Acronym	**PRO-AFTER**		
Titre du projet	Prospectives pour une expérience sur cible fixe sur les faisceaux du LHC : Physique, Design, Intégration, R&D et communication.		
Proposal title	**PRO**spectives for **A** **F**ixed-**T**arget **E**xper**R**iment on the LHC beams : Physics case, Design, Integration, R&D and communication.		
Evaluation Committee	SIMI 5		
Type of research	X Basic Research ☐ Industrial Research ☐ Experimental Development		
International cooperation (if applicable)	X OUI ☐ NON		
Grant requested	569 660,00 €	**Project duration**	48 mois

1. Executive summary

The research project PRO-AFTER is an ambitious proposal which aims at forming in the long run a new international collaboration working on a fixed-target program using the 7 TeV proton and the 2.76 TeV lead beams of the CERN Large Hadron Collider extracted by bent crystals. At the heart of the proposal is the integration of the expertise of experimentalists, theorists and engineers at the very beginning of the conception of this fixed-target experiment, which we believe will become the first of a new generation. Beam extraction by bent crystals offers an ideal way to obtain a clean and very collimated high-energy beam, without decreasing the performance of the LHC. This technique is now becoming mature with successful tests at SPS (450 GeV) and at the Tevatron (900 GeV) and with approved tests at the LHC (3.5 or 7 TeV).

Using the unprecedented energies of the LHC beams, such an experiment, tentatively named AFTER for "A Fixed-Target ExperRiment", gives access to new domains of particle and nuclear physics complementing that of collider experiments, in particular that of Brookhaven's Relativistic Heavy Ion Collider (RHIC) and the projects of Electron-ion colliders (EIC). We have already evaluated that the instantaneous luminosity achievable with AFTER using typical targets would surpass that of RHIC by more than 3 orders of magnitude. As simple as it seems, the multi-TeV LHC beams will also allow for the most energetic fixed-target experiments ever performed.

The fixed-target mode will permit us to carry out unprecedented precision measurements of hard QCD processes. In particular, our aim is to perform novel studies of rare configurations of the proton wave function which contain gluon or heavy-quarks with high momentum fraction; the gluon content in the deuteron and neutron in a wide momentum-fraction range; the correlation between the proton spin and the gluon angular momentum through the Sivers effect and novel spin correlations; the production of W and Z bosons in their threshold domain; the deconfinement dynamics in the target-rest frame in heavy-ion collisions and the melting of excited heavy-quark bound states in the deconfined QCD phase; the nucleus structure function for momentum fractions close to and above unity; and ultra-peripheral collisions (UPC) in a fixed-target mode.

The main asset of our consortium is the capacity to work in synergy to provide the most ambitious physics case for an optimal detector, designed with the constraints of the mechanics, the beam and the target. We plan to work in close coordination on the physics case, the simulation and design of the detector, its integration and two critical R&D actions; these correspond to 4 of the 5 tasks of our proposal. The fifth task is devoted to writing a conceptual design report and towards advertising our project to attract more colleagues to our effort. Indeed, we believe it is well worth exploring this option and bringing our nuclear and particle physicist colleagues' attention to all these new physics opportunities.

2. Context, position and objectives of the proposal

2.1. Context

Within the Standard Model of elementary-particle physics, Quantum ChromoDynamics (QCD) is the theory of strong interaction – one of the four fundamental interactions in physics. It binds quarks and gluons inside the nucleons as well as the nucleons inside the nuclei. While one understands QCD at short distances (the perturbative domain), phenomenon such as confinement of quarks and gluons in the nucleons is still not understood at a fundamental level. There is also no *ab initio* understanding of their dynamics within both nucleons and nuclei.

With the advent of the Large Hadron Collider (LHC) at CERN, a new era of particle and nuclear physics has begun. The LHC allows us to delve into QCD dynamics with protons and lead ions accelerated to a record nominal collision energy of 14 TeV and 5.5 TeV respectively – one order of magnitude beyond the previous colliders. The primary goals of the LHC were the discovery of the Higgs boson and the search for physics beyond the Standard Model. Two years after the first recorded collisions, the LHC has however also been recognized as an outstanding machine to study QCD with a remarkable precision, thanks to its large reaction rates and the modern detection techniques of its detectors.

Nevertheless, these detectors do not permit us to study processes producing very high longitudinal momentum particles. Such reactions are, however, particularly important in understanding the dynamics and confinement of quarks and gluons which carry the largest momentum fraction of the projectile particles.

By extracting a small fraction of the intense LHC beams to collide it with fixed targets, we can study produced particles without restrictions since the beam comes from one side only. Using the unprecedented energies of the LHC beams, our project, named AFTER[1] for "A Fixed-Target ExperRiment", gives access to new domains of particle and nuclear physics complementing that of collider experiments, in particular the Brookhaven's Relativistic Heavy Ion Collider (RHIC) and the to-be Electron-ion colliders (EIC).

2.2. Position of the project

The multi-TeV energy of the LHC beams would make this fixed-target physics program unique. As simple as it seems, the high energy LHC beams will allow for the most energetic fixed-target experiments ever performed. We believe that such a facility will be of much interest to a wide range of hadron, nuclear and particle physicists. The collision of the high energy LHC beams with fixed targets, including polarized and nuclei targets will greatly expand the range of fundamental physics phenomena accessible at CERN.

The fixed-target mode will permit us to carry out unprecedented precision measurements of hard QCD processes. In particular, our aim is to study:

- rare configurations of the proton wave function which contain gluon or heavy-quarks with high momentum fraction ;
- the gluon content in the deuteron and neutron in a wide momentum-fraction range;
- the correlation between the proton spin and the gluon angular momentum through the Sivers effect and novel spin correlations;
- the production of W and Z bosons in their threshold domain;
- the melting of excited heavy-quark bound states in the deconfined QCD phase in heavy-ion collisions;
- the nucleus structure function for momentum fractions close to and above unity;
- the deconfinement dynamics in the target-rest frame;
- ultra-peripheral collisions in a fixed-target mode.

[1] Hence the name of this proposal "PRO-AFTER" for prospectives for "AFTER".

Compared to the RHIC experiments, which benefit from similar center-of-mass energies, our proposal will bear upon a huge luminosity –typical of a fixed-target set-up– and upon a complete versatility of target species. Compared to Electron-ion collider projects, our proposal will certainly be highly competitive in terms of cost and it will be of complementary design, with a specific focus on the study of parton content at large momentum fractions – in particular that in terms of gluons.

High-energy fixed-target experiments have already been discussed in the 90's, both at the European LHC and the American SSC. The main differences between our proposal and earlier ones are :

- the fact that the LHC is now built and runs –very well indeed–,
- bent-crystal beam-extraction techniques have now been successfully tested at the SPS and the Tevatron up to nearly 1 TeV and they will be tested on the LHC beams,
- a number of modern detection techniques have been developed in the meantime –in particular, ultra-granular detectors– and, finally,
- our proposal is, in essence, a multi-purpose experiment, not only focusing on one specific aspect of particle physics, as it was the case for the LHB project, for instance.

We believe it is well worth exploring this option and bringing our nuclear and particle physicist colleagues' attention to all these new physics opportunities. To do so, we plan

- to work out the detail of the physics case in adequacy with the current experimental possibilities –and limitations– ,
- to develop a first robust –but ambitious– design of the experiment and its assembly compliant to the physics case, and
- to advertise our project all over the world-physics community to create an experimental collaboration large enough to make this project viable and fruitful for the years to come.

2.3. STATE OF THE ART

The scope of the physics program at such a fixed-target facility is certainly beyond what can be presented here. In particular, a major goal of this proposal will be to map out many of the possible physics avenues. In the following description of the state-of-the-art, we shall limit ourselves to the following 6 items:

- *Large-x_B domain and gluon distributions*

Whereas momentum sum rules tell us that gluons carry about 40% of the proton momentum at Q^2 = 10 GeV^2, it is very difficult to probe them directly. Deep-Inelastic Scattering (DIS) experiment can only directly probe the target-quark content. Indirect information on the gluon content can be extracted from the Q^2 dependence of the quark distribution –the scaling violation– and from sum rules. Recently, it has been re-emphasized [Bra11] that a better knowledge of gluons at high x_B is relevant for the production study of heavy-boson, W' and Z', beyond the Standard Model.

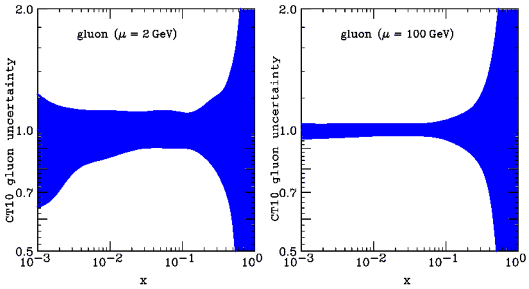

Fig. 1: Gluon-distribution uncertainty in a proton at high x_B for low and high scales, μ.

