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Acronyme/short title	**PROVA**
Titre du projet *(en français)*	Prototype pour un ensemble de detection de γ.
Titre du projet/Proposal title *(en anglais)*	PROtotype for a Versatile γ-Array

Les pages seront numérotées et l'acronyme du projet devra figurer sur toutes les pages du document en pied de page.
Un sommaire du document est bienvenu

A summary is included at the end of the present document.

S'il s'agit d'un projet déposé dans le cadre d'un accord de coopération internationale*, préciser avec quelle agence étrangère :
☐ National Natural Science Foundation of China (NSFC)
☐ Japan Society for the Promotion of Science (JSPS)
☐ Japanese Science and Technology Agency (JST)
☐ National Science Council of Taiwan (NSC)

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1. Programme scientifique / Description du projet *Technical and scientific description of the proposal*

1.1 Problème posé/Rationale *(1/2 page maximum)*

Présentation générale du problème qu'il est proposé de traiter dans le projet et du cadre de travail dans lequel il sera effectué.

Gamma rays produced in nuclear reactions have provided a wealth of important breakthrough on behaviours of nucleus under extreme conditions. The advent of new nuclear facilities as for example SPIRAL2, ALTO and FAIR, delivering a wide panoply of high intensity radioactive and stable beams, will allow to investigate phenomena in an unexplored part of the nuclear chart. The adequate tool for numerous physics case addressing the large spectra of behaviours of the nuclear fluid is a dedicated γ-calorimeter made of two shells. There is a large consensus in the international community for such dedicated array. The role of the inner shell is for event characterization, while the outer shell is for the measurement of the high-energy γ-ray associated to many nuclear collective phenomena. To exploit efficiently the full capabilities of the future facilities, the γ-calorimeter device must fulfil strong requirements: a large dynamical energy range from 100 keV to 50 MeV; a good energy resolution on a large dynamical range and a good granularity to ensure both γ-multiplicity and energy-sum measurements; a spatial coverage as close as possible of 4π; for flexibility and coupling to other detectors, this 4π device, has to be easily convert to a 2π or 1π geometry: a clean neutron-γ discrimination is requested for event characterization. Moreover, the data collection from such complex apparatus will imply to handle a very high data flux and to allow pulse shape analysis. These call for using fast electronics together with fast timing detector.

Recent developments on new scintillation material could provide innovative solutions for future large acceptance array to be operated during few tenths of coming years. The goal of the present ANR proposal is to test a new and original concept of a kind of phoswich composed of two components. The first one is a novel scintillation material (LaBr3:Ce), having unique capability of good energy resolution, fast emission and good linearity over a broad temperature range. The second component is a CsI(Na) for light emission compatibility with the LaBr3. Our project is to establish the performances of such a phoswich coupled to a fast electronic. This is of prime importance, since such an ensemble will provide innovative solution for the design and the manufacturing of future γ-calorimeters as the PARIS array (*paris.ifj.edu.pl*). The PARIS array has been selected as a part of the SPIRAL2 Preparatory Phase within the European FP7 program

The work covered by the ANR demand is divided in Working Packages (WP) on a four years period. The teams involved in the project (from IPN Lyon, IPN Orsay, IPHC Strasbourg, GANIL Caen laboratories) have a high scientific and technical expertise needed to achieve successfully this R&D phase, and they are well recognised at national and international level. Each participant has been assigned to a WP. The planned research will be performed in collaboration with the company Saint-Gobain Crystal factory and in the frame of an international collaboration with the University of York (UK) and the University of Krakow (Poland)

1.2 Contexte et enjeux du projet/*Background, objective, issues and hypothesis*

a) The general context.

The study of the shape phase diagram at high rotational motion and finite temperature plays a crucial role in the understanding of the properties of nuclei under extreme condition. Many experimental investigations have proven the perfect adequacy of high-energy γ-rays to probe the properties of hot and rotating nucleus. For example, abundant literature has reported that the high-energy γ-rays from the Giant Dipole Resonance (GDR) (Ref.1) built on excited states give precious insights on many facets of the complex nuclear system, where various degree of freedom are involved. High-energy γ-rays are also a probe to investigate other phenomena specific of the nuclear system like the isospin mixing at finite temperature, molecular configurations in nucleus through the radiative capture in heavy-ion reactions. All these topics are related to the understanding of nuclei behaviour far from stability, which is the driving theme of modern nuclear science. Besides, atomic nuclei is an excellent terrestrial laboratory to study, under controlled conditions, the shape diagram of material under fast rotation, a topic that covers the stability of rotating object encountered at different scale in the universe. Last, the disappearance of collective phenomena and the transition towards disordered phase is a major issue of the science of the mesoscopic systems which nucleus is a perfect example.

b) The scientific issues: high energy γ-rays as a probe of hot nuclei and reaction mechanisms.

The mechanism of fusion between heavy ions colliding at bombarding energy around the coulomb barrier is the adequate tool to form a hot and rotating nuclei in a controlled way on the external parameters of excitation energy E^* and angular momentum J. Up to now, the studies of nuclei at very high J have been carried out at facilities delivering mainly stable beams. This influences strongly the angular momentum range accessible due to the limit imposed by the fission. Indeed, it has been argued that hyper-deformed shape has not been firmly observed due to the possible competition of the fission process. In near future, the fusion mechanism induced by high intensity neutron-rich beams delivered at new facilities, will allow producing exotic compound nuclei at initial angular momentum (up to 100 $h/2\pi$) larger than currently achievable with stable beams. Calculations indicate that nuclei with large excess of neutrons will be much more stable against fission even at highest angular momentum. Exploration of the shape phase diagram at finite temperature for nucleus in an unknown part of the nuclear chart becomes open up.

One of the expected phenomena at high angular momentum is the Jacobi shape transition that corresponds to a nuclear shape change from oblate to tri-axial and very elongated prolate configurations. It has been predicted (Ref.2) to appear in many nuclei in the liquid drop regime and is considered as a gateway to hyper-deformed states. So far firm evidence of a Jacobi transition has been found only in light nuclei (Ref.3, 4). The difficulty inherent to the experimental study of these phenomena is related 1) to the width of the spin window covered by the oblate-triaxial Jacobi shape transition 2) and to the proximity of the maximal angular momentum a nucleus could sustain without fission. The first difficulty could be overcome by adding a multiplicity filter to control the J window. Favourable conditions are expected with neutron-rich nuclei beams delivered at SPIRAL2 facility since it will be possible to form compound nucleus at high angular momentum in the intermediate mass domain.

Thermal excitations play also a definite role in the shape diagram at finite temperature T. In the absence of rotation, thermal excitations wash out shell effects above a critical temperature and the equilibrium shape is spherical. For a rotating nucleus, one generally expects a non-collective oblate (i.e. rotating around the symmetry axis) shape. However, theoretical calculations (Ref.5) predict that many nuclei (mostly in the A=170-200 region) possess a temperature interval where rotation generates a prolate spheroid rotating along its symmetry axis: this is the non-collective prolate rotation, in contrast to that caused by the Jacobi transition described above. In such nuclei, a second critical temperature exists, above which the nucleus takes a non-collective oblate shape. These critical temperatures depend on the angular momentum *J* and on the chemical composition (respective number of protons and neutrons). One expects also the existence in the *T*-*J* diagram of a tri-critical point, around which non-collective oblate, non-collective prolate, and collective triaxial or oblate shapes coexist. The wide variety of neutron-rich beams at SPIRAL2 will be a great benefit for such investigations.

γ-rays from the GDR in hot nuclei are unique tool to study nuclear structure at finite temperature and angular momentum. Recent measurements reported on the importance of disentangling temperature *T* and spin *J* influences on the GDR width. The thermal shape fluctuation model (Ref.6) has been found to be very powerful in explaining the *T* and *J* dependence. Nuclear structure at finite temperature and angular momentum in neutron-rich nuclei will be explored using SPIRAL2 beams. This unique opportunity will extend our knowledge on hot GDR for neutron rich nuclei, which is crucial for going further since the GDR strength function may change when going towards more neutron rich systems – e.g. soft dipole modes can emerge.

As far as the measurement of isospin mixing in highly excited N=Z nuclei is concerned, a number of systems have been investigated so far, and the expected trend of decreasing mixing at high temperature has been observed (Ref.7). This effect is studied by measuring the hindrance of E1 emission in T(isospin)=0 nuclei produced when two T(isospin)=0, N=Z nuclei fuse. The GDR yield of this self-conjugate system is compared to that in a nearby N,Z nucleus. The isospin mixing coefficient α^2 is extracted using a statistical model. Nuclei have been studied in the mass range from A < 30 to A=60. As already mentioned, a decrease of the mixing coefficient at increasing temperature has already been measured, while there are hints of an increasing trend going towards heavier systems. The future availability of radioactive beams will make it possible to study heavier N=Z systems using for example ^{44}Ti, ^{56}Ni and ^{72}Kr beams.

The existence of GDR build on excited states is a good indicator of the cohesion of an excited nucleus. Conversely, the disappearance of the GDR might be considered as a signature of a transition towards a disordered regime. Numerous works have shown that the onset of multifragmentation process is around 3 AMeV of excitation energy. Many observables indicated that this mechanism sign a disordered phase of the nuclear system. Up to now, no attempt has been made to study the evolution of the GDR with excitation energy up to the onset of the multifragmentation process. With modern apparatus operated at future facilities, it would be possible to address the crucial issue of the fate of nuclei as a function of its neutron enrichment and its size, since finite size and Coulomb effects play a major role in both collective modes as GDR and instabilities development (Ref.8).

