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# Key FEBE parameters and diagrams

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Illustrative purposes only.
For development of experimental sketches.

ASTeC, TD
Daresbury Laboratory

Provided in advance of 4th CLARA User Meeting, November 2024

# Purpose of slides

- Top level parameters and dimensions for producing experimental sketches and rough methodologies
- Prospective Users are highly encouraged to engage with ASTeC staff and the CLARA team:
  - Before proposal calls; to help develop sketches and answer questions
  - During proposal calls; to help develop proposals and ensure technical feasibility
- Before and during calls we will endeavour to collect common questions and provide updated information as fast as reasonable.
- During the initial CLARA and FEBE commissioning period please allow for additional time for the team to respond. Our capacity for engagement will be limited during this first period.

# Contents



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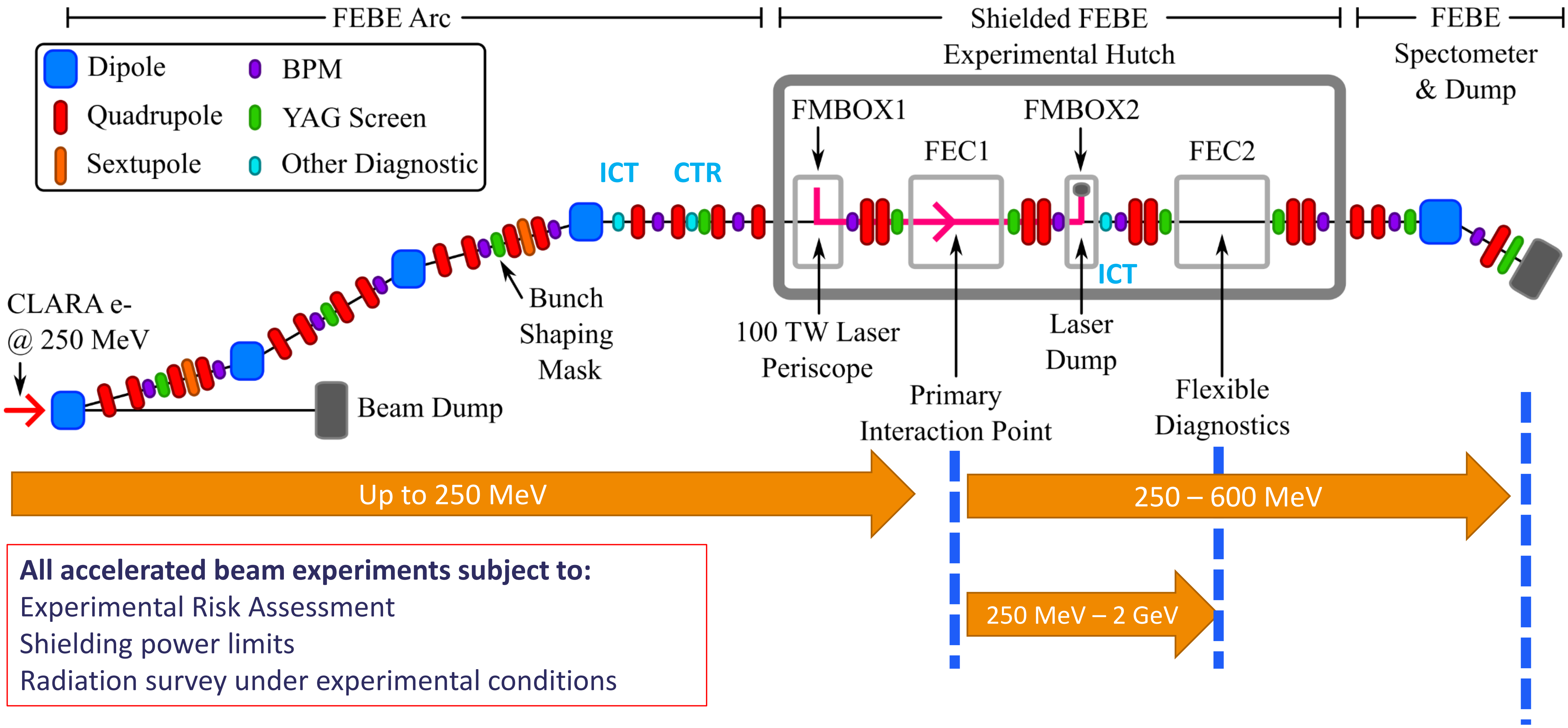
# FEBE Beamline & Energy Sectors




**All accelerated beam experiments subject to:**
Experimental Risk Assessment
Shielding power limits
Radiation survey under experimental conditions

Further detail on FEBE beamline design can be found in
Snedden, E. W., et al. *"Specification and design for full energy beam exploitation of the compact linear accelerator for research and applications."* PRAB 27.4 (2024): 041602.
https://doi.org/10.1103/PhysRevAccelBeams.27.041602

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# FEBE Hutch and Experiment Chambers

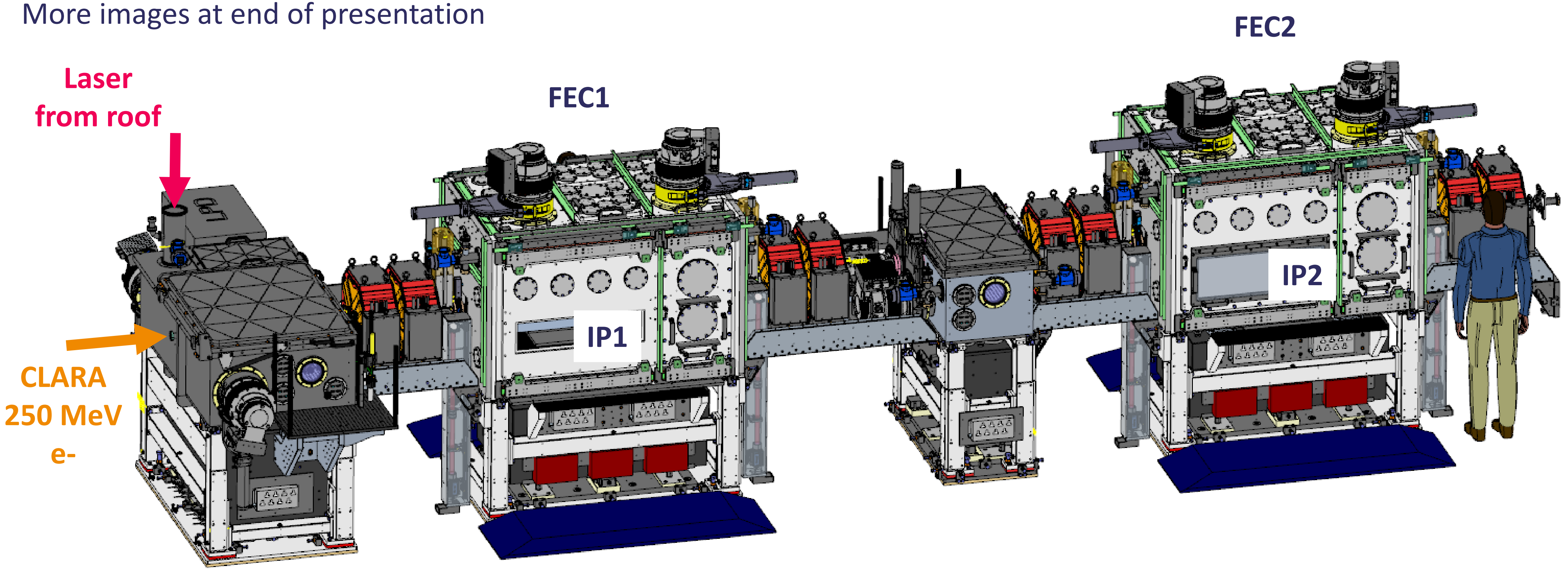
# FEBE Hutch Beamline:

**viewed on orientation similar to previous schematic**

FEC = FEBE Experiment Chamber

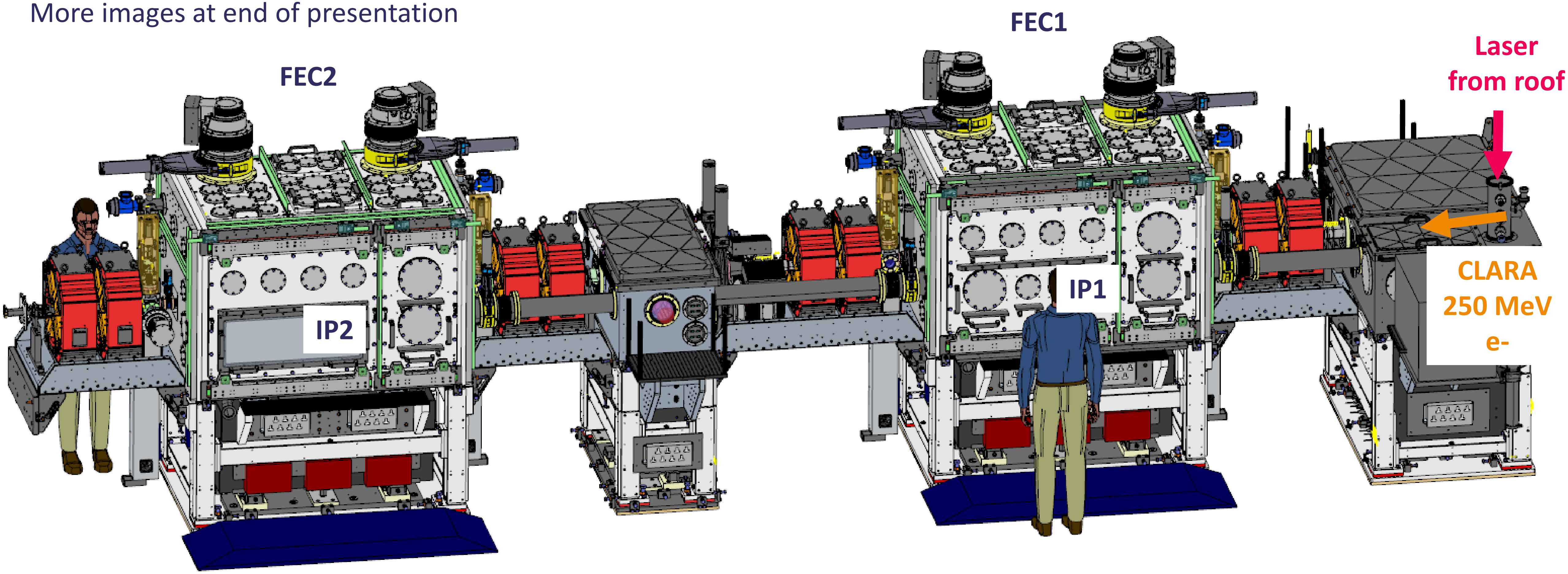
IP = Interaction Point (e- foci)

More images at end of presentation



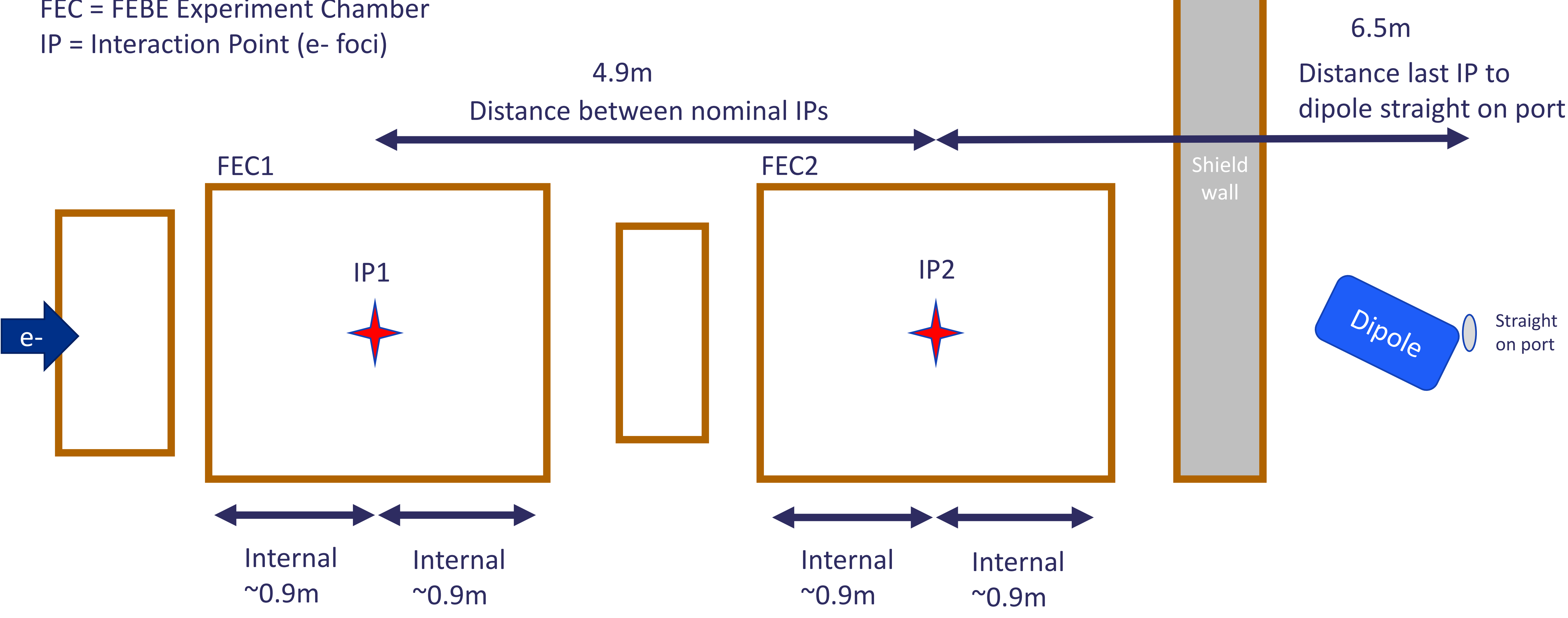
# FEBE Hutch – Viewed as one enters

FEC = FEBE Experiment Chamber
IP = Interaction Point (e- foci)
More images at end of presentation



