CLEAR@CERN
New user beam line and dedicated equipment

W. Farabolini on behalf of the CLEAR team:
R. Corsini – A. Aksoy – A. Malyzhenkov – P. Korysko – V. Rieker – L. Wroe – D. Gamba
E. Granados – M. Calderon – R. Rossel (Laser and Photocathode experts)
S. Doebert - S. Curt – A. Chauchet (RF experts)
K. Sjobaek (remotely from Oslo)

What is CLEAR ?

See R. Corsini talk, Monday 28 Oct.

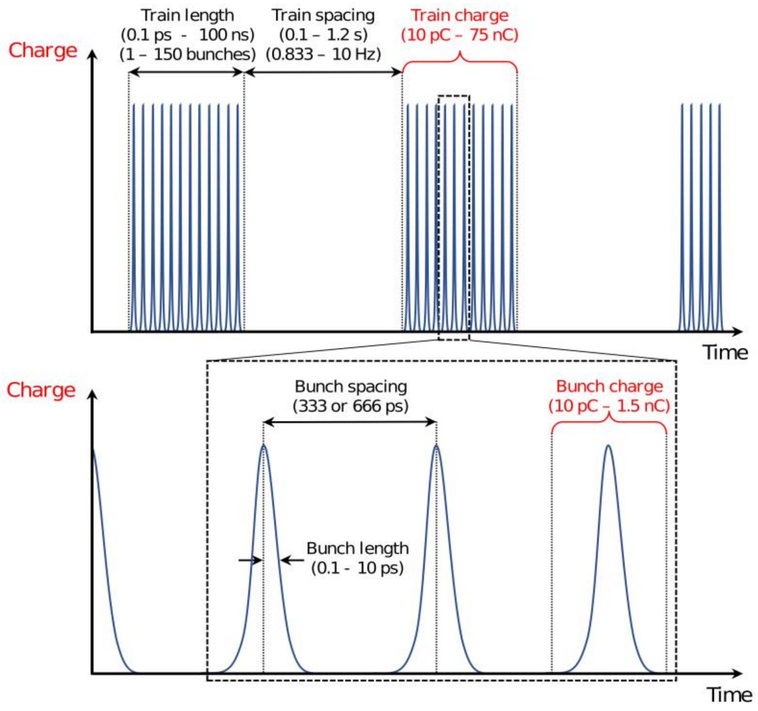
Scientific and strategic goals:

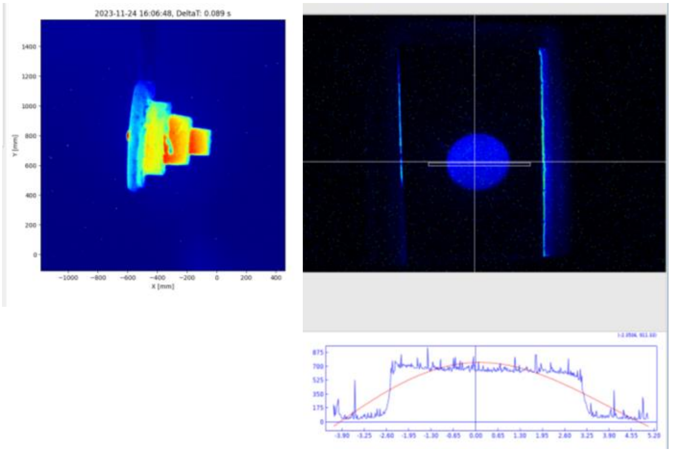
- **Unique electron beam test facility at CERN** with high availability, easy access and high-quality. Part of Euro-Labs transnational access program
- R&D on accelerator components, **beam instrumentation**, high gradient RF technology.
- **Irradiation facility** with Very High Energy Electrons (VHEE) and Ultra-High dose rate (UHDR), 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	30 - 230 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

