UKRI Science and Technology Facilities Council

ASTeC

Making a brighter future through advanced accelerators

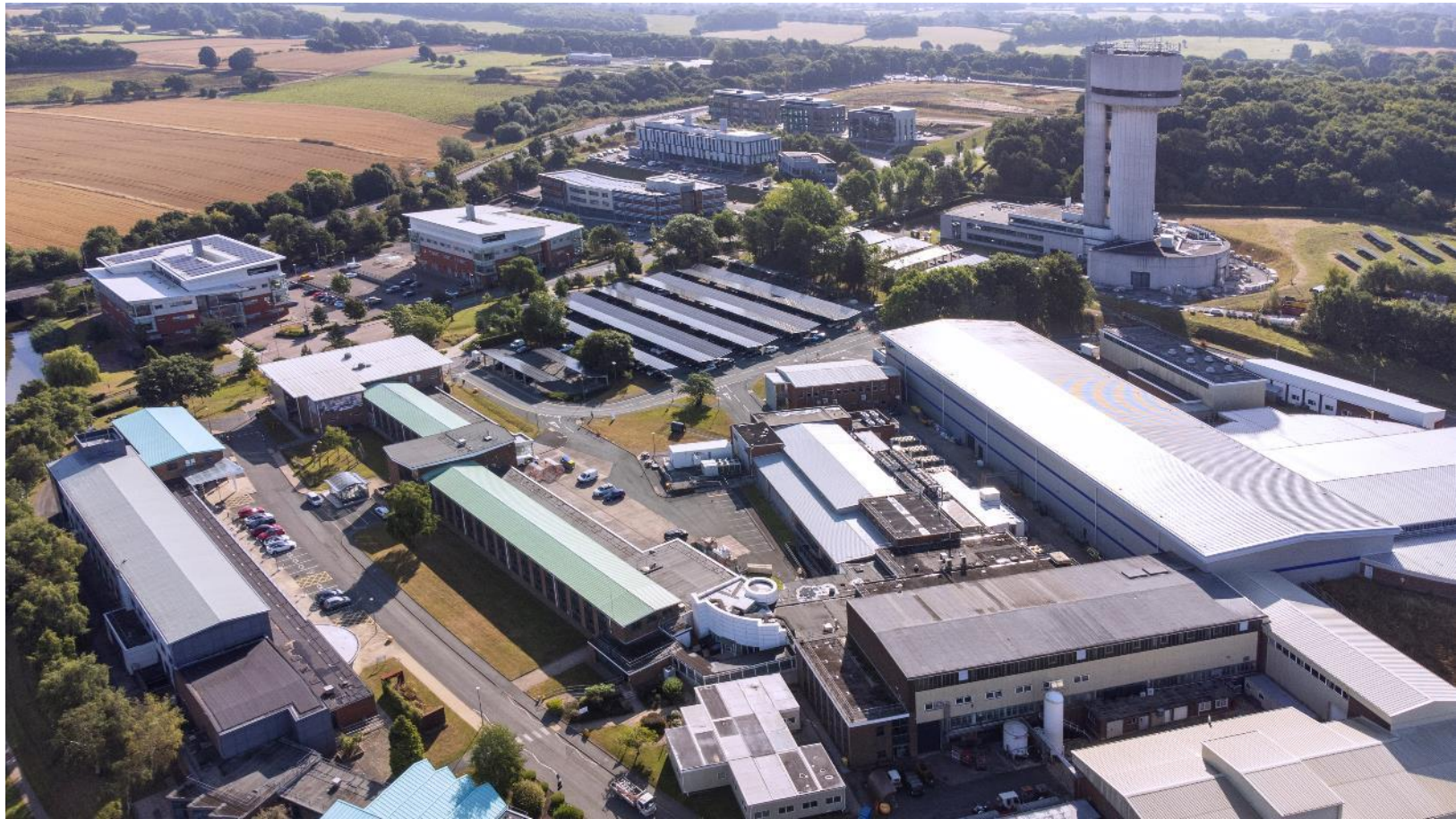
Report from Daresbury Laboratory

Jim Clarke
Director of ASTeC

Plenary ECFA
INFN Frascati July 2024

Daresbury Laboratory and Campus

- Daresbury Laboratory is an **STFC National Laboratory with ~700 staff**
- Major activities are centred around **particle accelerators, scientific and high performance computing and nuclear physics**
- The campus hosts **>150 companies and the Cockcroft Institute**
- **2000 people in total, ~300 accelerator researchers** including STFC staff, university academics, post docs and PhD students



Science and Technology Facilities Council

ASTeC

Accelerator Science and Technology Centre

- UKRI's **centre of excellence** in particle accelerator R&D
- The team that enables UKRI to propose major new types of infrastructures based upon accelerators and to make in-kind contributions overseas

- We are all based at **Daresbury Laboratory** with around **120 staff**
- We lead and operate **CLARA**, which is STFC's flagship accelerator test **user facility**
- We lead **STFC's In Kind Contributions** to new international infrastructures
- We have an excellent track record in supporting **industry** to develop and test new products
- We are an active partner in the **Cockcroft Institute**

Science and Technology Facilities Council

ASTeC

In Kind Contributions

Daresbury is currently delivering major in-kind contributions to three international accelerator projects

European Spallation Source

- Superconducting RF Accelerating Cavities
- Proton Beam Transport Units
- RF Waveguide Distribution System

