ICRC2015

ICRC

The Astroparticle Physics Conference

34th International Cosmic Ray Conference
July 30 - August 6, 2015
The Hague, The Netherlands

Contribution ID: **980** Type: **Oral contribution**

A universal description of temporal and lateral distributions of ground particles in extensive air showers

Monday 3 August 2015 15:45 (15 minutes)

Extensive air showers are traditionally described with phenomenological models - often called Lateral Distribution Functions (LDFs) - of the density of particles at the ground and derived quantities. The concept of air shower universality aims at a deeper understanding of the shower development in the atmosphere by taking into account physical properties of different types of secondary particles. Our extended model is based on the well known universal behaviour of the electromagnetic as well as of the muonic component and of its accompanying electromagnetic halo. A fourth component of electromagnetic particles from pion decays close to the observation level is considered in addition. Eventually the model allows for a description of particle distributions at observation level as a function of a few macroscopic quantities: the total energy E, the depth of the shower maximum X_{max}, the muon content N_μ and the geometry of the shower. The pure electromagnetic component is determined by E and X_{max} while differences between hadronic interaction models and primary particles are absorbed in the muon scale, affecting the three remaining components. We will detail the basic concepts of the extended universal description of air showers and describe the application using the detector response of the water-Cherenkov detector array of the Pierre Auger Observatory as an example. Both, the signal response of particles and their time of arrival in the detectors are accounted for in the reconstruction. The universal parameterizations of the components allow us to estimate X_{max} and N_μ event-by-event solely based on the measured footprint of the air shower at observation level. The shower maximum is reconstructed with a resolution of $30 - 50$ g/cm^2 depending on energy and zenith angle of the shower. The applicability of the method, limitations and model dependence will be discussed.

Collaboration

– not specified –

Registration number following ”ICRC2015-I/”

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Session Classification: Parallel CR14 Hadr Int

Track Classification: CR-EX