Gamma/hadron discrimination using a small-WCD with four PMTs

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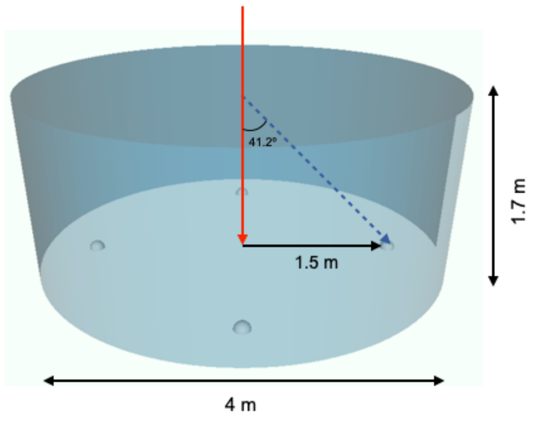
Water Cherenkov Detector Design

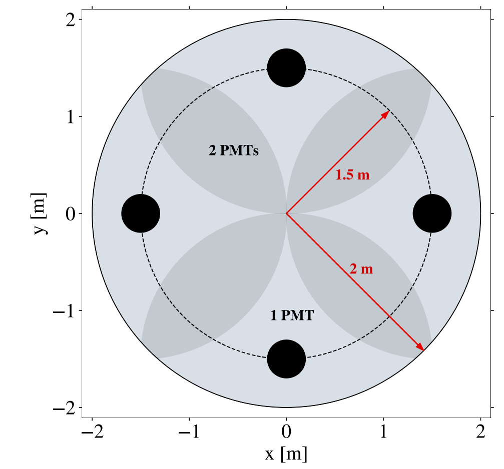
One of the **candidate WCD stations** for the **Southern Wide-field Gamma-ray Observatory [1]** being studied.

Exchange water height and structural complexity by an increased number of photo-sensors

WCD properties:

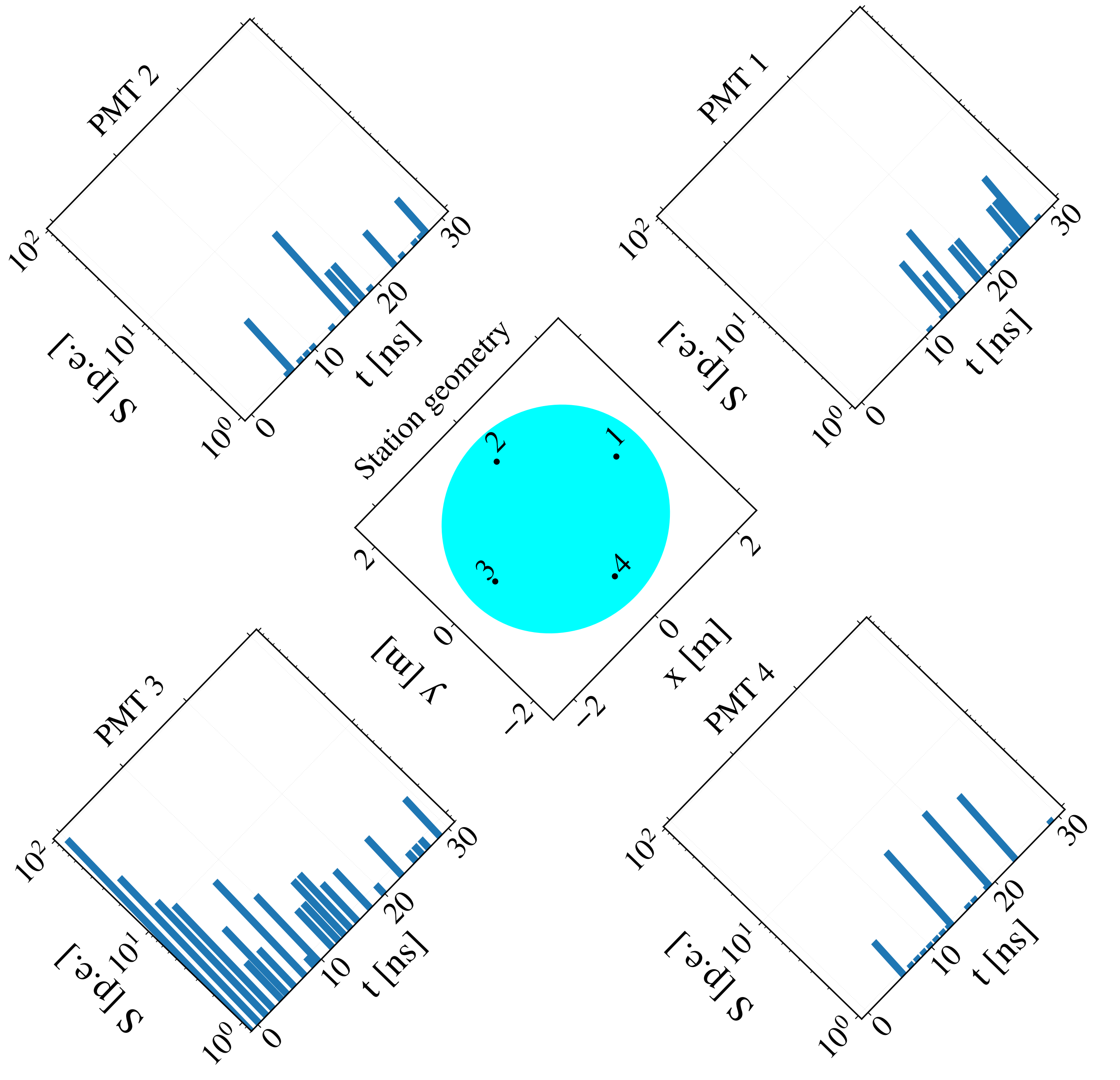
- **Dimensions: Diameter 4 m ; Height 1.7 m**
- **White diffusive walls**
- **Four PMTs at the tank bottom**
- **PMT position chosen to maximize signal uniformity and muon signal asymmetry**





