21-11-12

Studying the Universe and the Earth from space with JEM-EUSO & Micro-UVT missions.

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INFN Rome Tor Vergata

JEM-EUSO Collaboration

13 countries, 77 institutions, >250 members

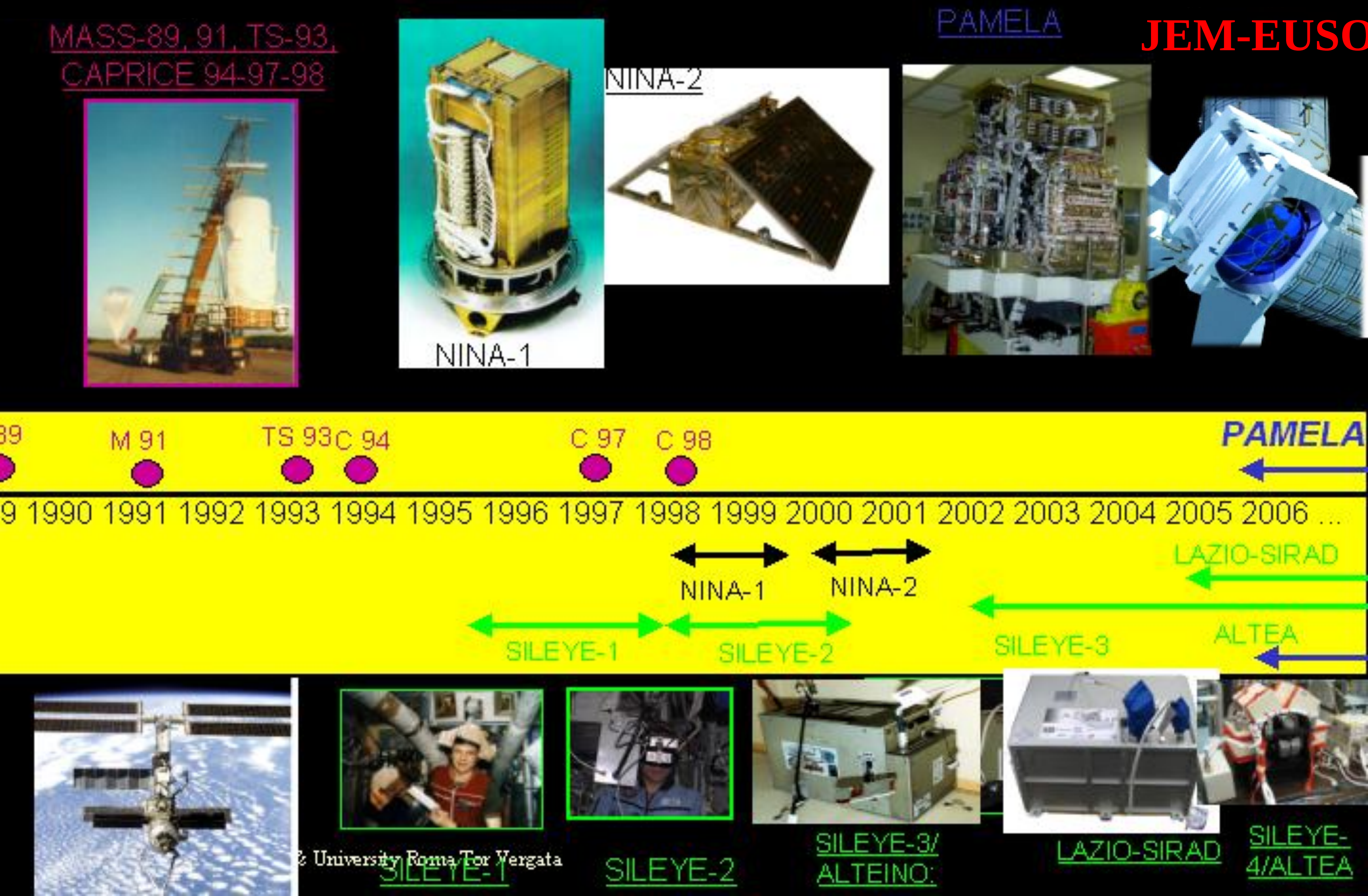
- Korea, Mexico, Japan, Russia, USA,
- *Western Europe*: Bulgaria, France, Germany, Italy, Poland, Slovakia, Spain, Switzerland

