The KASCADE-Grande Experiment

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Abstract

A scintillator array (Grande) of large collecting area (700m x 700m) has been set up at Forschungszentrum Karlsruhe in Germany to operate jointly with the existing KASCADE multi-detector experiment. The enlarged EAS experiment provides comprehensive observations of cosmic rays in the primary energy range of 0.1 PeV to 1 EeV, i.e. a full coverage of the primary energy region around the knee. Status and capabilities of the KASCADE-Grande experiment are presented.

1. Introduction

The major goal of KASCADE-Grande is the observation of the 'iron-knee' in the cosmic-ray spectrum at around 100 PeV (Fig. 1), which is expected following recent KASCADE observations where the positions of the knees of individual mass groups suggest a rigidity dependence (Roth, Ulrich et al. [8]). The reconstruction of the energy spectra of various mass groups over the large energy range accessible with KASCADE-Grande will provide a comprehensive picture of the physics around the knee. Additionally, the validity of hadronic interaction mod-

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els used in CORSIKA Monte Carlo simulations of ultra-high energy air showers will be tested with KASCADE-Grande. Investigations of radio emission in high-energy air showers will be performed with a further upgrade of the experimental set-up by installing an array of broad-band antennas provided by the LOPES collaboration [7].

2. The Set-Up

The existing multi-detector experiment KASCADE [1], which takes data since 1996, was recently extended to KASCADE-Grande by installing a large array of 37 stations consisting of $10\,\mathrm{m}^2$ scintillation detectors each, with an average spacing of 137 m. The scintillators were taken from the former EAS-TOP experiment. The stations comprise 16 photo-multipliers each providing a high dynamic range from 1/3 to 30000 charged particles per station for the reconstruction of particle densities and timing measurements. The signals are amplified and shaped inside the Grande stations, and after transmission to a central DAQ station digitalized in peak sensitive ADCs (Chiavassa et al. [3]).

Parallel to the standard DAQ the Grande array will be equipped with FADCs and a continuous data sampling using a ring-buffer system to store the full history of energy deposit at the stations, improving significantly the energy and time measurements.

KASCADE-Grande provides an effective area of more than $0.5\,\mathrm{km}^2$ and operates jointly with the existing KASCADE detectors. Grande is electronically subdivided in 18 hexagons of 6 outer and one central station. Grande is readout and jointly analyzed with KASCADE for showers fulfilling at least one 7-fold coincidence in a hexagonal cluster. The joint measurements are ensured by an additional cluster (Piccolo) close to the center of KASCADE-Grande for trigger purposes. Piccolo consists of $8 \times 10\,\mathrm{m}^2$ stations equipped with plastic scintillators. The trigger conditions at Piccolo can be chosen as a double multiplicity trigger ($> n$ of 8 huts and $> m$ of 48 electronic channels). The expected trigger efficiency for Piccolo with $n = 2, m = 4$ is shown in Fig. 4. The efficiency is calculated by Monte Carlo simulations for the acceptance region shown as circle in Fig. 3.

While the Grande detectors are sensitive to charged particles, the original KASCADE detectors measure the electromagnetic component, the muonic and the hadronic components separately. The 252 KASCADE stations covering an area of $200 \times 200\,\mathrm{m}^2$ consist of unshielded liquid scintillators above shielded plastic scintillators [1]. This enables to reconstruct the lateral distributions of muons and electrons separately on an event-by-event basis. Further muon detector systems at an underground tunnel and at the Central Detector of KASCADE allow to investigate the muon component of EAS at four different threshold energies. A liquid ionisation hadron calorimeter with more than 44000 electronic channels in 9 layers reconstructs the hadronic core of air showers.

Table 1. Compilation of the KASCADE-Grande detector components.

