WP2: Diagnostics, Instrumentation & Targetry

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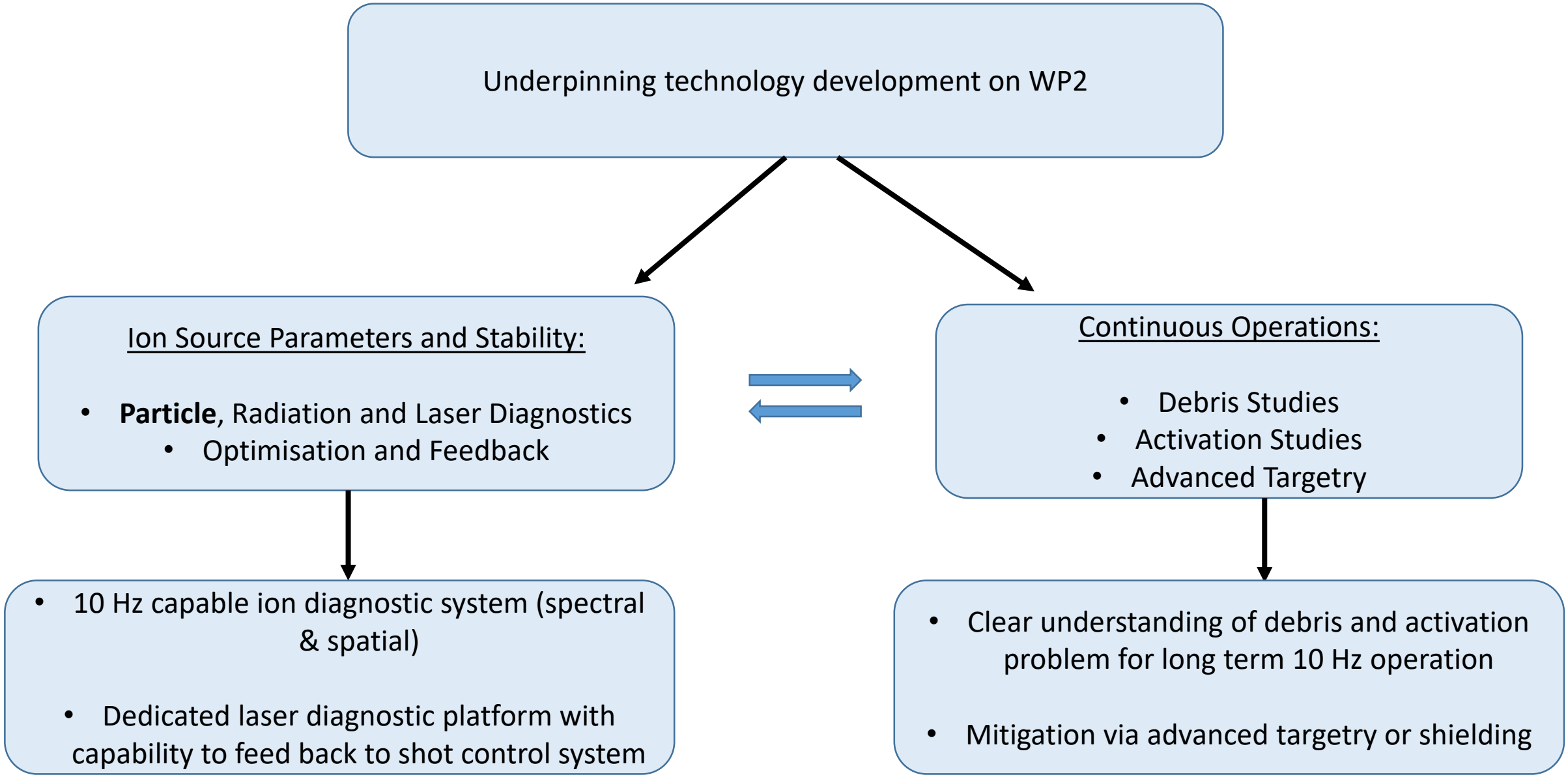
WP2 Technology R&D Plans: Instrumentation and source characterisation



