63rd MEETING OF THE LNF SCIENTIFIC Committee – 16-17/5/2022

Because of the favourable evolution of the pandemic, the Scientific Committee (SC) had again the pleasure to meet in person at the premises of LNF. As in November 2021, the interactions among the SC and with the LNF colleagues were highly appreciated. The presentations of the open session can be found at this indico page:
https://agenda.infn.it/event/30737/timetable/#20220516.detailed

First, the SC chairperson welcomed three new members of the SC: J.R. Pelaez, who will take over from À. Ramos, N. Pastrone as successor of B. Heinemann and U. Bassler, who will take over from G. Dissertori as SC chairperson.

The director Fabio Bossi summarized the status of the lab and recent developments and achievements in the closed session. In particular, he emphasized the need to discuss with and obtain advice from the SC regarding the upcoming operations plan for DAΦNE and LINAC/BTF, in order to serve the two main ongoing experiments SIDDHARTA-2 and PADME. Details about these discussions and recommendations by the SC can be found in section 1 below.

A key topic of the closed session was a presentation by A. Gallo regarding the estimated resource requirements, in case a substantial DAΦNE consolidation project would be launched. Such a consolidation effort would definitely be required for a possible extended DAΦNE running over several

more (e.g. 3-5) years. In this context, the LNF director highlighted the recent significant rise in electricity costs that the lab must cope with. Again, further details can be found in section 1.

During this meeting of the SC special attention was given to the ongoing LNF efforts towards axion searches (ColdLab activities), with particular focus on the possible re-use of the Finuda magnet for setting up the FLASH experiment. More details are given in section 3 below.

In the context of big magnets, a report shall be scheduled for one of the upcoming SC meetings regarding the preparations of the shipment of the KLOE magnet to Fermilab. At the next SC meeting, the director also plans to give a report on the developing person-power situation at the lab.

The SC commends the lab for several achievements made in recent months and thanks all people involved for the clear presentations during the public session and for the open and constructive discussions during the closed meetings. The SC appreciated very much that the recommendations from the last report were, once more, clearly addressed and that the speakers respected the allocated presentation time.

Finally, the lab director expressed his thanks to the two outgoing members of the SC, À. Ramos and G. Dissertori, for their contributions to the SC and for providing important advice for the advancement of the lab throughout these recent years. Àngels and Günther expressed their gratitude for the many constructive discussions and for the great atmosphere that they always encountered in the lab and in the SC. They present their best wishes to their successors and to the lab for a great future.

1. DAΦNE, SIDDHARTA, BTF, PADME and KLOE

Findings DAΦNE:

- DAΦNE run from 25th November to 21st December in 2021. Operations could be resumed only at the beginning of April 2022 due to a major stop of the LINAC required for replacing a Klystron (Klystron A). Once the beam was made available from the LINAC, collisions were re-established quickly. Operation is expected to continue until mid-July.

- The performance of the machine is still worse compared to that achieved during KLOE-2 operation. The injection efficiency was improved and the positron current from the LINAC was increased as compared to 2021. As a result the injection process duration was halved. Coupling and positron emittance blow-up are identified as sources of the lower luminosity, but they could not be addressed so far because no machine development time has been allocated. An unexplained intensity limitation has been observed on the circulating positron beam. Despite the optimization of the transverse feedback working point, no significant improvement in intensity was achieved. In addition, a dependence of beam orbit on intensity (also observed with independent beam diagnostics) has been measured, pointing to an unknown source of impedance in the machine. The present rate of luminosity production, including the overall machine availability, is about 3 pb^{-1}/day. The background rate in the SIDDHARTA-2 detector has increased by a factor 2 as compared to the end of 2021.
- The accelerator physics team is confident that realignment of the elements close to the IR would allow to increase the specific luminosity and to provide a higher luminosity (by 20 to 30%) as compared to the present value, even in the presence of the observed intensity limitations. This would require interventions in the tunnel, additional measurements and working point adjustments during working hours, over a period of 2 weeks. The signal to background ratio is also expected to benefit from the above actions. Positron emittance blow-up is attributed to electron cloud and conditioning with beam during regular operation appears to be the only effective way to mitigate this phenomenon. The understanding of the other observed intensity limitations would require more studies, but their outcome is uncertain given the limited time and resources.
- SIDDHARTA-2 is presently collecting data with a helium target to commission the detector and the aim is to collect 100 pb^{-1} with the deuterium target in 2022 before the summer stop. At least 500 pb^{-1} (up to a maximum of 700 pb^{-1}) are required in 2023 to complete the physics programme with the deuterium target. Considering the running time (at least 200 days) necessary to achieve the above targets at the present luminosity production rate, the proposed actions and interventions are a worthwhile investment.
- The Committee congratulates the accelerator team for the sustained effort to support luminosity production by the DAΦNE complex despite the limited resources.

