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Organisation of the AGATA collaboration and physics campaigns

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Abstract The AGATA spectrometer has a well-established organisational and management structure for its construction and operation. The roles and responsibilities of each of the management committees and their interaction, as well as the scientific organisation is described in this contribution. The organisation of the present campaign, which aims to realise the 4π spectrometer, is presented. General comments on the previous physics campaigns at LNL (2010–2011), GSI (2012–2014) and GANIL (2015–2021) are made.

1 Introduction

The Advanced GAmma Tracking Array (AGATA) [1,2] is a European γ-ray spectrometer that is pushing the sensitivity of nuclear γ-ray spectroscopy to an unprecedented level [3]. Major breakthroughs in the fundamental understanding of the nuclear force will be achieved in the next decades by performing the high-resolution gamma-ray spectroscopy of very rare isotopes produced in heavy-ion reactions [4]. A similar project in the USA called GRETINA/GRETA is also being realised [5–9]. AGATA will operate at existing and next generation European heavy-ion facilities, such as at LNL, FAIR, GANIL, Jyväskylä (JYFL) and ISOLDE, which will deliver high-intensity stable and radioactive beams to reach the rarest events in exotic nuclei. Maintaining high performance and sensitivity in high activity environments while the numbers of detectors continues to increase is a technical challenge. AGATA is designed to be a 4π γ-ray tracking spectrometer consisting of 180 highly segmented HPGe detectors. AGATA is one of the most complex instruments in the European low energy nuclear community. It has continually increased in the number detectors and has operated science campaigns at different major facilities in Europe since 2010. Therefore, it has had to adapt to the different instrumentation, complementary detectors and local environments at each host facility. These complexities require a comprehensive and efficient management structure that encompasses the science, technology and financial aspects.

The AGATA collaboration is governed by a Memorandum of Understanding (MoU) that defines all these aspects including planning, funding, construction and operation. The MoU is signed by funding agencies or institutions in each country that provide the resources for the project. The first MoU, which concerned a research and development phase to realise the technical ingredients for γ-ray tracking, was signed in 2003 by 10 countries. Its first science campaign started in 2010 in LNL, Italy and an updated MoU was signed, again by 10 countries, to define both the realisation of a 60 detector system (1/3 4π) and scientific operation. This MoU finished at the end of 2021 and a new MoU was required for the next phase that is to realise the 4π 180 detector array. This was motivated by the need for a more sensitive instrument to answer the scientific questions that will be addressed with the new radioactive beam and high intensity stable beam facilities. This was highlighted in the 2017 NuPECC Long Range Plan for European nuclear physics [10] that supported the completion of the full geometry. This new MoU, started in 2021, and has been signed by 11 countries and involves 38 institutions. The aim of this phase of the project, as defined in the MoU, is to realise a 3π instrument in 10 years, and subsequently the 4π array.

The MoU specifies the management structure with the overall aim to maximise the scientific output at each facility. The management of AGATA, its committees and their interaction is described in this paper. In addition, general comments on the first series of physics campaigns at LNL (2010–2011), GSI (2012–2014) and GANIL (2015–2021)

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are given with a forward look to campaigns in this phase of the project.

2 The AGATA management structure

The management structure consists of four main committees, the AGATA Steering Committee (ASC), the AGATA Collaboration Council (ACC), the AGATA Resource Review Board (ARRB) and the AGATA Management Board (AMB). Figure 1 shows the management structure and the relationship between these committees.

The ASC acts on behalf of the parties who have signed the MoU that contribute to the resources, and is responsible for the overall coordination and science policy. It is the decision making body for the project and collaboration. Members of the ASC are nominated by the signatories of the MoU. Signatories that commit more than 10% of the total capital investment have two members, all other contributing parties for a country have one member. The ASC elects a chair who serves for two years. The ASC decides on the location and duration of each experimental campaign. The ASC appoints the AGATA Project Manager (PM), who is the chair of the AMB, and the members of the AMB. The PM reports to the ASC on technical achievements, financial status, progress, and any issues in the project.

