



Extreme Universe Space Observatory

The JEM-EUSO Mission to Explore the Extreme Universe

Marco Ricci

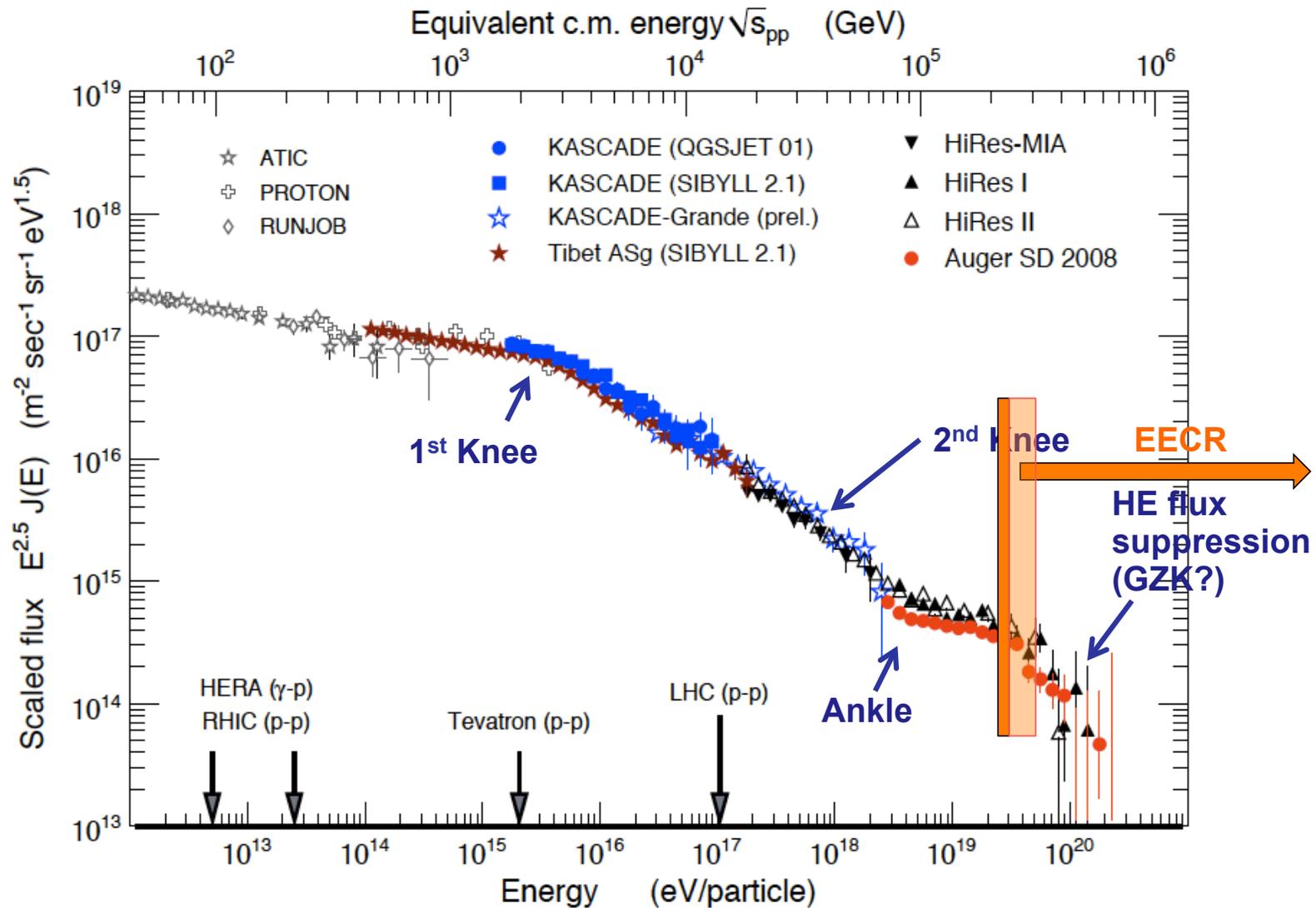
*INFN, Laboratori Nazionali di Frascati, Frascati (Roma), Italy
On behalf of the JEM-EUSO Collaboration*

TAUP 2011
Munich, September 5-9, 2011



The Scientific Case

UHE or EE region

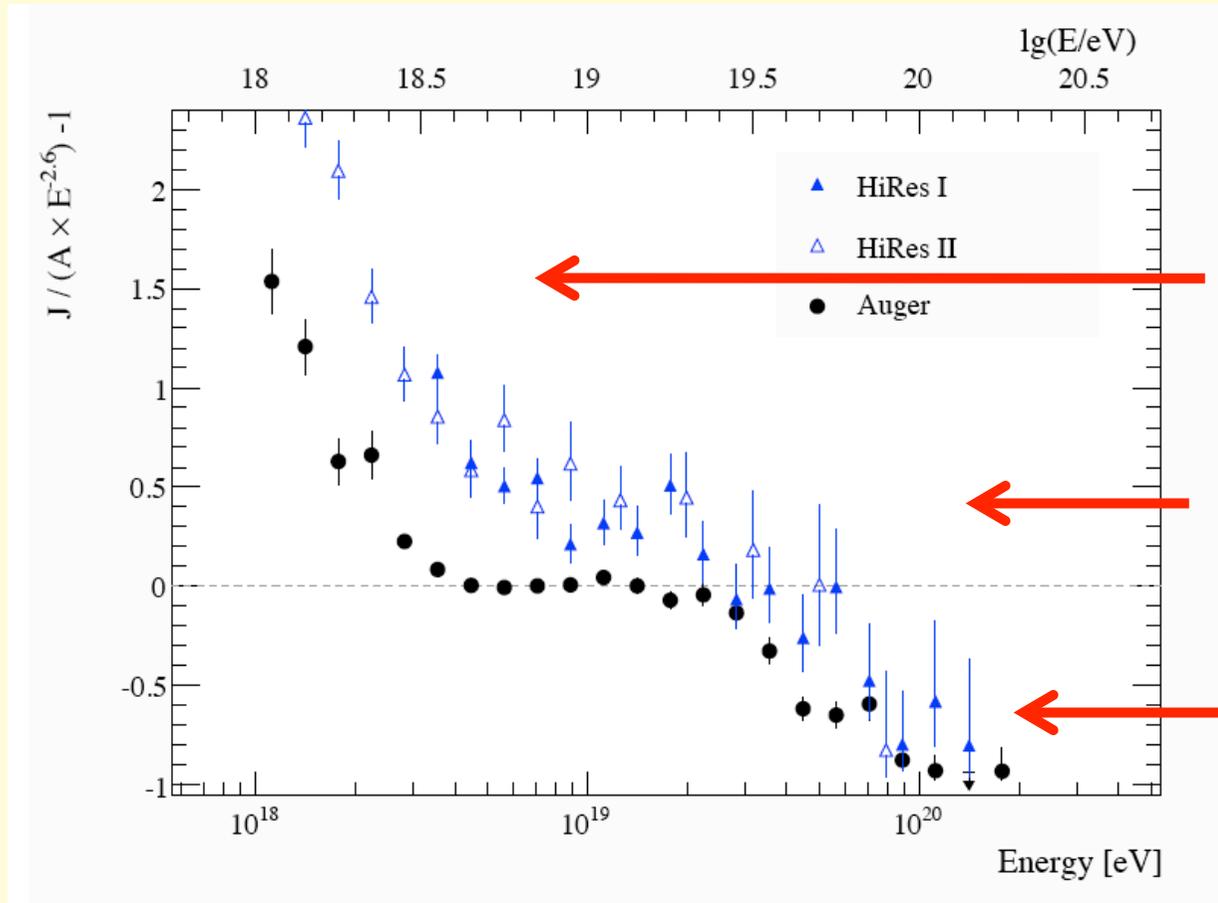


Question:

*Do we have evidence for
the GZK effect?*

A key result of Auger South and HiRes

The Auger Collaboration (2008a), Abbasi et al. (2008), Bergman (2008), Fukushima (2011)



