LhARA

William Shields

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JAI Advisory Board Meeting

16th April 2026

ROYAL HOLLOWAY UNIVERSITY OF LONDON

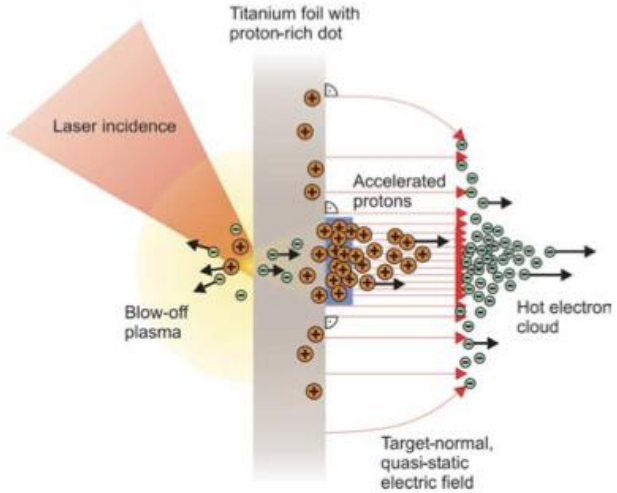
LhARA

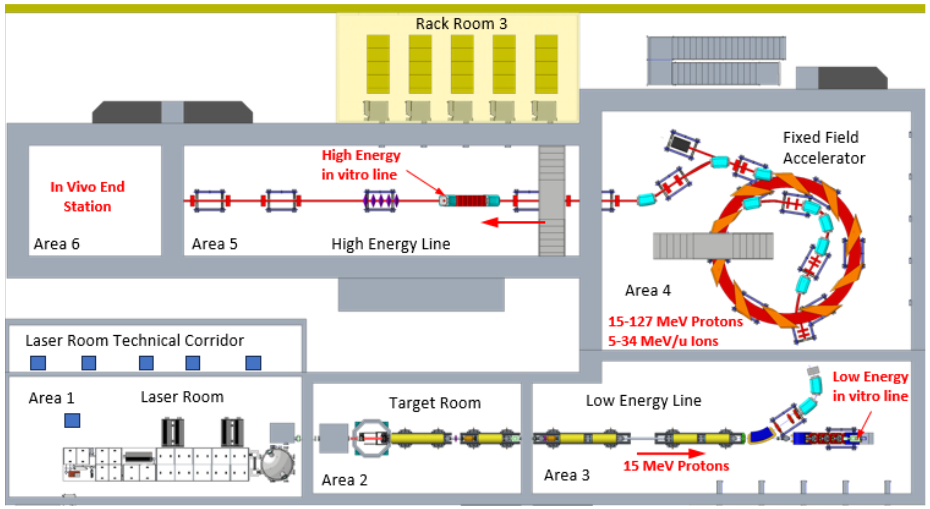
JAI John Adams Institute for Accelerator Science

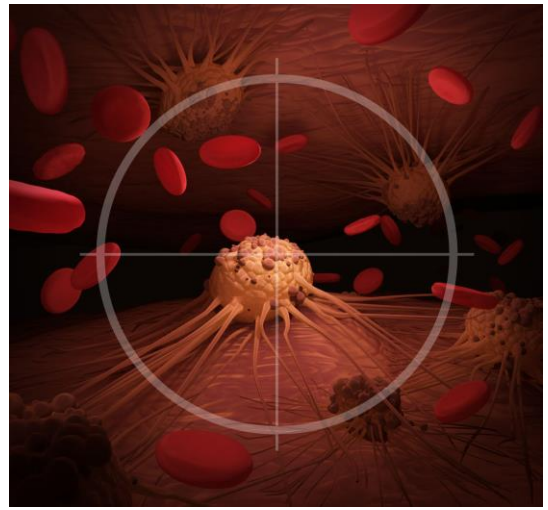
LhARA Initiative

Our mission is to:

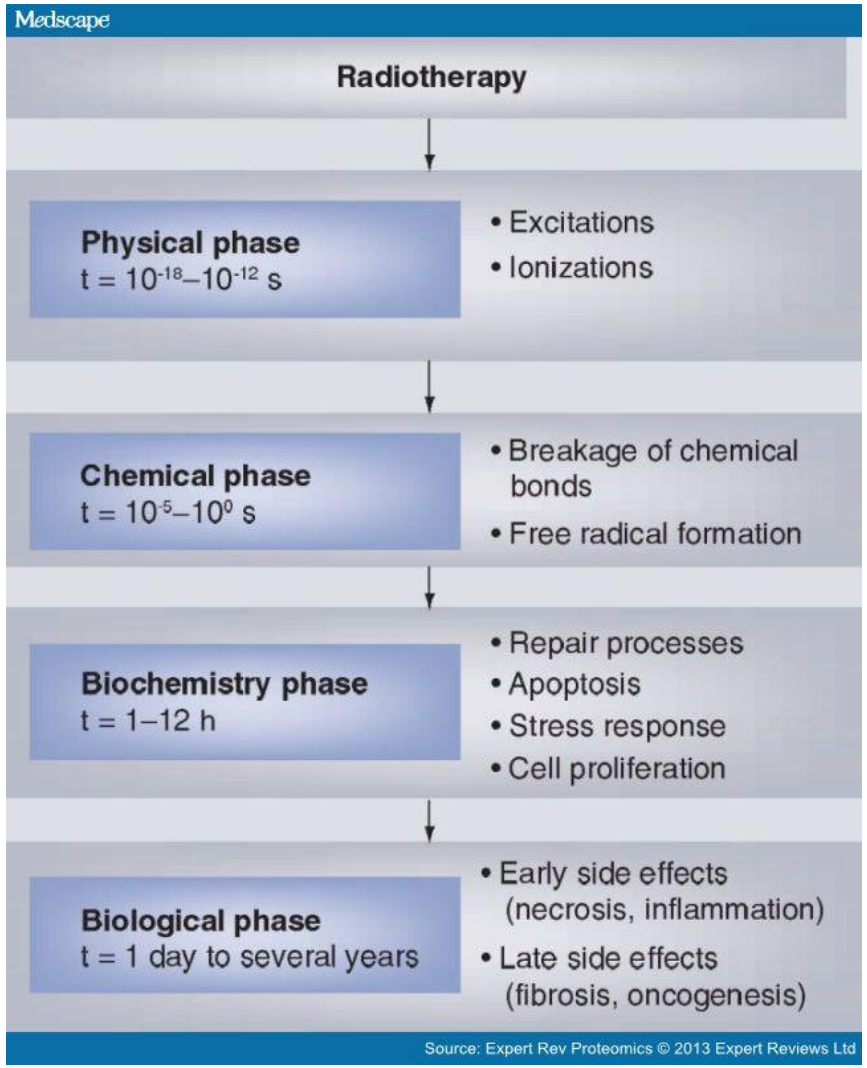
- Prove the feasibility of laser-driven hybrid acceleration
- Deliver a systematic and definitive radiation biology programme
- Lay the foundations for the transformation of PBT
  - Automated, patient-specific proton and ion beam therapy







Radiobiology in New Regimens



Time domain

Space domain

The ideal flexible beam facility can deliver it all!

⇒ substantial opportunity for a step-change in understanding!

