ACTIVITIES AND FUTURE PLANS AT LNF

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Abstract

The Frascati National Laboratory (LNF) is the largest unit of the National Institute for Nuclear Physics (INFN). It hosts the main high energy accelerator facilities in Italy and is presently running DAΦNE [1], an electron-positron collider for the production of K mesons from the decay of the Φ resonance at 1.02 GeV c.m. INFN is going to present its three years plan to the Italian Government next May, and decisions on future programs are being discussed by the Scientific Committees of the Institute. After a short presentation of the main activities under way in the lab, I concentrate on the discussion about future developments in the accelerator field on site and participation to the realization of large facilities abroad in the framework of international collaborations.

1 ACTIVITIES AT LNF

LNF is the largest National Laboratory of INFN, with a staff of 128 between physicists and engineers, 156 technicians and 33 administrative employees. About 100 physicists from universities and INFN sections in Italy are also routinely participating to the experiments in the lab. The research personnel is organized in two groups, the Accelerator Division and the Research Division. It supports activities and collaborations in all the five scientific lines of the institute:

- particle physics with accelerators (Scientific Committee 1, SC1)
- particle physics without accelerators (SC2)
- nuclear physics (SC3)
- theoretical physics (SC4)
- technological research (SC5)

LNF presently runs two important facilities on site: DAΦNE [1], an electron-positron collider with a center of mass energy of 1.02 GeV, which produces a large rate of kaons from the decay of the Φ resonance, and NAUTILUS, a cryogenic gravitational wave detector. However, an important fraction of the activity of its scientific staff takes place as collaborations at experiments performed at other laboratories in Italy or abroad.

SC1 activities can be subdivided into two main categories. The first one are general purpose experiments at the "high energy frontier" in operation or under construction, like CDFII at Fermilab and ATLAS at LHC, the second are the experiments on the "statistical frontier", mainly on CP violation, like KLOE [2] at DAΦNE and BaBar at SLAC. While CDFII, ATLAS and BaBar are international collaborations, KLOE is carried on mostly by physicists from LNF and italian universities and INFN sections. It consists of a large cylindrical detector (5 m length by 5 m diameter) embedded into a superconducting solenoid, and its goal is the study of CP violation in kaonic decays of the Φ resonance. KLOE is presently running on one of the two interaction regions of DAΦNE.

The main subjects explored in SC2 are the study of neutrino oscillations in natural or artificial beams, the research for gravitational waves and astroparticle physics. Most experiments with large detectors (ICARUS, LVD, MACRO, OPERA) are performed at another important National Laboratory of INFN, the underground facility at Gran Sasso. In the field of gravitational waves the NAUTILUS antenna at LNF is running continuously at extremely low temperature (less than 0.1 K) in coincidence with another antenna at CERN (EXPLORER). LNF physicists also participate to a 3 km long laser interferometer (VIRGO) under construction near Pisa. Conserning astroparticles the PAMELA project is active in the field of antimatter and cosmic rays research based on particle detectors onboard a satellite expected to be launched next year.

The main activities on site in the field of nuclear physics are two experiments on DAΦNE. DEAR [3] is dedicated to the study of exotic atoms where the kaons produced by electron-positron interactions are captured in the electronic shells. DEAR is presently taking data on the other interaction region of DAΦNE and is expected to run until summer 2002. FINUDA [4] is a large magnetic detector to be installed at DEAR's place, and will study the physics of hypernuclei, running together with KLOE. Several experiments are under way at laboratories abroad, such as AIACE at TJNAF, DIRAC at CERN, GRAAL at ESRF and HERMES at DESY. LNF collaborates also at the ELFE project, a high duty cycle european electron facility for nuclear physics.

The theory group of LNF consists of ≈15 people working in the fields of strongly correlated electrons, condensed matter physics, non-perturbative aspects of gauge theories in gravitation, superstrings, QCD, CP violation and particle phenomenology, bozonization in many bodies.

Finally, activities in SC5 include synchrotron radiation research on three high intensity beam lines from DAΦNE in the infrared, UV and soft X-rays, studies on accelerator components, detectors and cold fusion.

Information on LNF activities can be found on the site http://www.lnf.infn.it.

2 ACCELERATOR ACTIVITIES

2.1 DAΦNE

The main activity at LNF in the accelerator field is DAΦNE. The status of the machine is extensively described in another paper at this Conference [1]. Obviously, the major effort of the Accelerator Division is in the direction of improving the performance of the collider in order to approach as far as possible its design luminosity of $5x10^{32}$ $cm^{-2}s^{-1}$. In terms of integrated luminosity, DAΦNE is presently delivering ≈1 pb^{-1} per day, to be compared to the upper limit of ≈40 pb^{-1} which could be delivered by running at full design luminosity and full efficiency.