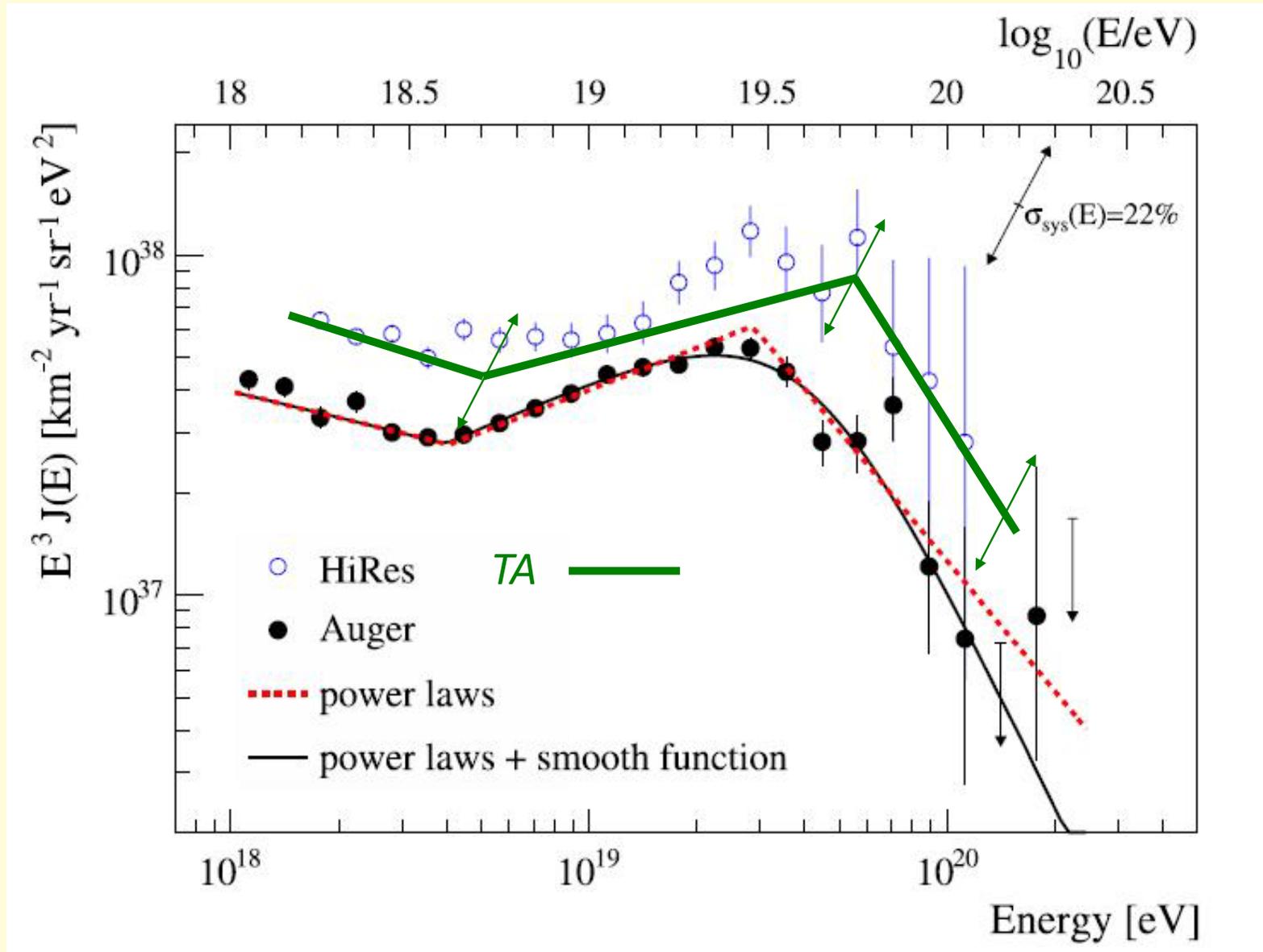
$$\gamma_1 = 3.26 \pm 0.04$$

$$\gamma_2 = 2.59 \pm 0.02$$

$$\gamma_3 = 4.3 \pm 0.2$$

*Observation of a “flux suppression” in the spectrum:
GZK feature (?)*

Recently confirmed by Telescope Array



UHECR status in just one word

Previous to Auger / HiRes :

$$\frac{1 \text{ particle}}{100 \text{ km}^2 \text{ yr sr}}$$



Key Auger / HiRes result:

$$\frac{1 \text{ particle}}{\cancel{100} \text{ km}^2 \text{ yr sr}}$$

1000

A quantitative jump in exposure

(orders of magnitude: e.g., $10^3 \rightarrow 10^6$ km² yr sr)

**is needed to effectively open such an
astronomical window @ $E > 10^{20}$ eV**

JEM EUSO: AN OBSERVATORY OF UHECRs FROM SPACE

Instantaneous aperture: up to $\sim 10^6$ km²



**Main Objective:
ASTRONOMY and ASTROPHYSICS
THROUGH PARTICLE CHANNEL**

An experimental pathfinder with
outstanding scientific capability

*The Extreme Universe
Space Observatory
on-board the Japan
Experiment Module
(JEM) of the ISS*

EUSO



2001- 2004

Heritage of the ESA EUSO study



JEM EUSO Collaboration

- Japan, USA, Korea, Mexico, Russia
- Europe: Bulgaria, France, Germany, Italy, Poland, Slovakia, Spain, Switzerland
- 13 Countries, 77 Institutions, more than 250 researchers
- RIKEN: Leading institution



Science Objectives

- Main Objectives :

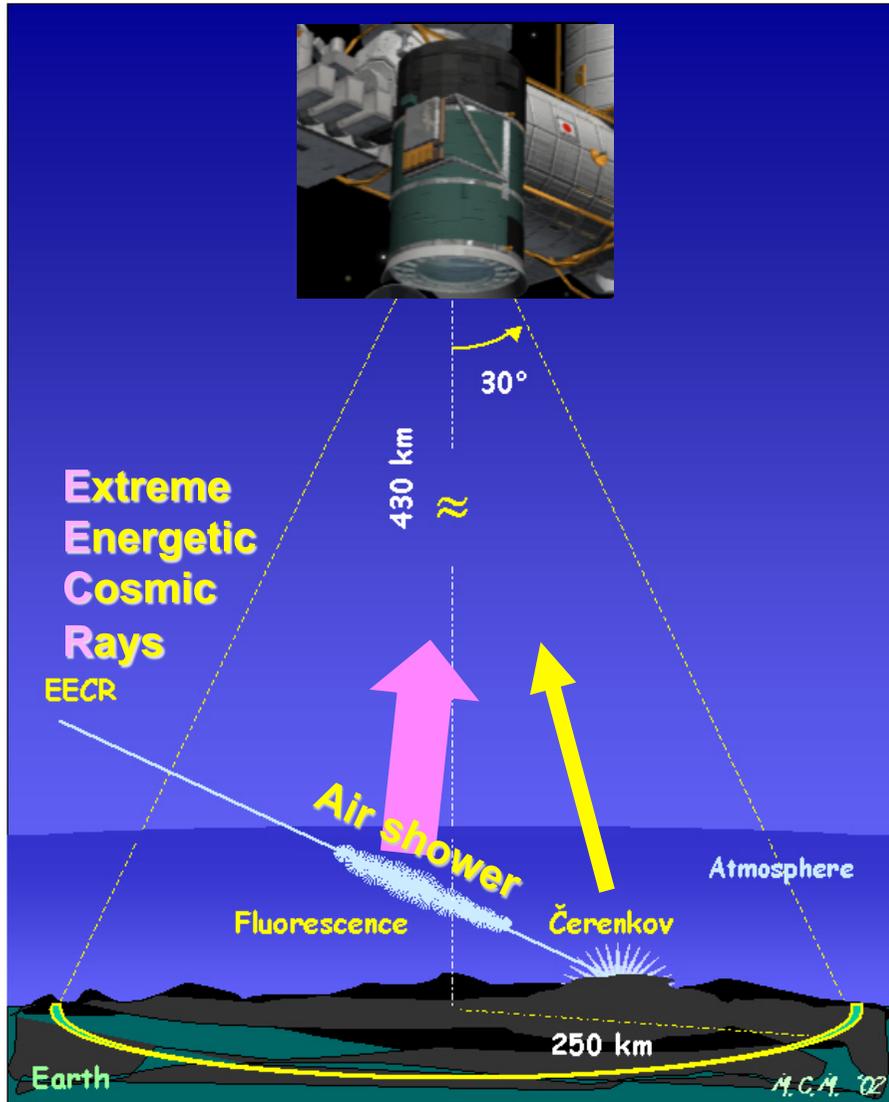
 - Astronomy and astrophysics through particle channel with extreme energies $> 10^{20}$ eV**

 - Identification of individual **sources** with high statistics
 - Measurement of the **energy spectrum** of individual sources
 - Understanding of the acceleration processes and source dynamics

- Exploratory objectives :

 - Detection of extreme energy **neutrinos**
 - Measurement of extreme energy **gamma rays**
 - Study the intensity and topology of Galactic and extragalactic **magnetic fields**
 - Global observation of **atmospheric** phenomena: nightglows, lightning and plasma discharges

JEM-EUSO Observational Principle



JEM-EUSO is a new type of observatory on board the International Space Station (ISS), which observes transient luminous phenomena occurring in the Earth's atmosphere.

The telescope has a super wide field-of-view (60°) and a large diameter (2.5m).

JEM-EUSO mission will initiate particle astronomy at $\sim 10^{20}$ eV.

