

INFN INTERNAL REVIEW COMMITTEE (CVI) REPORT

Rome May 4-6, 2001

Contents

Executive Summary

1. Introduction
2. Structure and organization
3. Scientific and technological activity
4. The National Laboratories and Sections
5. Institutional and Resource Management
6. Internal review system
7. Future reviews
8. Conclusions, Remarks, Recommendations

Appendix A – Membership of the committee

Appendix B – Agenda of the INFN Evaluation Committee (CVI) (Rome, May 4-6, 2001)

Executive Summary

The Istituto Nazionale di Fisica Nucleare is the institute for research in particle, astroparticle, and nuclear physics in Italy.

The Comitato di Valutazione Interna (CVI) was appointed (Appendix A) by the Board of Directors of INFN and charged with performing reviews of the activities of the institute on a regular basis. The activities of the CVI are part of a more global response to the Italian governmental requirements for assessment, using criteria of certified validity and the highest possible objectivity, through the auspices of the Comitato di Indirizzo per la Valutazione della Ricerca (CIVR).

The initial meeting of the CVI took place in October 1999, under the Chairmanship of Prof. N. Cabibbo. At that time, the committee concentrated on understanding how to perform reviews of INFN, which would be responsive to the needs of the CIVR and to the management of INFN. During late 1999 and 2000 there were interactions between INFN, and all its National Scientific Committees (CSN) to establish the criteria to be used in the conduct of their selection processes. The criteria are accompanied by a weighting scheme, which appropriately reflects the relative importance of the different criteria. The weighting varies slightly from activity to activity. The criteria were presented to the CIVR, which approved.

In October 2000, the CVI was provided with the Piano Triennale 2001-2003. They were also provided with the written reports, from the five CSN. The reports contain the decisions concerning the allocation of resources for 2001. In addition, the committee was provided with access to the summaries of the activities of, and the milestones anticipated by, each of the experimental activities. The provision of this information had been a recommendation of the 1999 CVI and the INFN is commended for its excellent response.

The CVI met in Rome, December 1-3, 2000. It heard verbal reports from principals in the INFN management and from the Chairpersons of the five CSN. Extensive time was devoted to questioning of the INFN representation and in deliberation in executive session. The CVI produced a written report, which it delivered to the President of INFN.

The CVI met again in Rome, May 4-6, 2001 (Appendix B). It heard verbal reports from principals in the INFN management and from the leaders of the Internal Evaluation Working groups (GLV) of each of the five CSN. As has become customary, extensive time was devoted to questioning of the INFN representation and in deliberation in executive session.

At this stage, the process of incorporating explicit objective criteria in the internal workings of INFN has completed one full annual cycle. A nearly complete framework and methodology have been put in place. However, the subsequent progress will involve considerable effort to consolidate and refine the process. For example, in the reports to the May meeting, the CVI saw for the first time, the internal evaluations performed by the evaluation working groups (GLV). For some of the CSN, the external, international data are limited to single countries. Nevertheless, these are already extremely informative. It must be emphasized that the effort in using the objective criteria for self evaluation has already been considerable. The committee was very impressed by the progress made by INFN in this area.

Following consideration of the categories of the agreed criteria, and after consideration of the internal evaluation results, we have the following comments:

The scientific content of the overall program is exciting and excellent. The particle physics and theory contributions have a strong impact on a global level. The initiatives in astroparticle physics have placed INFN in the forefront of European efforts. The spectrum of nuclear physics, both in Italy and at external laboratories, is on a high level and touches all the primary fields of interest.

The execution of the experimental program has stimulated development of many innovative detector techniques, which have greatly benefited the physics. The impact on society and industry in particular has been strong in some areas and its impact is measurably expanding into new areas of medical and life science applications.

The resource management process is judged to be very good. The general financial situation seems to be balanced, even if the introduction of cash limits, since 1998, has significantly conditioned the research activity.

The following caveats apply to the conclusions:

- a) The view taken by the CVI was "International"; the implication is that the standards being used are those of physics on a worldwide scale. As far as the committee is aware, there is no comparable review, of any national physics institution, anywhere in the world. Indeed, the comparisons between countries presented by the GLV represented the first examples of such comparisons seen by several of the members of the committee.
- b) The first annual cycle of the full process is only just complete, both reviewers and reviewees are still learning the system; as such, the conclusions may be treated as tentative.

We note with pleasure, the substantial efforts on the part of INFN to be responsive to our main recommendations made in earlier reports.

1. Introduction

The CVI (Appendix A) met May 4-6, 2001 (Appendix B). This was the third meeting of the CVI. The initial meeting of October 1999 had a primary goal of establishing a methodology. The second review in December, 2000 was the first of the regular reviews but it lacked input data concerning institutes in other countries. Given the short time between the December, 2000 and May, 2001 reviews, it was agreed that this report be based substantially on that of December, with incremental changes to reflect the new information and perceptions. A separate report was also generated in response to a request from the CIVR, that INFN produce a concise report of its activities in the period mid 1999-2001 and that CVI, in turn, produce a concise review.

The committee was provided with:

1. Report on the Activity of the INFN in the last two years: 1999-2001.
2. Annual Reports from each of the CSN for the year 2000.
3. Report of the GLV including the reports of the individual GLV associated with each of the five CSN.

The committee was very impressed with the presentations of the activities of the institute. Many exciting opportunities are offered to Italian physicists working within INFN to initiate, to lead, and to participate in, international programs of nuclear, particle and astroparticle physics at the forefront of attempts to reach a fundamental understanding of our world and its origins.

The structure of this report is as follows. In Section 2, we provide a brief overview of the internal organization of INFN, its structures and its committees. In Section 3, we summarize the scientific programs associated with each of the National Scientific committees. We give an appreciation of the strengths of each. We started a cycle through the major operational units so Section 4 is devoted to National Laboratories and Sections. In Section 5 we discuss the Institutional and Resource management of INFN. Section 6 contains a discussion of the Internal Review processes by which INFN decides on the allocation of resources to the individual initiatives. Following the initial report of 1999, we use Section 7 to make suggestions for the evolution of the CVI process, in particular if there are any recommendations for modifications to the process they will be found in this section. Finally in Section 8, we attempt a synthesis of the report into a series of findings and commentary on the individual aspects of INFN, the activities of the CSN, and the overall Institutional and Resource Management.

2. Structure and organization

The Institute is organized in local research centers, which comprise 19 "Sezioni", research units located in physics departments of Italian Universities, and 4 National Laboratories, research centers which host major research facilities open to Italian as well as foreign research groups. Smaller units, the "Gruppi collegati" are hosted in Universities which do not host "Sezioni", one of them being in the Istituto Superiore di Sanita' (the National Health Institute). Each of the eight existing Gruppi collegati relies on a Sezione or National Laboratory for their administrative services, but its members share with other INFN physicists the possibility of taking part in a variety of research activities. The presence of INFN research in Italian Universities is larger than implied by these numbers. Although about half of the Italian Universities do not have a Sezione or Gruppo Collegato, many of them have faculty members active in INFN research.

Thus, INFN represents a strong presence in the Italian university system, a fact which is reflected in the large number of laurea degrees and doctoral theses obtained by students participating in the research of INFN. These data were available only for some

of the research lines – theory and technological research – and it would be interesting in the future to have wider statistical information on this important subject.

The management of INFN is the responsibility of a Directive Council (Consiglio Direttivo), the President and a five member Executive Board (Giunta Esecutiva) that includes the President and is embodied in the Directive Council. In their deliberations these managing bodies use the advice and recommendations of the five National Scientific Committees (Commissioni Scientifiche Nazionali), one for each of the main research lines:

- I experimental subnuclear physics with accelerators;
- II experimental subnuclear physics without accelerators and astroparticle physics;
- III experimental nuclear physics;
- IV theoretical physics;
- V technological research.

These committees contain elected representatives of the researchers active in each of the major units, Sezioni and National Laboratories. The committees issue recommendations on the research programs in each research line, the experiments to be accepted for financing, and the allocation of resources among the different experiments.

The National Scientific Committees are peculiar to INFN. They allow a good balance between the need to assure a well managed program, which is the responsibility of the Council, the Executive Board and the President, and the free initiative of scientists, represented by proposals emerging "bottom up" from the research groups. The principle of democratic participation of the personnel extends to other aspects in the life of the institute. For example, the Directors of the Sezioni, and the Directors of the National Laboratories, are nominated by the Council, after a consultation-by-ballot of the personnel. In addition to the National Scientific Committees, the National Laboratories each have an international Scientific Advisory Committee or Program Advisory Committee.

