CALIFES to CLEAR, 2017+ status update

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CLIC Project meeting, November 29, 2016

Background

- CTF3 on schedule to reach its main objectives by the end of 2016. **Scheduled to shut down end of 2016**
- We have proposed to continue the operation of the electron probe beam, CALIFES, beyond 2016
- Initial statement of interest to CERN management fall 2015
    - A more detailed proposal sent, on management's request, Feb 2016. This proposal included statements of interests from interested parties
- Proposal presented at **CLIC Review March 2016**
- The review committee gave **encouraging remarks**, but were worried about the resources needed
- Review committee also **advised to hold a workshop** to map the interest of users (internal to CERN and external institutes), also with respect to other electron test beam lines available

CALIFES Workshop 2016

10-12 October 2016
CERN
Europe/Zurich timezone

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- CALIFES Parameters and Information

Administrative Support

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It has been proposed to convert the 200 MeV S-band electron linac CALIFES, currently being part of the CLIC Test Facility 3 (CTF3), into a new general stand alone electron beam facility at CERN.

The foreseen use of such a facility is not linked to any particular project or technology. On the contrary we seek input and ideas from the widest possible user community about its use. This workshop is organised to explore the potential accelerator R&D programme at such a facility. The purpose is 1) to collect ideas, suggestions and proposals for accelerator R&D topics, including 2) ideas for possible improvements of the beam line itself beyond its initial configuration. It is also important to explore possible collaborations, complementarity or overlaps with other European electron beam facilities.

For the purpose of the workshop the period 2017-2021 will be considered, following the completion of the overall CTF3 programme by the end of 2016.

The workshop will be divided into a number of sessions, led by a session chair :

1. High gradient research (Walter Wuensch, CERN)
2. Beam instrumentation (Thibaut Lefevre, CERN)
3. Light source related R&D (Sven Reiche, PSI)
4. THz radiation (Massimo Petrarca, University of Rome "La Sapienza" and Roma1- INFN)
5. Impedance measurements (Benoit Salvant, CERN)
6. Plasma wakefield acceleration (Erik Adli, University of Oslo)
7. Radiation tests (Markus Brugger, CERN)
8. Other ideas, including for long term facility improvements (Roberto Corsini, CERN)
9. Education and training (Carsten Welsch, University of Liverpool).

The workshop will be followed up by a summary document, including and based on short written reports from the session chairs, covering the ideas, proposals and discussions in the respective sessions. This will provide a basis for CERN's decisions about a potential implementation of the facility.

- Workshop was a **success**: 97 participants from different laboratories came to present their ideas and wishes for how to use the CALIFES beam (~50 talks)
- A workshop report is about to be submitted to the CERN management
- Final decision expected around the turn of the year
- After a vote the **name CLEAR - "CERN Linear Electron Accelerator for Research"** - was proposed for the new test facility
- Preliminary program set-up for 2017, **Re-start planned around May 2017.**

Appendix D: Agenda of the workshop October 10-12 with links to talks

High-gradient research

Walter Wuensch (CERN), Introduction

Marek Jacewicz (U. Uppsala),

From Two-to-One beam test stand

Frank Tecker (CERN),

The effect of beamloading on breakdown rate

Benito Gimeno (U. Valencia), Induced multipactor experiments satellite communication development

Frank Gerigk (CERN), Superconducting RF Structures R&D and testing with beam

Light source related R&D

Sven Reiche (PSI), Introduction

Jim Clarke (STC), CLARA needs and XBand Testing

Andrea Latina (CERN), XBand FEL Project

Jurgen Pfingstner (U. Oslo), FEL THz pump

Impedance measurements

Benoit Salvant (CERN), Introduction

Andrea Latina (CERN), Experience from FACET impedance measurements and application to CALIFES

Lee Robert Carver (CERN), CALIFES for impedance measurements

Wilfrid Farabolini (CEA), Charge dependent effect in CALIFES

Beam instrumentation

Thibaut Lefevre (CERN), Beam Diagnostics R&D

Stewart Boogert (U. London, Royal Holloway), BI developments for CLIC/Hilumi

Reidar Lunde Lillestol (U. Oslo), CLIC Wake-Field Monitor experimental Tests

Stefano Mazzoni (CERN), Optical Transition Radiation Interferometry (OTRI) experiment in CALIFES

Plasma wakefield acceleration

Erik Adli (U. Oslo), Introduction

Edda Gschwendtner (CERN), AWAKE plans and possible use of CALIFES

Nelson Lopes (IC London and IST Lisbon), Discharge source

Carl Lindstrøm (U. Oslo), Apochromatic plasma lens lattices

Sebastien Corde (Ecole polytechnique and LOA), Emittance preservation studies

Spencer Gessner (CERN), Plasma-based bunch compression techniques

Guoxing Xia (U. Manchester), Compact plasma based beam dump

Oznur Mete (U. Lancaster), Existing equipment at Cockcroft Institute; emittance growth due to scattering in plasma.

