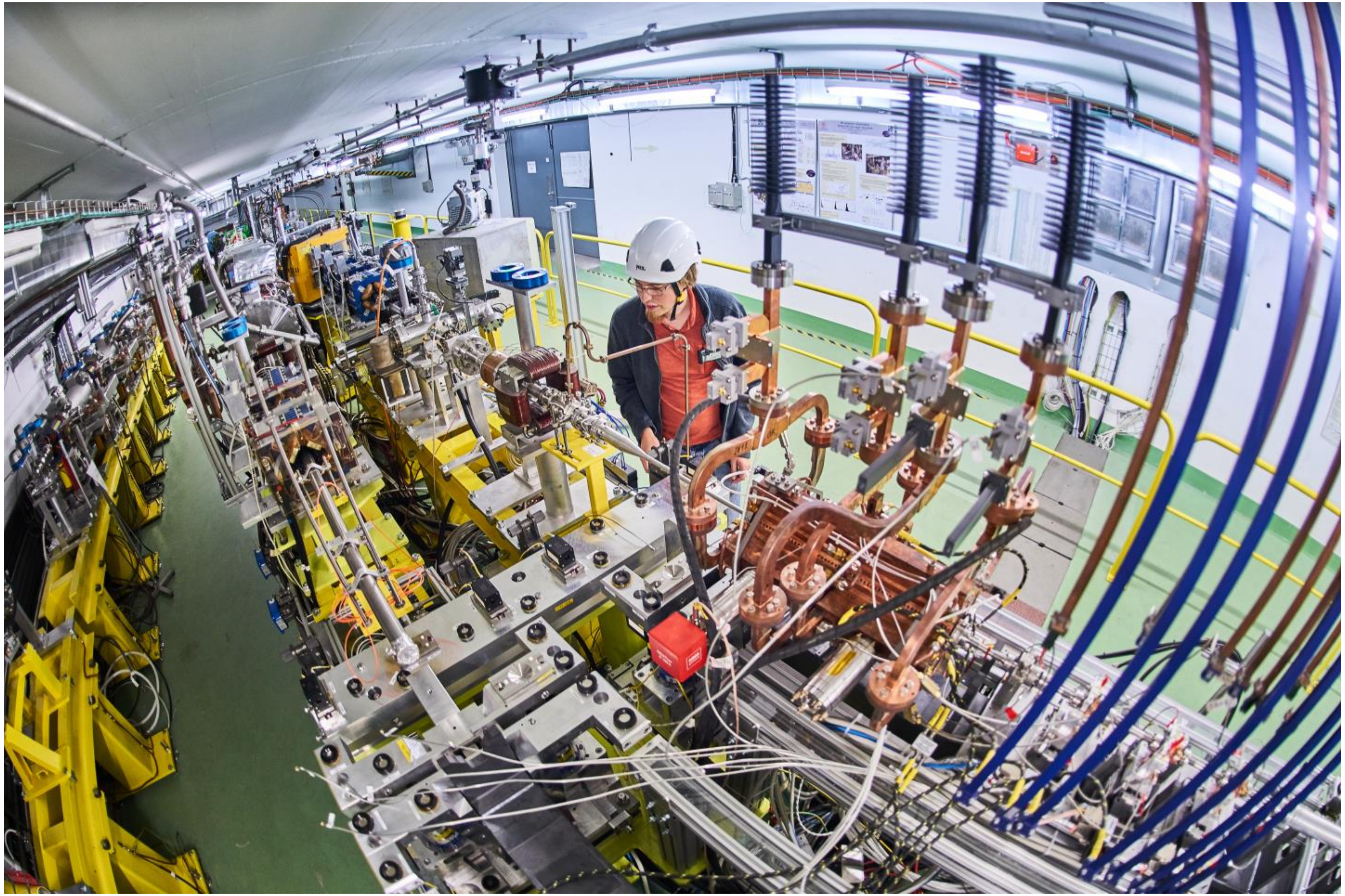
CLEAR

- Status & past achievements
- Recent results
- Future perspectives



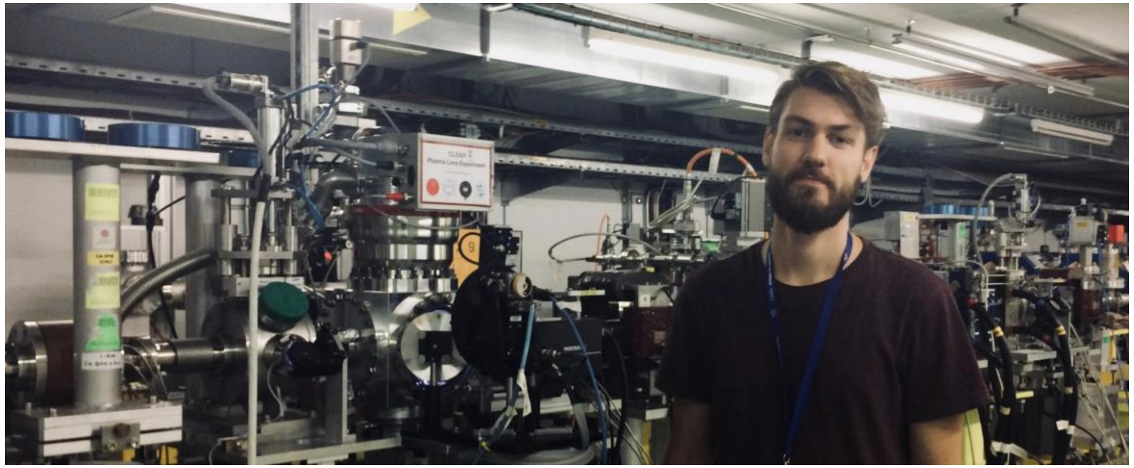
CLEAR operation so far

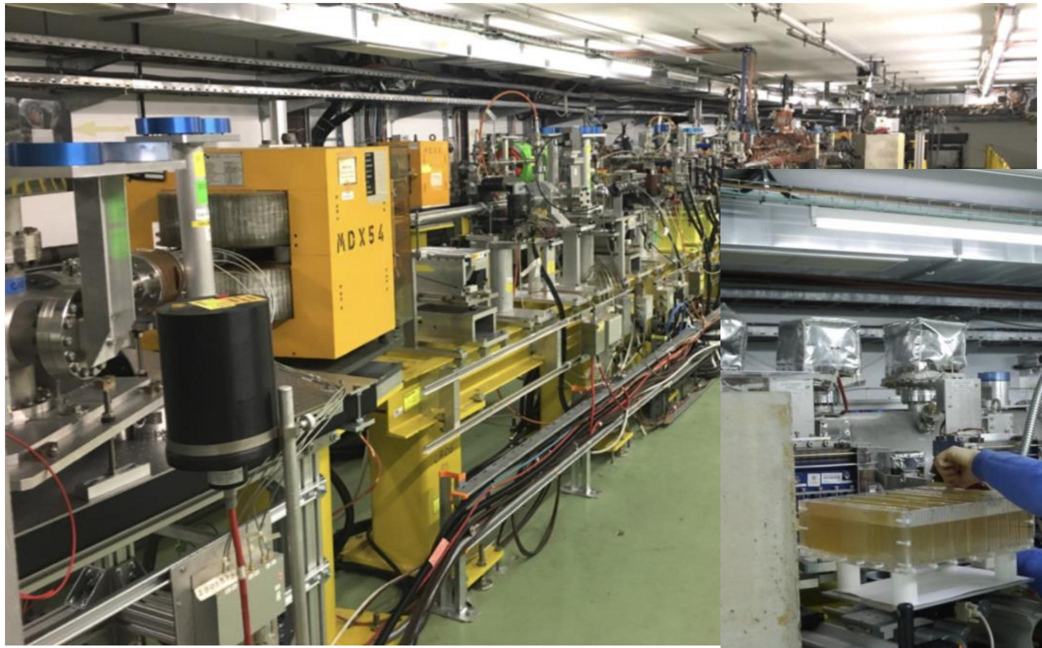
Start with beam August 2017

- 19 weeks of operation in 2017
- 27 weeks in 2018 so far, with a 2-months summer
- About 8 weeks still available

Main activities:

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





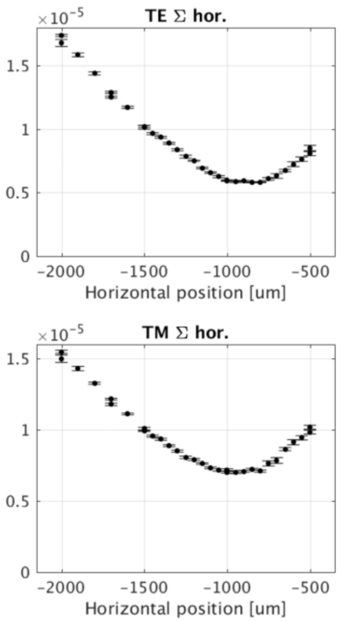
