INFN REVIEW COMMITTEE

Rome 24-26 October 1999

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1. Introduction

This review represents the first contact of the Committee with the Institute. The committee was invited to analyze the structure and programs of the Institute on the basis of documentation, which included:

- the Three-year plan of the INFN 2000-2002;
- the report of the INFN International Review Committee: B.Richter, P.Kienle, G.Ross and V.Soergel - June 1997;
- the report of the INFN Review Committee on the 1999-2003 Five-year plan - August 1998;
- the reports of the five National Scientific Committees on the activity in 1998;

and oral presentations of the President and the members of the Executive Board (Giunta Esecutiva) on the structure of the Institute and its programs along the different research lines (see appendix B), with particular attention being devoted to the results obtained in 1998 and the milestones reached in the course of that year. An animated discussion took place, during and after the presentations, on different aspect of the Institute's structure and research program.

One of the goals of this first meeting was a discussion on the review process itself. The committee felt that in evaluating a program so vast and complex as that of INFN it would be of great help on the occasion of future reviews to have at their disposal a more systematic and analytic presentation of the different activities.

2. Structure and organization

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

In conclusion, INFN represents a pervasive presence in the Italian university system, a fact which is reflected in the large number of laurea degrees and doctoral theses obtained by students participating in the research of INFN. These data were available only for some of the research lines – theory and technological research – and it would be interesting in the future to have wider statistical information on this important subject.

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

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

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

The National Scientific Committees are a key feature of INFN and their equivalent is not found in other countries. They allow a good balance between the need of assuring a well managed program, which is the responsibility of the Council and the President, and the free initiative of scientists, taking into account the proposals emerging "bottom up" from the research groups. The principle of democratic participation of the personnel extends to other aspects in the life of the institute. As an example, the directors of Sezioni and National Laboratories are nominated by the Council after a consultation by ballot of the personnel. In addition to the National Scientific Committees, the National Laboratories each has an international Scientific Advisory Committee or Program Advisory Committee.

INFN has a staff complement of about 2000, of which 621 researcher physicists, 251 technological experts (applied physicists, engineers, etc.) and 843 technicians. The INFN research personnel also includes research and other staff belonging to Universities and to a lesser extent to other organizations such as CNR, ENEA, etc. A part of this extra personnel, more heavily involved in INFN research, shares with INFN personnel a number of important privileges, including that of participating into the elections of members of the National Scientific Committees, and in the ballots for the nomination of directors of the Sezioni and Laboratories. This includes 950 research associates and 200 technical support members. Research people with only partial involvement in INFN projects, including thesis students, can also be formally associated to INFN without sharing electoral privileges.

3. Scientific and technological activity

3.1 Physics with accelerators: Commissione I

The program of Commissione I encompasses essentially two thirds of the field which traditionally is labelled Elementary Particle Physics. The excluded one third concerns neutrino physics which falls within the purview of Commissione II. There is a total of sixteen approved experiments in various stages. Some are taking data, as is the case for the four experiments at the Large Electron Positron (LEP) collider at CERN. Some, as the K-Long Experiment (KLOE) at Frascati National Laboratory, are just starting to operate. Finally some are in the early stages of detector construction such as the ATLAS and CMS experiments for the Large Hadron Collider (LHC) at CERN. The general level of this program is excellent. All experiments are international in character and there is an unusually large number of leadership roles occupied by Italian INFN supported physicists.

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

The committee noted a numerically large number of experiments with the potential to explore CP violation in both the kaon and bottom systems. INFN physicists have or have had leading roles in several of these experiments. One of the experiments is the keystone of the L.N. Frascati experimental program and indeed CP violation is a primary theme in particle physics experimentation worldwide. Nevertheless some question was raised as to whether the appropriate balance had been achieved between individual initiative and coherence in this sub-field.

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

This committee did not examine in any detail individual components of the program. The comments which follow, and which are structured in the same way as the written report from the chairman of Commissione I, are therefore brief.

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

There is Italian participation in each of the LEP experiments. This program which will culminate in 2000 continues to advance the limits on masses of new particles and contributes strongly to the world knowledge of the mass of the W boson. The final year of LEP operation still holds potential for discovery and continued participation to the end of the program is natural.

