65th MEETING OF THE LNF SCIENTIFIC Committee – 4-5/05/2023

The Scientific Committee (SC) met at the *Laboratori Nazionali di Frascati* (LNF) for its spring session on the 4-5 May. Besides the Open Session, the committee 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/35533/timetable/#20230504.detailed

The director of LNF, Fabio Bossi, welcomed the committee, in particular its new member: A. Ringwald who took over from A. Polosa.

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. The SC appreciated very much that the recommendations from the last report were directly addressed.

1. Director's Report

Findings:

- Energy prizes have been falling to a level that allow lab to have the full DAΦNE and BTF run in 2023.
- Within the National Recovery and Resilience Plan (**PNRR**), LNF will receive funding for six projects and a total of 20M€ and 20 temporary positions. The largest project is EuAPS for the implementation of a betatron source @SPAC_Lab. All spending must be finalised by the end of 2025.
- About 3000m^2 of additional real estate could be purchased neighbouring the laboratory and equipped with a warehouse and a parking lot, giving additional space to the laboratory.

Recommendation:

- *The committee congratulates LNF for obtaining the additional funding and positions. In particular the EuAPS project may be challenging and impact on EuPRAXIA with a risk of dispersion. Careful monitoring will be mandatory to fulfill the engagement taken with EuPRAXIA.*
- *Despite a very successful running of DAΦNE delivering unprecedented luminosity to the Siddharta-2 experiment, the situation remains fragile, and the committee urges the directorate to evaluate the future perspectives of DAΦNE for discussion at the November meeting, and decisions to be taken in the following.*

2. LINAC-BTF and DAΦNE

Findings LINAC-BTF:

- The dedicated LINAC run for the X17 experiment was completed successfully by the end of 2022 with an energy scan from 200 to 400 MeV, exceeding the initial requirements. The beam availability was ~90% over the whole run, except for about 1 week when the LINAC was stopped because of failure of a vacuum window of SLED B. The fault might be related to the emergency stop of all the machines following a request from the electricity network operator on 12/11/2022.
- The LINAC has continued to serve a large variety of users, among others an experiment to study the production of ^{99m}Tc, an important radioisotope for medical diagnostics.
- During the winter stop the replacement of klystron C was completed successfully and within schedule, leading to a significant increase of the reliability of the LINAC for DAΦNE operation.
- An analysis of the major sources of LINAC down-time and of the elements that might require consolidation for long-term operation has evidenced the power converter for the switching magnet DHPTB101 as a critical element. Failure of this component would prevent interleaved operation of DAΦNE and BTF. Such an event already occurred during the X11 run and the pulsed power converter was replaced with a DC one allowing to operate exclusively X11.

Findings DAΦNE:

- DAΦNE has started operation in the mid of March after 8 months of shut-down and has started to deliver luminosity for SIDDARTHA-2 by the end of March. Collider operation has largely benefitted of the improved reliability of the LINAC following the replacement of Klystron C.
- The injection transfer lines were kept operating between injections enhancing the reproducibility of the process. As a result, the fraction of time spent at injection has been reduced (now at ~10%) and the injection efficiency has increased (now at 70-80%).
- Thorough verifications of the low-level RF and transverse feedback systems have been carried out. Beam scrubbing during the commissioning has allowed to increase

the positron current. The maximum positron current could be increased from 650 to 1050 mA and conditioning is continuing. The maximum electron current could be increased from 1200 mA to 1500 mA.