At large x_B, sum rules are of no help due to the strong suppression of PDF for $x_B \to 1$. The gluon distribution is indeed very poorly known for $x_B > 0.2$ at any scale, as shown on Fig.1. One of the historical golden probe for gluons [Mar88] is quarkonium hadro-production since it comes from gluon fusion and it is thus sensitive to the gluon distribution squared. It may thus be expedient to reassess the possibility to probe gluon with them. This requires a specific experimental program dedicated to quarkonium (excited-state) studies at low P_T, such as cross-section, polarization and correlation measurements.

To access the gluon distribution in the neutron, one has to resort to a deuterium target. A very interesting study using ϒ production by E866 [Zhu08] has shown a production ratio pp/pd for ϒ compatible with an isospin symmetry of the gluon with a visibly different behaviour than that of the same ratio for Drell-Yan – sensitive only to the quarks. This study is the most precise to date, but it only covers the range $0.1 < x_B < 0.22$. Recently, ϒ production has been measured in dAu collisions by PHENIX in the backward region. Even though the experimental data are scarce, they may exhibit [Fer11] the first hint for gluon EMC effect for $x_B \sim 0.3$.

As regards the heavy-quark content in the proton, it is surprising that the original 1983 EMC experiment [Aub83], which first observed a large signal for charm at large x_B in $\gamma^* p \to cX$, has never been repeated.

- *Single spin asymmetries (SSA)*

Recently, it has been re-emphasized that a class of parton-distribution functions, known as "Sivers functions" [Siv89], may be accessed in SSA for hard-scattering reactions involving a transversely polarized proton (see [Bar10] for a recent review). These functions express a correlation between the transverse momentum of a parton inside a polarized proton and the proton-spin vector. As such they contain information on orbital motion of partons in the proton. Sivers-type single-spin asymmetries have been observed in semi-inclusive DIS (SIDIS) at HERMES [Air05] and COMPASS [Ale05] as well as in single forward π and K production at Fermilab and Brookhaven (see [Bar10]).

Last year, PHENIX measured [Ada10] that the transverse SSA in $p^\uparrow p \to J/\psi\ X$ deviates significantly from zero at $x_F \sim 0.1$. If this is confirmed, this will be the first sign of a non-zero Sivers effect for gluons. No such measurement exists as yet for open charm and open beauty, neither for isolated photons, which are the other usual probes for gluons.

- *Cold nuclear matter studies*

One of the main advantages of a fixed-target experiment is the versatility of the target species. This has been used by e.g. the NA38 and NA50 (see e.g. [Abr98b]) experiment, but it suffered from a reduced cms energy, from a limited rapidity range, as well as from somewhat less advanced detector technologies compared to now. *A contrario*, RHIC detectors benefit from a larger cms energy allowing one to probe smaller x_B [Adl06], but with a limited choice of species (only dAU in 10 years of runs) and a limited luminosity. Yet, these experiments emphasized the importance of cold nuclear matter effects on many hard pA process used as a baseline for AA studies.

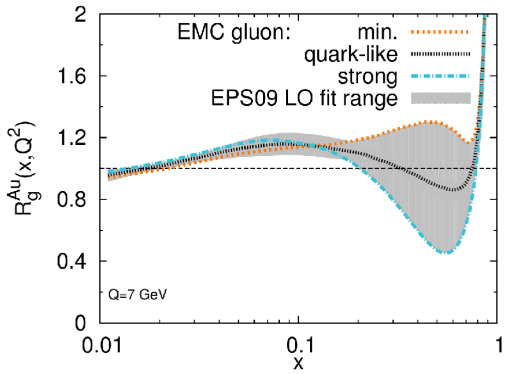

Fig. 2: Gluon-distribution uncertainty in a nucleon in a Au nucleus in the EMC region at Q=7 GeV.

Anti-shadowing (i.e. a parton excess at a given x_B in a bound nucleon compared to a free one) has recently been found to be non-universal : present in electron-nucleus DIS but absent in DY and neutrino charge current reactions [Kov11]. Similar studies for gluon-initiated process are rare. Gluon distribution in a bound nucleus is indeed poorly known in the anti-shadowing and EMC region (see Fig 2). Heavy-flavours, isolated γ and quarkonia are ideal candidates for such investigations. In the case of J/ψ, we have nonetheless shown [Fer09] that kinematical effects specific to their production mechanisms [Lan06, Lan08, Hab08] should be taken into account if (anti-)shadowing was to be studied. It may thus be better to resort to the production studies of $\chi_{c,b}$ and $\eta_{c,b}$ whose production kinematics is closer to that of DY and for which QCD corrections are expected to be smaller [Art08, Bro11]. The backward region with an hydrogen target using the 2.76 TeV LHC Pb beam can also be analysed to probe gluon in Pb in a lower x_B domain, along the same lines as future measurements during expected Pb+p runs at the LHC [Had11].

It is also clear now that a systematic study of large-x_F (be it positive or negative) effects, such as intrinsic charm, energy loss and the Sudakov effect, can only be achieved with a global analysis of several hadronic reactions, with several targets in a large enough rapidity range.

- *Quark Gluon Plasma studies*

Sequential suppression of quarkonia [Mat86] has long been considered as a thermometer of the deconfined phase of QCD created in the most central relativistic heavy ion collisions. An anomalous suppression of J/ψ was indeed observed at SPS [Abr99] and then at RHIC [Ada07, Ada08], partly attributed to quarkonium melting in the QGP. The first data from the LHC [Pil11, Sil11] seem however to indicate that a novel mechanism, charm recombination, could strongly compete with the suppression induced by the melting process. Specific studies at lower energies –where the number of charm is too low for recombination to appear– which would be focused on the excited states $\chi_{c,b}$ and ψ(2S) seem therefore necessary. This statement will remain valid nearly independently of the LHC results to come in the next years, since, in essence, these energy range are complementary physics-wise. Such novel quarkonium studies would require a better resolution than previous SPS experiments and a state-of-the-art photon calorimetry with similar – if not larger– luminosities.

Current studies of the deconfined phase of QCD go beyond quarkonium studies. Heavy-quark energy loss is indeed also recognized as an interesting probe as well as elliptic flow and related azimuthal asymmetries. It is thus relevant to emphasize that an apparatus able to study quarkonium melting with high precision will also allow one to carry out these complementary studies of QGP.

- *W and Z production*

With the advent of Fermilab and the LHC, W and Z bosons are nearly now part of the bread-and-butter physics of the standard model. However, their production studies at sub-TeV energies is still state-of-the-art. Recently, first spin-asymmetry production data from RHIC at 500 GeV were released and they brought new information on Δq and $\Delta\bar{q}$ [Ada11, Agg11]. Studies at the lower RHIC energy (200 GeV) are for the time being out of reach. This would give us much information on the quark content at larger x_B or perhaps on specific dynamical effects appearing near threshold. Similarly, their production study in pA collisions, out of reach at RHIC, would bring unique information on the quark distribution at very high momentum fraction, maybe above unity.

- *Ultraperipheral collisions in the nucleus rest frame*

Ultra-relativistic grazing nuclei can scatter electromagnetically with a coupling proportional to the product of their atomic charge squared, $Z^2 Z'^2$, since the interaction would be coherent over the entire nuclei. For a lead-lead collisions, Z^4 is close to 5 10^7, which clearly compensates for the smallness of α^2_{em}. The 2-photon cross section can then compete with that of pomeron exchange. At relativistic energies, the photon-photon or photon-nucleon are energetic enough to create particles. J/ψ production in UPC was for instance measured by PHENIX in AuAu collisions [Afa09] and preliminary studies are carried out by ALICE. Such types of analyses have never been carried out successfully at fixed-target set-ups, mainly because of the small collision energy. In pA collisions with a 7 TeV beam, the nucleus target A can be used as a photon source in order to reproduce some of the semi-inclusive photoproduction measurements done at HERA and potentially some exclusive reactions as has been done at JLab and Hera (see for instance [Had05] and [Air08]).

2.4. Objectives, originality and novelty of the project

The principal goal of this proposal is to form a new collaboration of high energy particle experimentalists, accelerator physicists and theorists who will explore the physics opportunities and feasibility of extracting the 7 TeV LHC proton and 2.75 TeV lead beams to provide a viable high-energy fixed-target experimental program at CERN, beyond the four years of this proposal.

