Science & Technology Facilities Council
ASTeC
Accelerators in a new light

VELA- Photoinjector Facility and CLARA- FEL test facility at Daresbury Laboratory

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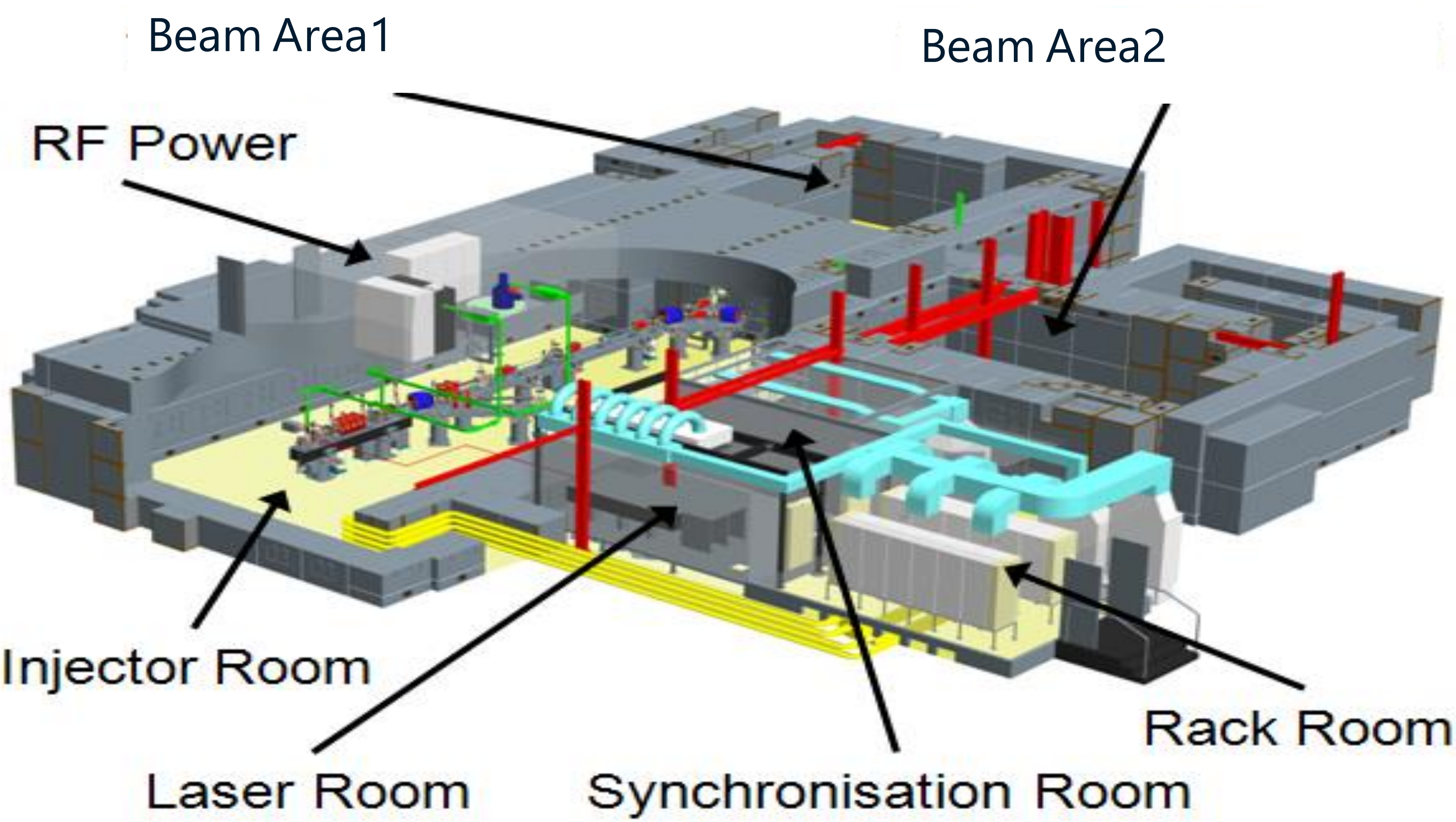
XXV ESLS Workshop, 21st-22nd November 2017, Dortmund, Germany

Timeline

September'11	Construction of VELA - Initiated following the capital investment announcement of 2.5M£ in DSIC from BIS.
April'13	**First electrons (ALPHA-X gun on loan from Strathclyde)**
July'13-Nov'14	Industrial and academic user experiments. Number of changes to the machine. Machine Development and characterisation.
Dec'14-March'15	VELA shutdown for re-configuration of shielding for CLARA Front End.
April'15-Oct'15	Machine Development and characterisation. Industrial and academic user experiments.
Nov'15-March'17	VELA shutdown for CLARA Front End installation. 10 Hz gun on CLARA line and 400 Hz gun on VELA line.
March'17-Nov'17	Resolved number of issues. Pulse stretcher on PI laser. **Accelerated beam from CLARA Phase 1 last week.**

