Science and Technology Facilities Council

Central Laser Facility

EPAC Experimental Area 2

James Green

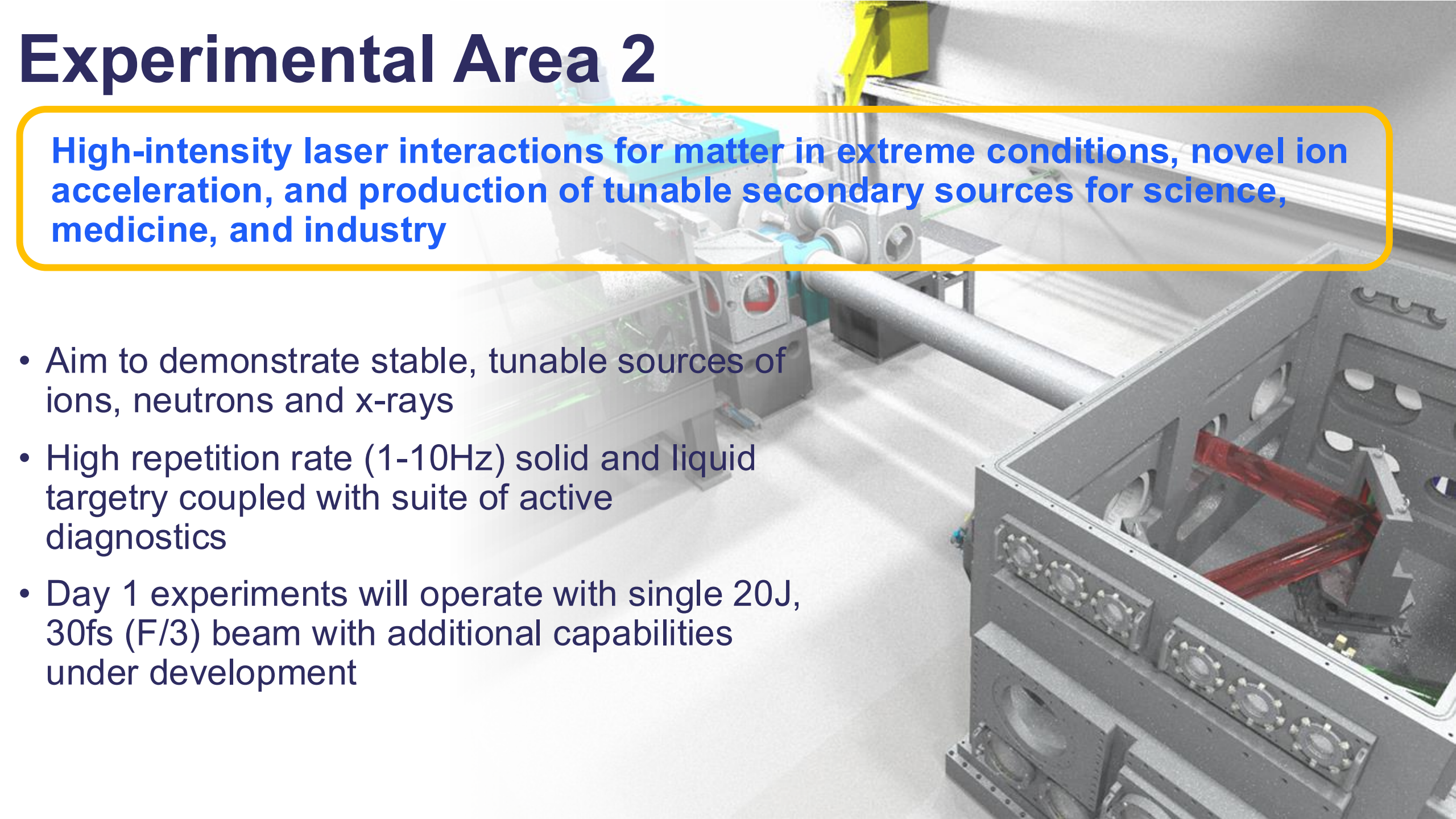
LhARA / CLF Workshop

2nd November 2026

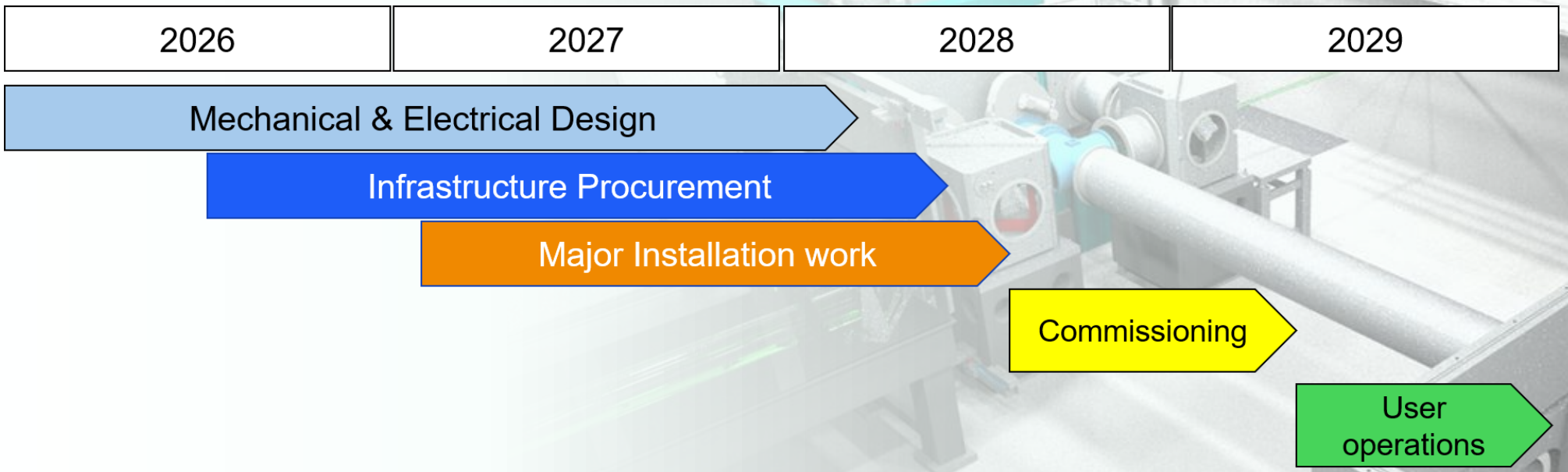
Experimental Area 2

High-intensity laser interactions for matter in extreme conditions, novel ion acceleration, and production of tunable secondary sources for science, medicine, and industry

- Aim to demonstrate stable, tunable sources of ions, neutrons and x-rays
