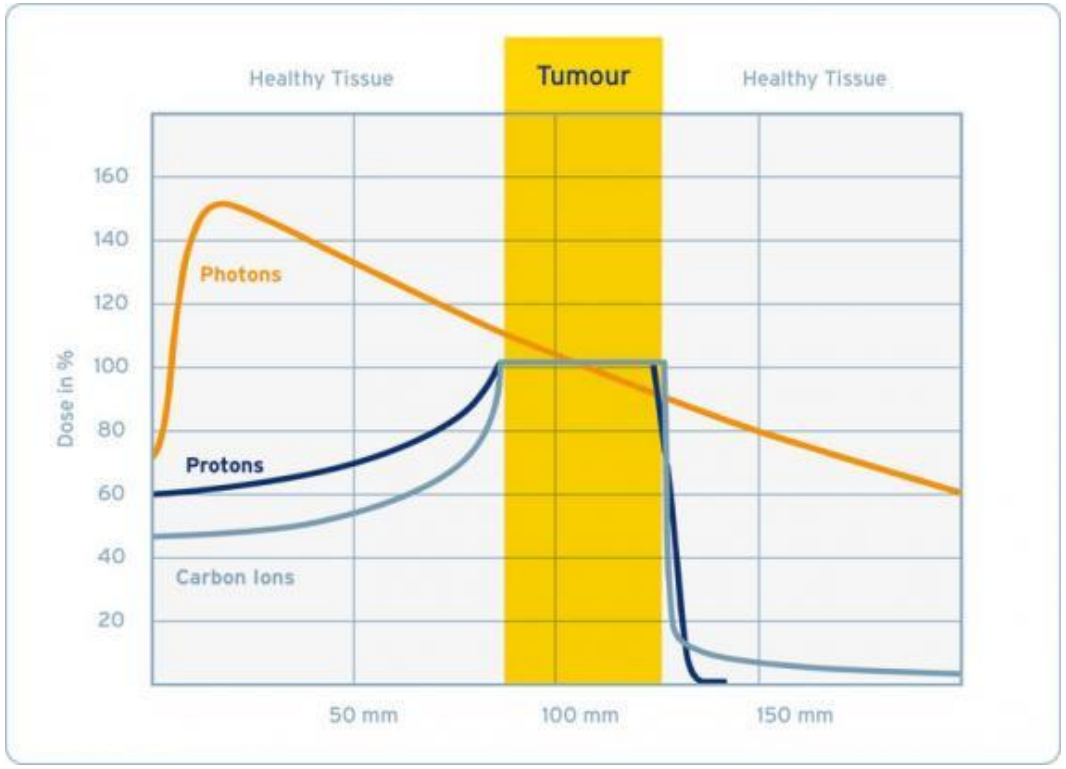
LhARA: the Laser-hybrid Accelerator for Radiobiological Applications

T. Greenshaw (Liverpool) for the consortium

Medical accelerators: the challenge

- Cancer is second most common cause of death globally.
  - Treatment using radiotherapy indicated in half of all cancer patients.
- Significant growth in demand for treatment anticipated:
  - 14.1×10^6 new cases in 2012 $\rightarrow$ 24.6×10^6 by 2030.
  - 8.2×10^6 deaths in 2012 $\rightarrow$ 13.0×10^6 by 2030.
  - Advantages of proton (ion) therapy increasingly recognised.
- Projections above based on reported cases, i.e. high-income countries.
- Could save 26.9×10^6 lives in low and middle-income countries by 2035.
- Provision on this scale:
  - Requires development of new and novel techniques.
  - Will generate substantial economic impact.



Medical accelerators: the opportunity

- R&D programme:
  - Incremental development.
  - System approach: produce robust, flexible next-generation facilities.
  - Multi-disciplinary R&D to harness novel techniques and provide opportunities for curiosity-driven science.
- Contribute to underpinning science:
  - Radiobiology – especially charged particle (p, ion).
  - In-situ dose-deposition imaging – especially p, ion.
  - Integration of on-treatment imaging, simulation, planning.

Particle beam therapy

- Proton:
  - Mostly cyclotron-based
  - Issues:
    - Energy modulation.
    - Shielding.
    - Source:
    - Injector per ion species.
    - Limit to instantaneous dose rate.
- Proton & ion (carbon):
  - Synchrotron based:
  - Issues:
    - Energy modulation.
    - Source:
    - Injector per ion species.
    - Limit to instantaneous dose rate.

