



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

We have omitted some results that have been superseded by later experiments.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	$dp \rightarrow \eta {}^3\text{He}$
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	(71.5 ±0.6 ) %	S=1.4
$\Gamma_2$ $2\gamma$	[a] (39.21±0.34) %	S=1.4
$\Gamma_3$ $3\pi^0$	(32.2 ±0.4 ) %	S=1.3
$\Gamma_4$ $\pi^0 2\gamma$	( 7.1 ±1.4 ) × 10 <sup>-4</sup>	
$\Gamma_5$ other neutral modes	< 2.8 %	CL=90%

**Charged modes**

$\Gamma_6$	charged modes		$(28.5 \pm 0.6) \%$	$S=1.4$
$\Gamma_7$	$\pi^+ \pi^- \pi^0$		$(23.1 \pm 0.5) \%$	$S=1.4$
$\Gamma_8$	$\pi^+ \pi^- \gamma$		$(4.77 \pm 0.13) \%$	$S=1.3$
$\Gamma_9$	$e^+ e^- \gamma$		$(4.9 \pm 1.1) \times 10^{-3}$	
$\Gamma_{10}$	$\mu^+ \mu^- \gamma$		$(3.1 \pm 0.4) \times 10^{-4}$	
$\Gamma_{11}$	$e^+ e^-$		$< 7.7 \times 10^{-5}$	CL=90%
$\Gamma_{12}$	$\mu^+ \mu^-$		$(5.8 \pm 0.8) \times 10^{-6}$	
$\Gamma_{13}$	$\pi^+ \pi^- e^+ e^-$		$(1.3^{+1.2}_{-0.8}) \times 10^{-3}$	
$\Gamma_{14}$	$\pi^+ \pi^- 2\gamma$		$< 2.1 \times 10^{-3}$	
$\Gamma_{15}$	$\pi^+ \pi^- \pi^0 \gamma$		$< 6 \times 10^{-4}$	CL=90%
$\Gamma_{16}$	$\pi^0 \mu^+ \mu^- \gamma$		$< 3 \times 10^{-6}$	CL=90%

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

$\Gamma_{17}$	$\pi^+ \pi^-$	$P, CP$	$< 9 \times 10^{-4}$	CL=90%
$\Gamma_{18}$	$3\gamma$	$C$	$< 5 \times 10^{-4}$	CL=95%
$\Gamma_{19}$	$\pi^0 e^+ e^-$	$C$	$[b] < 4 \times 10^{-5}$	CL=90%
$\Gamma_{20}$	$\pi^0 \mu^+ \mu^-$	$C$	$[b] < 5 \times 10^{-6}$	CL=90%
$\Gamma_{21}$	$\mu^+ e^- + \mu^- e^+$	$LF$	$< 6 \times 10^{-6}$	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 15 branching ratios uses 40 measurements and one constraint to determine 9 parameters. The overall fit has a  $\chi^2 = 31.0$  for 32 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.

$x_3$	60							
$x_4$	3	3						
$x_7$	-85	-86	-5					
$x_8$	-72	-73	-5	76				
$x_9$	-10	-11	-1	-6	-6			
$x_{10}$	0	0	0	-1	0	0		
$x_{13}$	-4	-4	0	-15	-11	-2	0	
$\Gamma$	-10	-6	0	8	7	1	0	0
	$x_2$	$x_3$	$x_4$	$x_7$	$x_8$	$x_9$	$x_{10}$	$x_{13}$

Mode	Rate (keV)	Scale factor
$\Gamma_2$ $2\gamma$	[a] 0.46 $\pm$ 0.04	1.8
$\Gamma_3$ $3\pi^0$	0.381 $\pm$ 0.035	1.8
$\Gamma_4$ $\pi^0 2\gamma$	(8.4 $\pm$ 1.9) $\times 10^{-4}$	1.1
$\Gamma_7$ $\pi^+ \pi^- \pi^0$	0.274 $\pm$ 0.026	1.8
$\Gamma_8$ $\pi^+ \pi^- \gamma$	0.057 $\pm$ 0.005	1.7
$\Gamma_9$ $e^+ e^- \gamma$	0.0058 $\pm$ 0.0014	
$\Gamma_{10}$ $\mu^+ \mu^- \gamma$	(3.7 $\pm$ 0.6) $\times 10^{-4}$	1.1
$\Gamma_{13}$ $\pi^+ \pi^- e^+ e^-$	0.0015 $^{+0.0015}_{-0.0009}$	

