CLEAR SCIENTIFIC BOARD REPORT
23/2/23

The CLEAR Scientific Board (CSB) met on 1/2/23 in order to review the achievements of the 2022 CLEAR run, take stock of the proposals for beamtime in the 2023 run, and examine options for future running of the facility. Presentations and background information can be found at https://indico.cern.ch/event/1246404/. A brief summary of findings and recommendations is presented below.

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1. Introduction

CLEAR started operations in August 2017 and has since been serving a growing number of users annually. CERN reviews were held in 2019 and 2021 and operation is currently approved (and in the MTP) through to the end of 2025. CLEAR is a 'standalone' installation which gives flexibility for operations. In a typical year 30-40 weeks of beam operation are provided between March and December with a short summer stop, usually via 2 shifts per day, 5 days per week. The operation team is lean, and comprises 1 staff, 1 fellow, 1 PDRA and 2 PhD students, plus one remotely-based associate.

User requests are made formally via a beamtime request form, and typically there follows a productive discussion between the proponents and the CLEAR team so as to better understand and define the user requirements. An EDMS infrastructure has been set up to allow convenient review of requests by the CSB. A final decision on implementation and scheduling of the request is made by the CLEAR Technical Board.

2. Scientific accomplishments of 2022 beam operations

In 2022 more than 20 user experiments were served during 37 weeks of operation. Scientists from 15 institutes, in addition to CERN, benefitted from beamtime, which led directly to 18 conference papers, 5 journal papers, experimental data for 7 PhD theses, and numerous presentations. It should also be noted that CLEAR is an important facility for training and outreach. In 2022 20 CERN tours and visits (including 'VIP's as well as journalists, companies, and artists) were hosted; CLEAR was mentioned in 5 international press articles as well as 4 internal CERN articles; students attending the Joint Universities Accelerator School (JUAS) spent a training week operating the facility.

Finding 1: User experiments capitalize on the unique CLEAR capabilities and address a broad range of accelerator-based science that spans advanced accelerator technology development, beam diagnostics, beam-based therapy and medical applications, and irradiation.

Finding 2: The CSB commends the CLEAR operations team for delivering the excellent scientific programme and efficient operation of the facility. Access to beamtime for users is managed very efficiently and smoothly so as to maximize the overall scientific output. The CSB notes that the team is very lean.

Finding 3: The CSB notes that, in addition to delivery of its main scientific mission, CLEAR represents an important CERN facility for training and outreach.

We comment briefly below on the main areas of scientific activity advanced in the 2022 run.

Beam diagnostics experiments

In 2022 five user experiments with a focus on beam diagnostics were performed, namely

a) Optical BLM tests (U. Huddersfield)
b) ChDR BPM tests (U. Oxford)
c) ChDR – based bunch length measurement (U. Manchester)
d) Electro optical sampling of ChDR (TU. Vienna)
e) Rad-hard fibres tests for FLASH and CERN Exp. Areas

All but the last in the list are part of a PhD project. Experiments b) and c) are instrument tests for AWAKE, e) is aimed for FLASH-Therapy applications (see also below), and a) and d) are more generic developments. 2023 beamtime requests for follow-ons to three of these experiments have already been filed.

Finding 4: The experiments are well in line with two of the key strategic goals of CLEAR, namely "Performing R&D on accelerator components" and "Providing a training infrastructure for the next generation of accelerator scientists and engineers".

Finding 5: The beam instrumentation techniques tested at CLEAR have many challenges in common with methods developed at FEL facilities in and outside the CERN member states; scientific exchanges between the respective user groups and FEL instrumentation groups, through workshops and conferences, would be beneficial.

Medical experiments

The activity report delivered by the CLEAR team regarding medical application was structured in 4 main steps performed in close collaboration with the users. Preparation of the beam for pre-clinical experiments (stability, size of the beam, optimization of the parameters) typically requires one day of preparation performed by the CLEAR team, subsequently 2 sessions of irradiation can be performed each day. The team has performed the:

1- Optimization of beam delivery. Operations have been optimized with the implementation of a heated water bath and a robot (c-Robot) for high throughput experiments. c-Robot enables irradiation of more than 30 samples at the same time under visual (camera monitoring) and dosimetric control. New holders are being tested to increase the number of samples to be irradiated in one session up to 70.
2- Optimization of the dosimetry using combination of passive dosimeters. Relative dosimetry is now available with an uncertainty in the range of 5%. More developments are ongoing in collaborations with users.
3- First preclinical experiments using chemical systems. Water and plasmid irradiation have been successfully performed. Some results have already been published (Small et al. 2019, Sc, Report), others were presented in conferences in 2022 and should be published in 2023.
4- First preclinical experiments using bio-dosimeters (eggs of Zebrafish and Flies) are ongoing and require some refinements.

Finding 6: CLEAR is currently a unique facility for addressing topical issues for medical applications via a range of user experiments.

Advanced accelerator technology experiments

In earlier years, though not in 2022, dedicated experiments related to CLIC, plasma-wakefield acceleration (including AWAKE), and THz-based acceleration were performed.

Finding 7: The CSB encourages groups working on these topics to resume relevant activities at CLEAR and reinforce their links and synergies with AWAKE and EUPRAXIA in areas of R&D of common interest.

