UKRI Science and Technology Facilities Council

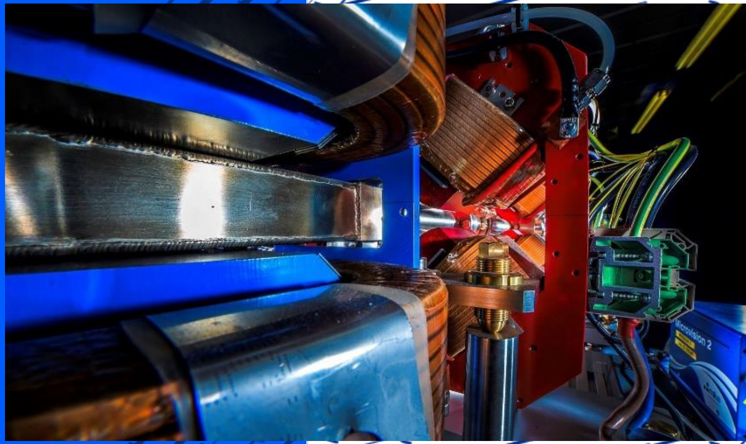
ASTeC

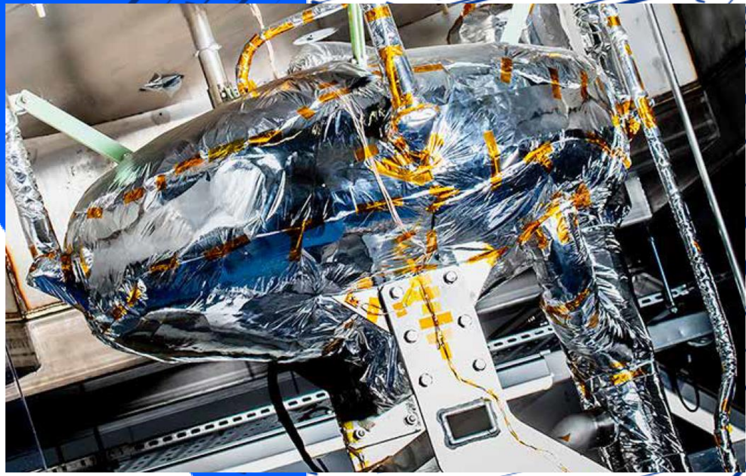
Making a brighter future through advanced accelerators

UK National Accelerator Facilities Landscape

Deepa Angal-Kalinin

ASTeC, STFC Daresbury Laboratory and The Cockcroft Institute





PAB Conference, 11th -12th June 2024, Workington

Outline

Science and Technology Facilities Council

- UK National Accelerator Facilities
- Infrastructure opportunities
- Status of new national projects

UK National Accelerator Facilities

Science and Technology Facilities Council
Rutherford Appleton Laboratory

Science and Technology Facilities Council
ISIS Neutron and Muon Source

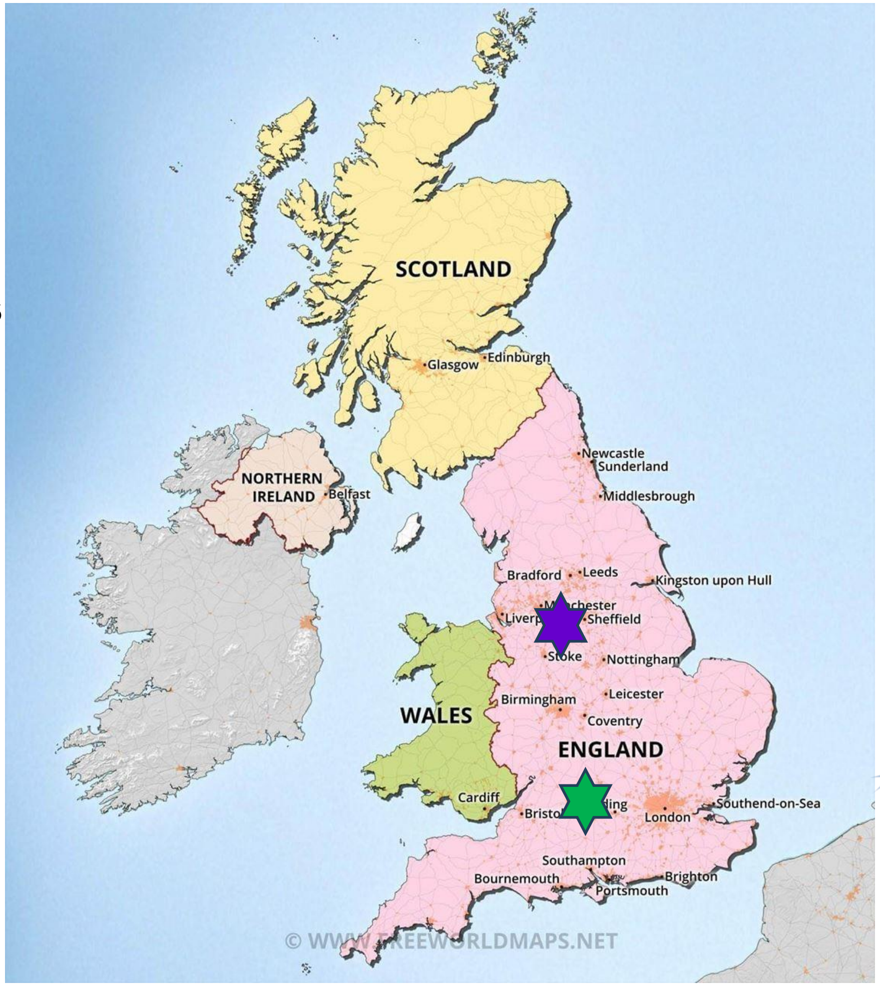
ISIS: 800 MeV protons, 50 Hz generating neutrons and muons
(Operational 1984 – Present)
ISIS II upgrade

Science and Technology Facilities Council
Central Laser Facility

EPAC: 1 PW, 10 Hz ; LWFA

diamond

Diamond: 3 GeV e- storage ring, 32 beamlines
(Operational 2007 – Present)
Diamond-II: 3.5 GeV, 35 (37) beamlines



Science and Technology Facilities Council
Daresbury Laboratory

Science and Technology Facilities Council
ASTeC

CLARA: 50 MeV e-, 10 Hz
(operational 2018 – 2023)
CLARA: 250 MeV e-, 100 Hz

RUEDI

RUEDI: 1-4 MeV e- diffraction & imaging,100 Hz (1KHz)

ITRF/ LhARA

ITRF/LhARA: protons (15-127 MeV)/ions (5-34 MeV/u)

Planned upgrades/ future projects

UK XFEL : Conceptual Design & Options Analysis

UK Infrastructure Funds

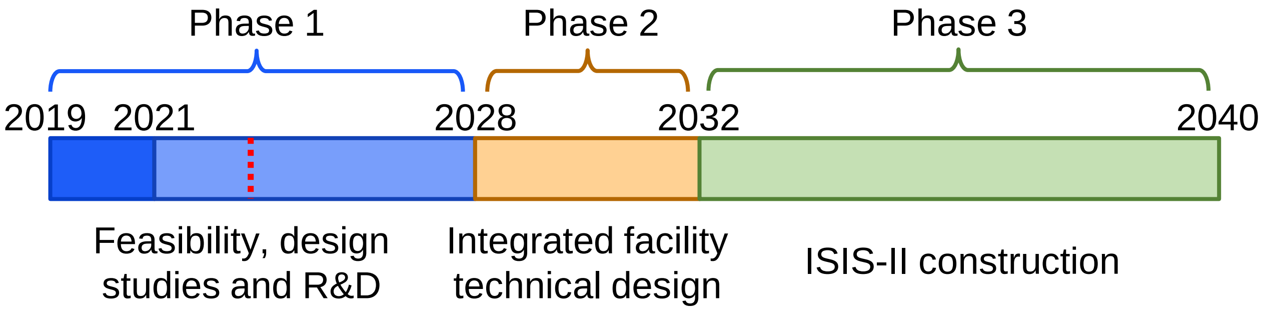
- **A prioritisation process** for identified infrastructure opportunities has now been running for three years
- **Two types of proposal** can receive funding:
  - **Full project** – requesting the funds for the full project
  - **Preliminary Activity** – requesting funds for some up-front activity (typically a design study) with the expectation of later being resubmitted as a Full Project request
- Current status:
  - **ISIS-II** (preliminary activity)
  - **RUEDI** (full project funding approved, business case submission 2024, construction starts 2026)
  - **Diamond-II** (full project funding approved, project completion March 2030)
  - **Ion Therapy Research Facility** (preliminary activity)
  - **UK XFEL** (preliminary activity)
- The **EPAC** was *funded prior to this process* (different route) and is under construction at RAL
- **CLARA**, *built in phases at DL also funded separately to this process*.

