Layered Water Cherenkov Detectors for Next Generation Air-Shower Arrays

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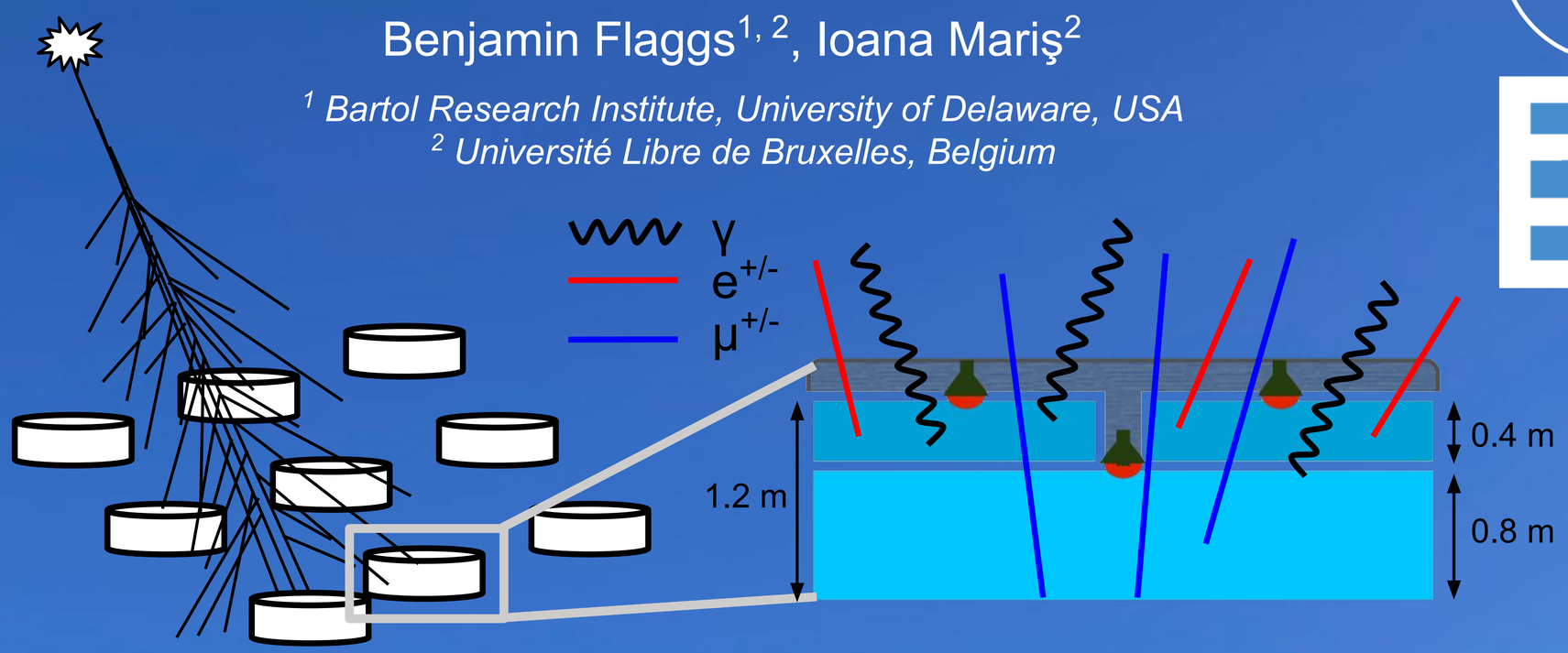


Layered water Cherenkov detectors are a proposed detector for next generation air-shower arrays that can separate electromagnetic and muonic signals on an event-by-event basis [1], [2].

Obtaining Electromagnetic and Muonic Signals

$$\begin{pmatrix} S_{\text{top}} \\ S_{\text{bot}} \end{pmatrix} = \mathcal{M} \begin{pmatrix} S_{\text{EM}} \\ S_{\mu} \end{pmatrix} = \begin{pmatrix} a & b \\ 1-a & 1-b \end{pmatrix} \begin{pmatrix} S_{\text{EM}} \\ S_{\mu} \end{pmatrix}$$

