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What next at LNF: Perspectives of physics research at the Frascati National Laboratories

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Abstract

The Frascati National Laboratories (LNF) are the oldest and largest research infrastructure of INFN, mainly devoted to the research in nuclear and particle physics, to the development of particle accelerators and frontier studies on new acceleration techniques. LNF is the place where the first electron-positron collisions were obtained in the early 60s.

Presently LNF operates two accelerator complexes: DAFNE, an e^+e^- collider with center of mass energy set to the mass of the ϕ meson, 1020 MeV. SPARC, a high intensity photoinjector capable of delivering electron beams up to 200 MeV, combined with a high power laser (FLAME), able to produce ultra short pulses, in the so called SPARC_LAB facility.

The laboratory hosts also the NAUTILUS gravitational waves resonant bar detector, and thanks to the availability of several infrastructures, workshops, clean rooms etc.., it is also widely used as a facility for constructing large particle detectors used in other laboratories.

The purpose of the present document is to address the question: is there a viable program on the development of internal activities which can allow the Laboratory to maximally exploit its capabilities and to maintain its role at the forefront of scientific research in the next decade? In particular, given the present Italian financial situation, is this possible by wisely upgrading the presently running infrastructures at moderate costs?

On November 10-11, 2014 a workshop was held at LNF with the aim to discuss the above issues, with a broad participation of researchers from Italian and foreign institutions. A second workshop dedicated to the applications of the existing facilities to Materials Science was held on February 26-27, 2015. This document tries to summarize the main conclusions of these discussions.

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1. DAFNE

The DAFNE complex is the largest scientific asset of the Laboratory. It was built in the mid 90's of the past century and started physics operations in year 2000. The complex consists of a 60 m long linear accelerator (Linac), a damping ring and two main rings intersecting in two interaction points. Electrons and positrons are accelerated at the required energy (510 MeV per beam) already at the Linac level. During physics operations, particles collide in one of the two possible interaction points, while on the other side they are kept separate to prevent the degradation of the beam quality and maximise the achievable luminosity. From the DAFNE Linac, a secondary beam line is derived, to extract electrons and positrons beams for the so called Beam-Test-Facility (BTF). The electron storage ring is used also as Synchrotron Radiation (SR) source. In the DAFNE-Light facility there are five beam lines: three operational (IR, UV, Soft-X) and two ready for commissioning (XUV energy range). These beam lines cover the whole SR energy range emitted by DAFNE.

1.1. DAFNE as a collider

The relevance of DAFNE as a collider is self-explanatory. At present it is the only e^+e^- collider in operation in Europe, one of the few in the world. Between years 2000 and 2008, it has provided collisions to three different experiments, KLOE, FINUDA and DEAR, reaching a peak luminosity of 1.4 x 10^{32} $cm^{-2}s^{-1}$ and a daily integrated luminosity of about10 pb^{-1} [1]. In total, in this first part of operations, DAFNE has delivered to the various experiments about 4 fb^{-1} of data, 2.5 of which to KLOE. This has overcome already by about two orders of magnitude the luminosity obtained by any other collider operating at similar center of mass energy.

Studies on how to increase the collider's luminosity have resulted into the implementation of a new interaction scheme, the so called crabbed-waist operation, in late 2007. A record peak luminosity of 4 x 10^{32} $cm^{-2}s^{-1}$ was obtained in year 2009, while running for the SIDDHARTA experiment [2]. SIDDHARTA was a table-top experiment that did not make use of magnetic field: this allowed somewhat simpler machine's operations with respect to those achievable when operating in the presence of a large solenoid, like in the case of KLOE and FINUDA. In fact, the KLOE detector, with some upgrades, has been reinstalled on the beam line during summer 2013, with the purpose of profiting of the improved luminosity deliverable by the machine. In the meantime, some relevant consolidation works on the accelerator hardware have been performed, to overcome the unavoidable deterioration due to ageing which has resulted in a rather low duty cycle of the machine.

1.1.1. KLOE-2

The KLOE-2 project originally aimed at collecting a data sample of about 20 fb^{-1} in a few years of run [3]. Up to now, a peak luminosity of 2 x 10^{32} $cm^{-2}s^{-1}$ and a daily integrated luminosity of 11 pb^{-1} could have been reached. Moreover, the rate of background particles observed in the detector is a factor 3-4 higher with respect to those measured in 2005.

The 20 fb^{-1} goal, with the present machine performance, looks unrealistic: the collaboration aims at acquiring 5 fb^{-1} of physics-grade data within year 2016. This would still allow KLOE-2 performing world-class studies in the fields of quantum interferometry with kaons, of low-energy QCD using light meson decays and, possibly with the implementation of new triggers, searches for new light neutral gauge bosons ("dark photons") [4].

Quantum interferometry is a distinctive feature of DAFNE, which allows performing detailed studies on the basic principles of quantum mechanics and on the conservation of fundamental symmetries like CPT. With the data collected in the first run, KLOE has already published important results on these issues [5]. These can be improved by the larger statistics aimed by KLOE-2, as well as by the use of the newly built inner tracker detector, which improves the reconstruction of the kaons decay path in the vicinity of the interaction point i.e. in the region more sensitive to interference effects [6].

Another important topic that can be addressed by KLOE-2 is the precision measurement of the π^0 width [7], a quantity dominated by the chiral anomaly, a fundamental property of QCD. The transition rate has an isospin breaking chiral correction of 4.5% which is proportional to the mass difference between the up and down quarks [8]. The π^0 lifetime is also a key ingredient for the determination of the hadronic contribution to the muon magnetic anomaly. It is well known that the present experimental value of the muon g-2 differs by approximately 3.5 standard deviations from the theoretical evaluation of the same quantity. At present, this is the largest observed deviation of a fundamental quantity from the Standard Model predictions. While new experiments are in construction to improve the experimental uncertainty, the theoretical one is dominated by the determination of the hadronic contribution, which must be evaluated by proper use of other experimental inputs. In particular there are two dominating components to this uncertainty: the hadronic vacuum polarization, that needs more precise $e^+e^- \rightarrow$ *hadrons* cross section measurements in the region between 1 and 3 GeV (see later on); the light-by-light contribution, which might profit of a better determination of the π^0 width, presently known with 3.5% accuracy. KLOE-2 aims at a precision of 1%, using 5 fb^{-1} of data taken with the electron/positron taggers recently installed for the purpose. An initial 2% measurement would be very important, and can by itself significantly improve on present results. Studies on the hadronic contribution to the muon magnetic anomaly can also been performed following [9].

