Annual Report to the President of the INFN

Il Comitato di Valutazione Internazionale (CVI)

M. Bosman, IFAE, Barcelona, Spain; A. Brandolini, Banca d'Italia, Italy; I. Dillmann, TRIUMF, Canada; R.K. Ellis, University of Durham, UK; W. Hofmann, MPI Heidelberg, Germany; A. Montanino, CDP, Italy; A. J. S. Smith, Princeton University, USA (chair); C. Spiering, DESY, Germany.

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Introduction and General Comments

The 2020 annual CVI meeting took place the 14th through 16th of October, virtually this year because of the pandemic. We acknowledge with thanks the outstanding efforts of INFN staff to organize and operate the meeting smoothly and efficiently. Our charge was to evaluate the accomplishments of the INFN National Scientific Commissions (CSN's), Technology Transfer group, National Laboratories, and Senior Administration; and to advise on priorities. We were pleased and impressed by the solidification of INFN leadership and management over the past year, and wish to acknowledge the outstanding response to last year's CVI report, and the attention to address our recommendations. Furthermore, the 2020 GLV report clearly described the excellent progress over the past year.

The organisation is in good hands to deal with the many challenges confronting their science programs and operations, and has done an outstanding job in dealing with COVID-19. INFN quickly set up a strong proactive crisis unit to deal with COVID-19 and has made several significant contributions to fighting the pandemic: Computing, ventilators, masks, etc. INFN has kept its main structures open, but 95% of people had to work from home. The in-person fraction had increased steadily to 60%in October 2020 before the second wave.

Governance and Strategy

Comprehensive changes in INFN management have taken place since our last meeting: a completely new executive board, new Director General, new Lab directors at LNL, LNF and LNGS. Importantly, a new senior position has been created – Director of Research Services – to assist and support researchers with proposals and grant management. We strongly support the new team and look forward to reviewing their accomplishments in the future.

INFN is a large and powerful research organisation that supports over 2000 permanent positions, approximately half of whom are directly engaged in research: 675 scientists, 348 engineers and technical staff, 671 technicians, and 315 administrative staff. There are also approximately 4000 university people, including students, associated with INFN research. The Stabilisation Project, which ends this year, will increase further the number of people given permanent positions, and the Extraordinary Recruitment plan will open a significant number of new entry-level positions for technicians and engineers over the next 2 years while it is in effect.

INFN operates with a traditional base budget of 260-270 M€. Half of this funding supports personnel; Research and Infrastructure receive ~50 M€ each; Operations receives ~20 M€. INFN also competes for and wins EU and national "one-shot" project funds, ranging from ~10-100 M€/yr. The 2020 FOE budget was just approved at a level of 300 M€ (same as for the previous year): ~270 M€ for INFN institutional activities, ~30 M€ for international projects. Ongoing commitments almost saturate the budget, leaving only ~10 M€ available for new ideas. INFN also has a ~300 M€ infrastructure budget for major long-term projects, including 108 M€ for EuPRAXIA and 120 M€ for HPC pre-exascale and Tier 1 (50% from

EU). The National Laboratories also benefit from ~65 M€ in regional funds. Finally, INFN has requested ~160 M€ for new projects: long-baseline neutrinos, neutrinoless double beta decay, Gran Sasso Laboratory enhancement, LHC research, superconducting magnets, etc. Funding for upgrades, e.g. EuPRAXIA and the Sardinia telescope, is critical, and an excellent investment. INFN continues to manage its budgets carefully and responsibly, and in the event of future budget cuts should be given strong consideration as an essential activity. Otherwise the fixed cost burden will starve research and damage quality. Finally, we applaud INFN's proactively seeking and obtaining funds from other sources**.**

The European Strategy for Particle Physics has recently been approved, featuring planning for a 100 km collider, Accelerator R&D, muon collider studies, high-field magnets, and high-performance computing. This resonates well with INFN's core capabilities, and we are pleased to note INFN's strong engagement. In particular INFN's great expertise in accelerator techniques and superconducting magnets, spanning different sections and laboratories should prove invaluable in the context of the European Strategy R&D on accelerators and superconducting magnets. We would welcome an overview in next year's GLV report.

Medical-related activities continue to increase, to the extent that INFN might consider finding a way to coordinate them across divisions, and to give more recognition to what has become a significant component of INFN research.

It is important to find ways to give INFN the room it needs to preserve its outstanding research and infrastructure. For example, the extraordinary hiring initiative and stabilization initiative will increase the staff by 10% over a very short time period Such a rapid selection process could be problematic both for the pressure on the INFN resources engaged in the selection and for the possibility there are not enough high-quality researchers to match the demanding INFN standards. It would be very helpful to stretch the hiring out over additional years, and to broaden the scope to include even a small number of more-senior positions. In this way INFN could ensure continuity of leadership and encourage expatriate scientists to return to Italy.

INFN needs flexibility in allocating new positions among institutes. Up to now, winners of competitions could decide where to work, resulting in worrisome imbalances because most people want to stay close to their home city. To address the problem, INFN will designate a significant fraction of new positions to specific institutes.

Recommendations:
GS1 **–** We welcome the extraordinary program allowing INFN to stabilize and enhance its staff.
To make optimum use of this outstanding opportunity and to attract the best scientists and technologists, including Italian scientists who started their careers abroad, INFN should work with the government to gain flexibility in the deployment of these positions:

a. To increase the timescale during which positions are filled.
b. To include positions above entry level.

GS2 **–** INFN mostly depends on governmental support but has been quite successful in securing funding from additional sources. INFN should further emphasise increasing and managing diversification of funding, which could have even greater importance in these days of fiscal peril.

a. We encourage INFN to develop closer relations with the private sector to build additional sources of funding.
b. For new projects INFN should strive to move hand in hand with new funding sources to make sure they will provide adequate support to sustain a project throughout its life.
c. Investigate possibilities to motivate mid-career and senior scientists to apply for ERC grants, e.g. Consolidator, Advanced, and Synergy Grants.

Central Administration

During the last year, in the difficult situation created by the COVID-19 pandemic, the INFN central administration has undergone important organizational changes. First, a new Director General took over in September 2020. Second, the new position of Director of Research Services was created. The new Director General has set a wide and ambitious list of objectives, which include a better alignment of administrative activities to the INFN mission, an enhanced dialogue and communication with personnel, and the elimination of the silos culture in order to facilitate internal connections. The Director General has identified several organizational weaknesses, such as too-complex processes, an unbalanced distribution of workload, the lack of adequate skills in certain activities, the need of introducing an economic budget system together with a multi-annual rolling budget (the latter was recommended by the CVI last year). The INFN president has asked the Director General to design a new organizational chart and the underlying administrative processes. This task will lead to a review of the administrative process. The excessive workload on the Director General and the impossibility to take care of crucial activities supporting research led to the institution of the Director of Research Services. The aims of the Director of Research Services are to help project management, to assist local structures and national laboratories in research activities, and to monitor project developments. A significant ongoing hiring plan should allow the central administration staff to increase by 34 units, 6 of which hired with an open-ended contract.

