$\rho(770)$

$I^G(J^{PC}) = 1^+(1^{--})$

THE $\rho(770)$

Updated March 2002 by S. Eidelman (Novosibirsk).

Determination of the parameters of the $\rho(770)$ is beset with many difficulties because of its large width. In physical region fits, the line shape does not correspond to a relativistic Breit-Wigner function with a P-wave width, but requires some additional shape parameter. This dependence on parameterization was demonstrated long ago by PISUT 68. Bose-Einstein correlations are another source of shifts in the $\rho(770)$ line shape, particularly in multi-particle final state systems (LAFFERTY 93).

The same model dependence afflicts any other source of resonance parameters, such as the energy dependence of the phase shift δ_1^1, or the pole position. It is, therefore, not surprising that a study of $\rho(770)$ dominance in the decays of the η and η' reveals the need for specific dynamical effects, in addition to the $\rho(770)$ pole (BENAYOUN 93, ABELE 97B).

The cleanest determination of the $\rho(770)$ mass and width comes from the e^+e^- annihilation and τ-lepton decays. BARATE 97M showed that the charged $\rho(770)$ parameters measured from τ-lepton decays are consistent with those of the neutral one determined from e^+e^- data of BARKOV 85. This conclusion is qualitatively supported by the high statistics study of ANDERSON 00. However, model-independent comparison of the two-pion mass spectrum in τ decays and the $e^+e^- \rightarrow \pi^+\pi^-$ cross section gives indications of discrepancies between the overall normalization: τ data are about 3% higher than e^+e^- data (ANDERSON 99, EIDELMAN 99). This effect can be partly explained by isospin violation (ALEMANY 98, CZYZ 01), but its complete understanding requires additional consideration of electroweak and QED radiative effects (CIRIGLIANO 01, EIDELMAN 01, MELNIKOV 01).

References

References may be found at the end of the $\rho(770)$ Listing.

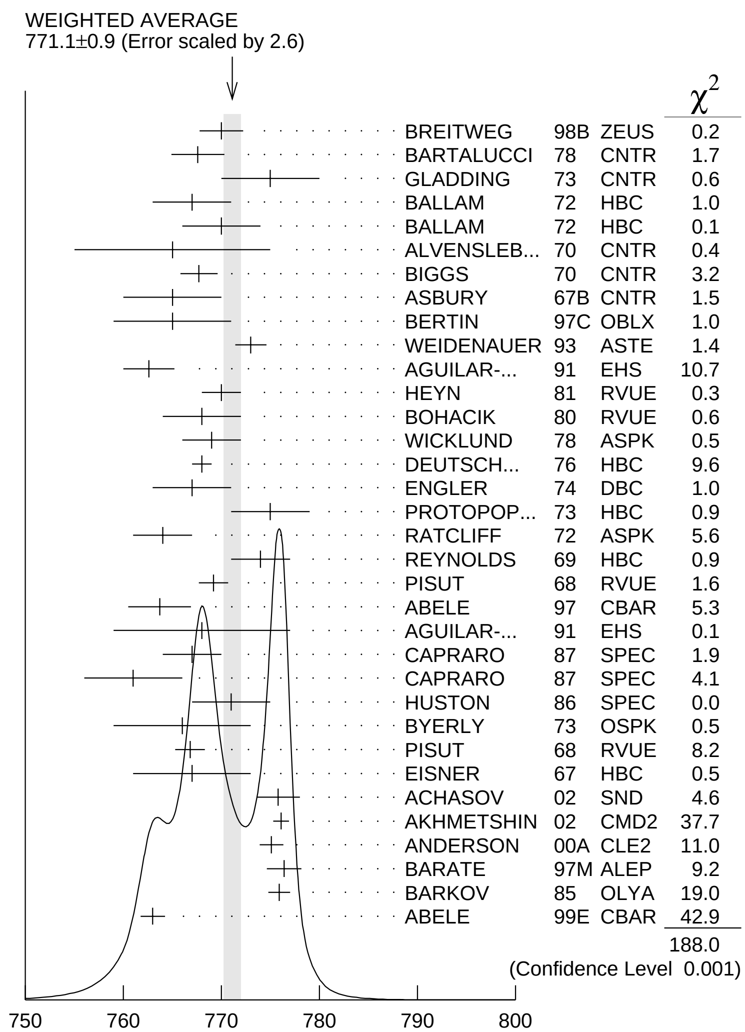
$\rho(770)$ MASS

We no longer list S-wave Breit-Wigner fits, or data with high combinatorial background.

MIXED CHARGES

VALUE (MeV) *DOCUMENT ID*

771.1±0.9 OUR AVERAGE Includes data from the 5 datablocks that follow this one. Error includes scale factor of 2.6. See the ideogram below.