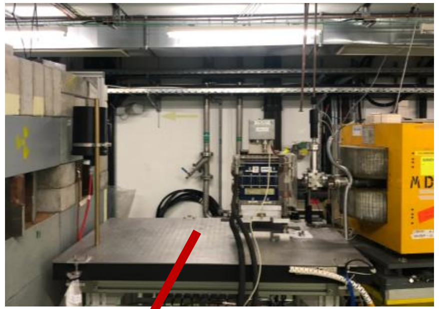




Double scatterers shaped for flat beam profile generation with collimator

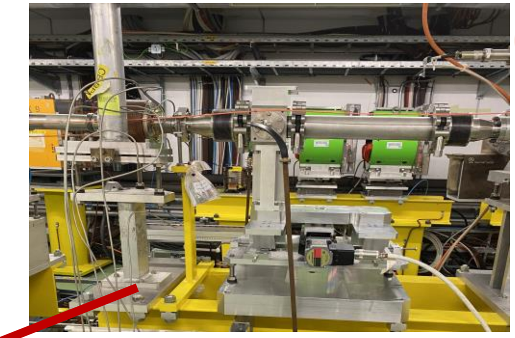
CLEAR beamline in 2024

Credit: P. Korysko

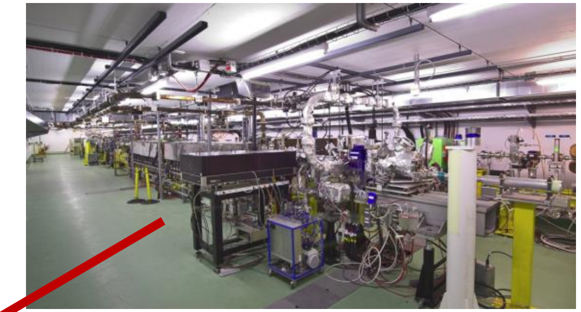


In-Air Test Stand

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

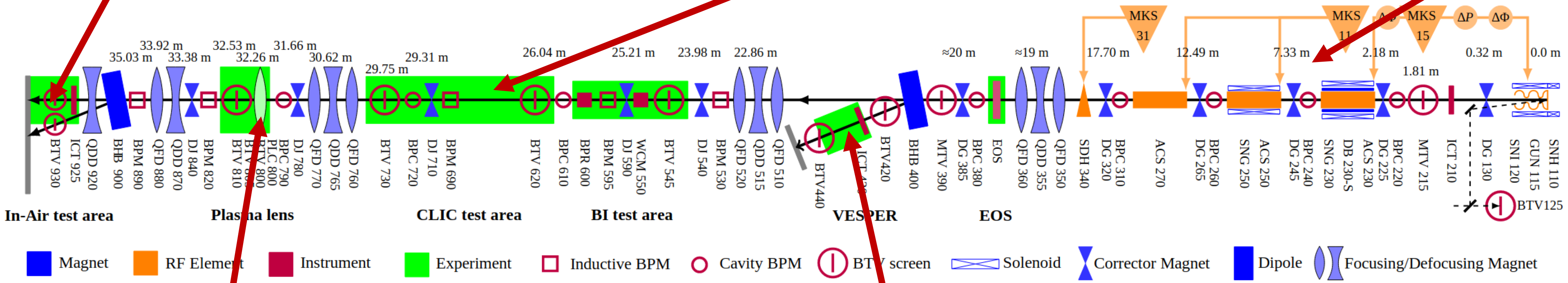


BI Test Stand

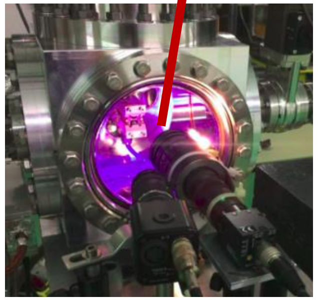


CLEAR Injector

- Flexible Linac
- 30 – 230 MeV

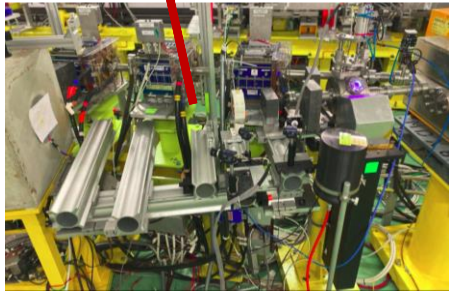


Beam direction



Plasma Lens

- Novel plasma based focusing



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

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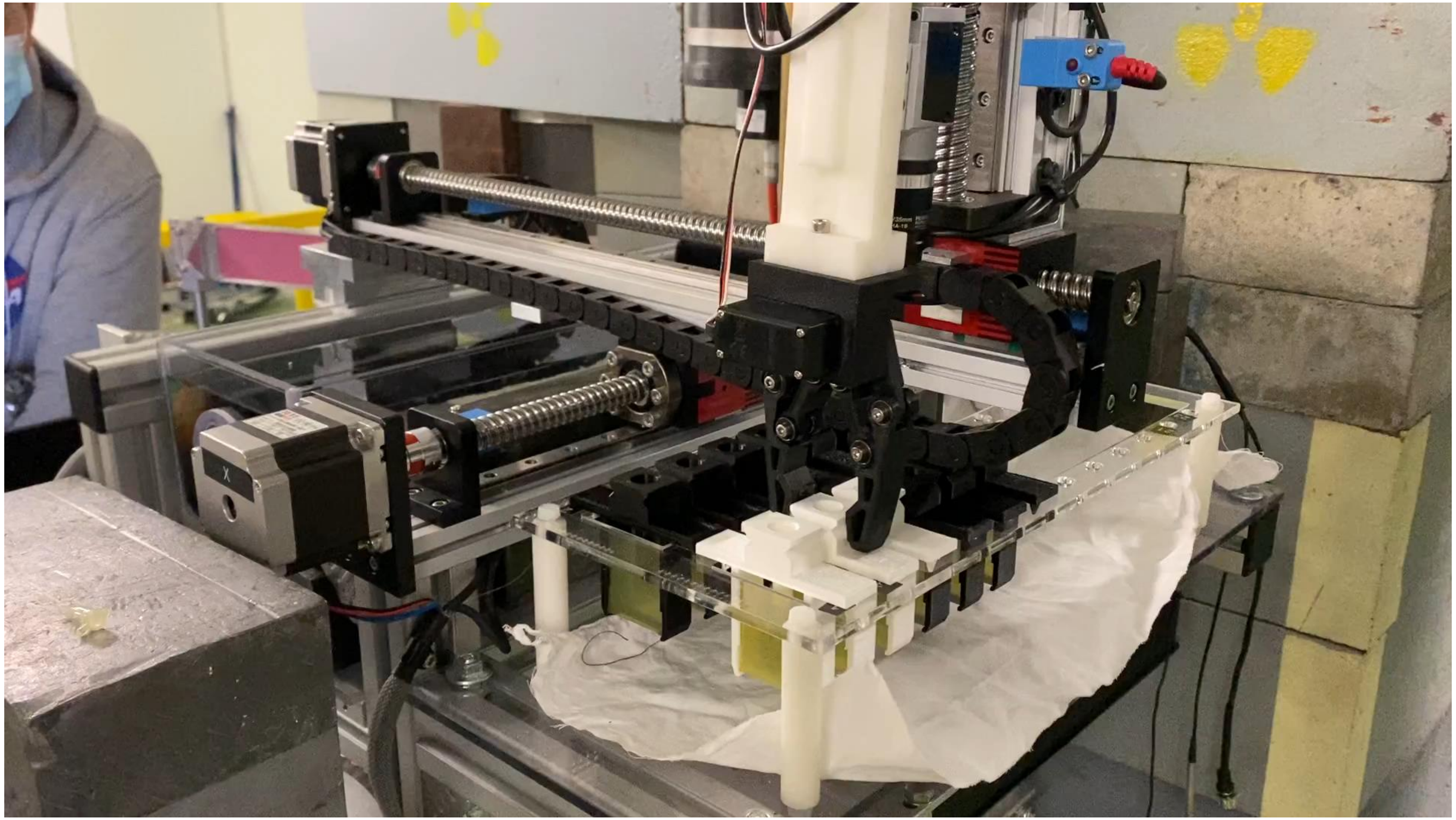
The C-Robot developed for medical samples



Recently reproduced by PITZ @ DESY

CLEAR user's experiments workflow

Experiment Request Form

A. REQUESTER DETAILS

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

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

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Week Summary Report
Supervisor: Pierre Korysko

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

	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

Experiment Review Form

Experiment Review Form
Experiments goals
Beam parameters achievements
Summary of operations
- problems encountered
- improvement axis

Future work at CLEAR
Possible publications

Rev. 2.0 Page 1 of 4

- 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

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 in 2023

- 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

