JEM-EUSO experiment for extreme energy cosmic rays observation

B.Pastirčák, K.Kudela and P. Bobík for the JEM-EUSO collaboration
Institute of Experimental Physics SAS, Košice

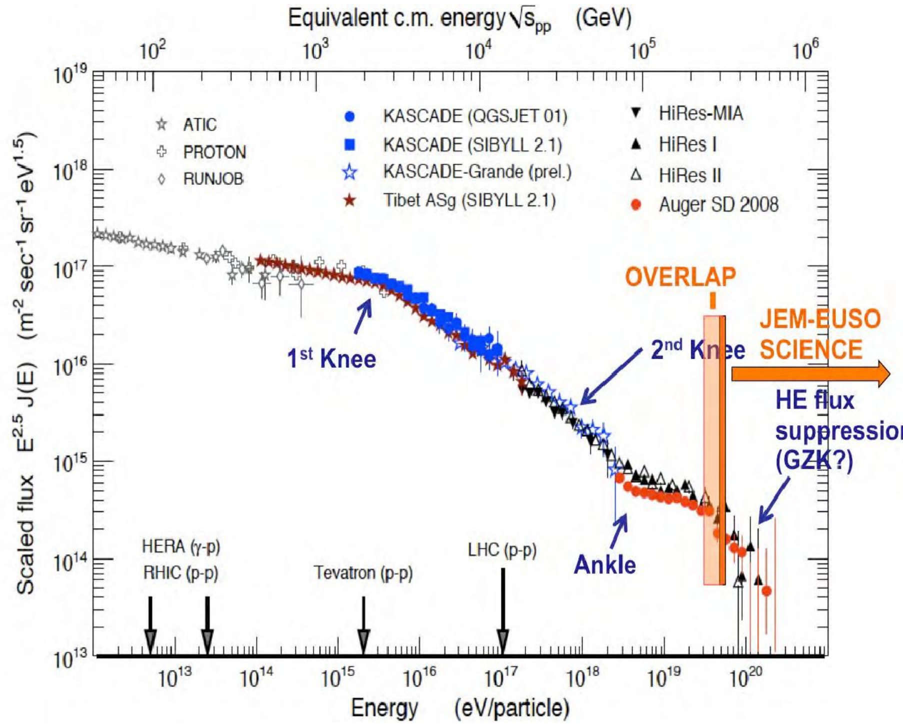
PIC 2012, Štrbské pleso, *12. - 15. september 2012*

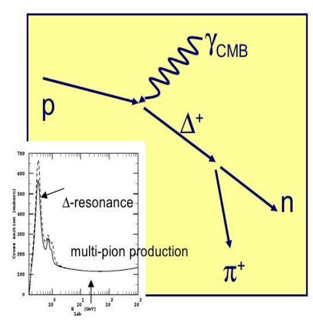
Extreme Universe Research by JEM-EUSO

JEM-EUSO is the first space mission devoted to the exploration of the Universe through the detection of the extreme energy cosmic rays. It is designed to achieve its main scientific objective: astrophysics through the particle channel to identify sources by arrival direction analysis and to measure the energy spectra from the individual sources with a very high collecting power

The highest observed cosmics rays energy is about $3x10^{20}$ eV - > 10^8 times over CERN LHC energy scale – is above so called GZK cuttof, which is due to interactions of cosmic rays with the cosmic microwave background. The registration of EECRs at the earth in ground based observatories (HiRes, AGASA, Pierre Auger Observatory) implies that the sources are up to several tens Mpc far.