- Except for the insertion region and the wigglers, DAΦNE has not undergone major consolidation or upgrades since its construction. The Committee was presented with a detailed list of necessary consolidations aiming at maintaining DAΦNE operation beyond 2023 for approximately 5 years with the present performance (i.e., assuming a luminosity of 10^{32} $cm^{-2}s^{-1}$). A first coarse-grained cost estimate of the consolidation campaign amounts to approximately 5 MEuros, it would require a machine stop of up to 2 years and it would involve a significant fraction of the Accelerator and Technical Divisions workforce over this period to be completed. The above costs do not include those for the consolidation of the LINAC/BTF section estimated at about 3.2 MEuros. The DAΦNE accelerator physics expert team is understaffed to continue operation support beyond 2023 and recruitment of physicists or engineers with the necessary expertise appears to be particularly difficult. The maintenance budget is of the order of 500 kEuros/year. The present electricity cost for operating the DAΦNE complex is approximately 5 MEuros/year (of which approximately 80% is required for the DAΦNE accelerator alone) and it is expected to increase because of the international situation.

Findings BTF/LINAC:

- Following the commissioning of the second beam line (BTF-2) radiation protection measurements identified an insufficient roof shielding of the BTF Experimental Hall 2 (BTFEH2) requiring its reinforcement during winter. This implied the re-scheduling of some users to BTFEH1: one of them, ERAD, testing radiation resistance for aerospace components, is funded by the Lazio region. A third and final run for this user is scheduled in July 2022.
- In February, Klystron A had to be replaced to maintain the power required for positron production and acceleration. The recovery after the intervention was hampered by vacuum problems that further delayed the restart. The status of Klystron C (faulty vacuum window), limiting the maximum repetition rate to 25 Hz (to be compared with the nominal value of 50 Hz) and power (34 MW) is of concern, and it constitutes a potential risk for DAΦNE operation in 2023.
- The BTF/DAΦNE schedule in 2022 was presented: it foresees DAΦNE operation until the summer stop, followed by the PADME run. The LINAC team is concerned by the amount of time and

resources required for the setting-up of primary positron beams of different energies for PADME. Particularly demanding is the specification of an energy spread of the primary beam significantly smaller than the energy difference between energy steps. Performance, reproducibility and workforce considerations might favor the choice of delivering a secondary beam, though with a potentially higher background to the experiment.

- In case PADME would need beam (at DAΦNE injection energy) for detector setting-up in September 2022, the BTF/LINAC team suggested that the LINAC could serve DAΦNE, in parallel. This could be considered as an option.
- We commend the commitment of the BTF/LINAC team in addressing the issues encountered in the first part of the year and in supporting an extremely varied programme.

Findings SIDDHARTA-2:

- Since the last SC meeting in Nov 2021, the collaboration reports the publication of the SIDDHARTINO K-He results on J. Phys. G49 (2022) 5, 055106, the submission of a publication to Nucl. Phys A, as well as about a dozen contributions to international conferences and workshops.
- The SC commends the collaboration for these scientific results and publications as well as for the remarkable performance of the SIDDHARTINO setup, which is a very promising towards the major goals of the experiment.
- Following the request raised in the previous SC meeting, concerning the minimum integrated luminosity required to get sensible results for the kaonic deuterium measurement, the collaboration notes that their Monte Carlo simulation for an integrated luminosity of 800 pb^{-1} resulted in an achievable precision of 30 and 80 eV for the shift and width of the K-d ground state (similar as for K-p). However, these numbers depend on the still unknown yield and it is thus estimated that no less than 500 pb^{-1} would be required to make this measurement significant.
- Concerning SIDDHARTA-2, the collaboration has performed several debug and optimization tasks without beam (SDD calibration, DAQ, change of cryo-lines…) and the installation and calibration of the HPGe detector.

- They resumed the K-He runs in April 2022, with the full setup. Simultaneously they carried out further debugging of the trigger and luminometer, as well as degrader optimization and veto trigger calibration.
- Until mid-May 2022 they have gathered approximately 25 pb^{-1} and were able to present to the 63rd SC Meeting their first preliminary K-He results with 12 pb^{-1}, as well as an analysis providing the most precise K-Al (7→ 6) line measurement to date. This, together with the confirmed improvement in precision of the K-He spectrum, should lead to two new scientific publications. At the time of the SC meeting the SIDDHARTA-2 collaboration was still collecting data on Helium and finishing the experiment calibration, in particular of the VETO systems.
- In addition, they have obtained, without any damage in the HPGe detector, the first spectrum showing a spectacular positron annihilation peak. With these data and a full GEANT 4 simulation, but without considering all backgrounds, it has been estimated that the 5 keV precision in the determination of the kaon mass could be attained with 480 pb^{-1}. This points towards the feasibility of the collaboration goal, once they obtain the planned integrated luminosity and take the extra backgrounds into account.
- The SC congratulates the collaboration for its sustained efforts towards the installation of the full SIDDHARTA-2 setup and in obtaining the first scientific results.

