EVENT SELECTIONS IN ICECUBE

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Bootcamp 2020

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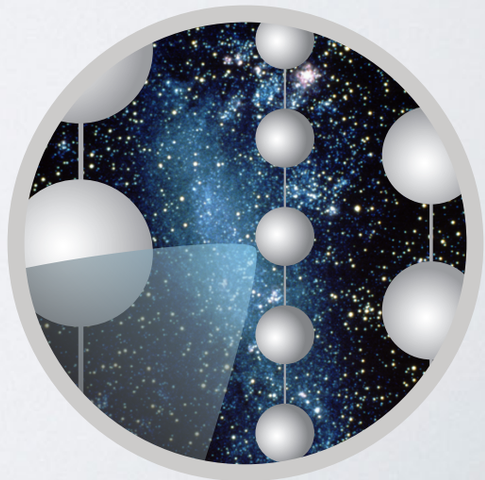
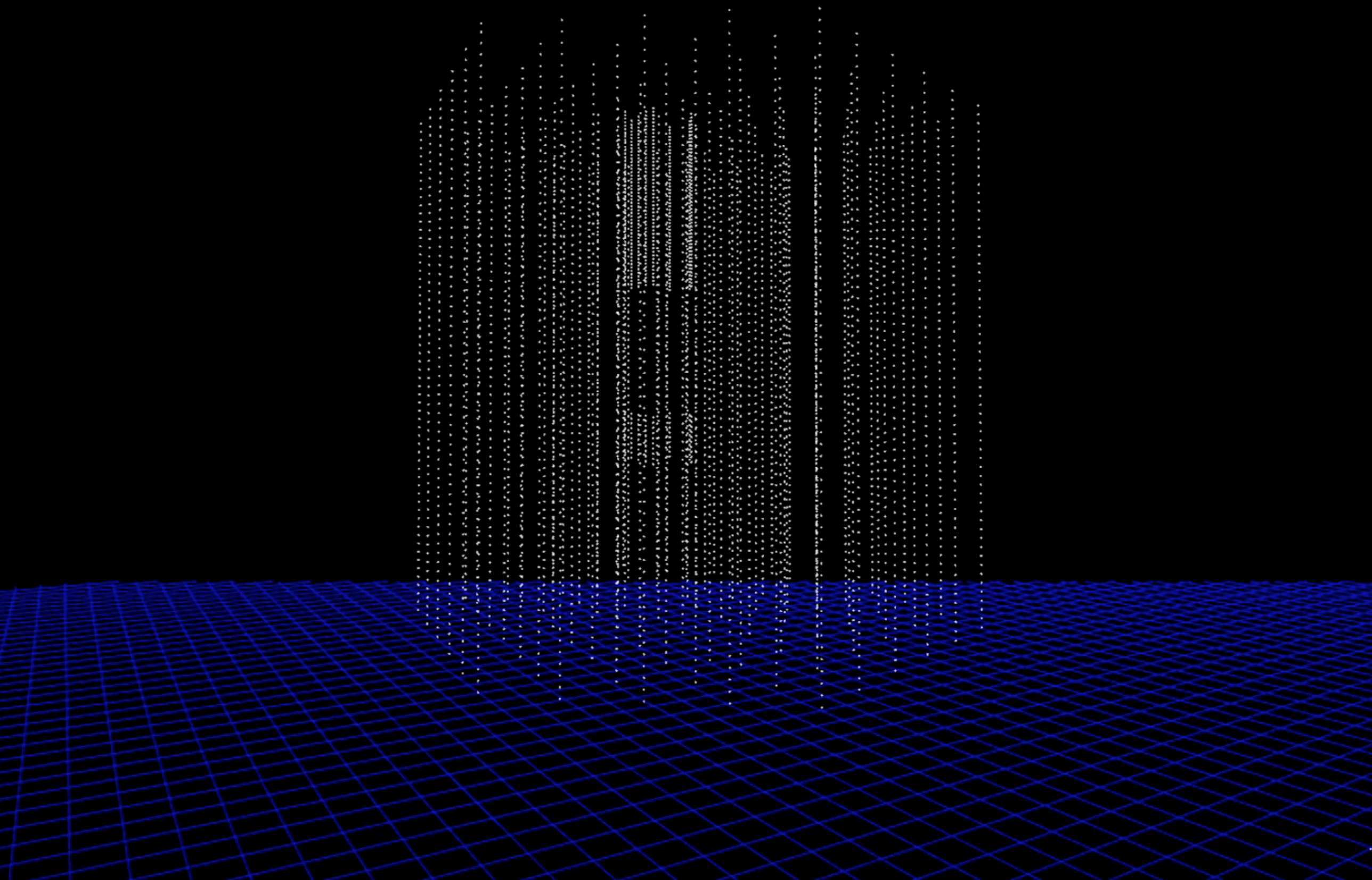
WISCONSIN

UNIVERSITY OF WISCONSIN–MADISON

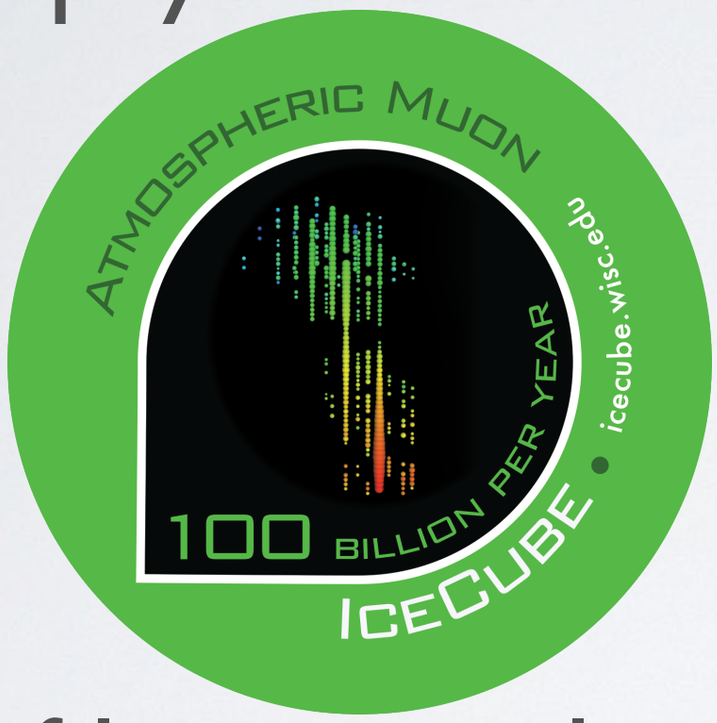


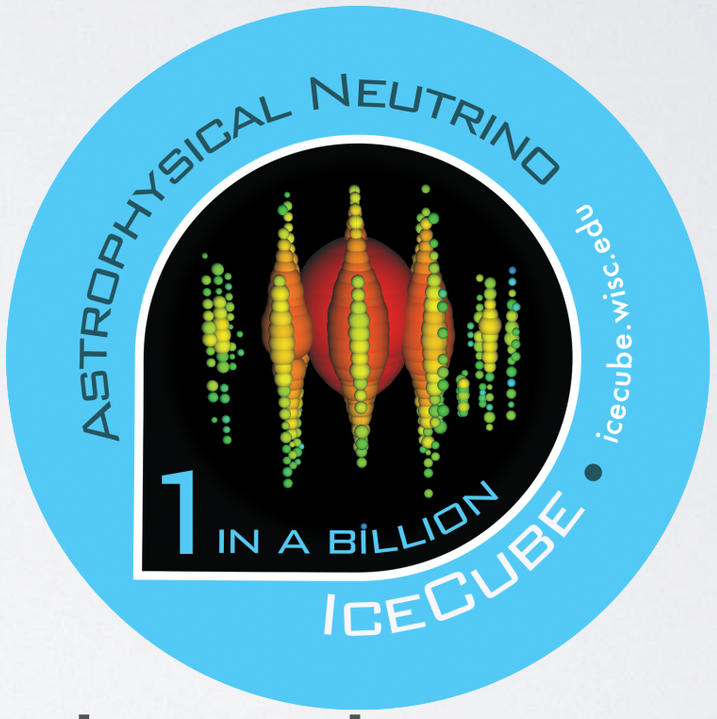
ICECUBE



INTRODUCTION

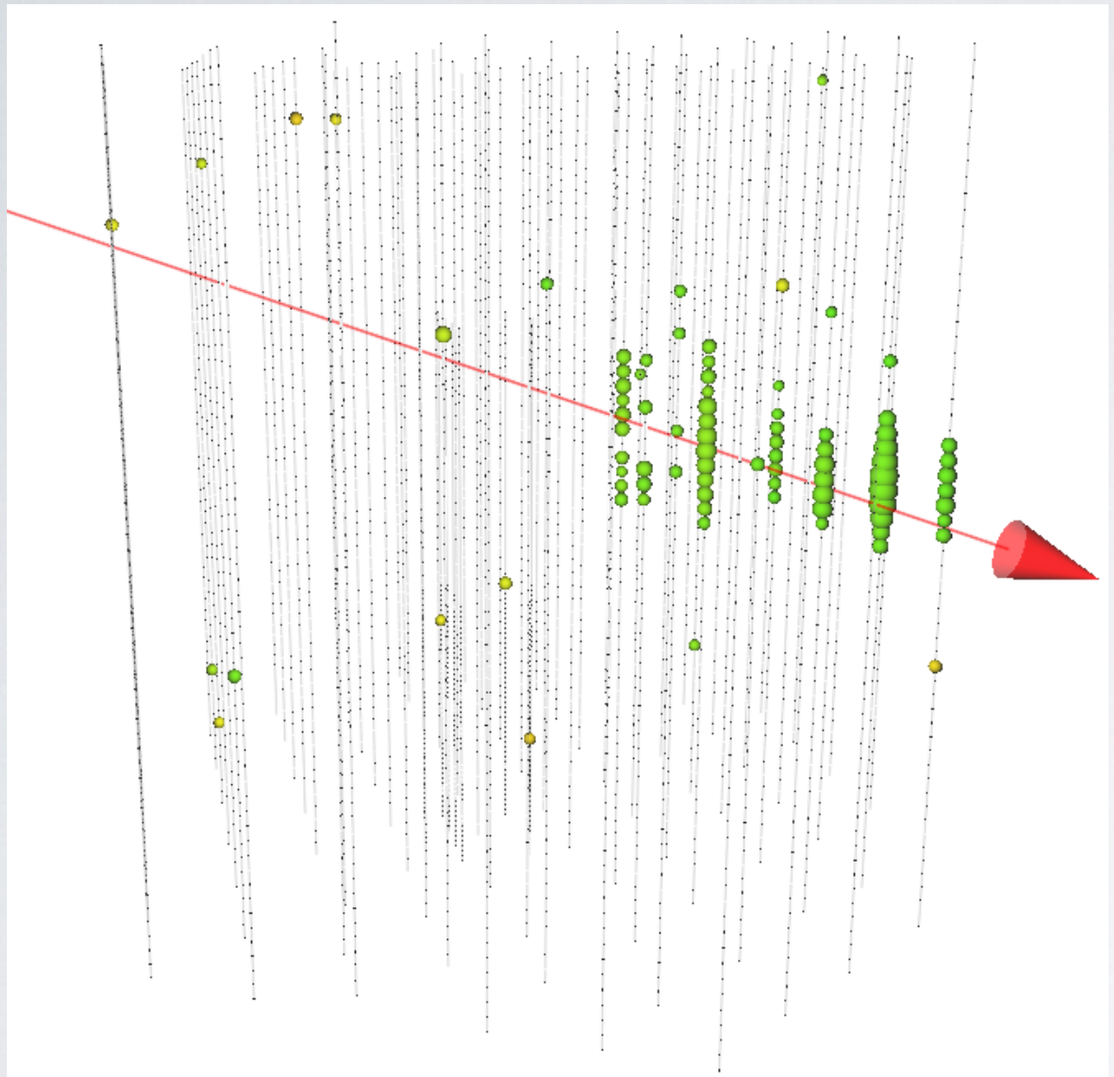
- IceCube records data continuously, for every billion muons, we only record a single astrophysical neutrino

