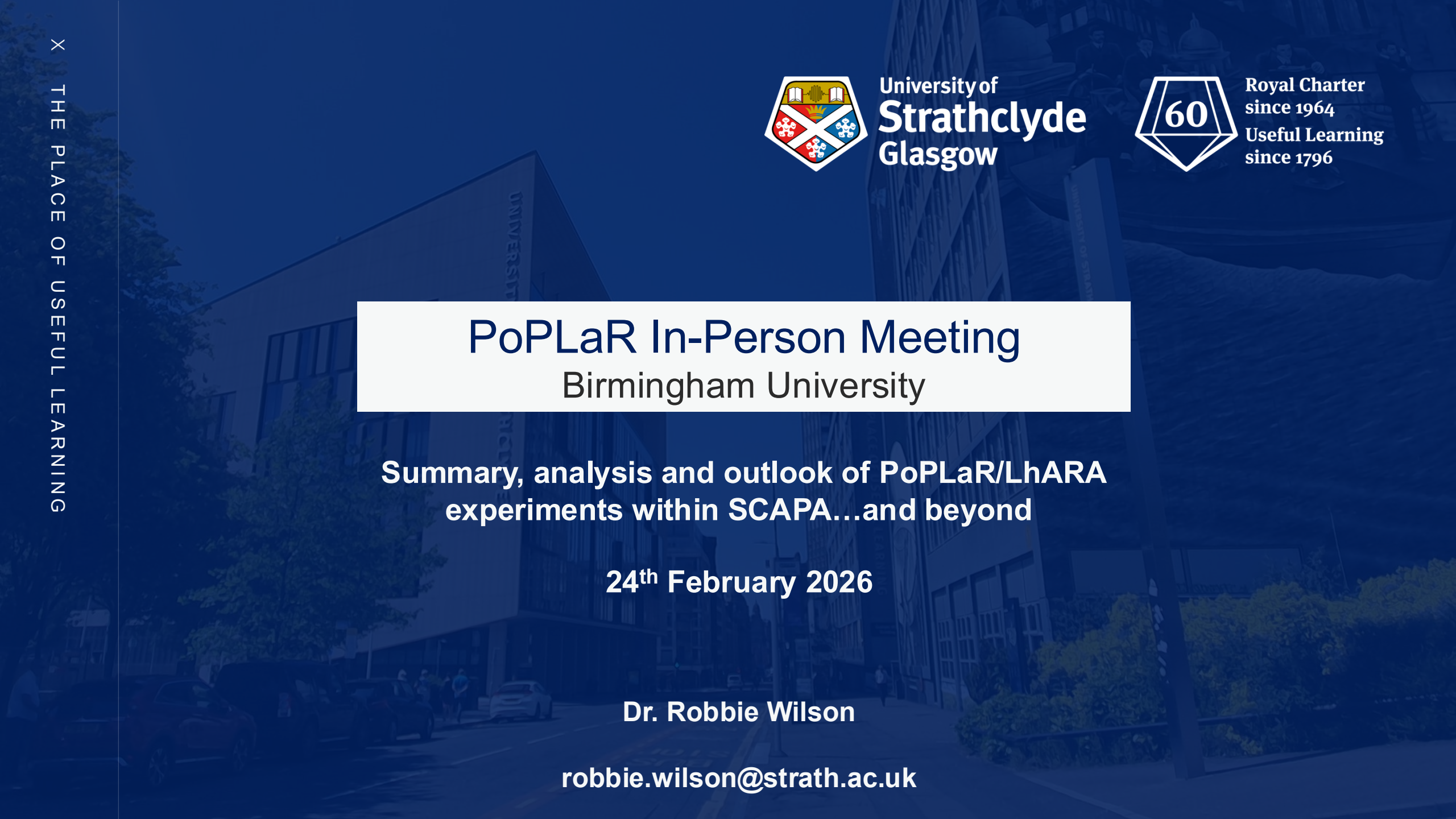


PoPLaR In-Person Meeting

Birmingham University

Summary, analysis and outlook of PoPLaR/LhARA experiments within SCAPA…and beyond

24th February 2026

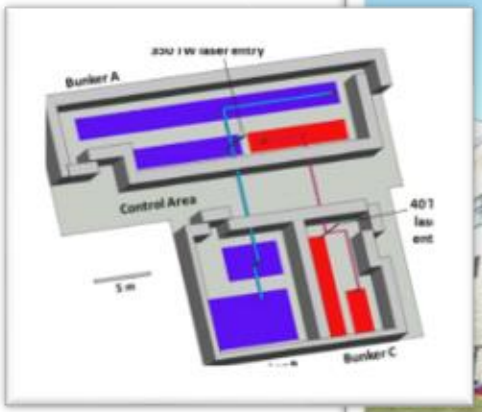
Dr. Robbie Wilson

robbie.wilson@strath.ac.uk

SCAPA: Scottish Centre for the Application of Plasma-based Accelerators

- Research is focused on the development and application of laser-driven particle acceleration.

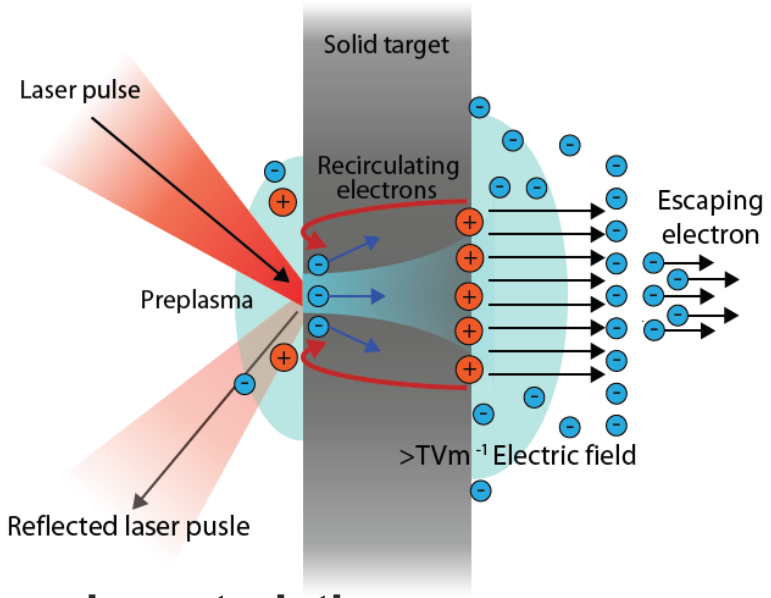
- Can deliver high particle numbers (>10^8 protons), within the MeV energy range, at Hz level repetition rate.



Parameters	
Peak Power	≥350 TW
FWHM pulse duration	≤25 fs
Energy per pulse (on target)	≥ 7 J
Pulse repetition rate	1 Hz
Temporal intensity contrast	10^{10}:1 @ 100 ps 10^8:1 @ 30 ps 10^4:1 @ 2 ps ASE contrast 10^{10}:1
Central wavelength	800 nm
Beam quality Strehl ratio	≥0.85

Mechanism for laser-driven ion acceleration

Target Normal Sheath Acceleration (TNSA)



Laser energy absorbed producing large population of hot electrons

↓

Hot electrons injected and propagate through the target

↓

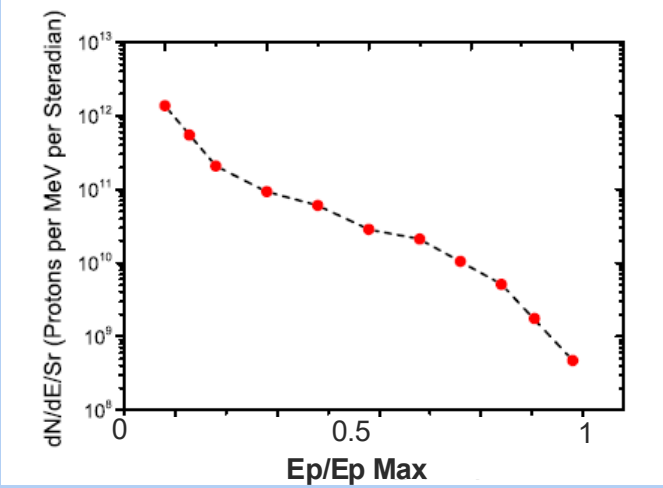
Generates strong (~TV/m) electrostatic sheath fields at target rear

