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FACT — LONGTERM MONITORING OF BRIGHT TeV BLAZARS

Katja Meier[a,*], A. Biland[b], T. Bretz[b], J. Buss[c], D. Dorner[a], S. Einecke[c], D. Eisenacher[a], D. Hildebrand[b], M. L. Knoetig[b], T. Krähenbühl[b], W. Lustermann[b], K. Mannheim[a], D. Neise[c], A.-K. Overkemping[c], A. Paravac[a], F. Pauss[b], W. Rhode[c], M. Ribordy[d], T. Steinbring[a], F. Temme[c], J. Thaele[c], P. Vogler[b], R. Walter[e], Q. Weitzel[b], M. Zänglein[a] (FACT Collaboration)

[a] *Universität Würzburg, Germany — Institute for Theoretical Physics and Astrophysics, 97074 Würzburg*
[b] *ETH Zurich, Switzerland — Institute for Particle Physics, Schafmattstr. 20, 8093 Zurich*
[c] *Technische Universität Dortmund, Germany — Experimental Physics 5, Otto-Hahn-Str. 4, 44221 Dortmund*
[d] *EPF Lausanne, Switzerland — Laboratory for High Energy Physics, 1015 Lausanne*
[e] *University of Geneva, Switzerland — ISDC Data Center for Astrophysics, Chemin d'Ecogia 16, 1290 Versoix*
[*] corresponding author: kmeier@astro.uni-wuerzburg.de

Abstract. The First G-APD Cherenkov Telescope (FACT), located on the Canary Island of La Palma, has been taking data since October 2011. FACT has been optimized for longterm monitoring of bright TeV blazars, to study their variability time scales and flare probability. G-APD photo-sensors allow for observations even under strong moonlight conditions, and the telescope can be operated remotely.

The monitoring strategy of FACT is discussed and preliminary results of the flare of Mrk501 in June 2012 are shown.

Keywords: Cherenkov astronomy; gamma astronomy; monitoring; AGN; blazar.

1. The FACT telescope

The First G-APD Cherenkov Telescope (FACT) is situated on the Canary Island of La Palma at the Observatorio del Roque de los Muchachos at 2200 meters above sea level.

For the experiment, the former mount of the HEGRA CT3 telescope was refurbished. The massive steel structure was taken over, but a new drive system was installed and the mirrors of the former HEGRA CT1 were repolished and newly coated, giving a total mirror area of 9.5 m^2.

The setup of the telescope was designed for the detection of very high energy (VHE) cosmic gamma-rays, ranging from several hundred GeV up to approximately 10 TeV, applying the Imaging Atmospheric Cherenkov Technique.

The telescope started taking data in October 2011. An outstanding feature of FACT is the possibility to operate the telescope remotely.

FACT is the first Cherenkov telescope using Geiger-mode Avalanche Photodiodes (G-APDs), instead of photo-multiplier tubes, for photon detection in regular observation.

The camera consists of 1440 pixels, each with an opening angle of 0.11 degrees. This results in a total field-of-view of 4.5 degrees. Each pixel has a solid light concentrator to allow for maximum area compression for photons arriving from the mirror, to reduce light loss due to Fresnel refraction, and also to shield the sensors of background photons not reflected by the mirrors.

A great advantage of G-APDs is their ability to operate even under strong moonlight conditions. This significantly increases the possible duty cycle of the telescope. More details on the applied technique and the design of the telecope can be found in [1].

The FACT collaboration was founded in 2008 with the aim to examine these silicon photodectectors for use in Cherenkov telescopes and to monitor bright TeV blazars in the longterm.

2. Longterm monitoring of bright TeV blazars

Longterm lightcurves with consistent sampling are needed to study such highly variable objects as blazars. They show variations in their fluxes on timescales ranging from minutes to years. A more detailed explanation of blazars and their related physics is discussed in Section 3.

Longterm monitoring in the VHE range also offers the opportunity to combine these data with observations at other wavelengths in Multi Wavelength (MWL) campaigns. Such complete sampling allows for a deep insight into the fundamental acceleration processes and related physics, that cause the observed radiative phenomena.

