# $\rho(770)$

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

## THE $\rho(770)$

Updated March 2000 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 multiparticle 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 $\delta_1^1$, or the pole position. It is, therefore, not surprising that a study of $\rho(770)$ dominance in the decays of the $\eta$ and $\eta'$ reveals the need for specific dynamical effects, in addition to the $\rho(770)$ pole (BENAYOUN 93, ABELE 97B). Recently, BENAYOUN 98 compared the predictions of different Vector Meson Dominance (VMD)-based models with the data on the $e^+e^- \to \pi^+\pi^-$ cross section below 1 GeV, as well as with the phase and near-threshold behavior of the time-like pion form factor. They showed that only the model based on hidden local symmetry (HLS) is able to account consistently for all low-energy information, if one also requires a point-like coupling $\gamma\pi^+\pi^-$, which is excluded by common VMD but predicted by HLS.

The cleanest determination of the $\rho(770)$ mass and width comes from the $e^+e^-$ annihilation and $\tau$-lepton decays. BARATE 97M showed that the charged $\rho(770)$ parameters measured

from $\tau$-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 $\tau$ decays and the $e^+e^- \to \pi^+\pi^-$ cross section gives indications of discrepancies between the overall normalization: $\tau$ data are about 3% higher than $e^+e^-$ data (ANDERSON 99, EIDELMAN 99). This effect is too big to be explained by isospin violation (ALEMANY 98).

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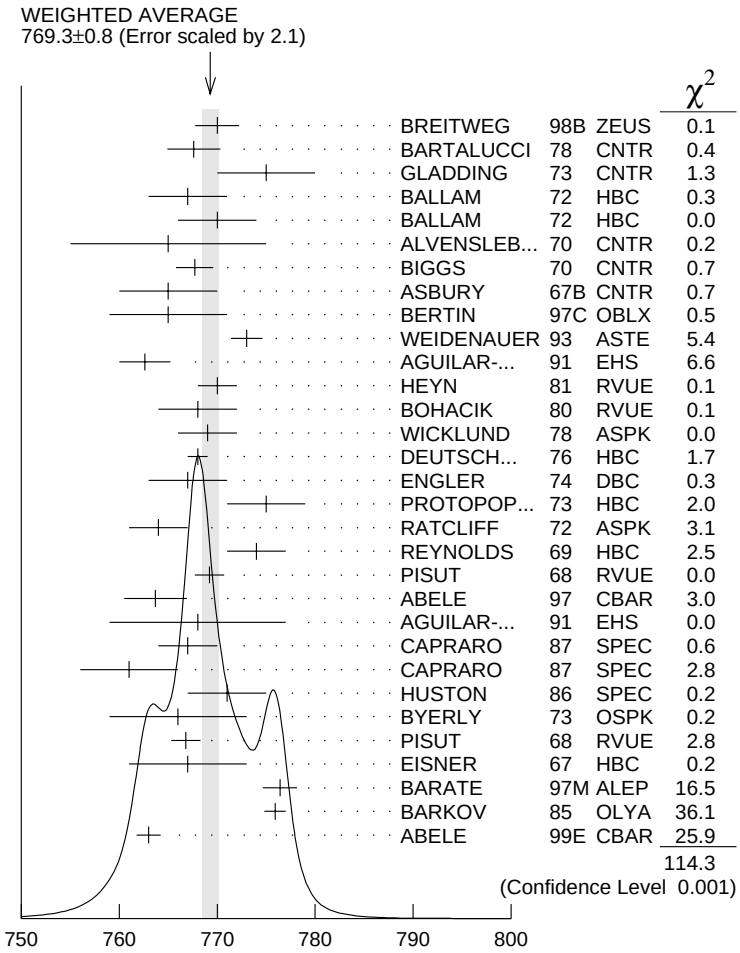
## $\rho(770)$ MASS

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

### MIXED CHARGES

| *VALUE* (MeV) | *DOCUMENT ID* | |
|---|---|---|
| **769.3±0.8 OUR AVERAGE** | Includes data from the 5 datablocks that follow this one. Error includes scale factor of 2.1. See the ideogram below. | |




$\rho(770)$ MASS MIXED CHARGES

## MIXED CHARGES, $\tau$ DECAYS and $e^+e^-$

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *CHG* | *COMMENT* |
|---|---|---|---|---|---|

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

**776.0±0.9 OUR AVERAGE**

| | | | | | |
|---|---|---|---|---|---|
| 776.4±0.9±1.5 | [1] BARATE | 97M | ALEP | | $\tau^- \to \pi^- \pi^0 \nu_\tau$ |
| 775.9±1.1 | [2] BARKOV | 85 | OLYA | 0 | $e^+ e^- \to \pi^+ \pi^-$ |

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

| | | | | | |
|---|---|---|---|---|---|
| 775.1±0.7±5.3 | [3] BENAYOUN | 98 | RVUE | | $e^+ e^- \to \pi^+ \pi^-, \mu^+ \mu^-$ |
| 770.5±1.9±5.1 | [4] GARDNER | 98 | RVUE | | 0.28–0.92 $e^+ e^- \to \pi^+ \pi^-$ |
| 764.1±0.7 | [5] O'CONNELL | 97 | RVUE | | $e^+ e^- \to \pi^+ \pi^-$ |
| 757.5±1.5 | [6] BERNICHA | 94 | RVUE | | $e^+ e^- \to \pi^+ \pi^-$ |
| 768 ±1 | [7] GESHKEN... | 89 | RVUE | | $e^+ e^- \to \pi^+ \pi^-$ |