- High repetition rate (1-10Hz) solid and liquid targetry coupled with suite of active diagnostics
- Day 1 experiments will operate with single 20J, 30fs (F/3) beam with additional capabilities under development

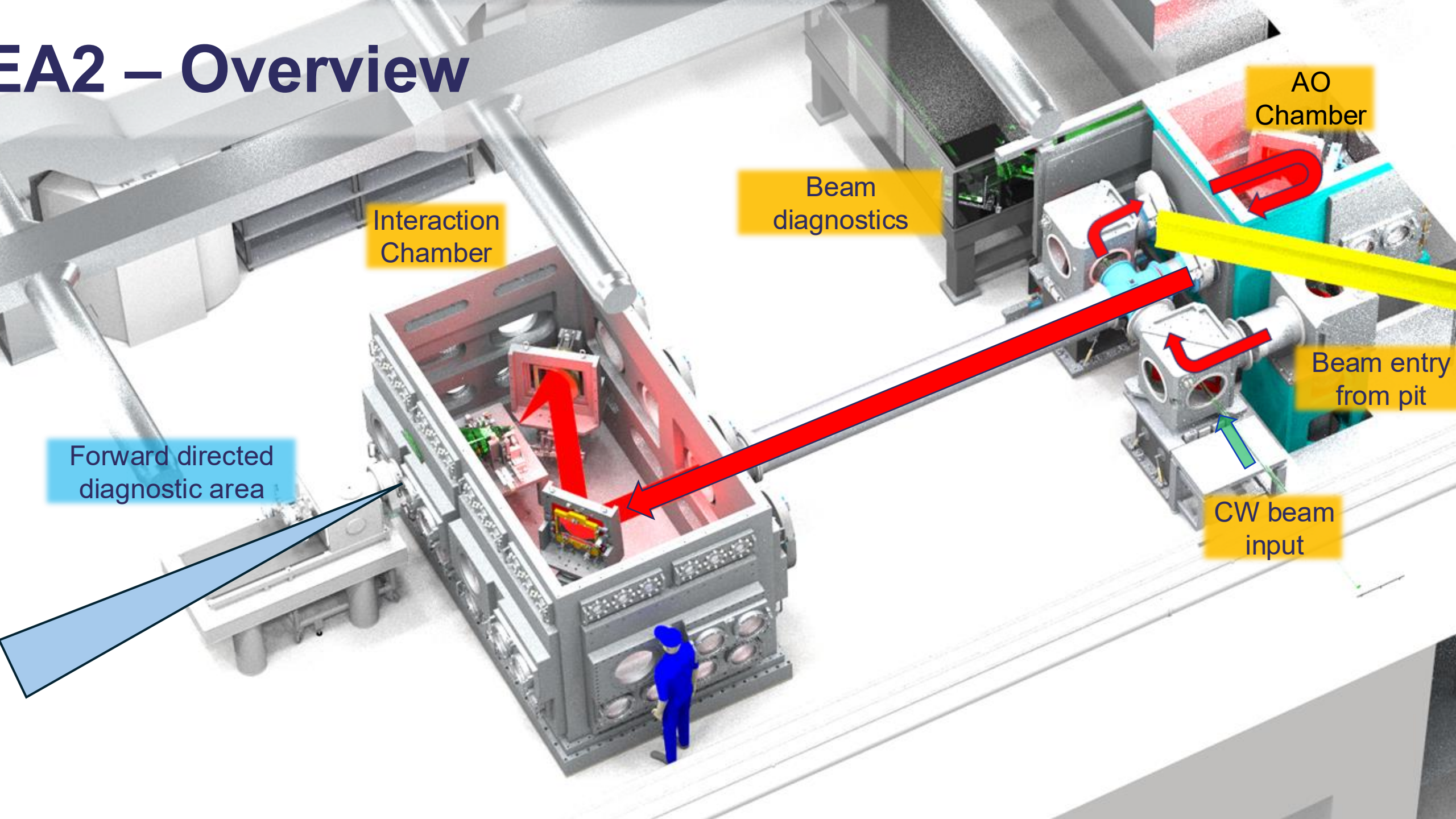


EA2 – Overview and Timeline

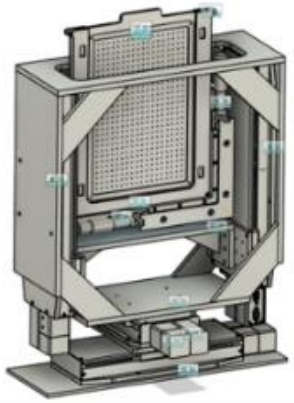


- User-assisted commissioning will focus on:
  - Characterising laser performance
  - Commissioning targetry and diagnostic systems
  - Initial optimisation of ion and X-ray sources
  - Debris and EMP mitigation
- Themed commissioning teams similar to EA1

