A research program to measure spin polarized fusion reactions*

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The use of spin polarized fuel could increase D-T fusion reactivity by a factor of 1.5 and, owing to alpha heating, increase fusion Q in ITER even more [1]. The use of polarized D and ^{3}He in an experiment avoids the complexities of handling tritium, while encompassing the same nuclear reaction spin-physics, making it a useful proxy to study issues associated with full D-T implementation. ^{3}He fuel with 65% polarization can be prepared by permeating optically-pumped ^{3}He into a shell pellet [1]. Dynamically polarized ^{7}Li-D pellets can achieve 70% vector polarization for the deuterium [1]. The polarization lifetimes in cooled ^{3}He fuel capsules are days but only minutes for ^{7}Li-D [1]. Cryogenically-frozen pellets can be injected vertically into tokamaks and similar geometries by special injectors that minimize depolarizing field gradients. The use of a Sona transition [2] to polarize neutral beams is also under investigation.
Theoretically [3], nuclei remain polarized in a hot fusion plasma but the predictions have never been tested experimentally.
Measurements that exploit spin-induced changes in differential cross section are more sensitive than measurements of the reaction rate alone [4]. One possible scenario uses an unpolarized ^{3}He fast-ion population and tensor-polarized deuterium pellets; in another, both species are polarized in a thermonuclear plasma with ion temperatures above 10 keV. Modeling shows that a T_i>10 keV DIII-D plasma generates 14.7 MeV proton and 3.6 MeV alpha signals that are sensitive to depolarization with high accuracy [4]; additionally, nearly all reactor-relevant depolarization mechanisms are accessible for study in DIII-D. With a sufficiently intense polarized beam, accurate measurements of the depolarization rate could also be performed in the Wisconsin HTS Axisymmetric Mirror. Experiments in a compact spherical tokamak are also under investigation.

[1] L.R. Baylor *et al.,* Nucl. Fusion **63** (2023) doi 10.1088/1741-4326/acc3ae
[2] R. Engels *et al.,* Eur. Phys. J. D 75:257 (2021).
[3] R.M. Kulsrud *et al.,* Nucl. Fusion **26** (1986) 1443.
[4] A.V. Garcia *et al.,* Nucl. Fusion **63** (2023) 026030.

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