The ACC represents all the institutions in the project as well as the scientific user community, in over 40 institutions in 13 European countries. The user community proposes, performs the experiments, analyses the collected data and publishes the scientific output. The role of the ACC is to advise the ASC on scientific matters. The ACC elects a chair who also serves as the AGATA Spokesperson. The ACC chair is invited to the ASC to report on scientific matters. The ACC is the science-driving body of the collaboration. A scientific campaign spokesperson is nominated by the ACC for each host laboratory. The campaign spokesperson acts as a link between the ACC, the local project manager and the host laboratory Director on scientific matters. The campaign spokesperson advises the Director of the host laboratory on the campaign, including experimental set-ups, and coordinates the proposal submissions of the collaboration.

The ARRB is composed of representatives of the funding agencies and institutions. It elects a chair who serves for two years. It is a direct link for AGATA with the resource providers of the project. The committee monitors the general financial status and human resources from the parties in the project.

The AMB is responsible for all technical aspects of the project and its realisation. The PM is appointed by the ASC and chairs the AMB. The PM defines the structure of the AMB by creating and dissolving working groups that have specific responsibilities for the delivery and operation of the

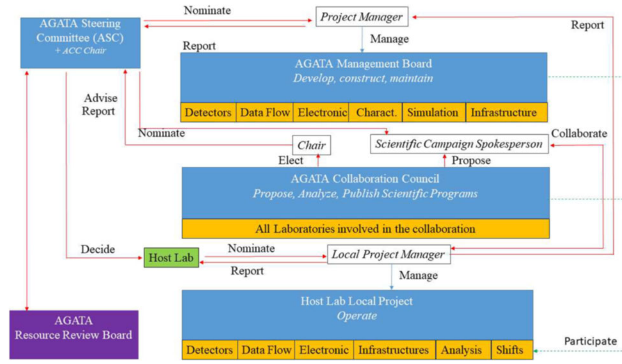

Fig. 1 The AGATA management structure

project. The PM proposes leaders of these working groups. The PM defines the structure of each working group in consultation with each working group leader. The PM is responsible for the management of the investment funds and operation costs. The PM, with the AMB members, prepares reports on the technical and financial status of the project that are reported to the ASC by the PM. The PM is responsible for the preparation and updates to the AGATA Project Definition that contains a description and planning of all technical and financial matters. The PM is assisted by a Resource Manager within the AMB who monitors the available funds provided by the signatories of the MoU and helps co-ordinate the budgetary planning. The host laboratory appoints a Local Project Manager (LPM) who is invited to the AMB. The LPM is responsible for the local resources for the installation and operation of the spectrometer. The LPM follows the host laboratory project framework and reports to the PM/AMB and host laboratory directorate. The LPM works closely with the local scientific campaign spokesperson.

3 Transfer between host laboratories

The AGATA array is designed for use at different host laboratories to maximise the breadth and quality of its scientific output. This enables a range of instrumentation, spectrometers and beams to be exploited. The LPM and the scientific campaign spokesperson organise each campaign. The LPMs from the previous and from next host laboratory coordinate the transfer between laboratories with the help of the teams in the AMB. The AGATA collaboration makes use of a database to track and identify all items in the project during the campaigns and, more importantly, during the transfer (see "AGATA: Mechanics and Infrastructures" article). The first in-beam commissioning was at LNL in 2009, and following the first science campaign it was transferred to GSI in January 2012 and then from GSI to GANIL in June 2014. The GSI commissioning was in the summer of 2012 and the GANIL commissioning was organised from October to December

