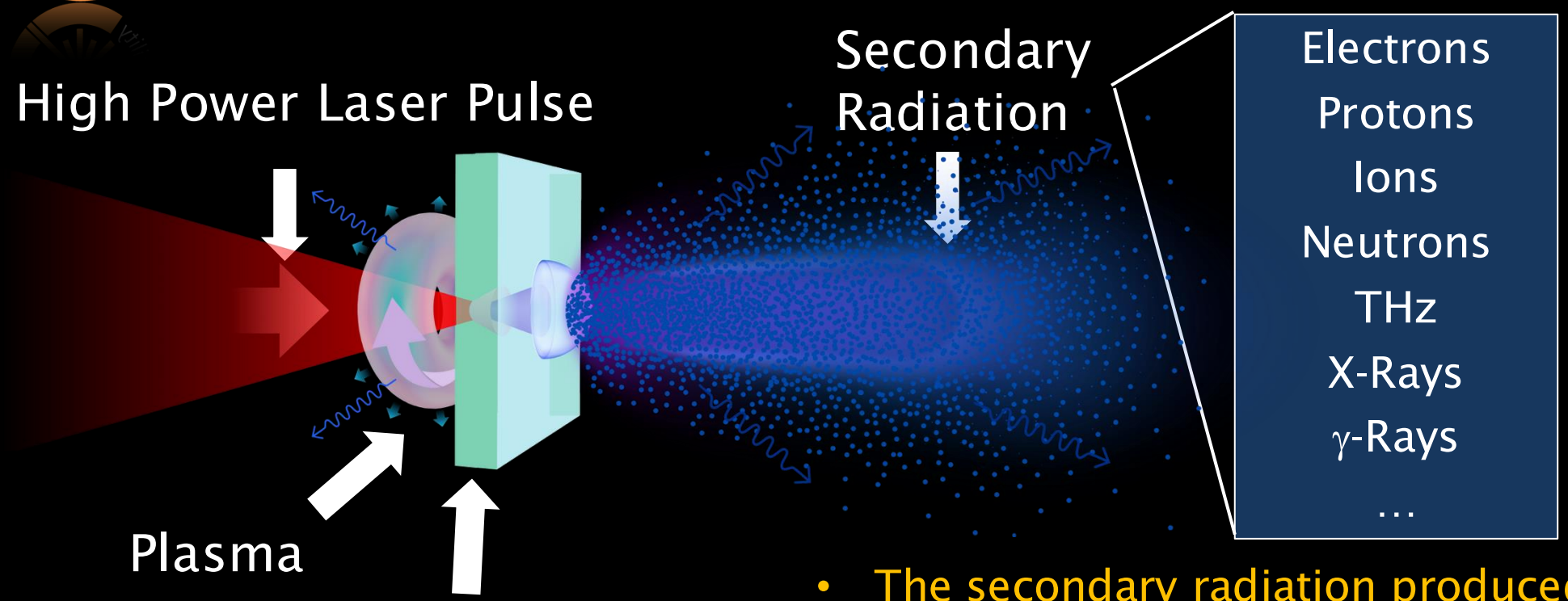
The Extreme Photonics Applications Centre (EPAC)

Rajeev Pattathil

Head, Novel Accelerator Science and Applications

Science and Technology Facilities Council

EPAC: Driving miniature accelerators with lasers



- The secondary radiation produced has unique, non-conventional properties
- Super bright, very energetic & penetrating
- Point like in space and time
- Change radiation by target type, not driver
- Switch off safe
- Tremendous application potential

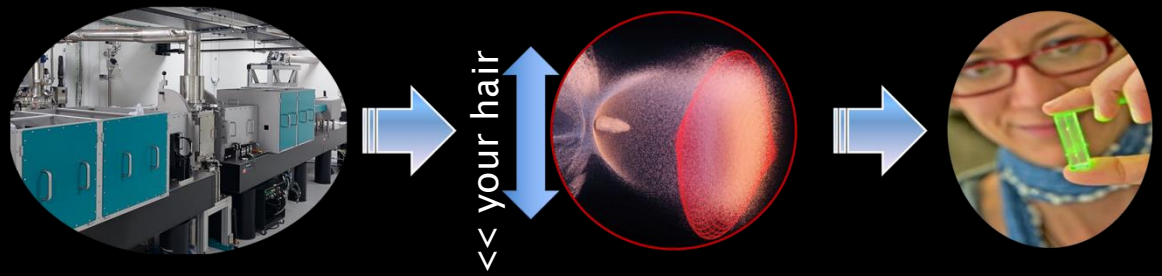
Science and Technology Facilities Council

Extreme Photonics Applications Centre (EPAC)



- New Flagship £120M Facility in partnership with Academia, MoD & Industry
- Drive the development and application of laser plasma-based accelerators & "*Extreme Photonics*": 10GeV electrons, >100MeV protons and high energy x-rays
- Operational in 2027

1 cm with laser is
equivalent to 1 km with RF



EPAC laser

Fields in the plasma 99.999999% light speed in 2cm

EPAC employs the patented diode-pumping laser technology developed in-house





DiPOLE Systems Ltd:
A new CLF spinout company based on UK innovation

Science and Technology Facilities Council

Laser capable of driving high-energy particle beams

Front End (OPCPA)

High gain, compact, low noise amplification.

Petawatt @ 10Hz Compressor

Large Aperture Optics in Vacuum.

Precise Alignment (µRads).

