Annual Report to the President of the INFN

Il Comitato di Valutazione Internazionale (CVI)

L. d'Agnese, CDP, Italy; M.J. Borge, CSIC, Madrid, Spain;
A. Brandolini, Banca d'Italia, Italy; J. D'Hondt, Vrije Universiteit Brussel, Belgium (chair);
B. Gavela, Universidad Autonoma de Madrid, Spain; W. Hofmann, MPI Heidelberg, Germany;
N. Lockyer, Cornell Laboratory for Accelerator-based Sciences and Education, USA

October 2024

Introduction

The 2024 annual CVI meeting was held at the Galileo Galilei Institute (GGI) in Florence from October 9th to October 11th. It gives us great pleasure to thank the INFN management and the GGI team for the outstanding hospitality and the fascinating visit of the laboratories of the *Opificio delle Pietre Dure*. Our charge was to evaluate the performance and quality of INFN's programs and management. In the sequence of biennial reviews of the four INFN national laboratories, this year's reviews focused on LNL and LNS.

Executive Summary

Perspective and Strategy – In the global landscape of astroparticle, nuclear and particle physics, INFN is a beacon with a bold ambition to unlock new science territories and to develop the enabling technologies. Led by a sustained long-term vision, the INFN management is decisive and effective, and the CVI appreciated the openness of the presentations and the discussions. The additional resources from the PNRR have an impressive catalyzing effect on INFN's ability to prepare its research infrastructures to pursue its current and future ambitions.

Central Administration – INFN has continued the modernization effort of its Central Administration (CA). As noted last year, the management of PNRR projects has proven to be a powerful driver of change, fostering cooperation between administration and researchers. The implementation of the accrual accounting model, required by law, has been an additional driver of change. This effort should extend beyond the PNRR horizon, taking advantage of the lessons learned during its realization, in order to develop integrated project management. The progress in the CA performance should be regularly monitored and assessed against pre-set indicators, while the INFN leadership should make full use of the monitoring tools developed by administration (dashboards; analytical information stored in data warehouse).

Directorate of Research Services – The Directorate for Research Services (DSR) has achieved important results in supporting INFN researchers in applying for grants and managing PNRR projects. Assignment of grants to INFN has substantially improved in the last 3 years and PNRR is progressing very well. DSR systematic approach and expertise should be leveraged by INFN leadership in developing a plan on how to integrate grants and funds assigned on a competitive basis into INFN funding strategy. This is especially important for infrastructures, like ICSC for computing, that have been built with PNRR funds and will require new funding sources for continuing operations beyond 2026.

Commissione Scientifica Nazionale 1 (CSN1, Fisica delle Particelle) – CSN1 has well integrated the accelerator-based neutrino physics experiments from CSN2. An essential enabling aspect for the physics potential in CSN1 was the excellent performance of data collection with the LHC at CERN. The INFN research groups have an outstanding impact, clearly beyond their expected fair share, in the large international collaborations of the LHC experiments. The upgrades of the ATLAS and CMS experiments are in full progress, although with a risk to not deliver on schedule. Relying on the strong and experienced shoulders of the INFN groups in ATLAS and CMS will be a decisive element in successfully realizing these, by now global, projects.

Commissione Scientifica Nazionale 2 (CSN2, Fisica delle Astroparticelle) – CSN2 with its four research lines covers a well-balanced mix of small-scale and large-scale experiments, including a number of flagship experiments on international scale. The number of researchers in CSN2 is growing steadily. INFN researchers have high visibility in their collaborations, as evidenced by the number of leadership roles. CSN2, LNGS and astroparticle physics in general benefit strongly from the PNRR activities, whose implementation is progressing well. The future of flagship experiments searching for neutrinoless double beta decay, of Xenon-based Dark Matter searches and the role of LNGS in this context are open, to be addressed in international context.

Commissione Scientifica Nazionale 3 (CSN3, Fisica Nucleare) – CSN3 supports a wide range of experiments in nuclear physics performed in national and/or international facilities including CERN (ALICE, ELENA, ISOLDE, n_ToF). The year 2023 has been characterized by a large increase (60%) of high-quality science output with an outstanding number of oral presentations across all the six research lines, as well as for several important events some of which are mentioned in the following. Strong involvement in the preparation and discussion of the Nuclear Long Range plan. The Italian gamma spectroscopy group has managed to keep AGATA at LNL until mid 2028. At the same time, the community is very concerned by the very reduced group of core scientists at LNL. Experiments are ongoing at the new Bellotti facility. The research groups in nuclear structure and astrophysics have launched an interesting initiative of collaboration with the FRIB facility at US (NUSDAF).

Commissione Scientifica Nazionale 4 (CSN4, Fisica Teorica) – The theoretical physics program of INFN keeps being strong, vibrant and provides international leadership. It exhibits a diversified and innovative portfolio. It is most urgent that theorists provide guidance now on the future accelerator choices, in common with experimentalists. The recruitment of permanent and tenure-track staff continuous at a healthy path. The postdoctoral program of ~15 positions/year should be (at least) maintained given the sustained abondance of high-level of applicants. The gender balance situation keeps being very unsatisfactory in this community: the groups should set their own concrete benchmark goals against which to assess progress, paired to an internationally proactive hiring search-strategy. A presentation on the interface of theory versus AI and quantum technologies developments will be welcome.

Commissione Scientifica Nazionale 5 (CSN5, Ricerca Tecnologica) – CSN5 coordinates advanced technological research for INFN core experimental activities. They have a system of projects that they sponsor with 6,2 M€ budget per year. This program has been running since a decade, and a review of the outcome has been presented to the CVI. The number of publications as well as the number of master and thesis projects supervised within CSN5 are very high. The CSN5 dominates by far (72%) the number of patents of the INFN. In 2023, 29 projects have been finished and 23 approved under very strict evaluation criteria and with a success rate of 60%. With this scheme of 2-3-year projects it is difficult to accommodate accelerator projects as many of them involve long-term developments. An analysis of the impact of the grants for young researchers (GfYR) proposed by CVI last year has demonstrated the importance of this initiative not only to identify bright candidates for future positions but also as a seed for promoting new ideas and obtaining ERC and other EU grants. We have learnt that, when averaged over the years, 85% of the winners have obtained a permanent or temporary position at INFN or at universities.

The gravitational-wave program – Gravitational wave (GW) research has a very strong base in INFN. The first entry in the field, VIRGO, currently does not match the Nobel-winning LIGO instruments in sensitivity, due to specific – in retrospect unfortunate but funding-driven – design choices. Appropriate measures are being taken by INFN and its partners to re-organize the management and technical leadership of VIRGO to enable a realistic upgrade plan into the future. In the Einstein Telescope (ET) project, aimed at constructing the next-generation GW observatory, Italy and INFN are providing outstanding leadership in driving the project. The Sardinia site proposed for ET is excellent, the Italian support for the project unequalled. INFN is promoting a configuration of two spatially separated double-arm interferometers, instead of the single-sited triangular configuration. For the success of the ET project, a strong partnership across Europe is crucial and the parties should make every attempt to enable a coordinated and consensual site proposal; the 2L configuration may indicate one possible path. It is also crucial that the ET Organization (ETO) is built, and empowered with adequate project management and engineering resources enabling it to exercise its decision authority.

