Experiments with extreme light at ELI-NP*

C.A. Ur[1]
[1] *ELI-NP/IFIN-HH, Măgurele, Romania*

The Extreme Light Infrastructure - Nuclear Physics (ELI-NP) project [1] was implemented at the National Institute for Physics and Nuclear Engineering "Horia Hulubei" in Măgurele, Romania. The project aimed of perform research activities in the field of nuclear physics and related applications using extreme electromagnetic radiation fields. A new multidisciplinary research center was created, where nuclear physics, laser and plasma physics, material physics, engineering sciences and life sciences converge to develop a rich, ambitious research program.

To achieve the main research objectives defined in the project's White Book [2], a high-power laser system has been implemented and is currently operational. A high-intensity gamma beam system is currently under implementation. These state-of-the-art systems enable research activities at the forefront of knowledge.

ELI-NP currently hosts the world's most powerful laser system. The system consists of two ultra-short pulse lasers, each of which can deliver light with 10 PW of power and reach levels of laser irradiance of 10^{23} W/cm^2. Laser pulses at maximum power can be delivered at a repetition rate of one pulse per minute. To increase the system's flexibility, each arm was provided lower power outputs at a higher repetition rate, as follows: 1 PW at 1 Hz repetition rate and 100 TW at 10 Hz repetition rate.

Over the past few years, ELI-NP has evolved from implementation of a project to operation of a research center. With the completion of the commissioning experiments, all the experimental setups have gradually become operational. Since 2022, the laser system has been operated as a user facility, with beam time awarded based on scientific merit through a competitive process. Some of the most relevant results obtained in developing acceleration schemes for multi-GeV electrons, hundred of MeV/u protons and ions, and producing GeV-energy gamma rays will be presented.

The availability of particle and photon beams generated with high-power lasers opens new perspectives for a multitude of applications that can benefit from the ultra-short pulse duration and high beam brilliance. The possibilities of using laser-based accelerated ion beams and X-rays to develop medical applications for cancer treatment and diagnostics will also be discussed.

The gamma beam system will provide quasi-monochromatic beams with energies up to 19.5 MeV and a relative bandwidth of approximately 0.5%. The current status of implementing the gamma beam system will be presented. The first results from preparatory experiments performed at the 9 MV TANDEM accelerator of IFIN-HH using some of the experimental setups developed at ELI-NP for high-energy gamma ray and neutron detection will also be presented.

[1] C.A. Ur, "Extreme light infrastructure-nuclear physics: overview and perspectives", Proc. SPIE 12580, Research Using Extreme Light: Entering New Frontiers with Petawatt-Class Lasers V, 1258004 (8 June 2023); https://doi.org/10.1117/12.2671369 (and references therein).

[2] https://www.eli-np.ro/whitebook.php .

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