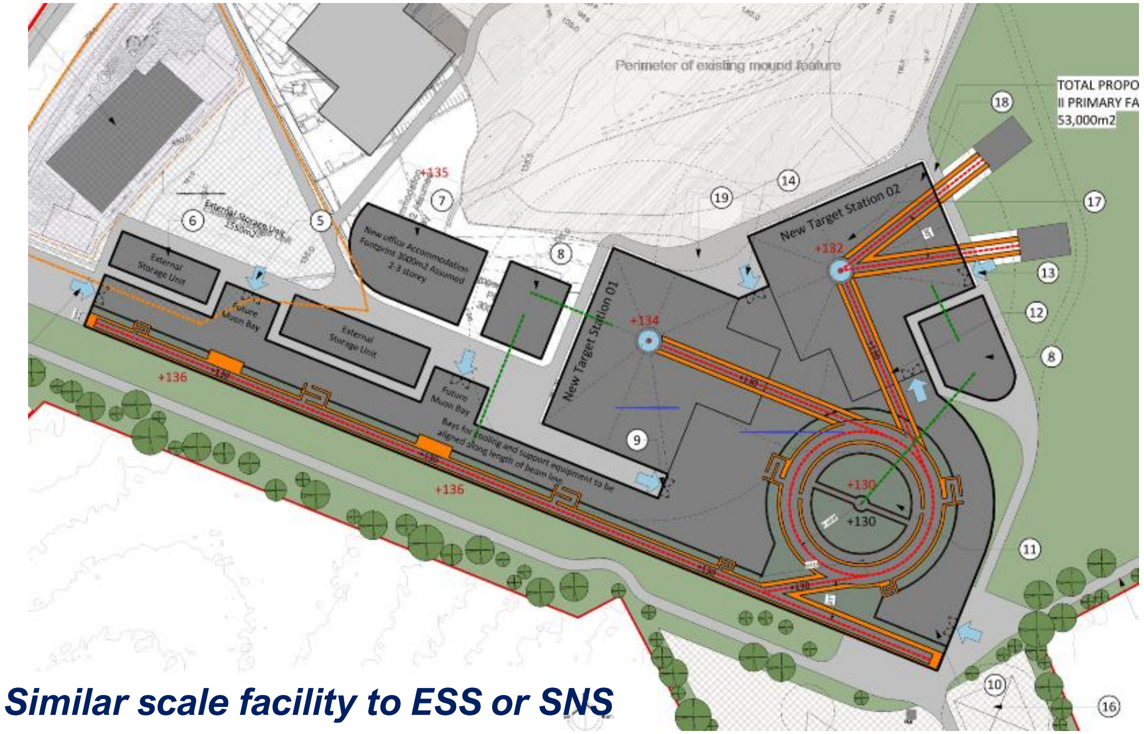
ISIS -II

- Favoured option is a **new, stand-alone facility**.
- **MW-class** is expected, but dependent on target technology.
- **Two target stations** from day one.
- Accelerator options:

– **Low energy linac with rapid cycling synchrotron** to bunch compress and accelerate up to 1.2 GeV.
– **Low energy linac with fixed-field alternating-gradient accelerator** to bunch compress and accelerate up to 1.2 GeV.
– **Full energy linac with accumulator ring** to bunch compress at 1.2 GeV.

ISIS upgrade talk by Billy Kyle next!





Similar scale facility to ESS or SNS

Courtesy of John Thomason

Diamond II - Objectives

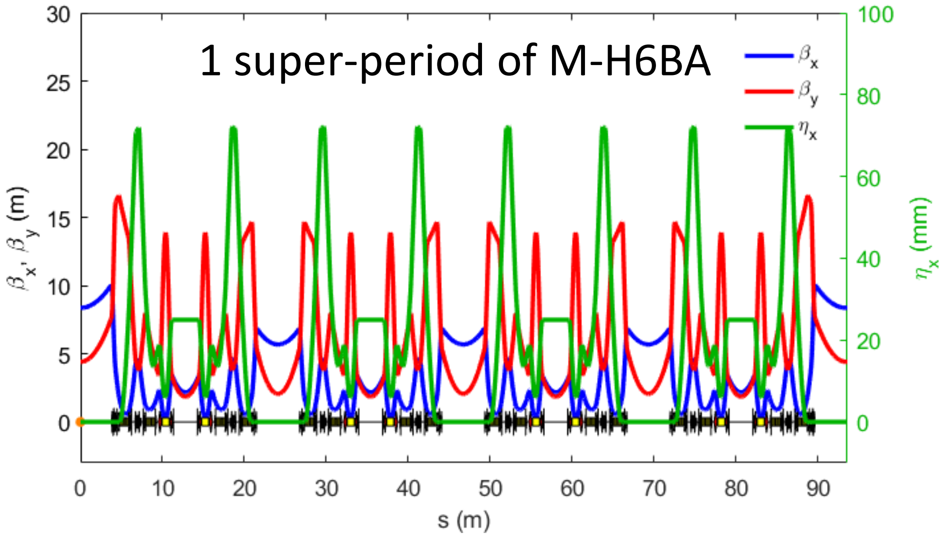
Objective #1: Optimise the science enabled at Diamond

Objective #2: Maximise the impact it has for researchers both in universities and in industry

- New Modified Hybrid 6-Bend Achromat (M-H6BA) storage ring
  - Lower emittance (x~20) to increase brightness and coherence
  - Double number of straight sections to increase capacity
- Raise energy from 3 GeV to 3.5 GeV to increase flux and brightness above 10 keV
- Upgrade insertion devices, new flagship beamlines
- Improved data handling/computation, automation, …

Technical Design Report published in October 2022:

https://www.diamond.ac.uk/Home/News/LatestNews/2022/14-10-22.html



	Bare lattice	With IDs
Average ε_x^*	163 pm.rad	120 pm.rad
Average σ_E^*	0.095 %	0.109 %
Average σ_L^* (RMS)	49.1 ps	48.1ps
Total Lifetime*	7.0 ± 0.2	7.0 ± 0.3

Courtesy of Ian Martin & Richard Walker

Diamond II - Top-Level Work Breakdown Structure

1. Diamond-II Project

- WBS 1.1 Machine
- WBS 1.2 Beamlines
- WBS 1.3 Core Software, Controls & Computing
- WBS 1.4 Buildings & Infrastructure
- WBS 1.5 Project Management

A major upgrade of the machine, replacing most of the Booster synchrotron and Storage Ring.

3 new ‘flagship’ beamlines + significant upgrades to many existing beamlines.

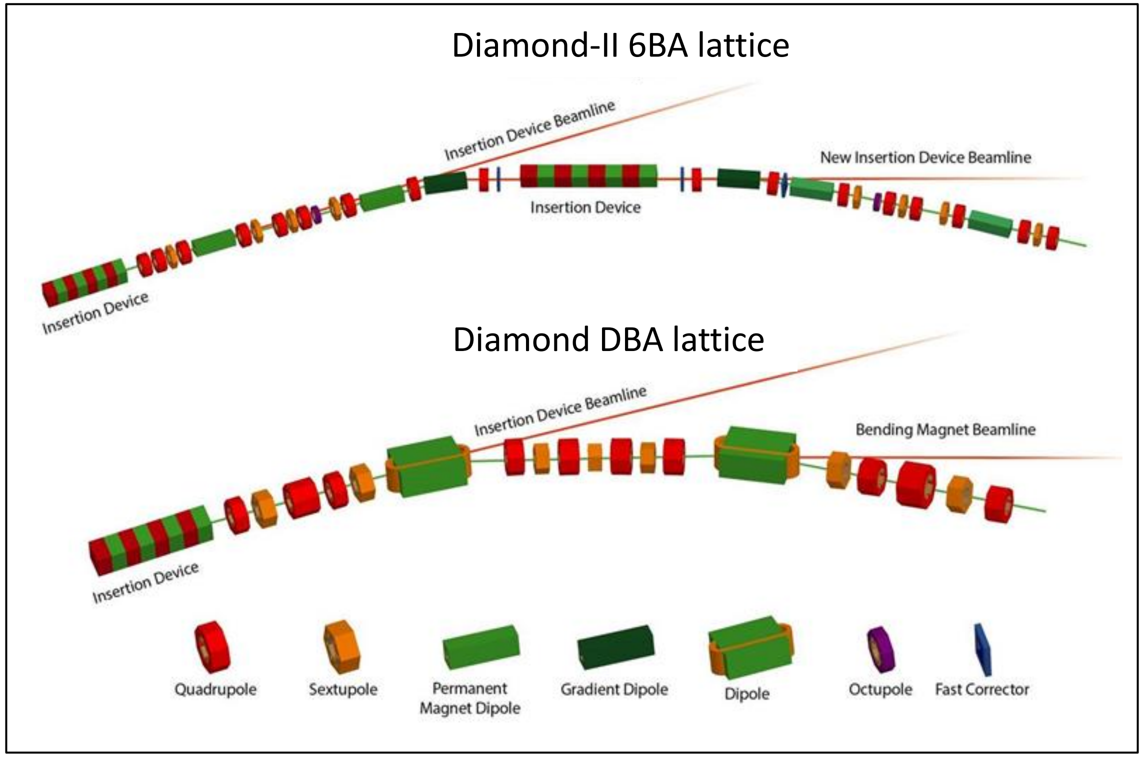
A boost in data handing and analysis hardware & software, to manage the increased data rates.

