\( \phi(1020) \)

\[
i^G(j^{PC}) = 0^-(1^{--})
\]

### \( \phi(1020) \) MASS

<table>
<thead>
<tr>
<th>VALUE (MeV)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 1019.461 \pm 0.016 ) OUR AVERAGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1019.463 \pm 0.061</td>
<td>2.3M</td>
<td>1 KOZYREV</td>
<td>18 CMD3</td>
<td>( e^+ e^- \to K^+ K^- ), ( K_S^0 K_L^0 )</td>
</tr>
<tr>
<td>1019.462 \pm 0.042 \pm 0.056</td>
<td>28k</td>
<td>2 LEES</td>
<td>14H BABR</td>
<td>( e^+ e^- \to K_S^0 K_L^0 \gamma )</td>
</tr>
<tr>
<td>1019.51 \pm 0.02 \pm 0.05</td>
<td></td>
<td>3 LEES</td>
<td>13Q BABR</td>
<td>( e^+ e^- \to K^+ K^- \gamma )</td>
</tr>
<tr>
<td>1019.30 \pm 0.02 \pm 0.10</td>
<td>105k</td>
<td>AKHMETSHIN 06</td>
<td>CMD2</td>
<td>0.98–1.06 ( e^+ e^- \to \pi^+ \pi^- \pi^0 )</td>
</tr>
<tr>
<td>1019.52 \pm 0.05 \pm 0.05</td>
<td>17.4k</td>
<td>AKHMETSHIN 05</td>
<td>CMD2</td>
<td>0.60–1.38 ( e^+ e^- \to \eta \gamma )</td>
</tr>
<tr>
<td>1019.483 \pm 0.011 \pm 0.025</td>
<td>272k</td>
<td>4 AKHMETSHIN 04</td>
<td>CMD2</td>
<td>( e^+ e^- \to K_L^0 K_S^0 )</td>
</tr>
<tr>
<td>1019.42 \pm 0.05</td>
<td>1900k</td>
<td>5 ACHASOV</td>
<td>01E SND</td>
<td>( e^+ e^- \to K^+ K^- ), ( K_S K_L, \pi^+ \pi^- \pi^0 )</td>
</tr>
<tr>
<td>1019.40 \pm 0.04 \pm 0.05</td>
<td>23k</td>
<td>AKHMETSHIN 01B</td>
<td>CMD2</td>
<td>( e^+ e^- \to \eta \gamma )</td>
</tr>
<tr>
<td>1019.36 \pm 0.12</td>
<td></td>
<td>6 ACHASOV</td>
<td>00B SND</td>
<td>( e^+ e^- \to \eta \gamma )</td>
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<tr>
<td>1019.38 \pm 0.07 \pm 0.08</td>
<td>2200</td>
<td>AKHMETSHIN 99F</td>
<td>CMD2</td>
<td>( e^+ e^- \to \pi^+ \pi^- \gamma )</td>
</tr>
<tr>
<td>1019.51 \pm 0.07 \pm 0.10</td>
<td>11169</td>
<td>AKHMETSHIN 98</td>
<td>CMD2</td>
<td>( e^+ e^- \to \pi^+ \pi^- \pi^0 )</td>
</tr>
<tr>
<td>1019.5 \pm 0.4</td>
<td></td>
<td>BARBERIS</td>
<td>98 OMEG</td>
<td>450 ( pp \to pp2K^+2K^- )</td>
</tr>
<tr>
<td>1019.42 \pm 0.06</td>
<td>55600</td>
<td>AKHMETSHIN 95</td>
<td>CMD2</td>
<td>( e^+ e^- \to \text{hadrons} )</td>
</tr>
<tr>
<td>1019.7 \pm 0.3</td>
<td>2012</td>
<td>DAVENPORT</td>
<td>86 MPSF</td>
<td>400 ( pA \to 4K )</td>
</tr>
<tr>
<td>1019.7 \pm 0.1 \pm 0.1</td>
<td>5079</td>
<td>ALBRECHT</td>
<td>85D ARG</td>
<td>10 ( e^+ e^- \to K^+ K^- X )</td>
</tr>
<tr>
<td>1019.3 \pm 0.1</td>
<td>1500</td>
<td>ARETON</td>
<td>82 AEMS</td>
<td>11.8 polar. ( pp \to K K )</td>
</tr>
<tr>
<td>1019.67 \pm 0.17</td>
<td>25080</td>
<td>PELLINEN</td>
<td>82 RVUE</td>
<td></td>
</tr>
<tr>
<td>1019.52 \pm 0.13</td>
<td>3681</td>
<td>BUKIN</td>
<td>78C OLYA</td>
<td>( e^+ e^- \to \text{hadrons} )</td>
</tr>
</tbody>
</table>

\( \bullet \bullet \bullet \) We do not use the following data for averages, fits, limits, etc. \( \bullet \bullet \bullet \)

<table>
<thead>
<tr>
<th>VALUE (MeV)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1019.469 \pm 0.061</td>
<td>1.7M</td>
<td>KOZYREV</td>
<td>18 CMD3</td>
<td>( e^+ e^- \to \phi K^- K^- )</td>
</tr>
<tr>
<td>1019.457 \pm 0.061</td>
<td>610k</td>
<td>KOZYREV</td>
<td>16 CMD3</td>
<td>( e^+ e^- \to K_S^0 K_L^0 )</td>
</tr>
<tr>
<td>1019.48 \pm 0.01</td>
<td></td>
<td>LEES</td>
<td>13F BABR</td>
<td>( D^- \to K^- K^- \pi^+ )</td>
</tr>
<tr>
<td>1019.441 \pm 0.008 \pm 0.080</td>
<td>542k</td>
<td>AKHMETSHIN 08</td>
<td>CMD2</td>
<td>1.02 ( e^+ e^- \to K^+ K^- )</td>
</tr>
<tr>
<td>1019.63 \pm 0.07</td>
<td>12540</td>
<td>AUBERT,B</td>
<td>05J BABR</td>
<td>( D^0 \to \phi K^+ K^- )</td>
</tr>
<tr>
<td>1019.8 \pm 0.7</td>
<td></td>
<td>ARMSTRONG</td>
<td>86 OMEG</td>
<td>85 ( \pi^+/pp \to \pi^+/p4K \rho )</td>
</tr>
<tr>
<td>1020.1 \pm 0.11</td>
<td>5526</td>
<td>ATKINSON</td>
<td>86 OMEG</td>
<td>20–70 ( \gamma \rho )</td>
</tr>
<tr>
<td>1019.7 \pm 1.0</td>
<td></td>
<td>BEBEK</td>
<td>86 CLEO</td>
<td>( e^+ e^- \to \Upsilon(45) )</td>
</tr>
<tr>
<td>1019.411 \pm 0.008</td>
<td>642k</td>
<td>DIJKSTRA</td>
<td>86 SPEC</td>
<td>100–200 ( \pi^\pm, \pi^\mp, \rho, ) a, on Be</td>
</tr>
<tr>
<td>1020.9 \pm 0.2</td>
<td></td>
<td>FRAME</td>
<td>86 OMEG</td>
<td>13 ( K^+ p \to \phi K^+ p )</td>
</tr>
<tr>
<td>1021.0 \pm 0.2</td>
<td></td>
<td>ARMSTRONG</td>
<td>83B OMEG</td>
<td>18.5 ( K^- p \to K^- K^+ \Lambda )</td>
</tr>
<tr>
<td>1020.0 \pm 0.5</td>
<td></td>
<td>ARMSTRONG</td>
<td>83B OMEG</td>
<td>18.5 ( K^- p \to K^- K^+ \Lambda )</td>
</tr>
</tbody>
</table>

HTTP://PDG.LBL.GOV

Page 1
Created: 8/2/2019 16:42
### \(\phi(1020)\) WIDTH

<table>
<thead>
<tr>
<th>VALUE (MeV)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.249 ± 0.013</td>
<td>2.3M</td>
<td>OUR AVERAGE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.245 ± 0.013</td>
<td>2.3M</td>
<td>1 KOZYREV</td>
<td>18</td>
<td>CMD3 (\pi^+ \pi^- \rightarrow K^+ K^-), (K_S^0 K_L^0)</td>
</tr>
<tr>
<td>4.205 ± 0.103 ± 0.067</td>
<td>28k</td>
<td>2 LEES</td>
<td>14H</td>
<td>BABR (\pi^+ \pi^- \rightarrow K_S^0 K_L^0 \gamma)</td>
</tr>
<tr>
<td>4.29 ± 0.04 ± 0.07</td>
<td>3 LEES</td>
<td>13Q</td>
<td>BABR</td>
<td>(\pi^+ \pi^- \rightarrow K^+ K^-\gamma)</td>
</tr>
<tr>
<td>4.30 ± 0.06 ± 0.17</td>
<td>105k</td>
<td>AKHMETSHIN</td>
<td>06</td>
<td>CMD2 (0.98 - 1.06 \pi^+ \pi^-)</td>
</tr>
<tr>
<td>4.280 ± 0.033 ± 0.025</td>
<td>272k</td>
<td>4 AKHMETSHIN</td>
<td>04</td>
<td>CMD2 (\pi^+ \pi^-)</td>
</tr>
<tr>
<td>4.21 ± 0.04</td>
<td>1900k</td>
<td>5 ACHASOV</td>
<td>01E</td>
<td>SND (e^+ e^-)</td>
</tr>
<tr>
<td>4.44 ± 0.09</td>
<td>55600</td>
<td>AKHMETSHIN</td>
<td>95</td>
<td>CMD2 (e^+ e^-)</td>
</tr>
</tbody>
</table>

**Notes:**
1. Average of KOZYREV 16 and KOZYREV 18 values taking into account the correlated uncertainties. Supersedes individual KOZYREV 16 and KOZYREV 18 results.
2. Using a vector meson dominance model with contribution from \(\phi(1020)\) and higher mass excitations of \(\rho(770), \omega(782), \text{and } \phi(1020)\).
3. Using a phenomenological model based on KUHN 90 with a sum of Breit-Wigner resonances for \(\rho(770), \omega(782), \phi(1020)\) and their higher mass excitations.
4. Update of AKHMETSHIN 990
5. From the combined fit assuming that the total \(\phi(1020)\) production cross section is saturated by those of \(K^+ K^-\), \(K_S K_L\), \(\pi^+ \pi^-\), and \(\eta \gamma\) decays and using ACHASOV 00b for the \(\eta \gamma\) decay mode.
6. Using a total width of 4.43 ± 0.05 MeV. Systematic uncertainty included.
7. Using a total width of 4.43 ± 0.05 MeV.
8. PELLINEN 82 review includes AKERLOF 77, DAUM 81, BALDI 77, AYRES 74, DE-GROOT 74.
9. Strongly correlated with AKHMETSHIN 04.
10. Systematic errors not evaluated.
11. Weighted and scaled average of 12 measurements of DIJKSTRA 86.
12. Mass errors enlarged by us to \(\Gamma/\sqrt{N}\); see the note with the \(K^*(892)\) mass.
\(\phi(1020)\) DECAY MODES

