QED Effects at Grazing Incidence on Solid-State-Targets

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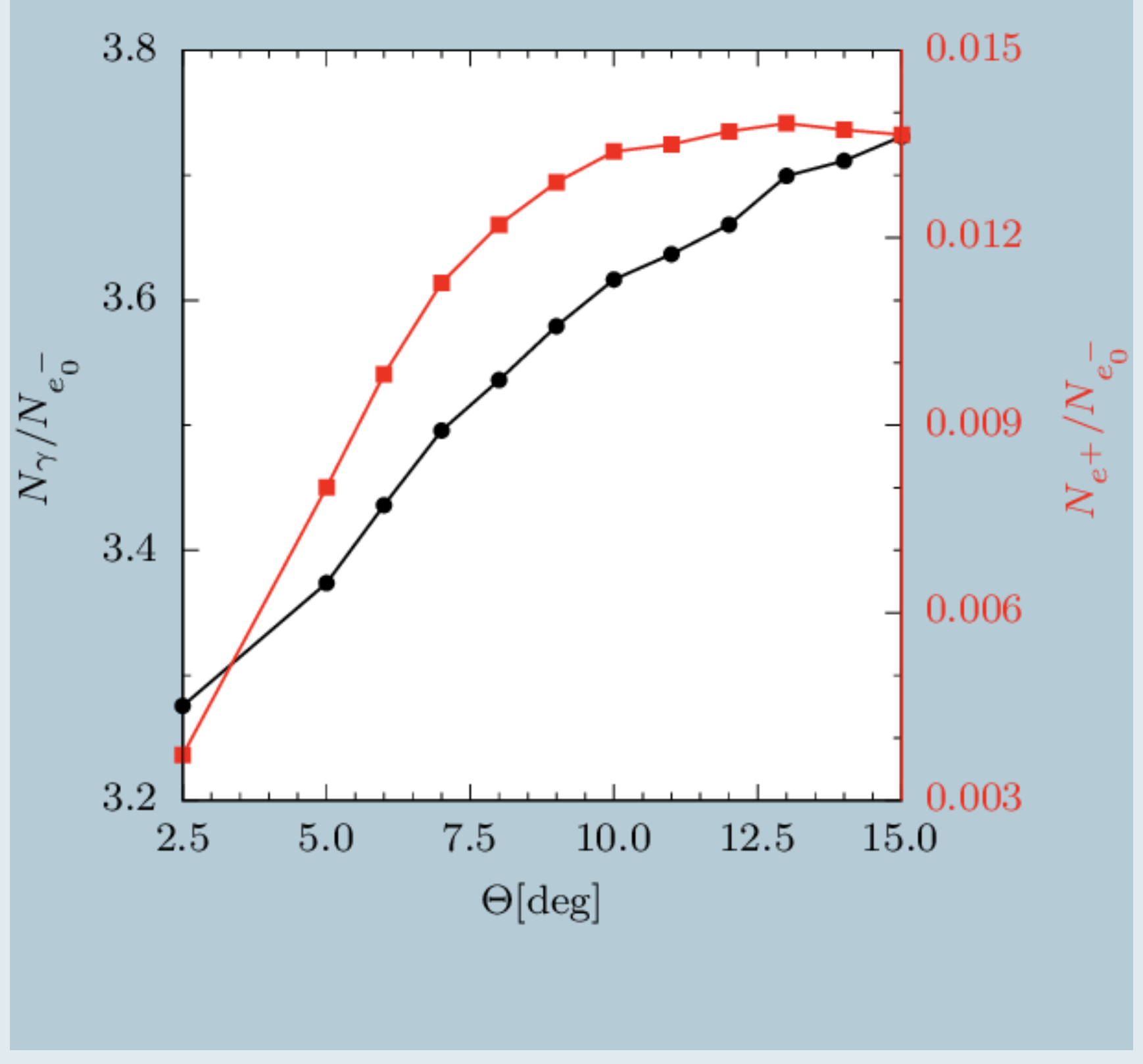
Introduction

As development of laser technology progresses, ever higher intensities and better beam qualities become available. This advance enables new experimental setups in the study of laser-plasma and quantum physics, where quantum photon emission and pair production in extreme fields and high densities become important.