To complete this process of continous monitoring, the idea of the DWARF project (Dedicated multi-

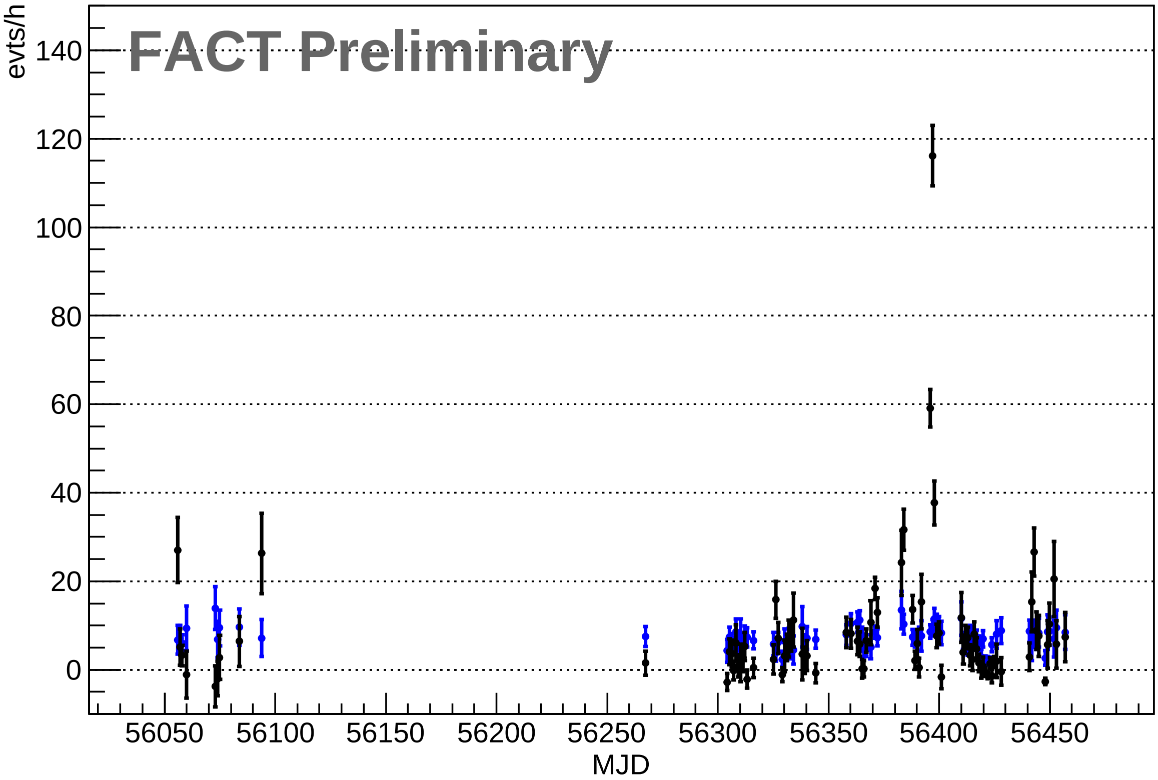

Figure 1. Excess rate in events per hour versus time in Modified Julian Date, for the blazar Markarian 421. The excess rate is plotted in black, while the background rate is in blue. A major flare in April 2013 can be seen.

Wavelength AGN Research Facility) is to position small, inexpensive telescopes around the world, to ensure monitoring all around the clock.

Hence FACT is the first telescope of this project and the first Cherenkov telescope using G-APDs in regular operation.

One major task of the large currently operating Cherenkov telescopes, is to search for new sources. Examples are MAGIC (Major Atmospheric Gamma-Ray Imaging Cherenkov Telescopes), H.E.S.S. (High Energy Stereoscopic System) and VERITAS (Very Energetic Radiation Imaging Telescope Array System). Their observing time is too expensive for longterm monitoring. Only small, inexpensive telescopes are ideally suited for this task.

3. Sources observed by FACT

FACT observes the Crab Nebula constantly up to very high zenith angles.

The Crab Nebula is a remnant from the well known supernova in 1054 and a pulsar wind nebula. It was discovered in 1989 in the VHE range by Whipple [2]. It is the strongest known persistent source of high energy radiation, and is therefore used as a standard candle in VHE astronomy.

