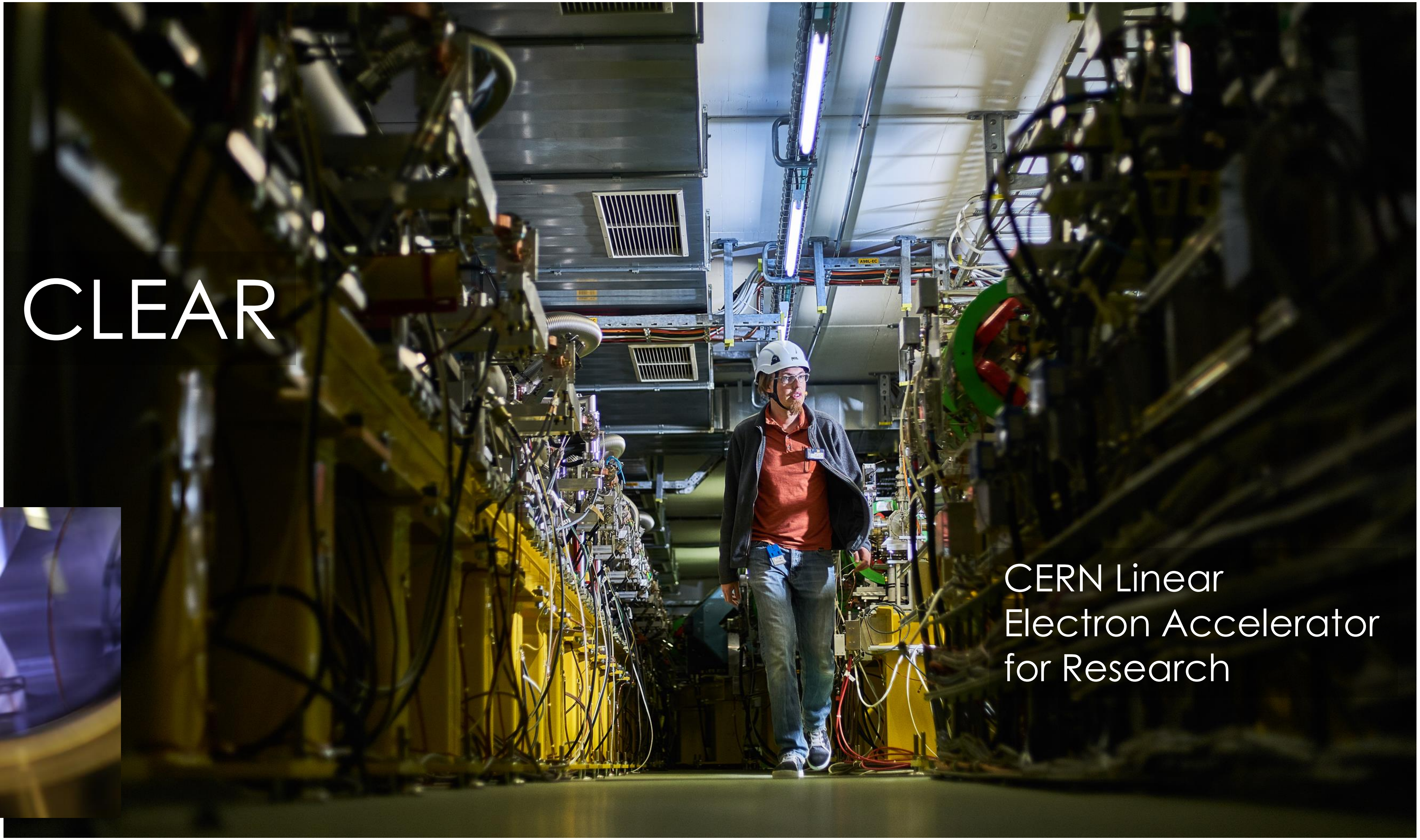
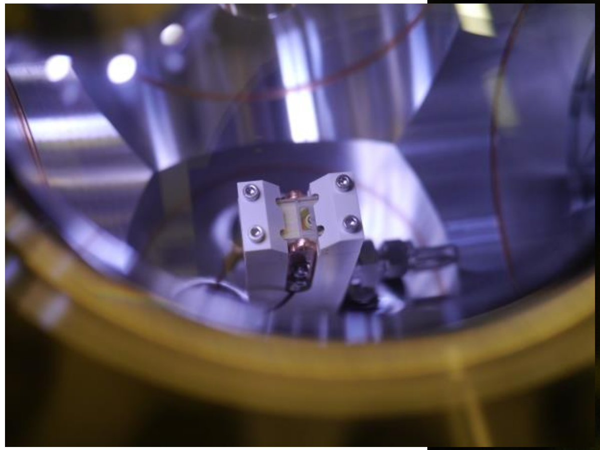
CLEAR overview and beam program



R. Corsini

for the CLEAR team



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 FCC-ee injectors), 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 Timeline

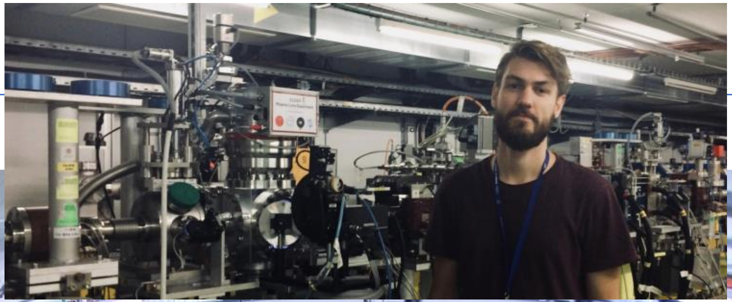
- Approved in December 2016, as a 2 + 2 years program
- Reviewed and extended until 2020 in February 2019
- Included in the new CERN Medium Term Plan 2021-2025 in spring 2020
    - Operational budget, independent from CLIC, 800 kCHF/year (material)
- MTP 2021-2025 approved by the CERN Council in September 2020

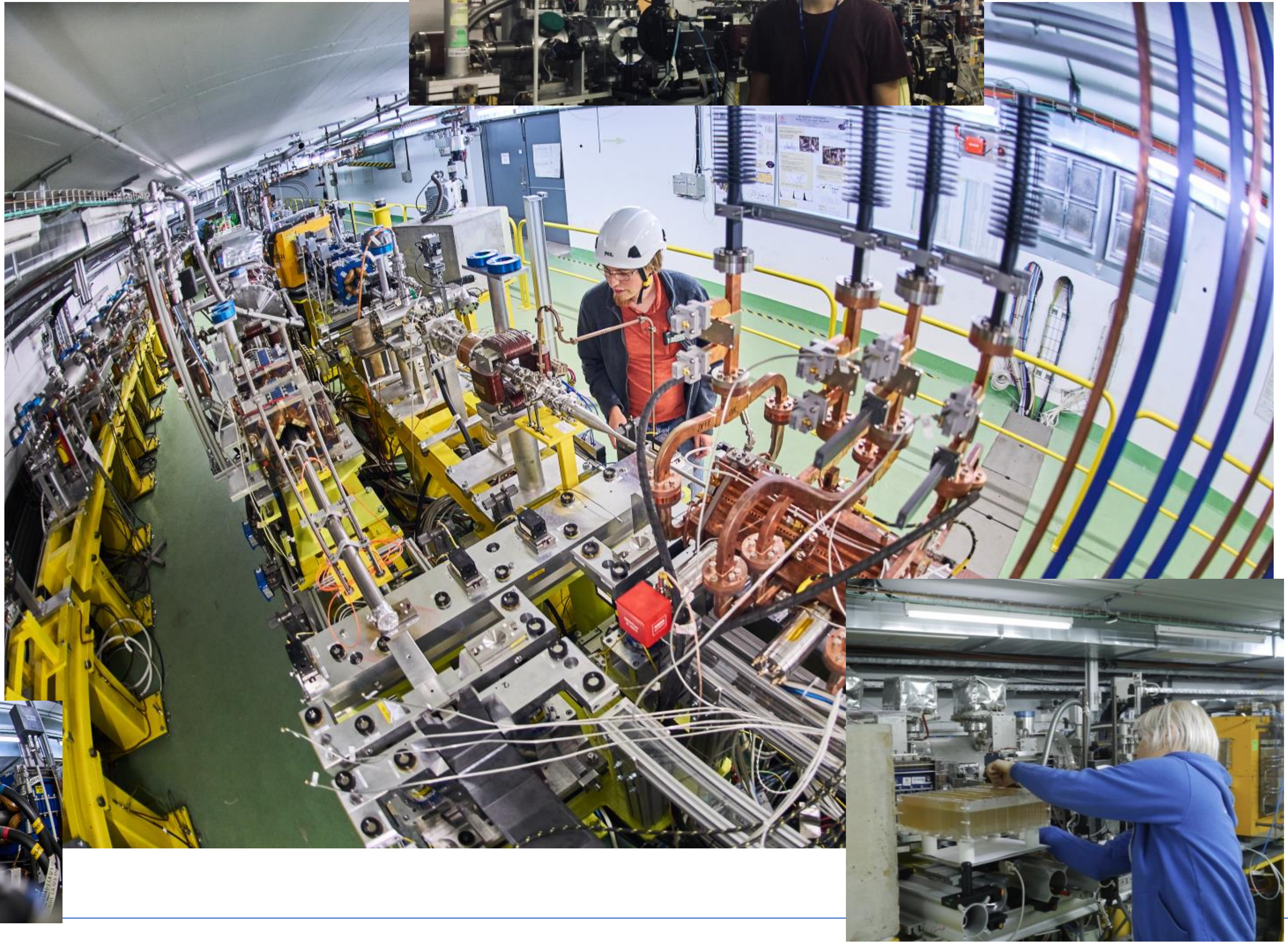
CLEAR operation 2017-2020

Start with beam August 2017

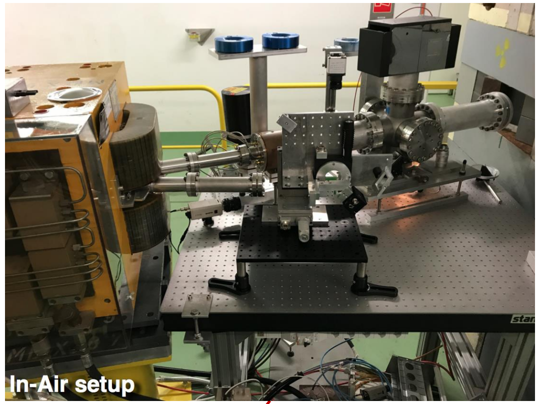
- 19 weeks of operation in 2017
- 36 weeks in 2018
- 38 weeks in 2019
- 29 weeks so far in 2020 with about two months lockdown

Due to Covid related measures, 2020 activities limited so far to CERN users





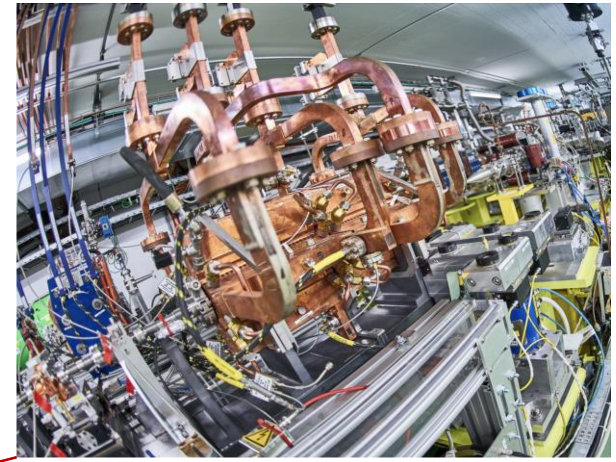
CLEAR Layout & main installations



In-air test stand

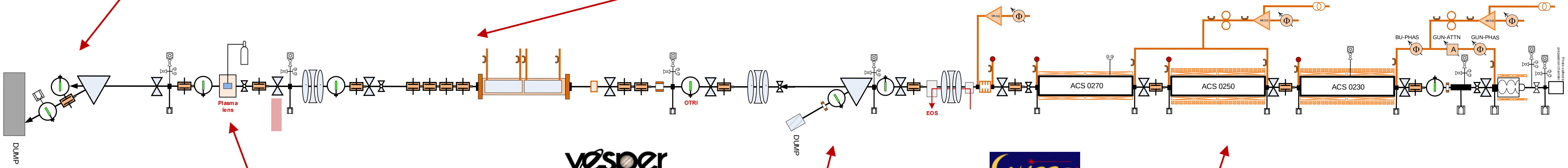
Testing ground for beam diagnostics R&D and THz radiation studies

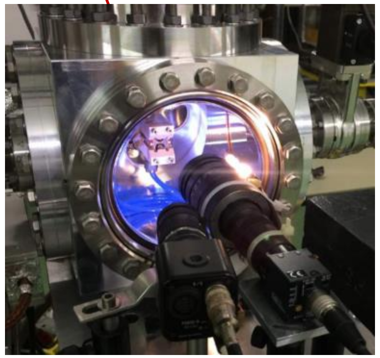
Irradiation for medical and other applications



