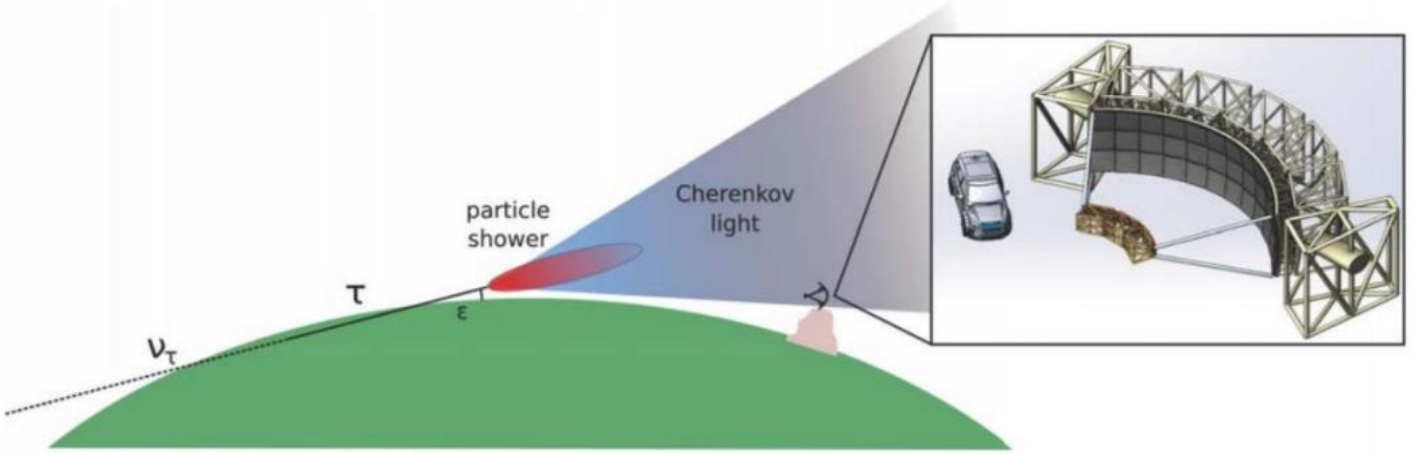
Trinity: An Imaging Air Cherenkov Telescope to Search for Ultra-High-Energy Neutrinos



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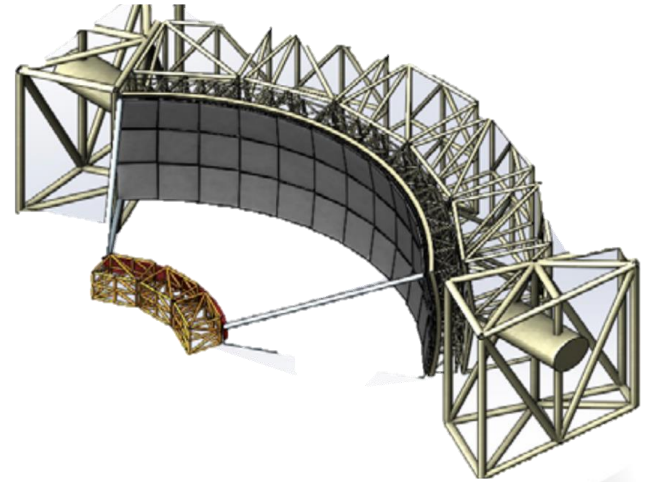
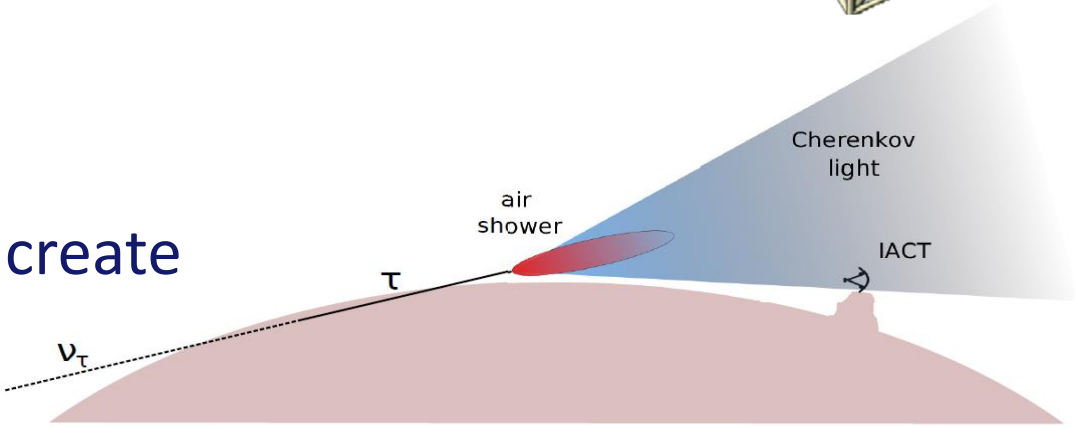
What is Trinity?

- Trinity is a proposed 18 telescope-strong network of dedicated Imaging Air Cherenkov Telescopes (IACTs) optimized to detect Earth-skimming tau neutrinos.
- Trinity will build on the rich heritage of IACTs, but also take of new technology designed for CTA & EUSO-SPB to reduce costs and improve sensitivity.
- Collaboration of US-UK-IT institutes.
- Currently in the design phase.
- NSF funding has recently been awarded to create a demonstrator system.