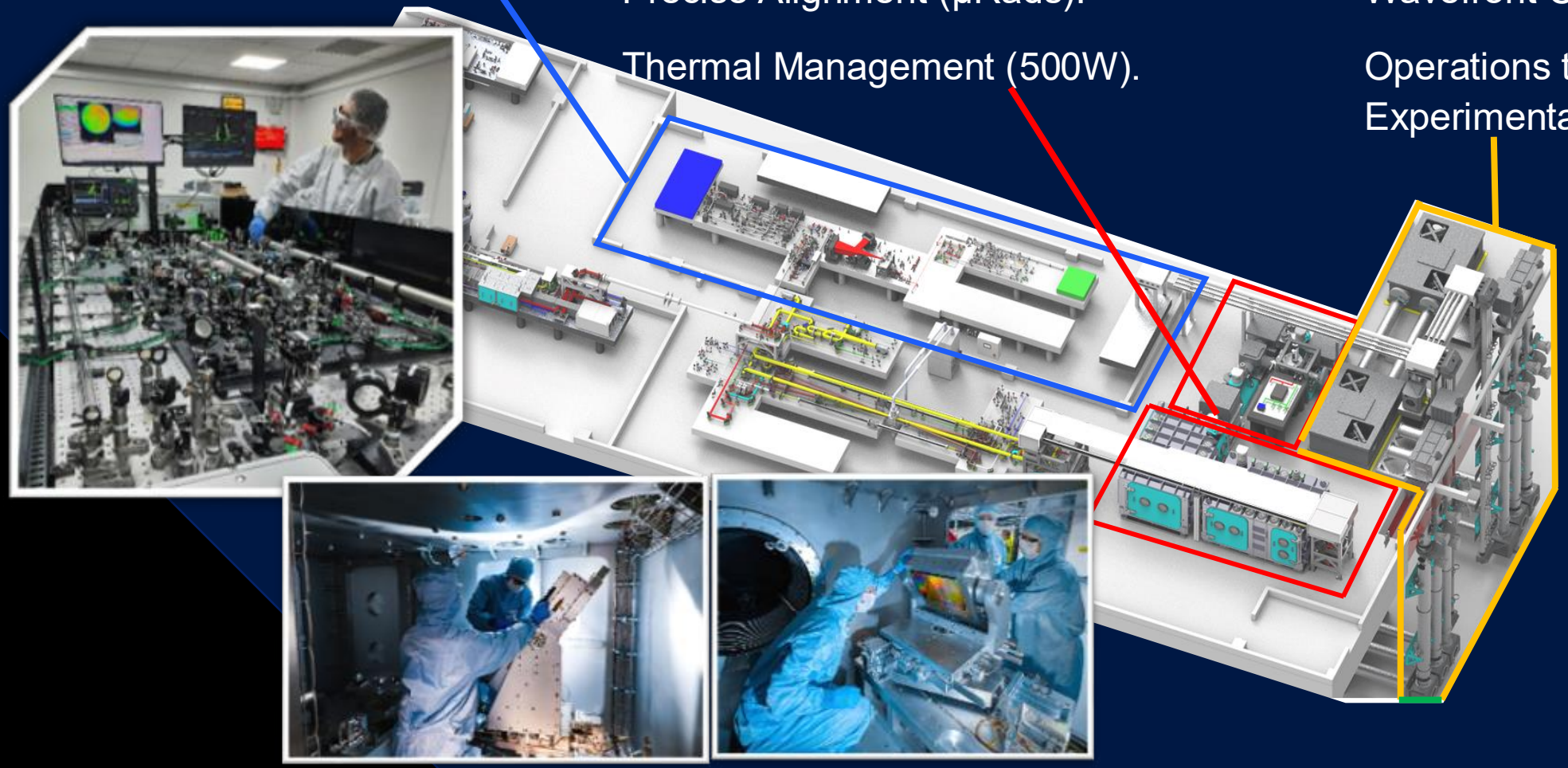
Thermal Management (500W).

