ISTITUTO NAZIONALE DI FISICA NUCLEARE

CONSIGLIO DIRETTIVO

DELIBERAZIONE n. 16564

Oggetto: Memorandum of Understanding FAZIA – Forward A and Z Identification Array – Mature Exploitation Phase.

Il Consiglio Direttivo dell'Istituto Nazionale di Fisica Nucleare, riunito a Roma in data 24 febbraio 2023 alla presenza di n. 34 suoi componenti su un totale di n. 34:

Premesso che

- l'Istituto, in collaborazione con numerosi partner stranieri, partecipa dal 2011 con numerose Sezioni e Laboratori alle attività sperimentali per la realizzazione del rivelatore FAZIA (Four π A and Z Identification Array), un apparato per la misura di reazioni nucleari con fasci radioattivi nell'ambito dei progetti SPIRAL2 e SPES;

- sulla base dei risultati ottenuti, la Collaborazione FAZIA ha successivamente rinnovato l'Accordo per il periodo 2018-2022 con lo scopo di completare la costruzione di un multi-rivelatore costituito da 12 moduli da accoppiare ad altri dispositivi esistenti (INDRA) e avviare una campagna sperimentale presso il laboratorio francese GANIL;

- la Collaborazione internazionale intende per i prossimi anni continuare a sfruttare l'attuale apparato in funzione a GANIL, garantire l'avvio dei primi esperimenti presso la facility RAON in Corea e portare avanti ulteriori esperimenti con fasci di ioni radioattivi presso altri laboratori;

- l'Istituto è chiamato in questa fase a fornire il suo contributo per la realizzazione di dispositivi, attrezzature, per attività di manutenzione dell'elettronica e dei rivelatori nonché per l'installazione e avvio di attività sperimentali in Corea;

Richiamati

- l'art. 2, commi 1 e 3 dello Statuto vigente;

- la deliberazione n. 11926 del 30 giugno 2011

- la deliberazione n. 14804 del 28 giugno 2018

Accertato che

- l'importo a finanziare le attività previste dal MoU di cui alla presente deliberazione è determinato in complessivi 220.000,00 Euro per il periodo 2023-2027;

- con nota del 18 febbraio u.s., il Presidente di Commissione Scientifica Nazionale III, Dr. R. Nania, ha espresso parere favorevole;

- con nota del 20 febbraio u.s., il Direttore della Sezione di Firenze, Prof. O. Adriani, ha formalizzato la proposta di approvazione dell'Accordo;

- con nota del 20 novembre u.s., è stata trasmessa la relazione di attività propedeutica al rinnovo in osservanza della circolare su "Rinnovo Accordi di collaborazione scientifica con Istituzioni straniere e Organizzazioni Internazionali" del 12 luglio 2016, prot. AOO_SRI-2016-0000037;

Considerato opportuno procedere al rinnovo dell'Accordo attraverso la conclusione di uno specifico MoU per la fase di utilizzo avanzato del rivelatore;

Esaminato lo schema di "Memorandum of Understanding FAZIA – Forward A and Z Identification Array – Mature Exploitation Phase", allegato alla presente deliberazione e di essa facente parte integrante e sostanziale;

su proposta della Giunta Esecutiva;

con n. 34 voti favorevoli

DELIBERA

1. Di approvare lo schema di "Memorandum of Understanding FAZIA – Forward A and Z Identification Array – Mature Exploitation Phase", allegato alla presente deliberazione e di essa facente parte integrante e sostanziale.

2. Di autorizzare il Presidente a perfezionarlo e a sottoscriverlo.

3. Di imputare gli oneri finanziari derivanti dall'attuazione dell'Accordo di cui al precedente punto 1), pari a complessivi 220.000,00 Euro per il periodo 2023-2027 sulle assegnazioni che saranno rese annualmente disponibili nei rispettivi capitoli dei bilanci di competenza dalla Commissione Scientifica Nazionale 3 per l'iniziativa NUCL-EX.

Titolario	SRI - Accordi di Collaborazione scientifica/MoU		
Data GE		**Data CD**	24 febbraio 2022
Componente di Giunta competente	Marco Pallavicini		
Persona Referente	Veronica Buccheri		
Struttura Proponenente	Sezione di Firenze		
Direzione AC che ha curato l'istruttoria	Servizio Relazioni Internazionali		
Tipologia di Atto (breve descrizione)	MoU. La Collaborazione FAZIA intende per i prossimi anni continuare a sfruttare l'attuale apparato in funzione a GANIL, garantire l'avvio dei primi esperimenti presso la facility RAON in Corea e portare avanti ulteriori esperimenti con fasci di ioni radioattivi presso altri laboratori		
costo complessivo			
copertura finanziaria anno	**progetto**	**capitolo di spesa**	**importo**
2023-2027	NUCL-EX	CSN 3	€ 220.000,00
Allegato 1	Memorandum of Understanding FAZIA – Forward A and Z Identification Array – Mature Exploitation Phase		
Allegato 2			
Allegato 3			
Note o riferimenti Atti precedenti	del n. 11926 del 30 giugno 2011 del n. 14804 del 28 giugno 2018		

FAZIA

Forward A and **Z I**dentification **A**rray

Mature Exploitation Phase

Memorandum of Understanding

2023-2027

Preamble

FAZIA is now an international collaboration aimed at operating a charged particle identification array. The FAZIA collaboration started many years ago, first as a R&D group in an attempt to improve significantly the identification capabilities and techniques of charged particles produced in heavy ion collisions. Today it is an international research group aiming to operate and maintain a large modular detector in various nuclear accelerator facilities worldwide. The FAZIA array will allow detecting a large set of identification parameters (A and Z, E, Θ & φ) of reaction products over the largest dynamical range and with low energy identification thresholds. This permits to investigate the characterization of the equation of state of nuclear matter up to its first phase transition and its behaviour as a function of the isospin degree of freedom. Moreover, advanced spectroscopic studies will be performed in collisions between relatively light nuclei, as all detected charged ejecta will be fully identified. The collaboration is now focused on experiments at GANIL where the FAZIA telescopes are used at the forward angles while the rest of the solid angle is covered by the INDRA multidetector, recently upgraded. In any case the group is open to joint activities and collaborations towards the use of detector arrays for several facilities in the near future.

