INFN INTERNAL REVIEW COMMITTEE (CVI) REPORT, 2004

Executive Summary

The CVI of INFN met June 30-July 2, 2004, and November 22-23, 2004. This report is written following the new CIVR guidelines which foresee a triennial basis for the evaluation of the activities of the several research institutes and of the universities. The report is based on summary reports of INFN activities and plans for the future, received this year and in previous years.

The CVI heard presentations from both the departing and incoming Presidents of INFN since the term of President Iarocci ended on June 30, 2004 and the start of that of President Petronzio occurred on July 1, 2004. E. Iarocci concentrated on the status during the past year while R. Petronzio gave his vision of the future. The committee also heard presentations from the presidents of all the five scientific committees and from the directors of each of the National Laboratories, those of Frascati, Gran Sasso, Legnaro and Sud.

A description of the activities of the self assessment working group was provided. This set the activities of both the CVI and the INFN in the context of the requirements of the CIVR. The number of potential products of the research of INFN far exceeds that requested by the CIVR. A selection procedure was adopted. Rather than concentrating entirely on refereed publications, INFN chose also to select a number of projects and pieces of equipment. The methodology applied to the choice of papers paid some attention to the impact factor of the publication but also gave some importance to the judgment as to the importance in terms of setting a direction for the research.

In the presentations of the leaders of the individual committees and laboratories, the CVI developed a judgment about the key areas of importance called out by the CIVR for evaluation. The CVI appreciated greatly the preparation, with this in mind, of the triennial report of the INFN. In this Executive Summary, we briefly address each of the points.

1. Scientific performance

The physics research which falls within the purview of the INFN has been marked by a phenomenal share of the Nobel prizes in physics over the past fifty years. The INFN was one of the first national organisations to form covering this field and its existence has coincided with this “belle époque”. Two recent examples of major discoveries in particle physics, that of the agents, the W and Z bosons of the weak force, and of the heaviest of the quarks, the top quark were marked by a very strong and recognised Italian participation. The work of the INFN in particle physics is among the strongest in the world. The innovation which has marked the relatively young field of astroparticle physics has been particularly important with the development of the Gran Sasso Laboratories and a series of seminal experiments. Nuclear physics has undergone considerable consolidation as a field and INFN has followed this consolidation and has embraced the new opportunities to study nuclear matter offered by the heavy nuclear beams soon to be available at the Large Hadron Collider. The drive of this experimental work has been complemented by a very strong Italian theoretical physics school often recognised across the world for its close ties to understanding the experimental results. In turn, the experiments themselves are underpinned by innovative technological approaches which also enhance the impact of the science on society.

2. The socio-economic impact arising as a result of research

As discussed in Chapter 8, the work of the INFN is consonant with the use of technologies which are at the cutting edge of what is possible. This is particularly true for the employment of advanced electronics and computing. The field has largely been defined by its use of accelerators. However, today, the majority of accelerators operate in the service of a broad spectrum of applied physics and medicine. The sensitivity of the field to this aspect of its work has continued to develop. The institute is aware that it is necessary to develop its ability to inform and help industry to a level at which there is a sense of full partnership by all.

3. Review of management and steering policies especially with regards to strategic planning and research implementation programs

There are two approaches to setting the direction for the research of the institute. The first involves the initiatives of the individual researchers, who generate ideas and self-organise into groups which, along with like minded groups elsewhere, in Europe or other parts of the world, decide to propose an experiment which the institute then considers carefully at multiple levels before approving support. The second involves the identification of strategic opportunities, especially with respect to innovative infrastructure, by the Directorate. These initiatives are then discussed within the Directorate and eventually by the Board of Directors. The system seems to have an excellent balance with the two approaches complementing each other and ensuring a vibrant program.

4. Appraisal of allocated human resources including aspects related to researcher training and growth.

Human resources are a key issue for the institute. INFN has demonstrated its capability as a fertile training ground for highly competent researchers with a top class Ph.D. program as its base. Nevertheless, the career path for physicists in INFN is hampered by the external constraints imposed by the fiscal laws. These are intended to prevent the unbridled growth of an unproductive bureaucracy. In the case of INFN, which relies on a healthy balance between salary costs and research investment costs, these external constraints have resulted in career paths which compete poorly with institutes in other parts of the world and indeed, within Italy, do not match the possibilities within industry.

5. State of international liaisons and research cooperation ventures

The largest part of the research, in both theoretical and experimental areas of the INFN, is conducted in concert with international partners. In many cases these are collaborations of researchers from a large number of countries who self organize to create the combined resources to embark on the execution of major experiments costing many hundreds of millions of Euros at one of the large laboratories of the world. Several experiments operate at the leading laboratories in Europe, for instance at CERN, Geneva, GSI, Darmstadt and DESY, Hamburg. Italian groups are active in experiments on other continents, primarily at several United States national laboratories but also in China and in South America. Finally an international collaboration in particle physics operates an experiment at the Laboratori Nazionali di Frascati, and other enterprises use the other INFN national laboratories; this demonstrates that the collaborations are bi-directional and that Italy plays its full role in also providing valuable contributions to the physics resources of the world.

6. Appraisal of research infrastructure and related services, with great emphasis on deployment of high technology.

The most prominent aspects of the INFN infrastructure are the four national laboratories and the European Gravitational Observatory at Cascina.

Each of the national laboratories has a distinguishing feature. LNF have been the leaders in colliding (electron-positron) beam machines since the first example AdA more than forty years ago. Currently the DAΦNE complex is the highest intensity of its energy range and, when attention is paid to the effect of energy in the calculation of luminosity, the performance is comparable to that of the highest luminosity performance of the B factories.

The Laboratori Nazionali del Gran Sasso are the youngest of the laboratory complexes and represented a major advance which made Italy world leaders in Astroparticle physics and other fields which demanded a well developed underground infrastructure. The support for sophisticated and large experimental structures in the low background underground environment continues to be competitive on a world scale. Currently several of the larger experiments have substantial non-Italian participation and contributions, in particular from the US and from Japan.

The Laboratori Nazionali di Legnaro is primarily a nuclear physics laboratory and, along with LNS, it operates accelerators which form key components of the European network of such accelerators. The special nature of its facilities have also lent themselves to use as a fabrication centre for the CMS experiment being constructed at the Large Hadron Collider at CERN.

At the Laboratori Nazionali del Sud, the high quality nuclear physics experiments performed on the accelerators are augmented by a very active program of treatment of cancer of the eye using proton based radiation therapy.

The VIRGO, gravitational interferometer, has been designated as the European Gravitational Observatory. The latter came as a result of its already international structure; VIRGO is constructed and operated by a strong INFN-IN2P3 (France) collaboration.

7. Establishment’s capacity to attract, manage and gain access to research related human, financial and material resources

INFN has received its funding predominantly from the Italian Government. However in addition to its primary mission, INFN was asked to perform the lead role in the development of the Italian network infrastructure. It is in this area that INFN has been a strong participant and has received funding from the EU, in particular for the EGEE project. There has been a concerted effort to develop a framework in which the participation in awards from such sources as those from the EU is consistent with the understood strategic directions of INFN.

8. The principle strengths and weaknesses with regard to research management and, where applicable with regard to quality and pertinence of all endeavours aiming at promoting research outcome and skills generated by it.

INFN has a rather sophisticated system of governance.

The basic work is generated by proposals from individual researchers, or groups of researchers within each of the five scientific fields. A proposal is scrutinised for quality and likelihood of success, for the consonance in direction with that of the institute, and is refereed in detail by other researchers, the first level of “peer review”. If successful the proposal is brought before the relevant national committee where a decision is taken whether or not to fund the proposal. It should be noted that each of the national committees contains representatives from each of the sections of INFN and of each of the national laboratories.

In addition, the INFN Directorate may create a “special project”. This is a device to provide support for a direction which may be broader than an individual field of research. It may also be that the initiative is a very large one and deserves to be steered by one of the members of the Directorate. This device is very effective in adjusting the direction of the institute. The “bottom-up approach normally in action is empirically inherently conservative. The top-down special projects often reflect a vision of the future adopted by, if not always generated by, the INFN Directorate.

9. Establishing a link between internal decision making and research program outcomes

As described in the comments above, the special projects are capable of generating major changes in the research program. One example is the VIRGO, gravitational interferometer at Cascina. It is the most advanced device of its type and has placed Italy, along with only the US and Germany, at the forefront of this field. A second example is the decision, taken eventually by the third national committee, for nuclear physics, but encouraged by the INFN Directorate, to have a major participation in the ALICE experiment at the Large Hadron Collider at CERN. This has effectively and substantially shifted the research emphasis within that sub-field in Italy. As a final example, the decision to approve Italian proponents of the BaBar experiment ensured a strong Italian participation in an experiment which was only possible at two facilities, one in Stanford, USA, the other in Japan. These experiments have been among the most prolific producers of results over the past four years.

10. Conclusions and recommendations

The general conclusions of this report are very positive. INFN has strength in most of the areas of research in which it participates. In this respect it sees correctly that its competitors and partners are the four large countries of Western Europe, the United States and Japan. Increasingly the size of the installations is global and partnership has already overwhelmed competition as the modus operandi.

Italy is a full partner and exploits in the best possible way the available resources.

The work of INFN is outstanding.

Where INFN and the CVI both see opportunities is in the dissemination of technology to industry, to medicine, to other science, and to the populace in general. Over the past 5 years the CVI has seen this aspect of the work of INFN receive more attention. This matches the developments elsewhere in the world. It has become less and less acceptable that the secrets of the field be limited to a few afficionados; there is no room for an exclusive quasi-priesthood. Further, the technology which the field generates and of which it is such a facile practitioner is just the kind of faculty needed by modern society in general. An educated populace will take wiser decisions about the power over nature which it wields so carelessly.

The CVI advocates that INFN continue to search for ways to enhance its material contributions to Italian society both through dissemination of its techniques and its knowledge and to share its excitement in its work.

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1. Introduction

This 2004 report of the Comitato Valutazione Interno, CVI, of the Istituto Nazionale di Fisica Nucleare, INFN, is part of the new triennial evaluation of research conducted under the direction of the Comitato di Indirizzo per la Valutazione della Ricerca, CIVR.

During 2004, the CVI met twice. First in July 2004, the CVI met to hear reports from the scientific arms of the INFN, including all the five National Scientific Committees and the four national laboratories. Second, in November, the CVI heard reports on important self assessments of the productivity and of the socio-economic impact of the work of the institute. The current CVI membership, which rotates periodically, is shown in Appendix A. The agendas of the two meetings are shown in Appendices B and C, respectively.

In many ways the CVI is conceived as an International Peer Review of the INFN. This concept of international peer review is built into the INFN fabric at several levels. The concept is used both at the Program Advisory Committee level for the INFN accelerator laboratories, and at the Scientific Policy Committee level. Recently the larger sections have also adopted the practice of having international visiting committees. At the level of the institute itself, ad hoc international reviews were conducted at the request of the President. It was therefore natural for the INFN President to turn to this approach in conjunction with the CIVR evaluations introduced in 1999. Since that time, the internal evaluation committee, CVI, has met at least annually.

Following this introduction, we use the subsequent three chapters to describe and comment on the Institute as a whole, the scientific program and the four national laboratories. In chapter 5, we describe and comment on the handling of resources fiscal and human.

We use chapters 6, 7, and 8, to describe the way in which INFN has responded to the evaluation procedures and its self assessment of its productivity and the socio-economic impact of its work.

The CIVR produced guidelines highlighting ten elements, which INFN were to use to in developing a three year report. We use chapter 9 to provide our own summary assessment of the performance of INFN within that framework. This assessment is then also included in the Executive Summary of this report.

2. The Istituto Nazionale di Fisica Nucleare

The INFN directs, manages, coordinates and conducts, sub-nuclear and particle physics, neutrino and astroparticle physics, nuclear physics, theoretical physics and technology within Italy through five national scientific committees, each associated with one of these elements.

