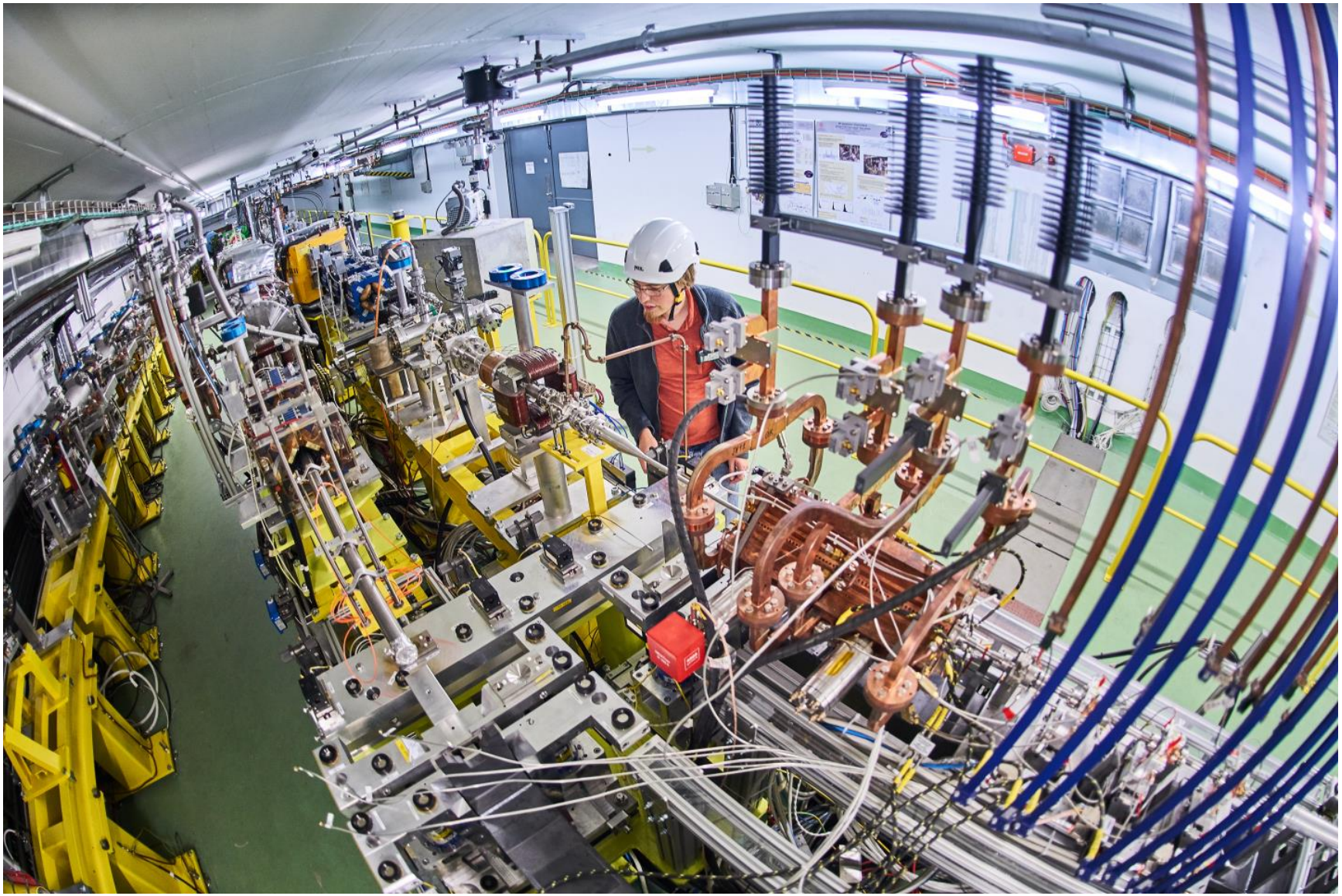


Report on CLEAR activities

R. Corsini for the CLEAR Team

Proposal of a CALIFES-based Accelerator Test Stand

CTF3 scientific program completed as planned in December 2016

What to do with CTF3 hardware & building?

➔

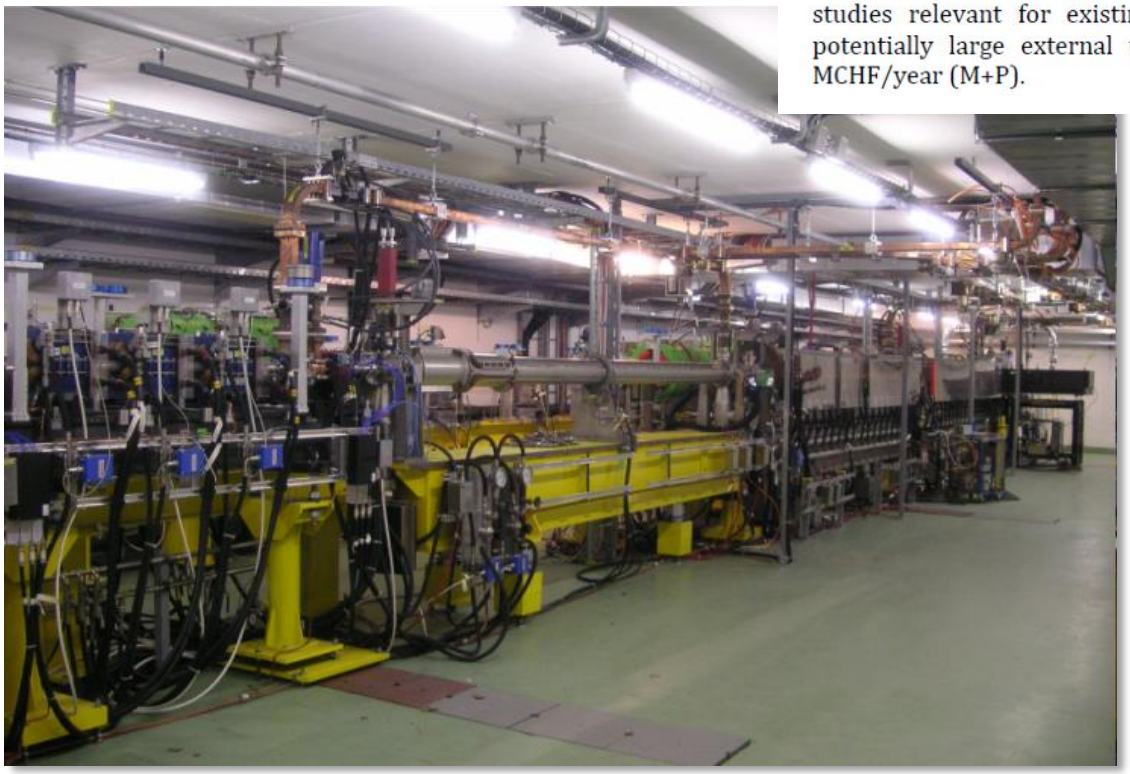
Interest in CALIFES

Expression of Interest for the future operation of the CALIFES linac

Prepared by: E.Adli (Univ. of Oslo), P.Burrows (Univ. of Oxford), R.Corsini (CERN), S. Stapnes (CERN)

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 when CTF3 is closed down. 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. The resources required are around 2 MCHF/year (M+P).



- Longer document send in February 2016 CALIFES_document.pdf
- Positive statement by the CLIC Review Panel in March 2016
- CALIFES Workshop, October 2016
- Final proposal (CLEAR) and approval in December 2016

The CERN Linear Electron Accelerator for Research, CLEAR

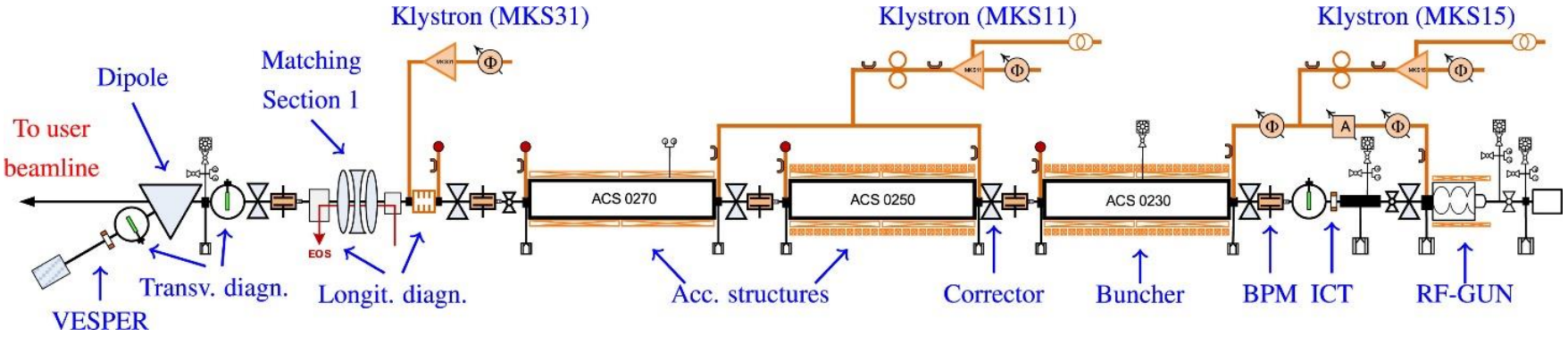
The primary focus for CLEAR is general accelerator R&D and component studies for existing and possible future machines at CERN, based on a broad internal and external user community.

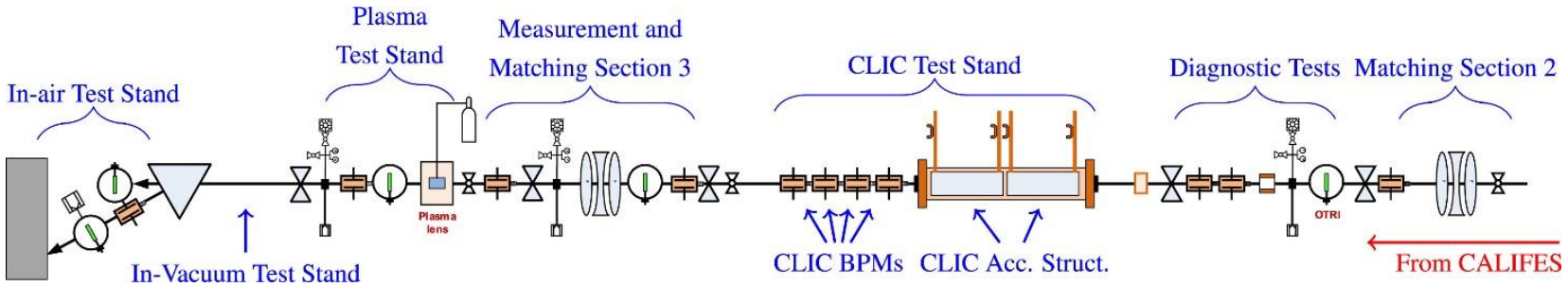
The program covers two of the top priorities identified by the European Strategy for Particle Physics, namely the prototyping and validation of accelerator components for the upgrade of the Large Hadron Collider and its injector chain, and studies of high-gradient acceleration methods.

The latter cover X-band studies for linear accelerators and also novel concepts as plasma and THz acceleration.

