Present and Future of the CERN Linear Electron Accelerator for Research

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CLIC Project Meeting #43
December 7, 2022

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Outline

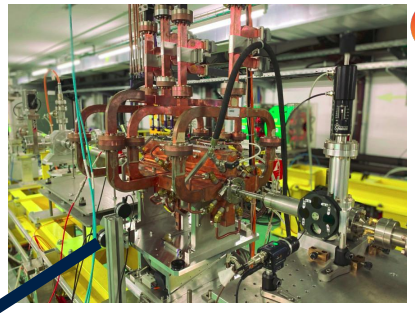
- CLEAR Beam Line, Parameters and Strategic Goals.
- C-Robot, what is it and what can it do?
- Non-exhaustive list of experiments done at CLEAR this year
- Future of CLEAR?
- CLEAR in the press
- Conclusions.

CLEAR Beam Line, Parameters and Strategic Goals.

The CLEAR Beam Line

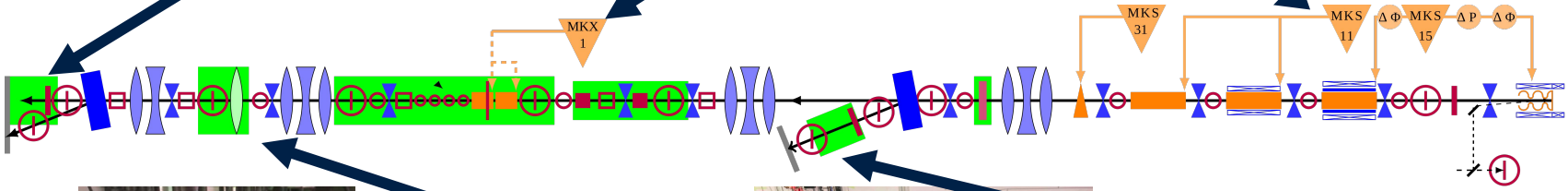
In-Air Test Stand

- Diagnostics studies
- Irradiation
  - Electronics
  - **VHEE**



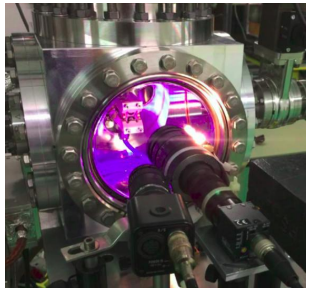
CLIC Test Stand

- High-Gradient R&D



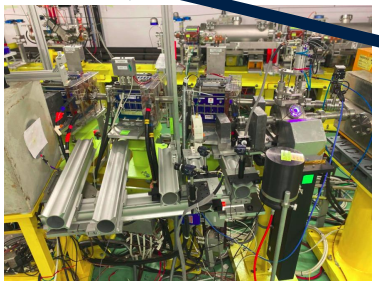
CLEAR Injector

- Flexible Linac
- 60 – 220 MeV
- Beam sent to users
- Running until 2025



Plasma Lens

- Novel plasma based focusing



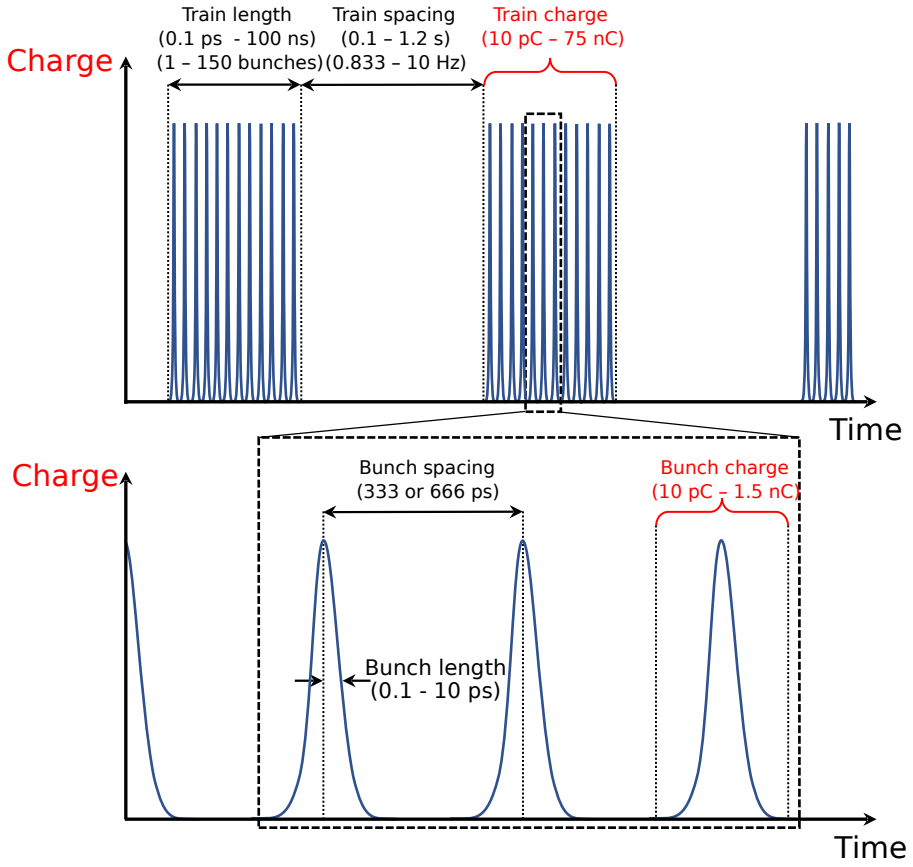
VESPER

- Irradiation facility
  - Space probes
  - Electronics
  - **VHEE**

CLEAR

CLEAR Beam Parameters

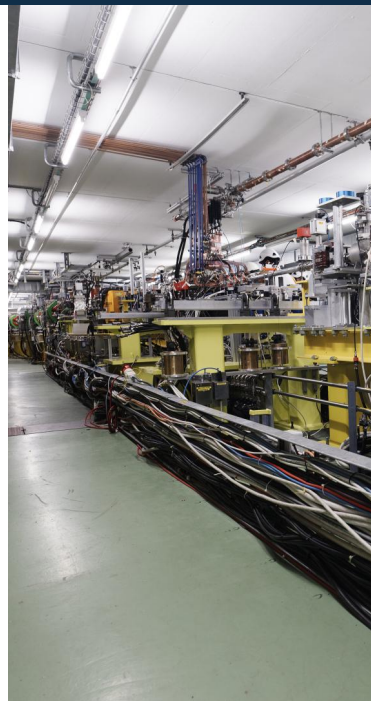
Parameter	Value
Energy	60 – 220 MeV
Energy spread	< 0.2 % rms (< 1 MeV FWHM)
Bunch length	0.1 – 10 ps RMS
Bunch charge	10 pC – 1.5 nC
Normalised emittance	3 – 20 µm
Bunches per pulse	1 – 150
Max. charge per pulse	75 nC
Repetition rate	0.833 – 10 Hz
Bunch spacing	1.5 or 3.0 GHz



