Science & Technology Facilities Council
ASTeC
Accelerators in a new light

Status of VELA/CLARA Accelerator Test Facilities at Daresbury

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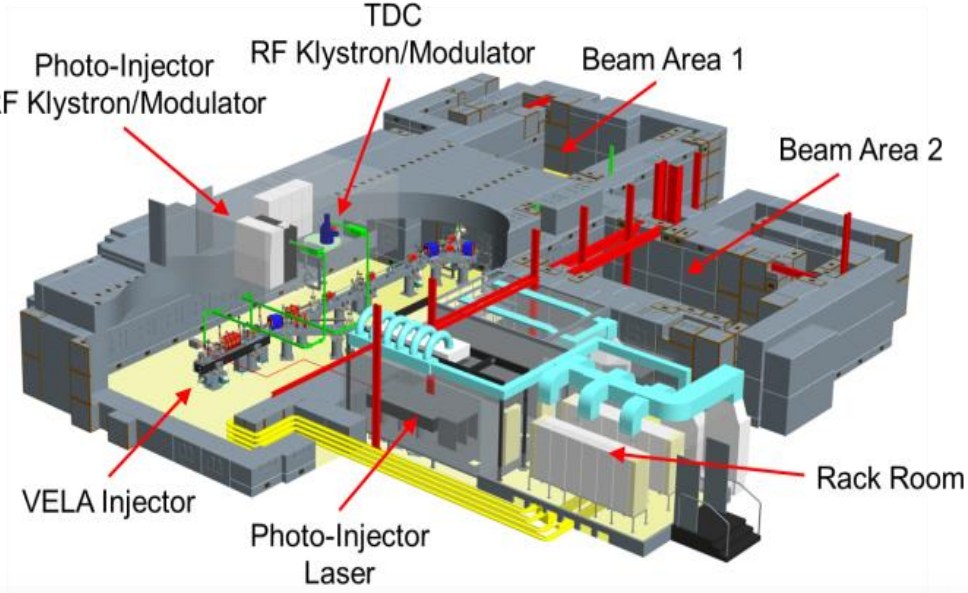
STFC Daresbury Laboratory & The Cockcroft Institute

John Adams Institute Fest, RHUL, 7th December 2018

Versatile Electron Linear Accelerator (VELA)

- A high performance, modular S-band RF photoinjector facility capable of delivering a high quality electron beam to two large, flexible, fully shielded experimental areas.
- Beam delivered to industry and academia between 2013-2015.
- Dedicated diagnostics section to develop state-of-the art photoinjector for future Free Electron Laser facilities.



Beam Parameters

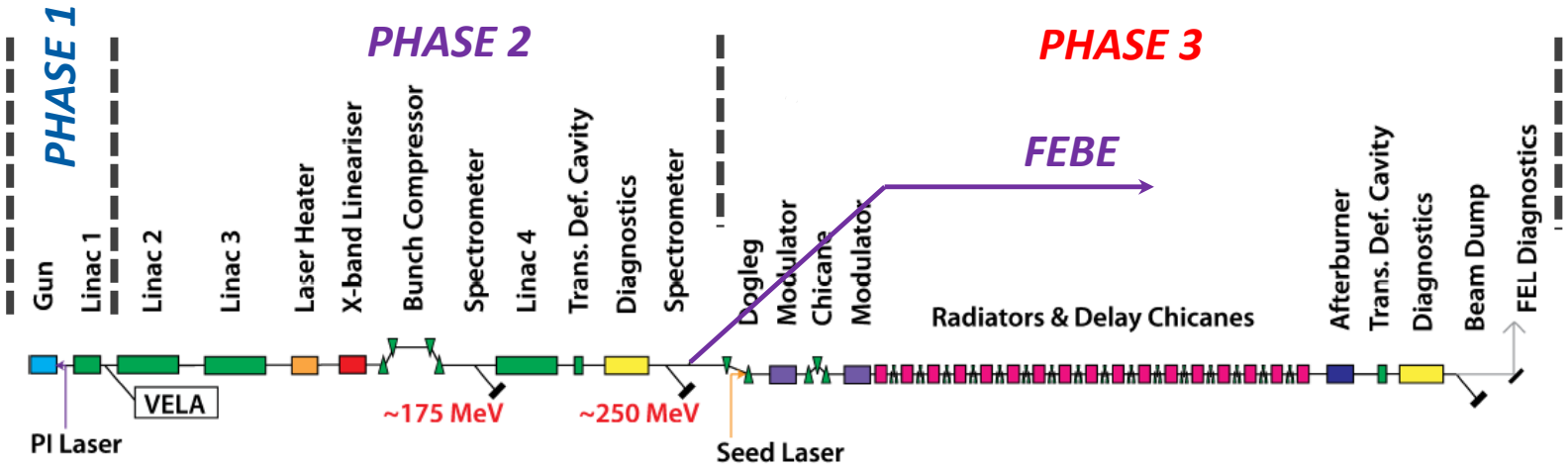
Beam Energy	4 – 6 MeV
Bunch Charge	0.04 – 250 pC
Bunch length ($\sigma_{t,rms}$)	0.5 – 10 ps
Normalised emittance	1 – 4 µm
Beam size ($\sigma_{x,y,rms}$)	0.5 – 5 mm
Energy spread ($\sigma_{e,rms}$)	1 – 5 %
Bunch repetition rate	1 – 10 Hz (400 Hz with HRRG)

Not all parameters achievable simultaneously. Beam parameters vary along the beam line.

Compact Linear Accelerator for Research and Applications (CLARA)

- An upgrade of the existing VELA Photoinjector Facility to 250 MeV
- Proof-of-principle demonstration and new FEL capabilities
- Will address many scientific and technology challenges for future large scale UK X-FEL facility
  - Shorter Pulses
  - Improved Temporal Coherence
  - Tailored Pulse Structures
  - Stability & Power
- Key technologies
  - New photo-injector technologies
  - Novel undulators (short period, superconducting….)
  - New accelerating structures: X-Band etc ...
  - Advanced single bunch diagnostics.

CLARA: Layout and Status



PHASE 1:
50 MeV, 100 pC at 10 Hz
ACHIEVED

- Beam characterisation, machine development and beam exploitation under way
- RF Conditioning of 400Hz gun on VELA line

PHASE 2:
250 MeV, BEING PROCURED AND ASSEMBLED

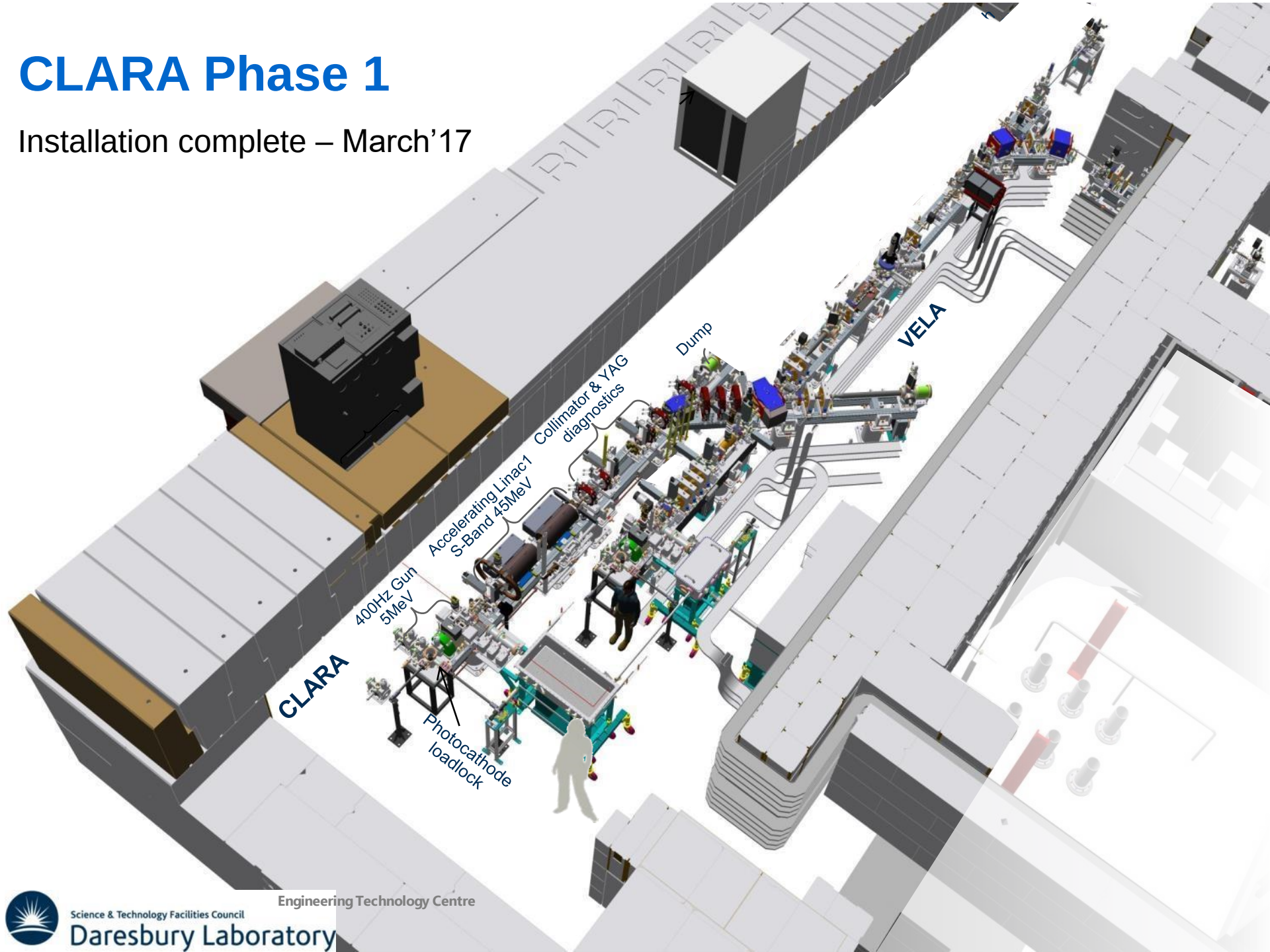
- 2018: Module assembly offline
- 2019: Shielding changes
- 2021: Installation
- FEBE part of Phase 2 now.
- **Still need some funding to complete**