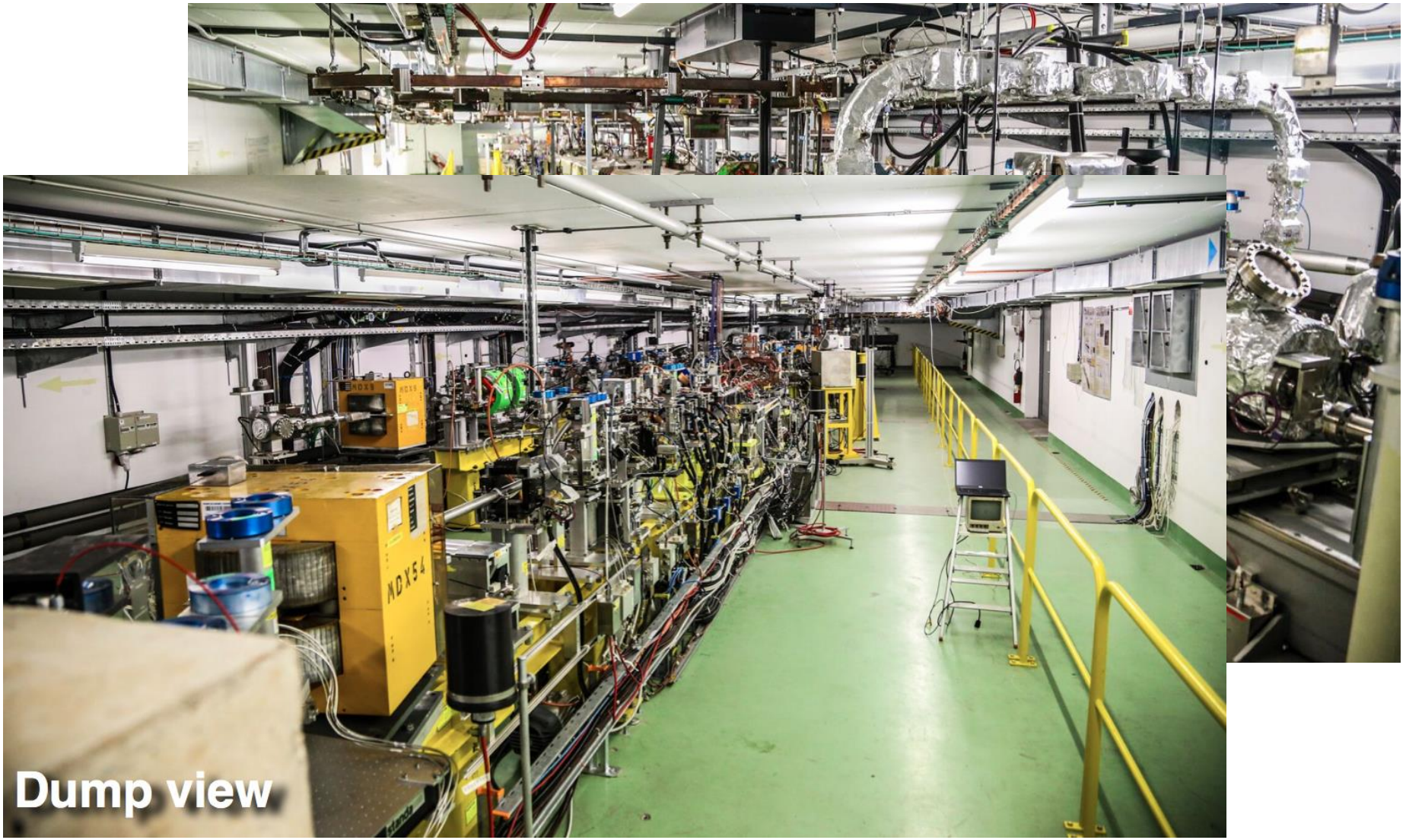
CLEAR also provides unique training possibilities, as well as irradiation test capability in the VESPER test stand, also in collaboration with the European Space Agency (ESA).

CERN Linear Electron Accelerator for Research

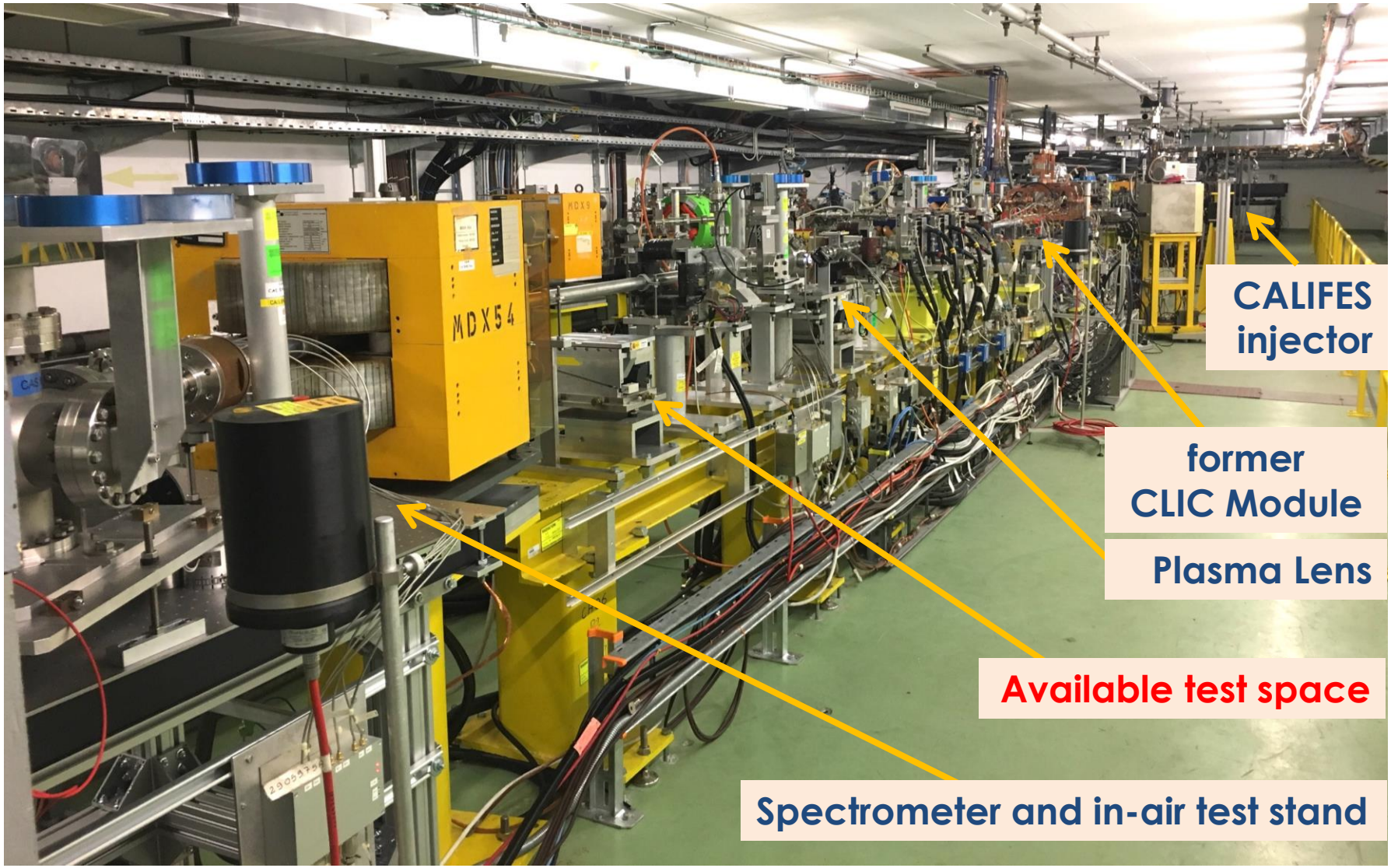




CERN Linear Electron Accelerator for Research



CERN Linear Electron Accelerator for Research

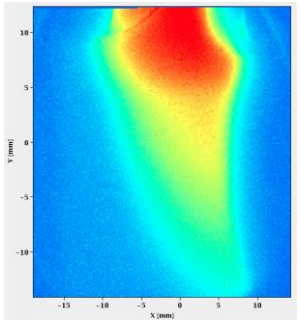


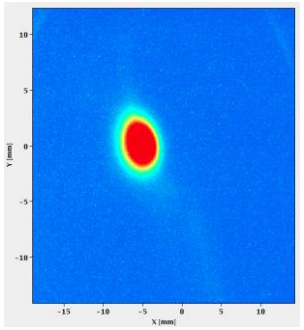
Start-up

- Hardware modifications took longer than foreseen (about 2 months delay)
  - (Initial) lack of resources
  - Larger scope than initially planned – beamline heavily modified
  - Some mishaps (accidental venting of RF gun, vacuum leaks…)

- First Beam on August 18th

18th August





1st September

Present Status - Experiments

- Planned "old" experiments under way, in different stage of advancement:
  - VESPER – irradiation of electronic components: many tests, first test in collaboration with ESA/TRAD
  - VESPER – irradiation for medical applications: thorough extensions of initial studies for VHEE in CALIFES (University of Manchester)
  - CLIC BPMs: fixed hardware problems, testing, now operational
  - CLIC structure wake-field studies/wake-field monitors: data taking, ongoing
  - Cherenkov diffraction radiation studies: initial tests started
- New experiment, Plasma Lens: after some initial problem got impressive results
- Other new experiments under preparation:
  - THz radiation studies: initial tests ongoing, THz radiation mini-Workshop organized and held in November 2016
  - Impedance studies: planning to start in 2018, new doctoral student in February

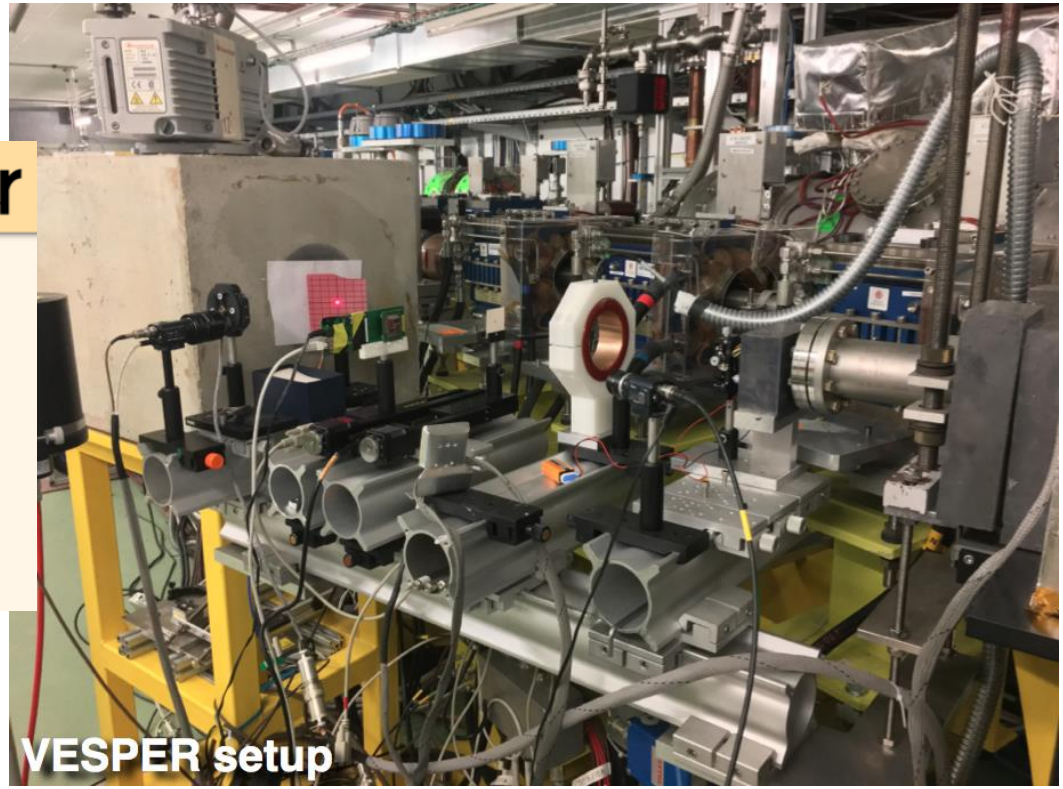
VESPER

Irradiation facility vesper

- Movable stages, laser alignment
- Dedicated dosimetry
- Beam charge calibrated with a Faraday cup and another BCT

Measurements done in 2016:

- Electron induced radiation effects
- Very High Energy Electrons for radiotherapy



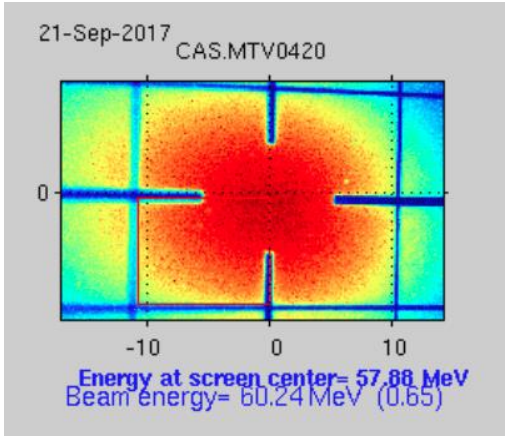
M. Talis, R. Garcia Alia, W. Farabolini et al.

