Muonic Atom of Unstable Nuclei

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For decades, the study of muonic atoms has played an important role in establishing and refining the nuclear structure model, through muonic X-ray measurements that yielded very precise and absolute values for the charge radii and other ground state properties of stable nuclei [1]. New intense muon beams, with fluxes several orders of magnitude higher than at present muon facilities, would allow many novel experimental studies that were statistically not feasible. The investigation of the nuclear properties of short-lived nuclei using muonic atom spectroscopy would become possible. Muonic X-ray measurements of unstable nuclei would be a unique tool to increase our knowledge of the nuclear structure far from stability, in particular the nuclear charge distribution and the deformation properties of nuclei.

We proposed the cold hydrogen film method [2] to extend muonic atom spectroscopy to the use of radioactive isotope (RI) beams to produce unstable muonic atoms. The basic concept of this method is to stop both negative muon and RI beams simultaneously in a solid hydrogen film, followed by the direct muon transfer reaction to higher Z nuclei to form muonic atoms. This method would allow studies of the nuclear properties of unstable nuclei, in particular the nuclear charge distribution, by means of the muonic X-ray method at facilities where both intense negative muon and RI beams would be available. For instance, the neutrino factory concept to produce intense muon beams is very attractive to realize the proposed study, because the same driver beam could also be used for next generation RI beam facilities. This would be a unique opportunity to combine massive amounts of muons with very intense RI beams.

An experimental program is in progress at the RIKEN-RAL Muon Facility to demonstrate the feasibility of this method. An apparatus has been constructed to perform X-ray spectroscopy with muonic atoms formed from stable ions implanted in solid hydrogenous films [2]. Already solid deuterium targets with various concentration of implanted argon ions showed very clearly delayed muonic argon 2p-1s transition X-rays at 644 keV from the muon transfer reaction. Also, as an intermediate step towards muonic spectroscopy with unstable nuclei, an experiment using long-lived isotopes is under consideration. Radium isotopes are of strong interest, since there are no stable isotopes for good measurements of nuclear parameters like the nuclear charge radius. These parameters would be urgently needed to exploit the full potential of the radium atom for atomic parity non-conservation studies [3]. A new surface ionization ion source is now under development with the goal of using later radioactive isotopes. At first, stable barium ions will produced for tuning and optimization, and to test the system safety. The latest experimental developments will be reported at the conference. Future perspective at the new Muon Experimental Facility in the J-PARC project will also be discussed.

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