



# Event Selections in IceCube

# Outline

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**1. Motivation**

**2. Techniques**

**3. Examples in IceCube**

## COSMIC MESSENGERS

EVERY YEAR,  
**ICECUBE**  
DETECTS ABOUT...

**10** ASTROPHYSICAL NEUTRINOS

Neutrinos are excellent messengers. They are neutral particles that rarely interact with matter and point back to their sources.

**100** THOUSAND ATMOSPHERIC NEUTRINOS

Cosmic rays are charged particles whose paths are bent by magnetic fields. Cosmic ray interactions in the atmosphere produce neutrinos and muons.

**100** BILLION ATMOSPHERIC MUONS



Matter

Gamma Ray

ICECUBE



# Types of events

- Atmospheric muons
- Atmospheric neutrinos
- Astrophysical neutrinos
- Cascades
- Tracks

Different analyses care about different types of events. Many techniques are used to curate pure samples of a given event type for different analyses.



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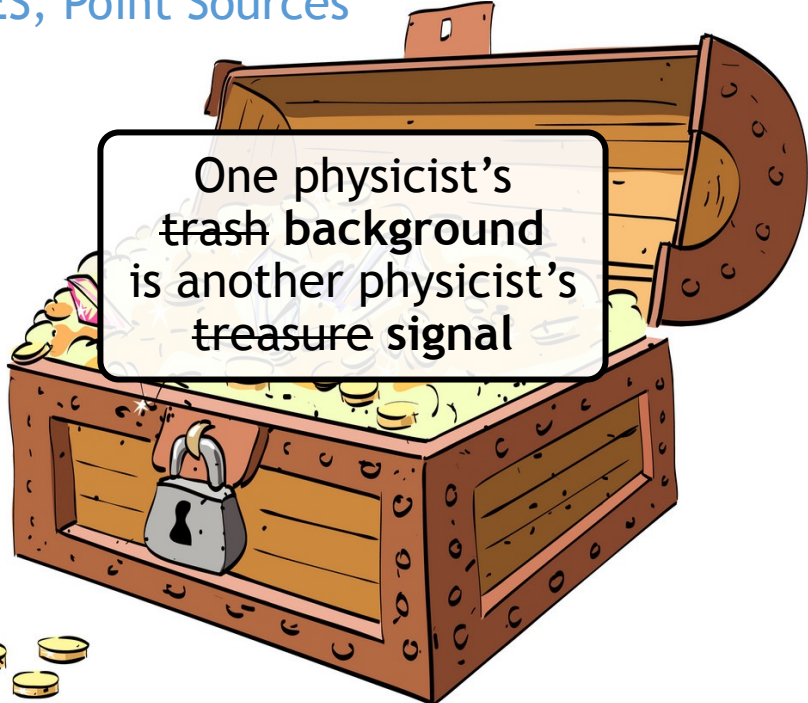
Black Hole

Matter

Gamma Ray

ICECUBE

- Atmospheric muons → Cosmic ray WG
- Atmospheric neutrinos → Oscillations, Diffuse
- Astrophysical neutrinos → Diffuse spectrum
- Cascades → HESE, DNN cascades
- Tracks → ESTES, Point Sources



One physicist's trash background is another physicist's treasure signal

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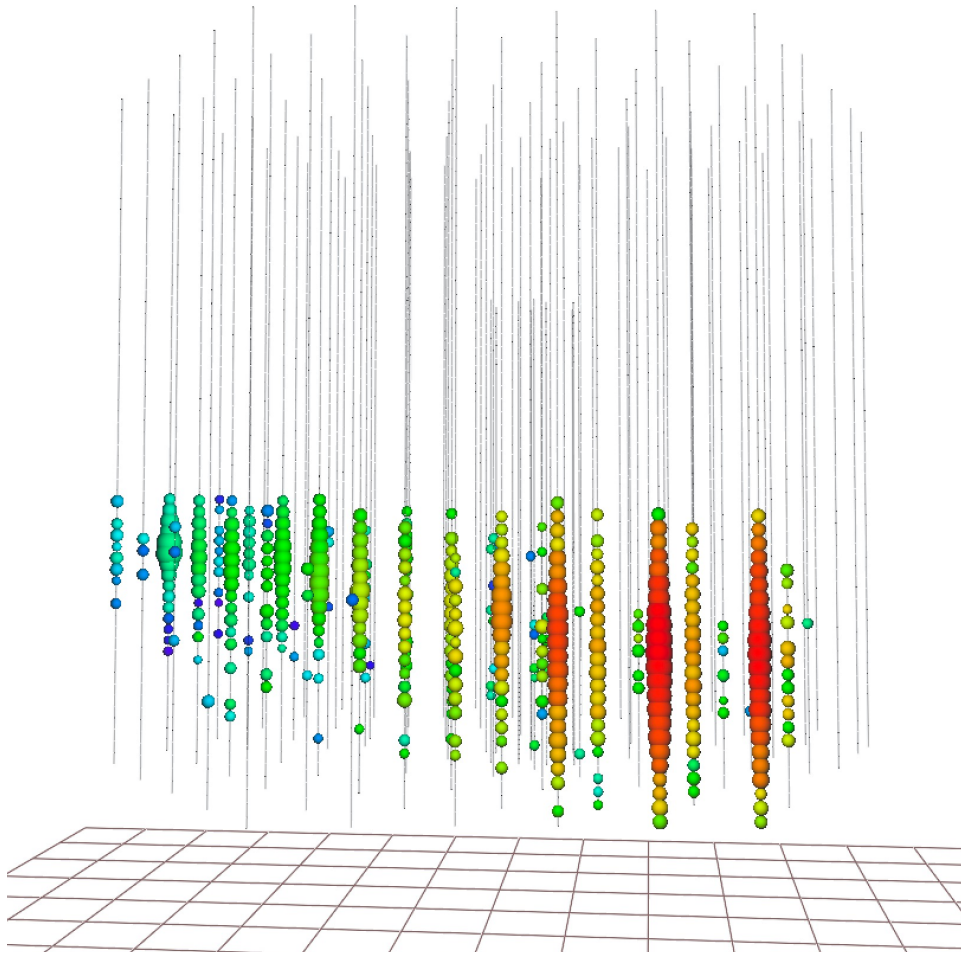
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# IceCube Events