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	[illegible]	[illegible]	[illegible]
16	Optic fiber dosimetry	Oxford U.	[illegible]	[illegible]	[illegible]
16	Film dosimetry	Oslo U.	[illegible]	[illegible]	[illegible]
16	MD Flat Beam space charge	ABP	[illegible]	[illegible]	[illegible]
17	Plasmid irradiations	Mancheste	[illegible]	[illegible]	[illegible]
17	Film dosimetry	Oxford U.	[illegible]	[illegible]	[illegible]
18	Medical irradiation Ch. ZFE Cells	CHUV	[illegible]	[illegible]	[illegible]
18	Optic fiber dosimetry	Oxford U.	[illegible]	[illegible]	[illegible]
19	Ch DR	CERN-BI	[illegible]	[illegible]	[illegible]
20	VHEE UHDR	Victoria U.	[illegible]	[illegible]	[illegible]
20	ZFE irrad. And phantom dosimetry	CHUV	[illegible]	[illegible]	[illegible]
20	MD	ABP	[illegible]	[illegible]	[illegible]
21	Scintillator dosimetry	Victoria U.	[illegible]	[illegible]	[illegible]
21	VHEE UHDR larve irrad.	EPFL	[illegible]	[illegible]	[illegible]
21	Spatially fractionated irrad.	Victoria U.	[illegible]	[illegible]	[illegible]
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
[illegible]	[illegible]	CERN-BI	1	1	18
[illegible]	[illegible]	RHUL	16	1	0
[illegible]	[illegible]	RHUL	16	1	25
[illegible]	[illegible]	iverpool U. / C	2	8	36
[illegible]	[illegible]	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
[illegible]	Real time dosimetry	Oxford U. and J	8	7	15
[illegible]	Ch DR BLM for FCC	CERN-BI	3	2	4
[illegible]	[illegible]	ABP	0	4	32
[illegible]	[illegible]	PSI	5	5	50
[illegible]	[illegible]	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**