CLIC Test-Stand

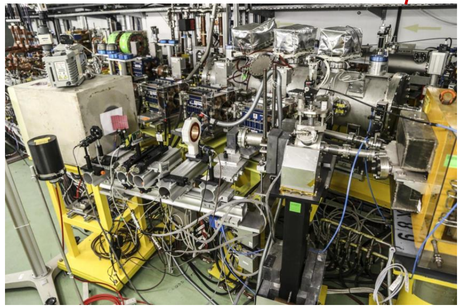
High-gradient and linear colliders R&D





The Plasma Lens Experiment

Novel concepts of plasma-based focusing and acceleration



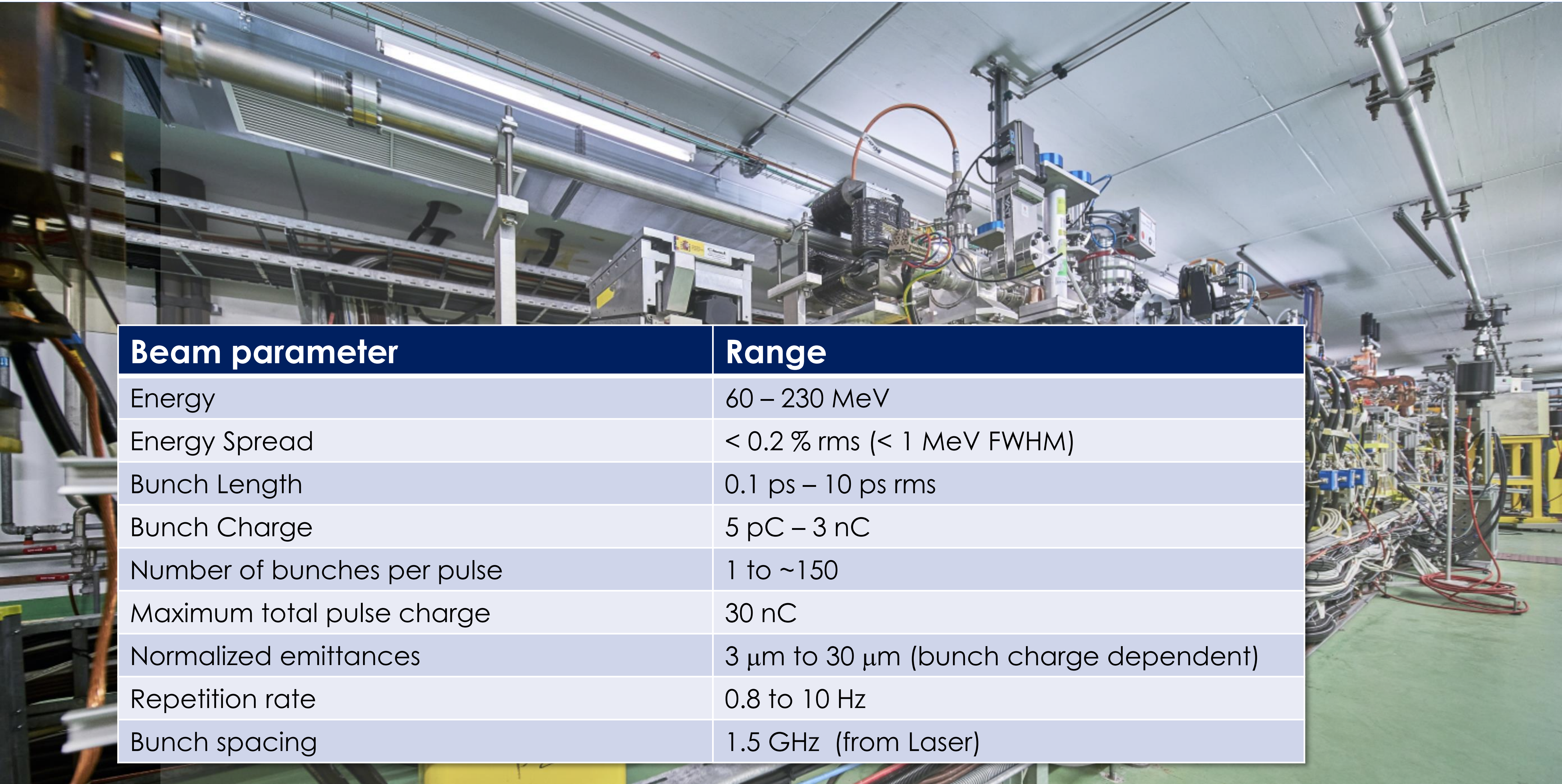
VESPER

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



Beam parameter	Range
Energy	60 – 230 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 ~150
Maximum total pulse charge	30 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)

CLIC related activities

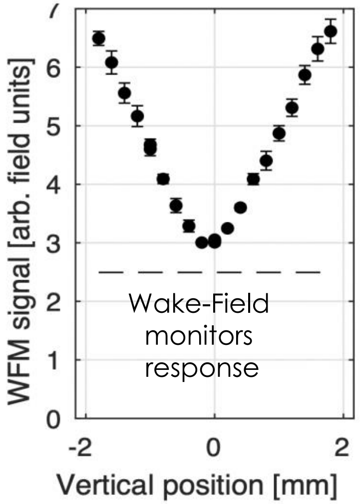
Ongoing experiments:

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

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

Main collaborators

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



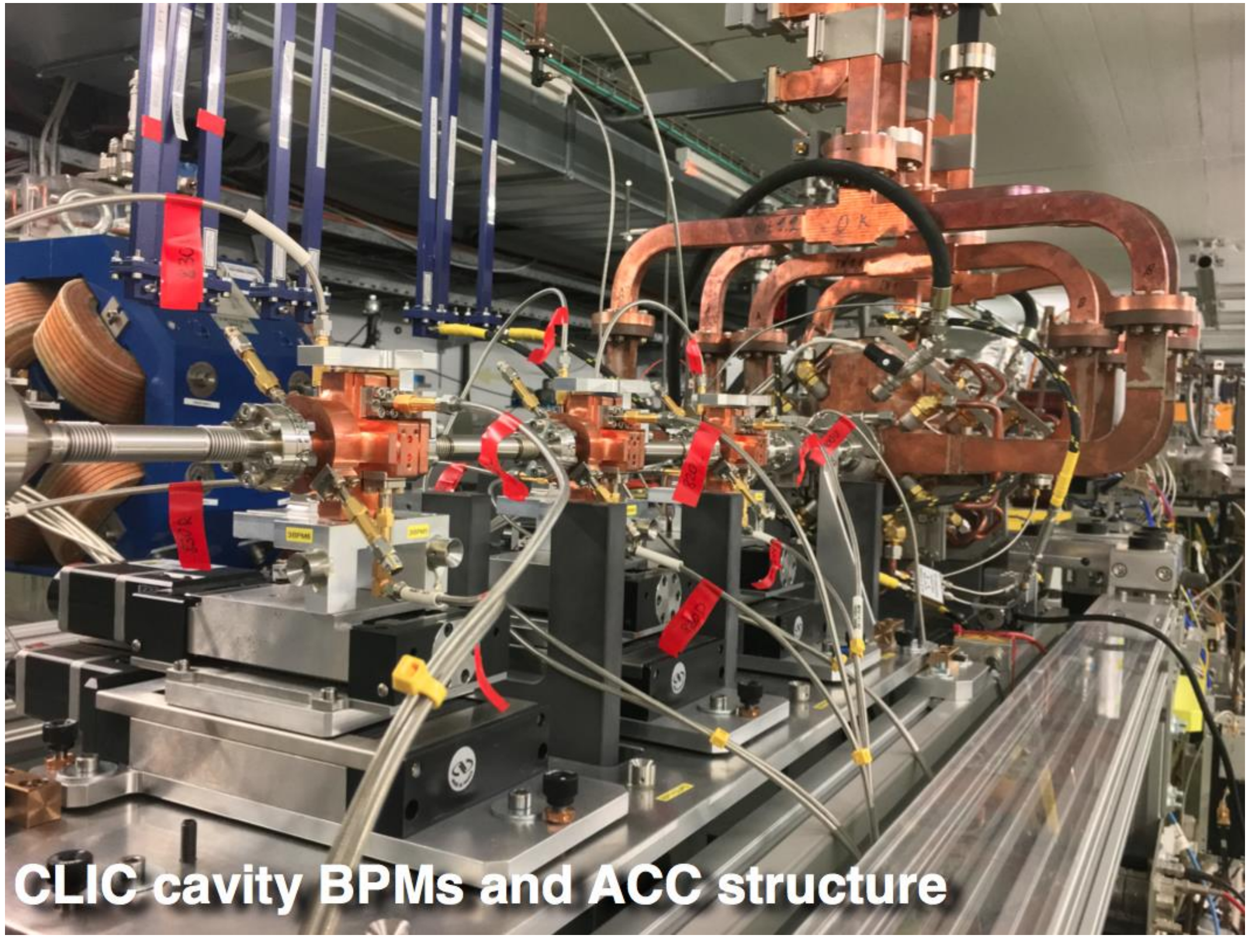
Future step, connecting the cavity to X-Box1

possible tests:

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

Figure 1: Prototype copper CLIC cavity BPM.

Former CLIC Module

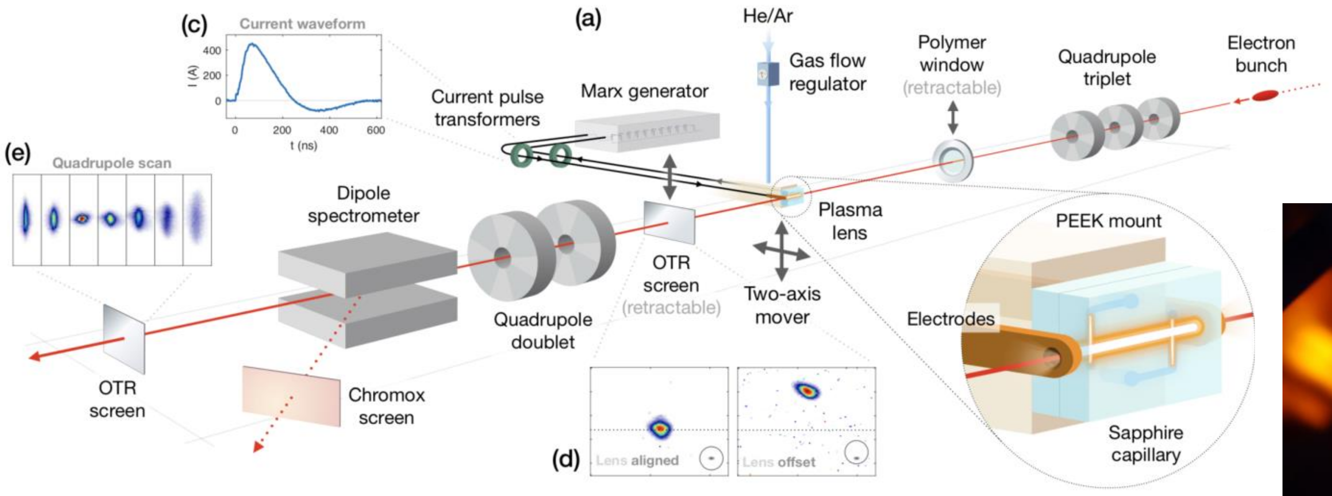


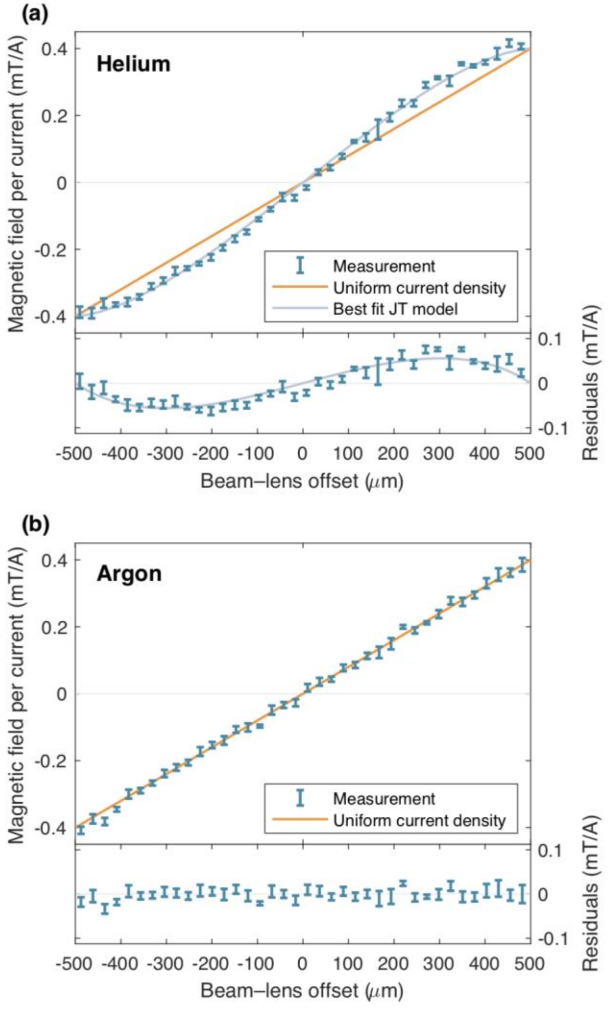
Past highlights – Plasma lens

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 and fully linear focusing in an active plasma lens demonstrated with the use of an argon-based discharge capillary.
- Direc… d nonlin… in helium.

