CLEAR 2023 - Highlights and status of the second beam line

W. Farabolini on behalf of the CLEAR team:
R. Corsini – A. Aksoy – A. Malyzhenkov – P. Korysko – V. Rieker – L. Wroe
E. Granados – M. Calderon (Laser experts)
S. Doebert - S. Curt – A. Chauchet (RF experts)
J. Bateman – C. Robertson (Oxford PhD students)
K. Sjobaek (remotely from Oslo)

What is CLEAR ?

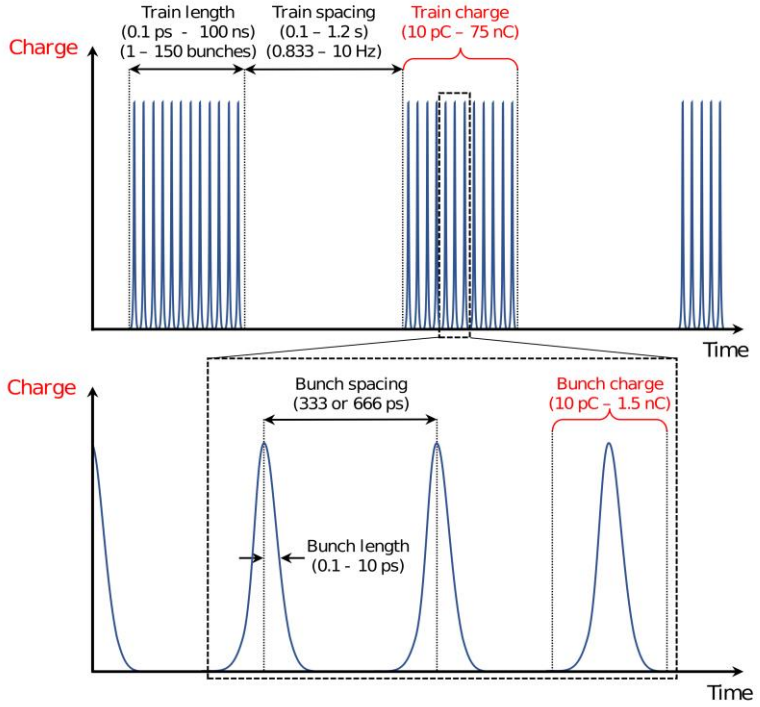
Scientific and strategic goals:

- **Unique electron beam test facility at CERN** with high availability, easy access and high-quality. Part of Euro-Labs, transnational access program
- R&D on accelerator components, **beam instrumentation**, high gradient RF technology.
- **Irradiation facility** with Very High Energy Electrons (VHEE) and Ultra-High dose rate, for technical and medical applications
- 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.

Beam Parameters

The beam parameters at the end of the linac are summarised in the following table:

Beam parameter (end of linac)	Value range
Energy	60 - 220 MeV
Bunch charge	0.01 - 1.5 nC
Normalized emittances	3 um for 0.05 nC per bunch 20 um for 0.4 nC per bunch (in both planes)
Bunch length	~100 um - 1.2 mm
Relative energy spread	< 0.2 % rms (< 1 MeV FWHM)
Repetition rate	0.8 - 10 Hz
Number of micro-bunches in train	1 - 150
Micro-bunch spacing	1.5 or 3.0 GHz

