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Appendix: Simulating CTA

The expectations for the scientific capabilities of CTA presented in this document are based on sensitivity and response functions derived from detailed Monte Carlo simulations of the CTA observatory. The simulations model extensive air showers initiated by high-energy (HE) primary particles (gamma rays or background cosmic-ray nuclei and electrons), the Cherenkov light production by the shower particles, and the measurement processes of imaging atmospheric Cherenkov telescopes.

The air shower simulations are based on the CORSIKA code [660] and include realistic assumptions of the atmospheric conditions at the two CTA sites in the southern and northern hemispheres. The absorption and scattering of the Cherenkov photons due to atmospheric aerosols and molecules and the response of the telescopes are simulated with the tool sim_telarray [661]. The telescope simulations include the ray-tracing of the photons through the optical structure and a detailed simulation of the focal plane detector, trigger system, and detector readout. The simulations also include the noise photons coming from the expected night-sky background light at each site, with a level equivalent to dark-sky observations towards an extragalactic field. The telescope array assumed for the southern site consists of four large-sized telescopes (LST), 25 medium-sized telescopes (MST) and 70 small-sized telescopes (SST), with an area covered by the array of $\sim$4 km^2. The northern array consists of four LSTs and 15 MSTs, with area covered by the array of $\sim 0.4\,\mathrm{km}^2$. For a more detailed description of the simulation parameters see Ref. [662].

For all performance estimations, a gamma-ray source with a power-law shaped energy spectrum with a differential spectral index of 2.57 is assumed.

The sensitivity calculations require a large number of simulated events from cosmic-ray protons and electrons/positrons, due to the excellent gamma-hadron separation capabilities of CTA. The simulation set for each CTA site comprises about one billion simulated gamma-ray and electron showers and about 100 billion proton showers.

Two independent analyses of the Monte Carlo samples have been carried out, yielding consistent results. The analysis codes used are derived from tools developed in the MAGIC and the VERITAS collaborations. These analyses apply imaging cleaning algorithms to remove channels with signals dominated by background light, a geometrical image parametrisation, and stereoscopic methods. Most events observed by CTA will have shower cores that lie inside the area of the array. Compared to presently operating observatories, these so-called contained events will lead to much better sampled showers by CTA with a larger number of telescopes and will result in significantly improved reconstruction accuracy for the gamma-ray direction and energy. The gamma-hadron separation will also be much more powerful in CTA, resulting in improved sensitivity in the background-limited energy range of CTA. The gamma-hadron separation methods applied are based on multivariate methods (random forests and boosted decision trees) and separation cuts are optimised for the given observation time that is typically 50 h, 5 h, or 30 min. All analyses are optimised for the best point-source sensitivity per differential energy bin (five logarithmic bins per decade of energy); better energy and angular resolution can be expected for dedicated high-resolution selection criteria.

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