Possible EECRs sources are: supernovas, pulsars, gamma ray bursts, active galactic nuclei and recent collisions of radiogalaxies. But most of these candidates are incapable of accelerating particles beyond 10^{20} eV by any known acceleration mechanism.





$$E_{th} = \frac{2m_N m_p + m_p^2}{4e} \rightarrow 5 \cdot 10^{19}\,\text{eV}$$

Extreme Universe Research by JEM-EUSO

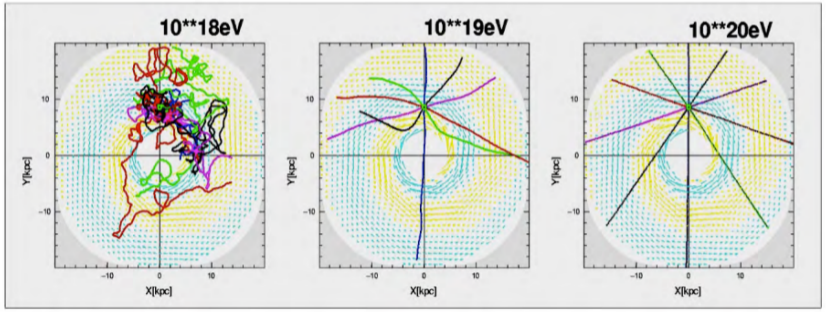
Lower energy charged particles are bent by magnetic field in intergalactic and galactic space. The directional information of their origin is lost. The highest energy particles are barely bent, so retain the information of the direction to the origin.

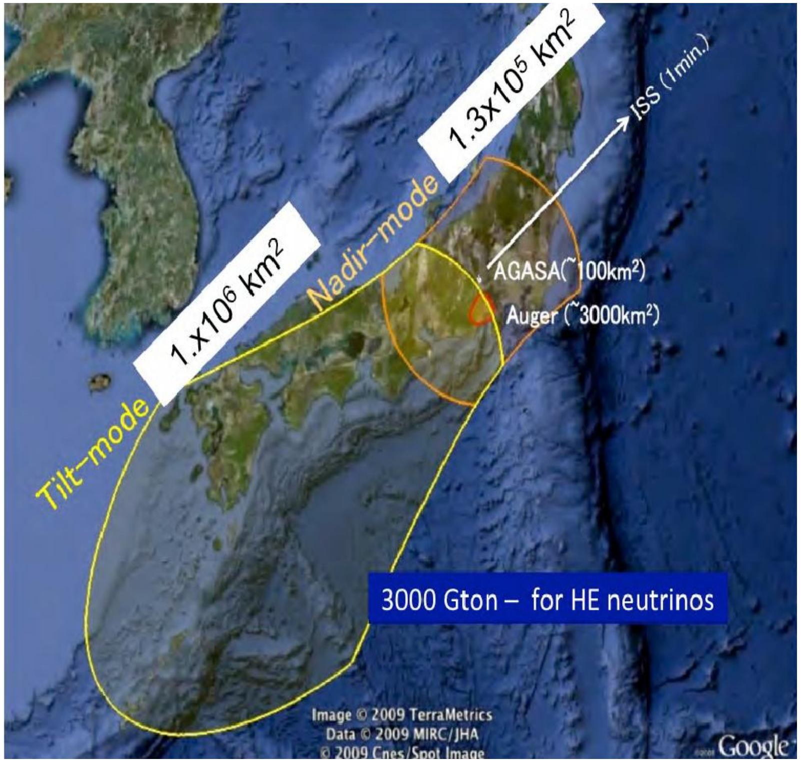
However, to observe the source enough statistics necessary - at ECCRs extremely low fluxes – it is very difficult.

Very large area for observation is essential to observe the rare EECRs events. Ground based observatories have nearly reached the maximum extent possible on earth. Space observatory makes a giant leap in the area size observed.

Second big advantage is that from orbit, JEM-EUSO will monitor, with a rather uniform exposure both hemispheres minimizing the systematic uncertainties that strongly affect any comparison between different observatories exploring, from ground, different hemispheres

Galactic-MF structure & UHECR propagation





JEM-EUSO Collaboration

Extreme Universe Space Observatory onboard the ISS Japanese Experimental Module

Common project of cosmic agencies JAXA, NASA, ESA, Roskosmos and 13 collaborating countries → (77 institutions, over 250 researchers).

The leading country is Japan, which provides the basic infrastructure including a vehicle HII-B, a spaceship HTV and the position for detector emplacement onboard the ISS Japanese Experimental Module Kibo.