↓

Drives acceleration of high energy (MeV) protons

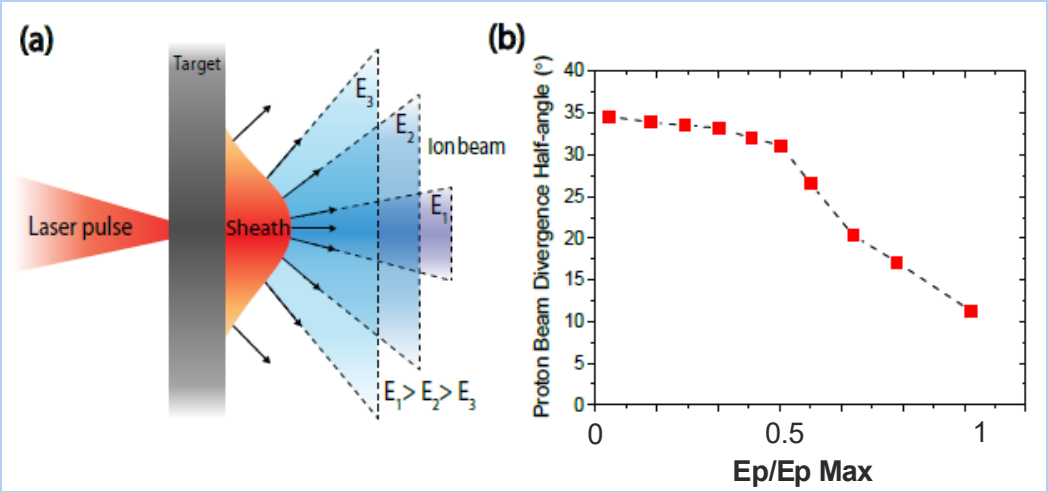
Proton beam characteristics

i)



- Broad energy spectrum, up to a maximum cut off energy.

ii)



- Proton energy-dependent beam divergence.

THE UNIVERSITY OF STRATHCLYDE

Update on Experiment Stages & Gateways

I. Design & Procurement

- Start of BP1 funding
- Order of PMQ XYZ stage (5-7 week delivery)
- Order of cell station vacuum parts (4 weeks delivery)
- Manufacture of thin window
- Manufacture of Oxford cell station

II. Assembly & Alignment

- Construction of the cell station
- Construction of updated TP beamline
- Definition of an offline alignment line
- Construction and offline alignment of PMQ setup
- Install of PMQ system in vacuum chamber
- Change of parabola

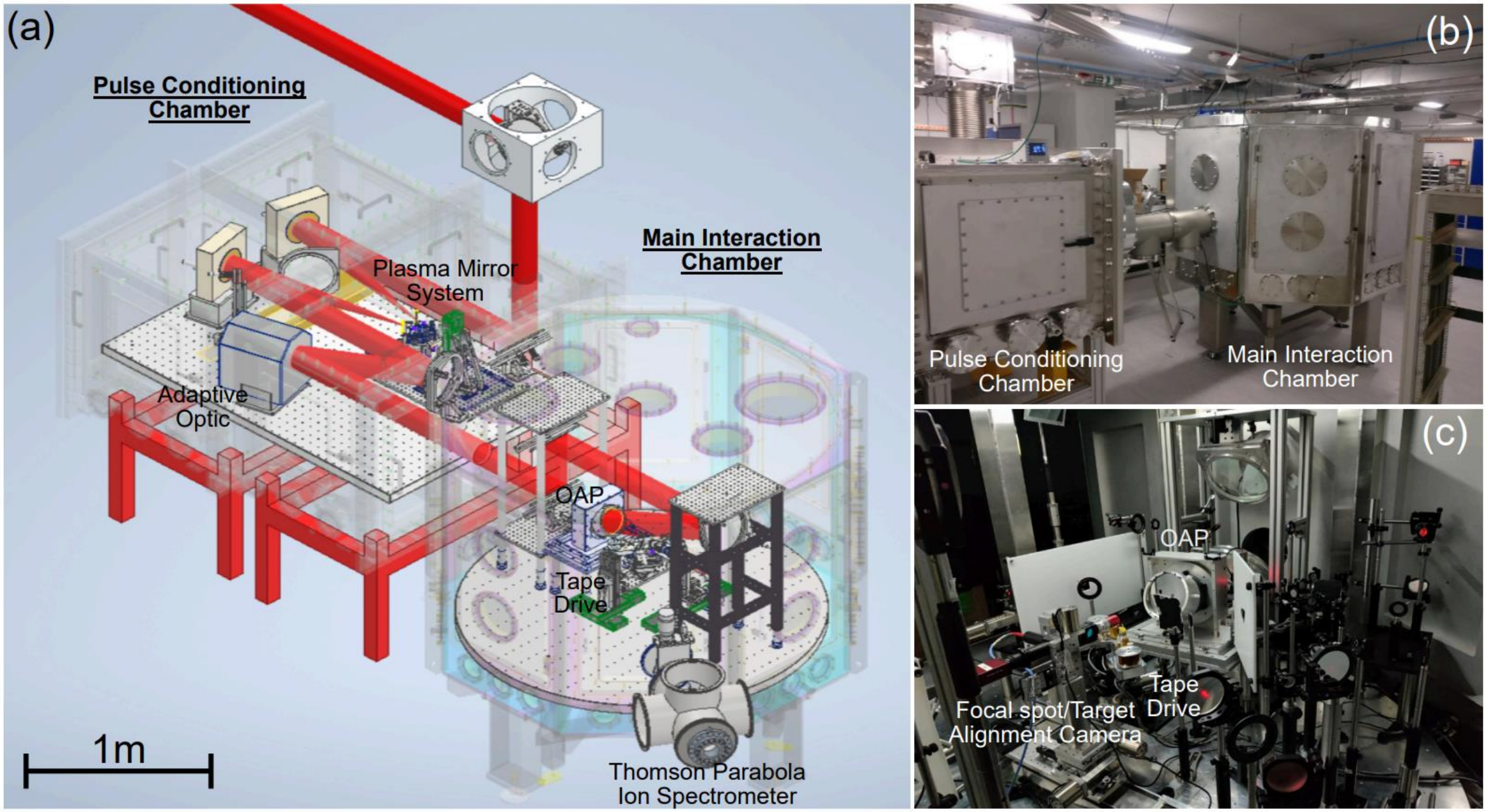
III. Source Characterisation: 16th – 28th June

- 1/2 weeks of SCAPA beamtime
- Laser Beamline alignment (0.5 days)
- Source optimisation w/o PMQ (0.5 days)
- PMQ transmission, activation and debris test (0.5 days)
- Lanex/beam profiler measurement at end of beamline (1 day)
- PMQ position optimisation (0.5 days)
- RCF measurements through beamline (0.5 days)
- Full cell assembly RCF measurement (0.5 days)

IV. Radiobiology: 27th Oct – 21st Nov

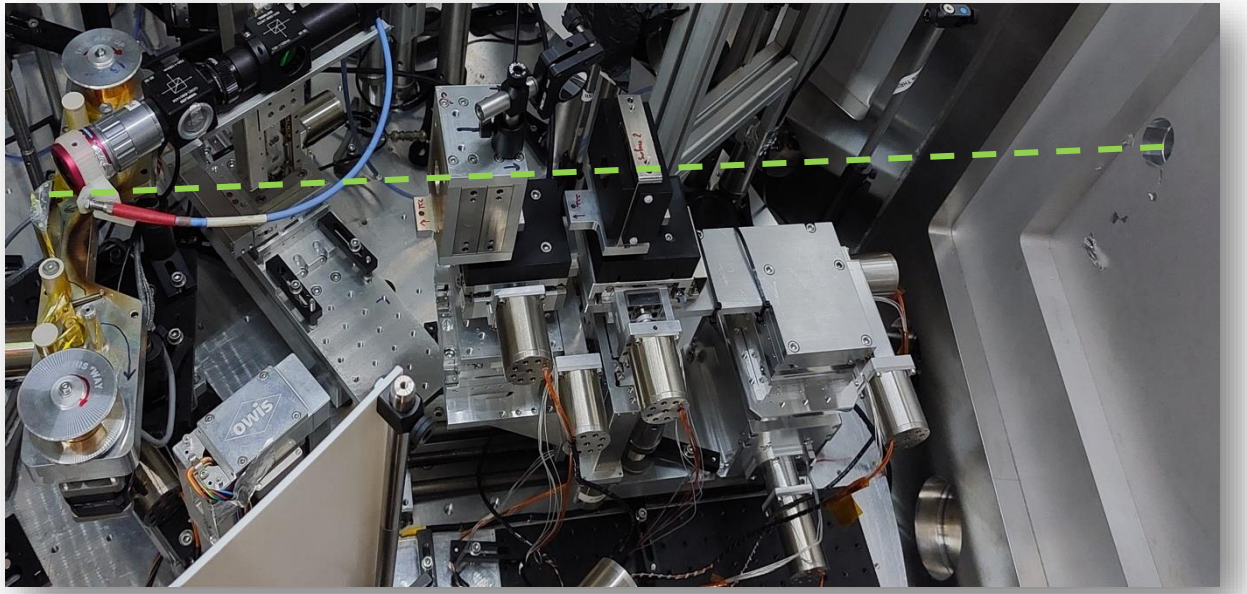
- 3 weeks of SCAPA beamtime (with potential for a gap between the alignment week)
- Laser Beamline alignment (0.5 days)
- Source optimisation with PMQs (1 day)
- Dosimetry and source stability measurements (2 days)
- Cell irradiation (6.5 days) + regular dosimetry

