John Adams Institute for Accelerator Science

Imperial College London

LhARA Laser-hybrid Accelerator for Radiobiological Applications

LhARA Laser-Driven Proton & Ion Source WP1.2

N. Dover (Imperial), R. Gray, R. Wilson (Strathclyde), E. Boella (Lancaster), C.A.J. Palmer (QUB) plus many contributors

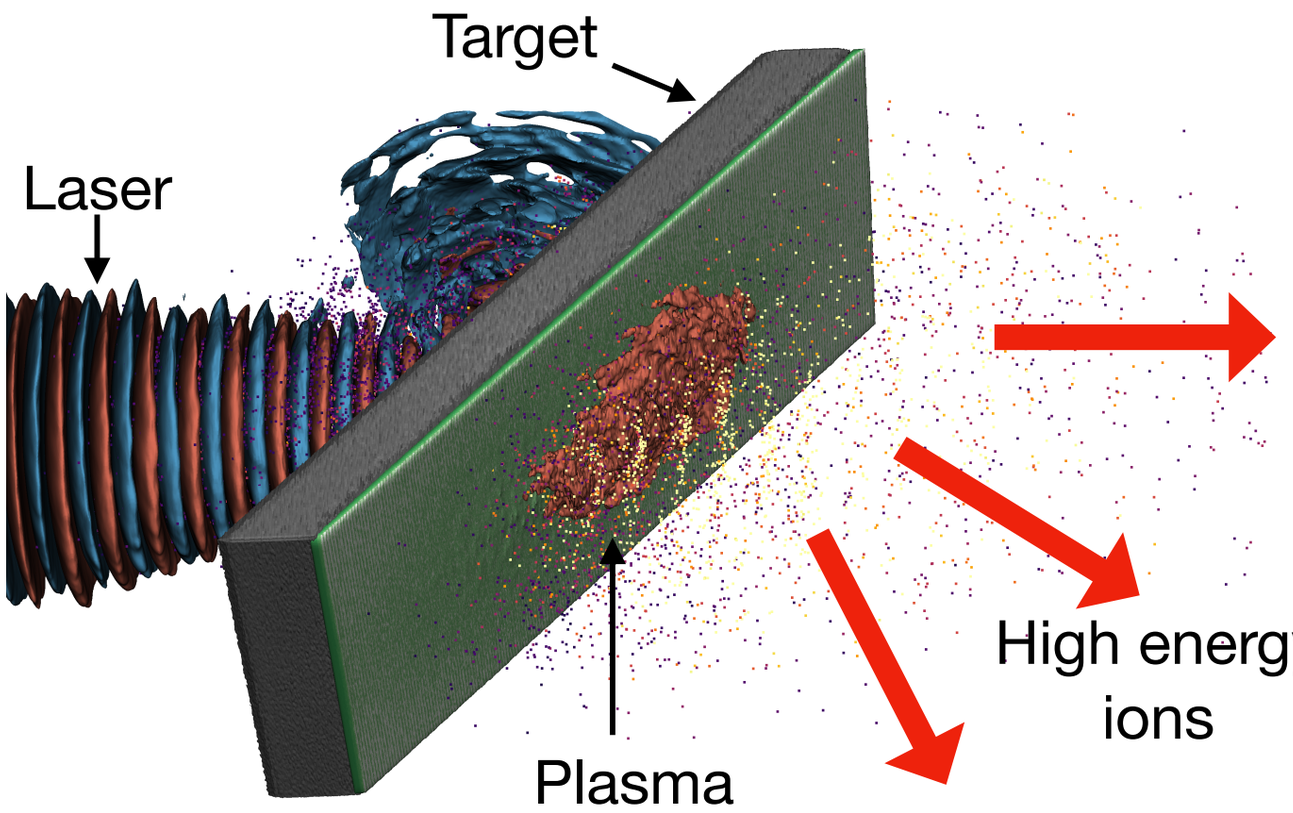
LhARA 12 month review, 20th September 2023

Session overview

- 10:10~10:30: WP1.2 overview and summary of activity at Imperial College / Lancaster

- 10:30~10:55: Activity at Strathclyde and results from first LhARA beamtime on SCAPA

Laser driven ion source for LhARA



- High energy (e.g. ~15 MeV p+, 4 MeV/u C6+) from source
- Minimised space charge issues, enabling high peak current
- Needs to operate at 10 Hz for long periods
- Aiming to deliver 10^9 protons or 10^8 carbon ions per shot, eventually other ions
- Initially tape targets, but developing other options, e.g. water jet