$\rho(770)$ MASS MIXED CHARGES

MIXED CHARGES, τ DECAYS and $e^+ e^-$

The data in this block is included in the average printed for a previous datablock.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
775.9 ±0.5 OUR AVERAGE					
775.8 ±0.9 ±2.0	500k	ACHASOV 02	SND	0	1.02 $e^+ e^- \to \pi^+ \pi^- \pi^0$
776.09±0.64±0.50	114k	[1] AKHMETSHIN 02	CMD2		$e^+ e^- \to \pi^+ \pi^-$
775.1 ±1.1 ±0.5	87k	[2,3] ANDERSON 00A	CLE2		$\tau^- \to \pi^- \pi^0 \nu_\tau$
776.4 ±0.9 ±1.5		[3] BARATE 97M	ALEP		$\tau^- \to \pi^- \pi^0 \nu_\tau$
775.9 ±1.1		[4] BARKOV 85	OLYA	0	$e^+ e^- \to \pi^+ \pi^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
774.5 ±0.7 ±1.5	500k	[5] ACHASOV 02	SND	±	1.02 $e^+ e^- \to \pi^+ \pi^- \pi^0$
775.0 ±0.6 ±1.1	500k	[6] ACHASOV 02	SND		1.02 $e^+ e^- \to \pi^+ \pi^- \pi^0$
775.1 ±0.5		[7] PICH 01	RVUE		$\tau^- \to \pi^- \pi^0 \nu_\tau$
775.1 ±0.7 ±5.3		[8] BENAYOUN 98	RVUE		$e^+ e^- \to \pi^+ \pi^-$, $\mu^+ \mu^-$
770.5 ±1.9 ±5.1		[9] GARDNER 98	RVUE		0.28–0.92 $e^+ e^- \to \pi^+ \pi^-$
764.1 ±0.7		[10] O'CONNELL 97	RVUE		$e^+ e^- \to \pi^+ \pi^-$
757.5 ±1.5		[11] BERNICHA 94	RVUE		$e^+ e^- \to \pi^+ \pi^-$
768 ±1		[12] GESHKEN... 89	RVUE		$e^+ e^- \to \pi^+ \pi^-$

MIXED CHARGES, OTHER REACTIONS

The data in this block is included in the average printed for a previous datablock.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
763.0±0.3±1.2	600k	[13] ABELE 99E	CBAR	0±	0.0 $\overline{p} p \to \pi^+ \pi^- \pi^0$

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The data in this block is included in the average printed for a previous datablock.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
766.5±1.1 OUR AVERAGE					
763.7±3.2		ABELE 97	CBAR		$\overline{p} n \to \pi^- \pi^0 \pi^0$
768 ±9		AGUILAR-... 91	EHS		400 $p p$
767 ±3	2935	[14] CAPRARO 87	SPEC	−	200 π^- Cu $\to \pi^- \pi^0$ Cu
761 ±5	967	[14] CAPRARO 87	SPEC	−	200 π^- Pb $\to \pi^- \pi^0$ Pb
771 ±4		HUSTON 86	SPEC	+	202 π^+ A $\to \pi^+ \pi^0$ A
766 ±7	6500	[15] BYERLY 73	OSPK	−	5 $\pi^- p$
766.8±1.5	9650	[16] PISUT 68	RVUE	−	1.7–3.2 $\pi^- p$, t <10
767 ±6	900	[14] EISNER 67	HBC	−	4.2 $\pi^- p$, t <10

NEUTRAL ONLY, PHOTOPRODUCED

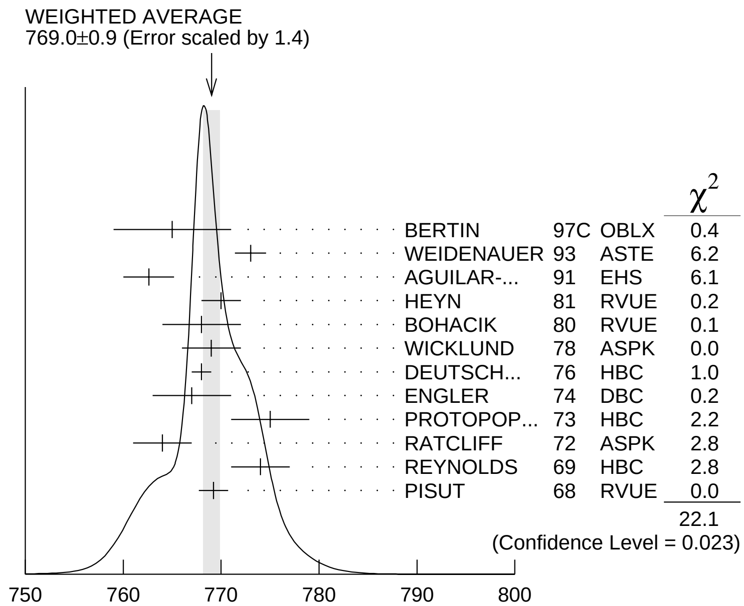
The data in this block is included in the average printed for a previous datablock.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
768.5± 1.1 OUR AVERAGE						
770 ± 2 ±1	79k	[17] BREITWEG	98B	ZEUS	0	50–100 γp
767.6± 2.7		BARTALUCCI	78	CNTR	0	$\gamma p \rightarrow e^+ e^- p$
775 ± 5		GLADDING	73	CNTR	0	2.9–4.7 γp
767 ± 4	1930	BALLAM	72	HBC	0	2.8 γp
770 ± 4	2430	BALLAM	72	HBC	0	4.7 γp
765 ±10		ALVENSLEB...	70	CNTR	0	γA, t <0.01
767.7± 1.9	140k	BIGGS	70	CNTR	0	<4.1 $\gamma C \rightarrow \pi^+ \pi^- C$
765 ± 5	4000	ASBURY	67B	CNTR	0	$\gamma +$ Pb
• • • We do not use the following data for averages, fits, limits, etc. • • •						
771 ± 2	79k	[18] BREITWEG	98B	ZEUS	0	50–100 γp