We present two-dimensional Monte-Carlo particle-in-cell (PIC) simulations of two high-intensity lasers grazing the surface of a solid-state target [1]. Fields near the target surface extract and accelerate electrons [2]. Finally, the extracted electrons collide with the counterpropagating laser, which generates a QED cascade [3].

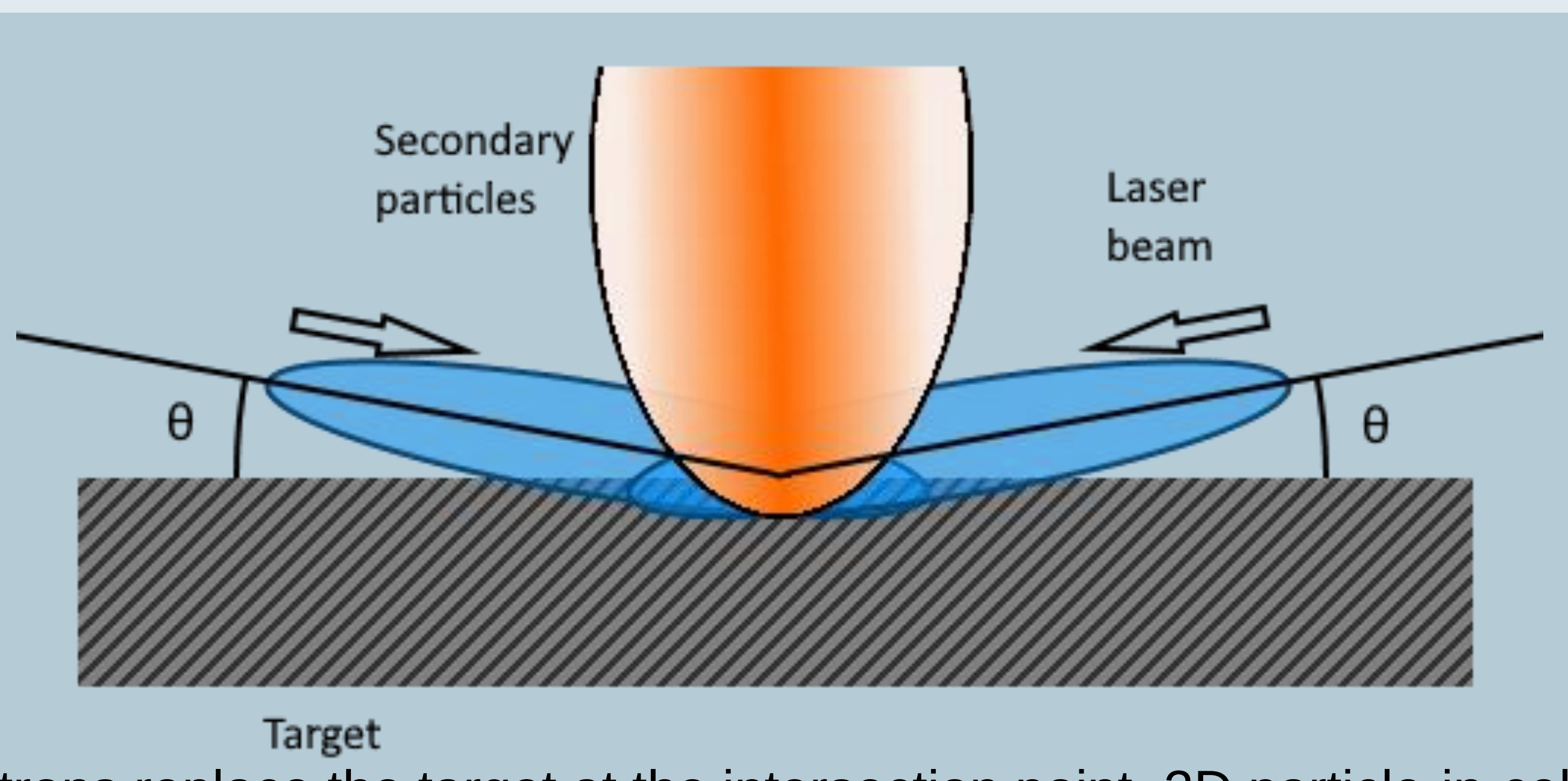
Fractions of secondary particles per initial electron

Increasing the angle of incidence Θ increases positrons of pairs up to a certain point.



