



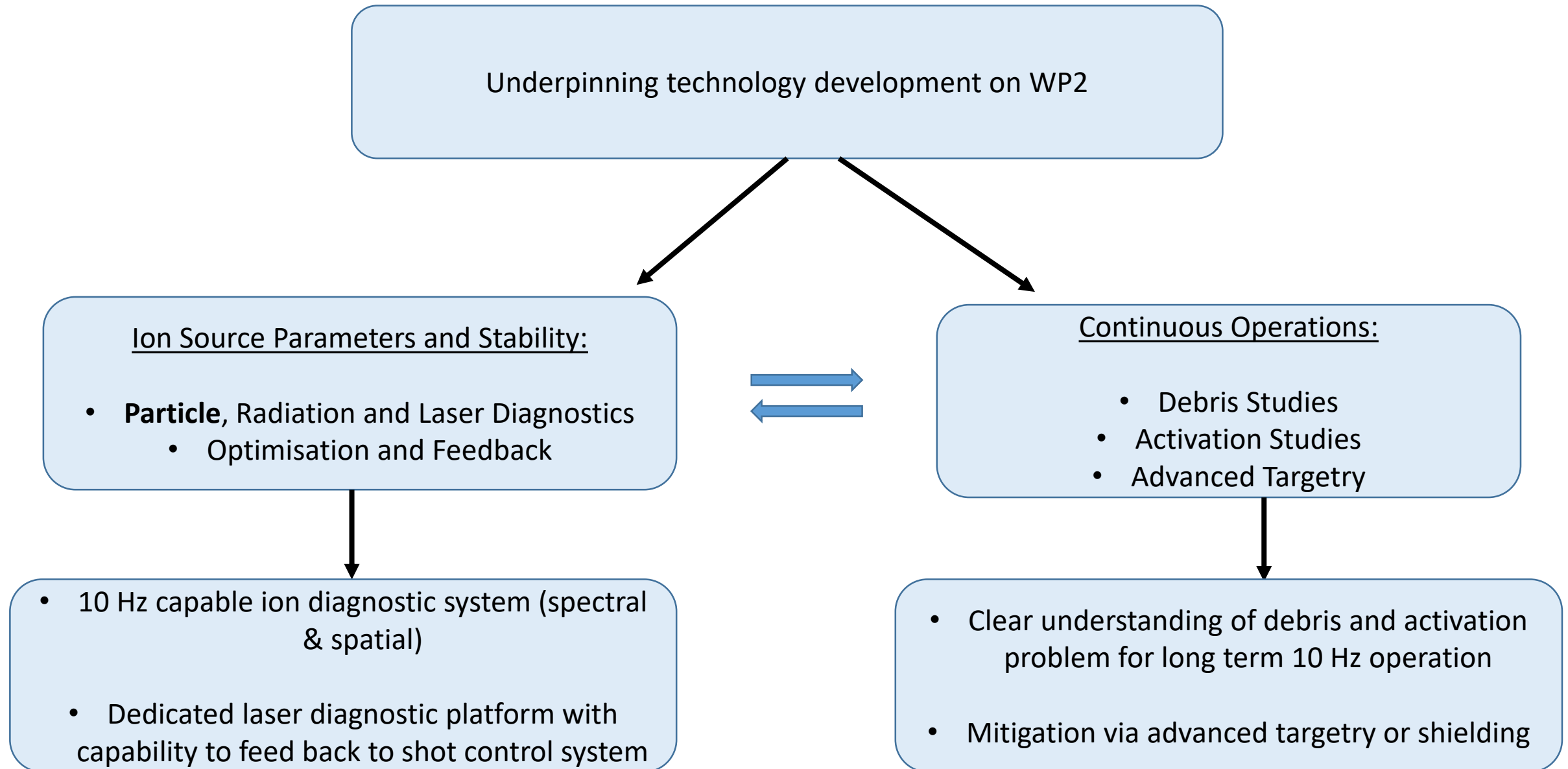
WP2: Diagnostics, Instrumentation & Targetry

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WP2 Technology R&D Plans: Instrumentation and source characterisation



Experiments & Technology Development in 2-year Programme: Characterising Source and Benchmarking Simulations

Established Diagnostics...