As aforementioned, beam extraction by bent crystal is now becoming mature with successful tests at SPS (450 GeV) and the Tevatron (900 GeV), as well as the planned tests at the LHC (3.5 or 7 TeV) to collimate the beam. It has been evaluated by one of us [Ugg05a,Ugg05b] that a flux of the order of 10^8 protons per second and 10^5 lead ions per second is easily extractable.

We have evaluated that this provides us with instantaneous luminosities of the order of tens of $\mu b^{-1} sec^{-1}$ for 1cm-long target, i.e. 3 orders of magnitude larger than that of BNL-RHIC and comparable to that of the LHC delivered at the LHCb interaction point. These numbers can easily be multiplied by 10 using a longer target.

A central aim of this proposal will thus be to explore the new physics horizons available at the extraordinary laboratory energies which would be accessible using the LHC beams in a fixed-target mode. These are

1) the gluon and heavy-quark content of proton, neutron and nucleus, particularly at large x_B;
2) the cold nuclear matter effects at work in proton-nucleus collisions at $x_F \sim -1$;
3) the deconfinement dynamics in the whole backward hemisphere;
4) Single spin asymmetries in open heavy flavour, direct γ and quarkonium production;
5) W and Z production near threshold in pp and pA collisions;

In addition to outlining the physics opportunities, our collaboration will also look into prospective designs of experimental facilities capable of making measurements over the full range of fixed-target kinematics. This will then require state-of-the-art simulations to back up the design and specific R&D actions. Some innovative detector techniques have already been identified as being very valuable to progress toward a new generation of fixed target experiments:

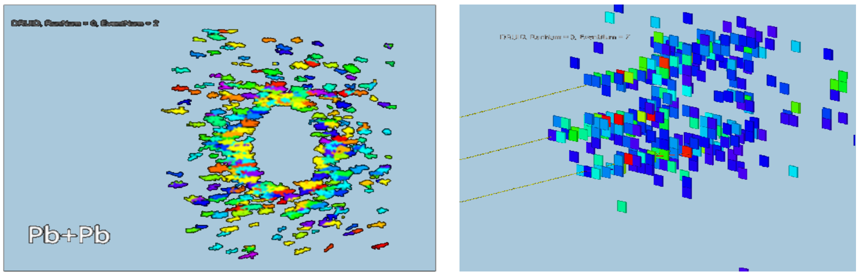

Fig. 1 Left: photons occupancy as reconstructed by the CALICE detector in a typical Pb+Pb collision at SPS. Right: performance of the calorimeter in shower separation; three photons separated by a 2cm distance when impacting the detector.

- The ultra-granular W+Si calorimetry developed for the International Linear Collider by the CALICE collaboration provides an original imaging approach to calorimetry. The development of this technology has been sponsored by ANR in 2010 through the CALIIMAX project whose purpose is to qualify a complete electromagnetic calorimeter with an unprecedented level of components integration in a pulsed mode. This technology is also envisioned for the CHIC project (Charm in Heavy Ion Collisions) at SPS whose goal is to measure the production of the χ_c in heavy ion collisions at SPS energies. Several simulations (see figure below) have already demonstrated that such a technology is very well suited to separate electromagnetic showers in a very busy environment. Since the CHIC project is developed at LLR, we plan to have strong synergies between CHIC, AFTER and CALICE.

- The CMOS monolithic pixel sensor technology appears as a compelling choice to shape a vertexing and tracking system able to reconstruct secondary vertices and perform a precise measurement of the particles momenta, especially in the high multiplicity environment typical of relativistic ion-ion collisions. They fulfill the characteristics required by a tracking detector intended to be located very close to the interaction point (high granularity, low material budget, fast read-out speed, high radiation tolerance, good power dissipation). This sensor technology is notably chosen to equip the Muon Forward Tracker (MFT) upgrade of the ALICE Muon Spectrometer, which R&D plan is about to crystallize, with IRFU institute being heavily involved. The likely scenario is to develop the MFT sensor architecture from the MIMOSA26 sensor sponsored in the framework of the European EUDET project, while improving from the 0.35 µm to the 0.18 µm CMOS fabrication process. The CMOS technology is also planned for CHIC and AFTER vertex and/or tracking detectors, with similar time scale for the MFT and CHIC, and hence likely similar CMOS fabrication process. The time-scale being longer for AFTER, a further improvement of the fabrication technology can be envisioned. We plan to take advantage of MFT and CHIC R&D to deliver a conceptual design of AFTER vertex detector, after investigating its specifications in adequacy with the environment of a fixed-target experiment at LHC.

The target-rapidity domain is particularly interesting for ion-nucleus collisions since it cannot be accessed in ion-ion colliders and because it may reveal new insights into the formation of the quark-gluon plasma. In addition, detectors need to be designed to detect particles produced in the target-rapidity domain, for example dilepton pair to measure PDF at large target x_B or new baryons containing heavy quarks. Our project would become even more competitive if we can prove that we are able to detect single and double diffractive reactions where the target proton or nucleus remains intact in order to access the gluon-rich phenomenology of diffractive processes. Along the same lines, we would then be able to study, for the first time, ultra-peripheral collisions in a fixed-target mode. The fixed target facility could also be designed to provide high energy secondary hadron beams and this certainly also deserves some attention in our future investigations.

3. Scientific and technical programme, Project organisation

3.1. Scientific programme, project structure

The principal objective of this project is to promote the benefits of a fixed target program with the extracted 7 TeV proton and 2.76 TeV lead LHC beams. The main output will be a Conceptual Design Report which will include the following items: i) a detailed physics case ; ii) the most complete specifications of one (or a couple of) possible detector designs; iii) a presentation of the overall performance for the possible designs; iv) a description of the outcome of the R&D actions; v) an extensive account of the integration issues; including constrains from the mechanics, the beam and the target.

In order to improve the efficiency of our investigations, we have structured the proposal into 5 tasks (see Fig. 2) :

1. Physics case
2. Experimental design
3. Integration
4. Critical R&D
5. Communication

The work break-down within these 5 tasks is self-explanatory and they emphasise the importance of the theoretical, experimental and engineering aspects of the project.

The physics case will be the cornerstone of the project. This will allow us to justify the project by outlining the physics possibilities in terms of measurements of universal observables of strong interactions and in terms of discovery potential. Nevertheless, such a physics case possesses a meaning only if it is backed up by detailed and realistic simulations. These require a dedicated computing framework incorporating the most experimental design. A constant interaction between these tasks is essential to maximize the potential of a given experimental design.

Obviously, detectors have to comply with constrains from the assembly of its parts as well as from limitations set by the target and the beam. A specific task devoted to these constrains is also necessary to provide a convincing design for a given accelerator. This task is also tightly bound to the first two: a longer target provides larger yields but may also reduce the detector acceptance and resolution.

Beside these well-known issues in conceiving a new particle-physics experiment, we have identified 2 specific critical R&D actions, which we do believe will be essential to our project. First, one of the key points of the proposed experiment will be the high level of detector granularity. From the technical point of view, it implies a high level of integration, both for front-end electronics and for large-surface detectors. This requires the construction of a representative demonstrator which could be tested for instance on local accelerator facilities and cosmic rays. Second, we need to carry out radiation hardness tests of FPGA cards which, for some, should be positioned close to the forward detectors and therefore in the high radiation environment near the beam pipe after the target. While we are confident in accessing the backward angles, it is indeed important to know how forward we can design the detector with such technologies.