CLIC related activities

Present experiments:

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

Main collaborators

- University of Oslo
- CEA - Saclay
- Università di Napoli Federico II
- BE/BI



Connecting the cavity to XBOX1:

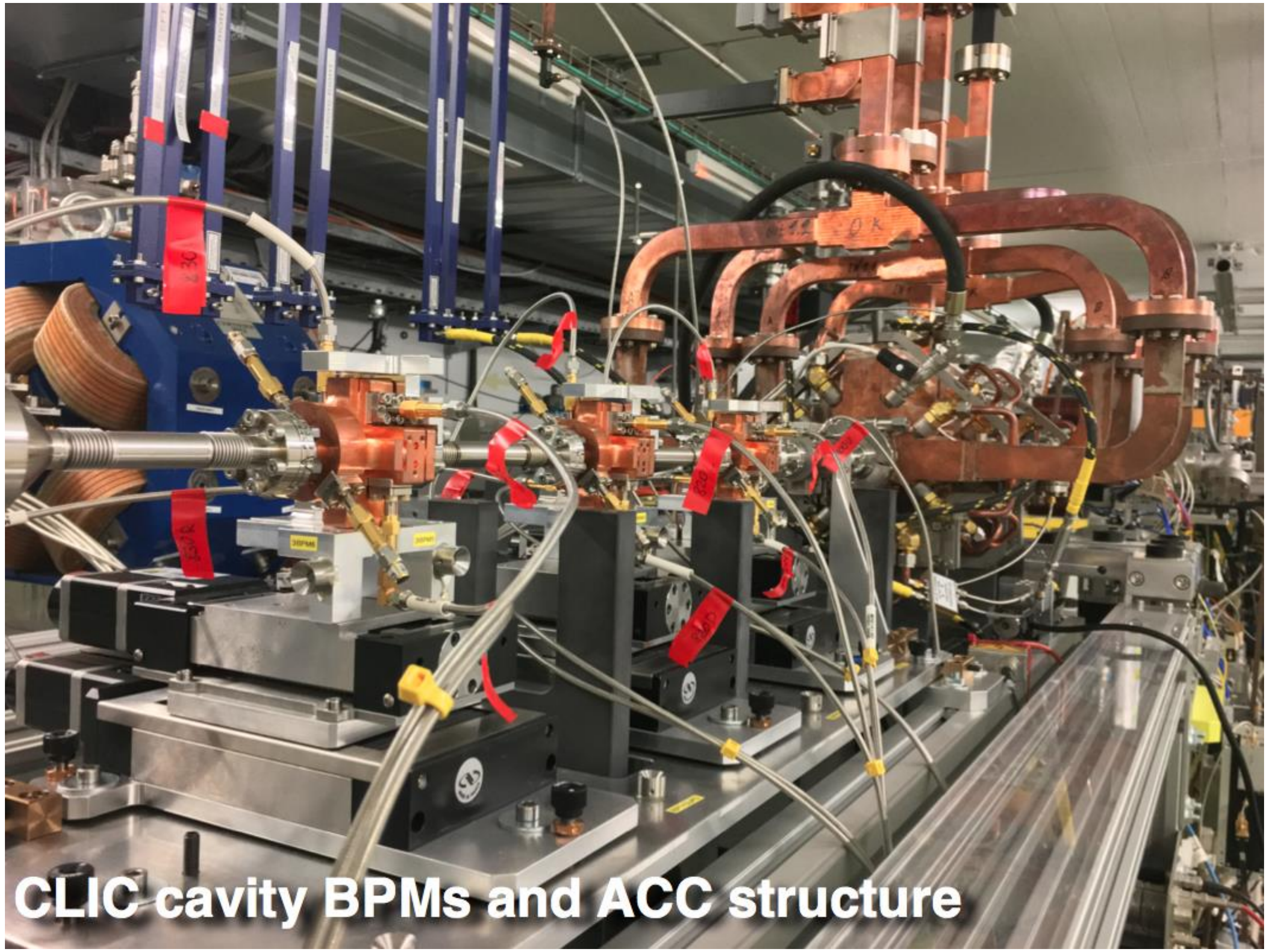
- Issues with klystron
- Waveguide installed
- RF conditioning – connect next year

Possible tests:

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

Figure 1: Prototype copper CLIC cavity BPM.

