Synergies with UK plasma wakefield research

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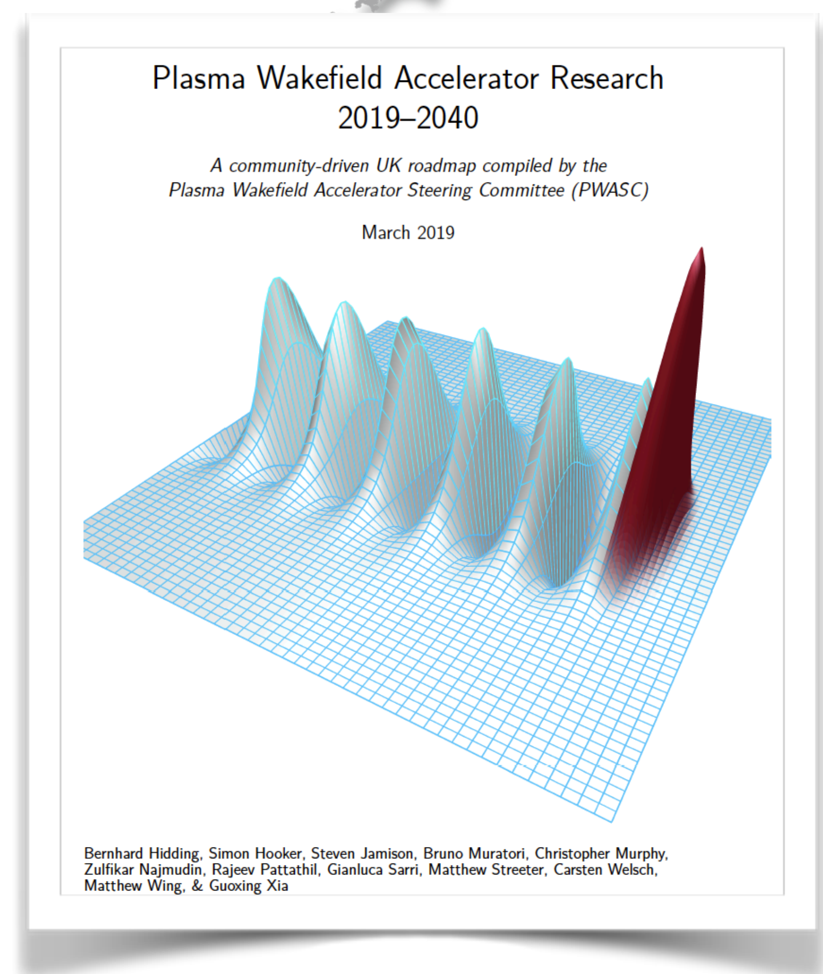
PWASC

- Plasma Wakefield Accelerator Steering Committee (PWASC) was established to represent UK groups working on plasma wakefield accelerators, and to help coordinate their activities.
- Members drawn from UK research groups, the Central Laser Facility, and the two Accelerator Science Institutes.
- Recently produced a roadmap for plasma accelerator research to 2040
    - Available at https://arxiv.org/abs/1904.09205