Beam Transport to Experiments

High Stability Optics

Wavefront Control

Operations to multiple Experimental Areas



EPAC Phase 1

1PW@10Hz

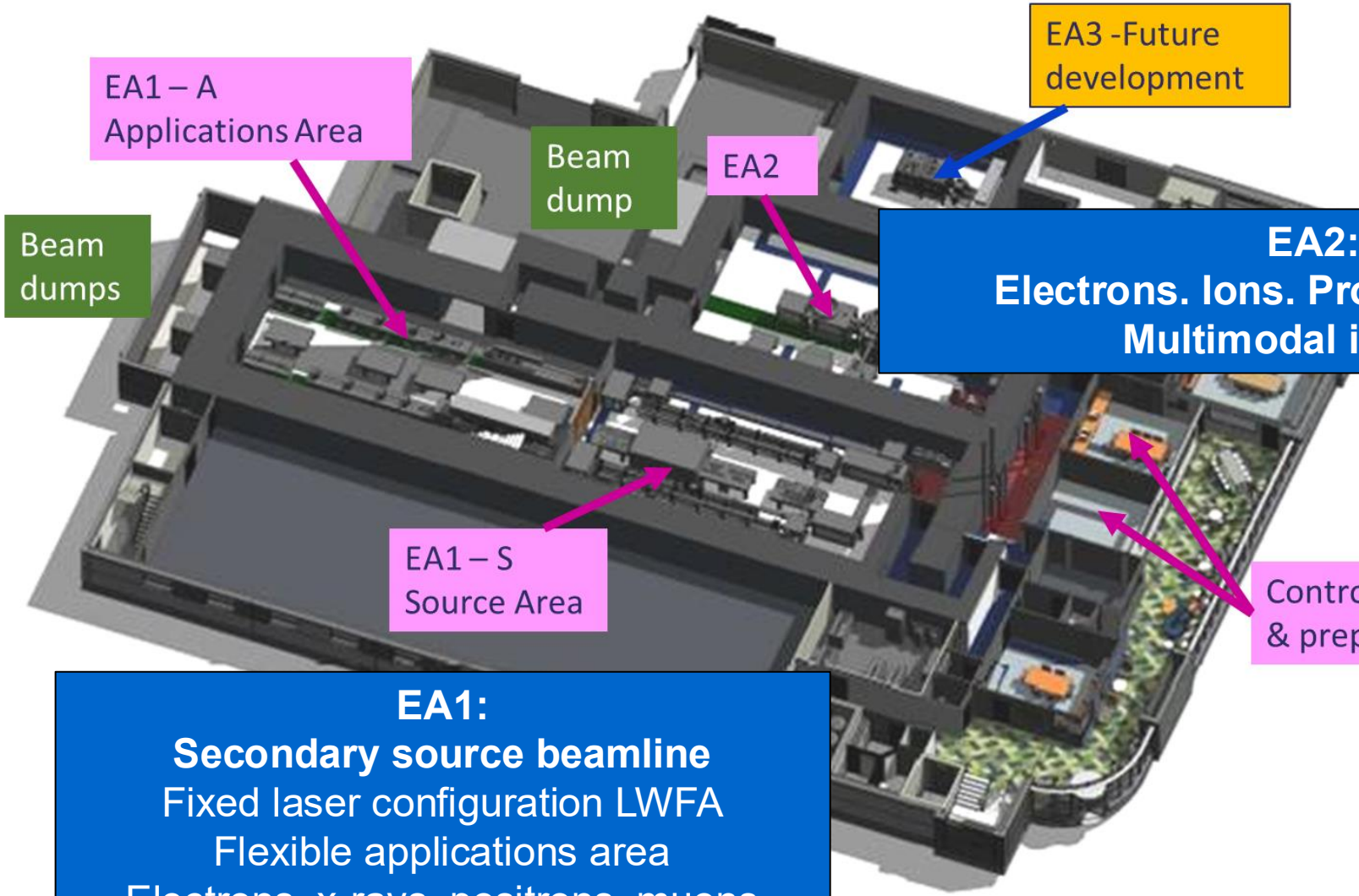
- Output Energy 30 J
- Pulse duration ≤ 30 fs
- 10 Hz, 1 Hz, SoD
- ~1% energy stability

EPAC Phase 2

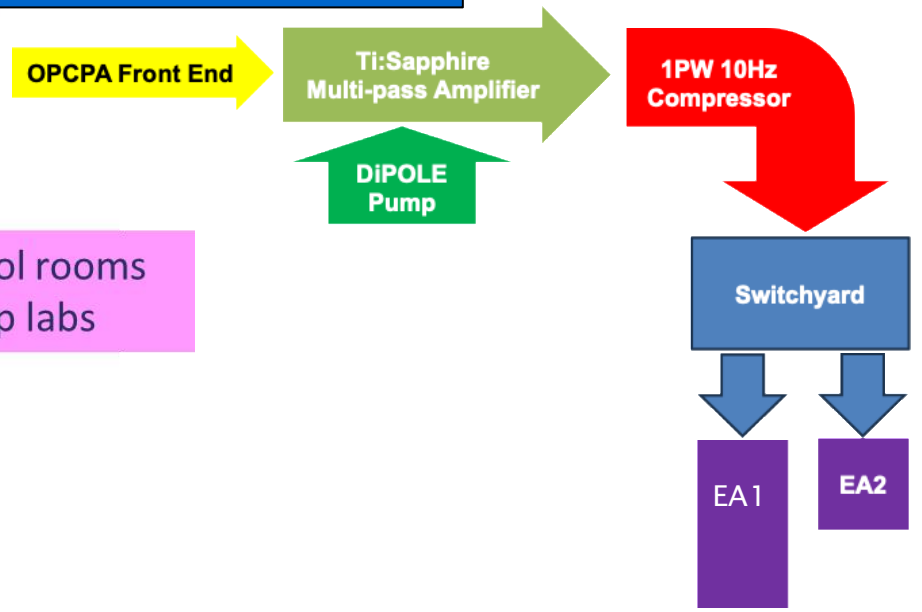
- Another 100J pump and another amplifier (auxiliary beamline
- Additional space for future laser and experimental areas (eg. a 100Hz system under development)