As a research institute INFN relies heavily on the most advanced technologies including those which have impact beyond its immediate goals. These include superconductivity, advanced application-specific integrated circuits, computing and networking. As a result it has on occasion been charged with leading Italy in the construction of the next generation of infrastructure. A prominent example is that of networking where a strong national computer network initiative evolved into a strong participation in international networking and in the initial World Wide Web. Recently the institute was charged with directing the deployment of the next level of the computer Grid.

A large part of its mandate comprises the operation of the four national laboratory complexes at Frascati , LNF, Gran Sasso, LNGS, Legnaro, LNL, and Sud , LNS near Catania, and the European Gravitational Observatory, EGO, at Cascina near Pisa. Each of these institutions operates large scale devices which are used and exploited by the international physics community. They are discussed in somewhat more detail below.

In addition to the national laboratories, the institute consists of about twenty sections each of which is, in general, associated with a prestigious Italian University. The synergy between the universities and the sections is vital. The professors are associate members of INFN and the students progress from undergraduate study at the universities to graduate research in the sections. The ability of the sections to give research experience to undergraduate assistants spreads the awareness of high technological techniques and the scientific approach even among those who do not pursue physics for a career.

Over the course of the years 2001-2003, INFN researchers have led or participated in a number of important advances in all the fields of research in which they participate. These include the discovery of new elementary particles at several levels, the establishment of the violation of charge-parity symmetry in the b quark system and the establishment of operation for several exciting new pieces of equipment in particle physics, gravitational wave study and nuclear physics. For 2004-2006, we can look forward to similar panoply of successes which will include the deployment of the next generation of computing engines for theoretical calculations in lattice gauge theory which promises deep insight into the nature of the interactions observed by the experiments.

The institute has an annual budget approaching 300M€ and employs about 2000 people, many of them physicists with doctorates, and enjoys the membership of a comparable number of associated university researchers.

The annual salary budget for INFN is significantly less than 50% of its total funding. Compared to many research organisations around the world, this would speak to an organisation, which is relatively healthy. An organisation of this type, which is moribund, with little opportunity to invest appropriately in new equipment, new infrastructure and new experiments is characterised by its salary costs being a large fraction of its total budget. Of course, as we discuss later, the budgets of different types of organisations may be dominated by salary costs.

We consider and discuss the health of the INFN, in terms of its resources, in more detail later. Nevertheless, it is worth remarking that the three year plan advanced by INFN is predicated on its ability to fill the indicated complement of positions and to reach a total of 2014 permanent staff in 2006. An examination of the numbers suggests that this modest increase in investment in the vital human capital is essential.

INFN recently celebrated its 50th anniversary. During that time it has nurtured a remarkable number of world class physicists. It has created some of the most renowned physics techniques in use to day and it has established itself as the Italian partner in European and worldwide nuclear and particle physics. The contributions it has made and continues to make to international experiments at all the major laboratories of the world and the facilities it constructs at its national laboratories for use by the international physics community match the best in the world.

3. The Scientific Program

3.1 Experimental Sub nuclear Physics with Accelerators: CSN I

The past three years comprise the first of a new decade for particle physics and CSN I.

In many respects, 1991-2000 was a decade of operation for the LEP Collider at CERN, the SLC collider at Stanford Linear Accelerator Center and of the Tevatron at Fermilab and of HERA at DESY. The first two ended operations and have now completed analysis, the latter two underwent major upgrades to both accelerators and detectors and are now operating again with enhanced parameters. The newcomers to the field are the flavor colliders, PEP II at SLAC, its competitor KEK-B at KEK in Japan, and the DAΦNE collider at Frascati. The first two and their experiments probe the B system and DAΦNE probes the kaon system. CSNI supports leading experiments at several of these colliders.

The excitement with the LEP data came early in the three year period under consideration. That occurred when there were indications of anomalies in the data which might have presaged a very light Higgs boson. The final analyses yielded some rather solidly based limits on new physics. This was enhanced by exploiting the particularly straightforward production processes which can be postulated in electron-positron interactions. In addition the precise determinations of the parameters of the electroweak model, including the mass of the W boson, may well turn out to among the most enduring legacies of LEP.

A staple of European particle physics over forty years has been the fixed target experimental program at CERN. The number of experiments has reduced and the goals have become much more refined and focused. The NA-48 experiment executed a very successful series of measurements of charge parity violation in the neutral kaon system. It set the standard for both of its competitors, the KTeV experiment at Fermilab and the KLOE experiment at DAΦNE. Charge-Parity (CP) violation was established at the level of seven standard deviations. In the past year the experiment has been transformed and enhanced to handle concurrent beams of charged kaons. The other surviving line of research is represented by the Compass experiment which has extended the series of important experiments over nearly thirty years in the CERN M2 muon beamline. Compass has taken data with a fully operational experiment; its initial emphasis is further investigation of the spin dependent structure functions of the nucleon. Extensive calibration work has resulted and first physics analyses are eagerly awaited.

During 2001-2002, the DAΦNE accelerator performance improved steadily and a substantial data set enabled the KLOE experiment to get into the regime of specific rare decays. The data were also exploited through initial state radiation to improve the world knowledge of the hadron production in electron-positron collisions. In 2003, KLOE has rested as other experiments took data. The future should see the data reach sensitivities comparable to NA48 and KTeV

Both the PEP II accelerator and the BaBar experiment have enjoyed stellar years. The luminosity has been high and rising. The impact of flaws in the experiment has been minimised and remediation is well under way; the parts of the muon system which did give some problems will have been replaced within about two years. CP violation has been well established in the B system with a solid measurement of the angle β. There is considerable discussion of the measurements relevant to the angle α. The measurements are more difficult as well as being more difficult to interpret and thus far agreement between the relevant measurements made by Belle and those from BaBar is not perfect. The Italian component of BaBar has performed rather strongly with Giorgi just completing a term as Spokesman. The challenge for the next couple of years will be to attempt to maintain the data doubling time below a couple of years or so. An interesting aspect of the data set is that it is very rich in conventional but unanticipated physics in the form of new states whose identity is not immediately obvious. One particular instance was the observation of a state with charm in its decays with a mass of 2320 MeV; the lead analysis was performed by an Italian group.

At the Tevatron, the period 2001-2 saw the upgraded CDF detector reestablish its credentials. One innovative new capability was the displaced vertex trigger. This device was the brainchild of Ristori who is currently the spokesman of the experiment and it represents a first for a hadron collider experiment. Rather surprisingly it led to a dramatic increase in the capability of the experiment not only in B physics but also in charm physics. The past year has seen a sharp change in the machine performance. With a record 10^{32} cm^{-2}. sec^{-1}., and more than 500 pb^{-1} now delivered, the CDF experiment is starting to produce some very interesting new results. For example they recently released a measurement of the relative lifetimes of the long and short-lived B_s meson and found it to be surprisingly large. As well as having Ristori as spokesman after earlier terms in that position from Belletini and Bedeschi, other Italians have taken leadership of two of the physics analysis groups thus demonstrating their standing in the experiment.

At HERA, the experiment Zeus with a large Italian participation enjoyed considerable success in which it explored new regimes of QCD, particularly at low

x_{Bj}. It is worth noting that the inventors of QCD received the 2004 Nobel Prize for physics. Unfortunately the recent modifications to machine and experiment have not yet led to strong success. The DESY plan is to redouble their efforts to exploit HERA in the period until 2007 at which point several components of the accelerator complex have been earmarked for use as a third generation light source. CSN I management also points out that this accelerator was the venue for an experiment, HERA-B, which although surpassed by the dramatic success of the b factories, was left with significant options in complementary fields that the experiment has been able to exploit mostly as a result of the work of the INFN group

Of the major particle physics experiments currently operating across the world, INFN makes major contributions to most. Examples of minor or zero contributions are the Belle experiment at KEK in Japan, the H1 Detector at HERA and the Dzero experiment at the Tevatron. In each case the Italian contribution to the direct competitor is very strong. It can therefore be argued that INFN continues to maintain its forefront position in the current generation; we can thus look forward to this high level being maintained into the mature physics phases of these initiatives.

Thus, the scene is set for the next several years of operation. However, this is only part of the story. Several experiments, to run later, in the last couple of years of the decade, are already in an advanced state of preparation. The Large Hadron Collider brings a new scale of energy for colliders. Similarly the large experiments CMS and Atlas represent a new scale in experimentation and the collaborations which are building the experiment represent a new level of cooperation; there are more than 1500 physicists in each collaboration.

Both experiments, the CMS, Compact Muon Solenoid and ATLAS, A Toroidal Lhc ApparatuS, are now well advanced in the production of many systems. The projected date for initial collisions at the LHC is spring 2007. This may be difficult to achieve for the machine builders, nevertheless the strategy is to be ready with as much of the eventual apparatus as possible so that the experiments do not drive the schedule. Of course there are many challenges to be met over the next few years but they appear to differ, it is not the same issue in each experiment.

Both experiments incorporate large magnets. The solenoid of CMS is larger than any previous one and the goal is to operate with a field of 4 Tesla; progress is good. The barrel toroids in Atlas have been one the items causing the greatest concern. Almost “as usual”, the issue was not one of high technology, rather it is one of detail in the final cryostat assembly which has caused some delay. During October 2004, the first of the barrel toroids was installed in the ATLAS pit. Italian industry has played a very large role in the current delivery of magnet components in particular the coils for both these elements.

The muon systems of each of the large experiments and indeed the other two smaller experiments at the LHC employ Resistive Plate Chambers (RPCs) and INFN has attempted, with some success to orchestrate the production of these elements across the experiments.

The electromagnetic calorimeter of CMS is constructed by assembling many crystals of Lead Tungstate in a honeycomb-like structure. In Italy this work involves collaboration between INFN and ENEA. Although the eventual delivery of all the crystals required by CMS is one of the largest concerns, the assembly so far completed in Italy exceeds any previous crystal assembly for particle physics. The electromagnetic calorimeter for Atlas uses a contrasting approach with interleaved plates and electrodes immersed in liquid argon. Again a large Italian participationfrom both INFN and industry has been evident in the construction of these devices which have now been successfully mounted in their cryostatic containers and have been tested at CERN. This was a major milestone for Atlas.

Finally in the inner regions of the detector are the trackers and Italy has chosen to exploit a proven expertise with silicon detectors, which comprise the totality of the CMS tracking detector. These devices are assembled from many components and that assembly and associated quality assurance is time consuming. It also stresses the ability to maintain high yields in each of the steps in the sub-assemblies. If this does not happen, rework costs, and schedule spiral out of control. Although productions lines across the world have been fed sufficient components to establish production capabilities, the complete line is not yet operating smoothly all of the time.

The gains from the higher energy at the LHC are less evident for the production of low mass particles such as B mesons. Nevertheless, the production rates are high enough that the LHC-b experiment feels it can outstrip the B factories. LHC-b has a relatively conventional design and looks like a large fixed target experiment; it profits from the transformation of rapidity, which is the relevant acceptance variable, to angle at large rapidity. An experiment at the Tevatron, BTeV, uses a superficially similar configuration. That experiment takes a step forward by using Lead Tungstate for its calorimeter to maximise its sensitivity to neutrals, but its key feature is a trigger based on an extensive pixel detector which would be contained within the machine vacuum. Participation in these two experiments will ensure a strong INFN participation in B physics well into the next decade; there are many who feel that new physics should appear in these experiments; the puzzle of the matter-antimatter (CP) asymmetry which is a prerequisite of our existence has not yet been solved.

All of these experiments rely on the new computing paradigm; the Grid. Just as networking transformed the way we communicated in the 80's, so the Grid is transforming the way we locate our computing resources. The current big experiments in which INFN participates, BaBar and CDF in the United States both are relying on widespread computing resources found in Padova or Bologna. For the LHC, this will be the way of life. Already demonstrations have been operating for more than a year. Atlas jobs run on CMS funded machines when they are idle, and vice versa. As a result of its manifest leadership among Italian research institutes, INFN was chosen to be the lead institution for the implementation of the Italian national computer network.

