Renewed performance of the ASTRI Mini-Array at the *Observatorio del Teide*

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ABSTRACT

The ASTRI Mini-Array is an international project led by the Italian *Istituto Nazionale di Astrofisica* (INAF), with the aim to build and operate a facility sensitive to very high-energy gamma-rays in the 1-200 TeV energy range. It consists of an array of nine small-sized (4-m diameter) and large field of view (~10°) imaging atmospheric Cherenkov telescopes under deployment at the *Observatorio del Teide* (Tenerife, Spain). The full array is expected to be operational within a couple of years and will guarantee a coverage for the Galactic and extragalactic gamma-ray sources of the northern sky, in synergy with other ground-based gamma-ray facilities, like MAGIC, HAWC, LHAASO, LST and, in the next future, CTAO. ASTRI-1, the first telescope of the array, was completed in mid-2024 and is currently fully operative. We generated detailed high-statistic Monte Carlo (MC) simulations for the whole ASTRI Mini-Array, tuned on the most updated configuration of the ASTRI-1 telescope. These were reprocessed by the official ASTRI Scientific Software (`A-SciSoft`), in order to assess the updated performance of the array and to generate suitable Instrument Response Functions (IRFs) for scientific analyses. In this contribution we present the latest performance of the ASTRI Mini-Array. We also describe two novel modules fully implemented in the official scientific pipeline which allows us to derive the instrument performance and to generate IRFs from MC simulations.

1) Introduction

The nine small-sized Cherenkov ASTRI Mini-Array [1] telescopes will observe the gamma-ray sky with an unprecedented angular resolution and a 10° field of view (FoV) at TeV energies [2]. The full array is expected to be completed in a couple of years.
We present the updated performance of the ASTRI Mini-Array, derived from a set of new detailed Monte Carlo (MC) simulations implementing realistic telescope configurations, obtained with new official modules of the `A-SciSoft` software package [3, 4].

2) Monte Carlo simulations

We exploited a dedicated production of MC simulations of gamma-rays and background air showers. The `CORSIKA` [5] and `sim_telarray` [6] software packages were used to obtain the ASTRI Mini-Array response. The telescopes' configuration was properly fine-tuned by exploiting a set of real data taken during the commissioning phase of ASTRI-1 [7] in dark and good weather conditions, at a zenith angle of 20° deg and azimuth 0-180°.

particle type (particle component)	spectral slope	energy range [TeV]	view cone radius [deg]	scatter radius [m]	azimuth angle [deg]	zenith angle [deg]	total number of simulated showers
gamma (point-like)	-1.5	0.1 – 330	0	2000	0/180	20	$4 \cdot 10^7$
gamma (diffuse)	-1.5	0.1 – 330	10	2400	0/180	20	$4 \cdot 10^8$
electron	-1.5	0.1 – 330	10	2400	0/180	20	$2 \cdot 10^8$
proton	-1.5	0.1 – 600	10	2400	0/180	20	$2 \cdot 10^9$
helium	-1.5	0.12 – 750	10	3200	0/180	20	$8 \cdot 10^7$

Table 1: summary of the simulated populations

3) Data analysis

`astriirf` and `astriana` are two `Python` modules of `A-SciSoft` able to handle MC and real data at 2b level (fully reconstructed data), returning IRFs and event lists at scientific level (DL3). Both modules are also capable of estimating array's performance as a function of energy and offset angles (see [3]). In the past, these tasks were largely performed with a code (hereafter "workaround"), which will now be decommissioned.

4) Updated performances

The updated performance (differential sensitivity, angular and energy resolution) of the ASTRI Mini-Array were calculated for both on-axis and off-axis angles (5 bins between [0:5]°), exploiting the point-like and diffuse gamma-ray MC components, respectively. Performance are calculated over the energy range [0.2-316] TeV, split into 5 bins per decade. The HEGRA spectrum of the Crab Nebula [8] was assumed as reference model.