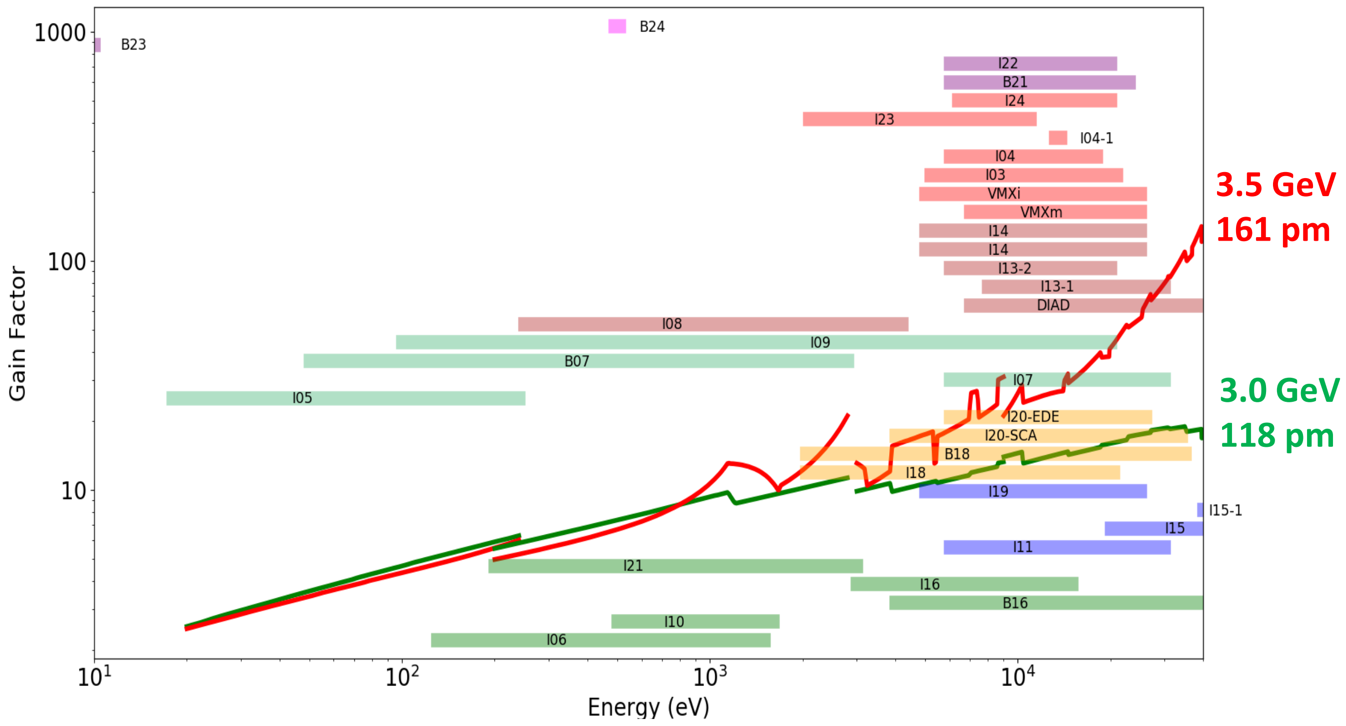
A new Diamond Extension Building for Diamond-II assembly work, as well as several other on- and off-site storage buildings.

Enhanced Project Management processes.

Courtesy of Ian Martin & Richard Walker

Diamond II – Layout & Brightness





	emittance (no IDs)	Ratio	emittance (IDs+IBS+3HC)	Ratio
Diamond	2.7 nm	16.8	3.1 nm	22.3
Diamond-II	161 pm		139 pm	

Courtesy of Ian Martin & Richard Walker

Diamond II – Project Status & Key Milestones

Project Status

Tendering for major components underway:

- Solid-state amplifiers for normal conducting RF cavities (ITT Aug ’23, contract placed Nov ’23)
- Storage ring quadrupole magnets (ITT Jan ’24, contract placed Mar ’24)
- Superconducting 3rd harmonic RF cavity (ITT Feb ’24 , contract placed May ’24)
- Storage ring sextupole magnets (ITT Mar ’24 , contract placed May ’24)
- Booster magnet power supplies (ITT Mar ’24)
- Booster girder assemblies (ITT Apr ’24)
- Transverse gradient (DQ) electromagnet dipoles (ITT June ’24)

Major items in next few months:

- Permanent magnet blocks and shunts for storage ring longitudinal gradient (DL) dipoles
- Main RF cavities
- Hybrid permanent magnet undulators
- Copper and stainless-steel girder vacuum vessels (NEG coated)

Key Milestones

- Project approval and first Calls For Tender – Jul. 2023
- Completion of Diamond Extension Building – Feb. 2025
- Start of the Diamond-II shutdown (the 18-month “dark period”) – Dec. 2027
- Start of storage ring commissioning – Dec. 2028
- Start of regular beamline X-ray commissioning – Jun. 2029
- First phase of operational beamlines – Sep. 2029
- First User on a flagship beamline – Jan. 2030
- Diamond-II Project completed – Mar. 2030

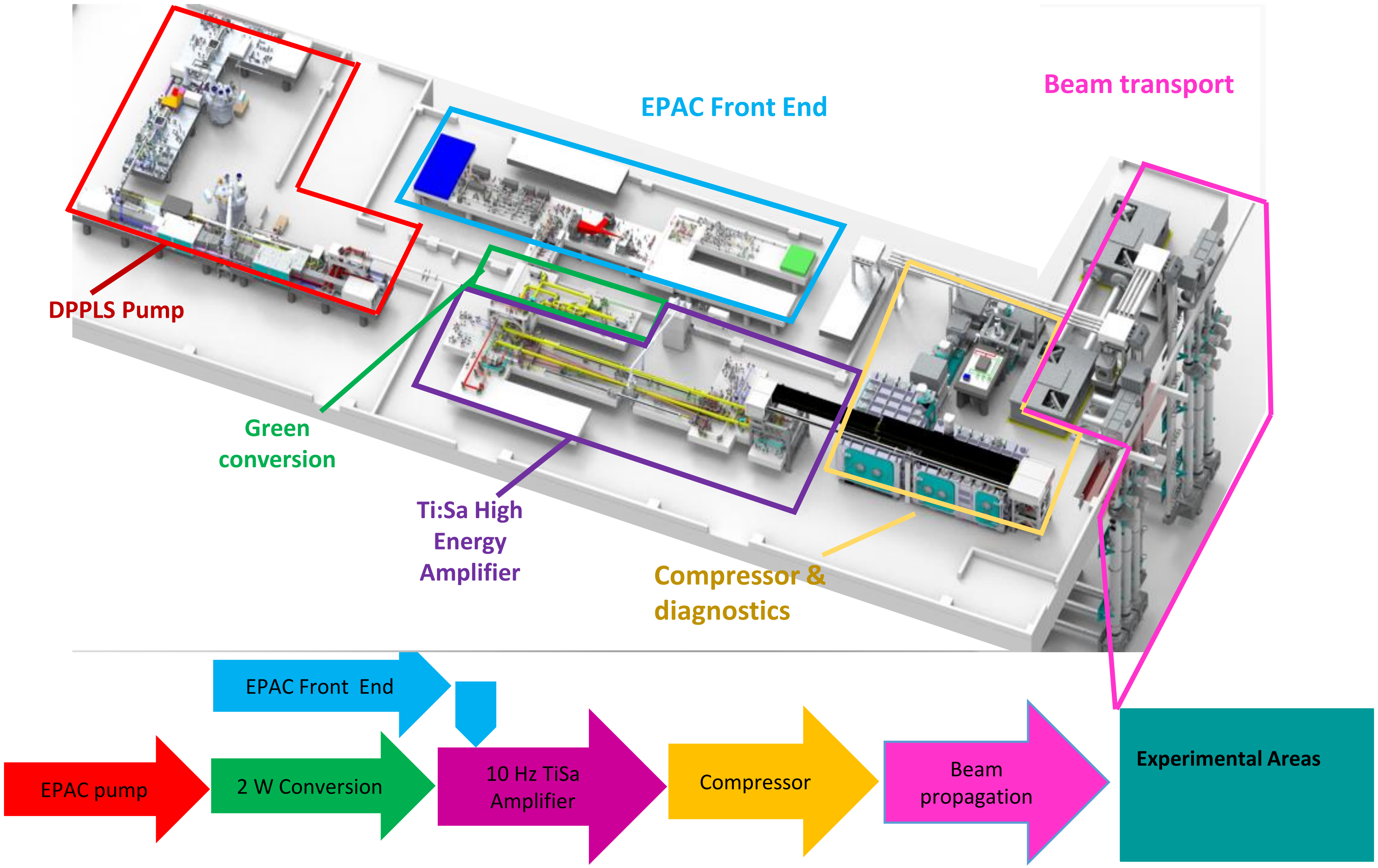
Courtesy of Ian Martin & Richard Walker

Extreme Photonics Applications Centre (EPAC)

- Centre for applications of laser-driven plasma sources in industry, medicine, security etc.
- New building housing a PW laser system operating at 10 Hz with two independent experimental areas.
- Focus on developing LWFA driven beams at 10 Hz: up to 10 GeV electron beams, x-rays.
- Improved capability for studies of fundamental science using laser-driven secondary sources.