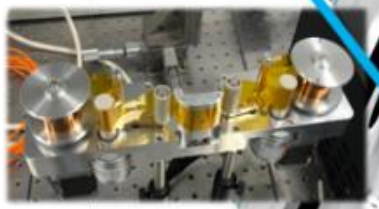
EA2 – Overview



EA2 – f/3 layout for Day 1



Targetry array



Tape drive

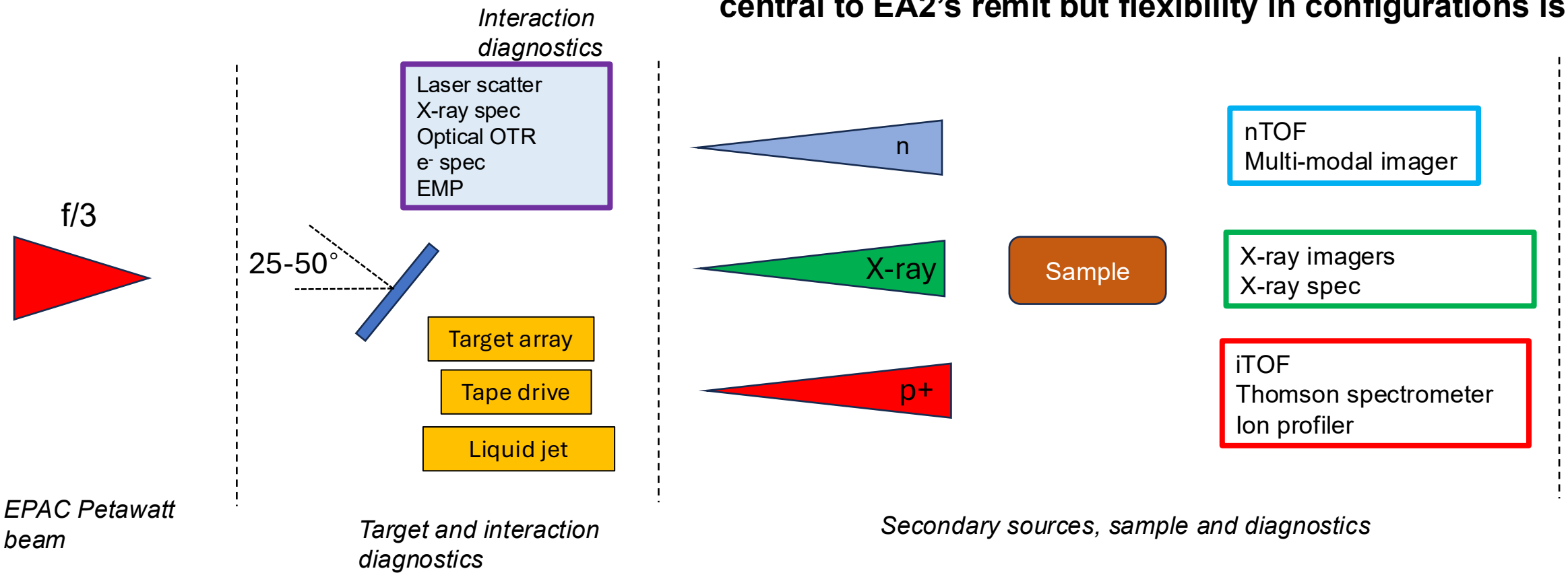


Liquid jet

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EA2 summary of capabilities – Day 1

Optimisation and application of laser-driven ion sources central to EA2's remit but flexibility in configurations is key



EA2 will operate in a configured access mode initially

- Experiments grouped by common set-ups / themes
- Minor / Major switchover periods between experiments

Priorities for EA2 source capabilities

Tuneable TNSA ion beams

- Tuneable proton acceleration over ~1-50 MeV
- Optimisation for protons and light ions
- Divergence control
- Ion beam transport
- Initial applications

Bright X-ray Brems from solid / liquid targetry

- Understanding fast electron generation and transport in femtosecond regime
- Optimising laser and target conditions for X-ray output
- Initial diagnostic and imaging tests

Laser-driven neutrons

- Achieving high-rep compact LDNS for fast (MeV) neutrons
- Tape drive or liquid jet + (Li) catcher
- Moderation to epi-thermal and thermal range
- Proof of principle imaging

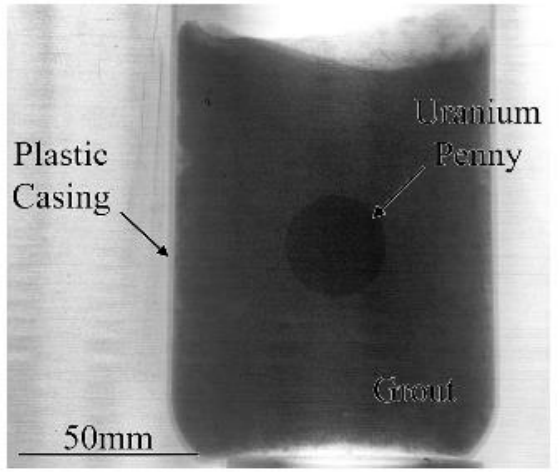
Large scale point projection X-ray radiography

