PROCEEDINGS OF SCIENCE

H.E.S.S. observations of PKS 1830-211

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PKS 1830-211 is a lensed, high energy emitting, AGN located at redshift z=2.5. The recent addition of a 28 m Cherenkov telescope (CT5) to the H.E.S.S. array extended the experiment's sensitivity towards low energies, providing access to gamma-ray energies down to 30 GeV. Data towards PKS1830-211 were taken with CT5 in August 2014, following a flare alert by the *Fermi-LAT* collaboration at the beginning of that month. The H.E.S.S observations were aimed at detecting a gamma ray flare delayed by 20-27 days from the alert flare. Preliminary H.E.S.S. results towards PKS 1830-211 are presented and discussed.

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1. The PKS 1830-211 gravitational lens

PKS 1830-211 is a high redshift (z=2.5) Flat Spectrum Radio Quasar. It is a known gravitational lens comprising two compact images of the blazar nucleus joined by an Einstein ring. The quasar source is lensed by a foreground galaxy at $z = 0.89$. The angular size of the Einstein ring and the typical separation of compact images is roughly 1" and cannot be resolved with high energy instruments such as H.E.S.S. or *Fermi-LAT*. PKS 1830-211 is seen as a bright, high energy source by the *Fermi-LAT* instrument. It had several flaring periods during the seven years of *Fermi-LAT* observations. PKS 1830-211 is listed in the 1FHL catalogue (Ref. [1]) with a spectral index above 10 GeV of ~ 3.9, which corresponds to the average "low-state" spectrum. Due to the different travel paths, the light curves of the two compact components of the lens have a mutual time delay of 26 ± 5 days, measured in the radio (Ref. [2]) and microwave (Ref. [3]) pass-bands. Barnacka, Glicenstein and Moudden (Ref. [4]) have used the first three years of the Fermi-LAT light curve to calculate a cepstrum and an autocorrelation function. A delay of 27.5 ± 1.3 days was found with a significance of 3 σ. The time delay between the compact images of PKS 1830-211 was also studied by the *Fermi-LAT* collaboration (Ref. [5]). They selected several flaring periods and calculated the auto-correlation function of the light curve. No significant peak was found. A possible peak of ~ 20 days was found with a 1-day binning of the data. This could be attributed to the ~ 20 days separation between two flaring events and could perhaps be attributed to gravitational lensing.

The *Fermi-LAT collaboration* has claimed the discovery of a gravitationally induced delay on another known gravitational lens object, the B0218+357 FRSQ (Ref. [6]). The high energy time delay ($\sim$ 11 days) was measured to be slightly longer than, but compatible with the radio time delay. The lensed AGN, located at z=0.94, was also detected and studied with the MAGIC Imaging Atmospheric Cherenkov Telescope (IACT) (see Ref. [7]). MAGIC was able to detected a delayed flare 11 days after an alert sent by the *Fermi-LAT collaboration*. H.E.S.S. observations of PKS1830-211 were triggered by an alert posted by the *Fermi-LAT* team on August 2, 2014 (Ref. [9]). The flare seen by the *Fermi-LAT* instrument started on July 27 and lasted $\sim$ 3 days.

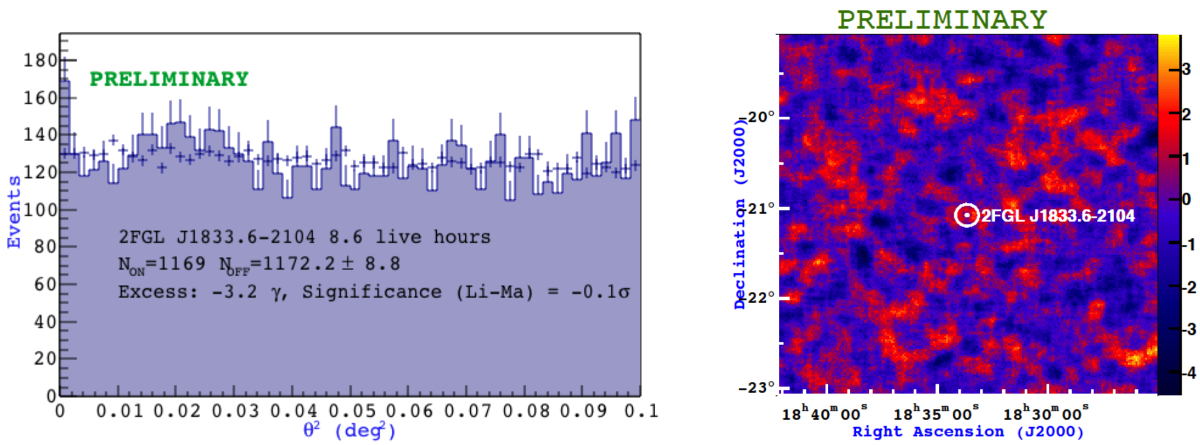

Figure 1: Left: θ^2 plot of PKS 1830-211. The background is estimated with the ring background method and the significance of the excess is computed with the formula of Li and Ma [8]. Right: H.E.S.S. significance map of PKS 1830-211. The background is substracted by the ring background method.