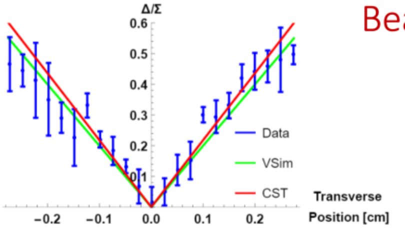
October 2019 – record magnetic field gradient of 5.2 kT/m !

- Quadrupole scans demonstrated expected emittance preservation and growth (respectively) consistent with the measured field profiles.

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

Past highlights – Beam Instrumentation R&D

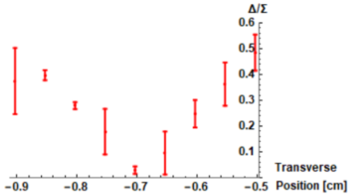
A Coherent Cherenkov-Diffraction-based Beam Position Monitor



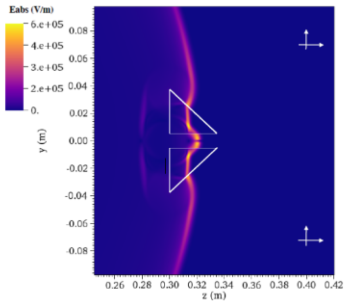
Beam centered

BPM formula

$$\left|\frac{\Delta}{\Sigma}\right| = \left|\frac{S_{left} - S_{right}}{S_{left} + S_{right}}\right|$$

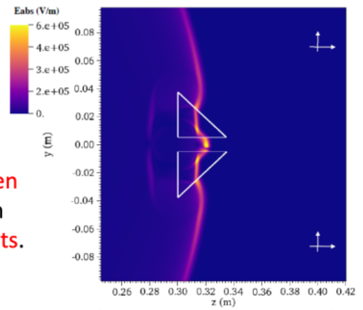


Beam not centered



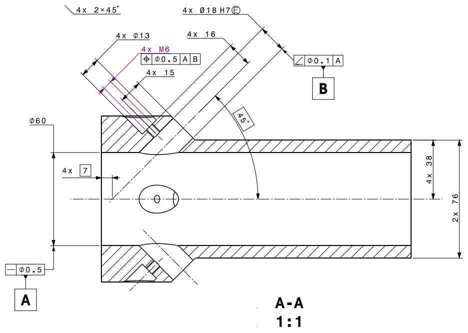
(courtesy of **K. Lekomtsev**)

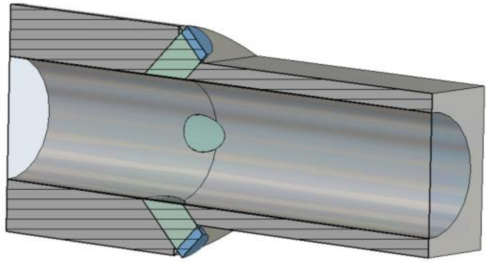
Important note: This BPM, based on coherent radiation, is sensitive only to bunches shorter than a certain threshold bunch length. This means that it can be used to distinguish between bunches of different length, or even to make bunch length measurements.

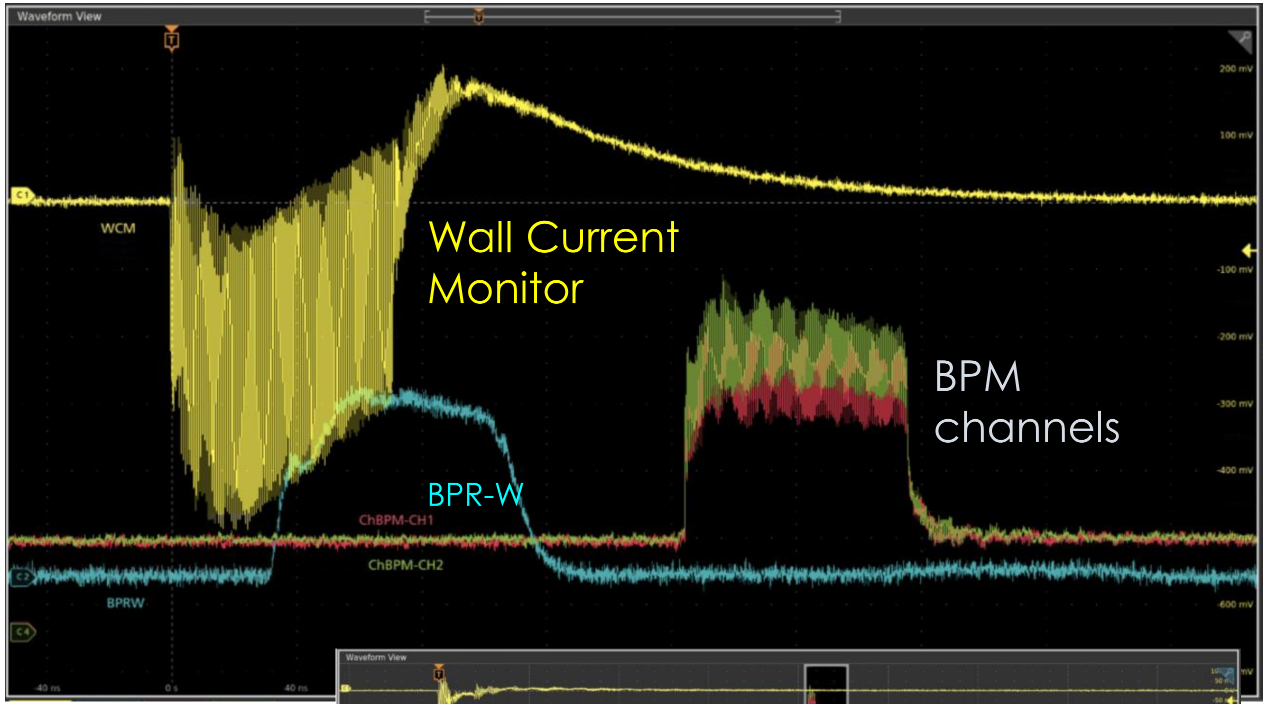


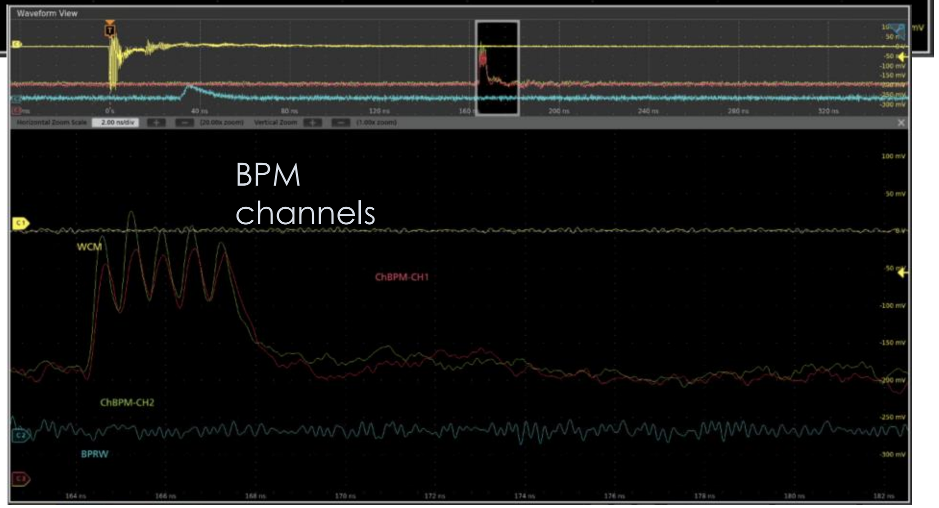
(courtesy of **K. Lekomtsev**)