Experimental areas on the ground floor

Three heavily shielded areas – only two to be operational in the first phase



EA2:
Electrons. Ions. Protons & x-rays
Multimodal imaging

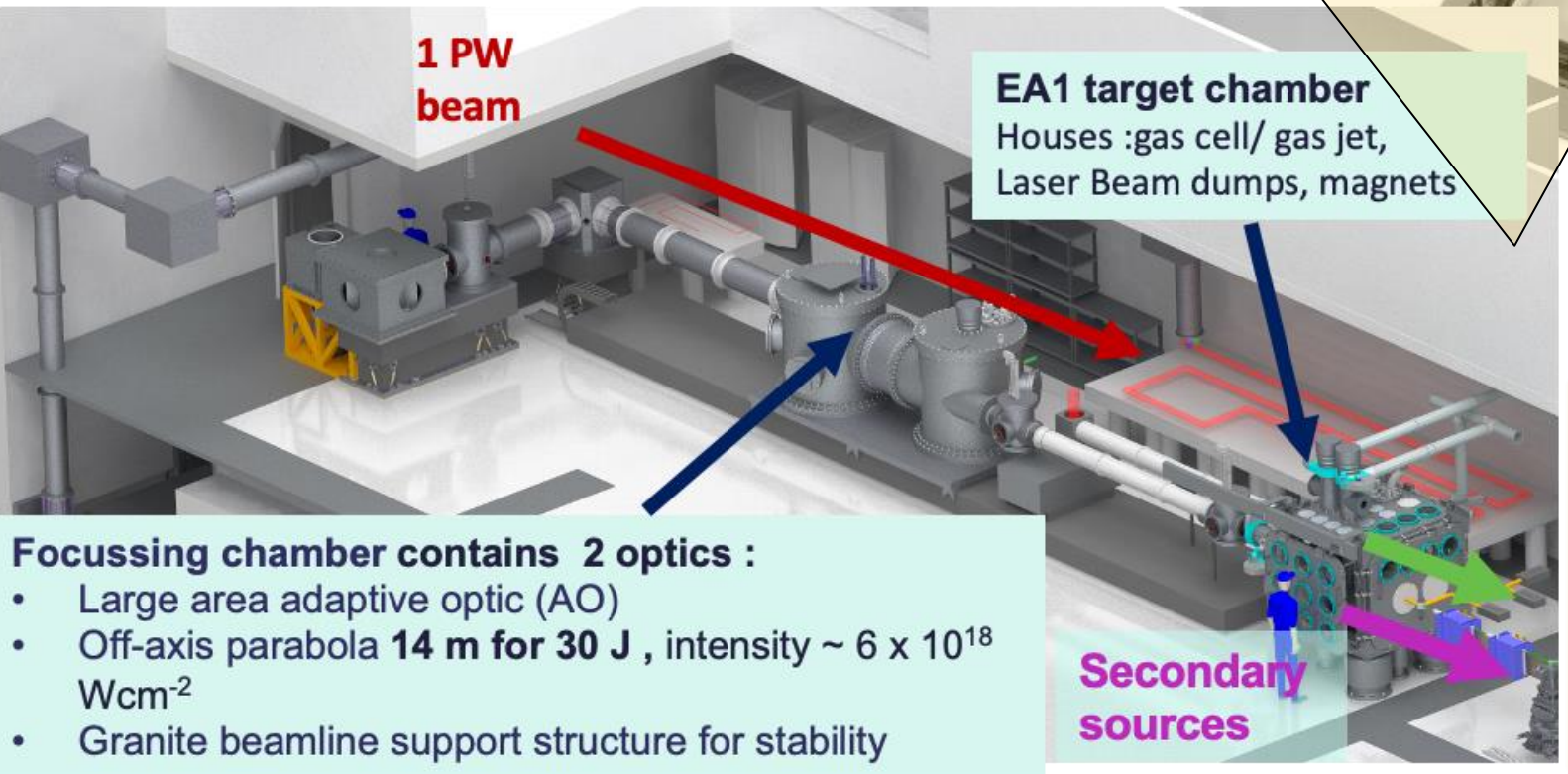


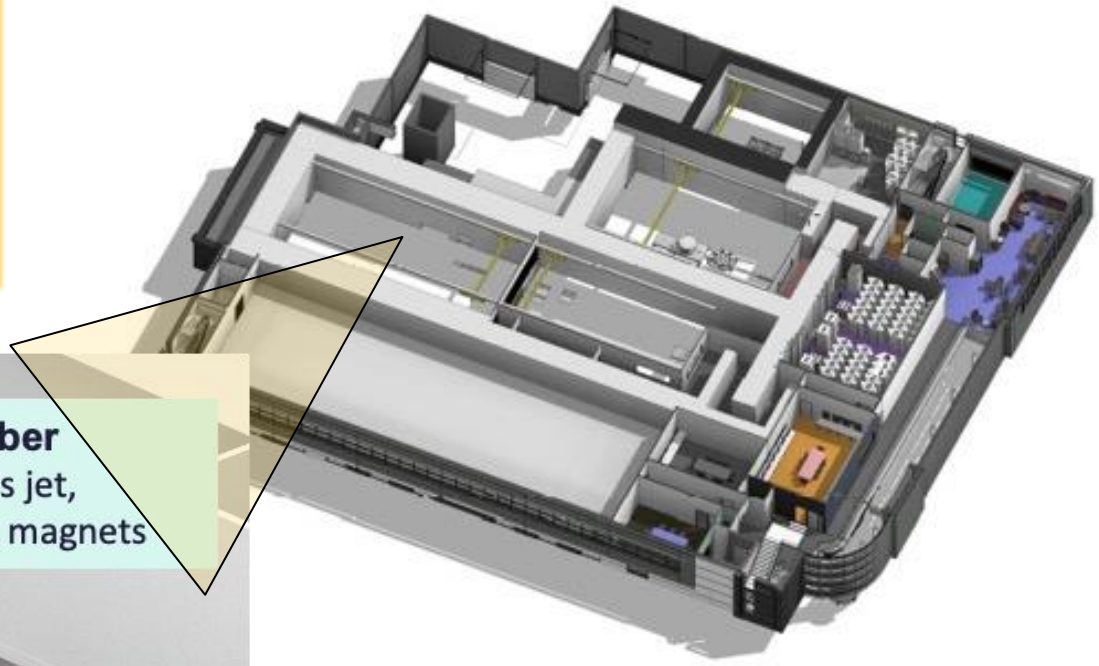
EA1:
Secondary source beamline
Fixed laser configuration LWFA
Flexible applications area
Electrons, x-rays, positrons, muons

EA1 is configured for driving wakefields

EPAC 1 PW drives a laser plasma accelerator

- Focused to relativistic intensity (above 10^{18} Wcm^{-2})
- Target is a few cm of gas
- Creates a plasma with extremely high accelerating fields
- Generates multi-GeV electron beams and x-rays





Focussing chamber contains 2 optics :

- Large area adaptive optic (AO)
- Off-axis parabola **14 m for 30 J** , intensity ~ 6 x 10^{18} Wcm^{-2}
- Granite beamline support structure for stability

Timeline:

2025: Commissioning with internal laser

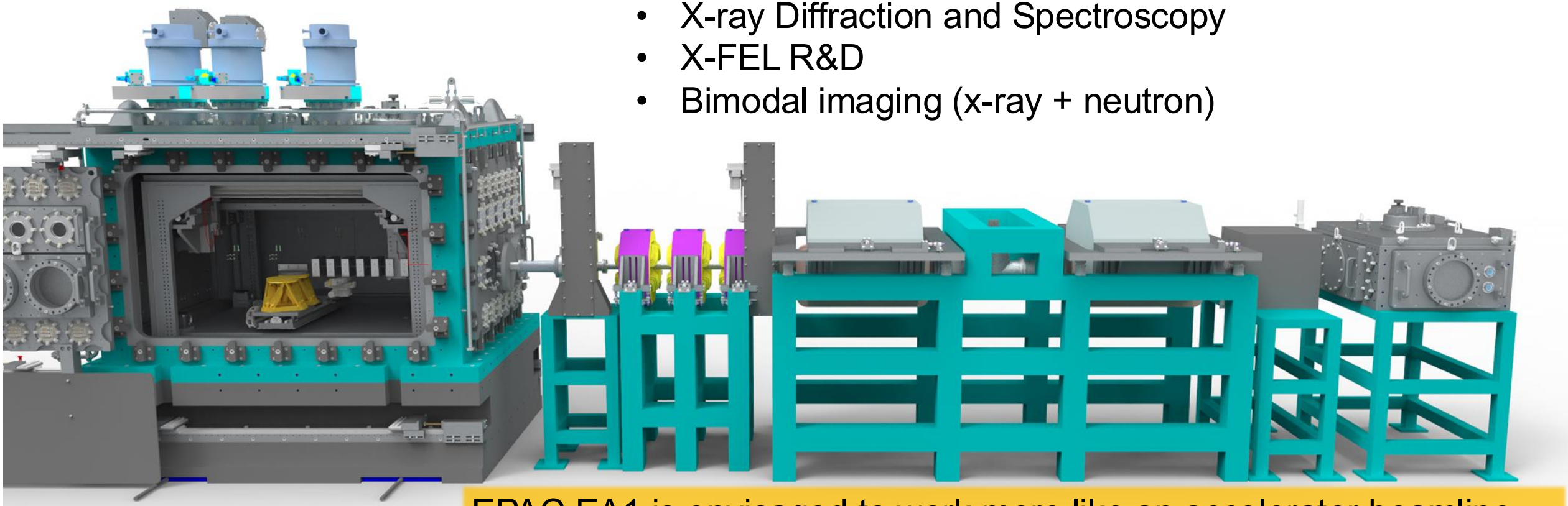
2026: Pulsed beam delivery and commissioning

2026: Secondary source optimization

2027: Operational user facility

Secondary sources for science and applications

- Impact (positrons / muons / bremsstrahlung)
- Collisions (Inverse Compton Scattering & QED)
- X-ray Diffraction and Spectroscopy
- X-FEL R&D
- Bimodal imaging (x-ray + neutron)



