# Diffuse Supernova Neutrino Background Search at SK with neutron tagging

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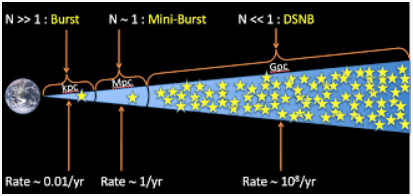
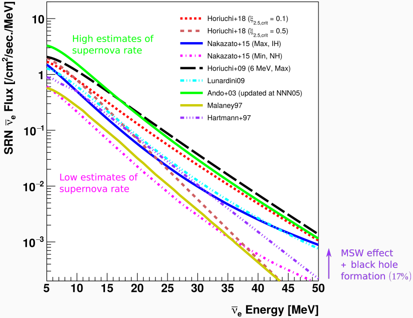
## Neutrino flux from all distant core-collapse supernovae




J. Beacom

2-3 galactic supernovae/century
1 SN/s in the observable Universe



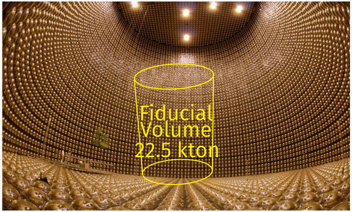

Y. Ashida

- Detection and characterization would allow for the study of aggregate properties of core-collapse supernovae, while probing the history of the universe and neutrino properties
- All flavors of neutrinos produced during CC SN, reaching Earth redshifted
- Expected signal is $\sim$10s of MeVs and has so far proved elusive

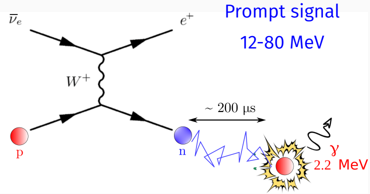
# The search for the DSNB at SK

## Detection of DSNB $\overline{\nu}_e$ via Inverse Beta Decay (IBD) in water

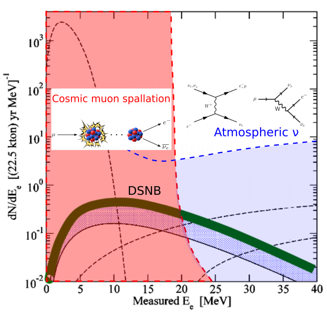
- **Super-Kamiokande**: a 50-kton water Cherenkov detector in Kamioka, Japan




- 5-20 events/year
  Energy range: 12-80 MeV
- Need extremely powerful algorithms to characterize spallation and atmospheric backgrounds and **identify the neutrons**
- Current analysis: uses runs from the **SK-IV** data-taking era (Sep 2008-May 2018)
- SK phases VI+ (starting summer 2020): water doped with Gadolinium, enhancing neutron signature

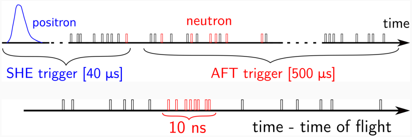



Weak delayed signal

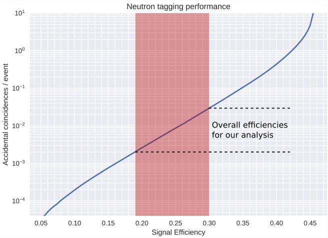



[Beacom and Vagins, Phys. Rev. Lett., 93:171101, 2004]

## A faint neutron capture signal amid a sea of low-energy background




- **New SK-IV trigger scheme** dramatically extends search time window, making the detection of neutron captures in water ($\tau_{\text{CAP}} \sim 200$ns) feasible.
- The **2.2 MeV neutron capture** signal is extremely weak and easily lost among the abundance of low-energy backgrounds (4 kHz PMT noise, radioactivity, flasher events...)




- Maximally exploit correlations with well-reconstructed primary vertex
- Use a BDT (a Machine Learning method) to classify neutron candidates, achieving ∼20%-30% overall efficiency

⋆ Gd has recently been dissolved inside the tank, producing **brighter, 8 MeV neutron capture cascades**. Efficiency is expected to increase to >80% for future analyses.

# DSNB spectral fitting with SK-IV with neutron tagging

- Fit the spectral shape of the data remaining after cuts against the expected irreducible background contributions and various DSNB models and parametrizations
- Perform an unbinned extended maximum likelihood fit, for 6 regions simultaneously:

| | Cherenkov angle | | |
|---|---|---|---|
| **Neutrons** | $[20, 38]^\circ$ | $[38, 50]^\circ$ | $[78, 90]^\circ$ |
| 1 | $\mu/\pi$ | Signal | NC |
| 0 or >1 | $\mu/\pi$ | Signal | NC |

- **Neutron tagging defines cleaner, more sensitive 1-neutron signal region**
- With the introduction of Gd in the tank, a much larger fraction of our signal will be contained in the clean signal region.
- Promising outlook for sensitivity of analysis with Gd