AWAKE Cherenkov BPMs





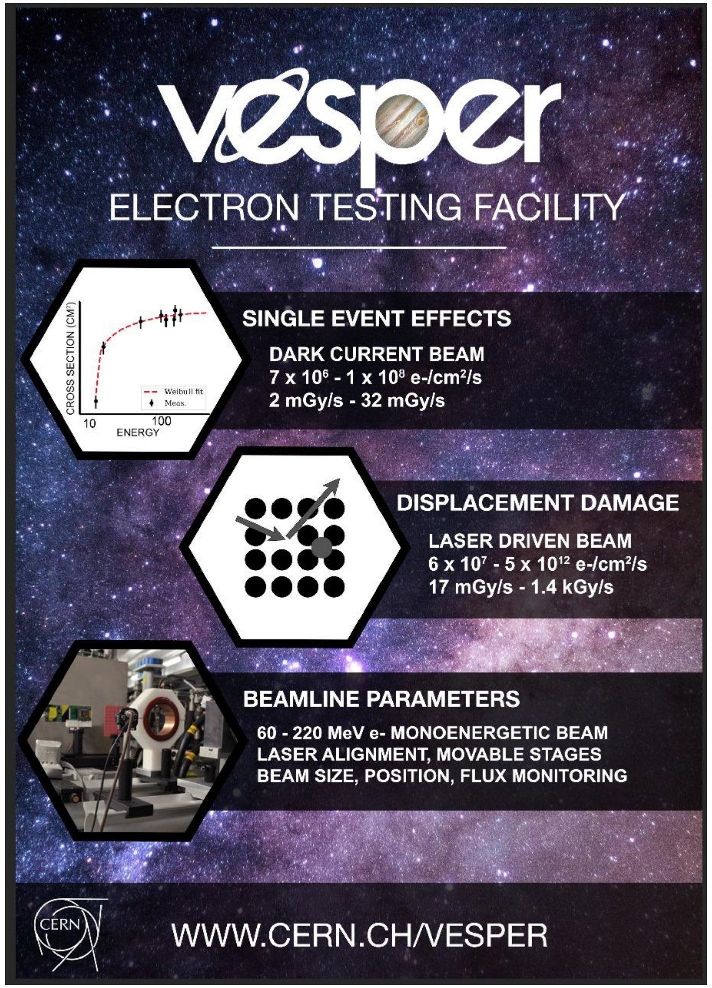


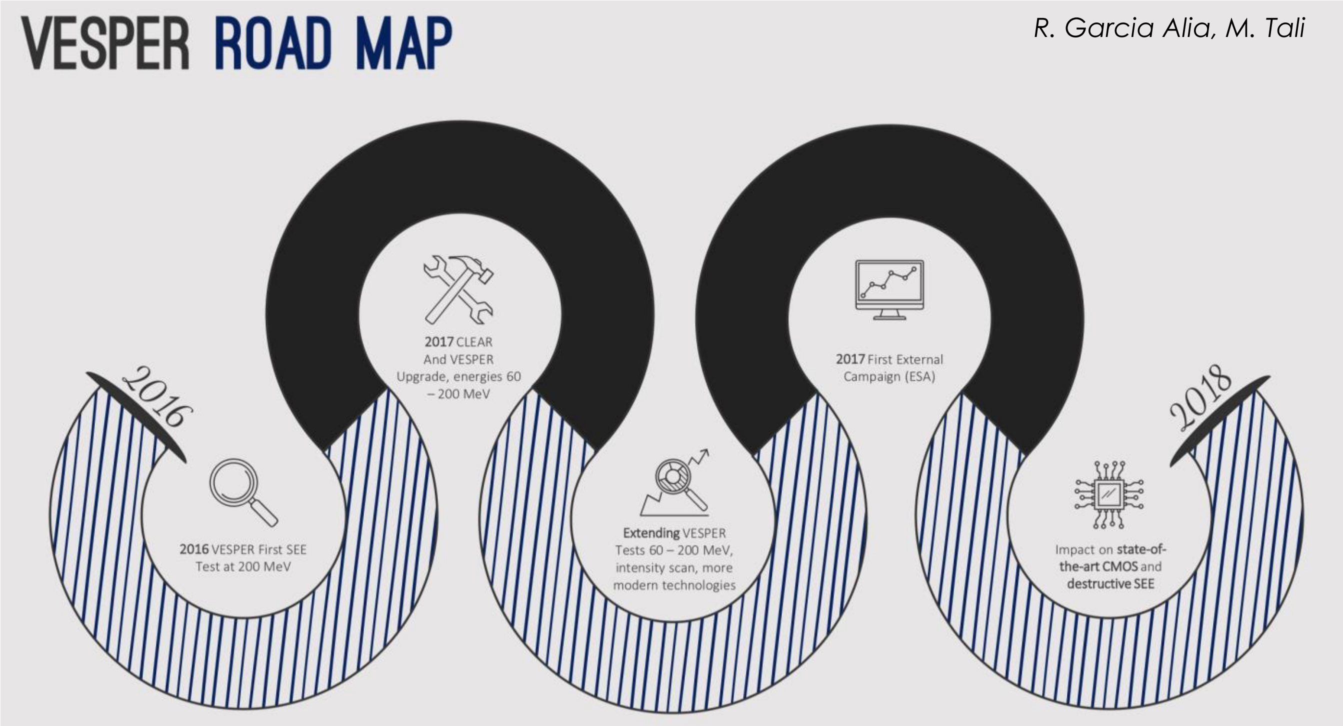


A. Curcio, E. Senes, S. Mazzoni, T. Lefevre…

vesper irradiation facility R2E

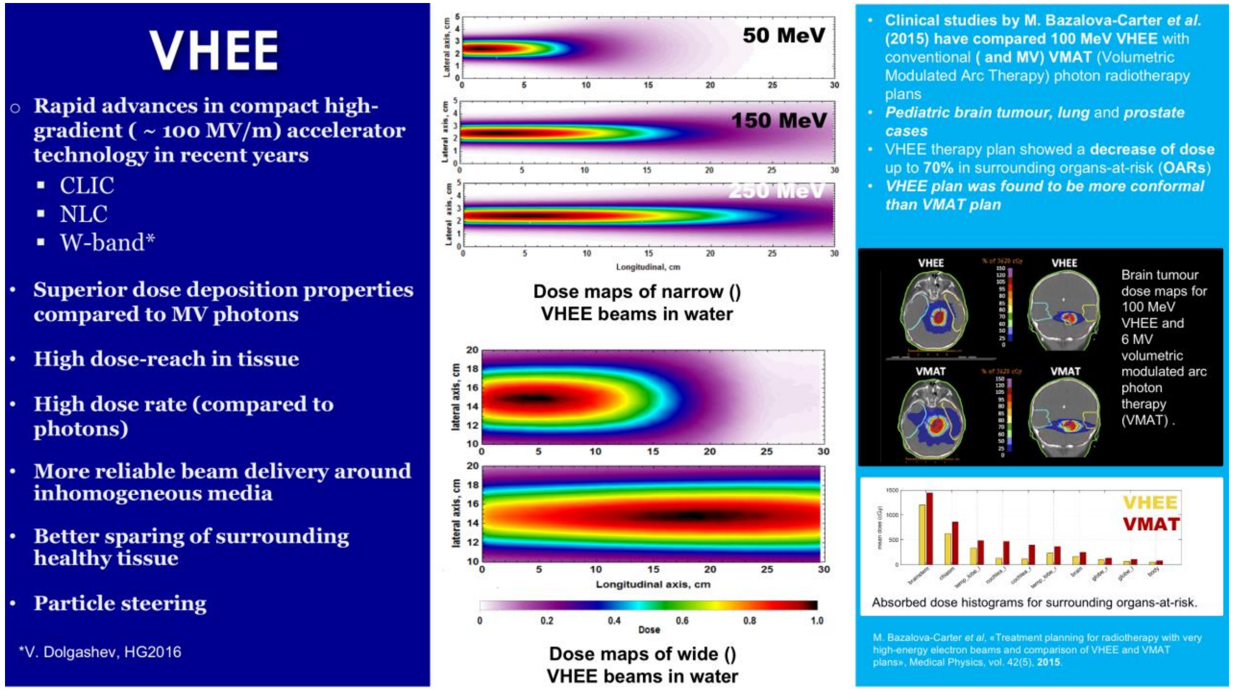
- Beam line already developed and tested in 2016, in collaboration with the CERN R2E team
- In CLEAR we improved diagnostics, stability and energy range (60 - 220 MeV)





- 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

Medical irradiation tests - VHEE



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

11

Activities:

- Experimental verification of dose deposition profiles in water phantoms
- Calibration of operational medical dosimeters – nonlinear effects with short pulses
- Demonstration of "Bragg-like peak" deposition with focused beams

Initial interest: Manchester Univ. *(A. Langzda, R. Jones)*
- Three measurements campaigns (2017-2018)

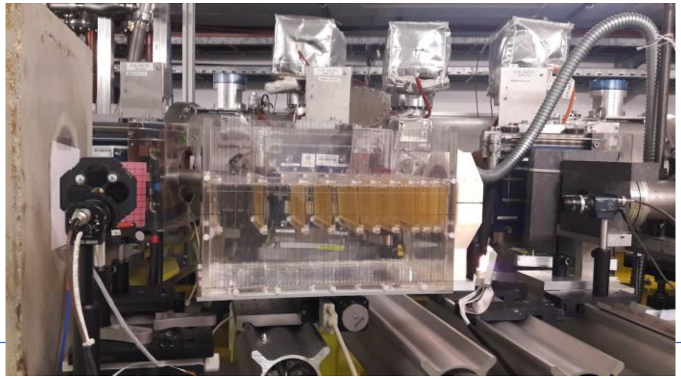
Further requests from:

Nat. Phys. Lab. UK *(A. Subiel et al.)*
- Two measurement campaigns (end 2018, spring 2019)

Strathclyde University *(K. Kokurewicz et al.)*
- One campaign completed (end 2018)

Oldenburg University and PTW *(B. Poppe, D. Poppinga et al.)*
- Two campaigns completed (end 2018, September 2019)

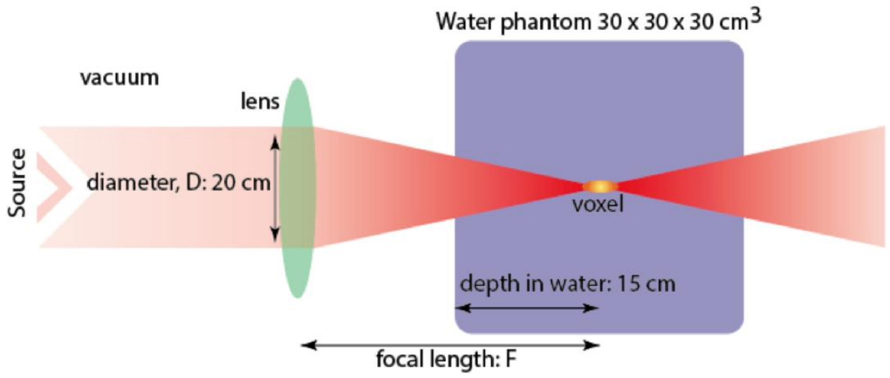
CHUV Lausanne *(M.C. Vozenin, C. Bailat, R. Moeckli et al.)*
- Preliminary tests (end 2018, spring 2019)



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

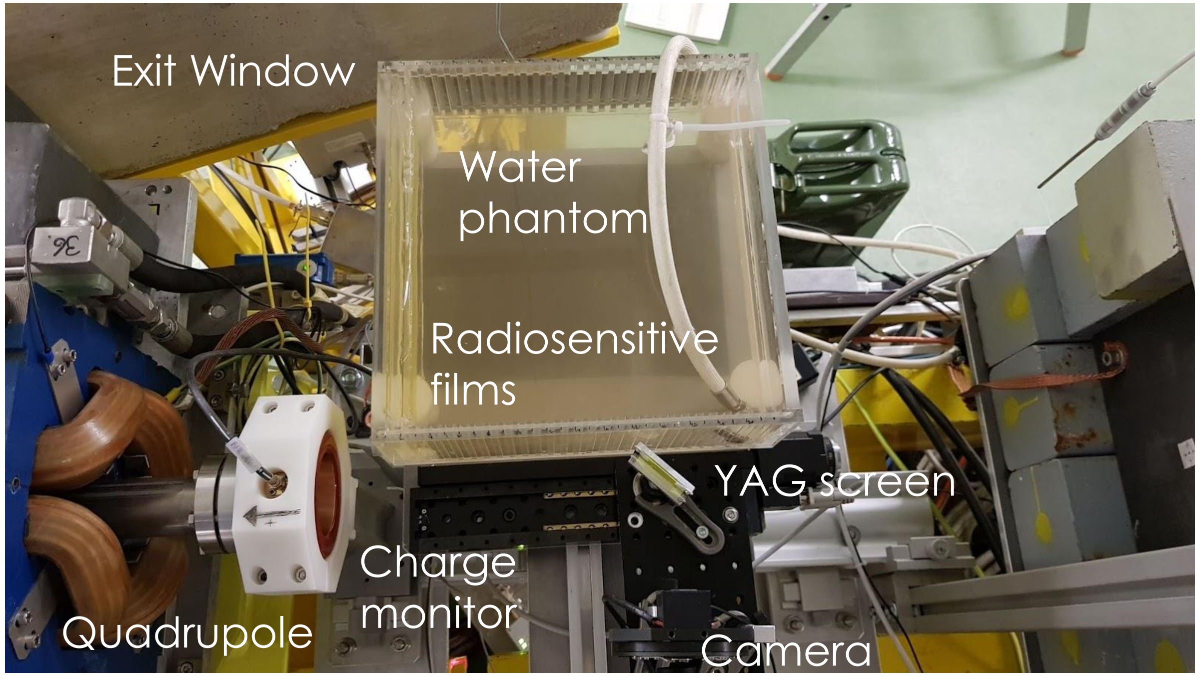
Past highlights – VHEE strong focusing



Aim:

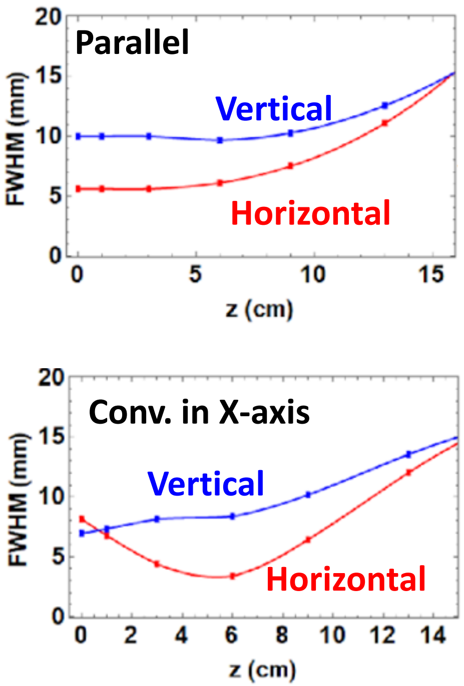
Focus the beam on the tumour to minimize the dose on the nearby healthy tissues

- 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.

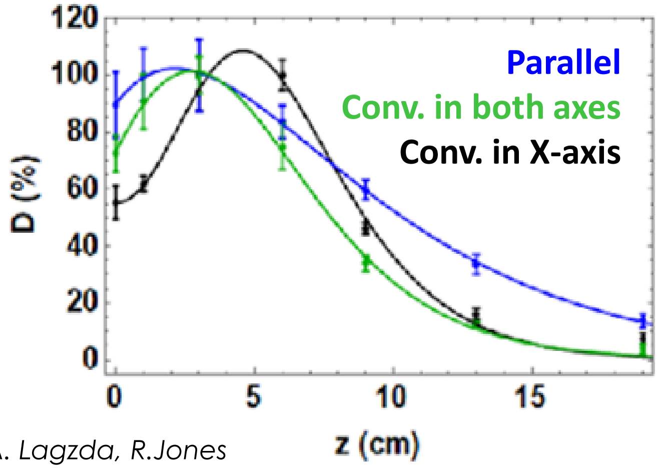


W. Farabolini, E. Senes, K. Kokurevicz

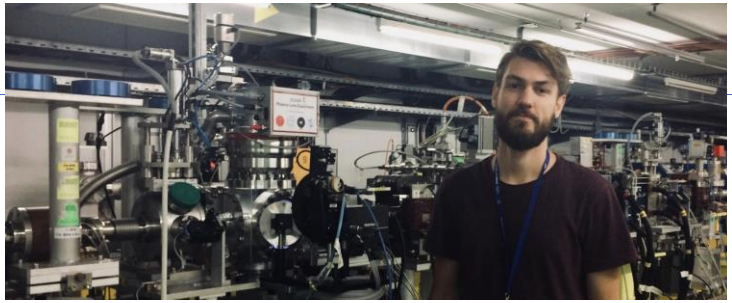
Beam size



Dose deposition



A. Lagzda, R.Jones



Experiments/Activities in 2019

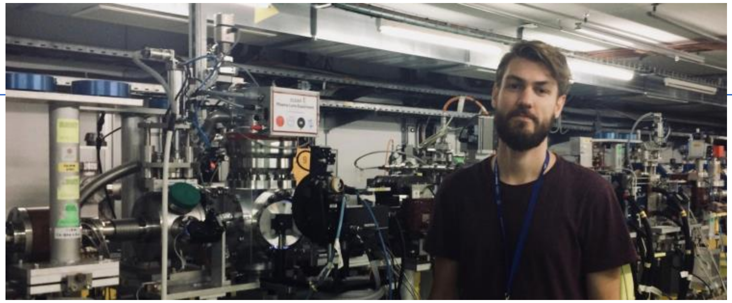
(Possibly not a complete list)

- JUAS Practical Work Days
- NPL – Irradiation/dosimetry
- CHUV – FLASH dosimetry
- AWAKE Cherenkov BPM
- CLIC Wake-Field Monitors
- EOS bunch length monitor
- Inductive BPMs

- CLIC Structure wake-field kicks
- THz Smith-Purcell radiation
- THz high power generation/bunch length monitoring
- Ionization chambers dosimetry (Oldenburg U. /PTW)
- R2E Irradiation studies SEU-SEE
- R2E – ESA monitor flash

- R2E – displacement damage
- Plasma Lens (Oslo, DESY, Oxford U.)
- VHEE radiobiology/plasmid irradiation (Manchester U.)
- AWAKE spectrometer calibration
- Cryogel radiation length evaluation (FCC detectors R&D)
- Cherenkov X-ray pre-tests (Belgorod)
- RP measurements/neutrons
- Double-bunch generation
- High Charge bunch compression

- Irradiation of DCDC converters for detectors (EP/ESE group)
- IRRAD Beam Profile Monitors prototype tests
- WSM-BPR diagnostics tests
- Cherenkov Plasmonic



Experiments/Activities in 2019 > 2020

(Possibly not a complete list)

- JUAS Practical Work Days
- NPL – Irradiation/dosimetry
- CHUV – FLASH dosimetry
- AWAKE Cherenkov BPM
- CLIC Wake-Field Monitors
- EOS bunch length monitor
- Inductive BPMs