## 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. | | | | | | |
| **763.0±0.3±1.2** | 600k | [8] 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. | | | | | | |
| **766.5±1.1 OUR AVERAGE** | | | | | | |
| 763.7±3.2 | | ABELE | 97 | CBAR | | $\overline{p}n \rightarrow \pi^-\pi^0\pi^0$ |
| 768 ±9 | | AGUILAR-... | 91 | EHS | | 400 $pp$ |
| 767 ±3 | 2935 | [9] CAPRARO | 87 | SPEC | − | 200 $\pi^-$ Cu $\rightarrow \pi^-\pi^0$ Cu |
| 761 ±5 | 967 | [9] CAPRARO | 87 | SPEC | − | 200 $\pi^-$ Pb $\rightarrow \pi^-\pi^0$ Pb |
| 771 ±4 | | HUSTON | 86 | SPEC | + | 202 $\pi^+$ A $\rightarrow \pi^+\pi^0$ A |
| 766 ±7 | 6500 | [10] BYERLY | 73 | OSPK | − | 5 $\pi^-p$ |
| 766.8±1.5 | 9650 | [11] PISUT | 68 | RVUE | − | 1.7–3.2 $\pi^-p$, $t$ <10 |
| 767 ±6 | 900 | [9] 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. | | | | | | |
| **768.5± 1.1 OUR AVERAGE** | | | | | | |
| 770 ± 2 ±1 | 79k | [12] BREITWEG | 98B | ZEUS | 0 | 50–100 $\gamma p$ |
| 767.6± 2.7 | | BARTALUCCI | 78 | CNTR | 0 | $\gamma p \rightarrow e^+e^-p$ |
| 775 ± 5 | | GLADDING | 73 | CNTR | 0 | 2.9–4.7 $\gamma p$ |
| 767 ± 4 | 1930 | BALLAM | 72 | HBC | 0 | 2.8 $\gamma p$ |
| 770 ± 4 | 2430 | BALLAM | 72 | HBC | 0 | 4.7 $\gamma p$ |
| 765 ±10 | | ALVENSLEB... | 70 | CNTR | 0 | $\gamma$ A, $t$ <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 | [13] BREITWEG | 98B | ZEUS | 0 | 50–100 $\gamma p$ |

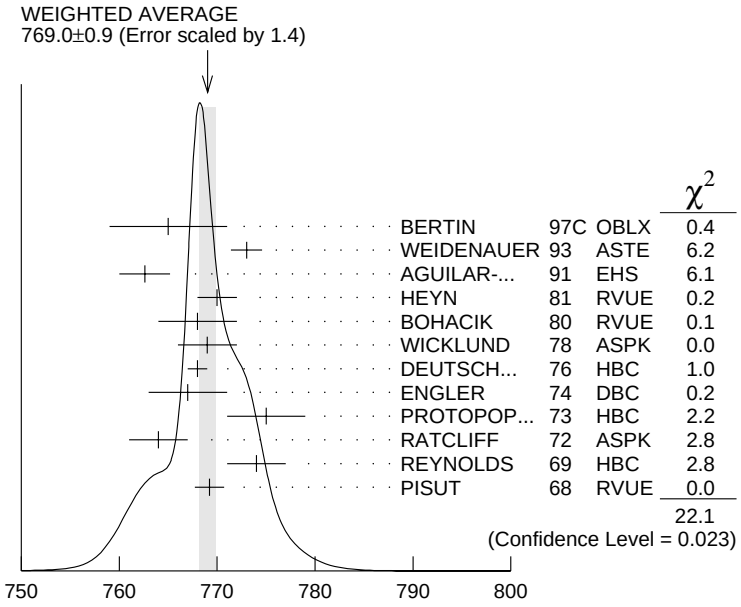
## NEUTRAL ONLY, OTHER REACTIONS

| *VALUE* (MeV) | *EVTS* | *DOCUMENT ID* | | *TECN* | *CHG* | *COMMENT* |
|---|---|---|---|---|---|---|
| The data in this block is included in the average printed for a previous datablock. | | | | | | |
| **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 $pp$ |
| 770 ±2 | | [14] HEYN | 81 | RVUE | | Pion form factor |
| 768 ±4 | | [15,16] BOHACIK | 80 | RVUE | 0 | |
| 769 ±3 | | [10] 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 | [15] | 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 | [17] | 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 | [18] | ABELE | 99E | CBAR | 0 | 0.0 $\overline{p}p \rightarrow \pi^+ \pi^- \pi^0$ |
| 777 ±2 | 4943 | [19] | ADAMS | 97 | E665 | | 470 $\mu p \rightarrow \mu X B$ |
| 770 ±2 | | [20] | BOGOLYUB... | 97 | MIRA | | 32 $\overline{p}p \rightarrow \pi^+ \pi^- X$ |
| 768 ±8 | | [20] | BOGOLYUB... | 97 | MIRA | | 32 $pp \rightarrow \pi^+ \pi^- X$ |
| 761.1±2.9 | | | DUBNICKA | 89 | RVUE | | $\pi$ form factor |
| 777.4±2.0 | | [21] | CHABAUD | 83 | ASPK | 0 | 17 $\pi^- p$ polarized |
| 769.5±0.7 | | [15,16] | LANG | 79 | RVUE | 0 | |
| 770 ±9 | | [16] | ESTABROOKS | 74 | RVUE | 0 | 17 $\pi^- p \rightarrow \pi^+ \pi^- n$ |
| 773.5±1.7 | 11200 | [9] | 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] From the Gounaris-Sakurai parametrization of the pion form factor. The second error is a model error taking into account different parametrizations of the pion form factor.

