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Editorial: Spin-polarized particles in relativistic plasmas for particle accelerators and fusion reactors

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Editorial on the Research Topic
Spin-polarized particles in relativistic plasmas for particle accelerators and fusion reactors

Polarized beams are essential for a number of applications, such as probing the nuclear structure of the proton, studying fundamental symmetries, and testing quantum electrodynamics and chromodynamics [1]. The required high-energy, polarized particle beams are usually delivered by radiofrequency accelerators. As the maximum attainable acceleration gradient in these structures is inherently limited, the next generations of accelerators would need to be significantly larger–and accordingly more expensive–than current facilities.

By contrast, plasma-based accelerators are of particular interest as they provide thousandfold stronger accelerating gradients, enabling the development of compact particle accelerators. They, however, also bring unique challenges for polarized beams due to the ultra-strong fields that can occur during laser-plasma interaction. Tremendous effort has been invested into finding feasible schemes for polarized lepton beams [2, 3], ion beams [4] and gamma quanta [5] from the theoretical side. Experimentally, the preservation of ^{3}He polarization in laser-plasma interaction has only recently been demonstrated in a first proof-of-principle experiment by Zheng et al. [6]. A general overview of the field is given in Reichwein et al. [7].

Beyond fundamental research, it was also shown that polarized reactants in nuclear fusion can improve the cross-section for the process [8]. In the case of the reaction $d + t \rightarrow \alpha + n$, for example, the cross section is increased by 50%. This increase could prove to be a crucial step on the way to future fusion reactors. Plans for upcoming experiments on polarized fusion have been detailed, e.g., by Baylor et al. [9]. These studies collectively underscore the critical need for further exploration at the intersection of spin dynamics and plasma physics.

The Research Topic "*Spin-Polarized Particles in Relativistic Plasmas for Particle Accelerators and Fusion Reactors*" directly aims at this intersection of various area of physics, covering aspects from accelerator, fusion and surface physics.

In the scope of plasma-based accelerators, pre-polarized targets are generally required. Sofikitis et al. have considered hydrogen-halides as a possible source of polarized electrons. Their generation relies on the UV dissociation of the molecules. The subsequent spatial separation of the polarized hydrogen from the unpolarized halide atoms is crucial in order to ensure a high degree of polarization of the accelerated electron beams. In their paper, the authors discuss geometries and timing for target preparation.

Within in the field of fusion, Heidbrink et al. detailed a research program to measure the lifteime of spin-polarized fuels. Polarized deuterium and ^{3}He can be utilized as proxies to understand spin physics of deuterium-tritium fusion processes. Different experimental scenarios to measure the polarization liftetime at the DIII-D tokamak are also discussed. In these setups, it is important that the polarized particles are shielded from any unwanted external fields, while still providing strong magnetic holding fields. Ciullo et al. discuss the use of bulk superconducting MgB_2 for better control of polarized fusion in reactors. The first successful preliminary results are detailed in their paper.

The role of low-energy polarized electrons in surface physics is highlighted by Tusche et al. In particular, they discuss sources and detectors for spin-polarized electrons. State-of-the-art spin-resolved momentum microscopy is shown to lead to a better understanding of various solid-state systems, including the very active area of topological matter.

The studies presented in this Research Topic show the far-reaching implications of spin dynamics in various areas of physics and point the way to future experimental campaigns for polarized particle acceleration and polarized nuclear fusion.

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