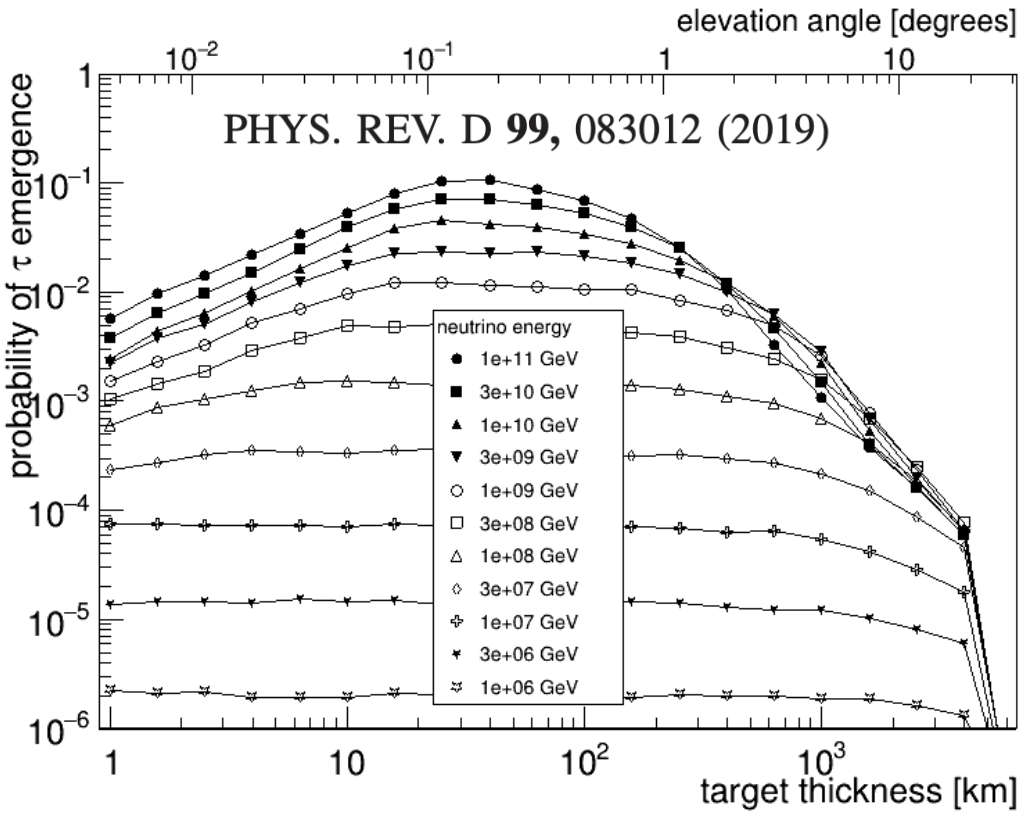


PHYS. REV. D **99,** 083012 (2019)

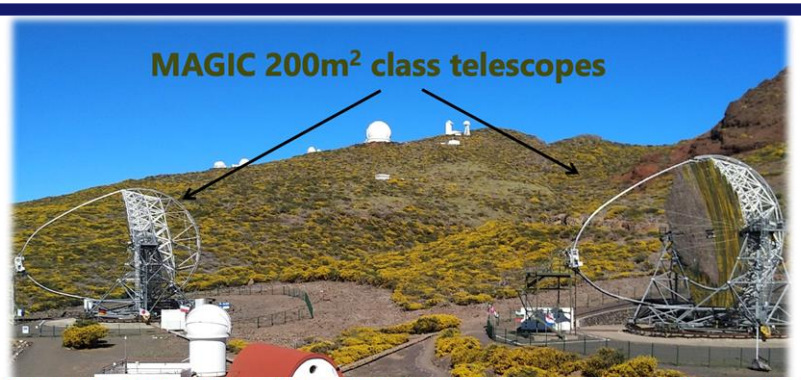
Earth-skimming tau neutrinos

- 1-10^4 PeV (UHE) tau neutrinos can pass through hundreds of km of bedrock, with a high probability that a tau lepton emerging before it decays
- Tau decays initiates an up-wards going air-shower
- A wide FoV IACT can image the Cherenkov radiation from this air shower to infer the presence and energy of the original tau neutrino

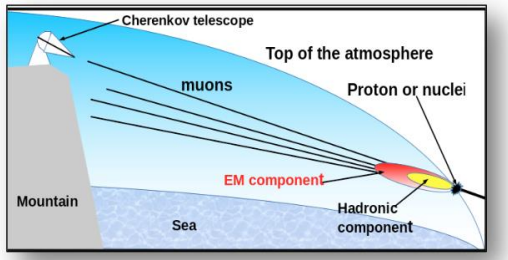
Decay	Secondaries	Probability	Air-shower
$\tau \to \mu^- \bar{\nu}_\mu \nu_\tau$	μ^-	17.4%	weak showers
$\tau \to e^- \bar{\nu}_e \nu_\tau$	e^-	17.8%	1 Electromagnetic
$\tau \to \pi^- \nu_\tau$	π^-	11.8%	1 Hadronic
$\tau \to \pi^- \pi^0 \nu_\tau$	$\pi^-, \pi^0 \to 2\gamma$	25.8%	1 Hadronic, 2 Electromagnetic
$\tau \to \pi^- 2\pi^0 \nu_\tau$	$\pi^-, 2\pi^0 \to 4\gamma$	10.79%	1 Hadronic, 4 Electromagnetic
$\tau \to \pi^- 3\pi^0 \nu_\tau$	$\pi^-, 3\pi^0 \to 6\gamma$	1.23%	1 Hadronic, 6 Electromagnetic
$\tau \to \pi^- \pi^- \pi^+ \nu_\tau$	$2\pi^-, \pi^+$	10%	3 Hadronic
$\tau \to \pi^- \pi^+ \pi^- \pi^0 \nu_\tau$	$2\pi^-, \pi^+, \pi^0 \to 2\gamma$	5.18%	3 Hadronic, 2 Electromagnetic