<table>
<thead>
<tr>
<th>Mode</th>
<th>Fraction ((\Gamma_i/\Gamma))</th>
<th>Scale factor/Confidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Gamma_1)</td>
<td>(K^+ K^-)</td>
<td>(49.2 ± 0.5 ) %</td>
</tr>
<tr>
<td>(\Gamma_2)</td>
<td>(K_L^0 K_S^0)</td>
<td>(34.0 ± 0.4 ) %</td>
</tr>
<tr>
<td>(\Gamma_3)</td>
<td>(\rho \pi^+ + \pi^+ \pi^- \pi^0)</td>
<td>(15.24 ± 0.33 ) %</td>
</tr>
<tr>
<td>(\Gamma_4)</td>
<td>(\rho \pi)</td>
<td></td>
</tr>
<tr>
<td>(\Gamma_5)</td>
<td>(\pi^+ \pi^- \pi^0)</td>
<td></td>
</tr>
<tr>
<td>(\Gamma_6)</td>
<td>(\eta\gamma)</td>
<td>( 1.303±0.025 ) %</td>
</tr>
<tr>
<td>(\Gamma_7)</td>
<td>(\pi^0\gamma)</td>
<td>( 1.30 ± 0.05 ) x 10^{-3}</td>
</tr>
</tbody>
</table>

1 Average of KOZYREV 16 and KOZYREV 18 values taking into account the correlated uncertainties. Supersedes individual KOZYREV 16 and KOZYREV 18 results.

2 Using a vector meson dominance model with contribution from \(\phi(1020)\) and higher mass excitations of \(\rho(770)\), \(\omega(782)\), and \(\phi(1020)\).

3 Using a phenomenological model based on KUHN 90 with a sum of Breit-Wigner resonances for \(\rho(770)\), \(\omega(782)\), \(\phi(1020)\) and their higher mass excitations.

4 Update of AKHMETSHIN 09.

5 From the combined fit assuming that the total \(\phi(1020)\) production cross section is saturated by those of \(K^+ K^-\), \(K_S K_L\), \(\pi^+ \pi^- \pi^0\), and \(\eta\gamma\) decays modes and using ACHASOV 06 for the \(\eta\gamma\) decay mode.

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

7 Strongly correlated with AKHMETSHIN 04.

8 Systematic errors not evaluated.
\begin{tabular}{lll}
\hline
$\Gamma_8$ & $\ell^+\ell^-$ & ---
$\Gamma_9$ & $e^+e^-$ & $(2.973 \pm 0.034) \times 10^{-4}$ S=1.3
$\Gamma_{10}$ & $\mu^+\mu^-$ & $(2.86 \pm 0.19) \times 10^{-4}$
$\Gamma_{11}$ & $\eta e^+e^-$ & $(1.08 \pm 0.04) \times 10^{-4}$
$\Gamma_{12}$ & $\pi^+\pi^-$ & $(7.3 \pm 1.3) \times 10^{-5}$
$\Gamma_{13}$ & $\omega\pi^0$ & $(4.7 \pm 0.5) \times 10^{-5}$
$\Gamma_{14}$ & $\omega\gamma$ & $<5\%$ CL=84%
$\Gamma_{15}$ & $\rho\gamma$ & $<1.2 \times 10^{-5}$ CL=90%
$\Gamma_{16}$ & $\pi^+\pi^-\gamma$ & $(4.1 \pm 1.3) \times 10^{-5}$
$\Gamma_{17}$ & $f_0(980)\gamma$ & $(3.22 \pm 0.19) \times 10^{-4}$ S=1.1
$\Gamma_{18}$ & $\pi^0\pi^0\gamma$ & $(1.12 \pm 0.06) \times 10^{-4}$
$\Gamma_{19}$ & $\pi^+\pi^-\pi^+\pi^-$ & $(3.9 \pm 2.8) \times 10^{-6}$
$\Gamma_{20}$ & $\pi^+\pi^-\pi^-\pi^0$ & $<4.6 \times 10^{-6}$ CL=90%
$\Gamma_{21}$ & $\pi^0e^+e^-$ & $(1.33 \pm 0.07 - 0.10) \times 10^{-5}$
$\Gamma_{22}$ & $\pi^0\eta\gamma$ & $(7.27 \pm 0.30) \times 10^{-5}$ S=1.5
$\Gamma_{23}$ & $a_0(980)\gamma$ & $(7.6 \pm 0.6) \times 10^{-5}$
$\Gamma_{24}$ & $K^0\bar{K}^0\gamma$ & $<1.9 \times 10^{-8}$ CL=90%
$\Gamma_{25}$ & $\eta'(958)\gamma$ & $(6.22 \pm 0.21) \times 10^{-5}$
$\Gamma_{26}$ & $\eta\pi^0\pi^0\gamma$ & $<2 \times 10^{-5}$ CL=90%
$\Gamma_{27}$ & $\mu^+\mu^-\gamma$ & $(1.4 \pm 0.5) \times 10^{-5}$
$\Gamma_{28}$ & $\rho\gamma\gamma$ & $<1.2 \times 10^{-4}$ CL=90%
$\Gamma_{29}$ & $\eta\pi^+\pi^-$ & $<1.8 \times 10^{-5}$ CL=90%
$\Gamma_{30}$ & $\eta\mu^+\mu^-$ & $<9.4 \times 10^{-6}$ CL=90%
$\Gamma_{31}$ & $\eta U \rightarrow \eta e^+e^-$ & $<1 \times 10^{-6}$ CL=90%
$\Gamma_{32}$ & invisible & $<1.7 \times 10^{-4}$ CL=90%
\hline
\end{tabular}

Lepton Family number (LF) violating modes

\begin{tabular}{lll}
\hline
$\Gamma_{33}$ & $e^\pm\mu^\mp$ & $LF < 2 \times 10^{-6}$ CL=90%
\hline
\end{tabular}
CONSTRANDED FIT INFORMATION

An overall fit to 30 branching ratios uses 82 measurements and one constraint to determine 14 parameters. The overall fit has a $\chi^2 = 63.7$ for 69 degrees of freedom.

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

\[
\begin{array}{cccccccccccc}
    x_1 & x_2 & x_3 & x_4 & x_6 & x_7 & x_8 & x_9 & x_{10} & x_{11} & x_{12} & x_{13} & x_{14} & x_{15} \\
    \hline
    x_2 & -78 & & & & & & & & & & & & \\
    x_3 & -59 & -4 & & & & & & & & & & & \\
    x_4 & & & & & & & & & & & & & & \\
    x_6 & -23 & 19 & 6 & & & & & & & & & & \\
    x_7 & -15 & 14 & 4 & 10 & & & & & & & & & \\
    x_8 & 54 & -52 & -17 & -38 & -27 & & & & & & & & \\
    x_{10} & -7 & 7 & 2 & 5 & 3 & -13 & & & & & & & \\
    x_{12} & -3 & 3 & 1 & 2 & 2 & -6 & 1 & & & & & & \\
    x_{13} & -5 & 4 & 1 & 3 & 2 & -8 & 1 & 1 & & & & & \\
    x_{17} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & & & & \\
    x_{18} & -11 & 10 & 3 & 19 & 5 & -20 & 2 & 1 & 2 & 0 & & & \\
    x_{19} & -1 & 1 & 0 & 1 & 0 & -2 & 0 & 0 & 0 & 0 & & & \\
    x_{23} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & & & \\
    x_{25} & -8 & 6 & 2 & 33 & 3 & -12 & 2 & 1 & 1 & 0 & & & \\
\end{array}
\]

\[
\begin{array}{cccccccccccc}
    x_{18} & x_{19} & x_{23} & & & & & & & & & & & & \\
\end{array}
\]

\textbf{PHI(1020) PARTIAL WIDTHS}

\begin{align*}
\Gamma(\eta \gamma) & \quad \Gamma_6 \\
\text{VALUE (keV)} & \quad \text{DOCUMENT ID} & \quad \text{TECN} & \quad \text{COMMENT} \\
\hline
58.9 \pm 0.5 \pm 2.4 & \text{ACHASOV} & 00 & \text{SND} & e^+ e^- \rightarrow \eta \gamma \\
\end{align*}

\begin{align*}
\Gamma(\pi^0 \gamma) & \quad \Gamma_7 \\
\text{VALUE (keV)} & \quad \text{DOCUMENT ID} & \quad \text{TECN} & \quad \text{COMMENT} \\
\hline
5.40 \pm 0.16^{+0.43}_{-0.40} & \text{ACHASOV} & 00 & \text{SND} & e^+ e^- \rightarrow \pi^0 \gamma \\
\end{align*}
\[
\Gamma(\ell^+ \ell^-)
\]

<table>
<thead>
<tr>
<th>VALUE (keV)</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
</table>
| 1.320 ± 0.017 ± 0.015 | AMBROSINO 05 | KLOE | 1.02 \( e^+ e^- \rightarrow \mu^+ \mu^- \)

1 Weighted average of \( \Gamma_{ee} \) and \( \sqrt{\Gamma_{ee} \Gamma_{\mu\mu}} \) from AMBROSINO 05 assuming lepton universality.

\[
\Gamma(e^+ e^-)
\]

<table>
<thead>
<tr>
<th>VALUE (keV)</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.27 ± 0.04</td>
<td>OUR EVALUATION</td>
<td>Error includes scale factor of 1.1.</td>
<td></td>
</tr>
</tbody>
</table>
| 1.251 ± 0.021 | OUR AVERAGE | 1 AKHMETSHIN 11 | CMD2 1.02 \( e^+ e^- \rightarrow \phi \)
| 1.32 ± 0.05 ± 0.03 | AMBROSINO 05 | KLOE | 1.02 \( e^+ e^- \rightarrow e^+ e^- \)
| 1.28 ± 0.05 | AKHMETSHIN 95 | CMD2 | 1.02 \( e^+ e^- \rightarrow \phi \)

1 Combined analysis of the CMD-2 data on \( \phi \rightarrow K^+ K^- \), \( K^0 S K^0 L \), \( \pi^+ \pi^- \pi^0 \), \( \eta \gamma \) assuming that the sum of their branching fractions is 0.99741 ± 0.00007.