Leading institution: Riken, Japan

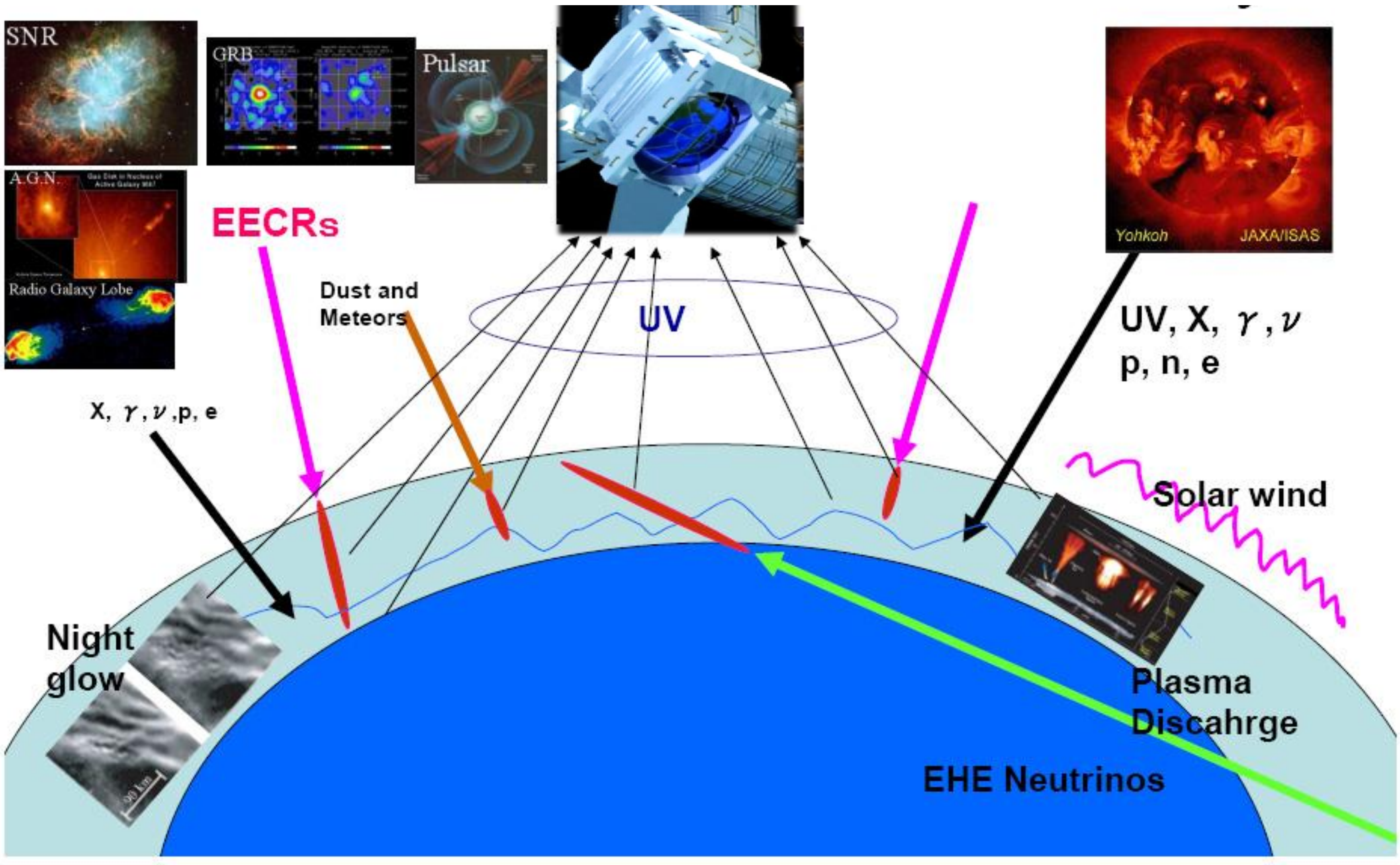
Principal Investigator: Piergiorgio Picozza *(also PI of PAMELA)*