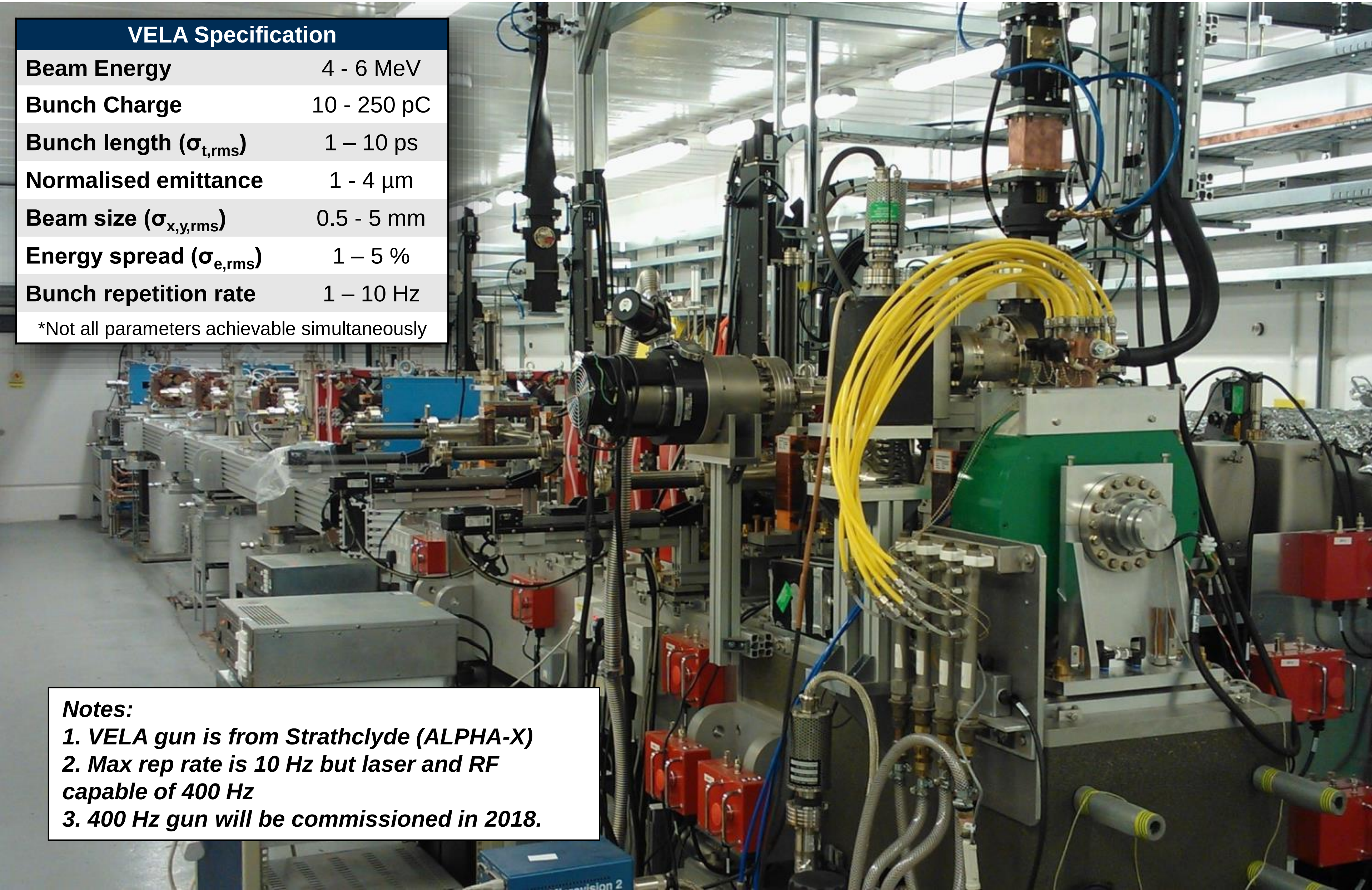
VELA

Versatile Electron Linear Accelerator (VELA) is a high performance, S-band RF photoinjector facility capable of delivering a high quality electron beam to two beam areas. It is located in the old outer hall of SRS at Daresbury Laboratory.



Location

VELA



VELA Specification	
Beam Energy	4 - 6 MeV
Bunch Charge	10 - 250 pC
Bunch length ($\sigma_{t,rms}$)	1 – 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

*Not all parameters achievable simultaneously

Notes:
1. VELA gun is from Strathclyde (ALPHA-X)
2. Max rep rate is 10 Hz but laser and RF capable of 400 Hz
3. 400 Hz gun will be commissioned in 2018.

CLARA

Compact **L**inear **A**ccelerator for **R**esearch and **A**pplications

An upgrade of the existing VELA Photoinjector Facility at Daresbury Laboratory to a 250MeV Free-Electron Laser Test Facility

Proof-of-principle demonstrations of novel FEL concepts and development of future accelerator technologies

Emphasis on ***Stability, Synchronisation and Ultra-short Pulse Generation***

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Imperial College London
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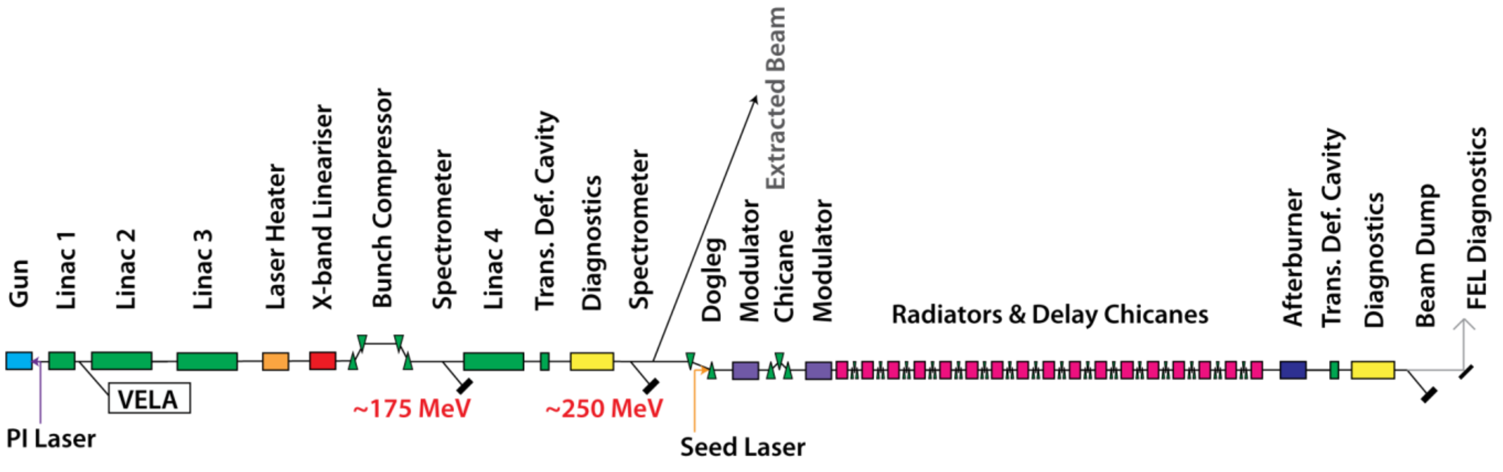
CERN
INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati
SLAC National Accelerator Laboratory

