Laser-driven proton and ion source (WP2)

Context, outline and roadmap

WPMs: E. Boella (Lancaster University), N. P. Dover (Imperial College London), R. Gray (University of Strathclyde)

LhARA collaboration meeting, 15th December 2021

Why laser driven ion sources?

- High intensity laser driven ion sources have unique features:
  - **Naturally extremely high peak current** (ultra-short generation time)
  - **High energy from source** (up to ~100 MeV)
  - **Initially approximately charge neutral**
  - **Triggerable and on-demand**

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- Generated beams are typically:
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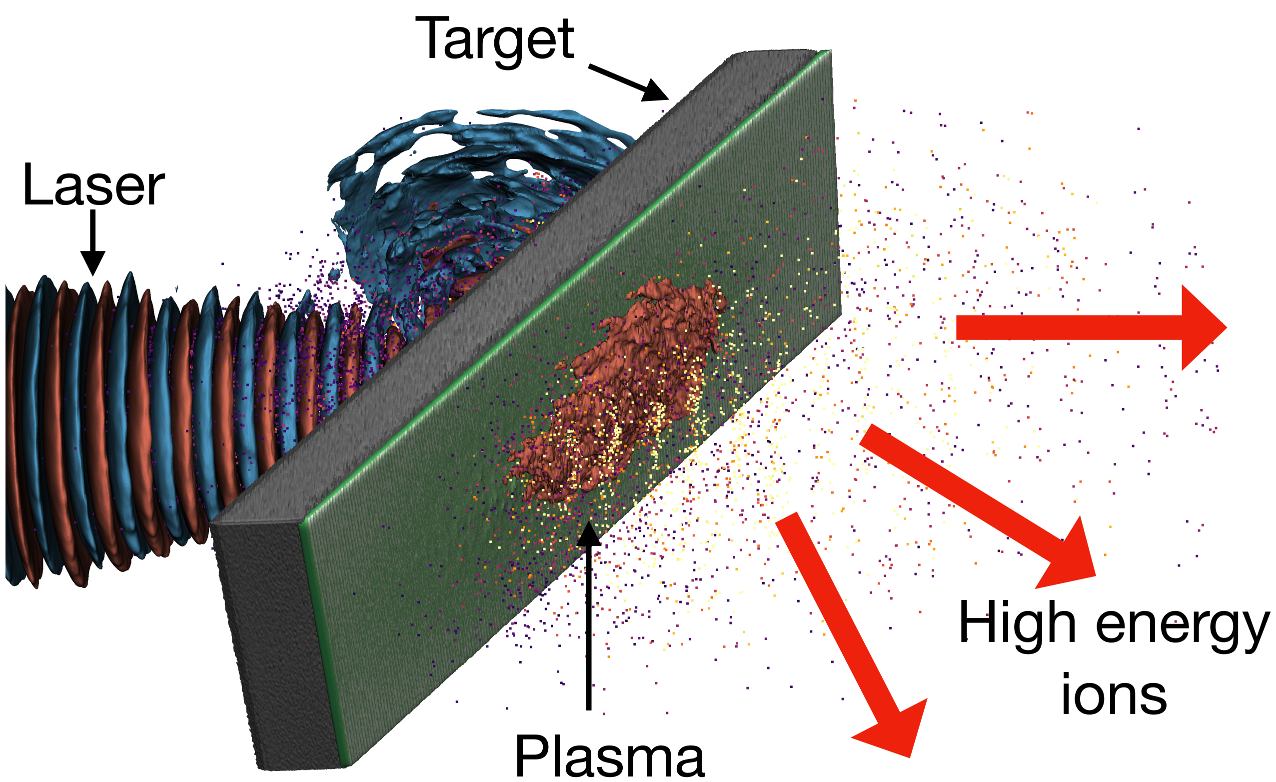
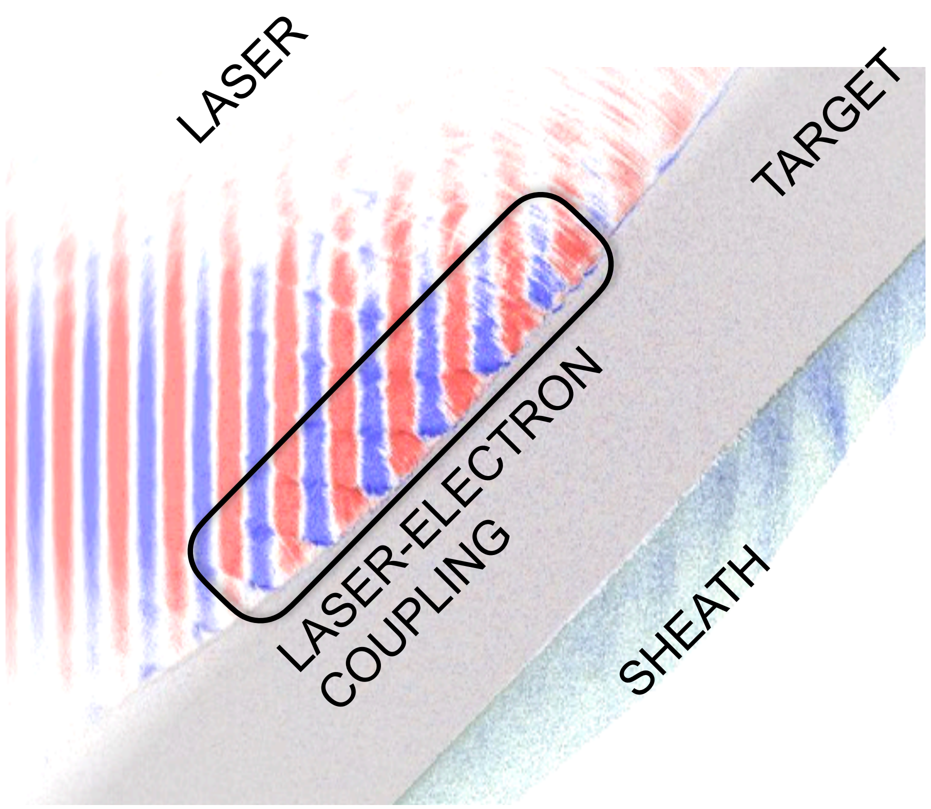
  - **Typically broadband energy** (quasi-thermal spectrum)
- Complementary technology to existing methods, <u>with new applications</u>
  - **Ultrafast heating**
  - **Temporally resolved probe**
  - **Ultrahigh dose rate radiobiology**