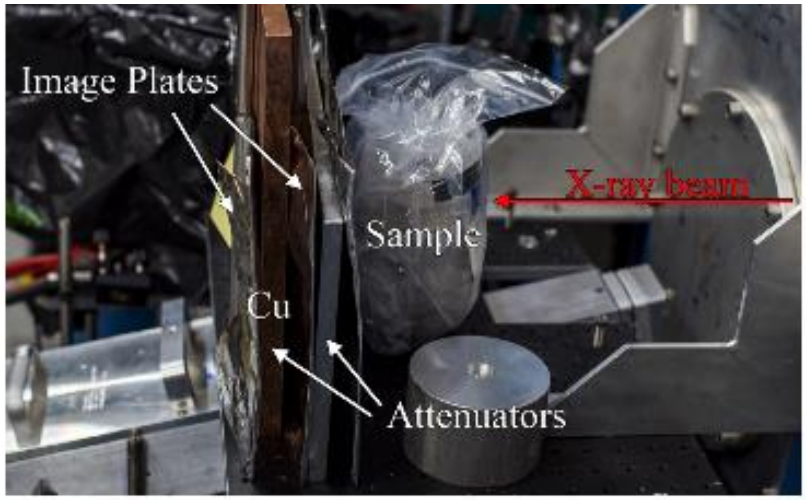
EA2 as a platform for high-resolution, large area X-ray radiography

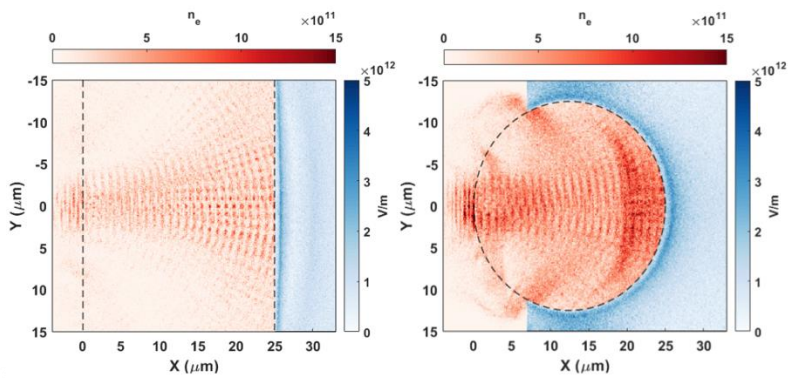
Broad range of X-ray energies possible from keV – 10s MeV

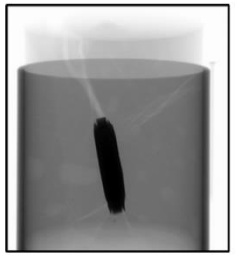
Pulse length sub-ps and resolution ~100 μm

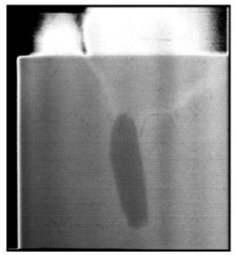
C. P. Jones, et al. Journal of hazardous materials 318 (2016): 694-701.