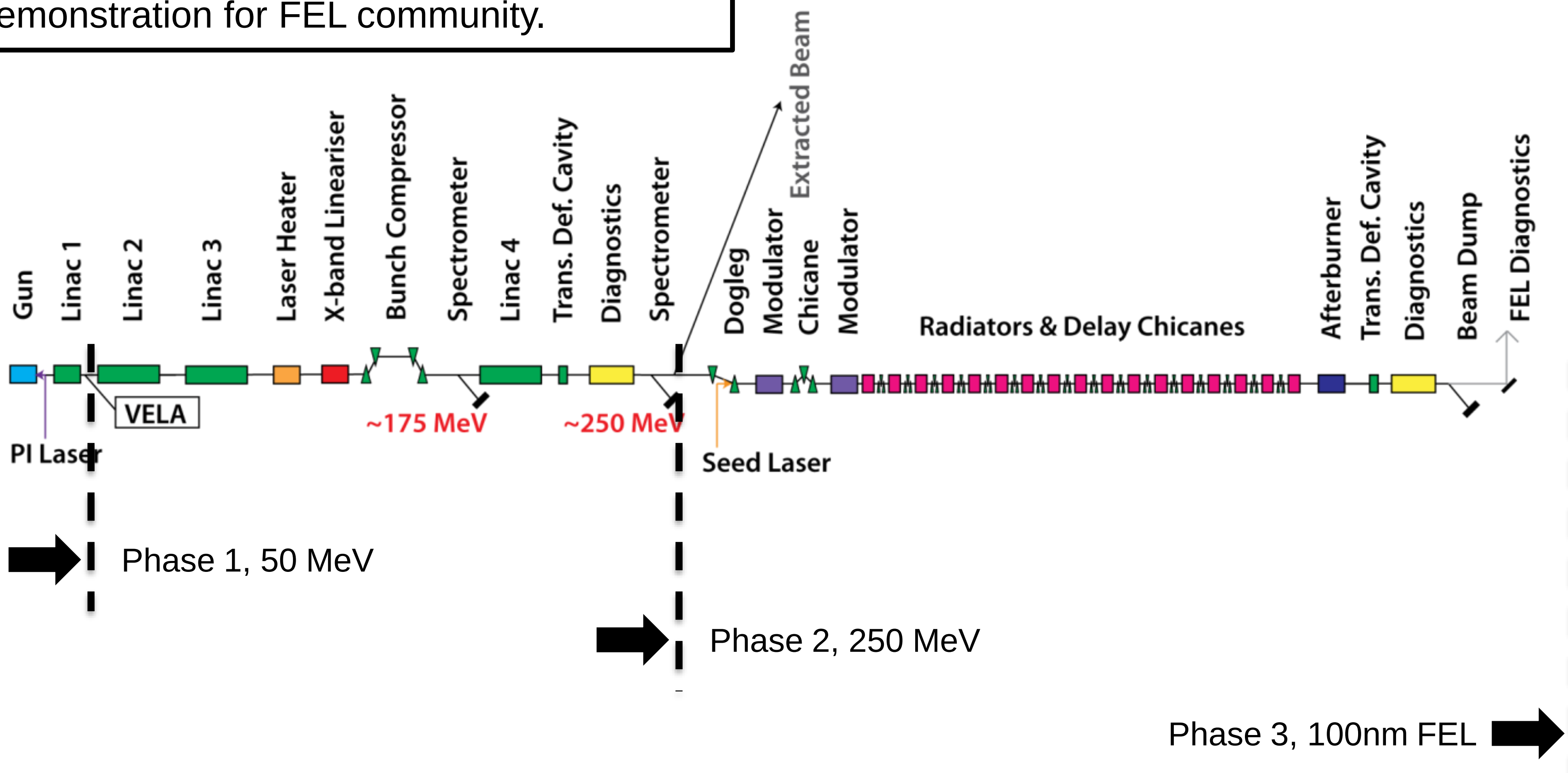
CLARA

- CLARA is a purpose built dedicated flexible FEL Test Facility
- CLARA is a scaled down version of an X-ray FEL containing all of the key technical components, where all lessons learnt can be directly applied to any future UK XFEL.
- The key objectives are:
  - To develop new methods for improving the quality of the light output from FELs
  - Prove new technologies
  - Develop the UK skill base
  - Lower the total cost of a UK XFEL
  - Lower the risks associated with UK XFEL.