### $\eta$ DECAY RATES

$\Gamma(2\gamma)$

$\Gamma_2$

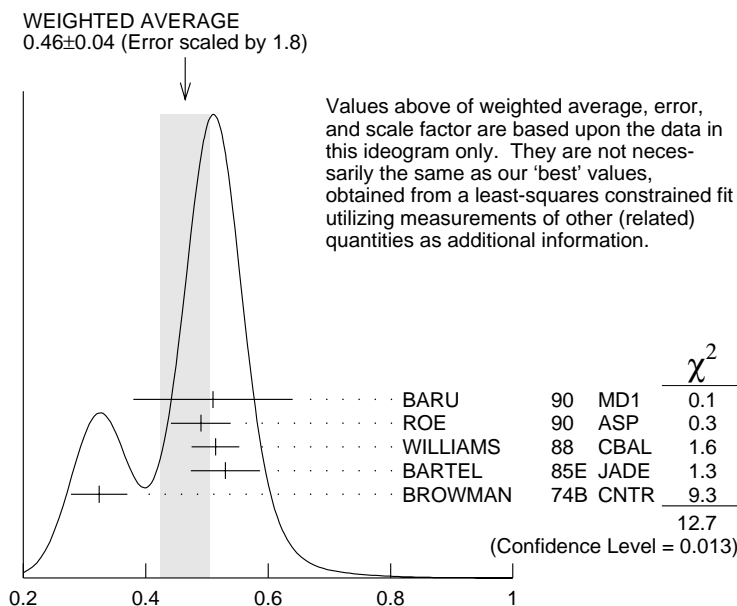
See the table immediately above giving the fitted decay rates. See also the "Note on the Decay Width  $\Gamma(\eta \rightarrow \gamma\gamma)$ ," in our 1994 edition, Phys. Rev. **D50**, 1 August 1994, Part I, p. 1451.

VALUE (keV)	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.46 <math>\pm</math> 0.04</b>	<b>OUR FIT</b>	Error includes scale factor of 1.8.		
<b>0.46 <math>\pm</math> 0.04</b>	<b>OUR AVERAGE</b>	Error includes scale factor of 1.8. See the ideogram below.		
0.51 $\pm$ 0.12 $\pm$ 0.05	36	BARU	90 MD1	$e^+ e^- \rightarrow e^+ e^- \eta$
0.490 $\pm$ 0.010 $\pm$ 0.048	2287	ROE	90 ASP	$e^+ e^- \rightarrow e^+ e^- \eta$
0.514 $\pm$ 0.017 $\pm$ 0.035	1295	WILLIAMS	88 CBAL	$e^+ e^- \rightarrow e^+ e^- \eta$
0.53 $\pm$ 0.04 $\pm$ 0.04		BARTEL	85E JADE	$e^+ e^- \rightarrow e^+ e^- \eta$
0.324 $\pm$ 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>0.715 ± 0.006 OUR FIT</b>				Error includes scale factor of 1.4.
<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>0.3921 ± 0.0034 OUR FIT</b>				Error includes scale factor of 1.4.
<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>
<b>0.5485±0.0022 OUR FIT</b>				Error includes scale factor of 1.1.
<b>0.549 ±0.004 OUR AVERAGE</b>				
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>
<b>0.4505±0.0022 OUR FIT</b>				Error includes scale factor of 1.1.
<b>0.450 ±0.004 OUR AVERAGE</b>				
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>
<b>0.821±0.007 OUR FIT</b>			Error includes scale factor of 1.1.
<b>0.833±0.012 OUR AVERAGE</b>			
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. • • •
0.822±0.009	<sup>3</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 result is not independent of other ALDE 84 results in this Listing, and so is omitted from the fit and average.

$$\Gamma(\pi^0 2\gamma)/\Gamma(\text{neutral modes}) \qquad \Gamma_4/\Gamma_1 = \Gamma_4/(\Gamma_2+\Gamma_3+\Gamma_4)$$

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>(1.00 ± 0.20) × 10<sup>-3</sup> OUR FIT</b>		
<b>0.0010 ± 0.0002</b>	ALDE	84 GAM2

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

These results are summarized in the review by LANDSBERG 85.

