ARRAY OF ANTI-COMPTON SPECTROMETERS AS A TRIGGER IN GDR STUDIES *,**

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Preliminary results of experiments combining an array of large BaF_2 detectors for high energy gamma-rays with an array of 17 Anti-Compton spectrometers are presented. The correlation between excited state giant dipole resonances and discrete line structures are discussed. Indications of the low lying components of GDR built on superdeformed ^{143}Eu are shown.

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High energy γ-rays (10-30 MeV) from the decay of the Giant Dipole Resonance (GDR) are often used to investigate the properties of hot and

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rotating nuclei [1–4]. The coupling of the GDR to the quadrupole nuclear deformation strongly affects the GDR strength function and angular distribution which allows information on the change of the nuclear shape when the excitation energy and angular momentum of the nucleus are varied to be obtained. The recent availability of large arrays of high resolution spectrometers offers the possibility of their efficient coupling with detectors for high energy γ-rays. In this way one can select one particular decay channel, leading to a specific final nucleus, and under certain conditions enhance the GDR yield compared to the general background.

Here we report on preliminary results from recent experiments made at the Tandem Accelerator of the Niels Bohr Institute, Risø. Seventeen Compton suppressed HPGe detectors, a multiplicity filter (30 BaF_2 detectors with a total efficiency of about 35%) and eight large volume BaF_2 were employed.

Two experiments focussing on different problems were made. One experiment was devoted to enhancing the GDR signal over the low energy statistical gamma background that otherwise dominates the spectra at $E_\gamma \leq 8$ MeV. The idea [5] is based on the fact that a γ-ray from the GDR decay removes as much energy as one or two evaporated particles but does not change the nuclear mass number. Statistical γ-rays, appearing as an exponential slope in the spectra, originate from the entry region, *i.e.* after particle evaporation. Since the situation in which a high energy γ-ray from GDR decay replaces one neutron occurs very rarely ($\Gamma_\gamma/\Gamma_n \approx 10^{-3}$), the number of statistical γ-rays associated with GDR decay is much smaller than for the normal decay. In the usual experiments one measures the GDR spectra together with these statistical γ-rays, which constitutes a "background" for GDR studies. If one chooses the reaction such that there is only one dominant decay channel (for example *5n*), the gate on discrete transitions in the very weak *3n* evaporation channel (appearing by replacing 2 neutrons by a GDR γ-transition) will enhance the GDR cases out of the total high energy γ-ray spectrum.

The reaction used [6] was ^{164}Dy + 142 MeV ^{30}Si, leading to the ^{194}Hg compound nucleus. The ungated germanium spectrum is dominated by transitions in ^{190}Hg and in ^{189}Hg, *i.e.* in the *5n* and *4n* decay channels. The transitions from the *3n* channel, in ^{191}Hg, are very weak. Making use of the sum energy and multiplicity measured in the innerball, one can enhance either the *4n* or *5n* channel. The upper part of Fig. 1 shows the spectrum gated by low sum energy and low multiplicity, enhancing *5n* channel over the *4n*. The lower part of the figure shows the same spectrum, but additionally gated by the γ-rays from the GDR decay ($E_\gamma \geq 10$ MeV) measured in the BaF_2 detectors. One can clearly see how the transitions in ^{191}Hg (*3n*-decay channel) are enhanced by such a gate.

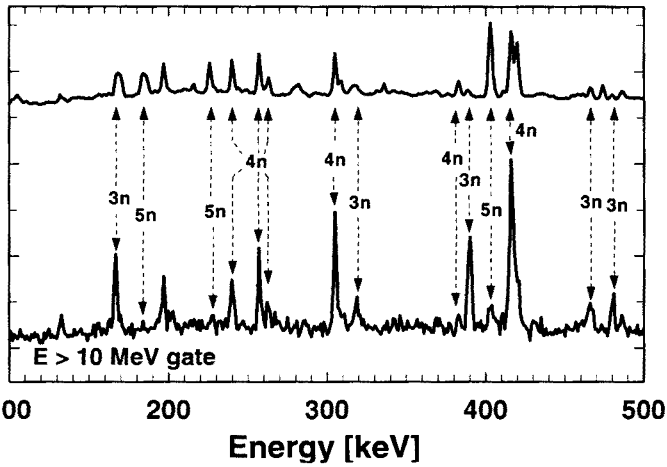

Fig. 1. Ge spectra from the ^{164}Dy+^{30}Si reaction in coincidence with low fold and low sum energy from the innerball, hence with enhanced *5n* channel over *4n* channel. The bottom spectrum is additionally gated by transitions from the GDR region ($E_\gamma \geq 10$ MeV).

