Report by the Committee on the 1999 – 2003 INFN Five-Year Plan (Quinquennial Plan)

August 1998

Introduction

The contribution to fundamental research in nuclear and subnuclear physics by the Italian National Institute of Nuclear Physics (hereinafter shortened INFN) has always been greatly appreciated in the international field. The realisations, discoveries and technical achievements accomplished by the researchers and technicians of the Institute, in collaboration with the teaching and research staff from the Italian Universities, in international laboratories [CERN, DESY, FNAL (Fermi National Accelerator Laboratory - in short Fermilab-), etc.] has contributed to the success of the programmes carried out in those laboratories ; one can reasonably state that the excellence of research, teaching and education performed in Italy has been at world level, enabling basic science to meet its challenge within society :

– to learn more about the world we live in ;

– to train our mind in order to improve the civilisation of our thinking and behaviour ;

– to provide society with the tools of knowledge and technology to solve the problems of the future.

Vice versa the National Laboratories of Frascati (LNF), of Legnaro (LNL), of Catania (LNS) and of the Gran Sasso (LNGS) have always hosted, thanks to the scientific facilities put at their disposal, scientifically qualified European and American research groups. Thus many scientists from foreign countries have interacted with our students, universities, industries, introducing their knowledge. They and their families have come to love and appreciate Italy, its way of living and its culture.

INFN has participated in the construction and in the operation of quite complex large instruments and has contributed to the analysis of the data acquired during the running of the experiments and to their scientific interpretation.

In the evaluation of the INFN 1999 - 2003 Five-Year Plan (hereinafter termed F.-Y.P.) one has to realise that this Institute has greatly magnified the standing and tradition of Italian basic science since its creation in 1951. And this in turn rested on the cultural and scientific tradition having its origins in nuclear physics research and in the study of cosmic radiation, performed since the early thirties in Italy.

Right from its constitution, scientific requirements have induced INFN to operate on the basis on five-yearly plans in order to define the scientific programmes better suited to the increasing complexity of the laboratories and the experimental facilities required by the study of the fundamental components of matter.

The research done by INFN constitutes an indispensable activity for the culture of our Country. As the resources available for the scientific national research are limited, it is imperative that the programmes to be carried out are clearly set out, indicating for each research sector the critical mass in personnel and in resources so as to ensure the correct working out and evolution of the research itself.

The presence of INFN in many international experiments and co-operation in Europe and in the USA represents a big asset of the F.-Y.P. and provides the INFN organisation with a continuous opportunity for benchmarking both the activities performed and the results obtained.

Italy must remain a trusted partner in international collaboration, just as it expects the other partners to meet their promises. If that fundament of mutual trust were endangered, all international collaboration could break up.

1999 - 2003 Five-Year Plan

Let us now move on to evaluate in its broad lines the F.-Y.P. presented by INFN for the next period 1999 - 2003.

The scientific activities of INFN are subdivided into the following research lines :

1. Research in Subnuclear Physics with Accelerators ;
2. Research in Subnuclear Physics without Accelerators, Neutrino Physics and Astroparticle Physics ;
3. Research in Nuclear Physics ;
4. Research in Theoretical Physics ;
5. Research of a technological and interdisciplinary character.

An opinion will be expressed for every research chapter dealing with the themes which INFN intends to carry out.

Chapter I. Research in Subnuclear Physics with Accelerators

The history of electron-positron colliders goes back almost thirty-eight years to March 1960 when Bruno Touschek gave a seminar at the Frascati National Laboratory, in which he pointed out the importance of systematic studies of electron-positron collisions. He proposed the construction of a single magnetic ring where beams of electrons and positrons at the same energy would rotate in opposite directions and collide head-on at discrete locations around the ring. The total energy of the two colliding beams goes to produce new matter in a very efficient way.

Subsequently the first e+ e− storage ring was built at Frascati and called ADA (Anello di Accumulazione – *Accumulation Ring*); this was followed by the construction of many other, higher energy e+ e− storage rings in Orsay (France), Novosibirsk (Russia), Stanford (USA), Frascati (Italy), Hamburg (Germany), Cornell (USA), Tsukuba (Japan) and finally the Large Electron-Positron collider (LEP at CERN, Geneva).

The physics motivation of the Group I experiments is the study of the properties of elementary particles.

Matter can be broken down into ever diminishing building blocks : liquids or solids are composed of molecules which are formed by atoms in turn composed of neutrons, protons (hadrons) and electrons (leptons) ; the neutrons and the protons are built up of quarks. It is the belief of physicists that the fundamental building blocks of all matter in the Universe are quarks and leptons, of which there are only six of each kind. The carriers of the electromagnetic and strong nuclear forces which bind quarks together are called photons and gluons and have been studied experimentally for years. However, the existence of the Z°, W^- and W^+, which are the "carriers" of the weak forces, was only verified experimentally in 1983 at CERN and studied in great detail at LEP, this started operating in 1989.

