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Trinity: Probing Very-High-Energy Cosmic Neutrinos with Imaging Atmospheric Cherenkov Technique

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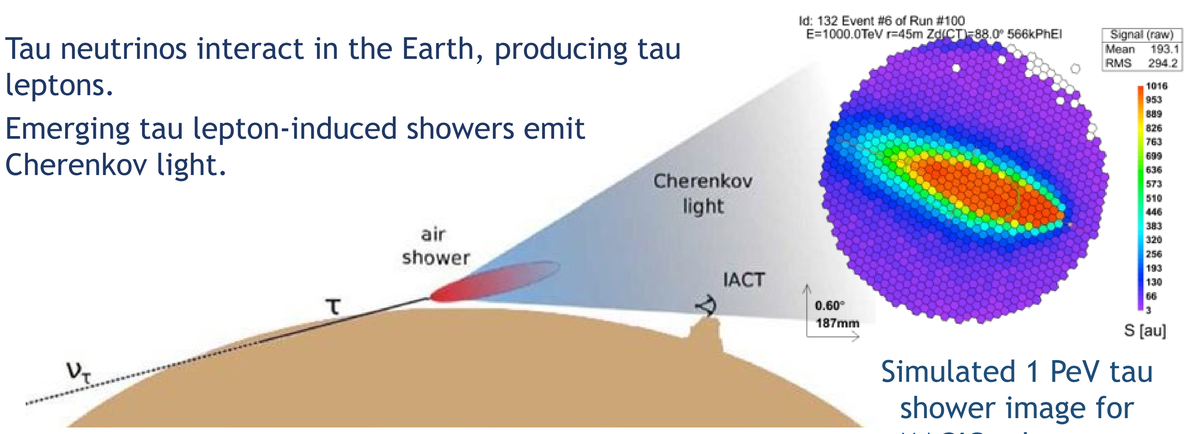
Earth-Skimming Tau Neutrino

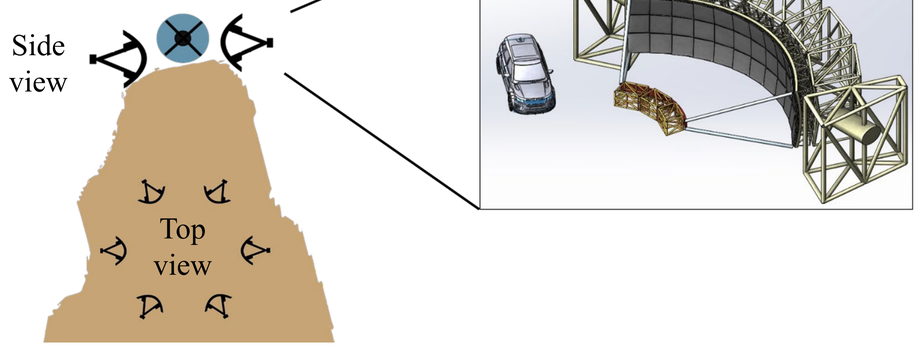
- Tau neutrinos interact in the Earth, producing tau leptons.
- Emerging tau lepton-induced showers emit Cherenkov light.



Simulated 1 PeV tau shower image for MAGIC telescopes

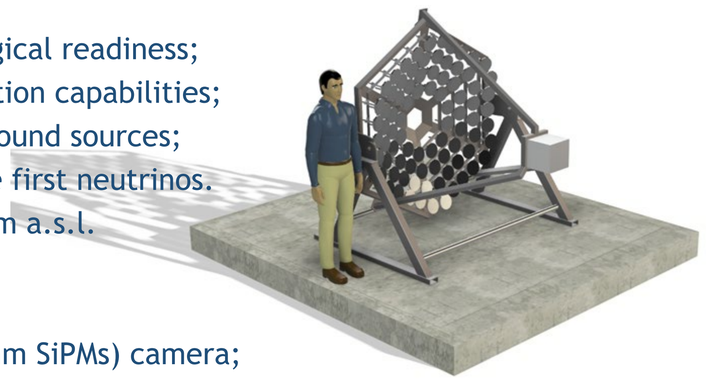
The Telescope System

- An IACT (imaging atmospheric Cherenkov telescope) with 5° x 60° FoV.
- Scalable:
  - array of up to 6 telescopes arranged in circle for covering the horizon;
  - expanding to different sites for close-to-all-sky coverage.
- Positioning: on a mountain peak pointed at horizon:
  - viewing Earth-skimming tau-neutrino induced particle showers;
  - maximizing detection volume (sensitivity).
- Operating at nights (1200 h/year).
- Detector Design:
  - Camera: array of high-red sensitivity photosensors – SiPMs;
  - Effective light collection area of 10 m^2 per telescope ;
  - Angular resolution 0.3°.