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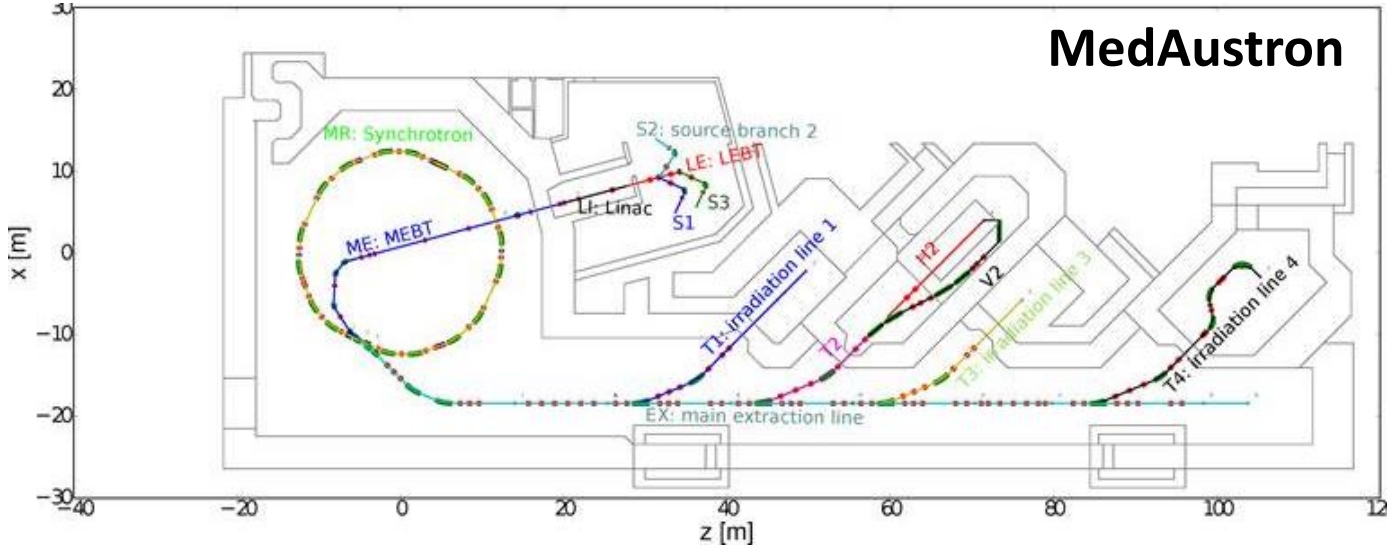
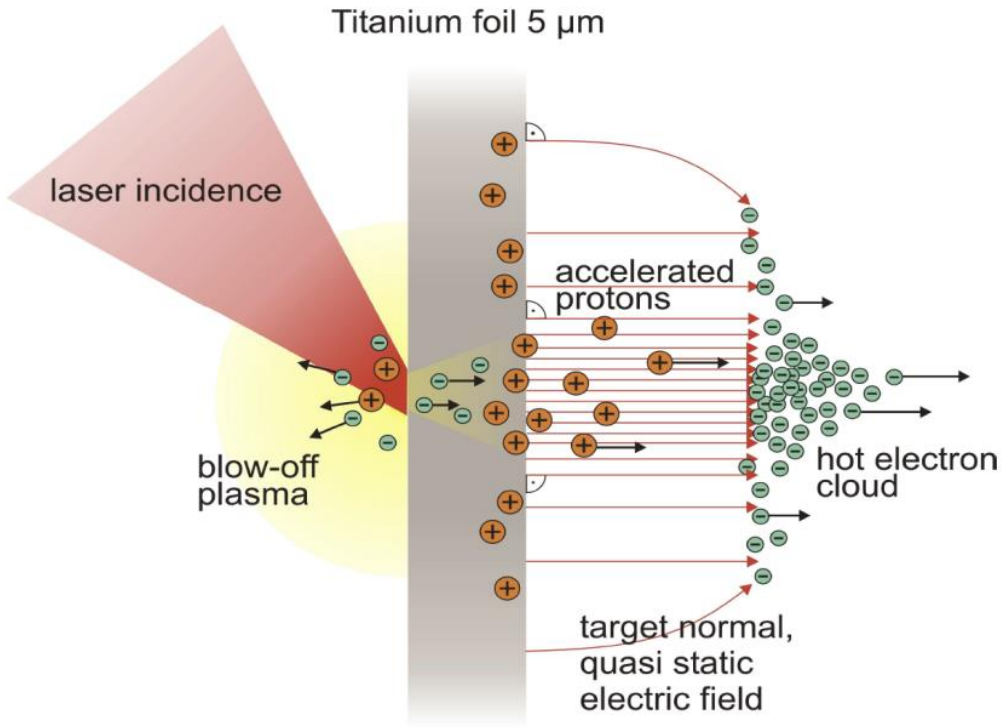
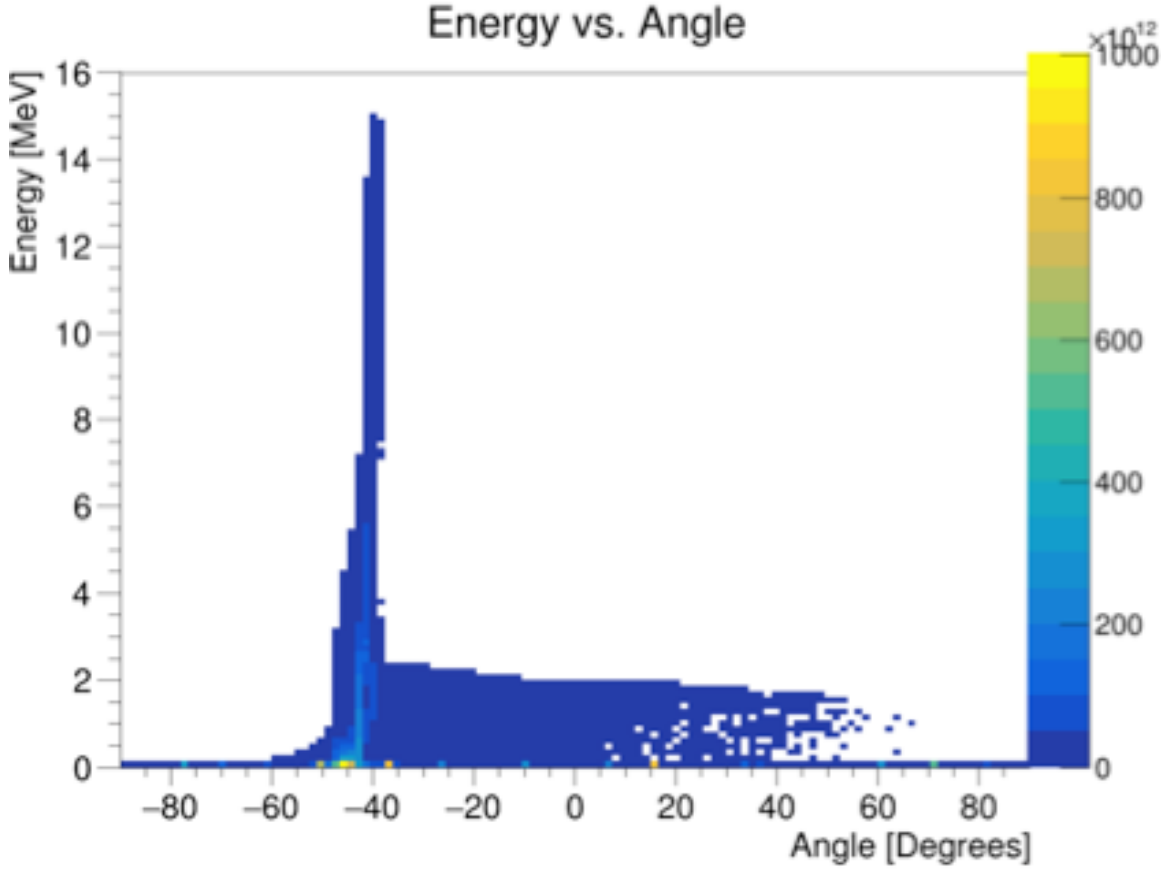


