Contribution ID: **274**

Type: **Oral Presentation**

Medical radioisotope production using laser-driven accelerators

In recent years, there has been a growing interest in laser-driven ion accelerators as a potential alternative to conventional accelerators [1]. A particularly promising application is the production of radionuclides relevant for medical diagnosis, such as 11C for PET imaging. Typically, the production of these nuclides is centralised at cyclotrons, reducing the number of facilities required, but limiting the range of usable radionuclides to those with longer lifetimes [2]. In this context, compact laser-driven accelerators appear as an appealing option for the in-situ generation of short-lived isotopes. Albeit the activities required for PET imaging (>MBq) are well above those achievable from a single laser irradiation (~kBq), the advent of high-power, high-repetition-rate laser systems opens the path to demonstrating relevant activities through the continuous irradiation, provided a suitable target system is developed. A target assembly based on a rotating wheel and automatic alignment procedure for laser-driven proton acceleration at multi-Hertz rates has
been developed and commissioned [3]. The assembly, capable of hosting >5000 targets and ensuring continuous replenishment of the target with micron-level precision, has been demonstrated to achieve stable and continuous MeV proton acceleration at rates of up to 10 Hz using our inhouse 45 TW laser system [3].
The continuous production of 11C via proton-induced reactions [11B(p,n)11C] has been recently demonstrated from our target assembly using the 1 Hz, 1 PW VEGA-3 system (CLPU, Spain) [4]. In an initial campaign, an activity of ~12 kBq/shot was measured, with a peak activity of 234 kBq achieved through accumulation of 20 consecutive shots [4]. Furthermore, results of a more recent campaign will be presented, where activation levels in excess of 4 MBq where achieved, as measured through using coincidence detectors, and supported by online measurements of high flux neutron generation. We demonstrate that the degradation of the laser-driven ion beam due to heating of optics is currently the only bottleneck preventing the production of pre-clinical (~10 MBq) PET activities with current laser systems. The scalability to next-generation laser systems will be explored to study the potential for production of clinical (~200 MBq) activities.

[1] A. Macchi et al., Rev. Mod. Phys. 85, 751 (2013)
[2] S. Fritzler et al., Appl. Phys. Lett. 83, 3039 (2003)
[3] J. Peñas et al., HPLSE 12 (2024)
[4] J. Peñas et al., Scientific Reports 14.1 (2024)

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Session Classification: Parallel session

Track Classification: Nuclear Physics Applications