Imperial College London

Science & Technology Facilities Council

Update on the LhARA initiative

K. Long, 12 July, 2021

CCAP Centre for the Clinical Application of Particles

ITRF and LhARA

- **Strong support from STFC Council**
  - **Added to that from STFC Executive, Science, and Tech. + Accel. Adv. Boards**

- **Moving now to prepare proposal to:**
  - **Infrastructure Advisory Board of UKRI**
  - **Deadline: 17:00, Tuesday 15Jun21**
  - **Writing team:**
    - **Massimo Noro, Jim Clarke, Hywel Owen, Charlotte Jamieson, Ken Long, Ailidh Woodcock, Rosanna Greenop**

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Preliminary details and descriptions

Name of project (and acronym or short name if relevant)	Ion Therapy Research Facility (ITRF)
Type of infrastructure project	**Establishment of new capability**
Submitting Council(s)/UKRI team(s)	☐ **AHRC** ☐ **BBSRC** ☐ **EPSRC** ☐ **ESRC** ☐ **Innovate UK** ☐ **MRC** ☐ **NERC** ☐ **Research England** ☒ **STFC** ☐ **E-infrastructure Team** ☐ **Large multidisciplinary facilities (STFC managed)**
Name(s)	Massimo Noro (massimo.noro@stfc.ac.uk)
UKRI Contact(s) Email address(es)	Jim Clarke (jim.clarke@stfc.ac.uk)
Phone number(s)	
One-line description of the preliminary activity for use in summary tables to IAC, ExCo etc. [22 words]	
The **ITRF** will allow the **biological impact of proton and ion beams** to be elucidated using **technologies** that will **transform clinical practice.**	
Long description of the preliminary activity [800 words, **please continue to the next box when full** – for IAC]	

Objectives:

The **Ion Therapy Research Facility** will deliver the world-leading, multidisciplinary programme necessary to:

- **Deliver the measurements required to** elucidate the biological and biochemical mechanisms that **underpin the clinical efficacy of proton- and ion-beam therapy;**
- **Demonstrate the** disruptive accelerator, diagnostic, imaging, and computing **technologies required to radically transform clinical practice** in proton- and ion- (particle-) beam therapy (PBT) by creating a compact, fully automated, highly flexible system; and
- **Create the capability to deliver proton- and ion-beam therapy in completely new regimens** by combining a variety of ion species, from proton to neon, exploiting ultra-high dose rates and novel spectral-, spatial- and temporal-fractionation schemes.

The novel beams that will be available at the ITRF promise a window on fundamentally new biological mechanisms of radiation cell-kill and immune response.

The **ITRF will place the UK** at the **forefront of the science and technology of particle therapy internationally, establish UK industry as a key player** in the delivery of novel clinical equipment, and **enable** significantly enhanced **access to state-of-the-art PBT across the UK.** The ITRF will enhance the UK as the destination of choice for cutting-edge research.

Transformative, multidisciplinary approach:

Laser-driven proton and ion sources are disruptive and have the potential to transform the delivery of PBT by providing more flexible, compact and cost-effective, high energy particle sources. The international, multidisciplinary Laser-hybrid Accelerator for Radiobiological Applications (LhARA) collaboration has developed the concept for a facility that meets the objectives set for the ITRF using laser-hybrid system, in which novel strong-focusing electron-plasma (Gabor) lenses capture and focus the large flux of protons or ions created when a short pulse, high-power laser strikes a target, thereby delivering a wide variety of ion species in almost arbitrary time, spatial, and spectral structures.

To realise the full potential of the ITRF requires that a multidisciplinary approach is taken from the outset. Therefore, by engaging with the LhARA collaboration of clinical oncologists, medical, particle, plasma, laser, ultrasound, and optical physicists, accelerator, computer, and instrumentation scientists, radiobiologists, industrialists, and patient representatives we have created the multidisciplinary team required successfully to deliver the ITRF.

