Imperial College London

Science & Technology Facilities Council

Overview of ITRF/LhARA

Laser-hybrid Accelerator for Radiobiological Applications to serve the Ion Therapy Research Facility

K. Long, 26 April, 2024

LhARA Laser-hybrid Accelerator for Radiobiological Applications

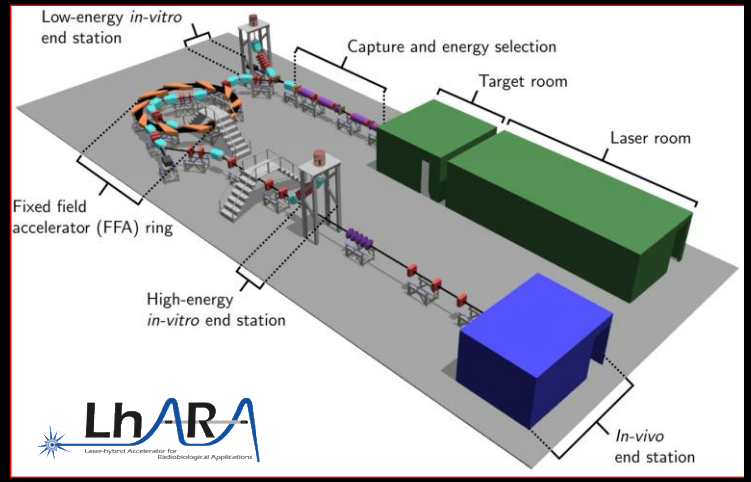
Our mission is to:

- *Deliver a systematic and definitive radiation biology programme*
- *Prove the feasibility of laser-driven hybrid acceleration*
- *Lay the technological foundations for the transformation of PBT*
  - automated, patient-specific proton and ion beam therapy

ITRF / 

What is LhARA?

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

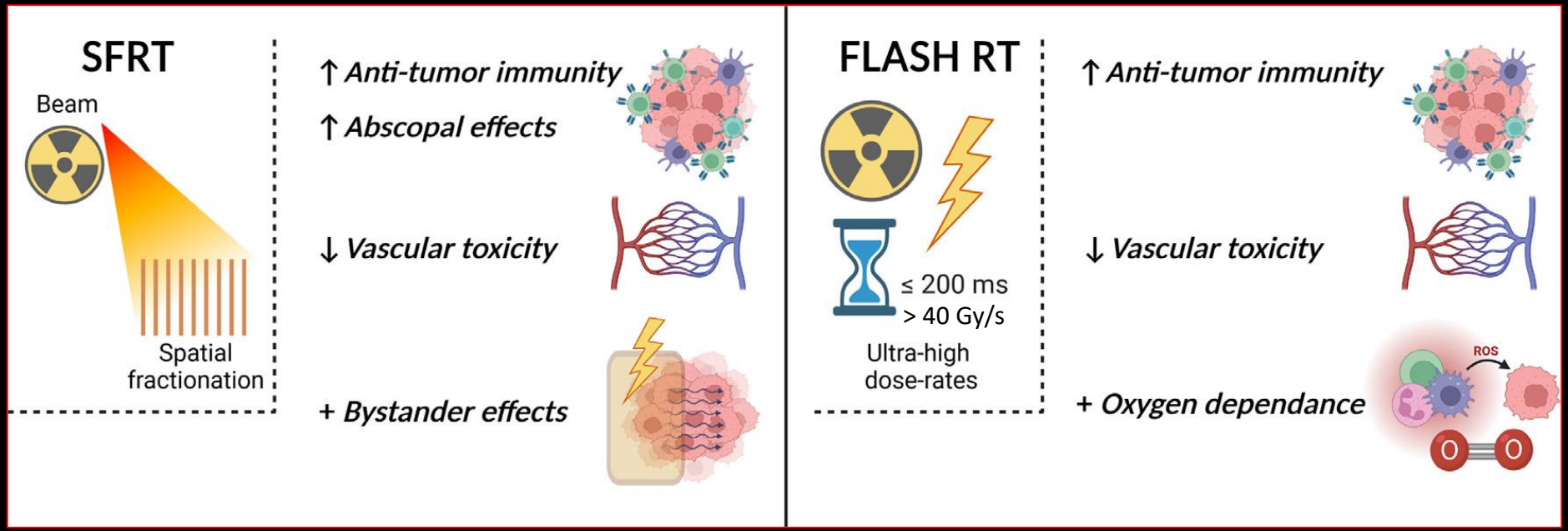
LhARA performance summary arXiv:2006.00493

	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

Radiobiology in new regimens

T. Schneider, C. Fernandez-Palomo, Annaïg Bertho et al.

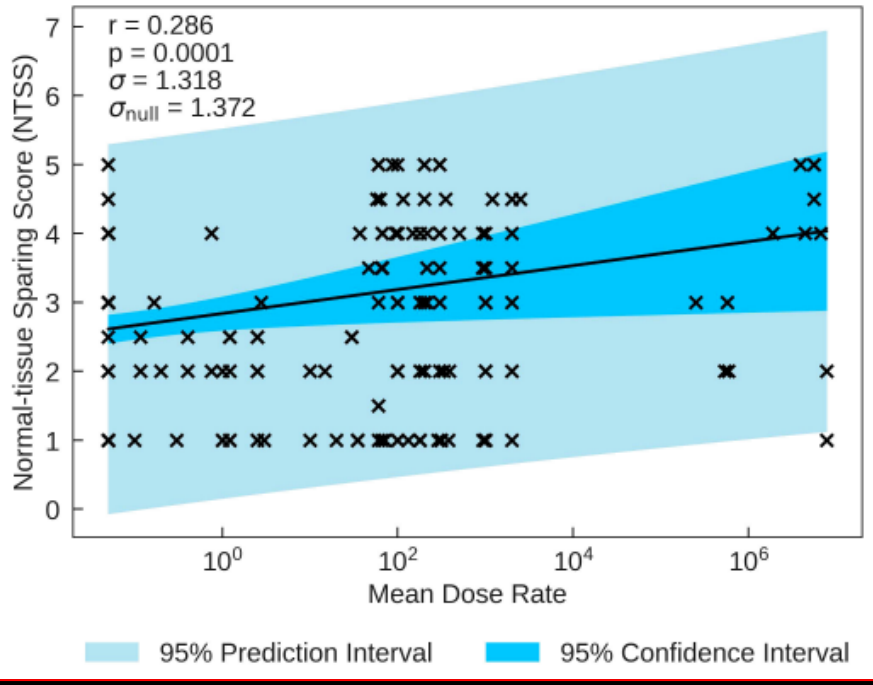


Dose escalation in the tumour possible – larger tumor control prob.

J. McGarrigle

To appear in
frontiers | Frontiers in Oncology

Proton FLASH data review

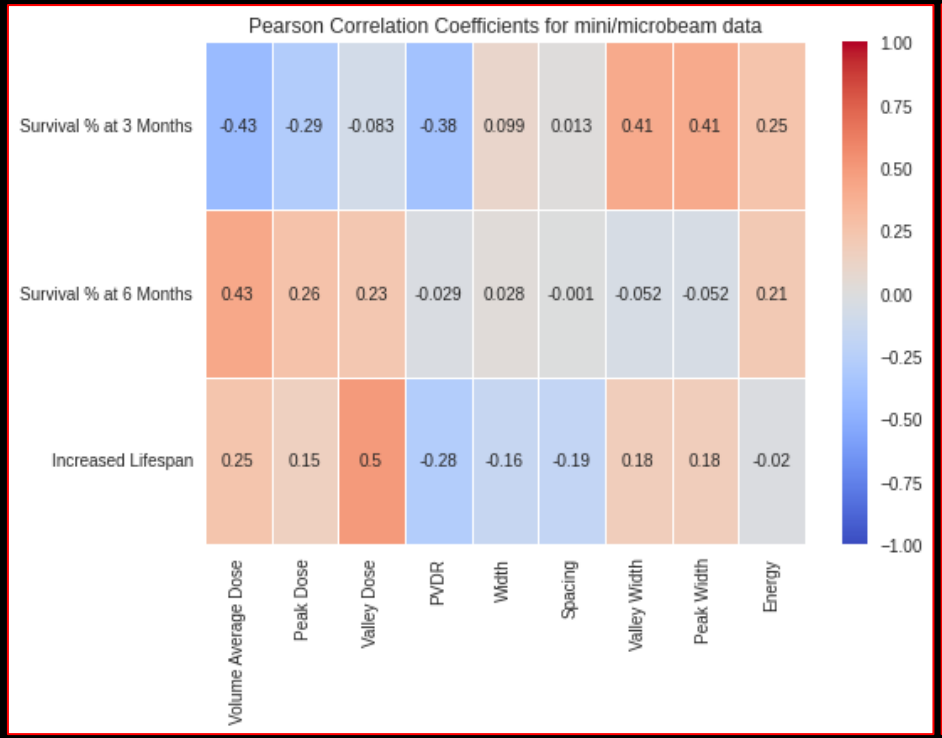


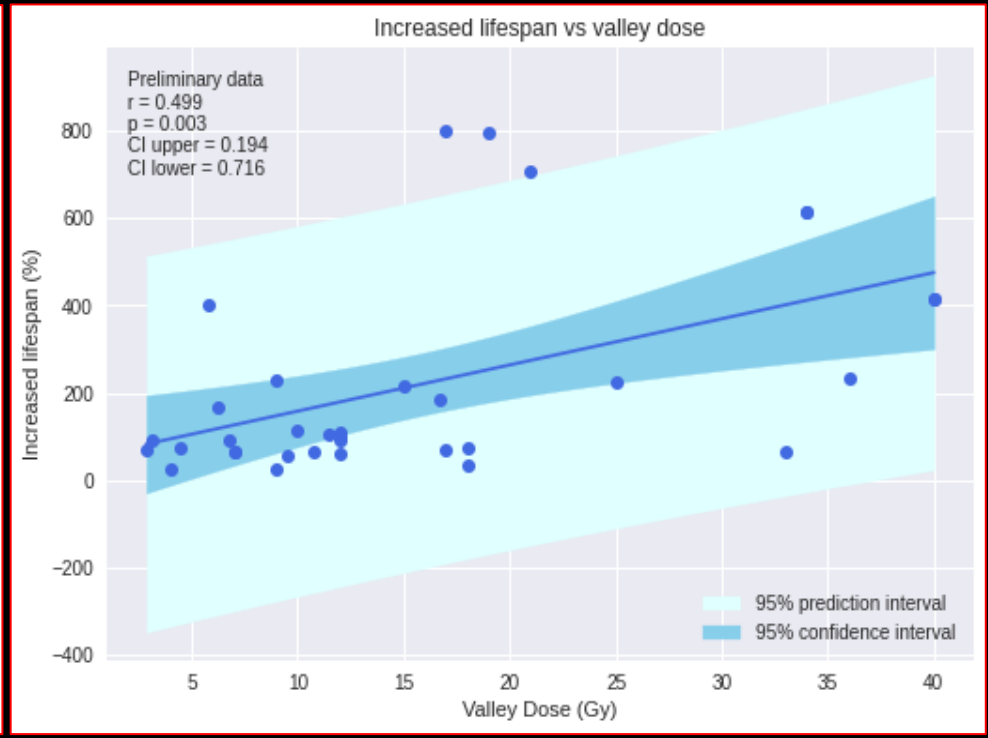
- Study impact of beam parameters *in vitro & in vivo*
- Overall picture somewhat unclear
- Continuing analysis of impact on LhARA specification