The Standard Model of particle physics which unifies the description of weak and electromagnetic interactions, not only predicts the existence of the Z°, W^-, W^+ particles, but also indicates ways in which these particles may be generated and detected.

The aim of the experiments programmed in Group I is to understand the electroweak and chromodynamic theories, this last theory explains the strong nuclear force. Further to this is the in-depth investigation of the symmetry properties in Nature, in order to detect signs of a greater unification.

The priority research programmes of Group I are based on the following lines :

The active follow-up of the LEP experiments at CERN, as the present phase of LEP increase in energy allows the study of the $W^+ W^-$ couple production and the high precision measurement of the W mass, as well as the search for the Higgs light boson and/or for new particles and finally the Z - W coupling.

The running of LEP will continue until the year 2000, but the analysis of the data acquired will take up a few years after that in order to be completed.

We simply recall that at LEP high precision results on the properties of the intermediate neutral boson Z° have been obtained ; the determination of the number of light neutrino types ; the lower limits on the Higgs boson mass, the particle which is thought to be at the origin of the formation mechanism of all masses ; and finally the precise verification of the Standard Model.

At the Tevatron a precision measurement of the W intermediate charged boson mass was made, and the first experimental evidence of the top quark by the CDF experiment was found. The Italian group, part of this international collaboration, has a large representation and has played a primary role in the discovery of the top.

The continuation of the experiments at the Fermilab Tevatron by the CDF collaboration comprising a strong Italian component. This programme foresees the acquisition of data up to the year 2002 in order to verify the Standard Model, the improvement in the measurement of the W^+ and W^- charged bosons, the studies on the top quark, discovered precisely by the CDF collaboration a few years back, and finally the search for the Higgs boson and for new particles.

The acquisition of data at the Hera electron-proton colliding ring (storage ring) in DESY. The Zeus collaboration which comprises a group of Italian experimental physicists, after having powered the present experimental apparatus, will continue to explore the quark and the electron structures with an ever increasing level of resolution trying to reveal

eventual substructures. We should recall here the active participation of Italian industry in the construction of the Hera magnets co-ordinated by INFN.

Hera is the first electron-proton storage ring enabling physicists to explore the structure of the quarks within the protons, down to dimensions of 10^{-19} m, equal to one ten thousandth of the proton diameter.

The superconducting magnet for the Zeus experiment, the large detector running at Hera, was planned and built in Italy, under the leadership of physicists and technical staff from INFN.

The violation of the matter-antimatter symmetry in the K° meson decays (CP violation).

Two experiments are being programmed, one at CERN (EPS1) through an international collaboration with ample Italian participation and the other at the LNF-KLOE on the DAΦNE accumulation ring. Both these experiments, with complementary experimental methods, are destined to clarify the mechanism of the CP symmetry violation (combined product of the charge conjugation operator and the parity operator), and establish the existence of a superweak force. The importance of this research lies in a thorough understanding of the matter-antimatter symmetry violation. It should be recalled that the CP violation has an extremely important role in the understanding of the evolution of our universe.

The matter-antimatter symmetry will equally be studied by experiments being prepared at Hera and at SLAC (Stanford Linear Accelerator Center) respectively, with the experimental facilities Hera-B and Babar. These two experiments will concentrate on the study of the matter-antimatter symmetry in bosons with Beauty.

It should be specified that these experiments are very difficult and because of the importance connected to the study of the matter-antimatter symmetry break, they should be done under differing experimental conditions so as to obtain a coherent and comprehensive picture of the phenomenon.

The participation in the preparation of the detectors to be used on the experiments at the LHC (Large Hadron Collider). This is the most exacting research programme being prepared by the European scientific community, in collaboration with American and Japanese teams. This programme in the 1999 - 2003 F.-Y.P. covers the preparation of the extremely complex experimental equipment required to carry out the LHC experiments. INFN participates in three experiments. The experimentation, that is the acquisition of data, will begin in the year 2005 and will continue for at least ten years. This is the biggest scientific, technical, organisational and financial commitment which the Italian, the European and the world Scientific Communities will have to face.

The study of neutrino anomalies (oscillations) indicative of a neutrino mass at CERN and at the Gran Sasso. We shall come back to this argument in Chapter II.

To come to a conclusion, the programme described in Chapter I is done in collaboration with International Institutions, for its major part it is already programmed and it is either in an advanced preparatory or executive phase. Therefore it carries first priority in the activities of the Institute.