<u>VALUE (units 10<sup>-4</sup>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>7.1 ± 1.4 OUR FIT</b>					

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

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>2.52 ± 0.08 OUR FIT</b>	Error includes scale factor of 1.5.		
<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>4</sup> JAMES	66	HBC
3.20 ± 1.26	53	<sup>4</sup> BASTIEN	62	HBC
2.5 ± 1.0	10	<sup>4</sup> PICKUP	62	HBC

<sup>4</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  $\eta \rightarrow \pi^+ \pi^- \gamma$ .

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>1.38 ± 0.04 OUR FIT</b>	Error includes scale factor of 1.5.		
<b>1.1 ± 0.4 OUR AVERAGE</b>			

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

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>3.09 ± 0.10 OUR FIT</b>	Error includes scale factor of 1.4.		
<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>5</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>5</sup> Error increased from published value 0.5 by Bloodworth (private communication).

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>1.70±0.05 OUR FIT</b>	Error includes scale factor of 1.5.			
<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>1.39±0.05 OUR FIT</b>	Error includes scale factor of 1.4.			
<b>1.34±0.10 OUR AVERAGE</b>	Error includes scale factor of 1.2.			
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	
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	

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

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 —————

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</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	

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

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>2.1±0.5 OUR FIT</b>				
<b>2.1±0.5</b>	80	JANE	75B OSPK	See the erratum

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

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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**3.1 ± 0.4 OUR FIT**

**3.1 ± 0.4**                      600                      DZHELYADIN 80    SPEC     $\pi^- p \rightarrow \eta n$

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

1.5 ± 0.75                      100                      BUSHNIN            78    SPEC    See DZHELYADIN 80

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

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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**< 0.77**                      90                      BROWDER            97B    CLE2     $e^+ e^- \simeq 10.5 \text{ GeV}$

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

< 2                      90                      WHITE                96    SPEC     $p d \rightarrow \eta^3 \text{He}$

< 3                      90                      DAVIES                74    RVUE    Uses ESTEN 67

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

<u>VALUE (units <math>10^{-6}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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**5.8 ± 0.8 OUR AVERAGE**

5.7 ± 0.7 ± 0.5                      114                      ABEGG                94    SPEC     $p d \rightarrow \eta^3 \text{He}$

6.5 ± 2.1                      27                      DZHELYADIN 80B    SPEC     $\pi^- p \rightarrow \eta n$

• • • 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

< 20                      95                      0                      WEHMANN            68    OSPK

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

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

5.9 ± 2.2                      HYAMS                69    OSPK

$$\Gamma(\pi^+ \pi^- e^+ e^-) / \Gamma(\pi^+ \pi^- \gamma) \qquad \Gamma_{13} / \Gamma_8$$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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**0.026<sup>+0.026</sup><sub>-0.016</sub> OUR FIT**

**0.026 ± 0.026**                      1                      GROSSMAN            66    HBC

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

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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**0.13<sup>+0.12</sup><sub>-0.08</sub> OUR FIT**

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

< 0.7                      RITTENBERG            65    HBC

$$\Gamma(\pi^+ \pi^- 2\gamma) / \Gamma(\pi^+ \pi^- \pi^0) \qquad \Gamma_{14} / \Gamma_7$$

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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**< 0.009**                      PRICE                67    HBC

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

< 0.016                      95                      BALTAY                67B    DBC



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

 $\Gamma_{15}/\Gamma_7$ 

VALUE (units $10^{-2}$ )	CL%	EVTS	DOCUMENT ID	TECN
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<0.24	90	0	THALER	73 ASPK
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• • • 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

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

 $\Gamma_{16}/\Gamma$ 

VALUE (units $10^{-6}$ )	CL%	DOCUMENT ID	TECN	COMMENT
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<3	90	DZHELYADIN 81	SPEC	$\pi^- p \rightarrow \eta n$
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————— Rare or forbidden modes —————

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

 $\Gamma_{17}/\Gamma$ 

Forbidden by  $P$  and  $CP$  invariance.

