JEM-EUSO

The Extreme Universe Space Observatory (EUSO) onboard the Japan Experiment Module (JEM) of the International Space Station

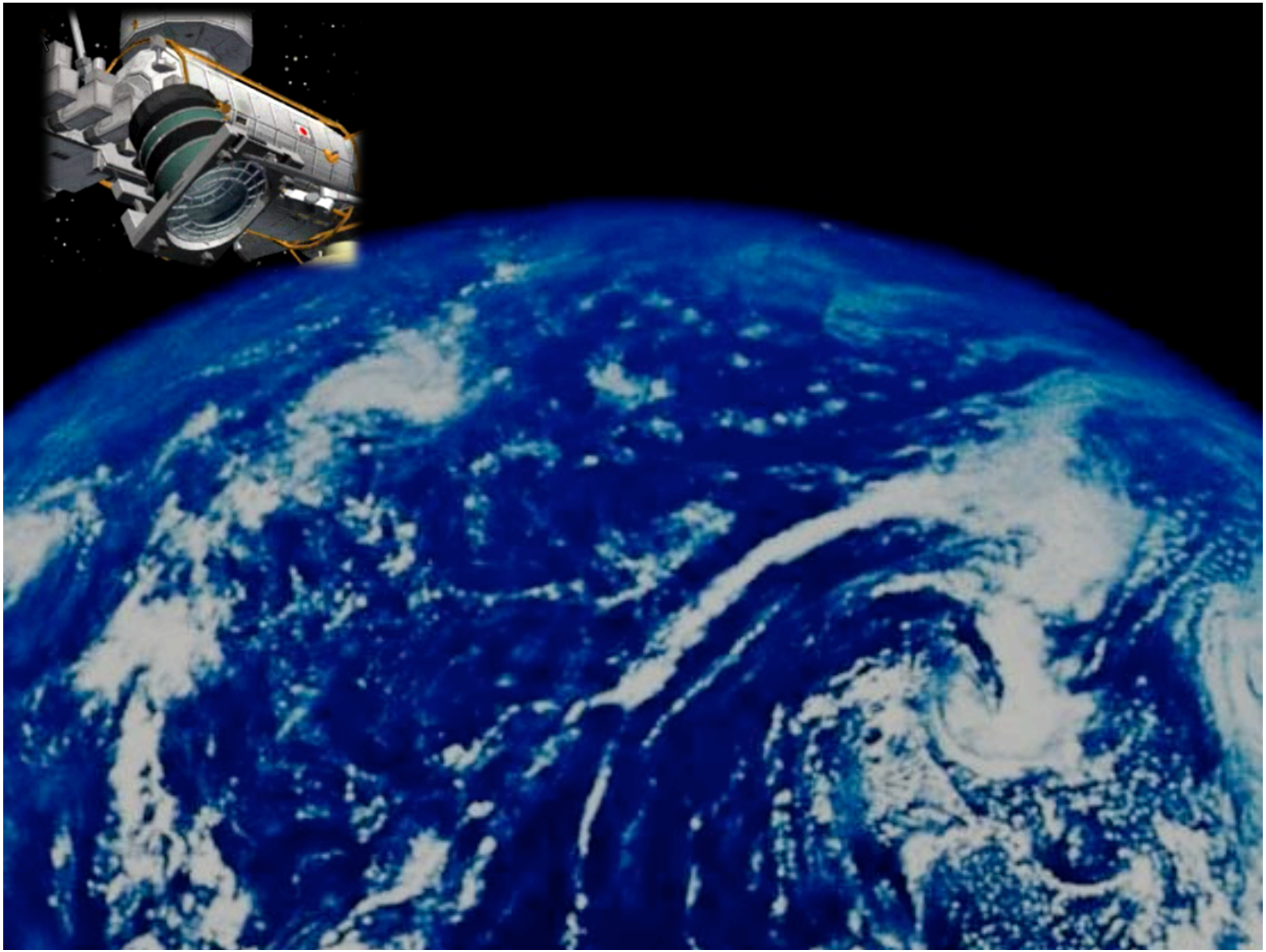
The JEM-EUSO Collaboration, led by RIKEN-Japan, brings together about 250 scientists, 76 Institutes from 13 Countries:

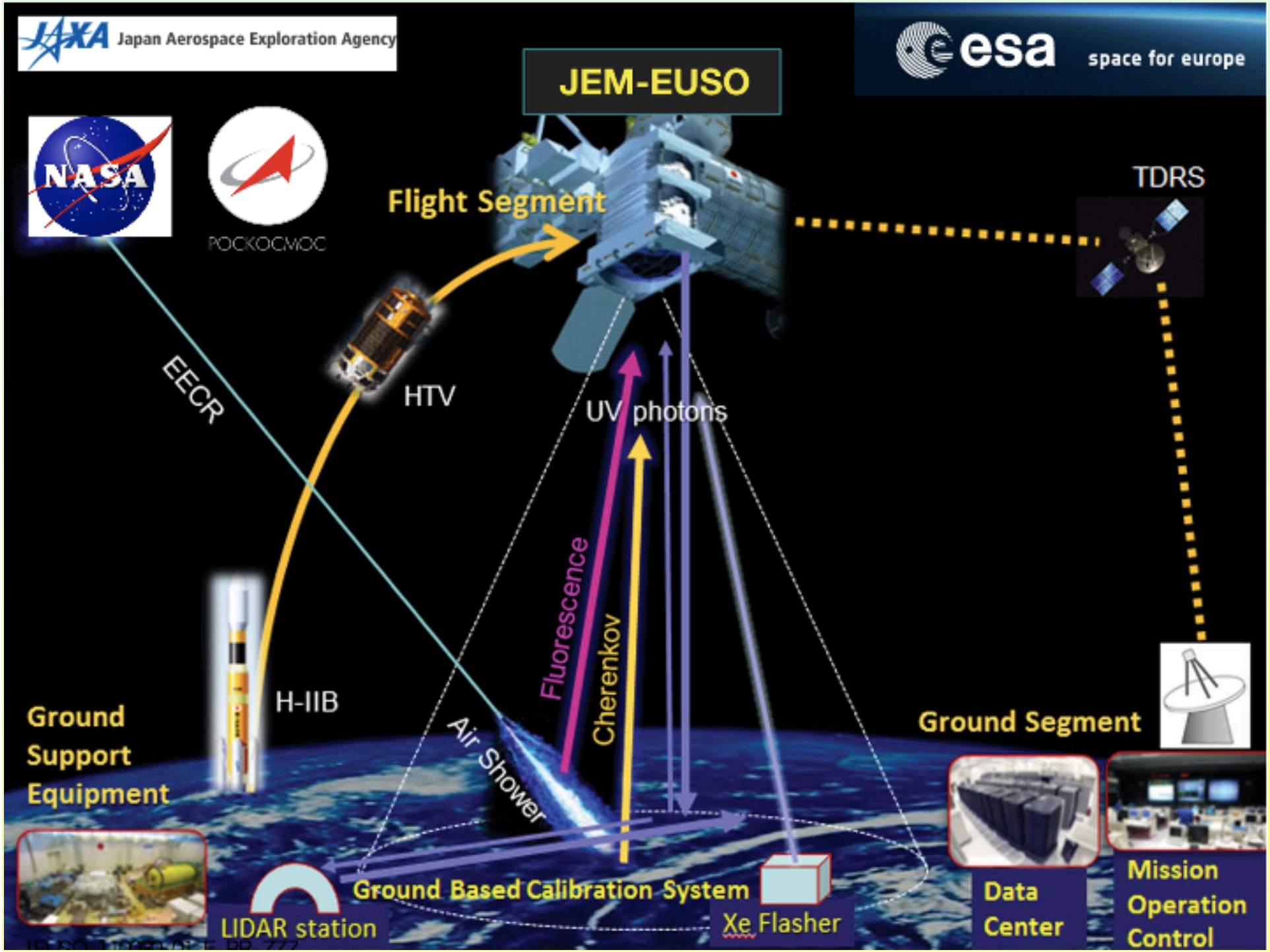
Japan, Europe, US, Korea, Mexico

Extreme Universe Space Observatory

An Innovative Space Mission doing astronomy by looking downward from the Space Station at the Earth Atmosphere.

EUSO is devoted to the exploration from space of the highest energy processes present and accessible in the Universe. They are directly related to the extreme boundaries of the physical world.




Japan Aerospace Exploration Agency
esa
space for europe
JEM-EUSO
NASA
POCKOCMOC
Flight Segment
TDRS
EECR
HTV
UV photons
Fluorescence
Cherenkov
H-IIB
Air Shower
Ground Support Equipment
Ground Segment
Ground Based Calibration System
LIDAR station
Xe Flasher
Data Center
Mission Operation Control

EUSO Science Goals

EUSO is intended to address basic problems of Fundamental Physics and high energy astrophysics.

- Investigation of the highest energy processes present and accessible in the Universe through the detection and investigation of the Extreme Energy Component of the Cosmic Radiation (EECRs / UHECRs with $E > 5 \times 10^{19}$ eV).
- Arrival directions and small-scale clustering will provide information on the origin of the EECRs and inter-galactic magnetic fields.
- Open the Channel of High Energy Neutrino Astronomy to probe the boundaries of the Extreme Universe and to investigate the nature and distribution of the EECR sources.

Parallel fields of scientific interest are represented by the systematic surveillance of Atmospheric Phenomena: Atmosphere as a Physical System, and Meteors.

DETECTION TECHNIQUE

Euso will observe the fluorescence signal looking to Nadir at the dark Earth atmosphere from its location on the ISS under a 60° full field of view. Fluorescence light will be imaged by a large Fresnel lens onto a finely segmented focal surface. A Cerenkov signal will be detected in a delayed coincidence with the fluorescence signal.

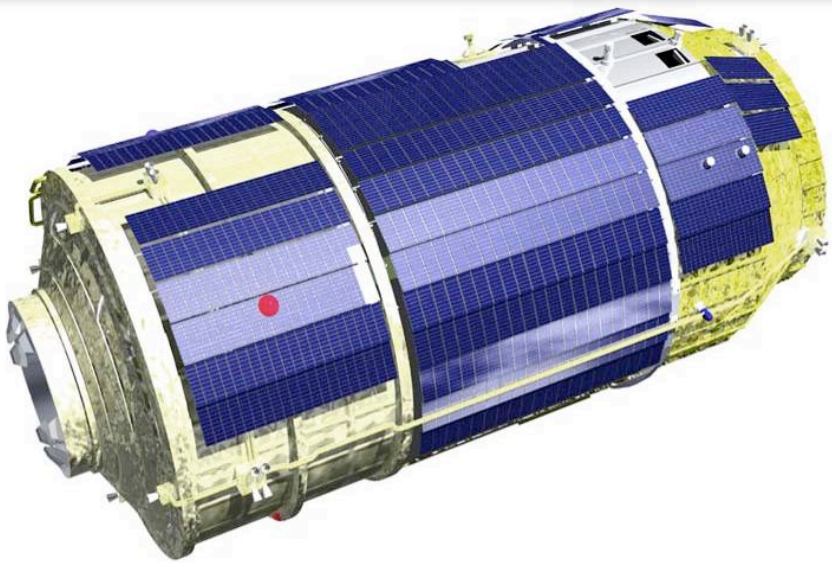
The segmentation and the time resolution adopted will enable the reconstruction of the arrival direction and EAS energy, with an accuracy of order $\Delta E/E \sim 30\%$, and arrival direction ranging from a fraction of a degree to a few degrees depending on energy and zenith angle of the primary particle.