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

Established Diagnostics…

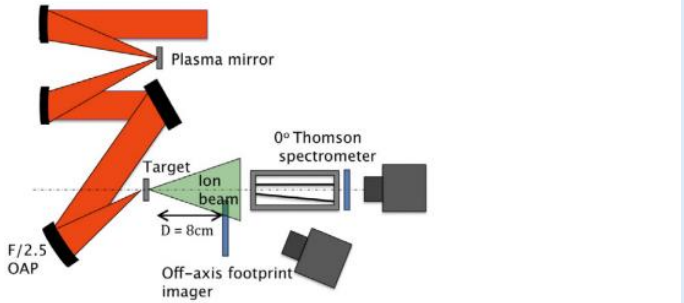
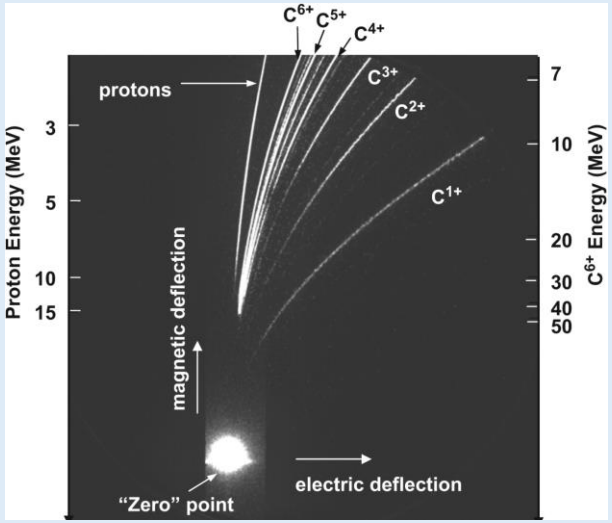


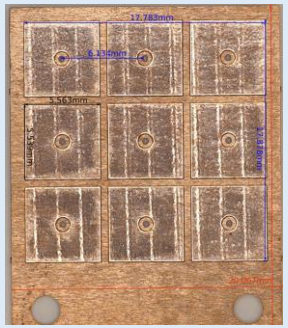
Figure 1. Experimental setup. A Thomson spectrometer deflects the ions onto a piece of plastic scintillator, which is imaged using an EMCCD camera. A second sheet of scintillator images the off-axis portion (>6° off-target normal) of the ion beam.

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

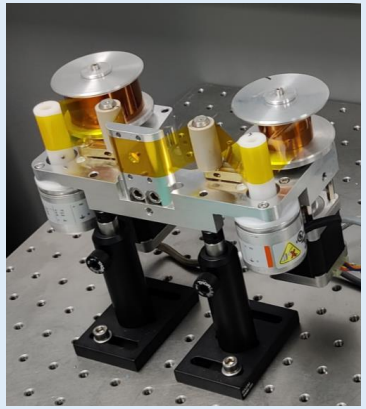


R. Prasad *et al.,* Nucl. Instrum. Methods. 623.2 (2010): 712-715.

Established Targetry…moving toward Hz-level targetry



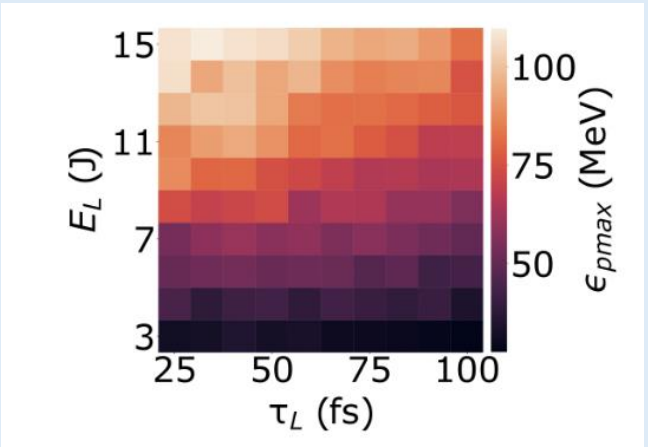
Typical 9-target array



Tape targetry system (online in SCAPA 2022)

