HESS-II expected performance in the tens of GeV

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***Abstract*. By the end of 2009 the four-telescopes-HESS-system will be upgraded to HESS-II with a new telescope with a 600 m^2 mirror area and a very high resolution camera. HESS-II will allow to lower the energy threshold from 100 GeV to about 30 GeV and enhance the HESS sensitivity.**

Therefore AGNs at higher redshift could be detected and searches for new classes of very high energy gamma-ray emitters (pulsars, microquasars, GRB, and dark matter candidates) will also be possible.

The evaluation of the instrument performance is presented in term of sensitivity, energy and angular resolutions, based on Monte Carlo simulation, using a multivariate analysis.

***Keywords*: Event reconstruction, multivariate analysis, energy reconstruction.**

I. Introduction

By the end of 2009 a new very large telescope will be included in the present HESS-I configuration [1]. The data taking configuration will consist of the four initial telescopes (called Cherenkov Telescope 1, CT2, CT3 and CT4) added to the new telescope (CT5) [2]. Since this new telescope will open a new window in the energy range from 30 to 100 GeV, it is important to develop a powerful analysis in order to optimize the gamma-ray detection and reconstruction. The new analysis presented here, includes only the fifth telescope. The selection of the gamma-ray events as well as the hadron rejection are described. A new energy reconstruction method is also reported.

II. Energy Domains

The overall trigger system of the HESS-II configuration will operate in various modes, allowing to trigger on two classes of events :

1) Mono mode : Only the largest telescope CT5 has triggered, dedicated for the lowest energies
2) Stereo mode : As the current HESS system with additional information from the central telescope (CT5).

For the evaluation of the low energy domain performance, spectrum of gamma-ray showers have been simulated from 5 GeV to 100 TeV as well as 18 discrete energy points from 5 GeV to 12.5 TeV, at the zenith, assuming an optimal optical efficiency. Proton showers were also simulated from 30 GeV to 100 TeV, in the same conditions. The gamma-ray source is simulated on the optical axis, thus the projection of the source is located in the center of the camera; proton showers are simulated isotropically (no point source). All the simulations are carried out on a large radius of 550 m from the center of the camera and a simulated night sky background of 100 MHz has been used. In what follows the performance of the standalone CT5 telescope is presented here without considering complementary information, if any, from the other telescopes.

III. Discriminant Variables

The proton rejection is a key issue, especially at lower energy, and a multivariate analysis is proposed to this end. The usual Hillas parameters [3] are used. In addition a new variable $\Delta\phi$ is included which takes into account the background morphology as detailed below. A pre-selection is applied for the events at the edge of the camera, their image being not fully contained: nominal distance[1] $< 1°$. The raw image in the telescope is first cleaned; different cleanings of the image are available, depending on the applied threshold. A tight cleaning (5/10)[2] with a high threshold allow to reconstruct the core of the shower, a second one (1/3) with a low threshold is sensitive to the sub-structures. Assuming the shower image is an ellipse, the six Hillas parameters for the core[3] of the shower are computed. $\Delta\phi$ is the difference between the orientations of the two ellipses using the two different cleaning. Therefore $\Delta\phi$ is dependent on the hadron topology and will not change for the gamma signal while it will for hadrons. Additional checks have been performed concerning the night sky background dependence assuming different frequencies ranging from 30 to 300 MHz, as depicted in figure 1.

IV. Multivariate analysis for gamma energy reconstruction

For a stereoscopic system, the charge and the impact parameter suffice to determine the energy. It is not the case when considering only one telescope. As it is well known the Hillas variables are sensitive to the energy, the fixed energy points have been used in what follows.

[1]The nominal distance is defined as the distance between the center of the camera and the barycenter of the reconstructed shower image

[2]Cleaning 5/10 corresponds to a charge threshold of 10 photo-electron (p.e.) and 5 p.e. to one neighbour.

[3]length, width, skewness, kurtosis, total charge and nominal distance.

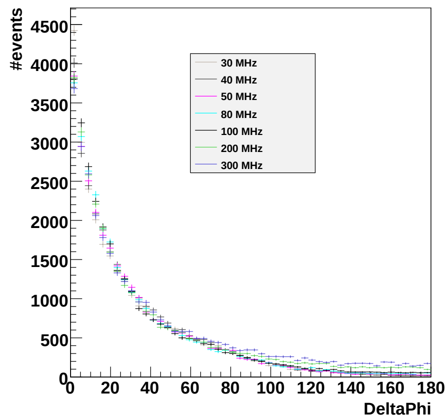

Fig. 1: Distribution of $\Delta\phi$ assuming different night sky background from 30 to 300 MHz.

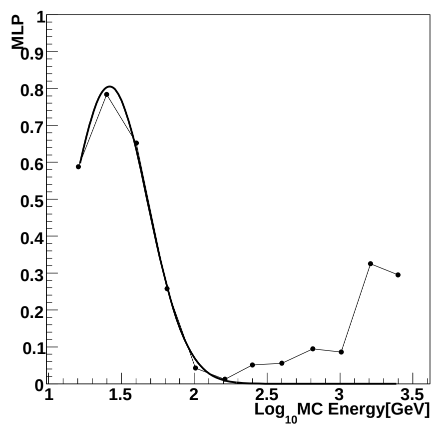

Fig. 2: The dots represent the probabilities output for the 12 energy bands. The full line is the a gaussian fit perform on data. The reconstructed energy is the peak value.