The GDR-decay is also a useful tool for investigating transport properties as viscosity in nuclear matter and deepens our understanding of the competition between the fusion and quasi-fission mechanisms. Both topics are crucial in the determination of the best conditions to explore the island of stability of super heavy elements.

The dynamical evolution of an excited nucleus is customary portrayed by transport theories. That brings in the concept of friction and diffusion forces that lead to a transfer of energy between collective and intrinsic degrees of freedom. This dissipation of energy affects the temporal evolution of the system. It is particularly important for fissile systems which splitting into two fragments can be strongly hindered. Experimentally, fission time scales are commonly inferred using particle and γ-GDR clocks (Ref.9). Nonetheless, due to the variety of shapes, excitation energies *E** and angular momentum *J* explored by the system along its decay, no consensus emerged yet about the strength of nuclear dissipation. The measure of the γ-ray multiplicity M_γ and energy sum E_γ in coincidence with the evaporation residue would allow to determine the entry point (*E*, J*) of those systems which do not fission. The knowledge of (*E*, J*) should permit unambiguously determining the magnitude of dissipation as well as its dependence on *E* and J* (Ref.10)

In heavy-ion collisions, capture by nuclear attraction is not necessarily followed by fusion. Instead, the intermediate di-nuclear system may re-separate due to Coulomb repulsion before achieving complete amalgamation into a compound nucleus CN. The resulting binary fragmentation is denominated quasi-fission (QF). Studying the competition between fusion and QF usually requires discriminating fission after CN formation (CNF) from QF, which differ in time and in the amount of energy dissipated. Yet, the excitation energy, angular momentum, nuclear structure and the shape at contact affect the dynamics and, thus, play a decisive role in defining the onset of QF (Ref.11). As noted above, the knowledge of M_γ and E_γ permits probing the influence of E^* and J. Furthermore, since the GDR line shape depends on the deformation of the emitter, the analysis of the γ-GDR component allow probing the distortion of the decaying system.

Since the earliest carbon-carbon scattering data in the 1950's, it has been speculated that anomalously narrow resonances in the carbon-carbon cross-section could be attributable to the formation of a short-lived molecular configuration. An approach to this problem that has not received so much attention is heavy ion radiative capture. In this case, for example, the putative molecular states in ^{24}Mg are formed through the fusion of two ^{12}C nuclei, and this highly excited system relaxes into the ^{24}Mg ground state through emission of γ rays. This purely electromagnetic mechanism has a very low cross-section in comparison to evaporation of light ions. One of the principal interests is whether this relaxation may take place via certain special high lying and highly deformed states in ^{24}Mg. This poses the simultaneous challenge of detecting high-energy (10-20 MeV) γ rays with high efficiency and high resolution in order to determine which states are involved. $LaBr_3$ with a resolution better than 100 keV at 10 MeV would be the ideal choice of detector for such studies, coupled with the very intense stable beams available at SPIRAL 2.

c) The device for the physics issues achievement.

This research area has been very productive thanks to the development of large acceptance arrays allowing high-energy γ-rays measurement with high efficiency (this emission process has a low probability), the best energy resolution (to extract accurate observables), a good timing property (to discriminate between the emitted neutrons and γ). Various arrays have been built worldwide as for example Château de Cristal (Ref. 15), HECTOR (Ref. 16), TAPS (Ref. 17). The more recent arrays comprised BaF_2 scintillation material, whose characteristics fulfil the requirement of high efficiency on a large range of energy, a good γ-neutron distribution using the time of flight method, and a good energy resolution. In most of the case, the time property of the BaF_2 leads to a relatively long flight path, and a large volume detector, placed relatively far from the target. Next generation devices require a better compactness and versatility. The good energy resolution is mandatory to have an accurate analysis of the energy distribution of the γ-rays.

Besides the measurement of the high-energy γ-rays, the characterization of the reaction is a key aspect to investigate the properties of excited and rotating nuclei. This characterization could be made by means of a high efficient array dedicated to the measurement of γ multiplicities and the γ-sum energy. In this way one could specify the angular momentum J and the excitation energy E^* of a reaction by selecting different gates on the γ-sum energy distribution and on the γ-fold. Experimental set-up including such a kind of multiplicity filter is very powerful to get new information on the J dependence of the shape of nuclei otherwise unreachable. This kind of device has been built in many laboratories and NaI scintillators were chosen for their energy resolution providing a gating procedure with good accuracy. Another example is the inner ball made of BGO installed in conjunction with EUROBALL IV (Ref. 18) with the aim to select specific reaction channels. Both examples indicate the power of a multiplicity filter.

Both kind of strategy were well adapted to specific cases. However, to fulfil the requirements shared by the described physics cases and to exploit efficiently the full capabilities of the future facilities, a new versatile γ-calorimeter is needed. Key characteristics of such new device are the following: the device need to handle γ-ray energies from 100 keV up to 40 MeV with the highest possible energy resolution; multiplicities Mγ from 1 to 30 and counting rates of about 10^4-10^5 Hz; high efficiency (>25% at 1.3 MeV, ~5% at 20 MeV) and good timing characteristics (a desired 1 ns time resolution, to separate γ and neutron induced events); highly segmented device, imposed by timing and efficiency constraints; a solid angle coverage of as close as possible to 4π; for flexibility, this 4π array has to be easily convert to a 2π or 1π geometry; for most of the physics cases described above, it will be necessary to operate the new array in conjunction with ancillary detectors. Neutron and light charged particles detection, as well as reaction mechanism tagging with spectrometers are particularly powerful. Intensive R&D program and GEANT4 simulations are needed to define a clear plan for such a new γ-calorimeter. Various scenaria of geometry have been carefully examined and global characteristics have been defined thanks to the ongoing activities within the PARIS collaboration.

d) The goal of the ANR demand: An innovative prototype for future γ-calorimeter, PROVA

The goal of the present ANR demand is to investigate a new and original concept of a phoswich composed of two components. The first one is a new scintillation material, the lanthanum halide (Ref. 19). It is characterized with unique capability of energy resolution, fast signal emission and good linearity over a broad temperature range. Here we are aware that the energy resolution of lanthanum halide is less than for Ge crystal which is the best for high resolution spectroscopy physics. However, the LaBr3:Ce detectors could be an alternative in γ spectroscopy in experiments in which the Doppler broadening due to the velocity of the emitting source is important. The second component of the phoswich will be a CsI(Na). Various options to collect and process the signals will be tested, to optimize the exploitation of the ensemble. Such a phoswich could provide innovative solutions and could be the prototype for two shells devices with the characteristics described above. This R&D phase will be done in close collaboration with the Saint-Gobain factory (see document for support from Saint-Gobain in the annex of the present document).

e) References

1 P. Bortignon, A. Bracco, R.A. Broglia, Giant Resonances: Nuclear Structure at Finite Temperature, Gordon Breach, New York 1998.
2 K. Pomorski, J. Dudek, *Phys. Rev.* **C67** (2003) 044316; J. Dudek, N. Schunck, N. Dubray, *Acta Phys. Pol.* **B36** (2005) 975
3 M. Kicinska-Habior et al., *Phys. Lett.* **B308** (1993) 225
4 A. Maj et al., *Nucl. Phys*. **A73**1 (2004) 319; M. Kmiecik et al., *Acta Phys. Pol*. **B36** (2005) 1169
5 A.L. Goodman, *Nucl. Phys*. **A687** (2001) 206c
6 W.E. Ormand, P.F. Bortignon, R.A. Broglia, *Nucl. Phys.* **A618** (1997) 20; N. Dubray, J. Dudek, A. Maj, *Acta Phys. Pol*. **B36** (2005) 1161; and references therein
7 M.N. Harakeh, et al., *Phys. Lett*. **B 176** (1986) 297; J. A. Behr, et al., *Phys. Rev. Lett.* **70** (1993) 3201; M. Kicinska-Habior, *Acta Phys. Pol.* **B 36** 1133 (2005); E. Wójcik et al., *Acta Phys. Pol.* **B 37** (2006) 207
8. D. Santonocito and Y. Blumenfeld, *EPJA,* ***A30*** (2006) 183.
9 D.J. Hinde et al., *NPA* ***502*** (1989) 452c and M. Thoennesseen et al., *PRL* ***59*** (1987) 2860
10 M.L. Halbert et al., *PRC* ***40*** (1989) 2558
11 M. Dasgupta, *NPA* ***734*** (2004) 148 and references therein
12 A.M. Sandorfi, Treatise on Heavy-Ion Science Vol. 2 Sec. 3, Plenum Press, New-York, 1985, and ref. therein
13 D.G. Jenkins et al., *Phys. Rev*. **C71** (2005) 04301
14 S. Courtin et al., Fusion 06, *AIP Conference Proceedings* **853** (2006) 134
15 F.A. Beck, Nuclear Science Research Conference Series (Oak Ridge1984), Vol7, Harvard Academy Publishers, ISSN 0250-4375
16 A. Maj et al. Nucl. Phys. A571 (1994) 185
17 TAPS Collaboration, Technical report, GSI Report 87-19, (1987).
18 Achievements with the Euroball spectrometer, W. Korten and S. Lunardi Eds., LNL, INFN Reports 201/2004.
19. A. Iltis, M.R. Mayhugh, P. Menge, C.M Rosza, O. Selles, V. Solovyev, NIM **A563** (2006) 359.

