



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

We have omitted some results that have been superseded by later experiments.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. Some early results have been omitted altogether.

<u>VALUE (MeV)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>547.30±0.12 OUR AVERAGE</b>				
547.12±0.06±0.25		KRUSCHE	95D SPEC	$\gamma p \rightarrow \eta p$ , threshold
547.30±0.15		PLOUIN	92 SPEC	$d p \rightarrow \eta \text{ } ^3\text{He}$
547.45±0.25		DUANE	74 SPEC	$\pi^- p \rightarrow n$ 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	

### η WIDTH

This is the partial decay rate  $\Gamma(\eta \rightarrow \gamma\gamma)$  divided by the fitted branching fraction for that mode. See 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.

<u>VALUE (keV)</u>	<u>DOCUMENT ID</u>
<b>1.18±0.11 OUR FIT</b>	Error includes scale factor of 1.8.

### η DECAY MODES

Mode	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level
<b>Neutral modes</b>		
$\Gamma_1$ neutral modes	(72.0 ± 0.5 ) %	S=1.3
$\Gamma_2$ $2\gamma$	[a] (39.43± 0.26) %	S=1.2
$\Gamma_3$ $3\pi^0$	(32.51± 0.29) %	S=1.2
$\Gamma_4$ $\pi^0 2\gamma$	( 7.2 ± 1.4 ) × 10 <sup>-4</sup>	
$\Gamma_5$ 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%
$\Gamma_{14}$	$\pi^+\pi^-e^+e^-$		$(4.0^{+14.0}_{-2.7}) \times 10^{-4}$	$S=5.8$
$\Gamma_{15}$	$\pi^+\pi^-2\gamma$		$< 2.0 \times 10^{-3}$	
$\Gamma_{16}$	$\pi^+\pi^-\pi^0\gamma$		$< 5 \times 10^{-4}$	CL=90%
$\Gamma_{17}$	$\pi^0\mu^+\mu^-\gamma$		$< 3 \times 10^{-6}$	CL=90%

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

$\Gamma_{18}$	$\pi^+\pi^-$	$P, CP$	$< 3.3 \times 10^{-4}$	CL=90%
$\Gamma_{19}$	$\pi^0\pi^0$	$P, CP$	$< 4.3 \times 10^{-4}$	CL=90%
$\Gamma_{20}$	$3\gamma$	$C$	$< 5 \times 10^{-4}$	CL=95%
$\Gamma_{21}$	$4\pi^0$	$P, CP$	$< 6.9 \times 10^{-7}$	CL=90%
$\Gamma_{22}$	$\pi^0e^+e^-$	$C$	$[b] < 4 \times 10^{-5}$	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] See 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.

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

## CONSTRAINED FIT INFORMATION

An overall fit to a decay rate and 18 branching ratios uses 42 measurements and one constraint to determine 9 parameters. The overall fit has a  $\chi^2 = 29.7$  for 34 degrees of freedom.

The following *off-diagonal* array elements are the correlation coefficients  $\langle \delta x_i \delta x_j \rangle / (\delta x_i \delta x_j)$ , 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.

$x_3$	46							
$x_4$	2	2						
$x_7$	-79	-82	-5					
$x_8$	-63	-66	-4	68				
$x_9$	-8	-8	0	-7	-6			
$x_{10}$	0	0	0	-1	0	0		
$x_{14}$	-7	-8	0	-17	-13	-1	0	
$\Gamma$	-7	-3	0	6	5	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] 0.46 ± 0.04	1.8
$\Gamma_3$ $3\pi^0$	0.383 ± 0.035	1.8
$\Gamma_4$ $\pi^0 2\gamma$	(8.5 ± 1.9) × 10 <sup>-4</sup>	1.1
$\Gamma_7$ $\pi^+ \pi^- \pi^0$	0.267 ± 0.025	1.8
$\Gamma_8$ $\pi^+ \pi^- \gamma$	0.055 ± 0.005	1.7
$\Gamma_9$ $e^+ e^- \gamma$	0.0071 ± 0.0011	1.5
$\Gamma_{10}$ $\mu^+ \mu^- \gamma$	(3.7 ± 0.6) × 10 <sup>-4</sup>	1.1
$\Gamma_{14}$ $\pi^+ \pi^- e^+ e^-$	(0.47 <sup>+1.70</sup> <sub>-0.32</sub> ) × 10 <sup>-3</sup>	5.8

## $\eta$ DECAY RATES

$\Gamma(2\gamma)$

$\Gamma_2$

See the table immediately above giving the fitted decay rates. 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.