EPAC EA1 is envisaged to work more like an accelerator beamline

EA2 will be a versatile area

Short focus

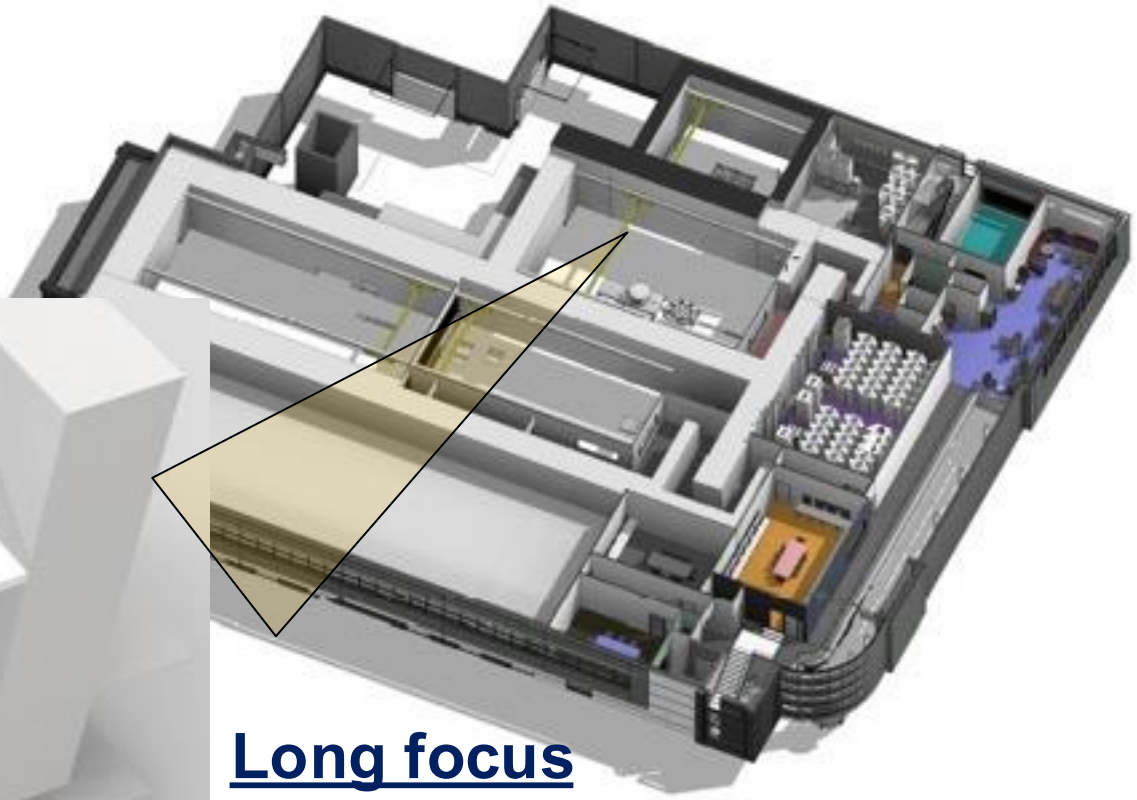
~4x10^{21} Wcm^{-2} a0 ≈ 40

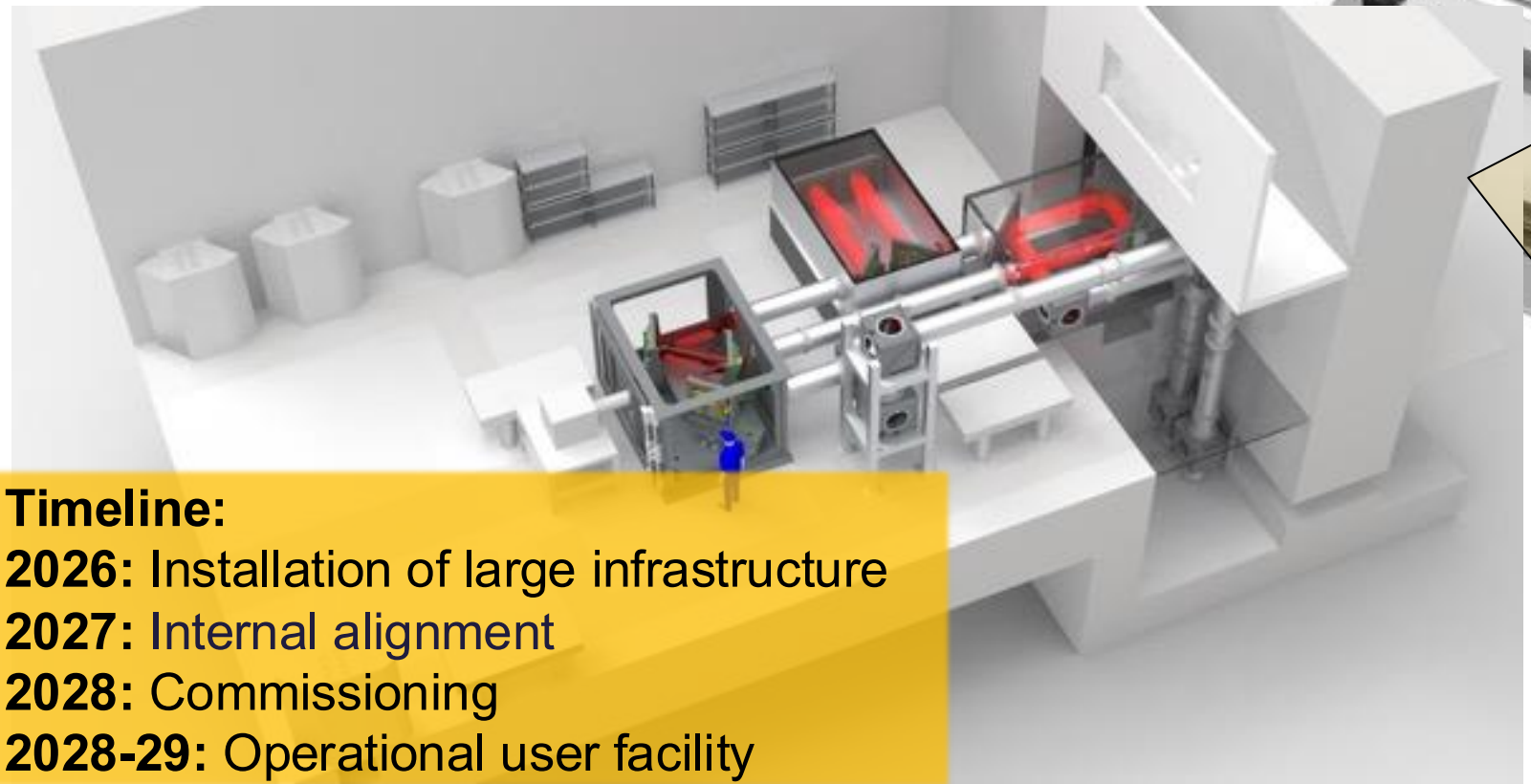
- RPA / RTA Proton/Ion acceleration (~ 100 MeV?)

Medium focus

~4x10^{20} Wcm^{-2} a0 ≈ 14

- TNSA Ion acceleration
- Bremsstrahlung
- Thermal neutron production





Long focus

~2x10^{19} Wcm^{-2} a0 ≈ 3

- LWFA source development
- Betatron source for imaging and probing

LhARA R&D can be done here

Timeline:
2026: Installation of large infrastructure
2027: Internal alignment
2028: Commissioning
2028-29: Operational user facility

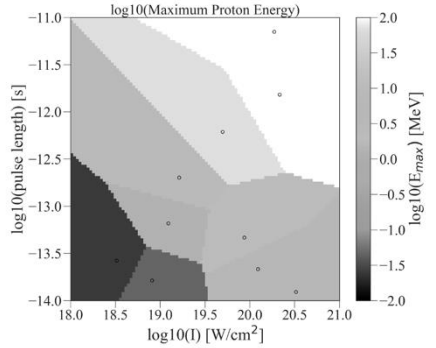
Ions/protons/neutrons & high field interactions

