Relativistic Screening Effects on Big Bang Nucleosynthesis and Low-lying Resonances [1]

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If an astrophysical environment is hot enough (greater than approximately 0.5 MeV or so), screening in the associated nuclear reactions can be modified by the presence of a relativistic electron-positron plasma. For non-zero electron chemical potentials, the effect is compounded as the Debye length (which creates an additional decrease in Coulomb energy with radius between two reacting nuclei) in a plasma can drop significantly, resulting in amplified reaction rates.

In a relativistic model, the Debye length decreases with temperature, as shown in Figure 1. The effect of screening is to shift the reaction energy in the cross-section. This can result in an enhancement of nuclear reaction rates, and the reaction rate enhancement factor is studied in several relevant scenarios. For sub- or near-threshold resonances, this could potentially change the reaction rates by a significant amount as the reaction energy effectively shifts the resonance above or below threshold.

Possible sites where relativistic plasma screening could have a significant effect on observed results include Big Bang Nucleosynthesis, α-rich freezeout in the r-process, x-ray bursts, and type Ia supernovae in white dwarfs. Most recently, the effects of the screening due to the relativistic electron-positron plasma during the Big Bang Nucleosynthesis have been explored. While the effects of relativistic screening were found to be relatively small in the standard Early Universe models, further work is being done to explore the same effects in the above-mentioned astrophysical sites. Additional work is currently focused on possible effects on the production of ^{56}Ni in type Ia supernovae, effects on light curves (both frequency and duration) in X-ray bursts, and effects on the electron fraction in the astrophysical r-process following α-rich freezeout.

In this work we explored in detail the consequences of the screening due to the relativistic electron-positron plasma on non-resonant and possible resonances on the secondary reactions destroying $A = 7$ nuclei during the Big Bang Nucleosynthesis. We found that effects of screening from the relativistic plasma are small even for the reaction with the largest charge , namely ^{3}He+^{7}Be. We note that this reaction is the least experimentally explored one in the network of BBN reactions.

Even though the effects we find are small, it still is worthwhile to demonstrate how robust our current understanding of the BBN is to effects not previously considered. This is especially important since the instruments scheduled to go online in the future, such as the Thirty Meter Telescope [2], will measure the abundances of the light elements resulting from the BBN with greater precision.

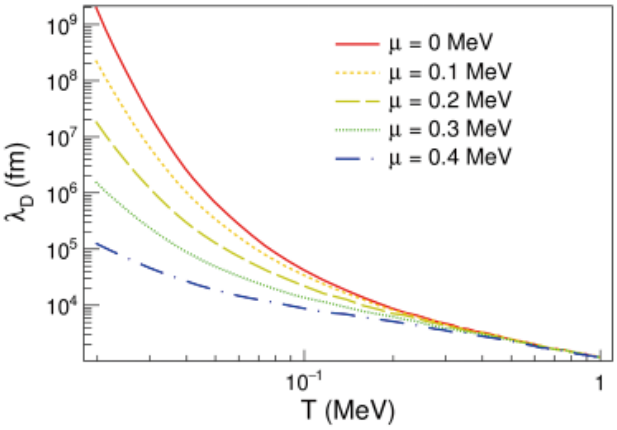

Figure 1: The Debye length for the ^{3}He+^{7}Be reaction as a function of temperature (in MeV) for several electron chemical potential assumptions.

References

[1] Famiano, M. A., Balantekin, A. B., Kajino, T.: 2016, *Phys. Rev. C*, **93**, 045804.
[2] Skidmore, W., et al.: 2015, *Research in Astron. Astrophys.*, **15**, 1945.