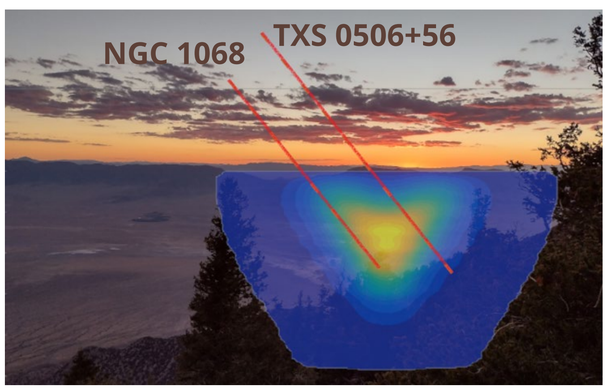


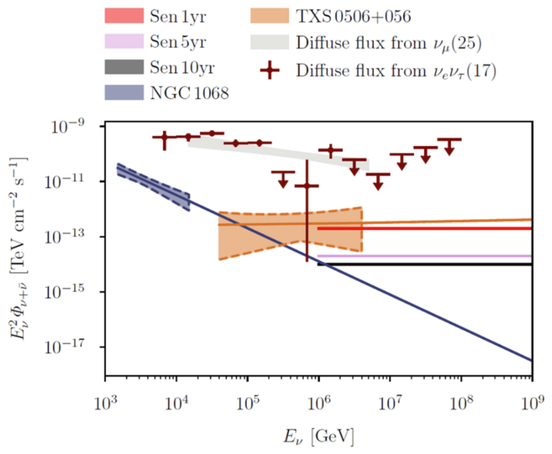
The Demonstrator

- First step of the phased approach:
  Demonstrator → Prototype telescope → Full observatory (up to 18 telescopes).
- Objectives:
  - Demonstrate technological readiness;
  - Validate remote operation capabilities;
  - Study potential background sources;
  - Potentially observe the first neutrinos.
- Location: Frisco Peak, UT, 2.9 km a.s.l.
- Specifications:
  - ~1 m^2 mirror area;
  - 256 pixels (6 mm x 6 mm SiPMs) camera;
  - 0.3° resolution;
  - 5° x 5° FoV.



Observations

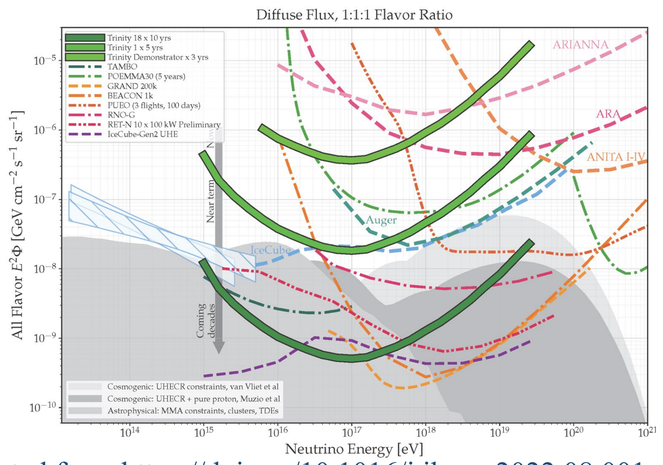




- Night sky background:
  - Study accidentals suppression to optimize sensitivity and energy threshold;
  - Camera characterization wrt. ambient conditions.
- Point sources:
  - Extend of IceCube's measurements to higher energies;
  - Study potential correlations between neutrino emission and flares in radio and optical from blazars;
  - Potential for observing transients (GRBs, GW events).

Isotropic sensitivity

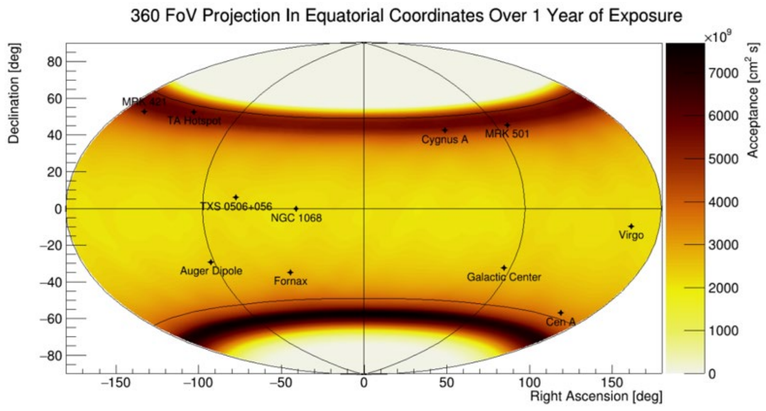
- Most sensitive in 1 PeV - 10 EeV.
- Overlap with high-energy tail of IceCube's astrophysical neutrino spectrum:
  - Guaranteed signal;
  - Cross-calibration.
- Measuring the shape of the high-energy end of the diffuse astrophysical neutrino flux to understand its nature and origin.