Courtesy of Dan Symes

EPAC Laser System



EPAC specification

1PW@10Hz

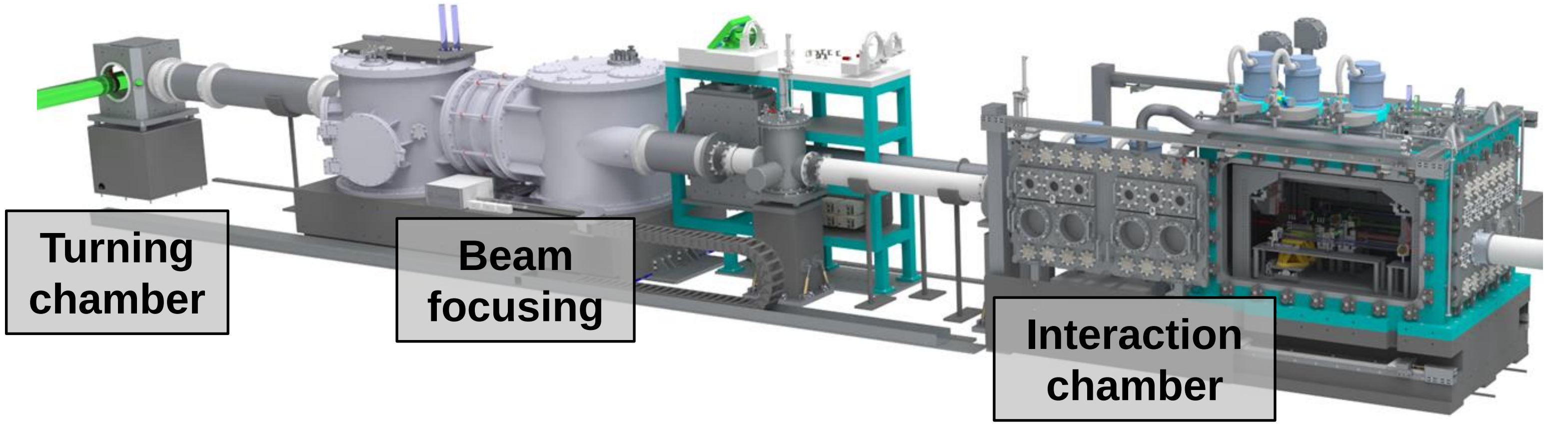
- **Output Energy 30 J**
- **Pulse duration ≤ 30 fs**

  Repetition rate 10 Hz, 1 Hz, Shot on Demand

- Pump for Ti:Sa is CLF developed 100J DiPOLE system.
- Additional space for future laser and experimental areas (eg. a 100Hz system under development)

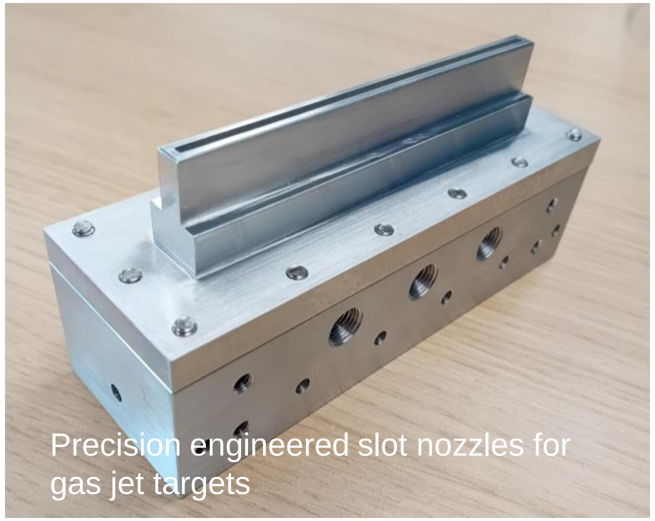
Courtesy of Dan Symes

EPAC EA1



- Off-axis parabola: focal length 6 m (*f* / 27) – 14.5 m (*f* / 65)
- Adaptive optic for focal spot control
- 20 x 9 m area for **flexible applications beamlines**


Focusing chamber in manufacture with HiVac , expected delivery by summer 2024


Precision engineered slot nozzles for gas jet targets


EA1: the optic mounts for adaptive optic and parabola, and the target chamber.
Courtesy of Dan Symes

Science and Technology Facilities Council
Central Laser Facility

EPAC – Electron Beam Line Design

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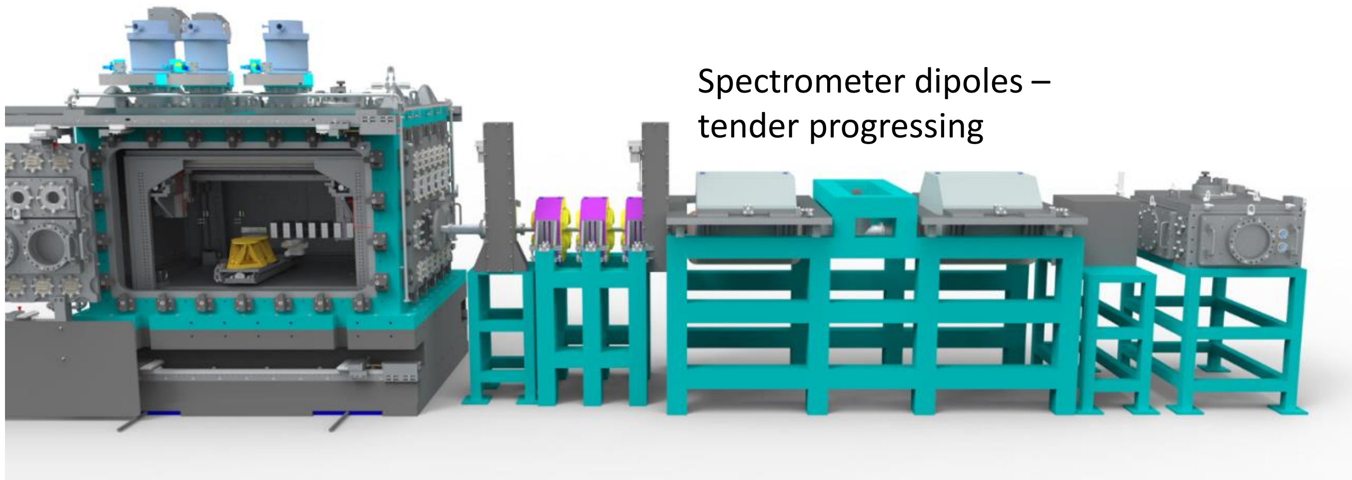
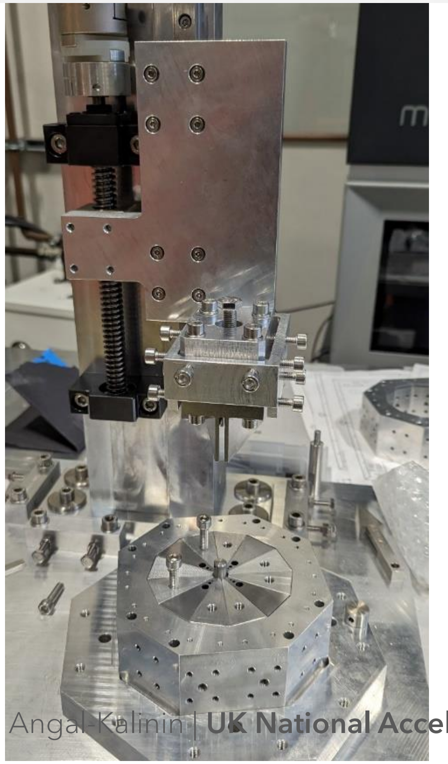
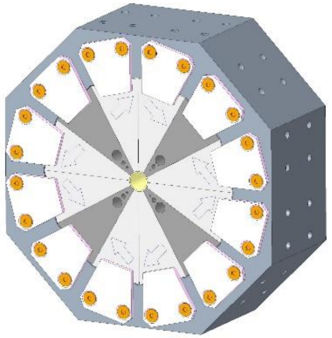


Spectrometer dipoles – tender progressing

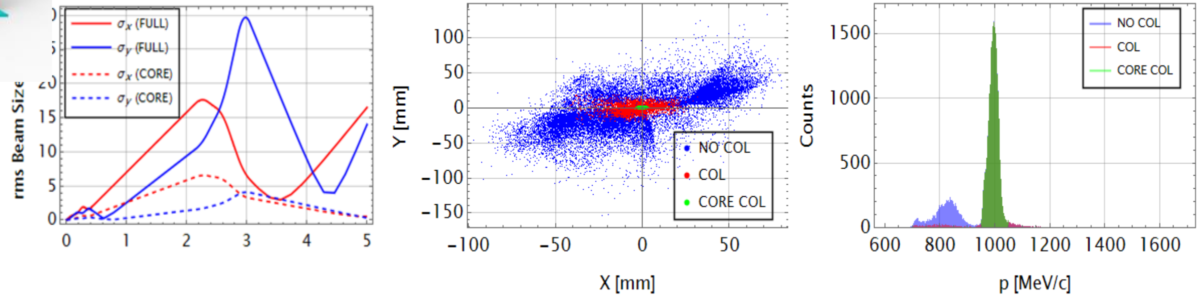




Four Halbach quads have been designed and being built at DL (~500T/m)

Start-to-end simulations

- FBPIC simulation output fed into beamline tracking code
- The **core** of the electron beam at 1 GeV forms a < 1 mm spot at 5 m



Permanent magnet quadrupoles used for beam capture at LWFA exit

- In-vacuum & low maintenance
- Design & assembly at STFC-DL
- Modular assemblies for 100 MeV, 1 GeV, 5 GeV
- Plasma mirrors and beam diagnostics inserted between PMQs