The DarkSide experiment under construction at LNGS – With its high sensitivity and excellent background suppression, DarkSide is complementary to the xenon dark matter experiments and offers high discovery potential. In the last year, DarkSide made excellent progress in all areas, including the installation of the Urania facility for underground Argon extraction. Many of the remaining funding holes were addressed. The Forti committee is instrumental in helping the experiment converge towards a stable baseline and realistic schedule. With the baseline and installation plan not yet fully defined, some additional schedule slip and cost increases are anticipated. Key items to be addressed remain the installation schedule and its interaction with other activities in the underground hall, and the agreement regarding Urania operation. The construction MoU remains to be concluded, with an operations MoU as next step.

Laboratori Nazionali di Legnaro (LNL) – The Legnaro National Laboratory (LNL) is a national facility offering a state-of-the-art research infrastructure to researchers in nuclear physics, nuclear astrophysics, accelerator technology R&D, and interdisciplinary fields of relevance to society. The lab is focused on completing accelerator upgrade projects to deliver ISOL rare isotope beams to users. Beam delivery for users is important because the lab is hosting the AGATA European multi-detector array. A new computing centre is underway in phases to support AGATA. There are emerging plans to further develop superconducting technologies, a historical strength. Plans for a new medical radioisotope facility are being developed and will have a positive impact on society.

Laboratori Nazionali del Sud (LNS) – The Laboratori Nazionali del Sud (LNS) research focuses on nuclear physics, astrophysics, and applications of nuclear physics along with development of acceleration systems. The POTLNS project has been the most ambitious initiative for LNS concerning infrastructural enhancements for nuclear physics research. The POTLNS is to be completed by June 2025. Science focus is on measuring matrix elements for neutrinoless double beta decay and producing rare isotope beams. There is a lot of new infrastructure as well as several ambitious equipment upgrades underway. The upgraded superconducting cyclotron will deliver much more intense beams. The new fragment separator FRAISE will handle the higher intensity and will deliver more intense rare isotope beams. Intense stable isotope beams will be delivered to the newly upgraded MAGNEX spectrometer for the neutrino-less double beta decay program. The KM3NeT-ARCA project is proceeding and will require the next 3-4 years to complete. The need for project management and increased staff is a top concern given the many projects.

Laboratory of nuclear techniques for Environment and Cultural Heritage (LABEC) – LABEC's personnel is both from INFN and Univ. of Florence with a total of 21 FTEs nearly gender balanced. They are also committed to the development of portable instruments, such as a 2 MV proton accelerator developed in collaboration with CERN KT to be placed at the "Opificio delle Pietre Dure". LABEC is an international reference in cultural heritage. They coordinate the 4CH project to create a center that gives advice, support and services to a network of cultural institutions on the preservation and conservation of historical monuments and sites. In addition, LABEC is a reference in environmental studies, it hosts the European mass calibration center for atmospheric dust. To remain highly competitive, they would like to have an upgrade of the laboratory and a document describing the proposed upgrade has been prepared.

Environmental impact – A first thorough study has been completed, restricted to the national laboratories. The energy consumption is dominated by electricity consumption, with LNF and next LNL as main consumers because they host accelerators. The dominant source of the CO_2 imprint is in the form of green-house gases (GHGs) and in particular from SF6 emissions, with LNL exhibiting the largest carbon footprint. The CVI strongly supports the initiatives towards GHGs substitution, complemented with a protocol of containment-control to prevent further leakages. Overall, it is urgent to propose a clear set of quantitative targets and benchmarks for each type of environmental analysis, against which progress can be assessed.

Computing Services and the National Centre CNAF – CNAF is the national center of INFN dedicated to research and development on information and communication technologies. CNAF continues to play a leading role in computing and related technologies in Italy. The new data center, Tecnopolo, is up and running, allowing substantial new growth into the next decade. Data and infrastructure from the previous facility were transferred successfully without loss of time and new collaborations across many disciplines are emerging. High performance computing, quantum computing, big data and cloud applications are the focus. Primary concerns are for staffing in the future when PNRR funds conclude. The PNRR public-private ICSC national project is largely on track and INFN has an important role.

Long report

Perspectives and Strategy

Based on a strong ambition, INFN remains an impactful global leader for research in fundamental physics with unique research infrastructures. For example, its four national laboratories are not only crown jewels for Italy but are essential research infrastructures for the global research community. While INFN has been very proactive and effective to attract additional competitive funding, it was noticed that over the years INFN has been operating with a flat structural budget (after taking into account inflation). Regional funds in Italy are collected effectively by INFN on the basis of high-tech developments. The CVI congratulates the INFN leadership to keep personnel costs limited below 50% of the total budget. In addition, INFN is very successfully managing the complexity of the PNRR resources, especially by modernizing its administration. Overall, the INFN is satisfied with the quality of the hired technologists on the PNRR budget. The hired staff has a profile typically matching the long-term needs of the various sectors. In addition, the ongoing efforts for a transition to a green, digital and technology-driven society are very well aligned with the main objective of INFN in fundamental physics.

The Italian government has the ambition to reduce the time spent in postdoc and temporary positions. In response, a career path was developed in INFN equivalent in length with the typical tenure-track procedure at universities, and importantly INFN has the financial resources to sustain this. In addition, actions are being taken to improve the gender balance on the long term.

The upcoming VQR evaluation will include an evaluation of research infrastructures. For INFN, LNGS will be reviewed, which is probably the leading low-background underground facility in the world. In particular, the CVI supports the INFN ambition to become the world-leading underground laboratory to host $0\nu\beta\beta$ experiments at LNGS. The CVI appreciates the argument of INFN to connect the outcome of the VQR with future funding opportunities.

The CVI supports INFN in their proactive preparations for the period after PNRR, especially with respect to finalizing projects, maintenance of infrastructure and to ensure the necessary staff are maintained (in numbers and in competences). The CVI appreciates the organization to mobilize the community to develop the Italian input to the European Strategy for Particle Physics (ESPP), especially with the involvement early-career researchers. Following a charge and support received from the INFN leadership, the early career researchers established a network and organize meetings among them. Preparation meetings are being organized with experimentalists and theorists while researchers in astroparticle and nuclear physics are involved.

Recommendations

GEN-1 *– The CVI recommends developing flagship actions to attract women to STEM.*

GEN-2 *– The CVI recommends a timely convergence to a coherent and crisp Italian input for the ESPP.*

GEN-3 *– INFN should prepare for a strong and coherent contribution to the development and implementation of a future collider program at CERN.*

GEN-4 *– The CVI recommends the INFN to explore and foster mobility programs for researchers between INFN and universities.*

Recommendations for the CVI meeting in 2025

- *Plan for a dedicated Technology Transfer presentation.*
- *Plan for a dedicated presentation on Health, Safety, and Environment.*
- *Plan for a presentation on initiatives enhancing the work-life balance.*
- *Plan to present a report on HTS magnet developments at INFN, including thoughts on a distributed national center on the topic.*

Central Administration

A complete overhaul of the INFN management model was a compelling need and was rightly given priority in the last years. The redesign process has been decisively boosted by two external factors: (a) the forced adoption of the accrual accounting model in line with Directive 85/2011/EU and PNRR Line 1.15; (b) the implementation of the PNRR-funded projects. The approach followed in redesigning CA has comprehensively tried to achieve impact on processes, information systems, and people. It is a continuous and sequential process, extending over multiple years and affecting all relevant areas: accounting, human resources, research and development, legal activities, archive management. New hires are seen to help implementation as well as cultural change.