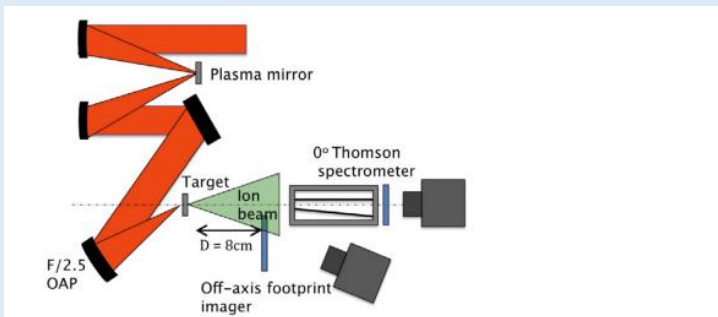
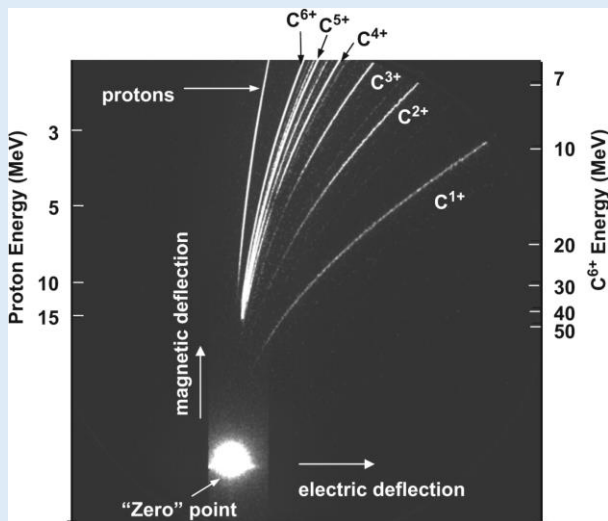


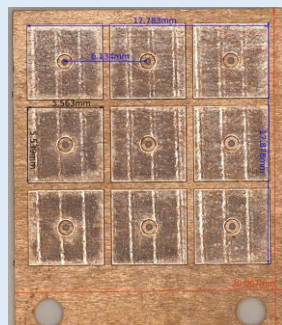
Figure 1. Experimental setup. A Thomson spectrometer deflects the ions onto a piece of plastic scintillator, which is imaged using an EMCCD camera. A second sheet of scintillator images the off-axis portion ($>6^\circ$ off-target normal) of the ion beam.

J.S Green *et al.*, NJP. 12 (2010) 085012

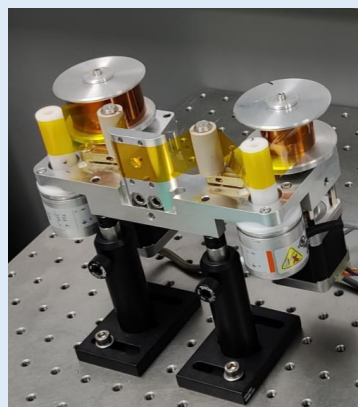


R. Prasad *et al.*, Nucl. Instrum. Methods. 623.2 (2010): 712-715.

Established Targetry...moving toward Hz-level targetry



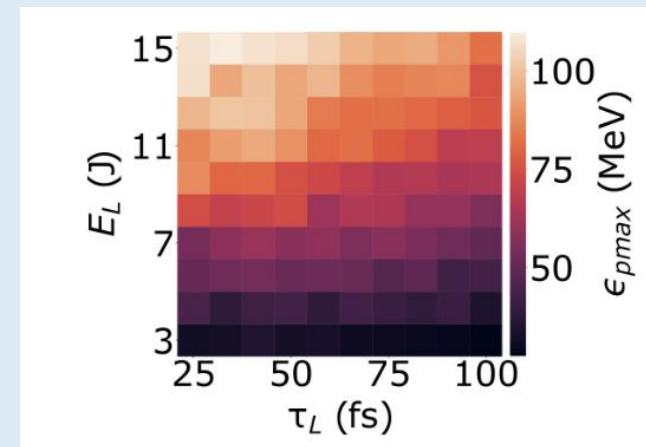
Typical 9-target array



Tape targetry system (online in SCAPA 2022)