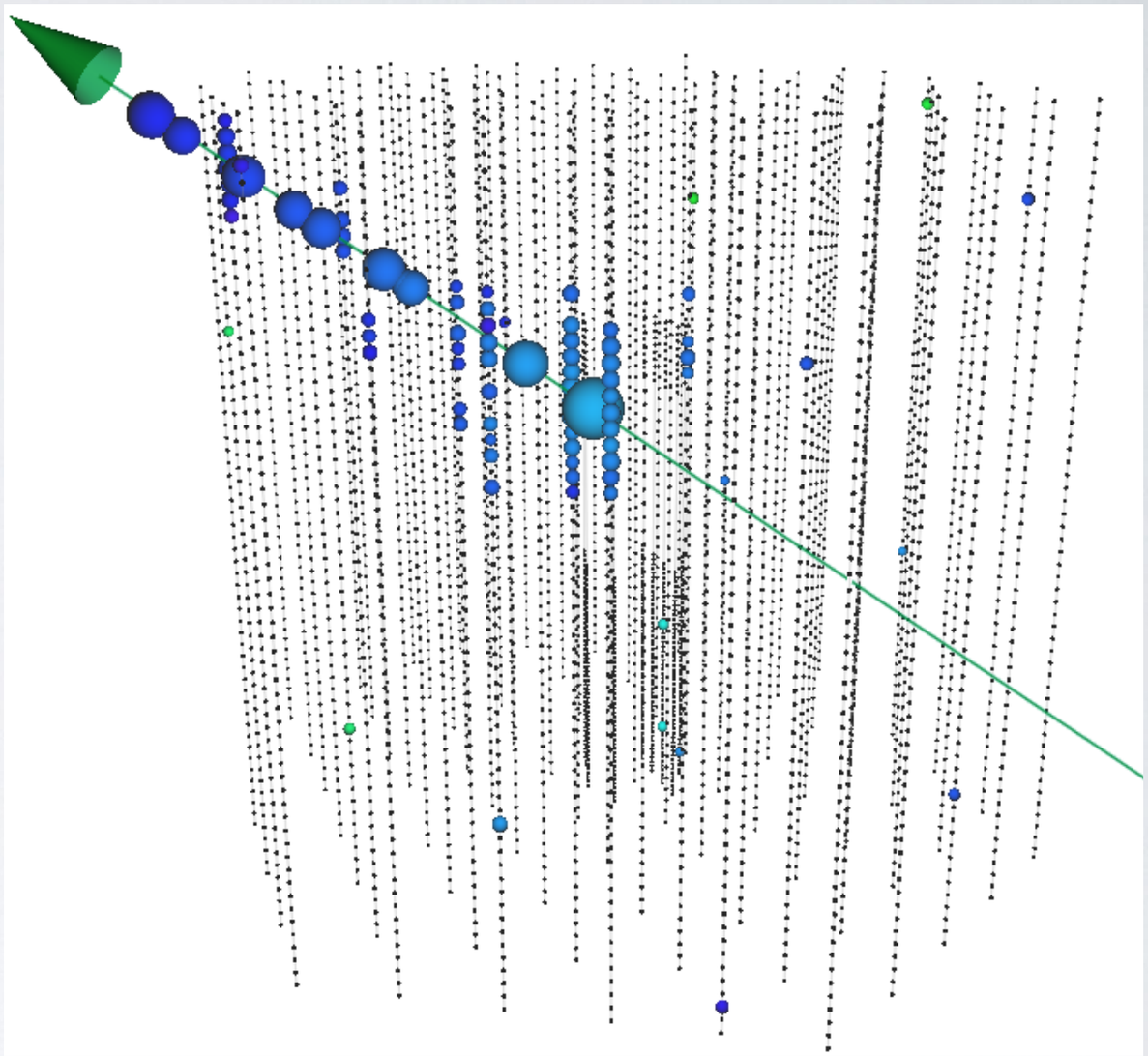




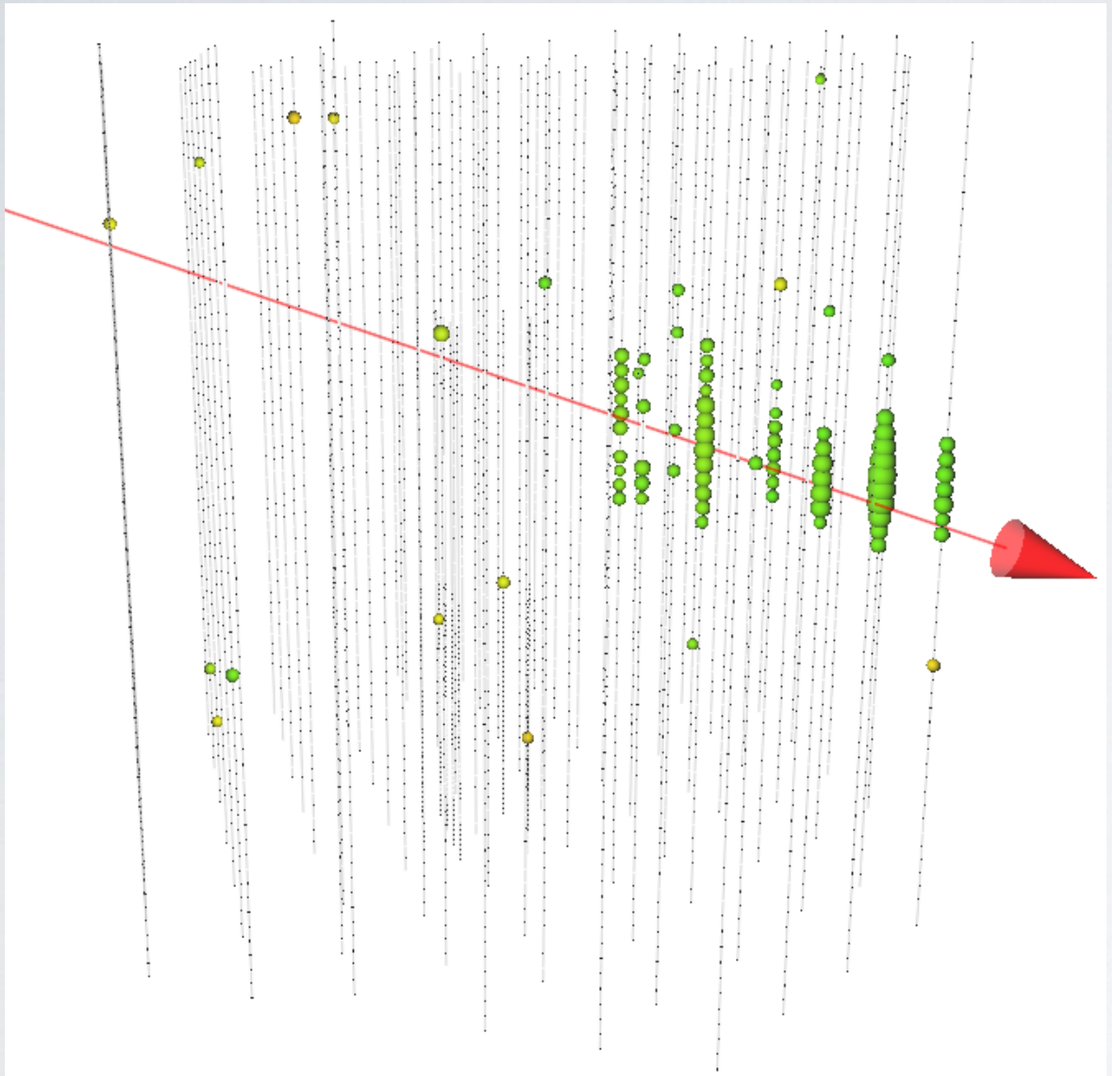
- But if I give you IceCube data, how do you identify a muon from a neutrino? What about a cascade vs track?

WHAT ARE THESE?

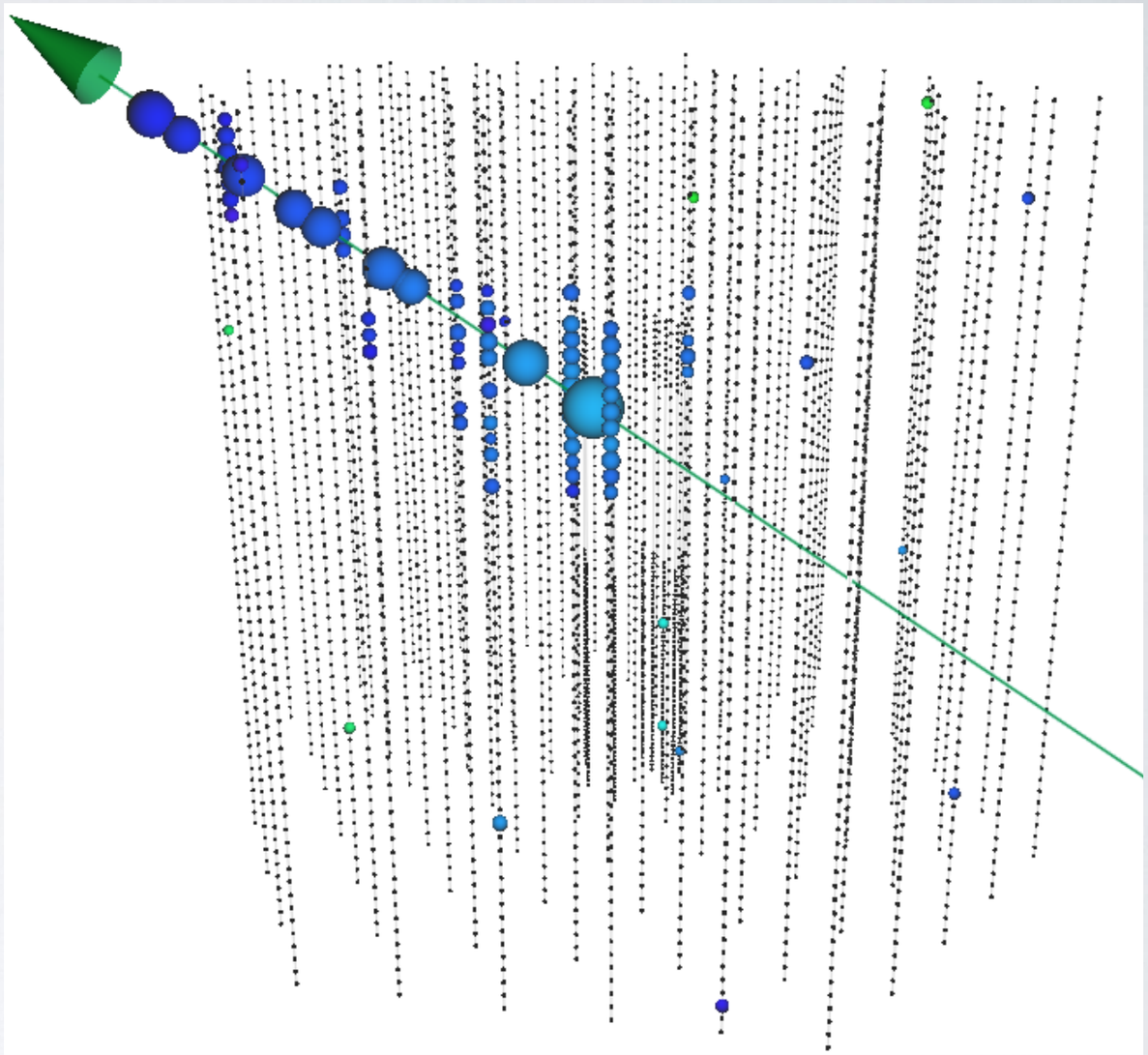




Downgoing



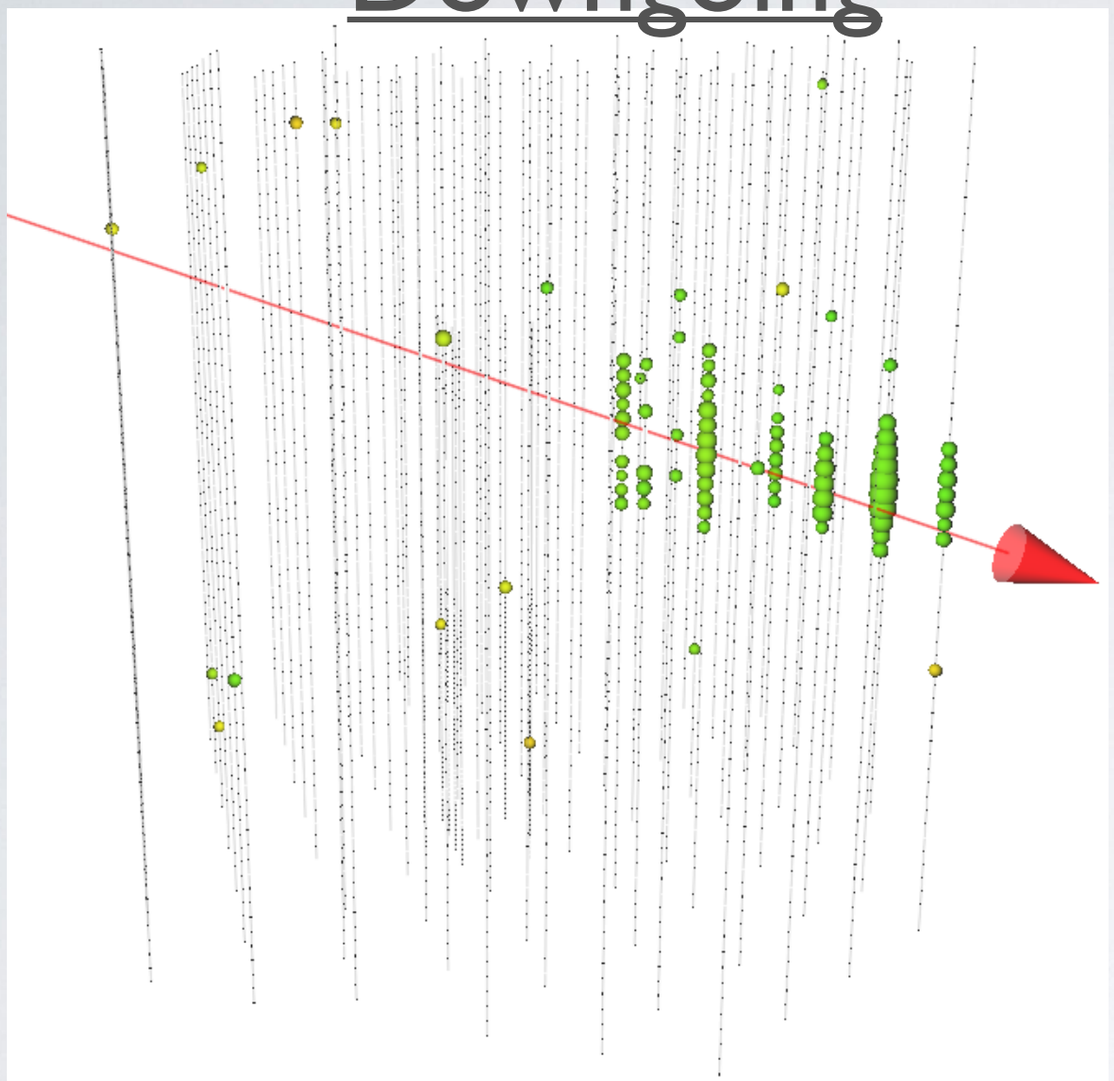
Upgoing



- Both “start” half-way in the detector and exit the detector
- Forms a line, therefore “track-like”
- Can be from either ν_μ of ν_τ undergoing CC interaction

