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AMS and ICP-MS Measurements of Radioimpurities Pb-210 and K-40 for the SABRE South Dark Matter Experiment

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DAMA/LIBRA (DArk MAtter/Large sodium Iodide Bulk for RAre Processes) is a low-background NaI:Tl crystal detector array in the Gran Sasso underground laboratory in Italy. It has been measuring purported dark matter signals for over two decades. DAMA/LIBRA reported an annual modulation signal in the 2 to 6 keV energy region that is claimed to be from dark matter [1]. SABRE (Sodium-iodide with Active Background REjection) South, located at the Stawell Undergrond Physics Laboratory (SUPL) in Australia, will provide an alternate and independent dark matter signal measurement with the same detector material as DAMA/LIBRA but with a higher sensitivity [2].

Ultra-high purity of the NaI:Tl crystals is a crucial feature of direct dark matter detectors. Radioimpurities in the detector material may mimic dark matter and must be studied and quantified. The metrology group at the Australian National University (ANU) is developing chemical procedures for ultra-sensitive measurements of radioimpurities with accelerator mass spectrometry (AMS) and inductively coupled plasma mass spectrometry (ICP-MS) towards qualification of SABRE materials. This study focuses on the radionuclides ^{210}Pb and ^{40}K, which are expected to be the dominant radioimpurities in the crystals impacting the background.

^{210}Pb (half-life of 22.2 yr) is a part of the uranium decay series and therefore naturally occurring in environment. Due to a limited amount of NaI available for radioimpurity analysis, not enough intrinsic lead can be extracted to produce an adequately large AMS sample. Therefore, it is essential to add an optimal lead carrier material with a low ^{210}Pb content to increase the size of the NaI sample. Potential carriers were measured via AMS at the 14 UD pelletron accelerator at the ANU, as well as at the 1 MV VEGA accelerator at the Australian Nuclear Science and Technology Organisation in Sydney. Due to the relatively short half-life of ^{210}Pb, carriers obtained from aged constructions were measured to have the lowest ^{210}Pb/Pb ratios in the order of 10^{-16}, two orders of magnitude lower than previously reported [3].

Due to its long half-life, the radioimpurity ^{40}K (half-life of 1.25 Gyr) is of primordial origin. The amount of the stable potassium isotope ^{39}K was measured via ICP-MS. The well-known natural abundances of these two isotopes were used to determine the amount of ^{40}K in NaI.

[1] R. Bernabei et al., Eur.Phys.J.C 67 (2010): 39-49.
[2] E. Barberio et al., Eur.Phys.J.C 83.9 (2023): 878.
[3] M. B. Froehlich et al., Nucl. Instrum. Meth. B 529 (2022): 18-23.

Student Submission

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