THz radiation

Massimo Petrarca (U. Rome "Sapienza", INFN LNF), Introduction

Thibaut Lefevre (CERN), THz radiation using Diffraction Cherenkov radiation

Steven Patrick Jamison (STFC), THz deflector + DATA

Vitaliy Goryashko (U. Uppsala), Unipolar Pulses of Light from a Tapered Undulator

Alessandro Curcio (INFN LNF), THz Shaping

Massimo Petrarca (U. Rome "Sapienza", INFN LNF), THz R&D and Conclusions

Radiation tests

Markus Brugger (CERN), Introduction

Ruben Garcia Alia (CERN), Radiation test challenges with high-energy electrons

Maris Tali (CERN), VESPER status and outlook

Agnese Lagzda (U. Manchester), Very High Energy Electron (VHEE) Simulations and Planned Experiments for a Potential New Paradigm in Radiotherapy Treatment

Education and training

Carsten Peter Welsch (CERN), Introduction and ITN

Philippe Lebrun (JUAS and CERN), JUAS

Wilfrid Farabolini (CEA), Experience from JUAS

Steven Patrick Jamison (STFC), Cockroft DATA project

Long-term facility improvements

Roberto Corsini (CERN), Ideas for medium and long term facility upgrade

Wilfrid Farabolini (CEA), CALIFES past experience as a user facility

Steffen Doebert (CERN), Very short bunches, possible injector for AWAKE or CALIFES