Former CLIC Module



Irradiation facility

Beam line already developed and tested in CALIFES

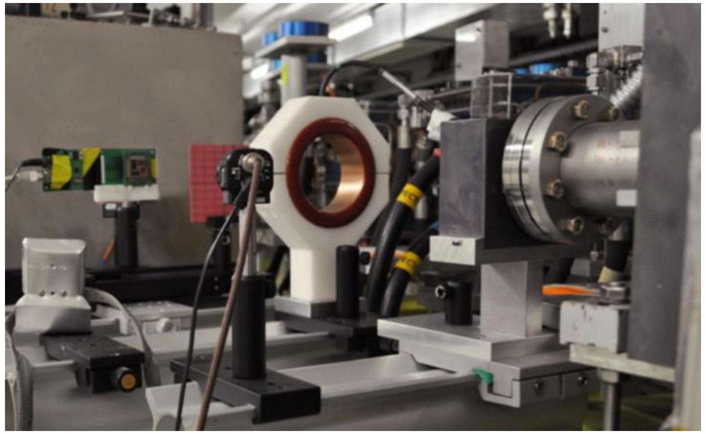
- Improved diagnostics, stability and energy range (60 - 220 MeV)

Scientific program

- ESA collaboration, SEU studies at high e- energy for JUICE mission
    - External campaigns with TRAD, IROC
- Extension to higher fluxes, destructive SEE
- Used also for test of AWAKE spectrometer screen
- Interest for detector electronics (Uppsala/ATLAS - wireless communication)
- Contact with NASA (pencil beams)

→ Medical applications VHEE

R. Garcia Alia, M. Tali



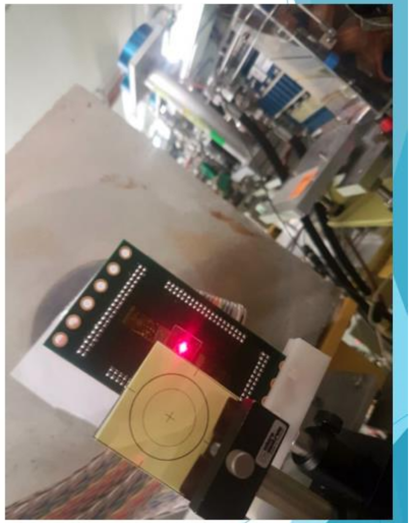
M. Tali, R. García Alía, M. Brugger, V. Ferlet-Cavrois, R. Corsini, W. Farabolini, G. Santin, and A. Virtainen, "Mono-energetic electron induced single-event effects at the VESPER facility", in *Proc. 16th Eur. Conf. Radiat. Effects Compon. Syst. (RADECS2016)*, Geneva, Switzerland, 2016 doi: 10.1109/RADECS20168093166

M. Tali, R. García Alía, M. Brugger, V. Ferlet-Cavrois, R. Corsini, W. Farabolini, A. Mohammadzadeh, G. Santin, and A. Virtanen, "High-Energy Electron-Induced SEUs and Jovian Environment Impact", *IEEE Transactions on Nuclear Science*, vol. 64, no. 8, (2017), pp. 2016-2022.

R. García Alía et al., "Electronics irradiation tests in VESPER: results and outlook for 2018", presented at the CLIC Workshop 2018. https://indico.cern.ch/event/656356/.

External Campaign

- In collaboration with ESA and TRAD
- The tests were driven by the JUICE mission
- Irradiation campaign over 3 days
- The users were very satisfied with the test
- The strength of the CLEAR beamline compared to other similar facilities
    - Higher energies (with respect to medical LINACs) → saturation energy for SEUs
    - Higher flux with respect to other high-energy research LINACs → lower testing time
- Further proposal from ESA and IROC to test more integrated technologies (16 nm FinFET), planned for March 2018



Medical irradiation tests

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

- two measurements campaigns – another coming

FEHVER proposal

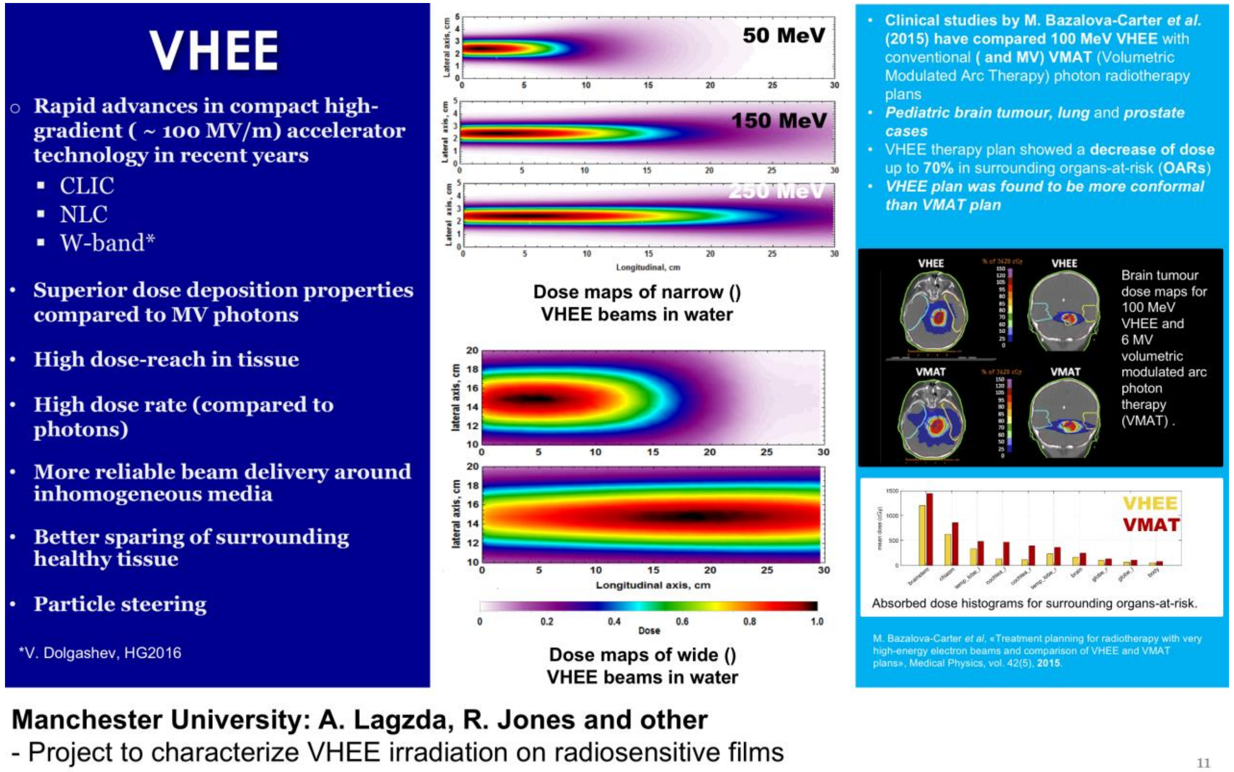
- passed first selection, failed at second

