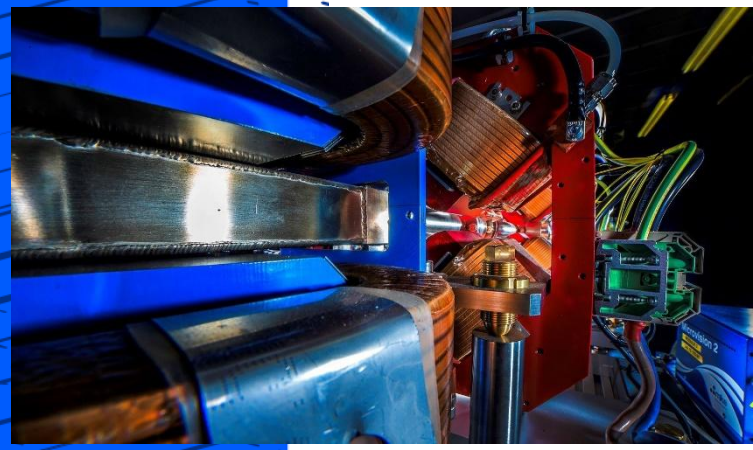
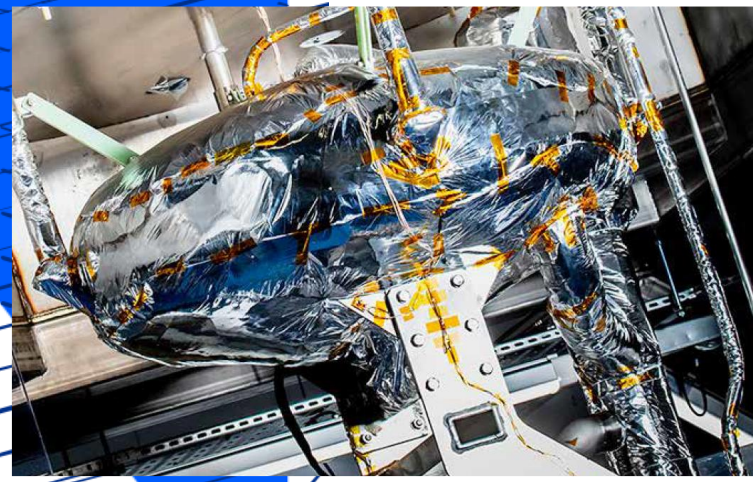
Science and Technology Facilities Council

ASTeC

Making a brighter future through advanced accelerators

Status of CLARA@STFC & Potential for VHEE/FLASH R&D





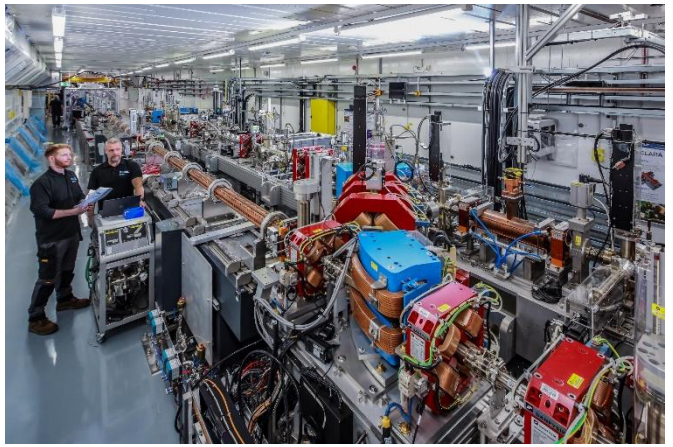
Deepa Angal-Kalinin
ASTeC, STFC Daresbury Laboratory
and The Cockcroft Institute

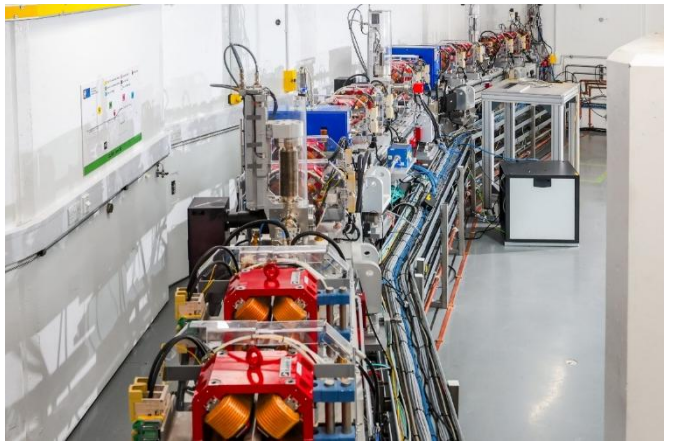
On behalf of the CLARA Team

VHEE25, Daresbury Laboratory, 15th September 2025

Outline

- Introduction to CLARA
- Upgrade to 250 MeV
- FEBE beamline and hutch
- Potential for VHEE/FLASH R&D
- Current Status & Plans
- Outlook
- Summary





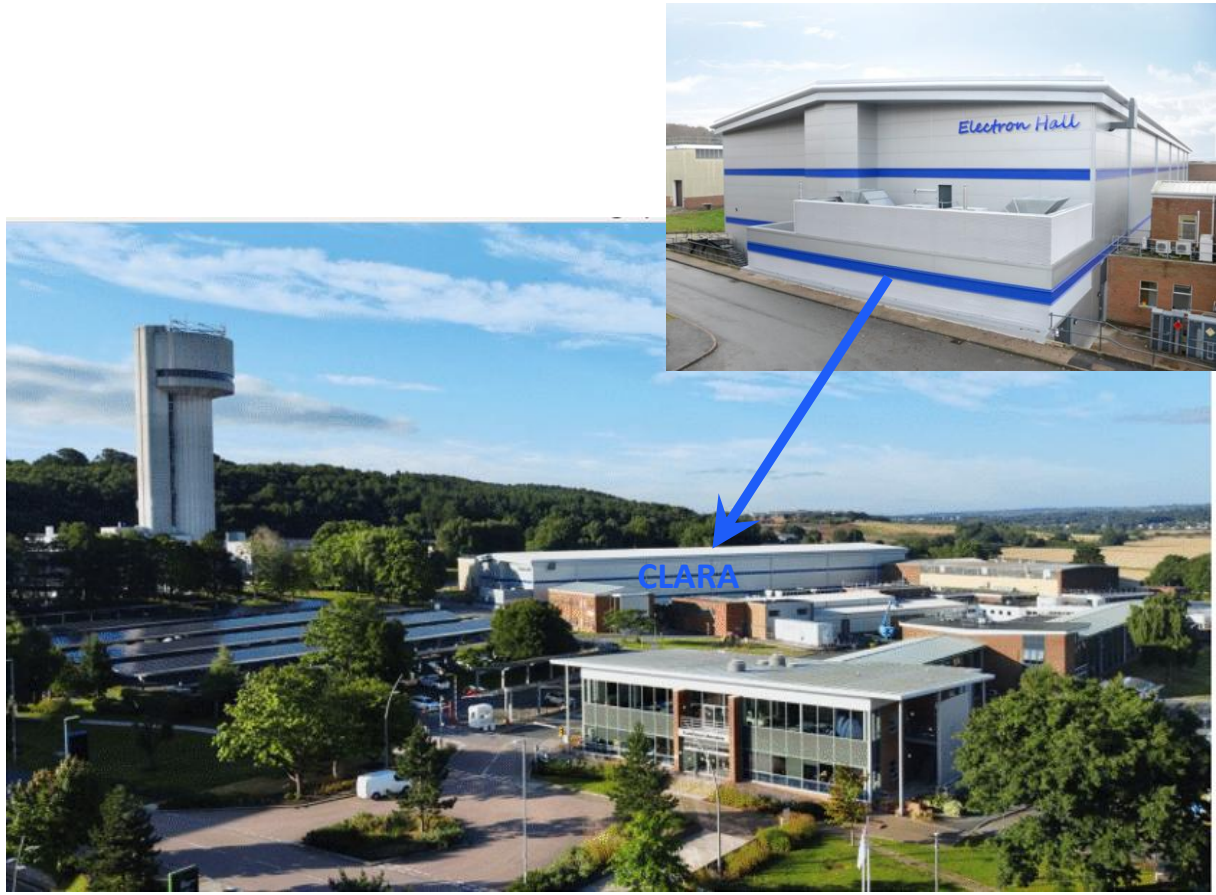
Introduction to CLARA

Compact Linear Accelerator for Research and Applications

- CLARA is a 250 MeV normal conducting RF based ultra-bright electron beam facility being commissioned at STFC Daresbury Laboratory.

