PROCEEDINGS OF SCIENCE

# Detection of the galactic supernova neutrino signal in NOvA experiment

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This work describes a data-driven trigger designed to detect neutrino signal from a galactic supernova using the NOvA detectors.NOvA experiment is designed to measure neutrino oscillations in a $\nu_\mu$ beam with average energy of 2 GeV and has little overburden, detecting interacting neutrinos with tens of MeV energy from a supernova requires dedicated data selection and background reduction. Studying these neutrinos can provide information about the processes affecting the supernova explosion, probe existing supernova models, and in comparison to other neutrino experiments with different sensitivities, could answer questions about the neutrino properties as the neutrinos transit both the protoneutron star and the empty space on their way to Earth. We present the efficiency for detecting the neutrino signal depending on the supernova model and the distance to the progenitor star.

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## 1. Supernova neutrino signal in NOvA detectors

Core-collapse supernovae produce about $10^{58}$ neutrinos during the first seconds after the explosion. These neutrinos carry away about 99% of the gravitational binding energy released by the collapse and also play a crucial role in the explosion mechanism. The NOvA detectors [1] can be used to register the neutrino signal from the next galactic supernova, measuring the neutrino flux and providing the trigger signal to other neutrino experiments [2].

Detailed simulations of the core-collapse supernova explosion predict various neutrino fluence depending on many parameters, such as the mass of the progenitor start and equation of state. In this work we use models with progenitor star masses $9.6M_{\odot}$ and $27M_{\odot}$ described in [3].

A dedicated simulation package was developed to simulate interactions of supernova neutrinos inside the NOvA detectors, producing particles that can then be simulated in the existing NOvA GEANT-based [4] detector simulation. This package interfaces several models of supernova neutrino fluence with the GENIE[5, 6] neutrino interaction generator, which is already used in the NOvA simulation for other analyses. This allows easy integration to the default NOvA simulation pipeline. For this study we consider only the processes of inverse beta decay and the elastic neutrino scattering on the electrons, planning to include additional detection channels in future.

## 2. Data driven triggering

NOvA utilizes a "data-driven trigger" (DDT) system to perform a fast data reconstruction online to decide which time range of data should be saved for further offline analyses. To achieve this, the data stream from the detector is sliced in 5ms blocks, which are distributed to a server farm of more than 80 nodes. This system is described in [7].

In contrast to other triggers where the trigger decision can be made based only on one 5ms slice of data, the neutrino signal from a nearby supernova would last for tens of seconds. It would also likely not be evident in any given 5ms time block, given the comparatively high background. Thus, the accumulated information from hundreds of 5ms blocks must be used to decide if a supernova has been observed in NOvA.

The supernova triggering system uses the DDT processes to reconstruct and select the interaction candidates inside each 5ms block. Then the likelyhood of the supernova burst is calculated based on the observed candidates rates within a 1s time window.

## 3. Candidates selection

A positron with several tens of MeV of momentum can light up about 1-4 scintillator cells inside the NOvA detectors. In order to reduce the background we reject the signals associated with muon tracks, Michel electrons, high energy showers and noisy electronic channels. Then we find clusters of signals, close in time and space, and if the summary amplitude of all the signals in cluster is within the signal region (see fig. 1), this cluster is considered an interaction candidate.