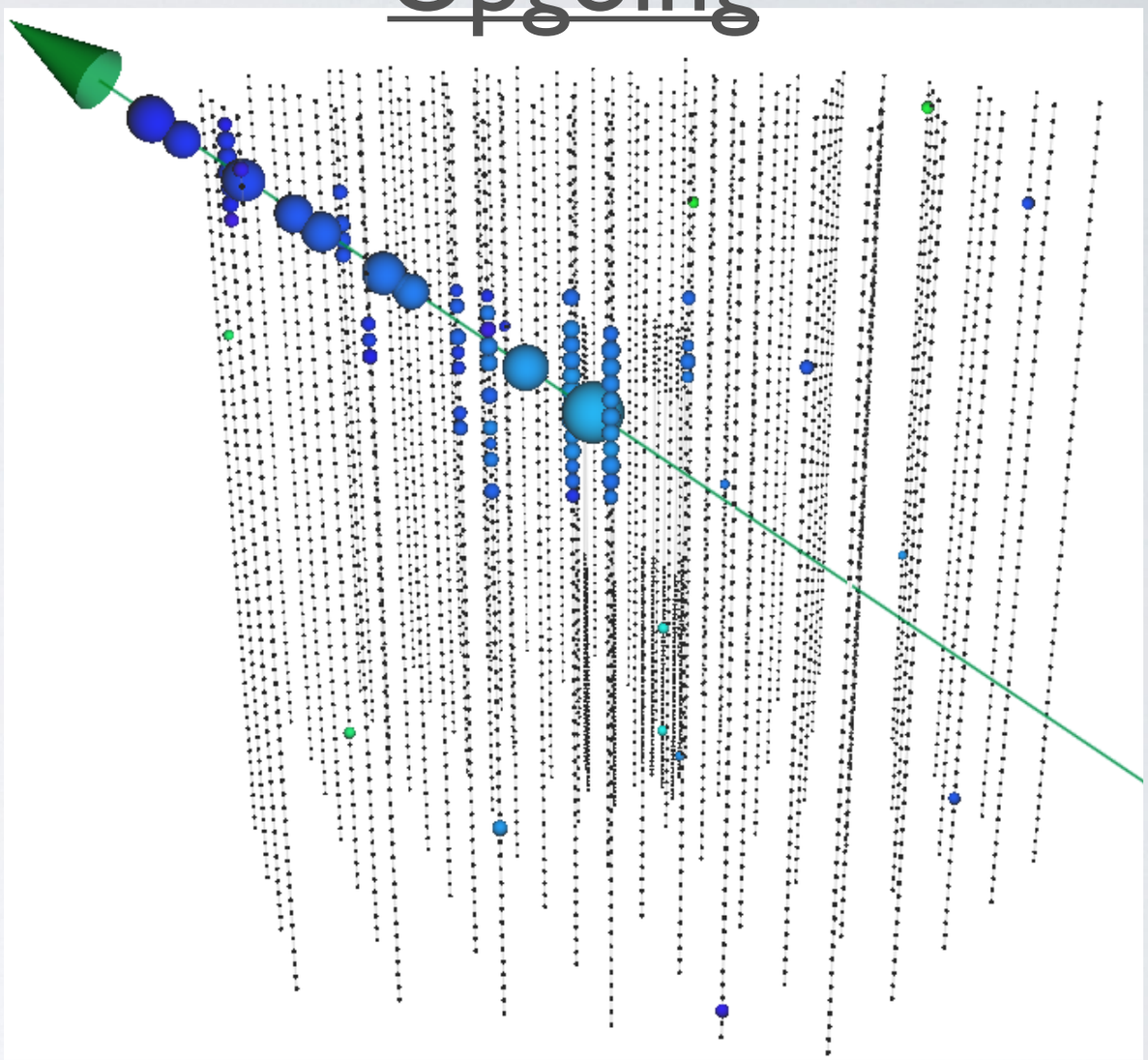
STARTING TRACKS

Downgoing



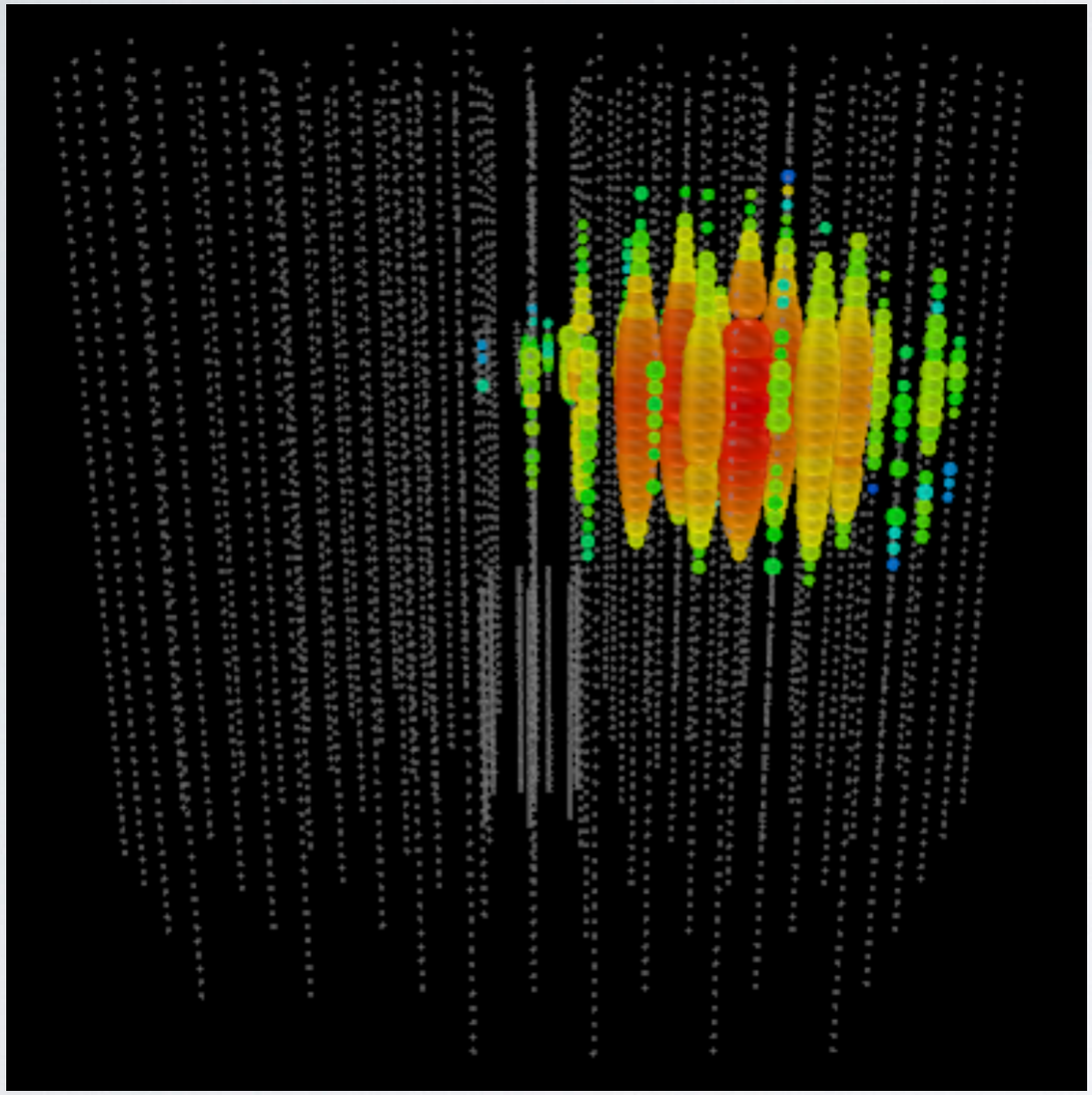
- 1.5km of ice before reaching IceCube, atmospheric muons dominate

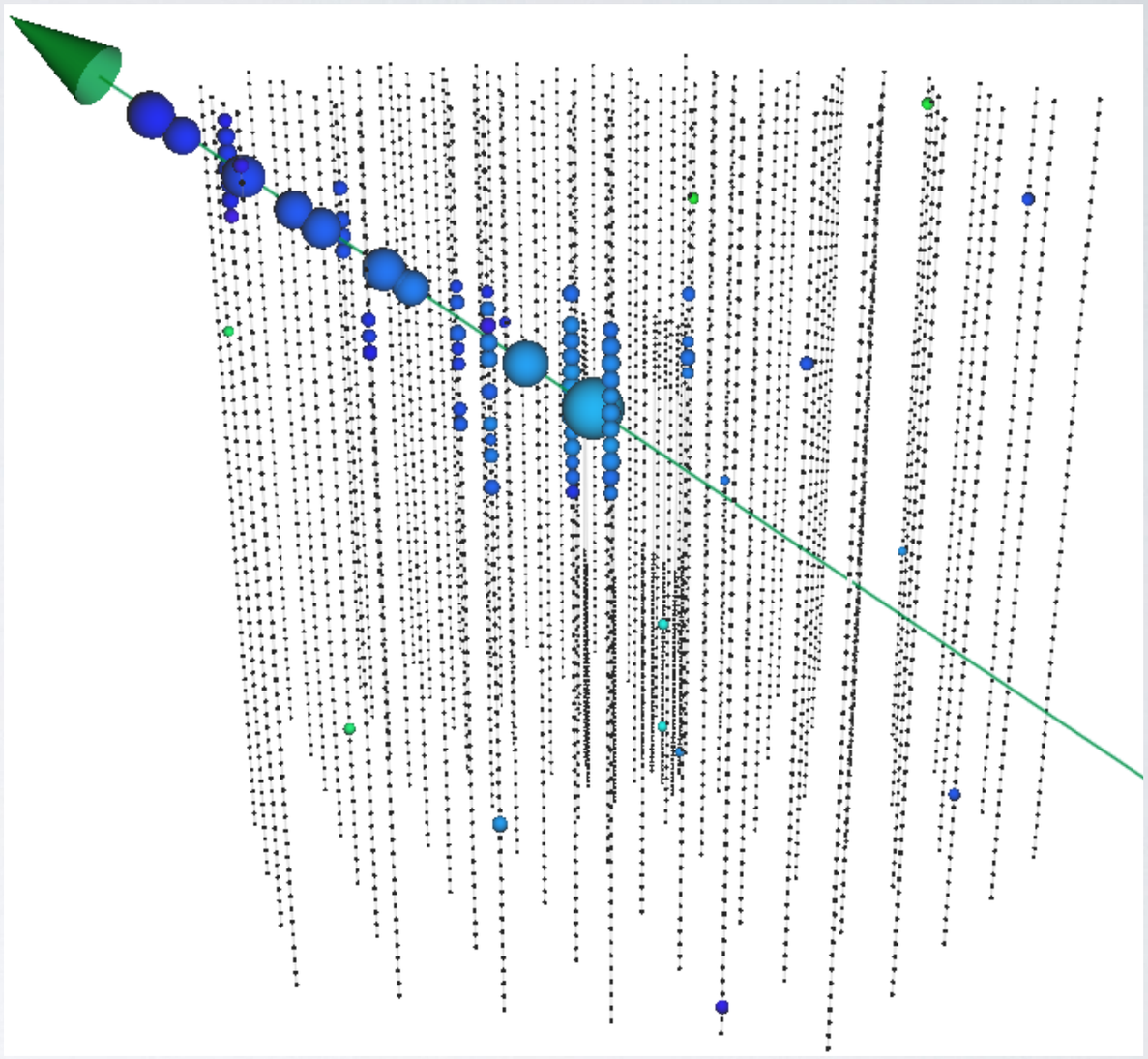
Upgoing



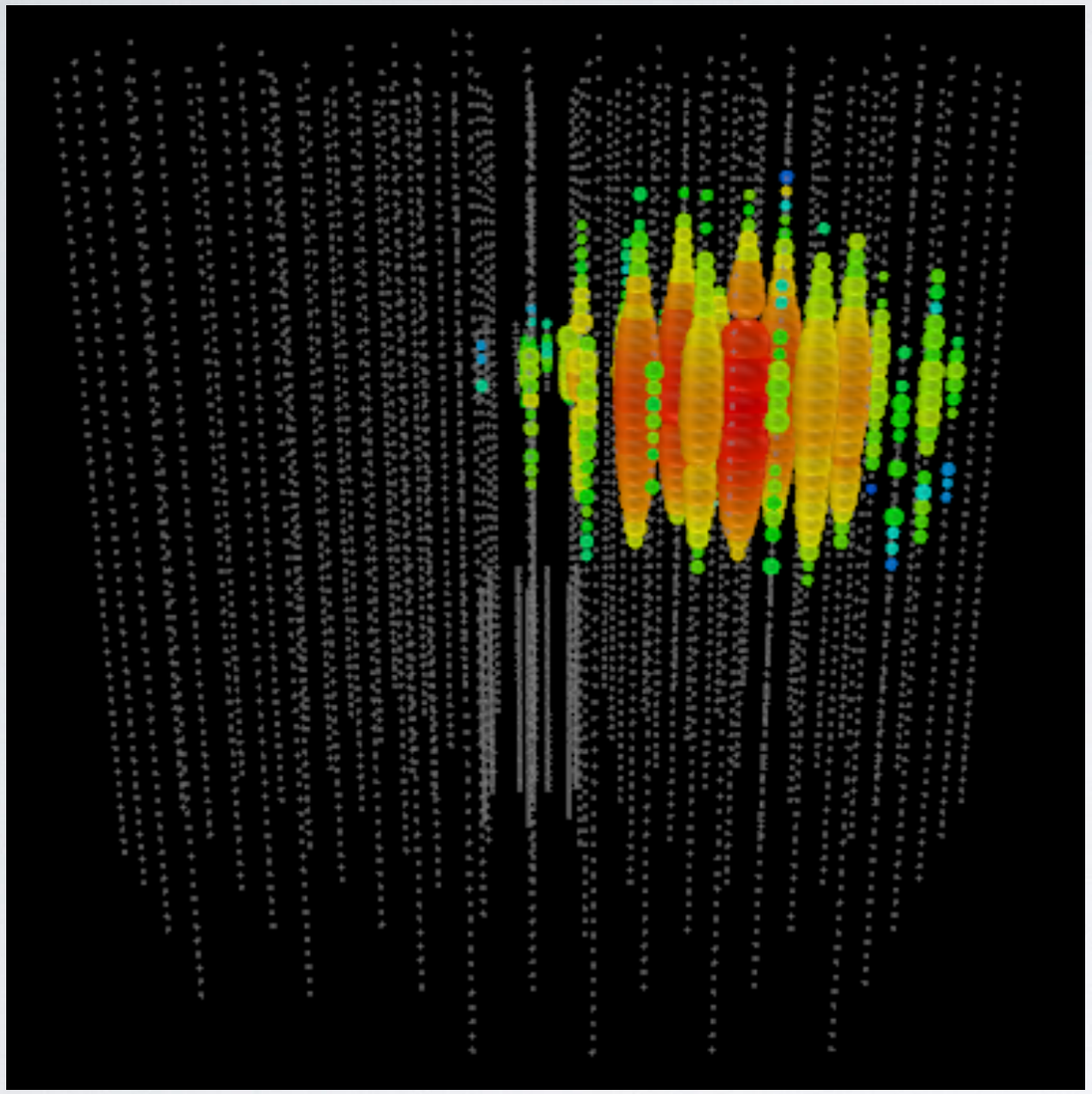
- Particles travel through the entire Earth before reaching IceCube, little to no atmospheric muons

WHAT ARE THESE?