How do laser driven ion sources work?





Well understood technique: **target normal sheath acceleration (TNSA)**

Laser electromagnetic fields

Energetic electrons

Sheath electrostatic fields

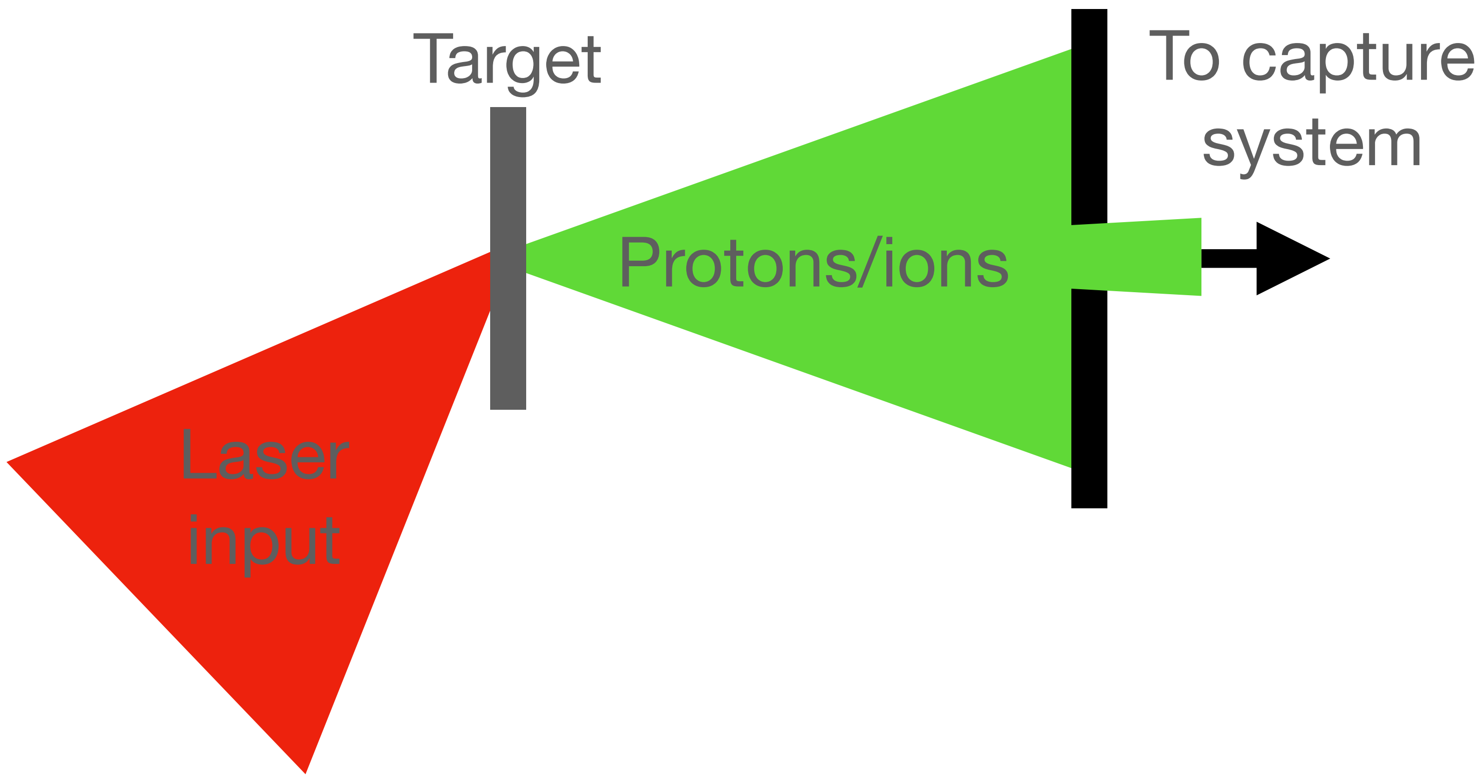
Accelerated surface ions

Source optimisation involves optimising energy conversion

What does LhARA need from its source?

LhARA beamline requirements from source:

- Proton energies up to 15 MeV
- Different ion types
  - e.g. C6+ up to 4 MeV/u
- Ultrashort generation time
- 10 Hz operation
- High stability
- High flux
- Coupling to capture system