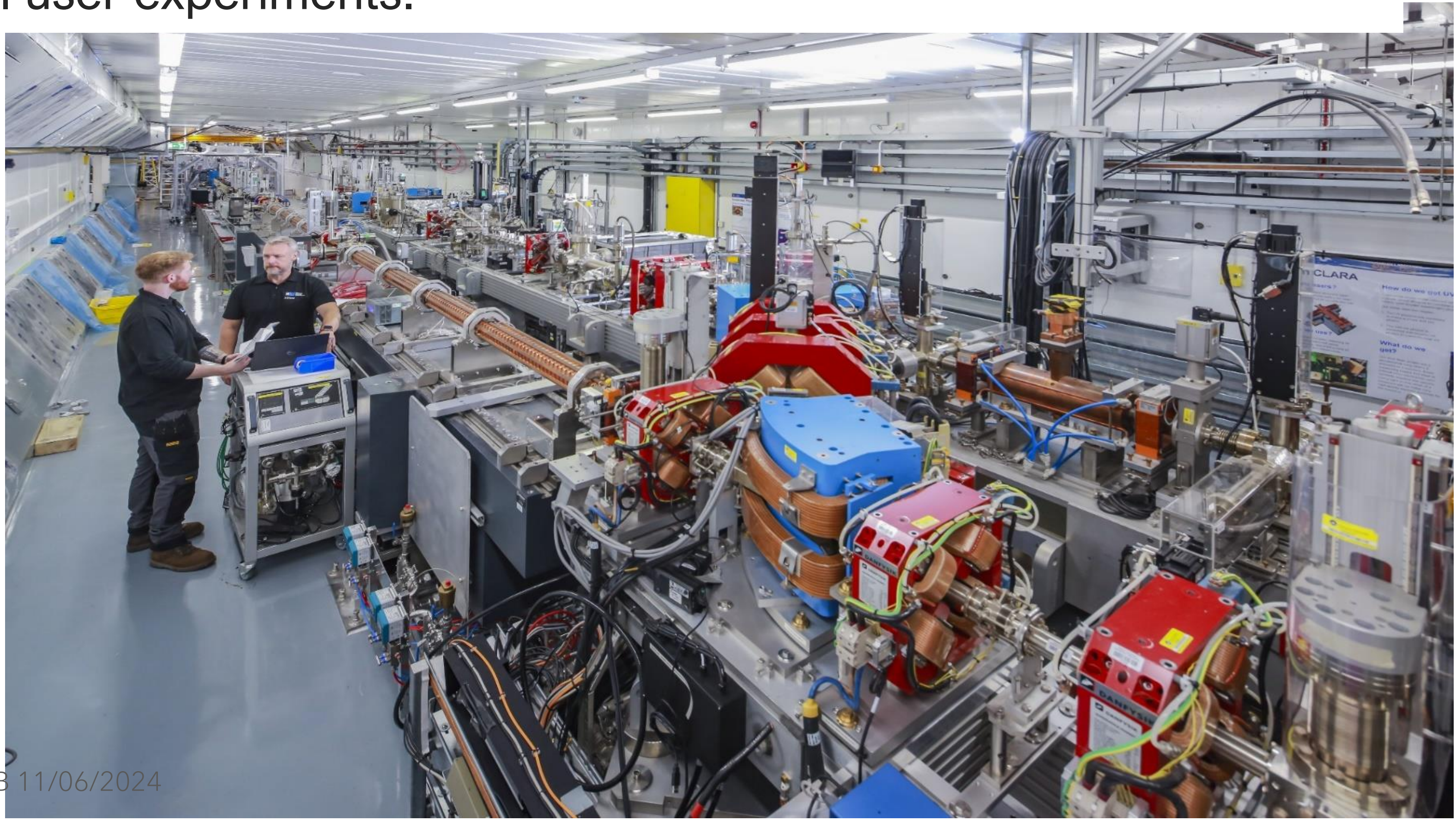
Compact Linear Accelerator for Research & Applications

Science and Technology Facilities Council

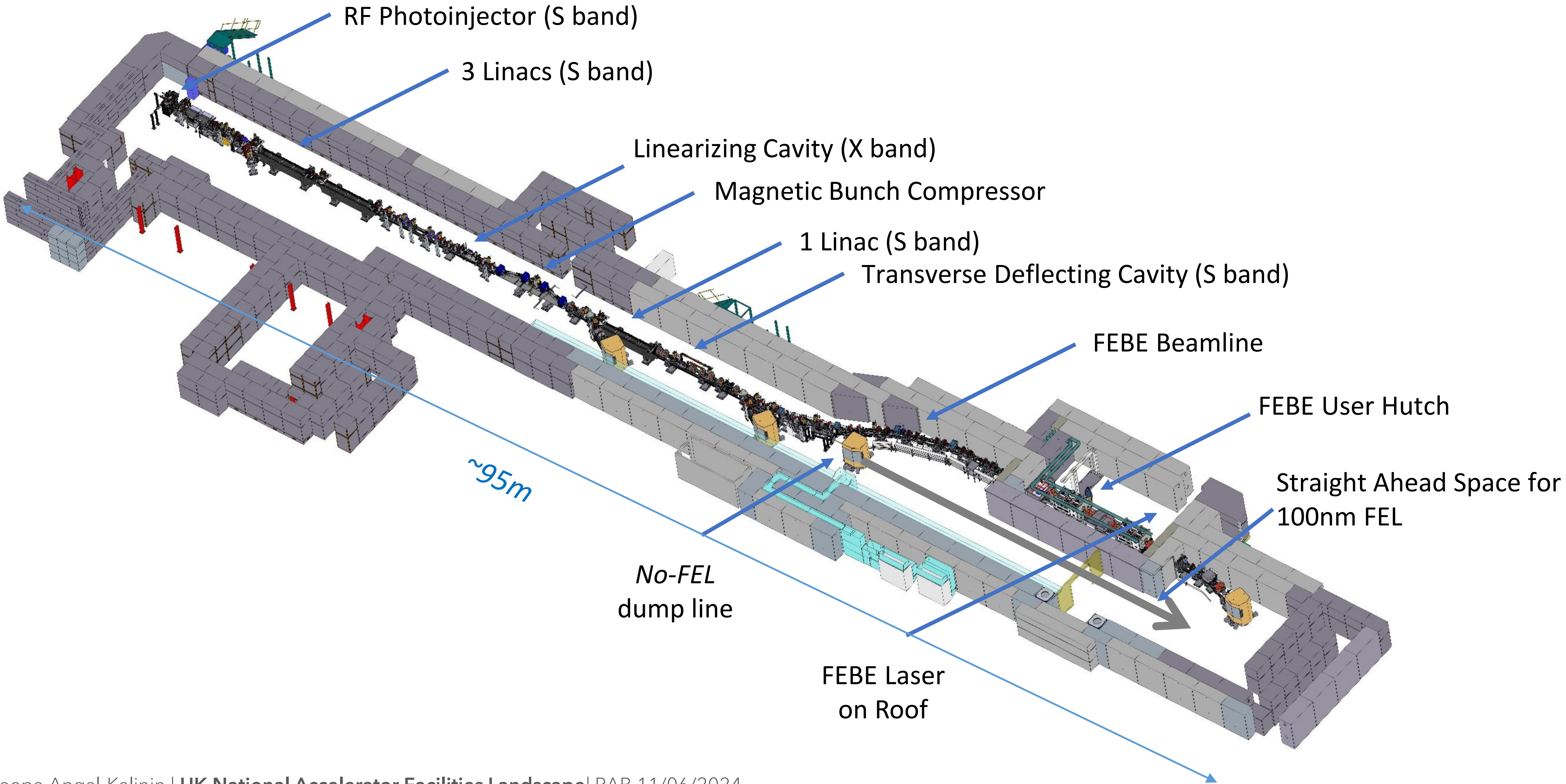
ASTeC

- CLARA is a 250 MeV ultra-bright electron beam test facility under construction at STFC Daresbury Laboratory.
- Built in phases, first phase of CLARA provided 35 MeV ultrabright electron beam at 10 Hz to number of novel applications.
- Phase 2 installation is nearly complete. This will deliver 250 MeV ultrabright electron bunches at 100 Hz and 120 TW laser at 5 Hz for novel user experiments.

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.

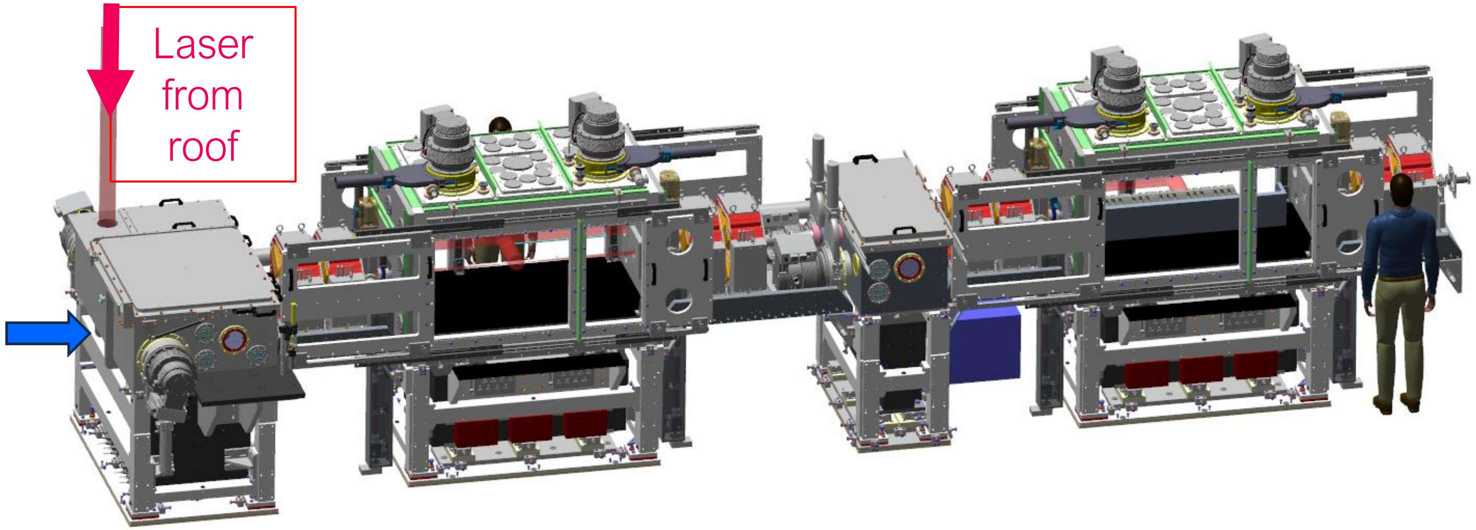


CLARA Overview



FEBE Experimental Hutch

Two chambers: possible route to 'interaction' and 'characterisation' experiments with novel components.