LBNF/DUNE

- Three Superconducting RF Accelerating Cryomodules
- 137 Neutrino Detectors

High Luminosity-LHC

- Superconducting RF Crab Cavity Cryomodules
- Laser Engineered Surfaces

Electron Ion Collider

- Approved contribution to deliver a crab cavity cryomodule – not yet started

UKRI Science and Technology Facilities Council

ASTeC

European Spallation Source

Daresbury has almost completed all of our deliveries to ESS

- Superconducting RF Accelerating Cavities
- Proton Beam Transport Units
- RF Waveguide Distribution System

LBNF/DUNE

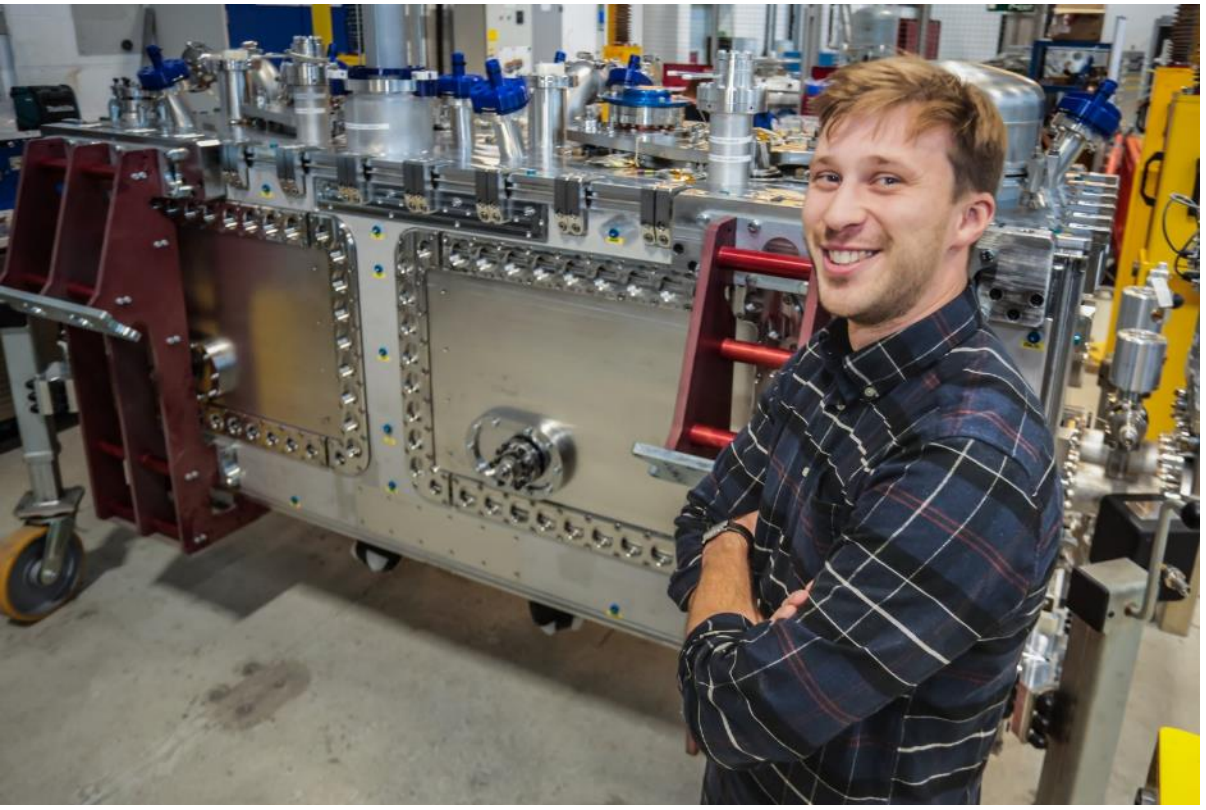
Daresbury is responsible for major contributions to the PIP-II accelerator at FNAL and the neutrino detectors for DUNE

- Three superconducting RF accelerator cryomodules – the infrastructure for cryomodule assembly is now complete, the first pre-production cavity has been delivered by Zanon, and the SRF cavity testing system has been reconfigured from ESS to PIP-II cavity testing
- 137 Anode Plane Assemblies, each 2.3 x 6.3m – a new ‘factory’ has been established at Daresbury that is up and running