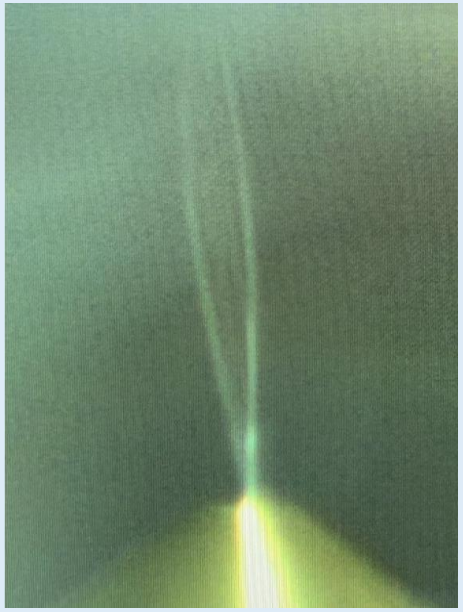
….to build a systematic parameter space map of the source performance

- Energy, Flux, Divergence across multiple ion species



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

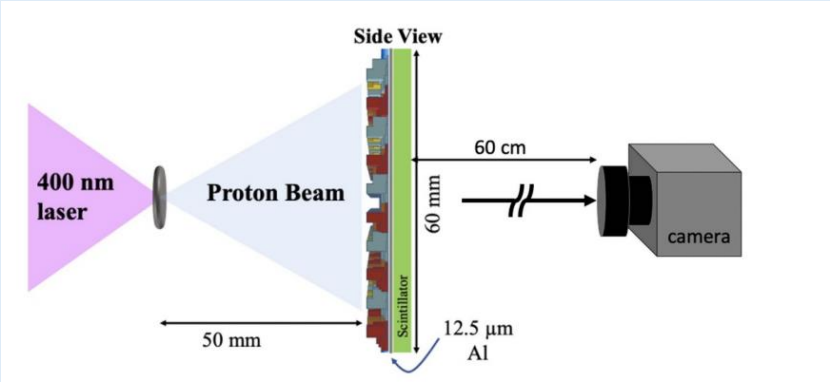
Novel Liquid Targetry



Courtesy of C. Palmer

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

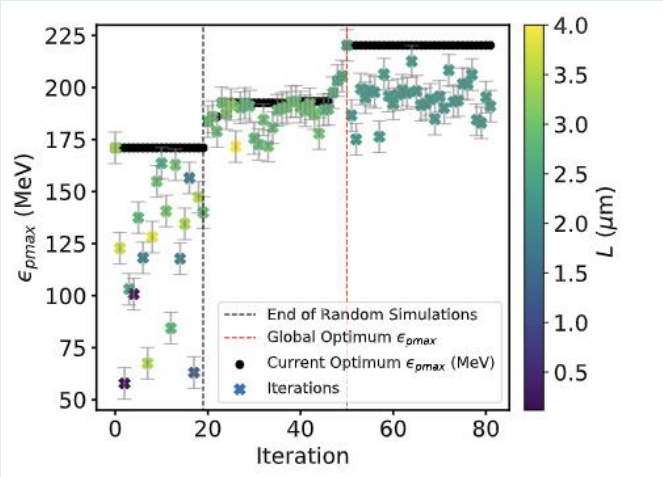
Advanced Particle & Laser Diagnostics



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.