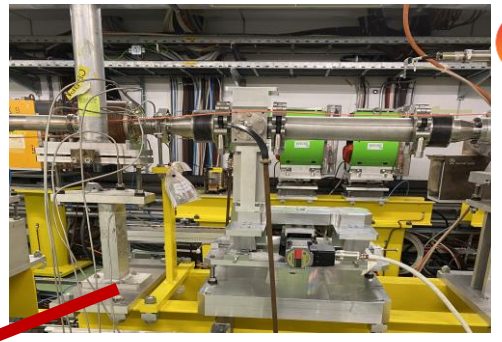


CLEAR beamline in 2023

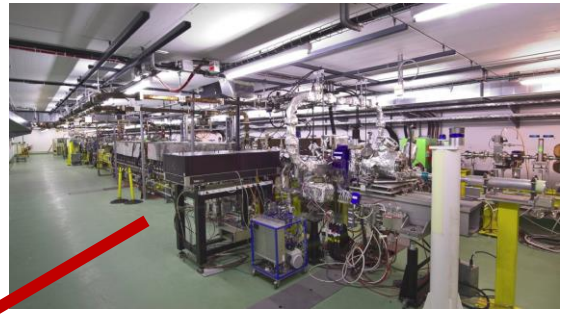
Credit: P. Korysko

In-Air Test Stand

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



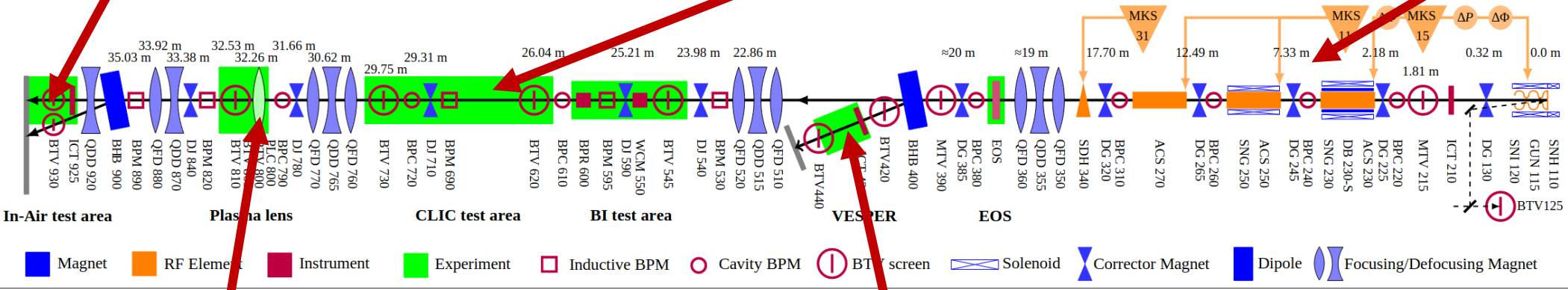
BI Test Stand

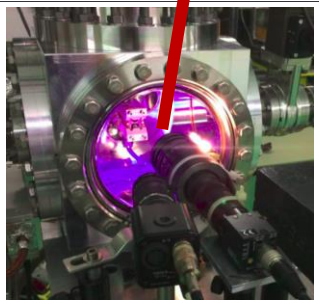


CLEAR Injector

- Flexible Linac
- 60 – 220 MeV

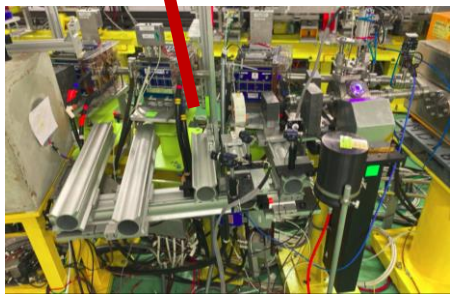
Beam direction





Plasma Lens

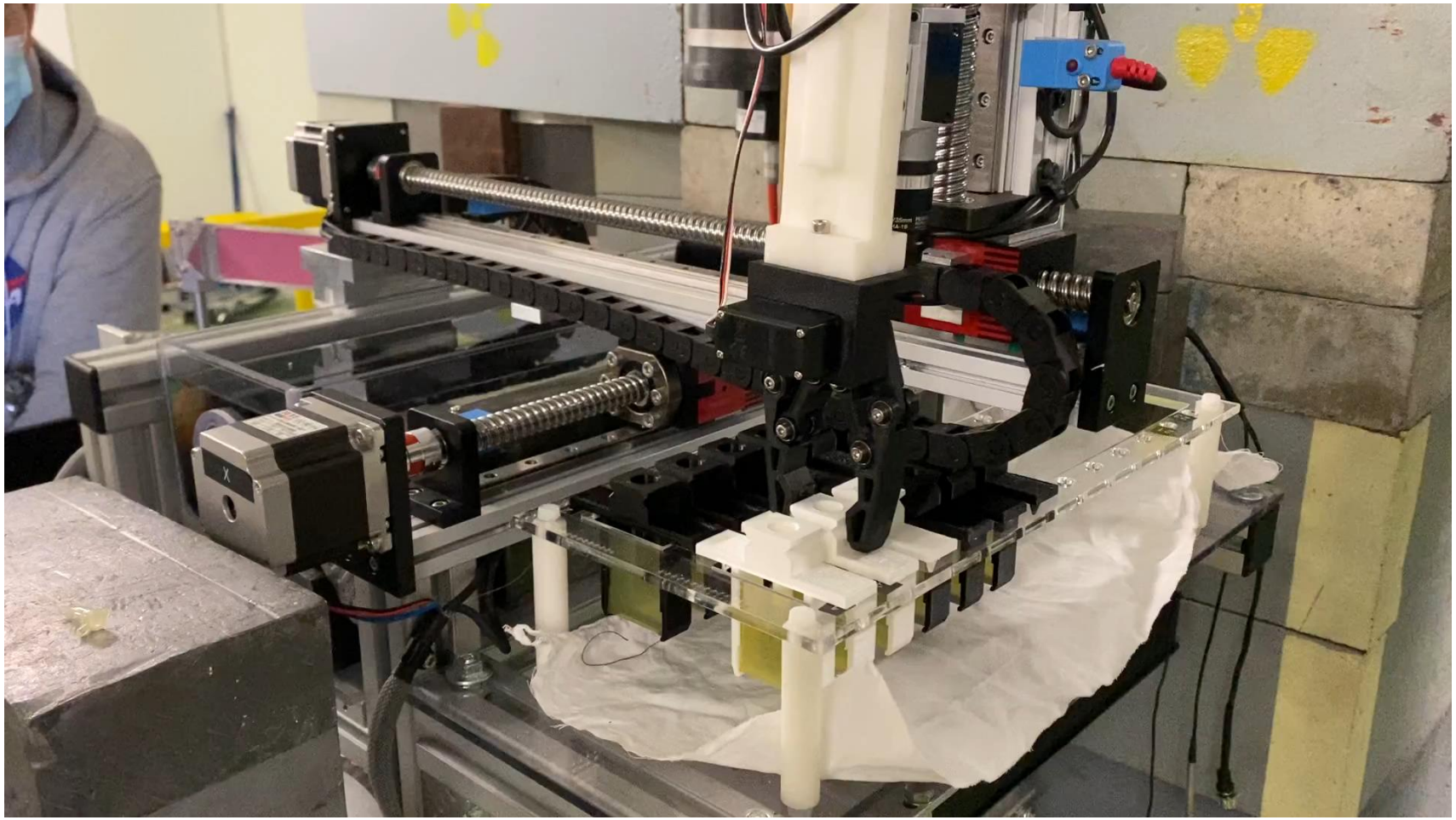
- Novel plasma based focusing



VESPER

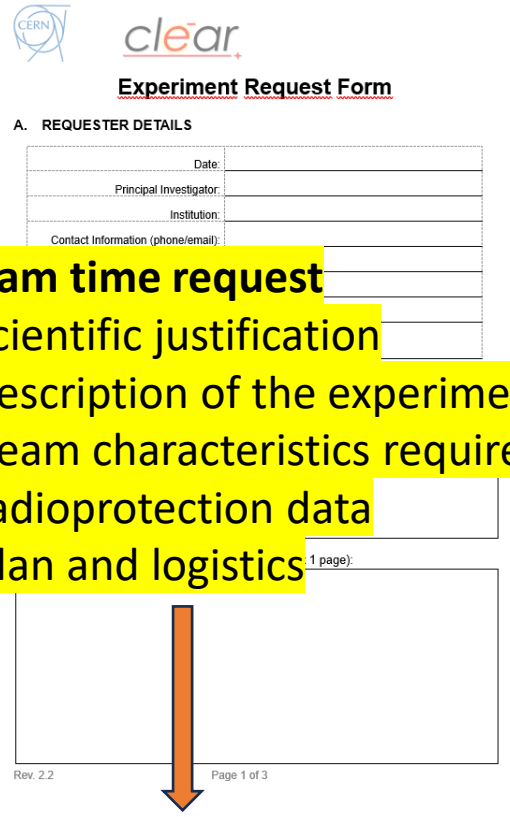
- Irradiation facility
  - Space probes
  - Electronics
  - **VHEE**

The C-Robot developed for medical samples



Recently requested by PITZ @ DESY

CLEAR user's experiments workflow


Experiment Request Form

A. REQUESTER DETAILS

Date:
Principal Investigator:
Institution:
Contact Information (phone/email):

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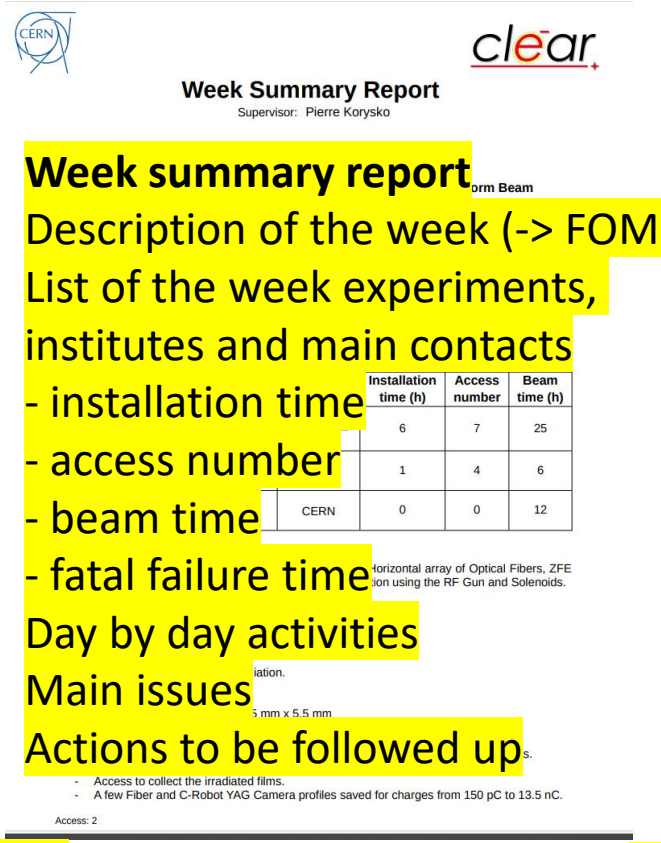
Beam time request
- scientific justification
- description of the experiments
- beam characteristics required
- radioprotection data
- plan and logistics

