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Stable laser-acceleration of high-flux proton beams with plasma collimation

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Supplementary Information

Stable laser-acceleration of high-flux proton beams with plasma collimation

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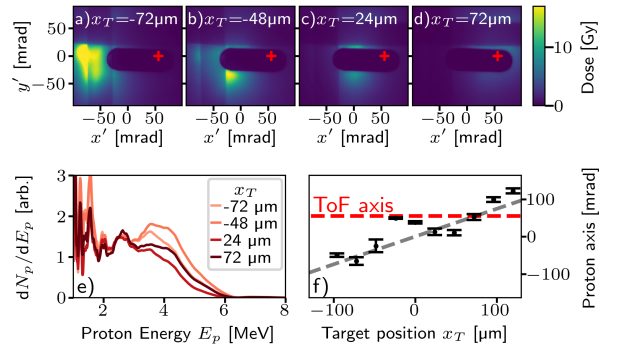
This Supplementary Information document provides additional information on the angular variation in proton beam pointing.

Angular variation in proton spectrum

When translating the target parallel to the water sheet surface in the horizontal plane, a horizontal shift in the proton beam axis was observed. We inferred that this behaviour was due to a curvature of the water sheet in the horizontal plane. Supplementary Figure 1a-d shows the spatial profiles for shots with different horizontal offsets (x_T) of the water sheet. At each position, the proton spectrum measured by the TOF spectrometer (Supplementary Figure 1e) remained relatively reproducible, illustrating the capability to steer the proton beam by simply translating the target.

The shift of the beam centroid as a function of x_T followed an overall trend consistent with a radius of curvature of the water sheet of $R_x = 1.3$ mm (see Supplementary Figure 1f). The reversal of the beam steering direction for $-24 < x_T < 48 \mu\text{m}$ indicates the presence of additional curves in the water sheet surface, which lead to a more complex behavior during the lateral position scan [1, 2]. However, at each fixed position the beam pointing was consistent, with a minimum standard devi-

ation of 2.1 mrad at $x_T = -48 \mu\text{m}$ and an average standard deviation of 7 mrad over all positions. Translation of the target in the vertical direction by 1 mm did not significantly affect the beam pointing, indicating that the vertical radius of curvature was $R_y \gtrsim 100$ mm.



Supplementary Figure 1. **Illustration of beam steering.** **a-d** Proton dose deposition profiles for different transverse positions of the water sheet (x_T). The ToF spectrometer position is indicated with the red “+”, and the average spectra recorded for each case is shown in **e**. **f** The proton beam axis (mean and standard deviation) as a function of target position x_T . The grey dashed line shows a linear fit, which corresponds to a radius of curvature of $R_x = 1.3$ mm.

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