1.3 Objectifs et caractère ambitieux/novateur du projet/*Specific aims, highlight of the originality and novelty of the project*

A two shells γ-calorimeter is the more appropriate tool to address several open questions related to nuclear matter at finite temperature and angular momentum. This includes topics as giant dipole resonance properties, isospin mixing, reaction dynamics around the barrier up to the multifragmentation domain and molecular states in nuclei. The scientific objectives require the simultaneous measurement of several observables with the highest possible efficiency: i) high energy γ-rays, ii) γ-multiplicity/sum-energy information. Various attempts have been already made to combine existing arrays to fulfil both functions. The main drawback of this choice is the coupling of likely non-identical geometry that leads to a significant loss of the global efficiency. This is not acceptable in the perspective of fully exploit at future high intense stable and radioactive beam facilities. The main lesson to be learnt from the accumulated expertise is that, a new dedicated γ-calorimeter is definitively needed to achieve major goals of modern nuclear physics. It is worth noticing that such kind of calorimeter is an innovative means for the community. Its exploitation at new radioactive facilities will be of great benefit for our understanding of nuclear system far from stability and reinforces the competitiveness of the French scientific community in the international context.

A large array for γ-ray measurements are very challenging since many factors have to be taken into account: energy resolution, high efficiency, timing properties, signal processing; encapsulation of scintillation material as thin as possible; minimization of the dead zone in a large array; pile-up and granularity. Thus, an initial phase of R&D and simulations is unavoidable and must be performed in close connection. Various scenaria have been studied by means of GEANT4 simulations and possible segmentation, size of the modules and compactness of the array have been obtained using as basic scintillation material a LaBr3 for the inner shell combined to a CsI(Na) for the outer shell.

The scintillation materials (LaBr3:Ce or LaCl3:Ce) have been recently available. Saint-Gobain is the European factory providing this material. The LaBr3 scintillators are extremely attractive and fit our needs due to their excellent time resolution (few hundreds of picoseconds) and their good energy resolution (<3% at 662 keV, <1% at 15 MeV). The timing properties allow the measurement of the time of flight with high resolution (<200ps) and thus good γ-neutron discrimination. The time resolution is a strong requirement, since the fusion process with neutron-rich beams will be the main way of preparing the nucleus of interest. It is expected that many neutrons will be emitted and it is mandatory to have neutron-γ discrimination as clean as possible. Meanwhile, a short flight path implies a more compact geometry. The energy resolution is 2-3 times better than NaI(Tl) which is a great improvement to have an accurate energy-sum distribution. The material has also a fast scintillation decay time (30ns) that supports high counting rates and a light yield of 61000 photons/MeV greater than NaI(Tl),

The goal of the present ANR proposal is to test a new and original concept of a kind of phoswich composed LaBr3 and CsI(Na) bounded all together. CsI(Na) has been chosen for wavelength compatibility. Various options to collect the signals will be tested. One with the collection at the back of the CsI(Na), both components being bounded together in a common package; in the second option, the signal produced by the LaBr3 is collected with an optical guide (Wavelenght-Shifter) coupled to an APD or PM, while the signal coming from the CsI(Na) is collected with an APD (or PM). In both cases, the collected signals will be processed with a fast electronics allowing pulse shape analysis for two reasons: the first one is to extract properly the signal coming from the LaBr3 and take advantage of the time properties of the scintillation material; the second one is to discriminate neutron and γ. These works will be done using 1) standard radioactive sources and 2) neutron and γ at defined energies delivered at existing facilities. The proposed project includes also a simulation program to analyze the results and estimate the impact on the specification of a full array. It is worth noticing that our project will address many issues of prime importance for the design and the manufacturing of future γ-calorimeters as the PARIS array.

1.4 Description des travaux : programme scientifique/*For each specific aim: a proposed work plan should be described (including preliminary data, work packages and deliverables)*

1.4.1 Description of work packages of the AAP PROVA, with aims and milestones.

The present project comprises 5 main working packages (WP). Each of them is dedicated to specific objectives. Besides, the work package **W0** is the organization and the coordination of the project PROVA. The IPHC Strasbourg is the coordinator laboratory. The IPN Lyon, IPN Orsay and GANIL are the partner laboratories.

WP1: *Detectors.*
Aims:

- Gaining expertise on new γ-rays scintillation materials, lanthanum halides (LaBr3:Ce and LaCl3:Ce)
- Validation of the phoswhich concept of a lanthanum halide bounded with a CsI(Na).
- Definition of a protocol with Saint-Gobain to control the mechanical stability of the phoswich.

Milestones: New kind of phoswich
Responsible: GANIL
Partners: IPN Orsay, IPN Lyon, IPHC Strasbourg

WP2*: Electronics*

Aims:

- Exploration of various solutions for the light collection (Wavelength-Shifter, coupling with APD or PM) and find the best option.
- Finding the best solution for the neutron-γ discrimination (fast electronics, pulse shape analysis, digitalization).

Milestones: data processing
Responsible: IPHC Strasbourg
Partners: IPN Orsay

WP3: *Mechanics*
Aims:

- Design of the structure of the prototype.
- Evaluation on the geometry of the full array.

Milestones: Cell element for future array.
Responsible: IPHC Strasbourg

WP4: *Simulations*
Aims:

- Simulation of the response of the scintillation material,
- Implementation of the various options and consequences on a large acceptance array.
- Improve the simulation package in the GEANT4 environment.

Milestones: qualify new data on new scintillation material for simulation tools as GEANT4.
Responsible: IPN Lyon
Partners: IPHC Strasbourg, IPN Orsay

WP5: *Physics cases*
Aim:

- Verify the impact of the various choices on the physics cases of the future program.

Milestones: feasibility and timetable of various physics cases.
Responsible: IPN Lyon
Partners: GANIL, IPN Orsay

1.4.2 Deliverables.

Properties of lanthanum halide scintillation material have been well explored, and their characteristics are very attractive (see R. Nicolis *et al*, NIM A 582 (2007) 554; G.L. Case *et al*, NIM A563 (2006) 355: see ref 18 above). The main objective of the present project is to demonstrate its potentiality for future large acceptance array dedicated to γ-rays detection. To achieve this objective, a working plan has been establish and the expected results will improve our knowledge on the response of the new material in an environment similar to those encountered in experiment. Studies will be done at various facilities to measure carefully the response to the γ and to the neutrons. This will enrich database on scintillation material. It is worth noticing that we have decided to concentrate our efforts on the scintillation material without accumulate potential adaptation work with specific electronics. We decide to use existing available products for data readout and processing. Specific electronics will be studied by others teams of the collaboration PARIS. All the expected results on the stability of the scintillation material, dependence on likely experimental conditions, dependence of the efficiency and energy resolution, timing resolution and discrimination properties, capabilities to work in high data flux, will be gathered in a paper for publication in an international review. During the grant it is planned to present our results in international conference. An experiment addressing some of the various physics cases presented in 1.2 is foreseen during the last year of the grant, to be probably performed at one of the European facility as for example LNL (Italy) or GANIL (France).

1.4.3 Methodology.

The main idea that has driven our strategy is based on the very fact that the light collection from a scintillation material must be as best as possible. Coupling all together a lanthanum halide with an existing scintillation module (for example a BaF2) from an available array would imply to adapt them with a clear risk to degrade the light collection. It is by far more profitable to follow a coherent program, starting with the study of an element and ending with the building of a cluster of elements, whose sizes have been already carefully shaped by the ongoing activities on GEANT4 simulations within the international collaboration.

Step 1

Test of separated components.

Both components are lanthanum halides (LaBr3:Ce and LaCl3:Ce) and CsI(Na). At this level, the choice of the shape is not crucial; it could be of cylindrical or square section. As we want to compare the respective performances of the phoswich, different basic sizes are chosen and we will start with a 25.4mm (diameter or square) with 50mm thick for the Lanthanum halide and 150 mm for the CsI(Na). The two types of La have to be explored for timing resolution purposes since they are slightly different properties. It is also necessary to study both materials alone, to check the influence of their subsequent coupling with the second stage of the phoswich (CsI(Na). For those tests, we will use the scintillation material BrilLanCe®350 and BrilLanCe®380 from Saint-Gobain.

The following actions will be done:

a) Measurements of the global characteristics of the Lanthanum halide scintillation material under likely conditions of temperature, and get the reference data for the following investigations (the coupling to the second scintillator) to control the stability of the properties.

b) Testing the light collection emitted from BrilLanCe®350 and BrilLanCe®380 using APD and PM

c) Testing the option of the light collection with an optical guide (wavelenght-shifter fibre readout) coupled to an APD or a PMT. In this case a thin back window is requested for lanthanum halide.

d) Processing of the signal with fast electronic and/or pulse shape analysis. Study of the neutron-γ discrimination using Am/Be and Cf sources.

e) Same planning will be applied for BrilLanCe®350 and BrilLanCe®380 with a biggest section (50.8mm).

The expected results are:

- Validation of the APD/optical guide solution. Comparison of the various solutions for readout.
- Test on the neutron/gamma discrimination for the LaBr3 and LaCl3.
- Comparison of pulse shape analysis and time of flight method.
- Impact on the geometry (flight distance from the target) if shape analysis signal does not provide a clean discrimination.

