Vol. 38 (2007) ACTA PHYSICA POLONICA B No 4

IN-BEAM TEST OF THE AGATA PROTOTYPE TRIPLE CLUSTER*

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(Received November 11, 2006)

The first in-beam test of the AGATA prototype triple cluster detector was carried out in the late summer 2005 at the Tandem laboratory of IKP Köln, Germany. A (d,p) reaction in inverse kinematics was performed, using a ^{48}Ti beam at an energy of 100 MeV, impinging on a deuterated titanium target. The preliminary results from the analysis of the experimental data, compared with the predictions of Monte Carlo simulations, give an estimation of the position sensitivity of these detectors of 6 mm FWHM for a 1382 keV γ-ray.

PACS numbers: 29.40.Gx, 07.85.Nc, 29.40.Wk, 29.40.–n

1. Introduction

The most powerful γ-arrays of the present generation, namely EUROBALL [1] and GAMMASPHERE [2], having a photopeak efficiency of the order of 10% and a peak-to-total ratio of the order of 50%, are composed of hundreds of High Purity Germanium crystals surrounded by anti-Compton shields. Their performances are insufficient for the future studies using radioactive beams, but on the other hand, it is not feasible to build an array with better performance based on the conventional technology. The next generation of arrays for in-beam γ-ray spectroscopy will be based instead on the novel concepts of pulse shape analysis (PSA) and γ-ray tracking. This implies identifying the energies and positions of the individual γ interactions within the germanium crystals (PSA) and following the scattering path of the incoming photons. In the past few years, two projects have been started

* Presented at the Zakopane Conference on Nuclear Physics, September 4–10, 2006, Zakopane, Poland.

with the goal of building such an array: AGATA in Europe and GRETA in the USA. In particular, AGATA will be built out of 180 detectors grouped into 60 triple clusters, while the configuration for GRETA will comprise 120 crystals grouped into 30 quadruple clusters.

The performance of a tracking array depends critically on the precision with which the PSA algorithms identify the individual interaction points: the Doppler correction capability and the efficiency of the tracking algorithm strongly depend on the obtainable position resolution. For this reason it was considered of fundamental importance to determine experimentally such value for the prototype cluster detector of AGATA, consisting of three 36-fold electrically segmented HP-Ge crystals [3].

2. The experiment

Any technique to measure the position resolution in a direct way implies determining the interaction points of the photons and comparing them with the corresponding values provided by the PSA algorithm. Although this is possible in principle, it is hardly feasible in practice since it relies on coincidence measurements and extremely tight collimated photon beams, resulting in very long measurement times to collect enough statistics.

In the recent past, the position resolution which can be obtained with PSA technique has been deduced from the Doppler correction capabilities of photons emitted in-flight following a nuclear reaction [4]. Since the Doppler broadening of the peaks depends both on the uncertainty of the photon direction and on the uncertainty of the vector velocity of the emitting nucleus, the position resolution can be evaluated, provided that the uncertainty of the source velocity is minimized, for instance by direct or indirect detection of the recoils.

The position resolution for the AGATA Triple Cluster prototype was measured in an in-beam experiment performed at IKP Köln using the inverse kinematic reaction $^{48}\mathrm{Ti}(d,p)^{49}\mathrm{Ti}$ at 100 MeV beam energy. A double-sided silicon strip detector (DSSSD) was used to determine the direction of the protons (hence of recoils) on an event-by-event basis. The AGATA detector was placed as close as possible to the target position (at about 10 cm) to emphasize the improvement in effective energy resolution when performing PSA.

The data acquisition system was based on GSI MBS. The germanium signals were digitized using XIA-DGF modules (14 bit, 40 MHz); these cards provide, together with the shape of the signals, also a digital measured value for the net charge deposited inside each segments. The silicon detector data were acquired using VME analog electronics.

The trigger required a charged particle to be detected in coincidence with the germanium detector(s).

3. Preliminary experimental results compared with simulation

The data were analyzed using the "Grid Search" PSA algorithm [5]. This method, using a χ^2 minimization between the recorded signal and the signals in a calculated basis, assumes at most a single interaction point per segment. The basis used, provided by the MGS [6] collaboration, consists in a database containing the response of the detector to single location γ-ray interactions on a cubic grid covering the full germanium crystal.