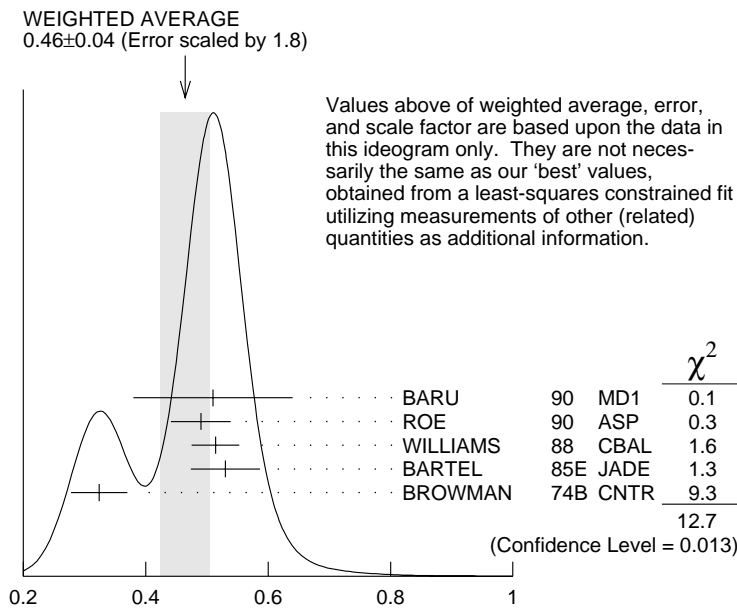
VALUE (keV)	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.46 ± 0.04 OUR FIT</b>				Error includes scale factor of 1.8.
<b>0.46 ± 0.04 OUR AVERAGE</b>				Error includes scale factor of 1.8. See the ideogram below.
0.51 ± 0.12 ± 0.05	36	BARU	90 MD1	$e^+ e^- \rightarrow e^+ e^- \eta$
0.490 ± 0.010 ± 0.048	2287	ROE	90 ASP	$e^+ e^- \rightarrow e^+ e^- \eta$
0.514 ± 0.017 ± 0.035	1295	WILLIAMS	88 CBAL	$e^+ e^- \rightarrow e^+ e^- \eta$
0.53 ± 0.04 ± 0.04		BARTEL	85E JADE	$e^+ e^- \rightarrow e^+ e^- \eta$
0.324 ± 0.046		BROWMAN	74B CNTR	Primakoff effect

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

0.64 ± 0.14 ± 0.13		AIHARA	86	TPC	$e^+ e^- \rightarrow e^+ e^- \eta$
0.56 ± 0.16	56	WEINSTEIN	83	CBAL	$e^+ e^- \rightarrow e^+ e^- \eta$
1.00 ± 0.22		<sup>1</sup> BEMPORAD	67	CNTR	Primakoff effect

<sup>1</sup>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.



$\Gamma(2\gamma)$  (keV)

## η BRANCHING RATIOS

### Neutral modes

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.720 ± 0.005 OUR FIT</b>				Error includes scale factor of 1.3.
<b>0.705 ± 0.008</b>	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
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$\Gamma(2\gamma)/\Gamma_{\text{total}}$   $\Gamma_2/\Gamma$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.3943 ± 0.0026 OUR FIT</b>				Error includes scale factor of 1.2.
<b>0.3949 ± 0.0017 ± 0.0030</b>	65k	ABEGG	96	SPEC $pd \rightarrow {}^3\text{He}\eta$

### $\Gamma(2\gamma)/\Gamma(\text{neutral modes})$

$$\Gamma_2/\Gamma_1 = \Gamma_2/(\Gamma_2+\Gamma_3+\Gamma_4)$$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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**0.5475±0.0021 OUR FIT** Error includes scale factor of 1.1.

**0.549 ±0.004 OUR AVERAGE**

0.549 ±0.004		ALDE	84	GAM2
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		<sup>2</sup> JONES	66	CNTR

<sup>2</sup> This result from combining cross sections from two different experiments.