- CP violation experiments (KLOE, NA48, BABAR, HERA-B)

The NA48 experiment was fully operational in 1998 and took a considerable volume of data. In 1998 the DAFNE accelerator reached design luminosity and the KLOE experiment was installed on the beamline. These two experiments, with the KTeV experiment at FNAL their only competitor, have as a goal the measurement of the ε'/ε parameter with a precision of one part in ten thousand. Given the present theoretical understanding these can be considered "asymptotic" measurements of this quantity.

BABAR is a new experiment at the (also new) PEPII storage rings at Stanford Linear Accelerator Center. Construction of the detector is at an end with running starting in 1999. An example of the potential of this experiment is the projected precision of 10% on the parameter $\sin(2\beta)$.

HERA-B at DESY is in construction.

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

- Deep inelastic scattering (ZEUS, COMPASS)

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

The new muon scattering experiment COMPASS at CERN is a successor to a series of experiments. As the only large fixed target physics initiative at CERN, and coming as it does in the hiatus between the end of LEP and the start of the LHC collider, it has attracted considerable support. The main goal is further elucidation of the partonic origin of the nucleon spin. As such it is related to the HERMES experiment discussed in the Nuclear Physics section.

- Proton-antiproton physics (CDF, E835)

The CDF and E835 experiments are at the highest and lowest ends of the proton-antiproton energy scale. The CDF experiment has made major contributions to knowledge of the highest energy collisions thus far available in the laboratory. Highlights of the program have included important measurements of the top quark, including its discovery, precision measurements of the mass of the W boson and a number of physics measurements and searches for new phenomena. The experiment is being upgraded fully to exploit the potential of the recently upgraded accelerator complex. Construction is in full swing. Ongoing analyses demonstrate that it is also a serious competitor in B-physics with the observation of the bottom-charm meson and a first measurement of the parameter $\sin(2\beta)$. CDF will share the energy frontier with the D0 experiment until the start of the LHC and there is some potential for observation of the Higgs boson, should its mass be low.

E835 is unique in the world and its technique is imaginative and novel. The experiment uses antiprotons in annihilation with protons in a gas jet to access several charmonium states in formation which cannot be produced in electron-positron collisions.

- Rare decays (E831, E781)

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

- The future energy frontier (ATLAS and CMS)

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

3.2 Non-accelerator and astroparticle physics: Commissione II

Astroparticle physics is a rapidly evolving field of fundamental research. INFN has a strong and already long-term engagement in the field, in which it is presently one of the leading institutions in the world.

- The role of the Gran Sasso laboratory

The Gran Sasso underground laboratory is a world-class laboratory. It gives the involved Italian physics community a unique opportunity to carry out experiments in a low background environment. At the same time it gives the involved groups a high and widespread visibility. Therefore the laboratory needs steady attention and special support from INFN in order not to loose its quality and leading role.

We would like to mention that an enlargement of the laboratory in view of its unique situation worldwide and the large demand for new experiments should be pursued. Even the addition of smaller halls for the many small experiments would ease the situation. In case of the construction of the neutrino beam from CERN the space situation might become critical.

- A general comment about experimental prospects and progress

Quite common in a newly developing field is that nearly all experiments in astroparticle physics are of exploratory nature and might fail in part their objectives due to unknown need of sensitivity or unreliable theoretical predictions. In many cases upper limits are important results. A good sign of the progress in the field is the large number of new technologies in instruments, found in nearly all experiments. Examples are ultrahigh purification for low radioactive materials, cryotechnology, detection methods on atomic levels, crystal technology or electronics for high rate signal processing.

In the following some activities will be briefly commented. It is not possible to give full justice to all activities because the field of Nonaccelerator/Astroparticle physics is rather widespread and also sometimes only limited information on experiments was available to the committee.

