# IRFU - Institut de recherche sur les lois fondamentales de l'univers

Rapport Hcéres

agence d'évaluation de la recherche
et de l'enseignement supérieur

Department for the evaluation of research units

# AERES report on unit:

## Institute for research into the fundamental laws of the Universe

## IRFU

# Under the supervision of the following institutions and research bodies :

## Commissariat à l'Énergie Atomique et aux Énergies Alternatives - CEA

January 2014

agence d'évaluation de la recherche
et de l'enseignement supérieur

Department for the evaluation of research units

*On behalf of AERES, pursuant to the Decree of 3 november 2006*[1]*,*

– Mr. Didier HOUSSIN, president
– Mr. Pierre GLAUDES, head of the evaluation of research units department

*On behalf of the expert committee,*

– Mr. Philippe BLOCH, chair of the committee

[1] The AERES President "signs [...], the evaluation reports, [...] countersigned for each department by the director concerned" (Article 9, paragraph 3 of the Decree n ° 2006-1334 of 3 November 2006, as amended).

# Evaluation report

This report is the result of the evaluation by the experts committee, the composition of which is specified below.

The assessments contained herein are the expression of independent and collegial deliberation of the committee.

| | |
|---|---|
| Unit name: | Institute for research into the fundamental laws of the Universe |
| Unit acronym: | IRFU |
| Label requested: | |
| Present no.: | |
| Name of Director (2013-2014): | Mr Philippe CHOMAZ |
| Name of Project Leader (2015-2019): | Mr Philippe CHOMAZ |

# Expert committee members

| | |
|---|---|
| Chair: | Mr Philippe BLOCH, CERN |
| Experts: | Mr Bernard BONIN, Direction de l'énergie nucléaire du CEA |
| | Mr Claude CATALA, Observatoire de Paris |
| | Ms Young-Kee KIM, University of Chicago, U.S.A |
| | Mr Jean-Paul Richard KNEIB, Ecole Polytechnique Fédérale de Lausanne, Suisse |
| | Mr Manel MARTINEZ, CTA, IFAE, Spain |
| | Mr Hugh MONTGOMERY, JLab, U.S.A |
| | Ms Gerda NEYENS, University of Leuven, Belgium |
| | Mr Leonid RIVKIN, Ecole Polytechnique Fédérale de Lausanne, Suisse |
| | Mr Pascal TIXADOR, Institut Néel Grenoble |
| | Mr Terry WYATT, University of Manchester, UK |

## Scientific delegate representing the AERES:

Mr Cristinel DIACONU

## Representative(s) of the unit's supervising institutions and bodies:

Ms Maria FAURY, CEA/DSM

# 1 • Introduction

## History and geographical location of the unit

IRFU - The Institute for Research into the Fundamental laws of the Universe - is one of the seven institutes of the Matter Sciences Division (DSM – Direction des Sciences de la Matière) of the French atomic energy and alternative energies commission (CEA). DSM gathers CEA's fundamental research cluster in physics and chemistry and is divided into seven institutes located on the CEA Grenoble, Cadarache, and Saclay centres with a local branch in Caen.

Located in Saclay, IRFU, originally named DAPNIA, was set up in 1992. It became an institute and took the name IRFU in 2008. IRFU gathers in one single department all astrophysics, nuclear physics, and particle physics activities carried out at CEA and all associated technical units. These three disciplines enable researchers to probe the Universe in a complementary manner, from the infinitely small to the infinitely large.

**IRFU's missions**

IRFU's mission is to carry out – in conjunction with academia and the international scientific community – excellent research in the fields of the infinitely small and the infinitely large. It plays a leading role in the construction of high technology instruments necessary to this research. IRFU puts its knowledge and knowhow in the service of France and its citizens by sharing them with other CEA divisions, with French and international research organisation, and with the industry. It contributes to the renown of CEA through its scientific collaborations, by sharing its knowledge, training junior researchers, and communicating on its research and the technologies it develops.

**IRFU's operational objectives**

IRFU has five operational objectives:

▪ Advancing worldwide knowledge of the fundamental laws of the Universe through studies of the Universe at small and large scale and by searching for the relationship, all along the history of the Universe, between elementary particles and complex structures.

▪ Collaborating with the best international teams on Very Large Research Infrastructures.

▪ Developing the high-tech instruments necessary to research in this field and to the whole scientific community.

▪ Transferring knowledge and technology to the industry.

▪ Participating in the research community's mission to enhance training and information sharing.

**Four major scientific questions in physics of the two infinities**

The research conducted at IRFU aims at advancing knowledge on fundamental laws of the Universe by answering four fundamental questions:

▪ What are the ultimate constituents of matter?

▪ What is the energy content of the Universe?

▪ How is the Universe structured?

▪ What are nuclear matter self-organisation processes?

## Management team

IRFU has both a scientific and technological mission. The Institute has a matrix organisation and calls upon the resources of its 6 divisions for all projects. This organisation enables IRFU to gather a coherent ensemble of professions, technological and financial means around each project.

IRFU counts six divisions according to CEA's standard organisation. These divisions are quite significant in size and range from about 100 to over 200 people

Each one of the three physics division focuses on one of the disciplines at the core of the Institute's research:

▪ SAp, the astrophysics division, conducts research related to ground and space observations, as well as theory and simulations. This division includes professionals and facilities related to specific spatial instruments.

▪ SPhN, the nuclear physics division, covers research on nuclear structure, from quark-gluon plasma, to hadron physics and its applications

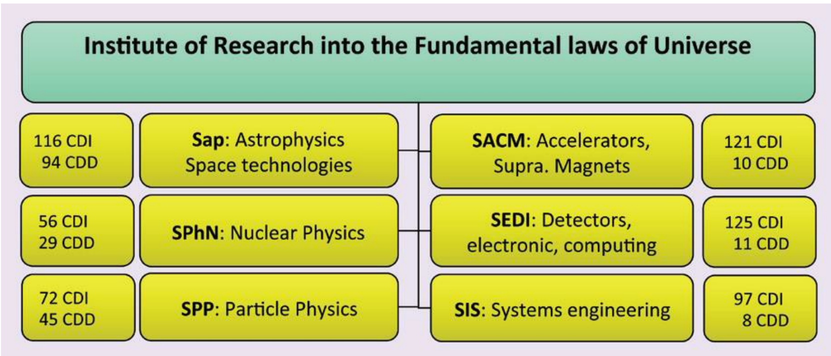
▪ SPP, the particle physics division, combines accelerator experiments, observations of radiations from the cosmos, and observations of radioactive and reactor sources

The three other divisions are technological units and gather the skills, tools, and facilities necessary to instrumental developments:

▪ SACM, the accelerator, cryogenics, and magnetism division, gathers the know-how on accelerators and magnets (superconducting or not)

▪ SEDI, the division for detector, electronics and computer sciences,controls the whole design and production process of detection systems andthe processing of real or simulated data.

▪ SIS, the system engineering division, provides all instrumental developments with the necessary mechanical engineering and general instrumentation skills.




## AERES nomenclature : ST2

## Unit workforce

| Unit workforce | FTE 2013 | FTE 2014 |
|---|---|---|
| **N1**: Permanent professors and similar positions | 10 | 9 |
| **N2**: Permanent researcher, engineer, managerial personnel (A1) from Institutions and similar positions | 430 | 427.7 |
| **N3**: Other permanent staff technical and administrative personnel | 166.1 | 164.3 |
| **N4**: Other professors (Emeritus Professor, on-contract Professor, etc.) | 7.5 | 7.0 |
| **N5**: Other researchers from Institutions (Emeritus Research Director, Postdoctoral students, visitors, etc.) | 146,1 | 108 (known at Jan. 2014) |
| **N6**: Other contractual staff (without research duties) | 23.3 | 18 (known at Jan. 2014) |
| **TOTAL N1 to N6** | **783** | **734 (low value)** |

| Unit workforce | Number 2013 (FTE) | Number 2014 (FTE) |
|---|---|---|
| Doctoral students | 77.4 | |
| Theses defended (January 2008- dec 2013) | 145<br>28 in 2013 | |
| Postdoctoral students having spent at least 12 months in the unit | 56,6 | |
| Number of Research Supervisor Qualifications (HDR) taken | 4 in 2013<br>40 since 2008 | |
| Qualified research supervisors (with an HDR) or similar positions | 140 | |

# 2 • Assessment of the unit

## Strengths and opportunities related to the context

IRFU is a large institute, part of the “Direction des Sciences de la Matière” (DSM) of CEA, which combines fundamental and technology research. Part of its strength relies on its ability to cover in depth the complete spectrum of competencies required for performing experimental research in the three fields (nuclear, particle and astrophysics) covered by the institute. These competencies include design, construction and operation of large/complex detectors or accelerators and superconducting magnets, processing of large set of data or simulations, and data analysis. IRFU contributes also to applications, in particular in the field of nuclear physics (nuclear energy, non-proliferation), large scale infrastructure and medical applications. The synergies between the technology developments and research in fundamental science, or between research on the “infinitely small” and “infinitely large”, offer strong opportunities to IRFU.

In fundamental science, IRFU is a major contributor to the leading international projects in the three fields mentioned above.

In particle physics, IRFU contributes to the two multipurpose LHC experiments at CERN (ATLAS and CMS) and has been leading the construction of major equipment for these experiments (including giant super-conducting magnets). The institute has also a strong involvement in the study of neutrino oscillations (experiment T2K in Japan, Double Chooz, Stereo in France).

In the study of the energy content and structure of the Universe, IRFU is involved in both ground-based and space-based experiments with strong connections with the corresponding European organisations (ESO, ESA) and CNES. One can cite major participations to cosmology (SLNS, BOSS), astronomy with neutrinos or gamma rays (ANTARES, H.E.S.S., CTA), search for axions (CAST) or Dark Matter (EDELWEISS) and a future study of antimatter gravity (GBAR at CERN). IRFU has been a key player in the implementation and plays a strong role in the exploitation of data from space missions such as Herschel, Planck and Fermi/GLAST. Members of the astrophysics Division (SAp) have also contributed to many experiments allowing large progress in understanding galaxy, planet and disk formations. IRFU has developed and delivered the mid-infrared instrument for the James Webb Space Telescope (JWST), which is the successor of Hubble. Irfu is a qualified centre for the construction of detectors for space applications, which enhances the strong role of IRFU’s teams in the projects and guarantees observation time. Irfu includes also a team specialized in numerical simulations.

In Nuclear physics, IRFU performs a broad programme of research covering the study of hot and dense matter (ALICE experiment at CERN), of the nucleon (COMPASS2 at CERN, CLAS12 at JLAB in the USA) and of nuclear structure around a number of international facilities such as GANIL in France, Legnaro in Italy, RIKEN in Japan, Jyvåskylå in Finland.

The position of IRFU in developing and realizing particle accelerators, cryogenic systems and superconducting magnets is unique in France. It is based on a backbone of scientific skills and a large technological platform of 25000 $m^2$ run by the SACM Division supported by the large System Engineering Division (SIS). As a result IRFU is a key partner for the construction of international accelerators for fundamental science such as LHC at CERN, E-XFEL in DESY (Germany), the FAIR complex at GSI (Germany), the SPIRAL2 accelerator at GANIL (France), ESS in Sweden, and of fusion-related facilities (ITER in France, JT60SA and IFMIF in Japan). Even if not directly related to the scientific activity of IRFU in fundamental sciences, some of these projects are an excellent way to position IRFU for future projects in these fields. For example, the cryomodules of the E-XFEL are similar to those of a high-energy electron- positron collider which is under discussion in the particle physics community. The increasing use of superconducting technology in accelerators and magnets offers strong opportunities to IRFU. It is also the source of societal applications, particularly in the field of health (for example Magnetic Resonance Imaging) and allows the involvement of numerous industrial partners.

Another strength of IRFU derives from its excellent matrix organisation. The three technical divisions can be deployed in a flexible way according to the evolution of the needs. For example, while during the LHC construction period the largest part of the resources was targeted towards LHC experiments and accelerator, the effort could be moved in 2007 towards astrophysics for the participation to Herschel and JWST. The project oriented organisation with monthly reviews ensures the delivery of instruments respecting performance, cost and schedule.

The strength of IRFU relies also on its highly skilled scientific staff. Scientists are recruited on an international basis. For example, 60 % of the physicists recruited during the last five years were coming from abroad. As a result, IRFU is very successful in its applications to regional, national and European competitive programs. For instance, the number of ERC grants obtained between 2008 and 2013 corresponds to 40 % of the grants obtained in France in particle and astrophysics, while IRFU includes only 8 % of the corresponding communities. IRFU members are also strongly involved in international relations and participate to numerous international scientific and strategic committees.

Finally, although IRFU is not formally a component of the education system in France, it contributes strongly to training of students through research. The proximity of prestigious universities and high schools ("grandes écoles") is a big asset. About 140 IRFU members are involved in lecturing or training at University. The recent creation of the ComUE (Communauté d'Universités et d'Etablissements) Paris-Saclay is clearly a strong opportunity to further increase this involvement.

As a consequence of all the above, the scientific production of IRFU is remarkable. IRFU has contributed in the past years to ground-breaking discoveries leading to some of the most cited papers in its scientific domain.

### Weaknesses and threats related to the context

The main threats identified by the committee are linked to the present budgetary situation and evolution which present challenges and tensions for the scientists and for the management which were not present in earlier times. The extent to which they may or may not jeopardize the future depends on how they are managed. They do not necessarily speak to an intrinsic weakness within the institution.

