Performance of a proposed **event-type** based analysis for the **Cherenkov Telescope Array**

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cherenkov telescope array

ABSTRACT

The Cherenkov Telescope Array (CTA) will be the next-generation observatory in the very-high-energy (20 GeV to 300 TeV) gamma-ray astroparticle physics field. Classically, data analysis in the field maximizes sensitivity by applying quality cuts on the data acquired. These cuts, optimized using Monte Carlo simulations, select higher quality events from the initial dataset. Subsequent steps of the analysis typically use the surviving events to calculate one set of instrument response functions (IRFs). An alternative approach is the use of event types, as implemented in experiments such as the Fermi-LAT. In this approach, events are divided into sub-samples based on their reconstruction quality, and a set of IRFs is calculated for each sub-sample. The sub-samples are then combined in a joint analysis, treating them as independent observations. This leads to an improvement in performance parameters such as sensitivity, angular and energy resolution. Data loss is reduced since lower quality events are included in the analysis as well, rather than discarded. In this study, machine learning methods will be used to classify events according to their expected angular reconstruction quality. We will report the impact on CTA high-level performance when applying such an event-type classification with respect to the standard procedure.

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Introduction

The success of *Fermi*-LAT in the use of event-type partitioning [1] justifies exploring such an analysis approach for CTA.

Methodology

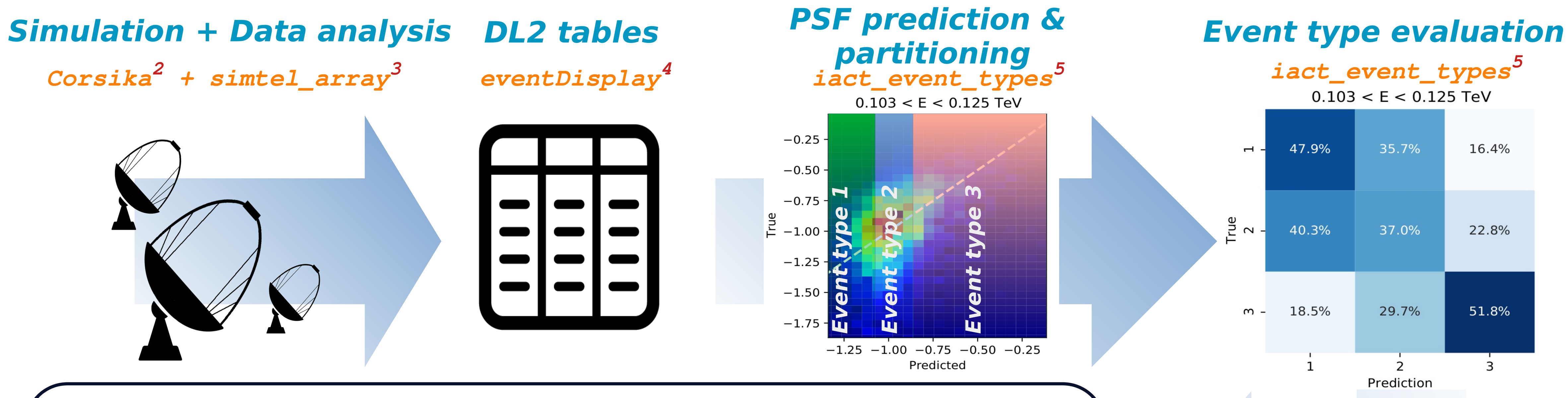
We propose the following methodology to compute CTA event-type-wise IRFs:

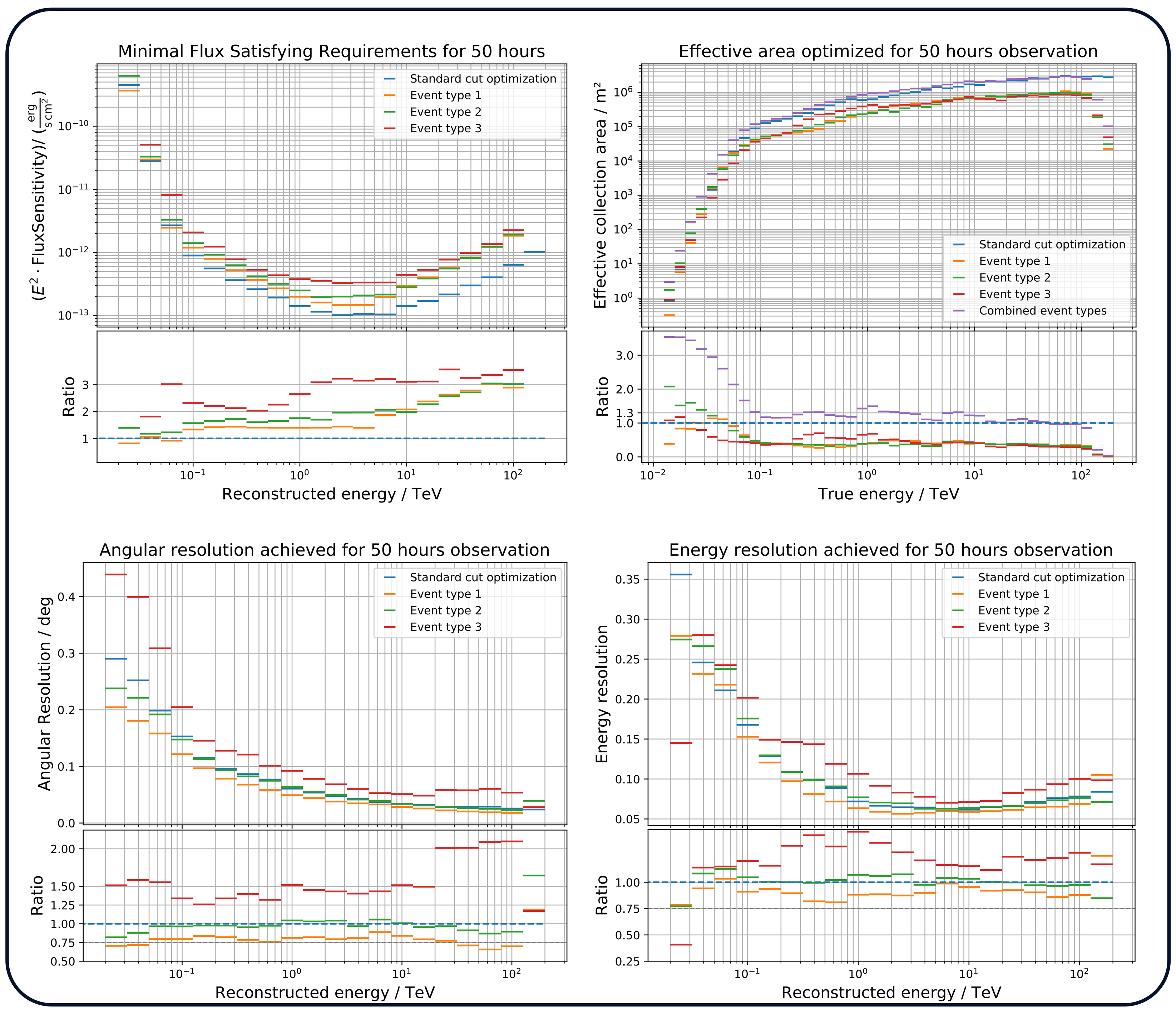
- **Starting from available "DL2" analysis products (event lists with all reconstructed quantities), a regression machine learning algorithm is trained to predict the angular reconstruction quality of each event**
- **On an independent sample, we apply the algorithm and rank the events according to their expected reconstruction performance, and separated into N event types (each with equal event statistics)**
- **We compute Instrument Response Functions from each of these N samples**

Results

By using a multilayer perceptron (MLP) neural network, we compute point spread function (PSF) event-wise IRFs to explore the potential of this alternative approach:

- **Effective area comparison shows that by combining all event types we retain more data than the standard analysis event selection**
- **Angular reconstruction quality seems to be well characterized by each event type, with the event-type 1 showing a 25% improved PSF across all CTA energies**
- **As angular and energy reconstruction are highly correlated, event-type 1 is also associated with an improved energy resolution**





Top left) Sensitivity vs reconstructed energy of a potential layout for the southern array (14 Medium-sized and 40 Small-sized Telescopes) for a point-source located at the centre of the field of view and 50 hours of observation time. Ratios are calculated with respect to the standard cut optimization. ***Top right***) Effective area vs true energy for the same array and conditions. **Bottom left**) Angular resolution vs reconstructed energy for the same array and conditions. **Bottom right**) Energy resolution vs reconstructed energy for the same array and conditions.

Conclusions

Here we show the potential of event-type partitioning for CTA high-level analysis:

- **Event reconstruction quality is properly predicted, and the proposed methodology could be realistically implemented for the future CTA data analysis**
- **Source localization and confusion will be significantly improved by the extra information provided by the PSF event partitioning shown here**
- **PSF event-type partitioning will strongly mitigate the high correlation between events angular and energy resolution, currently presenting a problem for full-enclosure 3D joint-likelihood analysis (2D sky coordinates + energy)**

Final conclusions on a net gain in sensitivity or quantifying the resulting improvement in resolution will be reached once we perform a high-level full-likelihood analysis combining the IRFs resulting from this study.

References:

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