- Validation by the Technical Committee
- Information to the Scientific Committee
- Validation by the RP (EDMS doc)

- Preparation of the set-up
- Beam delivery under the responsibility of the week supervisor


Week Summary Report

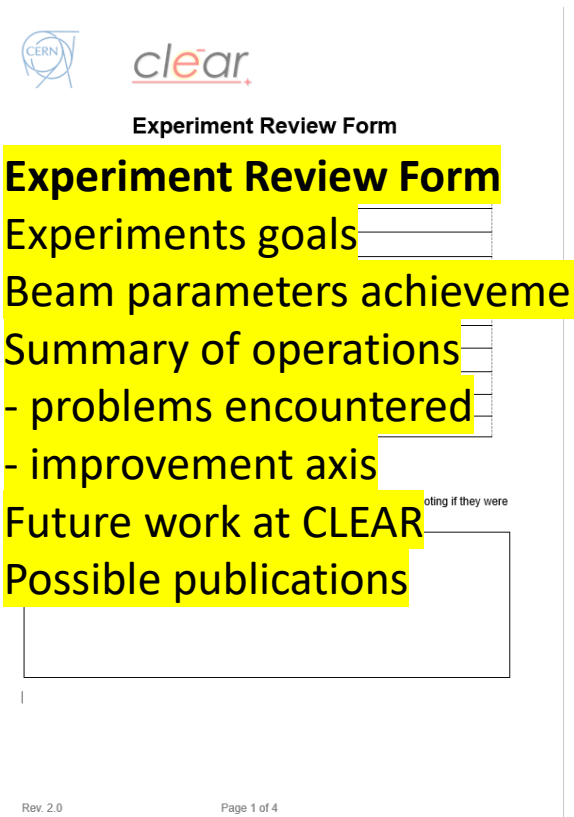
Supervisor: Pierre Korysko

	Installation time (h)	Access number	Beam time (h)
	6	7	25
	1	4	6
CERN	0	0	12

- Access to collect the irradiated films.
- A few Fiber and C-Robot YAG Camera profiles saved for charges from 150 pC to 13.5 nC.

Access: 2

Week summary report
Description of the week (-> FOM)
List of the week experiments, institutes and main contacts
- installation time
- access number
- beam time
- fatal failure time
Day by day activities
Main issues
Actions to be followed up


Experiment Review Form

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Experiment Review Form
Experiments goals
Beam parameters achievements
Summary of operations
- problems encountered
- improvement axis
Future work at CLEAR
Possible publications

Dear Colleague,

The following document has changed status from "In Work" to "Engineering Check":
- 2816170 v.1 - "86-Real-Time Beam Dose Monitors"
: https://edms.cern.ch/document/2816170/1

Best regards,
Roberto CORSINI

CLEAR summary of operations weeks

Week	Type of experiment	Institute	Install (h)	Acces nb.	Beam time (h)
11	MD	ABP	6	1	6
11	Neutron monitors	CERN- RP	2	7	22
12	Optic fiber dosimetry	Oxford U.	5	8	20
12	Film dosimetry	Oslo U.	5	2	19
13	LUXE BPM	INFN Bol./Pad.	16	5	46
14	Scatterers	Oxford U.	8	5	24
14	Real time dosimetry	Oxford U.	2	0	6
14	Uniform beam generation	Cern-ABP	0	0	6
15	Wall current transformer	Bergoz	2	2	12
15	MD Cavity BPMs	ABP	0	0	16
16	MD Dispersion free steering	ABP			
16	Optic fiber dosimetry	Oxford U.			
16	Film dosimetry	Oslo U.			
16	MD Flat Beam space charge	ABP			
17	Plasmid irradiations	Mancheste			
17	Film dosimetry	Oxford U.			
18	Medical irradiation Ch. ZFE Cells	CHUV			
18	Optic fiber dosimetry	Oxford U.			
19	Ch DR	CERN-BI			
20	VHEE UHDR	Victoria U.			
20	ZFE irrad. And phantom dosimetry	CHUV			
20	MD	ABP			
21	Scintillator dosimetry	Victoria U.			
21	VHEE UHDR larve irrad.	EPFL			
21	Spatially fractionated irrad.	Victoria U.			
21	MD	ABP	0	0	6
22	Ch DR BPMs for Awake	Oxford U.	2	2	20
23	EOS	CERN-BI	4	9	25
23	LUXE BPM	INFN Bol./Pad.	0	0	4
24	MD	ABP	1	0	50
25	Quarz fiber Cherenkov	Bologna U.	10	5	32
25	LUXE BPM	INFN Bol./Pad.	1	0	3
26	MD	ABP	8	7	36
27	Ch DR EOS	CERN_B	4	4	35
28	MD BBA	ABP	0	0	8
28	CHUV preparation	CHUV	3	3	12
29	Bunch Length Monitor EOS for FCC	KIT	8	3	25
29	LUXE BPM	INFN Bol./Pad.	2	1	5
30	Real time dosimetry	Oxford U.	6	7	25
30	ZFE irrad	CHUV	1	4	6
30	MD uniform beam	ABP	0	0	12
31-33	Summer shut-down PL installation		30	1	
34	Plasma Lens	Oslo U.	6	5	25
35	Dual Scatterers for flat beam	Oxford U.	6	9	30
36	Ch DR BPMs for Awake	Oxford U.	4	6	15
36	VHEE chemnistry	CHUV	0.5	2	6
37	Fluorescence dosimetry	Strathclyde U.	1	6	17
37	Alanine dosimetry	PTB	0.5	1	4
		CERN-BI	1	1	18
		RHUL	16	1	0
		RHUL	16	1	25
		iverpool U. / C	2	8	36
		BP	0	0	3
41	Cable Ageing Research	SY-STI-BMI HSE	5	5	50
41	MB	ABP	0	0	5
42	VHEE Beam monitoring	ABP	12	7	18
	Real time dosimetry	Oxford U. and J	8	7	15
	Ch DR BLM for FCC	CERN-BI	3	2	4
		ABP	0	4	32
		PSI	5	5	50
		ABP	0	2	5
45	P-cubed BBP	PSI	4	3	30
46	microBPMs	CERN-EP-DT	3	7	12
46	Detectors	Kansas U.	3	6	20
47	VHEE irradiation of cells	CHUV	2	5	20
48	optic fiber BPM	Oxford U.	8	2	15
48	Dual Scatterers for flat beam	Oxford U.	2	1	15
48	YAG/film comparison	Oslo U.	1	1	2
48	MD dosimetry prediction code	ABP	0	0	5
49	MD BBA	ABP	0	0	50
49	Flat beam generation	ABP	0	0	10
total			**279**	**230**	**1209**

- 37 weeks of beam
- 279 hours of set-up installation
- 230 accesses with the radioprotection
- 1209 hours of beam
- 40 hours of fatal failure
- 1.9 experiments per week in average

