One of the most important question in nuclear astrophysics is the impact of low energy reaction processes on stellar evolution and stellar lifetime. Stellar model simulations rely on either purely theoretical reaction rates or the theoretical extrapolation of higher energy measurements for these underlying nuclear processes. With one exception none of the nuclear reaction rates have been confirmed experimentally at the stellar energy conditions. These kind of measurements are extremely difficult since they are handicapped by the extremely low cross section and the large cosmic ray induced background in the detectors. An underground low energy accelerator facility would provide the opportunity to study low energy reaction processes of relevance for stellar hydrogen and helium burning.

A most striking recent example for the necessity and relevance for such measurements is the recent study of $^{14}N(p,\gamma)^{15}O$ which as the slowest reaction in the CNO cycles determines the lifetime of massive main sequence stars. While this reaction was thought to be reasonably well known in the past [1], a recent experimental study at the LUNA European underground accelerator in the Gran Sasso laboratory [2] has revealed a significantly lower cross section than suspected in the beforehand not explored energy range. This result has significant impact not only for the life span of massive stars but also for interpretation of globular clusters and the age of the universe [3].

The uncertainties in the reaction rates impose limits on the validity of our solar model calculations through the uncertainties in the pp-chain reactions, it leaves open the interpretation of the CNO reactions for massive main sequence stars and its impact on later burning phases. It questions the basis of or description for the red giant and the asymptotic giant helium and carbon burning phase which are the sites for the s-process responsible for the origin of more than half of our known elements. It limits our interpretation and understanding of rapid convection processes which link the nucleosynthesis site deep inside the star with the stellar atmosphere where we can observe the freshly produced elements. To solidify our models, our interpretations, and predictions of stars and stellar processes we have to optimize the microscopic parameters for the nuclear engine of stars by minimizing the experimental uncertainties in the reaction rates. While proton induced reactions are targeted by the LUNA collaboration, α induced processes during stellar Helium and Carbon burning would present the main challenge for a future US underground accelerator facility.

An underground facility would provide the opportunity to study stellar reactions at stellar energies by significant reduction of cosmic radiation background through passive shielding. A working group on studying the possibilities for optimized design of an underground accelerator has been formed and a first workshop sponsored by the Joint Institute for Nuclear Astrophysics JINA has been quite successful in identifying the needs for the community (www.jinaweb.org/html/jinaworkshops.html#event3). Two options on accelerator design and needs are being debated, a high intensity light ion machine such as LUNA [2] or a high intensity low energy ($\leq$1 MeV/amu) heavy ion accelerator in ac-mode to provide better experimental conditions through inverse kinematics measurements. A detailed technical design and feasibility study in collaboration with accelerator physics groups will be necessary to evaluate the advantages and disadvantages for these two different approaches. The second important aspect will be the development and planning on experimental detector equipment. This has to combine high efficiency with event identification ability to improve the background reduction conditions will be the development. LUNA experiments have shown that this capability was crucial in all experiments [4]. The working group will therefore focus on the development of low energy recoil separation techniques, 4π Si strip detector arrays (in close communication with RIA working groups) and of high energy γ tracking techniques in collaboration with the GRETA group at Berkeley National Laboratory.

References

[1] E. J. Adelberger et al., Review of Modern Physics **70** 1265 1998

[2] A. Formicola et al., Nucl. Instr. Meth. **A 507**, 609 (2003)

[3] G. Imbriani et al., Astron & Astrophys. **420** 625, (2004)

[4] M. Junker et al., Phys. Rev. C **57**, 2700 (1998)