Installation of the AGATA Demonstrator and commissioning experiments at LNL

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Abstract. The first phase of the AGATA project, namely the AGATA Demonstrator Array, consists of a subset of 5 triple clusters of the final array and will be used to demonstrate the feasibility of the $\gamma$-ray tracking. The performance of the instrument has been estimated up to now only through Monte Carlo simulations and indirect measurements. The first installation is presently ongoing at the Laboratori Nazionali di Legnaro, Italy, where it has replaced the CLARA array at the target position of the PRISMA magnetic spectrometer. In the present contribution, the details of the installation will be reviewed and preliminary results from the first in-beam commissioning test will be given.

A new generation of $\gamma$-ray spectrometer has been developed, based on the $\gamma$-ray tracking concept. The performance foreseen for a full 4$\pi$ spectrometer exceeds the previous generation of escape-suppressed germanium arrays by 2-3 orders of magnitudes. Thanks to the position sensitivity obtained exploiting this technology it will be possible to obtain an unprecedented absolute efficiency approaching 50% while preserving the superb resolution of germanium detectors even in high recoil velocity ($\beta \approx 0.5$) Doppler corrected spectra. This performance is obtained through the use in real time of pulse shape analysis (PSA) and $\gamma$-ray tracking algorithms.

During the initial phase of the project, a subset of the array, composed of five triple clusters and known as the AGATA Demonstrator, will operate at the Laboratori Nazionali di Legnaro. The initial goal of the campaign at LNL is to prove that indeed PSA and $\gamma$-ray tracking can be successfully performed in real time. The validation of the $\gamma$-ray tracking at LNL will occur on the most demanding conditions achievable in a low-energy stable-beam facility, i.e. with reactions with velocities of the $\gamma$-emitting products up to $\beta \approx 10\%$ and relatively high intensity beams. Once this is achieved, the AGATA Demonstrator will be used in coupled operation with the PRISMA magnetic spectrometer [1] to perform spectroscopic studies of moderately neutron-rich nuclei populated by grazing reactions as multi-nucleon transfer or deep inelastic collisions with the stable beams delivered by the Tandem-ALPI and the PIAVE-ALPI accelerator complex. Nevertheless, the coupling of the AGATA Demonstrator with complementary detectors, other than PRISMA, opens experimental possibilities beyond the aforementioned reactions, with direct, Coulomb excitation as well as fusion-evaporation reactions.

The compact arrangement of five triple clusters of AGATA is the optimal geometry of the array for the experimental activity of the Demonstrator foreseen at LNL. The detectors will be placed in front of the PRISMA spectrometer input aperture, therefore distributing the active volume in the best positions regarding Doppler broadening, considering that the nuclei of interest
will be detected by PRISMA. The photopeak efficiency of the AGATA Demonstrator placed at the nominal 23.5 cm target-to-detector distance is roughly 3%. Given the low solid angle coverage, the Demonstrator can be also used at shorter target-to-detector distances, with an increase in photopeak efficiency (the value is approximately 7% when the detectors are moved by 10 cm closer to the target position) and without significant losses in the resolution and peak-to-total performance [2].

PRISMA is a large acceptance magnetic spectrometer designed to work with grazing reactions with the heavy ion beams provided by the LNL accelerator complex. The basic characteristics of PRISMA are described in ref. [1]. For the following discussion it is relevant to mention that PRISMA uses ion-tracking position-sensitive detectors to achieve the mass resolution. The tracking detectors provide the basic information to obtain the trajectory and velocity of the reaction products. According to the Monte Carlo simulations [3], up to velocities of approximately \( v/c = 10\% \), the intrinsic AGATA detector resolution is almost fully recovered if the recoil velocity module is measured with a relative precision better than 1%, and if the recoil velocity direction is measured with a precision better than 1°. These values are actually well within the possibilities of PRISMA.

As mentioned before, the AGATA Demonstrator at LNL is strongly constrained by the experimental campaign coupled to PRISMA. The different elements of the mechanics and infrastructures are such that the coupling and experimentation with both setups are possible. In the following, the different elements of the infrastructure will be described in more detail.

The setup is intended to measure coincidences between the \( \gamma \)-rays detected by the AGATA Demonstrator and the reaction products detected by PRISMA. The AGATA Demonstrator is installed on a mobile platform that will rotate together with PRISMA in such a way that reaction products, detected in the spectrometer focal plane in coincidence with the \( \gamma \)-rays, will have a forward trajectory with respect to the array in order to benefit from the lowest Doppler broadening. The detectors are hosted into a shell made out of 15 elementary AGATA flanges. The shell is positioned on a trolley which can slide on the same platform, rigidly linked to PRISMA. It is thus possible to easily modify the target-detector distance and to access the scattering chamber and to the instrumentation placed closed to the target. The whole support structure has minimal impact on the rotation of PRISMA. Taking into account the rest of the mechanical structure (beam line, scattering chamber), the angular range 41° to 110° is possible (with the Demonstrator placed at the closest distance from the target), while for the largest distance from the target the possible range is 37° to 110°. If one or more of the detectors are removed, PRISMA can be positioned at smaller angles, respectively 15° – 32° and 14° – 29°.