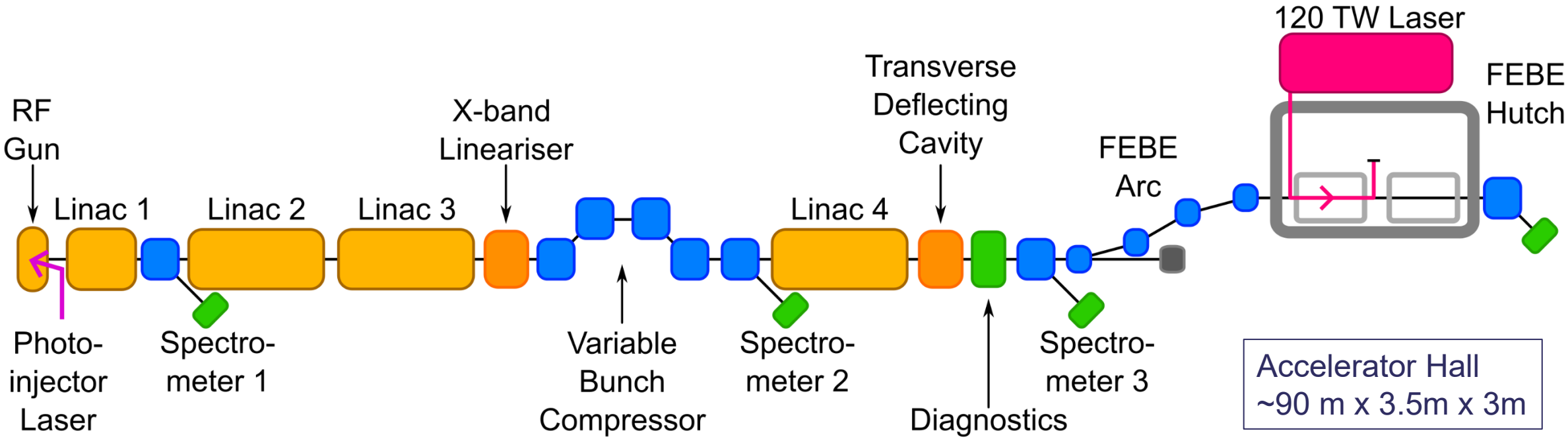
- Conceived to test advanced Free Electron laser schemes, it has since become a unique facility for user-led experiments in a wide range of disciplines.

- Two highly successful VHEE experiments with ‘CLARA Front End’ at 35 MeV (2018-2022).



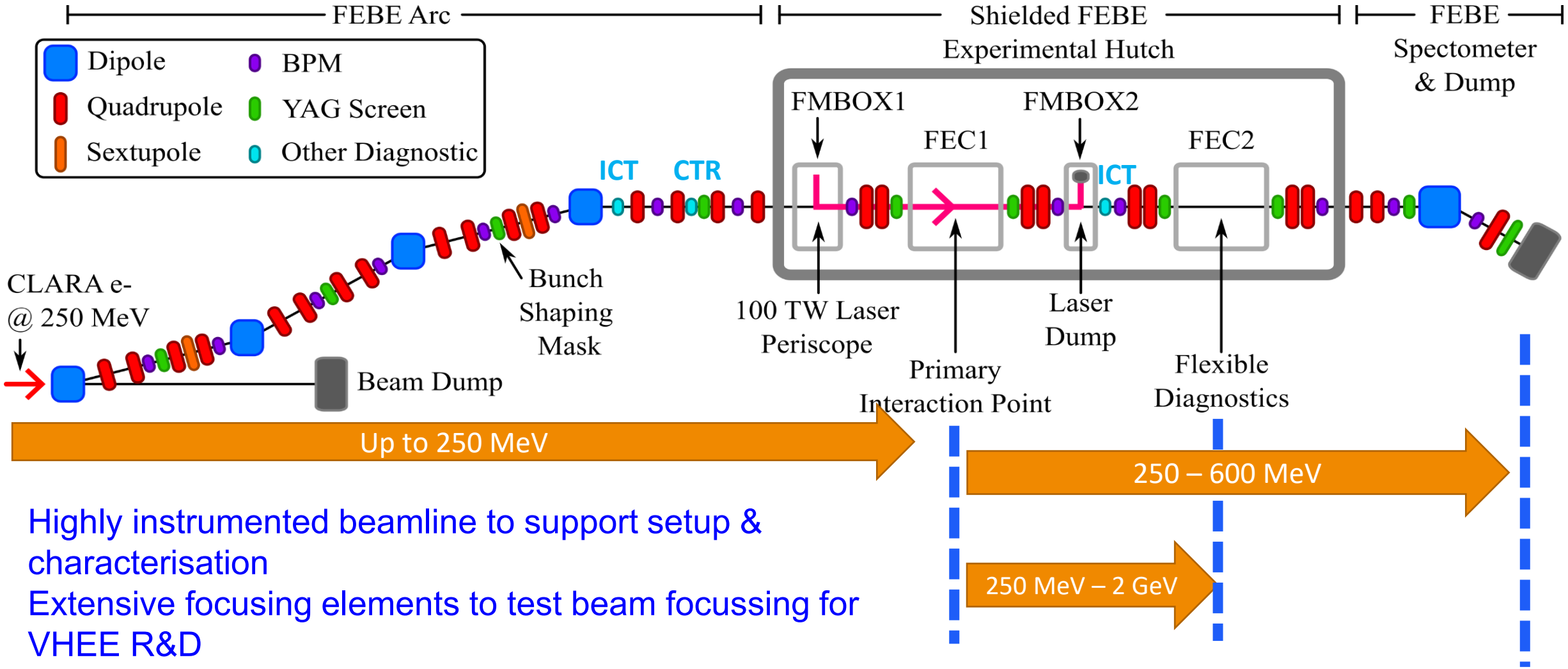
Introduction to CLARA

FEBE – Full Energy Beam Exploitation beamline



- High brightness beam
- Flexible & optimised parameters
- Thoroughly instrumented beamline
- Delivered to a shielded hutch

