGLIN | 67 | PL 24B 637 | C. Baglin *et al.* | (EPOL, UCB) |
| BAGLIN | 67B | BAPS 12 567 | C. Baglin *et al.* | (EPOL, UCB) |
| BALTAY | 67B | PRL 19 1498 | C. Baltay *et al.* | (COLU, STON) |
| BALTAY | 67D | PRL 19 1495 | C. Baltay *et al.* | (COLU, BRAN) |
| BEMPORAD | 67 | PL 25B 380 | C. Bemporad *et al.* | (PISA, BONN) |
| Also | 67 | Private Comm. | I. Ion | |
| BILLING | 67 | PL 25B 435 | K.D. Billing *et al.* | (LOUC, OXF) |
| BUNIATOV | 67 | PL 25B 560 | S.A. Bunyatov *et al.* | (CERN, KARL) |
| CENCE | 67 | PRL 19 1393 | R.J. Cence *et al.* | (HAWA, LRL) |
| ESTEN | 67 | PL 24B 115 | M.J. Esten *et al.* | (LOUC, OXF) |
| FELDMAN | 67 | PRL 18 868 | M. Feldman *et al.* | (PENN) |
| FLATTE | 67 | PRL 18 976 | S.M. Flatte | (LRL) |
| FLATTE | 67B | PR 163 1441 | S.M. Flatte, C.G. Wohl | (LRL) |
| LITCHFIELD | 67 | PL 24B 486 | P.J. Litchfield *et al.* | (RHEL, SACL) |
| PRICE | 67 | PRL 18 1207 | L.R. Price, F.S. Crawford | (LRL) |
| ALFF-... | 66 | PR 145 1072 | C. Alff-Steinberger *et al.* | (COLU, RUTG) |
| CLPWY | 66 | PR 149 1044 | C. Baltay | (SCUC, LRL, PURD, WISC, YALE) |
| CRAWFORD | 66 | PRL 16 333 | F.S. Crawford, L.R. Price | (LRL) |
| DIGIUGNO | 66 | PRL 16 767 | G. di Giugno *et al.* | (NAPL, TRST, FRAS) |
| GROSSMAN | 66 | PR 146 993 | R.A. Grossman, L.R. Price, F.S. Crawford | (LRL) |
| GRUNHAUS | 66 | Thesis | J. Grunhaus | (COLU) |
| JAMES | 66 | PR 142 896 | F.E. James, H.L. Kraybill | (YALE, BNL) |
| JONES | 66 | PL 23 597 | W.G. Jones *et al.* | (LOIC, RHEL) |
| LARRIBE | 66 | PL 23 600 | A. Larribe *et al.* | (SACL, RHEL) |
| FOSTER | 65 | PR 138B 652 | M. Foster *et al.* | (WISC, PURD) |
| FOSTER | 65B | Athens Conf. | M. Foster, M. Good, M. Meer | (WISC) |
| FOSTER | 65C | Thesis | M. Foster | (WISC) |
| PRICE | 65 | PRL 15 123 | L.R. Price, F.S. Crawford | (LRL) |
| RITTENBERG | 65 | PRL 15 556 | A. Rittenberg, G.R. Kalbfleisch | (LRL, BNL) |
| FOELSCHE | 64 | PR 134B 1138 | H.W.J. Foelsche, H.L. Kraybill | (YALE) |
| KRAEMER | 64 | PR 136B 496 | R.W. Kraemer *et al.* | (JHU, NWES, WOOD) |
| PAULI | 64 | PL 13 351 | E. Pauli, A. Muller | (SACL) |
| BACCI | 63 | PRL 11 37 | C. Bacci *et al.* | (ROMA, FRAS) |
| CRAWFORD | 63 | PRL 10 546 | F.S.Jr. Crawford, L.J. Lloyd, E.C. Fowler | (LRL+) |
| Also | 66B | PRL 16 907 | F.S. Crawford, L.J. Lloyd, E.C. Fowler | (LRL+) |
| ALFF-... | 62 | PRL 9 322 | C. Alff-Steinberger *et al.* | (COLU, RUTG) |
| BASTIEN | 62 | PRL 8 114 | P.L. Bastien *et al.* | (LRL) |
| PICKUP | 62 | PRL 8 329 | E. Pickup, D.K. Robinson, E.O. Salant | (CNRC+) |