At this stage, attempt will be made to start the study of the coupling of LaBr3(and LaCl3)/CsI(Na) with a readout of the light emitted from the lanthanum using an optical guide coupled to a PM/APD. This is a complementary option to a bounded ensemble with readout at the back of the phoswich. This attempt will require to couple the ensemble (scintillation material plus optical guide) to the CsI(Na). The Saint-Gobain factory will directly collaborate with the teams of the PROVA project for the specific mounting of both separated scintillation materials.

Step 2

Validation of the concept of bounded La/CsI(Na) phoswich.

Same shape and size as in Step1 will be employed first: 25,4mm section, 50 mm thick LaBr3 (and LaCl3) bounded to CsI(Na) 150 mm thick (means mounted in the same packaging). The ensemble is backed with APD/PMT and fast electronic.

a) A major issue is the mechanical stability of the ensemble, and the stability of performances under likely conditions of temperature, humidity and transportation. It is clear that the concept should be operational and the key issue is whether it stays in good optical contact. A possible foreseen solution would be to increase the thickness of the packaging with the requirement to not negatively impact the physics case. A protocol will be defined with Saint-Gobain factory to control the stability.

b) The light collection of the bounded LaBr3 (LaCl3)/CsI(Na) phoswich will be studied as in b) and c) in Step1. The comparisons of the performances, on timing, energy resolution, neutron-γ discrimination will be done, for phoswich and separated scintillators obtained in Step1

c) Same planning for a phoswich with biggest section (50.8 mm). The aim is to compare its performances i) with those obtained from the attempt made in Step1, and ii) with those obtained with a smallest section. Both ensembles with different section need to be explored, for future applications. This study with a 50.8 mm section is important because the expertise is absolutely needed to have a reference, and we could not based our project on extrapolations by means of simulations from the results obtained from measurements using a smallest size.

The expected results are

- Validation of the phoswich concept.
- Validation of the light collection and the signal processing (APD/PMT/optical guide, pulse shape analysis)

To get relevant information the LaBr3(LaCl3) used in Step1 and Step2 must have same characteristics. The manufacturing stages are not the same (one ensemble is bounded to a CsI(Na), the second one is separated), however the company handle the whole processing and it has been verify that properties of the material are reproducible.

Step 3

Test on beams.

A necessary step is the study of the response of the lanthanum halide (BrilLanCe®350 and BrilLanCe®380) and the various detector options (phoswich with readout at the back, ensemble with readout by optical guide) to neutron and γ-beams at different energies. The main purpose is to study the efficiency, the evolution of the energy resolution and the discrimination.

Neutrons and gammas beams of defined energies. This will be performed at different facility and the reference point between neutron and γ facilities will be obtained by means of the signal from standard sources and cosmic rays. Possible facility exists in France, Belgium, Germany and Italy.

Step 4

Building a cluster and test on beam: the add back techniques and the Doppler correction algorithm..

At this stage of the R&D program, we will be able to define our nominal prototype and we plan to build an ensemble/cluster of 3x3 of this prototype. This cluster will be tested at various facilities in Europe delivering tagged photon in order to study and test simulations that provide the efficiency of such system for high energy gamma rays, using the add-back techniques. This technique consists of adding signals of neighbouring detectors if the event is consistent with a single gamma ray event. This will be tested in dedicated experiments that will be performed during the last year of considered grant period. The other important property expected from the future array PARIS that will be used at SPIRAL2 is the capability of Doppler correction for γ-rays that are emitted from fast recoiling nuclei. This is mandatory of many future experiments that use PARIS as a spectrometer for in beam γ spectroscopy. This property will also be tested in dedicated experiments.

Step 5

The last step that will start beginning of last year of the grant period and will be the production of the detailed physics case for PARIS. Even though the scientific case is well established and accepted by the various scientific evaluations of SPIRAL2 physics, there is a need of pushing the description of typical experiments to details that prove the feasibility. This will be done by merging event generators that describe the physical ingredients and various detectors systems together with the PARIS array for a complete description of the experiment and the proof of its feasibility.

1.4.5 Summary and planning.

A prototype of a new phoswich will be defined during the two first years of the grant. An ensemble of 3x3 of these prototypes will be built on the third year and tested on beam. The last year will be devoted to perform an experiment.

1.5 Résultats escomptés et retombées attendues/*Expected results and potential impact*

The goal of the present ANR demand is to investigate a new and original concept of a phoswich built with a new scintillation material, the lanthanum halide. Such a phoswich could provide innovative solutions and could be the prototype for two shells large acceptance array as PARIS project. This R&D will be done in conjunction with the PARIS project. Once the phoswich concept is validated, this will allows us to seek for funding the full device among international institutions.

1.6 Organisation du projet/*Project flow*

The coordinator of the PROVA project is IPHC Strasbourg and partner 1(coordinator Marc ROUSSEAU).
IPN Lyon is partner 2 (scientific and technical correspondant, Olivier STEZOWSKI)
IPN Orsay is partner 3 (scientific and technical correspondant, Fayçal AZAIEZ)
GANIL is partner 4 (scientific and technical correspondant, Jean Pierre WIELECZKO)

Tâche/Tasks	Partenaires/Partners				Année 1 Year 1		Année 2 Year 2		Année 3 Year 3		Année 4 Year 4	
	1	2	3	4	6	12	18	24	30	36	42	48
1. W0 Project management, IPHC Strasbourg												
2. W1 Detectors, GANIL												
3. W2 Electronics, IPN Orsay												
4. W3 Mechanics, IPHC Strasbourg												
5.W4 Simulations, IPN Lyon												
6.W5 Physics cases, IPN Lyon, IPN Orsay, IPHC												
Rapports d'avancement semestriel Progress report/expenses												
Accord de consortium / rapport final Consortium agreement/final report						✪						☆

☺ : Rapport d'avancement semestriel/6 month-progress report
✪ : Accord de consortium (obligatoire dans le cas d'un partenariat public/privé, conseillé dans tous les autres cas)/Consortium agreement
☆ : Rapport de synthèse et récapitulatif des dépenses/Final report and expenses summary

TABLEAU des LIVRABLES et des JALONS (le cas échéant)/*Deliverables and milestones*			
Tâche Task	Intitulé et nature des livrables et des jalons/ *Title and substance of the deliverables and milestones*	Date de fourniture ***nombre de mois à compter de T0*** ***Delivery date, in months starting from T0***	Partenaire responsable du livrable/jalon *Partner in charge of the deliverable/ milestone*
1. Report Management			
	Report progress	Every six months	1
	Final report of PROVA grant	48	1
2. Detector			
	Validation of a prototype and test on beam	24	1
	Building cluster	36	3
	Physics case	48	3
3. Mechanics and Simulations			
	Mechanics	36	1
	Report on Simulation	Every 6 months	2
4. Publications			
	Database on prototype	24	4
	Synthesis report	48	4

Since the needs for the project is shared by the partners, to follow-up the status of the material and to rationalize the contacts with the industrial we decided to set-up a correspondent for the detectors (GANIL), a correspondent for the electronics (IPHC Strasbourg) and a correspondent for the light collection material (IPHC Strasbourg).

1.7 Organisation du partenariat/*Consortium organisation*

1.7.1 Pertinence des partenaires/*Consortium relevance*

All partners of this request have a long and reliable experience in spectroscopy studies (mainly with large gamma multi detectors such as EUROBALL, EXOGAM, Château de Cristal, HECTOR) and in particle detection. Close to accelerators, all teams have been really active in the experimental detection field and particularly in pulse shape analysis and Data processing in recent project as AGATA (IPHC, IPNL, IPNO) or FAZIA (GANIL).

Nuclear physics group of IPHC is involved since many years in the Research and Developments of γ multi detectors arrays as well as neutron detection system as DEMON. The laboratory was hosting EUROBALL when the VIVITRON accelerator was running and gained during this period an important knowledge in the mechanical design of large array. Moreover since height years this group is strongly involved in the digital electronic development in the context of AGATA.

The Matière Nucléaire group, from IPNLyon, has been involved for about eight years in Research and Developments to build AGATA. Its implication in AGATA covers several aspects to understand, to emulate and to analyze data coming out from the detector with, in particular, the development of original methods : as

- **Automatic Energy Calibration of Germanium Detectors Using Fuzzy Logic**
  NIMA 488 (2002) 314
- **Multidimentional calibration of the EXOGAM segmented clover**
  NIMA 4565 (2006) 623

The technics and knowledges gained, in terms of γ–ray reconstructions, will certainly benefit to the present project. Since one year, the IPN Lyon group leads the simulation required by the PARIS project which benefits from the expertise in GEANT4 simulations.

The IPNOrsay group has a long experience in γ-ray detection and in nuclear spectroscopy techniques. The expertise of some of this member in this domain are universally recognize (trough some project as *Château de cristal, EUROGAM, EUROBALL, EXOGAM, AGATA, RISING*). Moreover this laboratory has an important expertise in the scintillation detectors development. IPNOrsay will be in charge of the step 5 of the present demand with the need of the ALTO accelerator based in this laboratory.

Since several years, the GANIL group are involved on the Pulse Shape Analysis techniques through the FAZIA project. They gained during this period and important background in this technique and already develop a digital electronic for this project.

Finally, our interests for building an array based on scintillators is strongly motivated by the letter of intent signed by the majority of the physicist of the PROVA project in the SPIRAL2 context called " High-energy γ-rays as a probe of hot nuclei and reaction Mechanisms ". We are very interested in the development of a detection system with high efficiency for high-energy γ and have already an important role in the PARIS collaboration developed around this Letter of Intent.

