

68th MEETING OF THE LNF SCIENTIFIC Committee – 20-21/11/2024

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The Scientific Committee (SC) met at the *Laboratori Nazionali di Frascati* (LNF) for its autumn 2024 session on the 20-21 November 2024. Besides the Open Session, received a briefing of the new Frascati director, Dr Paola Gianotti, discussed with the project leaders and the directorate in closed meetings and presented its findings. These exchanges between the SC and the LNF colleagues were highly appreciated. The presentations of the open session can be found at this [indico page](https://agenda.infn.it/event/43903/timetable/#20241120.detailed):

<https://agenda.infn.it/event/43903/timetable/#20241120.detailed>

The SC commends the lab for several achievements made in the recent months and thanks all people involved for the clear presentations during the open session and for the constructive discussions during the closed meetings.

This meeting is the first meeting with Dr Paola Gianotti as director of the Frascati Laboratory. The Committee expresses its warmest congratulations to Dr Gianotti and looks forward to a collegial and constructive collaboration during her mandate.

Findings:

- The project office has been put in place and is fully operational. It evaluated a 50% increase in the number of projects since 2020 to reach 134, essentially due to an increase in externally funded projects, with the same administrative resources to manage these resources.
- The 2025 run plan foresees essentially no beam-time for DAΦNE, but the running of BTF, Spar-Lab and the TEX facility.
- Contacts have been taken between CERN and LNF to discuss about the possibility to use DAΦNE as an FCC-ee test facility.

- The LoI for the FIREBALL experiment has been send to the committee and is presented in the Open Session.
- The SSRIP (accelerator project at ELI-NP) has taken momentum and it status is presented to the committee.

Comments:

- The committee welcomes the creation of the project office as a helpful instrument for the directorate. Externally funded projects may sometimes concern only a few staff and be part of larger research efforts. Feedback from experience in other places (PSI), indicate a ramp-up time until the information is fully reliable and can be used efficiently.
- The committee is pleased with an effort taking up to define the future of DAΦNE. The fact that DAΦNE will not be running in 2025 will allow the stakeholders to assess different scenarios, including the time and the resources necessary for a potential refurbishment of the facility for any future use.
- The committee is very pleased receiving the LoI for the FIREBALL experiment, and the clarification provided in the presentation during the open session.

Recommendation:

- *Steering such a large number of projects is impossible without any structuration e.g. in different research programs, that can be qualified by their priority and resources required. Experience with Project Offices in other places, e.g. PSI should be taken into account in order to increase efficiency*
- *We encourage LNF strongly to establish a resource loaded plan for the future of DAΦNE in 2025, taking into account the possibility to run DAΦNE as a test facility of FCC-ee, have a physics program associated (EXKALIBUR?) and look into the compatibility with FLASH installation and running.*
- *The committee will send comments and questions on the LoI of FIREBALL to LNF in a timely manner. An update should then be given in the May session.*

1. LINAC-BTF and DAΦNE

Findings LINAC-BTF:

- The LINAC has been operated for BTFEH2 and DAΦNE until the summer stop on July 15 and restarted on September 30 to serve BTFEH2 users and PADME in BTFEH1 for detector tests. The run will continue until December 20.
- The beam availability has been excellent, and it is expected that the planned operational schedule will be met.
- Klystron B has been replaced by another one refurbished in-house. The presently planned and funded maintenance is considered to be sufficient to guarantee reliable operation of the linac. In particular, manpower has been secured for the consolidation of the RF hardware control.