It should be mentioned here that there are current detections of the Crab Nebula flaring in the gamma-ray regime for photon energies greater than 10 MeV [3].

The assumed persistent flux of the Crab Nebula, at the VHE range, can be used to study the performance of the telescope. This is important for understanding the dependence of the measured rates on effects such as the zenith angle and the ambient light.

The other two sources mainly observed by FACT are the blazars Markarian 501 and Markarian 421.

Blazars belong to the class of AGN (Active Galactic Nuclei). This class can be divided into radio loud and radio quiet sources. Subclasses are for example Seyfert galaxies, broad and narrow line radio galaxies, as well as blazars.

The unifying AGN model [4] explains the different types as an effect of the viewing angle to the physically same object.

It is believed that all AGNs consist of a supermassive black whole at the center of the host galaxy, surrounded by an accretion disk, a dust torus and gas clouds circulating around. Perpendicular to the accretion disk a jet of relativistically accelerated charged particles is formed. Due to relativistic Doppler boosting, the emitted radiation of the jet is strongly amplified and focussed in the direction of the jet axis.

For blazars, this jet axis is close to the line of sight, allowing for an insight of the jet.

This explains the VHE radiation and the extreme flux variability of blazars.

The high energy radiation of blazars is dominated by nonthermal processes. Their spectral energy distribution (SED) has a typical two hump shape.

The first hump is caused by synchrotron emission from relativistic electrons in magnetic fields. The second one in the gamma ray regime is attributed to

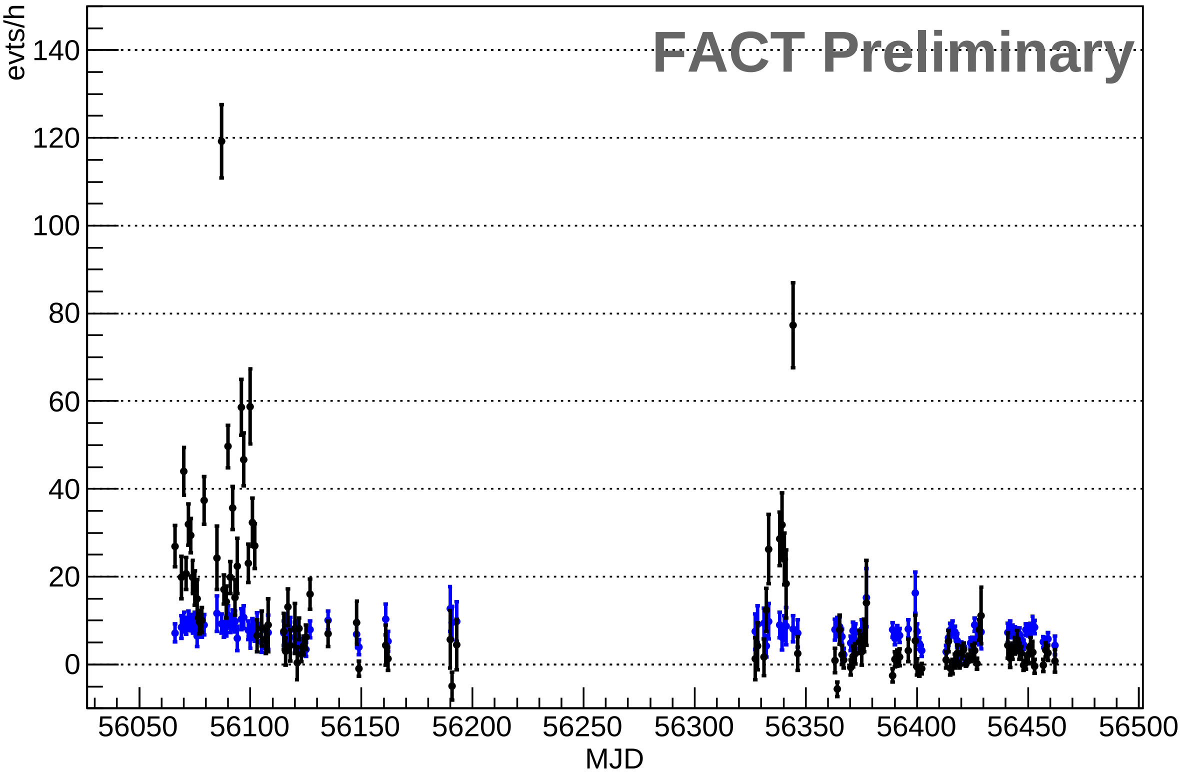

Figure 2. Excess rate in events per hour versus time in Modified Julian Date of Markarian 501, from May 2012 until June 2013, including two flares. The excess rate is plotted in black, while the background rate is in blue.

inverse Compton scattering.