2. H.E.S.S. observations

PKS 1830-211 has been observed by the H.E.S.S. IACT array between August 12 2014 and August 26 2014, to allow for the detection of delayed flares with time delays between 20 and 27 days. The data were taken with the large 28-meter diameter telescope, installed in 2012. This paper is based on a preliminary analysis on a sub-sample of 8.6 hours of high quality data. The data were analyzed with the Model analysis (Ref. [12]) and cross-checked with the ImPACT analysis (Ref. [13]), the two methods giving compatible results.

A point source was searched for by stacking all the data towards PKS 1830-211. Fig. 1 shows the θ^2 distribution of the photons, where θ is the angular distance from the target position. The background from mis-identified hadrons was calculed with several methods, giving identical results. The significance of the photon excess was calculated by Li and Ma formula [8]. No significative excess over background was seen towards PKS 1830-211.

Because of the very soft spectrum measured by *Fermi LAT* in the low state, PKS 1830-211 might be observable by H.E.S.S. only during flares. The delayed flare would last only about 3 days, however, its date is not accurately predicted and it could have happened at any time between August 17 = MJD 56886 (time delay of 20 days) and August 24 = MJD 56893 (radio time delay of 27 days). The left side of Fig. 2 shows that no important daily photon excess was detected in the observation period. The significance of the photon signal versus date is shown on the right side of Fig. 2. Again, no significant daily increase of the photon flux is seen over the whole observation period.

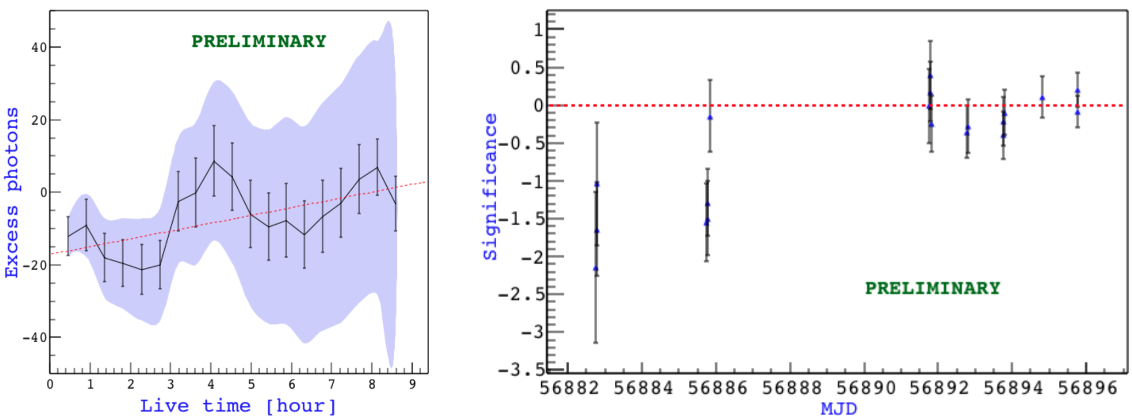

Figure 2: Left: Excess signal in the PKS 1830-211 region vs. livetime for H.E.S.S. August 2014 observations. Right: Significance of the H.E.S.S. signal versus date. The significance is computed according to the recipe of Li and Ma. The delayed Fermi flare would be expected around MJD 56886 if the time delay between flares was 20 days.

3. Flux upper limits and comparison to the *Fermi-LAT* spectra

The null result of the H.E.S.S. observations translates into 99% C.L. upper limits on the average very-high-energy flux of PKS 1830-211 during H.E.S.S. observations. These upper limits