- A significant effort is ongoing to rejuvenate the controls for the LINAC-BTF keeping in mind the requirements and needs for SPARC_LAB, EUPRAXIA@SPARC_LAB and other facilities.
- The committee was presented with:
 - a proposal for an additional run of PADME extending over the full 2025 operational year either for commissioning of the detector or for data taking at 16 different energies.
 - A Letter of Intent for an experiment (FIREBALL) to be conducted at the BTF1 experimental hall ideally starting in mid or fall-2026 once the CERN SPS enters LS3.
- Considerations relevant for the PADME run preparation and planning:
 - A national network to support radiation hardness assessment for space application has been established for the period 2025 – 2027. This implies the availability of BTFEH2 for irradiation tests for approximately 1 month in 2025. This mode of operation is not compatible with PADME running.
 - Drifts of the beam position at the PADME detector have been observed during Run 3 and affect the systematic errors and the experiment's physics reach. The origin of the drifts, in particular over timescales of a few/several days, has not been studied. On-line monitoring of the position (and angle?) at the experiment was not available to the LINAC-BTF team and drifted by ~10 mm.
- Considerations relevant for the FIREBALL proposal:
 - The design and procurement of the flux concentrator as well as the modifications of the experimental area (BTFEH1) are expected to be taken care of by LNF. The material and personnel required are expected to be covered by an ERC Synergy Grant to be submitted at the beginning of 2025. The possibility of procuring the flux concentrator via a collaboration with PSI is being also investigated.
 - Dismantling of PADME is required to install FIREBALL. The present planning of FIREBALL is compatible with the continued operation of PADME in 2025 and possibly 2026. FIREBALL's installation is compatible with the installation of another user in BTFEH1.

Findings DAΦNE:

- DAΦNE availability and performance have continued to be remarkable until the end of the run. The integrated luminosity targets for SIDDHARTA-2 have been exceeded.
- Time for machine experiments has been given and important reference data have been collected to qualify and document DAΦNE machine performance and its limitations.
- The committee was presented with:
 - the 2025 accelerator schedule not including DAΦNE running;
 - the proposal of a first module of a programme for kaonic-atom spectroscopy along the periodic table. The first module would require the accumulation of

an integrated luminosity of 500 pb^{-1} . The proposed plan, extending over 5 months and considering data taking for 3.5 months appears to be realistic, taken into account the average luminosity production achieved in 2024.

- Some initial subjects for tests of hardware prototypes and new accelerator physics concepts to be conducted at DAFNE for FCC-ee have been presented.

Comments LINAC/BTF:

- The Committee congratulates the LINAC/BTF team for the remarkable performance.
- The simulations performed for the FIREBALL experiments are based on the maximum capabilities of the LINAC, the requirement of shorter pulses (1.5 ns instead of 10 ns) needs to be verified, though appears to be feasible but it might entail a reduction of the intensity below the required. The compatibility of the LINAC running with short pulses with operation as injector for DAFNE needs to be assessed.

Comments DAΦNE:

- The Committee congratulates the DAΦNE team for the excellent performance of the machine.
- LNF provides significant contributions to the FCC-ee design (MDI, damping rings, etc.). DAΦNE is the only e⁺/e⁻ collider presently running in Europe and SuperKEKB pressed to improve performance.
- Exclusive operation of DAΦNE as test-facility might incur in significant overhead in terms of human resources and energy consumption. Interleaved physics runs/machine studies sessions could offer a more efficient use of the complex.

Recommendations on LINAC/BTF:

- *Make sure that sufficient diagnostics for on-line monitoring of the beam position (and angle?) is available to the LINAC-BTF team for PADME Run 4. This is even more important considering the longer runs (5 days) and the need to move out the target for 1 day for reference measurements at each energy. Sufficient time should be allocated for the beam setting-up.*
- *The LINAC/BTF facility serves a wide community of users in different domains (health, industry, etc.), while providing a valuable test facility for detectors and therefore assures wide visibility to the laboratory. Sufficient time should be allocated for user operation.*

Recommendations on DAΦNE:

- *The committee encourages the DAΦNE team, in collaboration with the CERN FCC-ee project team, to identify and prioritize a set of activities and tests, to be conducted at the collider (or its complex), that could be validate models, concepts, hardware choices considered for FCC-ee. Feasibility, possible timelines and resources requirements should be evaluated. Compatibility with physics operation should be assessed. We suggest involving the younger members of the DAΦNE team in this process as they are expected to implement it. An analysis of the necessary maintenance and consolidation of the DAΦNE complex should be conducted and possible descoping options identified with the associated risks. The results of the above work should be*

presented at the next SC to allow sufficient time for decisions, preparation and implementation.