The main goal of the KLOE experiment is the measurement of the CP-violating parameter Re(ε'/ε). This study is presently being carried out also with extracted proton beams at Fermilab (KTeV) and CERN (NA31 and NA48). Recent results from both collaborations indicate that this parameter is in the range $1\div2x10^{-3}$. KLOE will measure Re(ε'/ε) starting from a much cleaner initial state where K_SK_L are produced in pairs from the Φ decay (tagged kaons) with a totally different systematics.

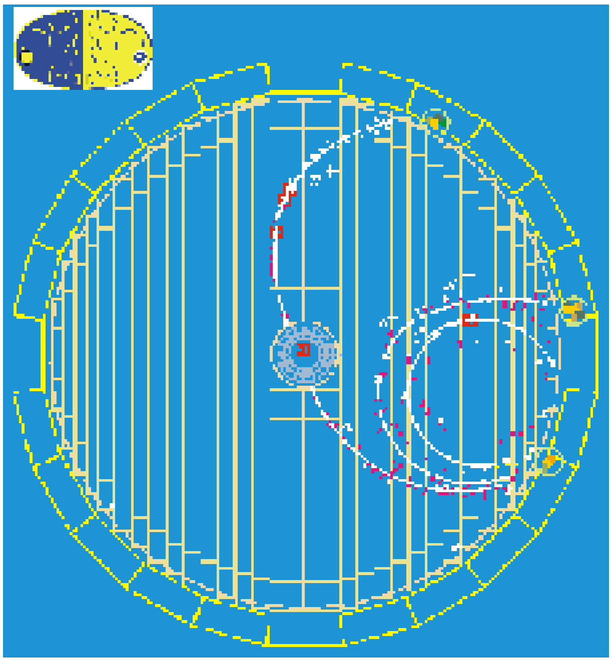

Figure 1: A typical event in the KLOE detector: the Φ decays in a K_s inside the vacuum chamber and a K_l in the detector; then the K_s decays into $\pi^+\pi^-$, the K_l into $\pi^+e^-\nu$.

KLOE can measure Re(ε'/ε) with an uncertainty of 10^{-3} with 200÷300 pb^{-1}. A result from KLOE is necessary to confirm the value found by the other two experiments with a different technique. Moreover, KLOE can also measure Im(ε'/ε), which will contribute significantly to the understanding of CP violation.

The plan of LNF, supported by its Scientific Committee, is to deliver at least 200 pb^{-1} to KLOE during this year. In addition, machine time will be allocated to DEAR in order to check if the signal-to-background ratio is high enough to perform the experiment: if this turns out to be possible, the plan is to deliver a fraction of the required integrated luminosity this year, and to complete the experiment within summer 2002, in order to leave place for the FINUDA detector to be installed on DAΦNE.

The installation of FINUDA will have a strong impact on the operation of the collider. This detector exploits a solenoidal magnetic field with the same field integral as KLOE; the compensation will be performed in the same way, by means of two superconducting solenoids of opposite field and by rotating the permanent magnet quadrupoles [1] embedded into the interaction region vacuum chamber. However, since it is not clear at the moment if it will be possible to deliver luminosity to both experiments with good efficiency, two new interaction regions are being designed which will allow the rotation of the quadrupoles around their longitudinal axis from zero to the angle needed for the compensation. In such a way it will be possible to operate each one of the two experiments with the other magnet switched off and to finely tune the coupling compensation through the additional degrees of freedom of the independent quadrupole rotation.

Two synchrotron radiation beam lines have already been opened on DAΦNE. The first ones conveys the radiation from a bending magnet and is designed to deliver radiation in the IR; in the second one the radiation comes from one of the wigglers in the electron ring and is dedicated to experiments in the UV and soft X-ray region (such as microlythography, microengineering etc.). Of course, DAΦNE is mainly a collider for high energy physics, and the emittance of its beam is large, in order to reach high luminosity, while a synchrotron radiation source should have low emittance in order to improve the brilliance of the source. However, DAΦNE is designed to operate with a large stored current (up to 5 A in each beam) and therefore the flux of photons is very high; in addition, the machine operates with very flat beams, and its vertical emittance (which is the most interesting parameter for synchrotron radiation sources) is rather small; this opens the possibility of realizing a large variety of experiments in better conditions than at other facilities. The machine can deliver synchrotron radiation during the normal operation of the collider in a parasitic mode. Otherwise, operating in a dedicated mode, the lattice can be modified to obtain a significantly smaller emittance. All these possibilities are still to be explored.

2.2 TESLA AND TTF

INFN is part of the international collaboration for the study of TESLA [5], a ≈33 km long electron-positron linear collider with a center of mass energy ranging from 500 to 800 GeV based on superconducting cavities.

A Technical Design Report (TDR) is being submitted to the Gerrman Government for evaluation. To establish the technical feasibility of such a large facility, a test accelerator called TTF [6] (Tesla Test Facility) has been realized and is now in operation. One of the most outstanding results from TTF is the operation of a free electron laser in the self amplified mode (SASE FEL) [7]. The contribution of LNF to TTF is mainly in the field of beam diagnostics based on optical transition radiation to measure beam position, profile, energy spread and emittance; a gated intensified camera is used to follow the beam parameters evolution along the 1 ms macropulse. The bunch length is also measured using radiation originated by coherent diffraction.

