CTAO
Cherenkov Telescope Array Observatory

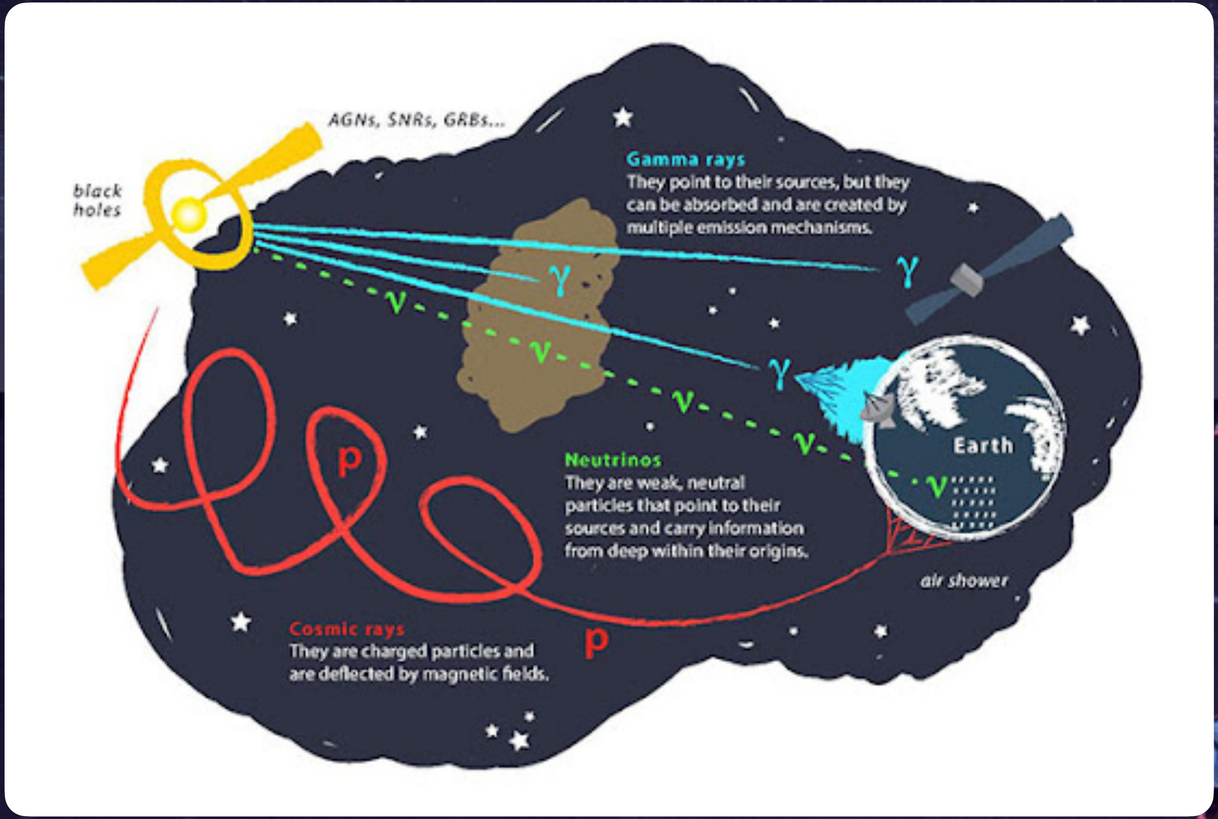
V Gravi-Gamma-Nu Workshop
9 October 2024, Bari

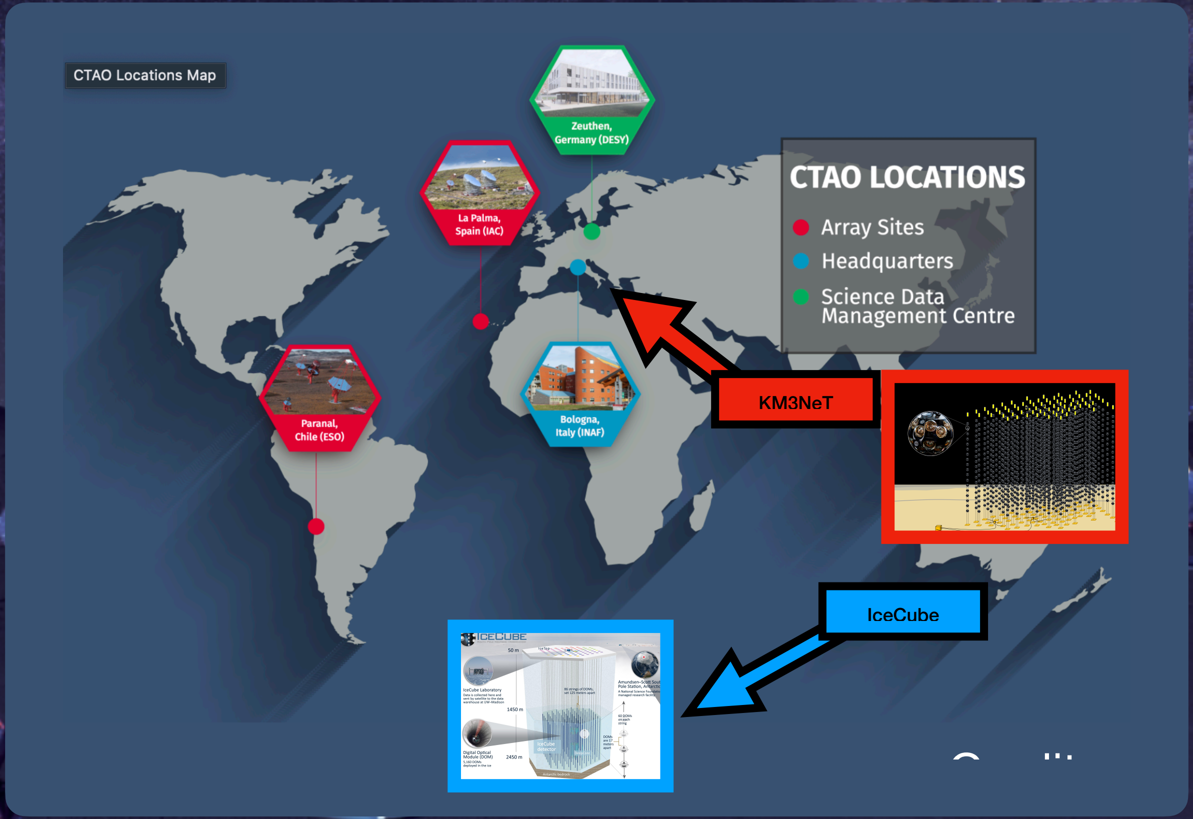
Evaluation of the CTAO performance to the gamma-ray emission from neutrino sources detectable by the IceCube and KM3NeT neutrino telescopes

