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Laser Wakefield Acceleration to Electron Energies in the GeV Regime

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For the creation of matter-antimatter pairs from the quantum vacuum via the Breit-Wheeler effect, an intense laser and energetic γ-rays need to interact with each other. At the Stanford Linear Accelerator Center the Breit-Wheeler experiment in the perturbative regime has been accomplished in 1997 but was not yet implemented in the non-perturbative regime, where the laser strength parameter a0»1 and pair production occurs when an electron from the negative energy Dirac-sea tunnels to positive energy levels. This experiment is at the moment in preparation in a fully laser-driven set-up with the ATLAS3000 laser at the Centre for Advanced Laser Applications in Munich. Laser Wakefield Acceleration (LWFA) will be used to accelerate electrons to high energies. This high energy electron beam will be sent onto a Bremsstrahlung converter to generate γ-rays that will interact with the intense laser. An electron beam with multi-GeV energies is needed for this. LWFA has been improved to reach multi-GeV electron energies in the recent years. However, building a reliable and stable source with low divergence and low pointing jitter with quasi-monoenergetic bunches over 2 GeV, as is needed for the Breit-Wheeler experiment, still holds challenges. Essential is the careful design of gas targets. These have to provide homogeneous gas densities over a distance of a few centimeters. In preparation for the Breit-Wheeler experiment, Computational Fluid Dynamic simulations were conducted to design centimeter-long gas nozzles. First LWFA results can be shown with electron energies reaching over 1.5 GeV using these nozzles and energies reaching over 2 GeV with a gas cell as target. Moreover, different injection techniques using these nozzles, or the gas cell were tested with the goal to obtain quasi-monoenergetic electron bunches in the GeV regime.

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