- A new optics, based on the measurements performed in 2022, was implemented in the crossing region opposite to the SIDDARTHA interaction point and has allowed to reduce vertical dispersion and therefore the vertical beam emittance. The instantaneous luminosity has been increased by a factor 2 and reached peak values of 2×10^{32} $cm^{-2}s^{-1}$.
- Beam-based realignment of the sextupoles was performed and crab-waist sextupoles are now powered to 70% of their nominal strength.
- A reduction of the background to the experiment with an increase of the Kaon to SDD rate by more than a factor 3 has been obtained allowing data taking also during injection.
- The CCAL and gamma luminosity monitors, even though they cannot provide an absolute measurement of the luminosity, have been used extensively for luminosity optimization by the accelerator team.
- The average machine uptime has been 67%, to be compared with 72% in the previous run, with significant downtime induced by an electrical network perturbation generating a series of equipment failures.
- The average luminosity production rate has been 3.8 pb^{-1}/day during the month of April but this has increased to about 6 pb^{-1}/day as a result of the performance improvements. The above value does not include the luminosity accumulated during injection.
- So far, close to 100 pb^{-1} have been delivered with a Neon target on request of the experiment. It is planned to switch to the deuterium target in the next days.
- Given the excellent injection efficiency and the significant reduction of the time spent at injection, as well as the possibility of the experiment to collect data during injection, it is expected that the increase in the repetition rate of the LINAC from 25 to 50 Hz would not have significantly increase the performance and could reduce the reliability of the machine; for that reason it was not pursued further.
- The committee was informed of a possible programme for the study of beam mono-chromatization at DAΦNE that could be highly relevant for the FCC-ee design at CERN.
- The committee has been informed that technician support for shift accelerator operation is expected to reduce in the coming years due to additional retirements.

Comments LINAC/BTF:

- We congratulate the LINAC/BTF team for the successful replacement of Klystron C and the excellent performance that has been crucial for the completion of the X11 run and the efficient operation of DAΦNE.
- The specifications of the DHPTB101 power converter depend on the mode of operation of the LINAC, namely on its operation as DAΦNE injector. The scope of the consolidation of this piece of equipment should depend on the future of DAΦNE.

Comments DAΦNE:

- The Committee is impressed by the systematic work done by the DAΦNE accelerator team and the results obtained in terms of luminosity production.
- Given the observed reduction of the electricity cost, it is reasonable to assume that DAΦNE could run in autumn and the goal of delivering 800 pb^{-1} by the end of the year appears to be within reach, provided the present performance and availability are maintained.

Recommendations LINAC/BTF and DAΦNE:

- *From past experience, machine availability during summer and in case of high temperatures might be lower. Optimization of the running period with an early restart in September might impact favourably machine availability.*

Recommendations DAΦNE /SIDDHARTA-2:

- *Any modification of the interaction region close to the experiment should not impair the performance of the CCAL and gamma luminosity monitors and should be agreed with the accelerator team.*
- *Highest priority should be given to the accumulation of luminosity in the K-d mode of operation.*

Comment on LINAC-BTF/ DAΦNE strategy:

- The SIDDARTHA-2 K-d programme could be completed by the end of 2023.
- The committee has been informed of potential future proposals including the continuation of the Kaon physics (EXCALIBUR), the possible use of DAΦNE as test facility for advanced e^+/e^- collider concepts (e.g. mono-chromatization) or other accelerator physics studies (see DAΦNE-TF workshop held on 17/12/2018 https://agenda.infn.it/event/16334/page/2177-program-timetable).
- Continued operation of DAΦNE will require a significant investment for consolidation of the accelerator and a long shut-down for the machine. In addition, the scope of the LINAC-BTF consolidation depends to some extent on the future of DAΦNE (e.g. DHPTB101 power converter).
- A consolidation of DAΦNE will require a significant mobilization of resources of the Accelerator Division in competition with approved programmes (EuPRAXIA and EuAPS). Accelerator operation presently relies on the availability of accelerator systems technicians on shift. A series of departures due to retirements are to be expected in the next few years. Training of these manpower profiles requires a significant time.

