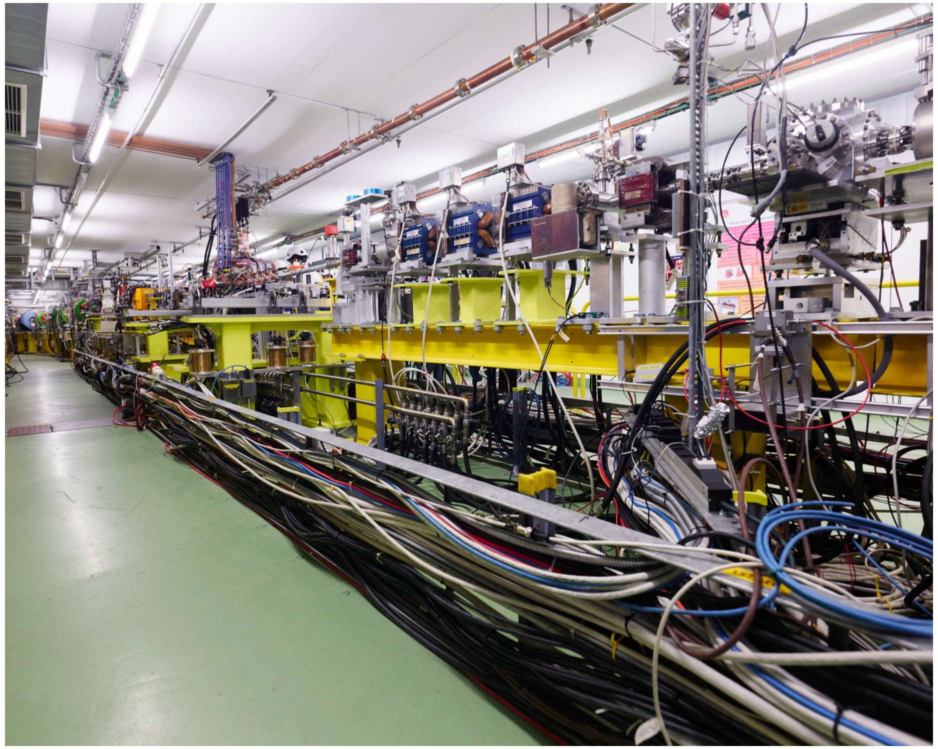
CLEAR Facility at CERN

Alexander Malyzhenkov for the CLEAR Team

CLEAR = CERN Linear Electron Accelerator for Research



CLEAR is a versatile 200 MeV electron linac + a 20 m experimental beamline, operated at CERN as a multi-purpose user facility.

Scientific and strategic goals:

- Providing a test facility at CERN with high availability, easy access and high quality e- beams.
    - Performing R&D on accelerator components, including beam instrumentation prototyping and high gradient RF technology
    - Providing an irradiation facility with high-energy electrons, e.g. for testing electronic components in collaboration with European Space Agency or for medical purposes(VHEE/FLASH)
    - Performing R&D on novel accelerating techniques – electron driven plasma and THz acceleration.
- Maintaining CERN and European expertise for electron linacs linked to future collider studies
- Using CLEAR as a training infrastructure for the next generation of accelerator scientists and engineers.

CLEAR Timeline

- Approved in December 2016, as a 2 + 2 years program
- Started operation in August 2017
- Reviewed and extended until 2020 in February 2019
- Operation extended in 2021 and possibly beyond, with independent budget included in the new CERN Medium Term Plan 2021-2025 (approved by the CERN Council in September 2020)
- CERN internal review, 16 March 2021 → positive outcome:

  Continued operation of the CLEAR facility for the next 5 years is fully justified for CERN core accelerator R&D, accelerator applications, collaborations and training

Operation

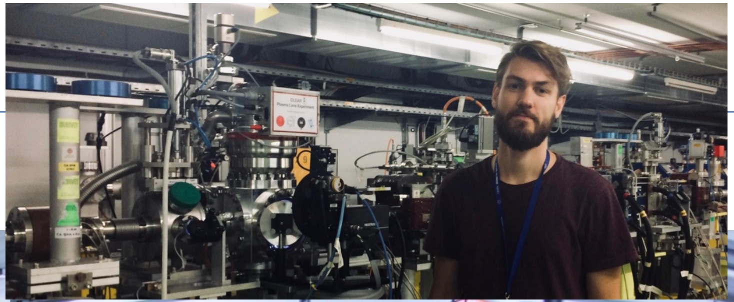
- CLEAR is a stand-alone installation, thus operation during general stops of the global CERN accelerator complex, including long shut-downs, is possible.

- CLEAR is operated for 30 to 40 weeks/year – typically from March to December, often 2-3 weeks stop in summer.
  - Operation organized over 2 shifts, roughly during working hours, 5 days/week
  - No night shifts or week-end running (apart few exceptions)
  - Sometimes remotely supervised operation in nights/week-ends (low-charge irradiation – none in 2020)

- Current operating team:
  2 Staff, 1 associate, 2 Postdocs, 3 PhD students, 1 part-time associate (in remote)

- Detailed weekly activities organized at the Monday operation meeting (often followed by access in the hall) and coordinated by a weekly supervisor (member of the operation team)