CLEAR Scientific and Strategic goals

Scientific and strategic goals:

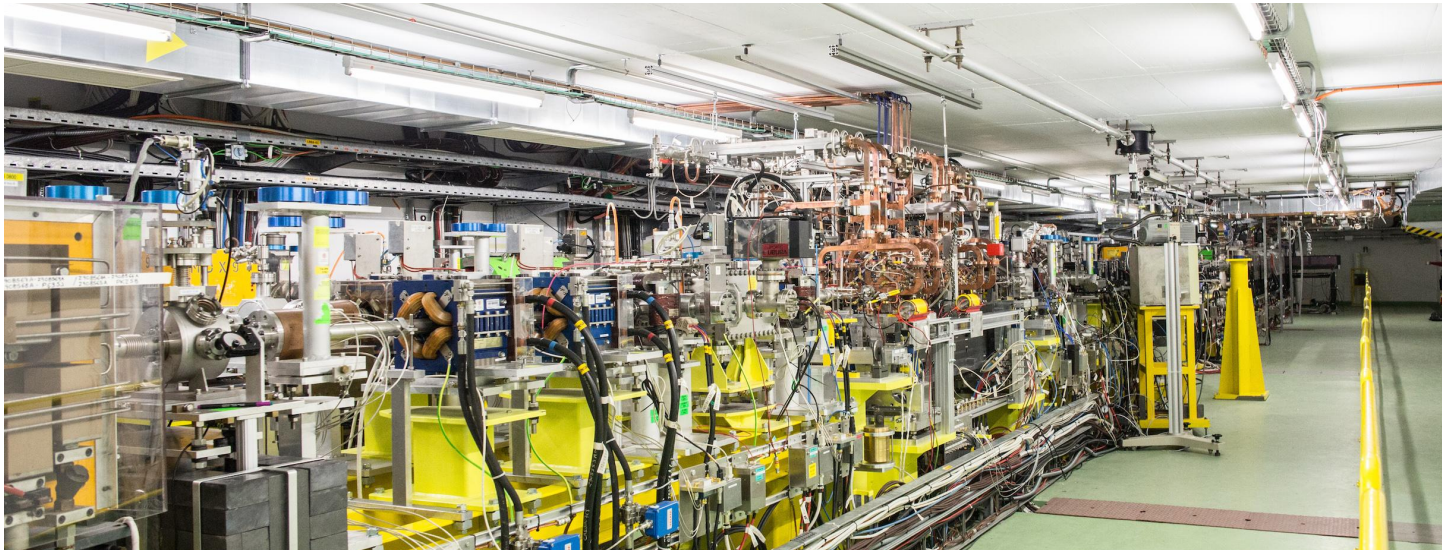
- Providing a test facility at CERN with high **availability**, easy **access** and **high quality e-beams.**
- Performing **R&D** on **accelerator components**, including beam instrumentation prototyping and high gradient RF technology.
- Providing an **irradiation facility** with Very High Energy Electrons (VHEE), e.g. for testing electronic components in collaboration with ESA or for medical purposes.
- 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 is a versatile electron linac and an experimental beamline, operated at CERN as a multi-purpose user facility.

CLEAR Timeline

- **Approved** December 2016.
- **Began operation** in 2017.
- **Flexible** beam program.
  - 8-12 hours a day.
  - 5 days a week.
- **Independent** of LHC runs and long shutdowns.
- **2017** → 19 weeks of beam.
- **2018** → 36 weeks of beam.
- **2019** → 38 weeks of beam.
- **2020** → 34 weeks of beam (despite Covid-19).
- **2021** → 35 weeks of beam (despite Covid-19).
- **2022** → 37 weeks of beam and more than 20 experiments.

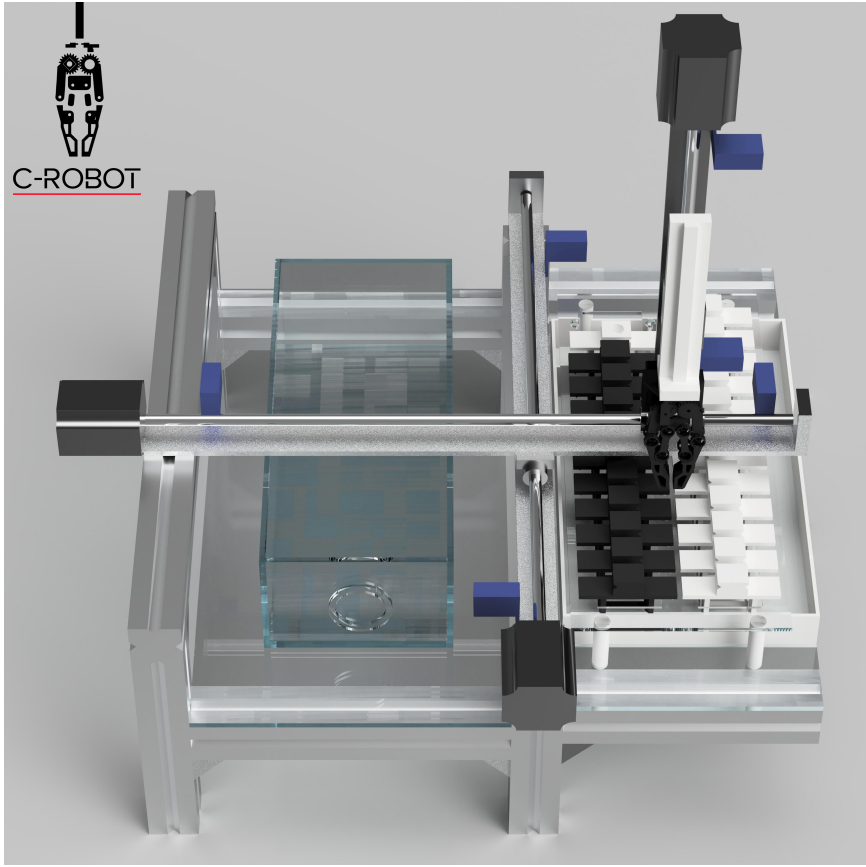


The C-Robot

C-Robot, what is it?