The base IRFU budget (taking 2012 as reference) includes 54 M€ of governmental subsidies (through CEA). To this, one should add 12 M€ of specific project budgets for basic science and fusion in the framework of TGI (Très Grands Instruments) and BA (Broad Approach, or "Approche Elargie" around ITER). The base budget has decreased over the past years, while the cost of the permanent manpower has increased by about 2.5 % per year, reaching 50 M€ in 2012. As a consequence, funding through external projects (including for projects from other divisions of the CEA) has become important and needs careful management. The IRFU management has been very successful in increasing total funds through these external contracts (an increase from about 14 M€ in 2008 to 19 M€ in 2012). Nevertheless, the number of permanent staff has decreased by 18 FTEs (-3 %) over the five year period, and the planned decrease for the three coming years is even stronger (-7 FTE's i.e. -1 % per year). This decrease affects particularly technicians (-30 FTE's over five years), and the age pyramid of the technicians is especially worrying with a large peak between 50 and 60. Furthermore, the financial situation leaves very little margin for new initiatives or R&D.

This strong dependence on external projects has important risks:

• Some scientific priorities may be dictated by results from external committees (e.g. ANR or ERC grants) whose results cannot be entirely predicted.

• Technological projects which are the main source of external funds may tend to get priority on fundamental science projects. Care should therefore be taken that this does not lead to a reduction of the science program nor involve the institute in projects of lower scientific interest. This would typically affect more nuclear and particle physics programmes than astrophysics projects which benefit from funding by external agencies such as CNES, ESA or ESO. Within nuclear and particle physics, small projects, without support of the TGI, are more vulnerable.

• Priority for opening permanent positions may be driven by results of project calls instead of remaining driven by the overall strategy.

• Generic R&D is at risk. Today's success of IRFU relies heavily on the R&D over the past 20 years. The technological field (both in the domains of accelerators and detectors) is evolving fast, the international competition is high and continuous R&D is therefore vital. One of the strengths of IRFU relies on its large spectrum of competencies, but this requires conversely R&D in a large number of disciplines.

• The increasing need to get external funding, combined with the multiplicity of agencies providing external grants, adds to uncertainty and lowers the efficiency.

Concerning the reduction of the permanent manpower:

- The reduction of the permanent manpower (CDI) has been mitigated by an increase of non-permanent (CDD) staff. However short term contracts have important drawbacks in terms of efficiency and continuity of the expertise. In particular, 18 months contracts imposed by the French legislation often have reduced efficiency. The committee has been informed that longer-term contracts (typically 3 years) may be awarded in the future and considers very favourably this evolution.

- Part of the technical staff is overloaded and has often to manage too many projects in parallel. The best example is the Design Office of SIS, where design engineers are typically working on three projects at the same time. Obviously, the staff overload is also a strong obstacle towards R&D.

- The lack of permanent positions opening may reduce on the long term the attractiveness of the institute. This is particularly true for young technicians, given the fact that salaries in the public sector are lower than in industry.

We will now mention some concerns expressed by the committee, which affect the unit as a whole. Additional points can be found in the detailed assessments of the unit and of each theme.

- The number of fresh positions to recruit young staff on permanent positions is very limited. The necessary rejuvenation of the staff and the transfer of knowledge from the retiring staff are at risk. Some corners (for example computing or CAD support) are already strongly affected.

- As already mentioned, the pool of technicians is getting thinner. High technology research implies R&D and prototyping, these tasks cannot be easily outsourced to industry or industrial services.

- The IRFU capacity to train students and postdocs is not saturated and more such young researchers could be hosted in the laboratory, in particular within the technical divisions where the number of students is low (this point is developed further in the section concerning training through research). One will never stress enough the vital role of PhD students and young postdocs in research units: being free of any other (administrative or teaching) tasks, they can concentrate 100% of the time on their research and increase drastically the productivity of the unit. They are also the source of fresh and innovative ideas.

- The load on the manpower does not favour technology and knowledge transfer actions.

- Finally, continued attempts to communicate the strategy and necessary changes is always helpful and is especially so when resources are limited.

As pointed out above the preceding narrative seeks to delineate the issues faced by the institute not necessarily its intrinsic weaknesses.

## Conclusions and recommendations

**The committee has been extremely impressed by the achievements of IRFU during the last five years in all fields**

In particle physics, IRFU contributes to the leading projects with intense and visible contribution to all aspects of ATLAS and CMS and to major neutrino experiments. In astrophysics, IRFU is one of the leading laboratories in France, again with major and recognized contributions in this fast developing and exciting field. IRFU is probably unique in its ability to contribute to all steps of the experimental chain, from conception and instrument development to analysis, modelling and theory. In nuclear physics, IRFU is also a key player with strong involvement and intellectual leadership at national and international level on many different topics, from the highest energy to nuclear structure. The competence and the infrastructure on the Saclay site in the field of accelerators and superconducting magnets are unique in France and put IRFU among the world leaders in this domain. IRFU scientists are highly competent, well visible at the international level and very successful in getting external resources through national and international project calls. The strength in technology, together with the close ties with other divisions of the CEA, allows a very strong interaction with industry and contribution to societal issues in the domain of medical and nuclear applications or future energies. All these achievements would not be possible without a well constructed, project-oriented organisation which ensures also a rich scientific life in the institute and satisfaction for the personal and students.

**In a word, the committee finds the quality of IRFU to be excellent, at top level on the international scene.**

Our recommendations are therefore mainly targeted towards the key question *"how to maintain this excellence in the future?"* given the difficulties induced by the reduction of resources, following the current economical situation.

• The know-how capitalised during the last 20 years should be protected by ensuring a continuous rejuvenation of the permanent staff and a good overlap between the newly recruited staff and the staff leaving for retirement. Particular attention should be brought to the issue of technicians who are vital for research in technological fields.

• A careful balance has to be found between large technological projects, not always directly linked to the mission of IRFU in basic science but which allow gathering external resources and projects in fundamental science which should keep some priority. In particular, these large projects should not jeopardize the technical support from SIS or SEDI towards the three physics divisions. Small innovative projects should be encouraged.

• The program must leave enough breathing space to the staff for involvement in basic R&D, which is vital for the long-term future in a competitive and fast evolving environment. This will also enable an even stronger involvement in technology and knowledge transfer.

• Links with universities, doctoral and engineering schools must be tightened and sufficient budget must be set aside to increase the number of PhD students, in particular in the technical sector. The creation of the ComUE Paris- Saclay may offer a strong opportunity for improving on this aspect.

• Difficult times imply difficult decisions and changes: frequent communication with the staff, to explain the overall strategy and collect its input, is of outmost importance to maintain motivation.

**IRFU's scientific program for the next decade is rich and ambitious and is strongly endorsed by the committee.**

In particle physics, it is important to prepare a strategy for the large upgrades foreseen for LHC experiments around 2023 and to enable the necessary R&D. In astrophysics, the committee recommends to strengthen the involvement in the preparation of physics exploitation of the CTA project, in order to ensure a high scientific return when the instrument is operational. A clearer articulation between SAp and SPP on this project could probably help to achieve this goal. In Nuclear physics, one should remain vigilant to the impact of potential delays of the phase-2 of SPIRAL2 as aggressive developments are taking place at other facilities in the world. Finally, strong R&D on emerging magnets technology ($MgB_2$ and HTS) is essential to keep the leadership in the superconducting magnets field.

The committee notes the excellent organisation of the review and the strong mobilization of IRFU staff which allowed an in-depth visit of the institute including very interesting and informative discussions.

# 3 • Detailed assessments

## Assessment of scientific quality and outputs

The scientific production of the three physics divisions is excellent. In the past five years, and mostly thanks to its collaboration on international projects, IRFU has contributed to most of the highlights and breakthroughs in the fields. Detailed accounting can be found in the various themes report, and we list below the most prominent results and some general statistics.

In the theme of “Ultimate Constituents”, the highlight is clearly the discovery of the Higgs Boson in 2012 which resulted in the Nobel Prize award in 2013. One should also cite the first observation of $\nu_e$ appearance in a $\nu_\mu$ beam by the T2K experiment, leading to a measurement of the $\theta_{13}$ mixing angle. Both results have an essential impact on the world strategy in high-energy physics for the near future.

In the theme “Energy Content of the Universe”, the IRFU groups contributed also to key results. The SLNS survey published the most precise Hubble diagram and confirmed unambiguously the acceleration of the expansion of the Universe. An IRFU team conducted the first Baryon Acoustic Oscillations study in intergalactic hydrogen clouds, showing that, in contrast, the expansion of the Universe was decelerating in an earlier era, 11 billions years ago. IRFU contributed also strongly to the first results of the Planck survey which became public in March 2013, with emphasis on the study of the clusters of galaxies.

In the theme “Formation of Structures”, there were major breakthroughs in various areas: results from Herschel showed that galaxy evolution is dominated by cold gas flows and that stellar formation occurs in filaments. 3D simulations performed by IRFU groups allowed strong progress in the understanding of stellar interiors and galaxy evolution.

In “Nuclear Matter”, the ALICE experiment allowed the unambiguous evidence (in lead-lead collisions at the LHC) of a new state of matter, the quark-gluon plasma. An IRFU group has built a software platform for the phenomenology of Generalized Parton Distributions, which constitutes a unique framework for 3D nucleon imaging. In the nuclear structure domain, an IRFU team published the first ab-initio calculations for medium mass semi-magic nuclei or gamma ray spectroscopic study of the element $^{256}$Rf, the heaviest element so far examined in this way.

The number of publications in refereed journals in the period 2008-mid 2013 exceeds 4000, out of which 388 have been published in the prestigious and high impact-factor journals, for example Nature, Science, and Physical Review Letters. This corresponds to about six publications per physicist and per year. Compared to 2008, the number of publications in 2013 has nearly doubled partly due to the very rich harvest of the LHC experiments and other important international programs. Two per cent of the publications are within the 0.1% most cited papers in the field. Among those one can particularly mention the discovery papers of the Higgs Bosons by ATLAS and CMS (each cited more than 1000 times), the T2K paper cited more than 700 times, two papers from the Herschel space mission each cited 230 times, the source catalogue of FERMI which is the most cited paper of 2012 in the field of astrophysics and a paper on simulations, using the in-house code RAMSES, revealing that cold flows feed galaxies (429 citations). Most of the publications are from projects performed in the frame of international collaborations.

Achievements in the technological field should also be included in the scientific production of the institute. The following list is not exhaustive and focuses on instruments delivered in the period 2008-2013 (i.e. after the large contributions to LHC at CERN): in astrophysics, IRFU delivered the PACS imager for Herschel, the mid-infra red imager MIRI for the JWST telescope (to be launched in 2018) or an array of novel detectors for the focal plane of ARTEMIS at the APEX telescope. The SACM has accumulated large and recognized expertise on SC magnets and accelerators. It delivered sources and injectors for IFMIF (in Japan) and SPIRAL2 at GANIL, the RFQ of the LINAC4 at CERN and is currently assembling cryo-modules for E-XFEL and SPIRAL2. The cold mass of the large spectrometer magnet for R3B- GLAD at GSI is tested and will be integrated in the next months. Many other projects are under construction.

## Assessment of the unit's academic reputation and appeal

Many IRFU members carry large responsibilities in their experiments or projects. The complete list including 305 operational responsibilities in international collaborations is given in the document submitted to AERES. Let us mention for example the function as spokesperson of several medium size experiments such as COMPASS2 and GBAR at CERN, S3 at GANIL or STEREO at ILL. IRFU scientists are principal investigators of Double Chooz, NUCIFER and of many astrophysics sub-programs (for XMM, Herschel, ARTEMIS…). It would be good to see an IRFU member appointed as project leader or level-1 coordinator of a very large international collaboration such as an LHC experiment at CERN.

IRFU has played a leading role to promote the EUCLID mission, which has been selected in 2011 by ESA as one of the next flagship programs for the study of the Dark Universe.

SPhN hosts a virtual theoretical nuclear physics institute in collaboration with CEA-DAM.

We have already mentioned the large number of ERC grants from European Union (12, including 3 advanced ones). IRFU has obtained 58 projects financed by ANR grants and is member of 4 EQUIPEX, 4 LabEx and the ComUE Paris-Saclay. Among recent awards, one can note one Silver and two Bronze CNRS medals, three Joliot Curie (Société Française de Physique) Prizes and several prizes from the scientific newspaper « La Recherche » received by IRFU personnel.

Physicists and engineers from IRFU are members of a large number of scientific panels in national and international institutions. A particular mention should be given to the fact that the Head of the Institute is chairing the “director meeting” of the large laboratories involved in the CERN program and has therefore played a key role in the definition of the Update of the European Strategy for Particle Physics by the CERN Council in May 2013. An IRFU staff member is chief editor of European Journal of Physics A, while about 10 other scientists are associated editors of various reviews in Physics (Nuclear Physics A or B) or in the field of technology (IEEE transactions).

IRFU has therefore been successful in attracting researchers from the whole of Europe and a few from North America. About 60 % of the physicists hired during the last five years are from outside France. In addressing the recruitement of scientists, it may be however useful to consider occasional strategic appointments at a leadership level which would be attractive to the very best scientists in the field at a stage when they have an established reputation.

Taken all these facts into consideration, the committee considers that the unit’s reputation and appeal are excellent.

## Assessment of the unit's interaction with the social, economic and cultural environment

The technical developments at IRFU have led to many important applications with societal impact and industrial transfers.