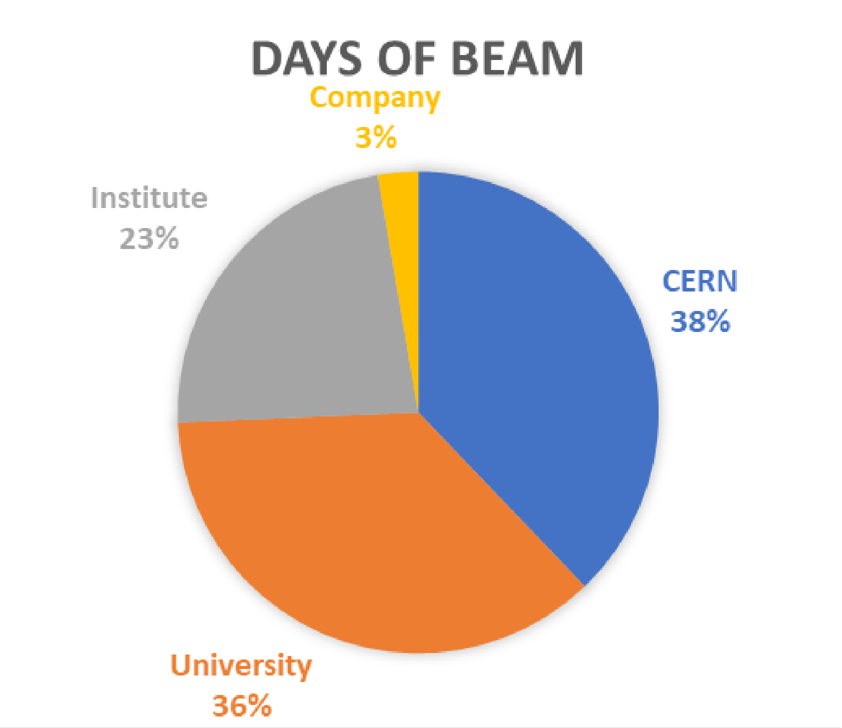
Type and origins of the experiments in 2023

- 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.

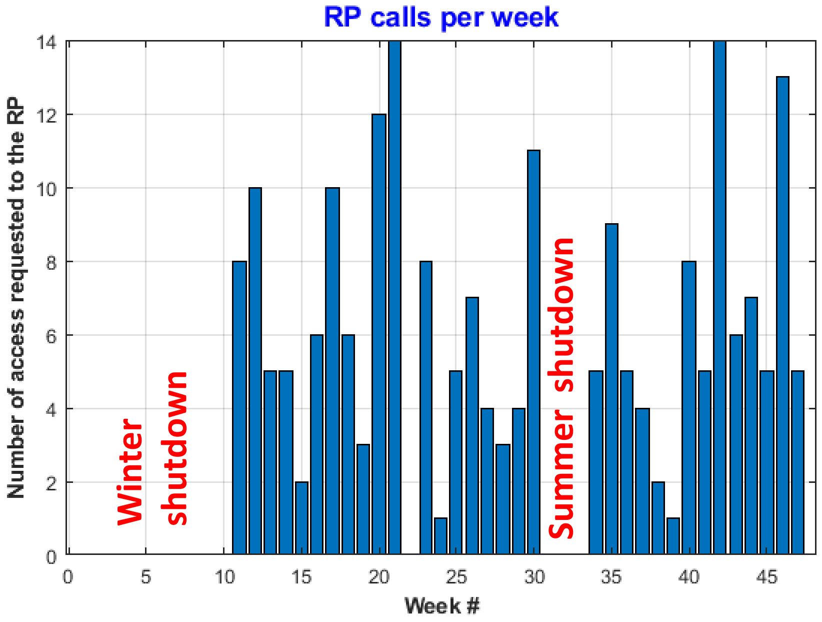
- PSI
- CHUV
- EPFL
- INFN Bologna
- INFN Padova
- KIT
- PTB
- RAL – ENEA
- Cockcroft Inst.
- JAI

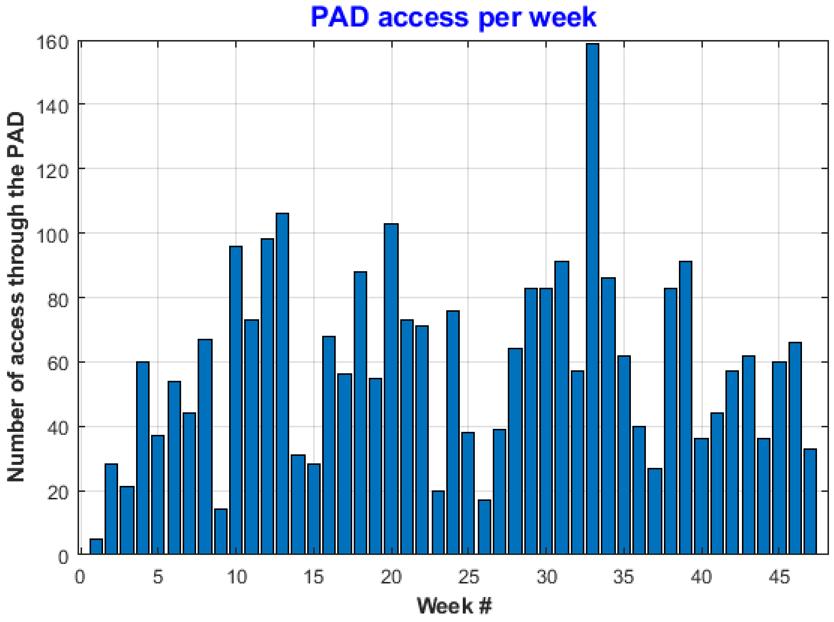
- BERGOZ
- DAES



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.

