Current status of ion source work package for LhARA

WPMs: E. Boella (Lancaster), N.P. Dover (Imperial), R.J. Gray (Strathclyde)

LhARA collaboration meeting, RAL, 27th April 2022

Laser driven ion source session:

11:15~11:35 - Nick Dover (Imperial):
Current status of ion source work package for LhARA

11:35~11:55 - Ross Gray (Strathclyde):
Underpinning ion source technologies and laser drivers

11:55~12:15 - Charlotte Palmer (QUB):
High-repetition rate laser-solid interactions: Automation, optimisation, challenges

Why laser driven ion sources?

- **High intensity laser driven ion sources have unique features:**
  - Naturally extremely high peak current (< ps generation time)
  - Triggerable and on-demand
  - High energy from source (up to ~100 MeV)
  - Neutralised by co-moving electrons

Negligible space-charge related limitations in source

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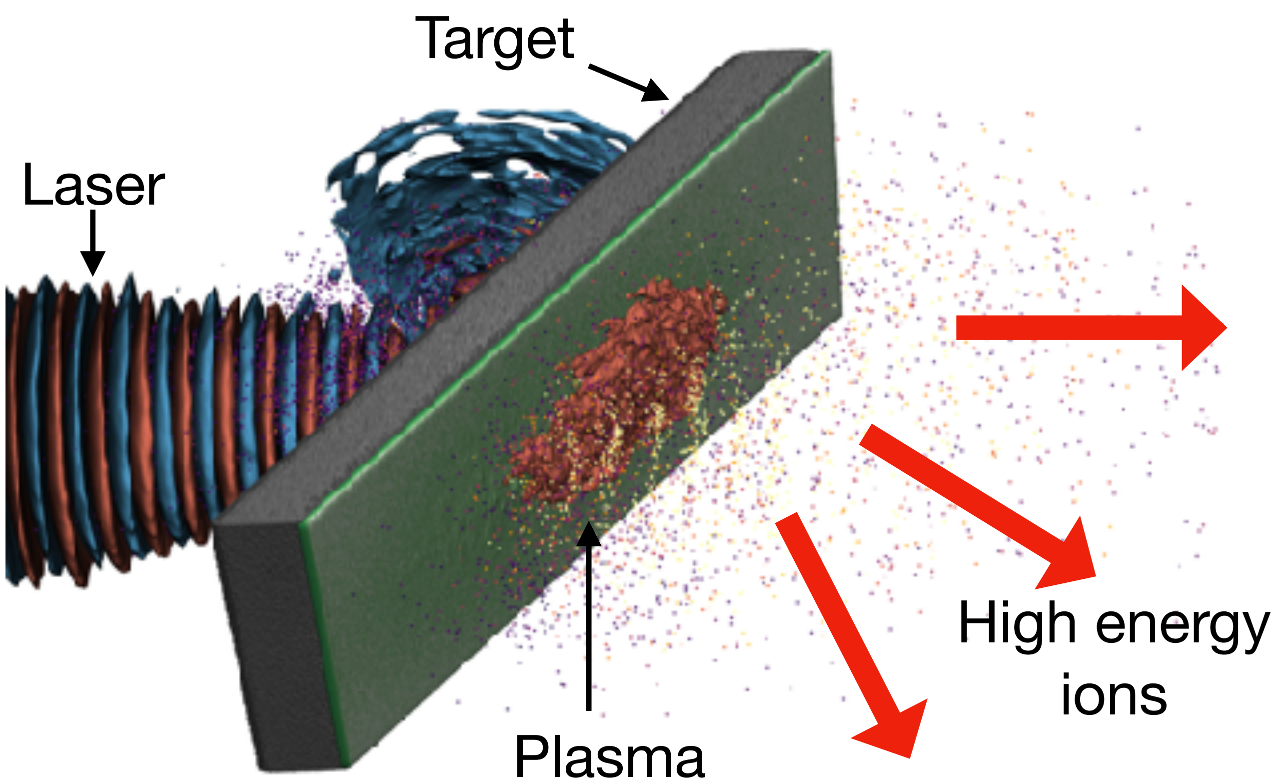
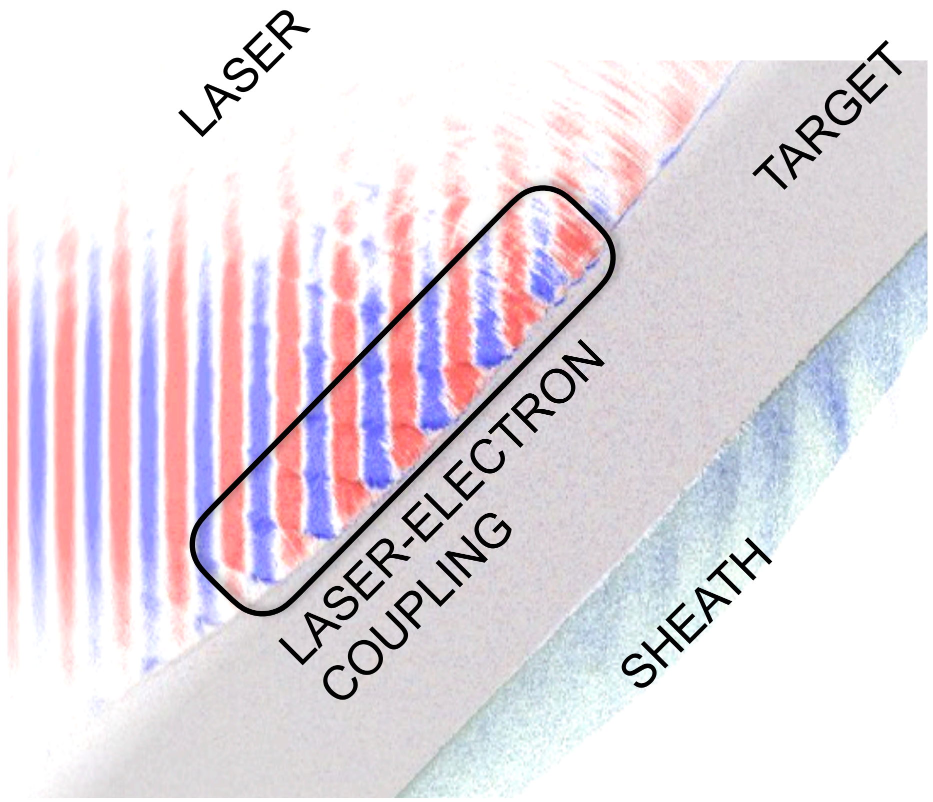
- **Attractive technology to deliver ions at high instantaneous dose rate**
- **Laser driven sources provide beams which are:**
  - Highly divergent (> 10° emission cone)
  - Broadband particle energy (quasi-thermal spectrum, up to >>10 MeV/u depending on laser)

