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Latest results and perspectives of the KASCADE-Grande EAS Facility

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ABSTRACT

KASCADE-Grande is a multi-detector experiment at KIT (Karlsruhe Institute of Technology) in Germany for measuring extensive air showers in the primary energy range of 100 TeV to 1 EeV. This paper does not provide a synopsis of all results of the KASCADE-Grande experiment. Rather it is focused on three aspects of current interests illustrating the advantages of a multi-detector facility. Results on the analysis of individual energy spectra of primary mass groups around the knee obtained by unfolding the shower size measurements of KASCADE with the help of the new hadronic interaction model EPOS and the all-particle energy spectrum at higher energies obtained by Grande measurements will be discussed. As KASCADE-Grande serves also as host of the LOPES radio detection experiment where both experiments measure the same showers, special emphasis will be given in comparing the characteristics and feasibility of both techniques in estimating the main parameters of high-energy primary cosmic rays: energy, composition, and arrival direction.

1. Introduction

The main goal of experimental cosmic ray research is the measurement of the primary energy spectrum and the elemental composition in order to understand the origin, acceleration and propagation of energetic cosmic particles. This task can be pursued directly or indirectly, depending on the energy range of the primary particle. At high energies, above 10^{15} eV, the energy spectrum must be determined indirectly from the measured properties of extensive air showers (EAS) that cosmic rays induce in the Earth's atmosphere.

Depending on the experimental apparatus, the environmental conditions, and the detection technique, different sets of EAS observables are available to estimate these properties, i.e. the arrival direction, the energy, and the mass of the primary cosmic particle [1]. As all the reconstructions rely on the characteristics of the development of the EAS in the atmosphere, i.e. on the extrapolations of the behavior of hadronic interactions to higher energies (beyond the range of Earthbound accelerators), in particular to the forward emission hemisphere, the validity of the

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particularly used hadronic interaction models is an important aspect for EAS experiments. Hence, one of the goals of sophisticated EAS experiments is to investigate the high-energy interaction and to improve the contemporary models to reduce systematic uncertainties. The way to do this is the installation of multi-detector set-ups in order to obtain as much as possible information on individual air showers. This is a basic reason for the development of new detection techniques, like the radio detection of extensive air showers.

The KASCADE-Grande experiment is such a multi-detector set-up measuring many components of the air-showers in the primary energy range from 10^{14} to 10^{18} eV. Along the past years, the original KASCADE experiment (and others) have shown that the energy spectrum of cosmic rays, extending from a few MeV up to 10^{20} eV, has a striking power-law behavior with a spectral index $\gamma \approx -2.7$ but exhibits some intriguing structures around $3-5 \times 10^{15}$ and $4-10 \times 10^{18}$ eV, known as the *knee* and the *ankle*, where the spectral index of the particle flux decreases and grows, respectively [2]. The precise interpretation of these features are not yet clear, but they could arise as a consequence of an interplay among different factors such as the loss of efficiency of the galactic accelerators, the dominance of a new component of extragalactic origin at the high-energy regime and the propagation effects of cosmic rays through space [3,4]. To test different scenarios, accurate and high-statistics measurements are needed between 10^{15} and 10^{18} eV. Although observations of this kind have been already performed around the knee, the picture is not yet complete due to the lack of quality EAS data at higher energies ($E = 10^{16}$–10^{18} eV) and due to the uncertainties of the hadronic interaction models underlying the analysis, in particular at knee-energies. The goal of the KASCADE-Grande experiment is to close this gap between the *knee* and the ultra-high-energy region with accurate EAS measurements.

The traditional method to study extensive air showers (EAS) is to measure the secondary particles with sufficiently large particle detector arrays. In general these measurements provide only information on the actual status of the air shower cascade on the particular observation level. This hampers the determination of the properties of the EAS inducing primary as compared to methods like the observation of Cherenkov and fluorescence light [1]. In order to reduce the statistical and systematic uncertainties of the detection and reconstruction of EAS, especially with respect to the detection of cosmic particles of highest energies, there is a current methodical discussion on new detection techniques. Due to technical restrictions in past times the radio emission accompanying cosmic ray air showers was a somewhat neglected EAS feature. For a review on the early investigations of the radio emission in EAS in the 60s see Ref. [5]. However, the study of this EAS component has experienced a revival by recent activities, in particular by the LOPES project.