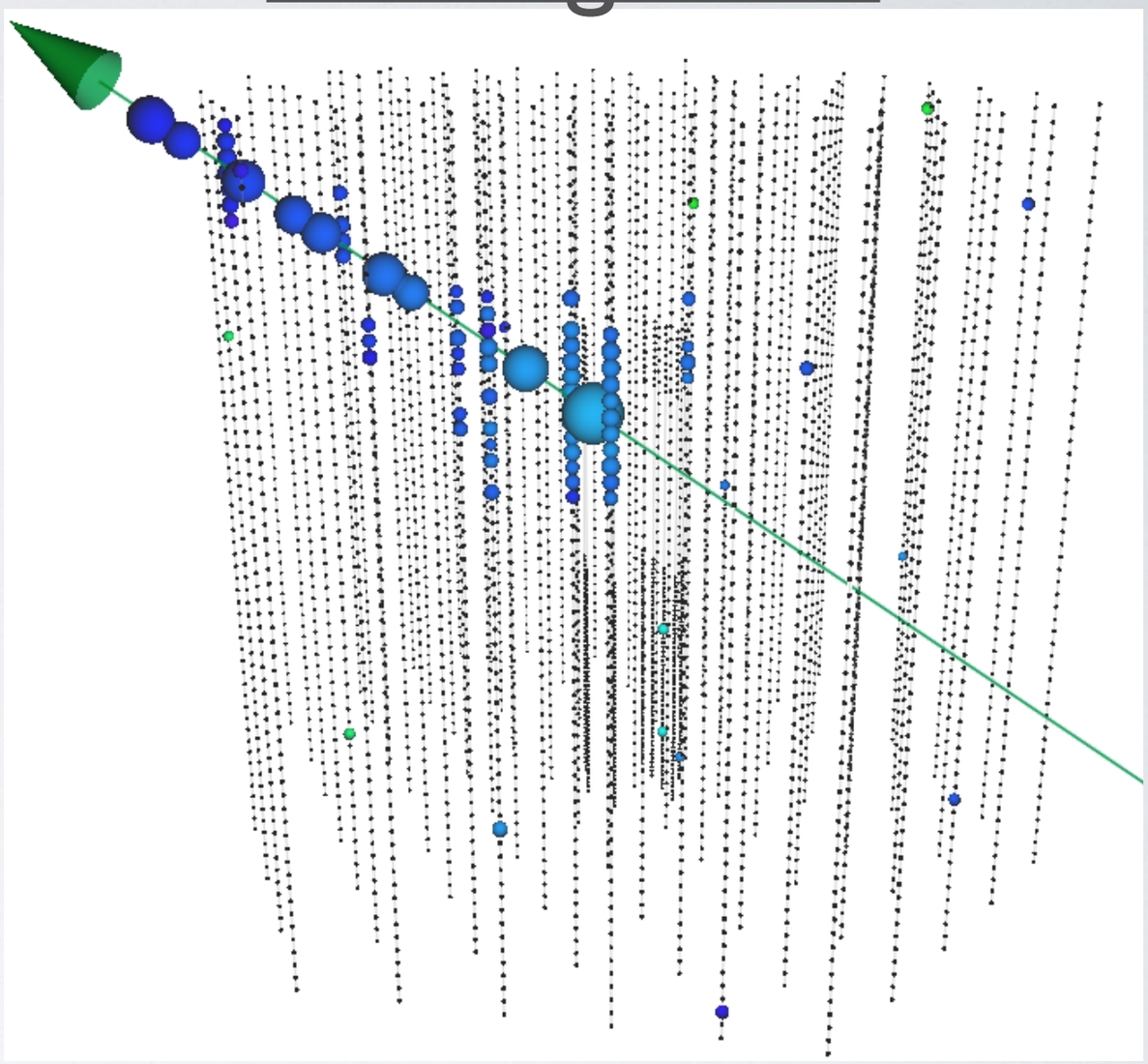


Cascade



- Very difficult to compute direction, but easy to compute energy deposited

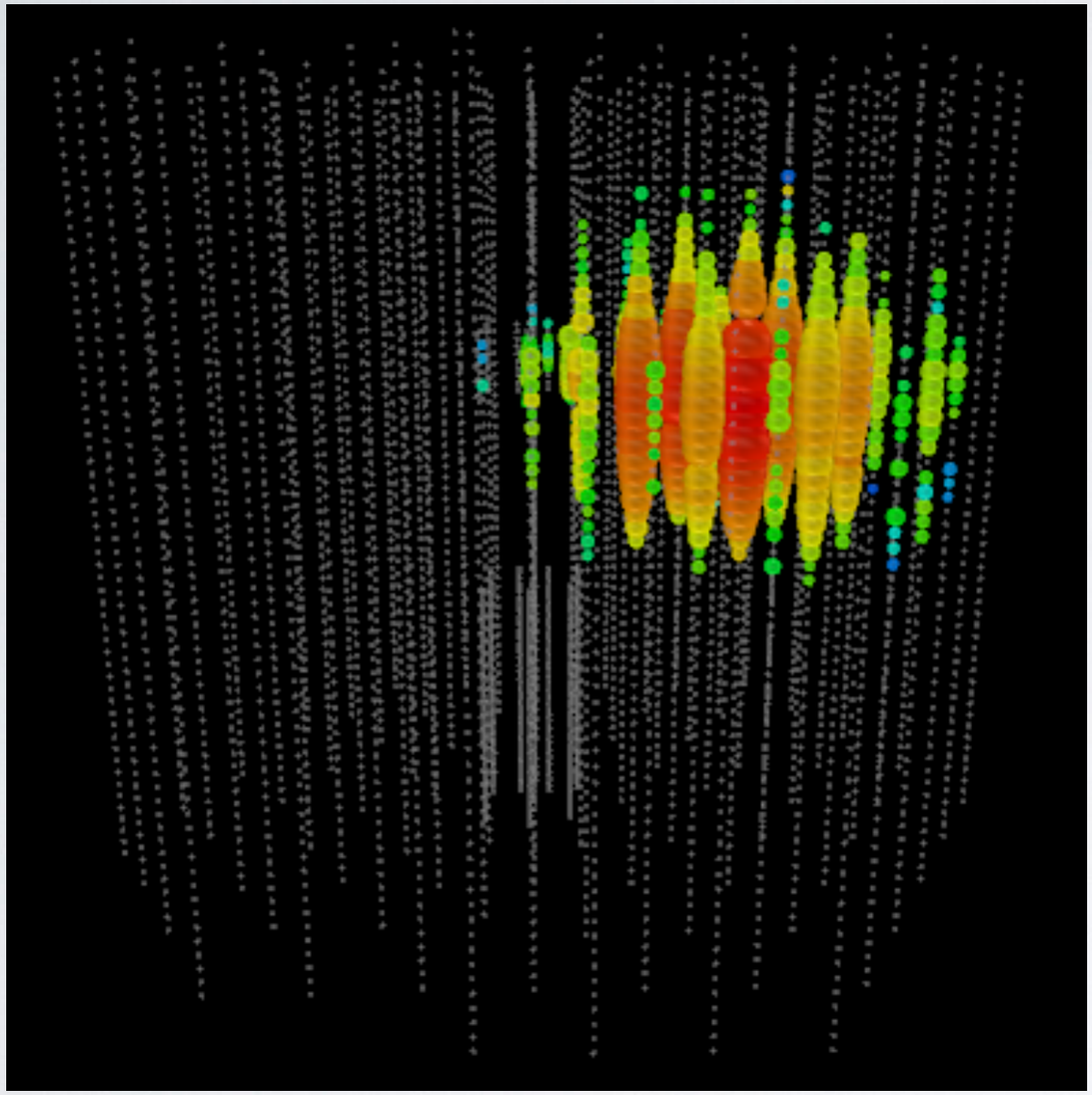
Starting Track



- Very easy to compute direction, but difficult to compute energy deposited

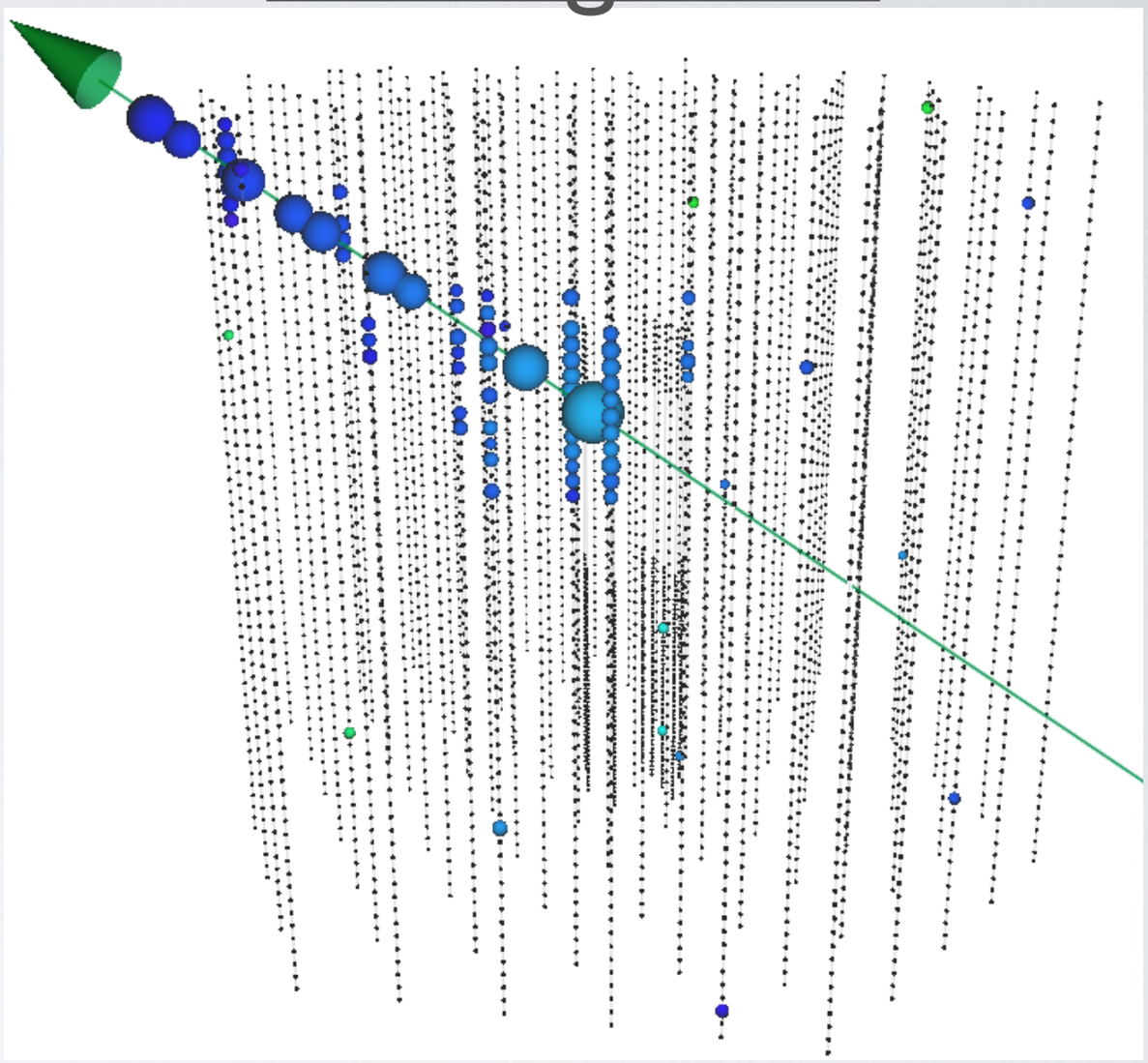
STARTING EVENTS

Cascade



- Neutral current or ν_e+ν_τ CC decays only

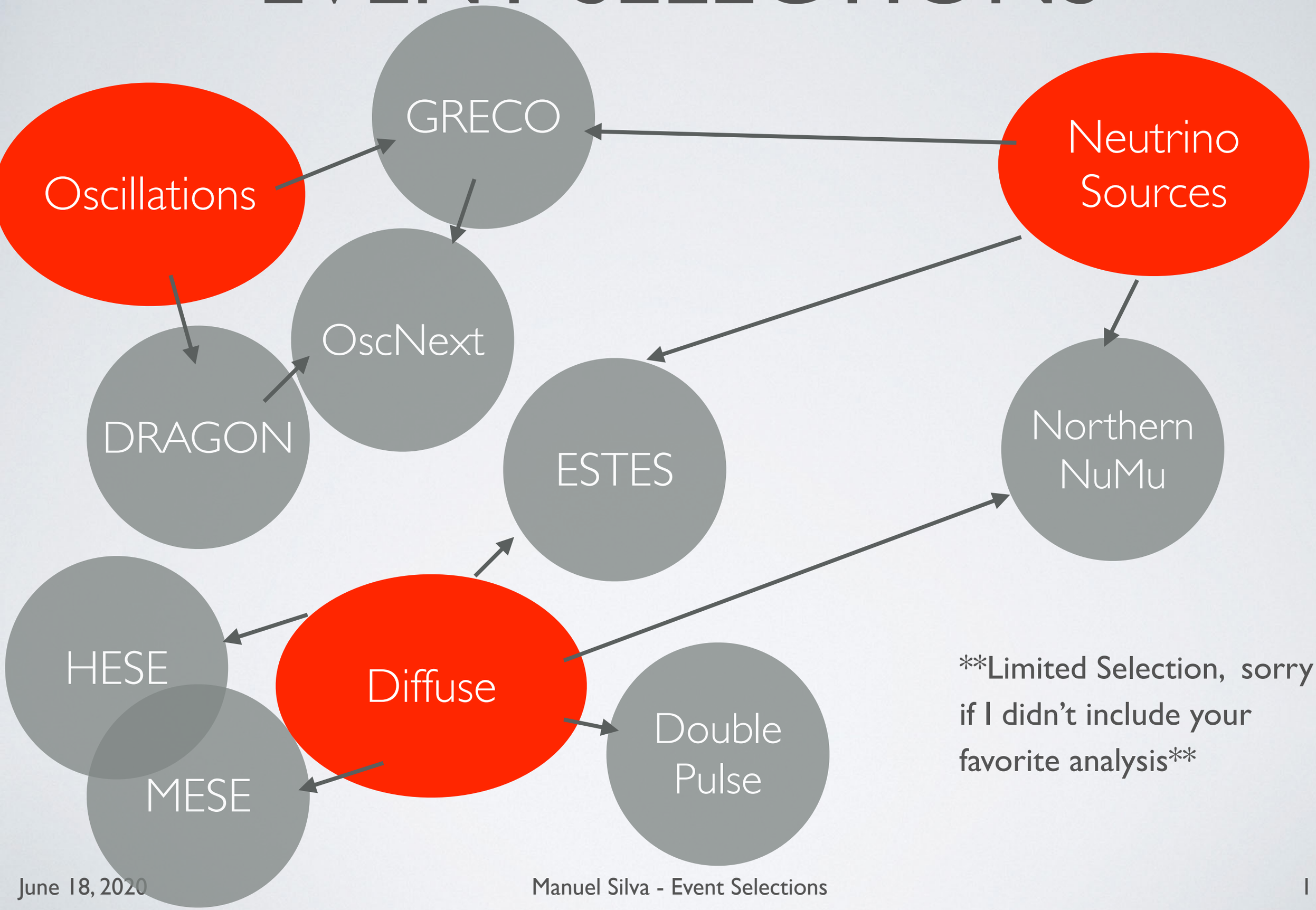
Starting Track



- ν_μ+ν_τ CC decay only
- ~4x as many ν_μ as ν_τ

What particles are you searching for?
Energy range?
Will you allow background contamination?

EVENT SELECTIONS

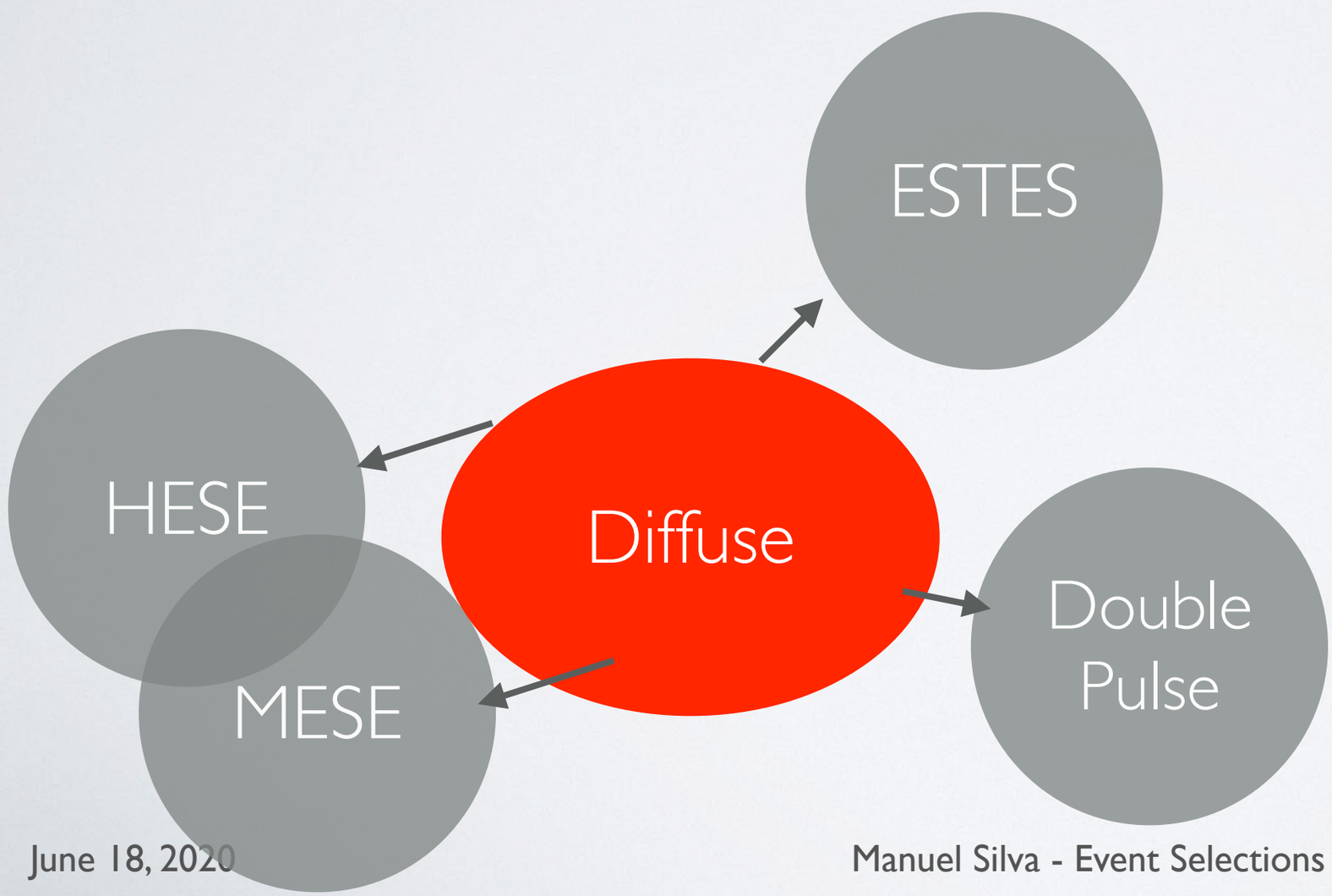


Limited Selection, sorry if I didn't include your favorite analysis

DIFFUSE

- Goal of group is to identify and measure atmospheric and/or astrophysical neutrino properties

