



Trinity

Opening the PeV Neutrino Window

trinity-observatory.org

Georgia Tech
University of Utah
University of Delaware
University of Iowa
Durham University, UK
University of Padova, IT
University of Bari, IT
University of Perugia, IT
INAF, IT



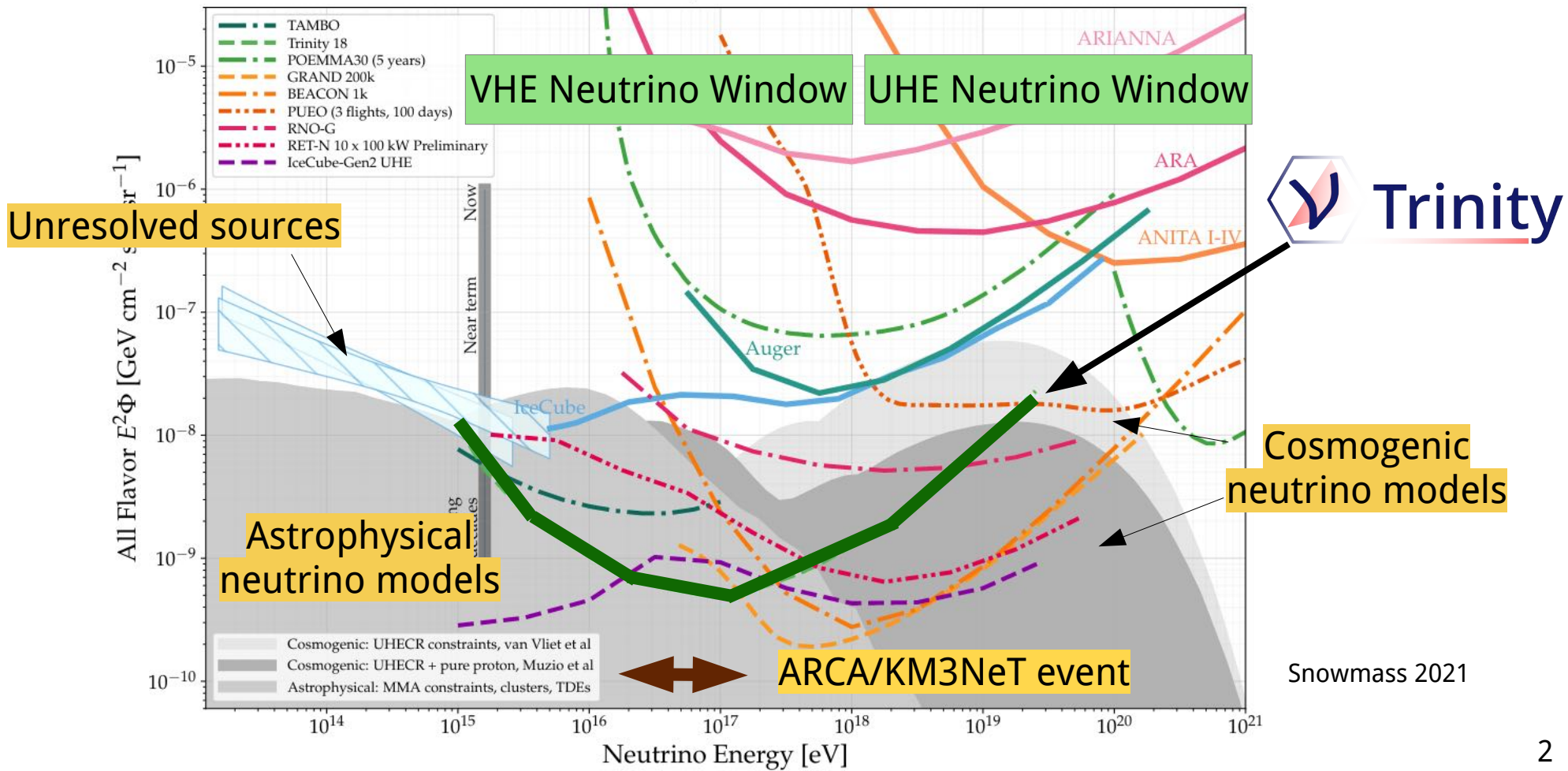
Nepomuk Otte





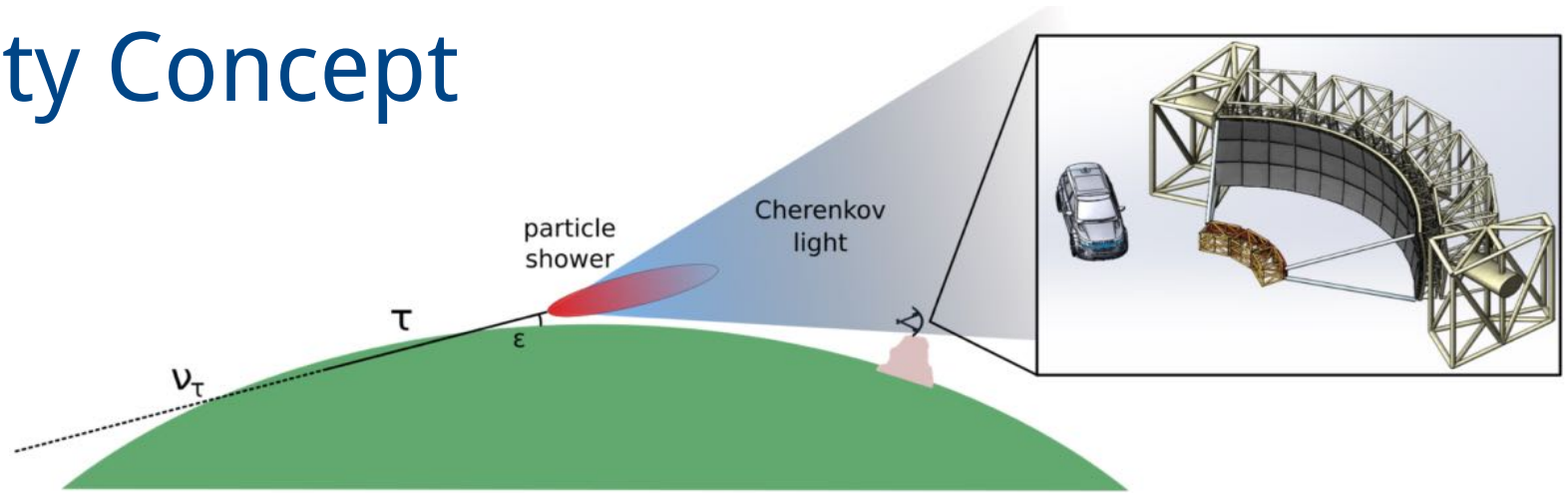
The VHE/UHE Neutrino Window

Diffuse Flux, 1:1:1 Flavor Ratio





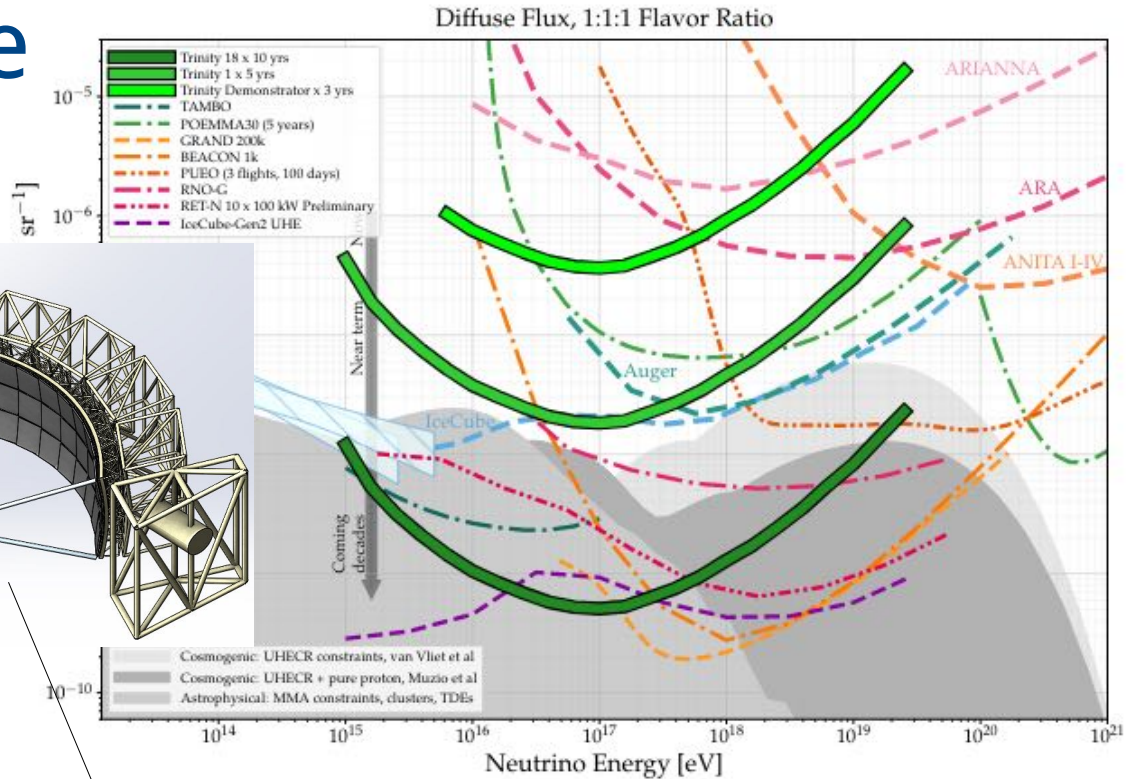
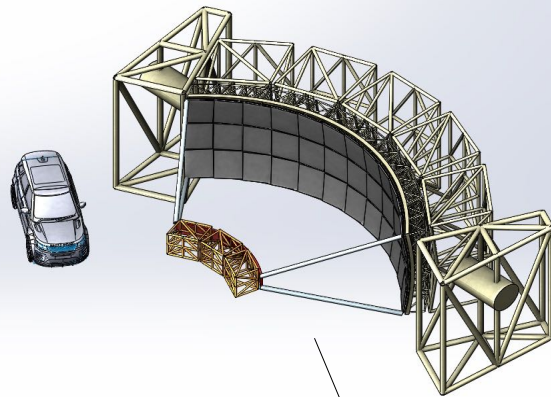
Trinity Concept



- Earth-skimming neutrino detection with air-shower imaging technique
 - Proven technique
 - Reliable identification of air showers, immune to noise
- Dedicated telescope design
 - 60 degree field of view telescope → \$1M costs
 - Design diffuse source sensitivity requires 18 telescopes
 - Point-source sensitivity almost optimal with one telescope



Trinity Timeline





Trinity Demonstrator

- Davies Cotton optics
- 1m² mirror area
- 3.8°x3.8° field of view
- 256 pixel camera (0.24° resolution)
- 100 MS/s AGET readout

Camera paper: <https://arxiv.org/abs/2406.08274>

Demonstrate:

- Atmospheric monitoring
- Long-term stability
- Backgrounds
- Camera concept
- Remote operation
- Analysis
- ...