Recommendation on LINAC-BTF/ DAΦNE strategy:

- *The committee encourages the LNF management to define a resource-loaded medium-term plan for the operation (and consolidation) of the LNF accelerator facilities.*

3. SIDDHARTA-2 and PADME

Findings SIDDHARTA-2:

- Since the last SC meeting in November 2022 the collaboration published their results on K-^{4}He L-series measured with SIDDHARTINO, their measurements of high-n transitions in intermediate mass kaonic atoms with SIDDHARTA-2 and the acceptance for publication of their report on CdZnTe detectors. Their simultaneous analysis of $K^-p \rightarrow \Sigma^0\pi^0$ and $K^-p \rightarrow \Lambda\,\pi^0$ have been submitted and the M-type K-^{4}He transitions final analysis has been completed. In addition, the published several contributions to conferences and workshops as well as two PhD and two Master theses.
- The SIDDHARTA-2 apparatus has been upgraded and was installed back in DAΦNE in February 2023. The optimization includes new cooling schemes for the SDDs and the target, which provide better control of its parameters. A new polyethylene entrance window was tested on site, but due to the failure in the material composition, it was replaced with Mylar, which still has reduced very significantly the signal contamination. The VETO3 system and the lateral shielding around the vacuum chamber have been improved. They are also working in further improvements on the lateral shielding and have proposed to redesign the bottom shielding near the interaction point. The latter may require the displacement or removal of other components (luminometers) and will require further studies coordinated with the DAΦNE team.
- As a result of the previous optimizations and the coordinated efforts of the collaboration with the DAΦNE team, the averaged integrated luminosity at SIDDHARTA-2 raised from roughly 1 pb^{-1}/day to more than 3 pb^{-1}/day without injection time (about 5 pb^{-1}/day with injection time), with peaks of more than 8 pb^{-1}/day. Simultaneously, the background has been reduced by a factor of 3-5 from (14-15)10^4 x-ray/cm^2/pb^{-1} down to (2-3)10^4 x-ray/cm^2/pb^{-1}.
- During the calibration technical run, required after 8 months without operation, a high yield target gas was needed, particularly for a fast cross check and optimization of the degrader and the MonteCarlo. Neon was chosen since Helium had already been studied by SIDDHARTA-2. Given the remarkable improvement in performance, particularly during the last half of April, data for about 84 pb^{-1} integrated luminosity was stored without injection (125 pb^{-1} with injection). Hence, SIDDHARTA-2 was able to complete the required calibrations and to present preliminary results on their analysis of the first ever measured kaonic-Neon transition energies. This was achieved without data from injection time, whose quality still has to be checked. Given the large amount of data stored in those two weeks, remarkably precise measurements and one or two scientific publications are expected to result from this calibration run.
- The collaboration claims that after these calibration and optimization procedures, they are ready for the kaon-deuterium run 1. It should start on the second week of May and extend until July. The request 300 pb^{-1} seem feasible given the present performance. An additional 500 pb^{-1} are requested in a second run after the summer shutdown.

- Studies on the CdZnTe detectors to measure transitions in intermediate mass kaonic atoms led to a technical publication accepted in EPJ_ST and one submitted to SENSORS. Their installation is expected by the end of May to start a test run, in parasitic mode, with an enlarged detecting surface and the degrader and geometry tuned with GEANT MC as well as a mechanical setup. The improved setup could also operate in parasitic mode during the kaon-deuterium run 2, together with the HDGe detector.
- The collaboration also reiterates the request for an extension after the Kd runs, using solid targets and 1 mm SDDs, to measure light kaonic atoms (e.g. Li,Be, B). With 150 pb^{-1} they expect to achieve a precision of 2-3 MeV.
- The collaboration restated the EXCALIBUR proposal to measure with precisions kaonic-atom spectroscopy along the periodic table. It consists of four programs requiring: 1) 200 pb^{-1} to reduce the precision on KH below 10 eV, 2) 200 or 400 pb^{-1} to study light kaonic atoms, 3) 200 or 400 pb^{-1} for intermediate and heavy atoms and 4) 400 pb^{-1} for ultra-high precision measurements. This provides the opportunity to extend the SIDDHARTA/DAΦNE physics program, taking advantage of the studies performed by SIDDHARTA-2 on solid targets as well as CdZnTe, HPGe and 1mm SDD detectors.