In the technology of ionization detectors, a specific type of Micro Pattern Gas Detectors (MICROMEGAS) developed in the SEDI has been patented and can have applications in homeland security, earth tomography or detection of fires in the forests. Furthermore, the production of the base PCB’s needed for MICROMEGAS detectors has been transferred to an industrial firm (ELVIA). Innovation in the field of low energy gamma rays is very useful for biomedical applications: for example, IRFU is developing a novel detector using a heavy organometallic liquid which may bring large progress in positron tomography (PET).

Industrial transfer is taking place with a “PME” for the cost effective production of large mirrors for the CTA high-energy gamma spectrometer; if successful, this could lead to a substantial order for this small size company.

The research done in the application group of SPhN provides data for nuclear energy development. The NUCIFER experiment (under the auspices of IAEA) aims at providing an innovative method (based on neutrino detection) for non-proliferation and for monitoring of reactors. Non-destructive investigation of nuclear-wastes may be performed using results of photo-fission experiments done in collaboration with CEA/DAM.

The field of accelerators and superconducting magnets development is a strong source of partnership with top- level industry (ALSTOM, Air Liquide, Siemens to name a few) or academic partners in different fields. Superconducting magnets are essential for future energy sources, and IRFU's facilities will be used to test large coils for ITER or JT60SA. Magnets are also used for medical applications (MRI): IRFU is currently developing the world most powerful MRI magnet (11.75 Tesla) for ISEULT, a full body setup which will be located at the NeuroSpin facility.

IRFU has developed a new technology for positron sources: positrons can be used for materials studies, and a new company is being created to commercialize both the source and diagnostic equipment. Similarly, a high intensity proton/deuteron source (SILHI) has been developed and licensed to the firm Pantechnik.

IRFU is involved in the LOTUS project (part of the CEA "Technologies for Health" program) to automate and speed-up the production of radiotracers for PET cameras. In addition, a small robot has been developed by the SEDI Controls group to load the tracers in a syringe without manual intervention.

As a consequence of this activity, the number of patents has doubled (from 25 to 47) over the last five years. It is however the committee's opinion that Technology Transfer (TT) could be further strengthened. An industrial transfer officer has been appointed last year, but this staffing seems rather low (taking into account that the officer must not only investigate possible TT topics but also take care of the contractual and financial aspects) if one considers the very large possibilities offered by the first-class technological developments in IRFU.

On the outreach side, IRFU is also very active. Its web site is well documented, including some general public pages. IRFU edits also a newsletter, "Scintillation", mostly used for internal communication within CEA. IRFU scientists have contributed to many national events (Fête de la Science, Nuit des deux infinis,…), exhibitions (a prominent example being the "Voyage au centre de la Galaxie" for the Palais de la Découverte in Paris) and conferences. They have also produced films and documents for physics teachers and their students. There is a central communication group in IRFU, with correspondents in each of the division. The committee believes that outreach activities could be further developed; in particular taking into account that astrophysics is a "gold mine" for outreach with the general public.

## Assessment of the unit's organisation and life

The Institute comprises three physics divisions (SAp for Astrophysics, SPP for Particle physics, and SPhN for Nuclear physics) and three technical divisions: one division specialized in cryo-magnetism and accelerators (SACM) and two support units for project management, engineering, detectors control and electronics development (SIS and SEDI). SAp includes also a small technical team, qualified for space instrumentation. This is beneficial, given the high level of specialisation required for space instrumentation, and brings mutual fertilisation for the physicists and the technical staff.

A slight concern is that, mainly for historical reasons, cosmology is split over two divisions: SPP and SAp. Similarly the involvement in the CTA project goes across the two divisions. To mitigate this problem, common actions (for example seminars) are organised. However the geographical separation between SAp and SPP does not help and in particular students, who often do not have their own means of transport, suffer from this separation. The committee believes that a strong interaction between SPP and SAp is essential. On the long term, this organisation may have to be revisited. In the short term special measures (for example shuttles to help attending common seminars or workshops) could help.

The managerial organisation of IRFU is project oriented, with monthly meetings of the project leaders with the IRFU and divisions management. This allows deployment of the support from the three technical divisions in a flexible way, depending on the project's needs. Project leaders organise internally reviews or focused meetings on particular issues. Minutes of all these meetings are available, with action lists and follow-up tables with milestones.

The top management meets bi-monthly. Specific yearly meetings address budget and HR issues. There is a general strategy meeting every year, and a rolling decennial roadmap. To help with scientific decision making, each division has its own Scientific Committee (CSTS), including both internal members and external experts, which meets once or twice per year. At the level of IRFU, a Scientific Committee (CSI), with only external experts, has also been recently set up and met once towards the end of 2013. Some of the CSTS members have expressed the feeling that the respective roles of CSTS and CSI should be better defined.

Each division has a committee with elected representatives (CU, conseil d'unité) where issues concerning the life of the division are regularly discussed. Two members of each CU are chosen to be part of the central committee of the institute.

The minutes of the decisions taken by the management are posted on the internal Web and visible by all staff. However several CU's expressed the feeling that, while the decisions themselves are clearly transmitted, the rationale behind some of them is not always properly communicated. The top management meets the staff at least once per year, but it is felt that a bit more collegiality and, above all, an improved communication concerning important and strategic decisions would be welcome.

The scientific life (seminars, workshops, informal meetings, and special events where students present their work…) is very rich and all personnel, including the students, has expressed a strong satisfaction about it. An interaction with the Institute for Theoretical Physics (IPhT) has been organised for cosmology (Cosmo-club). Particle physics could benefit from a similar interaction or alternatively from a visiting phenomenology program.

## Assessment of the unit's involvement in training through research

IRFU offers many possibilities for the training of young students. The IRFU personnel is involved in the doctoral schools "Astronomie et astrophysique" (ED127) and "Particules, Noyaux, Cosmos" (ED517) and participate to the definition of the related doctoral schools within the Paris-Saclay University project.

A budget of 300 k€ is earmarked for trainees ("stages"), allowing about 100 students to spend on average three months at IRFU. Many of them are at the level of Master 1 or 2. This is an excellent way to attract PhD students and, indeed, 80 % of the Master2 trainees continue with a PhD at IRFU. There are also about 20 sandwich courses ("formations en alternance") per year.

There are currently 99 PhDs in progress at IRFU, corresponding to typically 20 to 30 PhD's per year, with a marked increase in 2012 (33). IRFU includes 140 staff members with accreditation to supervise PhD students (HDR). The large majority of PhDs are in the fields of fundamental science and the number of PhD's in the technical domain is very small. For example, there are only 3 PhD students in SACM, while this division includes 75 engineers/physicists. Even in the three physics divisions, the number of PhD students is below the supervision capability (about 0.2 student per engineer/physicist or 0.6 per HDR holder on average). This situation is not due to a lack of effort from the IRFU scientists, who organise events like the Master's Days to inform potential candidates and who are also making a strong effort to be involved in teaching activities at the University (see below). There may be several reasons for this low number of students and postdocs:

- The limited possibility of R&D particularly in the technical divisions (see discussion above) may limit the number of attractive topics for theses.

- About 55 % of the PhD students are recruited on special CEA contracts called CFR (contrat de formation par la recherche). IRFU has a quota of 12 CFRs per year. The selection procedure (decided at the top level of CEA) is very competitive and to some extent elitist. This does not favour the recruitment of PhD's in the technical domain.

Having young PhD students and postdocs is essential for the life of a research unit. The committee believes that an effort should be made to increase their number. For example, a small fraction of the IRFU budget could be set aside to increase the number of CFR's.

The AERES committee met the PhD students and postdocs. They have expressed a strong satisfaction about their supervision and the scientific life in the Institute. A PhD contact person, appointed in each division, regularly follows their work. IRFU encourages PhD students wishing to teach. Every year, a special event (D-days) allows the second year PhD students presenting their work publicly. PhD students have a representative in each CU. During the discussion, the following concerns were however mentioned:

- Foreign students would need stronger help to go through the French administrative formalities at their arrival (subscription to Social Security, getting the Vital card…) or about the tax system. Finding housing in the region is also not easy.

- Training programs are available (organised by INSTN) but access seems more difficult (due to cost) for those who are not under a CFR or EU contract.

- A better structure is needed to help students and postdocs to find jobs at the end of their contract. In particular, information concerning possibilities in other parts of CEA would be welcome.

Though IRFU is not directly linked to a University, about 140 IRFU scientists are contributing to teaching actions at a total level of 2500 hours per year. They are involved in several Master-2 governances (one co-responsible for a master in astrophysics, one co-responsible for the master on subatomic and cosmology). It is clear that the future ComUE Paris-Saclay, which is being setup, can offer many opportunities to even increase this effort and tighten the links with the Master students. An IRFU member will be co-manager of a new Doctoral School created in the frame of this new University. Furthermore a new Master's degree in the field of accelerators and superconducting magnets will be created, hopefully allowing an improvement of the situation with technical PhDs described above.

## Assessment of the strategy and the five-year plan

The strategy and the near term project result from a well defined and ambitious decennial roadmap. In the following, we summarize some of the main points in the various themes, including remarks from the review committee.

*Ultimate Constituents:*

IRFU has a strong planned contribution to CMS and ATLAS, whose program is foreseen to continue over the next

20 years. For the so-called phase-1 upgrades which will take place in 2018-19, IRFU will contribute to new muon chambers (New Small Wheels) using the MICROMEGAS technology and to the renewal of the Level-1 calorimeter trigger. Both are adequately funded and the challenge will be to perform this work while maintaining the strong current contribution to operation, software development and analysis. Other, much larger (phase-2) upgrades are foreseen for 2023-2024 for both ATLAS and CMS. It is important to develop the strategy for SPP's involvement in these projects and their funding and to enable the necessary R&D very soon to meet these challenging projects.

A rich neutrino program is defined for the next years with the continuation of T2K, Double Chooz, Sterile neutrino searches (CELAND and STEREO) and NUCIFER. It is essential not to take any delay with Double Chooz start-up since competing experiments (Daya Bay, RENO) have already produced rather precise results on $\theta_{13}$ and the interest in the complementary measurement of Double Chooz may fade out with time.

*Energy Content of the Universe:*

The strategy is well inserted in the international context. The EUCLID project, accepted by ESA in 2012 with a launch planned for 2020, is the flagship project for the study of the Dark Universe. IRFU is strongly involved in its preparation. The BOSS project on Baryonic Acoustic Oscillations will continue with e-BOSS and IRFU prepares an instrumental contribution to DESI, an American project on the same subject planned also for the end of the decade. The analysis of Planck data will continue.

Direct searches of dark matter with bolometers (EDELWEISS) will continue. There is however a strong competition with other techniques allowing larger target masses. A reflexion is therefore needed whether and how to progress further in this domain.

IRFU should ensure that decisions concerning resource allocation are taken in timely manner so as to ensure that the projects in which they have significant investment are not disadvantaged compared to other competing projects. A current example might be the GBAR experiment (an approved project at CERN to study antimatter gravity, to start around the new ELENA decelerator in 2016-17) for which there is a competing experiment.

*Formation of Structures:*

The scientific strategy is also here dictated by external context (CNES, ESA, ESO). IRFU is involved in a variety of promising projects such as the JWST space telescope, ARTEMIS at APEX or the very large E-ELT telescope of ESO. IRFU is also very active in promoting new scientific themes for the Cosmic Vision program of ESA. This multi-way strategy takes well into account the uncertainties inherent in these large astrophysics projects. Of course, the analysis of current data obtained with Fermi or Herschel and the work on numerical simulation to understand better the Universe remain a high priority.

CTA is the flagship project of high energy Gamma astronomy. IRFU's involvement in the instrumentation development is high, but positioning in data treatment and future science exploitation should be consolidated, especially in the SAp group.

*Nuclear Matter:*

The heavy ion program has a clear line of continued participation in ALICE, with the upgrade of the ALICE detector foreseen for 2018 followed by many years of running. IRFU will concentrate on the MTF muon tracker upgrade, funded through TGI, which will improve the resolution and triggering capability for J/$\psi$ and Y studies in Pb- Pb collisions. For this physics topic, the forward coverage and the ability to measure very low $p_t$ production are unique to ALICE.

In the medium energy domain, IRFU is a leader in the field of Generalized Parton Distributions with COMPASS2 at CERN and CLAS12 at JLAB, both approved, and there is therefore a clear program for 4 years or more

The nuclear structure program is directed towards the exploitation of SPIRAL2 at GANIL. The schedule of the phase-1 program is well defined, with a start-up in 2016, and will provide a strong physics program with the observation of heavy nuclei and their spectroscopy. The schedule of the phase-2, for the study of exotic nuclei, is somewhat more uncertain and may suffer from competition at other facilities.

Programs in the field of nuclear applications will continue with strong ties with CEA/DAM.

*Superconducting magnets and Accelerators:*

The Technical divisions are involved in an impressive number of world-class projects which have been presented above. Projects and collaborations have often been chosen to acquire the technology, the knowhow and the infrastructure which could position favourably IRFU for future potential projects linked to fundamental science. For example, the E-XFEL cryo-modules are “prototypes” of the cryo-modules needed for the International Linear Collider currently under discussion in Japan. Similarly, the technology developed for ESS could be very useful for a future high intensity facility for neutrino physics in USA or Europe. The committee notes however that the multiplicity of projects may lead to fragmentation, saturates the technical services and may hamper the necessary R&D to stay up-to-date and competitive in emerging technologies (for example $Nb_3Sn$ and HTS magnets).