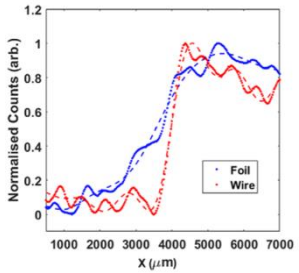




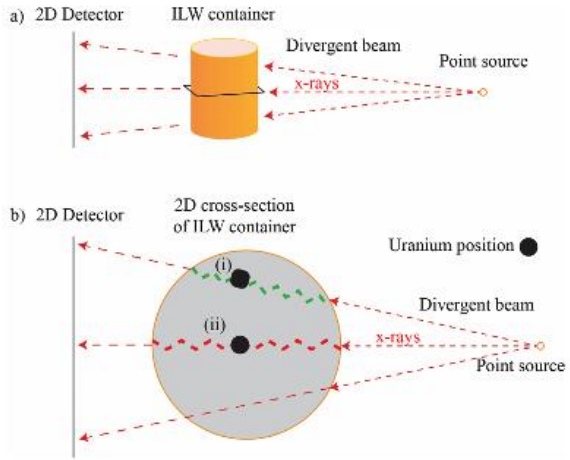

(a) XRT


(b) Foil


(c) Wire



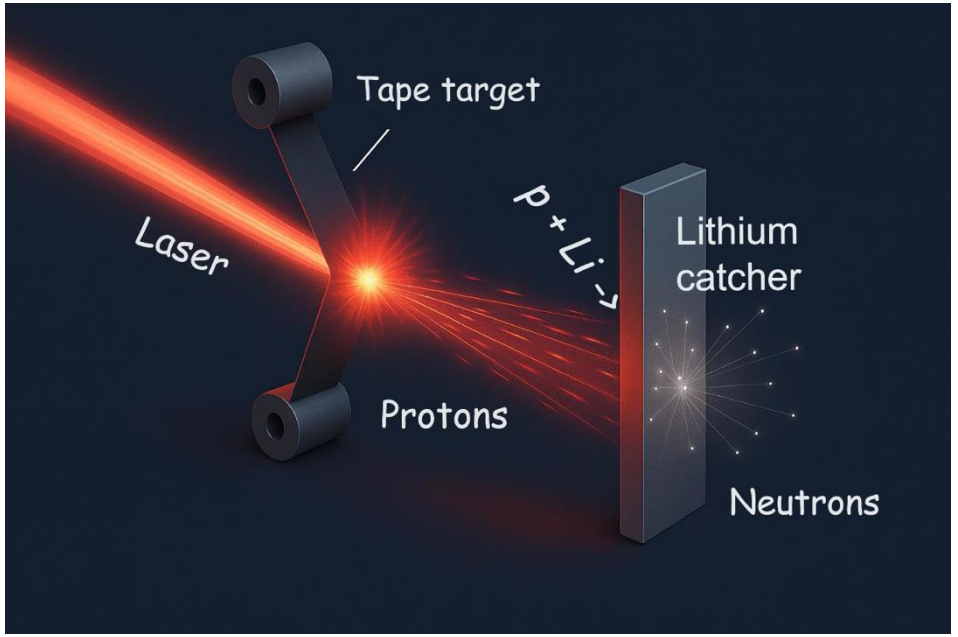
(d) Lineouts



C. D. Armstrong et al. HPLSE . 2019;7:e24. doi:10.1017/hpl.2019.8

Neutron source & applications

High rep rate operation in pitcher–catcher configuration



Single shot imaging on Vulcan

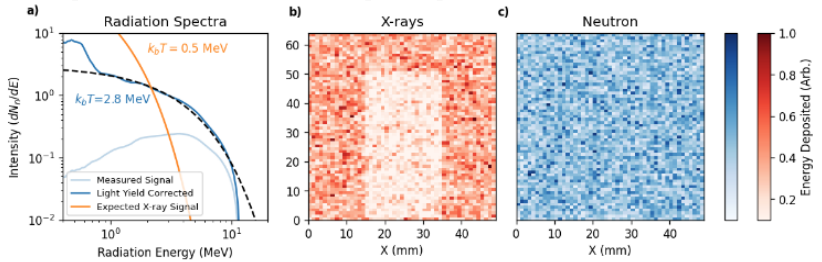
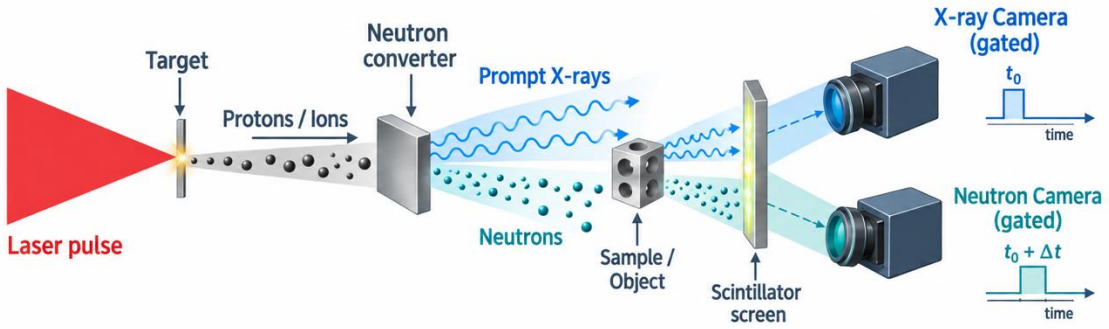


FIG. 5: a) Measured neutron spectra from same shot as Figure 4, with expected x-ray spectra from laser intensity parameters[4]. Simulated radiograph for b) x-rays and c) neutrons matching the spectral conditions in panel a) - 2.8 MeV exponential distribution for neutrons and a 200 keV exponential distribution for x-rays.

C.D.Armstrong RSI 2024

Multi-Modal imaging

- Combining X-ray sensitivity to high-Z materials with neutron sensitivity to light elements (e.g. H, Li, water) provides complementary imaging of complex objects.
- **High-repetition-rate image reconstruction**
  Accumulating and stitching together data from many shots improves neutron image quality, signal-to-noise ratio, and spatial resolution.
- **Time-resolved and multi-modal studies**
  Short neutron and X-ray bursts enable pump–probe experiments and dynamic imaging of transient phenomena that conventional neutron facilities cannot access.

