Report of the

Instituto Nazionale di Fisica Nucleare

International Review Committee

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I. Introduction and Summary

Our committee was asked by the President of the INFN, Professor Luciano Maiani, to do a comprehensive review of the entire INFN, from the functioning of the headquarters to the details of the program. We spent eleven days in Italy over three different visits. During this period, we met in Rome to review the committee's charge with Professor Maiani as well as the functioning of headquarters, visited all four of the national laboratories, heard overviews of the programs from the chairmen of all five groups as well as having specific presentations on each program's major elements, had five separate meetings with the young scientists from each of the groups in the absence of any senior scientist or members of INFN, and visited five sections (four large and one small) to better understand the functioning of the system.[1]

The INFN program is very large and quite diverse. It should not be surprising that a committee as small as ours did not have the time and in some cases the expertise to review all elements of the program in the depth that they deserved. Where we feel further reviews are appropriate, we have so indicated in the text.

In the rest of this section we will summarize our main observations and recommendations. The format will follow the Table of Contents, and the technical details as well as a fuller justification of our specific recommendations will be found in the main body of the report.

INFN Issues

The INFN itself is a remarkably effective organization. Its democratic structure, coupled with the authority of the President and the members of the Executive Board (Giunta), have struck an excellent balance between the need for the scientists to have a very strong voice in the direction that research will take, and the need for the organization to have some authority to conduct the program in an orderly and financially responsible fashion. From conversations some of us have had with scientists in Italy from disciplines not supported by INFN, it seems that INFN is highly regarded in the broader scientific community for the role the working scientists have in deciding on the directions of the program, the speed with which the organization can respond to changing directions in science, and the small ratio of administrative costs to total INFN budget. We agree.

The system of limited terms of office for the President, the Executive Board, the Laboratory Directors, and the Section Leaders, has resulted in a constant flow of new ideas into these important positions. In a sense, this has kept the organization young and scientific by preventing the leadership from staying too long in office and becoming bureaucratic.

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[1] Our work benefited greatly from the support of the INFN staff in making the necessary arrangements, and we are especially indebted to Professor Alesandro Bettini who helped us with arranging our agenda, setting up the meetings, arranging for speakers, and keeping us going.

We have only two observations about INFN itself. The first has to do with the international experience of young scientists. In Groups I, II and IV, they traditionally work outside of Italy soon after obtaining their degrees. This has a good effect on the program because it involves these young people in the most important work occurring internationally. This has not happened to the same extent in Group III, perhaps because of the existence of two accelerator laboratories for nuclear physics in Italy itself.

- It would benefit Group III if more of their young people spent time at leading nuclear physics institutions outside Italy.

The second issue arises from our observation that very few young people from outside Italy spend time in Italy, thus hindering the flow of new perspectives to the INFN Sections.

- We believe that the very low salaries provided by Italy for young foreign visitors are a major part of the problem. They should be adjusted upward.

We next turn to the situation of young scientists. We had five meetings of about an hour each with the young scientists from all groups. The discussions were remarkably similar. All agreed that the INFN provides more opportunities than other agencies for interesting well-financed projects in excellent research conditions. However, we were surprised at the apparent lack of mobility for young scientists in Italy. Of those who had obtained permanent posts, most had attained them at the place where they received their degrees. The young scientists clearly felt that only by staying with their professor did they have any reasonable assurance of obtaining a permanent position. We also found criticism of the lack of an organized post doctoral program in which young scientists could qualify themselves outside of their home institutions; of the centralized selection of permanent appointments through a "concorso" which was felt not always to select the best people; and of the very low salaries which made it difficult to support a decent standard of living and family. We recognize that it may not be in the power of the INFN to correct all of these problems, but believe it should do its best.

- INFN should introduce a post graduate program with appointments of up to five years to create opportunities for research outside of a person's home university. The Sections should have special positions for post docs and should make their own selection of the candidates.

- For permanent appointments, each Section should be given the responsibility for candidate selection using a selection committee including some outside members and making use of external letters of reference.

- Salaries should be adjusted to an appropriate level. This is especially true for young scientists who have obtained the Ph.D. degree, recognizing their longer experience and demonstrated scientific achievement.

- Young scientists would like more responsibility for subprojects within a larger activity. The committee finds this very positive and encourages INFN and the Sections to find such opportunities in the ongoing program.

- Some of the younger scientists, particularly in theoretical physics, do not appear to have enough independence in choosing their research projects. They should be encouraged to widen their perspective by collaborating with people and on projects outside of their own group for part of the time. This can only work successfully if the senior scientists recognize and encourage this kind of work.

We visited five of the INFN Sections to allow us to sample the structures, relevance and impact of the INFN program on the physics departments of Italian universities. These visits were not intended to review the programs of the Sections in depth. They are powerful research units which are able to carry out large programs and research projects and thus can play a leading role in international collaborations. The technical support provided by INFN is used very well and has given rise to a research program of a wide scope. Altogether, this has led to remarkably high-class research activities at the universities which particularly benefits students and young scientists. We have two comments here.

- The Sections are the heart of the INFN program and should be given more attention. External reviews of every Section should become routine. Such reviews will give INFN a much better idea of the quality of each program, and the preparation for such a review requires that each Section review its own present and planned program — a healthy thing.

- At some of the Sections we visited, the laboratory space was old and inadequate. INFN might consider contributing to the improvement of the laboratory space in the university section.

The National Laboratories

The Frascati laboratory (LNF) has a very broad program whose main emphasis is on elementary particle physics and astroparticle physics. The technical staff is quite strong and the laboratory is well managed. The largest single project at the laboratory now is the construction of the Φ-factory, DAFNE, which represents a kind of return to the Frascati tradition of the 1960's when, with the building of the ADA and ADONE storage rings, it was a pioneer in colliding beam work. Both the machine and the detector are proceeding well. We have two observations about the Frascati laboratory.

- The scientific program is very dispersed. Concentration on fewer projects would give the scientists at the laboratory greater impact on each project and could stimulate scientific life on site.

- The laboratory should aim at closer academic links with a nearby university active in particle physics. This would stimulate future developments in the laboratory by bringing more scientific discussions and more students to the site, thus making it a more lively place.

The laboratory at Catania (LNS) is focused on nuclear physics and uses two accelerators — a compact superconducting cyclotron (CS) and a Tandem van de Graf generator which also serves as an injector into the CS. Currently the program is limited by poor operation of the CS and increased efforts are needed to develop and improve the ion beams required for experiments. The detector systems available or under construction are impressive and a number of foreign collaborations have been established for work at LNS. The project for production and acceleration of radioactive beams in the Tandem is interesting and will provide unique beams. We have two specific recommendations here.

- We recommend increased effort in accelerator engineering, accelerator physics, and ion source development aimed at improving operational reliability.

- We recommend increased efforts at cooperation with other medium-energy heavy-ion centers such as GANIL (France), GSI (Germany), MSU (U.S.A.) and RIKEN (Japan) in order to perform the best experiments in a complex field of medium-energy heavy-ion physics.

The laboratory at Legnaro (LNL) is becoming a European center for nuclear structure physics. It is also a center for advanced accelerator technology development, large detector construction for particle physics, applications of nuclear methods in biology materials, science and medicine, and houses one of the two antennas for gravitational-wave research (the other is at LNF). The main nuclear physics facilities are at present a Tandem van de Graf accelerator providing relatively low-energy heavy-ion beams, and the ALPI superconducting linear accelerator which uses the Tandem as an injector to provide medium-energy heavy-ion beams. The ALPI facility has attracted the European nuclear structure community and LNL was chosen as the site for construction and first use of EUROBALL, a full solid-angle gamma ray detector for gamma spectroscopy. The project for constructing a new positive ion injector (PAVE) for ALPI is very welcome for it will raise the energy, intensity, and range of heavy ions that can be accelerated, thus keeping Europe competitive in its program with accelerators in other regions of the world. Plans are also being discussed for developing a 100 kW radioactive beam facility. We have three recommendations here.

- INFN should try to assure that LNL makes the most efficient use of EUROBALL (and GASP) during the coming years.

- INFN should compete to keep EUROBALL at LNL for the longer term and, if such endeavors are not successful, to participate in a new European gamma-detector development program for future gamma spectroscopy work at LNL.

- The 100 kW radioactive beam facility being discussed will be a complex and costly project capable of making important contributions to science. INFN should consider carefully the role it wishes to take in such a project and it should only proceed in a European-wide framework.

The underground facilities at the Gran Sasso laboratory (LNGS) are a unique resource for high energy and nuclear physics. The number of users has grown to about 500 with about 50% of those users coming from outside Italy, indicating that the world community finds LNGS important. The experimental program is broad and strong, and the support staff seems to be very good. We have two recommendations here.

- The laboratory has an excellent program committee system to assure that only the best experiments are approved. However, it has no mechanism to periodically review ongoing experiments to assure that their continuation is worthwhile. Considering how valuable space and support resources at Gran Sasso have become to science, we recommend that all experiments undergo a periodic review to determine how well they are performing and if they should be continued.

- The support staff is planned to be increased and it is important that some of the best young people are attracted to positions at LNGS. To do so will require that they be given an opportunity to participate in the physics programs as equals and we thus recommend that staff physicists at LNGS be allowed for part of their time to collaborate on experiments at the laboratory, taking part in the preparation of apparatus, data taking, and data analysis.

Research Programs

Group I (particle physics with accelerators) is the largest of the INFN programs and is participating in experiments at all the major accelerator centers in Europe and the U.S. The INFN program in this area is truly outstanding and Italy has become one of the major players in particle physics worldwide. The technical infrastructure and expertise at several of the INFN Sections allow advanced R&D work and innovative contributions to detector facilities, and are part of the reason that Italian collaboration is highly desired by projects outside of Italy. There are two general problems that we note here that apply to the other groups as well.

- The mobility of younger scientists inside the country between universities and/or INFN Sections is much smaller than in other European countries. An INFN policy to stimulate mobility would be helpful.

- Most Group I experiments are carried out abroad. Since it is attractive for personnel to stay in a foreign country, there is the potential for an imbalance to develop between staff in Italy and outside Italy. This is an issue that could affect large projects in Italy such as KLOE, VIRGO, large Gran Sasso experiments, etc. INFN should look into the situation.

With regard to the experimental program, we limit our observations here to the large-scale experiments that involve long-term INFN commitments. There are three major experiments currently in the data-taking phase; at LEP (CERN), the TEVATRON (FNAL, U.S.A.), and at HERA (DESY). All three are important and are having a significant impact on high energy physics. We have three recommendations.

- LEP will run through 1999 or 2000 and analysis of the data will continue for several years thereafter. This work should be strongly supported.

- At FNAL, the CDF collaboration is involved in a major upgrade of the detector to go with the increased luminosity possible from an upgrade of the TEVETRON itself. Until the beginning of operations of the LHC, FNAL will have the world's highest energy hadron collider and the experimental work should continue to be supported.

- The HERA electron-proton collider at DESY is unique and, with the planned luminosity upgrade in the years 1999-2000, it will remain highly productive for many years. This program also should continue to be supported.

In the next few years two major experiments will begin to take data. One of these is the KLOE experiment at DAFNE. The other is the BaBar experiment at the Stanford Linear Accelerator Center's B-Factory. Italian participation in KLOE is, of course, dominant, and Italy is the largest group from outside the U.S. on the BaBar experiment. Both of these projects seem to be coming well, but there is one potential problem with DAFNE/KLOE that deserves INFN attention.