With the strong participation in the LHC and other experiments it would seem that CSN I has a well understood progression to about the middle of the next decade. Of course the LHC experiments will operate for fifteen to twenty years.

The further future has been the subject of much debate across the world in the past year. The possibility of a TeV scale Linear Collider has stimulated R&D for a decade or more and a decision is expected in this calendar year as to the most promising technology. Italy has collaborated on all of the relevant technologies. However, that may not be the only way forward. Neutrino and other physics tends to point to powerful proton sources. These could also be the foundation for other devices such as neutrino factories. Italy has been a strong player organising a number of studies and workshops. There are also discussions about what would be the appropriate next machine in Italy. Would it be an upgraded DAΦNE, or a completely different machine? It is entirely appropriate that INFN should have cast its net wide in looking at these options. There are many ways in which narrow initiatives can fail and a single country no longer controls its own destiny completely; at least that is true if the country involved seeks to retain an influential position. This is manifestly the case for INFN.

In summary the years 2001-2003 have seen a very high level of production of results based both on mature programs which have now finished and on young programs just establishing operation. The foundations are in place for continued world partnership in particle experiments for the next five years and for the ten years beyond that. Discussions are in progress to plan a longer term thrust for CSN I.

- 3.2 Astroparticle and Neutrino Physics: CSN II

Astroparticle Physics and Neutrino Physics are fields where major developments have taken place during the past three years. As a consequence many new projects have been undertaken and therefore also the future of these fields will be dynamic with many interesting results to look forward to. INFN is very strongly present at the frontier of developments in Astroparticle Physics and Neutrino Physics and has arguably played a major role in the recent successes and in defining the future. The Gran Sasso National Laboratory (LNGS), the largest underground laboratory in the world, is of prime importance for many of the projects supported by CSN II.

Productivity and impact of the research sponsored by CSN II are large, as illustrated, for example, by comparison to other major European nations.

INFN is a founding member of ApPEC (Astroparticle Physics European Coordination), presently chaired by R. Petronzio. Under the auspices of ApPEC a funding request for an astroparticle physics European network, including several R&D projects, has been successfully submitted to the EU (FP6) and further initiatives (e.g. design studies) will follow.

The discovery of neutrino oscillations in atmospheric and solar neutrinos (Kamiokande and Superkamiokande in Japan), a few years ago, certainly has been a major breakthrough. INFN is extremely well placed to build on its past involvement in this field and continue a program of exploration of the physics of ‘oscillating’ (i.e. massive) neutrinos, a field wide open for new measurements (e.g. of neutrino mass differences and neutrino masses) and new discoveries (CP violation in the neutrino sector; the ‘Dirac’ vs. ‘Majorana’ nature of neutrinos).

The GNO experiment (at Gran Sasso) has completed data taking recently and measured solar neutrinos due to the pp reaction, the most abundant but hardest to measure. The Borexino experiment suffered a delay because infrastructural improvements relating to safety had to be put in place at LNGS, but is now ready to resume installation. It is mainly aimed at measuring ^{7}Be solar neutrinos, a monochromatic line at 863 keV.

The Opera experiment will, starting in 2006, measure □□ - □□ oscillations in an appearance experiment, certainly the most direct proof of neutrino oscillations. The Opera experiment will use a neutrino beam sent from CERN to Gran Sasso (CNGS), i.e. over a distance of 730 km. Also the Icarus experiment will receive this beam in its unique 600 (ultimately 3000) tons liquid Argon detector. (This detector has a larger physics program, including proton decay searches and more). The participation of INFN in K2K (neutrino beam from KEK to Kamiokande) naturally fits in the 'oscillation program' covered by Opera and Icarus.

We would like to comment on the accelerator-based neutrino programme. CSN II foresees a 10 year programme of CNGS (CERN neutrino beam to Gran Sasso) and wants to concentrate the efforts on this programme. The OPERA Collaboration, with a sizeable international component, will look for tau-neutrino appearance and has also some sensitivity to $\sin^2 2\theta_{13}$. Although the potential of Icarus is large it is not yet a truly international collaboration with a clearly defined timeline. We agree that CSN II concentrate on the exploitation of CNGS and that a 10 year program be worked out in detail, at the same time we see discussions in the neutrino community on superbeams, neutrino factories. These deliberations are occurring in many parts of the world. INFN physicists should continue to take an active part in these developments. So we recommend the formulation of a long term strategy of the accelerator-based neutrino program including CNGS and the longer term future.

The neutrino physics program of INFN furthermore contains highly relevant, but also particularly challenging projects aiming a measuring the □$_e$ mass (MI-BETA), neutrinoless double beta decay (CUORE, preceded by CUORICINO) and at finding direct evidence for dark matter interactions - an intriguing observation by DAMA, annual modulation of an 'unexplained' signal, will now be verified by LIBRA.

The cosmic ray program covered by CSN II is practically comprehensive and of particularly high quality. It covers high energy cosmic rays, high energy cosmic neutrinos and high energy gammas. It includes observatories in the sky (balloons, satellites), on the ground and under water. Although many of these projects are of an exploratory nature the scope for discoveries is large, because new windows on the universe are opened for the first time. Auger will measure the 'all cosmic ray spectrum' up to the highest energies with a Cerenkov tank array effectively covering 3000 km^2 , complemented with fluorescence detectors. Auger is 'modular' and started data taking, the full detector will be complete by the end of 2005. The ARGO project (a large RPC array in Tibet) will be operational in 2005 and look for high energy (> 100 GeV) gamma ray sources. The MAGIC telescope at the Canary Islands has started data taking in October 2003 and has already observed continuous TeV gamma ray emission from the Crab nebula. The observation of 'direct' high energy cosmic neutrinos would represent a major discovery; it requires very large detectors, 1 km^3 of water (or ice). It is clear that such a huge project requires a smaller 'first step' and INFN is involved, in a leading way, in the Antares project and is developing plans for the NEMO project close to Sicily, both in the Mediterranean.

INFN is involved in various 'leading edge' projects for detecting cosmic rays (including gamma rays) in space, thus avoiding absorption by and background from the earth atmosphere. AGILE will, following EGRET but with improved sensitivity, measure an all sky gamma ray map; it will be launched in 2005. GLAST (a collaboration involving NASA) will be launched in 2007 as the next step, putting a rather large 'particle physics detector' in space. AMS2 will be the first magnetic spectrometer in space using a superconducting magnet, following the successful test of AMS1 in 1998, using a permanent magnet. It will allow unique measurements of the cosmic ray spectrum.

A very important activity of CSN II is in the field of gravitational wave detection. Various INFN groups have made pioneering contributions to cryogenic resonant bar detectors and very intriguing coincidences have been observed by EXPLORER (located at CERN) and NAUTILUS (in Frascati). AURIGA2, implementing the latest technological improvements, started data taking in December 2003. The EGO consortium (between INFN and IN2P3, France) is operating the Virgo laser interferometer, this extremely challenging instrument is now in the commissioning phase. The (somewhat farther) future of gravitational wave detection will exploit an interferometer in space (LISA) and INFN is very well placed to participate in a leading way.

In conclusion the research conducted under the auspices of CSN II in the fields of astroparticle physics and neutrinos is of the highest quality and has a very promising future. We can look forward to (first) results of many of the new projects underway now or in the near future, at the next tri-annual review in 2007.

3.3 Nuclear Physics: CSN III

INFN plays a significant role in nuclear physics, within Europe and worldwide. The research ranges from the study of the nuclear building blocks, neutrons and protons (more generally hadrons) to complex nuclei representing the matter composition of our solar system and beyond, to extended nuclear matter in astrophysical scenarios such as neutron stars and supernovae, and finally to very hot and compressed matter as it should have existed in the first moments after the big bang, with a phase transition from a deconfined, chirally symmetric quark-gluon plasma to hadronic matter.

As a result the INFN research in nuclear physics is structured along four main programs: i) quark and hadron dynamics; ii) phase transitions of nuclear and hadronic matter; iii) nuclear structure and dynamics; iv) nuclear astrophysics and interdisciplinary researches. The total of 586 researchers (434 FTE's; 38% of the researchers from universities) distributes very roughly with comparable size over the first three areas, with the fourth less than half of the others.

There is a distinct trend over the last decade of about 50% of the researchers from the first area moving to the second (which now is the largest group). It reflects the increased interest in quark-gluon plasma physics, in particular in view of the large ALICE experiment now under construction at the LHC (CERN). Beyond the specific case of

ALICE, there is an overall trend in the field to consolidate efforts towards larger experiments, due to the complexity and technical challenges that forefront research in nuclear physics now requires.

In each of the four research areas listed above there have been substantial achievements over the past three years. In the area of hadron and quark dynamics, experiments at TJNAF provide important information towards our understanding of the theory of strong interaction, quantum chromo dynamics (QCD), in the non-perturbative regime, i.e. at the large distance and consequently low-momentum scales relevant for nuclear dimensions.

Specifically, in the AIACE experiment at TJNAF (at the large-acceptance CLAS detector) nucleon resonances and spin structure functions were pursued with precision, generalized parton distribution functions explored, and evidence established for new multi-quark hadron configuration. In the ELETTRO experiment (a high-resolution spectrometer) new results on spin structure, relevant sum-rules, and hypernuclear productions were obtained.

In the large international experiment HERMES at DESY (large-acceptance spectrometer with polarized targets) polarized electron scattering provided important information and tests of theory for spin physics (first results on transversity; first glimpse on gluon contributions) and in-medium effects on form factors. GDH sum rules are studied at Mainz (MAMI) and Bonn (ELSA) and at Grenoble (ESRF).

At the DAPHNE facility high-luminosity phi-meson and thus secondary kaon beam production allowed important measurements with the DEAR detector (anti-kaon nucleon scattering, chiral perturbation theory tests) and the FINUDA set-up (lambda hypernuclear studies). The best measurements yet on kaonic hydrogen were obtained, and prospects for kaonic deuteron studies are quite exciting.

Future plans include programs targetted at the 12 GeV upgrade capability at TJNAF, the antiproton program at the FAIR facility, and PANDA detector at GSI. This will open opportunities for precision spectroscopy into the charm region, glueball searches, searches for new multi-quark hadrons, multi-strange hypernuclei etc., to mention just a few of the planned research goals.

The second area of research concerns the strong-interaction matter phase transitions. INFN has had a successful and growing involvement from low energies (liquid-to-gas nuclear transition) to the higher energies (quark-gluon phase transition). For the latter, at the SPS at CERN, key results were multi-strange hyperon production and J/Psi suppression. The data have been instrumental in what has been considered– together with other observables – as strong indication for the observation of the transition to the quark-gluon plasma.

The current effort is focussed on the future ALICE experiment at the LHC at CERN. The LHC will provide a factor 20 higher centre-of-mass energy than presently attainable with RHIC at Brookhaven. The expectation of a full realization of the weakly coupled (ideal) quark-gluon plasma is stimulating broad participation of the Italian community. Within CSN III this has become the largest effort. The Italian community is also strongly involved in the technical developments for ALICE: it has responsibility for parts of the inner tracker (silicon drift, pixel, and strip detectors), the time-of-flight system (multi-gap RPC's), the di-muon spectrometer, the zero-degree calorimeters, and ALICE GRID computing. All of these are central to the ALICE program and give the Italian community a strong position in this experiment.

The INFN program in low-energy nuclear structure and dynamics is predominantly carried out at the INFN's own facilities, the Legnaro National Laboratory (LNL) and the National Laboratory Sud (LNS) in Catania. In addition, user facilities elsewhere are employed. The program, in general terms, addresses two key areas: nuclear matter at low energies and temperatures and the nuclear liquid-gas phase transition, and the study of nuclear structure at the extremes, i.e. excitation energy and angular momentum, but increasingly also in isospin, by moving away from stability with beams of short-lived nuclei ('radioactive' beams).

