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Long-term solar neutrino flux and geological 205Pb assay

LOREX, the acronym for LORandite EXperiment, attempts the determination of the solar neutrino flux by measuring the 205Pb content in the thallium-bearing mineral lorandite, TlAsS2, from the mine of Allchar, FYR Macedonia. 205Pb is formed there via the neutrino-capture reaction 205Tl + νe ⟶ 205Pb + e-. This geochemical detector offers the lowest threshold among all the detectors of only 52 keV for solar pp-neutrinos. The final step of LOREX, which is now underway, is the extraction of lorandite, while the ensuing quantitative determination of the ratio of 205Pb / 205Tl atoms would provide the product of solar neutrino flux and neutrino-capture cross section, integrated over the age of the lorandite of 4.3 · 106 yr. The cosmogenic 205Pb produced by fast muons, which constitutes the main background, is strongly depth-dependent and very sensitive to the long-term erosion history of the field area. It is estimated that, depending on paleo-depth, 10kg of lorandite contains about 3.5 −11.6 x 105 atoms of 205Pb. This report presents new data on the accurate geological age of the minerals at Allchar, as well as the recent results for erosion rates at two lorandite rich locations. These are based on accelerator mass spectrometry determinations of 10Be, 26Al, 36Cl and 53Mn in characteristic samples as well as on the independent geo-morphological studies. Provided that thus determined high values of erosion rates are corroborated by remaining measurements of additional samples, the experiment is expected to reach an acceptable signal-to-background ratio. We also discuss the pending measurement of the lifetime for the bound beta decay of the completely ionized 205Tl, which is aimed at finding the still unknown capture probability of solar pp-neutrinos on 205Tl.
Separation and identification of the 205Pb nuclei (T1/2~15mio years) from stable lead isotopes and the 205Tl isobar are significant challenges at the trace-element level expected (~ 10-14 to 10-15). The approach chosen is accelerator mass spectrometry (AMS) at the high energies sufficient for full stripping. Injection into a high-energy ion-storage ring has allowed single-particle identification in such settings (Experimental Storage RING (ESR) at the GSI facility). A major challenge remains the overall isotope detection efficiency, which is marginal for the expected total sample size. We have explored alternatives including atom trap trace analysis (ATTA) with an optical trap. However, we have not been able to identify suitable optical transitions. A promising improvement is expected from the RIKEN mass ring, an ion storage ring similar to the ESR but with super-fast pre-injection particle ID which allows a fast kicker to inject individual ions onto the main orbit. This is expected to provide a one order-of-magnitude higher detection efficiency.

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Track Classification: Solar Neutrinos