Yannis Papaphilippou (CERN), Damping Ring Injector

Introduction

Steinar Stapnes (CERN), Welcome

Roberto Corsini (CERN), CALIFES description

Erik Adli (U. Oslo), Practical information

Closing session

Steinar Stapnes (CERN), Workshop summary

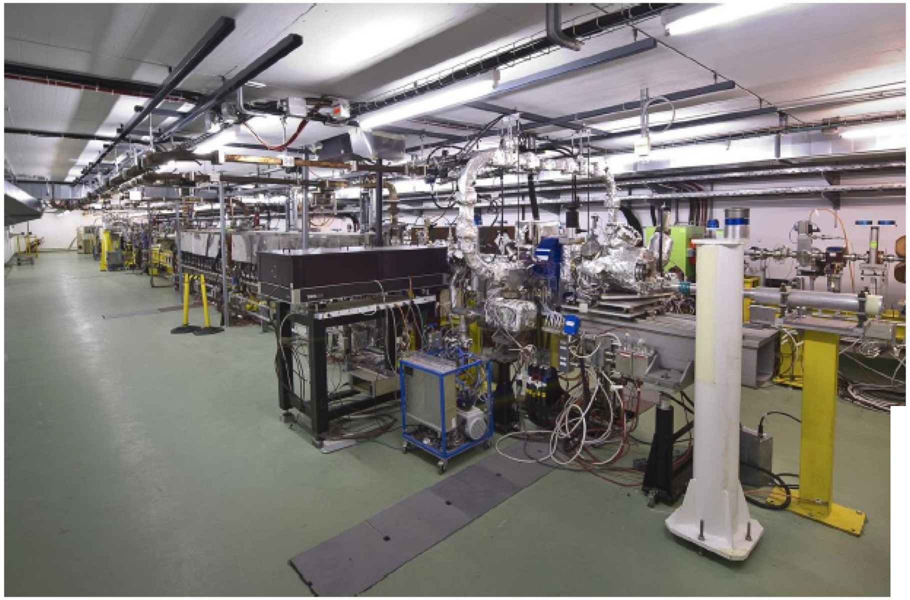
Erik Adli (U. Oslo), Session summaries

Roberto Corsini (CERN), Thoughts for 2017

CALIFES visit

F. Tecker (CERN) and G. Mcmonagle (CERN)

The CLEAR[1] facility at CERN



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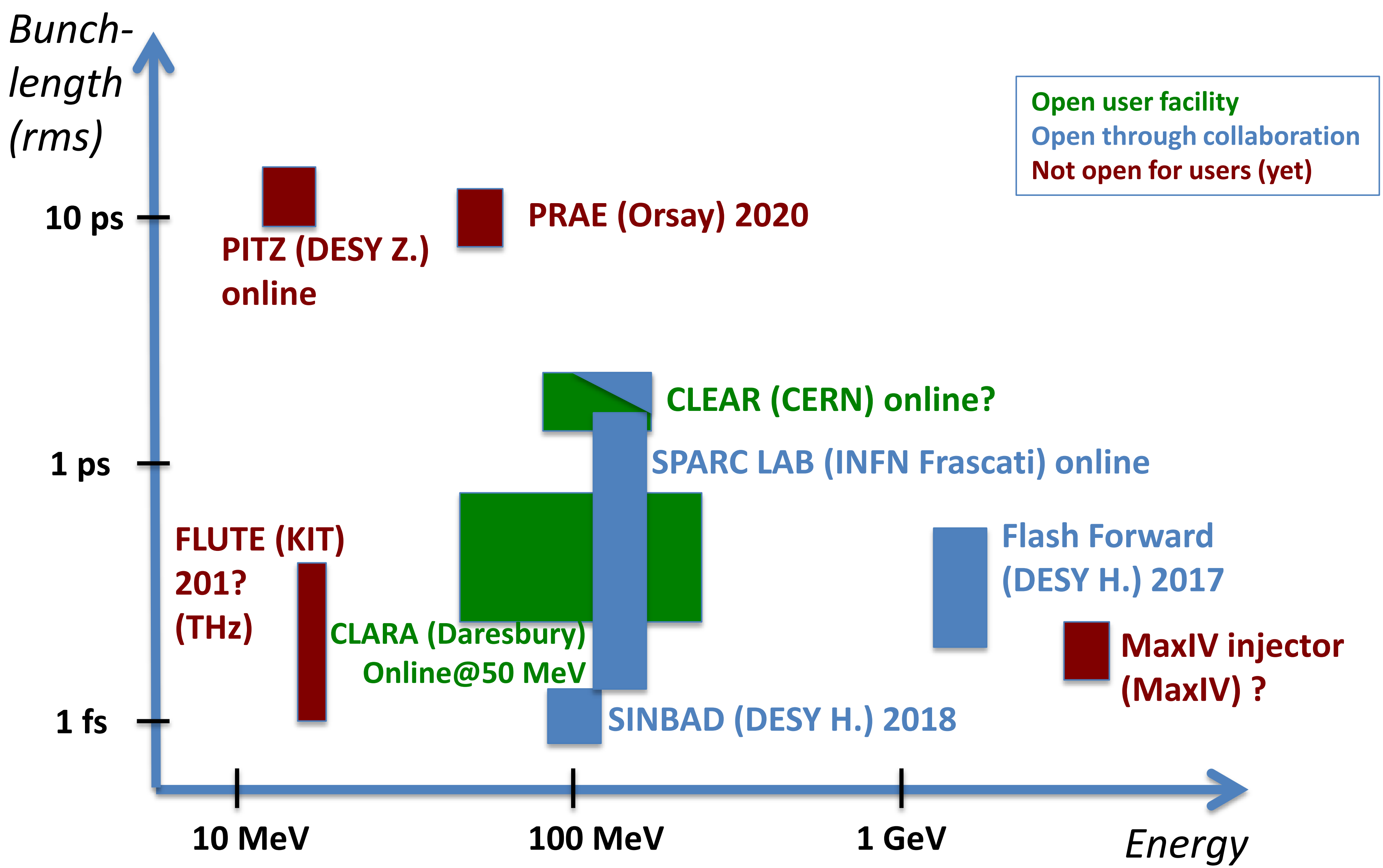
C.Welsch - U. of Liverpool
E.Adli - U. of Oslo
P.N. Burrows - U. of Oxford

[1] CLEAR: CERN Linear Electron Accelerator for Research

Present and planned European electron test beams

not complete



More details can be found at **https://goo.gl/sn4dqP**

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Research areas and proposed program

- The program covers two of the top priorities identified by the European Strategy for Particle Physics, namely the **prototyping and validation of accelerator components for the upgrade of the Large Hadron Collider a**nd its injector chain, **and studies of high-gradient acceleration methods**.

