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Supernova neutrinos as a precise probe of nuclear neutron skin

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A precise and model-independent determination of the neutron distribution radius $R_{\rm n}$ and thus the neutron skin thickness $R_{\rm skin}$ of atomic nuclei is of fundamental importance in nuclear physics, particle physics and astrophysics but remains a big challenge in terrestrial labs. We argue that the nearby core-collapse supernova (CCSN) in our Galaxy may render a neutrino flux with unprecedentedly high luminosity, offering perfect opportunity to determine the $R_{\rm n}$ and $R_{\rm skin}$ through the coherent elastic neutrino-nucleus scattering (CEνNS). We evaluate the potential of determining the $R_{\rm n}$ of lead (Pb) via CEνNS with the nearby CCSN neutrinos in the RES-NOVA project which is designed to hunt CCSN neutrinos using an array of archaeological Pb based cryogenic detectors. We find that an ultimate precision of $\sim 0.1\%$ for the $R_{\rm n}$ (~ 0.006 fm for the $R_{\rm skin}$) of Pb can be achieved via RES-NOVA in the most optimistic case that the CCSN explosion were to occur at a distance of ~ 1 kpc from the Earth.

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