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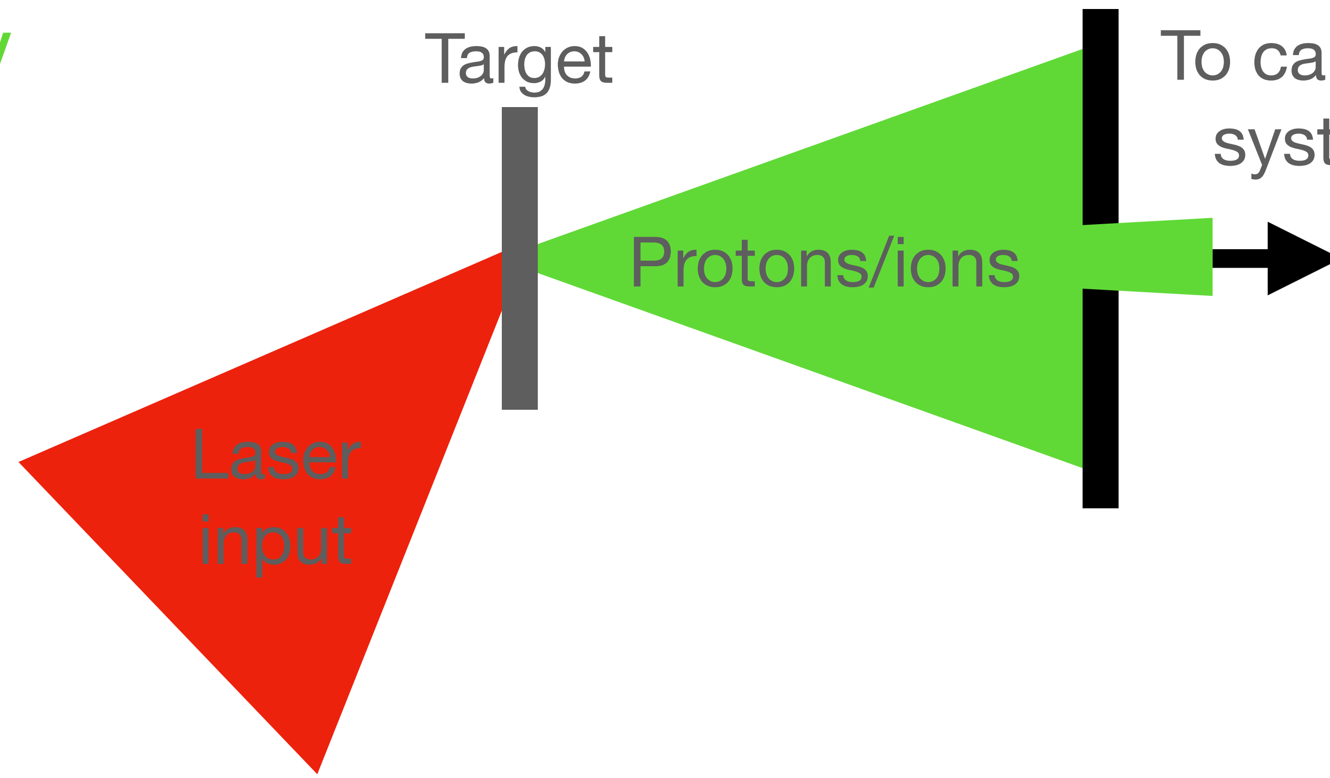