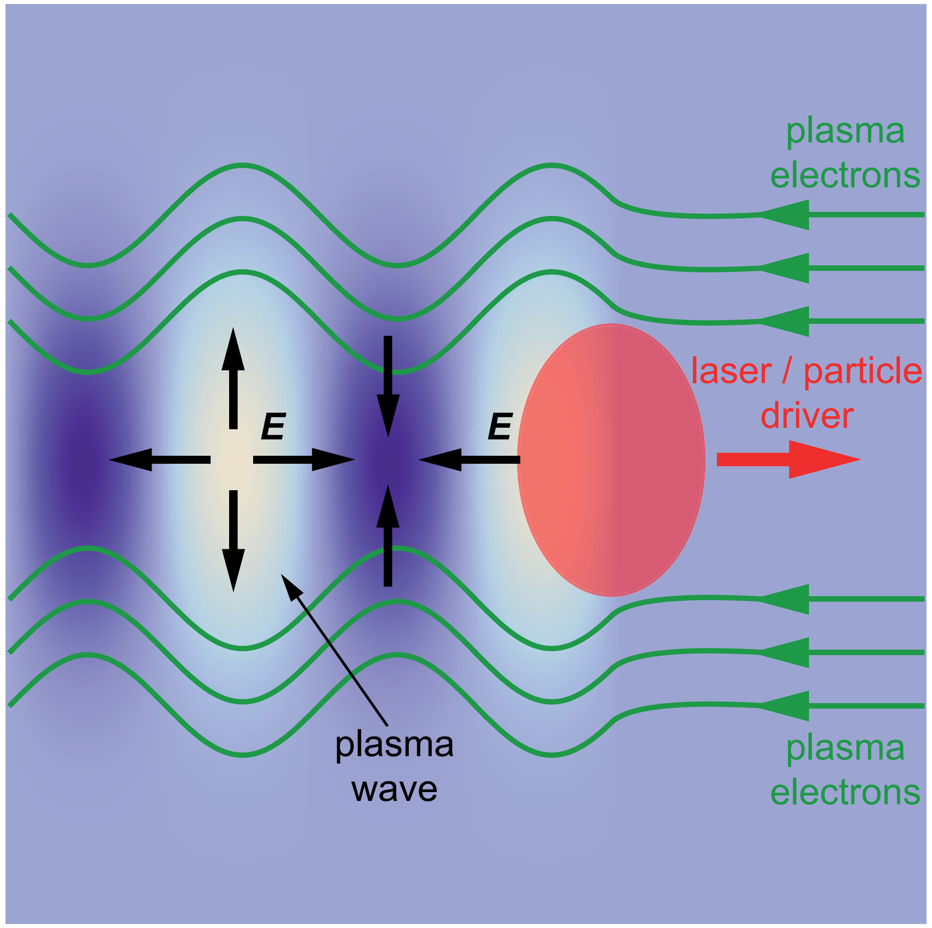

Plasma Wakefield Accelerator Research
2019–2040

A community-driven UK roadmap compiled by the Plasma Wakefield Accelerator Steering Committee (PWASC)

March 2019

Bernhard Hidding, Simon Hooker, Steven Jamison, Bruno Muratori, Christopher Murphy, Zulfikar Najmudin, Rajeev Pattathil, Gianluca Sarri, Matthew Streeter, Carsten Welsch, Matthew Wing, & Guoxing Xia

