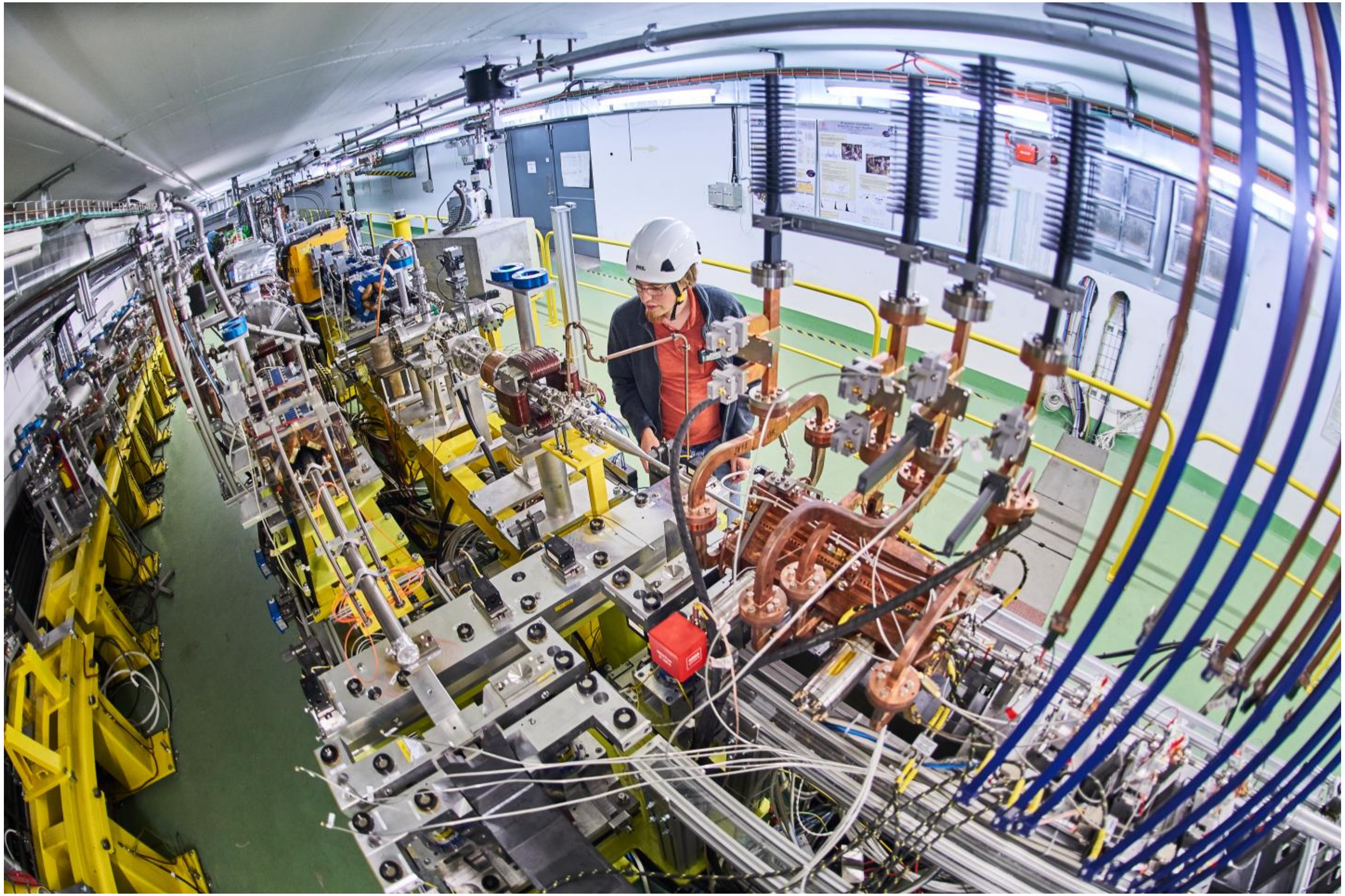
CLEAR Achievements, Status and Plans

Highlights on:

- past achievements
- recent results

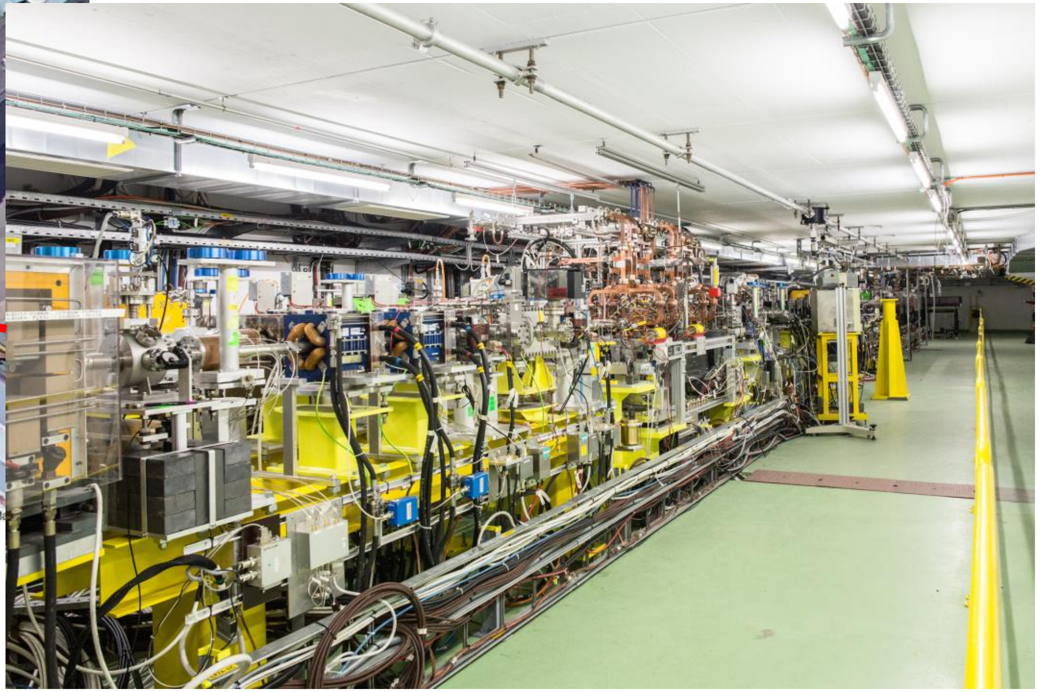
Status and potential planning for next run

Extension in 2019 and future perspectives



CLIC Test Facility (CTF3) - completed its experimental program in 2016

Proposal to reuse the CLEX area and the CALIFES e- linac for accelerator R&D



CLEAR is a user facility at CERN, running in parallel with the main CERN accelerator complex, with the primary goal of enhancing and complementing the existing accelerator R&D and testing capabilities at CERN.

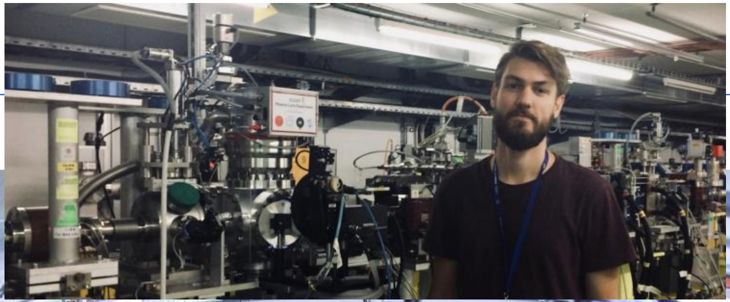
Approved December 2016

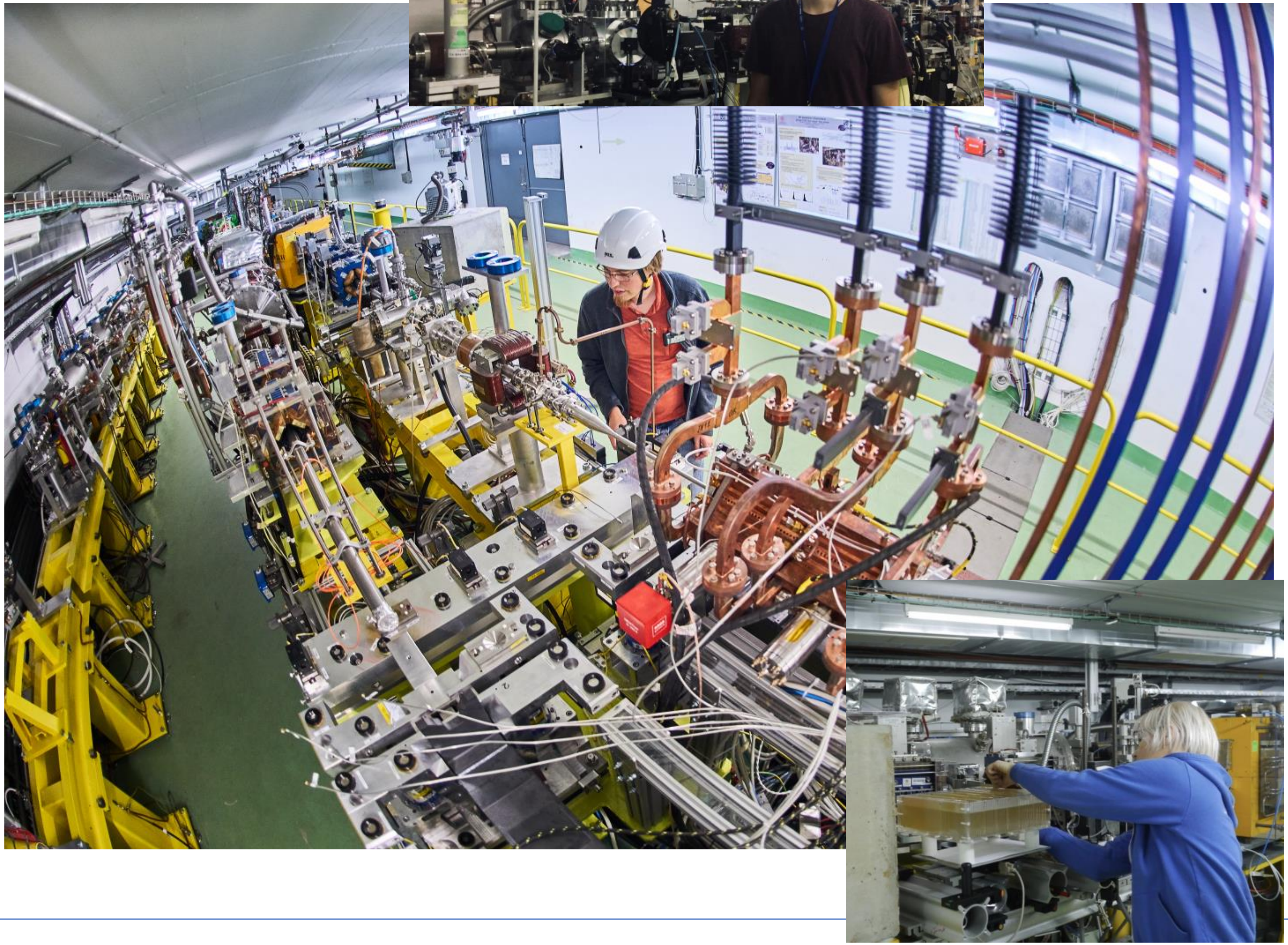
Motivation

CLEAR - 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 innovative beam instrumentation prototyping, high gradient RF technology realistic beam tests and beam-based impedance measurements.
  - Providing an irradiation facility with high-energy electrons, e.g. for testing electronic components in collaboration with ESA or for medical purposes(VHEE), possibly also for particle physic detectors.
  - Performing R&D on novel accelerating techniques – electron driven plasma and THz acceleration. In particular developing technology and solutions needed for future particle physics applications, e.g. beam emittance preservation for reaching high luminosities.
- Maintaining CERN and European expertise for electron linacs linked to future collider studies (e.g. CLIC and ILC, but also AWAKE), and providing a focus for strengthening collaboration in this area.
- Using CLEAR as a training infrastructure for the next generation of accelerator scientists and engineers.