FAZIA is designed in such a way that it is easily movable; it can be reconfigured and coupled to other apparatuses in order to permit a very rich scientific program exploiting various stable and radioactive beams, with the complementary campaigns at several research facilities: GANIL/SPIRAL/LISE in Caen, LNS/Fraise in Catania, LNL/ALPI/SPES in Legnaro and RAON in South Korea.

The different previous phases have consisted of:

- The phase I of the FAZIA project (2002-2010) has been devoted to the R&D which included detectors, identification technics, electronics, acquisition system and has been supported in the framework of FP7 SPIRAL2PP Project (grant agreement n°212692).
- The phase II (2011-2014), whose object was the realization of the demonstrator (few modules of the final FAZIA multi detector) for tests under beam at LNS Catania Italy, to verify the capabilities in real final conditions. This phase initiated with the first FAZIA MoU, which was extended up to 2017.
- The phase III (2015-2018) which concerned the commissioning step including experiences at LNS Catania in configurations for real physics. This phase included four experiments devoted to investigate different topics (namely ISOFAZIA (2015), FAZIASYM (2015), FAZIACOR (2017) and FAZIAPRE (2017-2018) experiments) with an increasing number of blocks, from four to six, for still larger solid angular coverage.
- The phase IV, which was covered by the last MoU (2018-2022), was devoted to complete the construction and operation of a large number (12) of FAZIA elemental modules (henceforth called blocks) corresponding to 192 telescopes (each FAZIA block consists of 16 telescopes Silicon 300 µm - Silicon 500µm - CsI(Tl) 10 cm) to be coupled with other devices such as INDRA at GANIL, nowadays. A reasonable number of additional spare blocks (4 units) have been also constructed. Two experimental campaigns have been achieved during this period with the INDRA-FAZIA set-up at GANIL.

Those different phases have been agreed as described in the previous MoUs of the FAZIA collaboration. The experiments performed during this period covered various topics in nuclear reactions around Fermi's energy. The use of the four remaining spare blocks was in priority dedicated to replace any possible faulty block in place during experiment at GANIL. Since 2019, colleagues

from South Korea expressed their interest to join the FAZIA collaboration. This was effective with the addition of an Addendum to the previous MoU in 2020.

The current MoU, covering the period 2023-2027, contains three pillars hereby referred as P1, P2 and P3.

1. **P1:** The first one is to exploit the current well-performing apparatus in operation at GANIL within the INDRA-FAZIA set-up and cyclotron beams;
2. **P2:** The second is to guarantee the starting of first experiments at the RAON facility in South Korea. The construction of at least four new updated blocks (in term of electronics, silicon detectors and upgraded mechanics) is the goal of the present MoU, in order to participate to the first commissioning with Ar beams;
3. **P3:** The third pillar concerns the developments to be done towards experiments with RIBs both at low-energies experiments, as those feasible at SPES and at SPIRAL2 and at Fermi energies via in-flight fragmentation, as available at GANIL-LISE and in future at LNS-FRAISE. It includes the collaboration with other groups of research physics enlarging the usual thematic of INDRA and FAZIA.

These three pillars are more precisely described in the Article 2, purpose of this MoU. In this context, we foresee parallel developments towards a still better angular coverage/acceptance and update of the electronics. Indeed, the object of the FAZIA collaboration is to keep the electronics as much as possible updated and to attempt at further lowering of the thresholds in view of the relatively low energies of SPES and Spiral2 ISOL facilities. At the same time, in the perspective of experiments towards the upper limit of the Fermi energies (>60-70MeV/u), studies and tests have been started to use thicker second layer Silicon sensors (750 or 1000 micron) instead of the usual 500 microns ones. These thicker detectors have been already used for the four most central blocks of the E818 INDRA-FAZIA campaign at GANIL in 2022, with Ar and Ni beams at 74 A MeV, with good success.

As for the activity at GANIL, during the next years, a series of experiments on additional researches/subjects will be proposed to be investigated with the efficient and well performing FAZIA-INDRA set-up; we mention that the experiments can benefit of the recent INDRA upgrade (2022) concerning both detectors and electronics (the old 30 years analogue electronics being replaced by a digital one). As said, additional experiments with other groups of research would be investigated both at GANIL and in other laboratories using spare detector blocks. These latter experiments should be scheduled in different periods than experiments at GANIL in order to allow the whole collaboration to participate in all experiments.

The art.2 below specifies in details the purpose of this MoU. The parties (France, Italy, Poland, Spain and South Korea) involved in the present MoU, are described in details in Annex A.1

THEREFORE, THE PARTIES HAVE AGREED THE FOLLOWING:

Article 1 - Parties to the MoU

This Memorandum of Understanding is between the Parties to this MoU (hereinafter referred to as "Parties"). These Parties are listed in Annex A.1. Each Party is representing its national or local Institution collaborating and funding the project and takes the institutional responsibility for the

project. The Parties and Institutions presently forming the FAZIA Collaboration are listed in Annex A.2.