Chapter II. Research in Subnuclear Physics without Accelerators, in Astroparticle Physics and in Neutrino Physics

The construction of the Gran Sasso National Laboratory began in 1982. The realisation of this laboratory was an undertaking of exceptional significance ; it came into operation in 1988. The Gran Sasso facility is the largest laboratory in the world for the research and the studies on the stability of matter, on solar neutrinos, on magnetic monopoles and on cosmic radiation. Just a reminder, in 1992 the Gran Sasso Laboratory detected the neutrinos originating from the hydrogen fusion reaction occurring in the Sun, a result of great scientific relevance.

The experiments on the solar neutrinos are mainly of two types : those using a radiochemical technique and those which observe the interactions in real time.

The Gallex experiment, at the Gran Sasso, uses the radiochemical technique, it was decisive in confirming the solar neutrino puzzle as it equally explores the low energy zones of the solar neutrino spectrum. It should be recalled that the "solar neutrino puzzle" is due to the fact that the neutrino flux measured [at the Gran Sasso, at Homestake (USA), at Kamiokande (Japan) and at Sage (Russia)] corresponds only to 30-40 % of the neutrino flux expected in the region of higher energies (above 7 MeV) whilst in the lower energy region (above 0.2 MeV) the flux measured is about 60-70 % of the neutrinos which the Sun should send us.

Since about twenty years the physicists are trying to find a solution to this puzzling problem. At present astrophysicists claim that it is unlikely that any modification in the calculations on the behaviour of the Sun could bring results consistent with the experimental measurements. If the properties assigned to the neutrino, based on the present knowledge of elementary particle physics remain valid, and if the theoretical forecasts are compared to the experimental measurements – quite difficult to carry out – one arrives at consequences which are scientifically paradoxical. The most probable solution at present is that the neutrino has properties different from those foreseen by the present-day theory of elementary particles. The experiments programmed in the new F.-Y.P. oriented to the solution of this problem must be fully supported and powered. These are the GNO project (Gallium Neutrino Observatory), the Borexino, and the Icarus projects.

The present conception of particle physics assigns a zero rest mass to the neutrinos and assumes that the three types of neutrinos (the neutrino flavours) – electron, muon and tau – are fixed, unchangeable qualities. But a quantum effect called "neutrino oscillation" could take place, this hypothesis was already put forward by the Italian physicist Bruno Pontecorvo in the fifties. The neutrino oscillations draw their origin from the hypothesis that the neutrinos associated to the electron, the muon and the tau are a mixture of three neutrinos ν_1, ν_2 e ν_3 having a non-zero rest mass with differing percentages according to the neutrino being considered.

This superposition of the non-zero states of mass, with the propagation of the neutrino beam, modifies their flavour changing, for example, a beam of ν_e into one of ν_μ and a beam of ν_μ into one of ν_τ. The confirmation of this phenomenon, implying that the neutrino masses are small but not zero, would have revolutionary consequences not only on the present-day conception of the elementary structure of matter, but equally in cosmology. If the neutrinos had a non-zero rest mass, even if it were of a few electronvolts, because of their enormous quantity in the cosmos, they would contribute to the fact that the value of the density of matter could be greater than the critical value and therefore the expansion of the Universe, according to the more reliable theories, would come to a halt because the force of the gravitational field (pull) would be greater than the inertial force connected to the motion of heavenly bodies moving apart.

The research carried out on the solar and atmospheric neutrinos has, in our opinion, a scientific priority for the Group II research programmes.

A programme entailing the study of neutrino oscillations with artificial beams issued from accelerating machines or nuclear reactors is about to end : in fact the data acquisition phase is coming to its end. The preliminary results enable us to outline the experimental strategy to be adopted in the near future (energy and source-to-detector distance).

An international community of physicists has shown great interest in continuing experiments with accelerators over short distances (Short Baseline), another option concerns an experiment of particular interest to INFN ; it involves sending a high energy beam of neutrinos produced at CERN to the Gran Sasso Laboratory, at a distance of about 700 km from the source (Long Baseline Neutrino Beam). The interactions could be studied in the three Icarus modules and in a second detector which INFN hopes will be proposed by an international collaboration. This last project is part of a Special Project which will be dealt with in another part of this report.

Among the Group II activities presented, one should mention the detection of gravitational waves. Virgo, the Franco-Italian collaboration for the construction of an L-shaped double-arm interferometer, each arm 3 km long, will be discussed as part of a special project. For the other gravitational wave detectors, the F.-Y.P. foreseen the continuation of the activity with the present cryogenic resonating bar detectors Auriga, Explorer and Nautilus which are all part of an international detector network. Up to the moment that Virgo becomes fully operational (after the year 2001), the INFN Direction is enjoined to continue this line of activity at the level of funding set forth in the F.-Y.P. Once Virgo is started up and running, a lot of thinking will have to be given to this type of research, so as to allow further developments for the future.