VALUE (units $10^{-4}$ )	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
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< 9	90		AKHMETSHIN 97C	CMD2	$e^+e^- \rightarrow \pi^+\pi^-\gamma$ , 0.99–1.04 GeV
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• • • We do not use the following data for averages, fits, limits, etc. • • •

<15	0		THALER	73 ASPK
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$$\Gamma(3\gamma)/\Gamma(\text{neutral modes})$$

 $\Gamma_{18}/\Gamma_1 = \Gamma_{18}/(\Gamma_2+\Gamma_3+\Gamma_4)$ 

Forbidden by  $C$  invariance.

VALUE (units $10^{-4}$ )	CL%	DOCUMENT ID	TECN
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<7	95	ALDE	84 GAM2
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$$\Gamma(\pi^0e^+e^-)/\Gamma(\pi^+\pi^-\pi^0)$$

 $\Gamma_{19}/\Gamma_7$ 

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

VALUE (units $10^{-4}$ )	CL%	EVTS	DOCUMENT ID	TECN
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< 1.9	90		JANE	75 OSPK
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• • • 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

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

 $\Gamma_{19}/\Gamma$ 

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

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

$\Gamma(\pi^0 \mu^+ \mu^-) / \Gamma_{\text{total}}$   $\Gamma_{20} / \Gamma$ 

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	

 $[\Gamma(\mu^+ e^-) + \Gamma(\mu^- e^+)] / \Gamma_{\text{total}}$   $\Gamma_{21} / \Gamma$ 

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>6</sup> GORMLEY 68C	ASPK
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<sup>6</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**

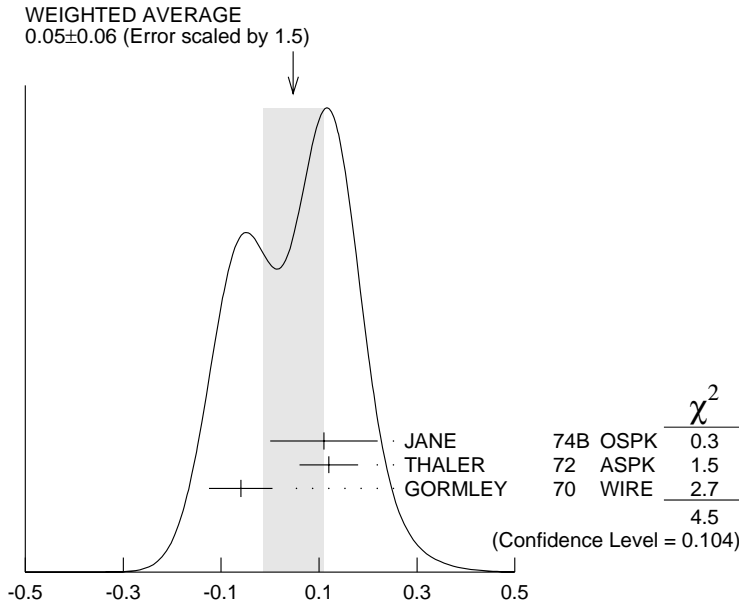
1.2 ± 0.6	35k	JANE 74B	OSPK
0.5 ± 0.6	36k	THALER 72	ASPK
1.22 ± 1.56	7257	GORMLEY 70	ASPK

**$\pi^+ \pi^- \gamma$  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>
<b>0.05 ± 0.06</b>	<b>OUR AVERAGE</b>	Error includes scale factor of 1.5. See the ideogram below.	
0.11 ± 0.11	35k	JANE	74B OSPK
0.12 ± 0.06		<sup>7</sup> THALER	72 ASPK
-0.060 ± 0.065	7250	GORMLEY	70 WIRE

<sup>7</sup> The authors don't believe this indicates *D*-wave because the dependence of  $\beta$  on the  $\gamma$  energy is inconsistent with theoretical prediction. A  $\cos^2\theta$  dependence may also come from *P*- and *F*-wave interference.