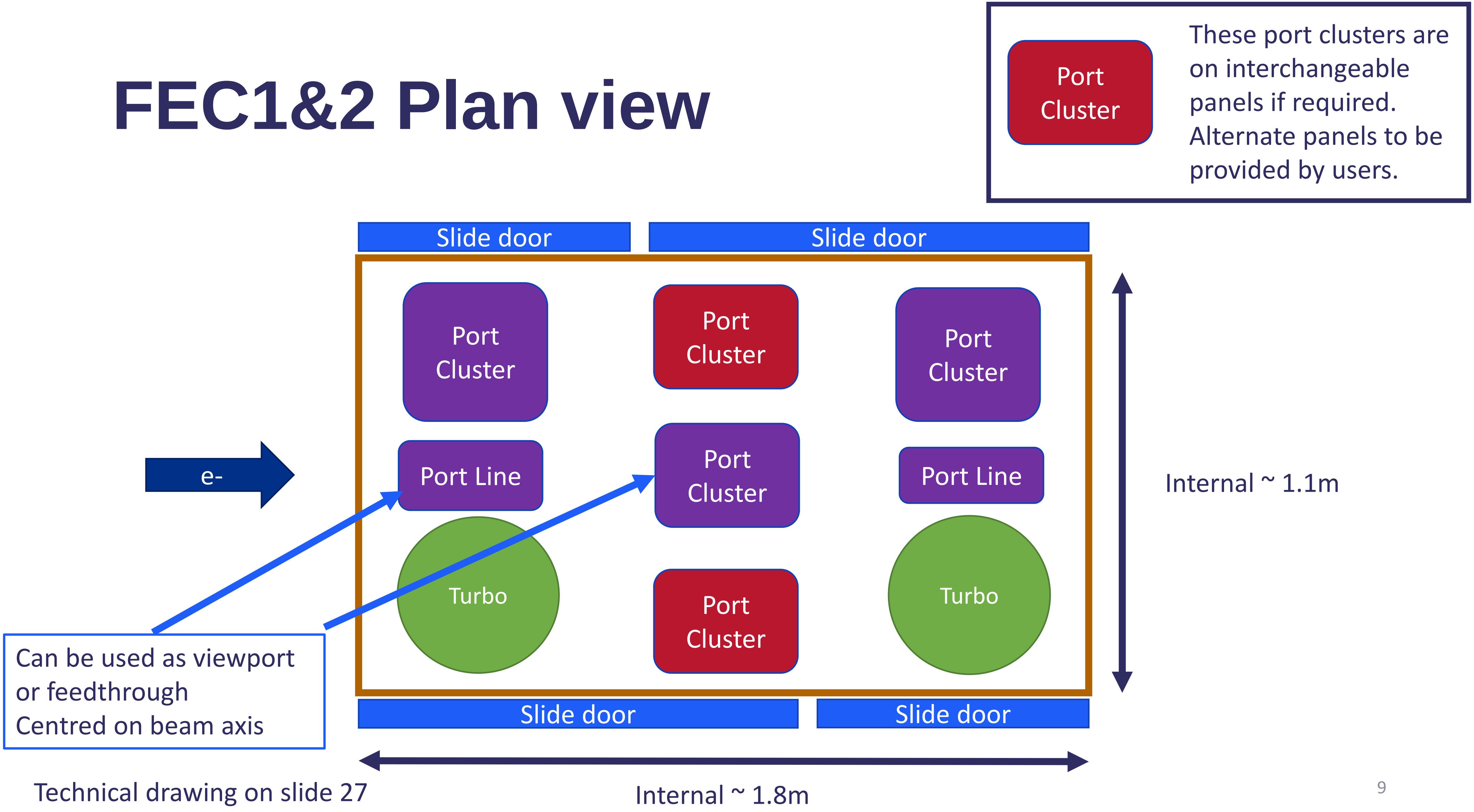
# FEBE Hutch Plan

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



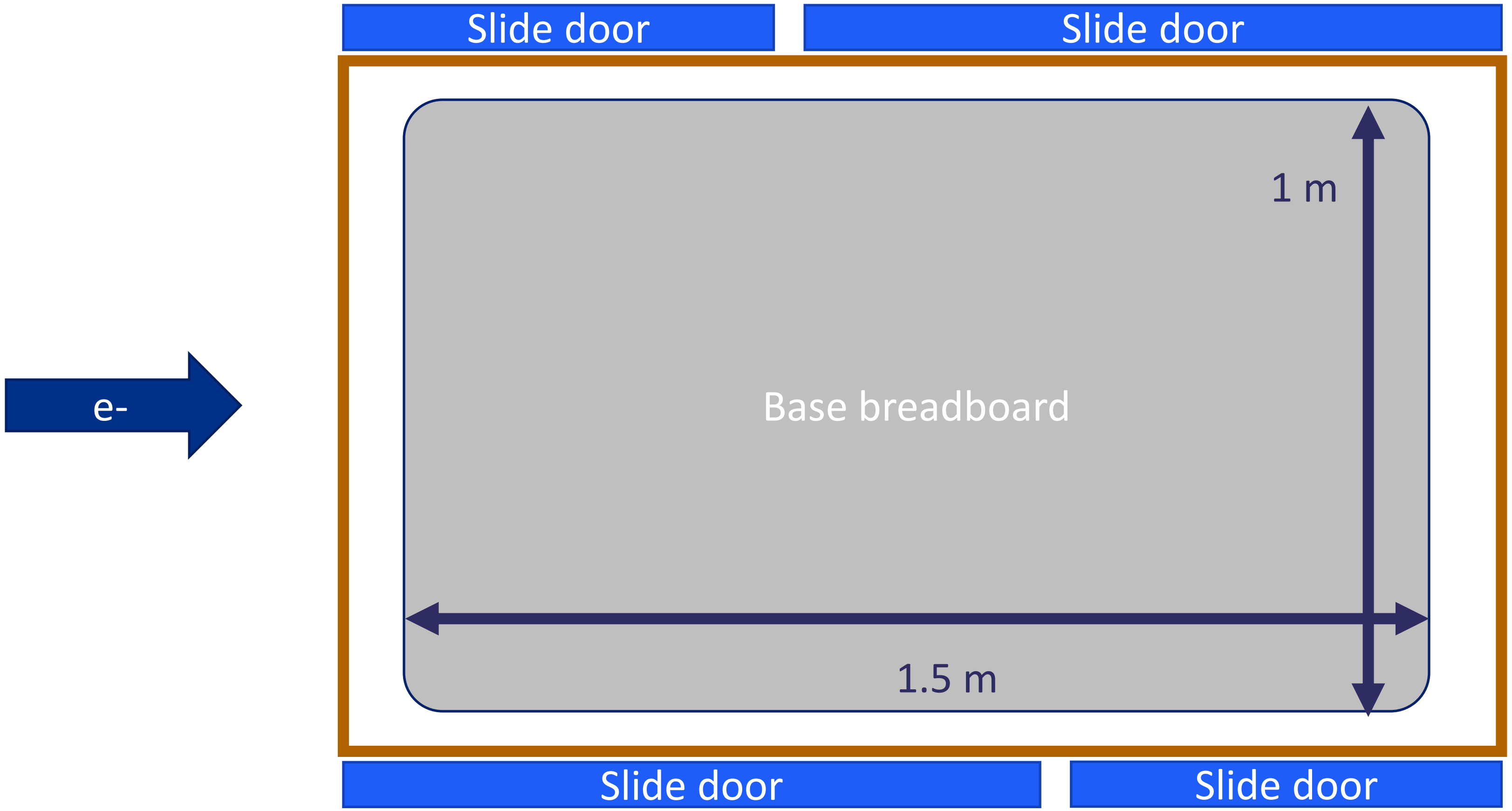

Technical drawing on slide 21

# FEC1&2 Plan view



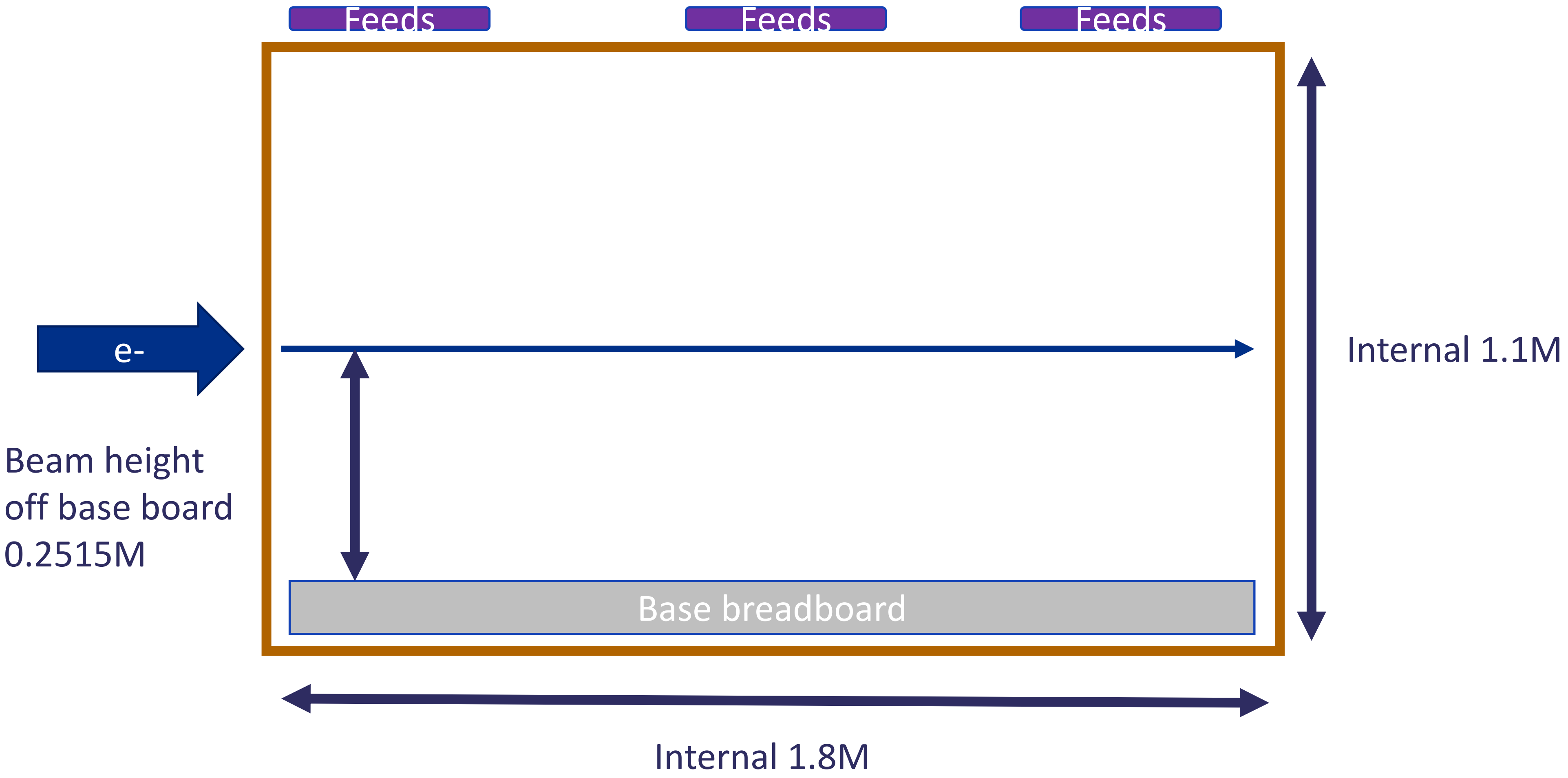

Technical drawing on slide 27

