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Search for neutrino and photon primary particles in the EeV energy range with the Pierre Auger Observatory

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Summary. — The Pierre Auger Observatory is the world's largest cosmic-ray observatory. Updated results on the search for ultra-high energy photons and neutrinos in the EeV (1 EeV= 10^{18} eV) energy range are presented. Ultra-high energy photons can be produced either in the interactions with the cosmic microwave background or by the decay of hypothetical super-massive particles. Ultra-high energy neutrinos may arise from astrophysical sources due to hadronic interactions in the surrounding matter. The reached sensitivity is shown to be better (for photons) or comparable (for neutrinos) to other detectors.

1. – Introduction

Ultra-high energy (UHE) neutrinos and photons are probes to explore the origin of cosmic rays at the highest energy. Nuclei produced in astrophysical sources and interacting with the extra-galactic background during their propagation are expected to generate fluxes of neutrinos and photons. Thus, the search for these particles can pose constraints on the origin and propagation of the ultra-high energy cosmic rays. We report here the current upper limits on the diffuse fluxes of neutrinos [1] and photons [2] as obtained at the Pierre Auger Observatory. The Observatory combines a surface detector (SD), composed of a grid of water-Cherenkov stations, with a fluorescence detector (FD). The SD covers an area of $\sim$3000 km^2 and it samples secondary shower particles at the ground level, while the FD measures the longitudinal development of a shower [3] propagating through the atmospehere. The FD can measure only during nights with a low moon fraction and good atmospheric conditions, yielding a duty cycle of about 15%. The SD instead has a duty cycle of 100%.

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2. – Search method and results

UHE neutrinos and photons, with energies above 1 EeV and 10 EeV, respectively, can be detected with SD. Instead, the search for photons with energy below 10 EeV is performed using the hybrid operation mode (the FD in combination with SD). Both FD and SD observables are identified using simulations of air showers, on the basis of the expected physical differences between signal and background.

Showers initiated by neutrinos can be identified by selecting signals with a large electromagnetic (e.m.) component in the events with zenith angle larger than 60°. This signature is almost background-free since, for inclined events, the electromagnetic particles in showers initiated by UHE nuclei and photons are almost completely absorbed by the atmosphere. The key observable sensitive to the electromagnetic component is the ratio of the signal trace integral over its peak value, AoP (AoP is large for events with dominant electromagnetic component) [4].

Shower initiated by photons are characterized by a lower content of muons and a larger atmospheric depth at the shower maximum, $X_{\max}$. The measurement at energies above 10 EeV, presented in [5], is performed for showers within the zenith angle range $30° < \theta < 60°$ using two estimators: the deviation of the measured signals from the average lateral distribution function derived from the Auger SD-data and the signal risetime (defined as the time difference between the 50% and 10% quantiles of the signal trace). These parameters are sensitive both to the composition of the shower (a larger e.m. component implies an increase of the risetime) and to $X_{\max}$. At energies below 10 EeV the number of SD stations in an event is too small to have a significant separation between signal and background. The increase in the event statistics allows us to use the FD precision measurements. The separation is performed with a multivariate analysis [6] using events with zenith angle $\theta < 60°$.

In fig. 1, the current upper limits on the diffuse flux of neutrinos are shown on the left [1] while upper limits on the diffuse flux of photons for the SD-based ($E > 10$ EeV) and hybrid-based ($E < 10$ EeV) analyses are shown on the right [2]. The reached sensitivity, profiting from about 15 years of accumulated data, makes these results an unprecedented record in the field and provides stringent upper limits to astrophysical and dark matter scenarios.

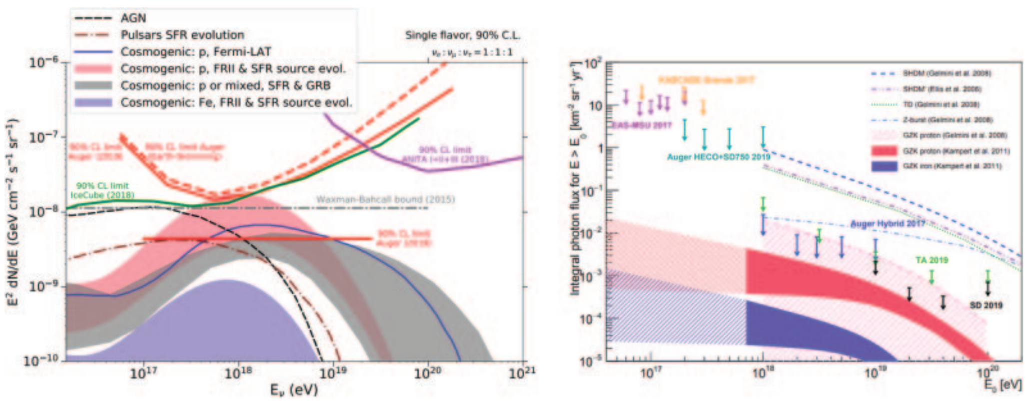

Fig. 1. – Current upper limits on the diffuse fluxes of neutrinos (left) [1] and photons (right) [2].

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