$\eta \rightarrow \pi^+ \pi^- \gamma$  parameter  $\beta$  (*D*-wave)

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ENERGY DEPENDENCE OF  $\eta \rightarrow 3\pi$  DALITZ PLOTSPARAMETERS 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>8</sup> ABELE	98D CBAR	$\bar{p}p \rightarrow \pi^0\pi^0\eta$ at rest
	1077	<sup>9</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>8</sup> ABELE 98D obtain  $a = -1.22 \pm 0.07$  and  $b = 0.22 \pm 0.11$  when  $c$  (our  $d$ ) is fixed at 0.06.

<sup>9</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>-0.039 ± 0.015 OUR AVERAGE</b>				
-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

ABELE	98C	PL B417 193	+Adomeit+	(CERN Crystal Barrel Collab.)
ABELE	98D	PL B417 197	+Adomeit+	(CERN Crystal Barrel Collab.)
AKHMETSHIN	97C	PL B415 452	+Aksenov+	(NOVO, BOST, PITT, YALE)
BROWDER	97B	PR D56 5359	+Li, Li, Rodriguez+	(CLEO Collab.)
ABEGG	96	PR D53 11	+Abela, Boudard+	(Saturne SPES2 Collab.)
WHITE	96	PR D53 6658	+Tippens, Abegg+	(Saturne SPES2 Collab.)
AMSLER	95	PL B346 203	+Armstrong, Heinsius+	(Crystal Barrel Collab.)
KRUSCHE	95D	ZPHY A351 237	+Ahrens+	(TAPS + A2 Collab.)
ABEGG	94	PR D50 92	+Baldisseri, Boudard+	(Saturne SPES2 Collab.)
AMSLER	93	ZPHY C58 175	+Armstrong, Merkel+	(Crystal Barrel Collab.)
KESSLER	93	PRL 70 892	+Abegg, Baldisseri+	(Saturne SPES2 Collab.)
PLOUIN	92	PL B276 526	+Fleury+	(Saturne SPES4 Collab.)
BARU	90	ZPHY C48 581	+Blinov, Blinov+	(MD-1 Collab.)
ROE	90	PR D41 17	+Bartha, Burke, Garbincius+	(ASP Collab.)
WILLIAMS	88	PR D38 1365	+Antreasyan, Bartels, Besset+	(Crystal Ball Collab.)
AIHARA	86	PR D33 844	+Alston-Garnjost+	(TPC-2 $\gamma$ Collab.)
BARTEL	85E	PL 160B 421	+Becker, Cords, Felst+	(JADE Collab.)
LANDSBERG	85	PRPL 128 310		(SERP)
ALDE	84	ZPHY C25 225	+Binon, Bricman, Donskov+	(SERP, BELG, LAPP)
Also	84B	SJNP 40 918	Alde, Binon, Bricman+	(SERP, BELG, LAPP)

Translated from YAF 40 1447.

