HADRONS IN A CALORIMETER MEASURED IN AIR SHOWERS AND AT AN ACCELERATOR

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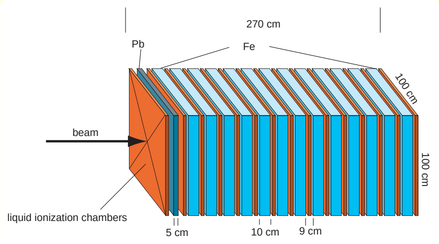
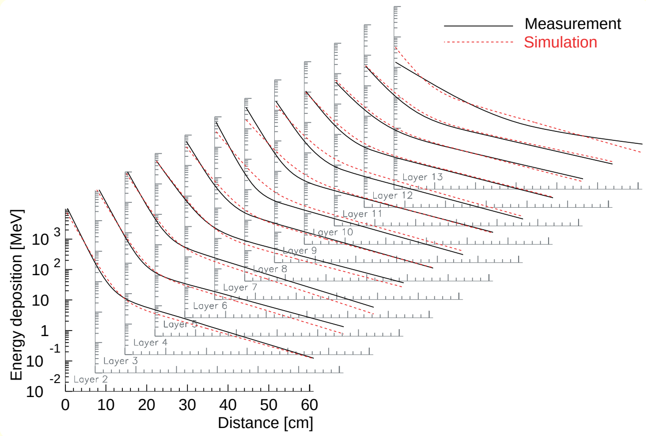
Introduction

The multi detector set-up KASCADE-Grande [1, 2] measures simultaneously the electromagnetic, muonic, and hadronic components of extensive air showers. To register the hadronic particles in EAS a large sampling calorimeter[3] is used, equipped with layers of liquid ionization chambers and iron absorbers. The energy reconstruction for this calorimeter is mainly based on Monte-Carlo simulations. To check these simulations and to provide further information about the properties of the calorimeter, a smaller set-up was exposed to a particle beam at the CERN SPS accelerator.

Experimental Set–Up

The CERN set-up has a sensitive area of 1 m^2 and a depth of about 9 λ_i. It consists of 15 layers of liquid ionization chambers (filled with tetramethylpentane (TMP,C_9H_{20})). Each layer consists of four chambers, which are divided in four pads of 25×25 cm^2.The first layer of absorber consists of 5 cm lead, the following layers of 10 cm iron, each. As projectiles electrons, hadrons, and muons with energies from 15 to 350 GeV were used. A schematic view of the detector and the actual set-up in the beamline are shown.

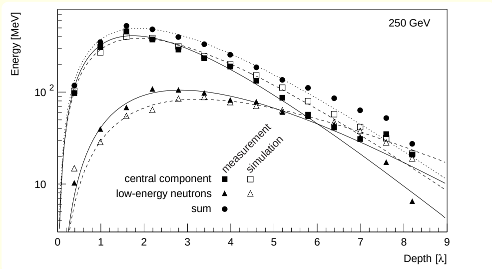




Lateral energy distributions in different layers for 300 GeV hadrons.

Energy deposition in the calorimeter

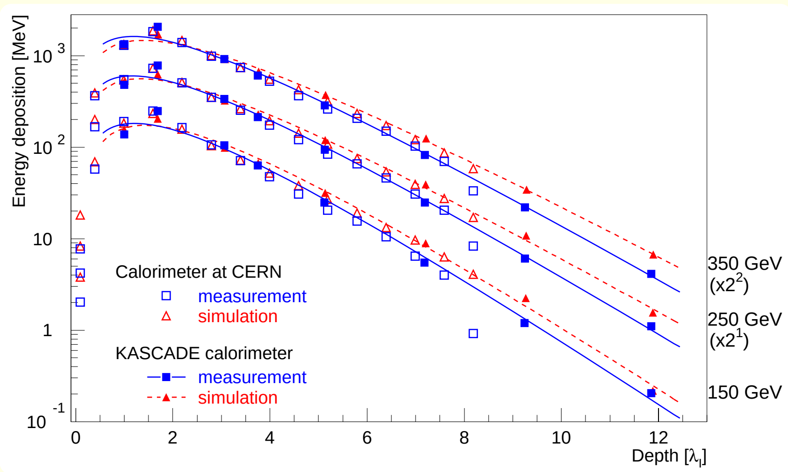
The energy deposit of hadronic cascades in the calorimeter seems to consist of two components, a strongly collimated one ($r < 20$ cm) and a weakly attenuated at larger distances. Simulations show that the latter (flat component) consists of low-energy neutrons. The measurements show that the lateral spread of the two components is almost independent of the energy of the incident particle. Both show an approximately linear dependence on the depth. Over all, there is a good agreement with GEANT/FLUKA [4, 5] simulations.



The integral of the lateral distribution function is the energy deposition per layer. These values are shown for 250 GeV hadrons. One can see that the outer component penetrates deeper and is less attenuated.

The longitudinal profiles are approximated by $E_{dep}(t) = A \cdot t^{\mu} \cdot \exp(-t/\lambda_0)$, where t is the depth in the absorber, λ_0 the attenuation length at larger depths, μ characterizes the grow of the particle multiplicity, and A is a normalization constant.

Comparison with air shower data



To compare the accelerator measurements with air shower data the KASCADE trigger conditions were applied to the CERN data and for the air shower data narrow energy intervals $\Delta\lg(E/GeV)=0.1$ have been chosen. Cosmic ray induced single hadrons [6] have been selected, because they should exhibit a similar behavior as artificially accelerated hadrons. The results of the two measurements show good agreement, but the simulations reveal a weaker attenuation in the deeper layers. This effect can also be seen in the figures above for the individual components. For both, measurements and simulations, the position of the cascade maximum increases as function of energy by about 0.67 λ_i/decade, but the maximum is shifted deeper into the absorber by about 0.1 λ_i for the simulations. The good agreement in the development of the cascade for the artificially accelerated and for the cosmic ray induced hadrons is an important result, since this verifies the calibration chain applied for the air shower measurements.

Summary

The accelerator measurements proof the validity of the calibration chain for the KASCADE-Grande hadron calorimeter and deficiencies in simulations of the cascades, as pointed out earlier [3], have been confirmed.

References

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[4] Geant 3.21 detector description and simulation tool, CERN Program Library Long Writeup W5013, CERN(1993).
[5] P.A. Aarnio *et al.*, FLUKA user's guide, Technical Report TIS-RP-190,CERN(1990).
[6] T.Antoni *et al.*(KASCADE Collaboration),*Astrophys.J.* 612,914(2004).