How do laser driven ion sources work?





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

Laser electromagnetic fields

Energetic electrons

Sheath electrostatic fields

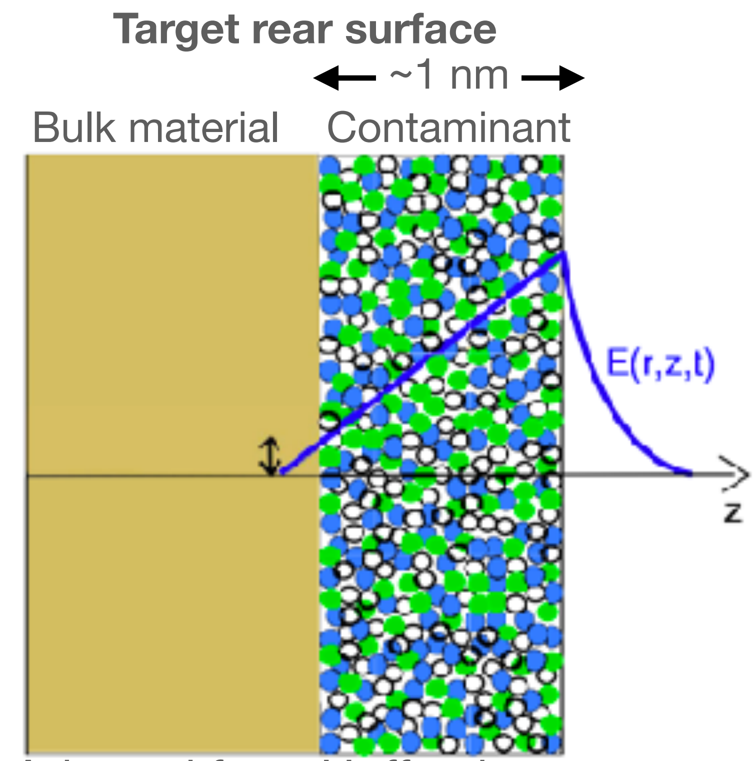
Accelerated surface ions

Source optimisation involves optimising energy conversion

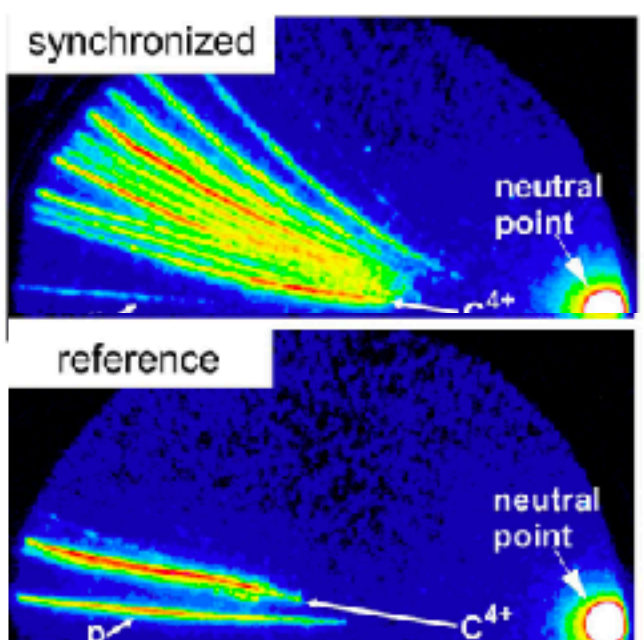
Generation of different ion types

TNSA accelerates surface ions!

- Surface contaminants always exist on target foils
  - Typically ~ 1 nm thick
