PhD Open Days

Muon identification and gamma/hadron separation using single-layered WCDs at TeV energies

PhD program in Physics

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Water Cherenkov detector design

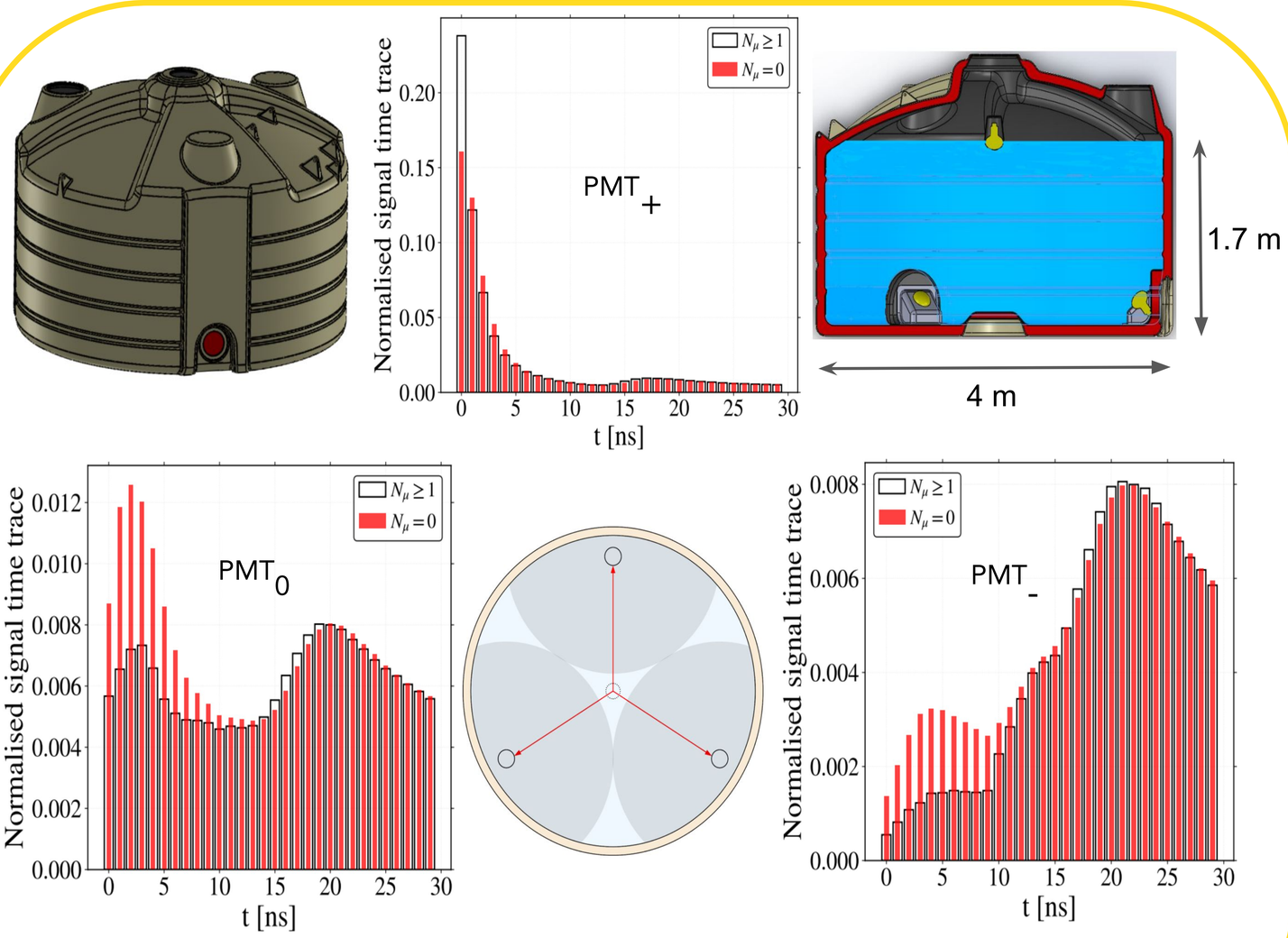
The **Mercedes WCD [1]** is currently one of the candidate WCD stations for the future **Southern Wide-field Gamma-ray Observatory (SWGO) [2].**

Design optimised for muon identification:

- Dimensions: Diameter 4 m; Height 1.7 m.
- White diffusive walls.
- Three PMTs at the bottom of the WCD.
- PMT position optimised to maximise total signal uniformity and muon signal asymmetry.
- Possible additional small PMT at the top to avoid saturation.

