DMICE-17 AS A MUON DETECTOR

8th October 2021

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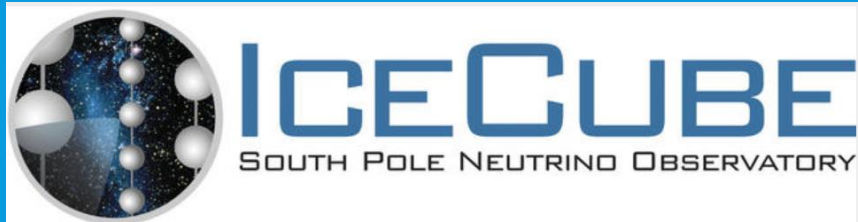
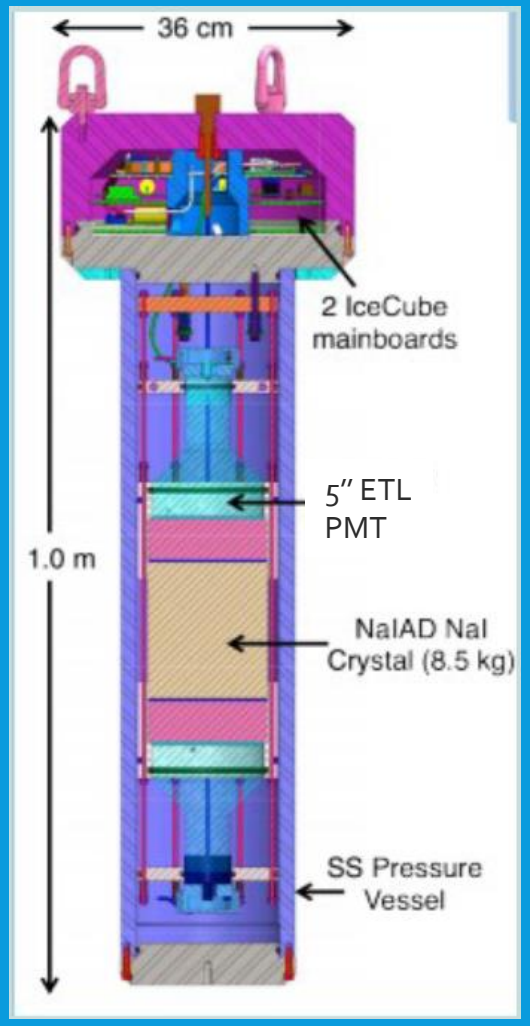


WHAT IS DMICE-17?



- A pair of modules suspended beneath IceCube strings 79 and 7
- Each comprises of a NaI(Tl) crystal (roughly 10cm x 10cm x 10cm) vertically surrounded by 2 PMTs
  - Sealed in a stainless steel canister, optically insulated from the ice
- Operating continuously since 2011

