The Mirror Alignment and Control System for CT5 of the H.E.S.S. experiment

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Introduction

H.E.S.S. is a stereoscopic system of five imaging atmospheric Cherenkov telescopes in the Khomas Highlands of Namibia. The experiment consists of four telescopes with a reflecting dish diameter of 12m (CT1 to CT4) and a newer large telescope (CT5) with a reflecting dish diameter of 28m. The performance of the gamma-ray observations of H.E.S.S. highly depends on a precise alignment of all 876 mirror facets of the telescope. The large number or mirrors requires a robust system with a large degree of automation, a high precision and stable results over a long period to avoid the need of regular realignments. Since the dish of the telescope is sufficiently stable an active alignment during observation is not necessary.

Mechanics

- Mirrors connected to the dish at three points, two points equipped with an actuator, one passive rotating bolt
- DC motor including a hall sensor
- Spindle: 1mm pitch, 40mm range
- Worm gear between spindle and motor, ratio 210/1
- Resolution of 1/420 turn of the spindle (2.4µm lift)
- Highly accelerated life-time tests: Precise within the expected life-time

Figure 1: Image of the backside of one mirror, actuators shown on the bottom, fixed at the top

Alignment procedure

- Light of a tracked bright star is reflected by the mirrors on the lid
- Images of the lid are taken before and after a mirror movement
- Spot finding algorithm determines spot positions
- From CCD positions and actuator positions two transformation matrices are calculated
- First matrix assumes a fixed angle of 120° between the tilting axis based on two positions (coarse alignment up to 25 mirrors)
- Second matrix based on 4 positions close to the center of the dish (fine alignment up to 4 mirrors)

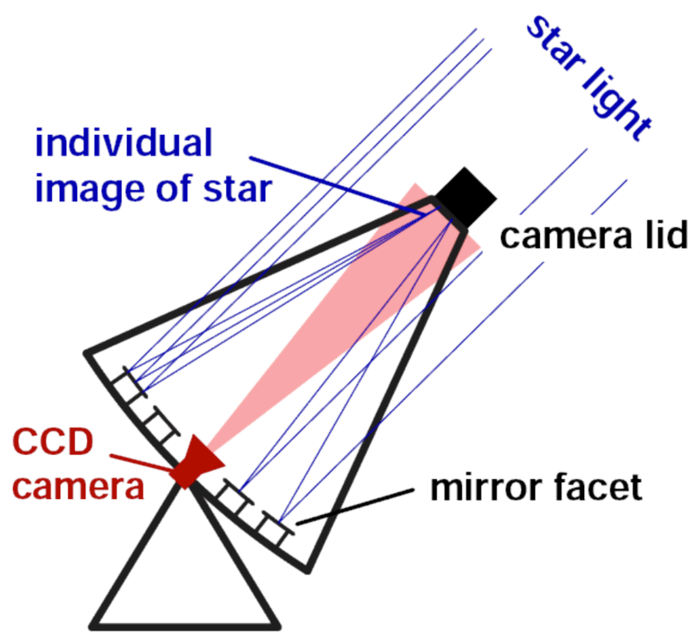

Figure 3: The light of a bright star is reflected to the lid forming individual light spot. Images are taken with a CCD camera in the center of the dish.

Stability

- Optical PSF, measured at 65° elevation
- Shown as a function of time since March 2014
- Linear fit: compatible with constant
- 1.5yr of operation
- Test of the system in January 2015
- Alignment system fully functional since deployment

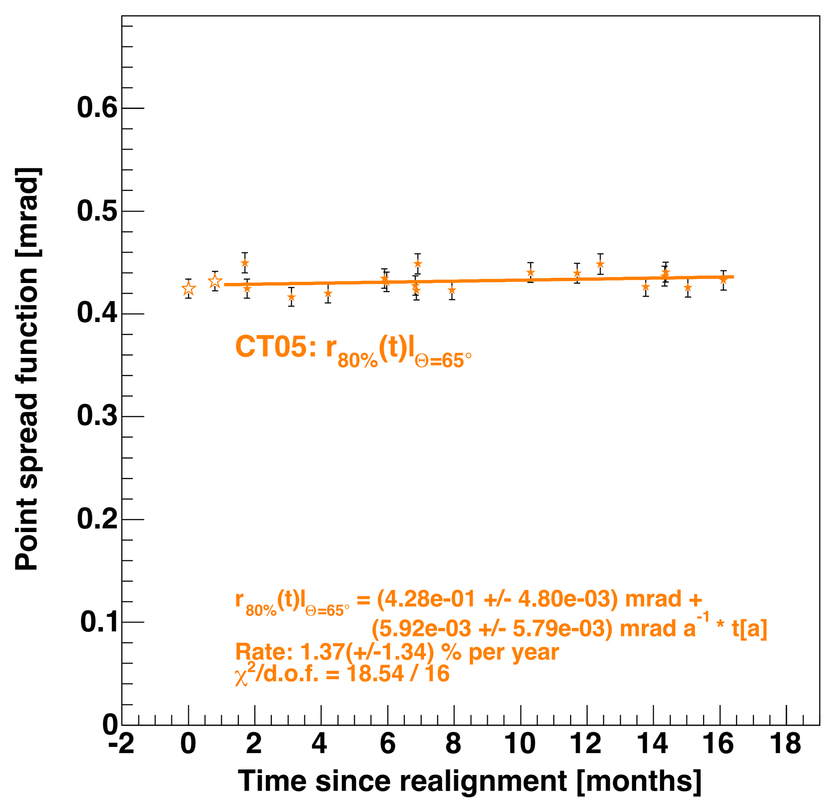

Figure 5: PSF at 65° shown over time

Electronics

- 25 panels, each serving up to 42 mirrors
- 1 electronic box per panel hosting 7 boards hosting motor drivers and 1 control board
- 1 control board with an interface to the motor control boards, an Ethernet interface and an interface to the analogue to digital converters
- Panel control boxes connected to a central box via optical fiber