2 From forward-backward asymmetry and using \( \Gamma_{\text{total}} = 4.26 \pm 0.05 \text{ MeV} \) from the 2004 edition of this Review.

\[
\left( \Gamma(e^+ e^-) \times \Gamma(\mu^+ \mu^-) \right)^{1/2}
\]

<table>
<thead>
<tr>
<th>VALUE (keV)</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
</table>
| 1.320 ± 0.018 ± 0.017 | AMBROSINO 05 | KLOE | 1.02 \( e^+ e^- \rightarrow \mu^+ \mu^- \)

\[
\phi(1020) \frac{\Gamma(i)\Gamma(e^+ e^-)}{\Gamma(\text{total})}
\]

\[
\Gamma(K^+ K^-) \times \frac{\Gamma(e^+ e^-)}{\Gamma_{\text{total}}}
\]

<table>
<thead>
<tr>
<th>VALUE (keV)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6340 ± 0.0070 ± 0.0039</td>
<td>1 LEES</td>
<td>BABR</td>
<td>e^+ e^- \rightarrow K^+ K^- γ</td>
<td></td>
</tr>
</tbody>
</table>

1 Using a phenomenological model based on KUHN 90 with a sum of Breit-Wigner resonances for \( \rho(770) \), \( \omega(782) \), \( \phi(1020) \) and their higher mass excitations. The first error combines statistical and systematic uncertainties. The second one is due to the parametrization of the charged kaon form factor and mass calibration.

\[
\Gamma(K_0^0 K_0^0) \times \frac{\Gamma(e^+ e^-)}{\Gamma_{\text{total}}}
\]

<table>
<thead>
<tr>
<th>VALUE (keV)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4200 ± 0.0033 ± 0.0123</td>
<td>1 LEES</td>
<td>BABR</td>
<td>e^+ e^- \rightarrow K_0^0 K_0^0 γ</td>
<td></td>
</tr>
</tbody>
</table>

1 Using a vector meson dominance model with contribution from \( \phi(1020) \) and higher mass excitations of \( \rho(770) \), \( \omega(782) \), and \( \phi(1020) \).
$\phi(1020) \Gamma(i) \Gamma(e^+ e^-) / \Gamma^2(\text{total})$

$\Gamma(K^+ K^-) / \Gamma_{\text{total}} \times \Gamma(e^+ e^-) / \Gamma_{\text{total}}$

$\Gamma_1 / \Gamma \times \Gamma_9 / \Gamma$

**Table 1:**

<table>
<thead>
<tr>
<th>Value (units $10^{-5}$)</th>
<th>EVTS</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.63 ± 0.29 OUR FIT</td>
<td></td>
<td></td>
<td>Error includes scale factor of 1.5.</td>
</tr>
<tr>
<td>14.6 ± 0.5 OUR AVERAGE</td>
<td></td>
<td></td>
<td>Error includes scale factor of 1.8. See the ideogram below.</td>
</tr>
<tr>
<td>15.789 ± 0.541 1.7M</td>
<td>KOZYREV 18 CMD3</td>
<td></td>
<td>$e^+ e^- \to K^+ K^-$</td>
</tr>
<tr>
<td>14.27 ± 0.05 ± 0.31 542k</td>
<td>AKHMETSHIN 08 CMD2</td>
<td></td>
<td>$1.02 e^+ e^- \to K^+ K^-$</td>
</tr>
<tr>
<td>13.93 ± 0.14 ± 0.99 1000k</td>
<td>1 ACHASOV 01E SND</td>
<td></td>
<td>$e^+ e^- \to K^+ K^-$</td>
</tr>
</tbody>
</table>

$K_S^0 K_L, \pi^+ \pi^- \pi^0$

From the combined fit assuming that the total $\phi(1020)$ production cross section is saturated by those of $K^+ K^-$, $K_S^0 K_L, \pi^+ \pi^- \pi^0$, and $\eta \gamma$ decays modes and using ACHASOV 00B for the $\eta \gamma$ decay mode.

WEIGHTED AVERAGE

14.6±0.5 (Error scaled by 1.8)

Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our ‘best’ values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

**Table 2:**

<table>
<thead>
<tr>
<th>Value (units $10^{-5}$)</th>
<th>EVTS</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.10 ± 0.12 OUR FIT</td>
<td></td>
<td></td>
<td>Error includes scale factor of 1.1.</td>
</tr>
<tr>
<td>10.07 ± 0.13 OUR AVERAGE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.078±0.223 610k</td>
<td>1 KOZYREV 16 CMD3</td>
<td></td>
<td>$e^+ e^- \to K_S^0 K_S^0$</td>
</tr>
<tr>
<td>10.01 ± 0.04 ± 0.17 272k</td>
<td>2 AKHMETSHIN 04 CMD2</td>
<td></td>
<td>$e^+ e^- \to K_L^0 K_S^0$</td>
</tr>
<tr>
<td>10.27 ± 0.07 ± 0.34 500k</td>
<td>3 ACHASOV 01E SND</td>
<td></td>
<td>$e^+ e^- \to K^+ K^-$</td>
</tr>
</tbody>
</table>

$K_S^0 K_L, \pi^+ \pi^- \pi^0$
From the combined fit assuming that the total $\phi(1020)$ production cross section is saturated by those of $K^+ K^-$, $K_SK_L\pi^0$, and $\eta\gamma$ decays modes and using ACHASOV 00B for the $\eta\gamma$ decay mode.

$$\left[\Gamma(\rho\pi) + \Gamma(\pi^+\pi^-\pi^0)\right]/\Gamma_{\text{total}} \times \Gamma(\phi^+\phi^-)/\Gamma_{\text{total}} \quad \Gamma_3/\Gamma \times \Gamma_9/\Gamma$$

<table>
<thead>
<tr>
<th>VALUE ($10^{-5}$)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4.53 ±0.10</strong> OUR FIT</td>
<td>Error includes scale factor of 1.1.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.46 ±0.12 OUR AVERAGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 4.51 ±0.16 ±0.11 | CMD2 | ACHMETSHIN 06 | 105k |
| 4.30 ±0.08 ±0.21 | 04N | AUBERT,B | BABR |
| 4.665±0.042±0.261 | 400k | 1 ACHASOV 01E | SND |
| 4.35 ±0.27 ±0.08 | CMD2 | 2 AKHMETSHIN 98 | 11169 |
| **4.38 ±0.12** | | | |

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

1 From the combined fit assuming that the total $\phi(1020)$ production cross section is saturated by those of $K^+ K^-$, $K_SK_L\pi^0$, and $\eta\gamma$ decays modes and using ACHASOV 00B for the $\eta\gamma$ decay mode.

2 Recalculated by us from the cross section in the peak.

$\Gamma(\eta\gamma)/\Gamma_{\text{total}} \times \Gamma(\phi^+\phi^-)/\Gamma_{\text{total}} \quad \Gamma_6/\Gamma \times \Gamma_9/\Gamma$

<table>
<thead>
<tr>
<th>VALUE ($10^{-6}$)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.87 ±0.07</strong> OUR FIT</td>
<td>Error includes scale factor of 1.2.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3.93 ±0.09</strong> OUR AVERAGE</td>
<td>Error includes scale factor of 1.3. See the ideogram below.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 4.050±0.067±0.118 | CMD2 | ACHMETSHIN 05 | 33k |
| 4.093±0.040±0.043 | 04N | ACHASOV 00 | BABR |
| 3.850±0.041±0.159 | CMD2 | 3 AKHMETSHIN 01B | 17.4k |
| 4.00 ±0.04 ±0.11 | CMD2 | 5 ACHASOV 00 | SND |
| 3.53 ±0.08 ±0.17 | CMD2 | 8 AKHMETSHIN 99 | 2200 |
| **4.19 ±0.06** | | | |

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

1 From a combined fit of $\sigma(\phi^+\phi^- \rightarrow \eta\gamma)$ with $\eta \rightarrow 3\pi^0$ and $\eta \rightarrow \pi^+\pi^-\pi^0$, and fixing $B(\eta \rightarrow 3\pi^0) / B(\eta \rightarrow \pi^+\pi^-\pi^0) = 1.44 \pm 0.04$. Recalculated by us from the cross section at the peak. Supersedes ACHASOV 00D and ACHASOV 06A.

2 From the $\eta \rightarrow 2\gamma$ decay and using $B(\eta \rightarrow \gamma\gamma) = 39.43 \pm 0.26\%$.

3 From the $\eta \rightarrow 3\pi^0$ decay and using $B(\eta \rightarrow 3\pi^0) = (32.24 \pm 0.29) \times 10^{-2}$. 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).

4 From the $\eta \rightarrow 2\gamma$ decay and using $B(\eta \rightarrow 2\gamma) = (39.21 \pm 0.34) \times 10^{-2}$. Recalculated by the authors from the cross section in the peak.

5 From the $\eta \rightarrow \pi^+\pi^-\pi^0$ decay and using $B(\eta \rightarrow \pi^+\pi^-\pi^0) = (23.1 \pm 0.5) \times 10^{-2}$. A simultaneous fit of $e^+ e^- \rightarrow \pi^+\pi^-$, $\pi^+\pi^-\pi^0$, $\pi^0\gamma$, $\eta\gamma$ data.
Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our 'best' values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

\[
\chi^2
\]

(Confidence Level = 0.176)

\[
\Gamma(\pi^0\gamma)/\Gamma_{\text{total}} \times \Gamma(e^+e^-)/\Gamma_{\text{total}}
\]

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

\[
\Gamma_{10}/\Gamma \times \Gamma_9/\Gamma
\]

\[
\Gamma_7/\Gamma \times \Gamma_9/\Gamma
\]

\[
\Gamma_6/\Gamma \times \Gamma_9/\Gamma
\]

- 3.88 ± 0.14 OUR FIT
- 3.87 ± 0.15 OUR AVERAGE

\[
3.93 \pm 0.09 \text{ (Error scaled by 1.3)}
\]

- 4.04 ± 0.09 ± 0.19
- 3.75 ± 0.11 ± 0.29
- 3.67 ± 0.10 ± 0.27

- 4.29 ± 0.11

1 From the VMD model with the interfering \( \rho(770) \), \( \omega(782) \), \( \phi(1020) \) resonances, and an additional resonance describing the total contribution of the \( \rho(1450) \) and \( \omega(1420) \) states. Supersedes ACHASOV 00.

2 From the \( \pi^0 \rightarrow 2\gamma \) decay and using \( B(\pi^0 \rightarrow 2\gamma) = (98.798 \pm 0.032) \times 10^{-2} \).