Physics goals:

- Lower the energy threshold - high trigger efficiency
- Good shower geometric reconstruction - take advantage of the narrow (~ 2 ns) direct Cherenkov
- Gamma/hadron discrimination - identify muons exploring PMT signal time trace using Machine Learning algorithms

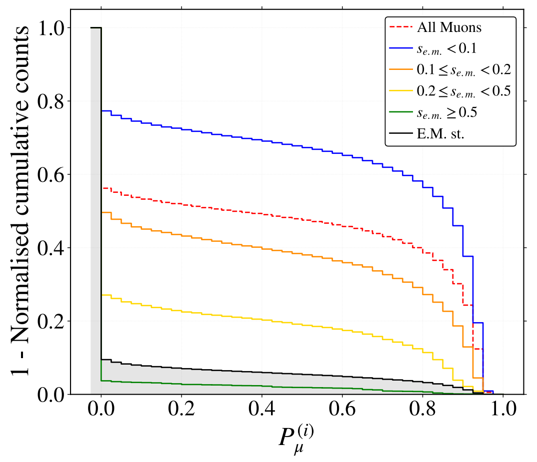


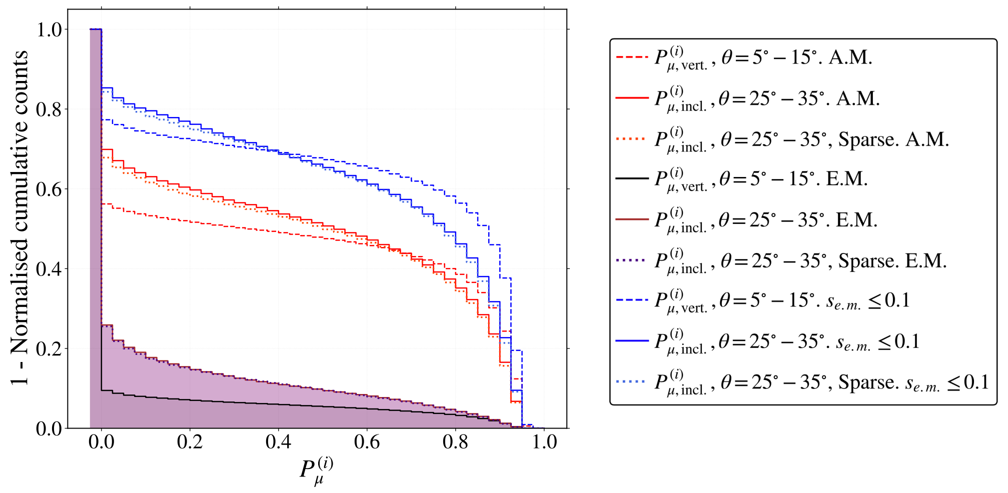
Top view of the WCD station and the signal detected in each PMT

(Single 2 GeV muon injected)

Muon Identification in the Water Cherenkov Detector

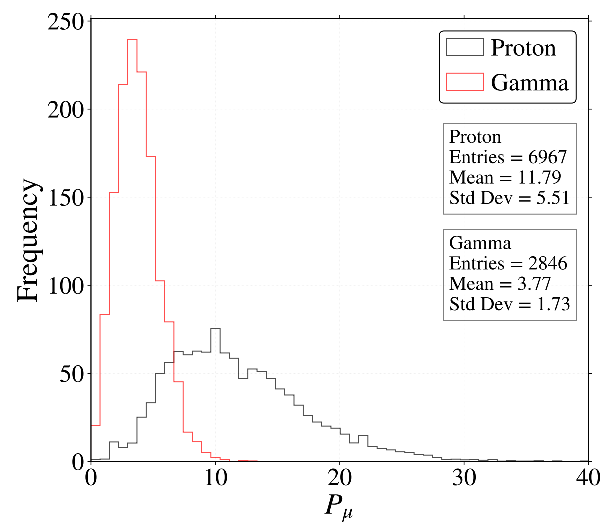
- End-to-end simulations [CORSIKA + Geant4] at 1 TeV (reconstructed energy)
- **Train Convolutional Neural Network [2] with single muons to compute the probability of having a muon in the WCD, $P_\mu^{(i)}$**
- Muon tagging efficiency is higher than 50% while getting a false positive rate of less than 10% (stations without muons)
- Method depends on the electromagnetic contamination level
- **Method has similar performance for vertical/inclined events and dense/sparse array**