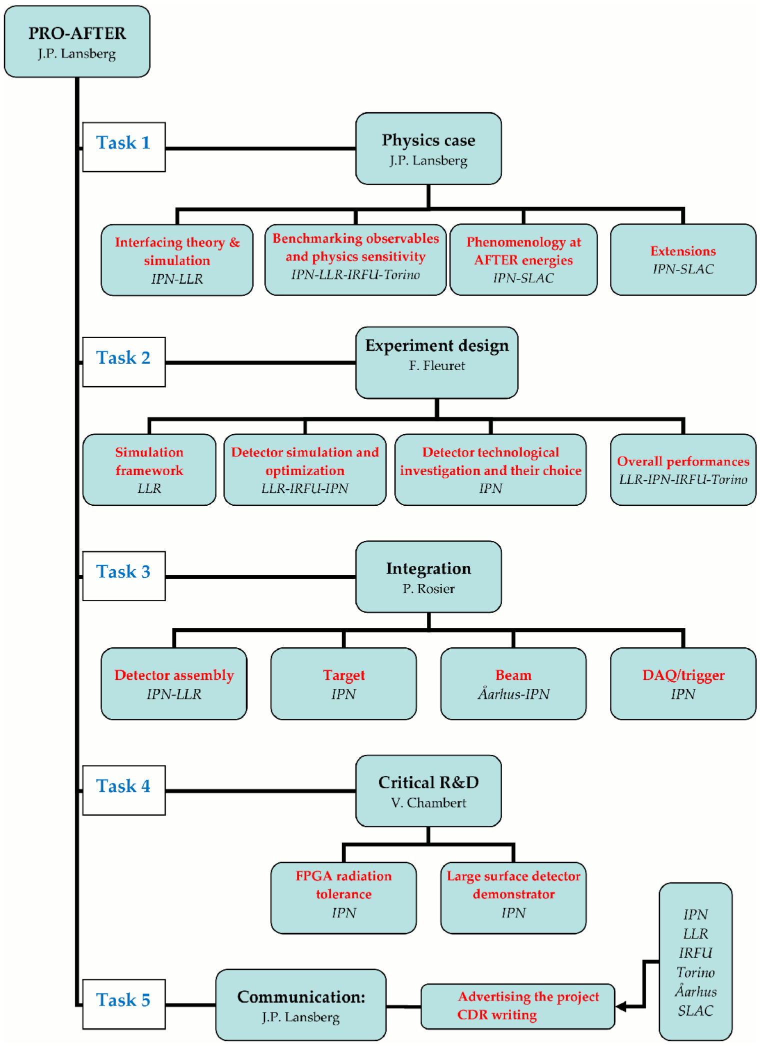

Fig. 3: The work break-down into 5 tasks and into 16 activities (in red) with the involved partners.

The last task is the communication. It will bear upon the four other tasks though the writing of the CDR and via the communications that we plan to constantly deliver to the physics community in order to reach a critical size for the collaboration AFTER which we expect to survive beyond the present project PRO-AFTER.

Most of these five tasks will involve participants from more than one French partners (IPNO, LLR, IRFU) and will require regular contacts as well as the essential support from 3 post-docs to perform the 16 activities detailed in the task description, see Fig. 3. The critical R&D actions will also require specific fundings. The project will also benefit from the participation of 3 partners from abroad, INFN Torino, SLAC and Aarhus (also see Fig. 3). The contribution of the different partners is indicated in the diagram below, task by task, activity by activity. Each task will be coordinated by one researcher, who will be responsible for the delivrables and the scientific management between the activities and more importantly between the tasks. The discussion of the links between the task is postponed to section after the description of the activities.

3.2. Project management

3.2.1 Coordination of the scientific activities

As described above, the scientific activities are gathered into 5 tasks. All the tasks depend on inputs or outputs of at least another and most of them on inputs and outputs of two or three tasks. This calls for an efficient coordination between the activities, especially for activities carried out only by one partner while being connected to other activities.

Within each task, we plan to have monthly meetings where the work progress will be discussed. This is important for the integration of the postdocs, whose work is essential to the project. Our 3 labs benefit from video conference systems which will be used to allow for co-partner members to join these meetings.

Each trimester, the task coordinators (see Fig 2.) will meet to discuss the progress. Since the tasks are time-dependent, they could modify the proposal timeline if they expect a work to be finished late or early. The minutes of the meeting will be made available to all the participants via a wiki-type website. This is particularly relevant for activities for which various expertises are required and where suggestions should be first shared between all the concerned members before attacking practical problems.

Each semester, we plan to organize more formal and larger meetings open to external participants upon invitation (for instance, experts to discuss specific issues) or to colleagues that would join our effort during the 4 years of the proposal. This will be the occasion for the post-docs to present preliminary results and to prepare the writing of the conceptual design report (and the mid-term report). Such meetings will be important to keep all the members informed on the project progress such that everyone would deliver engaging in international workshops and conferences.

We also plan to set-up a scientific committee at the end of the first year which will review our work. This committee will gather recognised colleagues in the field. Depending on the progress, we plan to give reports the scientific committee of our 3 laboratories and eventually to both IN2P3 and IRFU scientific committees.

3.2.2 Management of the human resources (post-docs)

The recruitment procedure will be as follows: for each topic (three post-docs should be recruited during the duration of the project, each of them in a different topic), an international job offer will be made, using « SPIRES » website as well as each of the partners' website.

All application folders will be made accessible electronically to each permanent member of the French partners. For each topic, three permanent members will have the responsibility to independently establish a short-list of candidates. If needed, candidates will be invited for an interview. The main emphasis will be made on the scientific level of the candidates, and on their adequacy to the project. In particular, the real motivation of the candidate for the proposed project will be very important for the final decision, which will be eventually taken by the coordinator of the partner by which the post-doc will hired.

3.2.3 Management of the financial resources

Each partner will have a minimal budget to help members to attend workshops, conferences and to travel in order to meet experts, as well as invitation money to benefit from the expertise of colleagues in the field by organizing short visits or one month stays in their laboratory. Each partner coordinator will be responsible for the use of this part of the budget.

The budget to organize the 3 milestone workshops will be managed by IPNO, although we plan to organize them with the local help of the 3 French partners and the scientific support of the foreign co-partner. The budget for R&D actions will also be managed by IPNO, more specifically by the permanent members of the D2I. In general, we will benefit from the support of the administrative division of IPNO.

3.3. Description by task

3.3.1 Task 1 : Physics case

The coordinator for this task is J.P. Lansberg. It will involve all the French partners (IPNO, LLR and IRFU) and will benefit from contribution of colleagues from INFN Torino and SLAC. Additional contributions from colleagues external to the proposal is very likely, though not formalized yet at the moment of the proposal submission. The aim is to work out the detail of the strongest physics case possible in adequacy with the input of task 2 « Experimental design ». This will imply a constant interaction between these tasks and justify the participation of members in both tasks. This important task will require the support of a high level and experienced postdoc will be plan to hire on a CDD contract. We will also prospects for complementary funding resources to extend the post-doctoral stay of of the postdocs already hired at IPNO who would contribute to the project.

Delivrables : publication in international refereed journal for activities B. and C. ; chapter(s) for the Conceptual Design Report (CDR), see task 5.

- *A. Interfacing theory and simulation*

For observables which are already recognized as benchmarks for the accomplishment of the overall project, we will work at the generation of events feeding in the simulation of task 2. In particular, we can mention basic QCD reactions such as the prediction of Drell-Yan pairs, J/ψ and Υ, heavy quarks, isolated photons. To do so, we would preferentially use Monte-Carlo tools such as Madgraph (and its extension to quarkonia, MadOnia), Pythia, Herwig, EPOS, …

In case we have to tackle with processes where existing codes are known not to be sufficient, e.g. where NLO and NNLO corrections are needed, we would envision to provide instead functional forms for the signal that may be encoded in the simulation framework of task 2. For quarkonia, a special attention will also be drawn on polarization degrees of freedom.

Milestones : Event generation for Task 2 for key processes ; Interface of information beyond the cross section to the simulation ; Event generation for Task 2 for processes newly identified in activity C or benchmarked in activity B ; Update of event generations after feed-back from Task 2 and 3.

- *B. Benchmarking observables and physics sensitivity*

For studies such as gluon and heavy-quark PDFs in the proton, gluon PDFs in the neutron, nuclear PDFs and spin-related densities, it is important to first determine which probes are best suited in order to draw a hierarchy in the process to be simulated. This requires are prior careful studies of some reactions; including isolated photon, charmonium/ bottomonium and heavy-flavour productions to measure gluon PDF. It may very well be that some reactions bring information in different phase space and thus impose various detection requirements which would be then precisely quantified in the simulation and which can influence the design. It is also relevant to foresee the future improvement in the years to come thanks to other experimental studies when benchmarking observables. This activity is very close to the first one and hence to the task 2.

This activity will also be very important to decide which process should be studied in pp, pA, PbA and/or Pbp collisions, as well as to if the target polarization is worth. This will strongly influence the eventual physics case.

Milestone(s) : Determination of the experimental precision (for Task 2) needed to improve the current knowledge of our key quantities ; Determination of the kinematical where the process should be studied (thus generated in activity 1).

- *C. Phenomenology at AFTER energies*

As mentioned earlier, the collision of the LHC beams with fixed targets, including polarized and nuclei targets, will expand the range of fundamental physics phenomena accessible at similar set-ups. Naturally, it will be necessary to develop a complete phenomenology of the reactions which can be studied as such energies (115 GeV with the 7 TeV p beam and 72 GeV with the 2.76 TeV Pb beam).

Let us cite the detail studies of

- W and Z production cross sections near threshold,
- quarkonium production in the limit $x_F \rightarrow 1$,
- production rate of multi-heavy baryon states,
- ultra-peripheral collisions where the target is the photon emitter,
- $\chi_{c,b}$, $\eta_{c,b}$ and associated quarkonium production in pp, pA and PbA collisions,
- etc.