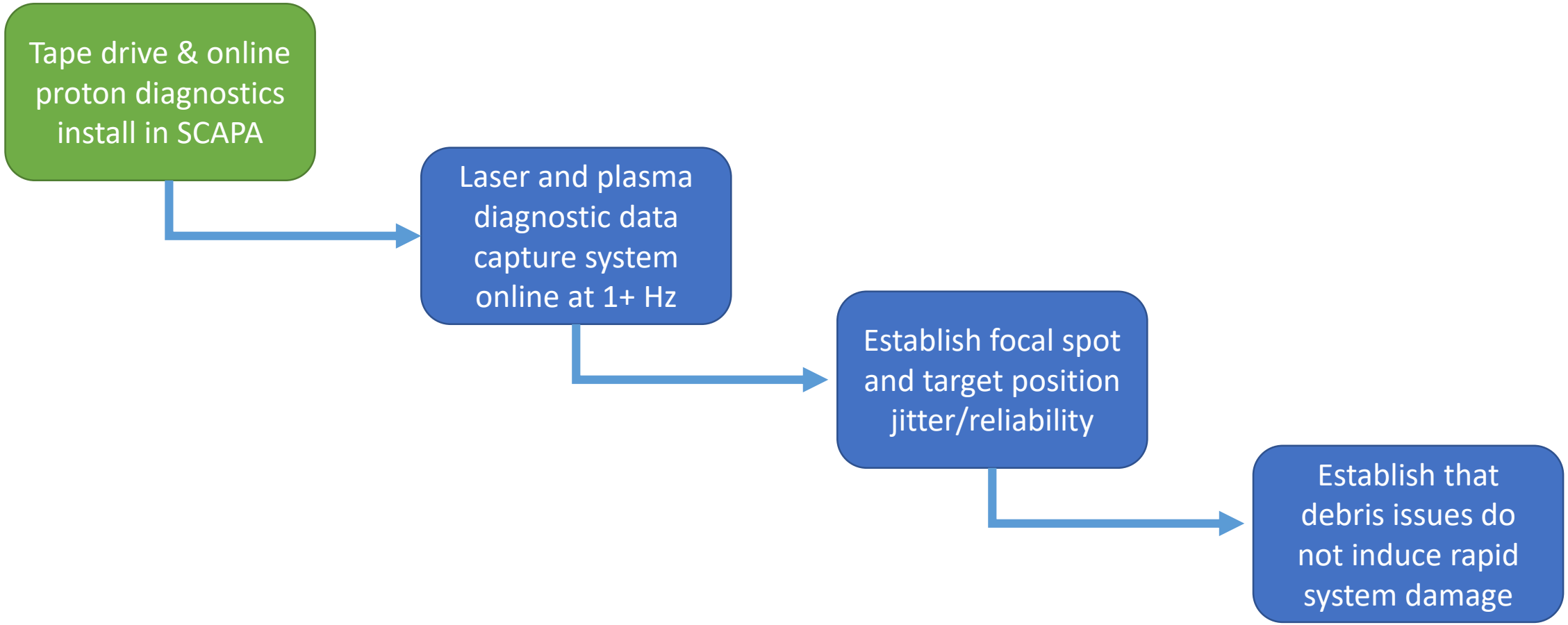
ML/AI Control & Optimisation



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

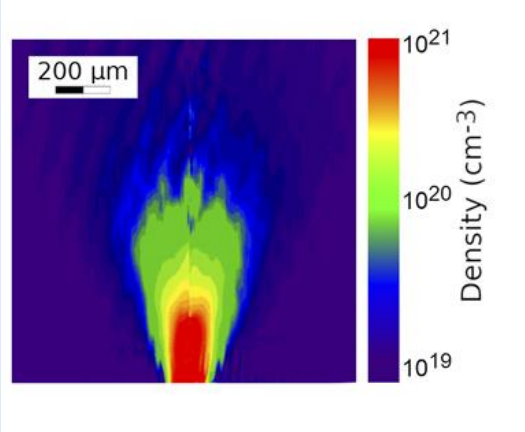
WP2 Technology R&D Plans: Getting to 1Hz and beyond

Detailed steps are captured in our Gantt chart but…



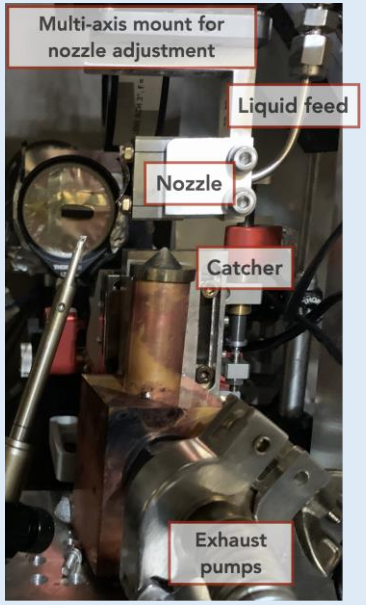
Targetry (range of potential rep-rated target development for ~ 10 Hz operation)

