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on behalf of Trinity Collaboration: trinity-observatory.org

PHYS. REV. D 99, 083012 (2019)
ASTRO2020 WHITE PAPER ARXIV:1907.08727
ICRC 2019 ARXIV:1907.08732

TRINITY

An Air-Shower Imaging Telescope to detect UHE neutrinos

https://agenda.infn.it/event/24250/

IX International Workshop on Neutrino Telescopes

Istituto Nazionale di Fisica Nucleare

Dipartimento di Fisica e Astronomia Galileo Galilei

800 1222·2022 ANNI

Università degli Studi di Padova

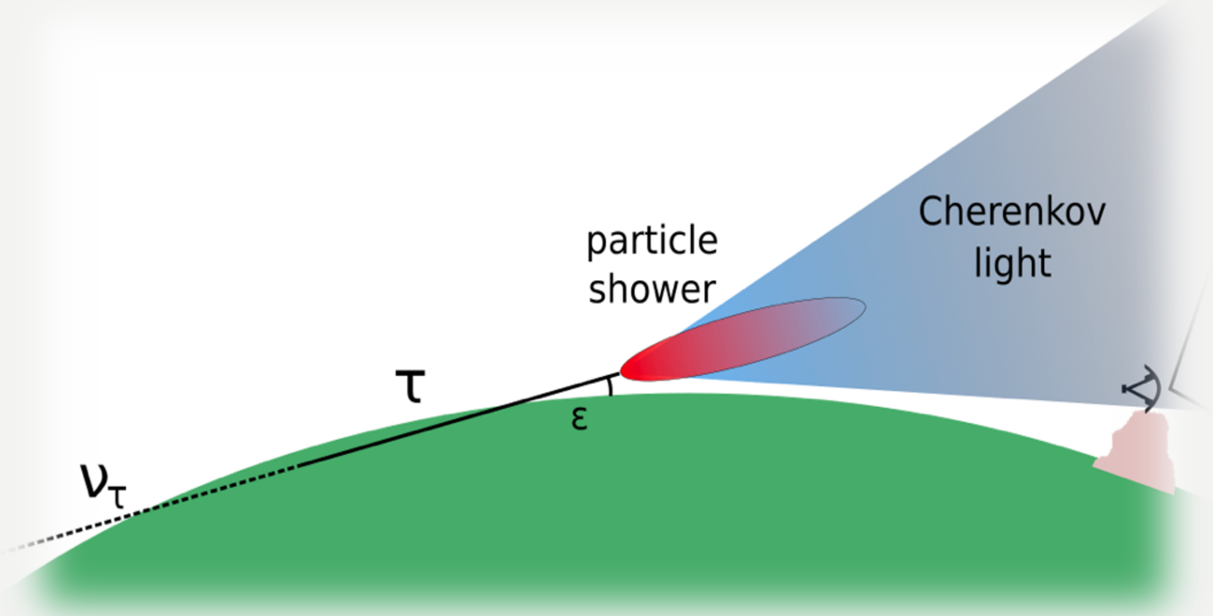
SPOILER

- We propose a 18-telescope system of air-shower imaging telescopes to detect Earth-skimming UHE tau-neutrinos

- US-UK-IT collaboration

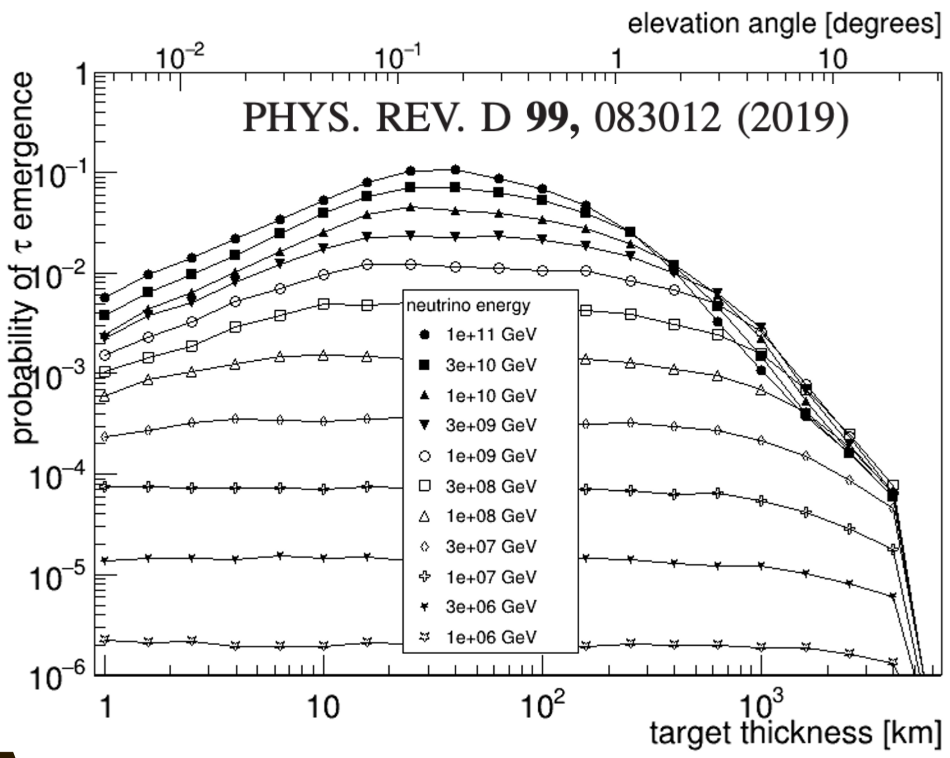
- Design phase, application for prototype funding is pending at NSF

- Location of prototype: Frisco peak, Utah (US)



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

EARTH-SKIMMING TAU NEUTRINOS

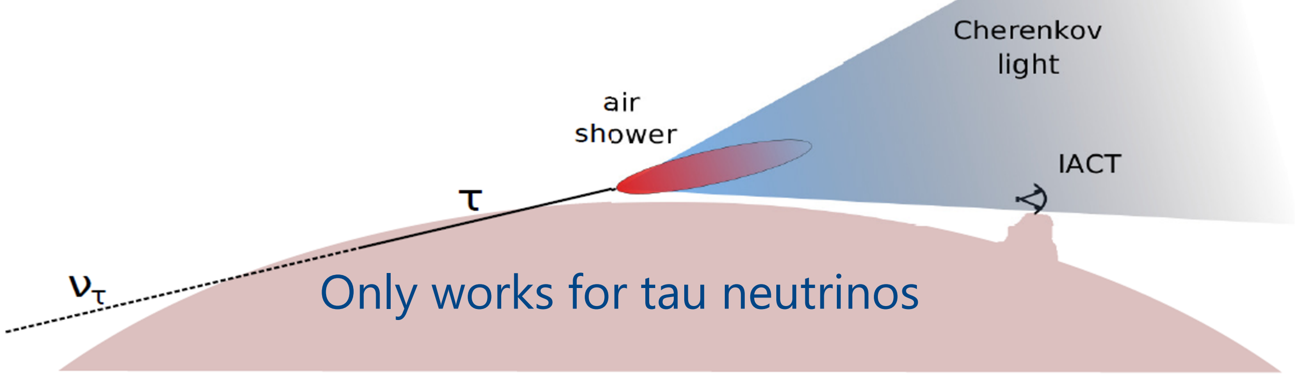


10^6-10^{10} GeV UHE nu-tau, when crossing 1-100 km of rock have significant **probability of emerge as tau-lepton**

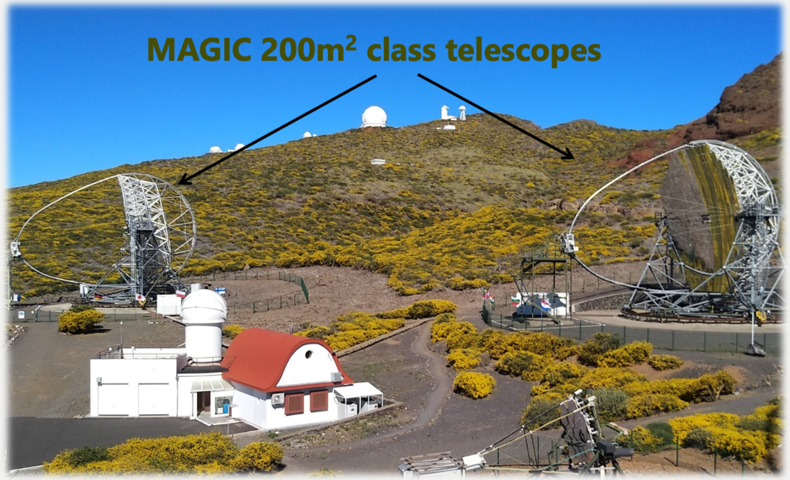
- Shown many times in this conference
- The emerging UHE tauons can generate e.m. atmospheric (sub)showers