CLARA FEBE

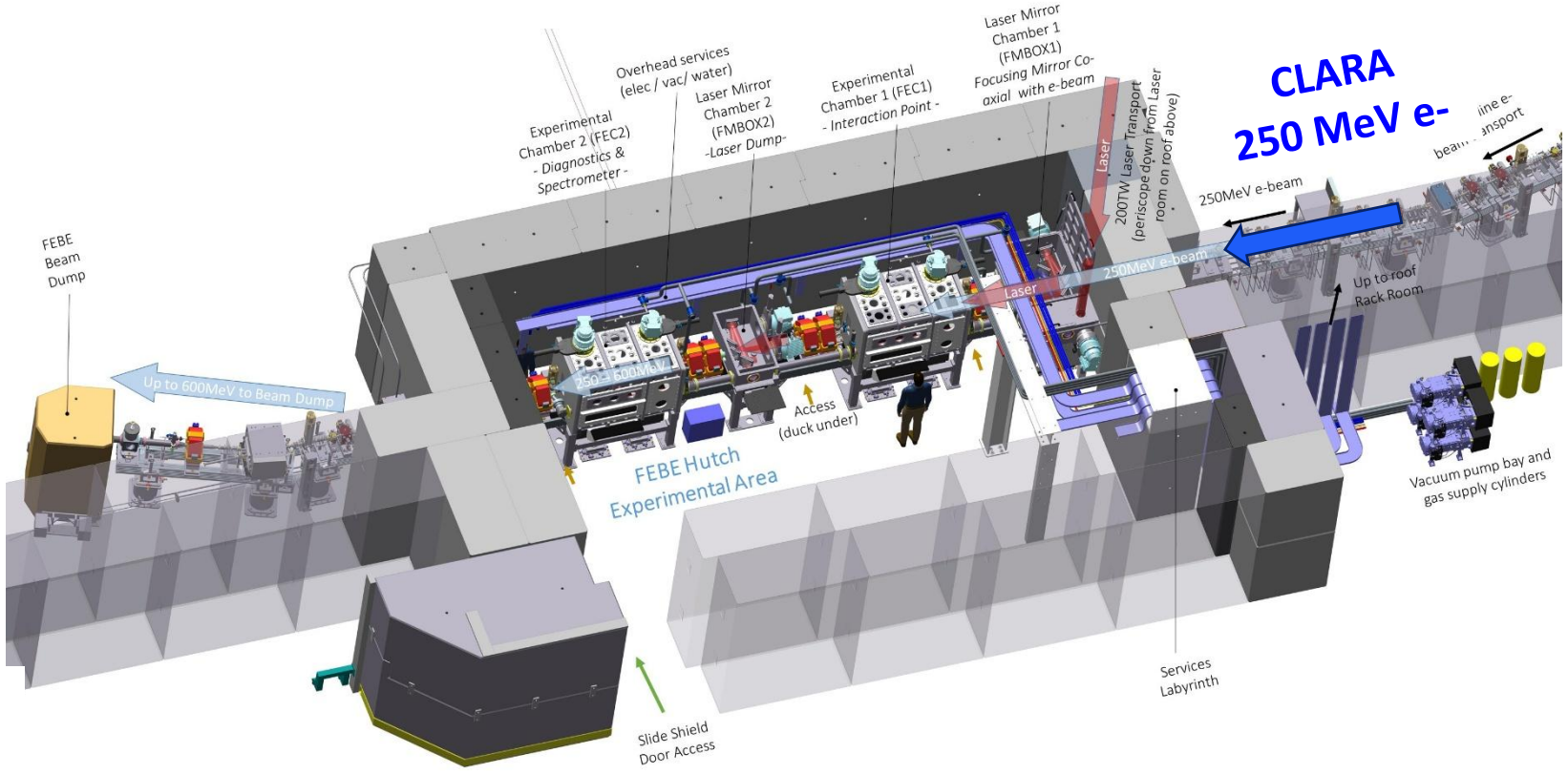


- Highly instrumented beamline to support setup & characterisation
- Extensive focusing elements to test beam focussing for VHEE R&D
- Novel acceleration concepts – beam energy above 250 MeV

FEBE Hutch Overview

Hutch footprint: 10×5.4×3 m³, Shielding: Total beam power 6 W

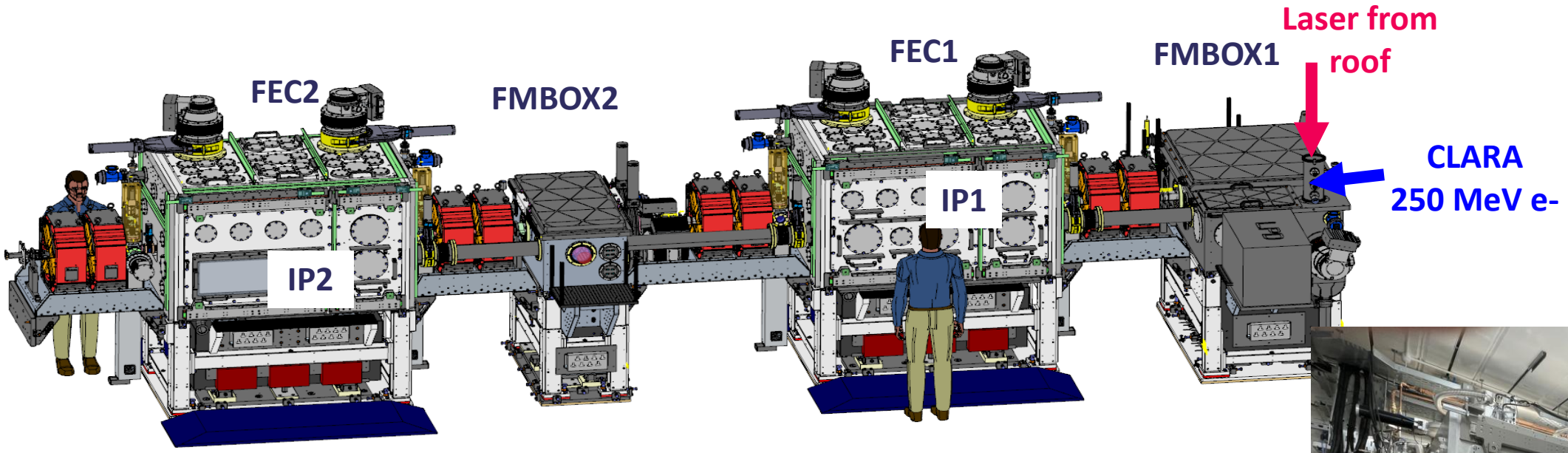
Flexibility with bunch charge (maximum 250 pC), bunch repetition rate (maximum 100 Hz), beam energy (50 MeV – 250 MeV)



FEBE Hutch Beamline

FEC = FEBE Experiment Chamber
IP = Interaction Point (e- foci)

FMBOX = FEBE Mirror Box for high power laser



Day 1 Electron Beam Parameters

To be delivered at Interaction Point in FEC1 and/or FEC2 chambers.