[344 words]

The Preliminary Activity (PA):

We will develop the detailed specification and design of the ITRF, evaluate its cost, and elaborate the first phase of the ITRF research programme. The principal deliverable will be a full Conceptual Design Report (CDR). The PA will be executed in three work streams:

1. Detailed specification and staging plan

Led from the MRC Oxford Institute or Radiation Oncology (OIRO) and Liverpool University's Institute of Systems, Molecular and Integrative Biology, the biological-research capabilities of existing and planned proton- and ion-beam facilities will be reviewed and the biomedical research strategy for the ITRF will be developed. Detailed specifications of beam and end-station parameters will be derived along with a staging plan for the timely provision of *in-vitro* (Stage 1) and small-animal *in-vivo* (Stage 2) capabilities. Consideration will also be given to a Stage 3 programme of clinical trials to be initiated when the Stage 2 programme becomes established.

2. Conceptual Design Report, technology choice, technical-risk management

A conceptual design study will be carried out to produce a full project plan together with evaluations of operational arrangements, the national/international user community, and a detailed scientific, technological, economic, and societal impact assessment.

The expertise required to deliver the CDR resides within the LhARA collaboration. For example: the laser-driven source design will be led by Belfast, CLF, Imperial, and Strathclyde; the novel accelerator developments will be led by the Cockcroft and John Adams Institutes and ASTeC; the novel dosimetry, instrumentation, and diagnostic developments will be led by the National Physical Laboratory, the Institute for Cancer Research, Birmingham, Imperial, Liverpool, Manchester, PPD, UCL; and systems engineering/integration will be led from the national laboratories.

Effective tensioning of the benefits and costs of parameter trade-offs, technology choices, and implementation strategies will be carried out through 6-monthly reviews. Technology choices will be supported by appropriate prototype and test programmes that build on the technical-risk-management activities presently underway within the LhARA collaboration.

3. Impact co-creation

The implementation plan will be developed to maximise the impact of the programme in the following areas:

Clinical: Exploitation of *in vitro* and *in vivo* biological measurements to enhance the accuracy of treatment planning software. Exploitation of techniques developed for use experimental end-stations to enhance automated on-the-couch patient- and dose-imaging, and patient-positioning systems.

Industrial: Prototypes of the novel accelerator, imaging, and automated systems will be developed and produced in partnership with industrial members of the collaboration so positioning UK industry to take a leading role in the implementation phase.

Scientific: Impact will be generated in the fields of laser-driven acceleration, imaging, instrumentation, diagnostic-technology, and software-system development. Biological impact will be delivered throughout the ITRF programme. Key technologies developed and proved in operation can be spun-out to benefit accelerator-based science and innovation.

[451 words]

[Total: 797 words]

Circulated to ITRF Advisory Board & LhARA SG


Imperial College London
Department of Physics
Faculty of Medicine
ICR The Institute of Cancer Research
Medical Research Council
UKRI
Oxford Institute for Radiation Oncology
University of Oxford
JAI John Adams Institute for Accelerator Science
CCAP Centre for the Clinical Application of Particles
Imperial College Academic Health Science Centre
CANCER RESEARCH UK
IMPERIAL CENTRE
NHS
Imperial College Healthcare NHS Trust
MANCHESTER 1824
The University of Manchester
University of Birmingham
NHS
University Hospitals Birmingham NHS Foundation Trust
NHS
The Clatterbridge Cancer Centre NHS Foundation Trust
institut Curie
QUEEN'S UNIVERSITY BELFAST
UNIVERSITY OF LIVERPOOL
Lancaster University
University
Clinical
Accelerator
Partners
Laboratory
Industry
UKRI
Science and Technology Facilities Council
INFN CATANIA
University of Strathclyde Glasgow
DEPARTMENT OF PHYSICS
UCL
MEDICAL PHYSICS & BIOMEDICAL ENGINEERING
ROYAL HOLLOWAY UNIVERSITY OF LONDON
ASTeC
Particle Physics Department
ISIS Neutron and Muon Source
CLF central laser facility
Swansea University
Prifysgol Abertawe
University of Birmingham
POSITRON IMAGING CENTRE
Corerain
鲲云科技
The Rosalind Franklin Institute
NPL
National Physical Laboratory
University of Birmingham
CYCLOTRON FACILITY
The Cockcroft Institute
of Accelerator Science and Technology
LEO Cancer Care
MAXELER Technologies
Maximum Performance Computing
LhARA
Laser-hybrid Accelerator for Radiobiological Applications