Overview of PA1 activities in WP1.2

Experimental R&D:

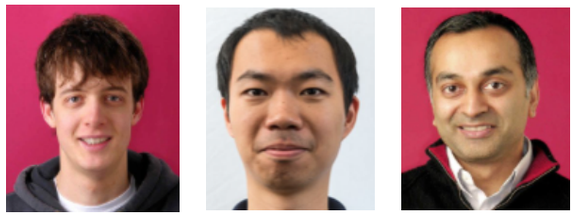
- ‘Full scale’ LhARA specification testing on SCAPA laser, Strathclyde
- Application focused diagnostic and targetry development
- High repetition rate, automation and longevity studies on Zhi laser, Imperial

Numerical modelling:

- State-of-the-art high fidelity 3D simulations of the ion source
- Parametric optimisation to support experimental studies

Experimental R&D at ICL - Zhi laser

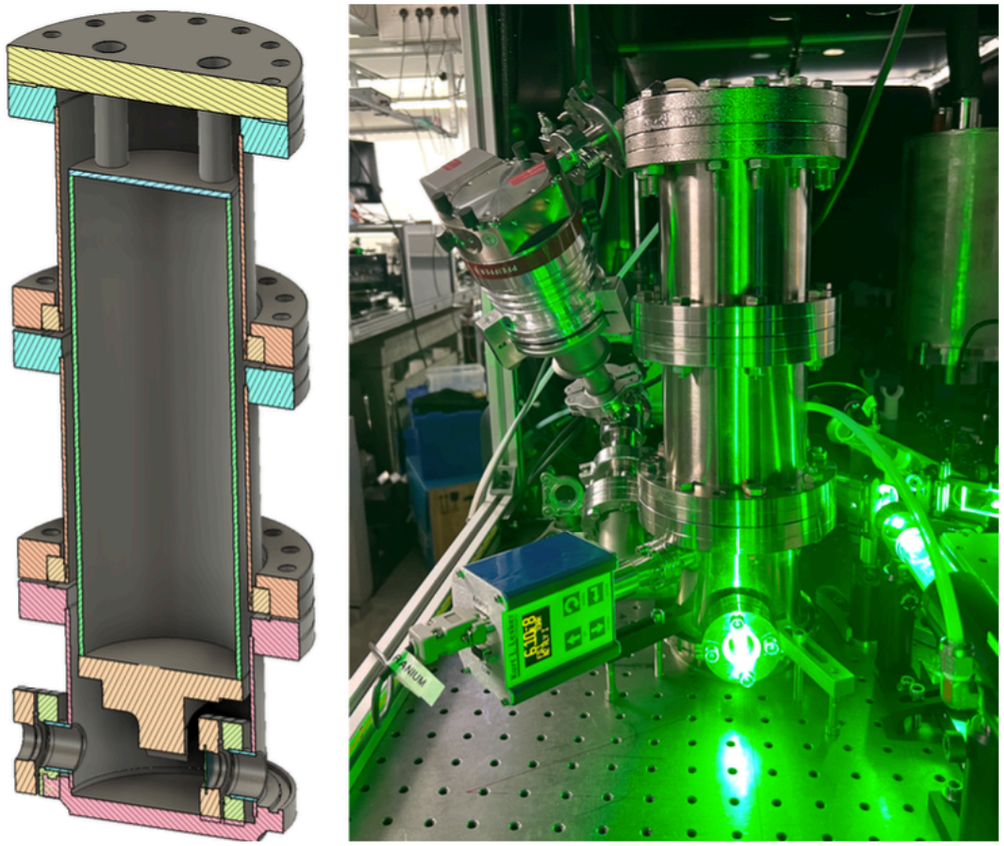
O. Ettlinger, N. Xu, Z. Najmudin



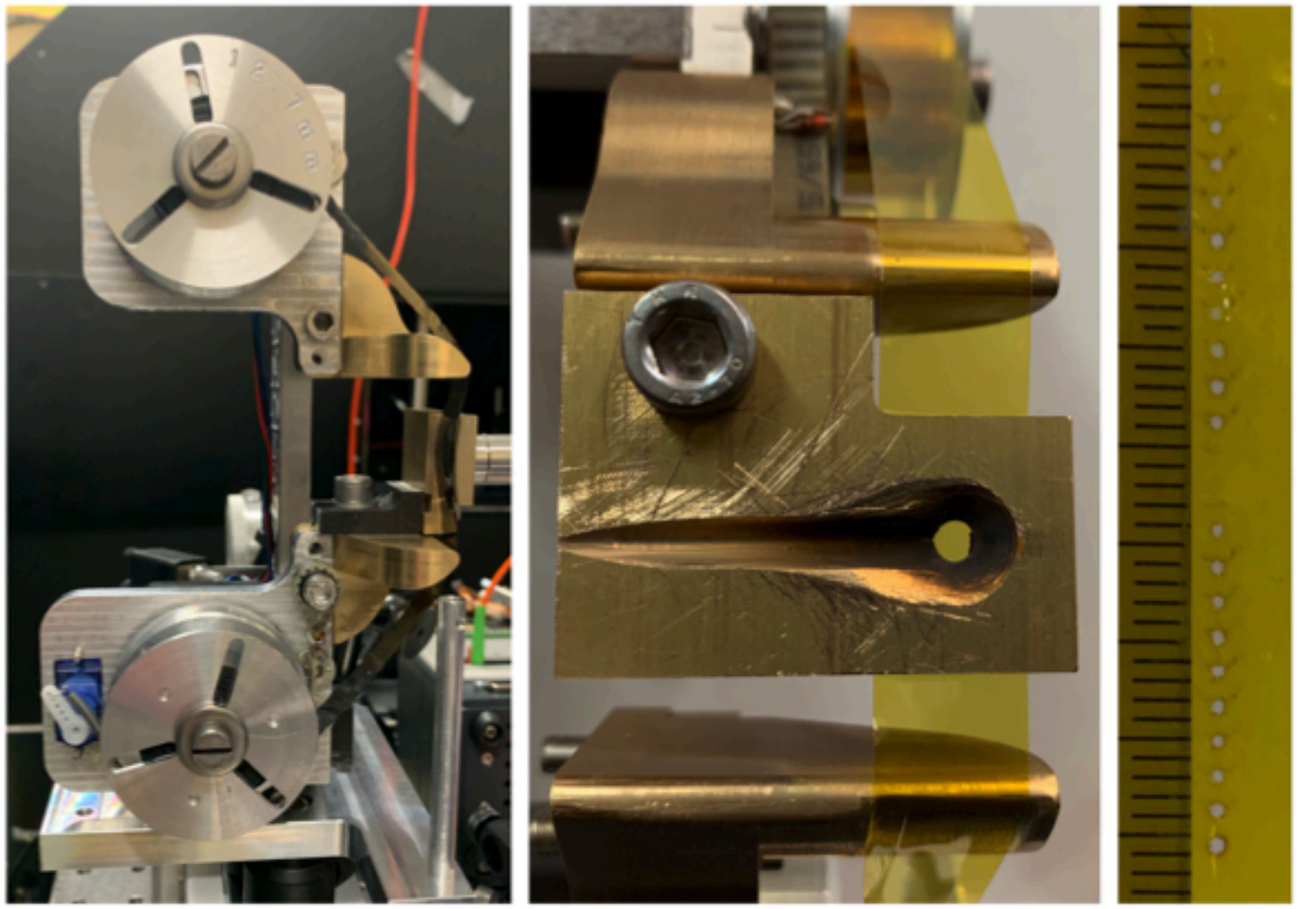
- 90 mJ of laser energy, 30 fs pulse width at 100 Hz
  - Relatively low laser energy
  - Predicted maximum proton energies ~ few MeV
  - Semi-continuous access allows long term R&D into technical issues in stabilisation, debris, targetry, etc