3 A simultaneous fit of \( e^+ e^- \rightarrow \pi^+\pi^-, \pi^+\pi^-\pi^0, \pi^0\gamma, \eta\gamma \) data.

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

\[
\Gamma_{10}/\Gamma \times \Gamma_9/\Gamma
\]

\[
\Gamma_7/\Gamma \times \Gamma_9/\Gamma
\]

\[
\Gamma_6/\Gamma \times \Gamma_9/\Gamma
\]

- 8.5 ± 0.5
- 8.8 ± 0.9

- 8.36 ± 0.59 ± 0.37
- 9.9 ± 1.4 ± 0.9
- 14.4 ± 3.0
- 8.6 ± 5.9

1 Recalculated by the authors from the cross section in the peak.

2 Recalculated by us from the cross section in the peak.
Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our 'best' values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

\[
\gamma \left( \mu^+ \mu^- \right) / \Gamma_{\text{total}} \times \gamma \left( e^+ e^- \right) / \Gamma_{\text{total}}
\]

\[
\gamma \left( \pi^+ \pi^- \right) / \Gamma_{\text{total}} \times \gamma \left( e^+ e^- \right) / \Gamma_{\text{total}}
\]

\[
\gamma \left( \pi^+ \pi^- \right) / \Gamma_{\text{total}} \times \gamma \left( e^+ e^- \right) / \Gamma_{\text{total}}
\]

\[
\gamma \left( \pi^+ \pi^- \right) / \Gamma_{\text{total}} \times \gamma \left( e^+ e^- \right) / \Gamma_{\text{total}}
\]

\[
\gamma \left( \pi^+ \pi^- \right) / \Gamma_{\text{total}} \times \gamma \left( e^+ e^- \right) / \Gamma_{\text{total}}
\]

\[
\gamma \left( \pi^+ \pi^- \right) / \Gamma_{\text{total}} \times \gamma \left( e^+ e^- \right) / \Gamma_{\text{total}}
\]

\[
\gamma \left( \pi^+ \pi^- \right) / \Gamma_{\text{total}} \times \gamma \left( e^+ e^- \right) / \Gamma_{\text{total}}
\]
$$\Gamma(\pi^0\pi^0\gamma)/\Gamma_{\text{total}} \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$$

<table>
<thead>
<tr>
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<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
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<tbody>
<tr>
<td>3.34±0.17 OUR FIT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.33±0.04+0.19</td>
<td>1 AMBROSINO 07 KLOE</td>
<td>e^+e^- → π^0π^0γ</td>
<td></td>
</tr>
<tr>
<td>3.09−0.20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Calculated by the authors from the cross section at the peak.

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

<table>
<thead>
<tr>
<th>VALUE (units 10^{-9})</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2 ±0.8−0.7</td>
<td>3285</td>
<td>1 AKHMETSHIN 00e CMD2</td>
<td>e^+e^- → π^+π^-π^+π^-</td>
<td></td>
</tr>
</tbody>
</table>

1 Recalculated by the authors from the cross section in the peak.

### $\Phi(1020)$ BRANCHING RATIOS

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

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.492±0.005 OUR FIT</td>
<td></td>
<td></td>
<td>Error includes scale factor of 1.3.</td>
<td></td>
</tr>
<tr>
<td>0.493±0.010 OUR AVERAGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.492±0.012</td>
<td>2913</td>
<td>AKHMETSHIN 95 CMD2</td>
<td>e^+e^- → K^+K^-</td>
<td></td>
</tr>
<tr>
<td>0.44±0.05</td>
<td>321</td>
<td>KALBFLEISCH 76 HBC</td>
<td>2.18 K^−p → ΛK^+K^-</td>
<td></td>
</tr>
<tr>
<td>0.49±0.06</td>
<td>270</td>
<td>DEGROOT 74 HBC</td>
<td>4.2 K^−p → Λφ</td>
<td></td>
</tr>
<tr>
<td>0.540±0.034</td>
<td>565</td>
<td>BALAKIN 71 OSPK</td>
<td>e^+e^- → K^+K^-</td>
<td></td>
</tr>
<tr>
<td>0.48±0.04</td>
<td>252</td>
<td>LINDSEY 66 HBC</td>
<td>2.1–2.7 K^−p → ΛK^+K^-</td>
<td></td>
</tr>
</tbody>
</table>

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

| 0.493±0.003±0.007 | 1 AKHMETSHIN 11 CMD2 | 1.02 e^+e^- → K^+K^- |
| 0.476±0.017 | 100k | 2 ACHASOV 01e SND | e^+e^- → K^+K^−, K_S K_L, π^+π^-π^0 |

1 Combined analysis of the CMD-2 data on $\phi → K^+K^−, K_S^{0}K_L^{0}, π^+π^-π^0, \eta\gamma$ assuming that the sum of their branching fractions is 0.99741 ± 0.00007.

2 Using $B(\phi → e^+e^-) = (2.93 ± 0.14) \times 10^{-4}$.

$$\Gamma(K_S^{0}K_L^{0})/\Gamma_{\text{total}}$$

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.340±0.004 OUR FIT</td>
<td></td>
<td></td>
<td>Error includes scale factor of 1.3.</td>
<td></td>
</tr>
<tr>
<td>0.331±0.009 OUR AVERAGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.335±0.010</td>
<td>40644</td>
<td>AKHMETSHIN 95 CMD2</td>
<td>e^+e^- → K_S^{0}K_L^{0}</td>
<td></td>
</tr>
<tr>
<td>0.326±0.035</td>
<td>91</td>
<td>DOLINSKY 91 ND</td>
<td>e^+e^- → K_S^{0}K_L^{0}</td>
<td></td>
</tr>
<tr>
<td>0.310±0.024</td>
<td>84</td>
<td>DRUZHININ 84 ND</td>
<td>e^+e^- → K_S^{0}K_L^{0}</td>
<td></td>
</tr>
</tbody>
</table>

HTTP://PDG.LBL.GOV Page 11 Created: 8/2/2019 16:42
We do not use the following data for averages, fits, limits, etc. ● ● ●

<table>
<thead>
<tr>
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<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.336 ± 0.002 ± 0.006</td>
<td>1 AKHMETSHIN 11</td>
<td>CMD2</td>
<td>e(^+) e(^-) \rightarrow K_S^0 K_L^0</td>
<td></td>
</tr>
<tr>
<td>0.351 ± 0.013</td>
<td>500k</td>
<td>2 ACHASOV 01E</td>
<td>SND</td>
<td>e(^+) e(^-) \rightarrow K^+ K^-</td>
</tr>
<tr>
<td>0.27 ± 0.03</td>
<td>133</td>
<td>KALBFLEISCH 76</td>
<td>HBC</td>
<td>2.18 K^- p \rightarrow \Lambda K_L^0 K_S^0</td>
</tr>
<tr>
<td>0.257 ± 0.030</td>
<td>95</td>
<td>3 BALAKIN 71</td>
<td>OSPK</td>
<td>e(^+) e(^-) \rightarrow K_L^0 K_S^0</td>
</tr>
<tr>
<td>0.40 ± 0.04</td>
<td>167</td>
<td>LINDSEY 66</td>
<td>HBC</td>
<td>2.1–2.7 K^- p \rightarrow \Lambda K_L^0 K_S^0</td>
</tr>
</tbody>
</table>

1 Combined analysis of the CMD-2 data on \( \phi \rightarrow K^+ K^-\), \( K_S^0 K_L^0\), \( \pi^+ \pi^- \pi^0\), \( \eta \gamma \) assuming that the sum of their branching fractions is 0.99741 ± 0.00007.

2 Using \( B(\phi \rightarrow e^+ e^-) = (2.93 \pm 0.14) \times 10^{-4} \).

3 Balakin error increased by Paul.

\[ \Gamma(K_S^0 K_L^0)/\Gamma(K^+ K^-) = \frac{\Gamma_2}{\Gamma_1} \]

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
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<th>COMMENT</th>
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</thead>
<tbody>
<tr>
<td>0.690 ± 0.015 OUR FIT</td>
<td>Error includes scale factor of 1.3.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>0.740 ± 0.031 OUR AVERAGE</td>
<td>0.70 ± 0.06</td>
<td>2732</td>
<td>BUKIN 78C</td>
<td>OLYA</td>
</tr>
<tr>
<td>0.82 ± 0.08</td>
<td>4.2 K^- p \rightarrow \phi \text{hyperon}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.71 ± 0.05</td>
<td>10 K^- p \rightarrow K^+ K^- \Lambda</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.71 ± 0.08</td>
<td>3–4 K^- p \rightarrow \Lambda \phi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.89 ± 0.10</td>
<td>144</td>
<td>AGUILAR-... 72B</td>
<td>HBC</td>
<td>3.9, 4.6 K^- p</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
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<th>EVTS</th>
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<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.638 ± 0.022</td>
<td>2.3M</td>
<td>1 KOZYREV 18</td>
<td>CMD3</td>
<td>e(^+) e(^-) \rightarrow K_L^0 K_S^0</td>
</tr>
<tr>
<td>0.68 ± 0.03</td>
<td>2 AKHMETSHIN 95</td>
<td>CMD2</td>
<td>e(^+) e(^-) \rightarrow K_L^0 K_S^0, K^+ K^-</td>
<td></td>
</tr>
</tbody>
</table>

1 Theoretical analysis of BRAMON 00 taking into account phase-space difference, radiative corrections, isospin breaking, and the Sommerfeld-Gamow-Sakharov factor gives 0.630.

2 Theoretical analysis of BRAMON 00 taking into account phase-space difference, electromagnetic radiative corrections, as well as isospin breaking, predicts 0.62. FLOREZBAEZ 08 predicts 0.63 considering also structure-dependent radiative corrections. FISCHBACH 02 calculates additional corrections caused by the close threshold and predicts 0.68. See also BENAYOUN 01 and DUBYNISKIY 07. BENAYOUN 12 obtains 0.71 ± 0.01 in the HLS model.

\[ \Gamma(K_S^0 K_L^0)/\Gamma(K \bar{K}) = \frac{\Gamma_2}{(\Gamma_1+\Gamma_2)} \]

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.408 ± 0.005 OUR FIT</td>
<td>Error includes scale factor of 1.3.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.45 ± 0.04 OUR AVERAGE</td>
<td>0.44 ± 0.07</td>
<td>1 LONDON 66</td>
<td>HBC</td>
<td>2.24 K^- p \rightarrow \Lambda K \bar{K}</td>
</tr>
<tr>
<td>0.46 ± 0.07</td>
<td>52</td>
<td>BADIER 65B</td>
<td>HBC</td>
<td>3 K^- p</td>
</tr>
<tr>
<td>0.40 ± 0.10</td>
<td>34</td>
<td>SCHLEIN 63</td>
<td>HBC</td>
<td>1.95 K^- p \rightarrow \Lambda K \bar{K}</td>
</tr>
</tbody>
</table>

1 This is probably not affected by their controversial background subtraction; the value is from their numbers of \( K_1 K_2 \) vs \( K^+ K^- \) events.
\[
\frac{[\Gamma(\rho\pi) + \Gamma(\pi^+\pi^-\pi^0)]}{\Gamma(K^+K^-)} \quad \Gamma_3/\Gamma_1
\]