[2] From the Gounaris-Sakurai parametrization of the pion form factor.

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

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

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

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

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

[8] Assuming the equality of $\rho^+$ and $\rho^-$ masses and widths.
[9] Mass errors enlarged by us to $\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.
[10] Phase shift analysis. Systematic errors added corresponding to spread of different fits.
[11] 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.
[12] From the parametrization according to SOEDING 66.
[13] From the parametrization according to ROSS 66.
[14] HEYN 81 includes all spacelike and timelike $F_\pi$ values until 1978.
[15] From pole extrapolation.
[16] From phase shift analysis of GRAYER 74 data.
[17] 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.
[18] Using relativistic Breit-Wigner and taking into account $\rho$-$\omega$ interference.
[19] Systematic errors not evaluated.
[20] Systematic effects not studied.
[21] 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* |
|---|---|---|---|---|---|---|
| **0.4±0.8 OUR AVERAGE** | | | | | | |
| 1.6±0.6±1.7 | 600k | ABELE | 99E | CBAR | 0± | 0.0 $\overline{p}p \to \pi^+\pi^-\pi^0$ |
| 0.0±1.0 | | [22] BARATE | 97M | ALEP | | $\tau^- \to \pi^-\pi^0\nu_\tau$ |
| −4 ±4 | 3000 | [23] REYNOLDS | 69 | HBC | −0 | 2.26 $\pi^- p$ |
| −5 ±5 | 3600 | [23] FOSTER | 68 | HBC | ±0 | 0.0 $\overline{p}p$ |
| 2.4±2.1 | 22950 | [24] PISUT | 68 | RVUE | | $\pi N \to \rho N$ |

[22] Using the compilation of $e^+e^-$ data from BARKOV 85.
[23] From quoted masses of charged and neutral modes.
[24] 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.

## $\rho(770)$ 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* |
|---|---|---|---|---|---|
| $\mathbf{5.3^{+0.9}_{-0.7}}$ | 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* |
|---|---|
| **150.2±0.8 OUR AVERAGE** | Includes data from the 5 datablocks that follow this one. |

## MIXED CHARGES, $\tau$ DECAYS and $e^+e^-$

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *CHG* | *COMMENT* |
|---|---|---|---|---|---|
| The data in this block is included in the average printed for a previous datablock. | | | | | |
| **150.5±2.7 OUR AVERAGE** | | | | | |
| 150.5±1.6±6.3 | [25] BARATE | 97M | ALEP | | $\tau^- \to \pi^-\pi^0\nu_\tau$ |
| 150.5±3.0 | [26] BARKOV | 85 | OLYA | 0 | $e^+e^- \to \pi^+\pi^-$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 147.9±1.5±7.5 | [27] BENAYOUN | 98 | RVUE | | $e^+e^- \to \pi^+\pi^-$, $\mu^+\mu^-$ |
| 153.5±1.3±4.6 | [28] GARDNER | 98 | RVUE | | 0.28–0.92 $e^+e^- \to \pi^+\pi^-$ |
| 145.0±1.7 | [29] O'CONNELL | 97 | RVUE | | $e^+e^- \to \pi^+\pi^-$ |
| 142.5±3.5 | [30] BERNICHA | 94 | RVUE | | $e^+e^- \to \pi^+\pi^-$ |
| 138 ±1 | [31] GESHKEN... | 89 | RVUE | | $e^+e^- \to \pi^+\pi^-$ |

## 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 | [32] ABELE | 99E | CBAR | 0± | 0.0 $\overline{p}p \to \pi^+\pi^-\pi^0$ |

## 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 | | $\overline{p}n \to \pi^-\pi^0\pi^0$ |
| 155 ±11 | 2935 | [33] CAPRARO | 87 | SPEC | − | 200 $\pi^-$ Cu → $\pi^-\pi^0$ Cu |
| 154 ±20 | 967 | [33] CAPRARO | 87 | SPEC | − | 200 $\pi^-$ Pb → $\pi^-\pi^0$ Pb |
| 150 ± 5 | | HUSTON | 86 | SPEC | + | 202 $\pi^+$ A → $\pi^+\pi^0$ A |
| 146 ±12 | 6500 | [34] BYERLY | 73 | OSPK | − | 5 $\pi^-p$ |
| 148.2± 4.1 | 9650 | [35] 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 | [36] BREITWEG | 98B | ZEUS | 0 | 50–100 $\gamma p$ |
| 150.9± 3.0 | | BARTALUCCI | 78 | CNTR | 0 | $\gamma p \to e^+e^-p$ |