### $\Gamma(3\pi^0)/\Gamma(\text{neutral modes})$

$$\Gamma_3/\Gamma_1 = \Gamma_3/(\Gamma_2+\Gamma_3+\Gamma_4)$$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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**0.4515±0.0021 OUR FIT** Error includes scale factor of 1.1.

**0.450 ±0.004 OUR AVERAGE**

0.450 ±0.004		ALDE	84	GAM2
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

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

$$\Gamma_3/\Gamma_2$$

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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**0.825±0.007 OUR FIT** Error includes scale factor of 1.1.

**0.832±0.011 OUR AVERAGE**

0.826±0.024	<sup>3</sup> ACHASOV	00D	SND $e^+e^- \rightarrow \phi \rightarrow \eta\gamma$
0.832±0.005±0.012	KRUSCHE	95D	SPEC $\gamma p \rightarrow \eta p$ , threshold
0.841±0.034	AMSLER	93	CBAR $\bar{p}p \rightarrow \pi^+\pi^-\eta$ at rest

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

0.796±0.016±0.016	ACHASOV	00	SND See ACHASOV 00D
0.822±0.009	<sup>4</sup> ALDE	84	GAM2
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

<sup>3</sup> This is a corrected result: see ACHASOV 02C.

<sup>4</sup> This result is not independent of other ALDE 84 results in this Listing, and so is omitted from the fit and average.

$\Gamma(\pi^0 2\gamma)/\Gamma(\text{neutral modes})$

$\Gamma_4/\Gamma_1 = \Gamma_4/(\Gamma_2+\Gamma_3+\Gamma_4)$

<u>VALUE (units <math>10^{-3}</math>)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>1.00±0.20 OUR FIT</b>		
<b>1.0 ±0.2</b>	ALDE	84 GAM2

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

$\Gamma_4/\Gamma$

Early results are summarized in the review by LANDSBERG 85.

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>7.2±1.4 OUR FIT</b>					

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

< 8.4	90	7	ACHASOV	01D SND	$e^+ e^- \rightarrow \phi \rightarrow \eta\gamma$
9.5±2.3		70	BINON	82 GAM2	See ALDE 84
<30	90	0	DAVYDOV	81 GAM2	$\pi^- p \rightarrow \eta n$

$\Gamma(\text{neutral modes})/[\Gamma(\pi^+ \pi^- \pi^0) + \Gamma(\pi^+ \pi^- \gamma) + \Gamma(e^+ e^- \gamma)]$

$\Gamma_1/(\Gamma_7+\Gamma_8+\Gamma_9) = (\Gamma_2+\Gamma_3+\Gamma_4)/(\Gamma_7+\Gamma_8+\Gamma_9)$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>2.58±0.06 OUR FIT</b>	Error includes scale factor of 1.3.		
<b>2.64±0.23</b>		BALTAY	67B DBC

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

4.5 ±1.0	280	<sup>5</sup> JAMES	66 HBC
3.20±1.26	53	<sup>5</sup> BASTIEN	62 HBC
2.5 ±1.0	10	<sup>5</sup> PICKUP	62 HBC

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

$\Gamma(\text{neutral modes})/\Gamma(\pi^+ \pi^- \pi^0)$

$\Gamma_1/\Gamma_7 = (\Gamma_2+\Gamma_3+\Gamma_4)/\Gamma_7$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>3.18±0.08 OUR FIT</b>	Error includes scale factor of 1.3.		
<b>3.26±0.30 OUR AVERAGE</b>			

2.54±1.89	74	KENDALL	74 OSPK
3.4 ±1.1	29	AGUILAR-...	72B HBC
2.83±0.80	70	<sup>6</sup> 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

<sup>6</sup> Error increased from published value 0.5 by Bloodworth (private communication).

