The Ion Therapy Research Facility and LhARA

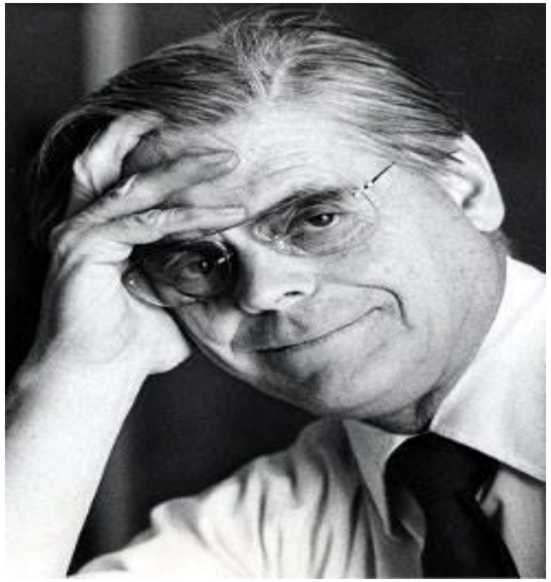
Hywel Owen (on behalf of the ITRF and LhARA Collaborations)
STFC Daresbury Laboratory
Accelerator Science and Technology Centre

24th January 2024
LhARA/ITRF 3rd User Consultation

(The work of many people is shown in these slides)

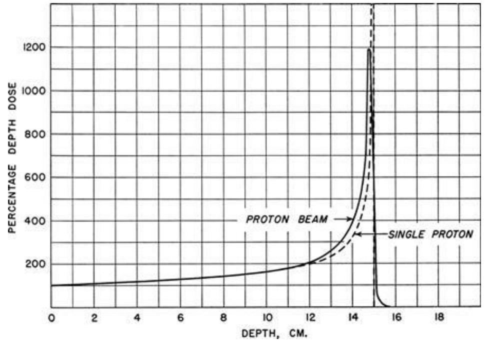
From physics to clinic

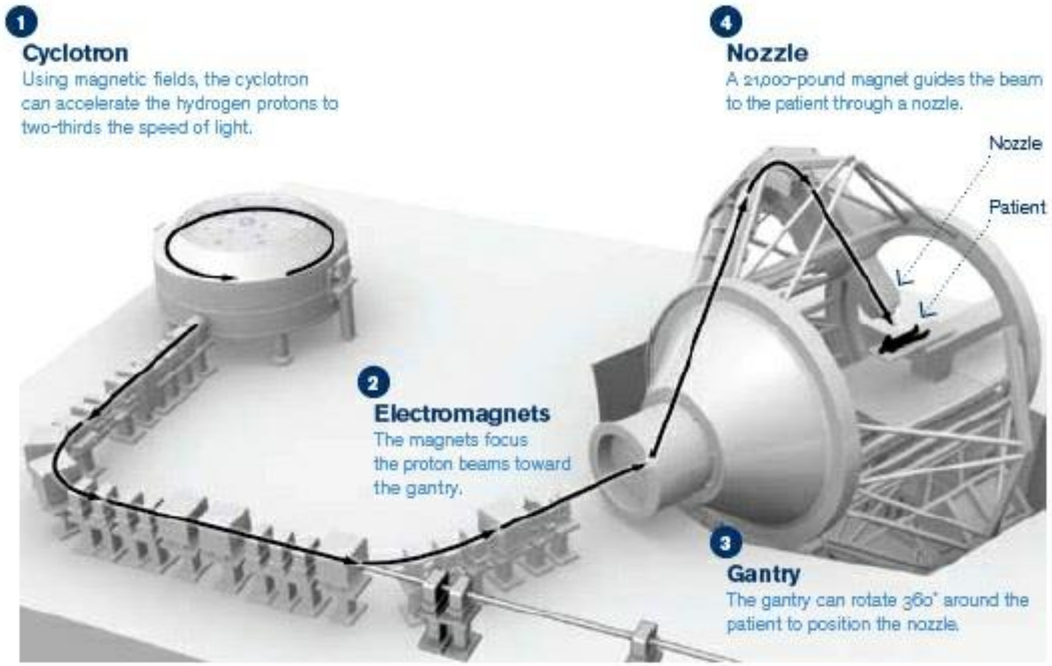
Ernest and John Lawrence



Robert R Wilson “*Radiological Use of Fast Protons*". Radiology **47** (5): 487–491. November 1946. doi:10.1148/47.5.487

$$-\frac{dE}{dx} = \frac{4\pi}{m_e c^2} \cdot \frac{nz^2}{\beta^2} \cdot \left(\frac{e^2}{4\pi\varepsilon_0}\right)^2 \cdot \left[\ln\left(\frac{2m_e c^2 \beta^2}{I \cdot (1-\beta^2)}\right) - \beta^2\right]$$