250 MeV FEL ready e- beam

FEC1
Primary IP
~1.5m length

FEC2
Flexible array of diagnostics

FEBE design details: E Sneddon et al, PRAB, 27, 041602 (2024)

CLARA talk by Deepa Angal-Kalinin

Offered parameters to evolve
'Day 1' → *Nominal* → *R&D*

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

To be confirmed through measurement using appropriate diagnostics (and R&D)

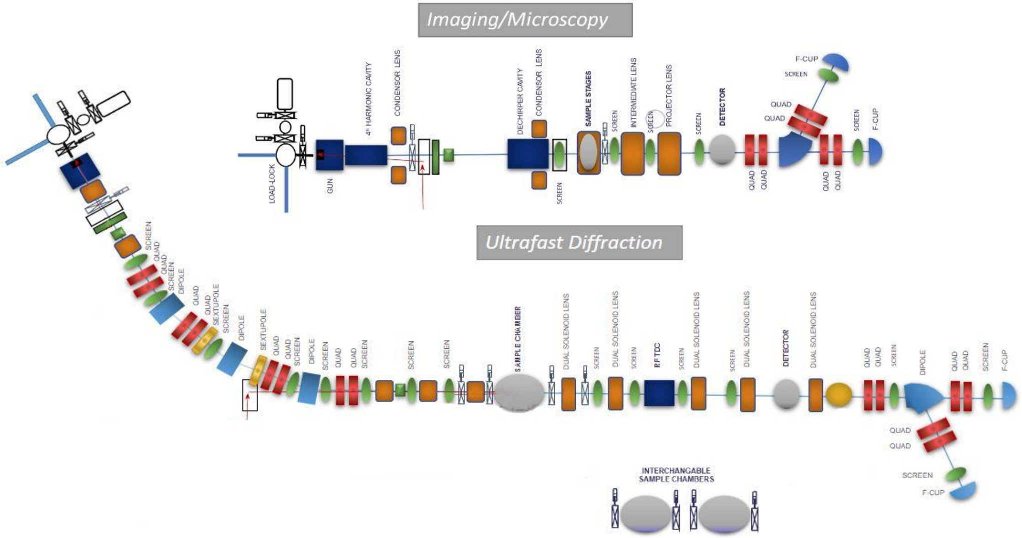
RUEDI

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

- Relativistic Ultrafast Electron Diffraction & Imaging
- A new UK National User Facility at Daresbury Laboratory. £124.4 million from the UKRI Infrastructure Fund approved.
- Time-resolved pump-probe experiments in both real ***and*** reciprocal space
- With a large variety of **pumps** and sample **environments** to enable a large range of science

UEM
ps scale
200 fC – 20 pC
Stroboscopic + Single-shot

UED
10-100s **fs** scale
Up to 400 fC
Stroboscopic + Single-shot



RUEDI talks by Tim Noakes &
Ben Hounsell

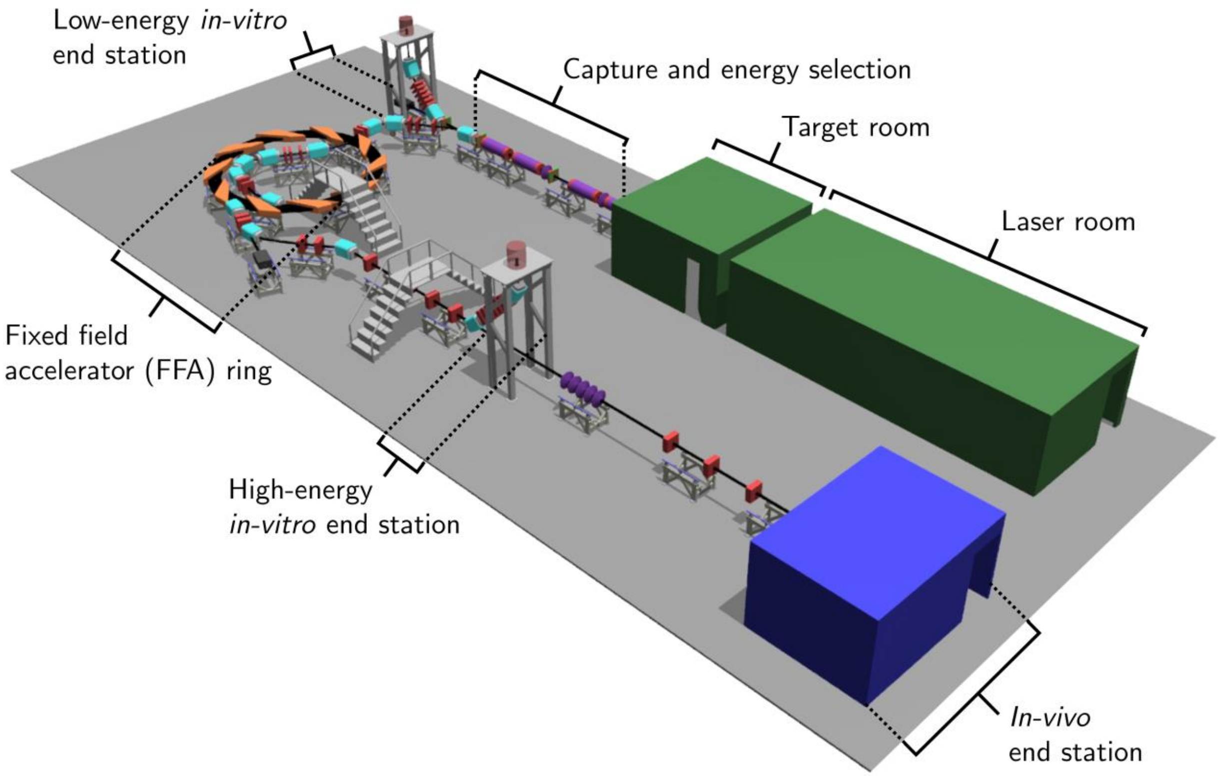
Courtesy of Julian McKenzie

Ion Therapy Research Facility

A medium-scale facility to enable user research programme to study radiobiology and cancer treatments with ions in the UK

- Multi-ion delivery p/He/C/N,O…
- Depth suitable for **in-vitro and in-vivo studies – not patient treatment!**
- High dose rate, suitable for FLASH >40 Gy/s

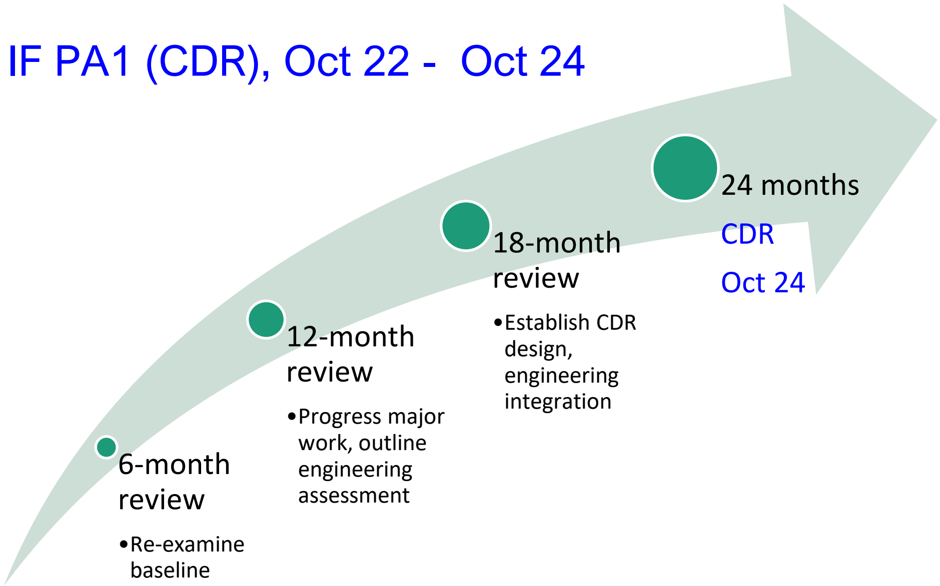
- Comparison of two technology choices (risk, cost, timescales):
  - Conventional ion source/synchrotron. Understood, lower intensity
  - Very high dose rate plasma/FFAG. Several novel technologies require demonstrations