As a conclusion, it is recommended that the research programmes of Group II be considered with priority : the study of the solar and atmospheric neutrino interactions, the search for rare decays of matter, of weakly interacting and subnuclear particles with mass, indicated with the abbreviation WIMP (Weakly Interacting Massive Particles), study the possibility of creating a neutrino beam issued from CERN and directed towards the Gran Sasso Laboratory (Cf. page 18).

The study of cosmic radiation in space is complementary to the study underground. It addresses two basic issues : the apparent absence of antimatter and the origin of the dark matter. INFN has a strong and leading role in the Alpha Magnetic Spectrometer (AMS) project, the first particle physics experiment in space. It is the only physics experiment

scheduled on the International Space Station. AMS uses particle detector technologies developed by INFN for accelerator experiments. This enables AMS to have a sensitivity four to five orders of magnitude better in antimatter and dark matter searches over existing knowledge. This project is putting the Institute at the frontier of astroparticle physics. The first results during the recent ten days' flight of AMS on Shuttle Discovery have proved the validity of the technical solutions adopted by INFN.

Another project foresees the placing of a magnetic spectrometer on a Russian satellite. INFN must consider very carefully if, taking into account the costs involved, it should fund a second experiment.

Finally, concerning those programmes dealing with the observation of cosmic rays on the ground, INFN should clearly evaluate the quality of each proposal so as to avoid an exaggeration of dispersion.

As a conclusion, the Group II programme is very ample and a lot of enthusiasm exists among the Italian and foreign physicists for the use of Gran Sasso National Laboratory and for the study of cosmic radiation. This is a positive fact and as such must be encouraged.

Chapter III. Research in Nuclear Physics

Nuclear physics studies the atomic nucleus, its properties and the interactions between the constituents it is made of. Nuclei are complex systems made up of two types of nucleons : protons and neutrons. Their binding energies are determined by strong, electromagnetic and weak interactions.

At low energies the nuclear properties are described by studying the interactions between the nucleons and the mesons ; information on the experimens performed is deduced making use of advanced techniques of nuclear spectroscopy.

At high energies the nucleon and meson substructures are revealed through the study of the quarks and the gluons.

The interaction between the quarks and the gluons is described by Quantum Chromo Dynamics (QCD). One of the most exciting aspects of the present-day nuclear physics is to understand how, starting with quarks and gluons, one arrives at complex structures such as nucleons and mesons, which in fact make up the structure of the nucleus.

All the information on the nuclear structure is not only deduced from spectroscopy measurements but also by the collision between beams of heavy ions. By compressing the nucleus, these collisions create the extreme conditions which enable us to better understand the dynamics at the base of nuclear matter.

An important aspect of the collisions between beams of heavy ions, is that of creating a new state of matter : the quark-gluon plasma.

Nuclear physics does not only present common aspects with particle physics, but equally with astrophysics and in particular with that research which tries to understand in depth the various evolution phases of the Universe.

The INFN nuclear physics programme is mainly based on the activities of two nuclear physics national laboratories, the first in Legnaro and the other in Catania, on an experiment at DAΦNE and on the ALICE experiment being prepared at the LHC for the study of quark-gluons plasma.

In the Legnaro and the Southern Laboratories the study of collisions at varying energies, of low energy and medium energy heavy ions is being conducted.

The main research lines for the Group III as foreseen by the 1999 - 2003 F.-Y.P. cover :

1. the study of strongly interacting systems running in a non-perturbative mode and making use of electromagnetic and hadron probes ;

2. the study of heavy ions using intermediate or high energy beams ;

3. the study of nuclear structures having high spin values, of the isotopic spin and high excitation energies. This last part of the programme will be carried out using beams of heavy ions and radioactive beams.

The INFN programme in nuclear physics is greatly diversified.

At this point in time no judgement can be made on these research lines ; the Committee leaves to the IIIrd Commission the task of evaluating and following-up those parts of the programme of an innovative nature to be developed.

As concluding remarks, the Committee deems that INFN has reached a remarkable synergy in the development of nuclear physics in the National Laboratories with the approval of competitive programmes as well as in laboratories based abroad by reinforcing the activities carried out. The research programmes in this sector tend to become ever more interdisciplinary with other fields of research such as astrophysics, atomic physics and those applications mentioned in the Five-Year Plan.

The Committee is in favour of the programmes proposed by INFN in their F.-Y.P. ; these should be realised without reductions, bearing in mind that the Legnaro and the Southern National Laboratories are equipped with all the scientific equipment allowing them to carry out complex experiments. Furthermore, the Laboratory personnel is competent and therefore contributes to the success of the programme approved.

The Committee appreciates the optimisation foreseen in the F.-Y.P. towards innovative research. The study of collisions between heavy ions at very high energies represents in fact one of the upcoming frontiers for nuclear physics and is one of the LHC machine objectives, thus realising a convergence of scientific interests between nuclear and high energy physics. Under these experimental conditions a new state of nuclear matter – called quark-gluon plasma foreseen by the more recent theories of nuclear forces – could emerge. The study of the quark-gluon plasma leads to an in-depth comprehension of the physical conditions prevailing in the primordial Universe.