INFN has a staff complement of about 1750, of which 621 are researchers, 251 technological experts (applied physicists, engineers, etc.), 851 are technicians and 291 provide administrative support. The INFN research personnel also include research and other staff belonging to Universities and to a much lesser extent to other organizations. A part of this extra personnel, fully involved in INFN research, shares with INFN personnel a number of important privileges, including that of participating into the elections of members of the National Scientific Committees, and in the ballots for the nomination of directors of the Sezioni and Laboratories. This includes 950 research associates and 200 technical support members. Research people with only partial involvement in INFN projects, including thesis students, can also be formally associated to INFN without sharing electoral privileges.

3. Scientific and technological activity

3.1 Physics with accelerators: CSN I

The program of CSN I encompasses essentially two thirds of the field, which traditionally is labeled Elementary Particle Physics. The excluded one third concerns neutrino physics, which falls within the purview of CSN II. There is a total of sixteen approved experiments in various stages. The four experiments at the Large Electron Positron (LEP) collider at CERN recently completed data taking. The K-Long Experiment (KLOE) at Frascati National Laboratory, recently started to operate. In contrast some experiments are in the early stages of detector construction such as the ATLAS and CMS experiments for the Large Hadron Collider (LHC) at CERN. The general level of this program is excellent. All experiments are international in character

and there is an unusually large number of leadership roles occupied by INFN supported physicists.

The spectrum of experiments ranges from the largest collaborations in science (ATLAS and CMS), with more than 1500 collaborators in each experiment, to modestly sized experiments such as the E835 charmonium experiment at Fermi National Accelerator Laboratory with approximately 55 collaborators. There is a good balance between participation in the mainstream thrusts of the field and the support of diversity. In almost all of the instances of small experiments one can readily identify a uniqueness factor associated to that experiment.

The committee noted the continued emphasis on experiments with the potential to explore CP violation in both the kaon and bottom systems. INFN physicists have or have had leading roles in several of these experiments. One of the experiments is the keystone of the L.N.Frascati experimental program and indeed CP violation is a primary theme in particle physics experimentation world-wide.

The emphasis on the energy frontier, first in CDF, one of two experiments at the Fermilab Tevatron Collider, then in the ATLAS and CMS experiments at the LHC demonstrates the determination of Italian physicists to attack the limits of human knowledge. That these and the other excellent programs can all be realised under the auspices of INFN demonstrates the effectiveness of this institution.

Based on the measures agreed with the CIVR, INFN particle physics is of the highest standard. Almost all of the work is performed within the aegis of large international collaborations, within which the INFN contribution of resources match its participation, and of which INFN provides a large fraction of the leadership. The physics results are of high quality and impact. The challenges involve maintaining schedules in the very largest projects and adapting the internal workings of INFN to match the changing international environment in which, even the subprojects involve multiple countries.

Highlights of the past two years include the new measurements of CP (charge conjugation times parity) violating parameters, in the kaon system, by NA48 at CERN, and in the B-meson system by CDF at Fermilab and by the new experiment, BaBar, at SLAC. In late 2000 the LEP program came to an end with the extra excitement of the observation of a few events with the characteristics of Higgs particle production.

This committee did not examine in any detail individual components of the program. The comments, which follow, are therefore brief.

- LEP experiments (ALEPH, DELPHI, L3, OPAL)

There is Italian participation in each of the LEP experiments. This program recently ended. During the final year of running the mass limit below which the standard model Higgs particle is not found was pushed to approximately 115 GeV. Considerable excitement was generated by hints of new physics in the final data. With the numerous precision measurements of the properties of the Z and W bosons, the experiments at LEP, which operated for 10 years, were a monumental success.

- CP violation experiments (KLOE, EPSI, BABAR, HERA-B)

The EPSI experiment at CERN suffered an accident in 1999. The apparatus has been refurbished and a final measurement of the CP violating parameter is anticipated in 2001. The program will evolve with further measurements, for example in the K_S system. The DAΦNE accelerator has had problems maintaining adequate luminosity with low backgrounds thus limiting the data accumulated by the KLOE experiment. These two experiments, with the KTeV experiment at FNAL their only competitor, have

as a goal the measurement of the ϵ'/ϵ parameter with a precision of one part in ten thousand. Given the present theoretical understanding these can be considered "asymptotic" measurements of this quantity. Recent good progress in improving the performance of the DAΦNE accelerator, suggests that, during 2001, KLOE will be able to obtain an initial measurement of ϵ'/ϵ .

BABAR is a new experiment at the (also new) PEP-II storage rings at Stanford Linear Accelerator Center. The detector started running during 1999 and during 2000 accumulated an impressive first sample of data. The machine worked very well and the experiment worked well, though not perfectly, permitting excellent first results to be presented at international conferences in mid-2000. Considerable effort is being expended to establish good operation of the RPC muon detectors which are an INFN responsibility.

HERA-B at DESY basically completed the initial construction of the experiment, however the success was less than complete and, given the initial success of both the BABAR and BELLE(KEK) programs, the physics goals are under reconsideration.

In addition to these existing dedicated experiments, there is considerable potential for CP violation measurements at the Tevatron Collider where INFN participates in the CDF experiment (this experiment is discussed in a different section). Further there is INFN participation in the BTeV and LHC-B proposals which are dedicated B-physics experiments for the Tevatron Collider and the LHC respectively.

- Deep inelastic scattering (ZEUS, COMPASS)

The ZEUS experiment at the HERA Collider at DESY, Hamburg, is continuing to operate in the hope that improvements to the machine luminosity will fulfill the need to complete the high momentum transfer measurements which will complement and extend the existing results.

The new muon scattering experiment COMPASS at CERN is a successor to a series of experiments. As the only large fixed target physics initiative at CERN, and coming as it does in the hiatus between the end of LEP and the start of the LHC collider, it has attracted considerable support. The main goal is to further elucidate the sum rules, which relate the polarized lepton scattering asymmetry to the axial charge (spin) of the nucleon. As such it is related to the HERMES experiment discussed in the Nuclear Physics section. The experiment had a test and commissioning run with beam and a partial apparatus in 2000. Data taking with a complete detector is expected in 2001.

- Proton-antiproton physics (CDF, E835)

The CDF and E835 experiments are at the highest and lowest ends of the proton-antiproton energy scale. The CDF experiment has made major contributions to knowledge of the highest energy collisions thus far available in the laboratory. Highlights of the program have included important measurements of the top quark, including its discovery, precision measurements of the mass of the W boson and a number of physics measurements and searches for new phenomena. The experiment is being upgraded fully to exploit the potential of the recently upgraded accelerator complex. The detector, except for the silicon tracker, enjoyed a successful commissioning run in Fall 2000. Final installation is underway and data taking is anticipated in March 2001. Ongoing analyses demonstrate that CDF is also a serious competitor in B-physics with the observation of the bottom-charm meson and a first measurement of the parameter $\sin 2\beta$. CDF will share the energy frontier with the D0 experiment until the start of the LHC. With the retirement of LEP from the field, the Tevatron is the only machine at which the Higgs boson might be observed before the LHC turns on. This lends added impetus to the CDF program.

E835 was unique in the world and its technique was imaginative and novel. The experiment used antiprotons in annihilation with protons in a gas jet to access several charmonium states in formation, which could not be produced in electron-positron collisions. The experiment completed data taking in November 2000, results are expected soon.

- Rare decays (E831)

The photoproduction experiment E831 has amassed a sample of one million charm decays at which level only the CLEO experiment at the Cornell Storage Ring is a competitor. Consequently E831 has been one of two major sources of progress in understanding the whole charm sector. Final data analysis and publication of results continues.

- The future energy frontier (ATLAS and CMS)

When the LHC starts operation the world of experimental particle physics will have just two flagship experiments at the energy frontier, ATLAS and CMS. The Italian participation is an essential component of each experiment. The influence of INFN physicists in each experiment has also been demonstrated in the experiment design, the technology choices, and the early construction. This large emphasis on the primary thrusts of elementary particle physics, the search for the Higgs particle, which is thought to be the generator of the masses of W and Z bosons, and higher symmetries of physics is laudable and appropriate.

The two experiments essentially completed the Research and Development stage and are now in the construction phase. It is already clear that considerable attention will need to be paid to the progress of the construction if these two experiments are to be ready for collisions in late 2005 or 2006.

3.2 Non-accelerator Physics and astroparticle physics

This area of the INFN activity covers a large section of fundamental particle physics not normally carried out with manmade accelerators (exception: physics of neutrinos generated by high energy accelerators or reactors).

The field can be subdivided into:

- long baseline neutrino experiments
- low energy non accelerator neutrino studies (solar, ...)
- high energy cosmic ray experiments (gamma ray astronomy, study of the highest energy cosmic rays), ground-based and satellite borne experiments
- dark matter searches
- gravitational wave detectors
- small scale experiments testing fundamental quantities

Most of these experiments fall under the area of astroparticle physics. Astroparticle physics is rapidly evolving into a major field of fundamental physics. This field will combine particle physics, astrophysics, nuclear astrophysics and cosmology and is in part highly interdisciplinary. Due to the rapid evolution, the boundaries of this research field are not always clearly visible and changes of the main research directions are quite common. Due to the unique situation of having an excellent laboratory at hand (see below), the Italian physics community is on the forefront of the field.