We regard positively the developments concerning central administration and appreciate the ideas sketched by the new Director General but reckon that there is a need to establish clear priorities and identify well-defined targets. The creation of the Director of Research Services is a very important step since his tasks are inherently different from those of the Director General. In a way, it is somewhat surprising that INFN had not foreseen earlier the need for this separate position. In the current very competitive research environment, supporting investigators along the whole grant process – from finding funding opportunities and catalyzing teams to finalizing proposals for submission – is definitely a highly-specialized activity that requires specific skills and knowledge and takes considerable time. We recognize that the Director of Research Services should allow INFN to better capitalize its great research capability. It is very important that he manages to coordinate activities across all different INFN units and substructures to maximize impact.

The expansion of the central administration staff is welcome, although it is a matter of some concern that it is achieved mostly by hiring people on temporary contracts. Unless the transformation into permanent contracts is envisaged and clearly outlined, administrative staff hired on a temporary basis may have insufficient motivation and learning incentives as well as being prevented from building experience. Moreover, in the light of the few resources devoted to certain tasks, the INFN could consider outsourcing some specific administrative activities (e.g., payroll management).

As for all large organisations, the COVID-19 pandemic forced an adjustment to an unprecedented situation, leading to extensive work re-arrangements centred on extensive use of remote work and the replacement at all levels of physical with virtual meetings. Some changes may persist once the pandemic is over, with deep implications for the INFN. It is worth investigating in the coming months as the experience built during the pandemic may inform a different work organisation, potentially increasing efficiency, reducing costs, and reconciling work and family needs.

Recommendations

CA1 – The Director General's ambitious program needs prioritization. In due time, it would help to fix targets to be achieved in the coming years.

CA2 – The Director of Research Services should elaborate a plan of re-organisation of research services and of actions that could enhance INFN capability to obtain grants.

CA3 – (*Last year's recommendation, still valid*) The Director General should launch a service satisfaction survey to be used for quality management of the central administration.

CSN1 – Accelerator-based Particle Physics

The First National Scientific Committee (CSN1) coordinates INFN activities in Particle Physics at Accelerators, making strong contributions to a broad set of international experiments. It is a large sector with 1160 researchers and technologists, and an annual growth of 3% in the last 5 years. The fraction of FTEs, of the order of 70%, remained constant during that period, indicating that the interest for CSN1 activities inside INFN is maintained. The annual budget is stable, 20 M€ with an additional 2 M€ of external funds. The fraction of women at the level of 20% does not show signs of increase and may need attention.

A wealth of scientific results has been produced in all CSN1 areas. Here, we quote a few highlights. At the CERN LHC, the potential of the full LHC Run 2 data is now being exploited. Higgs boson physics, Standard Model precision measurements and search for new physics are key parts of the program. CMS presented first evidence for Higgs coupling to the second generation of fermions $H \rightarrow \mu\mu$. ATLAS did so for the very rare Standard Model four top quark production. This augurs well for the Run 3 physics potential. LHCb extended lepton universality tests to baryon decay. NA62 at the SPS presented 3.5σ evidence for the very rare $K^+ \rightarrow \pi^+ \nu\nu$ decays. A 20% statistical precision with systematic below 10% could be reached by the end of data taking.

BES-III at IHEP in Beijing produced many results including high-precision D meson decays measurements at the ψ(3770) resonance producing important input for the determination of fundamental parameters of the standard model. At SuperKEKB the Crab Waist technique was decisive in the mitigation of the background, resulting in a record instantaneous luminosity of 2.4×10^{34} $cm^{-2}s^{-1}$, and enabling the BELLE-II experiment to begin taking data. At FNAL, the *g-2* experiment completed Run 2 in 2019 and collected Run 3 data during 2019-20. At PSI, the MEGII $\mu^+ \rightarrow e^+\gamma$ experiment started operating after overcoming some technical problems.

Many experiments in the data-taking phase managed to take data despite the difficulties resulting from the COVID-19. Supporting operations of experiments abroad has been difficult but was palliated by an increased load by host institutions, and implementation of remote shifts whenever possible. If the situation persists, travel necessity and conditions should be carefully evaluated.

In order to evaluate the quality of INFN's contribution to the experiments, new indicators applicable across different experiments have been developed. Some characterize the role of INFN researchers in the management and operation of the experiments, quantifying the fraction of positions of responsibility held at different levels. Others quantify the level and relevance of participation in data analysis for every publication. The results show that INFN performs always better than expected according to its funding fraction.

There are many activities in preparation for the future. In particular, Long Shutdown 2 is ongoing at LHC featuring Phase I upgrade activities at ATLAS, CMS and LHCb with important INFN participation. Detector construction is in most cases progressing despite suffering delays, typically of a few months, due to COVID-19. INFN has made great efforts to send additional crews to CERN when travel was again permitted. The revised LHC schedule with Run 3 starting in February 2022 alleviates the delays, but there are still items on the critical path like the timely completion of the second ATLAS New Small Wheel. There is also intense activity towards the Phase II upgrade. The main Memoranda of Understanding have been finalized and put out for signature. Most Phase II projects have been defined in detail, although in some areas R&D is still ongoing. CSN1 management closely monitors the many upgrade projects to mitigate as much as possible the impact of COVID-19 or possible technical problems, especially in a period where a lot of work has to be carried out and significant amount of funds have to be spent. The availability of contingency plans would be an asset.

INFN played an important role in the update of the European Strategy for Particle Physics approved in June 2020 by the CERN Council and has quickly taken following-up steps. Two new lines of R&D have been opened to prepare for a potential Future Circular Collider (R&D_FCC) and a Muon Collider (R&D_MUCOL). The tentative schedule for FCC, including a Technical Design Report for a detector by 2025, is quite ambitious considering all the other ongoing LHC activities. The muon collider studies include the development of the LEMMA positron source among others. The increase of support for these R&D activities from the current 1% to 2.8% of the Budget seems adequate.

Other new activities are contemplated by CSN1 that are important in complementing the large long-term experiments and maintaining interest in experimental particle physics. The MUonE experiment at the CERN SPS proposes a measurement of the hadronic part of the running of the electromagnetic coupling constant that is of great interest to reduce the uncertainty on the predicted muon *g-2* anomalous magnetic moment. The COMPASS collaboration proposes the AMBER/COMPASS++ program encompassing several hadron physics measurements.

Recommendation:

CSN1-1 – Develop contingency plans to adapt efficiently to potentially fast-changing schedules of the experiments.

CSN2 – Astroparticle Physics

CSN2 activities support four main scientific lines: neutrino physics, radiation from the Universe, the Dark Universe and gravitational waves. The growth of the FTE count in CSN2 by almost a factor 1.7 since 2013 demonstrates the strong interest in astroparticle physics, and separate funding channels were opened for some of the large projects, providing adequate funding for this growing community. INFN scientists and LNGS as a lab have a highly visible role in the field, and are driving a number of new developments.

In all of four areas, key scientific results were achieved; examples include in particular:

- **Neutrino physics:** the GERDA search for neutrinoless double beta decay completed data taking, setting records both in background suppression and in the limit on the ^{76}Ge half-life. CUORE, searching for neutrinoless double beta decay of ^{130}Te, achieved an exposure of 1000 kt-y. T2K reported in September 2019 a 3σ level indication for CP violation in the lepton sector. In solar neutrino physics, one particular achievement to be highlighted is the final Borexino results, measuring the components of the solar pp-chain, and most recently, the solar CNO neutrinos.
- **Radiation from the Universe:** the MAGIC Cherenkov telescopes on the Canary Islands reported, for the first time, the detection of TeV gamma rays from a Gamma-Ray Burst afterglow, and using multiwavelength data, were able to narrow down the emission mechanism. The DAMPE satellite-borne detector measured the cosmic-ray proton spectrum up to 100 TeV with unprecedented precision, revealing structure in the spectrum.
- **Dark Universe:** XENON-1T detected the longest radioactive decay ever observed in a direct measurement: the double electron capture of ^{124}Xe. The experiment not only provided the best limits on spin-independent WIMP interactions, but also discovered a tantalizing excess of electronic recoil events, whose origin remains to be understood.
- **Gravitational wave astronomy:** VIRGO-Adv, jointly with LIGO, collected data over 11 months in the O3 run, providing numerous results, such as the detection of an extraordinarily massive merging binary system: two black holes of 66 and 85 solar masses, which generated a final black hole of 142 solar masses.

