Laser-driven proton and ion source (WP2): brief highlights

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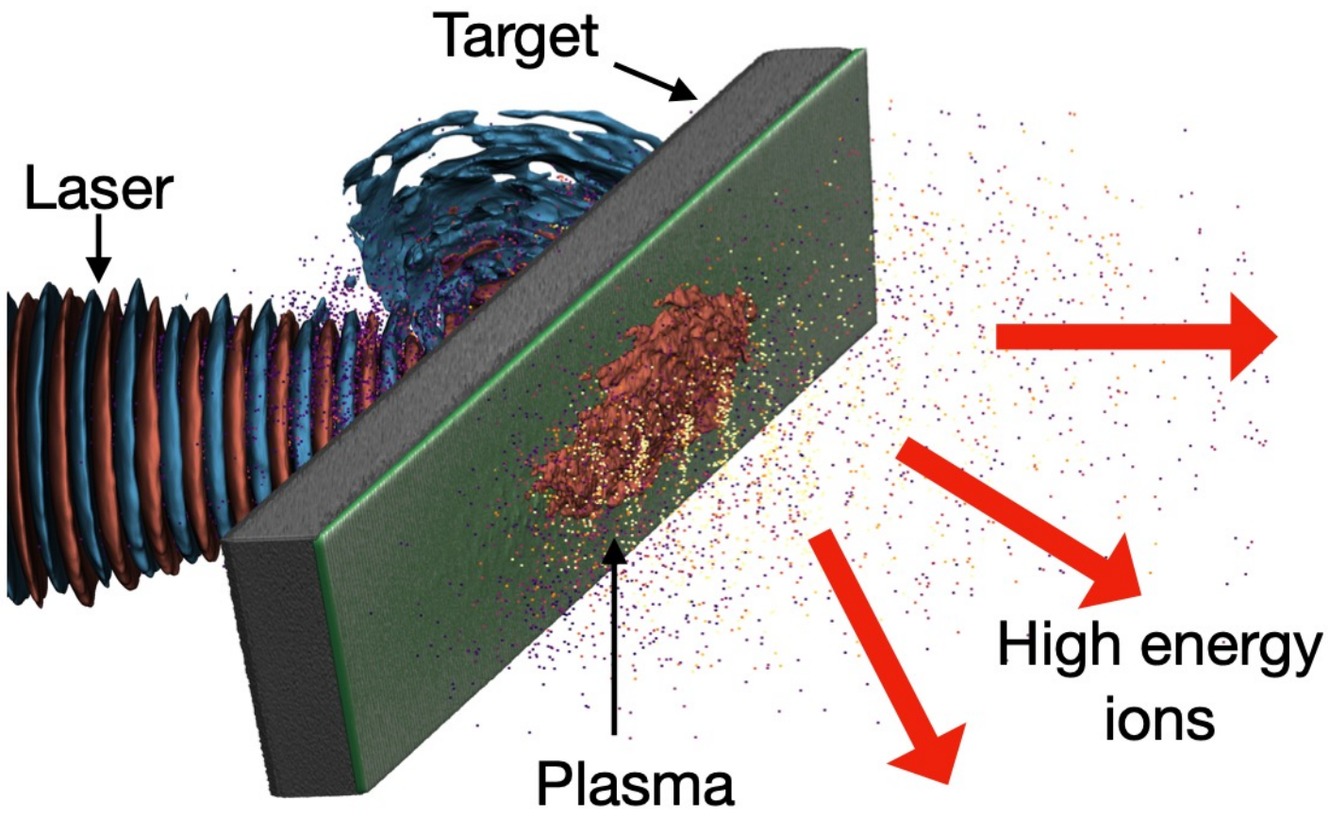
LhARA 24 month review, 2nd September 2024

Laser driven ion source for LhARA



- High energy (e.g. ~15 MeV p+, 4 MeV/u C6+) from source
- 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

Overview of de-risking activities

Source demonstration

What laser do we need? What targets?

Technical R&D

How can we run our source stably at 10 Hz for long periods?

Simulations

How do we optimise source without costly experiments?

ITRF/LhARA Milestone M2.2 report

First SCAPA Ion Source Simulations and Experiments

Work Package 1.2

R.J. Gray[1,2], T.S. Dascalu[3], R. Wilson[1], T. Wilson[1], C.A.J. Palmer[4], N.P. Dover[5], P. McKenna [1]

ITRF/LhARA milestone M2.1 report

Baseline simulations of the future LhARA proton and ion source

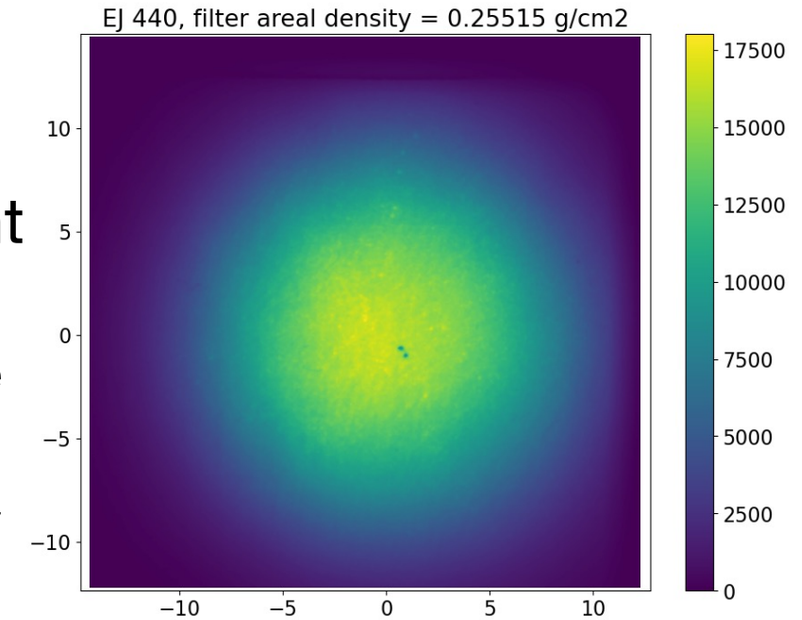
Work Package 1.2

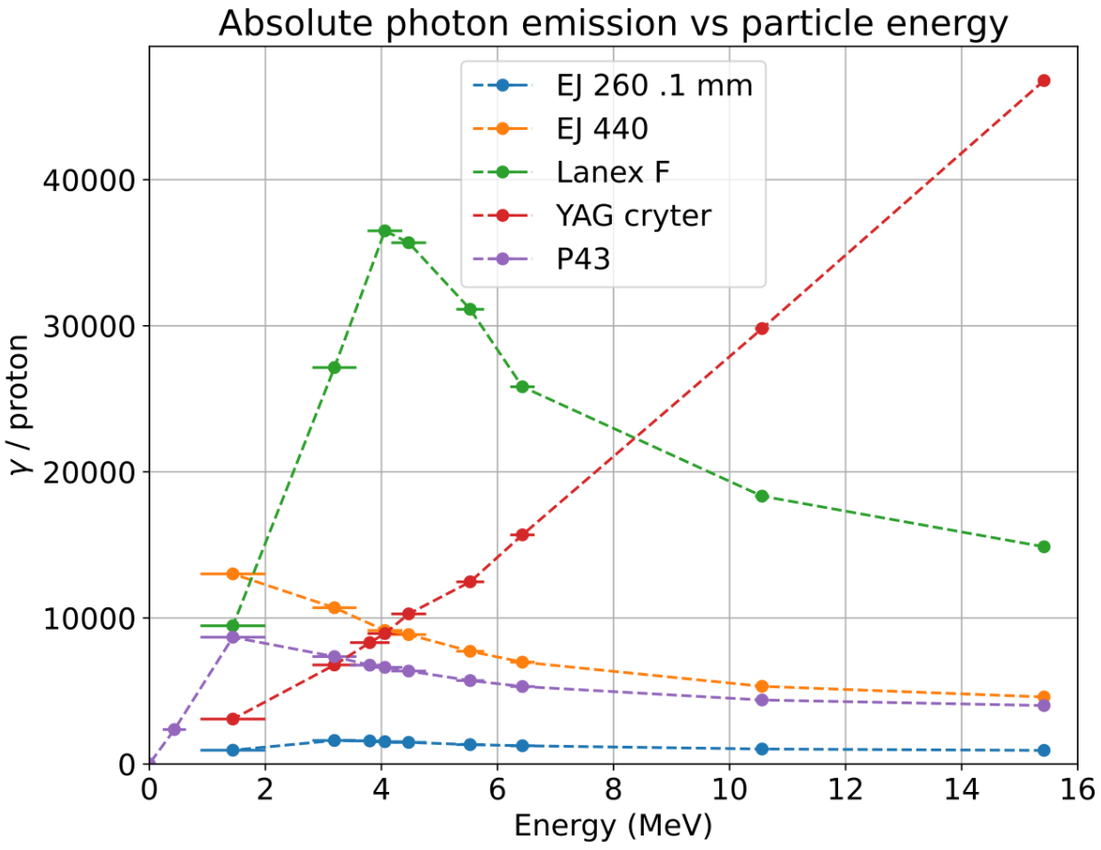
T.S. Dascalu[1], E. Boella[1,2], N.P. Dover[3], R.J. Gray[2,4]