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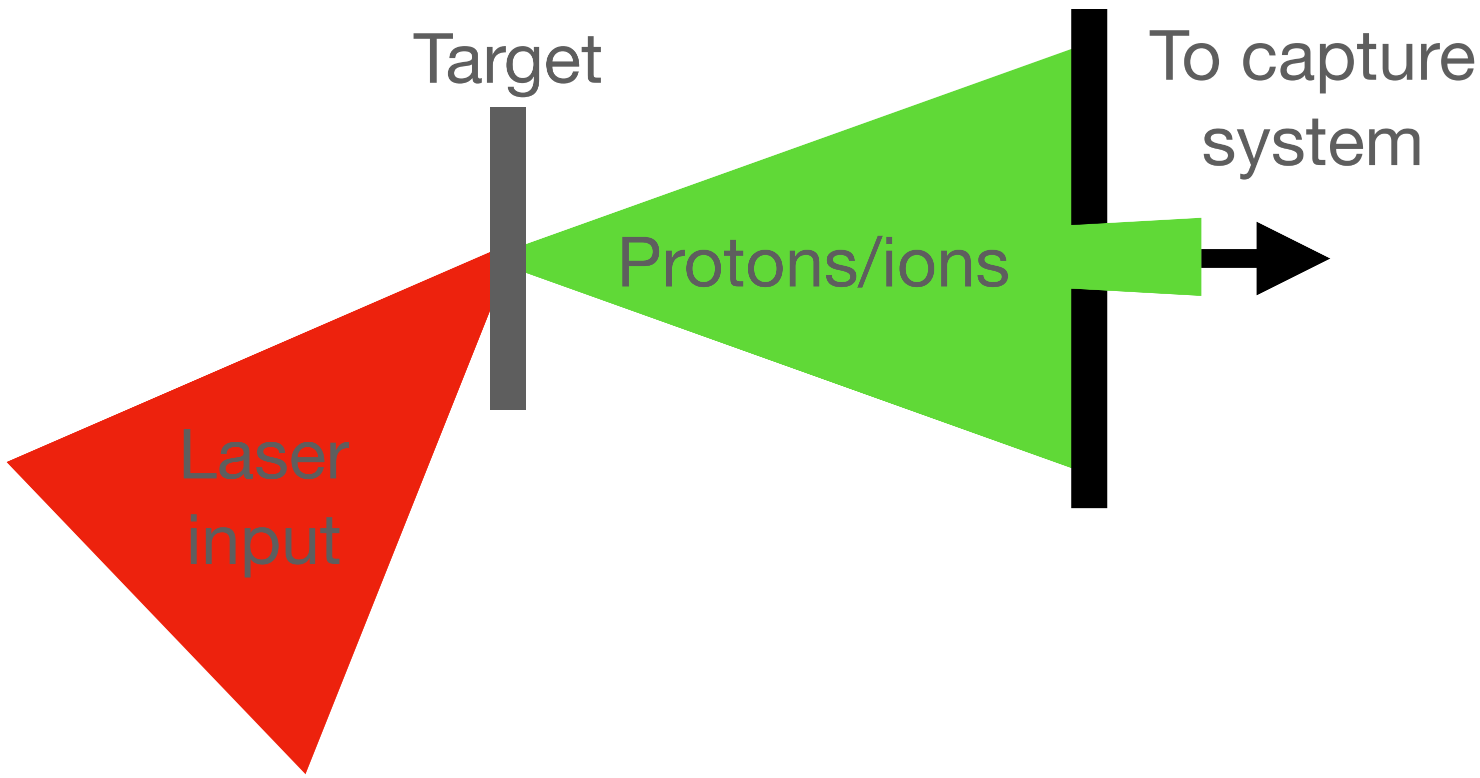

