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

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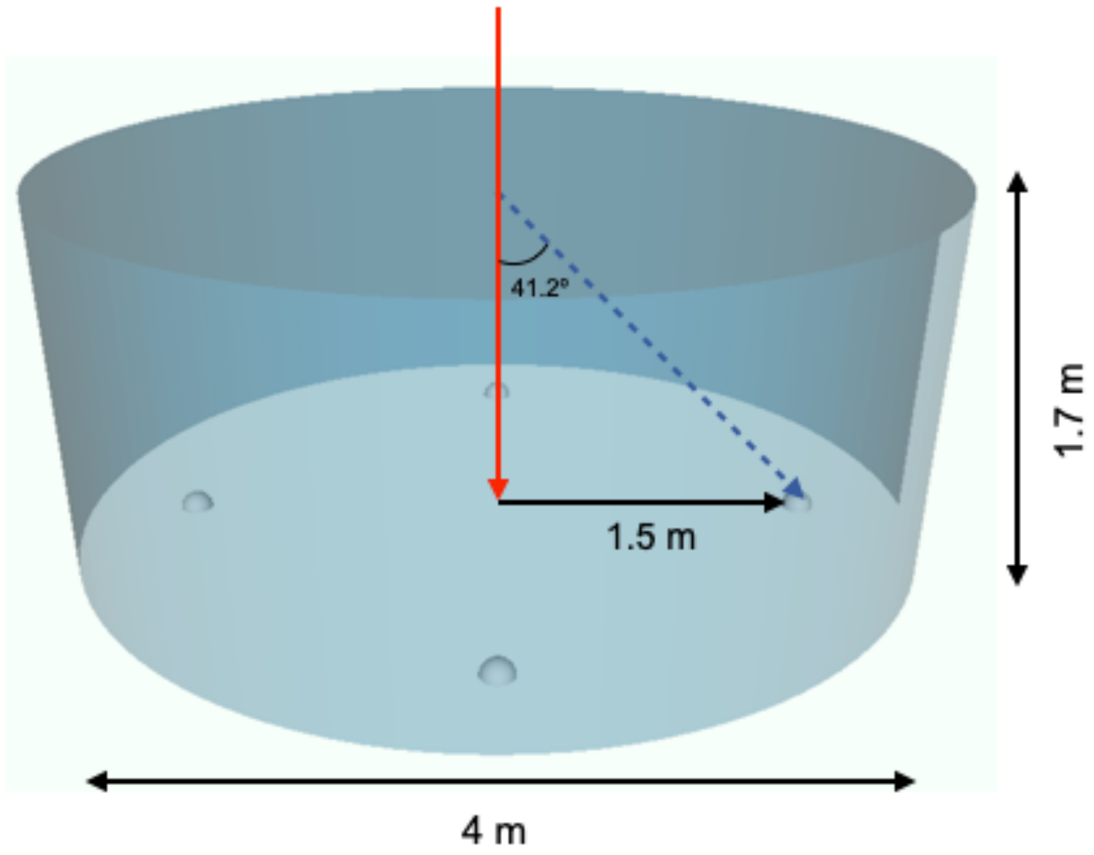
The Southern Wide-field Gamma-ray Observatory