a + b → from simulations, depend on detector specifics

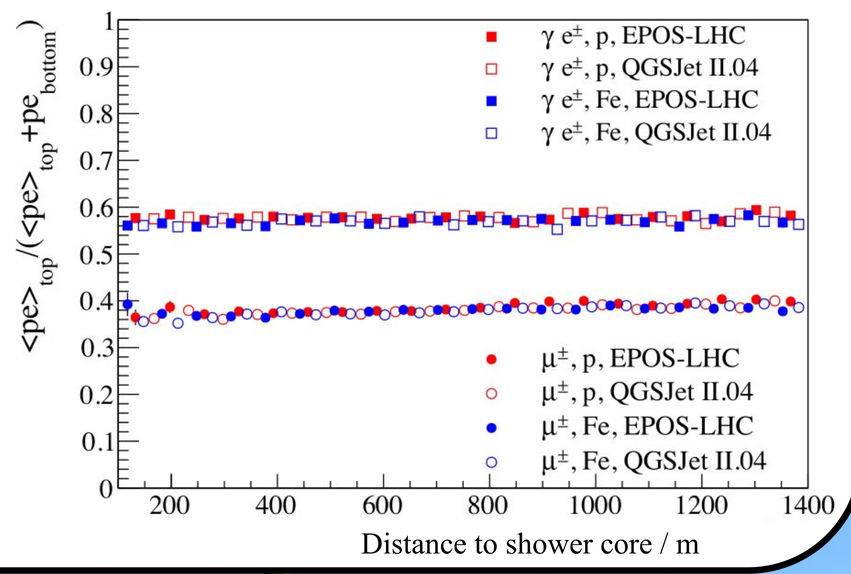
S_{top} + S_{bot} → from calibrated PMT signals

Analysis Goal: Obtain calibrated S_{top} and S_{bot}
Can then invert matrix to obtain S_{EM} and S_{μ}

Determination of Matrix Coefficients (a + b)

From simulations: a + b are independent of air-shower properties

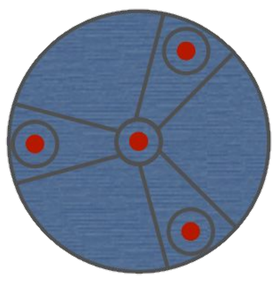
Depend on detector geometry

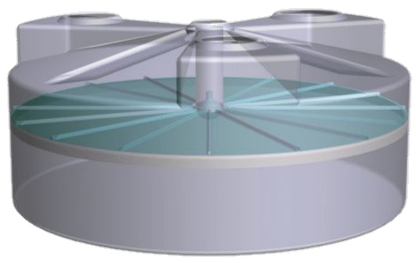


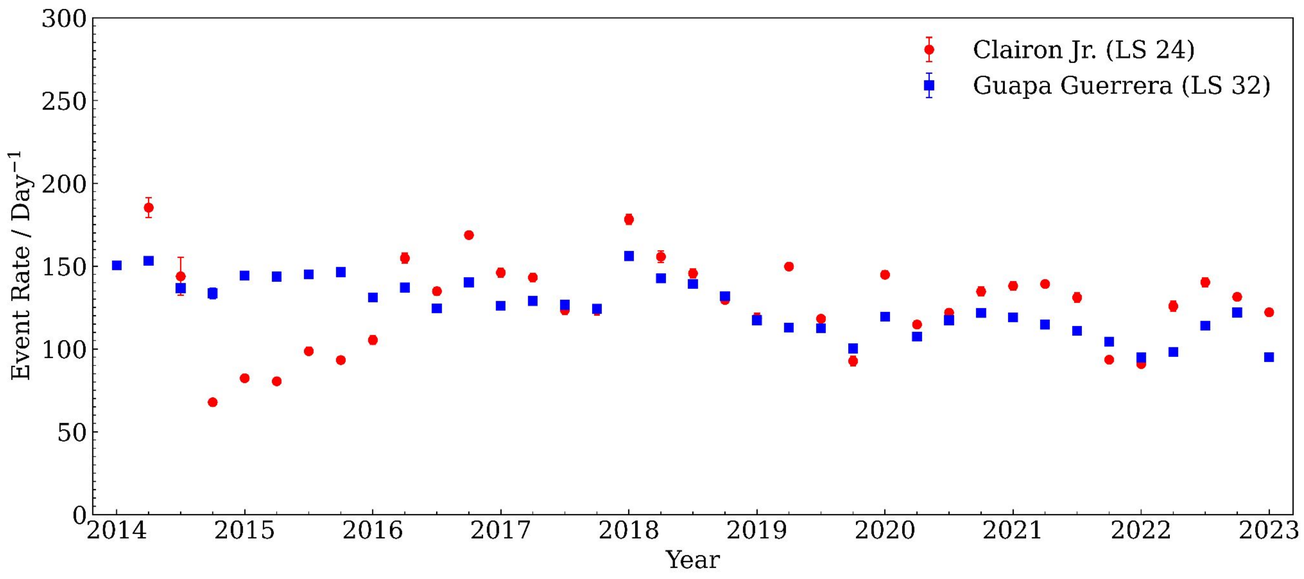
Prototype Detectors at the Pierre Auger Observatory

Two prototype layered water Cherenkov detectors were deployed at the Pierre Auger Observatory in Malargüe, Argentina in 2014 and have since been stably recording data.