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Start with:

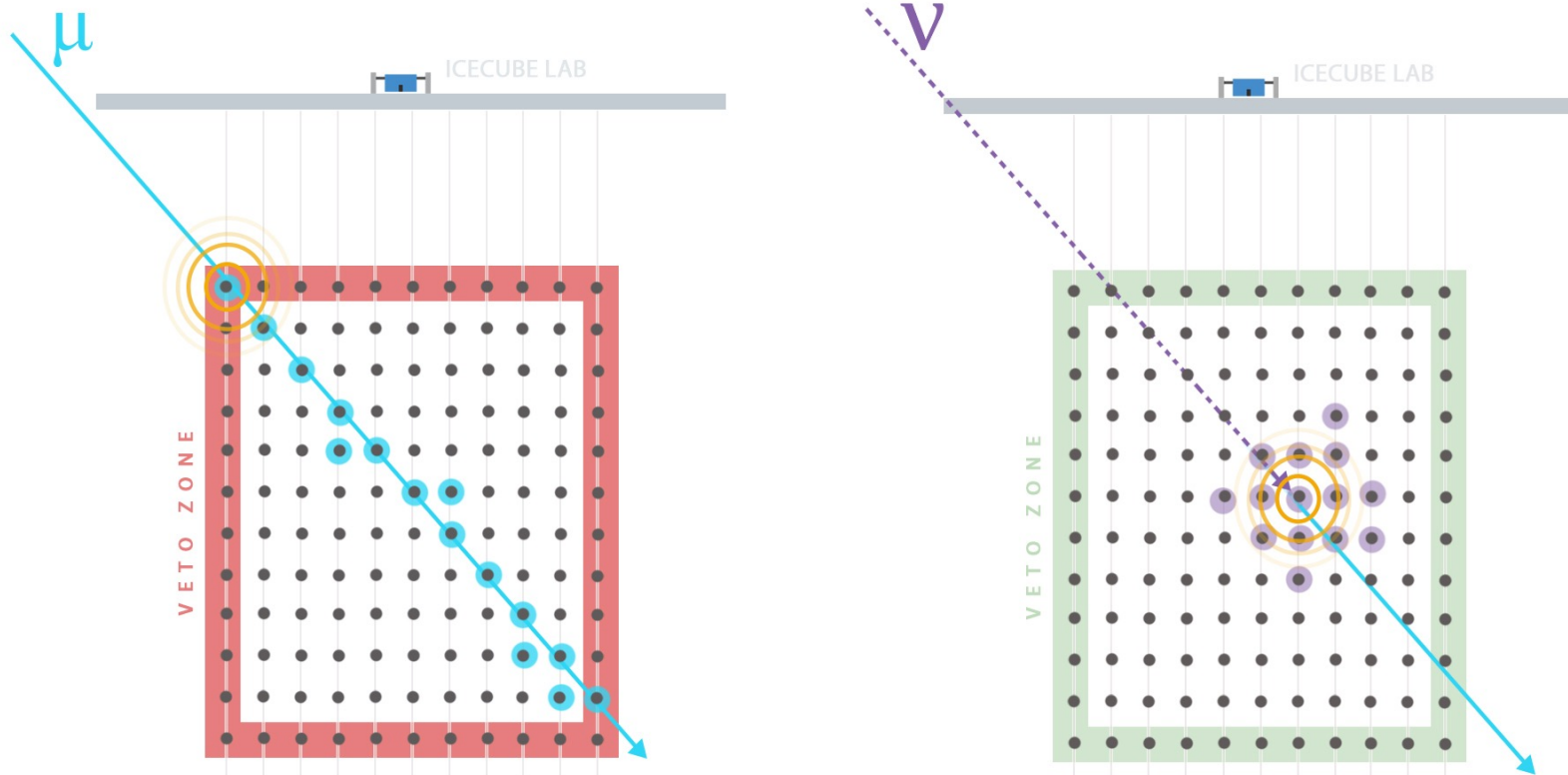
- Charge
- Time

for every DOM in detector

We want to determine what type of events they are before sophisticated reconstructions become computationally feasible