- CLIC Structure wake-field kicks
- THz Smith-Purcell radiation
- THz high power generation/bunch length monitoring
- Ionization chambers dosimetry (Oldenburg U. /PTW)
- R2E Irradiation studies SEU-SEE
- R2E – ESA monitor flash

- R2E – displacement damage
- Plasma Lens (Oslo, DESY, Oxford U.)
- VHEE radiobiology/plasmid irradiation (Manchester U.)
- AWAKE spectrometer calibration
- Cryogel radiation length evaluation (FCC detectors R&D)
- Cherenkov X-ray pre-tests (Belgorod)
- RP measurements/neutrons
- Double-bunch generation
- High Charge bunch compression

- Irradiation of DCDC converters for detectors (EP/ESE group)
- IRRAD Beam Profile Monitors prototype tests
- WSM-BPR diagnostics tests
- Cherenkov Plasmonic

CLEAR operation & experimental program in 2020

- Started operation end-February, stopped with lockdown mid-March
- Resumed operation end of May
- Short shutdown in August – photocathode renewal and manpower availability

- Had received 24 formal requests for beam time for 2020
- About 15 completed or under way at present
- A couple of other informal requests being followed up

- Limited until now to CERN users

2020
- 2337478 (v.1) 18-Calibrate Gafchromic EBT3
- 2337479 (v.1) 19-Response of secondary standard ionisation chambers to VHEE
- 2337580 (v.1) 20*-CHUV
- 2337586 (v.1) 21-light yield and spectrum of Chromox screens
- 2337591 (v.1) 22-Optical Transition Radiation Interferometry (OTRI) and Digital Micro-mirror Device (DMD)
- 2337596 (v.1) 23-Dosimetry control and characterisation for R2E + ESA Monitors
- 2337890 (v.1) 24-IRRAD BPM test
- 2337894 (v.1) 25-Fiber optic dosimetry
- 2337898 (v.1) 26-R2E impact of neutrons
- 2337902 (v.1) 27-radiation damage and stuck bits in SDRAMs
- 2337905 (v.1) 28-Yield of the Cherenkov radiation within soft X-ray
- 2337909 (v.1) 29-Coherent Cherenkov diffraction radiation by Surface Plasmon Polariton
- 2337910 (v.1) 30-Coherent Cherenkov diffraction radiation in dielectrics
- 2337913 (v.1) 31-CLIC wake field monitor studies
- 2337914 (v.1) 32-Plasma Lens Studies
- 2337918 (v.1) 33-CLIC Cavity BPMs
- 2337920 (v.1) xx-Test of new Rad-tolerant cameras from Microcameras
- 2337922 (v.1) xx-EOS bunch length measurement for AWAKE
- 2337924 (v.1) xx-Impedance studies on Coherent Cherenkov radiation
- 2337926 (v.1) xx-JUAS
- 2396415 (v.1) 38-Machine Learning for beam imaging system
- 2396850 (v.1) 39-Investigation on Degradation of Irradiated EPI (epitaxial) Silicon Pad Diodes
- 2440179 (v.1) 40-Irradiation of SmartFusion 2 FPGA
- 2442530 (v.1) 41-Test of OTR and YAG screens exposed to Rubidium vapour

New experiments – examples

Mask Sterilization

Ionizing radiation sterilization

STAR DOME

(STerilizzAzione e Riutilizzo di DispOsitivi e Mascherine Ecosostenibili per Covid-19)

STAR DOME. A proposal to Lombardy region
- NUCLEAR DETECTION INNOVATION s.r.l. (Capofila), GAMMATOM s.r.l. (a company near Como performing industrial irradiation of medical equipment, food, etc),
- M3R s.r.l. (a spin-off company of University Milano Bicocca having access to the microbiology laboratory of the Polytechnic of Milan,
- CERN HSE-RP. CLEAR
- University of Brescia

Solving the following problem
- Billions of facial masks needed per month worldwide
- Up to 24 PPE/day/patient needed in hospitals (source ECDC)
- production & distribution issues
- Most PPE are single use, made with of non-recyclable material and after use potentially contaminated with bacterial and viral patogens
- Logistics and environmental problem

CERN AGAINST COVID-19

STAR DOME

IRRADIATION WITH Co-60

STERILIZATION WITH ELECTRON BEAMS

Microbiological analysis of PPE pre-irradiation
- Irradiation at different doses
- Microbiological analysis post-irradiation
- Verification of mechanical and filtration integrity of PPE

CERN Linear Electron Accelerator for Research

With STAR DOME we already have the embryo of a larger consortium in which CERN can be full partner

CERN AGAINST COVID-19

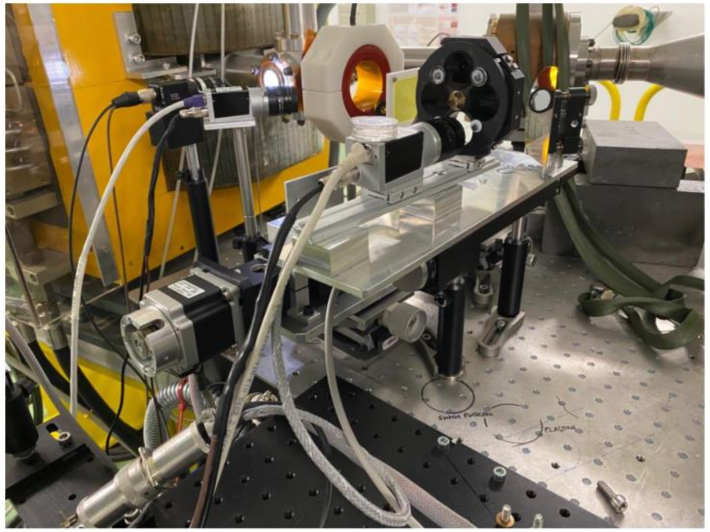


Figure 4. Experimental location at CLEAR for the irradiation tests of the PPE.

Sample	Af (600nm)	Af-Ai	k	Dose (kGy)
reference	0.18	0	0.000	FILM
1	0.462	0.282	6.635	3.8
2	0.444	0.264	6.212	3.6
3	0.458	0.278	6.541	3.7
4	0.454	0.274	6.447	3.7
BG 1	0.277	0.097	2.282	1.6
BG 2	0.280	0.1	2.353	1.6
BG 3	0.280	0.1	2.353	1.6

- First irradiation test in CLEAR
- Next steps:
  - Irradiation optimization
  - BFE (bacterial filtration efficiency) tests – likely by CERN
  - Sterilization tests – with University Bicocca Milan

New experiments – examples

- LHCb Photonic Crystal Experiments

Potential beam test experiments of novel
LHCb RICH radiator materials

CERN clear

Experiment Request Form

A. REQUESTER DETAILS

Principal Investigator: Michele Piero Blago

Institution: CERN; University of Cambridge

Contact Information (phone/email):

Experiment Members: Sajan Easo, Carmelo D'Ambrosio, Giovanni Cavallero

Collaborating Institutions: CERN

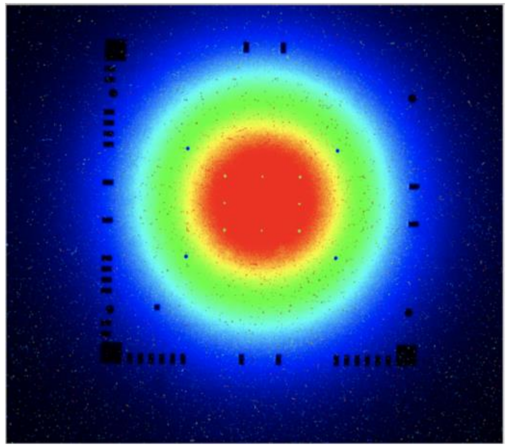
Funding Source (optional)

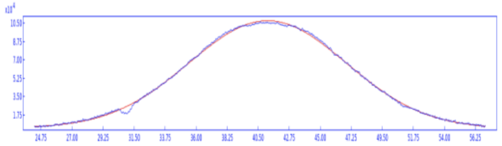
Approximate Duration: 1 day

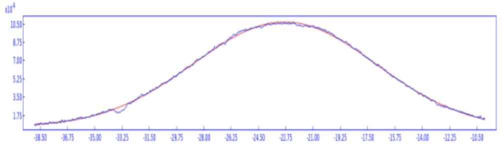
B. EXPERIMENT DESCRIPTION

1. Scientific justification (one paragraph)
Test of the effect of irradiation on a polymer photonic crystal. That is to prepare for a more sophistaced beam test at CLEAR at a later stage.

2. Experiment short description and goals (max 1 page)
The polymer photonic crystal strip should be irradiated with varying exposure times. Each exposure time session should hit a separate part of the crystal sheet. For that purpose the photonic crystal may be placed on a translation stage and moved between irradiations. The irradiation times should ideally spread between 1 s and 1000 s (e.g. 1 s; 10 s; 100 s; 1000 s) and the accumulated charge measured for each irradiation step.



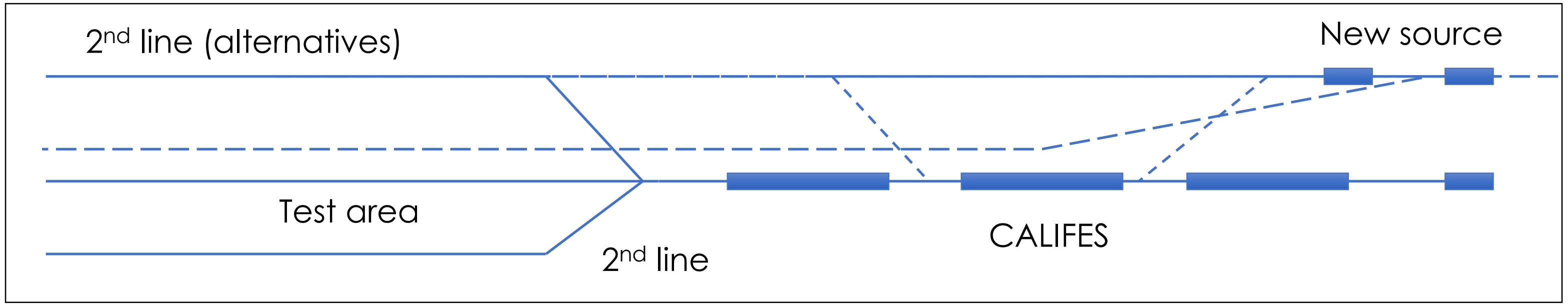


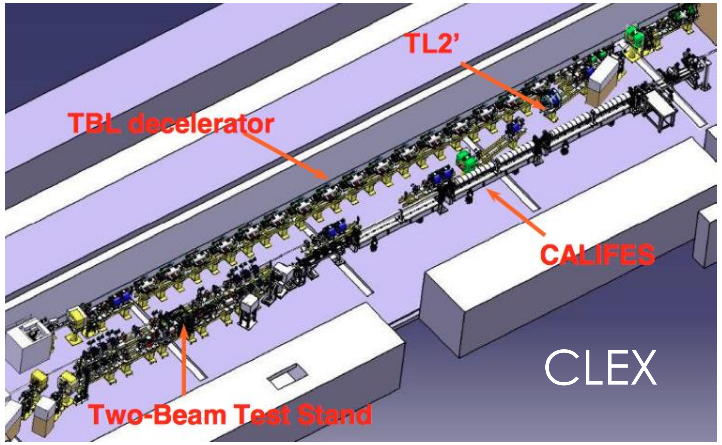


High dose irradiation – about 100 μC delivered in less than 15 minutes and 1 mC delivered in about 2 hours

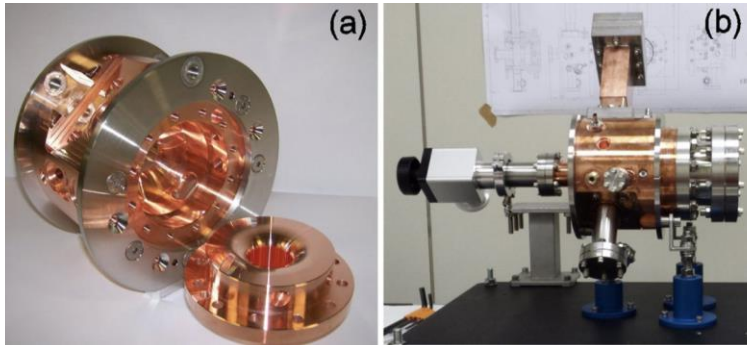
(15 nC/pulse at 10 Hz)

Options for a second beam line + source



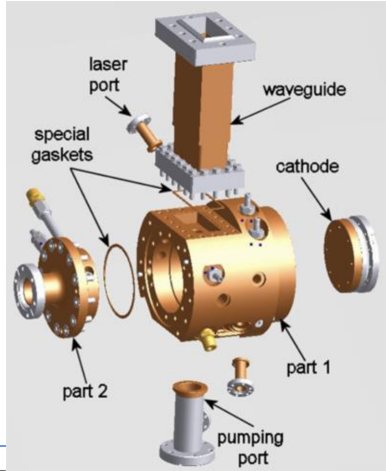


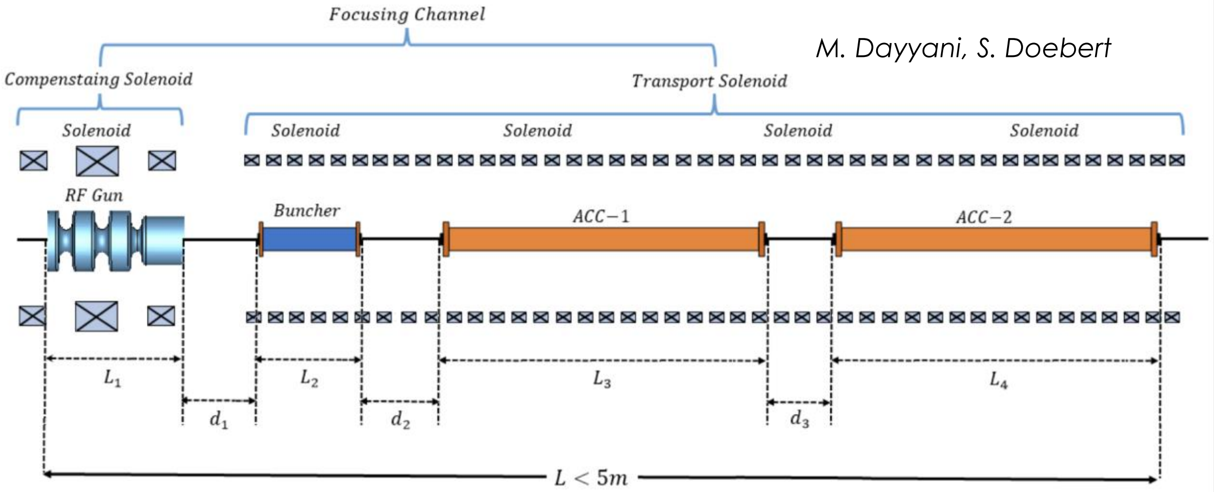
D. Alesini, M. Ferrario et al.