Siemens/Varian

Mevion

Science and Technology Facilities Council
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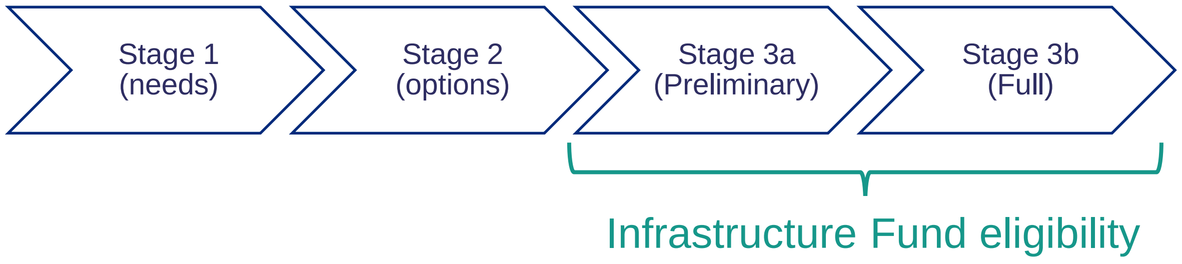
Technology > Experiment > Infrastructure > Clinic

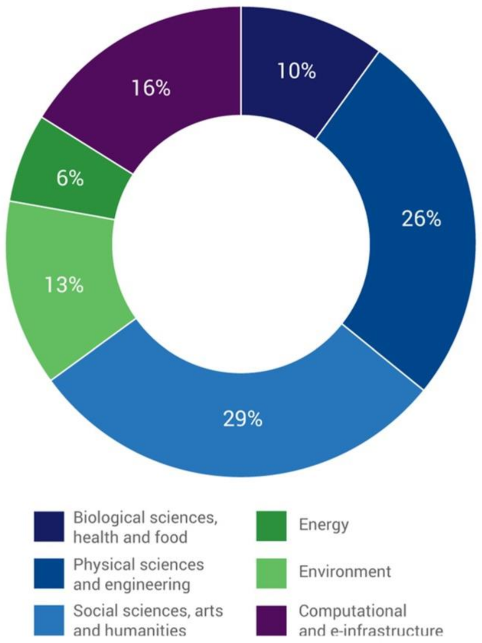
UKRI, STFC, ASTeC and Infrastructures

- STFC Strategic Framework:
  - ‘giving priority to infrastructures that support the science mission needs’
  - ‘ensure that critical technologies are developed for future infrastructures’
  - ‘provision and operation of research facilities in… …any area of UKRI’s activity’

- UKRI Infrastructure Fund:
  - ‘aimed at supporting significant investments that enable a step change in research and innovation infrastructure’
  - New build, upgrades, or decommissioning

  - Full Project or Preliminary Activity





Over **500** nationally and internationally significant infrastructures

A breadth of expertise: **92%** work across more than one topic domain

Three quarters work with UK business and **42%** with public policy organisations

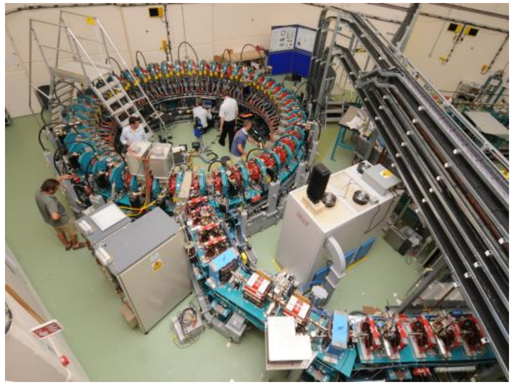
Infrastructures employ just under **25,000** staff

- UKRI Infrastructure Projects:
- 32 Full Projects
- 9 Preliminary Activities – ASTeC pivotal in 1/3 of PAs
- Total investment 481M 2022-2025
- Includes projects such as DIAMOND-II, SKAO, Hyper-K

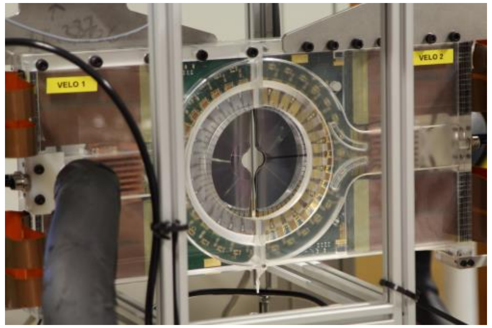
- Accelerator Science and Technology Centre (100 staff)
- Science and Technology Facilities Council (1900 staff)

- ‘Coordinates research and development of national infrastructures’