HL-LHC Cryomodules

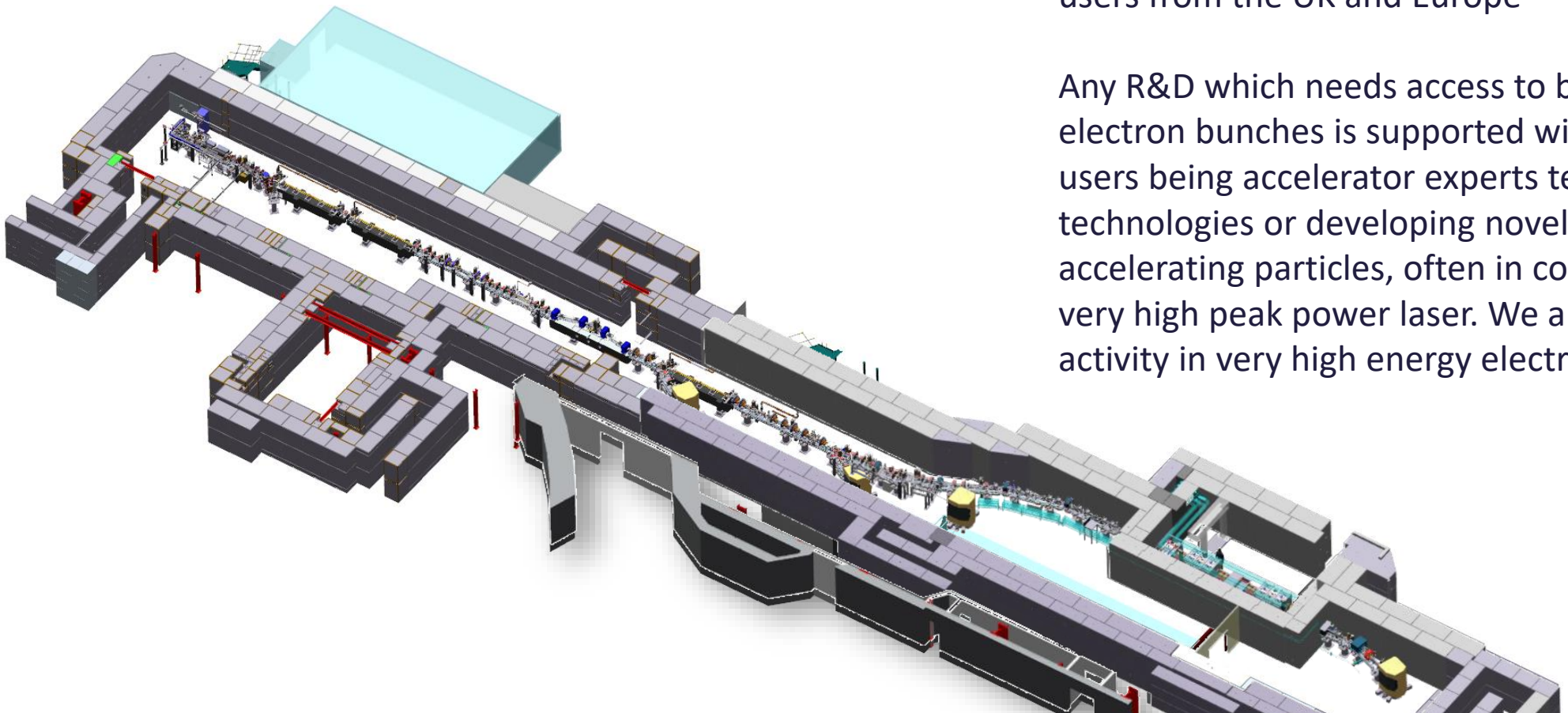
Daresbury, in close collaboration with the Cockcroft Institute, is responsible for the delivery of five crab cavity cryomodules

- The first pre-series module was recently delivered to CERN for testing on the SPS
- Four more production modules will now be assembled at Daresbury



CLARA

Our primary accelerator test facility is CLARA – an electron linear accelerator, currently being upgraded to 250MeV



CLARA is an open access user facility which supports users from the UK and Europe

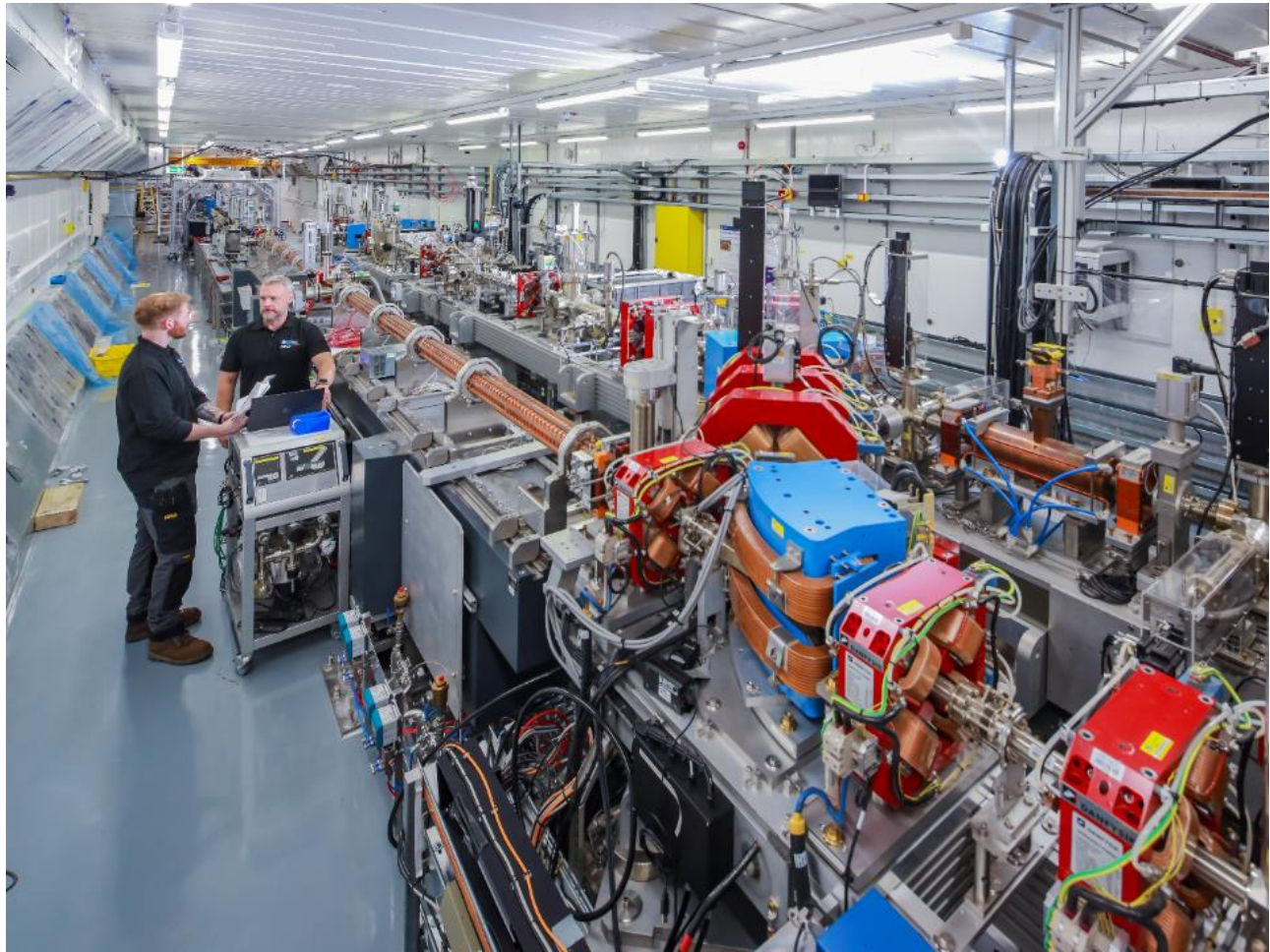
Any R&D which needs access to bright, high energy electron bunches is supported with the majority of users being accelerator experts testing new technologies or developing novel techniques for accelerating particles, often in combination with a very high peak power laser. We also have a significant activity in very high energy electron therapy.