A data taking campaign of KLOE-2 has started on November 2014, with the purpose of determining whether the above mentioned goal is reachable. At the time of writing this document (April 2015), the machine has alternated positive periods of stable and fruitful data taking conditions to periods of lower efficiency operations. At best, a weekly integrated physics-grade luminosity of 52 pb^{-1} was achieved, very close to the minimum KLOE-2 request. Background conditions still remain a concern.

1.1.2. Low Energy K-N interactions

A lower integrated luminosity (of order 1 fb^{-1}) is enough to perform unique measurements in low-energy QCD with strangeness, by studying kaon-nucleon/nuclei interactions and hypernuclei formation. These physics issues were addressed in the past by the DEAR [10], FINUDA [11] and SIDDHARTA [12] experiments with data samples of a few hundredths pb^{-1}, and should be completed and complemented with different experimental set ups and with much improved accuracy by SIDDHARTA-2 and AMADEUS [13].

SIDDHARTA-2 aims to perform the first measurement ever of the kaonic deuterium transitions, which, combined with the measurement of the kaonic hydrogen performed by the SIDDHARTA experiment in 2009, will deliver the isospin-dependent kaon-nucleon scattering lengths – fundamental quantities to understand the low-energy QCD in strangeness sector, in particular the chiral symmetry breaking mechanism.

The SIDDHARTA-2 setup is being under construction, and will be ready to perform the kaonic deuterium measurement starting by the second half of 2015. The required integrated luminosity is of the order of 600-800 pb^{-1}. Other types of measurements – kaonic helium 3 and 4 or of other exotic atoms – could be, as well, performed; such measurements are very important to establish the dependency of the strength of the strangeness interaction in nuclear matter at low energies.

On the same line, the idea to perform a new experiment using Transition Edge Detectors (TES) has recently been proposed [14]. This new type of detectors in performing spectroscopy of X rays would allow to perform an extremely accurate measurement of the mass of the negatively charged kaon, by measuring kaonic atoms with few hundredths pb^{-1}. Other kaonic atom transitions can be as well performed with a precision never achieved before. Presently the negatively charged kaon mass is rather poorly known; moreover the two most precise measurements of it provide results that are incompatible between each other. This new measurement can reach a keV precision.

For what regards the study of the low-energy charged kaons interactions with the nuclear matter, the AMADEUS collaboration plans to perform a series of measurements by implementing within the KLOE detector a series of targets and additional detectors. The proposed measurements are going to investigate: the possible formation and decay of the so-called “deeply bound kaonic nuclear stated”, various channels with hyperons in the final state, as well as low-energy scattering of charged kaons in nuclear matter. Moreover, dedicated measurements can be realized on hot items in hypernuclear physics (channels with neutral pions in the final state or neutron-rich hypernuclei). All these studies are having a very strong impact in astrophysics – especially after the recent discovery of the two-solar mass neutron stars. The luminosity required for these measurements is at the level of 1 fb^{-1}.

It is worthwhile stressing that the big advantage of these experiments with respect to those performed at other facilities, is the unique feature of DAFNE of producing monochromatic kaon beams with basically no hadronic background. However the competition from other facilities, in particular with JPARC, is relevant so that the timing of the LNF experiments is a major issue.

All in all, DAFNE operated in collider mode at the $\phi(1020)$ peak can be a source of relevant nuclear and particle physics results up to year 2020, provided that the continuity of operations is guaranteed at acceptable levels. The KLOE-2 program covers a wide set of possible particle physics topics, from fundamental symmetries conservation tests to precision measurements of SM parameters, to searches for new unconventional gauge bosons. On the other hand, it requires a considerably large amount of collected statistics, which in turn implies a long period of data collection at the highest possible luminosity and operation efficiency of the machine. The K-N interactions program focusses on a smaller set of possible measurements, which however needs much less stringent requirements on the machine performance. Due to the strong international competition, the proper balance between these two programs has to be decided as soon as possible on the basis of the actually measured machine performance and on realistic cost-benefit considerations.

1.1.3 DAFNE at variable energy

In recent years, the possibility of running DAFNE at higher center of mass energies was taken into consideration. A scan in energy, with 5-10 MeV steps, between 1 to 2.5-3 GeV, would provide a precise determination of the e^+e^- cross section to hadrons in that energy range, which is at present the main limiting factor in the theoretical evaluation of the muon g-2. Important studies on the structure of the nucleon can also be performed. Also, since the mass region between the ϕ and 1400 MeV is certainly the worst known so far, and according to most theoretical studies, is central in the quest for gluonic hadrons and in the study of quark confinement, it is quite clear that the DAΦNE+KLOE complex seems actually best suited to confirm the existence of both a 1100 MeV and a 1250 MeV states, which were observed in an old photoproduction experiments of e^+e^- pairs and perform a thorough analysis of its characteristics in a reasonable time. A detailed discussion of these topics can be found in [15].

Obviously, in order to reach the above mentioned energies, some major modification of the machine hardware is needed. For instance, the Linac must be upgraded to the proper energy, a feature which is of interest also for other applications (see section 1.3). At present, no detailed estimate of the costs for this operation exists, however it is reasonable to think that they would be in the ballpark of 20 Million euros.

1.2 The DAFNE-Light facility

DAFNE-Light is a Synchrotron Radiation Facility with three operational beamlines, using in parasitic and dedicated mode the intense photon emission of DAFNE, with a routinely circulating electron current higher than 1 Ampere [16]. Two of these beamlines, the soft x-ray (DXR1) and UV (DXR2) ones have as SR source one of the DAFNE wiggler magnets, while the third beamline SINBAD (Synchrotron Infrared Beamline At DAFNE) collects IR radiation from a bending magnet. Two XUV bending magnet beamlines, designed to perform different spectroscopies like photoemission, core absorption and emission, working in the low energy (35-200 eV) and the high energy(60-1000 eV) range, are ready for commissioning.

DAFNE-Light must be considered a material science facility but also a laboratory where it is possible to test new detectors and optics in a wide energy range, from IR to soft X-rays.

Using the IR, the UV and the other facilities, it will also be possible to apply to projects related to nano-technologies for biomedical and biotechnological applications, cultural heritage, to the development of new instrumentation for 2D and 3D IR imaging and also give contributions to HEP experiments by performing UV radiation tests of CSI crystals or continue investigations on e-cloud that are relevant for accelerator physics but also for space applications (see also paragraph 4.1).

Within the upgrades of the DAFNE-Light facility there is also the commissioning of the two XUV beamlines and their foreseen operation that will open the possibility to perform surface studies, using SR. In the near future, using one of these beamlines and combining the use of STM microscope and photoelectron spectroscopy, the crystallographic and electronic structures of many systems, including graphene on metals, will be studied to understand the mechanisms that determine the interface properties and allow one to discriminate between different contributions in the bonding in these systems.