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

- **Imaging Cherenkov telescopes (IACT)** record image of air shower →



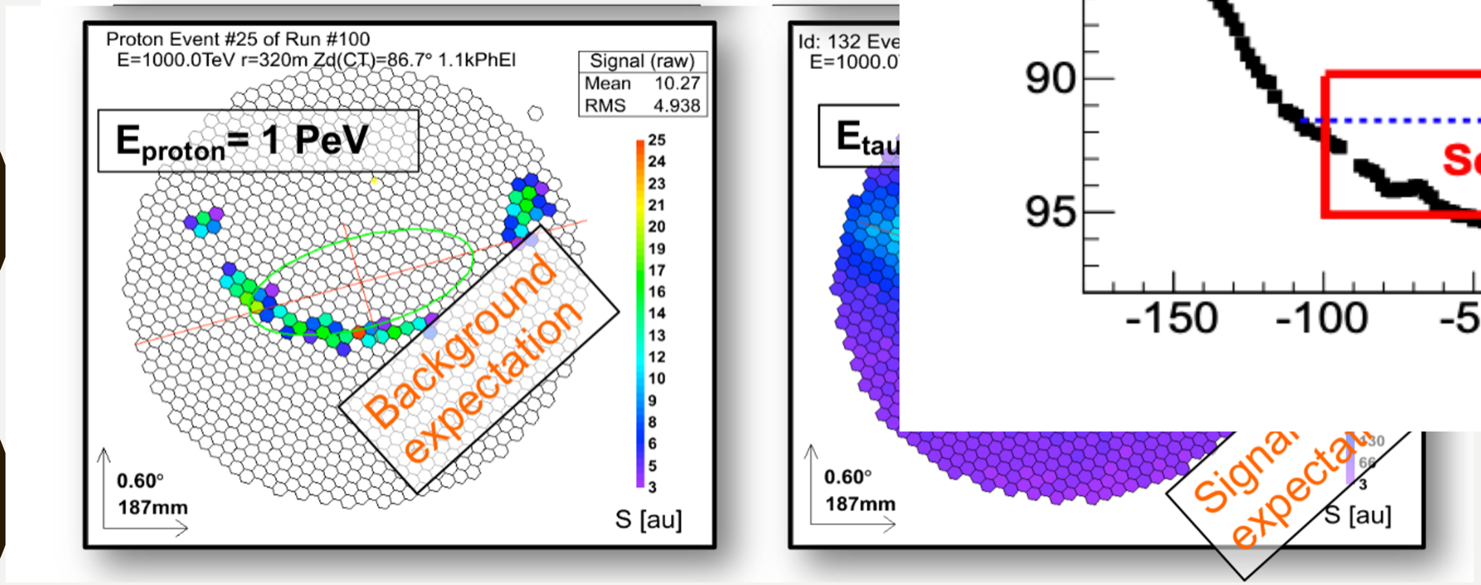
DEMONSTRATED BY MAGIC

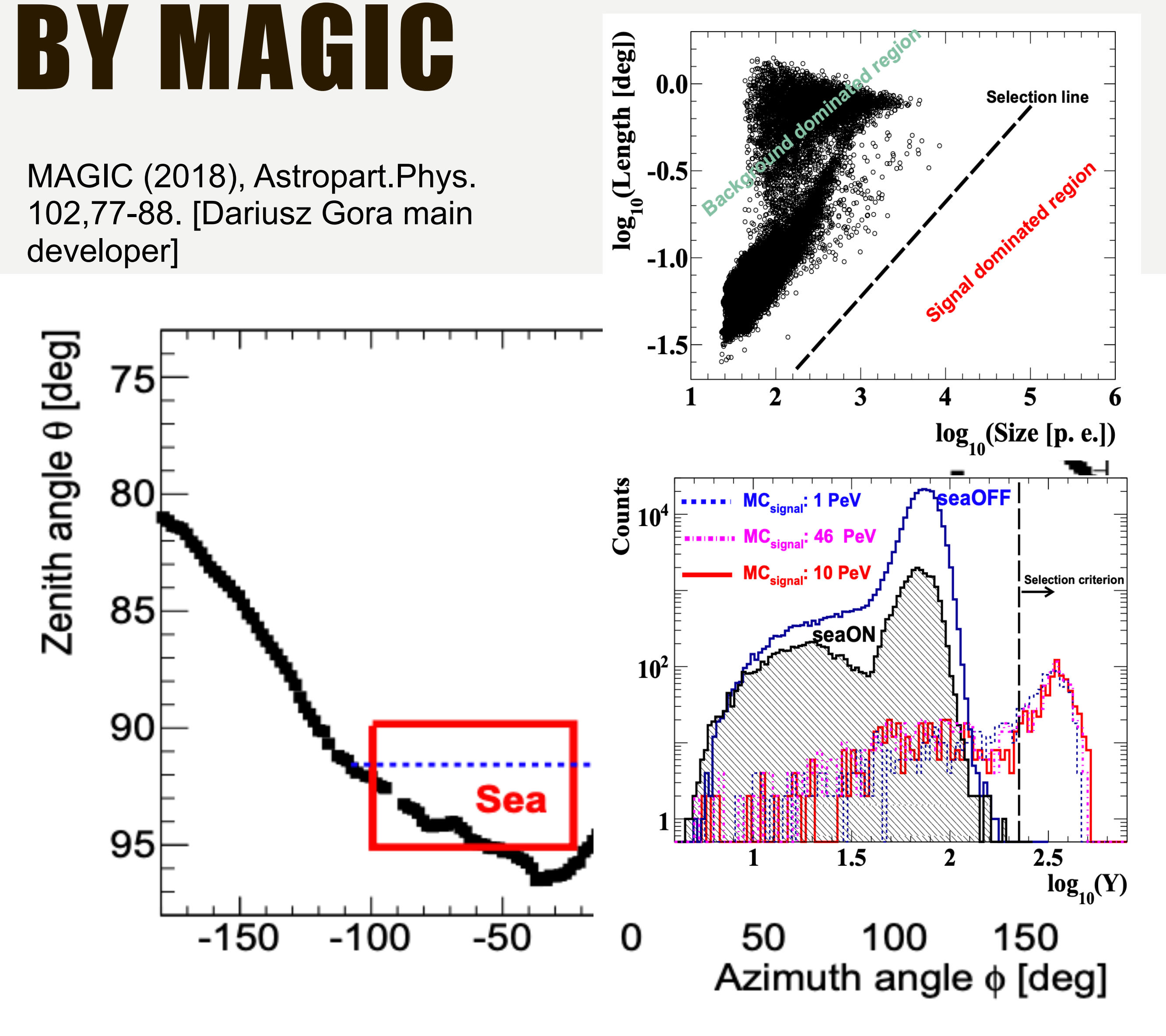


MAGIC (2018), Astropart.Phys. 102,77-88. [Dariusz Gora main developer]

Proton injected at the top of the atmosphere

(~800 km to the detector for 87°)





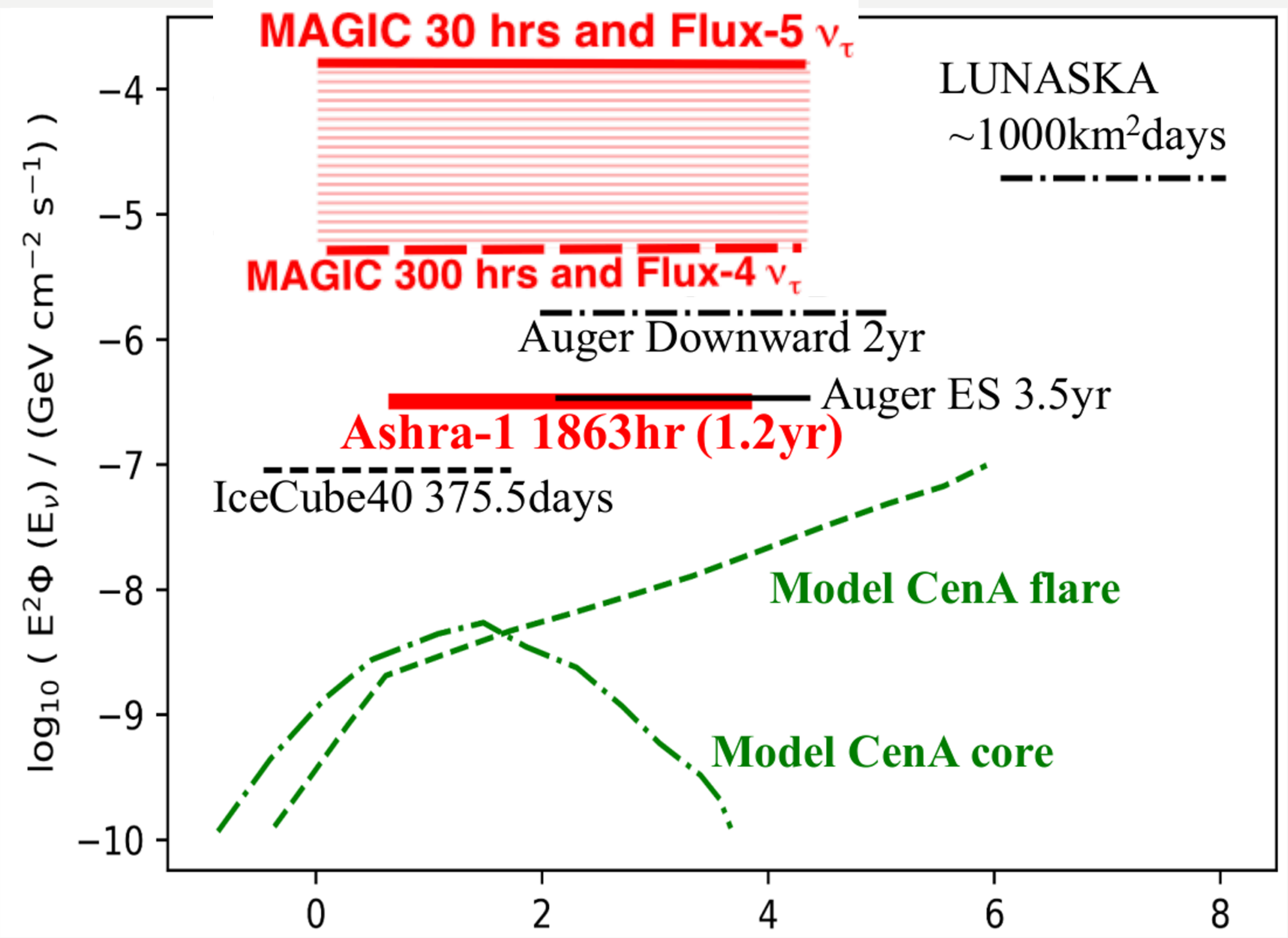
Energy resolution: <15%

Angular resolution: 0.1°

AND ASHRA

Ashra-1 PoS(ICRC2019) 970

- Electrostatic lenses with an optical system to generate convergent beams,
- Mauna Loa island facing Mauna Kea
- 3300 m above sea level



