Bokeh Alignment

If the Bokeh of a segmented reflector is equal to its aperture up to a scale factor, then the mirrors are aligned.

In May 2014 FACT was pre-aligned using the Bokeh technique which gave good results. In daylight, we took a picture of the aperture function and printed it onto a template screen which was mounted in front of FACT’s image sensor. A bulb placed in $g \approx 50$ mm behind the template screen is highlighted in yellow. Two of the four mirror rays are shown in red and blue. Both reflectors depicted are aligned.

NAMOD Alignment

NAMOD Normalizes the mirror responses and records Azimuthally from the pointing of the telescope drive to its Near-Aperture Osmation Determination.

NAMOD reconstructs the mirror facet orientation by recording the facet’s normalized response for various telescope pointing directions while wobbling the telescope close to a bright star in the night sky. Two cameras, a star $S$ and a reflector $R$, are recording the telescope’s field of view and the reflector facets simultaneously, see figure 1.

For each ray, we reconstruct the telescope pointing, the star’s light flux and the flux of the facet’s response in the focal point. Several hundred records are taken while wobbling close to the bright star. Both cameras’ radiometric properties are known to estimate and compare the light fluxes [3, 4]. Our star camera, geometrically calibrated, obtains the telescope’s pointing relative to the bright star. To correct for atmospheric effects and to enable switching the reference star during recording, we normalize the facet response, see figure 2. There is no communication needed with the telescope drive.

Bokeh alignment was developed on Mini FACT. Needing only a light bulb, a consumer photo speedlight, a desktop printer, and a level, Bokeh alignment is cheaper and faster compared to computer vision based solutions. Bokeh alignment can be done during daytime when the light source is powerful enough, e.g. a consumer photo speedlight. Watch our Bokeh demonstration video showing the alignment of Mini FACT.

In Figures 4 and 5 we compare the PSF series are compared to ray tracing simulation results. Reconstructions of muon events show a reduction of the muon ring width in muon events caused by the alignment, see [5].

Mini FACT

The development on a test bench like Mini FACT dramatically reduced overlap with observation time, total costs, and debugging time of the NAMOD system.

Mini FACT was developed on a 1/10th scale model of FACT, both our alignment methods resulted in a highly telescope independent procedure, e.g. both our methods run without communication to the telescope’s drive. We compare alignment results by using the point spread function of star images, ray tracing simulations, and muon ring widths before and after the alignment.

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References


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FACT – the First G-APD Cherenkov Telescope

Sebastian Achim Mueller for the FACT-Collaboration

Imaging Air Cherenkov Telescopes, including the First G-APD Cherenkov Telescope (FACT), use segmented reflectors [1]. These offer large and fast apertures for little resources. However, one challenge of segmented reflectors is the alignment of the single mirrors to gain a sharp image. For Cherenkov telescopes, high spatial and temporal resolution is crucial to reconstruct air shower events induced by cosmic rays. Therefore, the first step to align the individual mirror positions and orientations precisely. Alignment is difficult due to the large number of degrees of freedom and because most techniques involve a star. Most current methods are limited, because they have to be done during good weather nights which overlaps with observation time. In this contribution, we present the mirror alignment of FACT, done using two methods. Firstly, we show a new method which we call Bokeh alignment. This method is simple, cheap and can even be done during daytime. Secondly, we demonstrate an enhancement of the SCCAN method by F. Arqub et al., and first implemented by the McGill VERITAS group. Using a second camera, our enhanced SCCAN is optimized for changing weathers, changing zenith distance, and changing reference stars. We call it NAMOD. Developed off site in the lab on a 1/10th scale model of FACT, both our alignment methods resulted in a highly telescope independent procedure, e.g. both our methods run without communication to the telescope’s drive. We compare alignment results by using the point spread function of star images, ray tracing simulations, and muon ring widths before and after the alignment.