SCAPA Bunker B Target Station

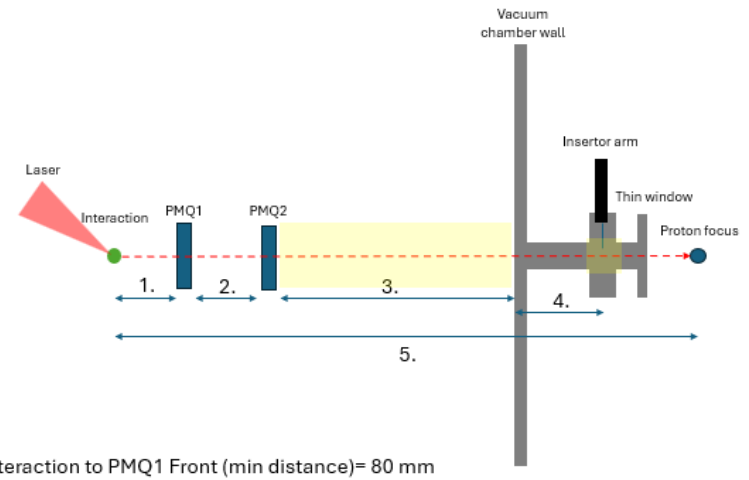


Proton Capture Beamline

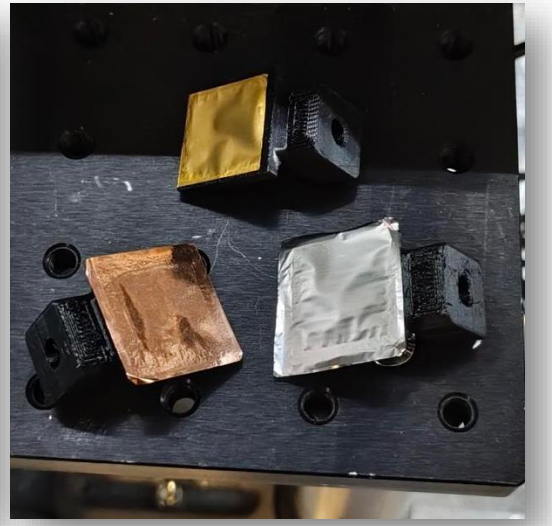
Internals

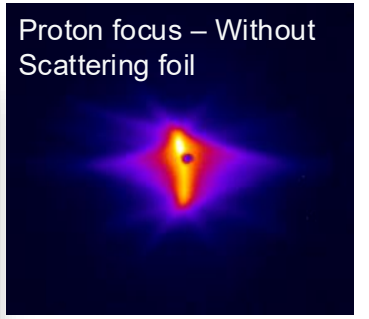


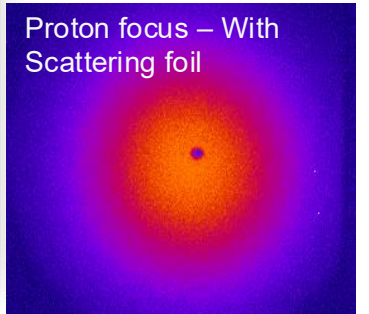
- Currently have a x2 PMQ system;
  - Target to PMQ1 front: 80 mm
  - PQM 1 to 2: 132 mm
  - Each xyz and rotation on each
- Can add proton beam scatterers to improve the proton focus spatial-profile. Tested various materials and thicknesses.
- Currently cannot operate our ion spectrometer without removing and realignment of PMQs.



1. Interaction to PMQ1 Front (min distance)= 80 mm
2. PMQ 1 middle to PMQ2 Middle (min distance)= 132 mm
3. PMQ2 rear to chamber wall= 725 mm
4. Chamber all to insertor arm position= 350 mm
5. Interaction to Proton focus= 1420 mm







Proton Capture Beamline

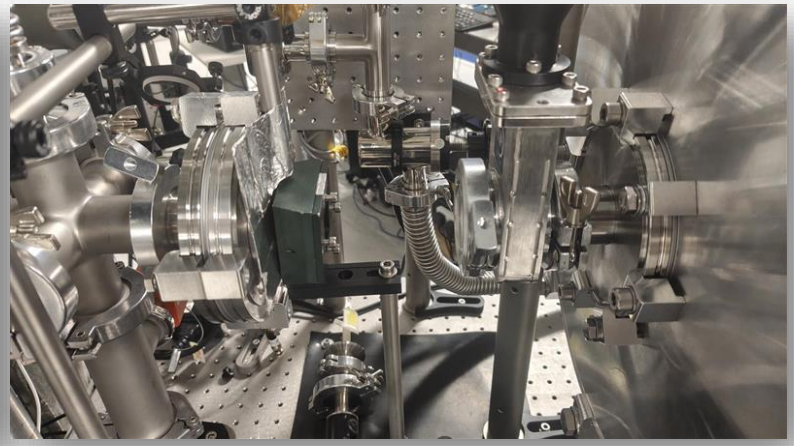
Externals

- 50 µm thick Mylar window for proton exit.
- Air gap length: 128 mm (can expand to 190 mm).
- We have variable path vacuum pumping and gate valves to enable rapid switching of modes.
- In vacuum insertors for extra diagnostics or filtering.

4 Operation Modes (currently)

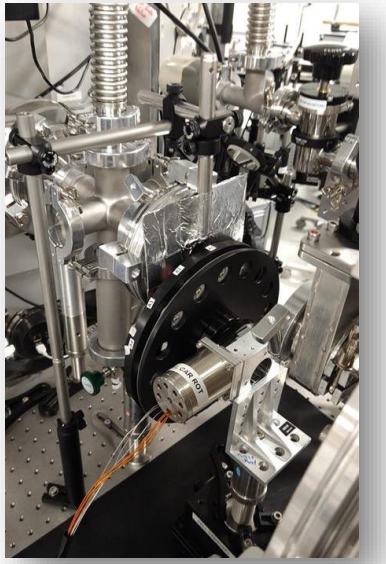
i) TP-Vacuum Mode

ii) RCF Stack



iii) Proton Focus Imager (Lanex)