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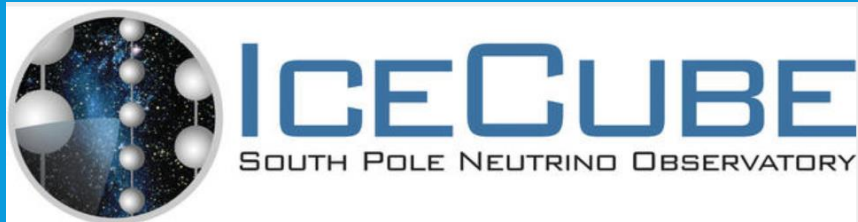
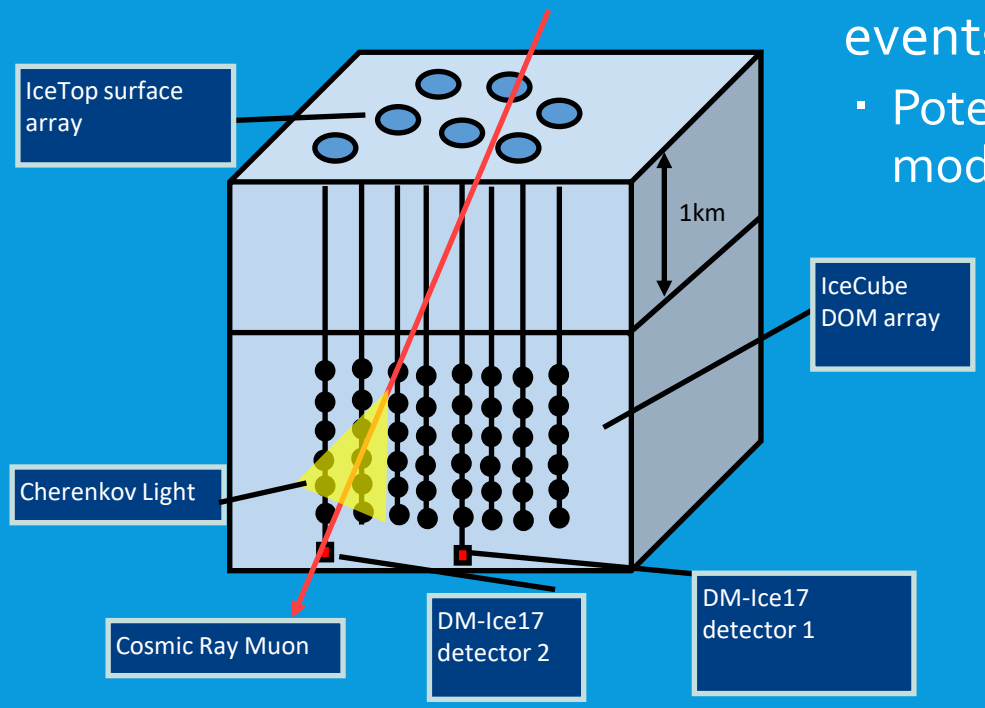
BRIEF HISTORY

- Original purpose was to detect yearly modulation in DM signal due to Earth's orbit
  - No luck
- Work done by Antonia Hubbard in 2015 to use DMIce-17 to detect non-DM particles, particularly muons
- Expand on her work to incorporate double the data sample and account for changes in DMIce-17 operation throughout the years



CURRENT GOALS



- Find coincidence sample between main polar detectors – IceCube, IceTop, and DMIce
- Aim to include DMIce-17 in reconstruction of track events
  - Potential improvement to angular resolution using most modern algorithms

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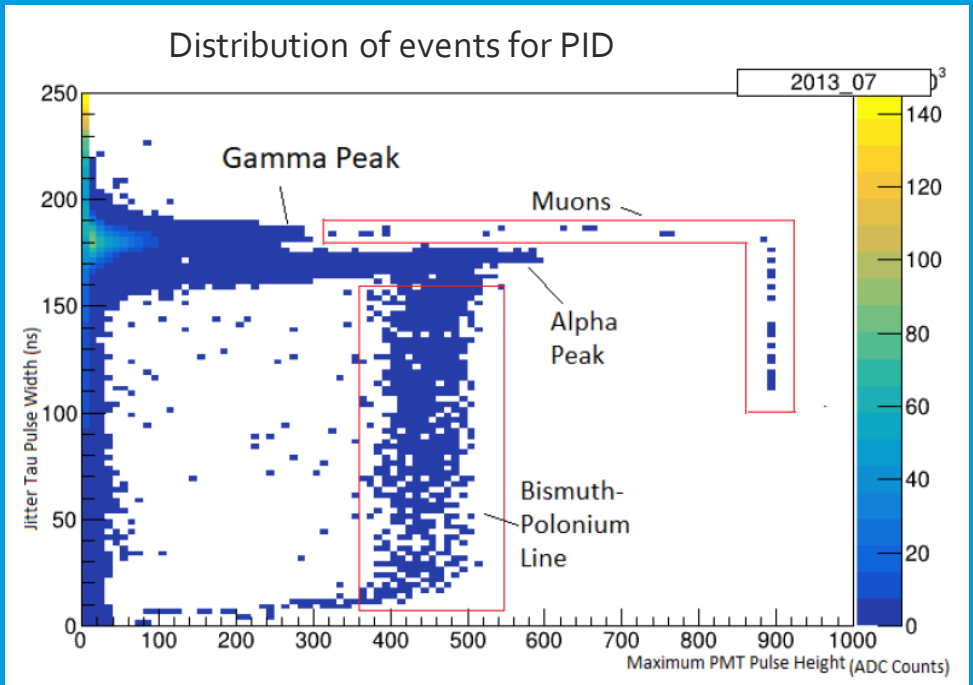
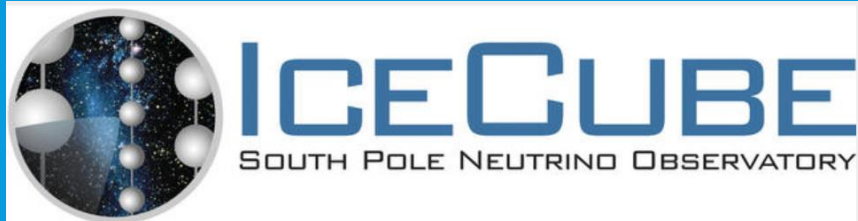
HOW TO USE AS A MUON DETECTOR