Chapter IV. Theoretical Physics

The Committee would like to emphasise here the great achievements by the Italian theoreticians over many years ; their skill has been adopted as a standard and they have left an indelible mark in many fields of science.

The present-day theory community in Italy, mainly University teaching staff, is universally recognised and constitutes a model, unique of its kind, for its integration with the experimental activities of the Institute, and the support given to such activities. Many of the Italian theoretical physicists play a first degree part at world level in the development of fundamental research. A rough breakdown of the effort covers in particular the following areas : field theory, including string ; mathematical methods ; particle phenomenology ; calculation with the lattice technique ; astroparticle/cosmology and nuclear physics.

In all these areas, theoretical research is at an internationally competitive level ; there is a strong collaboration with CERN physicists, with those from other European countries and from America.

Italian theorists have pioneered the study of supersymmetry, supergravity and the structure of low-energy effective theories and are now extending this to study effective theories derived from superstring. There is an excellent phenomenological research programme covering most aspects of phenomenology. In strong interaction and electroweak physics, Italian physicists are making substantial contributions, developing precision tests of the Standard Model and quantifying expectations for physics beyond the Standard Model.

The lattice effort is also of a world-class level, having made important contributions to the development of lattice techniques in order to study phenomenologically interesting processes. The development of theoretically elaborated advanced instrumentation and the significant computing power developed for the APE series of supercomputers allows the community to tackle such problems.

The effort devoted to the particle physics/cosmology interface is done by too few physicists, although their contribution is of a high quality. This new subject has become one with an increasing amount of data. It is an area attracting young physicists because it offers them the opportunity of making significant contributions to a rapidly developing field.

There is an active nuclear physics research programme which covers a wide range of energies from the keV scale of astrophysics relevance to the TeV scale overlapping the particle physics region.

Chapter V. <u>Technological and interdisciplinary research</u>

The technological development is essential for any experimental research activity. This makes ample use of new, sophisticated particle detectors, of electronics, of informatics, of accelerator physics and of superconductivity.

In general, these activities are finalised to the realisation of new instruments capable of obtaining results of increasing performance. The

scientific development is conditioned by the development of new technologies and this last finds its roots in the results coming from fundamental research.

Much of this research is finalised to interdisciplinary applications which often allow important technological innovations leading to a possible industrial-type spin-off.

A few examples here are quite appropriate : :

1. the development of high-speed complex electronics ;
2. the development of the informatics systems ;
3. the instrumentation for LHC ;
4. APE 1000 ;
5. the development and realisations in the field of superconductivity (LHC magnets, LEP 200 cavities, cavities for future linear accelerators) ;
6. the realisation of mechanical structures for low temperatures (cryostats for LHC magnets, cryostats for future electron accelerating machines, the development and realisation of vacuum technologies).

One could list many more examples of technological developments achieved during the preparation of experiments of a high innovative content. These developments, which can have applications equally in other fields, are possible today thanks to the competence and the imagination of researchers, technology staff and other technicians doing research in the nuclear and subnuclear physics sector.

The formation of these researchers, which requires years of work and which is refined through confrontation with research people from foreign international laboratories, is for a nation a precious manpower reserve.

Almost all the experiments require the use of advanced technologies and most of the investments for the realisation of those instruments used in the experiments have been given to the national industry and in particular to sectors of industrial metallurgy for the construction of superconducting alloys and cables ; to the mechanical industry for the construction of cryogenic and vacuum equipment ; to the electrotechnical and high technology mechanical industries for the construction of superconducting coils and cavities. It is worth mentioning that the INFN programme in the field of superconducting radio frequency cavities has contributed greatly to the development of this sector. The work carried out by the Genoa section, i.e. the development of spherical cavities which have permitted the elimination of single-point multipactoring, was the critical element which has allowed the use of superconducting cavities to obtain the very high-gradient electric fields used in accelerators. Today, this technology is widely diffused : for example LEP uses this technology to reach about 100 GeV per beam.

The Committee has taken this example to show that investments in research which at first sight might not have been programmed, but lead to a specific application, can have remarkable consequences. Today this technique is diffused and is the object of further research in the field of new acceleration techniques for electrons and positrons.

The Committee deems that the Group V activities should be encouraged and that even the modest research lines, which are engaged in finding highly innovative solutions, should mainly be financed.

Although it fully recognises the effort made by INFN in collaborating with the Italian industries for the commissioning of instrumentation requiring advanced technological developments, which in turn contribute to increasing the industrial market towards INFN and other similar research centres, the Committee must draw the attention on the judgement expressed by the International Review Committee chaired by Prof. Burton Richter and annexed to the F.-Y.P. The judgement is reported in full :

"We noted that there seems to be no systematic effort to work with the 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 the Italian Society of effective technology transfer are significant if this can be made to work".