NEUTRAL ONLY, OTHER REACTIONS

The data in this block is included in the average printed for a previous datablock.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
769.0±0.9 OUR AVERAGE	Error includes scale factor of 1.4. See the ideogram below.					
765 ±6		BERTIN	97C	OBLX		0.0 $\overline{p} p \rightarrow \pi^+ \pi^- \pi^0$
773 ±1.6		WEIDENAUER	93	ASTE		$\overline{p} p \rightarrow \pi^+ \pi^- \omega$
762.6±2.6		AGUILAR-...	91	EHS		400 $p p$
770 ±2		[19] HEYN	81	RVUE		Pion form factor
768 ±4		[20,21] BOHACIK	80	RVUE	0	
769 ±3		[15] WICKLUND	78	ASPK	0	3,4,6 $\pi^\pm N$
768 ±1	76000	DEUTSCH...	76	HBC	0	16 $\pi^+ p$
767 ±4	4100	ENGLER	74	DBC	0	6 $\pi^+ n \rightarrow \pi^+ \pi^- p$
775 ±4	32000	[20] PROTOPOP...	73	HBC	0	7.1 $\pi^+ p$, t <0.4
764 ±3	6800	RATCLIFF	72	ASPK	0	15 $\pi^- p$, t <0.3
774 ±3	1700	REYNOLDS	69	HBC	0	2.26 $\pi^- p$
769.2±1.5	13300	[22] PISUT	68	RVUE	0	1.7–3.2 $\pi^- p$, t <10
• • • We do not use the following data for averages, fits, limits, etc. • • •						
762.3±0.5±1.2	600k	[23] ABELE	99E	CBAR	0	0.0 $\overline{p} p \rightarrow \pi^+ \pi^- \pi^0$
777 ±2	4943	[24] ADAMS	97	E665		470 $\mu p \rightarrow \mu X B$
770 ±2		[25] BOGOLYUB...	97	MIRA		32 $\overline{p} p \rightarrow \pi^+ \pi^- X$
768 ±8		[25] BOGOLYUB...	97	MIRA		32 $p p \rightarrow \pi^+ \pi^- X$
761.1±2.9		DUBNICKA	89	RVUE		π form factor
777.4±2.0		[26] CHABAUD	83	ASPK	0	17 $\pi^- p$ polarized
769.5±0.7		[20,21] LANG	79	RVUE	0	
770 ±9		[21] ESTABROOKS	74	RVUE	0	17 $\pi^- p \rightarrow \pi^+ \pi^- n$
773.5±1.7	11200	[14] JACOBS	72	HBC	0	2.8 $\pi^- p$
775 ±3	2250	HYAMS	68	OSPK	0	11.2 $\pi^- p$



$\rho(770)^0$ mass (MeV)

[1] Using the GOUNARIS 68 parameterization with the complex phase of the ρ-ω interference.

[2] $\rho(1700)$ mass and width fixed at 1700 MeV and 235 MeV respectively.

[3] From the GOUNARIS 68 parametrization of the pion form factor. The second error is a model error taking into account different parametrizations of the pion form factor.

[4] From the GOUNARIS 68 parametrization of the pion form factor.

[5] Not independent of ACHASOV 02 measurements of m_{ρ^0} and $m_{\rho^0}-m_{\rho^\pm}$.

[6] Assuming $m_{\rho^\pm} = m_{\rho^0}$.

[7] From a fit of the model-independent parameterization of the pion form factor to the data of BARATE 97M.

[8] Using the data of BARKOV 85 in the hidden local symmetry model.

[9] From the fit to $e^+e^- \rightarrow \pi^+\pi^-$ data from the compilations of HEYN 81 and BARKOV 85, including the GOUNARIS 68 parametrization of the pion form factor.

[10] A fit of BARKOV 85 data assuming the direct $\omega\pi\pi$ coupling.

[11] Applying the S-matrix formalism to the BARKOV 85 data.

[12] Includes BARKOV 85 data. Model-dependent width definition.

[13] Assuming the equality of ρ^+ and ρ^- masses and widths.

[14] Mass errors enlarged by us to $\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.

[15] Phase shift analysis. Systematic errors added corresponding to spread of different fits.

[16] From fit of 3-parameter relativistic P-wave Breit-Wigner to total mass distribution. Includes BATON 68, MILLER 67B, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 66B, JACOBS 66B, JAMES 66, WEST 66, BLIEDEN 65 and CARMONY 64.

[17] From the parametrization according to SOEDING 66.

[18] From the parametrization according to ROSS 66.

[19] HEYN 81 includes all spacelike and timelike F_π values until 1978.

[20] From pole extrapolation.

[21] From phase shift analysis of GRAYER 74 data.

[22] Includes MALAMUD 69, ARMENISE 68, BACON 67, HUWE 67, MILLER 67B, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 66B, JACOBS 66B, JAMES 66, WEST 66, GOLDHABER 64, ABOLINS 63.

[23] Using relativistic Breit-Wigner and taking into account ρ-ω interference.

[24] Systematic errors not evaluated.

[25] Systematic effects not studied.

[26] From fit of 3-parameter relativistic Breit-Wigner to helicity-zero part of P-wave intensity. CHABAUD 83 includes data of GRAYER 74.

$m_{\rho(770)^0} - m_{\rho(770)^\pm}$

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
0.5±0.7 OUR AVERAGE						
1.3±1.1±2.0	500k	ACHASOV	02	SND		1.02 $e^+e^- \rightarrow \pi^+\pi^-\pi^0$
1.6±0.6±1.7	600k	ABELE	99E	CBAR	0±	0.0 $\overline{p}p \rightarrow \pi^+\pi^-\pi^0$
0.0±1.0		[29] BARATE	97M	ALEP		$\tau^- \rightarrow \pi^-\pi^0\nu_\tau$
−4 ±4	3000	[27] REYNOLDS	69	HBC	−0	2.26 $\pi^- p$
−5 ±5	3600	[27] FOSTER	68	HBC	±0	0.0 $\overline{p}p$
2.4±2.1	22950	[28] PISUT	68	RVUE		$\pi N \rightarrow \rho N$

[27] From quoted masses of charged and neutral modes.