Further requests from National Physical Laboratory (UK, A. Subiel & others)

- one measurement campaign – other in preparation

… and Strathclyde Univ. group
(K. Kokurewicz & others))

- preparing measurements now



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

Relative Insensitivity to Inhomogeneities on Very High Energy Electron Dose Distributions

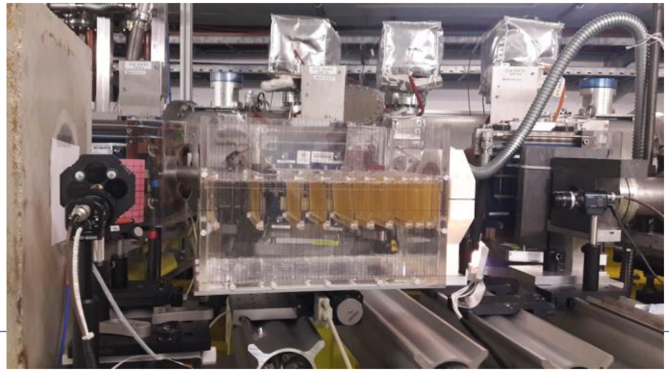
IPAC 2017 Proceedings • May 19, 2017

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



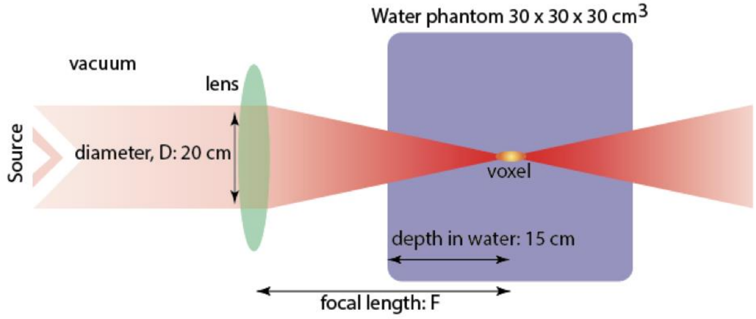
Medical irradiation tests – strong focusing

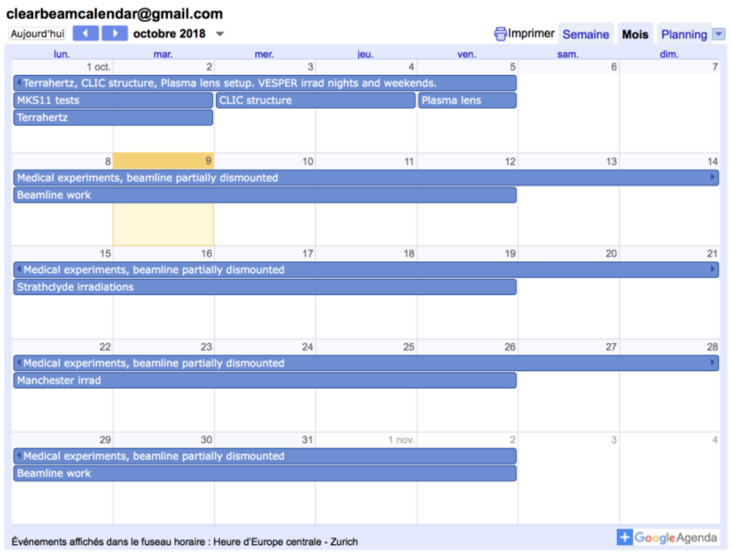
Scope of the experiment

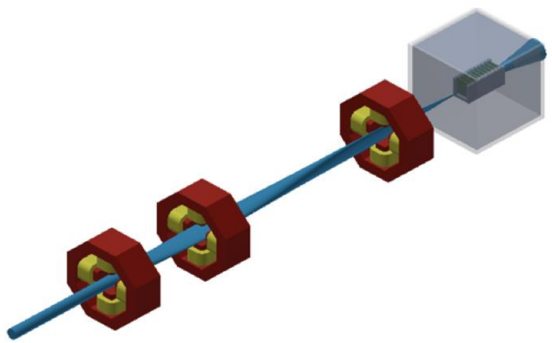
Focus the beam on the tumour to minimize the dose on the nearby healthy tissues