Gloria Maria Cicciari, Ph.D. Student
gloriamaria.cicciari@cta-observatory.org

SIGILLVM PANORMITANÆ STVDIORVM VNIVERSITATIS

Multi-messenger astronomy





NToO

CTAO

Neutrino Sinulations (FIRESONG)

↓

Neutrino Telescope "Filter"

↓

IceCube

↓

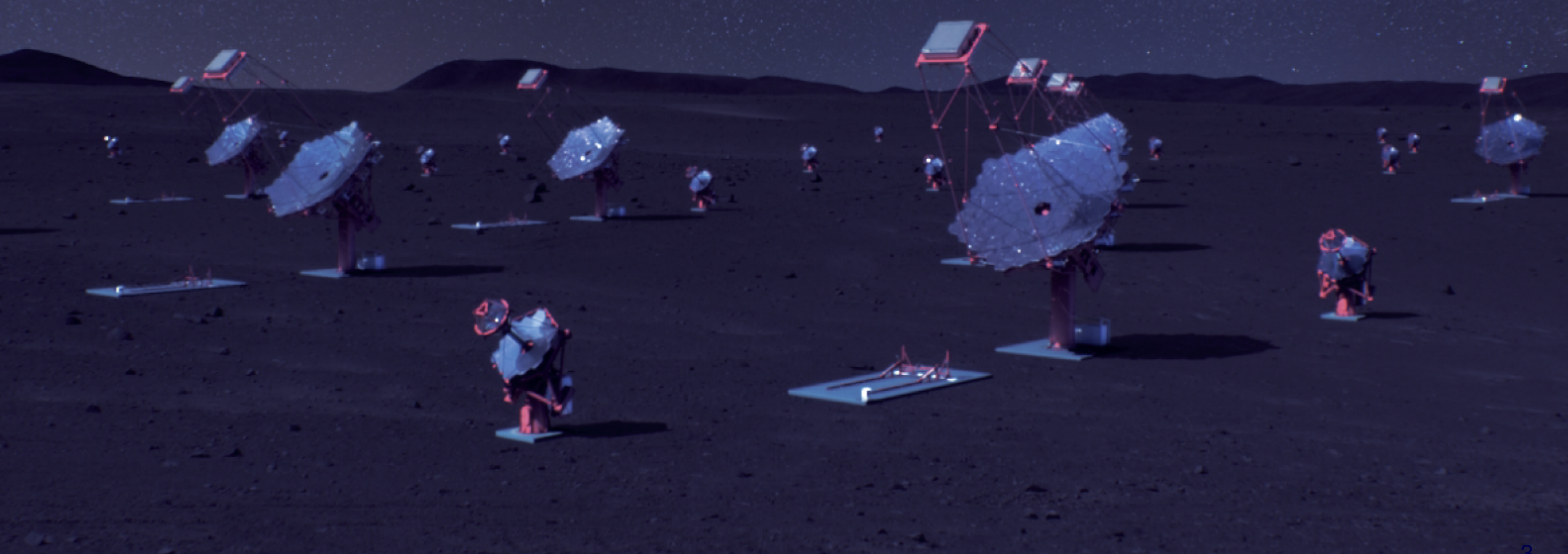
Gamma Simulations

↓

The Alpha configuration of the array

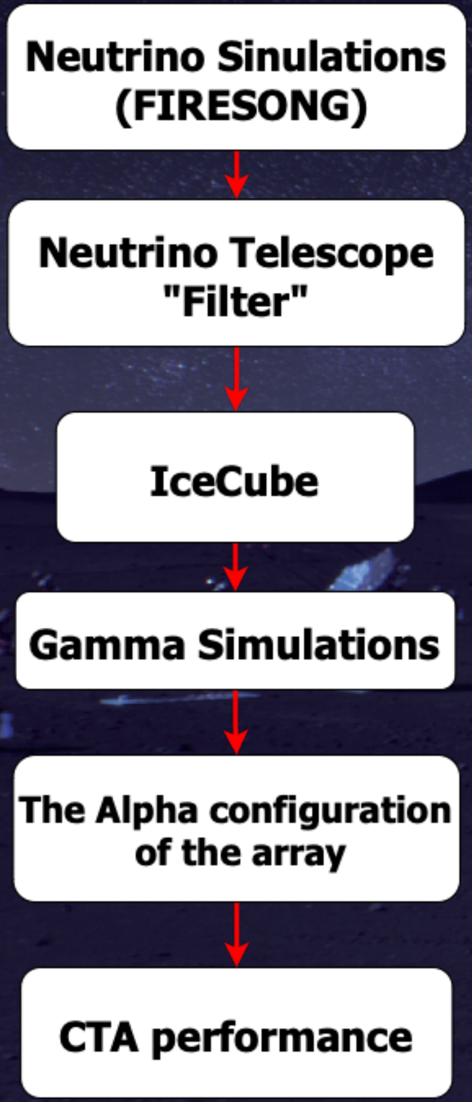
↓

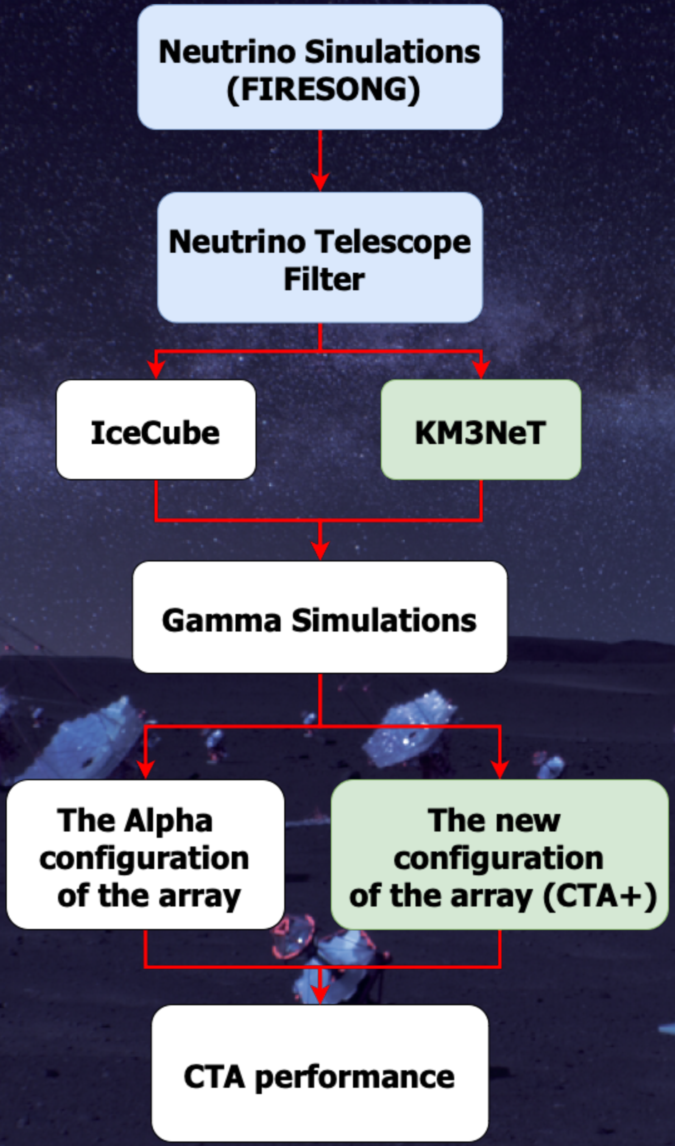