CLARA

CLARA, and our other, smaller electron accelerators, are all housed within the Electron Hall

CLARA Upgrade

- A major upgrade of CLARA is now being installed and commissioned which will increase the capabilities of CLARA significantly.
- Operations for our users will resume in 2025.
- The upgraded performance of CLARA will establish this facility as Europe's **premier open access accelerator test facility.**



CLARA Upgraded Beam Parameters

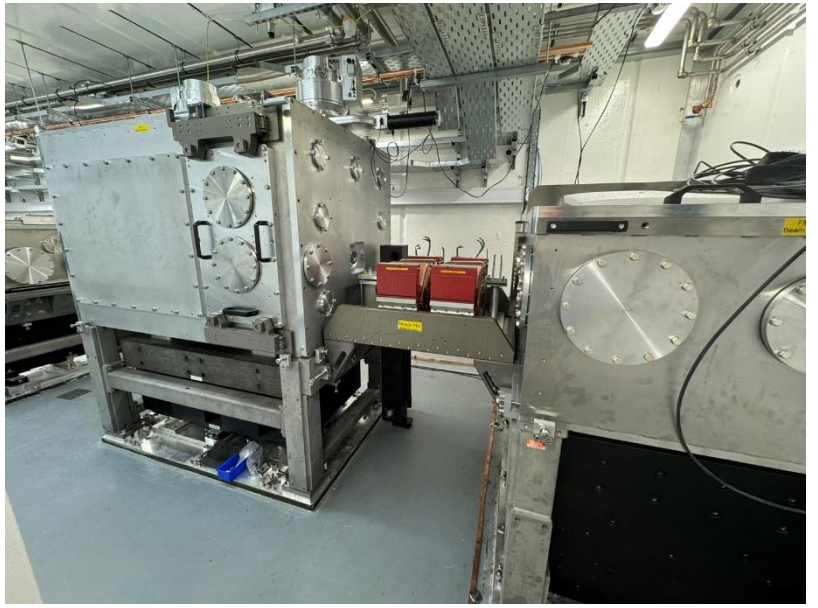
• Up to 50 MeV	**250 MeV**
• 10 Hz	**100 Hz**
• 10 TW laser	**120 TW**
• ~1 ps bunch length	**~50 fs**

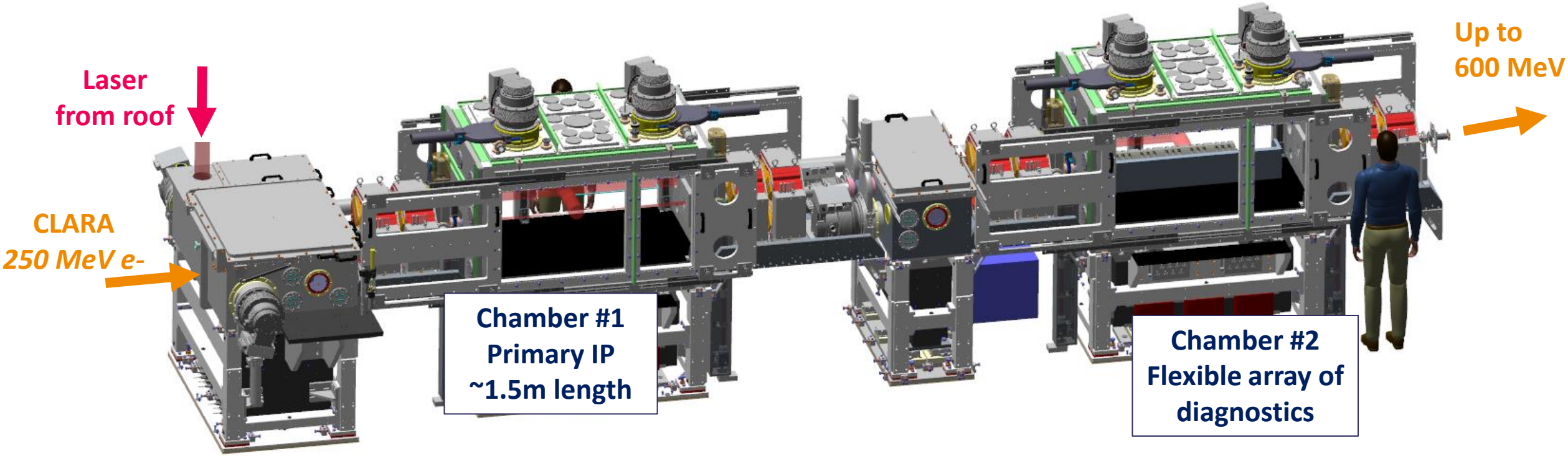
UKRI Science and Technology Facilities Council