THE NATURAL DETECTOR

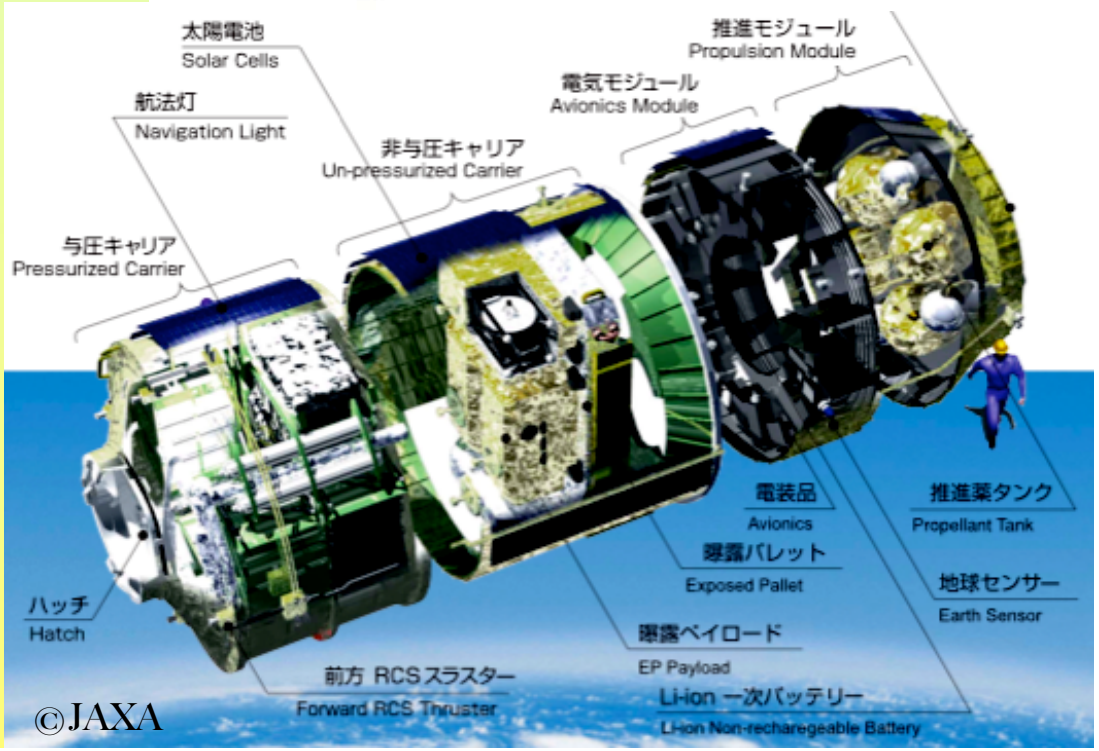
EARTH ATMOSPHERE

- Atmosphere is required for the primary particle to interact and develop shower with a production of :
  - Cherenkov light
  - fluorescence light
- Details of the UV light production yield details of the primary particle :
  - the amount of UV light produced is ∝ to the particle's energy
  - the shape of the shower profile and the atmospheric depth of the shower maximum contain information about particle mass composition

HTV Transfer Vehicle



4m diameter, 10 m long



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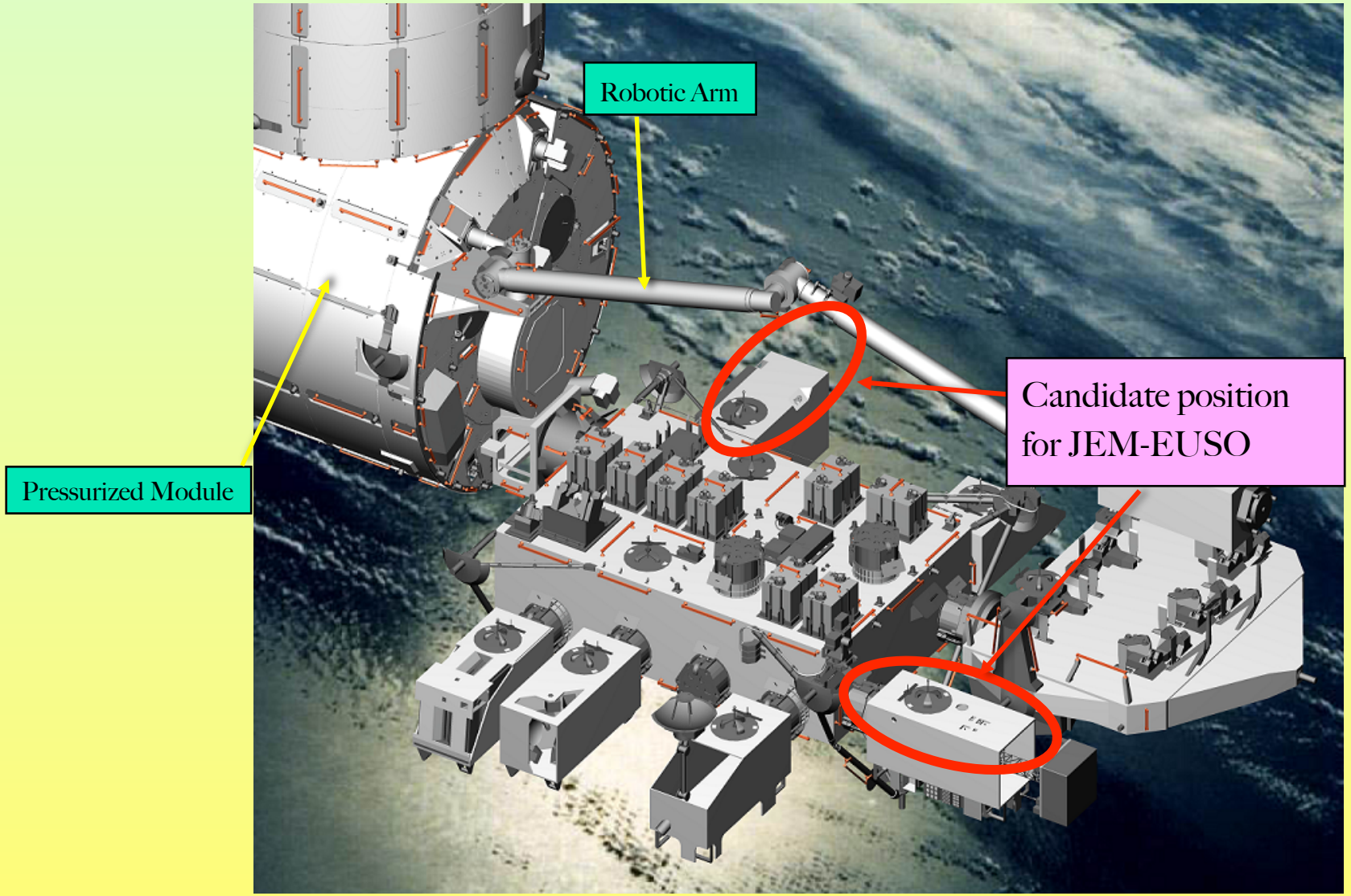
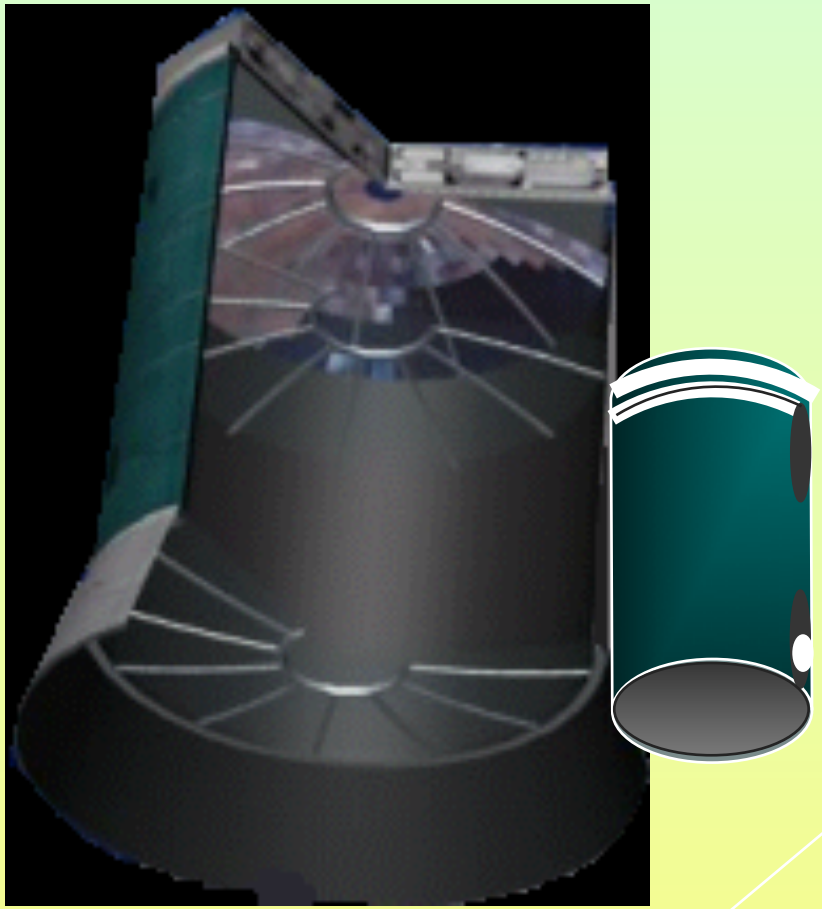
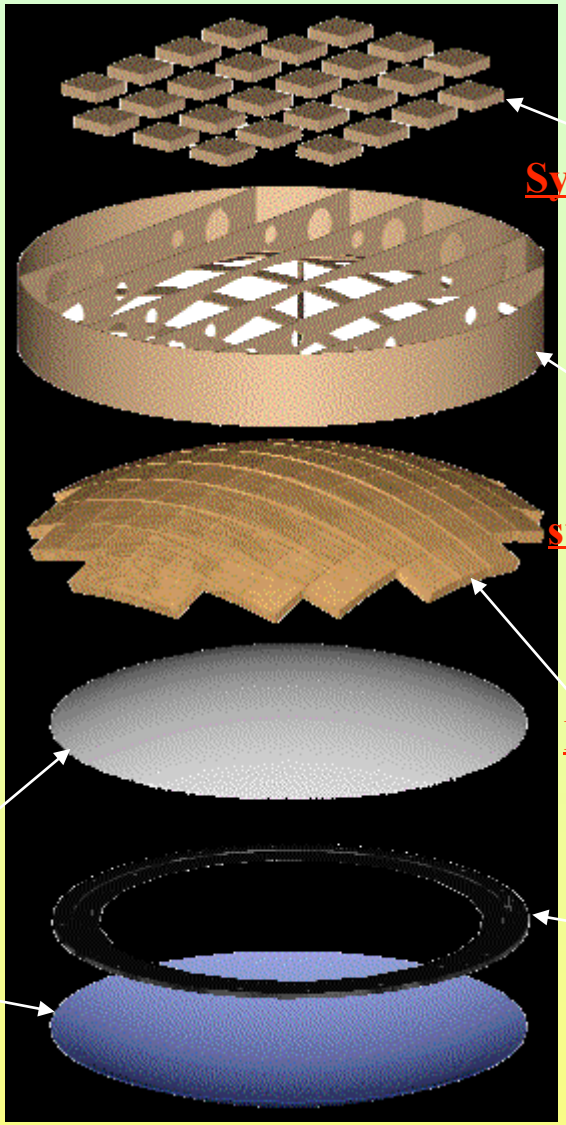
Outline of JEM Exposure Facility