JEM-EUSO telescope observes fluorescence and Čerenkov photons generated by air showers created by extreme energetic cosmic rays

Peculiarities from space

- *Far and almost constant distance* of the shower (no proximity effect)
- Shower is contained in the FOV: *observation of the entire profile*
- Possibility of *observing in cloudy conditions* (in most cases X_{max} above the cloud-top)
- *Less contamination* by Cherenkov
- *Efficient gamma/hadron separation* using different geographical areas
- Measurement of neutrino showers at high altitude *with less LPM effect*

Two advantages:
1. Monitored area

$$A_{geo}^{Nadir} \approx 1.3 \times 10^5 \text{ km}^2$$

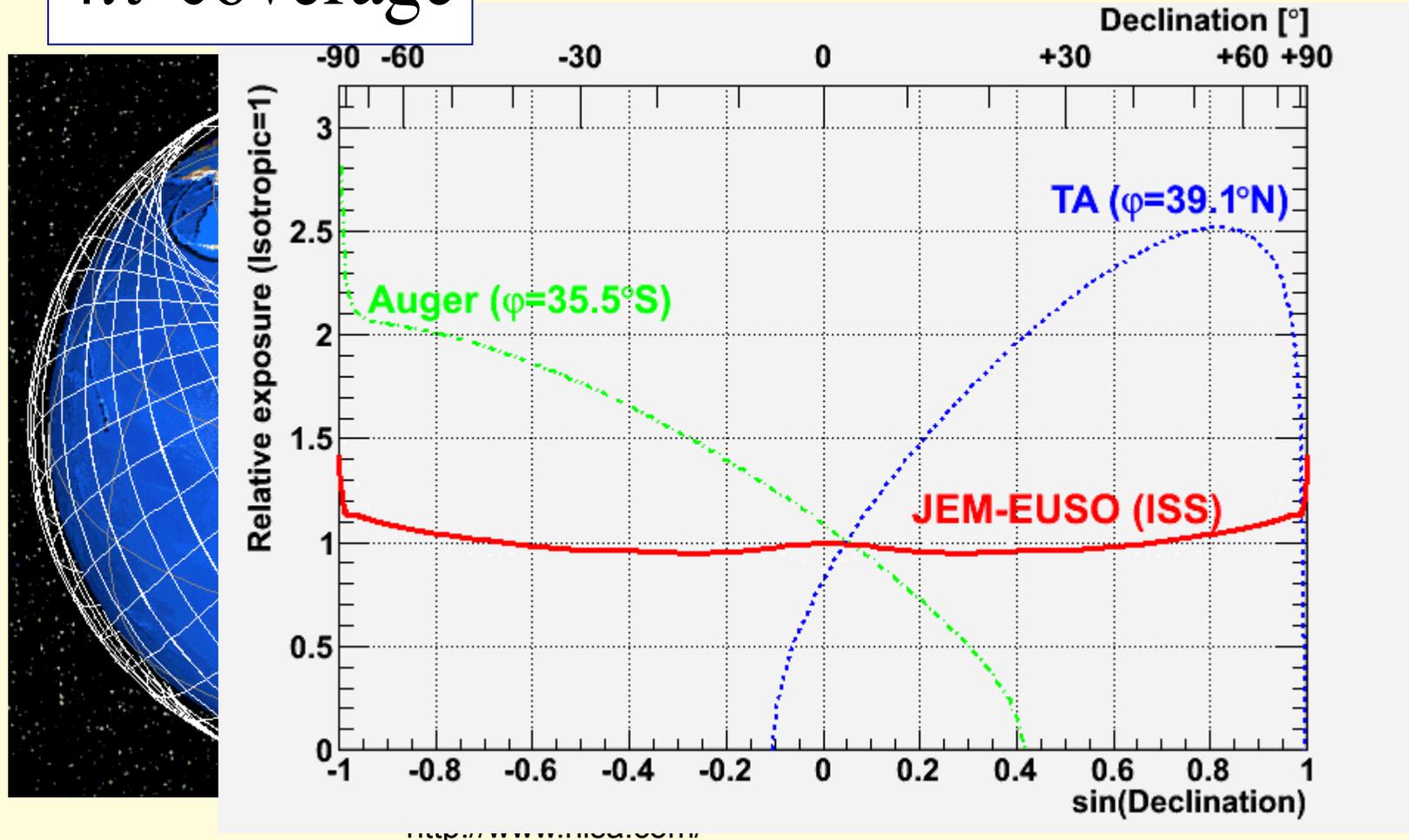


Tuebingen

$$A_{geo}^{Tilted} \approx 1. \times 10^6 \text{ km}^2 [@ 40^\circ]$$

2. ISS Orbit \rightarrow Full sky Coverage...

4π coverage

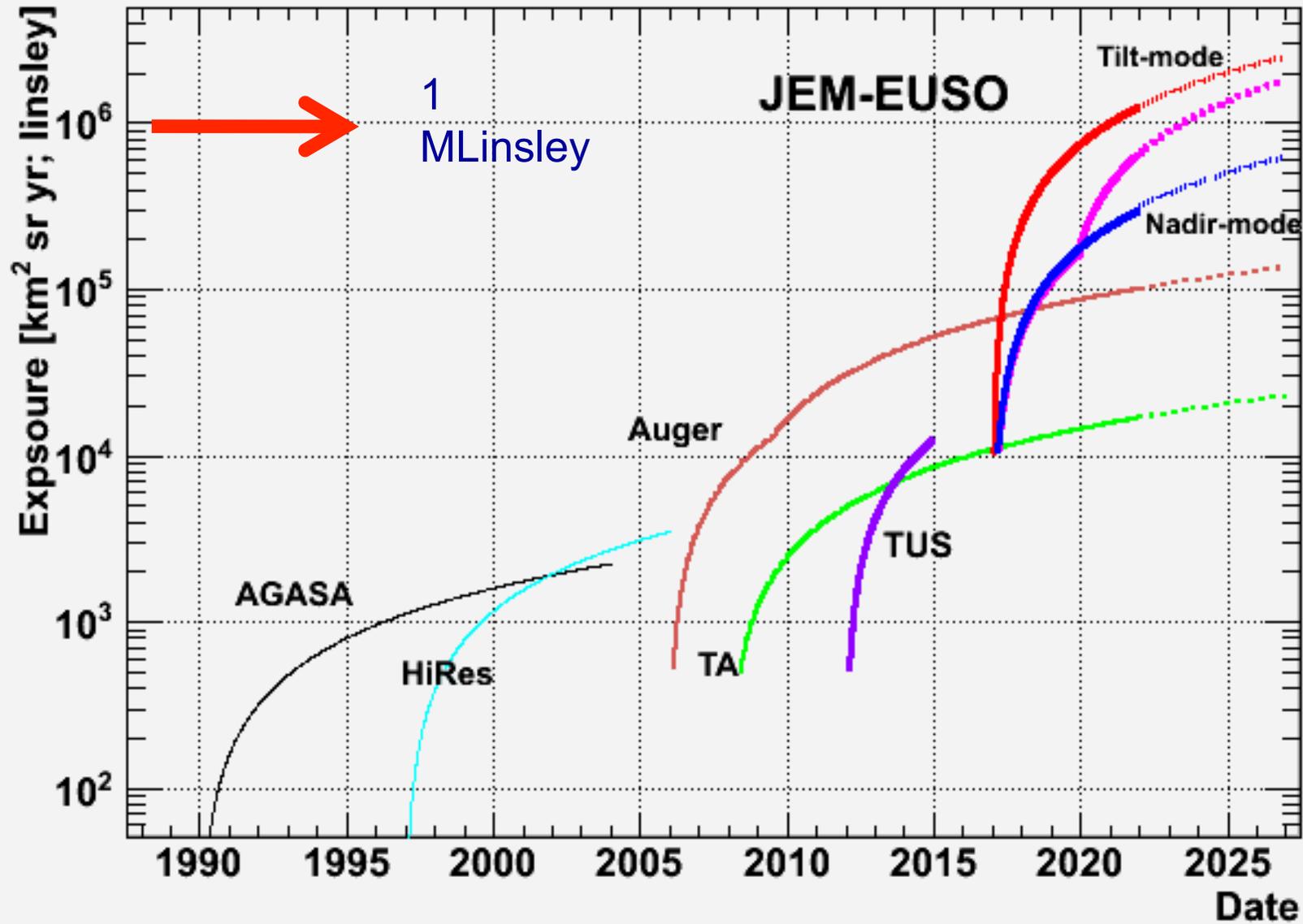


... and uniform exposure

Comparison with current observatories

Observatory	Aperture km ² sr	Status	Start	Lifetime yrs	Duty cycle	Annual Exposure km ² sr yr	Relative to Auger
Auger	7,000	Running	2006	4 (16)	1	7000	1
TA	1,200	Running	2008	2 (14)	1	1,200	0.2
TUS	30,000	Developed	2012	5	0.14	4,200	0.6
JEM-EUSO ($E \approx 10^{20}$ eV)	430,000	Design	2017	5	0.14	60,000	9
JEM-EUSO (highest energies) Tilted mode 35°	1,500,000	Design	2017	5	0.14	200,000	28

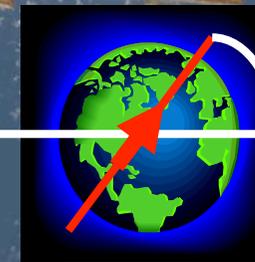
Why JEM-EUSO? Large exposure + Full sky coverage