The CVI takes note of several promising signals: (a) a progress in the integration of the different "cultures" of administrative and scientific communities; (b) the insistence on data literacy, and the related production of dashboards that allow monitoring progress in different areas; (c) the stress on achieving full digitalization and phasing-out of paper documents.

The CVI regards as extremely positive that the PNRR management is running on schedule, given the scale of the INFN involvement (and in comparison with other institutions, based on anecdotal evidence). According to the presentation "Transforming Central Administration processes", 399 procurement procedures were contracted out for a total of €370,4 million; 266 people were hired (241 on fixed-term contracts, 9 on research grants, and 16 with scholarships). According to the presentation on "PNRR present status and next steps", procurement procedures were completed for 82% of the assigned funds (€199 million out of €244 million); 87% were large procurements exceeding €140.000, and 13% were below that threshold. (Note that somewhat different figures are provided in the two presentations.)

The CVI observes, however, that little hard information has been provided on the progress of the CA reorganization, aside from PNRR implementation. In particular, the CA redesign lacks:

- indicators that allow to monitor the stages of its implementation, and to assess its progress against pre-set targets;
- measures of the extent to which changes are approved and internalized by the INFN community;
- information on how the pressure on IT systems is addressed.

The CVI welcomes the effort made in the implementation of the CA reorganization, and recommends the INFN to keep going!

Recommendations:

CA-1 *– Fix a set of indicators to regularly measure administration performance and set proper targets for each indicator. Examples of indicators are: number and complexity of steps required by back-office processes; length of hiring procedures; procurement times; extent of integration of different internal data sources; use of dashboards for strategic decisions.*

CA-2 *– Ensure proper program management in the organization of critical transversal projects, such as accrual accounting and digitalization.*

CA-3 *– INFN leadership should have a real-time view of all projects and use it in its decision making process (e.g. make extensive use of dashboards as well as of the analytical information stored in data warehouse).*

Directorate of Research Services

The Directorate for Research Services (DSR) has been created recently to support INFN scientists in the application process for research grants and in the management of PNRR projects. On both accounts initial results have been very encouraging.

Participation and awarding of ERC grants to INFN researchers has grown significantly in the 2021-2024 period. Submitted proposals have increased by 24% (+15 proposals), projects invited to the final selection by 40% (+7) and grant awards by 130% (+4). In addition, DSR is involved in the support to INFN in several other categories of funded projects, at national level, like PRIN projects funded by the ministry of Research, or in European calls. Some of the calls involve projects promoted by individual researchers, like ERC grants, other, like Horizon projects, have a broader scope. In the context of ordinary funding remaining approximately constant, additional funds dedicated to specific projects, often assigned on a competitive basis, are essential to sustain the growth of the institution.

PNRR progress has also been quite satisfactory. INFN is managing 149 projects for a total expense of € 319 million; so far, all targets set by the European Commission have been met, and a very high percentage of procurement procedures (900 procedures representing 80% of total value) has been already awarded. A total of 314 people (mostly technician and technologists for the buildout and startup of infrastructures) have been hired with fix term contracts and fellowships.

DSR has been instrumental in these two successes combining three actions:

- Collecting data on grant availability, on progress on PNRR projects and performance benchmarks with other institutions in the number of applications, and on success rate in grant awarding.
- Creating transparency on project performance and grant opportunities within INFN organization by creating dashboards on PNRR and a portal showing calls for applications.
- Fostering an effective cooperation between scientists and administrative personnel on processes for procurement, hiring and reporting by conducting idea generation workshops to identify opportunities to improve processes.

The CVI thinks that the prosecution of this activity, and especially the systematic performance measurement and benchmarking with other institutions, will be key to understand the improvement potential and the necessary actions to achieve it.

We noticed, however, that work remains to be done in two areas where DRS and PNRR project leadership cannot progress without strong input and guidance from INFN leadership, which were included in recommendations of the last two years:

- Define overall targets and strategy for grant acquisition, including the role of grants vs structural funds in supporting different research areas. In that respect an opportunity for expanding the role of DRS exists, since its support in grant applications has been mostly leveraged by individual researchers applying for funding, like those obtaining ERC grants. The structured approach and skills of professionals in DRS could be leveraged also for more ambitious efforts to acquire funds in large European and national programs (e.g. Horizon).
- Ensure that PNRR projects and infrastructure receive sufficient funding and resources for their maintenance and operation beyond the PNRR horizon. This need is particularly acute for infrastructures, such as the new computing infrastructure of ICSC, requiring almost continuous investments in technological upgrade. A specific effort was recommended to provide this investment with an appropriate funding plan, leveraging opportunities to provide computing services to other public and private users. While important initiatives, like the participation to the European Call for proposals for AI factories, are already underway, a comprehensive plan is still to be finalized.

Recommendations

DSR-1 *– Develop programs, supported by INFN leadership and groups in charge of individual PNRR infrastructures, to acquire funds necessary to their continuous operation after the expiration of PNRR funds. As a part of this effort INFN should develop a plan to generate revenues for the computing infrastructure from the provision of services outside the scientific community.*

DSR-2 *– Pursue a systematic effort to integrate processes with other Central Administration directorates: appoint a program management leadership to guide this effort.*

DSR-3 *– INFN leadership should promote and drive a process, supported by DSR, to define ambitions and targets for fund raising through competitive projects (European and national). INFN leadership should leverage skills and support of DSR to help INFN senior scientists to capture an important, and possibly growing, share of funds for bigger programs.*

CSN1

The accelerator-based neutrino physics projects have been well transferred from CSN2 to CSN1. After correcting for the recent inclusion of the accelerator-based neutrino experiments, the growth in FTE numbers for CSN1 continues and the number of publications is back at the level it was before the 2022 interruption due to the war in Ukraine. Continuously new physics results emerge from the LHC program, unlocking additional rare processes for which their measurements can be confronted with theoretical predictions. The impact of INFN in the performance indicators for the international LHC experiments is clearly above its expected fair share.

The 2023 data taking at the LHC was interrupted to allow specific interventions following a technical incident in the summer. The luminosity collection at the LHC for 2024 is outstanding, projecting now 500/fb to be collected by the end of Run3. In 2024, an impressive improvement in the data collection of LHCb is noted, both in quantity and quality, significantly enhancing the potential of the physics program. In contrast, the reduced luminosity forecast for SuperKEKb (and the unexpected backgrounds) with no clear solutions would be an argument to consider the LHCb Upgrade 2; however, a concrete commitment might depend on the outcome of the ESPP update. While postponing the start of the HL-LHC operations by one year (now June 2030) has put the upgrades of the experiments back on schedule, the upgrade projects have very limited contingency to deliver on schedule.

The INFN detector R&D activities are now well integrated in the new DRDs towards experiments at future colliders. The ongoing accelerator and detector R&D at INFN follows the European roadmaps on the topic.

Also in 2023, CSN1 has been involved in an impactful portfolio of accelerator-based experiments in the USA, Japan, China and Europe.

Based on the current success of SND@LHC, it is a good moment to consider an upgrade towards SND@HL-LHC with potentially solid-state detector technologies (replacing emulsions).

