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Searching for >177 TeV Gamma Rays in the Vicinity of Mrk 501 with HAWC

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HAWC has recently developed 2 new analysis techniques that reconstructs the energy of each gamma-ray event. With this new analysis HAWC has detected several Galactic sources with emission above 100 TeV. Additionally the HAWC Collaboration has developed new event reconstruction algorithms called "Pass 5". Using the energy estimators and Pass 5 we search for >177 TeV emission in the vicinity of Mrk 501. High-energy emission from Mrk 501 could, for example, be evidence of Axion Like Particles, a theoretical dark matter candidate. We find a hint of a high-energy lobe within 0.5° of Mrk 501 using both energy estimators.

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PoS(ICRC2021)873

The High Altitude Water Cherenkov (HAWC) Observatory is a gamma-ray survey instrument that observes $\frac{2}{3}$ of the sky every day. The main array consists of 300 tanks of water equipped with 4 photomultiplier tubes (PMTs). When a gamma ray enters the atmosphere is creates an extensive air shower of lower energy relativistic particles that enter the tanks and produce Cherenkov radiation that is observed by the PMTs. Which PMTs were hit, the amount of charge deposited, and when each PMT was hit is used to reconstruct the direction and energy of the initial gamma ray. More information on the HAWC Observatory can be found in Ref. [2].

HAWC is more sensitive than Intensive Airshower Cherenkov Telescopes (IACT, e.g. VERITAS) above about 20 TeV. Previous HAWC analyses only binned in the fraction of PMTs hit per shower, which limited the dynamic range of the energy estimation causing the median energy in the highest energy bin to > 30TeV. Recently event-by-event energy reconstructors have been developed. Now the highest energy HAWC energy bin is 177 TeV to 316 TeV, significantly extended HAWC's energy reach. Two independent energy reconstruction algorithms were produced: one that measure the shower lateral energy distribution (Ground Parameter, GP) and the other using a Neural Network (NN). More on these algorithms can be found in Ref. [1].

With these new energy estimators the HAWC Collaboration has detected >100 TeV emission from 3 sources [4]. This analysis used 1038.8 days of data reconstructions with the "Pass 4" algorithms. Recently the HAWC Collaboration has developed an improved data reconstruction suite called "Pass 5". Pass 5 improves all aspects of HAWC analysis and increases the sensitivity at high energies by a factor of 4.

While the entire HAWC dataset is still being processed with Pass 5, a preliminary high-energy dataset is available. We use this dataset to search for >177 TeV photons in the vicinity of Mrk 501. Mrk 501 is an Active Galactic Nuclei (AGN) observed by HAWC [3]. A spectral cutoff at 20 TeV is observed as expected given attenuation of gamma rays by the Extragalactic Background Light (EBL).

However, exotic models like the existence of Axion Like Particles are expected to produce high-energy gamma rays above the EBL cutoff [6]. For this reason we searched for gamma rays >177 TeV using the preliminary Pass 5 high-energy dataset. We search using both the GP and NN energy reconstruction algorithms. We find a hot spot about 0.5° from Mrk 501 in both datasets. A 3.31σ excess in the GP dataset and a 2.35σ excess in the NN dataset.

While the hotspot is not coincident with Mrk 501, there is a known spatial location systematic uncertainty of up to 0.5° [7] depending on the zenith angle of the event [7]. The HAWC Collaboration is currently working on algorithms to correct this systematic. Therefore, this excess may be associated with Mrk 501. Future studies of this systematic will elucidate this.

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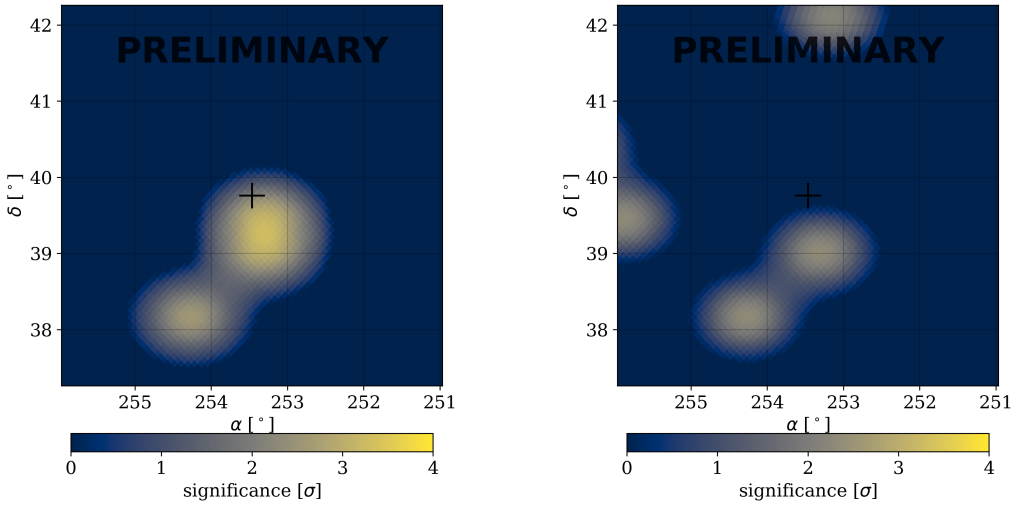

Figure 1: Gamma-ray significance maps for >177 TeV using preliminary Pass 5 data in the vicinity of Mrk 501 (black cross) using the Ground Parameter (left) and Neural Network (right) energy reconstruction algorithms.

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PoS(ICRC2021)873