J. McGarrigle

SFTR data review

Publication in preparation



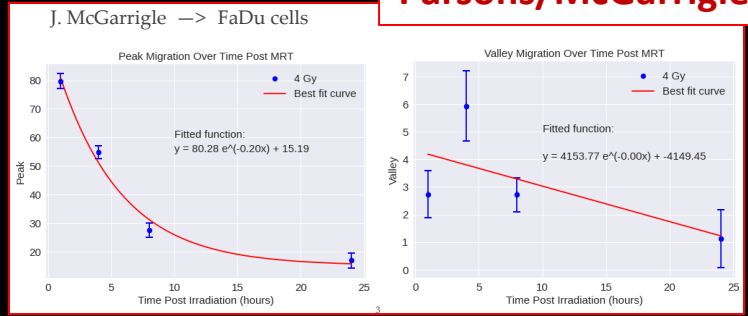


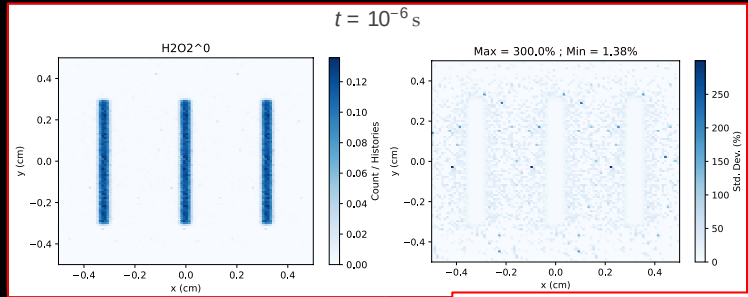
- Study impact of beam parameters on effect *in vivo*
- Seeking now to pursue experimental programme

Impact on specification of LhARA?

- Initiative to build-up evidence base leading to prioritised parameter set underway:
  - Measurements:
    - At Birmingham MC-40 cyclotron
    - Later at SCAPA (see later)
  - Simulation/study:
    - TOPAZ-nBio
- Develop programme to build:
  - Evidence base and understanding
  - Collaborations with biologists
  - Provide basis for prioritised beam/instrumentation specification

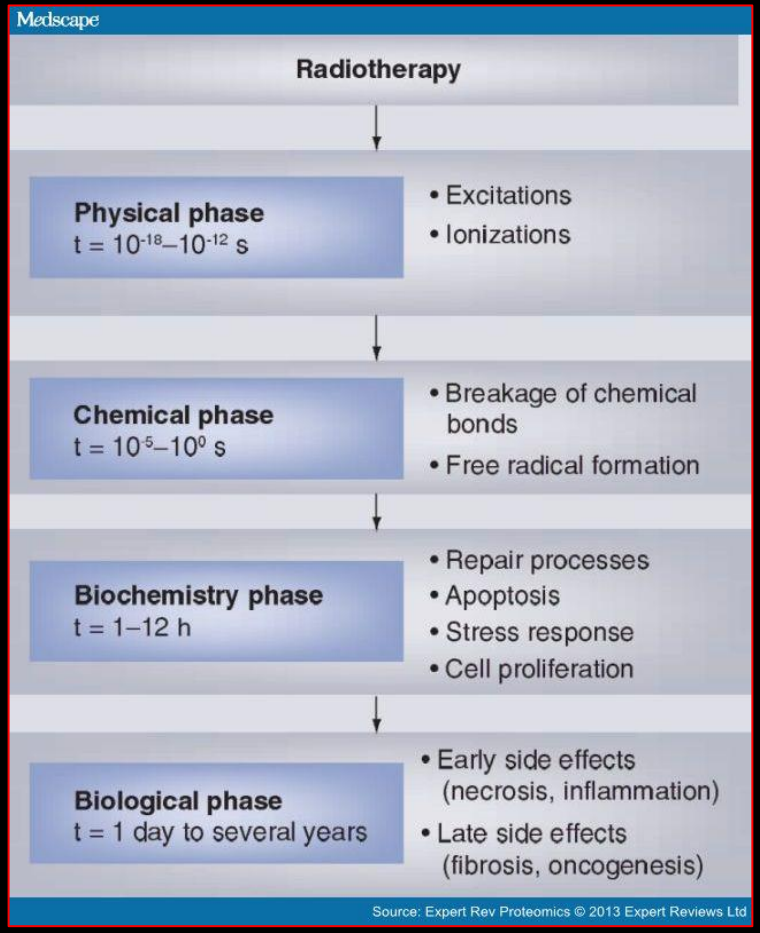
Parsons/McGarrigle





Puerta/Prezado

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!

Energy

Ion species

In combination and with chemo/immuno Therapies

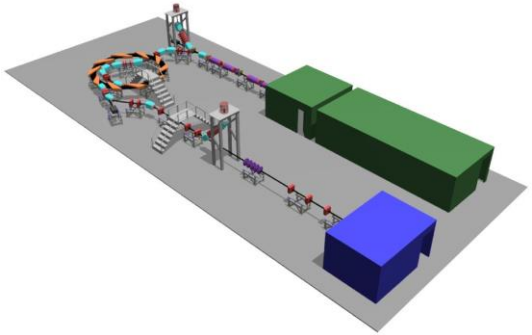
Status: resources

2-year Preliminary Activity – Project start 01Oct22

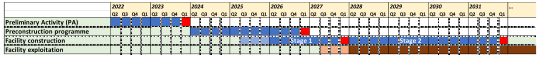
J. Clark, M. Noro, A. Woodcock 14Jun21

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

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

P. Allport[1], A. Aymar[2], C. J. Baker[3], J. Bamber[4], P. Beard[5], T. Becker[6], S. Benson[7], A. Beqiri[8], W. Bertsche[9,10], R. Bingham[11,12], N. Bliss[13], E. Boella[14,10], S. Boogert[15,16], M. Borghesi[17], P.N. Burrows[18,19], A. Carabe[20,21], M. Charlton[3], J. Clarke[13], B. Cox[5], T.S. Dascalu[22], M. Dosanjh[23,18], N.P. Dover[24,22], S. Eriksson[3], O.C. Ettlinger[24,22], A. Giaccia[25,26], S. Gibson[15,16], R. Gray[11], S. Green[27], T. Greenshaw[28], D. Gujral[29], H.C. Hall[30], E.M. Hammond[25], C. Hardiman[31], E.J. Harris[4], L. Holland[32], A. Howard[24], W.G. Jones[24,30], K.J Kirkby[33,34], A. Kirkland[32,35], A. Knoll[36], T. Kokalova[1], D. Kordopati[24], T.J. Kuo[22], A. Kurup[22,2], J.B. Lagrange[2], H.T. Lau[24], K.R. Long[24,22,37], W. Luk[38], A.E. MacIntosh-LaRocque[24], R. Mamutov[39,40], T. Masiela[41,42], J. Matheson[37], M. Maxouti[22,37], J.M. McGarrigle[24,41], P. McKenna[11,43], R. McLauchlan[31,24], I. McNeish[44], M. Merchant[33], Z. Najmudin[24,22], S.R. O'Neill[14], U. Oelfke[4], H. Owen[13], C. Palmer[17], J.L. Parsons[45,46], J. Pasternak[22,2], H. Poptani[47], J. Pozimski[24,22,2], Y. Prezado[41,42], P. Price[44], T. Price[1], K.M. Prise[48], P.P. Rajeev[12], P. Ratoff[14,10], C. Rogers[2], F. Romano[49], G. Schettino[50,51], W. Shields[15], R.A. Smith[24], D. Spiers[11,43], R. Taylor[22], J. Thomason[2], S. Towe[52], P. Weightman[28], C.P. Welsch[28,10], C. Wheldon[1], C. Whyte[11,43], R. Xiao[53]

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[2] *ISIS Neutron and Muon Source, STFC Rutherford Appleton Laboratory, Harwell Oxford, Didcot OX11 0QX, UK*
[3] *Department of Physics, Faculty of Science and Engineering, Swansea University, Singleton Park, Swansea, SA2 8PP*
[4] *The Institute of Cancer Research, 123 Old Brompton Road, London, SW7 3RP, UK*
[5] *Dept of Medical Physics and Biomedical Engineering, University College London, WC1E 6BT, UK*
[6] *Maxeler Technologies Limited, 3 Hammersmith Grove, London W6 0ND, UK*
[7] *Department of Radiology, Netherlands Cancer Institute-Antoni Van Leeuwenhoek, Amsterdam, The Netherlands*
[8] *Faculty of Mechanical Engineering, Ss. Cyril and Methodius University, Ruger Boshkovikj, Skopje 1000, Republic of North Macedonia*
[9] *Department of Physics and Astronomy, The University of Manchester, Oxford Rd, Manchester, M13 9PL, UK*
[10] *Cockcroft Institute, Daresbury Laboratory, Sci-Tech Daresbury, Keckwick Ln, Daresbury, Warrington UK*
[11] *Department of Physics, SUPA, University of Strathclyde, John Anderson Building, 107 Rottenrow East, Glasgow G4 0NG, UK*
[12] *Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Oxford, Didcot OX11 0QX, UK*
[13] *STFC Daresbury Laboratory, Daresbury, Cheshire, WA4 4AD, UK*
[14] *Department of Physics, Lancaster University, Bailrigg, Lancaster LA1 4YW, UK*
[15] *Department of Physics, Royal Holloway University of London, Egham, Surrey, TW20 0EX, UK*
[16] *John Adams Institute, Department of Physics, Royal Holloway, University of London, Egham, TW20 0EX, UK*
[17] *School of Mathematics and Physics, Queen's University Belfast, University Road, Belfast, BT7 1NN, Northern Ireland, UK*
[18] *John Adams Institute, University of Oxford, Keble Rd, Oxford, OX1 3RH.*
[19] *Particle Physics, Denys Wilkinson Building, Keble Rd, Oxford, OX1 3RH*
[20] *Department of Medical Physics, Hampton University Proton Therapy Institute, Hampton, VA 23666*
[21] *Hampton University*
[22] *John Adams Institute for Accelerator Science, Imperial College London, London SW7 2AZ, UK*
[23] *DG Unit, CERN, CH-1211 Geneva 23, Switzerland*