CTA performance



NToO

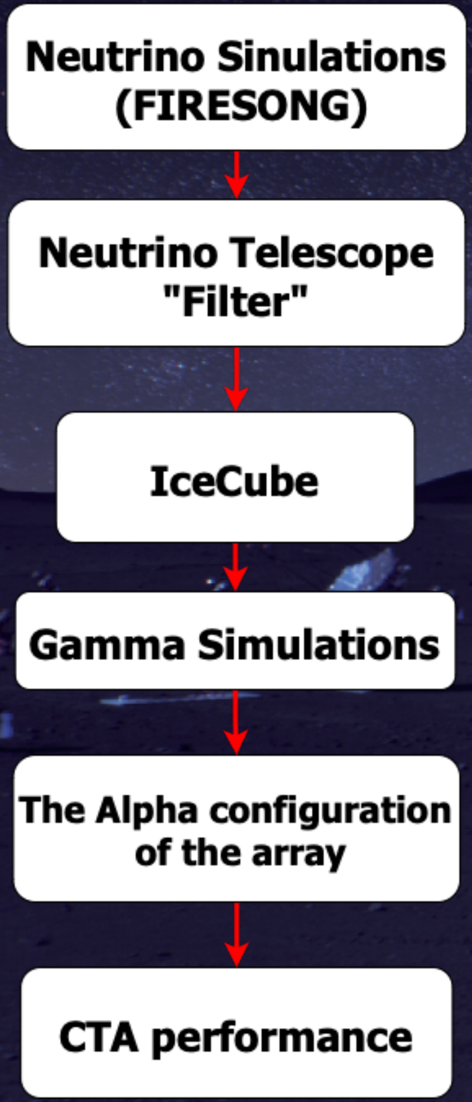
CTAO

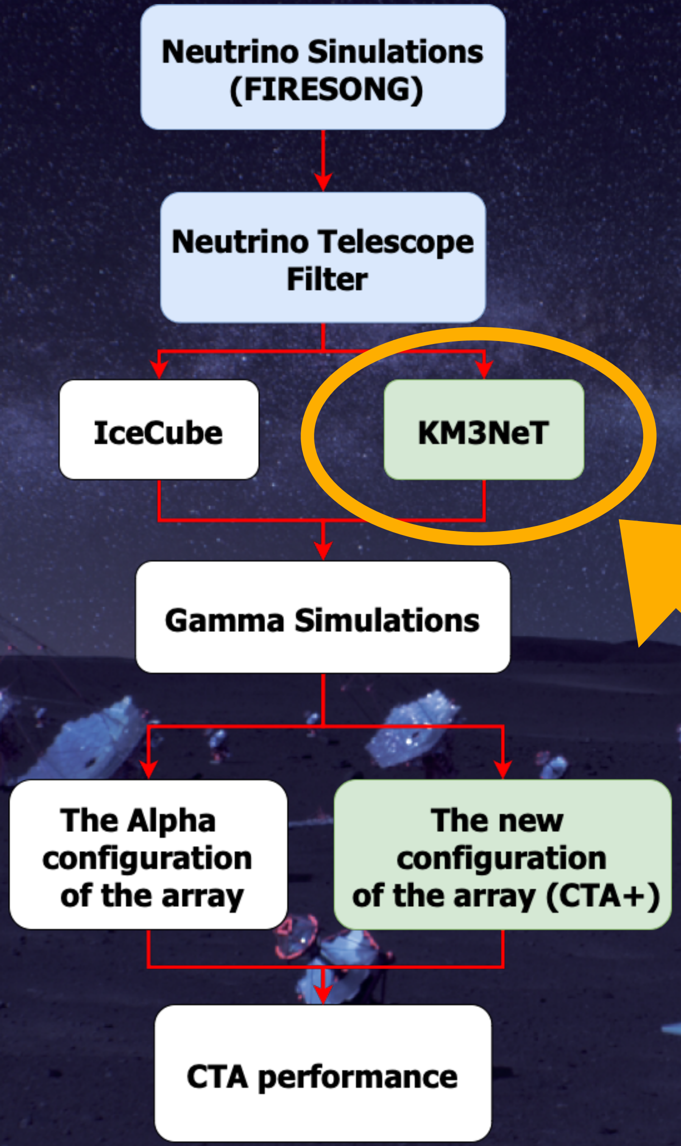

Neutrino Sinulations (FIRESONG)
Neutrino Telescope "Filter"
IceCube
Gamma Simulations
The Alpha configuration of the array
CTA performance


Neutrino Sinulations (FIRESONG)
Neutrino Telescope Filter
IceCube
KM3NeT
Gamma Simulations
The Alpha configuration of the array
The new configuration of the array (CTA+)
CTA performance