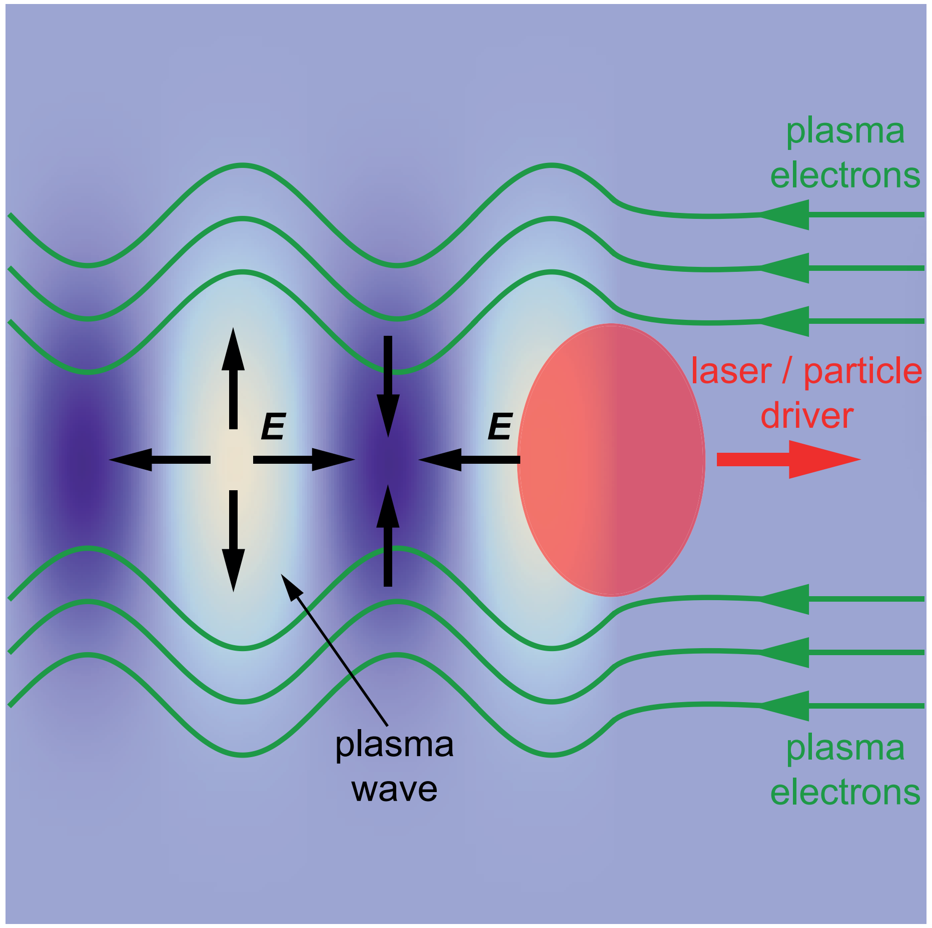
Plasma wakefield accelerators



- A laser or particle beam driver expels electrons from the region of the pulse to form a trailing plasma wave (a Langmuir wave)
- Wake amplitude greatest when $\omega_p \tau \approx 1$
- The wakefield moves at speed of laser pulse (close to speed of light)
- Electric fields within wakefield can accelerate charged particles

		Comment
Laser intensity	10^{18} W cm^{-2}	1 J, 50 fs, 25 µm
Plasma density	10^{18} cm^{-3}	i.e. 100 mbar
Accel. field	100 GV m^{-1}	10^3 to 10^4 > RF machine
Plasma period	**100 fs**	Need short laser pulses, get short electron bunches
Plasma wavelength	**30 µm**	

Plasma wakefield accelerators



A note on nomenclature
LWFA: Laser Wakefield Accelerator
PWFA: Plasma Wakefield Accelerator (i.e. beam-driven!)

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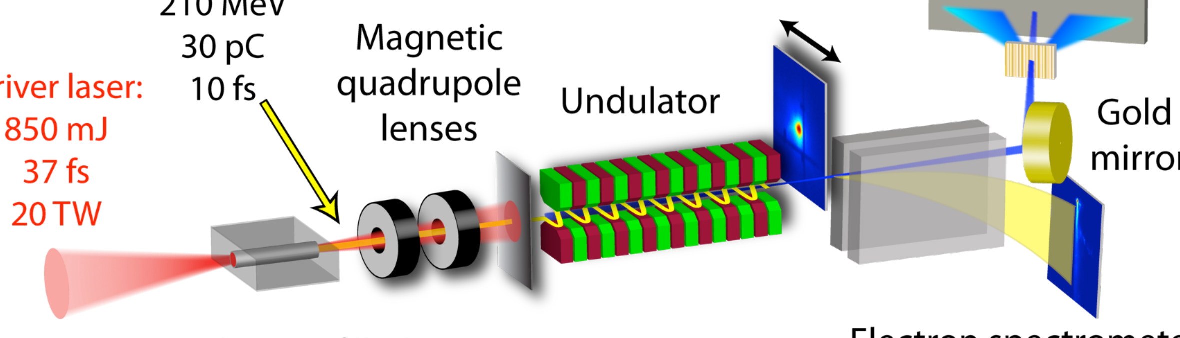
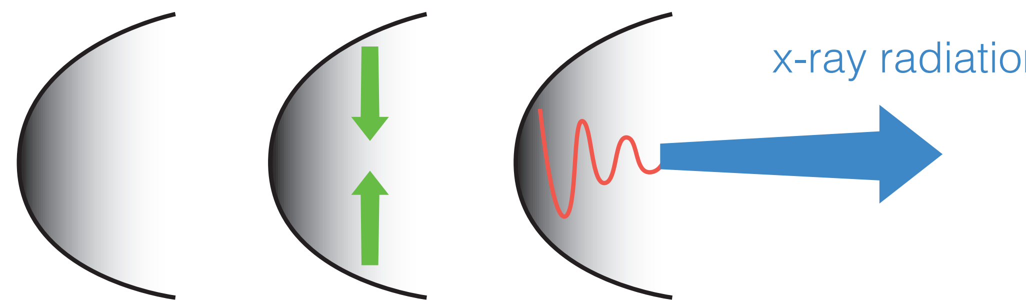
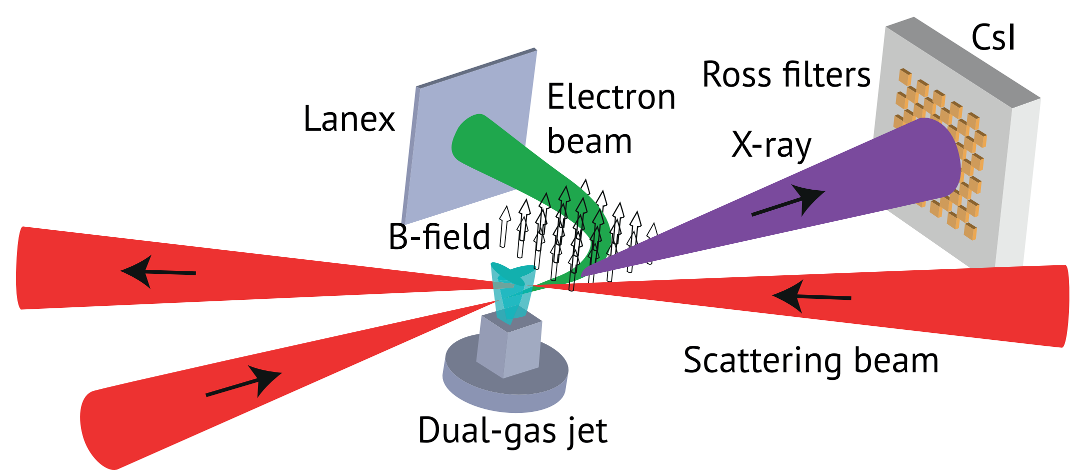
Status