The Mission

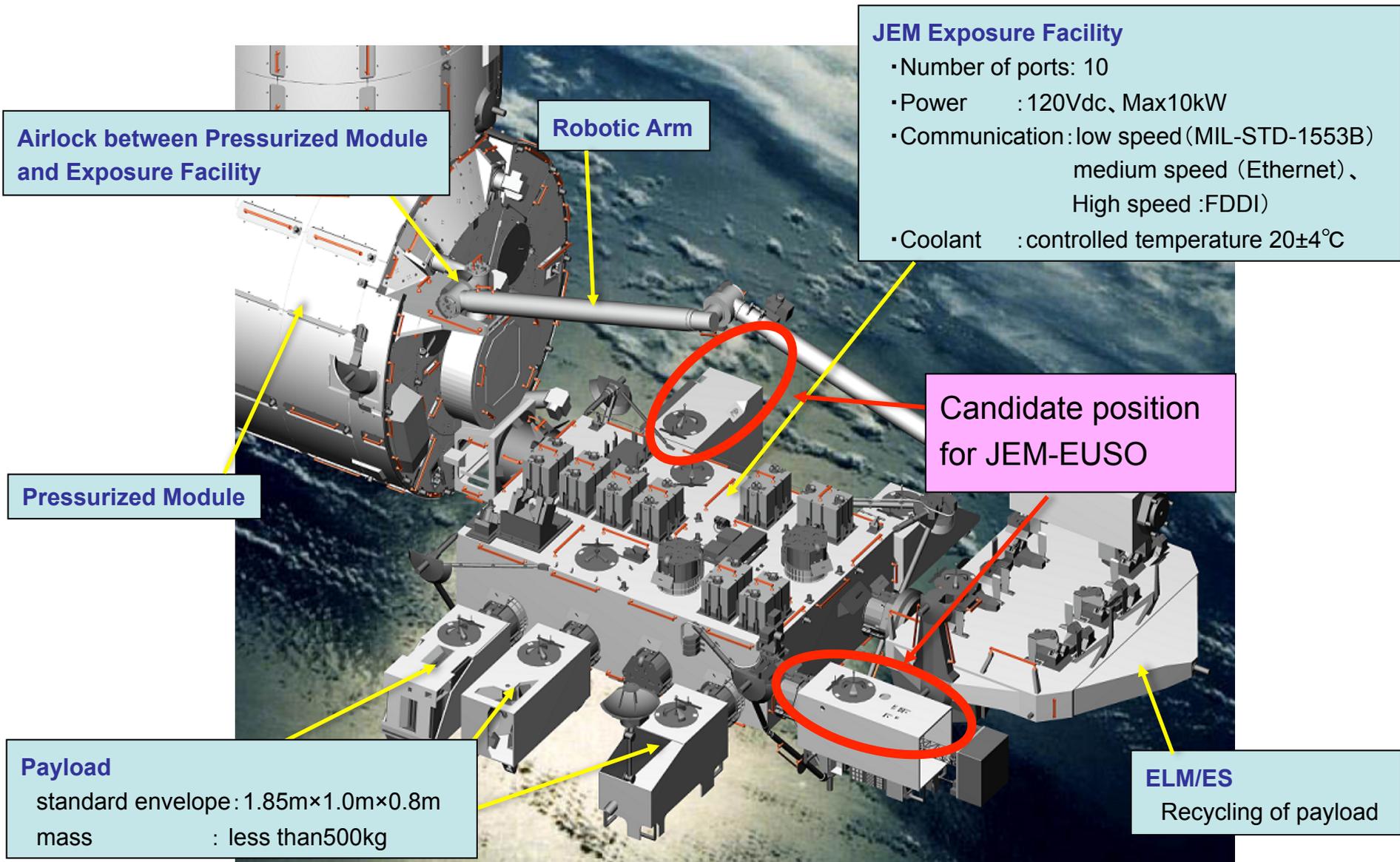
きぼう, Hope

*Japanese Experiment Module
"Kibo" July 2009*



51.6°

Outline of JEM Exposure Facility Japanese Experiment Module “KIBO”



Mission aspects have been successfully studied by JAXA and RIKEN

Parameter	Value
Launch date	JFY 2016
Mission Lifetime	3+2 years
Rocket	H2B
Transport Vehicle	HTV
Accommodation on JEM	EF#2
Mass	1938 kg
Power	926 W (op.) 352 W (non op.)
Data rate	285 kbps (+ on board storage)
Orbit	400 km
Inclination of the Orbit	51.6°
Operation Temperature	-10° to +50°