Dense Gas Targets



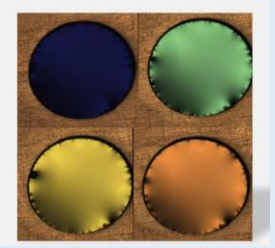
Henares *et al.*, Rev. Sci. Instrum. (2019);

Novel Liquid Targets



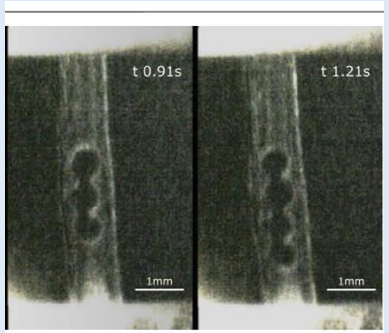
Courtesy of C. Palmer

Liquid Crystal

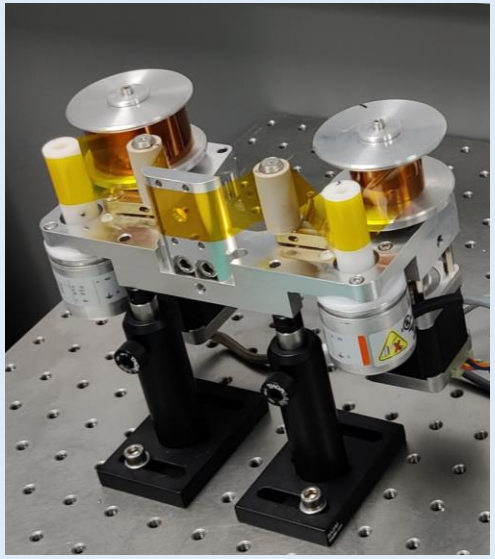


Poole *et al.*,Sci. Rep. (2016)

…and cryo targets



Fixed Solid Targets (Tapes)



Highest Repetition rate, lowest debris, longest continuous operation

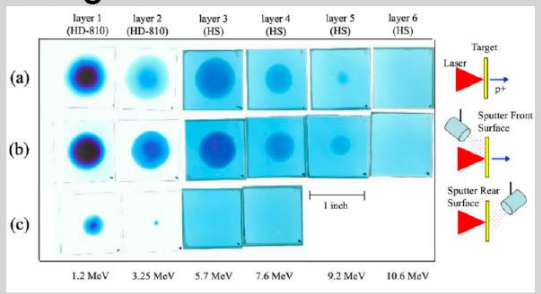
Technical readiness

Optimal Source Performance

Ion Species Selection – For solid density targets

For solid targets…

Sputter gun

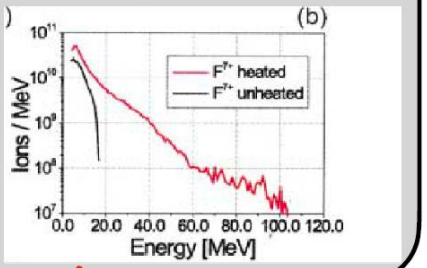


e.g. Allen et al. PRL 93, 265004 (2004)

Resistive heating

- Heat entire foil by passing through high DC current

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



Targeted removal of contaminant

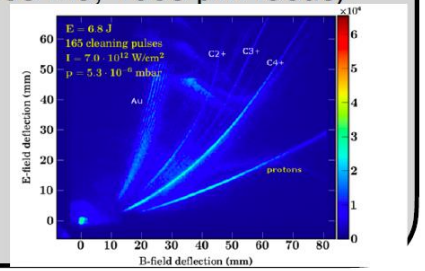
Heat target to "boil off" hydrocarbons - ~1000 K

Pulsed laser cleaning

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

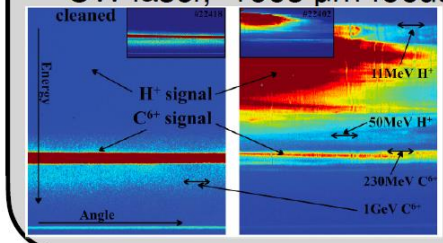
e.g. Sommer et al. PPCF 60, 054002 (2018)

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

Important issues we have included in the design..

