Challenges in decay rate change measurement in a Penning Trap

Parnika Das[1,2†], Arindam Kr. Sikdar[1,2], Joydip Nandi[1], N. Chaddha[1,2],A. Ray[1*,2*(Ex)]

[1]Variable Energy Cyclotron Centre, 1/AF, Bidhannagar, Kolkata, INDIA
[2]Homi Bhabha National Institute, Anushaktinagar, Mumbai, Maharashtra, INDIA
[3]Delta Q, IMJ Institute of Research, Moodlakatte, Karnataka, INDIA

Synopsis The wide range of applications of nuclear science and technology are based the consideration that decay rate of a radioactive element is constant. Yet, continued experimental efforts have been made in search of conditions which would change the decay rate and questioned the accuracy of this "natural clock". Reported results show that the variation in decay rate in different terrestrial environment is ~ 1 %. However, dramatic change in decay rate has been observed in Storage ring experiments where extreme environment could be created. It is expected that tailored environmental conditions can be created in a Penning Trap by storing electron capturing nuclei in different charge state and substantial effects in decay rates will be observed. Efforts at VECC and at different labs and challenges in conducting such experiments will be discussed.

Among the different types of nuclear decay processes, electron capture by the nucleus is most susceptible to the surrounding environment. Since,^{7}Be is the lightest radioactive nucleiwhich decays via electron capture process, it is considered most susceptible. So, numerous studies have been performed and decay rate of ^{7}Be has been measured placing in different host media. In certain host lattice environment, where compression is not substantial, it is observed that the decay rate is directly proportional to the number of electrons in the 2s orbital of decaying ^{7}Be [2]. Number of 2s electrons in the 2s orbital (ns) of ^{7}Be, in a particular host media can be determined using density functional calculation [1].In Fig. 1, relation of (ns) with measured decay rate of ^{7}Be is shown. Qualitatively, loss of electrons from 2s orbital of ^{7}Be in a host medium due to hybridization can be considered as an effective ionization resulting reduction in electron density at the nucleus leading to change in decay rate. However, quantitative determination of decay rate change in a host medium is based on number of 2s electrons which is obtained from model dependent calculations.

In a storage-ring experiment, ionisation dramatically reduced the half-life from 41.6 billion years for neutral ^{1}87Re to about 33 years for fully ionized ^{1}87Re^{7}5+, demonstrating the profound influence of the atomic-electron environment on radioactive decay [3]. Such direct effect could be observed in a storage ring as an extreme condition of ionizing the decaying radioactive atoms could be achieved.

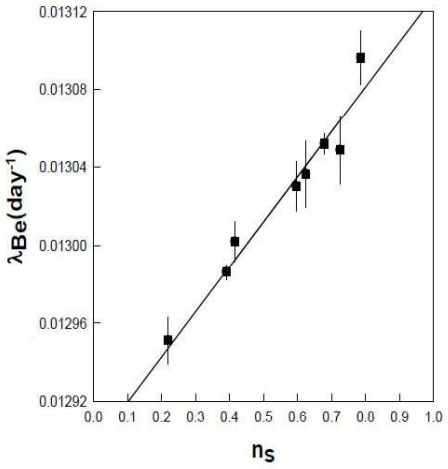

Figure 1. Decay Rate versus number of 2s electrons of 7Be

It is expected that such dramatic effects in ^{7}Be will be observed from measurement of ^{7}Be in different charge state in a Penning Trap. Exper imental setups for such measurements are being made at VECC and other labs [4]. Challenges in performing such experiments will be discussed.

References

[1] Andersen, O. K. *et al.* 1986 *Phys. Rev. B 34, 5253*
[2] P. Das *et al.* 2008 *Phys. Rev. C 71, 025801.*
[3] Bosch, F. *et al.* 2015 *Phys. Rev. Lett 77. 5190* **114** 162501
[4] https:/koethgroup.umd.edu/curie/

†E-mail: parnika@vecc.gov.in