ASTeC

Experimental Chambers

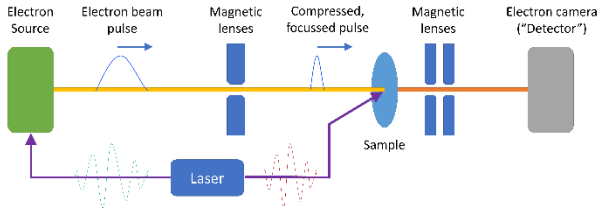
- Flexible space for novel acceleration studies in a separate hutch
- 2 identical chambers: Double interaction point configuration
- Dedicated laser in-out coupling chambers
- Accelerated beam up to 2 GeV possible in hutch

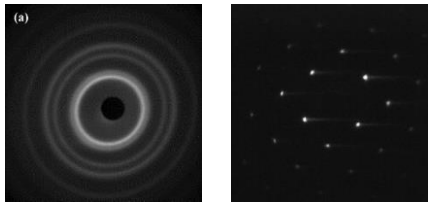




The RUEDI Facility

- **RUEDI** (Relativistic Ultrafast Electron Diffraction & Imaging) will be a new user facility at Daresbury which has recently been **approved for funding (£124.4m)**
- RUEDI will enable **MeV** Ultrafast Electron Diffraction ***and*** Microscopy
- Time-resolved pump-probe experiments with a large range of pumps and sample environments to enable a broad spectrum of science





- **Pumps**:
  - Wide variety of laser wavelengths, THz, TW, keV ion source
- **Environments**:
  - Solid, liquid cells, liquid/gas jets, plasmas, cryogenic (down to mK level)

Science and Technology Facilities Council
Daresbury Laboratory
UNIVERSITY OF LIVERPOOL
The Rosalind Franklin Institute
RUEDI

Enabling Science

- Stakeholder user meetings held throughout 2022
- Prioritised experiments, electron parameters, pump sources and sample environments

Mostly Diffraction

Dynamics of Chemical Change

- Chemical complexity across scales
- Hydrogen bonding
- Pulse radiolysis
- Heterogenous catalysis

UNIVERSITY OF LEEDS

Quantum Materials & Processes

- Ultrafast low-energy optical switching
- Magnetic textures & skyrmions
- Topological superconductors
- Thermoelectric energy harvesting

Swansea University
Prifysgol Abertawe

Mostly Imaging

Biosciences

- Photosynthesis & energy transfer
- Cardiac disease related dynamics
- Virology & infection
- Biological self-assembly/toxicity

The Rosalind Franklin Institute

Materials in Extremes

- Astrophysics & warm dense matter
- Advanced manufacturing
- Nuclear fission/fusion/space
- Response to shocks

UNIVERSITY OF LIVERPOOL

Energy Generation, Conversion & Storage

- Photocatalysis & induced electro-chemistry
- Defect kinetics in solar cells
- Ion solvation kinetics in batteries
- Kinetics of glasses

