AGATA Risk Analysis

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Risk Analysis

1. Introduction

The present risks analysis focuses on the AGATA Phase 2 project. With the Project Manager, chairman of the AMB, the methodology is defined as:

Table for risk evaluation allowing to define the impact level on the project:

Level	**Impact**	**Consequence**		
		Cost	**Delay**	**Performances**
4	Critical	Cost increase by > 50 %	Delay increased by > 5 years	Thread on the scientific program
3	Major	between > 25% and < 50 %	Between > 2 years and < 5 years	Do not reach the minimum performances
2	Significant	between >10% et < 25 %	Between > 1 year and <2 years	Reach the minimum performances
1	Minor	Lower than < 10 %	Lower than 1 year	Without impact

The second table describes the probability of the risk:

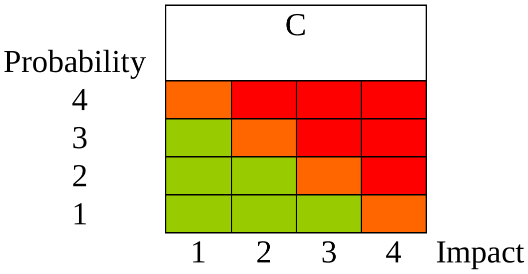
Level	**Probability**	**Criteria**
4	High	>80% chance
3	Possible	Between 50% and 80% chance
2	Low	Between 20% and 50% chance
1	Almost impossible	Less than 20% chance

The three types of criteria: cost, delay and performances are considered with equal importance in the analysis.

The criticality is equal to the product of the Impact and the Probability.

- C = P x I

The following matrix is used to define the criticality. Three levels are defined with low criticality (green index), medium criticality (orange index), and high criticality (red index).



Risk Analysis

After the identification of the risks and their evaluated criticality, for each of them, actions are proposed to minimize their impact on the project.

High criticality risks are "unacceptable" and actions are proposed to control and minimize them. Medium criticality risk are under survey.

2. Risk identification

The following risks have been identified:

i. The MIRION Technologies company is presently the only company worldwide which produces the high quality, high purity, segmented encapsulated Ge crystals. Such products are today ordered by the AGATA project in Europe. It is also the case of the encapsulated detectors of the GRETA project funded by U.S.A.

ii. The CTT company is presently the only company constructing the AGATA cryostats. It is a spin-off from the University zu Köln with one person. In the case of AGATA we have this unique provider CTT at the moment for the complex cryostat with cold FET for all segments, that requires enhanced cooling capabilities.

iii. The new LN2 autofill system doesn't fulfil the high reliability standard requested.

iv. Obsolete electronic component for production and maintenance in the FEBEE in a long term view. AGATA has built customized electronics since the Demonstrator phase. Along the time problems have appear due to the obsolescence and the difficulties to maintain customized electronics for long periods of time.

v. The newly SMART clock and trigger system does not fulfil the needed performances

vi. Long term vision of the availability of Engineers and Technicians on specific tasks which are the detectors and data acquisition activities because they require a long term involvement until 2030.

vii. Long term commitment on budget allocated by the partners. Funding Scheme and Project costs. The cost of the project is evaluated under a construction plan. The funding of the AGATA collaborators follows quite different schemes, from yearly budgets to plurennial grants. The failure to fund the expected number of items per year, especially detectors, has consequences for all the collaborators in terms of costs.

viii. The Tracking performances do not reach the expected standard. The Tracking procedures are key elements in the performance of the tracking arrays such as AGATA and GRETA. There have been continuous improvements on the AGATA procedures in the last decade. Nevertheless, to be able to perform the tracking in reasonable processing times, we resort to shortcuts like the so called "clusterization" procedure, i.e. try to extract the interaction point ahead from the tracking procedure.