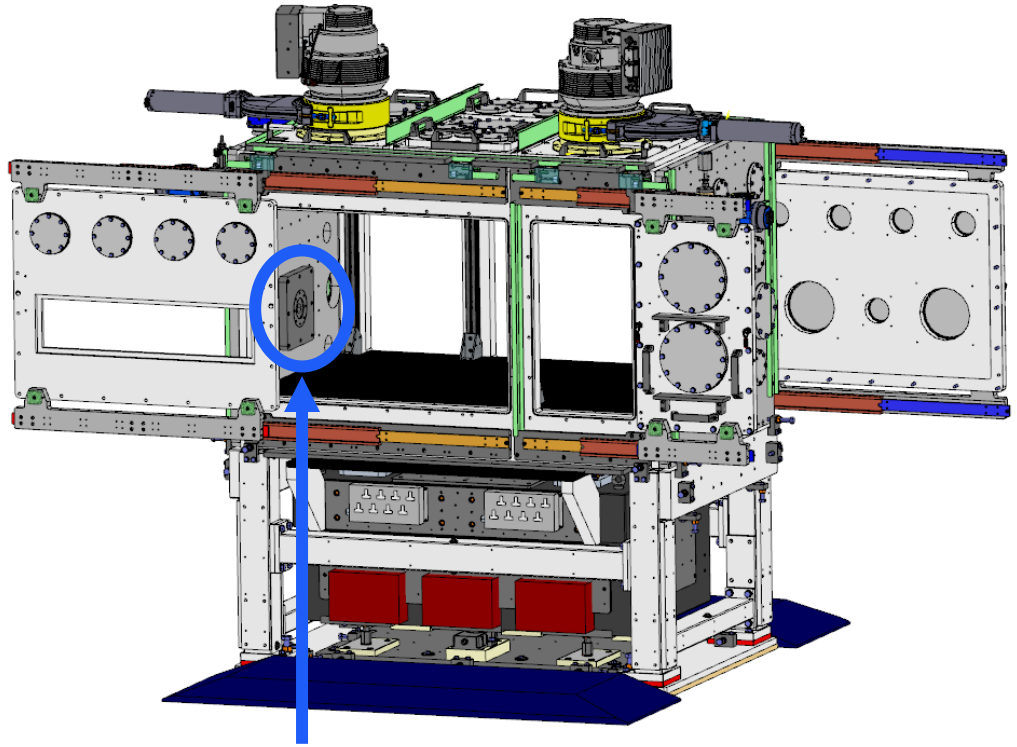
Parameter	High charge	Low charge
Energy [MeV]	250	250
Charge [pC]	250	5
RMS t [fs]	100	50
σ_E/E [%]	<5	<1
RMS x [μm]	100	20
RMS y [μm]	100	20
ε_N x [μm]	5	2
ε_N y [μm]	5	2

These parameters are for short bunches.

As longitudinally compressed bunches will not be required for VHEE/FLASH, emittance will be reduced.

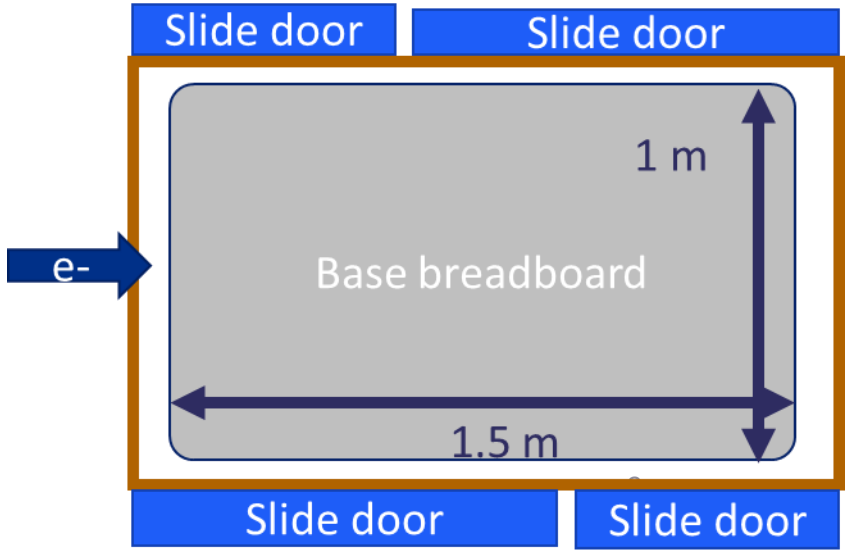
In-Air Experiments

- Experiments can be performed in air in either FEC1 or FEC2
- There is an operational *preference* for FEC2 so that beam scatter and excess radiation is delivered to FEH back wall and not to other components
  - If required by beam parameters, FEC1 can be used
- There is an ICT before FEC2, providing on-shot absolute charge measurement for irradiation experiments



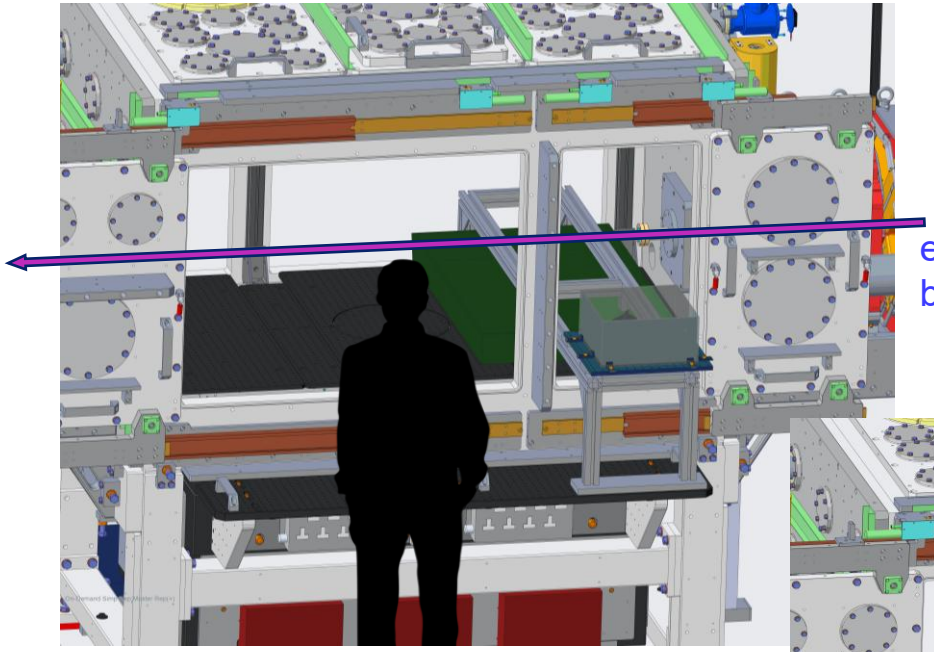
Internal flange mount for vacuum isolation window