POCKOCMOC

JEM-EUSO

Flight Segment

TDRS

EECR

HTV

UV photons

Fluorescence

Cherenkov

Air Shower

H-IIB

Ground Support Equipment

Ground Segment



LIDAR station

Ground Based Calibration System

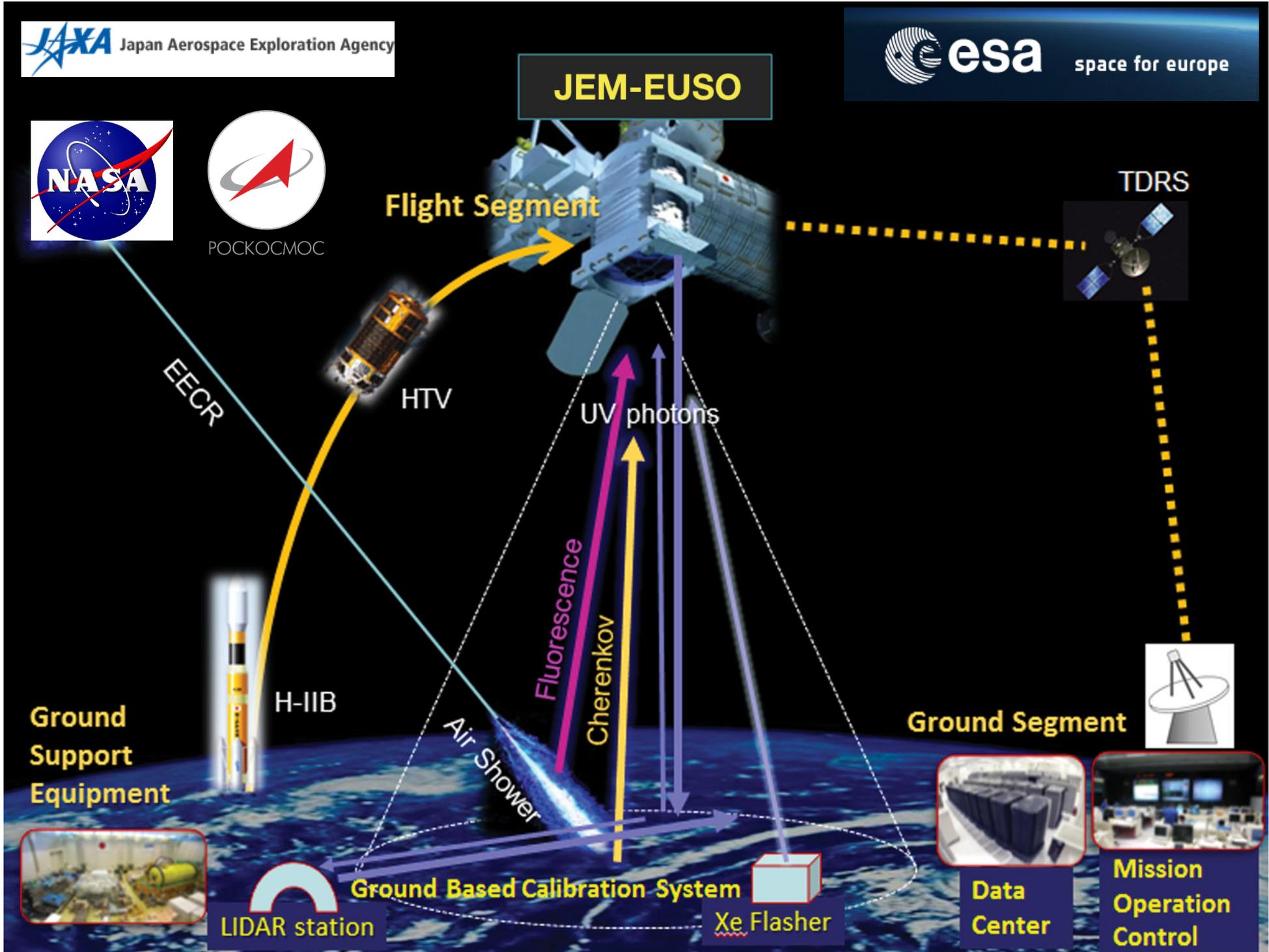
Xe Flasher



Data Center

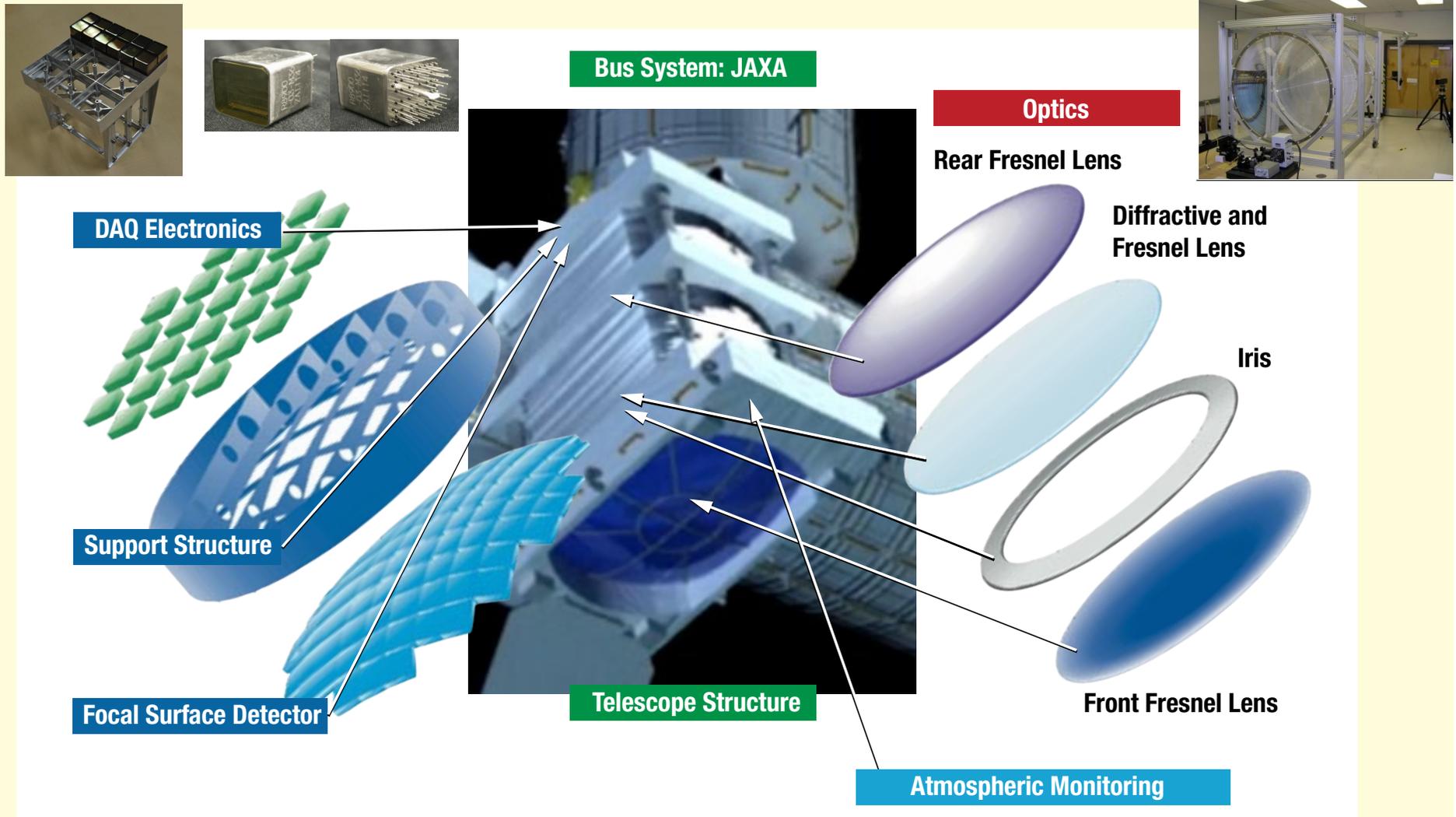


Mission Operation Control

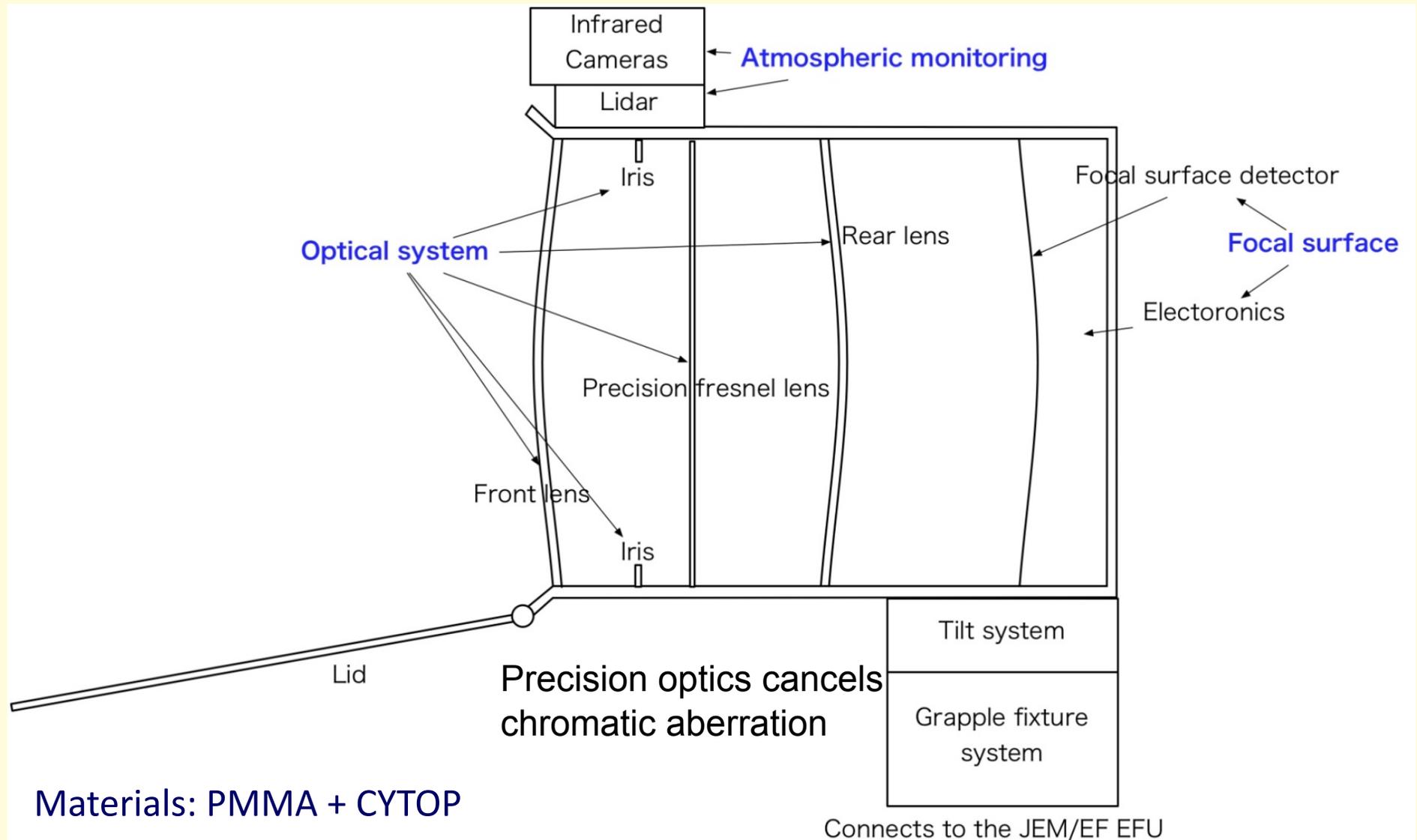


The Instrument

Science Instrument: UV Telescope + Atmospheric Monitoring



Conceptual View of the JEM-EUSO Telescope

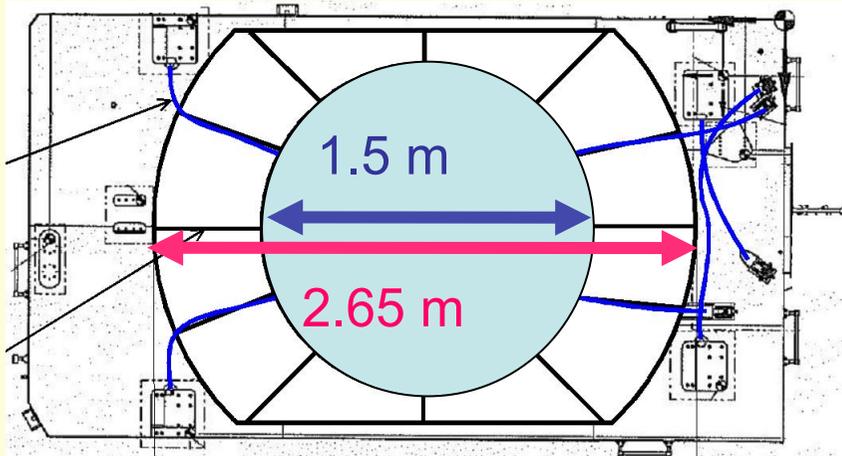


The UV Telescope Parameters

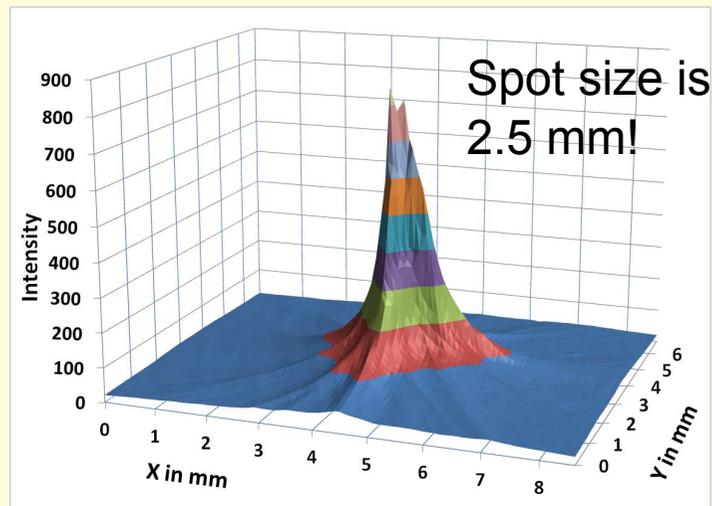
Parameter	Value
Field of View	$\pm 30^\circ$
Monitored Area	$>1.3 \times 10^5 \text{ km}^2$
Telescope aperture	$\geq 2.5 \text{ m}$
Operational wavelength	300-400 nm
Resolution in angle	0.075°
Focal Plane Area	4.5 m^2 +
Pixel Size	$< 3 \text{ mm}$
Number of Pixels	$\approx 3 \times 10^5$
Pixel size on ground	$\approx 560 \text{ m}$
Time Resolution	$2.5 \mu\text{s}$
Dead Time	$< 3\%$ +
Detection Efficiency	$\geq 20\%$