ix. PSA capabilities do not improve. The PSA is a key component for the position sensitivity of the array and the tracking performance. Over the time the AGATA collaboration has improved the calculated signal data bases. An important role in this improvement has been the detector characterization facilities such as the scanning tables.
A failure on obtaining realistic signal data bases will prevent the array to reach the full performance figures. The capability to deconvolute several interaction points happening in a segment is as well necessary to reach full performance. In all cases the efforts on characterization are of paramount importance. Secondly, the PSA is presently the most CPU time consuming in the on-line processing and being presently the limiting factor.

x. A universal mechanical implementation is not achievable. The AGATA mechanics should allow the detectors to be positioned in the system with an accuracy of 500 microns. Being complex systems build in a flange honeycomb, the mechanical construction survey procedures became critical. Presently the AGATA collaboration is trying to build a universal mechanics to be compliant with most of the Host Laboratories where we expect to install the array. Other risk is the manipulation of the heavy and extreme sensitive ATCs which installation is a critical procedure that requires jigs and rotation of the honeycomb to facilitate the installation.

xi. The Data Flow system in AGATA is NARVAL/DCOD originally developed at IPNO and CSNSM by a collaborator that is not anymore in the institutions. While all indicates that the present software might be able to cope with the full AGATA Data Flow, it has been tested only in a reduced configuration <45 capsules ($< 1\pi$). Regarding the very high level of involved technology, possible problems could appear when enlarging the array and might require extra efforts.

xii. The performance of AGATA in certain aspects as angular distribution, angular correlations and linear polarization analysis, but also the quasi-continuum analysis require the construction of response functions of the tracking array that are not trivial and not yet produced. The tracking arrays, working as instruments for “complete” γ-ray spectroscopy, require the construction of the proper response functions for all the aforementioned experimental goals in a reproducible manner for any of the configurations of the array.

xiii. The Monte-Carlo simulations have been over the time key techniques to obtain expected performance of the array. AGATA has a functional code based on GEANT4, the AGATA Simulations Package, since the early stages of the project. The simulations, as detailed as they are, failed to reproduce accurately part of the experimental measured figures. The problem might be connected with the risk identified in the sense of knowledge of the single detector response.

3. Impact evaluation

i. The risk is **major** on the minimum performance by simply reducing the solid angle coverage by Ge detectors that impacts efficiency, P/T and all in all the resolving power of the array. The probability is **low** since the MIRION company is solid and collaborating with the nuclear community since decades. The risk impacts delay, cost and performances. Criticality is Orange.

ii. The risk is **major** on the minimum performance by simply reducing the solid angle coverage by Ge detectors that impacts efficiency, P/T and all in all the resolving power of the array. The probability is **possible** since the AGATA collaboration is the major customer of CTT. A significant decrease of annual funding to purchase cryostat is a major thread on the company. The cryostat technology is not unique to this company but they have developed an efficient cryostat that allows having cold pre-amplifier FETs for all channels. The risk impacts delay, cost and performances. Criticality is Red.

iii. The cryogenic system is the most critical part of the instrument. Any uncontrolled event could lead to serious damages to the detectors inducing significant budget and downtime for repair. The present but obsolete system was reliable. A similar high quality system is requested for the new version. The risk is **major** but probability is **almost impossible.** The risk impacts cost and performances. Criticality is Green.

iv. The risk is **significant** based on the past experience when electronic component becomes frequently and soon obsolete before completing the construction of the system. This requires new R&D and delays the production of needed channels. The probability is **high.** The risk impacts delay, cost and performances. Criticality is Red.

v. The risk is **critical** since the present GTS system is based on obsolete component and on a lack of human expertise, and barely scalable to the full array. The SMART system is proposed to replace the GTS system that handle clock distribution AND low level hardware trigger. The requested performances are high and compatibility with the complementary detectors of LNL, FAIR, HIE-ISOLDE, JYFL and GANIL is mandatory. The probability is **low**. The risk impacts delay and performances. Criticality is Red.