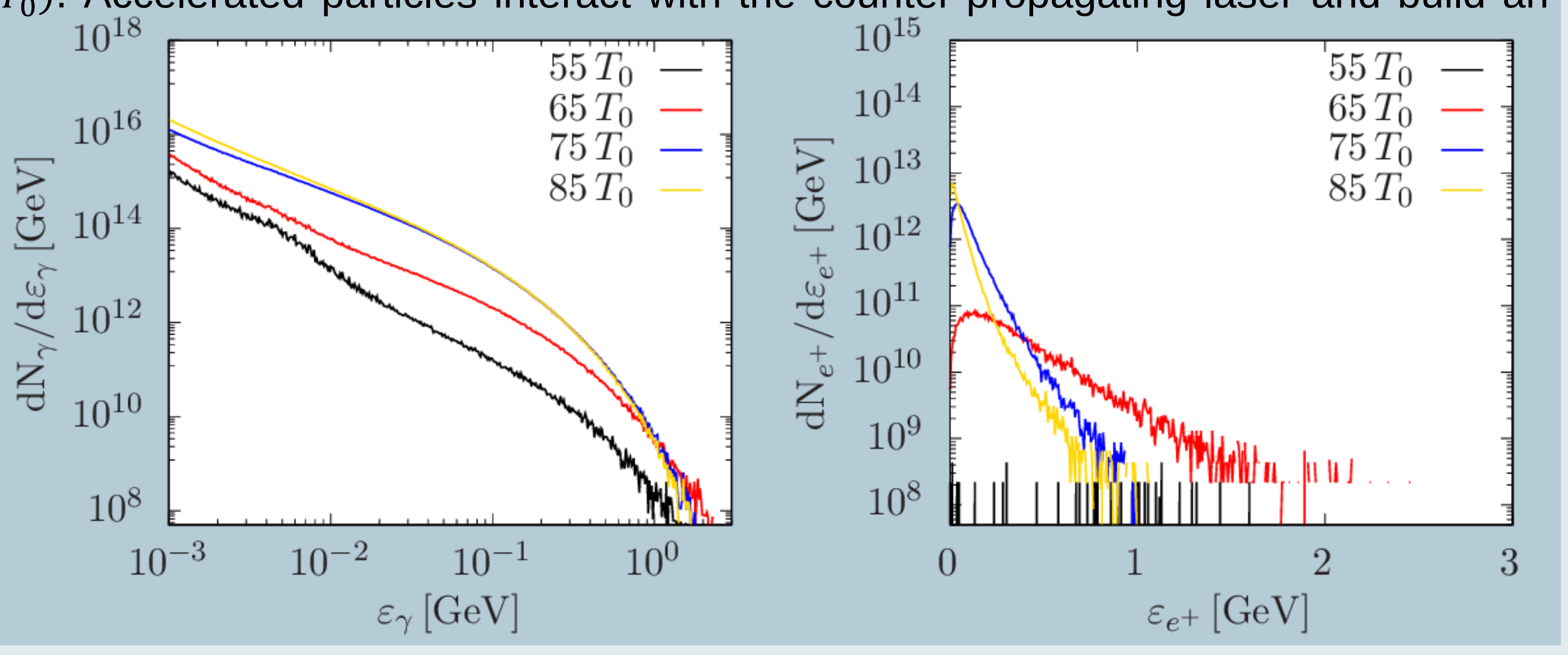
Configuration

Two linearly p-polarized lasers with a pulse duration of $25\mathrm{fs}$ and $\lambda = 910\mathrm{nm}$ scrape a solid-state target. Intersection point of the propagation axis of the lasers is on the surface of the solid-state target, which has an electron density of $n_{e^-}/n_{cr} = 505.55$ and an equal ion charge density. For a comparison with an imperfect vacuum, 72 resting seed electrons replace the target at the intersection point. 2D particle-in-cell simulations have been performed in the "Virtual Laser Plasma Laboratory" QED PIC code [4].