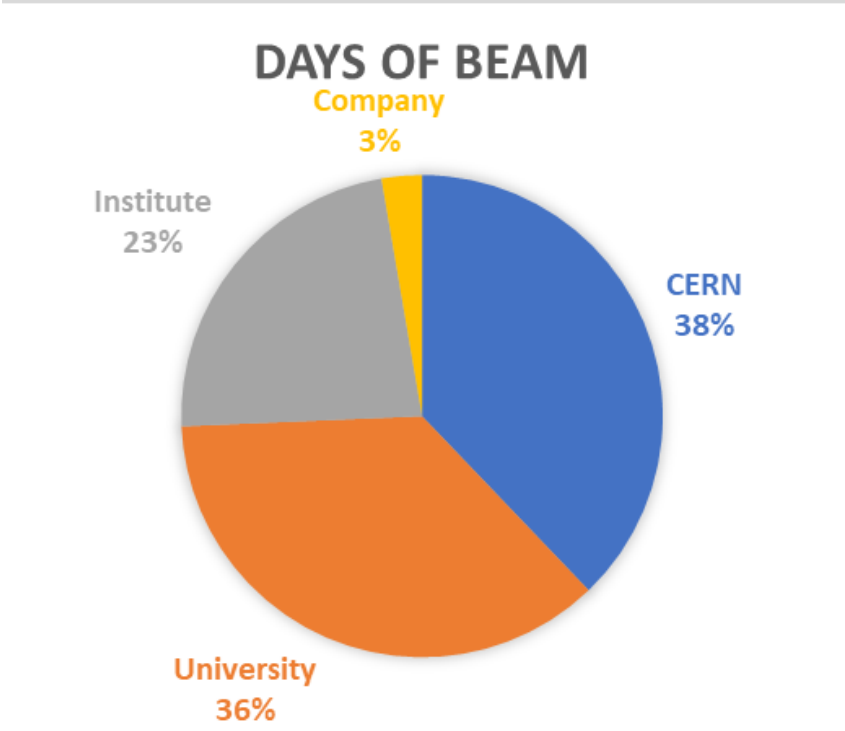
Type and origins of the experiments in 2023

- CERN – ABP
- CERN – BI
- CERN – RP
- CERN – EP
- CERN – TE
- CERN – SY

- Manchester Univ.
- Oxford Univ.
- RHUL
- Liverpool Univ.
- Strathclyde Univ.
- Queen's Univ.
- Oslo Univ.
- Bern Univ.
- Victoria Univ.
- Kansas Univ.

- PSI
- CHUV
- EPFL
- INFN Bologna
- INFN Padova
- KIT
- PTB
- RAL – ENEA
- Cockcroft Inst.
- JAI

- BERGOZ
- DAES



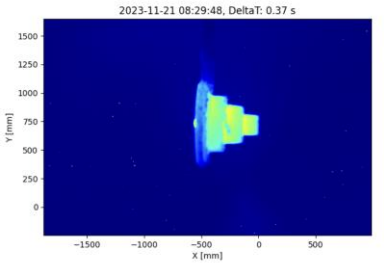
Operation 2023

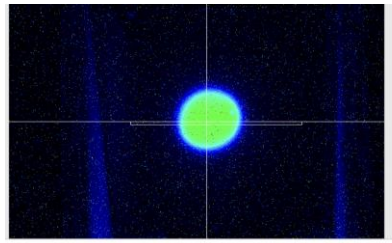
- 27 Experiments
- About 18 User Groups internal/external
- More than 13 external collaborating institutes
- Beam from February 27th to December 15th (with 3 weeks summer stop)
- 39 weeks of operation in total

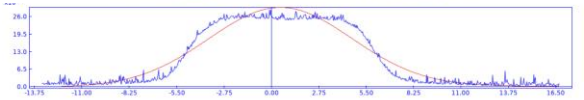
Credit R. Corsini

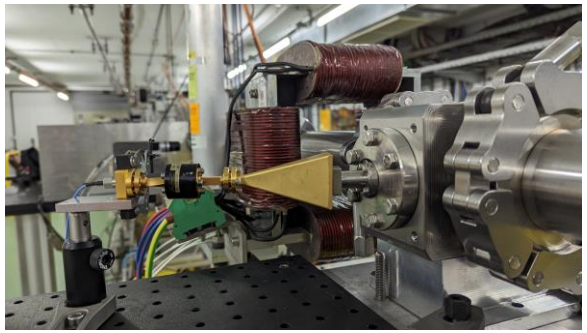
A few Highlights

Double-scattering system for uniform beam delivery for VHEE radiotherapy (CERN/Oxford U.)

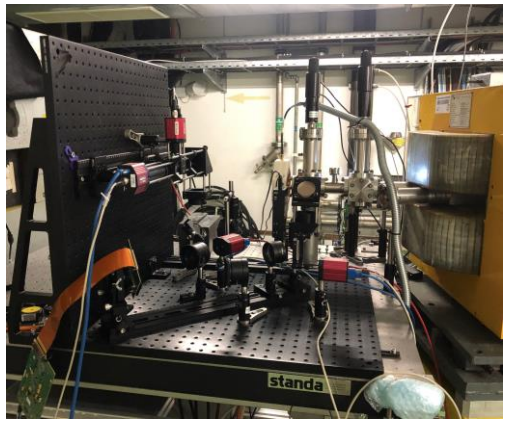




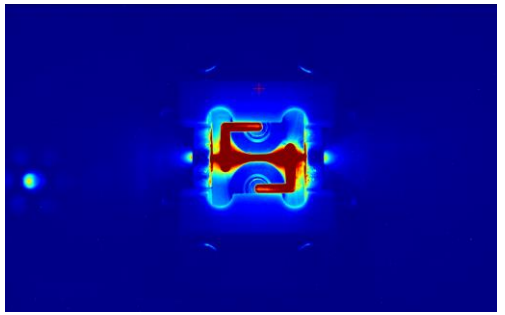




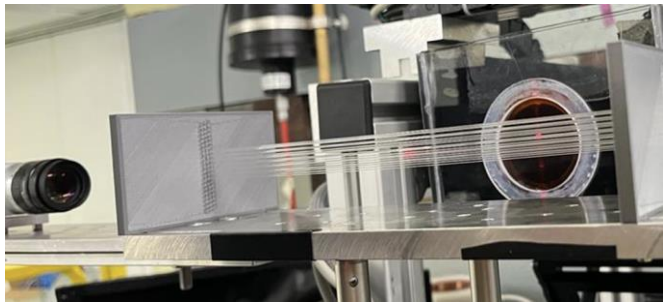
AWAKE Cherenkov Diffraction Radiation BPM



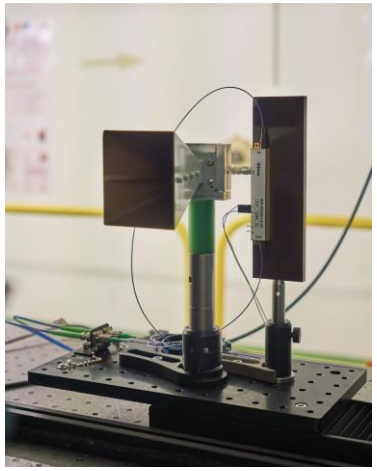
Novel OTR-based emittance meas. system for AWAKE (Liverpool U.)



