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The CALorimetric Electron Telescope (CALET) space experiment for the direct measurement of high energy electrons in cosmic rays

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Summary. — The CALorimetric Electron Telescope (CALET) is a Japanese-led international space mission by JAXA (Japanese Aerospace Exploration Agency) in Collaboration with the Italian Space Agency (ASI) and NASA. The apparatus was launched to the International Space Station on 19 August 2015. Its main objective is to explore the region above 1 TeV with precise direct measurements of the electron+positron and nuclei spectra. The instrument consists of a charge detection device composed of two layers of plastic scintillators, a finely-segmented sampling calorimeter with scintillating fibers (3 radiation lengths) and a homogeneous calorimeter made of PWO scintillating bars (27 radiation lengths). In parallel with the calorimeter another instrument, the CALET Gamma-ray Burst Monitor (CGBM), operates as a gamma-ray burst monitor using two different kinds of scintillators to detect photons from 7 keV to 20 MeV. In this work a brief review of the electron analysis will be discussed focusing on the electron/proton discrimination power estimated with different Monte Carlo simulations. Some published results about calibration and search for electromagnetic counterparts of the LIGO GW 151226 gravitational wave event will be presented too.

1. – The CALorimetric Electron Telescope experiment

The CALorimetric Electron Telescope (CALET) is a calorimetric space experiment for the direct cosmic ray (CR) measurement. The apparatus was launched and installed on the Japanese Experiment Module - Exposed Facility (JEM-EF) of the International Space Station (ISS) in August 2015. The main objectives of the mission are the measurement of the CR electron+positron (hereafter "electron") and nuclei spectra up to 20 TeV and hundreds of TeV per nucleon, respectively, the precise measurement of high energy gammas and the detection of Gamma Ray Burst (GRB) signals. These measurements are

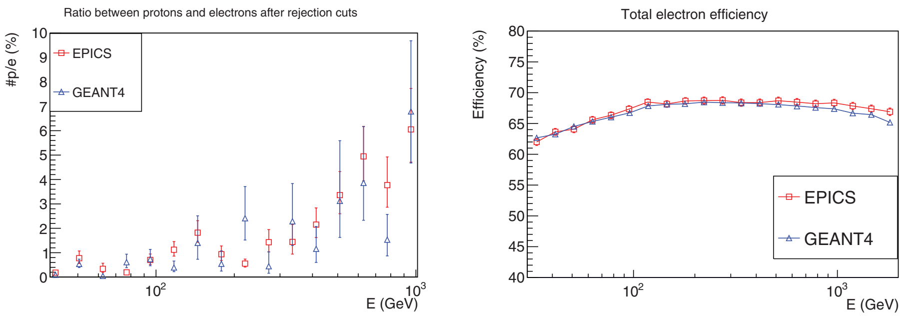

Fig. 1. – Expected performance of the electron identification analysis using Monte Carlo simulation based on EPICS (red squares) and GEANT4 (blue triangles) packages. Left: proton contamination in electron sample. Right: total efficiency for the electron measurement.

crucial to address important questions regarding the CR acceleration and propagation in our galaxy.

The CALET detector is composed by a large acceptance calorimeter for the high energy particle measurement and the Calet Gamma-ray Burst Monitor (CGBM) for the low energy gammas and X-rays observation. The CALET calorimeter consists of three main detectors: a *"Total AbSorption Calorimeter"* (TASC) composed of PWO bars with a good energy resolution for electrons thanks to its thickness of about 27 X_0; an *"IMaging Calorimeter"* (IMC) with 8 layers of scintillating optical fibers oriented in X and Y directions and readout individually, interleaved with thin tungsten sheets for a total thickness of 3 X_0; a *"CHarge Detector"* (CHD) composed by two layers of segmented plastic scintillators. In order to achieve a high dynamic range the TASC PWO bars are read-out by an APD and a PD, each with two different gains. The CGBM consists of 3 detectors: one *"Hard X-ray Monitor"* (HXM) composed by a LaBr3(Ce) scintillator for the detection of X-rays from 7 keV to 1 MeV, and two *"Soft Gamma-ray Monitor"* (SGM) BGO scintillator optimized for low-energy gamma measurement from 100 keV to 20 MeV.

2. – Detector calibration

Since the first days of October 2015 CALET is in science operation mode for a first initial period of 2 years with a target duration of 5 year. During the first months of data acquisition the CALET Collaboration focused on the detector calibration: the TASC energy calibration is described in more detail in [1]. The first step of the calibration is the determination of the conversion factor between ADC output and energy deposit with the identification of the MIP energy deposit of protons and helium nuclei with no interaction in the calorimeter taking into account the signal dependence on both the temperature and the position on the PWO bar. A further step is the linearity measurement in each gain range: the response of each channel was determined on-ground by using a UV pulse laser. The final step is the correlation measurement between adjacent gain ranges for each channel using the energy deposited by high energy showers during the flight.

3. – Electron identification

The main background for the electron measurement are protons since their abundance is 100–1000 times larger than electrons. In CALET the e/p discrimination is mainly based on the development of the shower in the TASC [2] while the particle direction is identified with the IMC. A discriminant variable related to the longitudinal shower development is the fractional energy deposited in the last TASC layer (F_E) while the variable used in order to take into account the lateral shower profile is the energy weighted spread (R_E)

$$R_E = \sqrt{\frac{\sum_i R_i^2 \times \sum_j \Delta E_{ij}}{\sum_i \sum_j \Delta E_{ij}}},$$

where ΔE_{ij} is the energy deposited in the j-th PWO crystal in the i-th layer and the R_i for the i-th layer is given by

$$R_i = \sqrt{\frac{\sum_j (\Delta E_{ij} \times (x_{ij} - x_{ic})^2)}{\sum_j \Delta E_{ij}}},$$

where x_{ic} is the coordinate of the intercept of the incident particle direction with the i-th layer, and x_{ij} is the coordinate of the center of the j-th PWO crystal in the i-th layer. The variables F_E and R_E are plotted in a two-dimensional plane and a linear cut is applied. Figure 1 shows a comparison of the expected proton contamination in the electron sample after this cut with respect to the total efficiency of the measurement, calculated with two Monte Carlo simulations based on EPICS (red squares) and GEANT4 (blue triangles). The proton contamination is $\sim 6\%$ at 1 TeV and the efficiency is about 65%. There is an overall agreement between the two different Monte Carlo simulations, with some small discrepancies, which will translate in a difference in the electron flux measurement of a few percent level at 1 TeV. An improvement of the proton rejection power is expected by adding to the analysis other variables related to the development of the shower in the IMC and using a Multi Variate Analysis approach.

4. – Upper limits on electromagnetic counterparts of GW 151226

The GW 151226 is the second gravitational wave detected by the LIGO experiment. During this event CALET was configured to observe X-ray and gamma counterparts using both the CGBM and the calorimeter, as described in [3]. No GRB events associated with GW 151226 have been detected with a 7 σ upper limit of $1.0 \cdot 10^{-6}$ erg cm^{-2} s^{-1} with the HXM and $1.8 \cdot 10^{-6}$ erg cm^{-2} s^{-1} with the SGM for one second exposure. In the time interval of about 700 seconds around the LIGO trigger no gamma candidate event was found in the calorimeter and a 90% upper limit of $2 \cdot 10^{-7}$ erg cm^{-2} s^{-1} in the 1–100 GeV range was established.

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