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A NaI(Tl) Split Annulus for Coincidence, Anticoincidence, Triple
Coincidence, and Pair Spectrometry

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During the last three years we have been using an 8.8-in. NaI(Tl) split annulus more or less routinely as a counterpart to Ge(Li) detectors in various coincidence and anticoincidence configurations. Its most common use has been for Compton suppression (external, collimated source) and simple anticoincidence experiments (internal source), most often with the insertion of an additional 3.3-in. NaI(Tl) detector at the end of its tunnel opposite the Ge(Li) detector in order to reduce Compton edges further. In fact, we have found it advisable to perform such experiments at the very outset of study of a new decay scheme so as to pinpoint immediately any delayed transitions or primarily β -fed ground-state transitions. The split feature of the annulus has made it very useful for other, more exotic experiments as well. Among these have been triple coincidence experiments involving short-lived nuclides or weak transitions, made possible only because of the high efficiency of the annulus. It has also been used as part of an efficient pair spectrometer for obtaining β^+ feedings and/or double-escape spectra, and it has been used to enhance the background reduction of a "Compton" or "duode" spectrometer.² As examples of its use in coincidence and triple coincidence experiments are straightforward and already appear in the literature,^{1,3} here we concentrate on examples of experiments in anticoincidence and pair spectrometry which are selected to illustrate both the advantages and the pitfalls inherent in the use of such a system.

In fig. 1 we show singles and anticoincidence (internal source) spectra of γ -rays from the decay of 2.6-h Nd^{141} . In this decay⁴ a level

at 1126.8 keV in Pr^{140} is depopulated by the 1126.8-keV γ directly to the ground state and also by the 981.3-keV γ , which is in coincidence with the 145.4-keV γ . Arbitrarily setting the intensity of the 1126.8-keV γ to be 100 in both spectra, one finds that the 145.4-keV γ drops from 30.3 in the singles spectrum to 11.1 in the anticoincidence spectrum, while the 981.3-keV γ drops from 3.0 to 1.1. Yet the background, especially under the 981.3-keV γ , has dropped even further. This can be explained partly because the Compton distributions, especially toward the edges, stand a somewhat greater chance of being rejected than do the (presumably isotropic) photopeaks. Additionally, Compton distributions originating from γ -rays in cascade can be rejected also because of that fact, although the degree to which this aids in revealing weak peaks depends intimately on the decay scheme in question. The weak 981.3-keV γ , although in a cascade itself, rides on a much more intense Compton background, a considerable portion of which also results from cascades, so the net result is an enhancement of the γ -ray over the background.

Although one normally gets the best results in Compton suppression by using external, collimated sources, the foregoing shows that with internal sources one also finds enhancement of photopeaks, even those in cascades, over the background. (Also, the use of an internal source plus the additional 3x3-in. NaI(Tl) detector affords the better reduction of Compton *edges*, unless one can collimate the γ -rays from an external source through a 3x3-in. annulus.) This is most important when one is studying short-lived activities, which require many bombardments to accumulate spectra with good statistics. In such cases a single anticom-

cidence spectrum often can produce reasonable suppression and at the same time yields information about which transitions are in cascades. As an example of the latter, the enhancement in the anticoincidence spectrum of the 1126.8-keV γ (non cascade) over the 1147.1-keV γ (cascade) should be noted.

In fig. 2 we show an example of the use of the annulus as part of a pair spectrometer used to determine β^+ feedings from Bi^{205} to the 703.4- and 987.5-keV states in Pb^{205} . Any β^+ feeding from such a heavy nucleus is expected to be very weak, and determining it requires a very efficient counting system plus a long counting time. Using a relatively hot internal source, the spectrum in fig. 2 took 90 hours to collect. The Bi^{205} decay scheme, however, is very complex,⁵ so the analysis of this spectrum is not straightforward. First, it should be noted that it is not so clean as a usual pair spectrum. This comes about because the low-energy background is much stronger than either the higher-energy γ -rays that could produce pairs or the very weak β^+ feedings to the 703.4- and 987.5-keV states. In the Bi^{205} spectrum, in particular, there is a very strong, complex background underlying the weak 511-keV γ , so one has to correct for this by taking comparison spectra with the gate of one half of the annulus set on either side of the 511-keV peak. One also has to worry about summing of lower-energy γ -rays into and out of the 511-keV gate. For chance summing this can be compensated for by careful control of the source strength. Finally, because high-energy γ -rays that can produce pairs feed both the 703.4- and 987.5-keV levels, the full decay scheme has to be relatively well known and corrections must be made for the enhancement of the

of the 703.4- and 987.5-keV γ 's because of these feedings. After making all the corrections that are presently possible, we found that the β^+ feeding to the 703.4-keV state was 0.05% and that to the 987.5-keV state was approximately an order of magnitude smaller.

We wish to thank not only Dwight Beery and Ken Kosanke, whose results we quote, but also all the other students whose exploration and exploitation of the possibilities of the annulus have usually brought exciting, even exhilarating results.

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Figure Captions:

- Fig. 1 Singles and anticoincidence γ -ray spectrum from 2.6-h Nd^{141} .
The $\text{Ge}(\text{Li})$ detector was a 7-cm³ 5-sided coaxial detector manufactured at MSU. For the anticoincidence spectrum it was placed inside an 8x8-in. $\text{NaI}(\text{Tl})$ split annulus. The source was placed inside the annulus between the $\text{Ge}(\text{Li})$ detector and an additional 3x3-in. $\text{NaI}(\text{Tl})$ detector. These spectra were taken by D. B. Beery.
- Fig. 2 Pair spectrum from Bi^{205} showing the 703.4- and 987.5-keV γ 's resulting from weak β^+ feedings to these respective levels in Pb^{205} . This spectrum was taken by K. L. Kosanke.

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