DAFNE-Light can be considered a solid scientific asset for the future of the Laboratory both as an instrument for technological researches of primary INFN interest, and as a scientific tool capable of attracting a wide community of researchers beyond INFN. However a proper planning for the access to the facility which foresees a reasonable amount of dedicated beam time must be guaranteed.

1.3. The BTF Complex

The BTF (Beam-Test-Facility) is a transfer line using the electron or positron beam from the DAFNE Linac. The particle beams can be attenuated, energy selected and collimated for a wide range of possible applications, typically HEP detector tests, but also for specific studies of electromagnetic interactions. The facility has been operational for more than 10 years, mainly in parasitic mode of the collider operations, delivering beams to the users for an average of about 220 days per year.

Several possible upgrades of the BTF are discussed with some detail in [17]: improvement of the environmental shielding for high-intensity operations; extension of the beam bunch time width; addition of new collimators to reduce beam divergence and backgrounds at low intensity; doubling of the beam extraction system and transport line; improvement of the tagged photon source; increase of the maximum energy from 750/550 MeV (e^-/e^+) to about 1000/750 MeV; improvement of the neutron line; improvement of the beam diagnostics and control systems.

All of the above would increase the BTF performance as a detector test facility. However, the upgrades that are of larger interest for the present discussion are those aiming at the use of the BTF as a facility for particle physics experiments. More specifically, there are proposals to use high intensity electron or positron beams from the Linac hitting a properly designed target, with the aim of searching for new light gauge bosons (A') and/or light dark matter (LDM) particles.

1.3.1. Dark photons and LDM searches

Photon like particles, often dubbed as "dark photons", "hidden photons", U or A' bosons, appear in several extensions of the SM [18]. They are massive, vector particles mediator of new type of interactions to which ordinary matter is very weakly coupled. It is customary to normalize the "dark charge" of SM particles to their e.m. charge through a "kinetic mixing" parameter ε. Although not fixed by theory, for phenomenological reasons the preferred value for the dark photon mass is supposed to be in the range 1-1000 MeV, approximately.

On the other hand, new matter states might exist which are charged under this new hidden symmetry, providing candidate(s) for the Dark Matter (DM). Therefore the A' decay mode is strongly dependent on whether these states are heavier or lighter than the A'. In the first case, the A' is forced to decay into SM particles (so called visible decays), while in the second it decays into light dark matter particles, (invisible decays). In recent years, there have been several experimental searches for the A', in several laboratories in the world, including LNF with KLOE, setting relevant limits in the $m_{A'}$-ε plane [18]; all of them were looking for visible transitions. Other experiments have recently started data taking or are under construction.

At the BTF there are three possible experimental techniques to be exploited. Firstly, a positron beam hitting a thin target, to look for the process $e^+e^- \rightarrow A'\gamma$, with the A' decaying invisibly, as in the PADME proposal [19]. Secondly, a search for visible (e^+e^-) decays, using the same experimental set up but a thick target. Thirdly, a search for e^+e^- pairs emerging from a dump of a high intensity electron beam, as signature of $A' \rightarrow e^+e^-$ transitions.

Moreover, the previous beam dump followed by a properly designed detector can be used to search for a signature of LDM particles, a technique which has been proposed by the BDX Collaboration for the 12 GeV electron beam of Jefferson Lab [20]. It is important to underline the fact that, although the Jlab experiment has the advantage of a higher energy, higher intensity beam, the specific timing structure of the BTF beam is of utmost importance, since it allows a background rejection several orders of magnitude better than the Jlab case.

The relevance of this physics program is clear and proven by the fact that there are several other laboratories in the world pursuing similar activities. For the same reason, also, the timing of the LNF program is relevant as well. The proposal under study at LNF foresees the installation of a simpler version of the experiment as early as the fall of 2016, followed by more complex installations later on.

It is important to underline the fact that the search for Dark Matter is becoming more and more *the* central issue for Particle Physics. Although the attention of the experimentalists has been concentrated in the past mostly on particles of relatively high mass, as a consequence of the WIMP paradigm, the option for low or very low mass candidates has not been ruled out and needs to be systematically experimentally tested. Under this respect there is the possibility to let LNF become one the leading laboratories in the field, an option that will for sure revitalize its role as a laboratory for Particle Physics.

The upgrade of the BTF complex has to be seen as one of the strategic development lines of the Laboratory in the near future. BTF is being widely used for detector characterization tests by several users coming from all over the world. The consolidation of these activities by the construction of new beam lines will increase the attractiveness of the facility. Moreover, there is a viable and competitive physics program connected to the Dark Matter quest that can have a duration of about a decade and that can start as early as 2017. These programs require modest investments, of order of a few million Euros. There are however a few points that need to be underlined: first, it is mandatory to keep the intensity of the beam as high as possible; second, of major relevance is also the beam energy (the higher the better), so that the proposed energy upgrade of the Linac would be extremely welcome; third, the competition from other Laboratories is tough, so the actual implementation of this strategy has to start as soon as possible.

1.4 Longer term programs

Other possible uses of DAFNE for purposes different from the ones discussed so far have also been taken into consideration.

For instance, in [21] a project is presented to transform DAFNE into a gamma-rays factory, by using Compton collisions of the electron beam with a high average power laser pulse, amplified in a Fabry-Perot resonator. Calculations show that the resulting gamma rays source has extremely interesting properties in terms of spectral density, energy spread and gamma flux, comparable to or even better than the last generation gamma sources. The physics case of such a facility must however be still fully understood.

DAFNE could also be used as a laboratory for advanced machine studies, of interest for the construction of future accelerators, as discussed in [22].

Both cases, however, conflict with the operation of the machine in collider mode and most likely also as a synchrotron light source, so they should be considered as possible developments for DAFNE in a longer term perspective.