- The latter cover **X-band studies** for linear accelerators and **also novel concepts as plasma and THz acceleration**. The proposed facility would also provide unique **training possibilities (student hands-on, JUAS, potential EU projects)**, as well **as irradiation test** capability, allowing for example, continuation of the collaboration with the **European Space Agency (ESA)**.

3.1 High priorities for the current CERN accelerator program

Key priorities at CERN are the LHC project and its upgrade program, including the injector chain, followed by the R&D work on future projects such as CLIC and FCC, focusing on high accelerating gradients and high field magnets, respectively. We present in section 3.1 in more detail the tests that would be carried out at CLEAR highlighting their relevance for CERN's main goals[2].

3.1.1 High-gradient energy-frontier R&D:

- High-gradient linacs are being considered for an increasing number of applications in addition to linear colliders, including compact light sources (see below) and medical linacs. Significant progress has been made in developing high-gradient accelerating structures with stand-alone RF test facilities, including routine operation of more than 100 MV/m gradients. However, a number of open issues, crucial for all the applications mentioned above, involve the interplay between the beam and the high-gradient fields. The CLEAR facility combined with the nearby X-band power station XBox-1 provide a unique opportunity to study key issues: the effect of a beam on the high-gradient behaviour and the effect of high-gradient phenomena on the beam, including kicks on the beam originating from structure breakdowns. In addition to CERN, a large number of institutes from the CLIC collaboration and the X-band FEL collaboration plan to participate in these studies. Routing of X-band power to CLEAR for beam tests could be carried out from 2018. More details can be found in appendix A1.
- FEL linac studies related to the studies above: There is growing worldwide interest in FELs as well as inverse Compton sources. An international collaboration with about 20 external institutes, in addition to CERN, is currently undertaking a design study for compact light sources using CLIC X-band technology. In addition to the high-gradient structure tests (above) CLEAR offers the capability for component tests and technology demonstrations needed to demonstrate high peak current and good beam quality. These include phase-space linearizers, transverse deflecting cavities (for bunch length diagnostics and RF spreaders) and wake-field monitors. The UK FEL collaborators express interest in collaborating with CLEAR on X-band FEL component tests, also since the UK CLARA facility (under construction at Daresbury Laboratory) is focusing on photon production with insufficient space and beam time left for extensive testing of RF technology and compression dynamic. More details can be found in appendix A2.

3.1.2 Impedance studies:

- Measuring the impedance of accelerator components is crucial prior to their installation on CERN accelerators, especially in high intensity machines (PSB, PS, SPS, LHC, FCC) as the beam coupling impedance may limit the machine performances. The measurement of impedance in CLEAR is proposed by the CERN impedance working group as a new and complementary tool to numerical simulations and RF bench measurements. In 2017 the impedance group is interested in measuring LHC wire scanner prototypes with the CLEAR beam. This can be done without changes to the current setup requiring only the integration of a wire scanner tank and RF measurement devices, although appropriate tapering in the device-under-test must be well controlled. A long-term program would benefit from a second injector in CLEAR, making direct impedance measurements effects possible using a witness beam to probe the wakefields. The CLIC collaboration, including external institutes (U. Uppsala, U. Oslo) are as well interested in continuing impedance studies (both transverse and longitudinal) in CLEAR. More details can be found in appendix A3.

3.1.3 Beam instrumentation tests:

- The LHC and its injector complex as well as CLIC, FCC and AWAKE require development of state-of-the-art beam instrumentation devices. In CLEAR, prototypes of such devices can be tested and calibrated under realistic beam conditions with full flexibility. Such tests have been carried out on the CALIFES

Appendix A1 High-gradient RF developments

Session chair: Walter Wuensch (CERN)

Introduction

There is growing interest in using high-gradient linacs in an increasing number of applications including linear colliders, XFELs, Compton scattering sources and medical linacs. Significant progress has been made in developing high-gradient accelerating structures using stand-alone rf test facilities. For example, prototype CLIC accelerating structures routinely operate at accelerating gradients in excess of 100 MV/m in the CLIC XBoxes. There are however a number of open issues, crucial for all the applications mentioned above, which involve the interplay between a high-gradient structure and a beam. Operational facilities will of course have beams, so the behaviour of the full configuration of beam and high-gradient structure must be understood and in many cases quantified.

