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Operation, Calibration and Accuracy of the Grande array of the KASCADE-Grande experiment

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The KASCADE-Grande experiment is in continuous and stable data taking since the beginning of 2004.The Grande array, made of 37 plastic scintillators detectors (10 m^2 each) placed at a distance of 140 m from each other, has been set up to cover a surface ($\sim$0.5 km^2) big enough to study the primary cosmic rays in the 10^{16}-10^{18} eV energy range. We present the status of the Grande array and discuss the calibration procedures and the accuracies achieved in the particle density measurements. Energy deposits (in 4 cm thick scintillators) are measured from $\sim$5 MeV to $\sim 5\times10^4$ MeV, allowing us to cover the dynamic range required to study the primary cosmic rays in the range previously mentioned. A comparison of the showers parameters reconstructed by the Grande and by the KASCADE arrays is shown.

1. Introduction

The KASCADE-Grande experiment[1] has been set up to study primary cosmic rays in the energy range from 10^{16} to 10^{18} eV, its main goal is the detection of the knee of the iron component. This observation would confirm the hypothesis that explains the knee of the primary cosmic rays spectrum with astrophysical motivations, and its existence is expected by the measurements of the KASCADE[2] and EASTOP[3] experiments.

The experiment is located at the Forschungszentrum Karlsruhe, Germany, where, beside the existing KASCADE [4] array, two new detector set ups (Grande and Piccolo) have been installed. The experiment is able to sample different components of Extensive Air Showers (electromagnetic, muonic and hadronic) with high accuracy and covering a surface of 0.5 km^2.

2. The Grande array

The Grande array[5] is made by 37 stations of plastic scintillation detectors, 10 m^2 surface (divided into 16 individual scintillators) and 4 cm thick. The distance between detectors is in average 137 m and they are located in a hexagonal grid (see fig.1). All 16 scintillators are viewed by a high gain photomultiplier (for timing and low particle density measurements), the four central ones are additionally viewed by a low gain one (for high particle density).

For triggering stations are arranged in 18 clusters of hexagonal shape with six detectors surrounding a central one. The minimum trigger requirement is the coincidence of the central and three neighbouring stations in one hexagon. The trigger rate is 5 Hz, the stability of the array is shown in figure 2 where the distribution of the number of counts (in 10 minutes bins) after the correction for the pressure variations is shown. The standard deviation of the distribution is $\sim$1.1 times the standard deviation of a poissonian distribution, thus the non poissonian fluctuations are equal to 46% of the poissonian ones.

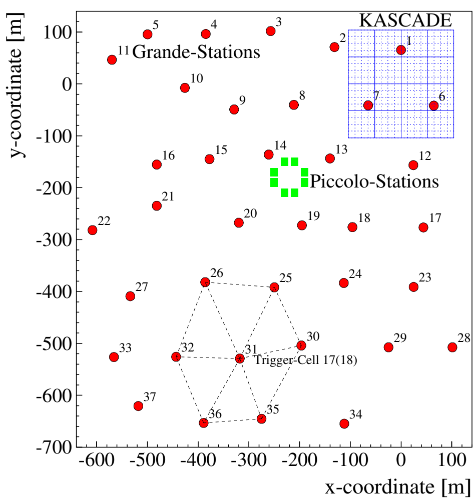

Figure 1. Layout of the KASCADE-Grande experiment

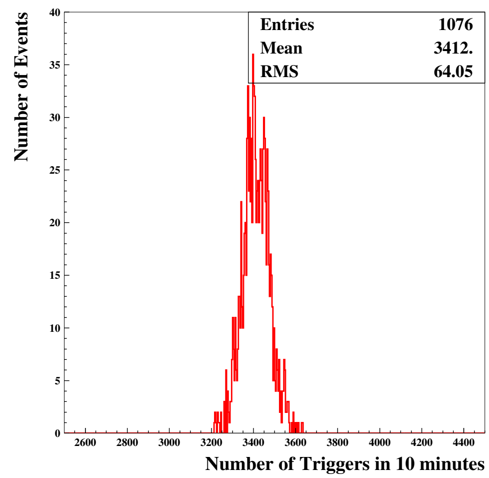

Figure 2. Distribution of the number of events, in 10 minutes bins, after the correction for the pressure coefficent.

The analog signals of the high gain photomultipliers are fed into a charge amplifier, then are shaped and reach the maximum amplitude after 8 μs, the output is split in two channels that go through a final amplification. The higher densities are measured using the low gain photomultipliers whose signals follow the same electronic chain (without being split in two signals).

To calibrate the peak sensing ADC we use a circuit that inject into the shaper-amplifiers a charge that is measured both by peak and charge sensing ADC. The charge values span over the whole peak ADC range, the curves obtained allow us to convert each peak ADC count into a charge ADC count.

The ADC value (in charge ADC scale) corresponding to the peak of the single particle spectrum is measured in each station during run time. In fact each EAS event ($\nu \sim 5$ Hz) is followed by three triggers given by a station in single mode ($\nu \sim 2000$ Hz), in this way we can measure the spectrum (15000 events) of each station every eight hours. This operation allows us to determine, for each run longer than $\sim$36 hours, the peak position with a precision of $\sim$3%. Using a simulation of single muons crossing the detectors we proof that the energy deposit corresponding to the peak of the single particle spectrum is 8.5 MeV.

Three stations of the Grande array are located (see fig.1) inside the e/γ detectors of the KASCADE experiment allowing a check of the previously described calibration method by comparing the energy deposit in a Grande station with the mean energy deposit of the four e/γ detectors that are located around it. Only events that have the core located at about 100 m distance from the Grande station are selected. In this way the KASCADE detectors, that are separated by 13 m from each other, are at a distance from the core where the lateral distribution of particles in the EAS is flat and the mean value of their energy deposit can be compared with the Grande stations one.