Deployed on Frisco Peak, Utah October 2023

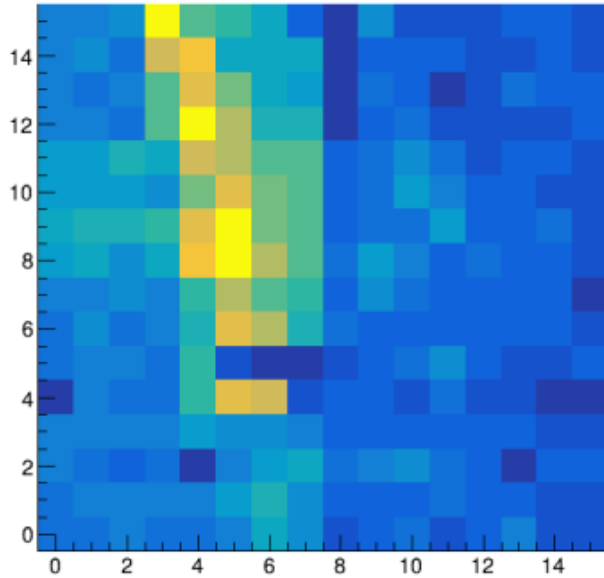
PHY-2112769; PHY-2411666

NASA APRAs 80NSSC19K0627 and 80NSSC22K0426

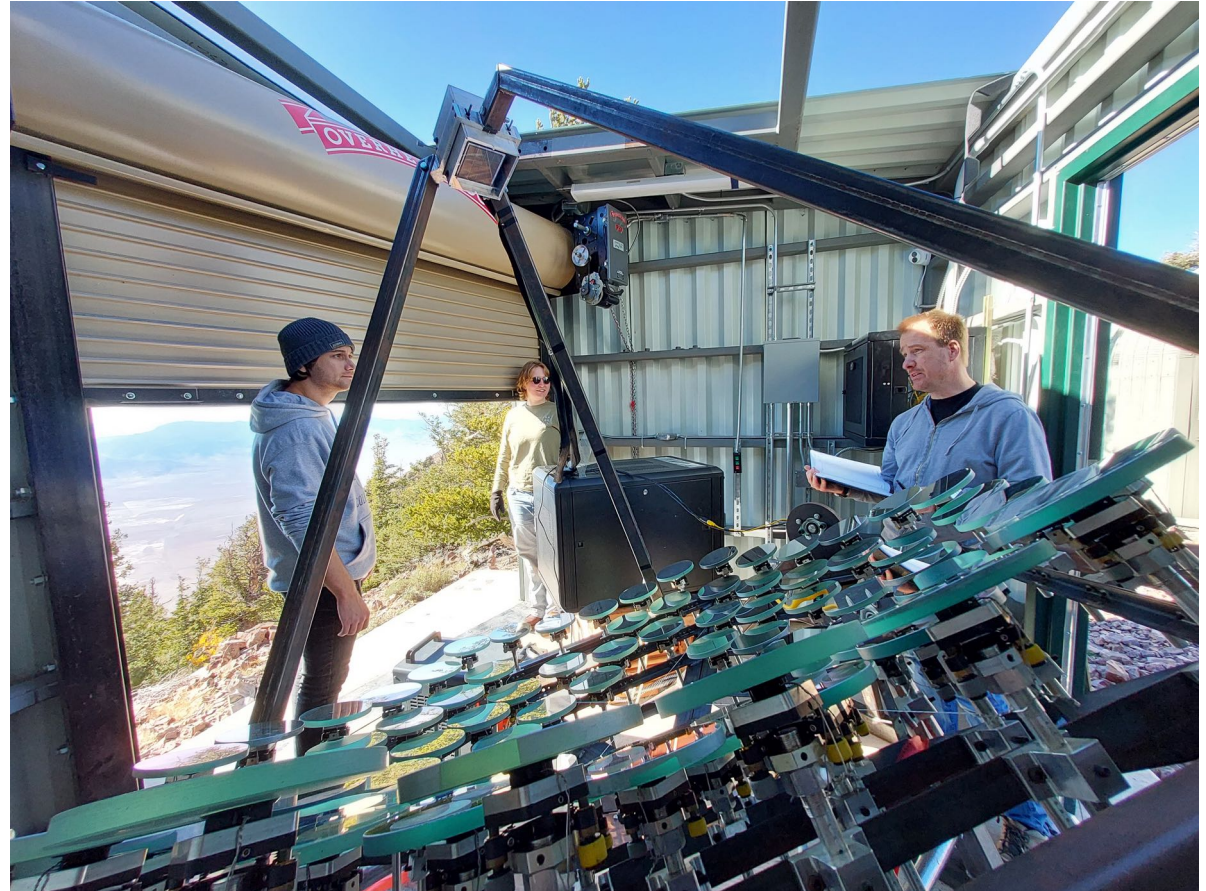




Cosmic-Ray Air Shower Images



← 3.8° →





Observers



Sofia Stepanoff



Mariia Fedkevych



Jordan Bogdan



Srikar Gadamsetty



Adam Barletta



Nolan Lew



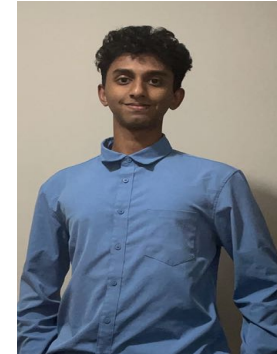
Ace Wilcox



Angelina Zhang



Luigi Cedeno



Arnav Menon



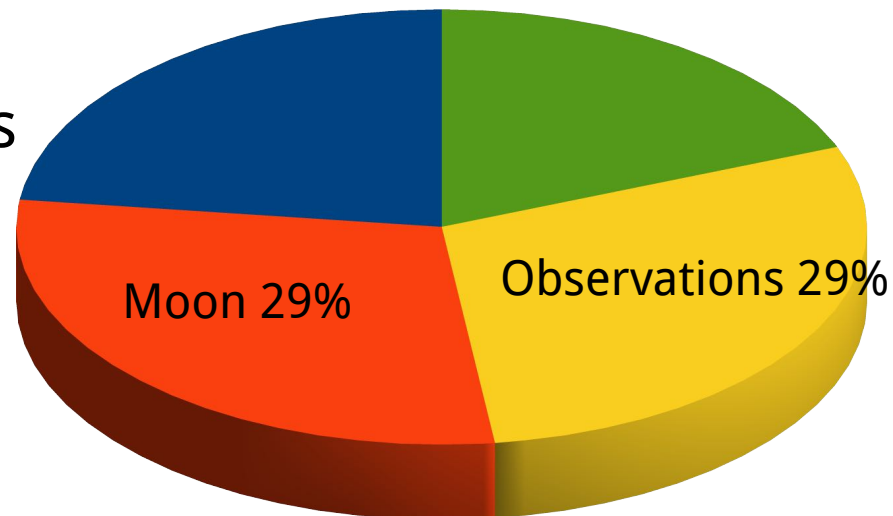
Observing Status

Trinity-observatory.org/demonstrator-live/

- Established Operations Specifications
 - Remote operations
 - Observer training
 - Instrument configuration
- Commission left-over tasks
 - Gain calibration
 - Trigger calibration and flatfielding
 - Pushing into moon-light