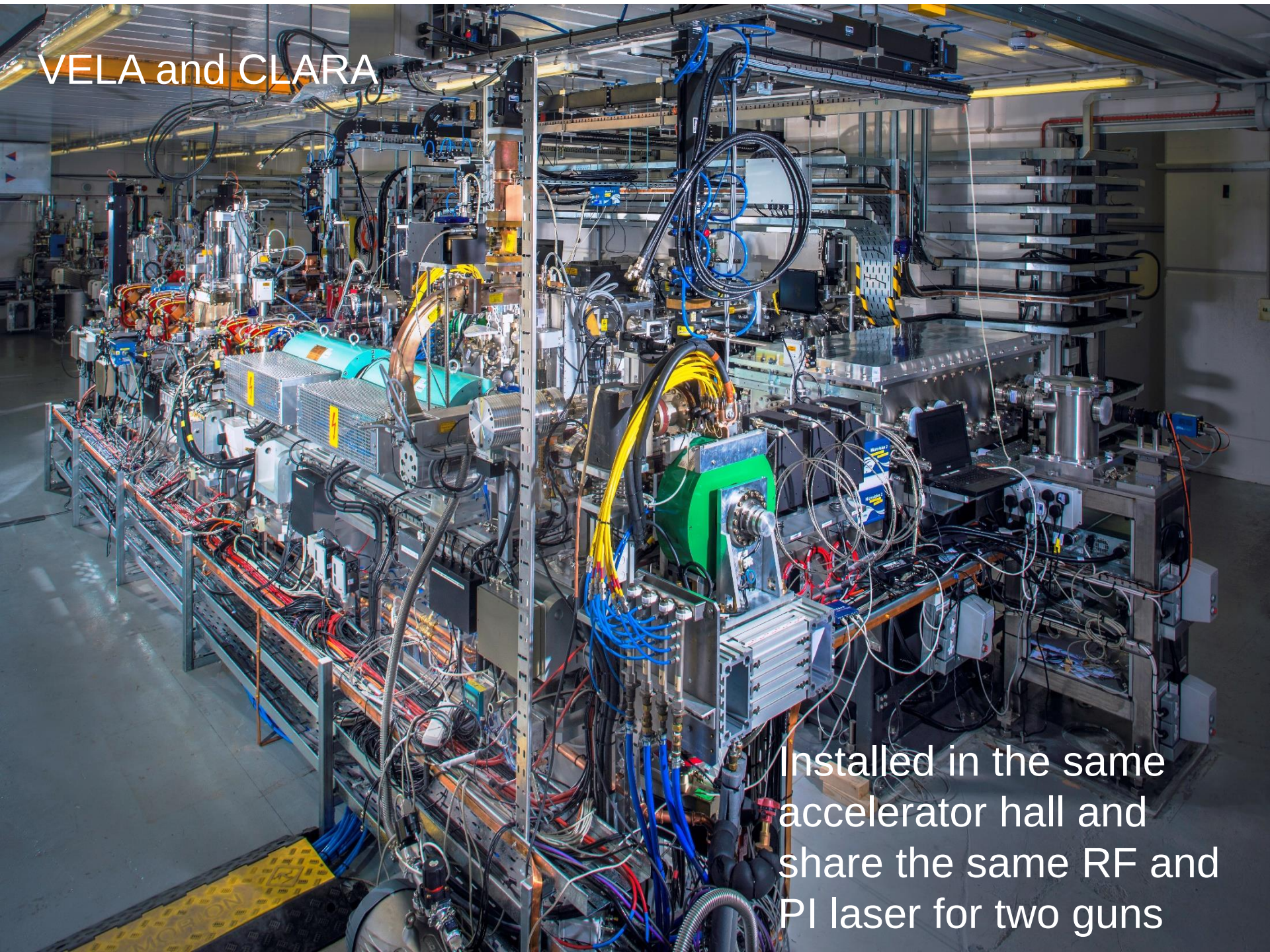
PHASE 3:
100 nm FEL
NOT YET FUNDED

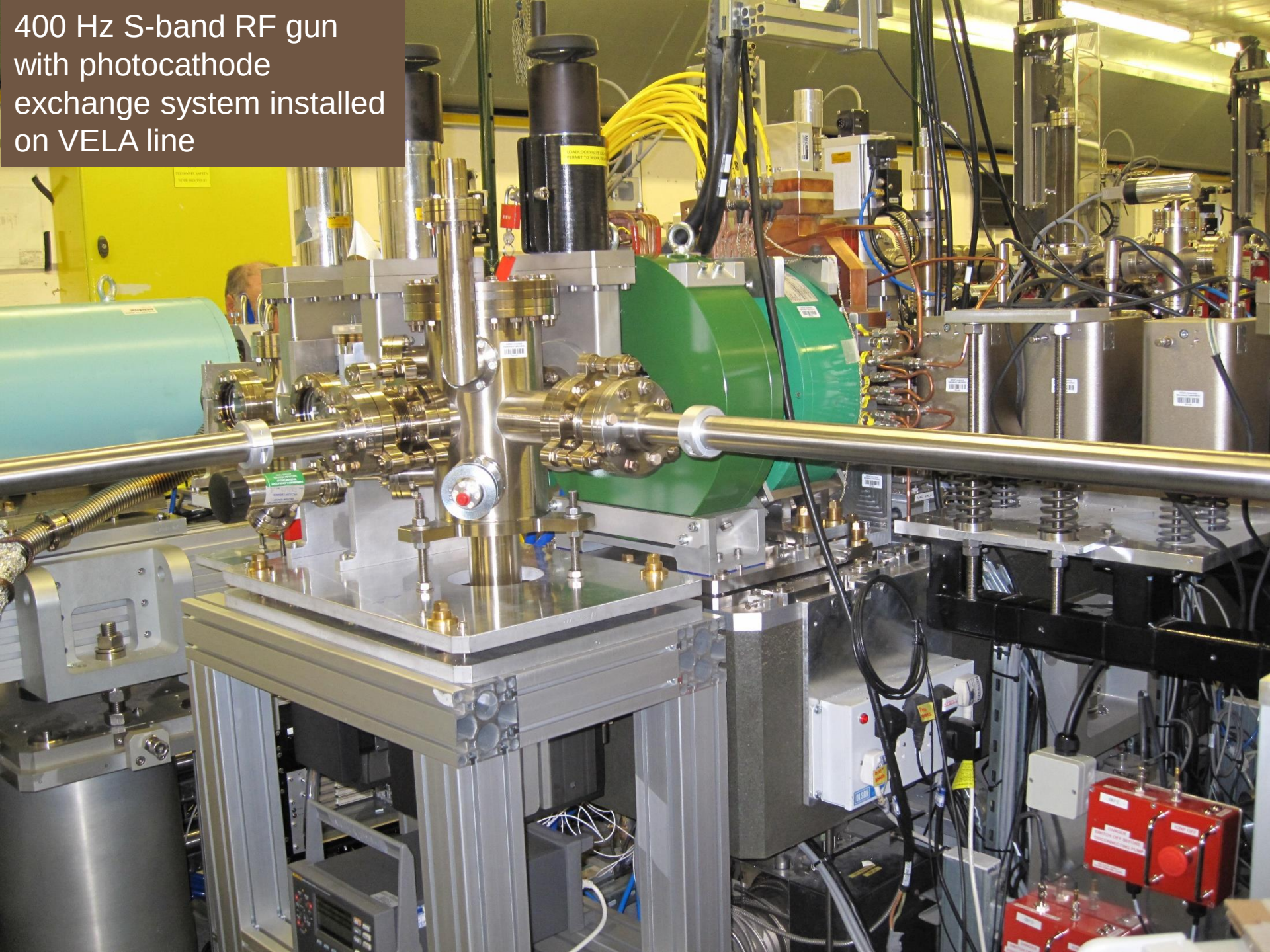
- Will take ~ 3-4 years till Lasing when funded