Interesting results have been obtained in the areas of sub-barrier fusion, fission dynamics and symmetry energy, multi-fragmentation at very low energies, two-body dissipation, nuclear transparency at Fermi energies, and isospin effects in cluster formation and the nuclear equation of state. Nuclear structure studies address neutron-rich light nuclei, isospin symmetry and mixing, nuclear shape phase transitions, exotic shapes, and dynamical symmetries. For both areas, powerful and innovative detector arrays have been constructed at both national laboratories, at LNL (for example GASP, 8pLP, GARFIELD, PRISMA) and at LNS (for example MAGNEX, CHIMERA).

The fourth research area within CSN III addresses issues of nuclear astrophysics and interdisciplinary research. This is the smallest of the four programs. In nuclear astrophysics this includes the pioneering low-energy accelerator(s) and research program at the Gran Sasso underground laboratory. In its background-free environment it has been possible for the first time to perform measurements at stellar energies, i.e. the actual thermal energies that prevail in the stellar environment. A new indirect reaction method (Trojan horse method) was developed at the LNS for measurements of key astrophysical reactions. Lithium-8 production, a key indicator for Big Bang nucleo-synthesis is in preparation at the EXCYT facility at the LNS which is nearing completion.

At CERN, neutron capture cross sections of importance for astrophysics were successfully carried out at the n-TOF facility, and anti-hydrogen studies performed at the antiproton decelerator (ATHENA experiment).

The research within CSN-III has led to interdisciplinary and technological developments of societal importance, which is addressed elsewhere.

The program has a noteworthy effort to disseminate science activities and scientific culture to the educational system and the general public. In particular the national laboratories attract high-school students and teachers at a level that compares well with large international laboratories that might be better known.

3.4 Theoretical physics: CSN IV

Activities of this group have continued in all five branches of theoretical physics covered by INFN.

Quantum Field Theory and Strings remains a strong area of research and is attracting a growing number of young researchers, particularly in the latter subject. String theory is indeed a promising and challenging framework for the construction of a theory that, encompassing the standard model, combines it with a quantum theory of gravity. There has been lately an evolution in the scope of string theory activity from mostly mathematical work to the understanding of its implications for accelerator and astro/cosmo-particle experiments. Other important activities in this sector are lattice gauge theories, till today the best tool for studying non-perturbative properties of QCD, such as confinement, high-temperature deconfinement, and QCD at high baryon density.

Particle Phenomenology, the other traditionally strong area of Italian theoretical physics, has also continued to produce a stable research output at the highest international level. Work in this area ranges from neutrino physics, to supersymmetric extensions of the standard model, to perturbative QCD, and to extracting basic parameters of the standard model from lattice calculations (CKM and weak matrix elements, heavy-flavour parameters, signatures for the quark-gluon plasma).

The *Nuclei and Nuclear matter* group, while continuing successfully its traditional lines of research in Nuclear structure and Nuclear reactions, has shown the further development of its component addressing the physics of relativistic heavy-ion collisions and the search for the quark-gluon plasma, a development that was recommended by the CVI a few years ago. Work in this area has become increasingly visible internationally. It is hoped that more openings to young researchers in this area will be created in the near future.

Activity in *Astro-particle and Cosmology* has grown at a considerable pace over the last few years, as the result of the quantity and quality of challenging data recently harvested in the field. Its development within CSN IV is well in line with our previous recommendations. It covers a large spectrum of subjects, from cosmological models, to neutrinos, to gravitational-wave sources, to dark matter and energy. Job openings to young researchers in this field look satisfactory. The good quality of research in this field is substantiated by the high level of ISI-citations.

The share occupied by *Mathematical Methods* continues its slow shrinking. This is probably the result of competition from String Theory with which it has important points of overlap, e.g. in the study of non-commutative geometry. Other interesting areas are those of non-equilibrium thermodynamics and of foundations of Quantum Mechanics. The smaller numbers in ISI-citations in this sector mainly reflects the smaller size of its community.

CSN IV has one special project, ***ApeNEXT*.** While the APEmille network now totals about 1.8 Tflops distributed in different nodes in Italy, France, Germany and the UK, the ApeNEXT project will soon make computing resources of the order of 10

Tflops available at various locations. INFN, DESY and Bielefeld are already envisaging the acquisition of several ApeNEXT units. Such an order of magnitude increase in computing power will allow important progress on the particle physics questions mentioned before, as well as in other areas, such as turbulence, the physics of complex systems, and computational biophysics.

- 3.5 Technological and interdisciplinary research: CSN V

The mission of CSN V spans from developments of new technologies for future experiments in nuclear, particle and astroparticle physics, to the use of the technological know-how in these fields for interdisciplinary or industrial applications. This specific purpose requires providing the means for testing innovating ideas and creative applications, yet within a frame where the soundness of proposed projects is evaluated, their progress closely monitored and their evolution followed up to their final application. To fulfill this purpose not only technical expertise is essential, but also the possibility to establish the necessary contacts with other fields of research or industrial partners.

Activities of CSN V are structured in three fields: detectors and electronics, accelerators and related technologies, and interdisciplinary applications. In each field three to seven conveners evaluate, approve and follow the projects. Funding is close to equilibrium between the different fields. Over the last three years, the budget of interdisciplinary activities increased by 8% and reached 38% of the total, which is the highest share among the three sectors. Interdisciplinary studies are related to environment and space (48%), bio-medical applications (38%) and cultural heritage (16%).

In total more than 100 different projects are currently ongoing, generally with a lifetime of 2-3 years. Projects are present in all INFN units as well as all national laboratories. A database containing the achieved milestones, current status and plans of each project is an impressive source of information and an adequate tool to supervise the variety of projects.

During the year 2003, the productivity in terms of achieved milestones has been very good (85%) and is also reflected in terms of more than 250 publications and about the same number of conference presentations.

Major projects include developments for the SPARC Free Electron Laser (FEL) -facility in LNF or research for improvements in detector technologies such as particle induced X-ray emission (PIXI). Most experiments are cross-disciplinary, for example at the interface with material sciences, such as MABO studying properties and applications of superconducting MgB2 and NANO manufacturing carbon nanotubes to realize field emitters.

One of the largest involvements in the bio-medical sector of CSN V is in cancer treatment, where the activities span over developments for dosimetry, imaging and particle accelerators, using innovative detector and computing techniques and providing facilities for research and clinical applications. After operating successfully the CATANA proton therapy facility at LNS, a hadron therapy institute is planed by the region of Sicily in Catania with a scientific collaboration of INFN. Besides, INFN has joined the CNAO foundation and is playing a central role in the construction of the most critical components for a new hadron therapy center in Pavia, which aims for first patient treatment in 2007. The CNAO-project is comparable to similar initiatives in Europe by GSI (Germany) and PSI (Switzerland) and will provide Italy with an adequate facility for this type of cancer treatment.

Traditionally CSN V has a close relationship with the domain of cultural heritage studies. The creation of a new laboratory in Florence provides ion beam analysis and atomic mass spectroscopy techniques for non-destructive analysis of historically and artistically important objects to provide accurate dating, to determine material compositions and to reveal used technologies. The involvement of CSN V in these fields allows optimising the use of equipment and technical expertise and is also internationally demanded.

Outreach initiatives are of vital importance in order to spread scientific culture within society. A good example in this area is ENVIRAD, a project to measure Rd-concentrations with high school students. Within this program, students acquire knowledge about radioactivity and effects on health as well as basic experimental skills. In view of the general decrease of students in the scientific domains, the importance of such programs can only be underlined.

The transfer of technologies developed within CSN V towards areas of research inside and outside INFN is well established. The implication of CSN V in the development of innovative technologies could in principal allow creating direct collaborations with industry. Initiatives have been taken from INFN and industry, but not without difficulties. It must be stressed, that the technology transfer to industry is not the main goal of the activities within CSN V. However efforts should be made to improve possible collaborations. A better knowledge on the activities of the "Committee for Technology Transfer" would be helpful. The role of such a committee could be to establish contacts with industrial partners, to give guidance in questions of intellectual property and to have a close link to similar structures outside Italy as for example the "Technology Transfer Office" at CERN.

4 The National Laboratories

4.1 Laboratori Nazionali di Frascati, LNF

The Frascati Laboratories were the first of the INFN laboratories to be established. This occurred almost 50 years ago. The major theme of the Laboratory, almost from its inception, has been the acceleration of electrons and subsequently the interactions between electrons and positrons in a storage ring collider. In this field INFN was a pioneer and Frascati acquired a worldwide reputation which it has never relinquished.

The Laboratory currently occupies about 135000 m^2 and employs 368 people. Of these more than 20% are physics researchers and 62 are highly qualified engineers or technologists. These staff members are complemented by more than 300 users (researchers from other institutions) of which about 20% are foreign. The activities of the Frascati researchers are not confined to the home laboratory. About 50% of the total budget of 42.5 M€ is expended on activities in other Laboratories both in Italy, in the rest of Europe and, quite prominently, in the United States.

Currently the flagship of the Laboratory is the DAΦNE storage ring which operates as a factory for ϕ mesons; these in turn decay into K mesons and the neutral kaons can be used for the study of Charge-Parity (CP) violation. The luminosity needed to compete with other techniques is very high. Over the past couple of years the device has made enormous strides and is on the threshold of reaching its goals. The machine is complemented by a beautiful detector (KLOE) which features a very large low mass tracking chamber and a beautiful calorimeter. The storage ring can be exploited for other experiments and is host of the FINUDA and DEAR experiments. These two experiments use the copious supplies of kaons to generate exotic states. In the case of FINUDA these states are hypernuclei in which a nucleon is replaced by a Λ hyperon, in the case of DEAR, they are kaonic atoms. The operations of the accelerator are compared with other facilities across the world and the performance indices, relative cost of human effort needed appear to be very good.

Electron storage rings are by now well known as sources of electromagnetic radiation by the synchrotron radiation. The DAΦNE facility is particularly versatile and produces Infrared, Vacuum Ultra Violet and X-ray beams. The far IR capability of this machine is relatively uncommon in the world.

At many accelerators, the eventual useful lifetime of the facility is determined by the time it takes the experimenters to double their existing data set corresponding to a significant advance in their science. This can be either in terms of the precision of their measurements or in their sensitivity to possible discoveries. The DAΦNE machine is entering its design regime which means that the data doubling time will soon get to two or three years. There are a number of possible options. Some involve relatively modest adiabatic changes but at some point these changes become a complete rebuild of the machine. Such an option is under study currently. There have been workshops to examine the potential physics gains; these are a necessary prerequisite.

Over the past few years advances in accelerator physics have resulted in the demonstration of the Free Electron Laser. A multi-institutional proposal has been developed by INFN, ENEA, CNR and the Tor Vergata University and submitted to MIUR. The approved R&D would lead to the construction of a high performance linear accelerator (SPARC) and an undulator. The latter would allow to study the coherent SASE production of power. If successful this could be continued by coupling the SPARC injector with the existing DAFNE LINAC, to produce a SASE Free Electron Laser in the VUV-Soft X-Ray wavelengths.

These accelerator projects lead to the participation of Frascati accelerator physicists in many projects and project designs across the world. In the realm of the linear electron positron colliders (LC), Frascati participated in the TESLA collaboration whose work was recently recognised by the choice of this technology for a TeV scale collider. For higher energies one possible option which is in its infancy involves the use of high power low energy beams as the power source for the main linear acceleration. Frascati is in the process of taking on some particular responsibilities to assist the lead laboratory in this novel approach dubbed CLIC (Compact Linear Collider). All these accelerator based efforts are the basis for the Frascati Director being a member of ICFA, the International Committee on Future Accelerators. Thus far this body with a membership of about ten Laboratory Directors from around the world has set the direction of particle physics for about forty years.