Recommendations

CSN1-1 *– The CVI considers it is important to allocate an additional budget to cover the 25% cost increase for the ATLAS and CMS upgrades.*

CSN1-2 *– The CVI recommends reviewing the commitments of INFN to SAND (Near Detector at DUNE) on the basis of its upcoming TDR in Spring 2025 and to develop a new implementation plan (incl. resources).*

CSN1-3 *– With the preparations for the SHiP experiment now being endorsed by CERN, and considering the synergies with SND@(HL-)LHC, the CVI recommends INFN to develop a vision for a potential participation in SHiP.*

CSN2

The four research lines (Dark Universe, Radiation from the Universe, Neutrino properties, General Relativity (GR) and Quantum Physics) cover a very wide range of topics. Almost all experiments are conducted in international collaboration. In CSN2 experiments, 1624 persons are active, with a total of 1040 FTE; the different lines have similar constituencies. The number of researchers shows a steady growth of about 5% per year; the number of students (Bachelor, Master, Ph.D.) grows significantly faster. About 250 persons are in leadership roles in their collaborations. The fraction of female researchers is about 25%, slowly improving over time by maybe 0.5% per year. The share of females in leadership roles and among conference speakers is slightly larger. In particular for the experiments with large Italian construction contributions, CSN2 provides only part of the funding, the bulk usually coming from direct project funding.

In the reporting year, a number of experiments reported highlight results, respectively major progress towards implementation. Maybe the most striking result was the detection of a O(100 PeV) cosmic neutrino in KM3Net, by far the highest-energy neutrino detected so far.

Comments

The CVI congratulates INFN on the PNRR strategy and the success in acquiring funding. The PNRR activities provide an enormous boost in particular to astroparticle activities. The timely implementation is very challenging but looks well on track, e.g. for the additional KM3Net detector modules or the refurbishment of LNGS infrastructure.

The CNS2 portfolio contains a number of flagship experiments of international scale. INFN researchers are highly visible in their experiments; about 15% of researchers are in leadership roles in their collaborations. The visibility and impact of INFN researches goes well beyond the numerical INFN share in projects. The CSN2 portfolio – combining a mix of small-scale and large experiments, and of experiments delivering a steady stream of observational results, and high-impact searches for rare phenomena – looks well balanced and well-managed.

On DAMA: With the end of 2024, the DAMA story will come to an end; even after almost two decades of operation it remains unclear if the DAMA periodicity is a Nobel-level effect or ununderstood systematics. The refusal of DAMA to open their data emphasizes need for open-data guidelines imposed when approving experiments. It is evident that the DAMA crystals should be kept intact and underground. With SABRE, for the first time a collaboration is able to produce crystals of DAMA quality, able to check the DAMA signal under identical conditions. However, the foreseen size of the SABRE detector is marginal – it should double in size else the results may well be inconclusive.

Regarding future flagship experiments, the perspectives for CNS2 experiments at LNGS seemed excellent last year but are suddenly more uncertain: the DOE support for LEGEND1000 at LNGS is again open, and the decision delayed; for the next-generation xenon experiment, there is strong competition by UK/Boulby and also from SURF.

International competition is also increasing through state-of-the-art astroparticle experiments in China: faster decision lines, large single-agency funding, and growing high-tech industry support allows relatively rapid implementation of experiments. For example, the Chinese teams are now pushing towards a neutrino detector of about ten times the scale of KM3Net, in the South China Sea, on time scale that may not be so much longer than that of the full KM3Net. An INFN strategy how to deal with the China challenge was not discussed at the meeting; INFN was forced to withdraw from HERD but there is fruitful collaboration in other experiments (JUNO, LIMADOU).

Recommendations

The recommendations go beyond the immediate CSN2 context and also concern LNGS, which is intimately connected with CSN2.

CSN2-1 *– Despite the uncertainties in the planning of $0\nu\beta\beta$ experiments, INFN is in a unique position to enable the start of CUPID construction. CUPID is very competitive in science reach with LEGEND1000 and nEXO. INFN funding of CUPID Phase I should be decided in a timely manner.*

CSN2-2 *– XENON is a flagship Dark Matter project and was worldwide leading the DM search, but is in danger of falling behind. INFN and LNGS should work towards a strategy regarding the mid-term future of XENON – whether to try further increasing the xenon mass at LNGS, or rather wait for the XLZD experiment that aims at combining European efforts in this area. XENON also claims to suffer from a lack of compute resources; given the compute facilities of INFN, this should be relatively easy to resolve.*

CSN2-3 *– In view of increased availability of underground lab space in the UK and the US, and the resulting competition for experiments, INFN and LNGS should continue and intensify the efforts for coordination among underground labs, and should continue to explore and encourage new (non-astroparticle) applications of underground labs.*

CSN3

CSN3 continues to provide a high science output across all six research lines: Quarks and Hadron Dynamics; Phase Transitions in Hadronic Matter; Nuclear Structure and Reactions; Nuclear Astrophysics; Symmetries and Fundamental Interactions; Applications and Societal Benefits.

The number of FTE's working on CSN3 projects has a moderate but persistence increase (~507 FTE) although the overall number of people has slightly decreased to 787, highlighting the interest in this section. The percentage of women is high, on average 29% of the FTE and the fraction is even higher reaching 50% at the level of master theses defended (25 female versus the 54 in total). However, this number drops for the PhD theses defended (7 female out of 28).

CSN3 supports an interesting and appropriate mix of large, mid-scale, and small experiments, and of "safe" and highly innovative / high risk / high impact experiments. The portfolio of a bit more than twenty experiments is well managed by CSN3, with clear procedures and detailed attention to critical cases when the number of participants in certain experiments is too low. Excellent science is being done in CSN3 with a very large number of publications and oral presentations that exceed one per FTE working in the section. Only some selected highlights will be listed in the following.

Highlights from Quark and Hadron Dynamics include the first ever measurement of the kaonic deuterium X-ray transitions to the ground state done at KAONNIS. The INFN group is largely involved in the definition of the characteristics of ePIC detector of EIC, INFN leads the R&D/TDR preparation of µvertex, end-cap disk trackers and forward dRich. These R&D efforts are largely coordinated with the LHC and FCC groups. In the line of Phase Transition in Hadronic Matter, ALICE is in full swing with extraordinary statistics with the Pb+Pb beams. In addition, an intense data analysis and paper production activity has continued throughout 2023, with a record number of 54 papers submitted to journals over the year. Experiment NA60+ submitted a letter of intend to SPSC that was well received and SPSC will start examining the proposal in 2024.

In the area of Nuclear Structure and Reactions, large efforts have been done to contribute to the topical collection on AGATA with guest editors from Italy. Among the results from the AGATA detector is worth to mention the determination of lifetime measurements of ^{20}O (PRL) and in ^{34}Mg with impact in astrophysics scenarios (Nature Com). The review article, highlighting the contribution of results in double charge exchange reactions, has been published in Prog. in Part. and Nucl. Phys. (MAGNEX). Further, it is important to mention the new results of LEA on the first measurement of the ani-hydrogen behavior on the Earth gravitational field published in Nature. Nuclear astrophysics studies require measurements in extreme conditions different from those on Earth laboratories, with this aim the Pandora experiment, that starts at the end of 2025, will measure the beta strength modifications in presence of a plasma. N_ToF has determined the capture cross section of ^{140}Ce and its implications in the chemical evolution of the Universe and LUNA has achieved the first measurement of the 64.5 keV resonance in ^{18}F, lowest energy resonance ever directly measured. Since 2023 the Bellotti facility is ready to provide beamtime to the users.

In the line of Symmetries and Fundamental Interactions one should mention the spectroscopic determination of the hyperfine splitting of muonic atoms (FAMU @RAL), and the R&D efforts that has allowed the FAMU collaboration to achieve the highest energy ever with the laser at 6788.9 nm. The VIP (violation of the Pauli Principle) experiment at LNGS is under finalization. In the line of Applications and Societal benefits it is important to mention the new infrastructure at SPES aiming to find new production methods of isotopes for theranostics medical studies, SPESMED, and the FOOT dedicate to determine fragmentation cross sections of interest for particle therapy.