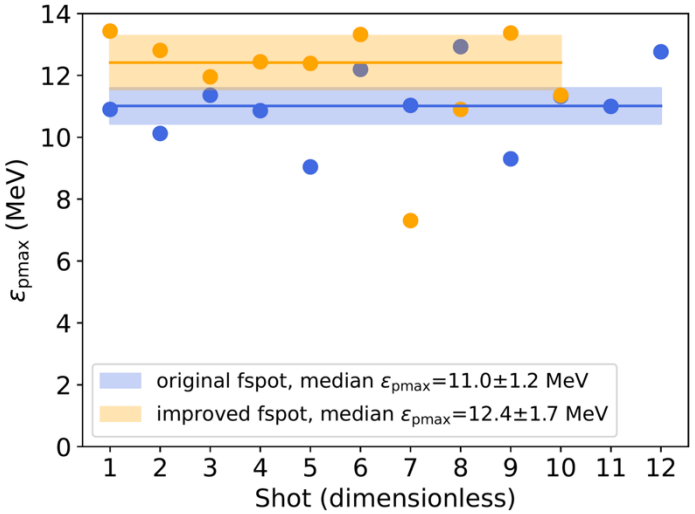
iv) Cell Irradiation Mode

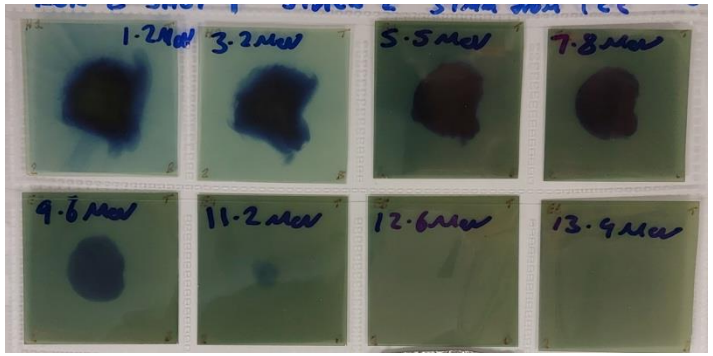


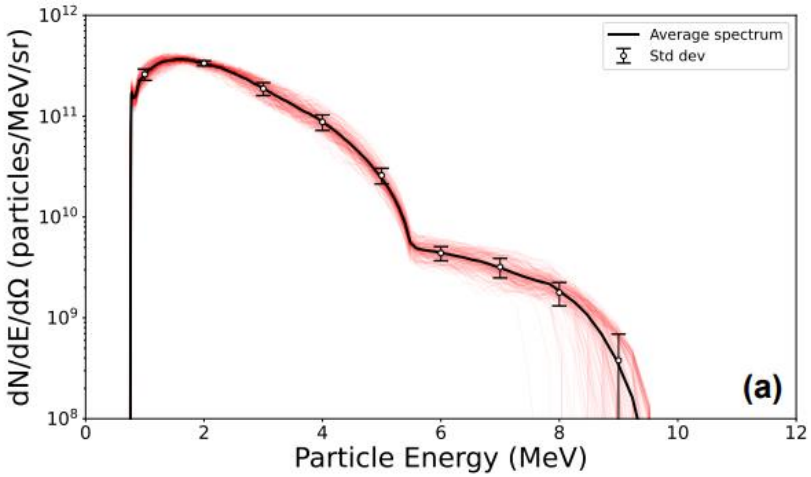
Source Updates

Experiment 1– June 2026

- Measured E_{pmax}= (12 ± 2) MeV using the Thomson Parabola (TP) Ion Spectrometer.
- E_{pmax} is relatively stable. However, did not do a longer scan (>100 shots) to see other sources of degradation (as we switched to PQM setup).
- Note E_{pmax} can drop to 10 MeV if the focal spot not optimised (demonstrates the sensitivity of alignment).
- RCF stack close to the target rear before the focal spot was optimised, to confirm E_{pmax} and beam divergence.
- Can now retrieve real proton numbers from our TP. A calibration was made with comparable RCF stack and TP spectra over several shots.