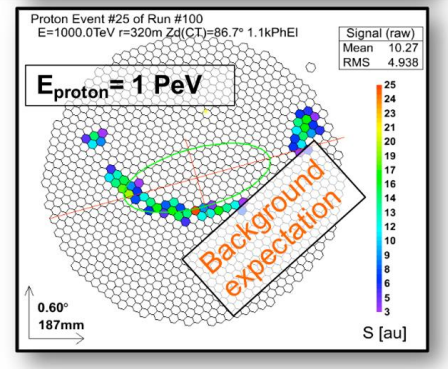


Past efforts with imaging telescopes

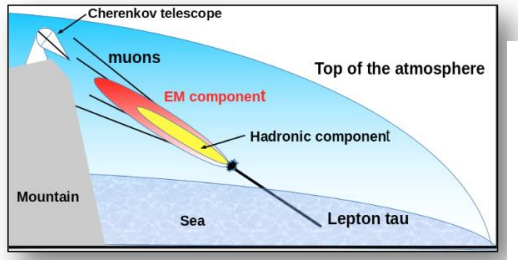


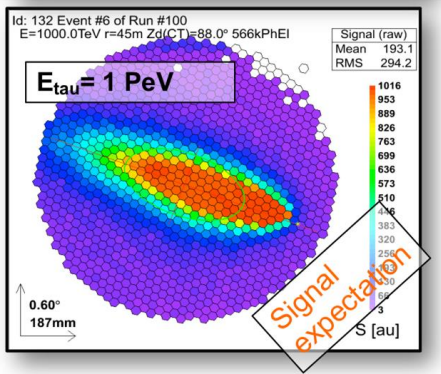
Proton injected at the top of the atmosphere
(~800 km to the detector for 87°)

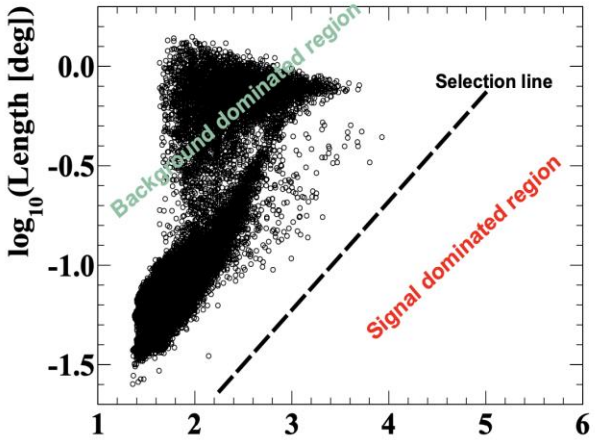


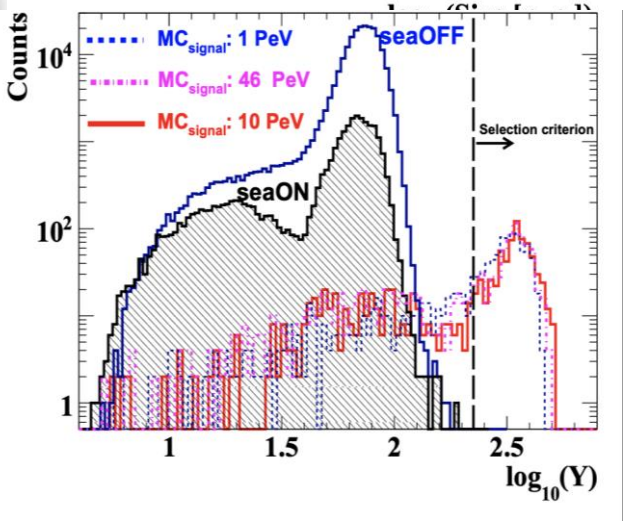


Deep tau-induced shower
(~50 km to the detector)









