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JOHANNES GUTENBERG UNIVERSITÄT MAINZ

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PRISMA+ Colloquium

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Nuclear Astrophysics with the Trojan Horse Method

The source of energy that sustains burning stars for millions to billions of years is provided by nuclear reactions that are responsible also for the element nucleosynthesis inside them.
Over the past forty years nuclear physicists have been trying to measure the rates of the most relevant reactions, but there is still considerable uncertainty about their values. Although the stellar temperatures are high, on the order of hundred million degrees, they correspond to sub-Coulomb energies. As a consequence, the Coulomb barrier causes a strong suppression of the cross-section, which drops exponentially with decreasing energy. Thus, the corresponding reaction rates are extremely small, making it difficult for them to be measured directly in the laboratory. In addition, the electron screening effect due to the electrons surrounding the interacting ions prevents one to measure the bare nucleus cross-section.
Typically, the standard way to get the ultra-low energy bare nucleus cross-section consists in a simple extrapolation of available higher energy data. This is done by means of the definition of the astrophysical S(E) factor which represents essentially the cross-section free of Coulomb suppression. However, the extrapolation may introduce additional uncertainties due for instance to the presence of unexpected resonances or to high energy tails of sub-threshold resonances.
A valid alternative approach is represented by the Trojan Horse Method (THM) that provides at present the only way to measure the bare nucleus S(E) factor of a relevant charged particle twobody reaction $A + x \rightarrow c + C$ in the Gamow energy window, overcoming the main problems of direct measurements. This is done by selecting the quasi-free (QF) contribution of an appropriate three-body reaction $A + a \rightarrow c + C + s$, where a is described in terms of clusters $x \oplus s$. The QF reaction is performed at energies well above the Coulomb barrier, such that cluster x is brought already in the nuclear field of A, leaving s as spectator to the A+x interaction.

The THM has been successfully applied to several reactions connected with fundamental astrophysical problems as well as with industrial energy production. I will recall the basic ideas of the THM and show some recent results. I will emphasis in particular those related to the 12C+12C fusion channel in stars, whose reaction rate was found to be strongly enhanced at the relevant temperatures.

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