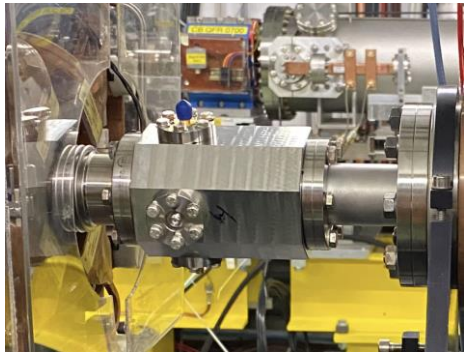
Plasma lens defocusing tests (Oslo U./CERN/Oxford U./DESY)



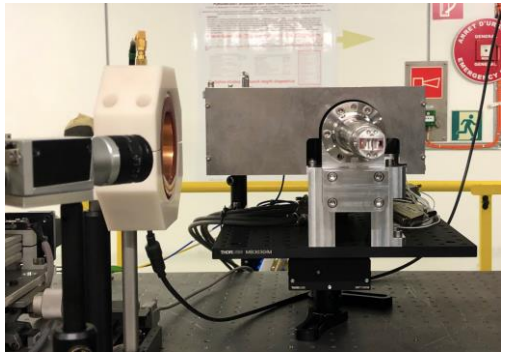
Fibre-optic beam profile and dose monitor for VHEE radiotherapy at ultra-high dose dates(CERN/Oxford U.)



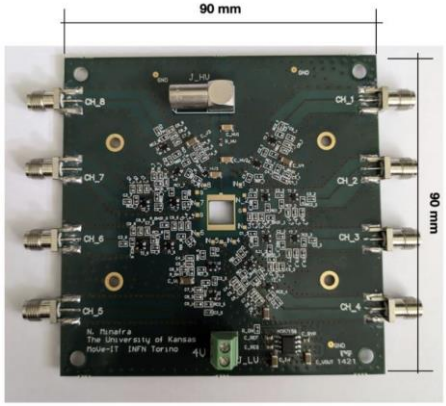
Coherent Cherenkov diffraction radiation dielectric buttons (FCC-ee bunch length monitors)



Broadband Pick-up for the PSI Positron Production Project (FCC-ee collaboration)

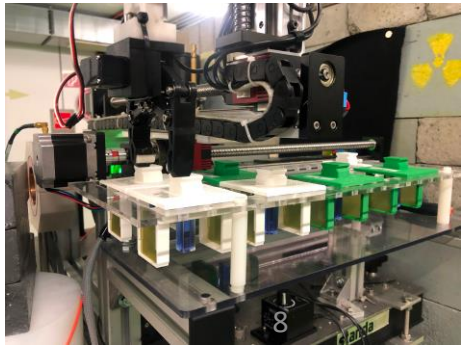


Bunch Profile Monitor for FCC-ee (Karlsruhe)



Beam testing of PCB + detectors using different technologies (Kansas U.)

Real-time dosimetry for VHEE radiotherapy using cuvettes (Strathclyde U.)



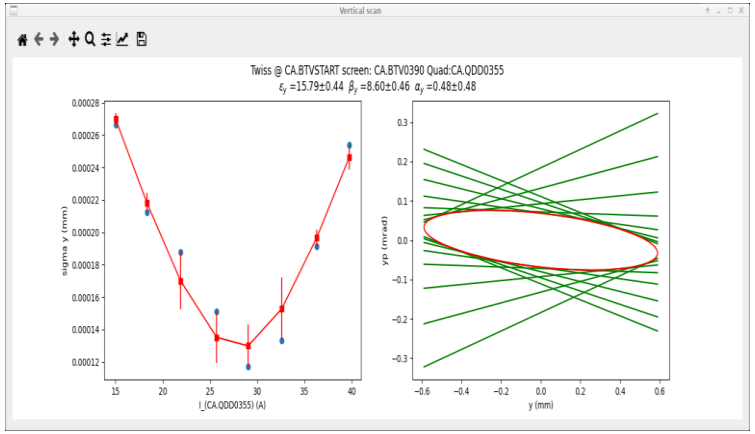
Beam availability

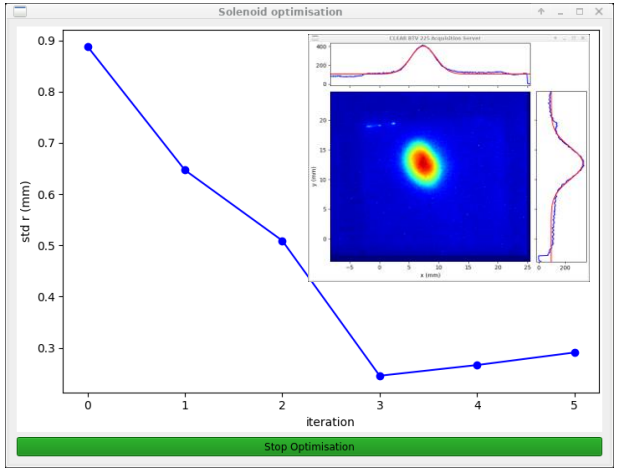
- Fatal failure time: 40 hours affecting 6 weeks (96.7 % beam availability)
  - Laser: chiller cartridge, attenuator controller, amplifier water leak, (continuous run during weeks)
  - Klystrons: some periods of recurrent trips
  - Turbo-pump (controller inside CLEAR)
  - Access control
  - Power cuts

- Consolidation program
  - New laser oscillator bought
  - Many amplifier spares from PHIN injector
  - New modulator station being prepared for klystron active spares
  - Turbo-pump controller being installed in the klystron gallery

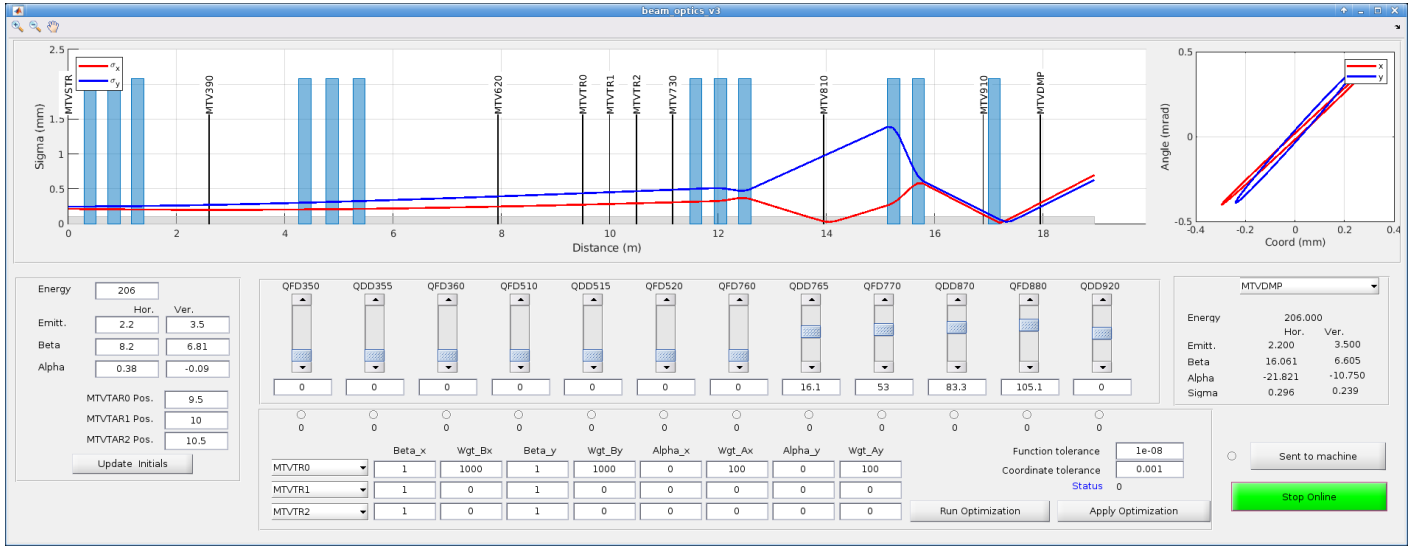
Some recent developments requested by users