Article 2 - Purpose of this MoU

The purpose of this MoU is to specify what the Parties intend with respect to the work plan, with special focus on the operation, maintenance and developments of the instrument system, both for the main INDRA-FAZIA initiative and for the other activities of the collaboration, as well as to provide the necessary capital and human resources to successfully carry out this project.

The items forming the instrumentation, their costing, the sharing of the required capital investments and human resources, the development schedule and the milestones for the project are also given in Annex A.3.

This MoU covers the operational and maintenance phase at GANIL basically related to pillar **P1** and including:

- Twelve (plus 4 spare) complete FAZIA blocks (detectors, mechanical frame and shielding, cooling system, power supply, optical fibers, command & control…).
- Detector maintenance (silicon) and upgrade (ionisation chambers) for INDRA
- The associated Front End Electronics, the acquisition system.
- The mechanical structure part and operative systems (vacuum, control & command, cooling, gas distribution) for coupling with INDRA.
- The experimental mounting, test procedures and running periods of experiments.

All parties of the present MoU are contributing to this effort either from the technical and mechanical point of view both in term of manpower as well as financial support.

In addition, this MoU will cover a development phase in various directions:

1. Development, integration and use of thinner or thicker Silicon stages of the FAZIA telescopes (16 existing plus 4 additional covered by this MoU), in order to comply with different bombarding energies experiments. INFN Italy and CENuM Korea are the parties more involved in this task.
2. Simplification/modification of the present mechanical mounting, possibly in view of a more flexible configuration and improving the reliability. GANIL and IN2P3 for France and INFN Italy are the leading parties in this process thanks to their historical background in the design, mounting and maintenance of the apparatus.
3. Renovation of the FEE cards, to substitute obsolescent components (in practice no more available), to simplify the old layout; this is a major item for the collaboration strongly favoured by the support and expertise of the Korean group who is the main party involved in this role. Of course, the others parties will bring their expertise and background in this field too.
4. Updating of the preamplifier stages separating them from the rest of the digitizing and processing circuits, for more versatile purposes and an easier coupling with others devices for collaboration with other groups at GANIL or elsewhere. This task involves all parties as for the design, the expertise and the test procedures. The Huelva University is contributing to the purchase of new electronics boards, designed by the Korean group to ease the FAZIA detector tests in lab with sources.

5. Construction of a new set of at least four complete blocks, implementing of the possible mentioned upgrades, to fully start the activity at the RAON facility in South Korea. All parties are involved in this task with a special role of Korea for electronics components and partnership with local companies and silicon detector manufacturers they are in relationship with.

These five items are all related to the second and third pillar **P2** and **P3** of this MoU as mentioned previously. All parties of the present MoU are contributing to the success of the project according to the respective manpower and to the available funds, year by year requested to the specific national agencies.

Article 3 – Nature of the MoU

This MoU is the non-binding expression of the current intentions of the Parties. None of the Parties will be bound by any legal obligation to the other Parties or incur any associated expenses. The Parties undertake to use reasonable efforts to perform promptly and actively all necessary actions to realize the purpose of the MoU, always subject to the availability of resources at the Parties.

Article 4 - Governance and Management of the FAZIA Collaboration

The governance and management bodies under this MoU shall be the FAZIA Project Management Board (hereinafter referred to as "FPMB").

4.1 FAZIA Project Management Board

The FPMB is in charge of the FAZIA Collaboration and responsible of the detector developments, operation and maintenance according to the physics program. More precisely, the main tasks of the FPMB are the following:

1. Supervises the effective and efficient implementation of the FAZIA Project;
2. Collects information on the progress of the Project, examines that information to assess the compliance of the Project with the funds.
3. Acts as the reference panel for any scientific output of the collaboration, thus collecting information on conference presentations, on paper publications, on young researcher projects and Thesis.
4. Provides reports of the progress of the Project at the authorized representatives of the various institutions.
5. Coordinates the four Task Groups of the FAZIA project (TG1 DAQ, TG2 Data Analysis, TG3 Infrastructure and TG4 Future programs) in agreement with the previous mentioned points. The FMPB members presently involved in the coordination of these Task Groups are listed in Annex A.4 as well as the task list.

The FPMB is managed by a spokesperson and a vice spokesperson. The FAZIA spokespersons are elected for 4 years by the Collaboration. At mid-term, the Collaboration may decide to change the FAZIA spokespersons. The FPMB shall meet once per year or more frequently on demand by one of the Parties.

The FPMB is composed by nine (9) members, three (3) of which represent France, three (3) represent Italy, one (1) represents Poland, one (1) represents Spain and one (1) represents South Korea.

To the furthest extent possible, all decisions of the FPMB shall be taken by consensus. If exceptionally it is not possible to attain consensus, the FPMB members will search for a solution by referring their institutions.

Article 5 – Intellectual property

5.1 Intellectual property means all property, including expertise, in all forms such as drawings, designs, documents, inventions, software programs, reports, processes and protocols that is protected by such means as secrecy, patents, copyrights and trademarks.

5.2 Any intellectual property rights owned or acquired by a Party prior to the conclusion of this MoU shall entirely remain the property of this Party.

Any intellectual property right generated by two or more Parties in the framework of this MoU shall be jointly owned by those Parties proportionally to their respective contribution to the achievement of such rights. In case it would be impossible to determine the contribution of each Participating Institution the intellectual property, rights shall be owned on an equalitarian basis.

Article 6 - Publications

6.1 Publications by one Party involving results developed by another Party shall be subject to the latter's prior written consent. The FPMB will finally take the decision

6.2 All publications shall acknowledge the collaboration between the Parties, including, the persons having taken part in the development of the results, which form the object of the publication.