CLEAR operation 2017-2018



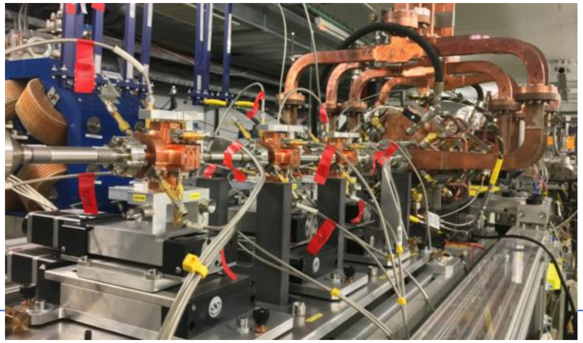


Start with beam August 2017

- 19 weeks of operation in 2017
- 36 weeks in 2018

Main activities:

- CLIC & high-gradient X-band
- Instrumentation R&D
- VESPER irradiation test stand:
    - Electronic components for space applications (with ESA)
    - Medical applications (VHEE, FLASH)
    - Electronic components for accelerators and detectors
- Novel techniques: plasma focusing and acceleration, THz radiation



CLIC related activities

Ongoing experiments:

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

Main collaborators

- University of Oslo
- CEA - Saclay
- Università di Napoli Federico II
- RHUL

Next step, connecting the cavity to X-Box1

possible tests:

- RF kicks
- Breakdown kicks
- RF effect on WFMs
- Stability & reliability runs

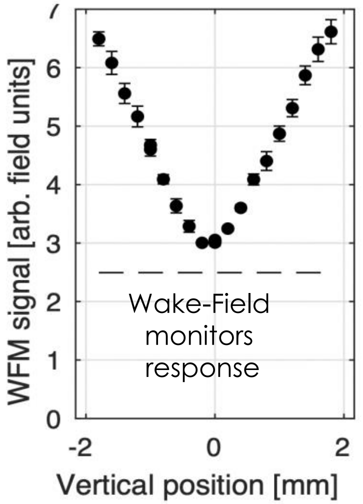
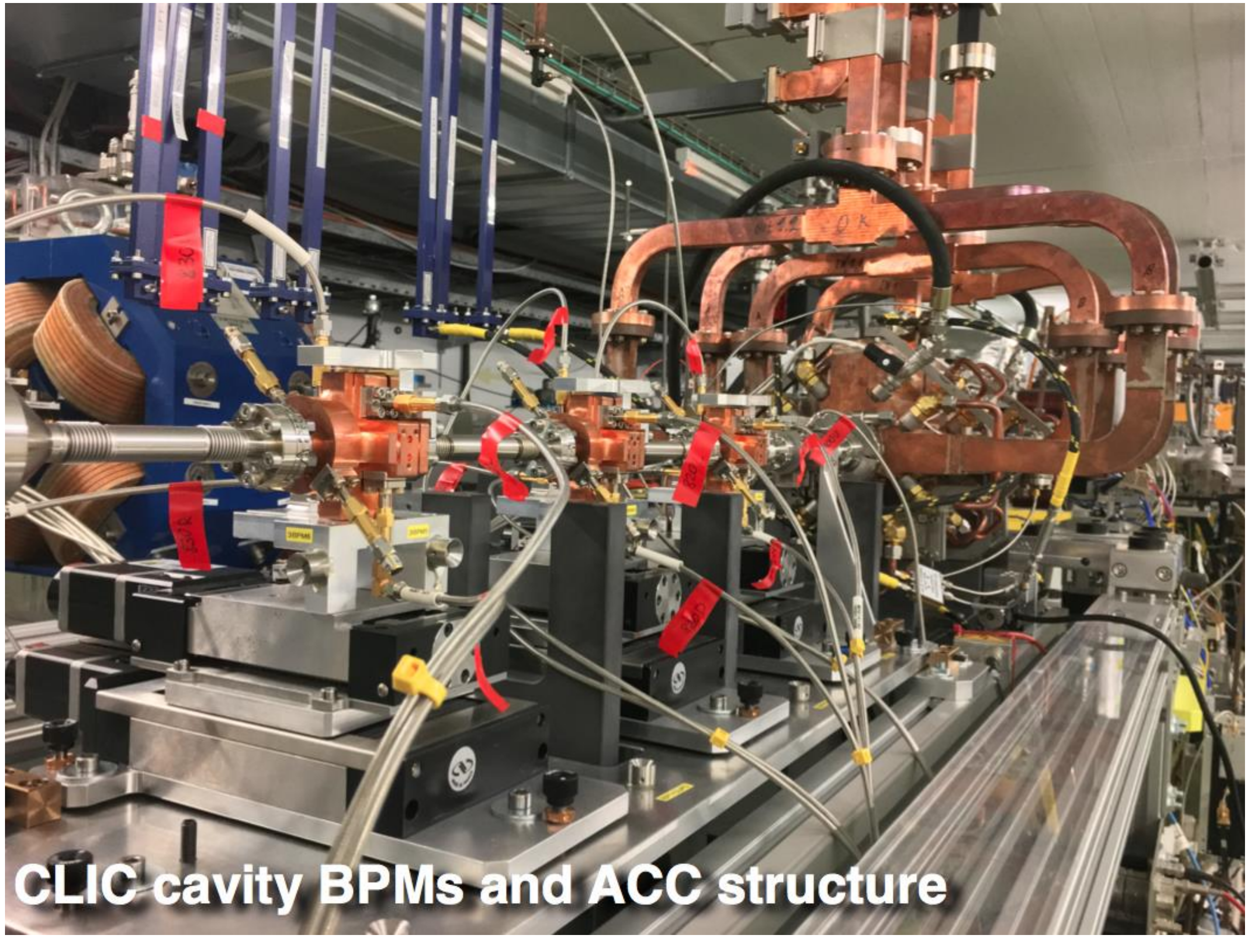



Figure 1: Prototype copper CLIC cavity BPM.

Tests of Wakefield Monitors at CLEAR — *K. Sjobaek, Tue 22*
Wake-fields measurements on the CLIC structure — *A. Gilardi, Thu 24*

Former CLIC Module



Beam Instrumentation R&D

Many activities planned (most ongoing)

Two main goals:

1) Consolidate and improve beam instrumentation for CLEAR

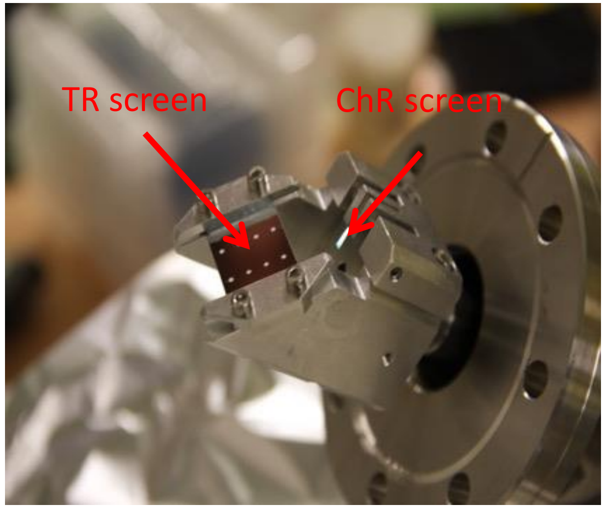
2) Diagnostics R&D

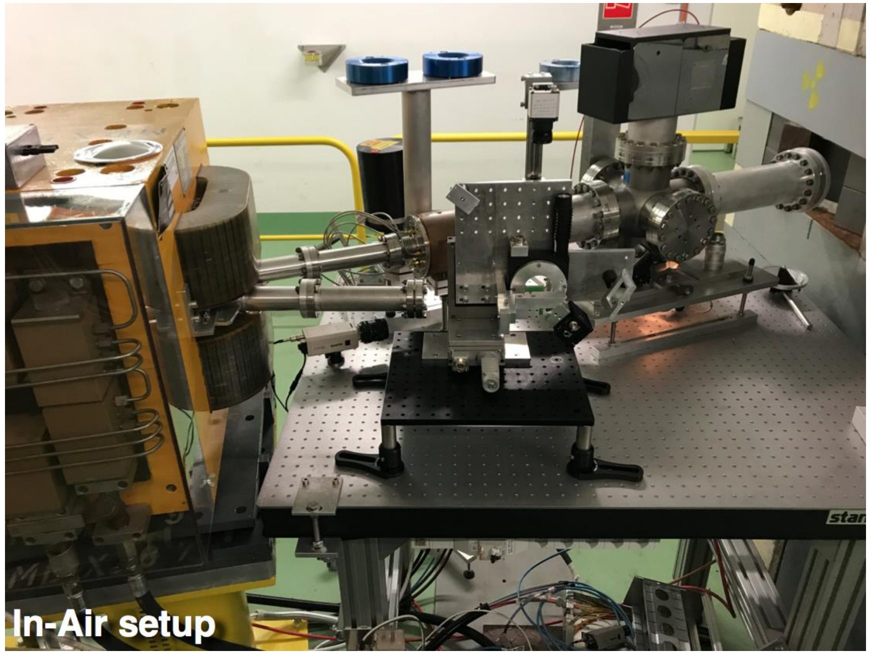
- Diffraction Cherenkov radiation
- Electro-Optical monitors
- …

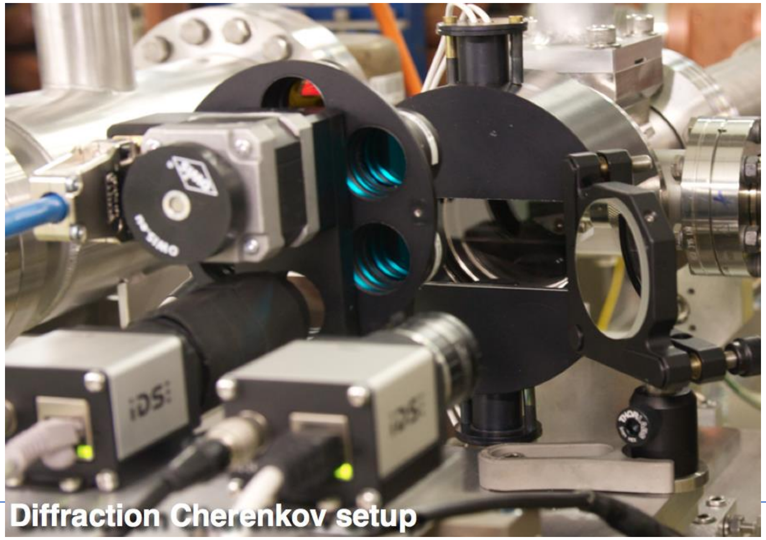
Collaboration at CERN with BE/BI group and several external collaborators