1.7.2 Complémentarité et synergie des partenaires/*Added value of the consortium*

GANIL. Pulse shape analysis, digital electronics, detectors, physics case.
IPN Lyon : simulations et physics case
IPN Orsay : detection, scintillators, physics case
IPHC Strasbourg : detection, scintillators, digital electronics, mechanics.

We already have been working for several years with the different partners involved in the PROVA project. The developments of an innovative technique to detect γ–rays is a strong motivation for a well established collaboration.

1.7.3 Qualification du coordinateur du projet et des partenaires/*Principal investigator and partners : résumé and CV*

Bibliography of member involved in more than 25% EFT is given in annex.

1.8 Accès aux grands instruments/Access to large facilities

Contacts and requests for beams will be made in forthcoming weeks at CEA/DAM Bruyère le Châtel (France), Gellina (Belgium) and TU Darmstadt (Germany) *e.g.* installation providing tagged neutron and γ beams. During the grant period the following European Transnational Access facilities may be used: GANIL, LEGNARO, TANDEM-ORSAY.

1.9 Stratégie de valorisation et de protection des résultats/*Data management, data sharing, intellectual property strategy, and exploitation of project results* *(1/2 page maximum)*

The teams involved in the PROVA project, are well known and are composed of physicist from IN2P3, CEA and University, working at large international facilities and having a great expertise on managing ambitious projects in large collaborations. As stated above, it is expected that, if the prototype is validated, this will be a significant argument to seek for funds and sign a future MOU between the involved institutions of the international collaboration PARIS.

FICHES BUDGÉTAIRES - Blanc

Fiche Partenaire 1

Nom Complet du partenaire	Catégorie de partenaire	Base de calcul pour l'assiette de l'aide
Institut Pluridisciplinaire Hubert Curien (IPHC)	Organismes de recherche+Fondation de recherche	Coût marginal

Données financières (montant HT en € incluant la TVA non récupérable) 1

EQUIPEMENTS (€)	Personnels						Prestations de service externe (€)	Missions (€)	Autres dépenses (€)	Dépenses justifiées sur facturation interne (€)	Totaux (€)
	permanents		non permanents à financer par l'ANR		Autres non permanents						
	personne. mois	Coût (€)	*personne. mois*	Coût (€)	*personne. mois*	Coût (€)					
81 000	*108,00*	446 326	*36,00*	140 955				5 000	70 000		743 281

Montant maximum des frais de gestion/ frais de structure (€)	11 878	11878	<--Frais de gestion / frais de structure demandés (€)-->	11 878
Uniquement pour laboratoire d'organisme public de recherche ou fondation financé au coût marginal, indiquer le taux d'environnement		80,0%	Frais d'environnement (€)	469 825
			Coût complet (€)	**1 224 984**
			Coût éligible pour le calcul de l'aide : Assiette (€)	**308 833**
1		Taux d'aide demandée)--> 100%	***Aide demandée (€)***	***308 833***

Fiche Partenaire 2

Nom Complet du partenaire	Catégorie de partenaire	Base de calcul pour l'assiette de l'aide
Institut de Physique Nucléaire de Lyon (IPNL)	Organismes de recherche+Fondation de recherche	Coût marginal

Données financières (montant HT en € incluant la TVA non récupérable) 1

EQUIPEMENTS (€)	Personnels						Prestations de service externe (€)	Missions (€)	Autres dépenses (€)	Dépenses justifiées sur facturation interne (€)	Totaux (€)
	permanents		non permanents à financer par l'ANR		Autres non permanents						
	personne. mois	Coût (€)	*personne. mois*	Coût (€)	*personne. mois*	Coût (€)					
30 000	*28,80*	140 668						5 000	13 000		188 668

Montant maximum des frais de gestion/ frais de structure (€)	1 920	1920	<--Frais de gestion / frais de structure demandés (€)-->	1 920
Uniquement pour laboratoire d'organisme public de recherche ou fondation financé au coût marginal, indiquer le taux d'environnement		80,0%	Frais d'environnement (€)	112 534
			Coût complet (€)	**303 123**
			Coût éligible pour le calcul de l'aide : Assiette (€)	**49 920**

1	Taux d'aide demandée)-->	100%	**Aide demandée (€)**	**49 920**

Fiche Partenaire 3

Nom Complet du partenaire	Catégorie de partenaire	Base de calcul pour l'assiette de l'aide
Institut de Physique Nucléaire d'Orsay (IPNO)	Organismes de recherche+Fondation de recherche	Coût marginal

Données financières (montant HT en € incluant la TVA non récupérable) 1

EQUIPEMENTS (€)	Personnels						Prestations de service externe (€)	Missions (€)	Autres dépenses (€)	Dépenses justifiées sur facturation interne (€)	Totaux (€)
	permanents		non permanents à financer par l'ANR		Autres non permanents						
	personne. mois	Coût (€)	*personne. mois*	Coût (€)	*personne. mois*	Coût (€)					
58 000	*19,20*	140 000		46 985				5 000			249 985

Montant maximum des frais de gestion/ frais de structure (€)	4 399	4399	<--Frais de gestion / frais de structure demandés (€)-->	4 399
Uniquement pour laboratoire d'organisme public de recherche ou fondation financé au coût marginal, indiquer le taux d'environnement		80,0%	Frais d'environnement (€)	149 588
			Coût complet (€)	**403 972**
			Coût éligible pour le calcul de l'aide : Assiette (€)	**114 384**
1		Taux d'aide demandée)--> 100%	**Aide demandée (€)**	**114 384**

Fiche Partenaire 4

Nom Complet du partenaire	Catégorie de partenaire	Base de calcul pour l'assiette de l'aide
Grand Accélérateur d'Ions Lourd (GANIL)	Organismes de recherche+Fondation de recherche	Coût marginal

Données financières (montant HT en € incluant la TVA non récupérable) 1

EQUIPEMENTS (€)	Personnels						Prestations de service externe (€)	Missions (€)	Autres dépenses (€)	Dépenses justifiées sur facturation interne (€)	Totaux (€)
	permanents		non permanents à financer par l'ANR		Autres non permanents						
	personne. mois	Coût (€)	*personne. mois*	Coût (€)	*personne. mois*	Coût (€)					
67 000	*38,40*	240 000	*24,00*	93 970				5 000	10 000		415 970

Montant maximum des frais de gestion/ frais de structure (€)	7 039	7039	<--Frais de gestion / frais de structure demandés (€)-->	7 039
Uniquement pour laboratoire d'organisme public de recherche ou fondation financé au coût marginal, indiquer le taux d'environnement		80,0%	Frais d'environnement (€)	267 176
			Coût complet (€)	**690 185**
			Coût éligible pour le calcul de l'aide : Assiette (€)	**183 009**
1		Taux d'aide demandée)--> 100%	**Aide demandée (€)**	**183 009**

Fiche Partenaire 5

Nom Complet du partenaire	Catégorie de partenaire	Base de calcul pour l'assiette de l'aide

Veuillez préciser la catégorie de partenaire

Données financières (montant HT en € incluant la TVA non récupérable)

2

EQUIPEMENTS (€)	Personnels						Prestations de service externe (€)	Missions (€)	Autres dépenses (€)	Dépenses justifiées sur facturation interne (€)	Totaux (€)
	permanents		non permanents à financer par l'ANR		Autres non permanents						
	personne. mois	Coût (€)	*personne. mois*	Coût (€)	*personne. mois*	Coût (€)					
											-

Montant maximum des frais de gestion/ frais de structure (€)	-		<--Frais de gestion / frais de structure demandés (€)-->	-
Uniquement pour laboratoire d'organisme public de recherche ou fondation financé au coût marginal, indiquer le taux d'environnement			Frais d'environnement (€)	-
			Coût complet (€)	**-**
			Coût éligible pour le calcul de l'aide : Assiette (€)	**-**
1	Taux d'aide demandée)-->		***Aide demandée (€)***	-

Fiche Partenaire 6

Nom Complet du partenaire	Catégorie de partenaire	Base de calcul pour l'assiette de l'aide

Veuillez préciser la catégorie de partenaire

Données financières (montant HT en € incluant la TVA non récupérable)

2

EQUIPEMENTS (€)	Personnels						Prestations de service externe (€)	Missions (€)	Autres dépenses (€)	Dépenses justifiées sur facturation interne (€)	Totaux (€)
	permanents		non permanents à financer par l'ANR		Autres non permanents						
	personne. mois	Coût (€)	*personne. mois*	Coût (€)	*personne. mois*	Coût (€)					
											-

Montant maximum des frais de gestion/ frais de structure (€)	-		<--Frais de gestion / frais de structure demandés (€)-->	-
Uniquement pour laboratoire d'organisme public de recherche ou fondation financé au coût marginal, indiquer le taux d'environnement			Frais d'environnement (€)	-
			Coût complet (€)	**-**
			Coût éligible pour le calcul de l'aide : Assiette (€)	**-**
1	Taux d'aide demandée)-->		***Aide demandée (€)***	-

Fiche Partenaire 7

Nom Complet du partenaire	Catégorie de partenaire	Base de calcul pour l'assiette de l'aide

Veuillez préciser la catégorie de partenaire

2

Données financières (montant HT en € incluant la TVA non récupérable)

EQUIPEMENTS (€)	Personnels						Prestations de service externe (€)	Missions (€)	Autres dépenses (€)	Dépenses justifiées sur facturation interne (€)	Totaux (€)
	permanents		non permanents à financer par l'ANR		Autres non permanents						
	personne. mois	Coût (€)	*personne. mois*	Coût (€)	*personne. mois*	Coût (€)					
											-

