# ABSTRACT

A clear understanding of the cosmic ray (CR) mass composition is essential to the solution of the long standing mystery about their origin. The mass and therefore the charge distributions can offer powerful constraints on the acceleration mechanisms and propagation from their sources. In the vicinity of several spectral structures (*viz.* the *knee*, the *ankle* and *GZK* suppression) in the primary CR energy spectrum, any measurement of the CR mass composition is expected to give important clues to the origin of these features. On the other hand, the interaction cross–section, multiplicity and elasticity of the interactions in the atmosphere may vary from one type to another type of the CR particle. Hence, the CR mass composition is very essential not only for exploring interesting astrophysical phenomena, but also for systematic studies of high–energy hadronic interactions.

The most salient feature of the thesis is to search relatively new CR mass sensitive air shower observables in a multi-observable approach exploiting different characteristics of extensive air showers (EASs) initiated by primary particles around the *knee* region from a detailed Monte Carlo simulation. Such a strategy ensures the reliability of our findings and the validity of applied detection techniques, and hadronic interaction models. For implementing our stated goals, a number of new EAS analyses sensible to the CR mass composition are proposed. Moreover, the practical realization of these proposed techniques on real experiments are also under consideration in this thesis. In some cases, our results obtained on mass composition from these new analyses are compared with observed results available publicly from the NBU and KASCADE experiments.

A study has been carried out on the lateral distribution of electrons in EAS by analyzing CORSIKA generated shower events in the *knee* region. The study takes into account the issue of the lateral shower age parameter associated with the lateral distribution of electrons as an indicator of the stage of development of EASs in the atmosphere. A multi-parameter study of EAS is exploited to correlate the lateral shower age parameter with other EAS observables to identify the nature of the shower initiating primaries. Using KASCADE data we have found a transition from light to heavy mass composition around the *knee*.

From the characteristics of lateral distributions of electrons and muons of simulated EAS, some important EAS observables are extracted by a novel approach, and their CR mass-sensitivity is demonstrated. The study focuses on the issue of the experimental lateral density profiles of EAS electrons and muons after introducing the notion of the local age and segmented slope parameters, aimed to extract information on CR mass composition from observed data. The estimated lateral shower age from the analysis of the KASCADE data agrees with the idea of a gradual change of CR mass composition from light to heavy around the *knee*.

The polar asymmetry in the lateral density distribution (LDD) of electrons in non-vertical showers opens up a possibility for the estimation of the CR mass composition. This polar asymmetry arises from a combination of the atmospheric attenuation of EAS electrons and geometric effects related to the arbitrary direction of propagation of electrons into the shower. The magnitude of these effects is quantified by a novel observable, called gap length (GL), which exhibits sensitivity to the CR mass composition. Incorporating geometric and attenuation effects into the longitudinal development of an EAS, a modified polar angle dependent lateral density function (LDF) is proposed for obtaining EAS observables from simulated/observed LDD data.

An estimation of the energy of CRs above 100 TeV based on the lateral distribution of EASs is made. We have shown that the determination of primary energy of a CR particle might deliver a better accuracy compared to standalone analysis.

A detailed analysis has been made over the asymmetry in the abundance of positive and negative muons in an EAS with higher inclination angle as a consequence of the influence of the Earth's geomagnetic field (GF). The asymmetry has been quantified by a parameter called the transverse muon barycenter separation. The polar variation of this parameter and its maximum value (MTMBS) exhibit sensitivity to CR mass composition. Possibility of practical realization of the proposed method in a real experiment is also discussed.
Moreover, the MTMBS parameter obtained from $\mu^+$ and $\mu^-$ asymmetries in an EAS solely due to the GF can be exploited to estimate Earth's magnetic field in an unknown place with certain geographical latitude and longitude.