Comments on SIDDHARTA-2:

- The SC praises the members of the collaboration, and their coordinated efforts with DAΦNE, for their magnificent improvement in performance on luminosity and background reduction.
- The committee was initially surprised by the duration of the calibration run with Ne target and the amount of integrated luminosity (~100 pb^{-1}) collected in this mode, given the high priority given to the K-deuterium run. In hindsight, the SC understands the choice of Neon for the target and commends the collaboration for profiting the calibration run for obtaining scientific results of interest.
- The committee also commends the collaboration for their new publications and for the results obtained on KNe atoms, which has also allowed the collaboration to understand and simulate the required degrader shape, of vital importance for the next Kd run.

Recommendations for SIDDHARTA-2:

- *The SC encourages the collaboration to move swiftly and decisively to the Kd data taking in two runs this year, with the aim of taking advantage of the maximum integrated luminosity attainable in 2023.*
- *To complete the quality studies of the data recorded during injection time, with the aim of obtaining valuable additional Kd data.*
- *Keep the usual maintenance and upgrading duties in signal/background reduction, as well as the coordinated effort with the DAΦNE team to study reinforcement options for the shielding (by removing, reshaping, or displacing the luminometers close to the SIDDARTHA setup).*
- *During runs 1 and 2 undertake data acquisition with the satellite HPGe and CdZnTe detectors, minimizing the interference with the Kd data taking.*

Findings PADME:

- The gamma-gamma paper was published in Phys. Rev. D. in early 2023.
- The ATOMKI anomaly in He-4, Be-8 and C-12 remains and several recent papers reanalyze the ATOMKI results and find a similar hypothetical 17 MeV particle.
- The PADME Run-3 ("X17 Run") scanning for the resonance around ~285MeV positron energy was finished at the end of 2022 with good beam stability. 47 energy scan points around 16.4 – 17.5 MeV X17 mass were collected. Additional points far below and above the hypothetical resonance were collected as sidebands. The collaboration is happy with the beam, it received more data over a wider energy range than even in the 'optimistic' scenario.
- The main PADME analysis activity is now the X17 resonance. The sidebands are used to find initial quality cuts and to develop reconstruction techniques. The newly installed ETAG detector appears to work well, additional studies are performed using cosmics for further understanding.
- The collaboration hopes to open the "X17 box" by the end of the year.
- The single photon analysis from Run-2 is still being pursued, but the local group is fully committed to the X17 analysis. The single photon analysis is now performed in Sofia. It needs new algorithms to handle the high pile up in the ECAL.
- The PADME collaboration will not ask for beamtime in 2023.
- Early career scientists play an important role in the analysis and are also prominent in the presentation of results.

Comment on PADME:

- The SC is pleased to see that the collected X17 data appear to be of high quality. The collaboration is rightfully prioritizing the X17 analysis. PADME has a unique opportunity to investigate this anomaly.
- The SC is eagerly awaiting the results of the unblinding, as this will inform the strategy for possible future PADME running.

Recommendations PADME:

- *The collaboration is looking at various control/sideband regions at the moment. Given the potential high impact of the result, it is essential to have a well-thought-out blinding strategy before the focus on the energy scans around the hypothetical resonance starts. The SC therefore recommends publish or at least to submit a short paper to the arXiv, with a sensitivity update and a blinding protocol before looking at the interesting region. This will be valuable from a scientific standpoint, and it will also raise community awareness that PADME is pursuing this effort.*

4. KLOE-2 and DUNE

Findings KLOE-2:

- Positive progress on 2 analyses published on KLOE data:
  - Direct tests of T, CP, CPT symmetries in transitions of neutral K mesons;
  - Measurement of the $K_S \rightarrow \pi e \nu$ branching fraction.