# 4 • Theme-by-theme analysis

**Important remark: at the request of IRFU, the review was split according to six scientific themes. A few projects are spanning over several themes (in particular between "Energy Content" and "Structure" of the Universe), In this case, to maintain the self-consistency of each theme assessment, the committee decided to repeat its finding and recommendations in each of the relevant sections.**

## Theme 1: Ultimate constituents

### Workforce

| Theme workforce in Full Time Equivalents | FTE 2013 | FTE 2014 |
|---|---|---|
| FTE for permanent professors | 0.5 | 0.5 |
| FTE for permanent EPST or EPIC researchers | 65.1 | 64.2 |
| FTE of other permanent staff without research duties (IR, IE, PRAG, etc.) | 9.6 | 10.3 |
| FTE for other professors (PREM, ECC, etc.) | 1.0 | 1.0 |
| FTE for postdoctoral students having spent at least 12 months in the unit | 7.8 | 2.2 |
| FTE for other EPST or EPIC researchers (DREM, etc.) excluding postdoctoral students | 4.5 | 3.5 |
| FTE for other contractual staff without research duties | 0.3 | |
| FTE for doctoral students | 21.8 | 16.4 |
| **TOTAL** | **110.6** | **98.1** |

### Assessment of scientific quality and outputs

IRFU has been a key player in carrying out research in the "Ultimate constituents" theme by being a major contributor to the leading international projects in collider and neutrino physics. IRFU's scientific productivity and quality in this them are excellent, with 1160 refereed papers over the past five years corresponding to more than 4 papers per FTE and per year. Two hundred twenty five (225) of these papers were published in journals of very high visibility such as PRL, Nature or Science, and the impact of these publications is very high, with an average of 8.5 citations per paper per year. Compared to 2008, the number of publications in 2013 has doubled, mostly due to the LHC experiments and the T2K neutrino experiment. Among those one can particularly mention the discovery papers of the Higgs Bosons by ATLAS and CMS (each cited more than 1000 times) and the T2K paper on $\theta_{13}$ cited more than 700 times.

The "Ultimate constituents" research is primarily performed in the SPP division and it benefits significantly from support by a strong, competent group of engineers and technicians at SIS, SEDI, and SACM divisions for detector development and construction.

Historically IRFU has had a coherent strategy covering in depth the complete spectrum of competencies required for performing experimental research. These include technological innovations, proposals of experiments, conceptual design, R&D and construction of detectors for the experiments, followed by detector performance studies (including alignment, software algorithms, calibration and maintenance) and key physics analyses using these detectors (for example, analysis of the Higgs discovery). Another strength is to use the same innovative technologies for multiple experiments and applications. A great example is the Micro Pattern Gas Detectors (MICROMEGAS) technology, for which basic R&D was done at Saclay, which was successfully used for the near detector of the T2K experiment, CAST and COMPASS, and will be used for the upgrade of the ATLAS muon system. This technology is being developed and/or prototyped for the ILC tracking system, the long-baseline neutrino experiment, and medical and national security applications. Another nice example is the analogue pipeline digitizer ASICS developed at IRFU. This technology has evolved in complexity and performance as it has been used for several different projects along the time.

Similarly IRFU has a coherent strategy in analyses, with the successful transfer of skilled personnel and analysis techniques from previous experiments to current experiments. This has been well demonstrated in top quark, electroweak, and QCD physics at the Tevatron and the LHC (e.g. from Tevatron's DZero to LHC's ATLAS and CMS). It also has a strategic strength to link neutrino oscillation physics (SPP) to nuclear physics (SPhN) to explore some of key questions in neutrinos such as reactor flux calculations and sterile neutrinos.

Given experimental and technical strength, IRFU has great opportunities to recruit stars in the field of Particle physics.

### Assessment of the unit's academic reputation and appeal

IRFU has leadership of important scientific and technical groups within large international experiments. IRFU staff is actively involved in international relations and IRFU scientists participate to numerous international scientific and strategic advisory bodies that develop future directions of particle physics in the world. Examples include serving on the European strategy preparation group, and U.S. high-energy physics advisory panel.

IRFU's scientific and technical strength in Particle physics is well demonstrated by 3 ERC grants given to SPP scientists and by leadership roles (physics group conveners, technical coordinators). The institute has been able to attract a significant fraction of postdocs and students from abroad.

The SPP division with 47 permanent researchers involved in the field has a strong record of publications. It has published 1149 peer- reviewed papers over the past five years, 20 % of which were in journals with a very high impact, such as Physical Review Letters, Nature, and Science. Twenty five of the published articles exceeded more than 100 citations and 60 articles were cited more than 50 times.

### Assessment of the unit's interaction with the social, economic and cultural environment

There have been very strong and effective outreach activities by IRFU staff associated with scientific discoveries in the « Ultimate constituents » theme (e.g. Higgs boson discovery) as well as in spin-off activities. Innovative technical developments driven by the « Ultimate constituents » research have various potential applications including national security and medical applications.

### Assessment of the unit's organisation and life

As mentioned above, the « Ultimate constituents » research is primarily conducted by the SPP division. Overall the SPP is well organized. The strategic plan is clear, focusing on high priority and high impact collider experiments at the LHC and a variety of neutrino experiments that address profound questions in particle physics. The technical support for the research program appears to be well coordinated and managed with technical service divisions: SIS, SEDI and SACM. However, scientific staff perceives lack of influence on the decision making for strategy at IRFU.

## Assessment of the unit's involvement in training through research

PhD students and postdocs are very well supervised and trained. They are well integrated into the daily work of the division. Over the last five years, there were 56 PhD dissertations defended or in progress. SPP scientists take initiative to participate in University teaching at both undergraduate and masters levels. There are opportunities to expand these activities, e.g., as part of the ComUE Paris-Saclay initiative.

## Assessment of the strategy and the five-year plan

As described above, IRFU has had a coherent strategy in covering in depth the complete spectrum of competencies required for performing experimental research for both collider experiments and neutrino experiments. The collider program will be concentrated on the continued participation in the ATLAS and CMS experiments and IRFU plans to make very significant contributions to the upgrades of ATLAS and CMS detectors. The diverse programme in neutrino physics is well aligned with IRFU leadership and expertise as shown in exploitation (Double Chooz and T2K) and future experiments (e.g. NUCIFER and Celand).

## Conclusion

- **Strengths and opportunities:**

The “Ultimate constituents” theme is very strong on an international scale. IRFU has been a key player in carrying out research in this theme by making a coherent strategy in choosing high impact, leading international experimental projects and by being a major contributor to these projects. IRFU’s scientific productivity and quality in this theme are very high. IRFU has strong leadership of important scientific and technical groups within large international experiments and its members play important roles in international scientific and strategic advisory bodies that develop future directions of particle physics in the world. The SPP division, where most of « Ultimate constituents » research is performed, is well organized and coordinates well with technical units. We see possible opportunties to strengthen the theme by recruiting a couple of stars in the field of particle physics to the institute.

Overall the « Ultimate constituents » theme can be described as excellent with a high visibility in the international community.

- **Weaknesses and threats:**

The success of IRFU in the “Ultimate constituents” theme heavily relies on generic and basic R&D. At a current

environment where technical projects are driven by external funds, generic and basic R&D is at risk.

Challenges are to maintain IRFU’s current visibility and reputation by fulfilling its commitments to hardware and software responsibilities for ATLAS and CMS experiments (muon and calorimeter systems) in the Run 2 machine environment and for neutrino experiments (T2K and Double Chooz) and high quality and volume of physics analysis, while taking on major work for the ATLAS phase 1 upgrade (Muon Small Wheel and Level-1 calorimeter trigger), developing and performing associated R&D for ATLAS and CMS phase 2 upgrades, and playing a leadership role for the ILC and the long-baseline neutrino program.

Interactions with particle theory groups from local institutes (IRFU does not have its own particle theory group) could be stronger.

The number of students and postdocs relative to the number of qualified (HDR) particle physicists is low (0.5 and 0.2 respectively), when compared to international competition. Internationally, the supervision PhD students and postdocs is seen as a significant fraction of the scientific productivity of senior researchers; increasing the number of students and postdocs represents an opportunity to maintain, or indeed increase, overall the scientific productivity of IRFU in an environment of decreasing numbers of permanent scientific staff. We recognise that this may require a change in attitudes and research “culture” within IRFU.

Scientific staff perceives lack of influence on the decision making process for strategy at IRFU.

The first measurements of $\theta_{13}$ were made by Daya Bay and RENO, not by Double Chooz due to lack of its near detector in time.

GBAR, a small innovative project originated by IRFU, is an approved project by CERN. Yet progress is slower than technically possible due to lack of resources.

- **Recommendations:**

IRFU should pursue its international recruitment at the highest level. Given experimental and technical strength of IRFU, the institute has enough opportunities to attract them.

We recommend IRFU to take steps to increase substantially the ratio of PhD students and postdocs to permanent scientific staff qualified to supervise them.

Given lack of a particle theory group, IRFU could institute a visiting phenomenologist programme or other links to local institutes with particle theory groups.

IRFU should examine critically current hardware and software responsibilities and desired future activities to make sure that IRFU will maintain its current visibility with successful deliveries of its commitments.

It is important to engage the staff in the strategic planning of IRFU and to communicate the strategy to the staff frequently. This will help motivating staff, especially during times of difficult decisions and changes.

The program should allocate modest resources to support generic and basic R&D and small innovative projects.

## Theme 2 : Energy Content

### Workforce

| Theme workforce in Full Time Equivalents | FTE 2013 | FTE 2014 |
|---|---|---|
| FTE for permanent professors | 0.3 | 0.3 |
| FTE for permanent EPST or EPIC researchers | 59.6 | 66.9 |
| FTE of other permanent staff without research duties (IR, IE, PRAG, etc.) | 15.3 | 15.2 |
| FTE for other professors (PREM, ECC, etc.) | 1.0 | 1.0 |
| FTE for postdoctoral students having spent at least 12 months in the unit | 27.0 | 15.0 |
| FTE for other EPST or EPIC researchers (DREM, etc.) excluding postdoctoral students | 1.9 | |
| FTE for other contractual staff without research duties | 0.4 | |
| FTE for doctoral students | 18.0 | 16.8 |
| **TOTAL** | **123.5** | **115.2** |

### Assessment of scientific quality and outputs

The scientific productivity and quality of the “Energy Content” theme is excellent, with 513 refereed papers over the past five years, or 170 papers per year in average for 52 publishing FTE, corresponding to 3.3 papers per FTE and per year. Remarkably 17 % of these 513 papers were published in journals of very high visibility such as PRL, Nature or Science, and the impact of these publications is very high, with an average of 7.9 citations per paper per year.

Research carried out at IRFU in this theme has lead to important milestones and contributions during these last five years:

The flagship ESA Euclid space mission to unravel the mysteries of the Energy Content of the Universe was selected in 2011, and accepted in 2012; IRFU has played from the very beginning a leading role in its selection and in managing this project.

IRFU scientists contribute significantly in the development of major numerical simulation tools (COAST and RAMSES) that are used successfully to produce large cosmological simulations used thereafter to interpret observational results. These tools are now used by a very large number of scientists throughout the world.

IRFU has focussed some significant resources on the Baryonic Acoustic Oscillation (BAO) measurement through the participation in the BOSS experiment, and in particular in the analysis of the BAO detection in the Lyman Forest of high redshift quasars, which first measured the early deceleration of the expansion of the Universe. This topic of research is in fact very well structured and planned, with coming participation in eBOSS (extension of BOSS) and then with a strong involvement in the preparation of DESI, the major future BAO experiment led by LBNL, by contributing to the cryostat for the 30 detectors expected.

With the successful launch of the Planck mission in 2009, IRFU scientists have played a major role in cataloguing massive clusters from the Planck data, validating their detection and using them to constrain the cosmological model. They also are successfully using the ESA XMM satellite to either confirm Planck detection or to discover the smaller clusters complementing the Planck detections.

IRFU scientists have also focussed on the detection of Dark Matter using direct search techniques with the EDELWEISS3 experiment, but also using indirect detection with neutrino telescopes using ANTARES and gamma telescopes (H.E.S.S. for now, and CTA in the future).

Finally, IRFU scientists are participating in the challenge to measure the gravity effect on anti-matter particles through the GBAR experiment to be installed at CERN.

To conclude, the “Energy Content” theme of IRFU has very high profile, with some key lines of research in this domain. Importantly, IRFU scientists are active at almost all levels in the chain of knowledge production: seminal idea, R&D, instrument development, data treatment and analysis, science exploitation, modelling, predictions.

Considering that this particular theme of research is evolving very rapidly, IRFU will need however to keep up with the fast development of this field. Strategic decisions may have to be taken to ensure the participation at high- level of IRFU.

### Assessment of the unit's academic reputation and appeal

In the “Energy Content” theme, IRFU has been successful within its academic environment with a participation in one LabEx, in 15 ANR projects (and leading 8 of them), 7 European FP projects, and with the attribution of two ERC grants. The attractiveness of this theme is thus very high.

The flow of PhD students is very high with 21 PhDs defended over five years, and 17 on-going PhD theses. The number of post-docs is also adequate. About half of the scientific staff members are PhD or postdocs. Remarkably the number of non-permanent staff has increased over the last five years.

The good scientific positioning of IRFU in this theme is certainly an important factor of attractiveness for students and post-docs, and needs to be preserved.

