PREFACE

The origin of cosmic rays remains one of the greatest challenges in modern physics. Cosmic rays span an enormous range of energy from about 10^9 eV to beyond 10^{20} eV. The energy spectrum of primary cosmic rays exhibits power law behaviour with an energy spectrum that is essentially a continuous power law. At about 3×10^{15} eV the primary cosmic ray spectrum steepens slightly. This feature is commonly called the *knee* of the spectrum. Because of the presence of the *knee* feature the PeV energy region is an area of intense study in cosmic ray research. The proper explanation of the *knee* is supposed to be a corner stone in understanding the origin of cosmic rays.

The knowledge about the composition of primary cosmic rays in the PeV domain is of fundamental importance for understanding the *knee*. However, despite several extensive experimental efforts no definite conclusion on change of composition across the *knee* could be drawn. This is mainly because of the inverse problem of deriving the mass composition of cosmic rays from EAS measurements, which is an indirect but only feasible way of studying cosmic rays at this energy range owing to low flux of primary cosmic rays, is quite difficult.

Under this context various aspects related to PeV cosmic rays, which include MC simulation study of detailed characteristics and primary mass sensitivity of few EAS parameters/observables (shower age and muonic dipole length) for the purpose of employing them to extract the nature of primary particle reliably through a multi-parameter approach of studying EAS, a critical examination of the proton-air and Fe-air interaction cross section measurements by the EAS technique in order to gain physical insight for the deviation of EAS absorption length from interaction mean free path of PeV cosmic ray particles in the atmosphere, and quantifying the neutrino and gamma ray signatures of PeV cosmic rays if they are accelerated by polar caps of pulsars, have been investigated and reported in this thesis.

The important findings of works reported in the present studies are listed below:

[i] The lateral distribution of electrons in EAS exhibits some sort of *scaling* behaviour in terms of the local lateral shower age parameter. This feature is

nearly independent of the primary energy, mass, observational level and hadonic interaction model.

[ii] The local age parameter (LAP) offers a good solution towards an unambiguous estimation of the lateral shower age.

[iii] The lateral shower age offers a good estimator of the longitudinal development of an EAS cascade on a statistical basis, as also noted in some earlier works.

[iv] The local/lateral shower age might be useful for extracting information about the mass of primary cosmic rays. The fluctuation of the LAP has also been found to be sensitive to the nature of the primary particle.

[v] It appears that the local age parameter, if measured with good precision can be employed in discriminating γ-ray initiated EAS from hadron induced EAS.

[vi] The "*muonic dipole length*" in inclined EAS is found sensitive to primary mass; it is larger for iron primary in compare to that for proton.

[vii] From a detail MC simulation study it is found that the air shower fluctuations has limited effect on hadron-air cross-section measurements using EAS technique, rather the characteristics of high energy interactions seem to play the major role for the deviation of EAS absorption length from mean free path of the hadron in air.

[viii] Cosmic rays at PeV energies might be accelerated at polar caps of pulsars. The presence of a hadronic component in the flux of pulsar accelerated particles should result in the emission of high-energy neutrinos and gamma-rays simultaneously as both charged and neutral pions are produced in the interactions of energetic hadrons with the ambient photon fields surrounding the acceleration region. We estimated gamma-rays and neutrino fluxes for some nearby gamma-ray pulsars and compared with the available observations. The present study suggests that pulsars are unlikely to be strong sources of TeV neutrinos.

As an additional support to the candidate, the reprints of the following **published papers** are attached at the end of the thesis.

1. A Bhadra and R K Dey, "TeV neutrinos and gamma-rays from pulsars", *Monthly Notices of the Royal Astronomical Society*, **395**, 1371 – 1375 (2009), e-Print: arXiv: **0812.1845v1** [astro-ph].

2. R K Dey, A Bhadra and J N Capdevielle, "Behaviour of the EAS Age Parameter in the Knee Energy Region", Fermilab *eConf* **C1006284**, *XVI ISVHECRI* (2010), e-Print: arXiv:**1009.5396v1** [astro-ph.HE].

3. R K Dey and A Bhadra, "Gamma-hadron discrimination of primary cosmic rays from EAS observations", *Exploring the cosmos*, ISBN – **978-3-8443-9165-7**, Ed. A Bhadra, *LAMBERT Academic Publishing*, Germany (2011), p 93-105.

4. R K Dey, A Bhadra and J N Capdevielle, "Primary mass sensitivity of lateral shower age parameter in EAS", *Proceedings International Cosmic Ray Conference*, Beijing (2011), HE.**1.2.**, vol. **1/11**, p.174 – 177.

5. J N Capdevielle, R K Dey and A bhadra, "Imprint of Geomagnetic field on charged particle distribution in EAS", *Proceedings International Cosmic Ray Conference*, Beijing (2011), HE.**1.1.**, vol. **1/11**, p. 133-136.

6. R K Dey, A Bhadra and J N Capdevielle, "Scaling behaviour of lateral distribution of electrons in EAS", *Journal of Physics G: Nuclear & Particle Physics,* **39** (2012), 085201.

7. R K Dey and A Bhadra, "Selecting gamma-ray showers from hadronic background using lateral shower age of EAS" *Astroparticle Physics* **44** (2013) 68 – 75.

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Work from the following publication is not included in the thesis:

1. A Bhadra and R K Dey, "Physical significance of the lateral shower age", *Proceedings International Cosmic Ray Conference*, Germany, Copernicus Gesellschaft (2001), **185**.

(Rajat Kumar Dey)

Department of Physics
University of North Bengal
P.O.- North Bengal University
Darjeeling (WB): India.