Recommendations DAΦNE - BTF/LINAC - SIDDHARTA-2:

- *DAΦNE should aim at reaching 100 pb^{-1} before the summer closure. During 2023 additional 700 pb^{-1} should be delivered.*
- *To this end, the SC supports an immediate action to improve the DAΦNE luminosity and backgrounds, as proposed by the DAΦNE team. Ideally this should take place during the helium run of SIDDHARTA-2, in order to then profit from the maximum luminosity for the K-d run.*
- *In case the PADME detector set-up should continue in September, the SC recommends considering the option that the LINAC could serve both PADME and DAΦNE to deliver some additional integrated luminosity to the SIDDHARTA-2 experiment.*

- *The beam studies to decide on the most effective way to deliver the positron beam for the PADME run should be performed as soon as possible, compatible with the DAΦNE and the other BTF users' runs.*
- *A risk analysis concerning the possible failure of Klystron C should be conducted and mitigation or intervention plans should be established in view of the 2023 BTF/DAΦNE run.*

1.2 PADME

Findings PADME:

- The PADME team has submitted two papers recently. The first paper describes the PADME beam line Monte Carlo simulation, the second paper describes the commissioning of the PADME experiment with a positron beam. Both papers are vital for the data analysis and lay an important foundation for future papers.
- The gamma-gamma cross section analysis is completed, and a paper draft is currently circulating in the collaboration. It is expected that the manuscript will be submitted before the Summer.
- The dark photon analysis is ongoing and looks promising. The gamma-gamma analysis was an essential stepping-stone for this analysis. Some cuts will have to be further optimized to suppress the large background, but the collaboration is confident that the largely data-driven approach will succeed.
- The collaboration is preparing for Run-3, with the explicit goal of investigating the reported X17 boson. Around 20 energy steps will be done around 280 MeV positron beam energy to look for a possible resonance. PADME will be run without its dipole magnet, in a purely calorimetric setup. The collaboration is completing a new tagging detector that will be placed in front of the ECAL. Almost all components for the new detector are in-hand, the expectation is that it will be completed at the beginning of July. The collaboration will need about two days to install the tagger and is willing to do it over a weekend in-between two BTF runs, when BTF-users are moving their equipment in and out.
- The experiment will need some BTF beam time to decide on the beam (Primary vs Secondary) and to do energy-spread studies.
- The X17 Run-3 could start in September and continue until December. Each beam energy step will need about 10^{10} POT. Some

additional studies, such as multiple measurements at the same energy spread over Run-3 will be necessary in order to fully understand the systematics.

Recommendations PADME:

- *The SC is happy to see the submission of the two recent papers and is looking forward to the paper reporting on the gamma-gamma cross section measurement.*
- *The dark photon analysis should be completed.*
- *LNF has a unique facility and experiment to search for the X17 boson, complementary to the other searches. The timing for this search is excellent and the SC recommends granting PADME BTF time before the summer break to perform the necessary beam studies and fully endorses Run-3 for PADME in the fall.*

1.3 KLOE

Findings KLOE:

- Last January, the KLOE2 collaboration completed data reprocessing, reconstructing 5.1/fb with version DBV-40. The MC simulation with version DBV-40 for an expected total of 4.7/fb will be finished in the next seven months - 200/pb missing. The data moving from the old library is over and the experiment restarted the data preservation procedure.
- A ROOT output production (now 2/fb are available – with the full dataset to be completed in four months) allows for fast access to reconstructed data on four different streams: Charged Kaons, Neutral Kaons, Rho-Pi and Radiative, later a Bhabha stream will be added. The aim is to facilitate new collaborators to join and contribute by even proposing new analyses.
- Of the six more advanced analyses, four were published and two have approved results ready to be published. There are ideas for new analyses. The SC commends the collaboration for these achievements.

Recommendation KLOE:

- *In order to promote new analyses and attract new collaborators a dedicated workshop should be envisaged at LNF.*

2. SPARC_LAB and EuPRAXIA@SPARC_LAB activities

Findings SPARC_LAB:

- The new RF injector of Sparc_lab has been successfully commissioned. With the new injector, a systematic study of beam quality with blue vs. UV cathode laser (i.e. 2nd vs. 3rd harmonic of TiSa laser) was performed. The results indicate a slight advantage for the UV, probably because of the smaller energy excess of the single photon photoemission in comparison with the two-photon process for blue light.
- For the beam driven plasma acceleration a comprehensive upgrade program is in progress. New focusing systems with permanent magnet quadrupoles have been installed and implementation of longer capillaries is in progress, with the overall goal to push the accelerating gradient as well as the total plasma acceleration to higher levels.