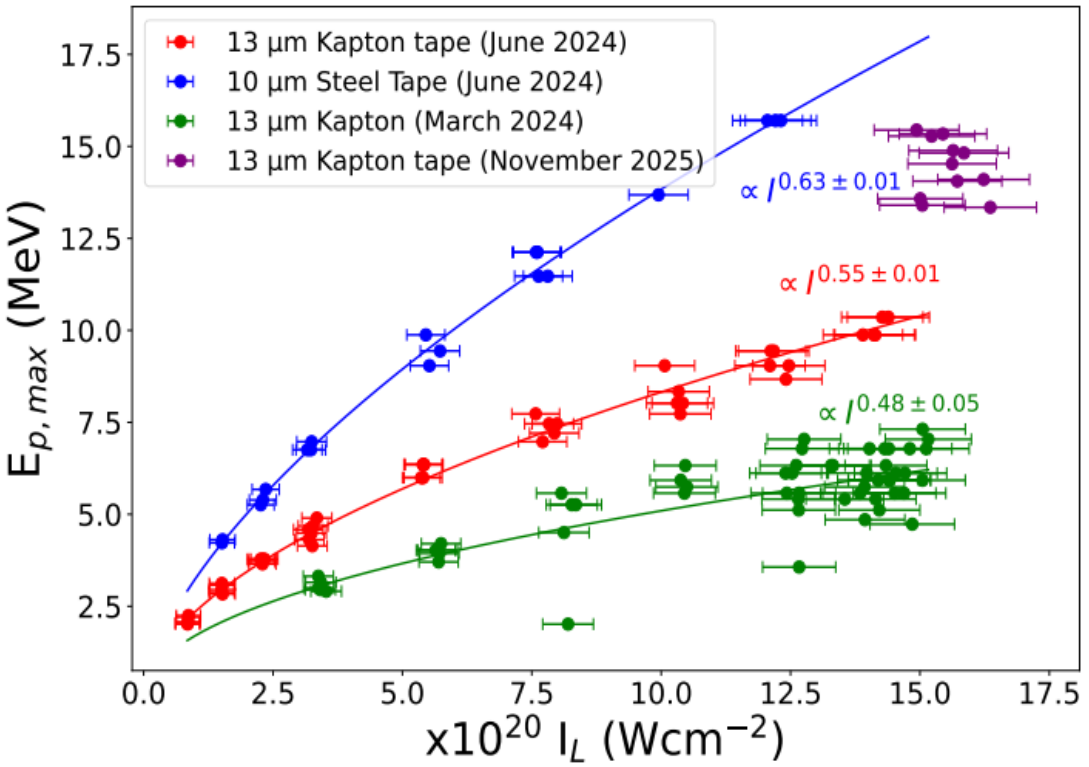


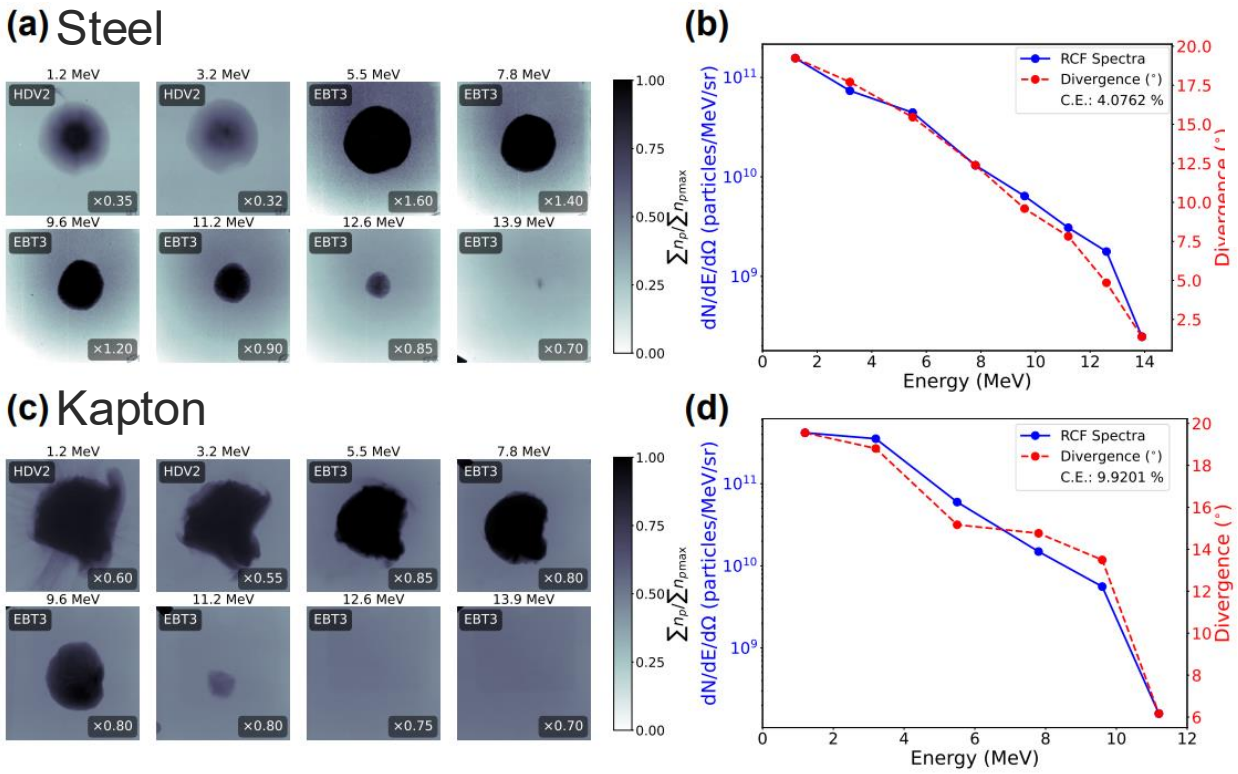


Source Updates

Experiment 2– October 2026

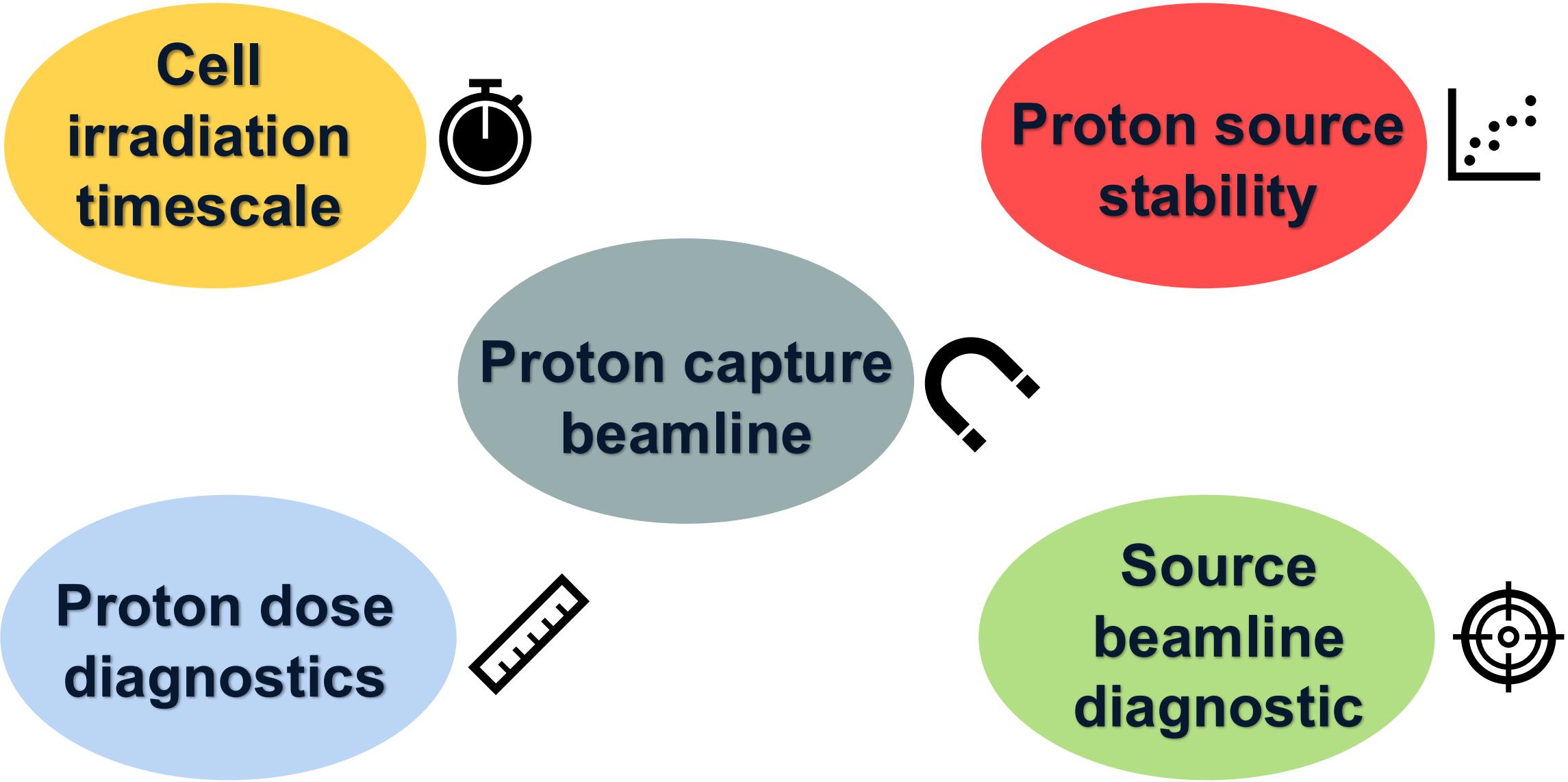
- We measured increased E_{pmax}= (14.4 ± 1.2) MeV using the Thomson Parabola (TP) Ion Spectrometer.
- This increase is in part due to higher pulse intensity, but this does not fully explain the result.





- Made RCF measurements comparing the beam generated for two target materials; Steel and Kapton.
- Steel provides a cleaner proton beam but opens us up to EMP issues.

Identified Issues, potential solutions and areas to improve



Irradiation Time and Routes to Improvement

Timescales November beamtime

Shot Rate Oct/Nov beamtime: **1 shot every 20 seconds**

- Most shots in one cycle was 50 (4,7,14 x2) so 1000 seconds = **16 mins 40 seconds.**
- This does not include transport time, time between runs (to rotate carousel), mounting time, lock up/prep time and post irradiation radiation checks…so more **like 30-40 mins**.

Timescale Improvements

- Aim for 1 shot every 5 seconds (could push to 1 Hz/1 second in future).
- 50 shots (4,7,14 x2) can be done in 250 seconds = **4 minutes 10 seconds.**
- Split cell irradiations from RCF irradiations or remove RCF shots for a new on-shot diagnostic with cells (RCF before cell dish?).
- Spilt cell irradiation runs. Would take longer overall, but much shorter in/out time.

Characterise proton focus with Lanex Imager /RCF stack

Open area and add cell carousel and RCF (rotation and alignment checks)

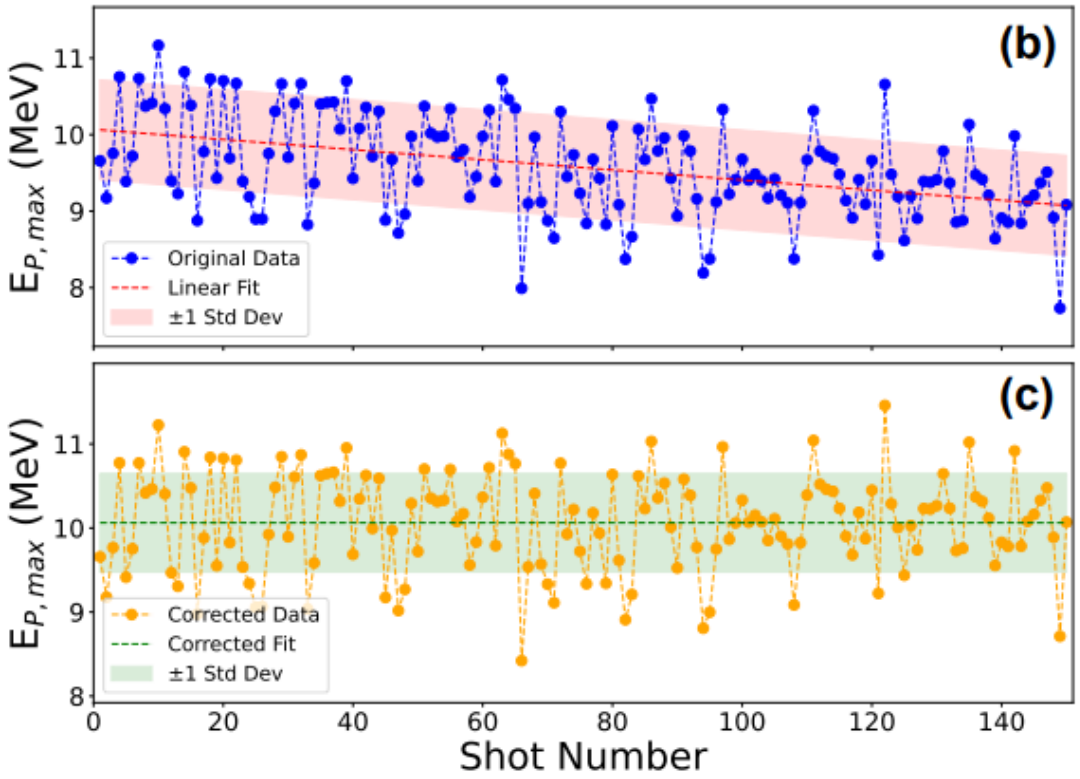
Lock up area and checklist

Irradiation runs and RCF shots

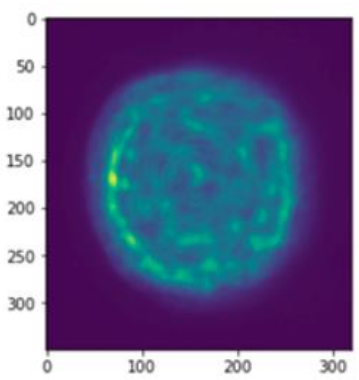
Open area and radiation check

Proton source stability- Known Issues

- Over a series of shots, we measure a decrease in E_{pmax} ; approx. 1 MeV over 120 shots.
- A result of reduced laser energy on target due to pellicle damage (the optical film protecting the focusing optic from debris).
- This occurs due to debris build up and asymmetry/structure in the laser near-field spatial-intensity profile.