Energy

Ion species

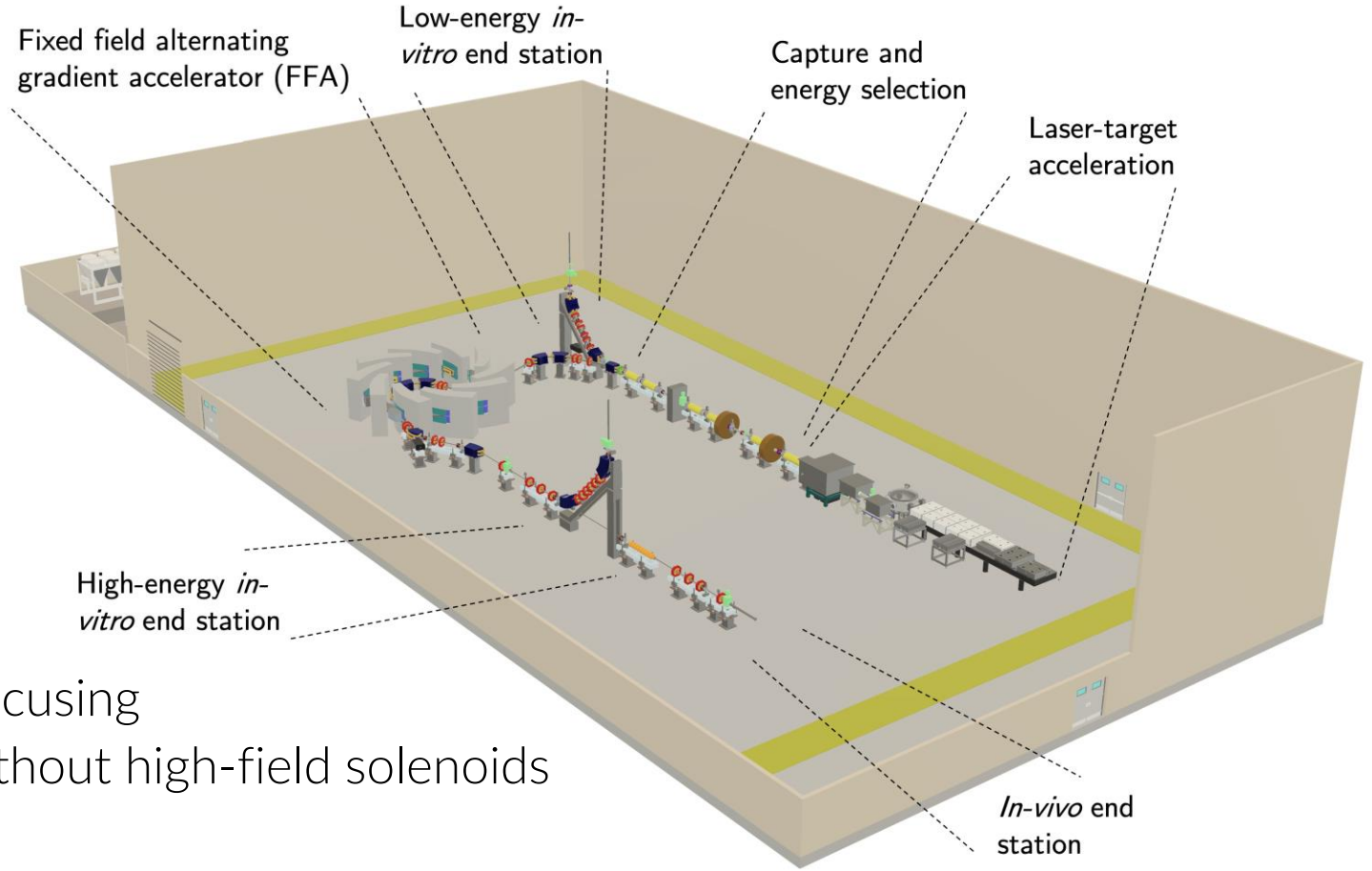
In combination

and with chemo/immuno therapies

A multidisciplinary approach is essential

LhARA

- 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

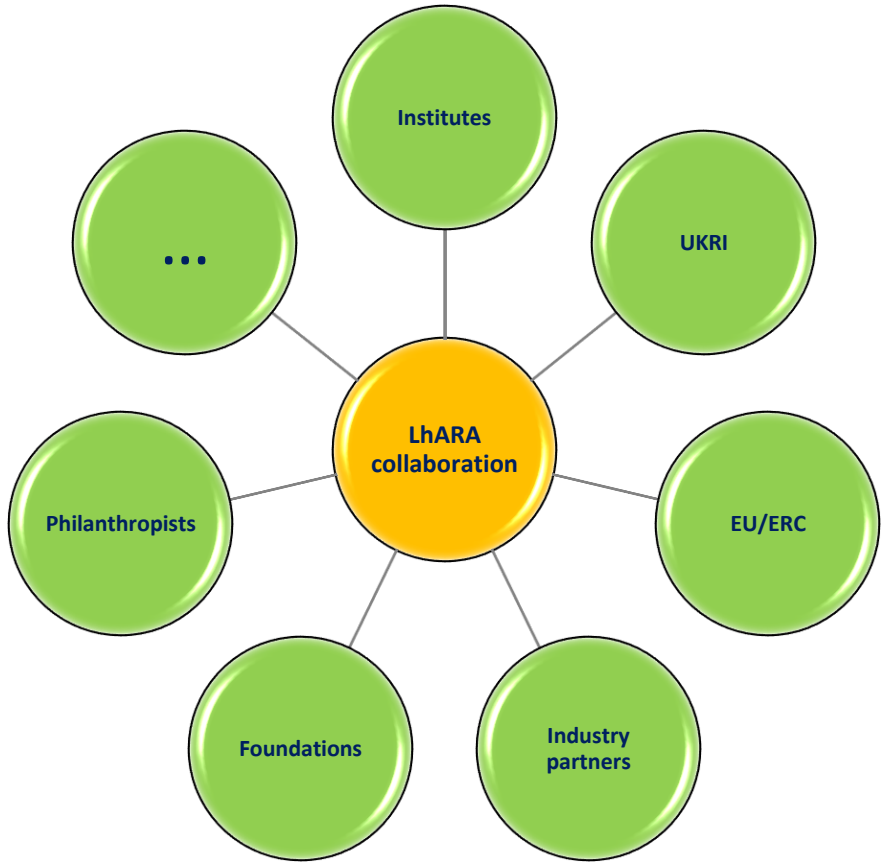


- Novel "electron-plasma-lens" capture & focusing
  - Strong focusing (short focal length) without high-field solenoids
- Fast, flexible, fixed-field post acceleration
  - Variable energy
    - Protons: 15—127 MeV
    - Ions: 5—34 MeV/u

	12 MeV Protons	15 MeV Protons	127 MeV Protons	33.4 MeV/u Carbon
Dose per pulse	7.1 Gy	12.2 Gy	9.7 Gy	83.8 Gy
Instantaneous dose rate	0.7×10^9 Gy/s	1.2×10^9 Gy/s	2.3×10^8 Gy/s	1.1×10^9 Gy/s
Average dose rate	71 Gy/s	122 Gy/s	97 Gy/s	838 Gy/s

Funding Status

- Transition period
  - UKRI -> multi-funder portfolio approach
- Resourcing model portfolio of co-investment and co-creation:
  - Industrial partnership
    - Including entrepreneurial/venture capital
  - Research council:
    - UKRI, EU, ERC, …
  - Philanthropic/Foundation
- Business plans:
  - LhARA business plan
    - Embodies common purpose
  - Business plan for each partner or stakeholder
    - Meets ambitions and KPIs of each partner
- Submittable bid prepared by end of 2026.



Project Structure

Radiobiological Science and Technology

Leaders: J. Parsons (Birmingham), R. Amos (UCL)

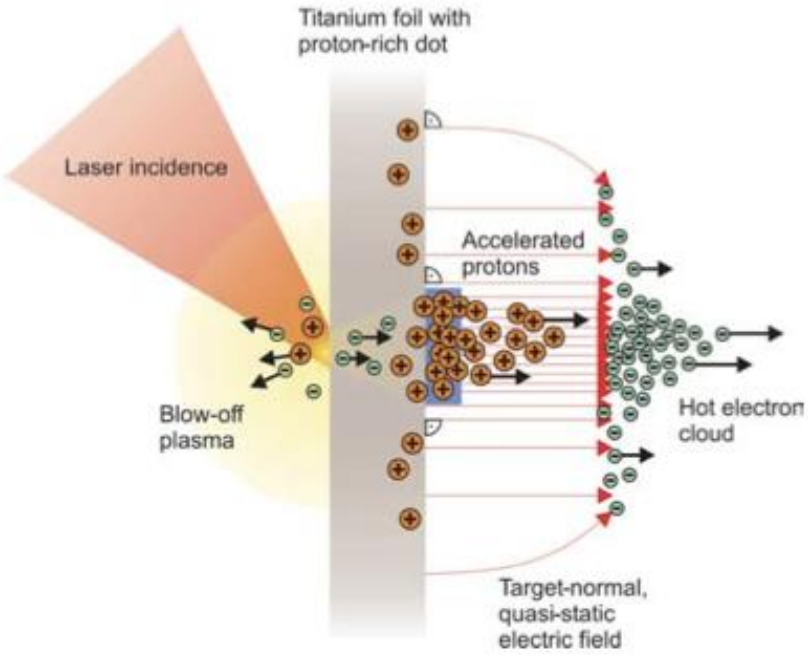
LhARA Project

Leaders: R. Wilson (Strathclyde/CI), W. Shields (RHUL/JAI)

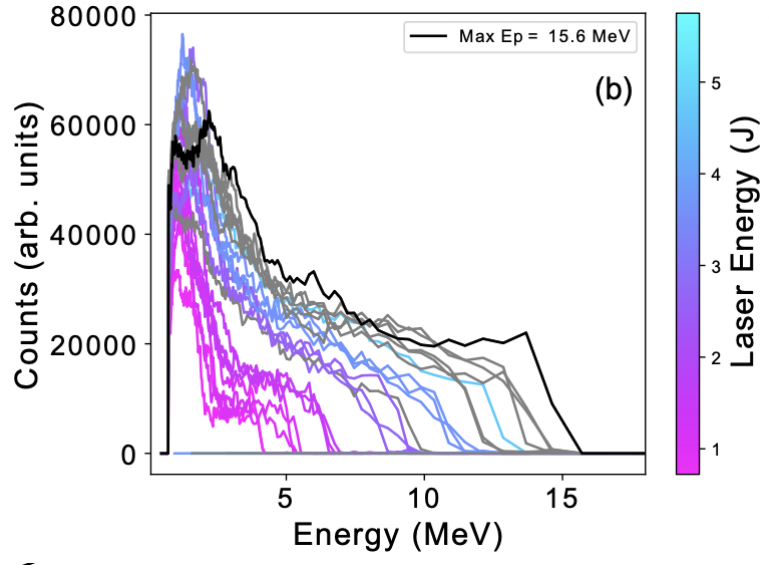
Project Management, Outreach, & Engagement