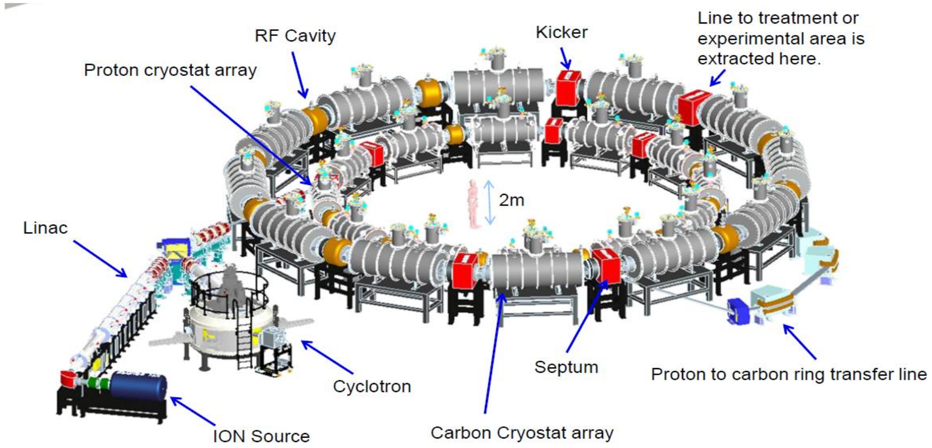
Developing New Capabilities



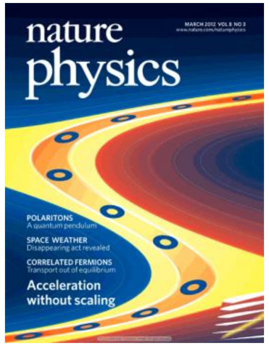
EMMA demonstrator (2012)



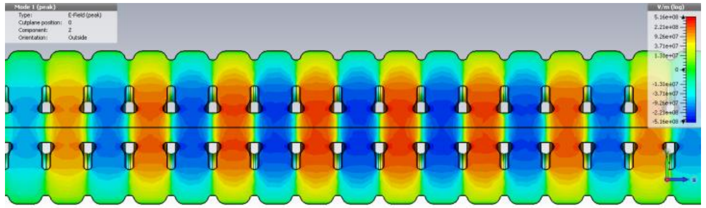
Diagnostic instrumentation (ULiv/CCC)



PAMELA design study (2013)



Christie research beamline (2019)



PROBE high-gradient proton linac (ULan/UMan)

www.oma-project.eu

Partnership between National Lab, academic groups, and clinical

Key enabling technologies: superconductivity, plasma acceleration, FFAs

UK has strength in combination of facilities and research: Birmingham, Christie, Clatterbridge, Dalton CF….

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Protons in the UK

- 1989: Clatterbridge UK world's 1st hospital proton therapy centre (62 MeV, ocular); 100 patients/year
- 2007: NRAG report 'Radiotherapy: developing a world class service for England' recommends proton facilities
- 2007: Cancer Reform Strategy
- 2008: Proton Overseas Programme; 1102 patients (2008 – 2018)
  https://doi.org/10.1016/j.ijrobp.2020.07.2456
  https://doi.org/10.1016/j.clon.2018.02.032
- 2012 NHS Strategic Outline Case
- 2015: Full Business Case approved for 2 NHS centres
- 2018: NHS Christie 1st patients – seen as a big success story
- 2021: NHS UCLH 1st patients
- 2024: A (varying) number of proton centres and companies

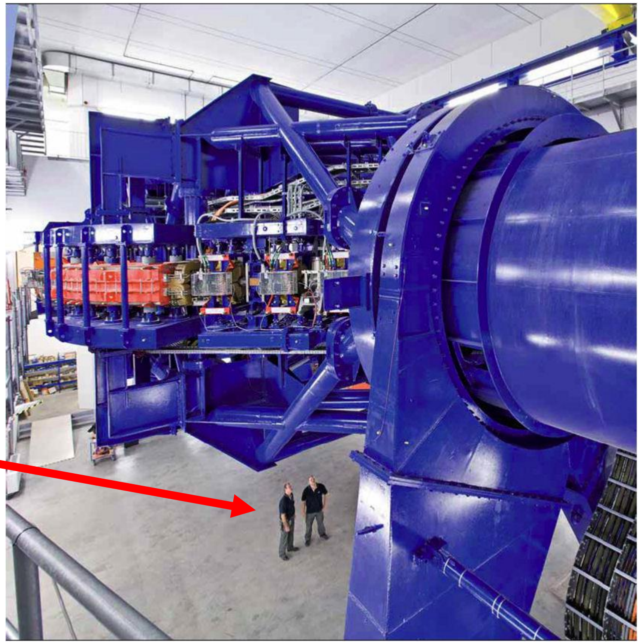
Clatterbridge – 62 MeV Scanditronix cyclotron
Basis for much UK technology and clinical-related research