The broad range of technologies needed to operate an accelerator complex for high energy particle physics are rarely found in other facilities. Thus the relative ease with which cryogenic expertise can be tapped has led to a program of gravitational wave research using a large metal bar cooled to cryogenic temperatures. This is just one example of a sub-dominant but broad program of physics research enabled by the facilities and expertise demanded by the primary mission.

Within Europe, Frascati participates strongly; it was recognized in FP5 as a Large Research Infrastructure, has successfully competed for funding and has delivered on the projects awarded.

In addition to its research activities, Frascati is a major educational centre. In any given year it provides 170 courses, awards eight Masters Degrees and ten doctorates.

4.2 Laboratori Nazionali del Gran Sasso, LNGS

The Gran Sasso National Laboratory (LNGS) is the largest underground laboratory in the world for astroparticle and particle physics. It was designed with the vision of receiving neutrino beams from CERN, a possibility that, indeed, will be realized in 2006, when CNGS becomes operational. LNGS attracts a large, international user community, presently nearly 800 scientists from about 25 countries. It is a large research infrastructure, recognized as such by the European Union. The laboratory has a permanent staff of 66 persons.

Operation of the laboratory has been temporarily and partly suspended at the end of 2002, because of an incident that led to a renewed assessment of infrastructure and rules and regulations related to safety. A number of infrastructural improvements have meanwhile been realized. In the course of 2004 practically all activities have been resumed.

The main research lines of LNGS are: neutrino physics (mass, oscillations, stellar physics); dark matter; nuclear reactions of astrophysical interest. There are also activities in geophysics and biology.

The scientific activities in astroparticle physics and neutrino physics have been reviewed as part of the program carried out under the auspices of CSN II. We only repeat here that this scientific program is of the highest quality, internationally competitive and attractive with a very ambitious and promising future program.

LNGS has an active ‘outreach’ program and a very active and successful ‘visitors program’.

LNGS is an underground facility with an excellent international reputation, an established part of the European, and, indeed, global research infrastructure, with a very exciting scientific program.

4.3 Laboratori Nazionali di Legnaro, LNL

The activities over the past three years at the Laboratori Nazionali di Legnaro (LNL) have, on the one hand, continued along established key programs: nuclear physics research, R&D of super-conducting radio-frequency structures, accelerator physics, interdisciplinary studies in solid-state and geophysics, biomedical studies, gravitational wave searches and general irradiation services. In addition, a major new project was initiated in 2003 with the funding of the 20MV section of a high power (5 MW) (partially) superconducting linear accelerator. This represents the front-end of the proposed radioactive beam (or rare isotope) facility, SPES, and will provide the neutron source for boron neutron capture therapy (BNCT), a novel medical application. The dual task of continuing with a successful research program and developing a major new facility represents a major challenge and requires careful planning and priority setting.

Central to most of LNL’s research are four accelerator facilities: the XTU tandem, the super-conducting linac ALPI, and two smaller machines, namely two single-stage Van De Graafs. Beams of most stable isotopes between hydrogen and ruthenium are now available. Altogether, about 10 000 hours of beam on target annually is provided by the set of accelerators with more than half from the two larger facilities. The latter two can also operate in two modes, stand-alone for the tandem or coupled with the tandem as injector. Stand-alone mode for the linac will also soon be available (see below).

The two smaller machines, i.e. the Van De Graafs, are essentially exclusively used for interdisciplinary and applied nuclear physics research. Instrumentation dedicated to cell irradiation, micro-dosimetry, and radiation hardness tests of electronic components and of detectors attract large numbers of researchers from other national research institutions and universities not directly associated with INFN. In particular the two micro-beam facilities for solid state and geology experiments, respectively , provide unique infra-structure capabilities sought by various research groups.

The two large accelerators, the XTU tandem and the sc-linac, are mostly engaged in fundamental nuclear physics research. The new superconducting high-charge state injector for heavy ions, PIAVE, was completed in 2003 and commissioning is expected to be completed in 2004. PIAVE will provide a major enhancement in ion-beam capabilities, in particular for heavier masses, and will allow full stand-alone mode for the sc linac.

Forefront detectors at the XTU/ALPI accelerator system, some just coming into full operation, are enabling an exciting research program. Isospin symmetry and isopspin mixing, wobbling motions of super-deformation and search for hyperdeformation, giant resonances on exotic shapes and rotational damping, deep-inelastic processes populating nuclei off stability, and high-spin studies near unstable doubly-magic nuclei are being performed. This involves the GASP multi-detector gamma array and the new PRISMA wide angle magnetic spectrometer, often coupled to the CLARA gamma-array.

A recent program on low-energy nuclear break-up and nuclear (multi) fragmentation and on the fusion-fission process uses the GARFIELD and 8piLP charged-particle spectrometers. The magneto-optical atom trap for fundamental symmetry studies is operating and first studies to produce, via fusion-evaporation reactions, the francium isotopes needed for these studies have started.

In addition to the research carried out at the four accelerator facilities, LNL has a strong program in certain technology developments, such as low-beta super-conducting rf structures and cryogenics, material surface modifications, cell cultivation, and construction of major detector components for large-scale experiments at the LHC, including the CMS and the ALICE experiments.

Furthermore, there is an experimental program in general relativity (gravitational wave search) and exploration of the quantum vacuum. The ultra-cryogenic bar detector AURIGA has recently been upgraded to higher sensitivity and is expected to be back in full operation soon. LNL hosts the coordination of IGEC, the International Gravitational Event Collaboration. The PVLAS apparatus (consisting of a slowly rotating 6-Tesla dipole magnet and a large optical cavity) has begun experiments to explore the QED prediction of the quantum vacuum as a birefringent medium.

The current program is of high quality and addresses many important issues in various areas of research. The laboratory and its management are to be congratulated that they have been able to serve these many functions successfully in the past. It is also clear, however, that the increasingly conflicting requirements from such a broad program, and in particular the additional large task of constructing the 20MV proton driver and BNCT therapy facility, will challenge the laboratories resources critically. It seems absolutely necessary to further establish clear priorities and define the mid-term and long-term key programs.

4.4 Laboratori Nazionali del Sud, LNS

With the combination of the two accelerators available at the LNS, the tandem and the super-conducting cyclotron, the laboratory has unique potential in certain areas of low-energy research with ion beams, in particular in the areas of nuclear structure and dynamics.

Over the past three years (2001-03) the laboratory's focus was first of all on ensuring reliable and continuous operation of the accelerators and thus to satisfy the increasing demand from the users for high quality ion beams, in particular also at the higher energies available from the super-conducting cyclotron (SC). The latter was crucial for the effective use of the high performance multi-detector system

CHIMERA in its recently completed full configuration of 1200 detectors inside the CICLOPE vacuum chamber. Several beams were delivered for calibration and tests of CHIMERA and finally, in 2003, for a series of eight experiments performed by large international collaborations. The series of experiments provided unique data for the study of multi-fragmentation and the nuclear matter equation-of-state. The data are under analysis; in the meantime data taken previously with the multi-detector MEDEA indicate surprising results in the production of high-energy protons and suggest strong cooperative effects in the reaction dynamics. It is noteworthy that the international collaborations performing the experiments with CHIMERA have very strong contingents from the leading laboratories in this subject area in the US, which testifies to the unique experimental opportunities and attraction provided by the combination of accelerator and detector system at the LNS.

Particularly noteworthy in the experimental program at the LNS tandem accelerator is also a series of experiments in nuclear astrophysics that uses an indirect method ('Trojan horse') to measure reaction rates. The method was pioneered at the LNS and allows to deduce important parameters in reactions of astrophysical interest and to study, in particular at the lowest energies, the difficult to calibrate effects of atomic screening on cross sections of nuclear reactions.

A major effort at the LNS was focussed on the completion of the EXCYT radioactive beam facility. The main goal of EXCYT is to produce radioactive beams of light nuclei for studies in nuclear physics and astrophysics. The LNS cyclotron is the (primary) beam production driver and the 15 MV tandem is the post-accelerator for the radioactive beams. In 2001 and 2002, the main components were designed and manufactured. In 2003 the target-ion source was built and tested at GANIL (France), confirming design values for lithium beams (neutron rich lithium beams will be the first radioactive beams anticipated for EXCYT). At the same time, major steps forward were achieved in cyclotron beam intensity, delivering as much as 100 watt of carbon beam on target. A license for up to 500 watt is being applied for. Commissioning of the full system is expected to start towards the end of 2004.

To have the critical spectrometer, MAGNEX, ready for experiments with first beams from EXCYT, major effort was put into completion of this important device. Design of the large momentum and large angle acceptance magnets was completed in 2001 and the magnets manufactured and mounted in 2002. The focal plane detector was developed together with French researchers, mounted and tested. The scattering chamber was designed and is now under construction. The full system should be ready for experiments with EXCYT as planned.

A further important activity concerned the completion of the high intensity proton source TRIPS for the national TRASCO/ADS project.

Several studies in applied areas were performed. Of these, the most significant is the completion and implementation of the CATANA proton therapy facility. Construction and preliminary testing and certification were completed in 2001 and at the beginning of 2002 first patient treatments were begun. Up to now 77 patients have been treated.

Several of the activities described have conflicting requirements, in particular the delivery of beams to the experimental program and the construction of EXCYT which use much of the same space. A decision was made during the last 3 years to concentrate the experimental activities during the first 7 months of the year and use the remaining time for the development of EXCYT. This allowed also a better scheduling and use of the available (and limited) technical manpower. The overall number of hours beam on target did not suffer, just the opposite: in 2002 the overall number of hours was the same as in 2001, and even higher in 2003 for the super-conducting cyclotron, while for the tandem it was even twice as high in 2002 and 2003 as compared to 2001. This was a prudent move by the management and should be applauded.

Finally, an important activity at the LNS is the NEMO project, an R&D program aimed at the realization of a km-cubed high-energy, under-water neutrino detector. Major developments have been achieved, including the determination of a suitable site, characterizations of short (and long) term optical properties (optical background, water transparency) and oceanographic parameters (currents, biological activity, sedimentation). A feasibility study has been made, including development of electro-optical cable, detector structures, data transmission etc. In 2005 the integration of subsystems, with deployment and connection of a prototype detector tower, will be carried out, and in 2006 a full tower will be completed and deployed.

In summary: the LNS program is unique in many respects, due to the availability and combination of two ion beam accelerators. It is also unique with regard to its location for the potential NEMO underground water neutrino detector. The accelerators are performing well now. The future plans are well-developed and focussed on selected priority programs: experimental studies with stable beams, fully utilizing the CHIMERA and MAGNEX detectors; commissioning of EXCYT and start of the program in nuclear astrophysics with radioactive beams from EXCYT and using MAGNEX; continuation of the successful CATANA tumor treatment program; and developments – within a large international collaboration – towards the under-water neutrino detector in the Mediterranean sea near the laboratory.

5. Resource and Financial Management

This section concerns both human and capital resources.

A large fraction of the personnel of the INFN consists of physicists with doctorates, the educational instinct is almost identical to that of University Professors. In fact the cadre of INFN researchers is considerably enhanced by about 1000 associated University teachers. The influence of INFN on the scientific education of the general public is treated elsewhere. However, there are issues associated with the training of researchers within INFN. At the level of the Ph.D. there are about 300 scholars in formation at any one time and the duration of the Ph.D. training is three years. In order for the research of INFN to maintain a healthy balance between capital investment and personnel, there must be a path for entry to the institute and for growth within the institute. Under normal situations, this would lead to the acceptance of the selected few for permanent positions a few years after Ph.D. Unfortunately, as a result of restrictions on personnel management coming from the government, it has been very difficult to manage this situation in a healthy manner and the age at which the successful applicant receives her or his permanent position has risen by more than ten years over the past 30 years.