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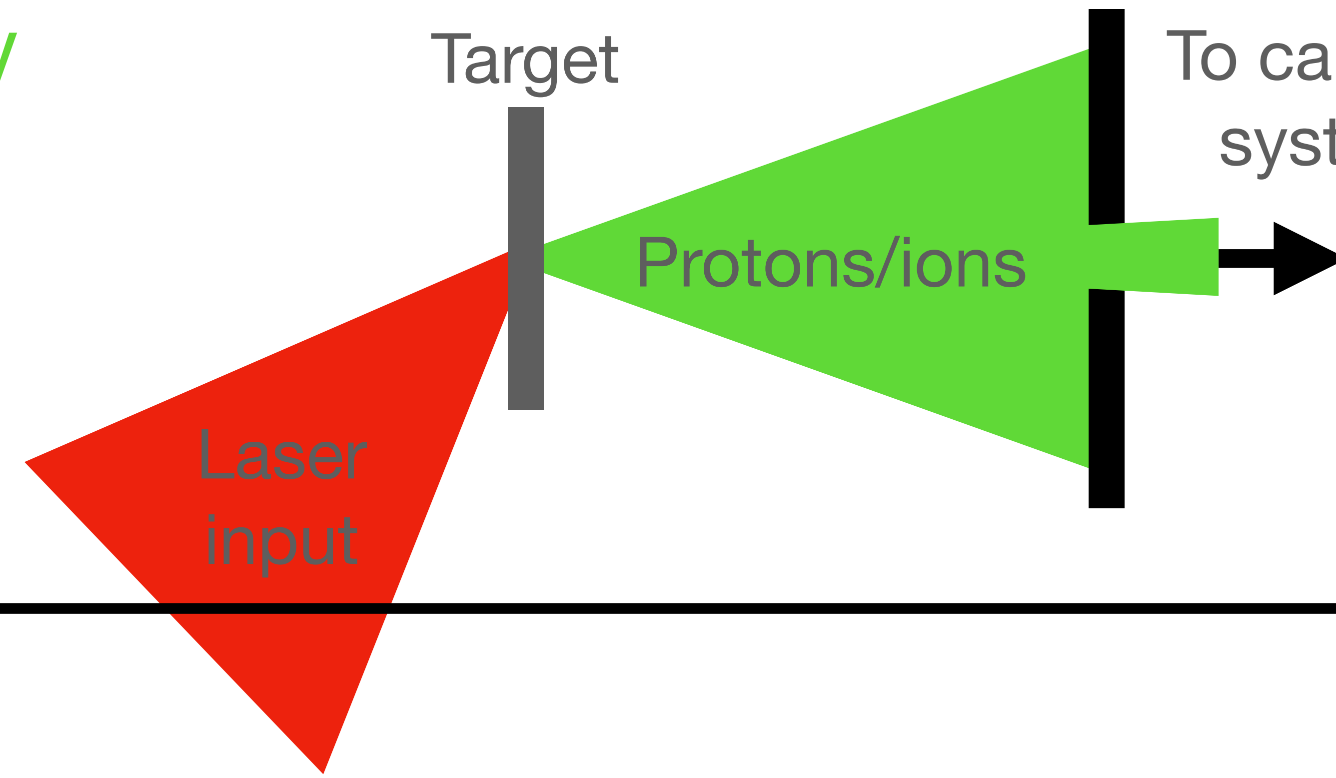