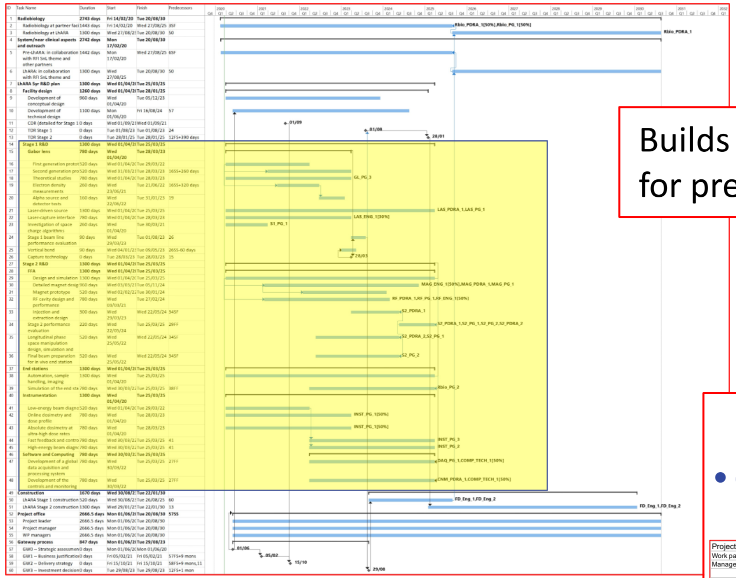
Goals for summer 2021

- **LhARA design revision paper:**
  - **Significant progress reviewed today should be published**
    - **Preparation to start next month**

- **White paper:**
  P.Price, A.Giacca, J.Parsons, S.Green et al.
  - **Review of biological understanding & LhARA's unique role**
    - **Specification document (PP) circulating; preparation to start soon**

- **Proposal for 2—year programme**
  [coincident with preliminary phase programme]
  - **Work packages:**
    1. **Laser-driven proton and ion source**
    2. **Proton and ion capture**
    3. **Real-time dose-deposition imaging**
    4. **Novel, automated end-station development**
    5. **Facility design and integration**
  - **Possible routes to submission:**
    - **As a single, large, proposal**
    - **Coordinated submission of several self-contained proposals**
    - **As basis of SoI to (e.g.) STFC Science Board**