Since 1997 INFN, like all the other Institutes of the Public Sector, is constrained by various limits, beginning with cash limits in 1997 and ending with staff limits:

- the budget authorisation of the Institute is constrained by a cash limit so that a forced saving is imposed; the cash limits apply bimonthly (with possible derogations);
- operational expenses are limited at 90% of the 2001 level and procurements are centralised by a public corporation;
- increases in permanent staff are forbidden;
- temporary staff is limited to 90% of the average of the 1999-2001 level.

As we noted in the previous report (2003), past cash-flow limits to budget authorisation led to an increasing forced saving, which reached a peak in 2002; in 2003, since the rate of increase of cash flow limits (5%) is greater than the funding on accrual basis (2%), cash expenses reached the accrual funding. The medium term financial plan (2005-2007) estimates that the forced saving of the previous years will allow an increase of total cash expenses in 2005 and a slight decrease in 2006 and 2007. Even in the case that the rate of growth of cash will be reduced by new financial law from 5% to 2%; the estimated expenses may remain under the cash limits. Of course when the forced saving will finish the constraining limit will be the funding on accrual basis; if the rate of growth will remain at 2% level, this will imply a decreasing share of resources relative to GDP.

INFN is conscious, and the committee is concerned, that in the long run, the scientific activity will be harmed, if the financial laws continue to impose these restrictions. It is hoped that the restrictions are indeed temporary. Meanwhile, INFN has coped with these restrictive rules and used the forced savings as a flexible instrument by which to conditionally finance some large projects.

From 2002 to 2003, as we noted in the previous report, there was a 3% shift of money from personnel to other expenses as a result of the above limits. This creates a real danger of a worsening of the human capital (mainly young researchers), which is as important as physical capital; in fact in the research field, physical and human capital are not substitutes for each other; rather, they are mainly complementary; moreover a general observation may be appropriate: staff recruitment and term contracts are the main item of budget expenses in many Institutes of the public sector in general, and also in Institutes of the research field; Institutes of statistical or economic, or research in humanities, direct 80% or more of their total expenses to human capital; the case of INFN is very different, since less than 40% covers personnel costs; this depends obviously on the cost of fixed capital and operational expenses. For this reason the use of the same limits (to human capital) for Institutes that have so different cost structures, may lead to difficulties and inefficiencies; perhaps those limits should take a ccount of the different distributions of the budget within the different Institutes.

At the time of writing (23-11-04), the financial bill for 2005 is still very uncertain, but will likely be agreed by the end of the year. It seems unlikely that this bill will offer any release from the constraints on recruitment. If the bill is not passed we can expect a continuation with month by month allocations which will impose further stress to INFN's work.

6. Assessment Working Groups, GLV, and Product Validation

Starting from 2000, the CIVR has developed a process for evaluating Italian research structures. The process considered ten criteria in the evaluation. Initially the emphasis was on the scientific criteria; subsequently the socio-economic impacts were considered. The current revision, envisages a triennial pattern and the identification of a certain (large) number of research products. This new methodology was introduced in 2003. There have been a number of clarifications up to June 2004.

INFN has identified a total research participation of 1319 FTE. The formula then requires that 660 products be identified by INFN and validated by the CVI. The guidelines specify a number of product types and INFN has recognized its selected products as belonging to three of these types: Equipment(s), Projects (designs, plans), and Publications. There is a specified format for a Product Card associated with each product. The large numbers involved pointed to a data-base solution. INFN has designed a database for which the utility will extend beyond the immediate evaluation process. The hope is that it can be integrated as a tool useful for the management of each of the scientific areas. The total number of qualified products from INFN is very large, for example an estimated 4400 papers have been written in this period. Initially INFN identified an excess of products for initial consideration before reduction to a final 660.

CSN I has included 206 publications, 13 pieces of equipment, and 6 projects; all 225 been validated. This permits the field to demonstrate well the breadth of the results of the research work. It gives a place for the very impressive technical contributions to the large experiments at the B Factories, at the Tevatron and at the LHC. The evaluation period of three years results in a balanced mix of products including the final phase of publications from the now ceased experiments at the large Electron Positron Collider (LEP) at CERN, the currently operating programs, especially at the B Factories and Tevatron, and the preparation work for the suite of new experiments, most noticeably at the Large Hadron Collider. The pieces of equipment included a number of major contributions to the world investment in this physics. The obvious example is DAΦNE, the high intensity electron positron collider at Frascati.

CSN II chose 114 papers and 8 pieces of equipment. CSN II covers the broad field of neutrinos and astroparticle physics, and as has often been remarked, this is a relatively young field. There are lots of initiatives as researchers examine what are the most productive paths for the astroparticle investigations. The publications well reflect the underlying excitement of this field. Among the pieces of equipment we can identify the equipment, which will enable the exploitation of the Cern-to-Gran-Sasso (CNGS) neutrino beam, which is itself featured, and other important initiatives. All of the 122 products have been validated.

CSN III covers Nuclear physics. The numbers of accelerators in the world available to researchers is larger than in particle physics. Among the 4 pieces of equipment submitted was the FINUDA experiment at the DAΦNE accelerator. The 127 publications demonstrate at one and the same time, the diversity of the field but also the way in which individual experiments mesh together into coherent sub-fields. These include a strong program understanding the many facets of the internal structure of the nucleon and the structure of the nuclear many-body system, through to examination of nuclear matter under extreme conditions of energy and density. The latter is exemplified by the ALICE experiment at the LHC, which is so large as to be a clear phase change in the sociology of the nuclear physics field. All 131 products have been validated.

The products submitted by the Theoretical physics group (CSN IV) are naturally dominated by the 110 publications. Nevertheless, they included one (1) piece of equipment, the APE lattice gauge computing system. This computing engine and its replicas are in use in several countries, particularly Germany, in addition to Italy. All the 111 products have been validated.

For technology and interdisciplinary research (CSN V), projects are not included since all the CSN V projects are, by definition, research projects and inadmissible within the CIVR rules. CSN V includes 5 pieces of equipment along with its 66 publications. As expected the publications are dominated by articles in Nuclear Instruments. Among the pieces of equipment one notices items of significant socio-economic impact such as the cancer treatment facility, Catana, at the Laboratori Nazionali del Sud at Catania. All 71 products have been validated.

In all, and as mentioned above, the grand total is 660 products.

The impact factor of the publications provided involves the particular INFN contribution to the paper. However, within a subfield, for example particle physics, the contributions follow rather closely the total numbers of researchers from each country. Consequently the dominant driver of the impact factor comes from the choice of journal in which the field publishes. There are also peaks of the impact factor distributions at the values driven by the various individual journals. These considerations are what result, for example, in the impact factors for CSN V, technology, being lower than those of other groups; the dominant journal, Nuclear Instruments, ranks lower than, for example, Physics Letters.

The CVI has examined the list of products provided by INFN. In all cases, a documented description, or the product itself was provided. This considerably facilitated the validation process. The committee also examined in a little more detail, some of the actual products. This gave a very positive though subjective view of the work of INFN. For example, it is clear that publications in both bottom and strange quark physics indicate the strong participation of INFN in attempts to understand fully the charge parity symmetry violation in quark physics.

It was remarked above that the total number of publications produced by INFN researchers far exceeds that required. The publications are predominantly in Physical Review Letters, Physical Review, Physics Letters, Nuclear Physics and The European Physical Journal with technical publications appearing in Nuclear Instruments. All these are high quality refereed journals. Three of the publications were in Nature, which is a relatively rare occurrence for any of the INFN fields. One might ask whether the chosen publications have a dramatically larger impact factor than those not chosen. For experimental particle physics the impact factor for the selected papers was about 4.75, however that for all papers was 3.46, lower but not excessively lower. The overall quality therefore also appears to be high.

The selection criteria adopted by INFN were as follows:

- for publications,
  - quality and scientific importance of the product, international level of the journals and bibliometric indexes;
- for projects and equipments,
  - outstanding quality, recognized scientific/technological significance, important involvement of INFN researchers.

In fulfilling its mandate, the CVI has had an opportunity to examine the process of identification and evaluation of products. Initially, the committee was somewhat concerned that the global performance of the institute, as compared for example, to that of individual University researchers, might not be well measured. However the process does permit one to develop a good impression of the actual quality of the work being executed and the results being obtained. In addition, INFN has embraced the need to participate and, a straightforward approach has been adopted; it is hoped that the resulting data base system will be of considerable internal value.

The CVI membership comes in large part from competitor or collaborator countries and institutions and has repeatedly praised the quality of the INFN research. The evaluation described here confirms that view but based on objective measures.

In conclusion, INFN has completed its identification of the research effort, the consequent requisite number of research products. The CVI has validated all the products individually.

7. Self Assessment: Productivity

Introduction and overall comments

In preparation for the CVI evaluation of the scientific programs of INFN, the institute developed a rather comprehensive summary using such objective measures as the numbers of publications per full time equivalent researcher and the impact factor associated with those publications. Comparisons were made in various ways in the context of international research since for the institute these are the primary ways in which it measures itself. In addition to the criteria associated with individual collaborations, the institute considered both the organisation of, and the presentations at, international conferences. Further measures of the internationalisation used were the fraction of work executed in international collaboration and the fraction of funding devoted to those efforts. Finally, the extent to which INFN researchers took positions of leadership in these international efforts was considered.

Subnuclear Physics

We have written in the earlier narrative chapters that the work in sub-nuclear physics (CSN-I) is of a very high quality with participation in at least one of the large collaborations in any of the key facets of the subject from the energy frontier, through to physics, especially the determination of CP violation, in the Beauty(Bottom) and Kaon systems.

The qualitative judgement is amply demonstrated by the numbers. A certain degree of innovation has been used to find a measure which differentiates the performance of INFN compared to the international partners. They find that in examples of experiments which are in direct binary competition, for example Zeus versus H1, BaBar versus Belle, CDF versus D0, those in which INFN participates compete well quantitatively with those in which it does not.

The level of internationalisation is extremely high, in the range 86% to 95%, depending on whether the measure used is participation, investments or publications.

Some measures of leadership in different areas are as follows: in the experiments in which they participate, INFN researchers occupy 24% of the leadership roles. A measure of front line participation is the number of contributed talks at international conferences. On a basis of 735 talks, INFN researchers with 11.8% exceed all countries except the US, and, in Europe, Germany, with which they achieve parity.

Over all the quantitative measures applied, the scientific productivity in his sub-field is outstanding.

Astroparticle Physics

All quantitative indicators show that the quantity and the quality of the scientific productivity of CSN-II is excellent and stands out favorably in international comparisons. This is true for the 508 articles produced during the three-year period covered by the review and it is particularly true for the 114 selected, outstanding papers. The explicit degree of internationalisation is 64%, and is influenced by the excellent facilities in Italy, available at the Gran Sasso Laboratories giving a consequent imbalance towards purely Italian groups, and the European Gravitational Observatory, EGO at Cascina, which is home to the Virgo experiment. At the Gran Sasso Laboratories, the number of non-Italian researchers equals that of Italians, and they come from all over the world.

The milestones, as defined by the various projects in the framework of the INFN internal funding procedure, are achieved on time at the level of 80%. This is a positive result, emphasizing that the projects have ambitious goals.

In conclusion, the INFN scientific activities in the field of astroparticle physics and neutrino physics score high in terms of productivity and quality. All major projects are well embedded internationally; the rate at which projects are concluded successfully and at which new projects are undertaken underlines the dynamic nature of this field of research.

Nuclear Physics

As in the other research areas within INFN, the statistical numbers on the activities within CSN-III reflect, overall, on the following three performance characteristics: i) the scientific impact factors and the productivities per researcher rank among the top group of the science organizations worldwide with major involvement in this area of research; ii) in this group, the Italian science participation shows above average scientific leadership responsibility (also internationally); iii) the latter is also true in terms of the INFN funding fraction which reflects well (being noticeably smaller than the leadership fraction) on the overall cost-to-benefit ratio of the program. An extensive study of publications shows that Italy, with slightly less than 13%, has a comparable fraction of publications to France. Both are significantly less than Germany which is recognised to emphasise investment in this field and twice that of the United Kingdom.