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

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 138 ± 3 | 79k | [37] | BREITWEG | 98B | ZEUS | 0 | 50–100 $\gamma p$ |
| 147 ±11 | | | GLADDING | 73 | CNTR | 0 | 2.9–4.7 $\gamma p$ |
| 155 ±12 | 2430 | | BALLAM | 72 | HBC | 0 | 4.7 $\gamma p$ |
| 145 ±13 | 1930 | | BALLAM | 72 | HBC | 0 | 2.8 $\gamma p$ |
| 140 ± 5 | | | ALVENSLEB... | 70 | CNTR | 0 | $\gamma$ A, $t$ <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 | $\gamma p$ |
| 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 | | $\pi$ form factor |
| 148 ± 6 | | [38,39] | BOHACIK | 80 | RVUE | 0 | |
| 152 ± 9 | | [34] | WICKLUND | 78 | ASPK | 0 | 3,4,6 $\pi^\pm p N$ |
| 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 | [40] | ABELE | 99E | CBAR | 0 | 0.0 $\overline{p}p \rightarrow \pi^+\pi^-\pi^0$ |
| 146 ± 3 | 4943 | [41] | ADAMS | 97 | E665 | | 470 $\mu p \rightarrow \mu X B$ |
| $160.0^{+\ 4.1}_{-\ 4.0}$ | | [42] | CHABAUD | 83 | ASPK | 0 | 17 $\pi^- p$ polarized |
| 155 ± 1 | | [43] | HEYN | 81 | RVUE | 0 | $\pi$ form factor |
| 148.0± 1.3 | | [38,39] | LANG | 79 | RVUE | 0 | |
| 146 ±14 | 4100 | | ENGLER | 74 | DBC | 0 | 6 $\pi^+ n \rightarrow \pi^+\pi^- p$ |
| 143 ±13 | | [39] | ESTABROOKS | 74 | RVUE | 0 | 17 $\pi^- p \rightarrow \pi^+\pi^- n$ |
| 160 ±10 | 32000 | [38] | PROTOPOP... | 73 | HBC | 0 | 7.1 $\pi^+ p$, $t$ <0.4 |
| 145 ±12 | 2250 | [33] | HYAMS | 68 | OSPK | 0 | 11.2 $\pi^- p$ |
| 163 ±15 | 13300 | [44] | PISUT | 68 | RVUE | 0 | 1.7–3.2 $\pi^- p$, $t$ <10 |

[25] From the Gounaris-Sakurai parametrization of the pion form factor. The second error is a model error taking into account different parametrizations of the pion form factor.

[26] From the Gounaris-Sakurai parametrization of the pion form factor.

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

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

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

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

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

[32] Assuming the equality of $\rho^+$ and $\rho^-$ masses and widths.

[33] Width errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.

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

[35] 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.

[36] From the parametrization according to SOEDING 66.
[37] From the parametrization according to ROSS 66.
[38] From pole extrapolation.
[39] From phase shift analysis of GRAYER 74 data.
[40] Using relativistic Breit-Wigner and taking into account $\rho$-$\omega$ interference.
[41] Systematic errors not evaluated.
[42] From fit of 3-parameter relativistic Breit-Wigner to helicity-zero part of $P$-wave intensity. CHABAUD 83 includes data of GRAYER 74.
[43] HEYN 81 includes all spacelike and timelike $F_\pi$ values until 1978.
[44] 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.

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

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **$-0.1\pm1.9$** | [45] BARATE | 97M | ALEP | $\tau^- \to \pi^-\pi^0\nu_\tau$ |

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

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## $\rho(770)$ DECAY MODES

| | Mode | | Fraction ($\Gamma_i/\Gamma$) | | Scale factor/ Confidence level |
|---|---|---|---|---|---|
| $\Gamma_1$ | $\pi\pi$ | | $\sim$ 100 | % | |
| | **$\rho(770)^\pm$ decays** | | | | |
| $\Gamma_2$ | $\pi^\pm\pi^0$ | | $\sim$ 100 | % | |
| $\Gamma_3$ | $\pi^\pm\gamma$ | | ( 4.5 $\pm$0.5 ) $\times 10^{-4}$ | | S=2.2 |
| $\Gamma_4$ | $\pi^\pm\eta$ | | $<$ 6 | $\times 10^{-3}$ | CL=84% |
| $\Gamma_5$ | $\pi^\pm\pi^+\pi^-\pi^0$ | | $<$ 2.0 | $\times 10^{-3}$ | CL=84% |
| | **$\rho(770)^0$ decays** | | | | |
| $\Gamma_6$ | $\pi^+\pi^-$ | | $\sim$ 100 | % | |
| $\Gamma_7$ | $\pi^+\pi^-\gamma$ | | ( 9.9 $\pm$1.6 ) $\times 10^{-3}$ | | |
| $\Gamma_8$ | $\pi^0\gamma$ | | ( 6.8 $\pm$1.7 ) $\times 10^{-4}$ | | |
| $\Gamma_9$ | $\eta\gamma$ | | ( 2.4 $^{+0.8}_{-0.9}$ ) $\times 10^{-4}$ | | S=1.6 |
| $\Gamma_{10}$ | $\mu^+\mu^-$ | [a] | ( 4.60$\pm$0.28) $\times 10^{-5}$ | | |
| $\Gamma_{11}$ | $e^+e^-$ | [a] | ( 4.49$\pm$0.22) $\times 10^{-5}$ | | |
| $\Gamma_{12}$ | $\pi^+\pi^-\pi^0$ | | $<$ 1.2 | $\times 10^{-4}$ | CL=90% |
| $\Gamma_{13}$ | $\pi^+\pi^-\pi^+\pi^-$ | | ( 1.8 $\pm$0.9 ) $\times 10^{-5}$ | | |
| $\Gamma_{14}$ | $\pi^+\pi^-\pi^0\pi^0$ | | $<$ 4 | $\times 10^{-5}$ | CL=90% |

[a] The $e^+e^-$ branching fraction is from $e^+e^- \to \pi^+\pi^-$ 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, $\Gamma(\rho^0 \to \mu^+\mu^-) = \Gamma(\rho^0 \to e^+e^-) \times 0.99785$.

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## 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 $\left\langle \delta p_i \delta p_j \right\rangle / (\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters $p_i$, including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\rm total}$. The fit constrains the $x_i$ whose labels appear in this array to sum to one.

| | | | |
|---|---|---|---|
| $x_3$ | −100 | | |
| $\Gamma$ | 15 | −15 | |
| | $x_2$ | $x_3$ | |

| | Mode | Rate (MeV) | Scale factor |
|---|---|---|---|
| $\Gamma_2$ | $\pi^\pm\pi^0$ | 150.2 ±2.4 | |
| $\Gamma_3$ | $\pi^\pm\gamma$ | 0.068±0.007 | 2.3 |

## CONSTRAINED FIT INFORMATION

An overall fit to the total width, a partial width, and a branching ratio uses 10 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2 = 9.9$ for 7 degrees of freedom.

