Estimation of γ rays from neutral-current neutrino-carbon and -oxygen inelastic reactions from supernova neutrinos

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Abstract: The first neutrinos outside the solar system were detected from SN 1987A by the Kamiokande-II, IMB, and Baksan experiments. This handful of data has provided new understanding of the physics of supernova (SN) and the properties of neutrinos. The huge number of neutrinos, with a total energy being equivalent to $\sim 10^{53}$ erg, are produced from an SN core in 10s and their mean energies are a few tens of MeV. While ν_e (and their anti-particles) can interact by both charged-current (CC) and neutral-current (NC) reactions in the SN core and in the neutrino detectors in the earth, ν_μ and ν_τ (and their anti-particles) have too low energy to produce muons and τ-leptons and they can only interact by NC interactions. In the next SN explosion in our Galaxy, it is important for us to measure all flavors of neutrinos and their spectra to obtain better understanding of the SN explosion mechanism.

Experimentally, the NC reactions in the tens of MeV were observed in $^{12}C(\nu,\nu')^{12}C^*(15.1MeV, 1^+)$ by KARMEN experiment and recently in coherent ν-NaI(Tl) scattering by COHERENT collaboration. Langanke and Kolbe et al. [1] proposed to measure NC inelastic events by ^{12}C, $^{16}O(\nu,\nu')$ reactions followed by γ-ray emission. The γ-ray emission probability was estimated by a statistical calculation.

In this presentation, we focus on the evaluation of the number of NC inelastic events by ^{12}C, $^{16}O(\nu,\nu')$ reactions followed by γ-ray emission as described in the following equation:

$$N_\gamma^{NC} = n_{tar.} \int_0^{E_\nu^{max}} dE_\nu \frac{d\Phi}{dE_\nu}(E_\nu) \left[\int_{E_x=16\text{ MeV}}^{E_x=32\text{ MeV}} dE_x \frac{d\sigma(E_x,E_\nu)}{dE_x} \times R_\gamma(E_x) \right],$$

where n_{tar} is the number of targets in the neutrino detectors, $d\Phi(E_\nu)/dE_\nu$ is the neutrino flux tabulated by Nakazato et al.[2], $d\sigma(E_x,E_\nu)/dE_x$ is the differential cross section for the giant resonance (E_x) at the incident neutrino energy E_ν [3], and $R_\gamma(E_x)$ is the γ-ray emission probability from the giant resonance (E_x). Since we use the values $R_\gamma(E_x)$ which were extracted from our (p,p') experiment [4], our evaluation is more reliable than a simple statistical calculation. We will present the estimation of the number of NC events for JUNO (20 kton, liquid scintillator) and Super-K (32kton, water) from the core-collapse supernova at 10 kpc.

Refs.

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