- Neutrino "beams"

INFN is involved in many of the leading experiments for the study of fundamental parameters of neutrinos. One area is the search for neutrino oscillations. The experiments at CHOOZ and at CERN - NOMAD and CHORUS - and in a certain aspect also MACRO, all with strong INFN participation, are now basically completed and have reached their objectives. The main next future issue in this area will be the search for neutrino oscillations, particularly for τ appearance, with experiments in the LNGS. This requires large installations and a neutrino beam from CERN. Approval needs a careful evaluation of the risks and of the potential for success. Once a positive decision has been made a prompt start and a vigorous pursuit of the detector construction will be needed to stay at the forefront of this important goal. A large international participation in these new experiments should then be encouraged.

- Solar neutrinos

The Gran Sasso low background laboratory is a natural place for the study of solar neutrinos and many leading experiments with large international participation are concentrated there. The most precise measurement of the deficit of solar neutrinos was made in the LNGS and research is going on at a fast pace. The GALLEX/GNO experiment is one of the highlights of the laboratory. Similarly, this is expected for the BOREXINO experiment which is expected to come on line in 2001. BOREXINO will be essential to understand the solar neutrino puzzle and is complementary to SNC. An important effort is needed to avoid a delay of the BOREXINO start-up.

The large number of new proposals, exceeding by far the available space in the laboratory, highlights on one hand the worldwide interest and guarantees on the other hand the possibility to select the best ones. The reviewing procedure set up by the laboratory is considered satisfactory (see also the comment of the Richter report).

LVD is a typical example of a longterm monitoring detector of cosmological events, such as neutrinos from SNRs and perhaps from Gamma Ray Bursts.

- Double Beta, dark matter and monopole detection

All three questions are of fundamental nature, both for the particle physics aspects and for cosmological aspects (dark matter, monopoles). Again, experiments profit very much from the low background of the LNGS. Without going into details of the many activities it is to be noted that the development of the detectors is still in full swing and many novel ideas are pursued. Also, due to the lack of precise theories, in some areas one is forced to proceed in an exploratory way and upper limits on some quantities are important results. The LNGS concentrates the largest number of such activities worldwide and creates therefore a highly competitive environment.

- Gravitational wave (GW) detectors

INFN has a large involvement in forefront gravitational wave experiments. The cryogenic bar antennas reached their predicted sensitivity and physicists from INFN have made many technical improvements and worldwide recognised contributions in this area. The most recent antennas are integrated in a worldwide net for searches of coincident signals from various astronomical objects predicted to generate GWs in the frequency band above 10 Hz. Because of the unpredictable arrival of GWs it is indispensable to keep the detector permanently operational. Here the INFN groups have made a significant progress in 1998.

The VIRGO detector will bring a quantum jump in sensitivity. VIRGO is again on the forefront of the next generation, high sensitivity detectors. Some of the technology developed for VIRGO is now considered by the competing experiments. The committee felt that VIRGO needs a tight control of the schedule and recommends an in-depth technical progress review by an international expert group. Efforts are needed in order not to endanger its forefront position.

- Balloon and satellite experiments related to astroparticle physics

The balloon and satellite experiments with significant INFN contribution have already or will soon produce results of high scientific value and of high international recognition. The results contribute to the understanding of the so-called relativistic (nonthermal) universe. The presence or absence of antimatter from the early universe is a key element for cosmology. The INFN involvement in AMS and the construction of PAMELA highlights again the participation in this frontline physics.

- Charged cosmic-ray and gamma-ray astronomy

The study of cosmic rays and their sources are another area of long-term Italian involvement. The INFN projects are EAS-TOP, CLUE and ARGO. EAS-TOP is still in its data-taking phase. It has made major contributions to the understanding of the total cosmic ray spectrum (partly in connection with MACRO) but, due to its high threshold, was not able to detect with high significance any gamma ray source. The CLUE experiment is a proof-of-concept experiment for a new method in gamma-ray astronomy, making use of the shielding function of the high atmosphere ozone layer. The detection principle was verified by the observation of the extragalactic source Mkn421. The third activity, ARGO, for the international experiment Tibet-AS, is still in the preparation phase. With the use of RPCs one hopes to make major contributions to the still enigmatic phenomenon of gamma ray bursts.