The following *off-diagonal* array elements are the correlation coefficients $\left\langle \delta p_i \delta p_j \right\rangle / (\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters $p_i$, including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\rm total}$. The fit constrains the $x_i$ whose labels appear in this array to sum to one.

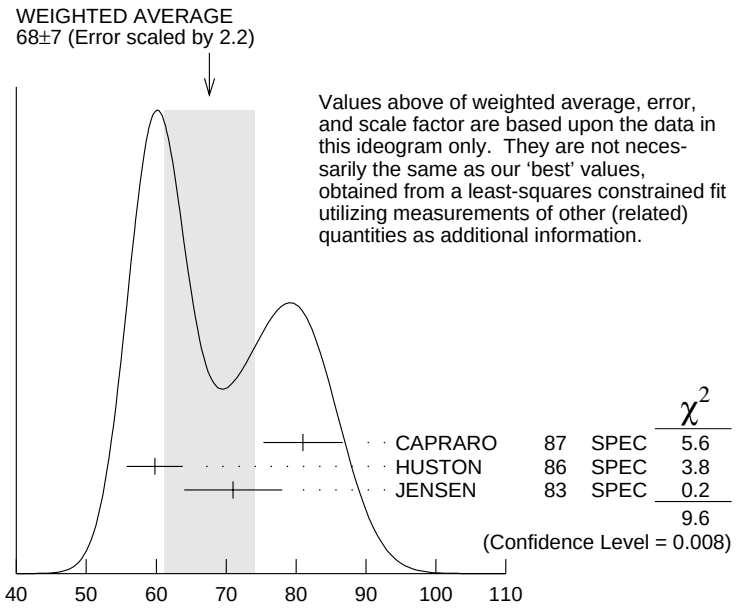
| | | | | |
|---|---|---|---|---|
| $x_{10}$ | −79 | | | |
| $x_{11}$ | −61 | 0 | | |
| $\Gamma$ | 16 | 0 | −27 | |
| | $x_6$ | $x_{10}$ | $x_{11}$ | |

| | Mode | | Rate (MeV) | Scale factor |
|---|---|---|---|---|
| $\Gamma_6$ | $\pi^+\pi^-$ | | 150.8 ±2.0 | 1.3 |
| $\Gamma_{10}$ | $\mu^+\mu^-$ | [a] | 0.0069 ±0.0004 | |
| $\Gamma_{11}$ | $e^+e^-$ | [a] | 0.00677±0.00032 | |

# $\rho(770)$ PARTIAL WIDTHS

## $\Gamma(\pi^{\pm}\gamma)$ $\Gamma_3$

| *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 → $\pi^-\pi^0$ A |
| 59.8±4.0 | HUSTON | 86 | SPEC | + | 202 $\pi^+$ A → $\pi^+\pi^0$ A |
| 71 ±7 | JENSEN | 83 | SPEC | − | 156–260 $\pi^-$ A → $\pi^-\pi^0$ A |




## $\Gamma(e^+e^-)$ $\Gamma_{11}$

| *VALUE* (keV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **6.77±0.32 OUR FIT** | | | | |
| **6.77±0.10±0.30** | BARKOV | 85 | OLYA | $e^+e^- \to \pi^+\pi^-$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 6.3 ±0.1 | [46] BENAYOUN | 98 | RVUE | $e^+e^- \to \pi^+\pi^-$, $\mu^+\mu^-$ |

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

## $\Gamma(\pi^0\gamma)$ $\Gamma_8$

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

### $\Gamma(\eta\gamma)$ $\Gamma_9$

| *VALUE* (keV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $62\pm17$ | [47] DOLINSKY | 89 | ND | $e^+e^- \to \eta\gamma$ |

[47] Solution corresponding to constructive $\omega$-$\rho$ interference.

### $\Gamma(\pi^+\pi^-\pi^+\pi^-)$ $\Gamma_{13}$

| *VALUE* (keV) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $2.8\pm1.4\pm0.5$ | 153 | AKHMETSHIN | 00 | CMD2 | 0.6–0.97 $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ |

## $\rho(770)$ BRANCHING RATIOS

### $\Gamma(\pi^\pm\eta)/\Gamma(\pi\pi)$ $\Gamma_4/\Gamma_1$

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

### $\Gamma(\pi^\pm\pi^+\pi^-\pi^0)/\Gamma(\pi\pi)$ $\Gamma_5/\Gamma_1$

| *VALUE* (units $10^{-4}$) | *CL%* | *DOCUMENT ID* | | *TECN* | *CHG* | *COMMENT* |
|---|---|---|---|---|---|---|
| **<20** | 84 | FERBEL | 66 | HBC | $\pm$ | $\pi^\pm p$ above 2.5 |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| $35\pm40$ | | JAMES | 66 | HBC | + | 2.1 $\pi^+ p$ |

### $\Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-)$ $\Gamma_{10}/\Gamma_6$

| *VALUE* (units $10^{-5}$) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **$4.60\pm0.28$ OUR FIT** | | | | |
| **4.6 $\pm0.2$ $\pm0.2$** | ANTIPOV | 89 | SIGM | $\pi^-$ Cu $\to \mu^+\mu^-\pi^-$ Cu |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $8.2\ ^{+1.6}_{-3.6}$ | [48] ROTHWELL | 69 | CNTR | Photoproduction |
| $5.6\ \pm1.5$ | [49] WEHMANN | 69 | OSPK | 12 $\pi^-$ C, Fe |
| $9.7\ ^{+3.1}_{-3.3}$ | [50] HYAMS | 67 | OSPK | 11 $\pi^-$ Li, H |

[48] Possibly large $\rho$-$\omega$ interference leads us to increase the minus error.