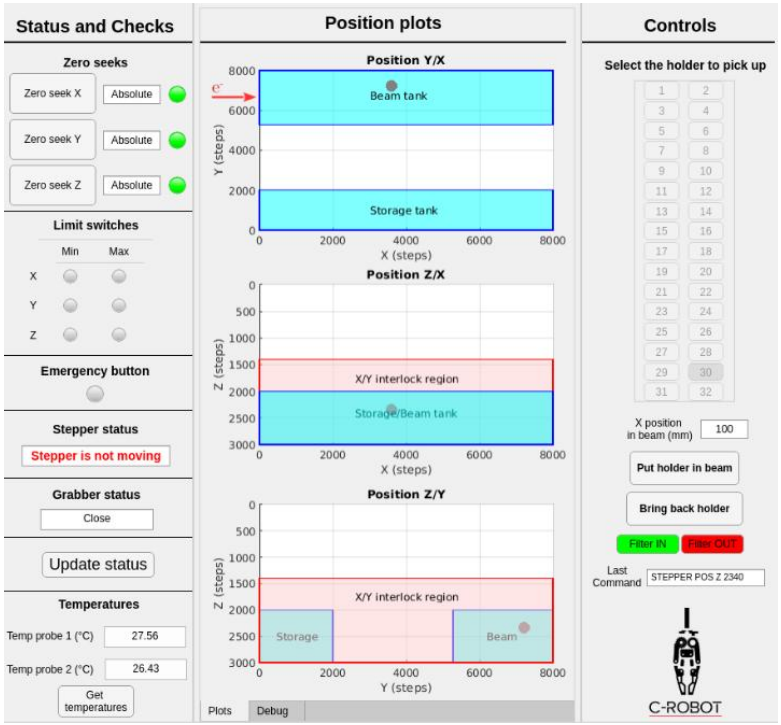
- In order to **facilitate** the **precise control** of **samples** for **multiple irradiations**, the CLEAR-Robot (**C-Robot**) was designed and built by members of the CLEAR Operation Team.
- It consists of **3 linear stages**, **6 limit switches**, a **3D-printed grabber**, **two water tanks** and an **Arduino board**.
- It has a **precision in position** in 3 axis of **50 µm**.
- It is **fully remotely controllable** from the **CERN Technical Network**.
- Thanks to a **mounted camera**, it can also measure the **beam sizes** and **transverse positions** at the longitudinal position of the sample.
- It is an **open-source project**: **pictures**, **3D renders**, **drawings** and all the **codes** for the **Arduino** and the **Graphical User Interface** can be found on:

  https://pkorysko.web.cern.ch/C-Robot.html

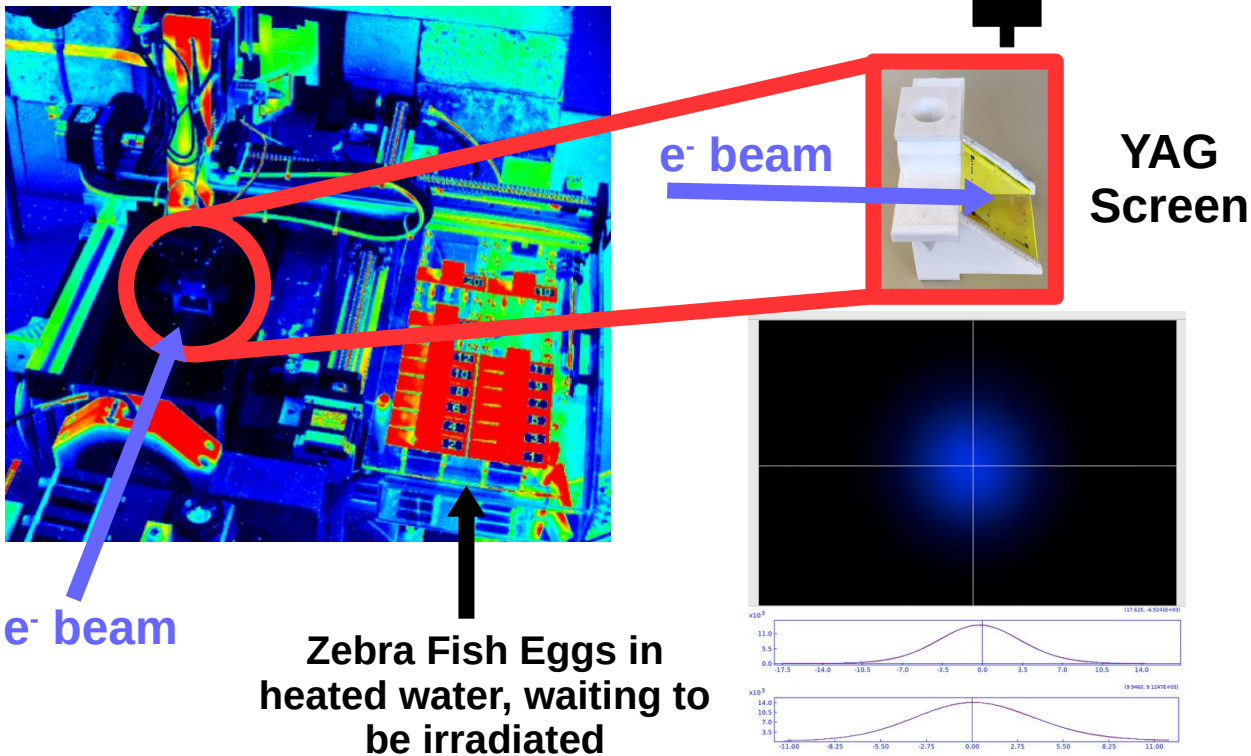


C-Robot, what can it do?