A monocular compact instrument

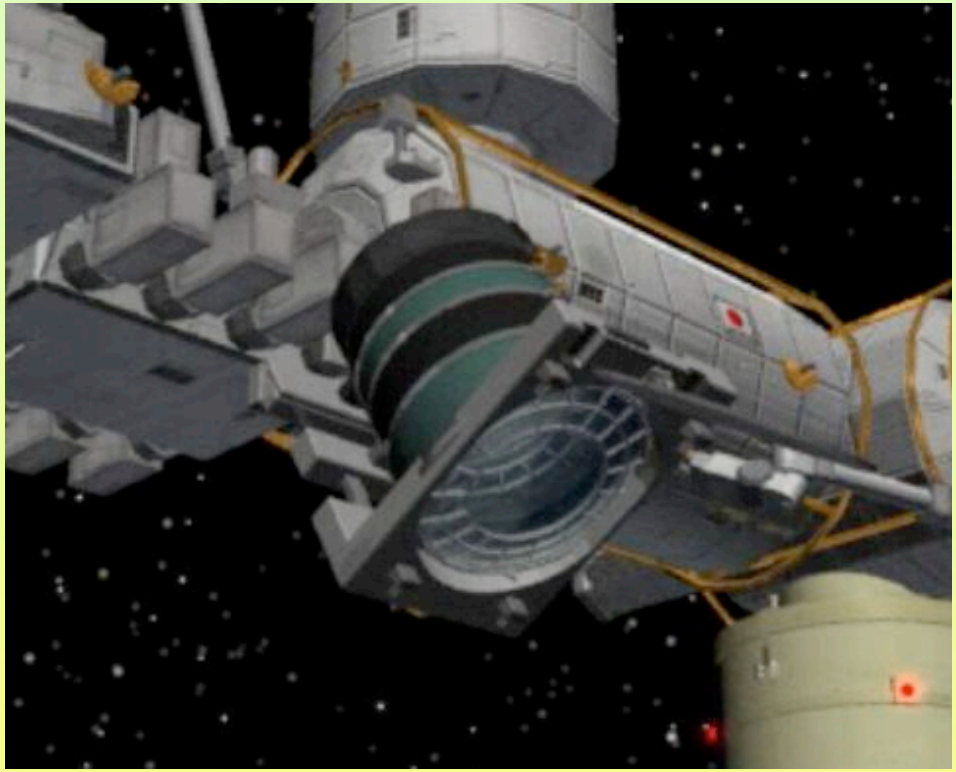




Fresnel lens

Observation mode of JEM-EUSO

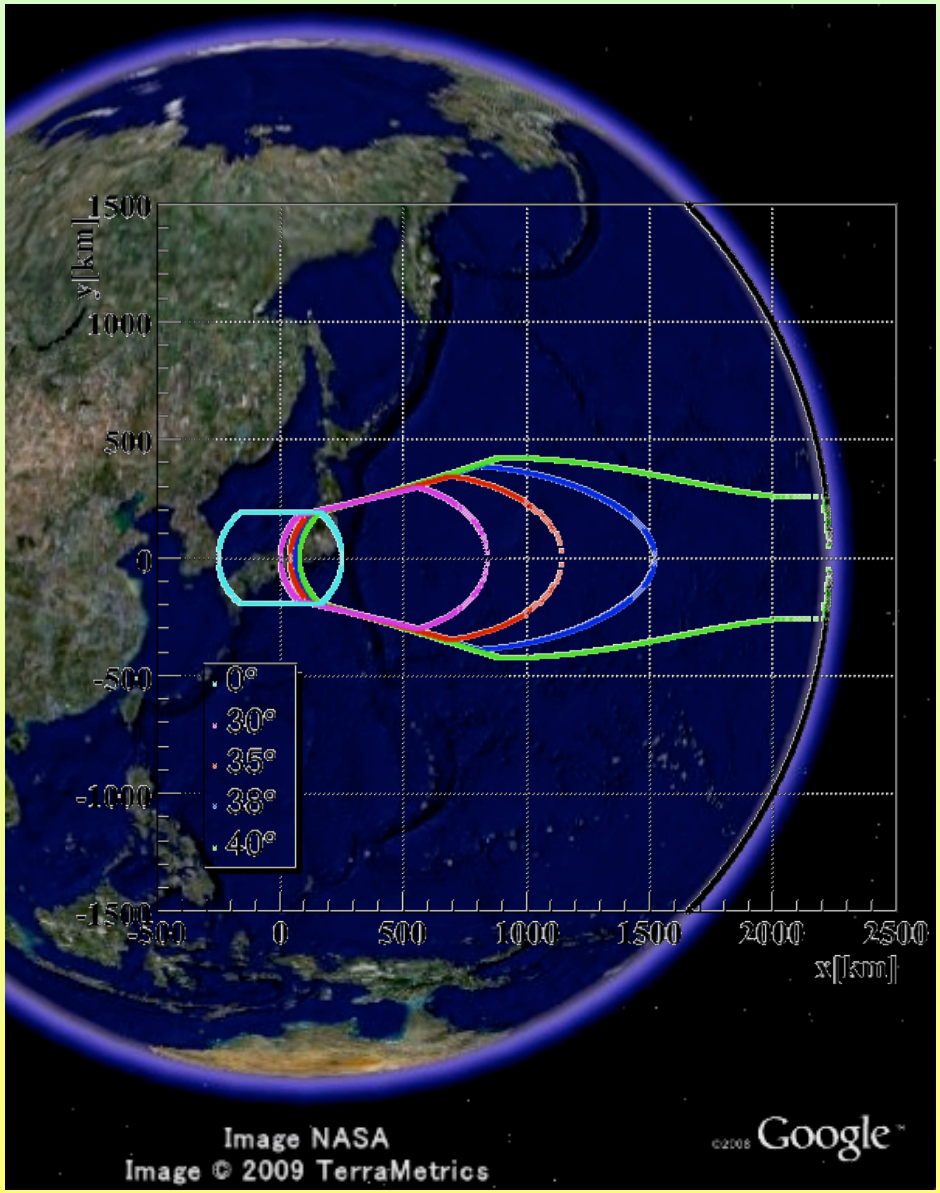
Vertical Mode

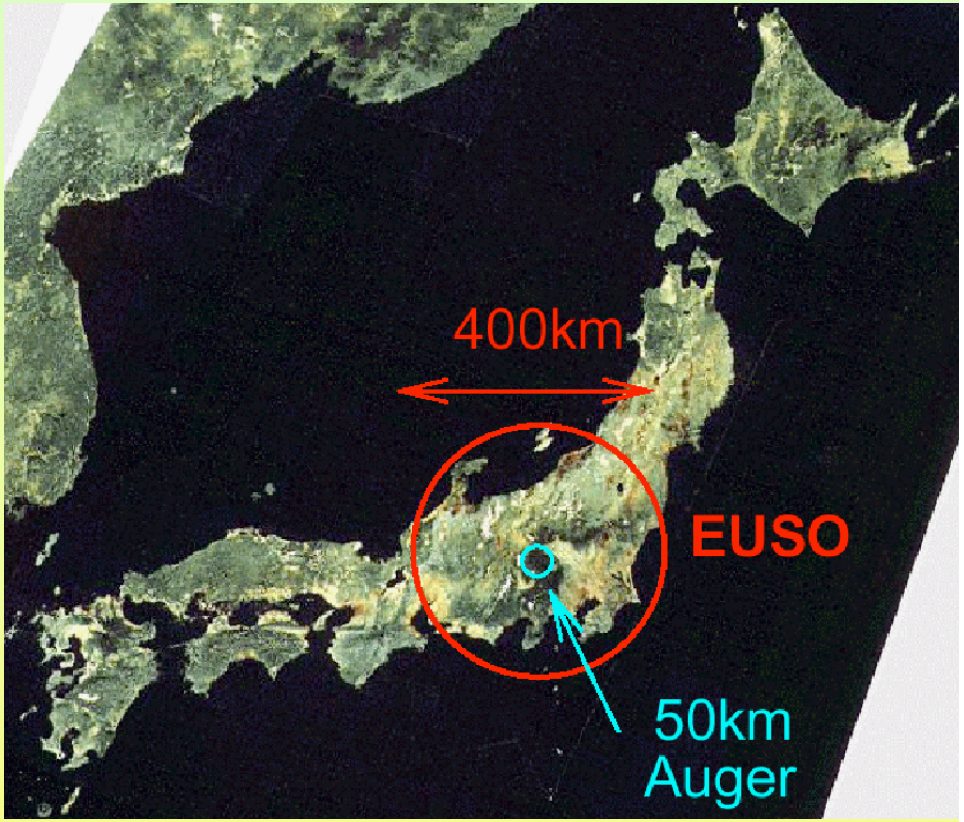


Tilted Mode

Larger exposure can be obtained

Field of View





SYSTEM ELECTRONICS

Multi-level trigger implementation

- **Trigger Mode 1 or *normal mode***

  (EECRs up to 300μs, GTU=833ns)

- **Trigger Mode 2 or *slow mode***

  (ex. Meteors up to 2 sec, GTU=833ns-- 1ms)