- Identify Minimally Ionising Particles (MIPs) from Pulse Shape Analysis of PMT waveform
- Compare width of pulse to maximum height to distinguish muons from main backgrounds



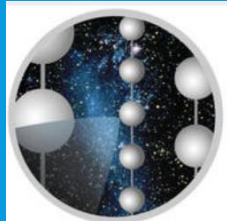
- A variety of hardware changes affect the exact method
  - Increase in PMT High Voltage in Detector 1
  - Change to OmicronDAQ in 2016
- Should be accounted for by new processing chain



LOCALISATION

- Muon travelling through ice produces a spray of secondary particles
- Electrons from this can travel some distance and potentially trigger a response in DMIce-17 which will pass our muon cut
- Current simulation work undergoing, but electron should be within O(~m) of parent muon

- Any cosmic ray we see in DMIce is well localised to a surrounding volume of O(m)



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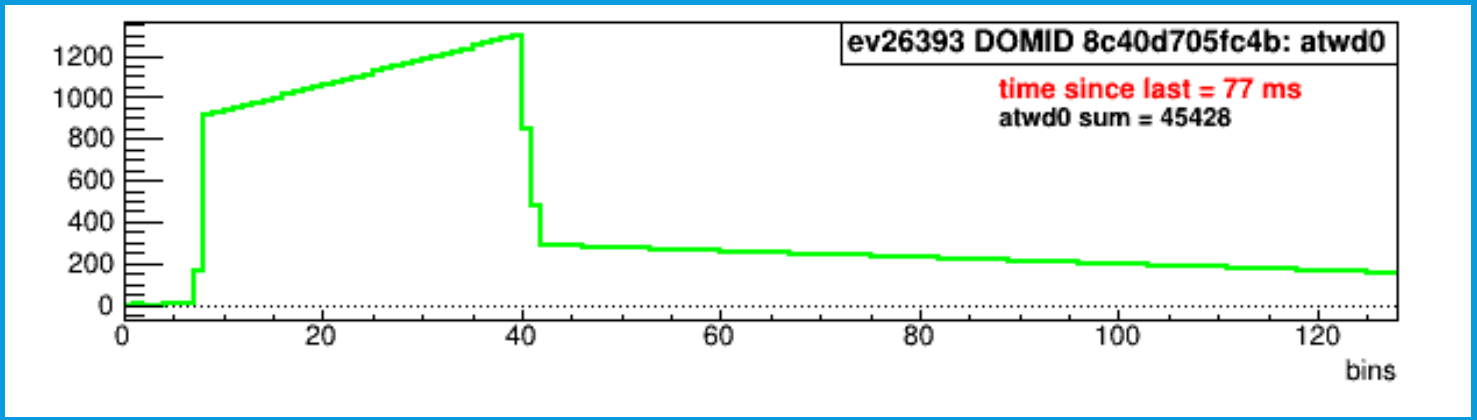
DOES ALL THIS ACTUALLY WORK?