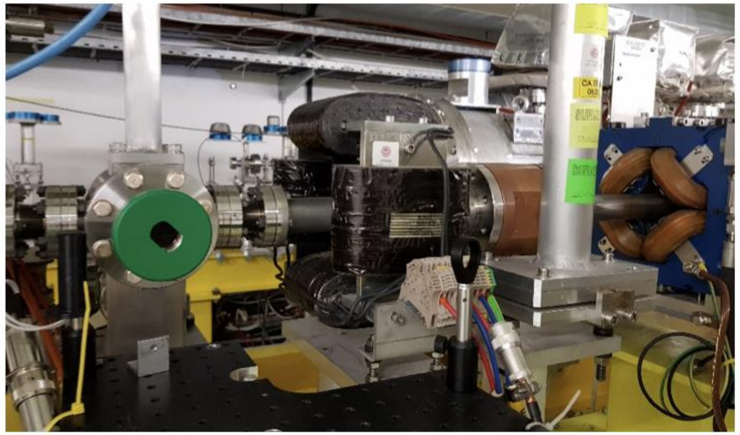
5.4 °

E = 200 MeV
F = 25 cm
D = 2.3 cm

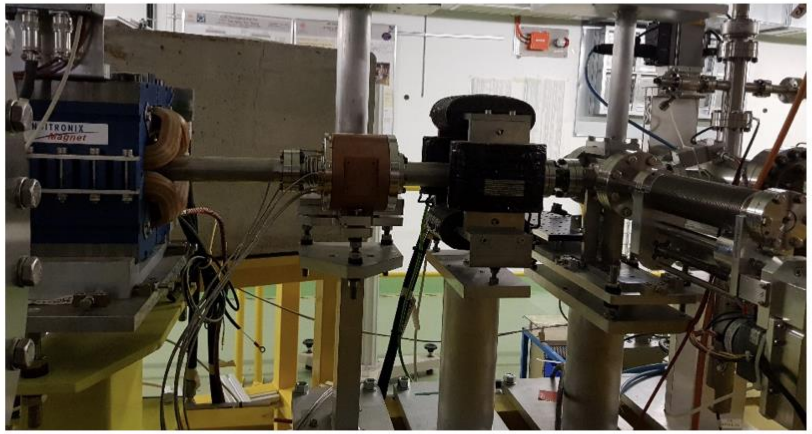








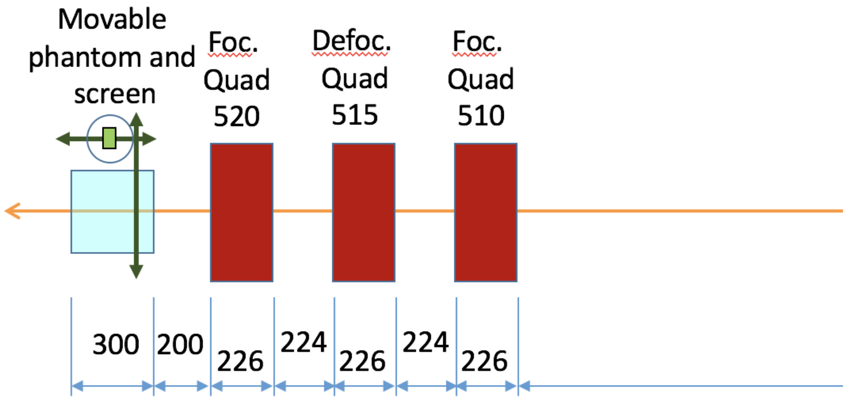
Port side



Starboard side

Medical irradiation tests – strong focusing

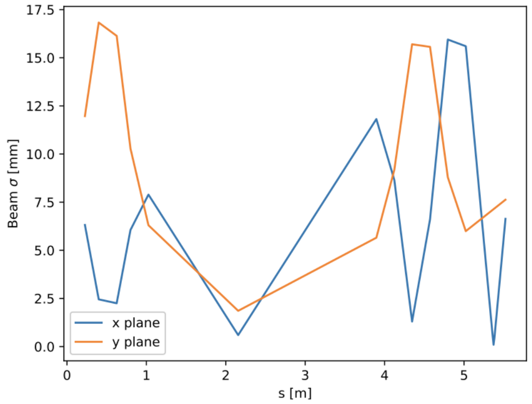
Beam dynamics model

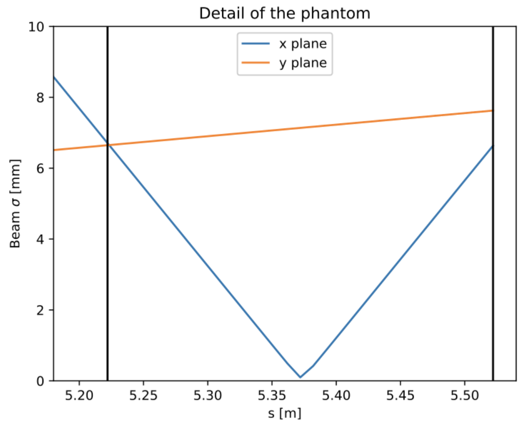


QL3 characteristics	
Nominal gradient [T/m]	11.2
Inscribed radius [mm]	29
Integrated gradient [Tm/m]	2.53
Nominal current at 11.2 T/m [A]	200
Temperature rise [ºC]	16

Convergent case: 5.1 deg beam cone aperture

- Convergent beam in the x-plane, slightly divergent on the y-plane.
- Result to be checked after:
  - Optics measurements for the initial parameters
  - Quadrupoles overpowering possibilities





Magnet	k1	Current set on 200A
QF350	12.33	74%
QD355	-15.43	92%
QF360	16.90	101%
QF510	15.89	95%
QD515	-15.68	93%
QF520	21.87	130%

Plasma lens

Activity started and led by University of Oslo

Collaboration with CERN, Desy and Oxford Univ.

Several measurements campaigns

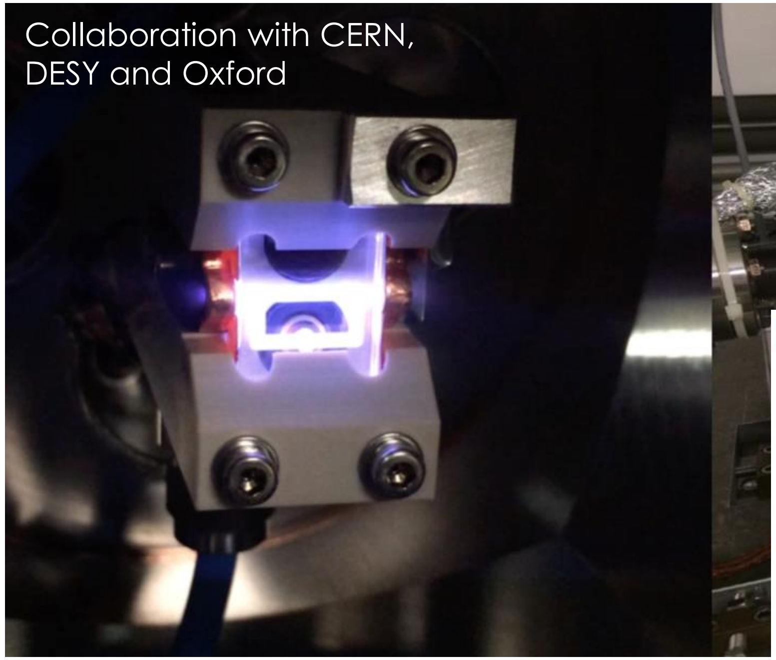
One PhD (Carl Lindstrom)

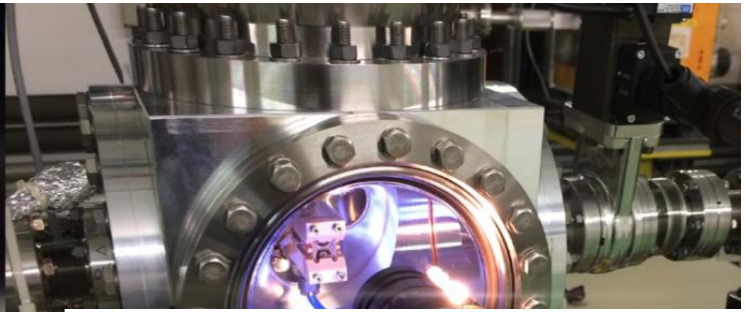
Very relevant results, beyond what has been done elsewhere so far