As many new initiatives in the field of astroparticle physics are building up in many other countries, steady attention of the INFN is needed to conserve the excellence of the research and to remain on the forefront.

The technology for the majority of experiments was based mostly on developments pursued by high energy particle physics but now the groups engaged in this field develop many cutting edge technologies. The inclusion of the work carried out under the framework of CSN V is very important.

An important prerequisite for many research projects is the need of experimental areas of very low radioactivity background. The Gran Sasso underground laboratory provides these conditions and is a very well managed world-class laboratory. It gives the Italian community a unique opportunity to carry out experiments under excellent conditions. At the same time, it gives the involved groups a high and widespread visibility, amongst the highest ones of the INFN activities. In addition, the exceptional working conditions attract many outside groups from other countries paving the way for many international collaborations. INFN should pay continuous attention to the developments and support to improve further the conditions. These could include a separate access tunnel, enlargement of the halls and/or new smaller halls for small-scale experiments, and an increase of staff. In order to enhance the scientific climate it would be very beneficial to enlarge the number of local scientists with the opportunity to participate in the experiments. Provision for on-site guesthouses for visitors to stay there for longer time is needed. The extent to which such a program is pursued depends on, and will determine, the long-term future of the laboratory.

In summary, the current experiments have the right mixture of small and large size to explore this new field of fundamental physics. Small groups, not necessarily of international composition normally carry out the exploitation of new technology, while in the follow-up phase concentration on a fewer large experiments of international composition is both natural and reasonable. The international standing of the INFN activities in the field of neutrino physics, astroparticle physics and gravitational wave experiments is very high and the quality of the results is mostly outstanding and excellent. The number of publications in leading journals and the citing coefficient is very high when compared with activities of other countries with the possible exception of the US. In many areas, Italian groups have developed decisive technologies and are world leaders. The level of innovation is exceptionally high. It is evident that in some areas only a few nations have the technological and intellectual basis for such a research, amongst them Italy. To remain on this forefront constant attention and willingness to accept changes are needed. The educational prospects in this field are large.

- Some comments on individual projects

Across the field, we currently see a culmination of changes in experiments. Many of the larger experiments of the first generation are terminated (NOMAD, CHORUS, CHOOZ, EAS-TOP, MACRO, GALLEX, CLUE...) and many new activities have started construction or have just been approved.

- Neutrino beam experiments

Besides the search for the Higgs and to understand CP violation, one of the main questions in particle physics is to understand neutrinos, fundamental building blocks of nature. Due to the extreme low interaction cross section the experiments are on the limit of today's technology and are the most challenging ones in this decade(s). The research to understand neutrinos is particularly strong in Italy. INFN is involved in many leading experiments. The currently leading direction is the search for neutrino oscillations. The experiments at CHOOZ and at CERN (NOMAD and CHORUS, all with strong INFN

participation) have reached their objectives and have set stringent limits on mixing parameters. As mentioned above, these experiments are now terminated. After the very strong evidence of a small but significant ν_μ to ν_τ transition, which was observed by the Superkamiokande experiment and supported by the MACRO and SOUDAN experiments, it became evident that the real experimental proof will come from direct observations of ν_τ events in a τ appearance experiment. A very important next step in this direction is the decision to direct the CERN neutrino beam towards Gran Sasso and to set up an ν_τ appearance experiment in the Gran Sasso underground laboratory. OPERA, a unique experiment specifically designed to observe with high precision ν_τ interactions, is expected to be ready when the CERN neutrino beam becomes operational. Although the experiment is a multinational activity, this experiment has a very strong Italian participation with leadership in many detector areas.

- Extraterrestrial and atmospheric Neutrinos (from the Sun, Supernova explosions, extragalactic sources, and atmospheric showers)

The Gran Sasso low background laboratory is a natural place for the study of solar neutrinos and many leading experiments with large international participation are concentrated there. The GALLEX experiment made the most precise measurement of the deficit of solar neutrinos and research is going on at high pace. GALLEX and its follow-up experiment GNO are highlights of the laboratory. Similarly, this is expected for the BOREXINO experiment, which will come on line in early 2002. BOREXINO will be essential to understand the solar neutrino puzzle and is complementary to SNO. Important efforts are needed to avoid a delay of the BOREXINO start-up.

As mentioned, the findings of the Superkamiokande experiment on neutrino mixing are of extreme importance for our understanding of neutrinos, respectively the development of particle physics models. While the implications of this experiment are pursued by the long baseline neutrino experiments, it can be argued that the Superkamiokande results need an independent high-significance confirmation by a second-generation experiment. The opportunity to install such an experiment in the Gran Sasso laboratory exists. Two detector projects, ICARUS and MONOLITH, have been proposed and are pursued strongly by INFN groups. Attention should be paid in considering this issue to the presence of a strong international contribution and to muster a large collaboration necessary for such experiments.

LVD is a typical example of a long-term monitoring detector of cosmological events emitting neutrinos, such as from SNRs and perhaps from Gamma Ray Bursts. Such detectors require very low background environments, large volumes, long operation time and nearly 100% uptime due to the unpredictable and rare Supernova explosions. One of the issues with such long term monitoring projects is the difficulty of maintenance, as the installed technologies slowly become obsolete.

Neutrino astronomy in the higher energy domain is beginning worldwide. One project (ICE CUBE) is foreseen to be located at the South Pole and a northern detector is needed to obtain a 4π survey. There are excellent prospects that the northern detector, possibly NEMO, might be located in the Mediterranean. Here the INFN activities, although currently rather modest, might pave the way to install such a detector south of Sicily where experimental conditions are excellent. The construction of such a facility-conceptually a Gran Sasso laboratory deep under the sea- will take many years and requires substantial technological progress not only in the field of particle detectors but also in areas of common interest such as marine technology, marine biology and geophysics. The nearby Catania lab might provide infrastructure. The committee appreciates very much the efforts to continue to collect experience (on modest scale) through the planned collaboration with France on the smaller scale ANTARES detector near Toulon. As very likely in the near future important decisions concerning this

direction will be made in other countries, serious discussions should be started soon inside the INFN.

- Gravitational Wave (GW) detectors

INFN has a large involvement in gravitational wave experiments. Activities had started many years ago when the field was only in a nascent state (NUSEX, 1978, in the Mont Blanc tunnel). This early start gave the Italian community an excellent position in the forefront of the field and a strong opportunity for the next generation of experiments, which should reach the sensitivity to observe gravitational waves from a variety of cosmic objects (coalescent binaries, collapsing black holes or a stochastic background of cosmological origin). The instruments are very demanding in technology, such as in cryogenics, mechanical precision and ultra-low noise electronics. Italian groups have made many innovative developments and have received worldwide recognition in this area. The recent achievements of the PACO project, an activity pursued in the framework of CSN V, promise another breakthrough in this area.

The cryogenic bar antennas basically reached their predicted sensitivity. The most recent antennas are integrated in a worldwide net for searches of coincident signals from various astronomical objects predicted to generate GWs in the frequency band above 10 Hz. Because of the unpredictable arrival of GWs from astrophysical sources, it is indispensable to keep the detectors permanently operational. Here the INFN groups have made a significant progress in the last two years.

The Virgo detector, a two-arm interferometer build by a collaboration of France and Italy near Pisa is close to the start-up. Again, it keeps the Italian physicists in the forefront of this important field of research. The VIRGO detector will bring a quantum jump in sensitivity. VIRGO is on the forefront of the new generation of high sensitivity detectors. Some of the technology developed for VIRGO is now considered by the competing experiment, LIGO, in the United States. The committee appreciates very much the widening of the European collaboration efforts by agreements with other groups with similar interest in Europe, which pave the way for the far future experiments (third generation antennas, LISA). As other areas of astroparticle physics (gamma astronomy, neutrino astronomy) are expected to provide information of cosmic events that should be coupled to gravitational waves, the current Italian activity is very well matched to the other activities in gamma astronomy and neutrino astronomy. It is recognised that Italy is one of the few countries worldwide that are so far able to master the very demanding technology for such detectors.

Attention should be paid that the start-up of VIRGO is not delayed. On the other hand, no shortcuts should be taken than can compromise performance

- Satellite experiments related to astroparticle physics

Recently, the INFN activities in astroparticle physics research have been considerably widened by the participation in experiments carried out with satellite-borne detectors.

One area, started already a few years ago, is the search for high energy antiprotons from outer space. INFN participates in the AMS experiment, to be built by a large, international collaboration and PAMELA, an INFN dominated satellite project. The experiments are partly overlapping but also over large areas they have complementary scientific goals. Pamela should also be seen as a technology demonstrator of the Italian research institutions to build such a detector.