- Each module sees sees roughly~90 hits a month (Gives ~20000 total muons)
- Unfortunately, no direction or energy reconstruction available natively from DMIce-17
- Current dataset runs from May 2011 to May 2021



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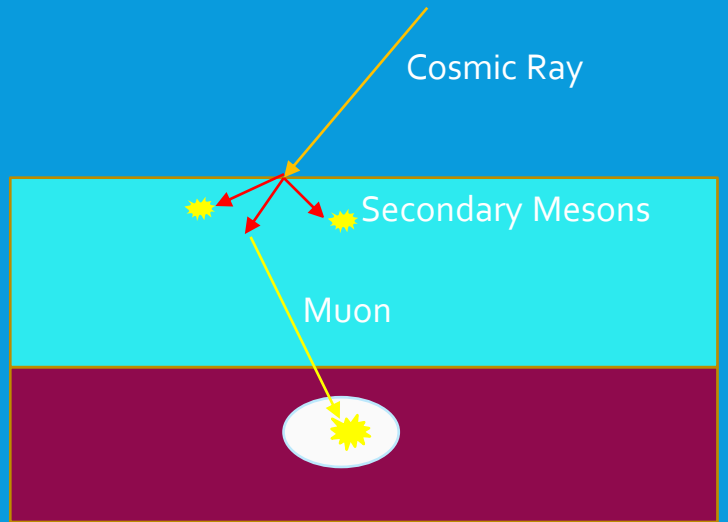
ATMOSPHERIC COSMIC RAY MODULATION - ORIGIN

- Muons are produced from decay of cosmic ray generated pions
  - Pions which interact directly with the atmosphere produce less muons
- In summer months, the atmospheric temperature is warmer, and thus the density is lower.
  - Lower density -> Fewer interactions -> More pions decay to muons
- We expect to see a sine wave which peaks in Antarctic summer



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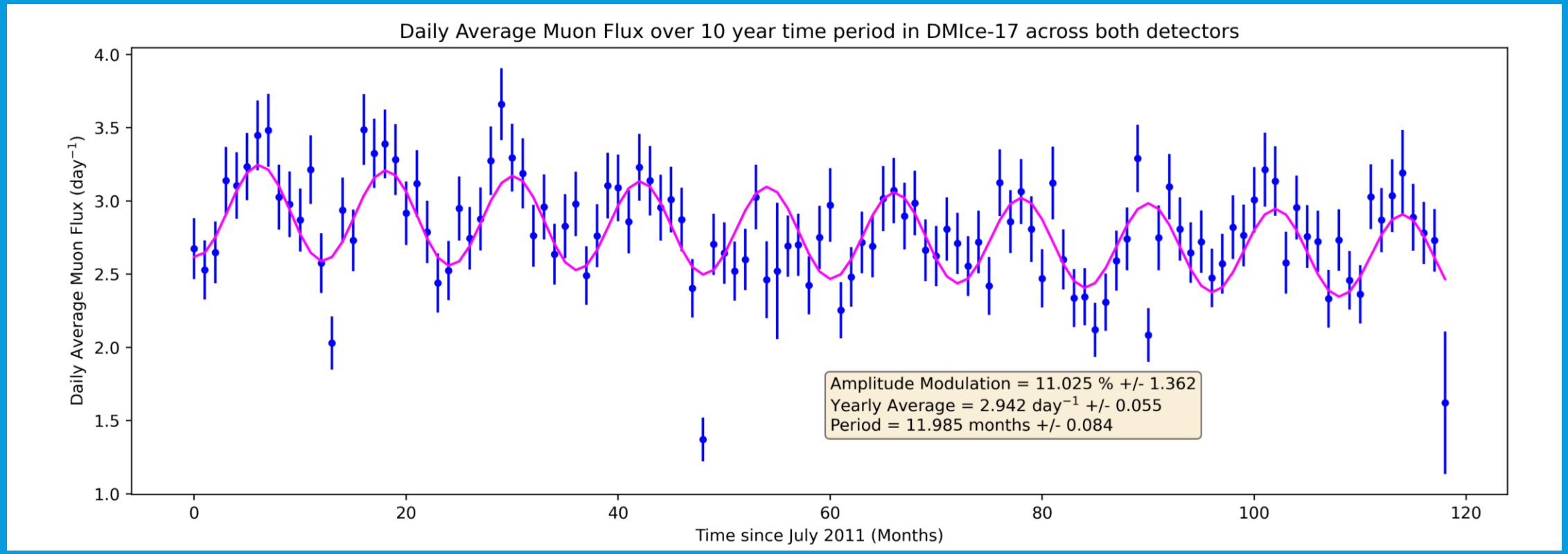
COMBINED DMICE-17 FLUX



