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Electron acceleration in deep plasma channels in the Bubble regime

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We study hollow plasma channels with smooth boundaries for laser-driven electron acceleration in the bubble regime. Contrary to the uniform plasma case, the laser forms no optical shock and no etching at the front. This increases the effective bubble phase velocity and energy gain. The longitudinal field has a plateau that allows for mono-energetic acceleration. We observe as low as $1e-3$ r.m.s. relative witness beam energy uncertainty in each cross-section and 0.3% total energy spread. By varying plasma density profile inside a deep channel, the bubble fields can be adjusted to balance the laser depletion and dephasing lengths. Bubble scaling laws for the deep channel are derived. Ultra-short pancake-like laser pulses lead to the highest energies of accelerated electrons per Joule of laser pulse energy. Simulations for the future APOLLON laser parameters suggest that electron energies as high as 24 GeV might be achievable.

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