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The ASTRI Mini-Array calibration software

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ABSTRACT

The ASTRI Mini-Array calibration plan requires several tasks for optics and electronics. These tasks are performed through dedicated software, part of the ASTRI Mini-Array Data Processing System, that perform the analysis of the data acquired during calibration procedures and extract the parameters needed for the optimal system configuration, the system monitoring and the Cherenkov data processing. In this contribution, we present the status of the ASTRI Mini-Array calibration software. The software is composed of three main Python packages: astricaltools library, aimed to provide the fundamental algorithms and methods for the calibration of the ASTRI cameras, as well as for low-level data inspection and visualization; V-TOOLS, designed to perform optics calibration using variance data; and A-MuSoft, devoted to the analysis of the muon rings to determine the telescope optical throughput and the optical point spread function.

Introduction

Specific calibration procedures have been defined to obtain the calibration coefficients needed for the scientific data analysis and for the determination of an optimal system configuration. They are necessary to ensure proper telescope functioning and data acquisition. For the analysis of data acquired during the calibration operations, dedicated software modules have been developed, which are included into the ASTRI Mini-Array Data Processing System. These modules have been successfully tested during the commissioning phase of the ASTRI--1 telescope.

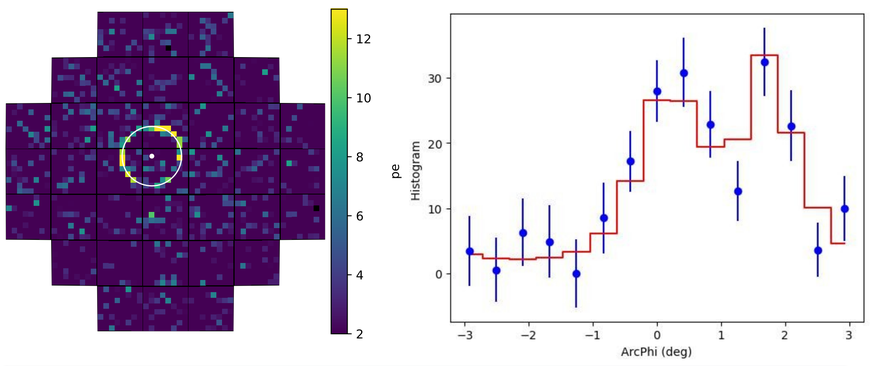

Fig. 1: Example of `A-MuSoft` muon ring geometrial reconstruction `(left) and ring light azimuthal distribution (right).`

A-MuSoft

`A-MuSoft` is a Python script developed for the analysis of muon ring images used for the telescope calibration [1]. It reads FITS files of calibrated scientific data, identifies muon events within the dominant background of hadron-induced air showers, reconstructs the geometrical parameters of the ring, and evaluates the optical Point Spread Function (PSF) from the ring width and the telescope optical throughput from the light distribution along the ring. `A-MuSoft` uses `astricaltools` library for visualization, reading of input data file, image processing and model fitting.

astricaltools

`astricaltools` is a Python library that provides all the necessary tools for the ASTRI telescopes calibration routines. In combination with an interactive development environment such as Jupyter, it provides a flexible framework for ASTRI low-level data exploration and analysis. The main library sub-modules are: `io`, which provides classes to read and inspect ASTRI RAW and FITS files; `visualization`, which provides visualization functions aware of the camera geometry; `models`, which provides model functions to extract calibration quantities; `muons`: which provides functions and classes needed for muon analysis; `image_processing`, dedicated to camera images analysis; camera: provides all classes and functions to handle camera calibration procedures [2], data inspection, data calibration, generation of camera configuration files and generation of calibration files. Calibration scripts are provided within the library as package entry points.