Sensitivity to diffuse neutrino emission PoS(ICRC2019) 970

+targets

RECIPE

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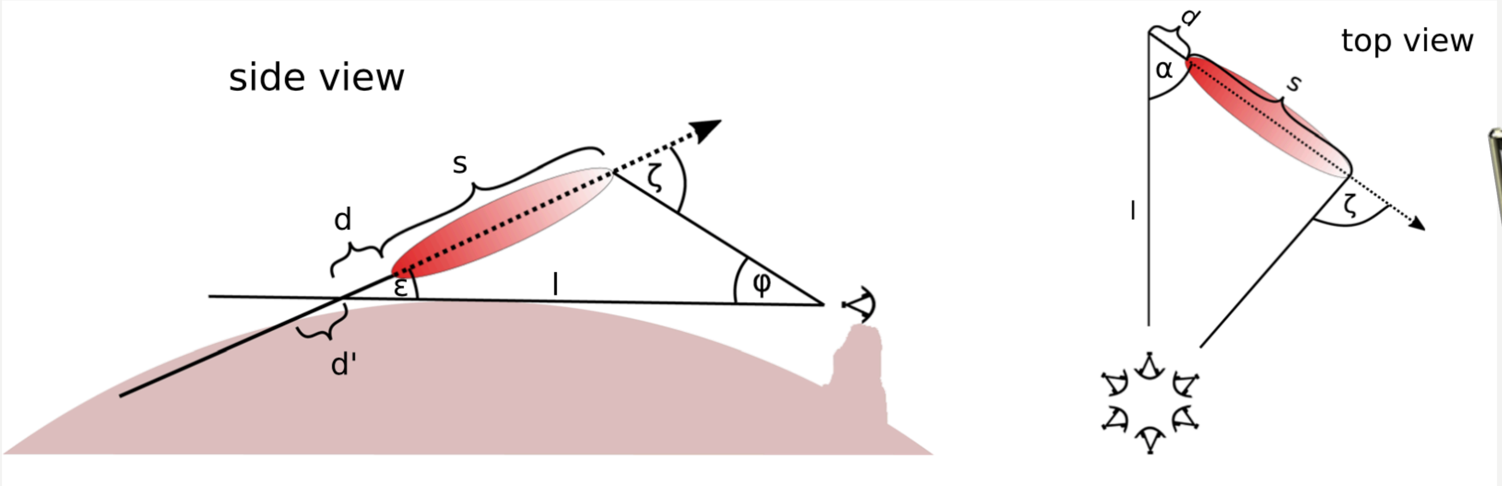
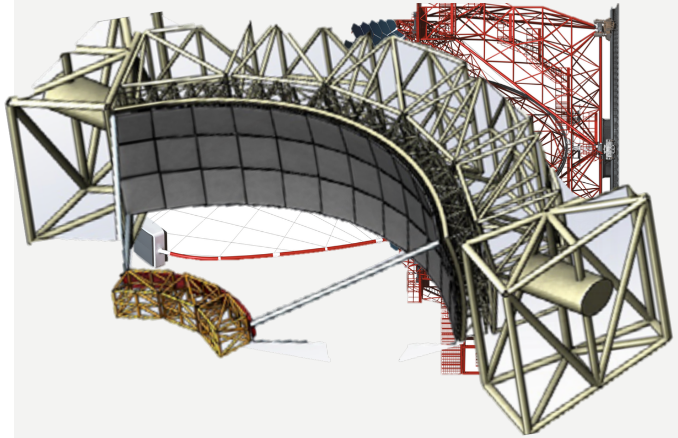


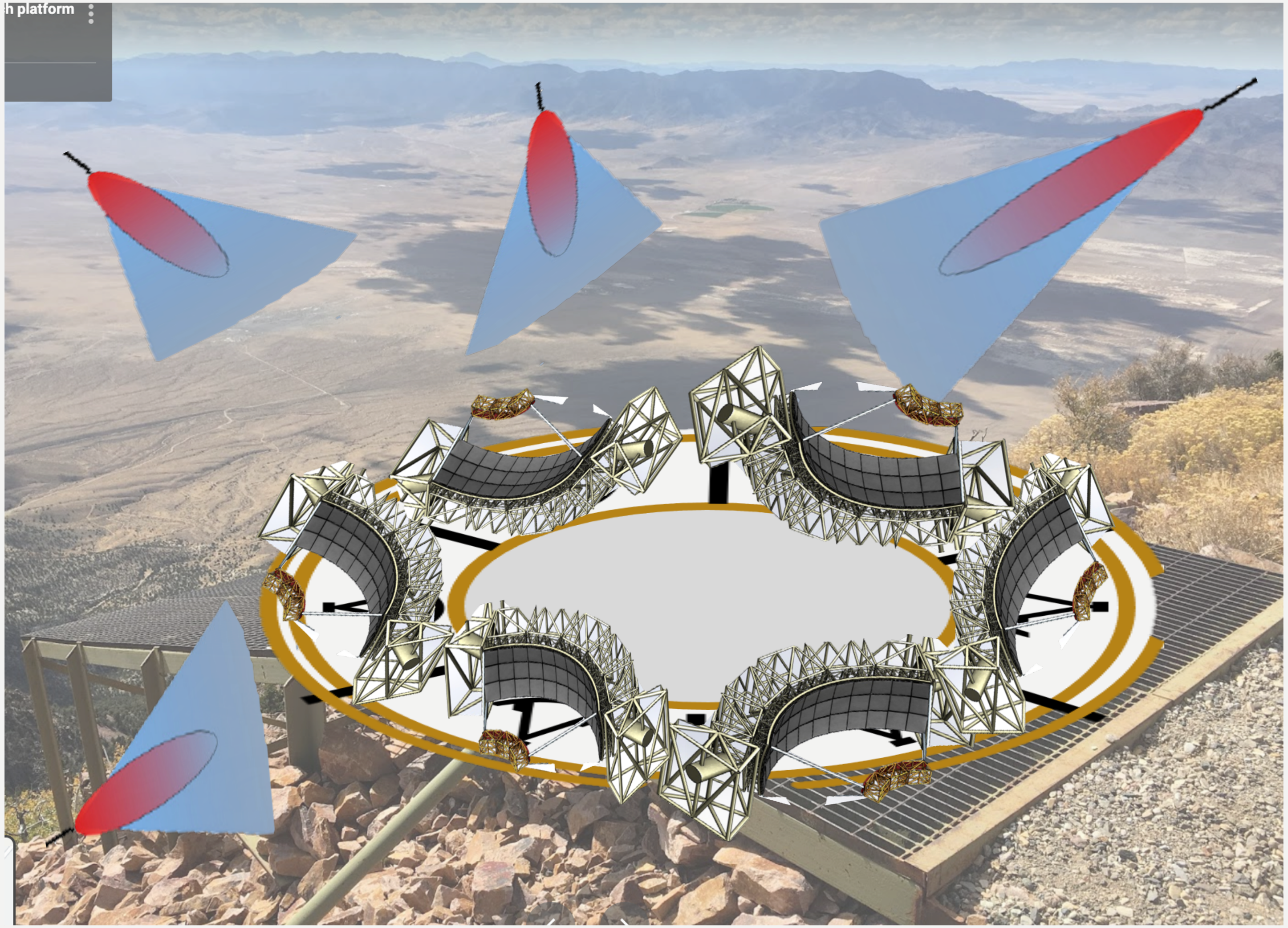


- Ingredients
  - Cosmic neutrino flux models
  - Model for nu-tau tau interaction and propagation inside the Earth crust
  - Model for emerging tau-lepton decays and electromagnetic showers
  - Telescope performance

- Goal:
  - Tau-shower must be contained in the FOV.
- Tools:
  - a wide-FOV instrument
  - dedicated observation mode

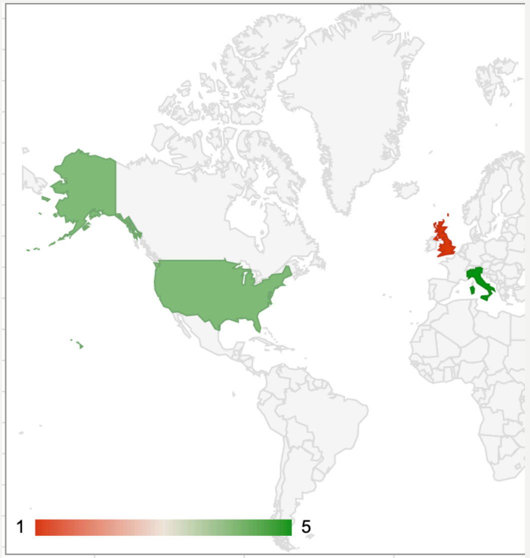
TRINITY IDEA

- array of of 6 telescopes
- mountain peak
- arranged in a circle
- covering the entire horizon
- operate at night (1200 h/y)