Leaders: C. Whyte (Strathclyde/CI)

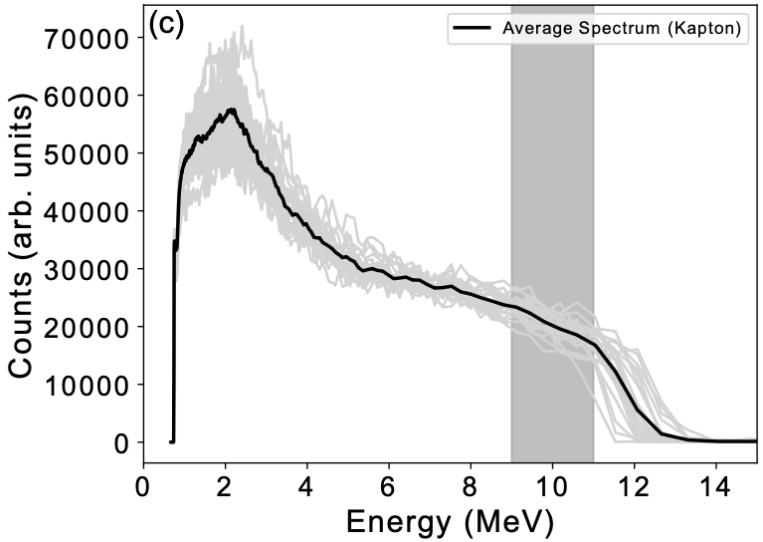
Laser-Driven Protons at SCAPA



- TNSA mechanism
- LhARA laser specification:
  - 800nm laser
  - >10 J
  - <50 fs
  - <3μm (FWHM)
  - 10 Hz
- Aim: 10^9 protons at 15 MeV

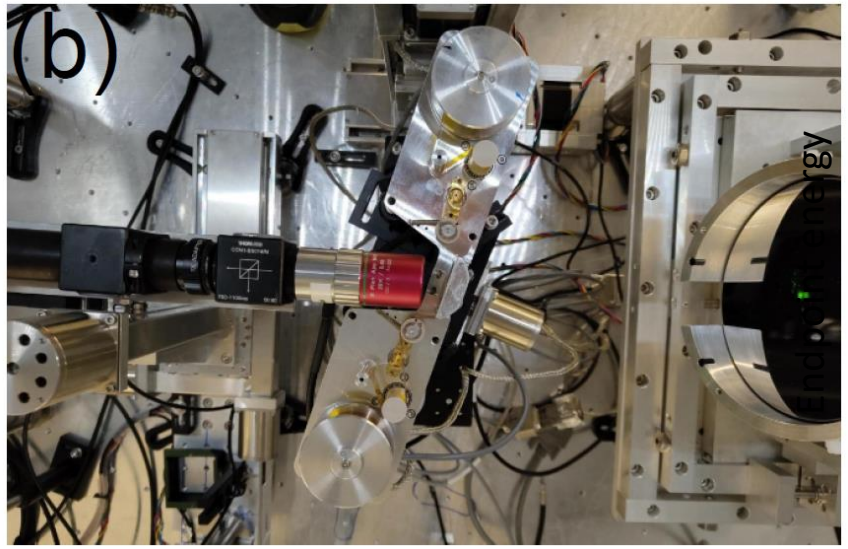


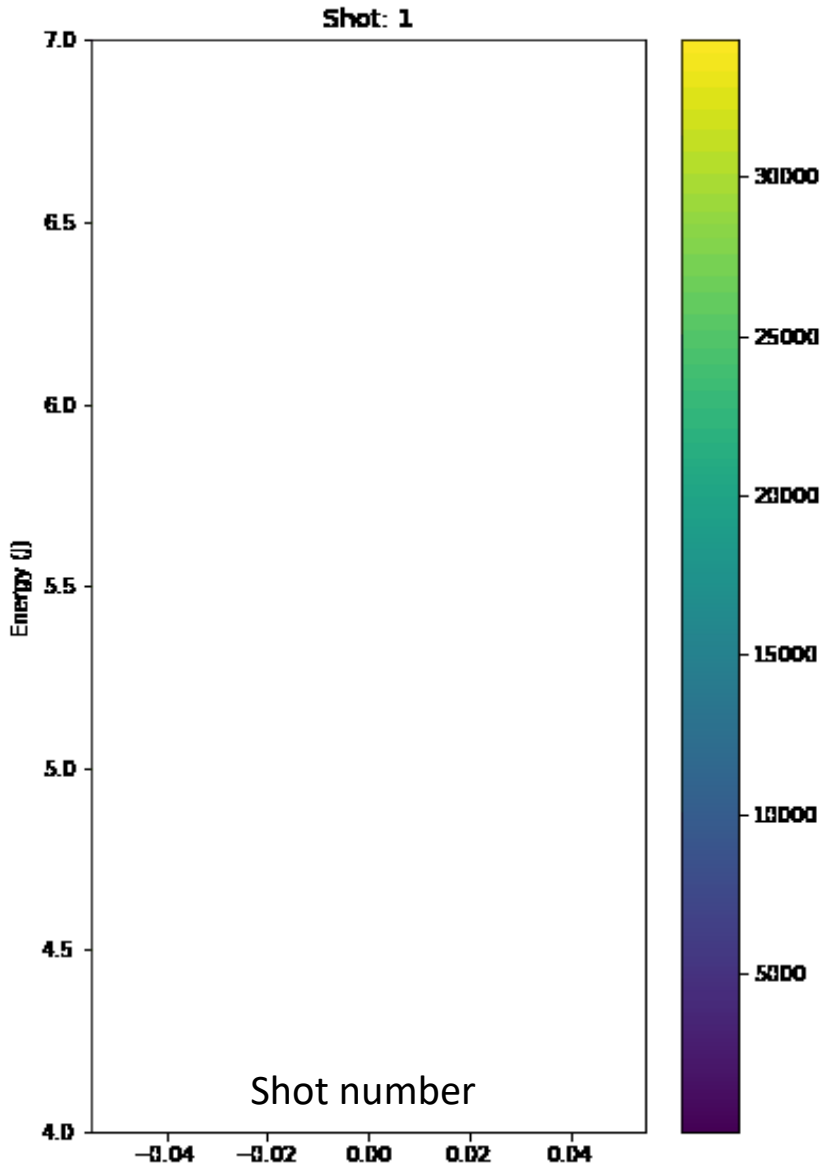
- LhARA laser source R&D :
  - "Full-scale" tests in conditions approaching LhARA specification
    - LhARA-focused diagnostic and target development
    - High-repetition rate, automation and longevity studies
    - Accurate numerical modelling 3D simulation codes
  - Develop understanding and demonstration of ion beam production



Nick Dover (IC)

SCAPA Laser Stability





SCAPA Experiment Team….

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

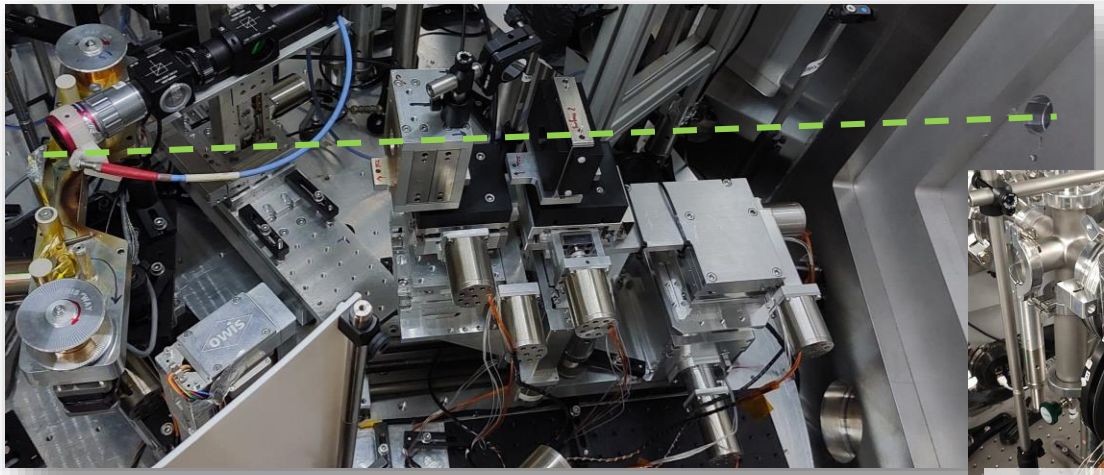
Imperial College
O. Ettlinger, G. Casati and N.P. Dover

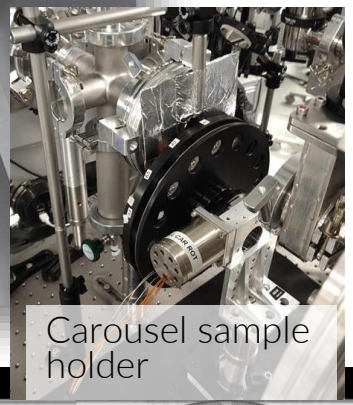
Queens University Belfast
P. Parsons and C. Palmer