- There may be a shortage of technical personnel developing at LNF that might affect the schedules of both the machine and the detector. INFN should carefully monitor the situation and take measures to avoid major delays.

The long-term program is now concentrated on the CERN LHC which should begin its operation in 2005. Italian groups collaborate in both of the large detectors. On present projections, a major fraction of the funds available to Group I (we were told about two-thirds) will be needed in the critical years of detector construction 2000-2003 assuming a constant funding of Group I at today's levels. The LHC experiments deserve strong support. We expect that if new important opportunities open up in the early 2000's, INFN will find a way to support them at an appropriate level.

The Group II program (non-accelerator physics and neutrinos) has excellent procedures for approving experiments. We will comment only on the largest elements of the program with emphasis on the future. We note that the recommendation made earlier in the section on LNGS relating to periodic review of experiments should apply to all the elements of the Group II program.

The GALLEX experiment has been a great success. In particular, the calibration of the apparatus with a radioactive source has been very convincing on the correctness of the GALLEX results. The continuation of this experiment is well worthwhile.

BOREXINO, a new experiment, will soon be taking data. Its expected low-background and low-energy threshold make it an important complement to GALLEX.

ICARUS is a new device that gives bubble chamber-like pictures of neutrino interactions in 600 tons of liquid argon (phase one). This pictorial quality will greatly reduce uncertainties in interpretation and background. It is probably most effective in long baseline neutrino oscillation experiments and in the study of electron-to-muon neutrino ratios produced by cosmic rays in the atmosphere. CERN's plans for the long baseline neutrino beam are uncertain at present.

- We recommend that INFN carefully consider the full cost of the long baseline program including both contributions to the beam and detector upgrades before proceeding.

Satellite and balloon borne experiments are a developing area in Group II. There are important questions in particle physics and particle astrophysics that can only be answered through these kinds of experiments, and so it is appropriate for INFN to be involved. We did not have enough time to give this program the attention it deserves. It is not clear to us if there is excessive duplication in the aims of various projects.

- We recommend that a special comprehensive review of this program be held to evaluate its coherence and future directions.

The VIRGO project is an important French-Italian collaboration to build a large laser interferometer for gravitational radiation research. The estimated project cost is 77 million ECU. A small test system is to be ready at the end of 1998, and the full project ready in 2000. We are concerned that both the budget and schedule are in danger because of a lack of the central direction and authority that are necessary on a project of this scale and complexity. The VIRGO organization is a very loose one, clearly designed to preserve maximum autonomy for the participating groups. Lines of authority and responsibility are unclear. Obviously a project involving two countries and eleven participating scientific groups has certain complexities and sensitivities. While all participating groups are strongly motivated and work very hard, it appears that for the benefit of the project as a whole these groups should be willing to give up some of their independence to the project leadership.

- We recommend that the VIRGO Science and Technology Advisory Committee be asked to review the project organization with the object of strengthening the role of the project leader and the technical manager.

It is recognized that VIRGO will need a core staff that goes beyond the assembly stage to maintain it, keep it running, carry out necessary modifications, and support the research program. The creation of this support staff has been deferred, which we believe to be an error.

- We recommend that the VIRGO project begin now to create the core group of engineers and technicians envisaged for the long term.

Italy operates two gravitational-wave bar antennas (at LNF and LNL). They will remain state-of-the-art detectors, at least until VIRGO is completed. However, their role for the long-term future is not clear to us.

- We recommend that INFN review the long-term future of the bar antennas to determine how long they should be continued once VIRGO is operational.

The program of Group III (nuclear physics) has become quite strong, thanks to INFN's support of competitive projects in the Italian national laboratories, as well as supporting activities at laboratories outside Italy. This has produced a strong home-based program with broad international links and with a tendency to spread beyond conventional nuclear physics borders. The main work in Italy is concentrated at the ALPI facility (LNL) and the CS facility (LNS) and will soon spread to Frascati with the start up of the DAFNE accelerator and its associated FINUDA detector. International and foreign teams are working at Italian facilities and particularly striking is the location of the large-scale European collaboration on EUROBALL at LNL. We have made several specific recommendations on the program which we leave to the main body of the report, and discuss here only those which have policy implications for INFN.

There are three interesting European initiatives for the study of strongly interactive systems; putting ions into the HERA machine at DESY for deep inelastic scattering experiments at the highest energy; a high-luminosity electron-proton/ion collider at GSI; and the use of the electron ring at HERA to provide a high-intensity continuous beam of polarized 15-30 GeV electrons. The two most cost effective projects seem to be the two at DESY.

- INFN should monitor developments at DESY in both the heavy ion and ELFE programs. Support should be considered at the appropriate time.

INFN has growing international use of the LNS facility and is the first home for EUROBALL at LNL.

- It is of critical importance that the accelerator facility at LNS gets into a state of reliable routing operation and that EUROBALL gets the necessary support so that it becomes a real scientific success.

There is a great deal of interest in Italy and in the rest of Europe in the development of radioactive ion beams (RIB) for the synthesis and study of nuclei far-off stability. The European discussion is focused on three alternatives. At GSI there is a project under discussion to produce high-intensity medium-energy RIB by projectile fragmentation. There is a European discussion on accelerating fission products to produce neutron-rich super-heavy nuclei. There is a discussion about use of a 100 kW proton or deuteron beam to produce, through the spalation process, radioactive nuclei which are then reaccelerated. LNL, in collaboration with LNS, is looking at possible modifications of their facilities that would bring them to a beam power of about 10 kW at the production target similar to the GANIL SPIRAL project that becomes operational in 1998. There is also preliminary discussion on proceeding into the 100 kW regime, and LNL has proposed starting R&D on the necessary high-intensity linear accelerator, which would become part of a European project with a site at Legnaro.

- We recommend that INFN study carefully whether it wishes to take a leading role in the development and construction of a European radioactive ion beam with LNL as a host laboratory. It will be a large and expensive undertaking and should be done in a European-wide context.

Group IV program (theoretical physics) spans a wide range of research that covers almost all of the major areas in particle and nuclear theory. Overall, we think that the balance among subfields is broadly acceptable, although there does seem to be a case for additional support in the areas of lattice simulations and astroparticle/ cosmology work. Italy has made a sizable investment in the development of supercomputer hardware (APE) and it is important that there should be a strong theoretical effort to extract the physics and exploit this facility.

- Lattice work is an area where additional resources should be deployed.

Astroparticle physics is enjoying considerable growth worldwide because of the rapid increase in data on large-scale structure in the universe, on the distribution of dark matter, etc. This rapidly developing field offers young theorists a chance to make quite significant contributions.

- Support in this area is at a relatively low level and should be increased.

In all areas, the theoretical research is at an internationally competitive level. The INFN policy requiring Italian post docs to go abroad for a period of time fosters integration at the international level as does the INFN provision of travel funds. There are strong international collaborations in all areas. The situation of young physicists in theory is discussed and the recommendations have been summarized earlier.

Group V (technology) is mainly in the areas of detectors, electronics, computing and networking, accelerator development, etc. It also has a component devoted to sectors where INFN technology might have a potential societal impact. It was not possible for us to go into any great depth in the time that we had available, and our conclusions and recommendations focus here on areas where even in our limited review it was apparent that there was some need for action on the part of INFN. If these activities are to be analyzed in greater depth, a special technical committee will be needed. We do note, however, that, as in the Gran Sasso and Group II programs, there does not seem to be a review process internally that monitors the progress of these programs once they have begun.

We noted that there seems to be no systematic efforts to work with industry in order to transfer technology or to develop new technology in areas of INFN expertise. There are some exceptions, APE for example. The potential benefits to Italian society of effective technology transfer are significant if this can be made to work.

- INFN should investigate the possibility of setting up a technology outreach function at headquarters.

The computing situation in INFN is good; the work is well organized and mechanisms are in place to assure that program needs are understood by the computing people. Local area networks within INFN institutions are in good shape. However, the situation of wide-area networks is not good and present bandwidths are already limiting activities of INFN groups. This situation will only grow worse as more data-intensive experiments come on line. Plans are in place to upgrade the links to CERN to 8 MBS, and to the U.S. to 8-16 MBS. This can only be a temporary solution because LHC, CDF, and BaBar will find that bandwidth limiting.

- INFN should be looking toward further increases in bandwidth by 1999-2000.

The societal programs of Group V (medical imaging, cancer therapy, environmental studies, etc.) do raise concerns about the project selection process. In these areas the INFN "bottom-up" project selection process can lead to a proliferation of poorly-coordinated activities. One does not want to discourage the INFN community from developing technology that will benefit the larger society, but at a certain hard-to-define-point it is necessary to have a review of each societal program that involves those experts from outside INFN who will be most affected.

- INFN needs a review process for societal programs that involves specialists in the relevant areas at an early point in these programs.

We looked briefly at two special programs. The rf superconductivity program has made great contributions to the development of rf superconductivity. The work of the Genoa Section was critical to developing practical spherical cavities. The continuation of this kind of work in the TESLA program is natural. The work being done is very good.

The energy amplifier technology promoted by Carlo Rubbia and colleagues appears to have great potential. It is based on a thorium-cycle subcritical facility driven by a high-intensity proton accelerator, and can be used either for energy production or burning up long-lived radioactive wastes. The main issues in this technology lie almost exclusively in the engineering aspects and most of them concern the reactor and its related systems. INFN expertise lies in proton accelerators and this is the area where there is some interest by INFN labs and groups in becoming involved. However, the accelerator technology has already been demonstrated from the ion source through the superconducting cavities at laboratories in the U.S. and in Europe. The most important issue is in systems engineering to hold the cost down and maintain very high reliability.

- If INFN is to become involved in the energy amplifier area, it should understand the issues clearly and determine that its expertise is appropriately matched to the problem. Participation should be as part of a coordinated larger scale effort, for ultimately the success or failure of this scheme will depend on the subcritical facility and its auxiliary systems.

II. INFN Issues

A. Structure

INFN is a remarkable organization. It was designed by its founders to keep control of the scientific program in the hands of the scientists and it has done so. The result is an unusual organization that has been very successful, particularly in high energy physics where Italian scientists play a leading role in many of the most important international collaboration in the field. The INFN structure is very complicated with a large number of committees and elections. It is amazing that it works, but it works very well.

The democratic nature of INFN structure creates a danger that has been largely avoided — that of spreading the resources uniformly over the professors in the universities so that all share equally at all times. This kind of distribution would prevent Italy from starting major initiatives by concentrating resources on a few people and groups. This has not happened and it seems to us that the good outcome has been caused by the effective functioning of the decision-making bodies at all levels. The ability of the President and the Executive Board (Giunta) to influence decisions is particularly important.

The INFN sections group together university scientists and INFN technical and scientific support in a broad program that covers all of high energy physics, nuclear physics, and relevant technology (the five Groups). The sections tend to be quite large when compared, for example, to entire physics departments in Europe or the U.S. This very size makes possible sections that have a technical infrastructure that is among the best in the world, which has allowed the Italian INFN program in high energy physics to play such a prominent role in the worldwide program. The engineers, technicians and equipment supplied by INFN are effectively used, and because they support such a broad program they are always busy.