- Contrast
- Laser Energy Stability
- Pulse duration
- ….

Issues we will investigate in our R&D programme…

- Debris
- Target cleaning stability and effectiveness
- Focal spot jitter/drift
- …

Our 1-5 yr R&D

Issues we are assuming are not a key consideration…

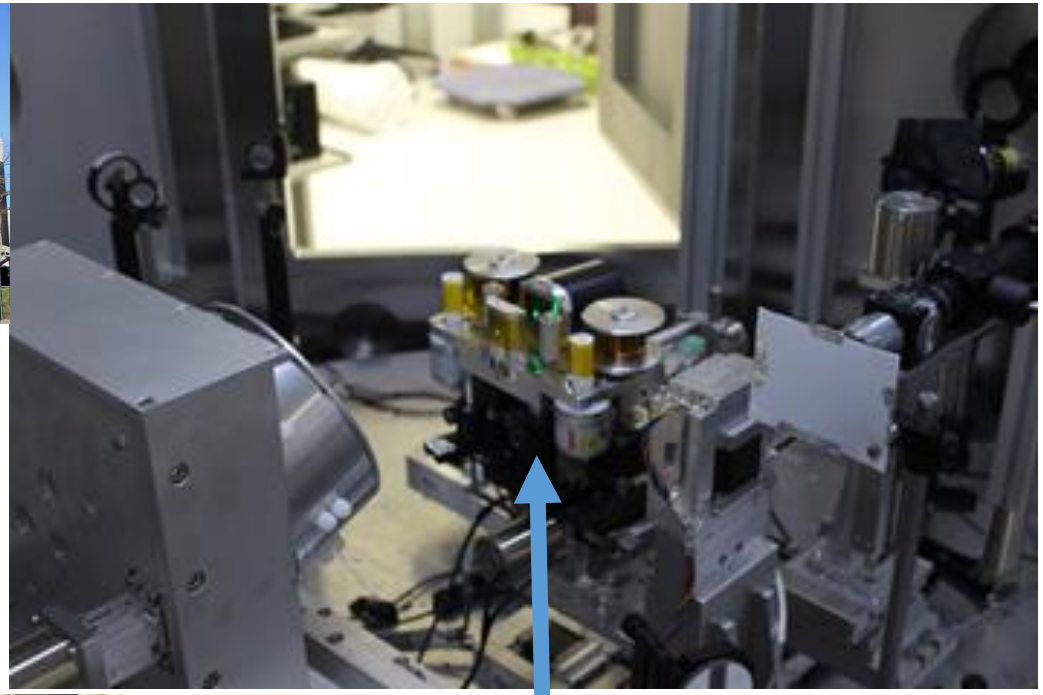
- Long term laser drift
- Compressor grating heating effects
- Laser chain failure rates

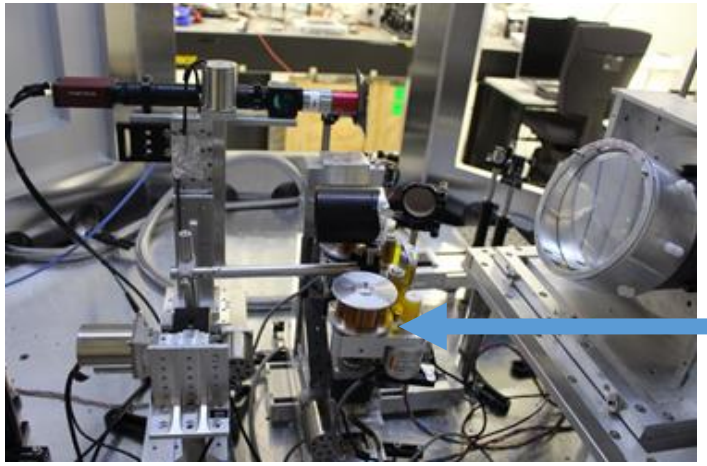
First time we are building a system with all the required parameters…

- Is there new physics related to TNSA that we will uncover via our detailed parameter scans?