[49] Result contains 11 $\pm$ 11% correction using SU(3) for central value. The error on the correction takes account of possible $\rho$-$\omega$ interference and the upper limit agrees with the upper limit of $\omega \to \mu^+\mu^-$ from this experiment.

[50] HYAMS 67's mass resolution is 20 MeV. The $\omega$ region was excluded.

### $\Gamma(e^+e^-)/\Gamma(\pi\pi)$ $\Gamma_{11}/\Gamma_1$

| *VALUE* (units $10^{-4}$) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **$0.41\pm0.05$** | BENAKSAS | 72 | OSPK | $e^+e^-$ |

## $\Gamma(\eta\gamma)/\Gamma_{\text{total}}$ $\Gamma_9/\Gamma$

| *VALUE* (units $10^{-4}$) | *DOCUMENT ID* | | *TECN* | *CHG* | *COMMENT* |
|---|---|---|---|---|---|
| **$2.4^{+0.8}_{-0.9}$ OUR AVERAGE** Error includes scale factor of 1.6. | | | | | |
| $1.9^{+0.6}_{-0.8}$ | [51] BENAYOUN | 96 | RVUE | | 0.54-1.04 $e^+e^- \to \eta\gamma$ |
| $3.6\pm0.9$ | [52] ANDREWS | 77 | CNTR | 0 | 6.7–10 $\gamma$ Cu |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $4.0\pm1.1$ | [52] DOLINSKY | 89 | ND | | $e^+e^- \to \eta\gamma$ |

[51] Reanalysis of DRUZHININ 84, DOLINSKY 89, and DOLINSKY 91 taking into account a triangle anomaly contribution. Constructive $\rho$-$\omega$ interference solution.
[52] Solution corresponding to constructive $\omega$-$\rho$ interference.

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

| *VALUE* (units $10^{-5}$) | *CL%* | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|---|
| **$1.8\pm0.9\pm0.3$** | | 153 | AKHMETSHIN | 00 | CMD2 | 0.6–0.97 $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| $<20$ | 90 | | KURDADZE | 88 | OLYA | $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ |

## $\Gamma(\pi^+\pi^-\pi^+\pi^-)/\Gamma(\pi\pi)$ $\Gamma_{13}/\Gamma_1$

| *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 $\gamma p$ |
| $<20$ | | 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 $\pi^+ p$ |

## $\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$ $\Gamma_{12}/\Gamma$

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

## $\Gamma(\pi^+\pi^-\pi^0)/\Gamma(\pi\pi)$ $\Gamma_{12}/\Gamma_1$

| *VALUE* | *CL%* | *DOCUMENT ID* | | *TECN* | *CHG* | *COMMENT* |
|---|---|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| $\sim 0.01$ | | BRAMON | 86 | RVUE | 0 | $J/\psi \to \omega\pi^0$ |
| $<0.01$ | 84 | [53] ABRAMS | 71 | HBC | 0 | 3.7 $\pi^+ p$ |

[53] Model dependent, assumes $I = 1$, 2, or 3 for the $3\pi$ system.

## $\Gamma(\pi^+\pi^-\pi^0\pi^0)/\Gamma_{\text{total}}$ $\Gamma_{14}/\Gamma$

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

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

| *VALUE* | *CL%* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **0.0099±0.0016** | | [54] DOLINSKY | 91 | ND | $e^+e^- \to \pi^+\pi^-\gamma$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.0111±0.0014 | | [55] VASSERMAN | 88 | ND | $e^+e^- \to \pi^+\pi^-\gamma$ |
| <0.005 | 90 | [56] VASSERMAN | 88 | ND | $e^+e^- \to \pi^+\pi^-\gamma$ |

[54] Bremsstrahlung from a decay pion and for photon energy above 50 MeV.
[55] Superseded by DOLINSKY 91.
[56] Structure radiation due to quark rearrangement in the decay.

## $\Gamma(\pi^0\gamma)/\Gamma_{total}$ $\Gamma_8/\Gamma$

| *VALUE* (units $10^{-4}$) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **6.8±1.7** | [57] BENAYOUN | 96 | RVUE | 0.54-1.04 $e^+e^- \to \pi^0\gamma$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 7.9±2.0 | DOLINSKY | 89 | ND | $e^+e^- \to \pi^0\gamma$ |

[57] Reanalysis of DRUZHININ 84, DOLINSKY 89, and DOLINSKY 91 taking into account a triangle anomaly contribution.