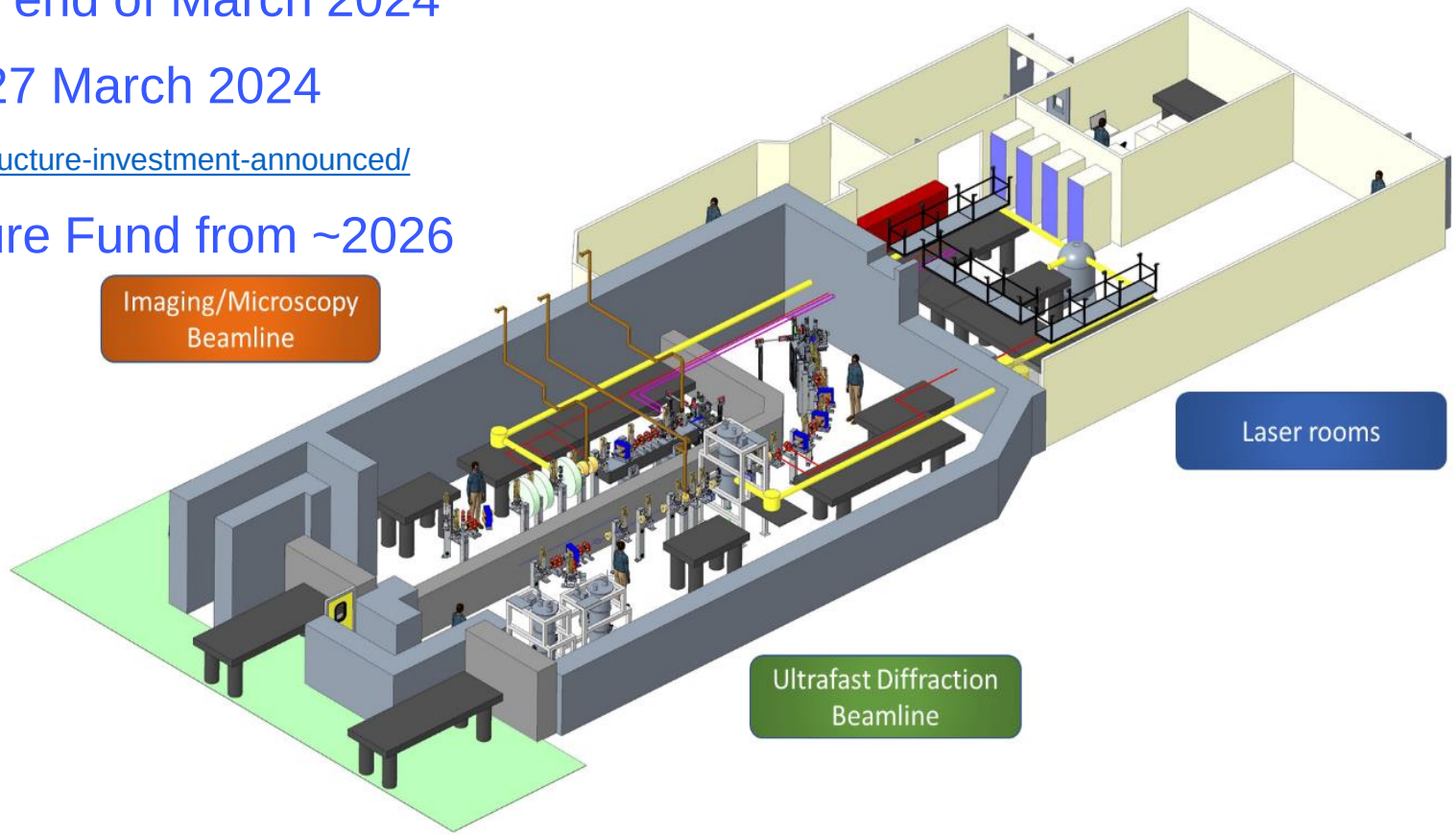
UNIVERSITY OF LIVERPOOL

RUEDI Status

- Technical design report completed at end of March 2024
- Full project approval announced on 27 March 2024

https://www.ukri.org/news/major-research-and-innovation-infrastructure-investment-announced/

- £124.4 million from UKRI Infrastructure Fund from ~2026



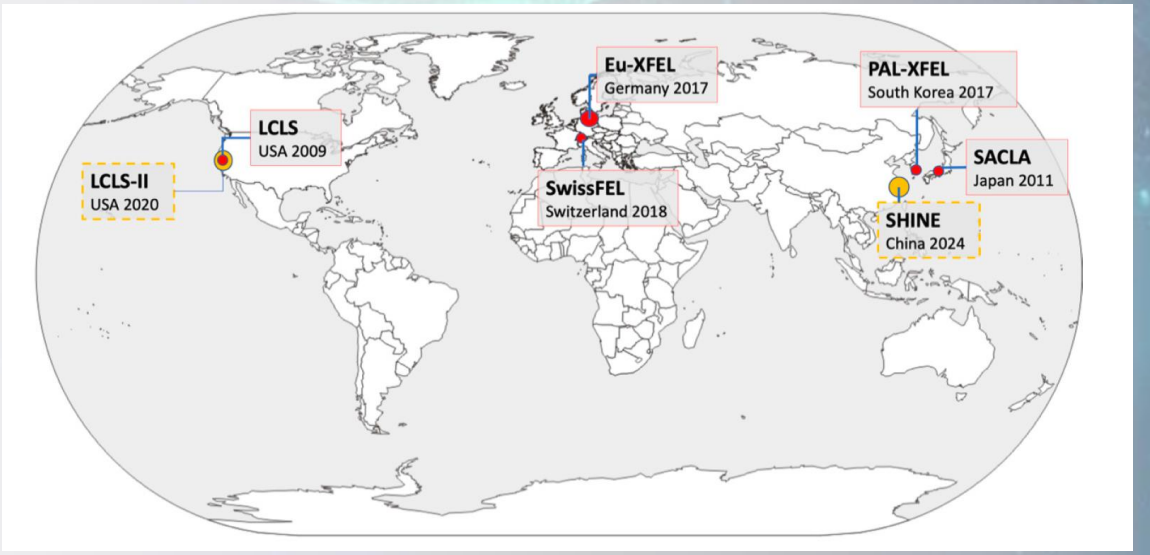
- To be sited at Daresbury Laboratory in the Electron Hall, close to CLARA and fully independent