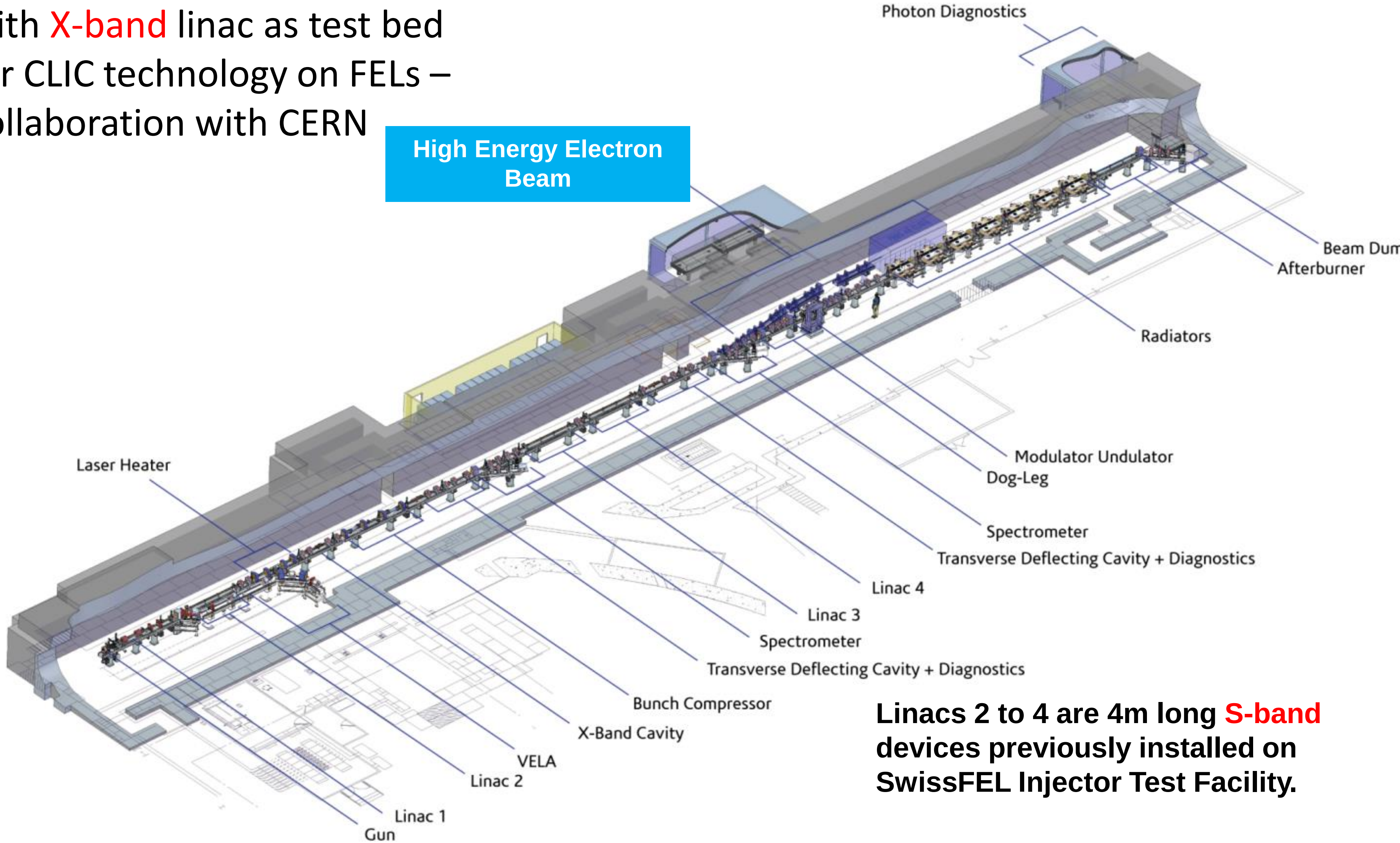
CLARA Schematic & Project Phases

CLARA assumes S-band acceleration and deflecting cavities and X-band linearization. Simulations show that Linac 4 could be swapped for X-band - would be excellent demonstration for FEL community.



CLARA Layout

We would like to replace Linac 4 with X-band linac as test bed for CLIC technology on FELs – collaboration with CERN



Linacs 2 to 4 are 4m long S-band devices previously installed on SwissFEL Injector Test Facility.

Linac 1 is 2m long S-band.

