Study of water Cherenkov detector designs for the SWGO experiment

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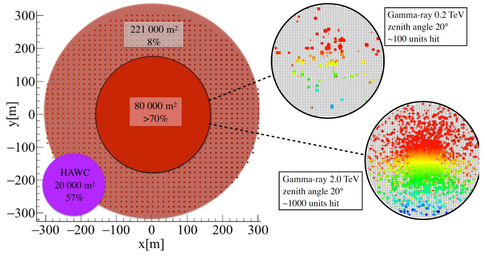
The Southern Wide-field Gamma-ray Observatory

ONLINE ICRC 2021 THE ASTROPARTICLE PHYSICS CONFERENCE Berlin | Germany
37th International Cosmic Ray Conference 12–23 July 2021

The Southern Wide-field Gamma-ray Observatory (SWGO)

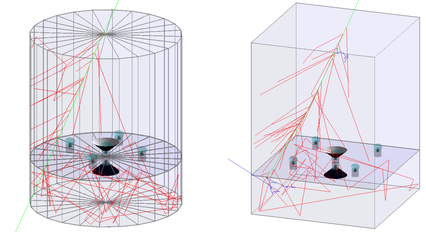


Configuration with an array of water Cherenkov detectors [1]

- SWGO [2,3] is a next-generation ground-based gamma-ray detector under development to be installed in South America → complementary to other gamma-ray experiments in the Northern Hemisphere (HAWC [4], LHAASO [5]).
- One of the experiment designs consists of an array of water Cherenkov detectors (tanks), with a high fill-factor inner array and a low-density outer array, covering an overall area of one order of magnitude larger than HAWC.

Simulations of Circular and Square Double Layer Tanks

Particle and tank response simulated with the HAWCSim framework [6]



Circular-DLT *Square-DLT*

Tanks

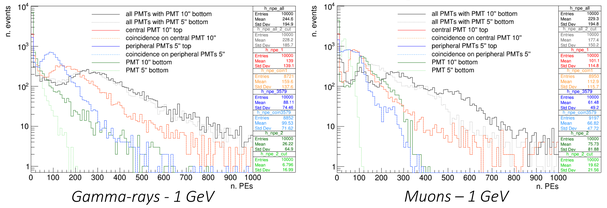
- Double layer water Cherenkov tanks [7] for gamma/hadron separation
  - Upper layer: reflective (Tyvek) and non-reflective (Polypropylene)
  - Lower layer: reflective walls (Tyvek)
- Circular (Circular-DLT) and square (Square-DLT) base
- Several sizes
- Different configurations of PMTs:
  - Upper layer: 1 central 10” PMT or 4 peripheral 5” PMT
  - Lower layer: 1 central 10” PMT or 5” PMT

Particles

- Muons (1, 10 GeV), electrons and gamma-rays (0.01, 0.1, 1 GeV)
- Zenith angle 0-60°, azimuth angle 0-360°

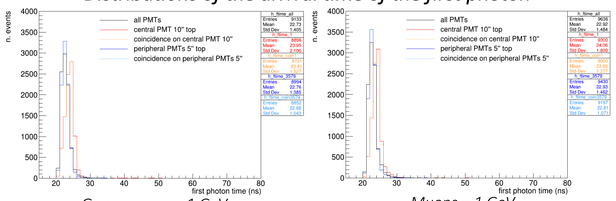
Analysis

Distributions of the number of PEs



Gamma-rays - 1 GeV *Muons – 1 GeV*

Distributions of the arrival time of the first photon



Gamma-rays – 1 GeV *Muons – 1 GeV*

We evaluated the tanks response by analyzing:

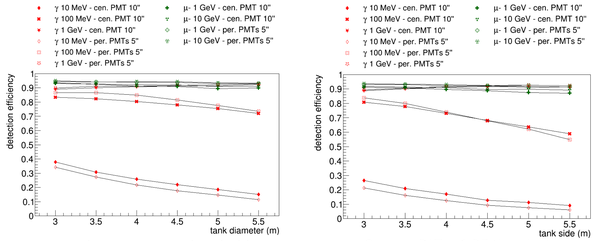
- Average number of photoelectrons (PEs)
- Width of the distributions of the first photon arrival time
- Detection efficiency as ratio between number of detected particle and number of particles entering the tank