WEINSTEIN	83	PR D28 2896	+Antreasyan, Gu, Kollman+	(Crystal Ball Collab.)
BINON	82	SJNP 36 391	+Bricman, Gouanere+	(SERP, BELG, LAPP, CERN)
		Translated from YAF 36	670.	
Also	82B	NC 71A 497	Binon, Bricman+	(SERP, BELG, LAPP, CERN)
DAVYDOV	81	LNC 32 45	+Donskov, Inyakin+	(SERP, BELG, LAPP, CERN)
Also	81B	SJNP 33 825	Davydov, Binon+	(SERP, BELG, LAPP, CERN)
		Translated from YAF 33	1534.	
DZHELYADIN	81	PL 105B 239	+Golovkin, Konstantinov, Kubarovski+	(SERP)
Also	81C	SJNP 33 822	Dzhelyadin, Viktorov, Golovkin+	(SERP)
		Translated from YAF 33	1529.	
ABROSIMOV	80	SJNP 31 195	+Ilna, Niszcz, Okhrimenko+	(JINR)
		Translated from YAF 31	371.	
DZHELYADIN	80	PL 94B 548	+Viktorov, Golovkin+	(SERP)
Also	80C	SJNP 32 516	Dzhelyadin, Golovkin, Kachanov+	(SERP)
		Translated from YAF 32	998.	
DZHELYADIN	80B	PL 97B 471	+Viktorov, Golovkin+	(SERP)
Also	80D	SJNP 32 518	Dzhelyadin, Golovkin, Kachanov+	(SERP)
		Translated from YAF 32	1002.	
BUSHNIN	78	PL 79B 147	+Dzhelyadin, Golovkin, Gritsuk+	(SERP)
Also	78B	SJNP 28 775	Bushnin, Golovkin, Gritsuk, Dzhelyadin+	(SERP)
		Translated from YAF 28	1507.	
MARTYNOV	76	SJNP 23 48	+Saltykov, Tarasov, Uzhinskii	(JINR)
		Translated from YAF 23	93.	
JANE	75	PL 59B 99	+Grannis, Jones, Lipman, Owen+	(RHEL, LOWC)
JANE	75B	PL 59B 103	+Grannis, Jones, Lipman, Owen+	(RHEL, LOWC)
Also	78B	PL 73B 503	Jane	
		Erratum in private communication.		
BROWMAN	74B	PRL 32 1067	+Dewire, Gittelman, Hanson, Loh+	(CORN, BING)
DAVIES	74	NC 24A 324	+Guy, Zia	(BIRM, RHEL, SHMP)
DUANE	74	PRL 32 425	+Binnie, Camilleri, Carr+	(LOIC, SHMP)
JANE	74	PL 48B 260	+Jones, Lipman, Owen+	(RHEL, LOWC, SUSS)
JANE	74B	PL 48B 265	+Jones, Lipman, Owen+	(RHEL, LOWC, SUSS)
KENDALL	74	NC 21A 387	+Lanou, Massimo, Shapiro+	(BROW, BARI, MIT)
LAYTER	73	PR D7 2565	+Appel, Kotlewski, Lee, Stein, Thaler	(COLU)
THALER	73	PR D7 2569	+Appel, Kotlewski, Layter, Lee, Stein	(COLU)
AGUILAR...	72B	PR D6 29	Aguilar-Benitez, Chung, Eisner, Samios	(BNL)
BLOODW...	72B	NP B39 525	Bloodworth, Jackson, Prentice, Yoon	(TNTO)
LAYTER	72	PRL 29 316	+Appel, Kotlewski, Lee, Stein, Thaler	(COLU)
THALER	72	PRL 29 313	+Appel, Kotlewski, Layter, Lee, Stein	(COLU)
BASILE	71D	NC 3A 796	+Bollini, Dalpiaz, Frabetti+	(CERN, BGNA, STRB)
STRUGALSKI	71	NP B27 429	+Chuvilo, Gemesy, Ivanovskaya+	(JINR)
BAGLIN	70	NP B22 66	+Bezagueta, Degrange+	(EPOL, MADR, STRB)
BUTTRAM	70	PRL 25 1358	+Kreisler, Mischke	(PRIN)
CARPENTER	70	PR D1 1303	+Binkley, Chapman, Cox, Dagan+	(DUKE)
COX	70B	PRL 24 534	+Fortney, Golson	(DUKE)
DANBURG	70	PR D2 2564	+Abolins, Dahl, Davies, Hoch, Kirz+	(LRL)
DEVONS	70	PR D1 1936	+Grunhaus, Kozlowski, Nemethy+	(COLU, SYRA)
GORMLEY	70	PR D2 501	+Hyman, Lee, Nash, Peoples+	(COLU, BNL)
Also	70B	Thesis Nevis 181	Gormley	(COLU)
BAGLIN	69	PL 29B 445	+Bezagueta+	(EPOL, UCB, MADR, STRB)
Also	70	NP B22 66	Baglin, Bezagueta, Degrange+	(EPOL, MADR, STRB)
HYAMS	69	PL 29B 128	+Koch, Potter, VonLindern+	(CERN, MPIM)
ARNOLD	68	PL 27B 466	+Paty, Baglin, Bingham+	(STRB, MADR, EPOL, UCB)
BAZIN	68	PRL 20 895	+Goshaw, Zacher+	(PRIN, QUKI)
BULLOCK	68	PL 27B 402	+Esten, Fleming, Govan, Henderson+	(LOUC)
CNOPS	68	PRL 21 1609	+Hough, Cohn+	(BNL, ORNL, UCND, TENN, PENN)
GORMLEY	68C	PRL 21 402	+Hyman, Lee, Nash, Peoples+	(COLU, BNL)
WEHMANN	68	PRL 20 748	+Engels+	(HARV, CASE, SLAC, CORN, MCGI)
BAGLIN	67	PL 24B 637	+Bezagueta, Degrange+	(EPOL, UCB)
BAGLIN	67B	BAPS 12 567	+Bezagueta, Degrange+	(EPOL, UCB)
BALTAY	67B	PRL 19 1498	+Franzini, Kim, Newman+	(COLU, STON)
BALTAY	67D	PRL 19 1495	+Franzini, Kim, Newman+	(COLU, BRAN)
BEMPORAD	67	PL 25B 380	+Baccini, Foa, Lubelsmey+	(PISA, BONN)
Also	67	Private Comm.	Ion	
BILLING	67	PL 25B 435	+Bullock, Esten, Govan+	(LOUC, OXF)
BUNIATOV	67	PL 25B 560	+Zavattini, Deinet+	(CERN, KARL)
CENCE	67	PRL 19 1393	+Peterson, Stenger, Chiu+	(HAWA, LRL)
ESTEN	67	PL 24B 115	+Govan, Knight, Miller, Tovey+	(LOUC, OXF)