RUEDI

UK-XFEL - Conceptual Design and Options Analysis Study

- Proposal and Aims

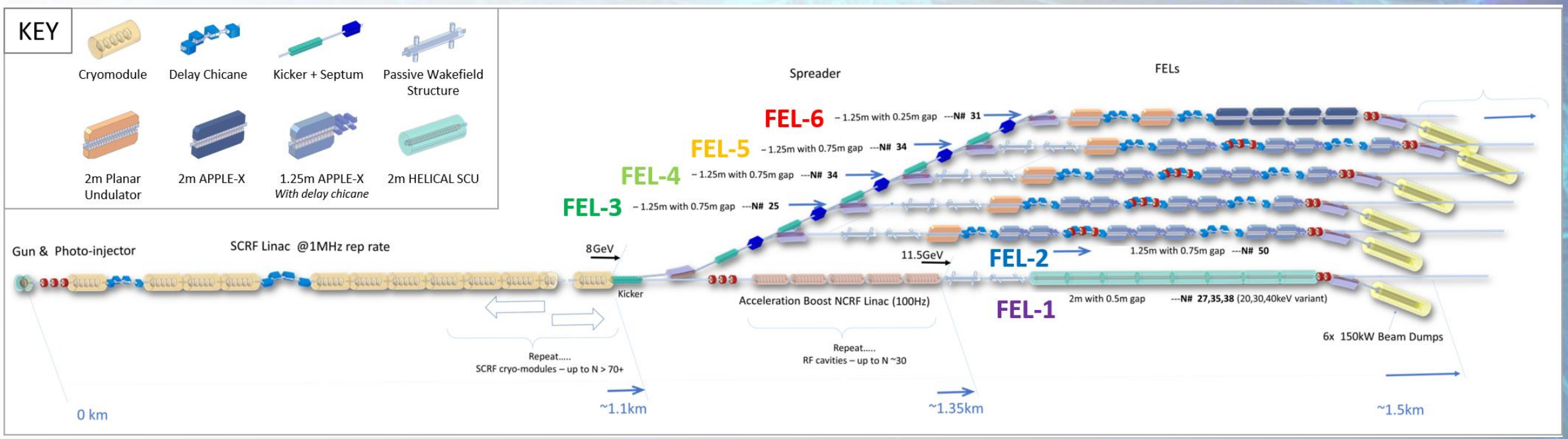
- In 2020, STFC funded and published a community based Science Case for a next generation **X-Ray Free Electron Laser**, aka the “UK XFEL”
- The question which this current project aims to answer is **'how best to achieve the UK XFEL Science Case?’.**
- The CDR will fully evaluate different options, either **build a UK XFEL** or **invest in an existing overseas XFEL** – the UK is already a member of the EU-XFEL (12% of users)
- The **science case will also undergo a refresh** along with broad **stakeholder engagement.**
- During this period research and development into new technologies required to deliver a **sustainable** next generation XFEL will also be identified .
- Project timescale **Oct 2022 to Oct 2025**



Science and Technology Facilities Council

UK XFEL Status

- Conceptual layout now starting to crystalize with an 8 GeV electron accelerator generating bunches at 1 MHz, shared among multiple beamlines (up to 10?), each able of operating independently and simultaneously



Sustainable Accelerators

- STFC plans to achieve Net Zero by 2040
- Accelerators consume very large amounts of electrical power and other resources
- ASTeC has been carrying out R&D into making accelerators more sustainable for many years, especially permanent magnets and new types of superconducting RF cavities
- STFC has ambitious plans, led by ASTeC, for a **Centre of Excellence in Sustainable Accelerators (CESA)** to rapidly increase the scale and pace of this R&D – incorporating the UK accelerator community, industry & CERN

Example Anticipated Impact of our Thin Film Superconducting RF R&D

For the **UK XFEL**, the power required for the cryogenic system will reduce from 8.7 MW to 2.9 MW since the RF will run at 4.2 K instead of 2 K. This equates to **£13 m per year** in operating costs at today's prices and **3.6 ktCO2e per year**.

Science and Technology Facilities Council

ASTeC

CESA – Agreement with CERN

STFC and CERN have signed an agreement to work together on sustainable accelerators

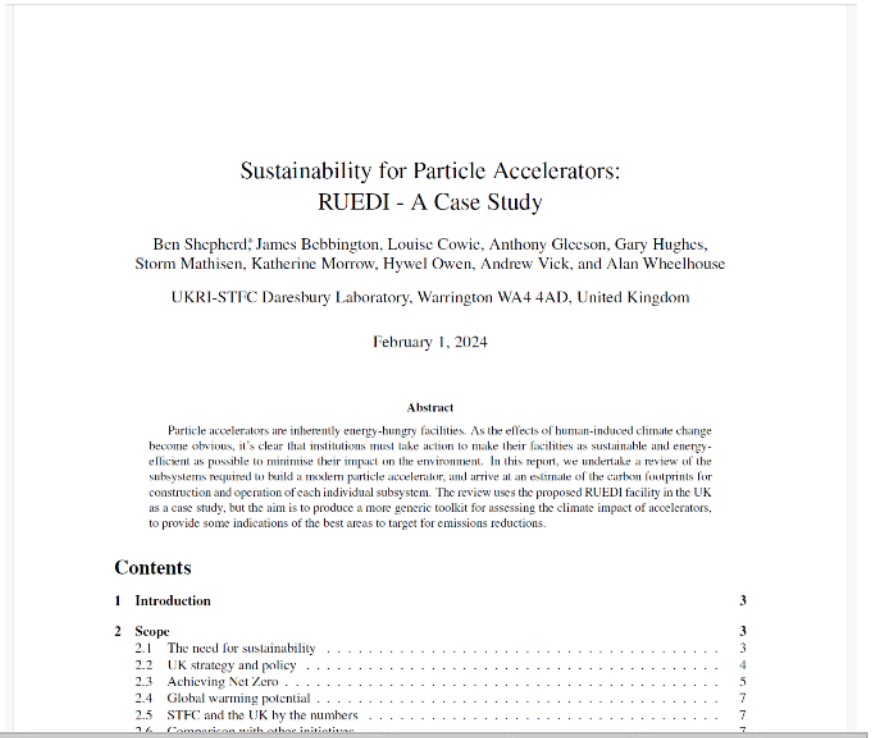
In recognition of the aims of CESA and the status of our activities CERN have signed an agreement to work with us on sustainable accelerator technology developments and CESA in particular