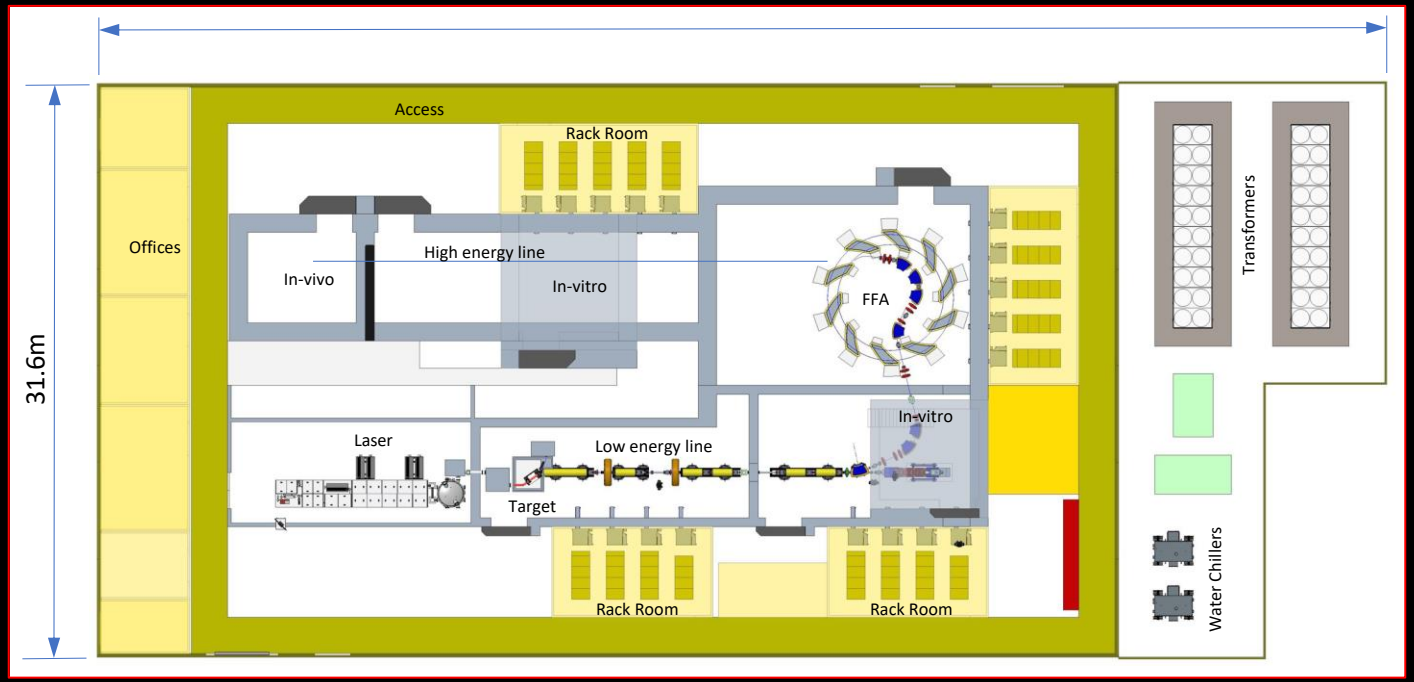
To serve ITRF: 2 + 3-year project in 6 work packages:

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 "Five-year plan"

CCAP-TN-10

Progress: design & integration: Stage 1



Activation study:

- Ongoing contract with TUVSUD; seek to determine:
  - Required shielding thickness and building constraints
  - Guidance on operation method
  - Guidance on material use & activation

T.J. Kuo
K. Long
J. Pasternak
R. Razak
W. Shields

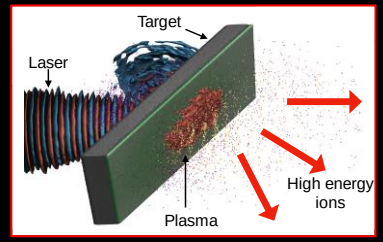
N. Bliss, A. Goulden,
C. Hill, H. Owen, C. Whyte

N. Dover
T.S. Dascalu

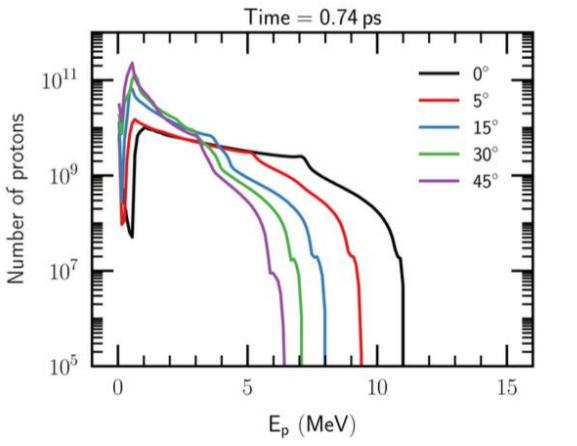
Progress: source

R&D objectives:

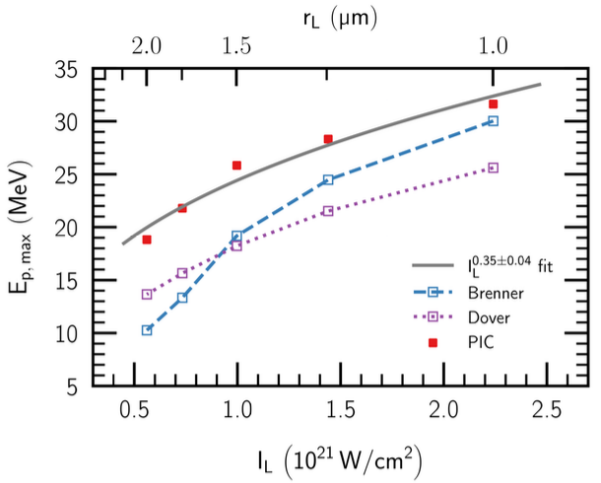
- "Full-scale" tests in conditions approaching LhARA specification
- LhARA-focused diagnostic and targetry development
- High-repetition rate, automation and longevity studies
- Accurate numerical modelling 3D simulation codes



Vary angle of incidence of laser



Vary f-number of focusing optic

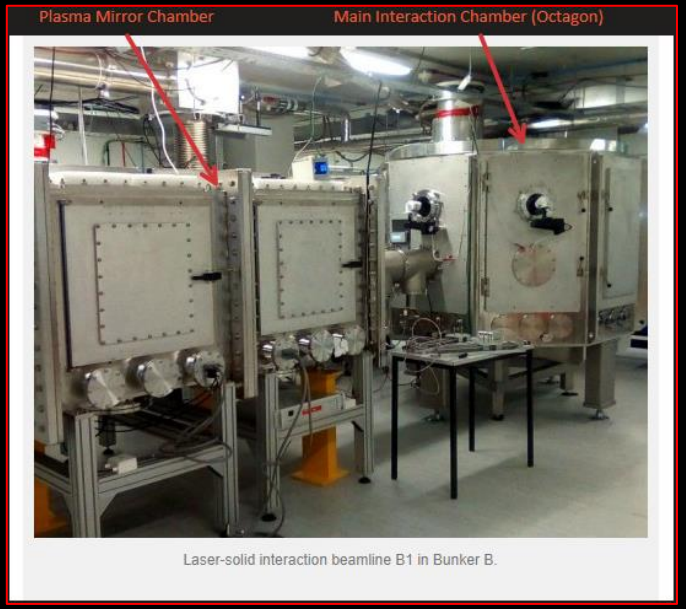


Realistic, 2-stage simulation on ARCHER2 using accurate "pre-plasma" profile

Study proton production as a function of angle of incidence, spot size, proton-layer thickness

Seek to benchmark against data

Experiments at SCAPA



Laser-solid interaction beamline B1 in Bunker B.

SCAPA Experiment Team....

University of Strathclyde
R. Wilson, T. Frazer, E. Dolier, C. McQueen, B. Torrance, R. Nayli and P.McKenna

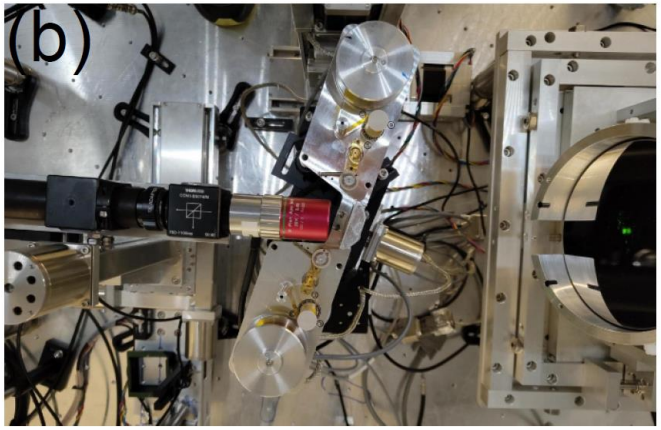
Imperial College
O. Ettlinger, G. Casati and N.P. Dover

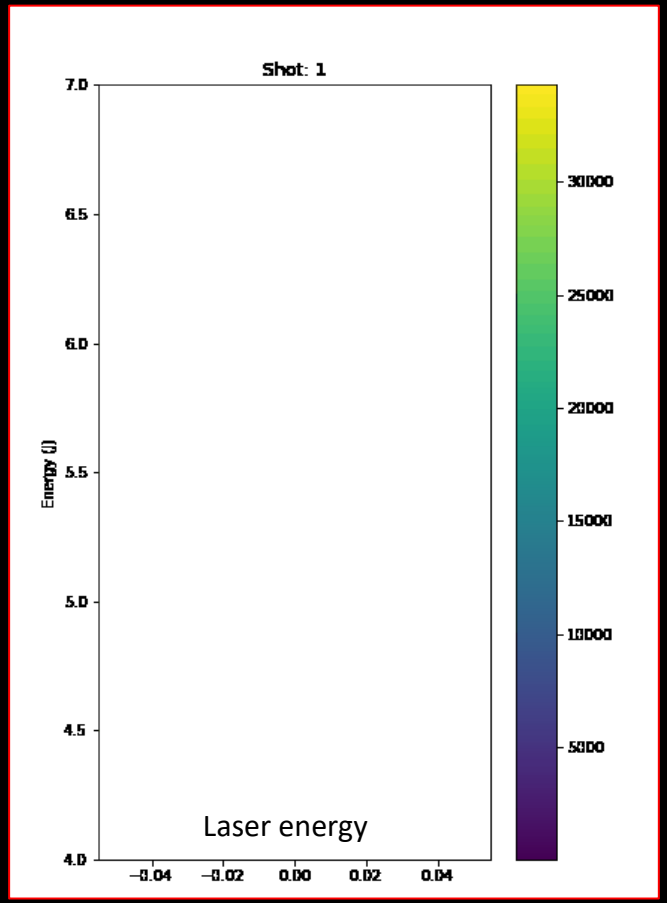
Queens University Belfast
P. Parsons and C. Palmer

