Reduced divergence of TNSA proton beams using a foil target and a gas jet

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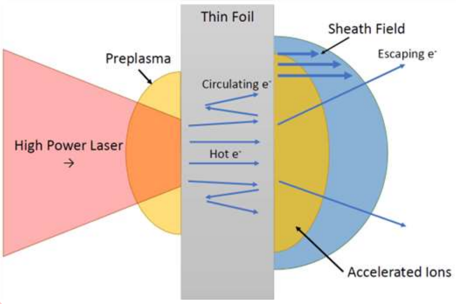
1. TNSA Proton Beam Divergence

Proton beams generated by target normal sheath acceleration (TNSA) usually have a high divergence, in the order of 10s of degrees [1]. Higher energy protons usually have less divergence than lower energy protons as they are accelerated earlier, when the electrostatic sheath field behind the rear surface of the target is flatter [2].

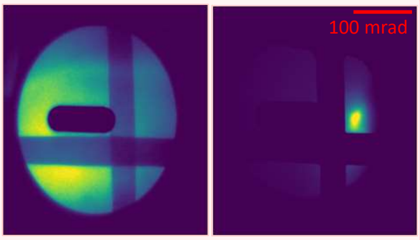


For many applications, such as those that require beam capture or transport, beams with a lower divergence are desirable. This motivates methods of reducing beam divergence, especially those compatible with high repetition rates.

2. Observation of low divergence proton beams using liquid targets

An experiment in Gemini TA2 at the CLF [3] using a water sheet target [4] indicated a reduction in divergence of an order of magnitude compared with solid targets.

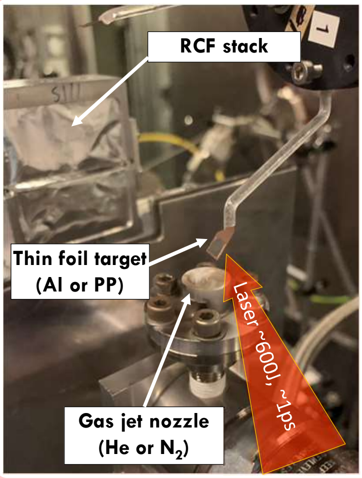
Simulations have suggested that this may have been due to collisional ionization and plasma instabilities in low density water vapour surrounding the target.



(a) Solid Target (b) Water sheet target

Image of the proton beam on a scintillator, for a solid target (a) and a liquid sheet target (b). Brighter colours indicate more scintillator emission.

3. Exploring divergence control with a combined foil and gas target



An experiment at the Vulcan PW facility at the CLF used a thin foil with a gas jet to explore the influence of a low density background on proton beam divergence. The position of the gas nozzle and the gas pressure were varied.

The targetry is shown on the left. The gap in the centre of the RCF is to provide a line of sight for diagnostics such as a Thomson parabola, electron spectrometer and a time of flight detector.

Acknowledgements

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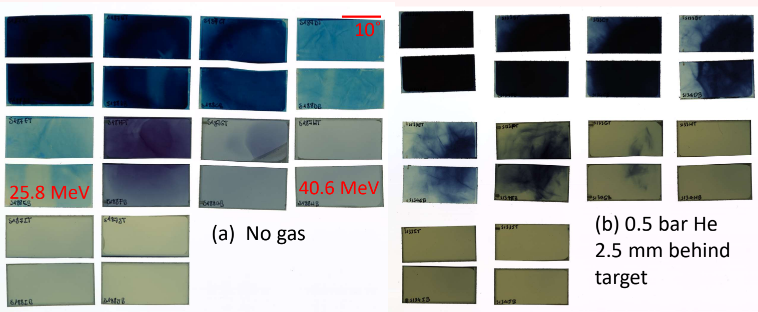
References

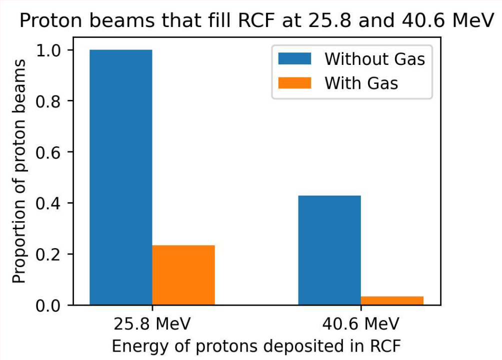
[1] Borghesi, M. et.al, Phys. Rev. Lett. **92**, 055003 (2004) [2] Schreiber, J. et.al, PoP **13**, 033111 (2006) [3] Streeter, M.J.V. et.al. Paper under review. [4] Treffert, F. et.al, PoP **29**, 123105 (2022)

4. Preliminary results: Reduction of beam diameter with presence of gas

- Initial results from the Vulcan PW experiment indicated that the divergence of the proton beam was reduced by the presence of a gas behind the foil.
- There appeared to be little effect on the resulting proton beam due to changing gas position or pressure.
- Raw RCF below shows the spatially resolved flux at target normal behind the target, each pair representing an energy up to 72 MeV - increasing in energy from top left to bottom right.



Both (a) and (b) are shots with 10 μm polypropylene and laser energy 544 J.

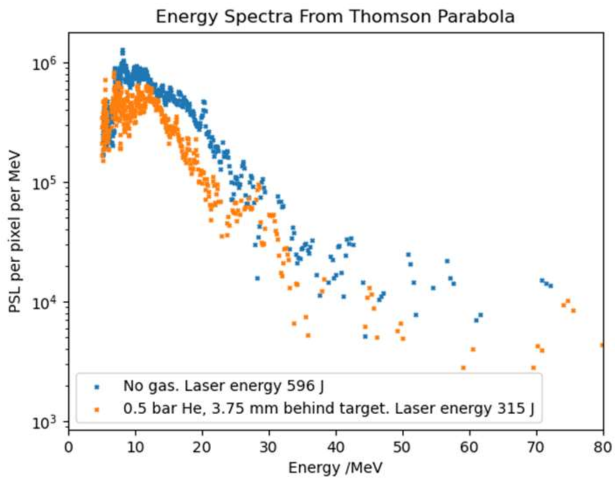


The effect of gas across all shots can be shown by the proportion of beams that were wider than the the RCF sheets – have a divergence ≳15°.

Beams were much more likely to have a divergence ≳15° at a given energy if there was no gas present.

5. Preliminary Results: Effect of gas on proton energy

- Initial results from the Vulcan PW experiment suggest that the presence of gas had little effect on maximum proton energy and proton number.
- The plot below shows Thomson parabola spectra (along target normal behind the target) for two shots, both on 10 μm Al.



- For heavier ions, there appeared to be a low energy cut-off in the energy spectra only when gas was present, dependent on gas nozzle position.

6. Summary

- An experiment at Vulcan PW explored the influence of low-density plasma on proton beam propagation, following observations of low divergence proton beams from a liquid sheet target. This experiment used a gas jet behind a foil target, producing a low-density plasma behind the foil.
- Results indicate a reduced proton beam divergence when there was gas compared to when there was none. There was small or no effect of the presence of gas on the maximum proton energy or proton number.