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MAGIC telescopes for the study of the electronic cosmic flux

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Summary. — The IACT technique (Imaging Atmospheric Cherenkov Telescopes) allowed recent Cherenkov telescopes to obtain several relevant measurements in the field of Gamma Astronomy. The main field of investigation is the cosmic photon radiation of energy between 50 GeV and few tens of TeV. Furthermore, with a dedicated analysis, IACTs may also be used to measure the electronic component of cosmic rays. Such particles, with energies of several hundreds of GeV, have a rather short lifetime, of the order of 10^5 years. The spectral structure of this radiation yields therefore information on the nearby sources, within the distance of 1 kpc, giving also cosmological and fundamental physics implications. MAGIC experiment can give a contribute in the measurement of two different components: the total flux of cosmic electrons and positrons ($e^+ + e^-$) and the ratio between positrons and electrons (e^+/e^-), as here presented.

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PACS 95.55.Ka – Gamma-ray telescopes.
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1. – Scientific case

Within the wide scenario related with the physics of cosmic rays, the origin and the nature of its electronic component is still to be well understood. There have been, to date, two kinds of measurement s: the total flux of electrons and positrons $e^+ + e^-$ [1-3], and the measurement of the ratio e^+/e^- [4]. But the results are not fully in agreement with the most commonly assumed descriptions [5]. To interpret these anomalies, there exist different models, invoking the presence of dark matter or nearby Pulsar sources (1–2 kpc).

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Measures in this direction, might then give an estimation of the relative abundance of these possible objects. MAGIC may carry out both of these two types of measurements helping both to discriminate between the discrepancies in the measurements of the total electronic flux, and to clarify the trend of the ratio e^+/e^-, extending this measure to a wider energy range, from 100 GeV up to 1–2 TeV.

2. – MAGIC and the $e^+ + e^-$ and e^+/e^- measurement techniques

MAGIC is a ground-based detector situated in Canary Islands (Spain) consisting of two telescopes with a reflective surface of parabolic shape that may collect and reveal a portion of the Cherenkov radiation produced by atmospheric showers. These showers are originated from high-energy incoming cosmic rays hitting the atmosphere. In case of a gamma cosmic ray, it is possible to reconstruct the direction of the extraterrestrial source originating it. In fact, the morphological distribution of the Cherenkov light collected into the telescope camera (pixelized by around 1000 photomultipliers) carries information on the nature, the direction and the energy of the primary particle. The study of this distribution on the camera represents the basis of the IACT technique and allows to discriminate between a shower of electromagnetic origin (*i.e.* produced by a gamma ray) and a shower of hadronic origin. This is crucial, since hadronic showers represent the main source of background for Gamma Astronomy by IACTs and only through this extremely powerful rejection method it is possible to isolate and identify the gamma signals. In the case here discussed, some changes in the analysis method must be applied, in order to recognize electrons instead of gammas. This is feasible [3,6] essentially thanks to the similarity between the gamma- and electron-induced atmospheric showers. The morphology of electron-induced atmospheric showers is identical to that of gamma-originated events. The difference is given by the fact that electrons are isotropically distributed, due to their interaction with the galactic magnetic field. This must be taken into account by discriminating electrons and hadrons only through the shape of the images collected and not by their orientation. Moreover, there is the need to produce a dedicated Monte Carlo dataset of hadronic showers only (besides the usual purely electromagnetic ones) in order to compare it with the real data (containing both hadrons and electrons). Thus, by a proper subtraction, it is possible to estimate the electronic excess. The analysis of data collected so far shows a signal for the *total flux* of around 12σ [6], with ~ 4700 excesses between 150 GeV and 2 TeV.

Concerning instead the study of the *ratio* e^+/e^-, MAGIC can make a measurement looking at a deficit in the flux, which is created by the presence of the Moon in the sky [7], which shields a portion of the incoming cosmic rays. This deficit is localized depending on the energy and the charge sign of the cosmic particles, because of the presence of the terrestrial magnetic field. Since for the involved energies the distance of the moon shadow from the moon itself is smaller than the camera field of view of 3.5°, the most serious problem is the incidence of a very high moonlight noise. But MAGIC has been built with low gain photomultipliers (6 dynodes only). So, by reducing furthermore their voltages and considering the smallest moon phases, it is possible to observe the moon shadow for 40 hours per year. The expected deficit in the electron flux is estimated to be approximately 3–5% of the Crab Nebula (the standard candle in gamma astronomy), with an extension of the shadow of $0.5° \times 1°$ (one pixel is 0.1° wide) [8]. Recently, after the first tests, it has been demonstrated the feasibility of this observation and the estimated required time resulted being around 50 hours. In case of success for the moon shadow observation with MAGIC, this would also open a new field in the study of cosmic rays: in a near future (CTA experiment) the antimatter/matter ratio in cosmic ray flux could be measured by ground-based experiments for electrons and also for other components, like protons.

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