Form 8

Research Result Report
ICRR Inter-University Research Program 2025

Research Subject:

Improving the sensitivity of IACTs using event classes via a joined-likelihood

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Summary of Research Result：

Introduction

The sensitivity of IACTs is determined by their instrument response functions: the angular resolution, effective area, and energy resolution. This project targets the angular and energy resolution by grouping events according to their reconstruction accuracy and analysing each group separately in a joint-likelihood framework. Since all events are retained in the joint likelihood, the effective area remains unchanged; the gain comes from exploiting the better angular and energy resolution of the higher-quality event classes. This approach, long established for the space-based Fermi-LAT instrument, has not previously been applied to ground-based IACTs and holds the potential to significantly improve the sensitivity of single-telescope systems such as the LST-1 without hardware modifications.

Progress and Results in FY2025

The analysis pipeline has been implemented and tested on both Monte Carlo (MC) simulations and real LST-1 observational data. The central result of the proposal, that separating events by angular reconstruction quality yields improved sensitivity, has been confirmed in real data. We also found that the correlation between energy and directional reconstruction quality seen in simulations is present in the actual observations.

During testing on real data, several bugs in the prototype code were identified and fixed, making the pipeline more reliable. Initial results show a sensitivity

improvement of approximately 10% on real LST-1 data, consistent with the lower bound anticipated in the proposal. Further optimisation is ongoing and expected to bring additional gains.

We have also joined forces with colleagues at CIEMAT (Spain), who have been independently working on related MC-based studies within the LST collaboration. This led to two additional developments. First, alongside the random forest classifier proposed for event classification, a regressor-based approach is being explored and will be added to the pipeline. The regressor assigns each event a continuous quality score, which means the number of event classes and their boundaries do not need to be fixed in advance. Instead, they can be chosen freely after the quality score is determined, making the analysis considerably more flexible. Second, having separate event classes opens up a new way to assess data–MC discrepancies. When all events are analysed together as a single sample, disagreements from events of different reconstruction quality get mixed, which can inflate the overall discrepancy. Comparing the data–MC agreement class by class, and tracking how it evolves from the best to the worst reconstructed events, makes it possible to distinguish discrepancies within each class from those arising between classes.

All observational data used in this work were obtained during shifts at the LST-1 site in La Palma, Canary Islands, supported by this funding. A manuscript documenting the methodology and results is currently in preparation.

Outlook

The primary near-term goal is to finalise the analysis and submit a publication presenting the event class method and its application to LST-1 data. This includes completing the optimisation of the event classification and the comparison of the classifier and regressor approaches, which will determine the final performance of the method. Further sensitivity improvements beyond the current 10% are anticipated from this ongoing optimisation. The originally planned extension to stereo observations with LST-4 is deferred, as the commissioning of LST-4 will take until later in 2026. The remaining work will be carried out within normal research activities, and no additional dedicated funding has been requested for FY2026.