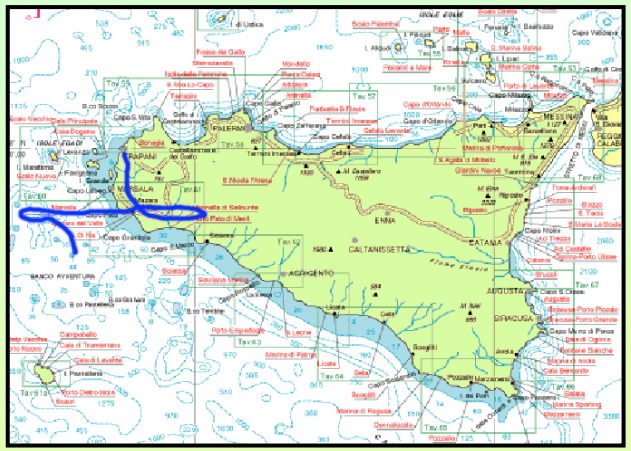
- **Trigger Mode 3 or *fast mode***

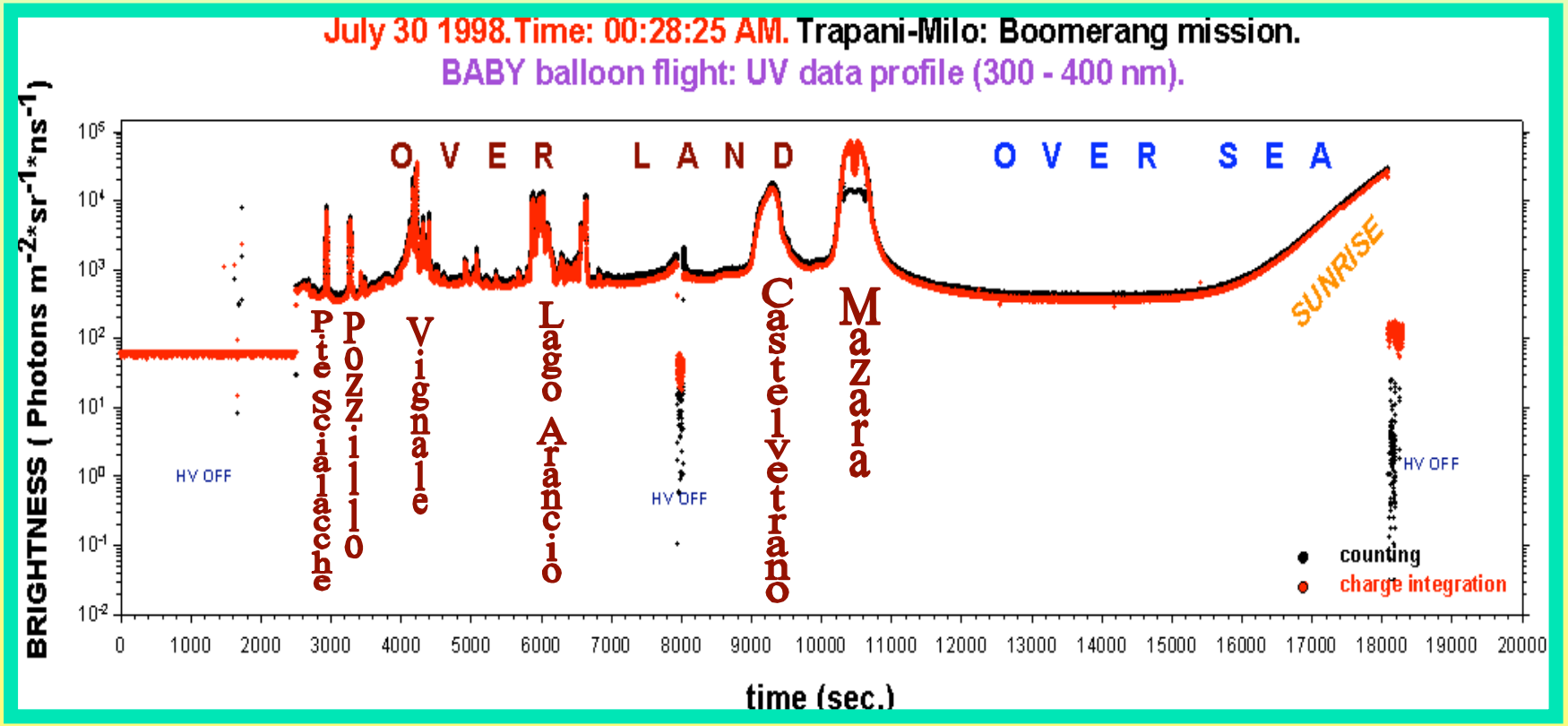
  (ex. Calibration, GTU=200ns)

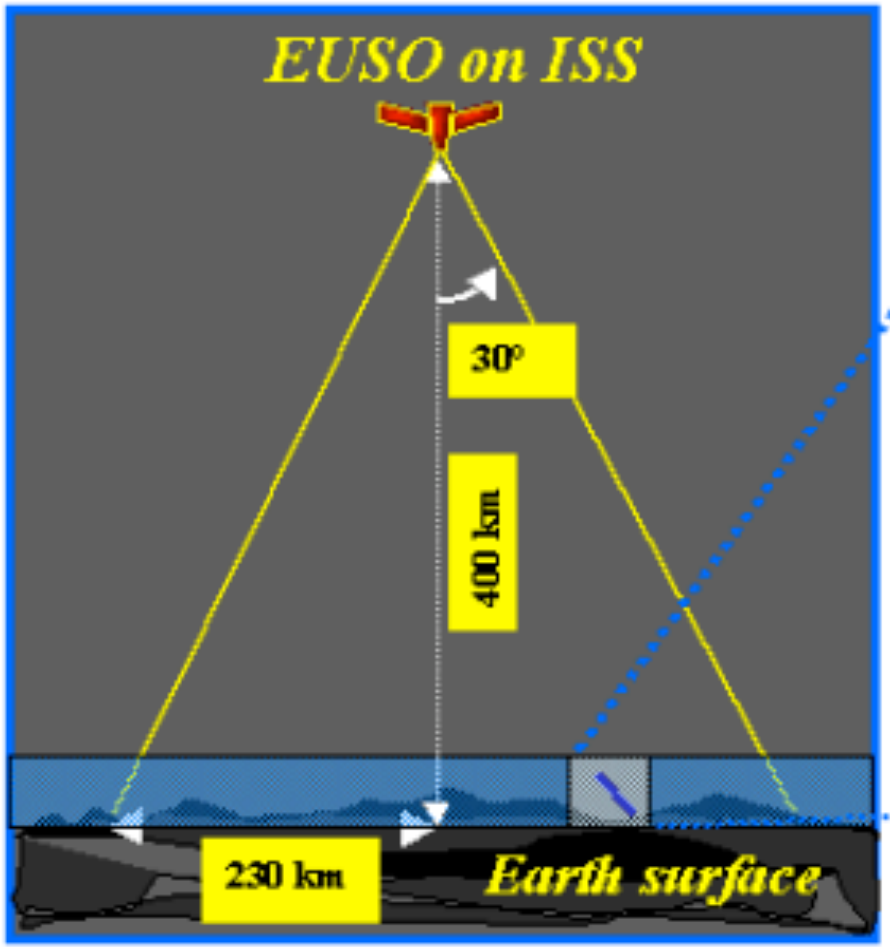
- …

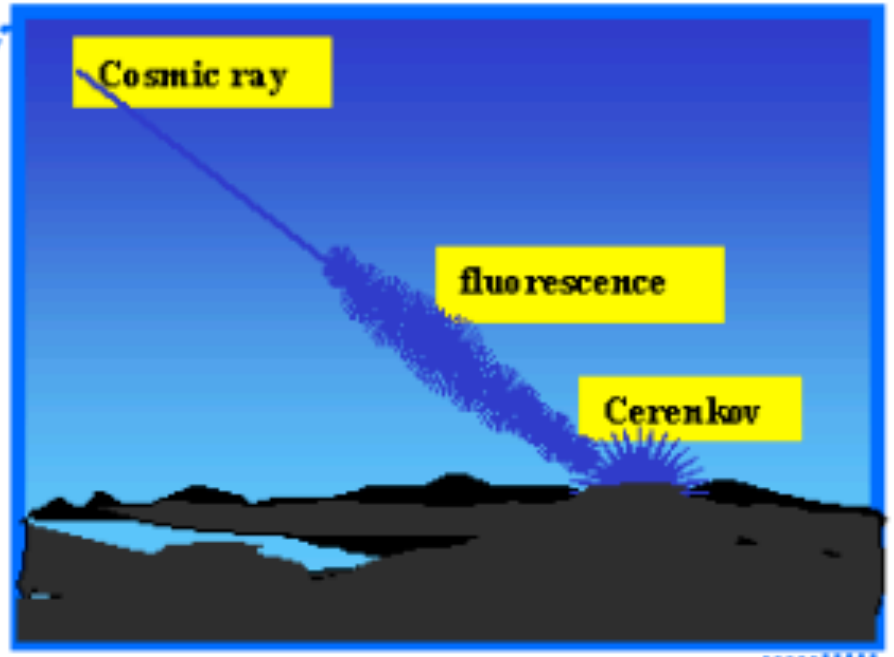
EUSO DETECTION TECHNIQUE

background measurement






EUSO on ISS
30°
400 km
230 km
Earth surface


Cosmic ray
fluorescence
Cerenkov

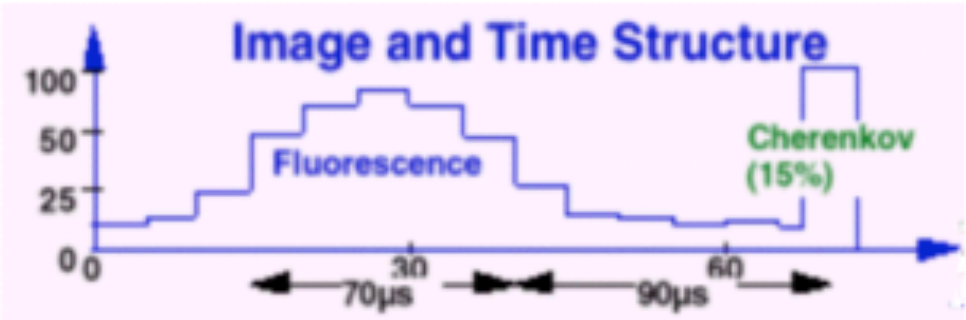
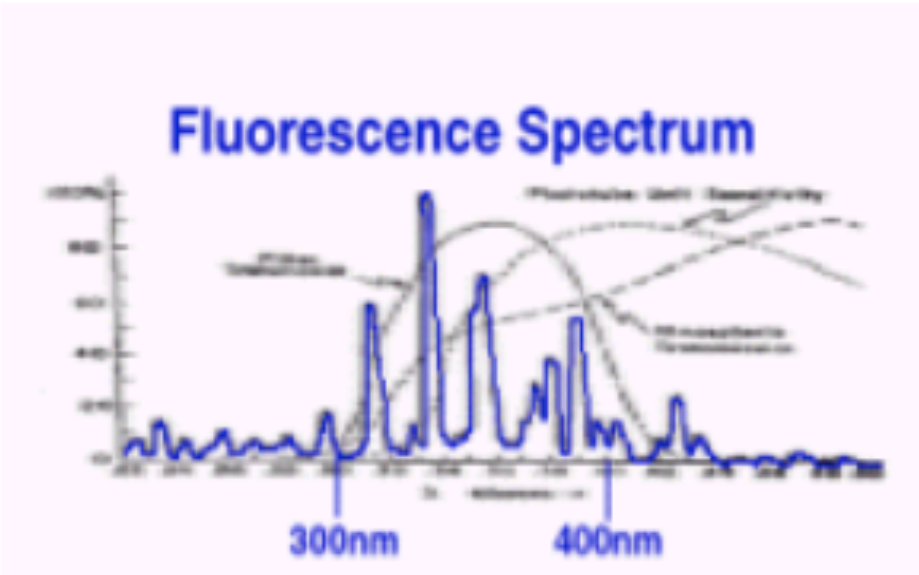