It is important to recognise that, due to the exploratory nature and the long time scale of observations on one hand and on the other hand the rapid progress in technology and rather rapid changes of scopes in this new field a subpanel for in-depth studies of the latest directions is needed quite regularly.

New directions in this field are the study of the highest energy particles by experiments such as AUGER and on the long run AIRWATCH/OWL, in gamma-ray astronomy both at ground level and by satellites (GLAST) and in neutrino astronomy with large volume detectors such as for example NEMO.

In summary the current experiments have the right mixture of small and large collaborations to explore this new field of fundamental physics. Small groups, not necessarily of international composition normally carry out the exploitation of new technologies, while in the follow-up phase concentration on fewer large experiments of international composition is natural. The international standing of the INFN activities in the field of neutrino and astroparticle physics is high. Another sign of the positive development in this field is that it attracts many students and postdocs, i.e. the educational prospects are large.

3.3 Nuclear physics: Commissione III

The INFN nuclear physics research covers a wide field extending from the more conventional nuclear structure physics to the investigation of subnucleonic degrees of freedom, and the studies of a possible transition to the quark-gluon plasma. It involves some strong and active groups. While about 60% of the research is done at the National Accelerator Laboratories in Legnaro, Catania and Frascati, there are strong involvements also at other European accelerator centers and at the Thomas Jefferson Laboratory in the USA. Vice versa we notice an increasing use of the national accelerators by groups from outside Italy, attesting to the attractiveness of these facilities.

The National Accelerator Laboratories are excellently equipped with elaborate and sophisticated detection systems. To be able, however, to fully exploit their potential it is important that every effort is made to assure a reliable operation of the accelerator systems in Legnaro and Catania, and that the completion of PIAVE in combination with ALPI is given the highest priority.

After considerable startup difficulties of the Catania K=800 MeV cyclotron with superconducting coils the operation of the cyclotron has steadily improved over the past years. In collaboration with Grenoble an ECR source with superconducting mirror and sextupoles coils has been designed and in 1998 installed in Catania. This source is the best of its type worldwide.

The planned radioactive beam facility EXCYT at Catania will offer interesting experimental possibilities, especially in the nuclear astrophysics field of explosive stellar burning. Most of the hardware is being assembled, but the problems along the path towards achieving useable radioactive beams should not be underestimated in view of the limited available manpower and the difficulties experienced at Oak Ridge with a very similar setup. The progress of EXCYT should be closely monitored within a wider European context, and care should be taken that the upstarting research with the Catania cyclotron is not unduely hindered by the EXCYT activities. Plans for second generation radioactive beam facilities in Legnaro and in Catania should be coordinated both nationally and on a wider European scale.

The productivity in 1998 of the nuclear physics research was high, and interesting results have been obtained. An in depth evaluation of all of these activities was clearly beyond the scope of this review. We will therefore restrict ourselves to some more general observations. The research in nuclear physics can be grouped into five major lines:

1) Electromagnetic probes
2) Hadronic probes
3) Heavy ion reactions at intermediate and relativistic energies
4) Heavy ion reactions at low energies
5) Nuclear structure

- Electromagnetic Probes

Studies with electromagnetic probes are being performed at DESY in Hamburg, at the European Synchrotron Radiation Facility ESRF in Grenoble, and at the Thomas Jefferson National Accelerator Laboratory (TJNAF) in the USA. In all these studies there has been a very sizeable Italian involvement both in manpower and in instrumentation, and the experiments have led to a large number of publications.

The HERMES experiment at DESY, involving a large international collaboration, is aimed at measuring the neutron and proton spin structure functions in deep-inelastic scattering of longitudinally polarized positrons from a polarized gas target (H, D, ^{3}He). In addition to the proton spin function, recent results involve a determination of the flavour asymmetry of the light quark sea in the nucleon and the deep-inelastic contribution to the generalized Gerasimov Drell Hearn integral. The HERMES experiments are internationally attracting much interest.

At TJNAL the first 18 months of data taking have resulted in a wealth of data on photo- and electro-induced reactions performed with the large angle spectrometer CLAS in the frame of the AIACE collaboration. The emphasis of these studies is on photoproduction and photodisintegration. In addition the analysis of a photoabsorption experiment performed at Bonn has been completed and the results have been published.