FEC1&2 Plan view – sectioned on beam axis

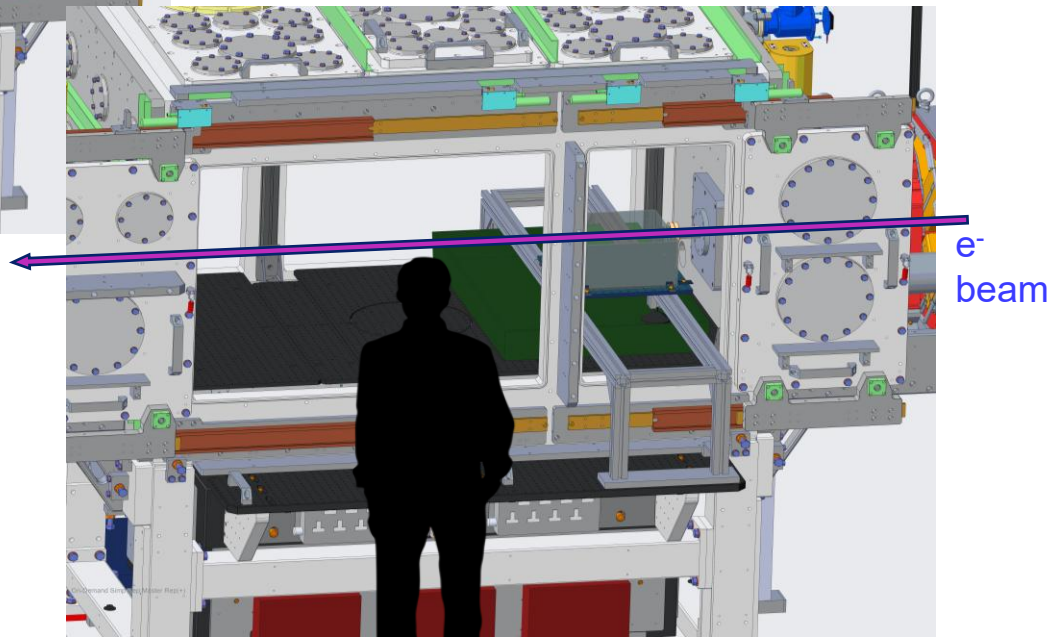


VHEE25 Experiments in-air

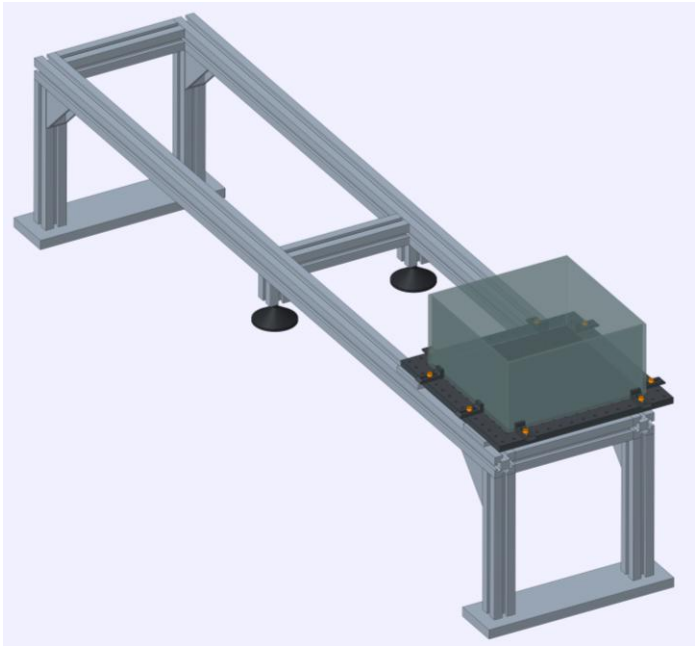
FEC1 and/or FEC2 chambers.



View from FEBE North side with breadboard in '**slid out**' position

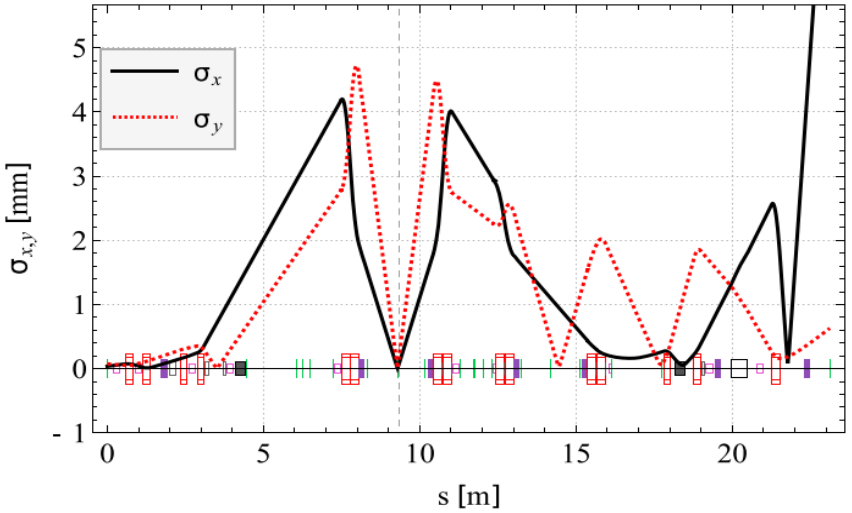


View from FEBE North side with breadboard in '**slid in**' position

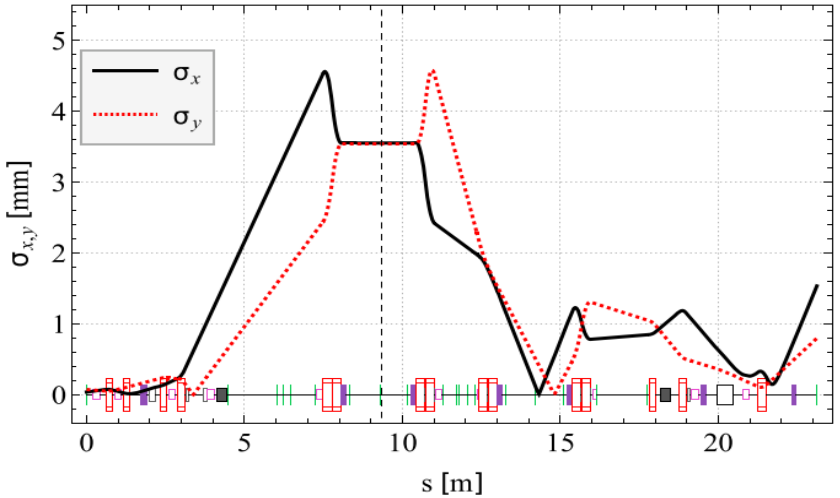


- Aluminium frame sits on exterior chamber shelves.
- Optical breadboard on sliders
- Can set 'Slid-in' position in middle of chamber, 'Slid-out' position clears doors for easy access.
- Low bund sits inside chamber for experiments with water phantom.

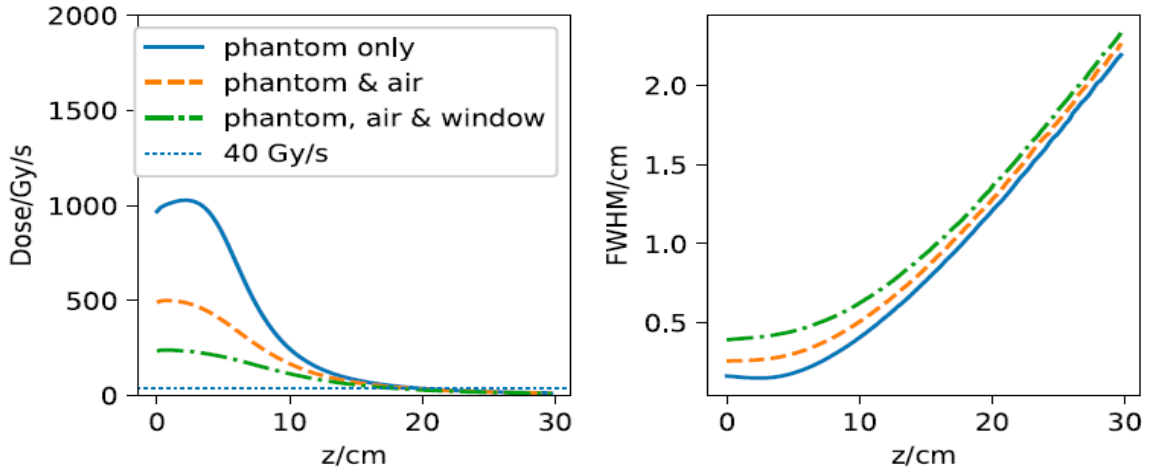
FLASH doses at CLARA



Transverse beam sizes for a focused beam at IP1 in FEC1 *in vacuo*.

