Science and Technology Facilities Council

K. Long, Y. Prezado 19 June, 2023

Imperial College London

LhARA

the Laser-hybrid Accelerator for Radiobiological Applications

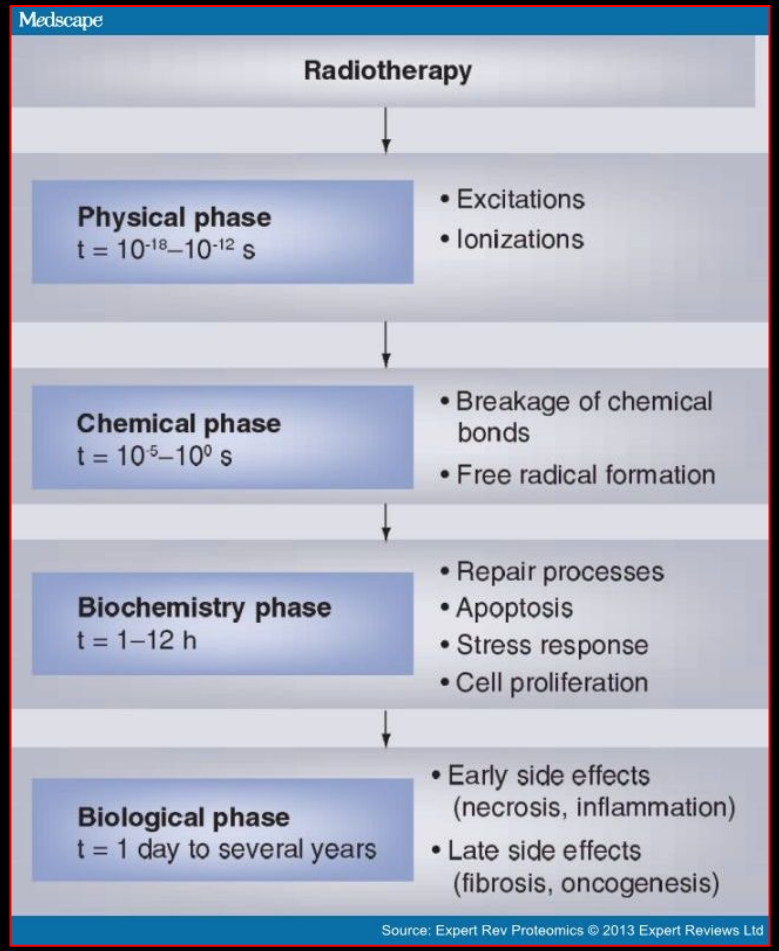
The LhARA initiative

Vision:

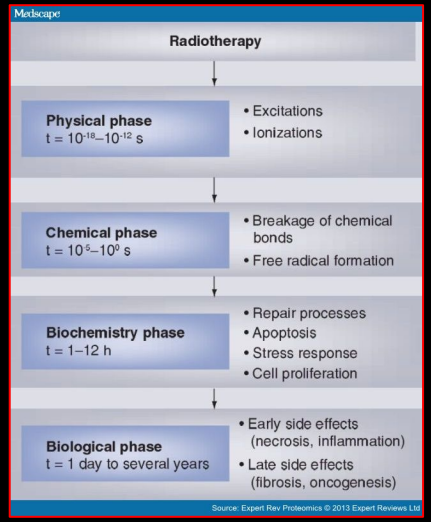
Transform clinical practice of proton/ion-beam therapy by creating a fully automated, highly flexible system to harness the unique properties of laser-driven ion beams

The case for fundamental radiobiology

- **Relative biological effectiveness:**
  - **Known to depend on:**
    - **Energy, ion species**
    - **Dose, dose rate, spatial fractionation**
    - **Tissue type**
    - **Biological endpoint**
- **Yet:**
  - ***p*-treatment planning uses 1.1**
  - **Effective values are used for C^{6+}**
- **Maximise the efficacy of PBT**



Radiobiology in new regimens



Time domain

Space domain

The ideally flexible beam facility can deliver it all!

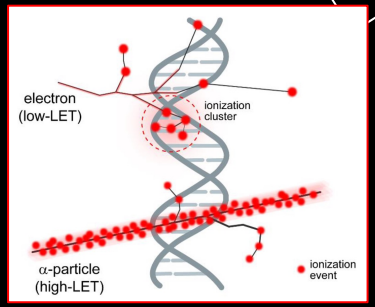
⇒ substantial opportunity for a step-change in understanding!