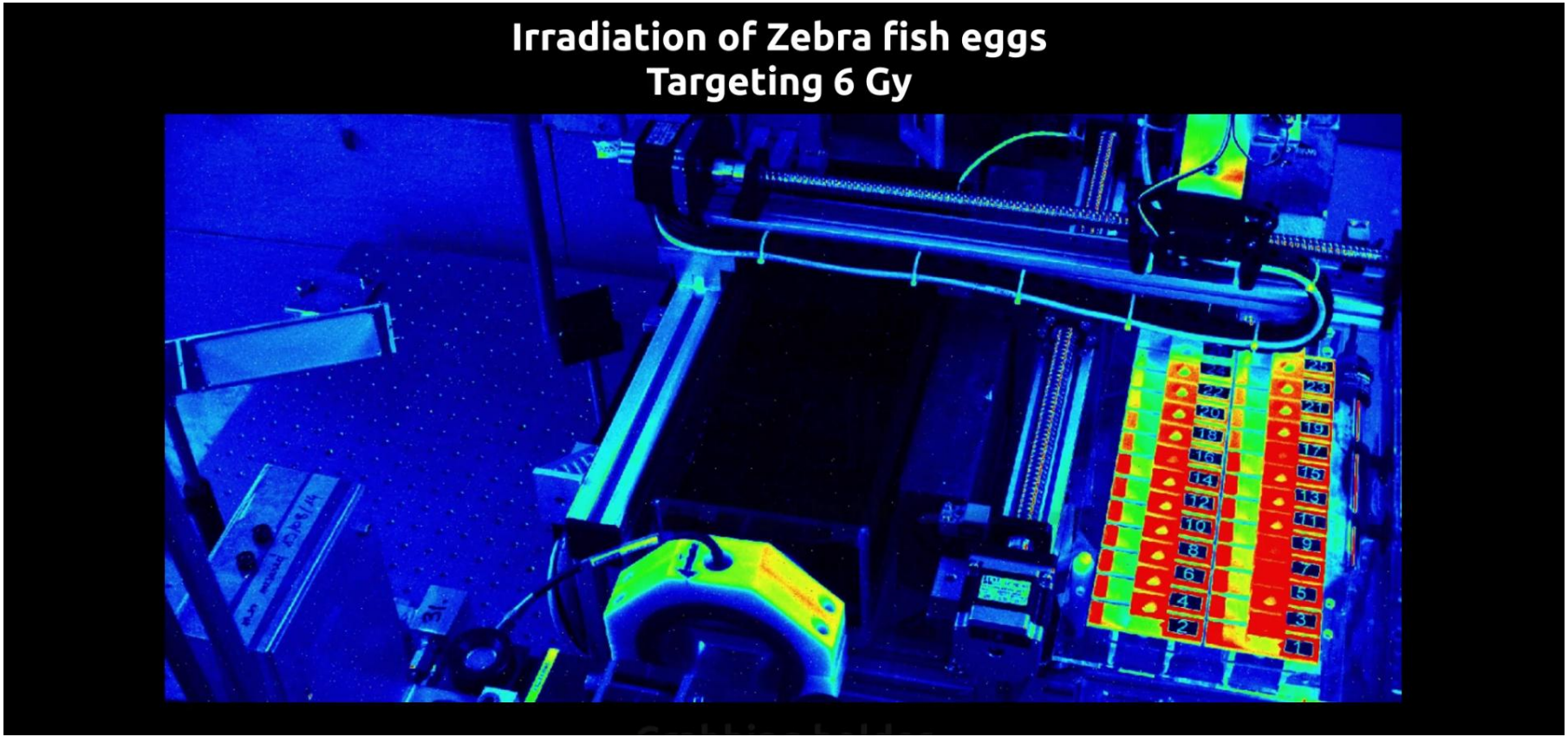
Graphical User Interface



Experiment setup w/ beam

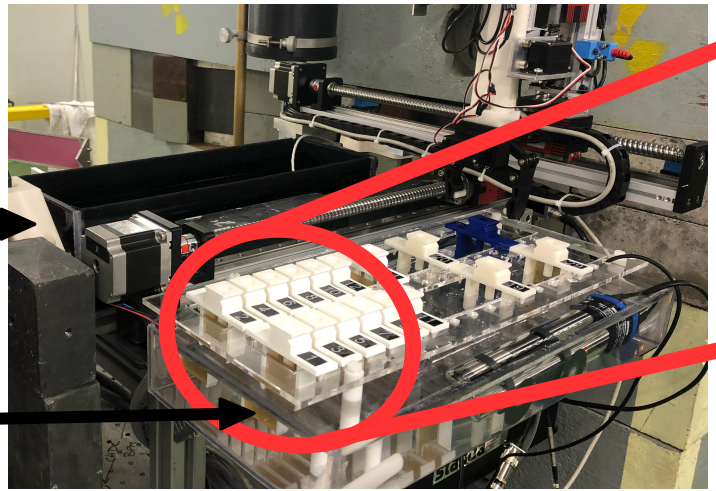


C-Robot in action with Beam



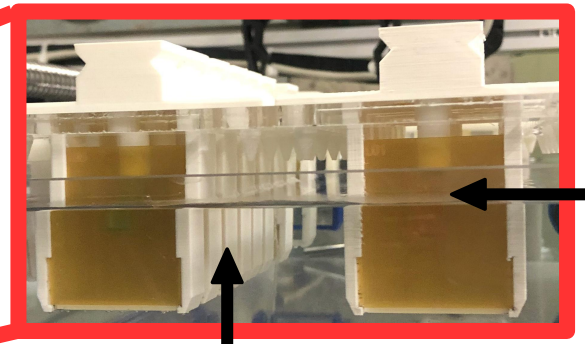
Some of CLEAR 2022 experiments

Experimental Setup & Dosimetry for VHEE UHDR irradiations

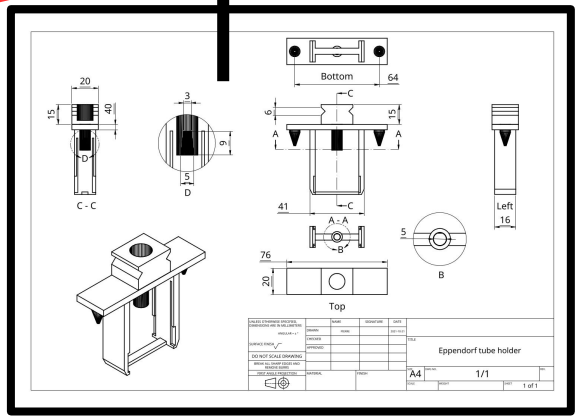


Beam water tank

Heated storage water tank



Eppendorf tube with sample to irradiate

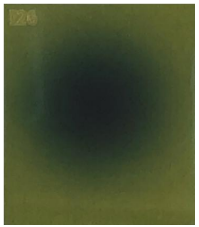


3D printed holder with 2 films: one before and one after the sample

