Some information about CALIFES and preliminary ideas for its use.

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Abstract

In this document we propose to operate the CALIFES electron linac at CERN, presently used as the probe beam line of CTF3, as a stand-alone user facility from 2017 onwards. The possible uses include general accelerator R&D and studies relevant for existing and possible future machines at CERN, involving a potentially large external user community.

1. PROPOSAL

We propose to adapt the CALIFES linac, presently part of the CTF3 facility (see chapter 2 below), to serve as a new user facility at CERN from 2017 onwards.

A small electron linac of this type can address the following goals (more details in chapter 4 for each point):

- Advancing high-gradient electron-based energy-frontier accelerator R&D (normal conducting and potentially superconducting).
- Enabling beamline and instrumentation component tests aimed at consolidating and upgrading the CERN accelerator complex, in particular the LHC
- Supporting strategic partnerships with other science fields in Europe that need electron-beam test capability, namely X-ray FELs, medical, space and industrial communities.
- Providing a unique and complementary test capability that serves CERN's European (and worldwide) user community in key areas of accelerator R&D.
- Maintaining an accelerator training capability, unique at CERN, for training the next-generation of accelerator scientists and engineers.

We consider that the proposed programme, at ~2 MCHF/year (M+P), with a similar amount of initial investment, could provide the opportunities outlined above. The facility will use 1/3 of the existing CTF3 area and ~80 % of the required equipment is available.

Implementing this proposal would establish a versatile small facility that is strategically sound in any conceivable future CERN scenario, with an R&D scope across many projects.

2. THE CALIFES linac

CTF3 contains the drive beam linac, delay loop and combiner rings, as well as the CALIFES probe beam linac. The CALIFES linac (Figure 1) produces electron beams with a wide range of parameters (Table 1). Of particular note are the low emittance, short bunch length, and range of bunch charge capabilities, available in single- or multi-bunch trains. CALIFES provides vital beam test capability at CERN, which can also, crucially, be available during both LHC operational periods and LHC shutdowns.

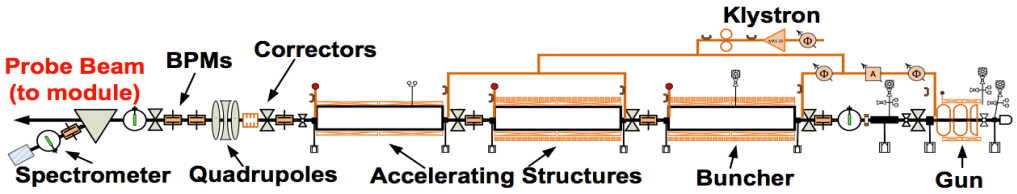

Figure 1: The current CALIFES beam line. The length of the facility (as shown) is ~20m.

Beam parameter (end of linac)	Value range
Energy	80 - 220 MeV
Bunch charge	0.01 - 1.5 nC
Normalized emittances	2 um in both planes
Bunch length	300 um -1.2 mm
Relative energy spread	1 %
Repetition rate	1 - 5 Hz
Number of micro-bunches in train	Selectable between 1 and >100
Micro-bunch spacing	1.5 GHz

Table 1: CALIFES parameters.

3. Main elements of a possible future programme

Following consultation with the relevant communities (see ref [1]) we conclude that such a facility can serve a number of strategic uses and engage a large user community (also beyond CERN) that has already expressed interest in it.

Three primary R&D areas linked to existing and possible future accelerators at CERN are identified:

- **High-gradient energy-frontier R&D:** Beam tests of next-generation high-gradient accelerating structures are required to progress the CLIC project preparation for the next European Strategy exercise. This activity will also enable further industrialisation studies of high-gradient structures, which have broader relevance e.g. to FEL-based light sources, as well as applications in industry and medicine. SCRF structures can also be tested if such tests are relevant for the R&D in this field; cryogenics systems are however not present in the area and would require some additional effort.
- **Beam instrumentation tests**: LHC and CLIC require development of state-of-the-art beam instrumentation devices: high-precision beam position monitors; transverse emittance and bunch length monitors, including UV, optical, and X-ray monitors and related imaging techniques; beam halo, beam loss, beam breakdown and luminosity monitors. Such devices will also be needed for FCC and AWAKE.
- **Impedance studies**: Impedance qualification of components is required prior to installation in CERN beamlines, in particular the PSB, PS, SPS and LHC, but also the AD and ELENA. CALIFES can allow direct measurements of beam-generated electromagnetic effects, including longitudinal and transverse wake functions (via the drive-/probe-bunch method), inter-bunch cross-talk, and beam-induced heating.