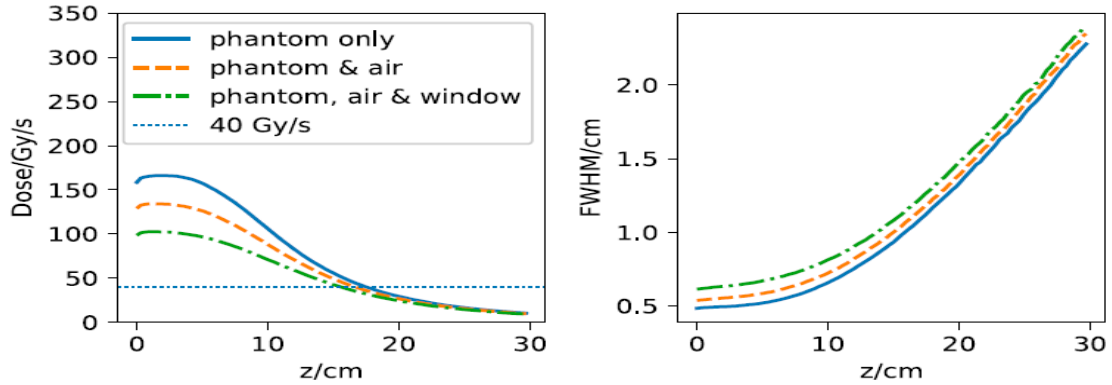


Transverse beam sizes for a pencil beam at IP1 in FEC1 *in vacuo*.



Be window 500-µm

Axial dose distribution for focused beam. FWHM at half maximum dose of the focused beam distribution as a function of depth in the water phantom.



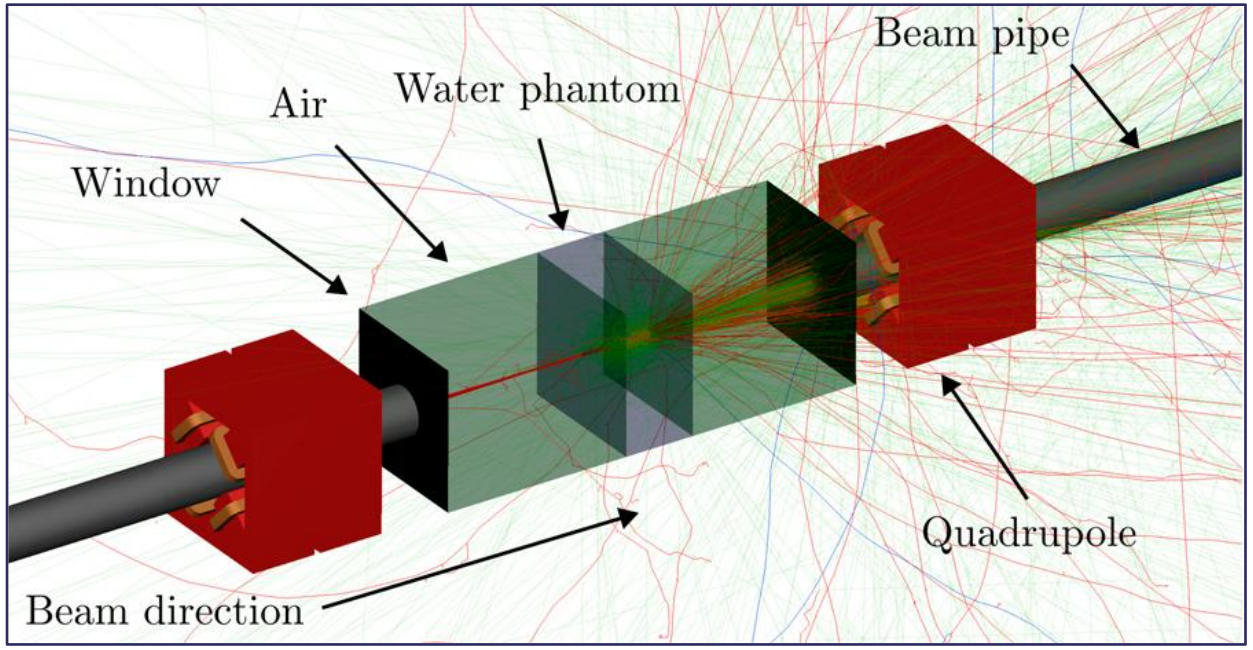
Be window 500-µm

Axial dose distribution for pencil beam. FWHM at half maximum dose of the pencil beam distribution as a function of depth in the water phantom.

Angal-Kalinin D, Boogert S and Jones JK (2024) Potential of the CLARA test facility for VHEE radiotherapy research. *Front. Phys.* 12:1496850. doi: 10.3389/fphy.2024.1496850

FLASH doses at CLARA

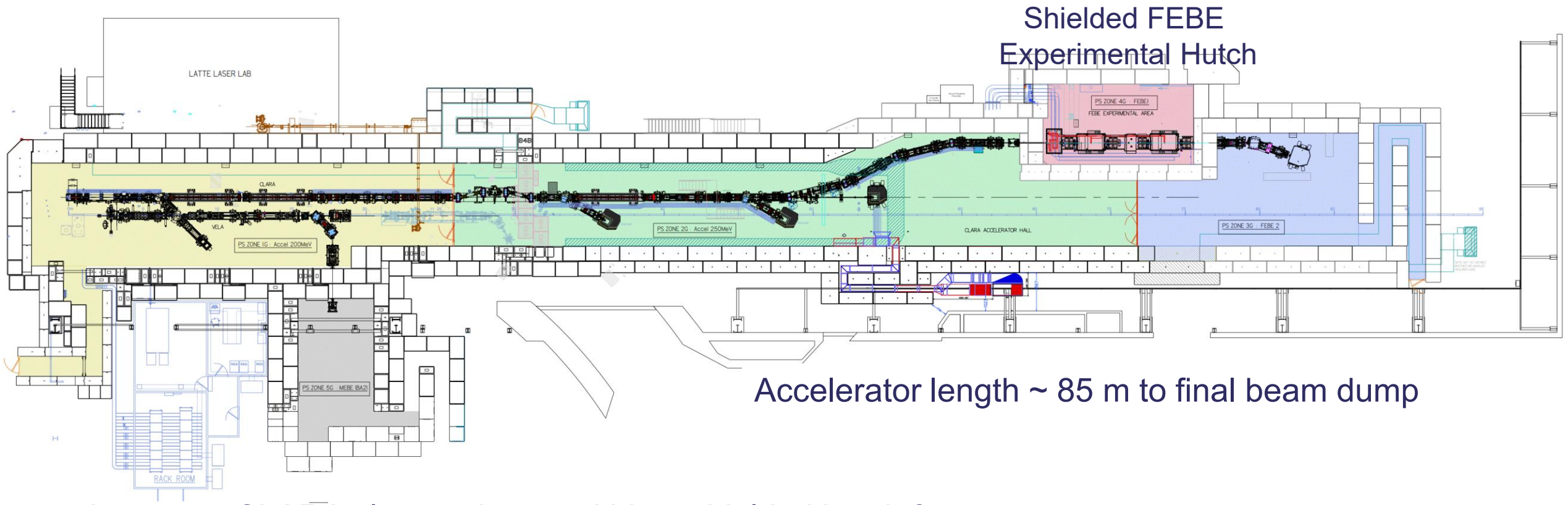
BDSIM/Geant4 visualisation region around the water phantom, including the quadrupoles before and after the experimental chamber FEC1.



- **Possible to deliver FLASH doses on CLARA.**
- Achieving a large dose uniformly over a large volume will either require a focus spot scanning system or a scattering system.
- Further simulation work will prioritise improved focussing models and enhancements to enable more rapid optimisation of other potential operating modes for VHEE and FLASH operations.
- Need further studies to explore spatio-temporal dose rate distribution.

Angal-Kalinin D, Boogert S and Jones JK (2024) Potential of the CLARA test facility for VHEE radiotherapy research. *Front. Phys.* 12:1496850. doi: 10.3389/fphy.2024.1496850

CLARA- As you will see this afternoon!