We note that the sections tend to do much more fabrication and assembly work than is done in other countries where design and development are done in the universities and laboratories, but production of high tech systems is often done in small- and mid-sized companies. This allows the physicists and engineers to concentrate on developing new systems that industry cannot, or which have too limited a market to make the development economical. We do not know enough about the high tech section of Italy's industry to be able to tell, for example, if moving some of the electronics work out of the section would both get the work done at a reasonable cost and benefit the Italian economy.

INFN practice has resulted in most of the young physicists of Groups I, II and IV spending time outside of Italy soon after their Laureandi or Ph.D. This has had a good effect on the program because it has involved these young people in the most important work occurring internationally. This has not happened to the same extent in Group III, perhaps because of the existence of LNS and LNL with accelerator facilities.

- It would benefit Group III if more of their young people spent time at leading nuclear physics facilities outside Italy.

- We note that movement of young people from outside Italy to Italy for a few years is practically nonexistent. The very low salaries provided by Italy are a major part of the problem. They should be adjusted as is discussed later.

B. Young Scientists

The committee had five meetings of one hour each with the young scientists of all groups, and enjoyed lively discussions on their situation within INFN and the universities. The young scientists pointed out to the committee that INFN provides a lot more opportunities than other agencies with interesting, well financed projects. It provides both experimentalists and theorists excellent research conditions. Nevertheless several points of concern and criticism were raised. We discuss here those that seem most important. We recognize that INFN may not be free to improve the situation because government regulations and the universities are involved, but we urge INFN to take the lead when possible and bring these matters to the attention of the appropriate Ministries.

1. Job Situation

There was general dissatisfaction about the career opportunities at INFN and the universities. Particularly criticized was the absence of an institutionalized post-doctoral program, in which young scientists could qualify themselves outside of their home institutes, and the centralized selection of permanent appointments through a "concorso," which is felt not always to select the most qualified people.

Another point of criticism is the very low salary which, the committee was told, hardly supports a decent living not to speak of supporting a family. It is also a blocking element for mobility, because young people can only afford to live in their home towns where they have to count on the support of their families. It may explain a fact that surprised us; that most of the young scientists have appointments at the university where they have studied and obtained their degree and which is normally close to their family home.

Another element of the low mobility is the feeling, right or wrong, that only staying with your professor and group gives reasonable assurance for later obtaining a permanent position — again in his group. It is also felt that a longer stay abroad and away from the group makes it more difficult to return and to find an adequate position in Italy.

The committee learned in these discussions about a problem which seems to be particularly evident in Italy; young physicists have very few opportunities to find work outside the university and the research sector. The INFN is encouraged to consider measures which could promote and facilitate transitions of young scientists to industry or to start their own business.

The committee recommends the following options be considered.

- Introduce a post-graduate program with appointments up to five years for which people must find an opportunity outside their home university and section following the well established practice in many countries. We suggest that the sections have special positions for such a program and should make the selection of the candidates.

- For permanent appointments we recommend a system in which each section is given the responsibility for the candidate selection. This could be done with a selection committee including some outside members and making use of external letters of reference for the candidates as an important element in the procedure. A longer and successful stay abroad should be considered as a bonus, as well as demonstrated mobility in general.

- A very important element should be an adjustment of the salaries of the young scientists to an appropriate level. We suggest giving a higher salary to scientists who have obtained the recently introduced Ph.D. degree, acknowledging in this way their longer experience and demonstrated scientific achievement.

2. Responsibility

Some of the young scientists, particularly in the experimental and technological sectors, expressed their wish to be given more responsibility, e.g., for interesting partial projects within a large activity.

- The committee finds this very positive and encourages INFN and the sections to find such opportunities in the on-going programs. The committee considers this also as an important policy for the development of the INFN program, because this will train young qualified people to manage larger responsibilities in the future.

3. Independence

It appears that some of the younger scientists, particularly in theoretical physics, do not have enough independence in choosing their research project. Phenomenologically oriented work in collaboration with experimental groups and with others in more distant areas of research seems not to be encouraged.

- The committee suggests that young scientists be encouraged to widen their views by collaborating with people and on projects outside of their own group for part of their time. This can only be successful if the senior scientists recognize and encourage this kind of work. Interdisciplinary seminars and workshops could help to establish fruitful contacts.

C. Sections

The committee visited four of the large INFN sections, Rome, Padova, Pisa and Milano, and one of the smaller ones, Ferrara, as an example of one in its growing phase. The visits allowed us to sample the structures, relevance and impact of the INFN research support system in physics departments of Italian universities. They were not intended to review in depth the programs of the sections.

The structure as presented to the committee is such that 18 university physics departments and the Instituto Superiore di Sanità (Rome) host INFN supported research sections, which enjoy complete independence from the university departments both in management and administration. There is a remarkable symbiosis in research and teaching of the university professors and the INFN researchers, whereby the university professors contribute strongly to the research and the INFN researchers help in teaching. The students (Laureandi and Ph.D's) do their research work within the INFN structure.

In general the majority of the research personnel are university professors and researchers complemented by INFN researchers (~30%). On the other hand the technical and administrative staff is mainly provided by the INFN. This system leads to very powerful research units, which are able to carry out large construction programs and research projects and thus can play a leading role in international collaborations in particle physics. The committee noted also that the sections specialize in the development and construction of certain detector components, such as calorimeters, vertex detectors, electronics, which they then can bring into various collaborations. This philosophy allows the sections to participate in a large number of collaborations without overloading the infrastructure. It also makes it possible for a large section to participate in projects of all five research groups of

INFN, giving the research program a wide scope. Altogether, this leads to a remarkably high class research activity at universities, which particularly benefits the education of students and young scientists.

There was only one deficit which we could notice; in some universities the available laboratory space is rather limited and the buildings are sometimes rather old and inadequate to house decent laboratories.

- The INFN might consider contributing to the improvement of the laboratory space in the university sections.

Although we spent eleven days in this review of the INFN program, it was not possible to review even the small sample of sections that we visited in the depth that they deserve. The sections are the heart of the INFN program, and they should be given more attention.

- External reviews of every section should become routine. Such reviews will give INFN a much better idea of the quality of each program, and the preparation for such a review requires that each section review its own present and planned program, a healthy thing.

III. The Laboratories

A. Frascati (LNF)

The LNF has a broad program whose main emphasis is on elementary particle physics and astroparticle physics. It has a strong effort in detector R&D and in accelerator technology (with the DAFNE project). It plays an important role in the assembly and test of large detector components in collaboration with INFN sections in cases where size and complexity are beyond the scale that can be accomplished with the infrastructure available outside a large laboratory. The LNF staff have themselves taken responsibility for elements of experiments in the lab and, as part of larger collaborations, working outside the lab. The LNF also supports and assists the national scientific community in areas such as publishing, computing, etc. The scientific and technical staff is quite strong and is one of the great strengths of LNF. Also, the lab appears to be well managed. Given the breadth of the LNF program, we could only look at a few areas in any depth. Below we comment briefly on DAFNE (see also Section IV.A.2.c) and the large-scale detector work.

The construction of a Φ-factory, DAFNE, at Frascati was decided by the INFN Council in the year 1990. With this bold decision, INFN renewed the mission of the LNF as an accelerator laboratory for a front-line research program in elementary particle physics in the great Frascati tradition of the 1960's, the time of ADA and ADONE. DAFNE, with the KLOE detector, opens the possibility of studying CP violation in K^0 decay with unprecedented precision, one of the burning questions in particle physics for many years. It also allows some other interesting research programs with low energy kaons (Finuda). With DAFNE, the LNF will have a unique accelerator facility. The construction of the storage ring and the injector system in the existing ADONE buildings allows important economies.

The committee was impressed by the progress of the DAFNE installation and by the good test results with the completed parts of the injection system. The commissioning of the whole facility is planned to be completed by December 1997, and luminosity should be available for KLOE in the course of 1998. DAFNE is a very ambitious project, it will be a challenge to achieve the design parameters in beam quality and luminosity. The DAFNE project has a very positive impact on the spirit of the whole Frascati laboratory, which was felt by the members of the committee during their visit.

In the assembly and test of large detector components, LNF plays an important role for particle physics in Italy. Many of the INFN/university teams rely on collaboration with the LNF with its powerful infrastructure and technical expertise when providing their contributions to large detectors. The lab also takes on as part of its own research program the development and construction of large detector components and subsystems that could not easily be provided by a university team. Good examples in recent times are the resistive plate detectors for the BaBar detector at SLAC, the central drift chamber for the KLOE detector for DAFNE, and the precision drift tube modules for muon detection in the ATLAS detector at CERN. We note two issues that deserve consideration.

- The scientific program is very dispersed. A concentration on fewer projects would give the scientists and the groups of the laboratory greater impact on each project, and could stimulate scientific life on site.

- The laboratory should aim at closer academic links with a nearby university active in particle physics. This may be difficult due to the geographical situation and the fact, that it is not always easy to reach the laboratory by public transport. However, the committee feels that stronger academic links would stimulate the future development of the laboratory by bringing more scientific discussions and more students to the site, thus making it a more lively place.

In conclusion, the committee had a very good impression about the LNF and the ongoing work and believes the laboratory has the potential to be a first class scientific institution in these coming years.

B. Catania (LNS)

At present, the heart of the LNS is a superconducting compact cyclotron, CS, with K=800, and a SMP-Tandem which also serves as an injector to the CS. In December 1994, 58 Ni-beams were accelerated for the first time with the CS to an energy of 30 MeV/A and extracted. This was a milestone in the development of the LNS which was founded in 1976. Research started in 1984 with the SMP-Tandem mainly in the field of low energy heavy ion reaction studies. Following an upgrade in 1992, terminal voltages of up to 15.5 MV are reached routinely. The CS-cyclotron was designed by the late Francesco Resmini in Milano. After several years of project delay during which he and his group helped Blosser to build the Michigan State SC, the CS was constructed in Milano during the eighties. After a cool down and field measurements in Milano it was disassembled and moved in 1990 to Catania and reassembled again, a rather time-consuming operation. During the cyclotron construction phase, several detector systems were built and used at foreign accelerator facilities while no CS-beams were available (for example, MEDEA which was installed at GANIL, France, and moved back to LNS in 1993 where it is now in operation).

Currently, the program is limited by poor operation of the CS. Increased efforts are needed to develop and improve the ion beams needed for experiments. The program requires a reliable accelerator operation to achieve the necessary efficiency in experimentation.

- We recommend increased effort in accelerator engineering, accelerator physics, and ion source development aimed at improved operational reliability.

The detector systems available or under construction are impressive and should be well suited to study the dynamics and structure of hot nuclei in a much improved manner. A number of foreign collaborations have already been established and many foreign individuals are participating in research programs carried out at LNS.

A concerted collaborative effort with the major centers of medium energy heavy ion physics, such as GANIL (France), GSI (Germany), MSU (USA) and RIKEN (Japan) would be worthwhile in order to perform the best experiments in this complex field of research.

- We recommend increased cooperation with the other medium-energy heavy-ion centers.

For the future, the EXCYT project for production and acceleration of radioactive beams in the Tandem van de Graf is interesting because it will provide unique beams with small momentum spreads and low emittances for nuclear reactions spectroscopy in inverse kinematics. In order to achieve sufficient intensities, one needs beam currents in the order of particle-μA, which are planned to be provided with an ECR-source. Such an intensity upgrade would, of course, also help the normal CS-program.