2. SPARC_LAB

SPARC_LAB [23] (Sources for Plasma Accelerators and Radiation Compton with Lasers And Beams) is an inter-disciplinary laboratory with unique features in the world. Born from the integration of the last generation photo-injector SPARC, able to produce electron beams up to 200 MeV energy with high peak current (> 1 kA) and low emittance (<2 mm-mrad), and of the high power laser (> 200 TW) FLAME, able to produce ultra-short pulses (<30 fs), SPARC_LAB has already enabled the development of innovative radiation sources and the test of new techniques for particle acceleration using lasers. In particular the following highlight results have been achieved:

- a Free Electron Laser has been commissioned producing coherent radiation tunable from 500 nm down to 40 nm and new regimes of operation like Seeding, Single Spike, Harmonic Generation and Two Colors have been observed [24];
- a source of both broad band, narrow band (<30%) and high energy (> 10 μJ) THz radiation has been tested, first experiments with users are underway [25];
- electrons have been accelerated up to 100 MeV in 4 mm long plasma wave excited by the high power laser FLAME [26];

More recently the electrons and photons beams have been synchronized at the scale of tens of fs, an essential requirement for the recent successful operation of the X-rays (~50 keV) Thomson back-scattering source and for the future investigation of new ultra-compact acceleration techniques (> 1 GV/m) based on external injection of high quality electron beams in a plasma wave.

Several proposals have been considered in the past years for possible upgrade of the facility: from the consolidation of existing radiation sources and a more focused users capability to new developments in the field of advanced accelerator concepts.

In any case an extension of the existing experimental hall is of paramount importance due to the fact that the present capability of the SPARC_LAB bunker has almost reached saturation. In the existing building the Linac energy could be upgraded up to 1 GeV, by using high gradient RF structures (C-band or X-band), and in the new building will be installed the radiation sources (FEL, Compton) including the FLAME laser and any new laser system, and the experimental beam lines to allow the use of the coherent radiation. A detailed project study of the infrastructure has just started, including a realistic cost estimate, which requires investments of the order 10-15 million Euros.

This upgrade will allow SPARC_LAB remaining at the forefront of scientific research for the next decade, as explained in the following paragraphs.

2.1 Plasma Acceleration

It is widely accepted by the INFN management that the main goal of the future SPARC_LAB activities will be focused on plasma acceleration development. This strategic choice is motivated by the recent progress obtained in the high gradient plasma accelerator test facilities in USA [27] and by the increasing effort in this field in many European countries. In addition a consortium of 16 laboratories and universities from 5 EU member states has recently announced an expressions of interest to elaborate a conceptual design report for the worldwide first plasma-based accelerator 5 GeV user facility. EuPRAXIA, the proposed European design study, is supposed to be a Large Research Infrastructure certainly beyond the capabilities of a single lab. It is supposed to bring together for the first time novel acceleration schemes, modern lasers, the latest correction/feedback technologies and large-scale user areas. It is of significant size, but significantly more compact than a conventional 5 GeV beam user facility. If the design study will be successful, EuPRAXIA could be constructed in the early 2020's. It would be the required intermediate step between proof-of-principle experiments and ultra-compact accelerators for science, industry, medicine or the energy frontier ("plasma linear collider"). Such a research infrastructure would achieve the required quantum leap in accelerator technology towards more compact and more cost-effective accelerators, opening new horizons for applications and research.

The proposed work will cover three major aspects:

- The technical focus is on designing accelerator and laser systems for improving the quality of plasma-accelerated beams, similar to the methods used in conventional accelerators.
- The scientific focus is on developing beam parameters, two user areas and the use cases for a femto-second Free Electron Laser (FEL) and High Energy Physics (HEP) detector science.
- The managerial focus is on developing an implementation model for a common European plasma accelerator. This includes a comparative study of possible sites in Europe, a cost estimate and a model for distributed construction in Europe and installation at one central site.

If a significant fraction of the proposed SPARC_LAB upgrade, discussed in the previous and in the following paragraphs, will be completed within the next 5 years it will be possible to successfully candidate SPARC_LAB to host the EuPRAXIA European Facility. The contributions of the main European research institutes and the collaboration with top class scientists in the field of Advanced Accelerator research will bring LNF at the forefront of accelerator physics and its applications for many years. Moreover the experience gained in this facility will certainly contribute to clarify the critical aspects still under discussion towards the application of plasma acceleration to Linear Colliders, opening new exciting perspectives to the entire particle physics community.

2.1.1 High quality electron beam from plasma to drive a compact FEL source

Plasma-based accelerators can be driven by laser pulses (LWFA) or by particle bunches (PWFA). A driving pulse can excite plasma wave in which electrons are trapped and gain energy as long as they are in phase with the accelerating region of the field. In just fifteen years, laser-driven plasma accelerators have advanced from making 10 MeV beams with ~100% energy spread to GeV bunches with a few percent energy spread. The steady increase in maximum energy was enabled by the rise of multi-hundred terawatt laser facilities around the world. The progress for beam-driven experiments has been even more remarkable, thanks to the development of high quality ultra-short electron bunches, with the maximum energy gained in the plasma increasing from a couple hundred MeV to over 40 GeV in just two years.

In a PWFA driven by a single electron bunch, the peak accelerating field is, in principle, limited to twice the value o the peak decelerating field within the bunch (transformer ratio R=2). Therefore the maximum possible energy gain for a trailing bunch is less than twice the incoming energy. Several methods have been proposed to increase the accelerating field. A very promising method is the so called *ramped bunch train* and consists of using a train of N_T equidistant bunches wherein the charge increases along the train producing an accelerating field resulting in a transformer ratio proportional to the number of driving bunches. For this application, it is essential to create trains of high-brightness femtosecond long microbunches with stable and adjustable length, charge, and spacing.

A lot of efforts are now ongoing worldwide to produce the required bunch train configurations. The method we will use to achieve the required bunch train quality is based on the so called *Laser Comb Technique* that we have proposed some year ago and which has been recently tested with the SPARC photoinjector in a not optimized configuration and without the plasma. For example train of 4 bunches with 16 pC/bunch separated by one plasma wavelength (160 μm), propagating in a plasma of density $3x10^{22}$ particles/m^3 can generate an accelerating field in excess of 3 GV/m.

Electron pulse trains with some hundreds pC charge, a sub-picosecond length and a repetition rate of some terahertz can be useful also to drive pump and probe or multi-color free-electron laser (FEL) experiments, generation of narrow-band terahertz radiation and to drive Dielectric Wake Field Acceleration (DWFA) experiments. Finally the high quality witness bunch can be injected in an undulator of new type, for example a short period (~1mm) magnetic undulator or in a RF undulator and investigate the possibility of an ultra-compact short wavelength FEL source, an extremely important contribution towards the V generation light sources development.

2.1.2 Positron acceleration in a plasma: a demonstrative experiment

To realize a future plasma-based linear collider, high gradient and high quality acceleration of positron and electron bunches are equally important. To obtain a high-energy positron bunch with a high beam quality, the positron bunch can be accelerated in the wake of an electron beam, a result not yet achieved anywhere.