In the GRAAL experiment at the ESRF in Grenoble a tagged beam of polarized and energetic photons is produced via Compton backscattering of laser light. A close to 4 π crystal ball for the detection of high-energy photons enables the identification with high efficiency of neutral mesons via the reconstruction of their invariant mass. The beams are used to study the photo-production on the nucleon of pseudoscalar and vector mesons with the aim to investigate the baryonic resonance structure. With its high-energy photons and the elaborate detection equipment GRAAL comprises an experimental setup of great promise.

- Hadronic Probes

These activities in the field of intermediate energy nuclear physics involve some 60 physicists in experiments at a number of different accelerators, some of which (LEAR, SATURNE) have been closed by now. The major future activities will concentrate on the FINUDA and DEAR experiments at DAFNE, where much of the effort in 1998 has gone into commissioning these detectors. The DEAR experiment is aimed at understanding the SU(3) chiral symmetry breaking through the determination of the KN sigma term, while FINUDA is directed towards the study of hypernuclei.

- Heavy Ion Reactions

Ultra-relativistic heavy ions

The study of ultra-relativistic heavy ions with the goal to create and investigate the quark-gluon plasma is one of the frontiers of nuclear physics. Italian physicists have been actively involved in this field, most recently in the Pb + Pb experiments at the CERN-SPS, and they are also engaged in the construction of the ALICE detector for the LHC. The CERN-SPS experiments have led to very exciting results on J/Ψ suppression and on strangeness production. The abrupt decrease observed in the J/Ψ production yield as the number of nucleons which take part in the collision exceeds a certain value might well be a first indication for the creation of the quark-gluon plasma.

Intermediate energy heavy ions

During the last decade much effort has gone mainly at GANIL and MSU into the study of the dynamics of intermediate energy heavy ion reactions. The questions asked concern the mechanism of multifragmentation of very hot nuclei, the coexistence of a gas-liquid phase, the nuclear caloric curve and equation of state, and a possible phase transition. With the unique CHIMERA multi-detector system and the heavy ion beams of the superconductive cyclotron, the laboratory at Catania is very well suited for such investigations. After the buildup and test of the CHIMERA detector the first experiments, involving a large participation of physicists from outside Italy, are in progress.

Another very powerful and complementary detector at Catania for the study of intermediate energy heavy ion reactions is OUVERTURE, which consists of the MEDEA detector for hard photons combined with a forward wall and the MACISTE time-of-flight spectrometer for the detection of heavy reaction products. MEDEA has been operational for a number of years and has originated a steady flow of interesting results.

Heavy Ion Reactions at low Energies

This work is mainly concentrated at Legnaro with studies on sub-barrier fusion in selected nucleus-nucleus systems, on deep-inelastic reactions and on fission induced by heavy-ion fusion and multi-nucleon transfer. A first experiment on proton emitters was performed recently with the IRIS setup. Work has also been proceeding on the very large acceptance PRISMA magnetic spectrometer and on the GARFIELD-4π heavy ion detector.

- Nuclear Structure

Very extensive work on high-spin nuclear physics has been carried out over the last few years at Legnaro with the GASP spectrometer and more recently with the European EUROBALL detector, which was stationed at Legnaro in 1997 and 1998. The field of high spin physics, utilizing the most advanced detection equipment such at EUROBALL in Europe and GAMMASPHERE in the US, is a very lively and competitive one. Some of the important results obtained in 1998 at Legnaro involved the first observation of the linking of the superdeformed band to the ground state band in selected nuclei and the observation of a new kind of nuclear collectivity, the magnetic rotation, and finally the observation of the Giant Dipole Resonance built on superdeformed states.

- Other Activities

These involve a number of cross section measurements of astrophysical interest. We wish to especially draw the attention to the unique LUNA setup in the Gran Sasso underground laboratory which for the first time allowed a measurement of fusion cross sections at star temperatures.

In the EXPLODET project work is proceeding to conceive a cost-effective method to detect hidden land-mines.