- All neutrino flavors, TeV-PeV energies

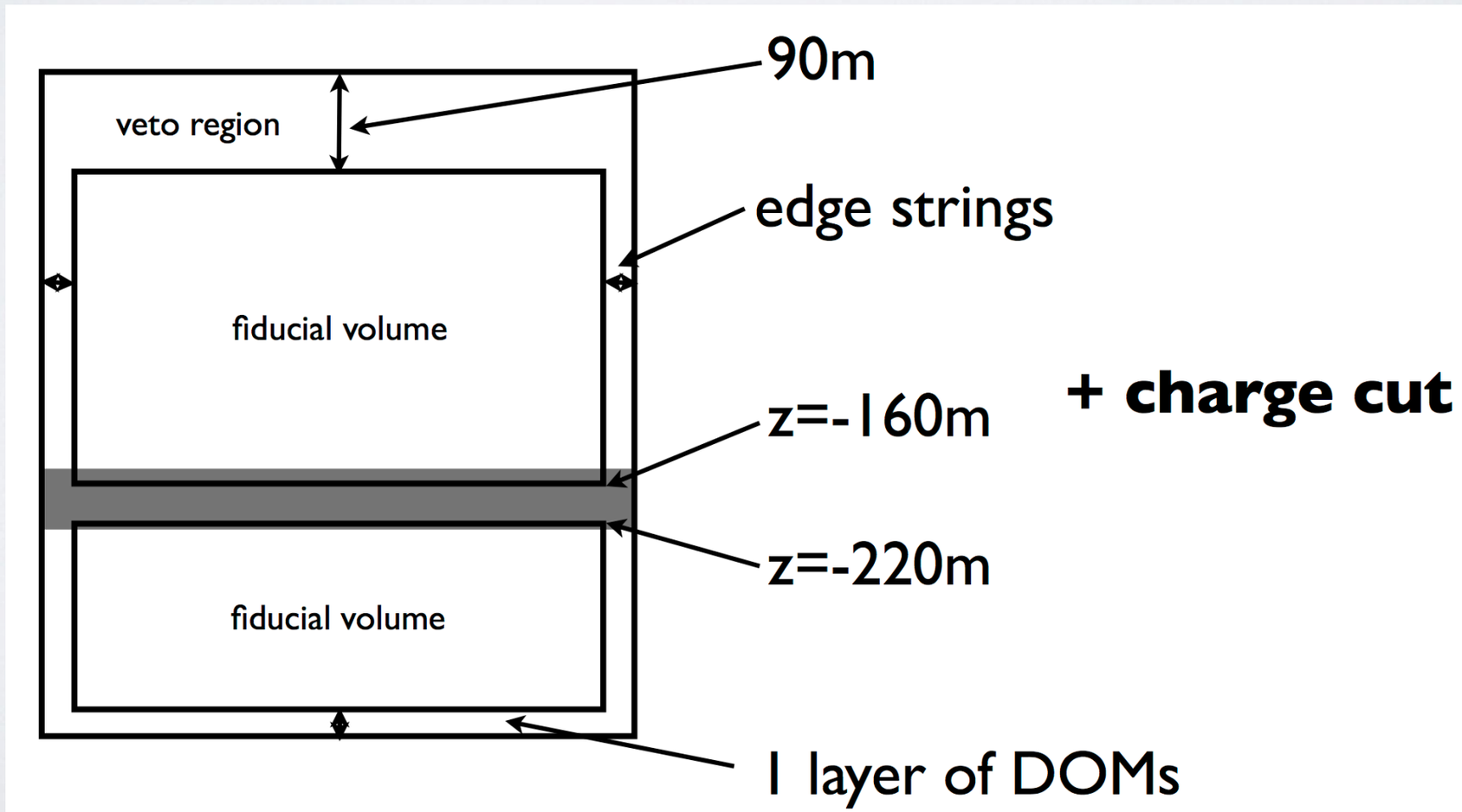


- Requires different techniques for Northern vs southern sky

HESE (E > 60 TEV)

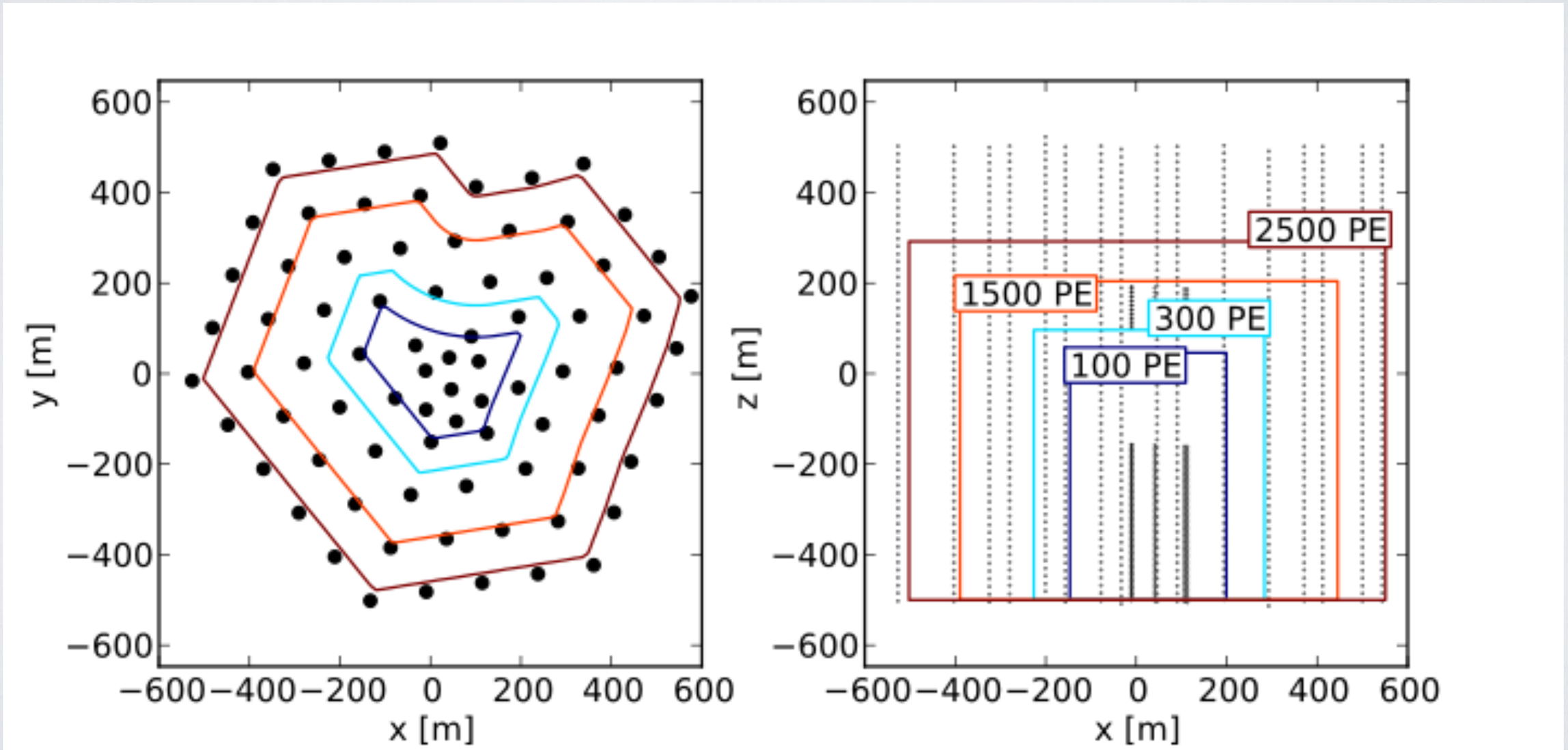
- High Energy (HE) Cut, Q_{tot} > 6000 PE

- Use outer layer of DOMs as veto region, cut on Starting Events (SE)



MESE (E > 1 TEV)

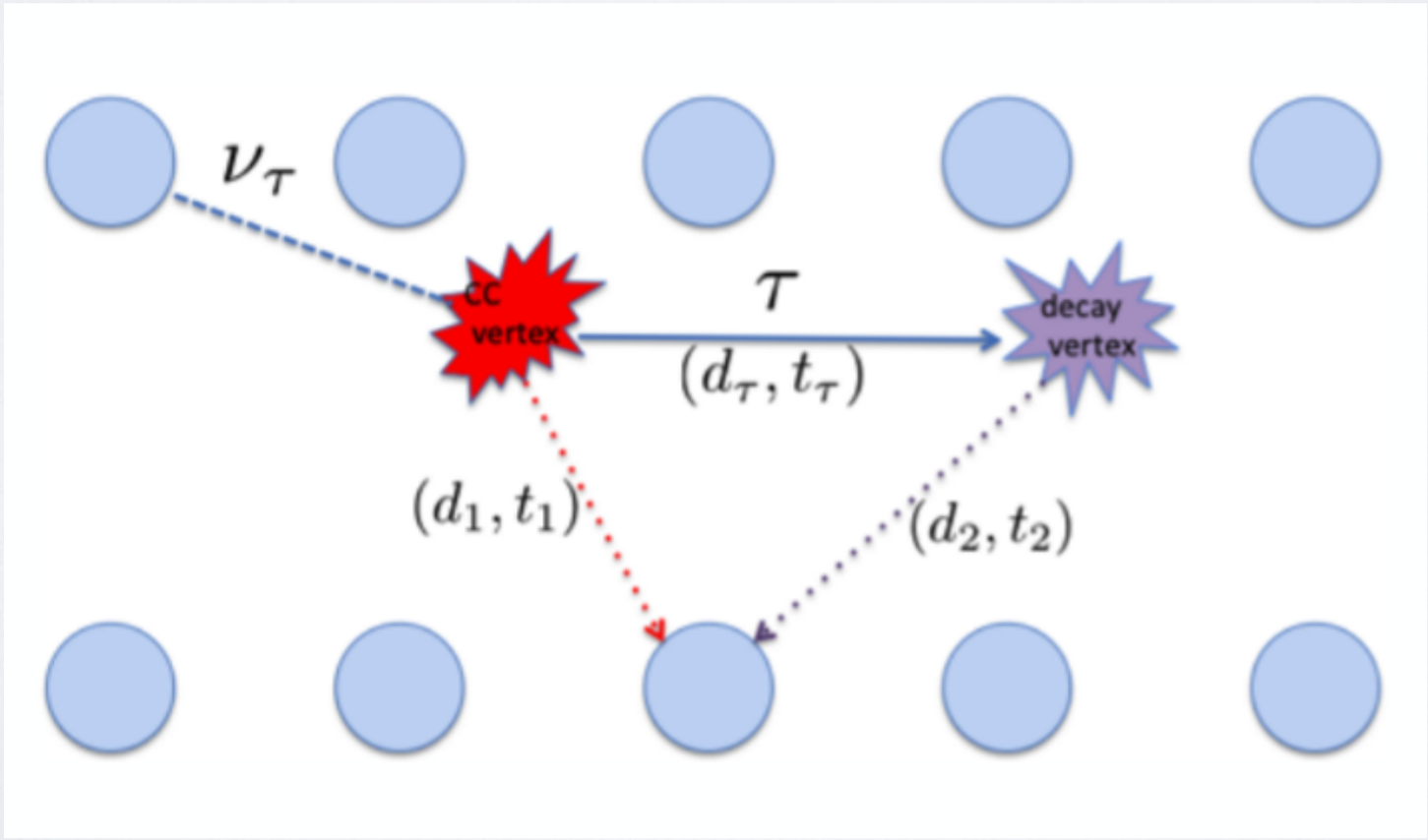
- Similar to HESE, but now add more veto layers for medium energies (ME)



DOUBLE PULSE

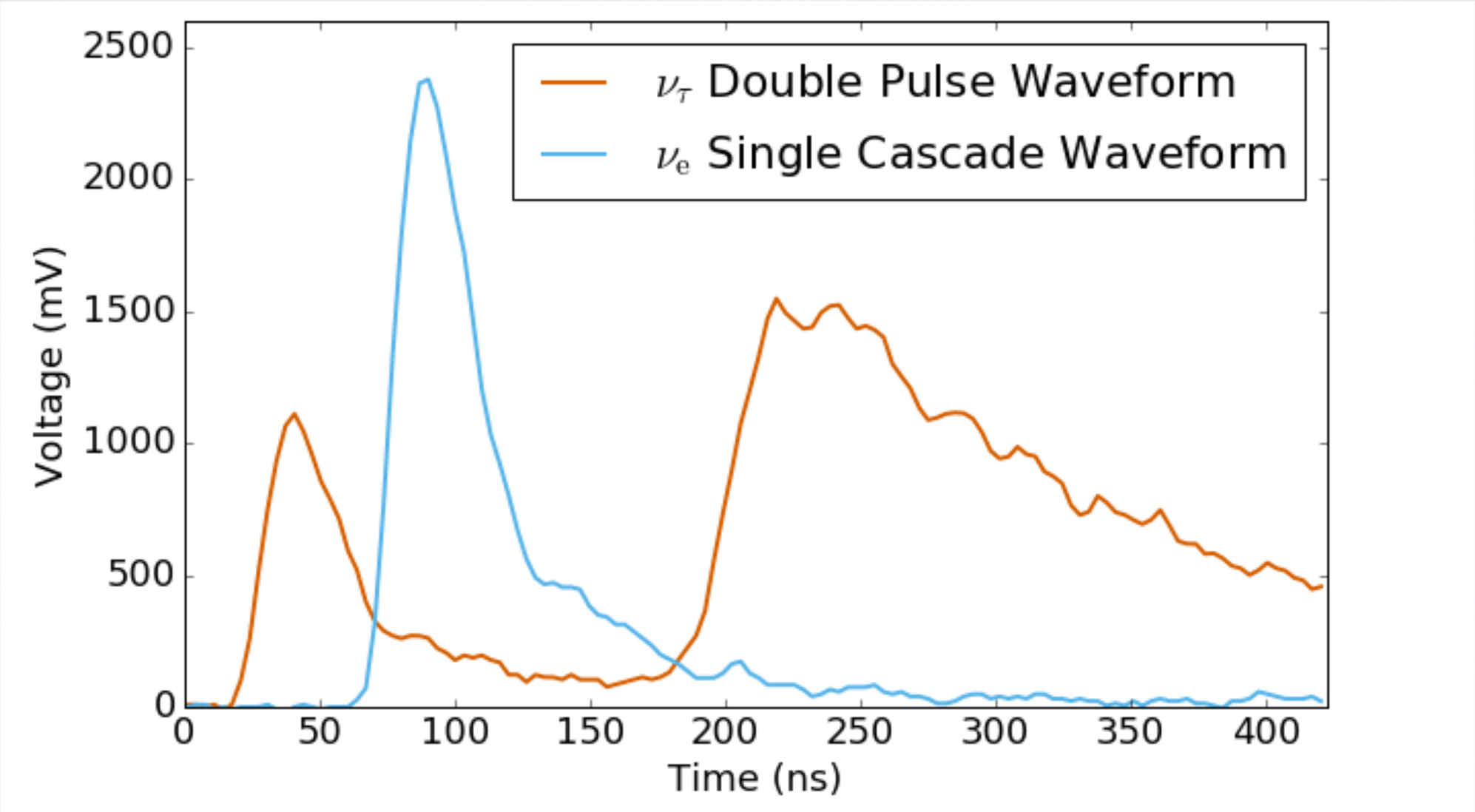
- Tau neutrino interacts within IceCube and produces a tau lepton

