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Extreme laser-matter interaction investigation at ELI - Nuclear Physics

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Europe is constructing an international research center, the Extreme Light Infrastructure (ELI), for conducting pioneering research in the laser-matter interaction and secondary sources of radiation [1]. The infrastructure will consist of 3 Pillars located in different countries: Romania, Czech Rep., Hungary. The Romanian pillar, ELI - Nuclear Physics, as main features, will have a High-Power Laser System (HPLS) composed of 2 arms with a power of 10 PW each; and a GAMMA Beam System (GBS) with a characteristic ~20 MeV photons beam maximum energy and high brightness. This unique research center will investigate a broad range of science covering frontier fundamental physics as well as applications in various fields, allowing significant advancement in knowledge. The first experiments are expected to be commissioned in 2020 and will realistically be the first worldwide High-Power Laser experiments performed at 10PW. This extreme laser intensity (~10^{23} W/cm^2) will give a new insights into the laser plasma acceleration mechanisms, generating high energy secondary particles, and bringing significant prospective of research and applications in fields ranging from High-energy-density physics and Laboratory Astrophysics to biology and medicine, neutron production and nuclear physics.

The technology development and the invention of the Chirped Pulse Amplification (CPA) technique have brought the laser power to reach multi-petawatt level in the last decade. Such laser power opened up the relativistic optics Era, where a large ponderomotive pressure can accelerate electrons to very close the speed of light. This phenomenon has allowed accelerating ions to energies of tens of MeV/u via laser. The laser-driven ion acceleration can occur by different mechanisms and among those the most studied is the Target Normal Sheath Acceleration (TNSA) and more recently the Radiation Pressure Acceleration (RPA). So far, most of the investigation worldwide has been done employing a petawatt-class laser system with wavelength in the infrared region and pulse duration ranging from picosecond to tens of femtoseconds. The acceleration process involves many factors, which affect the maximum ion energy and the quality of the beam. Therefore, an extensive study has been done to characterize these key factors with particular attention to the effect of the polarization of the laser light on the acceleration [2]. The maximum proton energy reached at the moment is about 100 MeV and has been obtained from laser-solid target interaction by employing the VULCAN laser (1 PW, 1ps) at Rutherford Appleton Laboratory (RAL) [3]. In the light of these results and as shown by particle-in-cell (PIC) simulations, by employing a 10 PW class laser it will be possible to reach energies of 100s of MeV/u for proton and ions. For instance, this extreme laser intensity will allow investigating more deeply processes occurring in laser-matter interaction and involved in the ion acceleration, like the relativistic self-induced transparency regime in TNSA and RPA mechanisms, and the generation of gamma flare with significant high conversion efficiency of laser power. Under suitable conditions, a few tens percent of the laser energy can be converted into gamma photons via nonlinear Thomson scattering, with some very high energy gamma photons (100s MeV) generated via Compton scattering process [4]. The laser-driven ion acceleration and the gamma-flare generation will be part of the commissioning experiments planned in ELI-NP, probably next year.

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References

[1] https://eli-laser.eu/

[2] C. Scullion, D. Doria, L. Romagnani, A. Sgattoni, K. Naughton, D. R. Symes, P. McKenna, A. Macchi, M. Zepf, S. Kar, and M. Borghesi, Phys. Rev. Lett. 119, 054801 (2017)

[3] A. Higginson, R. J. Gray, M. King, R. J. Dance, S. D. R. Williamson, N. M. H. Butler, R. Wilson, R. Capdessus, C. Armstrong, J. S. Green, S. J. Hawkes, P. Martin, W. Q. Wei, S. R. Mirfayzi, X. H. Yuan, S. Kar, M. Borghesi, R. J. Clarke, D. Neely & P. McKenna Nature Communications 9, 724 (2018)

[4] K. V. Lezhnin, P. V. Sasorov, G. Korn, and S. V. Bulanov, Physics of Plasmas 25, 123105 (2018)