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

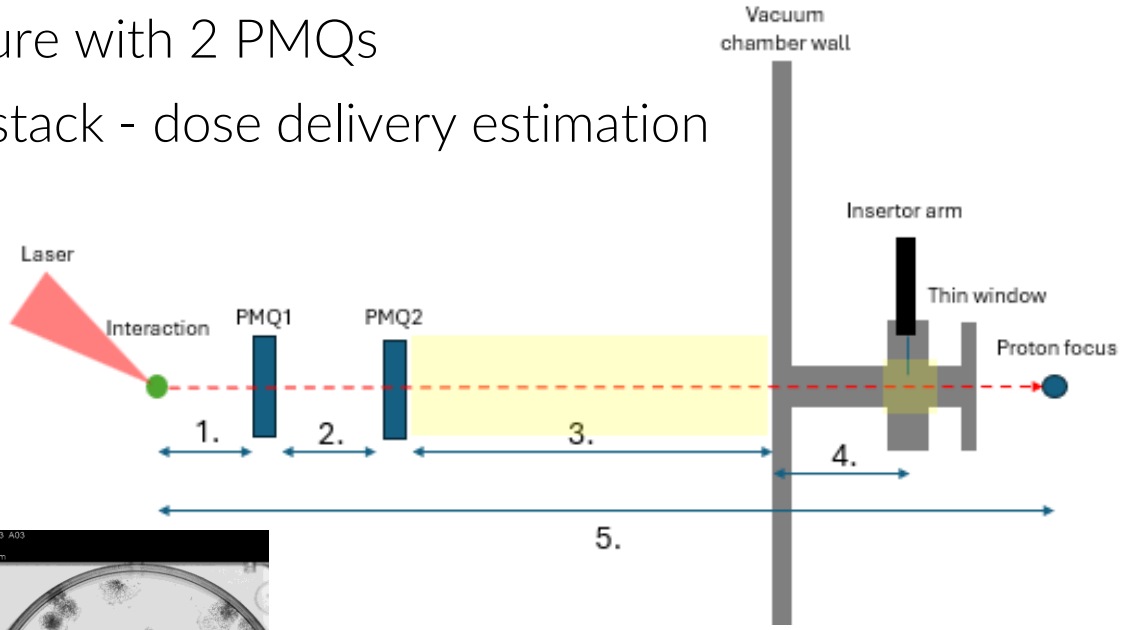
Central Laser Facility
J. Green, C. Armstrong, C. Spindloe, W. Robins, S. Astbury

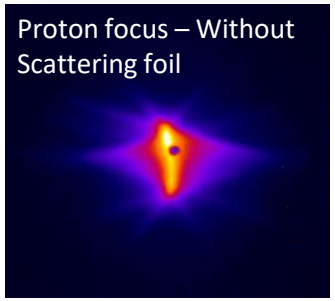
PoPLaR at SCAPA

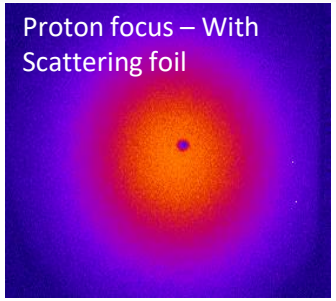


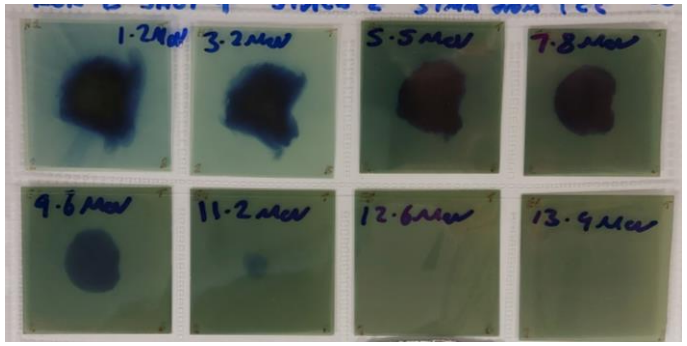


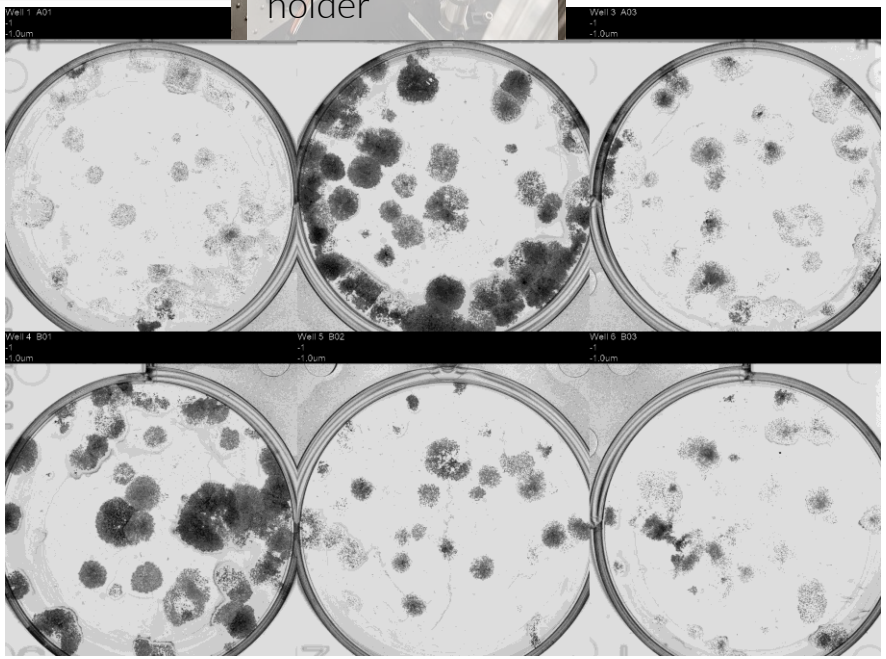
- Capture with 2 PMQs
- RCF stack - dose delivery estimation







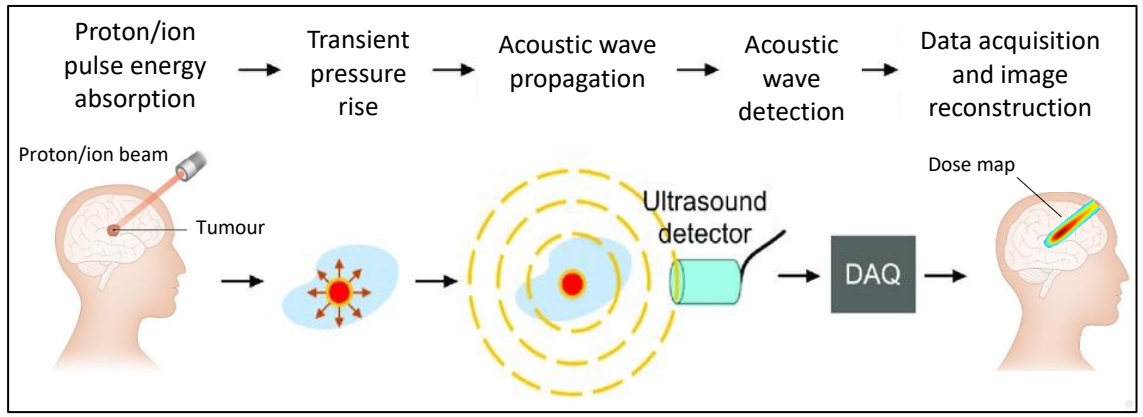


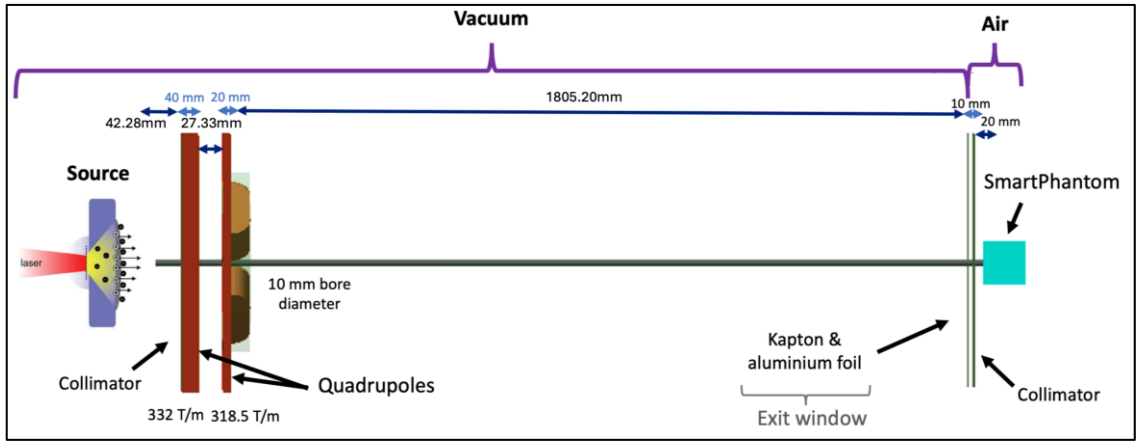


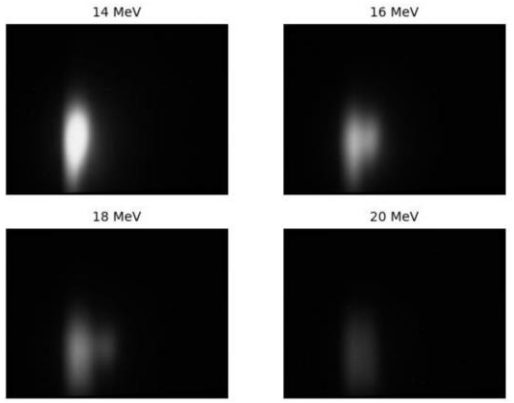
- Irradiation experiments to determine cell survival curves
  - Reproduce results from Birmingham cyclotron
  - 0, 1, 2, & 4 Gy
  - Promising results, some uncertainty in delivered dose