Development of diagnostic techniques for LhARA

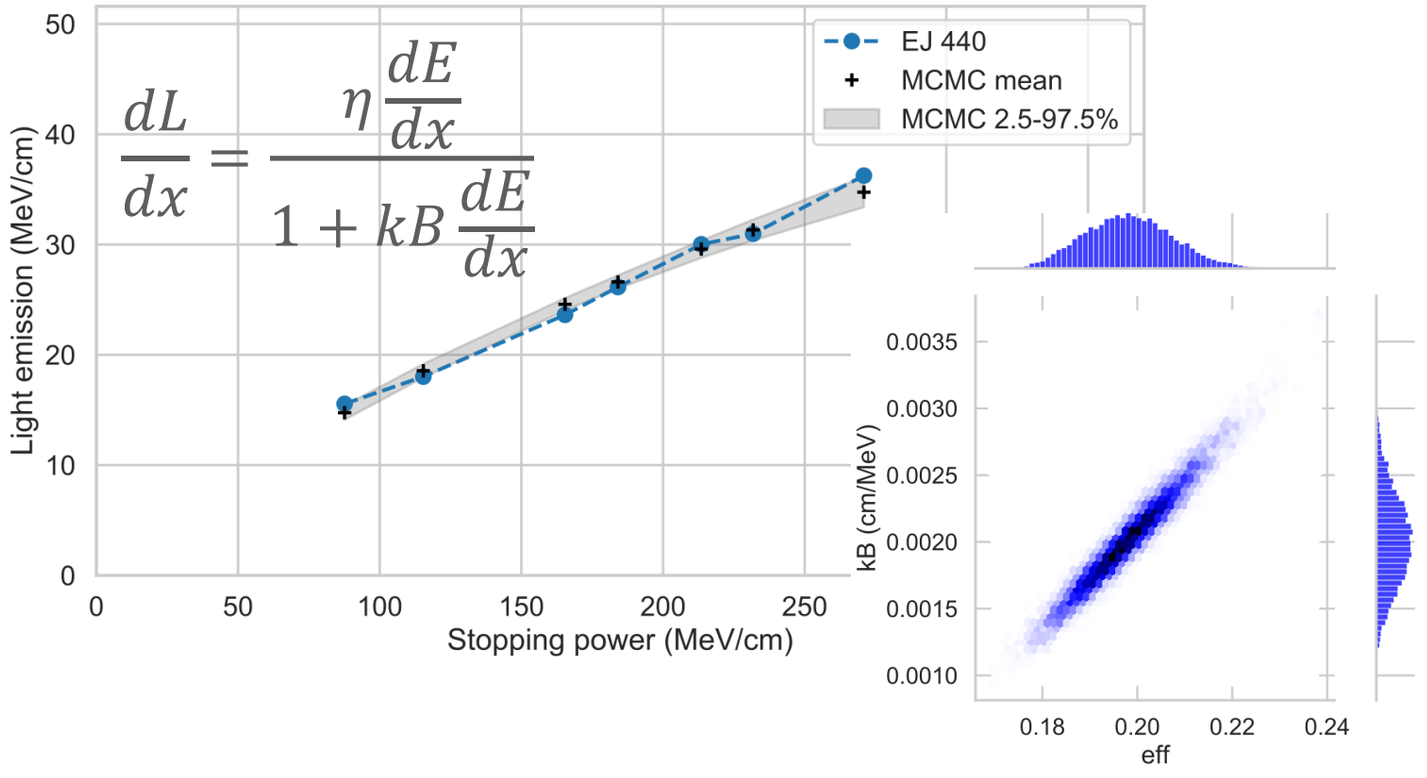
Scintillator studies

- Suitability for high repetition rate ion measurement with large radiation background
- Experiments at MC40 to choose candidates to be tested on laser source
- Measuring efficiency and stopping power linearity

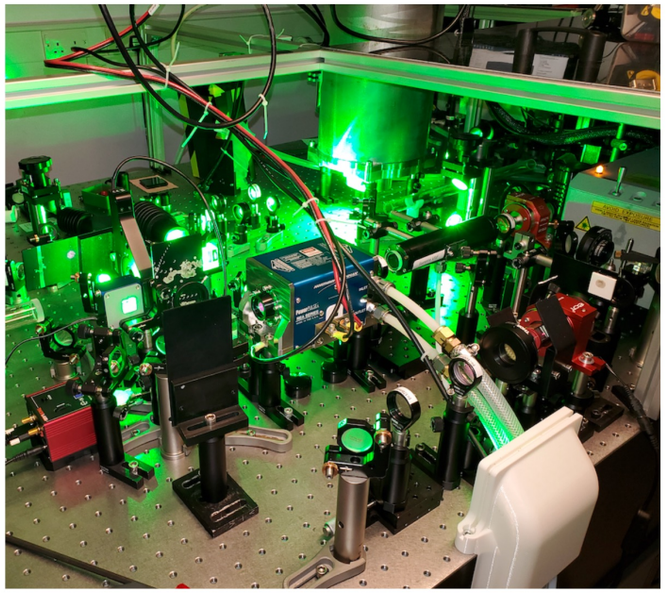




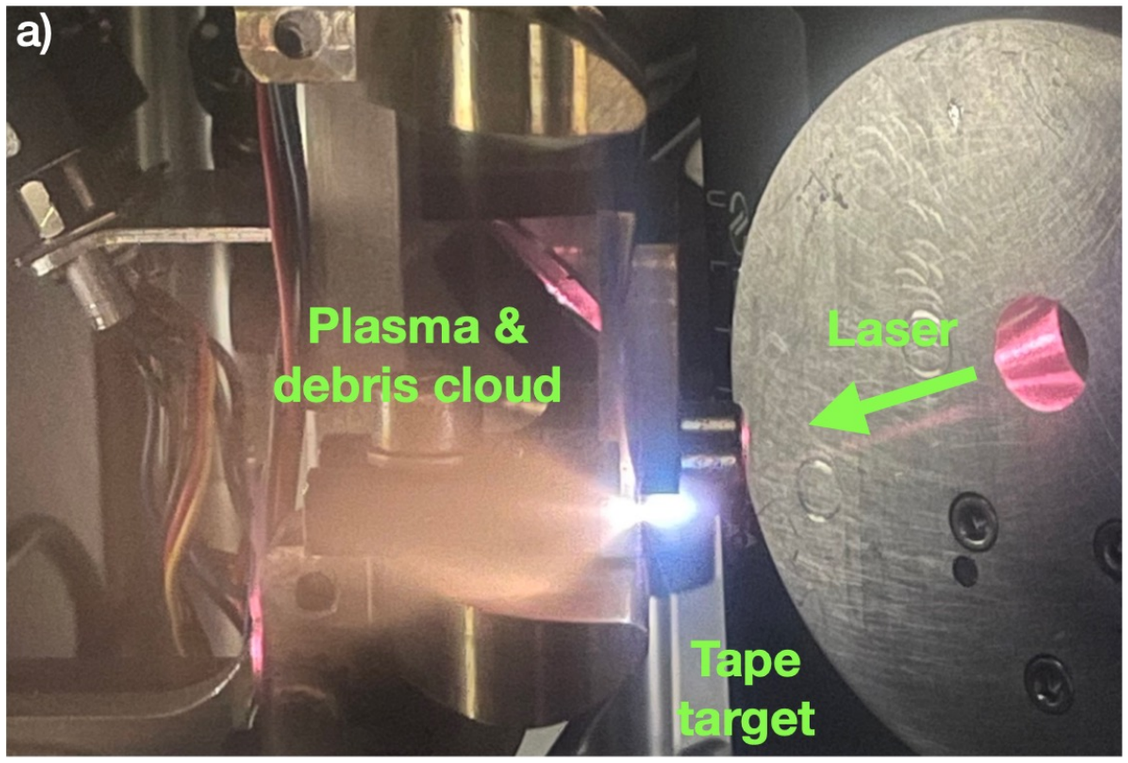
$$\frac{dL}{dx} = \frac{\eta \frac{dE}{dx}}{1 + kB \frac{dE}{dx}}$$