Good behaviour! Minima in Winter, 12 month period, modulation of ~11%

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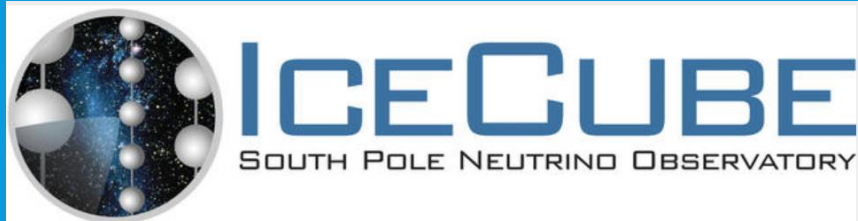
EQUATION FOR TEMP COMPARISON

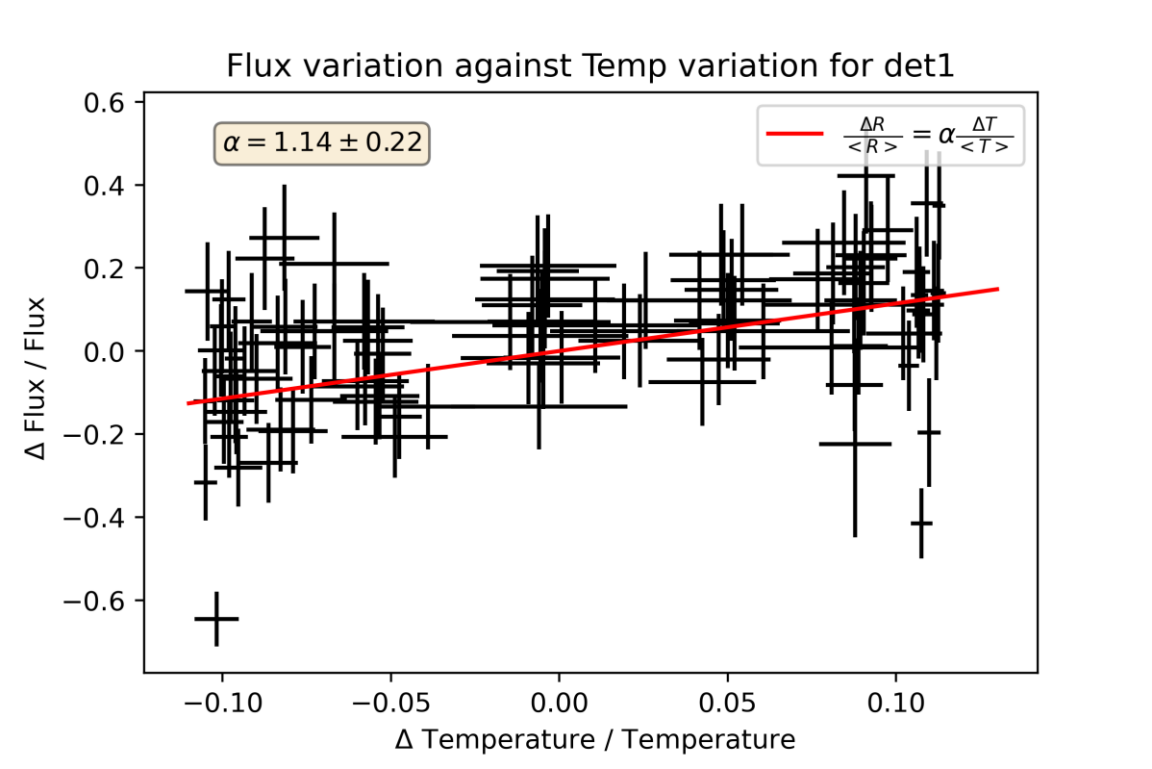
- Flux should increase linearly with Temperature variations
- Model with a simple equation