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





M. Dayani, S. Doebert

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	$< 10\ \mu m$	$0.6\ \mu$

Upgrades and future plans

- Now we have finally a longer horizon, 5 years and more
- Need to re-evaluate the experimental program and the available resources:
  - Will held a CLEAR advisory committee meeting soon (early 2021?)

- Short term (winter shut-down 2020/2021 and during 2021)
  - Consolidation for extended running (5y or more) – laser, RF, controls, …
  - Repair, conditioning and connection of X-box1
  - Design and prepare for installation of a new (simple) beam-line

- Long term
  - New source – it will be developed, tested and commissioned in CTF2 hall
  - May be installed in CLEAR from 2022
  - New AWAKE timeline requires new source in 2026 – no potential conflict

Potential areas for collaboration with Frascati/SPARC

- X-band beam tests (wake-field monitors, …)
- Plasma (lenses, acceleration in capillaries? diagnostics? – link with AWAKE
  N.B.: collaboration with Oslo and others)
- THz radiation – dielectric structures (paused for now in CLEAR)
- General beam diagnostics R&D
- Suggestions?

Conclusions

- The CLEAR facility provides access to high quality e- beams to a wide community of users, with high availability and easy access
- The 2020 experimental run is being completed, with only relatively partial disruption by the Covid crisis

- Beam parameters and experimental infrastructure have been improved, and keep improving, since the facility start-up in 2017
- CLIC related activities are still playing a large role in CLEAR, and can be further extended with the connection to X-BOX1
- Beam time requests are increasing, further extending the scope of the facility

- CLEAR running has been de-facto extended at least to 2025, the longer time span implies a consolidation of the facility hardware, and gives the opportunity for a proper planning of upgrades

The CLEAR team warmly welcomes further opportunities for collaboration with INFN-Frascati!

Thanks for your attention!

RESERVE

Beam Instrumentation R&D

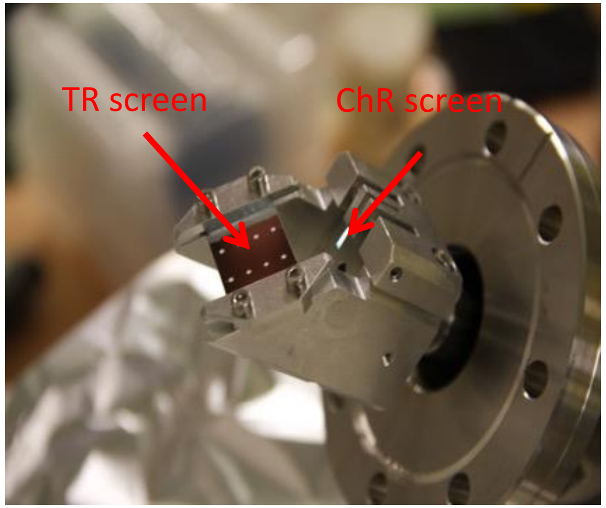
Many activities planned (most ongoing)

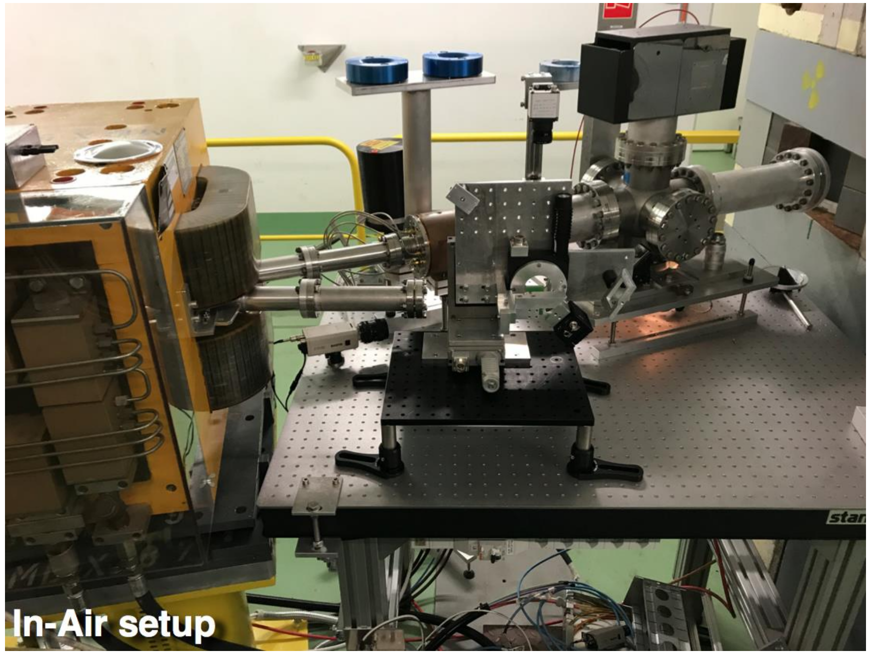
Two main goals:

1) Consolidate and improve beam instrumentation for CLEAR

2) Diagnostics R&D

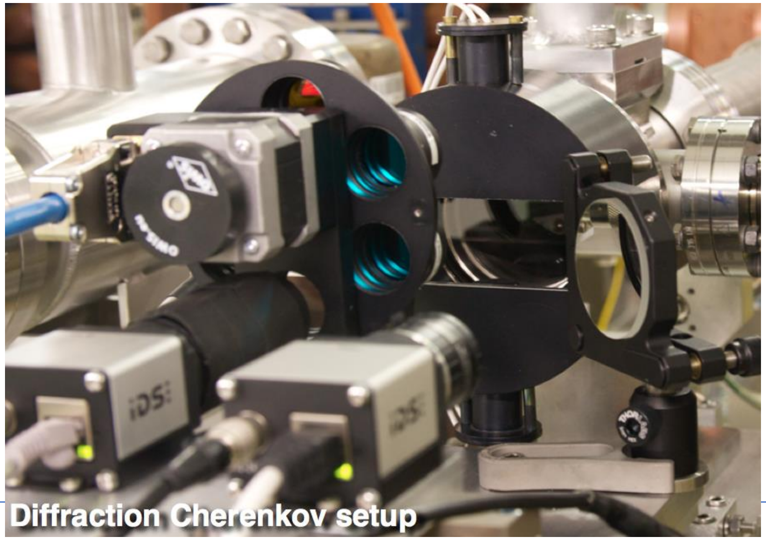
- Diffraction Cherenkov radiation
- Electro-Optical monitors
- …

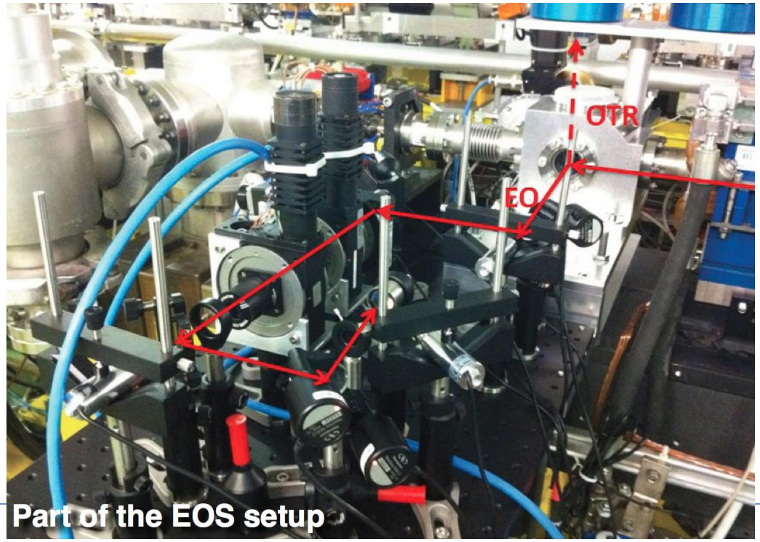




Collaboration at CERN with BE/BI group and several external collaborators

Direct applications to CERN accelerator complex & potential for future applications





Medical irradiation tests – FLASH therapy

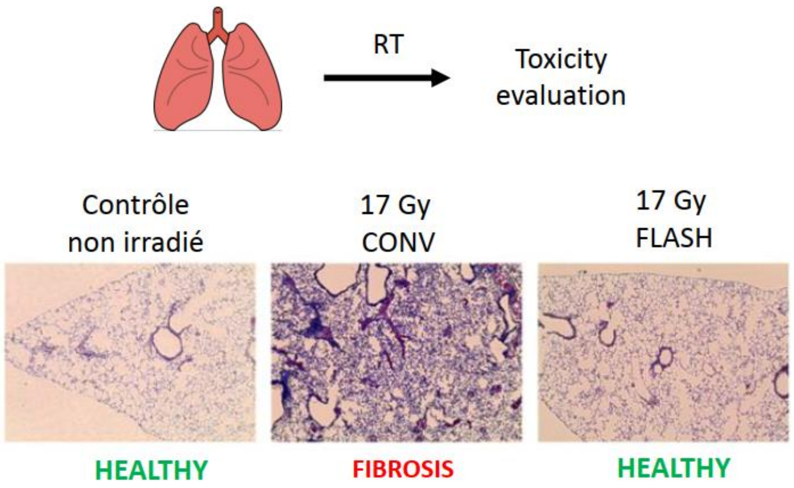
Fast (<100ms) delivery of high dose (>10 Gy) radiation seems to retain the same effect on the tumoral tissue of similar integrated doses delivered with the standard fractional method, minimizing at the same time the impact on healthy tissues.

- 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 → tests in CLEAR

RADIATION TOXICITY

Ultrahigh dose-rate FLASH irradiation increases the differential response between normal and tumor tissue in mice

Vincent Favaudon,[1,2*] Laura Caplier,[3†] Virginie Monceau,[4,5‡] Frédéric Pouzoulet,[1,2§] Mano Sayarath,[1,2¶] Charles Fouillade,[1,2] Marie-France Poupon,[1,2||] Isabel Brito,[6,7] Philippe Hupé,[6,7,8,9] Jean Bourhis,[4,5,10] Janet Hall,[1,2] Jean-Jacques Fontaine,[3] Marie-Catherine Vozenin[4,5,10,11]

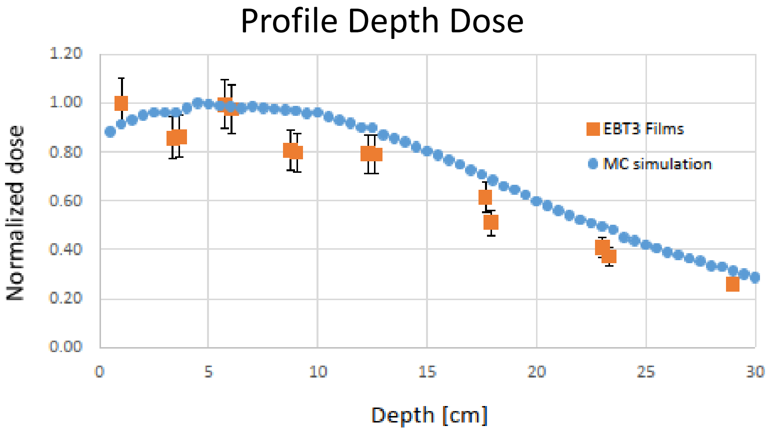


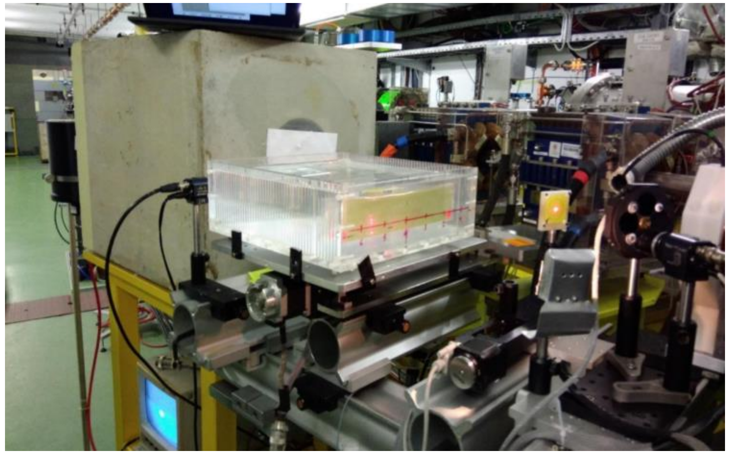
Pierre Montay-Gruel

Preliminary tests in CLEAR in collaboration with CHUV in December 2018:

- Calibration
- Profile Depth Dose
- Feasibility of biological dosimeters irradiation

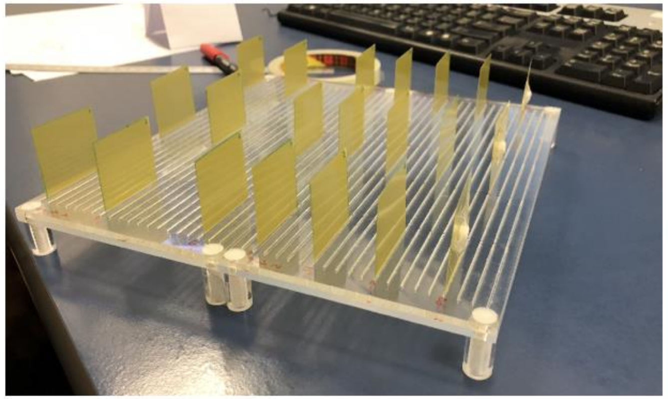
New measurements in March 2019 – using biological dosimeters

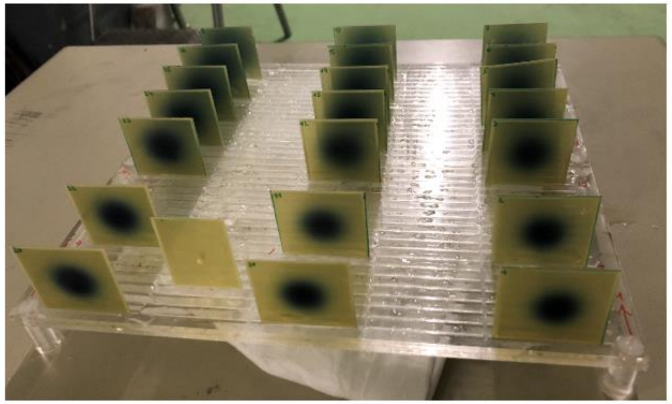


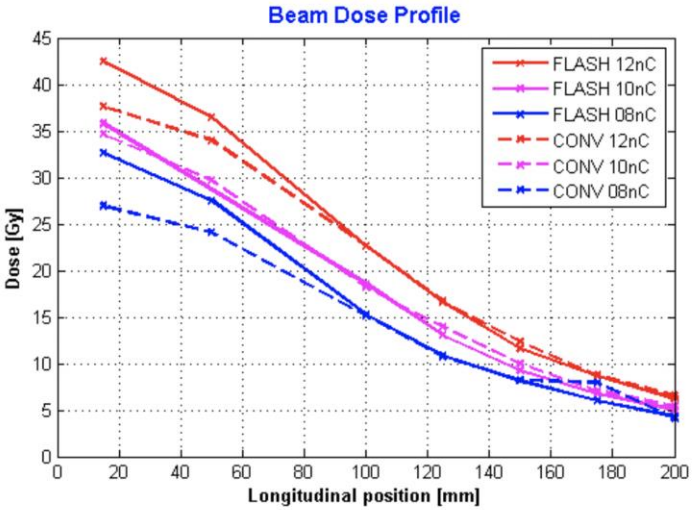


M.C. Vozenin, P. Goncalves, C. Bailat, R. Moeckli, W. Farabolini

FLASH dosimetry







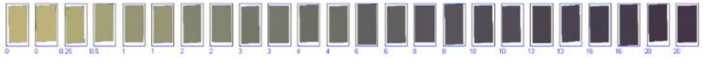


Figure 1: Calibration films with corresponding doses in Gy

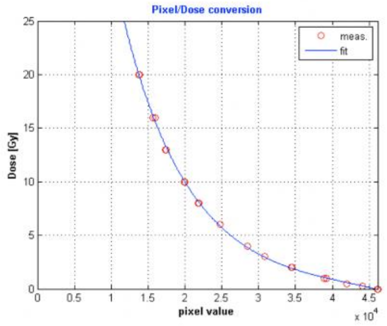
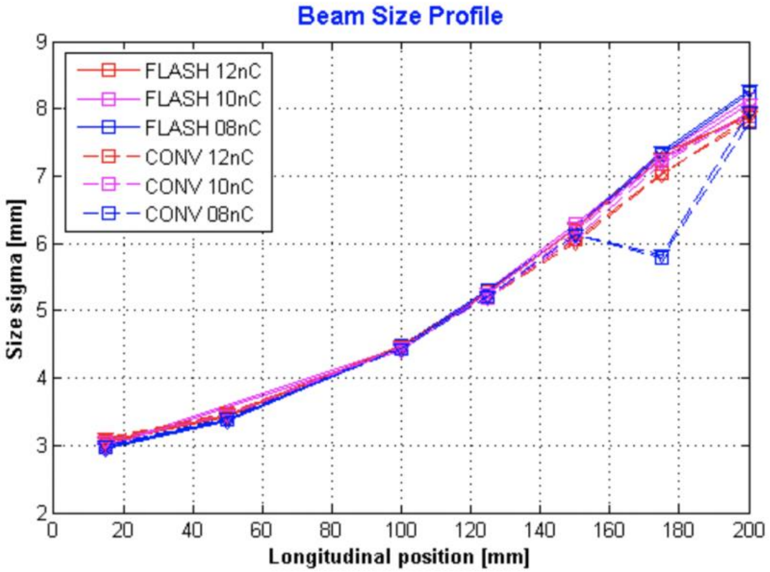
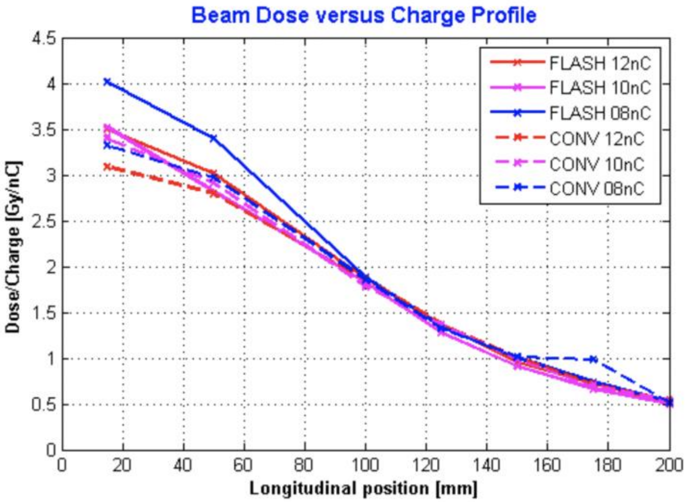


Figure 2: Film doses and calibration fit function





W. Farabolini, A. Gilardi, R. Moeckli, P. Goncalves

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 (> 1 MW) from different sources
  - Tested so far: diamond, TR screens, Teflon, gratings, metamaterials

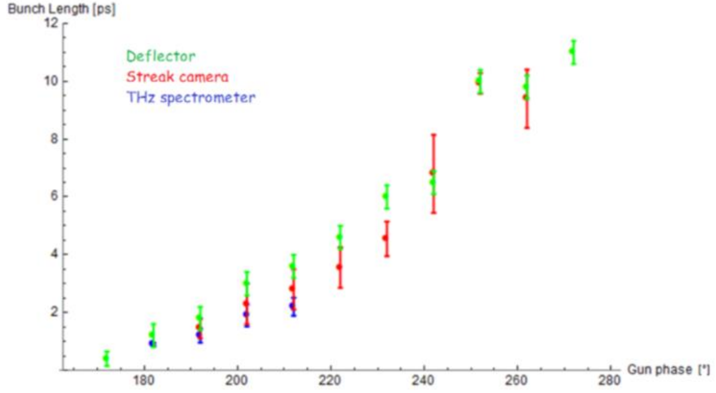


Figure 2: Bunch length measurement with different techniques/detectors. The bunch length compression in this case was made only by varying the gun phase, March 2018.

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

Many possibilities beyond that…

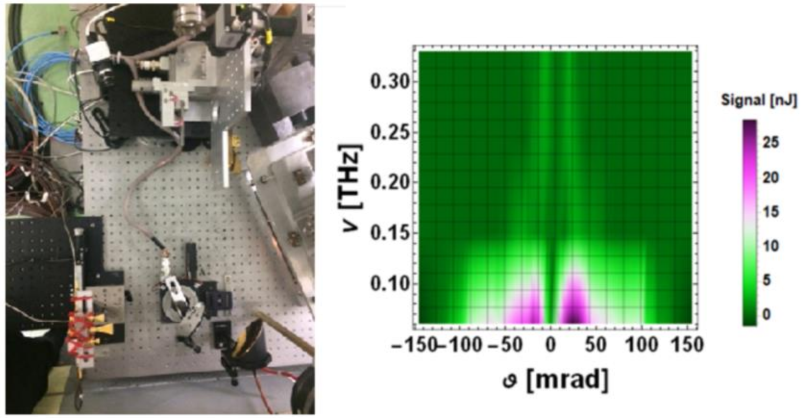
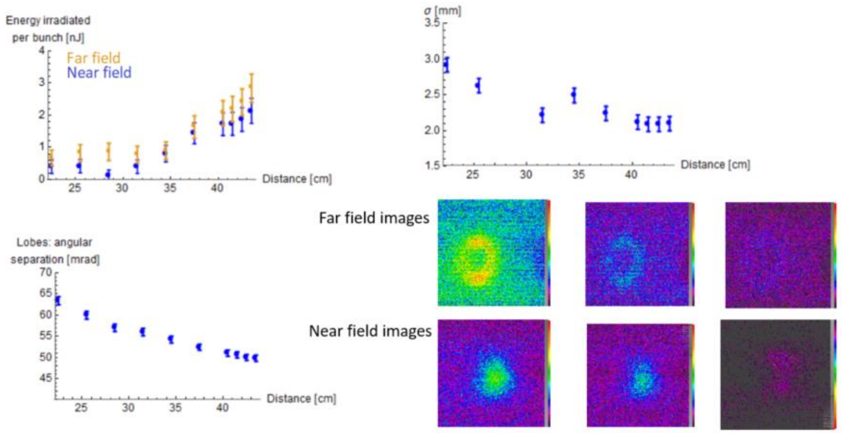


Figure 3: **Left**: Experimental setup for the spectral-angular characterization of CTR light. **Right**: Experimental results on spectral-angular characterization of the CTR light emitted by a 215 MeV, 40 pC, 1.5 ps long electron bunch, April 2018.



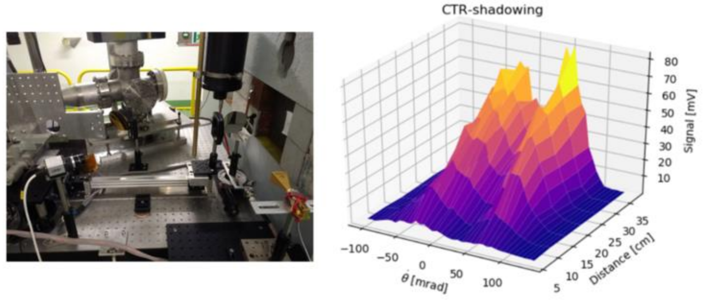
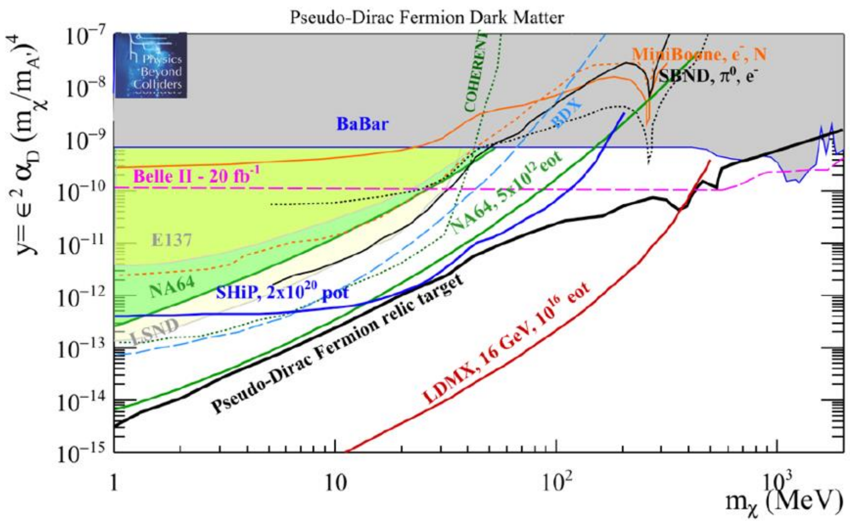


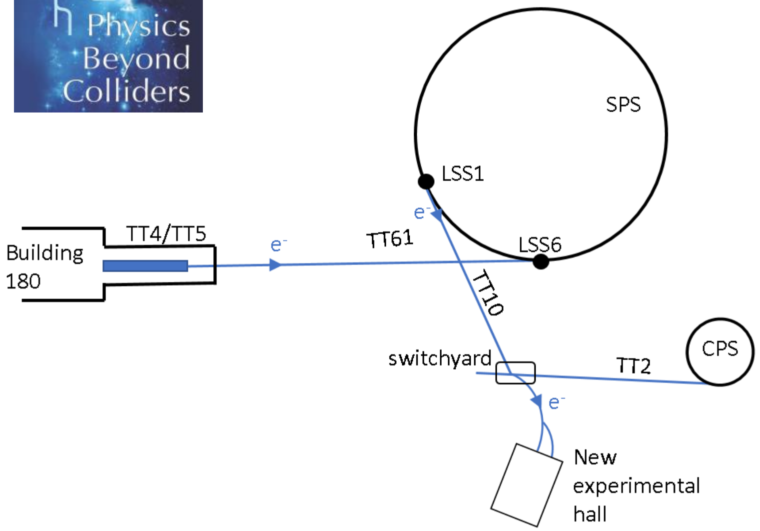
Figure 4: **Left**: Experimental setup for the two-screens experiment. **Right**: Experimental results on the electromagnetic shadowing at $\lambda = 4\ mm$. The distance axis is understood to be the distance between the two CTR screens, May 2018.