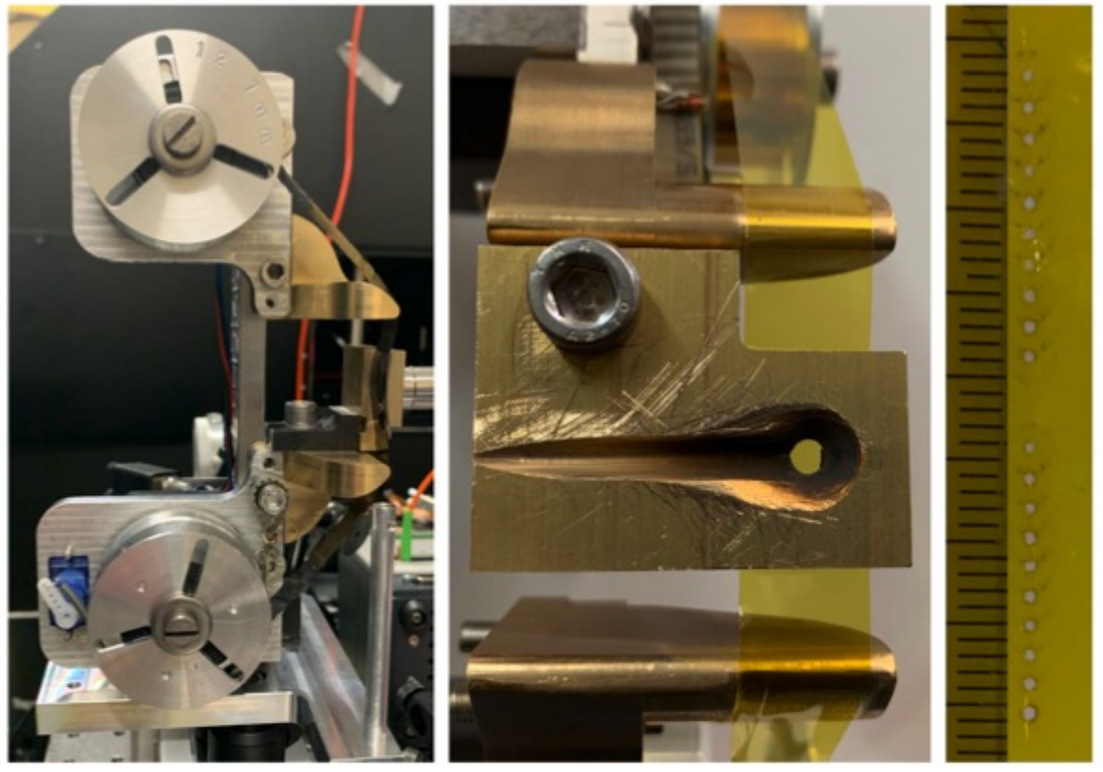
Platform for R&D of high repetition ion sources - Zhi laser



- 100 Hz high power laser at Imperial College London
- Low energy laser compared to LhARA; but, flexible platform for technical R&D



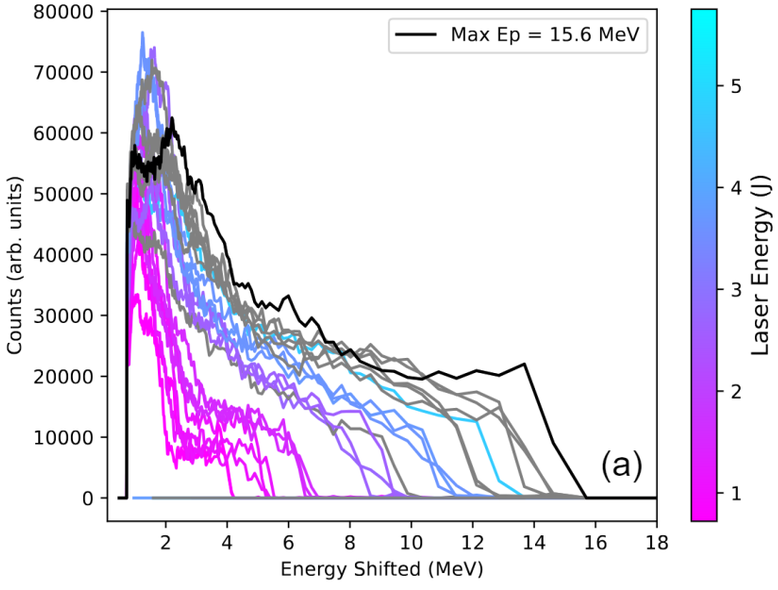
Laser driven source running at 100 Hz

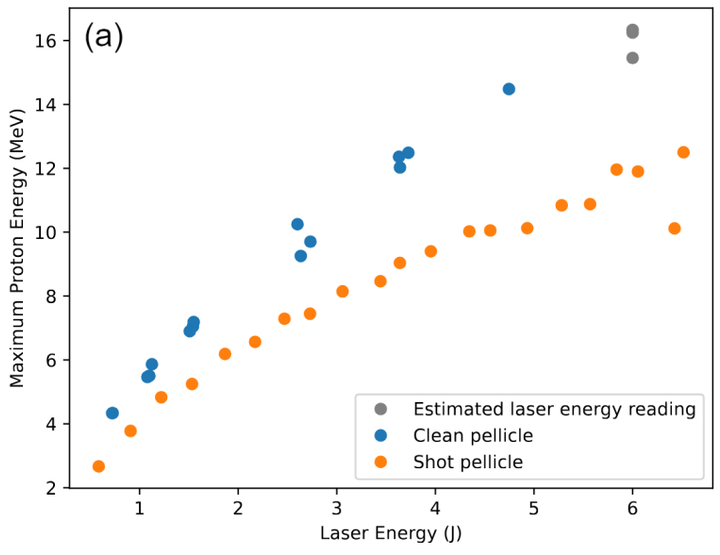


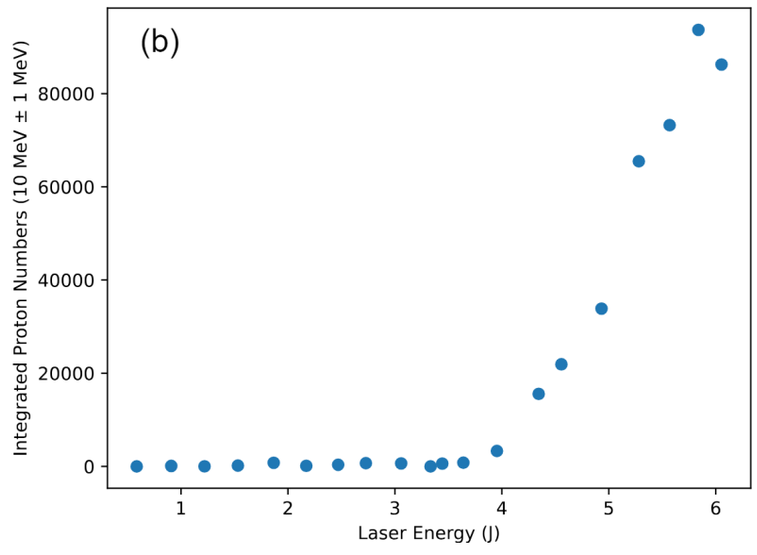
High stability tape target

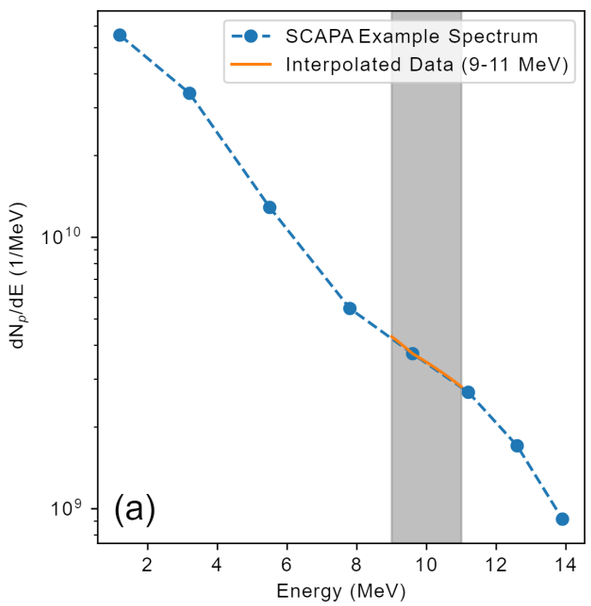
Xu et al., HPLSE 11, e43 (2023)