2014. AGATA was transferred from GANIL to LNL for the present phase of the project in September 2021.

4 Phase 1 scientific campaigns (2010–2021)

During phase 1 of the project, in which the number of detectors increased to 60, AGATA was hosted at the LNL facility [11], GSI [12] and GANIL [13]. Each experimental campaign required 18 to 24 months of preparation of the local infrastructure at the host in a close collaboration between the host laboratory teams and the AMB working groups. At LNL, AGATA was coupled to the PRISMA magnetic spectrometer [14], to large volume scintillators [15], and to heavy-ions detectors such as DANTE and TRACE [11]. At GSI, AGATA was coupled to the FRagment Separator, the HECTOR array [16,17] and the LYCCA calorimeter [12,18,19]. At GANIL, AGATA was coupled to VAMOS++ [20], the large volume scintillator PARIS [21], the fast-timing array FATIMA [22,23], the neutron detectors NEDA [24], the charged particles array DIAMANT [25] and the MUGAST [26] and LEPS detectors. This demonstrates the large variety of experimental techniques and instrumentation, and the flexibility and integration capabilities of AGATA. The overall organisation of the campaigns also had to be in collaboration with many other complementary detector projects. This enabled a very broad physics programme to be addressed as described in reference [3]. Each scientific campaign was initiated by an open workshop organised by the LPM and the scientific campaign spokesperson during which all proposed experiments were presented. This workshop defined the main ideas of the campaign and hence possible sub-campaigns based on main experimental apparatus to be used. This was reported to the host laboratory management before an official call, with guidelines, for proposals to be submitted to the Programme Advisory Committee (PAC) was announced. The scientific campaign spokesperson and the LPM then organised pre-PAC workshops for all letters of intent (LoI) for individual experiments to be presented so that final proposals could be prepared that take into consideration local constraints (beams, ancillary detectors etc.) in discussion with the local management [27–30]. The initial open and pre-PAC workshops enabled experimental spokespersons to be given vital feedback from the host laboratory and the AGATA collaboration on the performance of AGATA itself and the complementary detectors. It also gave the opportunity for Spokespersons to combine proposals where the science objectives are similar. These workshops were to improve the quality of each proposal, maximise success at the competitive PAC's, and ensure that the best quality science experiments are performed. During the LNL pre-PAC workshop 20 LoIs were presented. The LNL campaign had 5 PAC meetings at which 46 proposals were submitted, and 20 experiments were successfully performed. During the GSI campaign 35 LoIs were discussed, 26 proposals were submitted and 4 experiments were performed. At the physics workshop for the GANIL campaign in 2013, 47 LoIs were presented with different configurations such as the use of VAMOS++ for heavy ion collisions at the Coulomb barrier, the coupling with the NEDA neutron array for fusion-evaporation residues, the use of SPIRAL1 radioactive beams with the MUGAST array and the development of a gas-filled mode for VAMOS++. In total, 8 PAC meetings were organised for the GANIL campaign for which 112 proposals in total were submitted, which highlights the high demand for using AGATA. Finally, 29 experiments were performed.

The ASC defines a policy for the submission of publications relating to AGATA. This includes physics publications, conference proceedings, technical papers and review articles. An AGATA physics publication is defined as a peer-reviewed article that is based on scientific results from an experiment (or experiments) performed. The first physics publication from an experiment may have, in addition to the collaborators in that experiment, authors from the wider project collaboration that are named on a core-author list for each of the campaigns. These lists are in recognition of the essential contribution of a person in a variety of ways to the success of the project and experiments. All persons on the list for the campaign are asked if they wish to be included as authors on the publication. The ASC with the chair of the ACC are responsible for controlling and updating the AGATA core author lists. Subsequent physics publications from the same experiment are not required to follow the core author list procedure.

Figure 2 shows the integrated number of published peer-review scientific papers (excluding conference proceeding) at each facility as a function of the years until 31/12/2022. The starting point is the first year of beam on target. The first publication occurred after 2–3 years from the start of a campaign and a maximum of production is reached after 5-6 years. This is illustrated in figure 3 showing the derivative of the number of publications as a function of time.

Due to the limited solid angle covered by AGATA during the first campaigns ($\leq 1\pi$), the detectors were placed either at backward (LNL and GANIL) or forward angles (GSI) with respect to the recoil direction to minimise the Doppler broadening after Doppler correction. This geometry is very sensitive to the Doppler effect, which is an ideal situation for measuring nuclear lifetimes. At GSI, an improved efficiency due to the Lorentz Boost [16] was also achieved. The combination of the unprecedented Doppler correction capabilities due to both the pulse shape analysis and tracking algorithms and the backward/forward solid angle coverage, made AGATA an excellent tool for lifetime measurements beyond the capabilities of existing arrays. This was the *niche* of the first series of experimental campaigns. More than 60% of the