TRINITY design operation and performance

TRINITY COLLABORATION

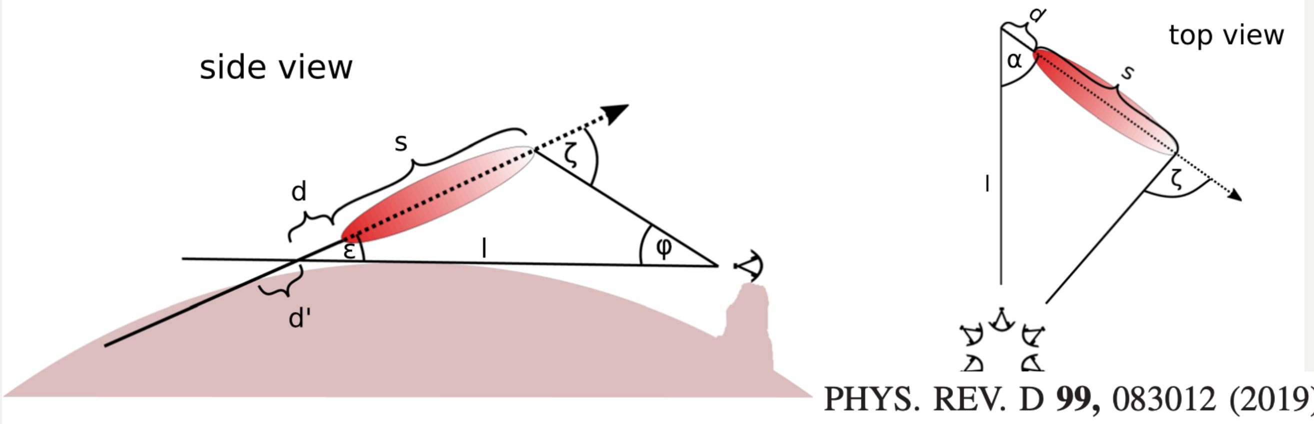


PI: Nepomuk Otte
Georgia Tech, US

- US
  - Georgia Tech University: Nepomuk Otte, Ignacio Taboada, Lauren K Stewart
  - University of Utah: David B Kieda, Wayne Springer
- UK
  - University of Durham: Anthony Brown
- Italy
  - University of Padova: Michele Doro, Mosè Mariotti
  - INFN Perugia: Giovanni Ambrosi
  - University of Bari: Francesco Giordano

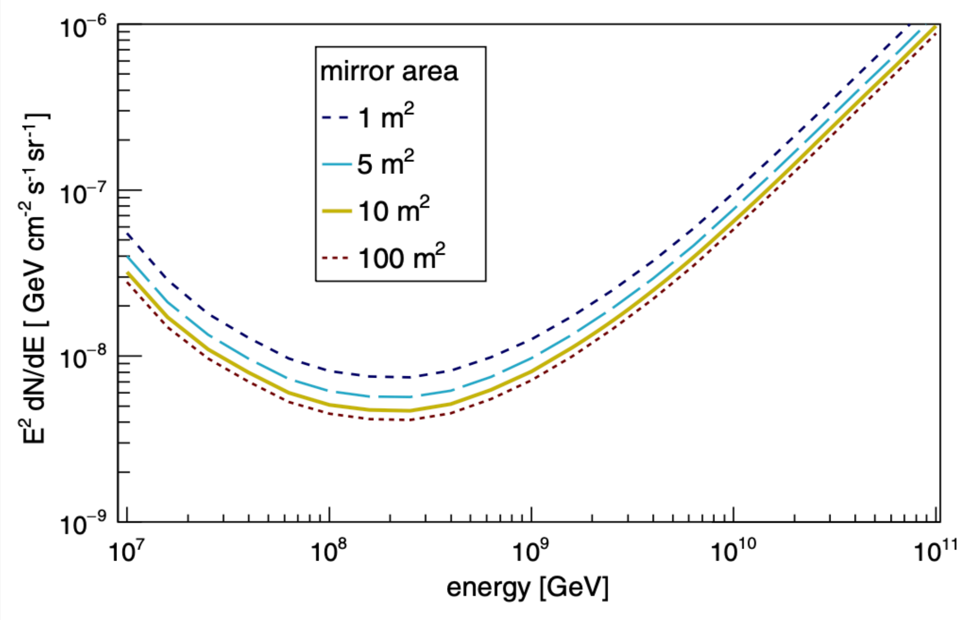
Open to new collaborators: trinity@lists.gatech.edu

DESIGN OPT: HOW BIG, HOW HIGH?

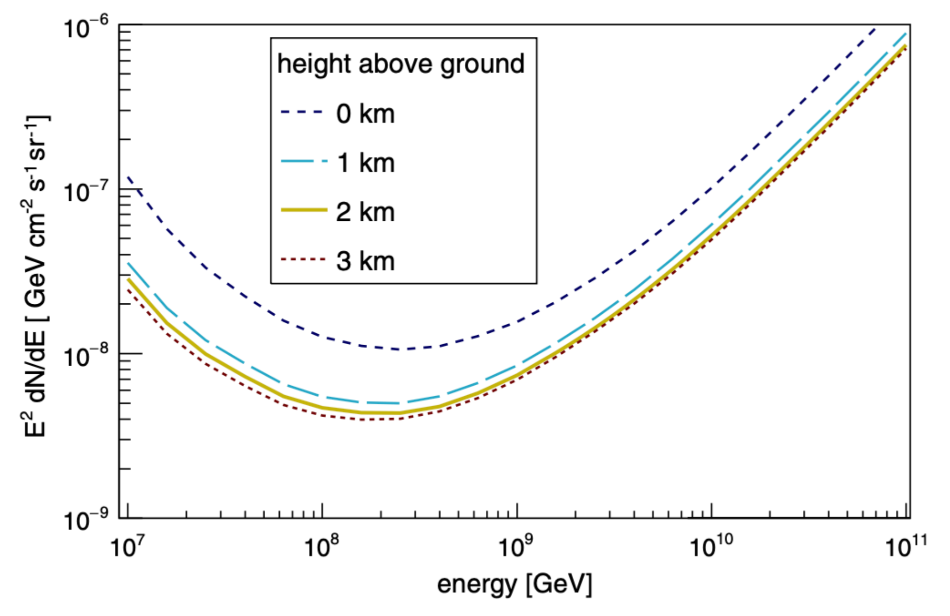


PHYS. REV. D **99,** 083012 (2019)

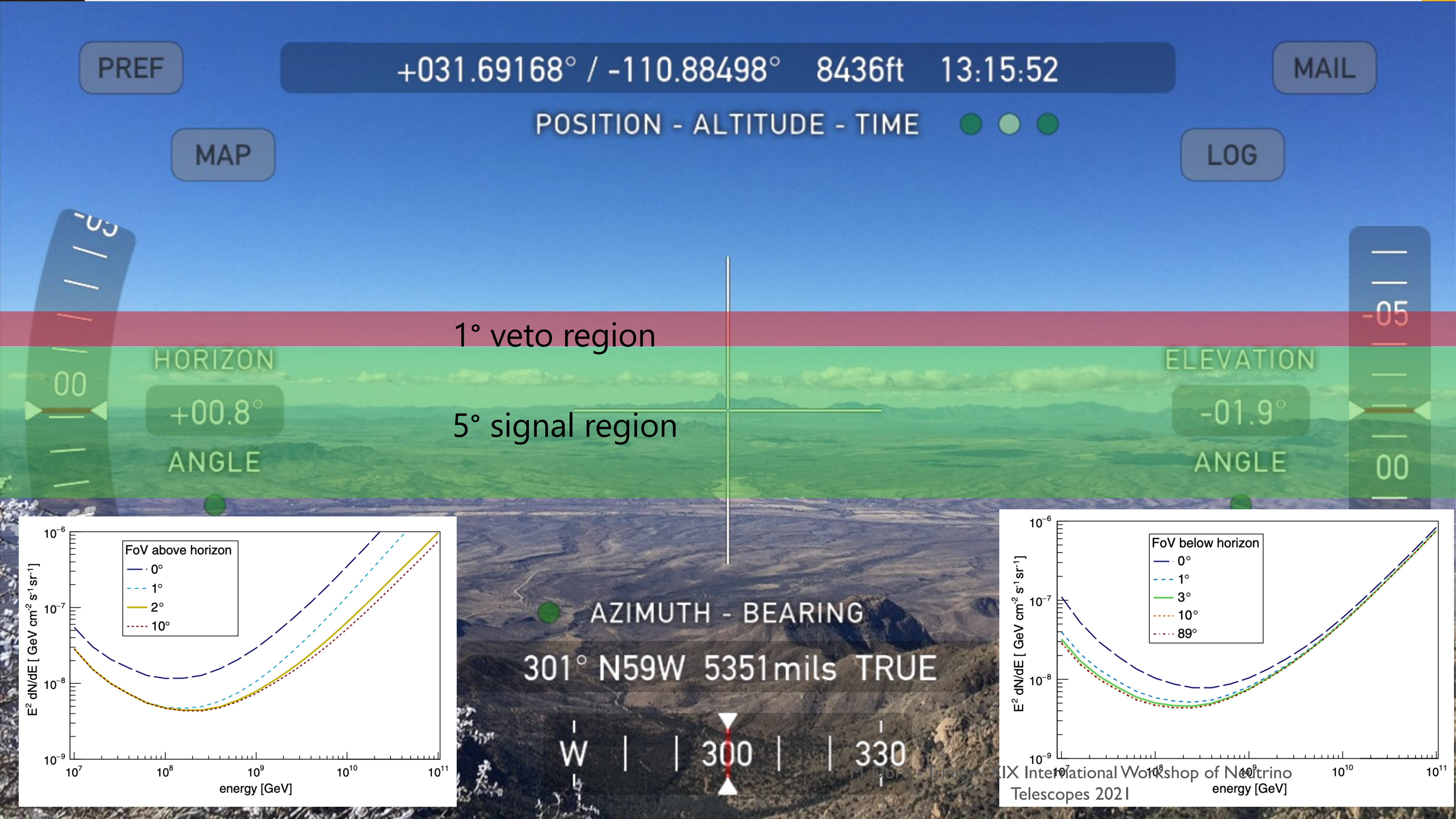
- Simulations with Corsika and NuTauSim (Phys. Rev. D 97, 023021)