3.4 Theoretical physics: Commissione IV

Italy has a very strong tradition in the theoretical studies of nuclear and elementary particle physics, a tradition continually renewed by the emergence of new young scientists in this field.

Theoretical research points in different directions: on the one side it explores the limits of our understanding of the structure of matter on the smallest scale, far beyond what is accessible to present day experimental research, on the other it works in close collaboration with experimental groups in analysing the potentialities of the different experimental strategies, and evaluating the significance of the experimental results in the framework of existing theories, as for example the Standard Model of elementary particles. The interests thus ranges from theory building on the one side to the extraction of testable predictions from established theories.

Another type of theoretical activity is concerned with the application of theoretical and mathematical tools created in the framework of studies on elementary particles and nuclei to other fields of physical sciences, such as condensed matter and statistical mechanics. As an example the study of QCD, the theory of quarks and their interactions within hadronic particles, has led to important fallouts on the study of amorphous systems, which find many applications to condensed matter (the vitreous state) but also in biology (an example is the study of neural networks or the properties of the immune system). Another example is the application to atomic clusters of methods developed for the study of the nucleus.

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

The number of theoretical physicists financed and organized by INFN with the help of the Commissione IV is close to 600, of which only 17% are INFN staff members, while the majority, about 50%, hold faculty positions in Italian universities, and the remaining 33% are postgraduate students or post-doctoral fellows.

Even taking into account the cost of computing apparatus theoretical studies are much less expensive than experimental ones, and are normally carried on by small groups. In spite of this the activity of Commissione IV has been precious in orienting the different activities, and in offering a forum for the discussion of the different programs and of their needs. It divides the theoretical activities in five sectors:

1) Field and String Theory
2) Phenomenological studies of Elementary Particles
3) Physics of Nuclei and Nuclear Matter
4) Mathematical Methods of Fundamental Interactions
5) Astroparticle physics

and within each sector it establishes "specific projects" aimed at a particular coherent line of research, typically emerging from a collaboration of researchers belonging to different Sezioni or Laboratories. As a general comment, theoretical studies seem to be well distributed over the different regions of the country, a circumstance which reflects the fact that most Universities offer a variety of courses on Theoretical Physics and Nuclear Physics.

We will make a few comments on each of these sectors and some concluding remarks on the productivity of INFN financed theoretical physics.

- Field and String Theory.

This sector includes the study of traditional field theories, such as QCD or the unified theories of weak and electromagnetic interactions, and of the general properties of quantum field theories. Of particular interest here are the methods of numerical simulation, which in some cases overcome the difficulties of analytical solutions of field theories.

This sector also includes the study of strings, an extension of field theory which could lead to a deeper understanding of elementary particles and their relations to the structure of space and time. It is also natural to include in this sector the applications of field-theoretical methods to statistical mechanics and complex systems in general.

- Phenomenological studies of Elementary Particles

This sector includes those studies which are in more direct contact with experimental research. The programs involve all aspects of elementary particle physics, from the precision tests of the Standard Model to the properties of heavy quarks. It also includes the study of theories which extend the Standard Model under those aspects which may become amenable to direct experimental tests, e.g. at the LHC.

Phenomenological studies employ a vast array of theoretical and mathematical tools, including the use of numerical simulation of particular processes.

- Physics of Nuclei and Nuclear Matter

This sector includes all aspects of nuclear theory, some of them more "theoretical" others more "phenomenological" and closer to the experimental programs. Among the first the study of nuclear structure and of nuclear matter, and among the second the study of heavy ion collisions which are the object of experimental programs in the

National Laboratories of Catania and Legnaro, but also, in the case of relativistic heavy ion collisions, at CERN. Another important field of study close to experimental activities concerns the interactions of nuclei and nucleons with electrons and photons.

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

- Mathematical Methods of Fundamental Interactions

This sector includes various developments of mathematical physics and of pure mathematics which emerge from field-theoretical studies. They find direct application in the development of field theories, but also in statistical physics and in the theory of condensed matter. Among these the general theory of nonlinear dynamical systems, of quantum groups and of quantum chaos.