C. Legnaro (LNL)

The LNL in Legnaro, established in 1968 as an INFN national laboratory is becoming a European center for nuclear structure physics. It is also a center for advanced technologies in accelerator development, large detector construction for particle physics, applications of nuclear methods in biology, material science and medicine, and houses one of the antennas for gravitational wave research. At present the laboratory operates two Van de Graf accelerators for interdisciplinary research, mainly as analytical tools. The most used facility for nuclear physics is at present a XTU-Tandem accelerator in operation since 1982. An upgrade of the terminal voltage to 18 MV was done in 1986. It provides heavy ion beams up to iodine with energies of 3 to 5 MeV per nucleon, just enough to reach the Coulomb barrier for lighter systems. To increase the energy range from 5 to 20 MeV per nucleon and allow the acceleration of elements up to uranium, the ALPI linear accelerator with superconducting rf cavities was constructed with the Tandem used as an injector. This unique facility attracted the European nuclear structure community, and LNL was chosen as the site for construction and first use of EUROBALL, a high resolution, highly segmented 4π Germanian gamma-ray detector for in beam γ-spectroscopy. In addition LNL owns GASP, a Ge-detector system with about half the efficiency as EUROBALL, which can be used in combination with a unique mass spectrometer for the identification of the reaction products in coincidence with the γ-cascades. This yields a high selectivity for the study of nuclei far off stability produced in the weakest reaction channel.

- INFN is advised to take all measures to assure that LNL makes the most efficient use of both instruments, EUROBALL and GASP, during the coming years.

The project to construct a new positive ion injector PIAVE for ALPI is strongly welcomed. It will be equipped with the first superconducting RFQ-linac and will substantially raise the energy, intensity, and capability of acceleration of very heavy ions up to uranium; thus allowing a competitive nuclear structure program with ATLAS at ANL (USA), the future site of GAMMA-sphere, the U.S. high-efficiency γ-detection system. In addition we feel that efforts are worthwhile to improve the transmission of the present accelerator system.

- We advise INFN also to be competitive concerning the future site of EUROBALL, and, in case such endeavors should not be successful, to participate in new European γ-detector development programs for future γ-spectroscopy opportunities at LNL.

Plans for developing a 100 kW radioactive beam facility are being discussed. This will be a complex and costly project capable of making important contributions to science.

- INFN should consider carefully the role it wished to take in such a project. It should only proceed in a Europe-wide framework.

D. Gran Sasso (LNGS)

The underground facilities of Gran Sasso are a unique resource for high energy and nuclear physics. The availability of space, infrastructure, and support staff has made possible a broad program that involves many users. Other underground facilities are each dedicated to a single experiment and so lack Gran Sasso's flexibility.

The number of users of the underground lab has grown to about 500 since the lab's opening in 1987. International teams participate and currently about 50% of the users come from outside Italy which indicates that Gran Sasso is regarded as important by the world high energy and nuclear physics communities. The experimental program is broad and generally strong. The support staff seems to be very good.

There are two issues that we raise concerning this laboratory. The first relates to the review of experiments. The laboratory has a program committee with an international membership that reviews experiments before they are accepted. This is a good feature and helps to assure that the limited space in the facility is used for important science. However, we note that experiments, once accepted, are not reviewed periodically to assure that their continuation is worthwhile. In contrast to the situation at accelerators where experiments are approved for a fixed period, experiments at Gran Sasso have no natural termination point. Indeed, only one experiment (MACRO) seems to have an end point (set by the experimental group).

- Considering how valuable space and support resources at Gran Sasso have become to science, we recommend that all experiments undergo periodic review to determine how well they are performing and if they should be continued.

The second issue relates to the physicists on the support staff. Currently there are five such and their number will increase as the new permanent positions that are now approved are filled. It is important to the laboratory that some of the best young people are attracted to positions at Gran Sasso and this, we believe, requires that they be allowed to participate in the research program. At present, they seem only to have a support role. This problem has been faced at other laboratories in Europe and the U.S., and scientists on the support staff are allowed to be full collaborators on experiments.

- We recommend that staff physicists at LNGS be allowed, for part of their time, to collaborate on experiments at the lab taking part in preparing the apparatus, data taking, and data analyses.

IV. The Research Program

A. Group I — Particle Physics with Accelerators

1. Introduction

The program of Group I, particle physics with accelerators, is the largest of INFN's programs: 19 sections, three collegiate groups and one national laboratory (Frascati) participate in 24 experiments, carried out at major accelerator centers in Europe and in the U.S. — DESY, CERN, PSI, FNAL, and SLAC. With this impressive program, Italy is one of the major players in elementary particle physics in Europe and worldwide. Common elements in these activities are close collaboration in most experiments between several INFN Sections/university groups and international collaboration; significant contributions to detector development and construction; data analysis and physics evaluation centered in the Sections/universities; and a large participation of students in all phases of the research.

The scientific program of the institutes participating in the program of Group I are first class in all areas of elementary particle physics. Italian teams have played a leading role in almost all front line experiments around the world. They have participated in setting up the detectors, running the experiments and data analysis and physics evaluation. This research is carried out in broad international collaborations. INFN gives its scientists the opportunity to make their own choice, based on their scientific interests, in where to do their work. The strong transatlantic collaboration of INFN groups at Fermilab (CDF, fixed target experiments), and at SLAC (BaBar) must be especially mentioned.

A crucial element for the success is the technical infrastructure and expertise available on several INFN sites for special detector technologies. This allows advanced R&D work as a basis for innovative contributions on detector facilities. Good examples are silicon vertex detectors, advances in calorimetry, and the pictorial liquid argon chamber for Gran Sasso. The strong electronic development groups at several INFN institutes are an integral part of these successful developments.

It is a good policy of INFN to have a large number of Ph.D. students participating in the experiments. This allows young scientists to get used to international collaboration and will certainly have a positive long-term impact on the academic atmosphere in the physics departments at Italian universities. In its visits to the various INFN Sections, the committee remarked the close collaboration with the scientists in the university institutes. This integration of INFN groups in the universities is considered very important.

When visiting a small Section (Ferrara), the members of the committee had the impression that there the younger scientists had a better chance to develop and follow their own initiatives, in comparison to the large sections.

We note two general problems that apply to other groups as well. First, the mobility of the younger scientists inside the country between universities or INFN Sections is small, much smaller than in other European countries. In the opinion of the committee it could help the young scientists to develop more independence and to have more impact on large projects if at the beginning of their career they would move from their home university or home institute.

- An INFN policy to stimulate mobility would be helpful.

The second problem is specific to Group I, where most experiments are carried out abroad. As it is attractive for personnel to stay in a foreign country, an imbalance may develop between the working force available in Italy versus outside Italy.

- This issue may affect large projects in Italy such as KLOE, VIRGO, large Gran Sasso experiments, etc., and could lead to problems in the building of the LHC detectors. INFN should look into the situation.

2. The On-going Experimental Program

a. Colliding Beam Program

The program is now dominated by research at LEP at CERN, TEVATRON at Fermilab, and HERA at DESY. At LEP, the LNF and all but five of the INFN institutes participate in this remarkably successful program. Italian groups have made important contributions to the conception and design of all four LEP detectors through the development of detector components, and the building of the detector facilities using the technical strengths of several institutes throughout the country. Outstanding examples for detector components presently developed and built in Italy include silicon precision vertex detectors, calorimeters, muon detectors, track chambers and sophisticated electronics. In addition, Italian groups are playing a leading role in extracting the physics results from the LEP data and contributed to the rich physics harvest from LEP. Specific examples of particularly visible Italian contributions are the evaluation of the top mass from electroweak precision measurements, the evaluation of the $B^0\overline{B}^0$-oscillation, and lifetime measurements. A large number of Italian students have been trained at the LEP experiments and in the analysis of LEP data. The international spirit of cooperation has been particularly beneficial to the training of Italian students and post docs.

- LEP will run through 1999 or 2000 and analysis of data will continue for several years thereafter. This work should be strongly supported.

At the TEVATRON (FNAL, USA) a large Italian team from four INFN institutes/universities and the LNF is participating in the study of proton-antiprotons collisions at the highest center of mass energies available today. INFN teams from Pisa and from the LNF have been partners in the CDF experiment from its beginning in the early 1980's and have been joined in 1991 by teams from Pisa, Padova and Bologna for the second phase of the experiment. The Italian groups have made or will make major contributions to the CDF detector mainly in the areas of calorimetry, forward detectors, silicon strip vertex detectors, muon detection systems, and electronics, relying again on the high technical competence available in their laboratories.

The Italian groups have set up an efficient data analysis in their home institutes using the INFN network. They contributed in a significant and independent way to many important physics results of the CDF, including the physics highlight of the TEVATRON, the discovery of the top quark. One outstanding Italian contribution to the top discovery was the search for top by B-tagging, by kinematics and $t\bar{t}$ in six jet events. Many Italian students had the chance to be involved in the CDF experiment in its several stages and to do their thesis work with data from CDF.

- The CDF collaboration is presently working on a major upgrade of their detector in preparation of high luminosity operation of the TEVATRON, after the completion of the Main Injector at Fermilab. The experiment has been and will continue to be highly productive. It should continue to be supported.

The HERA electron proton collider at DESY in Hamburg allows the study of lepton-nucleon collisions at much higher center-of-mass energies than previously attainable with fixed target experiments. INFN made an important contribution to the HERA storage ring facility by providing 240 large superconducting dipole magnets manufactured by Italian industry. This, together with contributions from other countries was a crucial element in obtaining approval for HERA from the German government, and opened a new era in international collaboration on large accelerators. INFN played a particularly important role in promoting this concept.

Several Italian teams (seven INFN/university groups and the LNF) participate in the experimentation at HERA as members of the international ZEUS collaboration, one of the two detectors presently taking data on electron-proton-collisions [smaller Italian groups are collaborating in the ep-experiment H1, the HERMES experiment to study the scattering of polarized electrons on polarized protons (gas jet target), and the HERA-B experiment to study CP-violation in the $B^0\overline{B}^0$ system]. In the ZEUS experiment, the Italian groups were involved from the beginning in the conception of the detector and in its design and fabrication. They contributed several major components including the superconducting solenoid and compensator, the forward toroidal muon spectrometer, to large muon chambers for the barrel part, the precision vertex chamber, the leading proton spectrometer and the electronics for all detector components provided.

Since the start-up of data taking with ZEUS in the year 1992, the Italian groups have played a leading role in the physics analysis of the ZEUS data, and the physics coordinator of ZEUS is presently an Italian physicist. Interesting physics results include new information about the structure of the proton at low x which shows an unexpected rise of the F_2-structure function, measurement of the photoproduction at the high energies now available with HERA, results on heavy flavors and diffractive physics, and charged and neutral current electron-proton scattering at high momentum transfer. An excess of events in this process may indicate something new. If confirmed by better statistics this would indeed be a major break through.

The INFN engagement in the ZEUS experiment has been very successful. The ZEUS collaboration is planning to continue their research program at HERA. An upgrade program for the detector is underway with participation of the Italian groups. This goes along with an upgrade of the HERA luminosity by about a factor of ten in the coming years (1999-2000). The HERA program will continue important data taking for many years to come.