Start-Up 23%

Weather 20%

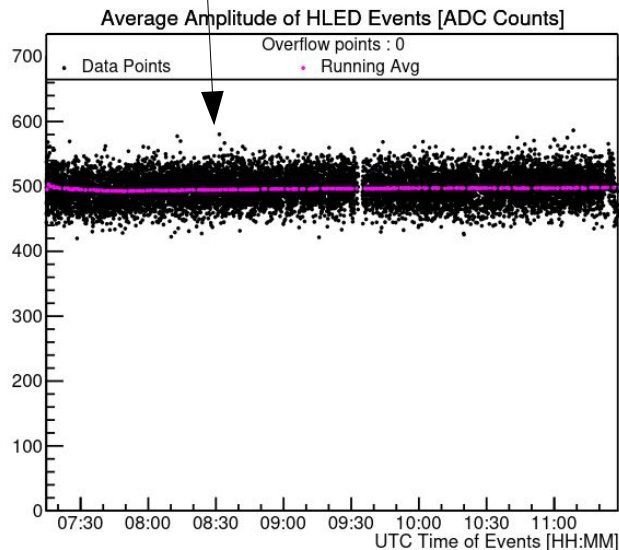


- 436 hours total
- 18 hours TXS 0506
- 15 hours NGC 1068

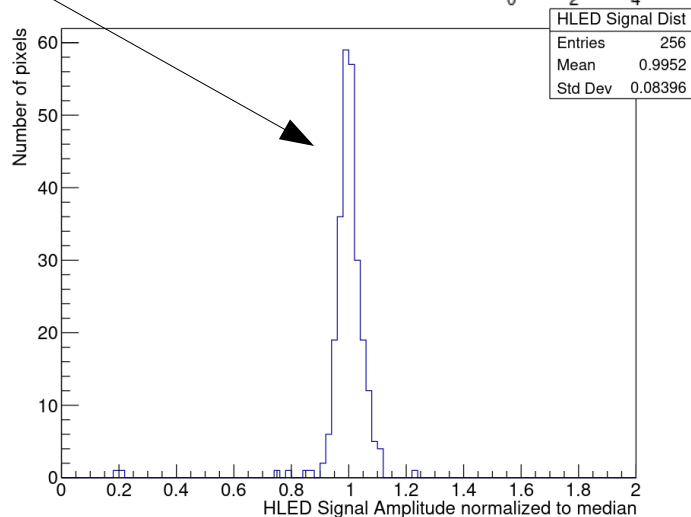
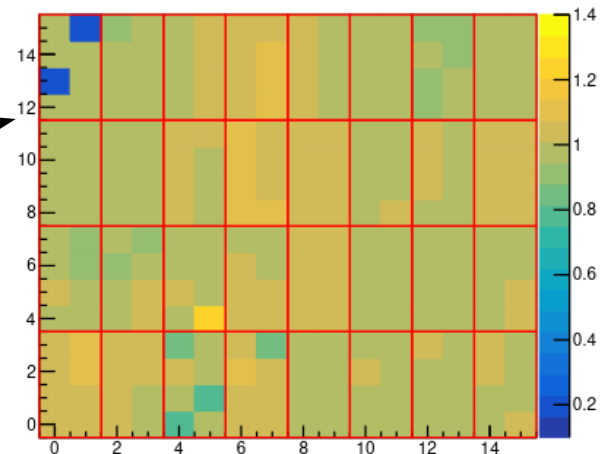


Demonstrator Performance: Camera

- Trigger rate is about 1Hz.
- SiPM temperature stable within 1°C over night.
- Durham CTA LED flasher monitors stability.
 - 2 dead pixels → 99% yield.
 - ~5% flatfielding residual.



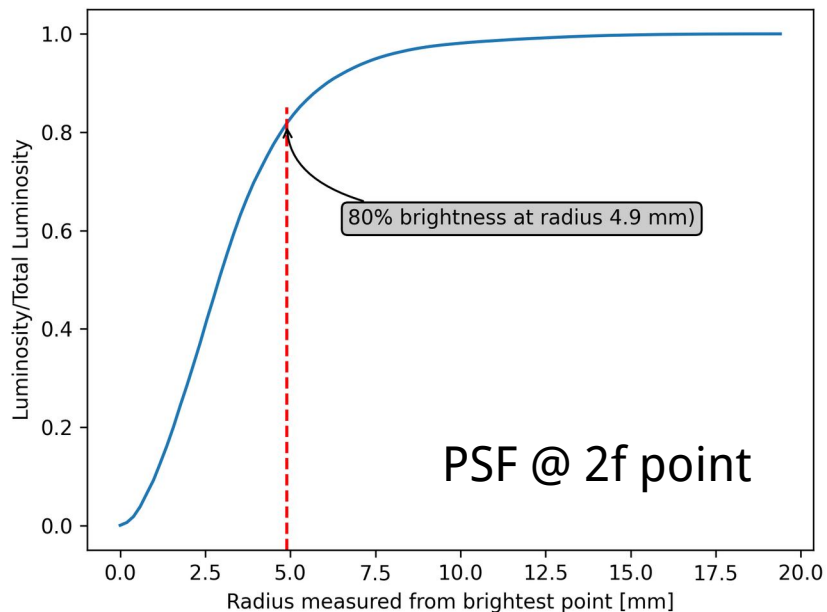
Average Amplitude of HLED Events normalized to median





Demonstrator Performance: Optics

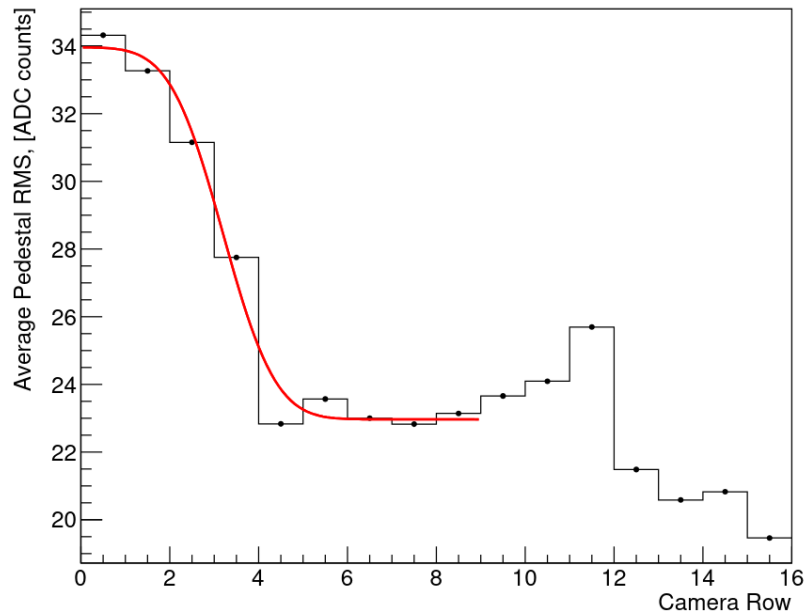
- Optical point spread function contained within 1.5 camera pixels.