From the numerous activities and results of the KASCADE-Grande Facility, in this paper three topics will be discussed a bit more in detail: (i) the energy spectra of individual particles around the knee obtained with the new interaction model EPOS version 1.99; (ii) the all-particle energy spectrum in the energy range of $E = 10^{16}$–10^{18} eV obtained by Grande data; and (iii) some general thoughts about the hybrid approach to measure cosmic rays by the combination of LOPES and KASCADE-Grande.

2. The KASCADE-Grande Facility

The experiments (see Fig. 1 and Table 1) are located at the Campus North of the Karlsruhe Institute of Technology, Germany, (49.1°n, 8.4°e, 110 m a.s.l.) and measure extensive air showers in a primary energy range from 100 TeV to 1 EeV. Their combination provides multi-parameter measurements on a large number of observables of the shower components: electrons, muons at four energy thresholds, hadrons, and the radio emission. The main detector components are the KASCADE array, the Grande array, and the LOPES antenna array.

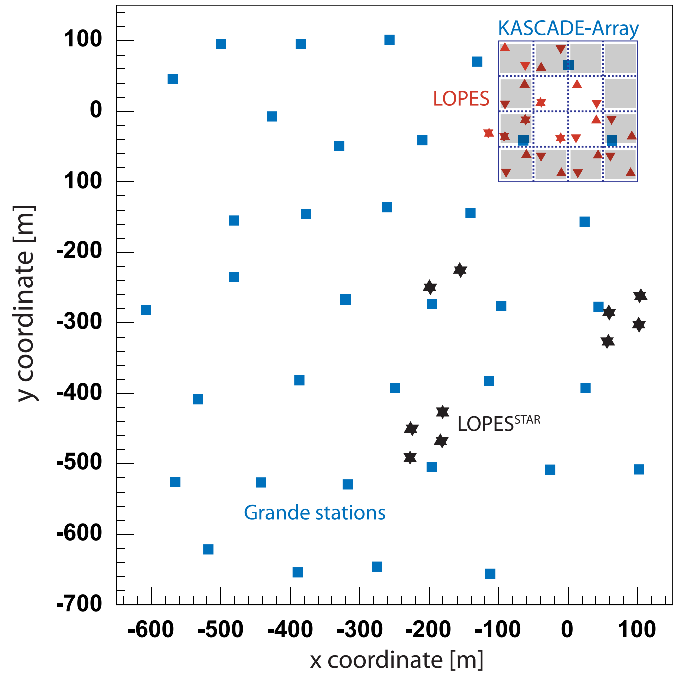

Fig. 1. The KASCADE-Grande Facility. Small squares represent the Grande stations. The KASCADE array is seen at the upper right hand of the figure. KASCADE detectors are arranged in 16 clusters. The outer 12 clusters contain muon detectors. LOPES antennas are displayed by triangles, i.e. a star signs a dual-polarized antenna with two channels.

Table 1
Some components of the KASCADE-Grande EAS Facility: total sensitive areas and threshold kinematic energies for vertically incident particles are presented. MTD refers to the muon tracking detectors. In case of LOPES the detection threshold for the primary energy is given.

Detector	Particle	Area (m^2)	Threshold (MeV)
Grande array (plastic scintillators)	Charged	370	3
Piccolo array (plastic scintillators)	Charged	80	3
KASCADE array (liquid scintillators)	e/γ	490	5
KASCADE array (shielded plast. scint.)	μ	622	230
MTD (streamer tubes)	μ	4×128	800
LOPES (radio antennas)	$e^{\pm}$	Full array	$\approx 5 \times 10^{16}$ eV

The KASCADE [6] array measures the total electron and muon numbers ($E_{\mu,\mathrm{kin}} > 230$ MeV) of the shower separately using an array of 252 detector stations containing shielded and unshielded detectors at the same place in a grid of 200×200 m^2. The excellent time resolution of these detectors allows also decent investigations of the arrival directions of the showers in searching large scale anisotropies and, if existent, cosmic ray point sources. The KASCADE array is optimized to measure EAS in the energy range of 100 TeV to 80 PeV.

A muon tracking detector measures the incidence angles of muons relative to the shower arrival direction. These measurements provide a sensitivity to the longitudinal development of the showers. The hadronic core of the shower is measured by a 300 m^2 iron sampling calorimeter (calibrated at CERN) installed at the KASCADE central detector. And three further components offer additional valuable information on the penetrating muonic component at different energy thresholds. The complementary information of the showers measured by the central and the muon tracking detectors is predominantly being used for a better understanding of the features of an air-shower and for tests and improvements of the hadronic interaction models underlying the analyses.