The other relatively new activity of INFN is the involvement in medium energy gamma ray astronomy. Gamma rays (and, to a certain extent in the future, neutrinos) are the main messengers of the development of the relativistic (astronomers prefer the term non-thermal) universe. The predominantly Italian-built satellite AGILE (to be launched in

2002/2003) will be the sole detector for this field for quite a few years until the launch of GLAST. Eventually GLAST will be the main MeV- 200 GeV gamma ray observatory with excellent prospects to produce a wealth of new data about cosmological events. The strong engagement of INFN groups gives them access to prime results and will keep the groups on the forefront of the technology.

Space based research will very likely intensify in the future. The committee appreciated very much the increased INFN activities of fundamental research making use of this kind of experimental direction.

- Charged cosmic-ray and gamma-ray astronomy

The studies of cosmic rays and their sources of origin are another area of long-term Italian involvement. Traditionally Italy is a main player in the field and has had outstanding successes. The recent INFN projects EAS-TOP and CLUE are now terminated (see last report). A series of new activities has been started or has been just approved. The main activity in the highest energy cosmic ray physics research will be the participation in the AUGER experiment. The origin of the highest energy particles (up to 10^{20} eV) are a puzzle and their study could shed light on extreme energetic processes in our universe and even perhaps on processes linked to the Big Bang. The low flux poses major challenges to experimenters. INFN groups participate in the construction of the fluorescent detector, which is very demanding in technology and an essential element to bring AUGER to success. Evidently, the groups profit very much from technology leadership of INFN in high energy accelerator experiments. The far future direction in this field, a possible satellite experiment along the line of AIRWATCH/OWL¹/EUSO, might open good opportunities for long-term continuity. Again, new technology will be decisive and the early and small activities are welcome.

As pointed out previously, high energy γ rays are the essential messengers of processes of the relativistic universe. The two leading activities in this field, ARGO and participation in MAGIC, will give INFN groups access to this strongly developing field which already produces important results. ARGO and MAGIC are complementary in their goals. ARGO, already approved some time ago, is currently installed at the Yangbanjing High Altitude Cosmic Ray Laboratory, Tibet, China site at 4300 m altitude. The use of a carpet of RPCs will ensure 100% area coverage for an all sky monitor. The main goal of this detector will be the monitoring of short-term events producing GeV and TeV gamma rays such as from the still enigmatic Gamma Ray Bursts or short-term flaring AGNs. MAGIC, with its predicted lowest energy threshold of all ground-based air Cherenkov telescopes for gamma astronomy, will concentrate on observations of high redshift objects thus also probing amongst other questions black hole physics and the IR background from the time of the early universe. The INFN groups bring leading technology from high energy physics experiments. The telescope will be installed in 2001 on La Palma.

- Double β decay, dark matter, and monopole searches

All three issues are of fundamental nature, both for particle physics and for cosmological aspects (dark matter, monopoles). Again, experiments profit very much from the low background situation and very good infrastructure of the LNGS. The main monopole search experiment, MACRO, has been terminated and was covered by the last report. Without going into details of the many other activities it is to be noted that the development of the detectors for Double β decay experiments is still in full swing and many novel ideas are pursued. The lack of precise theories in some areas dictates the exploratory methods of the experiments. In such a situation, upper limits on some quantities are important results. The LNGS concentrates a larger number of such

¹ Not to be confused with a ultralarge optical telescope project

activities than any place in the world and therefore creates a highly competitive environment.

The nature of the so-called Dark Matter poses an exceptional experimental challenge and is of fundamental importance to understand our universe. The recent exciting findings of DAMA demand a very careful evaluation of the systematic uncertainties. Detector improvements should be expediently and rigorously pursued and the internal examination and verification process should be intensified. Independent crosscheck is needed. It will be soon necessary to enlarge the experiments and to concentrate on only a few ones of the most promising directions. It is indispensable to increase also the collaborations and (hopefully) widen their international basis. It should be added that the cryotechnology developed, respectively pushed close to the temperature limit would eventually be of great importance for other research field and many measuring and diagnosis devices.

- Small experiments for fundamental tests.

In the frame of INFN activities a number of small-scale experiments are carried out. Due to limited time, the committee had no possibility to obtain an in-depth insight. This type of experiment needs a good ‘home’ and the best possible surrounding conditions. It seems that the broad integration of the INFN into the universities, and the excellent condition facilities within INFN, provides exactly this type of atmosphere.

- Additional general conclusions

It is important to recognise that, due to the exploratory nature and the long time scale of experiments the path to new observations and discoveries is less sure than for accelerator experiments. Experiments are per se more risky. This has to be accepted if one wants to stay on the forefront of the field. The committee would like to stress again the need for early in-depth reviews of new projects, strict monitoring of progress, and the sometimes-difficult decision to end activities when the general goals of the research field have changed, or when the prospects for good results are diminishing. Experience from the long and steady developments in particle physics is not always applicable. The observational nature of this field of science demands bold moves for progress but not all that seek will find.

The committee feels that the structure of INFN and its dedication to stay on this forefront is very well suited for such a research. The so-called Bottom-up structure allows these changes and the rapid adaptation to new directions in this emerging field of fundamental research. However, there are some risks that too many activities be started given the present level of allocated resources.

W.r. to the Gran Sasso Laboratory: a large number of new experiments, which exceed by far the available space, are proposed. This highlights the worldwide interest and provides the opportunity to select the best ones. The reviewing procedure, as set up by the INFN, to select experiments of high standard and to monitor their progress is considered very satisfactory (see also the comment of the Richter report).

3.3 Nuclear physics: CSN III

The broad spectrum of research activities, ranging from nuclear structure and reactions at tandem energies to quark and hadron dynamics and the quark gluon plasma, very positively reflect the diversity of modern nuclear physics. Italian nuclear physics can take pride that it is strongly represented in most of these fields.

Low and medium energy nuclear physics research with light and heavy ions is mainly concentrated in the National Accelerator Laboratories in Legnaro and Catania. These laboratories are excellently equipped with very elaborate and sophisticated detectors, thus offering the possibility for cutting edge research. Experiments requiring higher energies or specific beams that are not available at the national facilities are carried out in international collaborations at large European and US accelerator facilities such as CERN in Geneva, ESR in Grenoble, GSI in Darmstadt, HERA in Hamburg or TJNAF at Newport, USA.

To fully exploit the potential of the national facilities and to reap the fruits of the sizeable investments in capital and manpower in the detector systems, it is essential to have the existing accelerators, the superconducting cyclotron CS in Catania and the postaccelerator ALPI, working reliably and at their full potential. The committee therefore strongly endorses the decision of INFN to give the highest priority to achieving a stable operation of CS and ALPI in order to give beams to the experiments. We also feel that a joint international advisory committee for both laboratories and distinct from the program advisory committees would be highly desirable in order to coordinate their research efforts and long-term strategies. As the CVI has learned with satisfaction, such a committee has been established since our December meeting.

With respect to the smaller research activities in the field of nuclear structure and reactions and in nuclear astrophysics, a bundling of the activities into joint project groups, rather than financing each experiment individually, might well be worth consideration. In addition, some improved focus of the research, especially in the field of nuclear reactions at low and intermediate energies, would be desirable.

Productivity and quality of the results is high, and there is a strong internationalisation of the research efforts in nuclear physics. Italian nuclear physics makes important contributions, both intellectually and in the instrumentation, to the large international collaborations, in which it is involved, with Italian nuclear physicists well represented in leadership positions. In addition to the international efforts a sizeable number of foreign physicists makes use of the national facilities. The latter has been duly recognised by awarding to the LNL in Legnaro the status of a large European facility in nuclear physics.

In addition to the purely fundamental research there is an increasing effort to exploit the potential of nuclear physics to other disciplines of socio-economic and intellectual relevance such as (nuclear) medicine, the environment and the dating and classification of cultural assets.

In the following we discuss the different research activities that are conveniently grouped into the European (NuPECC) classification scheme:

- 1) Quark and hadron dynamics
- 2) Phase transitions of nuclear and hadronic matter
- 3) Nuclear structure and reaction dynamics
- 4) Nuclear astrophysics and interdisciplinary research.

An in depth evaluation of all the activities is clearly outside the scope of this review. We therefore restrict ourselves to more general comments.

1) Quark and hadron dynamics

- Electromagnetic probes

Electromagnetic probes are the preferred tools to study sub-nucleonic degrees of freedom in nucleons and nuclei via real and virtual photons. These studies are being carried out at the major accelerator facilities in Europe and the United States in international collaborations, ALICE and ELETTRA at TJNAF (USA), HERMES and NUCSPIN at HERA (Hamburg, Germany), GDH at MAMI (Mainz, Germany), and GRAAL at the ESRF (Grenoble, France). All these very successful programs have a strong Italian contribution to the physics as well as to the instrumentation, with Italian spokespersons in many of the experiments. At HERA the deep-inelastic scattering of 27.5 GeV electrons on nucleons and on selected light nuclei is being investigated with the aim to study spin structure functions utilising both polarised beams and targets. The related GDH sum rules are investigated in several experiments at different accelerators. The production of vector and isoscalar mesons with real and virtual photons and the structure of mesons and nucleons is being studied at TJNAF and the ESRF. Among the many and important results obtained by the different groups we especially mention the first evidence of gluon contributions to the nucleon spin that has been obtained by the HERMES-NUCSPIN collaboration.