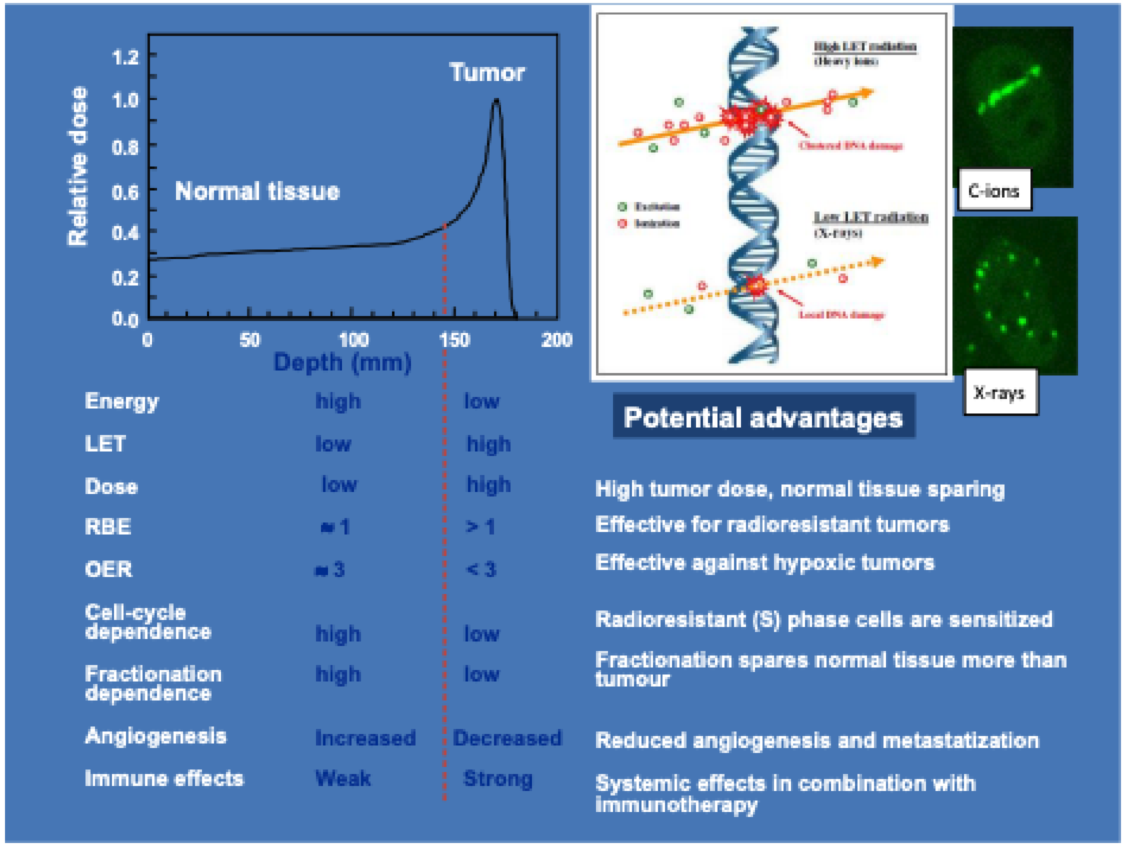
Christie – 250 MeV Varian cyclotron
+ unique research beamline

Protons in UK:
- Evidence-based
- Intention to cure
- Emphasis on children, young adults (<25), adults with rare tumours

Use of (Heavy) Ions

- Tinganelli and Durante *Cancers* 2020, *12*(10), 3022; https://doi.org/10.3390/cancers12103022
- ‘Cancers of unmet need’
- BUT…
- Need to reduce size and increase capability





- Japan: 6 centres
- China: Shanghai
- Germany: HIT; MIT (GSI He trials)
- Austria: MedAustron
- Italy: CNAO
- USA: NAPTA (led UCSF), NPTRC (led UTSW) design studies: Mayo Clinic & Hitachi to build a C centre
- Other centres proposed world-wide. A number being proposed in Europe (NIMMS, SEEIST)