Comments SPARC_LAB:

- The SC applauds the publication of "Free-electron lasing with compact beam-driven plasma wakefield accelerator" in Nature vol. 605, which documents the quality and importance of the SPARC_LAB activities and is well in line with LNF's tradition to be a leading laboratory for accelerator R&D.
- The SC appreciates again that the SPARC_LAB team has considered all recommendations from the 62nd SC meeting report and given competent response to the recommendations.
- As follow-up of the SC report #62 recommendations the SC concurs with the SPARC_LAB strategy not to prioritize an upgrade of the K2 modulator but rather to explore what are the most promising approaches to improve RF phase stability relative to the reference signal.
- The SC is looking forward to plasma acceleration results with the up-graded set-up.
- The SC would appreciate to get, in a future meeting, more information how the EXIN effort for laser driven plasma acceleration integrates with the overall EuPRAXIA strategy.

Recommendations SPARC_LAB:

- *Execute your plans for the next run as presented. No specific other recommendations.*

Findings EuPRAXIA:

- The application to the ESFRI Preparatory Phase was approved on April 12, 2022. Applications for further grants are in progress.
- With SPARC_LAB and the recently implemented TEX facility for X-band RF testing the key test facilities for EuPRAXIA@SPARC_LAB are now both available.
- The design activities on the large variety of technical systems are progressing well and in mutual interaction with the SPARC_LAB and TEX facilities. The building design is almost completed and has been successfully reviewed last December.
- The project schedule planning made good progress.
- The project preparation phase will officially start on November 11.
- Most aspects for the 400 Hz option have been studied and so far, no showstoppers have been identified. Further studies and tests will clarify if 400 Hz can be made the baseline repetition rate.
- A SWOT analysis of the two X-band power source options has been performed. Although one option shows a slight advantage both options will be tested in TEX. The SC concurs with this approach.

Comments EuPRAXIA:

- The SC appreciates that the EuPRAXIA team has considered all recommendations from the 62nd SC meeting report and given competent responses to the recommendations.
- Further clarifications of the long-term schedule and resource needs of all LNF accelerators is a boundary condition for a successful *EuPRAXIA@SPARC_LAB* project execution.

Recommendations EuPRAXIA:

- *The implementation part of the EuPRAXIA@SPARC_LAB schedule needs further refinement. In particular, the assumptions on procurement have to be adjusted for sufficient margins. Typical procurement times for long lead items as well as the current issues with supply chains need to be considered in this context.*

- *The efforts to develop the future photon user community of EuPRAXIA@SPARC_LAB have to continue.*
- *Implementation of the staffing plan for EuPRAXIA@SPARC_LAB needs the full attention of the LNF management. This is not only a question of funding but also needs efforts to make project posts attractive for highly qualified experts. In particular, clarifying the perspectives for long-term employment early on in the hiring process could facilitate this process.*

3. ColdLab

Findings:

- The ColdLab group is searching for axions. The team is currently working on the QUAX-series of experiments at LNF and LNL and preparing for a possible future FLASH detector at LNF. The relatively small group is also involved in developing several technologies that are related to superconducting devices.
- The running QUAX experiment is searching for axions with a 10 GHz cavity, making it sensitive to 35-50 μeV axions. There were several new developments over the past period, such as the arrival of a new magnet, new tuning rods, construction of a new cavity etc.
- A promising idea is to use the Finuda magnet, installed in the DAFNE hall, for a new experiment called FLASH. This would allow for a scan in the 100 MHz range, looking for 0.5 μeV - 1.5 μeV axions. The group has recently completed a detailed simulation, showing that the experiment could reach a sensitivity at the QCD axion scale. This experiment is complementary to other axion experiments currently running or in planning stage.
- The Finuda magnet has not been operational since 2007, the group has made a detailed plan to test this magnet. This is an essential step in determining if it is feasible to continue the pursuit of the experiment. It requires the installation of various insulated lines and refurbishment of valves, power supplies etc. The refurbishment is straightforward and could be completed by January 2023.
- The Finuda magnet is in the DAFNE hall and work on a possible experiment would interfere with DAFNE beam operation. The engineering team has determined that it is not possible to move the

magnet out of the hall or put up the necessary shielding around the magnet.

Recommendations:

- *The SC is impressed by the progress and impact that the ColdLab team has made.*
- *The science case for FLASH is strong and the large Finuda magnet bore would give a world-class and unique experimental facility for the search of axions.*
- *The SC fully supports the proposed plan to investigate the state of the Finuda magnet and testing it.*

4. Next Meetings

November 14-15, 2022 and May 9-10, 2023.