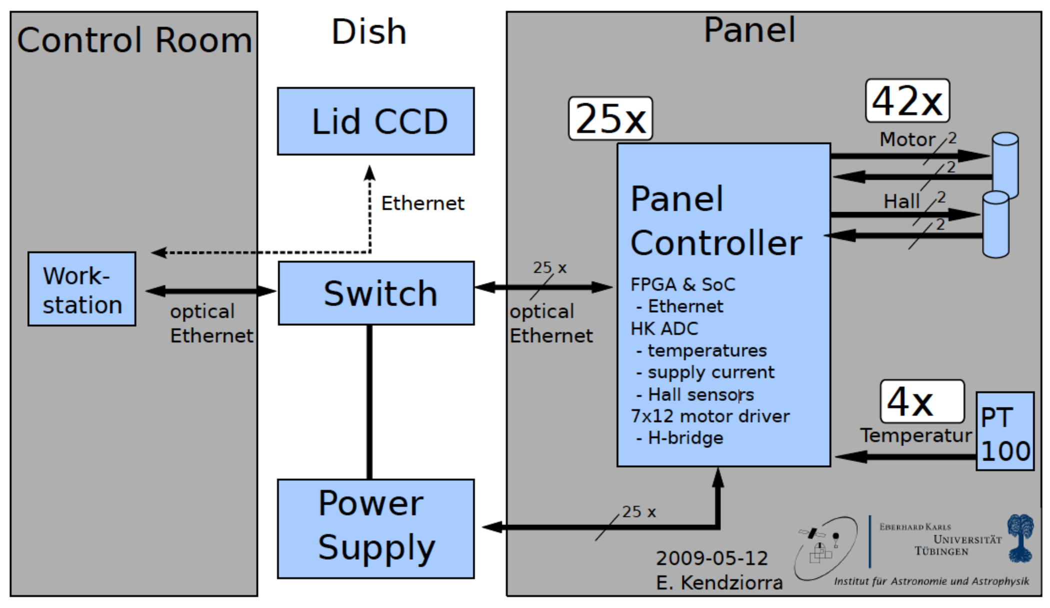

Figure 2: Schematic of the electronics for the alignment

Optical PSF

- PSF is monitored monthly for 30 elevation angles
- For each measurement a CCD image of the image of a bright star on the lid is taken
- From the CCD image the size of the light spot is determined
- Elevation-dependent slight deformation of the dish is expected and affects the PSF
- No azimuthal dependency
- Function fitted to the data to describe the elevation dependency
- The fitting parameters are used as an input for telescope performance simulations

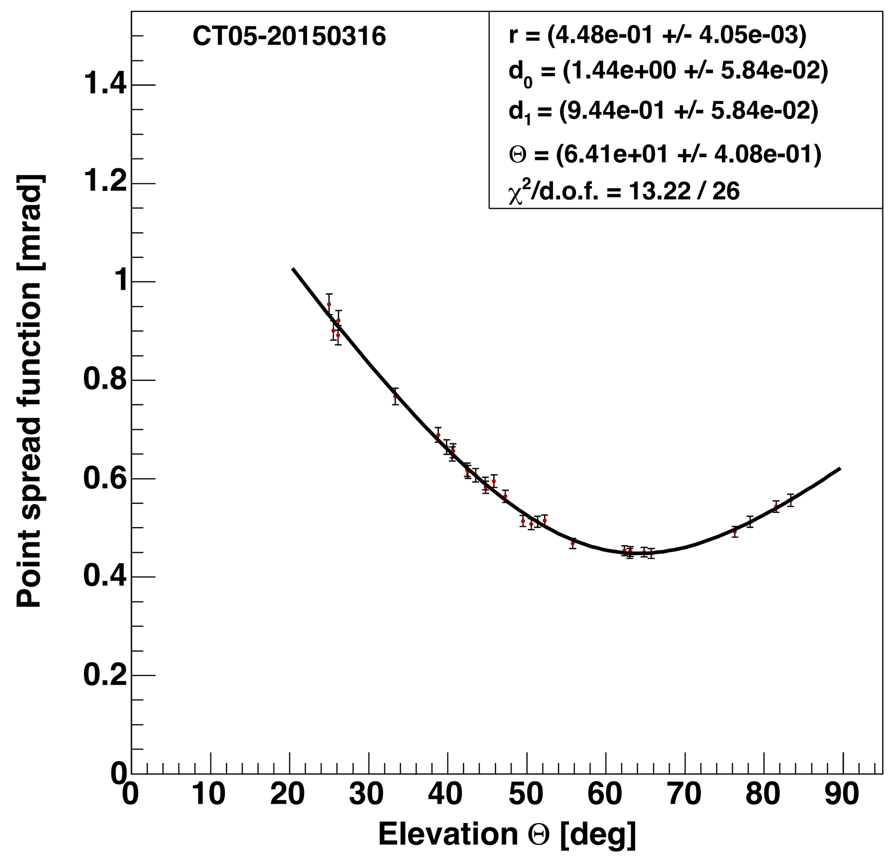

Figure 4: PSF size as a function of the elevation angle of the telescope

Conclusion

The achieved PSF is within expectations and meets the instrument requirements. For typical gamma-ray observations between 30° and 80° elevation angle the diameter of the light spot spans between 0.9mrad and 1.6mrad compared to the diameter of a PMT camera pixel of 1.22mrad. So far, we do not measure a significant increase of the PSF after more than 1.5yr of operations with the current alignment. The time needed for a full alignment is in the expected range and the software, mechanical components, and electronics fulfill all expectations.

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