The e-SPS / LDMX proposal

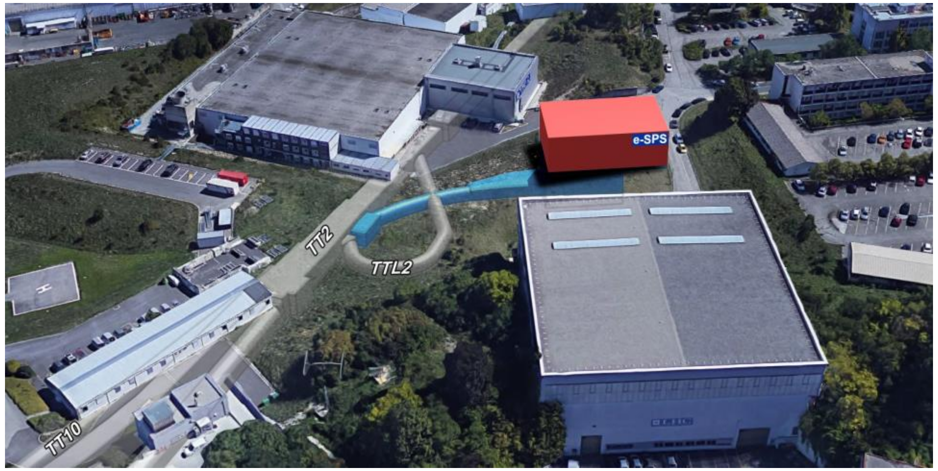
Accelerator implementation of
e-beams at CERN for physics – Light Dark Matter search

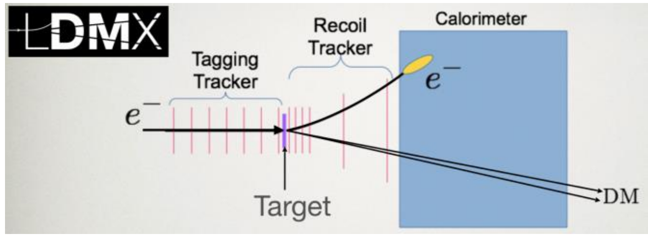
- **70 m long X-band based linac (CLIC technology) in TT4-5 accelerates e- to 3.5 GeV**
- SPS filled in 1 to 2 s via TT60
- Acceleration to 16 GeV in the SPS
- Slow resonant extraction down the TT10 transfer line in ~10 s
- Beam delivered via the existing TT10 line to the Meyrin site
- A new, short beamline would branch from TT10 to the experimental hall (LDMX)





- Input to EU Strategy for Particle Physics Update
- Preparing CDR (beginning 2020)

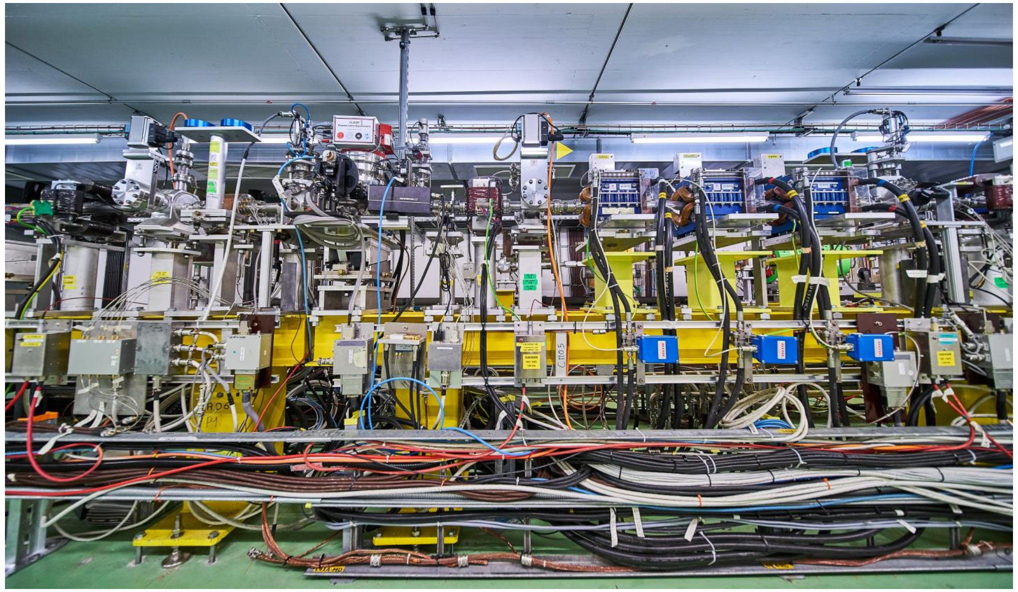




S. Styapnes, today

CLEARER*, perspectives for a 3 GeV linac

* CERN Linear Electron Accelerator for Research, Extended Energy Range

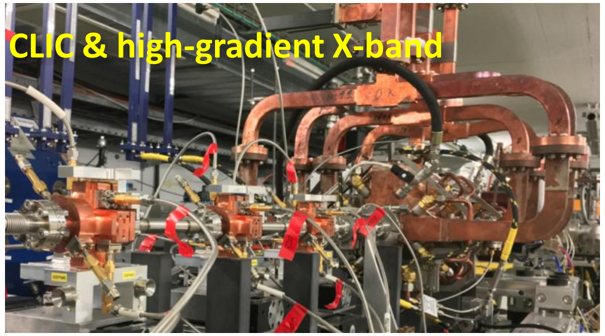


CERN Linear Electron Accelerator for Research

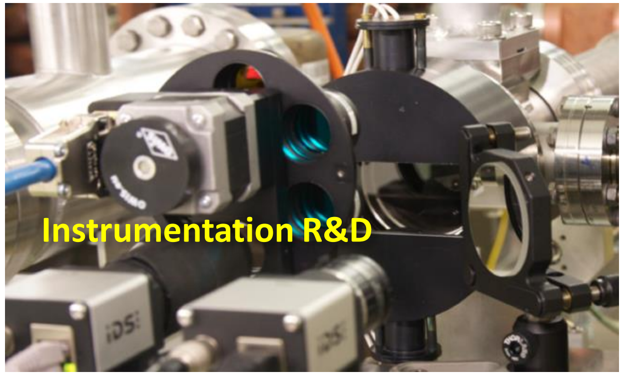
- User facility for general accelerator R&D and component studies for existing and possible future machines at CERN
- 200 MeV, S-band electron linac

- The 3.5 GeV Linac injector has to be be very similar to CLEAR → **present baseline is re-use CLEAR linac**
- In-house know-how available in any case
- 3.5 GeV Linac may be used to **extend** in a significant way the present CLEAR program – by sharing beam time with e-SPS

Relevance in different areas



The 3.5 GeV linac itself is a perfect show-case for the technology. Dedicated tests.



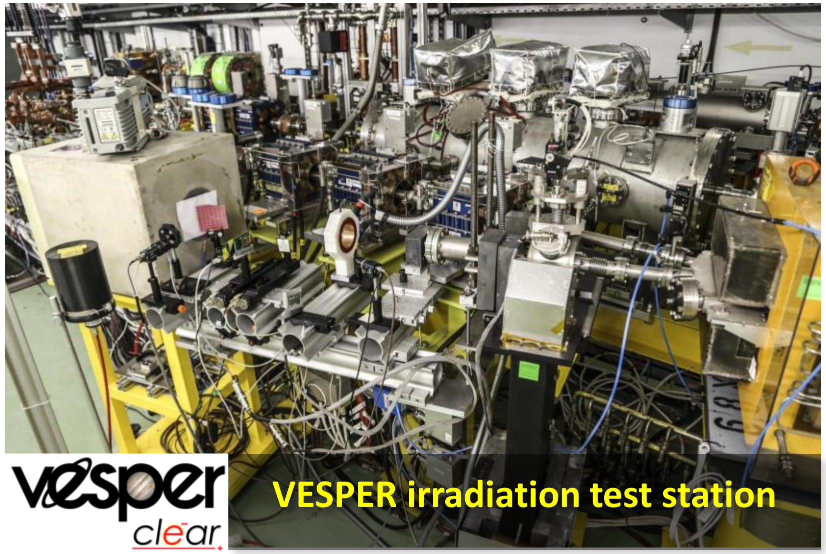
A 3.5 GeV, better quality beam will extend the R&D scope dramatically (e.g., for diffraction radiations studies, high-res BPMs) .

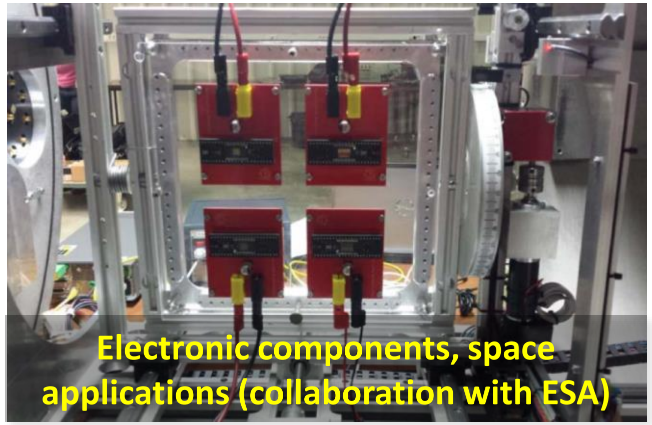
Potentially important options: single bunch capability, two independent-timing sources, positrons?

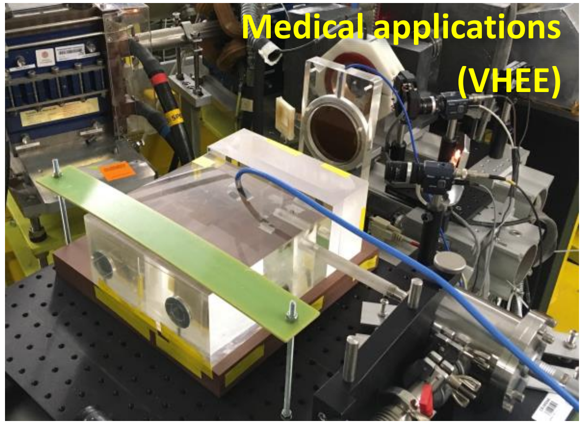
Higher beam energy makes easily accessible extended interaction regions and staging.

CLEARER*, perspectives for a 3 GeV linac

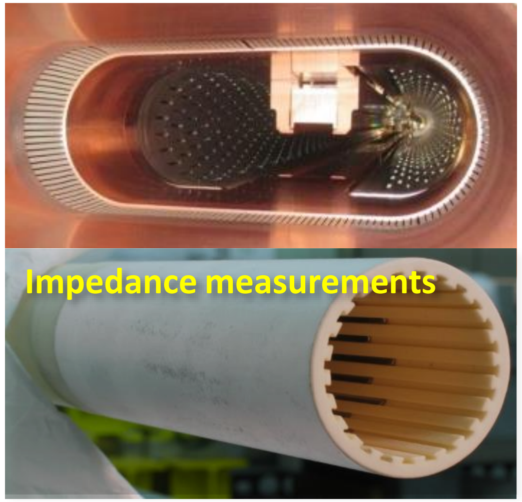
* CERN Linear Electron Accelerator for Research, Extended Energy Range







Potential of higher energy reach unclear. Continuation of present program (intermediate stations along the linac) desirable.



Impedance measurements in time domain (wake-fields) may reach higher precision with a 3.5 GeV beam.

An electron test beam:

- Electron beams can also be used for detector tests of course - 200 MeV in CLEAR low, but 3-15 GeV interesting – repetition rates can be very high
- A good example of a successful facility is the LNF BTF up to 750 MeV (BTF: Beam Test Facility - see recent summary (link)
  - Used 200day/year, 25-30 groups, 150-200 users
  - Examples of use: calorimeter studies, diamond detector studies, calibration systems, air shower plasma, etc
- DESY another example, several e-beams up to ~6 GeV (recent workshop) very much used