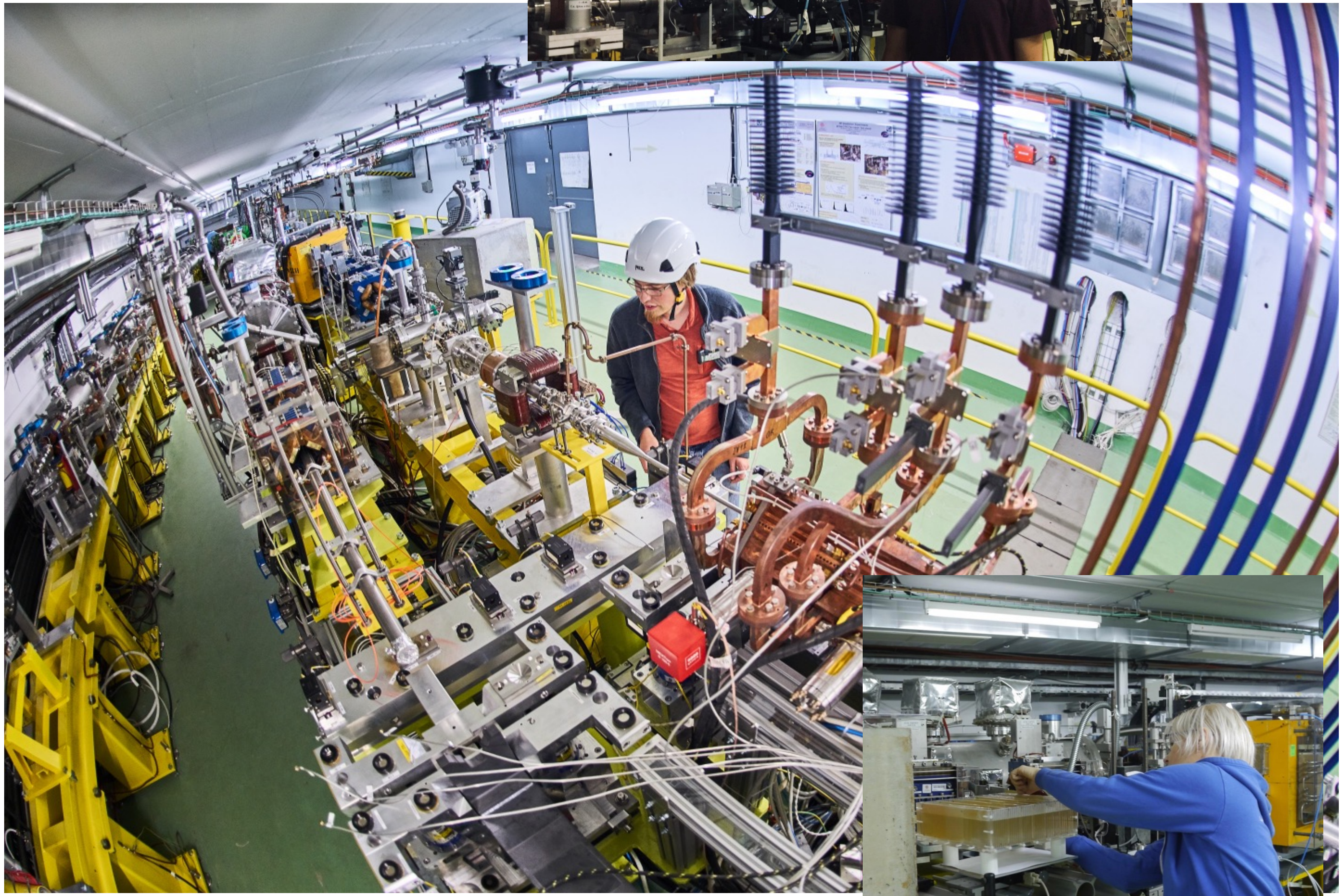
CLEAR operation 2017-2022



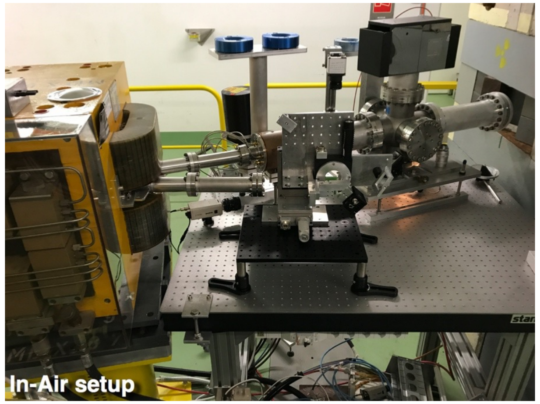
Start with beam August 2017

- 19 weeks of operation in 2017
- 36 weeks in 2018
- 38 weeks in 2019
- 34 weeks in 2020
- 35 weeks in 2021
- 33 weeks so far in 2022 (40 expected in December)

Due to Covid-19 related measures, 2020 2021 activities were impacted, and mainly limited to CERN users



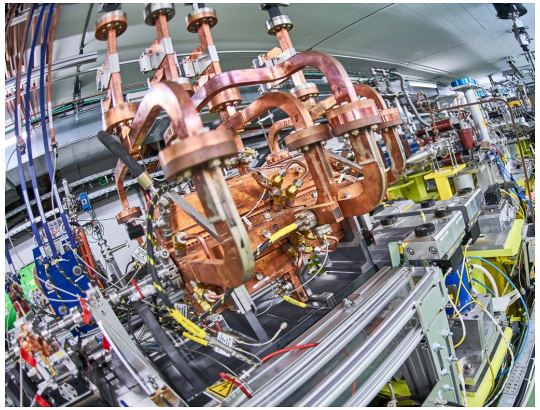
CLEAR Layout & main installations



In-air test stand

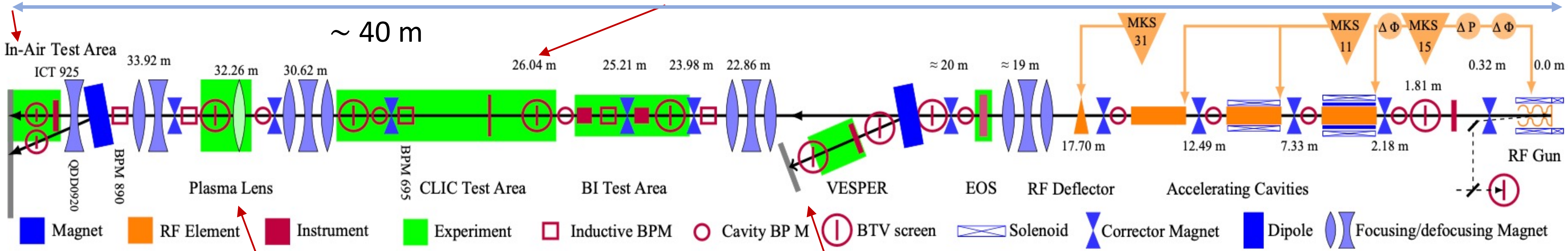
Testing ground for beam diagnostics R&D and THz radiation studies