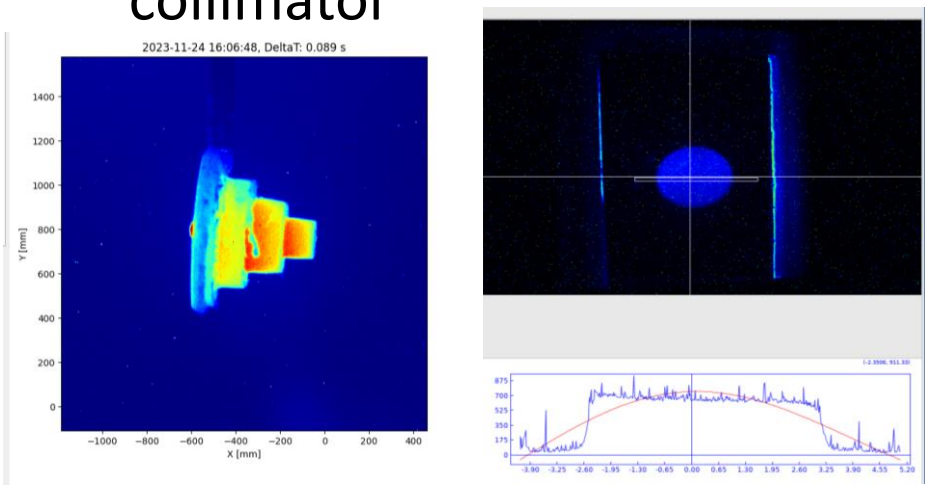
- Codes:
  - Quad Scan
  - Orbit simulation
  - Dose prediction
  - Multi-standard cameras control
  - Beam Base Alignment
- Devices:
  - Double scatterers shaped for flat beam profile generation with collimator





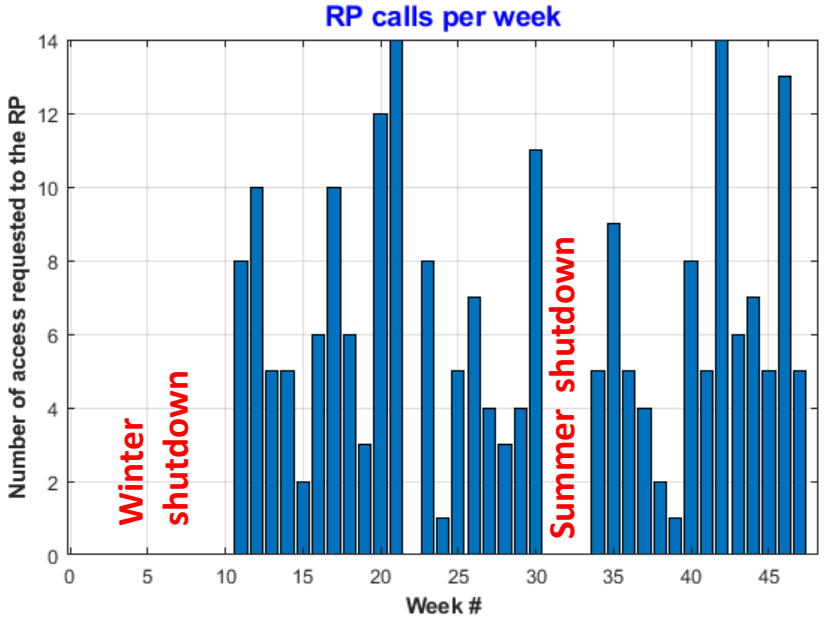
See Avni's talk

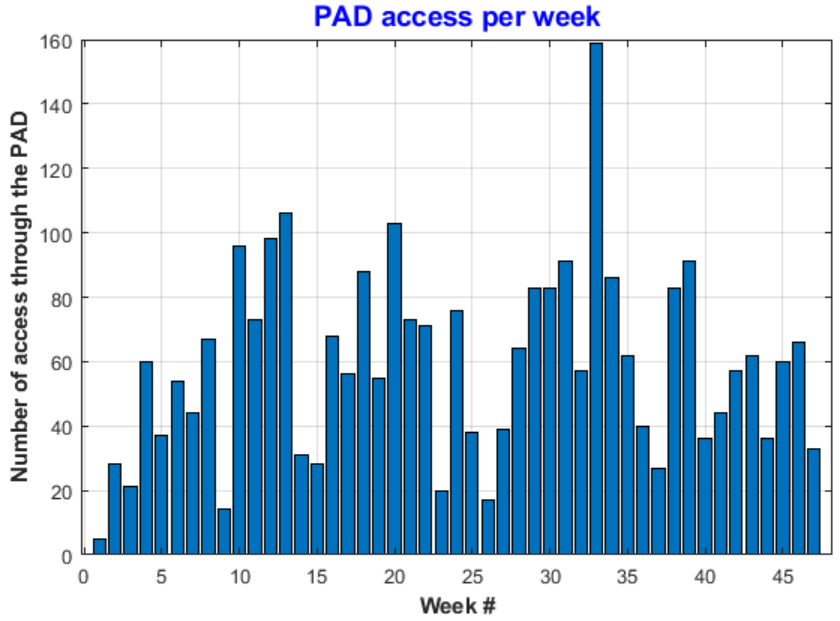




Access number

- A very large number of accesses for experiment installation and user's interventions on their set-up.
  - RP calls: **213** from 01/01/23 to 30/11/23 (minimum delay 30 min, require klystron stop, limited to working hours)
  - PAD accesses: **2802** D. Chapuis: « Access Point sur le complexe PS. Vous êtes en tête de liste ! »





In average:
- **9 per day**
- **59 per week**
- **253 per month**

Mutualizing accesses with two experimental beam lines will increase the overall running time and allow more experiments per week. Complex set-up could stay installed for longer time.

Constraints for the second beam line

- To fulfil **new experiments requirement** (large beam size, bunch compression, larger experimental areas)
- **Time**: no operations interruption apart of the usual shutdowns (summer: 3 weeks, winter: 2 months)
- **Resources**: Only the annual material budget (+ some Eurolabs founding)
- No up-to-date drawings of the actual beam line (due to many user's driven quick changes)
- Limited support availability during the YETS

Solutions:

Optimize the design (accurate beam dynamic study, large chamber size, magnetic chicane, use of sextupoles)

Reuse of the existing equipment (taken from Drive Beam or DL/CR)