The facility can support European accelerator R&D in three other key areas:

- **Plasma wakefield (PWFA) R&D:** There is intense worldwide interest in plasma-based particle acceleration. The CALIFES beam combined with a plasma source with a density of $\sim 10^{14}/cm^3$, available from external collaborators, would provide a complementary facility for demonstrating key concepts such as emittance preservation in a PWFA linear collider. Electron experiments at CALIFES would be complementary to the proton driver experiments at AWAKE.

- **FEL linac studies:** There is rapidly growing worldwide interest in FELs and CLIC X-band technology offers the prospect of more compact (and cheaper) linacs. An international collaboration is currently undertaking a design study for such a compact FEL. In addition to the high-gradient structure tests, CALIFES offers the capability for component tests and technology demonstrations, needed to demonstrate high peak current and good beam quality, which are not normally possible at operating user facilities. These include phase-space linearizers, transverse deflecting cavities (for bunch length diagnostics and RF spreaders) and wakefield monitors. More generally, all future LC technologies (NC and SCRF, plasma) are expected to be initially implemented in FEL linacs, and connecting to the FEL project developments in an effective and constructive manner is strategically very important.
- **Training:** There are relatively few accelerator facilities worldwide where significant time can be made available for 'hands-on' training of students and junior staff. CALIFES can continue to provide such opportunities in the context of a cutting-edge R&D facility with often extreme beam-performance demands. Remote running of the facility would be a possibility; this would require control and operation system development, and offer training potential locally for outside users and students.

Some more specific possibilities have also been identified:

- **Irradiation tests:** Electronic devices for use in extreme environments need to be qualified for radiation-damage effects. For example, the ESA JUICE spacecraft will be located in a severe environment of high-energy electrons with energies extending up to a few hundred MeV. CALIFES can provide relevant electron-beam energies and fluxes for such tests that are otherwise not available today.
- **Medical:** Low-energy (10-100 MeV) electron-beam therapy for certain specialised applications is an area of growing medical interest, and CALIFES could offer relevant beam test capability. The production of X-ray pulses for imaging and treatment remains of high interest. More compact electron-beam sources, e.g. based on X-band technology, could offer significant cost/footprint advantages for hospital-based (commercial) X-ray facilities.

Other possible uses are also under consideration.

4. Uniqueness and complementarity

There are electron linacs in Europe with similar beam parameters; these are, however, in general in continual use as injectors for light sources or as FELs. As such, major strengths of the proposed CALIFES facility are its availability for R&D, the supporting CERN infrastructure for RF and instrumentation development, the low marginal cost and easy local access, and the flexible adaptability to specific experiments and future developments. It would, in addition, provide complementary capability to existing R&D beamlines such as ATF and FACET, or plasma R&D facilities in the pipeline, and not compete with them.

5. Possible next steps

This proposal was originally worked out in response to questions from the CLIC Collaboration Board and CTF3 users about future test-facilities for X-band and instrumentation studies. However, CALIFES is considered a possible user facility at CERN in a much wider context that for High Gradient studies alone, and other potential users inside and outside CERN were consulted during the preparation phase (ref [1]). A workshop focusing on possible uses of the beamline, with participation from the widest possible community, is planned autumn 2016, before a final decision can be made about setting up the facility.

REFERENCES:

CLIC workshop Jan. 2015: https://indico.cern.ch/event/336335/timetable/#20150127
CLIC Project Meeting October 2014:
https://agenda.linearcollider.org/event/6389/session/18/#20141009
CLIC Project Meeting December 2014: https://indico.cern.ch/event/356495/
CLIC Project Meeting March 2015: https://indico.cern.ch/event/379754/