The COVID-19 pandemic has delayed some of the activities, but its impact was efficiently managed and crucial LNGS experiments could continue taking data. Sustained operation was enabled by a combination of local staff and remote operation of the experiments.

Several large projects with a significant and/or dominant INFN contribution are expected to start operation in the next 2-5 years: KM3NeT, JUNO, DarkSide-20k, DUNE/ICARUS, CTA; these provide excellent science potential but will also stretch CSN2 resources. Two key projects are briefly highlighted here, DarkSide-20k and KM3NeT. The progress of DarkSide-20k as a major INFN initiative is good, with the TDR submitted and positively reviewed, but – as emphasized in last year's recommendation – the tight schedule and open budgetary issues will require continuing monitoring and attention, also in view of the competition from XENONnT and LZ. In KM3NeT, the extended operation of 6 ORCA strings and the successful start-up test of the KM3NeT-ARCA offshore system with one string are encouraging. The next critical deadline is the deployment of six ARCA strings by mid-2021. This deployment step and the successful operation of the six strings over a period of few months are crucial for the further evolution of KM3NeT-ARCA.

In CSN2, INFN is engaged in a rather large portfolio of experiments and R&D projects. For future reviews we suggest that INFN provide a summary table for all projects (similar to the table in the "Dark Universe" presentation), also listing FTE and financial resources. Among the R&D projects, PTOLEMY is an initiative that promises very high impact in neutrino physics, but despite significant progress PTOLEMY is still facing a number of extremely difficult R&D challenges on the path towards a first proof of principle. CSN2 should monitor progress, ensure a realistic planning and timeline, and review the support required through INFN facilities and experts. Another interesting and much needed R&D project is SABRE that now has demonstrated in a proof-of-principle experiment the capability to produce NaI crystals of the sufficient quality to probe the modulation signal detected by DAMA two decades ago, the interpretation of which remains mysterious.

Recommendations:
CSN2-1 – The project hierarchy and strategy for selecting new projects were presented to the CVI. Maintaining balance between large and well-established projects and new initiatives and R&D projects is a non-trivial challenge. Fragmentation of the research program is viewed as a risk, and lack of manpower is an issue for a number of projects. We caution against a further expansion of the portfolio, and recommend careful monitoring of the projects and the priorities, and identification of activities that are or become subcritical.

CSN2-2 – The scientific case for SABRE is high. INFN should start and support the project implementation, carefully monitoring the progress.

CSN2-3 – The situation and plans of DAMA/LIBRA should be clarified, as already recommended in last year's report.

CSN3 – Nuclear Physics

CSN3 has a well-balanced, internationally acknowledged, diverse research program with a healthy amount of external funding. The research portfolio spans all four INFN national labs, as well as a multitude of Italian universities and international accelerator facilities. In addition to fundamental research, application-oriented interdisciplinary research is being pursued in radiobiology and biomedicine, matter/antimatter studies and quantum physics. CSN3 has been reorganized in 2020 into six strongly interconnected research lines to align with the NUPECC research structure: *Quarks and Hadron Dynamics; Phase Transition in Hadronic Matter; Nuclear Structure and Reactions; Nuclear Astrophysics; Symmetries and Fundamental Interactions; Applications and Societal Benefits.*

A very positive outcome this year is the award of ERC Starting Grants to two young CSN3 researchers (F. Bellini/ INFN Bologna and A. Celentano/INFN Genova). The participation in the 2-year ERASMUS Mundus Joint Master Degree in Nuclear Physics between universities in Spain and France, and in Italy with the universities in Catania and Padova, and LNF, LNS, and LNL is a great opportunity to attract international students as well as expose Italian students to international nuclear physics facilities.

The FTE numbers have stayed fairly constant over the past years, however with a slightly declining budget. CSN3 research covers all National INFN Laboratories with major upgrades in progress, as well as the planned participation in new major international projects (like the Electron-Ion Collider (EIC) in the USA). Increases in the budget and FTE numbers would be needed in the upcoming years to allow this exciting expansion. Conversely, careful setting of priorities may be required to optimize the program in case of shortages.

The EIC was approved by the US DOE in 2020 and is now moving quickly forward, with the first call for experimental setups in March 2021, followed by the call for detector designs in September 2022. Various INFN scientists have expressed interested in contribution to the EIC program, from building detectors to software tools to theoretical support. The expected ramp-up will go from ~ 10 FTE in Phase 1 (2021-23) up to ~60 FTE in Phase 3 (2026-29), with a projected start of first experiments in fall 2029. These involvements come with a R&D contribution from INFN of ~$1 million and an estimated total in-kind contribution to detector construction of $7-8 million. The Yellow Paper with strong involvement from Italian scientists will be published in early 2021.
There is progress on the LUNA MV project: the accelerator has passed all acceptance tests at the manufacturer (High Voltage Engineering Europe) in the Netherlands and is ready to be shipped to LNGS in early 2021, once the last missing approvals by local authorities are received. For the installation and commissioning phase ~6 months are foreseen, which should allow a timely start of the LUNA-MV research program by the end of 2021 or early 2022.

The major facility upgrades at LNL and at LNS are proceeding very well, despite some unavoidable slowing-down during the pandemic. LNS could still deliver beams to users until early summer 2020 before shutting down for the planned upgrades of the superconducting cyclotron and the fragment separator. The TDRs for NUMEN-GR3 and PANDORA have been finalized and the construction phase can start, with the first experiments expected in 2024. At LNL the SPES project is progressing, and the next critical milestone for the nuclear physics community will be the installation of the AGATA spectrometer starting at the end of 2021. More details on these two facilities are given in the separate LNS and LNL discussions in this report.

Highlights from CSN3 include :

- Hints of the d*(2380) hexaquark, a potential candidate for Dark Matter, have been observed by MAMBO.
- The ALICE collaboration has achieved the most precise measurement of the lifetime of $^{3}H_{\Lambda}$. The result is compatible within 1σ with the free Λ lifetime, confirming that the hypertriton is a weakly bound state of a deuteron and a Λ.
- FORTE is a new project that investigates the different timescales of fusion-fission and quasi-elastic processes near the Coulomb barrier. A recent experiment at the ALTO facility in Orsay allowed to disentangle the two reaction channels via the detection of γ-rays (Physical Review C, Editors' Suggestion)
- The LUNA collaboration has just published their results for the $D(p,\gamma)^{3}He$ reaction. Their results are in excellent agreement with a recent analysis of the Cosmic Microwave Background and removed one of the most uncertain nuclear physics inputs from Big Bang Nucleosynthesis (Nature, Nov. 2020).
- ASACUSA has demonstrated antimatter interferometry with positrons for the first time (Science Adv., 2019).
- VIP-2 at LNGS is investigating the validity limits of the Pauli principle and of quantum gravity models. Their data sets a lower limit on the effective size of the mass density of nuclei, which is about three orders of magnitude larger than previous limits. This data now excludes the natural parameter-free version of the Diósi–Penrose model (Nature Physics, Sept. 2020).