Multidisciplinary approach essential

Energy

Ion species

In combination and with chemo/immuno therapies



Laser-hybrid Accelerator for Radiobiological Applications

A novel, hybrid, approach:

- **Laser-driven, high-flux proton/ion source**
  - **Overcome instantaneous dose-rate limitation**
    - **Capture at >10 MeV**
  - **Delivers protons or ions in very short pulses**
    - **Bunches as short as 10—40 ns**
  - **Triggerable; arbitrary pulse structure**

- **Novel "electron-plasma-lens" capture & focusing**
  - **Strong focusing (short focal length) without the use of high-field solenoid**

- **Fast, flexible, fixed-field post acceleration**
  - **Variable energy**
    - **Protons: 15—127 MeV**
    - **Ions: 5—34 MeV/u**

LhARA performance summary arXiv:2006.00493

	12 MeV Protons	15 MeV Protons	127 MeV Protons	33.4 MeV/u Carbon
Dose per pulse	7.1 Gy	12.8 Gy	15.6 Gy	73.0 Gy
Instantaneous dose rate	1.0×10^9 Gy/s	1.8×10^9 Gy/s	3.8×10^8 Gy/s	9.7×10^8 Gy/s
Average dose rate	71 Gy/s	128 Gy/s	156 Gy/s	730 Gy/s

Front. Phys., 29 September 2020; DOI: 10.3389/fphy.2020.567738

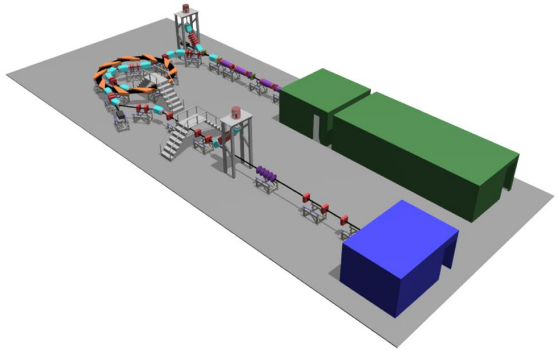
LhARA to serve the Ion Therapy Research Facility

2-year Preliminary Activity – Project start 01Oct22: CCAP-TN-10

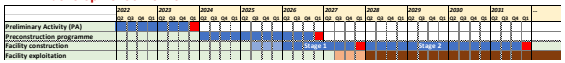
J, Clark, M. Noro, A. Woodcock 14Jun21

Ion Therapy Research Facility

1. Schematic diagram of the Ion Therapy Research Facility



2. ITRF development timeline



3. Institutes that make up the ITRF collaboration

2-year preliminary phase;
Flagged need for further 3-year preconstruction phase

June 1, 2022 CCAP-TN-10 (2022) LhARA

The Laser-hybrid Accelerator for Radiobiological Applications

R&D proposal for the preliminary, pre-construction phases

The LhARA collaboration

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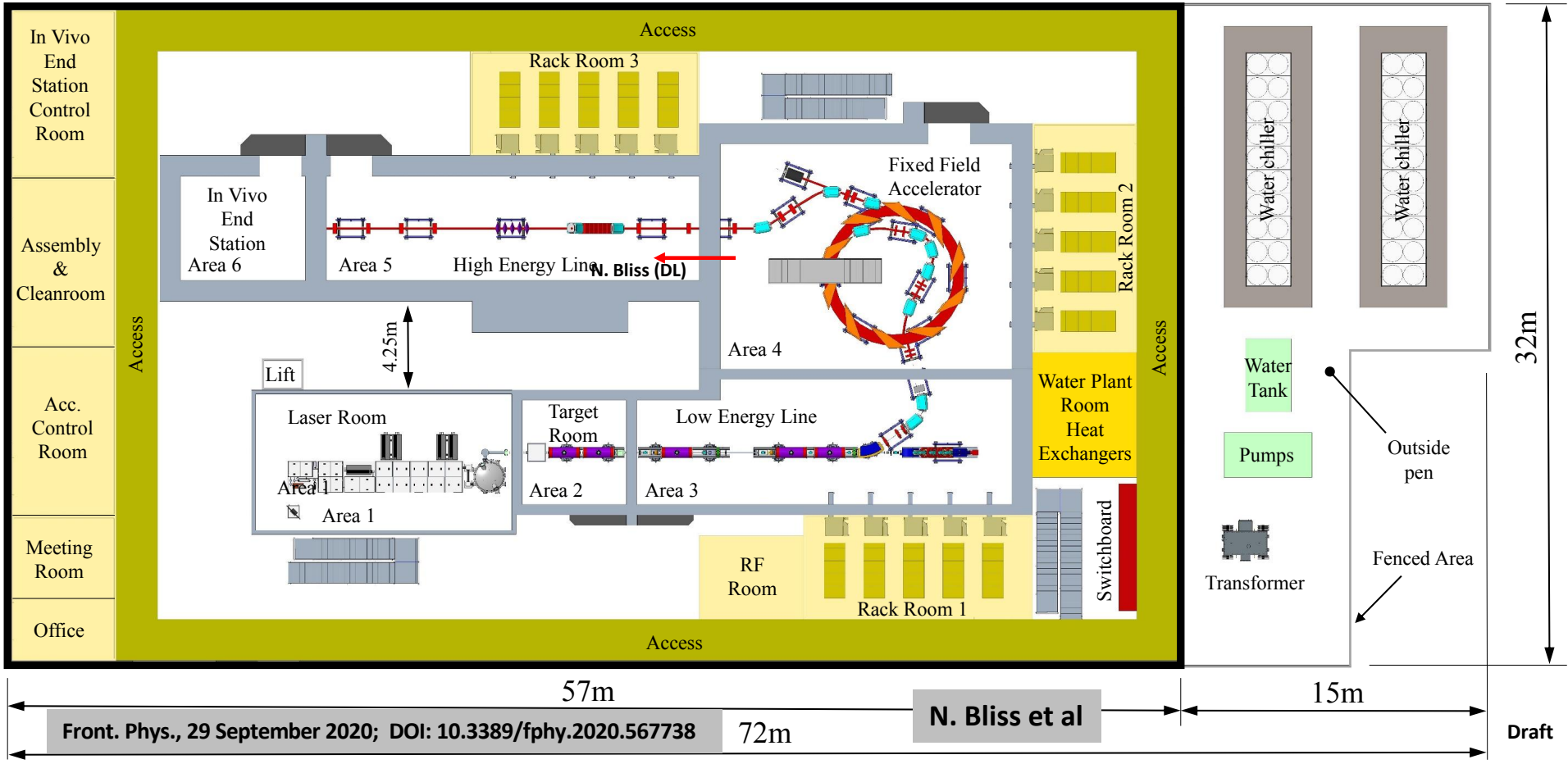
To serve ITRF: 2 + 3-year project
in 6 work packages:

1. Project Management
2. Laser-driven proton and ion source
3. Proton and ion capture
4. Real-time dose-deposition profiling
5. Novel, automated, end-station development
6. Facility design and integration

First two years of
"Full five-year proposal"
CCAP-TN-10

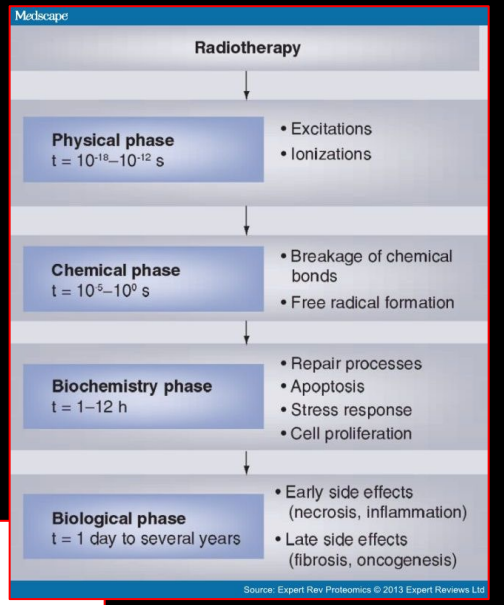


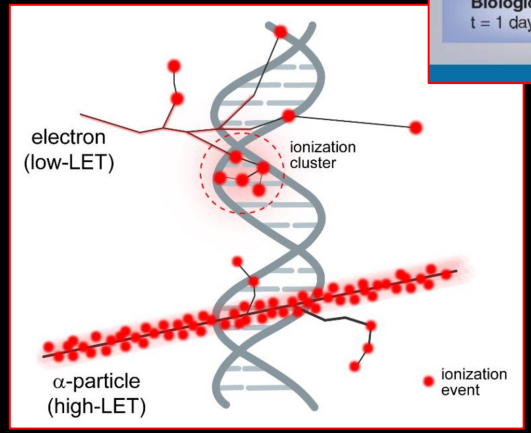
⇒ *compact, uniquely flexible facility*

LhARA
Laser-hybrid Accelerator for Radiobiological Applications

Low-energy *in-vitro* end station

- Maximum rep rate 10 Hz
  - With current specification
- Realisation of full scientific potential requires:
  - Automation
  - Novel instrumentation:
    - High dose rate
    - Spatial fractionation
    - “Readout” in < 0.1s





Conclusions

- Laser-driven sources are disruptive technologies …
  - With the potential to drive a step-change in clinical capability

- Laser-hybrid approach has potential to:
  - Overcome dose-rate limitations of present PBT sources
  - Deliver uniquely flexible facility:
    - Range of: ion species; energy; dose; dose-rate; time; and spatial distribution
  - Be used in automated, triggerable *system* → reduce requirement for large gantry
    - Disruptive/transformative approach to “distributed PBT for 2050”

- Peer-group consultation critical:
  - Maximise scientific potential through:
    - Automation
    - Novel techniques, instrumentation, operation, procedures …

LhARA Laser-hybrid Accelerator for Radiobiological Applications

CCAP Centre for the Clinical Application of Particles

Beyond today

- Peer-group essential preparation for bid for continuation:
  - Start from and extend:
    - Full five-year proposal

CCAP-TN-10	*P. Allport et al.*	**The Laser-hybrid Accelerator for Radiobiological Applications** *R&D proposal for the preliminary, pre-construction phases*	Revision 1	27/07/2022	BibTeX

- Target UKRI cross-council call to secure resource for multidisciplinary end-station development activity