- We recommend continued support for this program.

b. Fixed Target Program

Italian groups supported by INFN are involved in several fixed target experiments at CERN and at Fermilab. We note here the current experiments.

NA48 at CERN is a specific experiment to study the very fundamental question of direct CP violation in the K^0 system. As a follow-up to the experiment NA31, it has been designed to give much higher precision than its predecessor. The experiment has a large Italian participation (six INFN groups and an Italian spokesman) which has taken responsibility for several crucial components in this very difficult and ambitious experiment, including the liquid krypton electromagnetic calorimeter. The experiment will begin data taking in 1997. (The KLOE experiment at DAFNE will address the same physics questions as NA48 with a complementary approach.)

E760/E835 at FNAL studies charmonium spectroscopy and also the timelike form factor of the proton. It is carried out at the anti-proton accumulator at Fermilab, and has a large Italian participation (60%), three INFN groups being involved, and an Italian spokesman. The INFN groups are responsible for several of the specific components of this experiment, and for more than 50% of the analysis. Nice results have been obtained from the 1990/91 data taking period (E760); data taking with seven times better statistics (E835) will be completed in 1997.

The E687/E831 experiment studies production and decay of charmed hadrons in a tagged photon beam at the TEVATRON at Fermilab. It has a large Italian participation (35%) coming from two INFN/university teams and the LNF. Some nice results on photoproduction and on several decay modes have been obtained from the 1990/91 data. The data taking period 1996/97 should increase the statistics of the experiment (E831) by a factor of ten. The E781 experiment studies the production of charmed baryons with a hadron beam at Fermilab. There is only a small Italian participation, with some responsibility for detector components. The experiment is presently data taking.

These three activities at Fermilab, where altogether 60 Italian physicists are involved, strengthens the transatlantic cooperation of INFN.

c. Future Program — Short to Medium Term

The KLOE experiment will be installed at the ϕ factory e^+e^- collider DAFNE presently under construction at the LNF. Its main scientific goal will be the investigation of direct CP violation in K^0 decays with unprecedented precision. It will also study some interesting properties of the K^0 system and in strong interaction physics. Nine INFN/university teams and the LNF play a dominant role in the international KLOE collaboration. The members of the committee have seen impressive preparations for the KLOE detector during their visit at Frascati, such as the stringing of the large central drift chamber with a sophisticated automatic machine and beautifully built modules of the electromagnetic lead/scintillating fiber calorimeter. KLOE is supposed to start taking data in the year 1998, the end of commissioning of DAFNE being planned for December 1997.

The committee has been informed about a serious shortage of manpower, in particular of technical staff, on the Frascati site during the critical year 1997, and probably early in 1998, that, if uncorrected, would almost certainly cause a major delay in the start up of KLOE. This shortage of manpower seems also to be linked to the special situation of the LNF, when compared with the large laboratories outside Italy.

- INFN should carefully monitor this situation and take measures to avoid major delays in the start-up of KLOE.

The BaBar experiment will be installed at the B-Factory (PEP II) of the Stanford Linear Accelerator Center. Its main scientific goal will be the study of CP violation in B^0 decays, and also the study of rare decays of the B mesons. Ten INFN/university teams and the LNF participate in BaBar, making Italy a major partner in the international collaboration. The Italian teams have taken responsibility for detector components in areas with traditional Italian expertise, like silicon vertex detectors, the central drift chamber (collaboration with KLOE) and calorimetry. The data taking of BaBar at PEP II is planned to begin in July 1999, which means a very tight schedule for the setting up of the detector. BaBar is again a good example of strong transatlantic cooperation of Italian groups.

The HERA-B experiment will also study the CP violation in B^0 decay, like BaBar, B mesons here being produced by the circulating proton beam of HERA, striking a wire target. One strong Italian team (Bologna) has joint the HERA-B experiment, which will start data taking in the year 1998. With four experiments on CP violation — NA48 and KLOE in K^0 decay, BaBar and HERA-B in B^0 decay — INFN has a strong program with complementary approaches for one of the most intriguing questions in the physics of the standard model — or beyond.

d. Future Program — Long Term

The long-term future program of Group I is at present concentrated on physics with the Large Hadron Collider (LHC) which should start its operation in the year 2005. Italian groups collaborate in both of the large detector facilities, ATLAS and CMS. Seventeen INFN institutes are involved; three participate in both. The Italian teams have taken major responsibilities building on their experience in previous collider experiments at LEP, TEVATRON and HERA. In ATLAS and CMS, Italian teams collaborate on the silicon tracking systems, calorimetry, μ-detecting systems and the superconducting magnets. Italy will thus play a major role in the building of the large LHC detectors with a good participation of Italian industry. A major fraction of the funds available to Group I, about two-thirds, will be needed in the critical years of construction, 2000-03, to satisfy the budget requests for the two experiments — assuming a constant funding of Group I on the level of today. The LHC experiments promise a very exiting physics program in the next decade.

4. Conclusions

The INFN program of Group I in the present five-year cycle has been very successful. Italy is one of the leading nations in elementary particle physics, and Italian scientists have made large contributions to the progress in this field.

The program for the next five-year period of INFN beginning 1998 again promises to be very exciting. Italian scientists will be involved in a first class program including KLOE, at their national facility DAFNE in Frascati; CDF detector at FNAL with much higher luminosity; the new BaBar detector at the PEP II B-Factory; the upgraded ZEUS detector at the HERA collider with improved luminosity, the HERA-B experiment at DESY; and at CERN, CP violation with the NA48 experiment, the high center-of-mass energy collisions available with LEP II until that machine is phased out; and the building of the LHC detectors ATLAS and CMS.

Italian physicists working in Group I are looking forward to a very exciting program in the next INFN period, which fully merits to be supported by INFN. This program is clearly one of the best in Europe.

B. Group II — Non-Accelerator Physics and Neutrinos

1. Introduction

The Group II program is very broad and includes the entire LNGS program, other neutrino experiments including those at accelerators, astrophysics experiments in space, gravity wave detection and fundamental tests of theory. The Group II procedures for approving experiments are thorough and good (particularly the setting of R&D milestones for complex apparatus) and the program is in general excellent. In this section we comment on the largest elements in the program with emphasis on the future. We note that the recommendation made earlier in the section on LNGS on periodic review of experiments should apply to all elements of this program.

a. GALLEX

The experiment has been a great success. The calibration of the apparatus with a radioactive source has measured the efficiency of the chemical extraction process and by doing so has convinced the scientific community that the measurement of the neutrino flux from the sun of about 70% of that predicted by the standard solar model is a real effect. The continuation of this experiment is well worth the cost.

b. BOREXINO

This new experiment will soon be taking data. Its aim is also at the solar neutrino puzzle and it is designed to look at the Be^7 line through neutrino-electron elastic scattering. Its expected low background and low energy threshold make it an important complement to GALLEX.

c. ICARUS

This new and technically sophisticated device gives "bubble chamber quality" pictures of neutrino interactions in 600 tons of liquid Argon available in its first implementation. The ability to observe tracks from events occurring in its fiducial volume will greatly reduce uncertainties in interpretation and background. However, its low energy neutrino sensitivity is not sure, having only been tested in a limited way. In the study of proton decay, the 50,000 ton Super Kamiokonde (Super K) detector will be more sensitive than even the full 5000 ton ICARUS for all modes whose decay products emit Cherenkov radiation in the volume of the Super K detector. While the pictures from ICARUS give better event identification, it is doubtful that this quality can compensate for Super K's quantity.

Recent results from Super K confirm their previous result, indicating that the rates of electron to muon neutrinos produced by cosmic rays in the atmosphere do not agree with theoretical estimates. Although the ICARUS mass is much smaller than that of Super K, the data quality obtainable with ICARUS should considerably reduce systematic uncertainties.

Long baseline neutrino oscillation experiments are particularly suited to the ICARUS detector. An experiment with a neutrino beam from CERN directed to ICARUS at Gran Sasso is probably better than one using a beam from the KEK 12 GeV proton synchrotron directed toward Super K. In this case, the higher energy and larger flux from CERN makes up for the lower mass of ICARUS. However this may change in the future when the Japanese Hadron Facility is completed (about 2003) and Super K can use neutrinos from the JHF's 50 GeV beam.

CERN's plans for the long baseline neutrino beam are uncertain at present. The laboratory has stated that this beam will only be constructed as a special project with outside funding that comes in addition to the regular CERN budget. We have no information on the cost or possible schedule of the CERN neutrino beam. Hence, it is difficult to advise on this program because the total impact on the INFN budget and on other activities is now not clear.

- We recommend that INFN carefully consider the full cost of the long baseline/ICARUS program, including both contributions to the beam and detector upgrades, before proceeding.

2. Space Experiments

This is a new area for INFN. There are important questions in particle astrophysics that can only be answered through satellite (and balloon) experiments and so it is appropriate for INFN to be involved. This is particularly so in those cases where the detector technology is that developed for the high energy and nuclear physics program.

We did not have enough time to give this program the attention it deserves. PAMELA and AMS are moving ahead — both involve magnets and tracking systems. GLAST is a gamma-ray detector with capabilities far beyond the existing EGRET experiment or the gamma-ray detection capability of AMS. It is in the R&D phase and seems very promising. We do not understand how the SPACEMAG program fits in to the overall program.

- We recommend that a special comprehensive review of the space program be held to evaluate its coherence and future directions.

3. Gravity Waves

a. VIRGO

The VIRGO project is an important French-Italian scientific collaboration that aims to build a 3 km × 3 km laser driven interferometer for gravitational radiation research. This 77 million ECU project (plus personal costs) aims to have a short interferometer (6 m × 6 m) ready at the end of 1998, and the full project ready in 2000. Both the budget and schedule are in danger because of a lack of the central direction and authority that are necessary on a project of this scale and complexity.

The VIRGO organization is a very loose one, clearly designed to preserve maximum autonomy for the participating groups. It has an excess of committees and is unclear on lines of authority and responsibility. For example, the project directorate has no means of setting required interface standards on subsystems or of redefining the scope of work of the participating groups should one of the groups have problems. Also, there is no external technical review committee composed of working level experts that can advise the project leader and technical manager on the status of work on the various subsystems.

Clearly, a project involving two countries and eleven participating scientific groups has certain complexities and sensitivities. The participating groups are strongly committed to the scientific objectives of the project and are individually working very hard. However, for the benefit of the project on a whole, these groups should be willing to give up some of their independence to the project leadership.

- We recommend that the STAC be asked to review the project organization with a view of strengthening the role of the project leader and technical manager.

VIRGO will be an observatory with a lifetime expected to be decades long, and a facility (the interferometer) that will require continual upgrades as technology developments allow improvements in sensitivity. It will need a core of staff that goes beyond the assembly stage to maintain it, keep it running, carry out the necessary modifications, and support the research program. This need is recognized in the VIRGO management plan, but the creation of such a group has been deferred. We believe that this is a mistake and that the creation of this group should begin soon so that its personnel can participate in the installation and commissioning phase. This step would considerably simplify the transition to the operational phase as well as providing help to the participating group in the installation phase.

- We recommend that the VIRGO project begin now to create the core group of engineers and technicians envisaged for the long term.

b. The Bar Antennas

The gravitational wave program includes a bar antenna at Frascati and at Legnaro. Both are working well and, with their planned upgrades, will remain as state-of-the-art detector at least until the VIRGO project is completed. We are not experts in this area, but it appears to us that the sensitivities of the bars are now, and will remain, below that projected for VIRGO. We are therefore unclear on the value of these two devices once VIRGO is operational.