Ideally, this activities will trigger –and then benefit from– the work of other theorists outside the proposal, which would then apply their ideas to a new range of species, energies and luminosities made available by AFTER. We expect the publication of a first letter physics co-signed by 4 members of proposal (S.J. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg) to initiate this process.

Milestone(s) : Determination of the rates and the theoretical uncertainties for the aforementioned key studies, if needed (see task 2 and activities A. and B.) their momentum and angular dependences ; Studies of specific branchings and decay channels .

- *D. Extensions (secondary beams, B physics, neutrino, ...)*

In order to further widen the scope of the physics-case exploration, it is also important to open the door to additional flagships beyond those we have identified. For instance, once the beam is extracted, it can be envisioned to use it to produce ultra high energy secondary beams. Delimiting a physics case for these requires a knowledge beyond the one of the members. Contributions from the outside will be then called for. The same is true for CP violation and neutrino physics. Depending on these external contribution, we would consider enriching the overall physics case of the project.

Milestones : Feasibility study of secondary beams (in relation with task 2 and 3); Evaluation of interest in relation with activity B and C.

3.3.2 Task 2 : Experimental design

The coordinator for this task is F. Fleuret. It will involve all the french partners (IPNO, LLR and IRFU) and will benefit from the beginning from the participation of members of the associated partner « INFN Torino ».

The goal of this task is to develop a detailed simulation of the apparatus to investigate its performances based on the physics simulations performed in Task 1. To achieve, we need to hire two postdocs, one during two years at LLR and one during one year at IRFU to maintain the full set-up and realize the required performances studies to optimize the design of the detector. We will also prospects for complementary fundings ressource to complete the post-doctoral work of the one-year postdocs. This will be particularly relevant if additional detector components are added to the set-up.

As a starting point, after having set up the simulation framework (A), we will incorporate the technologies previously mentioned and already identified as promising in the detector simulation (B): the ultra-granular W+Si technology for the calorimetry and the CMOS technology for vertexing/tracking. The other parts of the detector envisioned must be investigated (C) before including in the simulation framework.

Delivrables: chapter(s) for the Conceptual Design Report (CDR), see task 5.

- *A. Simulation framework*

To perform this task (coordinator: GM/LLR) we will take advantage of the expertise gained by the LLR in the context of CALICE/ILC project, where a simulation framework, Mokka (mokka.in2p3.fr), based on GEANT4, has been developed to perform full simulations of the detector. The core idea of Mokka is to serve as a user interface between a geometry database which can be easily modified trough steering files and GEANT4 to simulate the interaction of incoming particles inside the detector. Gabriel Musat, one of the creators of Mokka will be in charge of the development and maintenance of the AFTER project within the Mokka framework. We expect to have a first version of the simulation framework roughly two months after the beginning of the project.

Milestones : fully operational simulation framework after six months

- *B. Detector simulation and optimization*

  - ECAL (coordinator: FF/LLR): the ultra-granular W+Si electromagnetic calorimeter developed by the CALICE collaboration has been simulated at LLR within the Mokka framework. We will take advantage of this expertise to implement the AFTER calorimeter geometry. We will also exploit the Garlic reconstruction code and test its performances in the specific environment of heavy ion collisions (very high multiplicity). This task will be started by FF for the first year of the project. We will then need the support of a post-doc for one year at LLR. The results obtained will be discussed with our CALICE colleagues in order to optimize the performance of the calorimeter in such a busy environment.

Milestones : first implementation in the simulation framework after one year. Performance studies for the following two years

- VERTEXING/TRACKING (coordinator: AR/IRFU): the CMOS technology spectro-meter currently investigated by the ALICE collaboration for the MFT detector will be used for the vertexing and investigated for the tracking. This task will be started by AR for the first year of the project. We will then need the support of a post-doc for one year at IRFU who will work be in close connection with the ALICE development.

Milestones : first implementation in the simulation framework after a year. Performance studies for the following two years

- *C. Further detector technological investigations and simulations*

- MUON (coordinator: CH/IPN): Several techniques such as Resistive Pad Chambers or micro-megas can be used to perform the muon ID/trigger. These techniques still necessitate further performance estimation before inserting them in the simulation framework. We plan to investigate all the techniques available as well as the possibility to magnetize the Fe absorber in the first year of the project. After one year, the chosen technology will be inserted into the simulation set-up.

Milestones: choice of technology after one year. Implementation and performance studies in the following two years

- HCAL/PID (coordinator: D2I/IPN): to complete the set-up and give access to a large variety of physics process, the capability to measure the energy of high momentum jets as well as the capability to separate charged hadrons are crucial. We have not yet started any investigation neither for a Hadronic Calorimeter nor for a particle ID detector such as Cerenkov detector. We plan to spend the first two years to investigate these techniques and search for new partners to help us making progress in these tasks. If some partners are identified, these new detectors will be inserted in the simulation framework.

Milestones: identify techniques and partners in the first two years. First simulations and detector optimizations in the following year.

- *D. Overall performance*

The study of the overall performances is a transverse activity which will be in close connection with task 1 and task 3. For the first year of the project the performances will be evaluated with the vertex + tracking + calorimeter systems for simple processes such as quarkonia states. When new systems will be added, we will extend the area of investigation to other physics processes. We will need the support of a post-doc for one year at LLR to achieve this goal.

Milestones: overall performances with vertexing+tracking+calorimetry in the first two years. Then study with muons in the following year. Add other technologies when additional partners are identified.

3.3.3 Task 3 : Integration

The coordinator for this task is P. Rosier. It will involve all the French partners (IPNO, LLR and IRFU) and will benefit from the beginning from the participation of members of the associated partner "Aarhus U."

A group composed of several partners will be created and will act for the Integration engineering in the following way:

- participation in the different detectors reviews,
- providing of an environmental inputs for the single detectors,
- keeping of an updated data base as a list of elements,
- check of the interfacing with help of a CAD system, and
- participation in the validation of solutions with the management board.

Delivrables : chapter(s) for the Conceptual Design Report (CDR), see task 5; Conceptual drawings of the experiment proposal.

- *A. Detector assembly*

The IPNO partner (coordinator: P.Rosier) has a long-experience in experiments assembly as for the Di Muon Arm ALICE experiment and others. The resources specialized in mechanical and instrumentation engineering will take in charge the design of the detector framework linked with the beam and with the environment like the hall where could sit the experiment. The livrable will consist in the assembly drawing, feasibility study and assembly procedures of all the detectors concepts in respect with the physicist's requirements.

Milestones : The activity will follow the detector reviews and the feasibility study report will be written for the conceptual design report.

- *B. Target*

We plan to investigate on the various possible types of target (e.g. active or not). In particular, we will carefully look at the consequence on the vertex detector size – and thus cost –, the acceptance limitation in the backward and forward regions as well as the versatility to change the species. We expect to be able to make a choice of target type after one year and to insert the target characteristics (length, species, etc.) in the simulation set-up.

Several techniques to polarise the target exist . We plan to analyse and quantify carefully the advantages and disadvantages of each solution in view of the figure of merit , the relaxation time, the acceptance – especially relevant for measurement in the target-rapidity region– and the impact on the detector geometry. We will also search for new partners to help us making progress in this task. Once some partners are identified, their proposed polarized target parameters will be inserted in the simulation framework.

Milestones: Initial quick survey of different target types and of their relevance for the key studies; Advanced analysis of the detector constraints and the performance of the chosen type. The same milestones apply for the polarisation.

- *C. Beam*

In the Aarhus group, we aim to intensify the study of bent diamonds, achieved by means of femto-second laser ablation. Such crystals are key elements for the extraction of the 2.76 Pb beam, not to mention the proton beam. Specifications of the beam will be obtained from simulations, verified by test beam measurements with which our group has >20 years of experience.

The outcome of these studies will be exchanged and discussed with the members of the project working on task 2 to update the simulation framework taking into account the luminosity of the beam, the focusing of the beam, extraction-collimation interplay as well as possible reductions in beam-halo generated backgrounds for the collider-experiments.

Milestones: Production of bent diamonds, bent to the desired curvature radius by femto-second laser ablation; Testing of the bent diamonds in a 400 GeV/c proton beam at CERN ; Establishment of an initial pilot-experiment at the CERN-LHC with an extracted beam based on bent diamonds

- *D. DAQ/Trigger*

The DAQ group at IPNO has a long experience in code development and support for nuclear physics experiments for many years. The proposal is to use NARVAL for DAQ. NARVAL is a work environment for writing acquisition systems. All control and configuration of an acquisition process of data are available. The manipulation of the data is supported for automatic way by a set of classes which are inherited when you want to write a new acquisition. Generic "actors" (the processes manipulating data) shipping C or C++ libraries are available to implement the code user in our acquisitions. The heart of NARVAL is written in ADA 95. All equipments for that project will be supported by NARVAL on demand of the project.

