Stellar electron-capture rates: recent theoretical and experimental advances.

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Electron-capture (EC) rates play a key role in various astrophysical phenomena [1], such as the final evolution of intermediate-mass stars, core-collapse supernovae (CCSN), cooling of the neutron star crust, and nucleosynthesis in thermonuclear supernovae. The stellar conditions cannot be reproduced in the laboratory and to estimate the EC rates at extreme thermodynamic conditions one has to rely on theoretical models. Previous studies show the importance of temperature-dependent effects for stellar EC calculations on few nuclei near N=50 [2, 3]. The effects of the temperature on EC rates have been further investigated recently, based on shell model and QRPA calculations, for nuclei that play an important role during the collapse phase of (CCSN) (N$\approx$50, Z$\gtrsim$28) [4]. In addition, to quantify the impact of the new temperature-dependent calculations on the dynamics of the collapse, numerical simulations of CCSN were performed with the spherically-symmetric GR1D simulation code.

Besides, the theoretical models must be benchmarked with experimental data where available, i.e. primarily from the ground state of the parent nucleus. Over the past decades, great progress has been made to constrain electron-capture rates on stable nuclei by using reactions in forward kinematics [1]. However, the unstable neutron-rich nuclei capturing the most during, for example, the core-collapse supernovae, remained inaccessible. The use of the (d,^{2}He) charge-exchange reaction in inverse kinematics with the Active-Target Time-Projection Chamber and the S800 Spectrograph was developed at NSCL/FRIB, for extracting Gamow-Teller strengths in the $\beta+$ direction on unstable nuclei. This makes it possible, for the first time, to constrain electron-capture rates on neutron-rich nuclei.

In this talk I will discuss recent results of the temperature-dependent EC rates study on N=50 nuclei and of the pilot ^{14}O(d,^{2}He) experiment.

1. K. Langanke et al., Rep. Prog. Phys. 84, 066301 (2021).
2. A. A. Dzhioev et al., Phys. Rev. C 101, 025805 (2020).
3. E. Litvinova et al., Phys. Rev. C 103, 024326 (2021).
4. S. Giraud et al., arXiv:2112.01626 (2021)