Recommendations:

CSN3-1 – An increase of budget and FTEs is advisable due to the growing number of high-priority commitments at upgraded domestic facilities (LNL, LNS) as well as a ramp-up towards new international projects like the EIC and FAIR. CSN3 should also make sure to set priorities that optimize the allocation of the actual budgets they receive.

CSN3-2 – Provide more detailed plans for the projected EIC contributions, e.g. how many new FTE are required (and how many existing FTE are moving to EIC), and how much INFN and external money is requested.

CSN3-3 – INFN should give high priority to complete the following important new projects, and prepare them for science, on schedule: LUNA MV at LNGS, for first experiments in 2021; AGATA at LNL, for first experiments in 2022; NUMEN and PANDORA at LNS, for first experiments in 2024.

CSN4 – Theory

The INFN effort in theoretical physics is one of the strongest national programs in Europe. In 2019 the program involved 1244 scientists contributing an effort of 1073 FTE. The number of scientific publications increased about 6% compared to the previous two years, and the citation record and impact factor for those publications are in line with previous years. The scientific work is divided into six research lines:

LS1: String and Field Theory
LS2: Particle Physics Phenomenology
LS3: Hadronic and Nuclear Physics
LS4: Mathematical Methods
LS5: Astroparticle Physics and Cosmology
LS6: Statistical and Applied Field Theory

The work of INFN in theoretical physics is supported by a post-doc program, with about 30 post-doctoral researchers in post at any one time. In 2021 and 2022 roughly 2/3 of these are supported by the Fellini COFUND program, in which applicants with a background in theoretical physics have been very successful.

Iniziative specifiche (IS)

We decided this year in our review of CSN4 to focus on the “iniziative specifiche,” the mechanism by which CSN4 distributes travel money and the funding for post-docs. These networks group together personnel from different INFN units with common scientific interests and run for three years. The program for the years 2021-2023 was decided during 2020 and we took the opportunity to review the process and results of the current funding round.

The review process followed by CSN4 was as follows. Pre-proposals for IS were submitted by the end of March, and following discussion within CSN4 complete proposals were submitted by the end of May. The proposals were reviewed by two independent external reviewers, addressing the following questions:

1. Quality and relevance of the proposed research activity: how relevant is the field of research at the international level? Does the project address important challenges in the field?
2. Research plan, methodology and strategy: is the research plan clearly stated, soundly based and feasible?
3. Project impact: does the project have the potential to improve the current state of the art in the field?
4. Research team qualification: how well designed and qualified is the research team to conduct the project?
5. Global evaluation: taking into account the four evaluations above, what is the overall scientific assessment of the IS?

The outcome of the review process is shown in the table below. Columns 2 and 3 show the number of IS in each Scientific sector. The total number of IS remains fixed at 35. The fourth column lists the new or modified IS. Although, as can be expected, there is considerable continuity in the topics of the IS, the table shows that 20% of the IS involve new projects. There has thus been considerable evolution in the topics under study in response to developments in the field.

Scientific sector	2016-2020	2021-2023	New or modified Iniziative Specifiche
LS1	8	8	Gauge theory and gravity (GAGRA)
LS2	7	8	Phenomenological Lattice gauge theory (QCDLAT) Theoretical Particle Physics and Cosmology (TPPC) Astro-particle, Intensity, Energy (APINE)
LS3	5	4	Modelling Nuclear Structure and Reactions (MONSTRE) Strongly Correlated Nuclear Systems (NUCSYS)
LS4	5	5	
LS5	5	5	
LS6	5	5	Complex learning networks (LINCOLN) Advanced Theoretical Methods for Emerging 2D Materials in Quantum Information technology studies (TIME2QUEST)
Total	35	35	

We were impressed with the thoroughness of the evaluation of the IS. The outcome of the evaluation process shows an appropriate level of evolution in the program. On the basis of the evidence presented the program appears to be both well managed prior to the award of the funds and monitored during the running of the IS.

In addition many aspects of the program display a high degree of support for the experimental program of INFN. A partial list of the initiatives with this focus would be

1. The most advanced techniques for the simulation of HL-LHC physics processes;
2. Reinforced connection between collider and astroparticle physics as well as the newly developing field of gravitational waves. The latter benefits from dedicated IS, using GR numerical simulations to model gravitational wave and electro-magnetic signals during and after the merger;
3. Lattice gauge theory: new efforts for the evaluation of the hadronic contribution to muon g-2;

Recommendation:
CSN4-1 – We have noted in previous years, that Laboratory theory groups are often below critical mass. It would be good to bear this in mind, if and when, positions with geographical restrictions are advertised.

CSN5 – Technological and Interdisciplinary Research

The Fifth National Scientific Committee (CSN5) coordinates advanced technological research for INFN experimental activities and promotes the development of instruments, methods and techniques for fundamental physics and their application in other fields. These transversal activities across committees contribute to strengthening links with universities and national research institutes.

There was a large renewal of the Committee between 2019 and 2020, with a substantial increase in the female presence. There are three main areas of activity: *i)* development of radiation detectors, electronics and software (39% of budget in 2019); *ii)* production and development of particle accelerators and new prototypes (24%); *iii)* interdisciplinary applications (37%). Resources are allocated to three types of projects: "Standard" projects (63% of the budget and 77% of FTE in 2019), "Calls for proposals" (30 and 19%), "Grants for young researchers" (6 and 4%). In 2020, CSN5 identified "Quantum technologies" as a strategic item and launched a Thematic Call on Quantum technologies in addition to the Open Call. Thanks to the excellent quality of the projects, 4 proposals were approved, out of the 4 submitted for the Thematic Call and the 6 for the Open Call.

In 2019, the number of experiments has kept growing, with standard experiments still prevalent. Results are good: scientific production has gone up in number of papers and average impact factor, both in total and per capita; talks in international conferences are at peak levels; milestones per experiment ratios and completion rates are high, if somewhat lower than in previous years. The overall budget is stable at around 5 million euros, with the residual in 2020 due to COVID-19 (around 1.3 million euros) being mostly retained by CSN5. The CSN5 has drawn attention to two critical aspects: *i)* the substantial decrease of the number of accelerator experts within CSN5; and *ii)* the fact that the contracts assigned to Grants for Young Researchers winners provide less benefits than other contracts such as “Assegni di Ricerca”.

The COVID-19 epidemic had a significant impact on CSN5 activities. Based on motivated requests, the completion of 24 experiments was delayed from 2020 to 2021, with no extra money assigned to these experiments. The CSN5 identified areas of expertise where the INFN researchers could provide valuable contributions in dealing with the COVID-19 epidemic.

We congratulate CSN5 management and researchers for all their results and achievements in the last years. In particular we happily take note of the welcome rise of the female membership in CSN5.

Thanks are due for the detailed information on the criteria for selecting proposals and assessing their success provided in response to last year’s recommendation, and we are pleased to see the positive assessment of the two new schemes introduced in 2013-14, the Grants for Young Researchers, and Calls for Proposals, which are both assigned through a highly competitive and rigorous process. In the light of this internal evaluation, We stress the need to pay greater attention to Standard Experiments, which still account for 63% of the budget, and more generally to the criteria governing the overall fund allocation among Standard Experiments, Calls for Proposals and Grants for Young Researchers. Finally, we greatly appreciate the way in which CSN5 dealt with the consequences of the pandemic for its activities, and mobilized INFN expertise to address relevant issues in the fight against the Coronavirus.

