



Contribution ID: 89

Type: **Poster presentation**

X-ray and gamma ray source from self-modulated laser wakefield accelerated electrons at PHELIX

X-ray sources are of growing importance as a diagnostic tool for High Energy Density (HED) experiments and Inertial Confinement Fusion (ICF) studies as well as the upcoming FAIR facility in Darmstadt. For these applications, so-called x-ray backlighters must meet requirements regarding low divergence, small source size to achieve a sufficient imaging resolution and high brightness to overcome x-ray self-emission from the plasma itself. X-ray sources from laser-driven electrons from the regime of self-modulated laser wakefield acceleration (SM-LWFA) show promising parameters to meet these requirements, which can be achieved by using gas targets and picosecond laser pulses provided by the PHELIX laser system.

We will report on the results of the commissioning experiment on electron acceleration in this regime, where Helium gas targets with backing pressures up to 100 bar were used, yielding target densities up to $1 \times 10^{19} \text{ cm}^{-3}$ with lengths up to 4 mm. Using laser pulses of 500 fs with energies up to 110 J on-target, resulting in intensities of up to $1.5 \times 10^{19} \text{ W/cm}^2$, electron beams with a maximum bunch charge of 500 nC, an exponentially decaying spectrum up to 380 MeV, and divergences ranging from 70 to 230 mrad were achieved.

We will also give a brief outlook on the follow-up experiment in 2026, which will focus on the generation and characterization of X-ray and gamma-ray emission from betatron radiation, inverse Compton scattering and bremsstrahlung. Both experiments will be backed and compared to 3D-PIC simulations using WarpX in order to optimize the electron and subsequent x-ray yield.

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Session Classification: Poster Session