6.3 All members of the collaboration must follow the "publication rules" available on the FAZIA web site before to submit an article.

6.4 In order to accurately and homogeneously guarantee the application of the rules and fix possible disagreements, a FAZIA Publication Committee (FPC) has been recently created.

Article 7 – Commencement, Duration, Withdrawal and Extension of the MoU

This MoU shall enter into force on the date signature by the last Party to sign and shall remain in force for a period of 5 years. This MoU may by modified or extended at any time only by an amendment to the MoU.

Any Party may withdraw from the present MoU by giving not less than twelve (12) months, notice by written communication to the FAZIA Project Management Board. It is expected that equipment provided by the Party will remain in custody and use by the FAZIA Collaboration for the period of this MoU.

Article 8 - General provisions

The Parties will conduct the collaboration in terms of this MoU in compliance with the applicable laws and regulations. The obligations of each Party are subject to the availability of appropriate funds and human resources.

Nothing in this MoU will affect any other agreements concerning cooperation between the Parties (applicable from the date on when this MoU comes into effect).

All questions regarding the interpretation of this MoU will be resolved consensually by the Parties. Any dispute as may arise between Parties hereto in connection with this MoU, which cannot be resolved amicably between the Parties, shall be finally settled by the authorized representatives of the various institutions. The decision of the signatories of the institutions will be final and binding upon the Parties concerned. Proceedings shall be conducted in English.

Information provided by any Party under this MoU and implementing agreements shall be accurate to the best of that Party's knowledge and belief but no warranty expressed or implied is given by that Party to such information.

The FAZIA multidetector is an open Collaboration. New parties may time by time accede to this MoU through a written procedure defined by the FAZIA Management Board.

The following documents and Annexes are an integral part of this MoU:

Annex A.1: List of Parties
Annex A.2: List of Collaborating Institutions
Annex A.3: Instrumentation equipment, capital investment, installation
Annex A.4: Organization, FPMB and Task groups definition
Annex A.5: References
Annex A.6: Members list

This MoU is drawn up and executed in English, in six original documents.

Signatures

As witness: The Parties have caused this Memorandum of Understanding to be duly signed by the undersigned authorized representatives in separate signature pages, the day and year first above written.

INSTITUT NATIONAL DE PHYSIQUE NUCLEAIRE ET DE PHYSIQUE DES PARTICULES (CNRS-IN2P3)

Date:

Signature:

Name: **Reynald PAIN**

Titles: Director

As witness: The Parties have caused this Memorandum of Understanding to be duly signed by the undersigned authorized representatives in separate signature pages, the day and year first above written.

GRAND ACCELERATEUR NATIONAL D'IONS LOURDS (GANIL)

Date:

Signature:

Name: **Patricia CHOMAZ**

Titles: Director

As witness: The Parties have caused this Memorandum of Understanding to be duly signed by the undersigned authorized representatives in separate signature pages, the day and year first above written.

INSTITUTO NAZIONALE DI FISICA NUCLEARE (INFN)

Date:

Signature:

Name: **Antonio ZOCCOLI**

Titles: President

As witness: The Parties have caused this Memorandum of Understanding to be duly signed by the undersigned authorized representatives in separate signature pages, the day and year first above written.

CONSORTIUM OF POLISH GOVERNMENTAL AND PUBLIC INSTIITUTIONS (COPIN)

Date:

Signature:

Name: **Tadeusz LESIAK**

Titles: Director General of the Henryk Niewodniczanski Institute of Nuclear Physics Polish Academy of Sciences, Krakow, Poland

Date:

Signature:

Name: **Adam MAJ**

Titles: Chair of the Council of the Consortium COPIN

As witness: The Parties have caused this Memorandum of Understanding to be duly signed by the undersigned authorized representatives in separate signature pages, the day and year first above written.

UNIVERSITY OF HUELVA (UHU)

Date:

Signature:

Name: **José Rodríguez Quintero**

Titles: Vice Chancellor for Research and Transfer

As witness: The Parties have caused this Memorandum of Understanding to be duly signed by the undersigned authorized representatives in separate signature pages, the day and year first above written.

CENTER FOR EXTREME NUCLEAR MATTERS (CENuM), Korea University, SEOUL, REPUBLIK OF KOREA

Date:

Signature:

Name: **Byungsik Hong**

Titles: Director

ANNEX A.1

List of Parties

FRANCE:

- IN2P3/CNRS, Institut National de Physique Nucléaire et de Physique des Particules: 3 rue Michel-Ange 75794 Paris Cedex 16
- GANIL, Grand Accélérateur National d'Ions Lourds: Boulevard Henri Becquerel BP 55027, 14076 Caen Cedex 05

ITALY:

- INFN, Istituto Nazionale di Fisica Nucleare: Via Enrico Fermi, 54 00044 Frascati (Roma)

POLAND:

- COPIN**,** Consortium of polish governmental and Public Institutions: The H. Niewodniczañski Institute of Nuclear Physics Polish Academy of Sciences, ul. E. Radzikowskiego 152, 31-342 Kraków

SPAIN:

- University of Huelva: Dr. Cantero Cuadrado 6, 21004 Huelva

SOUTH KOREA:

- CENuM (Center for Extreme Nuclear Matters), Korea University, Seoul 02481, Republic of Korea

ANNEX A.2

List of Collaborating Institutions:

FRANCE

- GANIL, Boulevard Henri Becquerel BP 55027, 14076 Caen Cedex 05
- IJCLab Orsay CNRS-IN2P3, Université Paris Sud, UMR8608, 15 rue Georges Clémenceau, 91406 Orsay
- LPC Caen, CNRS-IN2P3, Université de Caen, ENSICAEN, UMR6534, 6 boulevard du Maréchal Juin, 14050 Caen Cedex 4
- L2IT Université Paul Sabatier, Maison de la recherche et de la valorisation, UMR 5033 CNRS-UT3, 118 route de Narbonne, 31062 Toulouse Cedex

ITALY

- Sezione di Catania (INFN), Via Santa Sofia 64, 95125 Catania CT
- Firenze (INFN & University), Via Bruno Rossi 1, 50019 Sesto Fiorentino FI
- Laboratori Nazionali di Legnaro (INFN), Viale dell'Università 2, 35020 Legnaro PD
- Napoli (INFN & University), Strada Comunale Cintia, 80126 Napoli NA

POLAND

- Jagellonian University, Golebia 24, 31-007 Cracow
- Institute of Nuclear Physics Polish Academy of Sciences, Radzikowskiego 152, 31-342 Cracow
- Silesian University, Bankowa 12, 40-007 Katowice
- Warsaw University, Krakowskie Przedmiescie 26/28, 00-927 Warsaw

SPAIN

- University of Huelva (UHU), Dr. Cantero Cuadrado 6, 21004 Huelva, Tfno 959 218000
- Centro de Estudios Avanzados en Física Matemática y Computación (CEAFMC), Ciencias Experimentales, Campus del Carmen, Universidad de Huelva

SOUTH KOREA

- CENuM (Centre for Extreme Nuclear Matters) & Department of Physics, Korea University, Seoul 02841, Republic of Korea
- CENS (Center for Exotic Nuclear Studies), Institute for Basic Science, Daejeon 34126, Republic of Korea
- Department of Physics, Inha University, Incheon 22212, Republic of Korea.

ANNEX A.3

Instrumentation equipment, capital investment, human resources, installation and provisional calendar

FAZIA description and achievements

The detection element of FAZIA presently consists of a Si-Si-CsI(Tl) telescope, implemented in such a way as to exploit the standard ΔE-E identification technique for particles punching through the first silicon layer and the more sophisticated approach of digital Pulse Shape Analysis (PSA) for lower energy particles stopping in it. The detector is implemented with a fully digital electronics.

The R&D phase permitted to make significant progress on many addressed issues (see list of publications below) here after reported:

a) Careful control of the silicon crystal orientation came out to be fundamental in order to get the best identification performances for both ΔE-E and PSA techniques.

b) The limits imposed by the doping non-uniformity often encountered in commercial silicon have been understood and quantified.

c) Non-disruptive techniques have been developed to select the highest-uniformity silicon material (nTD wafers) by means of test-bench on silicon detectors

d) Suppliers able to provide the necessary high-uniformity, property-cut silicon wafers as well as silicon detectors manufactures have been identified and are currently providing the detectors.

e) The fluorescence properties of CsI(Tl) with digital sampling techniques have been studied in order to select the optimum doping concentration of Thallium. Investigation of the Single Chip Telescope configuration where the second silicon layer acts also as a sensor of the luminescence produced in the following crystal has been performed. Special custom photodiodes, properly fitting the FAZIA geometry, have been designed by the collaboration and produced by external companies in a number originally sufficient for about 190 detectors

f) Time of Flight technique (ToF) has been also taken into account as a complementary information with PSA for low energy particles stopping in the first layer thanks to the digital electronics and to the embedded precise clock, also in absence of a pulsed beam.

g) Front End Electronics (FEE) able to fully exploit the characteristics of the detectors has been developed. Beyond the analogue circuitry, the fast sampling ADCs and the devices for the logic treatment of the signals, the developed electronics presents many important features in the slow control side.

h) Implementation of a novel ad-hoc Digital signal processing technique has been done.

Instrumentation equipment for the INDRA-FAZIA campaign at GANIL

The INDRA-FAZIA coupling at GANIL is constituted by the standard INDRA set-up except the five first rings (polar angle from 2°-14°) replaced by twelve FAZIA blocks in a "wall" forward configuration see figure 1 below.

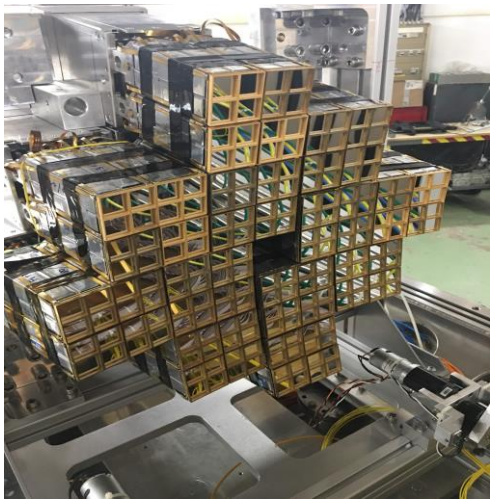

Figure 1: The FAZIA twelve blocks forward configuration for the INDRA-FAZIA coupling at GANIL.