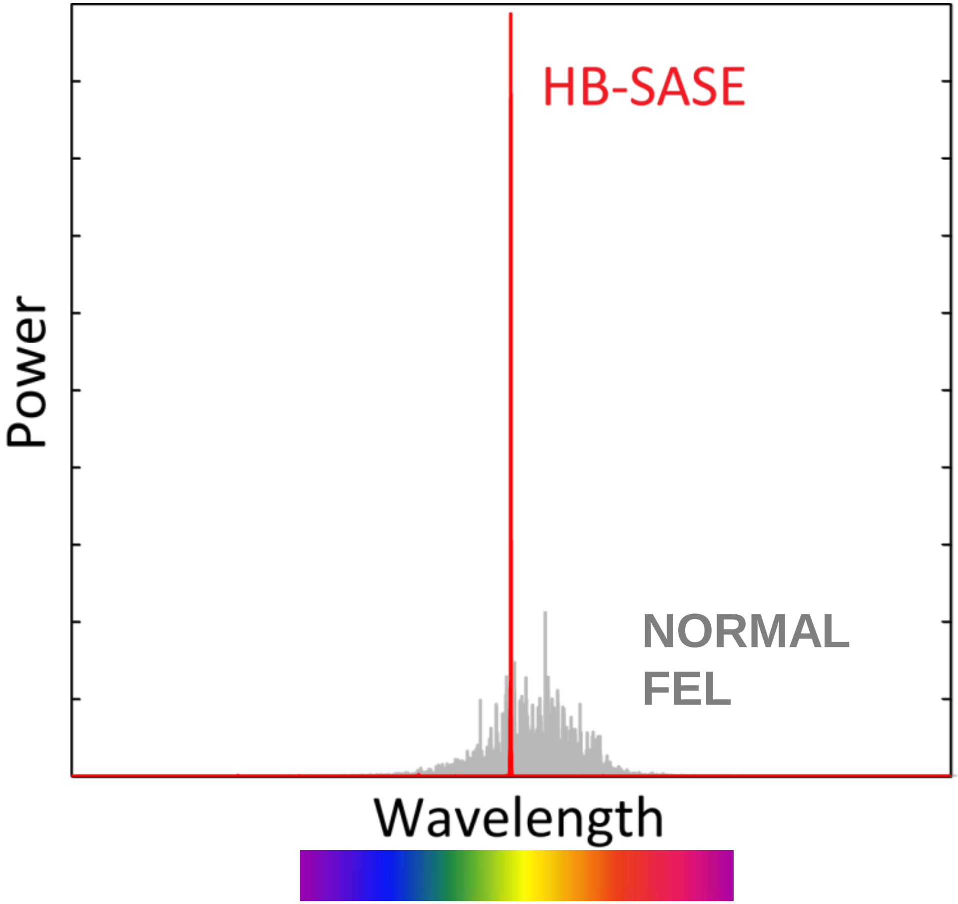
Summary of Operating Modes

MODE	*FLAT – Seeded HG*	*ULTRASHORT – SSS*	*SHORT – HB-SASE*	*LONG – ML*
Energy	240 MeV	240 MeV	150—**240** MeV	**150** – 240 MeV
Pulse Duration	250fs flat region	50 —35 fs FWHM	585 fs FWHM	1.875 ps FWHM
Charge	250 pC	25—50 pC	250 pC	250 pC
Peak Current	400 A	500 — 1500 A	400 A	125 A
Norm Emittance (mm-mrad)	0.5 (Target) 1.0 (Max)	1.0 (Target) 1.5 (Max)	0.5 (Target) 1.0 (Max)	0.5 (Target) 0.8 (Max)
RMS Energy Spread (keV)	25 (Target) 100 (Max)	100 (Target) 150 (Max)	25 (Target) 120 (Max)	25 (Target) 75 (Max)
Purpose	• 800nm Seeding and Harmonic Generation	• Single Spike SASE (+ mode-locked single spike SASE)	• 100nm saturation • Schemes only requiring spectral characterisation, • Highest harmonic upconversion potential • Shortest pulse durations in absolute terms.	• 266nm schemes requiring long wavelength modulation of the pulse energy (Mode-Locking, Mode-Locked Afterburner, Slice + Taper).

What will CLARA be able to do?

- **Example 1: Reducing the FEL output bandwidth**
- Prove that a new idea called **HB-SASE** actually works
  - Could then build it in from the start of the UK XFEL

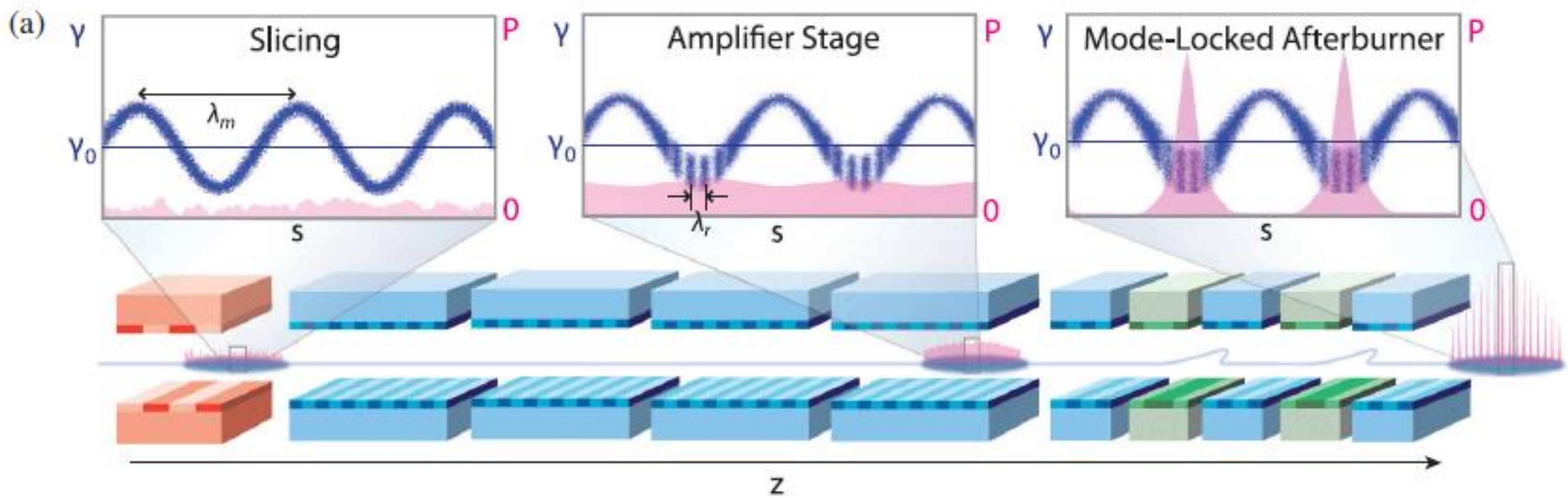
Will work at any wavelength and any repetition rate, no fancy optics required!



B.W.J. McNeil, N.R. Thompson & D.J. Dunning, PRL 110, 134802 (2013)

What will CLARA be able to do?

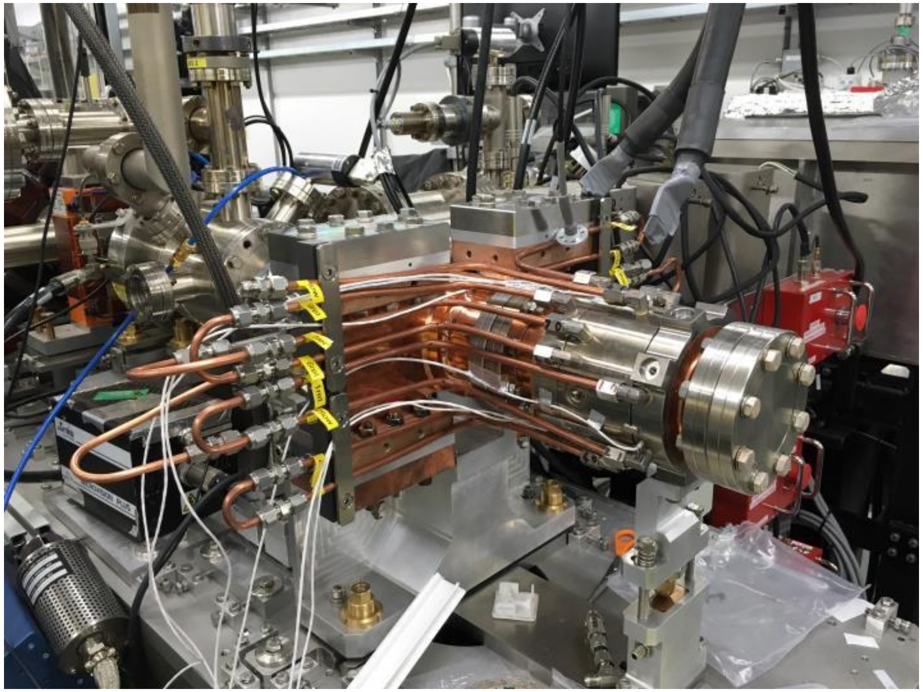
- **Example 2: Generate few cycle pulses**
- Prove that a new idea called **Mode-locked Afterburner** actually works
  - Could then build it in from the start of the UK XFEL
  - Able to probe ever faster processes (down to *sub-attosecond*)