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

- Astroparticle physics

This sector has only recently been recognized as separate from the more general one of elementary particle phenomenology. Recent developments in astrophysics and cosmology have revealed an increasing role of the properties of elementary particles and field theory in the understanding of our universe. Among the many subjects investigated we recall the problem of dark matter, matter-antimatter symmetry, inflationary cosmological models and sources of gravitational waves.

The Commissione IV has analysed the productivity of INFN-funded theoretical research, a methodology which gives a weight to each scientific paper according to the importance of the journal where the paper is printed. This is an international recognised methodology which is widely used and it allows comparison with institutes elsewhere. The total impact factor for 610 papers published in 1998 by 520 participants in research projects monitored by the Commissione IV was 1665. The analysis does not include the contributions of theoreticians not involved in "specific projects".

The impact factor per paper, ~ 2.7, indicates that these papers were published in medium to high impact journals, and is typical of the mix of journals used by theoretical physics elsewhere. The impact factor per author, ~ 3.2, is comparable or better than that in European institutions, with the exception of the CERN theory group (which is favoured by the fact that its members are free of teaching loads). This result certainly confirms the excellent level of theoretical research funded by INFN.

As is the case with experimental programs, INFN theoretical physics enjoys a very strong interconnection with ongoing research in other countries. The vivacity of this interconnection is demonstrated by the frequent presence of italian theoreticians at CERN and in other foreign research centers, as well as by the large number of foreign visitors in INFN centers, both in Sezioni and Laboratories. INFN theoreticians also appear in many research networks funded by the EU, and each year INFN centers host a number of worldwide appreciated international seminars and workshops.

3.5 Technological research: Commissione V

Progress in physics depends on advances in detector data handling and computational technology and methodology. A fraction of these advances are achieved as a result of dedicated detector and technological research and development. There are a number of potential applications of nuclear and particle physics detectors outside of the field, in particular in medical or environmental applications.

The demands of the INFN activities excite a natural motivation for industrial advancement as companies compete for contracts. More recently some emphasis has been placed on explicit technology transfer. Memoranda of Understanding have been developed with Confindustria and Confapi. These initiatives are laudable and the committee recommends a continued aggressive posture on the part of INFN to enhance the visibility and utility of its work to society at large through its technological and educational competence.

With respect to specific areas of the work under the National Scientific Committee for technological research, the comments are limited to a selection of the topics reported and discussed in presentations.

- Education

The typical career path for the young people trained in this sector of INFN activities is to go to industry. This is an effective form of technology transfer. In 1998 about 100 Laurea and 30 Ph. D. degrees were awarded in these subjects.

- Interdisciplinary physics

This work includes the spin-off to other academic and medical work. In 1998 the Digital Mammography Project provided a highlight.

- Detectors

The INFN contributions to experiments worldwide have been characterised by a utilization of the most advanced electronics, semiconductor and other technologies in their detectors. In 1998 a particular theme concerned the prototype work for the LHC experiments which place a particular demand on large scale productions and survivability in hostile environments.

- Electronics and informatics

The use of VLSI technology is pervasive across the INFN activities and the level of expertise is impressive. The training received by the young researchers involved has attracted the attention of industry which now provides an attractive competitive career path for young physicists.

The APE project provides computing for lattice gauge calculations and is now in its third generation. The longevity of the basic approach is remarkable. This project involves students from engineering and computing faculties.

- Superconductivity

Dominated by the special projects such as the collaboration on the Tesla Test Facility with DESY, superconductivity enjoys a special place in the activities of INFN. It is especially interesting that fabrication techniques normally used for kitchen utensils have been applied to the fabrication of superconducting radiofrequency cavities. The committee also notes the strong efforts of ANSALDO in particle physics worldwide in the fabrication of superconducting experimental and accelerator magnets.

- Accelerator Physics

The accelerator physics within INFN is primarily associated with the construction and operation of the accelerators at LNF, LNL and LNS. Besides these activities in the National Laboratories, important contributions are given to the use of accelerators as sources of synchrotron radiation for condensed matter, chemistry and biology as well as for medical applications.