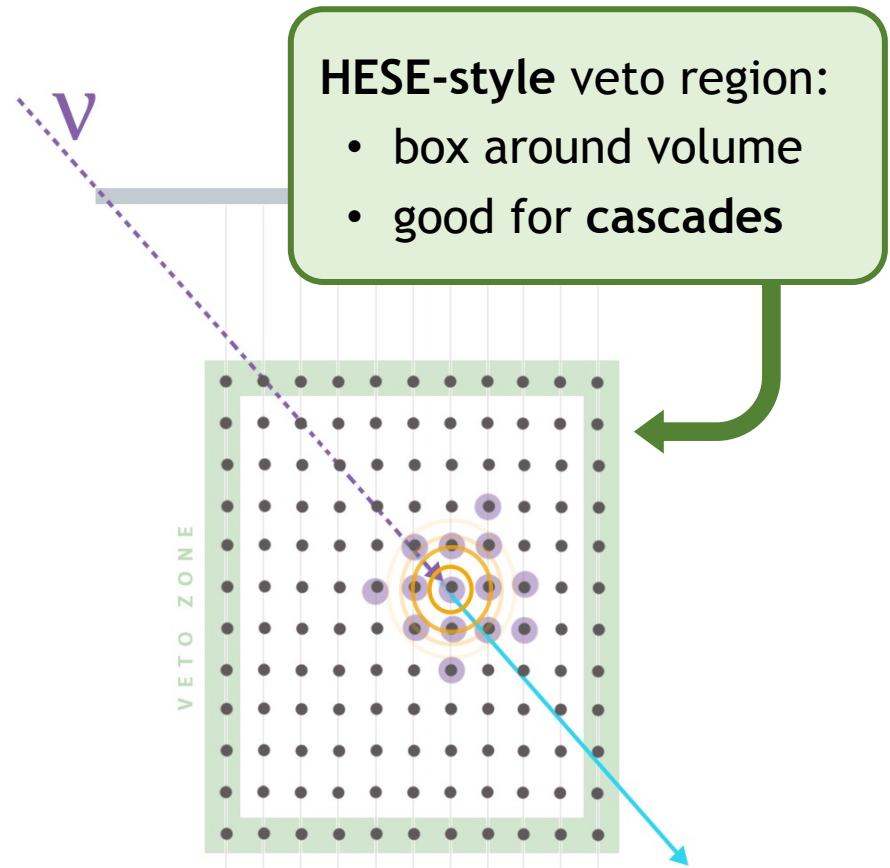
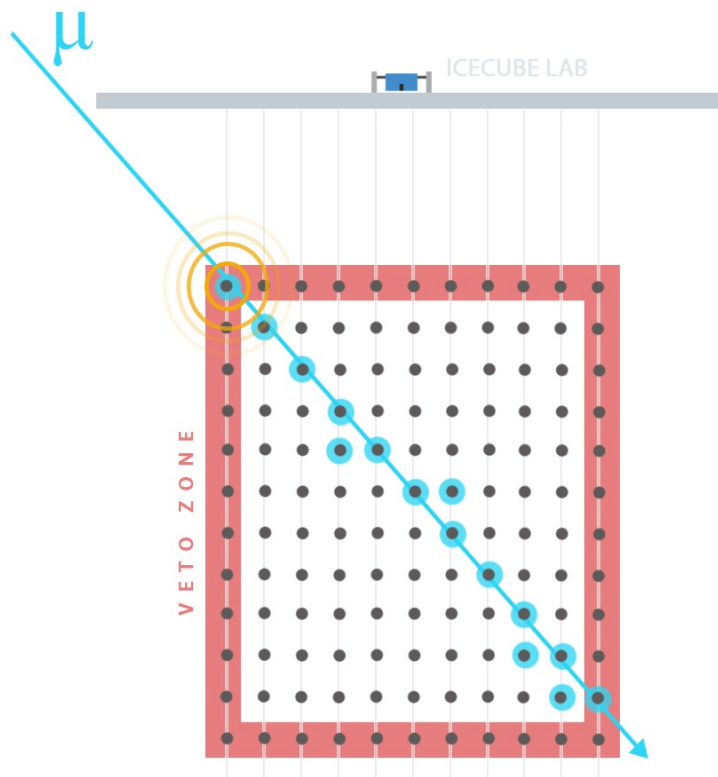
# Muon vs. Neutrinos: Veto Regions

- Muons leave light along their whole path
- We can identify neutrinos by looking for events that start inside the detector (“Starting Events”)