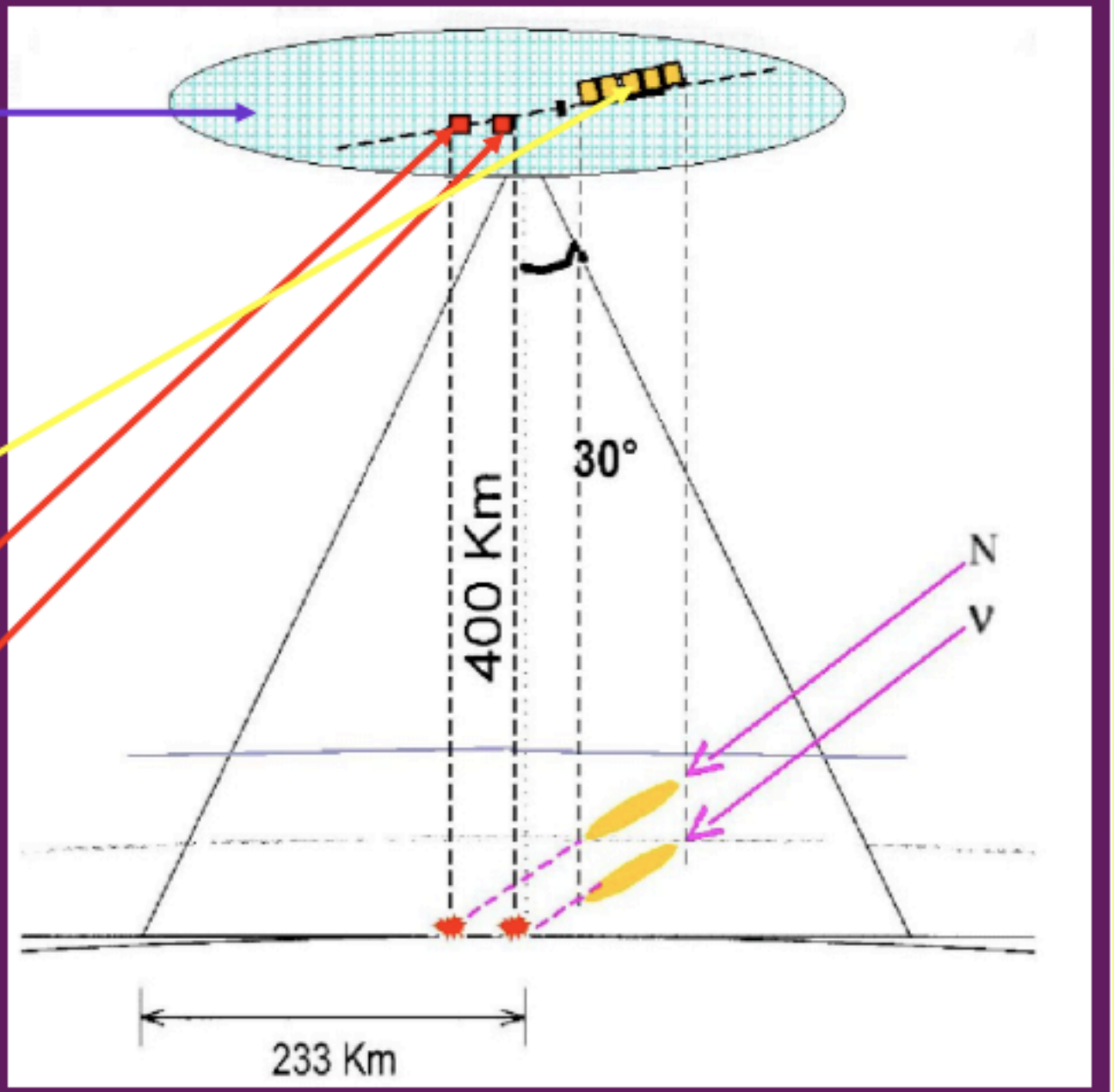
Image and Time Structure
100
50
25
0
0
30
60
Fluorescence
Cherenkov
(15%)
70µs
90µs


Fluorescence Spectrum
300nm
400nm

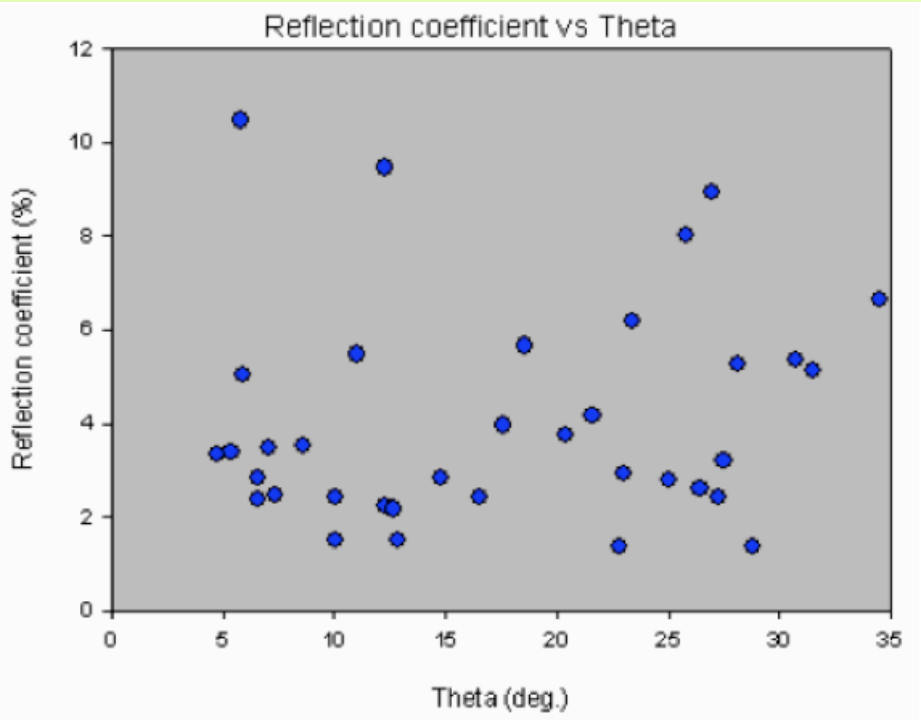
Focal Surface

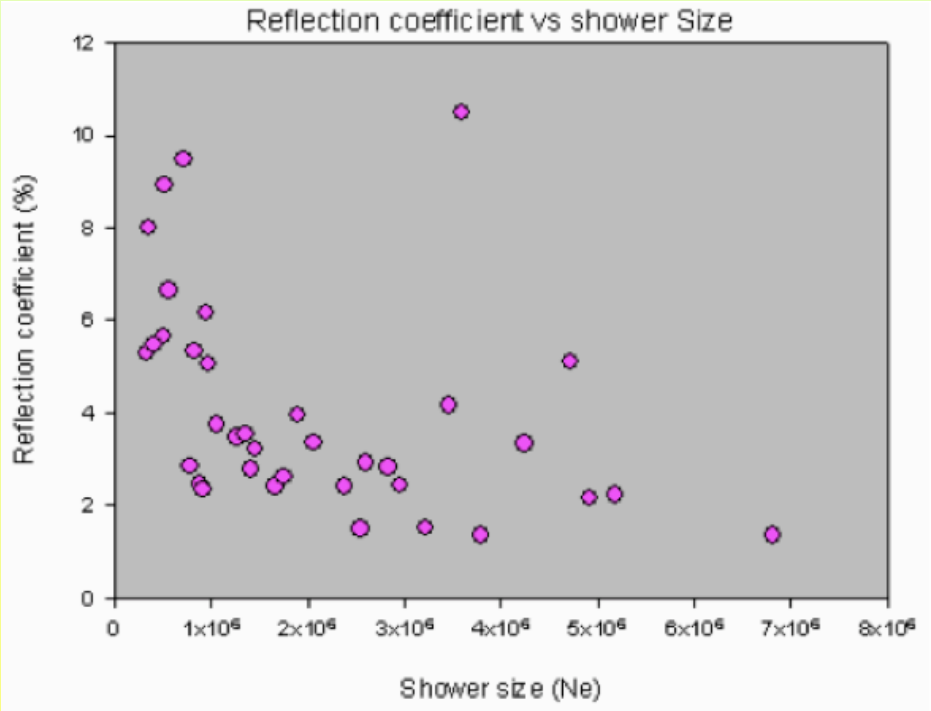
Fluorescence signal

Čerenkov signal




2005 - ULTRA @ Capo Granitola
ex-tonnara di Torretta Granitola, Mazara del Vallo (TP, Italy)


Reflection coefficient vs Theta
Reflection coefficient (%)
Theta (deg.)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35


Reflection coefficient vs shower Size
Reflection coefficient (%)
Shower size (Ne)
0
2
4
6
8
10
12
0
1x10⁶
2x10⁶
3x10⁶
4x10⁶
5x10⁶
6x10⁶
7x10⁶
8x10⁶