### Assessment of the unit's interaction with the social, economic and cultural environment

The “Energy Content” theme has a relatively low level of technology transfer, which is expected for these fundamental research topics. Nevertheless, the projects embraced by the teams are pushing the development of new or improved technologies (e.g.: high-efficiency detectors for Dark Matter direct search or low-cost mirror production for CTA…). Possibly some aspects of these technologies may be transferred but a stronger organization within IRFU should take responsibility to valorise these developments.

Although there is an interest and a number of actions about outreach activities, it seems that there is room for improvement for story telling at the division and IRFU levels.

### Assessment of the unit's organisation and life

The “Energy Content” theme benefits from the strong implication of technical services (SEDI and SIS) in the instrumentation developments for its research (e.g. cryostat development for the DESI experiment, low-cost mirrors for CTA, bolometer technology for EDELWEISS, computer software development for the COAST project). The availability of the engineers and technicians support can however be questioned sometime due to internal competition of projects and possibly external contracts.

There has been some tension in the SPP service regarding its structure and way of functioning (whether staff should organize themselves in laboratory or not), which seems still to be addressed properly.

The fact that the "Energy Content" theme is mainly split over the two services, SAp and SPP, which are both located two kilometres apart on the two CEA campuses, is making day-to-day interaction sometime inefficient (e.g. seminars, working group meeting). It may be important for some projects (CTA and dark energy projects such as possibly in the future DESI and EUCLID) to address this communication issue.

Compared to the other scientific themes in IRFU, the number of seminars in the "Energy Content" theme is low, despite the large number of international activities in this topic. Either a better balance is to be reached across the different scientific themes, or an effort should be made to increase the number of seminars in this theme.

### Assessment of the unit's involvement in training through research

The flow of PhD students at SPP and SAp is well suited for the "Energy Content" theme. This is certainly due to the high attractiveness of this theme among students, as well as a large number of funding sources for doctoral contracts: CFR, Ministry grants, Région Ile-de-France, LabEx…, as well as to a strong involvement of IRFU researchers in training at master level and their excellent insertion in the governing bodies of the various doctoral schools in this area.

The involvement in teaching of IRFU researchers is remarkable, considering that the vast majority of them have in principle no teaching duties. We note that implication in teaching, especially at M2 level, is of great importance to attract PhD students to IRFU, and certainly plays a crucial role in the attractiveness for PhD students of the "Energy Content" theme. This is an opportunity that IRFU must recognize and maintain in the future.

IRFU researchers are well involved in the governance of doctoral schools and masters. This involvement is also seen as strength for IRFU, as it gives some opportunity to tune some of the training toward the themes of interest of the institute, therefore increasing its attractiveness.

The new university in construction (ComUE Paris-Saclay) is seen as a nice opportunity to further improve the implication of IRFU in teaching, especially in technological areas. If correctly exploited, this potential for improved involvement in teaching and training may contribute to attract more PhD students to technological and instrument development subjects, which represent a severe need for the institute.

Following the same logical path, a deeper implication of IRFU in the construction of the Paris-Saclay ComUE would allow the institute to take a more important part in crucial decisions for this new university and prepare for itself a better position in this federal establishment.

### Assessment of the strategy and the five-year plan

The strategy of IRFU in the "Energy Content" theme is well placed in the national and European prospective at the crossroads of astrophysics and fundamental physics. The scientific strategy in this area is largely dictated by external context at national (IN2P3, INSU), European (ESA, CERN) or international level (DOE), which is a potential threat since the institute cannot control all elements of its own prospective. Nevertheless IRFU has been very selective and smart in defining its strategy and in pushing the projects in which it is involved. The selection by ESA of the EUCLID mission, which was originally proposed by IRFU in the form of the DUNE proposal, is a good example of a successful IRFU strategy. The stopped contribution of IRFU in the KM3NeT neutrino project is another strategic decision that is likely to be positive in the long term.

The need for a potential improvement in IRFU scientific strategy, belonging partly to the “Energy Content” theme, has been identified in the framework of the CTA project. IRFU has set a clear priority on CTA and is strongly involved in the instrumental development of this project, especially in the fabrication of mirrors and cameras for the medium size telescopes. IRFU is providing, to a large extent, the backbone for the French contribution to the construction of CTA. This vigorous technical effort ought to correspond to a clear ambition of IRFU to play a leading role in some of the scientific objectives of CTA. This ambition does not appear clearly at this moment in the SAp group. This is due on the one hand to the very preliminary stage in which the overall CTA project finds itself in terms of consortium organization and share of tasks and responsibilities, especially in the area of data treatment and scientific exploitation, and on the other hand to an internal articulation between SPP and SAp that deserves some improvement. Whereas the first difficulty occurs at an international level where IRFU can hardly exert a decisive influence, the second one is purely internal and may be overcome by a better organization of the institute. Clearly cosmology, especially in its links to high-energy astrophysics, is a new subject at IRFU, addressed by various teams in both SPP and SAp, having different historical backgrounds. There seems now to be a need for an evolution of this organization, leading to a better coordination and improved synergy in this area between both divisions. A path that could perhaps be explored would be to rely more on cooperation with the APC laboratory at P7, of which IRFU is “cotutelle”, and that could be seen as a cement between particle physics and astrophysics.

As far as the SAp service is concerned, the final place of IRFU in CTA is at stake. It indeed appears essential that IRFU must end up playing a leading role in one or several scientific objectives of this project in the theme of “Energy Content.

## Conclusion

- **Strengths and opportunities:**

- excellent record in scientific publications and citations

- some major breakthroughs and milestones in several scientific areas

- excellent positioning for instrumental developments

- remarkable presence at every step in the chain of knowledge production

- excellent success in academic environment

- remarkable implication in teaching and training

- high attractiveness for PhD students

- opportunity to use ComUE Paris-Saclay to further improve implication in teaching, especially in technological areas.

- opportunity to further develop outreach activities

- IRFU has a good influence for the definition of overall scientific strategy at national and European levels

- **Weaknesses and threats:**

- The split for the “Energy Content” into two services: SAp and SPP, located 2 kilometres apart is a weakness to bring this theme to its best.

- scientific strategy and institute organization could be improved around the CTA project, for which IRFU should better define its ambition to play a major role in some of the scientific objectives and better adapt its internal organization toward this goal

- technology transfer could be improved, IRFU having the potential for it.

- **Recommendations:**

- Investigate possible solutions to overcome or reduce the split of the “Energy Content” into two divisions/geographical locations. This will be particularly important when major projects are getting ready (CTA, DESI, EUCLID) for implementation and exploitation.

- maintain/improve level of involvement in teaching and training, especially at M level

- use participation to the ComUE Paris-Saclay to improve involvement in training, especially in technological areas

- improve internal organization, especially articulation between SPP and SAp, for a better definition of scientific ambition for IRFU in the CTA project

- improve technology transfer

- intensify outreach activities.

## Theme 3 : Formation of Structures

### Workforce

| Theme workforce in Full Time Equivalents | FTE 2013 | FTE 2014 |
|---|---|---|
| FTE for permanent professors | 8.5 | 7.5 |
| FTE for permanent EPST or EPIC researchers | 65.9 | 67.0 |
| FTE of other permanent staff without research duties (IR, IE, PRAG, etc.) | 8.2 | 7.7 |
| FTE for other professors (PREM, ECC, etc.) | 3.5 | 3.0 |
| FTE for postdoctoral students having spent at least 12 months in the unit | 10.8 | 7.1 |
| FTE for other EPST or EPIC researchers (DREM, etc.) excluding postdoctoral students | 1.5 | |
| FTE for other contractual staff without research duties | 4.5 | 2.7 |
| FTE for doctoral students | 19.3 | 19.6 |
| **TOTAL** | **122.2** | **114.5** |

### Assessment of scientific quality and outputs

Scientific productivity and quality of the “Formation of Structures” theme are at an excellent level, with 1550 refereed papers over the past five years, i.e. more than 300 papers per year in average for about 90 publishing FTE, which come up to more than 3 papers per FTE and per year. These 1550 papers over five years include 60 in journals of very high visibility such as Nature or Science. The impact of these publications is also quite high, with an average of 6.5 citations per paper per year.

Research carried out at IRFU in this theme has led to major breakthroughs in various areas of astrophysics. For instance, IRFU teams, using the Herschel satellite, have shown that galaxy evolution is dominated by cold gas flows rather than by galaxy merging as previously thought. Other studies with the Herschel satellite have demonstrated that stellar formation preferentially occurs along filaments in the interstellar medium. Other examples of such breakthroughs are 3D simulations of galaxy evolution and of MHD processes in stellar interiors.

The IRFU teams in the “Formation of Structures” theme are also very well positioned for the development of major space and ground-based instrumentation, in particular in the infrared and sub-mm wavelength ranges as well as in the area of high energy astrophysics. Among other realizations, they have played a central role in the development of the PACS instrument on Herschel, on MIRI for the JWST, and are now strongly involved in various aspects of the EUCLID mission. On the ground, IRFU teams have developed the VISIR instrument on the VLT, as well as ARTEMIS on the APEX sub-mm dish at Chajnantor. In the area of high-energy astrophysics, they have participated to studies of instruments for the SIMBOL-X dual satellite, and have capitalized on these studies for their current participation to the Solar Orbiter STYX instrument. They are also strongly involved in the ECLAIRS and MXT instruments on the French- Chinese SVOM satellite, currently frozen. On the ground, they have participated to the H.E.S.S. Cherenkov Telescope Observatory and are currently working on the Cherenkov Telescope Array (CTA) project.

It therefore appears that, in the "Formation of Structures" theme, IRFU is present at the highest worldwide level at every step in the chain of knowledge production: seminal idea, R&D, instrument conception, instrument development, data treatment and analysis, science exploitation, modelling, theory, predictions. This universal positioning constitutes a tremendous strength of the IRFU teams in this theme, and contributes to their very high visibility in the international scene.

A potential threat, universally present in all institutes involved in instrument developments in astrophysics, is related to the very fast evolution of this area, implying the necessity to rapidly adapt to technology evolution on one hand, and on the other hand to our constantly improving understanding of the universe, calling for innovative instrumental developments. IRFU teams are doing rather well, and it can be claimed that they are actually playing a leading role in these two kinds of evolution.

### Assessment of the unit's academic reputation and appeal

In the "Formation of Structures" theme, IRFU has been very successful within its academic environment: with a participation in three LabEx, in many ANR projects, and with the attribution of up to six ERC grants, the "Service d'Astrophysique" (SAp), which is mainly involved in this theme, is certainly among the most successful laboratories in Europe. This record is a good indication of its "aura" and its academic attractiveness.

Thanks to this attractiveness and to a variety of funding sources (CFR grants, Ministry grants, other grants), SAp benefits from a satisfactory flow of PhD students (40 PhD defended over five years, and 38 on-going PhD thesis). The number of post-docs is also adequate.

The universal positioning of IRFU in all aspects of astrophysical research (instrumentation, observations, laboratory experiments, modelling, theory), shared by only a handful of institutes in Europe, is certainly an important factor of attractiveness for students and post-docs, and needs to be preserved.

### Assessment of the unit's interaction with the social, economic and cultural environment

The "Formation of Structures" theme seems to have a low level of technology transfer, which is not unexpected in an area where this culture is usually weak, but the IRFU teams working in this theme seem to have more potential for technology transfer than currently used. Perhaps a better articulation between IRFU and SAp support for technology transfer should be sought. In particular, some top-down organization, possibly at IRFU level, could be set up to identify transferable technological developments, then provide financial, technical and administrative support to build-up valorisation projects.

As far as outreach is concerned in the framework of the "Formation of Structures" theme, IRFU benefits from the usual appetite of the public for this kind of science, and from the presence of a few « stars » capable of raising enthusiasm in the general public. However, there seems to be some room for further improvements in outreach, and the teams could communicate more frequently and more efficiently toward various types of public: general public, school children, high schools and universities. A better complementarity between outreach support at IRFU and at SAp level could perhaps be achieved.

### Assessment of the unit's organisation and life

It is clear that the excellent results mentioned above in instrumentation developments strongly benefit from the presence of skilled technical staff within SAp and in the other instrumental divisions of IRFU. This is especially true for space instrumentation, which is very specific and requires the long acquisition of a specific culture, but this availability of engineers and technicians in the immediate vicinity of scientists is also very important for ground based instrument developments. This proximity of the science and technical teams improves the motivation and efficiency of technical staff, brings scientists some acute visibility on technological opportunities, difficulties and challenges, and finally provides mutual fertilization between fundamental and technological research.

Teams involved in the "Formation of Structures" theme are working in close collaboration with the technical services of IRFU, mostly SEDI and SIS. The dual mode of operation, which implies relying on both internal technical staff and cooperation with other technical services of IRFU, seems to work well and to bring an excellent level of flexibility for the development of SAp projects. The articulation between technical teams within SAp and those at SEDI or SIS seems satisfactory.

The global organization of the life of SAp is fluid and efficient, with an apparently correct level of transparency and collegiality. The CSTS meets once a year and brings a well considered partially external guidance for the mid- and long-term strategy of the service, including R&D developments. The unit council deals with more operational aspects of the life of SAp, and its way of functioning seems to bring general satisfaction among the staff.

## Assessment of the unit's involvement in training through research

The flow of PhD students at SAp is well suited for a unit of that size, and SAp does not seem to suffer from the same lack of PhD students as some other IRFU services. This is certainly due to the high attractiveness of astrophysics among students, to a large number of funding sources for doctoral contracts: CFR, Ministry grants, Région Ile-de- France, LabEx…, as well as to a strong involvement of IRFU researchers in training at master level and their excellent insertion in the governing bodies of the various doctoral schools in this area.

