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Stopping Power of ions in laser-induced plasmas for nuclear astrophysics studies

Stopping power (SP) refers to the rate at which a charged particle loses energy as it moves through a medium; however, it is substantially different between ordinary (cold) and plasma matter. As a consequence, a precise determination of SP in plasmas is essential for nuclear astrophysics [Ber04, ADGL99] and energy production [LP93, ZZZ+22], because it plays a central role in determining nuclear reaction rates both in stellar and reactor environments. In addition, deviations of SP expectations on Big-Bang Nucleosynthesis and supernova explosions are significant because the proportion of nuclear product content is influenced by the photon production rates resulting from ion braking.

The main components of stopping power are: "electronic SP" and "nuclear SP". Electronic SP is the energy loss due to interactions with electrons, while nuclear SP is the energy loss due to collisions with nuclei. In plasma, electronic SP is significantly influenced by electronic screening, where free negative charges modify the potential between ions, facilitating the overcoming of the Coulomb barrier and enhancing fusion probabilities. Since the electronic distribution affects the energy loss of projectile nuclei, screening also alters the stopping power itself [CFJ+00]. Investigating this phenomenon is essential to resolve the discrepancies between theoretical predictions and laboratory data, ultimately improving the understanding of nuclear fusion processes in stellar and reactor environments.

Further experimental and theoretical SP studies are thus necessary to gain more and more detailed information on entire universe, even though the conditions of these environments are typically difficult-to-access and critical in terms of high temperature and density. Hence, it is useful to develop experimental setups and theoretical approaches that simplify the study of the SP. In this framework, our collaboration, named SPILL (by INFN), aims to study the SP under conditions of astrophysical interest by means of laser produced plasmas (LPP) [Alt17]. Through high intensity lasers and short duration pulses, it is, in fact, possible to generate non stationary and highly concentrated plasmas [Gil96].

Our simulations implement SP through the electrodynamical characterization of a non-thermalized LPP in such a kind of complex environment. In this contribution, the preliminary performances and results of our experimental apparatus, designed to measure the energy loss of light and heavy ions passing through an LPP, will be presented together with a theoretical model accounting for the SP effects in a simplified nucleosynthesis scenario.

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