## $\rho(770)$ REFERENCES


| | | | | |
|---|---|---|---|---|
| AKHMETSHIN | 00 | PL B475 190 | R.R. Akhmetshin *et al.* | (CMD-2 Collab.) |
| ABELE | 99E | PL B469 270 | A. Abele *et al.* | (Crystal Barrel Collab.) |
| BENAYOUN | 98 | EPJ C2 269 | M. Benayoun *et al.* | (IPNP, NOVO, ADLD+) |
| BREITWEG | 98B | EPJ C2 247 | J. Breitweg *et al.* | (ZEUS Collab.) |
| GARDNER | 98 | PR D57 2716 | S. Gardner, H.B. O'Connell | |
| ABELE | 97 | PL B391 191 | A. Abele *et al.* | (Crystal Barrel Collab.) |
| ADAMS | 97 | ZPHY C74 237 | M.R. Adams *et al.* | (E665 Collab.) |
| BARATE | 97M | ZPHY C76 15 | R. Barate *et al.* | (ALEPH Collab.) |
| BERTIN | 97C | PL B408 476 | A. Bertin *et al.* | (OBELIX Collab.) |
| BOGOLYUB... | 97 | PAN 60 46 | M.Y. Bogolyubsky *et al.* | (MOSU, SERP) |
| | | Translated from YAF 60 53. | | |
| O'CONNELL | 97 | NP A623 559 | H.B. O'Connell *et al.* | (ADLD) |
| BENAYOUN | 96 | ZPHY C72 221 | M. Benayoun *et al.* | (IPNP, NOVO) |
| BERNICHA | 94 | PR D50 4454 | A. Bernicha, G. Lopez Castro, J. Pestieau | (LOUV+) |
| WEIDENAUER | 93 | ZPHY C59 387 | P. Weidenauer *et al.* | (ASTERIX Collab.) |
| AGUILAR-... | 91 | ZPHY C50 405 | M. Aguilar-Benitez *et al.* | (LEBC-EHS Collab.) |
| DOLINSKY | 91 | PRPL 202 99 | S.I. Dolinsky *et al.* | (NOVO) |
| ANTIPOV | 89 | ZPHY C42 185 | Y.M. Antipov *et al.* | (SERP, JINR, BGNA+) |
| DOLINSKY | 89 | ZPHY C42 511 | S.I. Dolinsky *et al.* | (NOVO) |
| DUBNICKA | 89 | JPG 15 1349 | S. Dubnicka *et al.* | (JINR, SLOV) |
| GESHKEN... | 89 | ZPHY 45 351 | B.V. Geshkenbein | (ITEP) |
| KURDADZE | 88 | JETPL 47 512 | L.M. Kurdadze *et al.* | (NOVO) |
| | | Translated from ZETFP 47 432. | | |
| VASSERMAN | 88 | SJNP 47 1035 | I.B. Vasserman *et al.* | (NOVO) |
| | | Translated from YAF 47 1635. | | |
| VASSERMAN | 88B | SJNP 48 480 | I.B. Vasserman *et al.* | (NOVO) |
| | | Translated from YAF 48 753. | | |
| AULCHENKO | 87C | IYF 87-90 Preprint | V.M. Aulchenko *et al.* | (NOVO) |
| CAPRARO | 87 | NP B288 659 | L. Capraro *et al.* | (CLER, FRAS, MILA+) |
| BRAMON | 86 | PL B173 97 | A. Bramon, J. Casulleras | (BARC) |
| HUSTON | 86 | PR 33 3199 | J. Huston *et al.* | (ROCH, FNAL, MINN) |
| KURDADZE | 86 | JETPL 43 643 | L.M. Kurdadze *et al.* | (NOVO) |
| | | Translated from ZETFP 43 497. | | |