After discussing with Prof. Iarocci, President of INFN, the Committee has identified the Group V main activities in the 1999 - 2003 F.-Y.P. which are grouped in five lines of research :

Interdisciplinary physics ;
Detectors ;
Electronics ;
Superconductivity ;

Accelerators.

Research on detectors has the largest budget in the F.Y.P.; this is mostly oriented to supporting institutional INFN experiments, a modest portion is devolved to medical applications.

Accelerator and superconductivity research are strongly connected and to a very large extent functional to major international projects. Part of the superconductivity research is devoted to material study and future applications ; the other part is functional to the development of devices foreseen in conjunction with detectors.

To a large extent the research activities in the electronics field are connected to fundamental research and are its support : front-end electronics, A/D conversion, signal processing, parallel computation, etc. The APE 1000 project computer, developed to support theoretical physics, has potential applications in other fields of science and technology.

Concerning electronics in general, it is recommended to primarily direct the research activities to system aspects rather than to the development of components which may be available from industry.

Interdisciplinary physics and co-ordinated activities require techniques and instrumentation similar to those used in fundamental research. Major applications are in the medical and environmental fields. It is very difficult to voice an opinion on these activities spread over a very large number of projects (23 sections/laboratories are involved !).

Chapter VI. Technological Transfer

INFN has a good record of co-operation with Italian Industries supplying equipment and advanced instrumentation for experiments : it is thus extremely important for industry to receive highly qualified engineers and technical people, their way of thinking, learned through working contacts in international collaborations, is a great asset.

The Committee takes up the recommendation on societal programmes of Group V made in the Report chaired by Prof. Burton Richter :

"The societal programmes of Group V (medical imaging, cancer therapy, environmental studies, etc.) do raise concern about the project selection process. In these areas 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 a certain hard-to-define-point is necessary to have a review of each societal programme that involves those experts from outside INFN who will be most affected".

It is important that the Institute identifies those technologies which have an industrial potential, this could lead to a productive activity, because it is generally recognised that the research centres have an amount of knowledge which is not directly transferable towards significant utilisations seen under the economic profile.

Fully aware of the engagement by INFN over the past years to turn to the national industries for the production of equipment of high technological content, if the Institute wishes to raise to a satisfactory level the probability of success in new technological transfer initiatives, the F.-Y.P. evaluation Committee invites the INFN Direction to :

a) identify the processes and significant results equally of common interest and advantage both to INFN and to industry ;

b) correctly estimate the resources to be used, also evaluate the results expected, for what concerns, budgets, costs/benefits, etc. ;

c) perform a continuous control on the evolution of eventual actions, looking at every aspect (technical, scientific, economic, etc.).

These indications constitute the reference point, indispensable in order to face the vast, complex and ever problematic rationalisation of any technological transfer activity, and as such are to be recommended to INFN.

The Committee points out the need to protect the intellectual properties through patents and copyrights which are 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.

The Committee appreciates the commitment undertaken by the Institute in financing and in contributing with the competence and experience of its personnel also in activities deriving from the main activities ; these may lead to later implications such as the development of instrumentation finding an application in a medical field and/or in the framework of the Funds for Applied Research, Law 46/81 or 95/96.

Chapter VII. The Special Projects

The Committee has examined with great attention the Special Projects. Some of these projects are turned to the study of future developments ; this activity which looks far ahead, should be carefully examined before approval is given, estimating precisely the funding required. Every special project must be followed by a committee of experts and regularly submitted to a critical evaluation during its realisation phase.

In particular, three projects must be mentioned : APE – the large parallel computer project; Virgo – the construction of a 2 x 3 km interferometer ; the Long Baseline Neutrino Beam – high intensity neutrino beam to the LNGS.

APE

Among the special projects, APE is one to be carried on. It is necessary in the accurate study of complex physical systems. Generally speaking, there are many physical systems interesting from a scientific point of view as well as from the point of industrial applications which can be simulated with great precision from mathematical models ; but enormous computer resources are necessary to realise these simulation programmes. The APE project in its different evolutions, has developed in a very efficient way optimised computer equipment for specific applications which have been recognised at a world level.

Therefore the Committee encourages the development of APE as well as of the model following APE 1000.

Virgo

Virgo is a Franco-Italian collaboration being realised in Cascina near Pisa ; its realisation is closely followed by a 'Virgo Council' made up of three French and three Italian scientists. Given the scientific importance of the project, the Committee recommends that among the Special Projects, Virgo be considered with particular attention. The day the gravitational waves are detected, the knowledge on the origins of the Universe and its evolution will take a giant step forward. The construction of the two-armed interferometer, each one 3 km long, requires the development of special techniques at the very limits of present-day possibilities.