Physics goals:

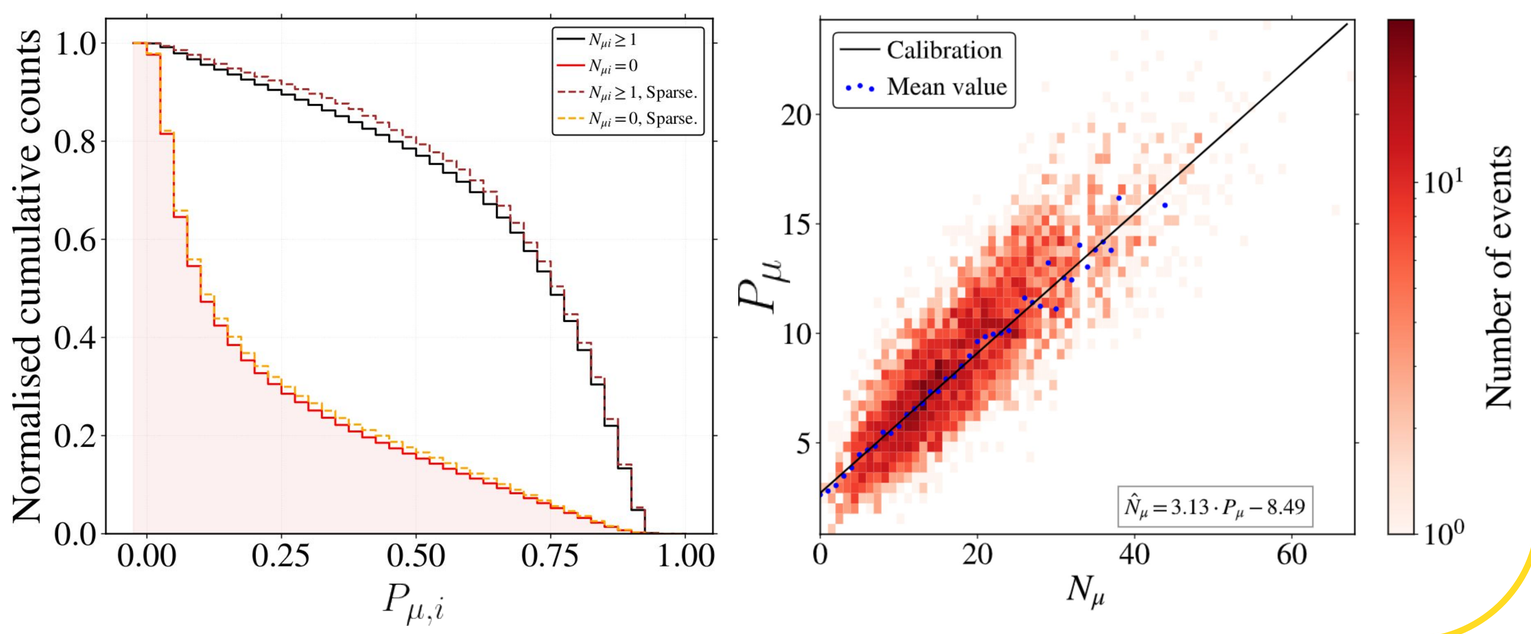
- Lower the energy threshold.
- Good shower geometric reconstruction by taking advantage of the narrow (~2 ns) direct Cherenkov light.
- Gamma/hadron separation - identify muons exploring PMT signal time trace using machine learning algorithms.



Average signal time traces at stations with and without muons.