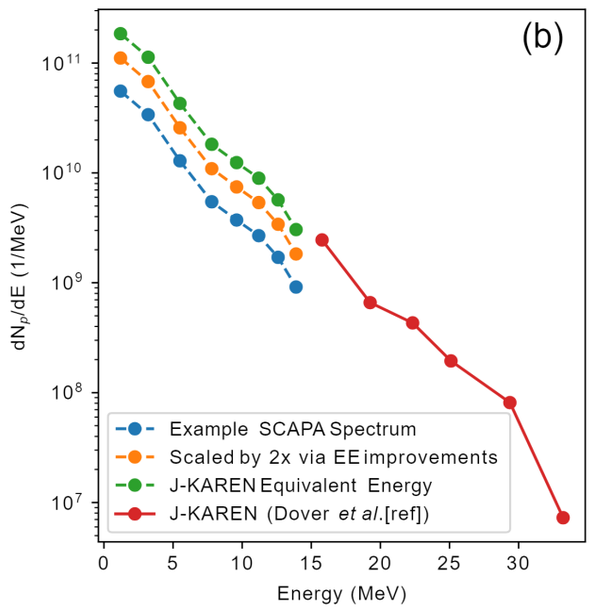
Overview of July 24 experiments on SCAPA (M2.2)





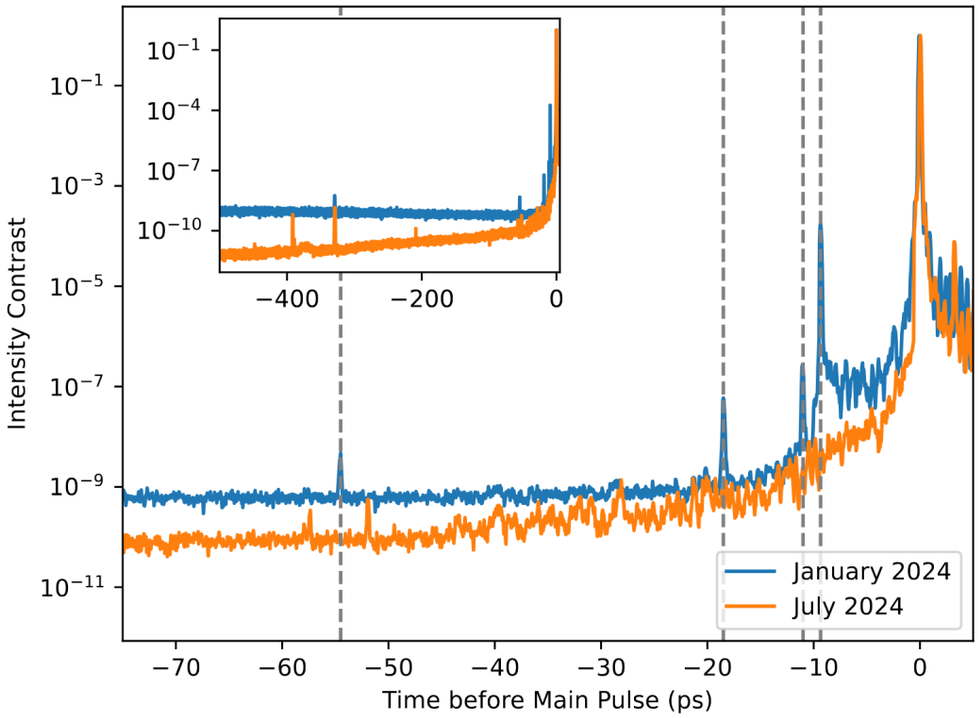


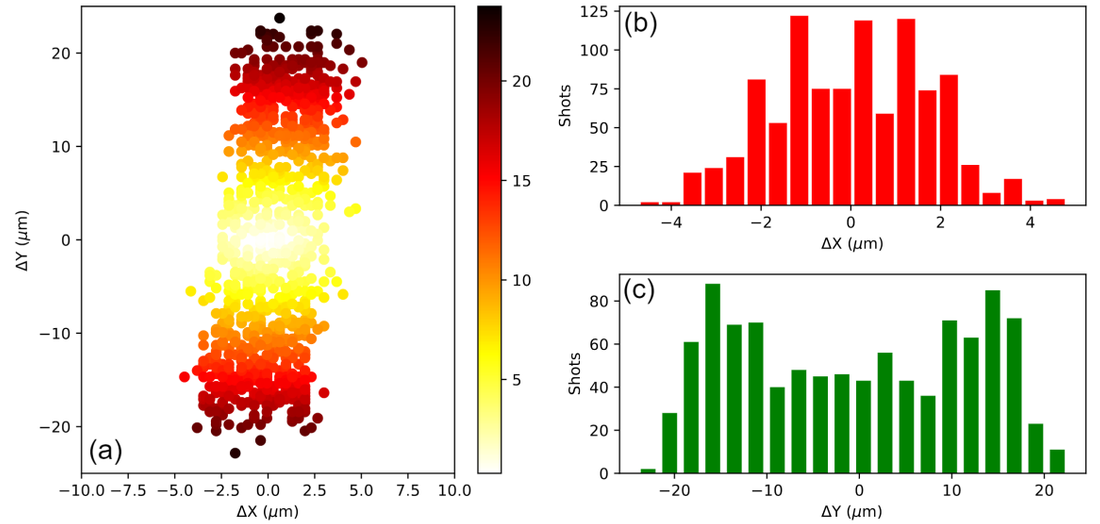


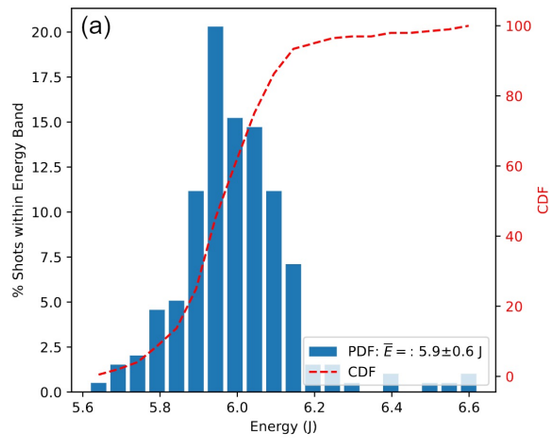


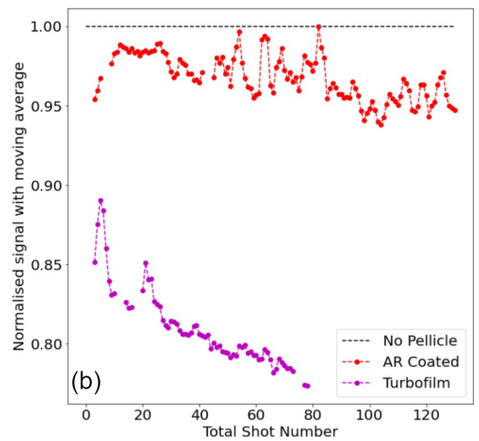
- We have now measured protons > 15 MeV on SCAPA at up to 1 Hz repetition rate (typically 0.3 Hz)
- This has been cross calibrated with RCF dosimetry and we find with >10^9 protons at 10 MeV.
- The scaling is linear with on target energy

Overview of July 24 experiments on SCAPA (M2.2)