Operation resumed in September:

- Using dark current only
- 10 pC total charge
- 5 Hz repetition rate
- Energy from 60 to 180 MeV

Successful measurements with ESA and TRAD in week 46!

Overnight and over weekend operation possible.

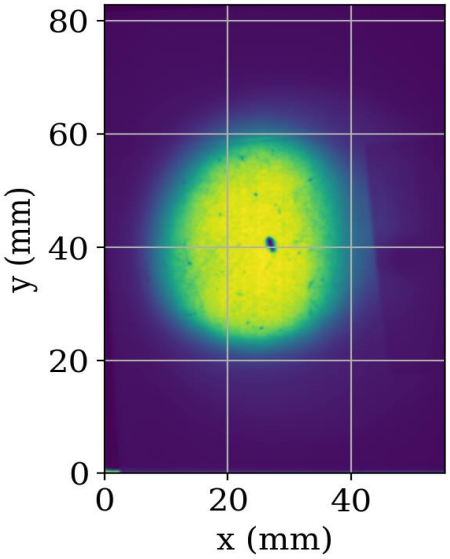


VESPER for medical applications

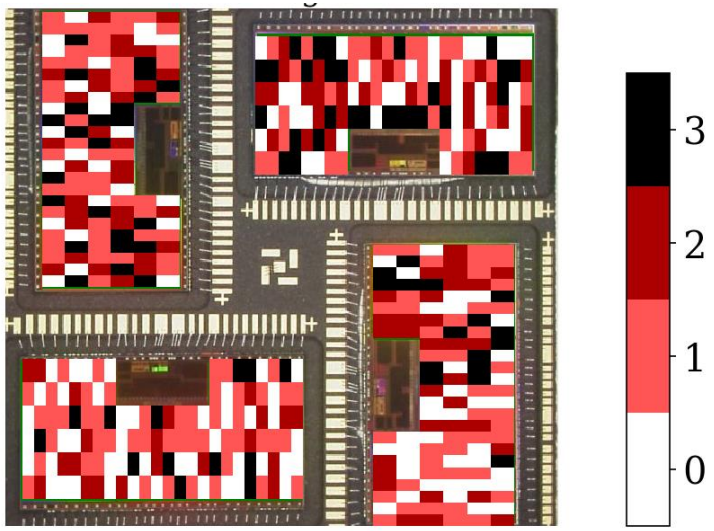
VESPER first tests: European Space Agency (ESA)

Maris Tali et al.

Beam homogenity - 175 MeV, 8 pC/pulse



Radiosensitive film



ESA SEU monitor

First tests have been performed with ESA SEU monitor, results compatible with previous years. Expanded energy range:

- 50, 115, 175 MeV
- ESA SEU monitor + Al
- Radiosensitive films

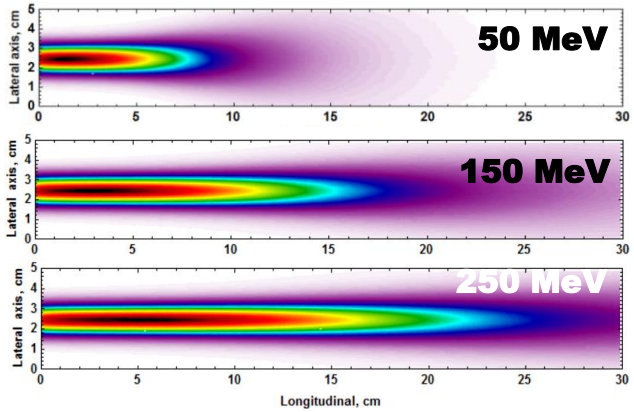
Week 46: first test in collaboration with ESA/TRAD

VHEE: Very High Energy Electron Radiotherapy

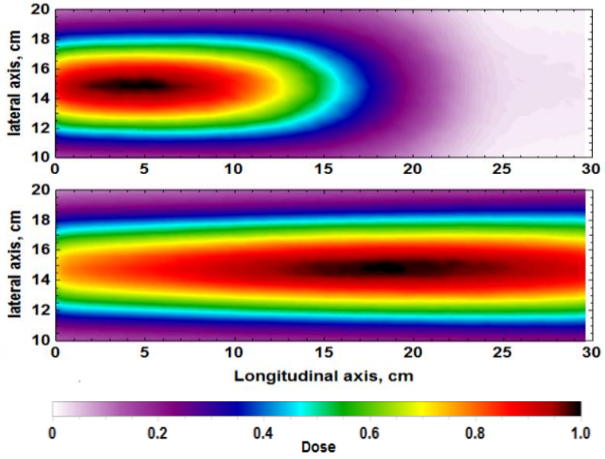
VHEE

- Rapid advances in compact high-gradient (~ 100 MV/m) accelerator technology in recent years
  - CLIC
  - NLC
  - W-band*
- **Superior dose deposition properties compared to MV photons**
- **High dose-reach in tissue**
- **High dose rate (compared to photons)**
- **More reliable beam delivery around inhomogeneous media**
- **Better sparing of surrounding healthy tissue**
- **Particle steering**

*V. Dolgashev, HG2016

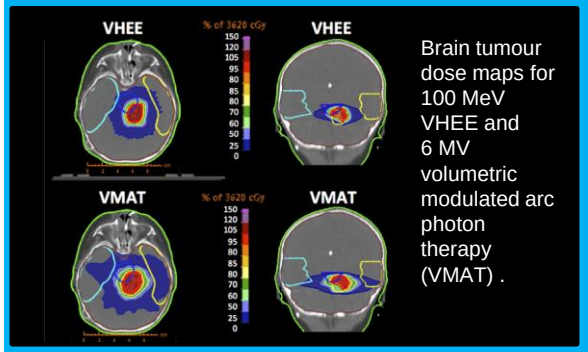


Dose maps of narrow () VHEE beams in water

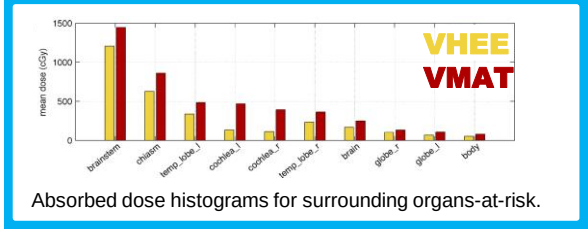


Dose maps of wide () VHEE beams in water

- **Clinical studies by M. Bazalova-Carter *et al.* (2015) have compared 100 MeV VHEE** with conventional **(and MV) VMAT** (Volumetric Modulated Arc Therapy) photon radiotherapy plans
- ***Pediatric brain tumour, lung*** and ***prostate cases***
- VHEE therapy plan showed a **decrease of dose** up to **70%** in surrounding organs-at-risk (**OARs**)
- ***VHEE plan was found to be more conformal than VMAT plan***



Brain tumour dose maps for 100 MeV VHEE and 6 MV volumetric modulated arc photon therapy (VMAT) .



Absorbed dose histograms for surrounding organs-at-risk.

M. Bazalova-Carter *et al*, «Treatment planning for radiotherapy with very high-energy electron beams and comparison of VHEE and VMAT plans», Medical Physics, vol. 42(5), **2015**.

Manchester University: A. Lagzda, R. Jones and other

- Project to characterize VHEE irradiation on radiosensitive films

FEVHER EU Synergy Grant proposal

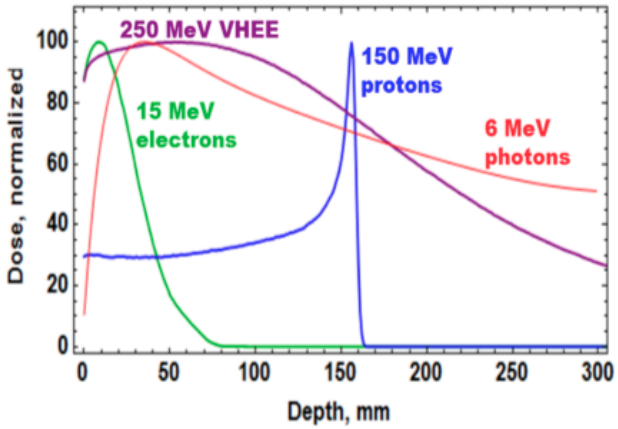
ERC Synergy Grant 2018 Research proposal [Part B2][1]
(not evaluated in Step 1)

Feasibility and Experimental Validation of Very High-Energy Electron Radiotherapy
FEVHER

Principal Investigators:

- Angeles Faus-Golfe (cPI), CNRS (cHI)
- Philip Poortmans (PI1), Institut Curie (IC) (HI1)
- Roger Michael Jones (PI2), University of Manchester (UMAN) (HI2)
- Manjit Dosanjh (PI3), CERN (HI3)

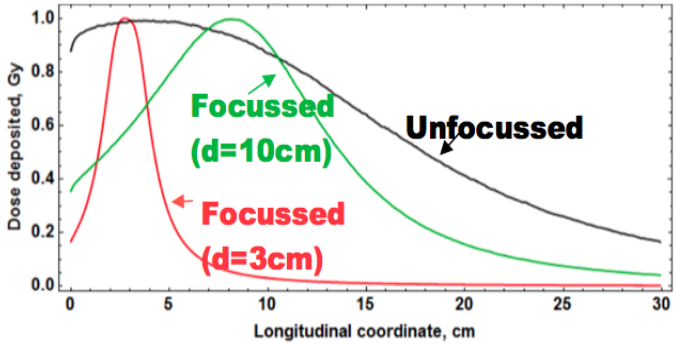
Duration: 72 months



European Commission - Research - Participants
Proposal Submission Forms
European Research Council Executive Agency

Proposal ID **810288** *Acronym* **FEVHER**

Abstract*



With recent High-Gradient linac technology developments, Very High Energy Electrons (VHEE) in the range 100–250 MeV offer the promise to be a cost-effective option in anticancer Radiation Therapy (RT) and open up innovative treatment modalities. Actually, their ballistic and dosimetric properties surpass those of photons, which are currently the most commonly used in RT, and may even compete with protons at a reduced cost. The potential advantages of VHEE with regard to RT applications are:
•A significant decrease of the integral dose to healthy tissues or sensitive organs compared to photon
•Providing high dose-rates and fast electromagnetic scanning over any field to provide an uniform dose distribution throughout the target and allow for unforeseen RT modalities (Grid mini-beam, FLASH high-dose rate)
•More compact and less expensive facilities than the used in proton therapy
The main goal of FEVHER project is to demonstrate that VHEE are suitable for innovative RT applications in particular by allowing Grid and FLASH methodologies, which are likely to represent a major breakthrough in RT. For this aim this a great deal of synergistic, multidisciplinary research has to be carried out from the accelerator technology as well physical and radiobiological comparisons with current photons and proton/particle applications to see how well VHEE can meet the current assumptions and become a radiobiological and clinical reality. The fundamental beams that are needed to drive this research forward will be made in the world-class electron beam facilities of CLEAR (CERN), VELA-CLARA (STFC) and PRAE (LAL). The accelerators will be upgraded to incorporate recent developments in high-gradient linacs and will be adapted to the specific needs. The FEVHER project is designed to uncover unforeseen, and completely new technology, to cross-fertilize disciplines and to solve important challenges that until recently could not be dreamt of solving.

VHEE experiments at CLEAR

- Beam dosimetry experiments in water tank with radiosensitive films.
- Preliminary studies done December 2016.