- Tau lepton travels before decaying, 2nd vertex



DOUBLE PULSE

- Use waveform from DOMs, apply series of cuts on the shape of the waveform

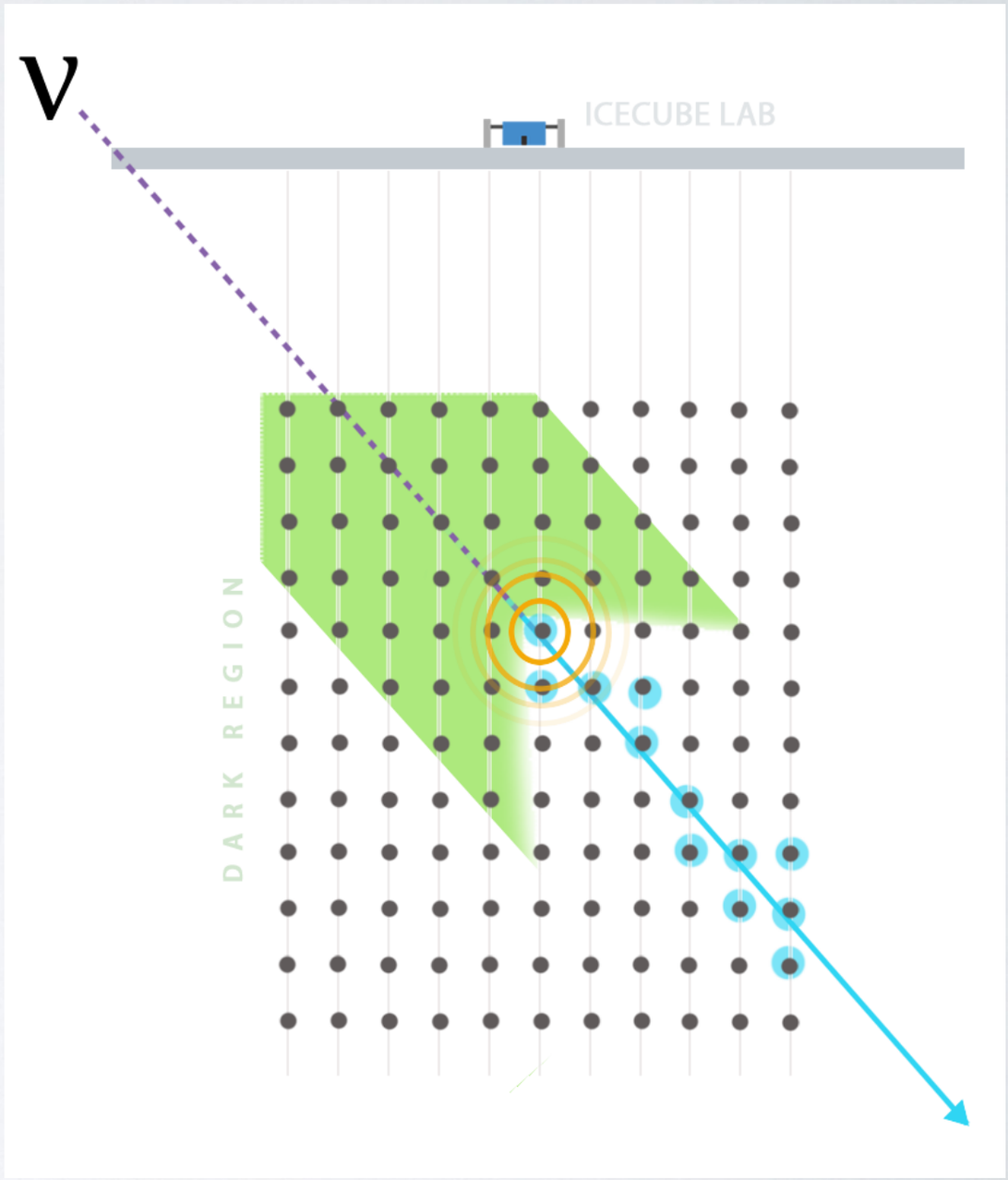


ESTES

- **E**nhanced **S**tarting **T**rack **E**vent **S**election

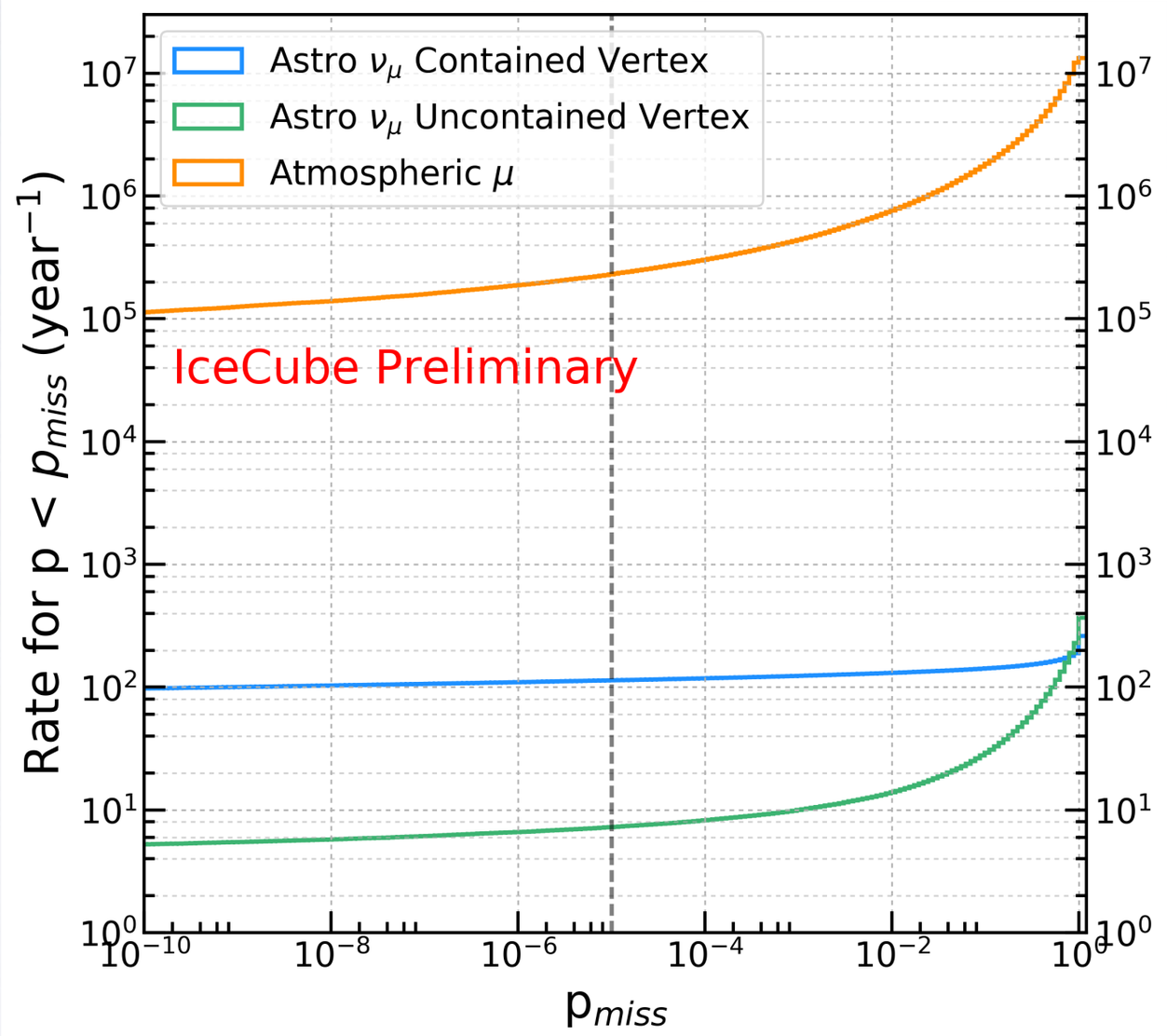
- Veto ~1 billion atmospheric muons

- Retain ~50 astrophysical neutrinos



CUT #1 - VETO

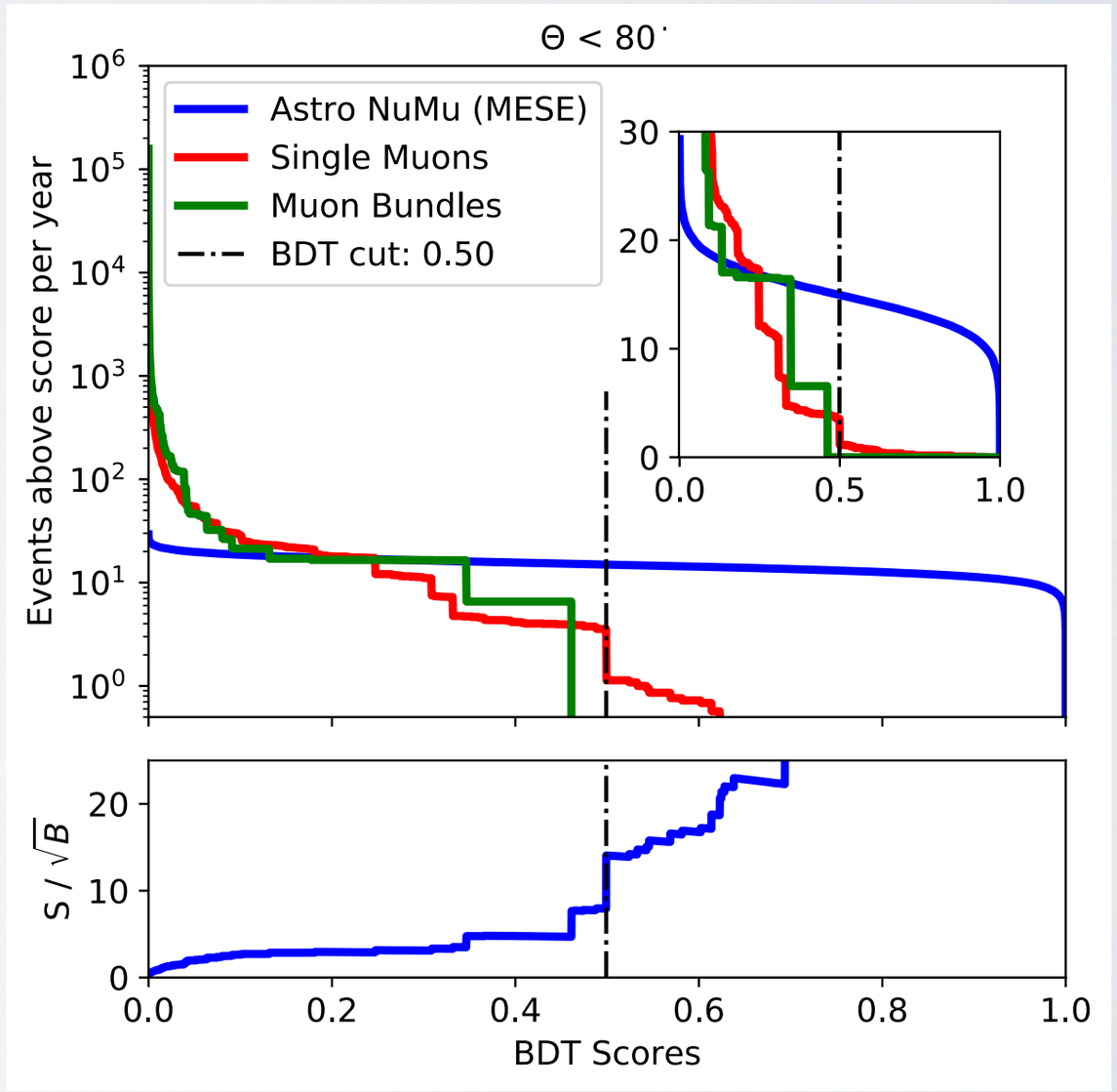
- Veto region probability denoted as p_{miss}
- Single cut on p_{miss}
- 10k atmospheric muons , 100 astrophysical neutrinos survive this cut



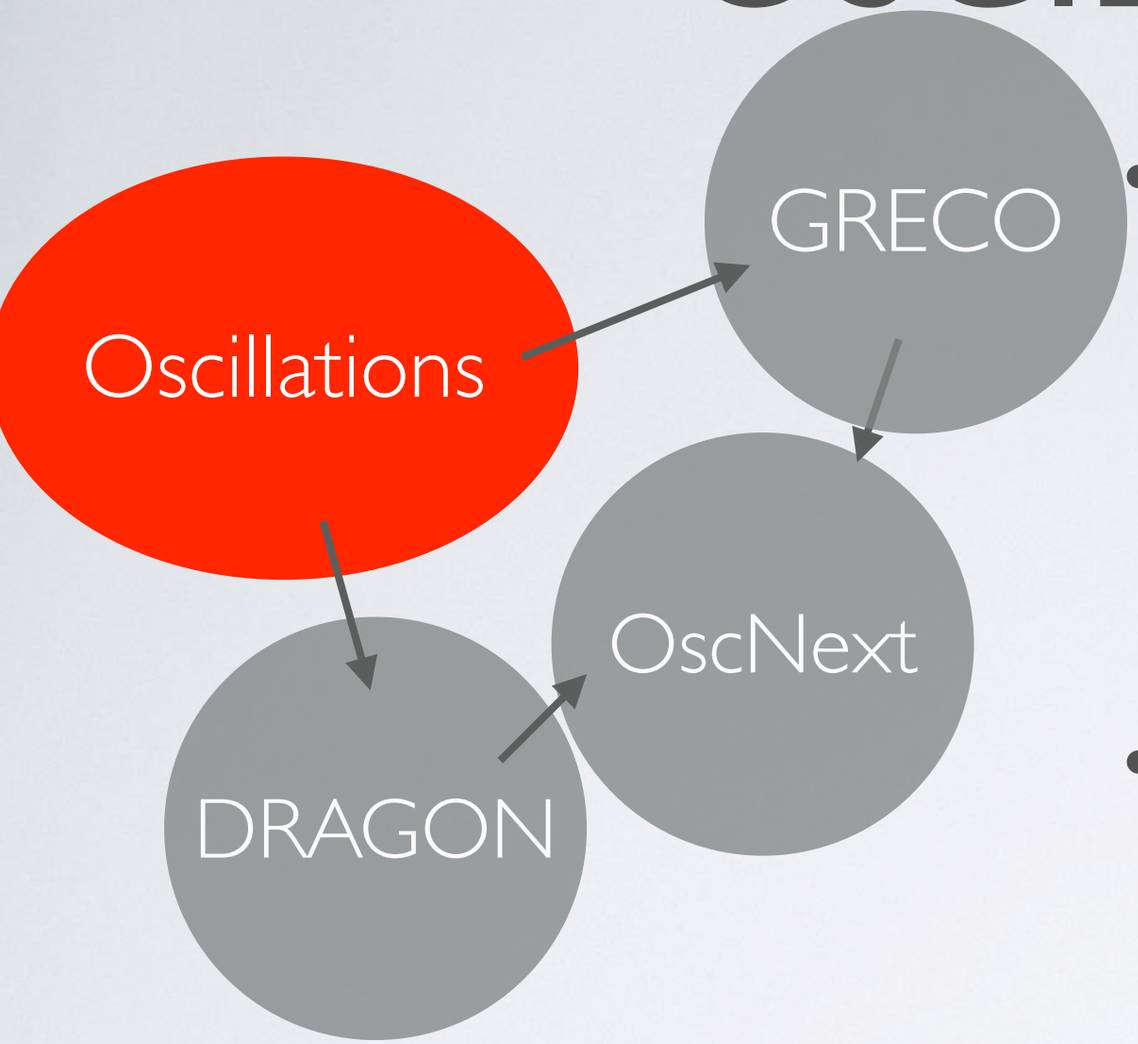
CUT #2 - BDT

- The BDT computes a probability for a particular event being a muon vs astrophysical neutrino
-
- Cut on BDT score aiming for < 1 muon per year

- Started at 1billion muons per astrophysical neutrino, now we're at 50 astrophysical neutrinos per muon