Recommendations

CSN3-1 *– The CVI would like to hear more details on the ALICE upgrades, Italian involvement, and commitments in the next meeting.*

CSN3-2 *– CVI commends the new initiative of the scientists of ASFIN planning experiments in several facilities to mitigate the effect of delays of the accelerators at LNS, including coordinated efforts with other groups of CSN3 and CSN4 in signing an MoU on NUSDAF-FRIB. The CVI recommend the support of INFN to the NUSDAF initiative.*

CSN3-3 *– The CVI recommends to further explore interdisciplinary links of nuclear energy and medicine with CSN5.*

CSN3-4 *– The coming years are crucial for the upgrade of accelerators at LNS and the start of SPES. It is a great news that AGATA will stay until mid-2028 to be able to profit from beams of SPES. At the same time the core of physicists at LNL is reducing to alarming numbers, the CVI recommends INFN to address this point.*

CSN4

The Italian program of theoretical physics pursued by the INFN continues to be one of the most successful in Europe, with strong international impact. Several scientific highlights have been accomplished in the last year. A healthy diversified portfolio is expanding including gravitational, axion and dark sector physics.

A significant part of the work is being developed in close contact with and is providing good service to the experimental efforts. Furthermore, in the last years the quantum-physics activities have increased in relative FTE percentage.

The recruitment of permanent or tenure-track staff, crucial to theory, continues at a reasonable path to sustain a healthy community. The training activities for early career researchers remains of high quality and very active. New initiatives include the "theory meets experiment" GGI school and the gender-balance targeted actions. The participation of INFN theoretical researchers in workshops, conferences and schools appears to be recovering to pre-pandemic levels.

Comments

The CVI looks forward to the continuation of the INFN lattice theory efforts towards the next release of results relative to the muon g-2 anomaly. The same applies to the theoretical effort on precision accelerator physics, including perturbative and non-perturbative physics.

The situation regarding gender balance in CSN4 remains unsatisfactory, and well under the average 25-30% gender rate for INFN researchers, in particular on the more theoretical and high-energy arena. This is about mirrored by the low percentage of INFN female researchers giving talks at conferences. Some new initiatives such as the special prizes for young female students could have a positive impact and are to be monitored.

While in general theoretical work does not require specific associated technical personnel, PhDs and postdoctoral fellows are crucial to the theorists' work. The present INFN support in this realm may be insufficient for optimal results.

The CVI stresses the huge potential of INFN to bring together and seed interactions among different theory groups and between theorists and experiments.

Recommendations

CSN4-1 – *It is urgent that INFN theorists deepen their efforts to provide scientific guidance on the choice of a future high-energy accelerator. In order to have a real impact on the European Strategy, the effort should intensify now and the vision should be developed in common with experimentalists.*

CSN4-2 – *In order to reach at least the average INFN gender rate for researchers in CSN4 and enable concrete steps, the theory groups should set their own quantitative benchmark goals against which to assess progress, in compliance with the EDI guideline of the EPSHEP board. A proactive hiring search-strategy could be useful in the national and international arena.*

CSN4-3 – *The CVI strongly recommends that INFN (at least) maintains the postdoctoral program of ~15 theoretical postdoctoral positions per year, given the theorists' needs and the sustained-in-time wealth of many very high-level applicants.*

CSN4-4 – *In view of further assessing the impact of technological innovation on the theoretical efforts (and vice versa) a targeted analysis of two aspects of their interface would be profitable: i) the impact and use in theoretical work of AI/machine-learning developments; ii) the developments related to quantum computing and quantum technologies. The CVI looks forward to a presentation in the next meeting.*

CSN5

CSN5 coordinates advanced technological research for core experimental activities of INFN and promotes the development of instruments, methods and techniques for fundamental physics and their applications in other fields. Its activities involve about 585 FTEs and have a significant social and economic impact. The gender balance is good at the level of 30 % of the FTEs.

CSN5 has three research lines dedicated to accelerators (including superconducting systems, cavities and coating), detectors, electronics and computing (including detectors, quantum sensing, AI) and interdisciplinary physics (including dosimetry, hadron therapy, AI in medical applications). Funding for projects is distributed among the three categories; in parenthesis the number of running projects in 2023: standard projects (64), 2-4 years receiving up to 100K€/y, calls for proposals (10), 3-4 years receiving up to a total of 1M€, and grants for young researchers (12). The share between the three lines of research was 16 projects for accelerators, 37 projects for detectors, electronics and DAQ, and 33 projects for the interdisciplinary physics line. This year, 29 projects have been finished and 23 new have been approved, resulting in a reduction of the number of active projects due to delays caused by COVID in running projects.

Standard projects account for the core of CSN5 research. They aim to foster new ideas, high risk-high impact projects, seed projects and medium-small experiments supporting wider activities. There are also the so-called calls for proposals. The aim is to select exceptional and very challenging projects involving a high number of researchers. The grants for young researchers (GfYR) last two years and cover both the salary and the research activity. The GfYR projects have in many cases been the seed for future initiatives and projects. It is important to notice that the GfYR have proven to be a good stepping stone to obtain EU-resources, as it is very selective, and the successful candidates acquire very soon the leadership mindset suitable for the challenges related to the high-risk/high-gain character of EU projects.

The CSN5 emphasis on fostering interdisciplinary activities is highly appreciated. The competitive assignment of internal funds after rigorous evaluation, as well as the follow up at different stages of the projects is remarkable. Following last year's request of the CVI regarding the impact of grants for young researchers, it is found that grant winners demonstrated to be able to realize a successful career as researchers and developed new research projects. The GfYR winners stay in 85% of the cases in academia, either at INFN or at universities. One can conclude that this is a good tool for identifying promising researchers or technologists, improve their motivation and fostering their independence and leadership.

The CSN5 has also reviewed the call for proposals. Their study reveals that the investment since 2014 has been approximately 15 M€. These investments have helped to attract funds from other sources than INFN of the order of 29 M€. In addition, during this decade 96 PhD students have defended and 11 patents have been registered. One can conclude that the calls for proposals have proven to foster R&D activities for the advancement of the technological and applied research in INFN. The financial returns in terms of new projects (also European) and collaborations are large. The CVI thanks CSN5 for the study presented on the results achieved by the GfYR and call for proposals.

Recommendations

CSN5-1 *– The CVI recommends INFN to consider enlarging the number of GfYR per year with the idea of using the developments proposed in the grants as a proof-of-principle to enhance the application for ERC grants and other EU projects.*

CSN5-2 *– The CVI would like to learn more about the involvement of foreign partners in the call for projects.*

The Gravitational-wave program[1]

INFN is participating in three major gravitational wave detectors: VIRGO, which is in operation, the Einstein Telescope as the European next-generation gravitational wave (GW) facility, and the planned space-based LISA interferometer. The Einstein Telescope will provide a huge improvement in sensitivity compared to the current instruments LIGO, VIRGO and KAGRA. Very low frequency GWs cannot be detected from the ground, due to overwhelming background noise. The space-based LISA instrument will address this frequency range.