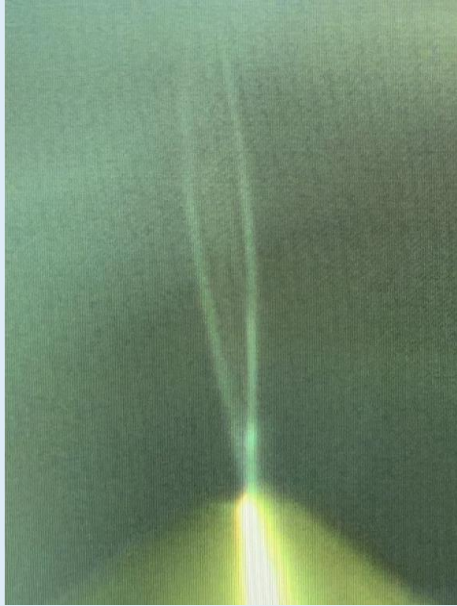
...to build a systematic parameter space map of the source performance

- Energy, Flux, Divergence across multiple ion species



Experiments & Technology Development in 3-year Programme: Producing a stable, high-rep source

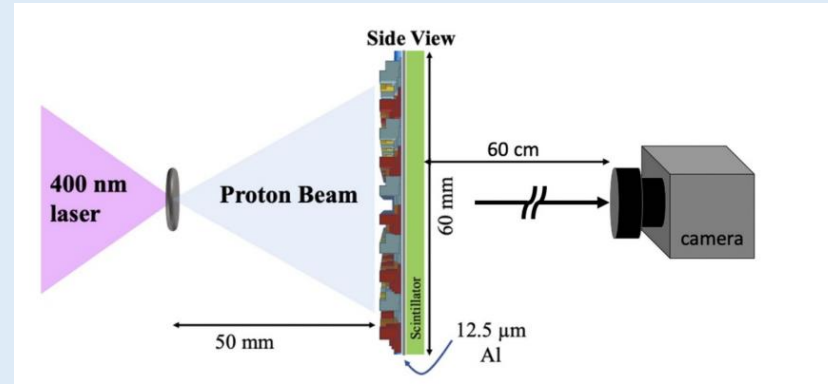
Novel Liquid Targetry



Courtesy of C. Palmer

- Reduces production of debris
- Increases operational time and possible rep rate

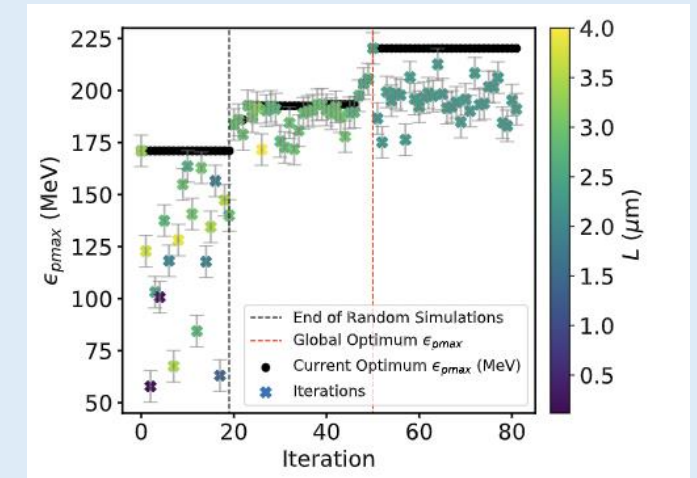
Advanced Particle & Laser Diagnostics



D. Marsical *et al.*, Plasma Phys. Control. Fusion 63 (2021) 114003

- Implementation of advanced (existing) particle diagnostics, taking account of long term operation.
- Implementation of full laser diagnostic suite to support automation, stabilisation.