Several papers/reports

Last results to be submitted
to Phys. Rev. Letters

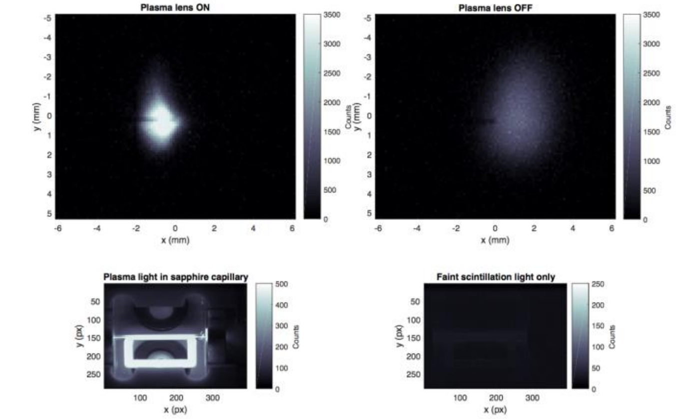
Lead by University of Oslo



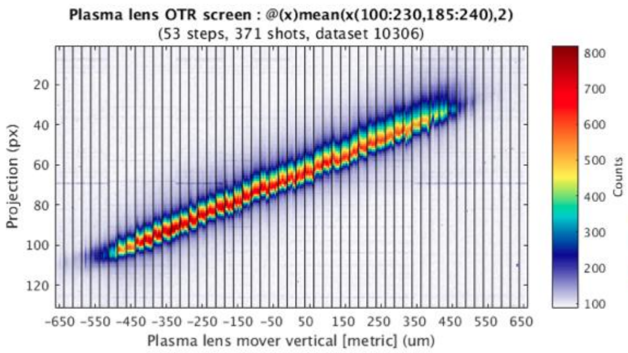


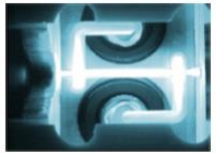
clear

Plasma lens on/off



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

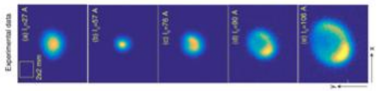




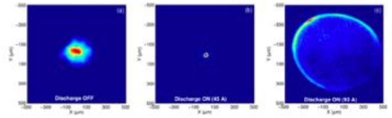
Vertical offset of the plasma lens using a pencil beam. Dipole kicks measured as offset downstream.

- **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:

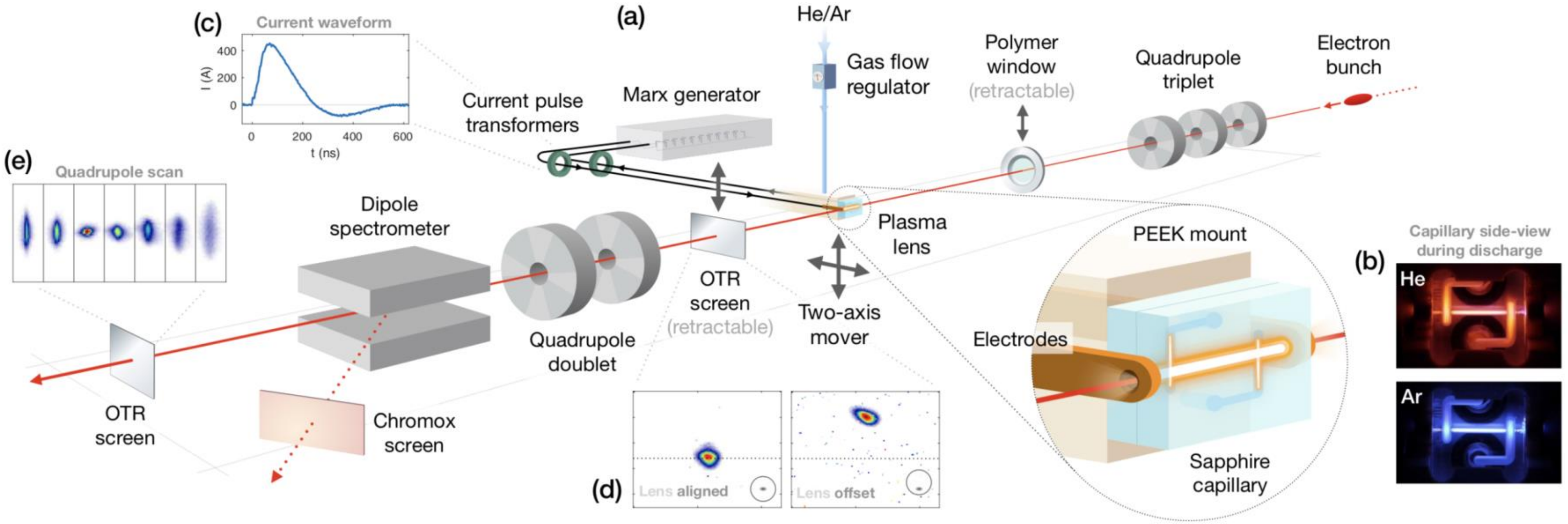


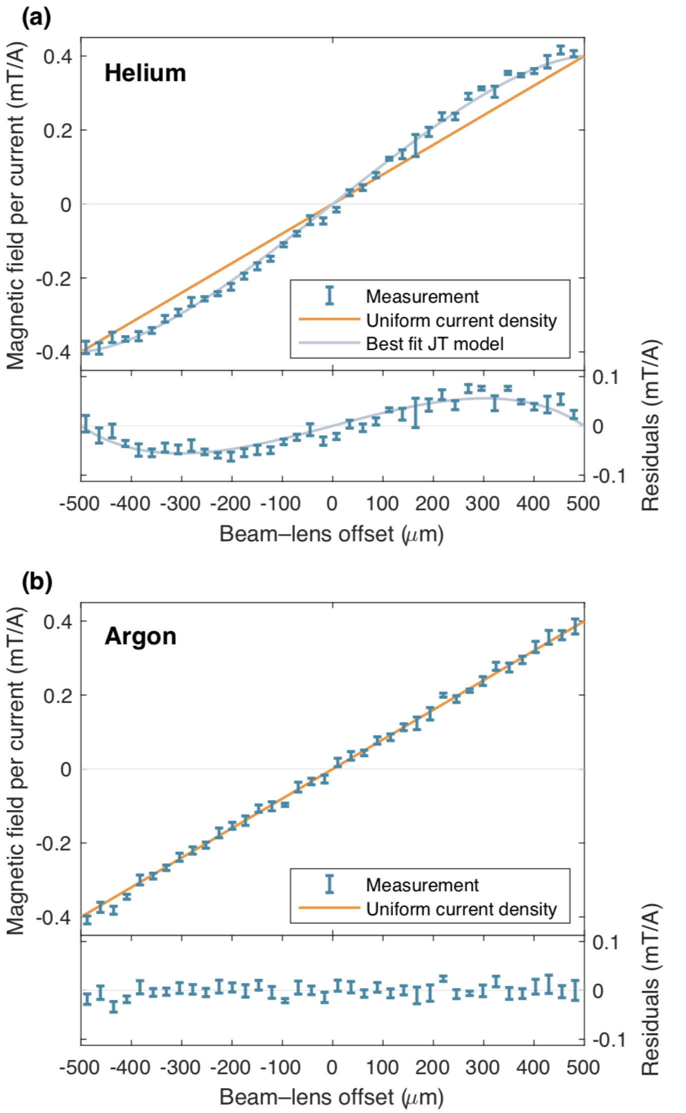
INFN results:



Plasma lens

Accepted for publication in Phys. Rev. Letters





- 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 the expected emittance preservation and growth, respectively, consistent with the measured field profiles.