VIRGO: VIRGO joined O4 GW run late; this run will continue until Mid-2025, followed by a two-year shutdown for upgrades. With a current range of 55 Mpc for neutron star merger detection, VIRGO is inferior to the US LIGO instruments with their 180-190 Mpc range, and is performing below its performance target. Significant effort went into the investigation of the VIRGO performance limitations. The marginally stable cavities and interaction with the signal recycling cavities were identified as a likely cause. The EGO organization formally responsible for operating VIRGO and the VIRGO Consortium were so far unable to appropriately address these problems. Since this was perceived at least partly due to deficits in the organization, the EGO Council, with INFN as a main party, set up a management review by a high-level external committee, as well as a technical review committee to review the planned fixes and upgrades towards the O5 run, once a TDR is available. The management review recommended to re-organize VIRGO/EGO to create a rigorous project management structure, strengthening the role of the resulting “VIRGO-lab” and creating a well-defined line of command.

Einstein Telescope (ET): The design initially proposed for ET consists of three 10 km long double-arm interferometers, arranged in a single large triangle. There is outstanding Italian support for the project, covering a significant fraction of project costs if realized in Sardinia, well exceeding the support offered for other sites. Also, very important large resources (via the PNRR ETIC projects and other sources) are provided for further characterization of the Sardinia site, for the preparation of a site bid book, and for instrument R&D. The Sardinia site is excellent as far as seismic noise and geology is concerned. INFN has been investigating and promoting an alternative 2L configuration. Two widely separated “L”-shaped detectors with 15 km arm length, rotated by 45 degrees relative to each other, provide performance exceeding that of a 10 km triangle configuration for most science cases except for high-frequency primordial GW. The 2L interferometers are less complex than a triangle, reducing technological risk. ET is in the process of getting organized, with the ET Organization (ETO) providing the formal structure and legal entity, and the ET Consortium (ETC). INFN has implemented the TETI team in charge of preparing the bid book for the Sardinia site proposal, and has initiated an external review of TETI and of its interaction with ETC/ETO. The review considered TETI understaffed and indicated that coordination and in particular decision lines between EGO, ETC and TETI need to be redefined, to enable an efficient and cost-effective design of this extremely complex project.

International Gravitational Wave Network (IGWN): While GW instruments already coordinate their data taking and share their data, the LIGO organization has proposed the creation of a more formalized IGWN, coordinating the individual observatories and their evolution. While such a network could indeed have a very positive impact, its exact role and its powers (if any) remain to be sorted out.

LISA: The INFN team working on LISA is relatively small, but it made key contributions towards developing LISA technology and successfully demonstrating these technologies with the LISA pathfinder. With the mission adoption by ESA, for launch in 2035, LISA has taken a big step in 2024.

[1] As director-elect of Nikhef, Jorgen D’Hondt will soon be co-coordinator with Antonio Zoccoli (INFN President) of the Einstein Telescope ESFRI project, and therefore he did observe a passive role during the discussions on the topic of Gravitational Waves.

VIRGO, ET and LISA share features of technology and address the same science. Workshops to enhance communication between GW projects in Italy will be organized.

Comments

<u>VIRGO</u>: Acting upon the key recommendations of the management review, the EGO Council and INFN have taken appropriate steps towards addressing the problem and re-organizing the project. The goal is to have the new structure in place by the end of 2024, providing a much higher degree of control to the management of a future "VIRGO-lab", and equipping it with sufficient project management resources and engineering resources, towards preparing a TDR for the O5 upgrade. This will require increased engagement and resources by all parties.

<u>Einstein Telescope</u>: Italy and INFN are providing outstanding leadership in driving the project. At this time – late 2024 – the project is in a complex situation, and many key decisions are open and intertwined: (i) two or potentially three sites are offered; (ii) the choice of a single-sited instrument in triangle configuration, or a double-sited instrument with an "L" configuration at each of the sites; (iii) the legal form of the Einstein Telescope Observatory (ETO) and the responsibilities of ETO and its interaction with the Einstein Telescope Collaboration (ETC). Current funding commitments – while of very large scale – are insufficient for any of the options; costs are driven by the tunnel infrastructure, with significant uncertainties. Finally, with Cosmic Explorer a similar project is proposed in the US, and decisions may interact. The INFN-initiated review of ETO + ETC + TETI indicated that the current organization may face similar issues than EGO/VIRGO, lacking strong central authority. Furthermore, the decision process towards an ET baseline design appears not yet well-defined.

Recommendations

GW-1 *– VIRGO: The EGO Council and INFN should continue the forceful and timely implementation of key recommendations of organization review. Once a technical solution and upgrade plan towards O5 is in hand and documented in a TDR, the already established technical review panel will review the plans for O5. Based on the result of this review, the EGO Council should address the longer-term evolution and sustained potential of the observatory.*

GW-2 *– Einstein Telescope (ET): A strong partnership across Europe is crucial for the success of the ET project. The parties involved, and in particular INFN, should make every attempt to enable a coordinated and consensual site proposal. This also includes:*

- *(i) Strengthening ETO and empowering with adequate project management and engineering resources to overview design and implementation;*
- *(ii) Deciding on and implementing the ETO legal entity as early as feasible;*
- *(iii) Defining and agreeing on the decision process, milestones and timeline towards baseline design;*
- *(iv) Clearly defining the respective roles of ETO and ETC, and their interfaces.*

DarkSide

DarkSide (DS) aims at detecting Dark Matter recoils using prompt scintillation and delayed electroluminescence from ionization electrons. Pulse shape discrimination is used to discriminate against electron recoil. DS provides excellent background suppression and hence discovery potential; it is complementary to the Xe-based experiments. A crucial ingredient of the experiment is the use of

Underground Argon (UAr, depleted of ^{39}Ar) as target material. The UAr is extracted in the US using the Urania plant and purified in Sardinia using the ARIA facility.

DS construction and installation at LNGS has made excellent progress during the last year. The cryostat has been closed, the cryogenic infrastructure for atmospheric Argon is being installed. The components of the Urania plant have been installed at the Kinder-Morgan site in Cortez, CO, with few months of work remaining for piping and connections; an in-depth safety review of Urania is starting soon. In summer 2024, the UAr project underwent a thorough international review, resulting in many detailed recommendations but not finding any showstoppers. The refurbishment of the ARIA Castello has been concluded. Regarding detector construction, the NOA clean-room facility at LNGS is fully operational, and 2/3 of the light sensor wafers have undergone cryoprobing, with an excellent 94% yield. Preproduction of TPC photodetectors in NOA is ongoing. Also, the production of veto tiles in the UK is 40% complete, with good yield.

A concern was and is that the experiment has a "reference" baseline but not yet a real baseline. While already under construction, and with a significant fraction of funding spent, there were many non-trivial design changes in the last two years, concerning e.g. the neutron shield of the TPC, the decision to assemble the TPC in-situ in the hall rather than in the NOA clean-room facility, the transport of underground Argon in liquid rather than gaseous form, and others. The Forti committee appointed by INFN, with its continued engagement and insistence, contributed crucially to guiding the experiment towards a real baseline. With the decision to use normal PMMA rather than Gd-loaded PMMA for the TPC wall, a major open design decision was taken. While neutron background increases by a factor 3, the background remains – at least in the fiducial volume of the TPC – uncritical. The complex installation procedure for the TPC remains to the detailed, and may require design adaptions.

Compared to the January 2023 schedule, there is a schedule slip of about 35 weeks. Most of the funding holes still present a year ago appear to be closed, through additional funding and release of contingency. The text of the construction MoU is largely agreed; work on the annexes detailing the contributions of the various parties is ongoing. The agreement with DOE regarding Urania operation is still open.