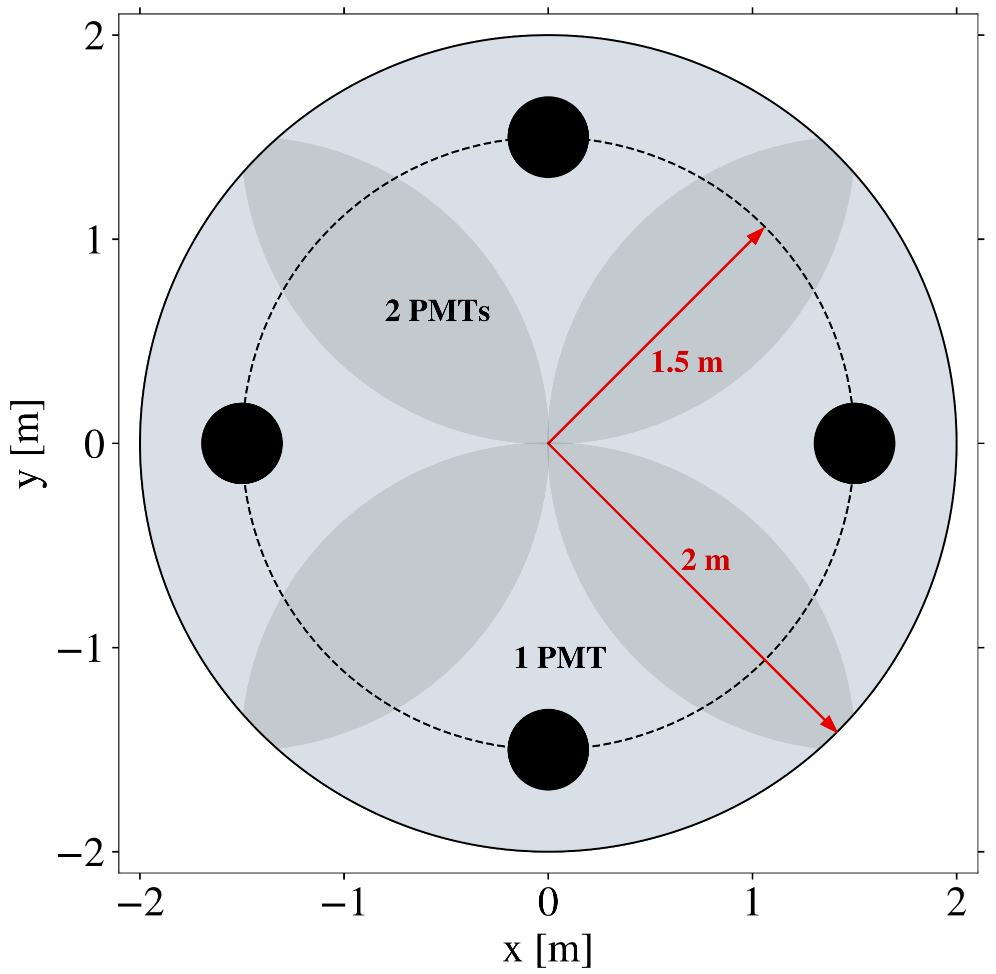
37th ICRC, Berlin, July 12th-23rd 2021

Water Cherenkov Detector Design

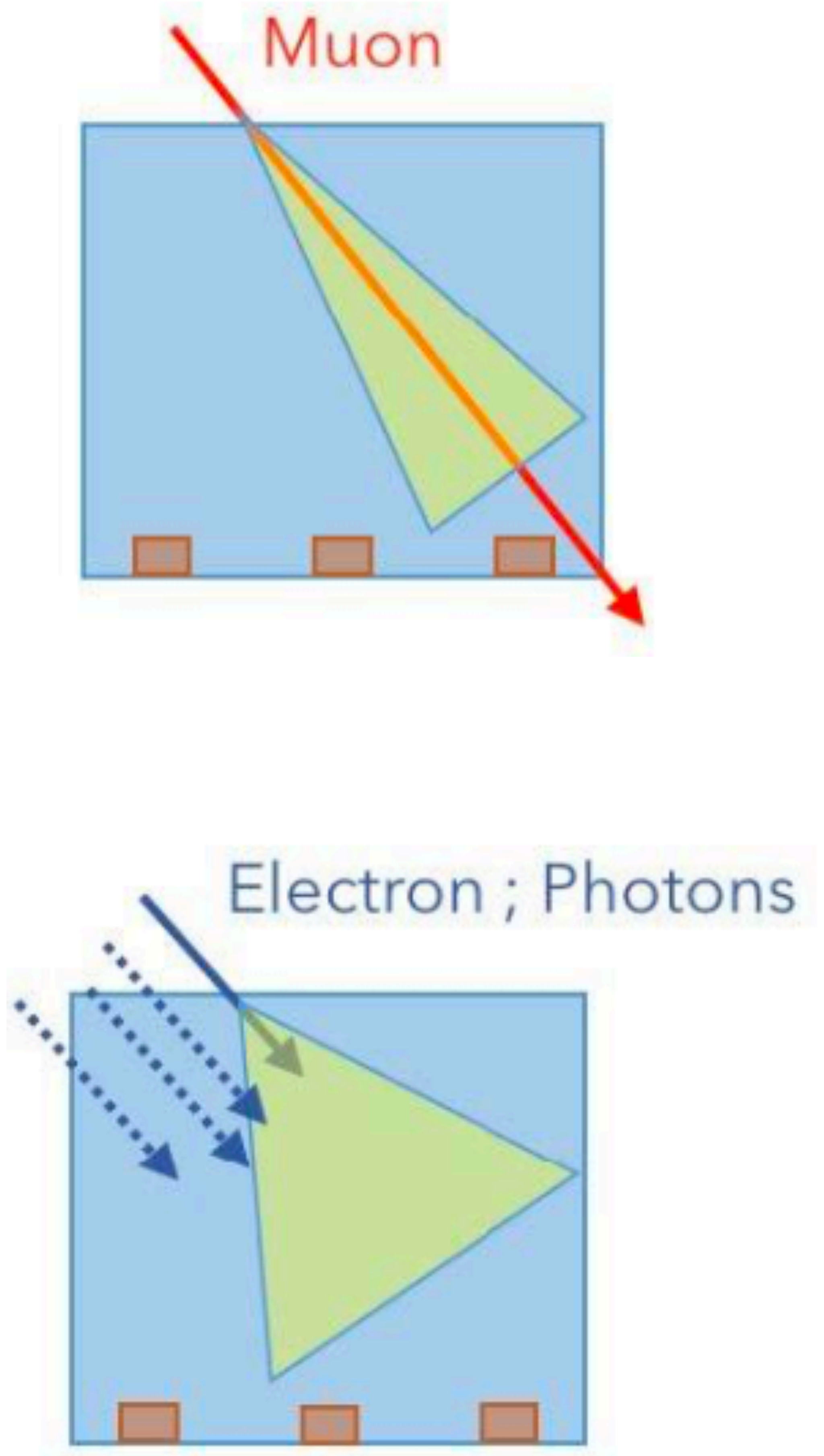
- One of the **candidate WCD stations** for the **Southern Wide-field Gamma-ray Observatory being studied**.
- Exchange water height and structural complexity by an increased number of photo-sensors
- WCD properties:
  - **Dimensions: Diameter 4 m ; Height 1.7 m**
  - **White diffusive walls**
  - **Four PMTs at the tank bottom**
  - **PMT position chosen to maximize signal uniformity and muon signal asymmetry**