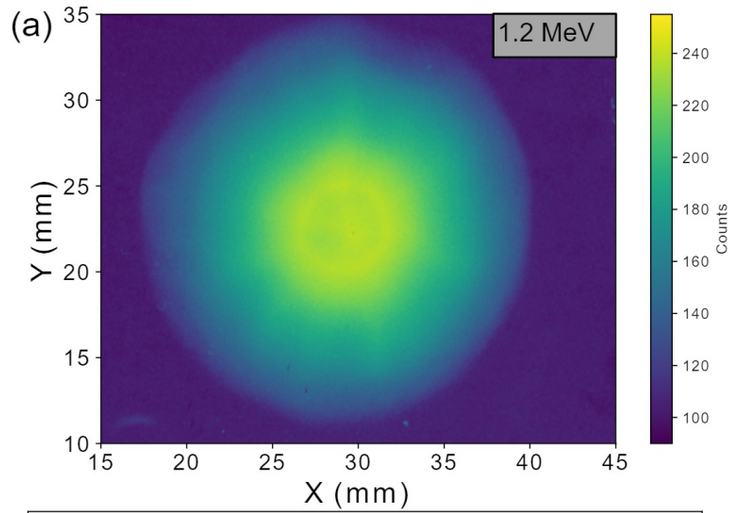


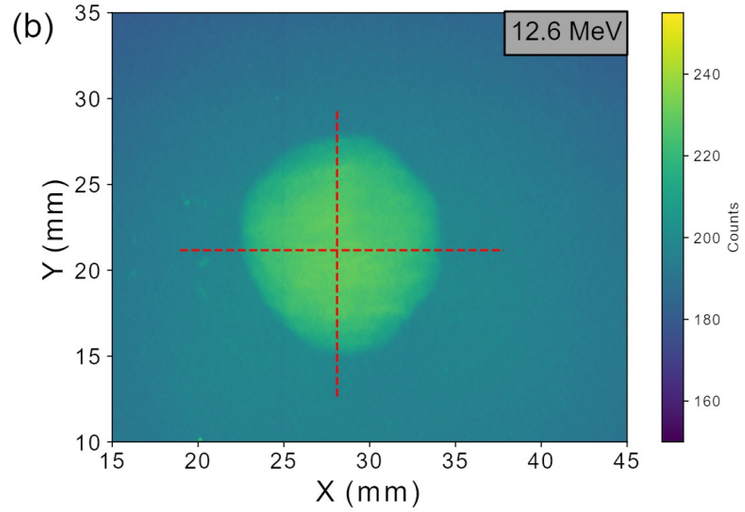


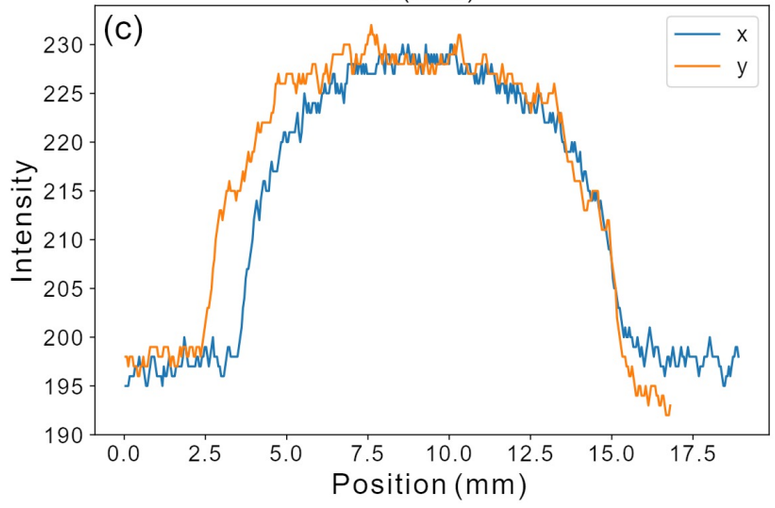
- As reported during the April CM there were significant prepulses measured in the system which were limiting our proton energy and flux

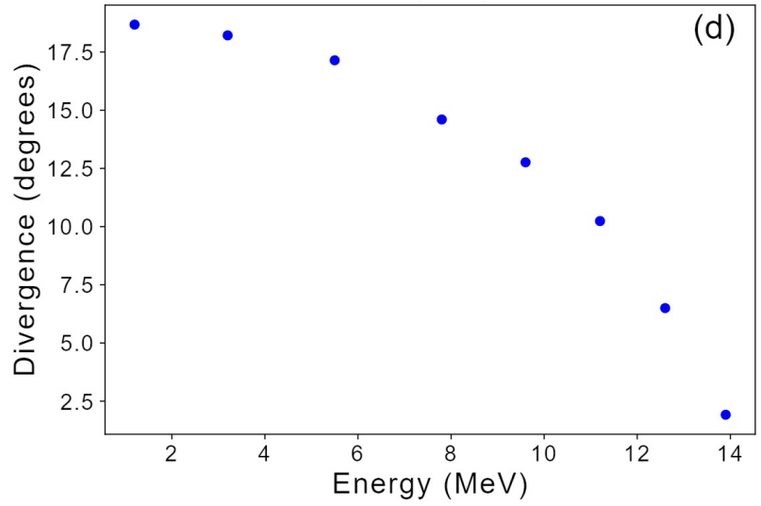
- Offending prepulses have been removed and the contrast is significantly improved and there has been detailed characterisation of laser stability

Overview of July 24 experiments on SCAPA (M2.2)



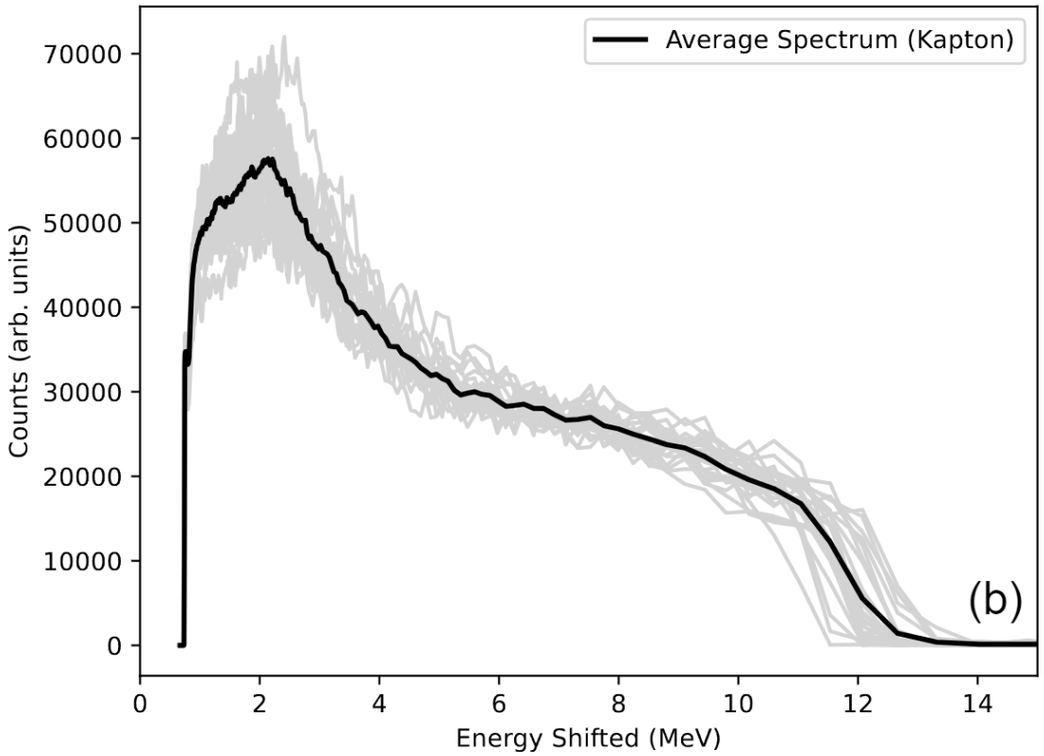


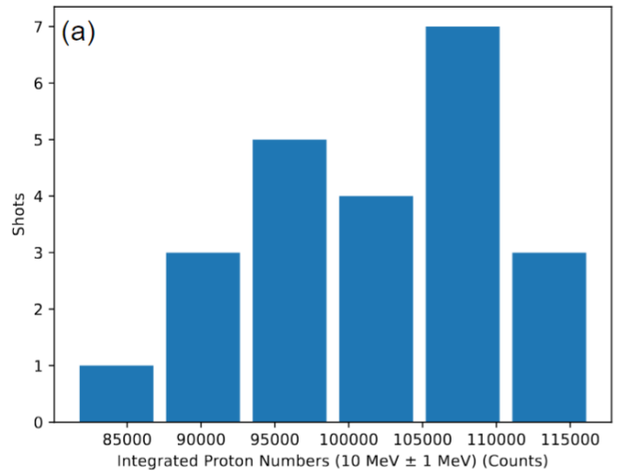


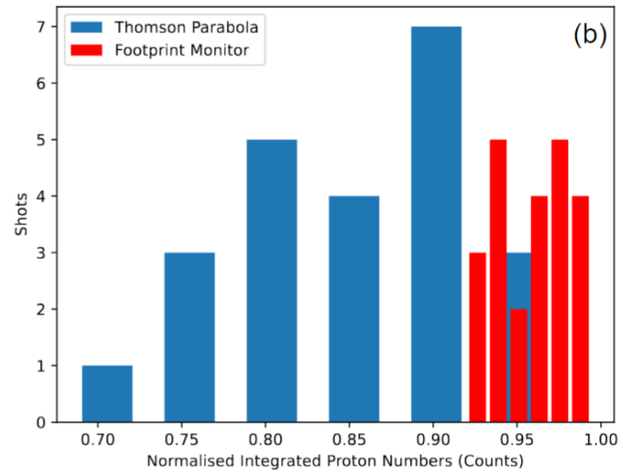


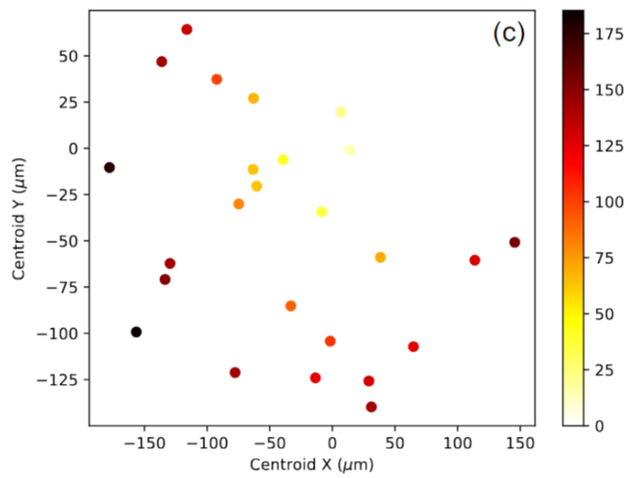
- We have characterised the beam profile using RCF and measured the beam divergence
- More measurements at high repetition rate would be important in the next phase