Short term upgrades (2017)

The CALIFES linac combined with the nearby X-band power station XBox-1 provides a unique opportunity to bring together high-gradient X-band acceleration along with a well instrumented relativistic electron beam in order to address these crucial beam and high-gradient interaction issues. Some infrastructure modification will however be needed before such a program can be carried out. There are two options. One is to transport 12 GHz power from the existing XBox-1 location to CLEX using the overmoded waveguide system now used for the so-called "dog-leg" experiment in the CTF3 drive beam linac. The other option is to move XBox-1 above the CLEX area.

Both options could be carried out in 2017 with the tests described in this section starting in 2018. An addition benefit of adding a high-gradient system to CALIFES would be to increase beam energy by well over 50 MeV.

Proposed experimental program 2018+

The experiments and tests which address beam and high-gradient structure using the XBox-1 installation and CALIFES can be grouped into four main categories:

1. The effect of a beam on the high-gradient behaviour of a structure
2. The effect of high-gradient phenomena on the beam
3. Wakefields and structure-based beam measurements
4. Full system tests

Specific experiments and measurements are described below along. Medical linac related tests, using CALIFES S-band equipment, are described in a final section.

The effect of beam on high-gradient performance

The effect of beam loading on breakdown rate – This measurement is of direct relevance to the CLIC project and to multibunch versions of the Compton scattering sources. In these applications a high current beam is accelerated, which changes the field distribution inside a structure. In the experiment the breakdown rate of a structure, and distribution of breakdowns inside it, is measured with and without beam. It is crucial to quantify this effect in order to optimize an accelerating structure for highest gradient and maximum rf-to-beam efficiency.

The effect of beam loss on breakdown rate – High-gradient phenomena include vacuum arcs and multipactor. These processes involve electron emission and initiation processes are strongly dependent on material state. Investigating the direct effect of controlled CALIFES beam loss on breakdown rate, especially in the low breakdown rate regime, in a high-gradient structure is important for both CLIC and XFELs. Additionally, the satellite community has proposed to use the CALIFES beam to induce multipactor in waveguide systems in a controlled way in order to benchmark multipactor simulation codes. This would significantly improve the current technique, which relies on a radioactive source. Finally the long-term effect of beam loss on material state, specifically dislocation density, and the resulting effect on high-gradient performance needs to be understood.

The effect of high-gradient on beam

Breakdown kick – Vacuum breakdown induced currents kick a beam transversely and result in reduced acceleration due to supressed rf power transmission through a structure. Measurement of these effects is important for all the applications mentioned above since an errant beam can damage accelerator components and result in radiation emission in an unexpected direction. The CALIFES beam can be used to measure the size and distribution of these kicks from an operating high-gradient structure. This information feeds directly into the design of collimator and radiation shielding for example.

Dark current – All of the applications listed in the introduction run above the dark current capture limit. Dark current will produce radiation, give background to instrumentation and possibly even deflect the beam. Measurement can be made of emitted dark current characteristics using the well understood and well instrumented CALIFES beam line downstream of an operating high-gradient accelerating structure. Additionally beam instrumentation should be tested in the vicinity of high-gradient accelerating structures to determine any performance degradation due to dark current or damage due to breakdown currents.

Wakefields and structure-based beam measurements

Wakefield validation - Many of the applications for high-gradient also require low emittance electron beams - CLIC, XFELs and Compton scattering sources – and consequently require well-known and well-controlled wakefields. Modern computer codes can give precise estimates but not over all parameter ranges. Combined with additional fabrication uncertainties, a wakefield measurement and/or validation is a very high priority for the high-gradient and low-emittance applications. This challenging measurement is described in section X.

Integrated wakefield monitors – CLIC and XFEL linearizing cavities have so-called wakefield monitors to