Milestones: The activity will follow the detector reviews and the feasibility study report will be written for the conceptual design report.

3.3.4 Task 4 : Critical R&D

The coordinator for this task is V. Chambert. It will mainly involve IPNO members. However, the other partners will interact strongly with them as regards the simulation output for the radiation mapping and the required size and granularity of the muon detector as detailed below.

It is indeed clear that a large granularity detector coupled with a large-surface detector is required to achieve the proposed measurements in particular in the forward region. This requires R&D actions for the electronics (FPGA radiation hardness test) and for the detector granularity (demonstrator).

As regards the timing, the FPGA test can be carried once we have first simulation of the radiation mapping both for pA and PbA collisions. The specification of the demonstrator will be determined once the most appropriate type of muon detector (micromegas detectors, Resistive Plate Chambers,…) is defined according to the physics requirements (See task 2 Experiment design), and once the minimal significant surface of the detector is evaluated according to the simulations. The two critical R&D actions which are identified are described below.

Delivrables : Publication of the FPGA test results as a CERN public note. Demonstrator. Chapter(s) for the Conceptual Design Report (CDR), see task 5.

- *A. FPGA radiation tolerance*

Concerning the electronics, the current developments focus on fast digitization as close as possible after the pre-amplification stages. The typical electronics channel is made of one analogue pre-amplifier, some fast wide-dynamics range ADC, one FPGA which collects and shapes the data, and which can perform various digital signal filtering before sending the data to the DAQ. With high-granularity detectors, the electronics will be installed on the detector or close to it in order to reduce the number of cables. It is critical to test the electronics against radiations and, specifically, the FPGA, which are very sensitive to SEU

(Single Event Upset). We propose to perform last-generation FPGA (e.g. Virtex 6-7) radiation-hardness tests according the radiation mapping which will be given by the physics simulations (task 2).

Milestones : Test beam, result analysis, note publication.

- *B. Large surface detector demonstrator*

We will carry out studies to reach the physics performance of the detectors with the smallest number of channels, given the technical and budget constraints. This requires the building of such a representative demonstrator for the muon detector which is the expertise of IPNO partner. The construction of this demonstrator will be coordinated by B. Genolini.

This detector demonstrator is going to be used on a defined set-up on local accelerator facilities and with cosmic rays in order to get the possibility to analyse samples and evaluate the performance. We will implement the detection with cosmic rays from existing rods of scintillators, for which we need to purchase the data-acquisition electronics. The implementation of these tests and their analysis will be done by the 1-year postdoc working with the D2I IPNO who should have the knowledge in detectors & instrumentation.

Milestones : Determination of the specification needed for the demonstrator after the feed-back from task 2. Building of the demonstrator. Test of the demonstrator.

3.3.5 Task 5 : Communication

The coordinator for this task is J.P. Lansberg. It will naturally involve all the French partners and the associated partners.

First communications have already been delivered by J.P.Lansberg and S.J. Brodsky in international meetings last year. We plan to increase our visibility in the community via further participation to well-chosen international conferences and also through more topical seminars. We have already organised two one-day workshop in Orsay in the framework of French Research Network Hadronic Physics and Quantum Chromodynamics (GDR Physique Hadronique et Chromodynamique Quantique). We plan to pursue on this side by continuing to organise regular one-day meeting each trimester with experts from outside the consortium in addition to 3 important topical workshops (one of the physics case, one of the simulation, one for the integration) involving a larger numbers of participants, expert in the corresponding fields.

We will also publish in 2012 an initial scientific paper on the potential offered by a fixed target experiment on the LHC beams co-signed by three participants of the proposal (FF, CH, JPL) and Pr. S.J. Brodsky.

Delivrables : Talks in international conferences with corresponding proceedings; Conceptual design report.

- *A. Advertizing the project*

Our aim is to advertise our project in the physics community to create an international collaboration large enough to make this project viable and fruitful for the years to come. On the one hand, we plan to deliver talks in conferences where we would be able to discuss with colleagues and motivate them to join our effort. This has already been successful last year given the interest shown by some colleagues from the US, the Netherlands and Portugal. We will also have the opportunity to publish and to advertise the progress of our work in conference proceedings.

On the other hand, we plan to have more direct contact with possible future partners by delivering seminars and by inviting experts to come to our laboratories. This is for instance how we obtained the support of the INFN Torino and Aarhus groups. We plan to continue in this very efficient way. In particular, we will reinforce the contacts already established with beam and machine experts at CERN.

- *B. CDR writing*

As mentioned above, the CDR will contain our results on the physics case, on the design and the simulation of the detector, on its assembly and on the R&D actions. Once the different activities belonging to these tasks are realised, we will progressively write the corresponding chapters of the report. If additional partners join the global effort on AFTER, we will welcome their contributions on additional activities which would complement the ones described above. However, the task coordinators will remain the editors of the CDR.

We also plan to write an internal mid-term report which would serve as a basis for the CDR and which will gather, in a less formal way, the preliminary conclusions of our first studies. We plan to have regular meetings devoted to this activity to keep a constant focus on it.

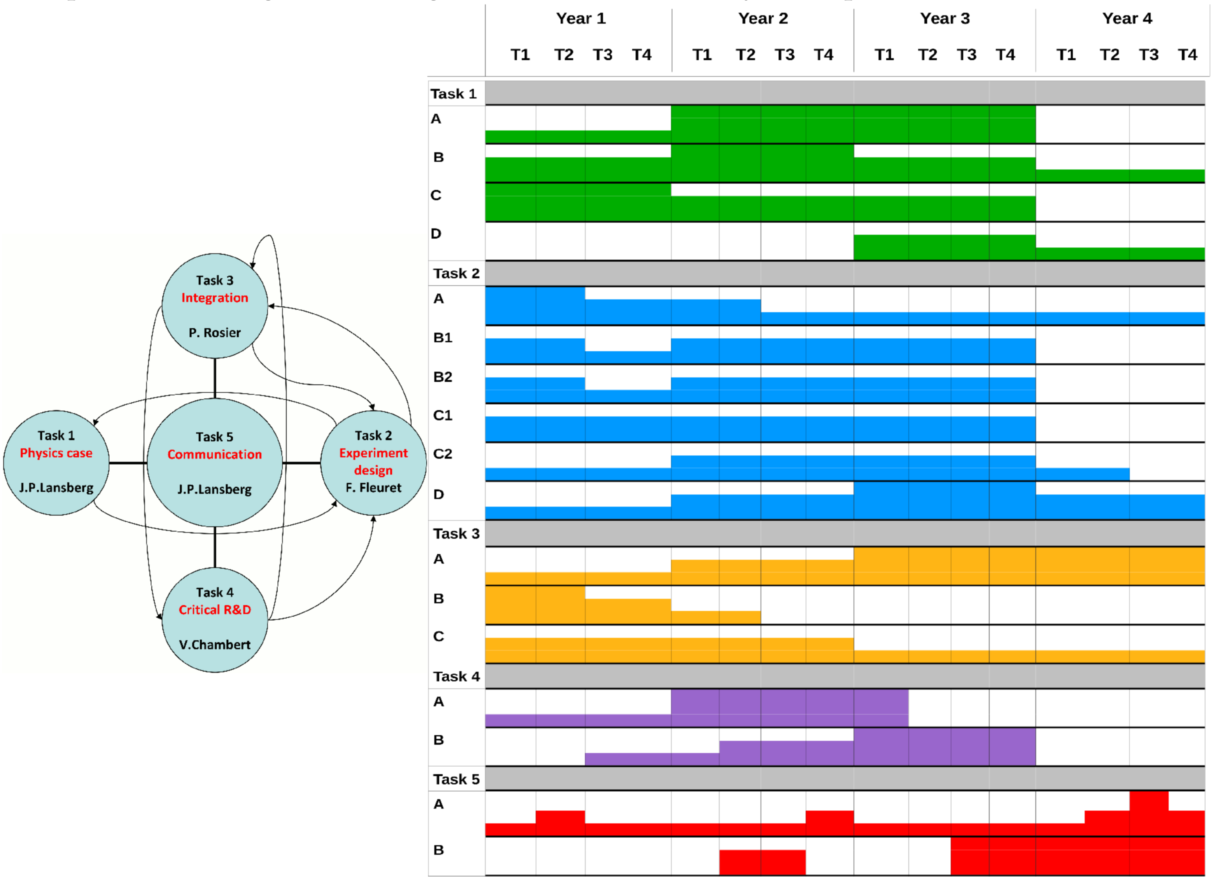

Fig 5. left: Task-connection summary; right: task and activity timeline (the thickness of the coloured band indicates the relative work intensity for this particular activity along the four year).

