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K600 magnetic spectrometer and the NUMEN project

The NUMEN (NUclear Matrix Elements for Neutrinoless double-beta decay) project aims to obtain the nuclear matrix elements (NME) to be used as inputs in models to determine the lifetime of neutrinoless double-beta ($0\nu\beta\beta$) decay, which is related to the absolute mass of the neutrino [1]. This will be achieved by conducting heavy-ion double charge-exchange (DCE) reactions and measuring the cross sections of these reactions for all isotopes that have been identified to undergo $0\nu\beta\beta$ decay [1]. The occurrence of the $0\nu\beta\beta$ decay will imply that the lepton number is violated [2]. It is, therefore, very important to determine the NMEs as they will assist in elucidating Physics beyond the Standard Model [2]. The transition operators of the $0\nu\beta\beta$ decay and DCE reactions have a similar mathematical structure with a combination of short $0\nu\beta\beta$ decay range Fermi, Gamow-Teller, and rank-2 tensor components [3]. The weights of such components are different, being controlled by the axial and vector coupling constants in the weak sector and by the energy-dependent isospin, spin-isospin, and tensor coupling strengths for the strong interaction [3]. Therefore, more experimental data are required from a range of incident beam energies for DCE measurements. Additionally, to explore the candidate nuclei of $0\nu\beta\beta$ decay in a systematic way, more experimental data are required. Previous experiments for the NUMEN project at Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali del Sud (INFN-LNS) have suffered from high signal rate due to the interaction of the target and projectile, which greatly outnumber any potential DCE events. Additionally, the limited energy resolution of the MAGNEX spectrometer for DCE measurements makes it a cumbersome task to decouple transitions of interest relevant to the NUMEN project. Particle-γ coincidence measurements are a plausible attempt at a solution for this problem. Thus, a high-resolution magnetic spectrometer like the K600 at the iThemba Laboratory for Accelerator Based Sciences (iThemba LABS), which is already used for coincidence measurements, is a perfect candidate for baseline measurements especially given that the LNS facility is still under upgrade. However, in its current design, the existing K600 detection system is limited in the detection of heavy ions (e.g. $^{6}\mathrm{Li},^{12}\mathrm{C},^{18}\mathrm{O},^{18}\mathrm{Ne}$) at moderate kinetic energies ($\approx$ 10~MeV$/u$) and light ions at low energies ($\approx$ 5~MeV$/u$)[4]. The development of a new low-pressure detection system for the K600 is currently underway to expand the spectrometer research program [4]. Thus, an already existing detection system from the MAGNEX large-acceptance spectrometer at INFN-LNS has been coupled to the K600 to provide a baseline as to how the K600 will operate with a low-pressure detection system. The coupling of the MAGNEX focal-plane detection system with the K600 is also beneficial for other nuclear-structure studies to be conducted with the K600 spectrometer.

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