Experimental R&D at ICL - technological development

O. Ettlinger, N. Xu, Z. Najmudin



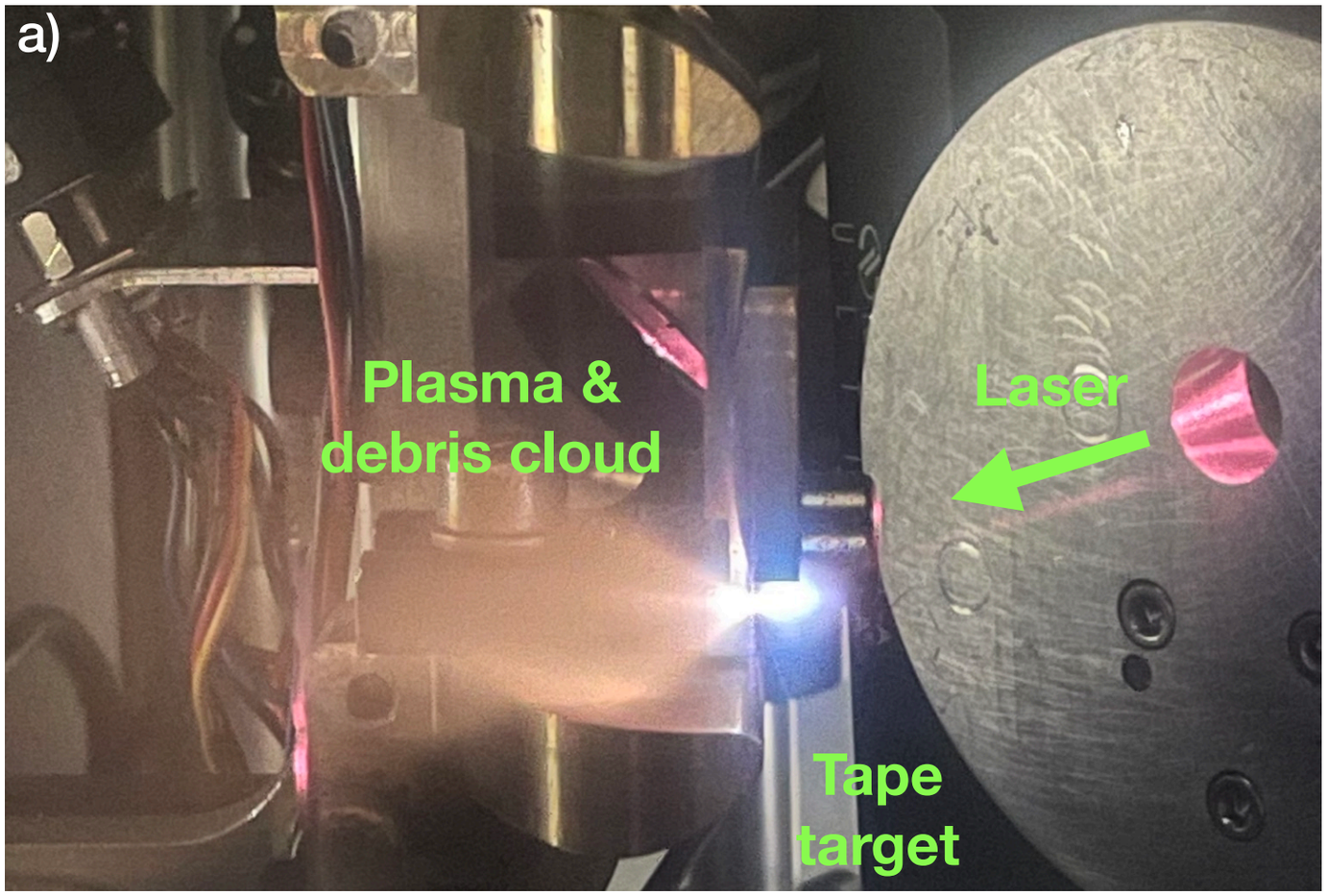
Cryogenic regenerative amplifier and 4-pass amplifier to mitigate thermal lensing