<table>
<thead>
<tr>
<th>VALUE</th>
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<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.310 ± 0.009 OUR FIT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\frac{[\Gamma(\rho\pi) + \Gamma(\pi^+\pi^-\pi^0)]}{\Gamma(K\bar{K})} \quad \Gamma_3/(\Gamma_1+\Gamma_2)
\]

<table>
<thead>
<tr>
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<th>EVTS</th>
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<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.183 ± 0.005 OUR FIT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\frac{[\Gamma(\rho\pi) + \Gamma(\pi^+\pi^-\pi^0)]}{\Gamma(K_L^0 K_S^0)} \quad \Gamma_3/\Gamma_2
\]

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.448 ± 0.011 OUR FIT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\frac{\Gamma(\pi^+\pi^-\pi^0)}{\Gamma_{\text{total}}} \quad \Gamma_5/\Gamma
\]

<table>
<thead>
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<tr>
<td>∼ 0.0087</td>
<td>1.98M</td>
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<tr>
<td>&lt; 0.0006</td>
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<td>&lt; 0.20</td>
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</tbody>
</table>

1 Combined analysis of the CMD-2 data on \( \phi \rightarrow K^+K^- \), \( K_L^0 K_S^0 \), \( \pi^+\pi^-\pi^0 \), \( \eta\gamma \) assuming that the sum of their branching fractions is \( 0.99741 \pm 0.00007 \).
2 Using \( B(\phi \rightarrow e^+e^-) = (2.93 \pm 0.14) \times 10^{-4} \).
3 Using \( B(\phi \rightarrow e^+e^-) = (2.99 \pm 0.08) \times 10^{-4} \).
4 Using \( \Gamma(\phi) = 4.1 \text{ MeV} \). If interference between the \( \rho\pi \) and \( 3\pi \) modes is neglected, the fraction of the \( \rho\pi \) is more than 80% at the 90% confidence level.

\( \Gamma_3/\Gamma \) includes scale factor of 1.2.

\( \Gamma_3/\Gamma_1 \) includes scale factor of 1.7.

\( \Gamma_5/\Gamma \) includes scale factor of 1.1.

---

Citation: M. Tanabashi et al. (Particle Data Group), Phys. Rev. D 98, 030001 (2018) and 2019 update

HTTP://PDG.LBL.GOV
### \( \Gamma(\eta\gamma) / \Gamma_{\text{total}} \)

<table>
<thead>
<tr>
<th>Value (units 10^{-3})</th>
<th>EVTS</th>
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<th>COMMENT</th>
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<tbody>
<tr>
<td>1.303 ± 0.025 OUR FIT</td>
<td>Error includes scale factor of 1.2.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.26 ± 0.04 OUR AVERAGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 1.26 ± 0.04 OUR AVERAGE
  - 1.26 ± 0.04 OUR AVERAGE
  - 1.26 ± 0.04 OUR AVERAGE

1.26 ± 0.04 OUR AVERAGE

### \( \Gamma_6 / \Gamma \)

<table>
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<td>1.31 ± 0.13 OUR AVERAGE</td>
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</table>

- 1.31 ± 0.13 OUR AVERAGE
  - 1.31 ± 0.13 OUR AVERAGE
  - 1.31 ± 0.13 OUR AVERAGE

1.31 ± 0.13 OUR AVERAGE

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

<table>
<thead>
<tr>
<th>Value (units 10^{-3})</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
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<tr>
<td>1.30 ± 0.05 OUR FIT</td>
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<td></td>
</tr>
<tr>
<td>1.31 ± 0.13 OUR AVERAGE</td>
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</tbody>
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- 1.31 ± 0.13 OUR AVERAGE
  - 1.31 ± 0.13 OUR AVERAGE
  - 1.31 ± 0.13 OUR AVERAGE

1.31 ± 0.13 OUR AVERAGE

### \( \Gamma_7 / \Gamma \)

<table>
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<tr>
<td>1.30 ± 0.05 OUR FIT</td>
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</tr>
<tr>
<td>1.31 ± 0.13 OUR AVERAGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 1.31 ± 0.13 OUR AVERAGE
  - 1.31 ± 0.13 OUR AVERAGE
  - 1.31 ± 0.13 OUR AVERAGE

1.31 ± 0.13 OUR AVERAGE

---

1. Using \( B(\phi \to e^+ e^-) = (2.99 \pm 0.08) \times 10^{-4} \) and \( B(\eta \to 3\pi^0) = (32.2 \pm 0.4) \times 10^{-2} \).
2. From \( 3\eta \to \pi^+ \pi^- \pi^0 \) decay mode of \( \eta \).
3. From \( 2\gamma \) decay mode of \( \eta \).
4. From \( 3\pi^0 \) decay mode of \( \eta \).
5. Combined analysis of the CMD-2 data on \( \phi \to K^+ K^- \), \( K^0_S K^0_L \), \( 3\eta \to \pi^+ \pi^- \pi^0 \), \( \eta \to \gamma \gamma \) assuming that the sum of their branching fractions is \( 0.99741 \pm 0.00007 \).
6. ACHASOV 07B reports \( [\Gamma(\phi(1020) \to \eta \gamma) / \Gamma_{\text{total}}] \times \left[ B(\phi(1020) \to e^+ e^-) \right] = (4.050 \pm 0.067 \pm 0.118) \times 10^{-6} \) which we divide by our best value \( B(\phi(1020) \to e^+ e^-) = (2.973 \pm 0.034) \times 10^{-4} \). Our first error is their experiment’s error and our second error is the systematic error from using our best value. Supersedes ACHASOV 00 and ACHASOV 06A.
7. Using \( B(\phi \to e^+ e^-) = (2.98 \pm 0.04) \times 10^{-4} \) and \( B(\eta \to \gamma \gamma) = 39.43 \pm 0.26% \).
8. Not independent of the corresponding \( \Gamma(e^+ e^-) / \Gamma_{\text{total}} \).
9. Using \( B(\phi \to e^+ e^-) = (2.99 \pm 0.08) \times 10^{-4} \) and \( B(\eta \to 3\pi^0) = (32.24 \pm 0.29) \times 10^{-2} \).
10. 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).
11. From the \( \eta \to 2\gamma \) decay and using \( B(\phi \to e^+ e^-) = (2.99 \pm 0.08) \times 10^{-4} \).
12. From \( 3\pi^0 \) decay mode of \( \eta \) and using \( B(\phi \to e^+ e^-) = (2.99 \pm 0.08) \times 10^{-4} \).
13. Reanalysis of DRUZHININ 84, DOLINSKY 89, and DOLINSKY 91 taking into account a triangle anomaly contribution.
\[ \Gamma(\eta\gamma)/\Gamma(\pi^0\gamma) \]
\[ \Gamma_6/\Gamma_7 \]

<table>
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<tr>
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<th>COMMENT</th>
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</thead>
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<tr>
<td>10.9 \pm 0.3 \pm 0.7 \pm 0.8</td>
<td>ACHASOV 00</td>
<td>SND</td>
<td>e^+ e^- \rightarrow \eta\gamma, \pi^0\gamma</td>
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</tbody>
</table>

\[ \Gamma(e^+ e^-)/\Gamma_{\text{total}} \]
\[ \Gamma_9/\Gamma \]

<table>
<thead>
<tr>
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<th>EVTS</th>
<th>DOCUMENT ID</th>
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<th>COMMENT</th>
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<tbody>
<tr>
<td>2.973 \pm 0.034</td>
<td>OUR FIT</td>
<td>Error includes scale factor of 1.3.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.98 \pm 0.07</td>
<td>OUR AVERAGE</td>
<td>Error includes scale factor of 1.1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.93 \pm 0.14</td>
<td>1900k</td>
<td>1 ACHASOV 01E</td>
<td>SND</td>
<td>e^+ e^- \rightarrow K^+ K^-</td>
</tr>
<tr>
<td>2.88 \pm 0.09</td>
<td>55600</td>
<td>AKHMETSHIN 95</td>
<td>CMD2</td>
<td>e^+ e^- \rightarrow \text{hadrons}</td>
</tr>
<tr>
<td>3.00 \pm 0.21</td>
<td>3681</td>
<td>BUKIN 78c</td>
<td>OLYA</td>
<td>e^+ e^- \rightarrow \text{hadrons}</td>
</tr>
<tr>
<td>3.10 \pm 0.14</td>
<td>681</td>
<td>PARROUR 76</td>
<td>OSPK</td>
<td>e^+ e^-</td>
</tr>
<tr>
<td>3.3 \pm 0.3</td>
<td>74</td>
<td>COSME 74</td>
<td>OSPK</td>
<td>e^+ e^- \rightarrow \text{hadrons}</td>
</tr>
<tr>
<td>2.81 \pm 0.25</td>
<td>681</td>
<td>BALAKIN 71</td>
<td>OSPK</td>
<td>e^+ e^- \rightarrow \text{hadrons}</td>
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<tr>
<td>3.50 \pm 0.27</td>
<td>CHATELUS 71</td>
<td>OSPK</td>
<td>e^+ e^-</td>
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</tbody>
</table>

1 From the combined fit assuming that the total \( \phi/(1020) \) production cross section is saturated by those of \( K^+ K^-, \ K_\Sigma K_L, \ \pi^+ \pi^- \pi^0 \), and \( \eta\gamma \) decays modes and using ACHASOV 00b for the \( \eta\gamma \) decay mode.

2 Using total width 4.2 MeV. They detect 3\pi mode and observe significant interference with \( \omega \) tail. This is accounted for in the result quoted above.

\[ \Gamma(\mu^+ \mu^-)/\Gamma_{\text{total}} \]
\[ \Gamma_{10}/\Gamma \]

<table>
<thead>
<tr>
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<th>DOCUMENT ID</th>
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<tr>
<td>2.86 \pm 0.19</td>
<td>OUR FIT</td>
<td>HAYES 71</td>
<td>CNTR</td>
</tr>
<tr>
<td>2.5 \pm 0.4</td>
<td>OUR AVERAGE</td>
<td>EARLES 70</td>
<td>CNTR</td>
</tr>
</tbody>
</table>

1 Using \( B(\phi \rightarrow e^+ e^-) \) from PDG 15. Supersedes ACHASOV 00.

2 Using \( B(\phi \rightarrow e^+ e^-) = (2.98 \pm 0.04) \times 10^{-4} \).

3 Not independent of the corresponding \( \Gamma(e^+ e^-) \times \Gamma(\pi^0\gamma)/\Gamma_{\text{total}} \).

4 From the \( \pi^0 \rightarrow 2\gamma \) decay and using \( B(\phi \rightarrow e^+ e^-) = (2.99 \pm 0.08) \times 10^{-4} \).