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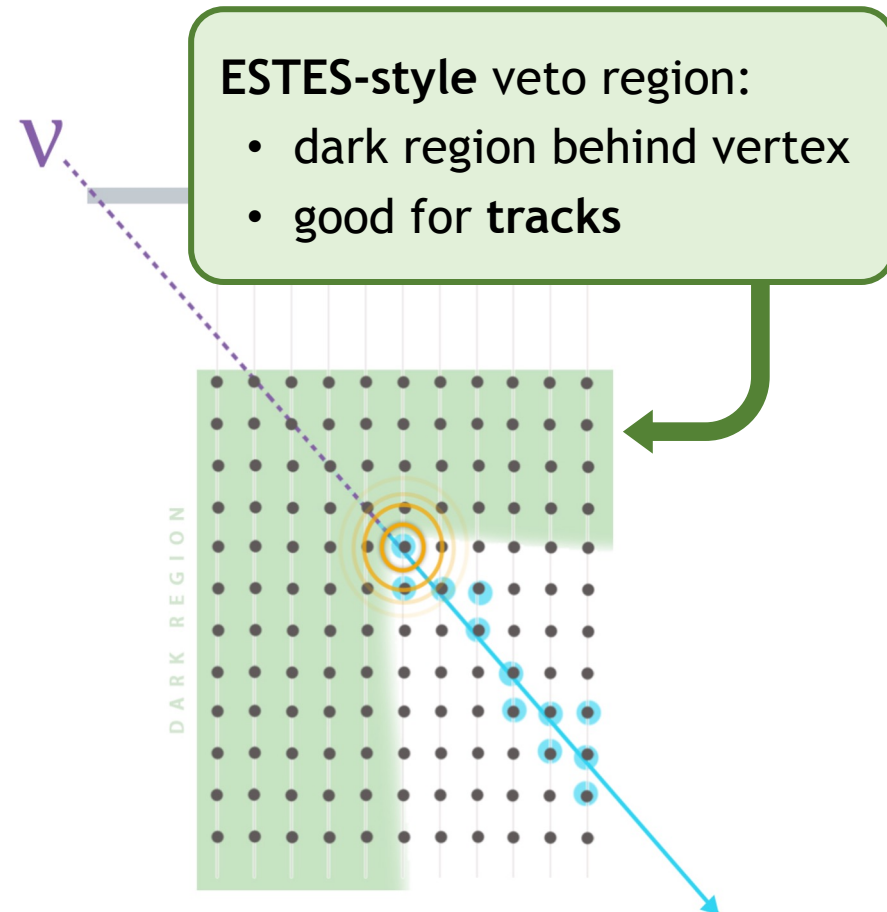
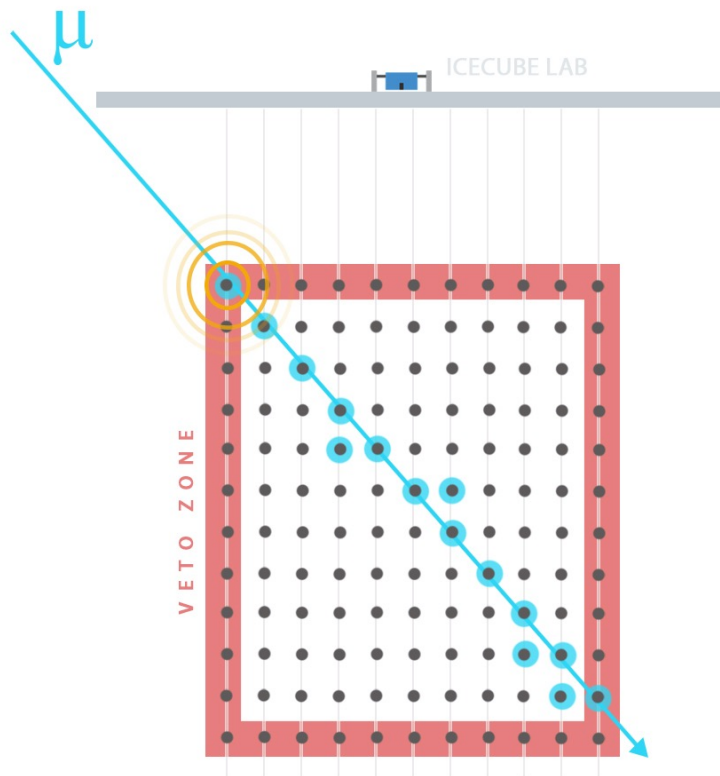
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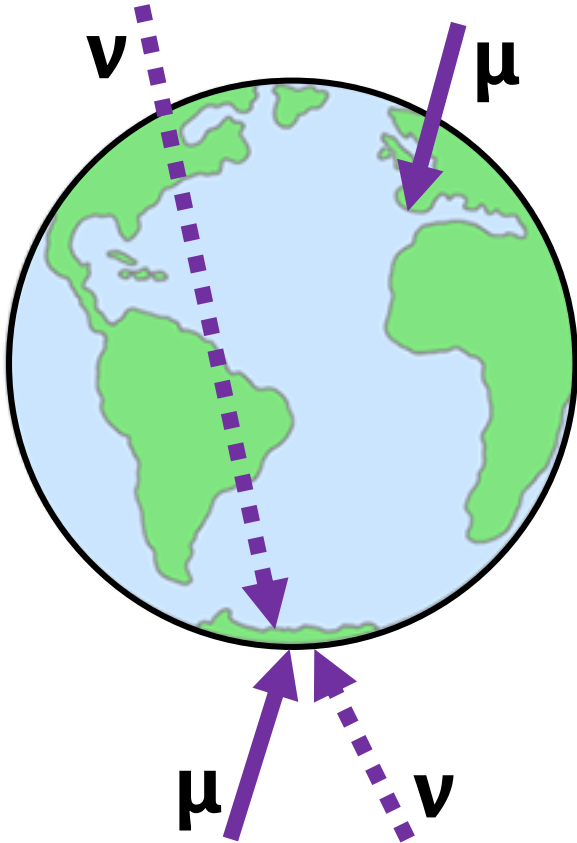
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# Muon vs. Neutrinos: Zenith

When looking at the northern sky, muons are blocked and only neutrinos reach IceCube

