Expected Performances of the JEM-EUSO Mission

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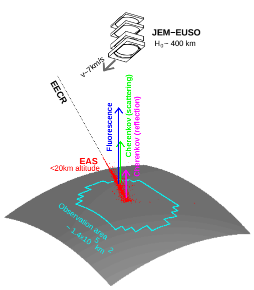
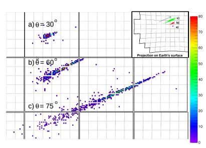
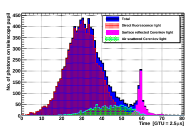
Abstract: JEM-EUSO (Extreme Universe Space Observatory on Japanese Experimental Module) is the new type space-based observatory to explore the extreme-energy-region Universe in particle channel by means of fluorescence technique. In the present work, we present the estimated aperture of the JEM-EUSO telescope in observing extreme energy cosmic rays for various conditions.

JEM-EUSO (Extreme Universe Space Observatory onboard Japanese Experiment Module, Ebisuzaki *et al.* 2012) is the new type space-based observatory for extreme energy cosmic ray (EECRs ; $E_0 \gtrsim$ several 10^{19} eV) observation. The JEM-EUSO telescope will be accommodated on the International Space Station.

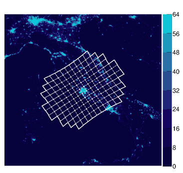


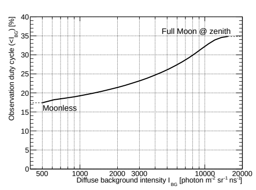




Observing from an $\sim$ 400 km altitude, substantial nubmers of photons from the EECR-initated extensive air showers (EASs) are detected in UV band (λ = 300–400 nm) by the JEM-EUSO telescope of a 4.5m^2 aperture Thanks to an $\sim$60°-wide FOV, the JEM-EUSO is capable of measuring the full portion of EAS development especially for large zenith angles θ. The detected singals are characterised by directly arriving fluorescence photons and by Cherenkov light scattered or reflected from the Earth's albedo.

Extremely low fluxes of EECRs (few km^{-2} per millennium!) essentially requrie the huge exposure that is primarily determined by the aperture (geometrical and instrumental as of trigger probability) and background (BG) and atmospheric conditions.



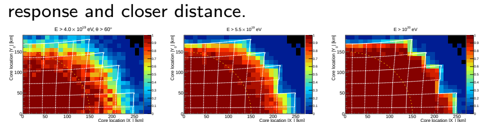


The geometrical aperture, when the telescope points to nardir, is product of solid angle acceptance π sr and observation area of $\sim 1.4\times10^5$km^2 as is comparable of a part of Italy. The BG conditions limits the observation time and effective aperture. The predominant BG source is night glow that has an intensity of $\sim$500 photons m^{-2} ns^{-1} sr^{-1} order (Garipov *et al.* 2005). Unlike ground-based observatories, the only back-scattered moonlight contributes to BG and therefore the observation time may be enhanced by accpeting the Moon presence. With a threshold 1500 photons m^{-2} ns^{-1} sr^{-1}, the observational duty cycle yields to 21%.

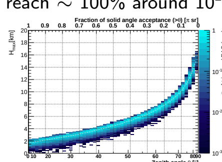
The locally affect BG sources include light pollution by the man-made light. The effect of such artifical light was evaluated using satellite data measured by DMSP which is also demonstrated in the previous FOV iamge. It was concluded that only $\sim$9% area exceeds the same threshold level (Adams, Jr *et al.* in preparation).

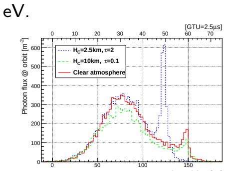
In the condition of nominal BG level with no Moon, the trigger aperture was evaluated by the Monte Carlo simulation based on ESAF (Euso Simulation and Analysis Framework) code (Berat *et al.* 2010). The ESAF which was originally developed for EAS-driven EUSO mission has been implemented with the baseline JEM-EUSO configuration and trigger algorithms (Catalano *et al* 2009, Kajino *et al* 2011 and Fenu 2011 *et al.*).