A new method is proposed to measure the energy in order to reduce the bias. The neural network approach uses the module MultiLayerPerceptron developed in the ROOT framework (TMVA) [4] in order to determine the most probable energy for each event.

1) Training step : The signal events are Monte Carlo gamma-ray in a given energy band, the other energy bands are considered as the background. For two different trainings, there is an overlap to insure the continuity of the energy reconstruction.
2) Analysis step : For each event the neural network (MLP) allows to determine the probability of each energy band (corresponding to the 12 previous trainings). The reconstructed energy is found to be the most probable value (i.e. the peak) as depicted in figure 2.

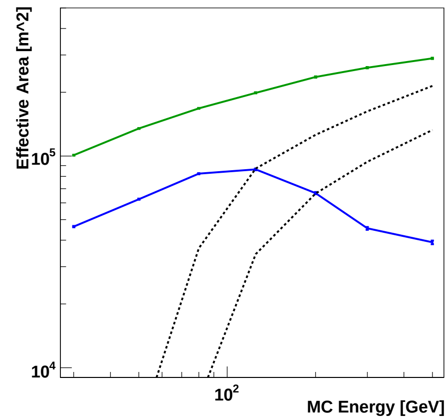

Fig. 3: CT5 standalone: acceptance after selection (continuous blue line) compared to the trigger acceptance (upper continuous green line). Superimposed: HESS-I acceptance (dashed line).

V. Hadron rejection

Thus for each event, the reconstructed energy is computed, applying the previous algorithm developed for gamma-ray events. The gamma/hadron separation is performed after using the reconstructed energy and different discriminant variables previously defined (Hillas parameters and $\Delta\phi$). A similar neural network frame is used for the selection and the hadron discrimination.

1) Training step : The signal events are Monte Carlo gamma-ray in the same energy bands, the background is the Monte Carlo proton spectrum.
2) Analysis step : The reconstructed energy is used to select the appropriate neural network. The final optimization corresponds to a global background rejection of 95%.

VI. Performance

For the events passing the selections (total background rejection of 95%), the expected energy and angular resolutions, and the effective area for CT5 standalone are estimated. The effective area after selections varies from 40,000 m^2 at 30 GeV to 80,000 m^2 at 100 GeV lowering the energy threshold to around 30 GeV, roughly one order of magnitude lower than HESS phase I (Fig. 3).

The new energy measurement method seems to be linear as depicted in figure 4. The difference between the energy simulated and reconstructed (so called bias) is flat in the [30 - 300] GeV range and lower than 5%. Thanks to the linearity, the energy resolution can now be estimated: it decreases from 40 % to 20 % for energies between 30 and 500 GeV as shown in figure 5.

The angular resolution, defined as the 68% containment radius, varies from 0.25 to 0.15 deg for 30 to 500 GeV energy range, as shown in figure 6.

VII. Conclusion

This new energy reconstruction method shows very promising results. In particular the energy measurement

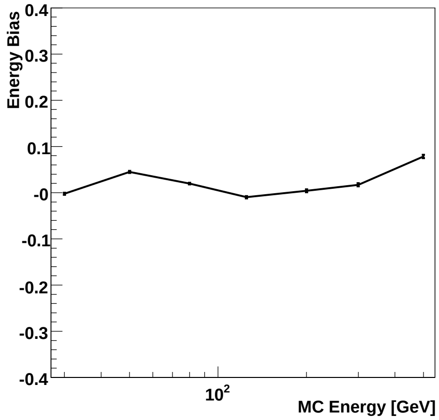

Fig. 4: CT5 standalone: Energy linearity measurement.

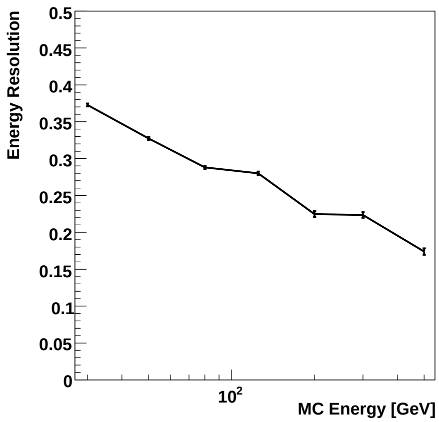

Fig. 5: CT5 standalone: Energy resolution.

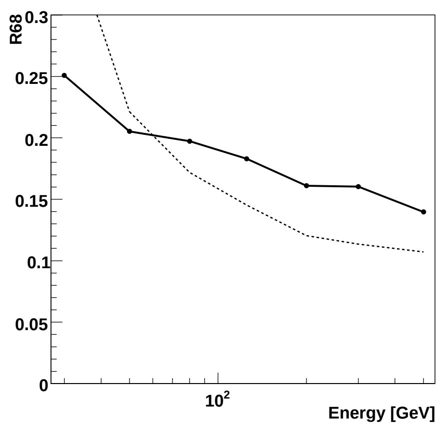

Fig. 6: CT5 standalone: Angular resolution (full line) compared to HESS-I angular resolution (dashed line).

is linear within 5% in the [30 - 300] GeV energy range. The effective area in the CT5 standalone mode after selections varies from 40,000 m^2 at 30 GeV to 80,000 m^2 at 100 GeV lowering the energy threshold to around 30 GeV. The energy resolution varies from 40 to 20% as a function of the energy. The angular resolution is also improved, better than 0.25 deg. Nevertheless, there is still some room for improvement such as exploiting the timing information, combining the data of all the telescopes or including the future HESS-II trigger.

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