+ Optics Throughput

BBM of the Optics (Prototypes)



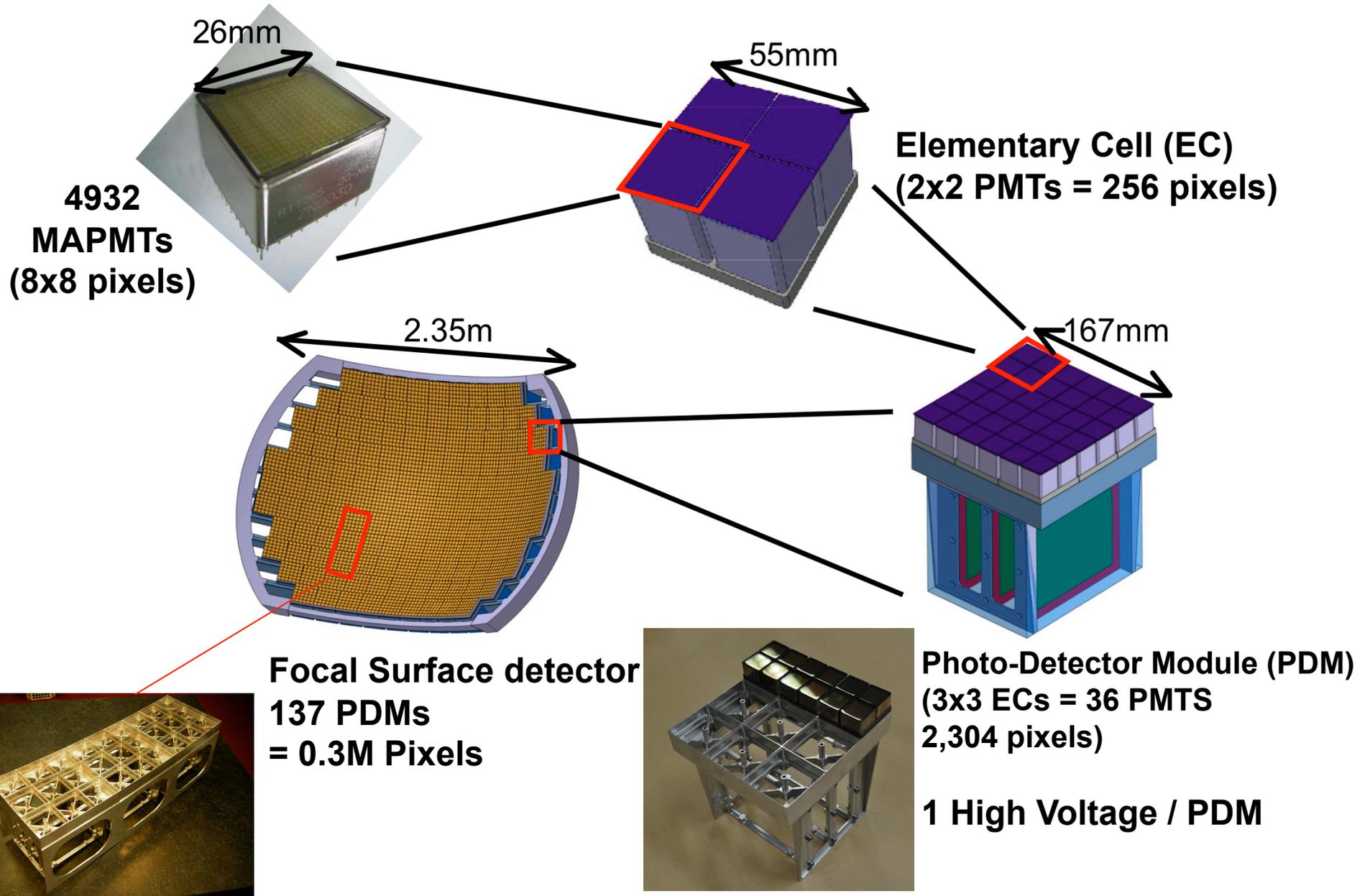
large diameter Fresnel lenses
manufactured in Japan and
tested in the US at the University
of Alabama (Huntsville) and at
MSFC (NASA)



Tested performances meet
already the requirements
(or are close to it)

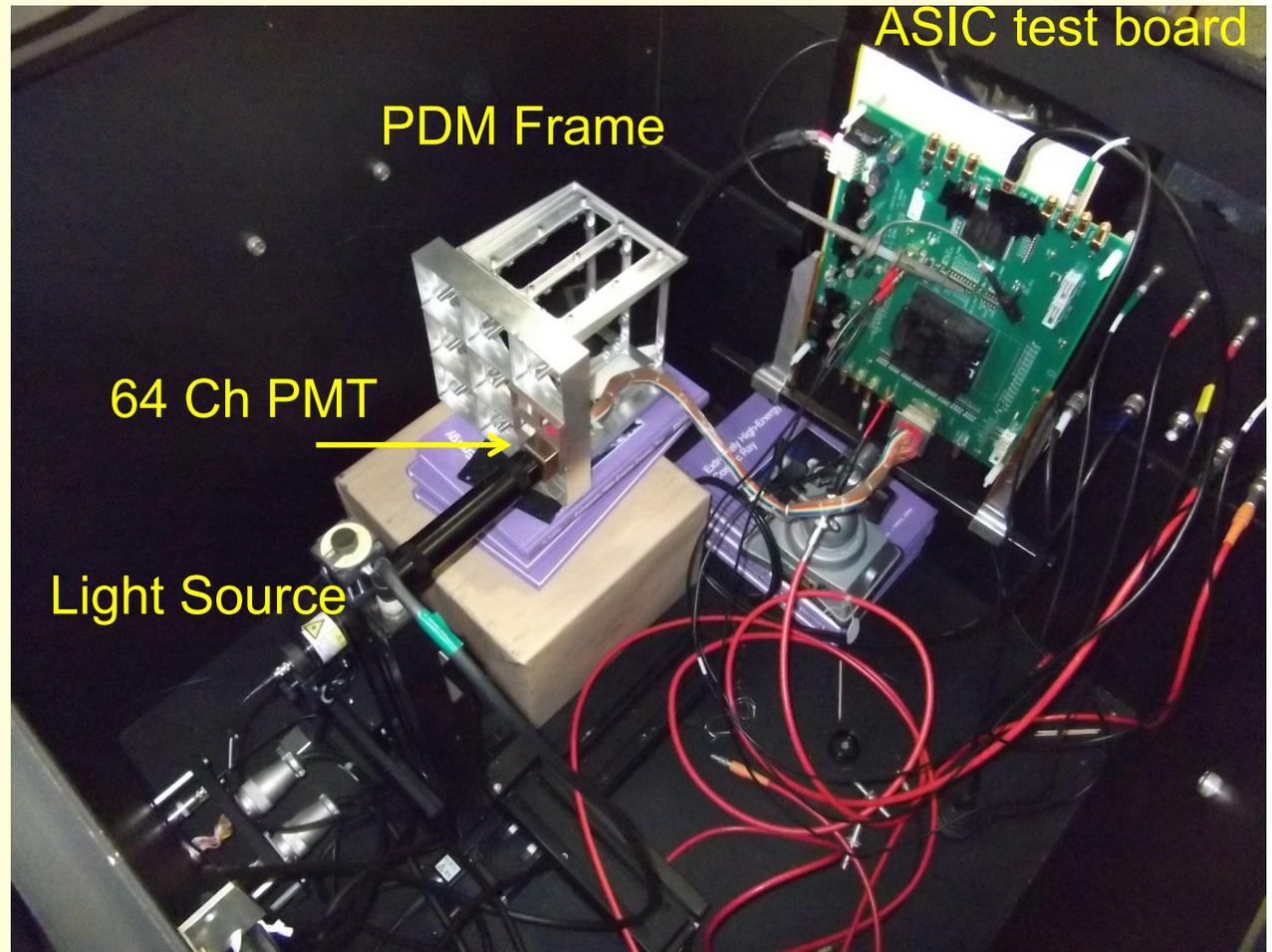


Focal Surface Detector



Detector and electronics

- MAPMT-64
- ASIC *Spaciroc*
- *Electronic Cell Board*
- 137 PDM *1st trigger and readout*
- CCB *2nd trigger*