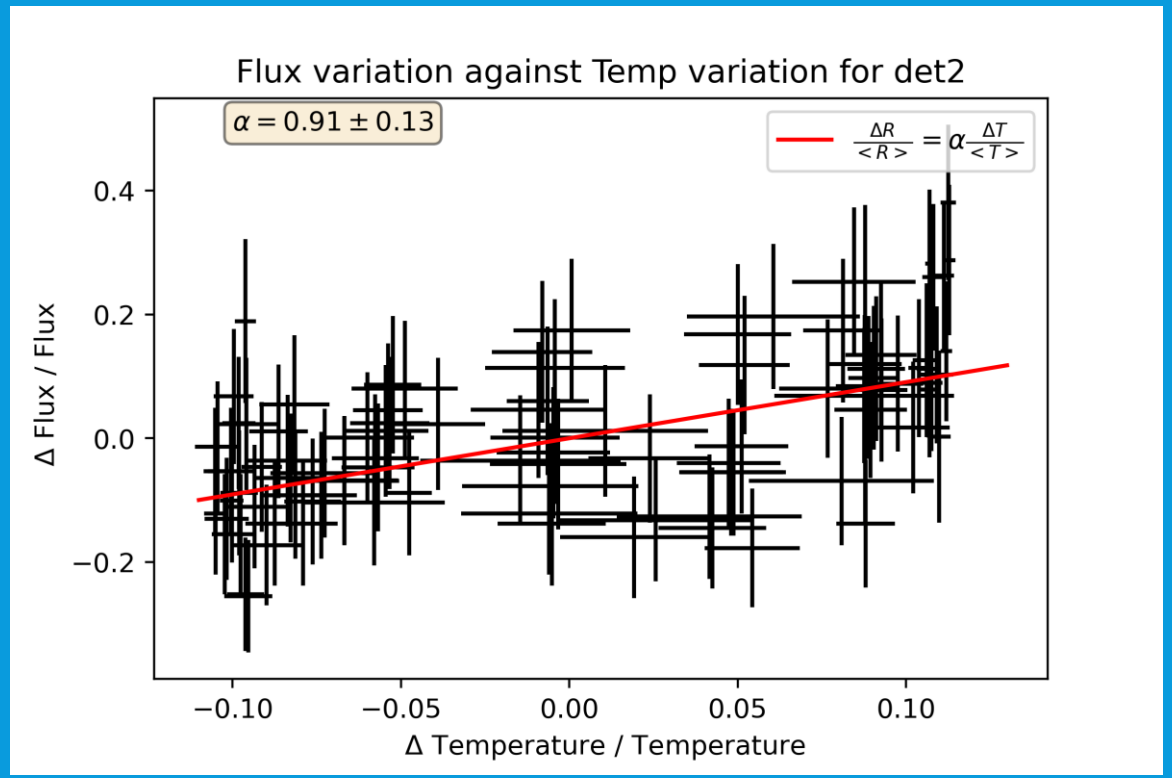
$$\frac{R(t) - < R >}{< R >} = \alpha \frac{T(t) - < T >}{< T >}$$