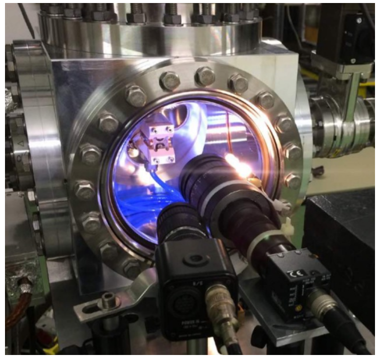
Irradiation for medical and other applications



CLIC Test-Stand

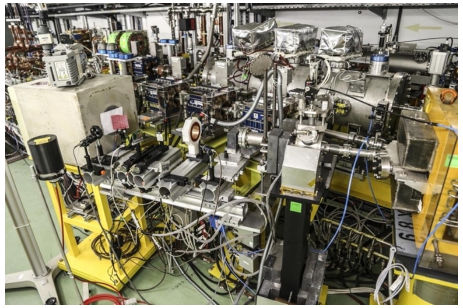
High-gradient and linear colliders R&D





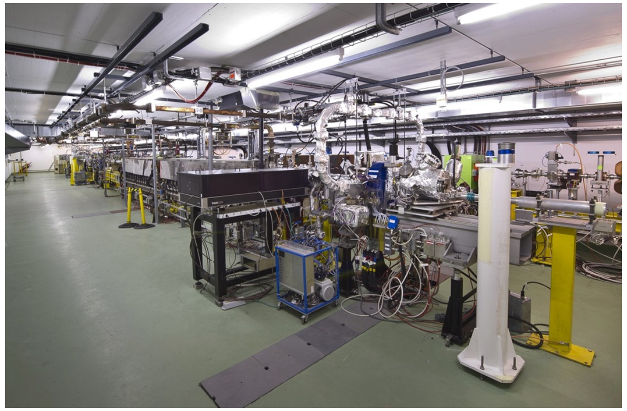
The Plasma Lens Experiment

Novel concepts of plasma-based focusing and acceleration



VESPER

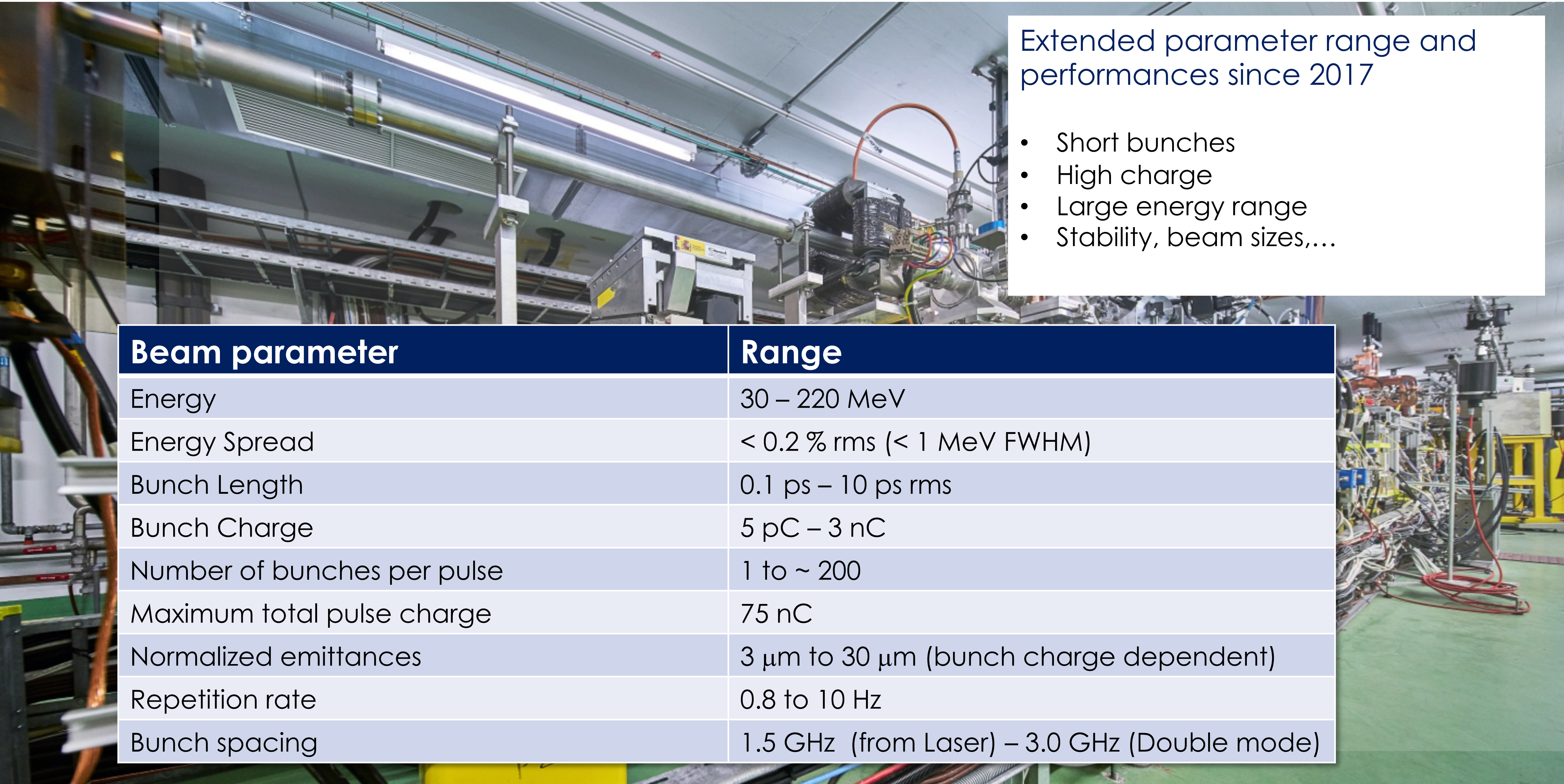
Beam irradiation facility for studies on radiation damage of electronics and medical applications