On 22nd March 2024, Mark Thomson and Fabiola Gianotti signed the agreement at CERN.

UKRI Science and Technology Facilities Council
ASTeC

RUEDI sustainability report

- Our Sustainable Accelerators Task Force has recently published a report on the carbon emissions of building and operating RUEDI
- Global warming potential values (tonnes CO_2 equivalent, or **tCO_2e**) for each machine area: manufacture and operation
- Priority areas for further investigation: **shielding**, **air conditioning**, **vacuum**
- Developed **toolkit** and **methodology** that can be used for future accelerators – UK XFEL case study next
- The report can be downloaded from here: https://www.astec.stfc.ac.uk



Sustainability for Particle Accelerators:
RUEDI - A Case Study

Ben Shepherd, James Bebbington, Louise Cowie, Anthony Gleeson, Gary Hughes, Storm Mathisen, Katherine Morrow, Hywel Owen, Andrew Vick, and Alan Wheelhouse

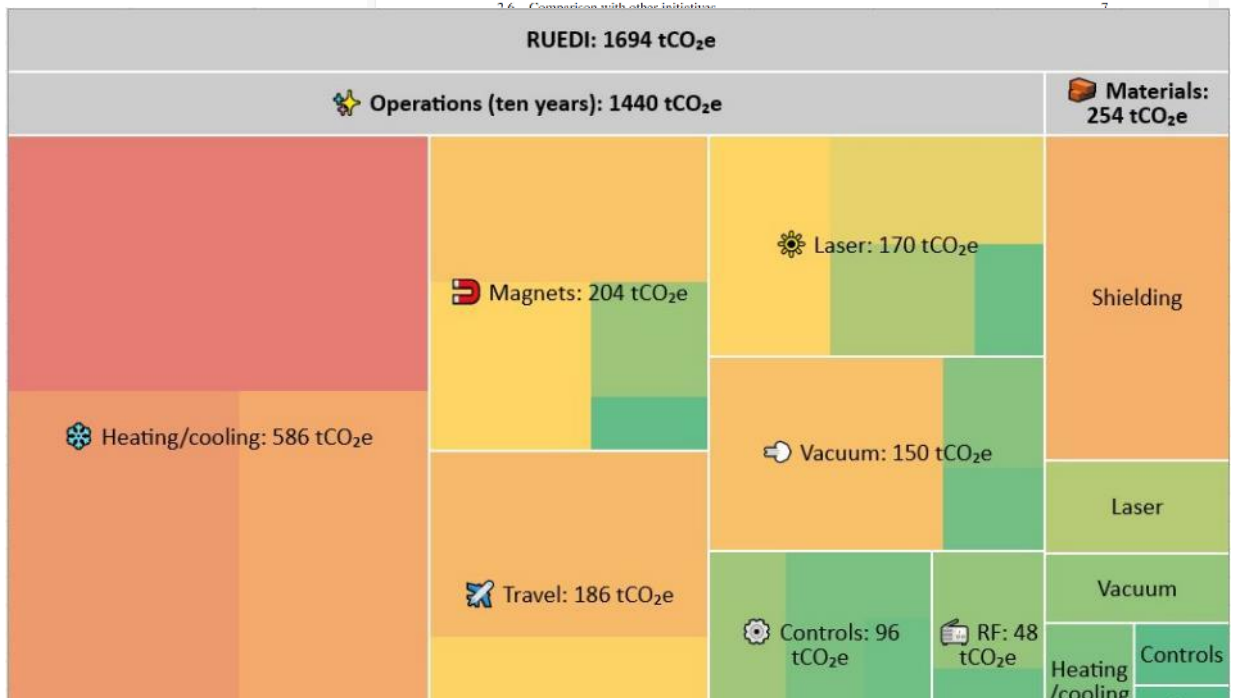
UKRI-STFC Daresbury Laboratory, Warrington WA4 4AD, United Kingdom

February 1, 2024

Abstract

Particle accelerators are inherently energy-hungry facilities. As the effects of human-induced climate change become obvious, it's clear that institutions must take action to make their facilities as sustainable and energy-efficient as possible to minimise their impact on the environment. In this report, we undertake a review of the subsystems required to build a modern particle accelerator, and arrive at an estimate of the carbon footprints for construction and operation of each individual subsystem. The review uses the proposed RUEDI facility in the UK as a case study, but the aim is to produce a more generic toolkit for assessing the climate impact of accelerators, to provide some indications of the best areas to target for emissions reductions.

Contents



Science and Technology Facilities Council
ASTeC