RICC Usage Report for Fiscal Year 2014

Project Title:

Study on the performances of the JEM-EUSO mission

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The JEM-EUSO collaboration is committed to the development of space based Ultra High Energy Cosmic Ray observatories. In this framework we are developing mission concepts like JEM-EUSO, K-EUSO, the EUSO-Balloon, mini-EUSO and TA-EUSO. This project sees the collaboration of more than 300 scientists from 16 countries. The Computational Astrophysics Laboratory led by Toshikazu Ebisuzaki and Marco Casolino plays a key role in this effort. The group leads, in fact, the development of detectors like K-EUSO, TA-EUSO and mini-EUSO, supervises the production of the Fresnel lenses and of the photodetectors of the telescopes.

Ultra High Energy Cosmic Rays (UHECR) are high energy particles (above 10^{19} eV) propagating in space. Both the sources and the mechanisms responsible for the production of such enormous energies are presently unknown.

The space detection of cosmic rays, the ultimate goal of the JEM-EUSO collaboration, offers the possibility to increase the observational exposure of such extremely rare particles of at least one order of magnitude compared to ground arrays. Above such energies just one particle per km^2 per century can in fact be detected and therefore only a detector from 400 km altitude and with a large field of view can achieve a sufficient exposure.

In such conditions space detectors can in fact monitor surfaces of the order of 10^5 km^2.

Due to the high risk related to the space 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 - ESAF (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 signal can be imagined as a spot moving on the focal surface. By means of fits on the position and timing of the signal the direction can be inferred. Thanks to the luminosity as function of time the energy of the primary can be also calculated. Another observable we are going to retrieve is the depth of the maximum of the shower. Thanks to this parameter we can give a rough estimation of the average mass of the particle population.

The main purpose of my activity at RICC was the study of the performances of the energy and X_{max} reconstruction algorithms for the JEM-EUSO mission. We can in fact reconstruct the amount of secondaries in the shower after the correction of the inefficiencies of the optics, the atmospheric transmittance and the fluorescence yield estimation. We then perform the fit of this profile with a standard shower function. Free parameters of this fit are the energy and X_{max}.

I performed a large set of simulations on the RICC cluster covering the entire parameter space in order to assess the energy reconstruction. Samples of 8000 showers have been therefore simulated in fixed direction, position and energy. The energy reconstruction has been performed and a series of plots showing the resolution in all such conditions has been produced. This is in order to characterize the algorithms in all the different conditions.

A larger sample with a continuous distribution of field of view positions, inclinations and energies has been also produced and the reconstruction has been performed on it. This is done in order to have an overall energy reconstruction resolution value. Plots giving the resolution for different energies for all the mixed conditions have been produced. I also set minimal quality cuts on the reconstructed events and I assessed the fraction of good quality events with respect to the triggered sample.

The same samples have been used to apply the X_{max} reconstruction but this time I limited the analysis just in the central part of the field of view and in fixed conditions. In fact, the X_{max} reconstruction proved to be much more challenging than the energy reconstruction. A preliminary study has been therefore performed in order to prove the

establishment of the entire chain for the reconstruction of X_{max}. The X_{max} resolution in such limited set of conditions has been calculated but future more detailed studies must be performed in order to assess the resolution of such parameter.

Such results are the core of the publication "Performances of JEM–EUSO: energy and X_{max} reconstruction" on the Experimental Astronomy Journal. This contribution has been accepted for publication. RIKEN has been included in my affiliation list and RICC has been included in the acknowledgements.

The above mentioned studies have been performed in clear sky conditions but I am currently adapting the code for the reconstruction in cloudy sky condition. In fact, being JEM-EUSO a space based observatory, which monitors the atmosphere from above, it will have to cope with clouds. I plan to start mass simulations in the next weeks and to prepare an assessment of the energy reconstruction performances in cloudy conditions. A publication will be prepared in this sense within the next months.

A further study is related to the K-EUSO detector. Such detector is, in the framework of the JEM-EUSO collaboration, a mission concept developed in collaboration with the KLYPVE collaboration and it consists of a reflective optics. The study currently carried out on RICC consist in the calculation of the trigger exposure in different detector configurations. Showers are therefore simulated in various conditions and the trigger efficiency is calculated. These results will be used by the collaboration to properly steer the development of the mission.

Fiscal Year 2014 List of Publications Resulting from the Use of RICC

"Performances of JEM–EUSO: energy and X_{max} reconstruction" on the Experimental Astronomy Journal. Accepted for publication.

[Publication]

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