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Presupernova neutrinos: directional sensitivity and prospects for progenitor identification

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We explore the potential of current and future liquid scintillator neutrino detectors of $\mathcal{O}(10)$ kt mass to localize a pre-supernova neutrino signal in the sky. In the hours preceding the core collapse of a nearby star (at distance D less than or equal to 1 kpc), tens to hundreds of inverse beta decay events will be recorded, and their reconstructed topology in the detector can be used to estimate the direction to the star. Although the directionality of inverse beta decay is weak ($\sim$8% forward-backward asymmetry for currently available liquid scintillators), we find that for a fiducial signal of 200 events (which is realistic for Betelgeuse), a positional error of $\sim 60^\circ$ can be achieved, resulting in the possibility to narrow the list of potential stellar candidates to less than ten, typically. For a configuration with improved forward-backward asymmetry ($\sim$40%, as expected for a lithium-loaded liquid scintillator), the angular sensitivity improves to $\sim 15^\circ$, and – when a distance upper limit is obtained from the overall event rate – it is in principle possible to uniquely identify the progenitor star. Any localization information accompanying an early supernova alert will be useful to multi-messenger observations and to particle physics tests using collapsing stars.

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