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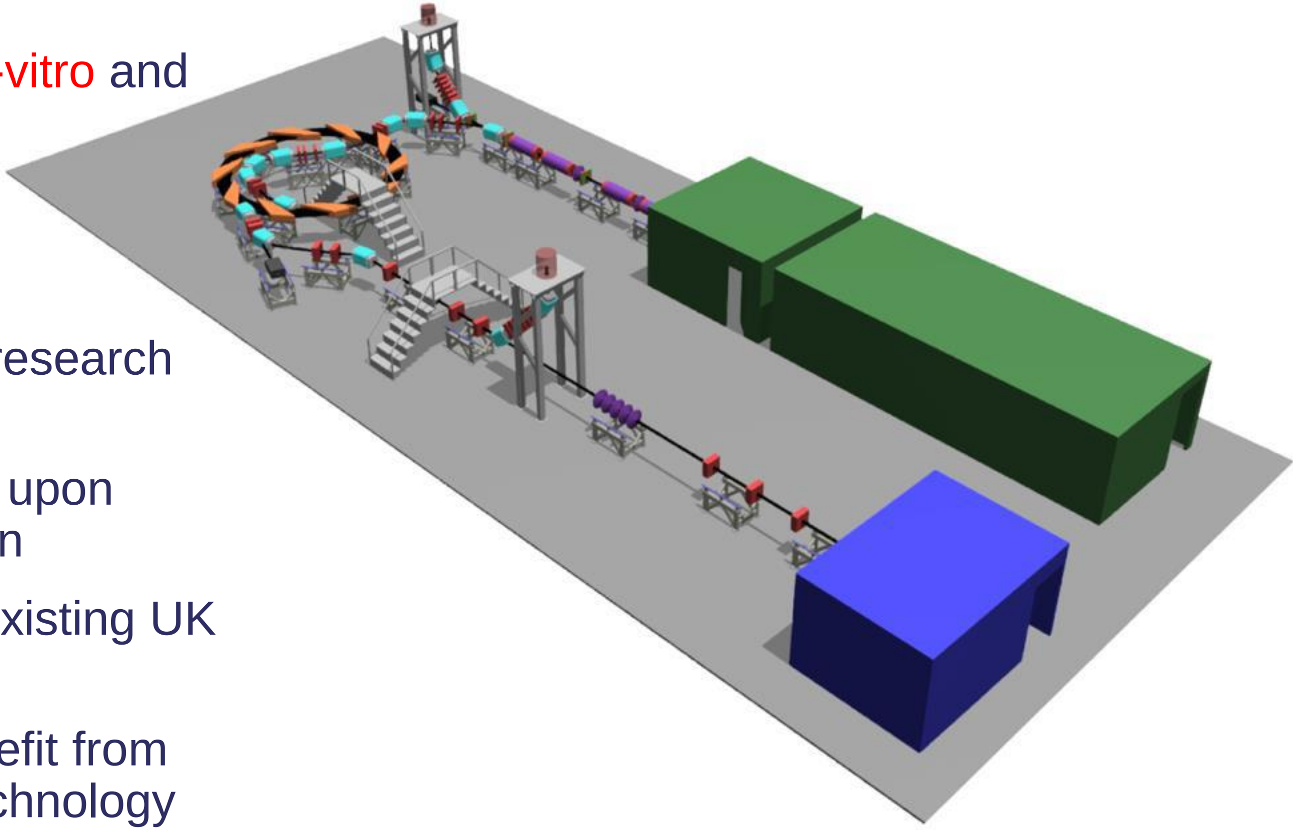
Ion Therapy Research Facility – an ambition for new capabilities

HOW:

- A compact, single-site national research infrastructure delivering very high dose rates and other unique (spatial and temporal features)
- Protons and beyond, at energies sufficient for both in-vitro and in-vivo studies