This configuration is composed by four triplets (one triplet=three blocks) placed between 85 and 100 cm from the target covering the polar angle from 1.5° to 14°-12.5°. One block consists of sixteen elemental telescopes each composed by three layers, Si1-300 µm, Si2-500 µm (the default thickness), CsI(Tl) 10 cm, meaning that the full INDRA-FAZIA configuration features 192 telescopes for FAZIA and 240 telescopes for INDRA (from 14° to 176°, with ionization chamber ChIo-Si-CsI(Tl) from 14° to 45° and ChIo-CsI(Tl) from 45° to 176°). This configuration, see figure 2, allows for a good solid angular coverage of almost 80% of 4π as well as a great-improved granularity with respect to the original INDRA geometry at forward angles. Moreover, since 2020 a large upgrade and renewal of the INDRA electronics and detectors has been achieved and the result is an improved isotopic resolution allowing mass identification up to Ne isotopes, Z=10, in INDRA ΔE-E telescopes. This identification capability was never reached so far and coupled with FAZIA mass identification up to Z~25, it fixes a new bench mark for 4π multidetection set-up for isospin and nuclear EoS related studies. As well, the new INDRA acquisition system now allows for higher count rates (above 1kHz) with low dead time (<10%).

This complete set-up can ensure a more accurate event characterization thus improving our understanding of the hot nuclei produced in nuclear collisions at Fermi energy and permitting a stricter link between the fragment features and the nuclear equation of state and its dependence on the neutron-proton disparity.

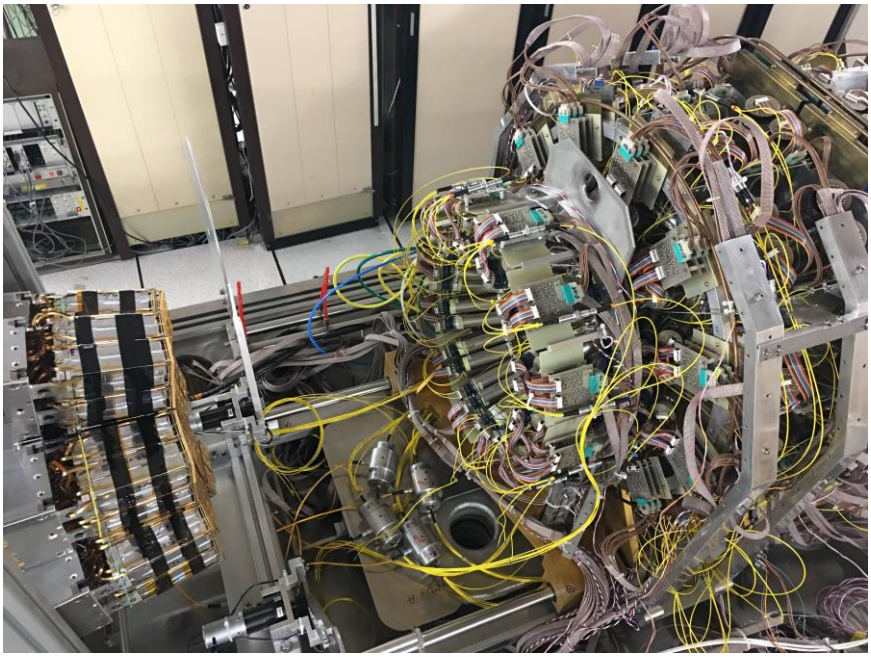

Figure 2: The INDRA (right) and FAZIA (left) multidetectors coupling at GANIL, this set-up has already been used during two long campaigns of measurements since 2019.

The complete acquisition is driven by the CENTRUM electronics module developed at GANIL which couples and manages both the new (2022) INDRA and FAZIA independent DAQ within the NARVAL distributed acquisition system. This versatile configuration permits different trigger choices able to fit with the different experimental constraints overall physical subjects that the Parties want to address. Already two whole campaigns of measurements and additional test have been performed at GANIL (2019 & 2022) with this set-up (figure 2), which has proved its efficiency and capability.

The FAZIA collaboration plans to operate at GANIL at least up to 2027 to benefit, during a long period, from any opportunities available with this large experimental set-up (including collaborations with any other interested groups).

Instrument equipment for additional (not only INDRA-FAZIA) experiments

Four FAZIA spare complete blocks have been built in addition to the twelve used in the GANIL experiments. In view of the proposed strategy towards experiments at other facilities (RAON, LISE, FRAISE), the collaboration is studying upgrading in various sectors of the project (mechanical improvement and more flexible geometry, new electronics, other Si-detector thicknesses). In the time period covered by this MoU, our intention is to build at least four new blocks featuring all the modifications and upgrading that are mentioned before. The new blocks will permit to the collaboration to carry on experiments at the facilities that are now under development and that are of our major interest, specifically RAON in Korea for which an important contribution is planned by our group.

The new additional blocks will complement the set of existing (16) blocks available for the GANIL program that will also be pursued in the next years. The increased number of blocks and the electronics upgrades will be important also to permit experiments in FAZIA stand-alone mode or in coupling with other devices both at Fermi energies (LISE at GANIL, FRAISE at Catania) and at near barrier energies (SPIRAL2, SPES). In this respect, we plan to develop and consider some specific physics cases where the FAZIA detectors can be valuable in experiments together with gamma arrays: in particular, we can take into account the coupling with the PARIS gamma calorimeter for

coincidence gamma-particle studies especially for exotic nuclear systems. Moreover, besides fundamental physics investigation, the collaboration will consider the use of the blocks for nuclear physics applications, as well, provided the scientific motivation will be judged of interest for the Collaboration.

General structure of the Party's responsibility

The proper operation of the FAZIA blocks during the period 2023-2027 is in charge of all the partners who will contribute to the success of the project according to the respective manpower and to the available funds, year by year requested to the specific national agencies.