- Access to CLARA electron beam within a shielded hutch for users.
- The hutch can be accessed whilst the accelerator is operating (and FEBE beamline magnets off), enabling users to set up their experiments and access the hutch during experiment without switching off the accelerator.
  - Beam stability and fast turn around.

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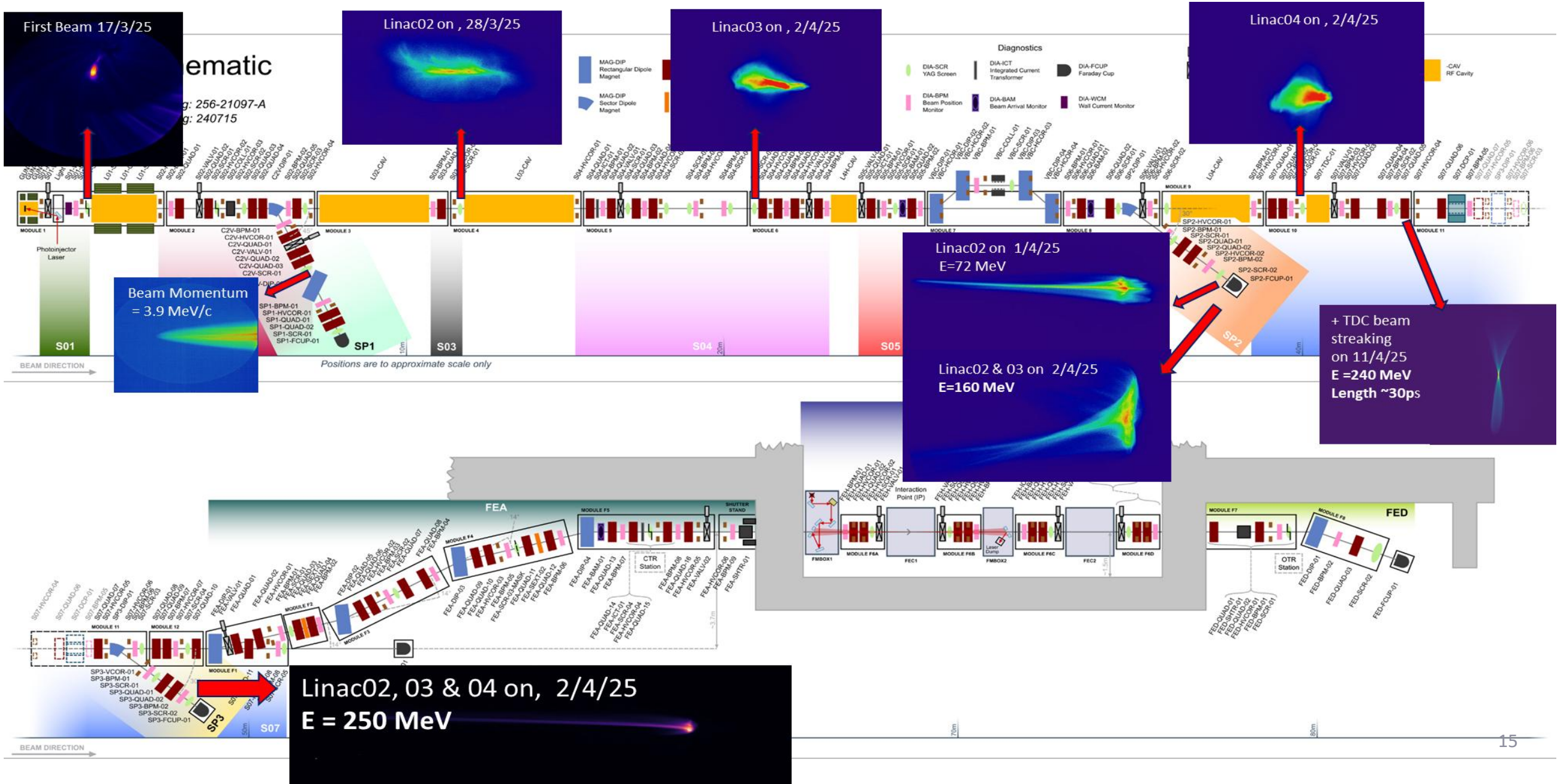
CLARA: Current Status

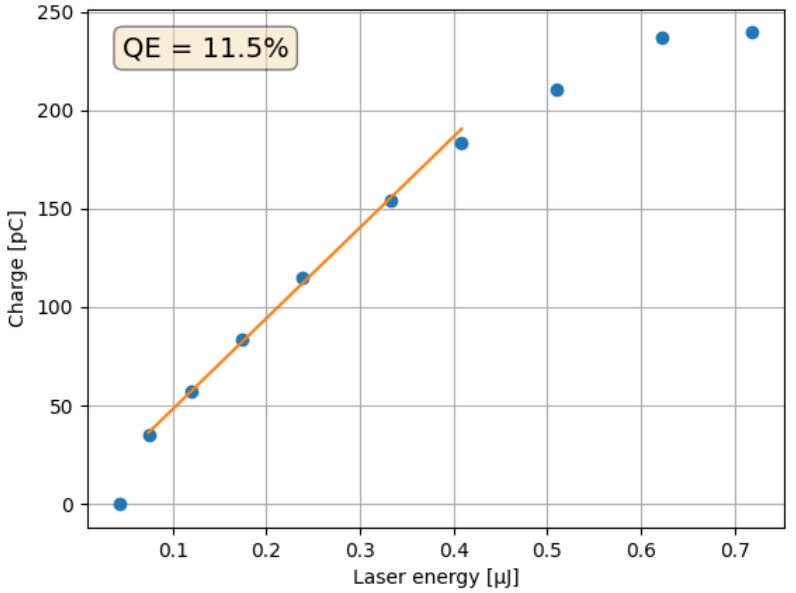
250 MeV at 100 Hz, 50 pC, Copper photocathode



Photocathode change from Cu to CsTe (Sep 25)

- Copper photocathode was recently replaced with CsTe photocathode.
- Laser transport was designed and modified to address expected QE increase.
- Increase in QE from Cu Photocathode ~ 10^{-5} to ~ 12 x 10^{-2}
  - Can achieve bunch charge of 250 pC with very low laser energy.
  - Lot of headroom to deliver 250 pC over operational period.

- Dark current lower than Copper photocathode and expect to reduce over time.
  - Most of the dark current is removed by first collimator, so expect there will be no or very small amount of dark current in FEBE.