Long Baseline Neutrino Beam

The project of a high-intensity neutrino beam was examined positively at CERN in 1997. The detectors will be installed in the Gran Sasso Laboratories. Given the importance and the complexity of the neutrino oscillation puzzle, the Committee invites INFN to evaluate accurately its participation in CERN's extraordinary financing in order to realise if the neutrino beam to be sent to the Gran Sasso is the optimal solution to the problem, bearing in mind the latest results obtained at Superkamiokande. In the hypothesis that this project is the optimal solution, and thus it contributes to the understanding of the neutrino puzzle, then the Committee encourages INFN to participate in CERN's extraordinary financing, premising that mentioned in the F.-Y.P. at page 42, i.e. that other Countries also contribute to the project and that at least a second experimental proposal to place alongside Icarus be put forward.

The Committee encourages nonetheless INFN to study and to propose a programme which contributes to the solution of the neutrino puzzle.

The Committee has examined the special projects concerning the development of new accelerators and it expresses itself positively on the development lines mentioned in the Five-Year Plan.

Chapter VIII. Considerations on the infrastructures

CNAF, Networks and Computational Facilities

The situation of the National Centre for the Analysis of Photographs, deploying its development and research activity in the Computer and the informatics network sector, is good. The informatic network system is well organised. The Institute must look carefully at the increased demands in the broadening of the pass band between 1999 - 2003, taking into account the activity in the analysis of data acquired at LEP, the preparation of the LHC experiments, those at FNAL and at SLAC. The costs involved in running the CENTRE are estimated correctly. The costs foreseen for the network management, for the infrastructures and for maintenance including computational expenses, amount to 98 thousand million Lires over five years. If we consider the increasing requirements due to the coming into being of new programmes, the Committee considers the request to be well proportioned.

Operating the Facilities

1. At the Frascati National Laboratory a very wide programme is envisaged, centred mainly on elementary particle physics and astroparticle physics. The technical personnel is highly competent and the laboratory is well organised.

   The most exacting project is the construction - now brought to its successful completion - and the running up of the DAΦNE Φ-factory storage ring. This is a return to the glorious old tradition of the Laboratory, which has on its active side the construction of ADA, the first electron-positron storage ring and of the more ambitious ADONE.

2. At the Southern National Laboratory in Catania programmes of nuclear physics are carried out. Two accelerators are operated there, a superconducting cyclotron (CS) and a Van de Graaff Tandem accelerator used as injector to the CS. The detectors built or under construction have remarkable characteristics and are quite striking. An important number of foreign collaborations use the LNS. The laboratory intends building exotic ion beams to study the properties of nuclei, very far from stability conditions.

   Another research line is the development of a 70 MeV proton beam for the treatment of eye tumours, in collaboration with the Catania University Faculty of Medicine.

3. The National Legnaro Laboratory is an important centre for nuclear physics and moreover is a research centre for accelerator technology, where large detectors used in particle physics are equally built. The centre also develops nuclear techniques applicable in the study of materials for various fields, for example in medicine. One of the cryogenic antennas for the detection of gravitational waves is installed here, the other is to be found at the LNF. A third antenna is located at CERN.

   The nuclear physics programme is based on a Van de Graaff Tandem accelerator for the acceleration of low-energy heavy ion beams ; a medium-energy heavy ion beam is produced by a superconducting linear accelerator (ALPI) using the Tandem as injector.

   ALPI has attracted a European community of physicists studying the nuclear structure. Another project in its construction phase is the innovative PIAVE, based on a structure of radio frequency superconducting cavities.

4. The Gran Sasso National Laboratory is a unique particle physics, cosmic radiation and astrophysics laboratory, as mentioned earlier. There are approximately 500 users, 50 % of these coming from foreign countries.

The Committee has taken due note of the financial requests needed, of the services and of the basic facilities of the various laboratories, these start from a minimum of 88 thousand million Lires to a maximum of 135 thousand million Lires over five years. This budget forecast does not take into account Personnel costs which are shown in a separate table.

The costs involved in running the facilities, in maintenance and in renewing the basic equipment, is justified by the quality of the scientific programmes being carried out in the laboratories and by the highly efficient organisation of these same. Most of the users come from Italian and foreign University Institutions ; the INFN personnel seems adequate and competent, thus contributing to the success of the programmes.

Chapter IX. Outline of expenses

The 1999 - 2003 F.-Y.P. foresees a research activity (consisting of five lines of research, special projects, networks and computational facilities) of a foreseen cost of 1266 thousand million Lires over five years. The Committee considers that almost all the research activity is fully justified. The Committee, having considered separately the different research lines, has clearly pointed out that various projects are excellent.