The multi-detector concept of the KASCADE experiment, which is operating since 1996 has been translated to higher primary energies through KASCADE-Grande [7]. The 37 stations of the Grande array extend the cosmic ray measurements up to primary energies of 1 EeV. The Grande stations, 10 m^2 of plastic scintillator detectors each, are spaced at approximately 130 m covering a total area of ~ 0.5 km^2. In addition, a small cluster of stations (Piccolo) close to the center of the Grande array is installed in order to provide a fast trigger to the muon detection systems of the original KASCADE array. The Grande array is integrated in KASCADE and therefore allows us to measure and separate the muon and electromagnetic components of the EAS. Once combined, both observables become a powerful tool to reconstruct the energy spectrum and to estimate the composition of primary cosmic ray events.

For the calibration of the radio signal emitted by the air shower in the atmosphere an array of first 10, later 30 and meanwhile more than 50 calibrated antennas measuring in the frequency range of 40–80 MHz (LOPES [8]) is set up on site of the KASCADE-Grande experiment. The basic idea of the LOPES (=LOFAR prototype station) project is to build an array of relatively simple antennas, where the received waves are digitized and sent to a central computer. This combines the advantages of low-gain antennas, such as the large field of view, with those of high-gain antennas, like the high sensitivity and good background suppression.

3. KASCADE shower size unfolding based on EPOS 1.99

The KASCADE data analysis aims to reconstruct the energy spectra of individual mass groups taking into account not only different shower observables, but also their correlation on an event-by-event basis [9]. The content of each cell of the two-dimensional spectrum of reconstructed electron number vs. muon number is the sum of contributions from the individual primary elements. Hence the inverse problem $g(y) = \int K(y,x)p(x)\,dx$ with $y = (N_e, N_\mu^{tr})$ and $x = (E,A)$ has to be solved. This problem results in a system of coupled Fredholm integral equations of the form

$$\frac{dJ}{d\lg N_e \, d\lg N_\mu^{tr}} = \sum_A \int_{-\infty}^{+\infty} \frac{dJ_A}{d\lg E} \cdot p_A(\lg N_e, \lg N_\mu^{tr} | \lg E) \cdot d\lg E$$

where the probability p_A is obtained by Monte Carlo simulations on the basis of specific high-energy hadronic interaction models as options embedded in CORSIKA [10]. By applying these procedures (with the assumption of five primary mass groups) to the experimental data energy spectra of individual mass groups are obtained. In a first attempt [9] two different models were investigated, QGSJet 01 [11] and SIBYLL 2.1 [12]. By summing up the individual spectra the all-particle spectrum is obtained, where the knee was clearly visible as well as in the spectra of primary proton and helium. No such features were observed in the heavy components. This demonstrated that the elemental composition of cosmic rays is dominated by the light components below the knee and by a heavy component above the knee feature. Thus, the knee feature originates from a decreasing flux of the light primary particles.

Comparing the unfolding results based on the two different high-energy hadronic interaction models QGSJet and SIBYLL, it was recognized that the structures (knees) and the total flux and features of the all-particle spectrum is quite similar, but the fluxes of the individual spectra differ significantly. Modeling the hadronic interactions underlies assumptions from particle physics theory and extrapolations resulting in large uncertainties, which are reflected by drastic differences in the relative abundances of the mass groups. More detailed investigations, including the hadronic observables of KASCADE have shown that none of the two models are able to describe the entire data set consistently.

Recently, the described analysis was repeated by using a new version of the hadronic interaction model EPOS (version 1.99 [14]). Fig. 2 displays the results, where it is seen that the above-mentioned findings are confirmed, in particular the knee like feature in the all-particle, the proton, and the helium spectrum. Also the flux of the all-particle spectrum is comparable with the results of the other two models (see Fig. 8). In contrast to the other two models, however, EPOS results in a similar abundant helium and proton component below the knee and, in consequence, a helium dominance above the knee. This is remarkable as an extrapolation of recent direct data by ATIC and CREAM [13] predicts such a dominance.

Another cross-check if the results based on a certain model are reasonable is performed by comparing the resulting proton spectrum with direct measurements, where many data are available (Fig. 3). Here, the QGSJet and Sibyll based results are in the range of the statistical uncertainty of the extrapolation of direct measurements, whereas the EPOS based results lie above though the newer version 1.99 (see Ref. [14]) agrees better than the older version 1.61.

