THE DECAY WIDTH $\Gamma(\eta \to \gamma\gamma)$

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In the measurements of $\Gamma(\eta \to \gamma\gamma)$ listed below, the results from two-photon production disagree with those from Primakoff production. Since the 1990 edition, one new two-photon measurement has been reported by MD-1; it is consistent with previous two-photon results, though the errors are somewhat larger. The weighted average of the two-photon measurements is 0.510 ± 0.026 keV, to be compared with the Primakoff-production measurement of BROWMAN 74B, 0.324 ± 0.046 keV.

In the two-photon measurements, η's are produced in the QED process $e^+e^- \to e^+e^-\gamma^*\gamma^* \to e^+e^-\eta$. The calculation of the rate is believed to be well understood. The uncertainty due to the virtual photon form factor is small; WILLIAMS 88 quotes an uncertainty of 0.2% from this source. Backgrounds to the η signal from beam-gas interactions and other two-photon interactions with missing particles are also small.

In the Primakoff experiments, η's are produced by the interaction of a real photon with a virtual photon in the Coulomb field of the nucleus. There is coherent background from strong production of η's in the nuclear hadronic field, and interference between the strong and Primakoff production amplitudes. The angular dependences of the Primakoff signal and the background are different, allowing $\Gamma(\eta \to \gamma\gamma)$ to be extracted from a fit to the angular distribution. In the best fit to their data, BEMPORAD 67 found the coherent hadronic background to be consistent with zero. BROWMAN 74B had a wider range of photon energies, a higher maximum energy, better angular resolution, and higher statistics. They found a significant contribution from the hadronic background, especially at lower energies. BROWMAN 74B also reanalyzed the data of BEMPORAD 67 and found that it was compatible with their fit, including background terms. This suggests that the background was underestimated by BEMPORAD 67, and we consider their result to be superseded by that of BROWMAN 74B.

There remains the disagreement between the two-photon results and the result of BROWMAN 74B. The errors assigned

by BROWMAN 74B include a 5.3% statistical error, a 12.2% systematic error for uncertainty in the accepted photon spectrum, and a 2.5% systematic error for uncertainty in the nuclear parameters used in the calculation of the Primakoff and nuclear form factors. The Primakoff form factor F_C is a function of the momentum transfer q and the production angle θ. As $q^2 \to 0$, the uncertainty in F_C due to the q^2 dependence vanishes. The minimum q^2 in this experiment ranged from -680 MeV^2 at the lowest energy to -174 MeV^2 at the highest. In this range, the result is sensitive to details in the calculation of F_C, but it is difficult to estimate the systematic error of this dependence. Another possible source of systematic error is in the phase of the interference term, ϕ. This was a free parameter in the fit, but was not well determined by the data because the interference contribution peaks in the same angular region as the Primakoff signal and so cannot be unambiguously separated by an angular fit. A reanalysis of the data would be necessary to determine whether any of these factors was overlooked in the determination of the systematic error.

Using the same apparatus, Browman *et al.* [1] measured $\Gamma(\pi^0 \to \gamma\gamma)$ to be 7.92 ± 0.42 eV, in good agreement with our world average of 7.7 ± 0.6 eV. (Our average includes the measurement of Browman *et al.*, but is dominated by a decay-length measurement by Atherton *et al.* [2] The error on the average involves a scale factor S=3.0 due to one outlying measurement.) However, the uncertainty due to F_C is reduced at lower momentum transfers, and q^2 was on the order of 100 times smaller in the π^0 measurement. The signal-to-background ratio is also larger, making the fit less sensitive to nuclear production.

A possible source of common systematic error in the two-photon experiments is the calculation of the two-photon luminosity function. However, WILLIAMS 88 measured the two-photon width of the π^0 as well as of the η, and their result, $7.7 \pm 0.5 \pm 0.5$ eV, is consistent with the world average quoted above.

To summarize, the two-photon measurements seem more reliable than the best Primakoff-production measurement. However, we include the latter in our average as there is no compelling reason to exclude it. The result, $\Gamma(\eta \to \gamma\gamma) = 0.46 \pm 0.04$ keV, is about one standard deviation from the average using only the two-photon measurements, 0.510 ± 0.026 keV, and the error is larger, due to the scale factor.

References

1. A. Browman *et al.*, Phys. Rev. Lett. **33**, 1400 (1974).
2. H.W. Atherton *et al.*, Phys. Lett. **158B**, 81 (1985).