2. SIDDHARTA-2

The Scientific Committee extends its condolences to the members of the SIDDHARTA-2 collaboration for the recent passing away of Prof. Carlo Guaraldo, a truly inspiring colleague and one of the main driving forces for the establishment of the LNF kaonic atoms program.

Findings SIDDHARTA-2:

- The Scientific Committee extends its condolences to the members of the SIDDHARTA-2 collaboration for the recent passing away of their dear colleague Dr. Johan Zmeskal.
- The Scientific Committee congratulates the members of the collaboration for completing their kaonic-deuterium data taking. Since the last SC they have gathered 200 pb⁻¹ of integrated luminosity in the low density run plus 20 pb⁻¹ in the post Kd calibration run with Boron and Fluorine solid targets. In total, they have gathered 815 pb⁻¹ + 200 pb⁻¹ (at low density), which are usable for the Kd data analysis.
- The collaboration has also completed the analysis of the calibration runs (obtained periodically during Kd runs) for Run1 and 2. The SDDs have shown excellent stability (<1 eV fluctuations) and the energy calibration accuracy is better than 3 eV (less than 10 eV was required for the Kd measurement). The energy resolution is approximately 170 eV in the region of interest, also appropriate for determining the Kd 1s energy-shift width. The calibration data analyses for Run3 and the low-density run are still ongoing.
- A very preliminary analysis of Kd was presented, showing a promising structure in the region of interest. The implementation of a refined calibration, veto1 selection, and the final fit of the energy spectrum, are still ongoing. The analysis of the Kd 1s energy shift and its width is expected to be completed and submitted to a journal within six months. In a longer term, two more articles are expected in collaboration with theoreticians, on the Kd scattering lengths and X-ray yields at different densities.
- There are also ongoing analyses of the data from the 3-day post-calibration run on B and F, as well as the X-ray tube calibration at BTF performed in July 2024. Their aim is to test the feasibility of the SDDs and veto systems for solid target measurements at the EXKALIBUR proposal. Boron and fluorine were chosen as targets, because their high yields provide significant signals with just 20 pb⁻¹. The collaboration has identified two KB and four KF transitions, which should lead to three publications. Of particular interest is the KF (4→3)@50.5 keV line, since for the first time SDDs have been used to measure kaonic-atom spectroscopy at such a high energy.
- The collaboration also reported the first measurement of kaonic atoms with their CdZnTe detectors.

- For their KNe data, the collaboration is developing a theoretical model to calculate transition energies and yields as well as studying cascade processes. In addition, they have published the first article about their kaonic lead measurements.
- Finally, the collaboration has informed of their progress in the first module of the EXKALIBUR proposal:
 - i) For the kaon mass measurement in KNe a new calibration system for movable targets with 7 different materials is financed and under construction.
 - ii) For the measurements in light kaonic atoms, a new support system for solid targets is under construction and MC simulations are ongoing and the material procurement is done. The new 1mm SDD were characterized using beam time from June to October 2024 at BTF, confirming the improved detection efficiency. Actually, new 1mm SDD are in production and a new detection module has been designed.
 - iii) Finally, for the parallel intermediate kaonic atoms program, a larger CdZnTe detector setup, with an improved geometry and shielding to reduce background, is being developed. The collaboration claims they will be potentially ready to start this module as soon as September 2025.

Comments SIDDHARTA-2:

- o The Scientific Committee commends the members of the collaboration for their encouraging new results and publications.

Recommendations for SIDDHARTA-2:

- *The SC reiterates the recommendation to aim for a very high-impact physics journal, not only for the publication of their full K_d 1s energy shift and width, but also for the yields, and their collaboration with theoreticians to determine the K_d scattering lengths and isospin-definite scattering lengths.*
- *The collaboration is encouraged to continue their development of X-ray detectors and to foster the formative aspects of this research beyond the kaonic atoms program, incorporating younger researchers, as a strategic opportunity for LNF.*

3. PADME SC

Findings

PADME experiment progresses well both towards the completion of the data analysis of RUN III and with the preparation of RUN IV. Several major findings during the data analysis delayed the opening of the box and the announcement of the result. However, they led to the development of a more systematics immune strategy for data analysis, new tools and validation techniques for the data quality and also pushed the preparation towards Run IV with new demands on the PADME setup and data taking. The developed analysis procedure does not improve the expected sensitivity but provides additional data consistency check and thus leads to a more credible result of the experiment. Since all

components for the unblinding procedure are already developed and are being tested, the actual unblinding can be expected before the winter break.