- GeV beams from cm-scale stages routine
- 100 eV radiation from undulators
  - Schlenvoigt et al. *Nat. Phys.* **4** 130 (2008)
  - Fuchs et al. *Nat. Phys.* **5** 826 (2009)
- 10 - 150 keV radiation from betatron motion
  - Kneip et al. *Nat. Phys.* **6** 980 (2010)
  - Cippiccia et al. *Nat. Phys.* **7** 861 (2011)
- 1 MeV from Thomson scattering
  - Powers et al. *Nat. Photon.* **8** 28 (2013)
  - Khrennikov et al. *Phys. Rev. Lett.* 114 195003 (2015)
- Proof-of-principle imaging with betatron radiation sources
  - flies, fish, human bone
  - transient phenomena (e.g. shocks)







Representative parameters*

Parameter	Typical values from plasma accelerators	Conclusion
Beam energy *E*	< 8 GeV (laser driver) < 42 GeV (beam driver)	✓
Energy spread Δ*E* / *E*	~ 1%	✗
Bunch charge	10 - 1000 pC	✓
Bunch duration	< 5 fs	✓
Rep. rate	< 10 Hz	✗
Norm emittance ε_n	0.1 - 2 mm mrad	✓
Jitter: energy	1 - 5%	✗
Jitter: charge	5 - 50%	✗
Jitter: pointing	0.5 - 3.0 mrad	✗

*These parameter values are representative of state of the art. They have not been obtained simultaneously!

Challenges

- Large energy spread
- Large jitter

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- Control of electron injection
  - See Bernhard's talk
- Feedback systems