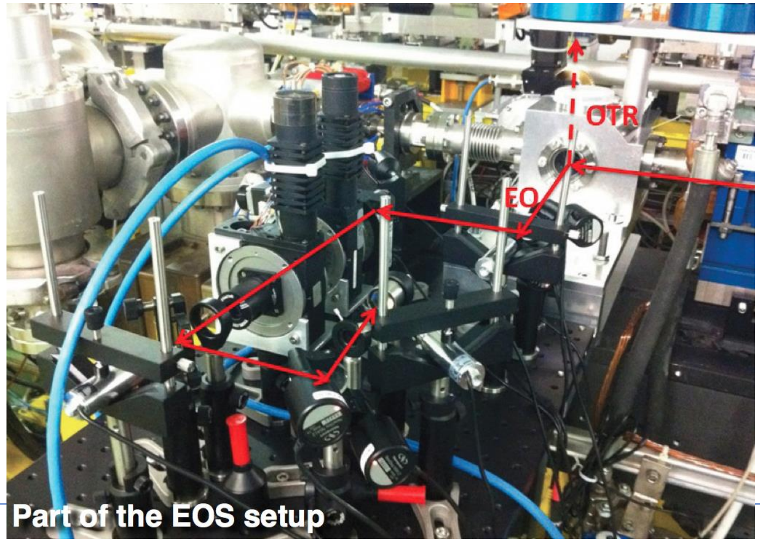
Direct applications to CERN accelerator complex & potential for future applications

Diagnostics R&D in the CLEAR Facility T. Lefevre, Thu 24

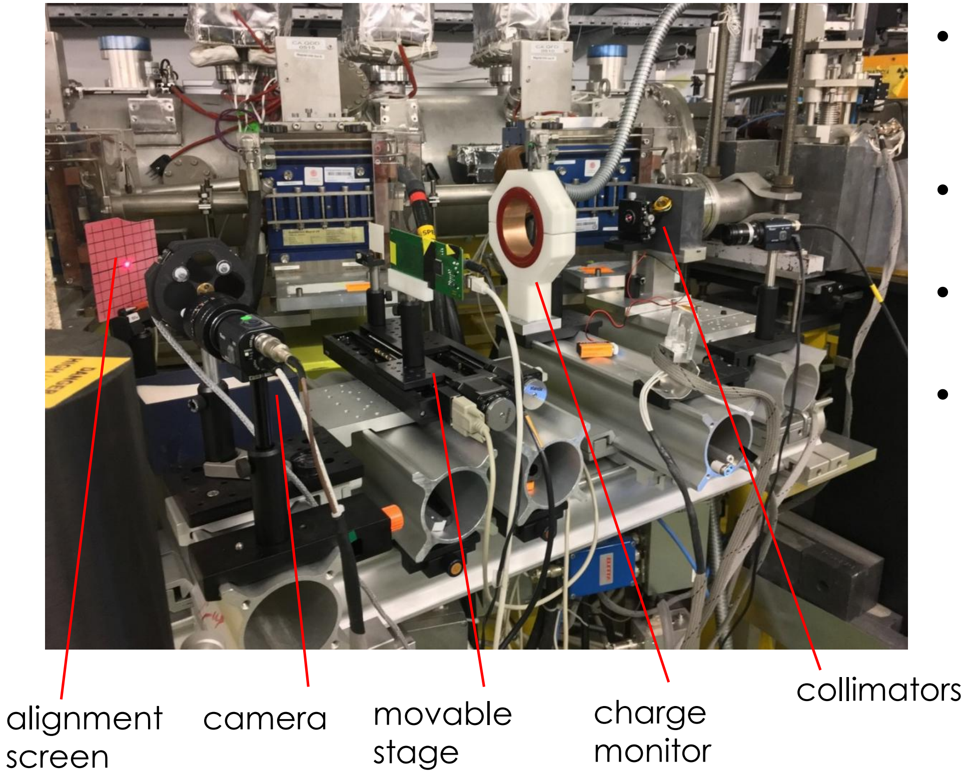






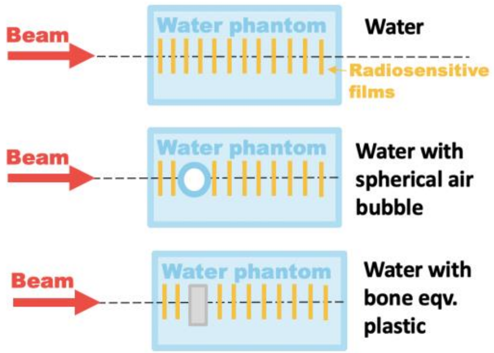


vesper irradiation facility



- Installed in a spectrometer line
- In air
- Fully equipped
- Large, homogeneus beam

Medical applications (VHEE, FLASH)

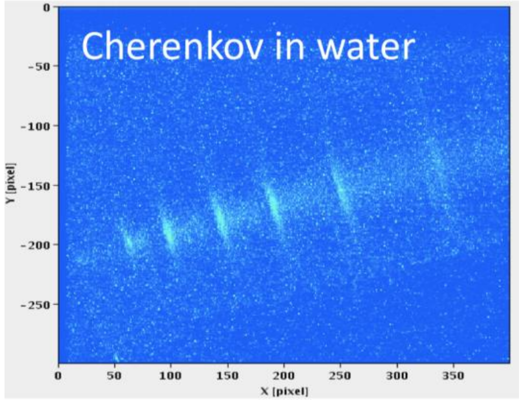


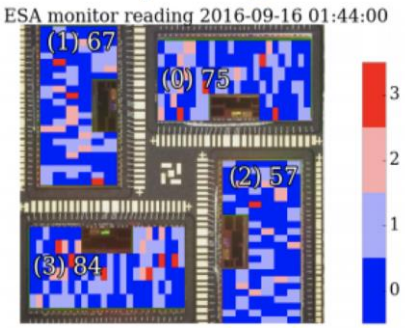
VHEE Experimental Studies in VESPER/CLEAR

AGNESE LAGZDA[†‡], R.M. JONES[†‡], D. ANGAL-KALININ[‡], J. JONES[‡], A. AITKENHEAD[*], K. KIRKBY[*], R. MACKAY[*], M. VAN HERK[*], W. FARABOLINI[¥]

UNIVERSITY OF MANCHESTER[†], COCKCROFT INSTITUTE[‡], THE CHRISTIE HOSPITAL[*], CERN[¥]

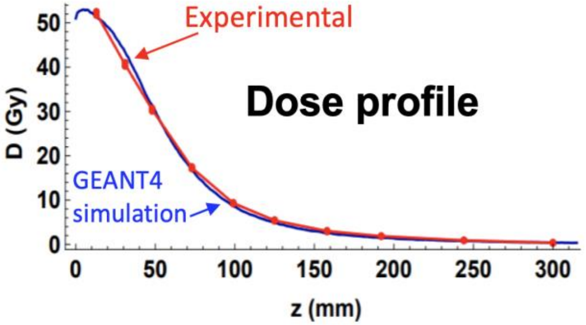
CLICWEEK 2018

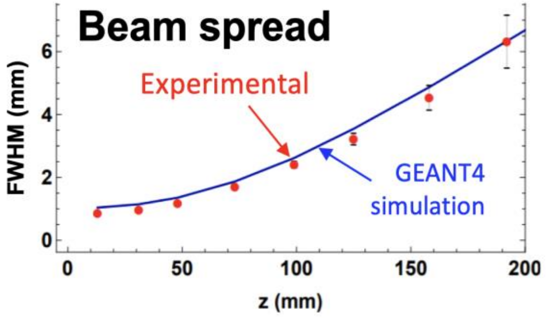




Radiation hardness of electronic components for space missions

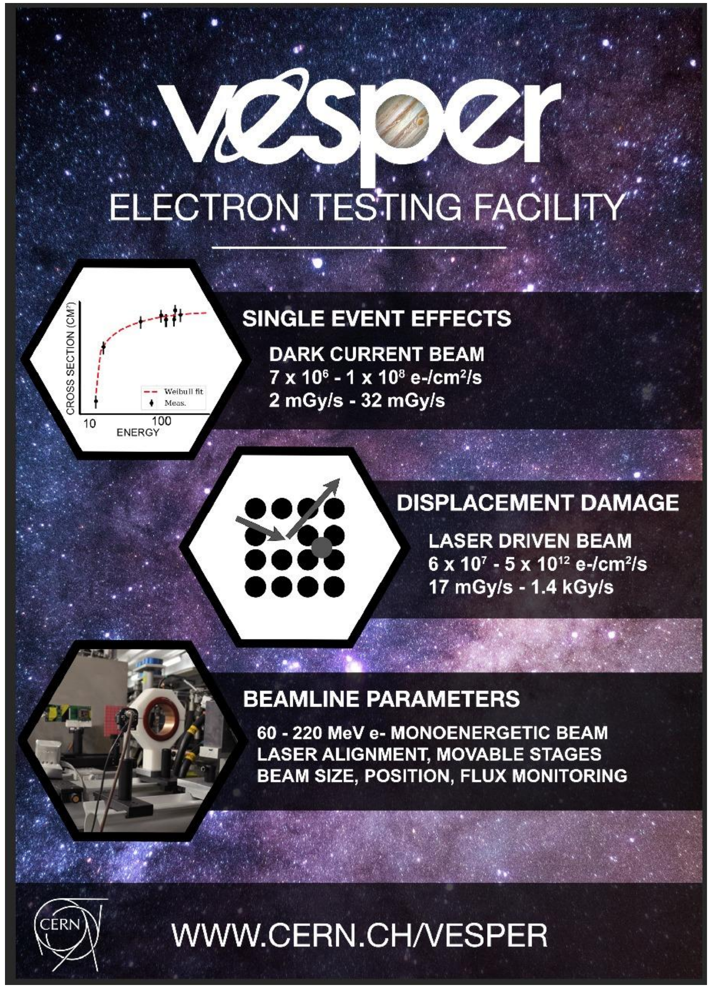
JUICE mission (ESA)