3.3.6 Task-connection summary

Fig. 5 (left) summarizes the connection between tasks with the corresponding responsibilities. All 5 tasks will contribute to the dissemination through the CDR. The physics case will give (event generation) and receive inputs (kinematical cuts, ...) from the design task. The design will then feed information in the integration task (detector geometry, ...) from which it will receive feed-back (constrains, performance) as well as from the result of the critical R&D activities (technology choice, constrains...).

3.4. Tasks schedule, deliverables and milestones

The tasks schedule is summarized in the Fig 5 (right). The delivrables are detailed, task by task, in the previous section (3.3) and the milestones are detailed, activity by activity.

4. Dissemination and exploitation of results. intellectual property

The dissemination and exploitation of our results at the heart of our project (through the CDR and the advertisement of the project) has been detailed in the previous section. We will not repeat its discussion here.

However, we plan to go beyond usual communication actions. The project should indeed be the basis of stronger links with foreign countries on the long term project AFTER. The proposal already involves colleagues from Denmark, Italy and the USA. Future collaborations are already expected with China, Germany, Portugal, Spain and Poland through bi-lateral collaboration with experimentalist and theorist colleagues.

5. Consortium description

5.1. Partners description & relevance, complementarity

As argued above, our proposal involves outstanding issues at the junction between theoretical, experimental and engineering particle physics and nuclear physics. As such, it requires expertises from three different communities, which are brought in by the 3 French partners and the 3 partners from abroad.

We are convinced that the strength of our proposal is to incorporate *from the beginning* these 3 aspects in the conception of a new experiment, with their constraints as well as their potential. Doing, we expect that an idea such as ours can become viable in the current state of particle and nuclear physics worldwide. Our duty is to maximise the physics case, to elaborate the most realistic and performing detector design, given the external physical – and budgetary– constraints.

Our proposal involves young permanent researchers whose work, combined with the expertise of the senior researchers, gives the hope for a mid- and long- term follow-up of the project. The ANR support which we require here is expected to the first essential seed for an international project in the long run which will may very well be the state-of-the-art hadronic fixed-target machine of the next decades. Without a doubt, this would impulse a renewal in the QCD and high-energy hadron/nuclear physics community in France.

We now present the various members of the 3 partners, with their participation to the project and their expertises.

Partner 1: IPNO

This partner gathers members of an institute with a long-standing tradition in the study of hadronic physics, both a medium energies at GSI (PANDA) and JLab (CLAS) and at high energies at BNL-RHIC (PHENIX) and CERN (NA50 & ALICE).

J.P. Lansberg is a specialist of phenomenology of QCD, in particular quarkonium physics. He has strong interests in the connection between theoretical and experimental particle physics. He supervises 2 postdocs, J. Albacete who works on theoretical aspects of saturation in pA collisions, and C. Lorcé who works on the study of the partonic structure of mesons and nucleons. During the first year of the project, they will both contribute to the physics case with theoretical and phenomenological works. C. Hadjidakis is a specialist of experimental hadronic physics between particle and nuclear physics. She worked on exclusive reactions in DIS for the CLAS and HERMES collaborations and now on quarkonium production in heavy-ion collisions for ALICE at the LHC. D. Tapia Takaki will contribute on the simulation for UPCs along the same lines as he did for ALICE. J.P. Didelez, who will work on the target is a world expert on target polarization, he has been working lately on HD polarized targets [Oht12].

The laboratory also benefits from a very strong technical division expertised in cutting edge experimental technologies proved by the excellent contribution to the aforementioned experiments. V. Chambert, the head of the instrumentation and computing division of IPNO (which gather more than 60 people), D2I, is an expert on analogue electronics and integrated circuits. Her group contributed to the dimuon arm of ALICE [Cha08]. This division is responsible for the design of the first set of muon chambers called "station 1" (J.Peyré), for the design and the production for the dimuon collaboration of the 1,1M electronics channels (V. Chambert), and for the dimuon readout software. P. Rosier the head of IPNO Detector R&D group, is an expert in mechanical engineering, he is responsible for the PANDA Ecal mechanics. He designed the mechanics of CLAS-DVCS and G0 experiments at Jlab, and those of Ntof at CERN. J. Peyré, the former head of IPNO D2I, is a specialist in detector design and measurements, he is an expert in photodetectors. B.Genolini is an expert in detectors design and simulations.

Partner 2: LLR

This partner is represented by Dr. Frédéric Fleuret. He has a long-standing experience in experimental quarkonium physics. He was a member of the NA38, NA50 and NA51 collaborations at the CERN SPS and is currently a member of the PHENIX collaboration at the BNL RHIC. The partner also has a leading role in the CALICE collaboration whose purpose is to develop an ultra-granular W+Si calorimeter for an original imaging approach to calorimetry for ILC experiments. Gabriel Musat is one of the expert computing engineers involved in the CALICE collaboration.

Partner 3: IRFU

This partner gathers members of an institute with a long-standing tradition in the study of hadronic and nuclear physics, both at medium energies at JLab (CLAS) and for COMPASS (CERN) and at high energies at BNL-RHIC (PHENIX) and at CERN (NA50 & ALICE). It is represented by A. Rakatozafindrabe who is a specialist of experimental relativistic heavy-ion collisions and the study of QGP with hard probes. She worked for the PHENIX collaboration at BNL and is now part of the ALICE collaboration. In particular, she is involved in the MFT upgrade of ALICE using the CMOS pixel technology.

Co-partner 4: INFN Torino

This partner is represented by Dr. Roberta Arnaldi and Dr. Enrico Scomparin. They have a long-standing experience in experimental quarkonium physics, both in pp and nucleus-nucleus collisions. They were members of the NA50 and NA60 Collaboration at the CERN SPS (E.S. was Physics Coordinator and Deputy Spokesman of NA60), and they are currently participating in the ALICE experiment at the LHC.

They closely collaborate with the other partners of this project in the framework of the ALICE Collaboration, and they also jointly supervised PhD students (co-tutelle). They have signed a letter of support to the project, which is joined to the online submission.

Co-partner 5: SLAC National Laboratory, Stanford U.

This partner is represented by Prof. Stanley. J. Brodsky who is a worldwide renowned expert on theoretical particle physics, and particularly on hadronic physics, author of more than 500 papers with more than 30 000 citations. He is the principal investigator for SLAC for a Stanford-France proposal on AFTER with F. Fleuret, C. Hadjidakis and J.P Lansberg. He is therefore a very natural support for our proposal. He has signed a letter of support to the project, which is joined to the online submission.

Co-partner 6: Physics Dept. Aarhus U.

This partner is represented by Dr. Ulrik Uggerhøj and gathers members of a department with a long-standing tradition in the study of channelling, from keV to GeV beams. A number of key investigations on beam extraction were performed by this group in collaboration with accelerator experts at CERN in the late 90's. Recently, the group has managed for the first time to bend diamond crystals, unparalleled in terms of radiation tolerance – a significant parameter for the extraction of protons and heavy ion at the LHC. He has signed a letter of support to the project, which is joined to the online submission.

5.2. Qualification of the project coordinator

J.P. Lansberg, 34 years old, is a first class CNRS associate researcher at IPNO. After postdocs at Ecole Polytechnique (France), Heidelberg (Germany) and Stanford (USA), he has been hired by CNRS in 2010. He is an expert in perturbative QCD and in phenomenology of strong interaction, in particular in the production of heavy-quark bound states. He is now supervising two post-docs on this subject.

He has organized 4 international workshops for which he was also the editor of the proceedings. He is the principal investigator for the French side of a Stanford-France project on AFTER. He is the principal investigator for the French side for a FCCPL and a IN2P3-COPIN project on quarkonium physics. He has also been elected as a representative of the IPNO institute council and is the convener of the working group « Electron-ion colliders and future experimental project » of the GDR PH-QCD. Finally, he is contributing to the long-term prospectives of both IPNO and IN2P3-IRFU.

During his postdoc in Stanford, he started to discuss with S.J. Brodsky (SLAC) and F. Fleuret (LLR) the opportunity of proposing a fixed-target experiment on the LHC beams. He has delivered five talks last year on this project in international conferences and has been therefore naturally chosen by the members of the projects as the coordinator.