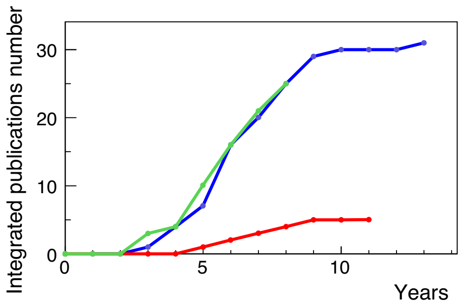

Fig. 2 Number of integrated AGATA science publications to 31/12/22 at LNL (blue), GSI (red), GANIL (green) as a function of the years after the start of the campaign

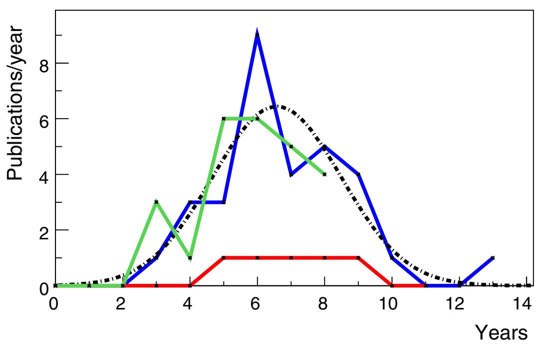

Fig. 3 Derivative of integrated AGATA science publications at LNL (blue), GSI (red), GANIL (green) as a function of the years after the start of the campaign. The black line is a Gaussian fit centred on 6.5 years

experiments at GANIL used a plunger device [31,32] or the DSAM technique to measure lifetimes from femto seconds to several pico seconds. A significant fraction of publications include a lifetime measurement.

The full statistics of peer-reviewed scientific and technical publications, conference proceedings, Bachelor, Diploma, Master's, Licentiate and PhD's theses are in reference [2]. The range of science papers cover topics at the forefront of nuclear structure and nuclear astrophysics with many in high impact journals.

5 AGATA phase 2 campaigns

The success of the overall science program, for example see [3], is based on the ability of AGATA to be operated at different facilities and hence broaden the breath of science that can be addressed. This phase of the project, as defined in the MoU, is to realise a 3π instrument in 10 years. When coupled to specific complementary detectors and spectrometers this configuration opens an exciting scientific programme. The MoU also defines the subsequent completion of the full 4π, 180 detector spectrometer. The science programme for this phase is detailed in Korten et al., [4]. AGATA is presently located at LNL. It will continue to exploit other facilities in campaigns, when the timing is optimum, to maximise the scientific potential of the instrument. The laboratories GSI/ FAIR, GANIL, CERN/ISOLDE and JYFL has expressed interest to host AGATA in this phase. The radioactive beam facilities are undergoing dramatic developments that will offer new beam opportunities, which AGATA will take advantage of. At LNL, measurements will utilise stable and radioactive beams at Coulomb barrier energies. In the first period of this campaign, experiments are profiting from newly developed stable heavy beams and a large range of complementary detectors. In the later period of this campaign, the new SPES facility will come online to provide radioactive beams. Neutron-rich fission fragments will be produced from a uranium (-carbide) target bombarded by a high-intensity 40 MeV proton beam. The nuclei of interest will be mass separated and re-accelerated using the existing accelerators. At the GSI site, the Facility for Antiproton and Ion Research (FAIR) is under construction. AGATA will take advantage of higher primary beam intensities from the new SIS-100 synchrotron and the improved transmission of fragmentation and fission products using the Super FRagment Separator (super-FRS) compared with the existing FRS. At GANIL, in addition to the high-intensity stable beams up to uranium, a range of radioactive beams will be available. These could be intermediate energy fragmentation beams at the LISE fragment separator or re-accelerated Coulomb energy beams of the SPIRAL1 ISOL facility. At ISOLDE, the HIE-ISOLDE post-accelerator provides a wide range of radioactive beams with energies between 4 and 10 MeV/u produced in spallation targets bombarded by 1.4 GeV protons. At JYFL, high-intensity stable beams, and the coupling to both vacuum mode and gas-filled recoil separators are available.

6 Conclusions

In this contribution, the management of the project that includes scientific, technical and financial aspects, is described. This well-organised structure has enabled AGATA to be very successful as evidenced by the impressive number scientific and technical publications and theses. AGATA has a significant impact on the scientific programme at each facility demonstrating very high interest of the nuclear physics community for this state-of-the-art instrument.

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