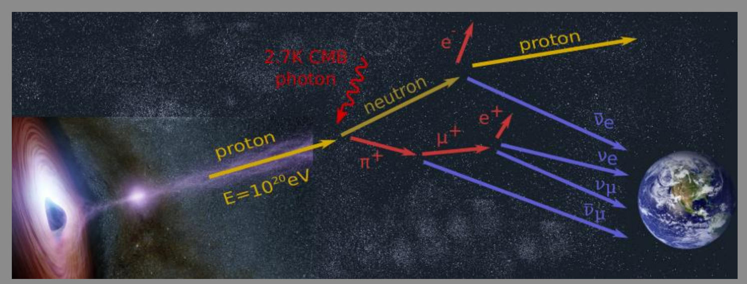
The Development of the UHE Neutrino Telescope for EUSO-SPB2

Eliza Gazda, Mahdi Bagheri, Chaoxian Lin, **Nepomuk Otte**, Oscar Romero Matmala, Andrew Wang

Objectives

- Development of an air shower imaging system for ultra-high energy (UHE) neutrino detection
- Study air-shower imaging techniques at high altitudes

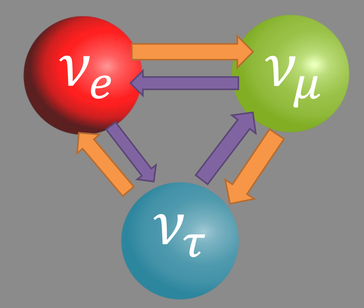
Motivation and Science



Composition of ultra-high energy cosmic rays

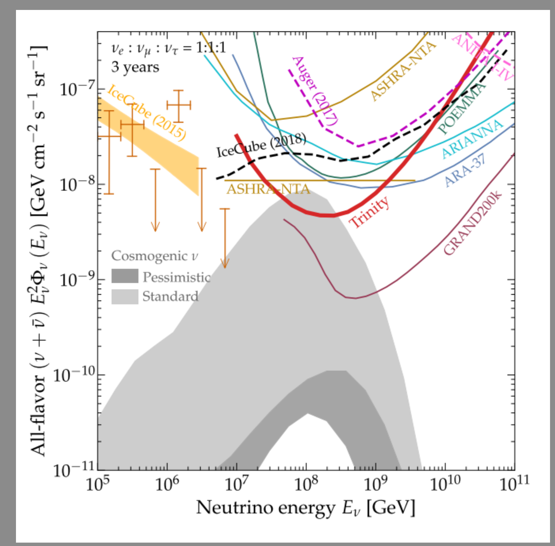
- UHE neutrinos are produced through interaction of UHECR with CMB photons
- Protons produce more UHE neutrinos (GZK mechanism)
- Heavy elements produce fewer UHE neutrinos (photodisintegration)

Neutrino flavor mixing: Earth skimming method is only sensitive to Tau neutrinos



Astrophysical Neutrinos

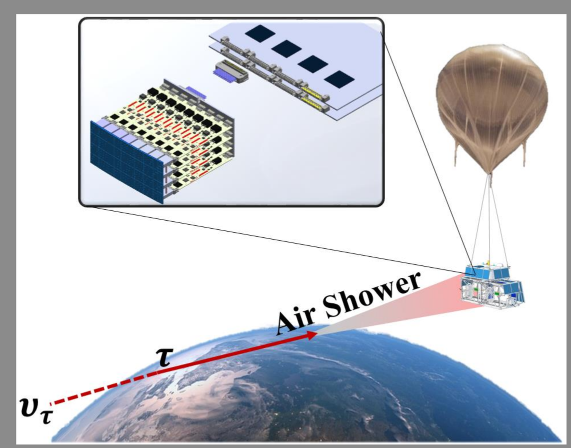
- IceCube detected astrophysical neutrino flux at higher energies
  - Spectral shape and flux levels help identity and exclude source classes
  - Possible detection of sources instrument
- Cherenkov astrophysical-neutrino telescope (CHANT) proposal discusses the technique to increase of acceptance to detect UHE neutrinos[1]
- Claimed detections by ANITA