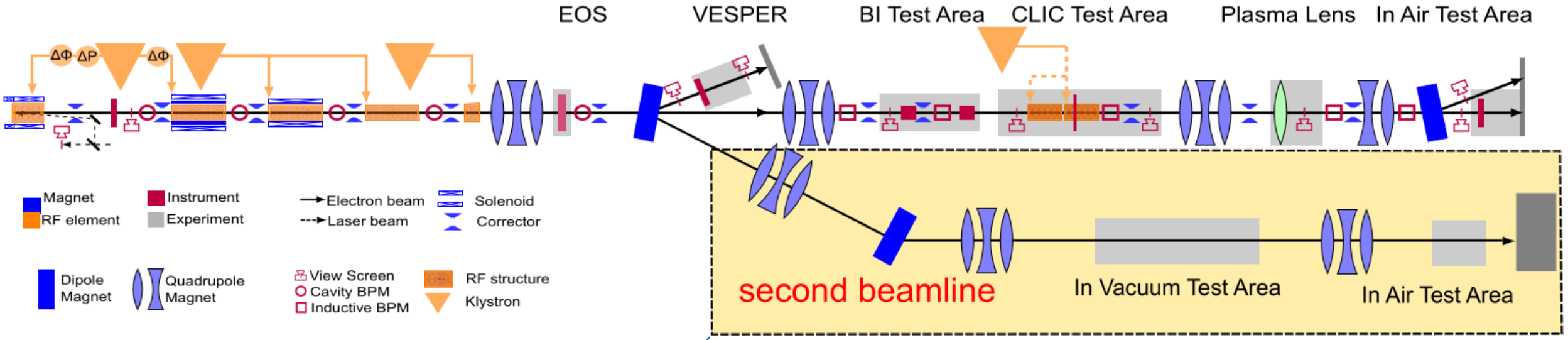
Reuse of the installed cables whenever possible, no general de-cabling

Tasks driven or even executed by the CLEAR team during shutdown, with the support of various groups experts.

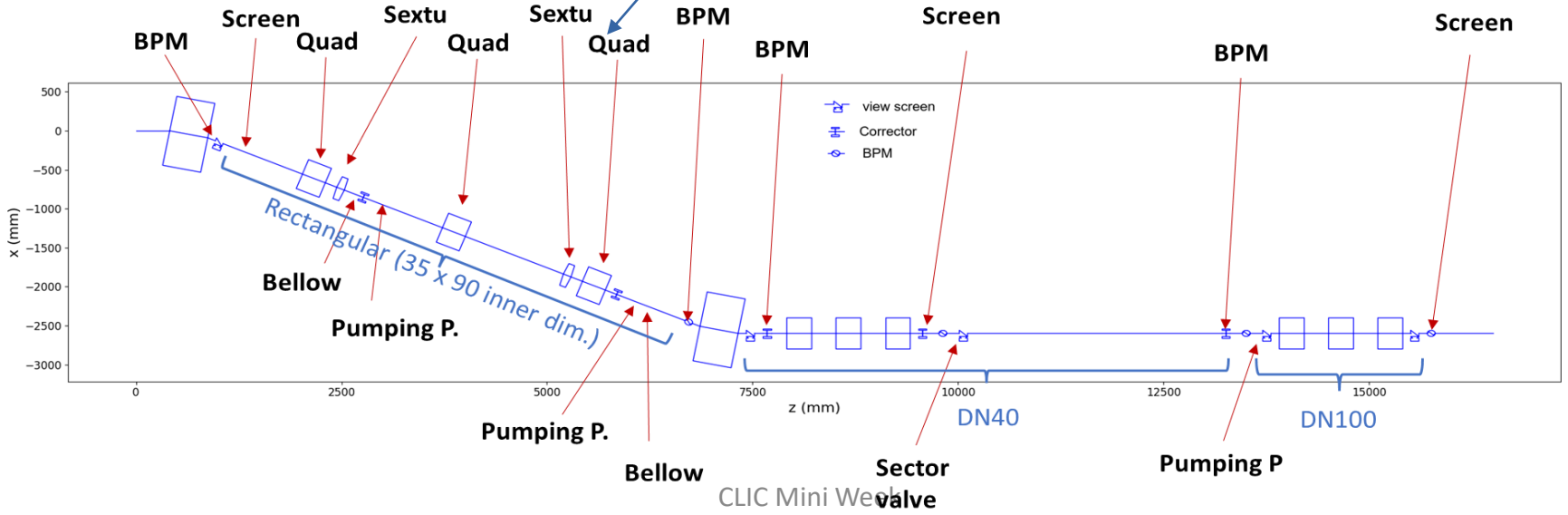
Flexibility in the commissioning date (Summer 24 or early 25)

Beamline Layout

Credit: A. Aksoy



22° Dogleg

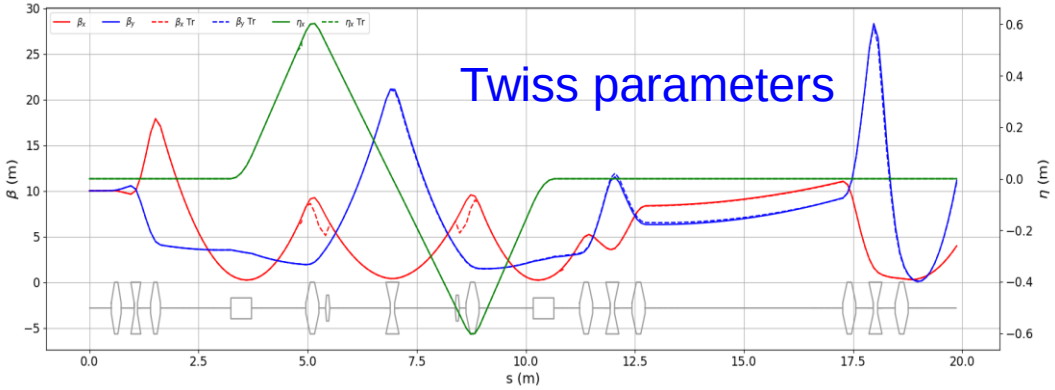


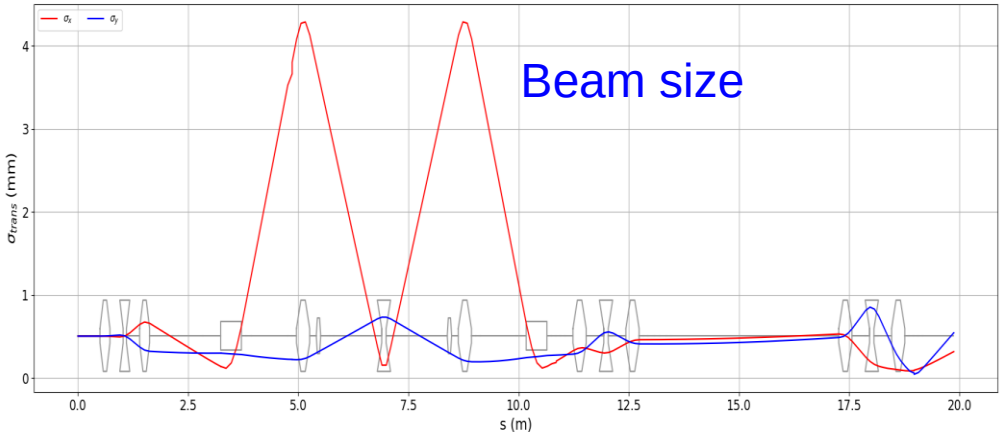
Beam dynamic studies

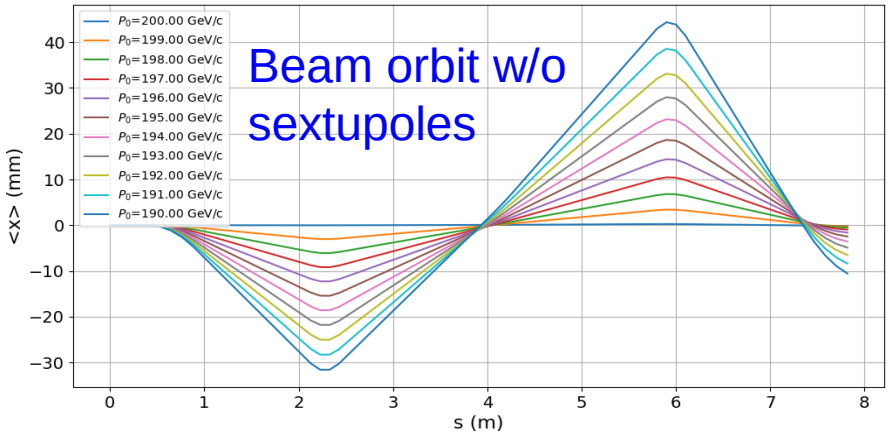
- The dispersion is closed by side quadrupoles of a standard dogleg.
- Flexible beam size adjustment with triplets on straight line