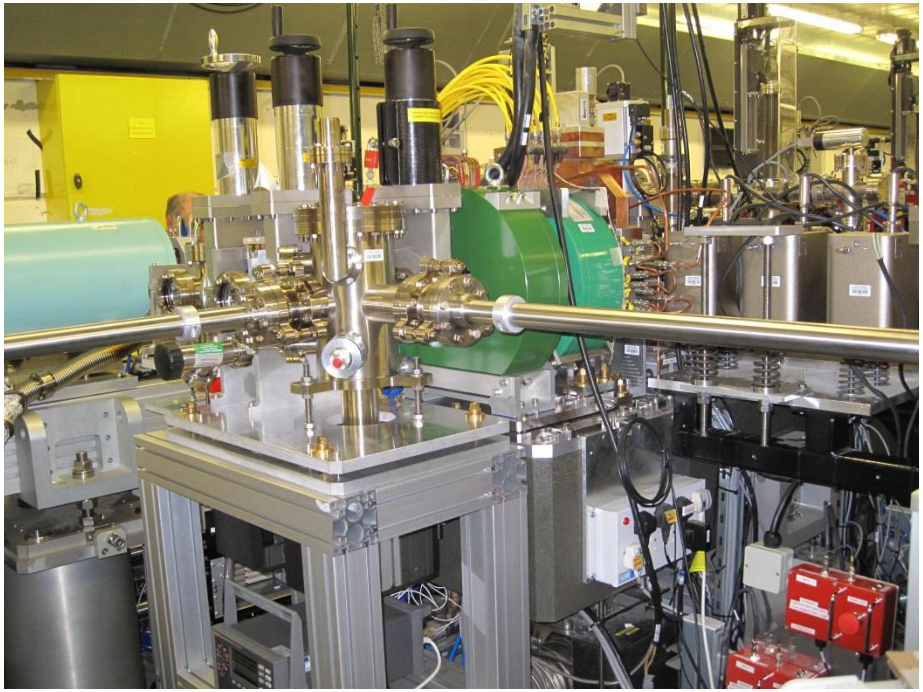


D.J. Dunning, B.W.J. McNeil, & N.R. Thompson
PRL 110, 104801 (2013)

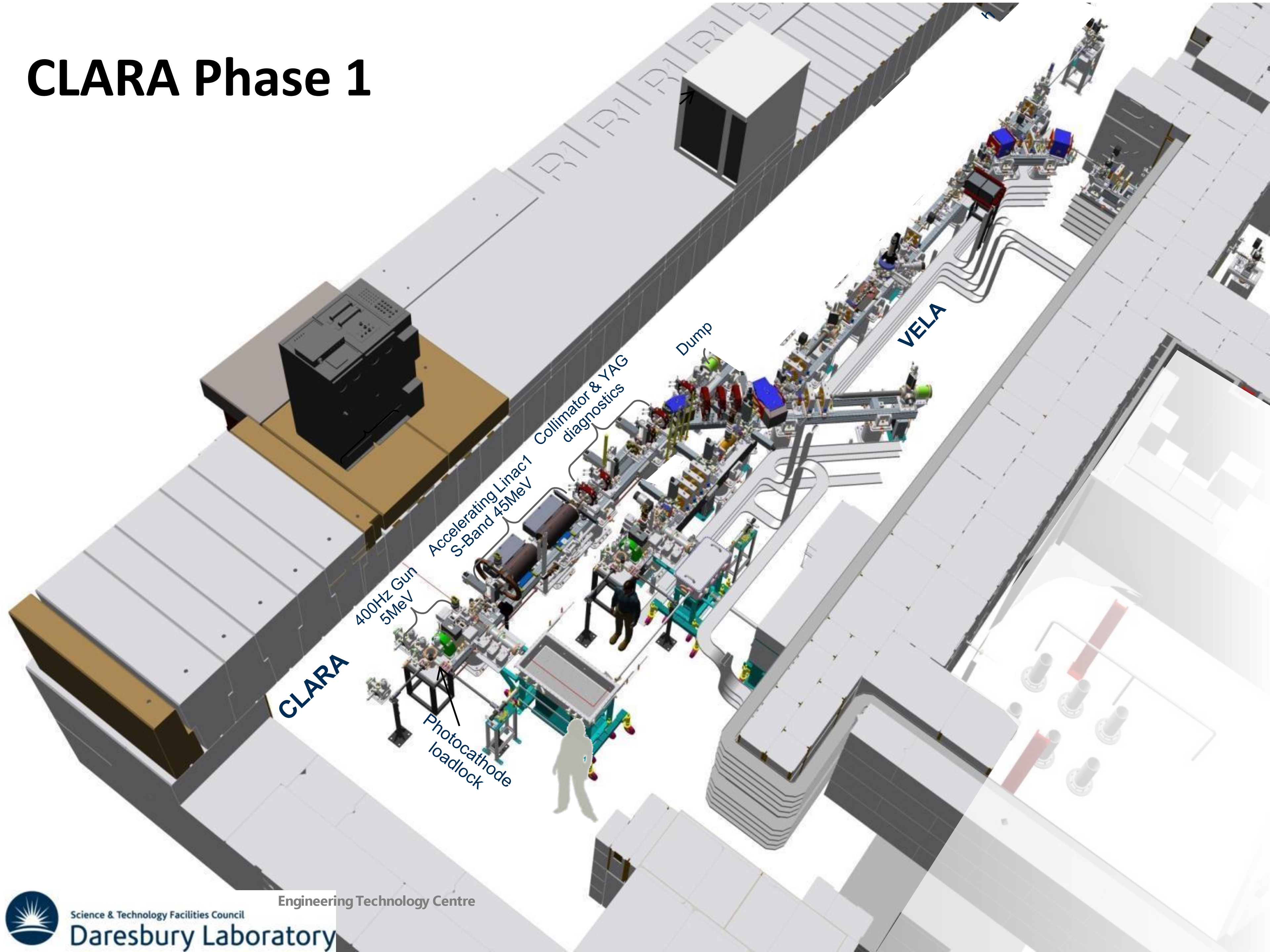
What will CLARA be able to do?