Science Objectives

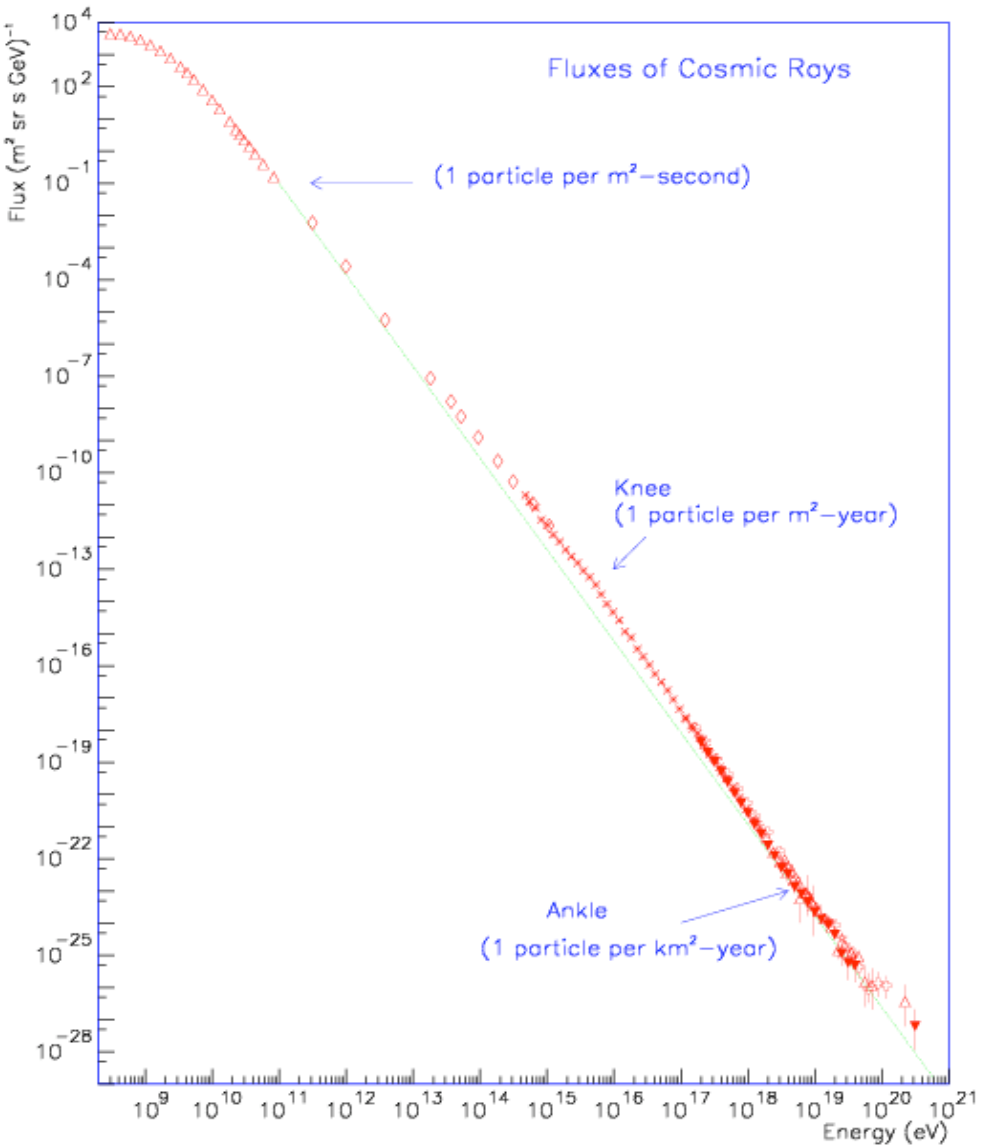
- Fundamental Objective

  Extreme energy astronomy by particle channel

  Determine their origin and the acceleration mechanism

- **Exploratory Objectives**
  - Detection of extreme energy gamma rays
  - Detection of extreme energy neutrinos
  - Study of the galactic magnetic field
  - Verification of the relativity and the quantum gravity effect in extreme energy
  - Global observations of nightglows, plasma discharges and lightning

Cosmic Rays Flux



From N. Sakaki
2nd AGASA
Mini Workshop, 2000

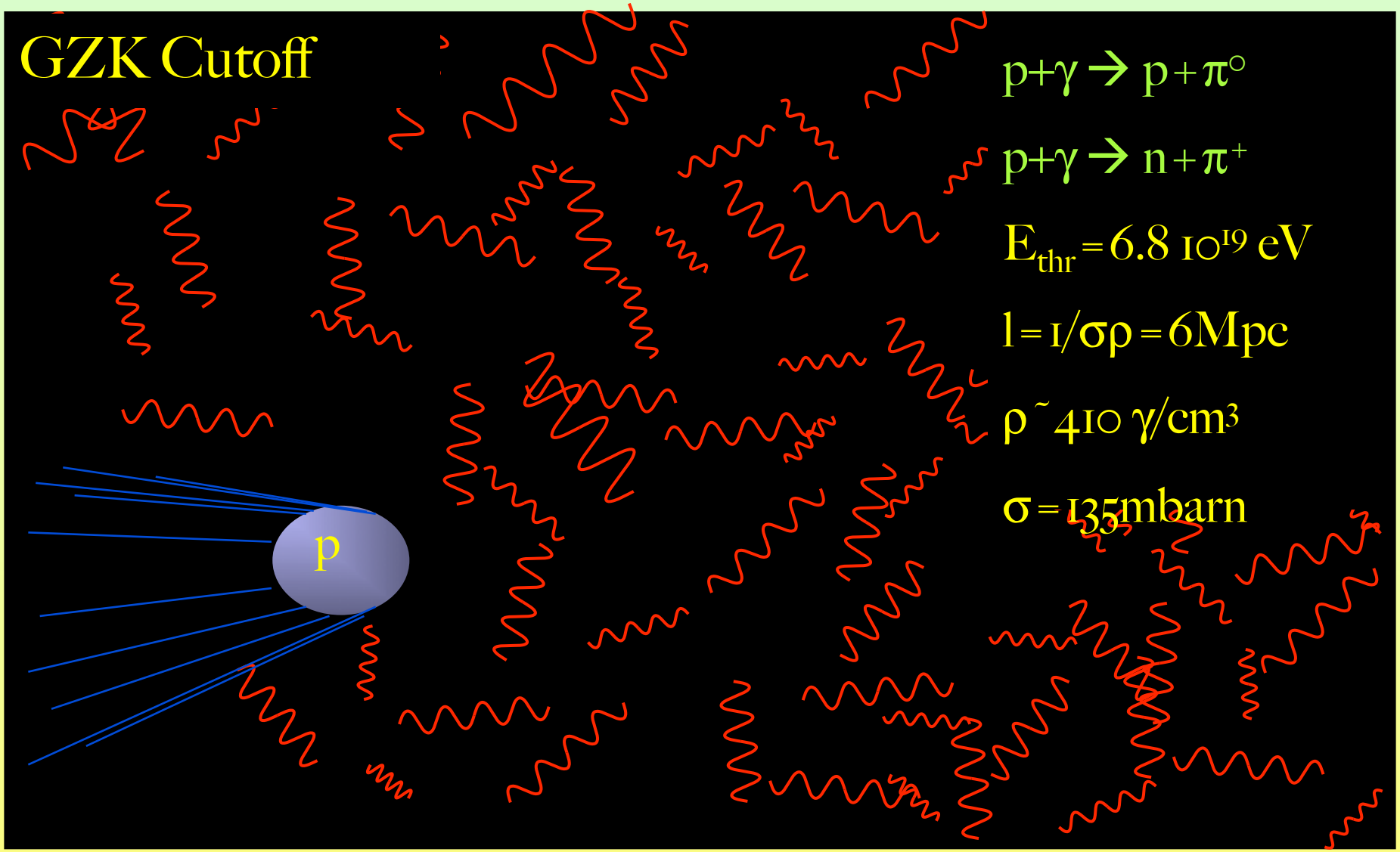
EAS DETECTOR: EUSO APPROACH

To obtain a statistical significant sample of EECR events at $E > 10^{20}$ eV, with flux value at the level of:

1 particle/year/100 km^2

or with very low interaction cross section (neutrinos), a giant detector is required.
The Earth atmosphere, viewed from space with an acceptance area of the order of **$5 \cdot 10^5$ km^2 sr**, and a target mass of the order of **$2 \cdot 10^{12}$ tons** constitutes an ideal target to UHE CR and cosmic neutrinos.