- Hadron probes

The experiments with hadron probes involve a wide range of topics in different stages of completion ranging from subthreshold kaon production (CLAMKAON), anti-proton (neutron physics) (OBELIX), strangeness and spin physics with proton beams (DISTO), and a search for the elusive H0 particle in relativistic nucleus-nucleus collisions (EOSIT). The OBELIX experiment, which had been the major Italian involvement at CERN-LEAR, is still producing a large number of important results on anti-proton physics 4 years after LEAR has been shutdown. DEAR and FINUDA are the major nuclear physics experiments at DaΦne. Both experiments are still in the set-up phase and have not yet reached the production stage. The novel DIRAC experiment at CERN is aimed at measuring the $\pi^+\pi^-$ final state interaction to determine the lifetime of the pionic atom that will allow to measure in a model independent way the isovector and isoscalar S-wave pion-pion scattering lengths to good precision. DUBTO makes use of a streamer chamber both as target and as a tracking device for the interaction of low-energy pions with nuclei. The low threshold of the streamer chamber makes it particularly suited if not unique for such studies.

2) Phase transitions of nuclear and hadronic matter

- Ultra-relativistic heavy ions

The study of nucleus-nucleus collisions at ultra-relativistic energies with the goal to produce and study the quark gluon plasma and chiral symmetry restoration is one of the foremost frontiers of nuclear physics. It is a field in which Italian nuclear physicists are very strongly involved. With the CERN SPS Pb on Pb collisions were most recently studied at 40 and 158 GeV/nucleon. Both the sharp onset with centrality of the reduction of the J/ψ production, observed in the IPER (Na50) experiment, and the enhanced strangeness production in the (Na58) experiment at CERN, are taken as the

strongest evidence so far for the formation of a quark-gluon plasma. These observations have been the corner stone of the official CERN announcement of the discovery of a new state of matter in which quarks and gluons are no longer confined. The Italian participation in the construction and the execution and analysis of these experiments has been very substantial. ALICE, the general-purpose heavy ion detector under construction for the LHC, involves a very strong Italian effort both in manpower and in capital funds, and the Italian physicists are well represented in all phases of the project leadership. In view of the very high multiplicities in the nucleus-nucleus collisions at LHC energies the instrumental developments are especially challenging.

- Relativistic heavy ions

There also is a modest Italian involvement in two experimental programs with relativistic heavy ions with the SIS accelerator at GSI in Darmstadt, Germany. The SIS experiment addresses the question of the gas-liquid phase transition in nuclear matter in the frame of the ALADIN collaboration, while HADES, which is not yet operational, intends to study the in-medium properties of vector mesons in hot and dense nuclear matter and virtual photon (e^+e^- -pair) emission. Extensive data have been obtained in the SIS experiment, corroborating earlier results on the gas-liquid phase transition. For HADES the Italian groups are working on the construction, installation and testing of the time-of-flight detector.

- Intermediate energy heavy ion reactions

The interest in the study of intermediate energy heavy ion reactions is in the investigation of the mechanism of multifragmentation of very hot nuclei, in which these nuclei spontaneously disassemble into several fragments, the coexistence of a gas-liquid phase and possible phase transitions, the nuclear caloric curve and the equation of state of nuclear matter. Although there has already been much effort during the last decade notably at GANIL and MSU into the study of the dynamics of intermediate energy heavy ion reactions, the highly sophisticated detector systems at Catania offer good possibilities for such investigations. This is reflected by the interest of several groups from outside Italy, from Europe and the US, to participate in experiments and to propose new ones. Current experiments, respectively detector systems, are CHIMERA, FIASCO, FORWARD/OUVERTURE, HOTCI and REVERSE. Unfortunately the study of the intermediate energy heavy ion reactions has been severely hampered by the less than optimally functioning of the CNS.

3) Nuclear Structure and Reaction Dynamics

- Nuclear structure

Current frontiers in nuclear structure physics are the exploration of the band structures and deformations of very fast rotating nuclei (high spin physics), the study of exotic nuclei far from the stability line, a field receiving new impulses through the availability of beams of radioactive nuclei, and the study of spin- and isospin excitations and giant resonances. More generally it is the study of nuclei and under extreme conditions in spin, isospin and nuclear temperature. Italian nuclear physics is involved in most of these topics. (COSA, ELCOM, EUROBALL, EXOTIC, GASP, MARS, PARIDE, SPREAD, TRARE). Some concentration of these efforts might be desirable. Very extensive nuclear structure studies in the highly competitive field of in-beam gamma-ray spectroscopy and high-spin physics have been carried out with GASP and with

EUROBALL. The work done is excellent on any scale, and the studies have been highly productive. Among the many important results obtained we mention the discoveries of biaxial and triaxial superdeformed nuclei, of band termination and of magnetic rotations, a new collective mode. Furthermore the first observation of the isovector giant dipole resonance (GDR) built on a superdeformed band. The latter is part of a more general study of the GDR in hot nuclei (PARIDE) of high international standing. With MARS an R&D project towards the development of position sensitive gamma-ray high-purity Ge-detectors has been started.

- Reaction dynamics

The study of fusion and incomplete fusion reactions, of fusion fission and of pre-equilibrium phenomena is attempted in many of the COSTHIR, EDEN, STREGA, TRASMARAD experiments making use of different accelerators at LNL, LNS, Texas A&M and NAC (South Africa). Data have been obtained on a variety of reactions, and a number of papers have been published during the last year. MAGNEX and PRISMA are aiming towards the construction of very large solid angle magnetic spectrographs for Catania and Legnaro. STREGA/GARFIELD involved the construction of a complex (close to 4π) particle detector designed for the study at Legnaro of heavy ion reactions in the energy range from 5 to 20 MeV/nucleon. The detector has been completed and successfully tested, and a first experiment has been scheduled.

4) Astrophysics and interdisciplinary research

Nuclear astrophysics dealing with element synthesis in the big bang, in stellar burning and in cataclysmic events is a field that has been attracting strong and renewed interest in recent years with the availability of new observatory data and of radioactive nuclear beams. The proposed and ongoing studies show great promise. The LUNA experiments in the Gran Sasso laboratory for the first time allowed to measure the cross section for a reaction of the pp stellar burning cycle in the vicinity of the Gamow peak. The set-up at the Gran Sasso offers unique possibilities for the measurement of ultra-low cross sections. Equally important and experimentally challenging is the measurement at Bochum (ERNA) of the $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$ reaction involving a recoil separator proposed by the Naples group. The $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$ reaction is one of the key reactions in the breakout of the hot CNO-cycle that determines the carbon to oxygen ratio in our solar system.

The neutron time of flight facility at CERN appears to have a great potential for the measurement of neutron capture cross sections of astrophysical interest (N-TOF). Whereas in the past it was thought that the cross sections for 30 keV neutrons were determining the s-process, and consequently most measurements have concentrated on this energy, very recent results point towards the need of obtaining data at much lower neutron energies.

Very interesting is also the ATHENA experiment aimed at forming and studying anti-hydrogen for a test of CPT invariance for leptons and baryons with unprecedented accuracy.

3.4 Theoretical physics: CSN IV

Theoretical research within the INFN has a very wide spectrum, basically covering all major topics of current interest in the field.

Phenomenological work, often done in collaboration with experimental groups, ranges from exploiting the potential of present accelerators for testing existing theories (like the standard model of particle physics), to the building of new models aimed at describing physics in the energy range of the next generation of particle accelerators. Supersymmetric extensions of the standard model occupy a prominent place in this category.

More speculative work deals with the structure of matter and with the nature of fundamental interactions at energies much beyond those attainable in accelerators. These theories, which typically further unify particles and interactions, can only be tested indirectly, either through the observation of very rare processes (e.g. proton decay), or through their relevance on physical processes in the early Universe (e.g. the origin of matter-antimatter asymmetry).

Reflecting a similar trend world wide, a large effort is also devoted within Group IV to string theory, the most promising candidate, at present, for a unified description of all particles and interactions, including gravitational phenomena at the quantum level. In particular, the implications of recent suggestions that our world could be a four-dimensional membrane (a "brane" for short) immersed in a higher dimensional space-time are receiving increasing attention.