This good performance has to be seen within the context of the program to operate and maintain the two Italian national laboratories in nuclear physics (LNL and LNS), which requires substantial infrastructure efforts and resources (plus the involvement in selected activities at the two other national laboratories not directly within CSN-III, but with supporting commitments). Direct measures of the degree of internationalisation yield 98% as the fraction of the budget, 93% of the researcher involvement, and 91% of the publications.

Theoretical Physics

The five sectors within CNS-IV have shown stable productivity over the last three years and sustained impact in their respective areas. The overall productivity corresponds to 3-4 papers signed on average by each FTE in a year. This is a very good score, even when compared with that of the theory group at CERN, a pure research-oriented group, whose number is only 30% higher. Similarly, the average impact factor of 2.8 for CNS-IV papers is only about 30% lower than the one of CERN/PH-TH. INFN's share of invited talks at International Conferences is also quite impressive (about 15.4% even in a sample that excludes Conferences held in Italy).

Out of a total of about 2400 publications 110, covering all five sectors, were selected. They are of very high quality and typically classify well within the top-cited ten papers in their respective areas. The single product of CNS IV, the APE project of a dedicated computer, is attracting much interest among lattice-gauge-theory practitioners across Europe.

The amount of internationalization is very good, with basically every *Iniziativa Specifica* operating within an international context. Almost half of the produced papers have at least one foreign affiliation, and about half of the budget is spent to foster international collaborations.

Innovation in CNS IV is excellent, perhaps also as a result of the smaller inertia of theoretical projects over long-term experimental ones. An international referee system guarantees that the approved projects are well tuned to tackle the most challenging problems as they arise. Over the period being reviewed three new initiatives were activated in astroparticle and cosmology and one in the theory of the QCD phase transition and its application to physics at LHC-ALICE.

Innovation and Technology

The work under the auspices of this scientific committee is characterised by the relatively small collaborations and their relatively short duration. The journals are international, for instance, Nuclear Instruments and Methods but they do not enjoy the cachet, except among the specialists, of Physical Review Letters. The primary contributors are INFN, France, Germany, Japans, Russia, the UK and USA. Italy produces essentially the same fraction as France and somewhat in excess of the UK.

Operationally, this is a very difficult field to manage. Research and Development has, by definition, nothing that is sure to work. Therefore the achieved rate of 84% of milestones agreed between researchers and referees is excellent. One of the goals of this research is to provide an understanding of detectors and their construction which will inform and influence the primary physics research experiments. Quantification of this "fallout" suggests that better than 20% of all CSN V experiments have an effect on primary experiments.

The field occupied by INFN is characterised by the rapid adoption of new detector techniques. To play a role, the CSN V researcher has to work at presenting the new ideas and results. The success of CSN V in this area is indeed reflected in a very healthy number of contributed talks, two rising to three over the evaluation period.

Consistent with the short term, frontier, nature of the work about 30% of the experiments were new in each of 2002 and 2003 rising to nearly 50% for 2004. The field is also remarkable for its ecumenical mix of technologies; there are substantial contributions to new materials, software, electronic, detectors and sources for particle accelerators.

Summary

The general level of scientific productivity of INFN is impressive. The resources are well used and it is noteworthy that the appreciation of the worth of the INFN participation is reflected in a participation in the international leadership which is more than proportional to the resources invested.

The primary measure of productivity, publications, compare favourably with those of institutes in other countries. It is a relatively straightforward conclusion that INFN places Italy in the top 5-7 countries worldwide in the relevant fields.

As a routine part of their process, the INFN researchers, define, in advance a number of milestones against which they are to be measured. The fraction of these milestones achieved by the predefined date is in the range 75-85%. This demonstrates two things; first the researchers are not setting for themselves goals, which are too easily achieved, rather they have challenged themselves; second, they are nevertheless achieving a considerable respectable fraction of their goals so they are not making falsely impossible goals.

In a word the work of INFN, as gauged by quantitative measures, is outstanding.

8. Self Assessment: Socio-economic Impact

Different fields are identified to evaluate the socio-economic impact of INFN. A first part is the communication and dissemination of scientific culture to the general public, up to the training of students, in particular to allow the preparation of diplomas such as the Laurea or the Dottorato (PhD). Further on, particular research projects have an interdisciplinary character, where the role of INFN is mainly to apply high level technologies for research in other fields, provide facilities or computational power and infrastructure. Finally the development of experimental equipment at the cutting edge of technology requires a collaboration with local industry and the fall-out of some technological developments can find industrial applications in other sectors and be commercially exploited.

Dissemination of scientific culture to the general public has several aspects: the organization of exhibitions and public events like "open days" or conferences aimed at a wide audience, up to the interaction with medias, journals, scientific magazines or radio and TV. These efforts are organized since 2002 by a communication office within INFN, comprising a staff person with scientific and journalistic background as well as four temporary fellowship positions. In each section or laboratory of INFN a person is in charge of public relation and in close contact with the central office, which ensures the liaison with other Italian and international institutions as well. The impact generated is impressive: about 70000 visitors attended events organized at the national laboratories, including events particularly targeted to High Schools, such as meeting with High School teachers or stages for High School students, which reached more than 700 schools. The importance of the interactions with High Schools can not be underlined enough in view of the decreasing number of University Students in the scientific sector. The coverage of INFN in the medias reached up to 60 articles worldwide in a month for the inauguration of VIRGO, however continuous attention is given also to local newspapers, covering events in the neighboring laboratories and creating a valuable contact with the local structures.

Via the close association of most INFN sites with Universities through the associated researchers as well as personal teaching by INFN staff, INFN contributes directly to the high level education in Italy. An integral part of the INFN activities is the supervision of research activities of students preparing a Laurea or doctoral degree. During the period of 2001-2003 close to 1100 Laurea diplomas were prepared in association with INFN and about 360 PhD theses. This is an impressive number, with in average fifteen Laurea and five PhD degrees per INFN-site and year. A study carried out on the professional evolution outside INFN after obtaining a degree, has shown that about 60% of the post-Laurea stayed within research either in Italy or abroad, and about 20% joined private industry or software companies. The possibilities for post-graduates to find work in the private sector should be enlarged, which requires to promote the faculties acquired during the preparation of a PhD, in order to increase the awareness in the private sector of the potential of candidates coming from physics. This can be achieved in particular by encouraging cross-training of students between INFN and a company, but also by organizing encounters between students and industrial representatives or keeping a contact list of former students working in industry.

Some of the projects carried out by INFN are focused on interdisciplinary research. The main contribution of INFN is to provide facilities, technological solutions or computing infrastructure to be used in other fields. Some projects to mention are the creation of a cultural heritage, a low radioactivity and a deep sea laboratory. Applications of nuclear technologies allow contributions in the domains of civil security, such as detection of explosives, and also in the treatment of nuclear wastes. With the pioneering work of INFN building the first synchrotron, a major contribution of INFN to multidisciplinary research is the use of synchrotron light sources. A major investment for INFN will be the future project of building a SPARC/SPARX multipurpose X-ray Laser with Ultra-High Brilliance, for which 96 Meuros have been already allocated by the Italian Government and which will allow Italy continue to be one of the few worldwide facilities that respond to the increasing demand on high intensity light sources from both public research and industry. Accelerator technology is also used in other domains, and Italian groups have been the initiators of the use of particle beams in cancer treatment. The facility Catana, in Catania, Sicialy, which is in operation, as well as the CNAO-project applies the know-how available within INFN directly in the medical sector. The use of advanced computer architecture and the development of worldwide network infrastructures for data analysis in the primary domain of INFN, has built up an expertise that lead to the realization of projects like GARR, APE or the GRID, which have been particularly appreciated by the Italian industry.

The huge variety of possible spin-offs reflects the intellectual and technological richness within INFN and the importance of providing a playground to experiment on new ideas. The annual school on Science and Industry, organised in Erice, Sicily, is a valuable meeting ground on which dialogues and contacts can be initiated. However to carry out the development of fall-out products through to industrial use, partners from industry are necessary and it is only possible in a few poles of excellence. The deposition of patents is to be further encouraged and the creation of a support structure to ease this process shows the concern of the institute to pursue this direction. Currently ideas are discussed on possibilities to facilitate the cooperation and transitions between researchers and companies.

The majority of interactions between INFN and industry occur via the acquisition of supplies and services from companies in order to built and exploit experiments. INFN purchases in particular high-technology items for which 68% of the budget allocated for experimentation is invested, and about 55% of this fraction are spent, in Italy. Among those supplies, 20% require a customized solution and 23% require some R&D. An analysis of the economic impact of INFN has been carried out using Leontief's model. The outcome shows that 1 euro spent by INFN on high-technology produces in average a return of 1.65 euros, with a particularly favorable return in the case of joint R&D, where the return factor reaches 2.73 euros. Another indicator of the positive socio-economic impact is the ratio of the Italian contribution to CERN, which has been 12.6% of the total budget in average from 2001-2003, and the fraction of the contracts awarded to Italian companies by CERN of 14.2%, leading to a return factor of 1.13, comparable to France, one of the host countries, and about twice as large as for Germany, the UK or Spain.

Overall the socio-economic impact of INFN can only be judged positively, even though a further increase of its role within the Italian society is anticipated and should be encouraged. Initiatives to spread scientific culture should be promoted by both providing enough means for communications as well as recognition of the individual efforts made by researchers. The importance of education in the modern society does not need to be stressed and the implication of INFN in this domain is most important and up to the level required. The contacts with industry are especially established in the sector of high technology and the development of customized products or common R&D are the most direct ways of collaboration and technology transfer, generally judged positively by the industrial partners. Interest in further improvements and extensions of the collaborations are expressed from both sides, and even if it is not the primary mission of INFN, the potential for INFN to act as an incubator for new technologies in some fields is clear.

9. Conclusions, Remarks, Recommendations

The CVI of INFN met June 30-July 2, 2004, and November 22-23, 2004. This report is written following the new CIVR guidelines which foresee a triennial basis for the evaluation of the activities of the several research institutes and of the universities. The report is based on summary reports of INFN activities and plans for the future, received this year and in previous years.

The CVI heard presentations from both the departing and incoming Presidents of INFN since the term of President Iarocci ended on June 30, 2004 and the start of that of President Petronzio occurred on July 1, 2004. E. Iarocci concentrated on the status during the past year while R. Petronzio gave his vision of the future. The committee also heard presentations from the presidents of all the five scientific committees and from the directors of each of the National Laboratories, those of Frascati, Gran Sasso, Legnaro and Sud.

A description of the activities of the self assessment working group was provided. This set the activities of both the CVI and the INFN in the context of the requirements of the CIVR. The number of potential products of the research of INFN far exceeds that requested by the CIVR. A selection procedure was adopted. Rather than concentrating entirely on refereed publications, INFN chose also to select a number of projects and pieces of equipment. The methodology applied to the choice of papers paid some attention to the impact factor of the publication but also gave some importance to the judgment as to the importance in terms of setting a direction for the research.

In the presentations of the leaders of the individual committees and laboratories, the CVI developed a judgment about the key areas of importance called out by the CIVR for evaluation. The CVI appreciated greatly the preparation, with this in mind, of the triennial report of the INFN. In this Executive Summary, we briefly address each of the points.

1. Scientific performance

The physics research which falls within the purview of the INFN has been marked by a phenomenal share of the Nobel prizes in physics over the past fifty years. The INFN was one of the first national organisations to form covering this field and its existence has coincided with this “belle époque”. Two recent examples of major discoveries in particle physics, that of the agents, the W and Z bosons of the weak force, and of the heaviest of the quarks, the top quark were marked by a very strong and recognised Italian participation. The work of the INFN in particle physics is among the strongest in the world. The innovation which has marked the relatively young field of astroparticle physics has been particularly important with the development of the Gran Sasso Laboratories and a series of seminal experiments. Nuclear physics has undergone considerable consolidation as a field and INFN has followed this consolidation and has embraced the new opportunities to study nuclear matter offered by the heavy nuclear beams soon to be available at the Large Hadron Collider. The drive of this experimental work has been complemented by a very strong Italian theoretical physics school often recognised across the world for its close ties to understanding the experimental results. In turn, the experiments themselves are underpinned by innovative technological approaches which also enhance the impact of the science on society.