A possible demonstrative experiment can be briefly described as follows: two closely spaced but relativistic electron bunches are focused on a thin high-Z foil target placed at the entrance of a plasma. Positrons are produced through pair creation as the incoming electron bunches traverse the target. After the target, two positron bunches with a lower charge than that of the original electron bunches emerge superimposed in space and time onto the electron bunches. The four bunches (electron and positron drive bunches, electron and positron beam loads) propagate downstream into the plasma. For a given plasma density, the distance between the two drive bunches and the two beam loads is adjusted such that the beam loads are placed directly after the blowout bubble created by the electron driver in a region of the plasma wake suitable to accelerate positrons and to decelerate electrons. The strong transverse plasma wakefields defocus the electron beam load, as well as the positron drive bunch located in the plasma ion column. Only the electron drive bunch and the positron beam load remain after a short propagation distance into the plasma. In this way the desirable configuration for accelerating and focusing a tightly focused positron beam load in the wake of an electron beam is established.

This scheme requires the production of two electron bunches closely separated in time [100 fs–1 ps.]. A method to produce such bunches has recently been demonstrated experimentally at SPARC_LAB with the so called COMB techniques, described in the previous paragraph. A similar method will be used to produce a drive/trailing bunch train for plasma wakefield accelerator (PWFA) experiments. The aim is to demonstrate the high gradient acceleration of a witness electron bunch with a narrow (a few percent) energy spread.

Higher quality positrons could be obtained with a more advanced source, as the one based on a Compton radiation source or by Channeling, another possible development with the upgraded SPARC_LAB facility.

2.2 FLAME Laser Upgrade

PW laser facilities currently starting their operations are delivering new scientific achievements at an unprecedented rate. New record values of the highest electron energy from laser-wakefield are emerging, with demonstration of multi-GeV electron energy and now aiming at 10 GeV. All-optical generation of gamma-rays from inverse Compton scattering from self-injected electron sources is now established and experiments to enter the non-linear regime or the QED regime are already in progress.

In this scenario the PW upgrade of the FLAME laser is a necessary step to keep the FLAME laser in the group of leading installations and further establish expertise on advanced laser sciences at SPARC_LAB, attracting much needed, motivated junior scientists. Most important, the FLAME PW upgrade will make possible to implement a new scientific program based on lasers at the highest competitive level.

Since FLAME installation, completed in 2010, important milestones have been reached, including the GeV scale acceleration with self-injection, the first evidence of laser-driven proton acceleration from a dedicated program, the advances in femtosecond LIDAR, just to cite the most important. More recently, with the first successful collisions of the FLAME laser pulses with the electrons from the SPARC Linac, the Thomson scattering X-ray source is also coming to reality. At the same time, FLAME stimulated a further growth of the national modeling capabilities, which are now becoming internationally competitive and fully embedded in the wider SPARC_LAB program.

In the meantime, many laboratories worldwide have recognized the need for a major upgrade of their respective laser systems to the PW power and, in several cases to the 10 PW power. These upgrades are driven by scientific motivations of paramount importance, which are emerging thanks to the parallel major effort in predictive numerical modeling of phenomena never approached so far in the Laboratory.

In this scenario, the upgrade of the FLAME laser system to the Petawatt power and dual beam capability will enable new regimes of plasma-based particle accelerators and to access the region of high electromagnetic fields of non-linear and quantum electrodynamics (QED) where new fundamental physics processes and promising new radiation sources can be achieved. A detailed description of the science cases that will be developed with the FLAME PW upgrade is in progress and includes:

1) Electron acceleration with self-injection beyond the GeV;
2) QED and generation of high energy radiation;
3) Proton and ion acceleration beyond the TNSA regime.

Among these phenomena, the most far reaching concerns the possibility of entering the radiation dominated regime of electron dynamics. Besides its impact on basic physics issues involving the fundamental nature of the electron charge, this regime may lead to the realization of extremely powerful and controllable sources of high-energy radiation. These sources may revolutionize many areas of great societal interest, from Health to Security, from Environment to Safety. In fact, a PW laser system makes it possible to create conditions in which the electromagnetic field is so strong that electron motion no longer follows the laws of classical mechanics. In the classical view, an electron entering an intense laser field will be scattered away by the strong ponderomotive force and will not experience high fields. This ponderomotively dominated regime is well explored in ultra-intense laser fields and is the basic mechanism that, for example, initiates the wake-field in a laser-driven acceleration scheme. When laser intensity is further increased, quantum processes govern the interaction of the electrons with the electromagnetic field and the force assumes a stochastic behaviour. In this case, an electron approaching an intense laser field may be able to experience a strong acceleration that will make it radiate much more efficiently than in the classical regime. Based on this principle, a powerful gamma-ray source can be conceived in a compact, all-optical configuration. This is only an example of the new physics that can be addressed with a PW laser.

2.3 Users Beam Lines

A relevant consequence of the upgrade of the SPARC_LAB accelerator is the possibility to produce a Synchrotron Radiation (SR) source with unprecedented degree of brilliance, in particular at UV and X-ray energies. Indeed, FELs generate beams with a peak brilliance of several orders of magnitude higher that the third generation SR sources, for both the spontaneous and coherent emission. They offer an extremely short pulse length, typically less than 10^{-13} s (femtosecond time domain), with some degree of tunability and a high degree of either linear or circular polarization. The advent of such short and powerful pulses of fs laser sources has disclosed the opportunity to make real time experiments in the fs time domain using many different techniques and to study the interaction of radiation with matter in a non-linear regime. Possible applications of these instruments range from spectroscopic investigations of the structure of molecules, clusters, to the characterization of nano-structured systems, as well as time-resolved studies of molecular dynamics.

Also the aforementioned THz and Thomson sources can be used for a wide spectrum of possible applications mainly in the Material Science domain. Spectroscopic, diagnostic and industrial applications of THz radiation have seen a tumultuous increase in the last years due, in particular, to the development of new radiation sources based both on lasers and sub-ps electron bunches. The TERASPARC source at SPARC_LAB is one of the most performant source worldwide on this regard. THz radiation, at variance with mid-infrared, penetrates down to several mm in dielectric materials, therefore one of the most interesting application concerns imaging. THz imaging, although is still in its infancy, could be used in different fields like biomedical diagnostic, cultural heritages and material science.

The Thomson source is still in the commissioning phase. For the first experiment the source was optimized for application in medical imaging, mammography in particular. However other possible applications are foreseeable, in crystallography, cultural heritage studies and identification of fissile materials, among others.

It is important to underline the fact that at present the space available for experiments using all of these facilities is dramatically limited. Therefore any sensible program for the usage of anyone of these beam lines will need a proper extension of the spaces dedicated to the users.

