COMITÉ NATIONAL DE LA RECHERCHE SCIENTIFIQUE
CONSEIL SCIENTIFIQUE D'INSTITUT

REPORT

Scientific Council of IN2P3

Session of July 8-9, 2025

IN2P3
Institut national de physique nucléaire
et de physique des particules

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Invited experts

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Speakers

Rachel Delorme (LPSC), Marie-Laure Gallin-Martel (LPSC), Anne-Marie Gué (LAAS), Etienne Testa (IP2I), Marie Vanstalle (IPHC).

1 Framework

The meeting of the Scientific Council was held on 8 and 9 July 2025 at IP2I in Lyon. The first day was dedicated to the presentation of the projects in an open session. The second day consisted of closed sessions of the Scientific Council, including discussions with the project PIs, the invited external experts and the IN2P3 management.

The Scientific Council was tasked with a global evaluation of the health research activities at IN2P3. It involved the identification of their added values and the assessment of the institute's positioning in relation to the main actors in the field. These were examined in both an international and a national context. At the national level, a comparison was made with other institutes within CNRS (namely INSB) and outside of CNRS (INSERM, CEA, ...). The following section 2 presents the precise questions that have been posed by the management of IN2P3, to aid understanding of the review and the recommendations formulated by the Scientific Council in sections 3 and 4 respectively.

The health research activities at IN2P3 refer to cancer treatment using radiotherapy techniques, in line with the expertise of IN2P3. The technical and scientific skills of IN2P3's teams have indeed led some of them to carry out their research in this field. They contribute to a wide range of research activities, including the measurement of fundamental nuclear data, the development of models to simulate the interaction of radiation with living organisms, and various instrumental developments related to hadron therapy and other innovative therapies. In addition, there are several dedicated facilities at IN2P3, namely for irradiation, radiobiology and the production of radionuclides for both diagnostic and therapeutic purpose. In total, the community working on health-related projects in IN2P3 laboratories represents approximately 100 full-time equivalent people.

The present evaluation process was conducted in conjunction with a restructuring of this activity at IN2P3, which was initiated in spring 2025 by a newly appointed deputy director. Furthermore, it followed the publication in 2024 of the new CNRS roadmap for health-related research, which required contributions from all ten CNRS institutes to develop an effective strategy for addressing major national health challenges. In this context, IN2P3 proposed the creation of new master-projects and the rationalisation of national support for health-related projects. This centralised model is similar to the one used in subatomic physics and cosmology at IN2P3, while so far IN2P3 health-related research has essentially been supported locally by laboratories and universities, and through calls for proposals. The background of this structuring aims also at improving the clarity of IN2P3 research in this field and enhance the visibility of the corresponding achievements. Consequently, the IN2P3 management requested the national research network Mi2B (Nuclear Tools and Methods for Cancer Treatment, formerly Instrumentation and Modelling for Biomedical Imaging) to formulate a proposal for new master-projects. At the time of this Scientific Council session, the discussion was still ongoing within the community and the Mi2B network. Hence, the evaluation of health activities by the Scientific Council is not an evaluation of future master-projects, rather an additional input to help structure the field and maximise its visibility.

Previous evaluations of related topics by the Scientific Council date back to five and ten years ago: "Irradiation facilities" in February 2020 and "Nuclear physics for health" in June 2015. See reports from here.

Agenda of the session and material

Description of the activities under review, agenda, slides and recording of the oral presentations, and the report issued by the Scientific Council including recommendations, are archived publicly on the web site of the Scientific Council of IN2P3.

Indico time-table of the open session: see https://indico.in2p3.fr/event/35720/.

2 Questions posed by the management

The questions from the management are closely linked to the strategy and to the management of health-related activities at IN2P3 and are presented below.

Through the CNRS research network Mi2B, the community is converging on four main areas that will form the master-projects in this field.

Questions Q_1 to Q_4
For each of the following subjects: hadrontherapy, flash radiotherapy, internal radiotherapy, and radionuclides in the theranostics approach, what are the scientific objectives, the associated strategy, the main milestones and the timetable clearly established?

Questions Q_5 and Q_6
Regarding hadrontherapy and radionuclide production (the most advanced developments to date), what is the current thinking on an economic model for adjusting the strategy to obtain medical treatments? What are the drivers and indicators for defining priorities in the methods:

- Proton vs. other hadrons?
- Which radionuclides should be produced?
- How should the hadron, energy and radionuclide be chosen for a given pathology?
- Which development choices are relevant for IN2P3?

Question Q_7
For all these subjects, what would be the best strategy for the use and the development of irradiation platforms at IN2P3 and elsewhere: inventory, management, instrumentation, beam monitors, imaging instruments, development of digital twins, etc.

Question Q_8
What strategy should be adopted for software developments (G4-DNA, GATE, Nanox) in terms of integration into computing infrastructures, code durability, monitoring operability?

