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Operational Performance and Experimental Advancements at the ELI-NP 10 PW Laser Facility for Nuclear Photonics Applications

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The Extreme Light Infrastructure –Nuclear Physics (ELI-NP) has established itself as a world-leading facility by operating the first dual-arm 10 petawatt (PW) laser system, HPLS, which serves as a cornerstone for experimental nuclear photonics research. In 2024 alone, ELI-NP achieved 67 operational weeks of beam delivery for users, including 30 weeks at full 10 PW output at a 1 shot/minute repetition rate. The E6 experimental area supported experiments targeting electron acceleration, Compton backscattering, and muon production using a gaseous target, reaching up to 274 shots per day. This operational throughput represents a milestone for high-repetition-rate ultraintense laser facilities and demonstrates ELI-NP's capacity for robust experimental deployment.

Beyond high energy output, HPLS provides optically synchronized 2×1 PW beams at 1 Hz with <11 fs pulse duration in the E5 experimental area. This capability enables novel dual-beam configurations for simultaneous generation of proton and electron bunches, facilitating secondary radiation production (x-rays, neutrons). A regenerating liquid target delivery system in vacuum is under implementation, set to support high-repetition-rate irradiation for radiation hardness testing of inertial fusion materials.

Ongoing developments include beam shaping and control via spatio-temporal coupling diagnostics, structured light fields (e.g., helical beams), and coherent combination techniques. These efforts aim to enhance experimental precision, optimize intensity delivery, and advance the field of strong-field QED and laser-plasma interaction physics. The ELI-NP infrastructure thus serves as a unique platform for both fundamental and application-driven advances in nuclear photonics.

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