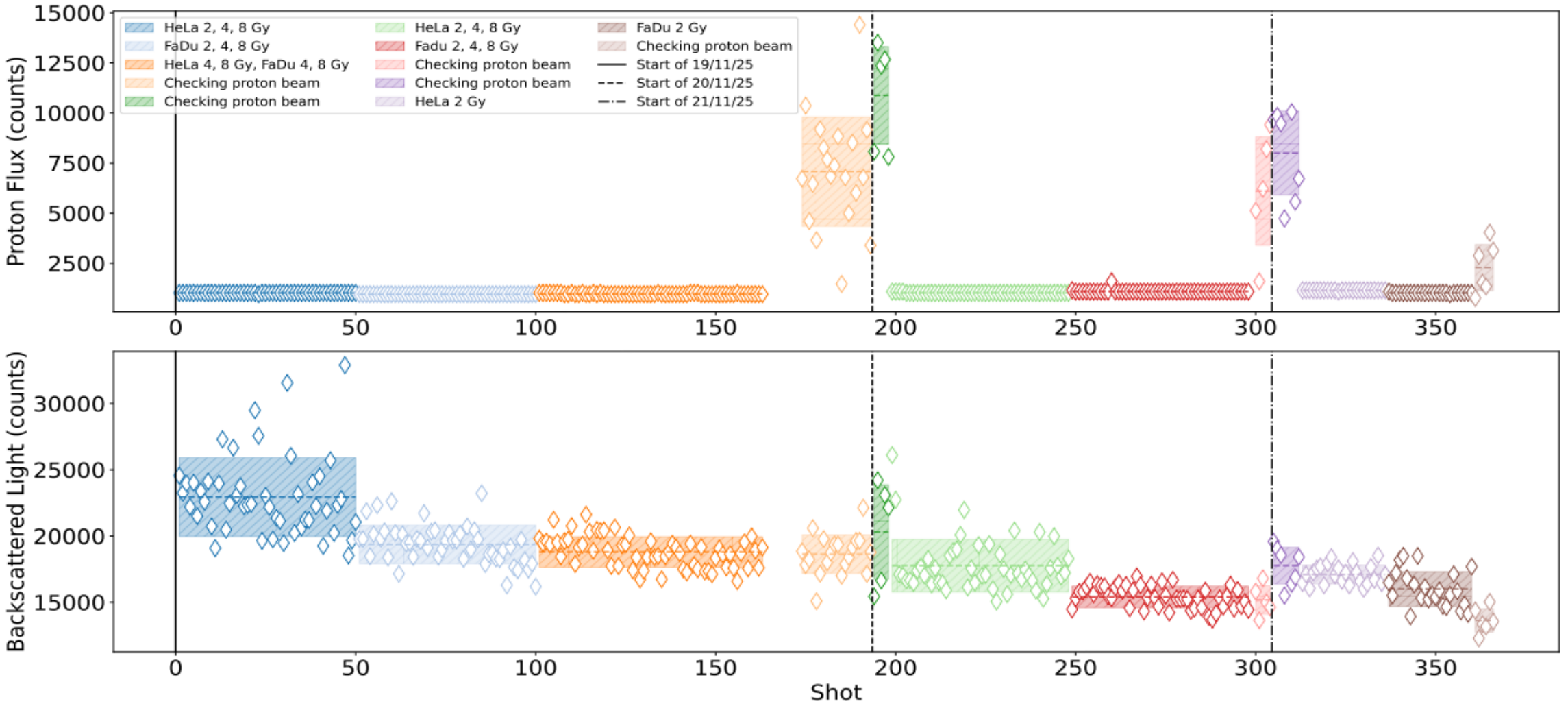


- **Key to PoPLaR-** We do not measure TNSA proton spectrum on every shot, so must rely on secondary correlated diagnostics.



Proton source stability- Unknown Issues

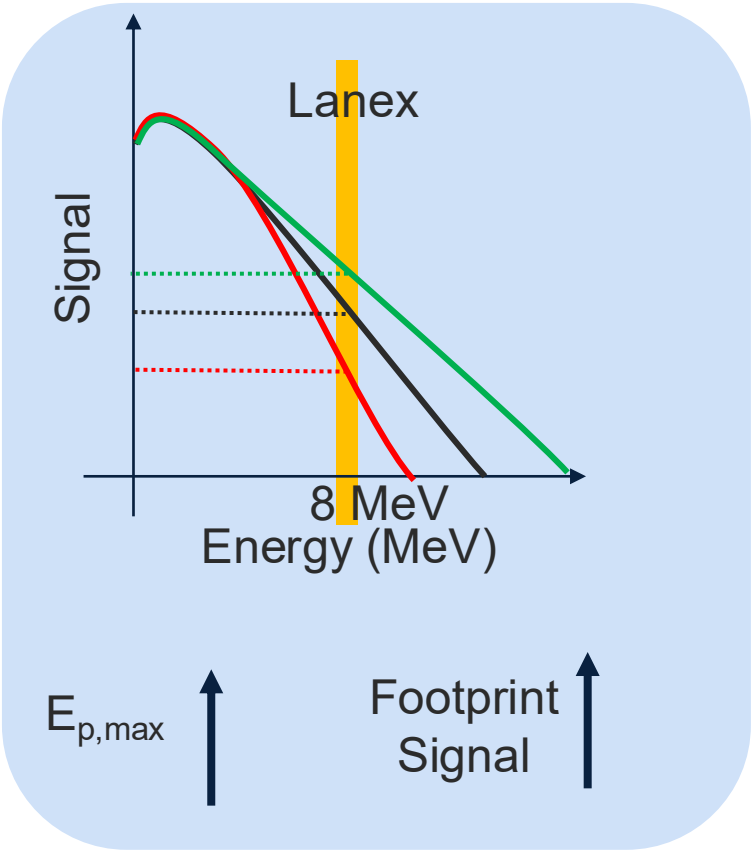
- Measured a large variation in proton focus dose using the RCF (more details on next slide).
- This is also seen using the diagnostics to measure the degree of laser light reflected from the target (both in backscatter and specular direction)



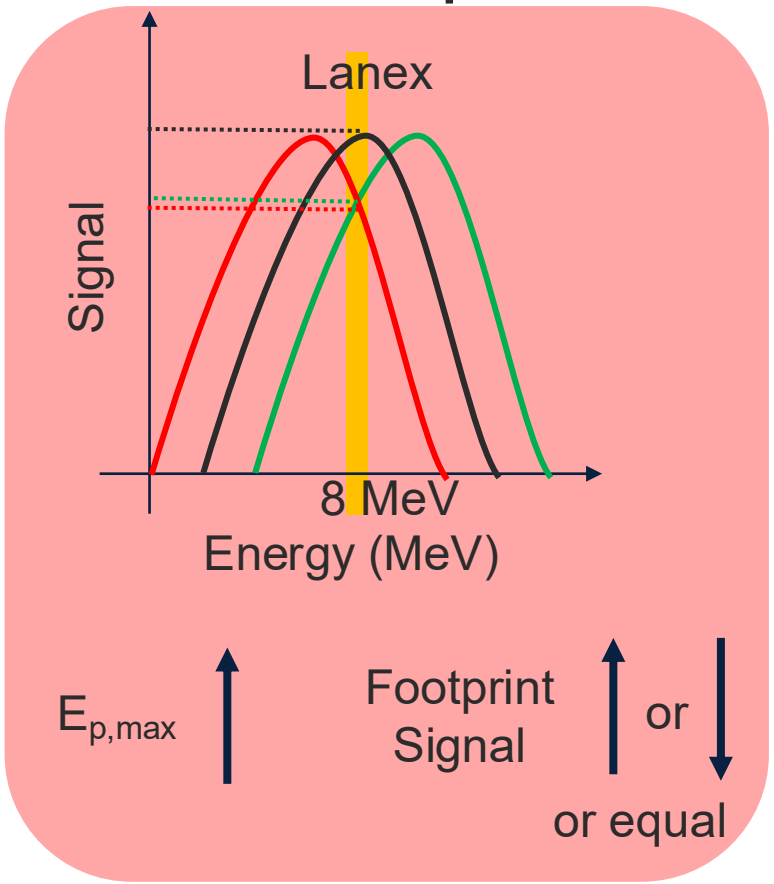
Proton source stability- Proton Imager Issue

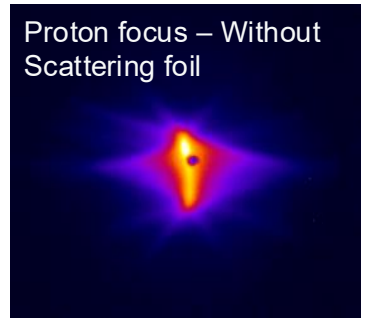
- Lanex scintillator, filtered for 8 MeV proton (7 layer of Mylar)

