AGATA Performance I: Resolution

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INTRODUCTION

The Advanced GAmma Tracking Array (AGATA) [1, 2], recently installed at Legnaro National Laboratories (LNL), is an instrument for high-resolution γ spectroscopy and, therefore, good energy resolution is a fundamental aim of the instrument. During experiments, the HPGe detectors are exposed to a continuous flux of fast neutrons generated in deep inelastic collisions, fission and fusion-evaporation reactions. Fast neutrons are well known to produce specific lattice defects in germanium crystals, which act as efficient hole traps. This leads to a reduction in the charge collection efficiency of the detectors observable by low energy tailing on the energy line shape [3] worsening the energy resolution. In Fig. 1 the FHWM resolution at 1.3 MeV of an AGATA detector during the first months of experimental campaigns at LNL is shown.

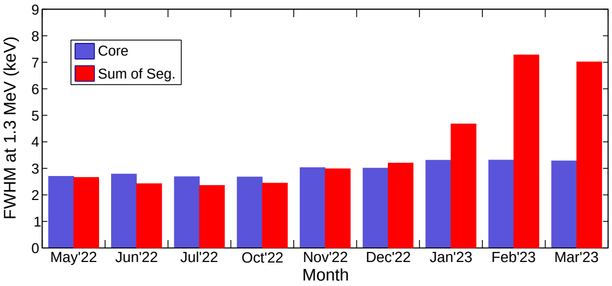

Fig. 1. FWHM resolution at 1.3 MeV for the encapsulated detector 00C since the beginning of the AGATA phase II campaign at LNL. The core energy resolution worsened from 2.6 keV to 3.2 kev, while the sum of segments deteriorated from 2.7 keV to 7 keV. Note: the measurements were performed by using 6μs of trapezoidal-filter risetime (May-Oct 2022 and Feb 2023) and 2.5μs of trapezoidal-filter risetime (Nov 2022-Mar 2023.

The worsening of the resolution is more evident after the fusion-fission reaction experiment performed in December 2022 followed by multi-nucleon transfer reaction experiments.

TRAPPING CORRECTION

Using the high position sensitivity of the AGATA detectors and assuming a distribution of the defects in the crystal is possible to apply a correction of the trapping effects. The description of the method can be found in Ref. [3]. The fraction of charge carriers lost in the collection process depends mainly on their travel path, the details of which can be easily obtained from the position of the interaction given by the Pulse Shape Analysis (PSA). The collection efficiency of the charge carriers is evaluated for each particular electrode and an interaction position in the detector. Using the position information given by the PSA and the detector-specific trapping sensitivity (based on collection efficiencies for electrons and holes) the energy deficit can be corrected. The effects of the neutron damage and its correction based on these principles are illustrated in Fig. 2 for a segment signal (top panel) and the core contact (bottom panel). As depicted in Fig. 1, the AGATA n-type HPGe detectors show that the segment signals are more sensitive to neutron-induced traps than the core electrode.

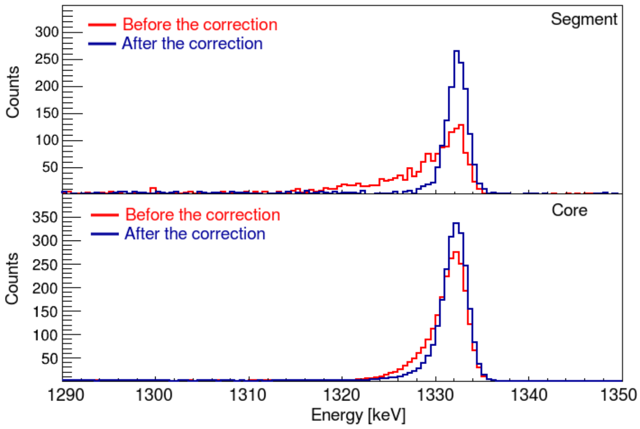

Fig. 2. Gamma-ray spectra of ATC 00C at 1.3 MeV for a segment signal (top) and the core contact (bottom) before (red) and after (blue) the correction of the neutron damage effects. The improvement of the energy resolutions goes from 5.8 to 3.0 keV of FWHM for the segment signal and from 3.3 to 2.7 keV of FWHM for the core contact.

RESOLUTION

Currently, AGATA is composed of 12 operational AGATA Triple Cluster (ATC) and the energy resolution has been evaluated for 34 encapsulated detectors. The clusters, the crystals and the positions of the AGATA arrangement currently at LNL are summarized in Table 1. Although the majority of them present trapping effects (see Fig. 3), the average FWHM of the energy sum of segments improved by around 60% becoming 3.1 keV. In the case of the cores, which are less sensitive to neutron-induced traps, the improvement of the average FWHM (2.5 keV) for the damaged detectors is about the 12%.

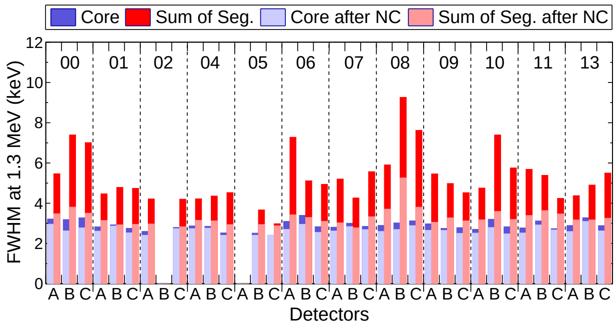

Fig. 3. Current FWHM resolution at 1.3 MeV for all the encapsulated detectors of the AGATA phase II campaign at LNL. 02B and 05A were excluded from the acquisition in this measurement. Note: The measurement was done with 6μs of trapezoidal-filter risetime.

Table 1. Crystal look up table for the 12 ATC present in the setup.

Cluster	Crystal A	Crystal B	Crystal C	Position Array
ATC12	A006	B005	C001	00
ATC10	A011	B006	C012	01
ATC17	A016	B017	C013	02
ATC11	A004	B004	C010	04
ATC9	A001	B001	C006	05
ATC6	A008	B009	C014	06
ATC14	A014	B010	C016	07
ATC3	A002	B007	C007	08
ATC18	A017	B018	C018	09
ATC15	A013	B015	C011	10
ATC1	A010	B011	C009	11
ATC19	A018	B012	C019	13

SUMMARY AND FUTURE WORK

The present contribution reported on the energy resolution during the first campaigns of the AGATA phase II at Laboratori Nazionali di Legnaro (LNL). The employment of the PSA minimized the trapping effects after the exposition to fast neutrons with the subsequent recovery of the resolution of the HPGe crystals. Nevertheless, the original energy resolution can be recovered up to a certain level due to statistical fluctuations caused by the trapping effects [3]. After this level, the crystals can recover from neutron damage only by annealing.

[1] S., Akkoyun et al., NIMA 668 (2012) 26–58.
[2] J.J. Valiente Dobón *et al.*, NIM A 1049 (2023) 168040.
[3] B. Bruyneel *et al.*, Eur. Phys. J. A (2013) 49: 61