Question Q_9
What is the international strategy? While countries such as Germany and Japan have adopted systematic clinical approaches, France has not. Is it worthwhile developing collaborative programmes that go beyond the use of irradiation platforms abroad (e.g. CNAO)? What is the link with CERN?

3 Review of IN2P3 research activities related to health

This section presents the Scientific Council's opinion on the questions posed by IN2P3 management. The recommendations are given in the conclusion of the document (see Section 4).

A wide range of high-quality developments was presented. Further insight into any of the themes discussed would require a dedicated session of the Scientific Council.

The main scientific objectives of the activities of IN2P3 teams in relation to health focus on optimising cancer treatments using radiotherapy, to improve cure rates and limit side effects on organs at-risk and surrounding healthy tissues. With respect to hadrontherapy, vectorised therapies or spatial and temporal fractionation techniques, IN2P3's expertise can be classified as follows:

- Production of data in the fields of physics, chemistry and radiobiology, as well as the development of theoretical models and Monte-Carlo simulation codes to calculate the effects of ionising radiation.
- Instrumentation for beam monitoring, dosimetry, online treatment control and imaging.
- Radionuclide production and characterisation (target, chemical separation, radionuclide-biological vector coupling).

As mentioned in Section 1, the July 2025 session took place in the context of the ongoing structuring of health activities at IN2P3. The Scientific Council acknowledges the significant progress made by the community in recent months towards an improved organisation of their activities. This ongoing restructuring appears necessary both to identify internally the key expertise of the teams' health-related activities, and to better position IN2P3 in relation to external partners at national and European levels, bearing in mind alignment with the CNRS's general health roadmap.

At the national level, the GDR Mi2B plays a major role in promoting scientific exchanges and collaboration between IN2P3 teams and other CNRS institutes or research organisations (primarily INSB at CNRS, INSERM, CEA). The GDR also plays a key role in gathering and sharing useful information. However, its involvement in IN2P3's management activities was not entirely clear to the Scientific Council.

Questions Q1-Q4 of Section 2
The current structuring into four master-projects (Hadrontherapy, Flash Therapy, Targeted Radiotherapy and Radiotherapies for Diagnosis and Therapy) is progressing well towards grouping the various ongoing activities around a limited number of themes that have been identified as the most promising for both improving our understanding of the effects of radiation and optimising radiotherapy treatments. As this work is still in progress and the master-projects have not yet been validated, it is premature to comment on the associated strategy, milestones or timetable.

However, the Scientific Council has found that the various projects brought together in each master-project are currently presented in a rather "flat" way (both in the written document and in the talks). This could be improved by more clearly identifying the main challenges that the IN2P3 teams wish to address. It would also be helpful to present the main activities with a clearer timeline, particularly highlighting the difference between past achievements and future objectives. A key feature of health-related activities at IN2P3 is the close connection between fundamental research projects and translational projects, which are often linked to commercialisation issues or even partnerships with industry. Basic research projects are mostly carried out through national and international collaborations, whereas translational activities tend to be more firmly rooted locally (e.g. local hospitals, universities and the technology transfer acceleration companies known as SATTs). These local or national links

are therefore a key factor in structuring the community. The difficulty lies in combining stronger national IN2P3 leadership — i.e. clearer positioning of IN2P3 within the national and international contexts — while maintaining the richness and strength of existing local collaborations. To improve organisation, the Scientific Council suggests better separating projects into three categories: basic research, translational projects and cross-technologies.

Questions Q_5 and Q_6
Concerning basic research, the main challenge is to obtain data under advanced controlled conditions so that they can be used to validate the theoretical and numerical models that reproduce our current level of understanding of the radiation-matter interactions. The two areas most closely aligned with IN2P3's expertise are currently the production and modelling of physics data (cross-section, ion fragmentation) and chemical data (radiolysis), as well as the production and characterisation of radionuclides. For these activities, IN2P3 teams work in well-established national and European collaborations. They have the knowledge and skills needed to be leaders in their research and develop their own instrumentation required to carry out their experiments independently. Whilst these research developments take place in the general context of cancer treatment, the selection of research topics must also remain motivated by an understanding of fundamental mechanisms and phenomena associated with the expertise of IN2P3 scientists, and not solely by clinical needs (e.g. treatment technique, specific pathology).

Basic research in radiobiology requires a different approach, as close collaboration with teams outside of IN2P3 is necessary (e.g., INSB at CNRS, INSERM). The existence of joint teams, in particular with INSERM and hospitals, is a key asset here. Having these joint teams working together around the irradiation platforms is advantageous for radiobiology research. However, the number of teams and projects must be carefully balanced against the available FTEs at IN2P3 for this collaborative work.

