

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

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received 8 June 2020

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 ($1 \text{ EeV} = 10^{18} \text{ eV}$) 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 $\sim 3000 \text{ km}^2$ and it samples secondary shower particles at the ground level, while the FD measures the longitudinal development of a shower [3] propagating through the atmosphere. 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 $30^\circ < \theta < 60^\circ$ 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 $\theta < 60^\circ$.

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.

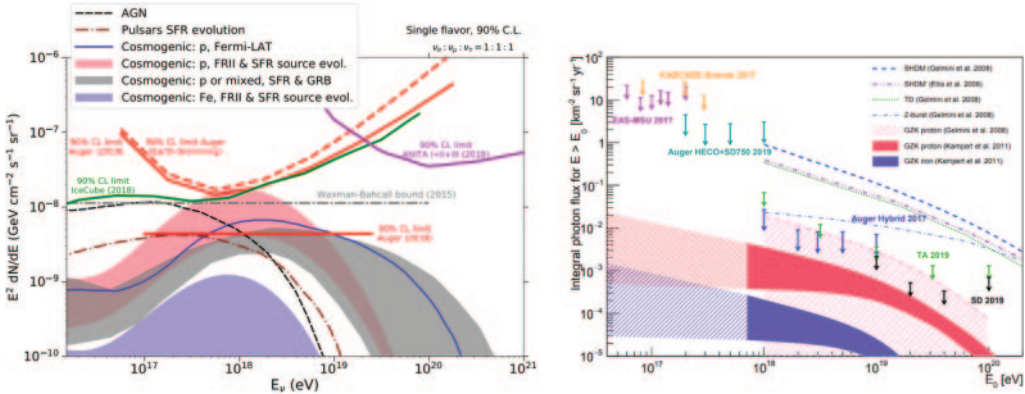


Fig. 1. – Current upper limits on the diffuse fluxes of neutrinos (left) [1] and photons (right) [2].

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Acknowledgments

The successful installation, commissioning, and operation of the Pierre Auger Observatory would not have been possible without the strong commitment and effort from the technical and administrative staff in Malargüe. We are very grateful to the following agencies and organizations for financial support:

Argentina – Comisión Nacional de Energía Atómica; Agencia Nacional de Promoción Científica y Tecnológica (ANPCyT); Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET); Gobierno de la Provincia de Mendoza; Municipalidad de Malargüe; NDM Holdings and Valle Las Leñas; in gratitude for their continuing cooperation over land access; Australia – the Australian Research Council; Brazil – Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq); Financiadora de Estudos e Projetos (FINEP); Fundação de Amparo à Pesquisa do Estado de Rio de Janeiro (FAPERJ); São Paulo Research Foundation (FAPESP) Grants No. 2010/07359-6 and No. 1999/05404-3; Ministério da Ciência, Tecnologia, Inovações e Comunicações (MCTIC); Czech Republic – Grant No. MSMT CR LTT18004,

LO1305, LM2015038 and CZ.02.1.01/0.0/0.0/16_013/0001402; France – Centre de Calcul IN2P3/CNRS; Centre National de la Recherche Scientifique (CNRS); Conseil Régional Ile-de-France; Département Physique Nucléaire et Corpusculaire (PNC-IN2P3/CNRS); Département Sciences de l'Univers (SDU-INSU/CNRS); Institut Lagrange de Paris (ILP) Grant No. LABEX ANR-10-LABX-63 within the Investissements d'Avenir Programme Grant No. ANR-11-IDEX-0004-02; Germany – Bundesministerium für Bildung und Forschung (BMBF); Deutsche Forschungsgemeinschaft (DFG); Finanzministerium Baden-Württemberg; Helmholtz Alliance for Astroparticle Physics (HAP); Helmholtz-Gemeinschaft Deutscher Forschungszentren (HGF); Ministerium für Innovation, Wissenschaft und Forschung des Landes Nordrhein-Westfalen; Ministerium für Wissenschaft, Forschung und Kunst des Landes Baden-Württemberg; Italy – Istituto Nazionale di Fisica Nucleare (INFN); Istituto Nazionale di Astrofisica (INAF); Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR); CETEMPS Center of Excellence; Ministero degli Affari Esteri (MAE); México – Consejo Nacional de Ciencia y Tecnología (CONACYT) No. 167733; Universidad Nacional Autónoma de México (UNAM); PAPIIT DGAPA-UNAM; The Netherlands – Ministry of Education, Culture and Science; Netherlands Organisation for Scientific Research (NWO); Dutch national e-infrastructure with the support of SURF Cooperative; Poland -Ministry of Science and Higher Education, grant No. DIR/WK/2018/11; National Science Centre, Grants No. 2013/08/M/ST9/00322, No. 2016/23/B/ST9/01635 and No. HARMONIA 5–2013/10/M/ST9/00062, UMO-2016/22/M/ST9/00198; Portugal – Portuguese national funds and FEDER funds within Programa Operacional Factores de Competitividade through Fundação para a Ciência e a Tecnologia (COMPETE); Romania – Romanian Ministry of Research and Innovation CNCS/CCCDI-UESFISCDI, projects PN-III-P1-1.2-PCCDI-2017-0839/19PCCDI/2018 and PN18090102 within PNCDI III; Slovenia – Slovenian Research Agency, grants P1-0031, P1-0385, I0-0033, N1-0111; Spain – Ministerio de Economía, Industria y Competitividad (FPA2017-85114-P and FPA2017-85197-P), Xunta de Galicia (ED431C 2017/07), Junta de Andalucía (SOMM17/6104/UGR), Feder Funds, RENATA Red Nacional Temática de Astropartículas (FPA2015-68783-REDT) and María de Maeztu Unit of Excellence (MDM-2016-0692); USA – Department of Energy, Contracts No. DE-AC02-07CH11359, No. DE-FR02-04ER41300, No. DE-FG02-99ER41107 and No. DE-SC0011689; National Science Foundation, Grant No. 0450696; The Grainger Foundation; Marie Curie-IRSES/EPLANET; European Particle Physics Latin American Network; and UNESCO.

Last modified on 2019-04-02.