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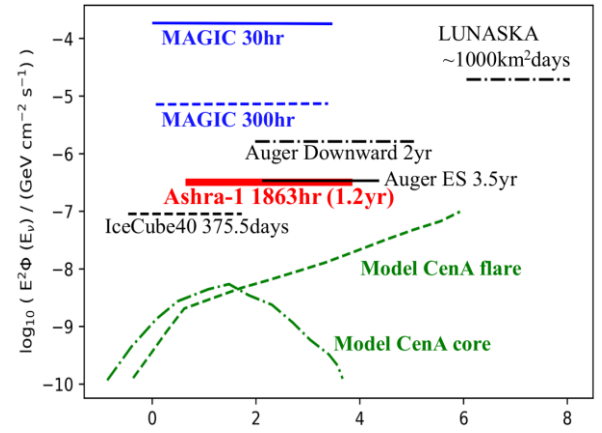
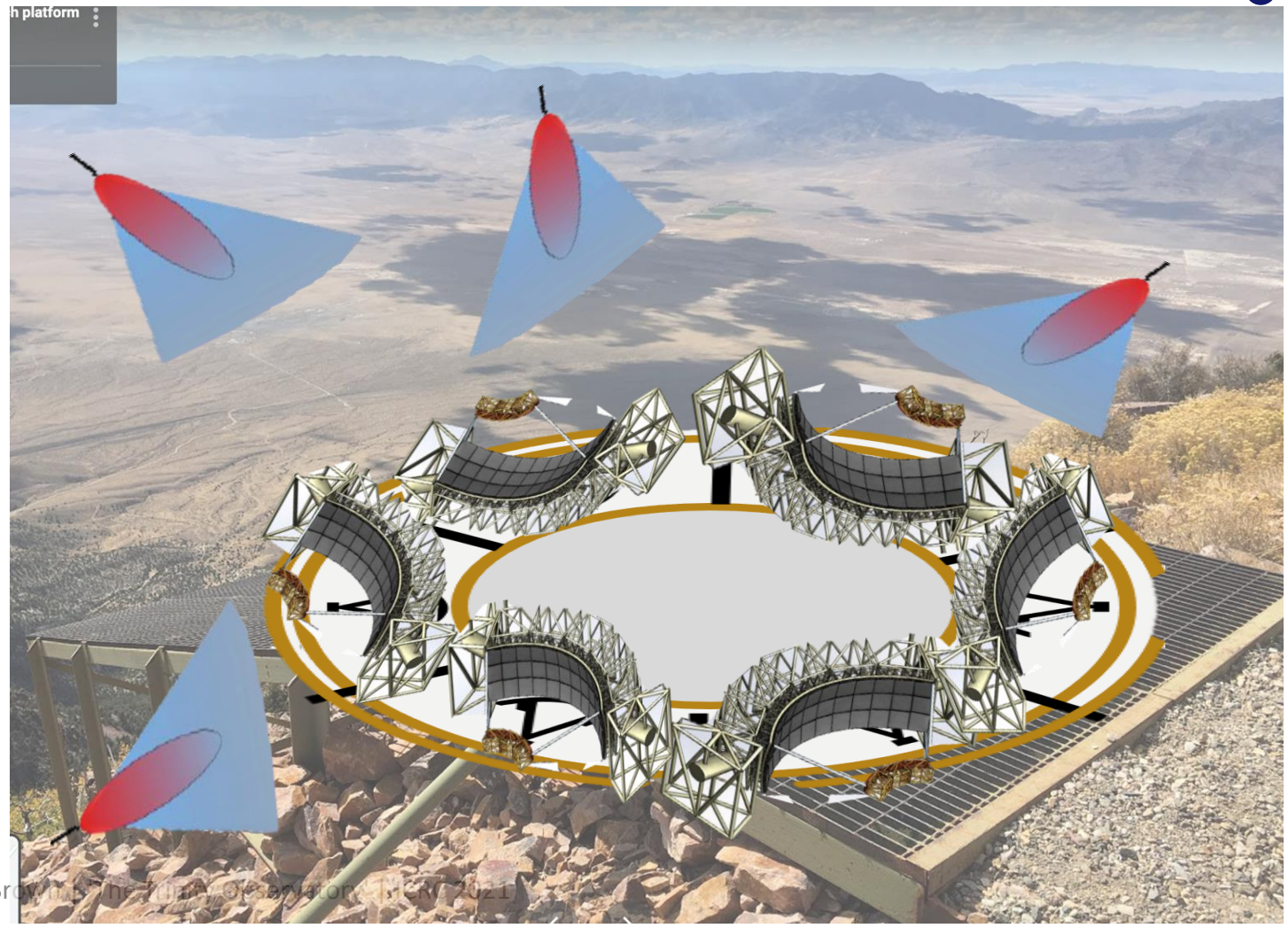
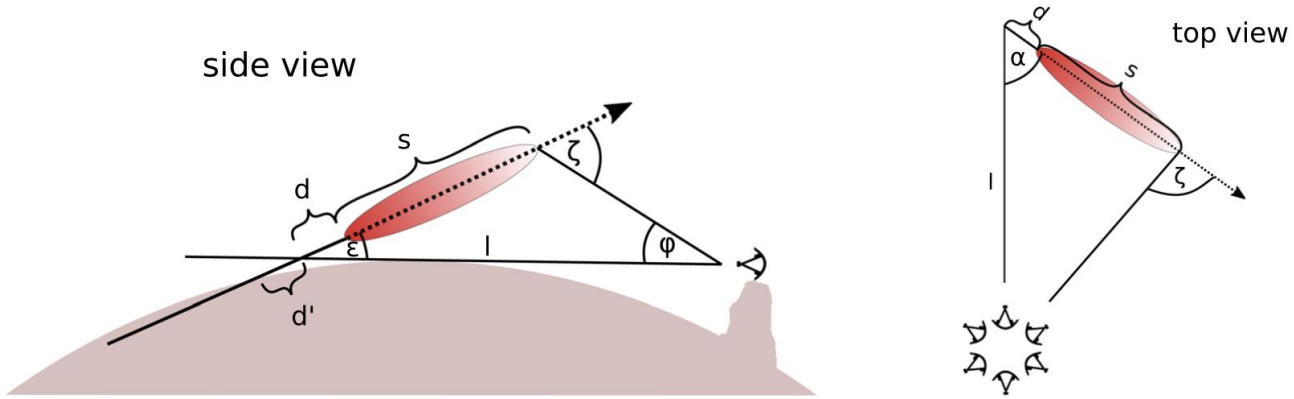


Recipe for Trinity

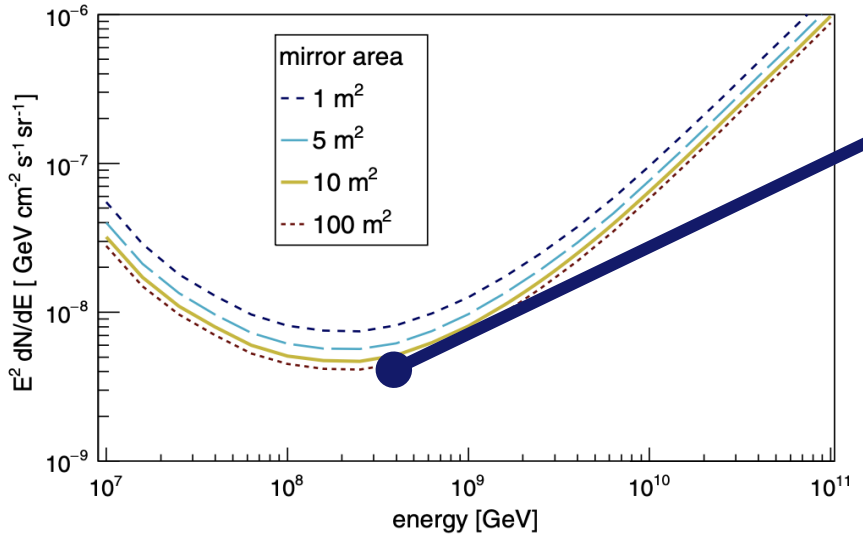
- Array of 6 wide FoV telescopes
- Place on a mountain peak
- Arranged in a circle
- Covering the entire horizon
- Operate at night (1200 h/y)
- Operate remotely
- Goal to have 3 Trinity site (the first of which will be Fresno peak, Utah)