5 Reanalysis of DRUZHININ 84, DOLINSKY 89, and DOLINSKY 91 taking into account a triangle anomaly contribution.
We do not use the following data for averages, fits, limits, etc.

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

<table>
<thead>
<tr>
<th>VALUE (units (10^{-4}))</th>
<th>EVTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.08 (\pm 0.04) OUR AVERAGE</td>
<td></td>
</tr>
</tbody>
</table>

1.075\(\pm 0.007\) \(\pm 0.038\) 30k
1.19 \(\pm 0.19\) \(\pm 0.12\) 213
1.14 \(\pm 0.10\) \(\pm 0.06\) 355

1.13 \(\pm 0.14\) \(\pm 0.07\) 183
1.21 \(\pm 0.14\) \(\pm 0.09\) 130
1.04 \(\pm 0.20\) \(\pm 0.08\) 42
1.3 \(\pm 0.8\) \(\pm 0.6\) 7

1 Using \(B(\eta \rightarrow 3\pi^0) = (32.57 \pm 0.23\%) \) from PDG 12.
2 Using \(B(\eta \rightarrow \gamma \gamma) = (39.25 \pm 0.32\%)\), \(B(\phi \rightarrow \eta \gamma) = (1.26 \pm 0.06\%)\), and \(B(\phi \rightarrow e^+ e^-) = (3.00 \pm 0.06\%) \times 10^{-4}\).
3 The average of the branching ratios separately obtained from the \(\eta \rightarrow \gamma \gamma\), \(3\pi^0\), \(\pi^+ \pi^- \pi^0\) decays.
4 From \(\eta \rightarrow \gamma \gamma\) decays and using \(B(\eta \rightarrow \gamma \gamma) = (39.33 \pm 0.25) \times 10^{-2}\), \(B(\eta \rightarrow \pi^+ \pi^-) = (4.75 \pm 1.1) \times 10^{-2}\), and \(B(\phi \rightarrow \eta \gamma) = (1.297 \pm 0.033) \times 10^{-2}\).
5 From \(\eta \rightarrow 3\pi^0\) decays and using \(B(\pi^0 \rightarrow \gamma \gamma) = (98.798 \pm 0.033) \times 10^{-2}\), \(B(\eta \rightarrow 3\pi^0) = (32.24 \pm 0.29) \times 10^{-2}\), \(B(\eta \rightarrow \pi^+ \pi^- \gamma) = (4.75 \pm 0.11) \times 10^{-2}\), and \(B(\phi \rightarrow \eta \gamma) = (1.297 \pm 0.033) \times 10^{-2}\).
6 From \(\eta \rightarrow \pi^+ \pi^- \pi^0\) decays and using \(B(\pi^0 \rightarrow \gamma \gamma) = (98.798 \pm 0.033) \times 10^{-2}\), \(B(\pi^0 \rightarrow e^+ e^-) = (1.198 \pm 0.032) \times 10^{-2}\), \(B(\eta \rightarrow \pi^+ \pi^- \pi^0) = (23.0 \pm 0.4) \times 10^{-2}\), \(B(\phi \rightarrow \eta \gamma) = (1.297 \pm 0.033) \times 10^{-2}\).

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

<table>
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<tr>
<th>VALUE (units (10^{-4}))</th>
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<tbody>
<tr>
<td>0.71 (\pm 0.11) (\pm 0.09)</td>
<td></td>
</tr>
<tr>
<td>0.65 (\pm 0.38) (\pm 0.29)</td>
<td></td>
</tr>
<tr>
<td>2.01 (\pm 1.07) (\pm 0.84)</td>
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1 Using \(B(\phi \rightarrow e^+ e^-) = (2.99 \pm 0.08) \times 10^{-4}\).
### \( \Gamma(\omega\pi^0)/\Gamma_{\text{total}} \)

<table>
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<tbody>
<tr>
<td>( 4.7 \pm 0.5 ) OUR FIT</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| \( 5.2^{+1.3}_{-1.1} \)     | 1,2 AULCHENKO 00A SND | e\(^+\)e\(^-\) \rightarrow \pi^+\pi^-\gamma^0\pi^0 \)
| \( \bullet \bullet \bullet \) We do not use the following data for averages, fits, limits, etc. \( \bullet \bullet \bullet \) | | | |
| \( 4.4 \pm 0.6 \)            | 3 AMBROSINO 08G KLOE | e\(^+\)e\(^-\) \rightarrow \pi^+\pi^-2\gamma^0,2\pi^0\gamma \)
| \( \sim 5.4 \)               | 4 ACHASOV 00E SND | e\(^+\)e\(^-\) \rightarrow \pi^0\pi^0\gamma \)
| \( 5.5^{+1.6}_{-1.4} \pm 0.3 \) | 2,5 AULCHENKO 00A SND | e\(^+\)e\(^-\) \rightarrow \pi^+\pi^-\gamma^0\pi^0 \)
| \( 4.8^{+1.9}_{-1.7} \pm 0.8 \) | 4 ACHASOV 99 SND | e\(^+\)e\(^-\) \rightarrow \pi^+\pi^-\gamma^0\pi^0 \)

1 Using the 1996 and 1998 data.
2 (2.3 ± 0.3)% correction for other decay modes of the \( \omega(782) \) applied.
3 Not independent of the corresponding \( \Gamma(\omega\pi^0) \times \Gamma(e^+e^-)/\Gamma^2(\text{total}) \).
4 Using the 1996 data.
5 Using the 1998 data.

### \( \Gamma(\rho\pi)/\Gamma_{\text{total}} \)

<table>
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<th>CL%</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
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</thead>
</table>
| \( <0.12 \)                | 90  | 1 AKHMETSHIN 99B CMD2 | e\(^+\)e\(^-\) \rightarrow \pi^+\pi^-\gamma \)
| \( \bullet \bullet \bullet \) We do not use the following data for averages, fits, limits, etc. \( \bullet \bullet \bullet \) | | | |
| \( <7 \)                   | 90  | AKHMETSHIN 97C CMD2 | e\(^+\)e\(^-\) \rightarrow \pi^+\pi^-\gamma \)
| \( <200 \)                 | 84  | LINDSEY 66 HBC | 2.1–2.7 \( K^-p \rightarrow \Lambda\pi^+\pi^- \) neutrons |

1 Supersedes AKHMETSHIN 97c.

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

<table>
<thead>
<tr>
<th>VALUE (units ( 10^{-4} ))</th>
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<th>COMMENT</th>
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</thead>
</table>
| \( 0.41 \pm 0.12 \pm 0.04 \) | 30175 | 1 AKHMETSHIN 99B CMD2 | e\(^+\)e\(^-\) \rightarrow \pi^+\pi^-\gamma \)
| \( \bullet \bullet \bullet \) We do not use the following data for averages, fits, limits, etc. \( \bullet \bullet \bullet \) | | | |
| \( <0.3 \)                   | 90  | 2 AKHMETSHIN 97C CMD2 | e\(^+\)e\(^-\) \rightarrow \pi^+\pi^-\gamma \)
| \( <600 \)                  | 90  | KALBFLEISCH 75 HBC | 2.18 \( K^-p \rightarrow \Lambda\pi^+\pi^-\gamma \)
| \( <70 \)                   | 90  | COSME 74 OSPK | e\(^+\)e\(^-\) \rightarrow \pi^+\pi^-\gamma \)
| \( <400 \)                  | 90  | LINDSEY 65 HBC | 2.1–2.7 \( K^-p \rightarrow \Lambda\pi^+\pi^- \) neutrons |

1 For \( E_\gamma > 20 \text{ MeV} \) and assuming that \( B(\phi(1020) \rightarrow f_0(980)\gamma) \) is negligible. Supersedes AKHMETSHIN 97c.
2 For \( E_\gamma > 20 \text{ MeV} \) and assuming that \( B(\phi(1020) \rightarrow f_0(980)\gamma) \) is negligible.
\[ \Gamma (f_0 (980) \gamma) / \Gamma_{\text{total}} \]

<table>
<thead>
<tr>
<th>VALUE (units 10^{-4})</th>
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<tbody>
<tr>
<td>3.22 \pm 0.19 OUR FIT</td>
<td>3.21 \pm 0.19 OUR AVERAGE</td>
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<tr>
<td>3.21 \pm 0.03 \pm 0.18</td>
<td>2 AMBROSINO 07 KLOE e^+e^- \rightarrow \pi^0\pi^0\gamma</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2.90 \pm 0.21 \pm 1.54</td>
<td>2 AKHMETSHIN 99c CMD2 e^+e^- \rightarrow \pi^+\pi^-\gamma, \pi^0\pi^0\gamma</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

4.47 \pm 0.21 2438 3 ALOISIO 02o KLOE e^+e^- \rightarrow \pi^0\pi^0\gamma |
| 3.5 \pm 0.3 \pm 1.3 \pm 0.5 | 4, 5 ACHASOV 00h SND e^+e^- \rightarrow \pi^0\pi^0\gamma |
| 1.93 \pm 0.46 \pm 0.50 | 6 AKHMETSHIN 99b CMD2 e^+e^- \rightarrow \pi^+\pi^-\gamma |
| 3.05 \pm 0.25 \pm 0.72 | 7 AKHMETSHIN 99c CMD2 e^+e^- \rightarrow \pi^0\pi^0\gamma |
| 1.5 \pm 0.5 | 8 AKHMETSHIN 99c CMD2 e^+e^- \rightarrow \pi^0\pi^0\gamma |
| 3.42 \pm 0.30 \pm 0.36 | 4 ACHASOV 98i SND e^+e^- \rightarrow 5\gamma |
< 1 90 9 AKHMETSHIN 97c CMD2 e^+e^- \rightarrow \pi^+\pi^-\gamma |
< 7 90 10 AKHMETSHIN 97c CMD2 e^+e^- \rightarrow \pi^+\pi^-\gamma |
< 20 90 DRUZHININ 87 ND e^+e^- \rightarrow \pi^0\pi^0\gamma |