Comments

The CVI congratulates DarkSide (DS) on the excellent progress in all areas; it is impressive to see this huge and highly complex project with it many components – Urania, ARIA, the cryostat, the TPC – being mastered. The CVI acknowledges the enormous and continued effort by the Forti committee; the interaction with and the constructive support by the committee interaction greatly benefits DS. The interaction and communication of DS with LNGS as the host lab improved significantly, but the support of DS will remain a large load and a challenge for the lab.

Regarding detector design, the decision to go for a pure PMMA neutron shield of the TPC – as opposed to Gd-loaded PMMA – settles a big remaining open issue. The many in-depth reviews of DS did not reveal showstoppers, but evidently major challenges remain, such as the installation planning for the TPC that is to be assembled in-situ, and bringing Urania + ARIA into stable operation. Since the project still does not have a stable baseline, further schedule slips and cost increases are to be expected, but hopefully at a modest level. But while the aim of DS clearly is to be first in probing lowest Dark-Matter cross-sections, the value of the experiment is equally in its ultimate reach, its powerful background suppression and its complementarity with other techniques.

Recommendations

DS-1 *– Given that the basic design of the TPC is now fixed, DarkSide must establish a realistic resource-loaded schedule for the installation and commissioning.*

DS-2 *– Darkside should establish with LNGS the interaction between the hall refurbishment schedule and the installation schedule, to foresee and prevent any logistical or safety issues. The planned works in the road tunnel may impose additional constraints.*

DS-3 *– The Urania final safety review, and the timely startup and commissioning of Urania are of vital importance for DarkSide and require utmost care and attention.*

DS-4 *– The still-open agreement with DOE regarding Urania operation is time-critical and must be addressed.*

DS-5 *– DarkSide should prepare in a timely fashion the MoU covering the operation of the experiment, defining the sharing of responsibility and of cost.*

LNL

The Legnaro National Laboratory (LNL) is a national facility offering a state-of-the-art research infrastructure to researchers in nuclear physics and in interdisciplinary fields. The researchers are involved in accelerator-based science and applications and in R&D in particle accelerator technology. The LNL counted 157 employees, of which 137 with permanent positions and 20 with temporary positions, 100 associates, and about 500 users per year.

The new Director Faical Azaiez has reorganized the upgrade projects from a work package approach to a multi-phase (5 phases) approach to account for limited human resources with a well-defined schedule. The highest priority is completing the long standing SPES (Selective Production of Exotic Species) accelerator complex and radioisotope production facility. The five phases are: Phase 1: SPES Superconducting cyclotron and beamlines complete with beam to experiments 2024. Phase 2: ISOL Target ion source and vault complete, and beamlines to experimental hall. Phase 3: Complete Adige new Injector & RFQ for SPES post accelerator. Phase 4: Plans for radioisotope facility will start from in 2025. Phase 5: Commissioning of post-accelerated Radioactive Ion Beams: mid 2027.

The new data center (CED) building construction was completed March 2024. The European Spallation Source (ESS) Drift Tube Linac (DTL) has been completed. The refurbishment of the Auriga building has been completed to house Superconducting RF facilities for future projects.

Comments

Congratulations to the new Director for implementing a phased approach to completing projects. It is important to continue to host the AGATA multi-detector array and provide adequate support for the user community, as well as to continue operating the accelerator complex and attract users back and identify the scientific niche. In addition, it is important to build off the historical strength in superconducting RF to get engaged in new projects and to determine the future of the three aged electrostatic accelerators: the TANDEM accelerator (43 years), the AN2000 accelerator (53 years) and the CN accelerator (63 years).

Recommendations

LNL-1 *– Focus on completing accelerator upgrade projects and deliver ISOL RIB beams to user community.*

LNL-2 *– Develop the Advanced Technology and Innovation platform (ATIP) for Superconducting RF capabilities for use with future projects like CERN's FCC-ee and industrial applications.*

LNL-3 *– Once accelerator complex upgrades are well advanced begin a new radioisotope facility for medical purposes.*

LNL-4 *– Develop a plan to attract high-level researchers.*

LNL-5 *– Make a sustainability plan to reduce SF6 leakage.*

LNL-6 *– Review the motivation for a continued tandem operation.*

LNS

The Laboratori Nazionali del Sud (LNS) very broad research program focuses on nuclear physics, astrophysics, theoretical physics, applications of nuclear physics along with development of acceleration systems and ion sources. The LNS total number of staff members at the end of 2023 was 164 (researchers, technologists, technicians, administrative) and 26 fixed terms contracts. The overall number of associated personnel units (not INFN staff) was about 130. LNS is very active on many projects. Only some are mentioned below.

LNS has as a priority focus on the ambitious KM3NeT-ARCA upgrades, the seafloor network which will require 3-4 years to complete. The KM3NeT-ARCA detector is currently operating a 28-string configuration. An additional 15 strings are to be deployed by the end of October 2024. The KM3NeT4RR-PNRR project is a large expansion of infrastructure and 50 Detection Units and should complete at the end of 2025.

The POTLNS project is the most ambitious initiative for LNS concerning infrastructural enhancements for nuclear physics research, with focus on neutrino-less double beta decay matrix elements. The POTLNS is to be complete by June 2025. There are other experiments preparing for the high intensity isotope running such as CHIRONE that will use the upgraded high granularity Chimera detector. In nuclear astrophysics, PANDORA is a new astrophysics experiment to study beta decays in magnetized plasmas. The future MAGNEX spectrometer configuration will allow handling higher rates from upgraded cyclotron with the NUMEN project, which is essential for neutrino-less double beta decay matrix elements.

The overall accelerator complex is undergoing several upgrades. There are two accelerators, a 15 MeV Tandem Van De Graaff and a K800 superconducting cyclotron, capable of producing stable and radioactive beams. The Tandem accelerator upgrade is complete, and testing will begin in the spring of 2025. The Superconducting cyclotron assembly is underway after nonconformities, causing two years in delay and 20% cost increase. The plan is to commission the hardware in 2026, and low intensity commissioning of the beam by the end of 2026 and high intensity commissioning in 2027. The fragmentation separator facility FRAISE is progressing well. FRAISE will be able to handle intense primary beams that will produce intense and high-quality radioactive beams. Further upgrades or replacement of the ECR ion sources will eventually be needed for high intensity operation.

I-LUCE (INFN-Laser indUCEd particle acceleration) will be a new facility for laser plasma acceleration dedicated to producing protons, ions, electrons, neutrons and gammas. The laser arrives at the end of 2025 and is high-power (up to 1 PW) producing ultra-short (down to 25 fs) laser pulses. Funding has been secured.

For FRIDA, the FLASH therapy program, tests are underway.

LNS is successfully managing bid package for Einstein Telescope feasibility in Sardinia.

Comments

The Laboratory is very busy with many projects and upgrading infrastructure. The team is to be congratulated on impressive KM3NeT progress. There is an ambitious plan for measuring neutrino-less double beta decay matrix elements, which is a scientifically important program. The MAGNEX spectrometer upgrade will allow handling higher rates from the upgraded superconducting cyclotron with the NUMEN project, which is essential for neutrino-less double beta decay matrix elements.

In addition, once completed, the inflight fragmentation RIB facility will provide an active experimental program for the next 30 years. New radiation protection licenses are needed due to the increased beam currents.

LNS staff is to be complemented on the multiple outreach activities.