- Final results and paper draft are expected on $\eta \to \pi^0\gamma\gamma$ analysis of KLOE-2 data.
- Progress on $\gamma\gamma \to \pi^0$ with High Energy Tagger (HET) and B-boson search.
- The offline: data production is completed; the MC simulation is in progress;
- Data preservation is in good shape thanks to the constant dedication of a single expert.
- There are new collaborators: a new group from the University of Liverpool (3 staff, 2 post-doc, 2 students) joined the collaboration with a strong interest in the analysis of the hadronic cross-section contribution to muon anomaly; other 4 people interested to join only for this specific analysis. Two informal expressions of interest for other specific analyses from two independent people/groups were also received. The KLOE-2 collaboration set rules to approve new people/group joining to guarantee contribution for each individual and also on service work (see MC production).

Comments KLOE-2:

- The SC commends the KLOE-2 collaboration for the overall progress made.

Recommendation KLOE-2:

- *For data preservation and their use by other groups, it would be crucial if a younger, but expert person (i.e. newly hired on PNRR funds) could start to help becoming a back-up and a support (see critical old tape library).*

Findings DUNE:

- First presentation of the activity of the newly formed LNF-DUNE group.
- The yoke, coil and e.m. calorimeter of KLOE2 will be dismounted and shipped to FNAL to be integrated as the new SAND near detector neutrino experiment.
- The KLOE2 drift chamber was taken apart.
- The tooling to dismount ECAL needs to be refurbished and certified both in EU and US.
- ECAL requires a new readout electronics, to be discussed, tested and defined. Part of the cables/infrastructure will be reused.
- The magnet will require a new power supply and tests on site before shipping to U.S.

Comments DUNE:

- The group is recognized as being expert on the detector and highly motivated to contribute to a win-win project.

Recommendation DUNE:

- *It would be important to have a report on the decision of the new ECAL readout electronics by next committee.*
- *Shipment will require to be carefully planned and revised in advance.*

5. SPARC_LAB and EuPRAXIA@SPARC_LAB

Findings SPARC_LAB:

- Beam driven plasma acceleration with >1 GeV/m was measured. While first results on acceleration were already shown at the SC meeting of last November, additional measurements have been performed on the plasma recovery times after drive bunch passage. These measurements extend the data from measurements performed at FLASH for an Argon plasma https://doi.org/10.1038/s41586-021-04348-8 with data for Hydrogen plasma.
- Installation of the new photo-cathode laser is ongoing. The new laser will have improved uniformity of the beam on the cathode and shorter pulse length (30fs instead of 100fs). This will improve the SPARC_LAB beam quality and performance.
- The poor field quality of the new PM magnet quadrupole triplet was confirmed with measurements of the multipolar coefficients. A new triplet is ordered from Vakuumschmelze. Furthermore, testing of a plasma lens as an alternative for the triplet is foreseen for the second half of this year
- The SPARCLAB team plans to order two solid-state klystron-modulators for EuPRAXIA@SPARC_LAB as replacement of two existing PFN modulators in order to improve RF stability and test operation with this modulator type.
- Test of beam driven plasma acceleration with a Nitrogen instead of Hydrogen plasma is planned for the second half of this year.
- The EuAPS betatron radiation source, driven by the FLAME laser, will be installed early 2024 in the in the SPARCLAB building. The X-ray photon beam from this facility will in terms of intensity and brilliance not be competitive with FEL sources, but may allow for first femto-second time scale photon science experiments at LNF.

Comments SPARC_LAB:

- The SC regrets that Vladimir Shpakov resigned from LNF to take a post at the JINR laboratory in Dubna. LNF loses with Vladimir a very competent and committed accelerator physicist, who made substantial contributions to the SPARCLAB program.
- The SPARC_LAB team should profit from the in-house know-how with the DAΦNE permanent quadrupoles to avoid in the future problems like those experienced with the PM triplet installed last year.
- The SPARC_LAB programs on photo-injector, beam driven plasma acceleration, FEL and THz beamlines are all very well suited as technical preparation for the EuPRAXIA@SPARC_LAB project. This is less obvious for the FLAME, EuAPS and EXIN activities.
- The SC fully supports tests and developments on the plasma capillary parameters to understand potential and limitations of high repetition rate operation with plasma acceleration.