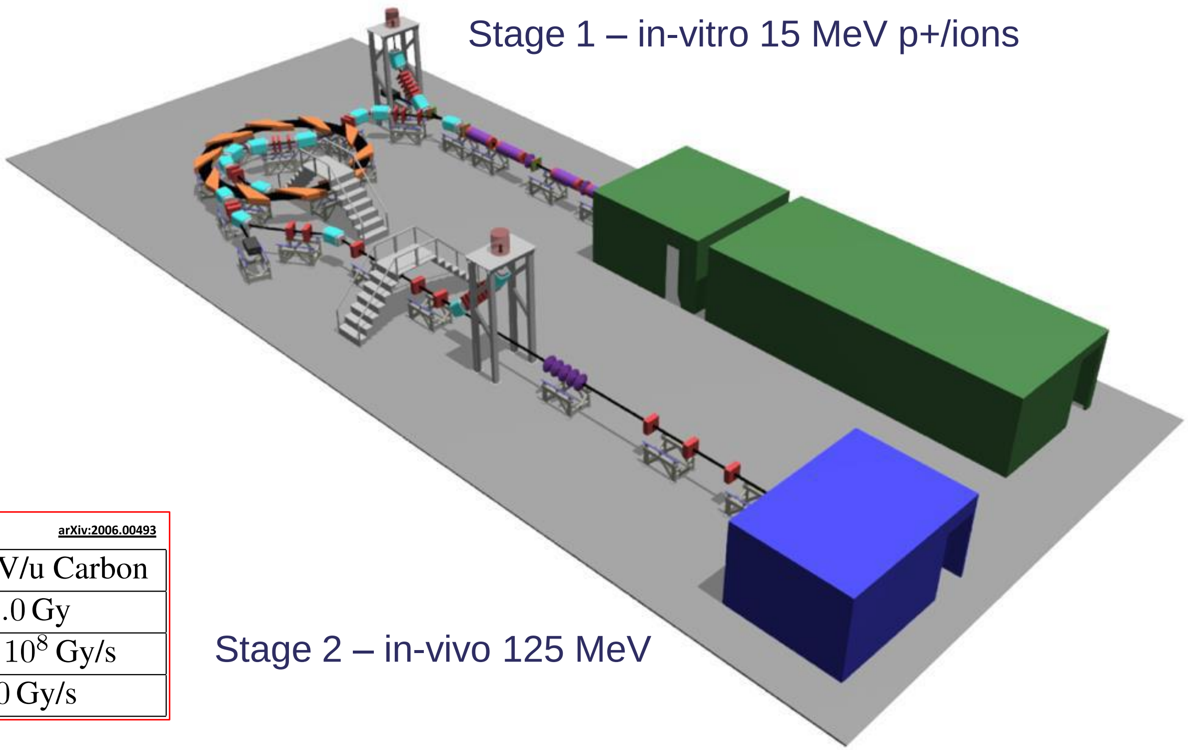
WHEN: WORK PLAN 2022 - 2024

- Conceptual design of layout, cost and operation of a research facility
- Develop innovative laser-plasma technology, building upon world-leading expertise within the LhARA collaboration
- Develop innovative end-station designs, building on existing UK expertise in proton radiobiology research
- Collaborative agreement with CERN allows us to benefit from enormous experience and expertise in accelerator technology and successful projects – synchrotron design

What is the Ion Therapy Research Facility?

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



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

- Stage 1: proton beams with energies in the range 12 MeV to 15 MeV to the Low-energy *in-vitro* End Station;
- Stage 2: proton beams of 127 MeV and ion beams of 33.4 MeV/nucleon to the High-energy *in-vitro* and *In-vivo* End Stations.

LhARA baseline design:
https://www.frontiersin.org/articles/10.3389/fphy.2020.567738/full

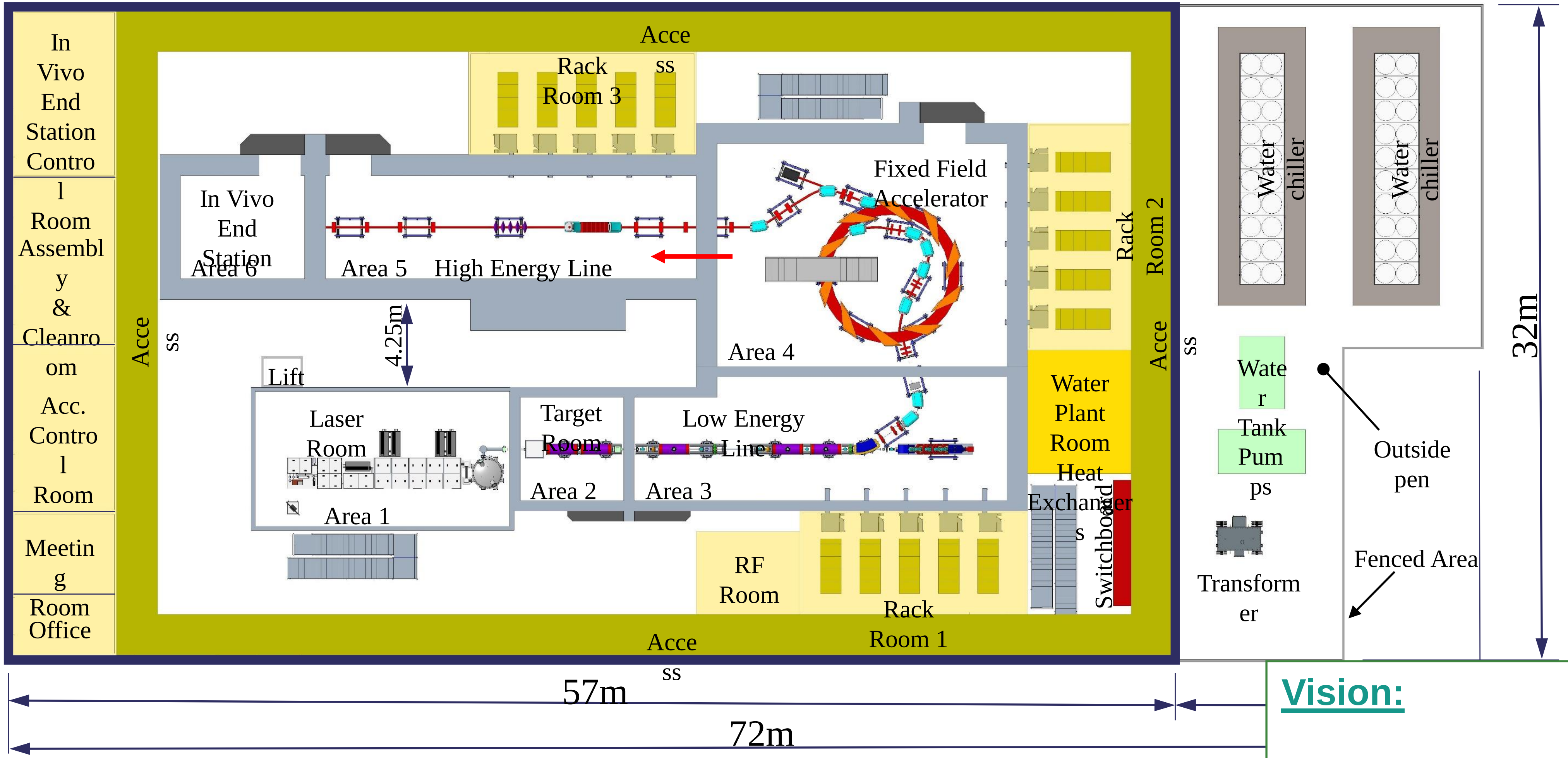
ITRF Research Need:
- Ion biology not yet well understood
- Likely benefits from heavier ions
- Clinical choice will require understanding of effects in tumour and normal tissue
- Ultimately might require individual patient research

ITRF Timeline – Where Do We Want to Get To?