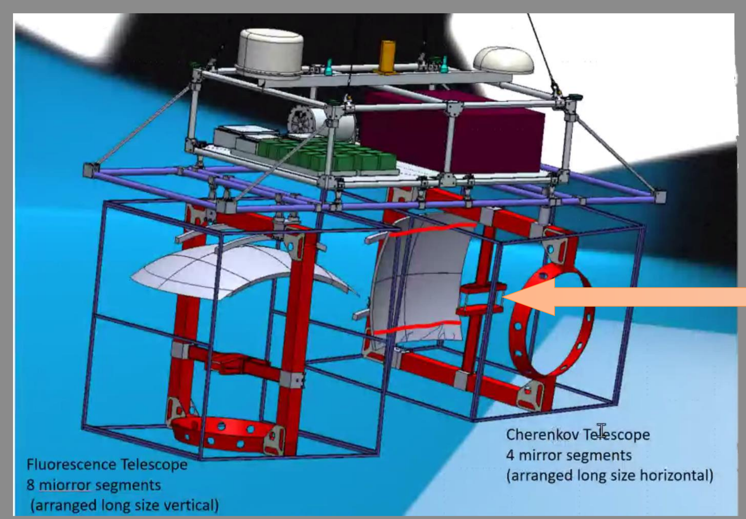
Sensitivity calculations of a CT on ground (Trinity) and satellite (POEMMA) [2]

Air Shower Imaging Technique

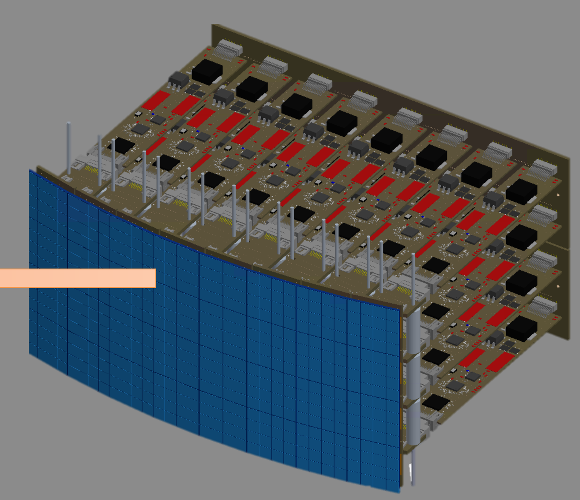
- **Earth Skimming Technique :** Tau neutrino enters Earth at a shallow angle, interacts and produces a Tau
- Tau emerges from Earth and decays in the atmosphere and produces an air shower
- Charged particles from the air shower emit Cherenkov radiation detected by the imaging telescope



Mechanical Structure and Camera



Preliminary design of telescope structure including mounting to gondola



Cherenkov camera. SiPM (blue), Front-end electronics attached to the back

Optical Characteristics

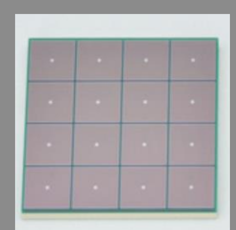
- Schmidt telescope
- Bi-focal optics with offset 0.8° (2 pixels)
- Field of View 12.8°x6.4°
- 0.7m^2 total collecting aperture

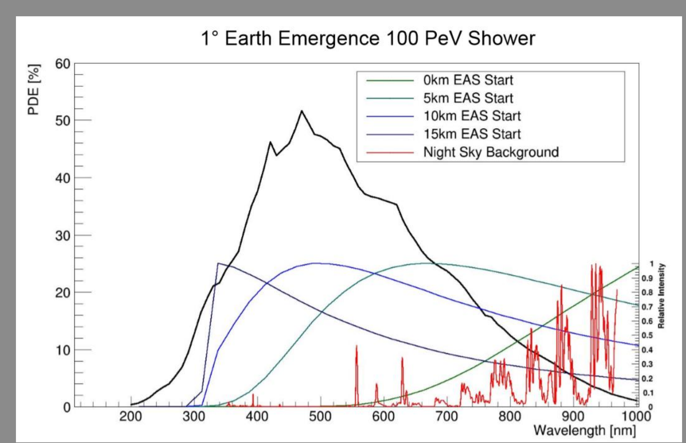
Camera

- 512 pixels
- pixel size: 6mmx6mm

Silicon Photomultiplier (SiPM)