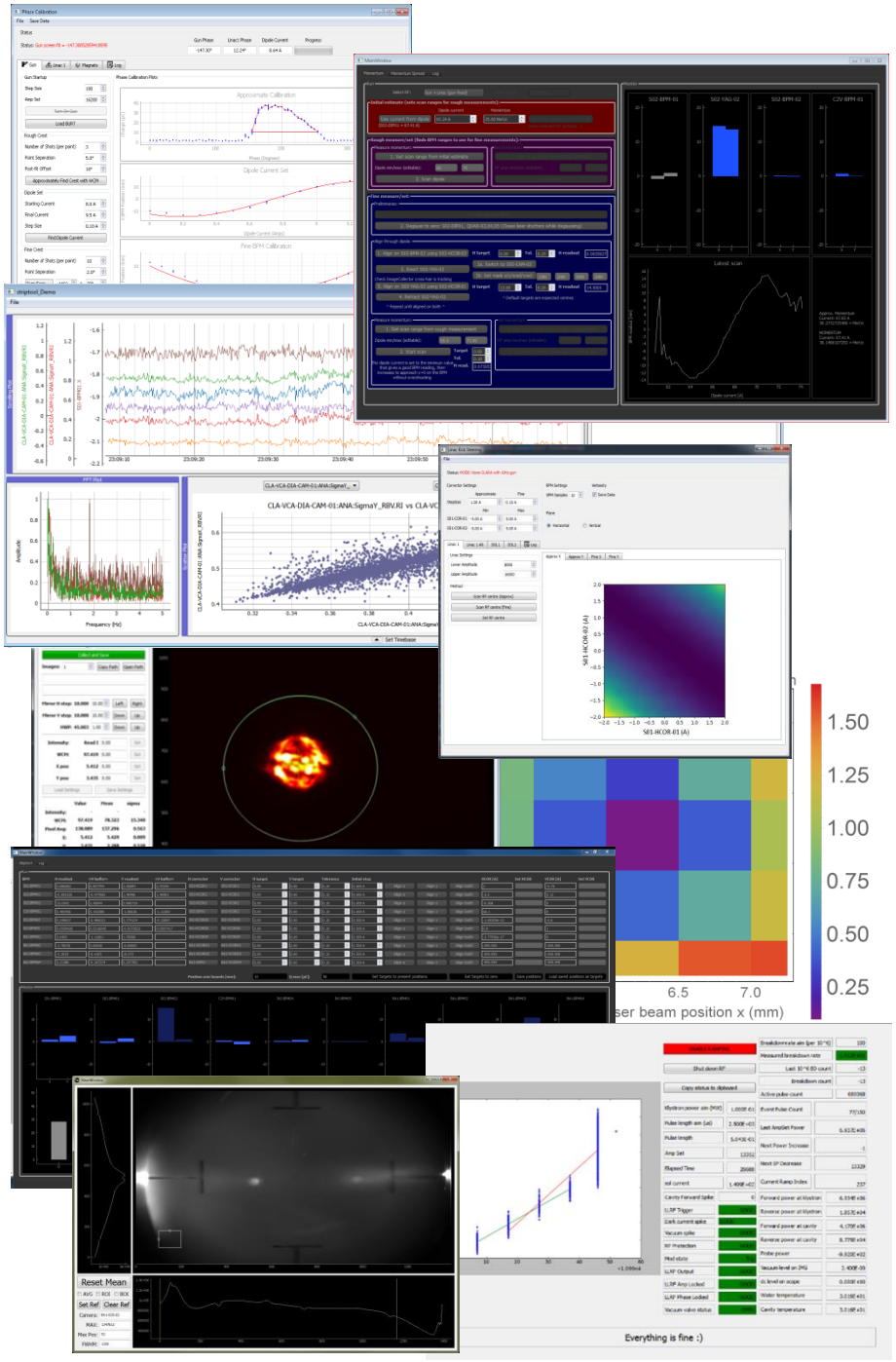
CLARA Phase 1

Installation complete – March'17




VELA and CLARA
Installed in the same accelerator hall and share the same RF and PI laser for two guns


400 Hz S-band RF gun
with photocathode
exchange system installed
on VELA line

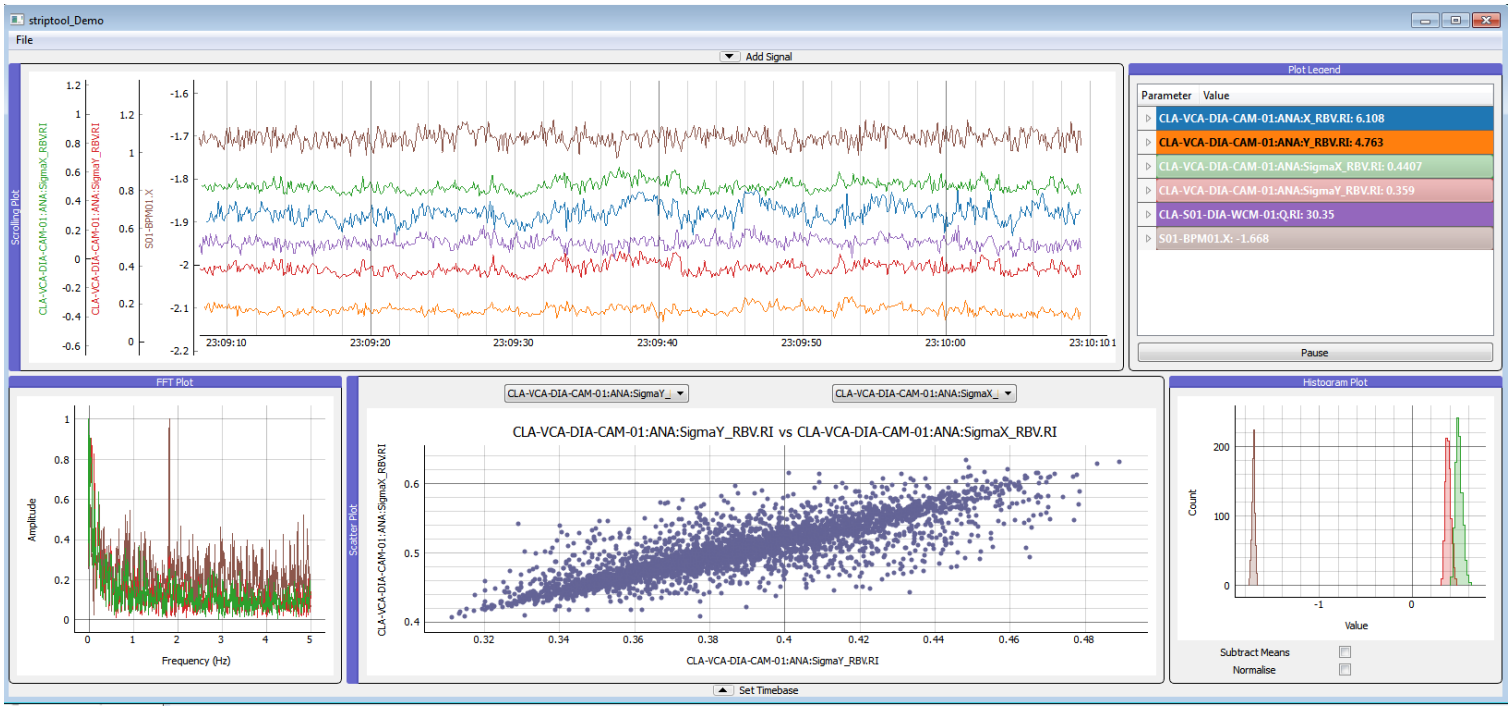


High Level Software

- In two years
  - Established a critical mass of engagement resulting in demonstrable successes
  - 40 apps (and growing)
  - 12 developers (and growing)