Motivations

CLEAR SCIENTIFIC BOARD REPORT 8/3/24

- **Near-term through 2025**
- Near-term improvements to the CLEAR facility include the introduction of a second beamline. This addition enables the creation of **more areas for in-air and in-vacuum testing, reducing the need for frequent mounting and dismounting** of experiments and diagnostics equipment. Consequently, **it increases the available beam time and operational flexibility**, allowing for the **parallel execution of 'non-compatible' experiments** within the same week or day, with a quick turnaround. **This modification also broadens the beam parameter space, for example allowing for larger beam sizes and stronger focusing**. Commissioning is scheduled for late 2024 or early 2025.
- Finding 8: The second beamline and laser-system improvements will enhance reliability and flexibility for operations in 2024/25, and can be executed within the existing planned resource envelope.
- **Beyond 2025**
- Completion of the **construction and commissioning of the new beamline will be crucial to support an extended programme beyond 2025**. This will provide more flexibility to cope with the increasing beamtime demands and will **enlarge the technical portfolio of the CLEAR facility**. Moreover, as preparations progress towards a future Higgs factory at CERN, there is growing consensus on the need for relevant electron-beam test facilities including, for example, prototypes of key system elements of the FCCee injector complex. If such future electron facilities are designed for versatile use, they could continue and expand the CLEAR programme, attracting a broad user community, in addition to serving as a foundational step towards a Higgs factory.

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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**)
- 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)

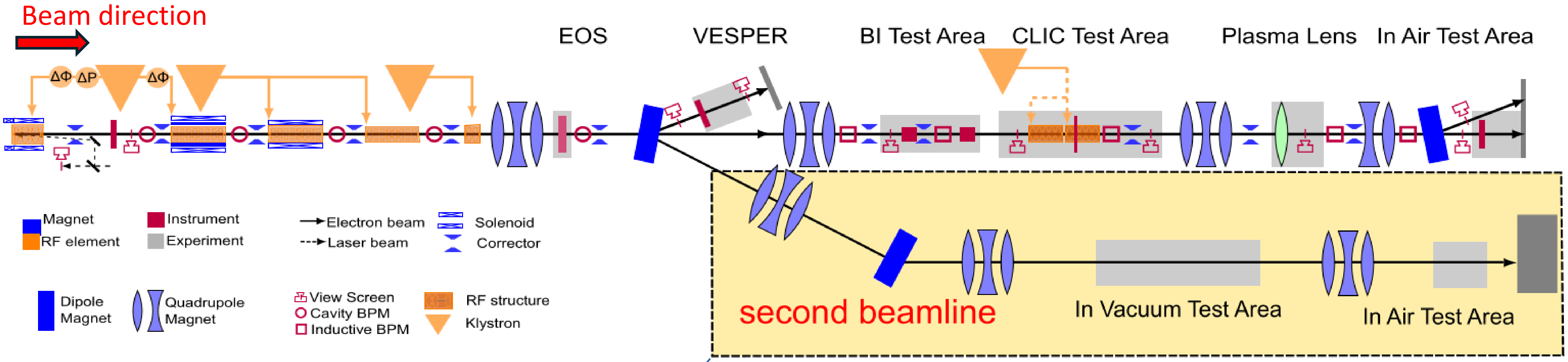
Reuse of the installed cables whenever possible, no general de-cabling

