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# High-repetition rate laser proton acceleration and plasma benchmark experiments using cryogenic hydrogen jets

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Laser plasma-based ion accelerators have not reached their full potential in producing high-radiation doses at high energies. The most stringent limitation is the lack of a suitable high-repetition rate target that also provides a high degree of control of the plasma conditions. For high-intensity laser-solid interactions, the absolute density and surface gradients of the target at the arrival of the ultrarelativistic peak is essential[1]. Accurate modeling of the leading edge-driven target preexpansion is required to strengthen the predictive power of computer simulations and thus to achieve higher beam energies. This calls for benchmark experiments with well-defined laser and plasma conditions.
In this talk, we report on high-repetition rate experiments in which cryogenic hydrogen jet targets are irradiated with intense laser pulses showing how such experiments open up new opportunities for understanding, improving and controlling the accelerator. The high-repetition rate is of interest not only for quasi-continuous acceleration, but also for addressing fundamental questions of the interaction. This cryogenic jet platform allows to experimentally benchmark simulations due to the large statistics. As two examples, we consider studies on the transition from an initial solid state to a plasma state[2], i.e. defining the starting point of subsequent target preexpansion and thus for modeling, and on expanding plasma density distributions[3], i.e. determining the plasma temperature evolution after laser irradiation as a comparison to simulations.

[1] M.Rehwald, et al. *Nature Communications* **14**, 4009 (2023)
[2] C.Bernert, et al. *Physical Review Applied* **19**, 014070 (2023)
[3] L.Yang, et al. *Communications Physics* **6**, 368 (2023)

## Working group

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