RICC Usage Report for Fiscal Year 2013

Project Title:

Study on the performances of the JEM-EUSO mission

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The JEM-EUSO mission is a space based Ultra High Energy Cosmic Ray observatory planned to fly on the International Space Station in FY 2016. This project sees the collaboration of more than 300 scientists from 15 countries. The Computational Astrophysics Laboratory led by Toshikazu Ebisuzaki and Marco Casolino plays a key role in developing the instrument and planning the mission. Ultra High Energy Cosmic Rays (UHECR) are extremely high energy (1e20eV) particles propagating in space. Both the sources and mechanisms responsible for the production of such enormous energies are presently unknown. Moreover the extremely high energies offer the unique opportunity to test the interaction of matter at energies many millions of times higher than reachable by any human made accelerator. In order to solve the longstanding UHECR origin problem and to start the study of physics at such high energy we are in the process of constructing a UV telescope to detect the light emitted by the cascades of secondary particles generated by UHECR as they interact with Earth's atmosphere. This telescope will be placed on the International Space Station (ISS) and monitor atmosphere from above. Due the high risk related to the space mission busyness massive simulation studies must be performed prior to the mission launch. Moreover the data processing framework has to be established in order to analyze the scientific output of the mission.

In particular, we are involved in the development of the simulation framework for the JEM-EUSO mission (Euso Simulation & Analysis Framework). The ESAF software takes care of the simulation of the Cosmic Ray events, the propagation of light to the instrument and the simulation of the instrument itself. Moreover it performs the data analysis on the detector response in order to recognize the signal on the focal surface, determine arrival direction, energy and type of incoming particle.

The most important contribution of FY 2013 work is related to the reconstruction of the primary particle parameters. More in detail during this year I was conducting an extensive study on the energy and Xmax reconstruction performances. For this purpose the recognized signal has been therefore rescaled through all the reconstruction steps. Each step is correcting the inefficiency factors of a particular stage of the detection process. I therefore start from the signal at the detector and apply the correction of the optics, the transmittance in the atmosphere and the amount of photons produced by each secondary electron in the shower in order to achieve an estimate of the shower profile. Such a feature is expressing the number of secondary particles as function of development and is then fitted with a standard shower parametrization. Eventually I get an estimate of the energy and Xmax parameters. The Xmax will be used for the determination of the particle type. A longer shower will be typically indication of a lower primary mass while a shorter one will indicate a heavier primary.

At first, the consistency between reconstruction and simulation processes has been verified. Each step has been therefore verified and the inefficiency factors obtained in the simulation have been compared with the one modeled in the reconstruction. A mismatch between the two factors has to be considered as a systematic and eventually to be corrected. The RICC facility was used to produce a large amount of cosmic ray events in fixed conditions in order to test the deviation of the Montecarlo simulation from the model applied in the reconstruction. The reconstructed shower geometry has been forced to be the same as the simulated one to reduce the amount of uncontrollable systematics. The systematics were assessed in several conditions and the corresponding tables have been produced. Such tables have been used to correct the total bias of the reconstructed energy and Xmax.

The following step was to verify the behavior of the algorithms in fixed conditions. The RICC facility was again used to simulate several sets of events in fixed conditions and to apply the reconstruction algorithms to them. A wide study has been performed to characterize the reconstruction in different conditions of zenith angle, energy and field of view position. In all such conditions I therefore calculated the average bias and the width of the distribution of the reconstructed energy and Xmax.

Part of this study consisted also in the estimation of the quality of the reconstructed events. The first quality parameters I used were the chi square per degree of freedom and the number of points. I defined also other quality parameters such as the distance of the signal from photomultipliers gaps. All such parameters were used for the definition of cuts which on their own were used to define efficiency curves. Such curves are used in the analysis phase to define the exposure associated to each cut.

The efficiency in the recognition of the shower ground impact through the detection of the so called Cherenkov reflection peak has also been estimated.

Another very important study consisted in the simulation of the entire event sample. The events have been therefore simulated with various inclinations, energies and field of view positions. The events have been reconstructed and a more realistic estimation of the JEM-EUSO performances has been given. The median and the sigma of the energy and Xmax distributions through all the spectrum has been calculated.

The reconstructed energy spectrum has been also produced and compared with the simulated one.

Such results have been produced for my PhD thesis which is now public. A further publication for the Experimental Astronomy journal has been prepared and is currently in the internal revision process of the JEM-EUSO collaboration. In the following weeks the publication will be submitted to the journal.

Fiscal Year 2013 List of Publications Resulting from the Use of RICC

[Publication]

[Proceedings, etc.]

[Oral presentation at an international symposium]

[Others]

- PhD Thesis, F. Fenu, Tübingen 2013, "A simulation study of the JEM–EUSO mission for the detection of ultra–high energy Cosmic Rays"

RICC and RIKEN have been included in the aknowledgements.