Finally, it must be remarked that all of the applications of SPARC_Lab discussed so far (including Plasma Acceleration studies) cannot be run in parallel, so that a wise and well defined allocation of the beam time will be a major managing issue.

Beyond any doubt SPARC_LAB will be one of the pillars of LNF in the years to come, with a scientific program that can produce world class results for more than a decade. At present it is probably the longest term program available for the Laboratory. To achieve the goal of long-lasting scientific excellence, however, strong investments are required under many respects: technical, manpower and financial resources have to be put in place by INFN. In particular, an extension of the existing experimental hall is of paramount importance due to the fact that the present capability of the SPARC_LAB bunker has almost reached saturation.

3. Particle Detectors

The capability of building large particle detectors as well as of developing innovative detection techniques has always been one of the main assets of the Laboratories. Random and largely non-exhaustive examples are the fundamental contributions of LNF to all of the LHC or the NA62 detectors at CERN, to many experiments of the Gran Sasso Laboratory, MACRO and OPERA for example, and, obviously, the construction of the KLOE detector at DAFNE and of its recent upgrades. At present, LNF groups are preparing for the construction effort for the planned upgrades of the LHC detectors. Such kind of activities were possible thanks to the presence in the laboratory of world class competences in all the fields relevant for the purpose (mechanics, electronics, computer science) and will remain an asset of the Laboratory also in the future. Even if all these enterprises were driven by the needs of a single experiment, they can bring to the Laboratory a specific know-how. For instance the Inner Tracking System of the ALICE experiment upgrade, a new solid state detector, is going to be built into the Laboratory and is bringing a new technology and expertise not present up to now. However, no explicit attempt of setting up a specific detector development and construction unit has ever been made.

Recently, ideas for creating such a facility have been strongly put forward. Obviously, given the dimensions of the Laboratory, it is not conceivable to create a multi-purpose facility devoted to all of the possible detection techniques; instead, attention has been put on two specific items, which, for totally different reasons, can represent a strong strategic asset of the Laboratory for the future.

3.1 Gas detectors Unit

Gas detectors have been developed and built at LNF since the times of their first appearance in HEP. As examples one can take the invention of the plastic streamer tubes by Iarocci and collaborators in the late 70s; the construction in the late 90s of the KLOE drift chamber, one of the (if not the) biggest drift chambers in operation in the world, the first one built with carbon fiber plates; the recent construction of the first cylindrical GEM detector as internal tracking device for the KLOE-2 experiment.

In fact, GEMs (Gas Electron Multipliers) and in general Micro Pattern Gas Detectors (MPGDs) are becoming more and more of frequent use in HEP experiments, thanks to their ability to overcome the known limitations of the traditional gas detectors (Wire Detectors and Parallel Plates Devices) while maintaining their positive features. MPGDs are in use nowadays in experiments like LHCb, CMS, ATLAS, COMPASS, TOTEM and many others. Attempts have been also successfully made to use GEMs in medical and in other non-HEP applications.

Despite the recent relevant progress in the field of MPGD, dedicated R&D studies are needed to go forward. These are requested to study the ultimate performance of these devices, in particular in terms of space and time resolution, rate capabilities, very high gain for single electron detection. Also, studies on how to improve and simplify their construction process are a must for very large scale applications in fundamental research and for the dissemination of this technology beyond HEP.

A facility (the MPGDLab) for R&D and construction of innovative MPGD substrates (flex-film, rigid-PCB) is proposed, with the aim of addressing a wide gas detector field, such as GEM-derived and Micromegas-derived detectors, and hybrid structures. MPGDLab will develop detectors by covering the full production chain: conceptual design, CAD design, resistive deposition, testing, characterization and qualification. The working model will be R&D workshop or service workshop, or a mixture of both, according to the requests of internal and external communities.

MPGDLab is motivated by the widespread interest both in the Italian and the international community. Most of the community is organized in the RD51 Collaboration, and comprises several fields, from research (LHC experiments and upgrades for High-Luminosity LHC, and EU priority), to applications (medical imaging, neutron beams monitoring, homeland security, etc).

The MPGDLab will act as a service for the various MPGD activities ongoing in the INFN sites. From an unofficial survey we have recognized 11 INFN sites involved in MPGD activities with 17-19 groups. Collaborations among INFN sites are already in place in the framework of the RD51 activities and for the AIDA2020 project.

Frontier activities of the MPGDLab will be performed in full synergy with TE-MPE-EM Workshop at CERN. Regular meetings will be scheduled. Exchange of personnel for training, as already successfully attempted for LHC upgrade projects, will be planned.

Interest in MPGDLab is expressed by groups associated to INFN Frascati. Materials engineering studies may characterize and qualify the materials produced (Universita` di Roma La Sapienza, Facolta' di Ingegneria), while optoelectronics sensors may be developed and applied on PCB and films for deformation monitoring and environmental monitoring (ENEA Frascati).

The infrastructures available at LNF that will act as natural support to the new proposed facility for the R&D activity on MPGDs and related electronics for HEP experiments or other radiation detection applications are manifold:

- Mechanical Design Service (Servizio Progettazione Apparati Sperimentali – SPAS);
- Mechanical Workshop (Servizio Progettazione e Costruzioni Meccaniche – SPCM);
- Mechanical Alignment Group, with three Laser Tracker units (Servizio Ingegneria Meccanica DA, Reparto Installazione ed Allineamento)
- Automation and Electronics Workshop (Servizio di Elettronica e Automazione – SEA);
- Large Clean Rooms, more than 300 m^2 with different level of classification (100-10000), equipped with tools for detector assembly, QC systems and shared among different groups working on MPGDs or classical gaseous detectors (ATLAS, BESIII, CMS, DDG, LHCb);

- Laboratories for detector test and qualification: DDG Lab (Detector Development Group Laboratory) equipped with multi-gas mixing systems, HV and DAQ systems, X-ray tube test station (5.9 keV X-ray energy), cosmic ray stand; CMS materials laboratory in ASTRA building, including MPGD test stations with two 3-component independent gas lines and a cosmic ray telescope for simultaneous test of MPGD with different gas mixtures; ATLAS and BESIII cosmic ray stand facilities;
- Beam Test Facility (BTF) for detector testing providing electrons, tagged photons and neutron beams.