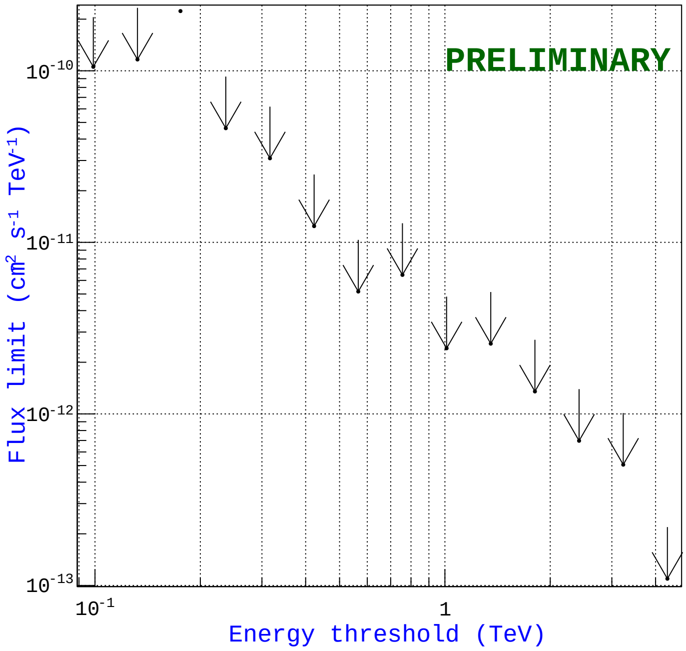

Figure 3: 99% CL upper limits (arrows) on the PKS 1830-211 flux between 100 GeV and 5 Tev for the August 2014 H.E.S.S. observations. A constant spectral index of 3, close to the spectral index of *Fermi-LAT* data during the observation period, was assumed.

are shown by arrows on Fig. 3. THE H.E.S.S. upper limits have been compared to the *Fermi-LAT* spectra. The *Fermi-LAT* observations have been analyzed with Fermi Science Tools v10-r0p5 and Pass8 data, in the framework of Enrico (Ref. [10]). The spectral data from 26-30 July 2014 (flare) are well described by a powerlaw spectrum with an index of $n_{flare} = -2.36 \pm 0.17$ for photon energies > 1 GeV. The flare spectrum is much harder than the spectrum measured in the low state of PKS 1830-211, but n_{flare} is compatible with the spectral indices of previous flare spectra, as measured by *Fermi-LAT* (Ref. [5]). The flare spectrum is shown by the green curve on Fig 4. The spectrum of PKS 1830-211 obtained from the *Fermi-LAT* observations of the HESS dataset time interval, is well described by a powerlaw with an index of $n_{low} = -2.97 \pm 0.44$ above 1 GeV. The value of n_{low} is slightly larger (at the 2σ level) than the value published in the 1FHL catalogue, which is presumably more affected by attenuation by extragalactic background light (EBL).

H.E.S.S. preliminary upper limits are compared to *Fermi-LAT* GeV spectra on Fig 4. H.E.S.S. upper limits are above the low-state spectrum, as anticipated, but below the extrapolation of the *Fermi-LAT* flare spectrum. A proper comparison has to take into account the effect of the absorption of the flux of PKS 1830-211 by the EBL. Barnacka, Bötcher and Sushch (Ref. [11]) have argued that gravitational lensing could help gamma rays from a distant source avoiding absorption. Fig. 4 shows that H.E.S.S. has clearly the potential to test this claim on future PKS 1830-211 bursts.

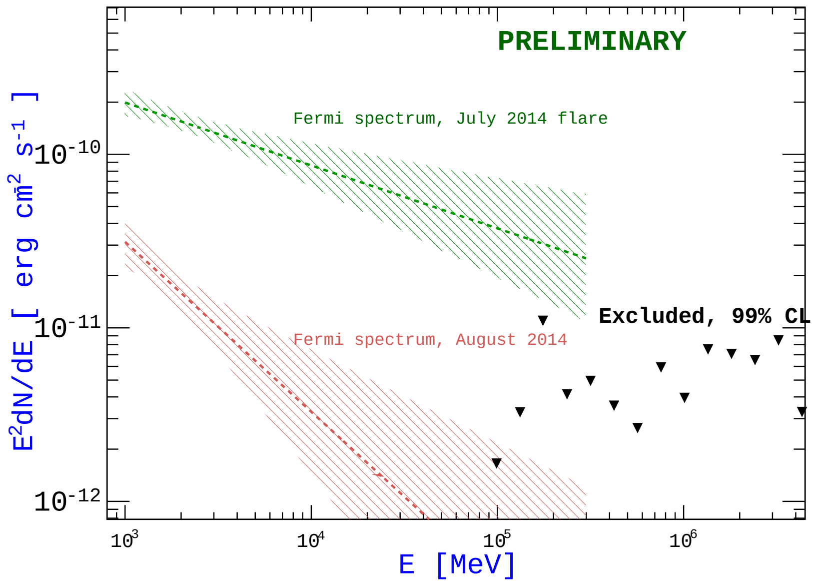

Figure 4: Comparison of H.E.S.S. flux 99%CL upper limits (inverted triangles, excluded region on the top) to the measured spectra in the GeV region obtained with the *Fermi-LAT* data. The brown curve is the GeV spectrum of PKS 1830-211 during H.E.S.S. observations. The green curve is the corresponding spectrum during the July 2014 flare. The comparison does not take into account the effect of attenuation by EBL.

Acknowledgments

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