For this analysis the subset of the events with only one firing segment per detector was used. In Fig. 1 the results for the 1382 keV decay of ^{49}Ti are reported. The Doppler correction is performed assuming 3 different positions for the first γ interaction, namely the center of the detector (as usually done for non-segmented detectors), the center of the firing segment and the position of interaction given by PSA. The preliminary result for the energy resolution in the latter case is 5.5 keV.

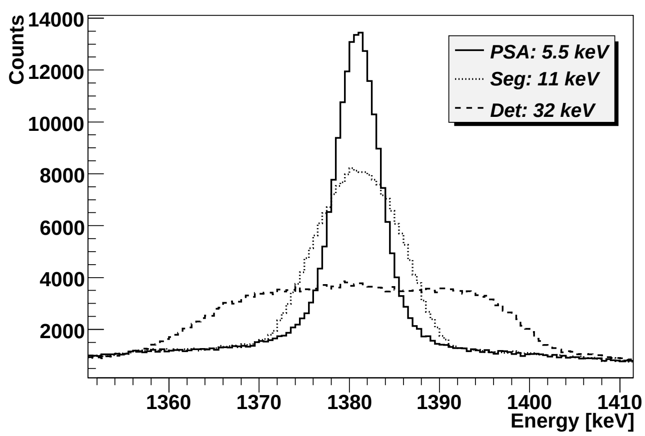

Fig. 1. Capability of Doppler correction of PSA: comparison between the energy resolution obtainable using as first interaction point the center of the detector, the center of the firing segment and the position given by PSA (3). These results are in agreement with simulation.

To estimate the straggling and the angular dispersion of the beam inside the target the Monte Carlo code SRIM [7] has been used. Using the same method the interaction of the emitted charged particles with the target and the absorbers have been taken into account. All these effects introduce uncertainty of the determination of the parameters used for Doppler correction and so contribute to the Doppler broadening. To evaluate the contributions to the Doppler broadening of all these sources of kinematic uncertainty a GEANT4 simulation [8] has been performed.

The experimental position resolution is extracted by comparison of the experimental peak FWHM and the simulated peak FWHM, calculated assuming different values of position resolution. As shown in Fig. 2, our experimental result of 5.5 keV corresponds to 6 mm of positional resolution at 1382 keV.

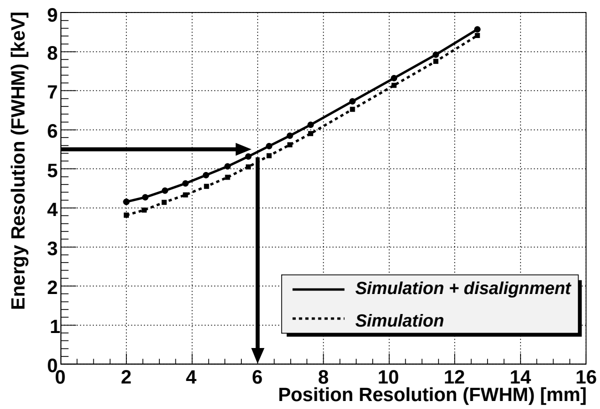

Fig. 2. Simulation of the FWHM dependence from the position resolution. The dotted line corresponds to the simulation results; the continuous line takes into account also the measured detector misalignment. The arrows correspond to the measured value.

4. Conclusion

Using PSA a good improvement in spectrum quality has been obtained and further analysis, still in progress, are giving even better results. The comparison with simulation gives an estimation for the reached position resolution of 6 mm FWHM for a 1382 keV γ-ray. This value is close to the 5 mm value expected for the final capability of the AGATA array and in agreement with previous results obtained for other segmented germanium detectors [4].

I would like to thank all the AGATA people, and in particular those from Cologne and GSI, who participated in the experiment. For this analysis I acknowledge the contributions of D. Bazzacco, E. Farnea, R. Venturelli and J. Ljungvall.

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