The MPGDLab inspired to (and in collaboration with) the TE-MPE-EM Workshop at CERN is essentially a Photolithography Workshop in strict synergy with all the main internal LNF-Services. The proposed facility will be equipped with different devices: a CAD/CAM processing Station, a polishing machine and oven, a drilling and milling machine, a photoresist lamination, an UV exposure device and photoresist developer (hosted in a Dark/Clean Room), a metal/kapton etching machine, a screen printer and pressing machine (for multi-layer PCB). An interesting additional investment could be on the very promising technology of the “3D Super Ink Jet Technology” for emerging electronic and optical manufacturing that allows the realization of sub-micrometric PCB substrates for very innovative MPGDs.

The space needed to host the MPGDLab is of the order of 150-200 m^2 with at least a 30-40 m^2 dark/clean room, while the estimated investment will be of the order of 500-600 k€. The technical manpower (2-3 technicians or engineers) required to set up the facility should have good knowledge of electronics, mecatronics and chemistry as well as detector physics.

Given the very large number of projects using MPGD for *Better Society* and *Societal Challenges* the proposed facility will place the LNF at the forefront of gaseous detector technology development for many different applications inside and outside high energy physics. Collaboration with National and International Companies and Research Institutes, with the objective to generate technological results having a potential for commercial exploitation, will be clearly part of the mission of MPGDlab.

3.2 Space facilities

The observation of the cosmos with different techniques has produced many of the most relevant breakthroughs in physics in the last few decades. Leptonic flavour oscillations were firstly observed by looking at solar neutrinos; the evidence for Dark Matter and Dark Energy rests on astrophysics observations; the detection of ultra-high energy cosmic rays is providing unique information on the Universe around us.

Many of these results have been obtained by experiments collecting data in the outer space, either on stratospheric-balloons or on satellites in orbit around the earth. The participation of INFN to these space enterprises has been growing along the years. At present there are four missions in flight with INFN instruments: Agile, AMS2, Pamela and Fermi. To all practical purposes, these can be seen as “flying” particle detectors, designed to systematically study the fluxes of photons, electrons, positrons, (anti)protons and nuclei, with a wide research program including the search for Dark Matter, solar system astrophysics studies, and the search for the origin of cosmic rays. Other eight experiments are either in preparation or in R&D phase, enlarging the physics scope of the whole enterprise also to the study of the Cosmic Microwave Background (CMB) of the Dark Energy and to tests of General Relativity.

The above described projects are being pursued in a few INFN sections, which have set up some important infrastructure for the purpose. Still, INFN has not yet a National Laboratory devoted to Space activities, with the result that important steps of the space characterization of the detectors must be performed either by other agencies or by private contractors, substantially enhancing the costs of the operation.

Because of its availability of infrastructures, space and technical competences LNF is the ideal place to set up this integrated laboratory for the design and the construction of space proof devices. In fact LNF hosts since several years a laboratory devoted to providing critical diagnostic, optimization and validation tools for satellite laser ranging to all GNSS program, the SCF_Lab.

SCF_Lab is a Clean Room of class 10,000 (ISO 7) of about 85 m^2, kept at an isothermal temperature of about 21°C, which hosts two Optical Ground Support Equipments (OGSE). The SCF (Satellite/lunar/GNSS laser ranging and altimetry Characterization Facility) is a set of specialized instruments that allow one to recreate a realistic space environment around the tested CCRs and the simultaneous monitoring of temperature variations of the tested payloads and of the optical performance, in terms of Far Field Diffraction Pattern (FFDP) and wavefront Interferogram. This new industry-standard space test is called SCF-Test, a background intellectual property of INFN [28]. The SCF is very versatile for its large number of measurement ports (side and back), very long horizontal translations and capabilities for lunar laser ranging (LLR) and laser altimetry CCR payloads. Based on the experience made with the SCF, a second OGSE was designed and built, the "Satellite laser ranging Characterization Facility optimized for Galileo and GPS-3".

A strengthening effort and an extension of the SCF_Lab can represent a viable boost for a further development of the LNF Space Hub under discussion. Actually a proposal is under study to use present Frascati test facilities (SCF_Lab, BTF, DAFNE-Light, possibly more) as an already-proven basis to develop an interdisciplinary, modular and evolutionary space test and research hub, called *SATELLES*-Frascati. Preparation to steady state will be 2015-2019 then *SATELLES*-Frascati should become a permanent LNF infrastructure [29]. This hub will be designed to test and develop instrumentation, detectors and general payloads for space research and space technology applications. *SATELLES*-Frascati is intended to serve strong user communities, including space agencies, space industries and universities.

A further idea under discussion is the creation of a facility aimed at giving technical and logistic support to scientific experiments to be launched on board of stratospheric balloons operated by ASI (Agenzia Spaziale Italiana). ASI is considering a program aimed at re-acquiring the Italian capability to organize and manage launching of stratospheric balloons with scientific payloads. LNF is suitable to be the site for integration of experimental payloads, providing industrial buildings, offices, test facilities, technical services and engineering and scientific competences. The contribution of our Lab could range from basic integration of INFN or third party payloads (scientific apparatus, structural *gondola*, telemetry), to the whole process from design of a complete scientific experiment, to its construction, functional and safety tests (inclusive of Flight Readiness Documentation) and even assistance during launch campaign, according to ASI needs and INFN availability and interests.

Similarly to what said for SCF_Lab, the activity to support ASI balloon missions could represent a solid basis for a natural development of the LNF Space Hub being considered and actually an easy and almost necessary starting point: facilities and personnel, used and trained in balloons payload design, integration and test, with adequate effort in terms of financing and specific training, could be upgraded to establish a space integration and qualification center. This has to be of course carefully considered by INFN and LNF management, since, though similar in principle, balloon and space integration/qualifying differ consistently in terms of money and technology involved; while the first is easily in the capacity of LNF at present, the latter would require some years of investments and work.

The development and construction of nuclear, subnuclear and astroparticle physics detectors will remain a major activity of LNF in the years to come. At present, the Laboratory is providing relevant contributions to the world-wide effort for the upgrade of all of the LHC experiments, as well as of other projects in China, Japan, Germany and USA. However, the creation of special, well focused Detector Units will represent a relevant strategic bonus for the Laboratory, strongly enhancing its visibility. In particular there is the possibility for letting LNF become the national hub for both R&D on innovative detectors and for Space activities. This will obviously require investments in terms of manpower and infrastructures, which has to be carefully studied by the INFN and LNF management.

4. Other facilities for Materials Science

Although DAFNE-Light and SPARC_LAB will remain the main assets for Materials Science studies of the Laboratory, few other smaller facilities have recently grown up, which can allow performing interesting studies in the same field.