GZK Cutoff



$p+\gamma \rightarrow p+\pi^{0}$

$p+\gamma \rightarrow n+\pi^{+}$

$E_{thr} = 6.8\ 10^{19}$ eV

$l = 1/\sigma\rho = 6$ Mpc

$\rho \sim 4\ 10\ \gamma/cm^{3}$

$\sigma = 135$ mbarn

Success Criteria of the Mission

- Full Success：

  Number of Events above 7×10^{19} eV > 1,000

- Minimum Success：

  Number of Events > 500

  Critical number to clarify the origin of EECRS

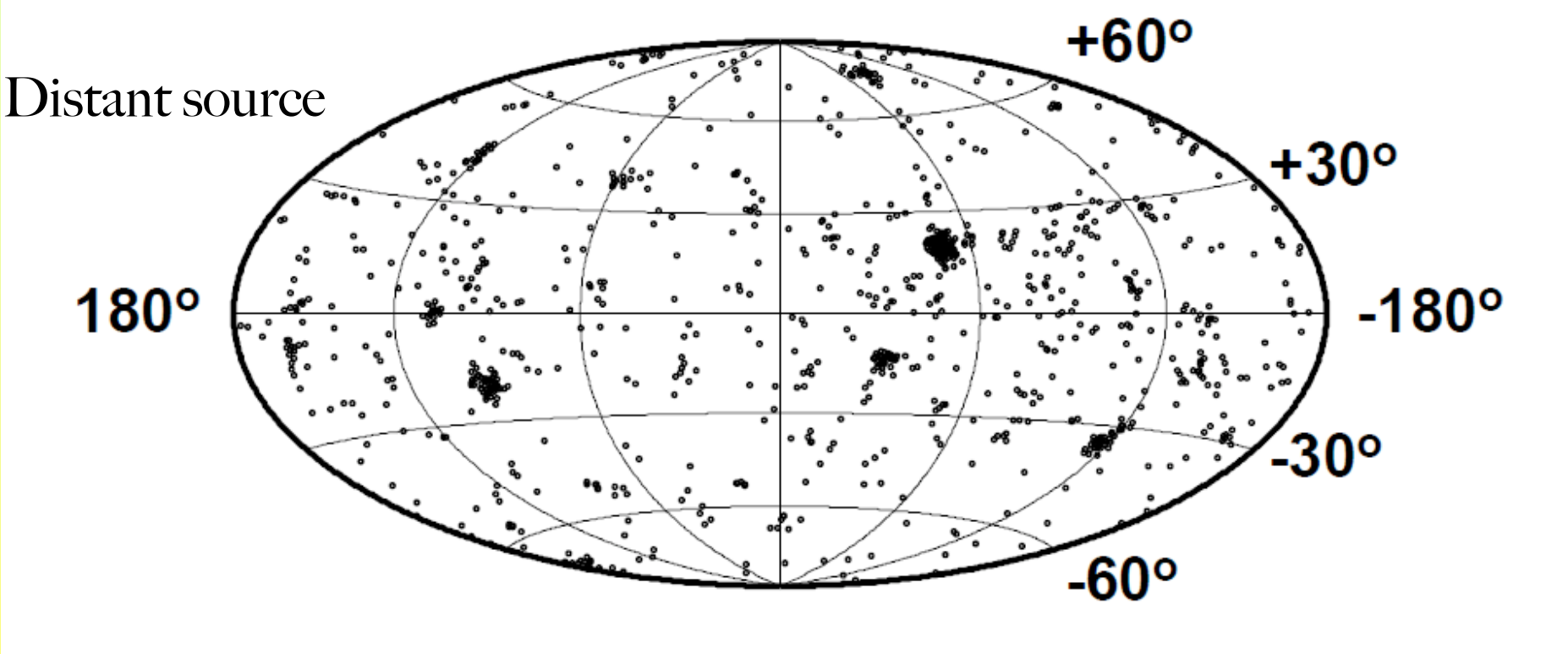
- Extra Success

  Achieve one or all of the exploratory objectives

Fundamental Objective

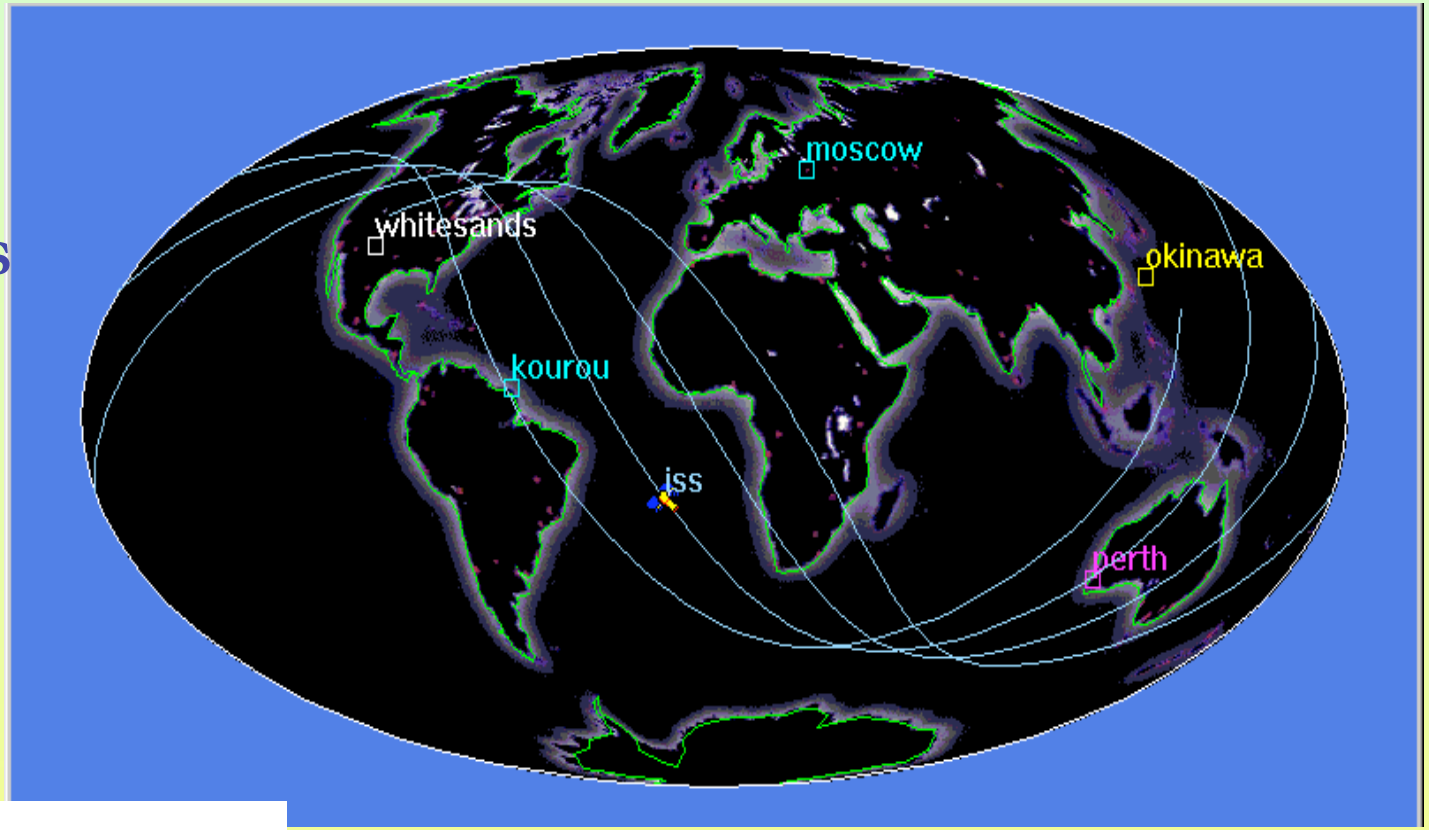
Particle Astronomy by JEM-EUSO

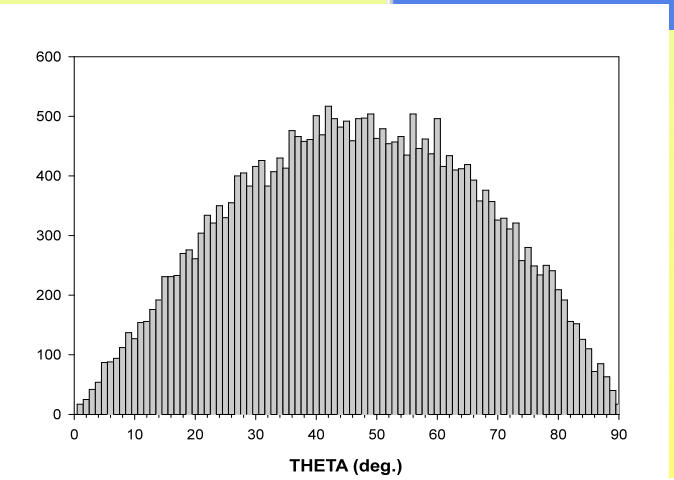
- 1,000 events : $E>7\times10^{19}$eV
- Several dozen clusters expected
- All sky coverage



EUSO PERFORMANCE

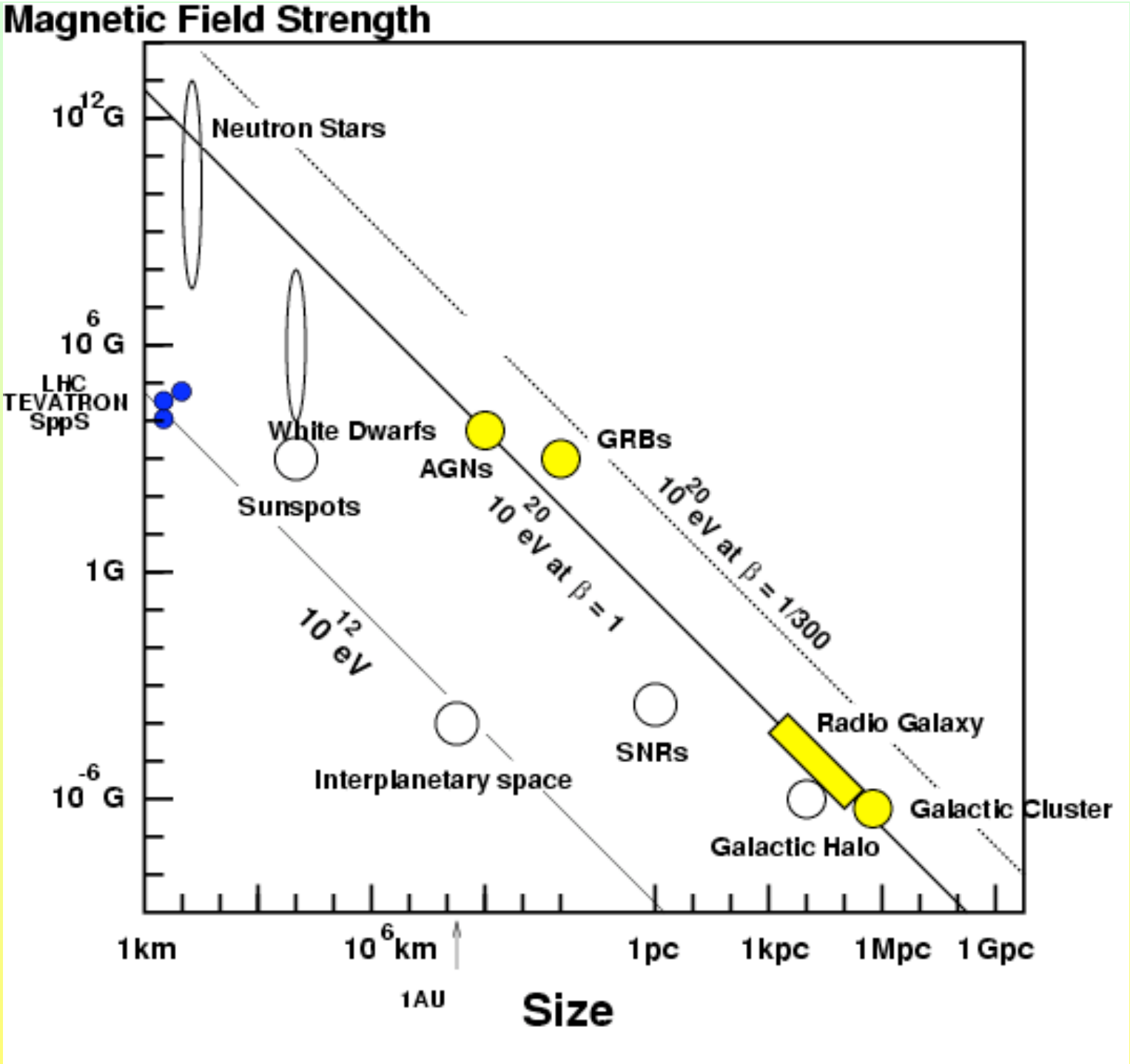
Total sky coverage plays an important role for anisotropy study





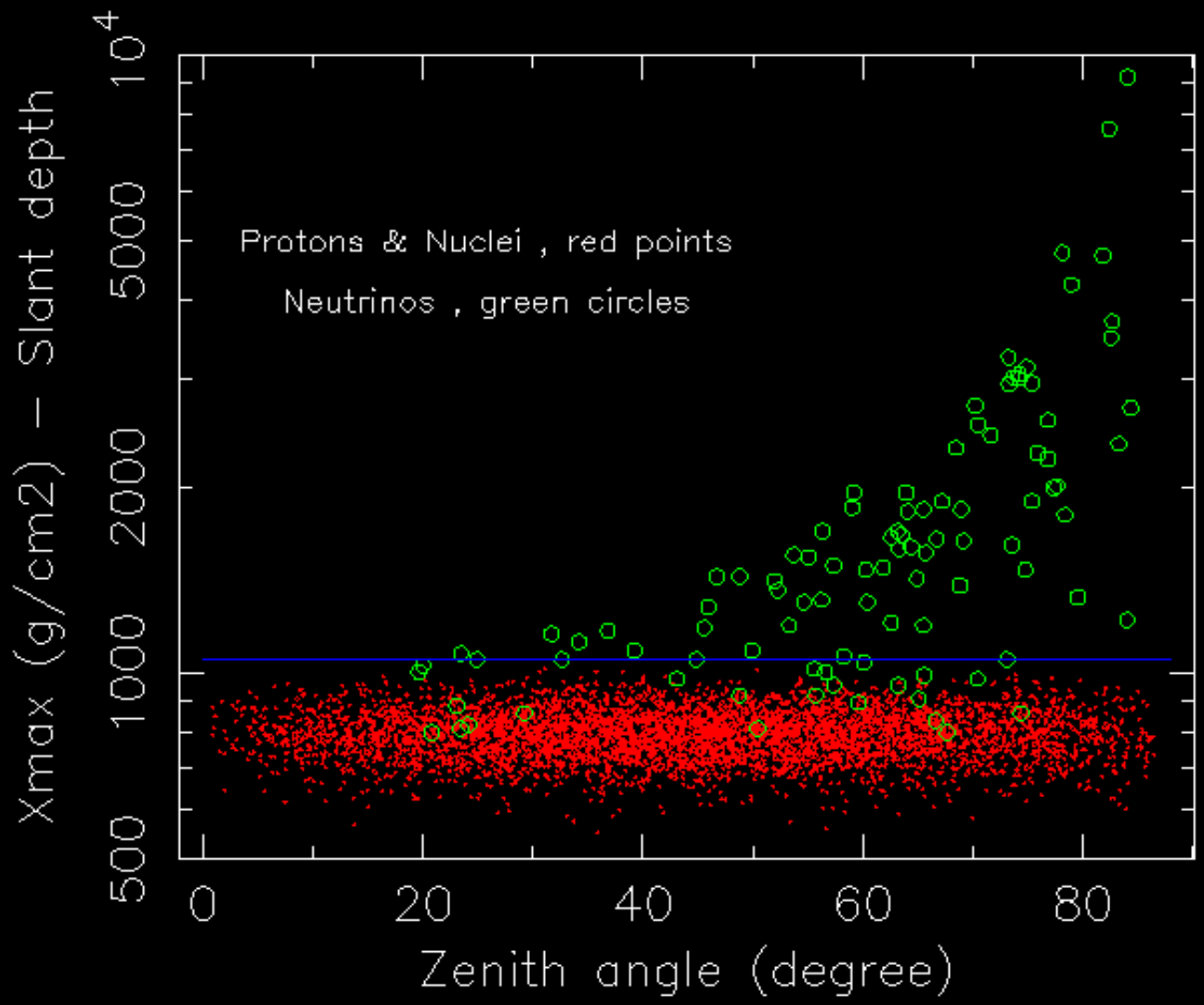
EUSO in a year operation will cover all sky directions