SCAPA, University of Strathclyde
M. Wiggins, E. Brunetti, G. Manahan, W. Li

Central Laser Facility
J. Green, C. Armstrong, C. Spindloe, W. Robins, S. Astbury

N. Dover, G. Casati



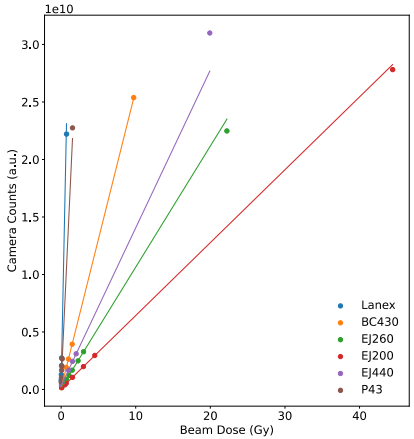


R. Gray

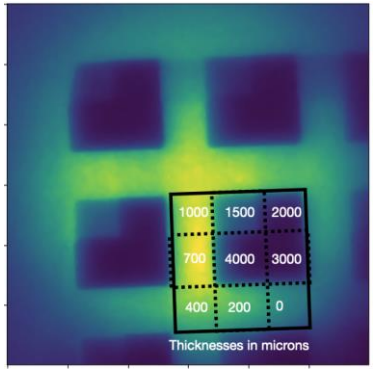
Progress source: diagnostics & high rep-rate

Diagnostics

Absolute calibration and dose linearity scan

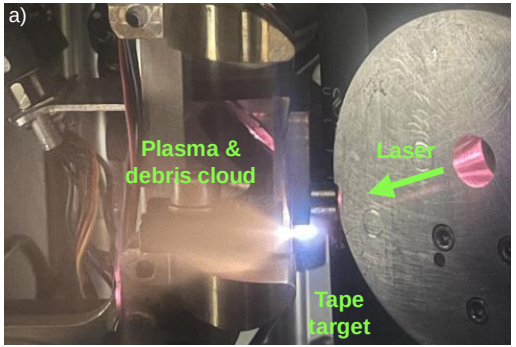


Energy dependent emission scan

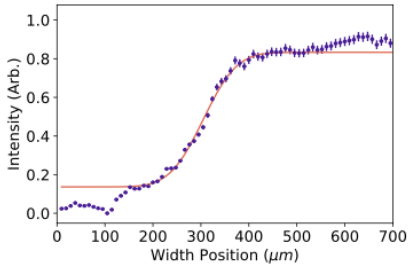


High-rep rate / longevity …

Experimental R&D at ICL - Initial results



b)



- Preliminary experiments run at 5 mJ level (without final amplifier)
- Continuous operation at 100 Hz for 10s minutes
- Plasma formation, x-ray generation (and debris production!) observed

O. Ettlinger, N. Xu, Z. Najmudin

90 mJ of laser energy, 30 fs pulse width at 100 Hz

Predicted maximum proton energies ~ few MeV

Semi-continuous access allows long term R&D into technical issues in stabilisation, debris, targetry, etc

Scintillators: key for high rep rate operation

- **Dedicated calibration effort led by N. Dover (ICL):**
  - **Birmingham MC40 cyclotron**

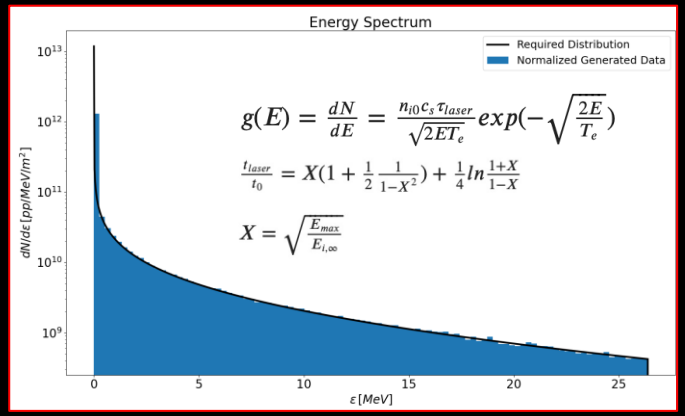
N. Dover, O. Ettlinger, N. Xu, Z. Najmudin

Progress: design & integration: Stage 1

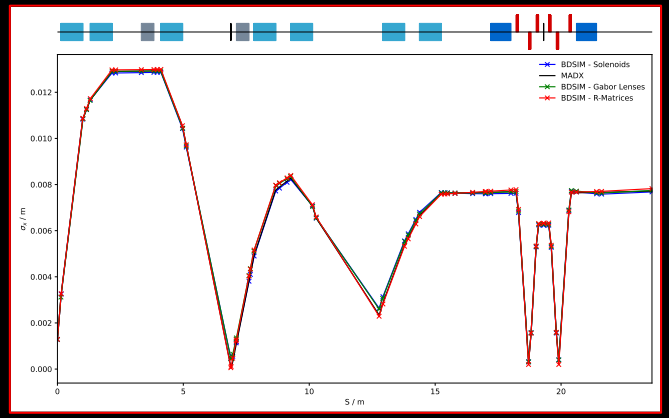
M. Maxouti, N. Dover, K. Long

W. Shields, J. Pasternak, K. Long

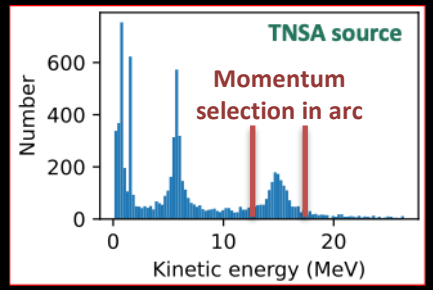
Standardised TNSA source

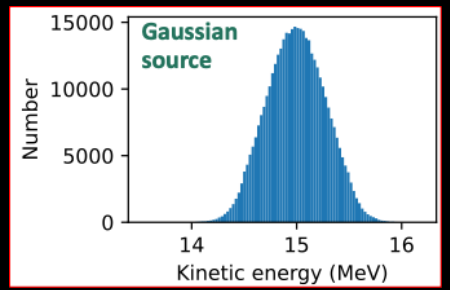


Revised Stage 1 baseline



Impact: look at entrance to arc:

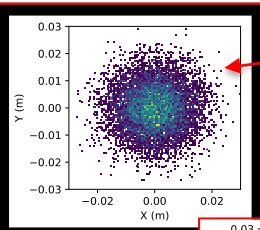




Important for (e.g.) activation calculation

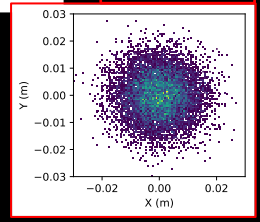
7 Gabor lens adopted

- **Greater flexibility**
- **Drifts longer:**
  - **Diagnostics**
  - **Shielding**
- **Gabor lens/solenoid focusing equivalence**



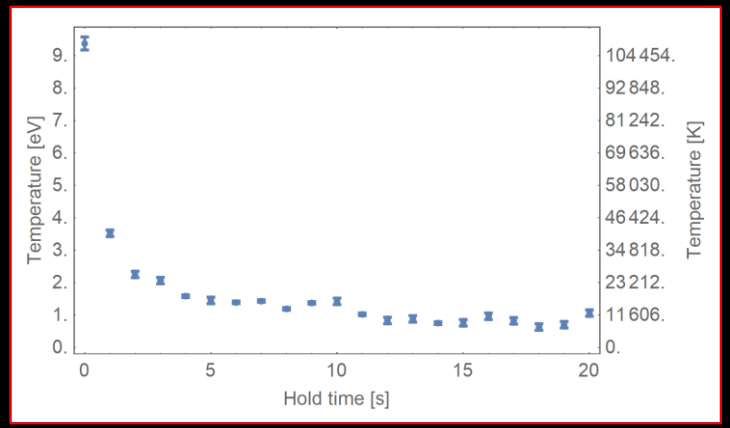
Gabor lenses

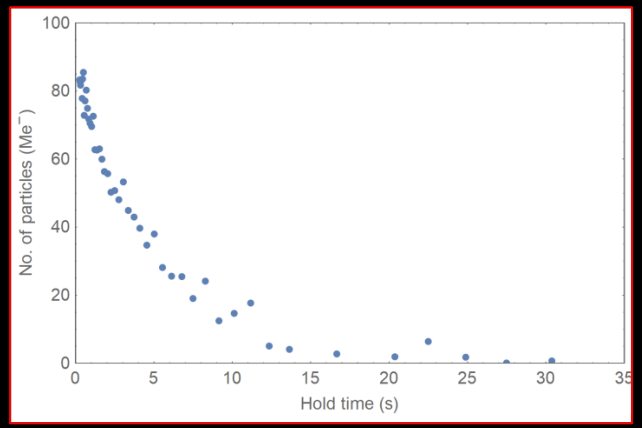
Solenoids



Progress: capture

- **Key issues:**
  - Electron density, plasma stability
- **Measurements on Penning-Malmberg trap at Swansea University**
  - "Moving potential well" capture
  - "Rotating wall" to "spin-up" plasma to gain stability



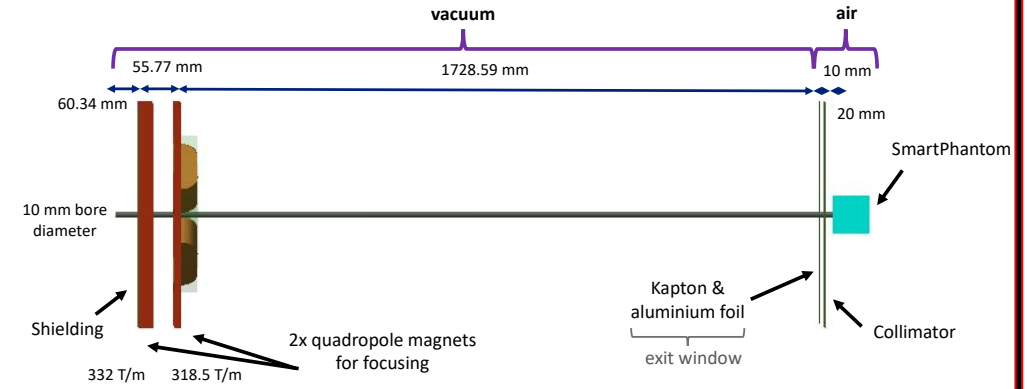


- **Ongoing campaign:**
  - Already significant increase in hold time and plasma density
  - Next steps:
    - Improved diagnostics
    - Numerical analysis to interpret and optimise experiments