Recommendation:

CSN5-1 – In consideration of the success of the new schemes (Calls for Proposals, Grants for Young Researchers) and their capacity to stimulate particularly innovative research, CSN5 could consider to gradually re-balance the composition of the overall budget away from Standard Experiments towards these new schemes.

Knowledge and Technology Transfer (KTT)

The KTT effort in INFN is based on a three-layer structure, which fits with its multi-laboratory, multi-unit organization. Over the course of the years, it has achieved relevant results especially in terms of patenting, and we recognize that there is a growing attention on the role it might play to promote the outstanding research produced by the INFN. We consider the decision to hire a patent-authorized representative to facilitate the patenting process an extremely positive step. However, the three-layer structure needs well codified procedures to make interactions smooth and efficient. To this end, it is key that the new Director of Research Services plan regulular meetings with the designated KT officer in the sections. Furthermore, the Comitato Nazionale per il TT (CNTT) must ensure that all units are active in pursuing technology transfer, even if, as we recognize, there are areas of research where TT is less meaningful and might harm basic research.

The TT service is the “heart” of the activity and should play a proactive role under three main domains:

1. Supporting researchers when they explore whether an idea or a research outcome can potentially be monetized;
2. Raising money through the various tools available to INFN, for example by increasing funding from the private sector, which now represents a mere 0.5% of the total budget. Likely, it would be reasonable to shift the focus from start-ups to licensing, which allows a better use of the patent portfolio.
3. Widening the network of companies that might have interests in the INFN research activity. In general, there is still little knowledge among the business community of the potential of INFN. It is also important to reach out to the financial sector.

Thus, it is essential to ensure that the service has the right mix of skills, which should include: a) some knowledge of the areas of research of the INFN; b) a deep knowledge of the potential markets or access to a network of experts if necessary; c) the ability to provide legal advice on licensing, patenting etc.; d)

the ability to provide support to design business plans or to identify external experts that can provide a valuable service in this domain.
In order to better evaluate the TT activities and achievements, it would be helpful to augment indicators based on benchmarks and comparisons with similar national and international institutions.

Recommendations:
KTT-1 – Explore the feasibility of building joint labs with private companies. We recommend the KTT to develop a study to identify areas where joint labs can make sense and to start a scouting activity with corporates, also international ones.
KTT-2 – Organize regular meetings between researchers, business angels/venture capitalists, and chief technology officers of key companies to expose INFN personnel with possible projects to the real economy. In order to make it operational, we recommend creating a list of stakeholders of KTT, and to provide a calendar to both researchers and stakeholders. The meetings should focus on the presentation of new patents, and potential applications of research activity.
KTT-3 – Streamline the selection process of the resources of R4I, with larger involvement of external evaluators. We suggest a three-step approach:
1. Validation from a research viewpoint by the supervisor within the centre where the researcher works;
2. Assessment by an external panel of the potential industrial viability of the idea. Members of the external panel must be business angels, venture capitalists, or chief technological officers from the private sector. This activity should be organized twice a year to put together a number of options.
3. Final decision by the 'Comitato Nazionale per il Technology Transfer'.

KTT-4 – Build some indicators to evaluate the performance of KTT in comparison with benchmark institutions.

Laboratori Nazionali del Sud (LNS)

The KM3NeT experiment, a major activity of LNS. It is also discussed in section CSN2 above. In addition some of the LNS nuclear physics activities are covered in the CSN3 section.

LNS has a very diverse research portfolio that not only includes experiments at local accelerator facilities but also operation of KM3NeT and other international collaborations, and applied science topics. The local science program is focused on the two accelerators, a 15 MV Tandem Van de Graaff accelerator and the K800 super-conducting cyclotron (SC). The two accelerators accelerate heavy-ion beams in a very wide range of mass and energy and allow nuclear structure, nuclear reactions, and nuclear astrophysics studies, as well as applications of nuclear physics techniques in particle therapy, cultural heritage and other multidisciplinary activities. The LNS facility upgrade is an important step and will start a new era at the facility for research with high-intensity stable and radioactive beams.

2020 has been an important year for LNS. Despite the impact of the global pandemic with a 2 month shutdown, beam could be delivered to more than 5 experiments before the planned shutdown for the upgrades of the superconducting cyclotron and the installation of the new fragment separator FRAISE in June. For the upgrades of the research infrastructure 19.3 M€ were awarded by the MIUR PON framework in 2019, to be spent within 32 months with a possible extension of 4 months. The first year of the project was dedicated to preparation of the Technical Specifications and the tendering process. It is expected that ~90% of the allocated budget will be contracted by the end of November 2020. Additional funding of ~1.5 M€ will be required from INFN this upgrade. The new Project Management Office is operational since summer 2019 and is vital for the coordination of the upgrade projects. There are however concerns that further delays in the delivery of crucial parts might be caused by external companies, e.g. the main magnet and parts for the SC cyclotron.

The NUMEN project, with an ERC Starting Grant awarded in 2016, has been the driving force behind the upgrade of the whole facility. It is measuring cross sections for double charge exchange nuclear reactions, relevant for the extraction of the nuclear matrix elements of double-β decays. NUMEN has finished data taking in Phase 2 and has finalized their TDR. After the facility and MAGNEX spectrometer upgrade first experiments are expected in 2024. A demonstrator experiment (G-NUMEN) is planned for 2021 at iThemba Labs in South Africa.

Also other groups will greatly benefit from the upgrade: CHIMERA will be able to investigate exotic clustering phenomena and study the density dependence of the symmetry term in the Equation of state, and the ASFIN group will be able to address indirect reaction studies with exotic nuclei of interest for nucleosynthesis in stars and explosive stellar events. The new PANDORA project for the measurement of stellar plasma lifetimes of astrophysically important nuclei has completed its feasibility studies and has published a TDR. A total budget of ~3.75 M€ is estimated, with major costs due to the magnetic trap and the photon detector array. The project is waiting for the funding decision by the INFN board for the magnetic trap. The local group is now better defined, and the potential research program has been extended to the measurement of plasma opacities for heavy nuclei which are required to interpret contributions of heavy neutron-rich nuclei to the kilonova light curves like the one that followed the binary neutron star merger that triggered GW170817. A collaboration with LNL has been initiated for the loan of detectors from the GALILEO setup which will be used to surround the trap and detect the emitted radiation.

Additional funding of 19 M€ was awarded in 2019 for KM3NeT to expand its research infrastructure. This will cover the construction and installation of 28 ARCA detection units as well as strengthen several integration sites. Italy and six European countries have created a working group for constitution of a European Research Infrastructure Consortium (ERIC) in 2021.

Data taking with KM3NeT-ARCA has been interrupted for almost one year to allow the refurbishment of the infrastructure at the Portopalo shore station. In the meantime, the first combined ARCA-ORCA analysis of the integrated muon flux as function of the sea depth has been published and is in good agreement with theoretical models. The completion of the ARCA network is unfortunately delayed. The installation of a second electro-optical cable in the IDMAR project is planned between late 2020 and summer 2021. The next critical deadline is the deployment of 6 ARCA strings and the test junction box in April 2021 and 20 more strings and 3 junction boxes in summer 2021.