The involvement in teaching of IRFU researchers is remarkable, considering that the vast majority of them have in principle no teaching duties. IRFU staff contributes globally 2500 teaching hours per year, mainly at M and D levels. We note that implication in teaching, especially at M2 level, is of great importance to attract PhD students to IRFU, and certainly plays a crucial role in the attractiveness for PhD students of the “Formation of Structures” theme. This is an opportunity that IRFU must recognize and maintain in the future.

IRFU researchers are well involved in the governance of doctoral schools and masters. This involvement is also seen as a strength for IRFU, as it gives some opportunity to tune some of the training toward the centres of interest of the institute, therefore increasing its attractiveness.

The new university in construction (ComUE Paris-Saclay) is seen as a nice opportunity to further improve the participation of IRFU in teaching, especially in technological areas. If correctly exploited, this potential for improved involvement in teaching and training may contribute to attract more PhD students to technological and instrument development subjects, which represent a severe need for the institute.

Following the same logical path, a stronger participation of IRFU in the construction of the Paris-Saclay ComUE would allow the institute to take a more important part in crucial decisions for this new university and prepare for itself a better position in this federal establishment.

## Assessment of the strategy and the five-year plan

The strategy of IRFU in the “Formation of Structures” theme is well positioned in the national and European prospective in the area of astronomy and astrophysics. Whereas scientific strategy in this area is largely dictated by external context (INSU, CNES, ESA, ESO, Astronet…), which can be seen as a threat since the institute cannot control all elements of its own prospective, it must be noted that IRFU has developed a remarkable network of influence which, combined with the recognized excellence of its scientific and technical teams, allows it to imprint some of its general goals to the overall orientation at national, European and even international levels. One example of this process has been the selection by ESA of the EUCLID mission, which was originally proposed by IRFU in the form of the DUNE proposal, and that IRFU has been able to push all the way to selection.

At the time when France is preparing its national prospective exercises for space (CNES) and ground-based (INSU) astronomy, IRFU must therefore get ready to play its expected role, which ought to be major. These exercises should come up to choices and conclusions that should in principle strengthen the position of IRFU.

The need for potential improvement in IRFU scientific strategy, belonging partly to the “Formation of Structures” theme, has been identified in the framework of the CTA project in high-energy physics and astrophysics. IRFU has set a clear priority on CTA and is strongly involved in the instrumental development of this project, especially in the fabrication of mirrors and cameras for the medium size telescopes. Thanks to that IRFU is providing, to a large extent, the backbone for the French contribution to the construction of CTA. This vigorous technical effort ought to correspond to a clear ambition of IRFU to play a leading role in some of the scientific objectives of CTA. This ambition does not appear clearly at this moment in the SAp group.

This is due on the one hand to the very preliminary stage in which the overall CTA project finds itself in terms of consortium organization and share of tasks and responsibilities, especially in the area of data treatment and scientific exploitation, and on the other hand to an internal articulation between SPP and SAp that deserves some improvement. Whereas the first difficulty occurs at an international level where IRFU can hardly exert a decisive influence, the second one is purely internal and may be overcome by a better organization of the institute. Clearly cosmology, especially in its links to high-energy astrophysics, is a new subject at IRFU, addressed by various teams in both SPP and SAp, having different historical backgrounds. There seems now to be a need for an evolution of this organization, leading to a better coordination and improved synergy in this area between both services. A path that could perhaps be explored would be to rely more on cooperation with the APC laboratory at Paris 7 University, of which IRFU is "cotutelle", and that could be seen as a cement between particle physics and astrophysics.

As far as the SAp service is concerned, the final place of IRFU in CTA is at stake. It indeed appears essential that IRFU must end up playing a leading role in one or several scientific objectives of this project in the theme of "Formation of Structures".

## Conclusion

- **Strengths and opportunities:**

- excellent record in scientific publications and citations

- some major breakthroughs in several scientific areas

- excellent positioning for instrumental developments

- remarkable presence at every step in the chain of knowledge production

- excellent success in academic environment

- presence of skilled technical staff within IRFU

- remarkable implication in teaching and training

- high attractiveness for PhD students

- opportunity to use Paris-Saclay ComUE to further improve implication in teaching, especially in technological areas.

- opportunity to further develop outreach activities

- scientific strategy well inserted in overall astronomy and astrophysics prospective

- IRFU has a significant influence for the definition of overall scientific strategy at national and European levels

- **Weaknesses and threats:**

- very fast evolution of overall field of research, implying fast adaptation of teams to external context, but IRFU is precisely one of the few institutes in Europe having the necessary faculty of adaptation

- scientific strategy and institute organization could be improved around the CTA project, for which IRFU should better define its ambition to play a major role in some of the scientific objectives and better adapt its internal organization toward this goal

- technology transfer could be improved, IRFU having the potential for it.

- **Recommendations:**

- maintain current organization within SAp, with the presence of technical teams in the immediate vicinity of fundamental research teams

- maintain/improve level of involvement in teaching and training, especially at M level

- use participation to Paris-Saclay ComUE to improve involvement in training, especially in technological areas

- improve internal organization, especially articulation between SPP and SAp, for a better definition of scientific ambition for IRFU in the CTA project

- improve technology transfer

- intensify outreach activities

## Theme 4 : Nuclear Matter

### Workforce

| Theme workforce in Full Time Equivalents | FTE 2013 | FTE 2014 |
|---|---|---|
| FTE for permanent professors | | |
| FTE for permanent EPST or EPIC researchers | 62.3 | 59.3 |
| FTE of other permanent staff without research duties (IR, IE, PRAG, etc.) | 13.3 | 12.1 |
| FTE for other professors (PREM, ECC, etc.) | | |
| FTE for postdoctoral students having spent at least 12 months in the unit | 6.8 | 4.3 |
| FTE for other EPST or EPIC researchers (DREM, etc.) excluding postdoctoral students | 2.3 | 1.0 |
| FTE for other contractual staff without research duties | 1.0 | 1.6 |
| FTE for doctoral students | 14.1 | 13.2 |
| **TOTAL** | **99.8** | **91.5** |

### Assessment of scientific quality and outputs

The nuclear matter research at IRFU is mostly performed in the SPhN division and it benefits largely from the fact that a very competent and enthousiastic group of engineers and technicians from SIS, SEDI and SACM are supporting their research with the development and construction of innovative experimental equipment.

The division has published 695 peer-reviewed papers in the previous period, which is an average of 4 papers per year per permanent staff member. Eight of these articles exceeded more than 100 citations and 31 were cited more than 50 times, while 1/8 of the papers were in journals with a very high impact, such as Physical Review Letters, Nature, and Science.

Heavy Ion Collisions permit the study of nuclear matter in a number of conditions, some of them extreme. The work at the LHC with collisions between lead ions is recognised as being at the forefront of these investigations. The dedicated heavy ion experiment ALICE has already made impressive progress. The IRFU group leads the muon physics investigations in this experiment; they are players both in the technical development of the muon spectrometer and of the physics. It is expected that heavy quark states have their origins near to the primary interaction; thus their behaviour carries information from the heart of the interaction. These heavy quark states can manifest themselves as vector meson (eg $J/\psi$ ) states which give a dimuon signal; the observed behavior was not exactly as expected based on the earlier RHIC (BNL) results.

The IRFU group has been a strong player in the Compass program in the north area at CERN using both hadron and muon beams, and in the program in the CEBAF Large Aperture Spectrometer (CLAS) in Hall B at Jefferson Lab. These involvements date to their predecessor measurements with the first muon beams at CERN and to the electron accelerator work at Saclay preceding the construction of Jefferson Lab. In both programs of strong interaction studies, the IRFU teams have been prominent players in the study of Generalized Parton Experiments which are accessible through measurements involving polarization. The IRFU teams have made some of the early measurements and are deeply involved in the phenomenology needed to extract the physics from the measurements.

The nuclear structure work is of a different character; the IRFU teams have exploited the possibilities at GANIL, for example, with the MUST2 detector, but have also done experiments at facilities such as Legnaro (Italy), Jyvåskylå (Finland), and RIKEN (Japan), which are providing different types of exotic beams. They have, for example, made studies of gamma ray spectroscopy of the element $^{256}$Rf; with Z=104, this is the heaviest element ever studied in this way. Currently the team plays a prominent role at the new Radioactive Ion Beam Factory (RIBF) at RIKEN in the study of new magic numbers very far from stability, using their newly-developed MINOS detector.

The work on nuclear applications, obtaining interaction and decay data, are carried out in strong collaboration with teams from DAM/CEA. This is important work from the socio-economic point of view supporting applications in energy, defense and medicine and the IRFU group is renowned in this domain. Of particular importance has been the work to understand fission.

There are also attempts to enhance interactions between theorists and experimental groups in nuclear structure and applications by the support of a nuclear theory school in collaboration with CEA/DAM. This initiative also involves other CNRS and foreign participants.

## Assessment of the unit's academic reputation and appeal

Thanks to the technical capabilities of the laboratory, and also due to the high quality of the physicists themselves, the SPhN can play a leading role in many high-quality international research experiments worldwide.

One example lies within the relativistic heavy ion the division, that is the coordinator for the upgrade of the MUON spectrometer in the ALICE experiment for which they also provide the technical coordination. The division also provides the convener for one of the physics analysis subgroups for the ALICE experiment.

For the study of the structure of the nucleon, IRFU provides both the co-spokesperson and the analysis coordinator for the COMPASS collaboration at CERN, as well as the technical coordinator for some of the detector components. Some of the group members are also spokespersons for experiments with the CEBAF Large Aperture Spectrometer (CLAS) at Jefferson Lab, where they are also involved in the steering committee. Together with the other nuclear matter teams in the Saclay area they are world leaders in the extraction of Generalized Parton Distributions which has emerged as an important thrust in the description of the structure of nucleons over the past two decades.

The nuclear structure group is providing the technical coordinator for the S3 project in SPIRAL2 and four of them are the spokespersons for physics projects at this new facility. The group is the PI for several experiments in nuclear accelerator centers worldwide, e.g. with the MINOS project that is about to get data at RIKEN (Japan), for the heavy elements studies at Jyvaskyla, for reactions studies at SPIRAL/GANIL and RIKEN with the MUST2 detector they developed or using the AGATA detector at Legnaro.

The SPhN also hosts a virtual theoretical nuclear physics lab together with their colleagues from CEA/DAM. This institute welcomes every year more than 100 theorists and organises about 5 workshops per year.

The members of the SPhN division have been active in receiving funding for realizing their projects, such as an ERC grant for the MINOS project, several ANR grants are supporting research in hadron and nuclear structure physics, an Equipex grant for the S3 project at GANIL.

## Assessment of the unit's interaction with the social, economic and cultural environment

The technical developments that have been made for the different detector systems have led to several applications with a large societal impact. An example of this is the patenting of the multiplexed micromegas detector system (in 2013) which is foreseen to have applications in homeland security, muonic tomography (in collaboration with the Institut de Physique du Globe), and perhaps archeology.

Especially the research done in the application group has a very strong link with society as one of their objectives is to provide nuclear data, models and instrumentation for a variety of applications. E.g. to provide data for new nuclear energy devices/developments, experiments are performed at ILL and will also be performed at the future NSF facility at SPIRAL2 (foreseen from 2016 onwards). The Nucifer experiment, in collaboration with CEA/DAM and under the auspices of IAEA, is doing antineutrino flux measurements with the aim of non-proliferation and the monitoring of reactors. The non-destructive investigation of packages or nuclear wastes is investigated using photo- fission experiments at Bruyères-le-Chatel with CEA/DAM. And for medical applications, in particular the production of radioisotopes and hadron-therapy, spallation reaction calculations are performed.

## Assessment of the unit's organisation and life

The Nuclear Matter theme, as we noted before, is dominated at the physics level by a single service, SPhN. Within the theme the organization is rather clear. Three of the four sub-groups span the energy scales from nuclear structure at a few Mega-electron volts to several Giga-electron volts for the medium energy physics and to very high energy densities in the heavy ion physics. The points of emphasis from this broadly comprehensive approach are also quite clear. Each of the sub-themes has an identifiable thrust, the muons in ALICE, the GPDs in the medium Energy, and heavy elements and gamma ray spectroscopy in the nuclear structure. Further, an important applied nuclear physics component is well integrated with this structure. It can be argued that this is a “full-service” nuclear physics theme, which is quite rare in the world.

The technical support for all this physics comes in a relatively seamless way from the technical services which are very strong. This means that the technical strength of IRFU can be fully deployed in support of any component of the nuclear physics program. Of special note is the silicon pixel development for the MTF of ALICE, the cylindrical Micromegas chambers for CLAS12, and especially the S3 spectrometer which is a major part of Spiral2 at GANIL.

In a formal sense the staff are well organized and participate in the life of the service through the “Conseil Scientifique” and the “Conseil d’Unité”. There is the usual tension created by the lack of expansion and the volte- face in the retirement policy over the past decade.

## Assessment of the unit's involvement in training through research

As with most scientific groups the training of their doctoral candidates and their post-doctoral staff is integrated into the daily work of the unit. In the SPhN division there are about 25 PhD students and post-docs trained by some 54 permanent physicists and a number of engineers from the different technical divisions (mostly SEDI). In the past period 19 PhD theses have been defended. Several members of the staff are involved in teaching at local universities or schools, which is a good method for recruiting PhD candidates. The division also welcomes regularly master students in their groups for short-term “stages”.