[28] Includes MALAMUD 69, ARMENISE 68, BATON 68, BACON 67, HUWE 67, MILLER 67B, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 66B, JACOBS 66B, JAMES 66, WEST 66, BLIEDEN 65, CARMONY 64, GOLDHABER 64, ABOLINS 63.

[29] Using the compilation of e^+e^- data from BARKOV 85.

ρ(770) RANGE PARAMETER

The range parameter R enters an energy-dependent correction to the width, of the form $(1 + q_r^2 R^2) / (1 + q^2 R^2)$, where q is the momentum of one of the pions in the $\pi\pi$ rest system. At resonance, $q = q_r$.

VALUE (GeV^{-1})	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
$5.3^{+0.9}_{-0.7}$	CHABAUD	83	ASPK	0	17 $\pi^- p$ polarized

$\rho(770)$ WIDTH

We no longer list *S*-wave Breit-Wigner fits, or data with high combinatorial background.

MIXED CHARGES

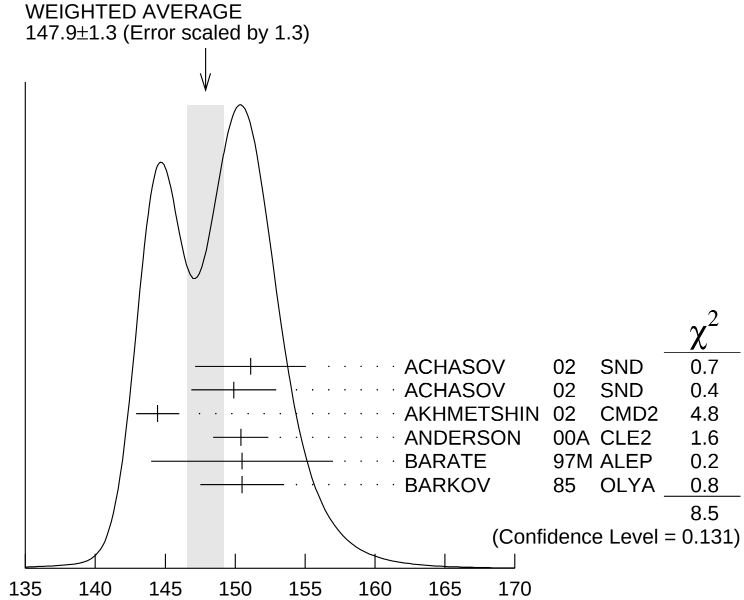
VALUE (MeV)	*DOCUMENT ID*
149.2±0.7 OUR AVERAGE	Includes data from the 5 datablocks that follow this one. Error includes scale factor of 1.1.

MIXED CHARGES, τ DECAYS and e^+e^-

The data in this block is included in the average printed for a previous datablock.

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
147.9 ±1.3 OUR AVERAGE		Error includes scale factor of 1.3. See the ideogram below.				
151.1 ±2.6 ±3.0	500k	ACHASOV	02	SND	0	1.02 $e^+e^- \to \pi^+\pi^-\pi^0$
149.9 ±2.3 ±2.0	500k	ACHASOV	02	SND	±	1.02 $e^+e^- \to \pi^+\pi^-\pi^0$
144.46±1.33±0.80	114k	[30] AKHMETSHIN	02	CMD2		$e^+e^- \to \pi^+\pi^-$
150.4 ±1.4 ±1.4	87k	[31,32] ANDERSON	00A	CLE2		$\tau^- \to \pi^-\pi^0\nu_\tau$
150.5 ±1.6 ±6.3		[32] BARATE	97M	ALEP		$\tau^- \to \pi^-\pi^0\nu_\tau$
150.5 ±3.0		[33] BARKOV	85	OLYA	0	$e^+e^- \to \pi^+\pi^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
149.8 ±2.2 ±2.0	500k	[34] ACHASOV	02	SND		1.02 $e^+e^- \to \pi^+\pi^-\pi^0$
150.9 ±2.2 ±2.0	500k	[34] ACHASOV	02	SND		1.02 $e^+e^- \to \pi^+\pi^-\pi^0$
147.9 ±1.5 ±7.5		[35] BENAYOUN	98	RVUE		$e^+e^- \to \pi^+\pi^-$, $\mu^+\mu^-$
153.5 ±1.3 ±4.6		[36] GARDNER	98	RVUE		0.28–0.92 $e^+e^- \to \pi^+\pi^-$
145.0 ±1.7		[37] O'CONNELL	97	RVUE		$e^+e^- \to \pi^+\pi^-$
142.5 ±3.5		[38] BERNICHA	94	RVUE		$e^+e^- \to \pi^+\pi^-$
138 ±1		[39] GESHKEN...	89	RVUE		$e^+e^- \to \pi^+\pi^-$

[30] Using Gounaris-Sakurai parameterization with the complex phase of the ρ-ω interference.



Mixed charges, τ decays and $e^+ e^-$

MIXED CHARGES, OTHER REACTIONS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
The data in this block is included in the average printed for a previous datablock.						
149.5±1.3	600k	[40] ABELE	99E	CBAR	0±	0.0 $\overline{p}p \rightarrow \pi^+\pi^-\pi^0$

CHARGED ONLY, HADROPRODUCED

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
The data in this block is included in the average printed for a previous datablock.						
150.2± 2.4 OUR FIT						
150.2± 2.4 OUR AVERAGE						
152.8± 4.3		ABELE	97	CBAR		$\overline{p}n \rightarrow \pi^-\pi^0\pi^0$
155 ±11	2935	[41] CAPRARO	87	SPEC	−	200 π^- Cu $\rightarrow \pi^-\pi^0$ Cu
154 ±20	967	[41] CAPRARO	87	SPEC	−	200 π^- Pb $\rightarrow \pi^-\pi^0$ Pb
150 ± 5		HUSTON	86	SPEC	+	202 π^+ A $\rightarrow \pi^+\pi^0$ A
146 ±12	6500	[42] BYERLY	73	OSPK	−	5 $\pi^- p$
148.2± 4.1	9650	[43] PISUT	68	RVUE	−	1.7–3.2 $\pi^- p$, $t<10$
146 ±13	900	EISNER	67	HBC	−	4.2 $\pi^- p$, $t<10$