Starting with 1Hz, leading up to 10Hz and beyond

Ion beam optimisation	Stable ion beam @ 1 Hz	High rep. neutrons @ 1Hz
• Optimisation of cut-off energy, flux and beam profile in TNSA regime	• Demonstration of stable ion acceleration in TNSA regime at 1 Hz	• Demonstration of high repetition rate neutron source at 1 Hz
• Varying laser and target parameters, using single shot mode and solid targetry	• Exploration of large parameter space	• Tape drive or liquid targetry ion driver target
• Characterisation of interaction conditions, EMP, Debris	• Tape drive or liquid targetry	• Development of neutron target via either bulk target production or replenishable catcher target
• Array of ion, electron, optical and x-ray diagnostics	• Verification of debris mitigation, data acquisition at 1 Hz	• Commissioning of neutron diagnostics, moderators
	• Progressing towards 10 Hz as we develop experience with operation	

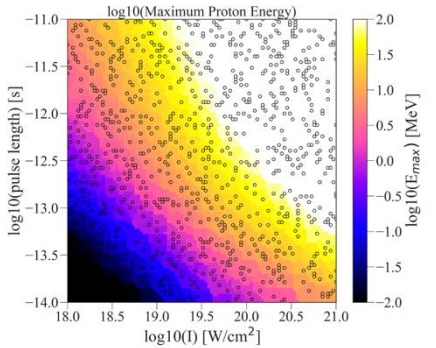
- Multimodal imaging
- High-dose FLASH radiobiology
- High Intensity/High Contrast Interactions
  - Relativistic Transparency
  - High-harmonic Generation

Current Paradigm

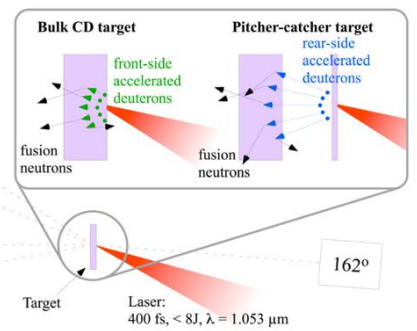


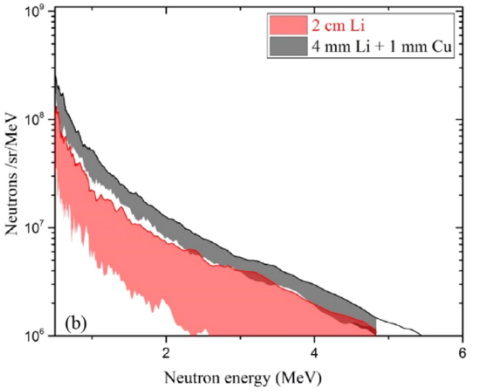
10 shots in 10 hours

New Paradigm



1000 shots in 2 min





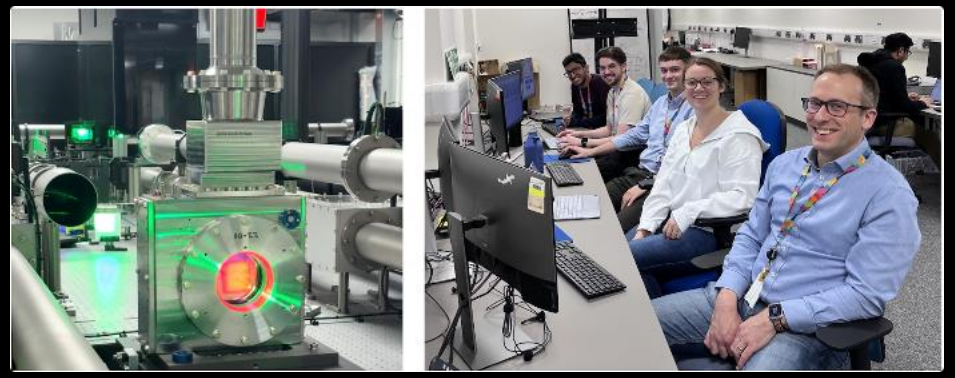
L. Willingale et al. *Phys. Plasmas 18, 083106 (2011)*

LhARA R&D can be done here

EPAC getting ready for operations

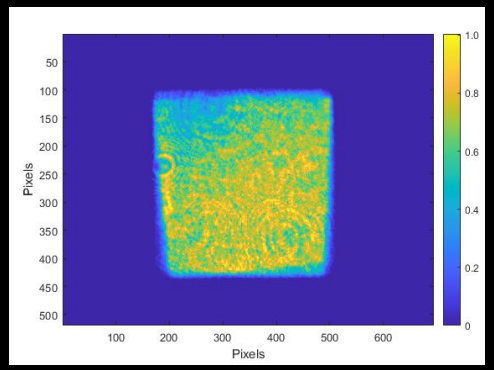


OPCPA front end: achieved 1J@ 10Hz signal output



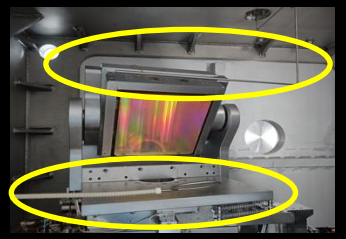
Final Ti:Sapph amplifier: amplification of the broadband seed
1Hz pulse rate demonstrated

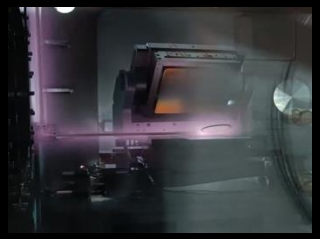




DiPOLE pump laser operating at 100J, @ 1Hz
>70% conversion to green tested







Compressor aligned; obtaining short pulses now
Starting off with gold gratings – restricted to 1Hz operation