  - Hydrocarbon and water, i.e. a mixture of hydrogen, carbon & oxygen
- Normally, protons preferentially accelerated (highest *q/m*)
- Contaminant removal leads to preferential acceleration of bulk ions
  - Heat up foil to “boil off” contaminants
  - Selectively remove contaminants using ablation or sputtering



Adapted from Hoffmeister+ PRSTAB 16, 041304 (2013)



Adapted from Sommer+ PPCF 60, 054002 (2018)

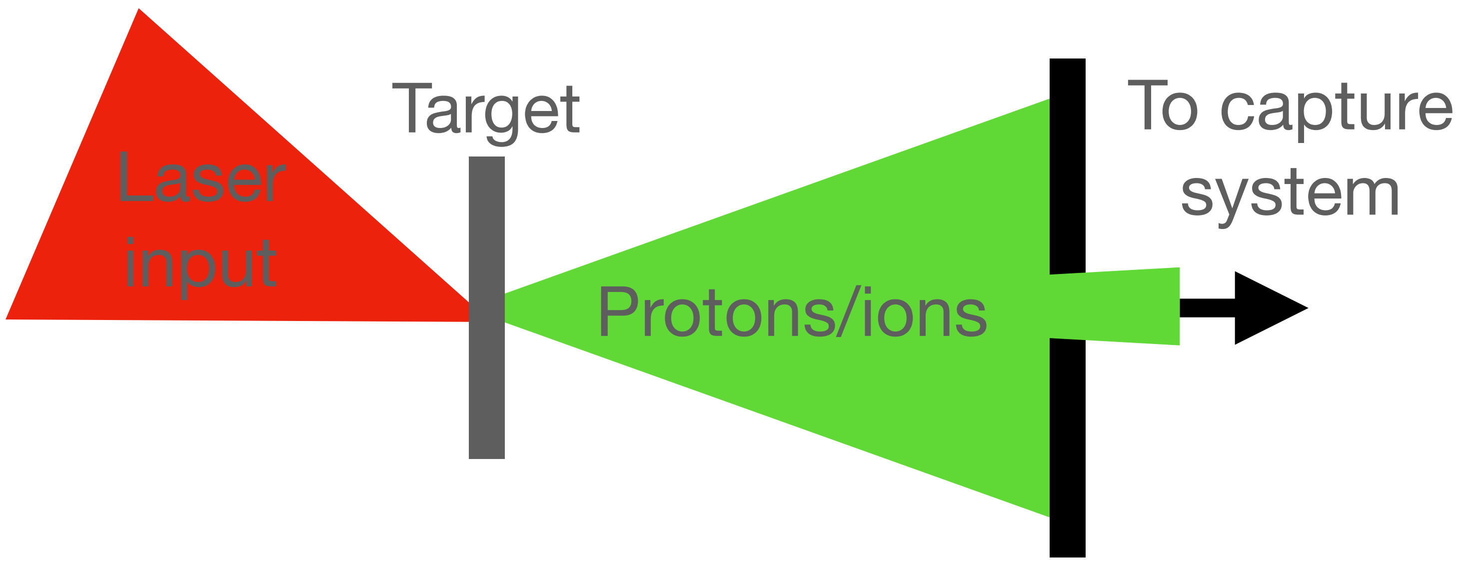
What does LhARA need from its source?