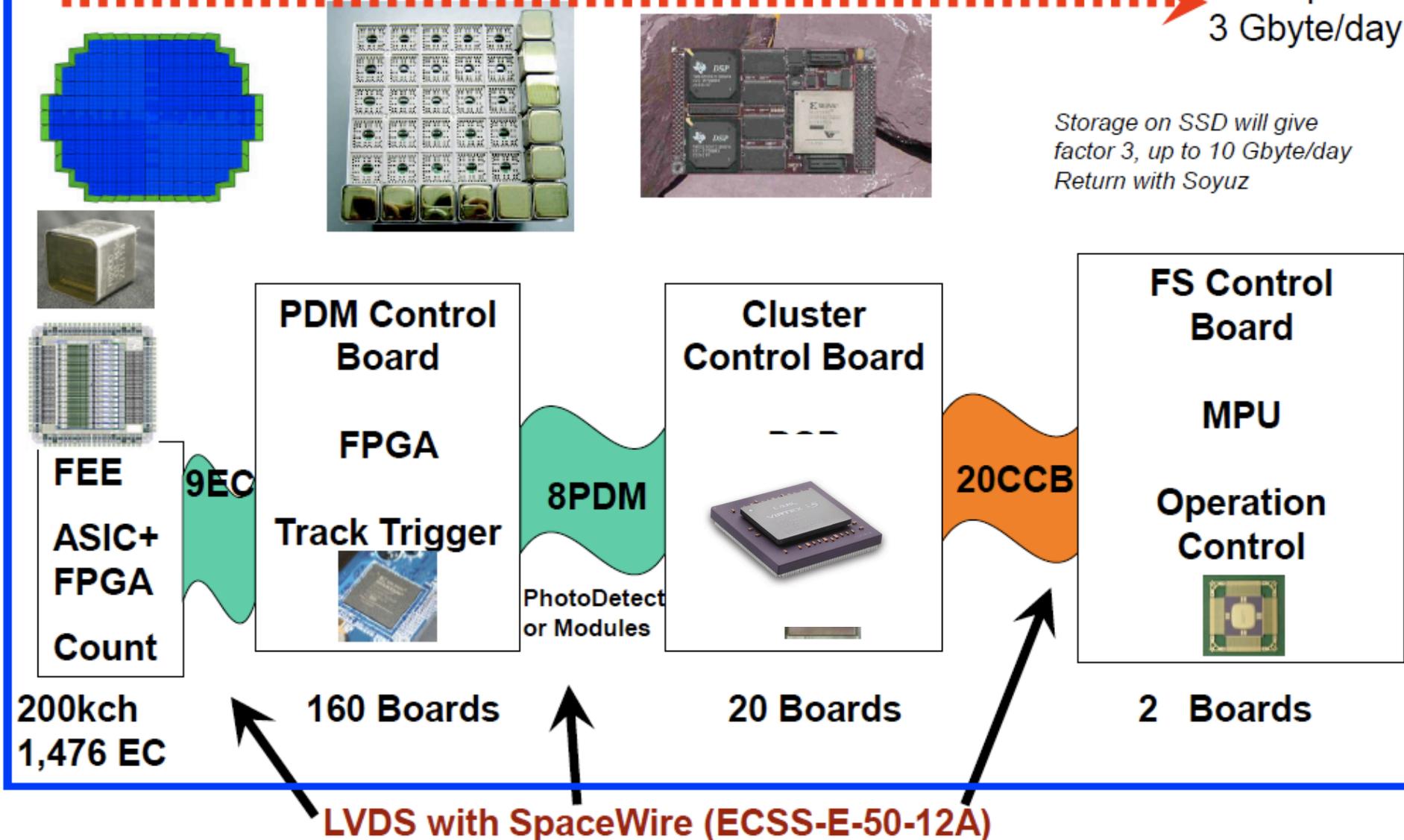
From 9.6 GB/s to 3 GB/day on the entire FS

PDM Bread board model integrated at RIKEN

JEM-EUSO DAQ – Data reduction block scheme

9.6 GB/s (FS) $4 \cdot 10^{-3}$ compression 10^{-3} compression \rightarrow 297 kbps
3 Gbyte/day

*Storage on SSD will give factor 3, up to 10 Gbyte/day
Return with Soyuz*



Atmospheric Monitoring System

- IR Camera

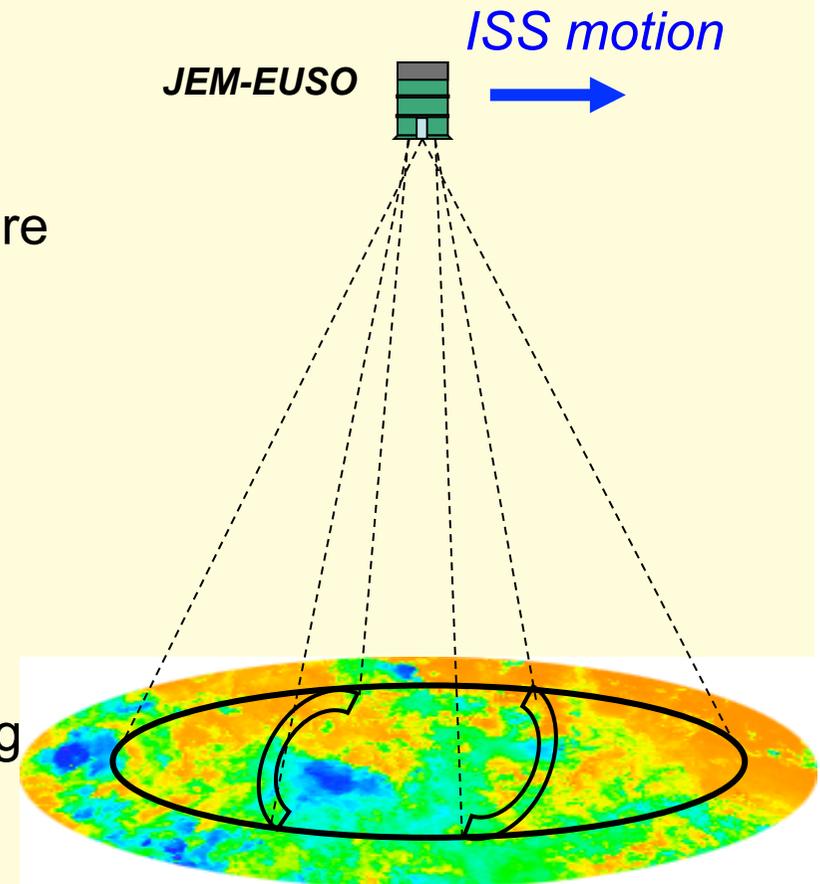
Imaging observation of cloud temperature inside FOV of JEM-EUSO

- Lidar

Ranging observation using UV laser

- JEM-EUSO “slow-data”

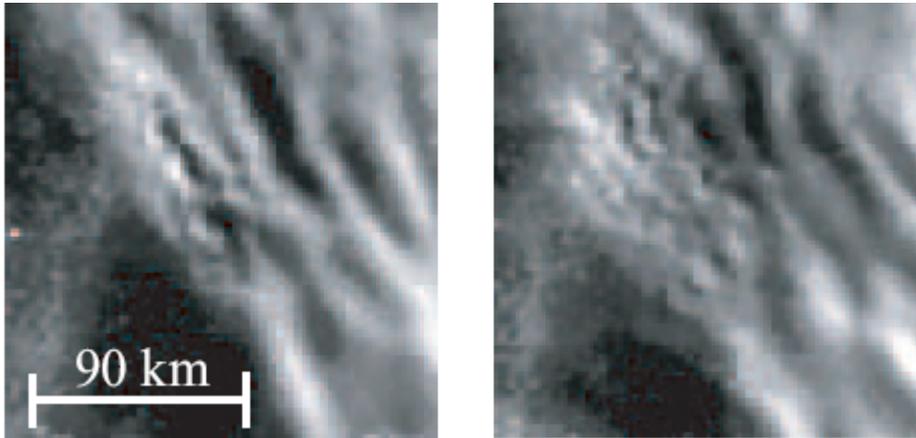
Continuous background photon counting



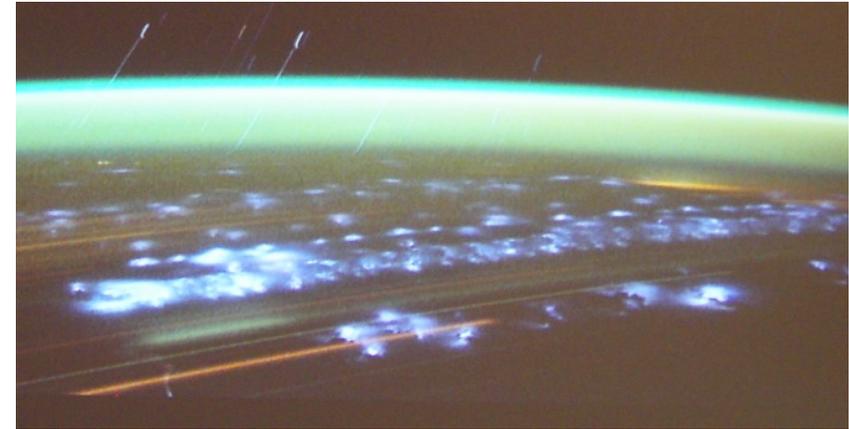
- *Cloud amount, cloud top altitude:* (IR cam., Lidar, slow-data)
- *Airglow:* (slow-data)
- *Calibration of telescope:* (Lidar)