FELDMAN	67	PRL 18 868	+Frati, Gleeson, Halpern+	(PENN)
FLATTE	67	PRL 18 976		(LRL)
FLATTE	67B	PR 163 1441	+Wohl	(LRL)
LITCHFIELD	67	PL 24B 486	+Rangan, Segar, Smith+	(RHEL, SACL)
PRICE	67	PRL 18 1207	+Crawford	(LRL)
ALFF-...	66	PR 145 1072	Alff-Steinberger, Berley+	(COLU, RUTG)
CLPWY	66	PR 149 1044		(SCUC, LRL, PURD, WISC, YALE)
CRAWFORD	66	PRL 16 333	+Price	(LRL)
DIGIUGNO	66	PRL 16 767	+Giorgi, Silvestri+	(NAPL, TRST, FRAS)
GROSSMAN	66	PR 146 993	+Price, Crawford	(LRL)
GRUNHAUS	66	Thesis		(COLU)
JAMES	66	PR 142 896	+Kraybill	(YALE, BNL)
JONES	66	PL 23 597	+Binnie, Duane, Horsey, Mason+	(LOIC, RHEL)
LARRIBE	66	PL 23 600	+Leveque, Muller, Pauli+	(SACL, RHEL)
FOSTER	65	PR 138B 652	+Peters, Meer, Loeffler+	(WISC, PURD)
FOSTER	65B	Athens Conf.	+Good, Meer	(WISC)
FOSTER	65C	Thesis		(WISC)
PRICE	65	PRL 15 123	+Crawford	(LRL)
RITTENBERG	65	PRL 15 556	+Kalbfleisch	(LRL, BNL)
FOELSCH	64	PR 134B 1138	+Kraybill	(YALE)
KRAEMER	64	PR 136B 496	+Madansky, Fields+	(JHU, NWES, WOOD)
PAULI	64	PL 13 351	+Muller	(SACL)
BACCI	63	PRL 11 37	+Penso, Salvini+	(ROMA, FRAS)
CRAWFORD	63	PRL 10 546	+Lloyd, Fowler	(LRL, DUKE)
Also	66B	PRL 16 907	Crawford, Lloyd, Fowler	(LRL, DUKE)
ALFF-...	62	PRL 9 322	Alff-Steinberger, Berley, Colley+	(COLU, RUTG)
BASTIEN	62	PRL 8 114	+Berge, Dahl, Ferro-Luzzi+	(LRL)
PICKUP	62	PRL 8 329	+Robinson, Salant	(CNRC, BNL)

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