LhARA beamline requirements from source:

- Proton energies 15 MeV
- Different ion types
    - e.g. C^{6+} 4 MeV/u
- 10 Hz operation
- High stability
- High flux

Within energy and angular acceptance of capture

- Environment suitable for coupling to capture system



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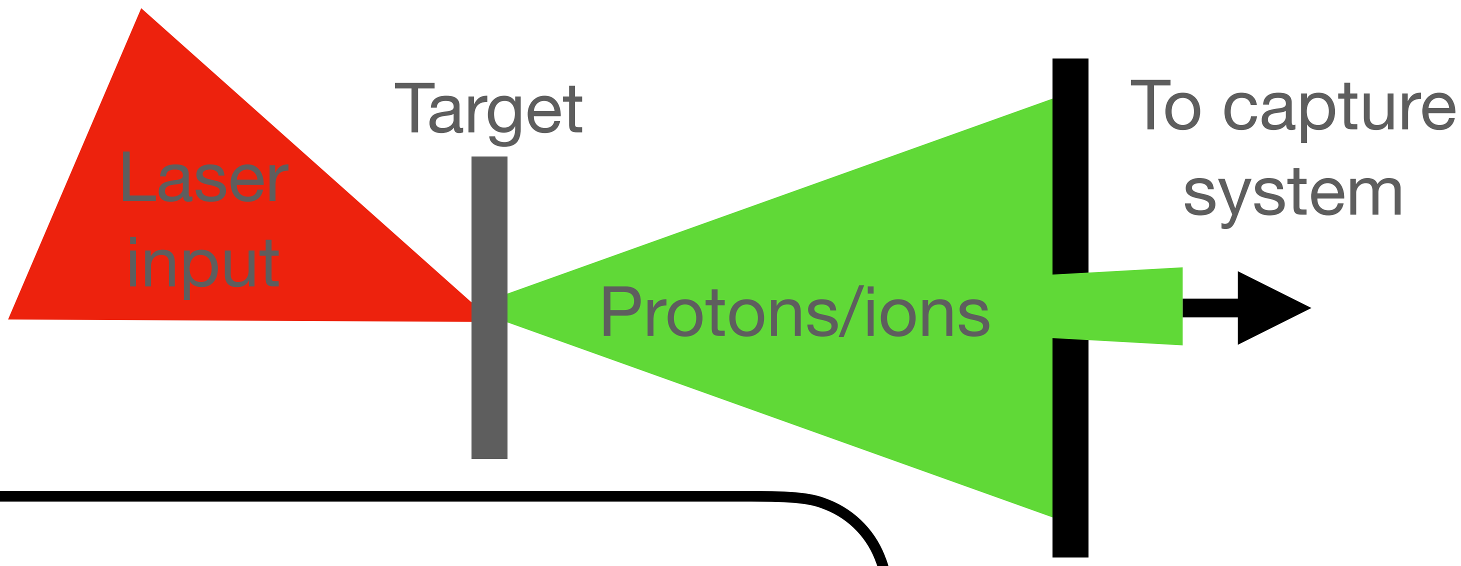

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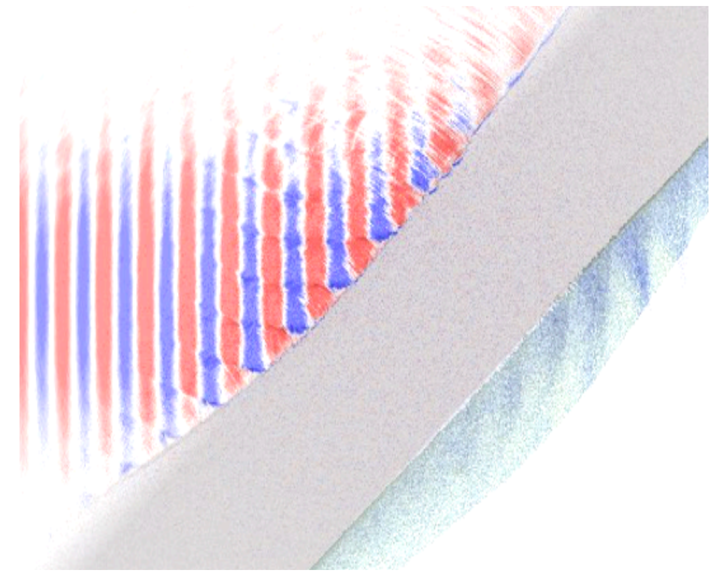
Demonstrating this is essential for de-risking LhARA ion source