Translational research projects mainly involve instrumentation and simulation, such as imaging, online monitoring and beam monitoring. Although they could stem directly from basic research, the Scientific Council considers it important to treat them as a separate category. Unlike basic research, these activities must be clearly motivated by clinical needs, taking into account economic constraints and possible industrial competition. Although this type of project most often originates from a local collaboration between a laboratory and a hospital, it must be designed to have a national scope. IN2P3 or CNRS knowledge transfer services can assist with this process.

Questions Q_7 and Q_8
The third category consists of cross-technologies shared between the different research themes. The main tools in this area are the irradiation platforms and the Monte-Carlo calculation codes, which build on IN2P3's historical experience with accelerators, instrumentation and computing. The irradiation platforms are essential for producing data and for testing instrumentation, given the very limited availability of clinical centres for research activities. It is worthwhile noting that IN2P3 is the main national player capable of delivering energetic and intense beams. On the software side, IN2P3 has made a remarkable contribution to the development of Monte-Carlo codes, including Geant4, Geant4-DNA and GATE. IN2P3 has also significant responsibilities and active participation in the technical development and coordinating of collaborations in this field.

It is important to distinguish cross-technology activities more clearly from research activi-

ties, in terms of both presentation and operation (human resources, funding, etc.). It is also important to have a better national coordination of IN2P3 activities in relation to irradiation platforms and modelling tools. The main objective should be to enhance the synergy and complementarity between the various individuals and teams involved in developing and operating these cross-technologies. However, IN2P3 coordination must also include the local context of operating an irradiation platform (including sources of funding and activities outside of IN2P3), as well as the international dimension of the collaborations developing the main softwares (Geant4, Geant4-DNA, GATE). For both irradiation platforms and softwares, the role and prerogatives of dedicated national frameworks should be better defined.

Question Q_9
Collaboration with clinical partners, through treatment centres, is crucial for both basic and translational research activities. IN2P3 collaboration contracts with the Nice proton therapy centre (CAL) and the Pavia hadrontherapy centre (CNAO) already provide privileged access to irradiation beamlines under clinical conditions, as well as collaborative projects with on-site physicians, researchers and medical physicists. Looking to the future, it is crucial to establish a clear framework for collaboration with the CYCLHAD centre. Moreover, it seems important to participate as much as possible in CERN or other European initiatives pertaining to medical applications, particularly in terms of fostering international inter-institutional networks.

4 Recommendations made by the Scientific Council of IN2P3

In conclusion, the Scientific Council makes the following recommendations:

- The current efforts to organise the community by defining master-projects must continue, bearing in mind the importance of clearly separating basic research, translational research and cross-technology activities.
- The Scientific Council recommends clarifying the precise role of the GDR Mi2B with respect to IN2P3's management of health activities.
- A roadmap needs to be defined for each future master-project, setting out the main scientific drivers and associated technologies, and outlining a clear collaboration strategy with other institutes and hospitals. This is particularly important for radiobiology and translational activities.
- The role of IN2P3 in radiobiology should be clarified at both the CNRS level, where IN2P3's expertise has been identified for the CNRS health roadmap, and at the level of other national stakeholders in the field, particularly INSERM and hospital research centres. The composition of current joint teams should be reviewed, and the possibility of forming new ones should be considered.
- Better national management of translational research projects, which often involve issues related to industrial development and intellectual property, should be put in place. Firstly, it seems important to avoid redundancy and pay particular attention to technical developments that can be shared between several IN2P3 laboratories. Secondly, it is also important to work closely with other CNRS institutes, especially on developments where IN2P3 is not identified as the main driver in the CNRS Health roadmap (numerical modelling, imaging, ...).
- A framework needs to be established to enhance the complementarity and synergies between the irradiation platforms, to facilitate exchanges between platform managers

at the local and the national level, and to improve communication and visibility. These accelerator facilities benefit also several other CNRS institutes and external partners. The role of IN2P3, which is responsible for their operation, should be better recognised in order to enable it, in turn, to maintain and improve the core funding for these facilities.

- A framework needs to be defined for the development of computational tools (NanOx, Geant4-DNA, GATE, etc.), especially with the aim of establishing closer connections between software users and developers to enable multi-scale modelling. Opportunities for creating a CNRS or national digital platform, which would bring together the main CNRS institutes and other organisations involved in developing digital tools for the treatment of cancer by radiotherapy, should be considered.

- The ongoing development of platforms combining irradiation (beams, radionuclides), imaging tools, biology laboratories and animal facilities necessitates coordination to establish joint multi-institute teams in order to exploit them.

- The future collaboration with CYCLHAD should be defined as soon as possible, with regard to the long-standing collaboration with the CNAO centre and the well established and efficient access to the beamline. It is also important to consider the irradiation possibilities offered by GANIL in order to assess the complementarity between these different options.

- Basic research projects related to data production must consider the issues of storing and sharing in order to promote the sustainability and future use of the produced databases.