Some preparatory work



Builds on planning done for pre-CDR

- **Colin Whyte (Strathclyde)**
  - **Has agreed to be the Project Manager**

Cost sheet

- **Cost-sheet by work package**

Project	LhARA	*Laser-hybrid Accelerator for Radiobiological Applications*					
Work package	IonAcoustic	Real-time dose-deposition imaging; ion-acoustic imaging, proof of principle					
Manager	WPM	*John Doe*					
	Staff	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**Total**
Flag		Fraction	Fraction	Fraction	Fraction	Fraction	Fraction
Task	***Task 1***						
Staff	Pasternak	0.10	0.10	0.10	0.10	0.10	0.50
Staff	Barber	0.25	0.25	0.00	0.00	0.00	0.50
Staff	Borg	0.25	0.25	0.00	0.00	0.00	0.50
Staff	Student 1	0.25	0.25	0.00	0.00	0.00	0.50
EndStaff	**Staff totals**	**0.85**	**0.85**	**0.10**	**0.10**	**0.10**	**2.00**
NonStaffHd	**Non staff**	£k	£k	£k	£k	£k	£k
Task	***Task 1***						
Equipment	Quadrupoles	127.50	12.00	5.00			144.50
Equipment	Quadrupole PSUs	60.00	12.00	5.00			77.00
Equipment	Dipoles	133.33	12.00	5.00			150.33
Equipment	Dipole PSUs	44.17	12.00	5.00			61.17
EquipEnd	*Sub-total*	*365.00*	*48.00*	*20.00*	*0.00*	*0.00*	*433.00*
RiskMitigationEquip	*Cost of risk mitigation (equipment)*	*5.00*	*12.00*	*5.00*	*0.00*	*0.00*	*22.00*
TotalEquip	**Eqipment total**	**370.00**	**60.00**	**25.00**	**0.00**	**0.00**	**455.00**
Consume	Consumables	2.00	3.00	4.00	5.00	5.00	19.00
Travel	Travel	2.00	3.00	4.00	5.00	5.00	19.00
OtherNonStaff	Review-committee expenses						
NonStaffEnd	**Total non-staff costs**	**374.00**	**66.00**	**33.00**	**10.00**	**10.00**	**493.00**
	Non-staff costs include VAT but not inflation.						

Staff FTE by financial year; quarters are noted for calendar year

Staff	**2022/23**				**2023/24**				**2024/25**				**2025/26**				**2026/27**			
	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Pasternak	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Barber	0.25	0.25	0.25	0.25	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Borg	0.25	0.25	0.25	0.25	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Student 1	0.25	0.25	0.25	0.25	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

- **Python code under development to automate financial reporting**
  - **Daughter of the "big spreadsheet" that some may remember fondly**
- **More detail to be circulated after the LhARA SG meeting next Monday (14Jun21)**

- **Dion Kordopati (HEP @ Imperial)**
  - **Dion has agreed to help us coordinate and manage the project and costing elements of the proposal**

Initial discussion at LhARA half day, 10Jun21:

LhARA half day meeting 10th June 2021; 09:30 -- 12:30 (13:30) BST

Presentations at the LhARA half day meeting will review the status of the LhARA initiative and identify the key development goals that will be taken forward of the summer. Talks in the half day will be organised in 7 "sessions".

Zoom link: https://cern.zoom.us/j/61287769114?pwd=UkQ1b2N5S1hJcGZXM2xwZk0xUWJEQT09

1. *09:30--10:00:* Introduction: aims and objectives: Conveners: K. Long, J. Parsons
   - Introduction (10+5): K. Long
   - Biology of ionising radiation; USPs for LhARA (10+5): J. Parsons

2. *10:00--10:50* Proton and ion source: Conveners: E. Boella, K. Long
   - Status of simulation of laser-target interaction (15+5): HT Lau
   - Progress towards 3D simulations of laser-target interactions (15+5): E. Boella
   - Towards the specification of a primary beam spectrometry experiment (7+3): K. Long

Break to 11:15

3. *11:15--12:00* Proton and ion capture: Conveners: C. Baker, C. Whyte
   - Understanding of first Gabor lens prototype (15+5): TS Dascalu
   - Development of electron plasma experimental programme at Swansea (15+5): C. Baker
   - The path to a second Gabor lens prototype (10+5): T.S. Dascalu

4. *12:00--12:20* Ion-acoustic imaging: Conveners: B. Cox
   - Ion-acoustic imaging; principle, status and plans (15+5): J. McGarrigle

5. *12:20--13:00* Vertical beam line for biological research on the Birmingham cyclotron: Conveners: J. Parsons, T. Price
   - Introduction and context (10+5): J. Parsons
   - Ideas for a vertical beam line for biological research on the Birmingham Cyclotron (20+5): T. Price

6. *13:00--13:30* Facility design and integration: J. Pasternak, W. Shields
   - Injection into FFA (10+5): W. Shields
   - FFA design update (10+5): J. Pasternak

7. *13:30* Close