NEUTRAL ONLY, PHOTOPRODUCED

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
The data in this block is included in the average printed for a previous datablock.						
150.7± 2.9 OUR AVERAGE						
146 ± 3 ±13	79k	[44] BREITWEG	98B	ZEUS	0	50–100 γp
150.9± 3.0		BARTALUCCI	78	CNTR	0	$\gamma p \rightarrow e^+e^- p$

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

138 ± 3	79k	[45] BREITWEG	98B	ZEUS	0	50–100 γp
147 ±11		GLADDING	73	CNTR	0	2.9–4.7 γp
155 ±12	2430	BALLAM	72	HBC	0	4.7 γp
145 ±13	1930	BALLAM	72	HBC	0	2.8 γp
140 ± 5		ALVENSLEB...	70	CNTR	0	γA, t <0.01
146.1± 2.9	140k	BIGGS	70	CNTR	0	<4.1 $\gamma C \rightarrow \pi^+\pi^- C$
160 ±10		LANZEROTTI	68	CNTR	0	γp
130 ± 5	4000	ASBURY	67B	CNTR	0	$\gamma +$ Pb

NEUTRAL ONLY, OTHER REACTIONS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT

The data in this block is included in the average printed for a previous datablock.

150.9± 2.0 OUR FIT Error includes scale factor of 1.3.
150.9± 1.7 OUR AVERAGE Error includes scale factor of 1.1.

122 ±20		BERTIN	97C	OBLX		0.0 $\overline{p}p \rightarrow \pi^+\pi^-\pi^0$
145.7± 5.3		WEIDENAUER	93	ASTE		$\overline{p}p \rightarrow \pi^+\pi^-\omega$
144.9± 3.7		DUBNICKA	89	RVUE		π form factor
148 ± 6		[46,47] BOHACIK	80	RVUE	0	
152 ± 9		[42] WICKLUND	78	ASPK	0	3,4,6 $\pi^\pm pN$
154 ± 2	76000	DEUTSCH...	76	HBC	0	16 $\pi^+ p$
157 ± 8	6800	RATCLIFF	72	ASPK	0	15 $\pi^- p$, t <0.3
143 ± 8	1700	REYNOLDS	69	HBC	0	2.26 $\pi^- p$

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

147.0± 2.5	600k	[48] ABELE	99E	CBAR	0	0.0 $\overline{p}p \rightarrow \pi^+\pi^-\pi^0$
146 ± 3	4943	[49] ADAMS	97	E665		470 $\mu p \rightarrow \mu XB$
$160.0^{+4.1}_{-4.0}$		[50] CHABAUD	83	ASPK	0	17 $\pi^- p$ polarized
155 ± 1		[51] HEYN	81	RVUE	0	π form factor
148.0± 1.3		[46,47] LANG	79	RVUE	0	
146 ±14	4100	ENGLER	74	DBC	0	6 $\pi^+ n \rightarrow \pi^+\pi^- p$
143 ±13		[47] ESTABROOKS	74	RVUE	0	17 $\pi^- p \rightarrow \pi^+\pi^- n$
160 ±10	32000	[46] PROTOPOP...	73	HBC	0	7.1 $\pi^+ p$, t <0.4
145 ±12	2250	[41] HYAMS	68	OSPK	0	11.2 $\pi^- p$
163 ±15	13300	[52] PISUT	68	RVUE	0	1.7–3.2 $\pi^- p$, t <10

[31] ρ(1700) mass and width fixed at 1700 MeV and 235 MeV respectively.
[32] From the GOUNARIS 68 parametrization of the pion form factor. The second error is a model error taking into account different parametrizations of the pion form factor.
[33] From the GOUNARIS 68 parametrization of the pion form factor.
[34] Assuming $g_{\rho^0\pi\pi} = g_{\rho^\pm\pi\pi}$.
[35] Using the data of BARKOV 85 in the hidden local symmetry model.
[36] From the fit to $e^+e^- \rightarrow \pi^+\pi^-$ data from the compilations of HEYN 81 and BARKOV 85, including the GOUNARIS 68 parametrization of the pion form factor.
[37] A fit of BARKOV 85 data assuming the direct $\omega\pi\pi$ coupling.
[38] Applying the S-matrix formalism to the BARKOV 85 data.
[39] Includes BARKOV 85 data. Model-dependent width definition.
[40] Assuming the equality of ρ^+ and ρ^- masses and widths.
[41] Width errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.
[42] Phase shift analysis. Systematic errors added corresponding to spread of different fits.

[43] From fit of 3-parameter relativistic P-wave Breit-Wigner to total mass distribution. Includes BATON 68, MILLER 67B, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 66B, JACOBS 66B, JAMES 66, WEST 66, BLIEDEN 65 and CARMONY 64.
[44] From the parametrization according to SOEDING 66.
[45] From the parametrization according to ROSS 66.
[46] From pole extrapolation.
[47] From phase shift analysis of GRAYER 74 data.
[48] Using relativistic Breit-Wigner and taking into account ρ-ω interference.
[49] Systematic errors not evaluated.
[50] From fit of 3-parameter relativistic Breit-Wigner to helicity-zero part of P-wave intensity. CHABAUD 83 includes data of GRAYER 74.
[51] HEYN 81 includes all spacelike and timelike F_π values until 1978.
[52] Includes MALAMUD 69, ARMENISE 68, BACON 67, HUWE 67, MILLER 67B, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 66B, JACOBS 66B, JAMES 66, WEST 66, GOLDHABER 64, ABOLINS 63.