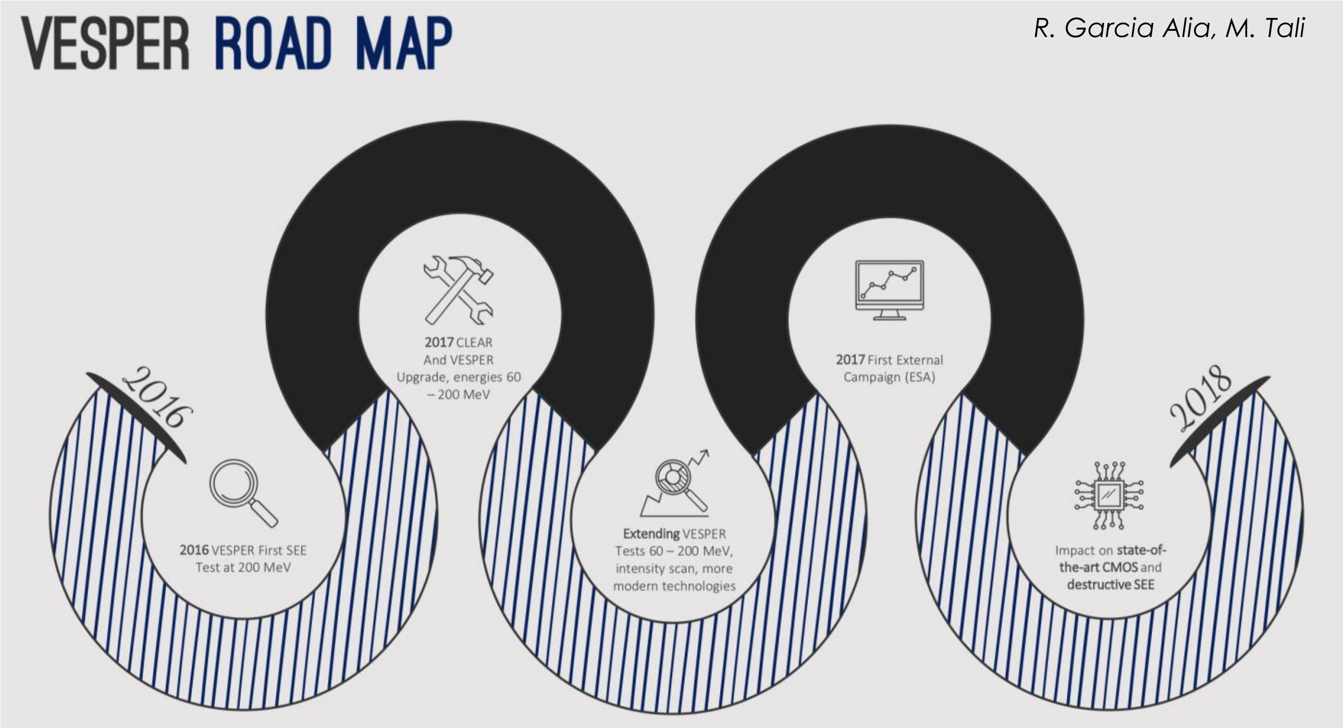




vesper irradiation facility - R2E

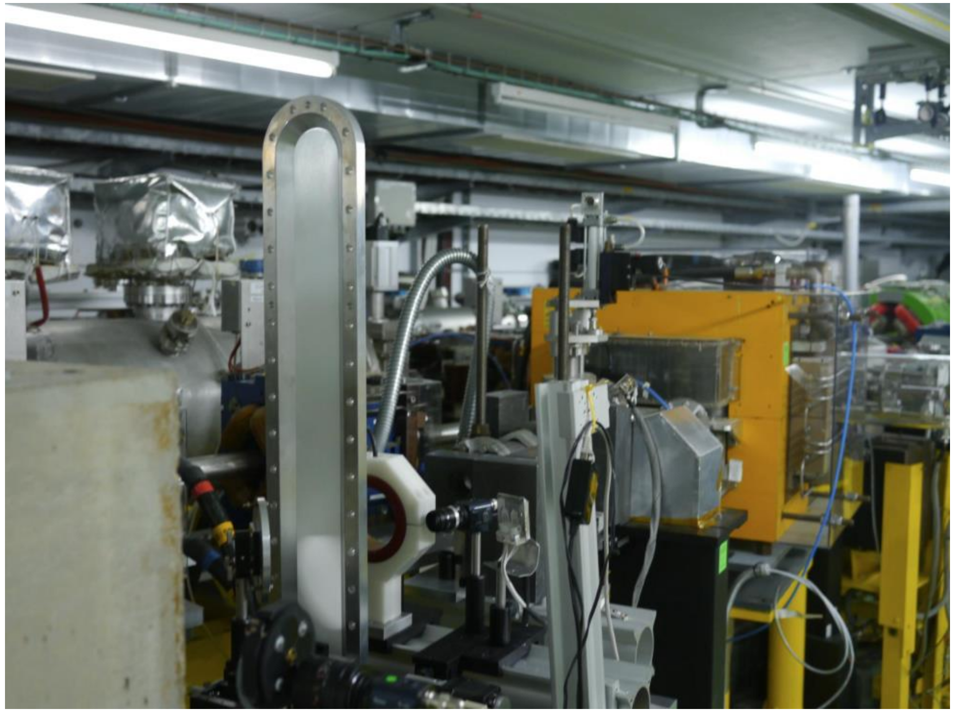
- Beam line already developed and tested in 2016, in collaboration with the CERN R2E team
- In CLEAR we improved diagnostics, stability and energy range (60 - 220 MeV)





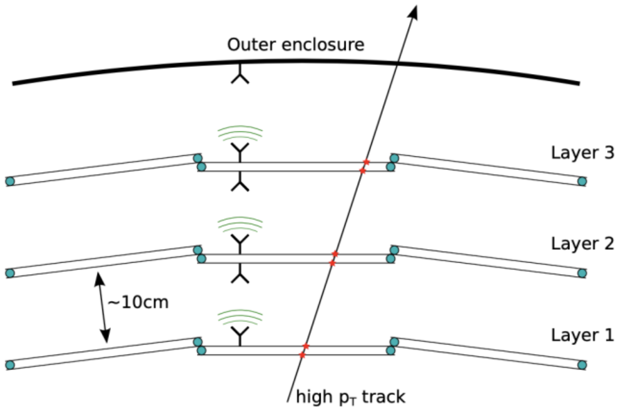
- ESA collaboration: SEU studies at high e- energy for JUICE mission, initial tests
- Campaigns with TRAD and IROC (ESA sub-contractors)
- Extension to higher fluxes, destructive SEE

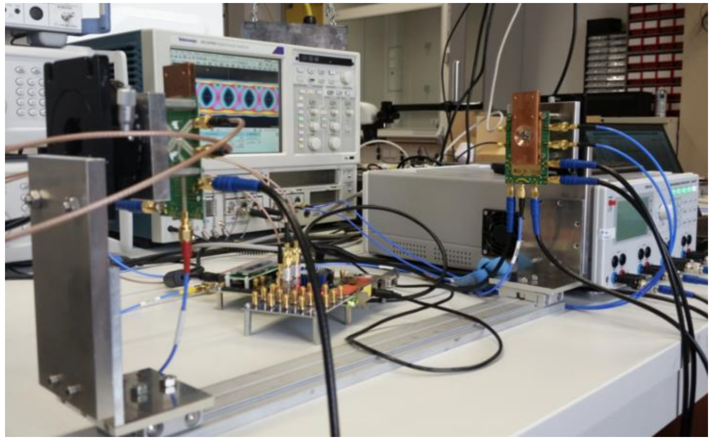
Further tests done in VESPER



- Calibration of the AWAKE spectrometer screen
  Done in 2018 - request for further tests in 2019

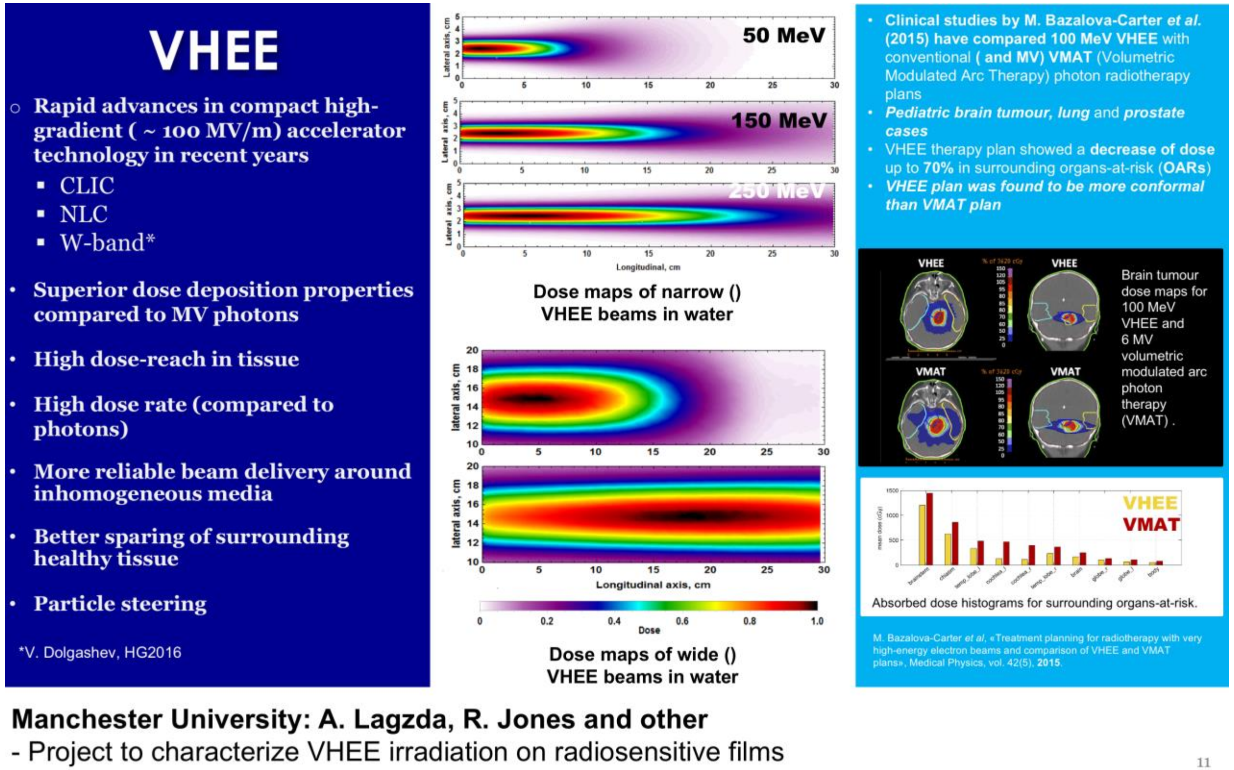
- First test in CLEAR of electronics for detector applications
  by the WADAPT group (R. Brenner - Uppsala/ATLAS)
  Wireless data transmission for silicon tracker detectors
  Irradiation of a 60 GHz receiver/transmitter
  Request for tests of a 120 GHz board