# FEC1&2 Plan view – sectioned on beam axis




Technical drawing on slide 28

# FEC1&2 Side, sectioned on beam axis

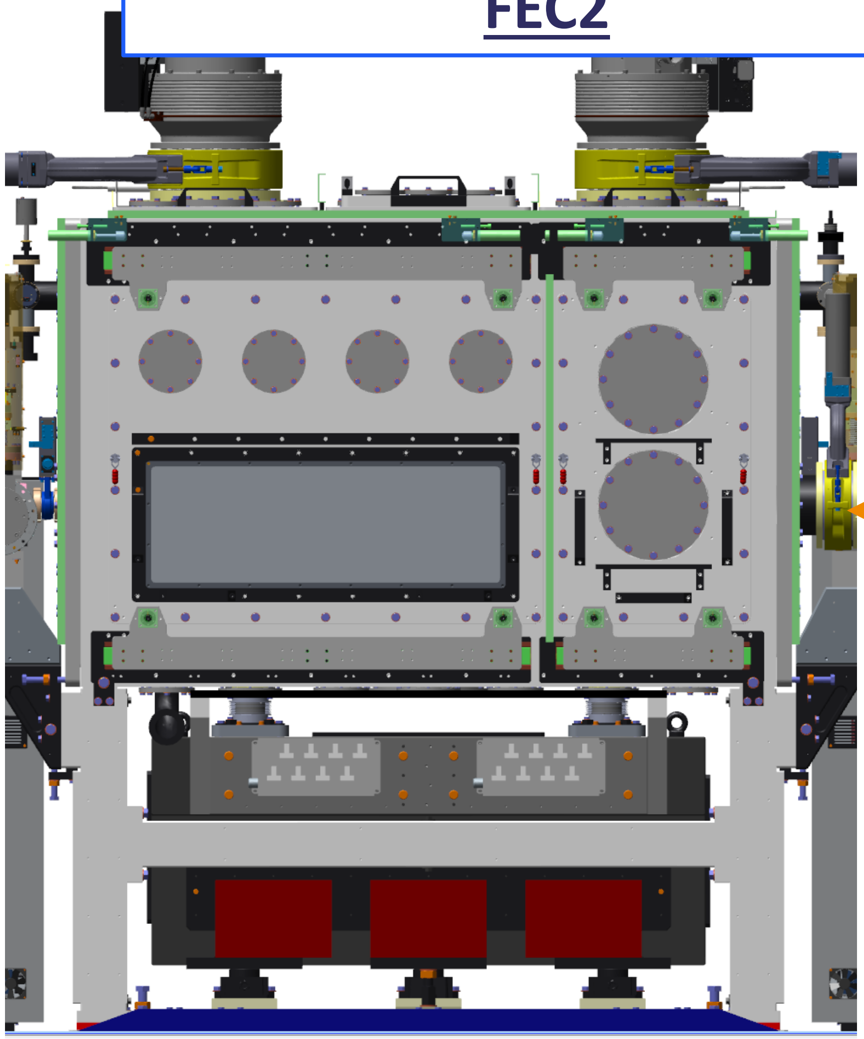



Technical drawing on slide 28

# FEC Chamber Doors

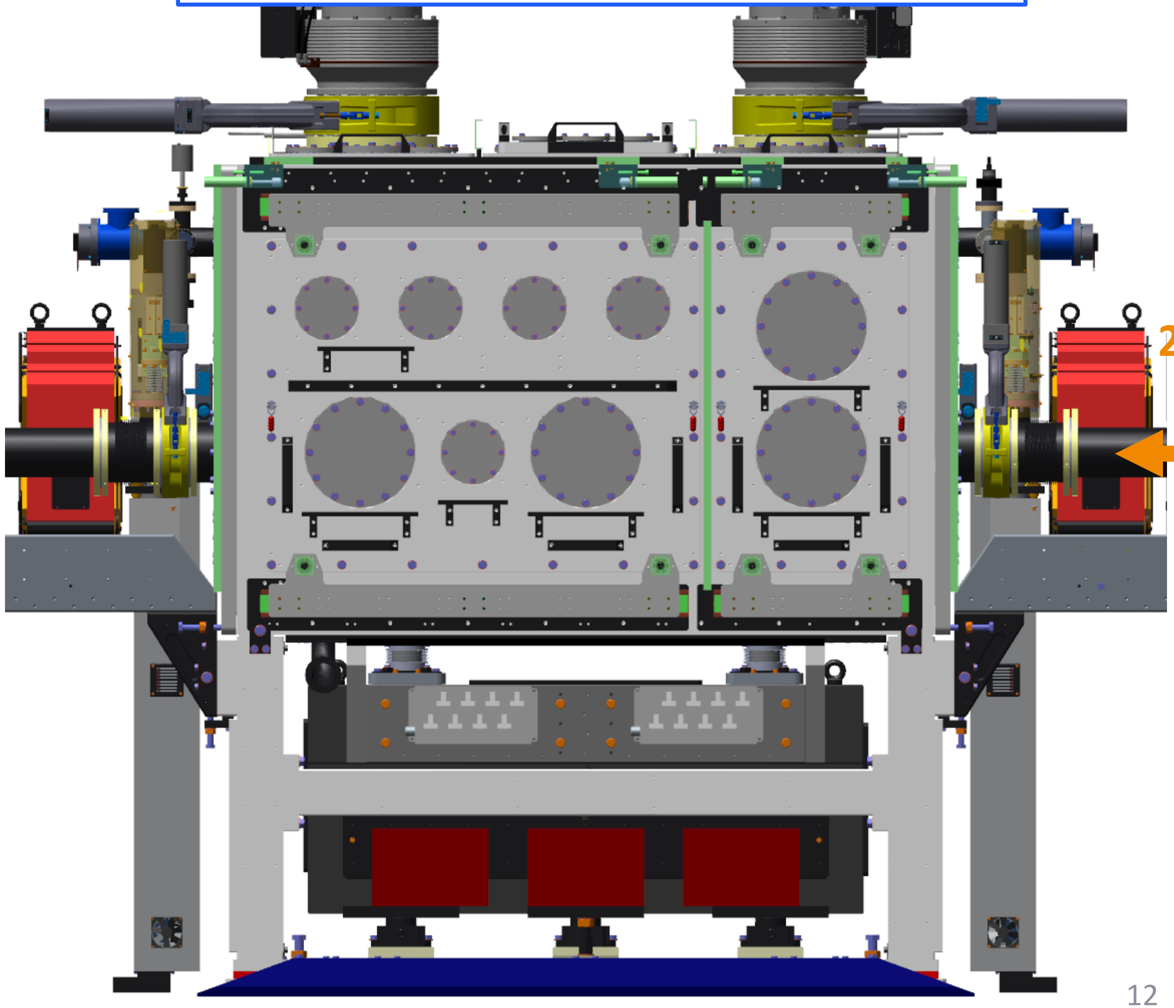
Design for FEC2 large doors to be confirmed. Circular ports all ISO flanges