LNF has also produced the cost estimate for the TESLA damping rings to be included in the TDR. The rings are required to reduce the emittance of the beams in order to reach high luminosity. They operate at 5 GeV and are 17 km long in order to damp the long TESLA macropulse; the energy loss required to obtain the short damping time of 28 ms is obtained by means of ≈300 m of wigglers at 1.5 T or 1.8 T depending on which solution will be adopted between the permanent magnet or conventional electromagnetic.

2.3 CLIC AND CTF3

The LNF Accelerator Division is also taking part in the R&D program towards the construction of CLIC [8], the CERN e^+e^- Linear Collider project. The design of CLIC is based on the two beams acceleration concept, where a high energy and low current primary beam is accelerated in a room temperature high gradient structure at high frequency (30 GHz) fed by the power delivered by a high current and low energy drive beam in a decelerating structure. This scheme offers the advantage of a large energy gain per unit length, and the CLIC design foresees a center of mass energy of up to 5 TeV with a total length of the two linacs of 35 Km.

As in the case of TESLA, a test facility is necessary to demonstrate the technical feasibility of this accelerating technique; first steps (CTF1-CTF2) have already been realized, demonstrating the acceleration of the drive beam, the deceleration and energy transfer scheme and the acceleration of the main beam. However, this was done on a reduced scale of parameters, much higher gradients being required to realize the energy gain necessary for CLIC.

In the CLIC design, the drive beam is accelerated in a long pulse at low frequency (<1 GHz) and then compressed by a factor 32 to reach the final 30 GHz bunch structure. The compression in time is obtained by a system of isochronous and achromatic rings where different portions of the primary bunch train from the Linac merge together. CTF3 [9] is the last test bench for CLIC and its aim is to demonstrate the feasibility of the overall acceleration scheme at parameters similar to those of CLIC and of the compression system in particular.

The compression factor for CTF3 is 10 and comes from a first "delay loop" which compresses the bunches by a factor 2 and a "combiner ring" giving a compression of 5.

In the framework of the international collaboration for CLIC, LNF foresees to take charge of the design and construction of the delay loop, combiner ring and transfer lines for CTF3. The LNF proposal has been submitted to INFN for evaluation and funding, and the process of memoranda negotiation between INFN and CERN has been started. In the meantime LNF Accelerator Division has completed the design of the two above mentioned rings, which is presented in the CTF3 Conceptual Design Report. INFN has already provided some funding to LNF in order to prototype critical project items.

Challenging issues for these two rings are:

- preservation of beam quality during compression, requiring second order chromaticity and isochronicity corrections to allow full acceptance of the energy spread of the beam accelerated by the linac
- stringent requirements on the vacuum chamber shape and impedance to avoid emittance degradation from parasitic losses and coherent synchrotron radiation effects
- the realization of transverse RF deflectors both for delay loop and combiner
- the construction of an extraction kicker for the combiner with a very flat pulse.

2.3 NEUTRINO FACTORY

Recently, a group of LNF researchers has joined the international Neutrino Factory Study Group [10], based at CERN, whose aim is to explore the feasibility of generating an intense neutrino beam from the decay of a muon beam, cooled and stored in a ring with very long straight sections.

The LNF contribution is mainly in the design and simulation of a test beam to demonstrate the feasibility of the ionization cooling scheme using low frequency RF cavities.

A preliminary study of possible RF structures has been already presented and requirements on beam instrumentation for the measurement of small emittance variations are being established.

2.3 X-FEL STUDIES

The Italian Government has included into the National Research Plan the construction of a synchrotron radiation source at high frequency (from far UV to X-ray) based on a Free Electron Laser in the SASE regime. As a first step in this direction, a first funding has been decided for R&D in the fields of accelerators, undulator magnets, beamlines and related diagnostics, in order to establish the general parameters for the facility and its technical feasibility. A first proposal is being prepared as a joint venture between various research institutes in Italy, (CNR National Research Council, ENEA National Institute for Alternative

Energy, INFN and Rome II University). LNF is proposed as the site to build a high quality preinjector for a Linac.

This accelerator will be mainly a test bench for a scheme of emittance compensation to reach a normalized emittance below 2 mm.mrad, and charge compression for peak currents in the order of 1 kA.

At the moment two possibilities are being discussed, one based on superconducting cavities, which would be mandatory if a high duty cycle system comes out to be required by the experiments to be performed on the future facility, and the other one based on room temperature cavities, which could reduce the overall cost of the accelerator.

3 CONCLUSIONS

The present activity and future plans of LNF in the accelerator field have been described. The main effort is concentrated on DAΦNE [1], which is expected to run for high energy physics, nuclear physics and synchrotron radiation experiments.

Collaborations with other institutions in Italy and abroad are under way towards the realization of high energy electron-positron colliders, muon colliders, neutrino factories and extremely high brilliance radiation sources at UV and X-ray wavelengths.

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