CALIFES electron linac

Flexible accelerator providing 200 MeV electron beams to all CLEAR users

CLEAR Beam Parameters



Extended parameter range and performances since 2017

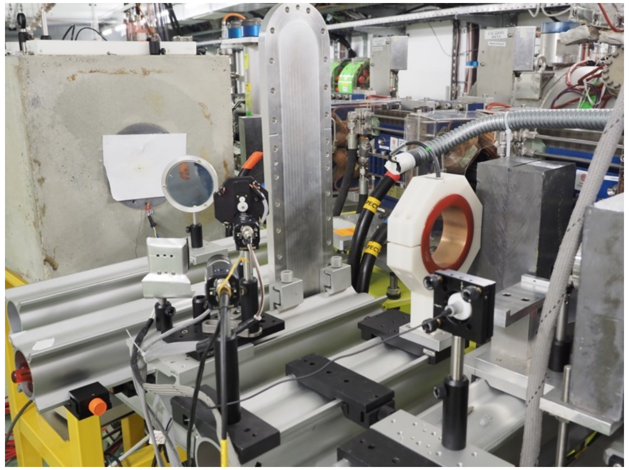
- Short bunches
- High charge
- Large energy range
- Stability, beam sizes,…

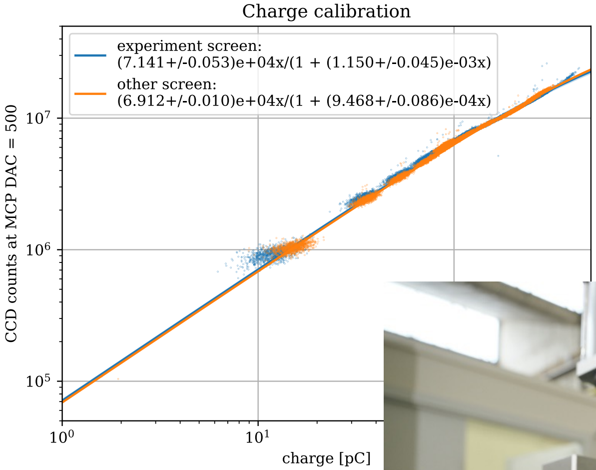
Beam parameter	Range
Energy	30 – 220 MeV
Energy Spread	< 0.2 % rms (< 1 MeV FWHM)
Bunch Length	0.1 ps – 10 ps rms
Bunch Charge	5 pC – 3 nC
Number of bunches per pulse	1 to ~ 200
Maximum total pulse charge	75 nC
Normalized emittances	3 μm to 30 μm (bunch charge dependent)
Repetition rate	0.8 to 10 Hz
Bunch spacing	1.5 GHz (from Laser) – 3.0 GHz (Double mode)

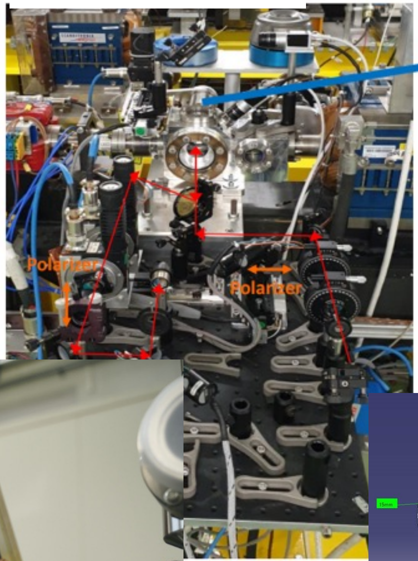
Some experiments at CLEAR: for AWAKE

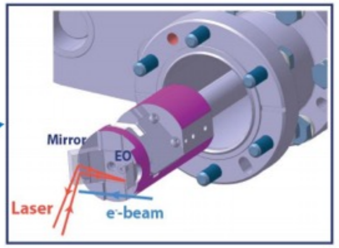
E. Gschwendtner

Charge calibration measurements of the AWAKE spectrometer scintillating screen/camera combination performed in 2017, 2018, 2019



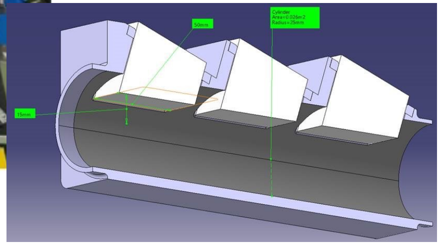


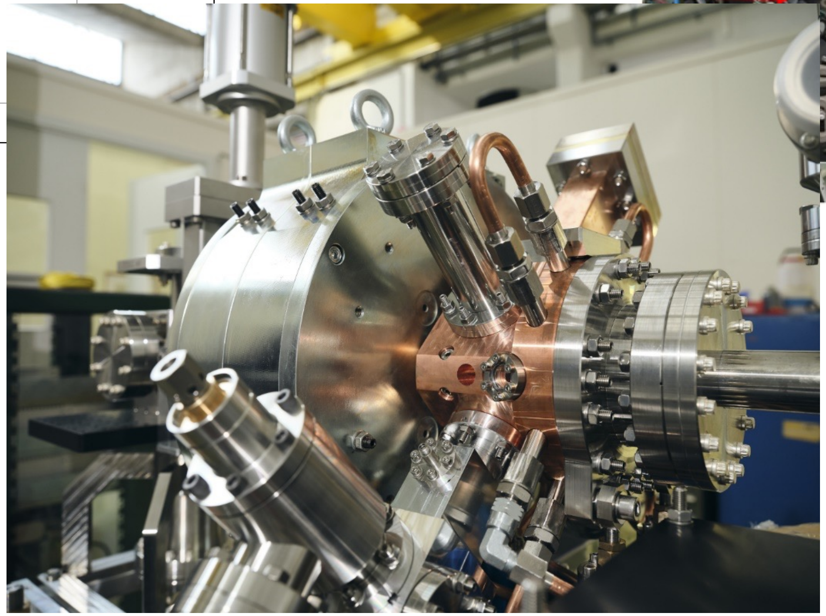




Bunch length monitors:

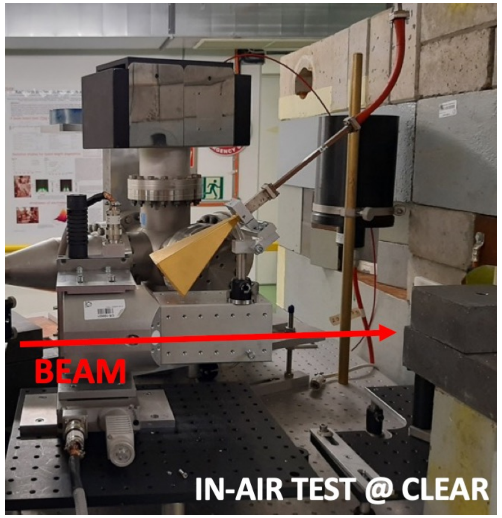
EOS and ChDR





Common development of novel electron source

CLIC-AWAKE-CLEAR



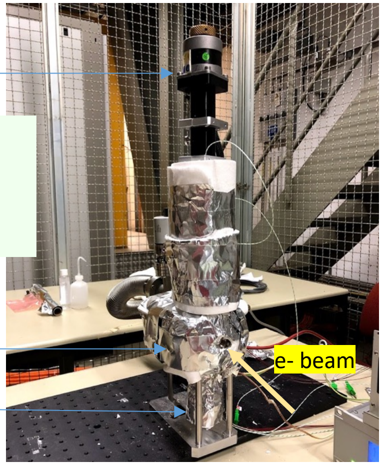
Cherenkov BPMs

Beam Screen Survival Tests in Rubidium

Screen actuator

Sapphire viewports

Rb reservoir (empty)



Some experiments at CLEAR: CLIC

S. Stapnes

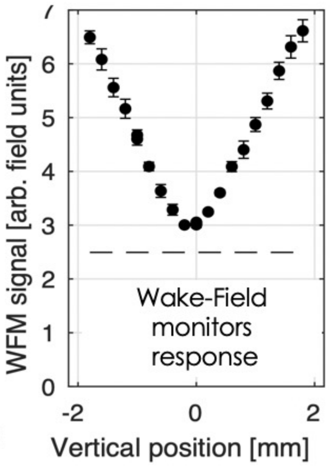
Key CLIC related activities

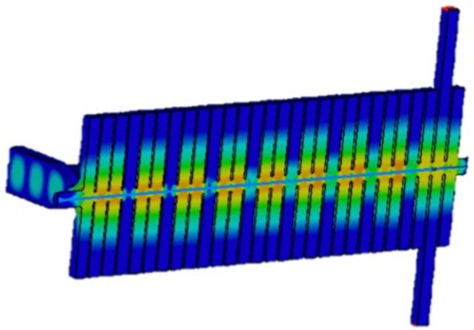
Experiments:
- Wake-Field monitors
- Wake-field kicks
- CLIC cavity BPMs

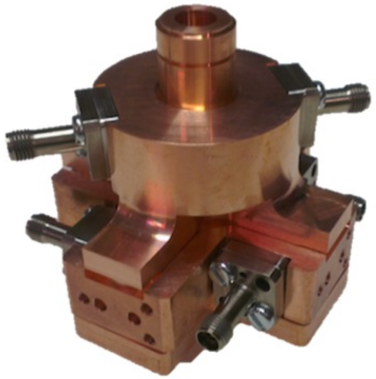
Main collaborators
- University of Oslo
- CEA - Saclay
- Università di Napoli Federico
- RHUL

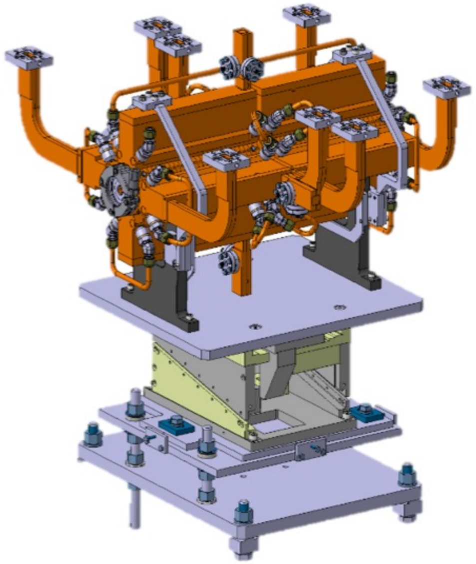
Future step, connecting the cavity to X-Box1

possible tests:
- RF kicks
- Breakdown kicks
- RF effect on WFMs
- Stability & reliability runs