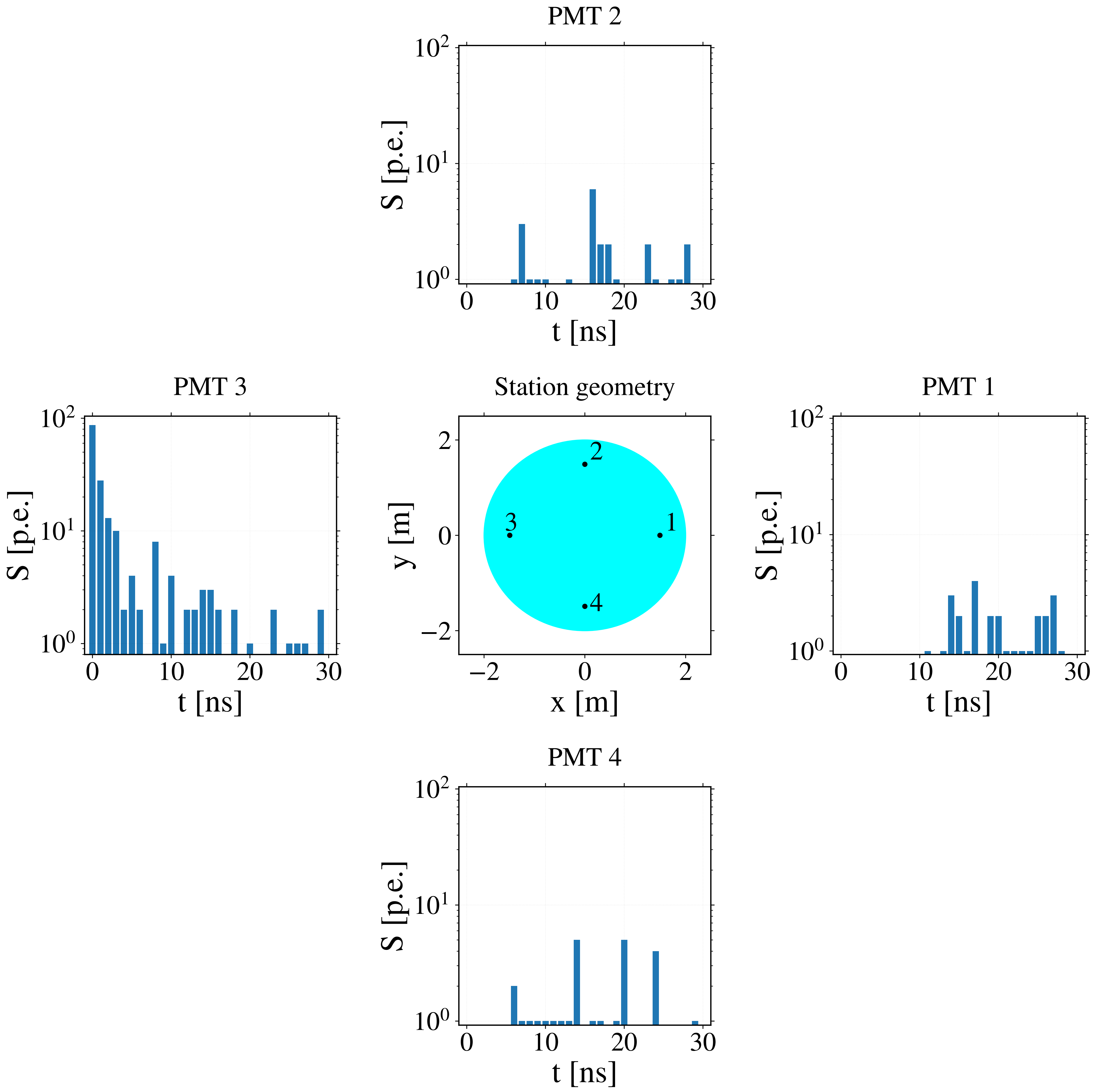


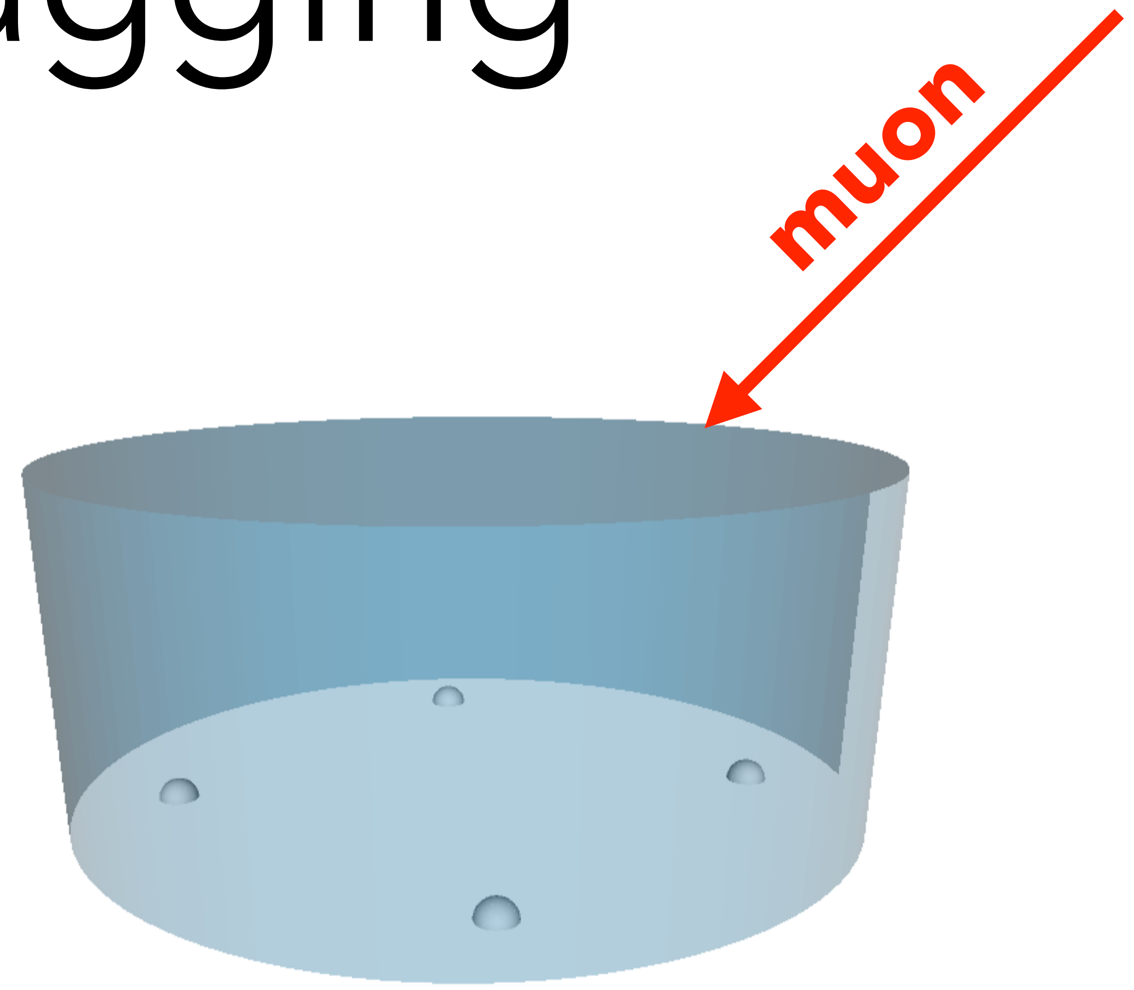
- Physics goals:
- Lower the energy threshold - high trigger efficiency
- Good shower geometric reconstruction - take advantage of the narrow (~ 2 ns) direct Cherenkov
- Gamma/hadron discrimination - identify muons exploring PMT signal time trace using Machine Learning algorithms