OSCILLATIONS



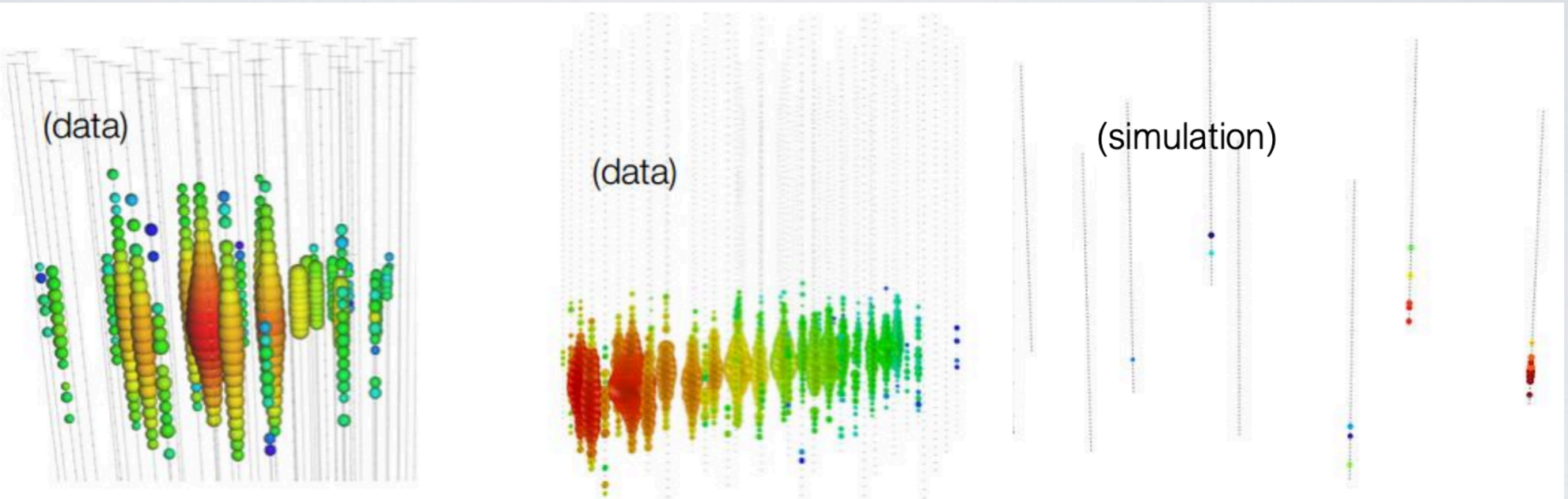
- 2 different event selection used up to 2019, <u>different physics goals</u>

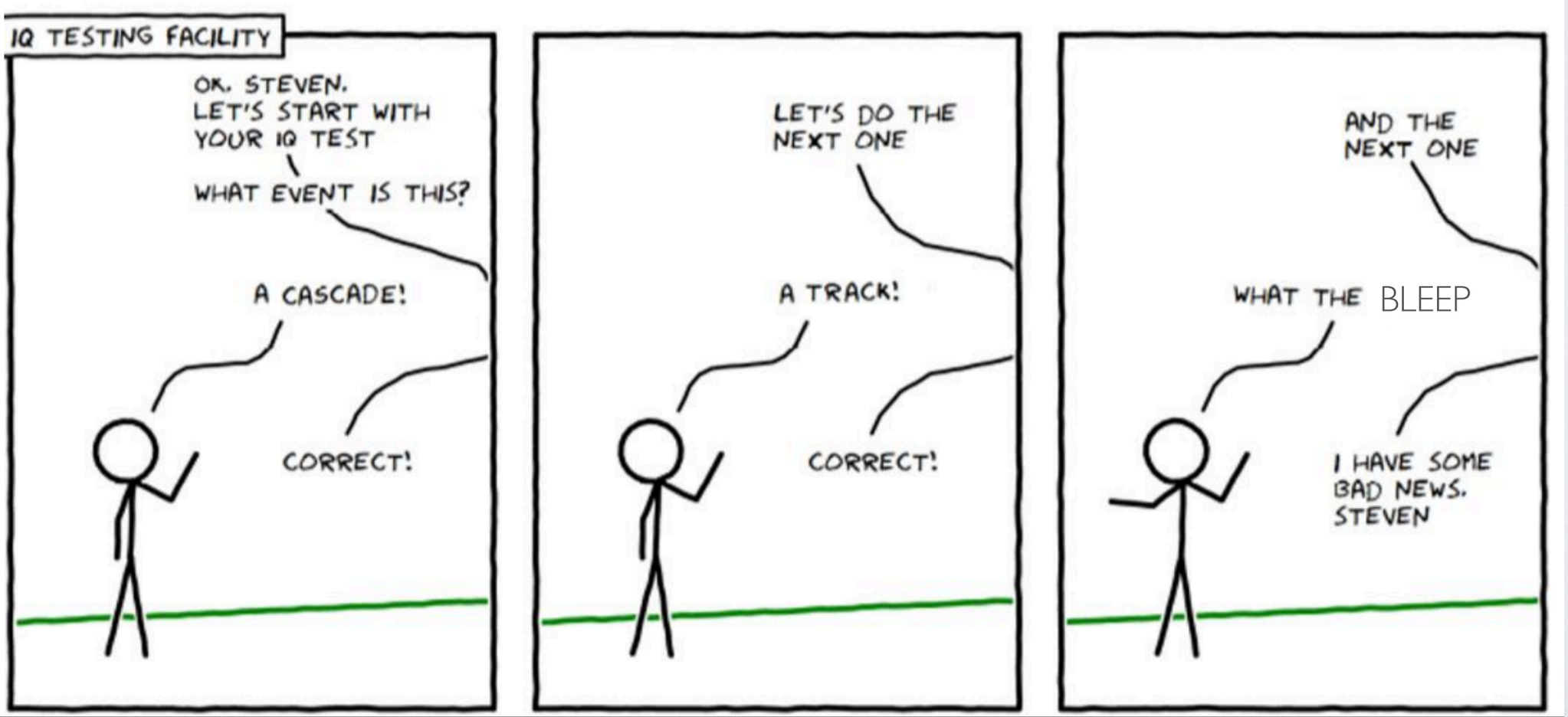
- GRECO and DRAGON now united under **OscNext framework**

- Low energy neutrinos, primarily atmospheric

Cred:
Jan Weldert

OSCNEXT





OSCNEXT

- Few strings in DeepCore means “noise” can accidentally be interpreted as an event

- This is in addition to the large presence of atmospheric muons

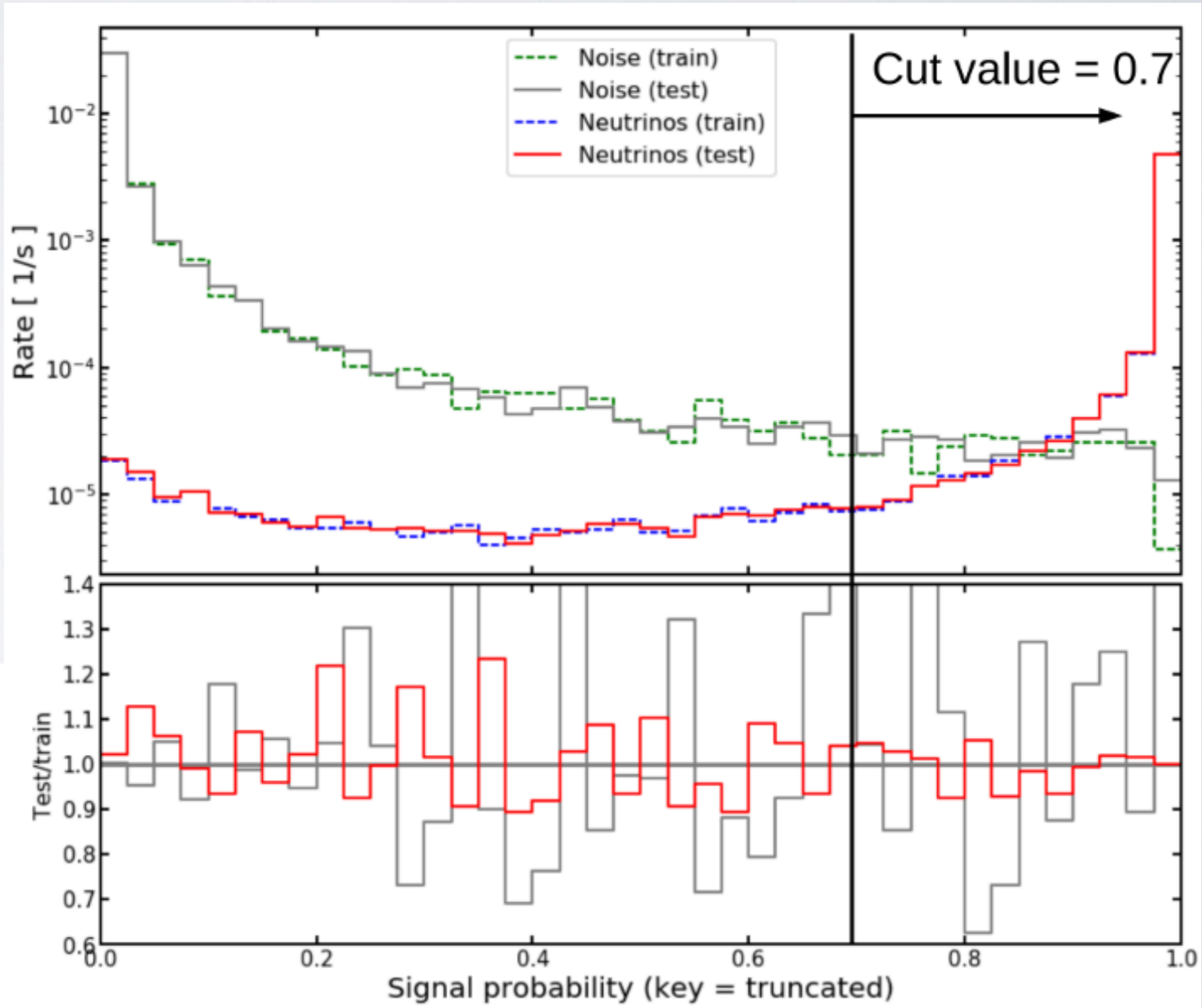
- Two BDTs now required to filter muons, Level 4 and 5

LEVEL 4

- DOMs have noise that can be interpreted as low energy event

- Use 5 variables as input

- Cut = 0.7 **reduces noise** rate by **over 100**



- IC2018_LE_L3_Vars.NchCleaned
- L4_micro_count.STW_m3500p4000_DTW200
- L4_iLineFit.speed
- L4_fill_ratio.fillratio_from_mean
- IC2018_LE_L3_Vars.FullTimeLengthRatio

LEVEL 5

- Primary background are now “clean” muons, time to filter them out!!

- Use **real data** and **train against simulated neutrinos** using BDT

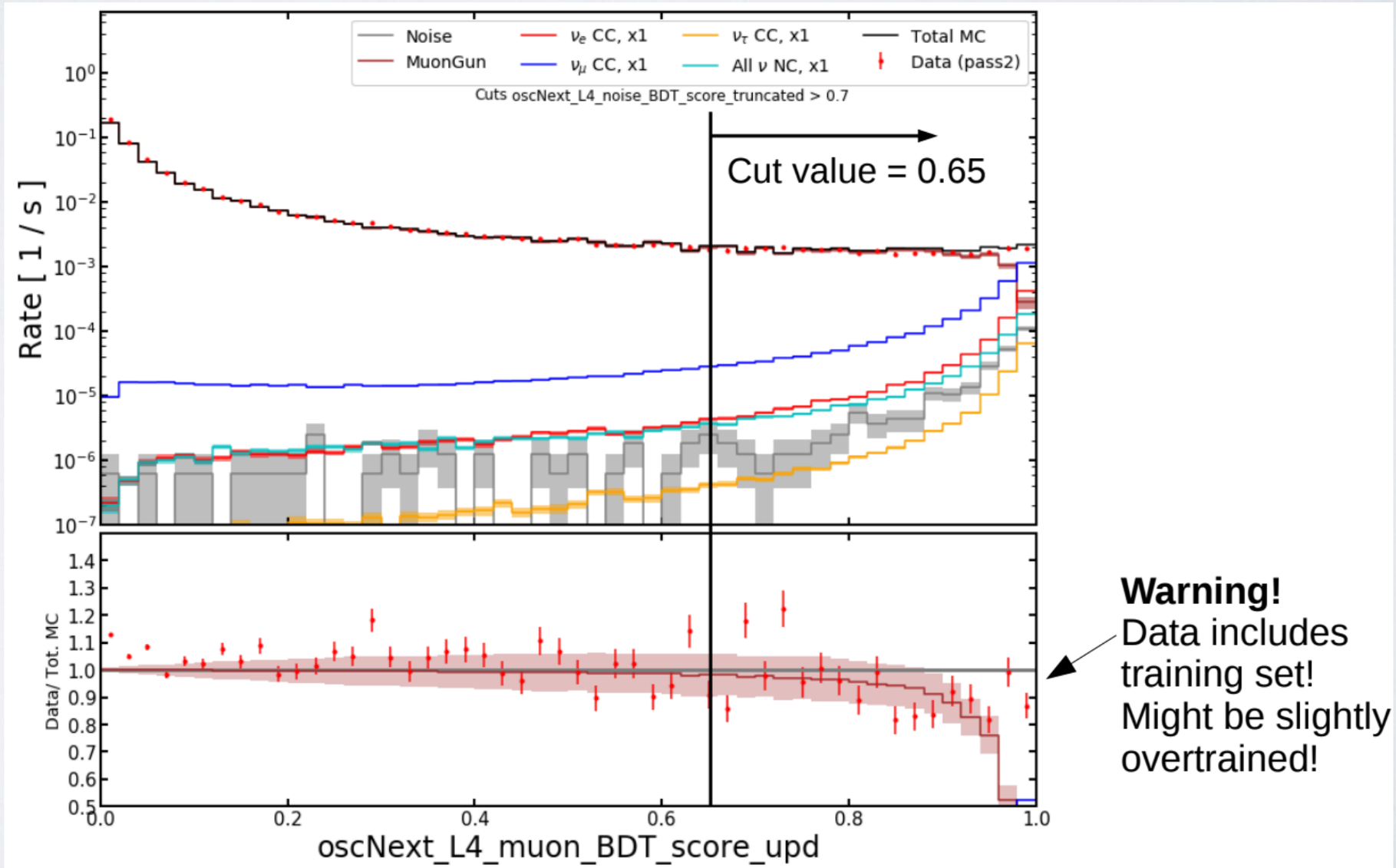
-

- IC2018_LE_L3_Vars.ICVetoHits
- IC2018_LE_L3_Vars.NAbove200Hits
- IC2018_LE_L3_Vars.RTVeto250Hits
- IC2018_LE_L3_Vars.NchCleaned
- L4_VICH_nch
- L4_accumulated_time
- L4_first_hlc_rho
- SRTTWOfflinePulsesDCHitStatistics.cog_z
- SRTTWOfflinePulsesDCHitStatistics.z_sigma
- SRTTWOfflinePulsesDCHitStatistics.z_travel