vi. The risk is **major** since the long term availability of technicians and engineers is difficult to secure with the number of projects under development in Europe. The probability is **possible.** The risk impacts the delays, cost and overall performances of AGATA. The risk impacts on delay and cost. Criticality is Red.

vii. The risk is **major** since long term commitments on allocated budget were already a difficult reality in the previous phase that delayed the project by 4 years. The probability is **possible**. The project is based on pluri-annual objectives and plans. Reduced annual funds induce delays that lead to increase of costs and breaking the discussed discounts with the industrial providers on the most expensive parts of the project (Germanium crystal and capsules, Cryostat). It increases the overall cost of the project inducing performances reduction and, finally, scientific output. Criticality is Red.

viii. The risk **significant**. Presently the performance in terms of efficiency of the individual crystal, the P/T and overall sensitivity of the system are understood as the minimum of performances. Phase 2 aims at overcome these uncertainties. Many advanced R&D are on-going with state-of-the art technologies in Detector scanning, simulation, IA and deep machine learning algorithm. The probability is **low**. The risk impacts performances. Criticality is Green.

ix. The risk is **significant** but probability is **low**. Improving the overall sensitivity pass by a better understanding of the response function of the detector in its position sensitive functionality. Improving this particular aspect will lead to an enhancement of the sensitivity and after all the science production. Regarding the processing performances, presently, the PSA CPU capability is the bottleneck of the on-line processing. Using multithreading approaches, the present limitation is 1 ms per event with 5 threads leading to 4kHz loss free events per crystal. The risk impacts performances. Criticality is Green.

x. The risk is **significant** and **possible**. Providing a universal mechanical structure for AGATA in all European host laboratory has been a challenge in the AGATA collaboration. Indeed, each specific mechanics increases the cost of the local project. With a larger array, this effort will increase. The risk impacts costs. Criticality is Orange.

xi. The risk is **major**. In case the system is not fully scalable in maintaining its performances, only part of the array could be used and not reaching the minimum performances. However, this risk is **almost impossible**. The risk impacts performances. Criticality is Green.

xii. The risk is **major** as the minimum performances need to be reached to complete the scientific project described in the AGATA White book. The probability is evaluated as **possible** since most of response function is known, the collaboration is expert in the field and efforts areinvolved. The risk impacts performances. Criticality is Orange.

xiii. The risk is **significant** and **possible**. Scientific results might rely on simulations. The collaboration is expert in the field and efforts involved. The risk impacts performances. Criticality is Green.

4. Discussion and proposed actions to minimize risks

i. The AGATA collaboration has started a **new collaboration** with the US Company ORTEC, well established in the HPGe crystal technology to evaluate the possible procurement of the needed segmented Germanium crystal. The company is very much interested on producing encapsulated segmented HPGe detectors and presently is producing a prototype of AGATA detector that should be ready before stating the procurement for AGATA Phase 2.
A home-made –European manufacture has been evaluated and was considered as riskier.

ii. The AGATA collaboration has **started discussion** with the MIRION Company in order to developed a dedicated cryostat for AGATA as backup option. This development will require R&D investment (time and budget) but is rather secured since the MIRION Company provide cryostats, with less performances on the cold electronic part, to the GRETA collaboration. The collaboration has also taken the initiative to search actively for a **third provider**.

iii. The CEA-Saclay institute is in charge of the system, as for the previous one, and maintains a very high level of development, reliability and an industrial approach for tests and maintenance.