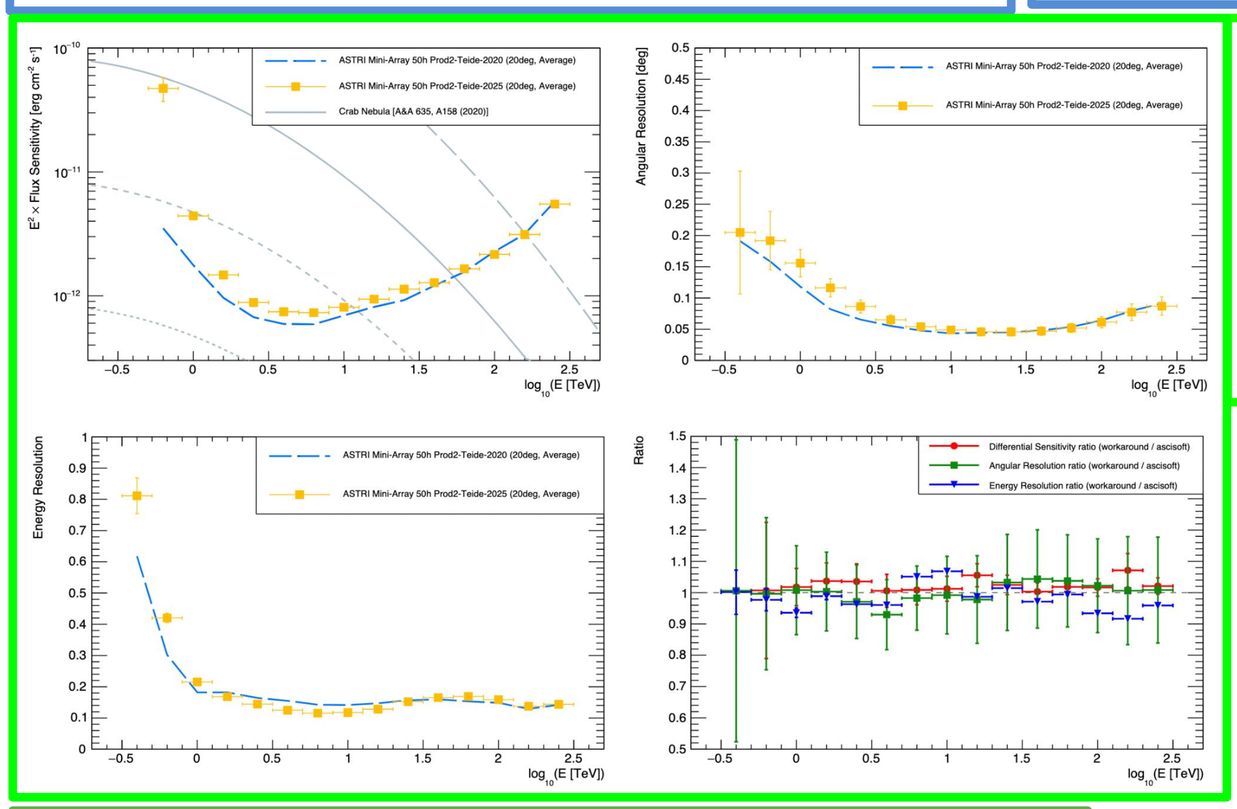

Fig. 1: On-axis differential sensitivity (top-left), angular resolution (top-right), and energy resolution (bottom-left), for the older (blue dashed line) and newer (yellow points) ASTRI Mini-Array performance obtained with the "workaround" code.

Bottom-right: ratio of the newer performance achieved with the workaround code and the two new A-SciSoft modules.

