Accelerator Quality Beams of High-Energy Protons Guided by Intense-Laser driven helical coils

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Ion acceleration is of significant interest due to its applications in a number of areas, including clinical cancer therapy, spallation neutron sources, radioisotope production, ion implantation in semi-conductor industry, and many more. Laser driven ion beams provide a promising alternative to conventional accelerators as, in addition to the compactness and possible cost-effectiveness, they exhibit remarkable properties such as high particle flux, short pulse duration and laminarity [1]. However, some of the inherent shortcomings of ion beams driven by target normal sheath acceleration (TNSA) mechanism, such as large divergence and broad energy spectra, have limited so far end-user applications [1]. The helical coil targets recently developed by our group [2] provide, in this context, a miniature and versatile setup for effective control of the spectral and angular properties of the proton beams [3], with potential for delivering high energy beams of near accelerator quality, and added scope for implementing the scheme in multiple stages.

By harnessing the intense EM pulse generated from a laser-irradiated target, the helical coil (HC) produces a large electric field structure (>10^9 V/m), which can be tuned to travel synchronously with the protons in transit through the coil. [3]. By employing these targets on PW-class laser systems, such as the Vulcan Petawatt, CLF (UK) and Titan, LLNL (USA), collimated and quasi-monoenergetic proton beams containing >10^8 particles at ~ 45 MeV were obtained by simultaneous focusing and post acceleration of ~30 MeV protons. Particle tracing simulations reproducing the experimental data, suggest an accelerating gradient of ~ 2 GeV/m within the miniature, linear accelerating module. Further optimization of the coil's accelerating and collimating effects were studied systematically by varying its dimensions (radius, pitch and length) at a given laser condition. Simulations and modeling suggest the use of coils with variable pitch for sustained post-acceleration over an extended length to overcome dephasing between the accelerated particles and the moving accelerating structure. The viability of staging coils in succession will also be discussed based upon preliminary data and simulations.

References: -

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