- 2022-2024 Conceptual Design Report (PA1)
- 2024-2027 Technical Design Report (PA2)
- 2028- Construction and Operation

- Where are we right now?
  - Baseline design is innovative plasma source and compact acceleration platform that is a pathway to future innovative treatment modalities
  - Unique combination of ion delivery options including UHDR, spatial fractionation
  - Initial design based on UHDR protons and carbon ions
  - Stage 1 (15 MeV protons) well developed, with defined pathway to experimental demonstration and validation – proof-of-principle experiments planned in next stage, compared with conventional acceleration and delivery
  - Stage 2 (127 MeV protons) making progress with design in collaboration with STFC-ISIS and CERN
  - Costing, timeline and resources > Conceptual Design Report in September 2024

ITRF Baseline Layout



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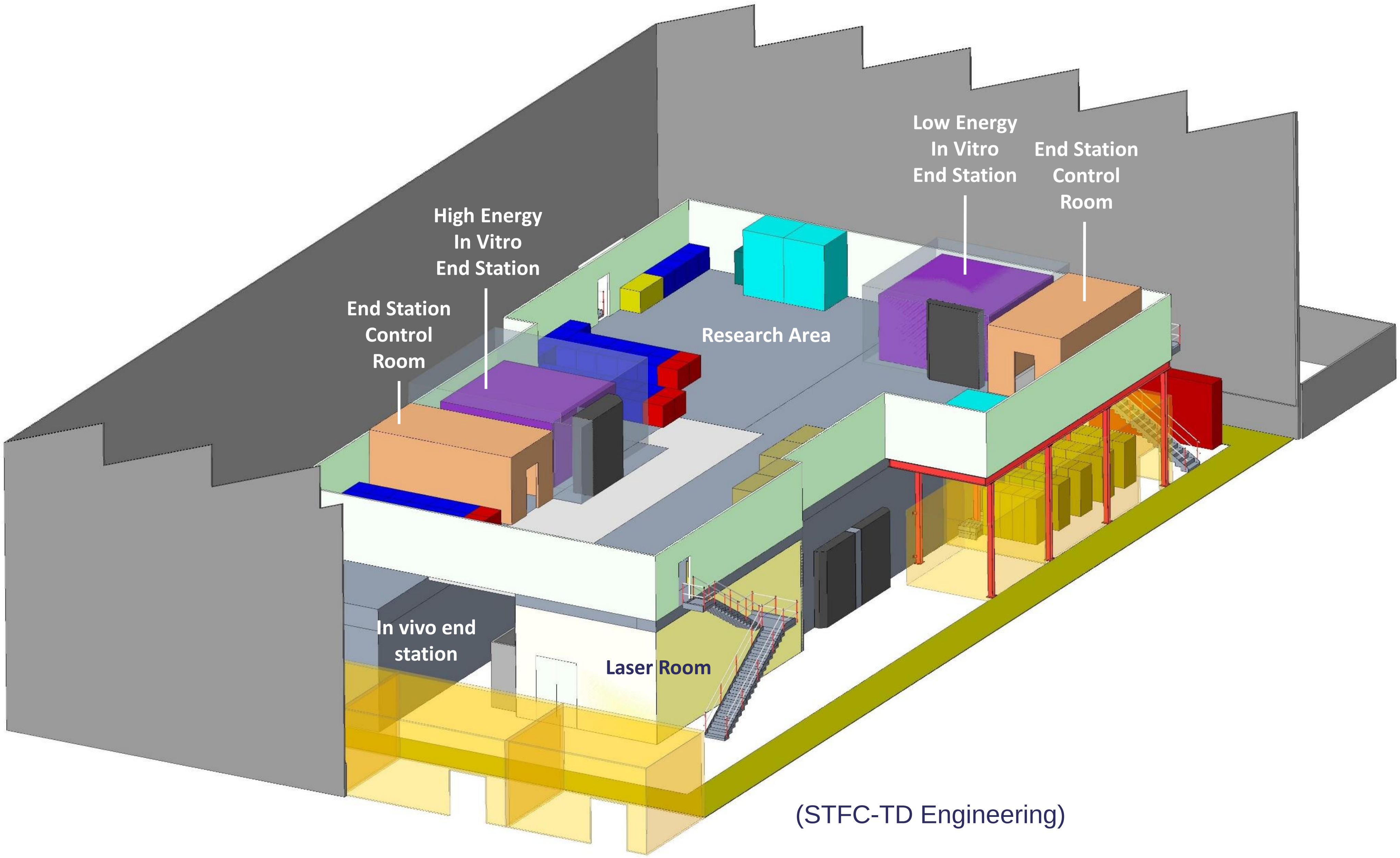
Vision:

High throughput, flexible end-station experiments with support laboratories enabling in-vitro and in-vivo research.