$\Gamma_{\rho(770)^0} - \Gamma_{\rho(770)^\pm}$

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
−0.1±1.9	[53] BARATE 97M	ALEP	$\tau^- \to \pi^- \pi^0 \nu_\tau$

[53] Using the compilation of $e^+ e^-$ data from BARKOV 85.

ρ(770) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	$\pi\pi$	$\sim$ 100 %	
	$\rho(770)^\pm$ decays		
Γ_2	$\pi^\pm\pi^0$	$\sim$ 100 %	
Γ_3	$\pi^\pm\gamma$	(4.5 ±0.5) × 10^{-4}	S=2.2
Γ_4	$\pi^\pm\eta$	< 6 × 10^{-3}	CL=84%
Γ_5	$\pi^\pm\pi^+\pi^-\pi^0$	< 2.0 × 10^{-3}	CL=84%
	$\rho(770)^0$ decays		
Γ_6	$\pi^+\pi^-$	$\sim$ 100 %	
Γ_7	$\pi^+\pi^-\gamma$	(9.9 ±1.6) × 10^{-3}	
Γ_8	$\pi^0\gamma$	(7.9 ±2.0) × 10^{-4}	
Γ_9	$\eta\gamma$	(3.8 ±0.7) × 10^{-4}	
Γ_{10}	$\pi^0\pi^0\gamma$	(4.8 $^{+3.4}_{-1.9}$) × 10^{-5}	
Γ_{11}	$\mu^+\mu^-$	[a] (4.60±0.28) × 10^{-5}	
Γ_{12}	e^+e^-	[a] (4.54±0.10) × 10^{-5}	S=1.1
Γ_{13}	$\pi^+\pi^-\pi^0$	< 1.2 × 10^{-4}	CL=90%
Γ_{14}	$\pi^+\pi^-\pi^+\pi^-$	(1.8 ±0.9) × 10^{-5}	
Γ_{15}	$\pi^+\pi^-\pi^0\pi^0$	< 4 × 10^{-5}	CL=90%

[*a*] The $e^+ e^-$ branching fraction is from $e^+ e^- \rightarrow \pi^+ \pi^-$ experiments only. The $\omega \rho$ interference is then due to $\omega \rho$ mixing only, and is expected to be small. If $e \mu$ universality holds, $\Gamma(\rho^0 \rightarrow \mu^+ \mu^-) = \Gamma(\rho^0 \rightarrow e^+ e^-) \times 0.99785$.

CONSTRAINED FIT INFORMATION

An overall fit to the total width and a partial width uses 10 measurements and one constraint to determine 3 parameters. The overall fit has a $\chi^2 = 10.7$ for 8 degrees of freedom.

The following *off-diagonal* array elements are the correlation coefficients $\langle \delta p_i \delta p_j \rangle / (\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i, including 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_2	x_3
x_3	−100	
Γ	15	−15

	Mode	Rate (MeV)	Scale factor
Γ_2	$\pi^\pm \pi^0$	150.2 ±2.4	
Γ_3	$\pi^\pm \gamma$	0.068±0.007	2.3

CONSTRAINED FIT INFORMATION

An overall fit to the total width, a partial width, and a branching ratio uses 11 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2 = 10.0$ for 8 degrees of freedom.

The following *off-diagonal* array elements are the correlation coefficients $\langle \delta p_i \delta p_j \rangle / (\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i, including 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.

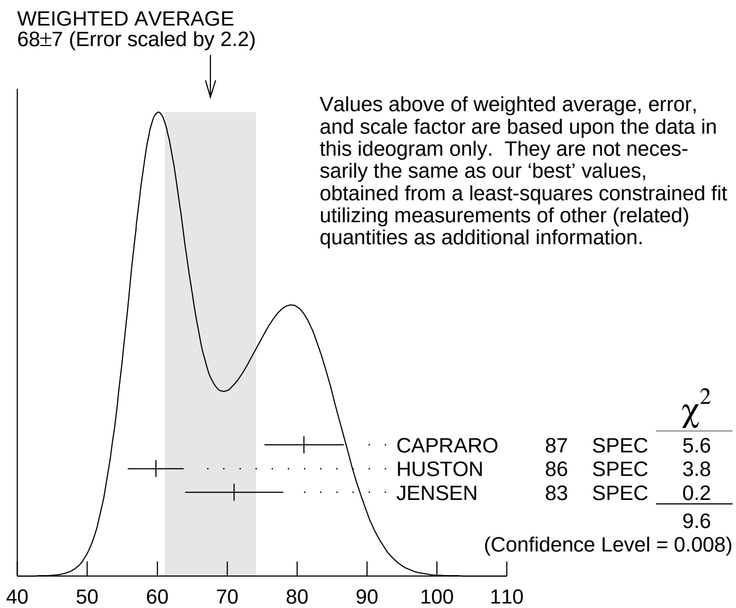
	x_6	x_{11}	x_{12}
x_{11}	−95		
x_{12}	−32	0	
Γ	20	0	−62

	Mode	Rate (MeV)	Scale factor
Γ_6	$\pi^+ \pi^-$	150.8 ±2.0	1.3
Γ_{11}	$\mu^+ \mu^-$	[*a*] 0.0069 ±0.0004	
Γ_{12}	$e^+ e^-$	[*a*] 0.00685±0.00011	