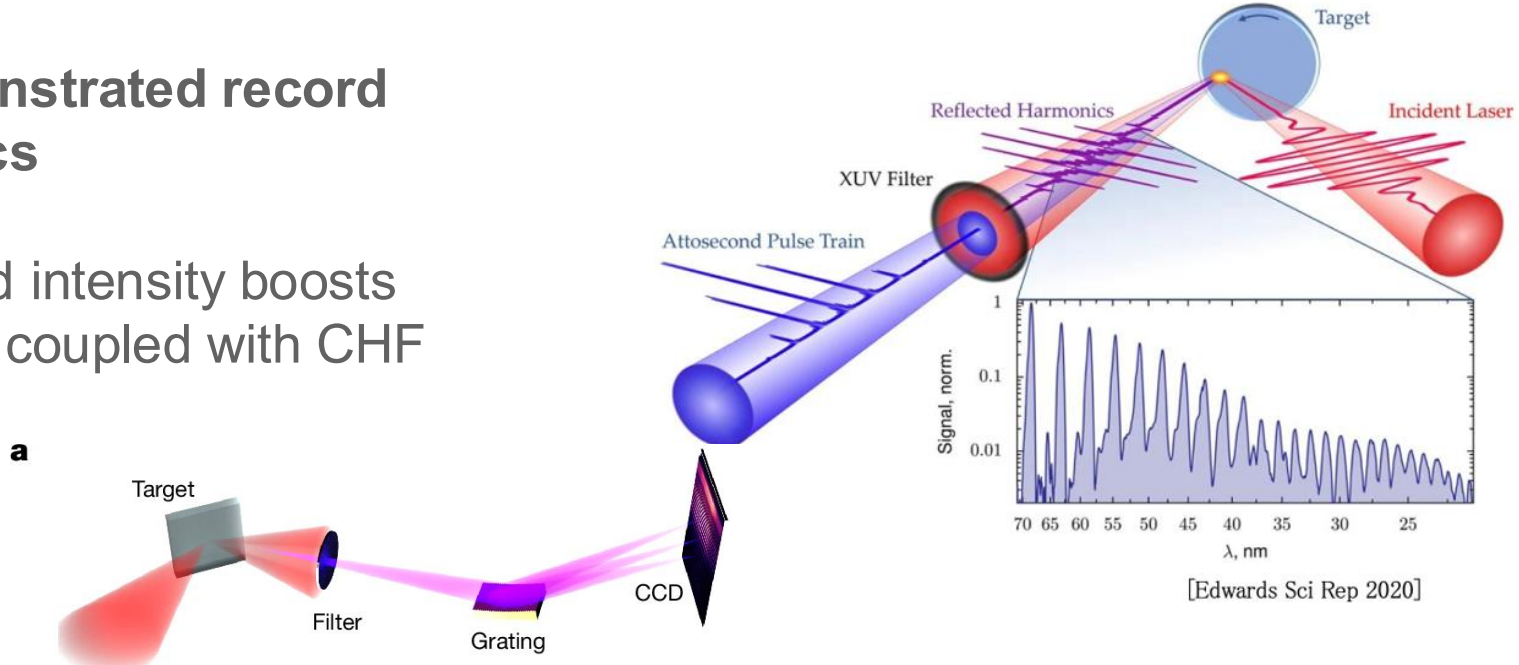


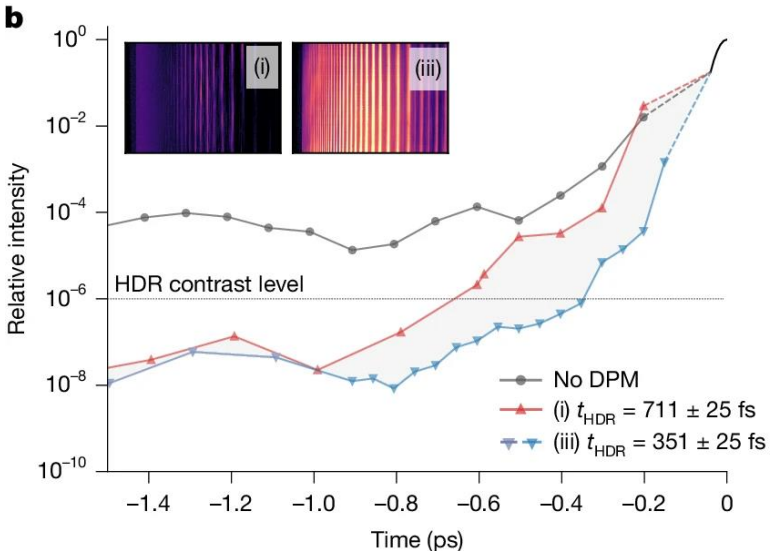
High Harmonics and Extreme Intensities

Experiment on Gemini recently demonstrated record breaking brightness of XUV harmonics

Potential to deliver attosecond pulse and intensity boosts orders of magnitude above drive laser if coupled with CHF

EA2 will be available as a platform to explore optimisation of laser contrast to potentiallyy open up new classes of user experiments





nature

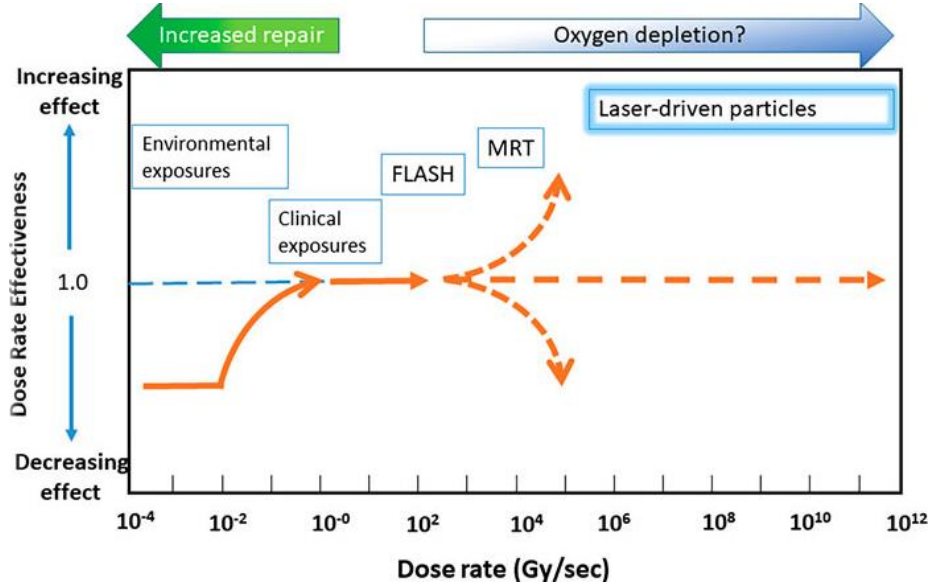
R. Timmis et. al., *Nature* **volume 652**, p 1153–1158 (2026)