The sliding seal scattering chamber previously used with CLARA was replaced with a new lower absorption chamber. The final part of the beam line as well was replaced by a specially designed telescopic beam line.

The digitizers and the Detector Support System (autofill and power supplies) will be hosted in racks mounted on the same platform used previously for the front-end electronics and power supplies of CLARA, which is rigidly linked to the structure of PRISMA. The 75 m long optical fibres connecting the digitizers to the pre-processing electronics are taken through the basement up to the Pre-Processing racks sitting in the AGATA-PRISMA control room. The racks for the pre-processing electronics are water cooled and fully protected for thermal and acoustic noise insulation. The pre-processing racks are connected to the PSA computer farm, placed in the main computer room of the Tandem building, via 15 m long fibres. The disk storage for AGATA is instead placed in another building, at the location of the TIER-2 centre for the CMS and ALICE experiments, and is connected to the computing farm via optical fibres.
Following the installation of the required infrastructures, an in-beam commissioning test was performed early in 2009. Besides providing the opportunity to verify the correct functioning of the several parts composing the front-end electronics and data acquisition chain of the AGATA Demonstrator, the main goal of the experiment was to measure the overall position resolution provided by the pulse shape analysis algorithms currently implemented in the system.

As discussed thoroughly in [4], this parameter, which is critical in determining the overall performance of the array, can be determined with an in-beam measurement by comparing the effective energy resolution of the detectors (taking into account the proper Doppler correction) at several target-detector distances.

During this test, a beam of $^{30}$Si with an energy of 70 MeV was fired onto a $^{12}$C target, 200µg/cm$^2$ thick. The prompt $\gamma$ radiation was detected with the first AGATA asymmetric triple-cluster detector (ATC1), positioned as close as possible to 90° with respect to the beam direction. The detector was operated with a partial version of the AGATA Detector Support System, including the autofill system and the low-voltage power supply. The high-voltage was provided instead with a standard SY527 system by CAEN.

A full AGATA system was used to collect data to disk, including AGATA digitizers, Global Trigger and Synchronization, pre-processing electronics and a Narval system [5] running on several nodes. The DAQ chain was started using the Cracow GUI, communicating with the Narval system via a Run Control server. Dedicated Narval actors were performing pulse shape analysis and $\gamma$-ray tracking in real time. As this was the first time in which the full system was running, the original digitized signals were stored to disk for later replay. Because of this, the overall counting rate was limited to approximately 1.5 kHz per crystal, corresponding to approximately 1 GB/min per crystal.

Through a preliminary data analysis it was possible to spot and to correct for some inconsistencies in the cabling and in the positioning of the detector. The Doppler-corrected spectra for the 1823 keV line of $^{40}$K, namely the pn evaporation channel, are shown in Figure 1. Since no ancillary devices to measure the recoil vector velocity on an event-by-event basis were used, Doppler correction was performed by assuming an average recoil velocity. Using
Figure 2. Position resolution as a function of the energy of $\gamma$-ray. The comparison is performed separately for each gamma-ray detector and two estimations are given corresponding to different datasets collected.

As during previous measurements [4] the main part of the uncertainty on the estimate of the position resolution comes from the difficulty in taking into proper account within the simulation all of the sources of Doppler broadening, a different strategy has been followed here in order to extract the position resolution directly from the experimental data in a model-independent way. This was possible because the data were acquired with the detector in two positions, the former having the detector as close as possible to the target, and the latter having the detector placed farther from the target. Hence, in this experiment, the estimate of the position resolution is reduced to a comparison between the two datasets, since the difference in energy resolution between the Doppler-corrected spectra gathered in the two positions is due to the solid angle subtended by the PSA voxel, i.e. the angular spread on the initial direction of the photon corresponding to the position resolution. From the comparison of the various datasets acquired it is possible to obtain an estimation of the position resolution as a function of the $\gamma$-ray energy as depicted in Figure 2.

The estimation of the position resolution that was obtained from this test-beam experiment suggests that the performance is of the order of 4 - 4.5 mm for photons with an energy above MeV. According to Monte Carlo simulations, such value is adequate to reach the design performance of the AGATA array in terms of efficiency and Doppler correction capabilities.

References
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