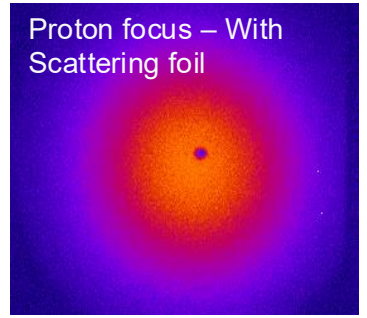
TNSA spectrum



PMQ focus spectrum







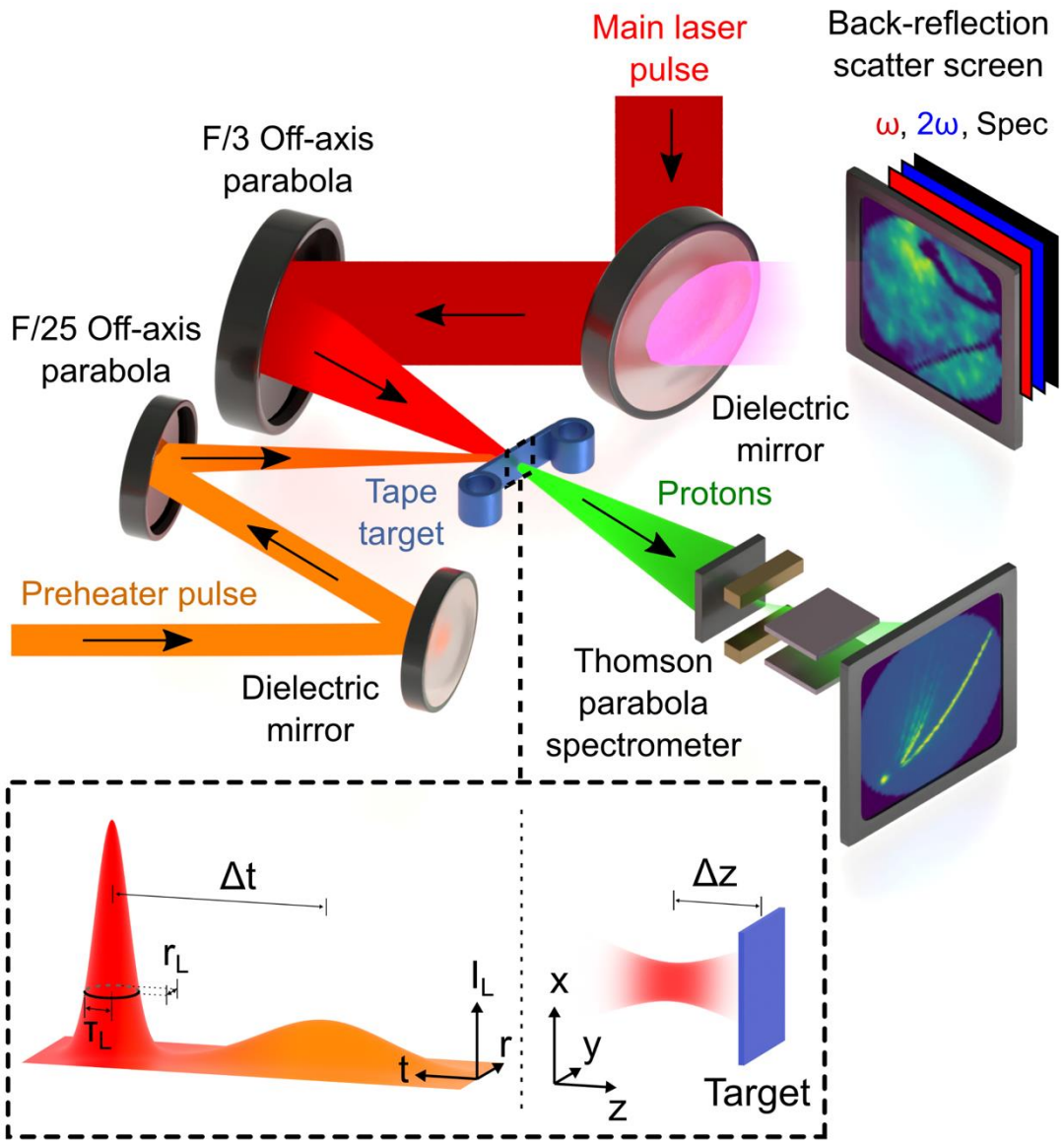
- Three key points of note from this;

i) Not having the ability to switch back to TP is a key issue to highlight.

ii) Relying on proton focus imager can be misleading due to narrow energy window. Require spectrum reconstruction.

iii) The need for on-shot primary or secondary diagnostics, that can map the full spectrum.

Synthetic diagnostic of proton spectrum



communications physics

Explore content · About the journal · Publish with us

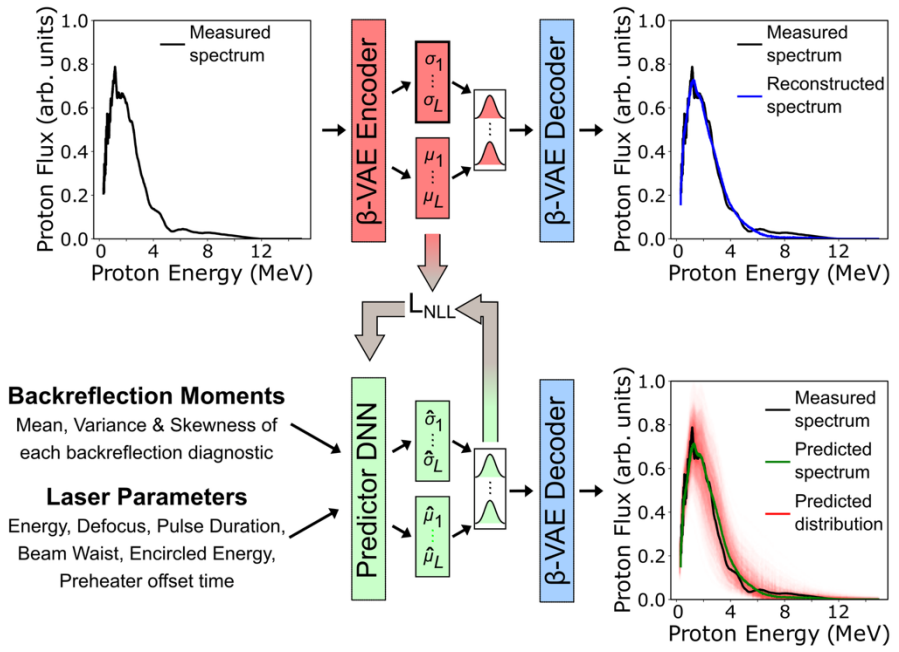
nature › communications physics › articles › article

Article | Open access | Published: 12 February 2025

A neural network-based synthetic diagnostic of laser-accelerated proton energy spectra

Christopher J. G. McQueen, Robbie Wilson, Timothy P. Frazer, Martin King, Matthew Alderton, Ewan F. J. Bacon, Ewan J. Dolier, Thomas Dzelzainis, Jesel K. Patel, Maia P. Peat, Ben C. Torrance, Ross J. Gray & Paul McKenna

Communications Physics **8**, Article number: 66 (2025) | Cite this article



C. J. McQueen et al., Communications Physics 8, 66 (2025)

Capture Beamline

Identified Issues	Potential Solutions/Improvements
• Proton focus- High degree of spatial structure (without scatterer).	• Upgrade to x4 PMQ system (would require significant engineering to add/modify setup).
• Distance to target limited, which influences proton capture.	• Modifications to mounting of PMQ1 and target.
• Proton focus- Low dose (with scatterer).	• Upgrade to x4 PMQ system (would require significant engineering to add/modify setup).
• No transverse movement to remove PMQs from TP line.	• Add larger stages to each PMQ to move out of beam central axis.
• Hysteresis on some drives, limiting accurate replacement of PMQs.	• Better monitoring solutions of PMQ positions and improved diagnostics.

Future Beamtime in SCAPA and Beyond

SCAPA

Cell Studies

- Repeat Nov 2026 beamtime with improved cell irradiation durations/lessons learnt.
- Test the influence of irradiation rate, through variation of shot rate to achieve the same overall dose.
- Reduce proton numbers to do fractionated dose irradiation shots.