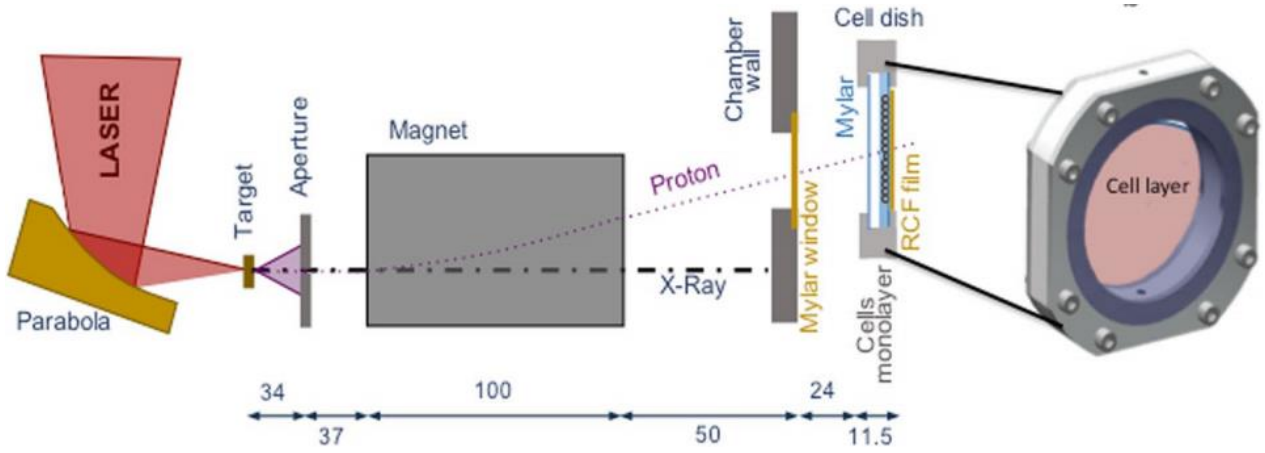
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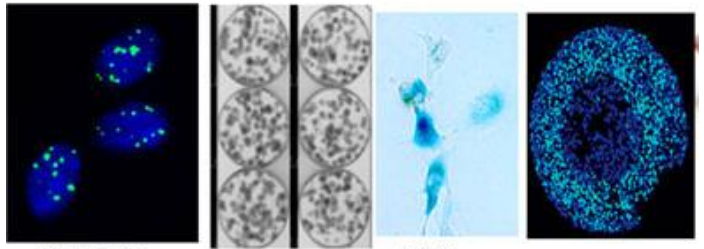
High Dose Rate Radiobiology

- High-brightness, short ion bunches can be exploited for radiobiological studies at a high-dose rate.
- The first experiment can build on Gemini and Vulcan campaigns by deploying a single dipole magnet setup for in-vitro studies.
- Irradiation at >1Hz would facilitate improving the understanding of the high dose rate radiobiology with fractionated dose delivery where, physical, chemical and biology knowledge is limited.





In-vitro Assays



DNA DSB damage 53BP1 foci, γH2AX

6-well plate Clonogenic Assay

SIPS Assay

3D Spheroids From Brack *et al* [70]

P. Chaudary *et al.* Front. Phys., 10,3389, 2021

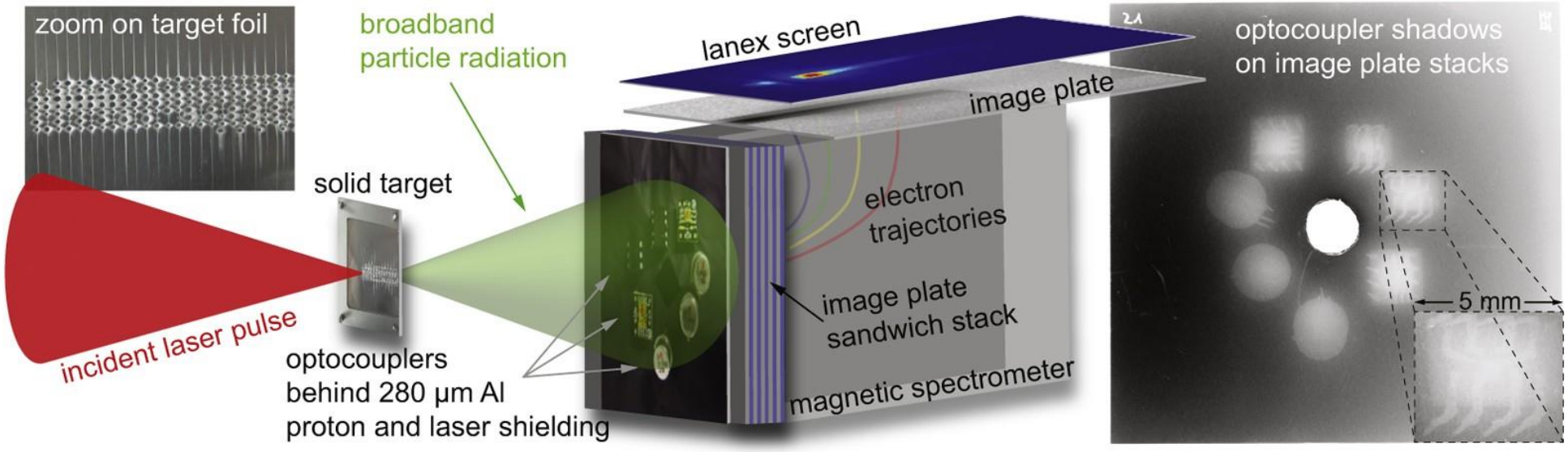
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Radiation hardness assurance