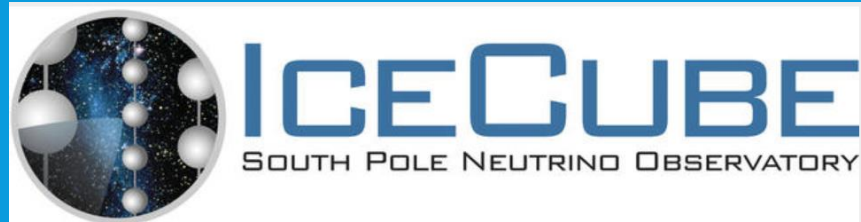
- Use Temperature data from Tom Gaisser and plot for each detector



TEMP FLUCTUATION



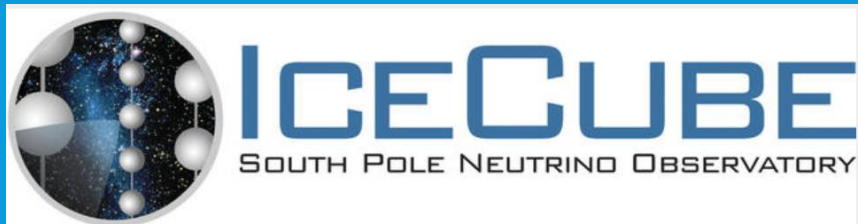




PROCESSING WITH ICECUBE

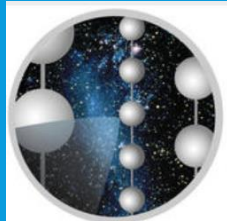
- Due to their separate origins, DMIce is not currently included in any inbuilt analysis or filters within IceCube

- We find coincident events based on time coincidence with reconstructed event start time
  - For a given DMIce-17 event, an IceCube event is labelled as coincident if it occurs within [-6, +1] μs.
- We then use IceTray to extract relevant data on the cosmic ray
  - Currently using MPEFit, other reconstructions may be available



HOW MANY COINCIDENCES?

- Low statistics – 4.2% of DMIce events coincident across both detectors using muonfilter
  - Detector 1 in much larger proportion (6.8%) than det2 (1.9%) due to position within IceCube
- Screen any with reconstructed zenith > 90˚, energy < 100 GeV