The following maps show the trigger probability as a function of core location with different cuts in E_0 or/and in θ (only quadrant of FOV projected on Earth surface is shown since the detector response is symmetric). Inner part of FOV allows higher efficiency due to better optical response and closer distance.



Applying tight cuts in θ >60°, ie 1/4 of solid angle acceptance, select EASs with more intense signals. Those EASs landing within 150 km from the FOV centre provide $\sim$ 100% trigger probability even at $\sim 4\times10^{19}$ eV. Releasing such cuts, the proabality increases with E_0 and reach $\sim$ 100% around 10^{20} eV.



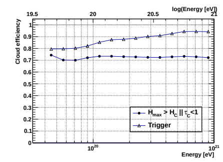


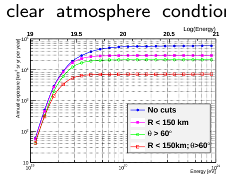
In the orbit the JEM-EUSO telescope inevitably observes the region with clods. The cloud impact compared to ground-based observation is less thanks to the fact that EAS development may reach its maximum above the typical cloud altitudes. Observed shower profiles in cloudy conditions may be attenuated by the presence of optically thin clouds (eg. cirri). In case of optically thick clouds (eg. strati), the photons emitted below cloud altitude are blocked, while intense reflection of Cherenkov light helps better indenty core location.

To investigate the cloud impact more quantitatively, the cloud occurances within the JEM-EUSO orbit were investigated using TOVS database in the matrix of cloud-top altitude H_C vs optical depth τ_C

Optical depth τ_C	Cloud-top altitude H_C [km]			
	<3.2	3.2–6.5	6.5–10	>10
>2	16%	5.9%	8.6%	5.0%
1–2	6.0%	3.0%	4.2%	2.5%
0.1–1	6.5%	2.0%	3.2%	5.0%
<0.1	31%	<0.1%	<0.1%	1.2%

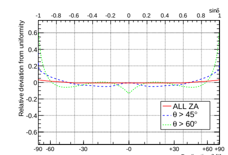
EASF simulation was made taking the cloud occurrence and resulted trigger aperture was compared as a ratio to the case of clear atmosphere condtion.





By selecting EAS with maximum above H_C or optically thin clouds τ_C, the ratio stays constant with energy and is $\sim$ 70%. Taking into account all factors previously argued, the expected expsosure per year was estimated for different geometrical cuts as a function of energy. With tight geomerical cuts, the constant expsoure allows direct comparions of EECR fluxes with ground-based observatories down to (3–4)$\times10^{19}$ eV. Once such comparison is established, full FOV provides about an order higher expsoure than Auger ($\sim$ 7000 km^2 sr per year; Abraham *et al.* 2010) at higher energies.

It is also worthy to mention that the JEM-EUSO if capability of observing EECRs at high degree of uniformity over the entire Celestial Sphere.



The reconstruction capabilities have been also estimated using the ESAF code. The technique to reconstruct the different shower parameters is extensively discussed in Fenu *et al.* 2011. At the current status of development of the reconstruction algorithms, proton EASs with $\theta > 60°$ are reconstructed in clear atmosphere at a typical energy resolution $\Delta E/E$ of $\sim$ 20% (25%) at $E_0 = 10^{20}$ eV (4×10^{19} eV). This result indicates that the reconstruction of events with $E < 5\times10^{19}$ eV is feasible confirming the possibility of overlapping with ground based experiments over a sufficient wide energy range. For the arrival direction analysis, our current results indicate that showers of $E \sim 7\times10^{19}$ eV and $\theta > 60$ ° can be reconstructed less than 2.5∘ (68% CL). Eventually our still preliminary results indicate that the Xmax resolution (Δ X_{max}) is better than 70 g cm^{-2} for $E \sim 10^{20}$ eV.

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