Telescope size & altitude

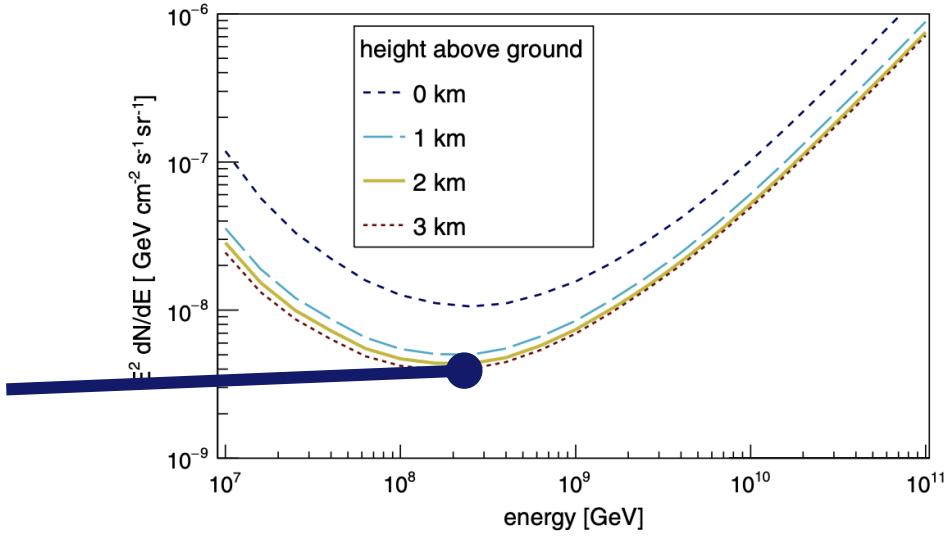


- Simulations with Corsika and NuTauSim (Phys. Rev. D 97, 023021)
- See Otte, 2019, PRD, 99, 083012 for more details