Planned objectives for WP2 activity

Years 1-2: preliminary activity

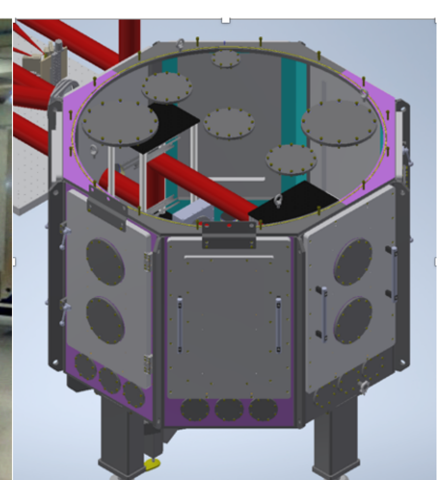
Baseline simulation campaign to optimise source

- Hydrodynamics simulations of low intensity “prepulse”
- Full-scale 3D particle-in-cell simulations of ion generation



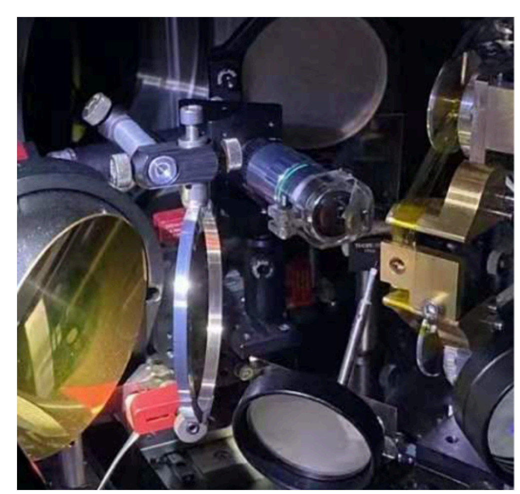
Single-shot LhARA spec. proton generation (SCAPA, Strath)

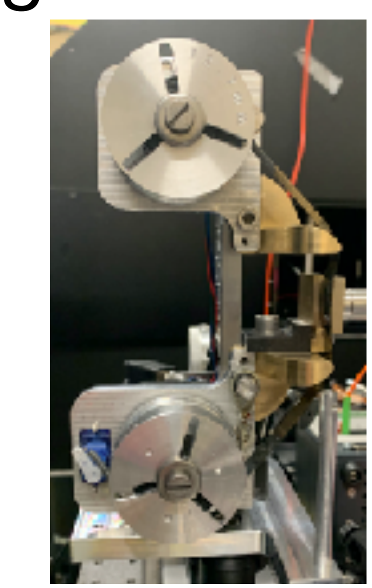
- Proton generation on SCAPA, matched to LhARA laser
- Parametric optimisation



Ion generation at 10 Hz (Zhi/ Cerberus lasers, ICL)