Beam Instrumentation R&D

Many activities planned (most ongoing)

Two main goals:

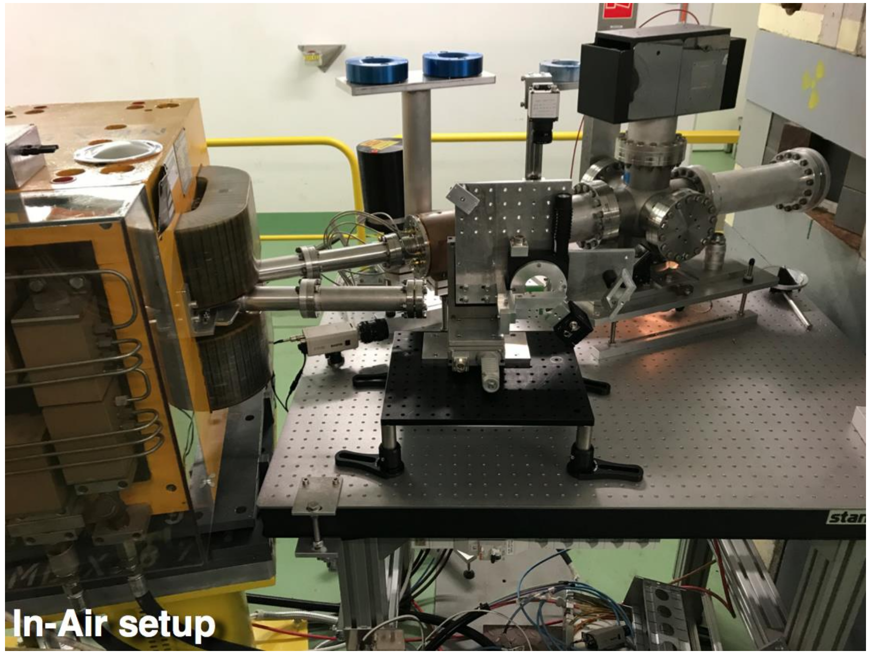
1) Consolidate and improve beam instrumentation for CLEAR

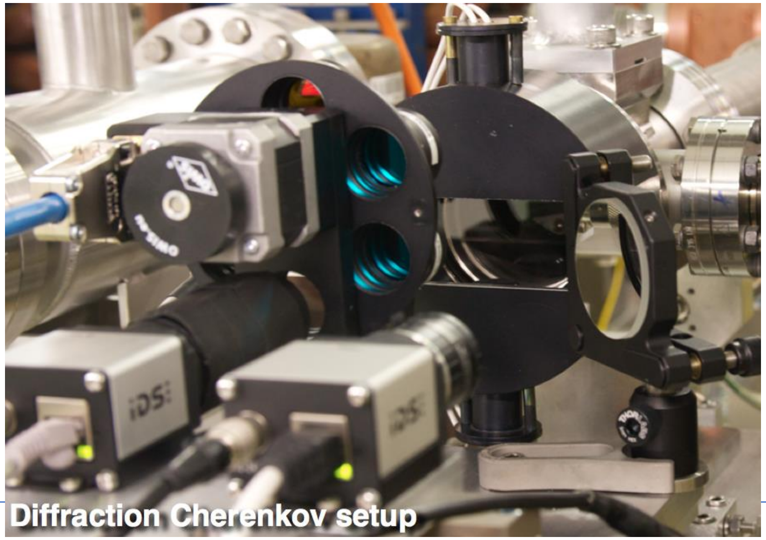
2) Diagnostics R&D

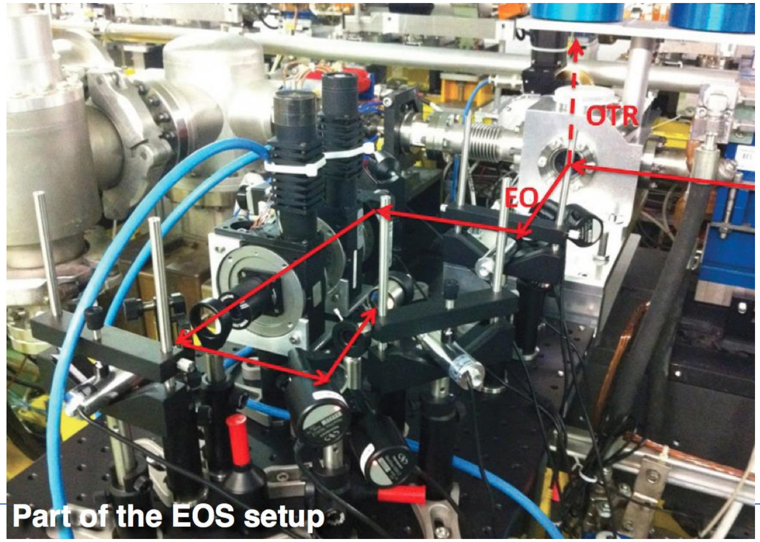
- Diffraction Cherenkov
- Electro-Optical monitors
- …

Main interest from BE/BI, plus several external collaborators

Direct applications to CERN accelerator complex & potential for future applications


In-Air setup


Diffraction Cherenkov setup



Part of the EOS setup

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…

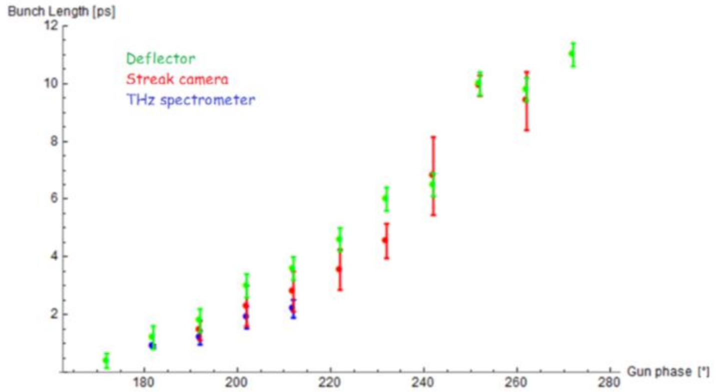


Figure 2: Bunch length measurement with different techniques/detectors. The bunch length compression in this case was made only by varying the gun phase, March 2018.