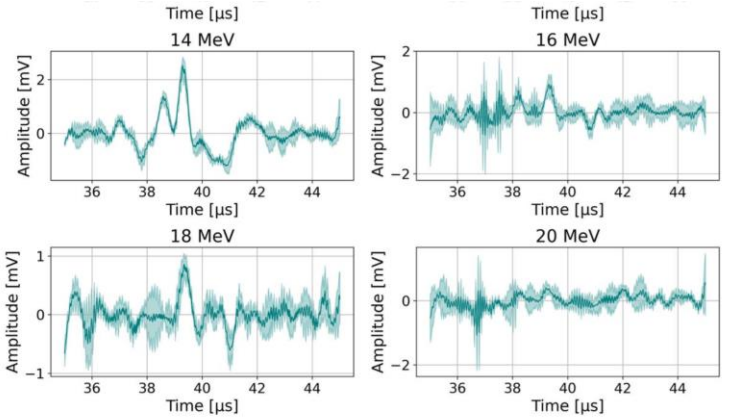
J. McGarrigle (IC), Calvin Dyson (IC)

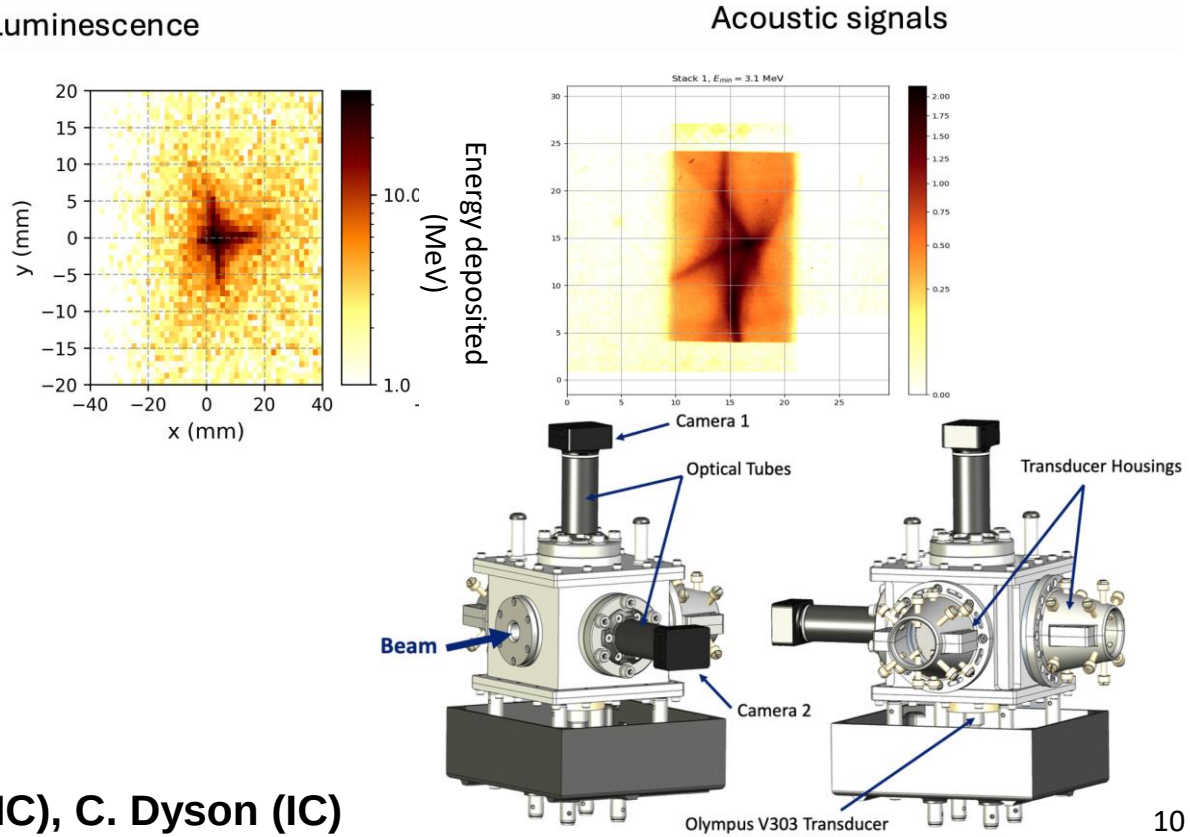
Ion Acoustic Dose Profiling







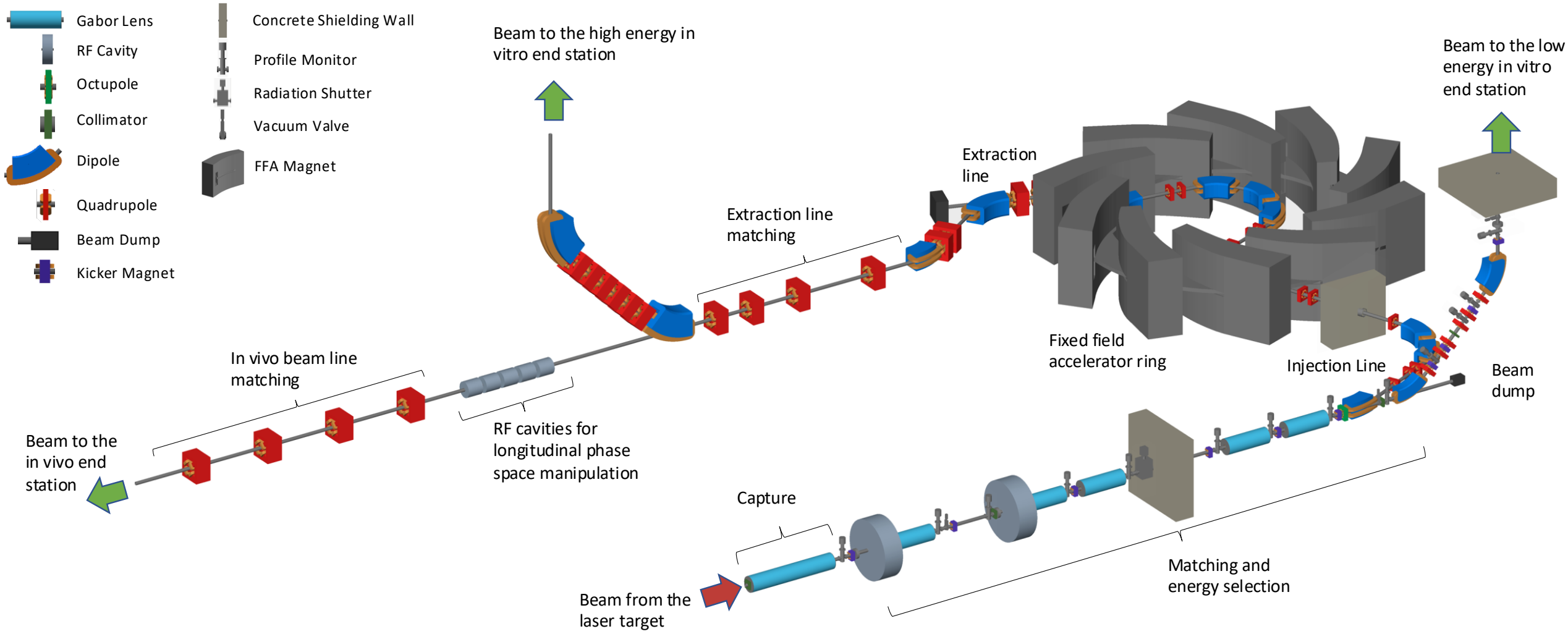




- Test exposure on LION at LMU
- Correlation: liquid scintillator and acoustic signal (transducer)
- Match experimental data to simulation (k-Wave & Geant4)
- Beamline modelling quad shifts & tilts, optics modelling
- Closer working with PoPLaR experiments

M.Maxouti (IC), J. McGarrigle (IC), C. Dyson (IC)

