New Measurement of the Flavor Composition of High-Energy Neutrino Events with Contained Vertices in IceCube

Juliana Stachurska
for the IceCube Collaboration

INTRODUCTION

- Expect ~ 1/3 of the astrophysical neutrino flux to be ν_τ, but no ν_τ interaction identified with IceCube yet [1, 2]
- ν_τ CC interactions may be identified via double cascade event topology [3] at a deposited energy $\gtrsim 100$ TeV
- We perform a search of ν_τ CC interactions by reconstructing events with a double cascade hypothesis
- We perform a flavor composition measurement using the IceCube High-Energy Starting Event (HESE) sample with 7.5 years of data [4]
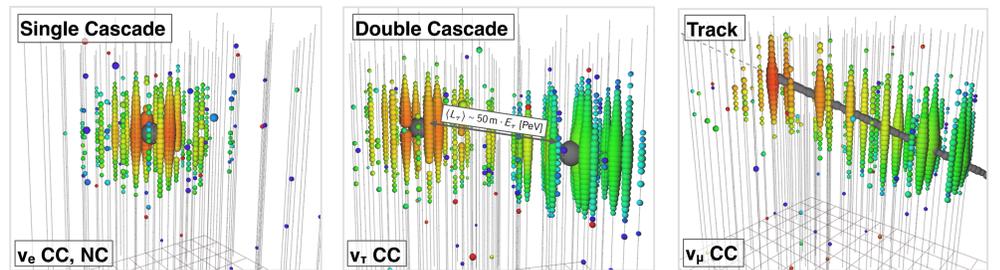

Figure 1 Simulated event topologies.

SEARCH FOR TAU NEUTRINOS IN A NUTSHELL

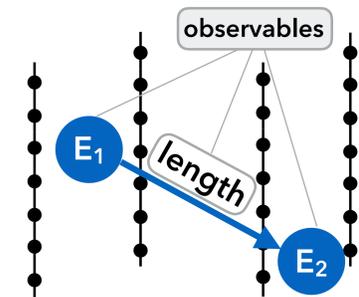**Re-analysis of IceCube HESE data** [2]

Figure 2 Observables of the double cascade hypothesis.

- 7.5 years of data; updated ice model, re-calibrated data and optimized reconstruction software
- Ternary topology Identifier (ID): single cascades, double cascades, tracks
- Events in double cascade subsample have:
  reconstructed length of $L \geq 10$m
  energy asymmetry
  $-0.98 \leq (E_1 - E_2)/(E_1 + E_2) \leq 0.3$
  energy confinement $(E_1 - E_2)/E_{\text{tot}} \geq 0.99$
- Events with a deposited energy > 60 TeV from all three topology subsamples used in a binned likelihood fit of the astrophysical flavor composition measurement
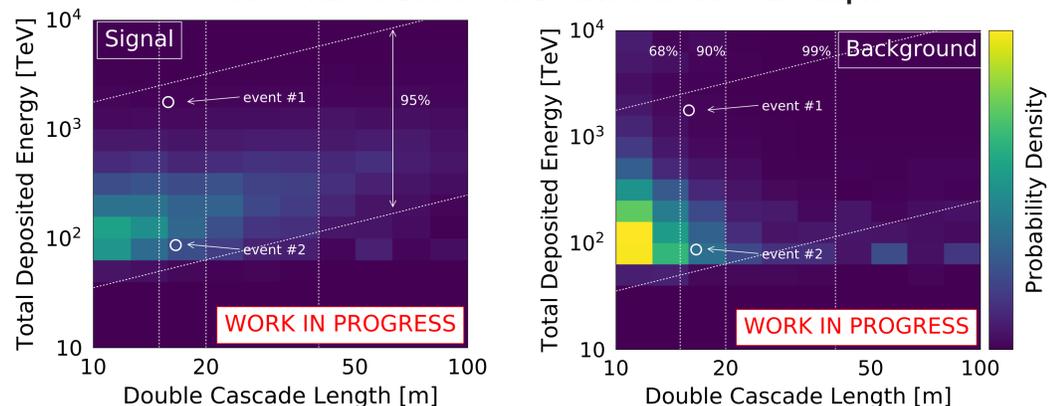
Observable PDFs of the Double Cascade Subsample

Figure 3 Double cascade observables histograms showing total deposited energy against reconstructed length for the double cascade sample. Signal (ν_τ-induced double cascade events) histogram (*left*). Background (all remaining events) histogram (*right*). The two tau-neutrino candidate events are overlaid as white circles (see below).