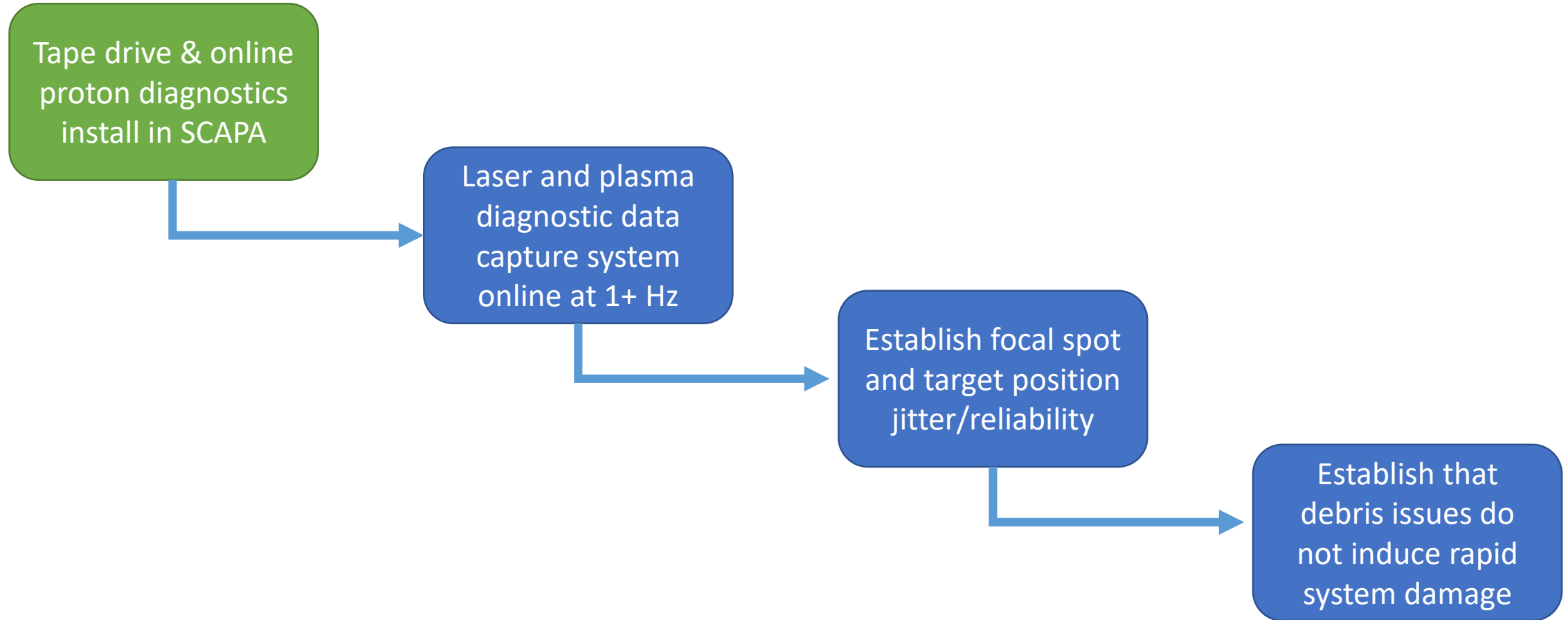
ML/AI Control & Optimisation



- Application of ML techniques (e.g Bayesian Optimisation) for parameter space
- Application of AI techniques (DNNs, CNNs) for system control and virtual diagnostics

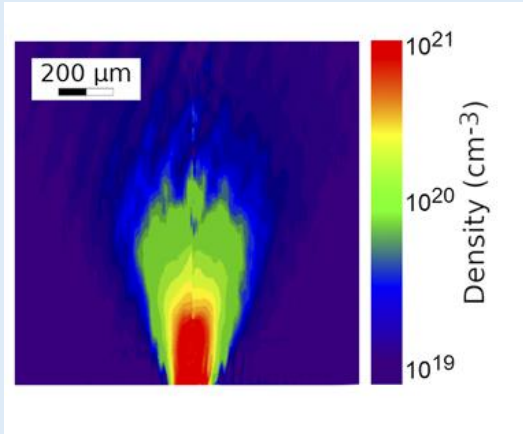
WP2 Technology R&D Plans: Getting to 1Hz and beyond

Detailed steps are captured in our Gantt chart but...



