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Ion Sources for Heavy Ion Fusion

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Heavy Ion Fusion requires ion beam, with several MJ energy, to compress and heat a fusion target to the required density and ignition temperature. Typical beam pulse length at the target is ~10 ns with beam current at ~ 100 kA (total charge ~ 1 mC) and energy at several GeVs. Even shorter pulse length is required for fast ignition beams. Beam pulse compression is needed because the beam pulse length at the ion source can be as long as 10 to 100 μs. Furthermore, even with a very high current density at the ion source, limitations from the injector and the accelerator beam transport physics will demand an accelerator system that is composed of multiple beams.

Depending on the requirement of the final beam kinetic energy, as dictated by the HIF target design, the total beam current can vary. For example, a 60 GeV ion driver system will require 10 times less beam current (or charge) than a 6 GeV system. Most likely, an RF accelerator system will be used to produce 60 GeV beams, whereas an induction system will be used to produce 6 GeV beams with high current.

The transverse emittance is an important factor limiting the ability to focus the beam current onto a small target spot. In other words, the HIF ion source must be simultaneously high current and high brightness. Often time, these two requirements are in conflict, e.g., the emittance increases with beam diameter at the ion source. Likewise, transverse merging of an array of small beamlets will cause emittance growth.

Heavy ions of ~200 amu are best suited to meet the stopping-power (dE/dx) requirements. Furthermore, it is desirable to use high charge state heavy ions in order to minimize the accelerator beam voltage (i.e. the accelerator length). Unfortunately, it is difficult to make high current beams with ions of a single (pure) high charge state. Improvement in this area can result in significant cost saving in fusion driver development.

In this paper, we review the scaling laws that govern the injector design and the various ion source options including the contact ionizers, the aluminosilicate sources, the plasma sources, the ECR sources, and the metal vapor sources.

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