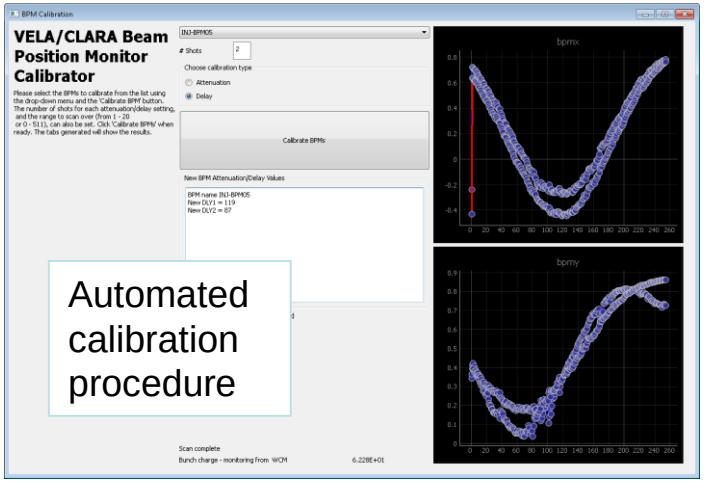
Software examples: Striptool++

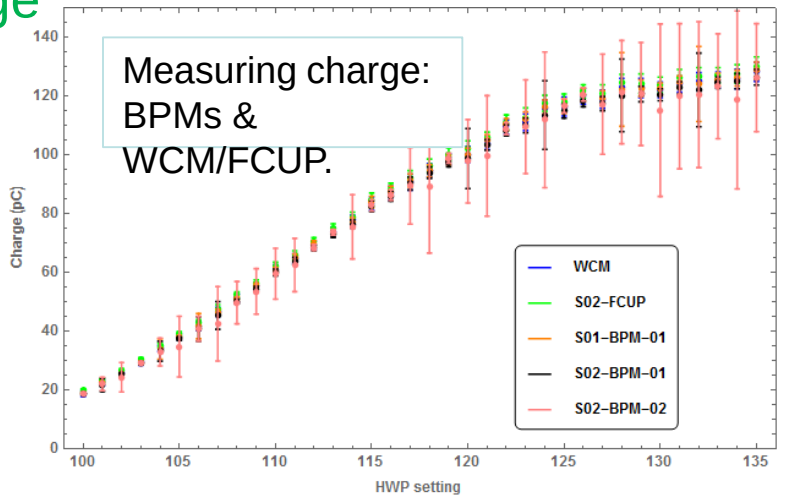
- Striptool, Correlation plots, Histogram, FFT, Data dumping , …



Software examples: BPM characterisation

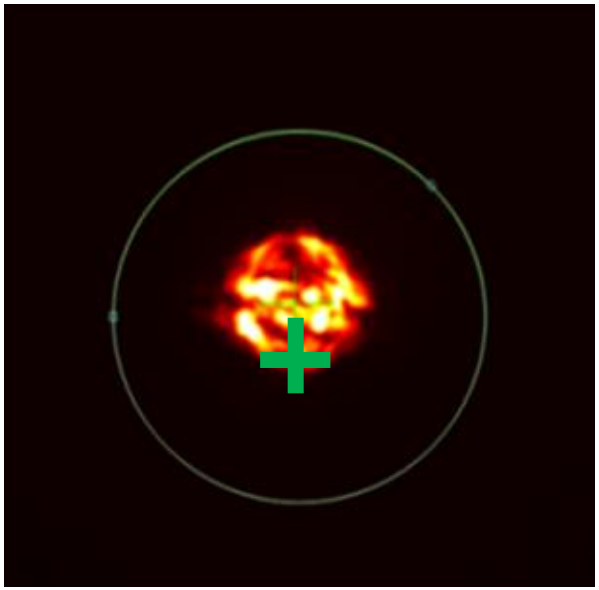
- All CLARA/VELA BPMs calibrated with beam.
  - Improved S/N ratio for a wide range of bunch charges.
  - BPMs can now be used to monitor charge.
- Automatic re-calibration program run regularly in MCR
- BPM response measured against a range of parameters (beam position, bunch charge, set attenuation).
  - Signal tagging (GOOD/BAD/NONLINEAR) implemented at mid-level.
  - High-level applications now discard unreliable signals.

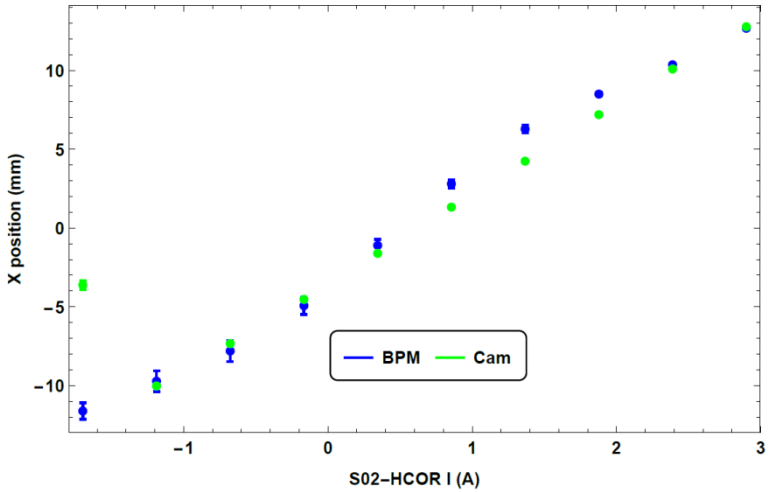




Software examples: Online Image Analysis

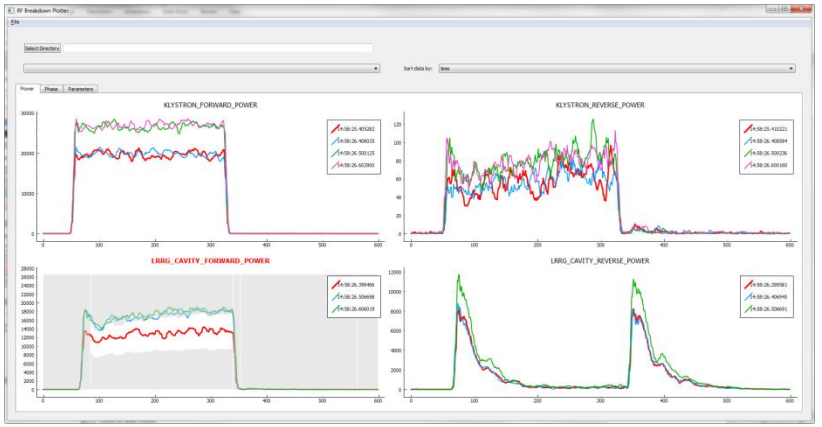
- Online calculation of beam expected position and covariance matrix in ROI of camera image
  - Proof-of-principle, (hi → low level)
- Used: set laser position on Virtual Cathode, Linac alignment, cross check BPM positions, RF phasing