RUN IV data taking of PADME is seen as the last period of data taking at BTF which will allow to probe the X17 parameter space. In this regard, it is assumed that the end of the run should be determined by the time of the acquisition of the necessary statistics to cover the unexplored X17 region. Currently, the existing extensive support from the laboratory is highly appreciated, both in the preparation of the new detectors and in the modification of the PADME setup to improve the sensitivity of PADME to X17.

Comments:

- The committee welcomes all the progress made in understanding the PADME data and experimental setup.
- The committee appreciate in particular the tight cooperation of PADME with theorists from LNF and outside, which should be continued.

Recommendations

- *Common PADME + Theorists Paper on unblinding strategy should really appear reasonably in time before box is opened. Ideally, the box should be opened after this paper is accepted for publication in a journal*
- *The preparation and the execution of Run IV should get full support from the lab.*

4. KLOE-2, DUNE and HL-LHC upgrades

KLOE-2

Computing remains the most critical point. Moreover, the experiment had to set up an emergency plan during the impairing illness and after the loss last August of the unique dedicated expert. Most of the reconstructed KLOE data and MC dst files are stored in the old tape library and cannot be retrieved so far. Now an IBM intervention on old tape library is about to start to possibly retrieve all the files. The completion of ROOT output production will be a matter of few weeks, and it will need the help of an expert from outside who already contributed during the past emergency period.

The Collaboration already planned a meeting in person to face the next steps and proceed on data preservation and data analysis results publication.

DUNE

The dismounting of the KLOE calorimeter is following the planned schedule.

All the tools for the dismounting of the EndCap are now ready to proceed in January. The procedure for the consolidation of the modules of the barrel is defined. A flood, beginning of September, involved several LNF buildings, and the KLOE hall as well, and some instrumentation (also PMTs) needs now to be cleaned and dried. This delay will be absorbed by the contingency of the schedule.

The tender for the purchasing of the new power supply of the magnet was closed and delivery is expected in 10 months. The old control system of the magnet will be updated to be compliant with Fermilab standards. Concerning the extraction of the magnet vessel, negotiation with Ansaldo-ASG about their possible involvement. Alternative companies are being contacted as well. Shipment to Fermilab is foreseen by the end of 2027.

HL-LHC experiment upgrades

These activities are now ramping up for ATLAS and they will review at the next meeting.

5. SPARC_LAB and EuPRAXIA@SPARC_LAB

Findings SPARC_LAB:

- Since last SC most activities of SPARC_LAB were on RF conditioning plus a first testing of the new PMQ triplets with beam. These tests showed already focusing capabilities, but the targeted spot sized still needs to be demonstrated.
- Beam physics experiments are just starting and are planned to continue until 14 March 2025.
- Installation of the SABINA line for providing tunable small bandwidth THz radiation will continue until end of '25 followed by commissioning until mid '26.
- In the SPARC_LAB-Plasmalab studies on long plasma capillaries for sustainable operation at high pulse repetition rates took place with test up to 10^7 pulses (corresponding to one day of 24h operation at 100 Hz).
- The modifications of FLAME to drive the EuAPS betatron radiation source is in progress with the goal to deliver photons to experiments before end 2025.
- The early procurement of a EuPRAXIA modulator for demonstrating the required RF stability of EuPRAXIA in SparcLab is presently stuck because of administrative procedures.
- Beam experiments in SPARC_LAB will continue until mid-March'25. Planned experiments include continuation of beam tests with the new PMQ triplets and experiments on plasma acceleration with focus on laser generated plasma filaments and resonant plasma wakefield acceleration.