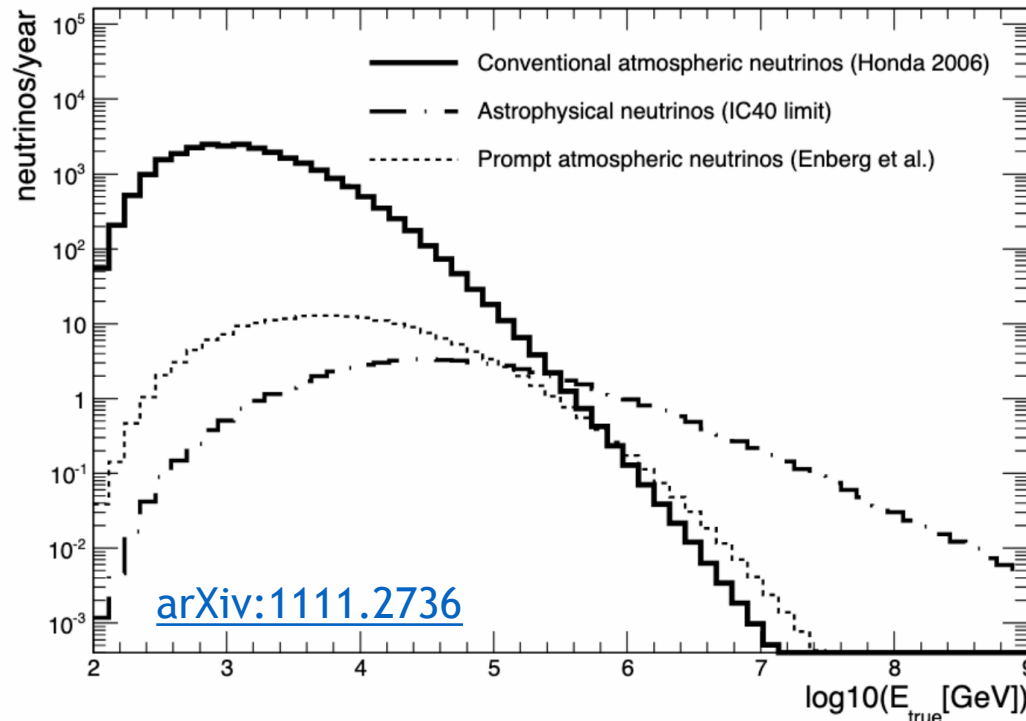


Looking at Northern sky  
(and cutting out Southern sky)  
allows one to eliminate  
virtually all muons from sample

When looking at the southern sky, muons and neutrinos can reach IceCube

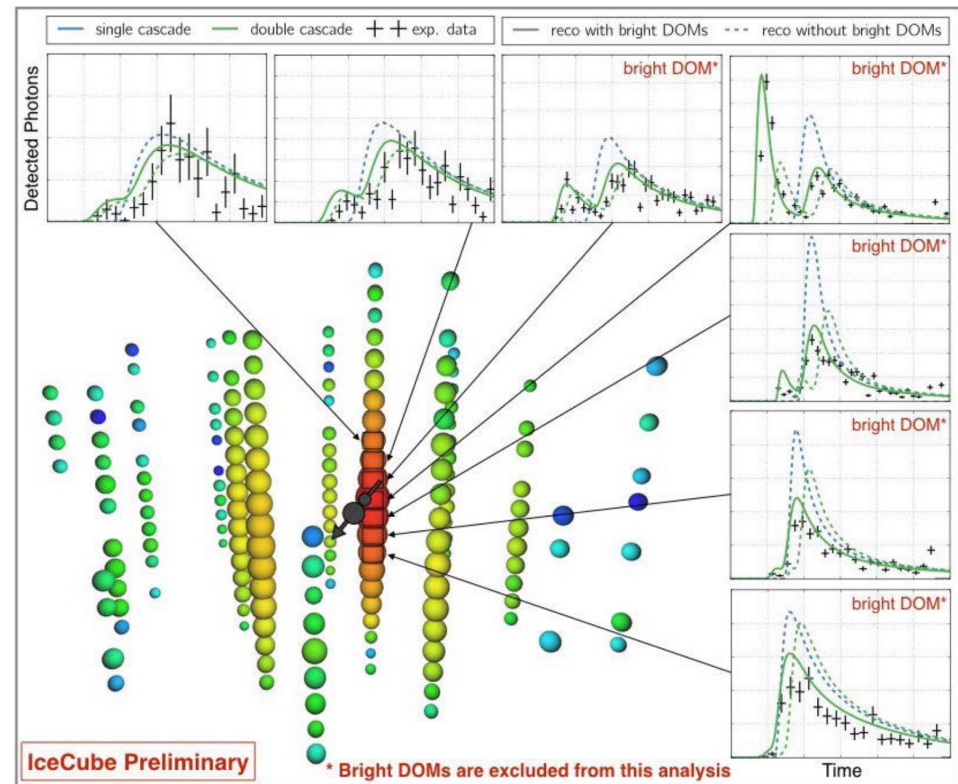
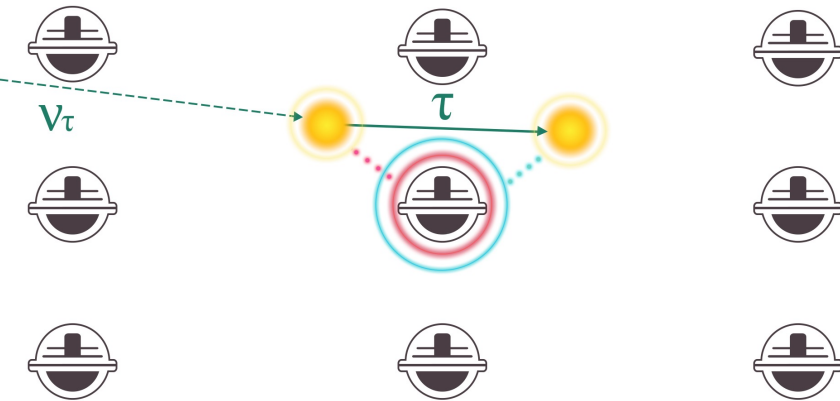
# Atmospheric vs. Astrophysical: Energy