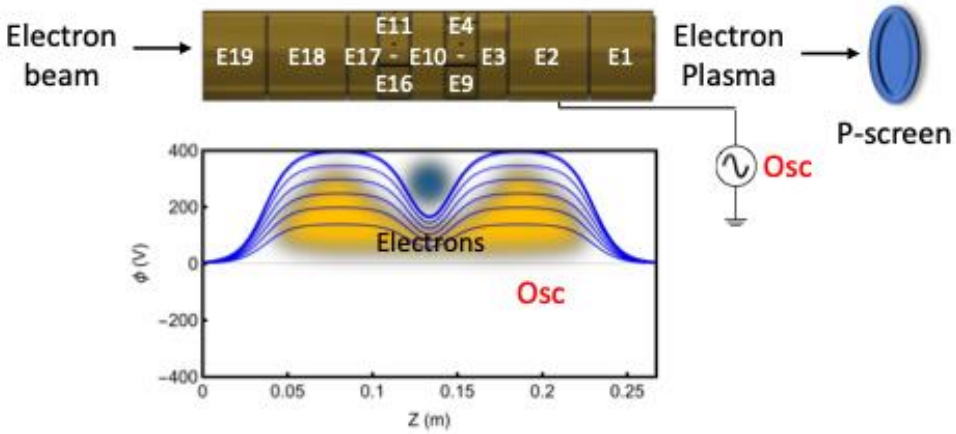
LhARA Accelerator

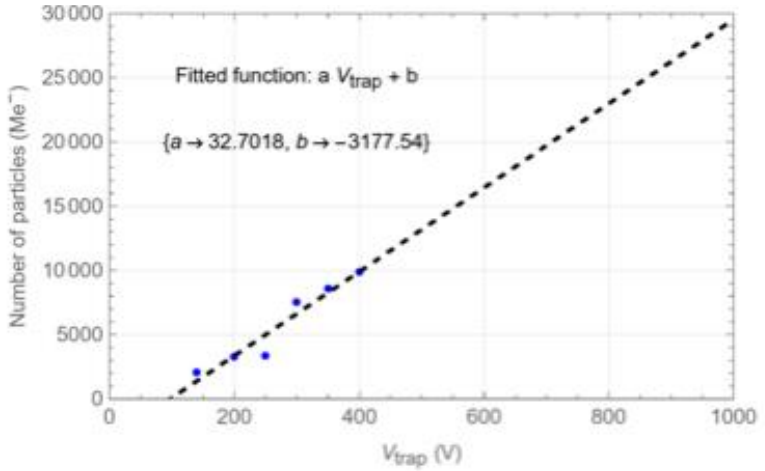


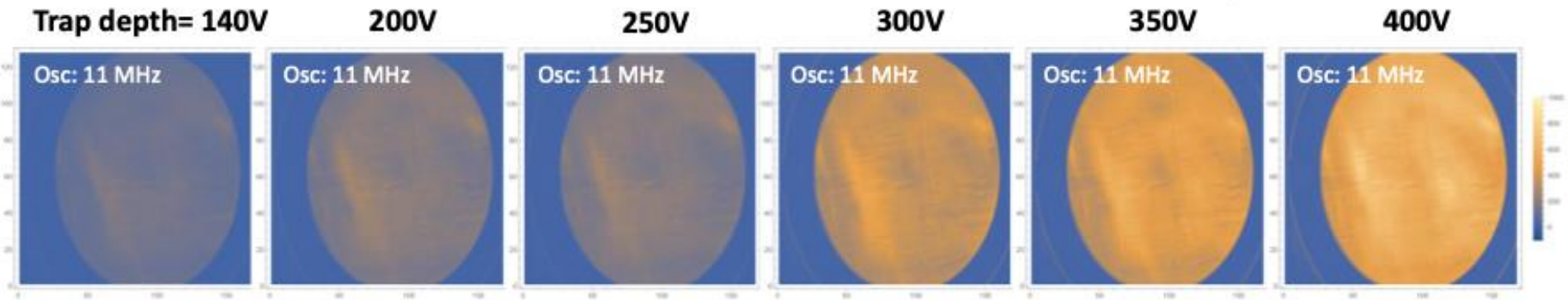
W. Shields (RHUL), M. Pereira (RHUL), J. Pasternak (IC), T-J Kuo (IC), R. Razak (IC)

Gabor Plasma Lenses

Plasma in HV traps







Peak densities:
140V trap ≈ 8x10^{13} m^{-3}
400V trap ≈ 1x10^{15} m^{-3}

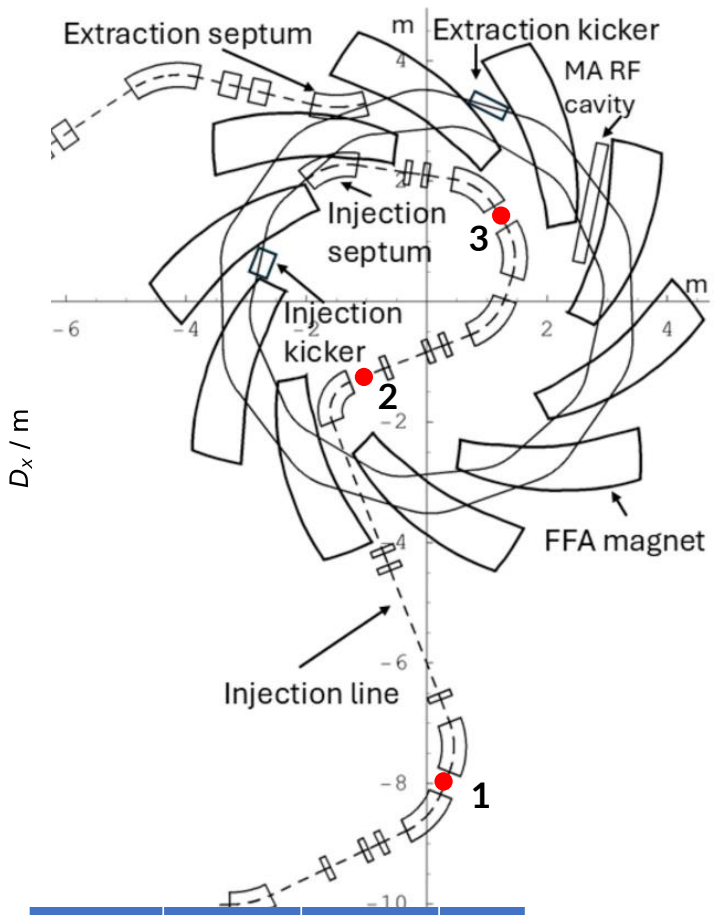
Demonstrate plasma size and stability for LhARA Gabor Lens

