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A Template-based UHE Neutrino Search Strategy for the Askaryan Radio Array (ARA)

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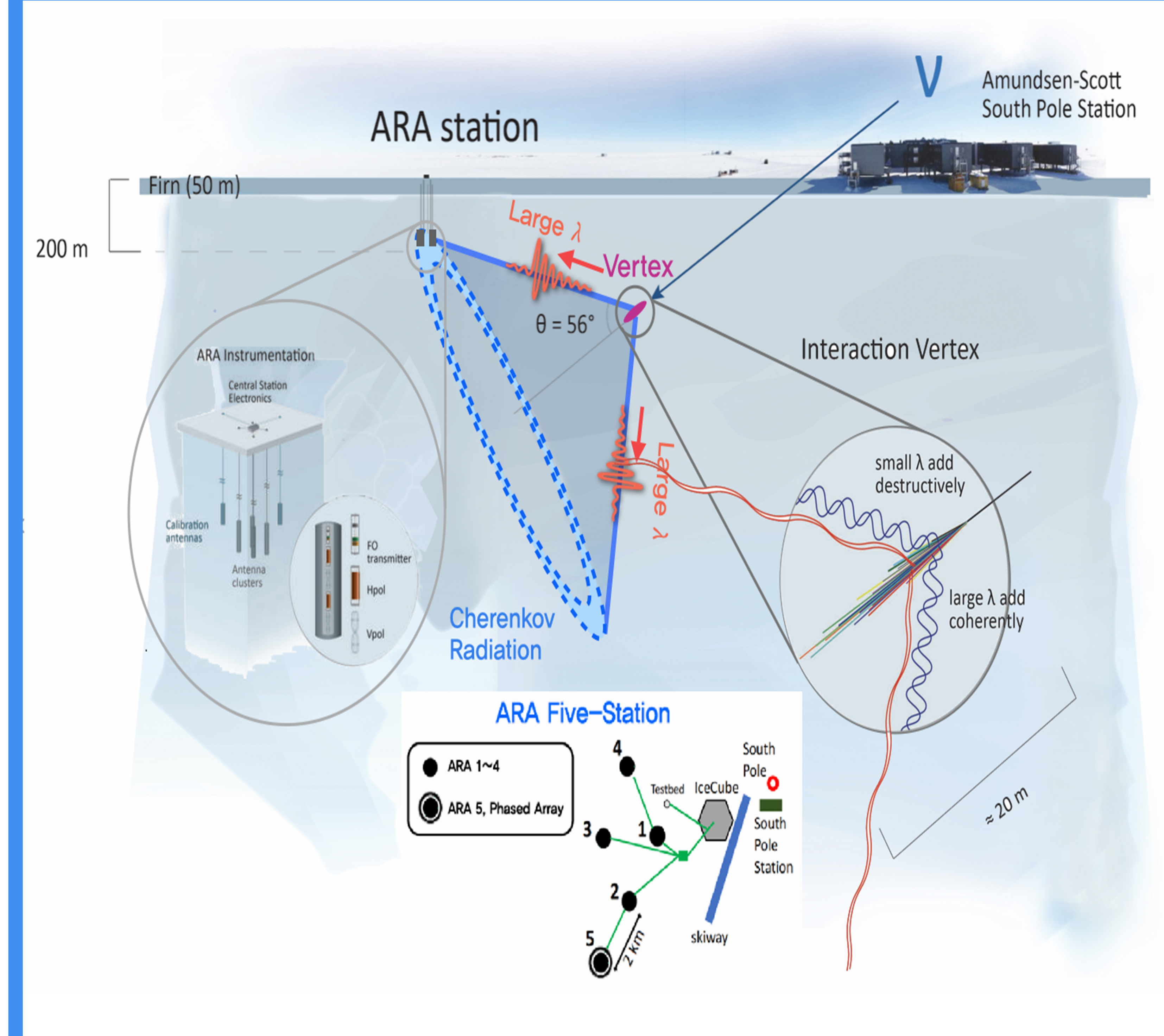
ABSTRACT