Demonstrator Performance: Optics

- Optical point spread function contained within 1.5 camera pixels.





Mirror Alignment / Atmospheric Monitoring



U.S. DEPARTMENT OF TRANSPORTATION FEDERAL AVIATION ADMINISTRATION CERTIFICATE OF WAIVER	
ISSUED TO	Adam Otte Responsible Party: Adam Otte Waiver Number: 107W-2024-00186
ADDRESS	3591 Sunderland Cir NE Brookhaven, GA 30319
<p>This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate, except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.</p>	
<p>OPERATIONS AUTHORIZED Small Unmanned Aircraft System (sUAS) operations at night and during civil twilight without anti-collision lights meeting the requirements of § 107.29(a)(2) & (b); Small Unmanned Aircraft System (sUAS) operations beyond the visual line of sight of the remote pilot in command (PIC); sUAS operations higher than 400 feet above ground level (AGL), when not within a 400 foot radius of a structure.</p>	
<p>LIST OF WAIVED REGULATIONS BY SECTION AND TITLE 14 CFR §§ 107.29(a)(2) & (b)—Anti-collision light requirement for operations at night and during periods of civil twilight, 107.31—Visual line of sight aircraft operation, 107.33(b) & (c)(2)—Visual observer and 107.51(b)—Operating limitations for small unmanned aircraft (sUA) - Altitude</p>	
STANDARD PROVISIONS	
<ol style="list-style-type: none"> 1. A copy of the application, made for this certificate, shall be attached to and become a part hereof. 2. This certificate shall be presented for inspection upon the request of any authorized representative of the Administrator of the Federal Aviation Administration or of any State or municipal official charged with the duty of enforcing local laws or regulations. 3. The holder of this certificate shall be responsible for the strict observance of the terms and provisions contained herein. 4. This certificate is nontransferable. 	
<p>NOTE—This certificate constitutes a waiver of those Federal rules or regulations specifically referred to above. It does not constitute a waiver of any State law or local ordinance.</p>	
SPECIAL PROVISIONS	
<p>Special Provisions 1 to 34, inclusive, are set forth on the attached pages.</p>	
<p>This Certificate of Waiver is effective from June 1, 2024, to January 1, 2026, and is subject to cancellation at any time upon notice by the Administrator or an authorized representative.</p>	
<p>BY DIRECTION OF THE ADMINISTRATOR ADAM A VETTER Adam Vetter Tactical Operations Manager FAA Western Service Center</p> <p><small>Digitally signed by ADAM A VETTER Date: 2024.05.29 13:13:33 -0700</small></p>	



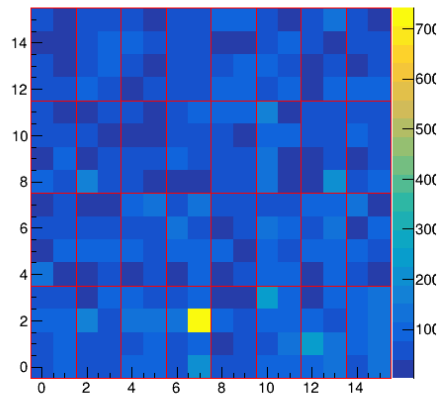
Snowpocalypse



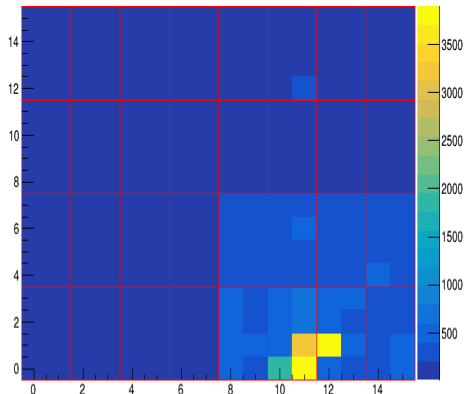


Some Events

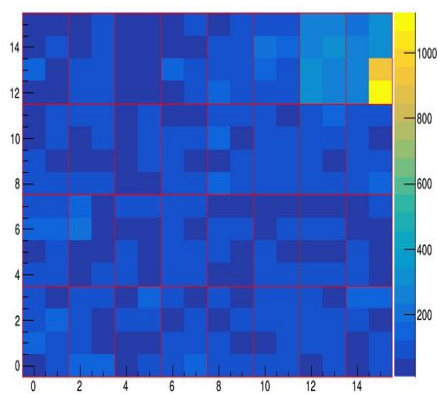
night-sky background
accidental



cosmic-ray candidate



muon?



