

Photon Array for studies with Radioactive Ions and Stable beams

Memorandum of Understanding

1. Introduction

PARIS is a collaborative European project (hereafter referred to as the “Project”) to construct and operate a novel 4π gamma-ray calorimeter, which profits wholly or in part from employment of novel, advanced scintillator materials, such as Lanthanum Bromide (more details on the *PARIS* web page <http://paris.ifj.edu.pl>).

PARIS should have a performance superior to any existing scintillator calorimeter in terms of energy resolution. For low to medium-energy (10 MeV) gamma rays, the calorimeter should have an excellent energy resolution equivalent to ca. 4% for 1 MeV gamma rays. The calorimeter should be sufficiently thick to absorb gamma rays with energies up to 30-40 MeV but not necessarily with as high an energy resolution as that required for the lower energy range. This can be achieved by a calorimeter constructed either entirely from novel scintillator, or with two shells – an inner shell of novel scintillator and an outer shell of a conventional scintillator. In practice, the two shells may be optically coupled as a single “phoswich” device. The scintillators employed should have excellent timing resolution, at least less than 1ns for 511 keV gamma rays to allow for neutron-gamma discrimination. The geometry of *PARIS* should be such that it allows good interoperability with other apparatus such as AGATA or EXOGAM, GASPARD, S³ and NEDA.

PARIS will facilitate a diverse Physics programme with both stable and radioactive beams. This programme will include studies of giant dipole resonances (GDR) and reaction dynamics. In particular, it will address exotic shape transition phenomena at high angular momentum, such as the Jacobi transition. Other Physics programmes are foreseen covering diverse topics from Coulomb excitation to heavy ion radiative capture and nuclear astrophysics.

Campaigns of experiments with *PARIS* will be pursued primarily at GANIL/SPIRAL2 (Caen, France), but the device would be eminently portable and could be used at other European and international RIB and stable ion-beam facilities.

The R&D phase 1 has been largely carried out with the support of the FP7 SP2PP programme, a French ANR grant (PROVA), and Polish-GANIL collaboration project COPIGAL and the French-Indian LIA project. The deliverables from this phase are a *PARIS prototype*, which will comprise a cluster of 9 phoswich modules, and this Memorandum of Understanding. The intention is that phase 1 will be succeeded by:

Phase 2: Construction of a *PARIS demonstrator* (hereinafter “the demonstrator”) comprising of five clusters each comprising nine modules and covering approximately $2/3 \pi$ of solid

angle (2015). PARIS Demonstrator will be already fully operational detector and it will be used in experiments, for example together with AGATA, EXOGAM and S³.

Phase 3: An intermediate phase of the full array comprising 2π solid angle (hereinafter “the 2π PARIS”) (ca. 2017)

Phase 4: The full PARIS calorimeter (hereinafter “the calorimeter”) covering almost 4π solid angle (ca. 2019-2020)

The R&D phase has addressed Monte Carlo simulations as well as detector research and development. Key milestones in this phase have included:

- GEANT4 simulations concerning the appropriate segmentation of the device and defining an appropriate module front-face dimension of 2” X 2”.
- Mechanical designs for spherical and cubical arrays of differing detector number
- Testing of different detector configurations of various sizes including both LaBr₃ and LaBr₃ coupled to CsI and NaI as phoswich modules investigating both energy resolution and timing resolutions as well as response to pile-up
- Explorations of various different types and configurations of photomultiplier tube
- In-beam tests of prototype modules to produce high energy gamma rays for tests of linearity
- Exploration of pulse shape analysis from phoswich detectors
- Investigations of LaBr₃ for neutron sensitivity
- Testing of novel light collection technology including different silicon photomultipliers (SiPMs)
- Initial work on GEANT4 simulations of realistic PARIS Physics cases

The R&D phase still has the following challenges as it enters the prototype phase, and which need to be tackled both for a demonstrator device and for a future full-scale calorimeter:

- Completion of testing of phoswich modules to determine the most appropriate choice of scintillator
- Obtaining the best possible linearity from the modules by developments of PMTs in association with manufacturers as well as stability through use of a LED feedback system and design of an appropriate regulated high-voltage supply
- Design of a pulse-shape analysis algorithm which can obtain the best possible energy and timing resolution from the phoswich modules
- Selection and/or design of the best digital electronics platform which can most appropriately match the demanding requirements of the LaBr₃ technology as well as providing interoperability with other SPIRAL2 apparatus
- Realistic Geant4 simulation for the final design
- Cost-benefit analysis of the competing designs of pure LaBr₃ and phoswich modules in relation to the key Physics cases (to be pursued through increasingly detailed simulation)
- In-beam tests and validation of an appropriate add-back algorithm for the prototype cluster

2. Parties of this MoU

This memorandum of understanding (hereinafter “MoU”) is between the Parties to this MoU (hereinafter “the Parties”). These Parties are listed in annexe A.1. The institutes or institutions forming the *PARIS* Collaboration are listed in annexe A.2 (hereinafter “the Collaborating Institutions”). The Parties must be contributing at least 5% of the capital cost or manpower. Participating institutions at less than this level may only have observer (consultative) status.

3. Purpose of this MoU

The purpose of this MoU is to specify what the Parties intend with respect to upgrade to phase 2 of the *PARIS* project, namely planning, seeking funding for, constructing and operating the demonstrator.

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 expense.

The intention of the Parties and/or the Collaborating Institutions as appropriate is to provide the necessary capital and human resources to successfully construct and operate the demonstrator.

The items forming the *PARIS* demonstrator, their costing, the sharing of the required capital investment and human resources, and the construction schedule and the milestones for the Project are given in Annexe B.

Any changes in the scope of the demonstrator will be agreed at the *PARIS* steering committee, as described in Annex C.

For the duration of this MoU, the demonstrator is expected to be principally sited at GANIL/SPIRAL2 (Caen, France). There may also be campaigns hosted by the Collaborating Institutions. Campaigns outside of the Collaborating Institutions are subject to negotiation within the *PARIS* Steering Committee. Formal letters of agreement between each Host and the *PARIS* Steering Committee, which represents the Parties as defined in Annexe C, will detail the commitment of the Host and the obligations of the Collaborating Institutions for each campaign.

4. Commencement, Duration, Withdrawal and Extension of the MoU

This MoU will become effective when at least three Parties have signed including GANIL/SPIRAL2.

This MoU shall continue in force until 31 December 2015. This MoU may be extended only by an amendment to the MoU.

Any Party may withdraw from the *PARIS* MoU by giving not less than twelve months notice in writing to the *PARIS* Steering Committee. It is expected that equipment provided by the Party will remain with *PARIS* for the period of this MoU.

5. Organisation and Management

The *PARIS* organisation and the governance bodies for the construction and operation of the demonstrator are described in Annexe C.

PARIS is an open collaboration. New members may accede to this MoU through a written procedure defined by the *PARIS* Steering Committee.

6. Amendments and Modification of the MoU

This MoU may be amended or modified at any time in writing if agreed by at least two thirds of the Parties and. the modifications may be vote at the Steering Committee meetings only.

7. 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 and/or Collaborating Institution 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 the Parties hereto in connection with this MoU, which cannot be resolved amicably between the Parties, shall be finally settled by the Rules of Conciliation and Arbitration of the International Chamber of Commerce by three arbitrators appointed in accordance with the said Rules unless the Parties agree on a single arbitrator. The award of the arbitrator 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.

Each Party and/or Collaborating Institution as appropriate takes charge of the insurance coverage for its own staff in accordance with applicable legal requirements for occupational injuries and occupational diseases. Consequently, each party and/or Collaborating Institution as appropriate must fulfil the required formalities and sustain all the costs, if any, involved in the insurances underwritten to cover its own staff against the risks.