$\rho(770)$ PARTIAL WIDTHS

$\Gamma(\pi^{\pm}\gamma)$ — Γ_3

VALUE (keV)	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
68 ±7 OUR FIT Error includes scale factor of 2.3.					
68 ±7 OUR AVERAGE Error includes scale factor of 2.2. See the ideogram below.					
81 ±4 ±4	CAPRARO	87	SPEC	−	200 $\pi^- A \rightarrow \pi^- \pi^0 A$
59.8±4.0	HUSTON	86	SPEC	+	202 $\pi^+ A \rightarrow \pi^+ \pi^0 A$
71 ±7	JENSEN	83	SPEC	−	156–260 $\pi^- A \rightarrow \pi^- \pi^0 A$



$\Gamma(\pi^{\pm}\gamma)$ (keV)

$\Gamma(e^+e^-)$ — Γ_{12}

VALUE (keV)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
6.85±0.11 OUR FIT					
6.85±0.11 OUR AVERAGE					
6.86±0.11±0.05	114k	[54] AKHMETSHIN	02	CMD2	$e^+e^- \rightarrow \pi^+\pi^-$
6.77±0.10±0.30		BARKOV	85	OLYA	$e^+e^- \rightarrow \pi^+\pi^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
6.3 ±0.1		[55] BENAYOUN	98	RVUE	$e^+e^- \rightarrow \pi^+\pi^-$, $\mu^+\mu^-$

$\Gamma(\pi^0\gamma)$ — Γ_8

VALUE (keV)	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
121±31	DOLINSKY	89	ND	$e^+e^- \rightarrow \pi^0\gamma$

$\Gamma(\eta\gamma)$ — Γ_9

VALUE (keV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
62 ± 17	[56] DOLINSKY	89	ND	$e^+e^- \to \eta\gamma$

$\Gamma(\pi^+\pi^-\pi^+\pi^-)$ — Γ_{14}

VALUE (keV)	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$2.8 \pm 1.4 \pm 0.5$	153	AKHMETSHIN	00	CMD2	0.6–0.97 $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$

[54] Using Gounaris-Sakurai parameterization with the complex phase of the ρ-ω interference.
[55] Using the data of BARKOV 85 in the hidden local symmetry model.
[56] Solution corresponding to constructive ω-ρ interference.

$\rho(770)$ $\Gamma(i)\Gamma(e^+e^-)/\Gamma^2(\text{total})$

$\Gamma(e^+e^-) \times \Gamma(\eta\gamma)/\Gamma^2_{\text{total}}$ — $\Gamma_{12}\Gamma_9/\Gamma^2$

VALUE (units 10^{-8})	EVTS	DOCUMENT ID		TECN	COMMENT
1.33±0.18 OUR AVERAGE	Error includes scale factor of 1.5.				
$1.61 \pm 0.20 \pm 0.11$	23k	[57,58] AKHMETSHIN	01B	CMD2	$e^+e^- \to \eta\gamma$
$1.21 \pm 0.14 \pm 0.04$	312	[59] ACHASOV	00D	SND	$e^+e^- \to \eta\gamma$

[57] From the $\eta \to 3\pi^0$ decay and using B($\eta \to 3\pi^0$)= (32.24 ± 0.29) × 10^{-2}.
[58] The combined fit from 600 to 1380 MeV taking into account $\rho(770)$, $\omega(782)$, $\phi(1020)$, and $\rho(1450)$ (mass and width fixed at 1450 MeV and 310 MeV respectively).
[59] From the $\eta \to 3\pi^0$ decay and using B($\eta \to 3\pi^0$)= (32.2 ± 0.4) × 10^{-2}.

$\rho(770)$ BRANCHING RATIOS

$\Gamma(\pi^\pm\eta)/\Gamma(\pi\pi)$ — Γ_4/Γ_1

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	CHG	COMMENT
<60	84	FERBEL	66	HBC	±	$\pi^\pm p$ above 2.5

$\Gamma(\pi^\pm\pi^+\pi^-\pi^0)/\Gamma(\pi\pi)$ — Γ_5/Γ_1

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	CHG	COMMENT
<20	84	FERBEL	66	HBC	±	$\pi^\pm p$ above 2.5
• • • We do not use the following data for averages, fits, limits, etc. • • •						
35 ± 40		JAMES	66	HBC	+	2.1 $\pi^+ p$

$\Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-)$ — Γ_{11}/Γ_6

VALUE (units 10^{-5})	DOCUMENT ID		TECN	COMMENT
4.60±0.28 OUR FIT				
4.6 ±0.2 ±0.2	ANTIPOV	89	SIGM	$\pi^- \text{Cu} \to \mu^+\mu^-\pi^- \text{Cu}$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$8.2^{+1.6}_{-3.6}$	[60] ROTHWELL	69	CNTR	Photoproduction
5.6 ± 1.5	[61] WEHMANN	69	OSPK	12 π^- C, Fe
$9.7^{+3.1}_{-3.3}$	[62] HYAMS	67	OSPK	11 π^- Li, H

$\Gamma(e^+e^-)/\Gamma(\pi\pi)$ — Γ_{12}/Γ_1

VALUE (units 10^{-4})	DOCUMENT ID		TECN	COMMENT
0.41±0.05	BENAKSAS	72	OSPK	e^+e^-

$\Gamma(\eta\gamma)/\Gamma_{total}$ — Γ_9/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
3.8 ±0.7 OUR AVERAGE						
4.0 ±1.1		[63] DOLINSKY	89	ND		$e^+e^- \rightarrow \eta\gamma$
3.6 ±0.9		[63] ANDREWS	77	CNTR	0	6.7–10 γCu
• • • We do not use the following data for averages, fits, limits, etc. • • •						
3.39±0.42±0.23	23k	[63,64,65] AKHMETSHIN	01B	CMD2		$e^+e^- \rightarrow \eta\gamma$
2.69±0.32±0.16	312	[66] ACHASOV	00D	SND		$e^+e^- \rightarrow \eta\gamma$
1.9 $^{+0.6}_{-0.8}$		[67] BENAYOUN	96	RVUE		0.54-1.04 $e^+e^- \rightarrow \eta\gamma$

