The identification of the sources of astrophysical neutrinos is one of the main motivations behind the IceCube real-time follow-up programs. Currently, there are two approaches to distinguish astrophysical neutrinos from atmospheric background. The first is to select single high-energy neutrinos assuming that the signal neutrino spectrum is harder compared to the background. The second is to search for neutrino events clustering in time and space. The latter approach is used by IceCube's optical follow-up program.

### Abstract

The identification of the sources of astrophysical neutrinos is one of the main motivations behind the IceCube real-time follow-up programs. Currently, there are two approaches to distinguish astrophysical neutrinos from atmospheric background. The first is to select single high-energy neutrinos assuming that the signal neutrino spectrum is harder compared to the background. The second is to search for neutrino events clustering in time and space. The latter approach is used by IceCube's optical follow-up program.

### Optical follow-up (OFU) program

- **Gamma-Ray Burst (GRB)**
  - Progenitor
  - \(\gamma \& \nu\) only

- **Supernova with choked jets**
  - \(\nu\) only


### Possible extensions of the program

#### Using the likelihood fits search algorithm

- **Goal:**
  - Identify electromagnetic counterparts to short neutrino signals (\(\leq 100s\))

- **Source candidates:**
  - GRBs and Supernovae with choked jets

- **Data:**
  - IceCube neutrino clusters
  - Follow-up with Swift XRT & ZTF

- **First results:**
  - No counterparts identified and clusters consistent with background expectation → stringent limits set

#### Two different search algorithms

- **Multiplets:**
  - Neutrinos arriving within 100s and \(\leq 3.5^\circ\) apart
  - Significance threshold for doublets
  - Triplets or higher multiplicities trigger immediately

- **Likelihood Fits:**
  - Sky around trigger neutrino is scanned under source hypothesis
  - Neutrinos arriving before trigger are clustered in all combinations
  - Signal and background modelled separately in likelihood

See also M. Mallamaci's poster: "Rapid response to extraordinary events with the IceCube experiment"

### References