As the Grande and the e/γ KASCADE detectors are surrounded by different materials and as they do not have the same thickness, we expect that the energy deposits, even if they are crossed by the same number of particles, are not equal. Figure 4 shows the measured energy deposits in the two detectors (full squares) compared with those expected by a full shower (CORSIKA) and detector (CRES) simulation (open circles).

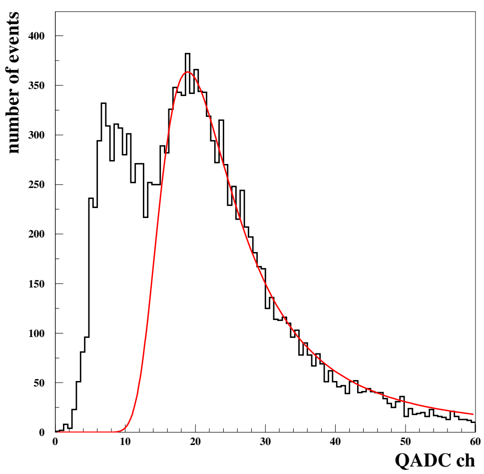

Figure 3. Single particle spectrum measured in station 5. The line shows the result of a Landau fit.

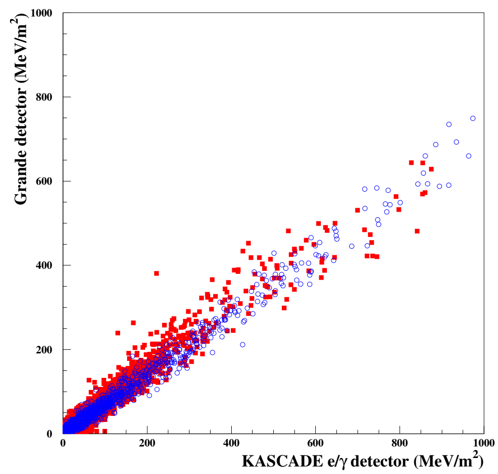

Figure 4. Comparison of the energy deposit measured (full squares) and expected from a full simulation (open circles) in the KASCADE e/γ and Grande detectors.

We also compare the shower parameters reconstructed, for the same events, by the Grande and by the KASCADE e/γ arrays separately. We select events with the core located inside both arrays and reconstructed by both of them. This is obtained requiring that: the maximum energy deposit in the Grande detectors is measured by station 7 (i.e. the center of the Grande trigger cluster located inside the KASCADE array, see fig.1); the core position, measured by KASCADE, is located inside a circle of 90 m radii centered in the middle of the array; 0.4$< s_{Grande} <$1.4 (i.e. events with a good reconstruction) and Log Ne$_{KASCADE}$ >5.6 (i.e. Grande efficiency near to one).

The distribution of the differences of the x (red solid line) and y (blue dashed line) coordinates of the core position are shown in figure 5. It can be seen that the mean value of the differences, on both coordinates, between two arrays is lower than 2 m and that the standard deviation of the distribution is about 12 m. As the errors on the core location for the KASCADE array[4] are, at these energies, ∼2 m we can say that this width is mainly due to the resolution of the Grande array that can be so evaluated being less than 12 m. Figure 6 shows the scatter plot of the shower size measured by the two arrays. This is dominated by the statistical uncertainties on the Grande reconstruction, that are (in the range 6.0< $LogNe_{KASCADE}$ <6.1) about 25%. Possible systematic uncertainties and their origin are under investigation.

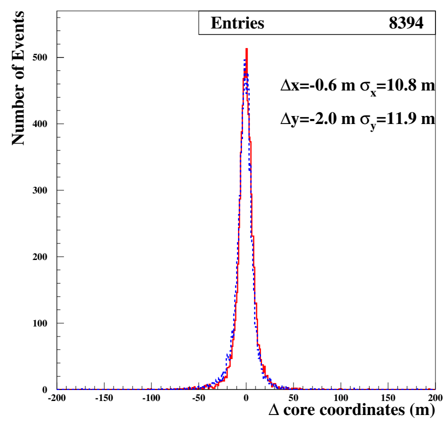

Figure 5. Distribution of the difference of the coordinates of the core position (x solid line and y dashed line) measured by the KASCADE and the Grande arrays.

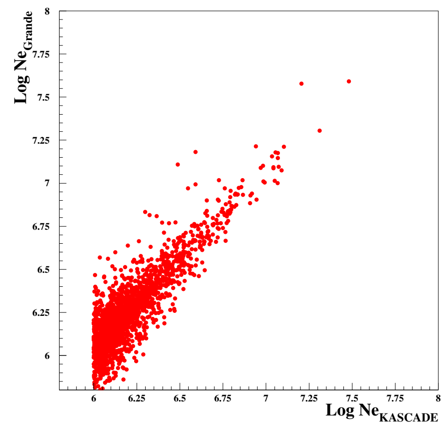

Figure 6. Scatter plot of the shower size measured by the Grande array vs the one measured by the KASCADE array

3. Conclusions

The Grande array is in continuous and stable data taking since January 2004. We have described the procedure used to calibrate the analog signals; comparing the energy deposits in the KASCADE and Grande detectors with the expectations from a complete shower simulation, we can conclude that the calibrations of the two arrays are coherent with each other. We have also reported the results of the event reconstruction obtained independently with the two arrays, showing that the resolution on the core coordinates of the Grande array is around 12 m reaching the value foreseen in the experiment proposal.

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