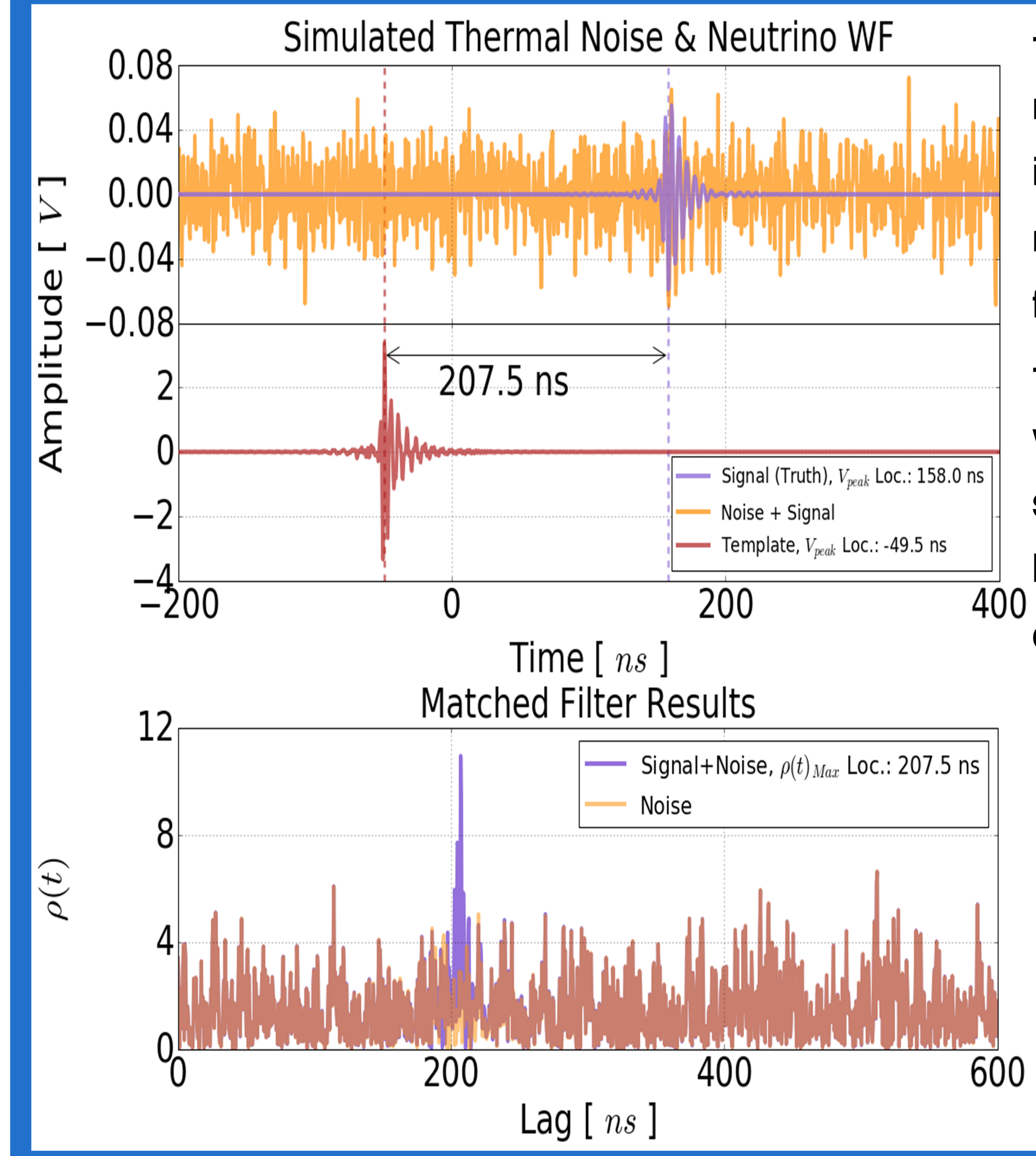
The Askaryan Radio Array (ARA) is a gigaton-size neutrino radio telescope located near the geographic South Pole. ARA has five independent stations designed to detect Askaryan emission coming from the interactions between ultra-high energy neutrinos (〉 10 PeV) and Antarctic ice. Each station includes of 16 antenna deployed in a matrix shape at up to 200 m deep in the ice. A simulated neutrino template, including the detector response model, was implemented in a new search technique for reducing background noise and improving the vertex reconstruction resolution. The template is used to scan through the data using the matched filter method, inspired by LIGO, looking for a low SNR neutrino signature and ultimately aiming to lower the detector's energy threshold at the analysis level. I will present the estimated sensitivity improvements to ARA analyses through the application of the template technique with results from simulation.

1. ASKARYAN RADIO ARRAY(ARA)



- Utilize the Askaryan effect to detect high energy neutrinos above10^{16}eV.
- The five autonomous stations have been deployed up to 200 m below the Antarctic surface.
- The vertically-polarized (VPol) and horizontally-polarized (HPol) are installed.