Besides its scientific content, INFN research programs should also be evaluated taking into account their contribution to the national industrial system, particularly in the high technology field, and the technical/scientific education and the international exposure of the new university graduates. This contribution should be measured both with qualitative and quantitative methods. A few examples are given below.

As for the industrial impact:

- The portion of capital expenditure (out of each project's total) commissioned to the Italian industry. This measurement should be applied both to projects led by INFN and to projects led by foreign partners of INFN which resulted in work assigned to Italian industrial companies.
- The transfer of technology to the Italian industrial system. The committee acknowledges that, also following the recommendations of the Richter report, INFN has already taken significant steps to establish a collaboration with industrial associations such as Confindustria and Confapi. The committee encourages INFN to undertake additional efforts to make the large and advanced technical know-how developed by INFN accessible to the industrial community. A suggested approach could be a comprehensive and detailed mapping of the different technical competences available within INFN. This database could then be made accessible through the World Wide Web.

For the educational benefits, for each technological project the following parameters should be measured:

- The number of theses (graduate and Ph.D.) written in relation with that particular project;
- The number of foreign researchers who have been (or are expected to be) working in INFN laboratories and Sezioni in Italy (measured in FTE × year);
- The number of Italian researchers who have been (or are expected to be) working abroad on international research programs (measured in FTE × year).

4. Internal review system

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

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

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

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

The Review Committee appreciates the internal review system that is basically a bottom-up structure with supervision of the management. It provides a good balance between quality of the programs, competition and scientific freedom. It is also a very effective training of young scientists for positions of responsibility. The general excellence and success of the INFN program testifies to the effectiveness of the National Scientific Committees.

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

5. Future reviews

The Review Committee has discussed possible ways to improve the documentation to be provided by INFN for future reviews. For an external evaluation of the programs, the Review Committee suggests to consider some objective criteria. Given the variety of subjects, dimensions and time scales, these criteria have to be adapted to the specific line of research. The Review Committee suggests to collect for each program a systematic documentation on:

- publications and invited papers to international conferences;

- leading responsibilities in large collaborations;
- PhD and undergraduate theses made within the programme;
- results of special relevance for other scientific disciplines or of special impact for applied research and industrial applications.

To this aim the Review Committee proposes a number of questions to be addressed to the management and to the single experiments.

Question list to the management and to the five scientific committees

- Fraction of foreigners holding permanent INFN positions
- Fraction of foreigners holding guest INFN positions
- How many foreigners come to Italy to use the INFN facilities
- How many INFN members and associates use foreign research facilities
- How many international conferences, workshops and schools are held in Italy
- Monitoring the number of INFN researchers and graduates taking industry positions
- How many foreign or international fellowships (e.g. Marie Curie, European Union, etc.) go to INFN programs

Question list to summarize a single experiment

- Goal of the experiment (few lines stressing also fundamental physics objectives)
- What has been achieved in the last year
- INFN contribution to the experiment in terms of manpower (including graduate students and technicians) and financial support
- Number of publication in refereed journals, impact factor, citing coefficient (if possible)
- Number of talks to conferences
- Number of undergraduate and doctoral thesis on the experiment
- Leadership role in the experiment
- Innovative instruments
- Competing experiments
- Which international committee has reviewed the experiment

Appendix A – Membership of the committee

- Prof. N.Cabibbo, University of Rome "La Sapienza" (chairman)
- Dr. E.Lorenz, Max Planck Institute
- Dr. H.E.Montgomery, Fermi National Accelerator Laboratory
- Prof. R.H.Siemssen, Argonne National Laboratory
- Ing. C.Vanoli, SNIA S.p.A.

Prof. F.Ceradini, University of Rome "Roma Tre" (scientific secretary)

Appendix B – Oral presentations to the committee

- Presentation of INFN by the President E.Iarocci
- Special projects of INFN (E.Iarocci)
- Theoretical research (E.Iarocci)
- Experimental subnuclear physics with accelerators (L.Mandelli)
- Experimental subnuclear physics without accelerators and astroparticle physics (A.Scribano)
- Nuclear physics (E.Migneco)
- Experiments on detection of gravitational waves (M.Cerdonio)
- Technological research (M.Cerdonio)