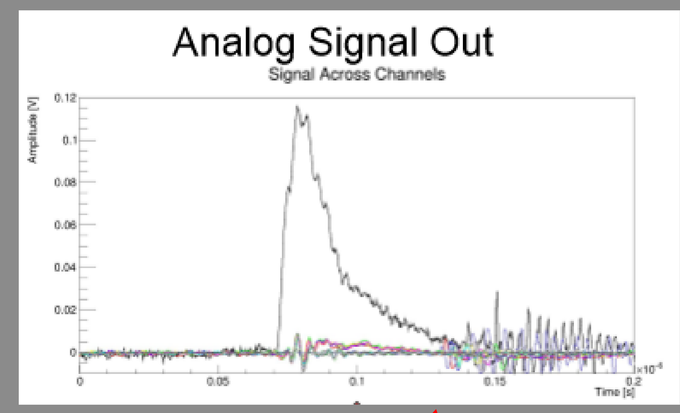
Photon detection efficiency of the red sensitive Hamamatsu SiPM S14521

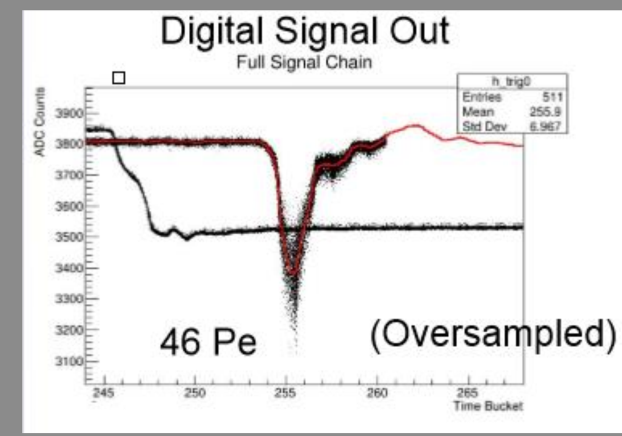


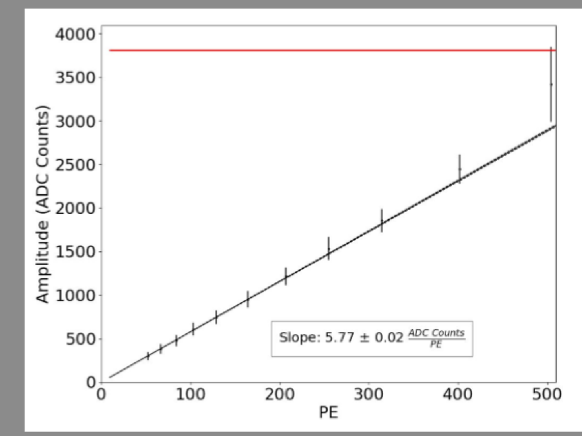


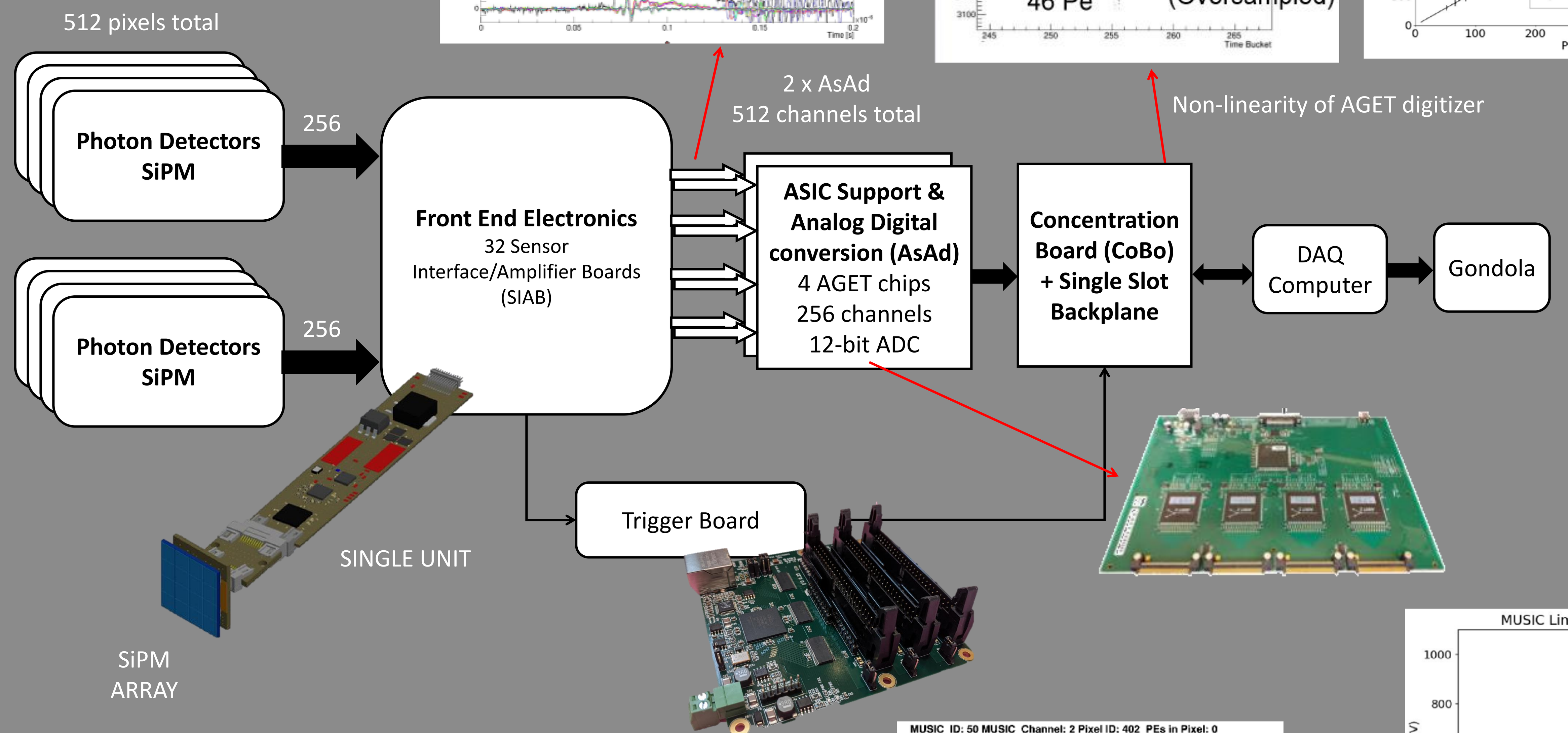
Black: PDE of SiPM

Signal Chain



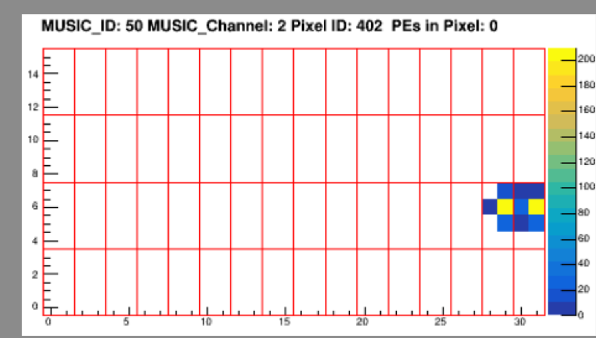




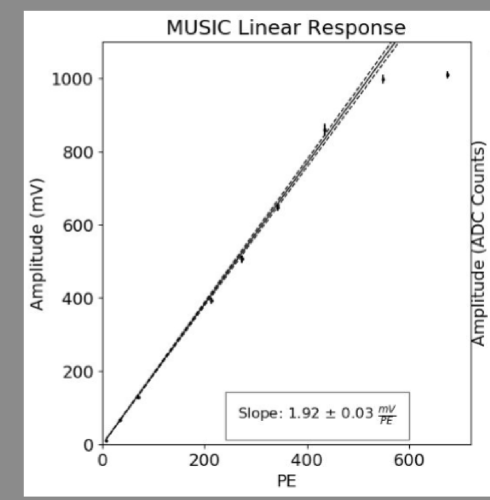


Camera Readout

- SiPM are in 4x4 array (16 pixels per SIAB unit)
- 8 pixels in array connect to a MUSIC chip [3]
  - Amplification and shaping of signals
  - Discrimination of all pixels
- Trigger logic: coincidence between neighboring MUSIC chips