Gafchromic films to measure the delivered dose

Dose range: 1 – 100 Gy

Before irradiation

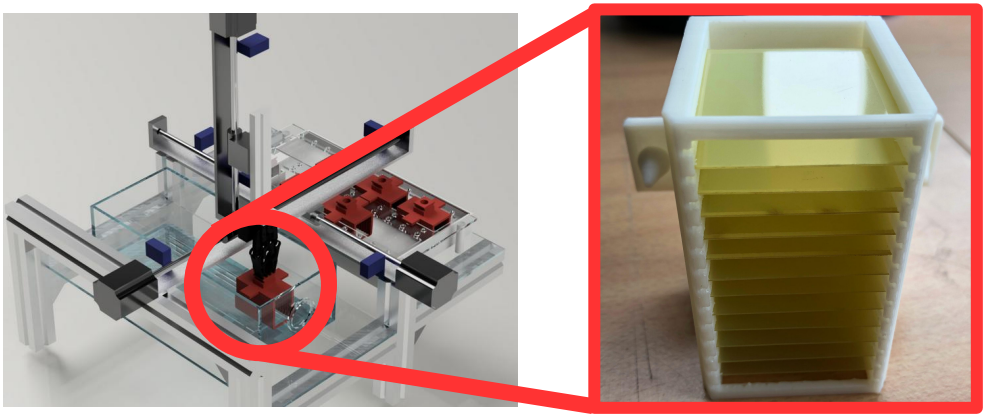


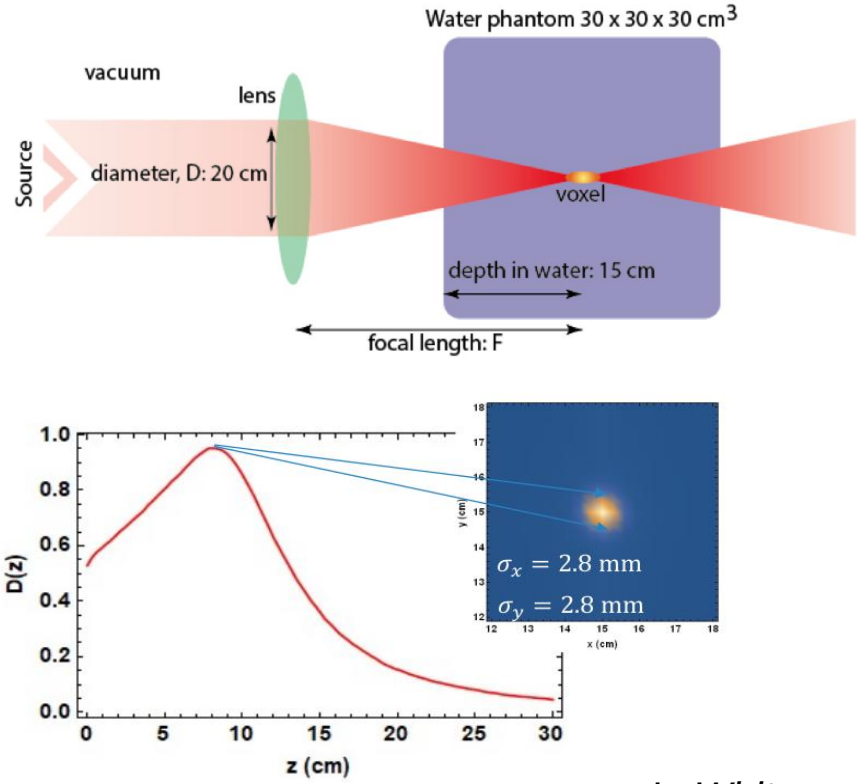
After irradiation

V. Rieker & J. Bateman

VHEE Strong Focusing

- **Goal:**
  Focus the beam on the tumor in order to minimize the dose and damage on the nearby healthy tissues.
- **Experiment:**
  Measure the beam sizes on a YAG screen in the water phantom (good model of the human body) and perform irradiations on long dosimetry films holders placed at different longitudinal positions.