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

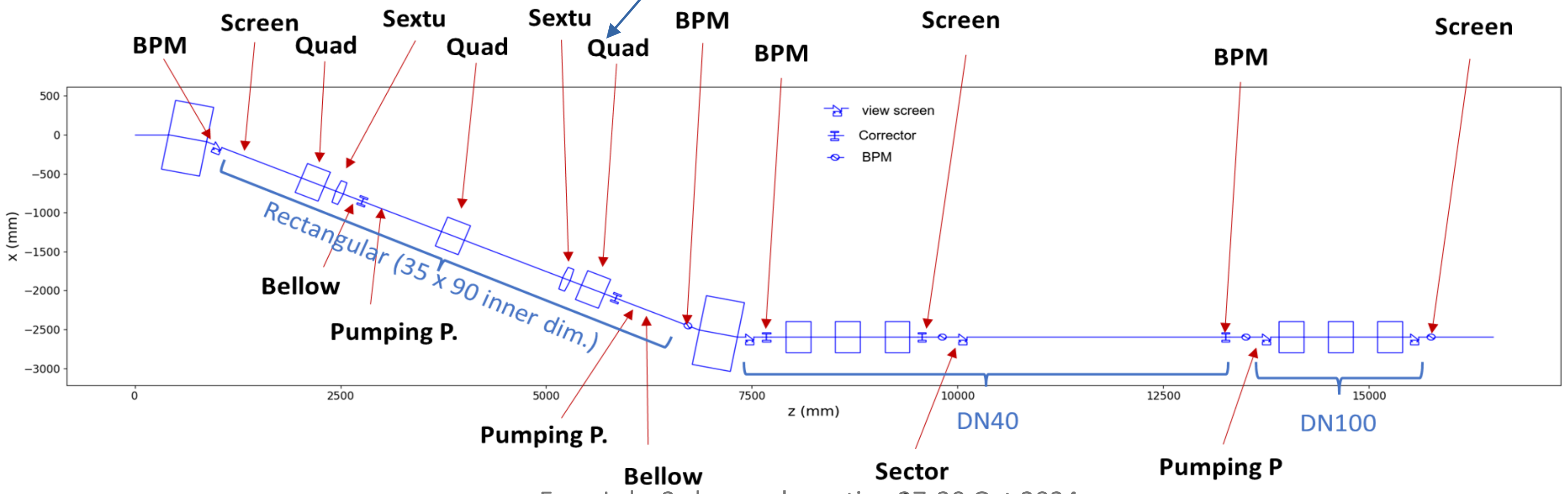
Flexibility in the commissioning date (Summer 25)