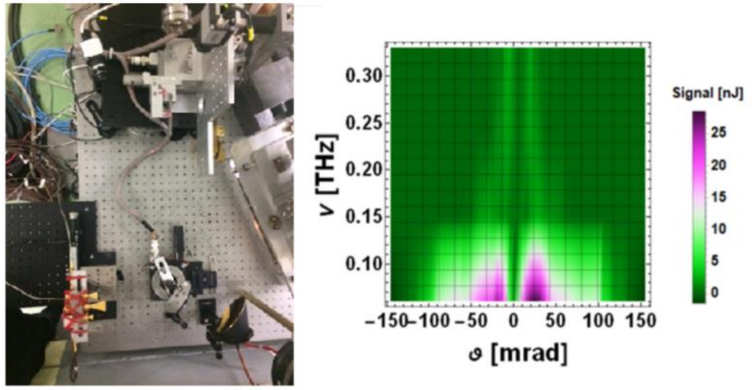
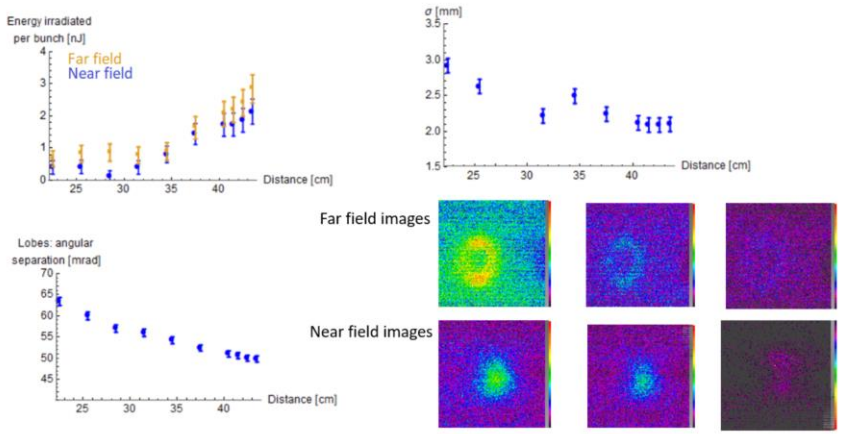


Figure 3: **Left**: Experimental setup for the spectral-angular characterization of CTR light. **Right**: Experimental results on spectral-angular characterization of the CTR light emitted by a 215 MeV, 40 pC, 1.5 ps long electron bunch, April 2018.



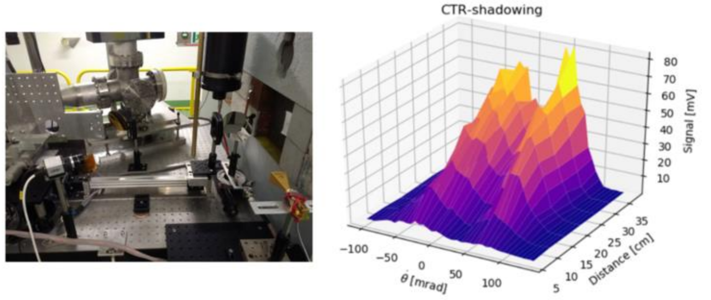
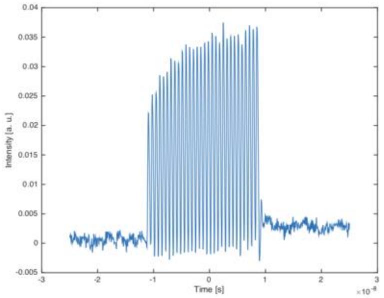
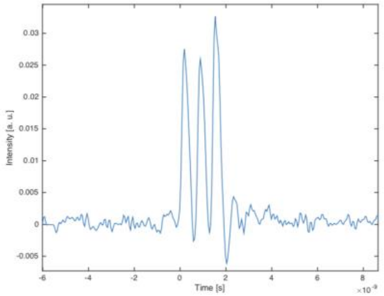


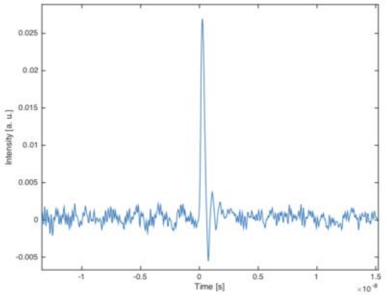
Figure 4: **Left**: Experimental setup for the two-screens experiment. **Right**: Experimental results on the electromagnetic shadowing at $\lambda = 4\ mm$. The distance axis is understood to be the distance between the two CTR screens, May 2018.

CLEAR Beam performances

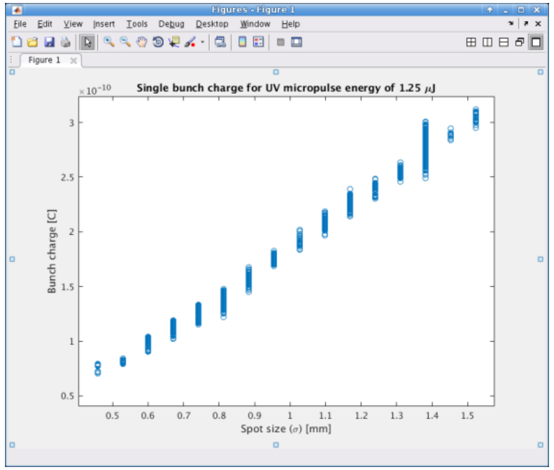
Beam parameters	Range	Comments
Energy	60 – **220** MeV	More flexible with 2 klystrons. > 220 MeV with pulse compression.
Energy Spread	< 1 MeV (FWHM)	
Bunch Charge	1 pC – **400** pC	Photocathode changed - laser improvement - ongoing studies
Bunch Length	**0.2** ps – 10 ps	0.1 ps with velocity bunching
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







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



Outlook

- Approval for the second 2 years: review 4-8 February 2019, if positive running until end 2020 - mid 2021
- Continuation of present activities, plus a few additions (impedance studies, plasma for acceleration, dielectric structures…)

- Major upgrades:
  - New electron source
  - Second beam line
  - CLIC klystron module? > makes sense only beyond 2020

- Running beyond 2020? Desirable, will depend on results and management
- Funding beyond 2020? Should be outside the CLIC budget (with a possible CLIC contribution)

- Towards 3.5 GeV Linac…