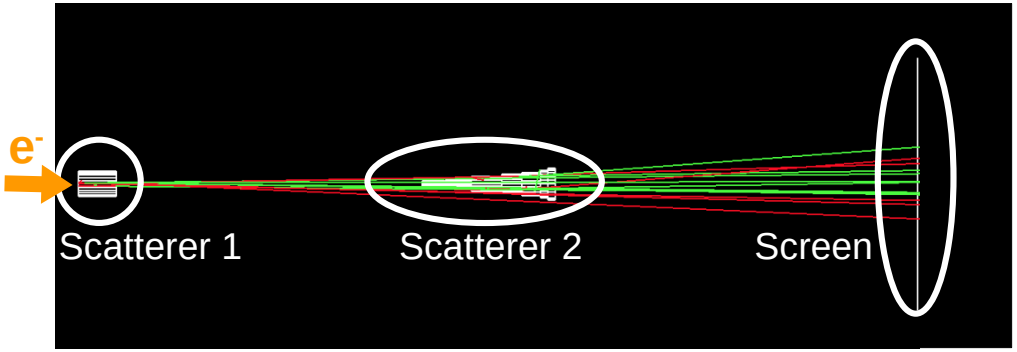


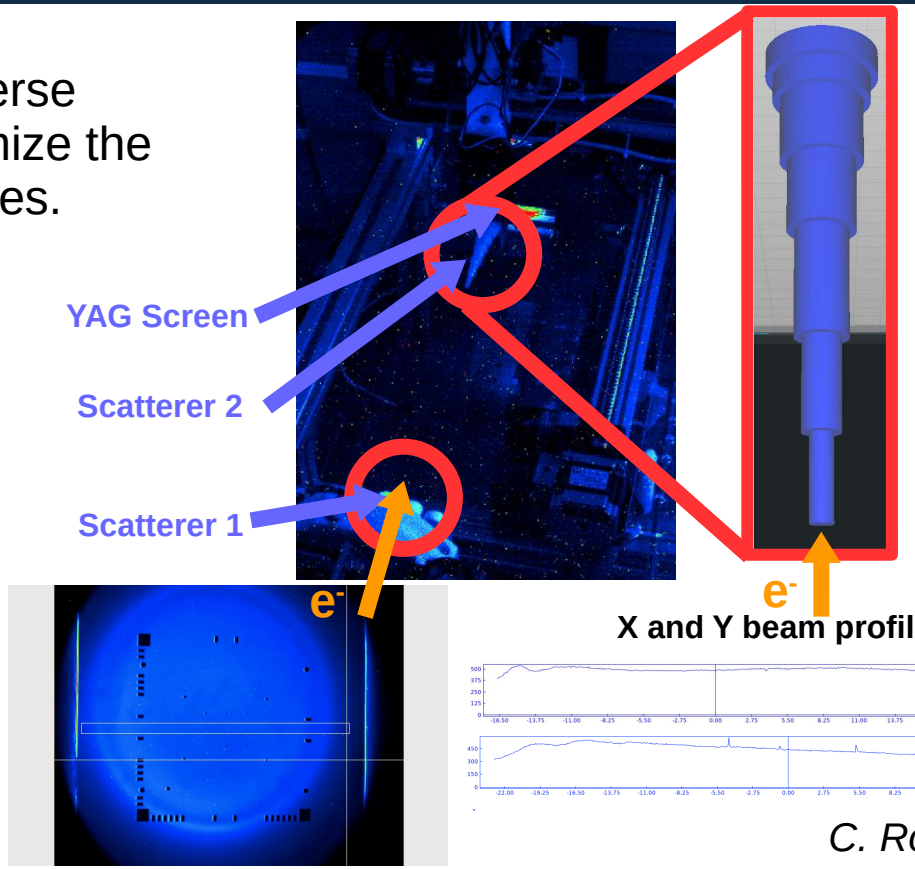


L. Whitmore

VHEE Scatterers

- **Goal:**
  Obtain a flat beam that has a constant transverse distribution at patient's tumor in order to minimize the dose and damage on the nearby healthy tissues.
- **Experiment:**
  Measure beam profiles, sizes and intensity on a YAG screen after carefully inserting two scatterers with the beam with the C-Robot.

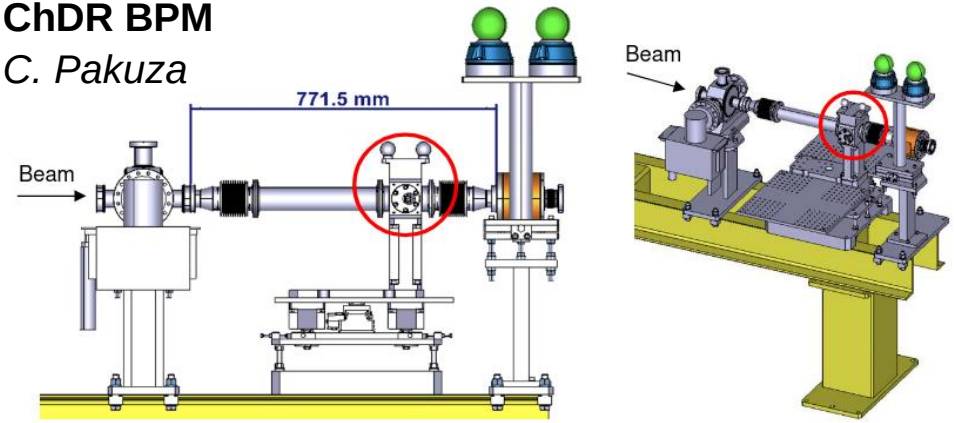




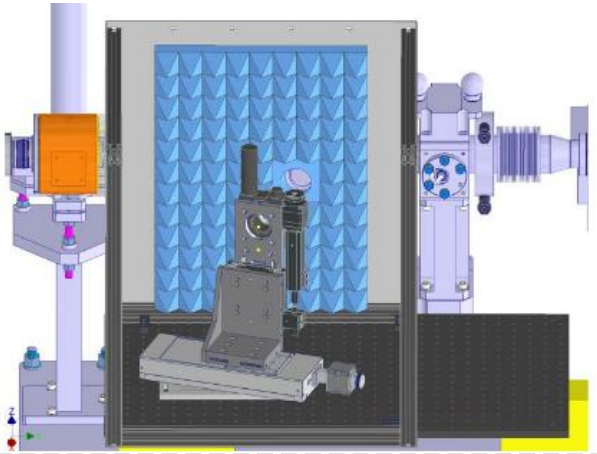
C. Robertson

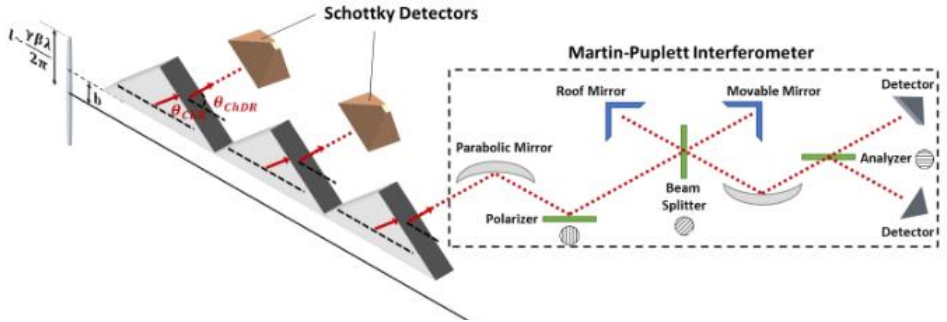
CERN BI Activities

ChDR BPM
C. Pakuza

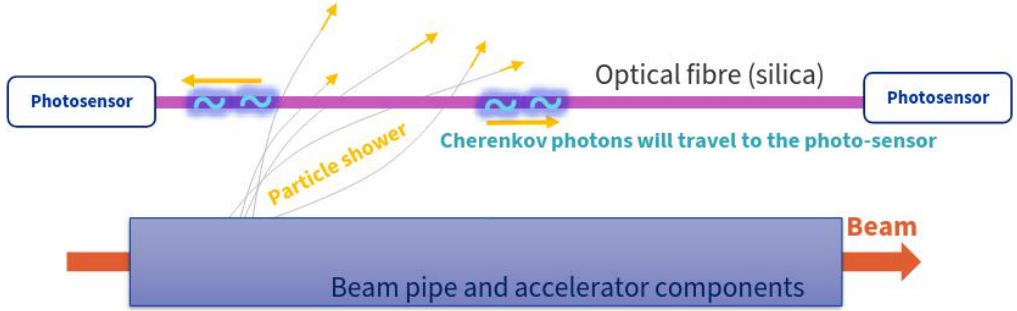


CChDR
A. Schloegelhofer





ChDR Bunch Length Measurements
C. Davut



Beam Loss Monitors
Sara Benítez

CLEAR Experiments

CLEAR EXPERIMENTS

Show 100 entries

Search: 2022

Date	Experiment	Main conctact	Institutes	Documents
2022-11	FLASH and spatially fractionated radiotherapy	Magdalena Bazalova-Carter	University of Victoria	
2022-10	CChDR sampling by KAPTEOS electro optical probes	Andreas Schloegelhofer	CERN	
2022-09	Beam Profiler detector for the LUXE experiment	Marco Bruschi	INFN Bologna	
2022-08	Scintillating Fibres VHEE UHDR Real-Time Dosimetry	Joseph Bateman	University of Oxford	
2022-08	Scintillating/Optical Fiber UHDR Dosimeters	Pierluigi Casolaro	University of Bern	
2022-08	ChDR Bunch Length Monitor	Can Davut	University of Manchester	
2022-06	Irradiation of collimator materials - benchmarking of Monte Carlo code	Raphael Moeckli	CHUV	
2022-05	AWAKE Cherenkov Diffraction Radiation BPM	Collette Pakuza	CERN	
2022-05	VHEE Scatterers	Cameron Robertson	University of Oxford	