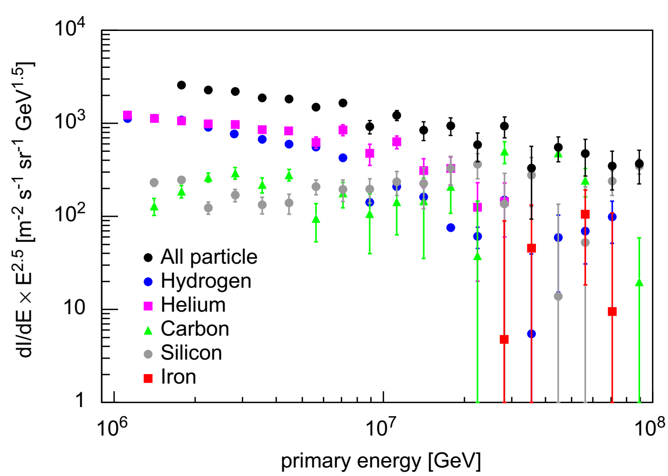

Fig. 2. All-particle and individual mass group cosmic ray energy spectra around the knee obtained by unfolding the two-dimensional shower size spectrum measured by KASCADE.

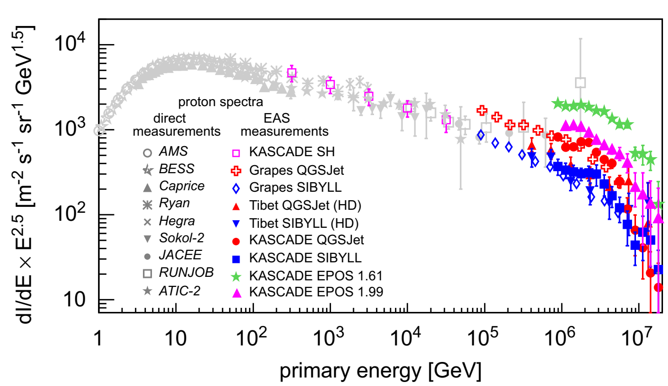

Fig. 3. Compilation of direct and indirect measurements of the cosmic ray energy spectrum of primary protons. In case of KASCADE the results of different models are included.

On the other hand due to the high abundance of light particles there is no room for heavy primaries (iron, see Fig. 2) by interpreting the measurements with the EPOS 1.99 model, which makes the results somehow unreasonable when compared with direct measurements.

In summary, in contrast to the first version of EPOS v.1.61 investigations of EPOS v.1.99 with KASCADE data give consistent results for the different observables and its correlations as well as an astrophysical solution around the knee which is promising for the future. First data from the LHC will further improve the possibilities in cross-checking the validity of the hadronic interaction models.

4. Grande obtained all-particle energy spectrum

To reconstruct the all-particle energy spectrum in the range of 10^{16}–10^{18} eV by use of the data obtained by coincident measurements of KASCADE with the Grande array – KASCADE-Grande – three independent techniques have been applied: one based solely on the total charged number of particles [15], another one on the muon number [16], and the last one on a combination of both observables [17].

In the ideal case, when the measurements are accurate enough, when the reconstruction procedures work properly, when the Monte Carlo simulations are a faithful description of the EAS and the cosmic ray composition is known one expects the same spectrum from all three methods. This strategy shows various advantages, it allows (1) to carry out different cross-checks of the reconstruction procedures, the influence of systematic uncertainties and the performance of the detectors, (2) to test the sensitivity of N_{ch} and N_μ to the elemental composition and (3) to study the validity of hadronic interaction models.

In order to reduce the influence of systematic uncertainties in the data, a fiducial area located at the center of KASCADE-Grande was selected and only events with zenith angles $\theta \leq 40^\circ$, which passed the KASCADE-Grande reconstruction without failures were considered. Additionally, several experimental cuts were imposed, which results in an effective time of observation of 1173 days and an exposure of 2.003×10^{13} m^2 $\times$ s $\times$ sr. Simulations show that for the above conditions full trigger and reconstruction efficiency at KASCADE-Grande is found above $E \approx 10^{16}$ eV.