**FEC2**



CLARA
250 MeV
e-

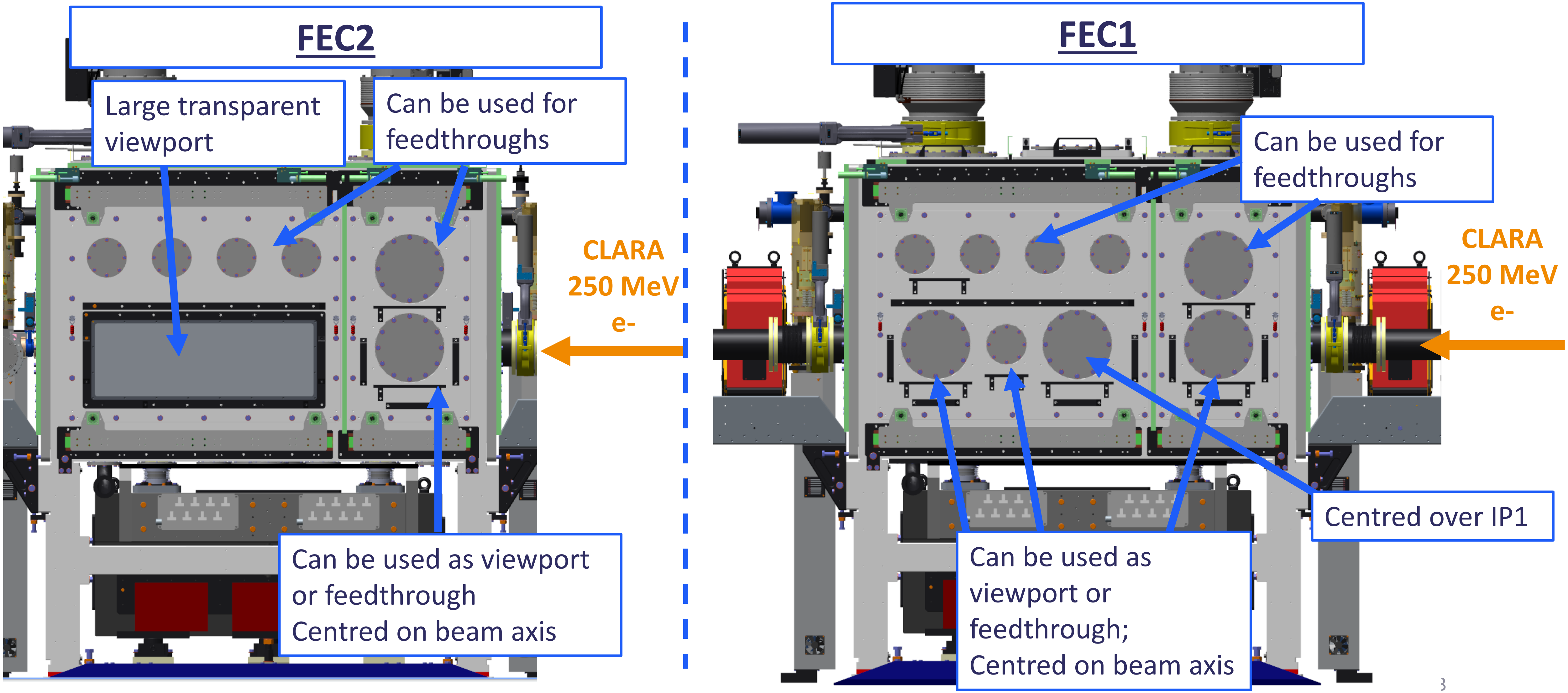
**FEC1**



CLARA
250 MeV
e-

# FEC Chamber Doors Annotated

Design for FEC2 large doors To be confirmed. Circular ports all ISO flanges



# Notes on chambers

- Doors will be on ½ - 2/3 split as shown, and slide open.
  - A clear access path to the centre of the chamber is possible from either side.
- Additional space is availible on the ‘north side’ of the chambers for tables and other breadboards
  - See Slide 23
- The final of design of the doors with large rectangular viewports is TBC
- Viewport over IP1 or 2 (both) is possible from the top
- Turbo pump locations cannot be changed
- Differential pumping apertures not shown. For experiments with high gas load these may be required.
  - A conceptual design has been prepared.
- Experiments can be performed in air in either FEC1 or 2
  - 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
  - There is an ICT before FEC2, providing on-shot charge measurement for irradiation experiments
- Gas delivery will be possible to FEC1 , from a manifold outside of the hutch
  - We will be able to deliver: hydrogen, inerts, and premixed cylinders
  - All gas delivery parameters subject to vacuum limitations and in-situ experimental verification of pumping performance. Specific limits will vary based on the geometry of gas target used.

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# Electron Beam Delivery

# Day 1 Electron Beam Parameters

To be delivered at either FEC1 or FEC2 IP

| Parameter | High charge | Low charge |
|---|---|---|
| Energy [MeV] | 250 | 250 |
| Charge [pC] | 250 | 5 |
| RMS t [fs] | 100 | 50 |
| $\sigma_E/E$ [%] | <5 | <1 |
| RMS x [μm] | 100 | 20 |
| RMS y [μm] | 100 | 20 |
| $\varepsilon_N$ x [μm] | 5 | 2 |
| $\varepsilon_N$ y [μm] | 5 | 2 |

*These parameters are for compressed beams. If compressed beam is not required, emittance will be reduced and transverse focus also reduced in size.*

Further detail on FEBE beam parameters can be found in
Snedden, E. W., et al. "*Specification and design for full energy beam exploitation of the compact linear accelerator for research and applications.*" PRAB 27.4 (2024): 041602.
https://doi.org/10.1103/PhysRevAccelBeams.27.041602

# Flexibility of Delivery: Electron Parameters

- Users must allow for beam time to tune to a beam setup when requesting time in a proposal
  - Especially for first run(s)
  - Please discuss any requests for setups with CLARA team in advance of proposal submission. We can advise an estimate of time required to tune, based on commissioning experience.
  - Over time our number of quickly repeatable setups will evolve and increase.
- We will strive to provide the beam most suited to experimental requirements; performance restrictions and time permitting.
- In order of easiest to tune away from a ‘working point’ machine setup:
- Electron focal position and size :
  - Focus can be moved up- or downstream in either FEC
  - This will compromise quality, best optics match is for IP1/2
  - Laser focus is always centre of FEC1 at IP1 for first run.
- Charge:
  - Can be varied between 5 and 250 pC
  - Tighter requirements on bunch length or size will require more tuning and optimisation time for a given charge
  - If no requirements on length, and with relaxed focusing requirements, charge is more readily tunable.
- Bunch Length and energy spread/chirp
  - These are both tunable, but initial setups will be at fixed working points
  - Delivering specific combinations of length or chirp will require dedicated modelling and setup time.

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# Laser Delivery

# FEBE laser system

- A commercial 120 TW peak power laser has been procured from Amplitude to deliver laser light to experiments at FEBE.
- Laser room is ISO7 clean environment directly above FEBE hutch.
- Laser is currently being installed with site acceptance testing planned for December 2024.
- Laser operates at 5 Hz, synchronised to the CLARA beam with option of 5/n Hz or single shot modes.
  - **It is anticipated that the first user run the laser will operate at 1Hz as the system performance and durability is assessed.**
- Two energy attenuators, compressor, DAZZLER & MAZZLER allow for control of laser properties of beam sent to FEBE hutch.

**FEBE laser room Oct 2024**

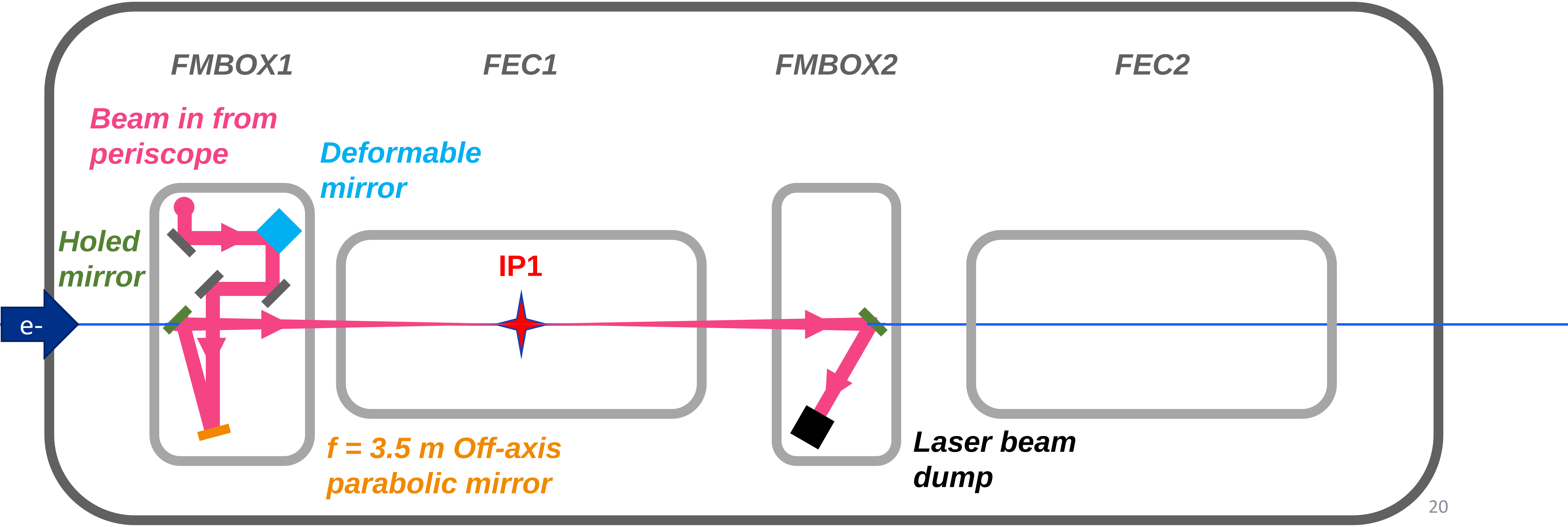
| At compressor exit | |
|---|---|
| wavelength | 807 nm |
| Peak Power | 122 TW |
| Energy | 2.8 J |
| $\tau_{FWHM}$ | 23 fs |
| Rep Rate | 5 Hz |
| $w_{FWHM}$ | 73 mm |
| Strehl ratio | 0.90 |
| Pointing stability | 3 µrad |
| Energy stability | 1% |