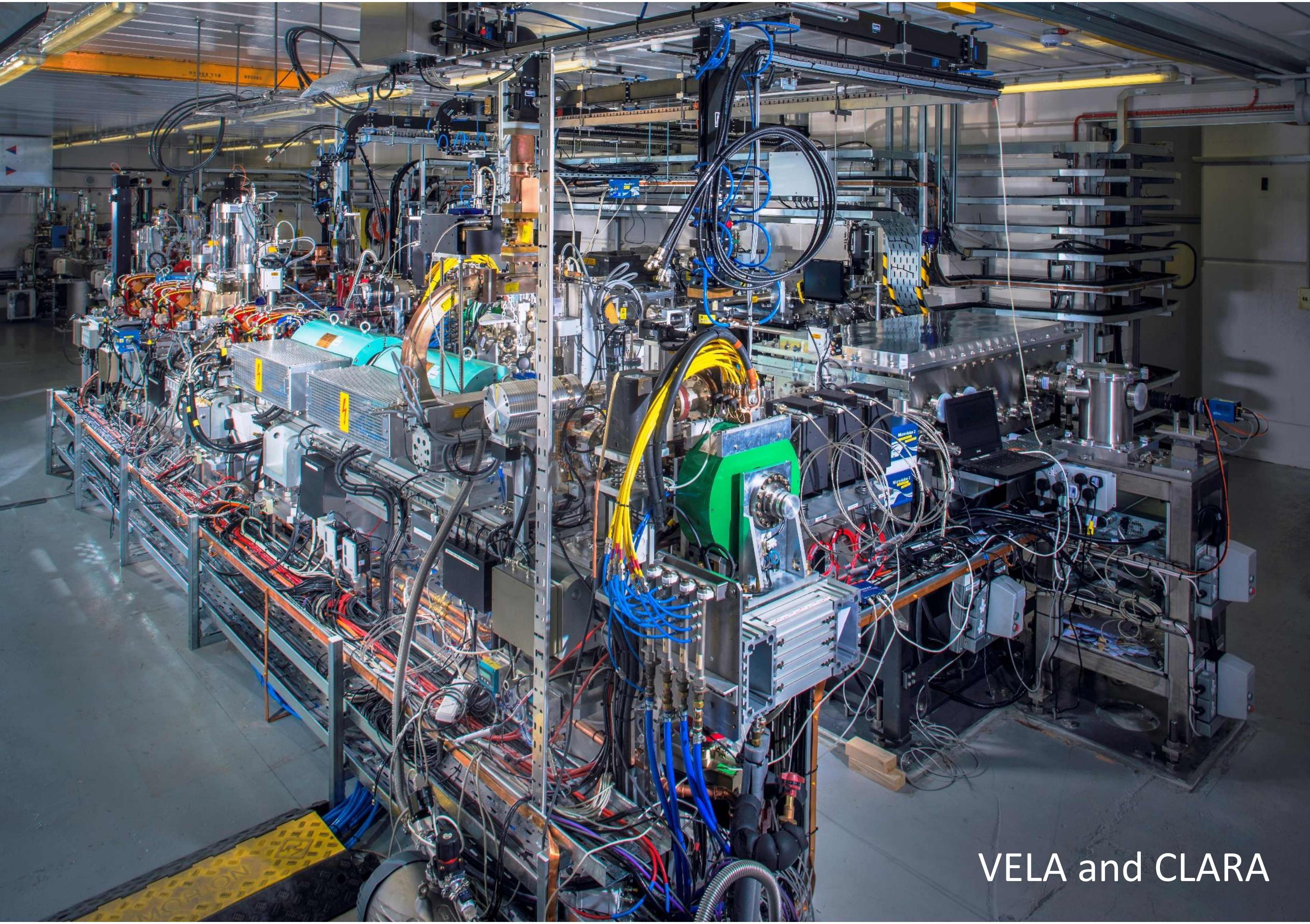
- **Example 3: Prove performance of 400 Hz Photoinjector Prototype**
- 1.5 cell S-band gun with RF probe
- Maximum gradient of 120 MV/m @100 Hz, or 100 MV/m @400 Hz
- 10kW cooling capacity
- Vacuum load lock system for easy replacement of cathode (e.g. Cu, CsTe, …)
- RF conditioning and beam characterisation with different cathodes planned in 2018.