→ **See also Poster P125** “Observation of UHECRs in cloudy conditions by the JEM-EUSO Space Observatory”

Atmospheric Luminous Phenomena



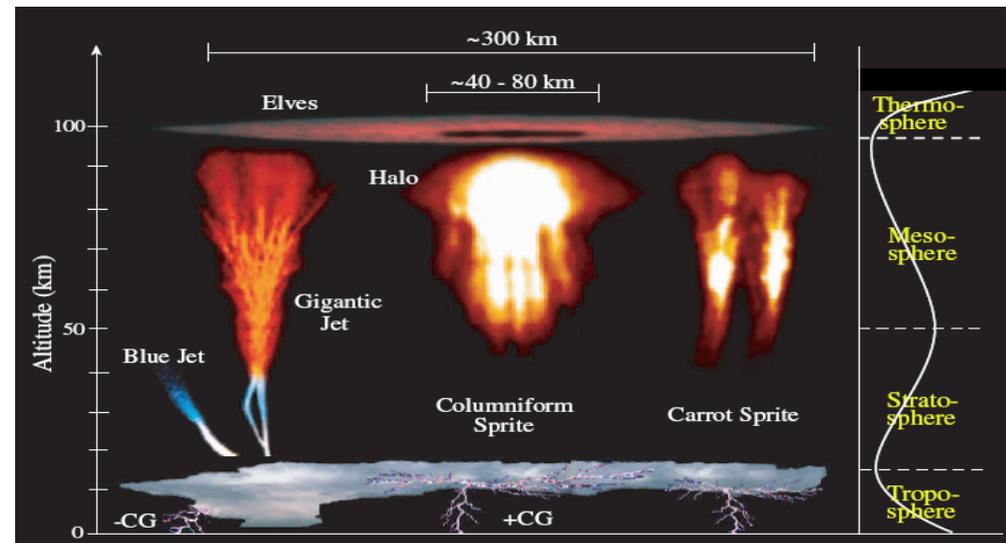
OH airglow observed from ground



Lightning picture observed from ISS

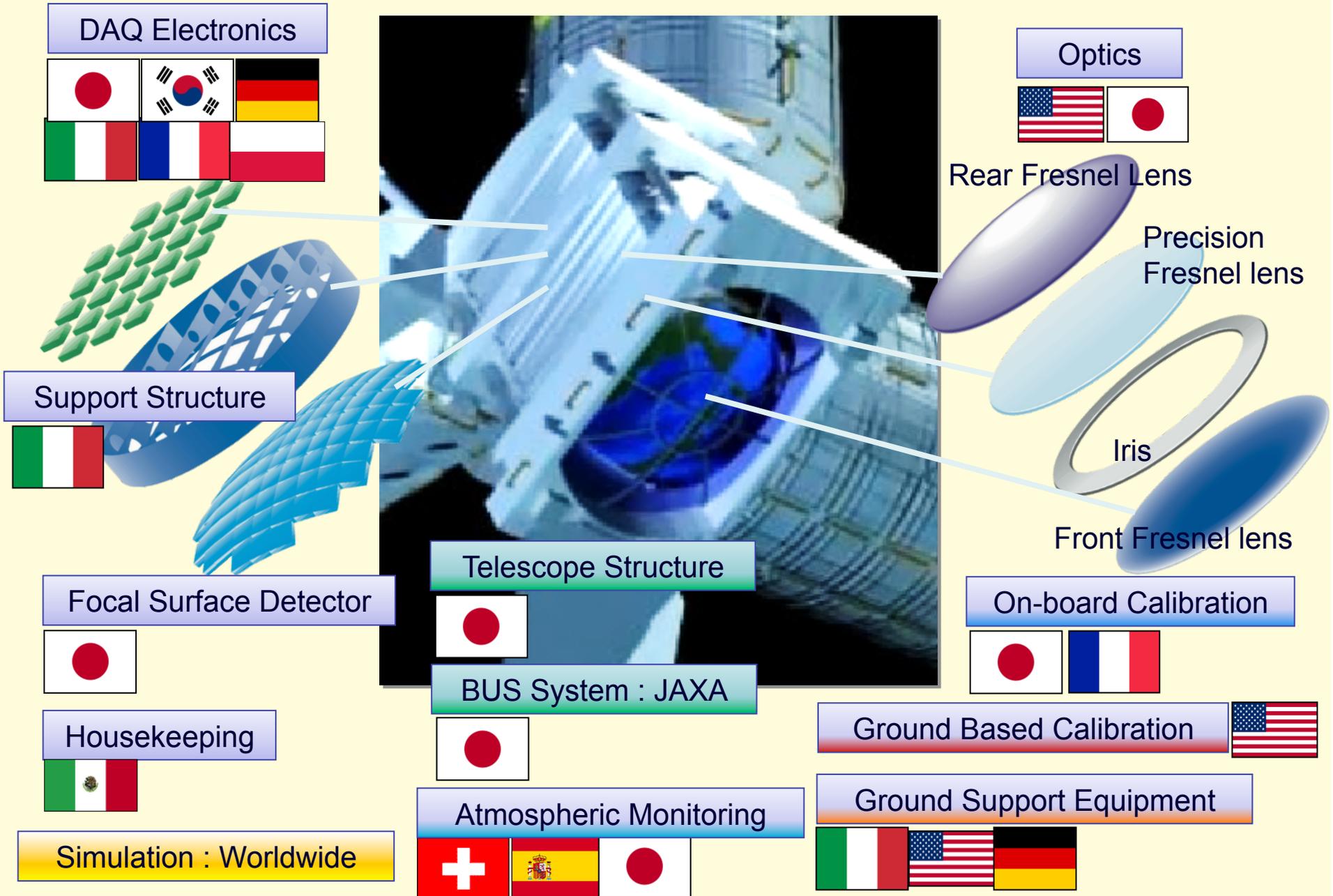


Leonid meteor swarm in 2001
taken by Hivison camera



Various transient airglows

International Role Sharing



Near Term Programmatic

- **Spring 2012:** Test and calibration of the Optics; integration of the PDM engineering model (EM)
- **Summer 2012:** integration of a prototype (optics + PDM EM)
- **October – December 2012**

Test of a prototype at the TA (Utah) site:
2 lenses system + 1 PDM EM
and ...

JEM-EUSO Balloon

- Look down from the balloon with an UV telescope (3 lenses system + 1 PDM EM)
- Engineering test
- Background test
- Airshower from 40 km altitude

2009 Proposal submitted to CNES (France)

2011/6 Approved by CNES

→ 2013, January, first launch from Kiruna (Sweden)

Current Status of the Mission

- Phase A study jointly conducted by JAXA and the JEM-EUSO consortium (Payload and Mission) is vigorously ongoing...
- JEM-EUSO has been included (in 2010) in the ELIPS program of ESA
- National contributions have been defined (and in many cases asked and in a few cases already approved!)
- US JEM-EUSO MO proposal (Explorer Call) is being reviewed by NASA (End Sept. – Early Oct. 2011)

Conclusions

- *Science*: Evidence for GZK, Indication for Anisotropy, hints of sources but *puzzling scenario* (PAO, HiRes, TA)
 - Current generation of UHE Observatories is too small
 - *We need next generation*
 - *Exploration of the unknown*: UHE neutrinos, photons and new physics
- *Breakthrough can come from space*:
 - Large exposures, uniform exposures of the entire sky
 - JEM-EUSO is the pathfinder with potentially outstanding science output.
- *JEM-EUSO is feasible*:
 - Phase A/B studies of JAXA and of the Collaboration confirms it
 - Prototyping phase has been started. Tests on the key mission elements have been conducted.
- *Launch in 2017*

Take home messages:

Physics and Astrophysics at $E > 5 \times 10^{19}$ eV

But also...

Explore new physics in the energy range $E \approx 10^{20} - 10^{21}$ eV

Highest statistics and therefore largest exposures at extreme energies

$$E \approx 10^{20-21} \text{ eV}$$

But also ... lower energies are important for overlapping with ground-based detectors and make a statistically significant comparison!

$$E < 5 \times 10^{19} \text{ eV}$$