Beam parameter (end of linac)	Value range
Energy	197 MeV
Energy spread	< 0.5 MeV FWHM
Bunch charge	0.5 nC
Train length	50 bunches
Beam spot size	1 mm
Charge Jitter	20 %
Relative energy spread	1 %

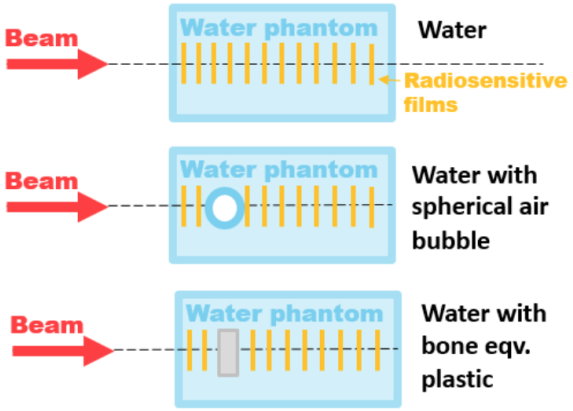
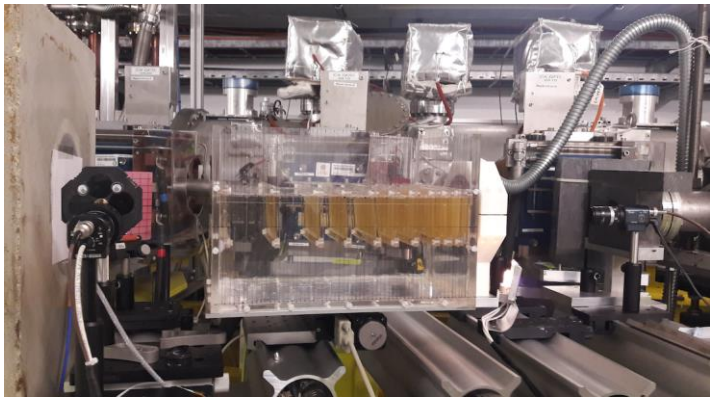
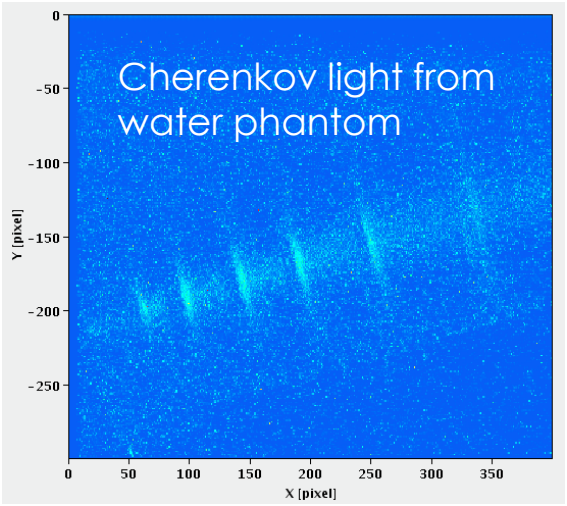


Figure 2: Schematic of irradiation set-ups.

A. Lagzda et al.



- *100 bunches of 50 pC/shot spaced by 1 sec. at 8 cm distance corresponds to 100 Gy.*



Week 49: extensive VHEE tests

Results being analyzed, will be presented at the CLIC Workshop, end January

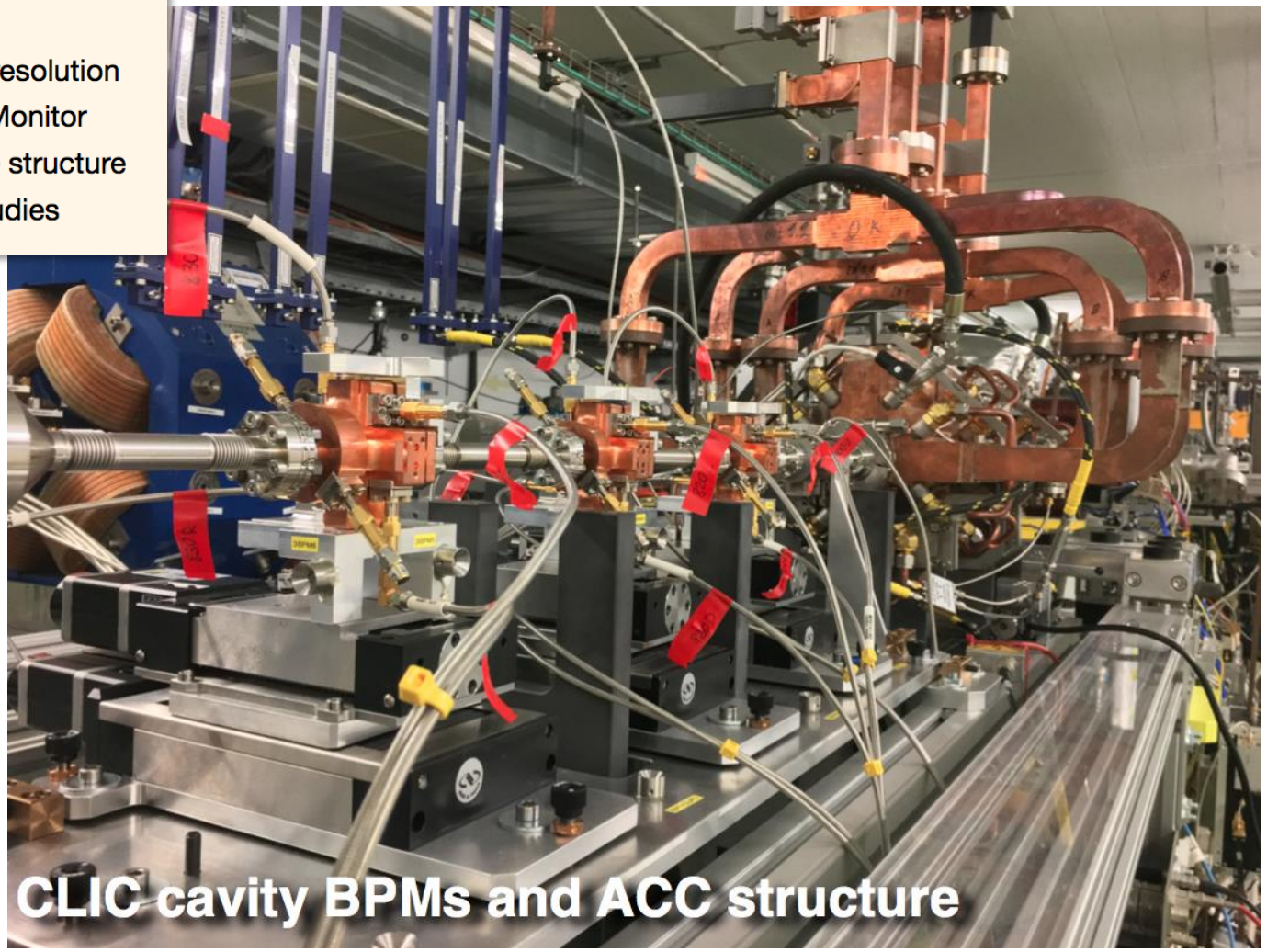
Former CLIC Module

CLIC R&D

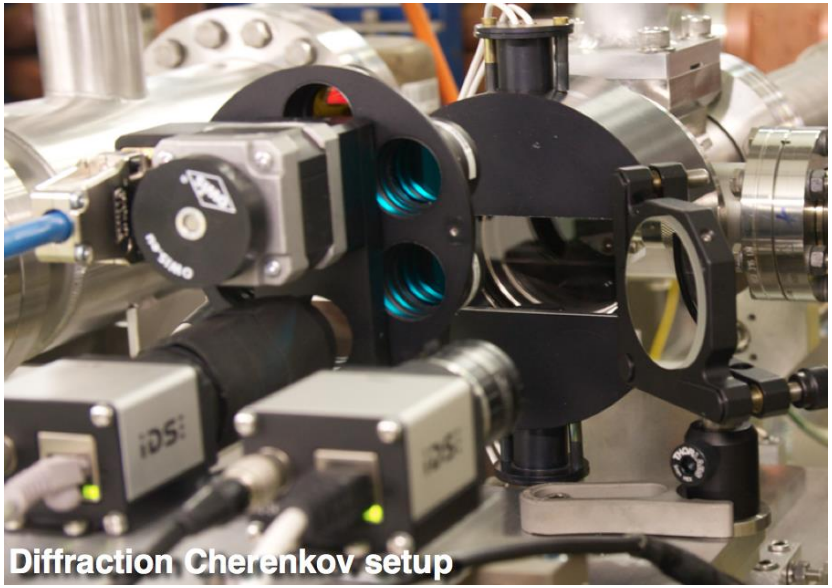
- CLIC cavity BPMS
  - Toward 50 nm and 50 ns resolution
- CLIC structure Wake Field Monitor
- Field characterisation inside structure
- Higher order mode kicks studies

Figure 1: Prototype copper CLIC cavity BPM.

Results will be presented at the CLIC Workshop 2018



BI Activities


Diffraction Cherenkov setup

Many activities planned (most ongoing).

Two main goals:

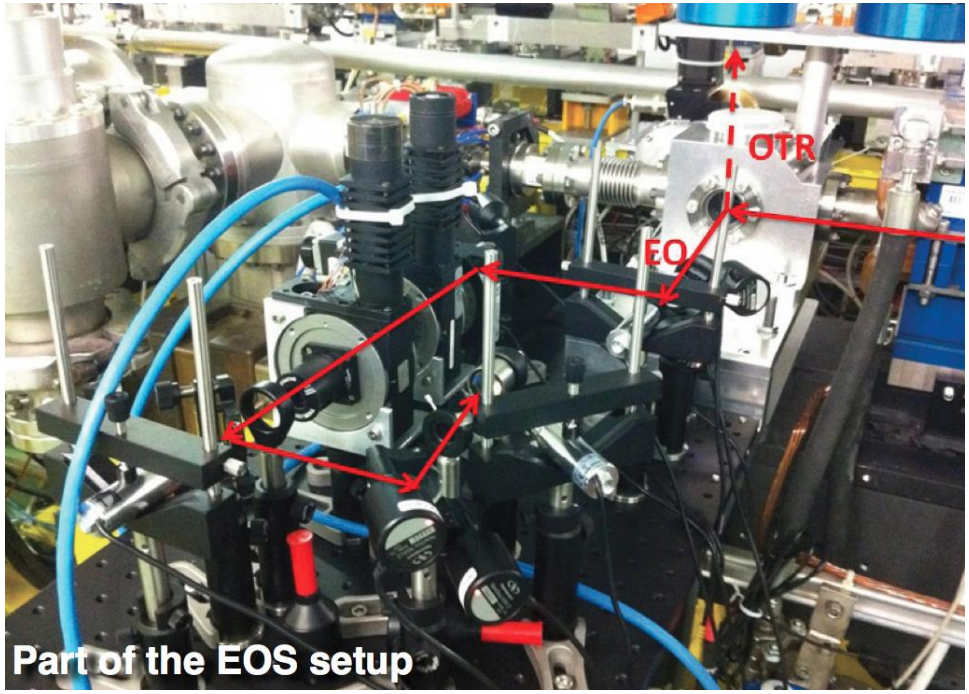
1) Consolidate and improve beam instrumentation for CLEAR

2) Diagnostics R&D

Beam Inst. R&D

- CLIC inductive BPMs
- High bandwidth Wall Current Monitor
- Cavity BPMs
- Electro-optical system for bunch length measurements
- Diffraction Cherenkov Radiation tests