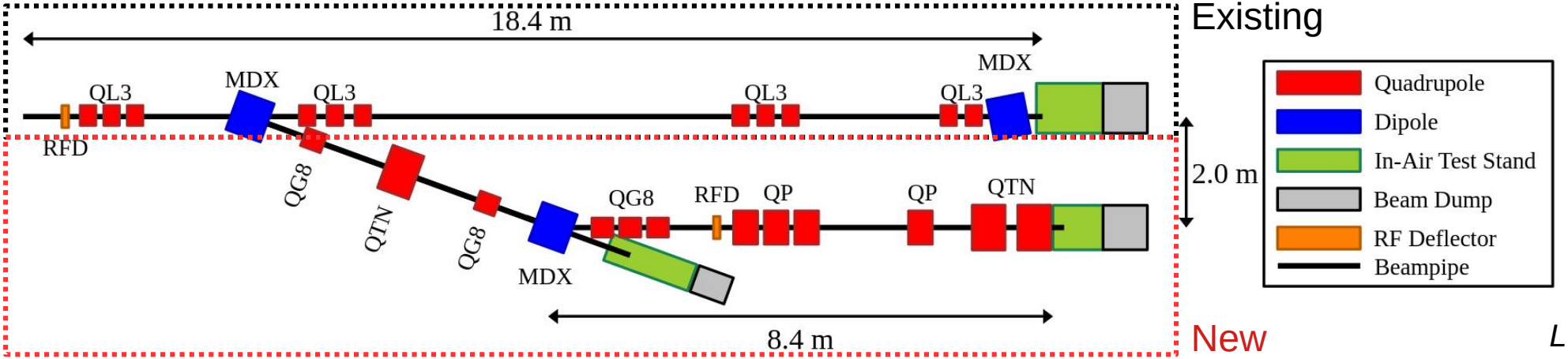
A list of all the Experiments done in CLEAR can be found on:

https://pkorysko.web.cern.ch/CLEAR/Table/CLEAR_experiments.html

The Future of CLEAR

CLEAR Plans

- **Short-term plans (2023):**
  - Renewing the CLEAR photo-cathode**.**
  - Replacing all CLEAR digital cameras by numerical ones.
  - Removing and cleaning some of the previous experiments.
  - Already 10+ experiments are scheduled for 2023.
- **Long-term plans (2023-2024):**
  - Installing a new beamline:



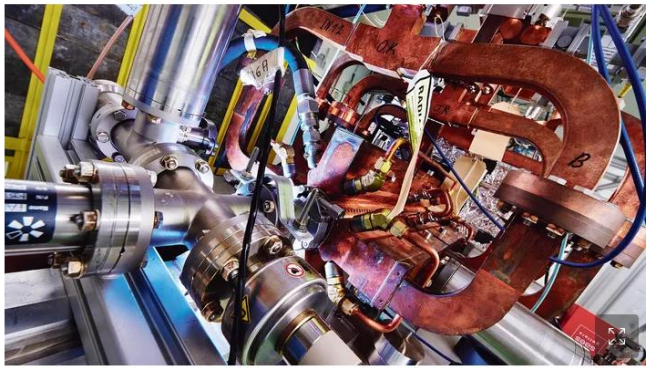
L. Dyks

CLEAR in the Press this year

Sciences

Le futur de la radiothérapie s'écrit au Cern à Genève

Par **Pauline Fréour**
Publié le 06/11/2022 à 18:28, mis à jour le 06/11/2022 à 18:28



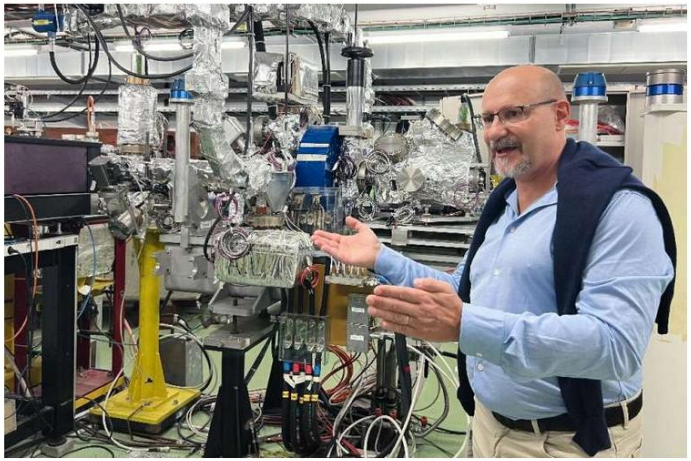
Située sur le campus du Cern, l'installation Clear est une technologie de pointe au service de l'innovation scientifique et médicale. *2020-2022 CERN*

PHYS.ORG JAPANTODAY

OCTOBER 22, 2022

Particle physics pushing cancer treatment boundaries

by Nina LARSON



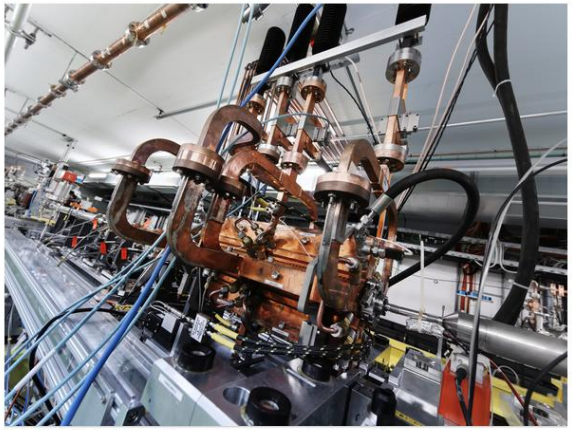
Facility coordinator Roberto Corsini shows off a 40-metre linear particle accelerator at CER...