2. THE MATCHED FILTER METHOD – LOWERING ENERGY THRESHOLD



- The matched filter method using a neutrino template, inspired by LIGO, is designed to distinguish low signal-to-noise ratio (SNR) signals from the noise waveforms.
- ρ (t) is the weighted correlation value, which is a measure of the similarity between the hidden signal and the template in each lag time.

$$C(t) = 4\int_0^{\infty} \frac{D(f)T^*(f)}{P_n(f)}\,df$$

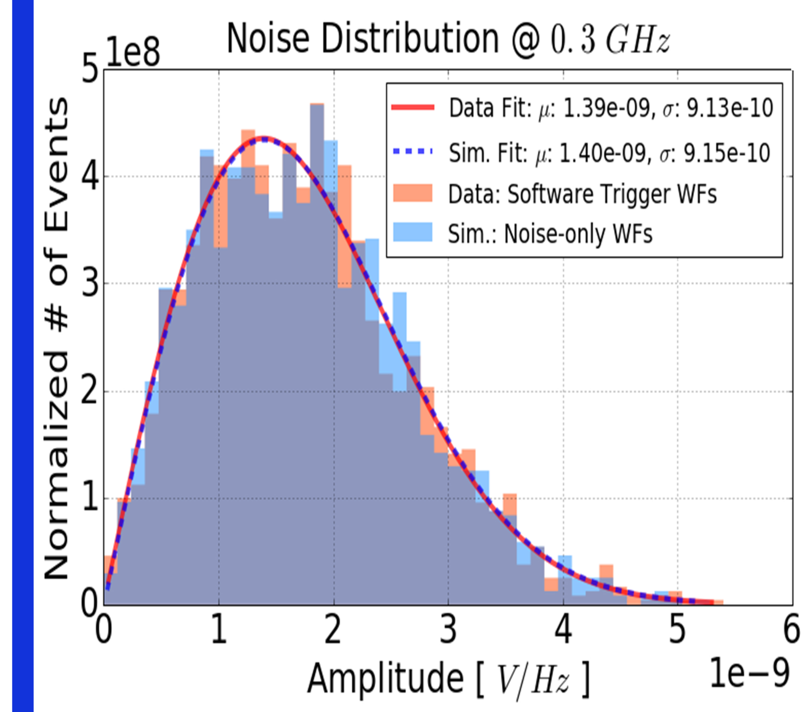
$$\sigma^2 = 4\int_0^{\infty} \frac{|T(f)|^2}{P_n(f)}\,df$$

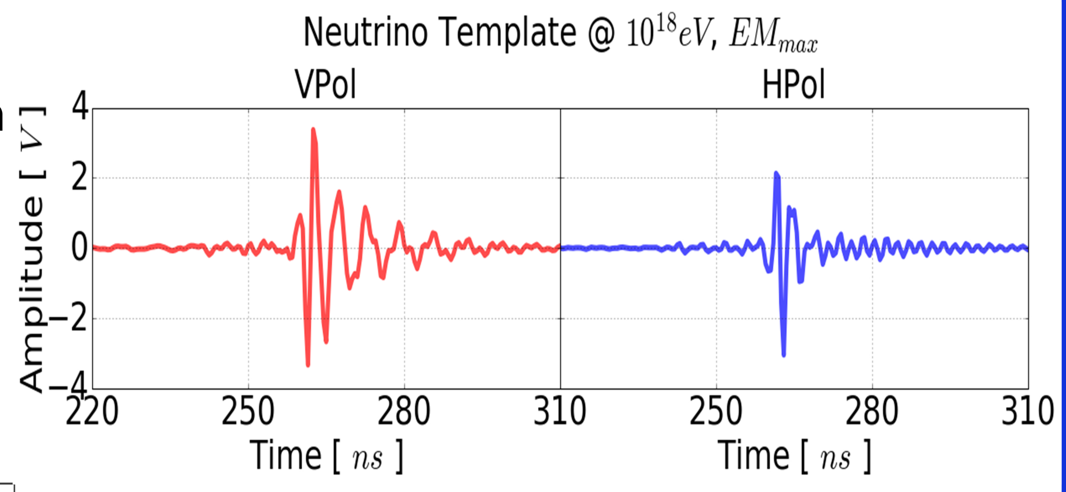
$$\rho(t) = \frac{|C(t)|}{\sigma}$$

3. SIMULATION

- The estimated thermal noise behavior including the detector response can be described by a Rayleigh fit, and implt-mented in the simulation.