Each Party and/or Collaborating Institution as appropriate is liable, in accordance with the applicable law, for damages caused by its staff to the staff of any other Party and/or Collaborating Institution as appropriate.

Each Party and/or Collaborating Institution as appropriate will bear the liability without any right of claim against any other Party and/or Collaborating Institution as appropriate, except in cases of gross negligence or wilful misconduct, for any damage to its own properties resulting from or in the course of fulfilment of this MoU.

Each Party and/or Collaborating Institution as appropriate remains liable, in accordance with the applicable legal regulations, for damages caused by itself or its staff to third Parties occurring under this MoU.

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

- Annexe A: List of Parties and Collaborating Institutions
- Annexe B: Equipment, Capital Investment and Installation pertaining to the *PARIS* demonstrator
- Annexe C: *PARIS* Management Structure

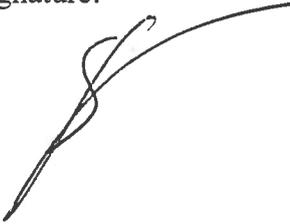
This MoU is drawn up and executed in English, in one original document.

8. Signatures

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

Date: 26/01/2012

Signature:

A handwritten signature in black ink, consisting of a stylized 'F' followed by a long, sweeping horizontal stroke that curves upwards at the end.

Florent STALEY

Director of Grand Accélérateur National d'Ions Lourds (GANIL)

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

Date: 26/01/2012

Signature:

A handwritten signature in blue ink, appearing to read 'JM' with a stylized flourish at the bottom.

Jacques MARTINO

Director of the Institut National de Physique Nucléaire et de Physique des Particules (IN2P3)

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

Date: 26/01/2012

Signature:

Marek Jeżabek, Ph.D
Professor of Physics
Director General



Marek JEZABEK

Director of the Henryk Niewodniczański Institute of Nuclear Physics Polish Academy of Sciences, Kraków, Poland

Coordinator of the Consortium of Polish governmental and public Institutions (COPIN)

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

Date:

Signature:

Tata Institute of Fundamental Research (TIFR)

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

Date:

Signature:

David JENKINS
University of York

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

Date:

Signature:

Dimitar TONEV
Institute for Nuclear Research and Nuclear Energy, Bulgaria Academy of Sciences
(INRNE BAS)

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

Date:

Signature:

Fernando FERRONI
Director of Istituto Nazionale di Fisica Nucleare (INFN)

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

Date:

Signature:



Sefa ETURK
Niğde University

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

Date: 25/01/2012.

Signature:

A handwritten signature in black ink, appearing to read 'Zamfir', written in a cursive style.

Victor ZAMFIR

Director of Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH)

Annexe A: List of Parties and Collaborating Institutions

Annexe A.1: List of Parties

FRANCE

- IN2P3/CNRS
- GANIL/SPIRAL2 (Caen)

POLAND

- Consortium COPIN

INDIA

- BARC Mumbai
- TIFR Mumbai
- VECC Kolkata

UNITED KINGDOM

- University of York

BULGARIA

- INRNE Sofia

ITALY

- INFN Milano
- LNL Legnaro

TURKEY

- Nigde University
- Sebahattin Zaim University
- Istanbul Technical University
- Akdeniz University

ROMANIA

- IFIN-HH Bucharest

Each Party is representing their national institutions collaborating in the PARIS Project and takes the institutional responsibility for the Project.