Software examples: RF Conditioning

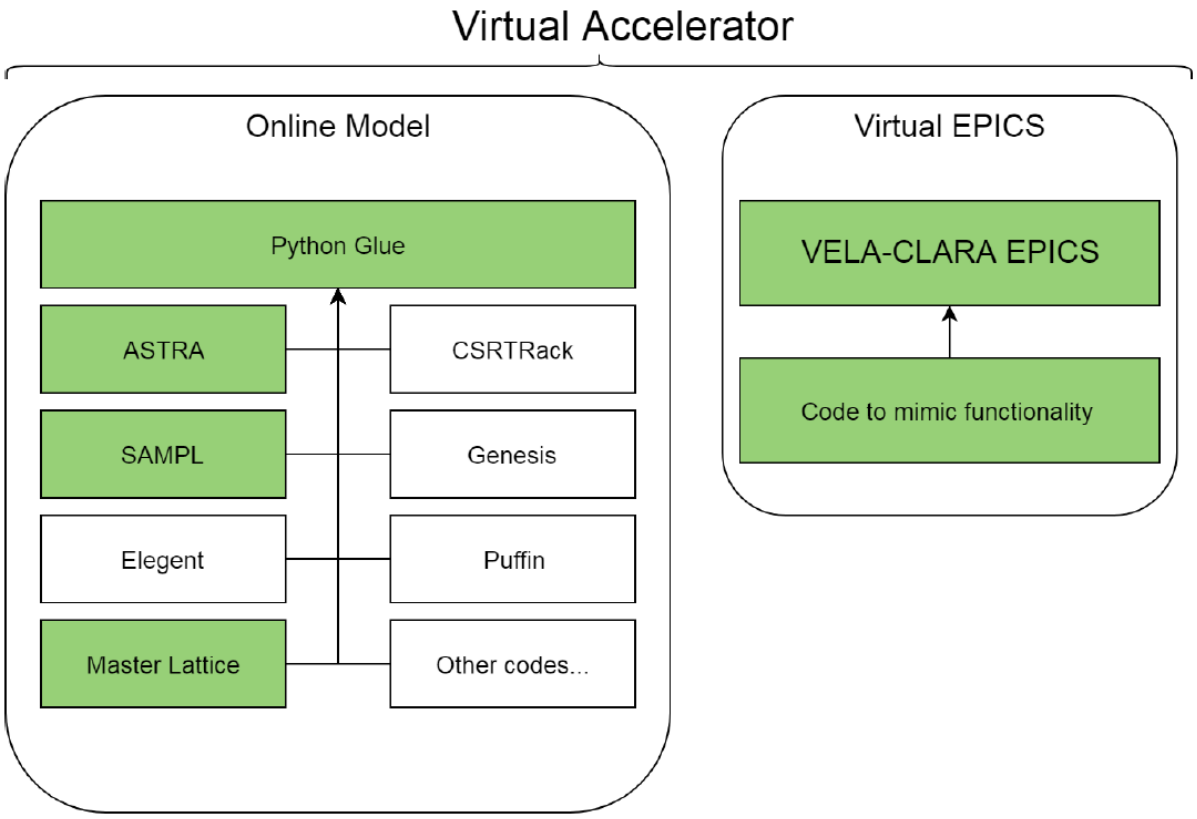
- Dedicated machine time: Initial prototyping
  - proof of principals
- Task management
  - Specific roles, planning, specifications, goals, built in flexibility
- More Data driven conclusions whilst on shift
  - less opinion driven conclusions
- 100 Hz operation, turn off within a single tick of the RF system
  - Working with LLRF manufacturers to improve their product
- Next Goal:
  - 24/7 unmanned conditioning



Virtual Accelerator

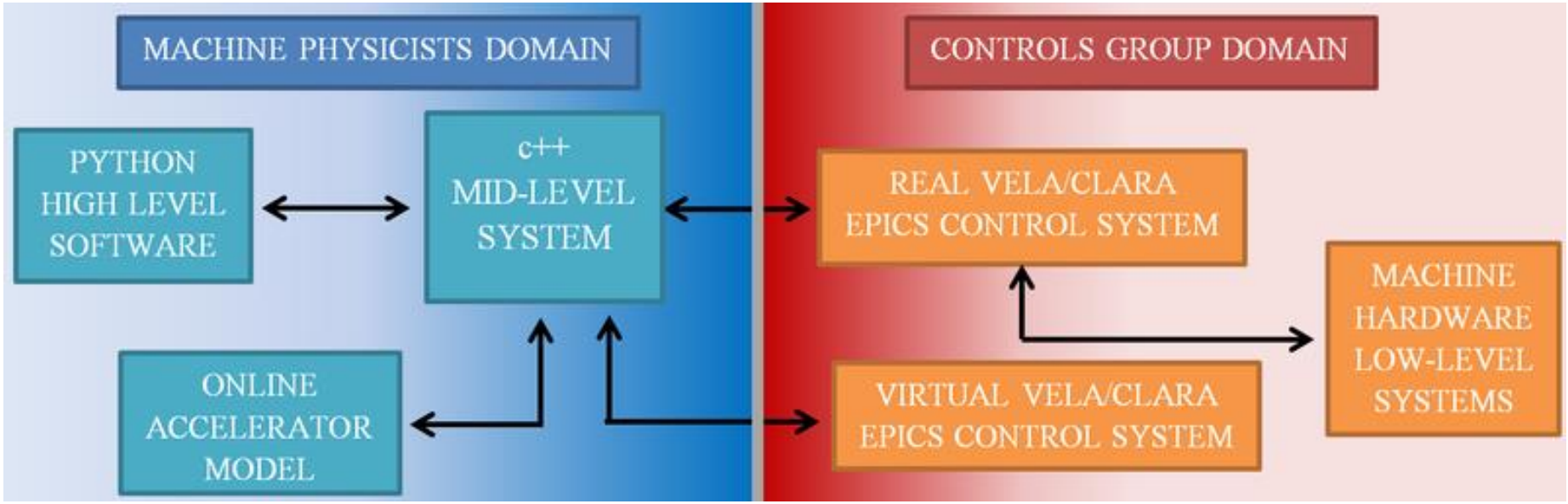
Uses:

- Develop control room applications
- Run start-to-end simulations with multiple simulation codes,
- Accurately reproduce measured beam properties,
- Conduct ‘virtual experiments’
- Gain insight into ‘hidden beam parameters’
  - bunch length
- All Available Online & In locally in a ‘Sandbox’



Virtual Accelerator

- Schematic of Main Components
  - (actually more, master lattice …)



CLARA Exploitation

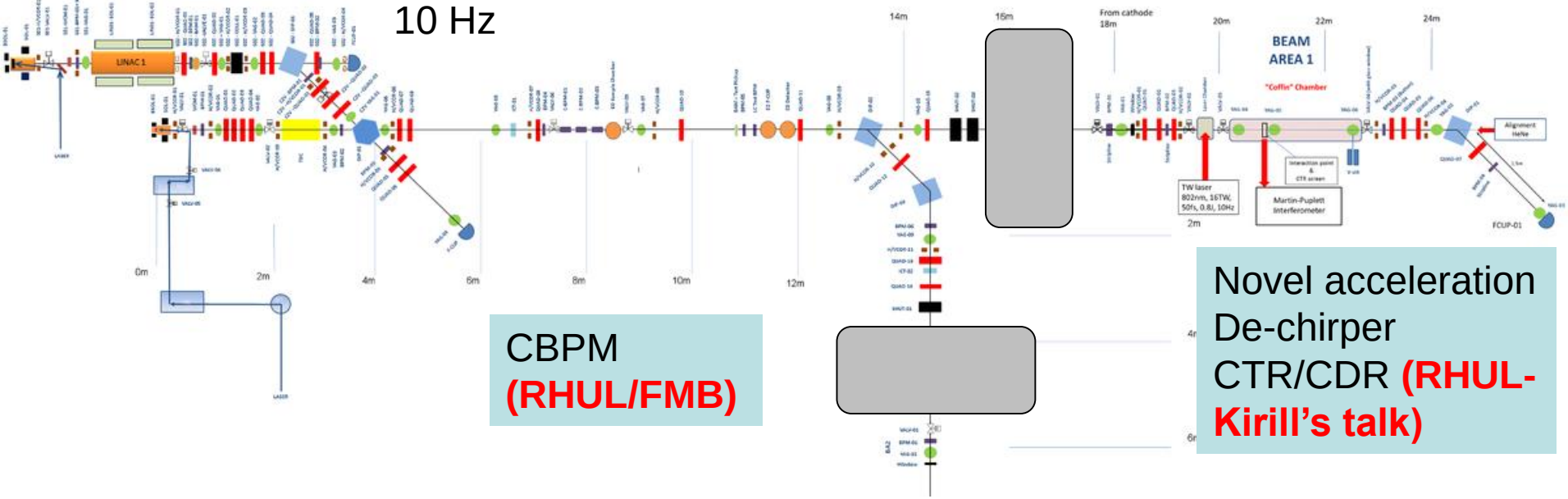
- An **open call** was made for access to beamtime in May 2018
  - This was the first call for CLARA beam access
- **Beamtime allocation panel**:
  - Andy Wolski (Chair), Liverpool University
  - Phil Burrows, Oxford University
  - Jim Clarke, ASTeC
  - Tim Noakes (technical assessment), ASTeC
- 20 proposals submitted, 12 approved
  - Total number of shifts requested = **135**
  - Total number of shifts allocated = **70**
- **Over subscribed by factor ~2**
- Every proposal was judged to be worthy of beamtime
- Two proposals will make use of Trans-national Access arrangements (ARIES, H2020)