Additional application-driven activities at LNS have started recently with focus on nuclear safety and waste management (MICADO: Measurement and Instrumentation for Cleaning and Decommissioning Operations). Another project is the development of a new generation of silicon carbide detectors for the measurement of the proton depth and dose distributions in real time with high spatial resolution for clinical hadron therapy (PRAGUE: Proton RAnGe measurement Using silicon carbidE). This project is a Young Investigators Grant that has been awarded by CSN5 will allow the collection of dose information in biological samples with a precision of the order of 3% as required by international protocols for the patient treatments.

Recommendations:
LNS1 **–**_(INFN Directorate) Support LNS management in the current hiring strategy to replace key positions and ensure stable operation of facilities after the upgrade
LNS2 **–** Ensure completion of ARCA string installations in 2021.
LNS3 **–** Support full funding to allow a timely completion of PANDORA since it will bring a unique research program to Italy. (Repeated from CVI 2019)
LNS4 **–** Medical physics: Support plans for FLASH radiotherapy (I-LUCE) and for new proton-therapy beamlines for ocular melanoma treatment (CATANA)

Laboratori Nazionali di Legnaro (LNL)

This report focusses on the ongoing facility upgrades and organizational restructuring. For comments on other efforts, see the sections of CSN2, CSN3, CSN5, and TT.

The laboratory continues to carry out a healthy mix of fundamental and applied research as well as accelerator technology developments. Local research is driven by the accelerator infrastructure, which involves the TANDEM-ALPI-PIAVE (TAP) complex consisting of a 15 MV Tandem accelerator and two superconducting linacs (ALPI and PIAVE) which are focussed on experiments in nuclear physics and nuclear astrophysics, and interdisciplinary research. Additionally, two small electrostatic accelerators, CN and AN2000, are used for applications of nuclear physics to environmental, material, and cultural heritage science. The dual-exit high-current B70 cyclotron will be the driver for rare isotope production at SPES as well as medical radioisotope production for the LARAMED and ISOLPHARM projects. This cyclotron has been restarted after a one-year shutdown and in June 2020 a 1 MeV beam with ~1 mA has been extracted.

The accelerator division has several international long-term commitments in the field of accelerator technologies, most importantly the construction and test of a Drift Tube Linac (DTL) for the European Spallation Source (ESS) in Sweden, and a Radiofrequency Quadrupole (RFQ) at the IFMIF (International Fusion Materials Irradiation Facility) in Japan. The DTL tanks are assembled by INFN staff in Sweden, and the first (of five) will be installed in December 2020. The IFMIF RFQ has been delivered and installed in 2017, and a 5 MeV-125 mA pulsed deuterium beam has been accelerated in July 2019. A new 4-year agreement has been signed by EURATOM and Japan to continue these activities, with involvement of LNL personnel, to reach a continuous 125 mA deuterium beam. On the long term, preparations are ongoing for participation in the construction of a high-intensity linac for a European neutron source for material tests, funded by the European Commission. All these activities (and future ones) motivated the construction of a dedicated laboratory at LNL as a test facility for accelerator components (LATA).

However, as pointed out in previous years, the highest priority for the lab is the timely (staged) completion of SPES. For these upgrades and installations, another one-year shutdown starting in spring 2021 is necessary for the TAP complex.

2021 will be a critical year for LNL with many installations and deadlines. One crucial milestone will be the completion of the AGATA (Advanced GAmma Tracking Array) Data Center and the start of the detector array setup by the end of the year. AGATA, currently located at GANIL, is a high-priority project for the European Nuclear Structure community, and the high demand on this detector array for experiments at other European accelerator facilities puts tight constraints on its availability for experiments at SPES. The first physics experiments with stable, non-accelerated 1^+ beams are scheduled for the end of 2022, and re-accelerated beams will be available in 2023. After the completion of the high-resolution mass separator (HRMS) the SPES facility should be fully operational by 2024/25.

The SPES plan permits simultaneous operation with two targets, allowing 5000h of beam per year for experiments with ISOL targets and 5000h/y for applications. With the LARAMED and ISOLPHARM program, the focus of the SPES facility will also shift towards research on new radioisotopes for medical applications and the medical radioisotope production (e.g. ^{64}Cu, ^{67}Cu, ^{68}Ge, ^{82}Sr…) in collaboration with Best Theratronics, Ltd. A Technical Board has been created to evaluate the documentation. However, since new Italian laws and procedures for radioprotection have been implemented in August 2020, the contracts for the supply of beam and lease of lab space to external companies are presently under revision.

Organizational Restructuring and Future Hiring Strategy:
A large organizational restructuring process has been started to better align the organization of the lab with the new challenges that arise with the SPES project and its special requirements (e.g. radioprotection). We fully support the new Director in this restructuring and hope the INFN Directorate is doing the same to ensure the long-term success of LNL. Two steps must be taken:

- A Project Management Office, similar to that at LNS, has to be created as soon as possible. This is a crucial step to support the new SPES project manager and allow a timely completion of the process.
- A dedicated hiring strategy must be developed to deal with the full operation of the SPES within the next years. This should not only include proper succession planning for soon-retiring staff (engineers, scientists, and technicians) but also the quick filling of open positions of recently retired personnel, the offering of permanent contracts to temporary staff in key positions, as well as the hiring of new staff for the enlarged science program at SPES.

We would like to see a status update of this strategy from LNL and the INFN Directorate in the next midterm report.

Recommendations:
LNL1 **–** The INFN Directorate should fully support the organisational restructuring to ensure the future success of the lab.
LNL2 **–** Ensure timely completion of SPES project to allow first experiments with AGATA in 2022.
LNL3 **–** Grow and strengthen the lab for the "SPES era": Ensure key personnel in temporary positions can get permanent positions and start planning for strategic replacement of soon-retiring staff. Prepare a dedicated plan showing where additional staff positions are needed in the next 2 years. Please present a status update of discussions with INFN Directorate and Giunta about this future hiring strategy in the next midterm report.

CNAF Tier-1 Center**:** Computing@Technopole

CNAF in Bologna has been the main INFN computing center since 2003. It hosts one of the 13 LHC Tier1 centers in the world, with growing needs for HL-LHC and other experiments. Substantially more space and power resources are required, as well as a safer site after the 2017 flooding.

The renovated Technopole in Bologna offers a great opportunity for CINECA and INFN to develop a common project and set up neighboring data centers sharing part of the infrastructure. The tender for the executive project of the Technopole site renovation was assigned in October 2020. Renovation work should start on 01/01/2021. The tender for the pre-exascale supercomputer, Leonardo, concluded in August 2020 and was won by ATOS-Bull. Delivery is foreseen for end of 2021. The installation in the Technopole is sequential: Leonardo Data Center comes first, then INFN. The timely completion of Leonardo is thus critical for INFN.

The transfer and modernization of the CNAF-Tier1 to the Technopole are called the "CNAF reloaded project". The project breakdown and migration plan should be ready by mid-2021, followed by tendering and orders. Installation should start early in 2022. The management of the infrastructure is shared with CINECA, and a significant fraction of the HPC machines will be dedicated to CNAF-Tier1. This fraction, still to be defined, conditions the design of the infrastructure.

