Differential magnetic confinement and mass separation in magnetized plasmas

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Plasma-based, high-throughput, mass separation techniques may facilitate the safe disposal of legacy nuclear waste [1]. Nuclear waste cleanup is now considered to be one of the major technological problems facing society. In the USA, it is estimated to cost hundreds of billions of dollars and will take decades to complete. For the most part, chemical precipitation techniques can usefully separate the highly radioactive materials for vitrification and burial. But these techniques have limitations. However, by operating on dissociated molecules, plasma separation can be used where chemical techniques are challenged. Beyond legacy waste disposal, such capabilities could also prove to be advantageous for advanced nuclear fuel cycle [2] and rare earth recovery.

Plasma can be rotated rapidly, enabling rapid mass separation. The most direct plasma separation method is the plasma centrifuge [3]. However, a centrifuge separates particles radially, which makes collection difficult and may not be the most energy efficient means. But rotating plasma can be exploited to produce mass-based separation in an axial rather than radial direction, either in an magnetic centrifugal mass filter configuration [4] or through double potential well configurations [5]. These novel techniques produce differential magnetic confinement by balancing centrifugal against magnetic forces.

These separation methods, discussed here primarily theoretically, can be thought of as differential magnetic confinement, a generalization of magnetic confinement. In the case of differential confinement, the focus is no longer on maximizing the overall confinement properties, but rather on maximizing differential confinement between different ions. In this talk, I will review the various separation mechanisms and key applications considered to date, and identify some of the key physics questions on which hinges the development of plasma mass filters.

* The author would like to thank N. J. Fisch and J.-M. Rax for their continued collaboration.

References