CLARA Phase 1 Beam Exploitation

VHEE
SCU
Fibre loss monitor

~40 MeV
100 pC
10 Hz

Beam Area 1
~40 MeV
100 pC
10 Hz



CBPM
(RHUL/FMB)

Novel acceleration
De-chirper
CTR/CDR **(RHUL-Kirill's talk)**

Beam Area 2
~25 MeV
100 pC
10 Hz

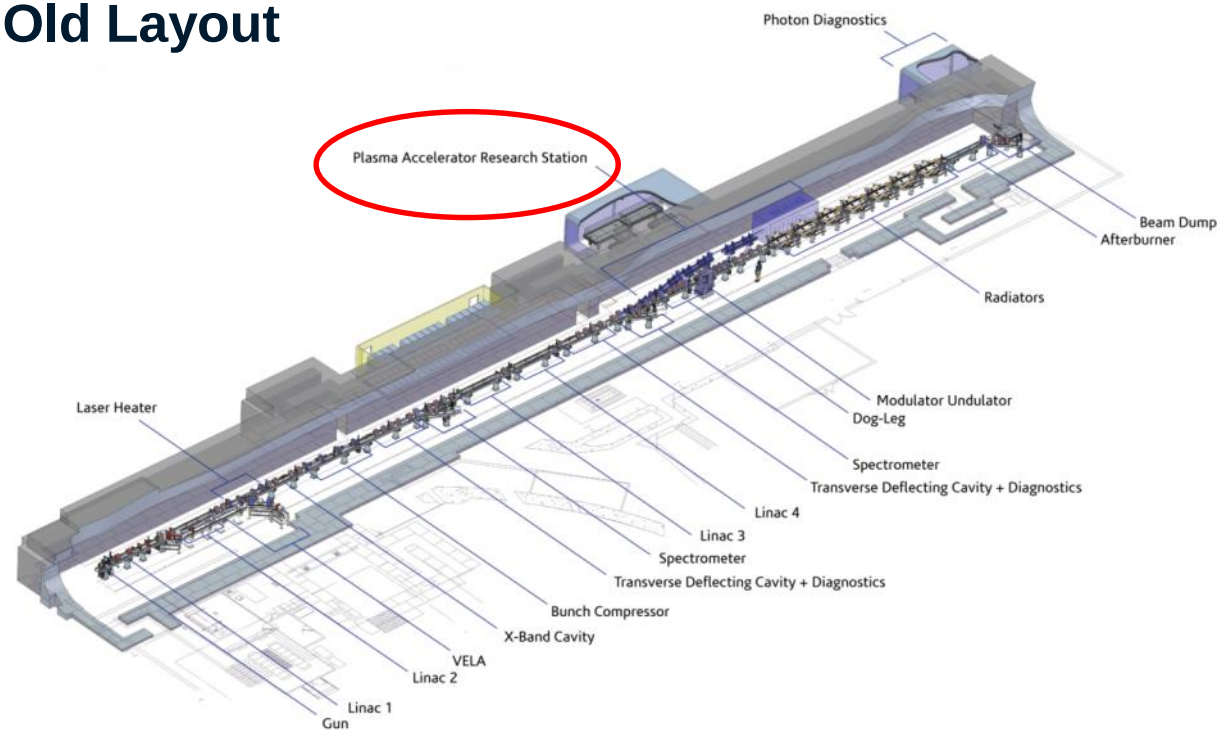
CLARA Exploitation

- Beamtime scheduled for 14 weeks (10th September–14th December 2018)
- During the first two weeks beam was delivered to Beam Area 1 for 2 experiments
  - Dechirper studies and coherent Cherenkov diffraction radiation measurements
  - Both were able to measure beam induced signals
- Unfortunately the Photoinjector laser oscillator failed overnight
  - Relatively minor component failure but factory repair needed!
- Remaining 12 weeks of beamtime pushed back and rescheduled to from 13th Nov - 7th March'19.
  - Dielectric Wakefield, Coherent CDR, fibre loss monitor and VHEE experiments completed successfully
  - CBPM tests (RHUL/FMB – Oxford) planned next week.
  - THz, plasma, SCU tests early 2019.
- **If all goes according to plan the next open beamtime call will be Spring 2019 for Autumn 2019.**

Future CLARA Exploitation

- We are now developing detailed layouts for the exploitation of the 250MeV beam **with a dedicated beamline**
- We always had shown this on layouts but with no real detail (previously called PARS)
- The extracted beamline is now renamed **FEBE** – Full Energy Beam Exploitation

Old Layout

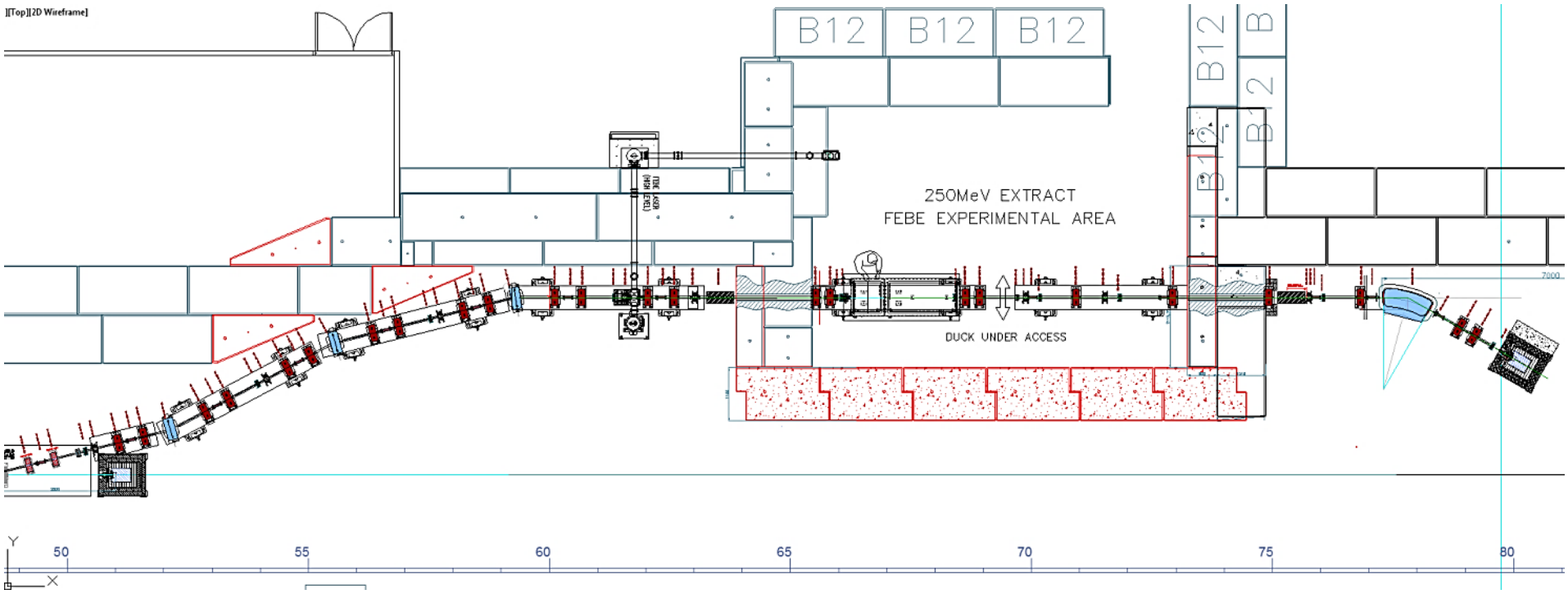


FEBE

- We have consulted potential users of FEBE and also other similar facilities (e.g. CLEAR at CERN) for advice on beamline layout and parameters
- The key change we have implemented as a consequence of this consultation is to have an **independent, separately shielded, experimental area at 250MeV**
  - Access without having to turn the accelerator off
  - Build up experiments whilst the facility is operational and so maximising the efficiency and effectiveness of CLARA as a whole
  - The hutch size will be approx. 8 x 5m
  - This will not prevent specific items being installed in the machine area if that is what that particular experiment needs