Applications in high-radiation environments where systems need to operate for extended periods without suffering significant adverse effects

Multi-modal electron / ion / x-ray source for irradiation of electronic components

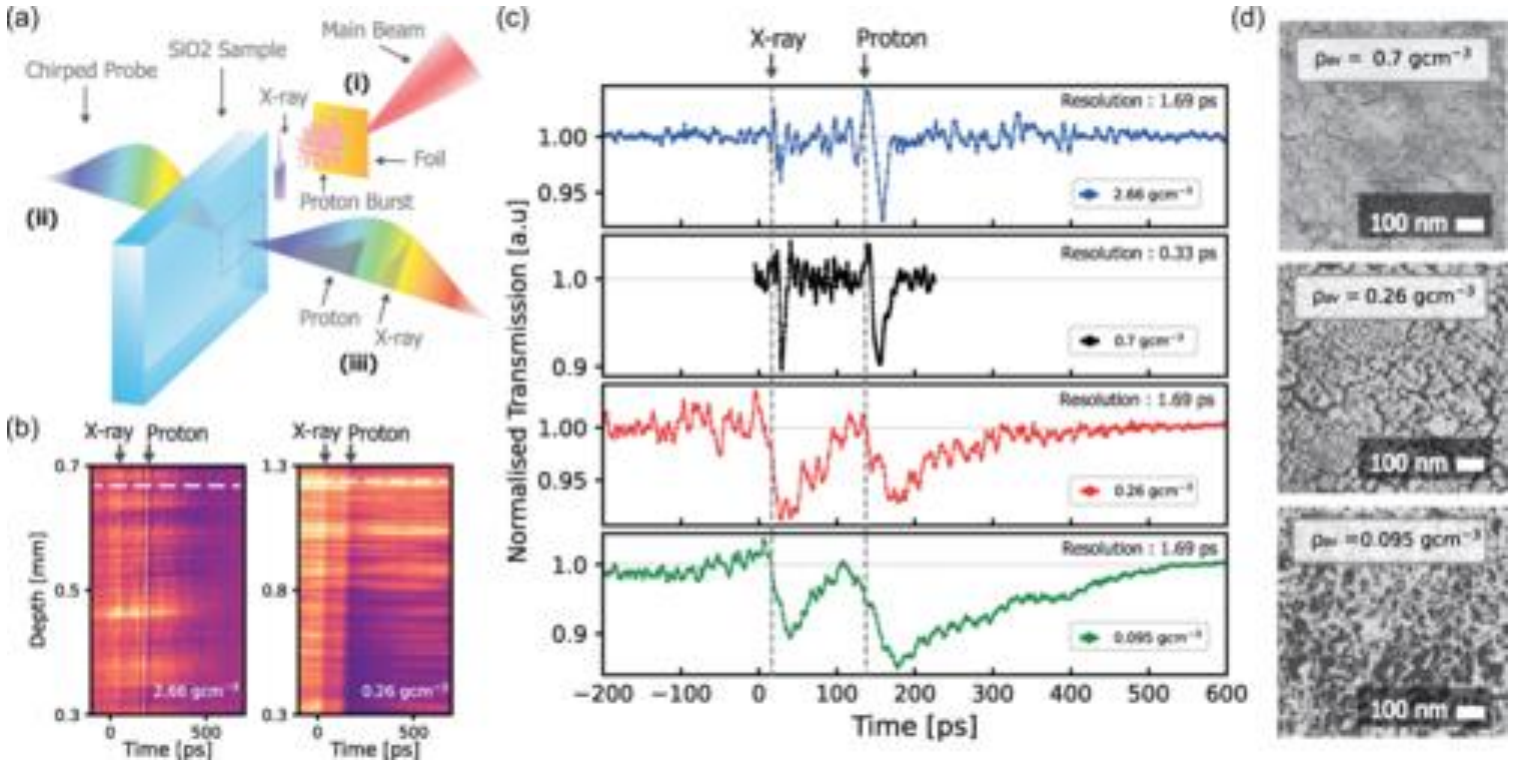
- Benefits from broadband, high divergence parameters not achievable via other sources
- Builds on facility characterisation and source tunability



B. Hidding *et al.* *Scientific Reports* **7**, Article number: 42354 (2017)

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Revealing ultrafast dynamics in materials



- Emission of Bremsstrahlung X-rays and synchronised proton pulse (TNSA) can be used to study the effect of nanoscale structure on material properties.
- Helps gain insight into how materials respond to ionising radiation, tracing macroscopic properties back to the nanostructure.

Kennedy et al. "Real-Time Observation of Frustrated Ultrafast Recovery from Ionization in Nanostructured SiO2 Using Laser-Driven Accelerators", PRL, 133, 135001 (2024)

Requires:
- TNSA Ion beam 10's MeV
- X-ray Brems
- Chirped optical probe

EA2 - Points for discussion

What are R&D priorities across ion beam source, transport and diagnostics?

Source parameters – energy, species, rep-rate

Invasive vs non-invasive ion diagnostics

Can we design beam transport and sample environments for multiple applications?

What needs to be demonstrated during commissioning to prepare for 1st user-led experiments?

What would be the ideal configuration for cell sample deployment?

Biolab requirements

How do we exploit the rep-rate of EPAC?

Operational considerations vs single shot era



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Thank you

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