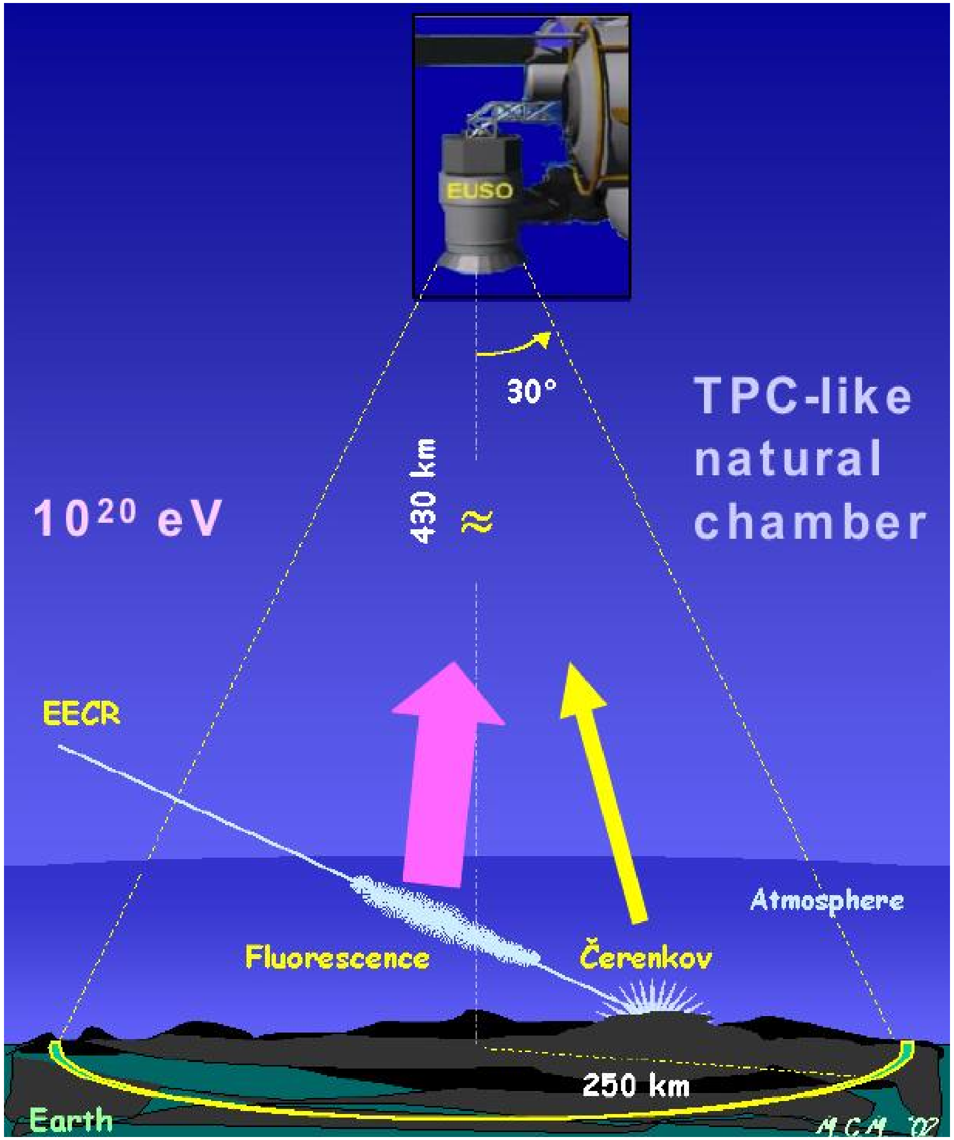
It will operate minimum 3 years of starting from January 2017

Principle of JEM-EUSO operation

On the orbit of altitude 400 km the JEM-EUSO telescope detects fluorescence and Cherenkov light from the EAS. The former directly heads to the telescope. The latter is observed either because of scattering in the atmosphere or because of diffuse reflection from the surface. An incoming 10^{20} eV EECR produces an order of 10^{11} particles. Secondary particles are still relativistic and the charged particles, dominantly electrons, excite the N molecules to emit UV fluorescence light of characteristic lines in the band $\lambda \sim 300 - 430$ nm. Along the development of a EECR EAS, an order of 10^{15} photons are isotropically emitted. Seen from $\sim$ 400 km distance it results in several thousands photons reaching the pupil of the telescope. A luminous spot of them moving by the speed of light are observed by the telescope.