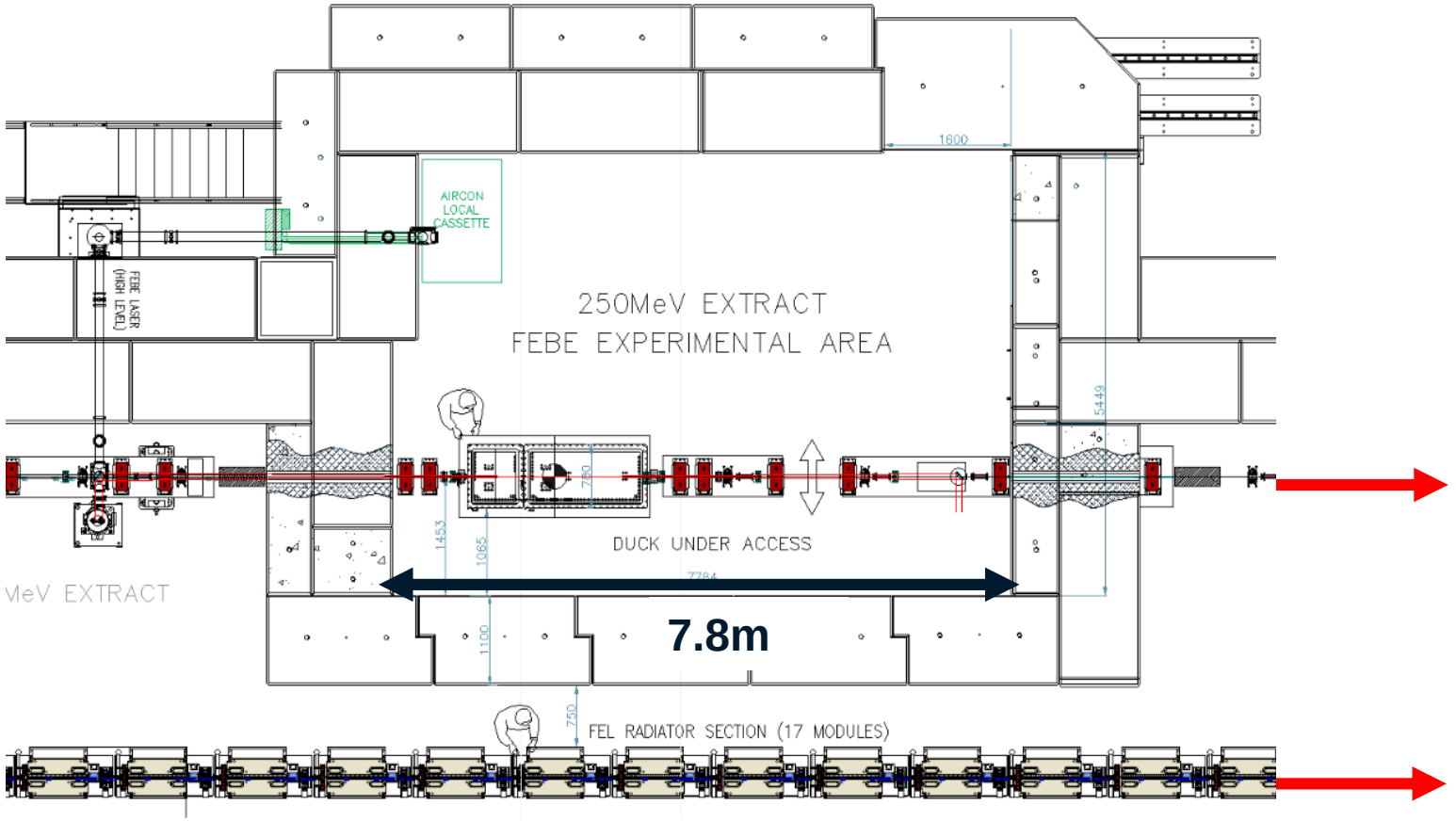
FEBE Layout

- **Close in view** (FEL not shown)
- 250MeV beam extraction line
- Magnets ***after*** laser interaction point currently sized for 600MeV



FEBE Layout

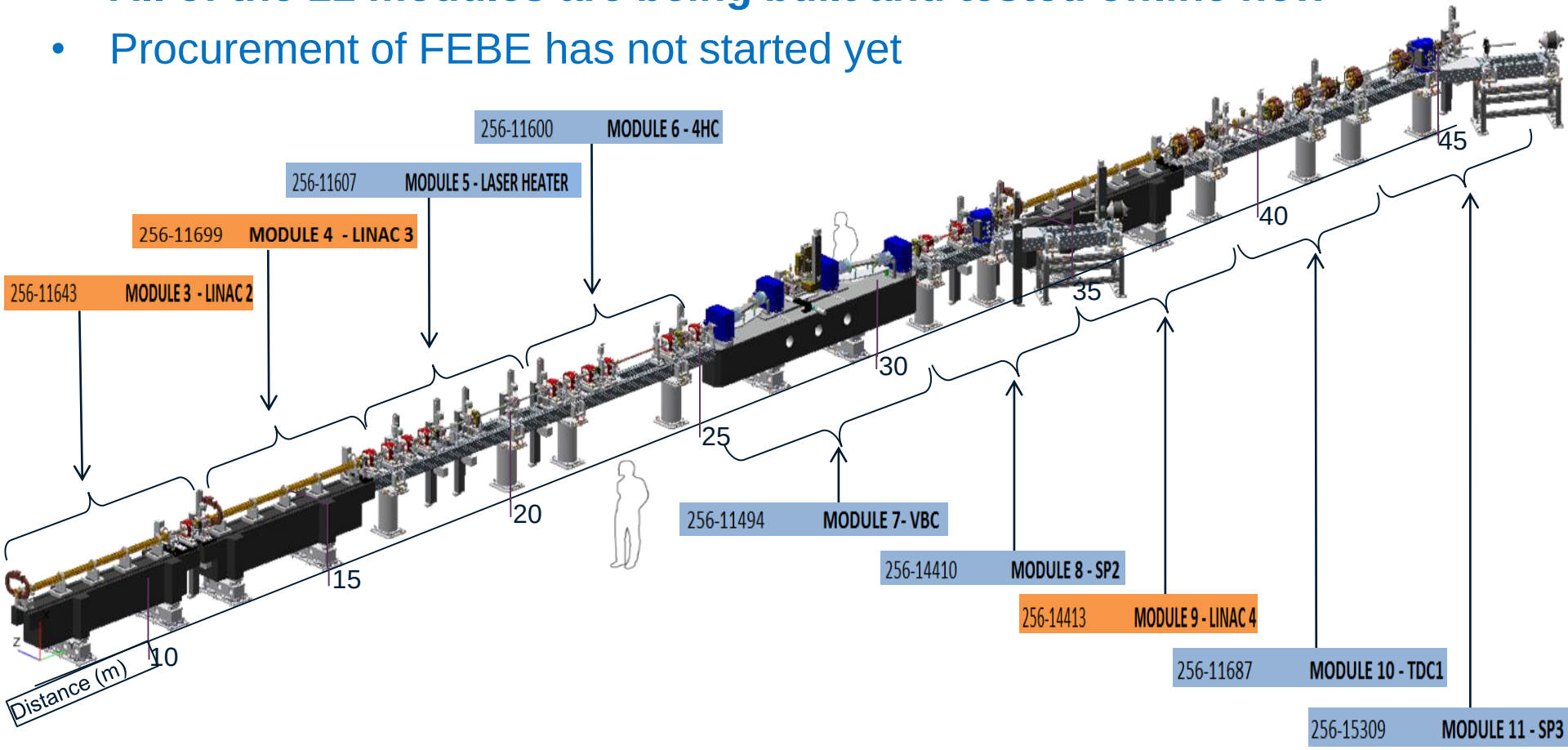
- Close in view with FEL undulators shown
- A ***second iteration*** with potential users will now be held to ensure the physical design and potential beam parameters matches their anticipated needs and expectations