| | | | | |
|---|---|---|---|---|
| BARKOV | 85 | NP B256 365 | L.M. Barkov *et al.* | (NOVO) |
| DRUZHININ | 84 | PL 144B 136 | V.P. Druzhinin *et al.* | (NOVO) |
| CHABAUD | 83 | NP B223 1 | V. Chabaud *et al.* | (CERN, CRAC, MPIM) |
| JENSEN | 83 | PR D27 26 | T. Jensen *et al.* | (ROCH, FNAL, MINN) |
| HEYN | 81 | ZPHY C7 169 | M.F. Heyn, C.B. Lang | (GRAZ) |
| BOHACIK | 80 | PR D21 1342 | J. Bohacik, H. Kuhnelt | (SLOV, WIEN) |
| LANG | 79 | PR D19 956 | C.B. Lang, A. Mas-Parareda | (GRAZ) |
| BARTALUCCI | 78 | NC 44A 587 | S. Bartalucci *et al.* | (DESY, FRAS) |
| WICKLUND | 78 | PR D17 1197 | A.B. Wicklund *et al.* | (ANL) |
| ANDREWS | 77 | PRL 38 198 | D.E. Andrews *et al.* | (ROCH) |
| DEUTSCH... | 76 | NP B103 426 | M. Deutschmann *et al.* | (AACH3, BERL, BONN+) |
| ENGLER | 74 | PR D10 2070 | A. Engler *et al.* | (CMU, CASE) |
| ESTABROOKS | 74 | NP B79 301 | P.G. Estabrooks, A.D. Martin | (DURH) |
| GRAYER | 74 | NP B75 189 | G. Grayer *et al.* | (CERN, MPIM) |
| BYERLY | 73 | PR D7 637 | W.L. Byerly *et al.* | (MICH) |
| GLADDING | 73 | PR D8 3721 | G.E. Gladding *et al.* | (HARV) |
| PROTOPOP... | 73 | PR D7 1279 | S.D. Protopopescu *et al.* | (LBL) |
| BALLAM | 72 | PR D5 545 | J. Ballam *et al.* | (SLAC, LBL, TUFTS) |
| BENAKSAS | 72 | PL 39B 289 | D. Benaksas *et al.* | (ORSAY) |
| JACOBS | 72 | PR D6 1291 | L.D. Jacobs | (SACL) |
| RATCLIFF | 72 | PL 38B 345 | B.N. Ratcliff *et al.* | (SLAC) |
| ABRAMS | 71 | PR D4 653 | G.S. Abrams *et al.* | (LBL) |
| ALVENSLEB... | 70 | PRL 24 786 | H. Alvensleben *et al.* | (DESY) |
| BIGGS | 70 | PRL 24 1197 | P.J. Biggs *et al.* | (DARE) |
| ERBE | 69 | PR 188 2060 | R. Erbe *et al.* | |
| MALAMUD | 69 | Argonne Conf. 93 | E.I. Malamud, P.E. Schlein | (UCLA) |
| REYNOLDS | 69 | PR 184 1424 | B.G. Reynolds *et al.* | (FSU) |
| ROTHWELL | 69 | PRL 23 1521 | P.L. Rothwell *et al.* | (NEAS) |
| WEHMANN | 69 | PR 178 2095 | A.A. Wehmann *et al.* | (HARV, CASE, SLAC+) |
| ARMENISE | 68 | NC 54A 999 | N. Armenise *et al.* | (BARI, BGNA, FIRZ+) |
| BATON | 68 | PR 176 1574 | J.P. Baton, G. Laurens | (SACL) |
| CHUNG | 68 | PR 165 1491 | S.U. Chung *et al.* | (LRL) |
| FOSTER | 68 | NP B6 107 | M. Foster *et al.* | (CERN, CDEF) |
| HUSON | 68 | PL 28B 208 | R. Huson *et al.* | (ORSAY, MILA, UCLA) |
| HYAMS | 68 | NP B7 1 | B.D. Hyams *et al.* | (CERN, MPIM) |
| LANZEROTTI | 68 | PR 166 1365 | L.J. Lanzerotti *et al.* | (HARV) |
| PISUT | 68 | NP B6 325 | J. Pisut, M. Roos | (CERN) |
| ASBURY | 67B | PRL 19 865 | J.G. Asbury *et al.* | (DESY, COLU) |
| BACON | 67 | PR 157 1263 | T.C. Bacon *et al.* | (BNL) |
| EISNER | 67 | PR 164 1699 | R.L. Eisner *et al.* | (PURD) |
| HUWE | 67 | PL 24B 252 | D.O. Huwe *et al.* | (COLU) |
| HYAMS | 67 | PL 24B 634 | B.D. Hyams *et al.* | (CERN, MPIM) |
| MILLER | 67B | PR 153 1423 | D.H. Miller *et al.* | (PURD) |
| ALFF-... | 66 | PR 145 1072 | C. Alff-Steinberger *et al.* | (COLU, RUTG) |
| FERBEL | 66 | PL 21 111 | T. Ferbel | (ROCH) |
| HAGOPIAN | 66 | PR 145 1128 | V. Hagopian *et al.* | (PENN, SACL) |
| HAGOPIAN | 66B | PR 152 1183 | V. Hagopian, Y.L. Pan | (PENN, LRL) |
| JACOBS | 66B | UCRL 16877 | L.D. Jacobs | (LRL) |
| JAMES | 66 | PR 142 896 | F.E. James, H.L. Kraybill | (YALE, BNL) |
| ROSS | 66 | PR 149 1172 | M. Ross, L. Stodolsky | |
| SOEDING | 66 | PL B19 702 | P. Soeding | |
| WEST | 66 | PR 149 1089 | E. West *et al.* | (WISC) |
| BLIEDEN | 65 | PL 19 444 | H.R. Blieden *et al.* | |
| CARMONY | 64 | PRL 12 254 | D.D. Carmony *et al.* | (UCB) |
| GOLDHABER | 64 | PRL 12 336 | G. Goldhaber *et al.* | (LRL, UCB) |
| ABOLINS | 63 | PRL 11 381 | M.A. Abolins *et al.* | (UCSD) |


## OTHER RELATED PAPERS


| | | | | |
|---|---|---|---|---|
| ANDERSON | 00 | PR D61 112002 | S. Anderson *et al.* | (CLEO Collab.) |
| BENAYOUN | 99 | PR D59 074020 | M. Benayoun *et al.* | |
| EIDELMAN | 99 | NPBPS 76 319 | S. Eidelman, V. Ivanchenko | |
| MARCO | 99 | PL B470 20 | E. Marco *et al.* | |
| ROOS | 99 | APS 49 N2 vii | M. Roos | |
| ALEMANY | 98 | EPJ C2 123 | R. Alemany *et al.* | |
| ABELE | 97B | PL B402 195 | A. Abele *et al.* | (Crystal Barrel Collab.) |
| ABELE | 97F | PL B411 354 | A. Abele *et al.* | (Crystal Barrel Collab.) |
| BENAYOUN | 93 | ZPHY 58 31 | M. Benayoun *et al.* | (CDEF, CERN, BARI) |
| LAFFERTY | 93 | ZPHY C60 659 | G.D. Lafferty | (MCHS) |
| KAMAL | 92 | PL B284 421 | A.N. Kamal, Q.P. Xu | (ALBE) |

| | | | | |
|---|---|---|---|---|
| KUHN | 90 | ZPHY C48 445 | J.H. Kuhn *et al.* | (MPIM) |
| ERKAL | 85 | ZPHY C29 485 | C. Erkal, M.G. Olsson | (WISC) |
| RYBICKI | 85 | ZPHY C28 65 | K. Rybicki, I. Sakrejda | (CRAC) |
| KURDADZE | 83 | JETPL 37 733<br>Translated from ZETFP 37 613. | L.M. Kurdadze *et al.* | (NOVO) |
| ALEKSEEV | 82 | JETP 55 591<br>Translated from ZETF 82 1007. | E.A. Alekseeva *et al.* | (KIAE) |
| 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) |