LEVEL 5

- Extract probabilities and apply single cut

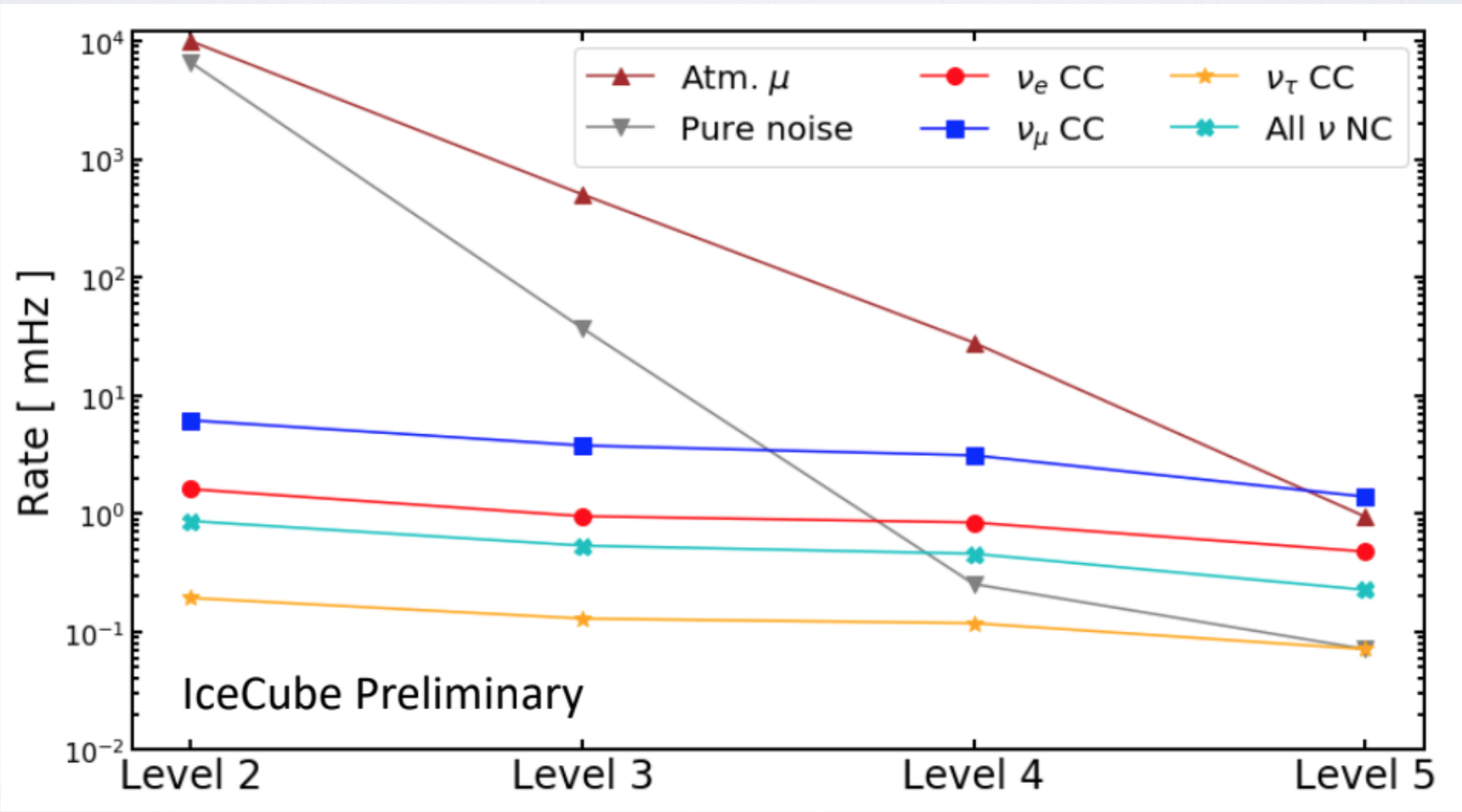
- Note: **overtraining** is sometimes an issue when using BDTs, always consult your resident machine learning expert



OSCNEXT - STATUS

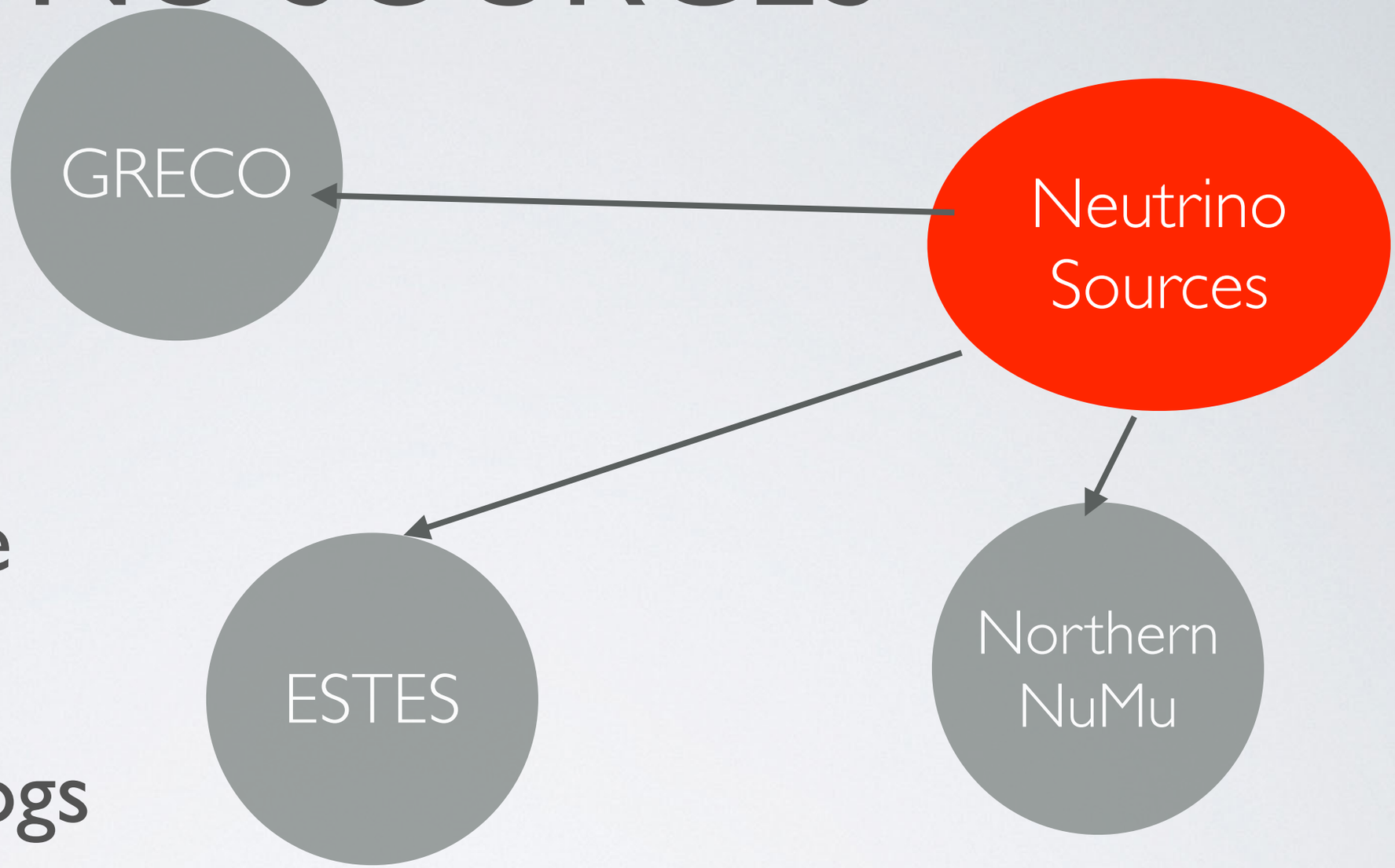
- Muon rates decreased from ~10^4 to ~1 per millisecond, neutrino rates barely affected

- Still much work to do in Oscillations group!!



NU SOURCES

- Search for neutrino sources, use blazar, GW, etc… catalogs

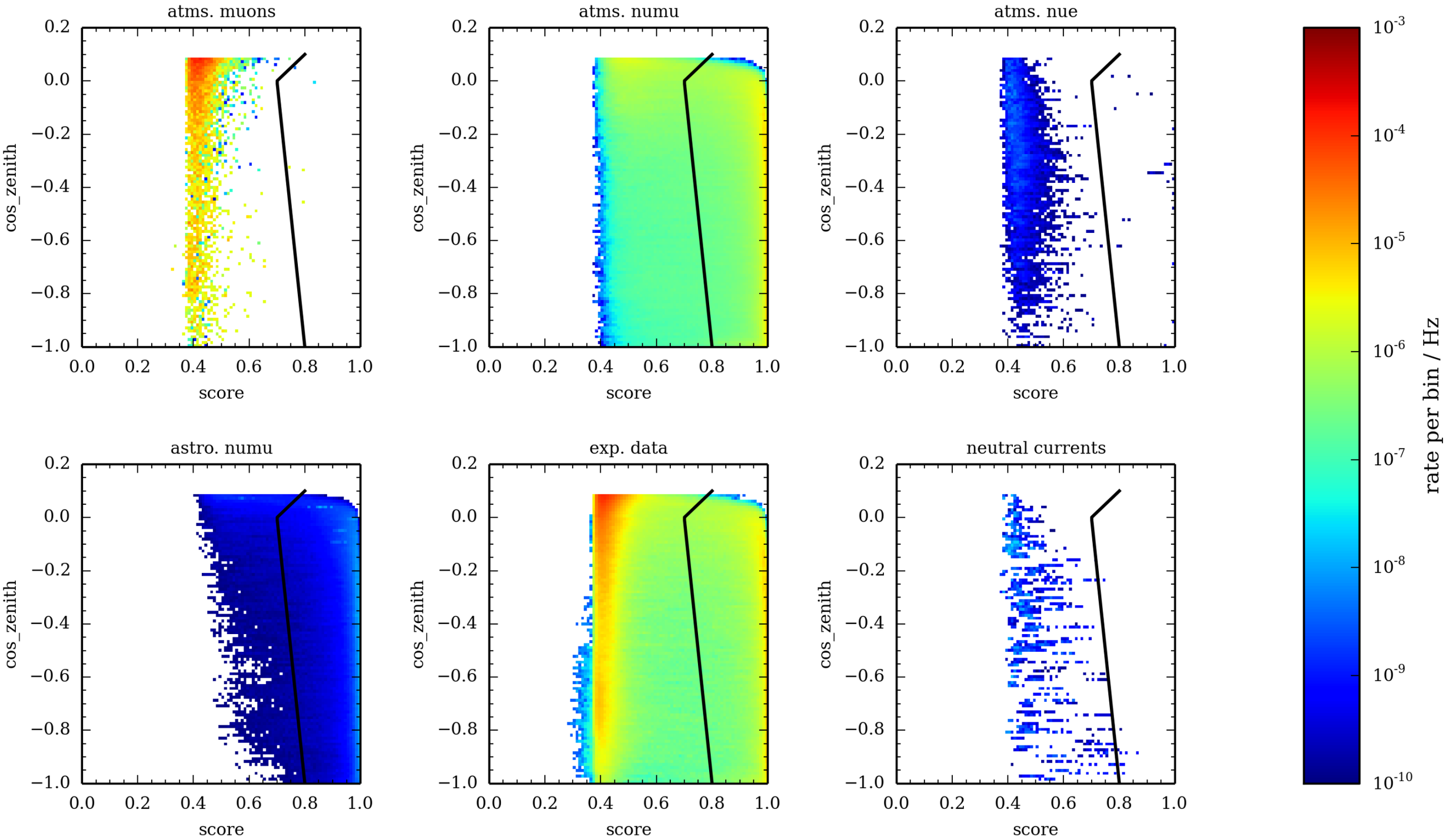


- Use muon tracks, need fast processing since these datasets tend to have ~100k events

NORTHERN NUMU

- Start at IceCube level3 data→wiki
- Use 10 variables as input to Adaptive Boosting BDT→wiki
- Cut on BDT score and cos(zenith), events coming from the horizon are difficult to reject

NORTHERN NUMU



NEUTRINO SOURCES

- Full list of datasets already processed and ready for use
- Choose the “best” for your analysis

Dataset	Creator	Description
Point Source Tracks	S.Coenders, T.Carver	All-sky sample of numu tracks optimized for point sources (IC86 2012-2017 updated by T.Carver)
Gamma-ray Follow-up (GFU) with online reco	T.Kintscher	All-sky numu tracks designed for quick response analyses. Quick reco online.
Gamma-ray Follow-up (GFU) with offline reco	T.Kintscher	All-sky numu tracks designed for quick response analyses. Re-processed offline for better sensitivity.
Northern Tracks	R.Reimann	Northern sample of numu tracks, same as used for diffuse analysis of northern sky
Fast Response	K.Meagher	All-sky numu tracks designed for quick response analyses
Low Energy Starting Events	M.Richman	Low energy starting events
STeVE	M.Richman	Something with starting events
Transient Tracks	A.Pizzuto	Northern numu tracks designed for short timescale analyses like GRB/FRB
Gamma Rays	Z.Griffith	PeV scale gamma-ray events from IceCube & IceTop

SUMMARY

- Various event selection already exist in IceCube
- Pick an event selection best suited for your particular analysis
- If it doesn't exist yet, make your own!!

WELCOME

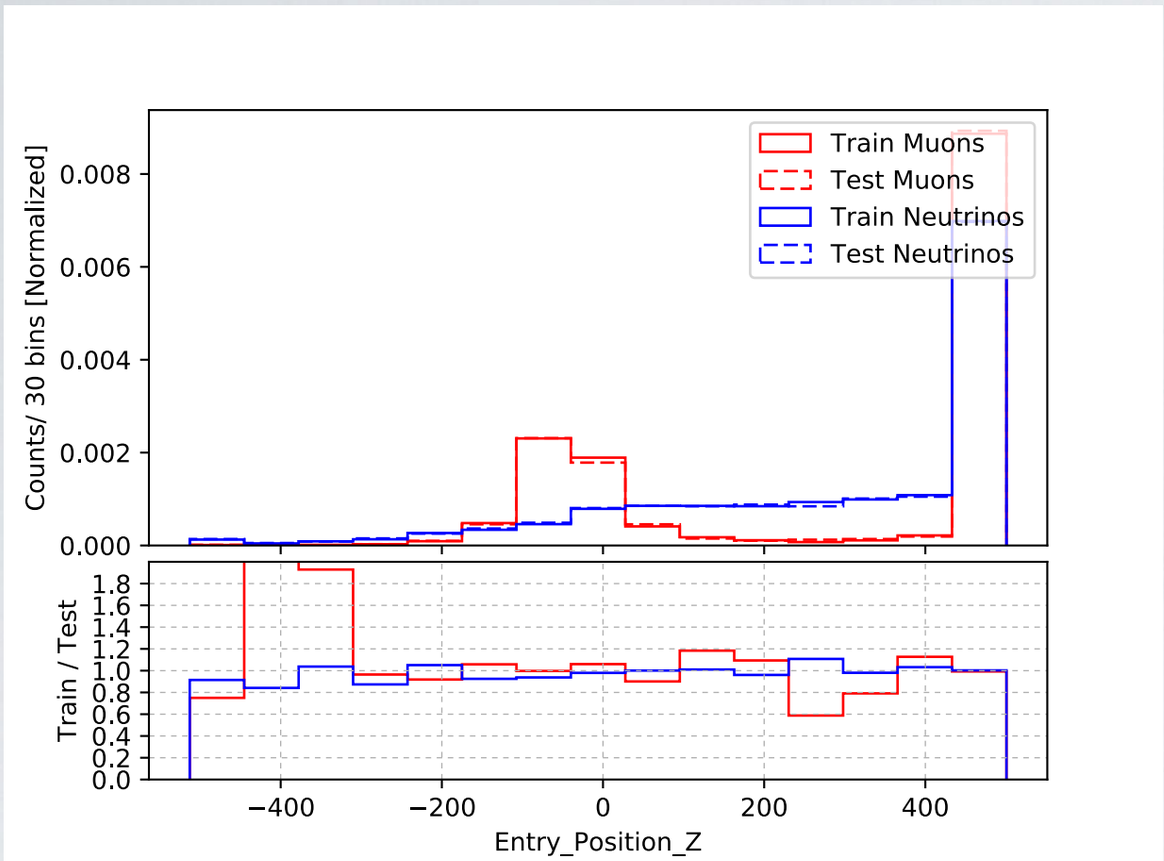
ESTES

- Use a Boosted Decision Tree (BDT) to minimize muons entering our final event selection

- Use 16 event properties as input to the BDT, in the end the BDT ranks them in order of "importance"

Z of entry position	Distance to from first millipede loss to edge (closest)	Fraction of energy in first millipede loss	Distance to edge along track	P_{miss} from segmented track calculation
Number of millipede losses	Total energy of millipede losses	Fraction of hits that are direct	Length of millipede losses	Millipede zenith angle
Fraction of charge on edge of detector	Number of fits tested in coarse search	LineFit speed	P_{miss} from Cherenkov calculation	Millipede ↔ LineFit space angle

ESTES



- Most important inputs according to the BDT shown here