Proton Capture system

- Greater knowledge on input source parameters and stability.
- Implementation of a > 4 PMQ capture system.
- Energy selector /monochromator to reduce proton focus to one energy.
- Alter PMQ relative positions to optimised lower Ep capture, potential more stable

Diagnostic Development

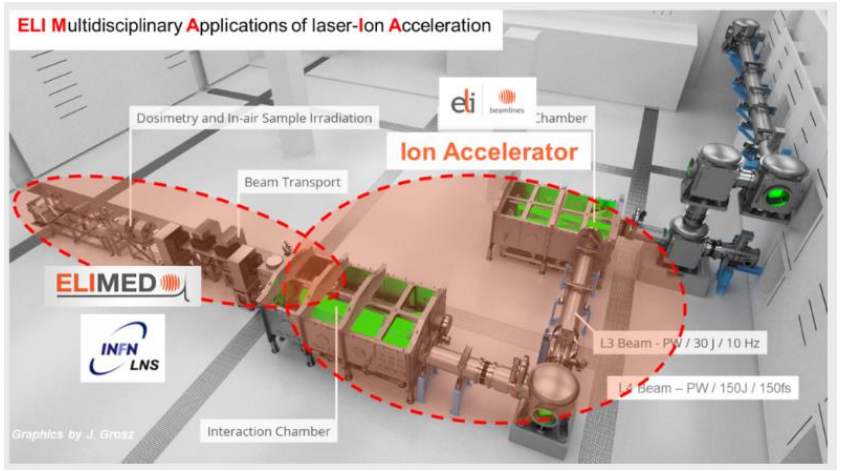
- Alteration to PMQ movement to enable TP use on demand.
- Improvements to the proton focus imager to enable spectral measurements
- On-shot dose measurement, either active or passive (RCF).
- Synthetic diagnostic development to predict on-shot TNSA spectrum/divergence.

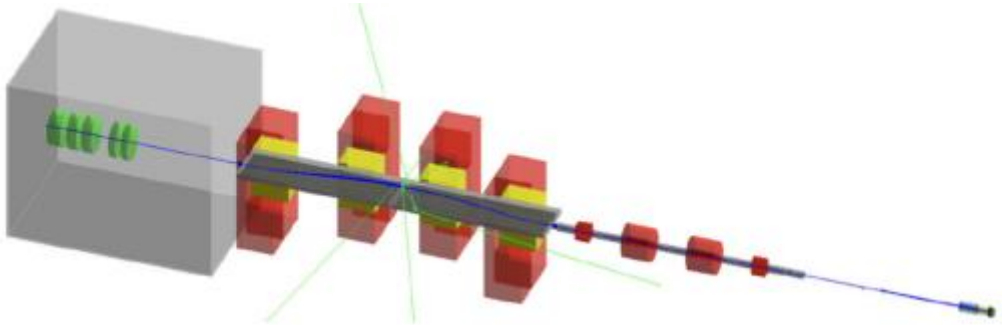
Future Beamtime in SCAPA and Beyond

ELI Beamlines – Target Area E4

ELIMED (ELI-Beamlines MEDical and multidisciplinary applications)

ELIMAIA (Multidisciplinary Applications of laser-Ion Acceleration)





- x5 PMQ beamline and energy selection system.
- Built in proton focus dose diagnostics: a Secondary Electron Monitoring (SEM), a Multi-Gaps Ionization Chamber (MGIC), and a Faraday Cup (FC) for absolute dosimetry.
- We have worked on this system, with the aim of developing a syntenic diagnostic of the TNSA driven proton beam.

https://www.frontiersin.org/journals/physics/articles/10.3389/fphy.2020.564907/full

Future Beamtime in SCAPA and Beyond

The 4th ELIMED Workshop MEDical and Multidisciplinary Applications of Laser-driven Ion Beams at ELI Beamlines Facility

16–18 Mar 2026
Europe/Prague timezone

https://indico.eli-laser.eu/event/229/

Workshop Topics:

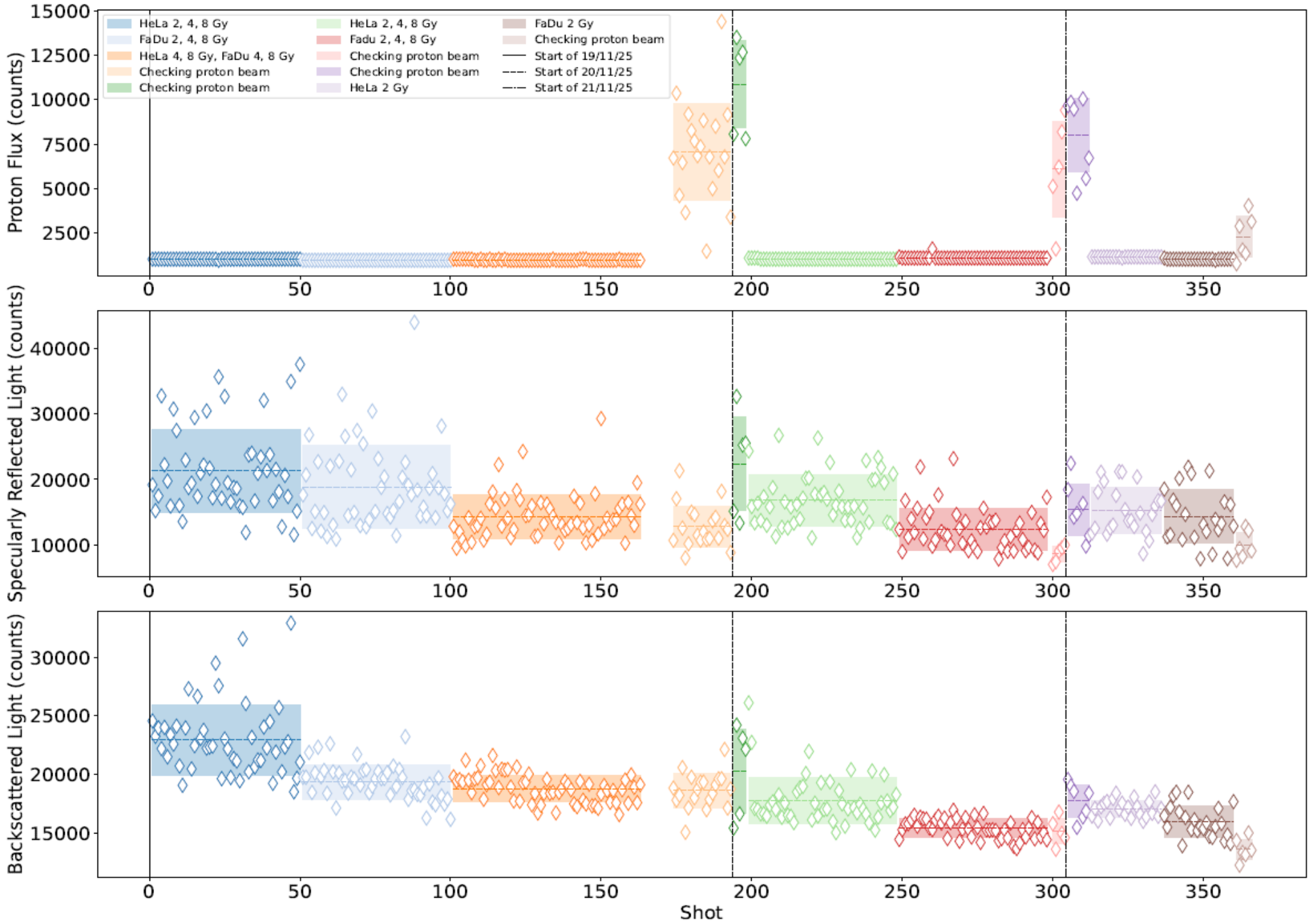
- Medical applications of laser-driven ion beams (ultrahigh dose-rate clinical dosimetry, radiation therapy, medical radioisotopes, medical imaging);
- Ultrafast Radiation Biology (in vivo and in-vitro)
- Recent development of compact laser-plasma ion accelerators for multidisciplinary applications.
- Radiation damage on electronics and space radiation applications with laser-driven ion beams
- Non-destructive material inspections for cultural heritage applications.

Thank you for your attention

University of Strathclyde Glasgow

Royal Charter since 1964

Useful Learning since 1796


HeLa 2, 4, 8 Gy
FaDu 2, 4, 8 Gy
HeLa 4, 8 Gy, FaDu 4, 8 Gy
Checking proton beam
Checking proton beam
HeLa 2, 4, 8 Gy
Fadu 2, 4, 8 Gy
Checking proton beam
Checking proton beam
HeLa 2 Gy
FaDu 2 Gy
Checking proton beam
Start of 19/11/25
Start of 20/11/25
Start of 21/11/25
Proton Flux (counts)
Specularly Reflected Light (counts)
Backscattered Light (counts)
Shot