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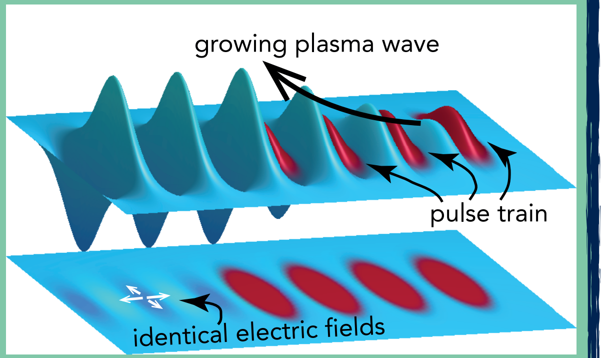
- New laser technology
  - DiPOLE at CLF: Horizon 2020 project to develop 10 J at 100 Hz
  - e.g. KALDERA project at DESY: 3 J, 30 fs (100 TW) @ 1 kHz
- New concepts
  - e.g. multi-pulse LWFA
  - Nb. thin-disk lasers provide > 0.5 J, few ps @ 1 - 10 kHz



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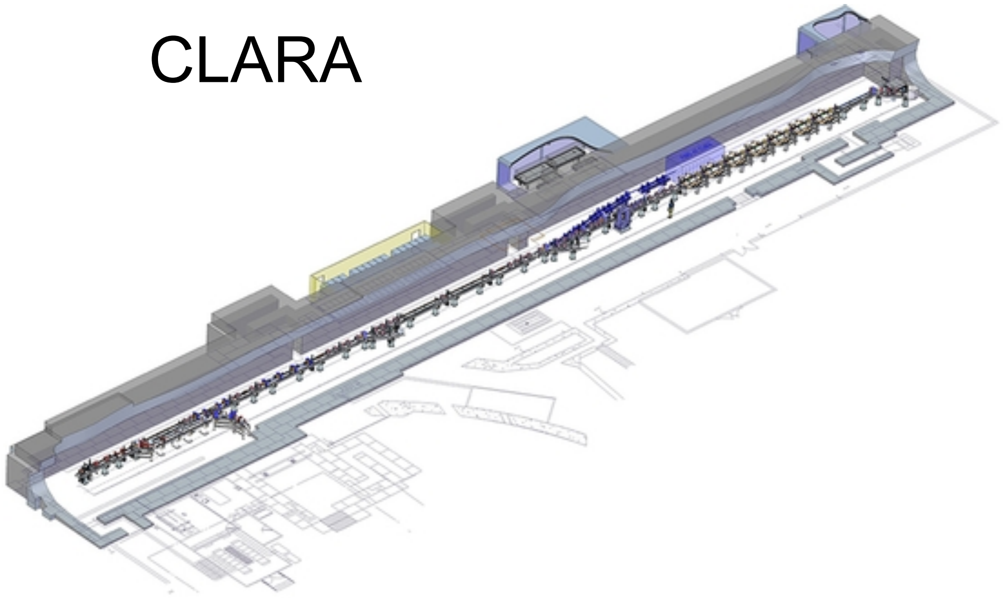
- Dedicated test beam facilities
  - E.g. LUX beamline at DESY has demonstrated > 24 hr operation @ 5Hz

Plasma accelerator research in the UK

- University groups
  - ~10 university groups
  - Several university-scale, multi-TW laser systems (Imperial College, Oxford, QUB,...)
- SCAPA
  - Peak laser power up to 350 TW @ 5 Hz
  - Capacity for 7 accelerator beamlines
- National laboratories
  - CLF at RAL
  - CLARA at Daresbury
- International facilities
  - AWAKE project at CERN
  - FACET & FACET-II at SLAC
  - ELI
  - Laserlab Europe
  - LaserNetUS