Laser-driven proton/ion source

- Advantage:
  - Enormous proton/ion flux at 10…15 MeV in short (30 fs) pulse.



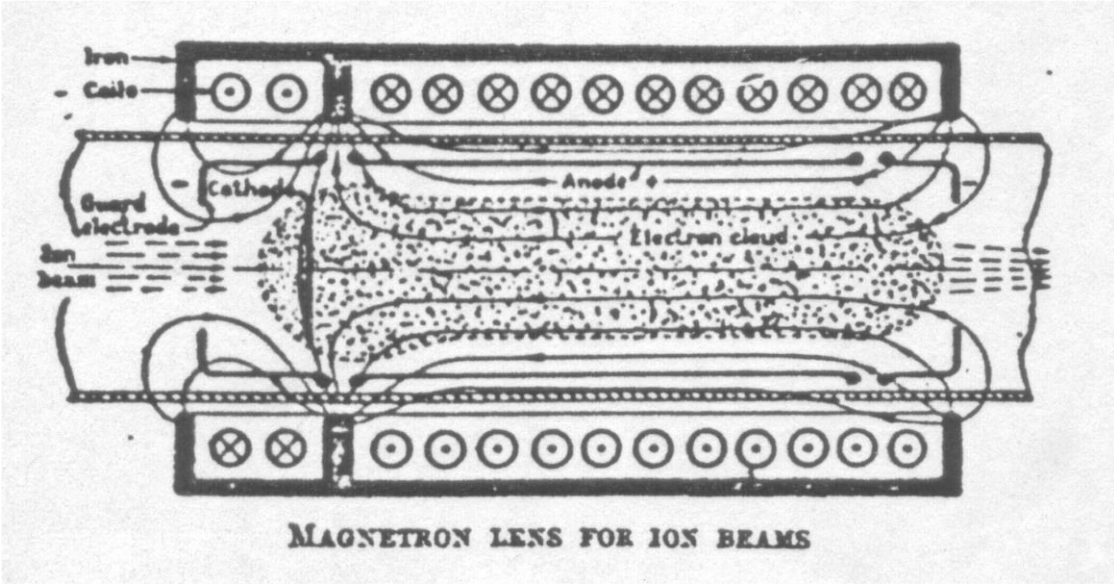
Positive ions from (hydrocarbon) contamination on target surface