CERN

CLEAR study paves the way for novel electron-based cancer therapy

The study, conducted at CERN's CLEAR test facility, demonstrates how very high-energy electron beams can be focused onto deep-seated cancerous tumours

By Thomas Hortala



CERN's CLEAR facility, where tests on very high-energy electron beams were carried out (Image: CERN)

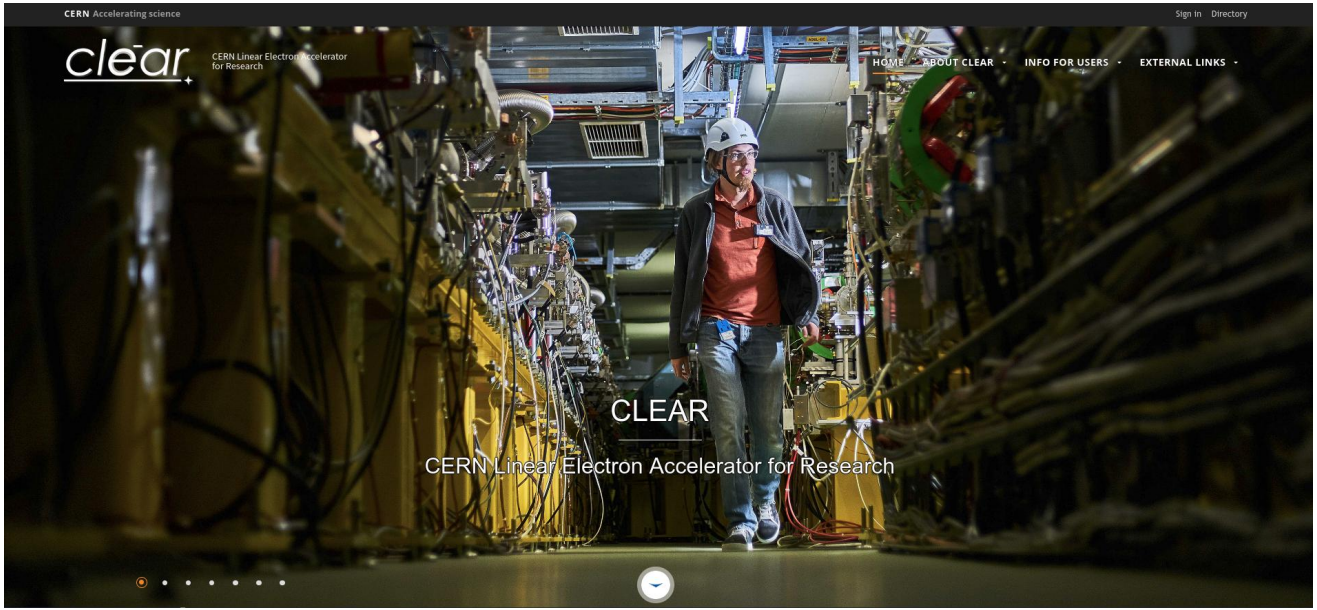
There are some cancer tumours that not even surgery, chemotherapy or traditional radiation therapy can cure. These resistant tumours contribute to making the disease one of the main causes of mortality worldwide, but the scientific community is teeming with ideas to make cancer fatalities a thing of the past. Among the latest

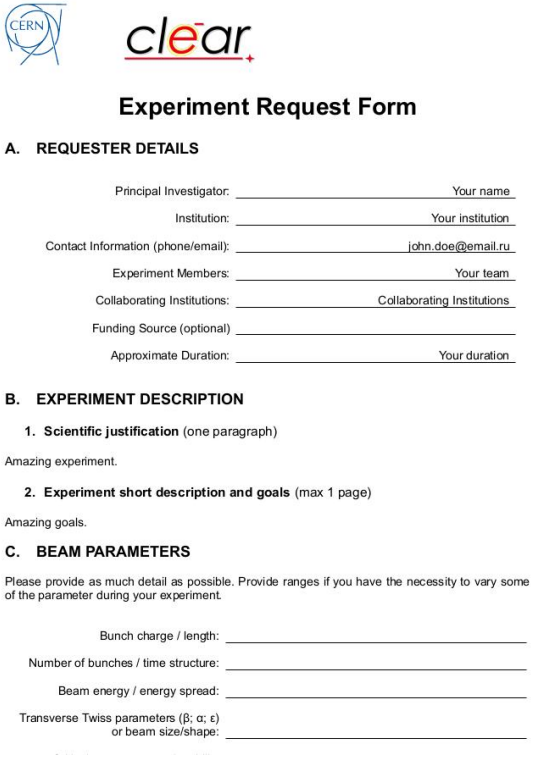
Take part!

You have an experiment in mind and you want to test it in a linear electron accelerator?

Find more information on our Website: https://clear.cern/

And fill out our Beam Request Form!





Experiment Request Form

A. REQUESTER DETAILS

Principal Investigator: Your name
Institution: Your institution
Contact Information (phone/email): john.doe@email.ru
Experiment Members: Your team
Collaborating Institutions: Collaborating Institutions
Funding Source (optional)
Approximate Duration: Your duration

B. EXPERIMENT DESCRIPTION

1. **Scientific justification** (one paragraph)

Amazing experiment.

2. **Experiment short description and goals** (max 1 page)

Amazing goals.

C. BEAM PARAMETERS

Please provide as much detail as possible. Provide ranges if you have the necessity to vary some of the parameter during your experiment.

Bunch charge / length:
Number of bunches / time structure:
Beam energy / energy spread:
Transverse Twiss parameters (β; α; ε) or beam size/shape:

Conclusions

- CLEAR offers a **unique VHEE and UHDR facility**:
  - 60 – 220 MeV.
  - 10 pC – 75 nC beam intensity.
  - Complete setup with **heated waters tanks**, **Robotic Arm**, **3D printed tools**, etc.
- **Numerous experiments** performed this year, including:
  - **VHEE** studies (strong focusing, Chemistry, Plasmids and Zebra Fish Eggs irradiations, etc).
  - **Beam Instrumentation** studies (ChDR BPM, ChDR BLM, CCDR, etc).
  - **Radiation to electronics (R2E)** studies.
- **Several new methods of dose measurements** were tested:
  - Different types of **Gafchromic films**.
  - **RPL** (Radio-Photo-Luminescence) Dosimeter.
  - **Alanine pellets**.
- **Further experiments** are scheduled.
  - **Detectors**, **Fruit Flies Larvae**, **other methods** to measure the **dose**, etc.
- **Further machine upgrades** are planned.

Thank you