Future plan:
K. Long, C. Dyson (PhD from Oct24)

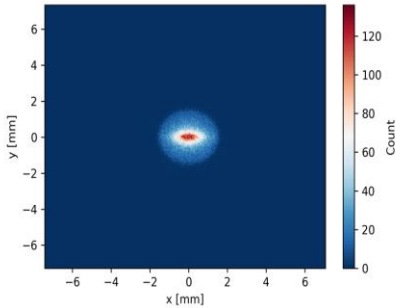
Progress: real-time dose measurment

LION beamline - BDSIM

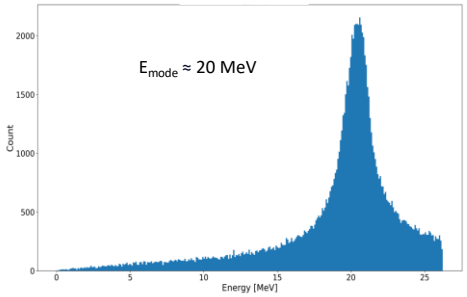


Proton Beam

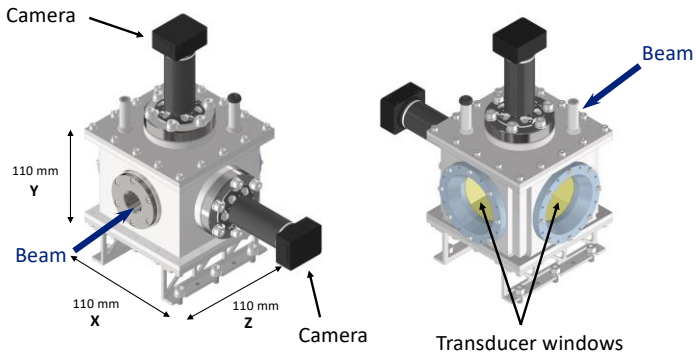
Spot Size



Energy Spectrum



Proposed Instrumentation
The SmartPhantom



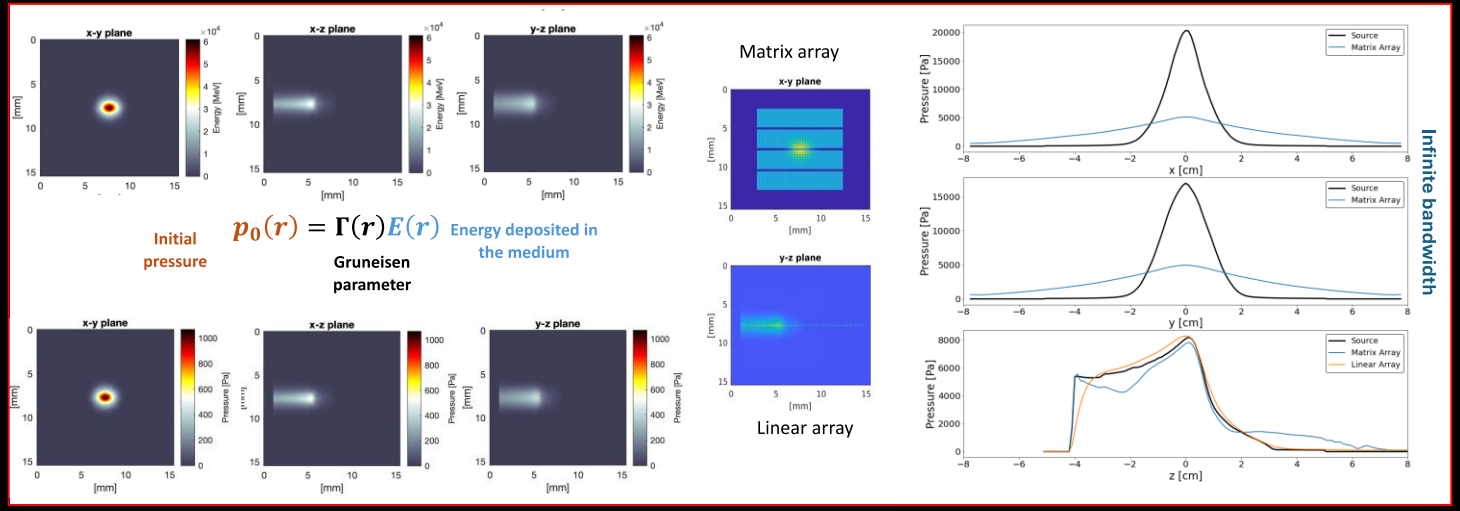
- Bragg peak localization
- Quantitative 3D dose mapping
- Pulse-to-pulse adaptive treatment
- Simultaneous anatomical imaging

Ion-acoustic imaging

M. Maxouti, C. Bird, O. Jeremy, K. Ladhams, K. Long, D. Nardini

B. Cox, J. Bamber

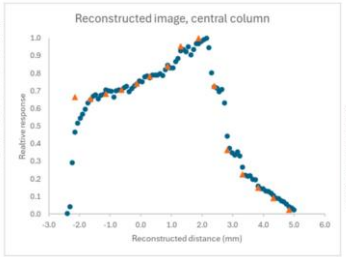
Progress: real-time dose measurment



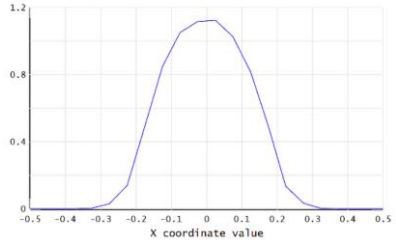
M. Maxouti,
C. Bird,
O. Jeremy,
K. Ladhams,
K. Long,
D. Nardini

Optical Reconstruction

Central column reconstruction



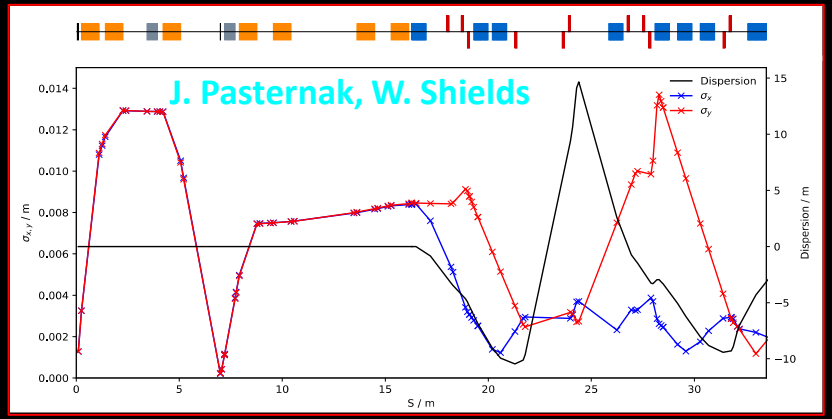
Reconstruction across a row near the Bragg peak



P. Hobson,
B. Cox, J. Bamber

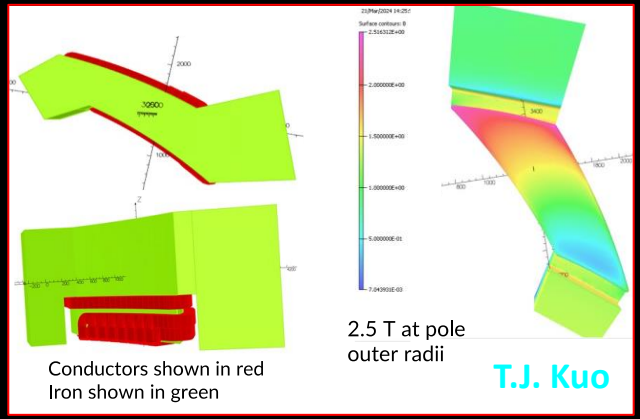
Progress: Stage 2: injection & FFA magnet

Injection-line update



T.J. Kuo
K. Long
J. Pasternak
R. Razak
W. Shields

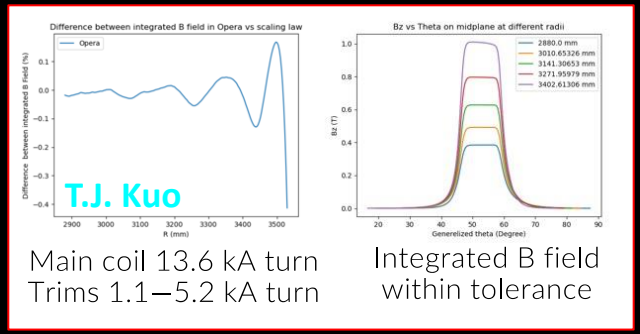
FFA magnet



Resign revision encorporates:

- **Shielding, collimation & diagnostics**
- **Continued design effort:**
  - **Match to FFA cell requirements**
  - **Study & mitigate space charge**
- **BDSIM model now synced with accommodates:**
  - **Vacuum valves, diagnostics, shielding shutters, correctors …**

Emerging collaboration with ISIS u/g team



N. Bliss, A. Goulden, C. Hill, J.B. Lagrange, H. Owen, C. Whyte

Progress: consultation & end-station

- Peer-group consultation:
  1. Stage 1 *in vitro* & 2 *in vivo*
  2. Focus on Stage 1 *in vitro*
  3. Focus on Stage 2 *in vivo*

Conclusions and recommendations documented at: https://ccap.hep.ph.ic.ac.uk/trac/browser/LhARA/Governance/ProjectManagementBoard/LhARA-Gov-PMB-2023-04 to be updated!

- Beam-line diagnostics:
  - Gas-jet (Liverpool): tested at DCF
- Seek increasing engagement with more novel techniques:
  - Initiated “ART” meeting series

Wave 4 STFC Preliminary Activity proposal form

Details and descriptions

Key Information	
1. Name of project (and acronym or short name if relevant)	Ion Therapy Research Facility (ITRF) Preliminary Activity 2
2. (a) Lead contact	Amato Giaccia (amato.giaccia@oncology.ox.ac.uk) Kenneth Long (k.long@imperial.ac.uk)
(b) STFC contact	Massimo Noro (massimo.noro@stfc.ac.uk)
3. Which submission route are you using (Advisory Panel, internal, resubmission) etc.)?	Internal
4. One-line description of the Preliminary Activity (22 words)	
The ITRF will be a unique radiobiological research facility exploiting technologies that can transform ion-bear and the treatment of "hard-to-treat" cancer.	