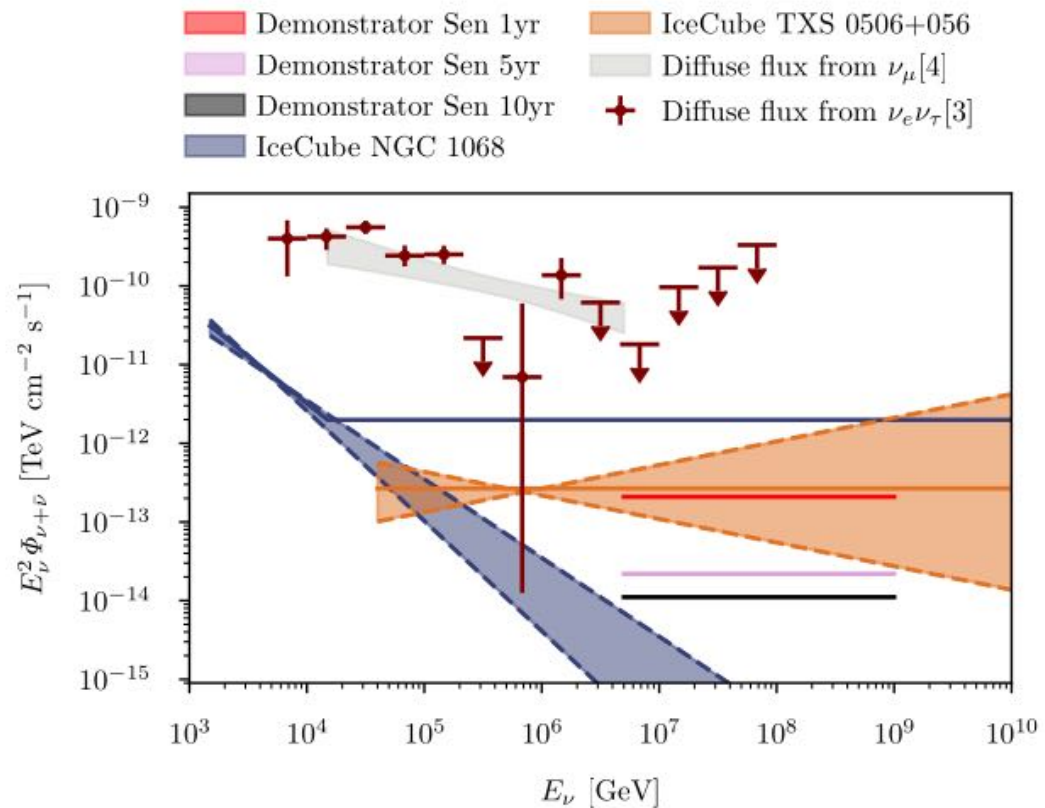
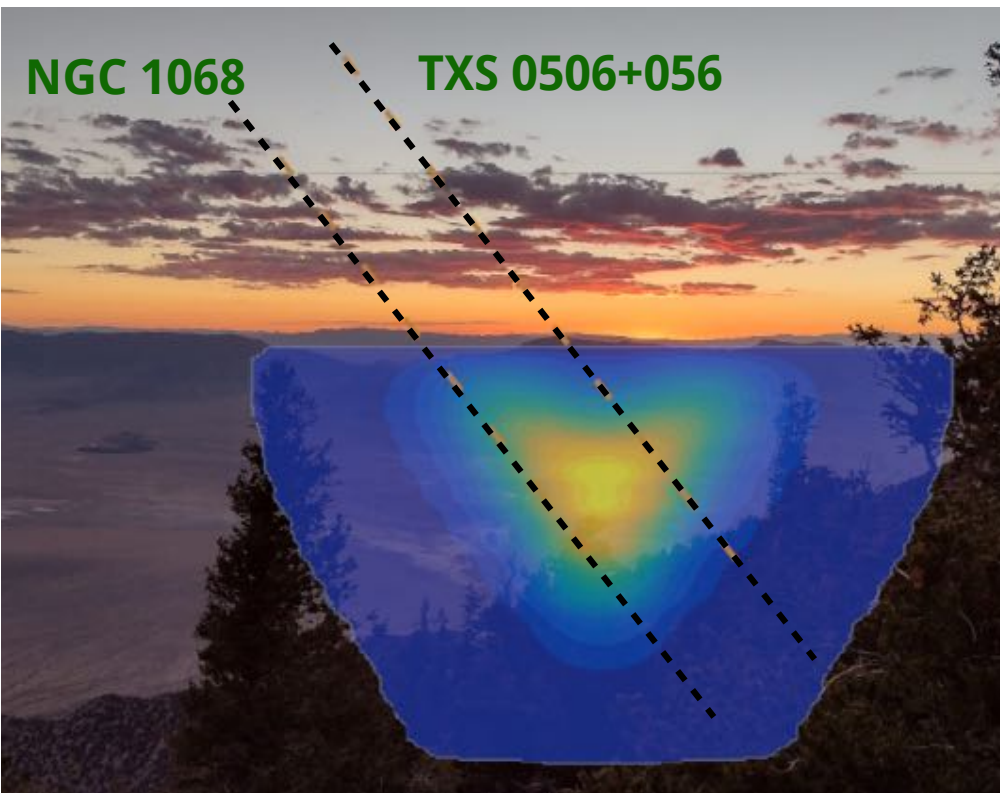
neutrino candidate

None yet

Event selection and Monte Carlo is under development.



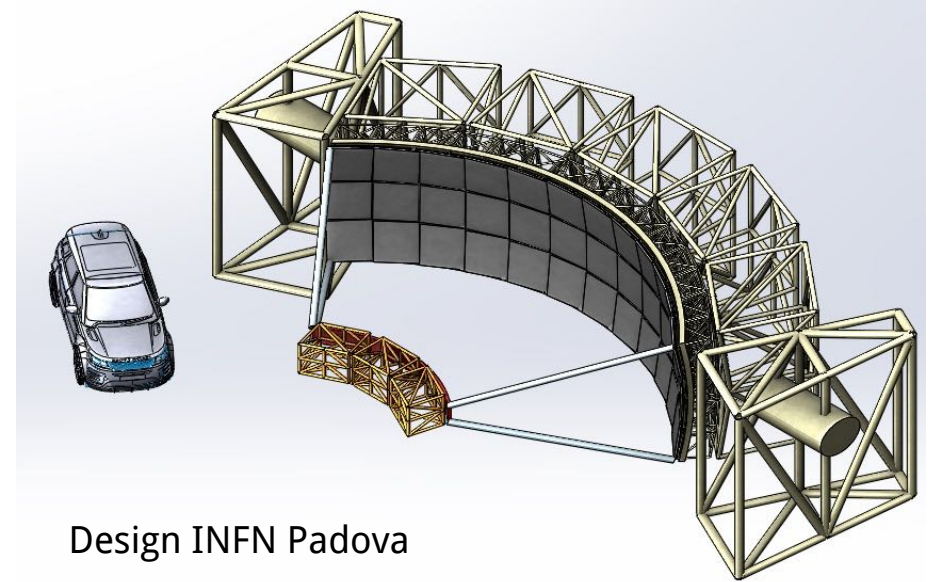
Going after TXS 0506+056 and NGC 1068



Next Step: Trinity One

Telescope concept based on J. Cortina et al., *Astrop. Physics* 72 (2016) 46

- **FoV 5° X 60°.**
- 5.6 m focal length.
- 68 m² mirror area → **16 m²** in any direction.
- 0.1° optical PSF.
- 3,300 pixel camera.
- 14 mm light concentrators coupled to **6 mm SiPMs.**
- CTA mirror technology ~\$3.5k/m².
- MAGIC-based mechanical structure.
- Rotates in elevation (and azimuth).