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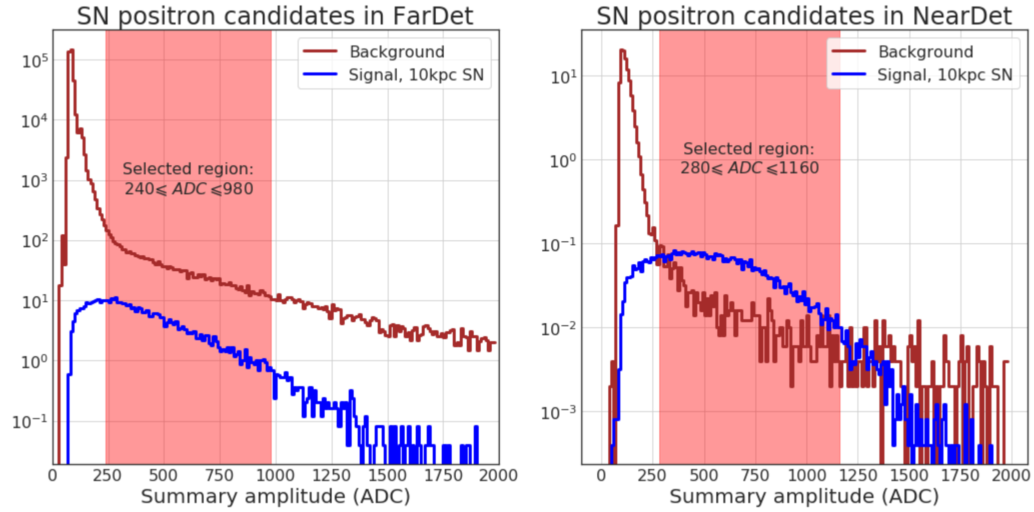


**Figure 1:** Selection of IBD interaction candidates in the Near and Far detectors of NOvA. Signal distribution is obtained from the simulation of $27M_{\odot}$ model. The background sample is the minimum bias data from the detectors. The selected regions were defined by maximizing the FOM value $s/\sqrt{b}$

## 4. Detection efficiency

We make a trigger decision based on number of candidates within a sliding 1s time window. The sensitivity of the NOvA triggering system is limited by the background fluctuation and requirement of maximum false triggering to occur not more often than once per week (as required by SNEWS system [2]). This requirement defines the threshold on the number of candidates for triggering.

We define the efficiency of supernova detection as the probability of a simulated supernova signal to exceed this threshold, assuming that number of both signal and background candidates follow the Poisson distribution.

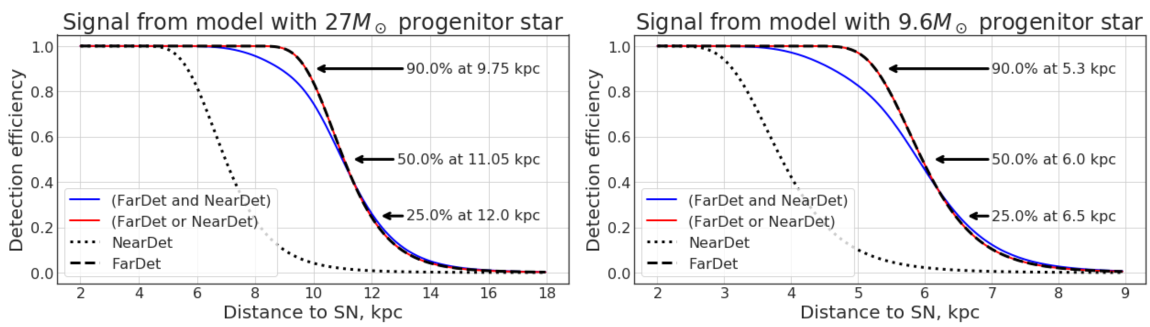


**Figure 2:** Probability of supernova detection in NOvA for the model with $27M_{\odot}$ and $9.6M_{\odot}$ progenitor star mass. For all triggers combinations we set maximum false triggering rate $\alpha = 1/week$

Also, since we have two detectors each issuing trigger signal based on its own data, we can combine them in two ways:

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- Require trigger signals from both detectors at the same time : *FarDet and NearDet*
- Require trigger signal from any detector: *FarDet or NearDet*

## 5. Results

The preliminary estimation of the supernova detection efficiency for NOvA is presented on fig.2. Currently the sensitivity is mostly defined by the Far Detector. This result can be improved by optimizing the selection criteria for the near detector and by using combined likelyhood from both detectors.

The supernova triggering system developed for NOvA experiment will be deployed on NOvA detectors during 2017 summer beam shutdown.

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