The XLab-Frascati laboratory [30] specialized in the study of X-ray optics, in particular polycapillary optical elements [31]. XLab is also focused on the application of this optics for X-ray analysis in various fields, such as cultural heritage, innovative materials, medical diagnostics, pharmacology, beam diagnostics, detectors characterization. Presently, two facility stations (RXR and XENA) are open to users. XENA is a facility dedicated exclusively to imaging, tomography and characterization of X-ray devices such as novel sources, optics - diffractive crystals. RXR (Rainbow X-Ray) is an optimized system of previous versions for 2D/ 3D XRF micro-imaging and TXRF.

The NEXT laboratory [32] operates since 14 years in nanotechnology experimental research. The team has an extensive expertise in nanomaterials and nanocomposites modelling, manufacturing, characterization and nanodevices realization. Activity on microwave assisted graphene growth has also been developed. The facilities available in the laboratory allow the production of high purity and low defect carbon nanotubes samples, chemical purification of nanocarbons, acquisition of images in darkfield and in brightfield, measurements of electric and magnetic permittivity in conductive samples [33].

The Laboratory for Magnetism high Pressure and Spectroscopy (LAMPS) [34] hosts operative cryogenics systems for magnetic characterization and transport properties of materials. Investigations on superconductors, magnetic materials as “bulk, tape nanoparticles” are performed, as well as development of new materials for micro sensors and micro devices such as micro-thermometers or micro-heaters [35].

All of these facilities have a relatively small impact on the Laboratory’s infrastructures and have been so far operated by small groups in a more or less self-organized mode. On the other hand, a more organized use of (at least some of) these facilities can open the possibility for a larger access of external users, with a wide spectrum of possible important applications including new materials characterization, innovative detectors development, cultural heritage studies, among others. This will enhance the visibility of the Laboratory without almost any additional costs.

4.1 Materials science for accelerators R&D

A dedicated laboratory has been developed over the last 15 years to conjugate some LNF competences in Materials Science (and SR) with some of the most advanced issues which the international accelerator community is facing in the design and construction of new high performance accelerators. This study well fits the laboratory core business and its tradition to always be on the forefront of the accelerator technology R&D. Accelerator’s materials and material coatings are required to fulfil properties necessary to control and /or mitigate beam instabilities, like Electron Cloud, that are well known to be a potential bottle-neck to the performances obtainable from particles accelerators.

LNF has a long-standing experience [36] in qualifying materials in terms of surface parameters of interest to e-cloud issues. Secondary Electron Emission (SEY) is being routinely measured, together with its dependence from electron energy, temperature and scrubbing dose. It is also possible to characterize "in situ" the surface chemical composition and eventual modifications occurring during electron or photon irradiation by using XPS with a conventional X-ray source. These experimental measurements of the relevant parameters can be also confidently compared to simulations, performed by running EC codes, in order to elucidate the final consequences on machine performances. Such a combined characterization effort is also suggesting ways to produce low SEY materials coatings. This issue is particularly important in view of the foreseen LHC luminosity upgrades, the ongoing research on Future Circular Collider (FCC) and ILC- Damping ring studies, where e-cloud issues are expected to be present.

The existence of a few, small but highly performing facilities is a further asset of the Laboratory, mostly in the fields of Material and Applied Science. If properly operated, they might become a pole of attraction for a wide community of external users, thus enhancing the visibility of the Laboratory without almost any additional cost.

5. Other proposals

During the November workshop the construction of completely new research facilities at LNF was also taken into consideration.

The Laboratory has been proposed to consider hosting the large solar axion telescope IAXO, presently under study by a large international collaboration, barycentered at CERN [37]. Axions appear in very well motivated extensions of the Standard Model, in particular as a solution of the Strong CP problem. Moreover axion-like particles are among the candidates of very low mass Dark Matter. This activity can therefore have a nice intellectual synergy with the LDM searches at the BTF discussed in paragraph 13.1. The project aims at increasing the sensitivity to solar axions by several orders of magnitude with respect to present limits. The basic detector component is a very large (~25 m length) superconducting toroidal magnet equipped with drives that allow solar tracking for about 12 hours per day.

A proposal for building an electrostatic storage ring to measure the electron Electric Dipole Momentum (EDM) has also been put forward [38]. Permanent EDMs (Electric Dipole Moments) of fundamental particles violate both time invariance and parity and, assuming the CPT theorem, this implies CP violation. This feature inserts EDMs among the highest sensitive probes of CP violation. The Standard Model predicts non-vanishing EDMs; however, their magnitudes are expected to be very small. The discovery of a non-zero EDM would be a direct signal for "new physics" beyond the Standard Model. Until now, EDM searches have been limited to trapped neutral system. Searches for EDMs of charged fundamental particles have hitherto been impossible because of the absence of the required new class of primarily electrostatic storage rings. The search of the electron EDM (eEDM) in a storage ring has to be inserted into this general physics framework. On the experimental side, one of the appealing features of eEDM searches is represented by the small size of the required machine. This is the result of the combination of the "magic-energy" required to provide the frozen-spin condition for the electrons (at a beam energy of ~14.5 MeV), and the use of state-of-the-art electric defector elements. Its compactness makes such a machine an ideal place for the development of technological innovations and exploring the systematics of a new generation electrostatic storage ring. From this viewpoint, a large synergy can be envisaged between this effort and the searches for proton and deuteron EDMs that require larger machines.

Both proposals imply relevant investments, and would have a major impact on the infrastructures of the Laboratory, therefore they go much beyond the kind of activities of interest for the present document.

Conclusions

In the course of the last months a lively debate was held at LNF, to elaborate a realistic scientific strategy for the Laboratory for the next decade. The main outcome of this debate is summarized in the present document.

We believe that there are a few, well defined research lines which must be pursued with strength to maintain the Laboratory at the forefront of scientific research, by maximally exploiting the existing infrastructures and/or by wisely upgrading them at reasonable costs.

In particular, LNF can be one of the leading laboratories in the development of new, revolutionary particle accelerations techniques that can allow us reaching the goal of accelerating gradients orders of magnitude higher with respect to the presently achievable ones.

At the same time the Laboratory can provide a wide community of internal and external users with high quality beams and other research infrastructures, for both fundamental and applied physics activities. After the completion of the current DAFNE program, there is a viable and competitive physics program connected to the Dark Matter quest that can have a duration of about a decade and that can start as early as 2017.

The long standing tradition of the Laboratory for particle detectors development and construction can be kept and enhanced by the creation of special units, which can either strengthen the LNF competence in specific areas or bring new technologies and expertise not present up to now.

All of these programs are viable and interesting per-se. However, a proper prioritization and implementation plan has to be carefully studied and ultimately agreed with the INFN management, taking into account the required and the available financial and manpower resources.

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