- We recommend that INFN review the long-term future of the bar antennas to determine how long they should be continued once VIRGO is operational.

C. Group III — Nuclear Physics

The nuclear physics community, with close to 400 "equivalent" physicists, has seen in recent years a significant growth of the role of the INFN-operated national laboratories as home bases of nuclear physics. This is mainly due to the opportunities given by the availability of low- and medium-energy heavy-ion beams from the ALPI (LNL) and CS (LNS) accelerator facilities, the start up of the DAFNE-Φ-factory (LNF) during 1997 for its use with the FINUDA detector, and the growing interest for the study of astrophysical relevant reactions in underground laboratories (LNGS). During recent years, the INFN-supported nuclear physics programs also became fully integrated in the global nuclear physics development by providing, on the one hand, unique facilities for large scale European collaborations such as EUROBALL, and, on the other hand, by making use of international and foreign national laboratories in joint international research programs. The main research lines at present are the study of strongly interacting bound systems in the nonperturbative regime using electromagnetic probes, hadronic probes and heavy ions from intermediate- to ultra-high energies. Nuclear structure in extreme states of spin, isospin and excitation energy is being studied using mainly low-energy heavy-ion and radioactive beams in the future. Interesting programs for the study of astrophysically relevant data have started. The distribution of equivalent physicists and the INFN NSC allocations among the various research lines, is appropriate.

- In the future one would like to see more focus on hadronic interactions studies with various probes and nuclear structure physics at the cost of a reduction of presently rather large activity in low energy heavy ions reaction studies.

The "half and half" balance of funding experiments performed in national versus international and foreign laboratories looks rather healthy, in view of the globalisation of nuclear physics, with each major country contributing its share to the internationally used facilities. In the future the major single investment item will be an increasing contribution to the construction of ALICE, a dedicated detector for the study of heavy collisions at the LHC-collider. This seems practical because of steadily reduced allocations for the FINUDA detector under construction at DAFNE for hypernucleus studies. This increased activity in ultra-relativistic heavy-ion physics also requires the build up of a correspondingly strong community by using the money and people which will become available in case of a proposed reduction of low-energy reaction studies.

In the following we will give a short review, some comments and recommendations to the main research lines supported by INFN in nuclear physics.

1. Electromagnetic Probes for the Study of Strongly Interacting Systems

In this lively field, frontier problems of strong interaction structure and dynamics, including subnucleonic degrees in nucleons, hadrons and nuclei are addressed. The experiments are exclusively performed in foreign laboratories, with DESY, CEBAF (TJNAF) and ESRF being the main ones.

At DESY the spin structure of the nucleon is studied in an experiment called HERMES, using 27.5 GeV polarized electrons and polarized He and H targets installed in the HERA-ring. INFN has made major contributions to the calorimeter, the magnet and the internal target technique. Two years of successful data taking provided inclusive scattering results and first semi-exclusive data on hadron production in deep inelastic scattering for the study of spin structure functions of the nucleon. The semi-exclusive and exclusive final states are the areas where HERMES experiments are important.

There is a considerable contribution of INFN supported groups to experiments using the 4 GeV continuous wave electron facility of CEBAF, for the studies of the structure of elementary systems (nucleon, few body), effects of the medium at nuclear density and nuclear structure at high momentum transfer. The installations are in the commissioning phase with major INFN supported contributions. Italian physicists are spokespersons of nine experiments and collaborators on 32 of the 80 approved experiments. While this is a strong program, it seems out of balance with the rest of the nuclear physics program.

- The large involvement of INFN at CEBAF should be reduced as the first round of experiments are brought to a successful end.

INFN also supported as a smaller activity, the construction of a high-energy, circular-polarized photon beam produced by laser light back-scattering from the 6 GeV electron beam of the ESRF storage ring (GRAAL). This photon beam will be used for studies of the spin dependence in photo reactions of the nucleons, the N*-resonances, the gKLN-coupling constant and the study of rare h-decays. First results on photoproduction π° and η-mesons have been achieved.

For the future, three interesting European initiatives for the study of strongly interacting systems are in discussion: first, putting ions into HERA for exploratory DIS-experiments at the highest energy; second, a high luminosity electron-proton/ion collider at 10-30 GeV at GSI, Darmstadt; and third, ELFE@DESY which should provide a high intensity continuous wave beam of polarized 15-30 GeV electrons for exclusive electron scattering experiments using the HERA electron ring as stretcher for beams from a superconducting linac-injector in order to achieve luminosities which are 10^4 times higher than with HERMES.

Putting ions into HERA is a cost effective way for exploratory studies of deep inelastic scattering on nuclei with high energy and momentum transfer range, and should deserve support by INFN. The project ELFE at DESY would provide first opportunities to study quark correlations in the nucleon and nuclei. It is also cost effective and would provide an interesting extension of HERMES experiments in the study of exclusive processes, and deserves attention by INFN.

- INFN should monitor developments at DESY in both the heavy ion and ELFE programs. Support should be considered at the appropriate time.

2. Hadronic Probes

With the closure of two main facilities LEAR at CERN (1996) and SATURNE at SACLAY (1997), nuclear physics has lost it's main opportunities for the study of antiproton properties and annihilation, meson spectroscopy, proton-proton and proton-nucleus interactions, associated production of strange particles, and other active programs. This is a loss for an active community, which is now looking for new opportunities also in context with GSI future plans.

- We recommend that INFN keep an eye on the developments at GSI with respect to hadronic probes.

For the moment, the interest of the INFN-supported community using hadronic probes is focused on nuclear physics at DAFNE, using low-energy kaons from ϕ-decay for programs (FINUDA) such as high-resolution spectroscopy of hypernuclei, non-mesonic decays, production of neutron rich hypernuclei, lifetime measurements of hypernuclei and s-wave K-interaction studies (DEAR). Furthermore a series of smaller experimental involvements are noticed with focus on low energy kaon and pion physics.

3. Heavy Ion Physics from Intermediate to Relativistic Energies

The start up of the experimental program at the CS-accelerator facilities of the LNS is a long awaited and important step for advanced studies of strongly dissipative nucleus-nucleus collisions leading eventually to the liquid-gas phase transition of nuclear matter. The new multi-element detectors, such as OUVERTURE and CHIMERA, will give a unique opportunity to study multifragmentation, the equation of state of nuclear matter at low density and, most importantly, the phase transition of a finite Fermi liquid.

- It will be of crucial importance that the accelerator facility of LNS gets into a state of reliable routine operation in the delivery of heavy ion beams requiring increased acceleration physics studies, and that the international collaboration on a European scale grows.

For higher energy heavy-ion programs, the facilities at GSI (Darmstadt) and CERN are to be exploited for the study of properties of hadronic matter at high density and temperature, and the search for and study of the quark-gluon plasma. At GSI, the transition of a Fermi liquid to a classical particle gas was observed for the first time in collaboration with INFN supported groups. In the future, di-lepton production and the properties of vector mesons in dense medium will be studied in a search for chiral symmetry restoration using HADES, a high-acceptance, high-resolution di-electron-spectrometer under construction with INFN participation and support. This is an interesting entrance road into the study of spontaneous symmetry breaking as the origin of hadron masses.

There has been a strong INFN contribution to the construction of a unique heavy ion facility at CERN, which has delivered 5×10^7 Pb ions per SPS supercycle at the highest presently available energy of 158A GeV. NA50 with INFN supported groups succeeded in their studies of muon pair and vector meson production in Pb-Pb-collisions to discover anomalous J/Ψ suppression beyond the expected absorption mechanism. This exciting experimental finding will be elaborated in future programs which include low mass pair suppression measurements. In addition, a considerable INFN involvement in WA87 succeeded in the study of the baryon/anti-baryon production using the Omega spectrometer to discover a strong enhancement of multistrangeness production relative to p-A-collisions. For the future, INFN is strongly supportive in the construction of ALICE, a dedicated detector for the exploration of (2.8 + 2.8) TeV/nucleon Pb-Pb-collisions in the LHC collider for the study of the equation of state at the highest energy densities, chiral symmetry restoration and hopefully the deconfinement phase. This engagement will draw more and more on the sparse human resources in nuclear physics.

- INFN is advised to encourage the move of more people into the field of relativistic heavy ion physics from some of the more classical nuclear physics areas.

4. Low Energy Heavy Ion Reactions

Experiments for studies of the nuclear dynamics in nucleus-nucleus collisions at energies below the Fermi energy are performed mainly at the ALPI-facility at LNL and some at higher energies at LNS. Powerful detectors are available or under construction to study the decay of the compound nucleus and the dynamics of dissipative collisions by the detection of light particles, evaporation residues, fission fragments, intermediate mass fragments and high energy gamma rays. Such complete measurements should allow to determine the size, time evolution, temperature and de-excitation chain of the emitting source. This ambitious program executed with a great variety of modern detectors should in a few years complete the work in this traditional field of low energy heavy-ion physics, allowing resources to move to more explorative studies at higher energies (such as programs at GSI and CERN) or into more emphasis on nuclear spectroscopy at LNL.

5. Spectroscopy

High resolution and high efficiency in-beam gamma-spectroscopy is the best tool to study nuclear structure with extreme values of angular momentum, excitation energy and isospin a field of continued actuality.

The presently available arrays of highly segmented 4π-Ge detectors have a photopeak efficiency of (3-5)%, with GASP sited at the ALPI-accelerator facility of LNL being one of the most powerful and versatile ones because it can reach an efficiency of 5.5% (GASP II), and, what makes it especially useful, it can be combined with a high transmission recoil mass spectrometer, CAMEL, and a Si-ball, ISIS. In this combined operation it will provide improved selectivity for weak reaction or decay channels which are of special interest. Since start of operation in June 1992, a multitude of experiments have been performed with GASP focused on the study of superdeformation, the search for hyperdeformation, high spin studies including M1-bands, octupole-excitations, the studies of rotational damping and giant resonances. Furthermore, low spin studies using the deep inelastic heavy ion reactions as new tool, and the recoil mass separator, allowed to investigate the structure of nuclei near doubly magic shells far off stability.

- Strong emphasis should be put in using GASP in combination with the selectivity filters before ANL with gamma-sphere and a recoil mass-separator becomes competitive.

The successful development and work with GASP lead to the choice of LNL as the construction and first operation site of EUROBALL, an array of 239-Ge-detectors optimized/for high spin physics, in which the nuclear structure is probed by the well-known centrifugal forces.

EUROBALL is the first large international construction project in low energy nuclear physics with the collaboration of six European countries, 28 institutes and 300 physicists. With a detection efficiency of 9% it reaches an observational limit close to 10^{-5} for gamma-branching. The installation has started in 1996 at LNL with commissioning being planned early in 1997. Some of the topics of the first accepted proposals deal with studies of the population and deexcitation of superdeformed bands, the search for hyperdeformed states, the coexistence of various shapes in nuclei, magnetic rotation, the study of the E2 continuum, nuclear state properties and dynamic studies — an impressive program.

- INFN and the host laboratory LNL are advised to focus its support on the EUROBALL project so that it becomes a real scientific success.