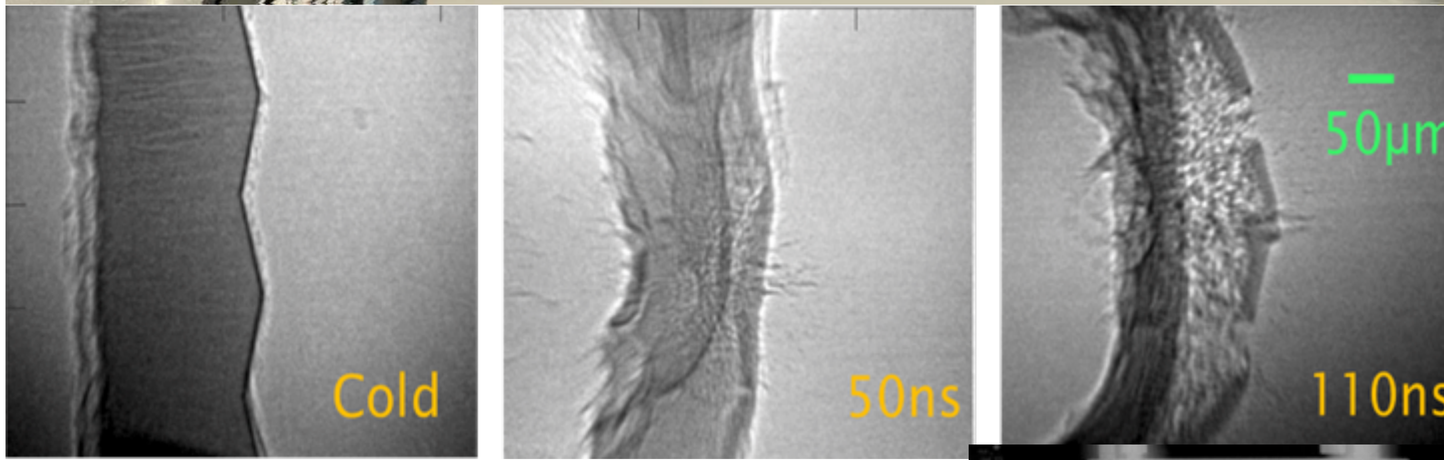
EuPRAXIA

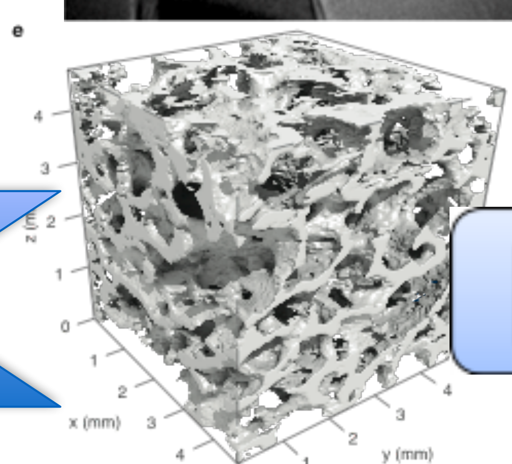
- EU-funded design study on plasma-based accelerators.
- 7"flagship science goals":
  - FEL: 10^{10} photons / pulse, 0.2 - 36 nm
  - X-ray betatron beamline: 10^{10} photons / pulse, 5 - 18 keV, 100 Hz
  - Positron beamline: 0.5 MeV - 10 MeV, 100 Hz
  - ICS source: 600 MeV
  - ...
- UK groups constitute 6 of 16 partners ... receive 21% of funding ... provide leader / co-leader of 3 of 8 WPs
- Next phase:
  - 10-year, multi €100M programme
  - Beam-driven plasma accelerator (1 GeV) & FEL; X-band technology
  - Laser-driven plasma accelerator (5 GeV) & FEL
  - Construct laser- and beam-driven plasma accelerator beamlines
  - UK likely to host Excellence Centre on applications

Extreme Photonics Application Centre (EPAC)

- £81.2M centre for applications of laser-driven sources in industry, medicine, security etc.
- £10M MOD funding
- LWFA driven beams at 1PW, 10Hz: Up to 10GeV beams, x-rays
- Significant Industrial backing based on proof-of-principle tests – cased approved based on economic impact
- Significant UK investment in plasma accelerators

Public announcement still embargoed!