Another type of theoretical activity deals with the application of theoretical and mathematical tools invented to describe elementary particles and nuclei to other fields of science, such as condensed matter and statistical mechanics. As an example, the study of Quantum Chromodynamics (QCD) has had important impact on the study of amorphous systems, with applications in condensed matter physics (the vitreous state) as well as in biology (an example is the study of neural networks or the properties of the immune system). Another example is the application of methods, developed for the study of the nucleus, to atomic clusters.

An important contribution emerging from theoretical studies is the development of dedicated parallel computers needed for the numerical study of theories of elementary particles, in particular of QCD. This development, in which INFN physicists have a leading role in Europe through the APE project, has found important applications in the study of fluid dynamics, chemistry, and various other aspects of applied science.

The number of theoretical physicists financed and organised by INFN with the help of the CSN IV is about 630, of whom only 16% are INFN staff members, while the majority, about 54%, hold faculty positions in Italian universities; the remaining 30% are postgraduate students or post-doctoral fellows.

Even taking into account the cost of computing facilities, theoretical studies require less resources than experimental studies, and are normally carried out by small groups. In spite of this, the activity of CSN IV has been very valuable in orienting experimental activities, and in offering a forum for the discussion of different programs and of their needs. CSN IV divides the theoretical activities in five sectors:

- 1) Field and String Theory
- 2) Phenomenological studies of Elementary Particles

- 3) Physics of Nuclei and Nuclear Matter
- 4) Mathematical Methods of Fundamental Interactions
- 5) Astroparticle physics

Within each sector it establishes "specific projects" aimed at a particular coherent line of research, typically emerging from a collaboration of researchers belonging to different Sections or Laboratories. As a general comment, theoretical studies are well distributed over the different regions of the country, probably reflecting the fact that most Universities offer a variety of courses on Theoretical Particle and Nuclear Physics. INFN also helps organise the annual meeting of Italian theorists (usually in Cortona), where particular attention is taken to give time for presentations by the younger members of the community.

The CSN IV has analysed the productivity of INFN-funded theoretical research using a methodology that gives a weight to each scientific paper according to the importance of the journal where it is printed. This is an internationally recognised measure, which is widely used, and which allows comparison with institutes elsewhere. The impact factor for a total of about 1700 papers is about 1900, these figures being reduced to 570 and 1500, respectively, after subtraction of non-INFN authors. The analysis does not include the contributions of theoreticians not involved in "specific projects".

The impact factor per paper, ~ 2.7 , indicates that these papers were published in medium to high impact journals, and is typical of the mix of journals used by theoretical physics elsewhere. The impact factor per author, ~ 2.6 , is comparable to, or better than, that in European institutions, with the exception of the CERN theory group (which is favoured by the fact that its members are free of teaching loads). This result certainly confirms the excellent level of theoretical research funded by INFN.

As in the case with experimental programs, INFN theoretical physics enjoys a very lively interconnection with ongoing research in other countries. This is clearly demonstrated by the frequent presence of Italian theorists at CERN and in other research centres abroad, as well as by the large number of foreign visitors in INFN centres, both in the Sezioni and in the National Laboratories. INFN theoreticians also participate in many EU-sponsored research networks, and each year INFN centres host or help organise a number of international seminars and workshops.

We will now make a few comments on each of these sectors and conclude with a few remarks on the productivity of INFN-financed theoretical physics.

- Field and String Theory

This sector includes the study of traditional field theories, such as the standard model of strong and electro-weak interactions, and of the general properties of quantum field theories. Of particular interest is the use of numerical simulations to overcome the difficulties of more standard analytical methods. It is natural to include in this sector the applications of field-theoretical methods to statistical mechanics and complex systems in general.

A strong component of this sector is the study of string theory, an extension/modification of field theory that could lead to a unified understanding of elementary particles and forces, by enlarging the standard model as to include a consistent treatment of quantum gravity. Possible consequences of the new, "brane-world" idea, such as modifications of gravity at sub-millimetric distances or the occurrence of new phenomena in accelerator experiments above the TeV scale, are vigorously investigated.

- Phenomenological studies of Elementary Particles

This sector includes those studies that are in more direct contact with experimental research. The programs involve all aspects of elementary particle physics, from the precision tests of the Standard Model to the properties of heavy quarks. It also includes those extensions of the Standard Model that may be brought to direct experimental test in the future, e.g. at the LHC.

Phenomenological studies employ a vast array of theoretical and mathematical tools, including the use of computers both for algebraic manipulations (e.g. computation of high-order Feynman graphs) or for Monte-Carlo simulation of particular processes (e.g. the development of hadron jets).

- Physics of Nuclei and Nuclear Matter

This sector includes all aspects of nuclear theory, some more "theoretical" others more "phenomenological", i.e. closer to the experimental programs. Among the first we find the study of nuclear structure and nuclear matter; among the second the study of heavy ion collisions, which are the object of experimental programs in the National Laboratories of Catania and Legnaro, but also, in the case of ultrarelativistic heavy ion collisions, at CERN. Another important field close to experimental activities concerns the interactions of nuclei and nucleons with electrons and photons.

The nuclear sector also includes interdisciplinary studies, regarding both nuclear processes of interest in astrophysics, and applications of mathematical tools developed in nuclear physics to the study of particular aspects of ordinary matter.

- Mathematical Methods of Fundamental Interactions

This sector includes various developments of mathematical physics and of pure mathematics as they emerge from field-theoretical studies. They find direct application in the development of field theories, in statistical physics, and in the theory of condensed matter. Among these areas of research we find the general theory of non-linear dynamical systems, of quantum groups, and of quantum chaos.

This sector also includes research on the foundations of quantum mechanics and possible alternatives to the usually accepted interpretation of quantum phenomena.

- Astroparticle physics

This sector, only recently recognised as separate from that of elementary particle phenomenology, is drawing more and more attention. Recent developments in astrophysics and cosmology have revealed an increasing role of the properties of elementary particles and field theory in the understanding of our universe. At the same time, data of increasing quality and physical interest have recently boosted theoretical activity in the field.

At the moment, 52 FTE physicists belong to this group. They fall in two specific projects: a small one concerning gravitational-waves, and one, with about 40 FTEP, covering all other aspects of astroparticle physics, such as dark matter, matter-antimatter asymmetry, neutrinos, highest-energy cosmic rays, CMB anisotropies and inflationary cosmology. This promising field is likely to grow further in the future, with additional input coming from the theoretical particle and nuclear physics communities.

3.5 Technological and interdisciplinary research: CSN V

CSN V's primary mission is to act as an incubator for projects in the field of instrumentation designed for experiment carried out by other INFN's Scientific Commissions (nuclear, sub-nuclear and astroparticle physics).

Although utilizing a minor part of the overall INFN budget (less than 9000 million lire/year), CNS V employs about 12% of the whole of INFN researchers (totalling 553 people) and, even more significantly, 16% of the External Resources (University personnel mainly, totalling more than 3000 people) working within INFN's projects.

In the year 2000, 368 full time equivalent researchers participated into CSN V activities, working in more than 100 projects, 30% of which were newly formulated proposals. Key technologies include advanced electronic and software developments applied to particle detectors and accelerators. Some of these cutting edge technologies have a concrete potential to be applied in other high-tech fields, such as medical/biological and space.

CSN V has therefore to perform several tasks: technology advance to support the INFN scientific activity, training of young researchers, technology transfer to the industrial world.

The training activity of CSN V is particularly significant, given the high number of external researchers (including many undergraduate and PhD students) involved in CSN V projects.

To accomplish the technology transfer mission, which is likely to have a growing importance in fulfilling overall INFN's social mission, a dedicated structure (TTFE, i.e. technology transfer and external training department) has been created.

In the medical applications, some interesting clinical data have been already obtained in digital x-ray imaging at low dose, which may be of particular importance in extensive tumor screening campaigns (i.e. mammography). This application has been developed as a fall-out of the Silicon Detector technology connected with the Alice and other LHC experiments.

Another interesting example of technology cross-fertilization is the development of a non-conventional hybrid polyamide material, with controlled optical and spectroscopic properties, starting from technology applied in the particle detectors field. The process to obtain this new polymeric material, which is also patented, could find concrete industrial applications in the electronic, opto-electronic and high resistance coatings field. In this project, as in other similar projects, CSN V is working together with private industrial partners. This approach is very important, and it would be advisable for INFN researchers to conduct, at least for the most promising projects, a wide survey of potential industrial partners (focused on but not limited to the Italian industry), taking into due consideration the competitive structure of the relevant sector.

A frame for assessing R&D projects priority has also been developed, based on time span and level of technology leadership of INFN/Italy in the relevant field. From the available data, it appears that the vast majority of the projects, scheduled for 2001, is expected to be concluded within 2-3 years, and a significant fraction is leveraging on existing technological leadership. Anyhow, given the limited resources available to CSN V and the large number of projects being carried out, it would be advisable to verify if screening criteria currently in place are adequate to properly ascertain research priorities, in order to avoid excessive fragmentation.