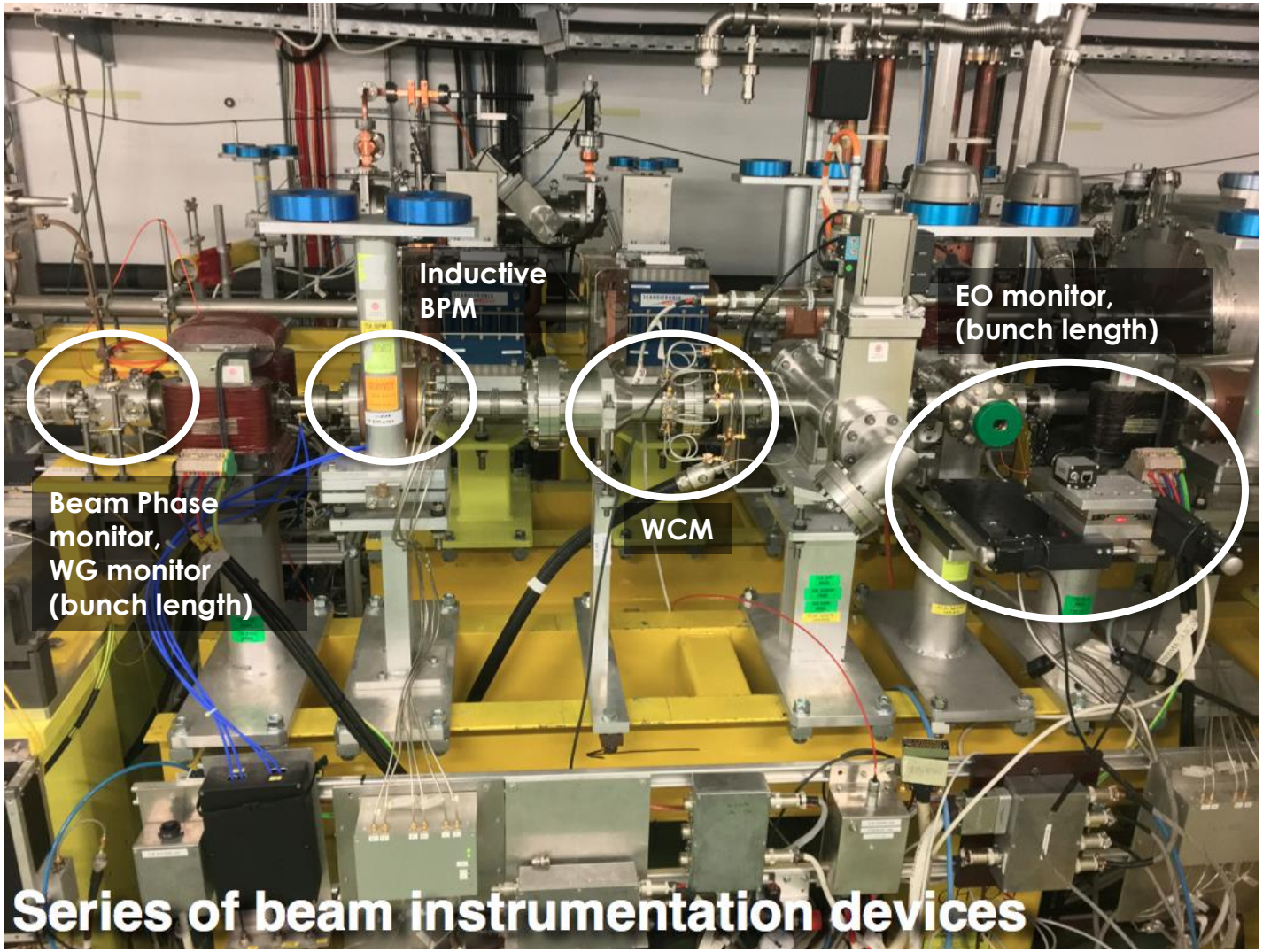
T. Lefevre, et al.



Part of the EOS setup

BI Activities

Several beam diagnostics recovered from CTF3, and adapted to CLEAR needs.
Will assess performances, modify if needed, eventually extend numbers.

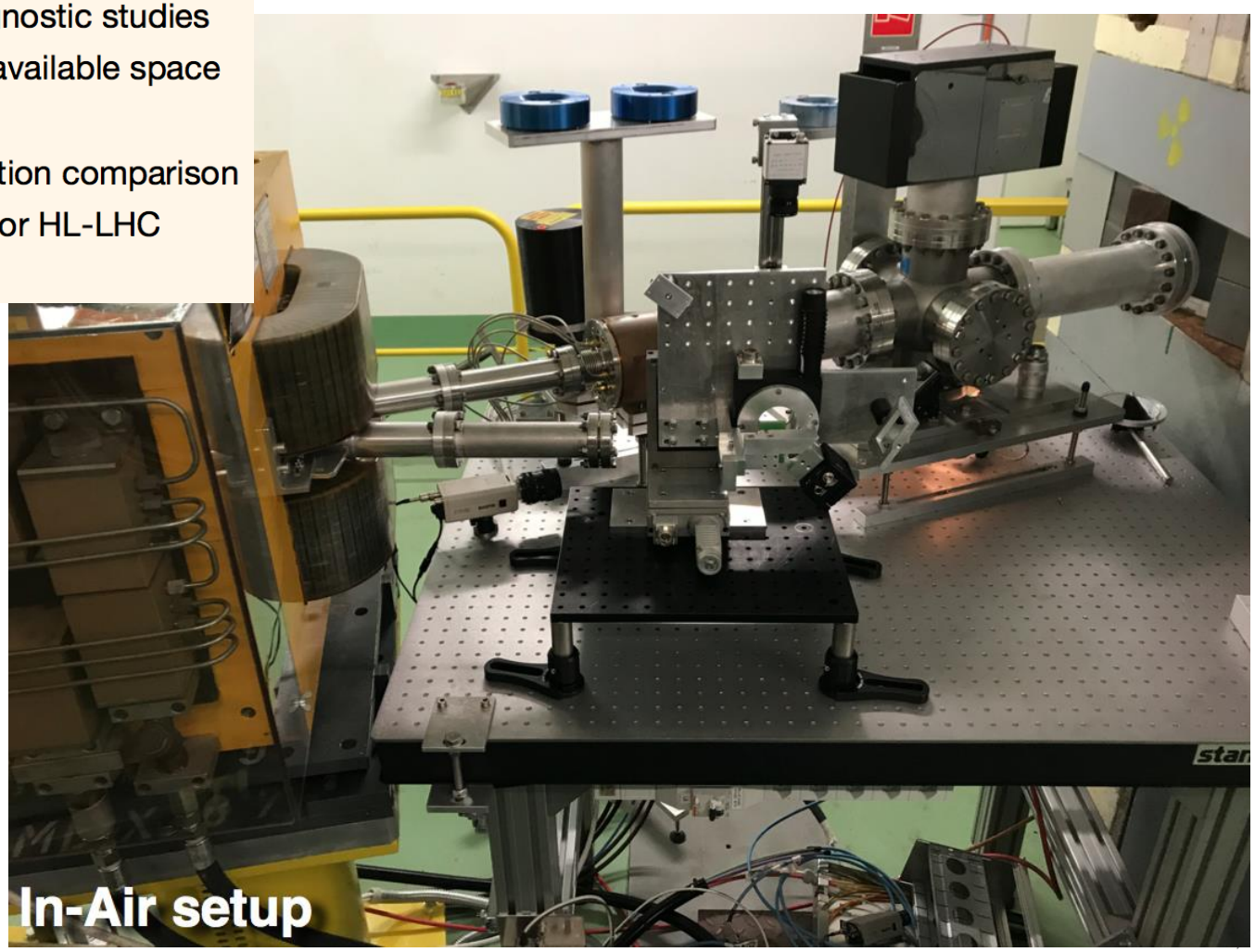


T. Lefevre, et al.

End-of-line in-air test space

In-Air Test Stand

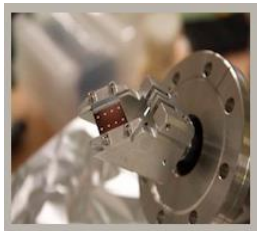
- Versatile space for in-air diagnostic studies
- About 1 m long, 0.4 m wide available space
- Foreseen experiments:
  - Transition/Cherenkov radiation comparison
  - Electro-optical BPM tests for HL-LHC
  - THz radiation studies



In-Air setup

THz Radiation

- Begin with characterization of beam-produced THz radiation from TR screen
- First tests in sub-THz region started, will use also as bunch length diagnostics
- Many possibilities beyond that, with several Institutes involved – Mini-workshop organized on November 7th



THz@CLEAR

https://indico.cern.ch/event/672235/

7 November 2017
CERN
Europe/Zurich timezone

Search...

Overview

Timetable

Speaker List

Vidyo connection

Registration

Participant List

Getting to CERN

- Accommodation
- CERN entrance opening hours
- CERN Maps
- CERN Network connection for your laptop

We are happy to welcome you at CERN for a one-day event on THz applications on the CLEAR facility. The main goals for the day are to review the possible applications of THz radiation on the CLEAR test facility and to discuss a realistic plan for beam-related tests on CLEAR in 2018.

The agenda of the event will be organised in 3 sessions:
1- Presentation of the facility
2- State of the art in THz applications, THz generation (including simulation tool) and THz detection techniques
3- Current and futur beam tests on CLEAR
followed by a general discussion on the plans for beam tests in 2018 and a visit of the CLEAR facility

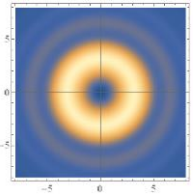
Please contact the organisers if you like to make a contribution or propose a beam test.

Looking forward seeing at CERN soon
Best regards,

Thibaut Lefevre and Roberto Corsini

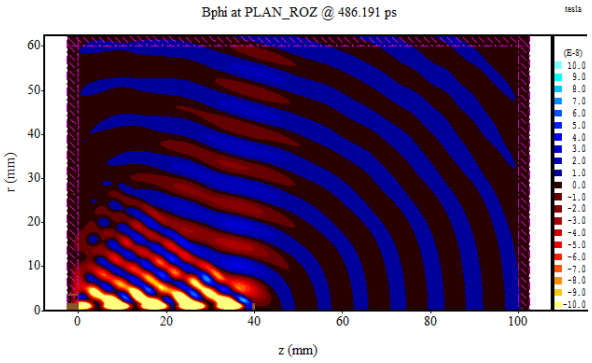
First topical CLEAR user workshop:

40 people from 15 institutes – 13 talks



Covering:

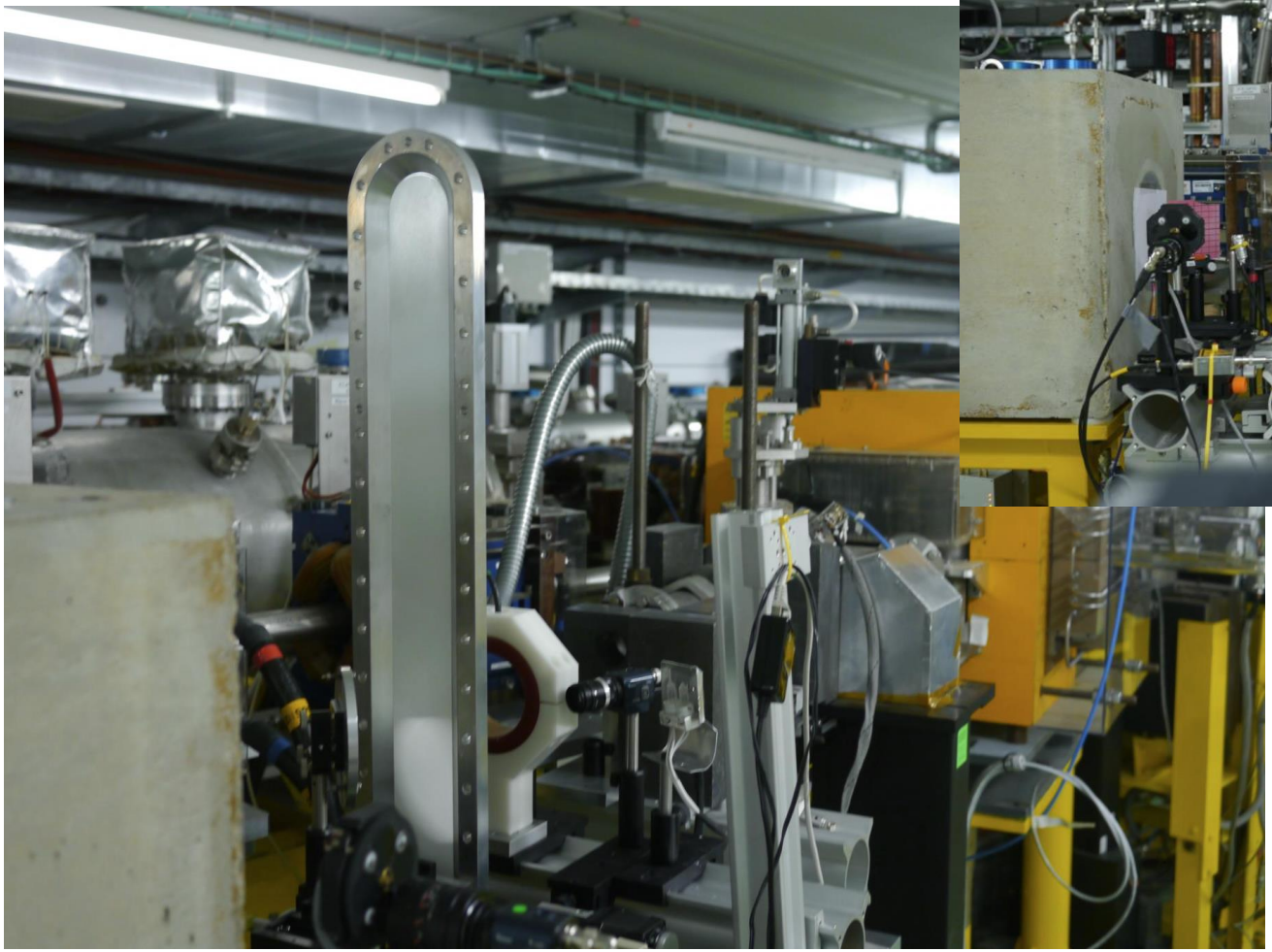
- Theory
- Applications
- Simulations
- Review of experimental activities
- Potential tests in CLEAR



Unforeseen: AWAKE electron spectrometer

Test and calibration of scintillator for AWAKE electron spectrometer.