6. Miscellaneous Experiments

INFN supports a series of unique low energy reaction studies of astrophysical relevance, such as cross-section measurements for the p-p- and CNO-cycles responsible for the production of stellar energy and relevant in context with the solar neutrino problem. There is also an interesting, exotic atom spectroscopy support, such as laser spectroscopy of muonic hydrogen and a new program for the production and spectroscopy of antihydrogen at a planned AD-facility at CERN. The construction of a facility with beams of ionized molecular clusters in Milano is interesting for model studies of shell and collective excitation in extended nuclear matter. The cold fusion work still pursued at LNF and Torino seem to be unscientific relics not worth of INFN support.

- INFN is advised to continue its support of astrophysical relevant data acquisition and the planned AD facility at CERN.

7. Current Trends of Nuclear Physics Research at INFN National Laboratories

In context with future developments, the nuclear physics oriented INFN-national laboratories have started a discussion concerning the development and realization of radioactive beams (RIB) for the synthesis and study of nuclei far off stability. This discussion should be seen in the frame work of the international scientific interest and especially the European involvement in this area of nuclear structure physics. At LNS an interesting special project (EXCYT) is funded by INFN to produce radioactive nuclei with CS-beams bombarding a target followed by forming negative ions in a special source, and acceleration after mass separation with the Tandem. This scheme will provide high quality (good energy resolution and low emittance) RIB's with easy and precise energy variation potential for nuclear structure research but moderate intensity only. It is an interesting approach which should lead to a specialized local facility. A similar one is under construction at ORNL (USA).

The European discussion is focused on three future directions to provide high intensity beams. GSI is proposing a high intensity fragmentation RIB-facility by raising the beam intensity of their heavy ion synchrotron with a new injector which produces high energy RIBS to be cooled in a cooler ring to the highest possible phase space density. There is a European proposal to generate high intensity, neutron rich beams by acceleration of fission products from high-flux thermal neutron-sources.

The main goal of such a project would be the synthesis of long lived neutron rich super-heavy nuclei. The third proposal is centered around a project in which the radioactivities are generated by the spallation process induced by high-energy (~1 GeV), high-intensity beams of p or d in a target exposed to a thermal power of about 100 kW. After efficient ionization using ISOL-techniques the RIB's are accelerated by modern acceleration methods.

We understand that LNL in collaboration with LNS is interested in a joint RIB-development which aims first at reaching higher ion intensities, charges and masses of their TANDEM-LINAC and TANDEM-CS-facilities by decoupling the Tandems using ECR-sources and new injection schemes. This would bring them at most to production targets in the 10 kW regime, similar to the GANIL, SPIRAL project, which becomes operational in 1998.

In order to proceed into the desired 100 kW regime, LNL proposes to start R&D work on high-intensity linear acceleration, which should contribute to a joint European project, with a site promotion in Legnaro.

- We recommend that INFN study carefully whether it wishes to take a leading role in the development and construction of a European RIB facility with LNL as a host laboratory. If it is so, it should be in a European context for it will be a large and expensive undertaking.

8. Summary

INFN has achieved a remarkable synergy in the development of nuclear physics by supporting competitive projects in their national laboratories and reinforcing cooperation activities in international and foreign laboratories. This produced a strongly home based, broad international research program with the tendency to spread beyond conventional nuclear physics borders. The ties to particle physics are growing to the advantage of both disciplines. The research is becoming more interdisciplinary with other fields such as astrophysics, atomic physics and applications of growing importance. In summary, nuclear physics as promoted by INFN is gaining a leading role in this changing field of science with added opportunities of applications in medicine, energy generation and other fields of research.

D. Group IV — Theory

1. Balance and Level of the Program

The theory community in Italy is numerically very large although the ratio of theorists to experimentalists is not very different to that in other European countries. As a result of the numerical strength there is a wide range of research activity covering almost all of the major research areas in particle and nuclear theory research. A rough breakdown of the distribution of effort is as follows:

◊ Field theory - including strings 1/3
◊ Mathematical methods 1/6
◊ Particle phenomenology 1/5
◊ Lattice 1/15
◊ Astroparticle/cosmology 1/15
◊ Nuclear 1/6

It is a subjective judgment whether this balance is optimal. Comparison with other European countries is made difficult because of the different methods of funding. For example, in the United Kingdom the proportion of support given by the particle physics and astronomy research committee to particle phenomenology, lattice and astroparticle/cosmology theory is much higher. However this discrepancy may be largely explained by the fact that mathematical physics is also supported by another funding agency. Overall we think that the balance is broadly acceptable although we feel there is a case for additional support in the areas of lattice simulations and astroparticle/cosmology. Given the sizable investment in developing the super computer hardware for running the lattice simulations capable of generating interesting physical quantities, we consider it important that there should be a comparable effort available to extract the physics and to exploit this facility. A significant international collaboration has been developed to alleviate this problem.

- Lattice work is an area where additional resources should be deployed.

The area of astroparticle physics is enjoying considerable growth worldwide due to the rapid increase in data on large scale structure, on the distribution of dark matter, on the development of gravitational wave detectors etc. This is a rapidly developing field in which the theoretical framework is still under construction and which offers young theorists the chance to make significant contributions.

- Although there is already support in this area it is at a relatively low level and we feel this support should be increased.

Finally there is a substantial nuclear theory effort in the program. Given the extensive experimental nuclear physics effort in Italy, it is important to have a theory program too and the present level of support is reasonable.

2. Quality of Research and Its Relevance

In all areas the theoretical research is at an internationally competitive level. The INFN policy requiring Italian post docs to go abroad does have the merit of fostering integration at the international level, as does the generous travel budget. In all areas there are strong collaborations with CERN, with other European countries and with America.

a. Field Theory, Strings and Mathematical Methods

Mathematical physics is the largest area of theory research, covering most of the fields of current interest. Italian theorists have pioneered the study of supersymmetry, supergravity and the structure of the low-energy effective theories and are now extending this to the study of effective theories following from the superstring and the determination of gauge and Yukawa couplings. There is also a considerable effort into the study of string theories themselves and to the recent developments in constructing string theories, in studying their duality properties and their related non-perturbative properties and in studying their astrophysical consequences. The implications of duality for quantum field theory is being explored with the hope of being able to compute non-perturbative effects in four dimensions. Two dimensional quantum field theory is also being studied to determine its topological and non-perturbative properties and as a model of two dimensional gravity. There is also ongoing work in many other areas of mathematical physics including statistical mechanics, neural networks, complex systems and chaos. The community has extensive international interaction and is involved in several European networks.

b. Particle Phenomenology

There is an excellent phenomenological program of research covering most aspects of phenomenology. In strong interaction physics Italian physicists are making substantial contributions to the study of small x physics, to the study of polarized and unpolarized structure functions, to b-physics, to the extraction of the strong coupling from a variety of processes and to the development of techniques needed to resum soft gluons and to deal with non-perturbative effects. In electroweak physics there has been significant work done in developing precision tests of the Standard Model and quantifying expectations for physics beyond the Standard Model. A particular strength has been the detailed study of supersymmetry and its phenomenology. In neutrino physics there is an active program of research including solar neutrinos, dark matter implications, cosmic rays and astroparticle implications. There has also been an impressive study program into the physics of DAFNE organized by the Italian community but involving a substantial international component.

c. Lattice

The lattice effort is also of world-class. Indeed Italian theorists have made important contributions to the development of lattice techniques to study phenomenologically interesting processes. The significant computing power developed by the APE series of supercomputers allows the community to tackle such problems. This is an area where one may argue that there is a shortage of theorists to exploit the computing power available. To a certain extent this has been alleviated by the development of international collaboration analyzing the lattice data produced. However there is still scope for an expansion of the program better to exploit this data.

d. Astroparticle Physics

The effort devoted to the particle physics/cosmology interface is quite small. This is another area where some more direct management of the resources might be profitable. The subject is a new one with an explosion of data and the prospect of much more to come. It is an area which attracts young physicists not least because it offers the chance to make significant contributions to a rapidly developing field. We feel that some consideration should be given to developing this field.

e. Nuclear Physics

There is an active nuclear physics research program which covers a wide range of energies from the KeV scale of astrophysics relevance to the TeV scale overlapping the particle physics regime. The research interest spans a wide area including the study of hadronic structure in the nuclear medium, the study of nuclear spin, isospin, excitation, density and shape and the use of the methods of nuclear physics to study new problems such as molecular aggregates, metallic clusters and Bose condensates. The most obvious omission is the lack of work related to the SPS-LHC heavy ion nuclear physics program.

3. Effectiveness of INFN Action

The support offered by INFN to theory amounts to some 10^7 Lire per person. It provides support for travel, for computing and for visitors which, in 1996, was roughly in the ratio 7:3:1. In our opinion this represents well-founded support and there was general agreement that the level is adequate. The committee was particularly impressed by the fact that all researchers had funds available to allow them to make regular international visits, an important ingredient in maintaining the competitiveness and vitality of the program. It might be advisable to increase the level of visitor support given that visitors generate the most efficient use of funds as they may be expected to interact with more than just a single member of the group they visit.

Perhaps the main area of disquiet expressed to us by the young physicists was the method of appointment to INFN positions and in the lack of opportunities for career advancement. Many expressed concern that the best candidates were not always successful. In particular it appears to be very difficult for appointments to be made of candidates not originating from the appointing institution. The problem is made more severe by the low starting salary which almost requires the fellow to rely on family support. The lack of a smooth career structure was also a concern and clearly the intermittent nature of promotional exercises does not encourage the best researchers to remain in Italy. These problems are not confined to theory and are discussed at more length elsewhere in this report.

In addition to the worrying possibility that the best candidates are not able to get positions, we think the appointment method also has the effect of reducing the flexibility of the system in responding to new initiatives. Indeed the present method of direction of the research program relies on a ``bottom-up" approach in which existing researchers respond to developments in the research activity. It is clear from the vitality of the on-going research that this is effective in maintaining an excellent program. However we feel that there is some lack of responsiveness built into the system with respect to new initiatives. In other European countries and in the US the appointment of short-term postdoctoral fellows provides an opportunity for mobility in young researchers. It also allows for concentration on specific areas of research providing a rapid response to new directions. We find this measure of control of the research program largely lacking in INFN.

One possible way to improve the situation would be through the introduction of some non-tenured postdoctoral positions to be held in Italian institutions. Mobility could be guaranteed by requiring that position could not be held at the postdoctoral fellow's home institution. These positions would offer some flexibility in following new initiatives for the appointing committee would have the ability to choose the subject areas it wishes to concentrate on in response to the developments in the subject.

E. Group V — Technology

1. Introduction

The area of activity covered by Group V is very large. The major part of the effort goes into detectors, electronics, computing and networking, and accelerator development. The Group V effort also has a component devoted to sectors where INFN technology can have a potential societal impact. In the time that the committee had available for the examination of Group V programs, it was not possible to go into any great depth. Thus our conclusions and recommendations focus on areas where even in our limited review it was apparent that there was some need for action on the part of INFN.

With apologies to those who work on some of the most important activities of Group V; detector development, electronics, accelerator physics and technology; we will not discuss these areas systematically. We note, however, that the method used to choose work to support seems good and the work itself seems well done. If INFN wants these activities analyzed in more depth, it will need a special technical committee. We also note, however, that there does not seem to be a review process internally to monitor the progress of these programs once they have begun.