In year 2000, about 300 publications were produced, and more than 200 contributions to conferences were made. In terms of productivity (number of papers/researcher) and scientific quality, CSN V publication activity compares favourably with similar foreign institutions. Moreover, a significant portion of these papers has been carried out in collaboration with other Italian and foreign research organisations. Finally, about 150 degrees in physics and engineering were obtained and 70 Ph.D. students are working within this frame.

In year 2000, a survey to ascertain the effectiveness of the technology transfer from the INFN to the Italian industry has also been conducted. A sample of 80 Italian companies, having a technical liaison with the INFN, mainly with a co-developer role, has been selected. The companies were located in 12 different Italian regions, 51% of them in central Italy, 41% in the north, and 6% in the south. Most of the companies in the sample were of medium/small size (annual revenues below 10 MLD and with less than 100 employees). Furthermore, for about 40% of the companies in the sample, revenues from INFN accounted for more than 30% of total company revenues.

It is interesting to note that more than 80% of the surveyed companies indicated a positive or very positive image fall-out arising from the relationship with the INFN. Furthermore, about 150 new job positions were created, with a ratio between new hires and revenues from INFN (in MLD) contracts between 1 and 10. This figure compares very favourably with the overall national average investment required to create a new job position. It has also to be considered that most of these new jobs have been created in the high tech industrial sectors, including the advanced materials, electronics, fine mechanics and medical technology fields.

It would be advisable to continue to routinely conduct this kind of survey, comparing trends and analyzing any significant success and failure (if any) story, to get guidelines for the future. Finally, it would be desirable for the INFN to identify proper recognition mechanisms for the most successful achievements.

In summary, it is clear that the INFN activity has had, and could have even more in the future, a significant impact on the technology development of the industrial system, particularly in Italy.

As of now, the activity of the CSN V is of very good quality, and is moving in the right direction.

4. The National Laboratories and Sections

There are four national laboratories, L.N. Frascati, L.N. Gran Sasso, L.N. Legnaro, L.N. Sud (Catania). Three of the laboratories Frascati, Legnaro, Sud are historically accelerator based while the Gran Sasso laboratory is based on underground experimentation. There are also nineteen sections.

At the December meeting the CVI heard a report from the Director of L.N. Frascati and were briefed on the other laboratories by the INFN President/Directorate.

The L.N. Frascati has a staff of 339 of which 88 are research physicists. Approximately half of the physicists work on experiments in other laboratories. There are approximately 300 external researchers, including 50 foreign physicists, who work at the laboratory. The laboratory has two external advisory committees, one addresses the physics program and the other concentrates on the accelerator program. Both contained renowned international experts.

The primary physics facility is the DAΦNE electron-positron storage ring which operates at the mass of the ϕ meson. The associated experiment (KLOE) executes a program of research

with the goal of measuring the CP violating parameter in kaons. The luminosity of the machine and the associated backgrounds are key to the success of the program. Until recently these had been a major source of concern. Recently some promising advances in understanding the machine behaviour presage significant improvements. The experiment can now imagine making a significant contribution to the primary physics issue within the next year.

There are other experiments concerning exotic atoms and hypernuclei (DEAR and FINUDA) as well as X-ray or infrared synchrotron light facilities on the machine. Also the laboratory has developed the large Nautilus cylindrical bar detector for gravitational waves.

The involvement of the accelerator physicists in a number of advanced projects including linear electron positron collider physics points to a future involving the exploitation of phenomena such as the Free Electron Laser as a future source of short wavelength light, which has enormous cross disciplinary interest.

At the May, 2001 meeting, the CVI heard a report about the L.N. Gran Sasso by its director Sandro Bettini. Besides its physics program the report covered many additional aspects such as the historical developments, the infrastructure, the resources, both human and financial, the economical and social impact, the outreach activities and plans for the future expansion. In addition, safety aspects were covered.

The laboratory was originally constructed to support a proton decay experiment, but already the layout took a possible beam from CERN into account. The LNGS is unique worldwide and has developed into a key laboratory in the field of neutrino physics and particle astrophysics. It provides attractive low background facilities, deep underground but with relatively easy tunnel access. The quality of management and infrastructure matches that of CERN and DESY. The laboratory and its outcome are one of the highlights of Italian research and contribute very much to the INFN visibility worldwide. The physics program is very rich and covers a wide variety of experiments, most of them addressing very important fundamental questions. The recently approved CERN to Gran Sasso neutrino beam project adds another important role to the laboratory and ensures its near-term high profile in the field.

The experiments are carried out by a total of more than 700 scientists, nearly half of them non-Italian, but only a fraction is continuously present at the lab. There are in total 32 physicist employed by the LNGS (9+1 staff position, 6 non-permanent positions and 17 fellowship positions, 9 of them for students). In addition there are short-term fellowships available (FAI), corresponding to 59 month/year.

The discussions for the future expansion by the addition of two halls and an extra access tunnel are ongoing. The CVI considers such an expansion as very important (see also the related comments in 3.2).

The early and far-sighted decision by Italy to build such a laboratory can be seen in the context of the present plans of the US (20 years later) to build a similar laboratory in the Homestake mine, and a similar less advanced plan of Spain to build an underground lab in Tenerife.

The Laboratories of Legnaro and Sud have been the domestic cornerstones of nuclear structure and nuclear interaction physics. Progress has been made towards improved operation of the base accelerator systems needed to satisfy the experimental measurements. While facilities on a national scale have been appropriate for nuclear structure or interaction physics it is possible that the future evolution of the field, perhaps Europe wide, will see a concentration of the field on a smaller number of more expensive, more globally supported, facilities. Recently it has been decided to form a joint scientific policy advisory committee of the two laboratories. It would be appropriate for there to be discussions and planning which

set the two laboratories appropriately in the context of both European nuclear physics and of the INFN physics.

4. Institutional and Resource Management

The integration of the physics community in the resource allocation process (see Section 6) is unusual. It appears to work remarkably well.

The apparent determination of the CSN to maintain their activities within the resource guidelines while vigorously representing their shortfall compared to requests is commendable. While a good fraction of the research of the institute is executed outside Italy, the expenditures targeted at Italian industry still dominate. There is a vigorous program to attract young foreign post-doctoral researchers to work in Italian physics institutes, both national laboratories and the sections. However the presence of non-Italian senior physicists is rare.

The INFN central management takes responsibility for a number of special projects such as APE, ELOISATRON, EXCYT, SPES, New Accelerator Technique, VIRGO, and CNGS. These represent strategic efforts in several directions. They are designed to maintain the general health of the organization and to set directions in the different fields of research. In the latter role, they are used by management as vehicles to shift emphasis from one particular line of research to another. For example the recent relative expansion of the research lines associated within CSN II has been fostered by the strong direct support for VIRGO and CNGS.

The VIRGO and CNGS projects are also strong attractors for international investment in Italian physics initiatives. The New Accelerator Technique project, which includes work associated with the TESLA Test Facility, demonstrates the determination of INFN to be a participant in what is likely the next world accelerator project. APE has strong symbiosis with the advanced computing industry in Italy.

The resource management is judged to be very good, given the constraints faced by INFN. In particular, the administrative structure is substantially appropriate: it blends centralization and decentralization in a reasonable way. The general financial situation seems to be balanced, even if the introduction of cash limits, since 1998, has significantly conditioned the research activity.

In our opinion, the use of available resources could be improved by an increased "mobilità" of researchers within the Institute. It must however be stressed that in the long run the attainment of the objectives of INFN will fundamentally depend on its capacity to offer competitive wages nationally (to attract gifted young people) and internationally (to offer positions to the best researchers in the international scientific community).

On the budgetary side, it would be useful to produce a multiyear projection of the financial situation of the INFN. This document should indicate that no imbalance will reasonably arise and show that the research activity is carefully forecast.

In the planning of the base activity of INFN it would be prudent to assume that in the future State funding will not increase substantially. Given this perspective, it is important to look for alternative sources of financing. In this respect the participation of external groups in experiments with INFN facilities and EU support for INFN initiatives are important and should be encouraged.

6. Internal review system

The CVI at its first meeting has examined the procedure of selection, review and evaluation of the scientific programs. The internal review system of the research program is organized with five scientific committees that follow closely all aspects of the research initiatives: scientific value, organization, resources in terms of personnel and budget, progress and scientific results. On the basis of their evaluation, the committees make recommendations to the President of INFN. The scientific committees meet on average five times a year. They present two reports, one in October on the research program and budget allocation for the next year and one in March with the account of the investments and achievements of the previous year.

The scientific committees members are elected representatives, of each Sezione or National Laboratory. They represent the staff and research associates active in the field. The chairperson of each committee is elected by the members (usually he/she is not a member of the committee). A member of the Giunta Esecutiva supervises the work of the committee acting as link between the committee and the management. The evaluation of the programs is done by the committee with the help of external referees, experts in the appropriate field. The scientific committees are also the forum where long term plans are discussed and proposal are formulated. These scientific committees are consultative bodies, all decisions being taken by the Consiglio Direttivo. As a matter of fact, it happens very seldom that recommendations of the scientific committees are not approved. The Review Committee takes note of the fact that each of the experimental activities is in general scrutinized by other bodies, e.g. the scientific committees of national and international laboratories, and in the case of smaller activities, the direction and local council of a Sezione.