Tentative schedule 2017

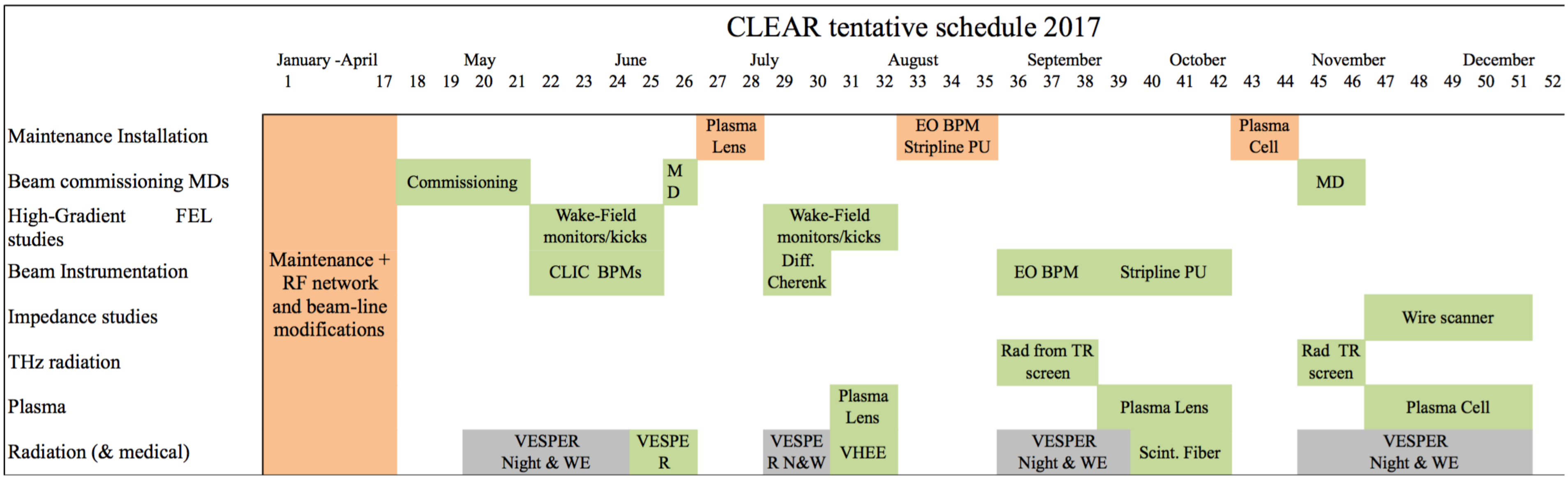
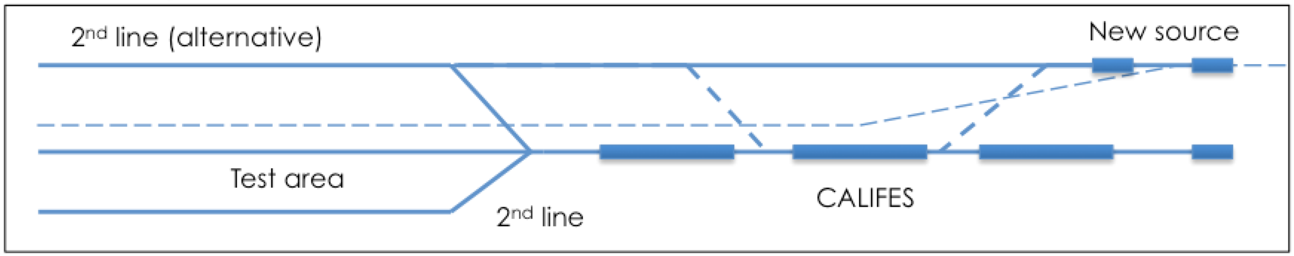


Figure 2 - Tentative experimental program and schedule of the CLEAR test facility in 2017.

Possible upgrades

Options for a second beam line + source



Desired beamline upgrades :
* compressed bunches
* second beamline
* second injector

- While CLEAR provides a test facility at CERN with high availability and easy access, the beam parameters are not unique with respect to other facilities
- Second injector will make CLEAR the only electron test facility with two independently operating RF guns, desired by many users
- A possible synergy with AWAKE: a new short-pulse source for its Run 2 (100 fs, ~ 400 A peak current, ~ 50 MeV). An interesting: S-band RF gun with X-band buncher and an X- band accelerating structure.
  – Develop and use as CLEAR second gun, before installing a copy for AWAKE towards 2020?

Conclusions

- CALIFES workshop a success. Strong interest, a large community of external users, and many concrete proposals, both for 2017 and for the longer term
  - High-gradient research, including novel acceleration methods
  - Component and irradiation tests
  - Training
- Workshop summarized in a document just about to be sent to the CERN management. We hope for a quick final approval
- Draft program for 2017 includes on-going and new activities including THz acceleration and PWFA
- CLEAR will depend on external institutes to fully support their experiments (material and personnel) and also help develop and operate the facility