Project description
5. Summary of the Preliminary Activity (800 words) – please note this box expands as you type.
Background:
Conventional X-ray therapy (RT) is needed in 40% of cancer cures but some tumours are radioresistant and difficult to treat and cure. In Ion Beam Therapy (IBT), X-rays are replaced by energetic particles such as carbon ions. The physics of IBT allows the dose to be more precisely localised in the tumour and IBT causes significantly more direct, difficult to repair, DNA damage and stimulates a robust immune response. As a result, more tumours will be cured and v side effects. However, IBT has yet to reach its full potential.
Globally, there is no facility that can be used to explore the fundamental biological processes underlyin which can be used to optimise radiation delivery in time, space, ion species, and energy spectrum, alo combination with new drugs. The project proposed here will create a facility to explore advanced radiotherap new cancer treatments fit for 2050 and beyond, and make the UK a leader in the global fight against cancer.
Objectives:
The Preliminary Activity (ITRF PA2) proposed here will complete the design and planning of the ITRF constructi to create the world-leading, compact, single-site research infrastructure that will deliver the multidisciplinary programme necessary to: ☐ Elucidate radiobiological mechanisms that underpin the clinical efficacy of particle therapy; ☐ Generate the accelerator, diagnostic, imaging, and computing technologies required to transform the clinical practice of IBT; and ☐ Deliver the capability to provide IBT in completely new regimens by combining ion species from protons to carbon exploiting ultra-high dose rates and novel spectral-, spatial- and temporal-fractionation schemes. The design, specification and planning carried out within ITRF PA2 will build on the complete Conceptual Design Report that is the principal deliverable of the current ITRF Preliminary Activity (ITRF PA1).

1

The deliverables for ITRF PA2 are:

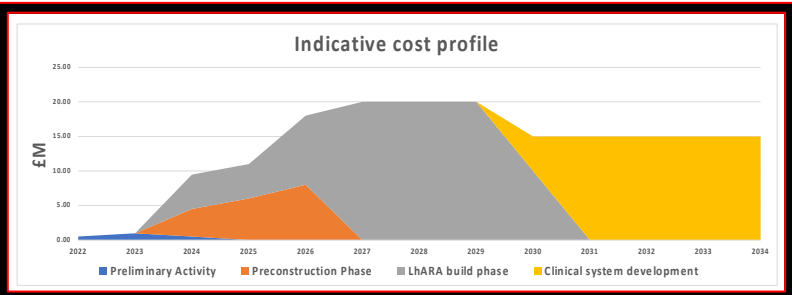
- ☐ Technical Design Reports for the staged implementation of the facility;
- ☐ A site study leading to site selection and building implementation plan; and
- ☐ A proof-of-principle demonstrator system at an existing pulsed-laser facility.

Engagement:

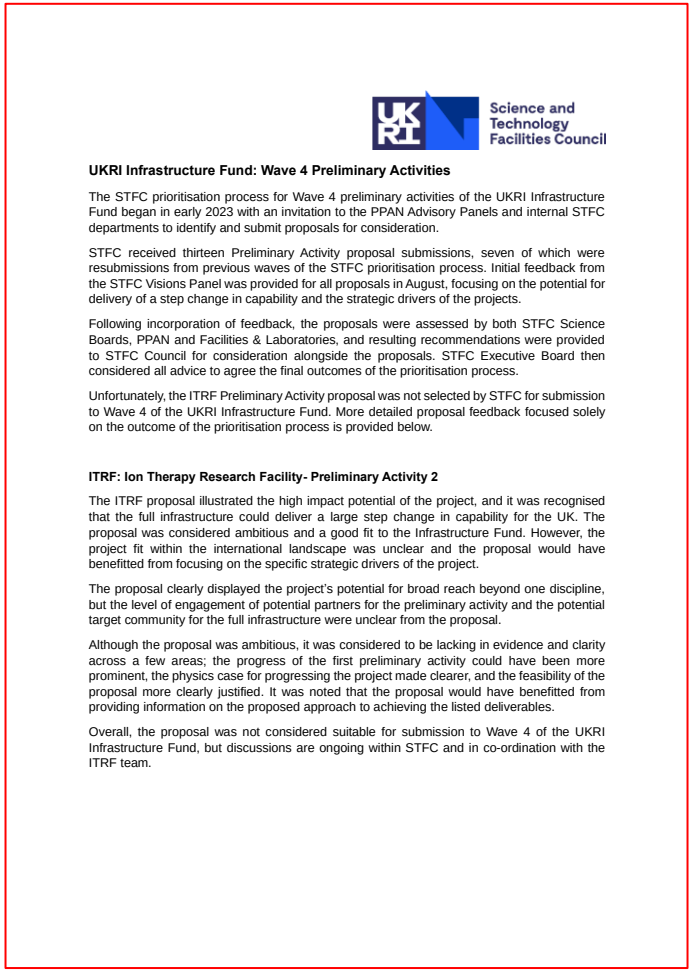
To ensure direct engagement of the target user community, members of the leadership team are drawn equally from the biomedical and natural science communities. On the biomedical side, key leadership positions include LhARA/ITRF collaboration Co-Spokesman, A. Giacca (Director Oxford Institute of Radiation Oncology), Institute Board Co-Chair, Y. Prezado (CNRS Institute Curie), Biological Science Programme Manager, J. Parsons (Birmingham, Vice-Chair of the Association for Radiation Research), and Impact; Clinical and Industrial Programme Manager, P. Price (Imperial, Chair Radiotherapy UK). The biological and medical communities are also strongly represented on the PA1 oversight and advisory bodies.

23. a. Complete the following table for UKRI Infrastructure Fund requirements, noting that costs are only approximations at this stage.

Infrastructure Fund requirement (£m) Point estimates.	Year												Total
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	
Project costs	22	50	81	50	22								225
TOTAL	22	50	81	50	22								225



Feedback on PA2 proposal to STFC Visions Team



Science and Technology Facilities Council

UKRI Infrastructure Fund: Wave 4 Preliminary Activities

The STFC prioritisation process for Wave 4 preliminary activities of the UKRI Infrastructure Fund began in early 2023 with an invitation to the PPAN Advisory Panels and internal STFC departments to identify and submit proposals for consideration.

STFC received thirteen Preliminary Activity proposal submissions, seven of which were resubmissions from previous waves of the STFC prioritisation process. Initial feedback from the STFC Visions Panel was provided for all proposals in August, focusing on the potential for delivery of a step change in capability and the strategic drivers of the projects.

Following incorporation of feedback, the proposals were assessed by both STFC Science Boards, PPAN and Facilities & Laboratories, and resulting recommendations were provided to STFC Council for consideration alongside the proposals. STFC Executive Board then considered all advice to agree the final outcomes of the prioritisation process.

Unfortunately, the ITRF Preliminary Activity proposal was not selected by STFC for submission to Wave 4 of the UKRI Infrastructure Fund. More detailed proposal feedback focused solely on the outcome of the prioritisation process is provided below.

ITRF: Ion Therapy Research Facility- Preliminary Activity 2

The ITRF proposal illustrated the high impact potential of the project, and it was recognised that the full infrastructure could deliver a large step change in capability for the UK. The proposal was considered ambitious and a good fit to the Infrastructure Fund. However, the project fit within the international landscape was unclear and the proposal would have benefitted from focusing on the specific strategic drivers of the project.

The proposal clearly displayed the project's potential for broad reach beyond one discipline, but the level of engagement of potential partners for the preliminary activity and the potential target community for the full infrastructure were unclear from the proposal.

Although the proposal was ambitious, it was considered to be lacking in evidence and clarity across a few areas; the progress of the first preliminary activity could have been more prominent, the physics case for progressing the project made clearer, and the feasibility of the proposal more clearly justified. It was noted that the proposal would have benefitted from providing information on the proposed approach to achieving the listed deliverables.

Overall, the proposal was not considered suitable for submission to Wave 4 of the UKRI Infrastructure Fund, but discussions are ongoing within STFC and in co-ordination with the ITRF team.

- **Broad support**
  - High impact potential
  - Could deliver step change
  - Potential for broad reach
  - Ambitious

- **But not selected**
  - Fit with international landscape unclear
  - Potential for target community unclear
  - Progress of first preliminary activity unclear (but only 9 months into 2 year project when written)

- **Now seeking access to bridging funds**

Structuring the bridging activity

Define bridging programme to optimise delivery of:

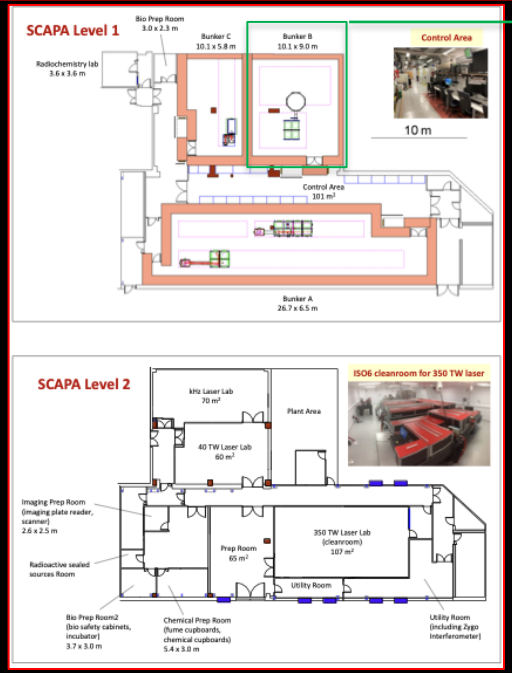
- **Biology/proof-of-principle programme**
- **R&D programme to address key project risks**
- **Strategic partnerships**

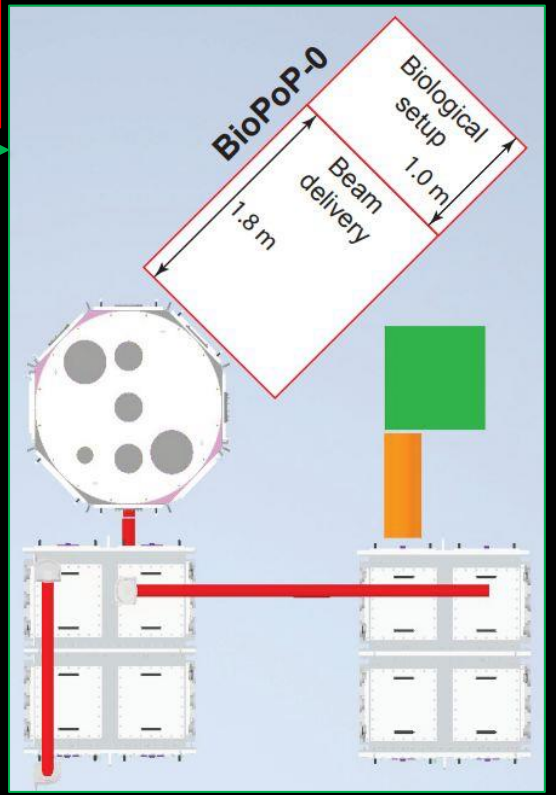
Radiobiological experimentation and modelling	**WP A**	WP A.7 - Radiobiology Experiment
		WP A.4 - Ion acoustic dose measurement
		WP A.5 - End station and novel diagnostics
		WP A.2 - Source for Radiobiology Expt
ITRF/LhARA R&D	**WP B**	WP B.6 - FFA feasibility study
		WP B.2 - Source
		WP B.3 - Capture
PM	**WP C**	WP C.1 - Proj Man
		WP C.8- Outreach & Engagement