Simulations were employed to study the systematic uncertainties, the performance and reconstruction methods in the experiment as well as the influence of the cuts. Both the air shower production and development were realized using CORSIKA and the hadronic generators FLUKA [18] and QGSJet II. Events with a homogeneous core distribution and isotropic arrival direction were produced for a $\gamma = -2$ power-law spectrum ($E = 10^{15} - 3 \times 10^{18}$ eV) and sets were generated for a mixed composition of H, He, CO, Si and Fe on similar abundances. A weight function was finally applied to the simulated data to describe a spectrum with $\gamma = -3$, which resembles the observed value. It should be remarked that all the features and resolutions obtained by simulations could be experimentally cross-checked by the unique possibility of KASCADE-Grande to reconstruct a subsample of showers independently with both arrays, KASCADE and Grande [7].

The simplest way to reconstruct the energy spectrum is by using one single parameter, as N_{ch} or N_μ [15,16]. Data are divided into five zenith angle intervals with equal acceptance. In each case, the corresponding shower size spectrum is extracted (see Figs. 4 and 5) and the constant intensity cut (CIC) method is applied to correct for attenuation effects in the atmosphere. A reference angle, θ_{ref}, must be chosen for this task. In this study, θ_{ref} corresponds to the mean of the corresponding zenith angle distribution, which for N_{ch} is 20° and for N_μ, 22°. The difference comes from the particular cuts applied in each case.

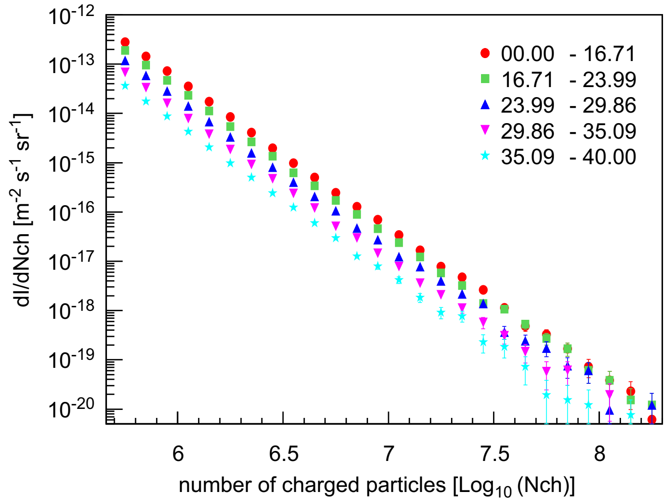

Fig. 4. The N_{ch} differential spectra derived from KASCADE-Grande measurements.

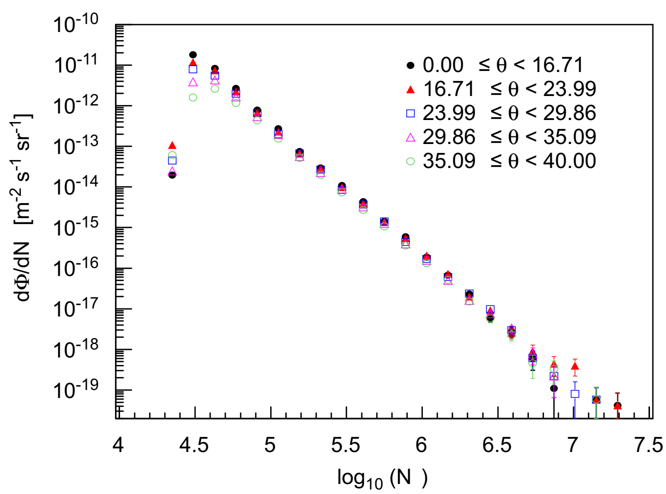

Fig. 5. The N_μ differential spectra derived from KASCADE-Grande measurements. The muon correction function was applied to the data.

As a next step, from the corrected observable the energy is inferred event-by-event by invoking a Monte Carlo calibration function, which is composition dependent. The calibration formula is obtained by fitting with a power-law expression, $E = \alpha \cdot N^{\beta}_{ch(\mu)}$, the Monte Carlo data points for true energy vs. shower size around θ_{ref} for different mass groups. Then, all data from the distinct zenith angle intervals are combined according to the energy and a single energy spectrum is obtained.

In a final step, the effect of migration of events in the reconstructed energy spectrum is taken into account by applying a response matrix, R_{ij} (also extracted from simulations). In Fig. 6, the unfolded spectra are plotted, where it is obvious that using one observable only result in a very large composition dependence of the results.