The working principle for muon tagging

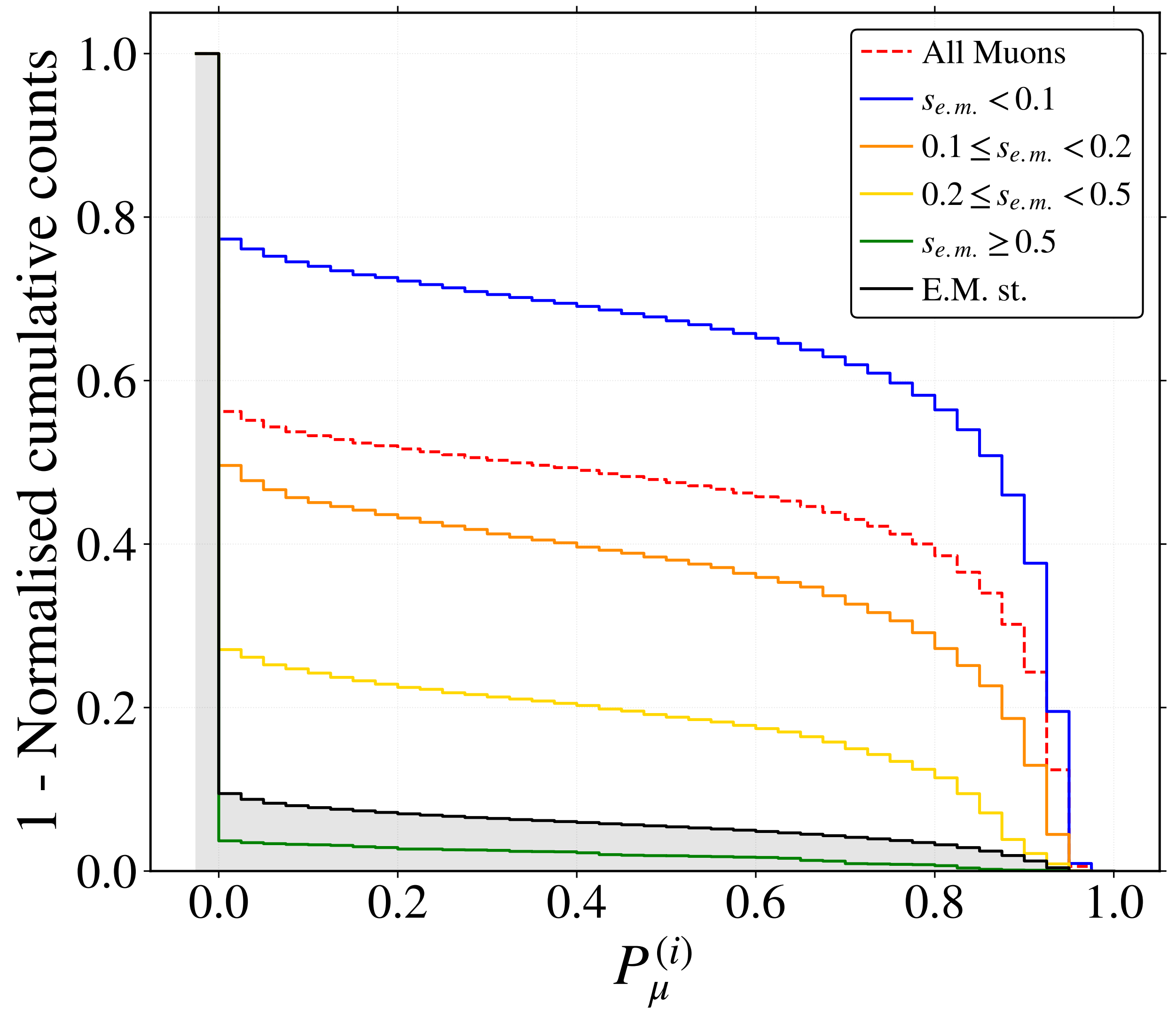


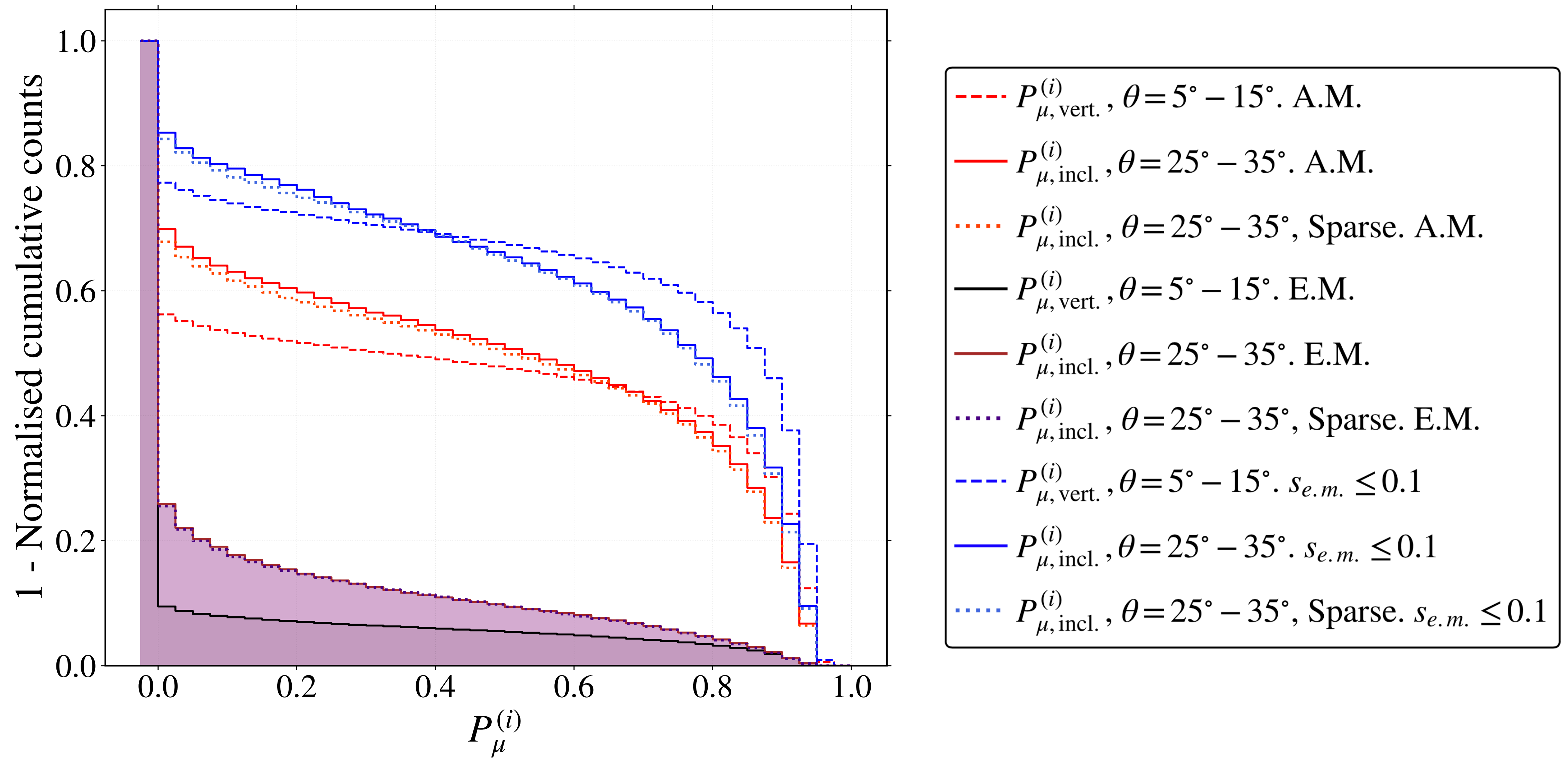




Muon Identification in the Water Cherenkov Detector

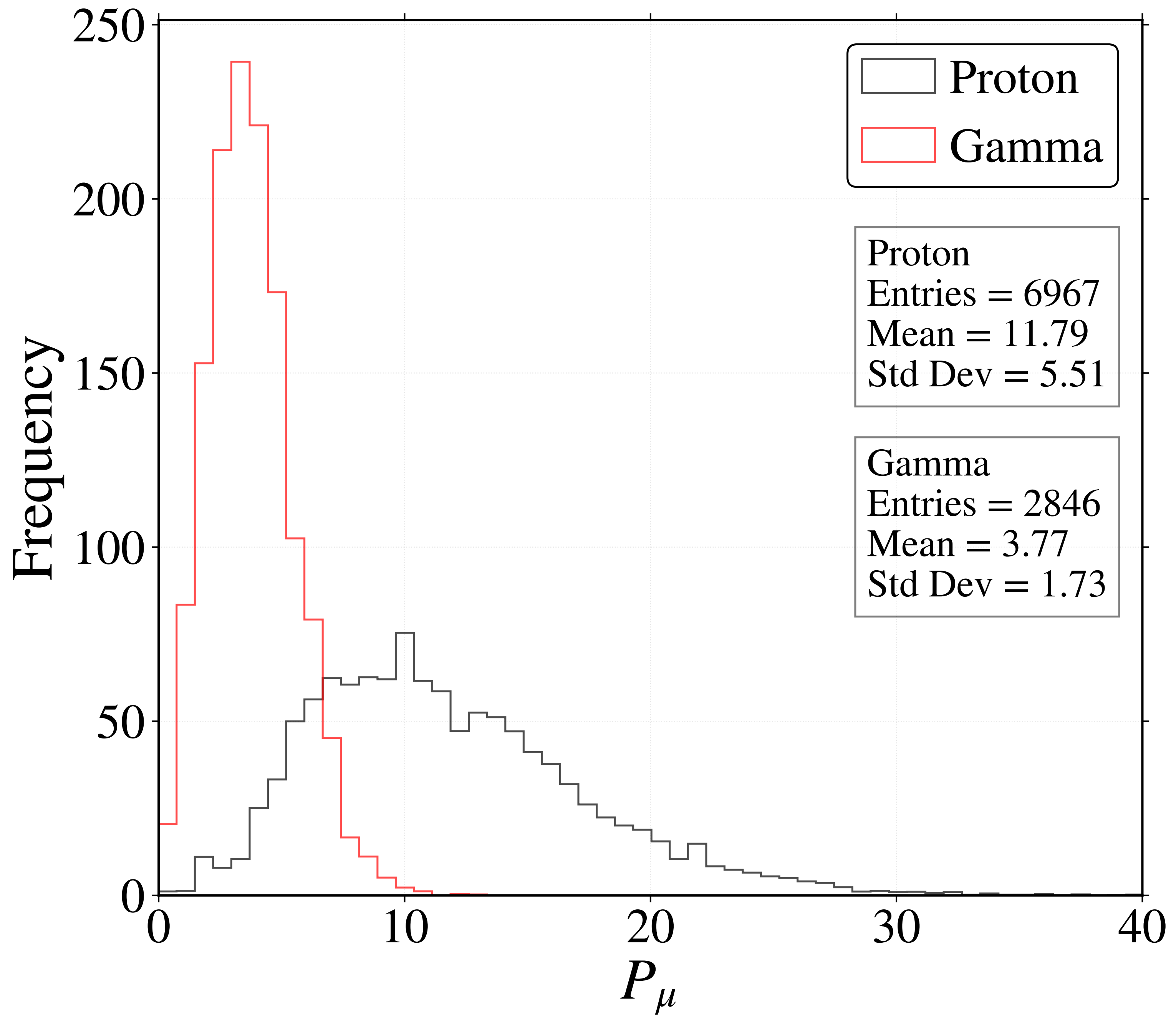
- End-to-end simulations [CORSIKA + Geant4] at 1 TeV (reconstructed energy)
- **Train Convolutional Neural Network with single muons to compute the probability of having a muon in the WCD, $P_\mu^{(i)}$**
- Muon tagging efficiency is higher than 50% while getting a false positive rate of less than 10%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