There are many projects underway, and many rely on an operating superconducting cyclotron. The dire need for project management across the laboratory and insufficient technical staff throughout the complex has led to delays and increased costs of the accelerator complex and detectors. Prioritizing of work by project management is necessary. This situation needs to be remedied by INFN with increased resources for more staff or continued slippage and increased costs will occur.

Recommendations

LNS-1 *– Effective project management with increased support from INFN is needed to successfully complete upgrades and successfully commission the accelerators, beamlines, and detectors.*

LNS-2 *– Continue with KM3NeT and start the Einstein Telescope work as a priority.*

LNS-3 *– I-LUCE potential is significant and once PNRR equipment is commissioned a review is appropriate to establish the scale of facility.*

Laboratory of nuclear techniques for Environment and Cultural Heritage (LABEC)

LABEC is a laboratory of nuclear techniques for environmental and cultural heritage. Its staff is both from INFN and Univ of Florence, with a total of 21 FTEs nearly gender balanced. They are articulated in three lines of research: cultural heritage and construction of instruments, environment and material modification. In addition, they have a group dedicated to digitalization and the tandem support staff. All lines are very active with several research grants. The facility has a 3 MV tandem dedicated to Atomic Mass Spectrometry (AMS) and Ion Beam Analysis (IBA), and ancillary laboratories for sample preparation.

LABEC's mission is to develop innovative techniques and technologies in nuclear physics for applications in material science, environment, archeological and historic-artistic context. On the part of development of instruments, one has to mention two initiatives: the development of portable instrumentation for X-ray material composition analysis within INFN-CHNET and, together with

CERN-KT, the development of a 2 MV proton accelerator called MACHINA that will be placed next spring at the “Opificio delle Pietre Dure”.

LABEC is an international reference for cultural heritage with national and international projects and high visibility. It coordinates the Italian network, CHNet, for joint efforts on cultural heritage of INFN centers, Italian universities and national and regional restorations centers with the mission of defining common R&D lines and activities. It addresses the needs of the Italian cultural heritage institutions and promotes technology transfer, knowledge exchange, and internationalization. Furthermore, LABEC coordinates the EU project 4CH (2021-2024) to set up the methodological and organizational framework of a Competence Centre for the Conservation of Cultural Heritage that gives advice, support and services to a network of cultural institutions on the preservation and conservation of historical monument and sites.

LABEC hosts a European mass calibration center for atmospheric dust. In addition, the project GAIA (PIN 2022, PNRR funds) develops advanced instrumentation for aerosol characterization with the aim to understand how these aerosols reach the Artic and to learn about their climate impact.

To remain highly competitive, they have prepared a document for an upgrade of the laboratory, with the aim of installing a low voltage tandem for AMS only and to reconfigure the existing tandem for IBA measurements and irradiations with controlled doses.

Recommendations

LABEC-1 *– The CVI is impressed by the LABEC research projects, but is concerned about the impact that the refurbished tandem infrastructure can have on current projects. Thus, the CVI supports the upgrades needed to remain at the forefront position and at the same time recommends careful planning in order to mitigate the impact on the present research activities. CVI recommends INFN to continue their commitment and support to LABEC's program.*

Environmental impact

A first thorough study has been performed covering five aspects: energy consumption, CO_2 imprint, water imprint, waste management and ionization radiation. The analysis has been restricted to the national laboratories, because of data availability. The energy consumption is dominated by electricity consumption, with LNF and next LNL as main consumers because they host accelerators, and LNGS comes next as consumer.

Two main points stressed are the carbon footprint and the waste management. The CO_2 imprint results from direct (scope 1) and from indirect contributions. Direct contributions are the dominant ones, in the form of green-house gases (GHGs) and in particular from SF6 emissions, resulting from the maintenance of the Tandem electrostatic particle accelerator, and the decommissioning of facilities. As a result, LNL has nowadays the largest carbon footprint. The indirect contributions considered (scope 2) include purchased electricity, while scope 3 includes other sources which are not yet analyzed.

Comments

The CVI praises the authors of the report for their excellent work and thoroughness. The CVI looks forward to the first quantitative analysis of the scope 3 indirect carbon footprint next year. It is appropriate that all new INFN constructions are informed and monitored by this group, in view of minimizing their environmental impact. It is commendable that some imprint-reducing actions have been already implemented.

The CVI praises the initiative of establishing a working group that is already devising how to reduce SF6 emissions, via the replacement of the GHGs used with other gases exhibiting a lower environmental impact. The same applies to the energy-saving working group.

Recommendations

EI-1 *– It is necessary to propose –for next year– a first clear set of quantitative targets and benchmarks, against which progress can be assessed.*

EI-2 *– Measures to prevent further leakages should be implemented, together with a protocol of containment-control measurements, in order to complement the substitution program for green-house gas emission.*

EI-3 *– The CVI strongly recommends to strengthen the collaboration on environmental-impact issues with international bodies, and in particular with CERN.*

EI-4 *– For illustration and communication purposes, a comparison with the environmental impact of other facilities (e.g. hospitals, some industry) would be most welcome for next year.*

Computing Services and the National Centre CNAF

CNAF is the national center of INFN dedicated to research and development on information and communication technologies. The current staff number is 65 with 23% female. CNAF manages the Tier-1 center for the WLCG (World-wide LHC Computing Grid, led by CERN), the main computing facility for INFN. The Tier-1 center has 60 collaborations, dominated by the large CERN experiments ATLAS and CMS. A main pillar of CNAF is the Data Cloud which is an INFN initiative to merge data centers, together with all Tier-1, Tier-2 and Tier-3 centers into a common national data-lake. The facility is also reaching out to other users of big data such as the medical community. CNAF has established collaborations with institutions operating in the bio-medical, genomic and oncological sectors.

Substantial investment in computing has been realized. Tecnopolo, a new modern data center located in Bologna, is a joint initiative by INFN and CINECA, for both the INFN Tier-1 center and the European supercomputer Leonardo. The center was inaugurated May 10, 2024. The new data center currently allows the use of up to 3 MW of power (up from 1.5 MW) and will reach 10 MW of power in 2027, adequate for HL-LHC needs and beyond. CNAF data has been migrated to Tecnopolo with no losses. The computing farms and disk storage were moved and a new tape storage facility installed. The G7 Ministers for Research and Innovation meeting was successfully hosted at the center.

The PNRR public-private national ICSC project is largely on track. There is a hub and spoke model with INFN focusing on High Performance (#1) and Quantum Computing (#10) being two of the 11 spokes, with spoke (#0) being cloud infrastructure. A new Director has been appointed for the ICSC: Daniela Gabellini. INFN has plans to purchase three quantum computers, two neutral atom and one superconducting.

Comments

The new facility is heavily subscribed but not oversubscribed. The effort to work with SMEs and startups is interesting. There are 12 proposals received. INFN and CNAF have several strategic objectives, including coordination of an INFN wide cloud in the context of the new ICSC national center funded by PNRR. However, there are concerns that long term financial sustainability is not evident. The team is concerned about losing the 30% staff funded through PNNR and yet the need of resources to operate the new facilities is clear. On the issue of cyber security, the team is taking advantage of the national team.

Recommendations

CS-1 *– Given the extreme importance and visibility of the new data center Tecnopolo, INFN should carefully analyze the number of PNRR temporary staff that need to become permanent.*

CS-2 *– INFN should continue to focus effort on quantum computing.*

CS-3 *– Consider a 3rd party cyber security review of business and scientific data.*