$\Gamma(2\gamma)/[\Gamma(\pi^+ \pi^- \pi^0) + \Gamma(\pi^+ \pi^- \gamma) + \Gamma(e^+ e^- \gamma)]$

$\Gamma_2/(\Gamma_7+\Gamma_8+\Gamma_9)$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>1.412±0.033 OUR FIT</b>	Error includes scale factor of 1.3.		
<b>1.1 ±0.4 OUR AVERAGE</b>			

1.51 ±0.93	75	KENDALL	74 OSPK
0.99 ±0.48		CRAWFORD	63 HBC

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

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

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>1.44±0.04 OUR FIT</b>	Error includes scale factor of 1.3.			
<b>1.49±0.06 OUR AVERAGE</b>				
1.52±0.04±0.08	23k	<sup>7</sup> AKHMETSHIN 01B	CMD2	$e^+e^- \rightarrow \phi \rightarrow \eta\gamma$
1.44±0.09±0.10	1627	AMSLER	95 CBAR	$\bar{p}p \rightarrow \pi^+\pi^-\eta$ at rest
1.50 <sup>+0.15</sup> <sub>-0.29</sub>	199	BAGLIN	69 HLBC	
1.47 <sup>+0.20</sup> <sub>-0.17</sub>		BULLOCK	68 HLBC	

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

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

<sup>7</sup> 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.

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;0.028</b>	90	ABEGG	96 SPEC	$pd \rightarrow {}^3\text{He}\eta$

————— Charged modes —————

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

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.315 ±0.007 OUR FIT</b>	Error includes scale factor of 1.3.		
<b>0.304 ±0.012</b>	<sup>8</sup> ACHASOV	00D SND	$e^+e^- \rightarrow \phi \rightarrow \eta\gamma$
0.3141±0.0081±0.0058	ACHASOV	00B SND	See ACHASOV 00D

<sup>8</sup> This is a corrected result: see ACHASOV 02C

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>0.207±0.004 OUR FIT</b>	Error includes scale factor of 1.1.		
<b>0.207±0.004 OUR AVERAGE</b>	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. • • •			
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
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**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	$e^+e^- \rightarrow \phi \rightarrow \eta\gamma$
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7.10 ± 0.64 ± 0.46	323	AKHMETSHIN	01 CMD2	$e^+e^- \rightarrow \phi \rightarrow \eta\gamma$
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$\Gamma(e^+e^-\gamma)/\Gamma(\pi^+\pi^-\pi^0)$   $\Gamma_9/\Gamma_7$

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
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**2.65 ± 0.35 OUR FIT** Error includes scale factor of 1.5.

<b>2.1 ± 0.5</b>	80	JANE	75B OSPK	See the erratum
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$\Gamma(\mu^+\mu^-\gamma)/\Gamma_{\text{total}}$   $\Gamma_{10}/\Gamma$

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
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**3.1 ± 0.4 OUR FIT**

<b>3.1 ± 0.4</b>	600	DZHELYADIN	80 SPEC	$\pi^-p \rightarrow \eta n$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

1.5 ± 0.75	100	BUSHNIN	78 SPEC	See DZHELYADIN 80
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$\Gamma(e^+e^-)/\Gamma_{\text{total}}$   $\Gamma_{11}/\Gamma$

VALUE (units $10^{-4}$ )	CL%	DOCUMENT ID	TECN	COMMENT
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<b>&lt; 0.77</b>	90	BROWDER	97B CLE2	$e^+e^- \simeq 10.5 \text{ GeV}$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

< 2	90	WHITE	96 SPEC	$pd \rightarrow \eta^3\text{He}$
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< 3	90	DAVIES	74 RVUE	Uses ESTEN 67
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$\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$   $\Gamma_{12}/\Gamma$

VALUE (units $10^{-6}$ )	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
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**5.8 ± 0.8 OUR AVERAGE**

5.7 ± 0.7 ± 0.5	114	ABEGG	94 SPEC	$pd \rightarrow \eta^3\text{He}$
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6.5 ± 2.1	27	DZHELYADIN	80B SPEC	$\pi^-p \rightarrow \eta n$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

5.6 <sup>+0.6</sup> <sub>-0.7</sub> ± 0.5	100	KESSLER	93 SPEC	See ABEGG 94
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< 20	95	0	WEHMANN	68 OSPK
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$\Gamma(\mu^+\mu^-)/\Gamma(2\gamma)$   $\Gamma_{12}/\Gamma_2$

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

5.9 ± 2.2	HYAMS	69 OSPK
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$\Gamma(e^+e^-e^+e^-)/\Gamma_{\text{total}}$   $\Gamma_{13}/\Gamma$