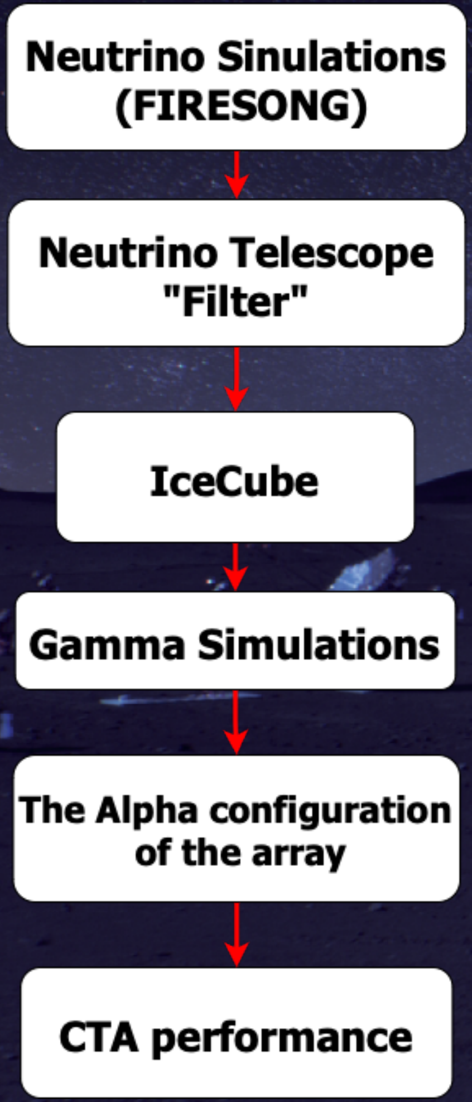
NToO

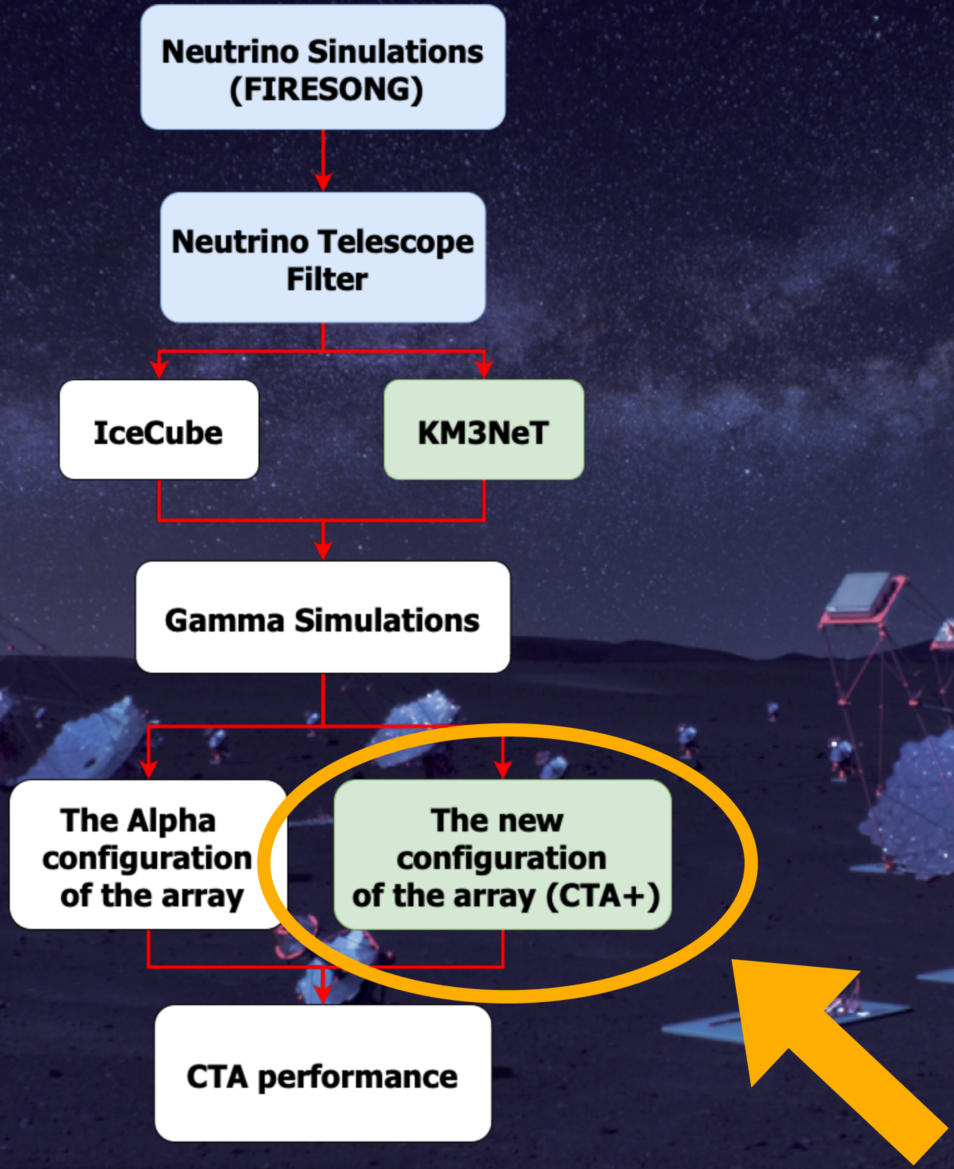
CTAO


Neutrino Sinulations (FIRESONG)
Neutrino Telescope "Filter"
IceCube
Gamma Simulations
The Alpha configuration of the array
CTA performance

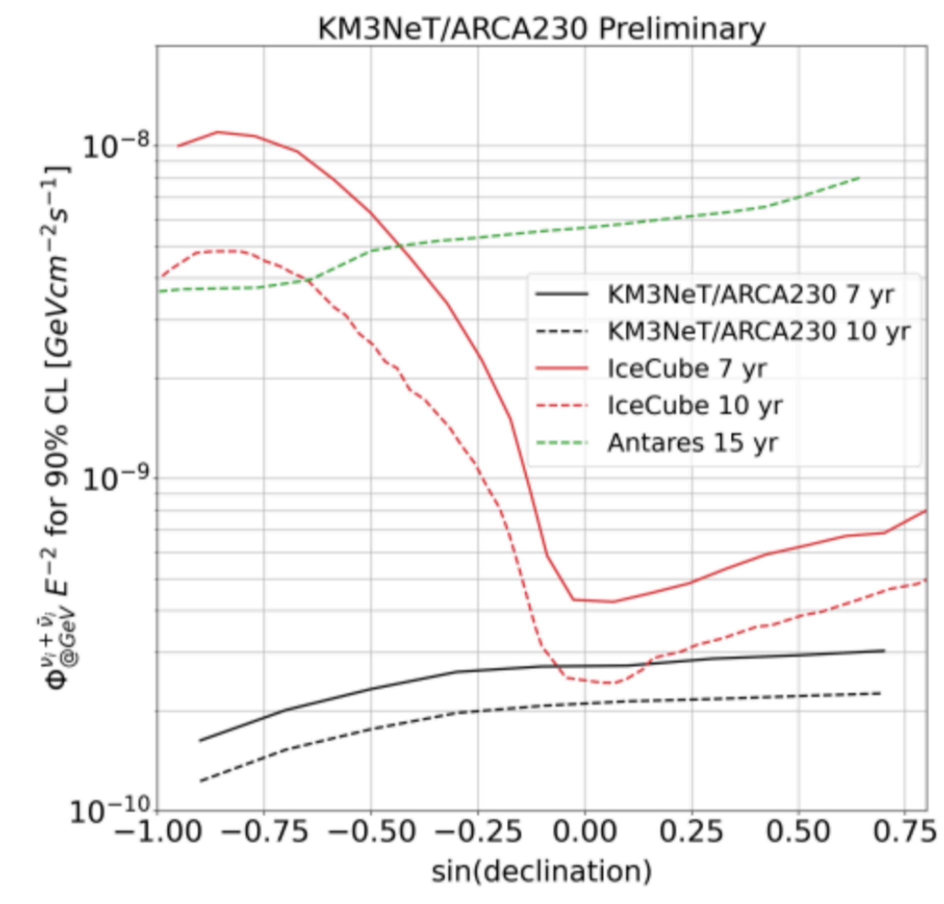

Neutrino Sinulations (FIRESONG)
Neutrino Telescope Filter
IceCube
KM3NeT
Gamma Simulations
The Alpha configuration of the array
The new configuration of the array (CTA+)
CTA performance