Comments SPARC_LAB:

- o The SC welcomes that the SPARC_LAB team took the recommendations from the last report into account and reported on the progress of the related items.
- o The measured timing jitter in the Klystron LLRF control loops of less than 20 fs puts SPARC_LAB on equal footing with state-of-the-art FEL facilities. The SC would appreciate an overview of the achieved timing jitters not only for the

RF but also for the cathode laser to RF stability in comparison with the EuPRAXIA requirements.

Recommendations SPARC_LAB:

- *Assure that despite of EuAPS and SABINA activities sufficient effort and time is put on experiments relevant for finalising EuPraxia@SPARC_LAB design. The following is mostly a repetition of the last SC report but remains valid.*
 - *Continue work on demonstration of robust plasma capillaries suitable for long term, high repetition rate operation*
 - *Comparison of PM magnet vs. plasma focusing*
 - *Studies of timing/bunching/energy stability with velocity bunching.*
- *Push procurement and installation of a solid-state klystron modulator for the velocity bunching section of the injector despite of the administrative hurdles. A high stability RF power source at this position is imperative for demonstrating the stability of timing/bunching/energy.*

Findings EuPRAXIA:

- The regional government commits 10 M€ for EuPRAXIA which reduces the 20M€ gap communicated at the last SC meeting.
- The TDR is in progress but far from complete. A first TDR draft with all chapters is planned for April'25.
- The TEX facility for X-band RF tests is now fully operational and the first successful power tests of prototype accelerating structures have been performed.

Comments EuPRAXIA:

- The SC appreciates that simulation of beam losses and related radiation shielding requirements have started and a concept for a controlled separation and dumping of the drive bunch after the plasma chamber has been developed.
- The SC welcomes the new planning office of LNF. This will help to improve the resource planning for EUPRAXIA@SPARC_LAB
- The SC commends LNF for the additional financial support from the regional government but emphasizes that this closes only a part of the cost-budget gap.
- The SC commends the LNF for the successful power test of a X-band prototype structure.

Recommendations EuPRAXIA:

- *A timely and successful realization of EuPRAXIA@SPARC_LAB is of paramount importance for LNF's future science program and reputation. Therefore, the finalization of the TDR and the call for tender preparation for building and components needs highest priority.*

6. SSRIP

Findings SSRIP:

- SSRIP is a new 100 MeV electron accelerator for isotope production under construction for the IFIN-HH research institute in Romania. The SSRIP project was created in the context of ending the legal dispute of the ill-fated ELI-NP project.
- LNF is responsible for the implementation of the SSRIP machine and the coordination with partners from industry. The target is to deliver the SSRIP machine by end February 2026.

Comments SSRIP:

- o The SC appreciated the information on the SSRIP activities and understands the importance of this activity for INFN in general and LNF in particular.
- o The SC commends LNF for the professional organisation and planning of the SSRIP activity, which is also a good training ground for the EuPRAXIA LINAC procurements and installation.

Recommendations SSRIB

- *The resource requirements for SSRIP are in competition with the needs of SPARC_LAB, EuPRAXIA@SPARC_LAB and BTF. LNF management together with the newly created LNF project office needs to monitor these requirements closely and take action in case a critical resource shortage for any of these four activities occurs.*

7. FLASH

Findings Flash

- New experimental setup possibilities have been explored to reach DFSZ axion sensitivity with FLASH.
- In Summer, a two-year project with the goal to write the FLASH TDR was submitted to the INFN National Scientific Commission 2. It was approved in September. The "proto"-FLASH Collaboration is composed of experimental (Mainz, Bonn, Cartagena, Valencia, Liverpool, Camerino) and theory (Zaragoza, Shanghai, Barcelona) groups, and INFN (LNF, Pisa, Trento).
- In October, an ERC Synergy Grant 2024 with a total budget of 10 M€ was awarded to the GravNet project of Diego Blas (Barcelona), Dima Budker (Mainz), Claudio Gatti (LNF), and Matthias Schott (Bonn). It aims at setting up the first network of high-frequency gravitational wave (HFGW) detectors based on haloscopes like FLASH and QUAX-LNF. COLDLab gets 37% of the ERC funding. The construction costs of FLASH are included in the ERC budget.