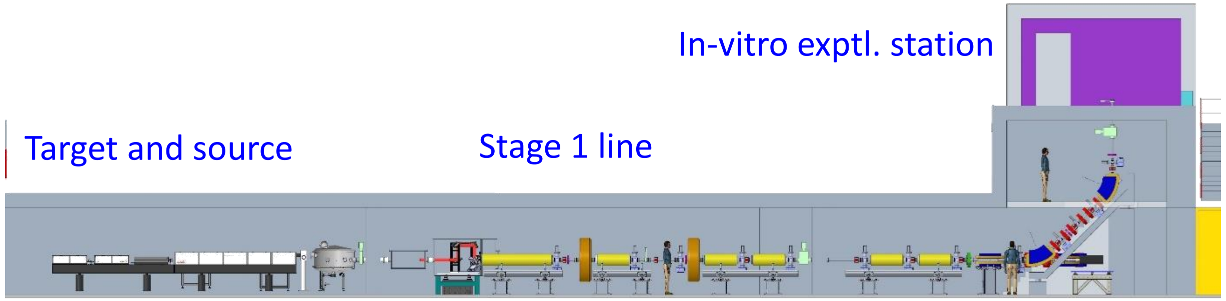


Courtesy of Hywel Owen

ITRF Status

IF PA1 (CDR), Oct 22 - Oct 24





- Significant physics/component design and engineering detailing
- **18-month design review last month**: https://indico.stfc.ac.uk/event/986/
- Experimental campaign at Strathclyde has resolved many source issues
- **No Stage 1 showstoppers** – plasma-based approach selected

- **Bridging funding beyond Oct 24 :**
- To establish baseline demonstration of Stage 1 output and user experiments
- Further de-risk source/capture/Stage 2 FFA to enable full project bid

Courtesy of Hywel Owen

UK XFEL – Conceptual Design & Options Analysis

The three years CDOA project formally started on **1st October 2022.** The Year 1 activities are largely complete – the activities in second year making good progress.

Year 1

- Project launch event January 2023
- Initial conceptual design and layout
- Preliminary engagement with overseas XFEL facilities
- Survey of the science team, workshops and town halls meetings begin

Year 2

- Developing the concepts
- R&D targeting gaps in key physics and technology areas
- Collaborative activities and working groups with overseas XFEL facilities
- Workshops and town hall meetings continue

Year 3

- Summary of R&D activities
- Preferred options identified, socio-economic analysis
- Revision to science case published
- CDOA phase completed September 2025

UK XFEL talk by Dave Dunning

UK XFEL

Our focus to date has been on some of the most challenging and fundamental features

- **Transform limited operation** across entire X-ray range (approx. 100 as – 100 fs and 50 eV to 20 keV)
- High efficiency facility with **a step change in the simultaneous operation of multiple end stations**
- **Evenly spaced, high-rep rate pulses** to match samples & detectors (~ 100 kHz per FEL, with flexibility)
- Improved synchronisation/timing data with external lasers to < 1 fs
- **Widely separated multiple colour X-rays** to at least one end-station (e.g. SXR+ HXR)
- Full array of synchronised sources:
  XUV-THz, e-beams, high power & high energy lasers at high rep-rate
- Minimise the carbon footprint and energy consumption for both operation and build.

Also significant interest in:

- High pulse energy (>>1 mJ)
- High photon energy (> 20 keV)

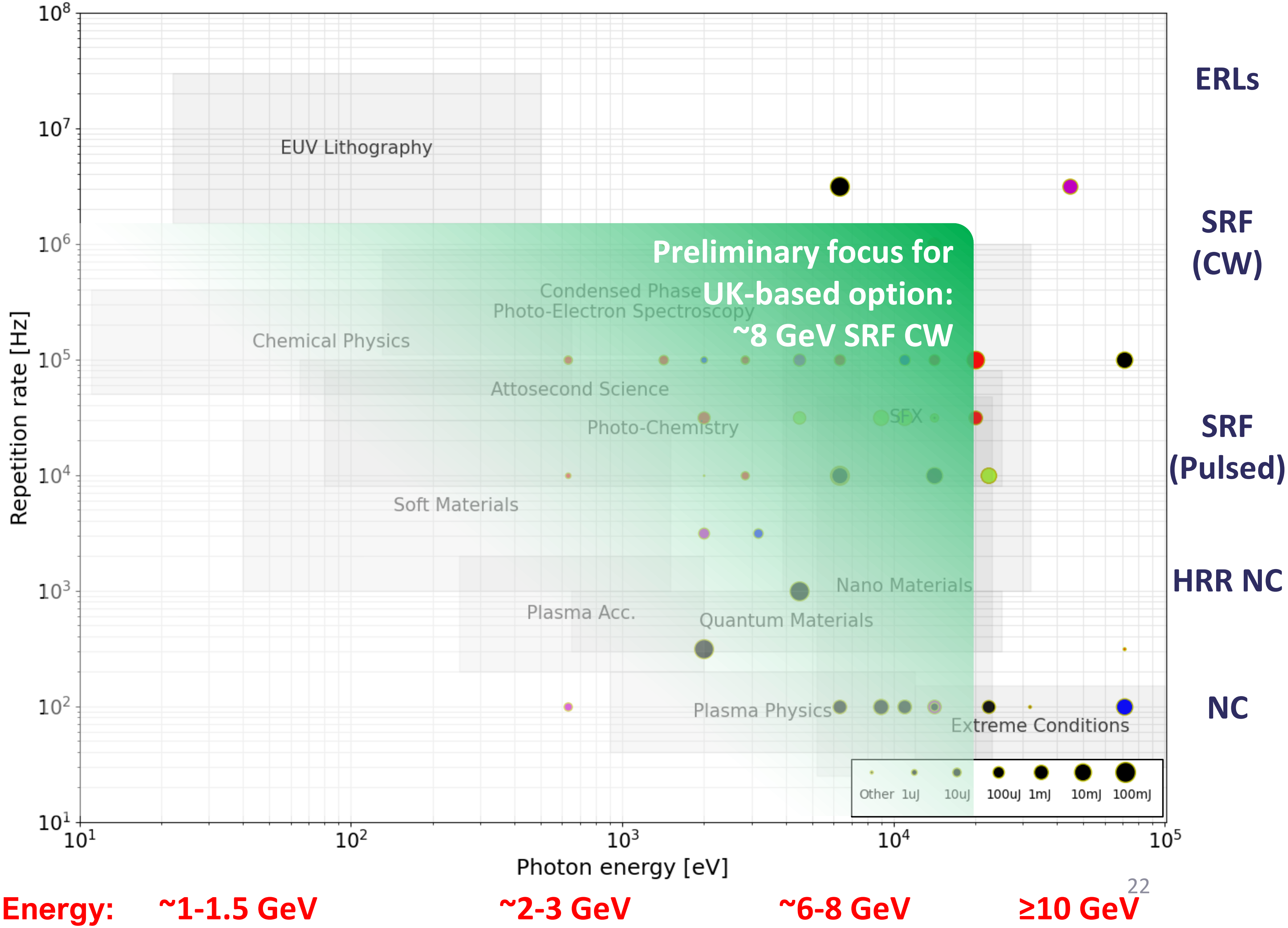
In some cases with less demand for high rep rate

Courtesy of Dave Dunning

UK XFEL – User Requirements from the Science Case & Survey

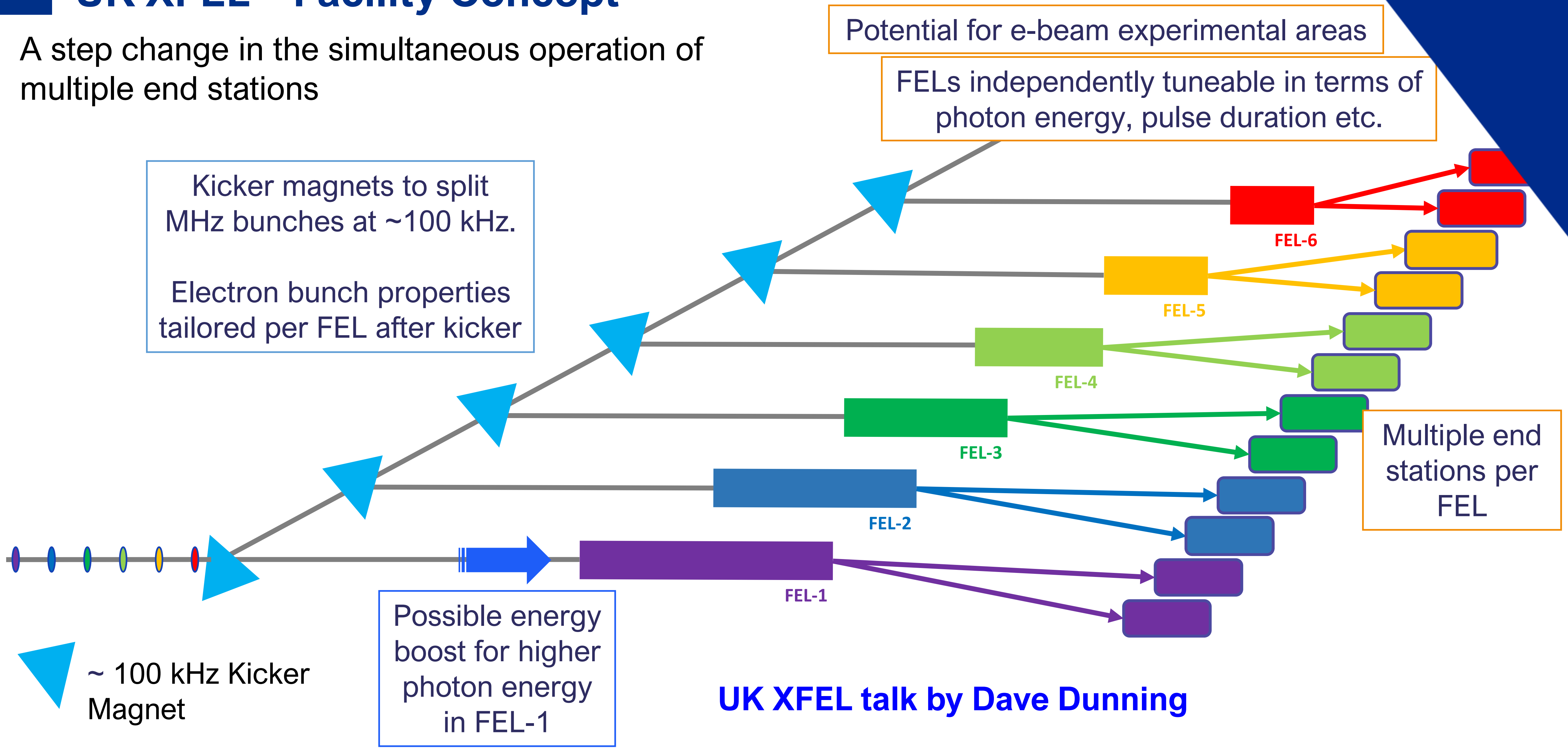
Evenly spaced, high-rep rate pulses

- Max. **photon energy** strongly influences the required **electron beam energy**
- **Repetition rate** largely dictates the **type of acceleration technology**
- Requirements suggest ~8 GeV superconducting RF linac