Montant maximum des frais de gestion/ frais de structure (€)	-	
	<--Frais de gestion / frais de structure demandés (€)-->	-
Uniquement pour laboratoire d'organisme public de recherche ou fondation financé au coût marginal, indiquer le taux d'environnement	Frais d'environnement (€)	-
	Coût complet (€)	**-**
	Coût éligible pour le calcul de l'aide : Assiette (€)	**-**
Taux d'aide demandée)-->	***Aide demandée (€)***	***-***

1

Récapitulatif des données financières

	EQUIPEMENTS (€)	Personnels						Prestations de service externe (€)	Missions (€)	Autres dépenses (€)	Dépenses justifiées sur facturation interne (€)	Totaux (€)
		permanents		non permanents à financer par l'ANR		Autres non permanents						
		personne. mois	Coût (€)	*personne. mois*	Coût (€)	*personne. mois*	Coût (€)					
Partenaire1	81 000	108	446 326	36	140 955	-	-	-	5 000	70 000	-	743 281
Partenaire2	30 000	29	140 668	-	-	-	-	-	5 000	13 000	-	188 668
Partenaire3	58 000	19	140 000	-	46 985	-	-	-	5 000	-	-	249 985
Partenaire4	67 000	38	240 000	24	93 970	-	-	-	5 000	10 000	-	415 970
Partenaire5	-	-	-	-	-	-	-	-	-	-	-	-
Partenaire6	-	-	-	-	-	-	-	-	-	-	-	-
Partenaire7	-	-	-	-	-	-	-	-	-	-	-	-
	236 000	**194,40**	**966 994**	***60,00***	**281 911**	**-**	**-**	**-**	**20 000**	**93 000**	**-**	**1 597 905**

Frais de gestion / frais de structure demandés (€)-->	25 236
Frais d'environnement (€)	999 124
Coût complet (€)	**2 622 264**
Coût éligible pour le calcul de l'aide : Assiette (€)	**656 147**
Aide demandée (€)	***656 147***

2 Justification scientifique des moyens demandés/*Requested budget : detailed financial plan*

*On présentera ici **la justification scientifique et technique** des moyens demandés par chaque partenaire sur le site de soumission et synthétisés à l'échelle du projet dans le tableau récapitulatif ci-dessus.*

Chaque partenaire justifiera les moyens qu'il demande en distinguant les différents postes de dépenses.

2.1 Partenaire 1/*Partner 1 (IPHC)*

2.1.2 Equipement/*Large equipment*

During the two first years of the grant our team will study the collection of light of different type coupled with a LaBr3 as Photomultiplier (PM), Avalanche Photodiodes (APD's), and Wavelength-Shifter. We plan in particular to build a test bench to check the stability of APD's with voltage and temperature.
We will be also involved in tests on phoswich made by the others partners of the present project. During the second and third years we will start the development of a fast digital electronic to obtain a good timing resolution and to be able to perform a pulse shape analysis.
In parallel, mechanical development needed for all partners will be performed during the three first years.
Last year, we will be involved in the mounting of the cluster and on the test on beam.
Equipment needed consist in scintillators, crystals (LaBr3, CsI(Na)), and electronic material (Fast digital card, power supply, crates).

2.1.3 Personnel/*Manpower*

The IPHC Strasbourg asks for a three years postdoctoral position devoted to the development of a detection system based on scintillation material.
The candidate will have to get reliable skills in detection systems, and in particular, in crystals typically used for particle and gamma-ray spectroscopy. He/She will have the responsibility of the complete characterization and optimization of several combinations of a set of crystals (new crystals such as LaBr3:Ce with CsI) with different kind of photodetectors for light collection (Photomultipliers, Avalanche Photodiode, optical fibres). An expertise on first electronics stage like pre-amplifier will be essential as well as a mastery in pulse shape analysis. He/She will have to deal with ease with the data analysis whose the outcomes should be the linearity and stability of the detection system with the temperature and counting rate, the timing and energy resolution, the total efficiency taking into account the neutron/gamma discrimination.
This request is based on the necessity to get a skilled physicist full time on the project having an overview on all different aspects (detection system, electronics, pulse shape analysis, data analysis) in coordination with results coming from the simulated calculations.

2.1.4 Prestation de service externe/*Services, outward facilities*

None

2.1.5 Missions/*Travels*

Progress in the research will be discussed during regular meeting every six months. It is foreseen to present results obtained during the grant at international conference. Funds to perform experiments at facility are needed.

2.1.6 Dépenses justifiées sur une procédure de facturation interne/*Expenses for inward billing*

None

2.1.7 Autres dépenses de fonctionnement/*Other expenses*

Other expenses consist in electronic material, and light collection material as small size APDs, PM, Wavelength-Shifter and mechanical material for the development of the test bench.

2.2 Partenaire 2/*Partner 2 (IPNL)*

2.2.1 Equipement/*Large equipment*

During the four years of the grant our team will develop the geant4 simulation program for the consortium and modelisation of the scintillation and light collection, analysis of the collected signal for a single element and γ–ray reconstruction in a cluster. In this context we plan to buy during the first year a single Phoswich and the third year a cluster of 3 Phoswich that we will test with gamma sources to compare with our modelisation.

2.2.2 Personnel/*Manpower*

None

2.2.3 Prestation de service externe/*Services, outward facilities*

None

2.2.4 Missions/*Travels*

Progress in the research will be discussed during regular meeting every six months. It is foreseen to present results obtained during the grant at international conference. Funds to perform experiments at facility are needed.

2.2.5 Dépenses justifiées sur une procédure de facturation interne/*Expenses for inward billing*

None

2.2.6 Autres dépenses de fonctionnement/*Other expenses*

Expenses consist mainly in computing material for all the partner (PC's, disk) to perfomed simulation and modelisation.

2.3 Partenaire 3/Partner 3 (IPNO)

2.3.1 Equipement/*Large equipment*

During the last years of the grant our team will work on the demonstrator, the building of the ensemble and on the test on different facilities. Our main activities will be related to the add back technique and the Doppler shift correction algorithm.

2.3.2 Personnel/*Manpower*

A post doc is requested for the last year of the grant. The candidate should have few years of research in experimental nuclear physics with an expertise in taking data and skills for data analysis and simulations. Capability in setting-up an some knowledge on γ detection is welcomed.

2.3.3 Prestation de service externe/*Services, outward facilities*

None

2.3.4 Missions/*Travels*

Progress in the research will be discussed during regular meeting every six months. It is foreseen to present results obtained during the grant at international conference. Funds to perform experiments at facility are needed.

2.3.5 Dépenses justifiées sur une procédure de facturation interne/*Expenses for inward billing*

None

2.3.6 Autres dépenses de fonctionnement/*Other expenses*

None

2.4 Partenaire 4/Partner 4 (GANIL)

2.4.1 Equipement/*Large equipment*

During the two first years of the grant our team will study the properties of scintillation material LaBr3 :Ce bounded to a CsI(Na) with light collection using a PM from Hamamatsu. Performances of this phoswich will be compared to those of the LaBr3 :Ce alone. Evolution in time and energy resolution will be examined. Pulse shape analysis and time of flight measurements will be performed to study the neutron-γ discrimination and to compare both methods. Scintillation Material and electronics adapted for PSA are needed for these studies. In the third year, we will check 2 prototypes and we will be involved in the mounting of the cluster and on the test on beam.

2.4.2 Personnel/*Manpower*

A post doc is requested for the two first years of the grant. The candidate should have few years of research in experimental nuclear physics with an expertise in taking data and skills for data analysis and simulations. Capability in setting-up an experiment and knowledge both pulse shape analysis and on the problematic of the neutron-γ discrimination are demanded. Experimental activities using large acceptance array is a plus.

2.4.3 Prestation de service externe/*Services, outward facilities*

None

2.4.4 Missions/*Travels*

Progress in the research will be discussed during regular meeting every six months. It is foreseen to present results obtained during the grant at international conference. Funds to perform experiments at facility are needed.

2.4.5 Dépenses justifiées sur une procédure de facturation interne/*Expenses for inward billing*

None

2.4.6 Autres dépenses de fonctionnement/*Other expenses*

Other expenses consist in electronic material, and light collection material as small size APDs, PM, Wavelength-Shifter.

Annexes IPHC PARTNER 1

Description des partenaires/*Partners informations* (cf. § 1.7.1) *(1 page maximum par partenaire)*

Nom	Emploi	% temps	**Taches :**
Rousseau Marc	McF	70%	**Coordination**+ banc de test + Discrimination
Courtin Sandrine	McF	20%	Responsable Design mécanique Cluster
Dorvaux Olivier	McF	15%	Gestion collecteurs lumière (Fibres, APD, PM) + banc de test +Discrimination
Beck Christian	DR	15%	Programme de physique, Design mécanique Cluster
Curien Dominique	CR	15%	tests détecteurs
Gamelin Emanuel	IR	10%	Bureau d'étude: Design mécanique Cluster.
Thomas Dominique	TCN	10%	Fabrication mécanique
Peaupardin Philippe	IR	20%	Développement banc de tests
Maazouzi Chacker	IR	20%	Electronique Front-end et Controle/Commande banc de tests
Chambit El Mehdi	IR	10%	Electronique digitale Programmation VHDL
Charles Laurent	IE	10%	Electronique digitale Programmation VHDL
Richer Marc	IE	10%	Electronique digitale Développement Software
Baumann Remy	IE	10%	Electronique digitale Développement Software

Biographies/*Résumés and CV* (cf. § 1.7.3) *(1 page maximum par personne)*

CURRICULUM VITAE

Nom : ROUSSEAU
Prénom : Marc
Age : 37 ans
Tél : 03 – 88 -10 – 64 – 58
Mèl : marc.rousseau@ires.in2p3.fr

Situation professionnelle :

maître de conférence Université Louis Pasteur (Strasbourg) .
Affecté à l'Institut Pluridisciplinaire Hubert Curien depuis le 01/11/2002.

