fit 2 above (before including BRFIT 94 values) are used along with the $K^0_L$ and $K^0_S$ mean lives and the $K^0_S \to \pi\pi$ branching fractions to compute the $K^0_L$ branching ratios $\Gamma(K^0_L \to \pi^+\pi^-)/\Gamma(\text{total})$ and $\Gamma(K^0_L \to \pi^0\pi^0)/\Gamma(K^0_L \to \pi^+\pi^-)$. These branching ratio values are included as measurements in the branching ratio section with a document ID of ETAFIT 94. Thus the $K^0_L$ branching ratio fit values in this edition include the results of direct measurements of $|\eta_{+-}|$, $|\eta_{00}|$, and $|\eta_{00}/\eta_{+-}|$. Details of these fits are given in the 1990 edition of this *Review* [8].

Since the last edition, results on $\epsilon'/\epsilon$ have been published by CERN NA31 (BARR 93D) and Fermilab E731 (GIBBONS 93B). These results dominate our fit to $\epsilon'/\epsilon$, $|\eta_{+-}|$, $|\eta_{00}|$, and $\mathrm{B}(K_L \to \pi\pi)$. The resulting value $\epsilon'/\epsilon = (1.5 \pm 0.8) \times 10^{-3}$ (S = 1.8) has a large scale factor S included in the error, indicating a continuing disagreement in the input data. The CERN NA31 result continues to indicate the presence of direct $CP$ violation with a result which is more than three $\sigma$ above zero while the Fermilab E731 result is consistent with zero.

The Fermilab E731 experiment also has published recent results on $\phi_{+-}$, $\phi_{00}$–$\phi_{+-}$, and $\Delta m$. GIBBONS 93 reports $\Delta m = (0.5286 \pm 0.0028) \times 10^{10}\ \hbar\ \mathrm{s}^{-1}$ assuming $\phi_{+-} = \phi_{00} = \phi_{\rm SW}$. GIBBONS 93C reports $\Delta m = (0.5257 \pm 0.0049) \times 10^{10}\ \hbar\ \mathrm{s}^{-1}$ when a joint fit with $\phi_{+-}$ is done. We use this value in our average rather than the GIBBONS 93 value to avoid the $\phi_{\rm SW}$ constraint. This is so that when we reevaluate $\phi_{+-}$ experiments using our average $\Delta m$, we will avoid biasing $\phi_{+-}$ toward $\phi_{\rm SW}$ The resulting average $\Delta m = (0.5333 \pm 0.0027) \times 10^{10}\ \hbar\ \mathrm{s}^{-1}$ (S = 1.2) is $0.0018 \times 10^{10}\ \hbar\ \mathrm{s}^{-1}$ lower than our 1992 average as a result of the lower E731 value. GIBBONS 93 reports $\phi_{+-} = 42.2 \pm 1.4°$ for their $\Delta m$ and $\tau_s$. We use their $\Delta m$ and $\tau_s$ dependence quoted in NAKADA 93. We revaluate all $\phi_{+-}$ measurements for the current $\Delta m$ and $\tau_s$ PDG averages. The resulting value $\phi_{+-} = 44.3 \pm 0.8°$ is two old standard deviations below our 1992 average and is now consistent with the "superweak" phase given in Eq. (7$a$).

### Footnotes and References

* The S values in parentheses are scale factors by which the errors have been increased to account for discrepancies in the data.

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## *CP*-VIOLATION PARAMETERS IN $K^0_L$ DECAYS

### CHARGE ASYMMETRY IN LEPTONIC DECAYS

Such asymmetry violates $CP$. It is related to Re($\epsilon$).

#### $\delta(\mu) = [\Gamma(\pi^-\mu^+\nu_\mu) - \Gamma(\pi^+\mu^-\overline{\nu}_\mu)]/\mathrm{SUM}$

Only the combined value below is put into the Meson Summary Table.

| VALUE (%) | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **0.304±0.025 OUR AVERAGE** | | | | |
| 0.313±0.029 | 15M | GEWENIGER | 74 | ASPK |
| 0.278±0.051 | 7.7M | PICCIONI | 72 | ASPK |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.60 ±0.14 | 4.1M | MCCARTHY | 73 | CNTR |
| 0.57 ±0.17 | 1M | [85] PACIOTTI | 69 | OSPK |
| 0.403±0.134 | 1M | [85] DORFAN | 67 | OSPK |

[85] PACIOTTI 69 is a reanalysis of DORFAN 67 and is corrected for $\mu^+\mu^-$ range difference in MCCARTHY 72.