UK XFEL – Facility Concept

A step change in the simultaneous operation of multiple end stations



UK XFEL talk by Dave Dunning

Courtesy of Dave Dunning

UK XFEL

Expert Science Team

Matter in extreme conditions

Andy Higginbotham (York), Andy Comley (AWE), Emma McBride (QUB), Sam Vinko (Oxford), Marco Borghesi (QUB), Malcolm McMahon (Edinburgh), Justin Wark (Oxford)

Nano/Quantum materials

Anna Regoutz (UCL), Marcus Newton (Soton), Ian Robinson (UCL/Brookhaven), Mark Dean (Brookhaven), Awan Shakil (Plymouth), Paolo Raedelli (Oxford), Simon Wall (Aarhus), Sarnjeet Dhesi (Diamond),*

Engineering/Materials/Applications

*David Rugg (RR), Sven Schroeder (Leeds), David Dye (IC) Dan Eakins (Oxford), Mike Fitzpatrick (Coventry) +**

Life sciences:

Allen Orville (Diamond), Jasper van Thor (IC), Xiaodong Zhang (IC), Shakil Awan (Plymouth), Adrian Mancuso# (Diamond), Tian Geng (Heptares)*

Chemical sciences:

Julia Weinstein (Sheffield), Russell Minns (Soton), Sofia Diaz-Moreno (Diamond), Alex Baidak (Manchester), Andrew Burnett (Leeds), Tom Penfold (Newcastle), Rebecca Ingle (UCL), Mark Brouard, Claire Vallance (Oxford)*

Physical sciences:

Amelle Zair (KCL), Adam Kirrander (Edinburgh), Jason Greenwood (QUB), Jon Marangos (IC), Elaine Seddon (Cockcroft) + #

+ around 100 additional experts from around the world contributing to Science Case

Opportunities to engage (Townhall Meetings)

1. Northern Ireland Townhall (hosted by: Queens Belfast) June 20th & 21st 2023
Focus discussion topic: Frontiers of measurement technology

2. Scotland Townhall (hosted in Glasgow at Strathclyde) Oct 2 & 3rd 2023
Focus discussion topic: Materials, chemistry and biology at extreme conditions

3. Southwest England Townhall (hosted by Plymouth) 18th & 19th Jan 2024
Focus discussion topic: AI, Quantum Computing and Fundamental Physics

4. North-East England Townhall (hosted by Sheffield 4th and 5th June 2024)
Focus discussion topic: Energy, environmental and climate technologies

5. Central England Townhall (hosted by Diamond, 29th and 30th July 2024)
Focus discussion topic: Lifesciences and biomedicine

6. North-West England Townhall (hosted by Royce Institute, 8th and 9th August 2024)
Focus discussion topic: Electronics, photonics and quantum technologies

7. Wales Townhall (in Cardiff ~ September 2024)
Focus discussion topic: Advanced materials and manufacturing

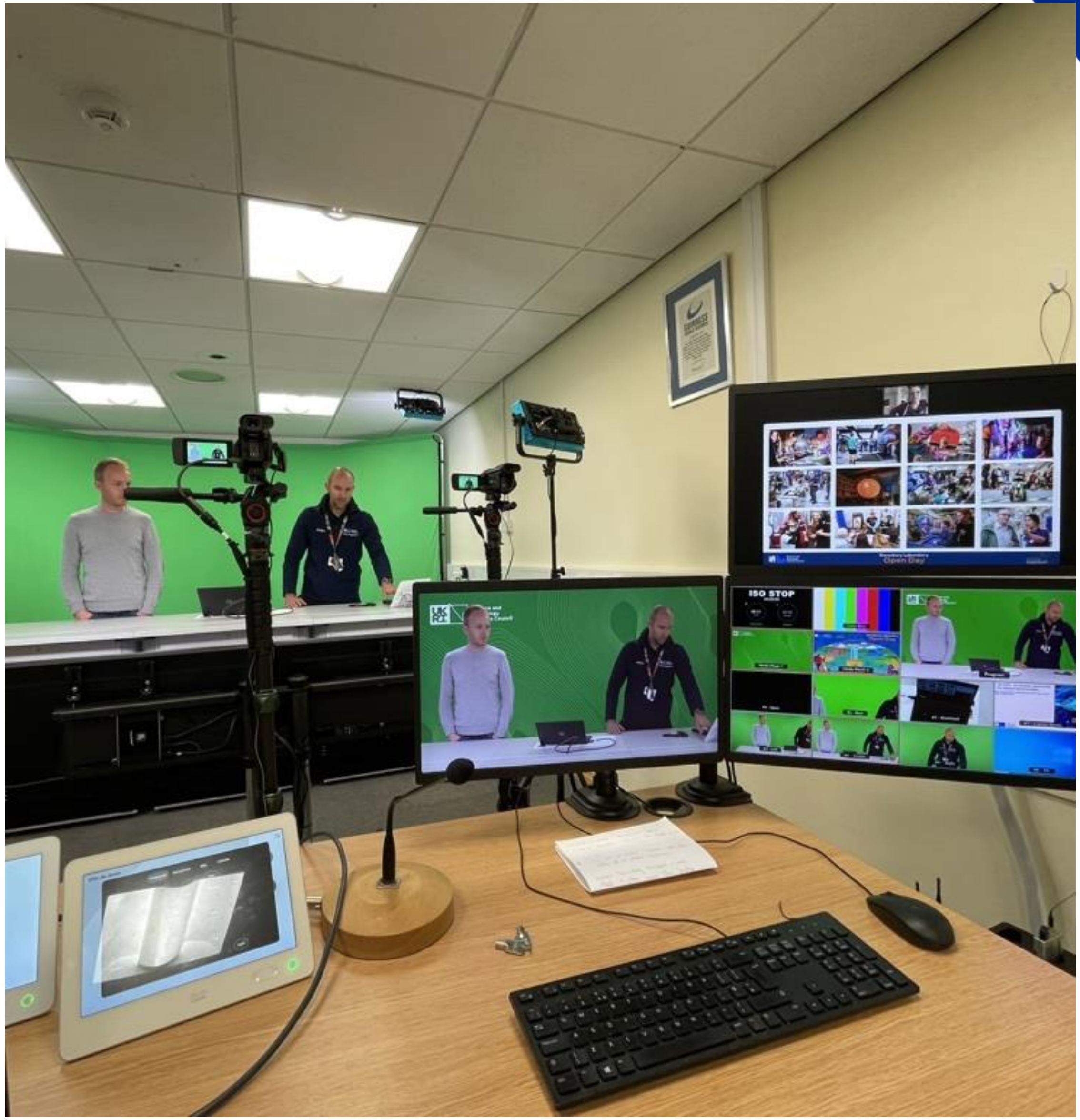
UK XFEL – Engagement & Communications

Wider Stakeholder Engagement

- Eu-XFEL visits + regular collaboration seminars
- SwissFEL visit + continuing engagement
- LCLS-II visit + engagement
- Multiple Conferences attended
- Science team meets monthly
  - Facility Design Team presents updates at this meeting
- International Advisory Board meetings:
  (11th Dec 23, 1st May 24, 10th Dec 24)

UK XFEL – Communications

- Website refreshed, and updated – xfel.ac.uk
- Community slides updated for use by anyone
- Social media presence via twitter and linkedin
- Two blogs written for Medium [1] [2]
- Update in FELs of Europe Newsletter
- Videos produced for YouTube
- Mailing list now over 360 people
- Engaging with the likes of IoP and TEDx for public talks and engagement



Summary

- **This decade promises to be a very busy one for UK national accelerator infrastructure!**
  - Diamond-II is fully on track to deliver the upgrade, with dark period starting from December 2027 & project completion by March 2030.
  - ITRF, UK XFEL and ISIS-II have multi-year technical design and prototyping phases ahead of them, after the current concept design activities
  - RUEDI is now ready to move to full construction and has received funding approval.
  - CLARA will be available to users in 2025
  - EPAC will be operational in 2026.

Science and Technology Facilities Council

Thank you

Science and Technology Facilities Council @STFC_matters Science and Technology Facilities Council