Comments

- o We congratulate Claudio Gatti and his crew for the big success of winning an ERC Synergy Grant. This presents a remarkable fabrication commitment for FLASH.
- o Had the largest fraction of the ERC funding (37%) but many tasks to do (100 MHz haloscope, 10 GHz haloscope, Quantum Sensing) and

- The funds appear adequate but there are uncertainties: vessel cost, infrastructure maintenance, ..., and, in principle, the overhead (25%) is destined to INFN.

Recommendations

- *FLASH must focus on HFGW. They should still also look for axion dark matter, but the priority now is different.*
- *There are reasonable resources for hiring personnel, but they must be distributed over the 6 years of the ERC project. We recommend permanent hiring of young researchers within these years.*
- *Study the compatibility of DAΦNE and FLASH data taking, in view of a possible use of DAΦNE as FCC-ee test facility and taking physics data.*

8. COLDLab: QUAX@LNF, Quantum Devices

Findings: QUAX@LNF

- First results published in a paper entitled “Search for axion dark matter with the QUAX–LNF tunable haloscope” [Phys.Rev.D 110 (2024) 2, 022008].
- Next run, now at “quantum limit”, foreseen in January/February 2025. To achieve this, there is ongoing work on testing and shielding the Josephson Parametric Amplifier (JPA) from the 9T magnetic field. But there are also improvements in the cryogenic setup, on the cavity tuning mechanics, on data acquisition and processing.

Findings: Quantum Devices

- The group is testing planar and “3D” qubits designed within their projects and fabricated at NIST and CNR-IFN. It also fabricated at LNL the 3D cavities to host the 3D qubits. In December this year, it is planned to measure the qubit in the cavity.
- The design for the fabrication of a JPA at 9 GHz is being completed.
- Work on the design of a two-qubits photon detector is ongoing. We now have a full quantum simulation of the system based on toolkits from theory of open quantum systems. With the quantum simulation we can now define the best parameters and proceed with the fabrication

Findings: ColdLab Infrastructure

- The tenders funded by the national recovery plan (more than 1M€ to COLDLab) where completed. These included a new dilution refrigerator (600 k€), the electronics for controlling and reading the state of superconducting qubits (200 k€) and new RF instruments (VNA, spectrum analyzer, an RF generator 20 GHz etc. for about 200 k€), and a cryocooler (50 k€) for 4K cooling of a cryostat.
- Now there are just 60 k€ left. It is planned to buy a couple of TWPA amplifiers next year.

Comments QUAX@LNF

- Congratulations to first paper on axion dark matter search with QUAX@LNF.

Comments Quantum Devices

- With the latter device one can make a "quantum" coincidence with two qubits detecting the same single photon, reducing the noise by orders of magnitude! Formidable!

Recommendations QUAX@LNF

- *Full support for run at quantum limit.*
- *Have to exploit QUAX@LNF as soon as possible also as a HFGW detector.*

9. Committee matters

The committee would like to thank LNF for the excellent organization of the meeting.

In view of the evolution of the project portfolio, we would like to invite LNF to consider the expertise of the committee members and to adjust in due time the membership of the committee.

In order to stay closer to the allocated timeframe of the Open Session, we would like to suggest 20/20/20 format of the presentations: 20 minutes, 20 slides, font-size 20. The committee always appreciates references to the recommendation of the previous session.

In view of the decisions that will need to be taken concerning the evolution of DAΦNE, the committee would appreciate to visit the facility at the next meeting.

10. Next Meetings

After the meeting of the Scientific committee, the dates next meetings in 2025 have been fixed for 14-15 May and 12-13 November.

Appendix:

Members:

U. Bassler (Chair)
G. Arduini (LINAC/BTF and DAΦNE),
H. Braun (SPARC_LAB and EuPRAXIA@SPARC_LAB)
N. Pastrone (PADME, KLOE-2, DUNE and HL-LHC upgrades)
J. Pelaez (SIDDHARTA-2)
A. Ringwald (FLASH, COLDLab)