Fig. 2 shows the high energy γ-ray spectrum gated by *3n* transitions, compared to the ungated spectrum. Indeed, the suppression of the statistical part of the spectrum is almost a factor of 10. It is evident that this technique could allow more accurate measurements of the low energy GDR component. This is important in general but essential for the identification of possible superdeformed shapes of hot nuclei and for a precise determination of the angular distribution of the low energy GDR tail. A more detailed analysis of the data, including statistical model analysis with a Monte Carlo version of the CASCADE code, is in progress.

The other experiment used the ^{110}Pd(^{37}Cl,*4n*) reactions at 160 and 170 MeV bombarding energy, forming the ^{147}Eu compound nucleus. Double germanium events in coincidence with high energy γ-rays in one of the BaF_2 detectors were collected. One of the goals of this experiment was to revisit the problem of the possible entrance channel effect: we have observed [7, 8] in previous experiments that the increase of the GDR yield in ^{162}Yb nucleus with the excitation energy seems to depend strongly on the entrance channel. By combining the difference technique [7] with the selection of the specific residua with NORDBALL we expected to obtain better normalization of the spectra from different reactions and a cleaner selection of the fusion channel. The strongest lines in the germanium spectra belonging to ^{144}Eu, ^{143}Eu and ^{142}Eu were used to select the corresponding *xn* channels. Additional conditions were put on fold from the multiplicity filter. Such spectra (background subtracted), summed over all three neutron decay

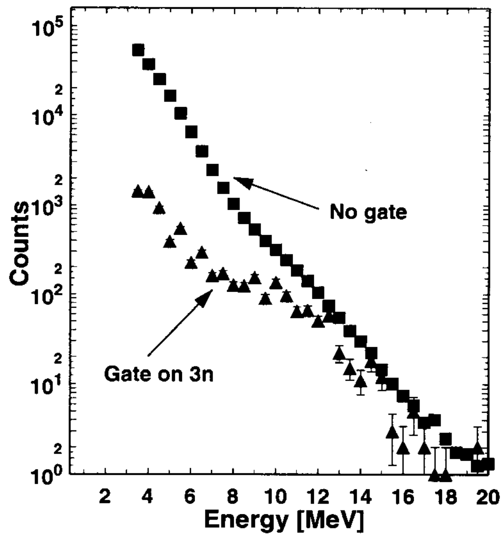

Fig. 2. High energy γ-ray spectra in the ^{164}Dy+^{30}Si reaction gated by high fold and high sum energy. The spectrum displayed by filled circles is gated by the discrete lines in ^{191}Hg (*3n* channel), whether as no gates was used for the spectrum displayed by filled triangles (normalized to the gated spectrum in the GDR region).

channels, are shown in the upper part of Fig. 3 for two different fold regions: 5–7 (corresponding to the angular momentum window 30$\pm$15$\hbar$) and 10-15 (48$\pm$10$\hbar$). The spectra were normalized to the same number of events in the gates. In the bottom part of the figure the corresponding relative differences between spectra taken at both bombarding energies are shown. In order to see the behavior of the GDR yield with the excitation energy and angular momentum, the relative difference of the integrated counts in the expected hot GDR region, namely above 11 MeV, is plotted in Fig 4. It is evident from the plot that the GDR yield predicted by statistical model calculations (dashed line) nicely reproduces the experimental data points obtained from total (not gated by particular discrete transitions) GDR spectra (circles). The triangles show the results when gated by the strongest lines in the *3n*, *4n* and *5n* channels. The data are very similar within the errors and in accordance with the standard CASCADE model predictions, as is in fact expected [9] for such an asymmetric reaction ($\Delta \approx 0.18$, $X_0 \approx 0.54$ of Fig. 5 in Ref. [9]). In addition the fact that the ungated results (corresponding to the experimental conditions used in the previous experiments without NORDBALL) are consistent with the gated results, gives more confidence on the conclusions of previous works.