NToO


Neutrino Sinulations (FIRESONG)
Neutrino Telescope "Filter"
IceCube
Gamma Simulations
The Alpha configuration of the array
CTA performance


Neutrino Sinulations (FIRESONG)
Neutrino Telescope Filter
IceCube
KM3NeT
Gamma Simulations
The Alpha configuration of the array
The new configuration of the array (CTA+)
CTA performance

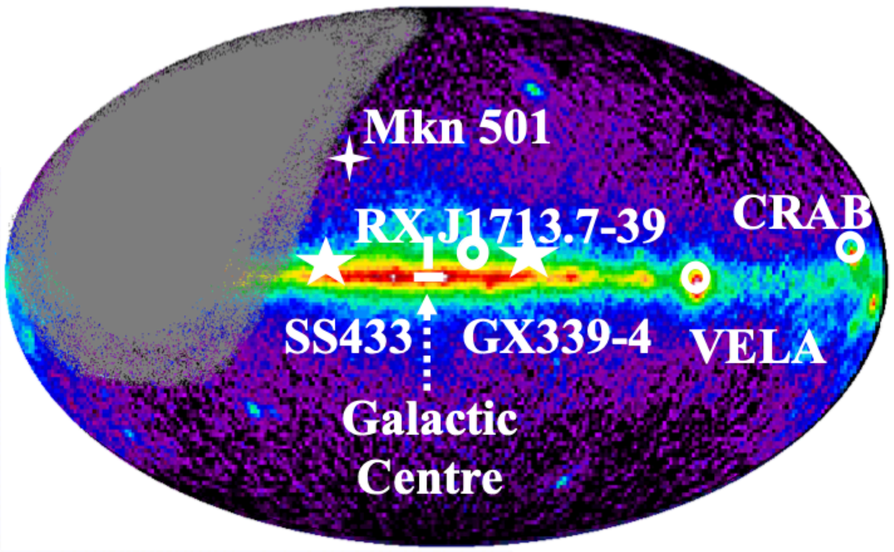
Neutrino Telescope Filter



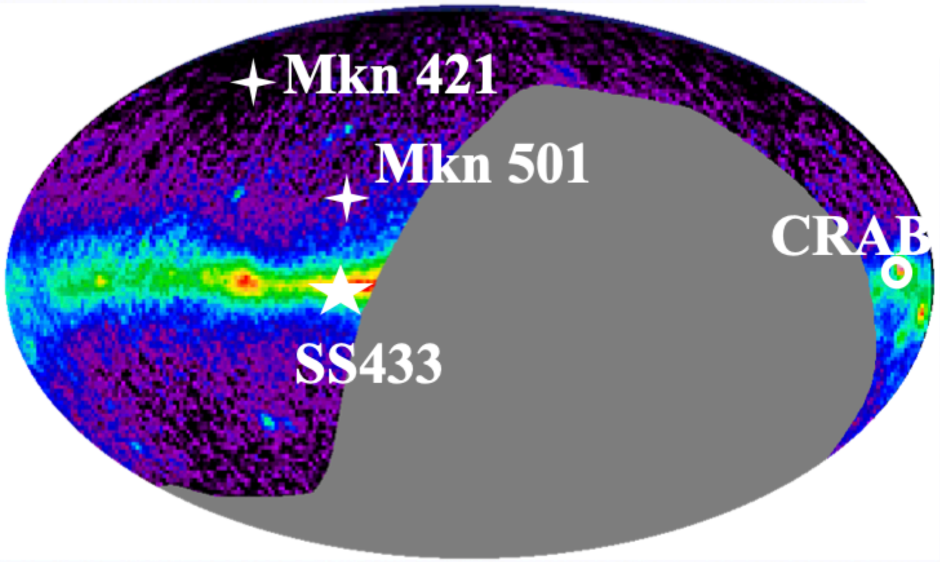
KM3NeT Collaboration, PoS ICRC2023 1075

Neutrino Telescope Filter

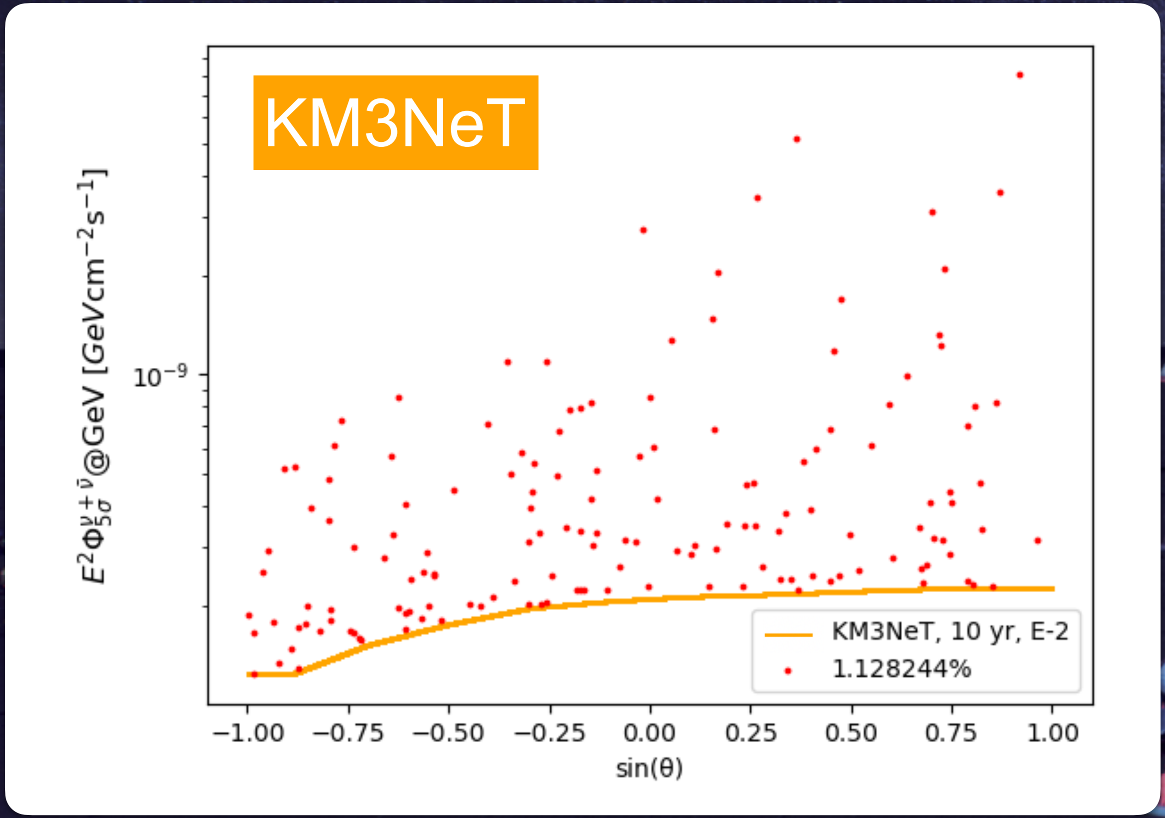
The sky seen from **KM3NeT**

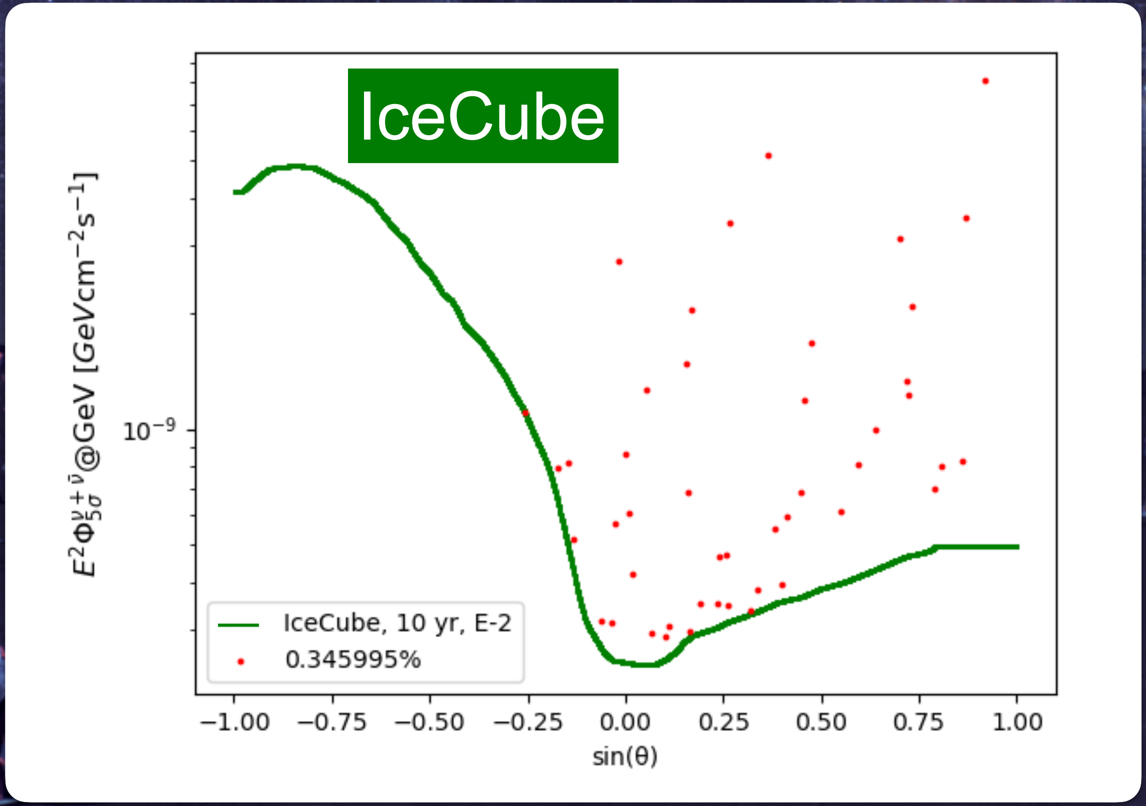


The sky seen from **IceCube**