No need for hugh reflectors

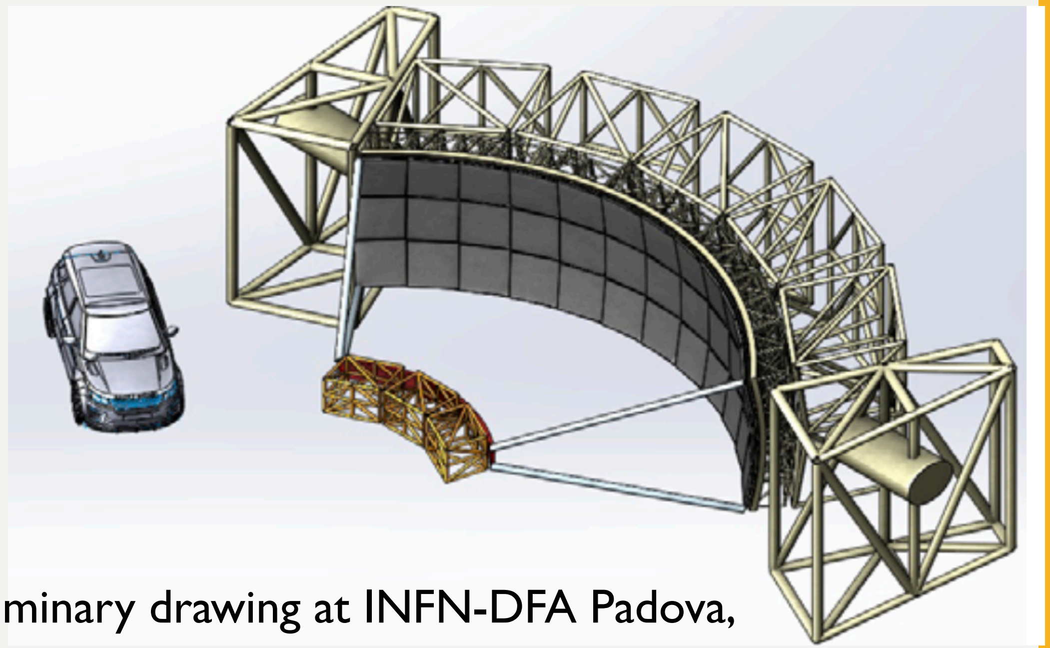


No need for extreme elevation


PREF
+031.69168° / -110.88498° 8436ft 13:15:52
MAIL
POSITION - ALTITUDE - TIME
MAP
LOG
1° veto region
HORIZON
+00.8°
ANGLE
5° signal region
ELEVATION
-01.9°
ANGLE
AZIMUTH - BEARING
301° N59W 5351mils TRUE
W
300
330
FoV above horizon
0°
1°
2°
10°
E^2 dN/dE [GeV cm^{-2} s^{-1}sr^{-1}]
energy [GeV]
FoV below horizon
0°
1°
3°
10°
89°
E^2 dN/dE [GeV cm^{-2} s^{-1} sr^{-1}]
energy [GeV]

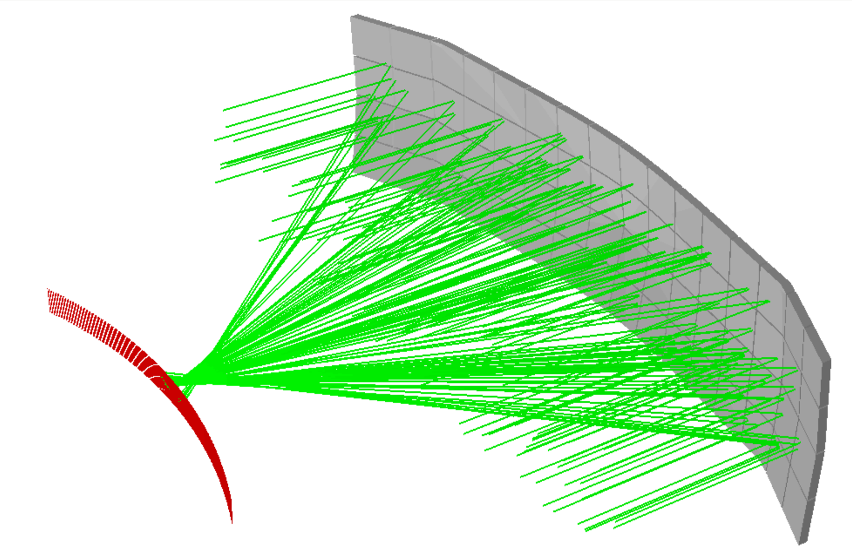
TELESCOPE DESIGN

- Optical support structure
  - Spherical profile
  - Focal length: 4.2 m
  - 0.3° optical PSF
  - 60x5 deg FOV: 12 x 3 m^2 area
  - Vertical elevation only
- Camera
  - Curved profile
  - 3300 SiPM pixels
  - Light-guides
- Robotic systems
  - Mirror shutter system
  - Remote operation



Preliminary drawing at INFN-DFA Padova,

Simulation of optical performance (C. Perennes (UNIPD) with ROBAST)



https://github.com/ROBAST

MACHETE

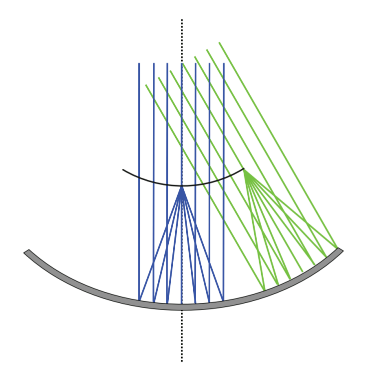
MACHETE: A transit Imaging Atmospheric Cherenkov Telescope to survey half of the Very High Energy γ-ray sky

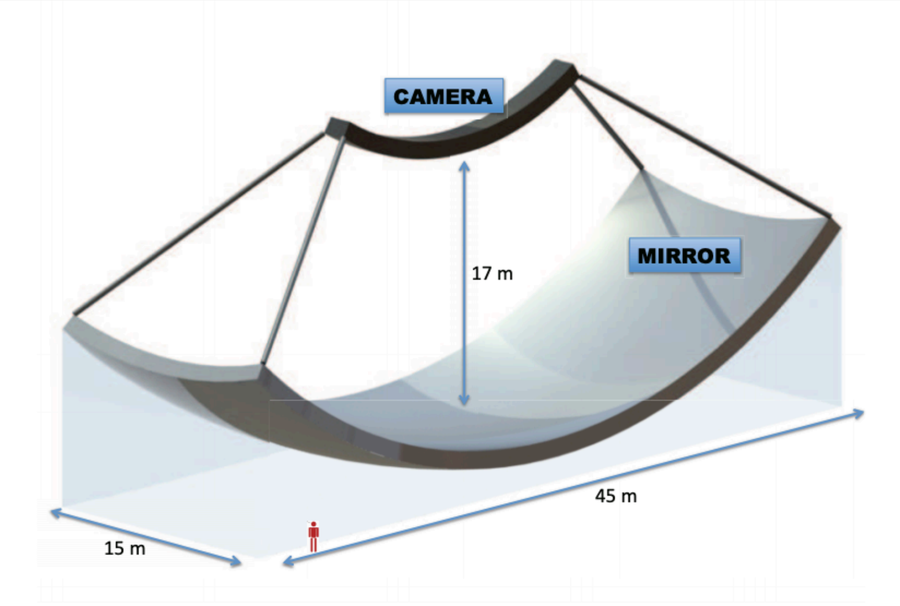
J. Cortina[a], R. López-Coto[a], A. Moralejo[a]

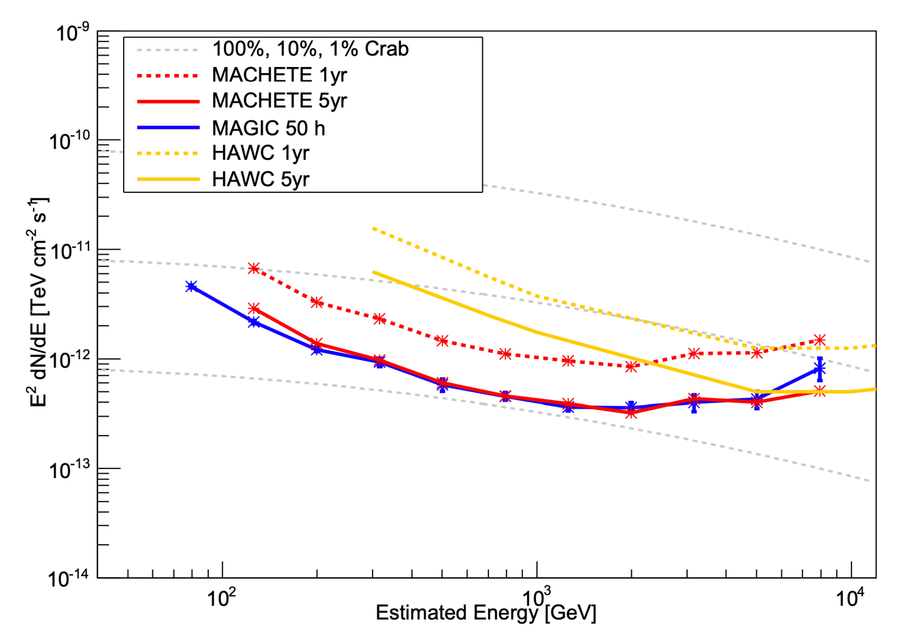
[a] *Institut de Fisica d'Altes Energies*
Edifici CN, Campus UAB
E-08193, Cerdanyola del Valles, Spain