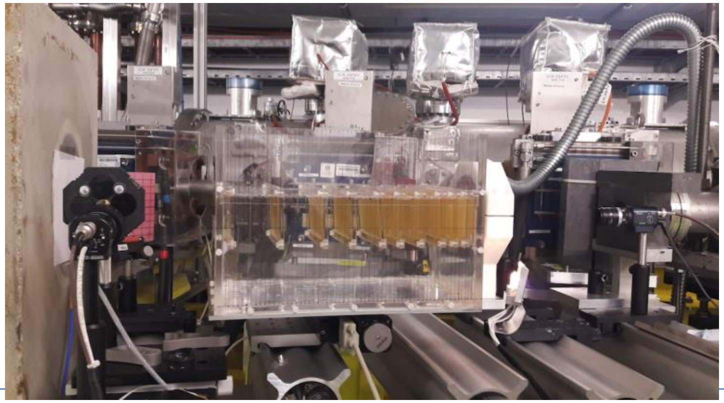


- Recent contacts with NASA (interested in pencil beams)

Medical irradiation tests in vesper



Manchester University: A. Lagzda, R. Jones and other
- Project to characterize VHEE irradiation on radiosensitive films



Relative Insensitivity to Inhomogeneities on Very High Energy Electron Dose Distributions

IPAC 2017 Proceedings • May 19, 2017

Agnese Lagzda, R.M. Jones, D. Angal-Kalinin, J. Jones, A. Aitkenhead, K. Kirkby, R. MacKay, M. van Herk, W. Farabolini, S. Zeeshan

Very-High Energy Electron (VHEE) Studies at CERN's CLEAR User Facility

IPAC 2018 Proceedings • 2018

Agnese Lagzda, R.M. Jones, A. Aitkenhead, K. Kirkby, R. MacKay, M. van Herk, R. Corsini, W. Farabolini

Initial interest from Manchester Univ. group (A. Langzda, R. Jones)

- Three measurements campaigns

FEHVER ERC Synergy Grant proposal

- CNRS, Institut Curie, Manchester U., CERN
- Passed first selection, failed at second
- Exploring re-submission

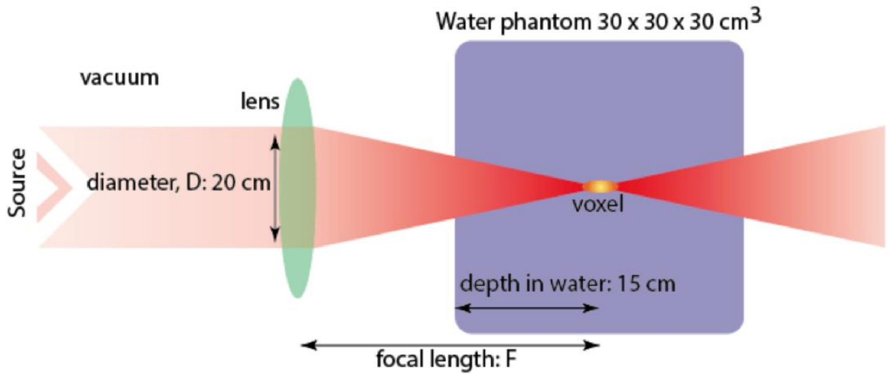
Further requests from Nat. Phys. Lab. (UK, A. Subiel et al.)

- One measurement campaign – another in preparation

… and Strathclyde University (K. Kokurewicz et al.))

- First campaign completed

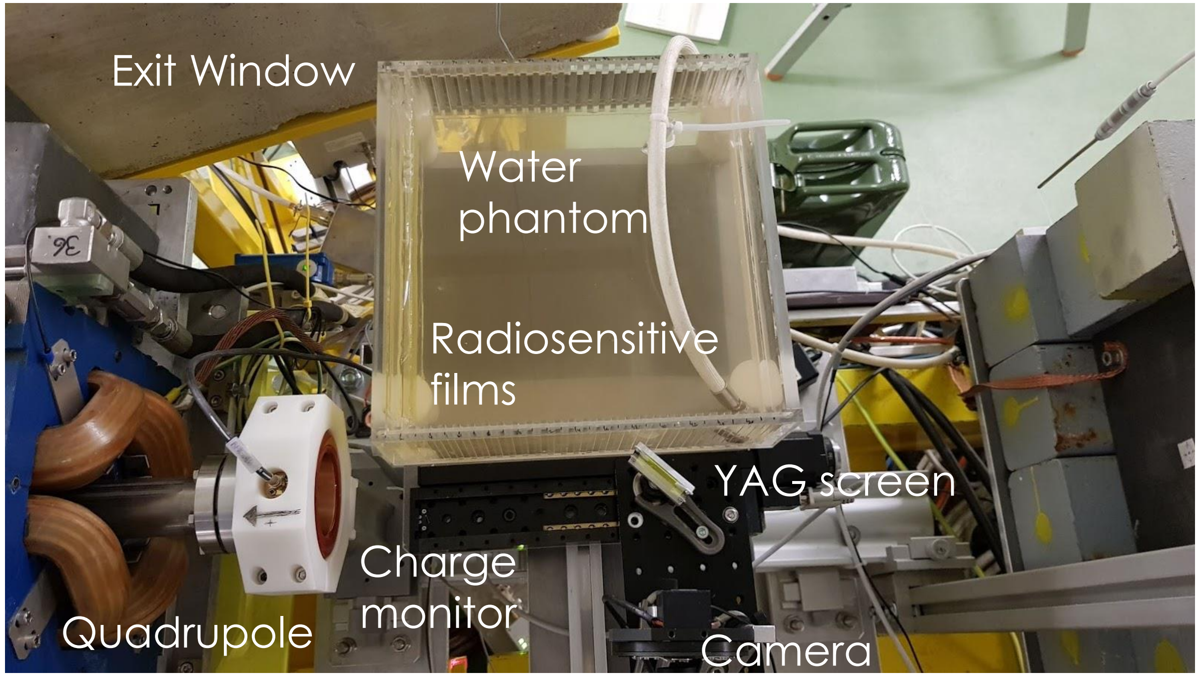
Medical irradiation tests – strong focusing



Aim:

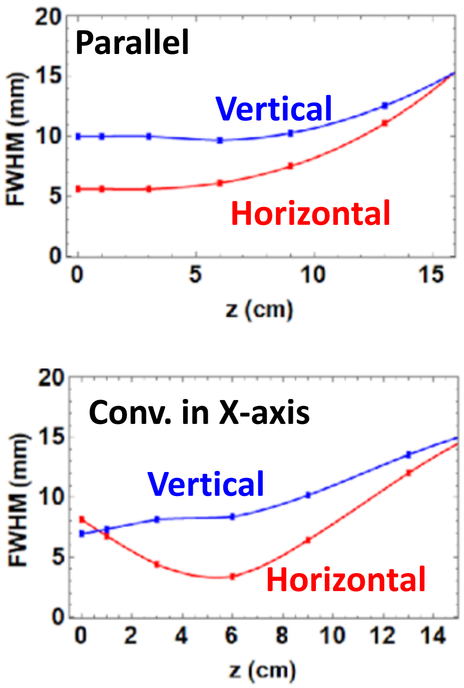
Focus the beam on the tumour to minimize the dose on the nearby healthy tissues

- Main activity in October 2019
- Two groups (Strathclyde and Manchester) Two full week of testing (plus installation and dismounting)
- Required rearrangement of beamline, with a temporary dump.



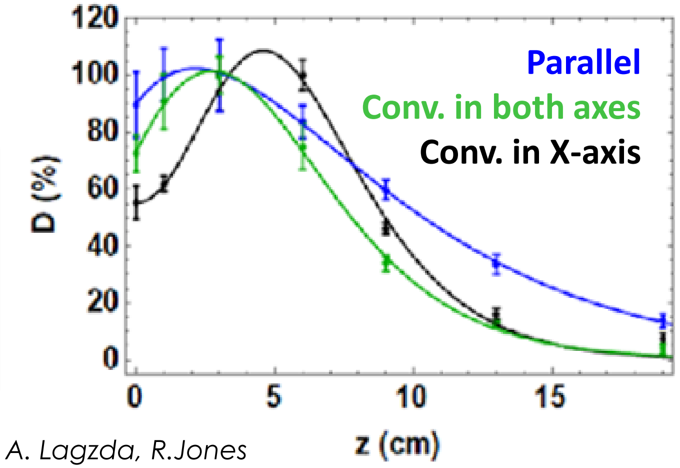
W. Farabolini, E. Senes, K. Kokurevicz

Beam size



SPOILER!

Dose deposition



A. Lagzda, R.Jones

Medical irradiation tests – FLASH

FLASH therapy

Fast (<100ms) delivery of high dose (>10 Gy) radiation seems to retain the same effect on the tumoral tissue of similar integrated doses delivered with the standard fractional method, minimizing at the same time the impact on healthy tissues.

- Such dose rates are not easily achievable with protons or X-rays
  → use of e- beams
- Tests with low energy electrons done by CHUV - Lausanne
- Energies in the 50-200 MeV range allow cure of deep seated tumours

Radiotherapy and Oncology 129 (2018) 582–588

Contents lists available at ScienceDirect

Radiotherapy and Oncology

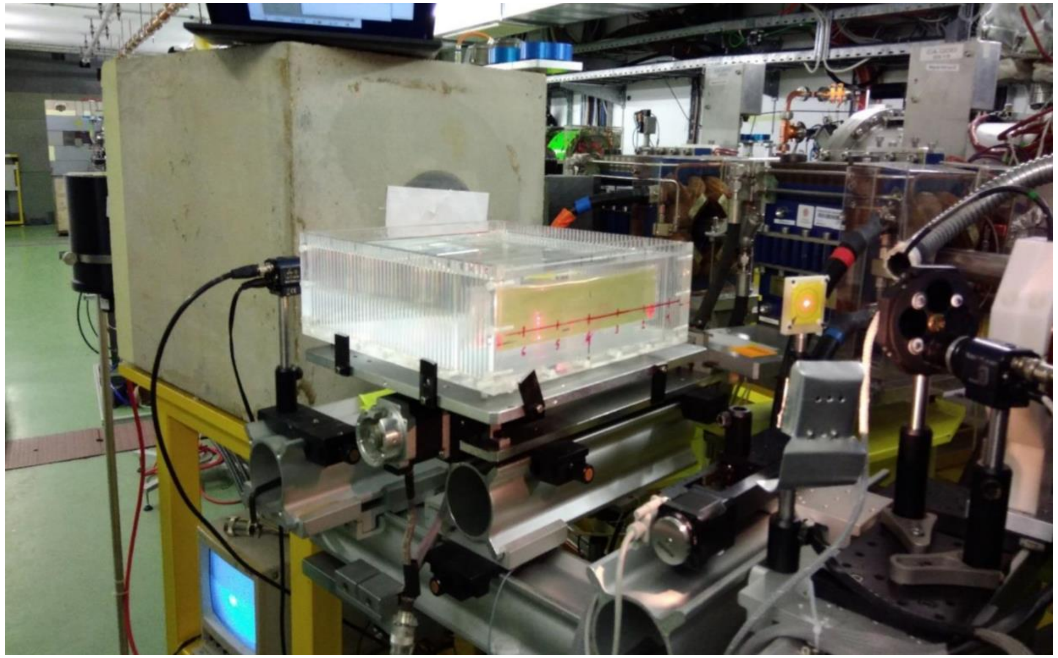
journal homepage: www.thegreenjournal.com