Therefore, the final path to reconstruct the energy spectrum at KASCADE-Grande exploits the information from both the N_{ch} and N_μ observables [17]. The energy of an EAS is derived through a Monte Carlo expression, which involves the values of the total number of charged particles and the muon size and its correlation on an event-by-event basis in order to reduce the composition dependence of the energy assignment for the EAS. The formula has

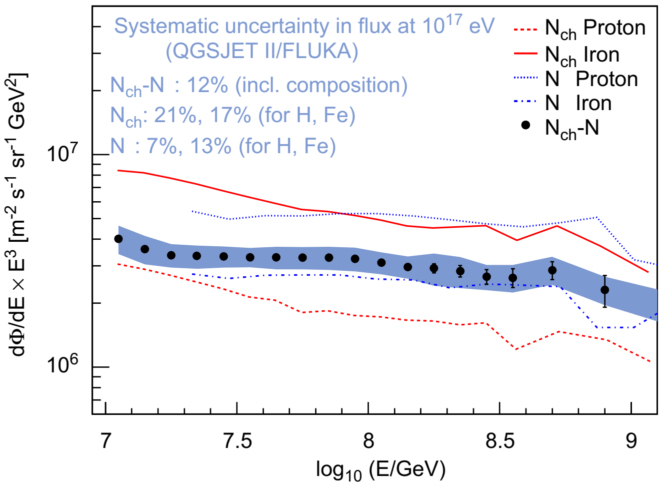

Fig. 6. Reconstructed all-particle energy spectrum, multiplied by E^3, as obtained from the KASCADE-Grande data and the different methods described in the present paper. The band represents the systematic uncertainty for the spectrum reconstructed through the $N_{ch}-N_{\mu}$ method.

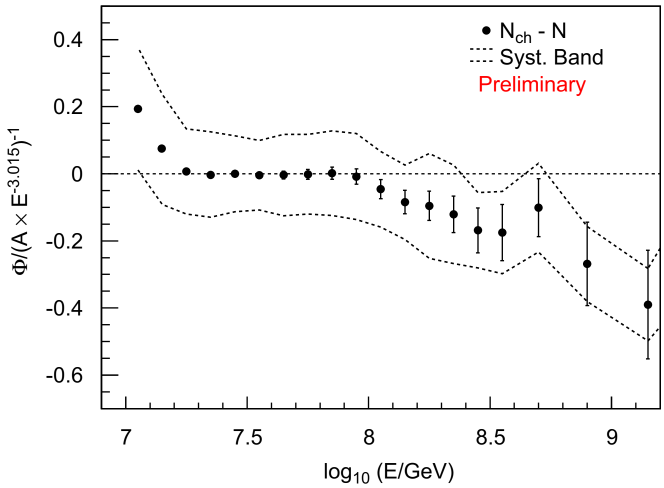

Fig. 7. Residual plot for the reconstructed all-particle energy spectrum obtained from KASCADE-Grande through the $N_{ch}-N_{\mu}$ method. The systematic error band is also shown (dotted lines).

the form

$$\log_{10}(E/GeV) = [a_p + (a_{Fe} - a_p) \cdot k] \cdot \log_{10}(N_{ch}) + [b_p + (b_{Fe} - b_p) \cdot k] \quad (1)$$

where $k = k(N_{ch}, N_{\mu})$ is a mass sensitive parameter defined as

$$k = \frac{\log_{10}(N_{ch}/N_{\mu}) - \log_{10}(N_{ch}/N_{\mu})_p}{\log_{10}(N_{ch}/N_{\mu})_{Fe} - \log_{10}(N_{ch}/N_{\mu})_p} \quad (2)$$

in such a way that for protons the average value of k is close to zero and approximately one for iron nuclei. The constants (a,b) and (c,d) are obtained from fits to the scatter plots of E vs. N_{ch} and N_{ch}/N_{μ} vs. N_{ch}, respectively, and performed in the region of maximum efficiency. To take into account the influence of the atmospheric attenuation in the EAS, the above formulas are built for every zenith angle interval and applied accordingly. As it was the case for the single parameter reconstruction, the energy spectrum obtained by the present method is corrected for the effect of the migration of events. The final spectrum is also included in Fig. 6.