Telescope optics borrows from MACHETE optics concept

Astropart.Phys. 72 (2016) 46-54





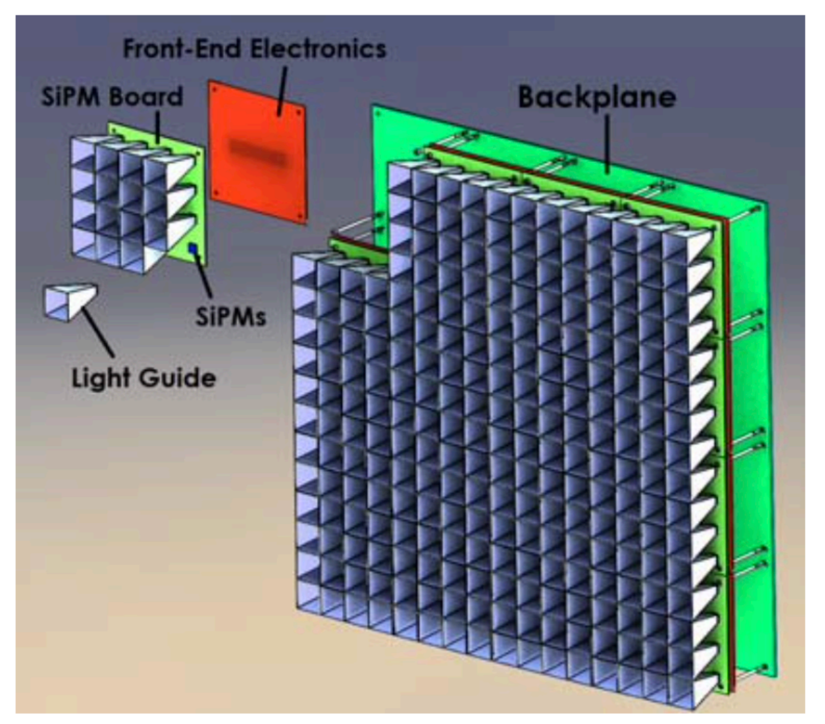


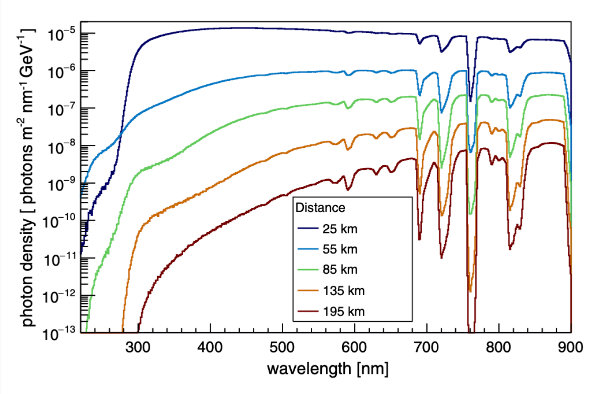
MIRRORS

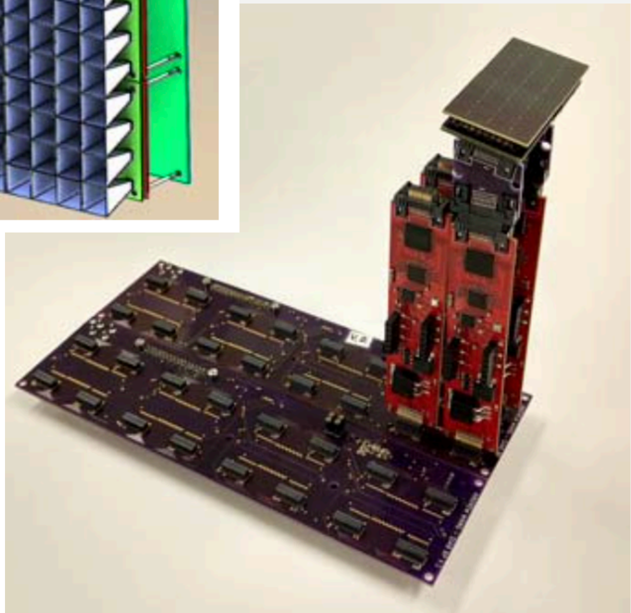
Prototype of cold-slumped thin glass foils produced at University of Padova

- Mirror
  - area 1 or ¼ square meter
  - Focal length: 4.2 m
  - <0.3° optical PSF
  - 36 $1 m^2$ mirrors / 144 $0.25 m^2$ mirrors
- Replica techniques already tested for CTA: superimposed thin glass foils (0.8 mm) possibly with stiffening separators
  - A) Cold slumping. However possibly too short focal length (too curved mirror)
  - B) Hot slumping
- Reflective layer:
  - A) pre-aluminized glasse sheet
  - B) reflective adhesive (3M)

CAMERA



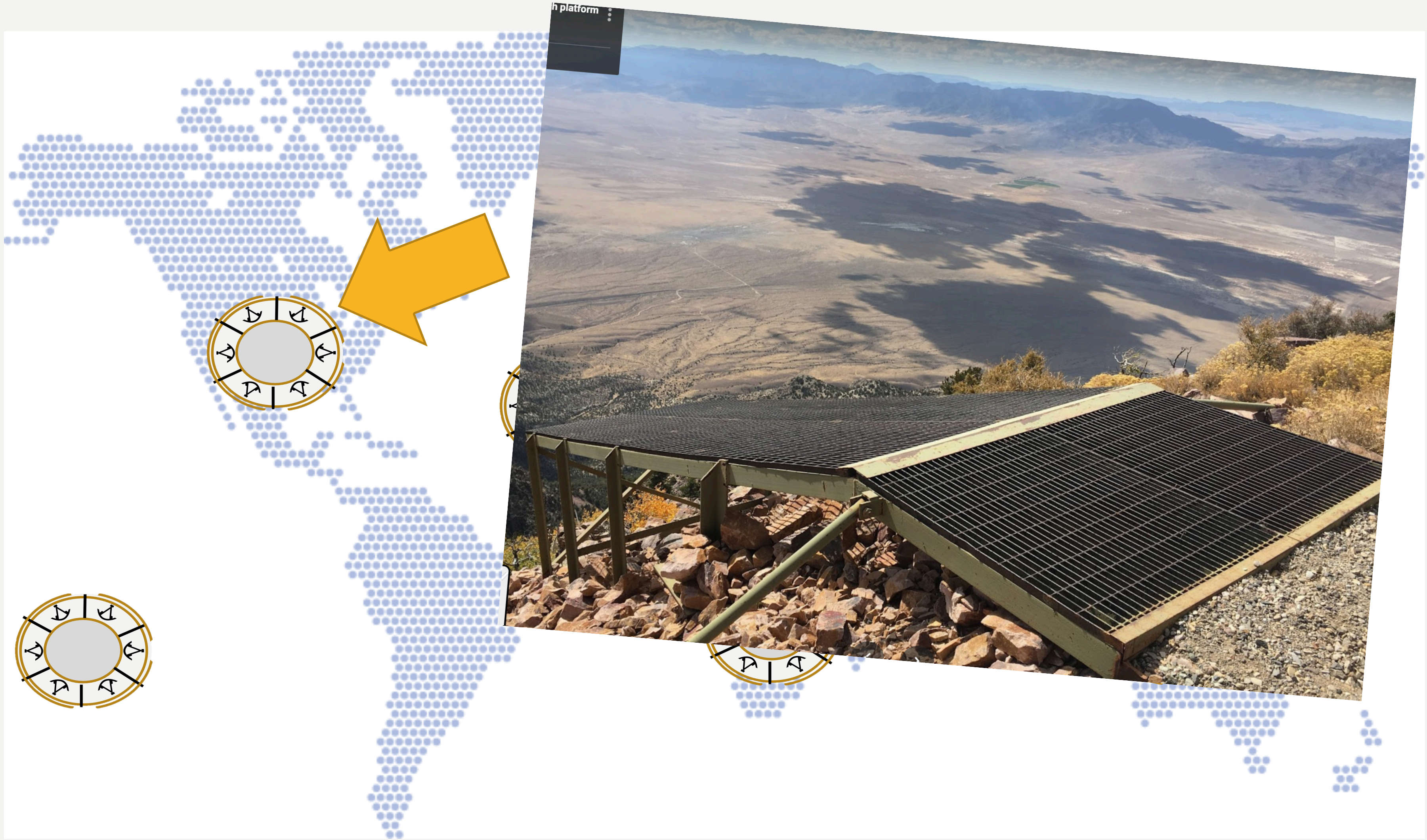




- Camera design adopted from EUSO-SPB2 Cherenkov telescope

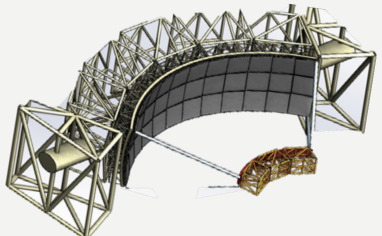
- 3300 SiPMs arranged in arrays to be plugged in a front-end board
- Photosensor: ~1cm^2 SiPM from CTA development (in coll. with FBK company, Trento Italy)
- Light guides (solid, PMMA) to select acceptance
- Digitizer: AGET from EUSO-SPB2 development

SITES: 3 ARRAYS OF 6 TELESCOPES



FRISCO PEAK:

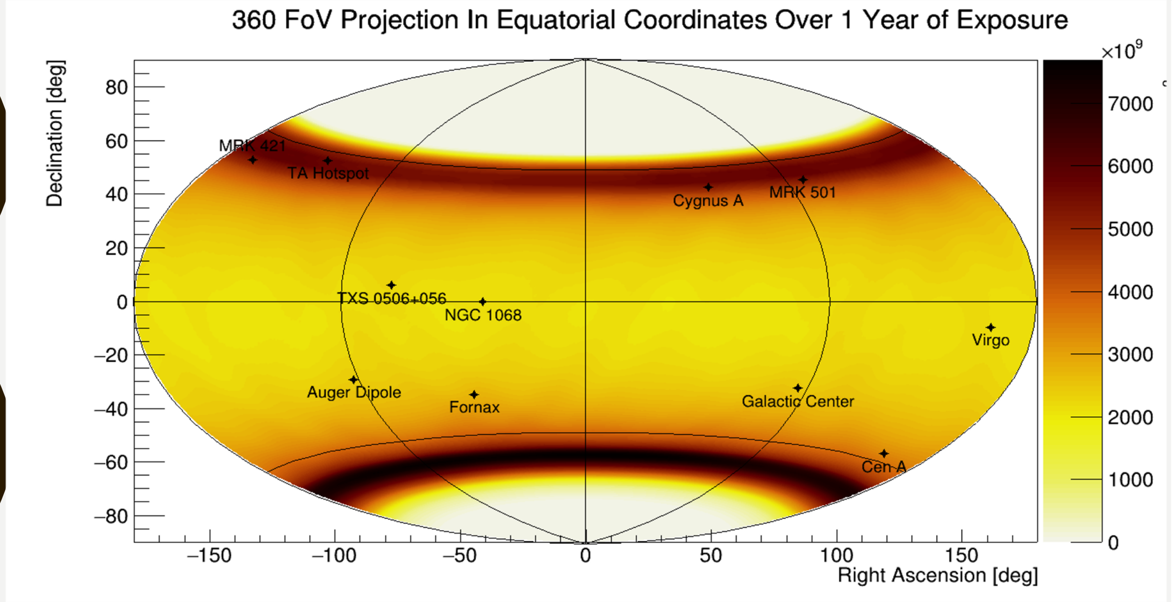
Negotiation with local authorities



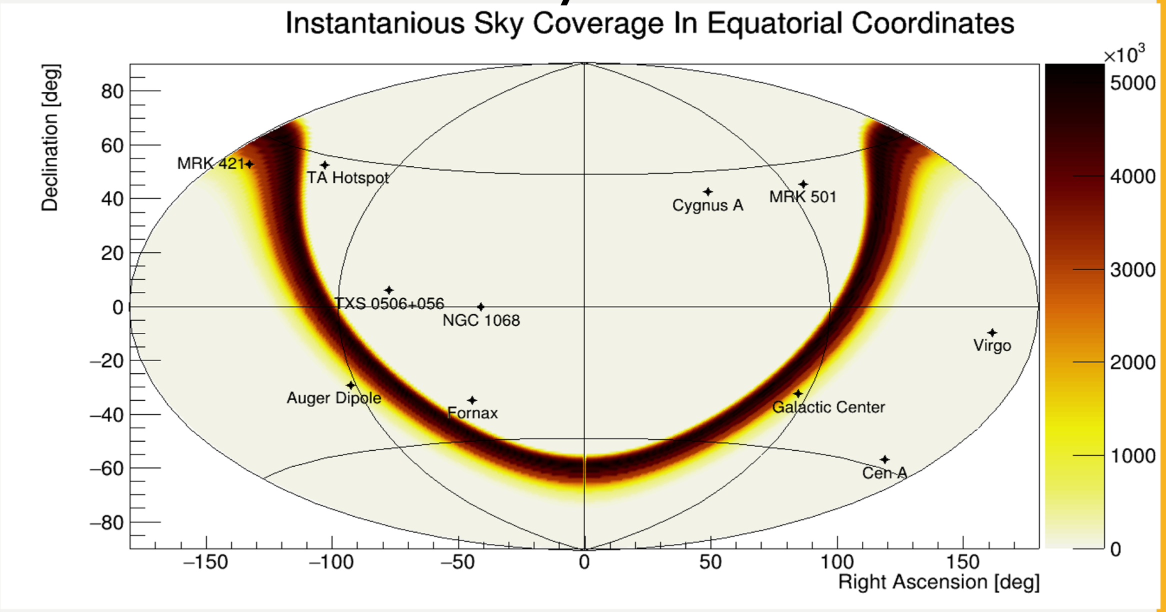
EXPECTATIONS

SKY COVERAGE PER SITE

Annual



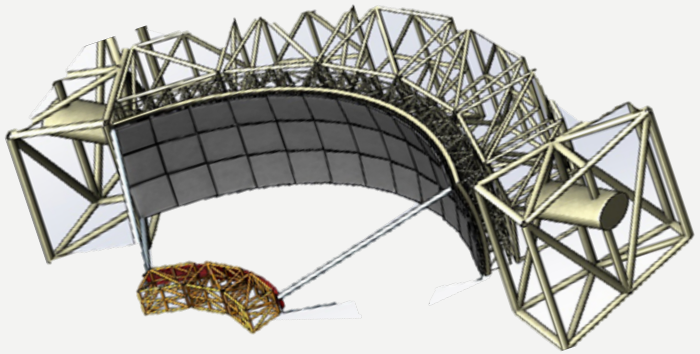
Daily



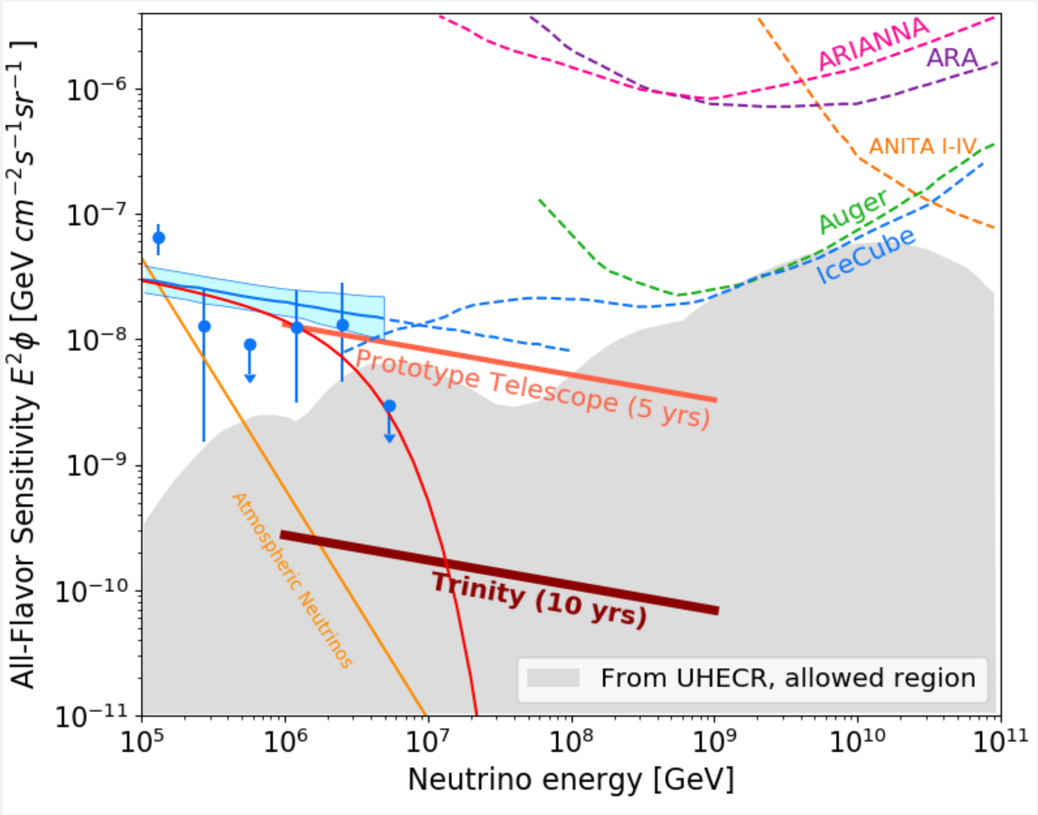
- Trinity has much of the same sky coverage as all major EM and GW multi-messenger instruments.
- Trinity observes 50% of the sky every night.