1 Obtained by the authors taking into account the \( \pi^+\pi^- \) decay mode. Includes a component due to \( \pi\pi \) production via the \( f_0 (500) \) meson. Supersedes ALOISIO 02d.
2 From the combined fit of the photon spectra in the reactions \( e^+e^- \rightarrow \pi^+\pi^-\gamma, \pi^0\pi^0\gamma \).
3 From the negative interference with the \( f_0 (500) \) meson of AITALA 01b using the ACHASOV 89 parameterization for the \( f_0 (980) \), a Breit-Wigner for the \( f_0 (500) \), and ACHASOV 01f for the \( \rho \pi \) contribution. Superseded by AMBROSINO 07.
4 Assuming that the \( \pi^0\pi^0\gamma \) final state is completely determined by the \( f_0 \gamma \) mechanism, neglecting the decay \( B(\phi \rightarrow K\bar{K}\gamma) \) and using \( B(f_0 \rightarrow \pi^+\pi^-) = 2B(f_0 \rightarrow \pi^0\pi^0) \).
5 Using the value \( B(\phi \rightarrow \eta\gamma) = (1.338 \pm 0.053) \times 10^{-2} \).
6 For \( E_\gamma > 20 \text{ MeV} \). Supersedes AKHMETSHIN 97c.
7 Neglecting other intermediate mechanisms \( (\rho\pi, \sigma\gamma) \).
8 A narrow pole fit taking into account \( f_0 (980) \) and \( f_0 (1200) \) intermediate mechanisms.
9 For destructive interference with the Bremsstrahlung process.
10 For constructive interference with the Bremsstrahlung process.

\[ \Gamma (f_0 (980) \gamma) / \Gamma (\eta\gamma) \]

<table>
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<tr>
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<th>COMMENT</th>
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<tr>
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<td>2.6 \pm 0.2 +0.8 \pm 0.3</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2.6 \pm 0.2 \pm 0.8</td>
<td>419 1 ACHASOV 00h SND e^+e^- \rightarrow \pi^0\pi^0\gamma</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Assuming that the \( \pi^0\pi^0\gamma \) final state is completely determined by the \( f_0 \gamma \) mechanism, neglecting the decay \( B(\phi \rightarrow K\bar{K}\gamma) \) and using \( B(f_0 \rightarrow \pi^+\pi^-) = 2B(f_0 \rightarrow \pi^0\pi^0) \).

\[ \Gamma (\pi^0\pi^0\gamma) / \Gamma_{\text{total}} \]

<table>
<thead>
<tr>
<th>VALUE (units 10^{-4})</th>
<th>CL%</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
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<tbody>
<tr>
<td>1.07 \pm 0.06 OUR AVERAGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.07 \pm 0.01 \pm 0.06</td>
<td>1 AMBROSINO 07 KLOE e^+e^- \rightarrow \pi^0\pi^0\gamma</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1.08 \pm 0.17 \pm 0.09</td>
<td>2 AKHMETSHIN 99c CMD2 e^+e^- \rightarrow \pi^0\pi^0\gamma</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

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

1.09 $\pm 0.03$ $\pm 0.05$ 2438 ALOISIO 02D KLOE $e^+e^- \to \pi^0\pi^0\gamma$
1.158$\pm 0.093$ $\pm 0.052$ 419 2,3 ACHASOV 00H SND $e^+e^- \to \pi^0\pi^0\gamma$
<10 90 DRUZHIIN 87 ND $e^+e^- \to 5\gamma$

1 Supersedes ALOISIO 02D.
2 Using the value $B(\phi \to \eta\gamma)=(1.338 \pm 0.053) \times 10^{-2}$.
3 Supersedes ACHASOV 98.

\[
\Gamma(\pi^0\pi^0\gamma)/\Gamma(\eta\gamma) = \Gamma_{18}/\Gamma_{6}
\]

\[
\begin{array}{lll}
\text{VALUE (units 10}^{-2}\text{) EVTS DOCUMENT ID TECN COMMENT} \\
0.86 $\pm 0.04$ OUR FIT \\
0.865$\pm 0.070$ $\pm 0.017$ 419 1 ACHASOV 00H SND $e^+e^- \to \pi^0\pi^0\gamma$
\end{array}
\]

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

0.90 $\pm 0.08$ $\pm 0.07$ 164 ACHASOV 98 SND $e^+e^- \to 5\gamma$

1 Supersedes ACHASOV 98.

\[
\Gamma(\pi^+\pi^-\pi^+\pi^-)/\Gamma_{\text{total}} = \Gamma_{19}/\Gamma
\]

\[
\begin{array}{llll}
\text{VALUE (units 10}^{-6}\text{) CL% EVTS DOCUMENT ID TECN COMMENT} \\
6.5 $\pm 2.7$ $\pm 1.6$ 6.8k 1 AKHMETSHIN 17 CMD3 $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$
3.93$\pm 1.74$ $\pm 2.14$ 3.3k AKHMETSHIN 00E CMD2 $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$
<870 90 CORDIER 79 WIRE $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$
\end{array}
\]

1 Using the cross section at the $\phi$ meson peak $\sigma(\phi) = 4172 \pm 42$ nb, the nonresonant cross section $\sigma(0) = 1.263 \pm 0.027$ nb and $Re(Z) = 0.146 \pm 0.030$, $Im(Z) = -0.002 \pm 0.024$ for the complex amplitude of the $\phi \to \pi^+\pi^-\pi^+\pi^-$ transition.

\[
\Gamma(\pi^+\pi^-\pi^0\pi^0)/\Gamma_{\text{total}} = \Gamma_{20}/\Gamma
\]

\[
\begin{array}{llll}
\text{VALUE (units 10}^{-6}\text{) CL% DOCUMENT ID TECN COMMENT} \\
<4.6 90 AKHMETSHIN 00E CMD2 $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$
<150 95 BARKOV 88 CMD $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$
\end{array}
\]

\[
\Gamma(\pi^0e^+e^-)/\Gamma_{\text{total}} = \Gamma_{21}/\Gamma
\]

\[
\begin{array}{llll}
\text{VALUE (units 10}^{-5}\text{) CL% EVTS DOCUMENT ID TECN COMMENT} \\
1.33$\pm 0.07$ $\pm 0.10$ OUR AVERAGE \\
1.35$\pm 0.05$ $\pm 0.05$ 9.5k 1 ANASTASI 16B KLOE $e^+e^- \to \pi^0e^+e^-$
1.01$\pm 0.28$ $\pm 0.29$ 52 2 ACHASOV 02D SND $e^+e^- \to \pi^0e^+e^-$
1.22$\pm 0.34$ $\pm 0.21$ 46 3 AKHMETSHIN 01C CMD2 $e^+e^- \to \pi^0e^+e^-$
\end{array}
\]

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

<12 90 DOLINSKY 88 ND $e^+e^- \to \pi^0e^+e^-$

1 Using $B(\pi^0 \to \gamma\gamma)$ from the 2014 Edition of this Review (PDG 14).
2 Using various branching ratios from the 2000 Edition of this Review (PDG 00).
3 Using $B(\pi^0 \to \gamma\gamma) = 0.98798 \pm 0.00032$, $B(\phi \to \eta\gamma) = (1.297 \pm 0.033) \times 10^{-2}$, and $B(\eta \to \pi^+\pi^-\gamma) = (4.75 \pm 0.11) \times 10^{-2}$.
\[ \frac{\Gamma(\pi^0 \eta \gamma)}{\Gamma_{\text{total}}} \]

<table>
<thead>
<tr>
<th>VALUE (units (10^{-5}))</th>
<th>CL%</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.06 ± 0.22</td>
<td></td>
<td></td>
<td>1 AMBROSINO 09F KLOE</td>
<td>1.02 e^+ e^- \rightarrow \eta \pi^0 \gamma</td>
<td></td>
</tr>
<tr>
<td>8.51 ± 0.51 ± 0.57</td>
<td></td>
<td>607</td>
<td>2 ALOISIO 02 C KLOE</td>
<td>e^+ e^- \rightarrow \eta \pi^0 \gamma</td>
<td></td>
</tr>
<tr>
<td>7.96 ± 0.60 ± 0.40</td>
<td></td>
<td>197</td>
<td>3 ALOISIO 02 C KLOE</td>
<td>e^+ e^- \rightarrow \eta \pi^0 \gamma</td>
<td></td>
</tr>
<tr>
<td>8.8 ± 1.4 ± 0.9</td>
<td></td>
<td>36</td>
<td>4 ACHASOV 00 F SND</td>
<td>e^+ e^- \rightarrow \eta \pi^0 \gamma</td>
<td></td>
</tr>
<tr>
<td>9.0 ± 2.4 ± 1.0</td>
<td></td>
<td>80</td>
<td>AKHMETSHIN 99 C CMD2</td>
<td>e^+ e^- \rightarrow \eta \pi^0 \gamma</td>
<td></td>
</tr>
<tr>
<td>7.01 ± 0.10 ± 0.20</td>
<td>13.3k</td>
<td></td>
<td>2,5 AMBROSINO 09F KLOE</td>
<td>1.02 e^+ e^- \rightarrow \eta \pi^0 \gamma</td>
<td></td>
</tr>
<tr>
<td>7.12 ± 0.13 ± 0.22</td>
<td>3.6k</td>
<td></td>
<td>3,6 AMBROSINO 09F KLOE</td>
<td>1.02 e^+ e^- \rightarrow \eta \pi^0 \gamma</td>
<td></td>
</tr>
<tr>
<td>8.3 ± 2.3 ± 1.2</td>
<td></td>
<td>20</td>
<td>ACHASOV 98 B SND</td>
<td>e^+ e^- \rightarrow 5 \gamma</td>
<td></td>
</tr>
<tr>
<td>&lt;250</td>
<td>90</td>
<td></td>
<td>DOLINSKY 91 ND</td>
<td>e^+ e^- \rightarrow \pi^0 \eta \gamma</td>
<td></td>
</tr>
</tbody>
</table>

1 Combined results of \(\eta \rightarrow \gamma \gamma\) and \(\eta \rightarrow \pi^+ \pi^- \pi^0\) decay modes measurements.
2 From the decay mode \(\eta \rightarrow \gamma \gamma\).
3 From the decay mode \(\eta \rightarrow \pi^+ \pi^- \pi^0\).
4 Supersedes ACHASOV 98B.
5 Using \(B(\phi \rightarrow \eta \gamma) = (1.304 \pm 0.025)\%, B(\eta \rightarrow 3 \pi^0) = (32.56 \pm 0.23)\%, and B(\eta \rightarrow \gamma \gamma) = (39.31 \pm 0.20)\%\).
6 Using \(B(\phi \rightarrow \eta \gamma) = (1.304 \pm 0.025)\%, B(\eta \rightarrow 3 \pi^0) = (32.56 \pm 0.23)\%, and B(\eta \rightarrow \pi^+ \pi^- \pi^0) = (22.73 \pm 0.28)\%\).