- Targetry requirements at 10 Hz
- Source monitoring and stabilisation

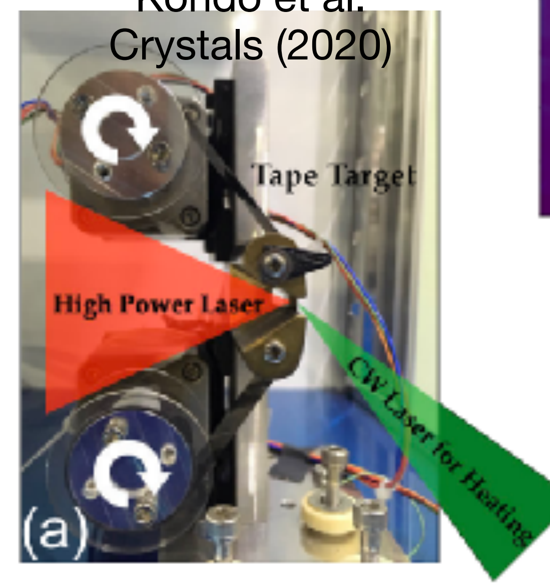




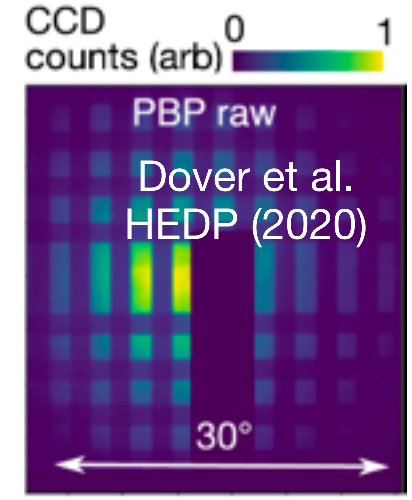
Planned objectives for WP2 activity

Years 3-5: preconstruction programme

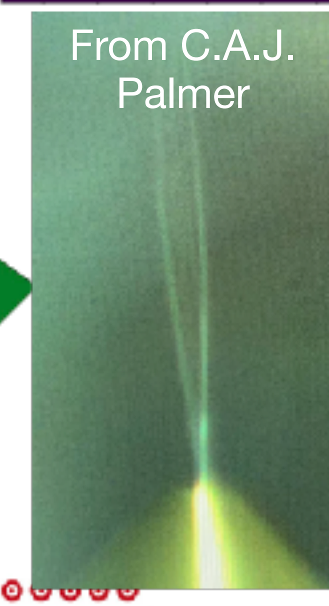
- **Construction of bespoke diagnostic suite**
  - Laser spatial and temporal measurement
  - Ion spectral and spatial measurement
- **Optimisation of heavy ion acceleration**
  - Contaminant control at high repetition
- **Development of advanced 10 Hz target platform**
  - Water jet target
  - Active target stabilisation and debris control
- **Integration of developed laser ion source technologies**
  - Demonstrate integrated source and diagnostic system and compatibility with capture
- **LhARA specification beam generation at 5 Hz**
  - SCAPA experiments for near-full scale LhARA beam generation over ~1 hr duration

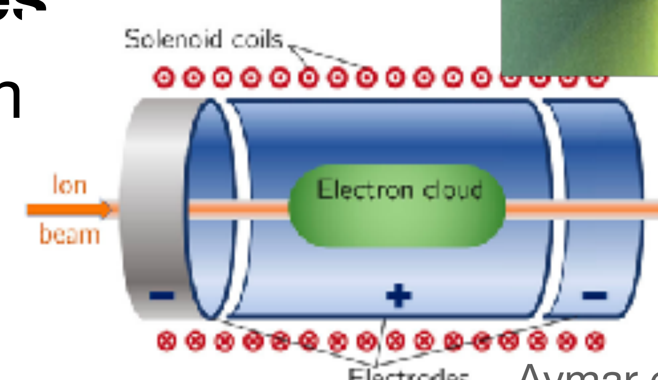


Kondo et al. Crystals (2020)

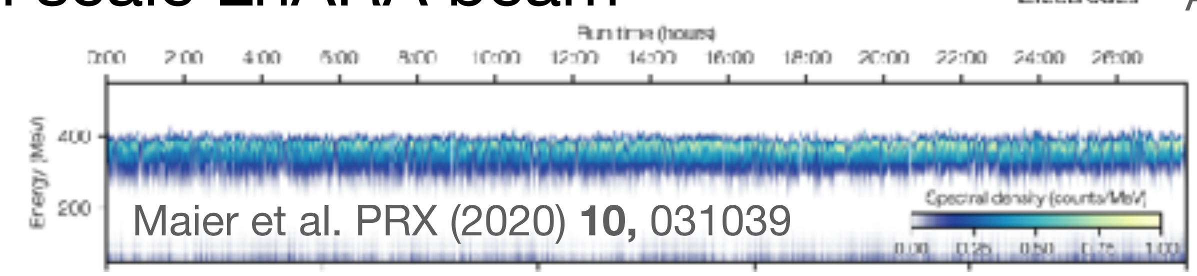


Dover et al. HEDP (2020)


From C.A.J. Palmer



Aymar et al. Front. Phys. (2020)



Maier et al. PRX (2020) **10,** 031039

Workplan includes all major UK laser ion source groups

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)

Prof Rajeev Pattathil
- *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

Summary

- **WP2 will deliver a comprehensive programme addressing technical development of laser ion source**
- **Key points to address in 5 year programme include:**
  - Benchmarking source using state-of-the-art simulations
  - Developing tailored high repetition rate diagnostics
  - Addressing technical issues related to continuous high repetition operation
  - Automating source optimisation and stabilisation
  - Experimental demonstration of LhARA spec beam at 5 Hz
- **Team and facilities in place to begin work upon project approval**