$\Gamma(\pi^+\pi^-\pi^+\pi^-)/\Gamma_{total}$ — Γ_{14}/Γ

VALUE (units 10^{-5})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
1.8±0.9±0.3		153	AKHMETSHIN	00	CMD2	0.6–0.97 $e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<20	90		KURDADZE	88	OLYA	$e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^-$

$\Gamma(\pi^+\pi^-\pi^+\pi^-)/\Gamma(\pi\pi)$ — Γ_{14}/Γ_1

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<15	90	ERBE	69	HBC	0	2.5–5.8 γp
<20		CHUNG	68	HBC	0	3.2,4.2 $\pi^- p$
<20	90	HUSON	68	HLBC	0	16.0 $\pi^- p$
<80		JAMES	66	HBC	0	2.1 $\pi^+ p$

$\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{total}$ — Γ_{13}/Γ

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<1.2	90	VASSERMAN	88B	ND	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$

$\Gamma(\pi^+\pi^-\pi^0)/\Gamma(\pi\pi)$ — Γ_{13}/Γ_1

VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
∼ 0.01		BRAMON	86	RVUE	0	$J/\psi \rightarrow \omega\pi^0$
<0.01	84	[68] ABRAMS	71	HBC	0	3.7 $\pi^+ p$

$\Gamma(\pi^+\pi^-\pi^0\pi^0)/\Gamma_{total}$ — Γ_{15}/Γ

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	CHG	COMMENT
<0.4	90	AULCHENKO	87C	ND	0	$e^+e^- \rightarrow \pi^+\pi^-\pi^0\pi^0$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<2	90	KURDADZE	86	OLYA	0	$e^+e^- \rightarrow \pi^+\pi^-\pi^0\pi^0$

$\Gamma(\pi^+\pi^-\gamma)/\Gamma_{total}$ — Γ_7/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
0.0099±0.0016		[69] DOLINSKY	91	ND	$e^+e^- \rightarrow \pi^+\pi^-\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.0111±0.0014		[70] VASSERMAN	88	ND	$e^+e^- \rightarrow \pi^+\pi^-\gamma$
<0.005	90	[71] VASSERMAN	88	ND	$e^+e^- \rightarrow \pi^+\pi^-\gamma$

$\Gamma(\pi^0\gamma)/\Gamma_{total}$ — Γ_8/Γ

VALUE (units 10^{-4})	DOCUMENT ID		TECN	COMMENT
7.9±2.0	DOLINSKY	89	ND	$e^+e^- \rightarrow \pi^0\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
6.8±1.7	[72] BENAYOUN	96	RVUE	0.54–1.04 $e^+e^- \rightarrow \pi^0\gamma$

$\Gamma(\pi^0\pi^0\gamma)/\Gamma_{total}$ — Γ_{10}/Γ

VALUE (units 10^{-5})	EVTS	DOCUMENT ID		TECN	COMMENT
$\mathbf{4.8^{+3.4}_{-1.8}\pm0.5}$	63	ACHASOV	00G	SND	$e^+e^- \rightarrow \pi^0\pi^0\gamma$

[60] Possibly large ρ-ω interference leads us to increase the minus error.
[61] Result contains 11 ± 11% correction using SU(3) for central value. The error on the correction takes account of possible ρ-ω interference and the upper limit agrees with the upper limit of $\omega \rightarrow \mu^+\mu^-$ from this experiment.
[62] HYAMS 67's mass resolution is 20 MeV. The ω region was excluded.
[63] Solution corresponding to constructive ω-ρ interference.
[64] The combined fit from 600 to 1380 MeV taking into account $\rho(770)$, $\omega(782)$, $\phi(1020)$, and $\rho(1450)$ (mass and width fixed at 1450 MeV and 310 MeV respectively).
[65] Using B($\rho \rightarrow e^+e^-$) = $(4.75 \pm 0.10) \times 10^{-5}$ from AKHMETSHIN 02 and B($\eta \rightarrow 3\pi^0$) = $(32.24 \pm 0.29) \times 10^{-2}$.
[66] Using B($\rho \rightarrow e^+e^-$) = $(4.49 \pm 0.22) \times 10^{-5}$ and B($\eta \rightarrow 3\pi^0$) = $(32.2 \pm 0.4) \times 10^{-2}$.
[67] Reanalysis of DRUZHININ 84, DOLINSKY 89, and DOLINSKY 91 taking into account a triangle anomaly contribution. Constructive ρ-ω interference solution.
[68] Model dependent, assumes I = 1, 2, or 3 for the 3π system.
[69] Bremsstrahlung from a decay pion and for photon energy above 50 MeV.
[70] Superseded by DOLINSKY 91.
[71] Structure radiation due to quark rearrangement in the decay.
[72] Reanalysis of DRUZHININ 84, DOLINSKY 89, and DOLINSKY 91 taking into account a triangle anomaly contribution.

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KENNEY	62	PR 126 736	V.P. Kenney, W.D. Shephard, C.D. Gall	(KNTY)
SAMIOS	62	PRL 9 139	N.P. Samios *et al.*	(BNL, CUNY, COLU+)
XUONG	62	PR 128 1849	H. Nguyen Ngoc, G.R. Lynch	(LRL)
ANDERSON	61	PRL 6 365	J.A. Anderson *et al.*	(LRL)
ERWIN	61	PRL 6 628	A.R. Erwin *et al.*	(WISC)