Supplemental Material

The whole proton signals on radio-chromic film (RCF)

Figure s1 shows the whole proton signals for different energy on the RCF sheets. We can see that the beam profiles show ringlike shape for the protons with energy < 3 MeV. But when the energy larger than 5 MeV the profiles reveal so many filamentous/bubble structures.

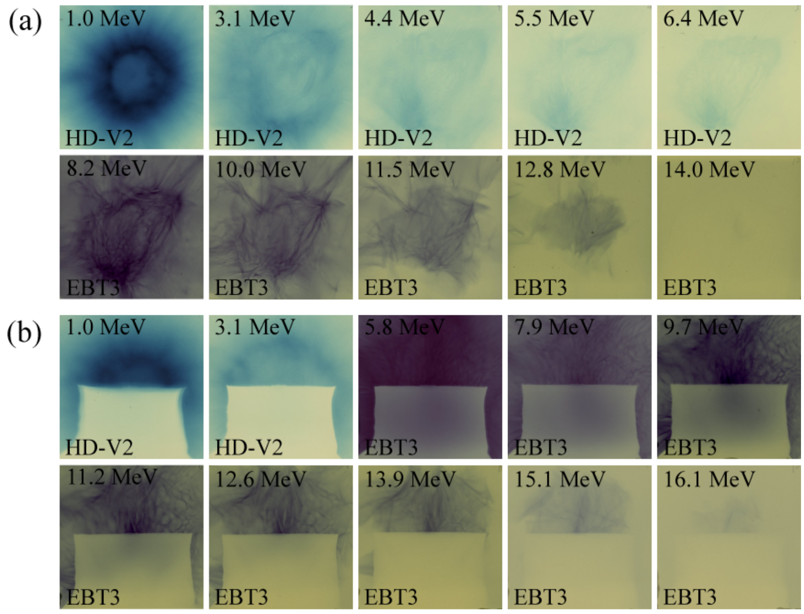

FIG. s1. The proton signals detected using RCF stacks, in the case without the knife edge (a) and with the knife edge (b).

Mesh images and proton source sizes analyzed in mesh method

As a comparison to the knife edge results, we further used the mesh method to measure the source sizes [1]. It should be mentioned that this method provides better imaging quality for quasi-laminar proton beams [1]. In our case, we can see from Fig. s2 that the grids are somehow distorted under the irradiation of non-laminar proton beam. Nevertheless, the periodic structure survives. It is therefore still applicable to identify the source size and hence the distance from the virtual source to the back surface of the target.

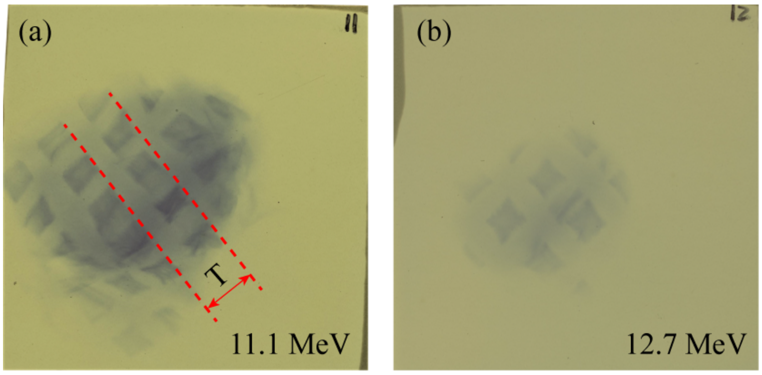

FIG. s2. Shadow image of the grid meshes on RCF stacks. Here T is the period of the imaged structure. The beam profile diameters in (a) and (b) are 30.5 mm (11.1 MeV) and 22.8 mm (12.7MeV), respectively. The distorted grid images are due to the irradiation of nonlaminar proton beam.

A Cu mesh was placed parallel to the foil rear at a distance of d ~ 150 μm which is the thick of the target frame, the RCF stack is placed at 94 mm behind the target. The mesh bar width is 6 μm and the hole size is 10.5 μm, corresponding to a mesh period of t = 16.5 μm. The magnification expected for a point-projection imaging is simply the ratio $M_G = L/d$, where L is the source-to-detector distance and d is the source-to-object distance. In Fig. s2(a), the image period T ~ 5.5 mm, which is averaged through 4 periods in the detecting plane. The experimental magnification is about $M_{exp}=T/t$~333. According to the relationship $M_{exp} = M_G(L+x)/(L+M_G x)$ in Ref. [1], one can get the distance x ~ 132.4 μm from virtual source to the target rear surface. The beam profile for 11.1 MeV protons in Fig. s2(a) is measured to be 30.5 mm in diameter, then the source size is about 43 μm according to sample geometric relationship. This works the same way with 12.7 MeV protons in Fig. s2(b) whose size is about 25 μm.

Electron density distribution according to hydrodynamics simulation

In our experements the laser prepulse intensity is ~1.8×10^{10} W/cm^2 for the amplified spontaneous emission (ASE) pedestal [2] and there is a ~10^{14} W/cm^2 prepulse at -3 ns prior to the main pulse. During the ablating, preplasma could be produced at both sides of the target [3]. We performed hydrodynamic simulation using the FLASH code [4] in two-dimensional under our laser condition and the electron density distribution is given in Fig. s3. The 1/e lengths ($L=n_e/(dn_e/dx)$) of the preplasma density profile are estimated at the critical density (for 0.8 μm laser wavelength) to be 1.6 μm and 1.0 μm for the target front and rear, respectively. These results are brought into particle-in-cell (PIC) simulations, the electron density is set as the solidline in Fig. s3. The preformed plasma are cut off at extention length of 10 μm and 5 μm, for target front and rear, respectively.

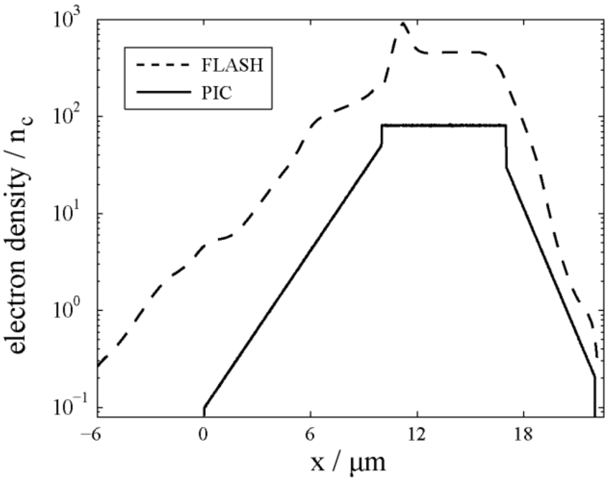

FIG. s3. Electeon density distribution. The dashed line is the hydrodynamic simulation result using the FLASH code and the solid line is the one input in PIC simulations.

References

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