N.B.: AWAKE BPMs were also tested in CLEAR/CTF.



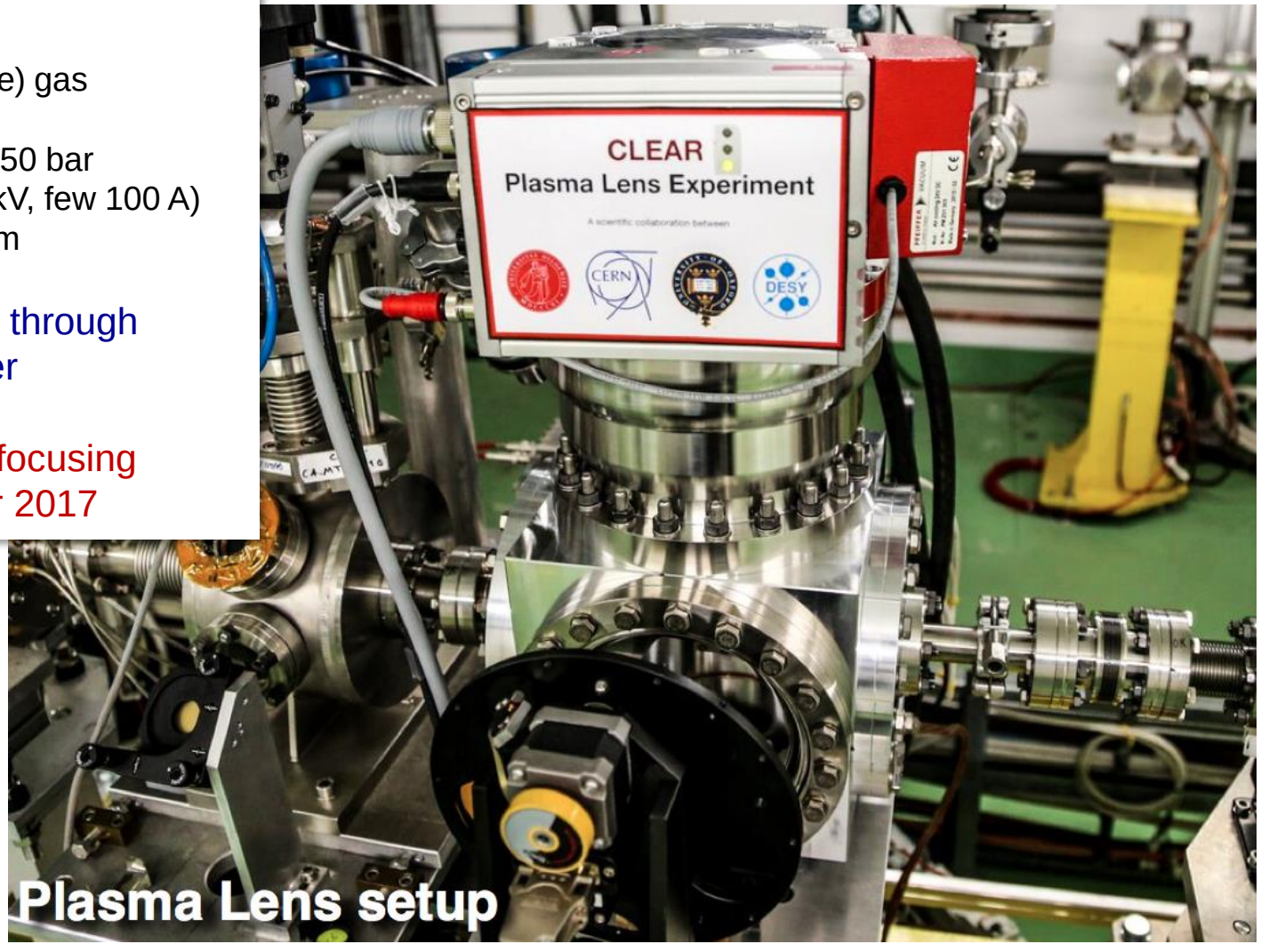
Plasma Lens Experiment

Beam focusing by high-current discharge in plasma

- Capillary for (transverse) gas confinement
- Gas delivery system 1-50 bar
- HV discharge unit (10 kV, few 100 A)
- Active alignment system

First beam sent cleanly through capillary end September

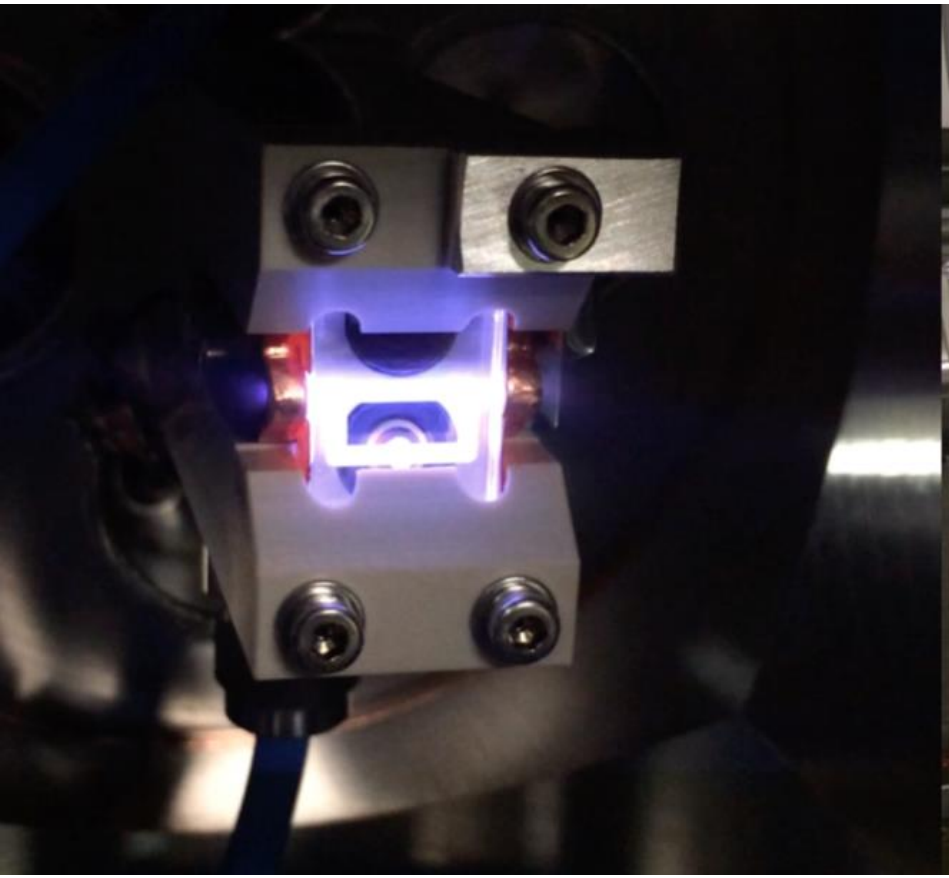
Clear measurement of focusing properties in December 2017