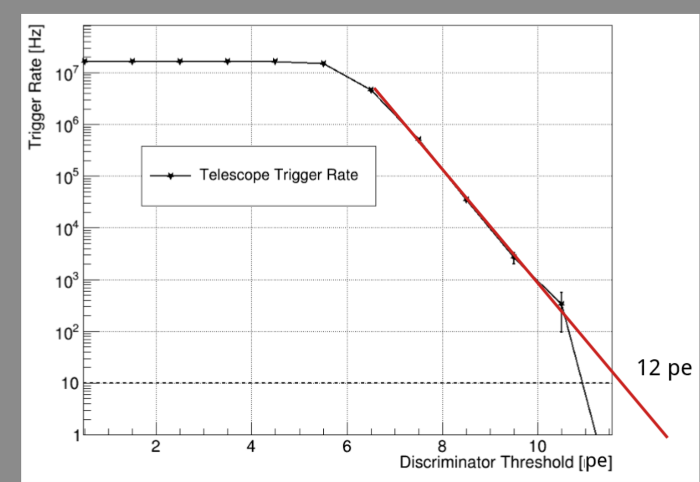
Trigger Logic



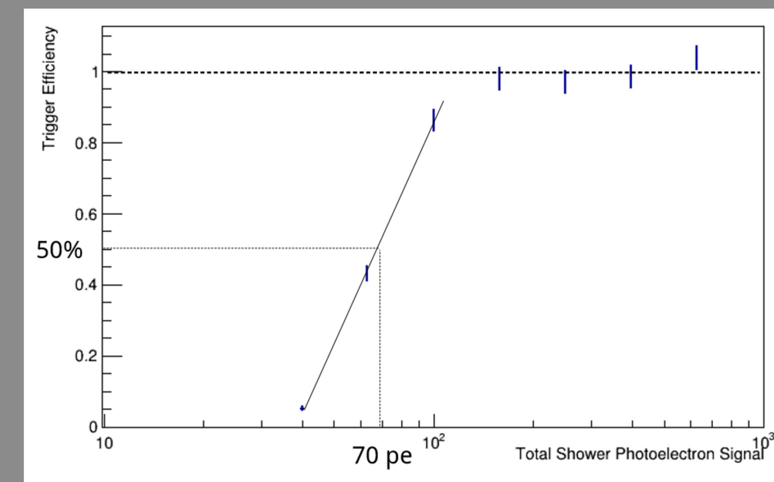
Linearity of MUSIC chip

Trigger-Bias Curve

- We set discriminator threshold at 10Hz and determine the trigger efficiency
- Parameters for Triggering:
  - Photon detection efficiency of SiPM
  - Point spread function of optics
  - Night sky background
  - Event frequency



Bias Curve shows we can read 12pe at 10Hz



Trigger Efficiency

Status and Conclusions

- Design of front-end electronics complete, prototype is under evaluation
- Design of mechanical structure and integration with telescope is in progress
- Verified entire signal chain from end to end
- Anticipated completion of camera by end of 2020
- Telescope integration and testing in 2021
- Expected flight is in 2022 from Wanaka, New Zealand with target duration of 100 days
- SPB2 mission will lay out the groundwork for building future telescopes such as POEMMA

References:
[1] Neronov, Andrii & Semikoz, Dmitri & Anchordoqui, Luis & Adams, James & Olinto, Angela. (2017). Sensitivity of a proposed space-based Cherenkov astrophysical-neutrino telescope. Physical Review D. 95. 10.1103/PhysRevD.95.023004.
[2] Otte, Adam. (2019). Studies of an air-shower imaging system for the detection of ultrahigh-energy neutrinos. Physical Review D. 99. 10.1103/PhysRevD.99.083012.
[3] Sergio Gómez , David Gascón, Gerard Fernández, Andreu Sanuy, Joan Mauricio, Ricardo Graciani, David Sanchez, "MUSIC: An 8 channel readout ASIC for SiPM arrays," Proc. SPIE 9899, Optical Sensing and Detection IV, 98990G (29 April 2016); https://doi.org/10.1117/12.2231095
This research is supported by NASA grant 80NSSC19K0627

Neutrino2020
Contact: egazda6@gatech.edu