Muon identification with the water Cherenkov detector

- End-to-end simulations (CORSIKA and Geant4) at ~1 TeV (reconstructed energy).
- Analysis of the signal time traces using 1D Convolutional Neural Networks to get the probability that a muon has passed through the station: $P_{\mu,i} \in [0,1]$.
- The muon tagging efficiency is about 80% while getting a false positive rate of less than 20% (similar performance for a sparse array).
- The sum of the probabilities of the selected stations provides an accurate estimator of the shower muon content with a resolution about 20% and a negligible bias for proton showers with Nμ ≥ 10.

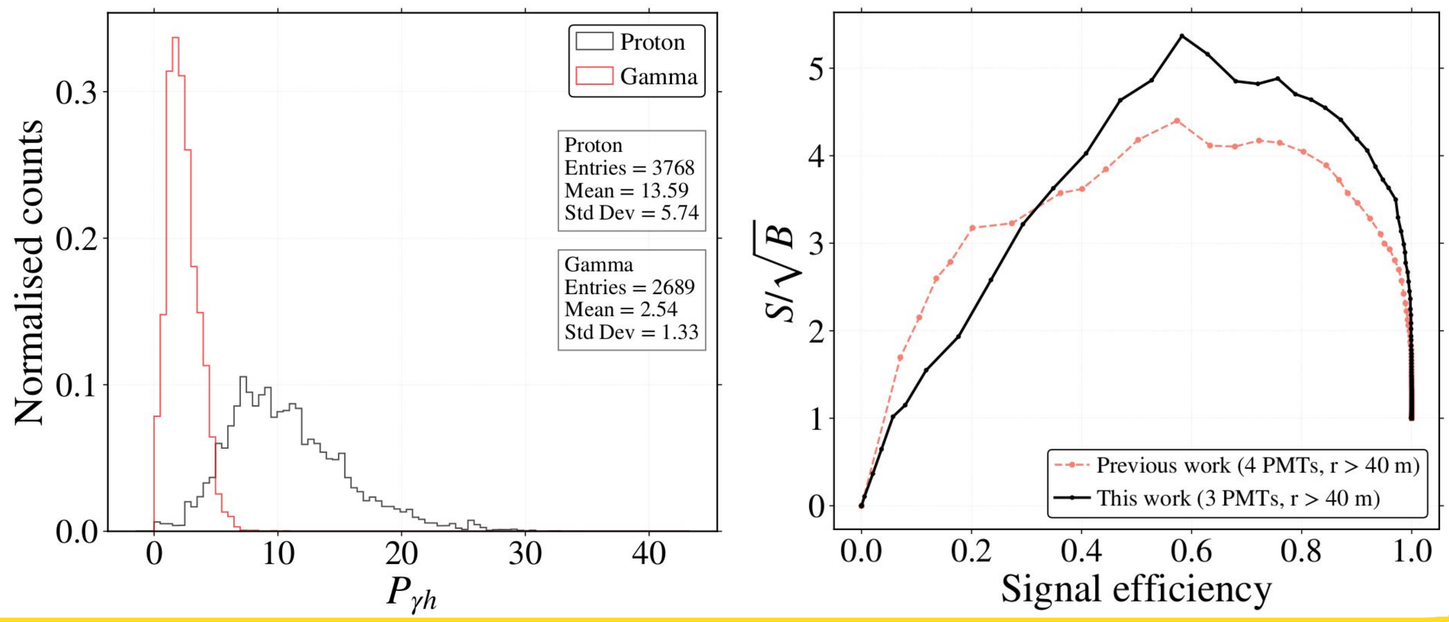


Gamma/hadron discrimination

The g/h discrimination variable:

$$P_{\gamma h} = \sum_{i=1}^{n_{stations}} P_{\mu,i} \; (r_i \geq 40m)$$

- **Excellent g/h separation** similar to the one reported in HAWC at a similar energy [3].
- Improvement over previous results using a WCD with the same dimensions and 4 PMTs [4,5].



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[1] P. Assis et al. Eur. Phys. J. C 82, 899 (2022).
[2] www.swgo.org
[3] A. Abeysekara et al. Astrophys. J., arXiv:1703.0696
[4] R. Conceição et al. EPJC 81 (2021) 6, 542
[5] B.S. González et al. Neural Comput & Applic 34, 5715–5728 (2022).