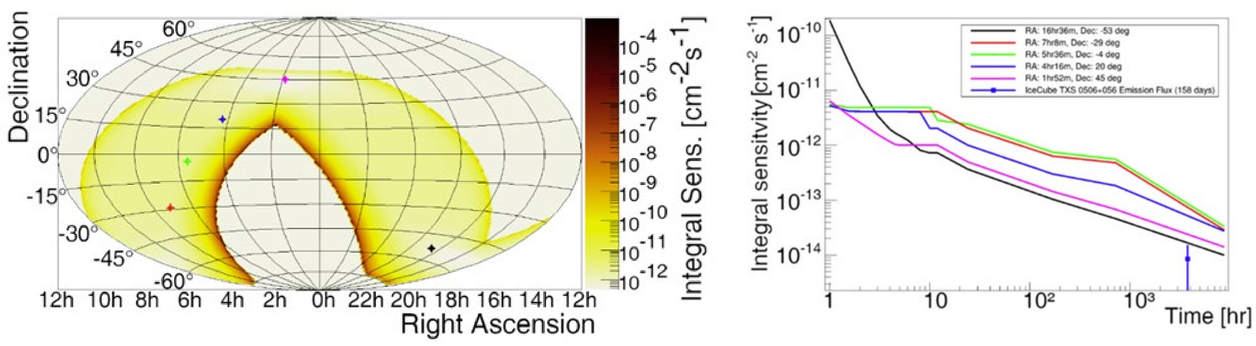
Adapted from https://doi.org/10.1016/j.jheap.2022.08.001

Point-source sensitivity

- Anticipate to detect VHE (> 10^6 GeV) and UHE (> 10^9 GeV) neutrinos - proof of existence of UHECR source.
- One Trinity site (Frisco Peak) acceptance:
  - 13% sky daily;
  - 80% sky annually (galactic + extragalactic).
- All sources with declinations -70° to +50°.

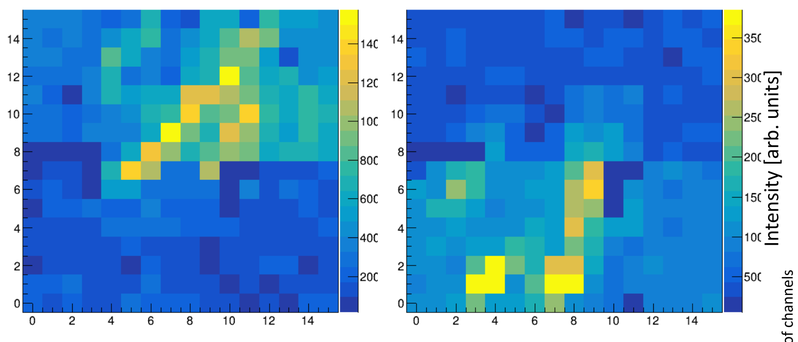


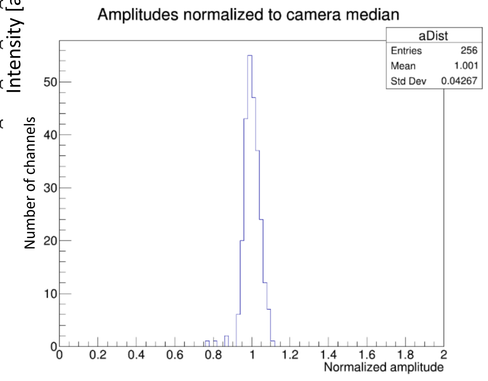
- Sensitivity is highest at extreme declinations, influenced by site latitude.
- Frisco Peak, UT optimal for TXS 0506+056, NGC 1068, TA hotspot, Cygnus A, and historic blazars MRK 421 and MRK 501.



Current Status

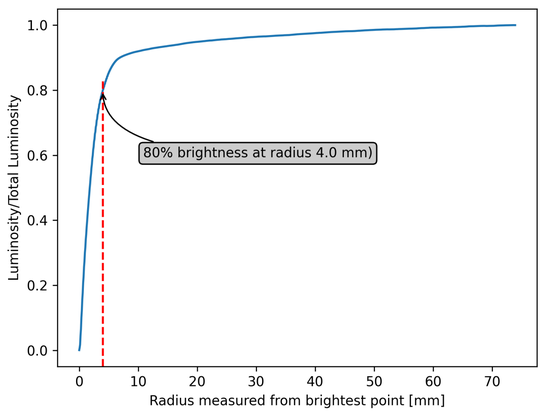
- Construction started summer 2022 – finished fall 2023
- Observations since October 3rd 2023.
- Camera performance checked recording air-shower images from cosmic rays taken pointing at 26° zenith angle. The telescope was then pointed back to horizon for regular observational operations.





- Camera flat-fielded for consistent photon detection efficiency, gain, and signal-chain characteristics.
- Mirrors aligned with PSF < 0.3° across the 5° camera FoV.

Point spread function of the Demonstrator after alignment. The inner ring in the picture is 6mm in diameter and the outer one 12 mm.



- Ongoing work:
  - Signal calibration.
  - Adjusting discriminator thresholds for each pixel to achieve uniform camera response.
  - Improving automation scripts to optimize remote operations.
  - Developing data-quality monitoring and analysis chain.
  - Optimizing observing strategies, risk assessment and mitigation.

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