It should be borne in mind that many of the programmes are the continuation of programmes already approved in the previous plan, and are part of international collaborations ongoing at CERN, at Desy, at Fermilab and at SLAC or in the four National Laboratories. Virgo is, moreover, a project in its construction phase : it is a collaboration between the CNRS (France) and INFN (Italy).

Furthermore, one should take into account that the realisation (construction, operation and data acquisition) of many experiments of a very complex nature, continues over a few years, some of these being covered by more Five-Year Plans.

The financial commitment for the construction of such sophisticated instruments generally covers some years. Therefore it is important that for each project the profile of expenditure and payments is carefully foreseen; normally these come to their expiration at differing times.

A large portion of the activities of the Institute are based on the correct operation of the INFN Sections which guarantee the integration with the University system.

Many INFN research activities are performed at Sections and University Departments on a wide spectrum of disciplines not always within the institutional mission of the Institute. These activities are very many and dispersed and not easy to assess in terms of performance and potential return. The recommendation of the Committee is to monitor and review yearly these activities, benchmarking the results obtained against the state-of-the-art and what is done outside INFN. Those activities not performing should be discontinued. Priority should be given to activities related to INFN core competences.

The link with industrial users should be strongly pursued in particular for those research activities which are outside the INFN mission ; avoiding the risk that some activities become open-ended.

The strong interaction of INFN with Universities has a positive impact on higher education, graduate student and young scientists. The role of INFN in higher education should be reinforced equally involving the industry whenever possible. Fellowships should include a stage at an industrial location (expenses borne by the Industry concerned).

The Committee has already voiced its opinion on the National Laboratories. The funding of the Laboratories which are a *"flower in a button-hole"* for the Institute is quite adequate. Any reduction in the budget forecast could prejudice the correct operation.

The National Institute of Nuclear Physics has a remarkably efficient organisation. Its democratic structure through the National Scientific Commissions, in parallel with the authority of the President, of the Executive Board and of the Board of Directors has enabled the Institute to reach an excellent balance between the scientists always ready to propose and to do research and the requirements of the Institute to have an Authority (the President, the Executive Board and the Board of Directors) ensuring and guaranteeing the organisation and the financial control of the programmes.

A more detailed presentation for Groups I, II and III, gives the following average yearly financing per research staff (full time equivalent). For simplicity, only the first financial year of the F.-Y.P. is considered. For Group I the average expense per person amounts to 104 million Lires ; for Group II is of 146 million Lires and 96 million for Group III. For Groups IV and V the expenses are somewhat lower, typically by a few tens of million Lires. To be more complete, it should be stated that the number of full time equivalent research people is of 690 units in Group I, of 348 in Group II and of 417 for Group III.

This average financing is comparable to that of CERN.

The foreseen Personnel costs amount to 1088 thousand million Lires over five years, for a percentage lower than 40 %.

The Personnel of the Institution amounts to 1810 units over 2014 positions, of which 621 are research staff, 743 technicians, 251 technological staff, 291 administrators and 8 directors. Further to this it manages a two-year fellowship programme concerning 178 units. The Institute has at its disposal a number of people with a given research responsibility, these are mainly University professors and researchers, for a total of 950 units, as well as University technical and administrative personnel totalling 200 units. It is quite clear from the above that the Institute is present in many University centres with benefits on both sides, for the Institute and for the Universities.

The average salary per year per unit is, for full-time personnel of the Institution, 86 million Lires because under the Personnel Expenses item, Table 6.1 includes other points such as personnel with fixed-time appointments, contracts for VIPs, INFN fellowships, contribution to the Universities for Doctorate fellowships, insurances, competitive examinations, updating courses and other expenses (meals, transport, etc.).

The breakdown in the expense forecast between the Personnel costs and the total costs foreseen in the F.-Y.P. has been optimised correctly for a research centre whose task is to build complex instrumentation and for its participation in national and international research. The breakdown of the expenses incurred by the Organisation between Personnel and Total Balance is comparable to that of CERN, universally recognised as being one of the best research centres in the world.

It goes without saying that this or any other proportion does not constitute an ideal parameter per se, unless it is accompanied by a highly

qualified scientific and technical personnel, as is the case for the Institution of which we are examining the F.-Y.P.

The Five-Year Plan foresees a research activity of a cost amounting to 1266 thousand million Lires over five years. The Committee deems it necessary that the outline of expenses – as proposed by the F.-Y.P. – be assured so that the activities can normally be carried out.

As shown by Table 6.1, the funding of the 1999 - 2003 F.-T.P. is in line with the scientific objectives foreseen by the Plan and is well commensurate with the running costs of the facilities belonging to the Institute, of its personnel and of the University personnel using the funding and the resources of the Institute.

Chapter X. Final Recommendation

Taking into account the above considerations, the Committee unanimously recommends the approval of the 1999 - 2003 Five-Year Plan.