Cursus :

2002-2008 : MdC – IPHC Strasbourg, UMR 7178-LC4
2001-2002 : Postoc - University of Surrey
2000-2001 : ATER – Université Louis Pasteur (Strasbourg)
1998-2000 : Thèse de doctorat en Physique Nucléaire

Responsabilités:

Coordinateur Scientifique et technique du projet Spiral 2 à l'IPHC, responsabilité d'une équipe de 12 ITA .

Coordinateur Scientifique pour le CNRS du Laboratoire International Associé : **LIA FJ-NSP** « French-Japanese Associated Laboratory for Nuclear Structure Problems »

Responsable du transfert et de l'installation du multidétecteur de particule chargée ICARE au Heavy Ions Laboratory (Varsovie).

Spokesperson de 2 experiences acceptées

Liste des cinq publications les plus significatives :

M.Brekiesz, A.Maj, M.Kmiecik, K.Mazurek, W.Meczynski, J.Styczen, K.Zuber, P.Papka, C.Beck, F.Haas, V.Rauch, M.Rousseau, A.Sanchez i Zafra, J.Dudek, N.Schunck *Deformation Effects in Hot Rotating ^{46}Ti Probed by the Charged Particle Emission and GDR γ-Decay* Nucl.Phys. A788, 224c (2007)

D.G.Jenkins, B.R.Fulton, P.Marley, S.P.Fox, R.Glover, R.Wadsworth, D.L.Watson, S.Courtin, F.Haas, D.Lebhertz, C.Beck, P.Papka, M.Rousseau, A.Sanchez i Zafra, D.A.Hutcheon, C.Davis, D.Ottewell, M.M.Pavan, J.Pearson, C.Ruiz, G.Ruprecht, J.Slater, M.Trinczek, J.D'Auria, C.J.Lister, P.Chowdhury, C.Andreoiu, J.J.Valiente-Dobon, S.Moon *Decay strength distributions in $^{12}C(^{12}C, \gamma)$ radiative capture* Phys.Rev. C 76, 044310 (2007)

M. Assunçao, M. Fey, A. Lefebvre-Schul, J. Kiener, V. Tatischeff, J.W. Hammer, C. Beck, C. Boukari-Pelissie, A. Coc, J.J. Correia, S. Courtin, F. Fleurot, E. Galanopoulos, C.Grama, F. Haas, F.Hammache, F. Hannachi, S.Harissopulos, A.Korichi, R. Kunz, D.Le Du, A.Lopez-Martens, D.Malcherek, R.Meunier, T.Paradellis, M.Rousseau, N.Rowley, G.Staudt, S.Szilner, J.P. Thibaud and J.L. Weil. *E1 and E2 S factors of $^{12}C(a,\gamma_0)^{16}O$ from γ-ray angular distributions with 4π-detector array.* Phys.Rev. C 73, 055801 (2006)

J.W.Hammer, M.Fey, R.Kunz, J.Kiener, V.Tatischeff, F.Haas, J.L.Weil, M.Assuncao, C.Beck, C.Boukari-Pelissie, A.Coc, J.J.Correia, S.Courtin, F.Fleurot, E.Galanopoulos, C.Grama, F.Hammache, S.Harissopulos, A.Korichi, E.Krmpotic, D.Le Du, A.Lopez-Martens, D.Malcherek, R.Meunier, P.Papka, T.Paradellis, M.Rousseau, N.Rowley, G.Staudt, S.Szilner
E1 and E2 capture cross section and astrophysical reaction rate of the key reaction $^{12}C(\alpha, \gamma)^{16}O$
Nucl.Phys. A758, 363c (2005)

D.Mahboub, C.Beck, B.Djerroud, R.M.Freeman, F.Haas, R.Nouicer, M.Rousseau, P.Papka, A.Sanchez i Zafra, Sl.Cavallaro, E.De Filippo, G.Lanzano, A.Pagano, M.Sperduto, E.Berthoumieux, R.Dayras, R.Legrain, E.Pollacco, A.Hachem
Light particle emission in $^{35}Cl + ^{24}Mg$ fusion reactions at high excitation energy and angular momentum
Phys.Rev. C 69, 034616 (2004)

Total : 47 publications dans des revues à comité de lecture

Implication des personnes dans d'autres contrats/*Partner's involvement in other projects* (cf. § 1.7.3) *(un tableau par partenaire)*

Partenaire Partner	Nom de la personne participant au projet Name of the person involved in the project	Personne. Mois Man.month	Intitulé de l'appel à projets Source de financement Montant attribué Name call for proposals Other fundings from different organisms Allocated budgets	Titre du projet Proposal title	Nom* du coordinateur Name Principal Inverstigator	Date début -Date fin Start-End of the project
N° 1	Rousseau Marc	5,4	SHELS ANR-06-BLAN-0034-01 435 000 €	Separator for Heavy ELement Spectroscopy	Araceli LOPEZ_MARTENS ,	6/11/2006 – 6/11/2009
N° 1	Dorvaux Olivier	32,4	SHELS ANR-06-BLAN-0034-01 **435 000 €**	Separator for Heavy ELement Spectroscopy	Araceli LOPEZ_MARTENS ,	6/11/2006 – 6/11/2009
N° 1	Curien Dominique	5,4	SHELS ANR-06-BLAN-0034-01 **435 000 €**	Separator for Heavy ELement Spectroscopy	Araceli LOPEZ_MARTENS ,	**6/11/2006 – 6/11/2009**
N° 1	Chambit El Mehdi	3,6	SHELS ANR-06-BLAN-0034-01 **435 000 €**	Separator for Heavy ELement Spectroscopy	Araceli LOPEZ_MARTENS ,	**6/11/2006 – 6/11/2009**
N° 1	Richer Marc	3,6	SHELS ANR-06-BLAN-0034-01 **435 000 €**	Separator for Heavy ELement Spectroscopy	Araceli LOPEZ_MARTENS ,	**6/11/2006 – 6/11/2009**
N° 1	Richer	10	Dispalened ANR 210000 €	Developpement innovant de la spectroscopie gamma et application à l'etude du nucleaire durable	Philippe dessagne	**2007-2010**
N° 1	chambit	10	Dispalened ANR 210000 €	Developpement innovant de la spectroscopie gamma et application à l'etude du nucleaire durable	Philippe dessagne	**2007-2010**

Demandes de contrats en cours d'évaluation[1]/Other proposals under evaluation

None

[1] *Mentionner ici les projets en cours d'évaluation soit au sein de programmes de l'ANR, soit auprès d'organismes, de fondations, à l'Union Européenne, etc. que ce soit comme coordinateur ou comme partenaire. Pour chacun, donner le nom de l'appel à projets, le titre du projet et le nom du coordinateur.*

Annexes   IPNL PARTNER 2

Description des partenaires/*Partners informations* (cf. § 1.7.1) *(1 page maximum par partenaire)*

Nom	Emploi	% temps	**Taches :**
Stezowski Olivier	CR	30%	**Correspondant IPN Lyon**, Simulation, gestion ressources informatique
Schmitt Christelle	CR1	30%	Simulation, Programme de physique

Biographies/*Résumés and CV* (cf. § 1.7.3) *(1 page maximum par personne)*

Implication des personnes dans d'autres contrats/*Partner's involvement in other projects* (cf. § 1.7.3) *(un tableau par partenaire)*

None

Demandes de contrats en cours d'évaluation[2]/Other proposals under evaluation

None

[2] *Mentionner ici les projets en cours d'évaluation soit au sein de programmes de l'ANR, soit auprès d'organismes, de fondations, à l'Union Européenne, etc. que ce soit comme coordinateur ou comme partenaire. Pour chacun, donner le nom de l'appel à projets, le titre du projet et le nom du coordinateur.*

Annexes IPNO PARTNER 3

Description des partenaires/*Partners informations* (cf. § 1.7.1) *(1 page maximum par partenaire)*

Nom	Emploi	% temps	**Taches :**
Azaiez Faical	DR2	25%	**Correspondant IPN Orsay**, Programme de physique, Cluster,
Franchoo Serge	CR1	15%	simulation, discrimination
Scarpaci Jean Antoine	DR2	15%	simulation,gestion ressources électroniques, discrimination

Biographies/*Résumés and CV* (cf. § 1.7.3) *(1 page maximum par personne)*

Implication des personnes dans d'autres contrats/*Partner's involvement in other projects* (cf. § 1.7.3) *(un tableau par partenaire)*

