Time-Charge HEALPix Direction Reconstruction Fitter for Supernova Neutrinos in Super-Kamiokande

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Supernova (SN) localization from water-Cherenkov neutrino detectors is critical for capturing early optical observations of the next galactic SN, as neutrinos are the earliest observables arriving well before shock breakout. SN neutrino bursts detected by Super-Kamiokande (SK) produce thousands of PMT time-charge (TQ) signals which contain directional information. Our current direction reconstruction pipelines at SK rely on first reconstructing the vertex, energy, and directions of all events. This enables highly resolved, but computationally costly, real-time SN localization that increases the alert latency when sending notices to the General Coordinates Network (GCN). We are developing a new reconstruction fitter that maps individual PMT hit TQ data onto a HEALPix sphere to directly extract directional information, bypassing individual event reconstruction. In this presentation, we describe the characteristics of the hit map and the methods of directional analysis. Preliminary results indicate direction reconstruction is done in $\mathcal{O}(1\ \text{sec})$ compared to $\mathcal{O}(90\ \text{sec})$ with our current reconstruction fitters, but consistent directional accuracy needs further development. This approach shows promise for improving rapid SN pointing and burst detection in future early-warning systems.

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