VALUE (units $10^{-5}$ )	CL%	DOCUMENT ID	TECN	COMMENT
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<b>&lt; 6.9</b>	90	AKHMETSHIN	01 CMD2	$e^+e^- \rightarrow \phi \rightarrow \eta\gamma$
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$\Gamma(\pi^+\pi^-e^+e^-)/\Gamma(\pi^+\pi^-\gamma)$   $\Gamma_{14}/\Gamma_8$

VALUE (units  $10^{-2}$ )    EVTS    DOCUMENT ID    TECN

**$0.9^{+3.1}_{-0.6}$  OUR FIT** Error includes scale factor of 5.9.

**$2.6 \pm 2.6$**                       1                      GROSSMAN    66    HBC

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

VALUE (units  $10^{-4}$ )    EVTS    DOCUMENT ID    TECN    COMMENT

**$4.0^{+14.0}_{-2.7}$  OUR FIT** Error includes scale factor of 5.8.

**$3.7^{+2.5}_{-1.8} \pm 0.3$**                       4                      AKHMETSHIN 01    CMD2     $e^+e^- \rightarrow \phi \rightarrow \eta\gamma$

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

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

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

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

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

VALUE (units  $10^{-6}$ )    CL%    DOCUMENT ID    TECN    COMMENT

**<3**                                      90                      DZHELYADIN 81    SPEC     $\pi^-p \rightarrow \eta n$

————— Rare or forbidden modes —————

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

Forbidden by *P* and *CP* invariance.

VALUE (units  $10^{-4}$ )    CL%    EVTS    DOCUMENT ID    TECN    COMMENT

**< 3.3**                      90                                      AKHMETSHIN 99B    CMD2     $e^+e^- \rightarrow \phi \rightarrow \eta\gamma$

• • • 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

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

Forbidden by *P* and *CP* invariance.

VALUE (units  $10^{-4}$ )    CL%    DOCUMENT ID    TECN    COMMENT

**<4.3**                      90                                      AKHMETSHIN 99c    CMD2     $e^+e^- \rightarrow \phi \rightarrow \eta\gamma$

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

<6                                      90                      <sup>9</sup>ACHASOV                      98    SND     $e^+e^- \rightarrow \phi \rightarrow \eta\gamma$

<sup>9</sup>ACHASOV 98 observes one event in a  $\pm 3\sigma$  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.

**$\Gamma(4\pi^0)/\Gamma_{\text{total}}$**   **$\Gamma_{21}/\Gamma$**   
 Forbidden by  $P$  and  $CP$  invariance.

<u>VALUE (units <math>10^{-7}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;6.9</b>	90	PRAKHOV 00	CRYB	$\pi^- p \rightarrow n\eta$ , 720 MeV/c

**$\Gamma(3\gamma)/\Gamma(\text{neutral modes})$**   **$\Gamma_{20}/\Gamma_1 = \Gamma_{20}/(\Gamma_2+\Gamma_3+\Gamma_4)$**   
 Forbidden by  $C$  invariance.

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&lt;7</b>	95	ALDE 84	GAM2

**$\Gamma(\pi^0 e^+ e^-)/\Gamma(\pi^+ \pi^- \pi^0)$**   **$\Gamma_{22}/\Gamma_7$**   
 $C$  parity forbids this to occur as a single-photon process.

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&lt; 1.9</b>	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

**$\Gamma(\pi^0 e^+ e^-)/\Gamma_{\text{total}}$**   **$\Gamma_{22}/\Gamma$**   
 $C$  parity forbids this to occur as a single-photon process.

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&lt;0.016</b>	90	0	MARTYNOV 76	HLBC
<0.084	90		BAZIN 68	DBC
<0.7			RITTENBERG 65	HBC

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

**$\Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$**   **$\Gamma_{23}/\Gamma$**   
 $C$  parity forbids this to occur as a single-photon process.

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;0.05</b>	90	DZHELYADIN 81	SPEC	$\pi^- p \rightarrow \eta n$

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

<5		WEHMANN 68	OSPK
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**$[\Gamma(\mu^+ e^-) + \Gamma(\mu^- e^+)]/\Gamma_{\text{total}}$**   **$\Gamma_{24}/\Gamma$**   
 Forbidden by lepton family number conservation.

