Analysis of High-Multiplicity Gamma-Ray Events

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ABSTRACT

A significant improvement in the measured peak-to-background ratio of highly-correlated gamma-ray cascades can be achieved through the use of high-multiplicity gamma-ray coincident events. We studied this effect using data from the $^{176}\text{Yb}(^{22}\text{Ne}, 6n)^{192}\text{Hg}$ reaction at a beam energy of 122 MeV using HERA at the LBL 88-Inch cyclotron facility. An enriched set of all four- and higher-fold coincidences was culled from these data.

The use of high-multiplicity (i.e. four- and higher-fold) gamma-ray events provides unique opportunities to study nuclear structure. One of the primary advantages is that analysis of this type allows one to study highly correlated gamma-ray cascades without the necessity of background subtraction! This ability has already been exploited in earlier work¹.

The data presented here were collected following the bombardment of three, stacked ^{176}Yb foils (~ 450 , 450 , and $700 \mu\text{g}/\text{cm}^2$ thick) by a ^{22}Ne beam with an energy of 122 MeV. The gamma rays were measured using the High Energy-Resolution Array (HERA) located at the LBL 88-Inch Cyclotron facility. HERA was designed to optimize the detection of high-multiplicity events; it is composed of 21 Compton-suppressed germanium (CSGe) detectors and was augmented by a 4π "inner ball" of 40 bismuth germanate (BGO) detectors which were put in place just prior to this run. All events in which two CSGe detectors fired in coincidence with eight or more BGO detectors were recorded on tape as were all events where three or more CSGe detectors fired in coincidence. In this run ~ 600 million events were recorded, and ^{192}Hg made up $\sim 75\%$ of the total reaction cross section. From the data recorded on tape an enriched data set that contained all of the events in which four or more CSGe detectors fired in coincidence (~ 10.7 million such events) was created and stored on disk.

We created four spectra to study the effects of different gating conditions on the measured peak-to-background ratio of high multiplicity events. The first was a total projection of all the gamma-ray energies. We then generated a list of seventeen energy gates that correspond to known^{2,3} energies of the superdeformed band found in ^{192}Hg . This band was chosen as a candidate for study because it is highly correlated (being composed of 17 transitions) and is populated at only $\sim 2\%$ of the reaction channel's cross section

Figure 1: The ^{192}Hg superdeformed band, composed of 17 transitions at energies of 214.6, 257.7, 299.9, 341.1, 381.1, 420.8, 459.1, 496.2, 532.4, 567.9, 602.3, 635.8, 668.6, 700.6, 732.1, 762.8, and 793.4, are denoted in each of the spectra by the black triangles. The spectra show the same quadruples data sorted with different gating conditions. The spectra are a) a total projection of all the quadruples, b) a sum of all spectra coincident with at least one band member, c) a sum of all spectra coincident with two or more distinct band members, and d) a sum of all spectra coincident with three or more distinct band members. In spectrum d) all of the transitions that are not members of the superdeformed band are known⁴ low-lying states in ^{192}Hg that the superdeformed band depopulates through. The increase in the peak-to-background ratio can be best seen in the 496.2-keV transition (denoted by *) since it is a relatively "clean" peak.

(thus letting us check the sensitivity of the technique). In each of the three remaining sorts we increased by one the number of gamma rays in the quadruple that had to lie within distinct energy gates. In Figure 1 we show the spectra that resulted from these sorts.

In these spectra we can measure the changes in the peak-to-background ratio under different gating requirements. For the case of the 496.2-keV transition (see Table 1) the peak-to-background ratio improves by an average of 5.0 (6) for each increase in the number of gates set. This results in an overall improvement by a factor of ~ 125 from the total projection (where the superdeformed band can barely be seen) to the triple-gated spectrum (where the superdeformed band is the principle structure in the spectrum). Thus, even for weakly populated cascades, triple-gated quadruples sorting provides a means of studying their member transitions without the necessity of background subtraction.

Number of Gates	Peak-to-Background Ratio	Improvement Factor
0	0.0352 (2)	—
1	0.200 (2)	5.7 (3)
2	1.00 (4)	5.0 (2)
3	4.5 (9)	5 (2)

Table 1: The peak-to-background ratio for the 496.2 keV transition measured from sorts using differing number of gates. This transition was chosen since it is relatively "clean". The values are different for other members of the superdeformed band, but for all but the most "contaminated" transitions the improvement factor going from two to three gates is ~ 5 .

This work was supported in part by the NSF (Rutgers) and in part by the U.S. Department of Energy under contract numbers W-7405-ENG-48 (LLNL) and DE-AC03-76F00098 (LBL).

¹ M. J. Brinkman et al., "Workshop on the Interface Between Nuclear Structure and Heavy Ion Reaction Dynamics", Notre Dame, 1990.

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³ D. Ye et al., Phys. Rev. C **41** (1990) R13.

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