Markarian 501 is a blazar, located in the constellation of Hercules. It was discovered in 1996 for photon energies above 300 GeV by Whipple [5]. It is one of the brightest and nearest objects in the VHE regime, and therefore one of the most studied blazars. Its historical flux maximum in the VHE range was detected in 1997 [6–8]. Markarian 501 has a redshift of $z = 0.034$.

Markarian 421 is located in the constellation of Ursa Major and has a redshift of $z = 0.031$. It was detected in the very high energy range in 1992 by Whipple [9].

4. Results of FACT

As a result of longterm monitoring of bright TeV blazars by FACT, the excess rates of Markarian 501 and Markarian 421 are presented here.

For Markarian 421, the time range in Figure 1 is from May 2012 until June 2013. The shown data includes a flare in April 2013.

For all plots the excess rate is plotted in black and the background rate is in blue. The data check used for these plots is described in [10] in full detail.

The gaps in which no data is taken is because of high zenith angles, the source being beyond the horizon, or bad weather.

The shown excessrate of Markarian 501 starts in May 2012 and lasts until June 2013. Clearly two enhanced flux states of the blazar can be seen in Figure 2, the first in June 2012 and the second in Feburary 2013.

Figure 3 gives an insight on the nights of the first flare, on a time range from May 2012 until June 2012. The highest bin shows a rise of the flux of nearly six times the previous value. This highest flux was measured in the night of 8/6/2012 during a major outburst of Markarian 501.

5. Conclusions

Studying AGNs requires longterm monitoring of very high energy sources, as their fluxes are highly variable.

DWARF (Dedicated multiWavelength AGN Research Facility) is a project to enable such constant monitoring with small inexpensive telescopes around the world. The First G-APD Cherenkov Telescope (FACT) is the first telescope of this project.

It is also the first Cherenkov telescope that uses Geiger-mode avalanche photo diodes (G-APDs) instead of photo-multiplier tubes in regular observations. G-APDs have the great advantage of being operable even under strong moonlight conditions. This allows for a considerably larger duty cycle.

FACT has been successfully taking data for more than 1.5 years. Two major flares of Markarian 501 and one of Markarian 421 with high significance have been detected so far. For the highest bin of the measured flux during the first flare of Markarian 501 the significance rate was around 5 sigma in 5 minutes. This nicely demonstrates that FACT is able to send flare alerts on short timescales to other telescopes.