**Laser performance validated at Factory acceptance tests (July 2023)**

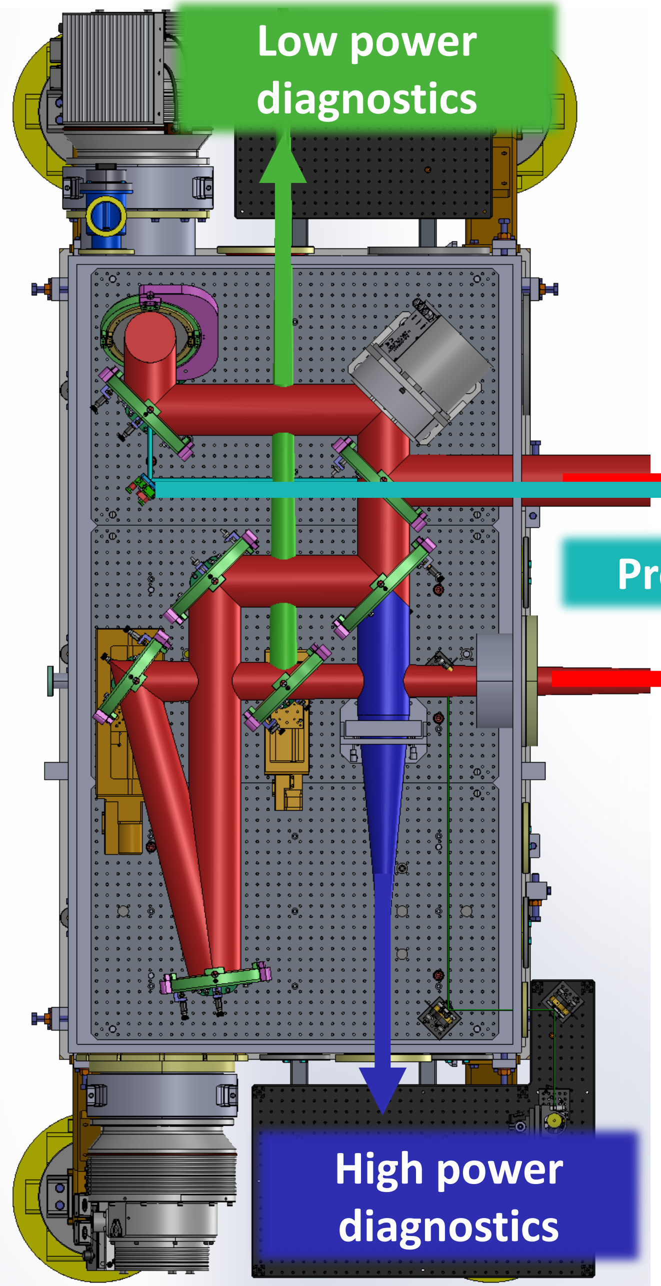
# FEBE laser delivery

- Nominal laser delivery brings laser into FEBE hutch from laser room via periscope, reflects off deformable mirror and OAP before being sent into FEC1 co-linear to electron beam.
- Laser is dumped in FMBOX2 however there is space for post-interaction diagnostics in the future.
- OAP has focal length of f = 3566 mm for estimated $\omega_0$ = 30 µm at IP1.
- Other laser geometries are possible.

Technical drawing on slide 28



# FEBE laser delivery




- Standard laser mode allows for co-propagation of laser to electron beam via f = 3566 mm OAP which focuses the beam at the centre of FEC1 (@ IP1).
- FMBOX1 has sets of standard “high-power” and “low-power” diagnostics including wavefront sensor to optimise laser focus.
- Deformable mirror available for optimising focus and to correct for hole in beam.

***The collimated pass-thru to FEC is not available for 1st user call***

*Estimated* laser parameters at IP1 taking into account transport losses from compressor to OAP and quasi-top hat beam shape.

| At IP1 | |
|---|---|
| Energy | 2.6 J |
| $\tau_{FWHM}$ | 23 fs |
| $\omega_0$ (radius) | 30 μm |
| $2Z_R$ | 7 mm |
| $I_{pk}$ | $8\times10^{18}$ $Wcm^{-2}$ |
| $a_0$ | 1.95 |

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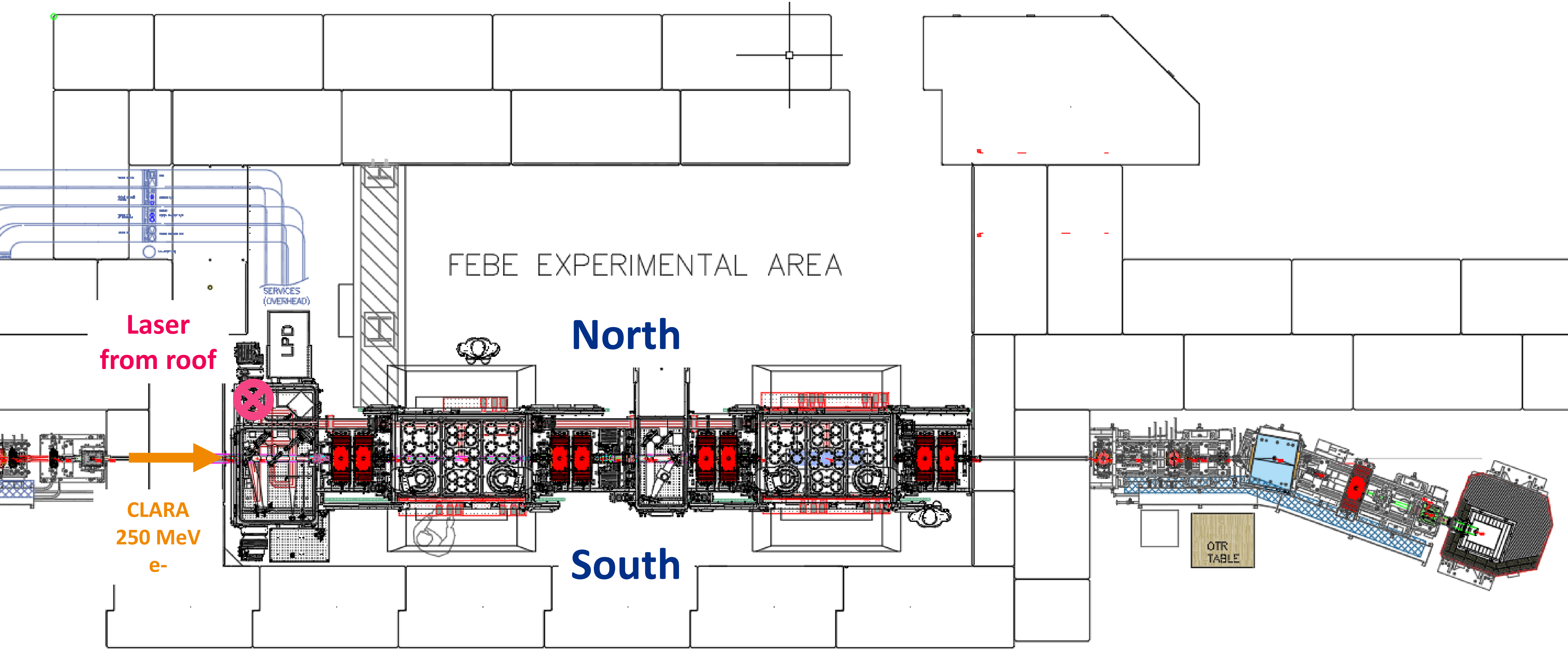
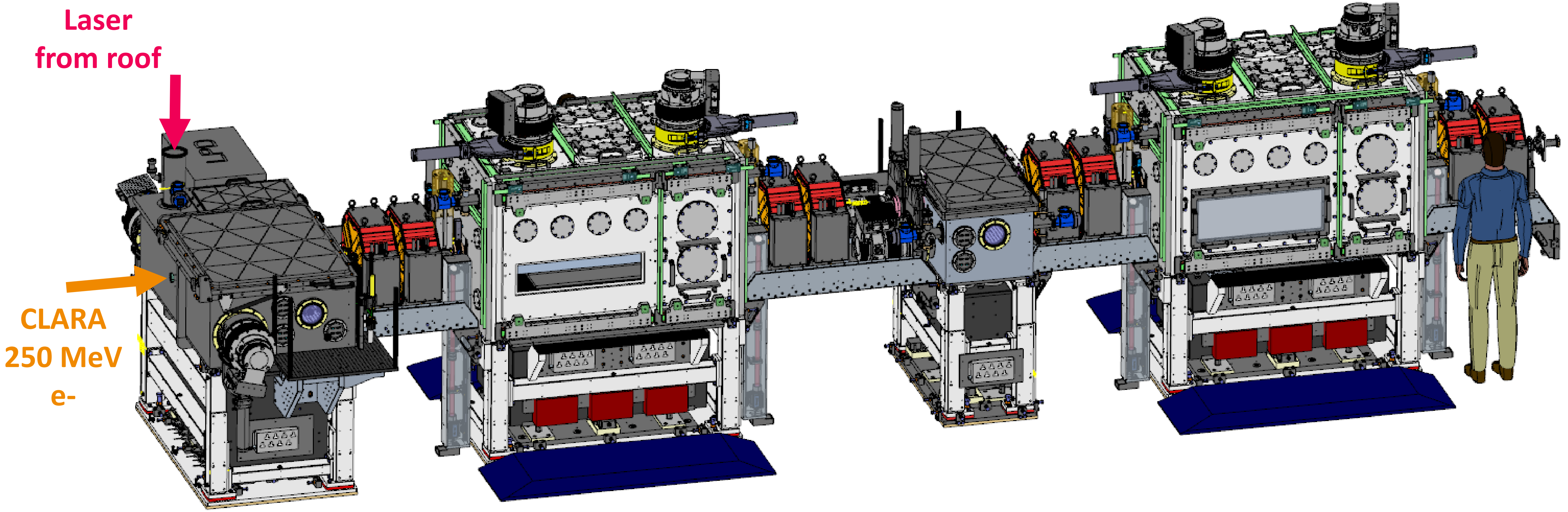
# Technical drawings