Annexe A.2

List of Collaborating Institutions:

FRANCE

- IPNO (Orsay)
- IPNL (Lyon)
- IPHC (Strasbourg)
- GANIL (Caen)

POLAND

- IFJ PAN Krakow
- HIL and UW, Warsaw
- NCBJ Otwock
- UMCS Lublin

INDIA

- BARC Mumbai
- TIFR Mumbai
- VECC Kolkata

UNITED KINGDOM

- University of York
- University of Surrey

BULGARIA

- INRNE Sofia

ITALY

- INFN Milano
- LNL Legnaro

TURKEY

- Nigde University
- Sebahattin Zaim University
- Istanbul Technical University
- Akdeniz University

ROMANIA

- IFIN-HH Bucharest

Annexe B: *PARIS* Equipment, Capital Investment and Installation

Annexe B.1: R&D Investment and Human Resources sharing

A R&D phase has been largely carried out with the support of the different Institutes, national and European programs. In table B.1, the expense of the material in this R&D phase is summarized. It covers the period 2007 to 2010. It includes different types of crystals, photo detectors and dedicated electronic for testing, but it excludes the cost of the *PARIS* prototype.

*Table B.1 Capital investment and human resources already committed to the *PARIS* project for the on-going R&D phase*

Parties	Funds invested in material (k€)	Personal (in person months)
EU FP7 SP2PP	60	18
ANR PROVA	60	48
IN2P3 - France	81	48
GANIL - France		24
COPIN - Poland	25	36
INDIA		12
United Kingdom		11
Italy	25	4
Bulgaria	10	5

Annexe B.2: Equipment and Capital Investment for the demonstrator

Definition of the demonstrator (*PARIS* Phase 2):

The demonstrator will comprise five clusters of nine phoswich detectors. Each phoswich will likely comprise a 2" cube of LaBr₃(Ce) coupled to a NaI crystal of 6" length. The light collection will be carried out by photomultiplier tubes (PMTs). Suitable high voltage supply will be required. Digital electronics will be used. The "demonstrator" which constitutes the phase 2 of the *PARIS* project includes the phase 1, i.e. the construction and test of a "PARIS prototype", comprising a cluster of 9 phoswich modules.

All cost estimates are based on 2011 prices in Euro without tax.

Table B.2 summarizes the cost estimate for the *PARIS* demonstrator.

Table B.2 Summary table of the cost estimates for PARIS demonstrator.

	Number	Cost/unit (k€)	Total (k€)
Prototype (Phase1)			
Crystal	9	17	153
PMT	9 + 1 spare	0.5	5
Base and associated mechanics	9 + 1 spare	0.6	6
Assembly in Cluster	1	3	3
Material for tests	Miscellaneous		33
Total Phase 1			200
Upgrade to Demonstrator (Phase 2)			
Crystal	36	17	612
PMT	36 + 4 spares	0.5	20
Base and associated mechanics	36 + 4 spares	0.6	24
Assembly in a Cluster	4	3	12
Demonstrator mechanics and support	1	10	10
High voltage	Crate	1	5
	Channels	45	0.25
Electronics *	Crate	1	4
	Channels*	45*	1*
Trigger and data acquisition**	1	10**	10**
Miscellaneous (spare crystals, cables, small components...)	Miscellaneous		60
Total Upgrade to Phase 2			813
Total Phase 2 (incl. Phase 1) – no tax			1013
Total Phase 2 (incl. Phase 1) – with estimated average tax rate of 11.5%***			1130

*Note: The indicated prices are for commercial 8 channels modules. The 9 channels cluster and their associated processing and triggering electronics system need specific developments, which are currently under study and realisation, but the final price (including the prototyping phases) will be similar

**Note: The data acquisition and trigger (probably base on the GTS system) is under study. The price is an indicative one.

***Based on the tax rates in the main partner countries: 23% tax in Poland and 0% tax in France

Annexe B.3 Sharing of Capital investment and Human resources

The Parties and/or Collaborating Institutions as appropriate are planning to make bids to contribute with the capital given in table B.3.1. In-kind contributions will be made, whenever possible, allowing the best use to be made of the expertise and experience acquired during the R&D phase.

The participating collaborating institutions are planning to make human resources (physicists, engineers and technicians) as given in table B.3.1 available to the *PARIS* project (personnel in person-months).

Table B.3.1 Summary table of the capital investment, personal resources for PARIS system and the planned sharing between the participating collaborating institutions of each country, Table includes the funds committed for the PARIS prototype and the funds planned or intentional until 2015 for the demonstrator phase.

