The Optical System of the H.E.S.S. II Telescope

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Abstract

The H.E.S.S. collaboration is planning to extend its stereoscopic system of currently four large imaging atmospheric Cherenkov telescopes located in the Khomas Highland of Namibia in order to expand its energy range for observations of high energy phenomena in our universe. The current telescopes with their 13m reflectors and fine-grained Cherenkov cameras with a large field of view are best suited for the exploration of the gamma-ray universe in the energy range from about 100 GeV to several 10 TeV. To lower the energy threshold to 20 GeV or below and to improve the sensitivity above 100 GeV the system will be complemented by a central very large telescope. The new telescope with its 30 m type reflector, called H.E.S.S. II, is designed to provide a total mirror area of 600 m^2 for the imaging of extensive air showers onto the Cherenkov camera consisting of 2048 photomultiplier tubes of about 0.07° size. In order to guarantee for a stable and reliable imaging of excellent quality for the whole field of view of 3.2°, intense technical studies as well as detailed Monte Carlo simulations of the optical system have been performed. The complete optical system of the new H.E.S.S. II telescope represents a natural evolution of the very successful system of the current H.E.S.S. telescopes.

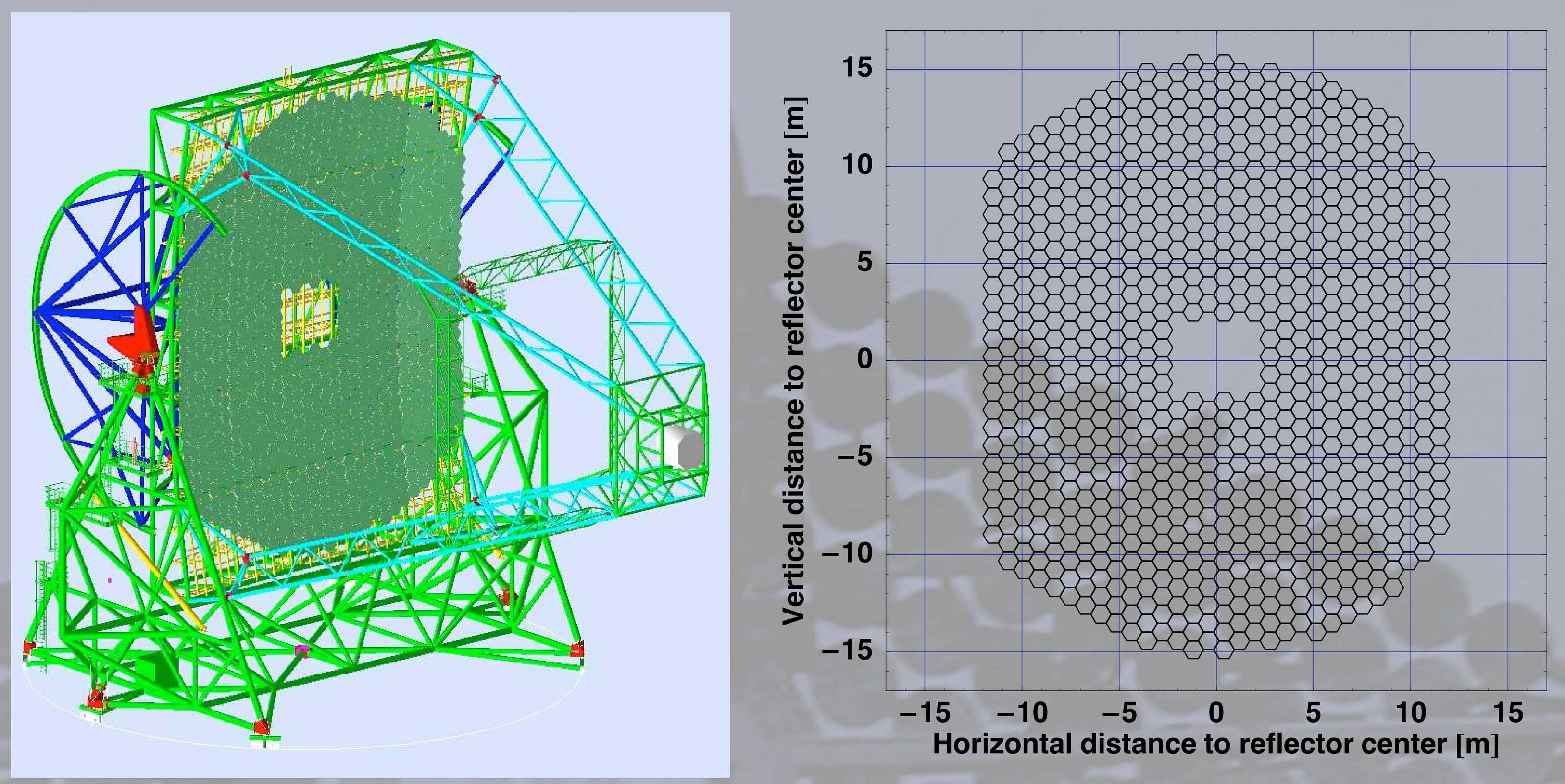
The Optical System

Requirements:

- considerable improvement of image quality and photoelectron statistics at 100 GeV
- threshold around 20 GeV, overlapping with satellite instruments but providing orders of magnitude larger effective detection areas by using the atmosphere as primary detector
  - ➡ reflector area of 600 m^2 ➡ dish diameter of about 30 m
- very good imaging over the field of view
  - ➡ minimum f/d ratio of 1.2 ➡ focal length of 36 m

Design:

- parabolic dish shape to minimize time dispersion of photons
- rectangular spatial truss of 32 m height and 24 m width
- 5x5 flat segments approximating a parabola, rectangular grid of beams
- optimized concerning stiffness and eigenfrequencies for stable imaging above 45° elev.
- 850 hexagonal mirror facets of 90 cm width (flat-to-flat)
- passive support of mirror facets for high reliability and ease of operation
- motors for remote alignment of mirror facets using images of stars, only required for initial alignment and occasional realignment
- camera supported by quadrupod attached to corners of dish for refocussing the telescope on shower maximum depending on zenith angle, range of 10 cm



Left: Sketch of the H.E.S.S. II telescope.
Right: Layout of the H.E.S.S. II reflector consisting of 850 hexagonal mirror facets of 90 cm diameter (flat-to-flat). The total reflector area is 596 m^2.

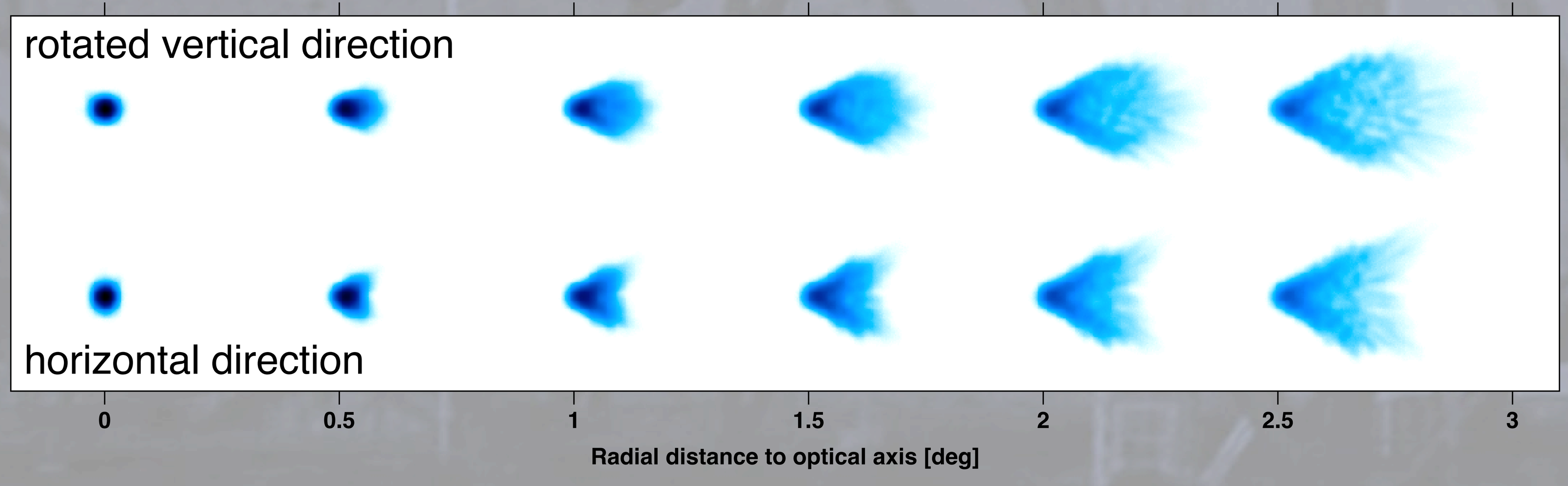
Simulation of Point Spread Function

Dependence on number of facet focal lengths

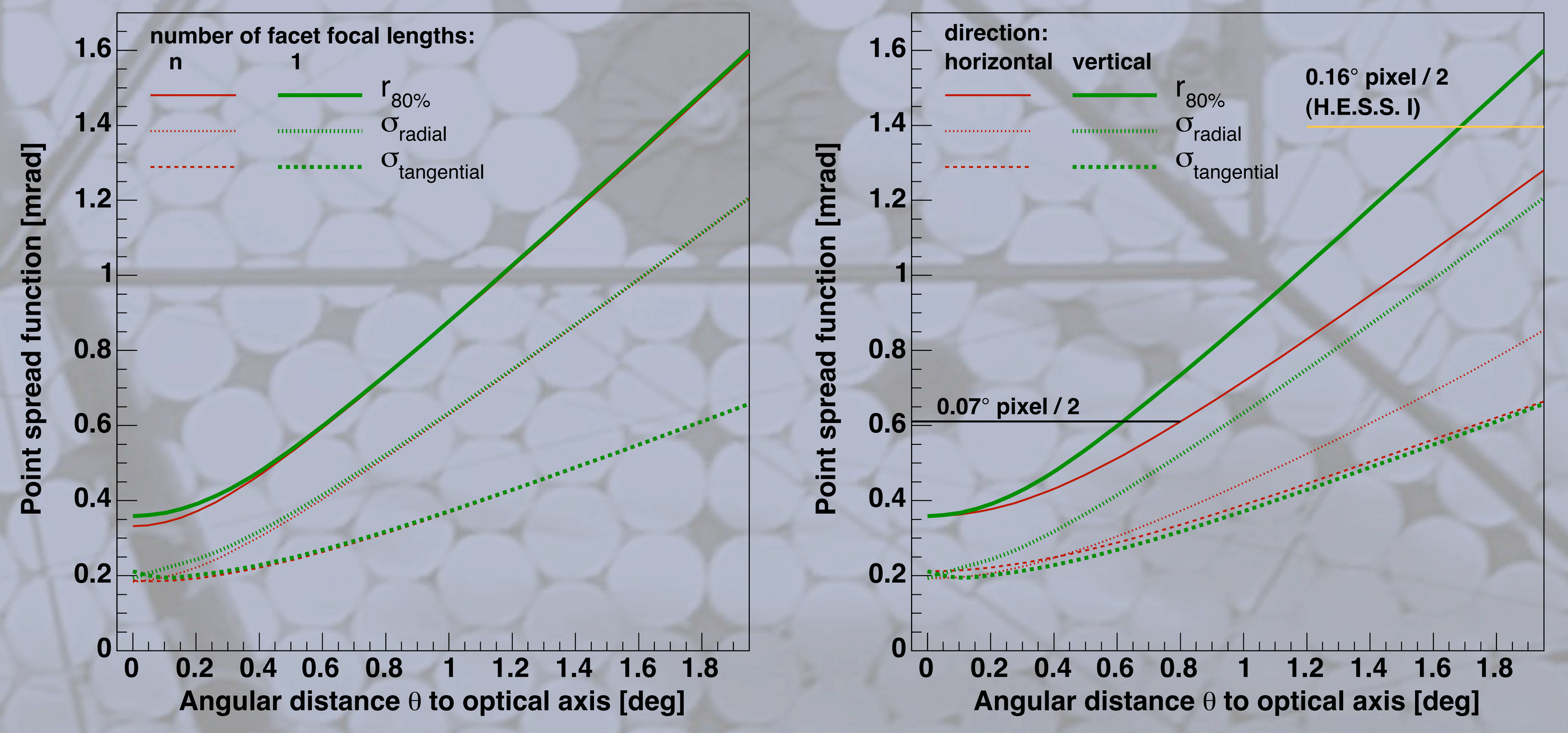
- parabolic reflector: nominal focal length of facets vary with distance to reflector center
  - ➡ actual number of different focal lengths is subject to minimization
- optimum: every facet manufactured to have its nominal focal length
- worst case: identical focal length of nominal mean (36.74 m) for all facets
  - ➡ due to large f/d ratio (40) for a single facet, variations in focal length of a few percent have a negligible effect on the overall imaging quality
    - ➡ uniform focal length for all facets adopted

Implications of reflector asymmetry

- asymmetry of reflector: PSF depends not only on radial angular distance to center but also on polar angle inside the focal plane