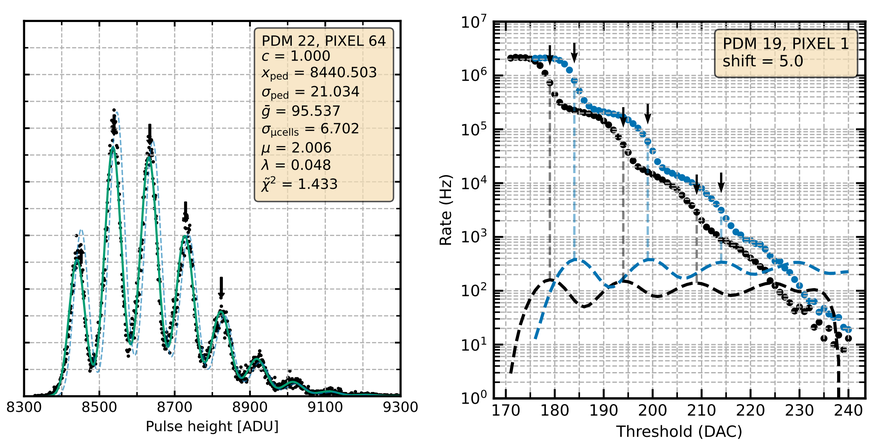

Fig. 2: Example of `astricaltools` calibration procedures: gain calibration (left) and trigger channels alignment (right)

V-TOOLS

`V-TOOLS` is a Python package designed to perform optics calibration using variance data. It implements different modules, such as: astro, for astronomy-related functions; db: for easy access related ASTRI database; processing, for variance-specific image analysis. Furthermore, this package features some entry points: `V-AXIS`, to assess the camera alignment with the telescope optical axis; `V-MAG` to estimate the magnitude of bright objects in the field of view; and `V-STAR`, to calculate the astrometry solution of variance images [3]. A web application, *`V-STAR` Web Utility*, is also provided to access information in real time, such as a simulation of the current sky map, the field of view rotation and the astrometry of the last variance image.

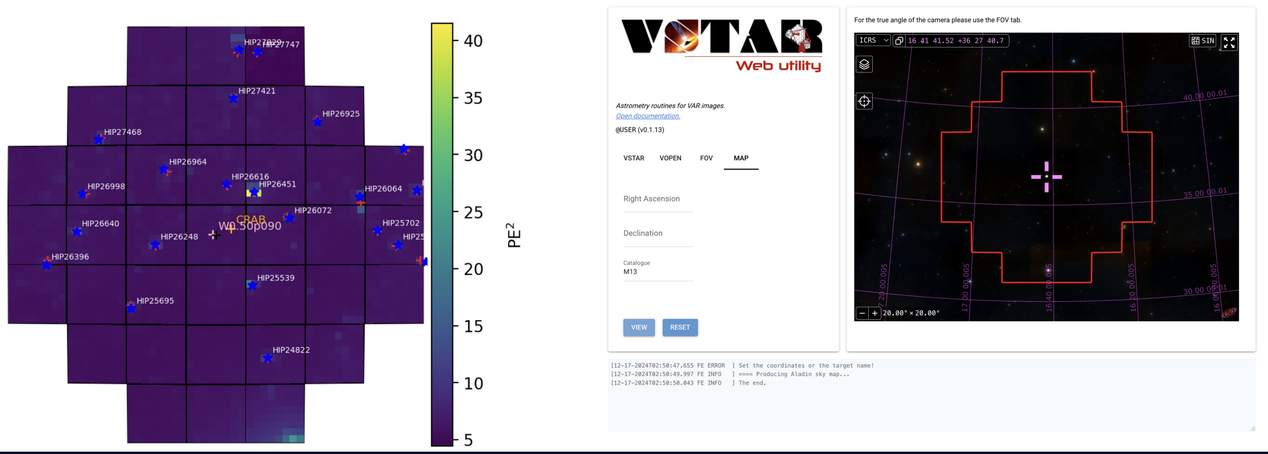

Fig. 3: Left) `V-STAR` astrometry of a variance image. Right) The `V-STAR` web utility.

ACKNOWLEDGEMENTS
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References: [1] T. Mineo et al., Using muon rings for the optical calibration of ASTRI-1 telescope: preliminary results, ICRC 2025
[2] D. Mollica et al., Calibration of the ASTRI-1 telescope camera, ICRC 2025
[3] S. Iovenitti et al., Measurement and monitoring of the ASTRI Mini-Array pointing accuracy, ICRC 2025

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