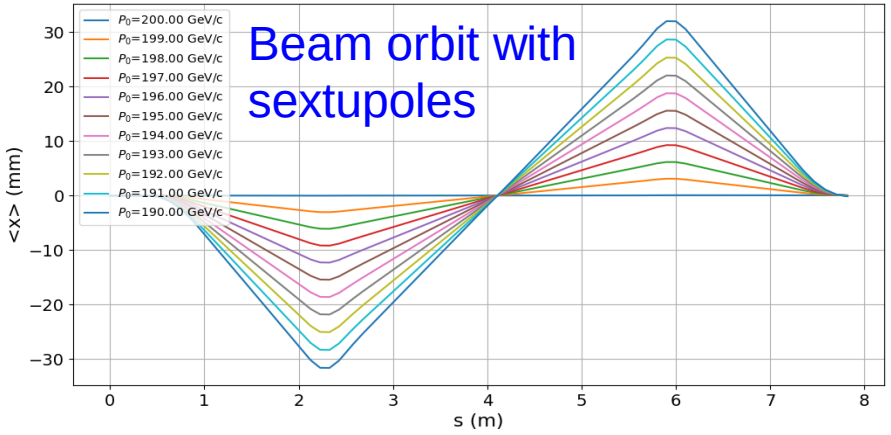
Credit: A. Aksoy

- Sextupoles are adapted to close second order dispersion when energy spread is large





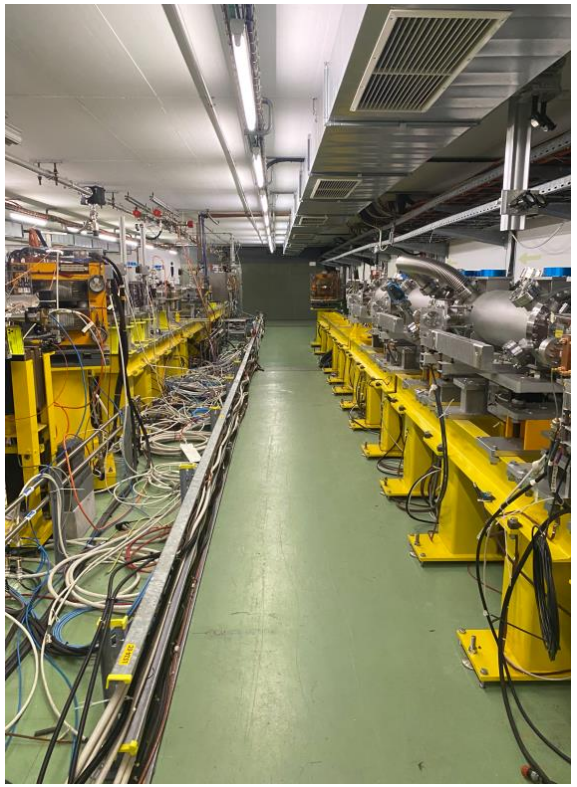




Work Progress

- Theoretical analysis performed (Luke, Alex, Avni), footprint validated
- Area cleared last summer (Transport group)
- Cables sorting started (by ourself, but EN-EL to provide help)
- 10 Quad and 3 Sextupoles taken from the CR renewed by the Magnet group TE-MSC-NCM (before YETS)
- Power supplies identified in the gallery by SY/EPC
- Survey work scheduled for January by BE-GM-ASG (footprint tracing)
- Vacuum chambers identified and result transmitted to EN-MME-EDS
- Vacuum layout being validated by TE-VSC
- New RP sensors ordered by HSE-RP
- Some components ordered (YAG screens, cameras, BCM, optical breadboard)
- Progress meeting every Tuesday

Area cleared during summer shut-down

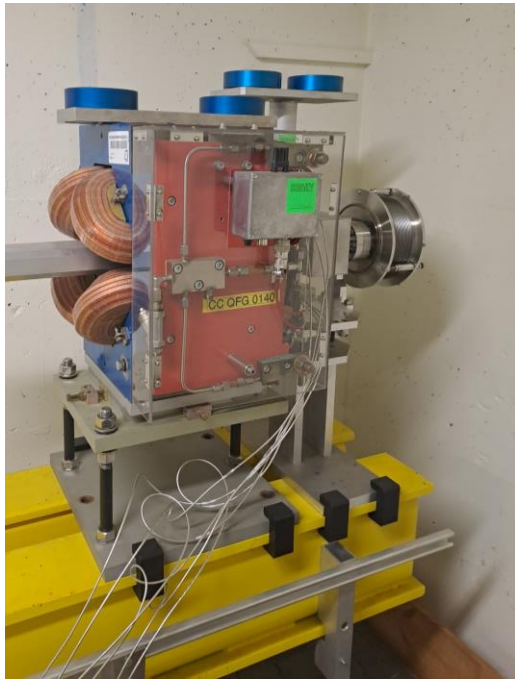


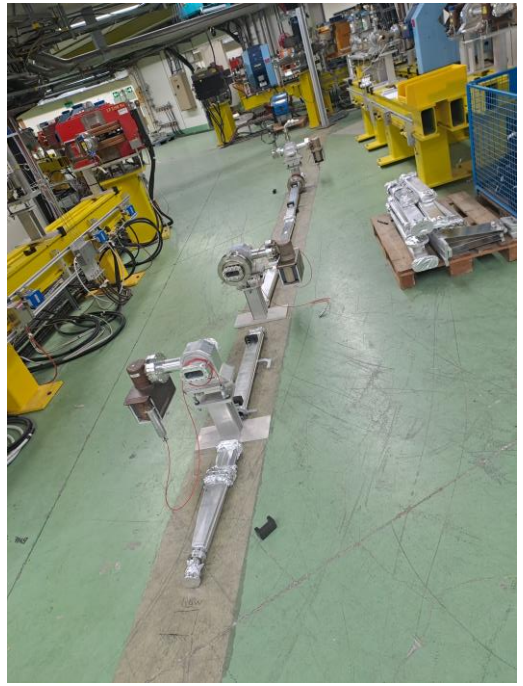
Alley ready to host the dog-leg

Former Drive-Beam dump still to be removed

Equipment being evacuated

Some recent pictures





Renewed quads and sextupoles with large aperture

Blank mounting and obtained solution for the dogleg.

Stay in touch on our website: https://clear.cern/

Thank you for your attention