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Carpet-2 search for PeV gamma rays associated with IceCube high-energy neutrino events

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Carpet-2 is an air-shower array at Baksan Valley, Russia, equipped with a large-area ($175\,\mathrm{m}^2$) muon detector, which makes it possible to separate primary photons from hadrons. We report the first results of the search for primary photons with energies $E_\gamma > 1\,\mathrm{PeV}$, directionally associated with IceCube high-energy neutrino events, in the data obtained in 3080 days of *Carpet-2* live time.

The origin of high-energy ($E \gtrsim 100\,\mathrm{TeV}$) astrophysical neutrinos detected in recent years by the IceCube experiment remains one of the most intriguing problems in modern astroparticle physics. The arrival directions of these neutrinos do not demonstrate any significant excess towards the Galactic disk, as it would happen for most models of Galactic sources, while serious tensions with Fermi-LAT observations of the diffuse gamma-ray flux are present for extragalactic source models.

In most astrophysical scenarios, energetic neutrinos are produced in decays of charged pions and are accompanied by gamma rays of the same energy from decays of neutral pions. Energetic gamma rays produce electron-positron pairs when propagating through the background radiation. The mean free path of gamma rays with energies $E_\gamma \sim (0.1{-}10)\,\mathrm{PeV}$, similar to those of IceCube neutrinos, is of order of the size of a galaxy, and therefore they become an important diagnostic tool for the origin of neutrinos: accompanying photons from Galactic sources arrive to the observer without a significant attenuation, while those from beyond the Galaxy lose their energy in the pair-production processes; their energy is transferred to the band observed by Fermi LAT through electromagnetic cascades.

We performed a search for photon-like events from the directions coincident with the arrival directions of IceCube events. We did not find any statistically significant excess of such events over the isitropic background. For 34 published IceCube events in the field of view of the installation and having the uncertainty in the arrival direction not worse than 3°, the stacked flux of photons with energies $E_\gamma \geq 1\,\mathrm{PeV}$ from these directions is bounded from above by $1.06 \times 10^{-14}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ at the confidence level of 95 % (assuming the steady flux). In addition, the neutrino event of December 10, 2016, happened in the field of view of the operating installation, which allowed to constrain the fluence of the hypothetical burst event in $E_\gamma \geq 1\,\mathrm{PeV}$ photons by $< 5.4 \times 10^{-5}\,\mathrm{PeV/cm}^2$ (95 % CL).

The *Carpet-3* installation with a $410\,\mathrm{m}^2$ muon detector and additional surface stations, to be commissioned in 2019, will have a much better gamma-ray sensitivity and a lower energy threshold, $\sim 100\,\mathrm{TeV}$.

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