We will comment below on networking and computing, societal programs, and some of the special projects. But, before getting into those areas, we do want to comment on Group V's work with industry to transfer technology, or to develop new technology in areas of INFN expertise. Some things are done well — APE computers for example. But, we do not see any systematic attempt to identify technology at an early stage that has industrial potential, to protect intellectual property through patents and copyrights which is essential if industry is to invest in the development of INFN technologies, and to seek out industrial firms that might turn INFN technology into products. These sort of activities may, at first glance, seem counter to the traditions of scientific openness, but the cost of turning a technology developed in an R&D program into a product is typically ten to a hundred times the cost of the R&D itself. Add to this the cost of bringing a product to market, one sees why industry needs some sort of intellectual property protection if they are to make the necessary investments. The potential benefits to Italian society are significant.

- INFN should investigate the possibility of setting up a technology outreach function at Headquarters.

2. Computing and Networking

The computing situation seems good. The work is well organized and good mechanisms are in place to assure that program needs are understood by the computing and networking people. The transition to client-server architecture, modern workstations, and p/c's is being run well, though there is still a lot of equipment around that it is understood will need replacing. Hardware maintenance costs have dropped significantly with the transition.

The local area networks within INFN institutions are in good shape. However, the situation with respect to wide area networks is entirely different and the present connectivity and bandwidths are already limiting activities of INFN groups. The situation is particularly bad in bandwidth to CERN (2 MBS) and the US (3.5 MBS). At CERN ongoing activities at LEP and design activities for LHC could use much more bandwidth than now available. In the USA, BaBar at SLAC and CDF at FNAL have large bandwidth needs and, if the Italian scientists get involved in the RHIC program at Brookhaven, bandwidth requirements will increase again.

The demand for bandwidth will only increase in the future. Videoconferencing during the design phase of a major experiment is important. It not only improves communication and coordination, but saves travel time and dollars as well. The physicists need access to large monte carlo data sets while planning for data analysis, and will need access to even larger data sets when new experiments begin. Plans are in place to upgrade the CERN link to 8 MBS and the US link to 8-16 MBS. This can only be a temporary solution, for LHC, CDF, and BaBar will still find that bandwidth limiting.

- INFN should be looking toward further increases in bandwidth by 1999-2000. While these links are costly, they are essential for the science and there is the possibility that European telecommunications deregulation will bring prices down.

3. Societal Program

We include here such things as medical imaging, cancer therapy, environmental studies, etc. We have some concerns about the project selection process. While physicists tend to believe that they can do anything (there is some truth in this) in developing new technology for another field, it is necessary to work with specialists in the other field to make sure as the project proceeds that what is being developed is what is wanted. In these societal areas, the INFN "bottom-up" project selection process can lead to a proliferation of poorly coordinated activities (as seems to be the case in mammography) or to the physicists moving in directions that specialists in the external field do not favor (as may be the case in hadron therapy).

One does not want to discourage the INFN community from developing technology that will benefit the larger society. In the early stages of such technology development, the INFN selection procedures are the correct ones. However, at a certain hard to define point, it is necessary to have a review of specific societal programs that involves those outside of INFN that will be most affected.

If INFN is to be successful in this kind of work, a more considered approach is needed after the initial R&D. To take a specific example, mammography, a technology roadmap needs to be developed that leads from the basic R&D work to the placement of effective systems into broad use. The development of these roadmaps has to involve the medical community, the equipment manufacturers, as well as the physicists. One must consider along with exotic technology, costs, convenience for the patient, ease of use by the professionals, etc. The problem for INFN is at what stage this kind of review is needed. It is a difficult question, but we think that both mammography and hadron therapy have gone beyond this point.

- INFN needs a review process for societal programs that involves specialists in the relevant areas at an early point in these programs.

4. Special Programs

a. RF Superconductivity

INFN programs have made great contributions to the development of rf superconductivity. The work of the Genoa Section to developing spherical cavities and their demonstration that such cavities essentially eliminate single-point multipactor was the critical element that has allowed rf superconductivity to come into widespread use in a reliable fashion with a reasonably high accelerating gradients.

It is natural that INFN should participate in the continued development of this field and, in particular, in the TESLA program. The work of the Genoa, Legnaro, Milan, Naples collaboration on developing an understanding of the metallurgy and surface treatments of cavities and the work aimed at reducing the cost of fabrication and multicell cavities while increasing the maximum accelerator gradient is most impressive. The multicell cavities fabricated by spinning look particularly promising as they may give lower fabrication cost. This work is very good and should be encouraged.

b. Energy Amplifier

The energy amplifier technology promoted by Carlo Rubbia and colleagues appears to have great potential. This system is based on a thorium-cycle subcritical facility driven by a high-intensity proton linear accelerator. Its attraction lies in its inherent safety, its simplicity, the reduced amount of long-lived radioisotopes produced, and its potential to consume long-lived radioactive waste. The practicality of this scheme will depend on its cost when compared to that of conventional reactors including the cost of radioactive waste disposal.

The issues in the development of energy amplifier technology lie almost exclusively in the engineering aspects because these are what will ultimately determine the cost. There is very little R&D that needs to be done on the accelerator driver. Most of the issues concern the reactor and its related systems.

INFN expertise lies in proton accelerators and it is in this areas that there is some interest by INFN laboratories and groups in becoming involved. The technology required has already been demonstrated from the ion source through the superconducting cavities at laboratories in the US and in Europe. The most important issue in the accelerator is in the area of systems engineering to design an accelerator complex of minimum cost and very high reliability. The design of an accelerator with a 30 MW beam must be inherently much more conservative than the design of the kind of research accelerators are in use in Italy and where INFN's expertise lies.

- If INFN is to become involved in the energy amplifier area, it should understand the issues clearly and determine that its expertise is appropriately matched to the problems. INFN should only participate as part of a larger effort, for ultimately the success or failure of this scheme will depend of the cost of the thorium cycle subcritical facility and auxiliary systems, and not on the cost of the linear accelerator which can only be a small fraction of the total budget.

APPENDIX

REPORT ON THE ACTIONS
OF THE
REFEREE INTERNATIONAL COMMITTEE

June 1997

Report on the actions of the Referee International Committee

1. INFN regulation foresees that "At least once every five years, INFN Council requires a comprehensive evaluation of its activity to a referee Committee strong of Italian and foreign scientists."

2. The INFN President in May 1996, with the aim to propose to the Council names of international scientists at the highest scientific level and with large experience in the management of research institutions, requested nominations to the following international organisations: to Organisation for Economic Co-operation and Development (OECD) of the chairman of the Committee, to the European Committee for Future Accelerators (ECFA, the European committee responsible of the co-ordination of the research in Elementary Particle Physics) of an expert in Particle Physics and to NuPECC (the European committee responsible of the co-ordination of the research in Nuclear Physics) of an expert in Nuclear Physics.
The Deputy Secretary General of Organisation for Economic Co-operation and Development (OECD), Prof. P. Vinde nominated on June 27th, 1996 Prof. Burton Richter - Director of the Stanford Linear Accelerator Center (SLAC) in California (USA) and Nobel prize for Physics, Prof. E. Fernandez, chairman of ECFA, proposed Prof. Volker Soergel - Director of Werner-Heisenberg-Institute in Munich and former of the Laboratory in Hamburg, finally Prof. S. Gales, chairman of NuPECC nominated Prof. Paul Kienle - presently at the Munich University and former Director of the GSI Laboratory in Darmstadt.

3. On September 6, 1996, INFN Council appointed the Committee, with the mandate to present "within June 1997 its evaluations on the scientific activity of INFN with particular attention to the following arguments:
- relevance of subjects, compared to the present state of the art, and integration at the international level;
- level and quality of research and effectiveness of INFN action;
- adequacy of the mechanisms for taking scientific decisions;
- advice for planning future activities, particularly in connection with the next five year plan, 1999-2003."

and charged Prof. A. Bettini, former vice-president of INFN, to act as the interface between INFN and the Committee.

4. In a first meeting of the Committee on September 23 and 24, 1996, President Maiani set the general framework and the guideline. A. Bettini gave an introductory report concerning the organisation, the structures and the researches of the Institute. The agenda of the works of the Committee was then defined.

5. The INFN research activity takes place in 19 "Sezioni" - located in 18 University Physics Departments and at Istituto Superiore di Sanità - and in four National Laboratories. The research activity is divided in five lines, each corresponding to a "national group". They are:

1. Subnuclear physics with accelerators
2. Subnuclear physics without accelerators and neutrino physics
3. Nuclear physics
4. Theory
5. Technical and interdisciplinary research

A National Scientific Committee for each line is responsible of the analysis of the experimental proposals to submit to the Council for approval and for the peer review of the scientific results.

6. The works of the Committee have been organised as follows:

a. the Committee visited all the National Laboratories and a sample of five "Sezioni" (in chronological order Roma1, Padova, Ferrara, Pisa and Milano). In each case the Director (and some other members of the structure) started with a description of the activity; a visit to the site followed with requests of details and discussions;

b. a session was dedicated to the research activity of each line. The chairman of the National Scientific Committee presented a report focused on scientific policy (criteria for the choices, for the allocation of resources, evaluation of the resources needed for future programs, etc.). Then the scientists responsible of the experiments presented to the Committee their reports, followed by discussion;

c. a closed session was dedicated for each scientific line to a meeting of the Committee with a representative sample of young scientists.

7. The Committee in examining the research activity in theoretical physics asked the assistance as a consultant of Prof. G. Ross of the Oxford University. Prof. Ross took part to the works of the Committee on February 5th, when the theoretical activity was discussed, and on February 6th in a closed meeting of the Committee.

8. The agenda of the Committee actions has been, in summary, the following:

First week. 1-7 December 1996

2/12 morning	Visit to the Frascati national Laboratory
2/12 afternoon	Review of the experiments in particle physics with accelerators (Group 1)
	Meeting with Group 1 young scientists
3/12 morning	Visit to Sezione of Roma1
	Transfer to Catania
3/12 afternoon	Visit to Laboratorio Nazionale del Sud
	Review of the experiments in nuclear physics (Group 3).

4/12 morning	Review of the experiments in nuclear physics (Group 3). Continues.
	Meeting with Group 3 young scientists
4/12 afternoon	Transfer to Gran Sasso National Laboratory
5/12 morning	Visit to Gran Sasso National Laboratory
5/12 afternoon	Review of the experiments in particle physics without accelerators and in neutrino Physics (Group 2) and of the VIRGO project.
	Transfer to Roma
6/12 morning	Review of the experiments in particle physics without accelerators and in neutrino Physics. Continues.
	Meeting with Group 2 young scientists
6/12 afternoon	Closed session of the Committee

Week February 2-6

3/2 morning	Visit to Legnaro National Laboratory
3/2 afternoon	Review of the technological and applied research (Group 5)
	Review of the activity on computing and networking
	Meeting with Group 5 young scientists
4/2 morning	Visit to Sezione of Padova
	Transfer to Ferrara
4/2 afternoon	Visit to Sezione of Ferrara
	Transfer to Pisa
5/2 morning	Visit to Sezione of Pisa
5/2 afternoon	Review of the theoretical activity (Group 4)
	Meeting with Group 4 young scientists
	Transfer to Milano
6/2 morning	Visit to Sezione of Milano
6/2 afternoon	Closed session

10/2 e 11/2 Munich

Closed session

The activity of the Committee to prepare the report continued during the following months and was finished by end of June.