Hillas plot


Magnetic Field Strength
10^{12}G
10^{6} G
1G
10^{-6} G
Neutron Stars
LHC
TEVATRON
SppS
White Dwarfs
Sunspots
AGNs
GRBs
10^{20} eV at β = 1/300
10^{20} eV at β = 1
10^{12} eV
Radio Galaxy
SNRs
Interplanetary space
Galactic Cluster
Galactic Halo
1km
10^{6}km
1AU
1pc
1kpc
1Mpc
1Gpc
Size

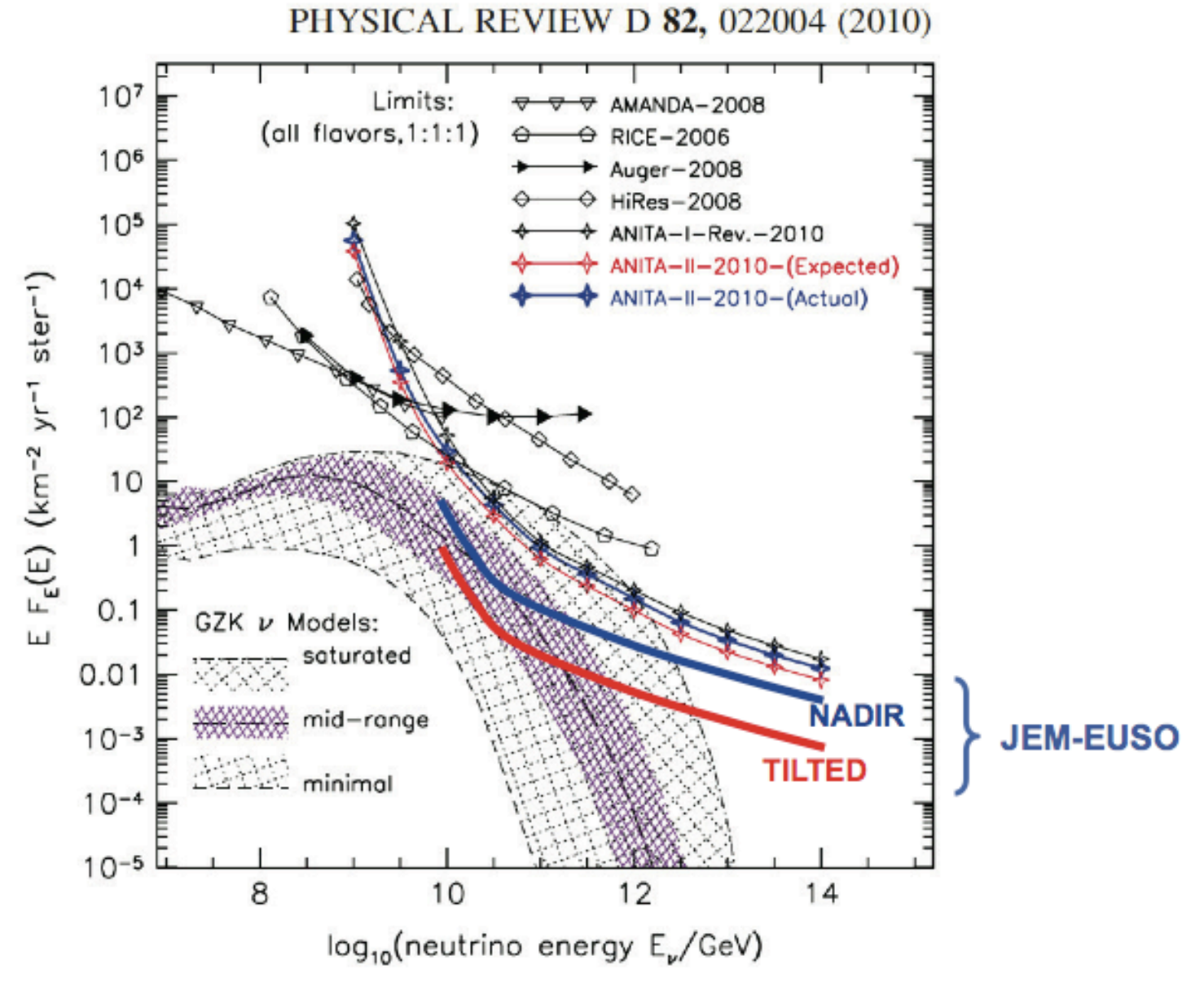
Comparison with current observatories

Experiment	Aperture km^2 sr	Status	Start	Lifetime (years)	Duty cycle (incl. clouds)	Exposure (km^2 sr y)	Relative to Auger
Auger	7,000	Operations	2006	4 (16)	1.0	27,370 (110,000)	1
TA	1,200	Operations	2008	2 (14)	1.0	2400 (16.000)	0.1
TUS	30,000	developed	2012	5	0.14	18,750	0.2
JEM-EUSO (E~100 EeV) Nadir-Mode	470,000 (10xAuger including DC)	proposed	2017	5	0.14	330000 (5 years Nadir)	3
JEM-EUSO (highest Energies) Tilted-Mode	1,300,000 (26xAuger including DC)	proposed	2017	5	0.14	910000 (5 years tilted)	8

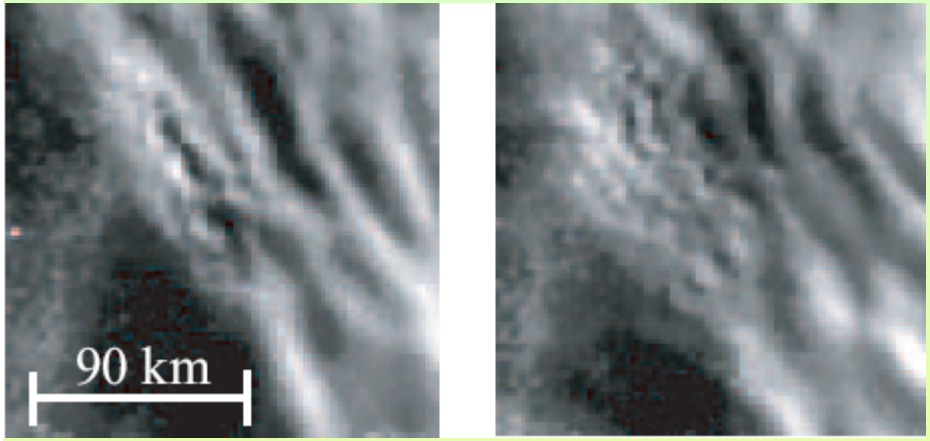


sacco 27-Sep-2000 16:29

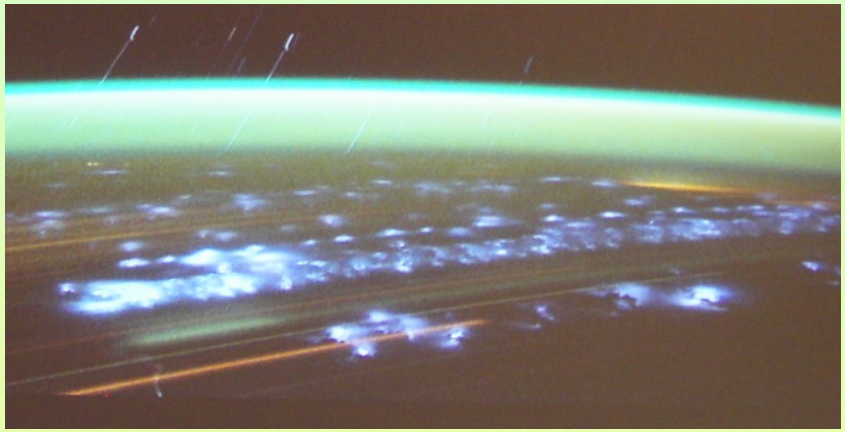
Upper limits on neutrino flux



Atmospheric Luminous Phenomena

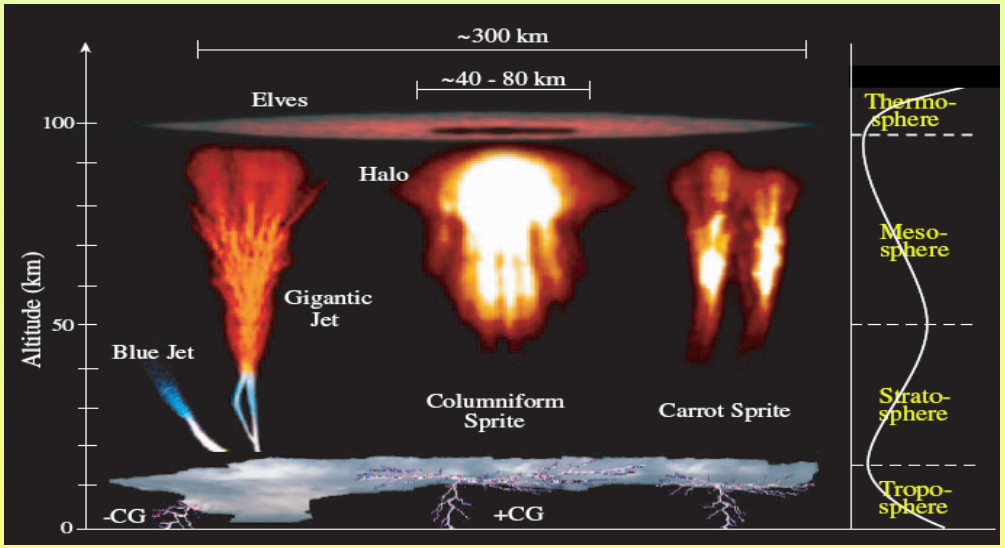


OH airlow from ground



Lightning picture observed from ISS

Leonid meteor swarm in 2001



Various airglows

SUMMARY AND CONCLUSIONS

JEM EUSO is an innovative Space Mission doing astronomy by looking downward from the Space Station at the Earth Atmosphere

JEM EUSO will provide unique results in:

- 1 – Astrophysics
- 2 – Astroparticle Physics
- 3 – Cosmology
- 4 – Neutrino Astrophysics
- 5 – Fundamental Physics
- 6 – Atmospheric sounding