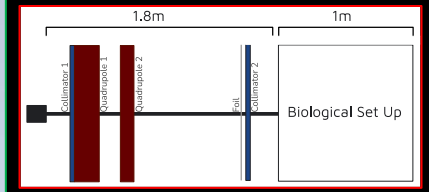
- Development of radiation biology programme:
  - At existing facilities:
    - Novel (e.g. laser driven)
    - Conventional
- LhARA proof-of-principle experiment:
  - CW: "… include as many of key LhARA elements as possible …"

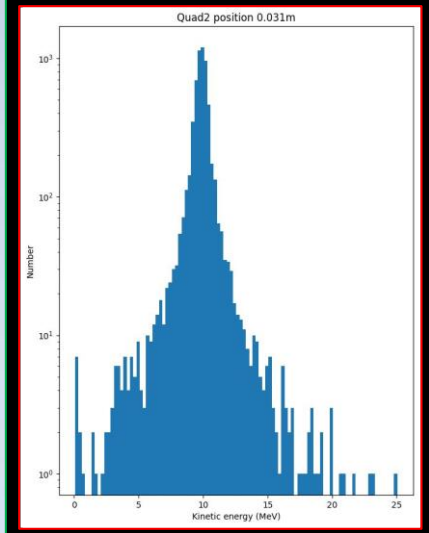
Biological measurement programme & proof-of-principle experiment

"WP7", led by J. Parsons
Increasingly import aspect of the programme going forward





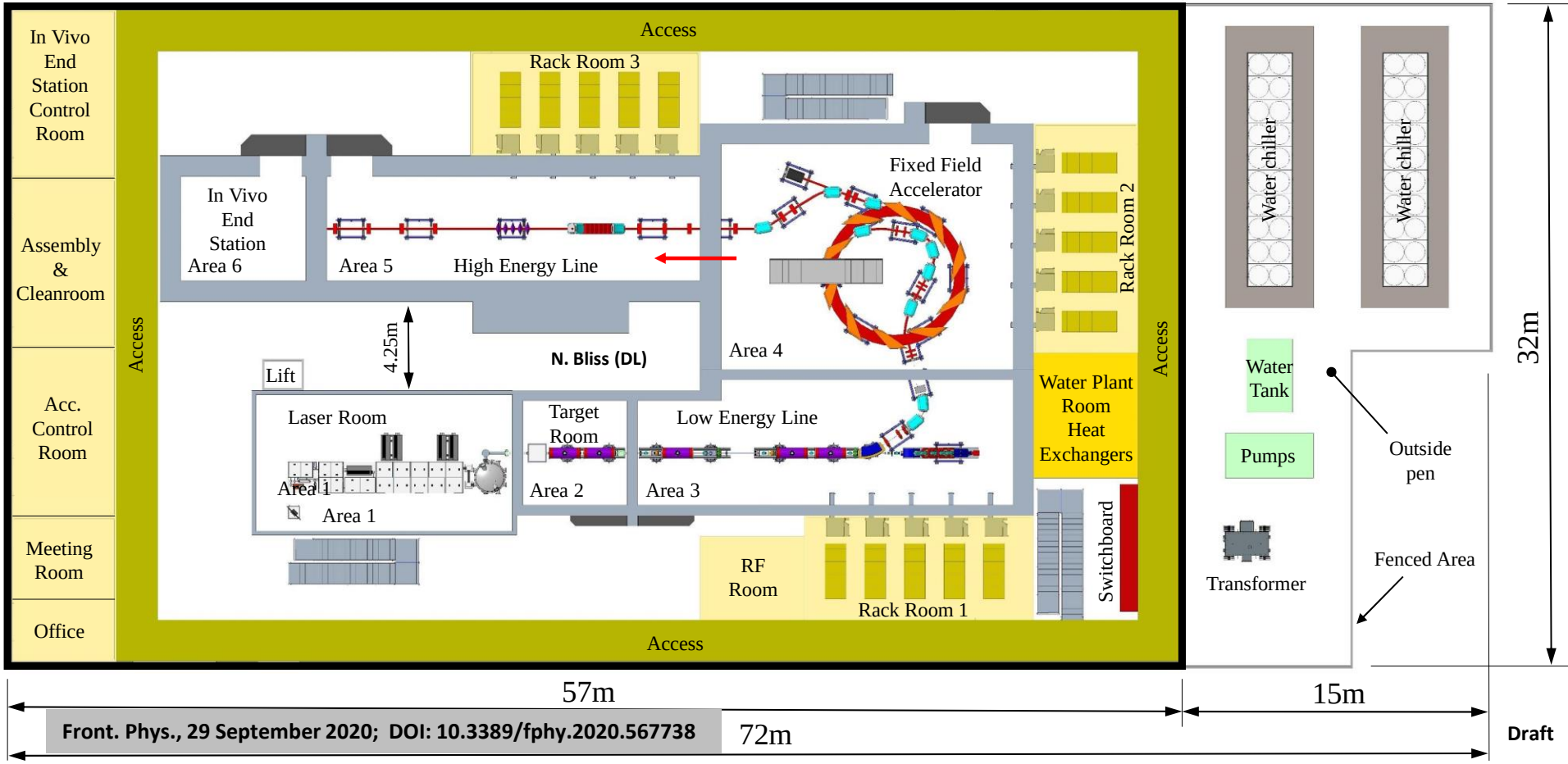




Conclusions

- Significant progress in ITRF/LhARA:
  - Beamline design and optimisation
  - Engineering, initial studies of FFA magnet
  - Initial characterisation of laser-driven source
  - Progress on understanding and stablisation of plasma for Gabor lens
  - Design of ion-acoustic proof-of-principle experiment
  - Peer-group consultation leading to specification of end-station
- Looking forward:
  - Recognition of importance of development of biological programme:
    - First steps in design and specification of proof-of-principle experiment as part of broader radiation-biology programme
  - Project programme for Bridging Period now being developed
- Exciting programme, but, clear need to ***make the case!***

BACKUP



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

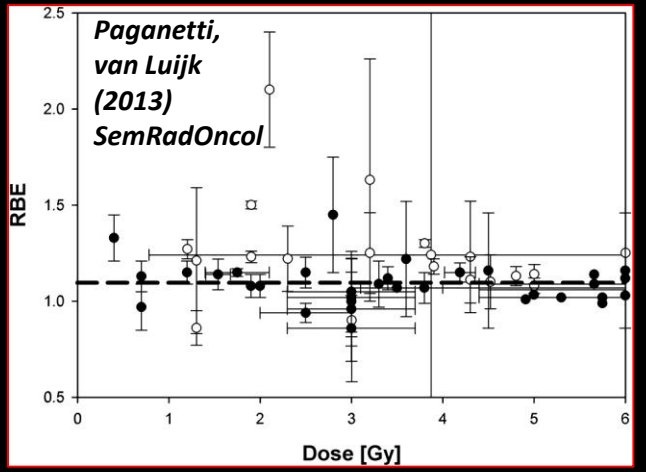
Draft

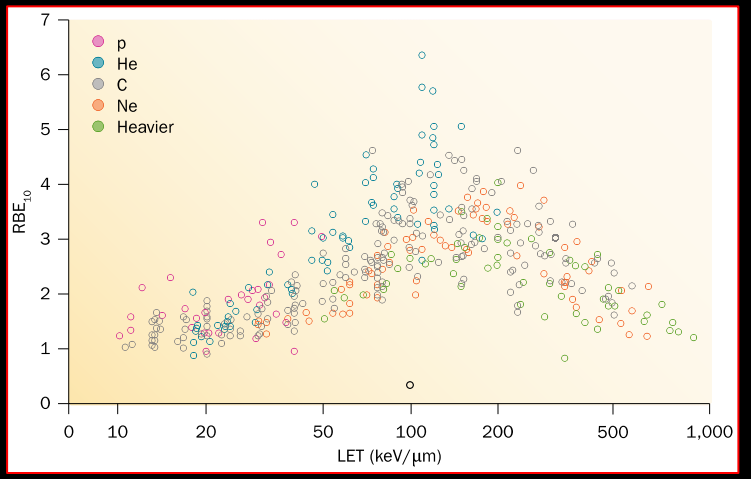
⇒ *compact, uniquely flexible facility*

LhARA Laser-hybrid Accelerator for Radiobiological Applications

The case for fundamental radiobiology

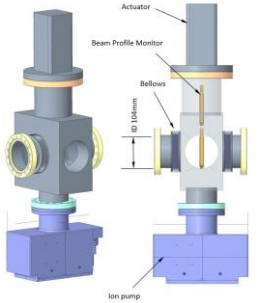
- Relative biological effectiveness:
  - Defined relative to reference X-ray beam
  - Known to depend on:
    - Energy, ion species
    - Dose & dose rate
    - Tissue type
    - Biological endpoint
- Yet:
  - *p*-treatment planning uses 1.1
  - Effective values are used for C^{6+}
- Maximise the efficacy of PBT now & in the future:
  - Require systematic programme to develop full understanding of radiobiology

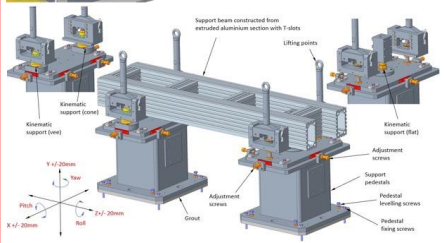




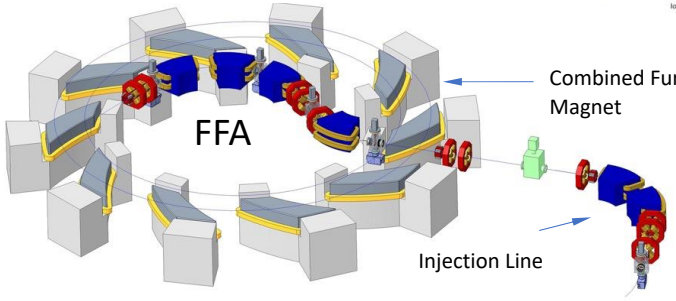
Progress: selected engineering highlights