Each method has its own systematic uncertainties, which were carefully estimated when calculating the energy spectrum. In the case of the single parameter reconstruction the sources of systematic uncertainties considered for this work were the following ones: the energy calibration relation, the CIC method, the muon correction function, the uncertainty of the spectral index and the response matrix. For the $N_{ch}-N_{\mu}$ method the contributions to the systematic errors of the spectrum come from the atmospheric attenuation, the energy calibration function, uncertainties in the primary composition (applying the method to MC simulations with different composition assumptions), the spectral slope, and the accuracy of the reconstruction of shower sizes. The total systematic uncertainties of the reconstructed spectra at 10^{17} eV for the different methods are displayed in Fig. 6.

As it was pointed out before, the reconstruction of the energy spectrum by using several methods allows to perform several tests and cross-checks. First, by a direct comparison of the resulting all-particle energy spectra from the KASCADE-Grande data, a good agreement is found inside the respective systematic uncertainties, which means that the experiment and its components are well understood, also that the reconstruction techniques are working as expected and that the hadronic interaction model employed, QGSJet II/FLUKA, is intrinsically consistent.

To investigate the details of the energy spectrum derived from the $N_{ch}-N_{\mu}$ approach, a residual plot was constructed by a direct comparison with a flux proportional to $E^{-3.015}$ (see Fig. 7). The spectral index of the reference flux was obtained by fitting the middle range of the experimental spectrum, i.e. the interval $E = 10^{16.2}$–10^{17} eV. Two features show up at Fig. 7, one is a concavity above 10^{16} eV and another one is a small break at $\approx 10^{17}$ eV. Both structures are found to be statistically significant. For example, a fit with a power-law spectrum above 10^{17} eV gives a spectral index of $\gamma = -3.24 \pm 0.08$. A preliminary statistical analysis with the F-test shows that the significance associated with this change of the spectral index is at a level of $\approx 99.8\%$.

In Fig. 8, the energy spectrum of cosmic rays obtained from the KASCADE-Grande measurements is compared with the spectra obtained by other cosmic ray instruments. In general, a good agreement is observed at low and high energies with the KASCADE-Grande data.

By now the analysis of the influence of the hadronic interaction models is restricted by the statistics of the Monte Carlo data sets generated with alternative hadronic models. However, some preliminary studies applying the reconstruction N_{ch} method and the two-observables approach have been already performed with EPOS v1.99. Those analysis shows that the differences between the reconstructed spectra using EPOS v1.99 and QGSJET II are of the order of 10–15%. The same preliminary tests done with EPOS v1.99 also suggest that the observed structures at the energy spectrum reconstructed with QGSJET II are not an artifact of the hadronic interaction model.

5. Hybrid EAS measurements by LOPES and KASCADE-Grande

The main goal of the investigations in Karlsruhe in the frame of LOPES is the 'calibration' of the shower radio emission in the primary energy range of 10^{16}–10^{18} eV. I.e. to investigate in detail the correlation of the measured field strength with the shower parameters, in particular of the orientation of the shower axis (geomagnetic angle, azimuth angle, zenith angle), the position of the observer (lateral extension and polarization of the radio signal), and the energy and mass (electron and muon number) of the primary particle. The achieved results of the combined measurements KASCADE-Grande and LOPES are summarized in Ref. [8].

Despite the impressing results, it is clear that the new detection technique is still in a developing phase. This concerns the hardware as well as software (i.e. analysis procedures like optimizing the interferometric methods for short pulses). One of the problems is that still the exact emission mechanism(s) is not known. The present results reveal the dominance of geomagnetic effects, but

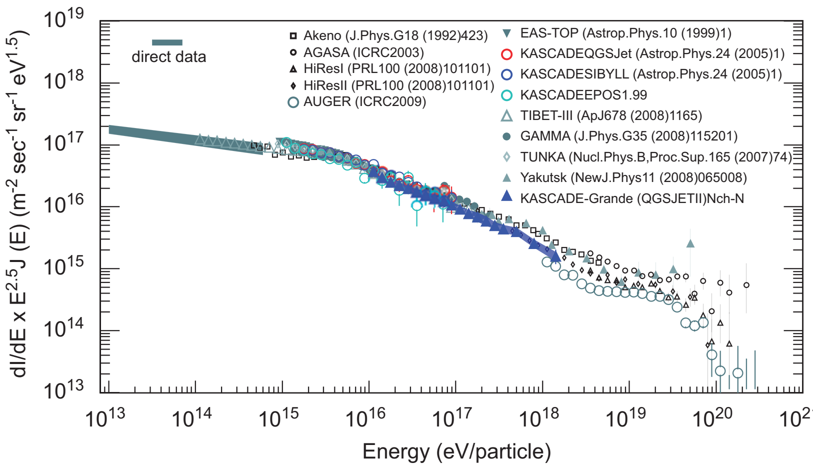

Fig. 8. A comparison of the all-particle energy spectrum reconstructed from the KASCADE-Grande data with the spectra by other experiments.

first hints indicate also the role of the charge excess in EAS, evidenced in the polarization of the signal.