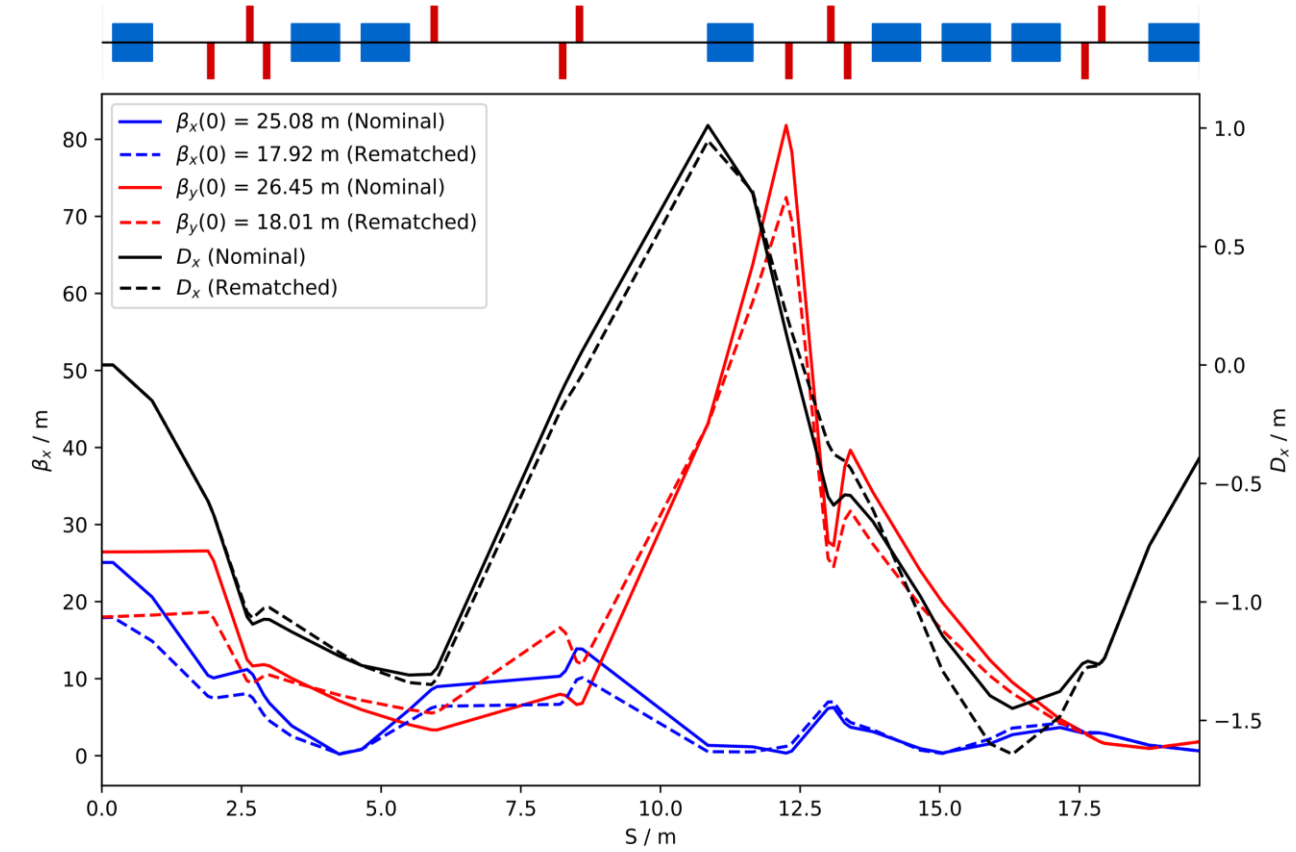
Match to simulations

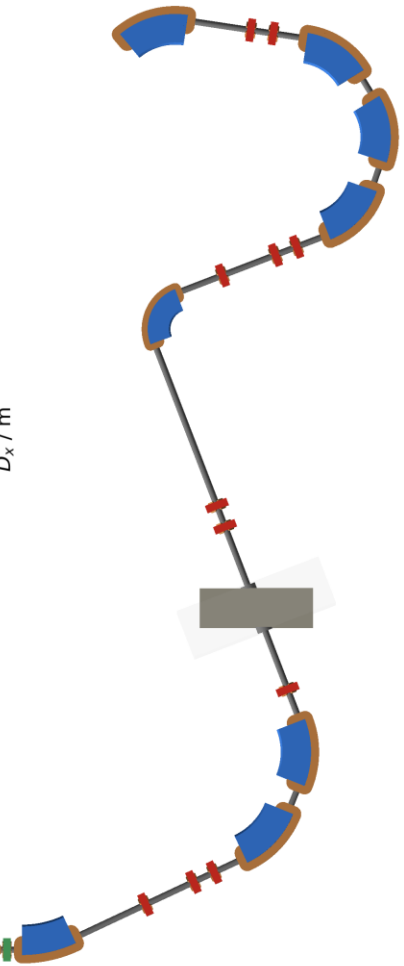
Integration into LhARA beamline modelling

Optimise: e-gun bias, magnetic field, trap potential, RF amplitude, dimple depth …

FFA Injection Line Design





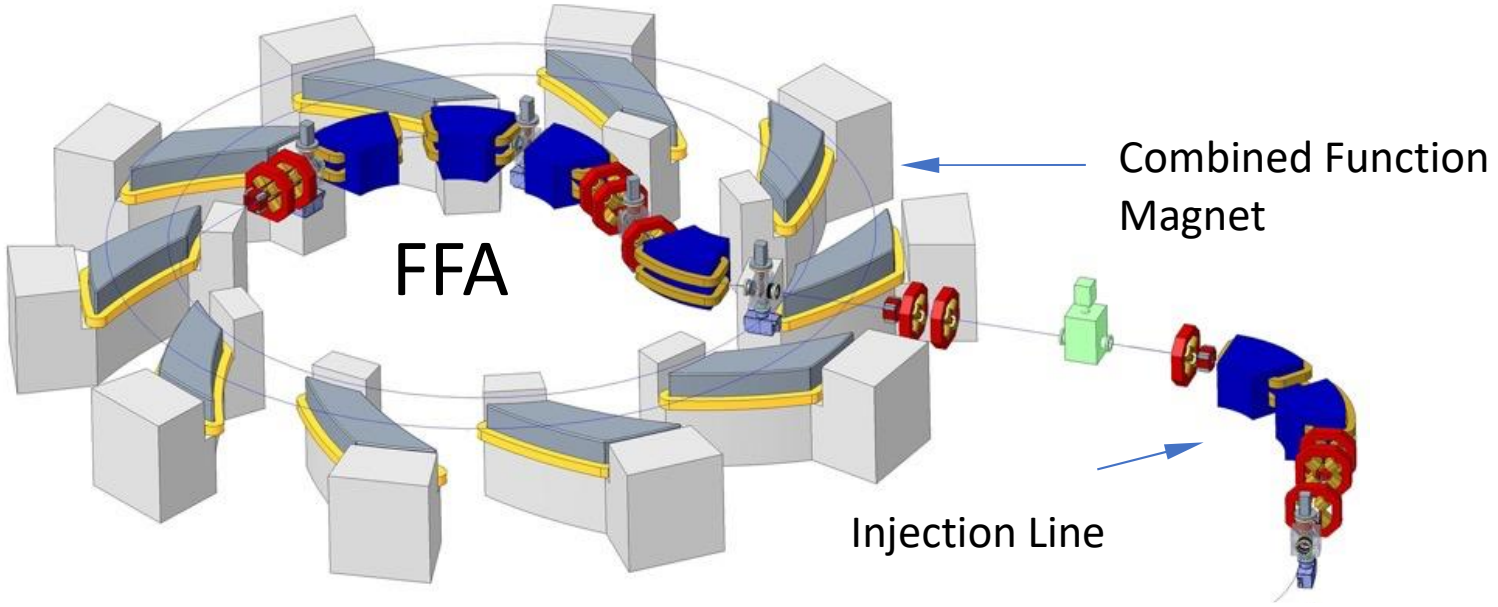


Beam Parameter	Switching Dipole Entrance	Injection Septum Exit	Unit
β_x	25.08	0.622	m
β_y	26.45	1.819	m
α_x	0	0.074	
α_y	0	-0.963	
D_x	0	0.392	m

- New simulation strategy: BDSIM– RF-Track coupling - in development
  - Losses (BDSIM) with space-charge tracking (RF-Track)
  - Injection line optimization required.

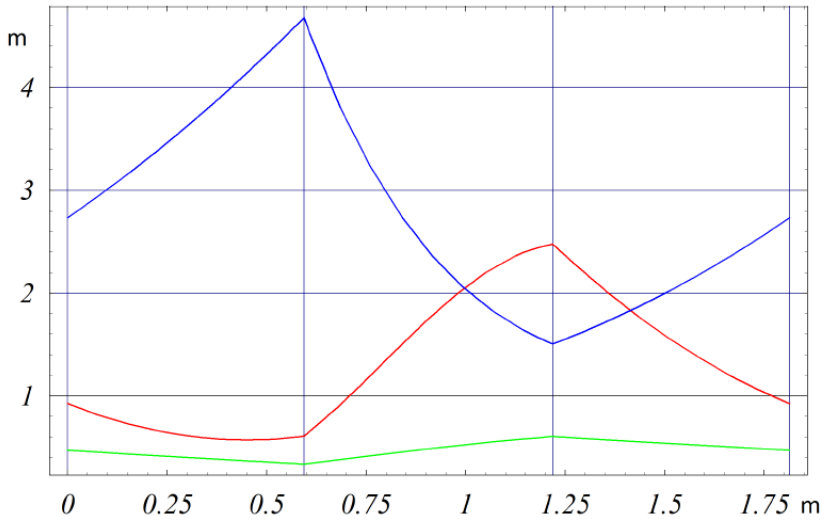
M. Pereira (RHUL), W. Shields (RHUL)

FFA Design and Tracking



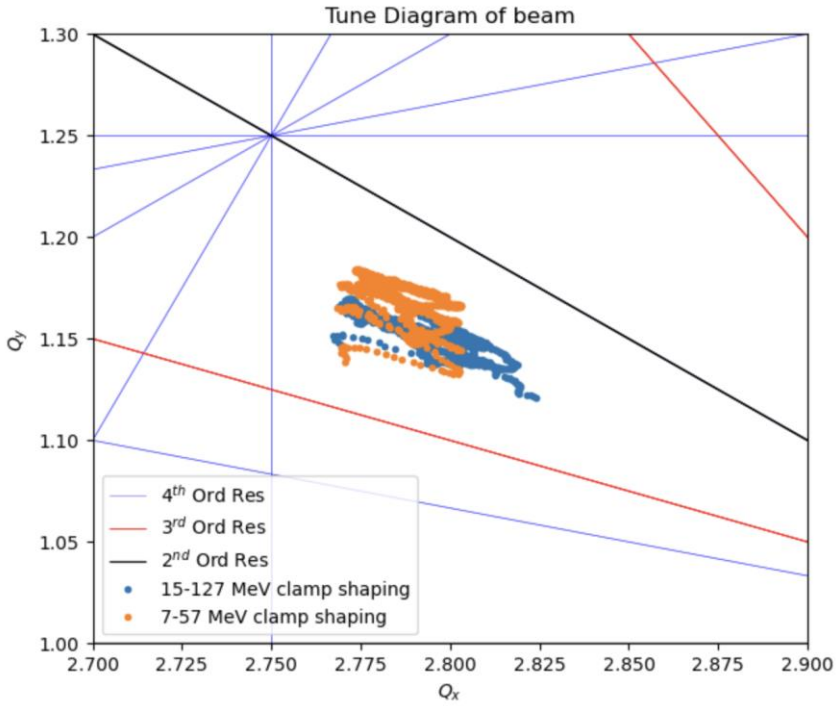
Variable-energy FFA

- 10 cell, single spiral design
- Multi-ion capability
- Single spiral design
- Max field ~1.4 T
  - Tunable
- 2 MA/ferrite loaded RF cavities



Tracking:

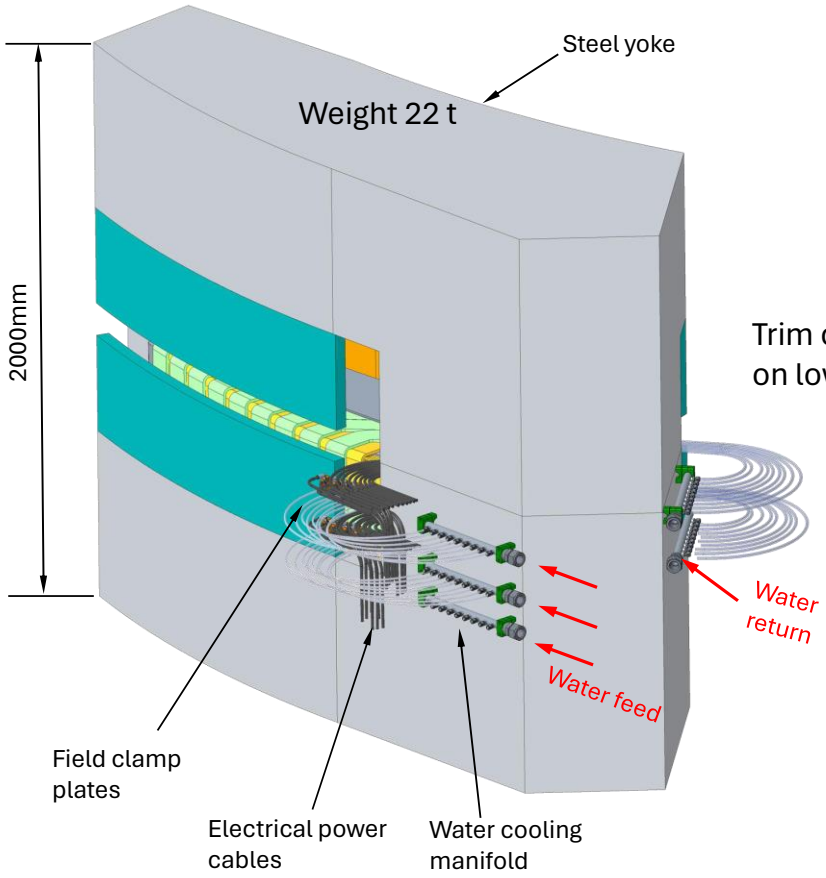
- No tune crossing up to fourth order
- Transverse dynamics (4D) are well modelled
- Space-charge & longitudinal dynamics requires further effort

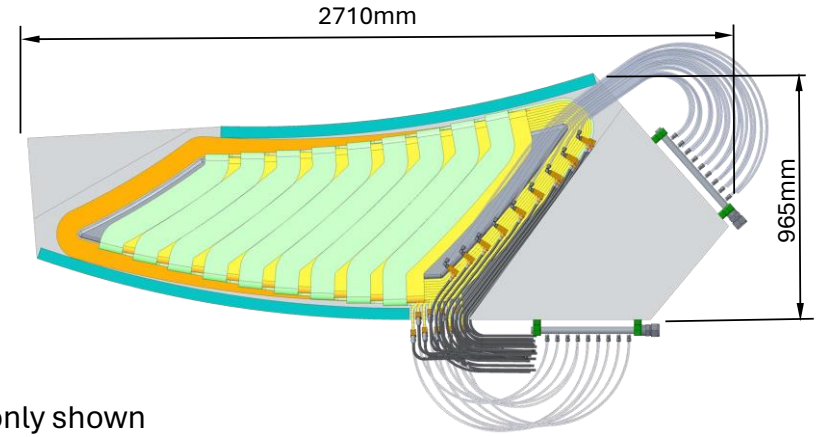


T.J. Kuo (IC), J. Pasternak (IC)

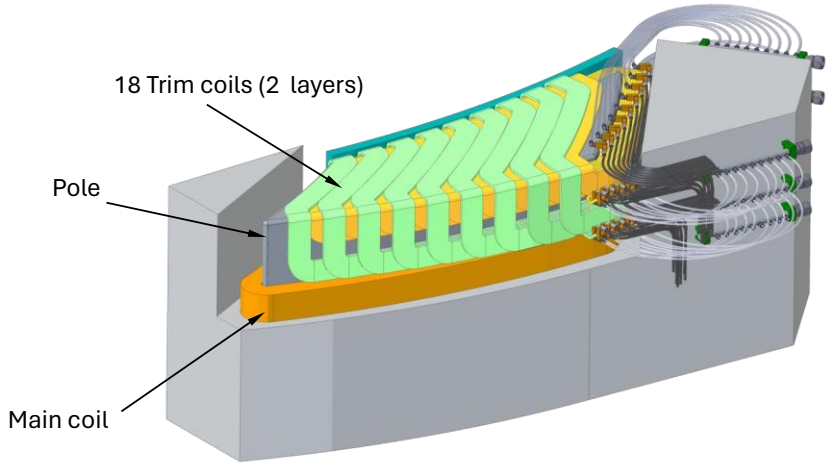
FFA Magnet Design and Simulation

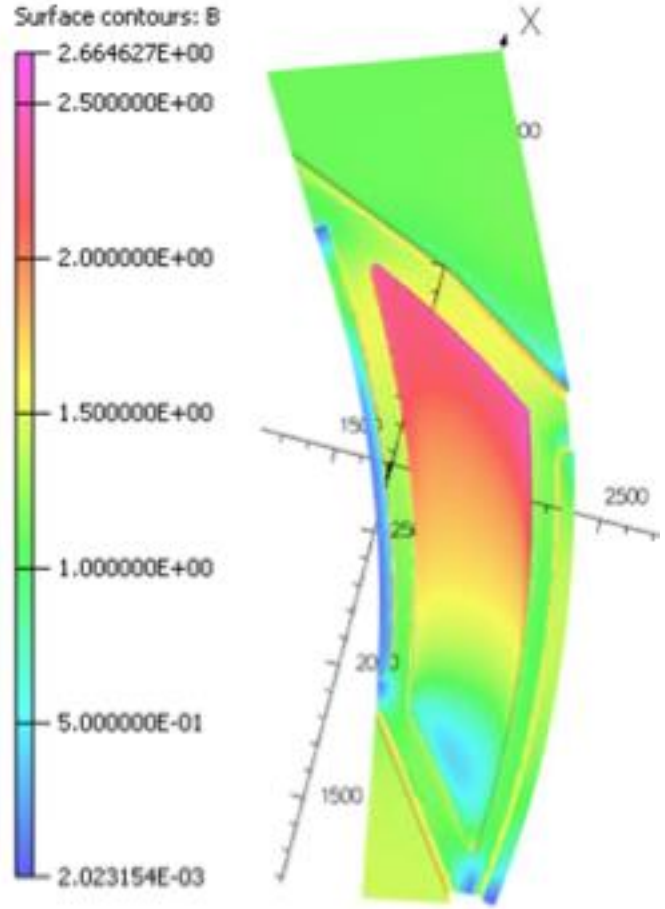
FFA Magnet





Trim coils only shown on lower pole





OPERA 3D magnet model

- Optimised configuration of field clamps and trim-coils

T.J. Kuo (IC)

Publications

The LhARA Conceptual Design Report has been published!

- https://epubs.stfc.ac.uk/work/64272701

Publication drive:

- LhARA – Frontiers
- Plasma Physics and Controlled Fusion
- Ion-acoustic
- Accelerator papers

Peer-Group Meetings

Engagement: International stakeholders: clinical, biological science, industry, policymakers
Aim: Establish strategy for the development of laser-driven charged particle beams for cancer therapy.
Outcome: "white paper" publication and road map.

Workshop series:

- **LhARA Particle Therapy Workshop - 27/02/26**
- Cylindrically-symmetric strong focusing of ion beams;
- Novel time-resolved and high-resolution imaging; and
- Biology, measurement, simulation and interpretation of ion beams.

LhARA Particle Therapy Workshop

- Review state of the art in particle beam therapy
- Discuss benefits of laser-driven beams and its potential to revolutionise particle therapy
- Identify key biological & clinical science to be addressed for personalized laser-driven ion therapy.

Invited talks: Alejandro Mazal, Sandro Rossi, Yolanda Prezado, Joao Seco, Marco Durante, **Manjit Dosanjh**, Konrad Nesteruk, Thomas (Rock) Mackie, **Alexander Gerbershagen.**

https://indico.stfc.ac.uk/event/1703/

LhARA Future

Radiobiological Science and Technology

LhARA Project

Co-creation: engagement, impact, & business planning

→ Systematic programme including PoPLaR, ion-acoustic dosimetry, automation, …

→ Laser-driven source, Gabor Lens, FFA, LhARA design and integration, …

→ Peer-group meetings, business plans, resource portfolio

Summary

- Committed and growing collaboration despite funding uncertainty

- Excellent progress on
  - Radiation biology programme:
    - Development of PoPLaR at SCAPA
  - LhARA project:
    - Source (rep rate, stability), capture ($10^{15}/m^3$), ion-acoustic, diagnostics, design and integration
  - Engagement:
    - Industry, peer-group workshops, public, …

- Continue undertaking LhARA initiative, build business plan.
  - Multi-funder resourcing portfolio model

Thank you for listening!

William Shields

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JAI Advisory Board 2026

16th April 2026