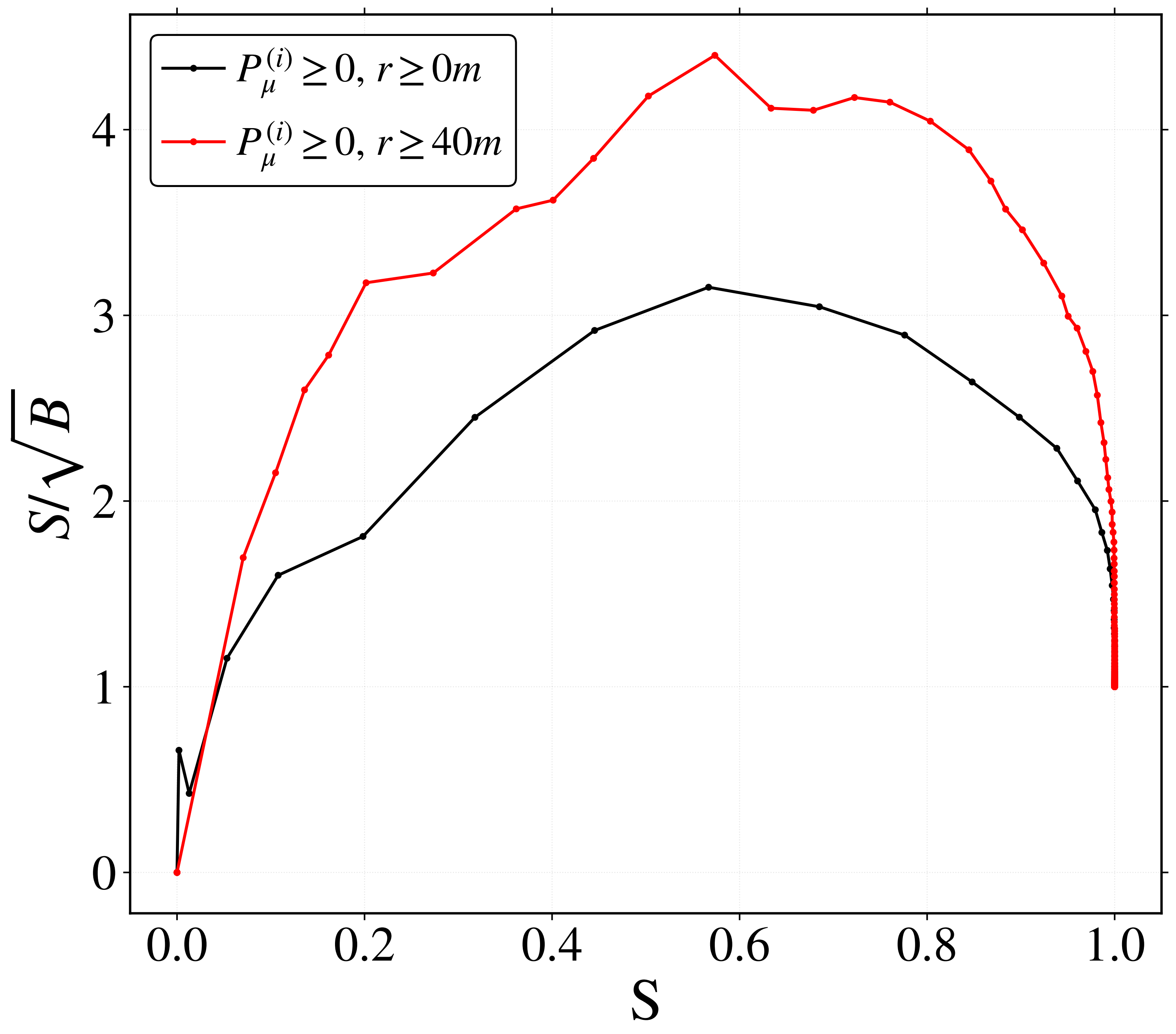




Gamma/hadron discrimination

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

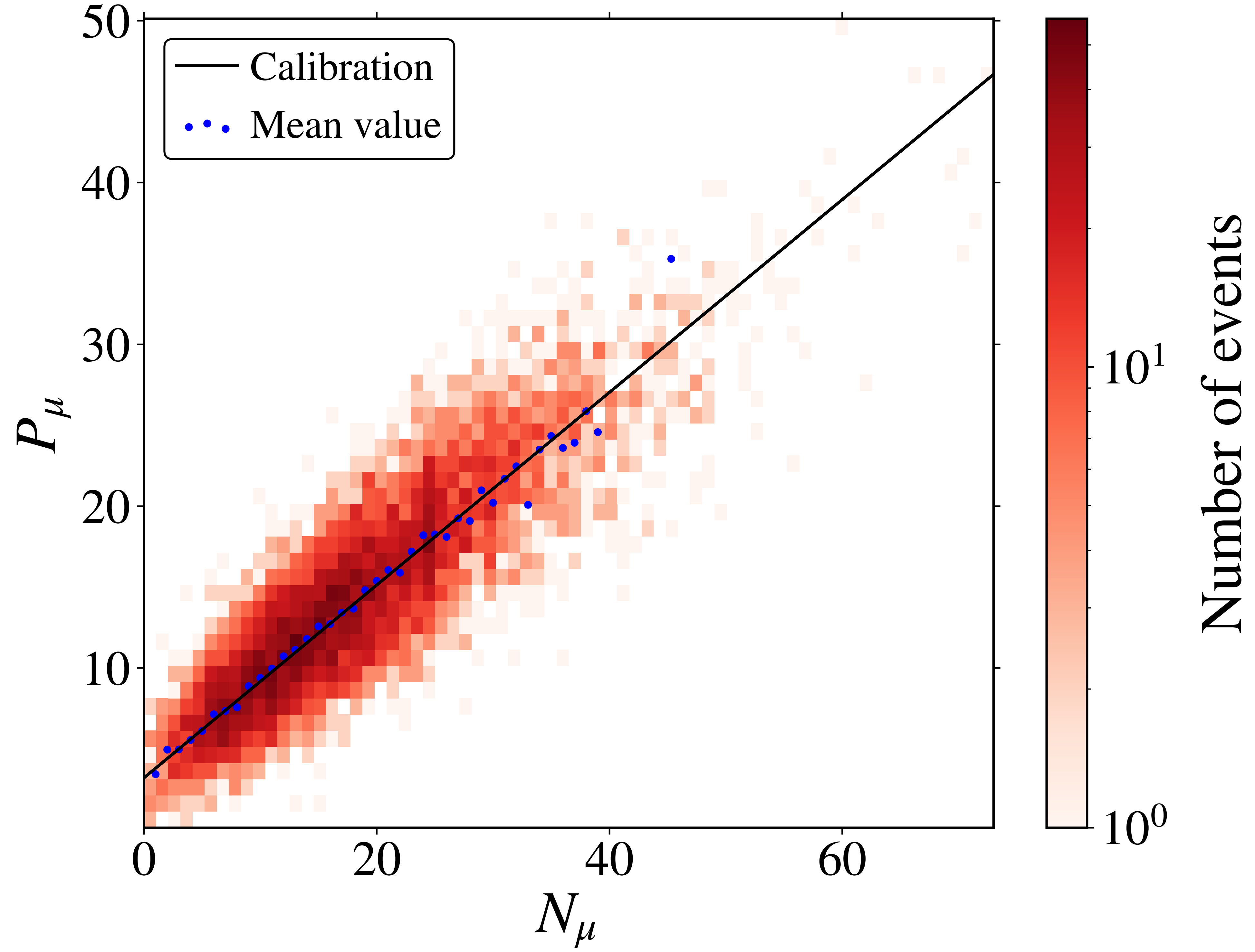


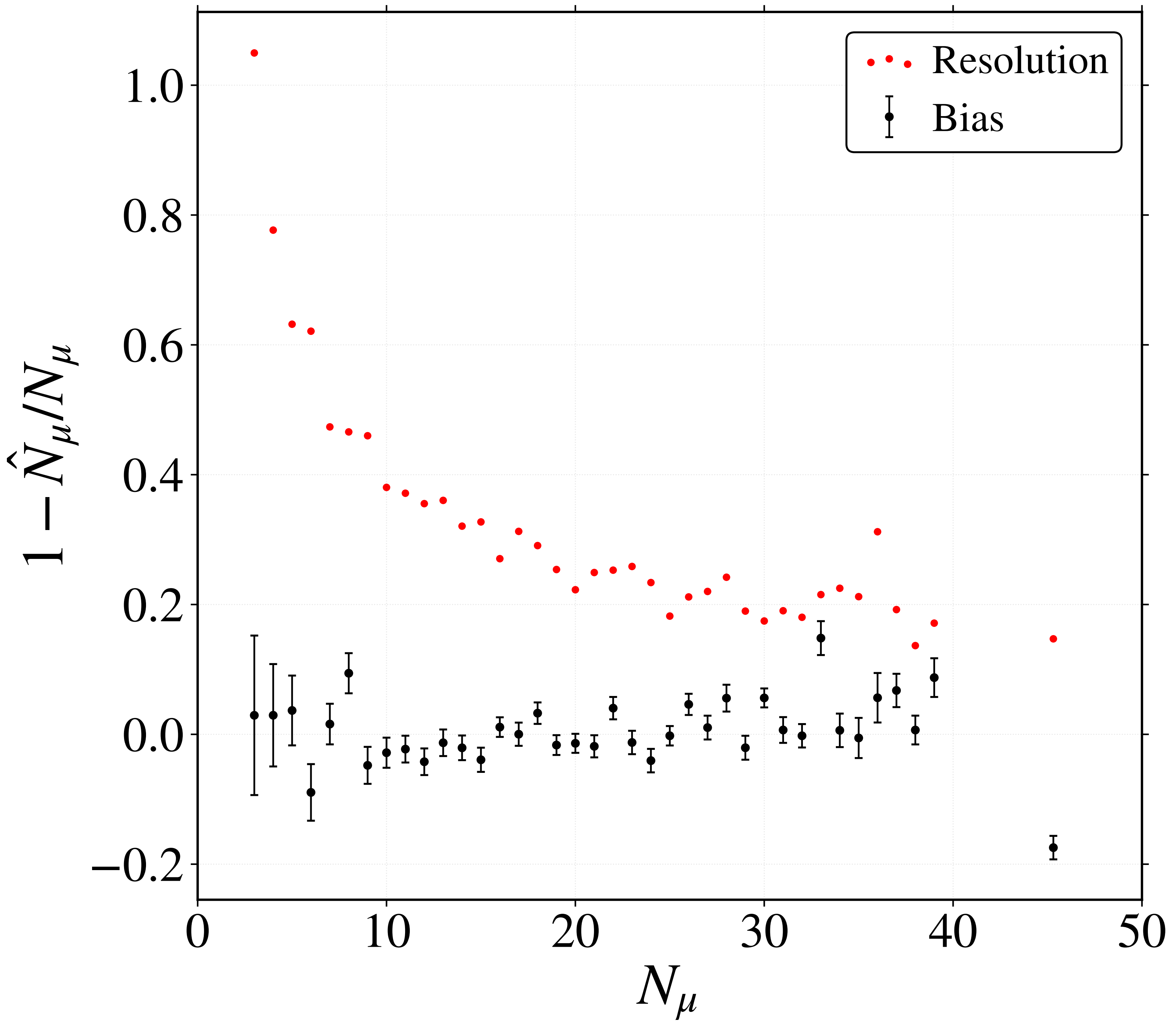


[S] - gamma efficiency
[1-B] - proton rejection

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

Muon counting capability





✧ 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)

For more details…

- ICRC proceedings - PoS(ICRC2021)707

- Eur.Phys.J.C 81 (2021) 6, 542 • arXiv: 2101.10109 [physics.ins-det]

Acknowledgements

FCT Fundação para a Ciência e a Tecnologia

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