FLASH irradiation

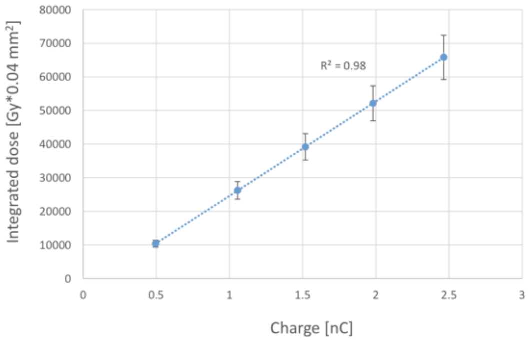
X-rays can trigger the FLASH effect: Ultra-high dose-rate synchrotron light source prevents normal brain injury after whole brain irradiation in mice

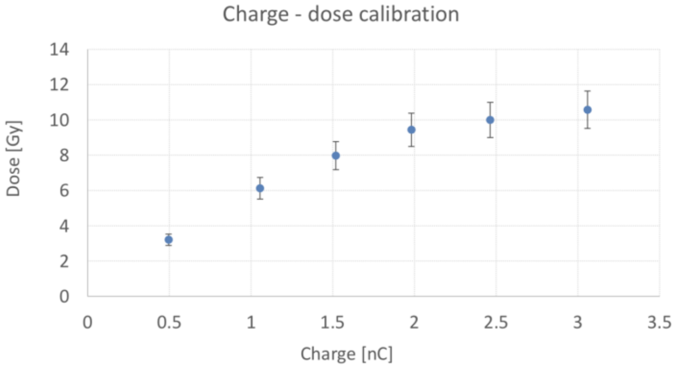
Pierre Montay-Gruel [a], Audrey Bouchet [b], Maud Jaccard [c], David Patin [c], Raphael Serduc [b,*], Warren Aim [b], Kristoffer Petersson [a,c], Benoit Petit [a], Claude Bailat [c], Jean Bourhis [a], Elke Bräuer-Krisch [d,1], Marie-Catherine Vozenin [a,1]

[a] Department of Radiation Oncology/DO/Radio-Oncology/CHUV, Lausanne University Hospital, Switzerland; [b] Rayonnement synchrotron et Recherche médicale, Université Grenoble Alpes, 38000 Grenoble, France; [c] Institute of Radiation Physics (IRA), Lausanne University Hospital, Switzerland; [d] ESRF, European Synchrotron Radiation Facility, Grenoble, France



Preliminary tests in CLEAR started in December 2018 in collaboration with CHUV - Lausanne.





Perspectives for electron FLASH therapy — *P. Montay-Gruel, Thu 24*
X-band based FLASH facility studies — *W. Wuensch, Thu 24*

Plasma lens

Activity started and led by University of Oslo

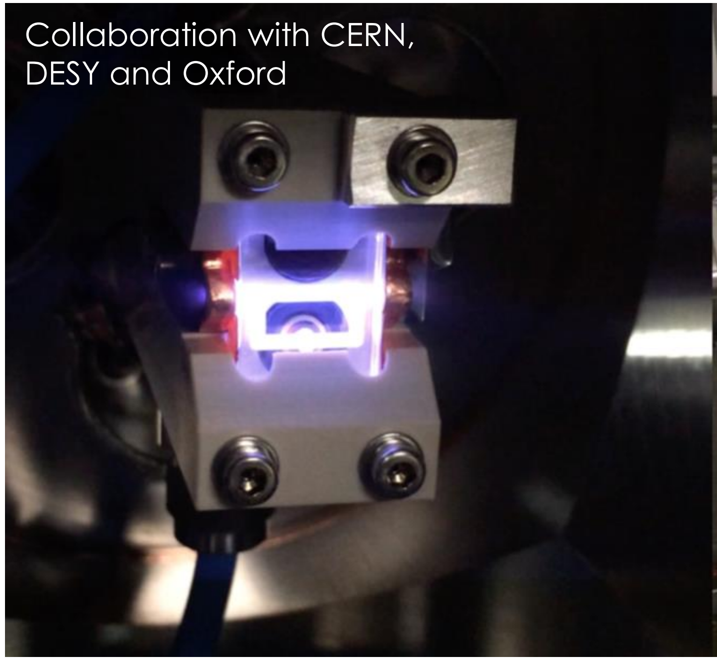
Collaboration with CERN, Desy and Oxford Univ.

Several measurements campaigns

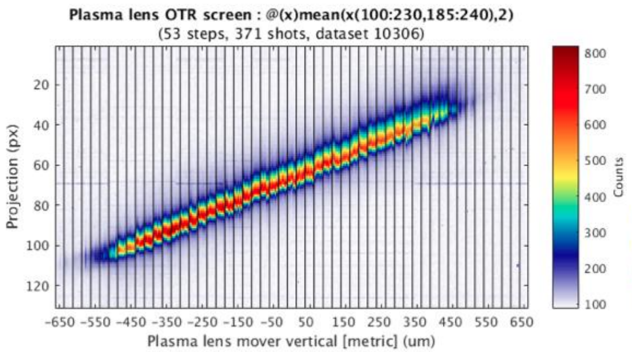
One PhD (Carl Lindstrom)

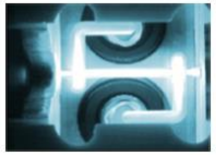
Very relevant results, clarifying seemingly contradictory observations

Lead by University of Oslo



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

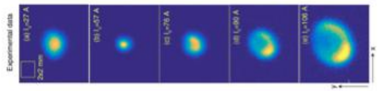




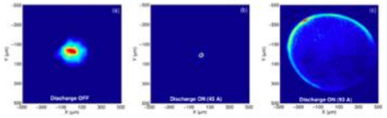
Vertical offset of the plasma lens using a pencil beam. Dipole kicks measured as offset downstream.

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

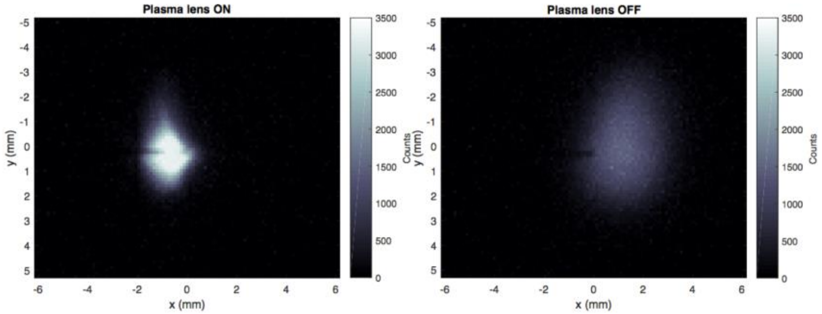
BELLA results:



INFN results:



Plasma lens on/off



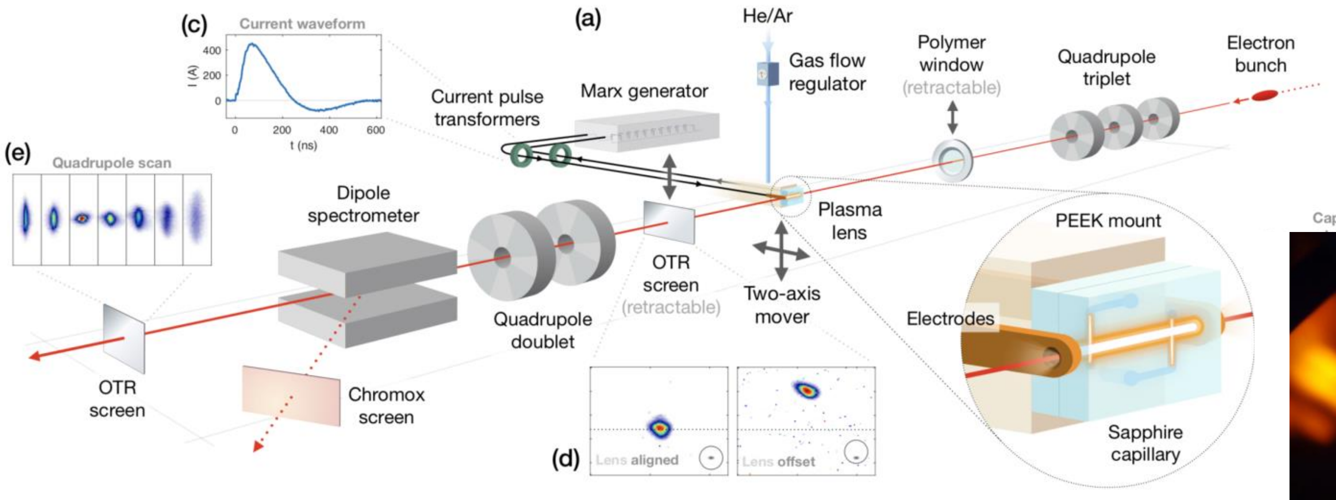
C. Lindstrom, E. Adli, K. Sjobeck et al.

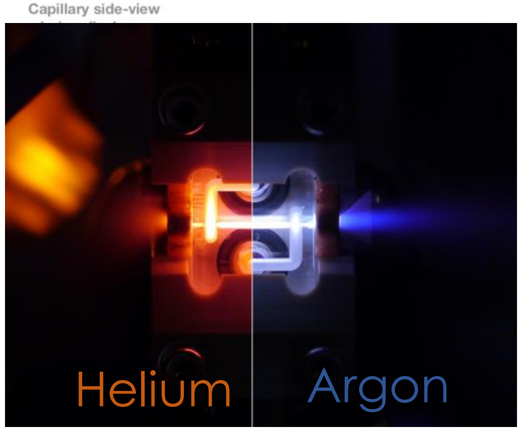
Plasma lens

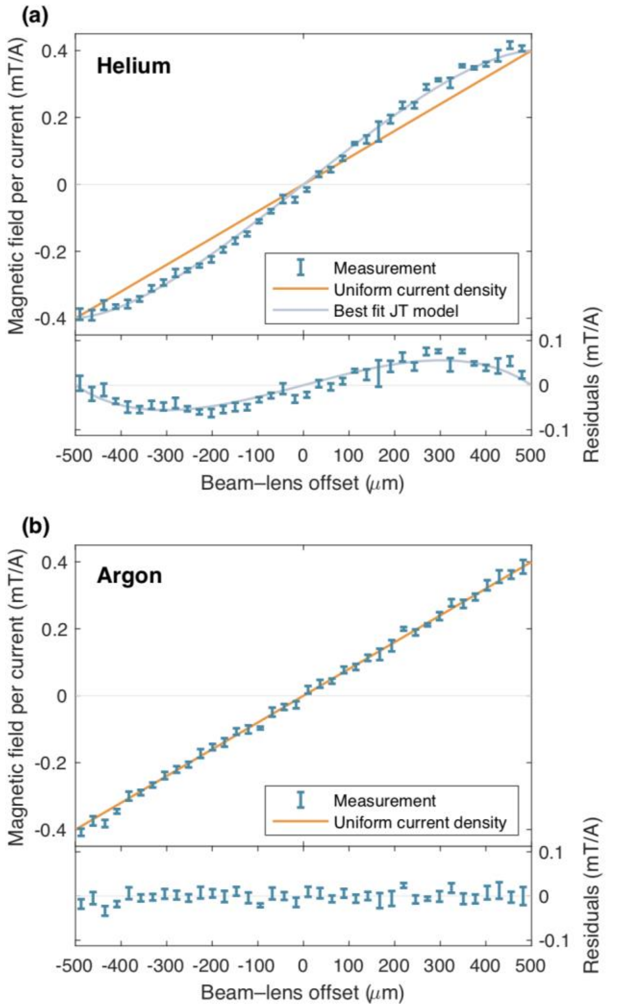
Emittance Preservation in an Aberration-Free Active Plasma Lens

C. A. Lindstrøm, E. Adli, G. Boyle, R. Corsini, A. E. Dyson, W. Farabolini, S. M. Hooker, M. Meisel, J. Osterhoff, J.-H. Röckemann, L. Schaper, and K. N. Sjobak

Phys. Rev. Lett. **121**, 194801 – Published 7 November 2018







- Emittance preservation in an active plasma lens demonstrated for the first time with the use of an argon-based discharge capillary.
- Direct measurements of magnetic fields across the full aperture showed linearity in argon and nonlinearity in helium.
- Quadrupole scans demonstrated expected emittance preservation and growth (respectively) consistent with the measured field profiles.