- Looking at individual events, we can't tell if a given neutrino is from astrophysical or atmospheric origin
- To get a very pure astrophysical sample, you have to go up to very high energies



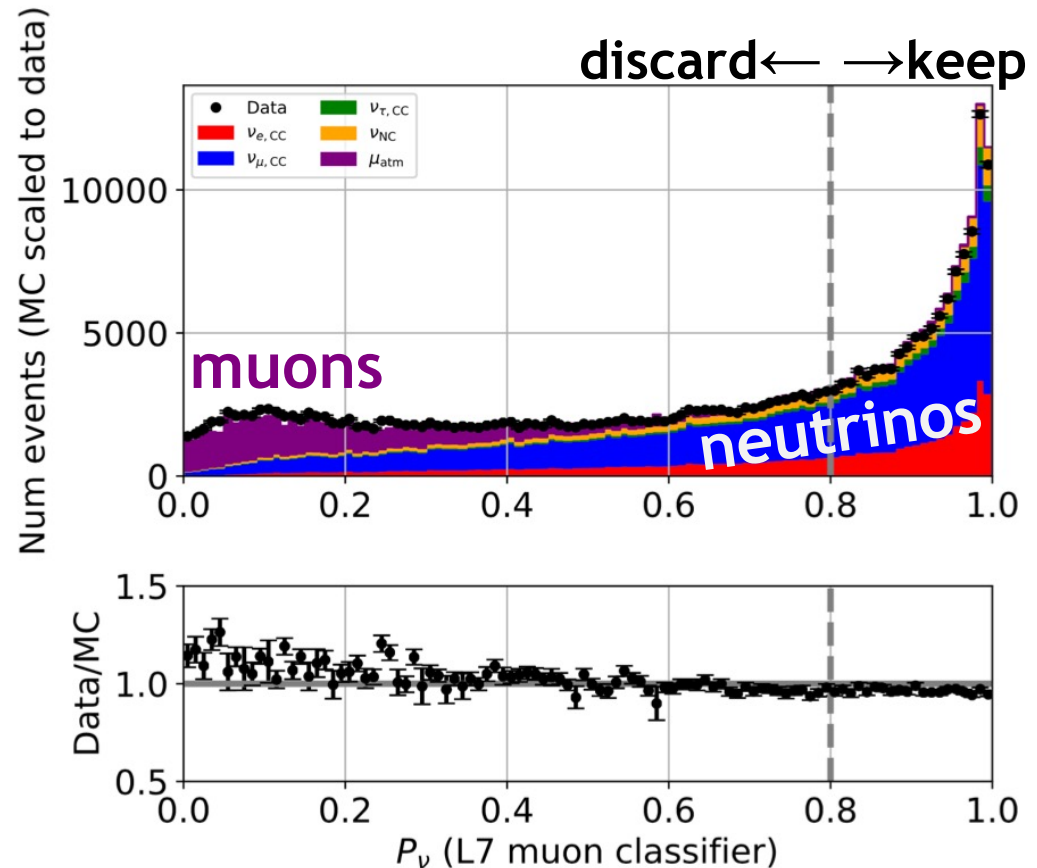
# Atmospheric vs. Astrophysical: Flavor

- Tau neutrinos produce a “double pulse” or “double bang” signature
- Not produced in atmosphere  $\Rightarrow$  if seen (at high energies), must be astrophysical
- Event selection looks at waveforms on individual DOMs



# Machine Learning Classifiers

- BDTs and Neural Networks can be trained to differentiate between event types
- Example from OscNext:  
Returns output from 0 to 1 indicating how muon-like or neutrino-like an event is