Beamline Layout

Credit: A. Aksoy



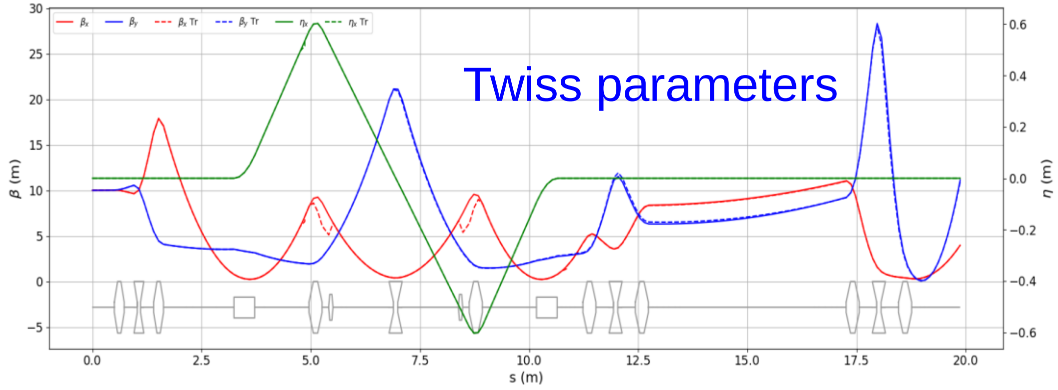
22° Dogleg

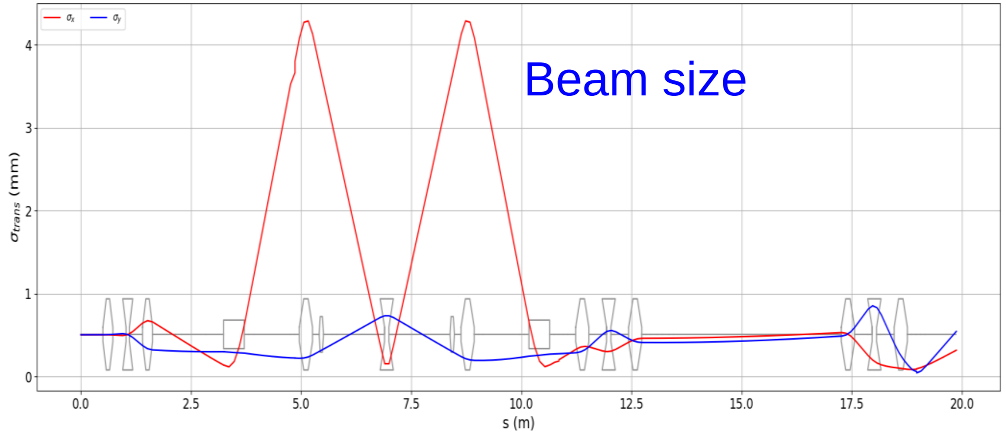


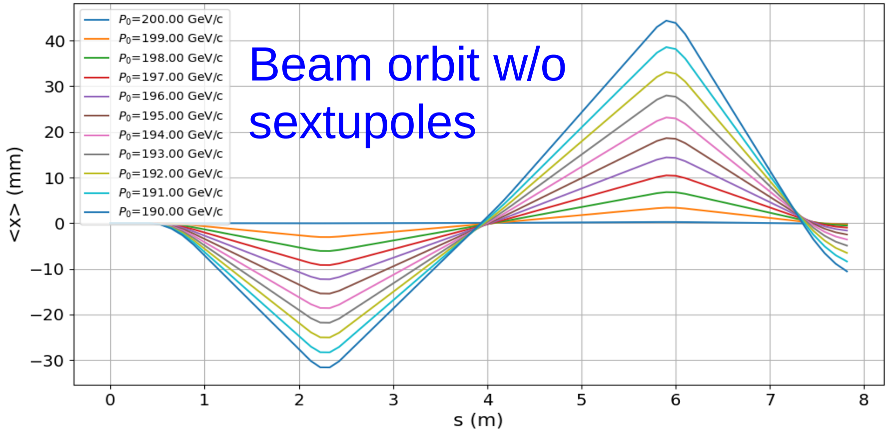
Beam dynamic studies

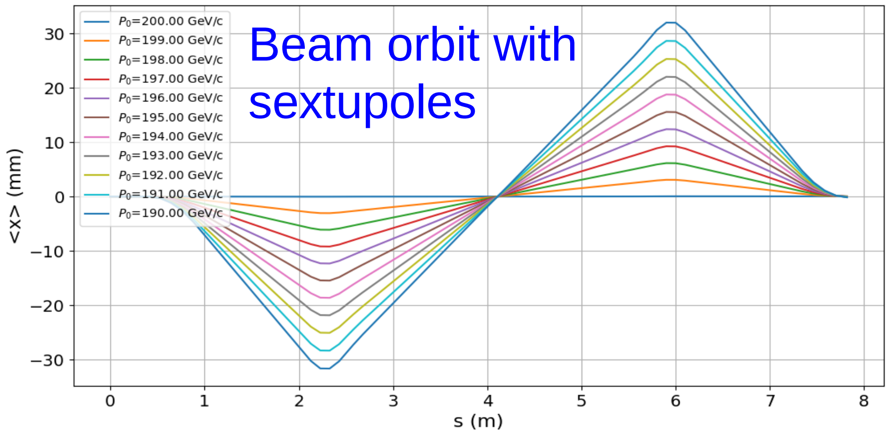
- The dispersion is closed by side quadrupoles of a standard dogleg.
- Flexible beam size adjustment with triplets on straight line
- Sextupoles are adapted to close second order dispersion when energy spread is large