Additional Slides

WP2 Technology R&D Plans: First SCAPA experiments



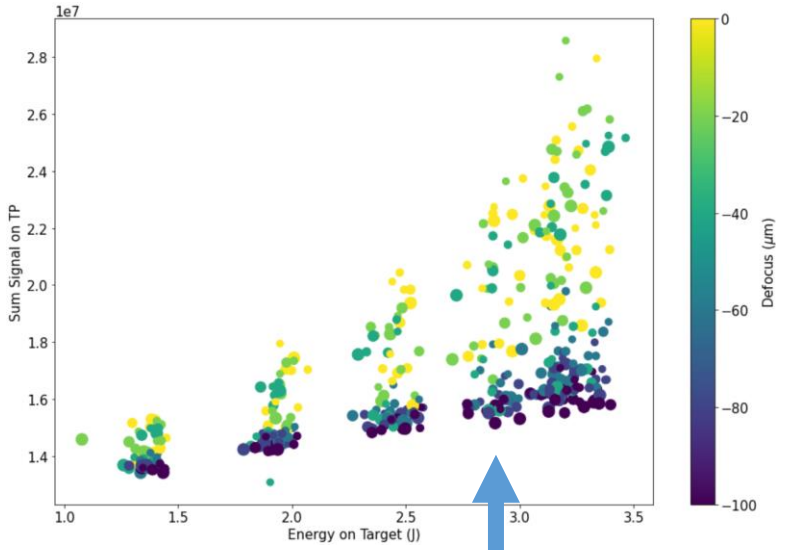


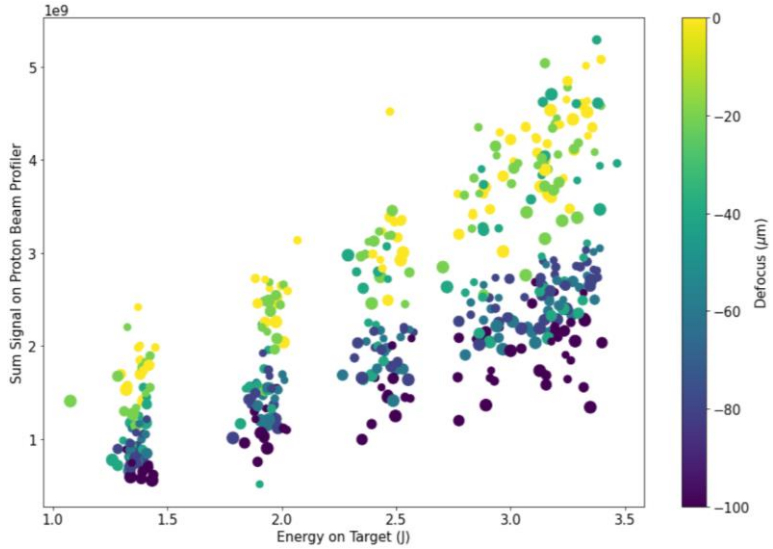
Tape drive target

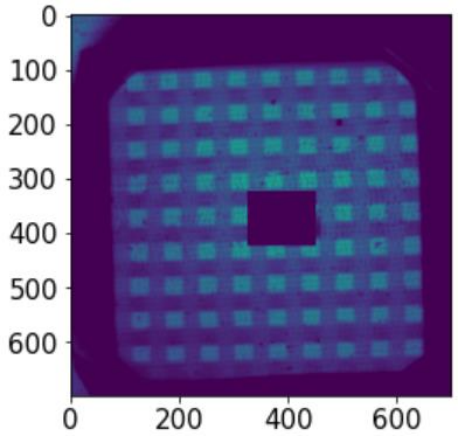
- First Bunker B commissioning experiment completed in September 2022
- Over 1000 laser shots taken in 3 weeks (in terms of shots taken that is equivalent to ~4x typical Gemini experiment)
- Tape drive target, online proton beam profiler, Thomson parabola spectrometer and laser absorption diagnostics 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