Planned Capital investment 2023-2027:

According to the three pillars of the MoU, referred as **P1** (INDRA-FAZIA operational phase at GANIL), **P2** (construction of at least four new complete FAZIA blocks for the start of the RAON facility), **P3** (development towards RIB and collaboration with other groups/devices)

Year	Funding	Details : investment, equipment, purchase, maintenance
2023	25 k€	LPC Caen : new prototype design for INDRA Ionisation Chambers (ChIo) **P1 & P3**
2023	45 k€	GANIL : INDRA Si detectors, new Ionisation Chambers (ChIo) and control/command **P1 & P3**
2023	50 k€	Italy : INFN Florence+Napoli+Catania: repair of FEE cards, production of mock up thin silicon detectors with mechanical and assembling developments; preproduction of ultrathin sensors 20micron in a geometry 2x2 sensor matrices. Construction of a forward counter for absolute cross section calibration **P2 & P3**
2023	100 k€	Korea: CENuM:–Construction of a new entire block from detectors to FEE boards for first-day experiment at RAON **P2**
2024	30 k€	LPC Caen : mechanical parts, additional FEE cards for 2 new blocks **P1, P2 & P3**
2024	70 k€	GANIL : Cryogenic pump, new gas-unit for Ionization Chamber, command and control, additional FFE card **P1, P2 & P3**
2024	50 k€	Italy : INFN Florence+Legnaro+Napoli+Catania**:** production of a first small set of ultrathin sensors (20micron) for low-E experiments (geometry based on 2x2 matrices 20micron sensors); detectors and equipment parts for the 2 new blocks. Contribution to installation and integration of detectors in Korea **P2 & P3**
2024	200 k€	Korea: CENuM: Construction of two entire blocks from detectors to FEE boards for first-day experiment at RAON **P2**
2025	30 k€	LPC Caen : mechanical parts, additional FEE cards for 2 new blocks, optical fibres and maintenance **P1, P2 & P3**
2025	70 k€	GANIL : additional FEE cards for 2 new blocks, renewal of silicon detectors **P1, P2 & P3**
2025	50 k€	Italy : INFN Florence+Legnaro+Napoli+Catania; maintenance of the whole FAZIA array (electronics, detectors); integration electronics for coupling blocks with other equipments; computing and disk storage needs for experiments; contribution to integration and installation of blocks both in Korea and at LNS in the new experimental site (according to the Fraise project) **P1, P2 & P3**
2025	40 k€	Korea: CENuM. **P2**
2026	20 k€	LPC Caen : upgrade of the electronics, maintenance **P1, P2 & P3**
2026	40 k€	GANIL : upgrade of the electronics, maintenance, mechanics **P1, P2 & P3**
2026	30 k€	Italy : INFN Florence+Legnaro+Napoli+Catania: maintenance of the whole FAZIA array (electronics, detectors); contribution to installation of experiments in Korea **P1, P2 & P3**
2026	40 k€	Korea: CENuM. **P2**

2027	20 k€	LPC Caen : upgrade of the electronics, maintenance **P1, P2 & P3**
2027	40 k€	GANIL : upgrade of the electronics, maintenance; mechanics **P1, P2 & P3**
2027	40 k€	Italy : INFN Florence+Legnaro+Catania+Napoli: maintenance of the whole FAZIA array (electronics, detectors); contribution to operation of experiments in Korea **P1, P2 & P3**
2027	40 k€	Korea: CENuM. **P2**

Annex A.4:

Organization and Task Groups

Organization:

- Spokesperson: *Giovanni Casini* INFN Firenze, Italy
- Co-spokesperson: *Nicolas Le Neindre* LPC Caen, CNRS-IN2P3, Université de Caen, ENSICAEN, France

FAZIA Project Management Board:

- *Giovanni Casini*, INFN Sezione di Firenze, Italy
- *Nicolas Le Neindre*, LPC Caen, CNRS-IN2P3, Université Caen, ENSICAEN, France
- *John Frankland*, GANIL Caen, France
- *Diego Gruyer*, LPC Caen, CNRS-IN2P3, Université de Caen, ENSICAEN, France
- *Sandro Barlini*, INFN and University of Firenze, Italy
- *Simone Valdrè*, INFN Sezione di Firenze, Italy
- *Tomasz Kozik*, Institute of Physics, Jagiellonian University, Poland
- *Josè Dueñas*, University of Huelva, Spain
- *Byungsik Hong*, Department of Physics, Korea University & CENuM

Task Groups, managers and duty list:

TG1: DACQ and control (Simone Valdrè & John Frankland)

- Updates and improves the current DACQ system; provides coupling with other devices; takes care of the slow control system. The TG1 covers the three main pillars of this MoU being involved in both old and new acquisition systems; it works to ensure back-compatibility with the old electronic cards and takes care of the installation in any site where the collaboration perform experiments. France, Italy and Poland are the main historical parties involved in this task.

TG2: Analysis and simulation (Sandro Barlini & Diego Gruyer)

- Takes in charge the data reduction (calibration/identification); updates the continuous data improvement; takes care of the data analysis; organize regular specific meetings (FAZIA days); manages the KaliVeda software (database, filter, simulations…); performs simulations. All parties are contributing to the TG2, having PhD students and Post Docs in their group, as well as any people wanting to access the reduced data for physics analyses and model comparisons.

TG3: Detector and instrumentation (Giovanni Casini & Nicolas Le Neindre)

- Develops and oversees the detector construction; maintains the various parts of FAZIA (detectors, electronics, mechanics…); improves the global set-up reliability; prepares the experiments in various facilities worldwide; manages the budget. Again, all three pillars of the present MoU will be addressed by the TG3. All parties are also involved here, with a special contribution of Italy and France, participating according to the respective manpower and to the available funds, year by year requested to the specific national agencies.