The JEM-EUSO telescope would act as a calorimeter and as a TPC at the same time.

The species, energy and direction of the primary particle could be well determined.

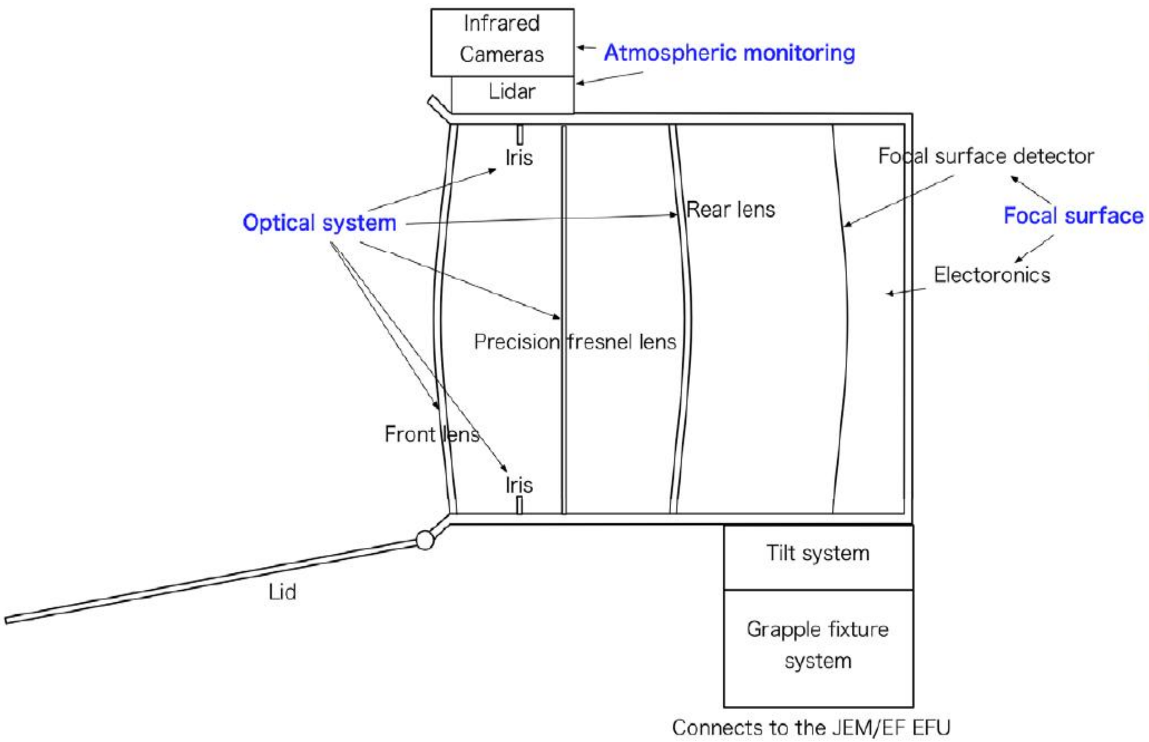


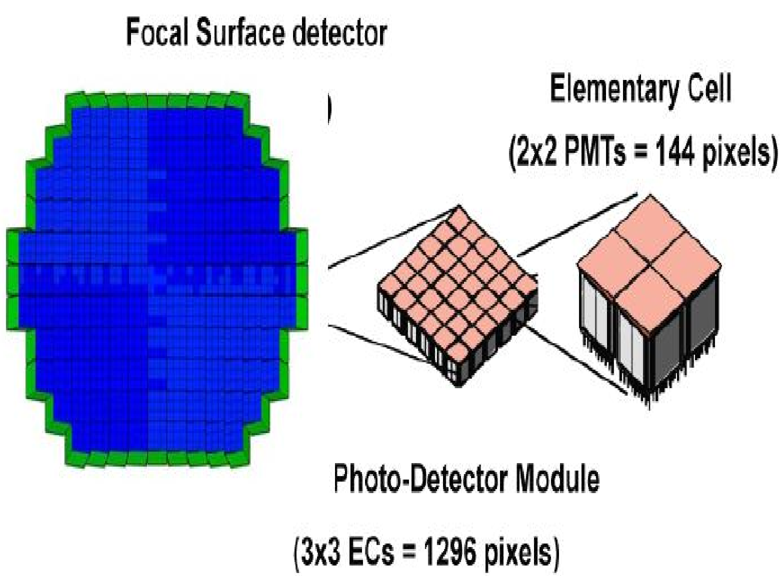
JEM-EUSO instruments

The JEM-EUSO telescope is an extremely fast, highly pixelized, large-aperture and wide-FoV digital camera, working in near ultraviolet (UV) wave-length band between about 300 and 430 nm with single photon counting capability. It records “video clips” of fast moving UV tracks sensing the fluorescence light representing the temporal development of EAS.Technically, telescope mainly consists of four parts: the photon collecting optics, the focal surface detector, the electronics and the mechanical structure

Diameter of telescope is 2.5 m. Camera takes 400000 frames/s. It defines the basic time unit of detector operation (GTU). Telescope on Focal Surface consists of more than 300000 pixels. It implies 500mx500m resolution at the ground. These allow to record cascade in angle and time.

Equiped by Atmospheric Monitoring System → LIDAR and IR camera to precise estimate atmospheric conditions





Our contribution to JEM-EUSO preparation

- **Estimation of the UV background on the night side of the Earth**
- **Determination of the JEM-EUSO operational efficiency**
- **The fake trigger background simulations and analysis**

UV background and operational efficiency

- Sources of the backgound:

reflections from sky (Moon, stars, planets), man made lights, lightnings, airglow, aurora, meteorites.

Operational efficiency is fraction of time when monitoring UV compared to full time on orbit. Above mentioned UV background sources together with ISS operation schedule had to be taken into account in the model of JEM-EUSO operational efficiency