Party or Country	Funds committed (before December 2011) (k€)	Personal resources already committed before December 2011 (person-month)	Planned (2012-2015) new capital investment (k€)	Planned (2012-2015) Personal resources (person-month)	Total capital investment (k€)	Total personal resources (person-month)
FP7 SP2PP	50				50	
FP7 CRISP				12		12
FRANCE-IN2P3	40	36	260	94	300	130
FRANCE-GANIL		29	180	22	180	51
POLAND	30	30	270	100	300	130
INDIA	80	6	100	44	180	50
UK		11		9		20
BULGARIA		5	15	15	15	17
ITALY			50	6	50	6
TURKEY			20	48	20	48
ROMANIA			70	24	70	24
Total	200	117	965	371	1165	488

GANIL/SPIRAL2 and other host institutions will incur costs directly related to the installation and operation of the *PARIS* system. Estimates of these costs and the required human resources are given in table B.3.2.

Table B.3.2 Capital investment without general infrastructure costs and human resources planned to be provided by GANIL/SPIRAL2 and other host laboratories for the testing, installation, commissioning and operation of PARIS Demonstrator.

Country	Host	Planned capital investment [k€]	Personnel in person months
France	GANIL/SPIRAL2	25	15
France	IPN Orsay / ALTO	20	15
Poland	HIL Warsaw IFJ PAN Kraków	10	6
Italy	LNL Legnaro	10	10
India	TIFR Mumbai BARC Mumbai VECC Kolkata	10	5

Annexe B.4: Construction schedule and Milestones

Provisional planning and milestones for the construction of the *PARIS* demonstrator system in 2012-2015.

Month	Item
April 2012 -	First cluster (the PARIS prototype) completed
December 2012 -	Source and in-beam tests of the PARIS prototype completed
January 2013 -	Design of PSA algorithms for phoswich completed
March 2013 -	Second cluster completed
December 2013 - completed	Implementation of PSA algorithm into the NUMEXO02 board
June 2014 -	Third and fourth cluster completed
September 2014 -	In-beam tests and application of PARIS Demonstrator in real experiments in various facilities completed
November 2014 - completed	Experiment using PARIS Demonstrator in Phase1Day1 experiments
March 2015 -	Report on PARIS Demonstrator ready
June 2015 -	MoU on further stages of PARIS signed

Annexe C:

***PARIS* Management Structure**

The organisation for the construction and the operation of the *PARIS* project comprises the following bodies:

- The *PARIS* Steering Committee, acting on behalf of the Parties, is responsible for the Project coordination and the science policy of the collaboration.
- The *PARIS* Collaboration Council, representing all the institutions collaborating under the *PARIS* project, advises the *PARIS* Steering Committee on scientific matters.
- The *PARIS* Project Manager and the *PARIS* Management Board are responsible for the execution of the Project along the lines defined by the *PARIS* Steering Committee.

The terms of reference of each of these bodies is given in more detail below.

***PARIS* Steering Committee**

Membership:

Members are nominated by the Parties of the MoU. Contributing Parties of a country, which represent more than 15% of the total capital investment, will have two members, all other Parties with contribution exceeding of 5% of the total capital investment will have one member.

The *PARIS* Project Manager and the *PARIS* Spokesperson attend meetings for consultation only and therefore without voting rights. The *PARIS* Steering Committee can invite others to attend as needed for consultation only, for example the Campaign Spokespersons and Campaign Managers.

Voting rights:

Members have voting rights if they represent a Party of the Project.

Terms of reference:

The *PARIS* Steering Committee is the decision-making body of the *PARIS* Collaboration and responsible for the allocation of resources supplied by the Parties and the collaborating institutions. The *PARIS* Steering Committee will ensure that the primary criterion for deployment of any equipment is based on scientific merit.