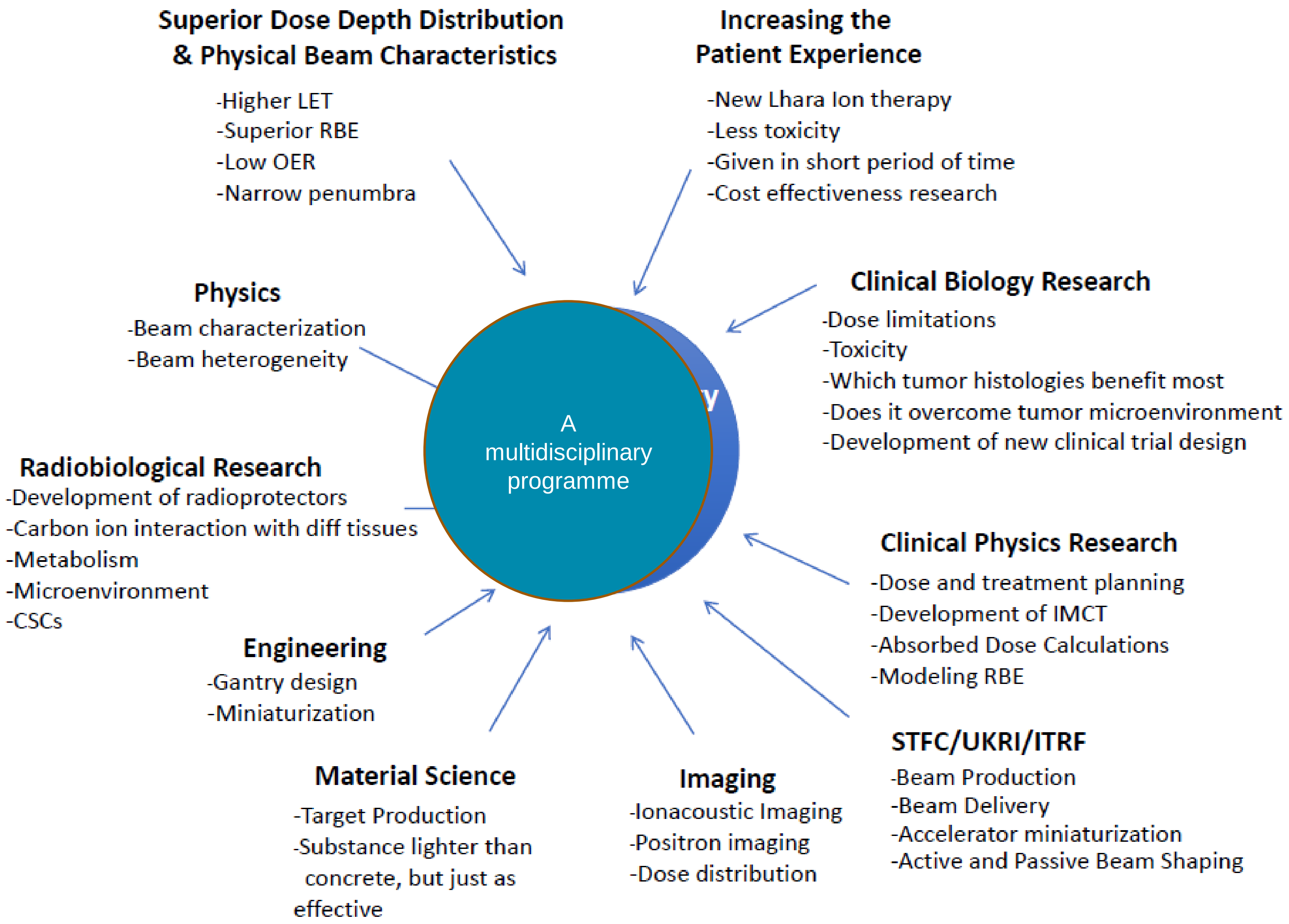
Building Concept Design showing the Research Area on the 1st floor



(STFC-TD Engineering)

Read More about ITRF/LhARA

- https://doi.org/10.1259/bjr.20200247
- https://www.frontiersin.org/articles/10.3389/fphy.2020.567738/full
- IPAC'23 (https://www.ipac23.org/preproc/index.html):
  - MOPL176, TUPA060, THPL106, THPM066, THPM083
- ITRF 12-month review: https://indico.stfc.ac.uk/event/823/
- IPAC'24 (https://ipac24.org/):
  - Update papers forthcoming in May



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