Polarized Fusion, its implications and plans for direct measurements in a tokamak plasma

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Our energy-hungry world is burning. A long-term solution, possibly the only ultimate one, that is just approaching the horizon after decades of struggle, is fusion. Recent developments allow us to apply techniques from spin physics to advance the viability of this critical option. The cross section for the primary fusion fuel in a tokamak reactor, $D + T \rightarrow \alpha + n$, would be increased by a factor of 1.5 if the fuels were spin polarized parallel to the local field. Simulations predict further non-linear power gains in large-scale machines such as ITER, due to increased alpha heating. These are significant enhancements that could lower the requirements needed to reach ignition and could be used to extend useful reactor life by compensating for neutron degradation of critical components. The potential realization of such benefits rests on the survival of spin polarization for periods comparable to the energy containment time. Interest in polarized fuel options had an initial peak of activity in the 1980s, where calculations predicted that polarizations could in fact survive a plasma environment. However concerns were raised regarding the cumulative impacts of fuel recycling from the reactor walls. In addition, the technical challenges of preparing and handling polarized materials prevented any direct tests. Over the last several decades, this situation has changed dramatically. Detailed simulations of the ITER plasma have projected negligible wall recycling in a high power reactor. In addition, a combination of advances in three areas - polarized material technologies developed for nuclear and particle physics as well as for medical imaging, polymer pellets developed for Inertial Confinement, and cryogenic injection guns developed for delivering fuel into the core of tokamaks - have matured to the point where a direct *in situ* measurement is possible. A Jefferson Lab - DIII-D/General Atomics - University of Virginia collaboration is developing designs for a proof-of-principle polarization survival experiment using the isospin mirror reaction, $D +^3 He \rightarrow \alpha + p$, at the DIII-D tokamak in San Diego[1]. In parallel, a European collaboration based at Forschungszentrum Jülich is pursuing a design for a polarized D+D plasma survival measurement.

[1] D.C. Pace, M.J. Lanctot, G.L. Jackson, A.M. Sandorfi, S.P. Smith and X. Wei, J. Fusion Energy 35 (2016) 54.

$gammaD \rightarrow\ pi^{-}p(p)$