Improved methods for finding transient neutrino sources with IceCube

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for the IceCube collaboration

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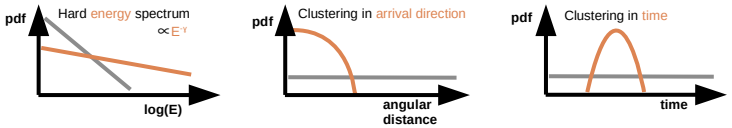
Distinguish signal from background



1. Maximize likelihood (n_s and γ)

$$\mathcal{L} = \prod_i \left[\frac{n_s}{N} \mathcal{S}_i + \left(1 - \frac{n_s}{N}\right) \mathcal{B}_i \right]$$

number of signal neutrinos

number of all detected neutrinos

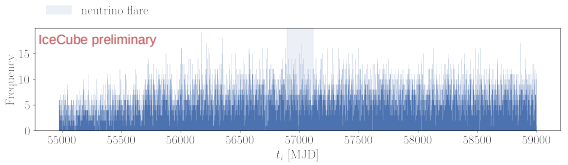
2. Unbinned likelihood ratio test
   → test statistic value TS

   TS = 2 x [log(S / B) - penalty factor]

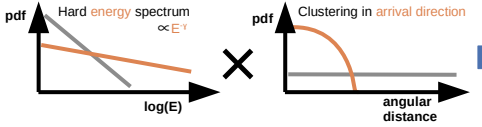
   penalty factor: more short flares than long flares → correct for look elsewhere effect

3. p-value based on test statistic distribution

Finding neutrino flares

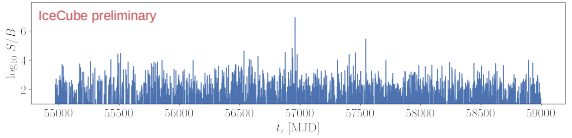


Need additional information than just arrival time of events:

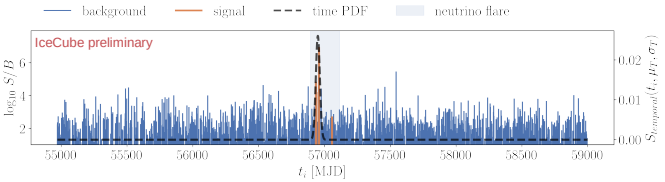


S/B ratio

Weight for signal-like events



Expectation maximization (EM) for flare finding

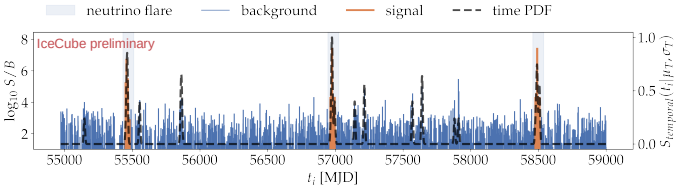


Before: brute force testing of possible time windows

NOW: expectation maximization looks for clustering of events in time.

→ Faster by a factor of > 10^5!

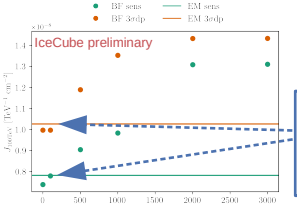
→ Easily applicable for multi-flare searches



Which sources could we see?

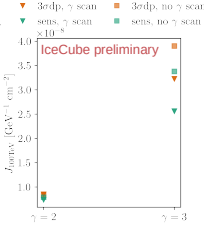
Fluence:	Sensitivity (sens):	3σ discovery potential (3σdp):
Source flux x time	fluence with 90% chance to get p-value < 50%	fluence with 50% chance to get p-value < 3σ

Comparison of EM with brute force considering events with S/B exceeding given threshold:

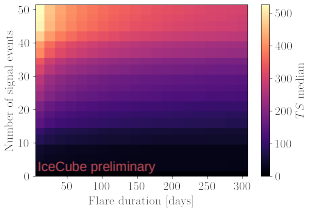


Compares to S/B threshold of ~ 100

Improving sensitivity for different spectral indices:
scanning different γ:

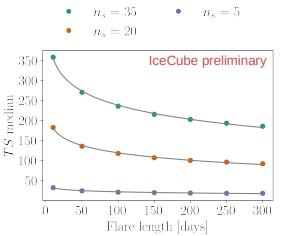


Simulating neutrino flares: Parametrization of test statistic

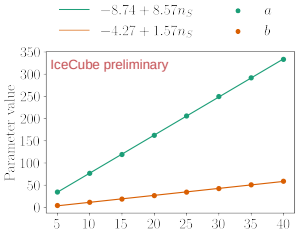


We can parametrize the shift of the test statistic median for different flare properties.

TS ∝ log (n_s / duration Δt) → $a + b \cdot \log\left(\frac{n_s}{\Delta t}\right)$



Fit parameter a & b depend linearly on n_s



Replace computationally expensive signal simulations by analytical approximations for sensitivity and discovery potential studies!