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Ultra-sensitive analysis with neutron activation of U, Th and K in the liquid scintillator of the JUNO experiment

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The Jiangmen Underground Neutrino Observatory (JUNO) is a multi-purpose neutrino experiment currently under construction in southern China.
The detector consists of a 35.4 m diameter acrylic sphere filled with 20 000 t of ultra-pure liquid scintillator and makes JUNO the largest liquid scintillator-based, underground neutrino observatory. The primary goal of JUNO is to determine the neutrino mass ordering with a significance greater than 3σ after 6 years of data taking and to perform high-precision measurement of neutrino oscillation parameters by measuring the spectrum of the oscillated reactor antineutrino. The detector construction is expected to be completed in 2024.
JUNO has extremely stringent requirements for its background that can overlap with the signals of interest. One of the main background sources is the decay of radioactive nuclides in the materials of the detector and a big effort is necessary to keep the radioactive contamination under control by selecting and purifying the materials used to build the experiment. The most critical component is the liquid scintillator (LS) which is the active material of the detector: the baseline requirements for its radiopurity are less than 10-15 g/g (ppq) for 238U and 232Th and less than 10-16 g/g for 40K.
To achieve the required sensitivities, a new measurement technique has been developed to increase the typical sensitivity of the Neutron Activation Analysis (NAA). We've combined the NAA with radiochemical treatments on the sample to concentrate the nuclides of interest and remove the interfering ones. A dedicated beta-gamma coincidence detector has been developed to reduce the measurement background and a new delayed coincidence technique has been applied for the measurement of 238U by exploiting the presence of a metastable state in the Uranium activation product to further increase the sensitivity. We achieved sensitivities of <0.4 (1.6) ppq for U (Th) on 1 L samples, and <0.7 ppq for K on 0.15 L samples. The first LS samples produced during the commissioning of the JUNO purification plants are validated.

Primary author: BARRESI, Andrea (Università Milano-Bicocca)

Presenter: BARRESI, Andrea (Università Milano-Bicocca)

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