**WEIGHTED AVERAGE**

7.27 ± 0.30 (Error scaled by 1.5)

\[ \chi^2 \]

(Confidence Level = 0.108)

\[ \frac{\Gamma(\pi^0 \eta \gamma)}{\Gamma_{\text{total}}} \] (units \(10^{-5}\))
**\( \Gamma(a_0(980)\gamma)/\Gamma_{\text{total}} \)**

<table>
<thead>
<tr>
<th>VALUE (units 10^{-5})</th>
<th>CL%</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.6±0.6 OUR FIT</td>
<td></td>
<td></td>
<td>1 ALOISIO 02C KLOE</td>
<td>e^+ e^- → η(^0)γ</td>
<td></td>
</tr>
<tr>
<td>7.6±0.6 OUR AVERAGE</td>
<td></td>
<td></td>
<td>2 ACHASOV 00f SND</td>
<td>e^+ e^- → η(^0)γ</td>
<td></td>
</tr>
</tbody>
</table>

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

1 Using \( M_{a_0(980)} = 984.8 \) MeV and assuming \( a_0(980)\gamma \) dominance.
2 Assuming \( a_0(980)\gamma \) dominance in the \( η\(^0\)\) final state.
3 Using data of ACHASOV 00f.

**\( \Gamma(f_0(980)\gamma)/\Gamma(a_0(980)\gamma) \)**

<table>
<thead>
<tr>
<th>VALUE</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1±0.6</td>
<td>1 ALOISIO 02C KLOE</td>
<td>e^+ e^- → η(^0)γ</td>
<td></td>
</tr>
</tbody>
</table>

1 Using results of ALOISIO 02 and assuming that \( f_0(980) \) decays into \( π π \) only and \( a_0(980) \) into \( η \) only.

**\( \Gamma(K^0\overline{K}^0\gamma)/\Gamma_{\text{total}} \)**

<table>
<thead>
<tr>
<th>VALUE</th>
<th>CL%</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1.9 \times 10^{-8}</td>
<td>90</td>
<td>AMBROSINO 09c KLOE</td>
<td>e^+ e^- → (K^0\overline{K}^0)γ</td>
<td></td>
</tr>
</tbody>
</table>

**\( \Gamma(\eta'(958)\gamma)/\Gamma_{\text{total}} \)**

<table>
<thead>
<tr>
<th>VALUE (units 10^{-5})</th>
<th>CL%</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.22±0.21 OUR FIT</td>
<td></td>
<td></td>
<td>1 AMBROSINO 07a KLOE</td>
<td>1.02 e^+ e^- → ( π^+)( π^-)7γ</td>
<td></td>
</tr>
<tr>
<td>6.22±0.30 OUR AVERAGE</td>
<td></td>
<td></td>
<td>2 AULCHENKO 03b SND</td>
<td>e^+ e^- → ( η')γ</td>
<td></td>
</tr>
</tbody>
</table>

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

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

1 6.7 ±5.0 \( \pm 4.2 \) ±1.5 7 AULCHENKO 03b SND e^+ e^- → 7γ
2 6.10±0.61±0.43 120 3 ALOISIO 02e KLOE 1.02 e^+ e^- → \( π^+\)\( π^-\)3γ
3 8.2 ±2.1 \( \pm 1.9 \) ±1.1 21 4 AKHMETSHIN 00b CMD2 e^+ e^- → \( π^+\)\( π^-\)3γ
4 4.9 ±2.2 \( \pm 1.8 \) ±0.6 9 5 AKHMETSHIN 00f CMD2 e^+ e^- → \( π^+\)\( π^-\)\( π^+\)\( π^-\) ≥ 2γ
5 6.4 ±1.6 30 6 AKHMETSHIN 00f CMD2 e^+ e^- → \( η'(958)\)γ
\[ \frac{\Gamma(\eta'(958)\gamma)}{\Gamma(K_0^0 K_S^0)} = \frac{\Gamma_{25}}{\Gamma_2} \]

\[ \frac{\Gamma(\eta'(958)\gamma)}{\Gamma(\eta\gamma')} = \frac{\Gamma_{25}}{\Gamma_6} \]

\[ \frac{\Gamma(\eta^0\pi^0\gamma)}{\Gamma_{\text{total}}} = \frac{\Gamma_{26}}{\Gamma} \]

\[ \frac{\Gamma(\mu^+\mu^-\gamma)}{\Gamma_{\text{total}}} = \frac{\Gamma_{27}}{\Gamma} \]
\( \Gamma(\rho\gamma\gamma)/\Gamma_{\text{total}} \)

<table>
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<tr>
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<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1.2</td>
<td>90</td>
<td>AULCHENKO 08 CMD2</td>
<td>( \phi \rightarrow \pi^+\pi^-\gamma\gamma )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;5</td>
<td>90</td>
<td>AKHMETSHIN 98 CMD2</td>
<td>( e^+e^- \rightarrow \pi^+\pi^-\gamma\gamma )</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>VALUE (units 10^{-5})</th>
<th>CL%</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1.8</td>
<td>90</td>
<td>AKHMETSHIN 08e CMD2</td>
<td>( e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^-\pi^0 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 6.1</td>
<td>90</td>
<td>AULCHENKO 08 CMD2</td>
<td>( \phi \rightarrow \eta\pi^+\pi^- )</td>
<td></td>
</tr>
<tr>
<td>&lt;30</td>
<td>90</td>
<td>AKHMETSHIN 98 CMD2</td>
<td>( e^+e^- \rightarrow \pi^+\pi^-\gamma\gamma )</td>
<td></td>
</tr>
</tbody>
</table>

\( \Gamma(\eta\mu^+\mu^-)/\Gamma_{\text{total}} \)

<table>
<thead>
<tr>
<th>VALUE (units 10^{-6})</th>
<th>CL%</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
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<tbody>
<tr>
<td>&lt; 9.4</td>
<td>90</td>
<td>AKHMETSHIN 01 CMD2</td>
<td>( e^+e^- \rightarrow \eta\mu^+\mu^- )</td>
<td></td>
</tr>
</tbody>
</table>

\( \Gamma(\eta \rightarrow \eta e^+e^-)/\Gamma_{\text{total}} \)

<table>
<thead>
<tr>
<th>VALUE (units 10^{-6})</th>
<th>CL%</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1 \times 10^{-6}</td>
<td>90</td>
<td>BABUSCI 138 KLOE</td>
<td>1.02 ( e^+e^- \rightarrow \eta e^+e^- )</td>
<td></td>
</tr>
</tbody>
</table>

1 For a narrow vector \( U \) with mass between 5 and 470 MeV, from the combined analysis of \( \eta \rightarrow \pi^+\pi^-\pi^0 \) and \( \eta \rightarrow \pi^0\pi^0\pi^0 \) from ARCHILLI 12. Measured 90% CL limits as a function of \( m_U \) range from \( 2.2 \times 10^{-6} \) to \( 10^{-6} \).

\( \Gamma(\text{invisible})/\Gamma(K^+K^-) \)

<table>
<thead>
<tr>
<th>VALUE ( \times 10^{-4} )</th>
<th>CL%</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
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</thead>
<tbody>
<tr>
<td>&lt;3.4 \times 10^{-4}</td>
<td>90</td>
<td>ABLIKIM 18S BES3</td>
<td>( J/\psi \rightarrow \phi\eta \rightarrow \phi\pi^+\pi^-\pi^0 )</td>
<td></td>
</tr>
</tbody>
</table>

Lepton Family number (LF) violating modes

\( \Gamma(e^\pm\mu^\mp)/\Gamma_{\text{total}} \)

<table>
<thead>
<tr>
<th>VALUE (units 10^{-6})</th>
<th>CL%</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
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</thead>
<tbody>
<tr>
<td>&lt;2 \times 10^{-6}</td>
<td>90</td>
<td>ACHASOV 10A SND</td>
<td>( e^+e^- \rightarrow e^\pm\mu^\mp )</td>
<td></td>
</tr>
</tbody>
</table>

\( \pi^+\pi^-\pi^0 / \rho\pi \) AMPLITUDE RATIO \( a_1 \) IN DECAY OF \( \phi \rightarrow \pi^+\pi^-\pi^0 \)

NIECKNIG 12 describes final-state interactions between the three pions in a dispersive framework using data on the \( \pi\pi \) \( P \)-wave scattering phase shift.

<table>
<thead>
<tr>
<th>VALUE (units 10^{-2})</th>
<th>CL%</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
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</thead>
<tbody>
<tr>
<td>9.1 \pm 1.2 OUR AVERAGE</td>
<td></td>
<td>80k</td>
<td>AKHMETSHIN 06 CMD2</td>
<td>1.017–1.021 ( e^+e^- \rightarrow \pi^+\pi^-\pi^0 )</td>
<td></td>
</tr>
<tr>
<td>9.0 \pm 1.1 \pm 0.6</td>
<td>1.98M</td>
<td>2,3 ALOISO 03 KLOE</td>
<td>1.02 ( e^+e^- \rightarrow \pi^+\pi^-\pi^0 )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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PARAMETER \( \beta \) IN \( \phi \to P e^+ e^- \) DECAYS

In the one-pole approximation the electromagnetic transition form factor for \( \phi \to P e^+ e^- (P = \pi, \eta) \) is given as a function of the \( e^+ e^- \) invariant mass squared, \( q^2 \), by the expression:

\[
|F(q^2)|^2 = (1 - q^2/\Lambda^2)^{-2},
\]

where vector meson dominance predicts parameter \( \Lambda \approx 0.770 \text{ GeV} (\Lambda^{-2} \approx 1.687 \text{ GeV}^{-2}) \). The slope of this form factor, \( \beta = dF/dq^2(q^2=0) \), equals \( \Lambda^{-2} \) in this approximation.

The measurements below obtain \( \beta \) in the one-pole approximation.

**PARAMETER \( \beta \) IN \( \phi \to \pi^0 e^+ e^- \) DECAY**

<table>
<thead>
<tr>
<th>VALUE (GeV(^{-2}))</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 2.02 \pm 0.11 )</td>
<td>9.5k</td>
<td>1 ANASTASI 16B KLOE</td>
<td>1.02 ( e^+ e^- \to \pi^0 e^+ e^- )</td>
<td></td>
</tr>
</tbody>
</table>

1 The error combines statistical and systematic uncertainties.

**PARAMETER \( \beta \) IN \( \phi \to \eta e^+ e^- \) DECAY**

<table>
<thead>
<tr>
<th>VALUE (GeV(^{-2}))</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 1.29 \pm 0.13 \langle \text{OUR AVERAGE} \rangle )</td>
<td>30k</td>
<td>BABUSCI 15 KLOE</td>
<td>1.02 ( e^+ e^- \to \eta e^+ e^- )</td>
<td></td>
</tr>
<tr>
<td>( 3.8 \pm 1.8 )</td>
<td>213</td>
<td>1 ACHASOV 01B SND</td>
<td>1.02 ( e^+ e^- \to \eta e^+ e^- )</td>
<td></td>
</tr>
</tbody>
</table>

1 The uncertainty is statistical only. The systematic one is negligible, in comparison.

**\( \phi(1020) \) REFERENCES**

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Citation: M. Tanabashi et al. (Particle Data Group), Phys. Rev. D 98, 030001 (2018) and 2019 update