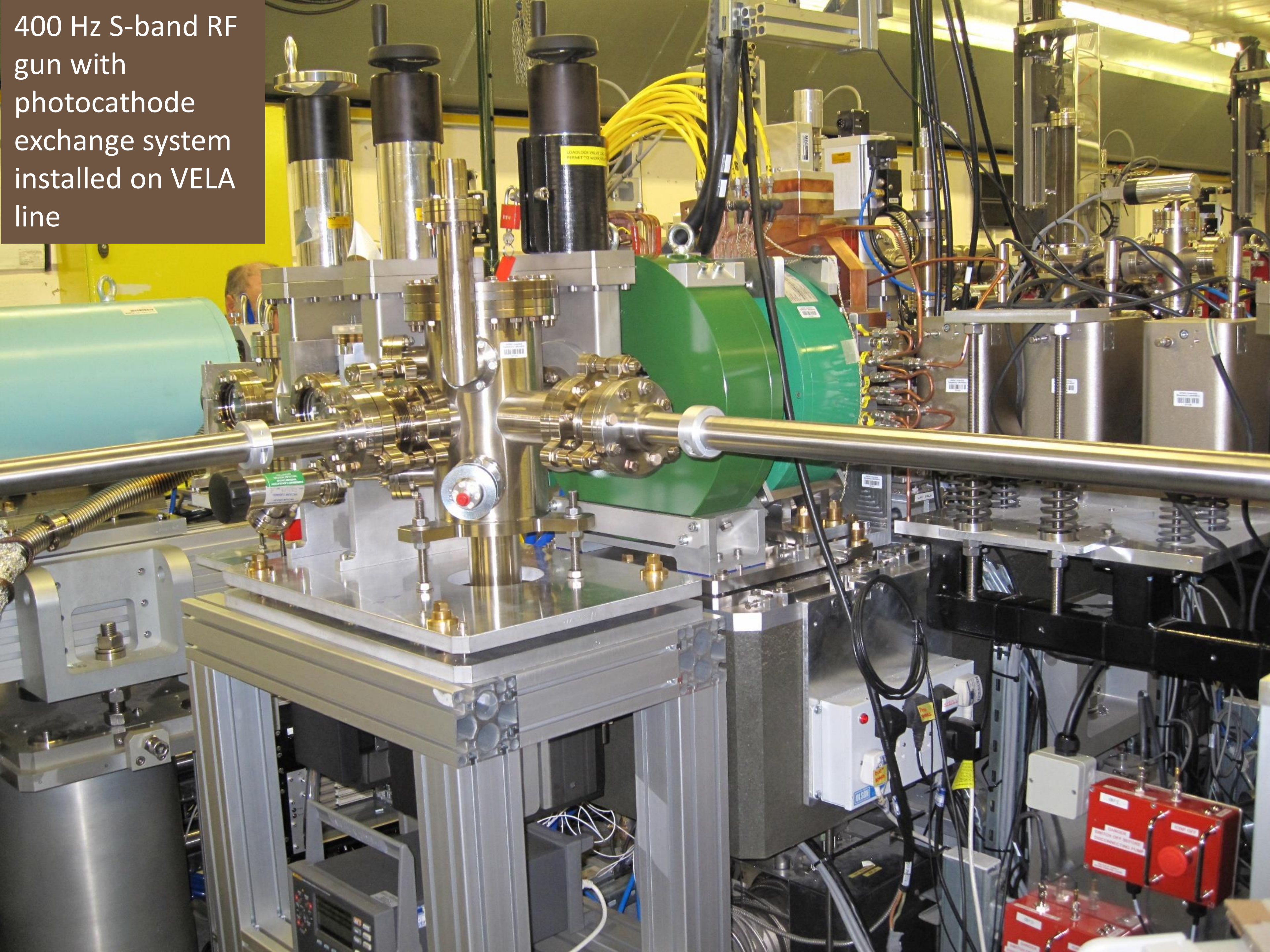


CLARA Phase 1





VELA and CLARA



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

The Electron Hall

- CLARA is cited within the Electron Hall at Daresbury Laboratory
- The Electron Hall was not fit for purpose so has been completely refurbished
  - For beam stability we need the temperature of the facility to be very stable
  - Previously the temperature within the building varied by at least 15 °C over the year
  - Now the measured variation is less than ±1 °C within the building
  - Within the shielded enclosure we have measured better than ±0.05 °C, as required

CLARA Status

- ***Phase 1, 50 MeV***
  - Installation complete.
  - Commissioning of 10 Hz gun and Linac1 underway.
  - First accelerated beam ((~50 MeV) from CLARA Front End last week.
  - Beam characterisation, machine development and exploitation planned in 2018.
  - HRRG gun conditioning and characterisation on VELA line planned.
- ***Phase 2, 250 MeV***
  - Procurement of equipment is ongoing.
  - Assembly offline of all modules during 17/18.
  - All shielding assembled by Spring 2018.
- ***Phase 3, 100nm FEL Test Facility***
  - Detailed design stage now.
  - Undulator tender documents being prepared.

Lessons Learnt

- Photoinjector
  - RF power meter measurements ←→ beam momentum
  - Dark current ←→ surface finish and processing of photocathode
  - Short Laser Pulse (control over longitudinal and transverse profiles was part of the long term development programme for CLARA) → damage to laser transport optics components
    - Pulse stretcher installed
    - Presently using Gaussian profile in longitudinal and transverse, will need flat top to reach CLARA emittance target <0.5 um (1 um max).
  - Precision on cathode dimensions
- Delays in procurement and delivery of some critical components.
- Not meeting technical specifications of few components.
- Unexpected issues, e.g. screwing of IR detectors after completion of waveguide assembly.

Summary

- CLARA is a purpose built dedicated flexible FEL Test Facility at the heart of the FEL R&D programme
  - To develop new methods for improving the quality of the light output from FELs
  - Prove new technologies
  - Develop the UK skill base
  - Lower the financial and technical risks associated with UK XFEL.
  - We are keen to work with international partners on all aspects of accelerator and FEL technology
- CLARA Status
  - Phase 1 now being commissioned
  - Procurement of remaining items for CLARA is ongoing
  - Electron Hall refurbishment is complete
  - First lasing in 2021 (subject to funding timeline)

Thanks to everyone who is contributing to the CLARA project

https://www.cockcroft.ac.uk/events/ICPA/

INTELLIGENT CONTROLS FOR PARTICLE ACCELERATORS

30-31 JAN 2018
DARESBURY LABORATORY

Where does the UK accelerator community want to be in 5-10 years in terms of controls?

To achieve their ultimate performance, the next generation of particle accelerators require advances in controls systems and feedback. Proposed techniques to realise this include; machine learning through neural networks, genetic algorithms, artificial intelligence, and adaptive controls. This workshop aims to discuss the state of the art and explore promising approaches for future development.

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