THz studies

- First tests in sub-THz region, demonstrated use as bunch length diagnostics
- Characterization of beam-produced THz radiation from TR screen + shadowing studies, using THz camera from Univ. Roma
- Bunch length diagnostics for CLEAR
  - Close to be operational - Teflon conical Cherenkov diffraction radiator, 4 frequency detection bands.
- High power THz from different sources
  - Tested so far: diamond, TR screens, Teflon, gratings, metamaterials

Many possibilities beyond that…

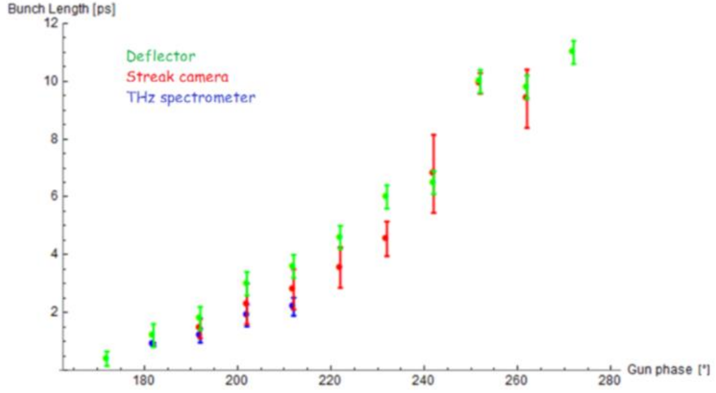


Figure 2: Bunch length measurement with different techniques/detectors. The bunch length compression in this case was made only by varying the gun phase, March 2018.

A. Curcio, M. Bergamaschi, T. Lefevre et al.

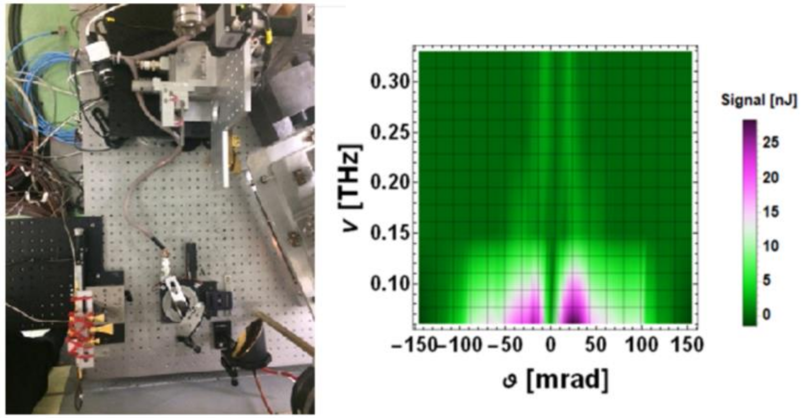
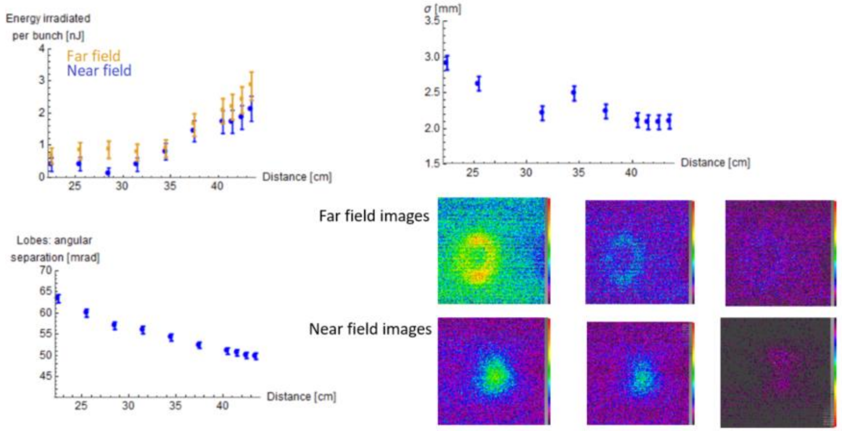


Figure 3: **Left**: Experimental setup for the spectral-angular characterization of CTR light. **Right**: Experimental results on spectral-angular characterization of the CTR light emitted by a 215 MeV, 40 pC, 1.5 ps long electron bunch, April 2018.



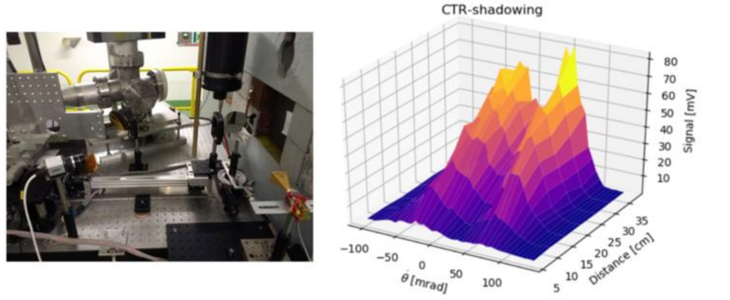
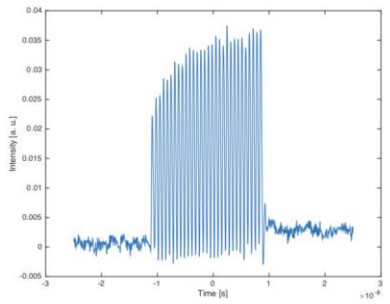
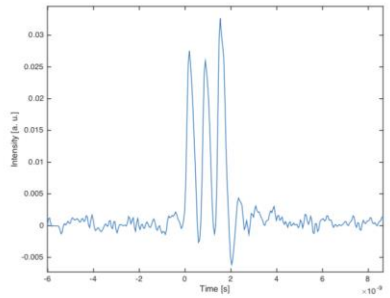


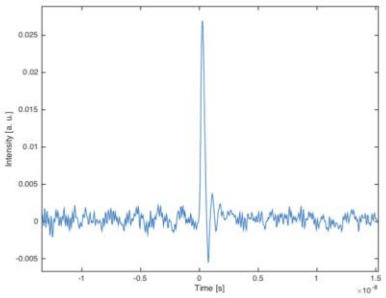
Figure 4: **Left**: Experimental setup for the two-screens experiment. **Right**: Experimental results on the electromagnetic shadowing at $\lambda = 4\ mm$. The distance axis is understood to be the distance between the two CTR screens, May 2018.

CLEAR Beam performances - improvements

Beam parameters	Range	Comments
Energy	60 – **220** MeV	More flexible with 2 klystrons. > 220 MeV with pulse compression.
Energy Spread	< 1 MeV (FWHM)	
Bunch Charge	1 pC – **400** pC	Photocathode changed - laser improvement - ongoing studies
Bunch Length	**0.2** ps – 10 ps	0.1 ps with velocity bunching
Normalized emittances	3 μm to 30 μm	Bunch charge dependent
Repetition rate	0.8 to 5 Hz	25 Hz with klystrons and laser upgrade
Number of micro-bunches in train	1 to >150	Single bunch capability assessed
Micro-bunch spacing	1.5 GHz (Laser)	3.0 GHz: Dark current

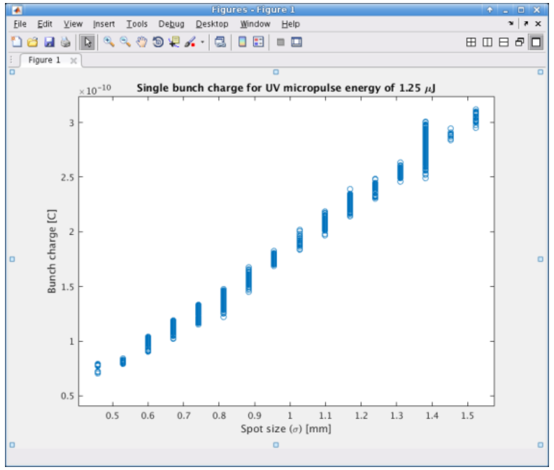






Recent Laser improvements:

- Consolidation - improved power and stability
- Tunable beam spot
- Remotely controlled position
- Fast pulse picker
- Double-pulse system