+other National Space Agencies

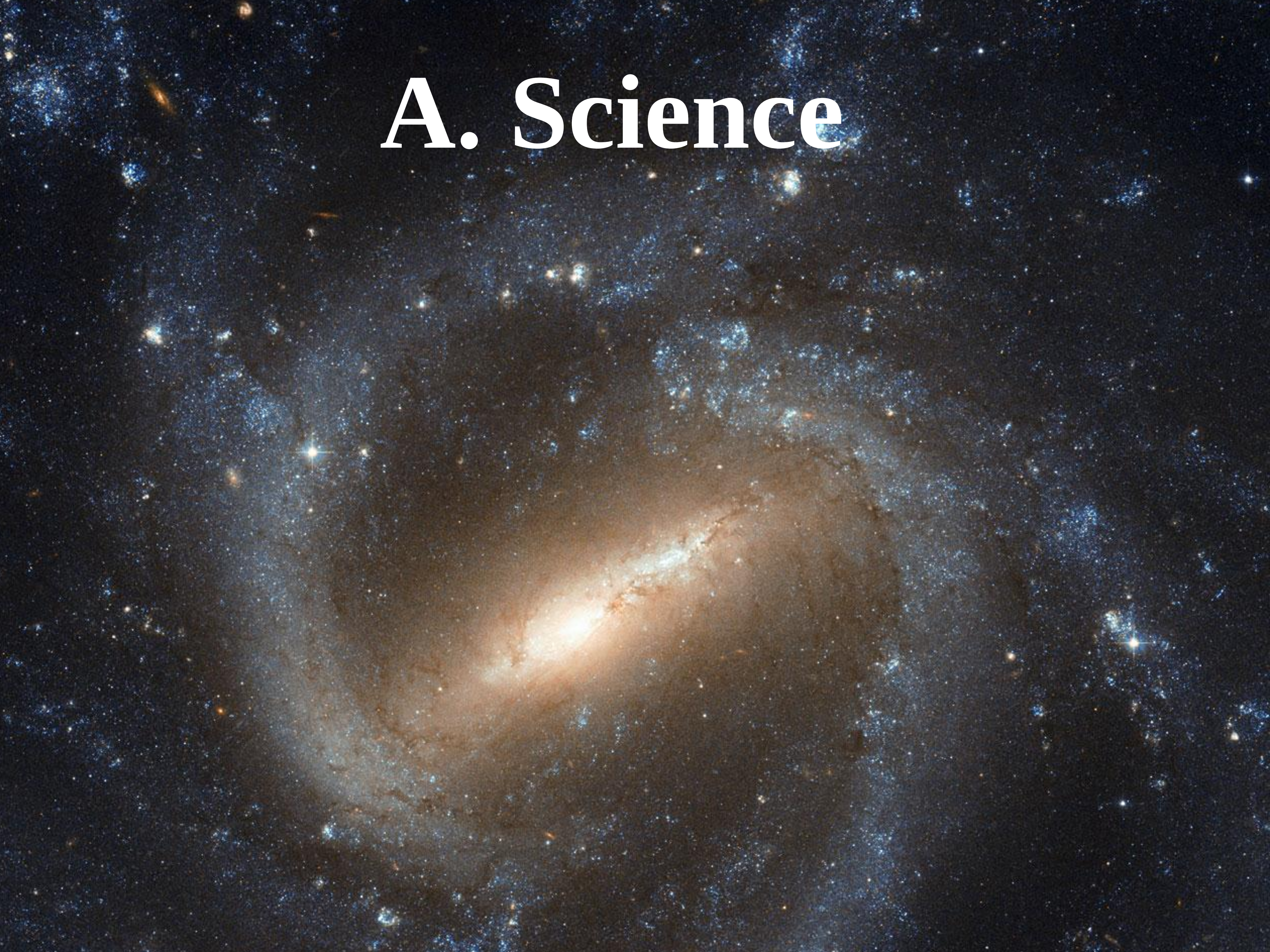
Previous balloon and space-borne experiments