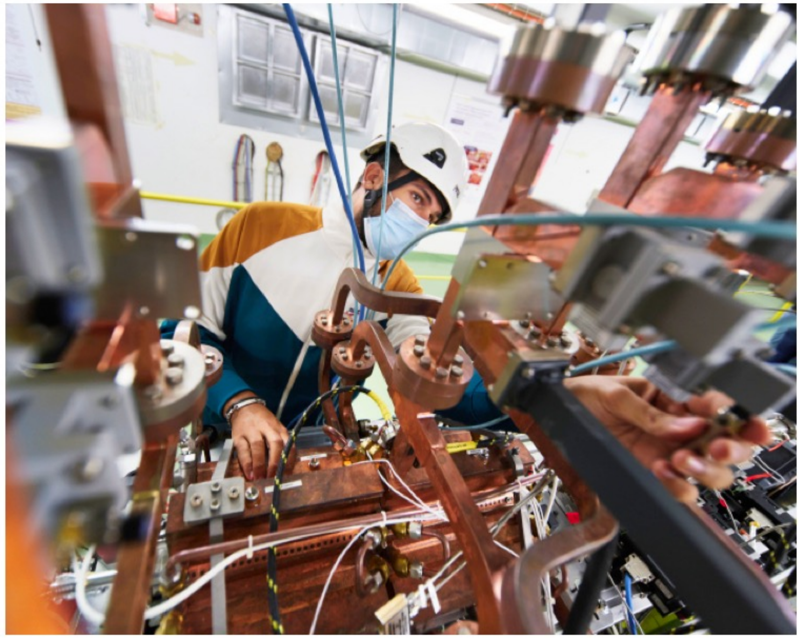








A. Gilardi, K. Sjobaek, M. Wendt, A. Lyapin

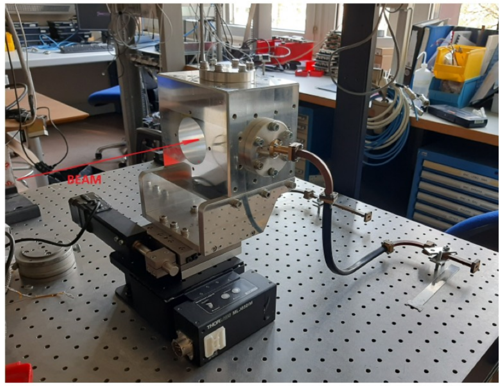


Cavity BPM and X-band structure on movers

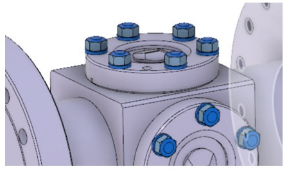
Other Beam Instrumentation activities

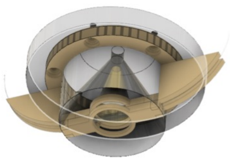
S. Mazzoni

- **Longitudinal profile ChDR / EO tests**
  - Test of vacuum ChDR pickups for longitudinal profile measurement with ns / tens of ps resolution
  - Detection scheme using 20 – 40 GHz electro-optical modulators and 780/1550 nm laser at CLEAR. Other EM probes to test
  - Proof of principle at CLEAR, then tests in HRM. Long term study for FCC



- **Test of LHC EO buttons** (CERN/RHUL)
  - Beam validation of a technology being developed in collaboration with RHUL for HL-LHC
  - Using fiber-coupled electro-optical waveguide coupled to a 50 Ohms terminated electrostatic button

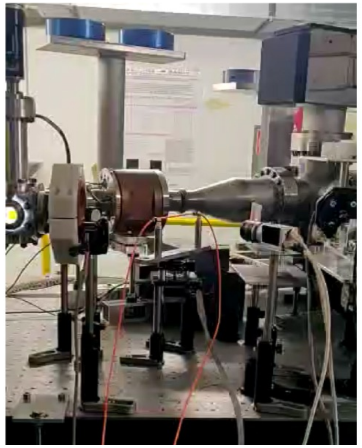




Recent Publications

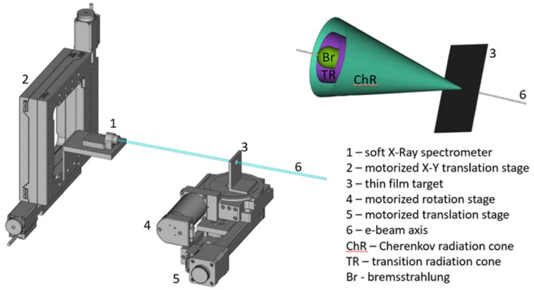
- A. Curcio et al, "Diffractive shadowing of coherent polarization radiation", Phys. Lett. A **391**, 127135 (2021)
- A. Curcio et al, "Noninvasive bunch length measurements exploiting Cherenkov diffraction radiation", PRAB **23** (2020)
- A. Curcio et al. "Beam-based sub-THz source at the CERN linac electron accelerator for research facility", PRAB **22** (2019)
- R. Kieffer et al, "Experimental Observation of "Shadowing" in Optical Transition Radiation", Phys. Rev. Lett. **120** (2018)
- Yearly reporting to conferences (IBIC, IPAC, LCWS, …)

- **Optical BLM tests** (CERN)
  - Test of new optical BLM. Loss signal: Cherenkov Radiation produced in fibres.
  - 2020: measurement of ChR as a function of angle to benchmark simulations
  - 2021: improved read-out electronics and new sensors (SiPM, PMT, PD) test with low intensity bunches / trains
  - Complement to BL tests in SPS

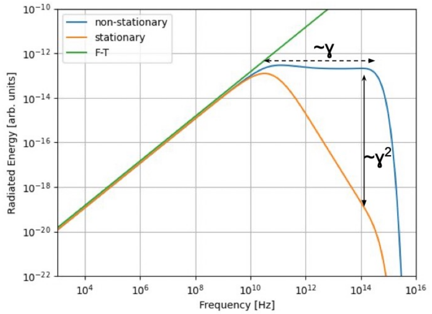


R&D

- **X-ray Cherenkov test** (Belgorod)
  - Study of ChR in soft X-rays regime.
  - Absolute light yield and angular distribution as a function target angle
  - Preparation affected by COVID. Foreseen 2nd half of 2021



- **Validation of ChDR theoretical model** (CERN)
  - Models for ChDR still not fully validated. Basic tests to measure ChDR spectrum in the range 100-300 GHz
  - Verification needed for applications to high energy beams (FCC)
  - Radiation produced by dielectric conical target, tests in Summer 2021



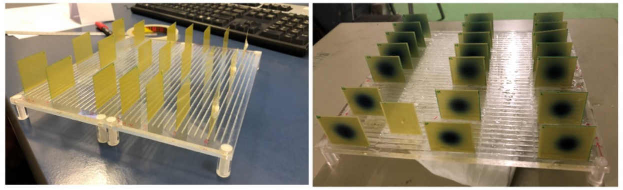
VHEE/FLASH activities in CLEAR

Calibration of operational medical dosimeters – nonlinear effects with high-dose short pulses

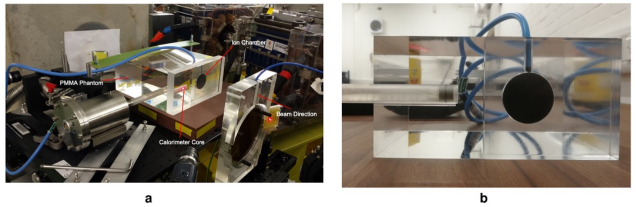
Verification of FLASH effect using biological dosimeters