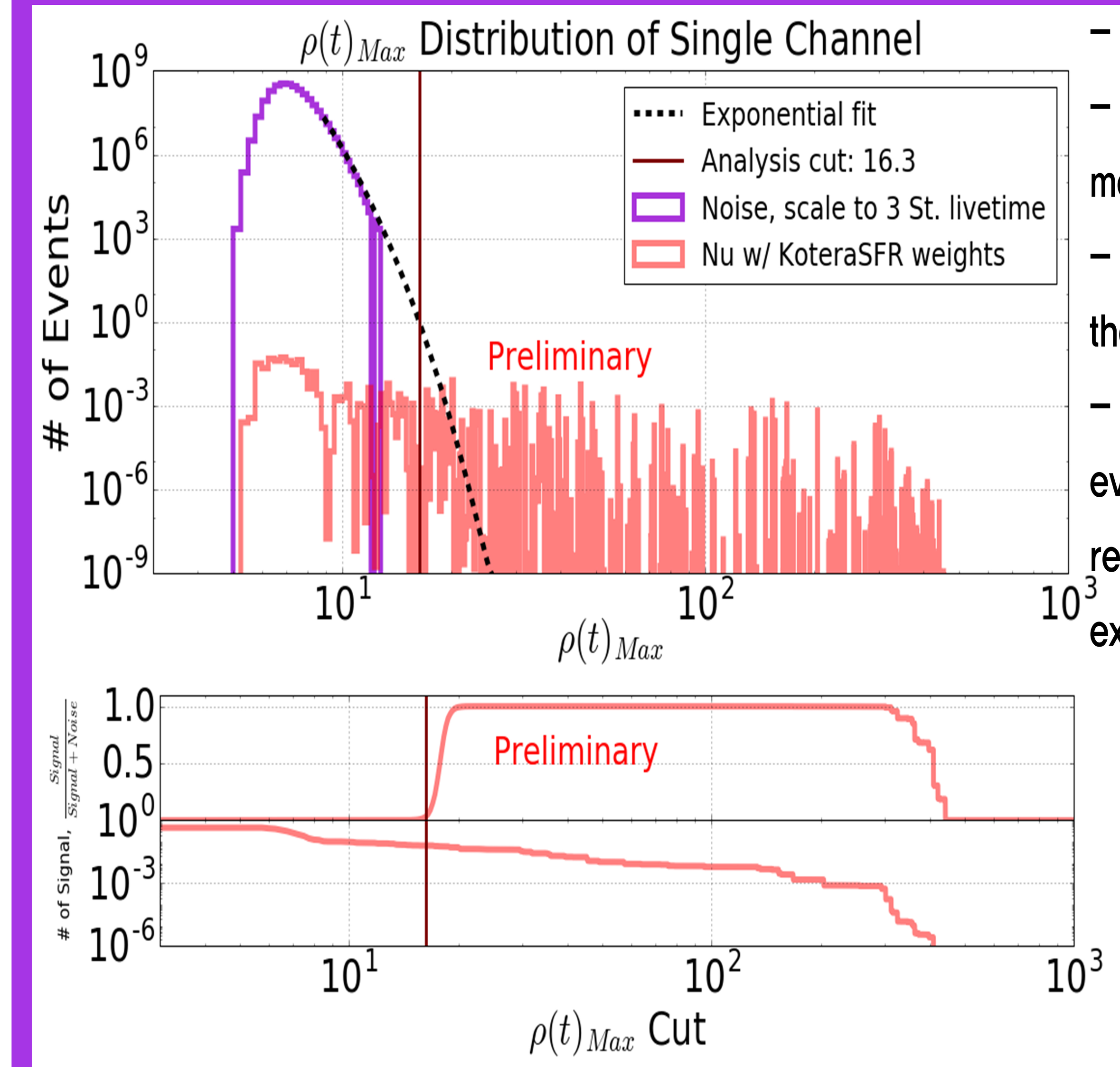
$$f(x;\alpha)_{freq} = \frac{x}{\alpha^2}e^{-x^2/(2\alpha^2)}$$