<u>VALUE (units <math>10^{-6}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;6</b>	90	WHITE 96	SPEC	$pd \rightarrow \eta {}^3\text{He}$

## $\eta$ C-NONCONSERVING DECAY PARAMETERS

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

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

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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**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	<sup>10</sup> GORMLEY	68C ASPK
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<sup>10</sup>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.

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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**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

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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**-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.

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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**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:  $dN/d\cos\theta = \sin^2\theta (1 + \beta \cos^2\theta)$ .

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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**-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		<sup>11</sup> THALER	72 ASPK
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<sup>11</sup>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 $\eta \rightarrow 3\pi$ DALITZ PLOTS

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

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	<sup>12</sup> ABELE	98D	CBAR $\bar{p}p \rightarrow \pi^0 \pi^0 \eta$ at rest
	1077	<sup>13</sup> AMSLER	95	CBAR $\bar{p}p \rightarrow \pi^+ \pi^- \eta$ 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

<sup>12</sup> 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.

<sup>13</sup> 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 $\eta \rightarrow 3\pi^0$

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
<b>-0.031 ± 0.004 OUR AVERAGE</b>				Error includes scale factor of 1.1.
-0.010 ± 0.021 ± 0.010	12k	ACHASOV	01C	SND $e^+ e^- \rightarrow \phi \rightarrow \eta \gamma$
-0.031 ± 0.004	1M	TIPPENS	01	CRYB $\pi^- p \rightarrow n \eta$ , 720 MeV/c
-0.052 ± 0.017 ± 0.010	98k	ABELE	98C	CBAR $\bar{p}p \rightarrow 5\pi^0$
-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