iv. In order to minimize the risk, the AGATA collaboration will use more **conventional** (Ethernet protocols) technologies for data readout and the use of **Commercial-Off-The-Shelf (COTS) System on Modules (SoM) boards** for the front-end electronic developments. Additionally, a close collaboration with the **ARRB** will help in placing large orders at the proper time to secure the component procurement. The implantation of the Phase 2 electronics, with the Ethernet data dispatching, is necessary to improve the performance of the array in terms of processing capabilities. Delays in the production of hardware and/or firmware will have consequences on the performance of the array. For Phase 2, we have reduced to the minimum possible the customized parts of the electronics and used new technologies like the COTS SoM with long guarantied production terms (at least 10 years). The R&D activity on the AGATA Phase 2 electronics **has been anticipated to late Phase 1**

v. In order to minimize the risk, a **careful R&D process is proposed with intermediate milestones to test, validate and construct** the different elements. **Periodic reviews** of the SMART project are foreseen. Similarly, to the front-end electronic the use of Commercial-Off-The-Shelf (COTS) System on Modules (SoM) boards is proposed. Additionally, SMART is a system developed by GANIL to be used in a number of detector arrays in addition to AGATA giving more security to the development. The change from the GTS to SMART will overlap the decommissioning of the Phase 1 electronics in 2024-2025. Prototypes are currently developed and first modules can be produced for test in early 2021. Particular care is taken on providing a system able to couple with complementary detectors from the foreseen host-laboratory. **A dedicated team is set** in the FEBEE WG consisting of experts and well experienced personson the subject.

vi. The present MoU and project definition aim at precisely define and quantify the human resources needed. **The role of the ASC and ARRB is crucial to consolidate the available human resources**. Clear commitments must be taken in the ARRB.

vii. The present MoU and project definition aim at precisely define and quantify the human resources needed. **The role of the ASC and ARRB is crucial to consolidate the available human resources.** Clear commitments must be taken in the ARRB. In addition, the collaboration is constantly looking for national grants in R&D to contribute on top of the MoU contribution.

viii. **Significant resource thanks to national grants and closer collaboration with the GRETA project** gave a boost in the recent years on the subject. Actions to improve the tracking procedure are ongoing, from including errors in the positions obtained from PSA, more realistic probability calculations and the use of Machine Learning algorithms are being evaluated.

ix. Two actions are being carried out to prevent the risk, first a **large collaborative effort** (also in synergy with the GRETA collaboration) to shed light on the problem of getting realistic calculated signals. The second action is related to **novel approaches** with the possibility to use Machine Learning algorithms to obtain the maximum from the data using experimental training information. The development of the DCOD data flow management is the root for future developments in real time processing. The use of the Ethernet protocol in phase 2 will allow a much more distributed architecture using high performance computing nodes. Additionally, significant efforts in neural network and machine learning using GPU architecture give promising results. A significant reduction of the GPU time is already seen.

x. A clear commitment for phase 2 is to have a mechanical structure more host-site independent. A new approach, inspired by the GRETA design, is proposed. Already, close collaboration with all potential host laboratories is on-going to anticipate the array implementation. **Frequent review and discussions are foreseen.** The team leading the mechanical design is part of the collaboration since the beginning and is well experienced.

xi. The transfer of the know-how has been done and an obvious learning curve is on-going. In addition, recent restructuration at the university of Paris-Saclay lead to an **increase of the critical mass** of available engineers able to participate into the development.

xii. Both AGATA and GRETA **collaborations** have joined efforts to find the optimal way to obtain the response functions for the tracking arrays and pin-out the critical aspects of the procedures. One difficult aspect will be the availability of dedicated beam times for such tests at accelerator where the competition for access to the beam is already high. Precise and elaborated plans for such key measurements are foreseen by the Performances and Simulation WG.

xiii. **Effort are in place.** Similarly, to the other aspects of the response function, an AGATA-GRETA collaboration is on-going to tackle the problem. Progress will be done in concert with the other progresses in PSA and Tracking. Finally, for phase 2, a closer involvement of the Commissioning and Simulation WG with all in-beam data taking is proposed.

5. Conclusions

5 red risks have been identified in detectors, front end electronic and available human and budget resources. Actions are proposed to minimize these risks. 3 orange risks in detectors, performances and mechanics have been identified. Specific attention will be organized on these risks. Finally, 5 green risks have been highlighted in detectors, infrastructure, algorithms and data flow aspects.