# 2D Plan View

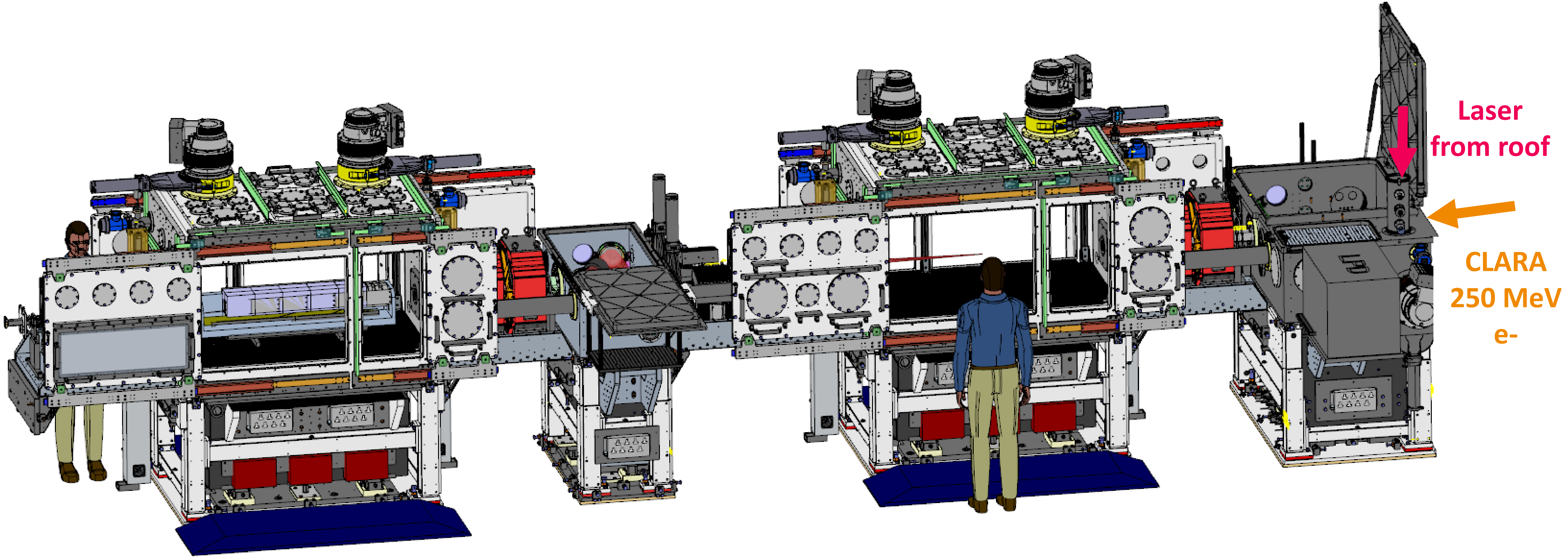
Dims



# View from South



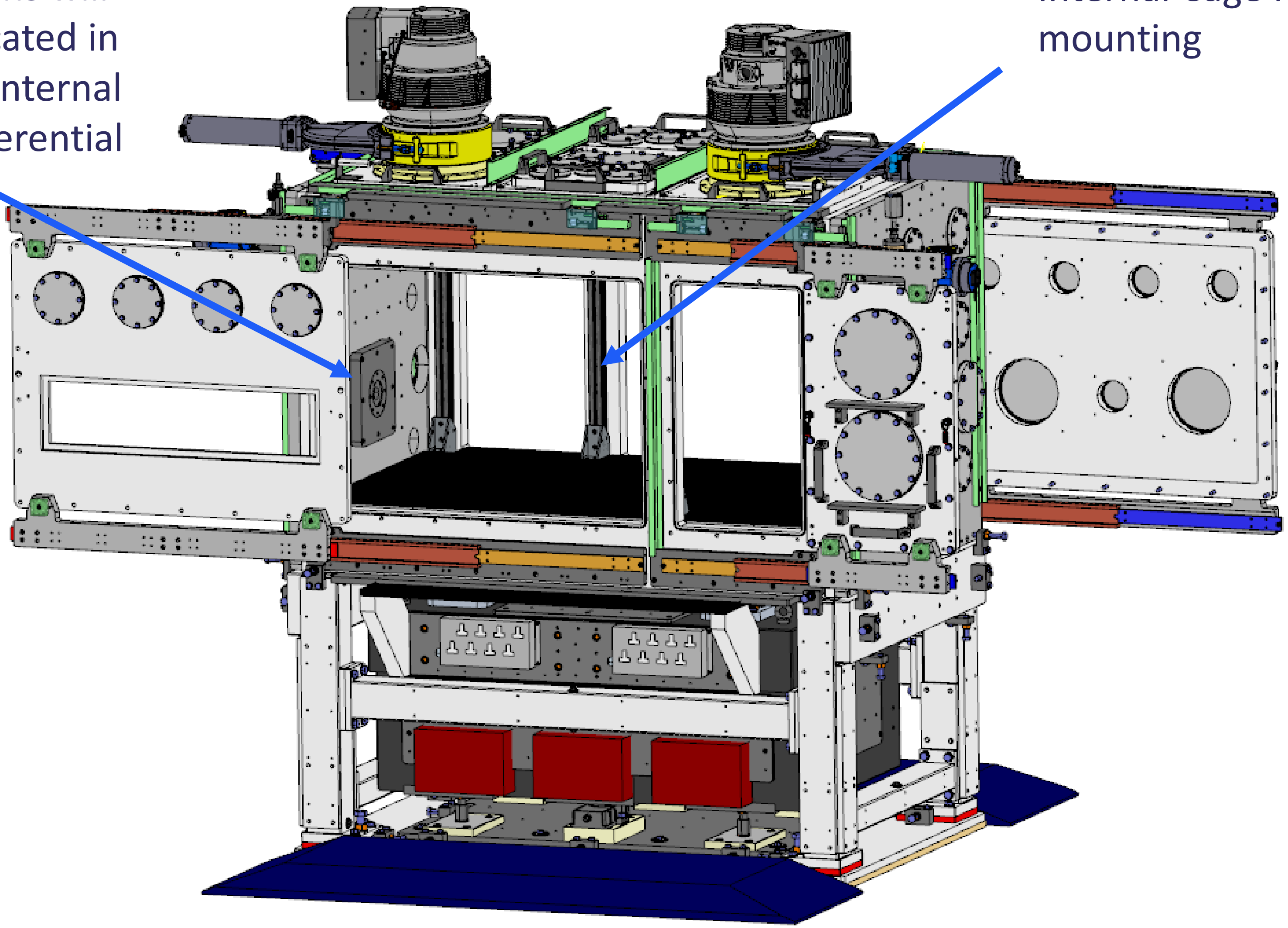
# View from North



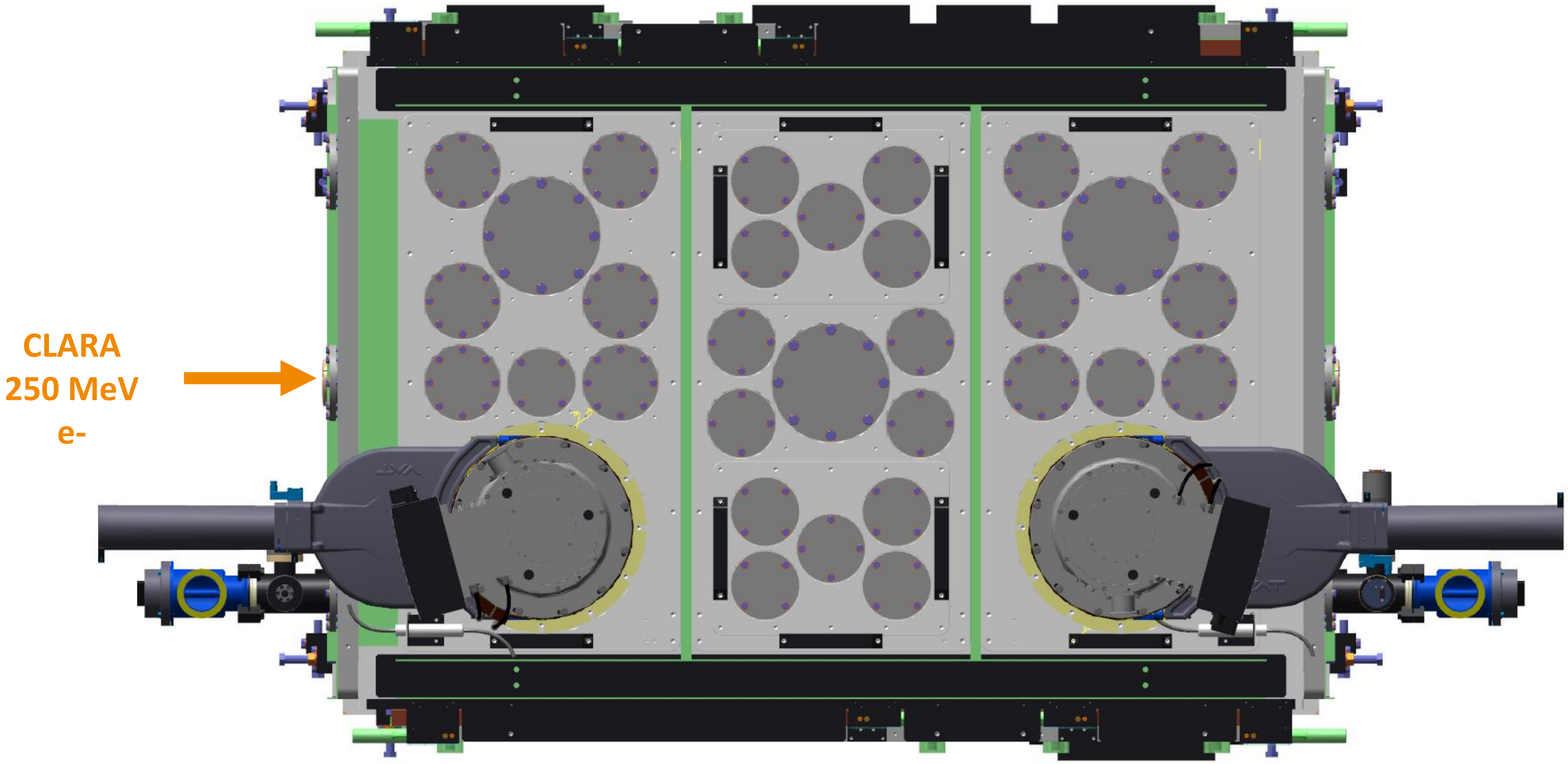
# FEC1- Some additional Details; view from south