#### $\delta(e) = [\Gamma(\pi^- e^+\nu_e) - \Gamma(\pi^+ e^-\overline{\nu}_e)]/\mathrm{SUM}$

Only the combined value below is put into the Meson Summary Table.

| VALUE (%) | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **0.333±0.014 OUR AVERAGE** | | | | |
| 0.341±0.018 | 34M | GEWENIGER | 74 | ASPK |
| 0.318±0.038 | 40M | FITCH | 73 | ASPK |
| 0.346±0.033 | 10M | MARX | 70 | CNTR |
| 0.246±0.059 | 10M | [86] SAAL | 69 | CNTR |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.36 ±0.18 | 600k | ASHFORD | 72 | ASPK |
| 0.224±0.036 | 10M | [86] BENNETT | 67 | CNTR |

[86] SAAL 69 is a reanalysis of BENNETT 67.

#### $\delta$ = weighted average of $\delta(\mu)$ and $\delta(e)$

(Combination of the above two sections.)

| VALUE (%) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.327±0.012 OUR AVERAGE** | | | | | |
| 0.313±0.029 | 15M | GEWENIGER | 74 | ASPK | $K_{\mu 3}$ |
| 0.341±0.018 | 34M | GEWENIGER | 74 | ASPK | $K_{e3}$ |
| 0.318±0.038 | 40M | FITCH | 73 | ASPK | $K_{e3}$ |
| 0.333±0.050 | 33M | WILLIAMS | 73 | ASPK | $K_{\mu 3} + K_{e3}$ |
| 0.278±0.051 | 7.7M | PICCIONI | 72 | ASPK | $K_{\mu 3}$ |
| 0.346±0.033 | 10M | MARX | 70 | CNTR | $K_{e3}$ |
| 0.246±0.059 | 10M | SAAL | 69 | CNTR | $K_{e3}$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.60 ±0.14 | 4.1M | MCCARTHY | 73 | CNTR | $K_{\mu 3}$ |
| 0.36 ±0.18 | 600k | ASHFORD | 72 | ASPK | $K_{e3}$ |
| 0.57 ±0.17 | 1M | PACIOTTI | 69 | OSPK | $K_{\mu 3}$ |

### PARAMETERS FOR $K^0_L \to 2\pi$ DECAY

$\eta_{+-} = \mathrm{A}(K^0_L \to \pi^+\pi^-)\ /\ \mathrm{A}(K^0_S \to \pi^+\pi^-)$
$\eta_{00} = \mathrm{A}(K^0_L \to \pi^0\pi^0)\ /\ \mathrm{A}(K^0_S \to \pi^0\pi^0)$

The fitted values of $|\eta_{+-}|$ and $|\eta_{00}|$ given below are the results of a fit to $|\eta_{+-}|$, $|\eta_{00}|$, $|\eta_{00}/\eta_{+-}|$, and Re($\epsilon'/\epsilon$). Independent information on $|\eta_{+-}|$ and $|\eta_{00}|$ can be obtained from the fitted values of the $K^0_L \to \pi\pi$ and $K^0_S \to \pi\pi$ branching ratios and the $K^0_L$ and $K^0_S$ lifetimes. This information is included as data in the $|\eta_{+-}|$ and $|\eta_{00}|$ sections with a Document ID "BRFIT." See the "Note on $CP$ Violation in $K^0_L$ Decay" above for details.

#### $|\eta_{00}| = |\mathrm{A}(K^0_L \to 2\pi^0)\ /\ \mathrm{A}(K^0_S \to 2\pi^0)|$

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **2.259±0.023 OUR FIT** Error includes scale factor of 1.1. | | | | | |
| **2.12 ±0.09 OUR AVERAGE** Error includes scale factor of 1.2. | | | | | |
| 2.084±0.080 | | [87] BRFIT | 94 | | |
| 2.33 ±0.18 | | CHRISTENS... | 79 | ASPK | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 2.71 ±0.37 | 56 | [88] WOLFF | 71 | OSPK | Cu reg., $4\gamma$'s |
| 2.95 ±0.63 | | [88] CHOLLET | 70 | OSPK | Cu reg., $4\gamma$'s |

[87] This BRFIT value is computed from fitted values of the $K^0_L$ and $K^0_S$ lifetimes and branching fractions to $\pi\pi$. See the discussion in the "Note on $CP$ violation in $K^0_L$ decay."

[88] CHOLLET 70 gives $|\eta_{00}| = (1.23 \pm 0.24)\times$(regeneration amplitude, 2 GeV/$c$ Cu)/10000mb. WOLFF 71 gives $|\eta_{00}| = (1.13 \pm 0.12)\times$(regeneration amplitude, 2 GeV/$c$ Cu)/10000mb. We compute both $|\eta_{00}|$ values for (regeneration amplitude, 2 GeV/$c$ Cu) = 24 ± 2mb. This regeneration amplitude results from averaging over FAISSNER 69, extrapolated using optical-model calculations of Bohm et al., Physics Letters **27B** 594 (1968) and the data of BALATS 71. (From H. Faissner, private communication).