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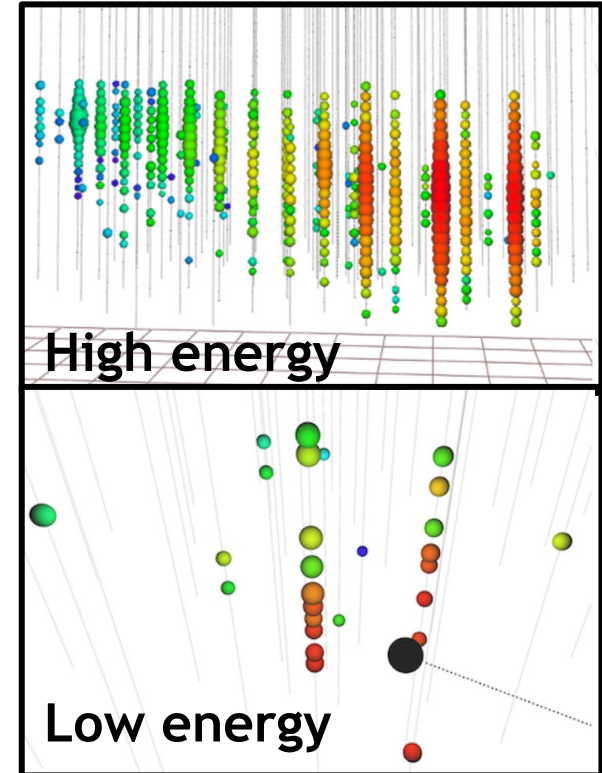
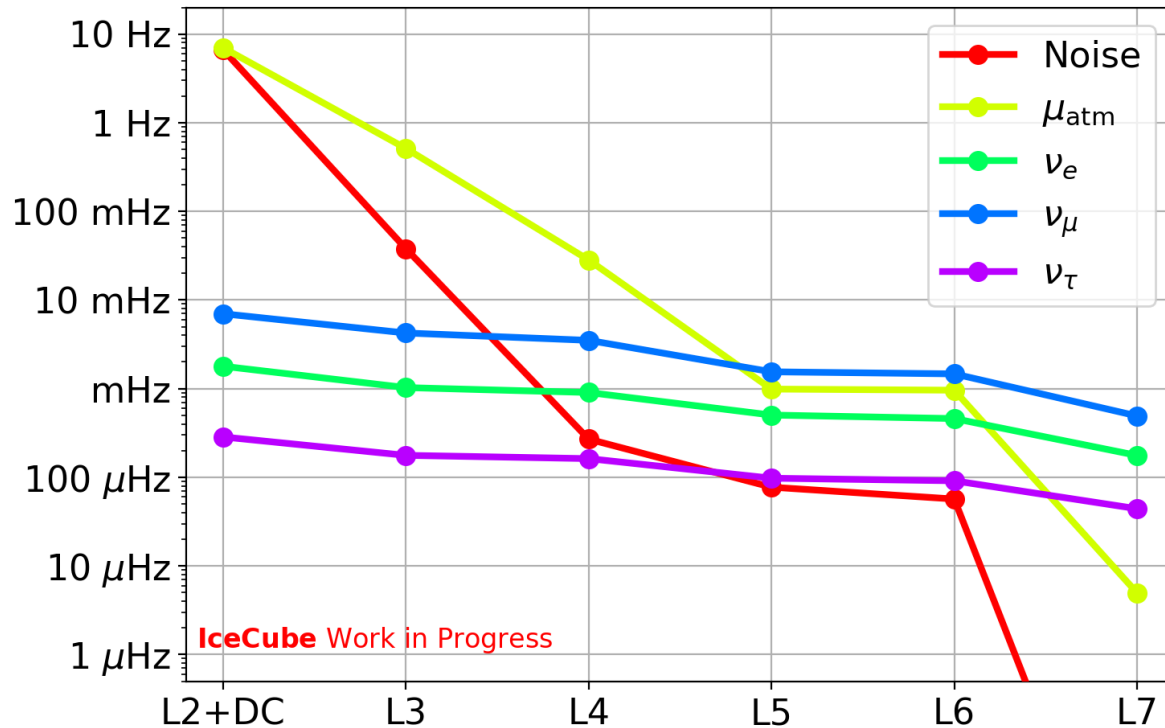
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# Case Study: OscNext

- In practice, it takes many levels of selection and types of rejection to great a sample that is ready for analyses