$I_{Allowed}$ [ph/(m^2 ns sr)]	I_{SUN} > 109.18°	I_{MOON} only [%]	Cities only [%]	I_{SUN} + I_{MOON} [%]	I_{SUN} + I_{BG} + I_{MOON} [%]	I_{SUN} + I_{BG} + I_{MOON} + Cities [%]
1		50.00	90.14	17.83	0.00	0.00
10		50.11	90.14	17.85	0.00	0.00
100		51.14	90.18	18.14	0.00	0.00
300		53.45	90.18	18.72	0.00	0.00
500		55.92	90.26	19.25	0.00	0.00
1000	34.84	62.06	90.26	20.41	19.25	17.46
1500		**68.08**	**91.06**	**21.43**	**20.41**	**18.51**
5000		89.73	95.97	26.73	26.07	23.61
10000		97.85	98.81	32.69	32.20	29.15
15000		99.99	100.00	34.83	34.80	31.55
30000		100.00	100.00	34.84	34.84	31.58

Fake trigger background and analysis

The goal of the trigger system is to detect the occurrence of scientifically valuable signal among very huge background noise detected by JEM-EUSO. The UV background registered by JEM-EUSO is randomly distributed. We study if these random processes produce fake pattern, which could be mistakenly interpreted as EECRs events. We are simulating huge amount of measurements on PDM with only detector noise. To distinguish between such simulated fake events and real ECCRSs events and find the probabillity of registration fake event we are applying and developing pattern recognition methods

Level		**Rate of signals/triggers at PDM level**	**Rate of signals/triggers at FS level**
1^{st} level trigger (PDM)	Photon trigger	$\sim 9.2 \times 10^{8}$ Hz	$\sim 1.4 \times 10^{11}$ Hz
	Counting trigger	$\sim 7.1 \times 10^{5}$ Hz	$\sim 1.1 \times 10^{8}$ Hz
	Persistency trigger	~ 7 Hz	$\sim 10^{3}$ Hz
2^{nd} level trigger (PDM cluster)		$\sim 6.7 \times 10^{-4}$ Hz	~ 0.1 Hz
Expected rate of cosmic ray events		$\sim 6.7 \times 10^{-6}$ Hz	$\sim 10^{-3}$ Hz