## Assessment of the strategy and the five-year plan

The heavy ion program of IRFU will be concentrated on the continued participation in the ALICE experiment and in particular in the muon spectrometer work. The team has developed a high resolution spectrometer based on highly integrated silicon pixel detectors. The LHC will have two phases of operations between now and the early ‘20s with a shutdown in 2018. ALICE recently obtaned endorsement for the the MTF muon tracker for installation in 2018. A Technical Design Report should now be developed. The program thus has a clear and well developed plan for the next five years and beyond. The only competition comes from the two general purpose detectors at the LHC, Atlas and CMS, but in general the ALICE designs are such as to give specific advantages albeit with more limited apertures.

In the medium energy domain Saclay, as evidenced by funding of the “partons” initiative, is seen as a leader in the field of generalized parton distributions and with both the Compass and CLAS12 experiments has a well defined path with already approved experiments. The Compass program will take approximately 4 years to execute and CLAS12 somewhat longer. These phases of the experiments do not appear to have significant competition. The longer term future imagines participation in the experimentation at an Electron Ion Collider designed to further explore QCD. At this stage, while the EIC is in development, it is some way from being an approved project.

The nuclear structure program is directed towards the exploitation of the GANIL/SPIRAL2 facility, which will be completed in phases. Completion of phase 1 is foreseen early 2016 with the acceleration of highly-intense deuteron and heavy ion beams and the production of exotic nuclei using the S3 spectrometer. IRFU is playing a major role in the design and conception of this central device at SPIRAL2. It will provide a very strong physics program permitting not only the observation of very heavy nuclei, but also the exploration of their spectroscopy using different complementary techniques. Phase 2 of the project, the construction of a target-ion source for exotic nuclei production to be coupled to the existing SPIRAL1 accelerator, is postponed to a later stage. There is the possibility of strong international competition at this point, as a result of the very aggressive developments at ISOLDE, ISACII, FRIB and other facilities across the world.

The nuclear applications program is motivated by the desire to better manage and develop our suite of nuclear capabilities associated with future energy needs and also security. As the applications develop, so does the need for more knowledge about the interactions and decays, and other properties of the nuclear states in use. We see this program as having very strong ties to the programs in the DAM and DEN directorates within CEA. Physicists from the applications group also plan to perform experiments at the NSF facility which will also be completed within phase 1 of the SPIRAL2 project.

## Conclusion

- **Strengths and opportunities:**

The Nuclear Matter theme competes extremely well on an international scale in all of its four primary subcomponents. In its relativistic heavy ion work, the team has an important role in the ALICE experiment; the experiment leadership has made that clear to the reviewers. In the medium energy there is clear leadership in the subject of Generalised Parton Distributions, and in nuclear structure we note the complementary use of different tools (reactions, spectroscopy, detection developments) to address exotic nuclear structure research at the extremes (driplines and super-heavy elements). All of these areas benefit from excellent coherence and support from the technical arms of IRFU. In the applications area we believe that this is perhaps the most influential group in France with respect to fundamental measurements relevant to nuclear energy, fission and medicine and is worthy of a very high mark.

- **Weaknesses and threats:**

The nuclear structure program is directed towards the exploitation of the GANIL/SPIRAL2 facility, The phase 2 of the project, is postponed to a later stage. There is the possibility of strong international competition at this point.

- **Recommendations:**

We see the possible opportunity to strengthen the theme by opening an occasional position for a mid-career leader, for example post-habilitation; this could ensure leadership, and perhaps new thrusts to maintain the IRFU strength in the future.

Overall this theme on Nuclear Matter can be described as excellent quality with a high visibility and ranking in the top 10-15 % world wide.

## Theme 5 : Magnets

### Workforce

| Theme workforce in Full Time Equivalents | FTE 2013 | FTE 2014 |
|---|---|---|
| FTE for permanent professors | | |
| FTE for permanent EPST or EPIC researchers | 36.6 | 36.6 |
| FTE of other permanent staff without research duties (IR, IE, PRAG, etc.) | 23.9 | 22.4 |
| FTE for other professors (PREM, ECC, etc.) | | |
| FTE for postdoctoral students having spent at least 12 months in the unit | 1.9 | 0.5 |
| FTE for other EPST or EPIC researchers (DREM, etc.) excluding postdoctoral students | 0.7 | 0.5 |
| FTE for other contractual staff without research duties | 5.1 | 3.9 |
| FTE for doctoral students | 2.0 | 1.9 |
| **TOTAL** | **70.1** | **65.8** |

### Assessment of scientific quality and outputs

This theme mainly concerns two divisions: SACM and SIS. The activities are carried out with large synergies and often imply real common work between the two divisions.

The superconducting magnets (SC) theme at IRFU is an historical activity at Saclay with the construction of very large superconducting magnets. Over the years, a tremendous and unique expertise has been gained and accumulated. IFRU has reached a worldwide top level for NbTi magnets. Due the outstanding know-how and the skills they own, IRFU has significantly contributed to a large number of of SC magnets throughout the world: quadrupoles for LHC, CMS solenoid and ATLAS Barrel toroid magnet... IRFU represents France in this area for all international projects. CEA responsibility and involvement are very important. The quality of the deliverables is at the basis of many breakthroughs and advances in big science: for example, without the SC magnets of ATLAS and CMS, the Higgs boson would not have been discovered. Large projects span usually over many years (about 10 years on average). In the 2008-2013 period, 4 projects have been successfully completed. Among them one can mention the start of operation of the ATLAS and CMS giant magnets at CERN and the test of 70 coils for the W7X stellarator for the Max Planck Institute at Greifswald. Some projects are nearing completion: the R3B Glad spectrometer for FAIR is under final test and the coil for the ISEULT 11.7T magnet is under assembly.

A strong point is also the expertise in the cooling and the protection of the magnets.

The cooling has been thoroughly studied including for transient conditions (quench) under different schemes: two-phase helium flow, superfluid He (Claudet bath) in micro-channels. The two-phase helium circulation with a thermosiphon loop has been investigated through simulation and experimental work including flow instabilities. In particular, a coupling between a cryorefrigerator and a natural circulation loop has been studied experimentally. This is very attractive for future HTS/MgB2 magnets.

For the protection of the magnets, simulation expertise has been developed but also expertise in assembling the magnet protection hardware with all the sensitive detection circuitry. This know-how is recognized internationally, for example by the Japanese who successfully use an IRFU system for the T2K accelerator arc section at KEK since five years.

IRFU has developed a test station with unique capabilities for large SC magnets: it has been used for W7X (70 coils tested) and will be used to test the coils of JT60SA in the future. IRFU actually leads the work package "Cold Test Facilities" for JT60SA. The committee was impressed during the visit of these test facilities, especially by the very large 11.5 m x 7.5 m x 4.8 m cryostat to be used for testing JT60SA coils. Such heavy equipment, with all the state-of-the-art ancillaries (26 kA power supply, data acquisition and analysis systems, cryogenic control…), is very rare in the world. IRFU has a very high record of publications about SC magnets with more than 100 peer-reviewed articles in the main and recognized relevant journals.

## Assessment of the unit's academic reputation and appeal

The large number of invited talks shows its international influence. IRFU members are involved in the main international committees in the field (Magnet Technology, Applied Superconductivity Conference…). IRFU actively participated in the organization of MT 22 in Marseille (12-16 September 2011). They successfully collaborate with the major groups in the world: Berkeley, CERN… They participate to international committee reviews for ITER and JT60SA. IRFU is a partner and often the principal investigator of numerous EC and ANR projects (EuCARD and EuCARD2, CoCaSCOPE, SuperSMES…).

## Assessment of the unit's interaction with the social, economic and cultural environment

The interactions of IRFU with the industry are numerous in the field of SC magnets. These interactions take the form of industrial collaborations, partnerships and transfers. Some of the collaborations are old and continuous, with Alstom for example. IRFU disseminates knowledge and know-how of SC magnets, making the industry more competitive and more innovative. The numerous articles signed with industrial partners show the research interactions with industry and their quality.

An important source of diversification for IRFU in the field of SC magnets lies in its implication for MRI magnets, illustrated by the essential participation of IRFU in the ISEULT project. The expertise of IRFU made possible to design and develop the technology to construct the most powerful ever built whole-body magnet for MRI, with a magnetic flux density of 11.7 T and an aperture of 900 mm (stored energy of 338 MJ). This magnet will significantly extend the current MRI performance, bringing a real breakthrough for neurosciences. This new activity reinforces the IRFU implication in the societal aspects. This project has led to very original developments in the domain of field homogeneities (5 10-7 T over the volume of a human brain) and stability (10-9 T in 10 ms), to give a few examples. SACM has carried out the necessary innovations to get the right homogeneity and it has been validated with the prototype HO coil. This resulted in five patents. The work on the associated RF antenna will bring innovations as well, based on the IRFU RF know-how. The antenna developed were already certified and authorized by the suitable French agency. Similar antenna will be used for ISEULT.

## Assessment of the unit's organisation and life

Work is extremely well organized in SACM and SIS.

As mentioned the synergy between SACM and SIS is total and common projects are numerous, even for basic research work. An example is the ANR project "CoCaSCOPE" carried out also with other partners. Its ambitious objective is a multi scale, multi dynamics mechanical 3D modelling of SC conductors for a better understanding of their mechanical behaviour and its optimization. The successful design of SC magnets is mainly driven by mechanics. The demands for higher performances/fields lead to an operation closer to the limits, requiring better knowledge and thorough design tools.

The main weakness and threat is the frightening age pyramid of technicians: 10 technicians (A2) out of 46 at

SACM (i.e. more than 1/5) are between 56 and 60 years, so will retire in the very next years. 17 have between 51 and

55 years. There is a real threat of loss of know-how. The retirement of technicians should be anticipated in order to have an overlap to transfer the large expertise. As mentioned by IRFU people themselves, "It is more than strategic, it is vital". Unfortunately the current budgetary rigour in France is not very favourable.

Another issue is that IRFU carries out a lot of projects in parallel. There is a risk to loose effectiveness and a difficulty to enter into new projects, with a possible demotivation of some people. The very high load of the SIS division is a concern.

## Assessment of the unit's involvement in training through research

It is difficult to understand why there are so few PhD students at IRFU in the field of SC magnets. Several PhD grants were funded but the candidates withdrew. The PhD student number is well below what it could be, taking into account that SACM is working on cutting edge technologies. Furthermore, most of the students have no difficulty to find jobs afterwards and some play a strong role in prestigious laboratories (Berkeley, MIT…). The number of HDR should increase as well. The IRFU staffs participate nevertheless to several masters (even European masters like a master on fusion), teach and propose many internships. The active participation of IRFU in the LabEx P2IO (Physics of the 2 Infinities and Origins) and in the ComUE Paris-Saclay is a great opportunity. It will foster more basic research, cooperation and international visibility with universities, engineering schools, national funding agencies and the large laboratories. The closer contact with students will be certainly very beneficial to attract PhD students.

## Assessment of the strategy and the five-year plan

IRFU is following the technological change towards Nb3Sn, MgB2 and HTS (High Temperature Superconductor) very high field magnets, but a lot of work and effort is still required to reach the same level of expertise they achieved on NbTi magnets. It is indispensable to develop and amplify these efforts for the future since these new types of magnets will play a growing role. In this respect, the participation of IRFU to EuCARD, with the design and construction of Nb3Sn outserts plus HTS (YBaCuO) inserts for the next generation of accelerator magnets is very important. This program is very ambitious (13 + 6 T) and a real challenge. It will bring a real breakthrough in the field. It is also a pioneering work for HTS magnets, well above today’s sate of the art. A first YBaCuO pancake has shown very attractive results, in particular in term of stability: it quenches only in the case of a high-energy deposit. HTS pose new issues for magnets, monitoring and protection should be fully rethought and new idea should emerge. No satisfying solution exists today for a high current HTS cable: the field of required investigation is therefore very large. IRFU should increase the forces to tackle this challenging task.

The future project in the field of SC magnets is consistent and ambitious. Many projects are underway or scheduled (ISEULT, R3B Glad and future FRS dipole for FAIR…). An obvious and absolute priority is to carry them out successfully: the credibility of SACM is at stake. All these projects require a lot of human ressources, currently limited, if not under reduction in the today context of reduction of public spending. The R & D works should be carried out to prepare for the future, especialy Nb3Sn/MgB2/HTS magnets. It is vital for the magnet activity in 10/20 years. Hiring more PhD students and post-docs is real opportunity in that perspective. As mentioned the present level is much too low, with a large progression margin. The LabEx P2IO and ComUE Paris-Saclay are a great opportunity to solve this issue.

## Conclusions

- **Strengths and opportunities:**

- Worldwide expertise in the field of NbTi magnets, cooling and protection of magnets

- Excellent organisation and collaboration with the other IRFU technical divisions

- Availability of a large technological platform with test stations for large size SC magnets

- Strong collaboration with industry and important source of diversification in the field of magnets for health applications

- Participation to European R&D projects towards new technologies

- Opportunity of increased links with university and engineering schools in the frame of the ComUE Paris- Saclay.