It has recently been shown [10] that an intense continuum of states exists in the superdeformed well of ^{143}Eu, and that the decay from these

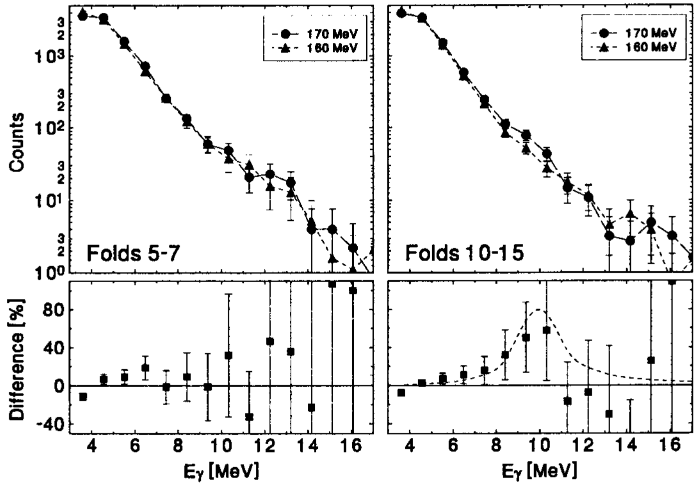

Fig. 3. GDR spectra from the ^{110}Pd + ^{37}Cl reactions at 160 and 170 MeV bombarding energy gated by *3n*, *4n* and *5n* lines and by two fold windows selecting low spin (left) and high spin (right). Below the relative difference of the spectra (S(170 MeV)/S(160 MeV)−1) is plotted. The dashed line corresponds to the prediction for the low energy component of the GDR built on superdeformed states [4, 11], with an arbitrary normalization.

states predominantly proceeds through the spherical states at lower spin. It is therefore natural to assume that GDR build on such superdeformed continuum states would decay through the same states. The superdeformed GDR will be split into mainly two components, one at ≈17.5 MeV (with a width of ≈5.5 MeV) and one at ≈10 MeV (width: ≈2.2 MeV) [4, 11]. Since the 10 MeV component is close to the binding energy of the last neutron of the cascade, and therefore not hindered strongly by the statistical factor in the GDR decay *e.g.* $\exp(-(E_{\mathrm{GDR}} - E_B)/T)$, as for the high component, it may be possible to observe the GDR transitions of the low component in the superdeformed well in coincidence with transitions in the spherical well, appearing much later in the cascade. We also know that at 160 MeV bombarding energy, the feeding of the superdeformed yrast states is most strong from the entry states near the SD yrast line. For there to be enough energy for a GDR transition as well, the bombarding energy must be higher by ≈ 9 MeV. With these considerations in mind it is interesting to inspect the results shown in Fig. 3 more carefully.

The relative difference for the highest spin window suggests the presence of an apparent peak located around 9.5 MeV for the bombarding energy of 170 MeV only. The possibility that this peak reflects the low energy component of the GDR build on superdeformed band in ^{143}Eu is quite likely. However, further analysis of the effect in the separate (xn) channels

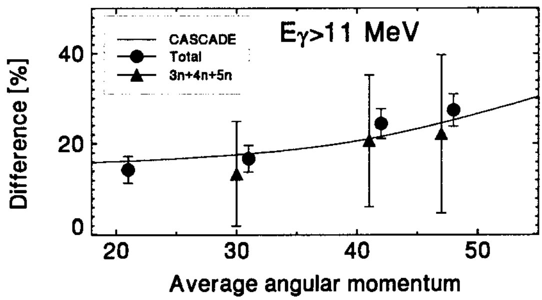

Fig. 4. The relative difference of the integrated yield in the γ-spectrum above 11 MeV as a function of angular momentum. The filled triangles correspond to the gated spectra by the *3n*, *4n* and *5n* channels. The filled circles are the results from the ungated spectra. The line corresponds to the theoretical difference from statistical model predictions.

is necessary before final conclusions can be drawn.

Summarizing, it has been shown that a large array of Anti-Compton spectrometers in connection with an array of high-energy γ-ray detectors can provide new interesting information about the structure of hot rotating nuclei. The first results discussed show that the GDR decay can be enhanced over the statistical background by almost a factor of 10, by applying specific gating conditions. The second results suggests that no entrance channel effects need to be assumed in describing the GDR decay by statistical calculations when asymmetric reactions as ^{37}Cl + ^{110}Pd are used. Finally a possible observation of the low lying component of GDR at 9.5 MeV built on superdeformed states in ^{143}Eu is advocated.

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