3. Scope of beamtime requests for 2023 operations

Roughly 40 weeks of beamtime operations are planned in 2023. To date a total of 32 'requests' had been identified. A number of requests are for follow-on experiments from previous years, and two are carried forward from 2022 (due to the earlier-than-planned CLEAR shutdown). The requests originate from teams led by user institutes (18), CERN (12), and companies (2). The requests can be categorised as: beam diagnostics (13), medical applications (13), accelerator technology development (5), and irradiation (1). Many requests comprise multiple beam operation periods and/or experimental setups; however, a number of the requested experiments can be performed in parallel. A provisional analysis yields a total of 182 'beam days' including 87 (medical), 65 (diagnostics), and 29 (accelerator development), not including time for preparation/set up or machine development. A detailed run schedule will be prepared but it already seems clear that the in-hand requests can be expected largely to fill the available beamtime.

Finding 8: Based on the 2022 and earlier runs, the SB has full confidence that the CLEAR management will attempt to schedule the requests so as to optimise the use of the beamtime and maximise the scientific outcomes.

Recommendation 1: The CSB recommends that a second call for 2023 beamtime requests be advertised promptly, with a definite deadline. Should this result in a serious over-subscription for the planned beamtime the SB recommends that proposals be evaluated on their merits (see below) and prioritised accordingly. The SB recognises that late requests can (inevitably) occur and recommends that they may be given consideration, subject to the constraints defined by the available beamtime and machine setup.

Recommendation 2: The CSB recommends that in the evaluation of beamtime requests the following criteria (not listed hierarchically) be taken into account:

- Scientific/technical excellence of the proposed research.
- Capitalisation on the unique capabilities of CLEAR.
- Compatibility with the beam parameters and machine setup possible at CLEAR.
- Direct support of CERN's scientific mission, including (where applicable) strategic partnerships with other institutes.
- Support (where applicable) for Trans-National Access (TNA) to CLEAR.
- Enhancement of stewardship of electron beamline expertise at CERN.
- Training of personnel, notably early-career researchers.

The CSB affirms its readiness to provide, where desirable, rapid feedback on beamtime requests.

Recommendation 3: The CSB recommends that an appropriate number of machine-development days be scheduled so as to maintain and enhance the CLEAR capabilities for serving current and future users.

Recommendation 4: The CSB recommends that efforts be made to increase modestly the size of the operation team for 2023, so as to widen the expertise pool and avoid excessive load on operators. One possibility is to seek additional involvement of associates from collaborating institutes that engage in the user experiments.

4. Future operations

The CLEAR operation is currently approved until end 2025. An internal CERN review is planned for 2023/2024, with one of its main objectives the evaluation of the future of the facility beyond 2025.

The user requests for experiments at CLEAR have expanded well beyond what was foreseen in the original proposal in 2016. First, the external and internal user activities related to accelerator technology developments for existing and new accelerators, beam dynamics and diagnostics, irradiation campaigns, novel accelerator technologies, and training are largely in line with the ambitions and goals presented in the original proposal, and have been carried out successfully. Secondly, the user community and requests for experiments related to medical studies and dosimetry development far exceed expectations, primarily driven by intense interest in VHEE and FLASH therapy. Finally, new ideas not fully developed in 2016, such as neutron production and an Inverse Compton Scattering (ICS) facility based on compact electron linacs, are foreseen to be tested and bench-marked at CLEAR in 2023-25.

Finding 9: The CLEAR programme fulfils the promise and goals outlined in the original 2016 proposal across a wide range of R&D studies. The user community is significantly larger than original foreseen, notably in the areas of medical studies and dosimetry.

Two obvious possible extensions to the facility are being considered: 1) installation of an additional experimental beamline so as to increase user space, and 2) installation of a new e-source which would allow very flexible drive- and probe-beam experiments, which, if combined with an extra beamline, would provide enhanced beam capabilities for users. Such a source, based on an RF injector built by INFN-LNF in the framework of the CLIC collaboration combined with an X-band structure, is being assembled in CTF2. It could either be moved to CTF3 for a period, or become a standalone ~60-70 MeV facility with its own scientific programme, and/or a potential e-source for AWAKE at a later stage. CLIC, AWAKE and CLEAR are all contributing to development of this source.

Finding 10: Several possibilities exist, and are already partly prepared, for extending the capabilities of the CLEAR facility. These expansions are not critical for the current programme as foreseen in 2023, but do represent opportunities for operations in 2024 and beyond.

One of the most critical factors in determining the future of CLEAR, beyond the science potential, user interest and training opportunities, is the strength and resource needs of its operational team. CLEAR users can already be supported by a EURO-LABS TNA. Such schemes, including training for students and technical and scientific personnel, as well as support for networks of small research facilities, are priorities in near-future EU programmes. R&D with relevance for EUPRAXIA, i.e. plasma lenses, could also be supported by EU programmes. Medical studies are high priority in EU and national research programmes. All of these, and more, are potential ways to increase external support of the facility.

Finding 11: The operational team of CLEAR is already lean and at this stage, looking beyond 2025, in several important cases the availability of personnel is not completely secure.

Recommendation 5: An upgrade strategy, with options, should be prepared during the coming year such that the potential extension of the CLEAR programme beyond 2025 can be evaluated, taking into account the potential offered by these upgrades.

Recommendation 6: Strengthening the operational team with external resources, potentially linked to training of external personnel spending significant time in CLEAR, should be pursued with high priority. External resources, for example EU projects, can also in some case support more user projects, research and activities.

Recommendation 7: Even if externally-supported projects have a high potential for growth, it is important that projects that are critical for on-going CERN priorities, for example instrumentation tests for HL-LHC, development of future particle physics technologies, as well as activities preparing CERN for a future electron-positron Higgs Factory facility, are supported with high priority.

Recommendation 8: The potential for using CLEAR for studies related to accelerator sustainability (e.g. higher-efficiency RF systems, permanent magnets) should be further investigated and taken into account in future reviews of the facility.

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