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Muon generation, detection and acceleration in laser wakefield

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Muons produced by short pulse laser can serve as a new type of muon source having potential advantages of high intensity, small source emittance, short pulse duration, and low cost. To validate it in experiments, a suitable muon diagnostics system is needed since high muon flux generated by short pulse laser shot is always accompanied by high radiation background, which is quite different from cases in general muon researches. A detection system is proposed to distinguish muon signals from radiation background by measuring the muon lifetime. It is based on the scintillator detector with water and lead shields, in which water is used to adjust energies of muons stopped in the scintillator and lead to against radiation background. A Geant4 simulation on the performance of the detection system shows that efficiency up to 52% could be arrived for low energy muons around 200 MeV and this efficiency decreases to 14% for high energy muon energy above 1000 MeV. The simulation also shows that the muon lifetime can be derived properly by measuring attenuation of the scintilla light of electrons from muon decays inside the scintillator detector. Furthermore, muons produced by the Bethe-Heitler process from laser wakefield accelerated electrons interacting with high Z materials have velocities close to the laser wakefield. It is possible to accelerate those muons with laser wakefield directly. Therefore for the first time we propose an all-optical "Generator and Booster" scheme to accelerate the produced muons by another laser wakefield to supply a prompt, compact, low cost and controllable muon source in laser laboratories. The trapping and acceleration of muons are analyzed by one-dimensional analytic model and verified by two-dimensional particle-in-cell (PIC) simulation. It is shown that muons can be trapped in a broad energy range and accelerated to higher energy than that of electrons for longer dephasing length. We further extrapolate the dependence of the maximum acceleration energy of muons with the laser wakefield relativistic factor γ and the relevant initial energy E0. It is shown that a maximum energy up to 15.2 GeV is promising withγ= 46 and E0 = 1.45 GeV on the existing short pulse laser facilities.

[1] Zhang, F; Deng, Z G; Shan, L Q, et al., All-optical mu(-) acceleration in the laser wakefield, High Power Laser Science and Engineering, 2018, 6: e63
[2] Zhang, F; Li, B Y; Zhang Z M, et al., A new method on diagnostics of muons produced by a short pulse laser, High Power Laser Science and Engineering, 2017, 5: e16

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