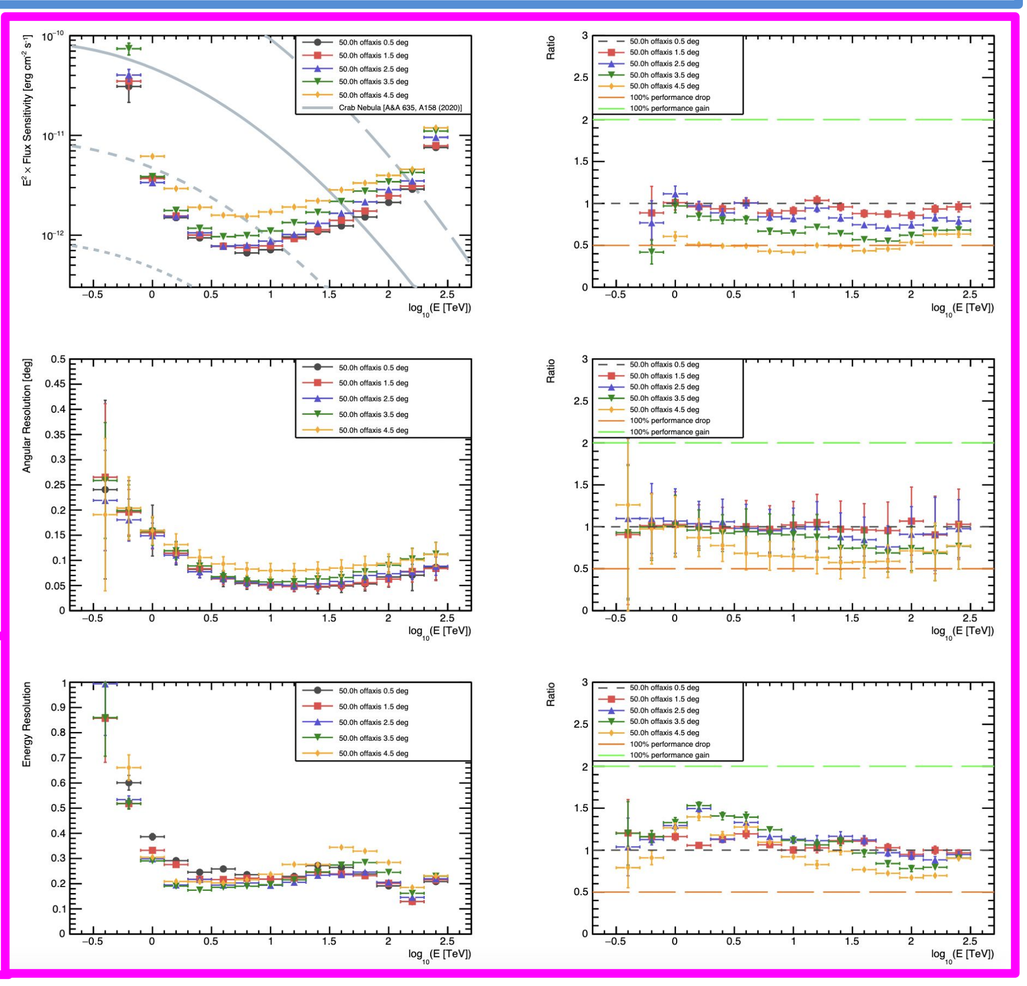

Fig. 2: Differential sensitivity (top-left), angular resolution (middle-left) and energy resolution (bottom- left) for different offset angles.

Right panels: ratio between each off-axis performance and that achieved in the first off-axis bin.

5) Results

A good agreement between previous [2] and updated performance is found (*Fig. 1*). The ASTRI Mini-Array sensitivity reaches its minimum at ~4-5 TeV with a value 7 x 10^{-13} erg cm^{-2} s^{-1} at 5σ and 50 hr of exposure. Its on-axis angular resolution is <0.1° down to 0.05° for energies >1 TeV (*Fig.1-top right*). Deviations at low energies are likely due to the effect of a higher energy threshold and a different level of night sky background.
The off-axis performance (*Fig. 2)* show that the sensitivity and the angular resolution remain quite constant along the FoV. This is a crucial aspect for the ASTRI Mini-Array to observe large and crowded regions.
Finally, the performance extracted with the two new modules of `A-SciSoft` is fully compatible with that obtained with the workaround code (*Fig. 1-bottom right*).

6) Conclusions

The most updated sensitivity, angular and energy resolution performance were provided by exploiting a new set of MC simulations fine-tuned on real data from ASTRI-1 telescope, in its commissioning phase. The new performance is comparable with older ones [3] above a few TeV. The unprecedented performance of the ASTRI Mini-Array at the TeV scale, combined with its large and almost flat FoV, will allow us to disentangle sources in crowded fields and perform detailed morphological studies in the 1-300 TeV energy band. Further MC simulations are currently underway for multiple azimuth/zenith bins, different night sky backgrounds, and sub-array configurations, in order to obtain performance for a relevant number of different observing conditions.

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References: [1] Scuderi S. et al., 2022, JHEAp, 35, 52; [2] Lombardi S., et al., 2021, Proceedings 37th ICRC, Berlin, Germany, PoS(ICRC2021)884; [3] Lombardi S., et al., 2022, Proc. of SPIE, 121890P; [4] Pintore F., et al., 2024, 38th ICRC, PoS(ICRC2023)722; [5] Heck D., et al., 1998, TIB Hannover, 998, 90; [6] Bernlöhr K., 2008, Astropart. Phys., 30, 149; [7] Crestan S., et al., 2025, these proceedings; [8] Aharonian F., et al., 2004, ApJ, 614, 897