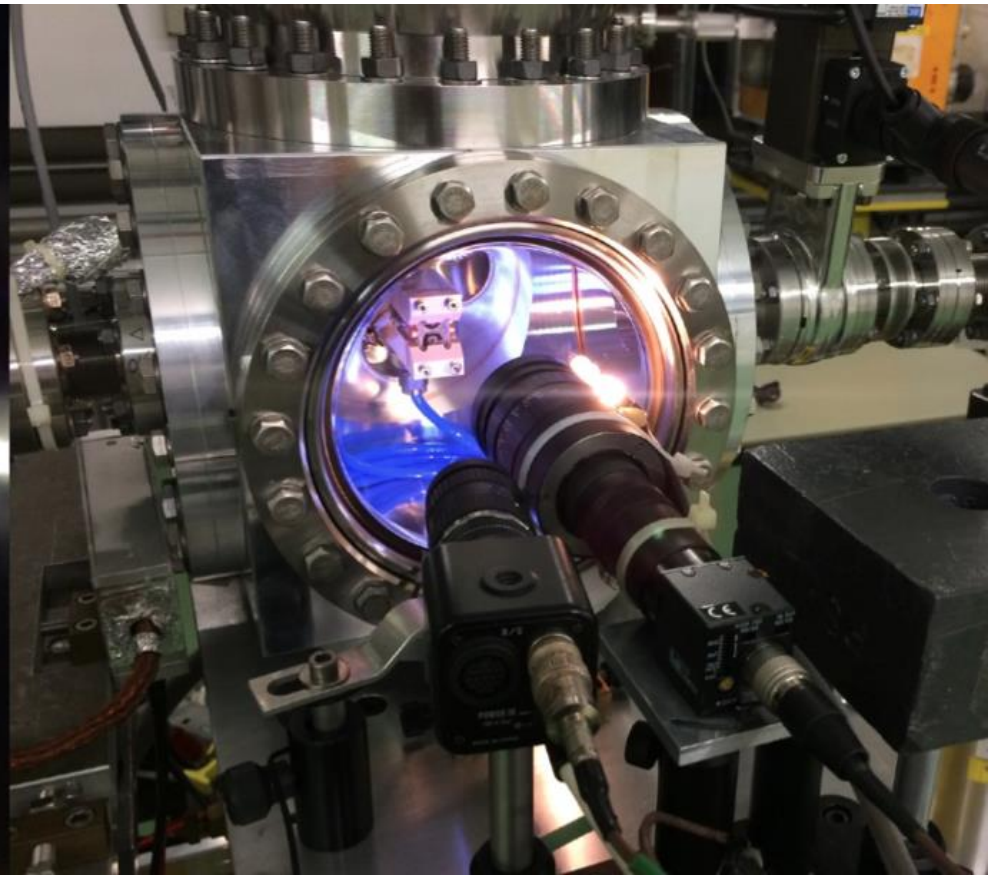


Lead by Oslo University

Collaboration with DESY, Oxford and CERN

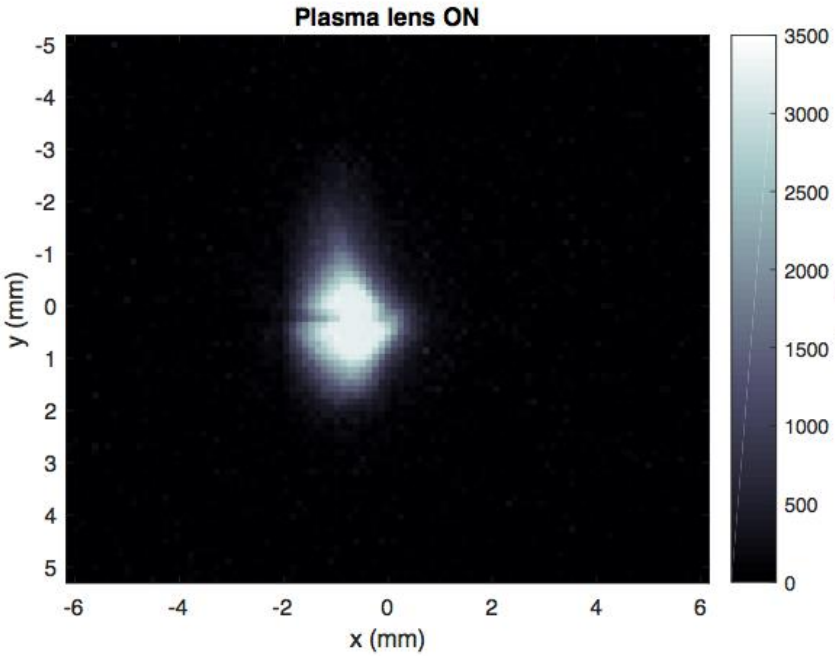
Plasma Lens Experiment

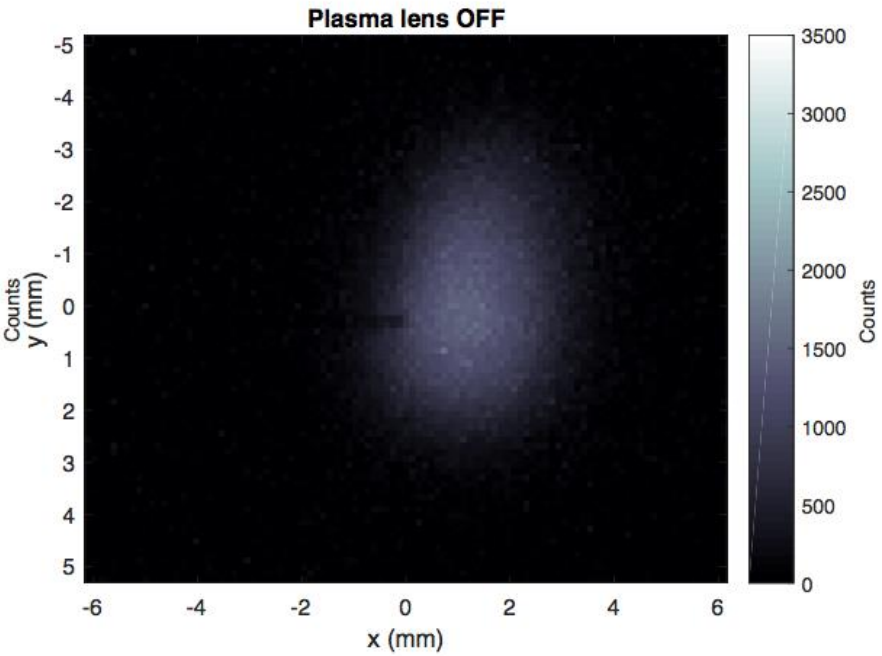


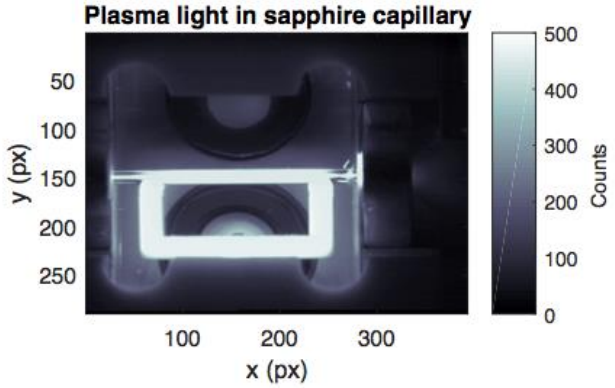


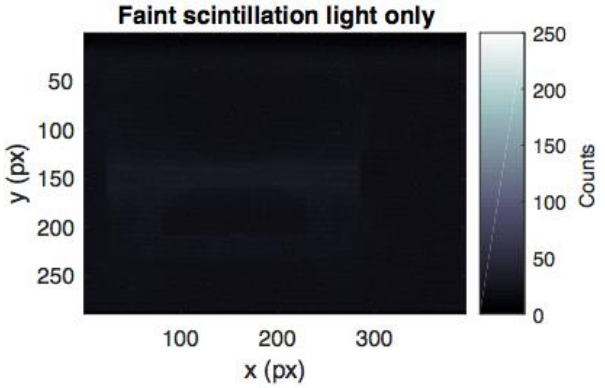
First beam through capillary without losses – end September
First focusing results – 1st December
Further results on linearity and self focusing – 12th and 13th December

Plasma lens on/off



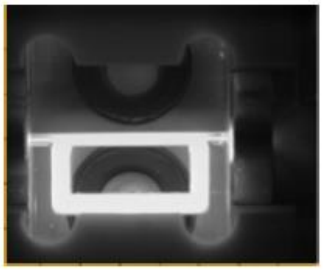




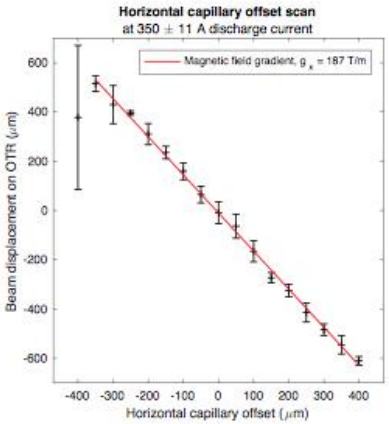


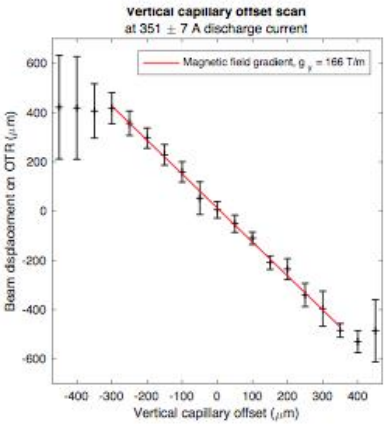
Recent results from the CLEAR Plasma Lens Exp.

- First results obtained Dec 1, 2017.

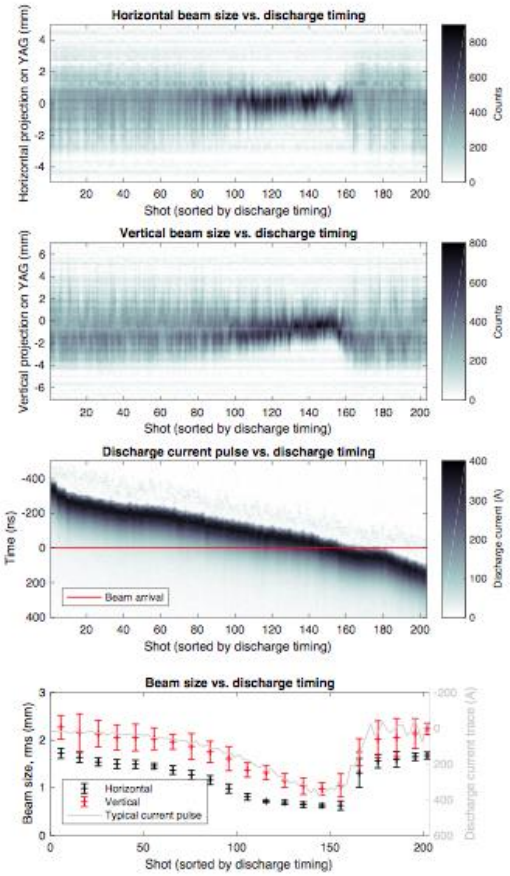


Offset scan

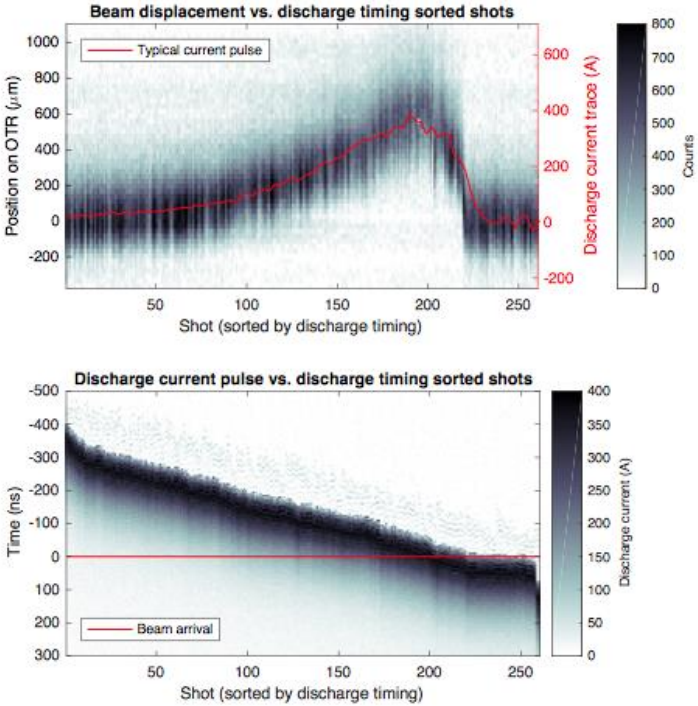




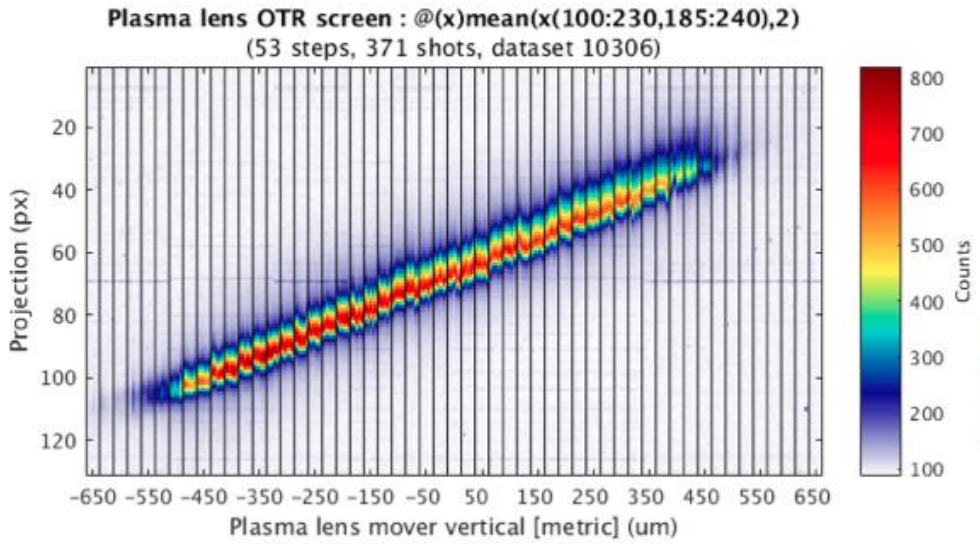
Timing scan – focusing

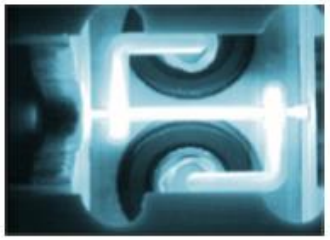


Timing scan – dipole kicks



Recent result from the CLEAR Plasma Lens Exp. – Obtained Dec 12, 2017

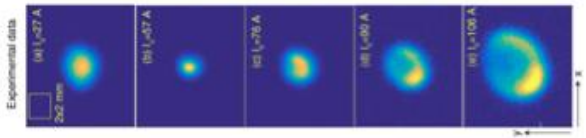




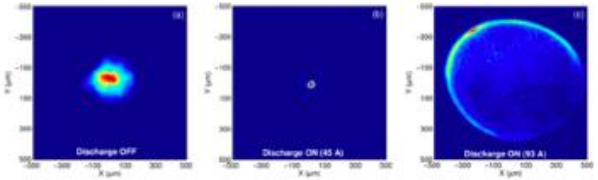
Vertical offset of the plasma lens using a pencil beam.
Dipole kicks measured as offset downstream.

- **No evidence of nonuniform focusing** in the first direct measurement of the field.
- Measurements thus far were only indirect measurements showing spherical aberrations.