Overview of July 24 experiments on SCAPA (M2.2)



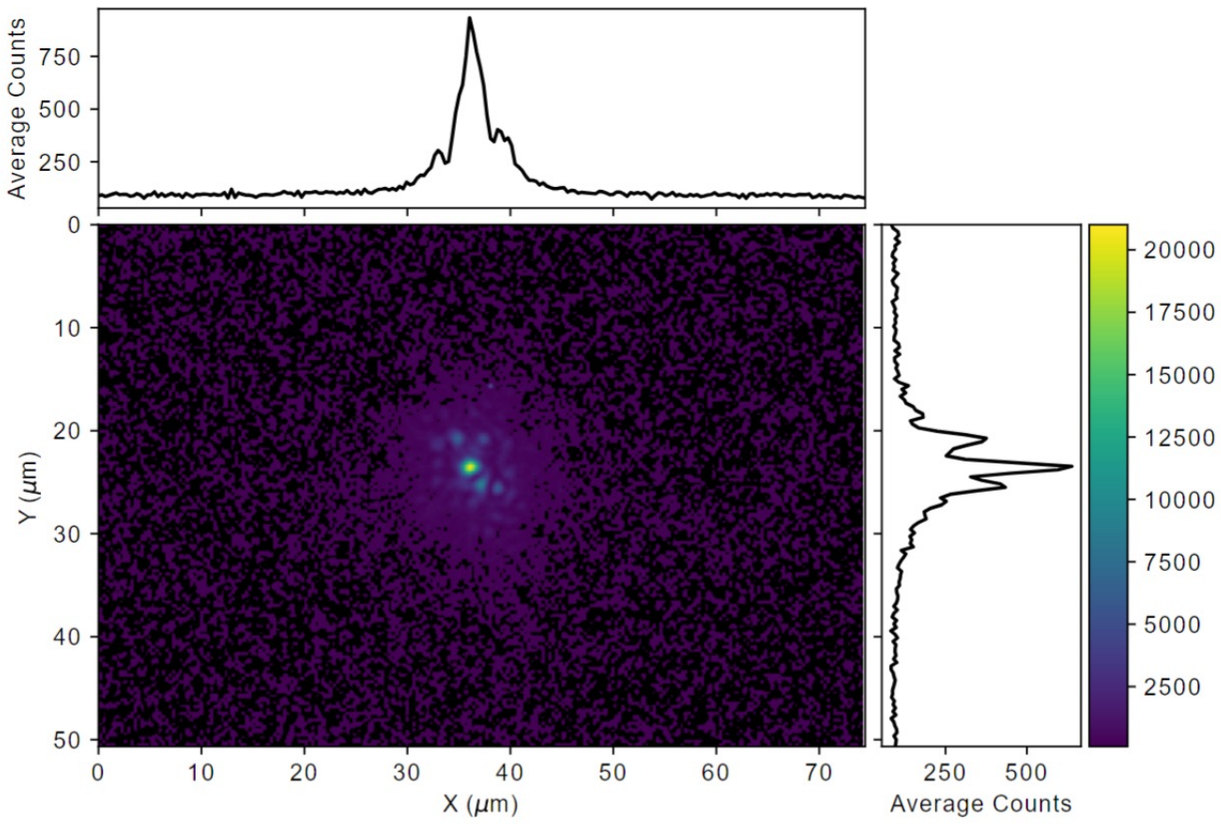


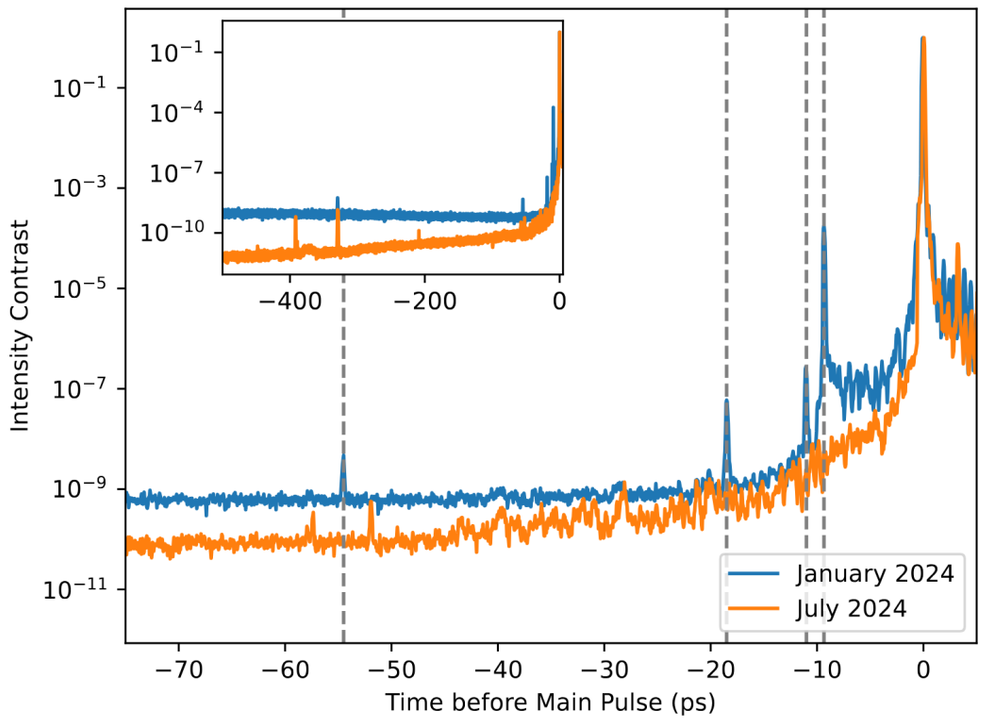




- Variability in the spectrum is low and is mainly driven by the small variation in the laser energy
- The TP spectrometer exaggerates the variability of the spectrum due to proton beam pointing stability

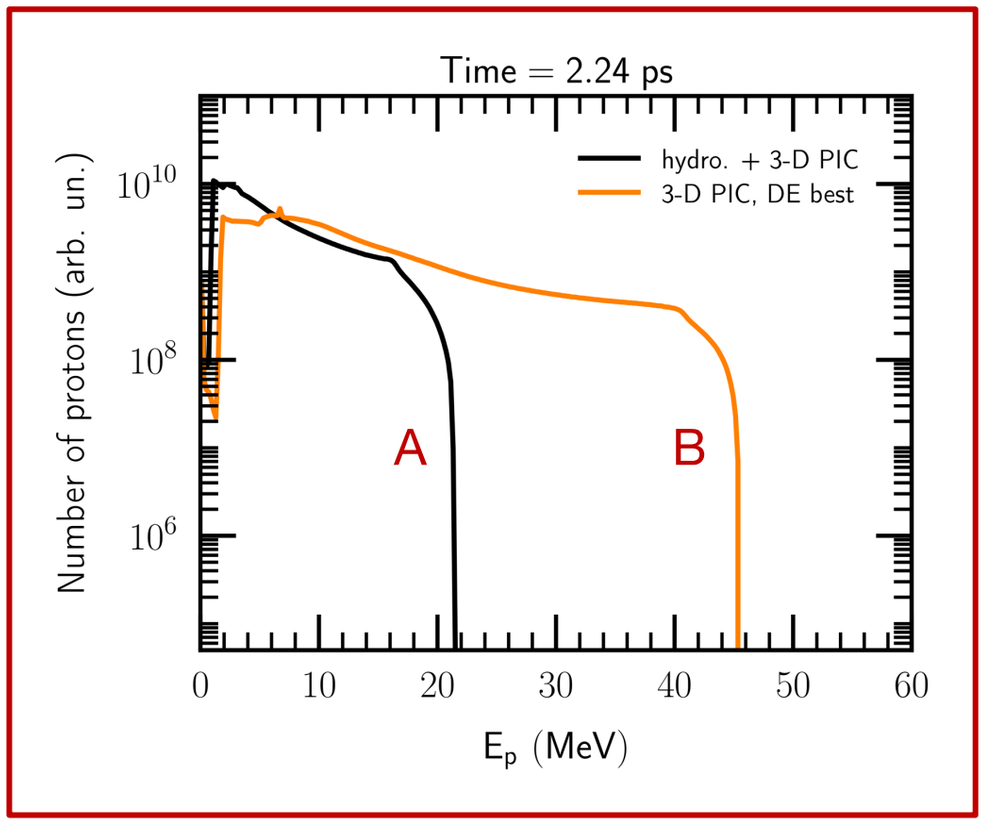
Overview of July 24 experiments on SCAPA (M2.2)