Some projects of strategic importance for INFN, the so-called "Special Projects" are scrutinized more directly by the management. Among these are: New Accelerator Technique, EXCYT, APE, VIRGO and others. Ad hoc, smaller, review committees, usually chaired by a member of the Giunta Esecutiva, follow the progress of these projects and make recommendations to the Consiglio Direttivo.

The four National Laboratories (Frascati, Legnaro, Catania and Gran Sasso) have each an International Scientific Committee that reviews periodically the programs and gives advice to the director of the laboratory on the research activities, schedule of the experiments and, in case of accelerators, on the allocation of beam time to the experiments. The members of the Laboratory Scientific Committee are proposed by the Director of the Laboratory and nominated by the Consiglio Direttivo. These committees meet on average twice a year. Following a suggestion of the Richter Committee, a similar external review system is being set also for the Sezioni.

The CVI appreciates the internal review system, which is basically a bottom-up structure with supervision of the management. It provides a good balance between quality of the programs, competition and scientific freedom. It is also a very effective training of young scientists for positions of responsibility. The general excellence and success of the INFN program testifies to the effectiveness of the National Scientific Committees. However, it is also clear that, at a time when physics emphases are changing, and when external influences are global, a vision of the future from the management and the ability to adjust directions is very important.

The Review Committee believes that external reviews of the research activity in the National Laboratories are important. The international committees, beside giving advice on allocation of beam time on the local accelerators, should examine the whole program of the laboratory and consider the balance of allocation of resources across the complete range of laboratory structures.

7. Future reviews

The 1999 CVI discussed possible ways to improve the documentation to be provided by INFN. In particular it was suggested that for each program systematic documentation be provided.

The documentation provided for the second CVI Review was responsive to all these recommendations. The documentation provided for each experiment was succinct and informative. It greatly aided the evaluation process.

The discussions during the course of 2000 between INFN and CIVR led to an accepted set of objective criteria. This also was responsive to a recommendation of the first CVI.

In the report of the December 2000 meeting of the CVI, it was remarked that a limitation to the process of evaluation was the unavailability (to the committee) of data from other countries than Italy. These data are quite difficult to obtain. Nevertheless, the efforts of the GLV associated with the individual C.S.N. have produced such data. Despite its unevenness, these data have provided the CVI with information, which reduces the reliance on their own, often anecdotal, knowledge.

8. Conclusions, Remarks, Recommendations

We summarise the report with a series of remarks pertaining to each of the aspects of INFN, which have been discussed. Given the nature of the committee the perspective is predominantly that of the international physics community. However, our deliberations are guided by the objective criteria agreed between INFN and CIVR. Where appropriate, our remarks take the form of recommendations.

- i. **CSN I:** The program of research directed by CSN I is predominantly of the highest quality. Almost every experiment is of international repute. Italian physicists occupy leadership positions, including that of scientific spokesperson. The spectrum of experiments within the program is balanced between experiments in the mature exploitation stage and those in the formative stage. The former are extremely productive in terms of scientific results while the latter are a major source of innovation. The latter also have a major interaction with the productive and social system.
- ii. **CSN II:** For the range of research activities covered by CSN II, INFN has established itself as the leader within Europe and is on the worldwide forefront together with the US and Japan. The Gran Sasso Laboratory is unique and offers the best conditions for many experiments in astroparticle physics. The activities of CSN 2 are of the highest visibility of INFN. Among the INFN activities, this area, which is also both highly technological and highly interdisciplinary, is enjoying the strongest growth. Care, attention, and innovation will be needed to nurture this growth in such a manner that this leadership is consolidated or enhanced. The opportunities are numerous. An example is the intensification of experiments carried out in space.
- iii. **CSN III:** Italian nuclear physics is well represented in the very diversified spectrum of modern nuclear physics. The overall quality of the research is very good, and some activities are excellent. We wish to especially mention here the work on in-beam gamma-spectroscopy with GASP and EUROBALL, and the very strong efforts on the physics with electromagnetic probes and with ultrarelativistic heavy ions leading to the formation of the quark-gluon plasma. The activities in the field of nuclear astrophysics look very promising to us with the LUNA experiments being unique in the world.
- iv. **CSN IV:** Italy has a very strong tradition in theoretical Nuclear and Particle physics. The quality of activities in CSN IV largely reflects this strong tradition and is mostly of the highest quality. Particle physics phenomenology in Italy is continuing its role of world leadership. The same applies to the development of dedicated computers for the study of fundamental interactions. More formal theoretical physics is also carried

out at the highest level in CSN IV, and the seminal work of Italian theorists in this area is widely recognised. Work in traditional theoretical Nuclear physics is also very good by any international standard and is beginning to expand in new interesting directions.

An area that may need strengthening, particularly in view of INFN experimental efforts in the field (VIRGO, CNGS), is that of astro-particle theory. Excellent poles of activity in this field have recently sprung out, and should be strongly encouraged.

- v. **CSN V:** The technological and research activity directed by CSN V is of high quality, and capable of providing a significant impact in terms of technology transfer, both through training of a number of young researchers and cross-fertilization to the industry. The latter has been verified and confirmed through a specific survey.

It is recommended to continue to monitor the effectiveness of this endeavour, to strengthen relationships with leading industrial partners and to continue to keep track of comparable results obtained by similar foreign institutions. Finally, it appears advisable to verify if project screening criteria are adequate to avoid resource dispersion.

- vi. **The National Laboratories and Sections:** The National Laboratories represent important accumulations of resources for INFN. Discussions emphasised the importance of developing, elaborating and discerning long term strategic plans. Such plans should take into account the evolving emphases within the physics fields and the opportunities for leadership within Europe.

INFN should consider enhancements to the human and physical structure of the Gran Sasso Laboratory within the context of its potential for growth in importance.

- vii. **Institutional and Resource Management:** The resource management is very good, given the constraints faced by INFN. Some improvements could stem from an increased mobility of researchers within INFN. The financial situation seems to be balanced and under control; it would nevertheless be good to formulate medium term financial projections.

We note with pleasure, the substantial efforts on the part of INFN to be responsive to our main recommendations made in earlier reports.

Appendix A – Membership of the committee

- Prof. R. Artoni, Bocconi University, Milan, Italy.
- Dr. E.Lorenz, Max Planck Institute, Munich, Germany.
- Dr. H.E.Montgomery(Chairman), Fermi National Accelerator Laboratory, U.S.A
- Prof. R.H.Siemssen, K.V.I., The Netherlands.
- Ing. C.Vanoli, SNIA S.p.A., Italy
- Prof. G. Veneziano, CERN., Geneva, Switzerland.

Prof. L. Mandelli (Scientific Liaison), University of Milan, Italy.

Agenda of the INFN CVI Meeting

Rome, May 4-6 2001

Friday, May 4

- 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 INFN activity in the last two years
Discussion* E. Iarocci
- Break*
- 11:10 *Evaluation exercise for the experimental subnuclear physics
with accelerators
Discussion* CSN1 (P. Campana)
- 12:20 *Evaluation exercise for the experimental subnuclear physics
without accelerators, astroparticle and neutrino physics
Discussion* CSN2 (E. Coccia)
- 13:30 *Lunch*
- 14:30 *Evaluation exercise for the experimental nuclear physics
Discussion* CSN3 (A. Bertin)
- 15:40 *Evaluation exercise for theoretical physics
Discussion* CSN4 (R. Floreanini)
- Break*
- 17:10 *Evaluation exercise for technological and interdisciplinary
research
Discussion* CSN5 (P. Cerello)
- 18:20 *Closed Session*
- 19:15 *Queries and questions to the INFN Executive Board and to the Scientific Committee
Chairmen*
- 20:30 *Social Dinner*

Saturday, May 5

- 09:00 *Report on the activities of the Gran Sasso National Laboratory* A. Bettini
Discussion
- 10:10 *Responses to queries and questions posed to the INFN Executive Board
and to the Scientific Committee Chairmen*
- Break*
- 11:30 *Closed session*
- 13:00 *Lunch*
- 14:00 *Report on organization and financial resource matters* A.Scribano
Report on resources, as required by CIVR G. Ricco
Discussion
- 15:30 *Closing discussion with the Executive Board*
- 17:00 *Closed session (report drafting)*

Sunday, May 6

- 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)*

Monday, May 7

Finalization of the report by H.E. Montgomery. Committee members may contribute.

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.*
- *The chairmen of the scientific committee are expected to be available for discussions also Saturday and only exceptionally Sunday.*