Targetry (range of potential rep-rated target development for ~ 10 Hz operation)

Dense Gas Targets



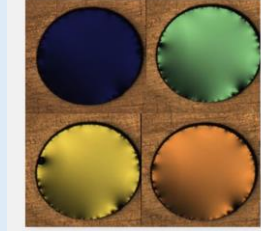
Henares *et al.*, Rev. Sci. Instrum. (2019);

Novel Liquid Targets



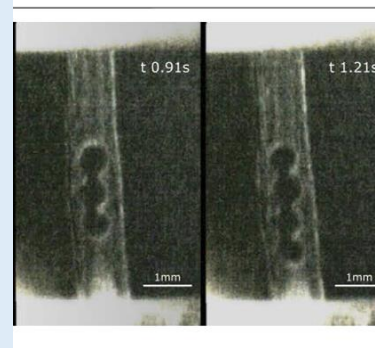
Courtesy of C. Palmer

Liquid Crystal

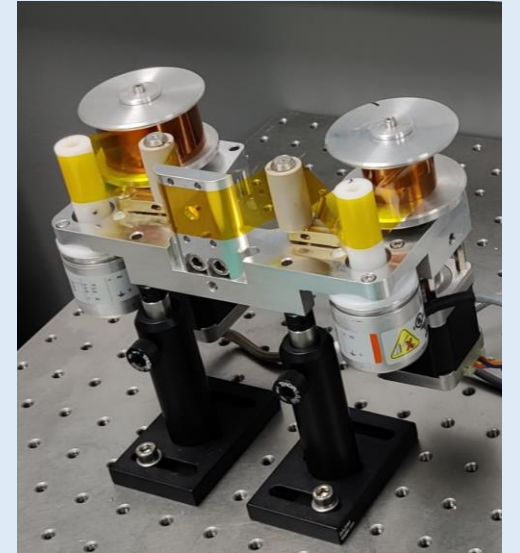


Poole *et al.*, Sci. Rep. (2016)

...and cryo targets



Fixed Solid Targets (Tapes)



Highest Repetition rate,
lowest debris, longest
continuous operation

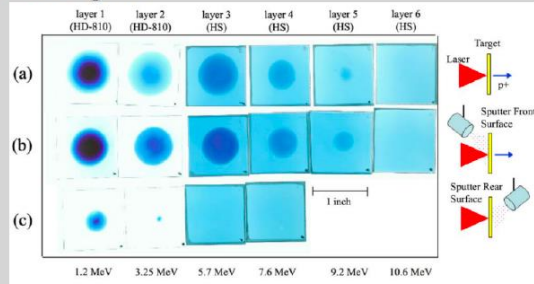
Technical
readiness

Optimal Source Performance

Ion Species Selection – For solid density targets

For solid targets...

Sputter gun

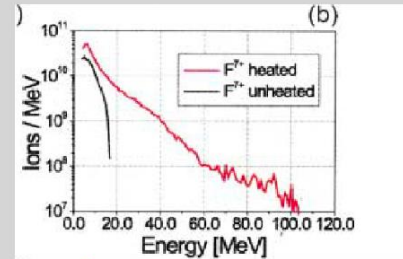


e.g. Allen et al. PRL 93, 265004 (2004)

Resistive heating

- Heat entire foil by passing through high DC current

e.g. Hegelich et al. PRL 89, 8 (2002)



Targeted removal of contaminant

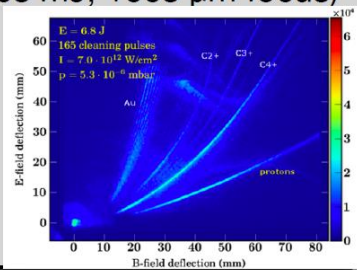
Heat target to “boil off” hydrocarbons - ~1000 K

Pulsed laser cleaning

- Focus pulsed laser (typically ns or sub-ns, 1-100s mJ, 100s μm focus)

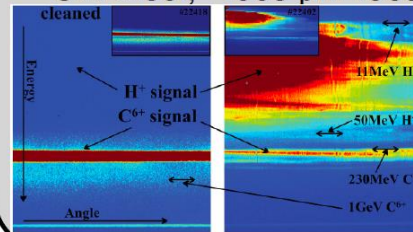
e.g. Sommer et al. PPCF 60, 054002 (2018)

e.g. Hoffmeister et al. PRSTAB 16, 041304 (2013)



CW laser cleaning

- Heat entire foil by irradiating with ~ 1 W CW laser, 100s μm focus



e.g. Safranov+ Phys. Plasmas 25, 103114 (2018)

e.g. Jung+ Phys. Plasmas 20, 083103 (2013)

For liquid/gas targets...