Usable internal dimensions will be slightly less than indicated in slides above because of internal cage, end plates and differential pumping baffles.

Internal Cage for Experiment support mounting

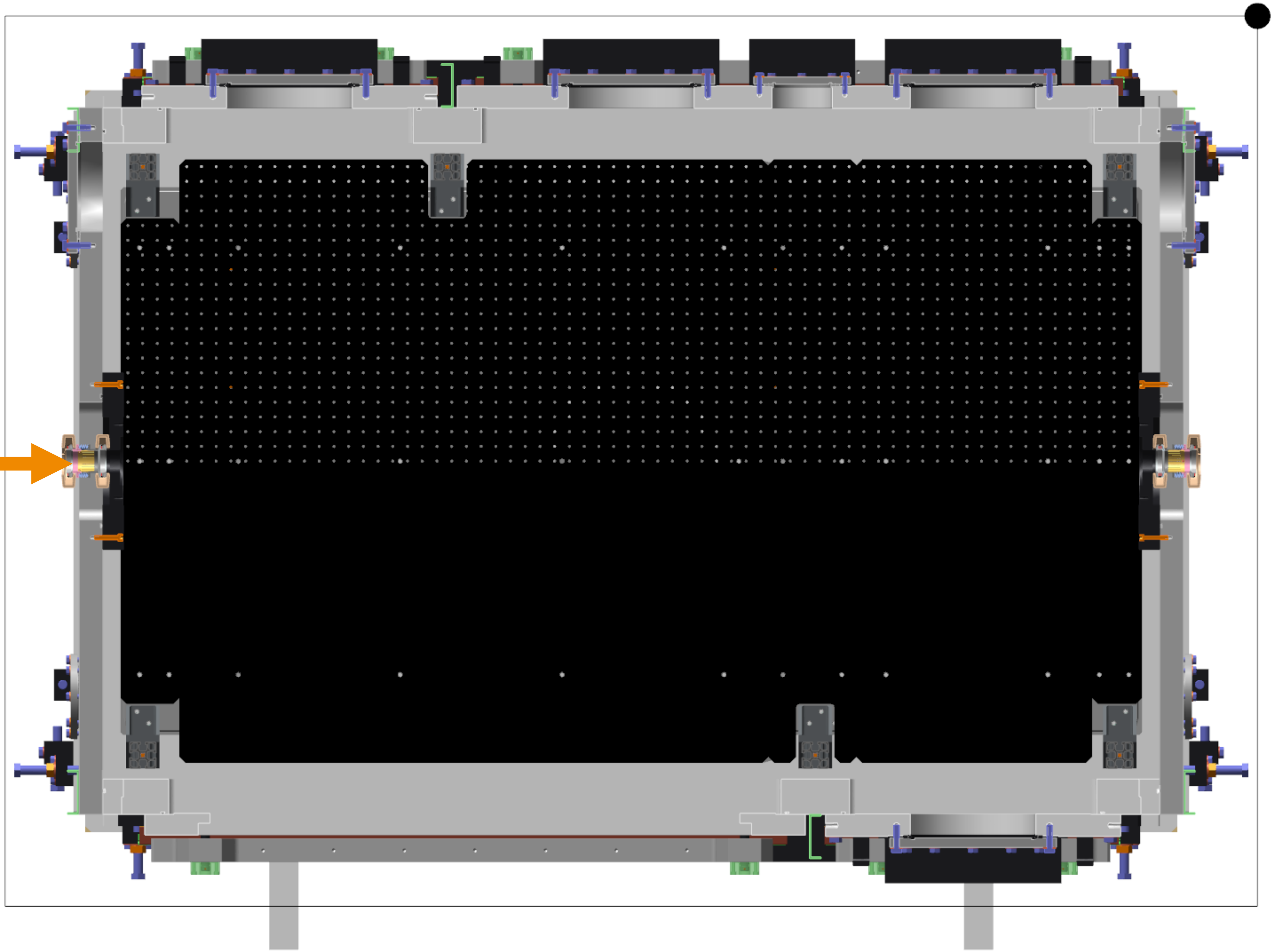


# FEC1 Top



# FEC1 Plan: Section on Beam Axis

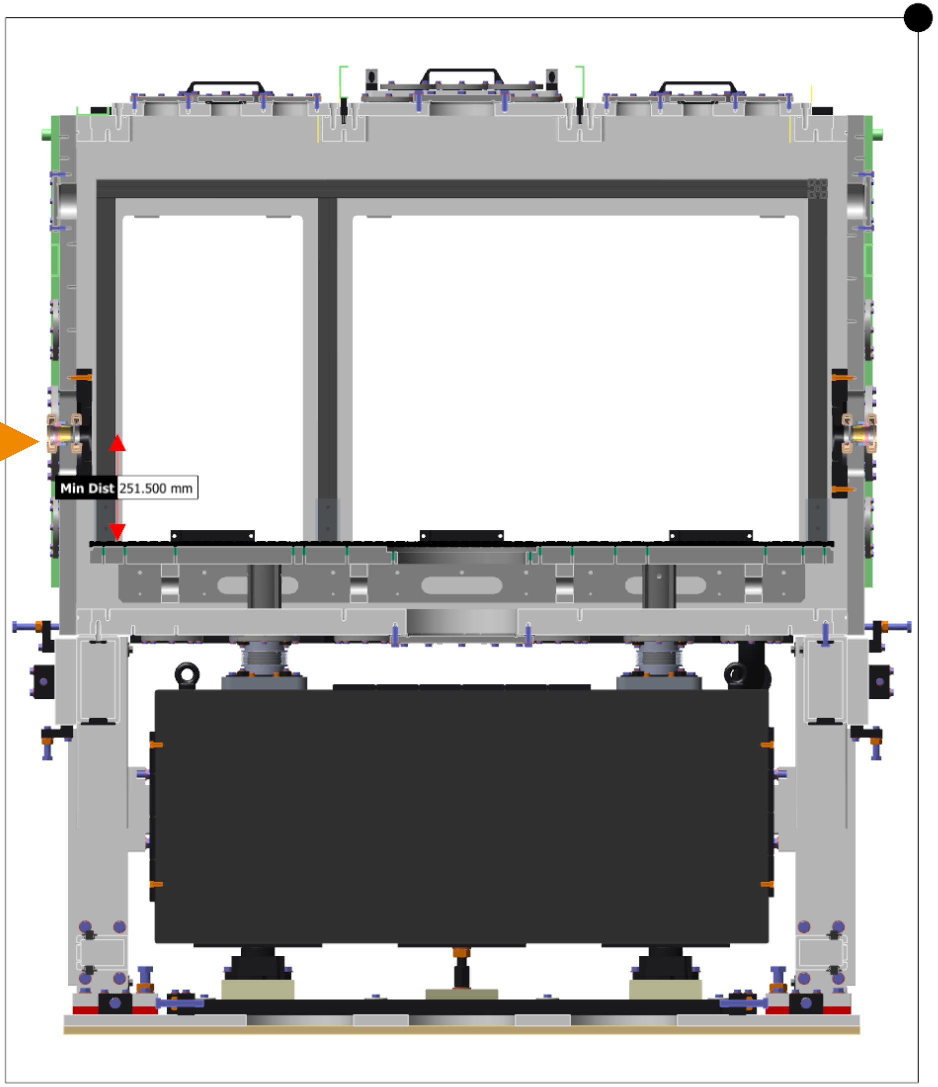
CLARA
250 MeV
e-



Internal breadboard holes span across whole chamber

# FEC1&2 Side – Section on Beam axis

CLARA
250 MeV
e-



# FMBOX1 – FMBOX2 Section on Beam Axis