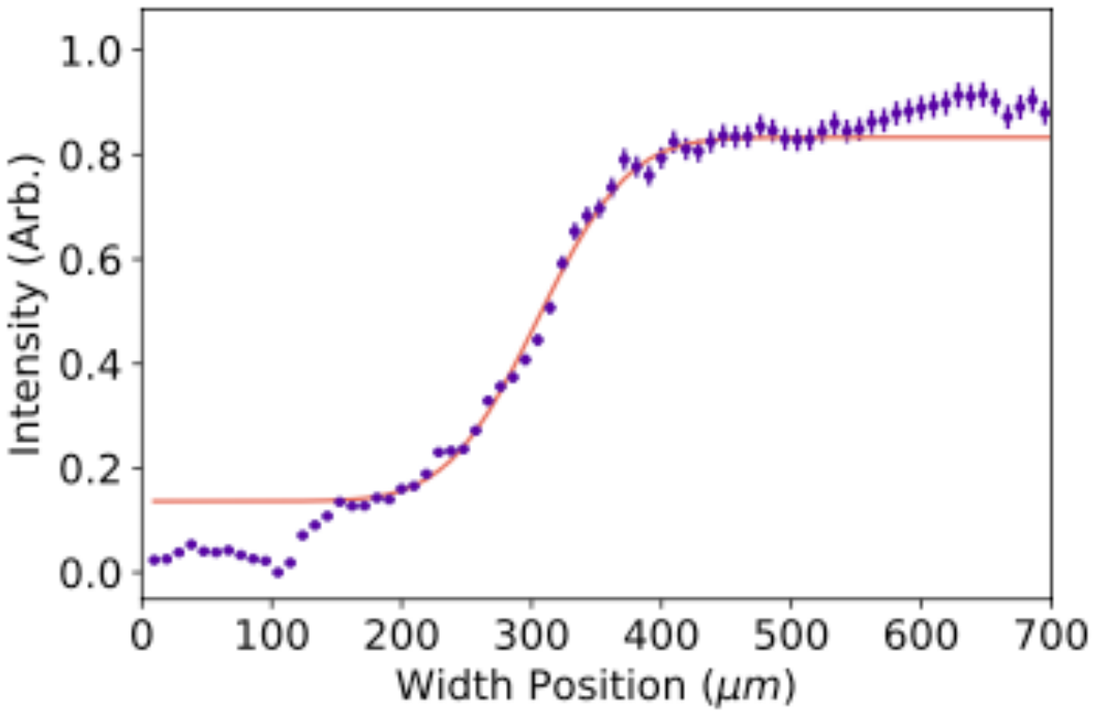


High stability homemade tape target for 100 Hz operation

Xu et al., HPLSE 11, e43 (2023)