Combined Beam Profile Monitor and Vacuum Pumping



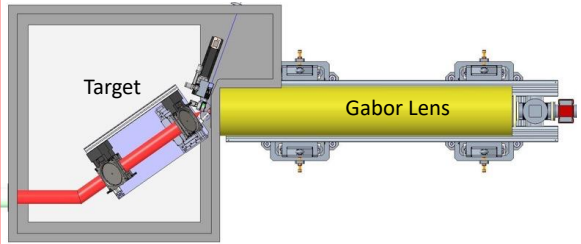


Modular Support System

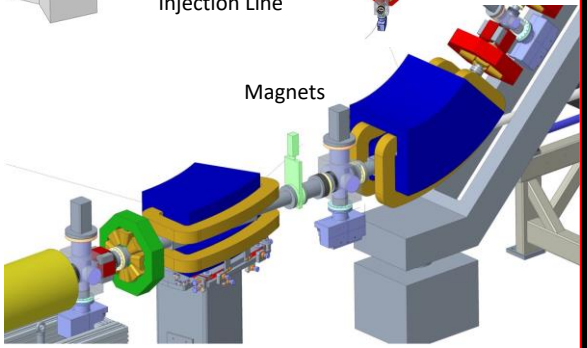


Combined Function Magnet

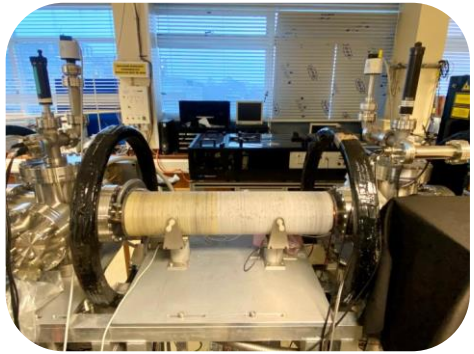
Injection Line

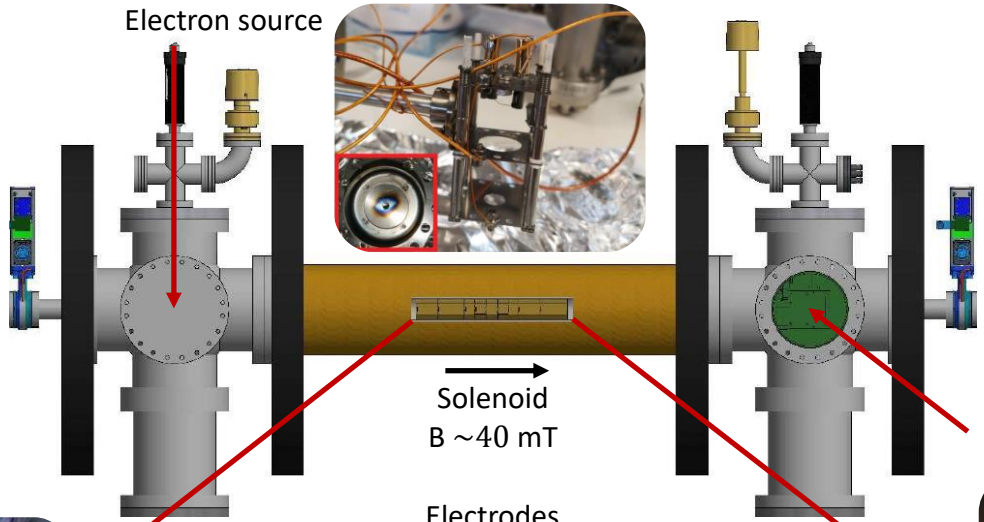


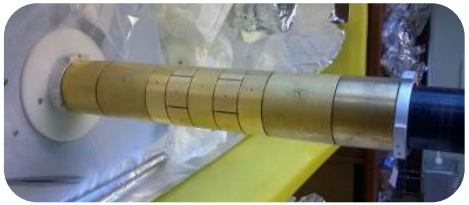
Magnets

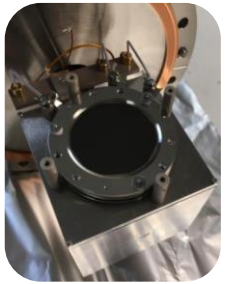


Current Apparatus (preliminary activity)





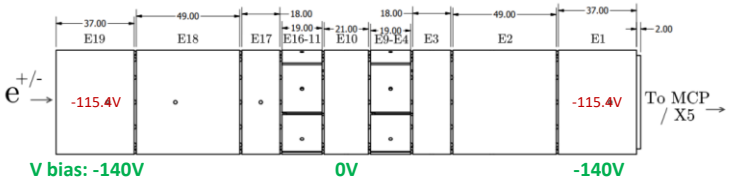


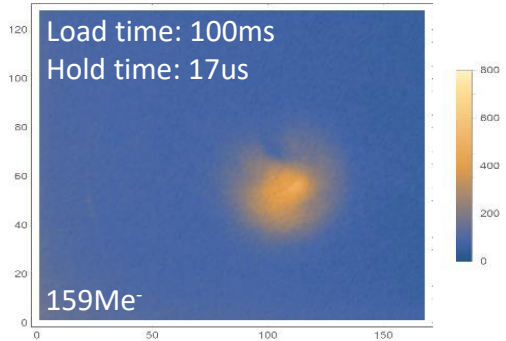


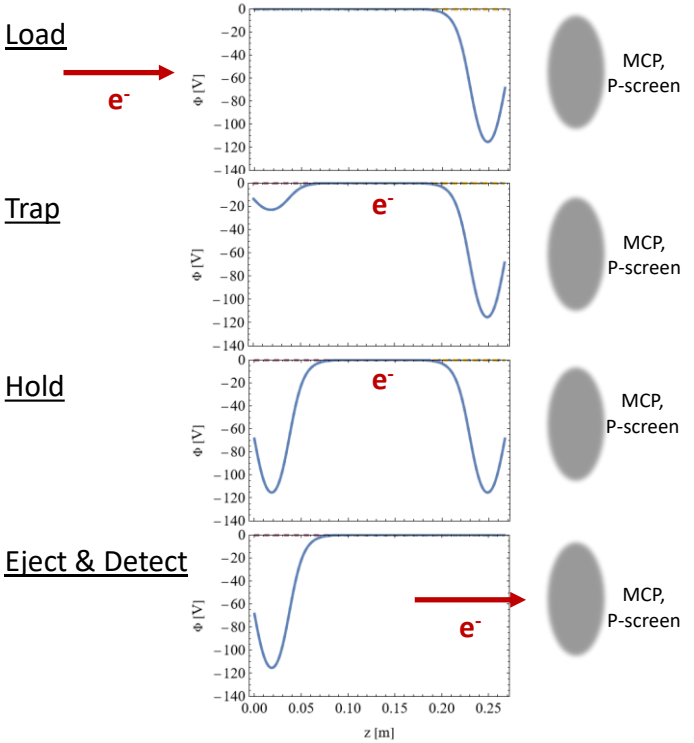
Progress on Plasma lens development (13th February 2024)

Progress: capture

Preliminary results (October 2023)

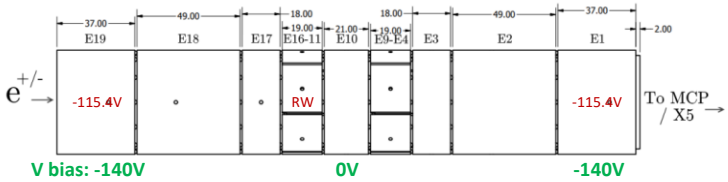


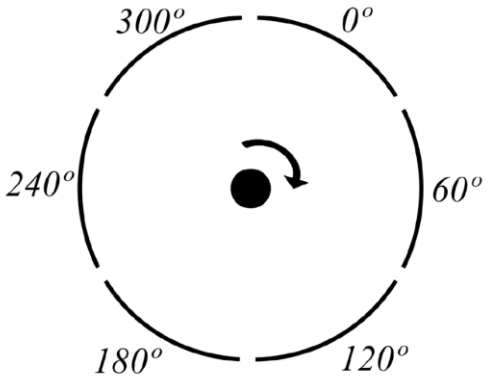




Progress on Plasma lens development (13th February 2024)

Rotating Electric fields / Rotating wall





https://alpha.web.cern.ch/science/rotating-wall

A six-segment rotating wall electrode is used to control plasma radii. The relative phase of the signal applied to each sector of the electrode is labelled.

This gives a rotating electric field perpendicular to the axis of symmetry of the plasma.

↳ The electric field induces an electric dipole moment in the plasma, leading to plasma compression.

Outreach & engagement (WP8); progress to date

Communication Strategy

- **Public:** LhARA Website – strategy devised for web development, management/domains/social media/LinkedIn for public and patient engagement
- **Public engagement events**: Planning for Great Exhibition and Royal Society Exhibition 2025
- **Media**: Mentioned as future innovation in cancer care on Radio4 Today podcast Feb 2024
- **Parliamentary**: Mentioned in UK Radiotherapy ten year Vision documents launched at HOC Feb 2024. Meetings being planned with Scottish SNP science spokesman Carol Monaghan and Shadow science minister Chi Onwurah. Planned to be included in future Westminster MedTech commission .

Stakeholder engagement

- Discission with MRC, the Radiotherapy UK charity and NGO-Global Coalition for Radiotherapy on engaging national and international clinical colleagues and radiobiology community, patients and the radiotherapy industry in parallel.
- International workshop of clinical/biologists planed for Q3 2024

Professional Bodies Engagement

- Links with IPO via Richard Amos and arranging engagement with other professional bodies

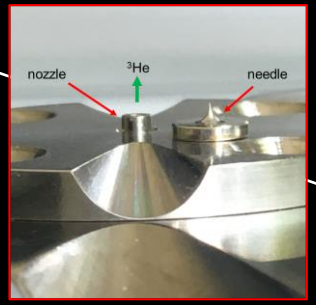
MRC Engagement

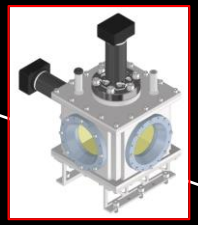
- Work started to engage MCR in biological/translational clinical areas

International Engagement

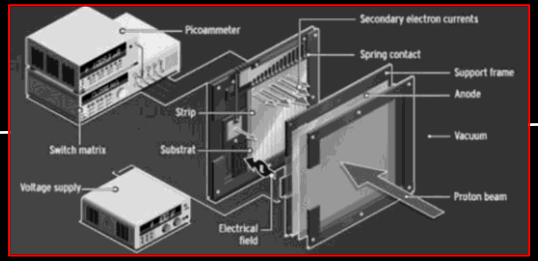
- LMU, HZDR, CNRS/Institute Curie
- CERN
- ELI/ELIMED

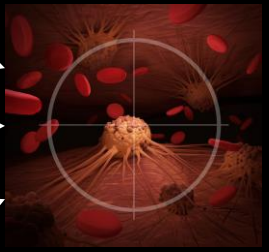
Multiple ion source & capture





Dosimetry, instrumentation image processing, fast feedback, control





Fundamental radiobiology