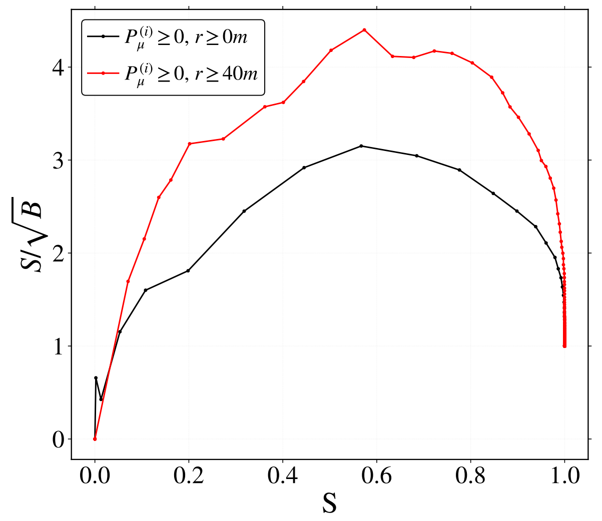




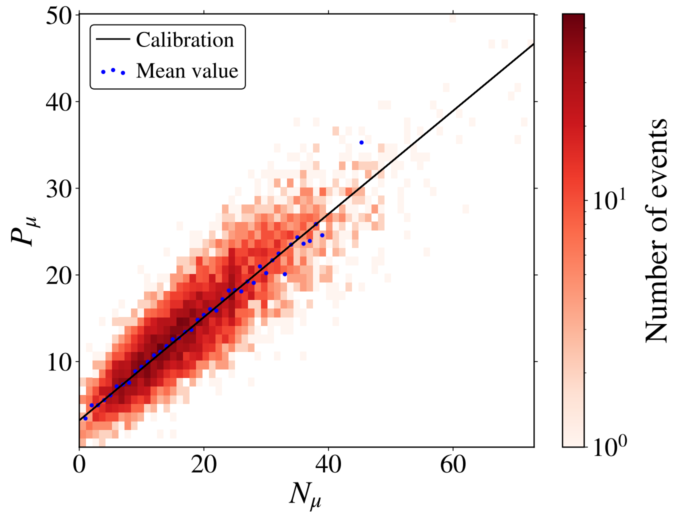
Gamma/Hadron Discrimination

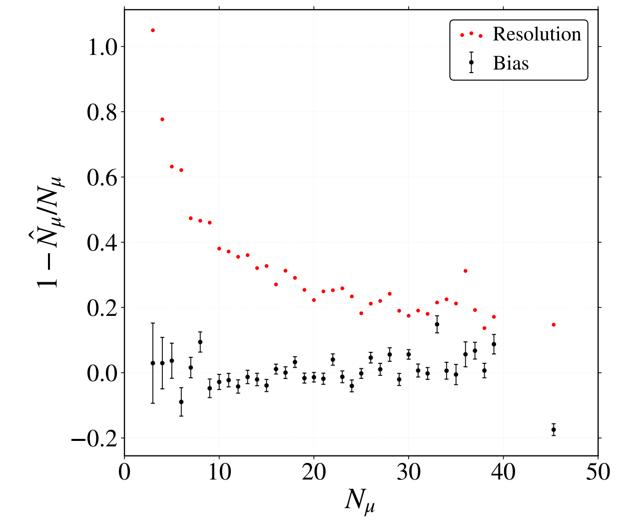
- **Simple g/h discrimination variable:** $P_\mu = \sum_{i=1}^{N_S} P_\mu^{(i)}$ *(sum WCD probabilities)*





- **Excellent gamma/hadron separation** similar to the one reported in HAWC [3]
- Cut in distance increase performance by reducing impact of electromagnetic contamination





- It is possible to derive a **calibration between P_μ and the number of muons** in the WCD and use it to estimate the shower muon content with a negligible bias and a **resolution of 20% for ~20 measured muons** (2% intrinsic resolution)

References

[1] *www.swgo.org*

[2] *R. Conceição et al EPJC, arXiv:: 2101.10109*

[3] *A. Abeysekara et al Astrophys. J., arXiv: arXiv:1703.0696*

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