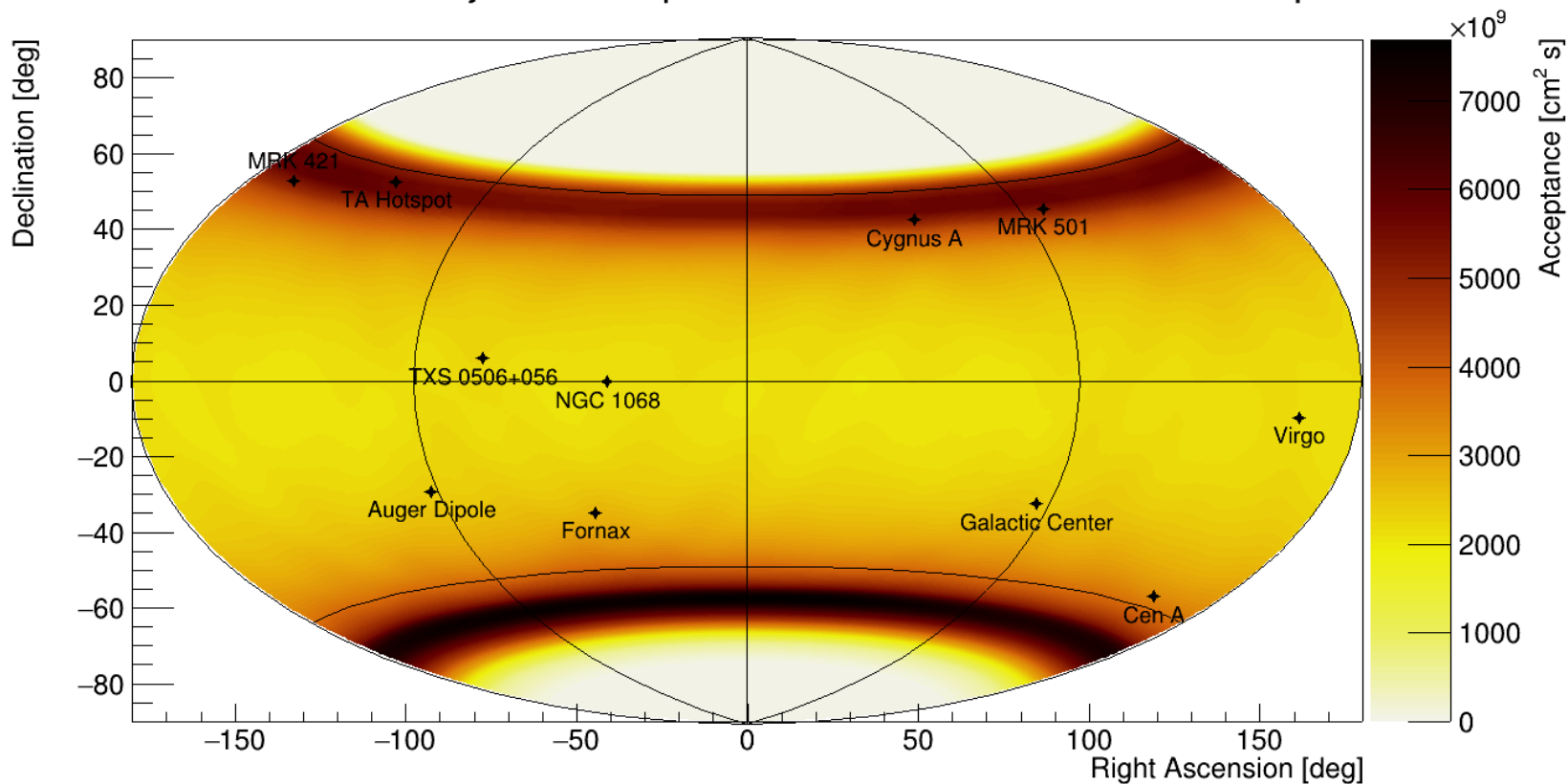


Astro 2020 APC White Paper arXiv:1907.08727



A PeV Point-Source Neutrino Detector

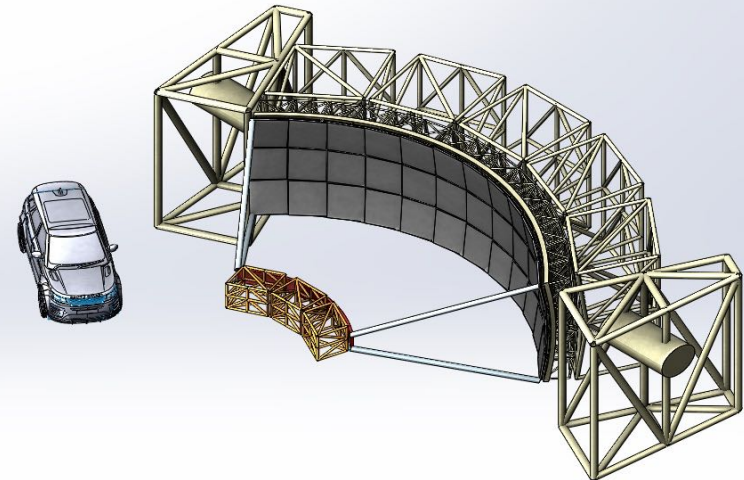
360 FoV Projection In Equatorial Coordinates Over 1 Year of Exposure





Summary

- We are in a golden era of neutrino astronomy.
 - The VHE window will be good for some exciting discoveries.
- The Trinity Observatory will unlock the VHE window.
 - Trinity Demonstrator is up and running.
 - Results are coming in.
 - Looking forward for the next observing season.
 - Towards Trinity One, the first Trinity telescope.
 - Outstanding point-source sensitivity.