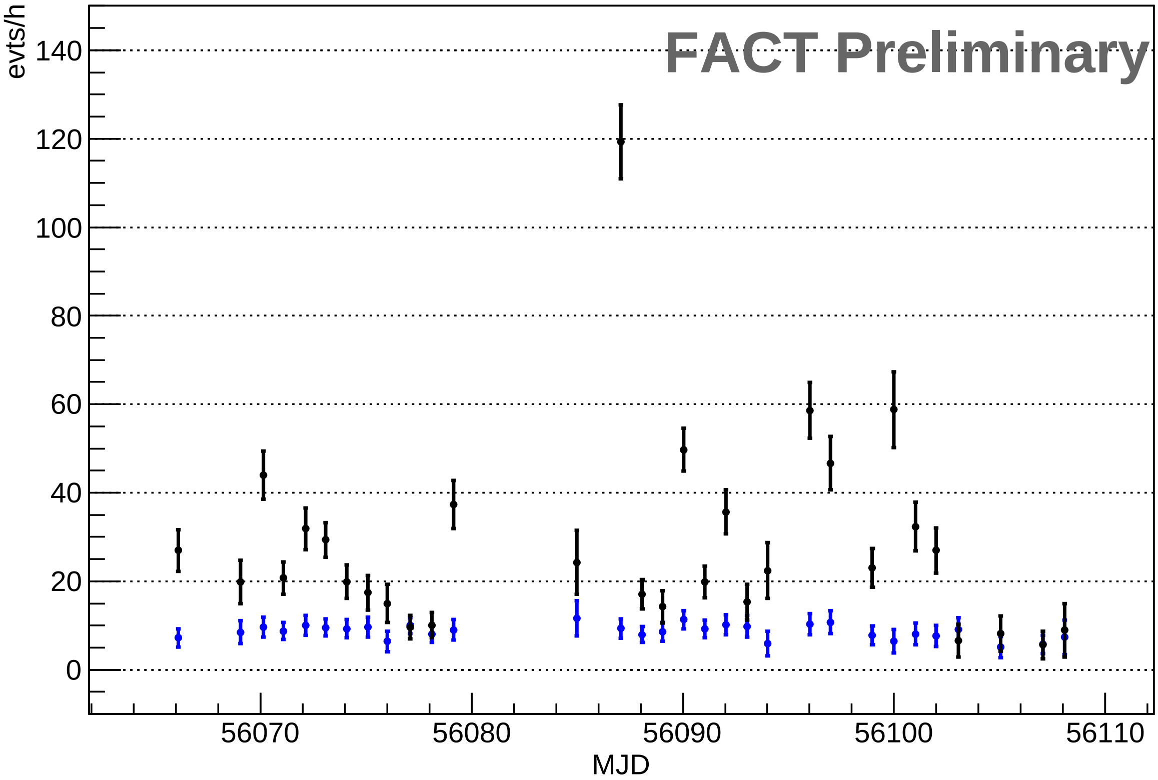

FIGURE 3. The first flare of Markarian 501 in more detail, for a time range from May 2012 until June 2012. For the highest bin of the excess rate, the flux rose to a value six times higher than the previous one.

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References

[1] H. Anderhub, et al. Design and operation of FACT – the first G-APD Cherenkov telescope. *JINST* **8**:P06008, 2013. 1304.1710 DOI:10.1088/1748-0221/8/06/P06008.

[2] M. F. Cawley, et al. Detection of TeV gamma rays from the Crab Nebula using the atmospheric Cherenkov imaging technique. *Irish Astronomical Journal* **19**:51–54, 1989.

[3] A. A. Abdo, et al. Gamma-Ray Flares from the Crab Nebula. *Science* **331**:739–, 2011. 1011.3855 DOI:10.1126/science.1199705.

[4] C. M. Urry, et al. Unified Schemes for Radio-Loud Active Galactic Nuclei. *PASP* **107**:803, 1995. arXiv:astro-ph/9506063 DOI:10.1086/133630.

[5] J. Quinn, et al. Detection of Gamma Rays with E > 300 GeV from Markarian 501. *ApJ* **456**:L83, 1996. DOI:10.1086/309878.

[6] A. Djannati-Atai, et al. Very High Energy Gamma-ray spectral properties of MKN 501 from CAT Čerenkov telescope observations in 1997. *A&A* **350**:17–24, 1999. arXiv:astro-ph/9906060 DOI:10.1086/308558.

[7] M. Amenomori, et al. Detection of Multi-TEV Gamma Rays from Markarian 501 during an Unforeseen Flaring State in 1997 with the Tibet Air Shower Array. *ApJ* **532**:302–307, 2000. arXiv:astro-ph/0002314.

[8] F. A. Aharonian, et al. The temporal characteristics of the TeV gamma-radiation from MKN 501 in 1997. I. Data from the stereoscopic imaging atmospheric Cherenkov telescope system of HEGRA. *A&A* **342**:69–86, 1999. arXiv:astro-ph/9808296 DOI:10.1038/358477a0.

[9] M. Punch, et al. Detection of TeV photons from the active galaxy Markarian 421. *Nature* **358**:477, 1992.

[10] T. Bretz, et al. FACT - The first G-APD Cherenkov telescope (first results). In F. A. Aharonian, et al. (eds.), *American Institute of Physics Conference Series*, vol. 1505 of *American Institute of Physics Conference Series*, pp. 773–776. 2012.