Experimental verification of dose deposition profiles in water phantoms

Demonstration of "Bragg-like peak" deposition with focused beams



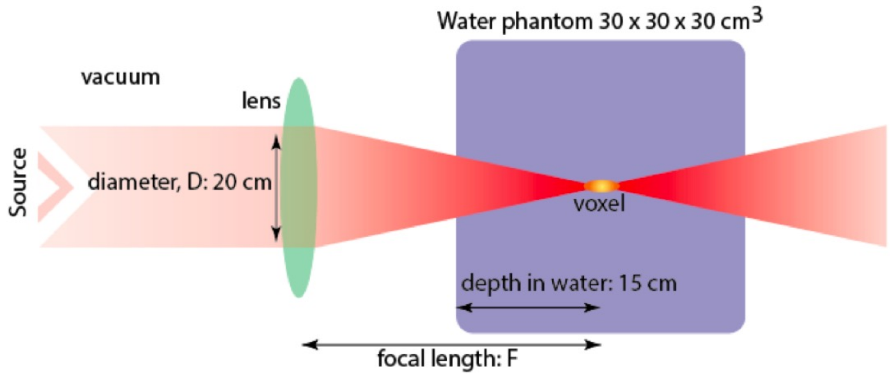
Films set-up for profile depth dose, CHUV Lausanne
(M.C. Vozenin, C. Bailat, R. Moeckli et al.)



Calorimeter and ROOS chamber, Nat. Phys. Lab. UK
(A. Subiel et al.)

High dose rate dosimetry

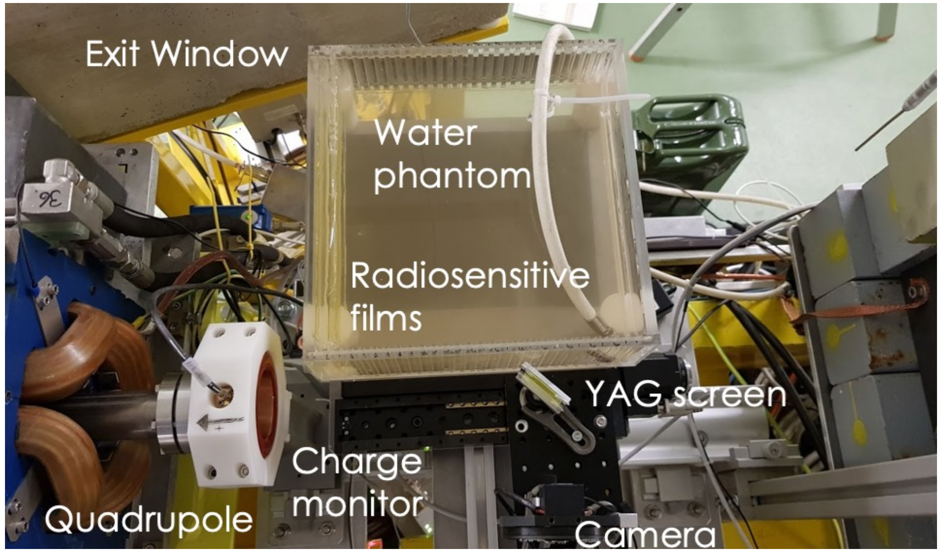
Advance Markus chambers and SRS Array, Oldenburg University and PTW
(B. Poppe, D. Poppinga et al.)



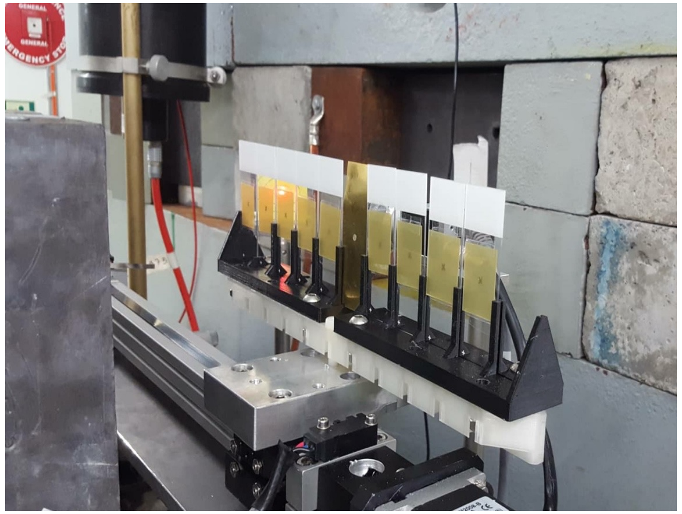
Aim:

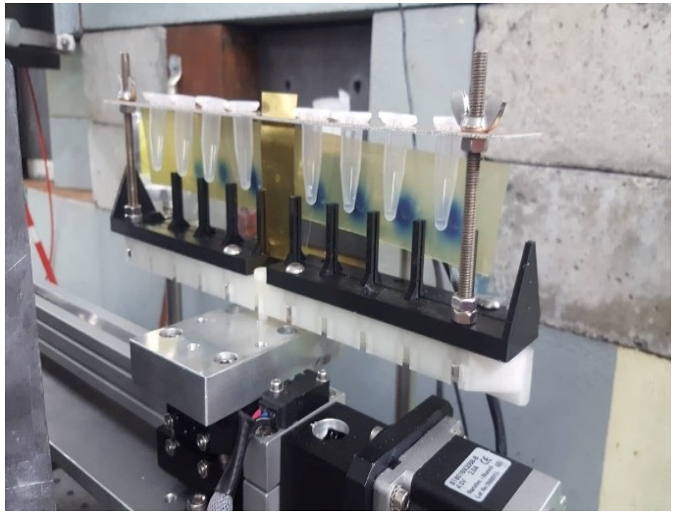
Focus the beam on the tumour to minimize the dose on the nearby healthy tissues