**Filtering**  
(see talk by Erik Blaufuss)

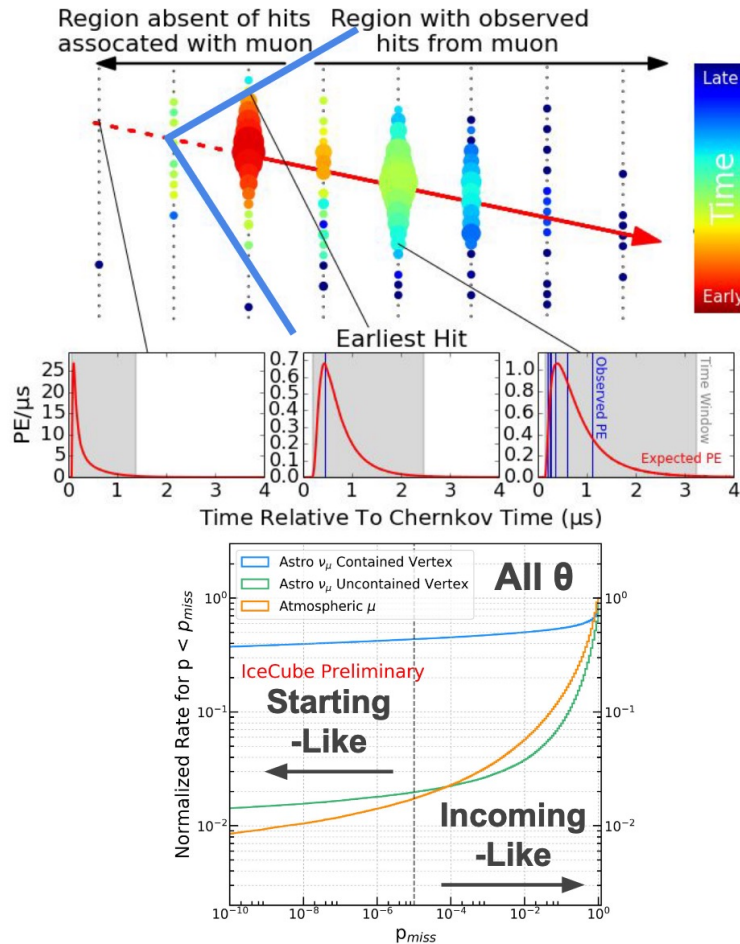
**Veto based cuts**

**ML classifier**

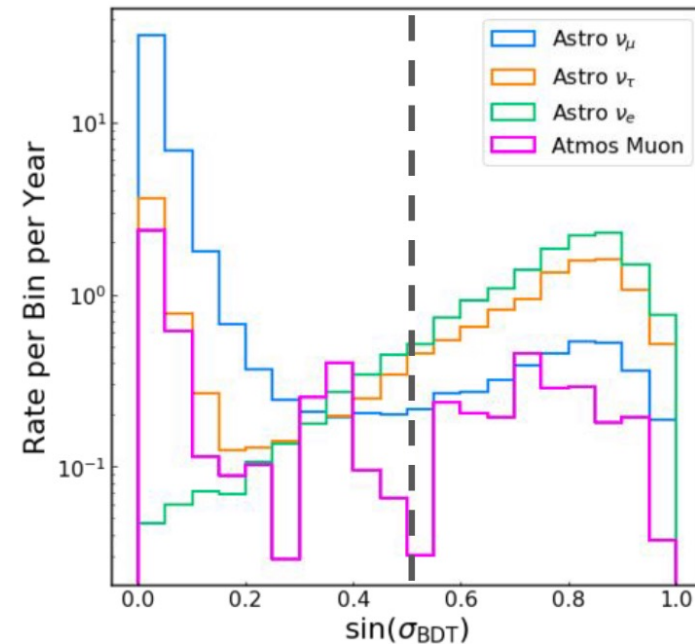
**Reconstruction**  
(see talk by Tianlu Yuan)

# Case Study: ESTES

Custom variable for probability of an event starting in the detector



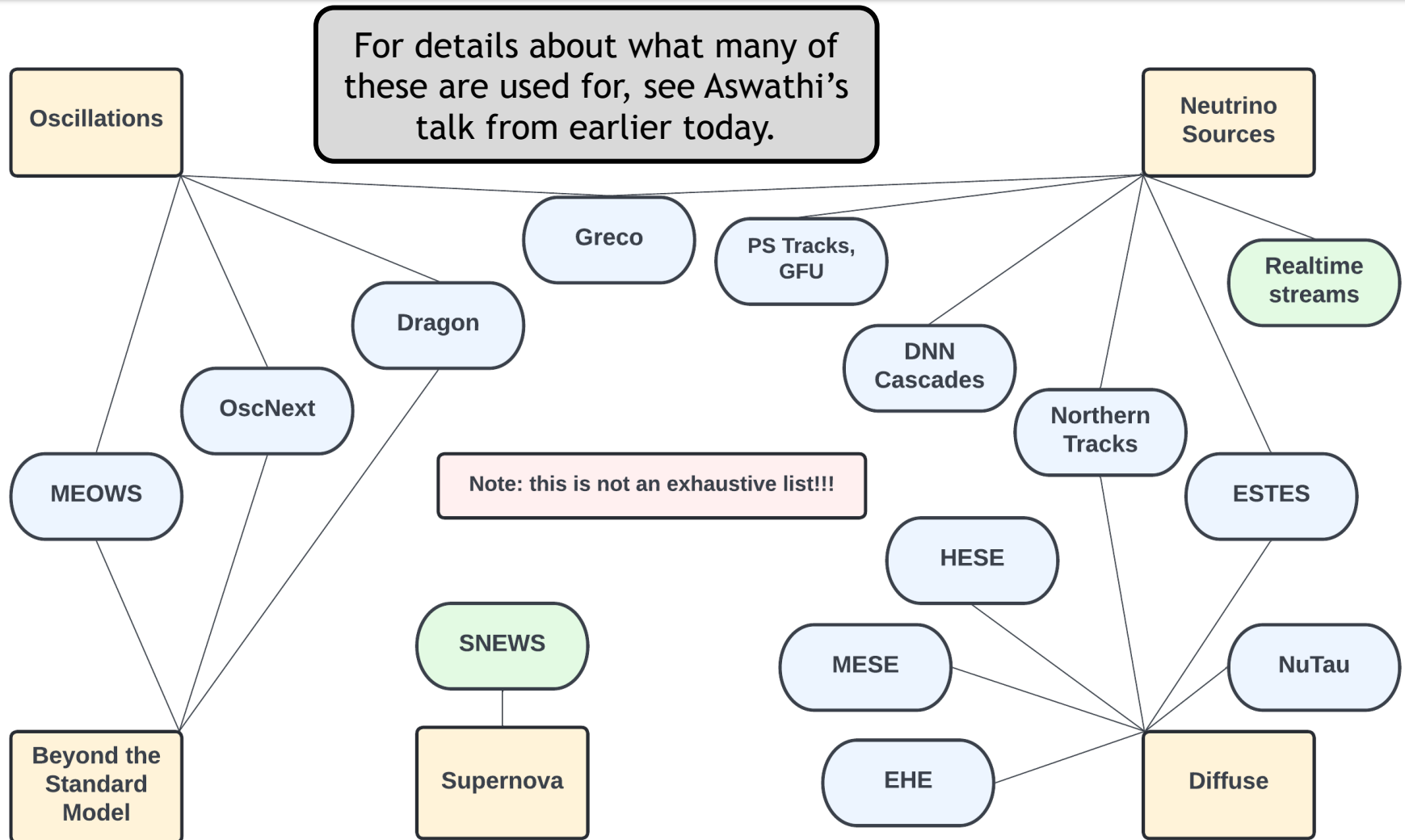
Boosted Decision Tree (BDT)



Applied only to NS data sample

Cut out events with large angular errors

# Event Selections in IceCube



# Summary

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- To select for different event types, you need to identify and exploit any differences in the event types
  - Morphology
  - Population distribution (energy or zenith)
  - Population composition (flavor)
- Most event selections rely on a combination of multiple cut types
- Event selections are often designed with a specific analysis in mind, but end up being used for many analyses