## $\eta$ REFERENCES

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ACHASOV	01B	PL B504 275	M.N. Achasov <i>et al.</i>	(Novosibirsk SND Collab.)
ACHASOV	01C	JETPL 73 451	M.N. Achasov <i>et al.</i>	(Novosibirsk SND Collab.)
		Translated from ZETFP 73 511.		
ACHASOV	01D	NP B600 3	M.N. Achasov <i>et al.</i>	(Novosibirsk SND Collab.)
AKHMETSHIN	01	PL B501 191	R.R. Akhmetshin <i>et al.</i>	(Novosibirsk CMD-2 Collab.)
AKHMETSHIN	01B	PL B509 217	R.R. Akhmetshin <i>et al.</i>	(Novosibirsk CMD-2 Collab.)
TIPPENS	01	PRL 87 192001	W.B. Tippens <i>et al.</i>	(BNL Crystal Ball Collab.)
ACHASOV	00	EPJ C12 25	M.N. Achasov <i>et al.</i>	(Novosibirsk SND Collab.)
ACHASOV	00B	JETP 90 17	M.N. Achasov <i>et al.</i>	(Novosibirsk SND Collab.)
		Translated from ZETF 117 22.		
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Also	02C	hep-ex/0202032	M.N. Achasov <i>et al.</i>	(Novosibirsk SND Collab.)
PRAKHOV	00	PRL 84 4802	S. Prakhov <i>et al.</i>	(BNL Crystal Ball Collab.)
AKHMETSHIN	99B	PL B462 371	R.R. Akhmetshin <i>et al.</i>	(Novosibirsk CMD-2 Collab.)
AKHMETSHIN	99C	PL B462 380	R.R. Akhmetshin <i>et al.</i>	(Novosibirsk CMD-2 Collab.)
AKHMETSHIN	99F	PL B460 242	R.R. Akhmetshin <i>et al.</i>	(Novosibirsk CMD-2 Collab.)
ABELE	98C	PL B417 193	A. Abele <i>et al.</i>	(Crystal Barrel Collab.)
ABELE	98D	PL B417 197	A. Abele <i>et al.</i>	(Crystal Barrel Collab.)
ACHASOV	98	PL B425 388	M.N. Achasov <i>et al.</i>	(Novosibirsk SND Collab.)
AKHMETSHIN	97C	PL B415 452	R.R. Akhmetshin <i>et al.</i>	(Novosibirsk CMD-2 Collab.)
BROWDER	97B	PR D56 5359	T.E. Browder <i>et al.</i>	(CLEO Collab.)
ABEGG	96	PR D53 11	R. Abegg <i>et al.</i>	(Saturne SPES2 Collab.)
WHITE	96	PR D53 6658	D.B. White <i>et al.</i>	(Saturne SPES2 Collab.)
AMSLER	95	PL B346 203	C. Amsler <i>et al.</i>	(Crystal Barrel Collab.)
KRUSCHE	95D	ZPHY A351 237	B. Krusche <i>et al.</i>	(TAPS + A2 Collab.)
ABEGG	94	PR D50 92	R. Abegg <i>et al.</i>	(Saturne SPES2 Collab.)
AMSLER	93	ZPHY C58 175	C. Amsler <i>et al.</i>	(Crystal Barrel Collab.)
KESSLER	93	PRL 70 892	R.S. Kessler <i>et al.</i>	(Saturne SPES2 Collab.)
PLOUIN	92	PL B276 526	F. Plouin <i>et al.</i>	(Saturne SPES4 Collab.)
BARU	90	ZPHY C48 581	S.E. Baru <i>et al.</i>	(MD-1 Collab.)
ROE	90	PR D41 17	N.A. Roe <i>et al.</i>	(ASP Collab.)
WILLIAMS	88	PR D38 1365	D.A. Williams <i>et al.</i>	(Crystal Ball Collab.)
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ALDE	84	ZPHY C25 225	D.M. Alde <i>et al.</i>	(SERP, BELG, LAPP)
Also	84B	SJNP 40 918	D.M. Alde <i>et al.</i>	(SERP, BELG, LAPP)
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WEINSTEIN	83	PR D28 2896	A.J. Weinstein <i>et al.</i>	(Crystal Ball Collab.)
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DAVYDOV	81	LNC 32 45	V.A. Davydov <i>et al.</i>	(SERP, BELG, LAPP+)
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DZHELADIN	81	PL 105B 239	R.I. Dzhelyadin <i>et al.</i>	(SERP)
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		Translated from YAF 33	1529.	
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BUSHNIN	78	PL 79B 147	Y.B. Bushnin <i>et al.</i>	(SERP)
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		Translated from YAF 23	93.	
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DAVIES	74	NC 24A 324	J.D. Davies, J.G. Guy, R.K.P. Zia	(BIRM, RHEL+)
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BAGLIN	70	NP B22 66	C. Baglin <i>et al.</i>	(EPOL, MADR, STRB)
BUTTRAM	70	PRL 25 1358	M.T. Buttram, M.N. Kreisler, R.E. Mischke	(PRIN)
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ARNOLD	68	PL 27B 466	R.G. Arnold <i>et al.</i>	(STRB, MADR, EPOL+)
BAZIN	68	PRL 20 895	M.J. Bazin <i>et al.</i>	(PRIN, QUKI)
BULLOCK	68	PL 27B 402	F.W. Bullock <i>et al.</i>	(LOUC)
CNOPS	68	PRL 21 1609	A.M. Cnops <i>et al.</i>	(BNL, ORNL, UCND+)
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BAGLIN	67	PL 24B 637	C. Baglin <i>et al.</i>	(EPOL, UCB)
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CRAWFORD	66	PRL 16 333	F.S. Crawford, L.R. Price	(LRL)
DIGIUGNO	66	PRL 16 767	G. di Giugno <i>et al.</i>	(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 <i>et al.</i>	(LOIC, RHEL)
LARRIBE	66	PL 23 600	A. Larribe <i>et al.</i>	(SACL, RHEL)
FOSTER	65	PR 138B 652	M. Foster <i>et al.</i>	(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)
FOELSCH	64	PR 134B 1138	H.W.J. Foelsche, H.L. Kraybill	(YALE)
KRAEMER	64	PR 136B 496	R.W. Kraemer <i>et al.</i>	(JHU, NWES, WOOD)
PAULI	64	PL 13 351	E. Pauli, A. Muller	(SACL)
BACCI	63	PRL 11 37	C. Bacci <i>et al.</i>	(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 <i>et al.</i>	(COLU, RUTG)
BASTIEN	62	PRL 8 114	P.L. Bastien <i>et al.</i>	(LRL)
PICKUP	62	PRL 8 329	E. Pickup, D.K. Robinson, E.O. Salant	(CNRC+)