Strathclyde and Manchester

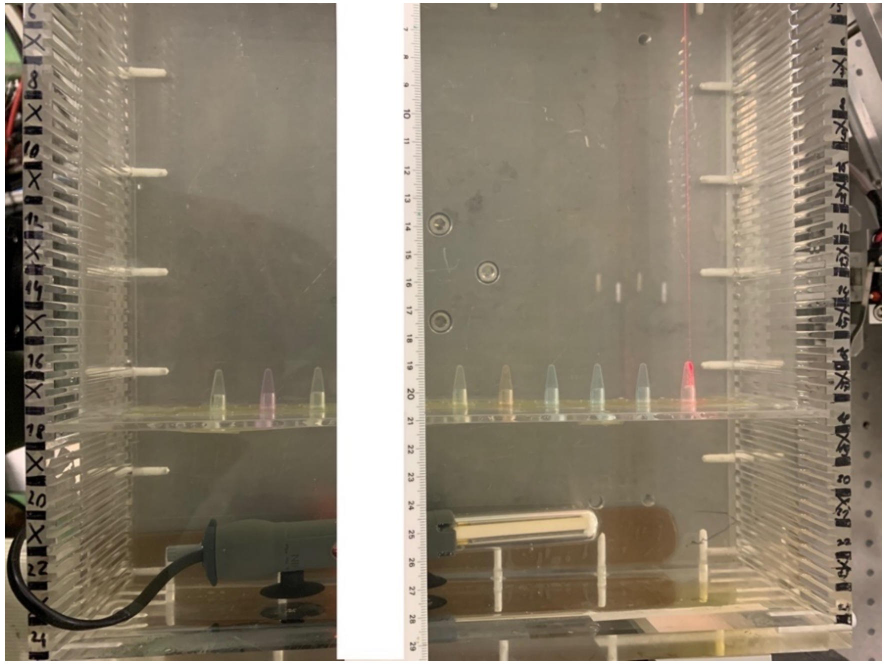


Biological effects of high dose rates





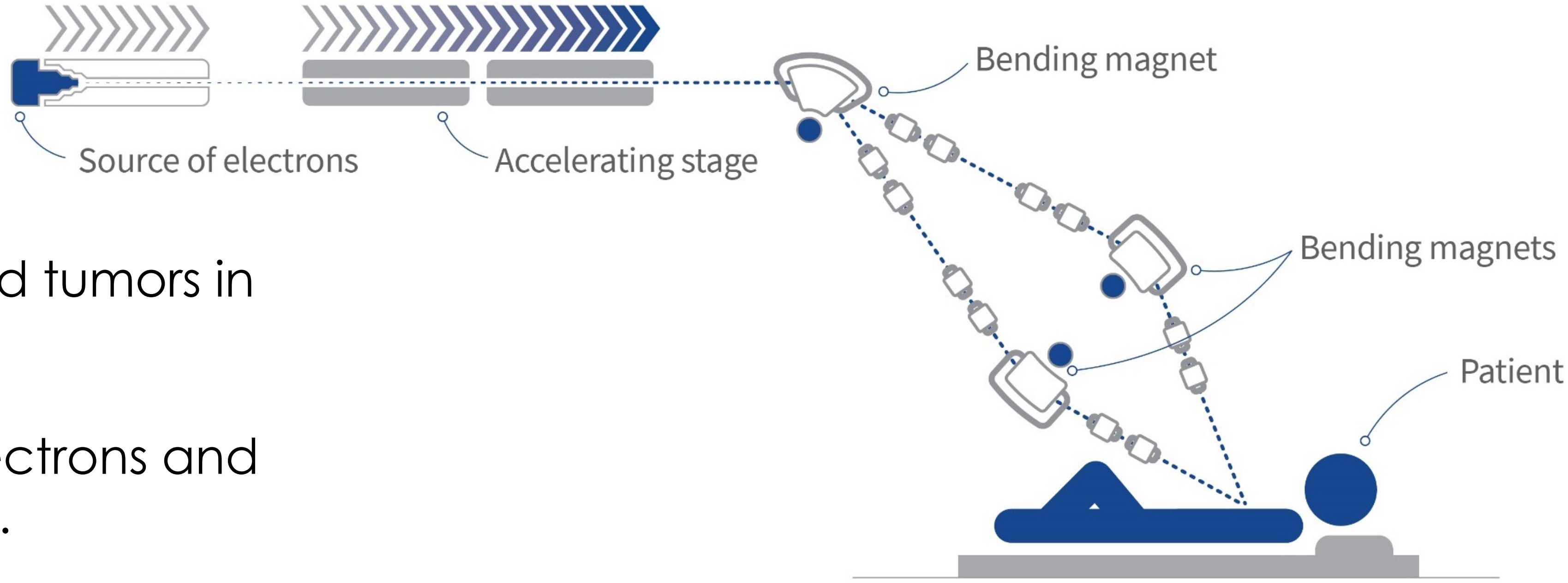
Left: dry plasmid samples on glass microscope slides.
Right: wet plasmid samples in Eppendorf tubes.
EBT-XD film placed behind samples, Manchester University
(K. Small, R. Jones et al.)



Set-up in the water tank. Zebra fish eggs, alanine pellets, gafchromic films,
CHUV Lausanne
(M.C. Vozenin, C. Bailat, R. Moeckli et al.)

CERN – CHUV collaboration on FLASH

CLIC technology for a FLASH facility being designed in collaboration with CHUV



Treat large, deep-seated tumors in FLASH conditions.

Uses 100 MeV-range electrons and optimized dose delivery.

Compact to fit on a typical hospital campus.

Access to beam

- Any user willing to access the facility has to fill-up a beam time request form (https://clear.cern/content/beam-time-request), specifying:
  - Experiment description, scientific aim and justification
  - Needed beam parameters
  - Experimental apparatus and logistics, safety aspects

- The CLEAR Technical Board is responsible to give the final authorization and allocate the beam time in the schedule, after checking technical feasibility and scientific interest and safety and RP issues, following guidelines by the CLEAR Scientific Board
(the formal approval procedure is carried out using the CERN EDMS infrastructure)

- User teams often ask for beam time on a given activity a few times during an year, and often over 2 or more years. Beam time requests beyond 1 year require to fill out a new form

Thanks for your attention!