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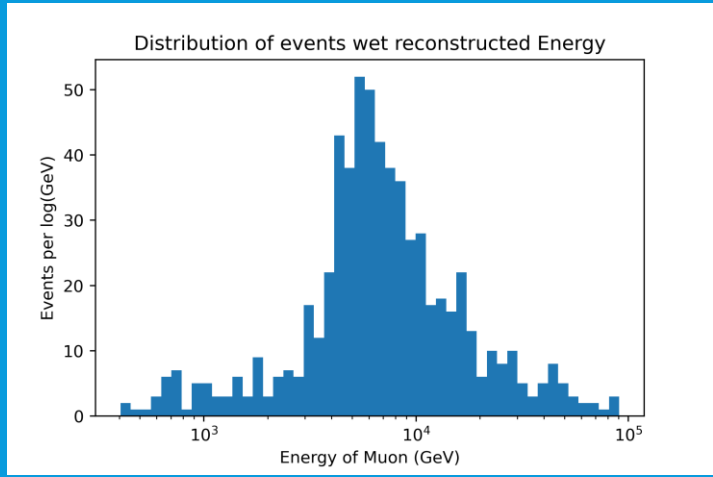
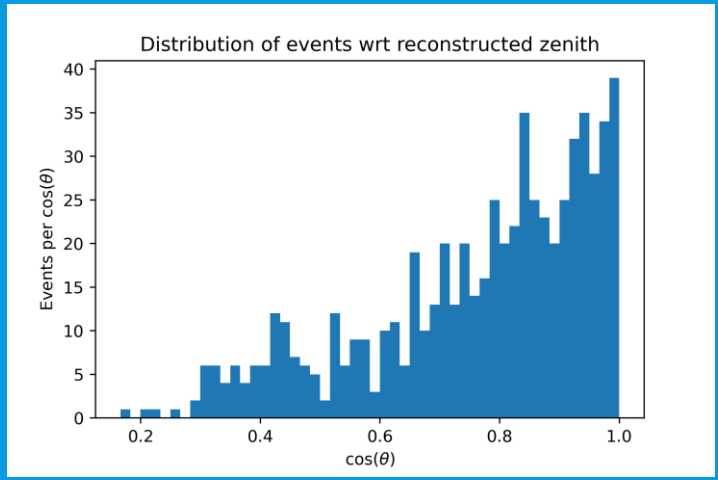
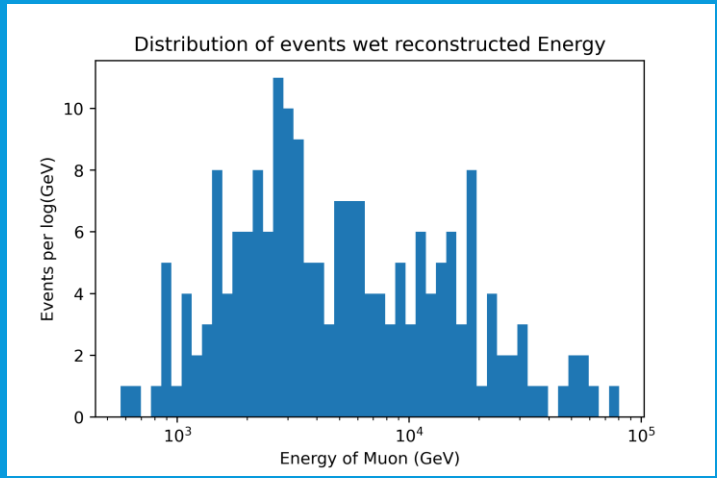
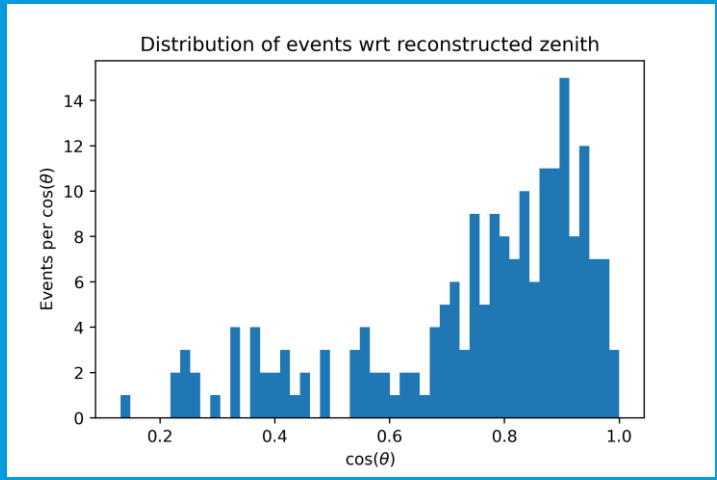
COINCIDENCE DISTRIBUTIONS





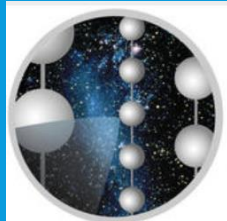
Detector 1 (Left)
Detector 2 (Right)





LIMITATIONS + ADVANTAGES

- Low statistics compared to, say, IceCube
  - Low granularity in flux plot – Yearly seasonal flux is the best you can do
- PID cuts have high, but not perfect efficiency
  - Antonia estimated ~ 3 gamma/year/detector (out of 1000)
- DMIce-17, due to large overburden, preferentially selects a higher energy of muon than most other detectors



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FUTURE WORK – PERSONAL AND BEYOND

- Explore reconstructive algorithms with / without DMIce location data
- Potential results of coincidence with IceTop – initial results show very low statistics
- Matt Kauer looking into integrating DMIce-17 fully into pDAQ
  - Would make coincidence searches easier for everyone
- COSINE-100 project expanding work looking for Dark Matter
- Potential to include more DMIce like modules in the upgrade, if reconstruction work proves promising

THANKS FOR LISTENING!

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