Partenaire Partner	Nom de la personne participant au projet Name of the person involved in the project	Personne. Mois Man.month	Intitulé de l'appel à projets Source de financement Montant attribué Name call for proposals Other fundings from different organisms Allocated budgets	Titre du projet Proposal title	Nom* du coordinateur Name Principal Inverstigator	Date début -Date fin Start-End of the project
N°3	F Azaiez	7.2	AAP blanc ANR 550 000 €	RAS2 Recherche Amont pour le projet SPIRAL 2	D. Gardès	01-2006 11-2008
N°3	S. Franchoo	25.2	AAP blanc ANR 550 000 €	RAS2 Recherche Amont pour le projet SPIRAL 2	D. Gardès	01-2006 11-2008
N°3	J.A Scarpacci	**7.2**	AAP blanc ANR 550 000 €	RAS2 Recherche Amont pour le projet SPIRAL 2	D. Gardès	01-2006 11-2008

Demandes de contrats en cours d'évaluation[3]/Other proposals under evaluation

None

[3] *Mentionner ici les projets en cours d'évaluation soit au sein de programmes de l'ANR, soit auprès d'organismes, de fondations, à l'Union Européenne, etc. que ce soit comme coordinateur ou comme partenaire. Pour chacun, donner le nom de l'appel à projets, le titre du projet et le nom du coordinateur.*

Annexes GANIL PARTNER 4

Description des partenaires/*Partners informations* (cf. § 1.7.1) *(1 page maximum par partenaire)*

Nom	Emploi	% temps	**Taches :**
Wieleczko Jean Pierre	Physicien CEA	40%	**correspondant GANIL,** Programme de physique, simulation, gestion ressources détecteurs
Chbihi Abdelouahad	DR2	20%	discrimination, Analyse des formes d'impulsion
Frankland John	CR1	20%	discrimination, Analyse des formes d'impulsion

Biographies/*Résumés and CV* (cf. § 1.7.3) *(1 page maximum par personne)*

Curriculum Vitae Jean Pierre WIELECZKO

Name: Wieleczko
Surname: Jean-Pierre
Âge: 58 ans
Docteur ès Sciences 1985
Permanent position since 1980, at CEA and senior scientist at GANIL since 1990.
Spokesperson of six experiments, one in USA at ORNL.
Member of Scientific Committee of International Workshop
Supervisor of 5 students and Co-supervisor of 3 students.
Spokesperson of the Collaboration INDRA
Member of the Steering Committee of the PARIS Collaboration.

Recent publications:

Yield scaling, size hierarch and fluctuations of observables in fragmentation of excited heavy nuclei.
N. Le Neindre, E. Bonnet, J.P. Wieleczko, B. Borderie, F. Gulminelli, M.F. Rivet, R. Bougault, A. Chbihi, R. Dayras, J.D. Frankland, E. Galichet, D. Guinet, P. Lautesse, A. LeFèvre, O.Lopez, J. Lukasik, D. Mercier, J. Moisan, M. Pârlog, E. Rosato, R. Roy, C. Schwarz, C. Sfienti, B. Tamain, W. Trautmann, A. Trzcinski, K. Turzo, E. Vient, M. Vigilante, B. Zwieglinski.
Nuclear Physics A 795 (2007) 47-69

Dynamical and thermodynamical features in the fragmentation process.
J.P Wieleczko, R. Bougault, A. Chbihi, D. Durand, C. Escano Rodriguez, J.D Frankland.
Revista Mexicana de Fisica S 52 (4) 109

Bimodality : a possible experimental signature of the liquid-gas phase transition of nuclear matter
Pichon M., Tamain B., Bougault R., Gulminelli F., Lopez O., Bonnet E., Borderie B., Chbihi A., Dayras R., Frankland J.D., Galichet E., Guinet D., Lautesse P., Le Neindre N., Parlog M., Rivet M.F., Roy R., Rosato E., Vient E., Vigilante M., Volant C., Wieleczko J.P., Zwieglinski B.
Nuclear Physics A 779 (2006) 267-296

Evolution of the fusion cross-section for light systems at intermediate energies
Lautesse P., Nalpas L., Dayras R., Rivet M.F., Parlog M., Bisquer E., Borderie B., Bougault R., Buchet P., Charvet J.L., Chbihi A., Colonna M., Demeyer A., Désesquelles P., Frankland J.D., Galichet E., Gerlic E., Guinet D.C.R., Legrain R., Le Neindre N., Lopez O., Manduci L., Maskay A.M., Noguère G., Rosato E., Roy R., Schmitt C., Stern M., Tamain B., Vient E., Vigilante M., Volant C., Wieleczko J.P.,
Eur. Phys. J. A 27 (2006) 349

Characteristics of the fragments produced in central collisions of
^{129}Xe+^{nat}Sn from 32A to 50A MeV
Hudan S., Chbihi A., Frankland J.D., Mignon A., Wieleczko J.P., Auger G., Bellaize N., Borderie B., Botvina A., Bougault R., Bouriquet B., Buta A.M., Colin J., Cussol D., Dayras R., Durand D., Galichet E., Guinet D., Guiot B., Lanzalone G., Lautesse P., Lavaud F., Lecolley J.F., Legrain R., Le Neindre N., Lopez O., Manduci

L., Marie J., Nalpas L., Normand J., Parlog M., Pawlowski P., Pichon M., Plagnol E., Rivet M.F., Rosato E., Roy R., Steckmeyer J.C., Tabacaru G., Tamain B., van Lauwe A., Vient E., Vigilante M., Volant C.

Physical Review C, Volume 67 , Fascicule 6. (2003) 064613-1-14.

Implication des personnes dans d'autres contrats/*Partner's involvement in other projects* (cf. § 1.7.3) *(un tableau par partenaire)*

Partenaire Partner	Nom de la personne participant au projet Name of the person involved in the project	Personne. Mois Man.month	Intitulé de l'appel à projets Source de financement Montant attribué Name call for proposals Other fundings from different organisms Allocated budgets	Titre du projet Proposal title	Nom* du coordinateur Name Principal Inverstigator	Date début -Date fin Start- End of the project
N°4	Wieleczko J.P	7.2	AAP Blanc ANR 37440 euros	AZ4π-France	Rémi Bougault	2005- June 2008
N°4	A. Chbihi	**9**	AAP Blanc ANR 37440 euros	AZ4π-France	Rémi Bougault	2005- **June 2008**
N°4	J.D Frankland	**7.2**	AAP Blanc ANR 37440 euros	AZ4π-France	Rémi Bougault	2005- **June 2008**

Demandes de contrats en cours d'évaluation[4]/Other proposals under evaluation

None

[4] *Mentionner ici les projets en cours d'évaluation soit au sein de programmes de l'ANR, soit auprès d'organismes, de fondations, à l'Union Européenne, etc. que ce soit comme coordinateur ou comme partenaire. Pour chacun, donner le nom de l'appel à projets, le titre du projet et le nom du coordinateur.*

SUMMARY of PROVA

The advent of new nuclear facilities delivering a wide panoply of high intensity radioactive and stable beams, will allow to investigate phenomena in an unexplored part of the nuclear chart. The adequate tool for numerous physics case addressing the large spectra of behaviours of the nuclear fluid is a dedicated γ-calorimeter made of two shells. There is a large consensus in the international community for such need of a new dedicated array. This will be of great benefit for our understanding of nuclear system far from stability and reinforces the competitiveness of the French scientific community in the international context. A large array for γ-ray measurements are very challenging since many factors have to be taken into account. Recent developments on new scintillation material could provide solutions for arrays to be operated during few tenths of coming years. The goal of the present demand called PROVA is to test a new and original concept of phoswich using this recent scintillation material. A clear methodology has been established to address the different technical issues. The teams involved in the project (from IPN Lyon, IPN Orsay, IPHC Strasbourg, GANIL Caen laboratories) come from IN2P3, CEA and University. They have a high scientific and technical expertise needed to achieve successfully this R&D program, and they are well recognised at national and international level. The planned research will be performed in collaboration with the company Saint-Gobain Crystal factory. Results obtained during the grant will be published in international reviews and presented in international conferences. The last year of the grant will be devoted to perform an experiment with a set-up including the cluster made of prototype. The prototype is expected to be an elementary cell for future γ-calorimeters as the PARIS which has been selected as a part of the SPIRAL2 Preparatory Phase within the European FP7 program.

Annexes support from Saint-Gobain

SAINT-GOBAIN
CRYSTALS

Prof. Jean-Pierre Wieleczko
GANIL
Boulevard Henri Becquerel
14076 CAEN Cedex

Nemours, February 26th, 2008

Objet: letter of interest to PROVA project

Dear Pr Wieleczko

We are pleased to confirm our support for your ANR grant application to PROVA (PROtotype for a Versatile γ-Array). In particular, you propose to advance Gamma / Neutron Discrimination technology by combining our BrilLanCe™ 350 or BrilLanCe™ 380 detectors with CsI(Na) scintillators. Your research is of considerable interest to us, as we will explain.

Through considerable internal development and investment, Saint-Gobain Cristaux & Détecteurs (SGCD) has been able to produce BrilLanCe detectors with upgraded spectroscopy performance to gamma rays of medium energy. PROVA' project to further explore high energy gamma and neutron response by combining BrilLanCe material and CsI(Na) into a phoswhich assembly is a unique concept consistent with our expertise and key for Physics projects.

We expect that SGCD's support will enhance collaboration to develop valuable new technology to the Physics community.

SGCD looks forward to an opportunity to assist PROVA's project and expects that the collaboration between SGCD and the teams involved in the PROVA project will accelerate the development of a new detection system to support physics experiments.

Sincerely,

Jean-Luc Allain

Position: General Manager

Date: Feb 27th 2008