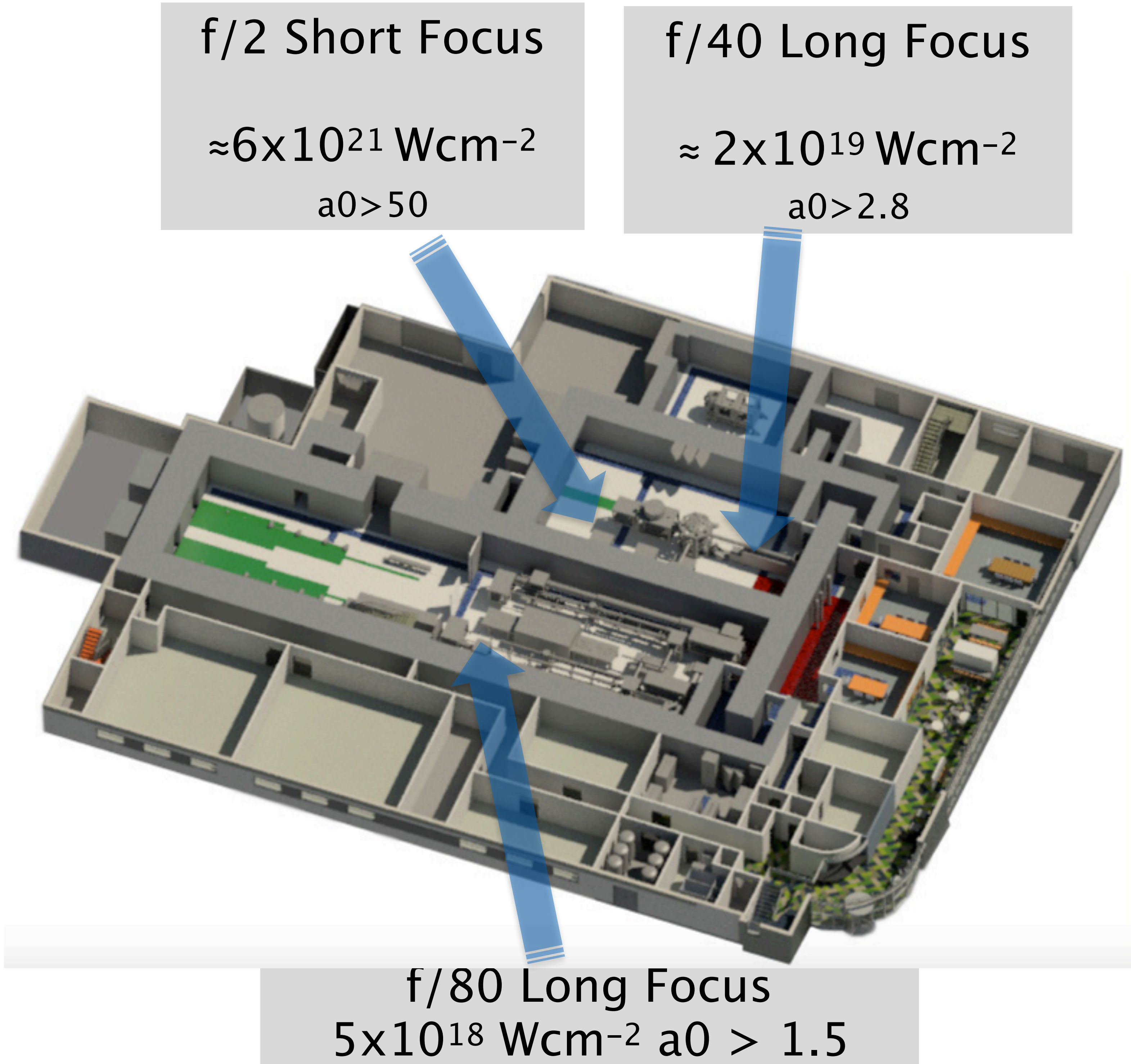




DiPOLE

EPAC Baseline Specs

- 30J, 30fs, 10Hz laser into two fully operational target areas:
  - 40m x 9m area for LWFA
  - 18m x 10m area for LWFA, proton / ion acceleration
- Plasma acceleration to produce multi-GeV electrons and bright x-ray sources spanning keV to multi-MeV.
- Ultrafast, small source-size x-rays to offer a powerful capability for scientific and industrial imaging and spectroscopy.
- High flux ion and neutron production from solid targets at high repetition rate
- Capacity to introduce second beamline as a future development