FEL Radiator section

CLARA Phase 2

- CLARA Phase 2 will complete the **accelerator (up to final energy of 250MeV) and includes FEBE** enabling immediate high energy beam exploitation
- **All of the 11 modules are being built and tested offline now**
- Procurement of FEBE has not started yet



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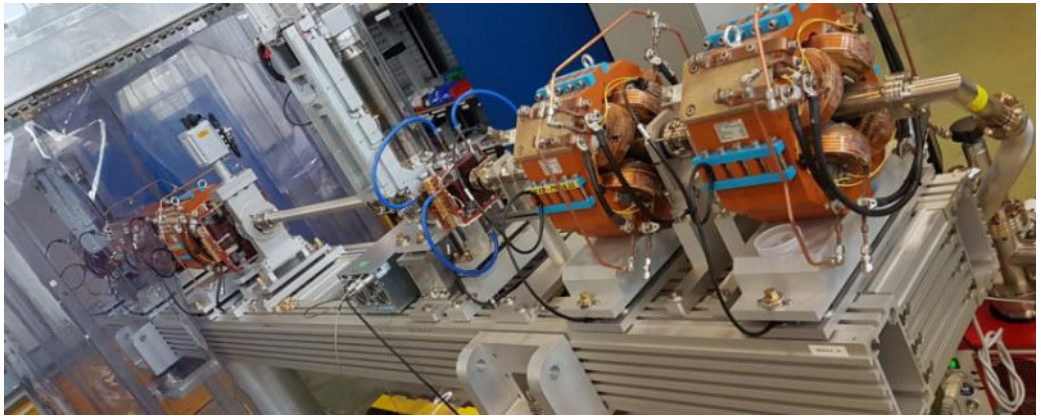


All systems on each module are tested under vacuum with the corresponding electrical rack.

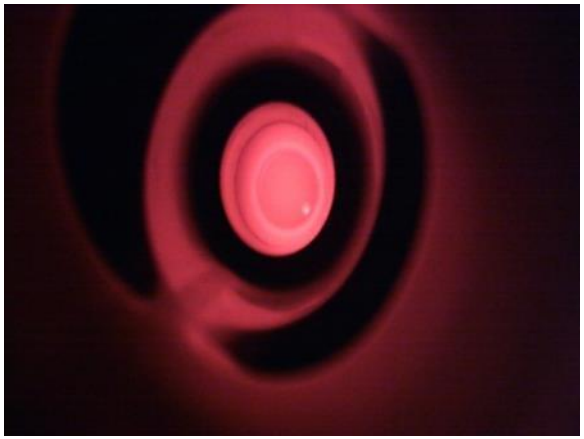
Three modules are completed, ready for installation, all others will be completed by end Jan 2019.

CLARA Phase 2

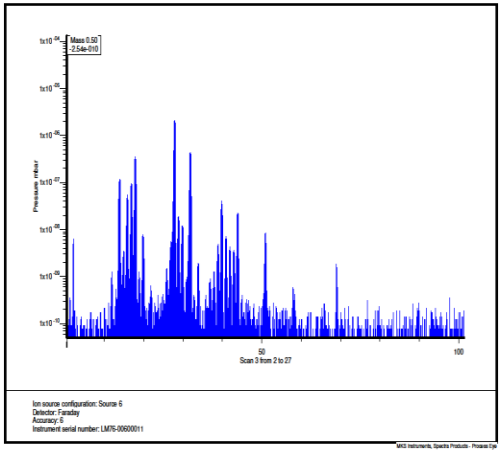
- Klystron and Modulator site acceptance tests are ongoing at Daresbury
  - Linacs 2, 3, & 4 (Diversified Technologies & Toshiba)
  - Transverse Deflecting Cavities x 2 (ScandiNova & CPI)
  - All tests are planned for completion by March 2019

CLARA Phase 2

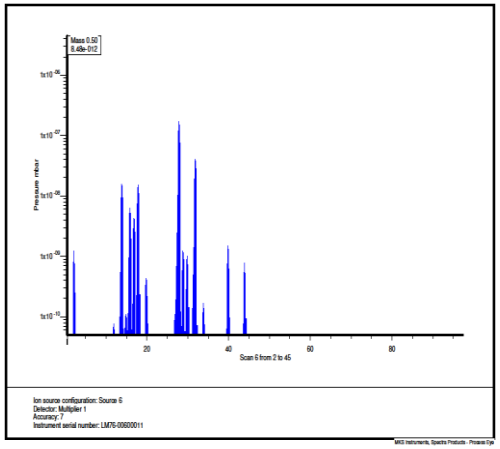
- Linacs 2, 3, and 4 (ex-SwissFEL Injector) have all been recently plasma cleaned at Daresbury and are now stored under vacuum



Initial RGA Scan

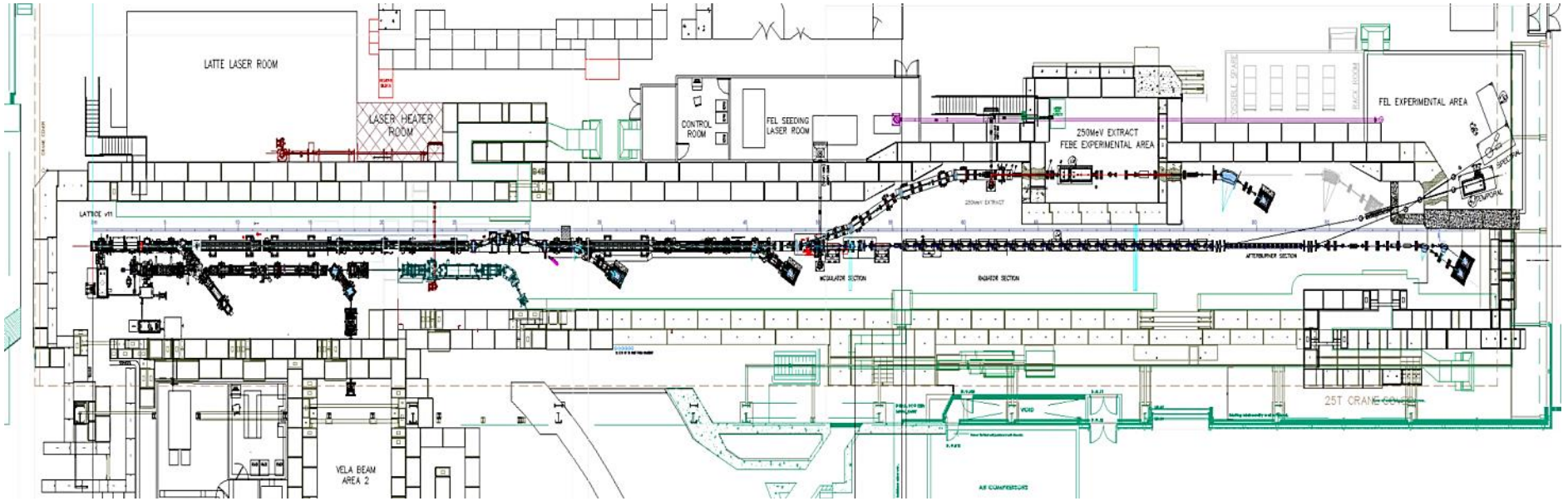


Post Neon Plasma Clean



CLARA Phase 3

- Beamline Lattice design finalised and detailed engineering in good shape
- Tender documents for radiator undulators completed
- Cavity BPMs – working closely with RHUL/FMB-Oxford to help industrialize their designs
- The main outstanding items still requiring significant attention are
  - Seed laser systems and laser transport
  - FEL photon beamlines and diagnostics



Summary

- **UK XFEL** – Waiting for the UKRI research and innovation infrastructure roadmap to clarify priority
  - In the meantime the UK accelerator community continues to work on our underpinning R&D programme
  - CLARA continues to address several technical challenges and develop skills for FEL.
- CLARA Phase 1 operational. Beam Exploitation has started and oversubscribed by factor 2
- CLARA Phase 2 module assembly on track
- FEBE design for efficient 250 MeV exploitation developed. Planning to hold 1 day meeting in Spring time 2019 with users
- Phase 3 design progressing
- Requesting STFC to complete Phase 2 whilst UK XFEL status becomes clear
- Top Level plan now shows Phase 2 installed by May 2021

Merry Christmas

Many Thanks