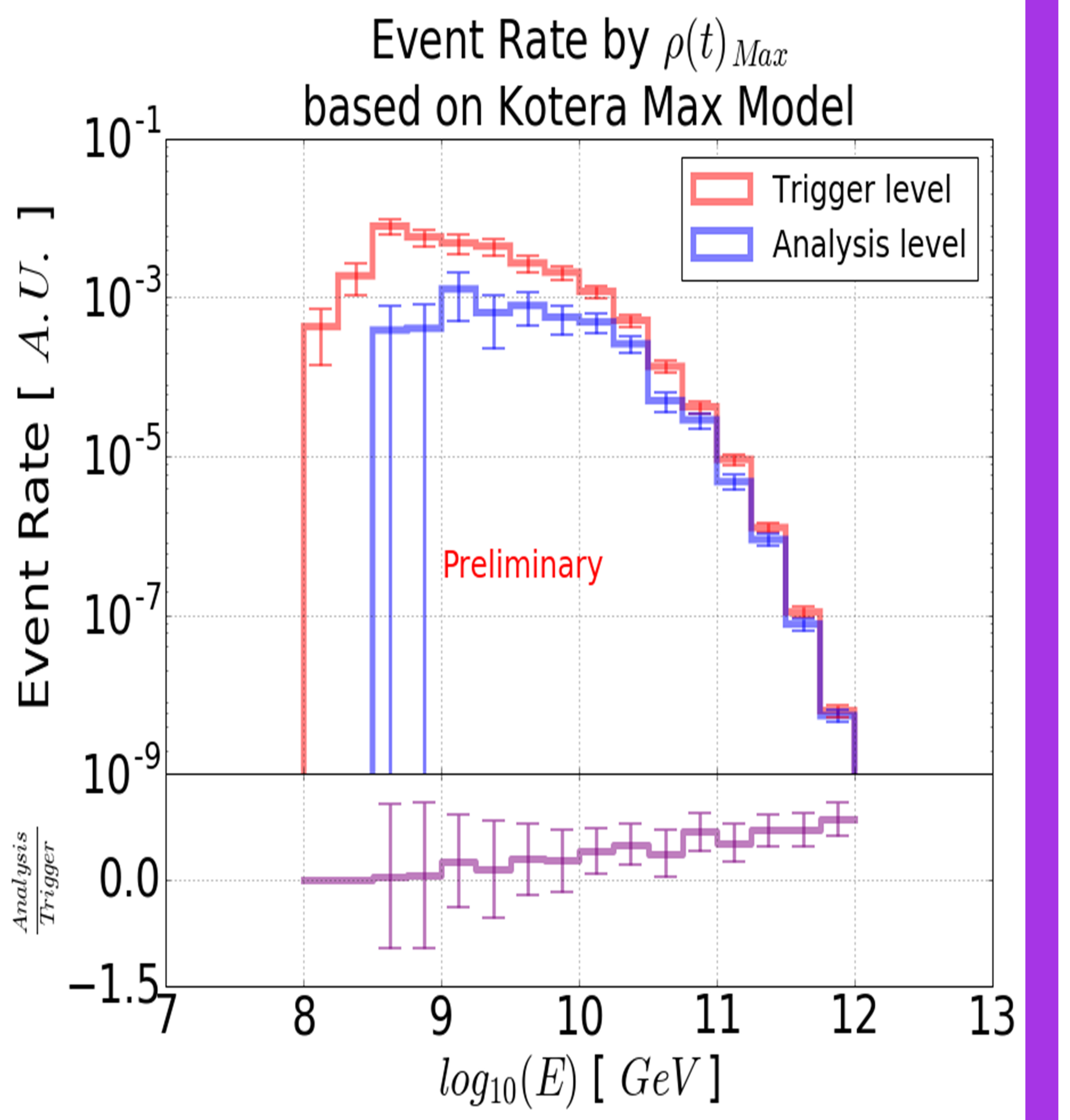
- The neutrino template in this proceeding is generated by AraSim.
- A zenith angle of 90 degrees, with maximal gain at all frequency range, is selected for this template.
- The electronic system is obtained by deconvolving the estimated in-ice noise from the in-situ noise spectrum calculated from a Rayleigh fit

4. ANALYSIS AND SUMMARY



- The analysis cut is set by the estimated three-station livetime
- The neutrino simulation is weighted by the Kotera neutrino flux model, and applied to the matched filter method
- If a minimum of three antennas pass the cut on ρ (t)max, then the event is a signal candidate.
- . In the future, the analysis cut value will be calculated at an event-wise level by adding up the results for ρ (t) from the individual antennas after removing the expected arrival time delay.

$$\rho_{sum}(t) = \sqrt{\frac{|C_1(t+\tau_1)+C_2(t+\tau_2)+\ldots+C_{16}(t+\tau_{16})|^2}{\sigma_1^2+\sigma_2^2+\ldots+\sigma_{16}^2}}$$



- The analysis level of the event rate is calculated by the cut parameters of individual antennas.
- The event rate based on different energies and the ratio of the analysis level to the trigger level.

SUMMARY

- The matched filter method gives a strategy to search for low-SNR signal in a radio detector.
- So, the understanding of the detector responses in the noise background will be crucial.
- The event-wise ρ (t)max, obtained by increasing the number of templates including double-pulse signals and vertex reconstruction will be implemented in the future.

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