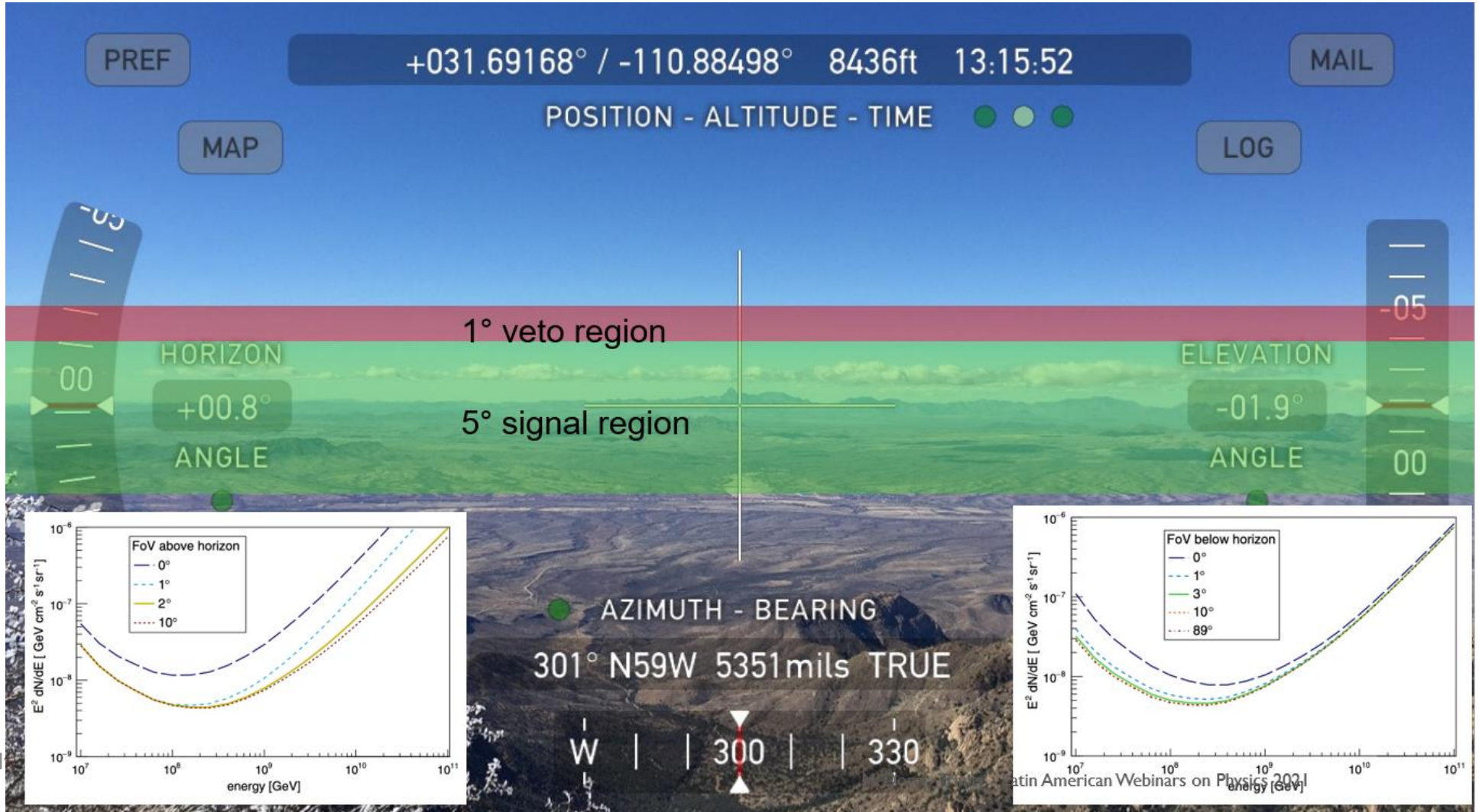


Don't need a big mirror area

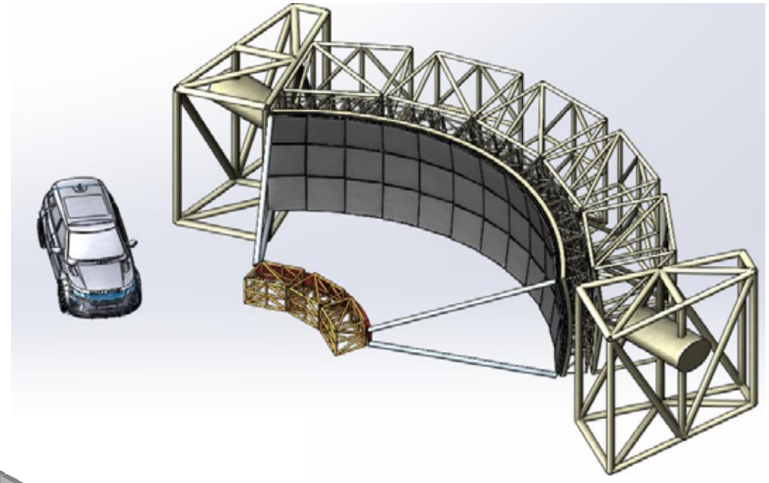
Don't need to go to high altitudes

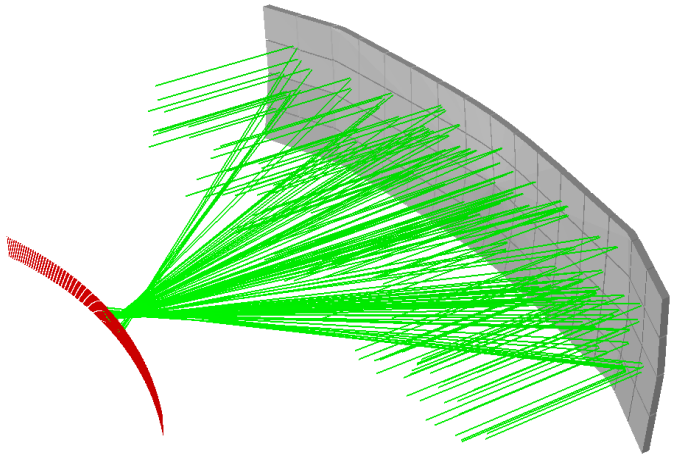


View of the horizon…



Telescope OSS





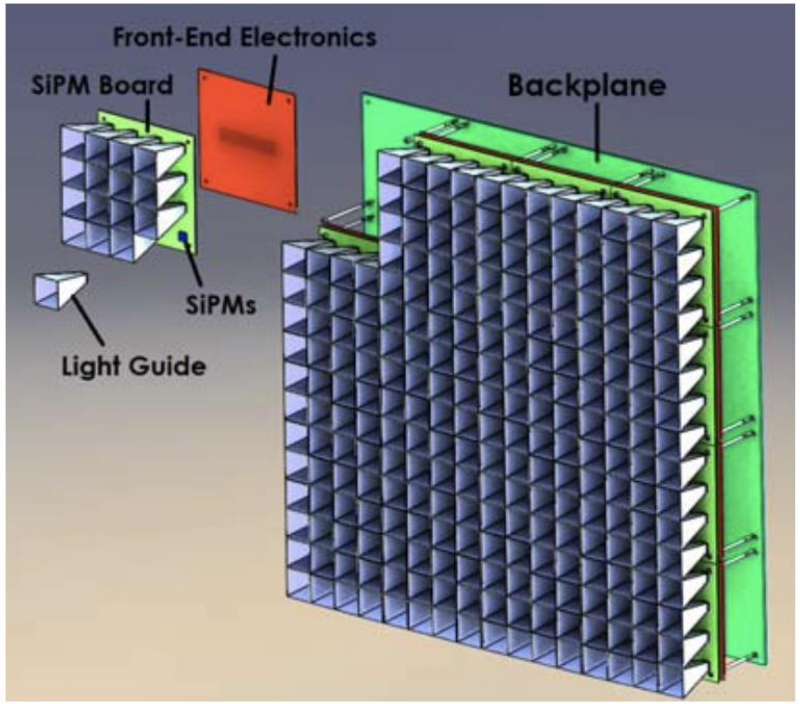
ROBAST sims.

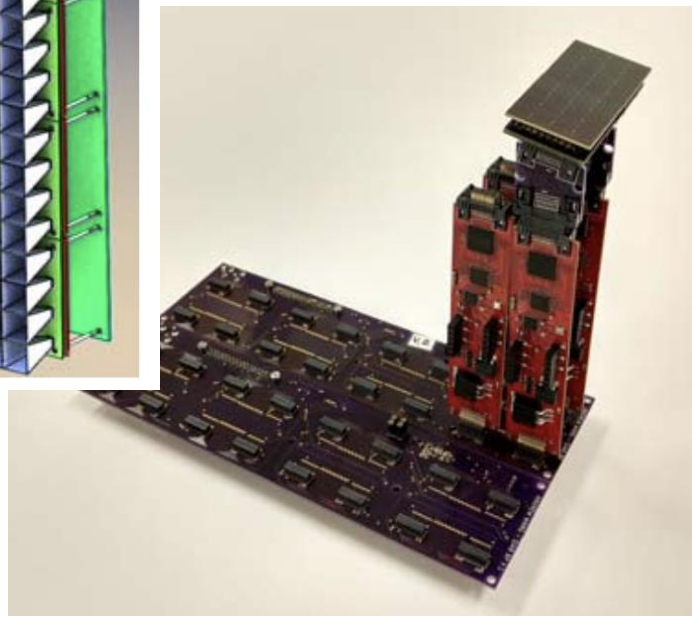
- Spherical mirror profile.
- Focal length ~4.2m.
- 0.3 deg. angular resolution.
- 60 deg x 5 deg FoV.
- 12 x 3m total mirror area.
- Fixed in azimuth.
- Movement in elevation only.