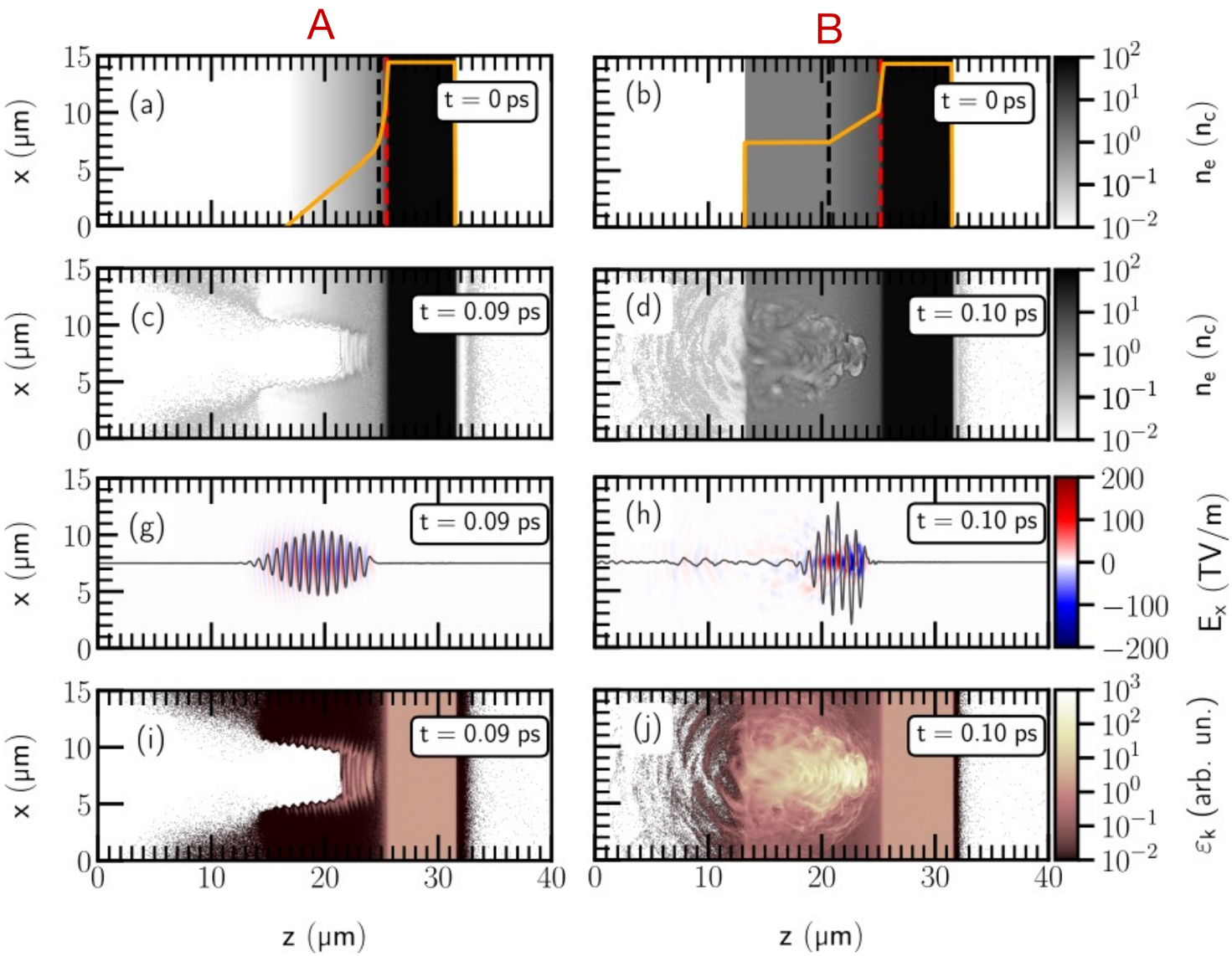




- Next steps would be to improve the encircled energy within the spot (this will lead to higher energy and flux)
- Further tests required on controlled preheater to optimise the scale length
- Reduction in laser jitter will support PoPLaR beamline and TP measurement

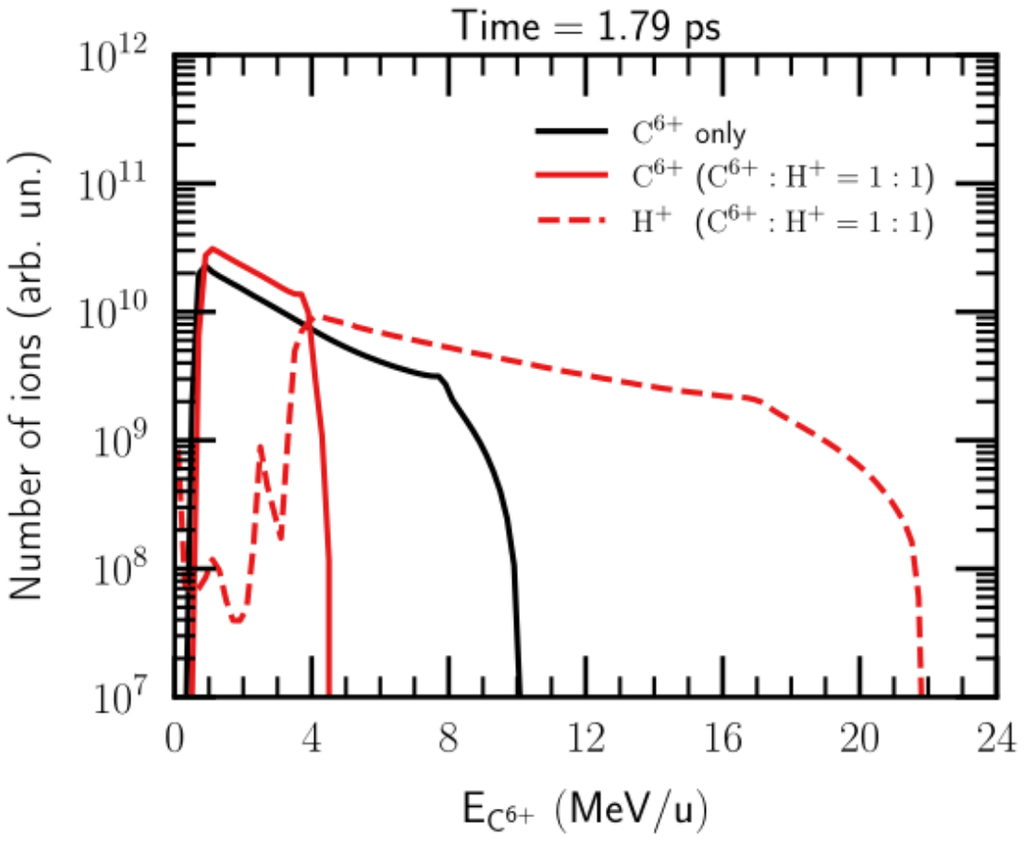
Prediction of optimal pre-plasma conditions (M2.1)