Various measures have been taken to guarantee the availability of the necessary computing resources during LHC Run 3, currently due to start in April 2022. It was decided that INFN infrastructure alone should be able to cover the full Run 3 needs and that the migration of the CNAF Tier1 can and should be done without service interruption. This implies some additional costs and operation for at least 12-18 months in a multiple site context: CNAF, CINECA and Technopole. We value positively this strategy.

The plans for the IT infrastructure and the migration are being worked out. Migration should last at least a year. All services would be running, although a decrease of performance in data access is expected. Steps have been taken also towards Tier1-Leonardo integration. So far, the project is carried out by the CNAF personnel with help from INFN. There is good collaboration with the Leonardo team and some joint tenders.

On a down note, despite the progress the levels of project management and risk assessment are not up to the standards required by the size and complexity of a such a project, especially so close to the start of execution time, and fast actions need to be taken to improve them.

We would like to see a progress report on the status of the project in the mid-term report.

Recommendations:
C@T-1

a. Reinforce project management in order to provide as soon as possible a detailed and realistic schedule with resource-loaded Gantt charts, considering all work packages and their interdependence.
b. Make a risk analysis and set up a risk register to be monitored and updated as the project proceeds.

C@T-2 – Promptly set up a group of experts to review in depth the technical details and the schedule of the whole CNAF relocation project (quality assurance, manpower, cost, risks, etc.). They should report to INFN management.

Quantum Science and Technologies

The CVI heard a presentation on the activities in Quantum Science and associated technologies at the INFN. The long-term goal of this enterprise is to use quantum systems, when they become available, to enhance and improve INFN's main research lines. The shorter term goals are to learn useful techniques from the quantum community (e.g. the manipulation and detection of very low energy quantum states) and to contribute to the development of quantum computing by introducing know-how and technology from high-energy physics, (e.g. theory, superconducting resonant cavities from accelerator development, and milli-Kelvin cryogenic expertise).

Much of the focus of the presentation was on quantum computing, which is an exciting area of research of great potential. The current state of this field can be characterized as the era of Noisy Intermediate Scale Quantum Devices, and the time scale on which quantum computing can contribute effectively to computing effort in the core mission of the INFN is unknown, and perhaps unknowable.

The INFN is involved in a number of high-prestige large consortia working on Quantum computing e.g. DOE-SQMS (Fermilab), Quantera, World Class Research Infrastructures, (Padova) as well as a dozen or so smaller initiatives. The projected future INFN expenditure in this area for 2021 and 2022 is about 1.5MEuro. A further increase of the scale of expenditure would need funding from outside INFN and a clearer view of strategic importance of Quantum Technologies in the INFN research portfolio.

It is perhaps worth noting that in addition to Quantum Computing/Quantum Information science there is a burgeoning interest in the ways which quantum science can contribute to the core mission of the INFN, using quantum sensors to detect dark matter, axions and axion-like particles, dark photons as well as measurements of fundamental constants using quantum metrology. Work in this area was not covered in this presentation to the CVI.

Covid-19 and INFN

Once the government established special legislation in spring 2020, the INFN acted promptly to establish rules and procedures to safeguard the workforce, while continuing to provide maintenance to prevent major damage to infrastructure, machinery and equipment. "Smart working" (Home Office) has been implemented and many research projects have continued, but travel restrictions have impacted research projects carried out jointly with research departments abroad. Notably, savings generated by the travel ban have been used wisely, in particular to finance scholarships.

While coping with the emergency, INFN researchers have been involved in a number of COVID-19 related activities: it developed a ventilator for intensive therapies and provided user-friendly information on the development worldwide of the pandemic, through an open source database. The INFN team is very active, with approximately ~25 FTE involved, at a funding level of ~1M€.

INFN has developed statistics on COVID-19 that represent an important tool to present data effectively to policy makers and public opinion. We caution that if INFN decides to provide predictions on the development of the pandemic, it is important to understand their consistency with official forecasts, if any.

Recognizing the need for a simple device to be available quickly, INFN scientists played a dominant role in the development of a simple, effective mechanical ventilator, the "Mechanical Ventilator Milano (MVM)", featuring easily available components, low cost, and simplicity of operation. The team consisted mainly of subatomic physicists from Italy, Canada, and the US, with strong participation of medical experts. The MVM has proved to be useful for all phases of treatment over many months, including in ICU's, with ~10,000 units being deployed in Canada, and prospects in other countries.

At LNS a new "anti-covid laboratory" has been set up to evaluate and certify fabrics for masks and other PPE. Four hundred types of masks were tested, with only 2% achieving certification. Of importance to mask-making companies, the LNS process has been approved for official ISS certification, a requirement in Italy for masks to be sold. LNL has tested a prototype laser-based X-ray tube for sterilization of surfaces.

As also described by CSN5, there have been new collaborations with industry: evaluation of a new diagnostic test, and a project proposal to develop an almost-real-time test; and a statistical analysis to evaluate vaccines, in which they found that a few 10K people must be tested along the way to evaluating effectiveness. Going forward, INFN will contribute its computing infrastructure, analysis of big data, and advanced techniques like machine learning, which are already working to identify and analyse distinct features of medical importance, eg lung CT scans (DORIAN LQC); and aerosol and pollution studies at the AUGER site.

Another interesting project concerns low dose radiation therapy, and microdosimetry, which is useful in diagnosing and measuring inflammations like those caused by viral pneumonia. GEANT-4, the detailed simulation program developed for particle physics, is being used to understand if stochastic effects reduce the risk of radiation damage.

We commend INFN for its quick and effective responses to the pandemic, and strong support and encouragement for new ideas. Activities are supported at an appropriate level and provide opportunities for young researchers. Several of the projects have had significant impact and have generated recognition and good will. We point out, however, that better communication would have generated great publicity and helped improve the knowledge of INFN among the general public.

Recommendations:

COVID1 – The pandemic has revealed that there are unpredictable events that can radically modify the way INFN can operate. To this end, we recommend establishing a permanent a group in charge of "business continuity and safety management" that has the authority to enforce emergency procedures and act promptly in case new emergencies arise in the future.

COVID2 **–** INFN should communicate its COVID activities more broadly, via its web page, social media, etc.

Appendix I. Recommendations

GS1 **–** We welcome the extraordinary program allowing INFN to stabilize and enhance its staff.
To make optimum use of this outstanding opportunity and to attract the best scientists and technologists, including Italian scientists who started their careers abroad, INFN should work with the government to gain flexibility in the deployment of these positions:

a. To increase the timescale during which positions are filled.
b. To include positions above entry level.

GS2 **–** INFN mostly depends on governmental support, but has been quite successful in securing funding from additional sources. INFN should further emphasise increasing and managing diversification of funding, which could have even greater importance in these days of fiscal peril.

a. We encourage INFN to develop closer relations with the private sector to build additional sources of funding.
b. For new projects INFN should move hand in hand with new funding sources to make sure they will provide adequate support to sustain a project throughout its life.
c. Investigate possibilities to motivate mid-career and senior scientists to apply for ERC grants, e.g. Consolidator, Advanced, and Synergy Grants.

CA1 – The Director General's ambitious program needs prioritization. In due time, it would help to fix targets to be achieved in the coming years.

CA2 – The Director of Research Services should elaborate a plan of re-organisation of research services and of actions that could enhance INFN capability to obtain grants.

CA3 – (*Last year's recommendation, still valid*) The Director General should launch a service satisfaction survey to be used for quality management of the central administration.