Preliminary drawing at INFN-DFA Padova

Camera

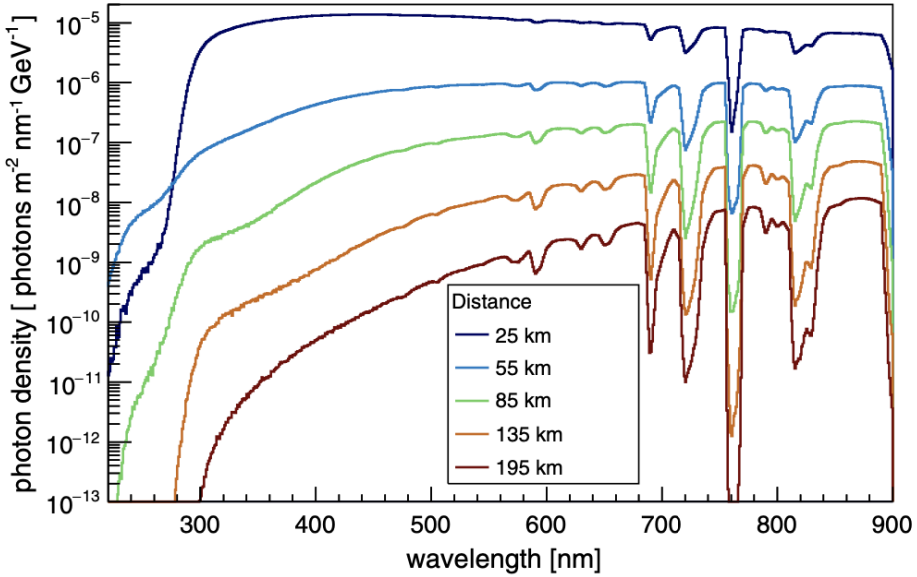
- Camera based upon the EUSO-SPB2 Cherenkov telescope
  - PMMA light guide
  - 3300 SiPMs (from CTA development)
  - MUSIC ASIC
  - AGET digitizer (from EUSO-SPB2)