Experimental R&D at ICL - Initial results

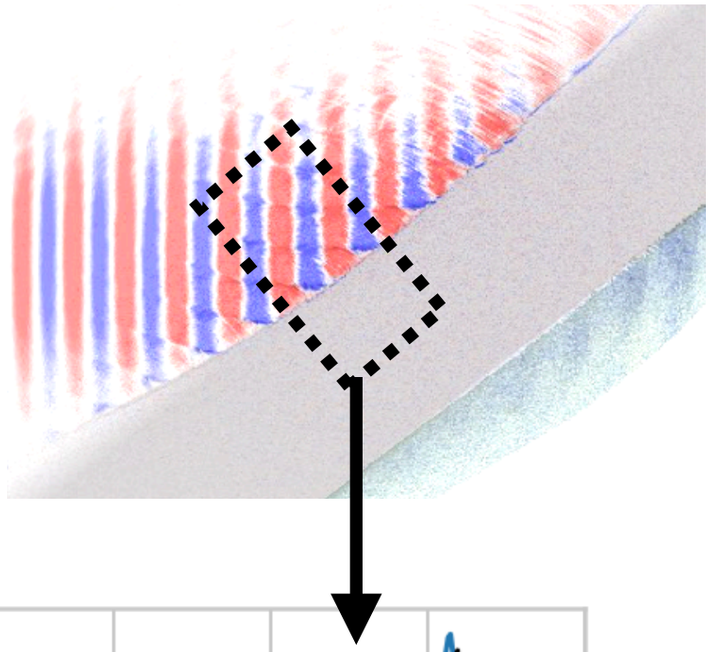


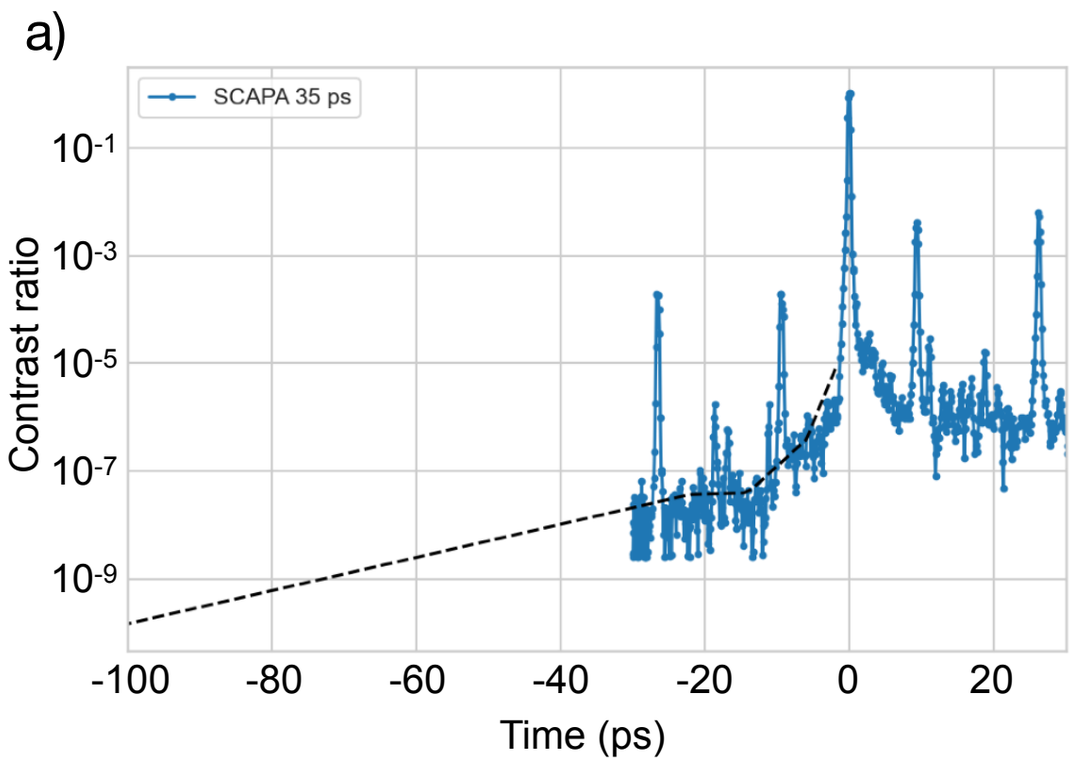


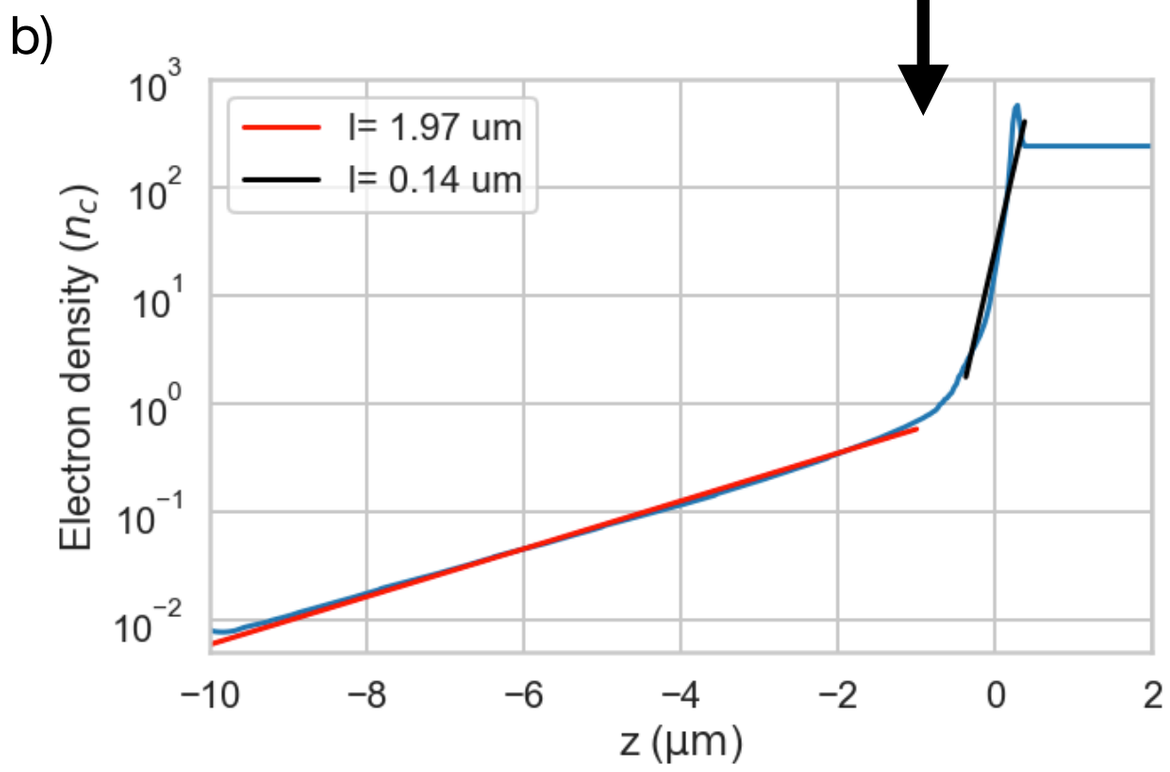
- Preliminary experiments run at 5 mJ level (without final amplifier)
- Continuous operation at 100 Hz for 10s minutes
- Plasma formation, x-ray generation (and debris production!) observed
- From next month, experiments begin at 100 mJ level