The tasks of the Steering Committee are as follows:

1. Define the scientific policy of the *PARIS* Collaboration taking advice from the *PARIS* Collaboration Council.
2. Elect a chair and vice-chair among its members who will each serve for a period of two years.
3. Appoint a project manager and members of the *PARIS* Management Board.
4. Monitor the Project based on reports received from the Project Manager.
5. Decide on any modification of the Project proposed by the Project Manager.
6. Decide on the experiment campaigns for *PARIS* and the timetable.

7. Appoint the Campaign Spokesperson for each experiment campaign.
8. Review the scientific progress of each experimental campaign based on reports received from the Campaign Spokesperson.
9. Review the running cost statements and allocations

Decisions in the *PARIS* Steering Committee shall be taken by consensus.

The *PARIS* Steering Committee shall not make any decision unless a quorum of two thirds of the votes are represented.

Minutes of each meeting shall be drafted by the chairperson to the other members without delay. The minutes of each meeting shall be considered as accepted by the other members if, within thirty calendar days from receipt, the other members have not objected in writing to the chairperson.

The *PARIS* Steering Committee chair signs on behalf of the *PARIS* Steering Committee all written agreements.

PARIS Project Manager

The *PARIS* Project Manager is appointed by the *PARIS* Steering Committee to coordinate the execution and implementation of the project. For this purpose the Project Manager can create and dissolve working groups as needed after acceptance of the *PARIS* Steering Committee. The Project Manager will propose and nominate, after approval of the Steering Committee, the chairpersons of these working groups.

PARIS Management Board

Membership of the *PARIS* Management Board:

The *PARIS* Project Manager; Chairpersons of all working groups; Chairperson of *PARIS* Steering Committee (ex-officio). The *PARIS* Project Manager will chair the *PARIS* Management Board.

The Campaign Manager(s) nominated by the host laboratory is invited to attend.

Voting rights:

All members have equal voting rights.

Terms of Reference:

The *PARIS* Management Board executes and implements the project. The *PARIS* Management Board shall report to and be accountable to the *PARIS* Steering Committee through the *PARIS* Project Manager.

The tasks of the *PARIS* Management Board are as follows:

1. Supervise the effective and efficient implementation of the Project.
2. Collect information on the progress of the Project, examine that information to assess the compliance of the Project with the programme decided by the *PARIS* Steering Committee and, if necessary, propose modifications of the programme to the *PARIS* Steering Committee.
3. Provide reports of the progress of the Project to the *PARIS* Steering Committee including an annual planning and resource report.
4. Advise the *PARIS* Steering Committee on technical issues.
5. Work with the Campaign Manager to ensure the successful operation of *PARIS*.
6. Organise *PARIS* working group meetings as needed.

PARIS Collaborating Council and PARIS Spokesperson

Membership:

One representative from each collaborating institution and the *PARIS* Spokesperson.
The *PARIS* Spokesperson chairs meetings of the *PARIS* Collaborating Council.

The Campaign Spokesperson is invited to attend.

Voting:

All members have equal voting rights. The *PARIS* Spokesperson is excluded from any vote concerning the Spokesperson role.

Terms of Reference:

The *PARIS* Collaborating Council is the advisory body of the *PARIS* Steering Committee on scientific matters concerning the *PARIS* project.

The tasks of the *PARIS* Collaborating Council are as follows:

1. Elect the *PARIS* spokesperson who will serve for a period of two years.
2. Advise the *PARIS* Steering Committee on scientific matters concerning the *PARIS* project and the research programme through the *PARIS* Spokesperson.
3. Nominate the Campaign Spokesperson for each experiment campaign to the *PARIS* Steering Committee.
4. Hold meetings, at least annually, to receive reports from the *PARIS* Steering Committee and *PARIS* Management Board on the progress of the Project and from the Campaign Spokesperson on the progress of the research programme.
5. Hold an annual open meeting of the *PARIS* Collaboration to present the status of the Project and to discuss future experiment campaigns.