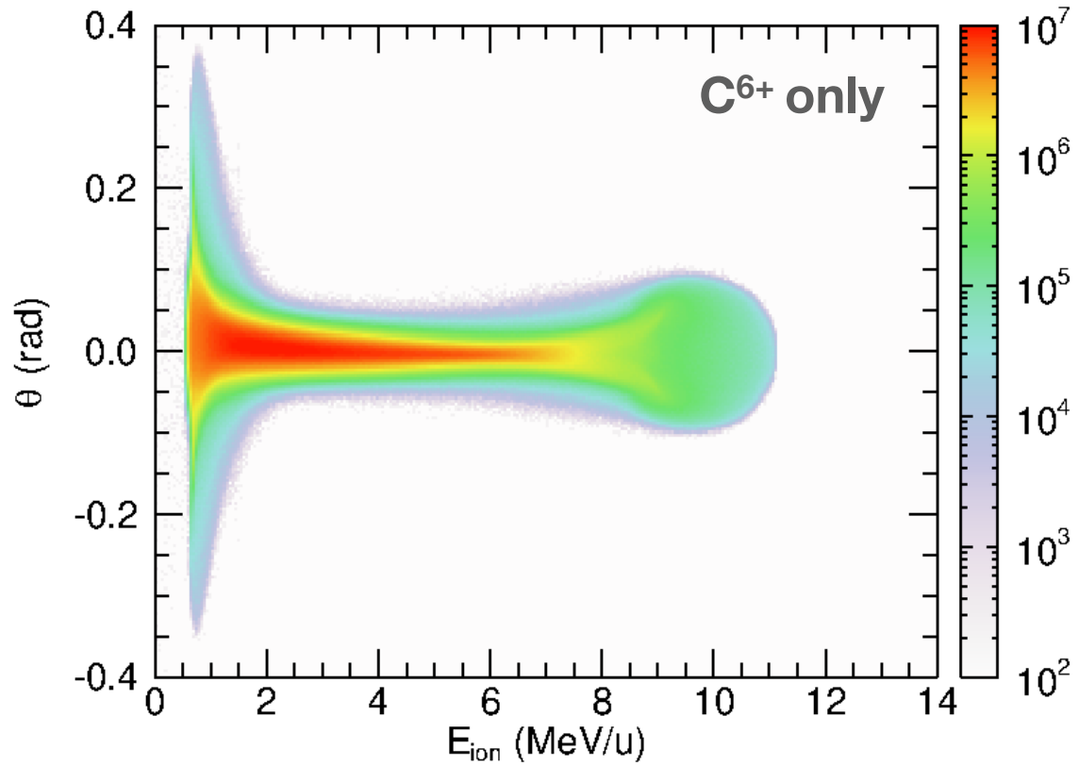




- Potentially optimal pre-plasma density profile found in 2D PIC optimisation study
  - Route to increase $E_{\mathrm{p,\,max}}$ without varying laser energy or target thickness
  - Validated with high-fidelity 3D PIC simulations
  - Need to explore how to reproduce optimal pre-plasma experimentally

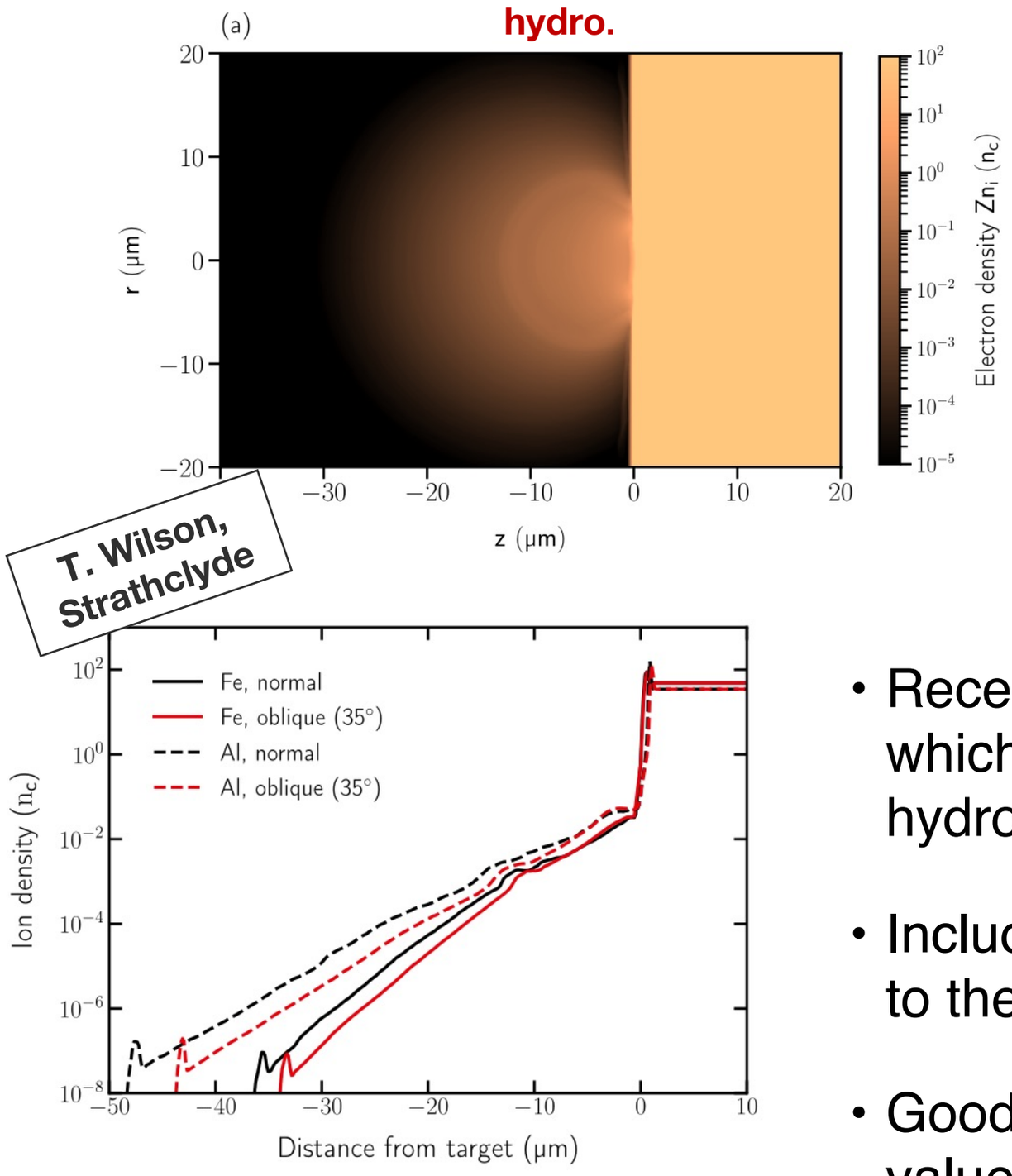
Modelling of TNSA for heavy ion acceleration (M2.1)

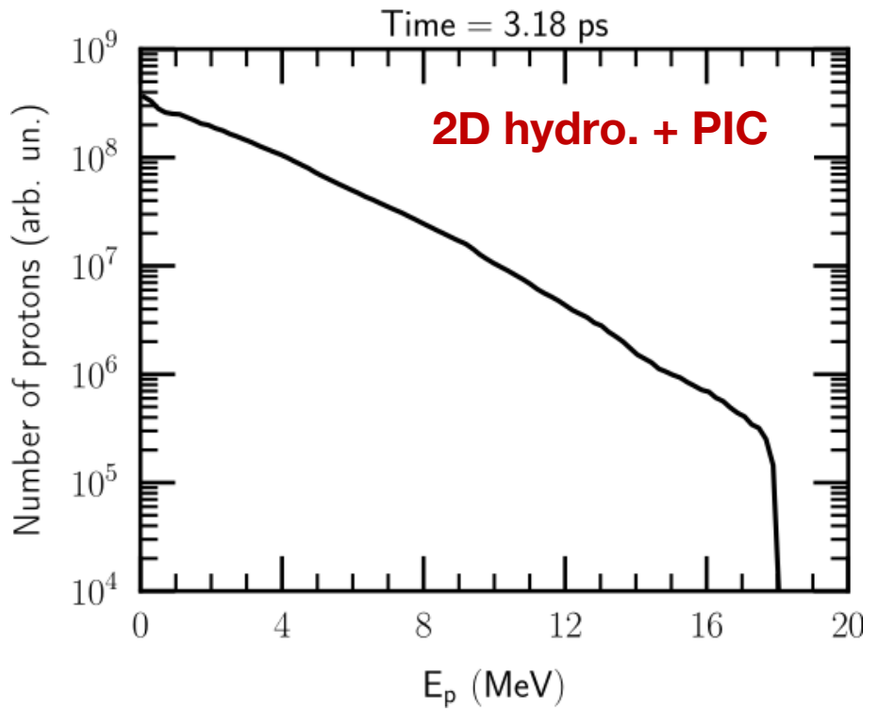




- First hydro. + 3D PIC simulations of carbon acceleration from $6\ \mu m$ Al solid target
- Carbon cutoff energy consistent with those predicted for protons under similar target and laser conditions
- Presence of lighter ion species on the back of the target screens the acceleration

Modelling of realistic conditions at SCAPA (M2.2)





- Recent work on realistic multi-scale simulations which combine outputs from both hydrodynamic and PIC codes
- Include values measured on SCAPA as inputs to the simulations
- Good agreement with experimentally measured values and will form an important part of the experimental design in next phase