Simulations of laser prepulse

- Laser “prepulse” is of key importance for optimising laser driven ion source
- Modelled using hydrodynamic or radiation hydrodynamic codes
- Established simulation model using FLASH code, using prepulse measurements from SCAPA

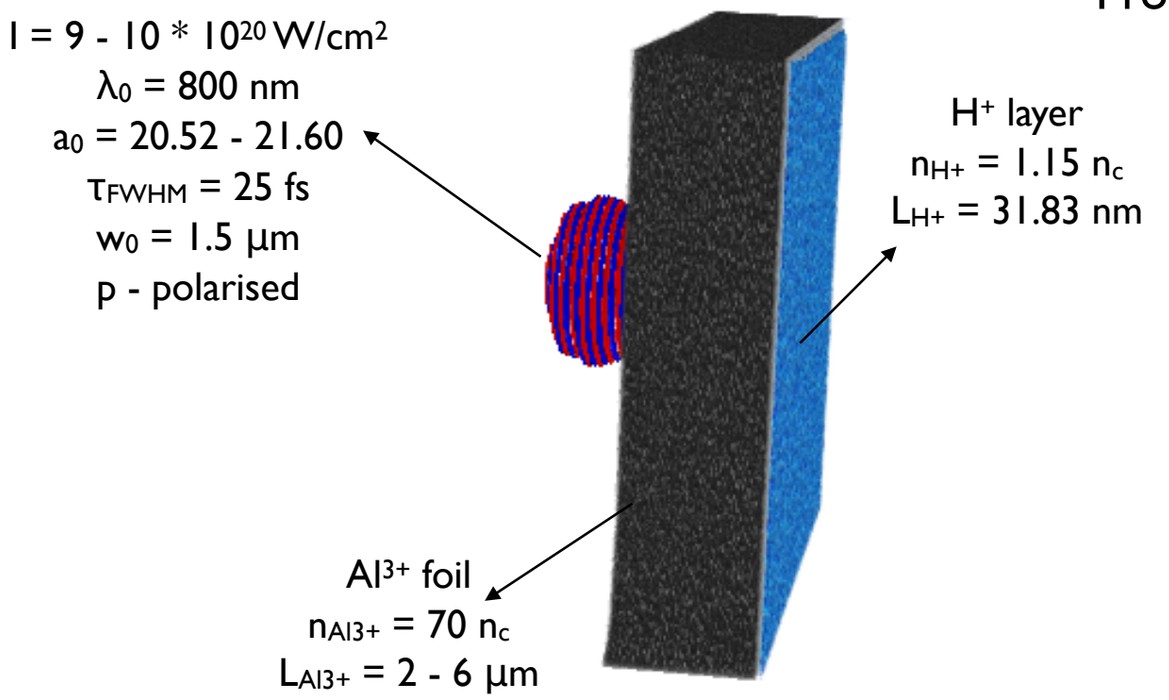




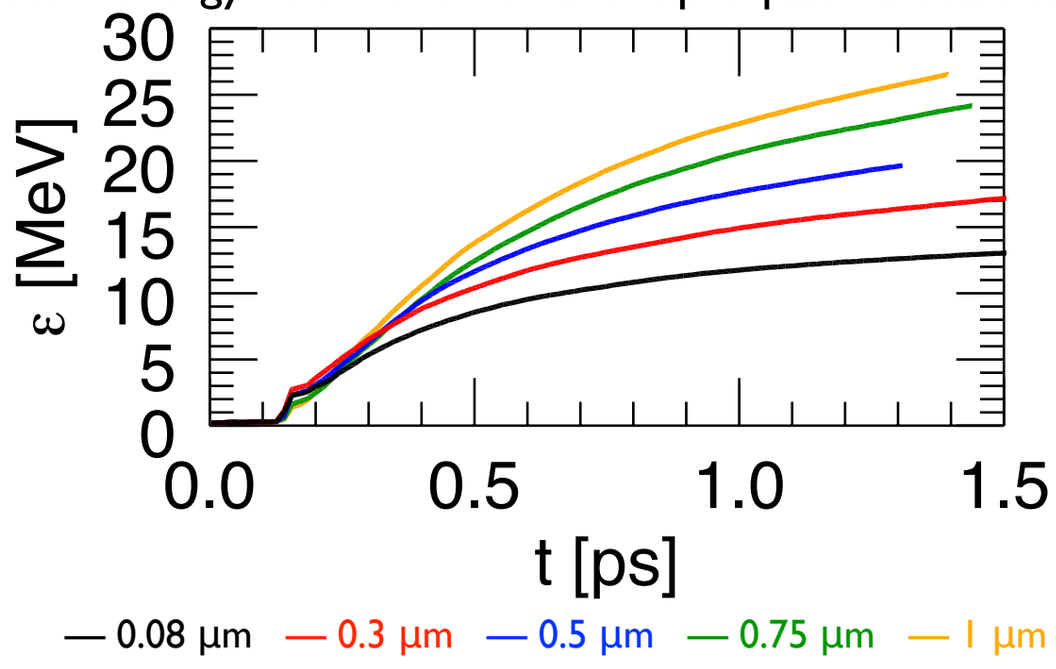


Progress on full 3D PIC simulations

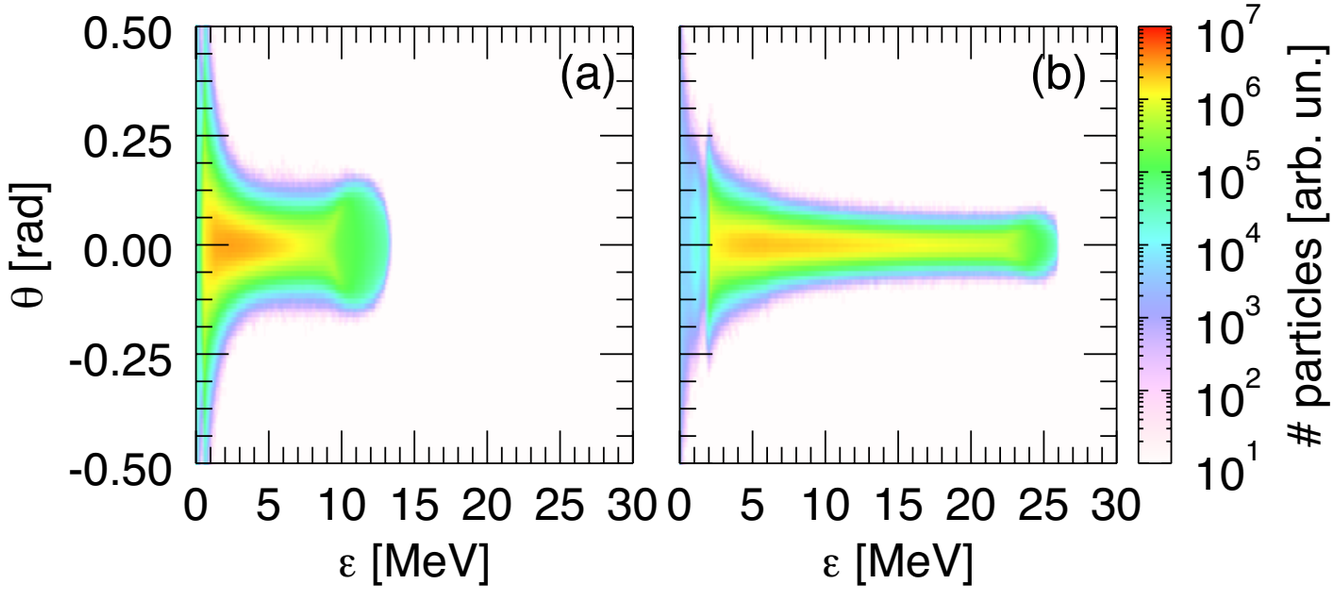
Simulations and analysis performed by E. Boella (Lancaster)



Proton cutoff energy vs time for different pre-plasma scale-lengths



- 3D simulations predict generation of ion beam parameters similar to LhARA baseline
- Optimal density profile will boost ion energies



Outlook for simulations

Forward outlook on simulations

Methods
- Particle in cell (2D/3D)
- Hydrodynamics
- BISHOP (parameter scans)

Titus Dascalu @ Lancaster

Laser parameters
- Laser contrast (effects of realistic pre-plasma scale-lengths)
- Laser spot size

Multiparametric optimisation
- 2D grid scans of various parameters
- 3D PIC simulations of identified optimal regimes

Target parameters
- Angle of incidence

One-off preliminary simulations
- Idealised carbon layer on back of target
- Water jet

Summary & passover to Ross

- Provided funding has given much needed impetus to LhARA related R&D and collaborative activity

- Ion source experiments at Imperial ongoing and will be ramped up to full energy in the next month

- Numerical simulations ongoing and further activity over the coming 12 months

- Great progress on experiments at SCAPA - see next talk!