Recommendations SPARC_LAB:

- *Implement the plans on solid state modulators as soon as possible, so that EuPRAXIA@SPARCLAB can still profit from the SPARC_LAB experience.*
- *Keep an eye on priority for activities which support the strategic goals of EuPRAXIA@SPARCLAB*

- *Follow both paths for focusing into the plasma, i.e. plasma lens and permanent magnet quadrupoles to assure that at least one is successful.*

Findings EuPRAXIA:

- Building design has been finalized, building authorization is in preparation.
- Injector RF design completed.
- Prototype contracts for one klystron type concluded, contract preparation in progress for the other klystron type.
- Plasma module design and tests are evolving and are getting more mature.
- TEX X-band high power test facility has been put in operation, first tests on accelerating structures will start soon.
- X-band structure mechanical prototype are completed; RF prototype work is progressing.
- FEL Apple-X Undulator prototype build and delivered. Construction of prototype for superconducting FEL undulator is in progress.
- Project-schedule and cost estimate evolving with good progress.

Comments EuPRAXIA:

- The SC was pleased and impressed to see the first EuPRAXIA@SPARC_LAB Apple-X prototype undulator build by KYMA.

Recommendations EuPRAXIA:

- *The SC re-iterates its recommendation from the last report that radiation levels and shielding dimensions for the drive beam collimator need to be computed. At a beam energy of more than 1 GeV and a mean beam current in the order of 0.1 μA this shielding may need considerable space and has to be known before building construction starts!*
- *Keep the focus on the key strategic goal of EuPRAXIA@SPARC_LAB, namely validation of beam driven plasma acceleration as an appropriate technology for a successful photon science user facility at LNF!*
- *Build-up of* EuPRAXIA@SPARC_LAB *workforce, in particular for RF systems, accelerator physics and operation needs more momentum.*

5. COLD Lab

Findings ColdLab:

- **FLASH** (Finuda magnet for Light Axion SearcH): Proposal draft almost ready to be submitted to arXiv on experimental setup and sensitivity forecasts for detection of axions, hidden photons and gravitons,
- Work needed to get cryogenic plant and superconducting magnet from FINUDA experiment: currently underway the helium transfer line reconnected to FINUDA magnet at new position
- **QUAX** on a good way to search for axion dark matter in previously uncharted mass ranges: QUAX@LNL reached KSVZ axion sensitivity (arXiv:2304.07505) at m_a

around 43 micro-eV. QUAX@LNF had successful test run and is now getting ready for physics run aiming at KSVZ axion sensitivity at m_a around 35 micro-eV

Comments ColdLab:

- The committee would like to thank the ColdLab team for the interesting and impressive visit and commends the team for its innovative research activities.

Recommendations ColdLab

- *The FLASH proposal should be published soon.*
- *A thorough test of FINUDA magnet should be supported.*
- *If no show stoppers are found, the FLASH "interest group" should try to enlarge the collaboration.*
- *COLD Lab would profit from more lab space and from more PhD students.*

6. Committee matters

The committee would like to thank LNF for the excellent organization of the meeting and for having taken into account the suggestion previously made. The visit of the ColdLab was highly appreciated and allowed to give some concrete insights in the working of the lab.

The committee would appreciate to pursue with such visits, possibly of DAΦNE if the planning has progressed. Discussions between LNF and INFN Directorate need to take place and we would urge the LNF Directorate to move forward on this suject. At the appropriate moment, the committee would also like to visit the ATLAS/CMS test labs, together with a presentation during the meeting of the status of the upgrade activities.

7. Next Meetings

The next meeting will be held on 8/9 November 2023, and for the spring meeting the 27-28 May are foreseen, with a fallback option on the 29-30 May as there may be a conflicting meeting at INFN.

Appendix:

Members:

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