The prototypes are modified Auger water Cherenkov detectors with a separation layer 80 cm from the bottom of the tank and a single additional PMT in the bottom layer.



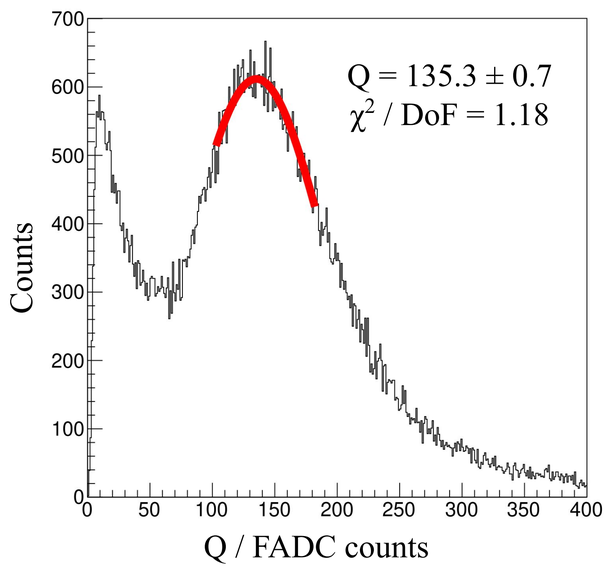


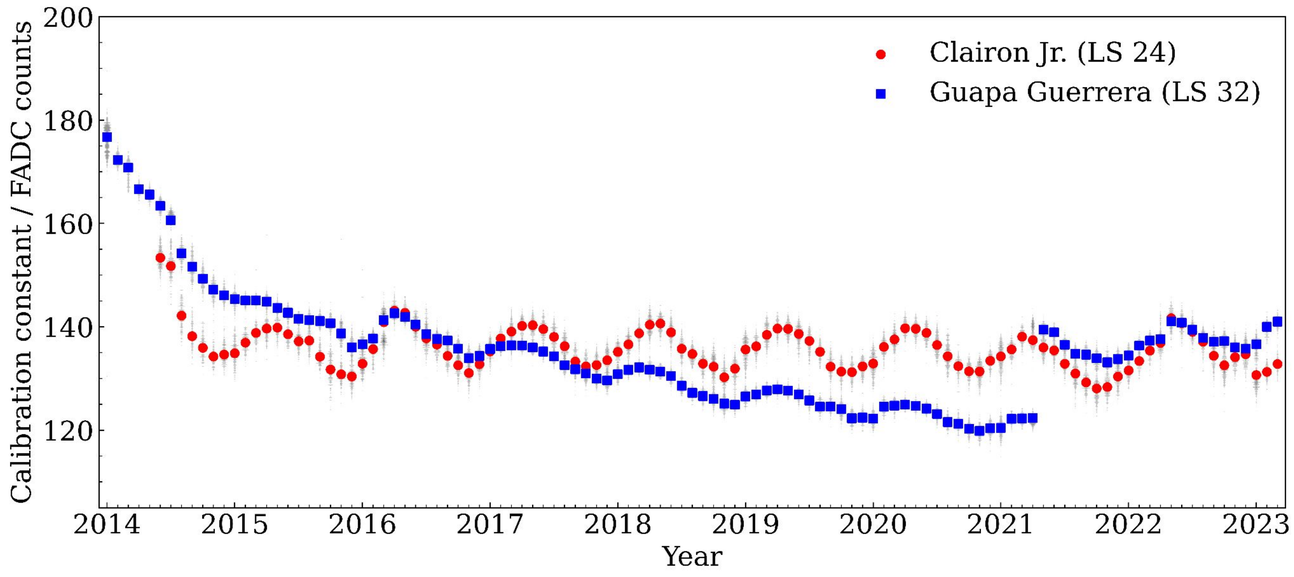


Bottom PMT Calibration

PMT calibration: Converting the PMT signal in FADC counts to units of a Vertical Equivalent Muon.

The peak position of the "muon hump" is obtained from a Gaussian fit, and used as the calibration constant.





Conclusions and Outlook

Calibration of the bottom PMTs show stable functioning of the bottom layer of the detector.

The muon hump of the top PMTs is swallowed by the electromagnetic contribution.

Outlook: Develop more advanced methods to extract the calibration constants of the top PMTs from the shape of the muon signals and coincidence calibration histograms with the bottom PMT.

References

[1] A. Letessier-Selvon et al., Nucl. Instrum. Meth. A **767** (2014).
[2] S. Kunwar et al., Nucl. Instrum. Meth. A **1050** (2023).

Supported by a Fellowship of the Belgian American Educational Foundation. Funding for this research was provided by the United States National Science Foundation through NSF award #2046386.