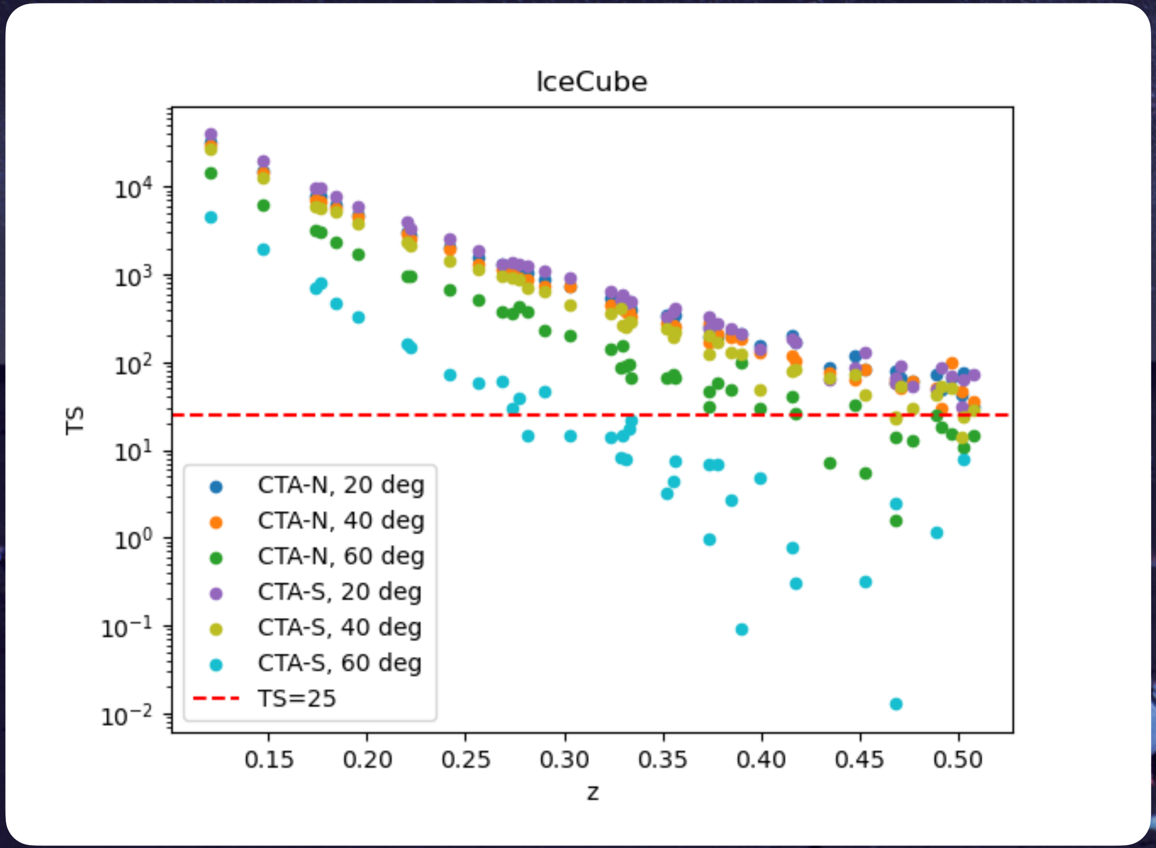


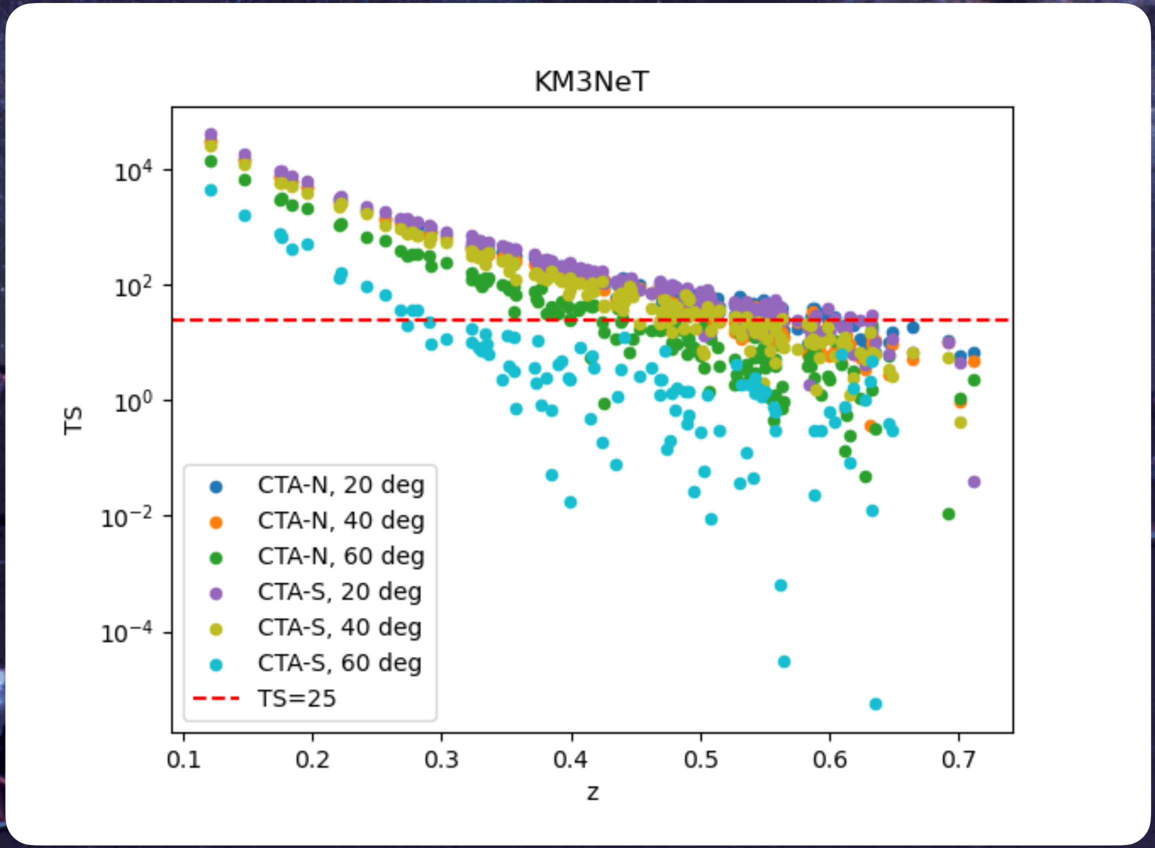
Neutrino Telescope Filter

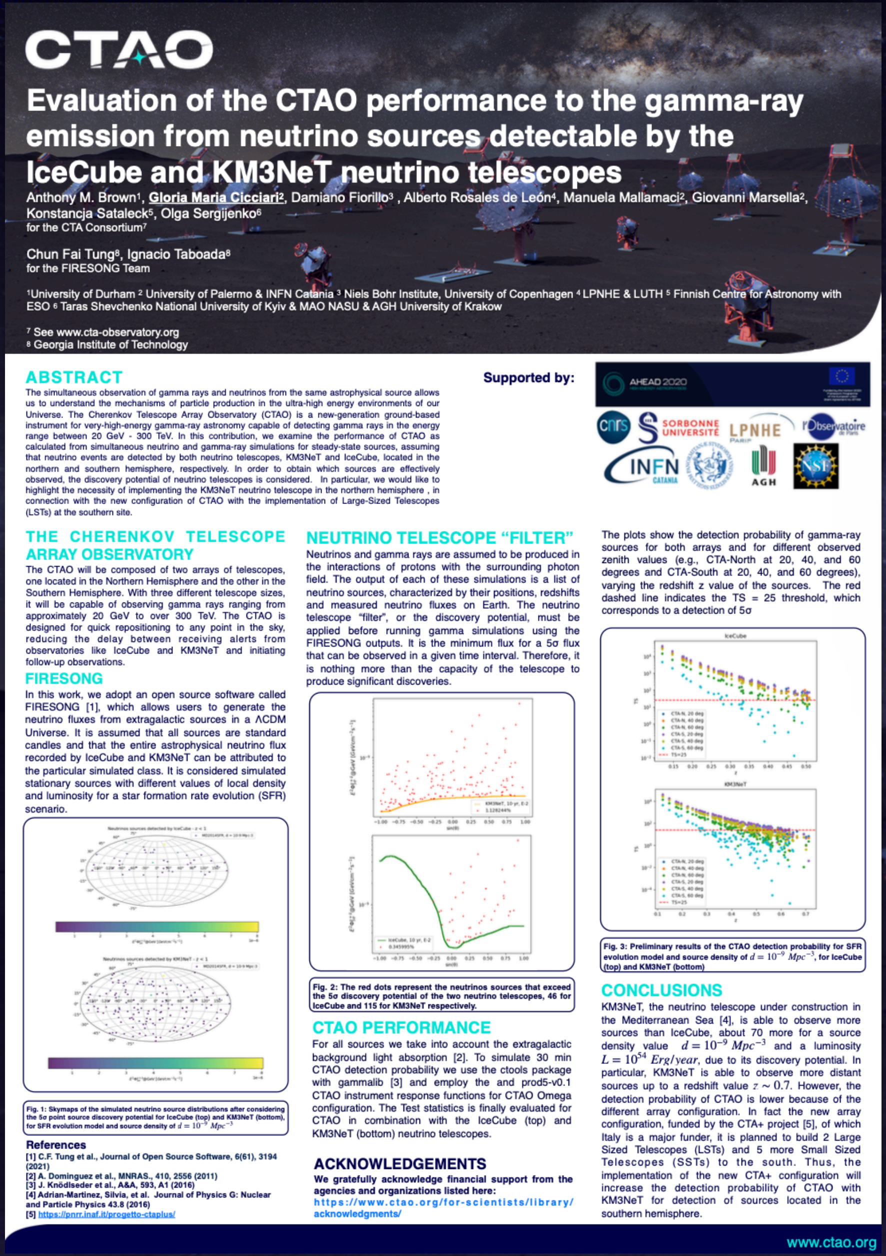




CTA detection probability







CTAO

Evaluation of the CTAO performance to the gamma-ray emission from neutrino sources detectable by the IceCube and KM3NeT neutrino telescopes