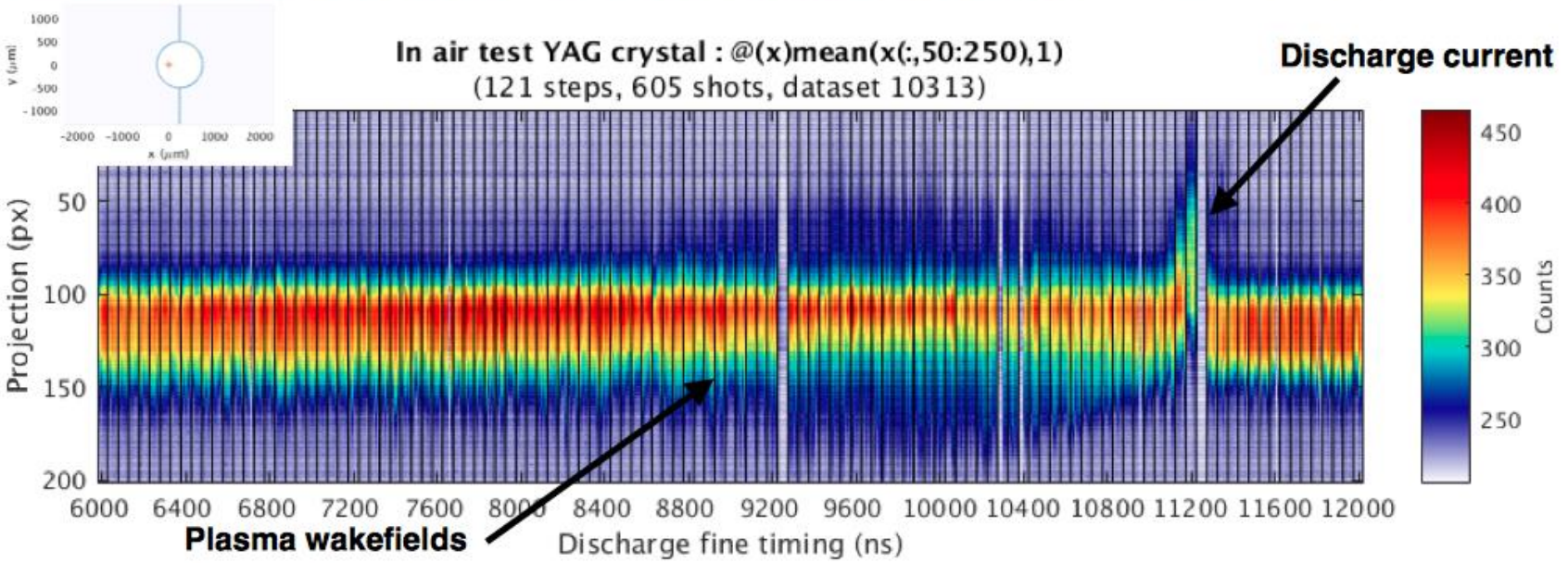
BELLA results:



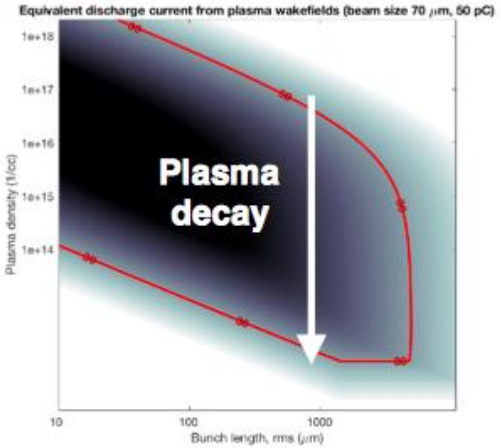
INFN results:



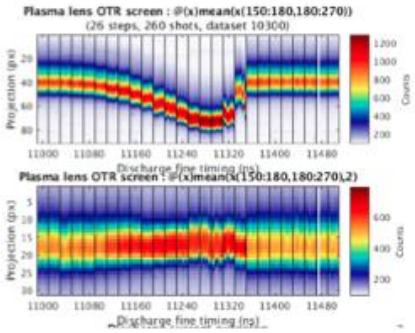
Recent result from the CLEAR Plasma Lens Exp. – Obtained Dec 14, 2017



- Dipole kicks during current: only focusing during wakefields.
- **First result showing plasma wakefield focusing in a plasma lens!**



Reference:
only from discharge



CLEAR operation in 2017

Week			
33 First beam! August 18	34 Cont'd commissioning	35 Cont'd commissioning	36 First beam to users VESPER
37 Installation of plasma lens	38 Beam through plasma lens	39 VESPER	40 Beam tuning, plasma lens
41 BCM improvement WFM	42 WFM First spark plasma lens	43 Inductive BPMs LAL: injector optimisation	44 Cavity BPMs
45 Laser spot study VESPER	46 ESA at VESPER THz studies	47 Combined WFM and Cavity BPMs	48 AWAKE screen Plasma lens!

49: VHEE

50-51: Plasma lens, instrumentation, THz….

Organizational issues

Proposed Organisation

- We propose an organisation at CERN similar to the one in the HiRadMat facility.
- The main elements are: a local facility responsible with a local operation team consisting of CERN staff/fellows complemented by external researchers staying at CERN to operate the facility - in some cases with subsistence support from CERN, a Scientific Board and a Technical Board.
- We will set up "External" Scientific Board (meet 2-4 times a year to review programme/proposals and progress).
  We aim to converge on names by Easter.
- A Technical board also meeting at the same frequency, setup to review the technical, safety and radio-protection issues on the recommended experiments by the Scientific Board. The Technical Board gives the final authorisation for the installation of the experiment, needed to get the beam permit within the agreed conditions.
- The researchers coming to CERN to carry out experiments/projects in CLEAR will need to register as users and we are discussing how to do this best. In practice many are already users but for some CLEAR will be their only and first connection to CERN.

→ successful so far

→ International Scientific Committee first official meeting in February 2018

→ Defining composition

→ Mainly dealt with on an "ad hoc" basis in 2017
General CERN rules for access to User Facilities under definition
Already used for ESA/TRAD expert access in Week 46

CLEAR International Scientific Committee members:

R. Aleksan (CEA), R. Assmann (DESY), J. Clarke (STFC), A. Faus-Golfe (IFIC & LAL), M Ferrario (INFN-LNF), S. Gilardoni (CERN), E. Gschwendtner (CERN), R. Losito (CERN), L. Rivkin (PSI), R. Ruber (Uppsala), M. Vretenar (CERN).

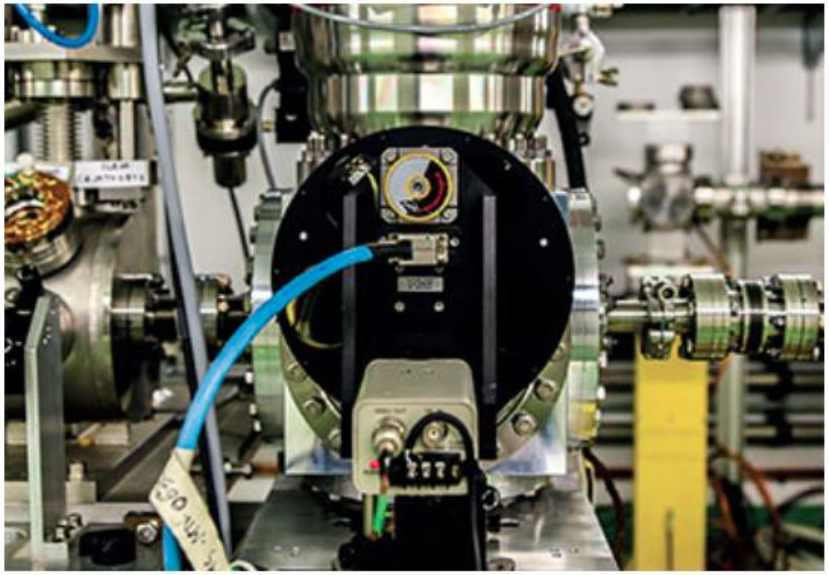
- CLEAR International Scientific Committee Kick-off Meeting – 11 December 2017
- First executive Meeting of the CLEAR ISC at CERN in February 2018.

Already making the headlines

CERN COURIER

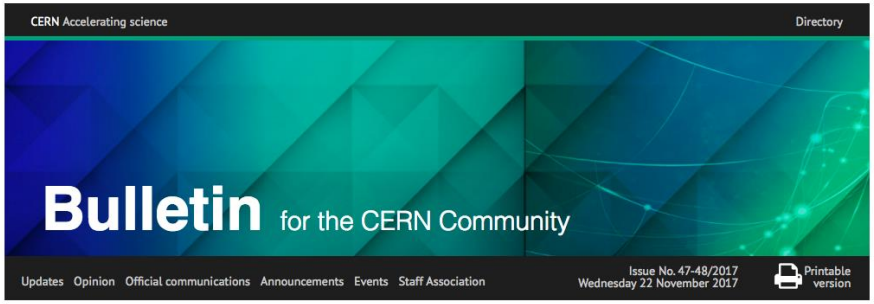
Oct 13, 2017

CLEAR prospects for accelerator research



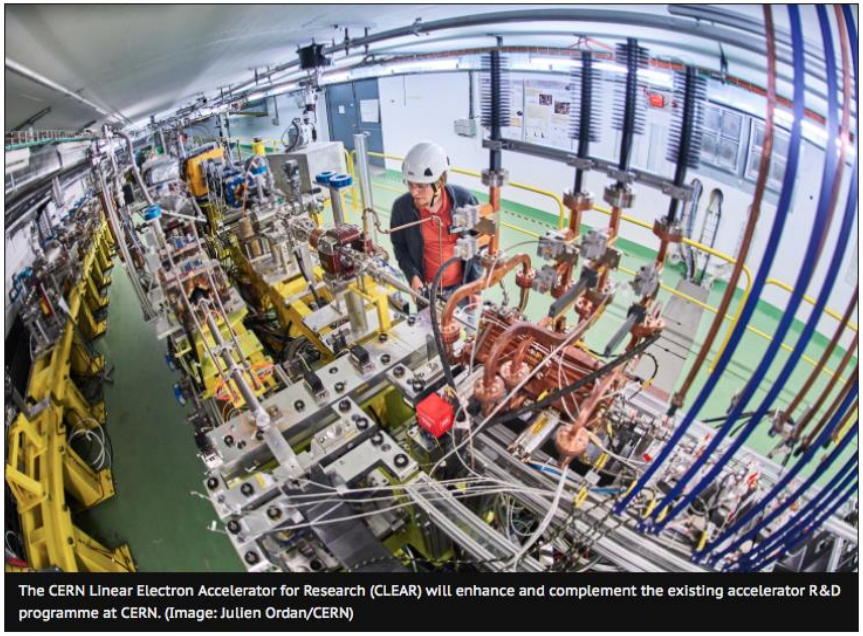
CLEAR's plasma-lens experiment (expand for full image)

A new user facility for accelerator R&D, the CERN Linear Electron Accelerator for Research (CLEAR), started operation in August and is ready to provide beam for experiments. CLEAR evolved from the former CTF3 test facility for the Compact Linear Collider (CLIC), which ended a successful programme in December 2016. Following approval of the CLEAR proposal, the necessary hardware modifications started in January and the facility is now able to host and test a broad range of ideas in the accelerator field.



CLEAR prospects for accelerator research

by *Matthew Chalmers*



The CERN Linear Electron Accelerator for Research (CLEAR) will enhance and complement the existing accelerator R&D programme at CERN. (Image: Julien Ordan/CERN)

Program 2018

- Restart as early as possible after winter shut-down
  - 12th February, goal for restart with beam
- Complete ongoing studies & improve beam performance. Detailed experimental program to be prepared in January, validated at the CLIC Workshop (22-26 January).
- First meeting of the CLEAR International Scientific Committee in February after the CLIC Workshop. It will assess the experimental program for the second half of 2018 and beyond.
- Possible upgrades, starting at the earliest in summer 2018:
  - Connection of CLIC R&D module to XBOX1
  - Consolidation and modifications of laser (double pulse? move closer to RF gun?)

THANKS
for
YOUR ATTENTION