  - ➡ simulations for vertical and horizontal directions carried out separately
- development of spot size differs between vertical and horizonal direction as expected
- spot asymmetry along vertical direction is dominant
  - ➡ actual dependencies are well understood
    - ➡ if required: results will serve to improve the analysis of shower images



Simulated point spread function of the H.E.S.S. II reflector for various angular distances to the optical axis. The top series of spot shapes represent the (rotated) development along the vertical direction; the bottom series are for the horizontal direction. The intensity scale is logarithmic. Note that the actual active field of view is limited to a radius of 1.6 degrees.



Left: Simulated point spread function as a function of the angular distance to the optical axis. The lower curves (n) show the scenario in which every mirror facet is manufactured to have its nominal focal length. The top curves (1) represent the case in which all facets are manufactured to have an identical focal length. A difference between these two cases is hardly seen. Curves are shown for the vertical direction only.
Right: Simulated point spread function for both directions with a uniform facet focal length. The top/lower curves are for the vertical/horizontal direction, respectively. The horizontal lines indicate different radii of the Cherenkov camera pixels for comparison.

Conclusions

The design of the H.E.S.S. II telescope represents a cost-effective solution for a 600 m^2 type Cherenkov telescope. Rigid steel structures guarantee for reliable imaging for the whole range of operation without the need to realign mirrors in-between observations. Intense simulation studies of the reflector design have been performed which led to a comprehensive understanding of the imaging. The results show that a uniform manufacturing focal length for all mirror facets will be sufficient to form the parabolic reflector; the impact on imaging quality is negligible.

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