E. Granados, V. Fedosseev, H. Panuganti

CLEAR Outlook

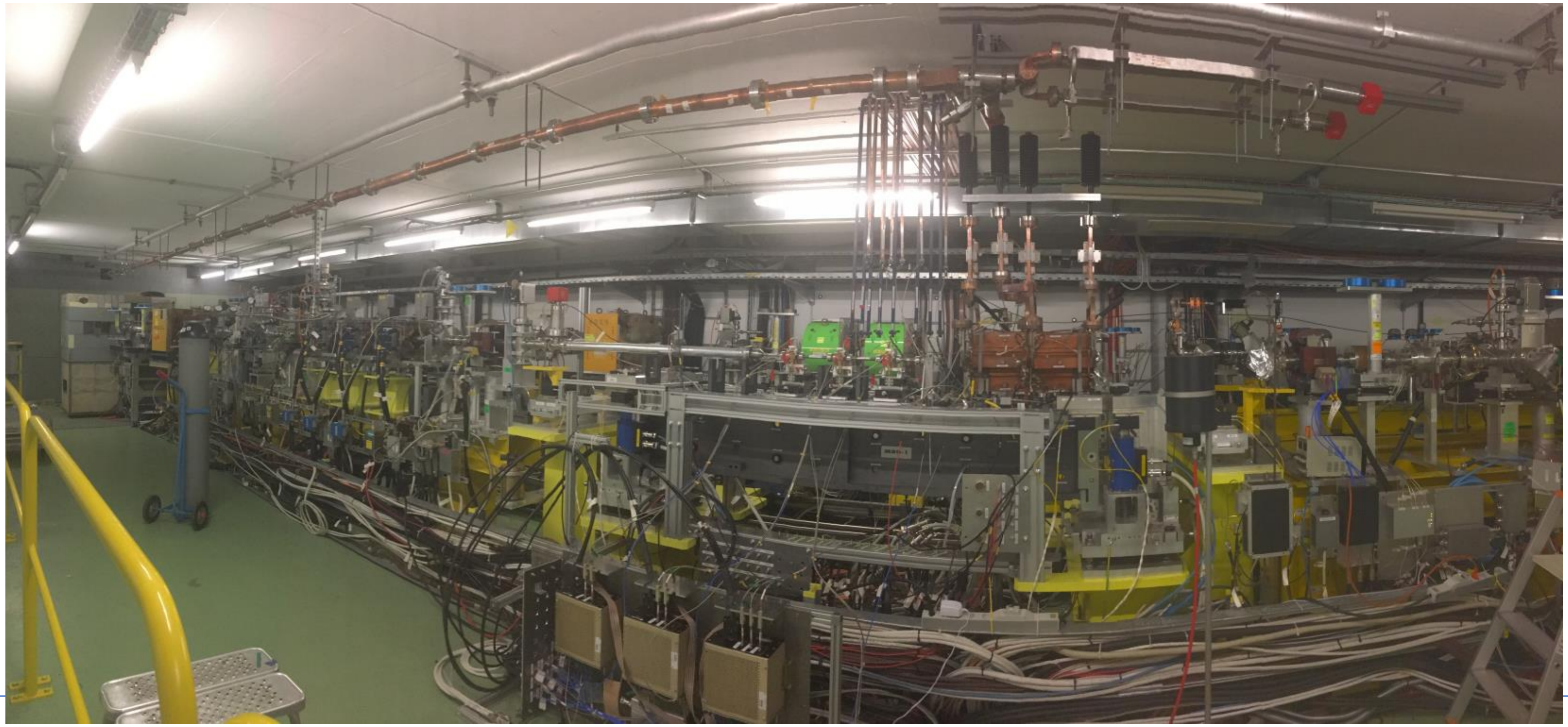
- The CLEAR facility started operation in 2017. At the time, a four year programme was outlined, with an intermediate review after the first two years
- The review of the CLEAR facility will take place on Thursday 7th February 2019
- The review will cover:
  - The status of the facility, the results obtained and on-going projects
  - The plans and potential for the facility and studies at the facility in the coming two years
  - The resource use and needs, plans for improvements and changes in the facility
  - The user community, foreseen development and potential for widening the community
- The review will recommend on the future operation and programme of the CLEAR facility
- In order to avoid delays in the program, our present planning assume a positive decision. In particular we ensured the running during LS2, and we aim to restart the facility at the beginning of February.
- We are now setting-up the detailed schedule for 2019 – starting with our annual commitment on practical work at CERN with JUAS students.

Connection with X-BOX1 - Status

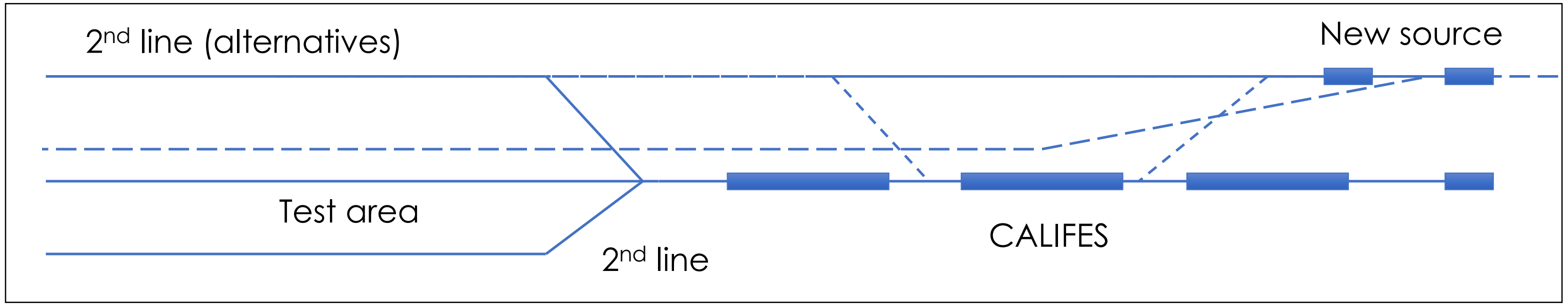
- Main reason for the 2018 summer interruption of CLEAR operation
- Problems to the X-box1 klystron delayed the connection

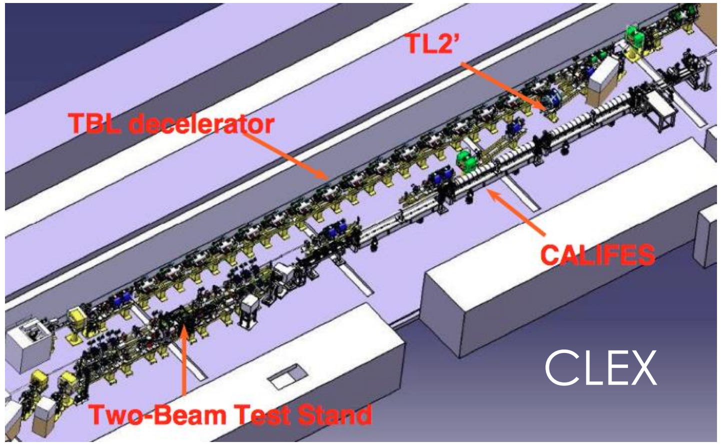
Present Status

- Klystron issues solved.
- Overmoded waveguide network installed and under vacuum – not connected to structure yet.
- X-Box1 upgraded (LLRF, Control Software, acquisition and control in CLEAR control room)
- Presently refurbishing modulator.
- Conditioning and test of presently installed structure to be completed
- Connect to structure after conditioning of RF network in load (most likely early summer).

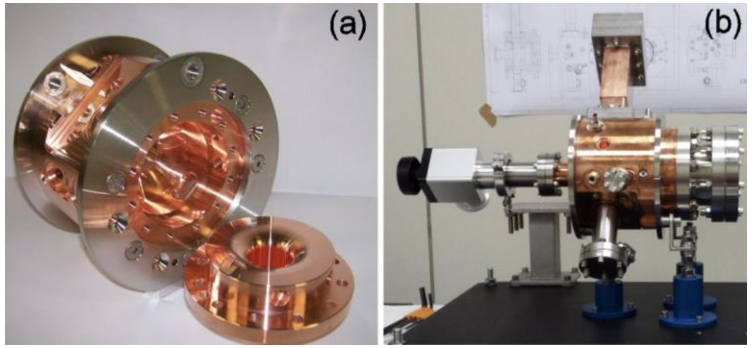


Options for a second beam line + source





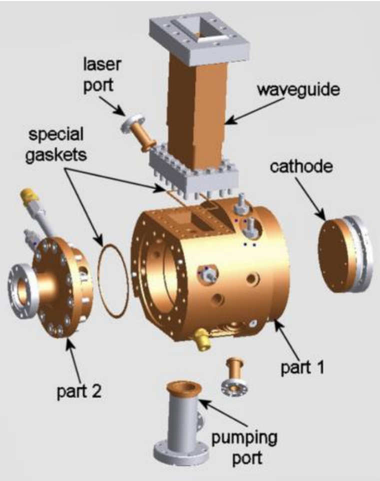
D. Alesini, M. Ferrario et al.

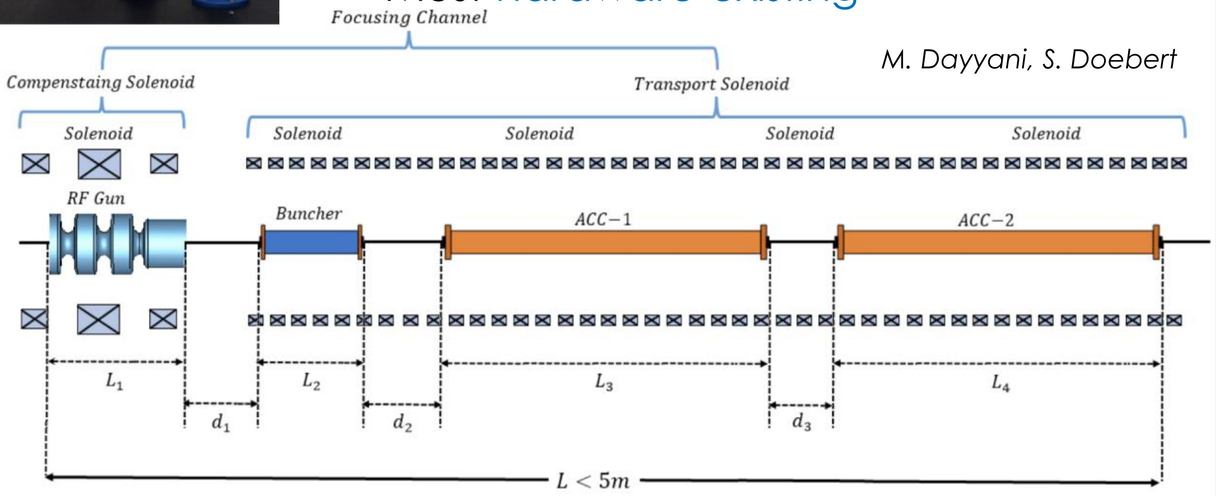


New Source common development
CLEAR/AWAKE

- RF gun provided by INFN-Frascati
- S-band gun + X-band high gradient acceleration validated by simulations
- Most hardware existing

Parameter	Nominal Value	Size
Total Length	$< 5\ m$	$4\ m$
Beam Energy	$220 > 60\ MeV$	$100\ MeV$
Energy Spread	$< 1\ \%$	$0.45\ \%$
Bunch Charge	$100\ pC$	$100\ pC$
RMS Bunch Length	$< 100\ fs$	$81\ fs$
Emittance	$< 10\ \mu m$	$0.6\ \mu$





M. Dayyani, S. Doebert

Design of a new e- injector for CLEAR/AWAKE
S. Doebert, Thu 24

An RF photocathode gun for CLEAR
F. Cardelli, Thu 24

Outlook beyond 2018

- Approval for the second 2 years: review 7th February 2019
- If positive, run during LS2
  - Checked no show stoppers with concerned groups and services

- Continuation of present activities, plus a few additions (impedance & wake-field studies beyond X-band, plasma for acceleration, dielectric structures…)

- Possible major upgrades:
  - Second beam line (end 2019)
  - New electron source, common development with AWAKE (beginning 2020)

- Beyond 2020?
  - Many activities present obvious further developments - profit from investment/upgrades
  - Synergy with possible 3.5 GeV X-band Linac for a CERN electron beam facility aimed at dark light matter searches.

Dark Sector Physics with a Primary Electron Beam Facility at CERN

T. Akesson et al.

CERN-SPSC-2018-023 / SPSC-EOI-018
05/10/2018

THANKS FOR YOUR ATTENTION