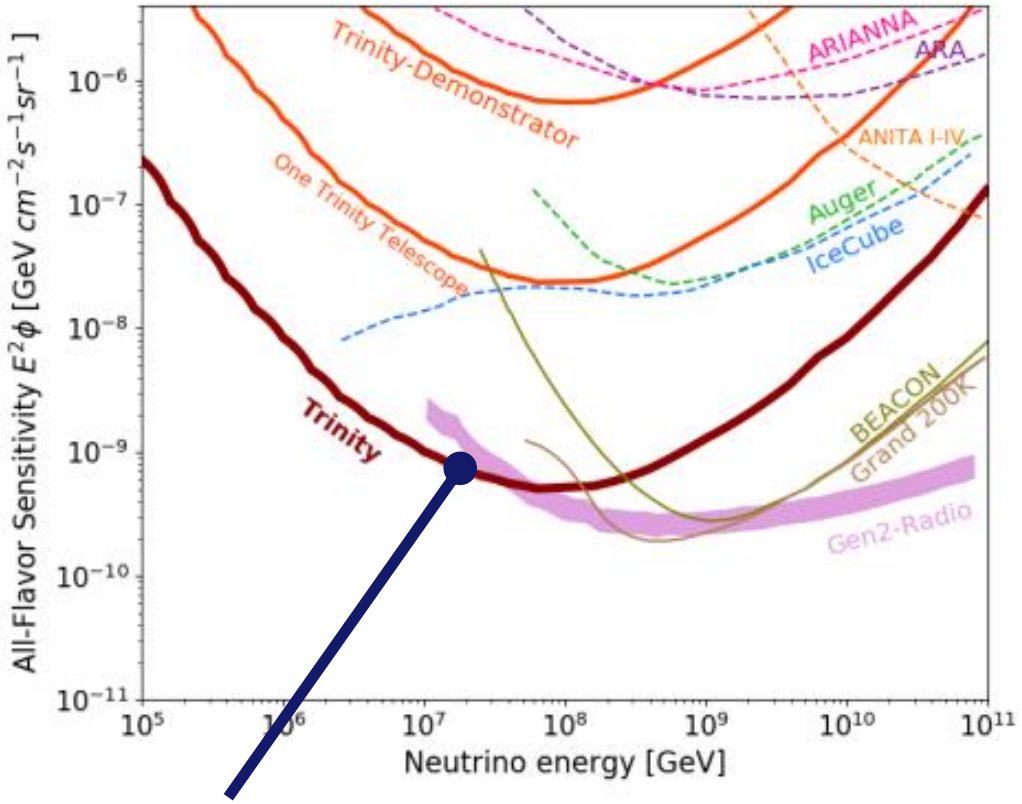


Atmospheric Calibration

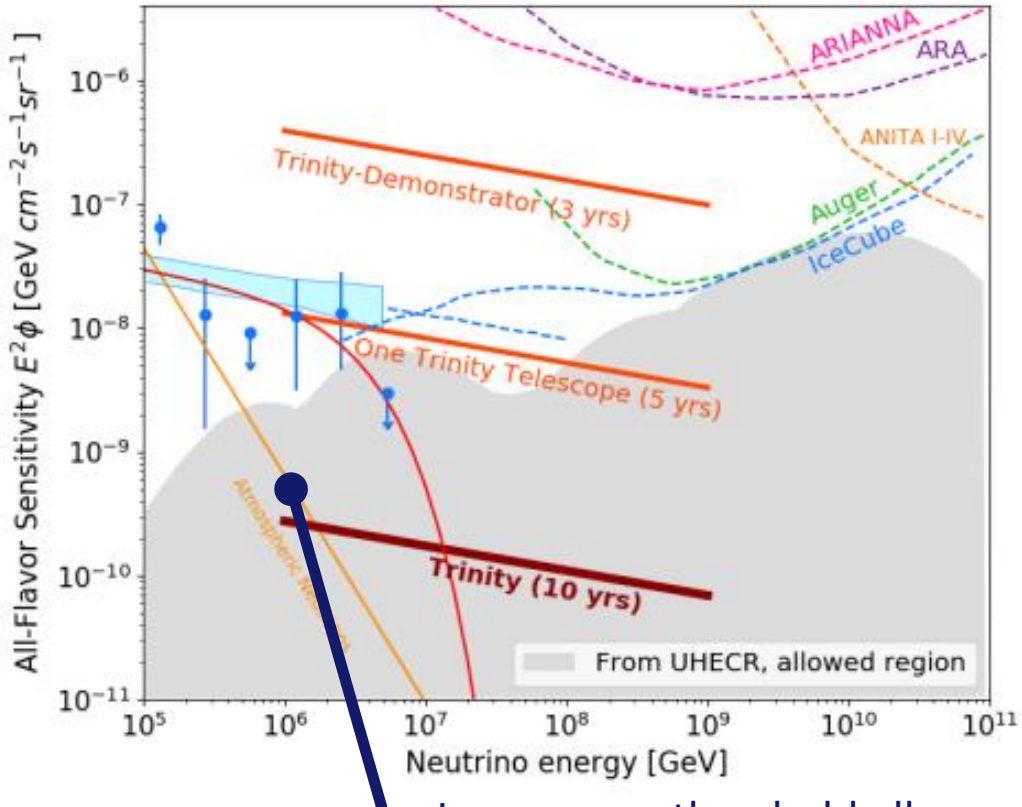
- Will observe air shower in ground-layer of atmosphere where there is a high and variable amount of atmospheric dust: implies we need to monitor atmospheric transmission
- Will have 3 separate, independent approaches
  - Monitor stars close to the horizon (Ebr et al. 2021)
  - Place calibration MWL light beacons on surrounding mountains (Weincke et al. 1999)
  - Periodically fly a UAV to cross-check the two approaches (Brown, 2018)



Expected Performance

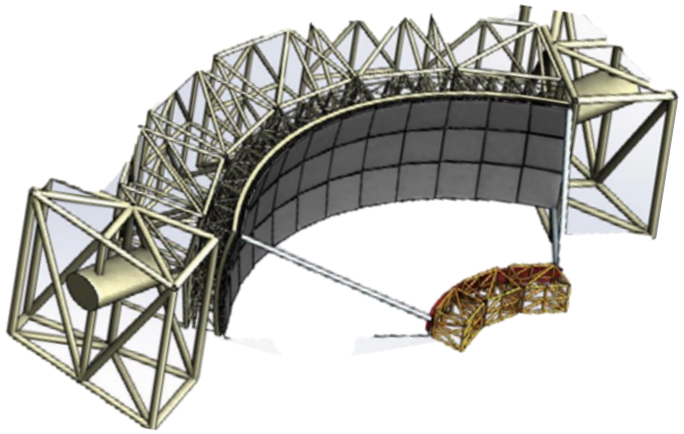


Leading sensitivity at low UHE regime

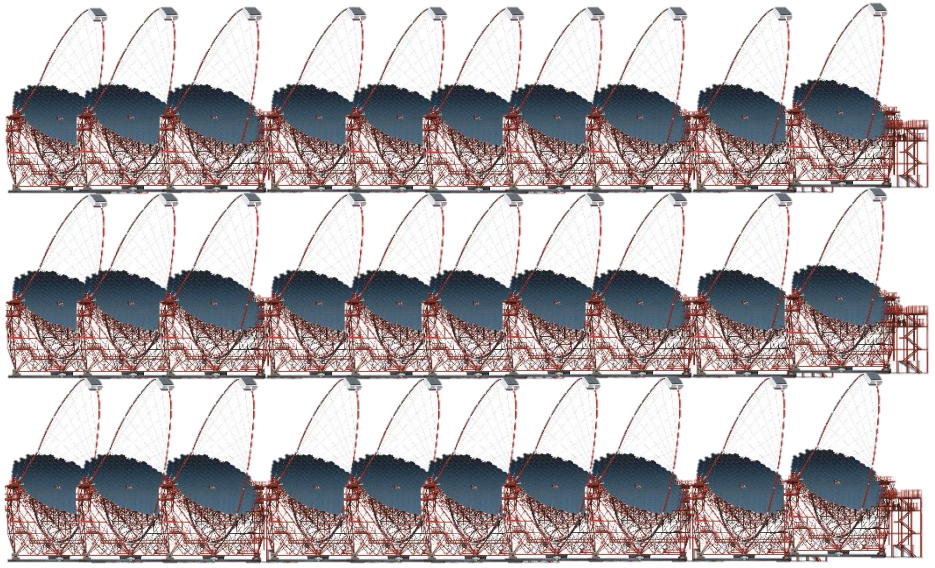


Low energy threshold allows to overlap with IceCube

Sensitivity in a nut-shell



= many x MAGIC



See Andrew Wang, et al. poster for a full description of Trinity's sensitivity calculations

Outlook and take-home points

- Trinity will use dedicated wide FoV IACTs to view the entire horizon from a mountain top, to search for Earth-skimming tau neutrinos
- Trinity will have the unique capability of a low-energy threshold allow it to observe the tail of the IceCube diffuse neutrino spectrum.
- Trinity will play a crucial role bridging the gap between IceCube's known signal, and expected sensitivity of UHE radio detectors.