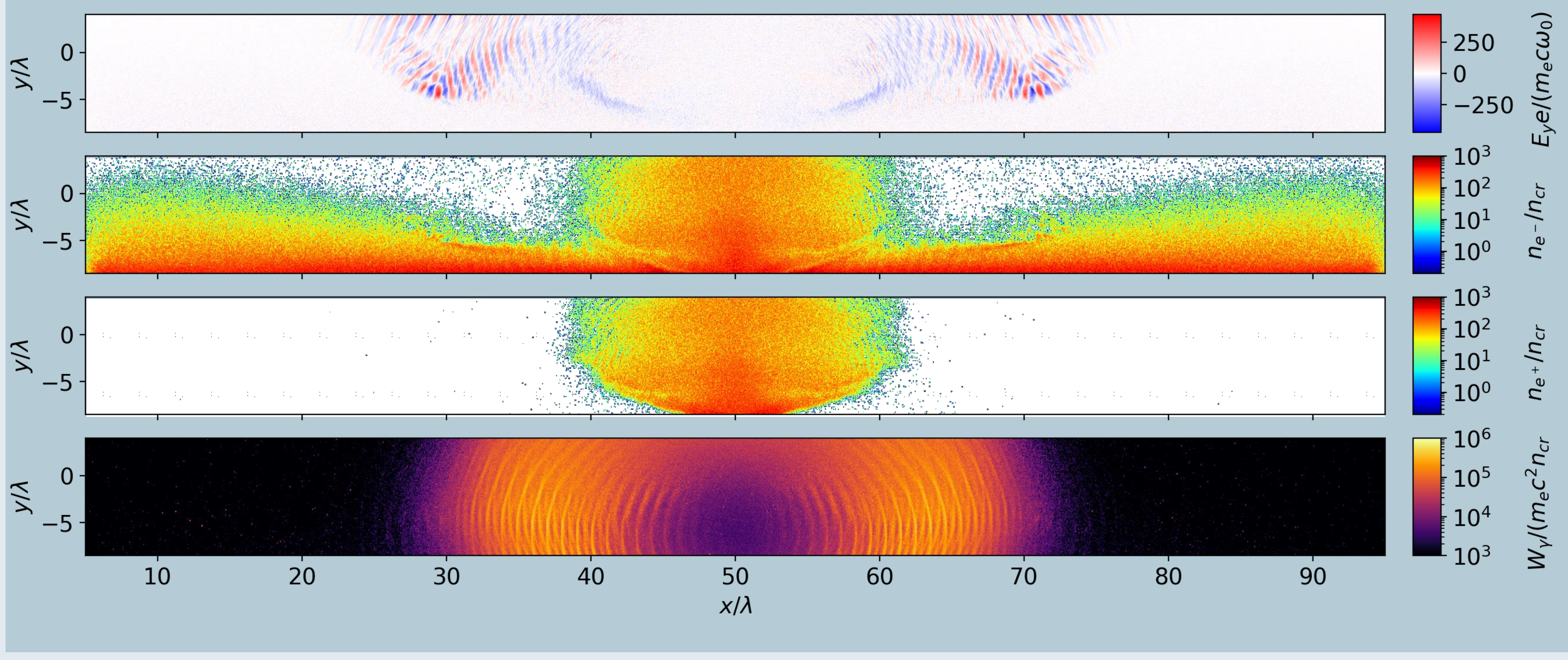
Time evolution of particle numbers for $\alpha = 15°$ and $a_0 = 1200$

Photons are emitted by the lasers, while propagating over the target surface $(t = 55T_0)$. Once the lasers overlap high-energy photon emission takes place again $(t = 65T_0)$. Accelerated particles interact with the counter-propagating laser and build an electron-positron plasma. Photons with energies up to $1\,\mathrm{GeV}$ are emitted and radiation-reaction reduces the maximum positron energy after interacting with the counter-propagating beam $(t = 75T_0)$. Maximum recorded quantum parameter in this simulation was $\chi_{\max} = 9.65$ for $a_0 = 1200$.