Considering:

- 6 sets of tank sizes for both the Circular-DLT and Square-DLT
- PMT configurations independently
- For the upper layer, a detection threshold of 1 PE and 2 PEs within 30 ns
- For the lower layer, a detection threshold of 1 PE

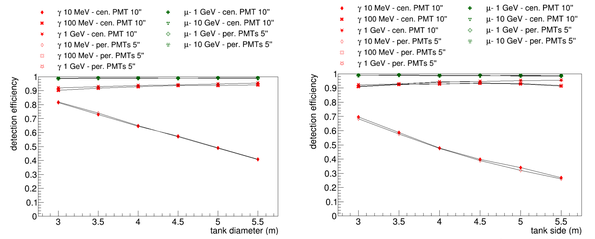
Results

Detection efficiency of the upper layer with non-reflecting walls



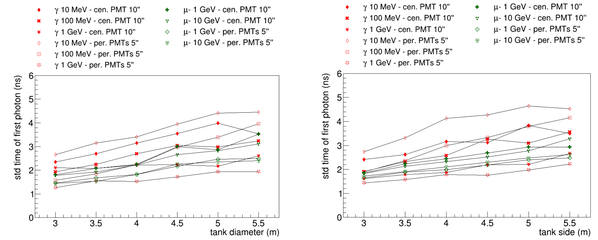
Circular-DLT – 1 PE threshold *Square-DLT – 1 PE threshold*

Detection efficiency of the upper layer with reflecting walls



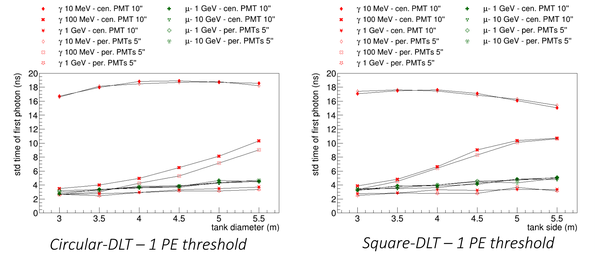
Circular-DLT – 1 PE threshold *Square-DLT – 1 PE threshold*

Time resolution of the measurement of the first photon in the upper layer with non-reflecting walls



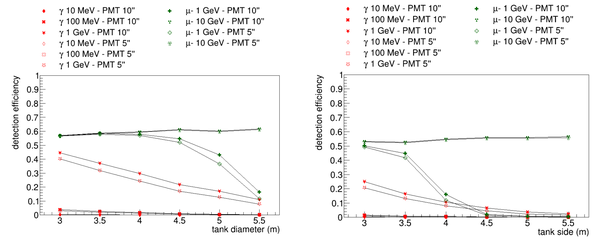
Circular-DLT – 1 PE threshold *Square-DLT – 1 PE threshold*

Time resolution of the measurement of the first photon in the upper layer with reflecting walls



Circular-DLT – 1 PE threshold *Square-DLT – 1 PE threshold*

Detection efficiency of the lower layer



Circular-DLT – 1 PE threshold *Square-DLT – 1 PE threshold*

- The performance worsen increasing the size of the tank (the area covered by the PMTs decreases with respect to the area of the base of the tank)
- Circular-DLTs have slightly better performance with respect to Square-DLT. Nevertheless, for the final design of the SWGO array we should take into account that with Square-DLTs a higher fill factor is achievable.
- By using reflective walls instead of non-reflective walls in the upper layers, the detection efficiency increases, but the time resolution of the measurement of the first photon widen, in particular for particle with low energy
- We plan to complete the study performing simulations of double layer tanks with hexagonal base

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[4] DeYoung T. (for the HAWC Coll.), *The HAWC observatory* (2012) Nuclear Instruments and Methods in Physics Research A, 692, 72
[5] X. Bai et al., *The Large High Altitude Air Shower Observatory (LHAASO) Science White Paper* (2019) arXiv:1905.02773
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[7] S. Kunwar (for the SWGO Coll.), *Double-layered Water Cherenkov Detector for the Southern Wide-field-of-view Gamma-ray Observatory (SWGO)* (2021) – this conference