- Changes to the liquid (e.g glycol) but would still need post selection
- Gas targets could enable helium acceleration but changes the mechanism
- If anything other than Carbon, Oxygen, Hydrogen ions needed then solid targets are the best option

Reproducibility and reliability considerations

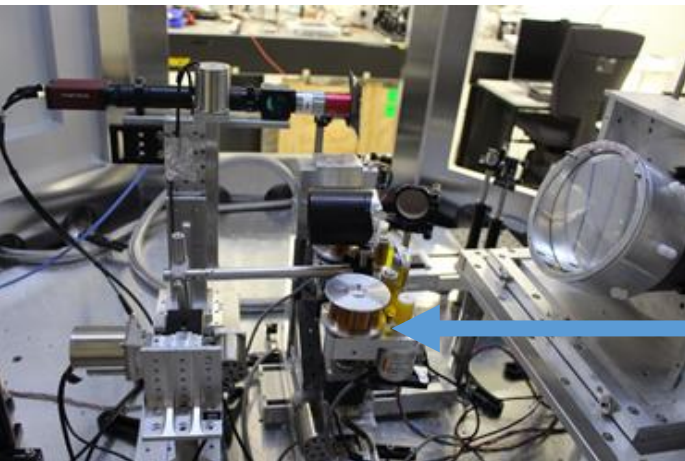
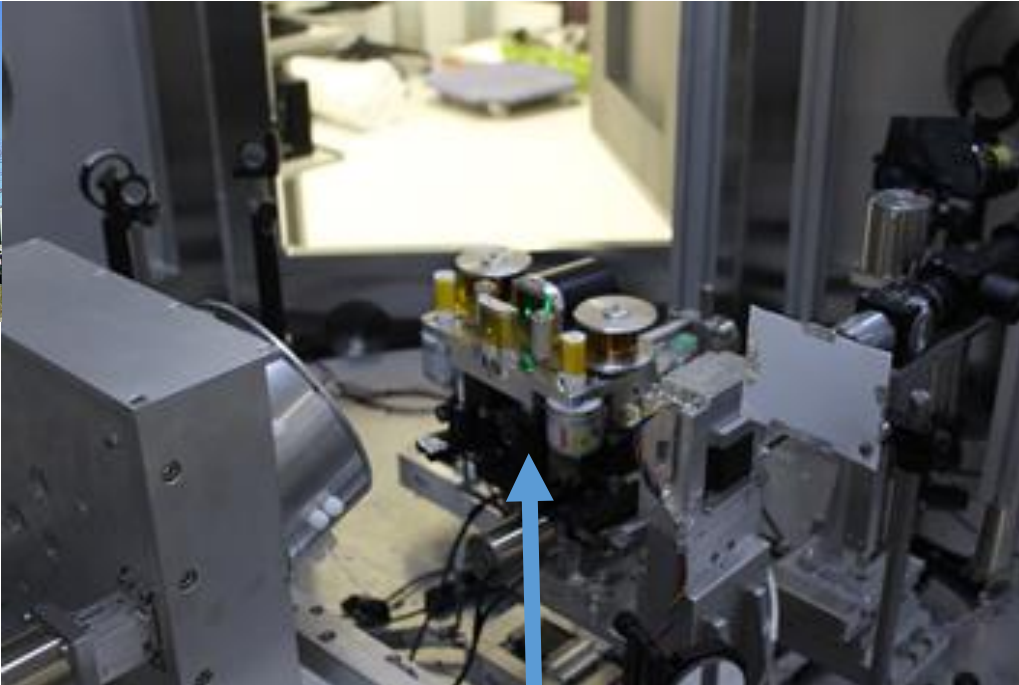


Additional Slides

WP2 Technology R&D Plans: First SCAPA experiments



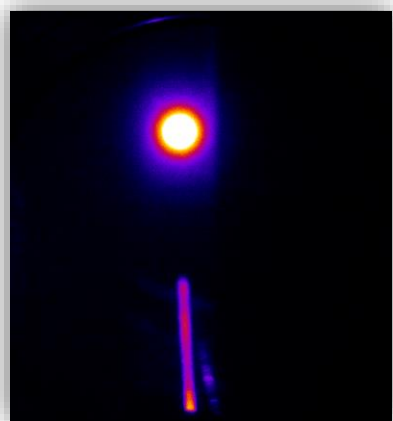
Laser-solid interaction beamline B1 in Bunker B.