5.3. Qualification and contribution of each partner

Partner IPNO	Name	First name	Position	PM	Contribution to the project
Coordinator	LANSBERG	Jean-Philippe	CR1 CNRS	20	Project coordinator ;

					Coordinator for the tasks: « Physics case « and « Communication »
Other members	HADJIDAKIS	Cynthia	CR2 CNRS	10	Detector technological investigations : muons
	DIDELEZ	Jean-Pierre	DR1 CNRS emeritus	5	Target polarization
	CHAMBERT	Valérie	IR1 CNRS / Director of IPNO Instrumentation & computing division	12	Coordinator for the task « Critical R&D » ; Detector assembly : electronics
	GENOLINI	Bernard	IR1 CNRS	12	Detector assembly : detection ; Detector technological investigations : HCal/PID
	ROSIER	Philippe	IR1 CNRS / Head of IPNO Detector R&D group	7	Coordinator for the task « Integration » ; Detector assembly : mechanics
	PEYRE	Jean	IRHC CNRS	7	Detector assembly : DAG/Trigger; FPGA radiation tolerance test
	ZERGUERRAS	Thomas	IR2 CNRS	9	Large surface detector demonstrator
	KY	Beng-Yun	IE2 CNRS	6	FPGA radiation tolerance test
	OZIOL	Christophe	IE1C CNRS	1	Board drawing for FPGA radiation tolerance test
	TAPIA TAKAKI	Daniel	Postdoc CNRS/IN2P3	2	Simulation for exclusive reactions and UPCs
	ALBACETE	Javier	Postdoc CNRS/IN2P3	2	Physics case : pA collisions, CGC, initial state condition for QGP
	LORCE	Cédric	Postdoc Paris-Sud	3	Physics case ; spin physics and exclusive processes
Partner LLR	**Name**	**First name**	**Position**	**PM**	**Contribution to the project**
Coordinator	FLEURET	Frédéric	DR2 CNRS	20	Coordinator for the task «Experiment design» ; Detector simulation & optimization : Electromagnetic calorimeter
Other members	MUSAT	Gabriel	IR2 CNRS	5	Simulation framework
Partner IRFU	**Name**	**First name**	**Position**	**PM**	**Contribution to the project**
Coordinator	RAKOTOZAFINDRABE	Andry	CR-CEA	12	Detector simulation & optimization : Vertex / tracking
Co-partner INFN Turin	**Name**	**First name**	**Position**	**PM**	**Contribution to the project**
Coordinator	SCOMPARIN	Enrico	INFN senior researcher	5	Physics case: benchmarking observables and physics sensitivity
Other members	ARNALDI	Roberta	INFN researcher	5	Simulation: overall performance
Co-partner SLAC	**Name**	**First name**	**Position**	**PM**	**Contribution to the project**
Coordinator	BRODSKY	Stanley J.	Professor	5	Physics : phenomenology and extension

Co-partner Aarhus U.	Name	First name	Position	PM	Contribution to the project
Coordinator	UGGERHOJ	Ulrik	Associate Professor, Deputy Dept. Head	5	Optimization and measurements of bent crystals for extraction
Other members	ANDERSEN	Kristoffer	Graduate student	5	Optimization and measurements of bent crystals for extraction

* à renseigner uniquement pour les Sciences Humaines et Sociales
** à renseigner par rapport à la durée totale du projet

Participation to other contracts:

	Name	PM	Project name, financing institution, grant allocated	Project title	coordinator name	Start and end dates
N°	F. Fleuret, C.Hadjidakis, J.P.Lansberg,	2, 1, 2	Stanford-France Center for Interdisciplanry studies, 8000$ for a year	High-energy physics with a fixed target experiment using the multi-TeV proton and nuclear LHC beams : motivation, simulation and feasibility	J.P. Lansberg & S.J.Brodsky	05/11 → 05/12
N°	F. Fleuret	2	EU. HP3: 3000€/year	Sapore Gravis	G. Martinez	01/12 → 01/15

6. Scientific justification of requested resources

As we have discussed in section 3.3, we need to hire 3 post-docs as an essential support for our activities. 1) A 2 year experienced post-doc at IPNO will support the investigations on the physics case and will be essential to make the connection between the phenomenology of the processes which we aim to study and the design/simulation task. 2) A 2-year post-doc at LLR (2 years) and a 1-year post-doc at IRFU (1 year) will be an indispensable support to the simulation activities needed to design the detector. 3) A 1-year post-doc at IPNO will allow us to carry out an efficient and smooth integration of the different parts of the detector taking into account the requirements from the beam, the target and the mechanics. She/he will also been an strong support to both R&D actions. We anticipate that the post-docs will strengthen the relations between different teams by being at the key position for the connection between the different tasks.

Finally, our project will also require specific fundings to invite and meet experts on technological, simulation and phenomenological issues. We also plan to advertise the project to enlarge the collaboration and to invite worldwide expert colleagues for monthly stays to deal with specific issues. In this respect, the reasonable travel budget we request from the ANR for our three partners will be very important. We also plan to complement our budget with other funding requests, in particular when possible via small bi-lateral agreements as we have already done with Stanford U.

6.1. Partner 1 : IPNO

Equipment

Critical R&D activities :

1. FPGA radiation-hardness test: oscilloscope 4 channels 1GHz - 1 GS/s : 12000 €

2. Demonstrator (tentative cost[2] for Micromegas): DAQ for a large number of channels (muon chambers + muon telescope): crate VME : 5 000 €

Staff

A 2-year postdoc position for an experienced physicist (equivalent "CDD chercheur", 2 to 5 years post-doctoral experience) for the physics-case task (event generation, specific phenomenological developments, Conceptual Design Report writing)

A 1-year postdoc for the Integration task (detector assembly, target and DAQ/trigger) and for the critical R&D on the large surface detectors (demonstrator construction and tests analysis), who should have competences in detection & instrumentation.

Subcontracting

Critical R&D activities : Demonstrator:

- Electronic circuits for the read-out: 10 000€
- Building of mechanical components : 16 000 € (supports, mainframe, tightness...)

Travel

10000 €/year travel "in" (invitation)

Long-term invitations for senior experts (physics case, design, integration, critical R&D, Communication) : 2 x 1 month /year : 5000€

Mid-term invitations for seminar and discussion with experts (physics case, design, integration): 2 x 2 week /year : 2000€

Short-term invitations for seminar and discussion with experts (physics case, design, integration): 6 x 1 week /year : 3000€

10000 €/year travel "out" (mission)

Shift (critical R&D) : 1 000€/year

Visit in laboratories abroad : 2 000€/year

Conferences : 7 000€/year (Participation to workshop and conferences abroad to advertize the project, to meet experts to received their feedback and to present our results)

Workshop organization for the whole project : 3 x 10 000€

Kick-off meeting (early 2013)
Mid-term meeting (mid 2014)
Conclusion meeting (end 2016)

[2] The estimated budget for the demonstrator of the critical R&D depends on the final chosen technology but we can estimate from our experience in building a medium large chamber (2m) that the amount is around 50 k€ distributed in subcontracting, equipment, and other expenses.

Total for travel : 110 000€

Other expenses

Equipment for critical R&D activities :
1. FPGA radiation-hardness test: 2 kits FPGA: 2 x 2 800= 5 600€ ; Power supply: 1 250€
2. Demonstrator: Mechanical pieces: 3 000€; Electronics components and boards: 4 000€; Micromegas: collection board: 2 000 €; Grid 3 000 €. DAQ: 4 boards: 4 x 4 000 € = 16 000 €

Total cost for IPNO: 379860 €

6.2. Partner 2 : LLR

Staff

A 1-year postdoc for the detector design task (ECAL detector simulation and optimization)
A 1-year postdoc for the detector design task (overall performance)

Travel

3000 €/year travel "in" (invitation)

Long-term invitations for senior experts (physics case, design, integration) : 1 x 1 month /year : 2500€

Short-term invitations for seminar and discussion with experts (physics case, design, integration): 2 x 1 week /year : 500€

2000 €/year travel "out" (mission)

Conferences : 2k€/year (Participation for the postdoc to workshops and conferences abroad to advertise the project, to meet experts to received their feedback and to present our results)

Total for travel : 20 000€

Total cost for LLR: 124 800 €

6.3. Partner 3 : IRFU

Staff

A 1-year post-doc for the detector design task (VERTEXING/TRACKING detector simulation and optimization)

Travel

1500 €/year travel "in" (invitation)

Long-term invitations for senior experts (physics case, design, integration) : 1 x 1/2 month /year : 1250€

Short-term invitations for seminar and discussion with experts (physics case, design, integration): 1 x 1 week /year : 250€

500 €/year travel "out" (mission)

Conference : 0.5k€/year (Participation to a workshop to meet experts to received their feedback and to present our results)

Total for travel : 8 k€

Total cost for IRFU: 65 000€

7. References

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ANNEXES:

- Cvs
- 3 letters of supports from our co-partners.