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Demonstrating these is essential for de-risking LhARA ion source

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Theme 1: Source demonstration & characterisation with established technology

- Objective 1: High fidelity **simulations** of ion generation for LhARA baseline conditions
  - Hydrodynamics and particle-in-cell simulations to identify key laser-plasma requirements
  - Extended programme of simulations to optimise for ion production.

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  - 10 Hz ion diagnostics: spectroscopy (Thomson parabola, time of flight), 2D imager
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- Objective 3: LhARA **baseline experiment** for proton and carbon generation at 1 Hz
  - Generate proton and carbon beams in LhARA energy range on SCAPA at 1 Hz
  - Benchmark PIC simulation output to help define future design concepts.

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  - Develop active stabilisation techniques of laser, target, and source properties

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  - Test source with integrated capture system

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- Objective 6: Demonstrate continuous operation of **full specification ion source**
  - Show stable source at 5 Hz (and 10 Hz capable) within beam capture specifications
  - Deliver specifications of required procurement for LhARA ion source

What is the current work schedule?

*Subject to change depending on funding levels

<table>
<tr><th></th><th>Y1</th><th>Y2</th><th>Y3</th><th>Y4</th><th>Y5</th></tr>
<tr><td>O1: Baseline simulations</td><td bgcolor="#57BFFF"></td><td bgcolor="#57BFFF"></td><td bgcolor="#57BFFF"></td><td></td><td></td></tr>
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<tr><td>O6: Full spec. source demo</td><td></td><td></td><td></td><td bgcolor="#57BFFF"></td><td bgcolor="#57BFFF"></td></tr>
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Who will be contributing to WP2?

Lancaster

- *2D/3D PIC Simulations*
- *Hydrodynamic modelling*

Strathclyde

- *LhARA baseline high power laser experiments via SCAPA*
- *Diagnostics & active feedback*

Imperial

- *High repetition rate ion generation on Zhi/Cerberus*
- *Diagnostics & active feedback*

Queen's

- *Development of high rep rate targetry*

CLF (STFC)

Scientific Computing (STFC)

Dr. Rajeev Pattahill

- *Machine Learning/Active Feedback*
- *High-rep diagnostic techniques*

Stanford/SLAC

Dr. Siegfried Glenzer

CLF/Scitech Precision Ltd.

Christopher Spindloe

High repetition rate targetry/ Water sheet

Science and Technology Facilities Council

Coming up next:

Ross Gray (Strathclyde): Experiments & Technology Development on LhARA WP2

Elisabetta Boella (Lancaster): What can we expect from TNSA for SCAPA-like conditions?