To standardize the radio detection technique and to pave the way for a large scale application it will be very important to answer the question to the sensitivity and resolution of the technique to the main characteristics of individual cosmic rays: (i) primary energy, (ii) arrival direction, (iii) primary mass.

(i) Primary energy: The radio emission is coherent leading to a strong correlation between the measured electric field strength and the energy ($\varepsilon_\nu \propto E_0^{\approx 1}$). LOPES reports about 20–25% resolution of the primary energy, whereas typical particle detector arrays can reach 10–20%. The question is whether the resolution could be improved when knowing more details about the emission mechanism.

(ii) Arrival direction: The sensitivity is given via the pulse arrival time and its phase. Reconstructed is the direction best with the help of interferometric methods, where at least three antennas at different locations, with not too far distances, are needed. Easily a resolution of better than 1° can be reached and is therefore very comparable with a dense particle detector array. The question here is, how many antennas in which distance are needed for a certain primary energy to obtain this accuracy.

(iii) Mass composition: In EAS physics it seems to be clear that the best mass sensitivity is reached if one is sensitive to the position of the shower maximum X_{max}. There are some ideas, first measurements, and theoretical investigations that the steepness of the lateral distribution of the radio signal as well as the form of the wave front and the pulse shape can provide X_{max}-sensitive observables. But here the studies are just at the beginning and much more statistics of high quality data is needed.

For exploring these questions it is absolutely necessary to perform further hybrid measurement of high quality, combined with well understood classical air shower observations, like presently done with KASCADE-Grande, and in future planned for higher energies with the Pierre Auger Observatory [19].

6. Conclusions

The KASCADE measurements demonstrate that the knee in the primary cosmic ray spectrum, positioned at few times 10^{15} eV is originating from the depletion of the light elements, and that we should expect consequently further kinks of the spectrum when the heavier elements are disappearing. In any case if this feature is Z- or A-dependent it remains a question of great interest.

The measurements give also evidence that cosmic rays of energies around the knee arrive at our Earth isotropically. In addition the careful analyses of the KASCADE data on basis of current hadronic interaction models, unavoidably invoked for the interpretation, reveal the deficiencies of the present models. None of them is able to describe the data satisfactorily, which is also the case for the new developed model EPOS version 1.99. The main uncertainties of the KASCADE results arise from such a kind of 'model' dependence. It is also a consequence of the lack of accelerator data at relevant energies, especially in the forward direction, which could help to tune the model descriptions adequately. Here, LHC will provide a new step in this iterative process of models and KASCADE data unfolding.

The extension of KASCADE to KASCADE-Grande aims at the question if there do exist at higher energies knee-like structure associated with the disappearance of the heavier elements. This feature is expected to constrain more details of the astrophysical models and conjectures. KASCADE-Grande proceeds with the multi-detector concept of the measurements in order also to investigate, in particular different aspects of the hadronic interaction models up to primary energies of 10^{18} eV. The all-particle energy spectrum of cosmic rays was reconstructed from the KASCADE-Grande data using three different techniques and the hadronic interaction models QGSJET II and FLUKA. The resulting energy spectrum shows statistical significant features that can be identified with a concavity and a small break at $\approx 10^{16}$ and 10^{17} eV, respectively. The nature of this structures are under discussion. Information about the composition in this energy interval will provide valuable clues to solve the mystery. These composition studies are now right underway at KASCADE-Grande.

With setting up an array of radio antennas within the area of KASCADE-Grande, using sophisticated electronic and reconstruction procedures, it is attempted to develop a concept of air shower detection by the radio frequency emission during the shower development. First results obtained by correlating the observed radio field strength with the shower parameters obtained by the KASCADE measurements appears to be very promising for a more detailed understanding of the emission mechanism from atmospheric showers. The main goal of the LOPES project is the investigation of the relation between the radio emission from extensive air showers with the properties of the primary particles by hybrid measurements with KASCADE-Grande. Such studies are hoped to pave the way for a large-scale application of a novel technique in future cosmic ray experiments.

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