2. The socio-economic impact arising as a result of research

As discussed in Chapter 8, the work of the INFN is consonant with the use of technologies which are at the cutting edge of what is possible. This is particularly true for the employment of advanced electronics and computing. The field has largely been defined by its use of accelerators. However, today, the majority of accelerators operate in the service of a broad spectrum of applied physics and medicine. The sensitivity of the field to this aspect of its work has continued to develop. The institute is aware that it is necessary to develop its ability to inform and help industry to a level at which there is a sense of full partnership by all.

3. Review of management and steering policies especially with regards to strategic planning and research implementation programs

There are two approaches to setting the direction for the research of the institute. The first involves the initiatives of the individual researchers, who generate ideas and self-organise into groups which, along with like minded groups elsewhere, in Europe or other parts of the world, decide to propose an experiment which the institute then considers carefully at multiple levels before approving support. The second involves the identification of strategic opportunities, especially with respect to innovative infrastructure, by the Directorate. These initiatives are then discussed within the Directorate and eventually by the Board of Directors. The system seems to have an excellent balance with the two approaches complementing each other and ensuring a vibrant program.

4. Appraisal of allocated human resources including aspects related to researcher training and growth.

Human resources are a key issue for the institute. INFN has demonstrated its capability as a fertile training ground for highly competent researchers with a top class Ph.D. program as its base. Nevertheless, the career path for physicists in INFN is hampered by the external constraints imposed by the fiscal laws. These are intended to prevent the unbridled growth of an unproductive bureaucracy. In the case of INFN, which relies on a healthy balance between salary costs and research investment costs, these external constraints have resulted in career paths which compete poorly with institutes in other parts of the world and indeed, within Italy, do not match the possibilities within industry.

5. State of international liaisons and research cooperation ventures

The largest part of the research, in both theoretical and experimental areas of the INFN, is conducted in concert with international partners. In many cases these are collaborations of researchers from a large number of countries who self organize to create the combined resources to embark on the execution of major experiments costing many hundreds of millions of Euros at one of the large laboratories of the world. Several experiments operate at the leading laboratories in Europe, for instance at CERN, Geneva, GSI, Darmstadt and DESY, Hamburg. Italian groups are active in experiments on other continents, primarily at several United States national laboratories but also in China and in South America. Finally an international collaboration in particle physics operates an experiment at the Laboratori Nazionali di Frascati, and other enterprises use the other INFN national laboratories; this demonstrates that the collaborations are bi-directional and that Italy plays its full role in also providing valuable contributions to the physics resources of the world.

6. Appraisal of research infrastructure and related services, with great emphasis on deployment of high technology.

The most prominent aspects of the INFN infrastructure are the four national laboratories and the European Gravitational Observatory at Cascina.

Each of the national laboratories has a distinguishing feature. LNF have been the leaders in colliding (electron-positron) beam machines since the first example AdA more than forty years ago. Currently the DAΦNE complex is the highest intensity of its energy range and, when attention is paid to the effect of energy in the calculation of luminosity, the performance is comparable to that of the highest luminosity performance of the B factories.

The Laboratori Nazionali del Gran Sasso are the youngest of the laboratory complexes and represented a major advance which made Italy world leaders in Astroparticle physics and other fields which demanded a well developed underground infrastructure. The support for sophisticated and large experimental structures in the low background underground environment continues to be competitive on a world scale. Currently several of the larger experiments have substantial non-Italian participation and contributions, in particular from the US and from Japan.

The Laboratori Nazionali di Legnaro is primarily a nuclear physics laboratory and, along with LNS, it operates accelerators which form key components of the European network of such accelerators. The special nature of its facilities have also lent themselves to use as a fabrication centre for the CMS experiment being constructed at the Large Hadron Collider at CERN.

At the Laboratori Nazionali del Sud, the high quality nuclear physics experiments performed on the accelerators are augmented by a very active program of treatment of cancer of the eye using proton based radiation therapy.

The VIRGO, gravitational interferometer, has been designated as the European Gravitational Observatory. The latter came as a result of its already international structure; VIRGO is constructed and operated by a strong INFN-IN2P3 (France) collaboration.

7. Establishment's capacity to attract, manage and gain access to research related human, financial and material resources

INFN has received its funding predominantly from the Italian Government. However in addition to its primary mission, INFN was asked to perform the lead role in the development of the Italian network infrastructure. It is in this area that INFN has been a strong participant and has received funding from the EU, in particular for the EGEE project. There has been a concerted effort to develop a framework in which the participation in awards from such sources as those from the EU is consistent with the understood strategic directions of INFN.

8. The principle strengths and weaknesses with regard to research management and, where applicable with regard to quality and pertinence of all endeavours aiming at promoting research outcome and skills generated by it.

INFN has a rather sophisticated system of governance.

The basic work is generated by proposals from individual researchers, or groups of researchers within each of the five scientific fields. A proposal is scrutinised for quality and likelihood of success, for the consonance in direction with that of the institute, and is refereed in detail by other researchers, the first level of "peer review". If successful the proposal is brought before the relevant national committee where a decision is taken whether or not to fund the proposal. It should be noted that each of the national committees contains representatives from each of the sections of INFN and of each of the national laboratories.

In addition, the INFN Directorate may create a "special project". This is a device to provide support for a direction which may be broader than an individual field of research. It may also be that the initiative is a very large one and deserves to be steered by one of the members of the Directorate. This device is very effective in adjusting the direction of the institute. The "bottom-up approach normally in action is empirically inherently conservative. The top-down special projects often reflect a vision of the future adopted by, if not always generated by, the INFN Directorate.

9. Establishing a link between internal decision making and research program outcomes

As described in the comments above, the special projects are capable of generating major changes in the research program. One example is the VIRGO, gravitational interferometer at Cascina. It is the most advanced device of its type and has placed Italy, along with only the US and Germany, at the forefront of this field. A second example is the decision, taken eventually by the third national committee, for nuclear physics, but encouraged by the INFN Directorate, to have a major participation in the ALICE experiment at the Large Hadron Collider at CERN. This has effectively and substantially shifted the research emphasis within that sub-field in Italy. As a final example, the decision to approve Italian proponents of the BaBar experiment ensured a strong Italian participation in an experiment which was only possible at two facilities, one in Stanford, USA, the other in Japan. These experiments have been among the most prolific producers of results over the past four years.

10. Conclusions and recommendations

The general conclusions of this report are very positive. INFN has strength in most of the areas of research in which it participates. In this respect it sees correctly that its competitors and partners are the four large countries of Western Europe, the United States and Japan. Increasingly the size of the installations is global and partnership has already overwhelmed competition as the modus operandi.

Italy is a full partnerand exploits in the best possible way the available resources.

The work of INFN is outstanding.

Where INFN and the CVI both see opportunities is in the dissemination of technology to industry, to medicine, to other science and to the populace in general. Over the past 5 years the CVI has seen this aspect of the work of INFN receive more attention. This matches the developments elsewhere in the world. It has become less and less acceptable that the secrets of the field be limited to a few aficionados; there is no room for an exclusive quasi-priesthood. Further, the technology which the field generates and of which it is such a facile practitioner is just the kind of faculty needed by modern society in general. An educated populace will take wiser decisions about the power over nature which it wields so carelessly.

The CVI advocates that INFN continue to search for ways to enhance its material contributions to Italian society both through dissemination of its techniques and its knowledge and to share its excitement in its work.

Appendix A – Membership of the committee

- Dr. U. Bassler, LPNHE- U. Paris VI/VII, France
- Prof. C. Castellano, ESAOTE SpA, Genova, Italy
- Prof. J. Engelen, Nikhef, The Netherlands
- Prof. W. F. Henning, G.S.I., Darmstadt, Germany
- Dr. H.E.Montgomery(Chair), Fermi National Accelerator Laboratory, U.S.A
- Prof. R. Paladini, University Roma 1, Italy
- Prof. G. Veneziano, CERN., Geneva, Switzerland

PROF. L. MANDELLI (SCIENTIFIC LIAISON), UNIVERSITY OF MILAN, ITALY

Appendix B

Agenda of the INFN CVI Meeting

Rome, 30 June - 2 July 2004

Wednesday, June 30

09:00	Welcome and Introduction from the President of INFN Discussion and approval of the Agenda *Closed session*	E. Iarocci
09:30	Report on the status and achievements of the INFN	E. Iarocci
	The 2005-2007 INFN Plan *Discussion*	R. Petronzio
	Break	
11:10	Report on the experimental subnuclear physics with accelerators-CSN1 *Discussion*	U. Dosselli
12:20	Report on the experimental subnuclear physics without accelerators, astroparticle and neutrino physics-CSN2 *Discussion*	F. Ronga
13:30	*Lunch*	
14:30	Report on the experimental nuclear physics-CSN3 *Discussion*	E. Chiavassa
15:40	Report on the theoretical physics-CSN4 *Discussion*	G. Marchesini

Break

17:10	Report on the technological and interdisciplinary research-CSN5 *Discussion*	U. Bottigli
18:20	Closed Session	
19:15	Queries and questions to the INFN Executive Board and to the Scientific Committee Chairmen	
20:30	*Social Dinner*	

Thursday, July 1

09:00	Report on the activity of the GLV *Discussion*	A. Bertin
10:20	Report on the Frascati National Laboratory	S. Bertolucci
10:40	Report on the Gran Sasso National Laboratory	E. Coccia
Break		
11.15	Report on the Legnaro National Laboratory	G. Fortuna
11.35	Report on the South National Laboratory	E. Migneco
Discussion		
12:15	Responses to queries and questions posed to the INFN Executive Board and to the Scientific Committee Chairmen	
12:45	Closed session	
13:30	*Lunch*	
14:30	Report on resource management: budget and personnel	A. Scribano G. Ricco
Discussion		
15:45	Closing discussion with the Executive Board	
17:00	Closed session (report drafting)	

Friday, July 2

9:00	Closed session (report drafting and preparation of closeout presentation)
Break	
11.30	Closed session (report drafting and preparation of closeout presentation)
13:00	*Lunch*
14:00	Closeout: Comments and remarks by the CVI members *Discussion* Closure of the official part of the meeting
15:00	Closed session (draft of the final report)

Final remarks

- INFN Executive Members will be present to the presentations and discussions. All other invited participants will be present at the presentations and at the pertinent discussions.
- The time reserved for the presentations of the scientific programs are expected to be equally shared between presentation and discussion.

Appendix C

Agenda of the INFN CVI Meeting

Rome, 22-23 November, 2004

Monday 22 November 2004

09:00	Welcome and Introduction from the President of INFN Discussion and approval of the Agenda	R. Petronzio
	Closed session	
09:45	GLV report on the scientific activity and on the socio-economic impact of the INFN research	A.Bertin
10:45	Data used for the CIVR report	U. Dosselli
11:30	*Break*	
12:00	Discussion and closed session	
12:45	*Lunch*	
14:00	Closed session	
15:00	Queries and questions to the INFN Executive Board	
15.30	*Break*	
16:00	Report drafting and preparation of closeout	
20:00	*Social Dinner*	

Tuesday, November 23

09:00 Responses to queries and questions posed to the INFN Executive Board

09:30 Closed session (Report drafting)

11:30 Closeout: Comments and remarks by the CVI members
Discussion

12:30 Closure of the official part of the meeting

13:00 Lunch

14:00 Closed session (draft of the final report)

Final remarks

- INFN Executive Members will be present to the presentations and discussions. All other invited participants will be present at the presentations and at the pertinent discussions.
- The time reserved for the presentations of the scientific programs are expected to be equally shared between presentation and discussion.