Detector	Particles	sensitive area [m^2]
Grande	charged	370
Piccolo	charged	80
KASCADE array e/γ	electrons	490
KASCADE array μ	muons ($E_{\mu}^{\rm thresh} = 230\,{\rm MeV}$)	622
MTD	muons ($E_{\mu}^{\rm thresh} = 800\,{\rm MeV}$)	3×128
Trigger Plane	muons ($E_{\mu}^{\rm thresh} = 490\,{\rm MeV}$)	208
MWPCs/LSTs	muons ($E_{\mu}^{\rm thresh} = 2.4\,{\rm GeV}$)	3×129
Calorimeter	hadrons ($E_{h}^{\rm thresh} = 10 - 20\,{\rm GeV}$)	9×304

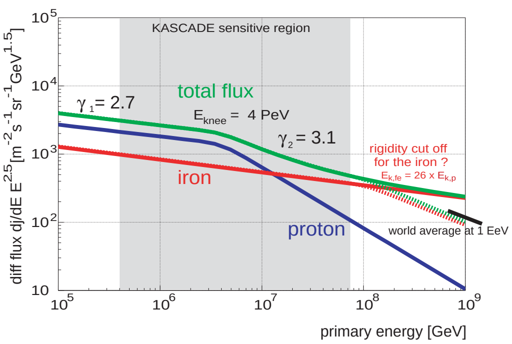

Fig. 1. Motivation for the extension of KASCADE to KASCADE-Grande: Is there also a knee at the spectrum of EAS induced by heavy primaries?

Fig. 2. Antennas for the measurement of radio emission in air showers are set-up at the KASCADE experiment.

Recently first 10 antennas with a large bandwidth (40-80 MHz) for the detection of radio emission in air showers were installed at the KASCADE site (see Fig. 2). Together with the LOPES collaboration KASCADE-Grande is calibrating the amount of the radio emission in high-energy air showers.

3. Capabilities of KASCADE-Grande

Like in KASCADE the concept of KASCADE-Grande is the measurement of as many as possible observables of air showers to perform multi-parameter analyses to disentangle the three-fold problem of determining the primary energy and mass reconstruction and the understanding of hadronic interaction mechanisms in the atmosphere.

Basic shower observables like the core position, angle-of-incidence, or total number of charged particles will be provided by the Grande stations. A core position resolution of $\approx$ 15 m and an angle resolution of $\approx 0.5^{\circ}$ will be reached by the present set-up. The estimation of energy and mass of the primary particles will be based on a combined investigation of the charged particle, electron and muon components measured by the detector arrays of Grande and KASCADE (Glasstet-

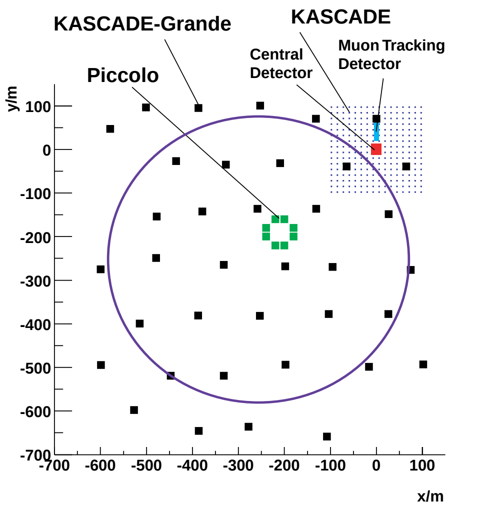

Fig. 3. Layout of the multi-detector experiment KASCADE-Grande.

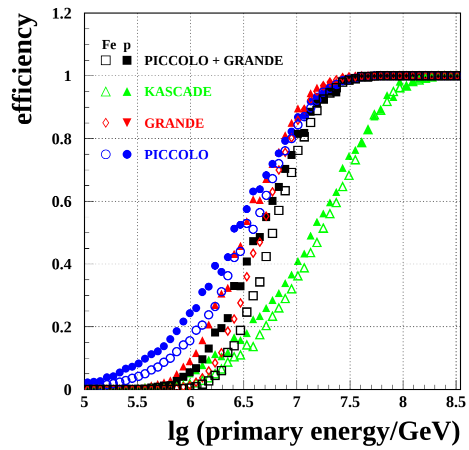

Fig. 4. Simulated trigger efficiency for different trigger sources of KASCADE-Grande for showers inside the area of a circle as shown at Fig. 3.

ter et al. [4]). A common fit to the energy deposits with the relative muon to electron ratio as additional free parameter enables a resolution of electron and muon numbers in the order of 15% and 25%, respectively, for primary energies of 100 PeV.

Additional sensitivity for composition estimates and interaction model tests is provided by muon density measurements at different muon energy thresholds (Haungs et al. [5]), by muon arrival time measurements (Brancus et al. [2]), by the analysis of muon angles-of-incidences (Zabierowski et al. [9]), and by measurements of the hadronic shower core (e.g. Iwan et al. [6]).

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