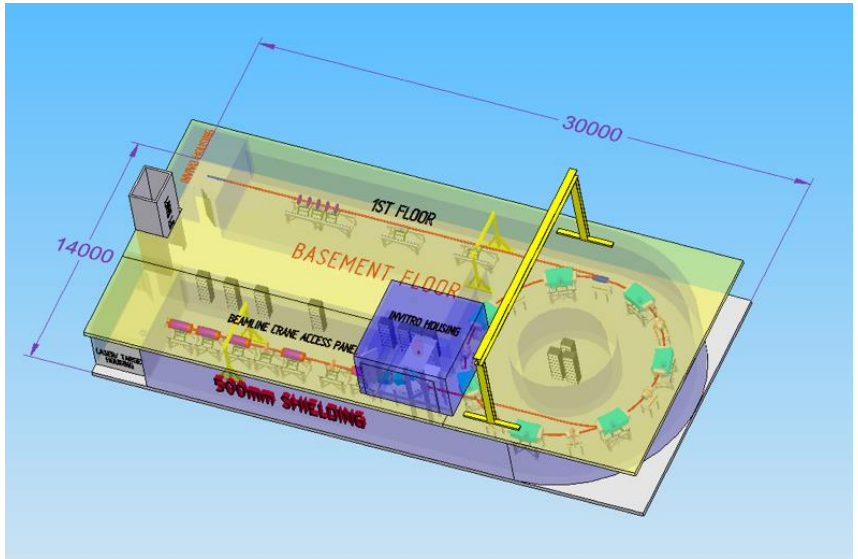


- Issue to be solved:
  - Efficient capture, focusing, selection and manipulation of divergent ion beam.

Laser-hybrid Accelerator for Radiobiological Applications

- LhARA; a novel, hybrid, approach:
  - High-flux, laser-driven proton/ion source.
  - Novel plasma (Gabor 1947) lens capture & focusing.
  - Post-acceleration and phase rotation: FFA &/or SC RF.
- Unique features:
  - Very large flux of *p* or ions in very short pulses:
    - Enormous instantaneous dose.
  - Inject at ~15 MeV into first accelerating structure.
    - Overcomes space-charge limit of today's ion sources.
  - Staged implementation:
    - In-vitro studies permitted at 15 MeV:
      - Source, capture, transport.
    - In-vivo studies using post-accelerator (127 MeV *p*; ~35 MeV/u).
- Uniquely flexible radiobiology facility:
  - Many ions, proton to carbon, in single facility.
  - Wide range of energy and dose rate, allows study of UHDR/FLASH radiotherapy.
- Technologies can be developed to create uniquely flexible therapy facility.





The Consortium

University partners:

Imperial College London

University of Liverpool

CCAP Centre for the Clinical Application of Particles

Manchester 1824 The University of Manchester

Department of Physics

University of Strathclyde Science

Royal Holloway University of London

Queen's University Belfast

Accelerator institute partners:

Science & Technology Facilities Council ASTeC

JAI John Adams Institute for Accelerator Science

The Cockcroft Institute of Accelerator Science and Technology

Laboratory partners:

Science & Technology Facilities Council Central Laser Facility

Science & Technology Facilities Council ASTeC

Science & Technology Facilities Council ISIS Neutron and Muon Source

Clinical partners:

Oncologists, medical/biophysics, providers

NHS Imperial College Healthcare NHS Trust

70 YEARS OF THE NHS 1948 - 2018

NHS The Clatterbridge Cancer Centre NHS Foundation Trust

Industrial partners:

Maxeler Technologies Maximum Performance Computing

Corerain 鲲云科技

LEO Cancer Care

Conclusions

- Laser-hybrid approach has potential to:
  - Overcome dose-rate limitations of present PBT sources.
    - Harness laser-driven beams for science and innovation.
  - Deliver uniquely flexible facility:
    - Range of ion species, energy, dose, dose-rate.
  - Disruptive/transformative approach ‘for 2050’ …

- Opportunity:
  - Develop and prove novel systems in production system.
  - Deliver research facility dedicated to radiobiology.
  - Contribute to study of biophysics of charged-particle beams.

- First and next steps:
  - Initial concept developed and prototype evaluation underway.
  - Working towards initial CDR for LhARA.