MEASURED FLAVOR COMPOSITION

- Observed 2 events in double cascade subsample
- Expected ~2.1 events (~1.4 signal + ~0.7 background)
- Best fit flavor composition: $\nu_e : \nu_\mu : \nu_\tau = 0.35 : 0.45 : 0.20$ but zero ν_τ flux cannot be excluded
- Observed flavor composition consistent with previous measurements and expectation of ~ 1 : 1 : 1 for astrophysical neutrinos.
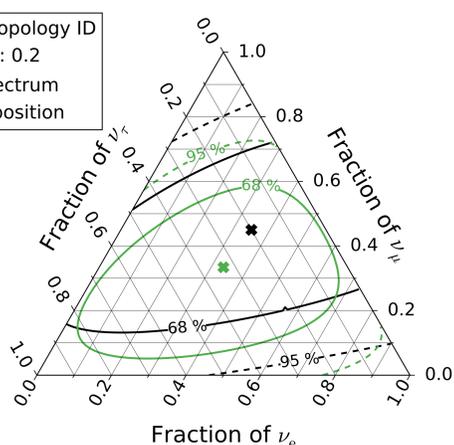

Figure 4 Measured flavor composition of IceCube HESE events with ternary topologyID and sensitivity at the best fit spectrum. Contours obtained using Wilks' theorem.
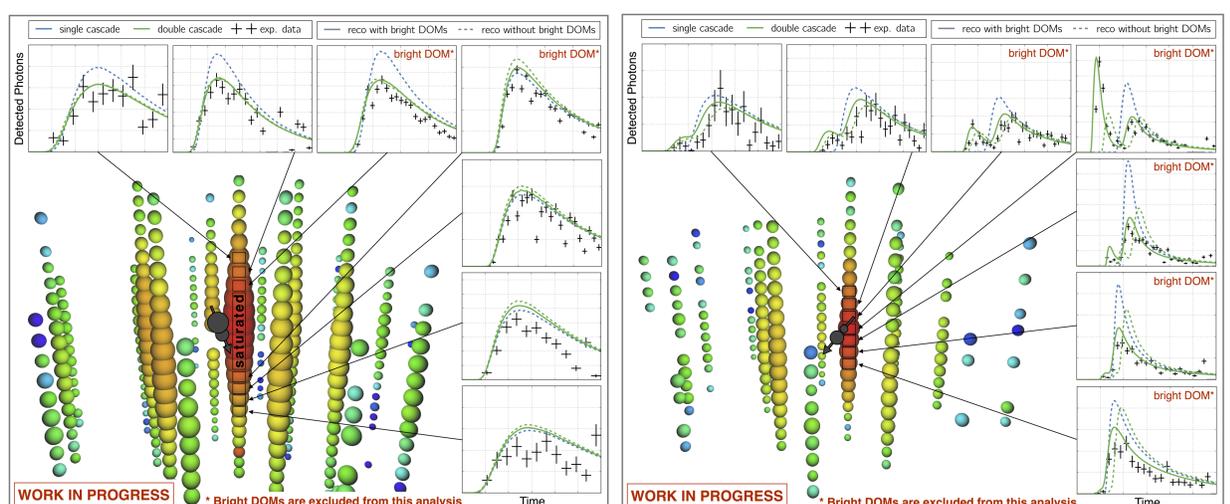
THE SELECTED DOUBLE CASCADE EVENTS

Figure 5 Double cascade events: Event#1 (2012, *left*), Event#2 (2014, *right*). The reconstructed double cascade positions are indicated as grey circles, the direction indicated with a grey arrow. The size of the circles illustrates the relative deposited energy of the two cascades.

Event#1:
- Shows no clear preference between a single cascade and a double cascade hypothesis
- Best-fit values: $L = 16$ m, $E_1 = 1.2$ PeV, $E_2 = 0.6$ PeV, $(E_1 - E_2)/(E_1 + E_2) = 0.29$

Event#2:
- The observed light arrival time pattern clearly favors the double cascade hypothesis
- Best-fit values: $L = 17$ m, $E_1 = 9$ TeV, $E_2 = 80$ TeV, $(E_1 - E_2)/(E_1 + E_2) = -0.80$

CONCLUSIONS AND OUTLOOK

- Two tau-neutrino candidate events identified in dedicated search for astrophysical ν_τ interactions
- One of the two events is an unambiguous double-cascade
- It is being further evaluated for possible backgrounds
- Complementary "double pulse" analyses are in preparation [5]

REFERENCES

[1] **IceCube** Collaboration, M. G. Aartsen et al., Phys. Rev. **D93** (2016) 022001.

[2] **IceCube** Collaboration PoS(ICRC2017)974 .

[3] J. G. Learned and S. Pakvasa, Astropart. Phys. **3** (1995) 267–274.

[4] **IceCube** Collaboration, Neutrino 2018, 292 (this conference).

[5] **IceCube** Collaboration, Neutrino 2018, 343 (this conference).