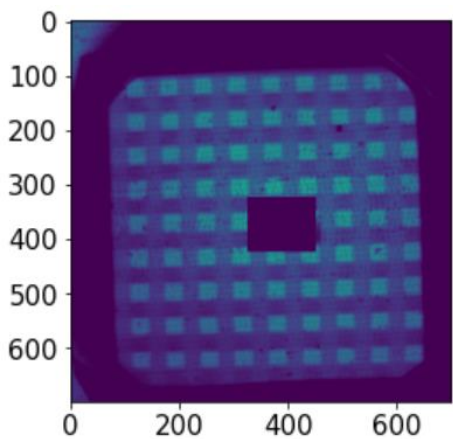
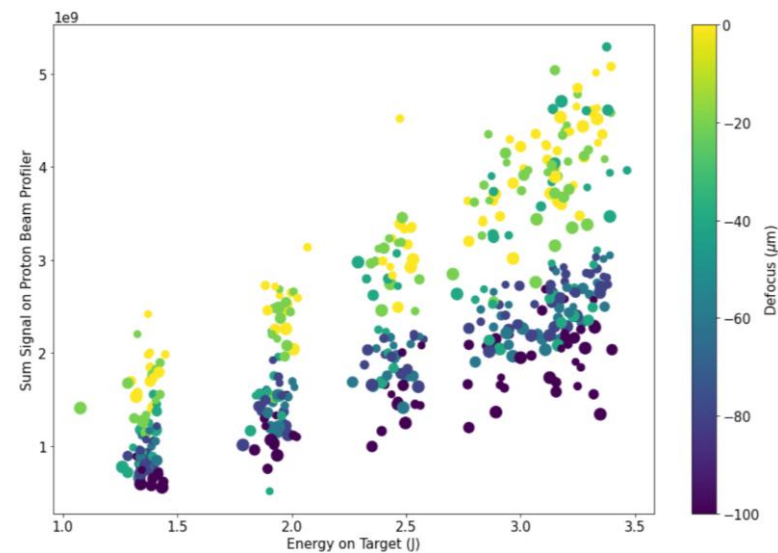
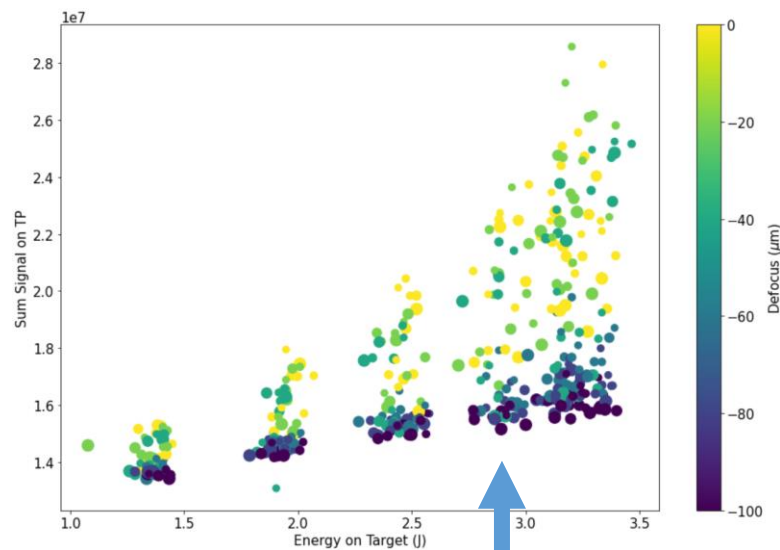
Tape drive target

- First Bunker B commissioning experiment completed in September 2022
- Over 1000 laser shots taken in 3 weeks (in terms of shots taken that is equivalent to $\sim 4x$ typical Gemini experiment)
- Tape drive target, online proton beam profiler, Thomson parabola spectrometer and laser absorption diagnostics all brought online
- Continuous repetition rate of ~ 0.1 Hz demonstrated but this is only limited by data transfer speeds and some manual data capture

WP2 Technology R&D Plans: First SCAPA experiments



Active TP Spectrometer



Active Proton Beam Profiler

- 3D parameter space scan of pulse duration, laser energy and defocus measuring total proton energy
- ~450 shots taken over 4 hour period