Expect 10 GRBs/year go off in FoV

wide band → 13% of sky



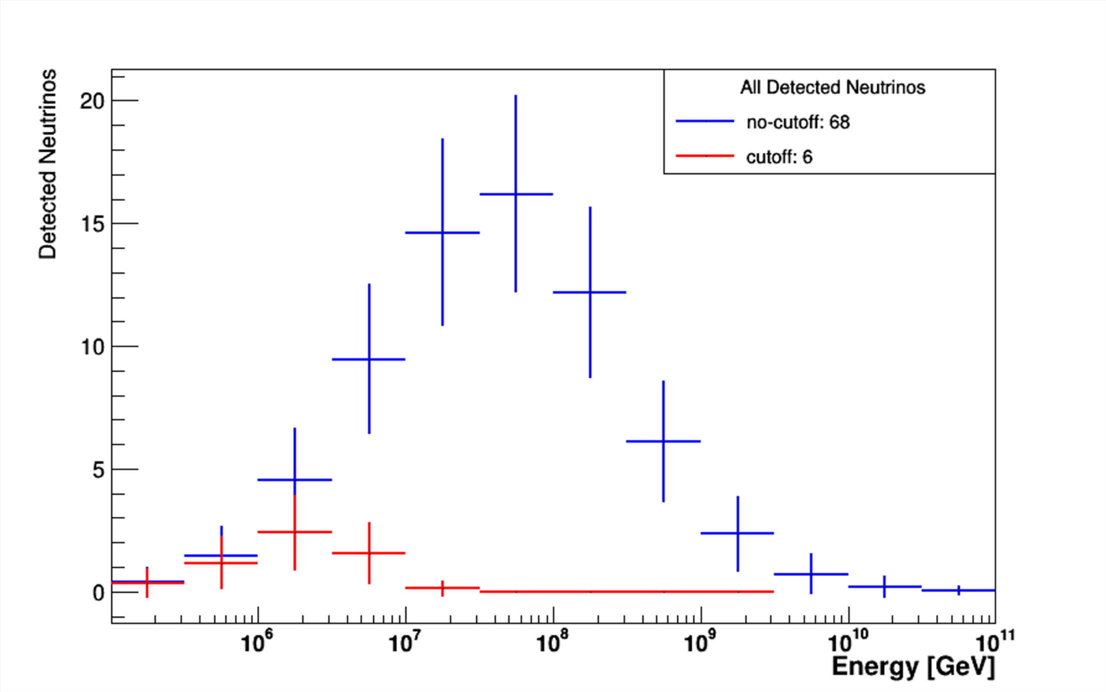
DIFFUSE NEUTRINOS



Extrapolating IC nu-spectrum -2.8

Without cutoff (blue) 68 neutrinos

With cutoff (red) 6 neutrinos

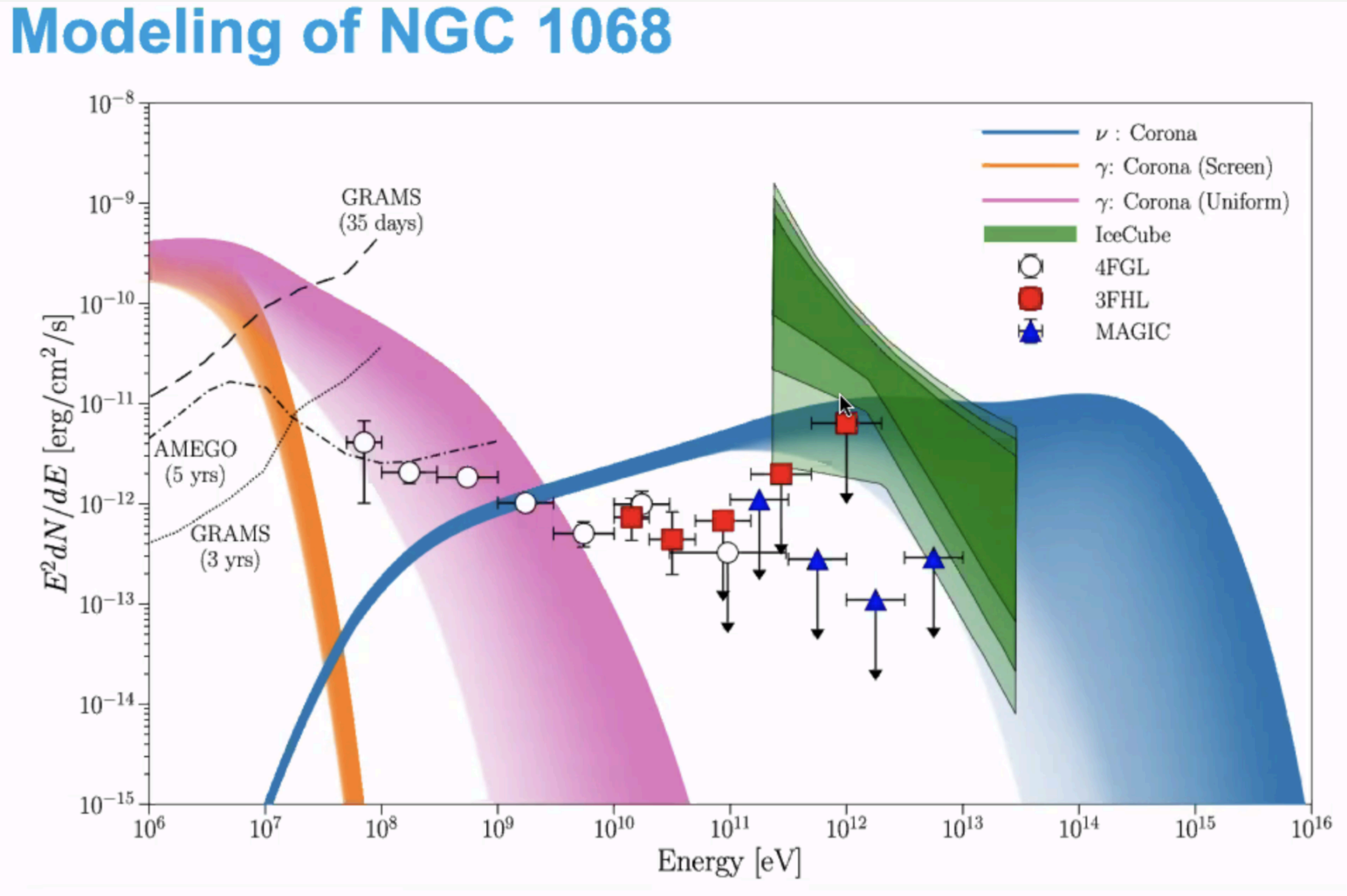


18 telescopes on three sites

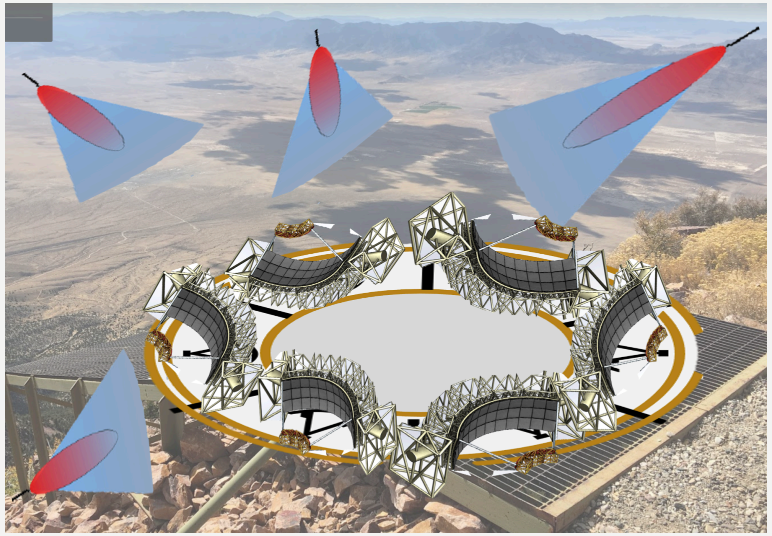
- 15M$ investment
- Useful sensitivity from $5x10^5$ GeV to 10^{10} GeV
- Sensitive to 1% of the astrophysical-neutrino flux

Single telescope has changes to detect diffuse nuetrino flux (if not cutoff)

ASTROPHYSICAL TARGETS



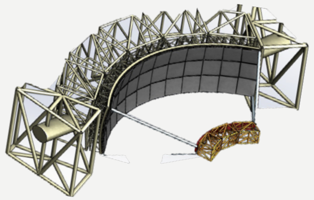
A. Franckowiak, this conference



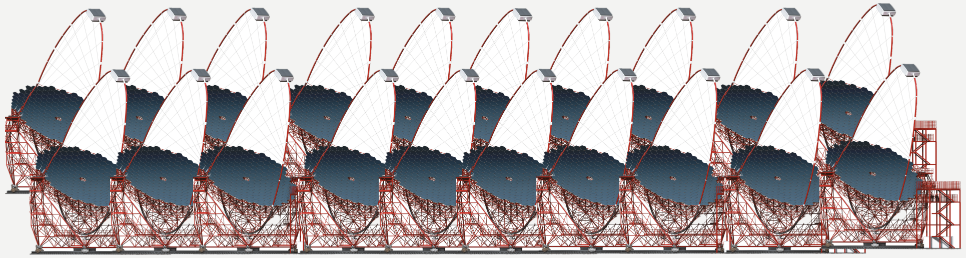
- When the target is just below the horizon it can be seen in neutrino
- (but also gamma-rays right before/after)

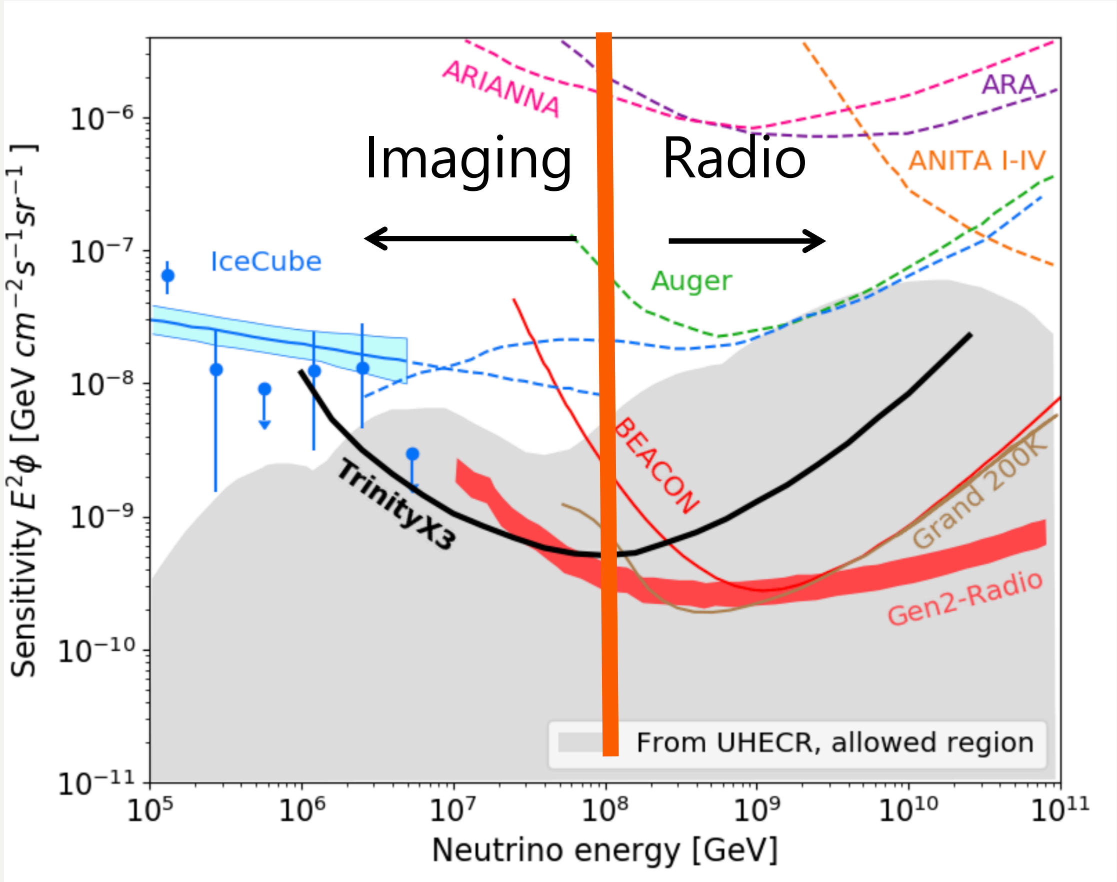
TAKE-AWAY

- Thanks to a wide-FOV optics and a dedicated instrument development it is possible to boost the sensitivity for Earth-skimming tau neutrinos with IACTs
- Sensitivity bridges region between IC and Radio detection
- We have completed the conceptual design and have applied for funding to build a prototype telescope



= 20 x MAGIC





BACKUP

MODELS OF NU-FLUX