- **Weaknesses and threats:**

- Very low number of PhD students

- Risk of loosing know-how due to large number of retirements of technicians in the coming years

- Risk to loose effectiveness due to the large number of projects run in parallel

- Insufficient level of R&D at a time where technology is evolving fast towards new types of superconducting magnets ($Nb_3Sn$/$MgB_2$/HTS)

- **Recommendations:**

The business model of SACM should be planned to allow a rejuvenation of the technical staff and enough effort on R&D to prepare for the long-term future. An increase of the number of PhD students and postdocs could help in this perspective.

## Theme 6 : Accelerators

### Workforce

| Theme workforce in Full Time Equivalents | FTE 2013 | FTE 2014 |
|---|---|---|
| FTE for permanent professors | | |
| FTE for permanent EPST or EPIC researchers | 58.9 | 55.6 |
| FTE of other permanent staff without research duties (IR, IE, PRAG, etc.) | 30.0 | 27.7 |
| FTE for other professors (PREM, ECC, etc.) | | |
| FTE for postdoctoral students having spent at least 12 months in the unit | 1.0 | 0.1 |
| FTE for other EPST or EPIC researchers (DREM, etc.) excluding postdoctoral students | 1.2 | 1.0 |
| FTE for other contractual staff without research duties | 5.8 | 7.2 |
| FTE for doctoral students | 1.0 | 1.0 |
| **TOTAL** | **97.9** | **92.6** |

### Assessment of scientific quality and outputs

IRFU designs, builds, commissions and operates an impressive portfolio of accelerators. A long-term investment in basic Accelerator R&D and significant engineering capability in key technologies make it a sought-after partner in a number of international accelerators-based projects and the institute is one of the world leading expertise centres for accelerator science and technology. This includes, but is not limited to, particle beam sources, superconducting RF systems for electron, proton and ion accelerators, superconducting magnets, and cryogenic technology.

Research and development in accelerator physics and associated technologies is important for the future of particle and nuclear physics, but also for the future of fundamental and applied research based on synchrotron light, neutron and other particle beams sources. IRFU is well positioned to make significant contributions to the recently updated European strategy for particle physics (CLIC, ILC, HL-LHC, HE-LHC). The same technologies allow key contributions to major global construction projects beyond particle physics (FAIR, IFMIF, SPIRAL II, ESS, X_FEL, JT60

SA, W7X, ITER), that are either on-going or will start in the near future. Among the main deliverables in the period

2008-2013, one can mention the RFQ and 7 (out of 12) cryomodules for SPIRAL2, the injector for IFMIF in Japan which is able to deliver a world-record current of 140mA deuterons, the high intensity demonstrator IPHI for ESS or the RFQ for the LINAC4 at CERN.

The accelerator infrastructure effort is world-class. The wide palette of key technological and engineering capabilities evolved from IRFU historical involvement in Nuclear, High-Energy Physics and Accelerator Technology.

Design, simulation, testing and production of accelerating cavities capability is being reinforced at IRFU through the contribution the institute is making to the European XFEL project in Hamburg. A similar in-kind French contribution to another international project about to be built in Lund (Sweden), the European Spallation Source (ESS), is in preparation now and will reinforce this capability in the long term.

The design, simulation, testing and production activities of advanced ion sources is recognised as a unique capability worldwide and has resulted in several breakthroughs in this field. Unprecedented intensity and beam quality ion sources have been delivered by IRFU to several leading international projects.

The number and quality of IRFU publications in the field of accelerators is unusually high compared to similar laboratories and institutes. Numerous articles in peer-reviewed journals are complemented by a large number of contributions to the major international accelerator conferences (about 190 presentations and 130 publications in refereed journals over the 2008-2013 period in the fields of magnets and accelerators).

### Assessment of the unit's academic reputation and appeal

The proceedings of these conferences have traditionally been fully open access and represent the publications of record for this field.

The reputation enjoyed by the members of IRFU in the field of accelerators and related technologies is amply demonstrated by their participation to a large number of advisory bodies and expert committees all over the world. Similarly remarkable is the number of collaborations with major groups, laboratories and institutes in the world.

Plans for the ComUE Paris Saclay represent an opportunity to increase the attractiveness of IRFU for PhD

students, especially in the technical domain.

### Assessment of the unit's interaction with the social, economic and cultural environment

IRFU is involved in an impressive number of partnerships with major industrial players locally and internationally. It has been also successful with technology transfer to industry in the field of accelerators. This successful engagement with the local industry clearly has not escaped the attention of the local community, as witnessed by the significant financial support offered to IRFU by the local authorities for example the Ile de France.

### Assessment of the unit's organisation and life

The accelerator and engineering divisions work efficiently on a large number of projects. Their involvement in external national and international projects is steadily increasing. Attention should be paid to the fact that the traditionally close ties between technological and physics divisions in IRFU is nevertheless maintained.

In general, IRFU divisions have collaborated closely in the past on contributions to accelerators and detectors e.g. in case of CERN LHC. Maintaining and strengthening these transverse relationships and cooperation should be an important factor in the life of the institute.

### Assessment of the unit's involvement in training through research

The number of PhD students and postdocs in the SACM division is very low (about 8 for 71 engineers). The projects to which the technical divisions of IRFU contribute present a unique opportunity for young people education through associated research projects. The number of students benefiting from these projects can be easily increased, given proper stimulus and encouragement.

### Assessment of the strategy and the five-year plan

SACM, in close collaborations with SIS and other divisions, strive to develop and operate a unique infrastructure that provides a platform for R&D and for involvement in future subatomic physics but also other advanced technology projects. Production, testing and commissioning of components, individual or in series, is part of this strategy.

The infrastructure, which is largely used to support these projects, allows R&D on High Field Magnets, superconducting RF and high intensity ion sources. The external funding received is the main source and driver of much of the investment into this infrastructure. In that sense, the resources are well aligned within SACM with the strategic priorities of IRFU.

Additional investments in basic accelerator R&D are essential to maintain and sustain this effort and to allow IRFU to remain in the top league worldwide in the future. In particular, accelerator physics and beam dynamics simulations effort at the institute has been essential for proper optimisation of the components and systems. Inasmuch, it is of strategic importance for the institute to enable successful contributions to the future accelerator based projects, be it in subatomic physics or in other scientific disciplines that benefit from such infrastructure, for example medical applications.

## Conclusion

- **Strengths and opportunities:**

- The accelerator and engineering divisions of IRFU form the backbone of a technology platform that is capable of contributing to and creating essential research infrastructures of international significance and scale, relevant to a large number of accelerator driven scientific fields.

- The project “ComUE Paris Saclay” represents an opportunity to increase the visibility and attractiveness of the accelerator sciences and related technical fields. In particular the Physics and Engineering Divisions there would be able to substantially increase the number of PhD students in these disciplines.

- **Weaknesses and threats:**

- Due to the heavy load of a large number of projects, there seems to be insufficient time and resources left to engage in an R&D effort that would prepare the future accelerators and associated technologies, the kind of investment over the past decades that prepared the success IRFU today.

- Presently the accelerator physics / beam dynamics effort seems too small to support on-going work and to develop future involvements in other projects.

- **Recommendations:**

- The business / service provider model at SACM delivers a large fraction of the funds for the infrastructure build-up and maintenance and therefore to the R&D platform. In order to maintain a stable base of manpower and materials & supplies funding, a continuous and aggressive acquisition strategy is required. A significant fraction, in some cases the majority, of the people and the infrastructure are funded through outside projects. Such a strategy requires a robust QA and risk management plan, in which a clear understanding of who carries the cost and schedule risk is necessary.

- An accelerator physics / beam dynamics / technology backbone would further support the presented strategy. It should be partially funded out of the project budgets, since the research funding inside CEA cannot fully support it anymore.

# 5 • Conduct of the visit

## Visit dates :

Start: 7January 2014 at 10.00

End: 10 January 2014 at 14.00

## Visit site

Institution : IRFU

Address : CEA Saclay

## Specific premises visited

The committee visited all the premises of IRFU, located in both campuses inside and outside (Orme des Merisiers) the fenced area of the Centre d'Etudes Nucléaires de Saclay.

## Conduct or programme of visit

The agenda of the visit is presented below. It included about: 9 hours of scientific presentations, >5 hours of visit of the laboratories and infrastructure, 7 hours of closed discussion with the staff (seven conseils d'unités, representative of students and postdocs, representative of doctoral schools and staff involved in teaching activity), 2.5 hours of discussion with the management and a representative of the "tutelle" and finally closed sessions of the committee.

**Tuesday January 7th**

| | |
|---|---|
| 10:00 -10:45 | Committee close session |
| 10:50-11:00 | Transfer to bld 526 |
| 11:00 -12:30 | Plenary session |
| | Presentation of Irfu, report & project (Institute's Head) |
| 12:30-12:45 | Transfer to bld 124 |
| 12:45-13:45 | Buffet lunch with members of management |
| 13:45-14:00 | Transfer to L'Orme des merisiers |
| 14:00-15:10 | SAp/AIM: Astrophysics Department |
| | Report & project (Department's Head) |
| | Highlight " Simulations of Universe structuration " |
| 15:10-15:25 | Coffee Break at Sap |
| 15:25-16:05 | Meeting with members of SAp |
| 16:10-17:25 | Visit of Sap |
| 17:25-17:40 | Transfer to SPP |

| | |
|---|---|
| 17:40-19:10 | SPP: Particle Physics Department |
| | Report & project (Department's Head) |
| | Highlight « Crossroads at the LHC » |
| | Highlight « BAO : a probe for cosmology » |
| 19:15-19:40 | Committee closed session |

**Wednesday, January 8th**

| | |
|---|---|
| 8:30-9:10 | Meeting with members of SPP |
| 9:10-10:20 | SIS: Mechanical Design and System Engineering Department |
| | Report & project (Department's Head) |
| | Highlight "Mini-channels cooling for high heat flux management " |
| 10:20-10:35 | Break |
| 10:35-11:15 | Meeting with members of SIS |
| 11:15-11:25 | Transfer to SIS |
| 11:25-12:40 | Visit of SIS |
| 12:40-12:50 | Transfer to bld 124 |
| 12:50-13:50 | Buffet lunch with Management and Highlight authors of Sap/AIM, SPP and SIS |
| 13:50-14:00 | Transfer to bld 141 |
| 14:00-15:30 | SEDI: Detectors, Electronics & Computing Department |
| | Report & project (Department's Head) |
| | Highlight « Micromegas detectors » |
| | Highlight « Cosmology & statistics » |
| 15:30-16:10 | Meeting with members of SEDI |
| 16:10-16:25 | Break |
| 16:25-17:40 | Visit of SEDI |
| 17:40-17:55 | Transfer to SPhN |
| 18:00-19:30 | SPnN: Nuclear Physics Department |
| | Report & project (Department's Head) |
| | Highlight « Towards nucleon 3D imaging from world experimental data » |
| | Highlight « S3 a Super Separator Spectrometer for very rare nuclei at Spiral2 » |
| 19:30-20:10 | Committee closed session |

**Thursday, January 9th**

| | |
|---|---|
| 8:30-9:10 | Meeting with members of SPhN |
| 9:10-10:20 | SACM: Accelerators, Cryogenics & Magnetism Department |
| | Report & project (Department's Head) |
| | Highlight1 « Beam dynamics studies for Hilumi LHC » |
| 10:20-10:35 | Break |
| 10:35-11:15 | Meeting with members of SACM |
| 11:15-11:25 | Transfer to SACM |
| 11:25 -12:40 | Visit of SACM |
| 12:50-13:00 | Transfer to 124 |
| 13:00-14:00 | Buffet lunch with Management and Highlight authors of SPhN, SACM and SEDI |
| 14:00-14:10 | Transfer to bld 141 |
| 14:15-14:55 | Meeting with the Staff Committee of Irfu (CU) |
| 15:00-15:40 | 2 parallel meetings with: |
| | Group 1: PhD students and post-docs |
| | Group 2: People involved in teaching and education (Doctoral school," theses correspondent", Masters, Teachers…) |
| 15:45-16:00 | Break |
| 16:00-16:45 | Meeting with DSM Director |
| 17:00-18:30 | Meeting with Heads of Institute and of departments |
| 18:30-20:00 | Closed session of committee |

**Friday, January 10th**

| | |
|---|---|
| 8:30 -14:00 | Closed session(discussion, recommendations, rapport, marks) |
| | (Coffee break, meal tray) Members |

# 6 • Supervising bodies' general comments

DE LA RECHERCHE À L'INDUSTRIE

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M. Pierre GLAUDES
Directeur de la Section des Unités de Recherche
AERES
20, rue Vivienne
75002 PARIS

Saclay, 28 avril 2014

**Objet** : **Commentaires sur le rapport AERES sur l'Institut de Recherche sur les lois Fondamentales de l'Univers**

**Réf** : Irfu/Dir/n° 14-00058

L'Institut de Recherche sur les lois Fondamentales de l'Univers et la Direction des Sciences de la Matière tiennent à remercier l'ensemble du comité pour l'important travail effectué et pour la qualité des échanges que nous avons eus lors de sa visite.

Le rapport élogieux à la fois sur le bilan et le projet présente des éléments en complète cohérence avec nos analyses et plans d'actions présentés dans notre rapport d'auto-évaluation, l'IRFU ne manquera pas de mettre en œuvre les recommandations constructives émises dans le rapport avec le soutien de sa tutelle et visera à conserver toute son attractivité, son leadership et son ambition malgré un contexte budgétaire particulièrement contraint.

Chomaz

Philippe CHOMAZ
Directeur de l'IRFU

M. Faury

Maria FAURY
Directrice adjointe des Sciences de la Matière

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