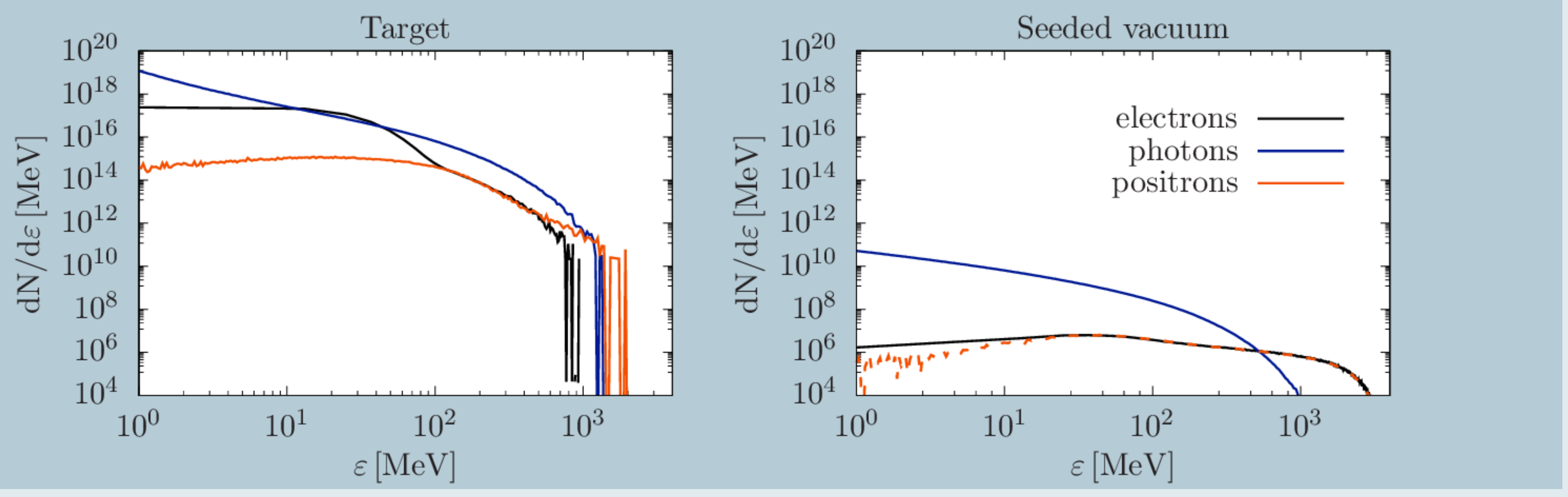
Fields and densities for $\alpha = 15°$ and $a_0 = 1200$

As the fields propagate on top of the surface photons are emitted by the electrons and extracted electrons co-propagate with the fields. Once the moving particles reach the region where they encounter the counter-propagating beam electron-positron pairs are generated due to the pair production process. The density of the new electron-positron plasma rises as more pairs are created and the fields of the lasers shield the new plasma.



Spectrum of secondary particles for $\alpha = 12°$ and $a_0 = 800$

Comparing the results to a seeded vacuum cascade shows using a target significantly increases particles yields. Not using a target enables further acceleration of particles, since the propagation direction is not obstructed.



Conclusion

1. We analysed a configuration of two high-energetic laser beams grazing solid-state target. Electrons emitted photons, which decayed in pairs and reemitted. This lead to a build up of an electron-positron plasma.
2. The configuration with a solid-state target yields more secondary particles produced by photon emission and pair production.

Acknowledgments

This poster presentation has received support from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 101004730.

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