CSN1-1 **–** Develop contingency plans to adapt efficiently to potentially fast-changing schedules of the experiments.

CSN2-1 – The project hierarchy and strategy for selecting new projects were presented to the CVI. Maintaining balance between large and well-established projects and new initiatives and R&D projects is a non-trivial challenge. Fragmentation of the research program is viewed as a risk, and lack of manpower is an issue for a number of projects. We caution against a further expansion of the portfolio, and recommend careful monitoring of the projects and the priorities, and identification of activities that are or become subcritical.

CSN2-2 – The scientific case for SABRE is high. INFN should start and support the project implementation, carefully monitoring the progress.

CSN2-3 – The situation and plans of DAMA/LIBRA should be clarified, as already recommended in last year's report.

CSN3-1 **–** An increase of budget and FTEs is advisable due to the growing number of high-priority commitments at upgraded domestic facilities (LNL, LNS) as well as a ramp-up towards new international projects like the EIC and FAIR. CSN3 should also make sure to set priorities that optimize the allocation of the actual budgets they receive."

CSN3-2 **–** Provide more detailed plans for the projected EIC contributions, e.g. how many new FTE are required (and how many existing FTE are moving to EIC), and how much INFN and external money is requested.

CSN3-3 **–** INFN should give high priority to complete the following important new projects, and prepare them for science, on schedule: LUNA MV at LNGS, for first experiments in 2021; AGATA at LNL, for first experiments in 2022; NUMEN and PANDORA at LNS, for first experiments in 2024.

***CSN4-1* –** We have noted in previous years, that Laboratory theory groups are often below critical mass. It would be good to bear this in mind, if and when, positions with geographical restrictions are advertised.

CSN5-1 – In consideration of the success of the new schemes (Calls for Proposals, Grants for Young Researchers) and their capacity to stimulate particularly innovative research, CSN5 could consider to gradually re-balance the composition of the overall budget away from Standard Experiments towards these new schemes.

KTT-1 – Explore the feasibility of building joint labs with private companies. We recommend the KTT to develop a study to identify areas where joint labs can make sense and to start a scouting activity with corporates, also international ones.
KTT-2 – Organize regular meetings between researchers, business angels/venture capitalists, and chief technology officers of key companies to expose INFN personnel with possible projects to the real economy. In order to make it operational, we recommend creating a list of stakeholders of KTT, and to provide a calendar to both researchers and stakeholders. The meetings should focus on the presentation of new patents, and potential applications of research activity.
KTT-3 – Streamline the selection process of the resources of R4I, with larger involvement of external evaluators. We suggest a three-step approach:

1. Validation from a research viewpoint by the supervisor within the centre where the researcher works;
2. Assessment by an external panel of the potential industrial viability of the idea. Members of the external panel must be business angels, venture capitalists or chief technological officers from the private sector. This activity should be organized twice a year to put together a number of options.
3. Final decision by the 'Comitato Nazionale per il Technology Transfer'.

KTT-4 – Build some indicators to evaluate the performance of KTT in comparison with benchmark institutions.

***LNL1* –** The INFN Directorate should fully support the organisational restructuring to ensure the future success of the lab.
***LNL2* –** Ensure timely completion of SPES project to allow first experiments with AGATA in 2022.
***LNL3* –** Grow and strengthen the lab for the "SPES era": Ensure key personnel in temporary positions can get permanent positions and start planning for strategic replacement of soon-retiring staff. Prepare a dedicated plan showing where additional staff positions are needed in the next 2 years. Please present a status update of discussions with INFN Directorate and Giunta about this future hiring strategy in the next midterm report.

***LNS1* –** (INFN Directorate) Support LNS management in the current hiring strategy to replace key positions and ensure stable operation of facilities after the upgrade
***LNS2* –** Ensure completion of ARCA string installations in 2021.
***LNS3* –** Support full funding and timely completion of PANDORA since it will bring a unique research program to Italy. (Repeated from CVI 2019)
***LNS4* –** Medical physics: Support plans for FLASH radiotherapy (I-LUCE) and for new proton-therapy beamlines for ocular melanoma treatment (CATANA)

C@T-1

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COVID1 – The pandemic has revealed that there are unpredictable events that can radically modify the way INFN can operate. To this end, we recommend establishing a permanent a group in charge of "business continuity and safety management" that has the authority to enforce emergency procedures and act promptly in case new emergencies arise in the future.

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Appendix II. Agenda

WEDNESDAY, 14 OCTOBER

14:00	→ 14:30	**A. Zoccoli/S.Smith: brief introduction and charge to CVI** 30m Speakers: Antonio Zoccoli (BO), Prof. Arthur John Stewart Smith (Princeton University)
14:30	→ 15:15	**INFN General talk** 45m Speaker: Antonio Zoccoli (BO)
15:15	→ 15:45	**DG presentation to CVI** 30m Speaker: Nando Minnella (Istituto Nazionale di Fisica Nucleare)
15:45	→ 16:10	**Report from CSN1** 25m Speaker: Roberto Tenchini (PI)
16:10	→ 16:35	**CSN1 Discussion** 25m
16:35	→ 16:50	**Coffee/Tea break** 15m
16:50	→ 17:15	**Report from CSN2** 25m Speaker: Oliviero Cremonesi (MIB)
17:15	→ 17:40	**CSN2 Discussion** 25m
17:40	→ 18:05	**Report from CSN3** 25m Speaker: Rosario Nania (BO)
18:05	→ 18:30	**CSN3 Discussion** 25m
18:30	→ 20:00	**CVI in closed session** 1h 30m

THURSDAY, 15 OCTOBER

13:30	→ 15:00	**CVI in Exec Session** 1h 30m
15:00	→ 15:25	**Report from CSN4** 25m Speaker: Fulvio Piccinini (PV)
15:25	→ 15:50	**CSN4 Discussion** 25m
15:50	→ 16:15	**Report from CSN5** 25m Speaker: Valter Bonvicini (TS)
16:15	→ 16:40	**CSN5 Discussion** 25m
16:40	→ 17:05	**Report from LNS** 25m Speaker: Santo Gammino (LNS)
17:05	→ 17:25	**LNS Discussion** 20m
17:25	→ 17:40	**Cofee/Tea break** 15m
17:40	→ 18:05	**Report from LNL** 25m Speaker: Fabiana Gramegna (LNL)
18:05	→ 18:25	**LNL Discussion** 20m
18:25	→ 18:50	**How did we cope with Covid19** 25m Speaker: Marta Dalla Vecchia (PD)
18:50	→ 19:10	**Covid19 Discussion** 20m

Friday, 16 October

13:30 → 14:30 **CVI in EXEC session** 1h

14:30 → 14:55 **Technological Transfer** 25m
Speaker: Ezio Previtali (MIB)

14:55 → 15:15 **TT discussion** 20m

15:15 → 15:40 **Quantum Technologies** 25m
Speaker: Raffaele Tripiccione (FE)

15:40 → 16:00 **QT Discussion** 20m

16:00 → 16:25 **Computing@Technopole** 25m
Speaker: Gaetano Maron (LNL)

16:25 → 16:45 **Computing@Technopole Discussion** 20m

16:45 → 17:10 **INFN & Covid19 (Research projects)** 25m
Speaker: Diego Bettoni (FE)

17:10 → 17:30 **INFN Covid19 Research discussion** 20m

17:30 → 20:00 **CVI in closed session + Closeout with INFN** 2h 30m