Credit: A. Aksoy



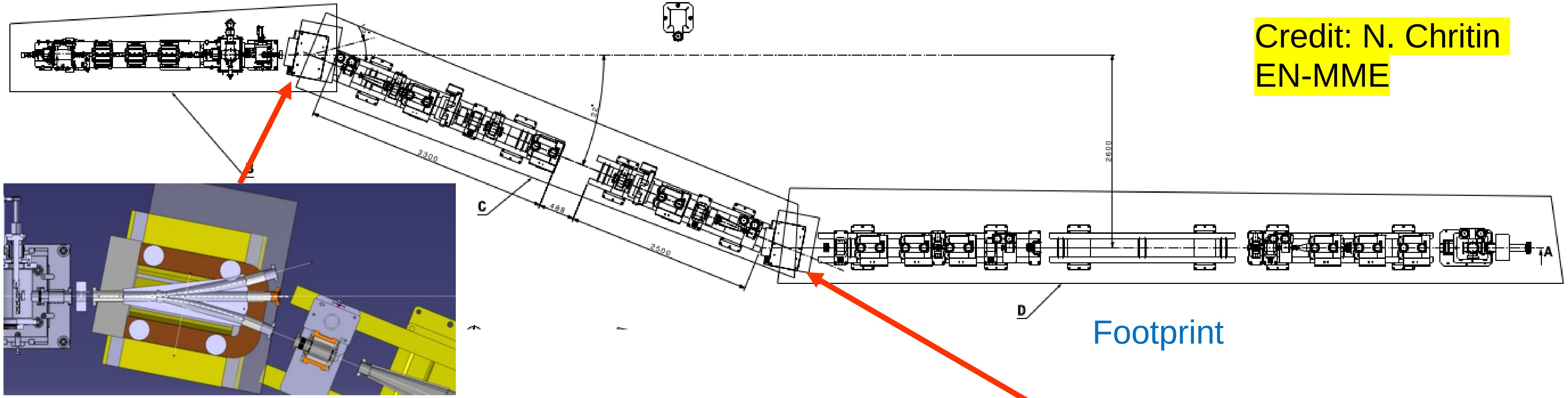




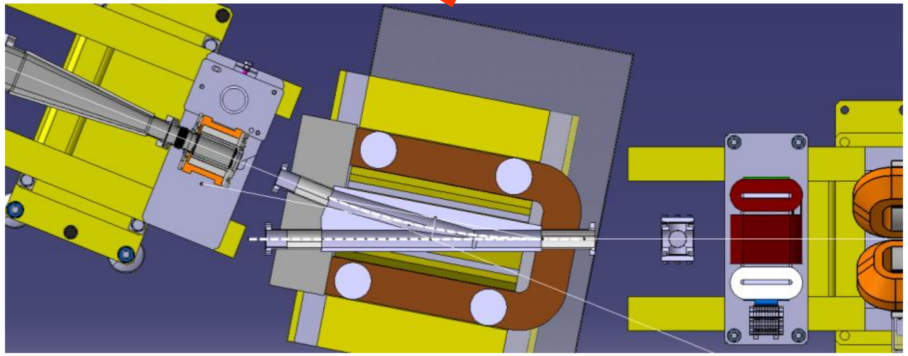


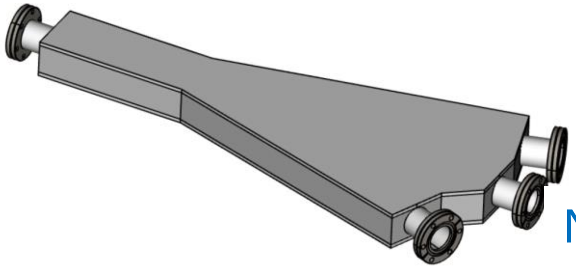
Implementation and manufacturing drawings

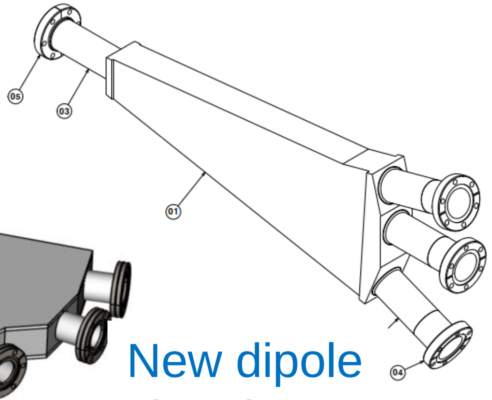
Credit: N. Chritin
EN-MME



Footprint





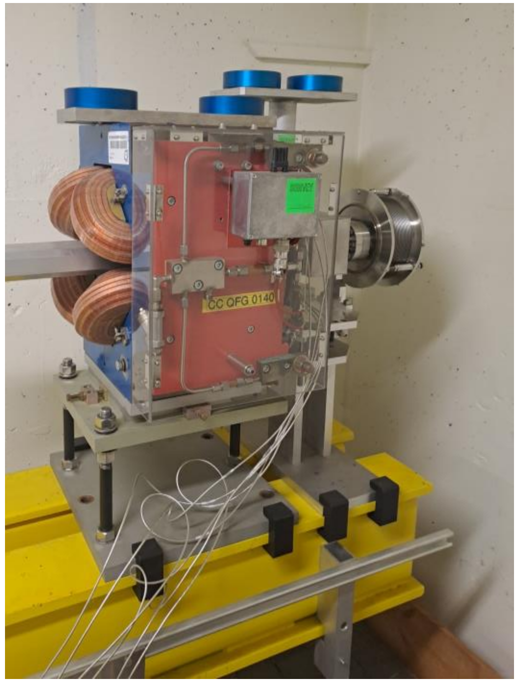


New dipole chamber

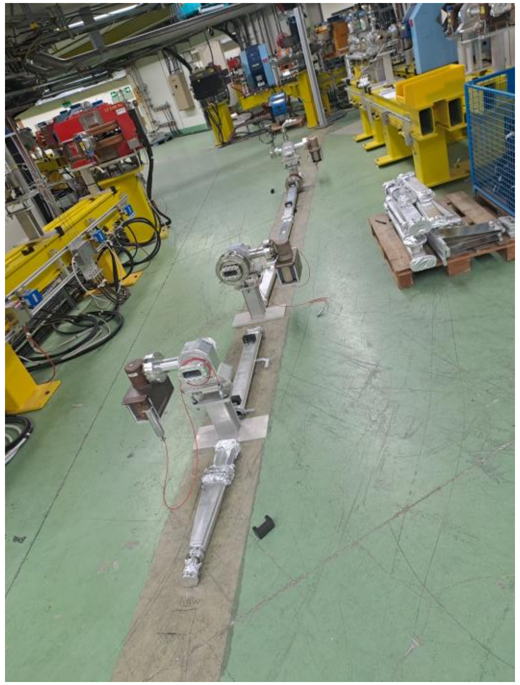
Work Progress

- Theoretical analysis performed
- Footprint traced on the floor by the survey team.
- 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
- Vacuum chambers identified and result transmitted to EN-MME-EDS
- Vacuum layout validated by TE-VSC
- New RP sensors ordered by HSE-RP
- Technical drawings of the new chambers transmitted to the workshop
- **Some components ordered (YAG screens, cameras, BCM, optical breadboard)**

Some recent pictures



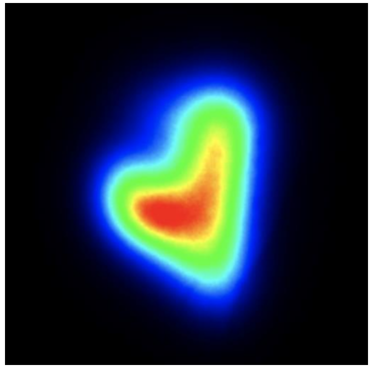




Renewed quads and sextupoles with large aperture

Blank mounting and obtained solution for the dogleg.

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



Thank you for your attention