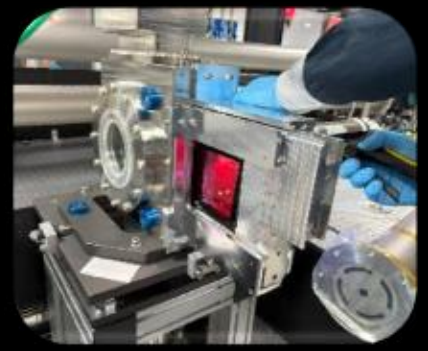
Science and Technology Facilities Council

EPAC getting ready for operations

- **Laser commissioning in final phase**
- Pump and Front-end are ready
- Amplifier and compressors being tested at 1Hz and 10Hz

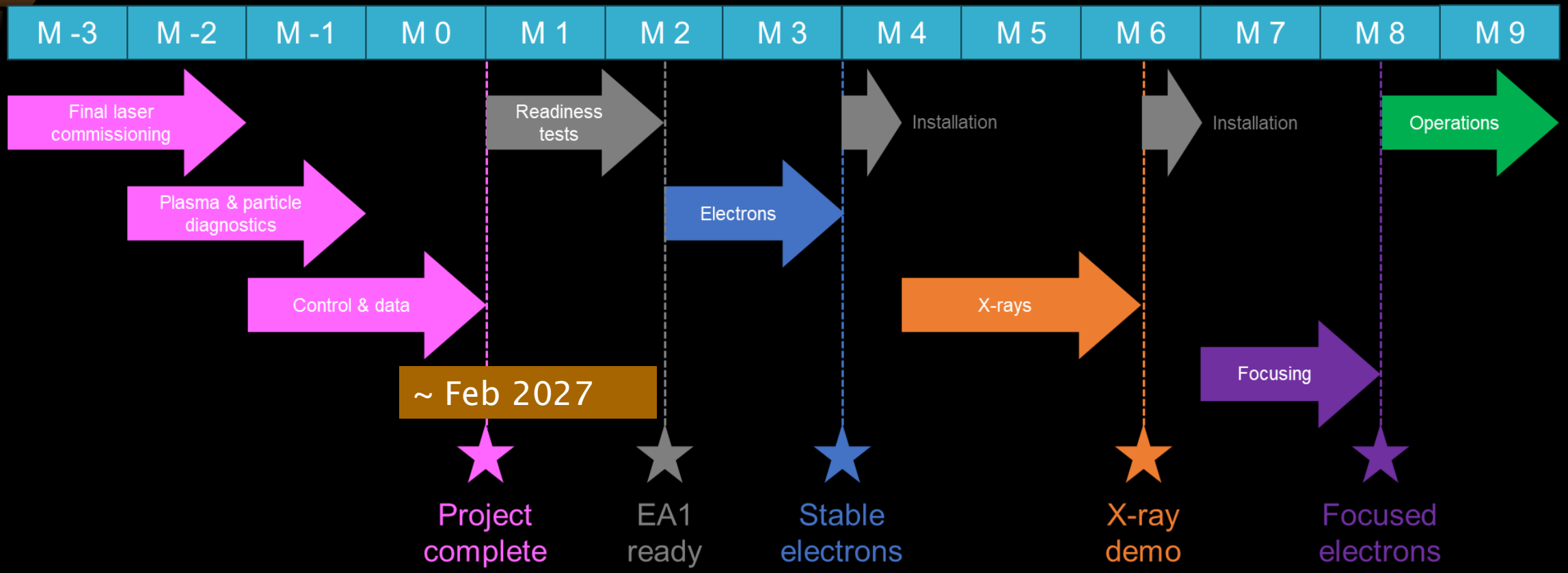
- **Beams propagated to EA1**
- No major issues in the ~50m vacuum beam transport
- Project-phase completion: by Feb 2027
- Plasma accelerator commissioning and tests of electron and x-ray beams: by July 2027
- First experiments likely to be in the Summer-2027 (subject to operational funds being allocated)






EA1 commissioning timescale



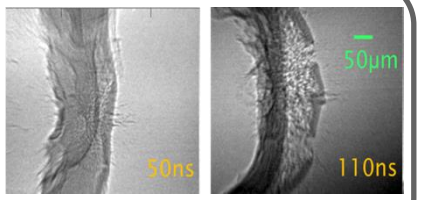
- Testing essential requirements are ready for operations
- 3 Distinct Commissioning Phases: Optimisation of electrons, x-ray imaging and beam manipulation - estimate about 6 months
- **User involvement throughout**

EA2 commissioning will begin later next year

Future phases of EPAC and capabilities

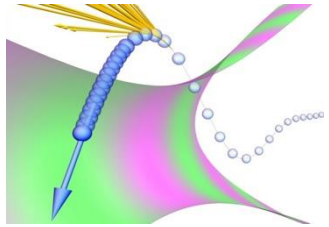
Second Pump – 100J, long pulse capability

New HED capabilities for MoD and the UK Inertial Fusion Programme



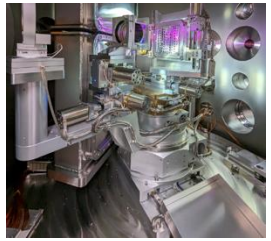
Second High Power Laser

Capabilities for high energy physics (HEP) and statistically relevant fundamental physics



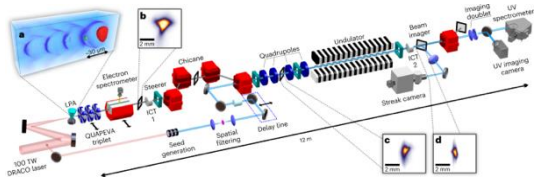
100Hz, (a few)100 TW Laser

Prototyping higher throughput (100Hz – kHz) secondary sources for industrial and strategic applications



R&D on advanced light sources

Complementary program towards a plasma-based FEL





[dstl]

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