Thank You



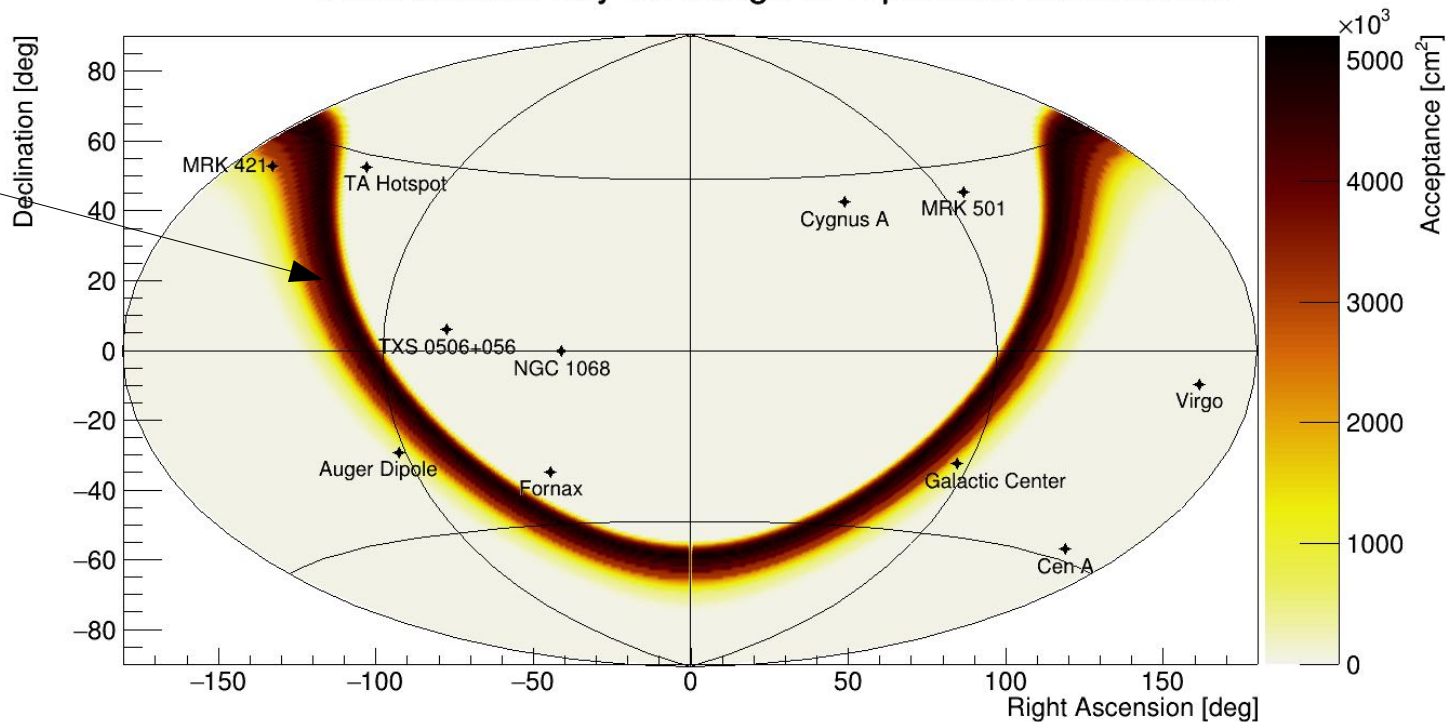
Instantaneous Sky Coverage (One Site)

Instantaneous Sky Coverage In Equatorial Coordinates

15° wide band
→ 13% of the sky

~50% of the sky observed
every night

1-2 hours
Nightly exposure per source





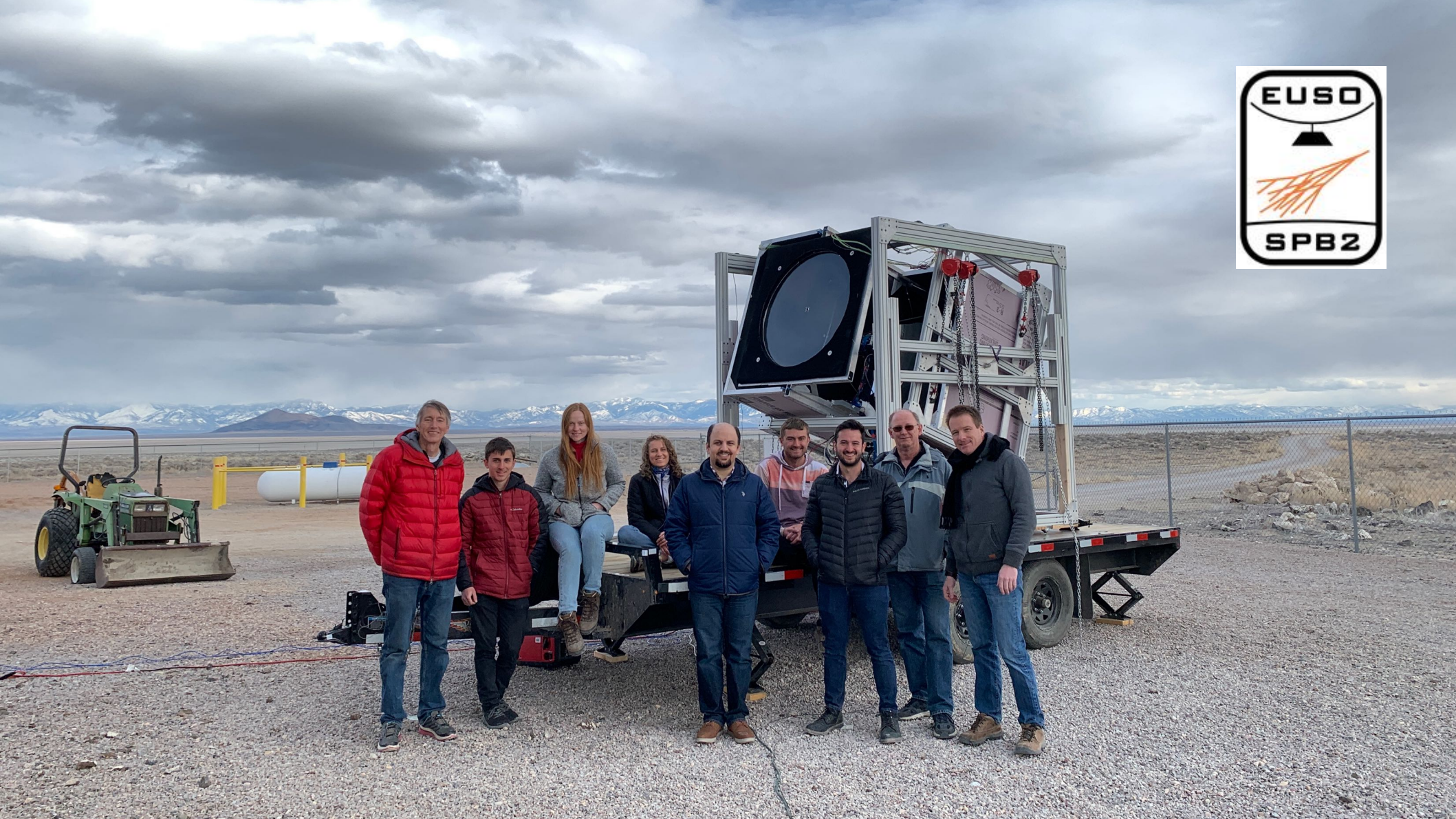
The Arctic Experience













EUSO-SPB2 Camera

- 512 pixel, 12x6 deg FoV
- Field-tested at TA site in Utah March 2022.