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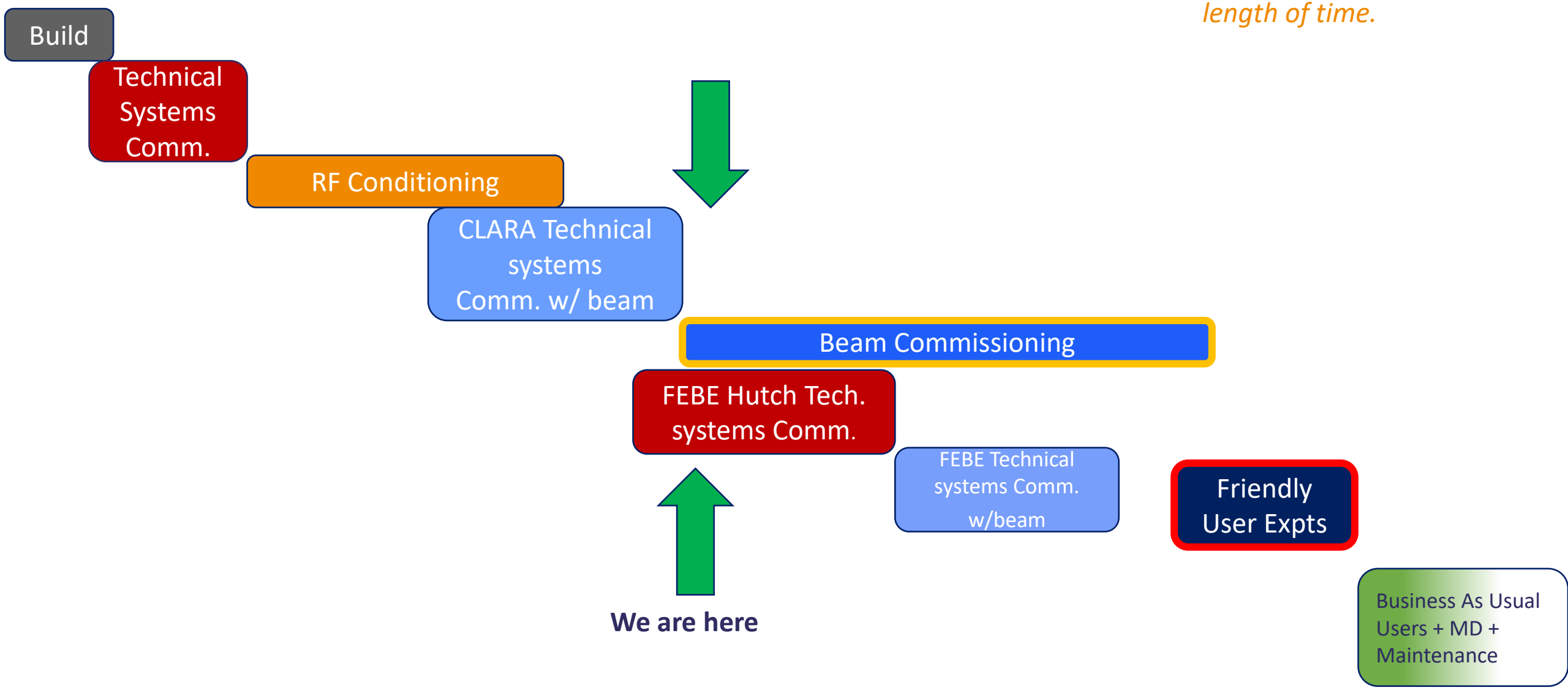
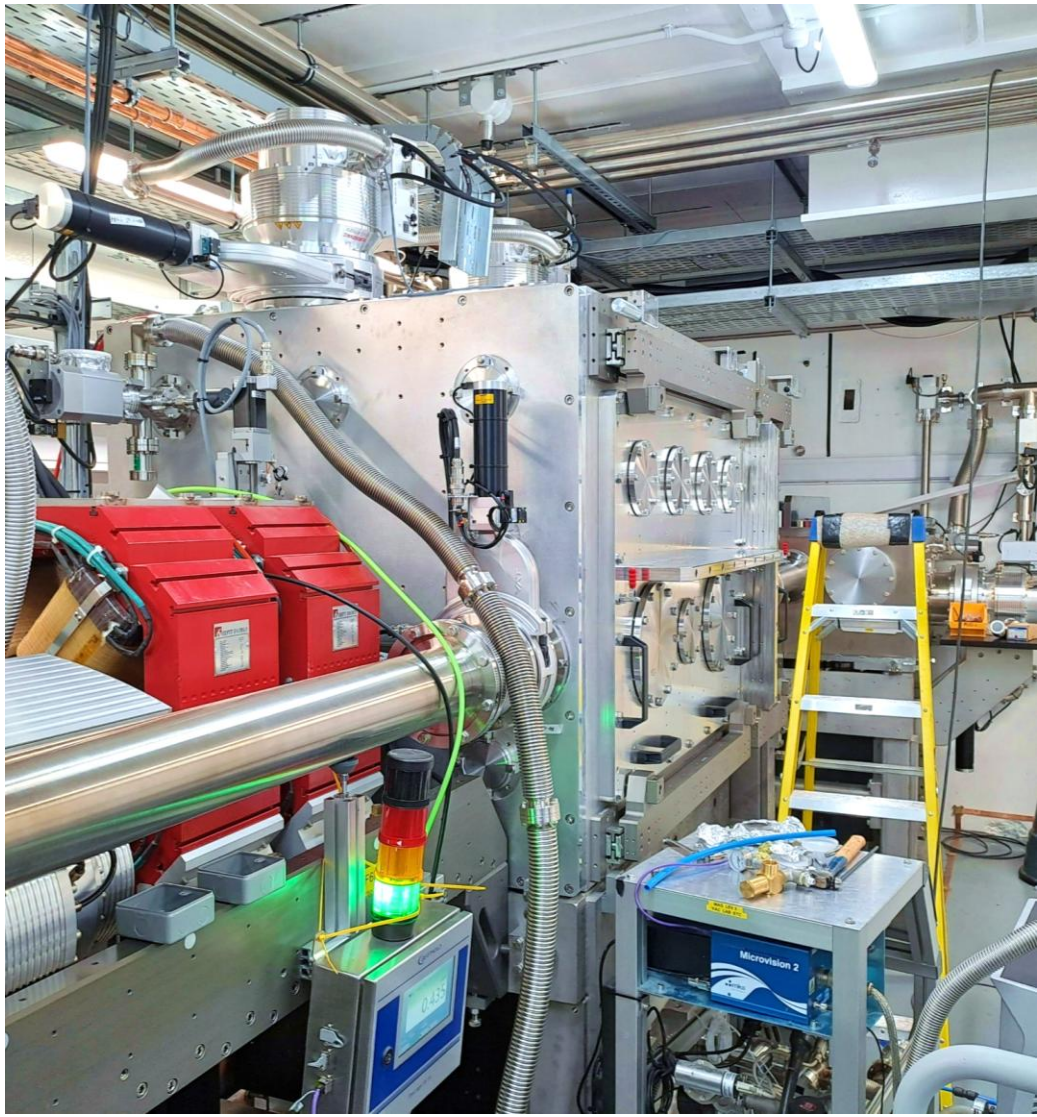
Where are we now?

NB this is a topographically transformed Gantt chart; box size does not indicate length of time.



Next steps for FEBE Commissioning

- FEBE Arc + Dump fully installed and commissioned
- Technical systems commissioning is currently progressing in the hutch
- FEBE 120 TW Laser has been installed.
  - Targeting SAT Completion Q3 25
- Targeting first electron beam threading through FEBE – early October 25



Outlook

- CLARA will transition next year into fully operational user facility.
  - First friendly user experiments likely to be in February/March 2026.
  - Open user call will be issued sometime in 2026 and then on a regular basis.
  - Beamtime Access Panel will assess the proposals for scientific excellence based on technical assessment.

- Arrangements for change to operational facility including web-based beam time call process, defining clear roles and responsibilities etc are currently being actively addressed.

- It is possible to achieve FLASH dose rates at CLARA. Delivery of uniform dose delivery or spot scanning options need further exploration.

Summary

- There is a huge potential to exploit the full flexibility and performance of the CLARA Beam & the FEBE Hutch.
- CLARA has achieved design beam energy (250 MeV), bunch charge (250 pC) and rep rate (100 Hz) and beam threading through the FEBE hutch is planned in October 2025.
- We will build up the complexity of experiments we can support.
- Please work with us and discuss with us throughout the proposal call and experiment process.
- Contact: thomas.pacey@stfc.ac.uk; deepa.angal-kalinin@stfc.ac.uk

Thank you for listening

Any Questions?