TG4: Physics case and collaborations (Giuseppe Verde & Gabriele Pasquali)

- Follows the scientific activities in various facilities worldwide and informs regularly the collaboration; keeps contacts with relevant laboratories, proposes possible developments regarding the future beams and general equipment in those facilities (SPES, FRAISE, FRIB, RAON, FAIR…); coordinates the preparation of proposals/LoIs for the various PACs; keeps connection with theoreticians; promotes and stimulates collaborations. This group is in close connection with TG2 and is mainly focused on the experimental program at GANIL with the INDRA and FAZIA coupled devices, (pillar P1) preparing PAC proposals and LoIs. Future programs and partnerships (pillars P2 and P3) with other collaborations are also discussed in the TG4. The possible nascent proposals are then evaluated within the FPMB.

Pillars of the MoU	FAZIA Task Groups	FAZIA parties	Tasks & responsibilities
P1 (INDRA-FAZIA operational phase at GANIL)	TG1	GANIL, IN2P3, INFN, COPIN	Acquisition system + coupling
	TG2	GANIL, IN2P3, INFN, COPIN, Huelva University, CENuM Korea University	Data reduction and analyses
	TG3	GANIL, IN2P3, INFN, CENuM Korea University	New detectors and electronics for maintenance, repairs, improving reliability
	TG4	GANIL, IN2P3, INFN, COPIN, Huelva University, CENuM Korea University	PAC proposals and LoIs
P2 (construction of at least four new complete FAZIA blocks for the start of the RAON facility)	TG1	GANIL, IN2P3, INFN, COPIN	Acquisition system for RAON
	TG2	GANIL, IN2P3, INFN, CENuM Korea University	Simulations
	TG3	GANIL, IN2P3, INFN, CENuM Korea University	Construction of four updated new blocks for RAON
	TG4	GANIL, IN2P3, INFN, CENuM Korea University	Physics cases and LoIs

P3 (development towards RIB and collaboration with other groups/devices)	TG1	GANIL, IN2P3, INFN, COPIN	Coupling with other devices
	TG2	GANIL, IN2P3, INFN, COPIN, Huelva University, CENuM Korea University	Simulations
	TG3	INFN, COPIN, CENuM Korea University	Thin silicon detectors 20-100 µm
	TG4	GANIL, IN2P3, INFN, COPIN, Huelva University, CENuM Korea University	PAC proposals and LoIs

Annex A.5: References

a) Web site FAZIA collaboration (http://fazia.in2p3.fr)

b) H. Hamrita et al. NIM A 531 (2004) 607

c) S. Barlini et al. NIM A 600 (2009) 644

d) L. Bardelli et al. NIM A 602 (2009) 501

e) L. Bardelli et al. NIM A 605 (2009) 353

f) M. Parlog et al. NIM A 613 (2010) 290

g) H. Hamrita et al. NIM A 642 (2011) 59

h) L. Bardelli et al. NIM A 654 (2011) 272

i) S. Carboni et al. NIM A 664 (2012) 251

j) G. Pasquali et al. European Physics Journal A 48 (2012) 158

k) N. Le Neindre et al. NIM A 701 (2013) 145

l) S. Barlini et al. NIM A 707 (2013) 89

m) S. Barlini et al. Physical Review C 87 (2013) 054607

n) S. Piantelli et al. Physical Review C 88 (2013) 064607

o) R. Bougault et al. European Physics Journal A 50 (2014) 47

p) G. Pasquali et al. European Physics Journal A 50 (2014) 86

q) A.J. Kordyasz et al. European Physics Journal A 51 (2015) 15

r) F. Salomon et al. Journal of Instrumentation (2016) Vol. 11, JINST 11 C01064

s) D. Gruyer et al. NIM A 847 (2017) 142

t) G. Pastore et al. NIM A 860 (2017) 42

u) S. Valdré et al. NIM A 930 (2019) 27

v) C. Frosin et al. NIM A 951 (2020) 163018

w) S. Piantelli et al. Physical Review C 101 (2021) 034613

x) S. Piantelli et al. Physical review C 103 (2021) 014603

y) A. Camaiani et al. Physical Review C 103 (2021) 014605

z) C. Ciampi et al. Physical Review C 106 (2022) 024603

aa) C. Frosin at al. Submitted to Physical Review C

Annex A.6 : FAZIA Members (2023)

- **Italy:** Barlini S. (Prof), Baldesi L. (PhD), Camaiani A. (R), Casini G. (DR), Cialdai C. (E), Dell'Aquila D. (R), Frosin C. (R), Lombardo I. (R), Gramegna F(R), Lanza G.E. (R), Marchi T. (R), Pasquali G. (Prof), Pellegriti M.G. (R), Piantelli S. (R), Poggi G. (Prof), Stefanini A. (Prof), Valdrè S. (R), Verde G. (R),Vigilante M. (Prof)
- **France:** Bonnet E. (CR), Borderie B. (DR), Bougault R. (DR), Chbihi A. (DR), Ciampi C. (Post Doc), Durand D. (R), Fable Q. (Post Doc), Frankland J. (CR), Genard T. (PhD), Gruyer D. (CR), Le Neindre N. (CR), Lopez O. (DR), Rebillard-Soulié A. (PhD), Valente A. (PhD), Vient E. (Prof)
- **Poland:** Mazurek K. (R), Kordyasz A. (R), Kozik T. (Prof)
- **Spain:** Dueñas J. (R), Gárcia Ramos J.E. (R), Pérez Bernal F. (R), Sánchez Benítez A.M. (R)
- **South Korea:** Hong B. (Prof), Kim J. (Post Doc), Lee J.W. (Post Doc), Nam S.H. (PhD), Park J. (PhD), Hahn K.I. (Prof), Kim S. (Post Doc), Kweon M.J. (Prof), Kim G. (PhD)