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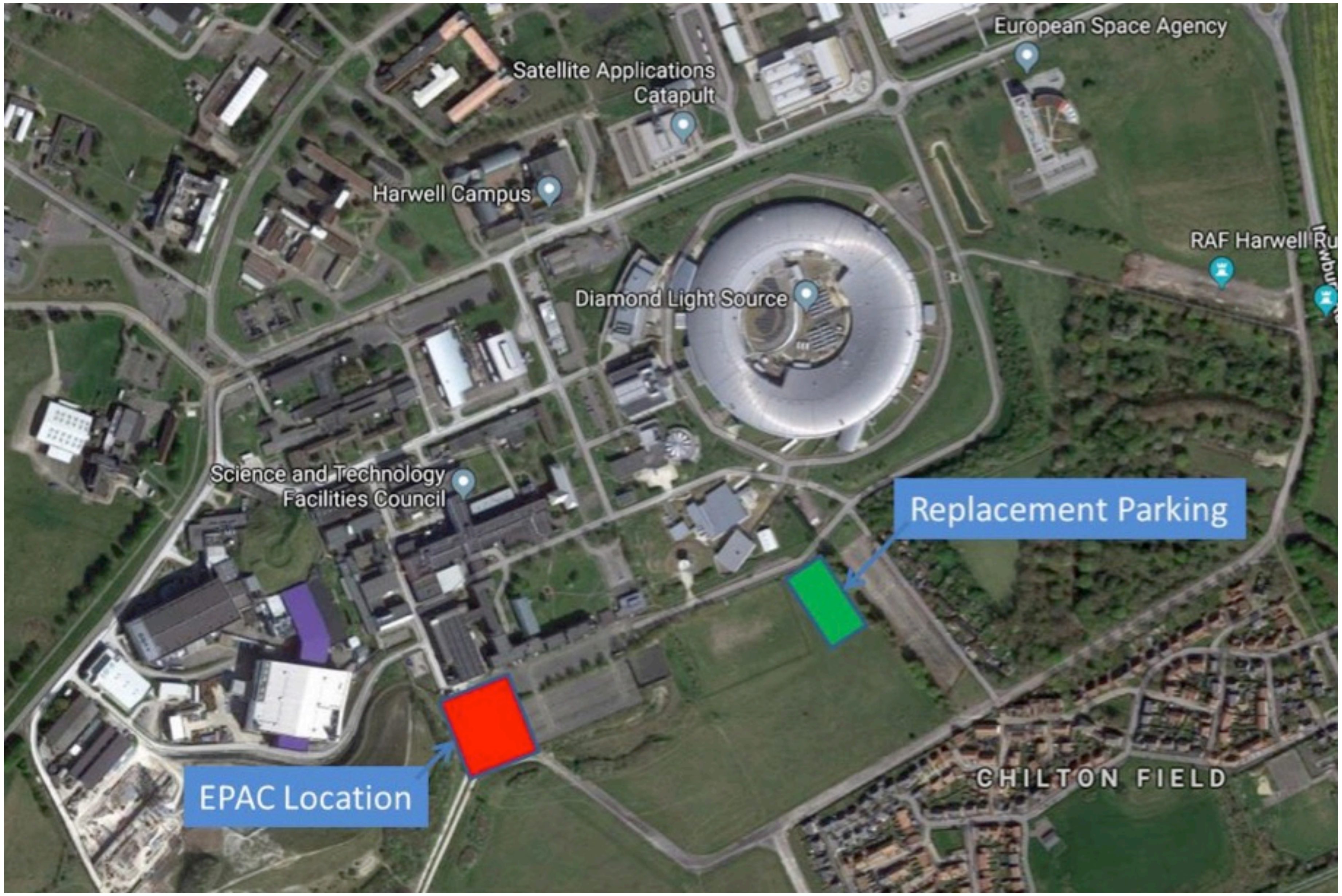
New Opportunities: EuPRAXIA @EPAC

- EU Funded development of 100Hz, 10J system, yielding multi-100TW @ 10Hz (10M€ H2020 funding)
- Potential to build additional beamlines, adding onto EPAC building



Possible synergies with a UK XFEL programme

- Future plasma stage as an energy booster ?
- Potential for plasma accelerators to boost brightness
- Future *additional* plasma-driven FELs (multi-FEL illumination?)
- Compact betatron or Compton sources?
- Utilization of target area "under the mound":
  - Access to post-FEL electron beam for LWFA / PWFA , high-field science research
- Diagnostics
- There maybe others ...