Anthony M. Brown[1], Gloria Maria Cicciari[2], Damiano Fiorillo[3], Alberto Rosales de León[4], Manuela Mallamaci[2], Giovanni Marsella[2], Konstancja Satalecka[5], Olga Sergijenko[6]
for the CTA Consortium[7]

Chun Fai Tung[8], Ignacio Taboada[8]
for the FIRESONG Team

[1]University of Durham [2] University of Palermo & INFN Catania [3] Niels Bohr Institute, University of Copenhagen [4] LPNHE & LUTH [5] Finnish Centre for Astronomy with ESO [6] Taras Shevchenko National University of Kyiv & MAO NASU & AGH University of Krakow

[7] See www.cta-observatory.org
[8] Georgia Institute of Technology

ABSTRACT

The simultaneous observation of gamma rays and neutrinos from the same astrophysical source allows us to understand the mechanisms of particle production in the ultra-high energy environments of our Universe. The Cherenkov Telescope Array Observatory (CTAO) is a new-generation ground-based instrument for very-high-energy gamma-ray astronomy capable of detecting gamma rays in the energy range between 20 GeV - 300 TeV. In this contribution, we examine the performance of CTAO as calculated from simultaneous neutrino and gamma-ray simulations for steady-state sources, assuming that neutrino events are detected by both neutrino telescopes, KM3NeT and IceCube, located in the northern and southern hemisphere, respectively. In order to obtain which sources are effectively observed, the discovery potential of neutrino telescopes is considered. In particular, we would like to highlight the necessity of implementing the KM3NeT neutrino telescope in the northern hemisphere , in connection with the new configuration of CTAO with the implementation of Large-Sized Telescopes (LSTs) at the southern site.

Supported by:

AHEAD 2020

THE CHERENKOV TELESCOPE ARRAY OBSERVATORY

The CTAO will be composed of two arrays of telescopes, one located in the Northern Hemisphere and the other in the Southern Hemisphere. With three different telescope sizes, it will be capable of observing gamma rays ranging from approximately 20 GeV to over 300 TeV. The CTAO is designed for quick repositioning to any point in the sky, reducing the delay between receiving alerts from observatories like IceCube and KM3NeT and initiating follow-up observations.

FIRESONG

In this work, we adopt an open source software called FIRESONG [1], which allows users to generate the neutrino fluxes from extragalactic sources in a ΛCDM Universe. It is assumed that all sources are standard candles and that the entire astrophysical neutrino flux recorded by IceCube and KM3NeT can be attributed to the particular simulated class. It is considered simulated stationary sources with different values of local density and luminosity for a star formation rate evolution (SFR) scenario.

Fig. 1: Skymaps of the simulated neutrino source distributions after considering the 5σ point source discovery potential for IceCube (top) and KM3NeT (bottom), for SFR evolution model and source density of $d = 10^{-9}$ Mpc^{-3}

NEUTRINO TELESCOPE "FILTER"

Neutrinos and gamma rays are assumed to be produced in the interactions of protons with the surrounding photon field. The output of each of these simulations is a list of neutrino sources, characterized by their positions, redshifts and measured neutrino fluxes on Earth. The neutrino telescope "filter", or the discovery potential, must be applied before running gamma simulations using the FIRESONG outputs. It is the minimum flux for a 5σ flux that can be observed in a given time interval. Therefore, it is nothing more than the capacity of the telescope to produce significant discoveries.

Fig. 2: The red dots represent the neutrinos sources that exceed the 5σ discovery potential of the two neutrino telescopes, 46 for IceCube and 115 for KM3NeT respectively.

CTAO PERFORMANCE

For all sources we take into account the extragalactic background light absorption [2]. To simulate 30 min CTAO detection probability we use the ctools package with gammalib [3] and employ the and prod5-v0.1 CTAO instrument response functions for CTAO Omega configuration. The Test statistics is finally evaluated for CTAO in combination with the IceCube (top) and KM3NeT (bottom) neutrino telescopes.

The plots show the detection probability of gamma-ray sources for both arrays and for different observed zenith values (e.g., CTA-North at 20, 40, and 60 degrees and CTA-South at 20, 40, and 60 degrees), varying the redshift z value of the sources. The red dashed line indicates the TS = 25 threshold, which corresponds to a detection of 5σ

Fig. 3: Preliminary results of the CTAO detection probability for SFR evolution model and source density of $d = 10^{-9}$ Mpc^{-3}, for IceCube (top) and KM3NeT (bottom)

CONCLUSIONS

KM3NeT, the neutrino telescope under construction in the Mediterranean Sea [4], is able to observe more sources than IceCube, about 70 more for a source density value $d = 10^{-9}$ Mpc^{-3} and a luminosity $L = 10^{54}$ $Erg/year$, due to its discovery potential. In particular, KM3NeT is able to observe more distant sources up to a redshift value $z \sim 0.7$. However, the detection probability of CTAO is lower because of the different array configuration. In fact the new array configuration, funded by the CTA+ project [5], of which Italy is a major funder, it is planned to build 2 Large Sized Telescopes (LSTs) and 5 more Small Sized Telescopes (SSTs) to the south. Thus, the implementation of the new CTA+ configuration will increase the detection probability of CTAO with KM3NeT for detection of sources located in the southern hemisphere.

References

[1] C.F. Tung et al., Journal of Open Source Software, 6(61), 3194 (2021)
[2] A. Dominguez et al., MNRAS., 410, 2556 (2011)
[3] J. Knödlseder et al., A&A, 593, A1 (2016)
[4] Adrian-Martinez, Silvia, et al. Journal of Physics G: Nuclear and Particle Physics 43.8 (2016)
[5] https://pnrr.inaf.it/progetto-ctaplus/

ACKNOWLEDGEMENTS

We gratefully acknowledge financial support from the agencies and organizations listed here: https://www.ctao.org/for-scientists/library/acknowledgments/

www.ctao.org

CTAO

Thanks for your attention!

Olga Sergijenko: Sensitivity of the Cherenkov Telescope Array Observatory to the gamma-ray emission from neutrino sources detected by IceCube