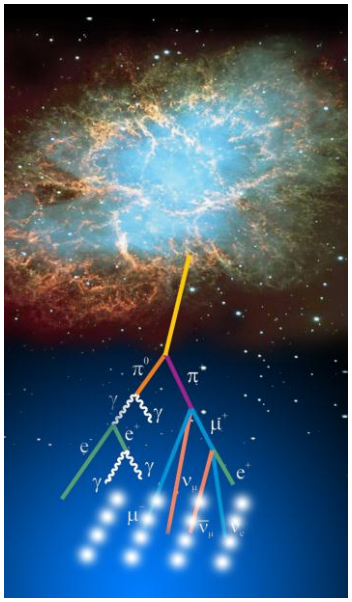
Kinks in the Knee

KIT's KASCADE-Grande Experiment Unravels a Mystery of Cosmic Rays



Cosmic rays, massive particles from the universe, trigger showers of particles in the Earth's atmosphere, which are detected on the ground by the KASCADE-Grande experiment. (Graphics: Tim Otto Roth and KIT)

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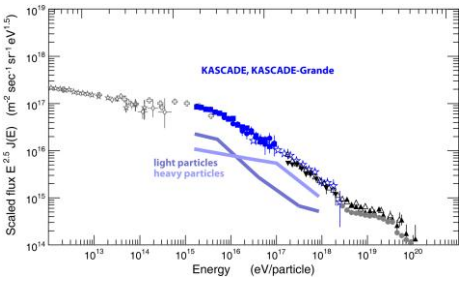
For many years, astroparticle physicists have been dealing with the question of what causes the "knee", a kink in the energy spectrum of cosmic rays. For light elements, such as hydrogen, the KASCADE experiment on the premises of Karlsruhe Institute of Technology supplied important hints. By extending the experiment to KASCADE-Grande, the scientists have now measured particles of ten times higher energy and, hence, the complete knee. The knee consists of several kinks. With increasing energy, more and more heavier elements disappear from the spectrum of cosmic rays. The results have now been published in the journal "Physical Review Letters".

KASCADE-Grande is a measurement field for cosmic rays on the premises of Campus North of Karlsruhe Institute of Technology. On an area of 700 x 700 m^2, 37 detector stations are located. In addi-

tion, the former KASCADE experiment has been integrated. “KASCADE-Grande extends the measurement area of the KASCADE experiment by a factor of ten,” says Dr. Andreas Haungs, who heads the KASCADE-Grande project at KIT. “ Now, we can measure particle showers generated by cosmic particles of up to 10^{18} electron-volts in energy.” 10^{18} electron volts: This energy exceeds the energies of the presently largest particle accelerators on Earth by a factor of 100.

The particle showers are caused by the primary particles of cosmic rays hitting the atoms of the Earth’s atmosphere and generating secondary particles. These secondary particles again produce particles that produce particles, etc. This shower, this cascade of particles, hits the ground within a few nanoseconds and can be measured there. “Due to their low flux, the primary particles, massive atomic nuclei, cannot be measured directly by balloon or satellite experiments,” explains Andreas Haungs. “As only one such high-energy particle occurs per m^2 and day, we have to rely on ground observations.” Here, the energy, the direction and the mass of the primary particle can be determined.



The "knee" of cosmic rays, a kink in the energy spectrum, occurs at variable energies for light and heavy particles. (Graphics: KIT)

The flux of cosmic rays, i.e. of primary particles prevailing everywhere in the universe, decreases strongly with increasing particle energy. A little above an energy of 10^{15} electron volts, the “steepness” of flux decrease changes: This results in a kink in the spectrum, the “knee” of cosmic rays. It was shown by the KASCADE experiment already that cosmic rays in the energy range up to 10^{17} electron-volts do not consist of photons, but of massive particles, atomic nuclei. These particles come from all directions with the same abundance – radiation is isotropic. And, most important, the data suggest that the first part of this “knee” is caused by the disappearance of lighter primary particles and the kink is shifted towards higher energies with the mass of the primary particles. The corresponding measurements have now been made after the extension of the energy range by KASCADE-Grande: The kink for iron nuclei is located at about 10^{17} electron-volts.

“The results of KASCADE-Grande allow the conclusion to be drawn that primary particles of cosmic rays can be generated and stored in our Milky Way up to energies of around 10^{17} electron-volts only,” summarizes Andreas Haungs the impacts on our astronomic conception of the world. “Accordingly, particles of even higher energy have their origin outside of the Milky Way.” These higher-energy particles of cosmic rays are measured by the Pierre Auger Observa-

tory in Argentina, in the setup and scientific evaluation of which KIT is also involved.

The KASCADE-Grande project is run by an international collaboration of scientists from KIT as well as from the universities of Michoacana (Mexico), Turin (Italy), Lodz (Poland), Bucharest (Romania), Siegen and Wuppertal (Germany), Sao Paulo (Brazil), and Nijmwegen (the Netherlands). After five years of measurements since the extension of KASCADE and another three years of operation as a test facility for novel detectors, KASCADE-Grande will be switched off at the end of this year.

First results by analyzing the rich data set have now been published by the scientific journal “Physical Review Letters”:
"Kneelike structure in the spectrum of the heavy component of cosmic rays observed with KASCADE-Grande", Physical Review Letters (Vol. 107, No. 17):
URL: http://link.aps.org/doi/10.1103/PhysRevLett.107.171104
DOI: 10.1103/PhysRevLett.107.171104

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