JEM-EUSO
Astronomical and Terrestrial Observatory

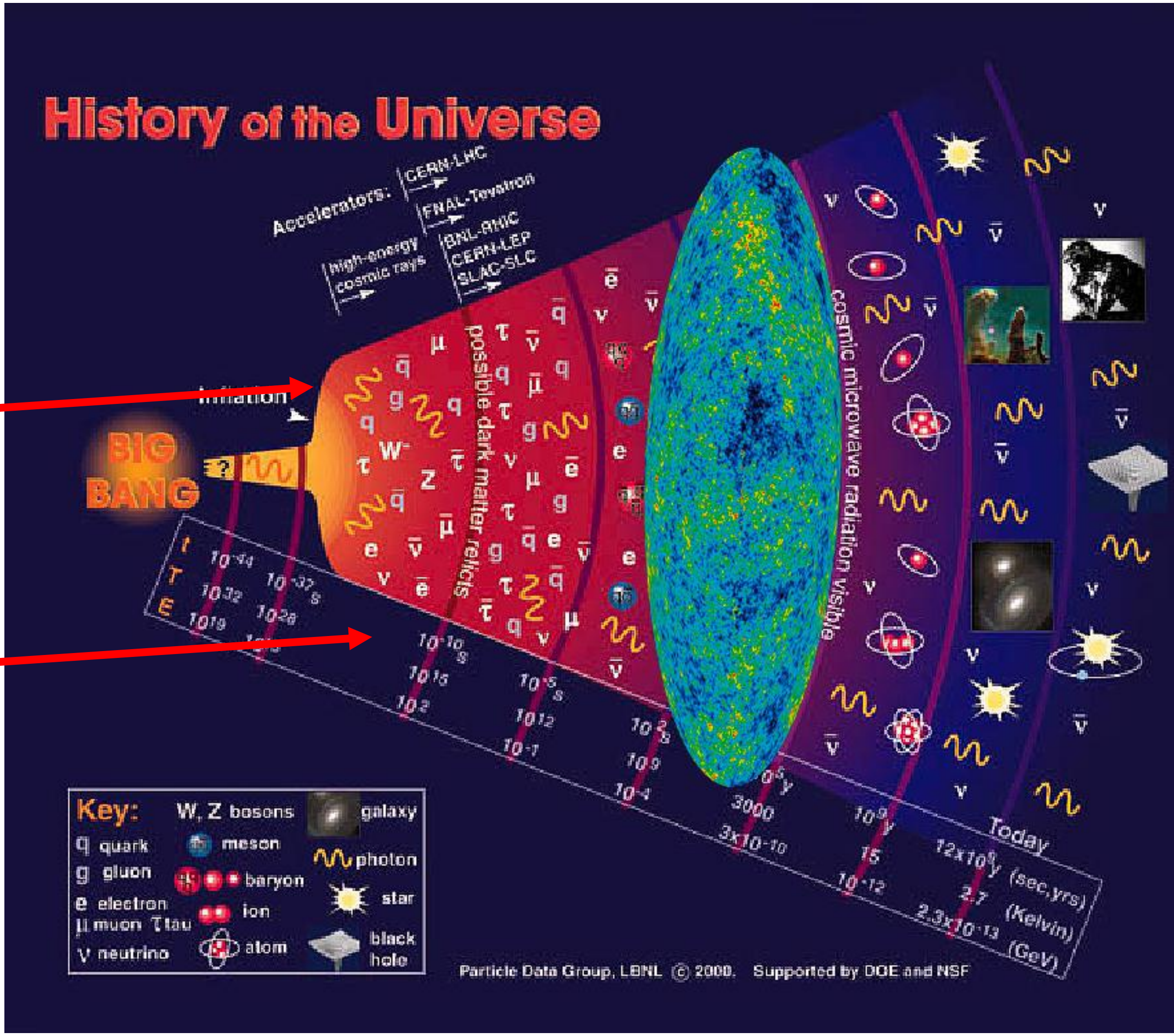


A. Science



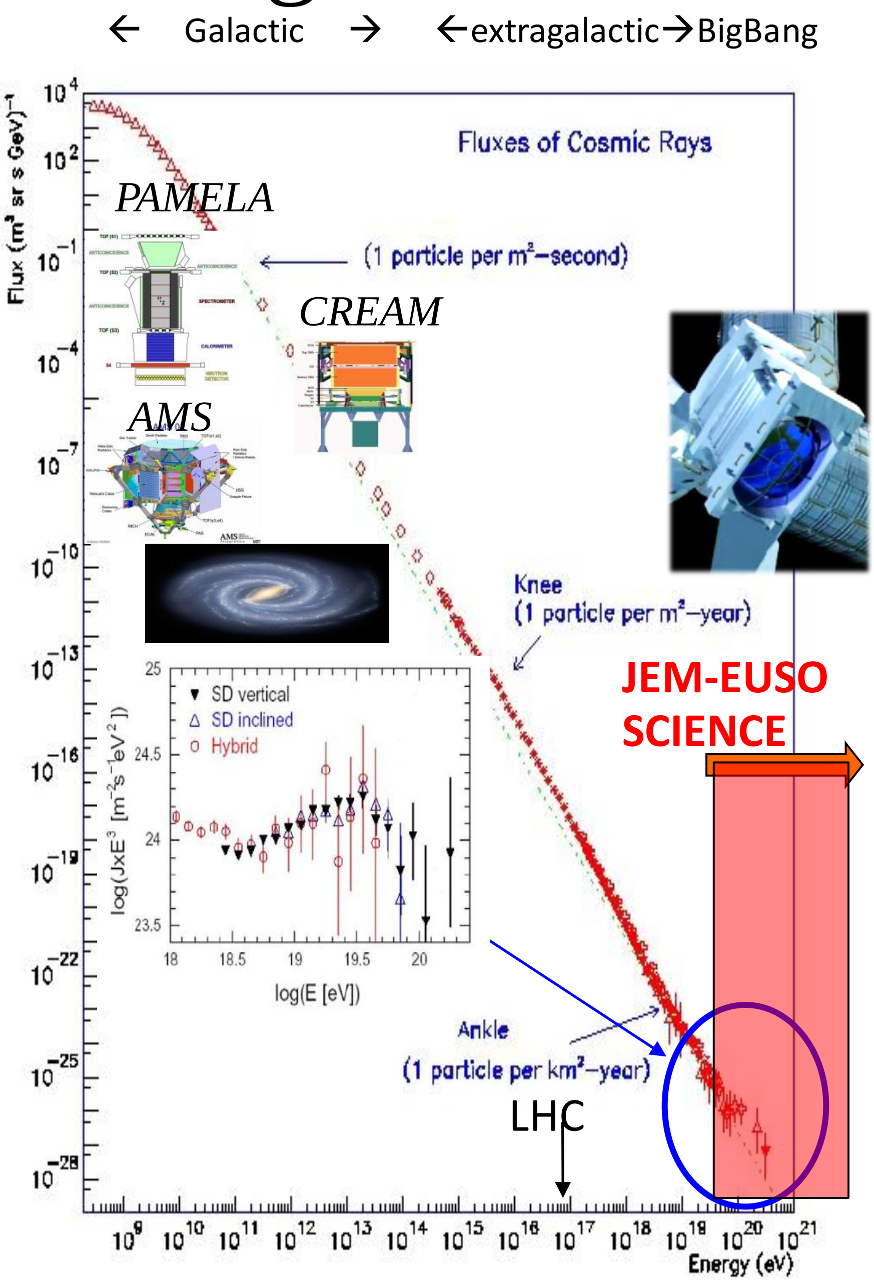
A1. Fundamental particle physics and Big Bang Cosmology

- Look beyond the Cosmic Microwave Background veil
- Why is the universe made of matter?
- What happened to the antimatter?
- Are there topological defects?
- Is there a Dark Matter component of ultra-high energy cosmic rays?



A2. Particle physics at the highest energies

- Beyond LHC threshold
- Extragalactic Astronomy:
  - 10kpc (Galaxy) vs 100Mpc (extragalactic)
- Door to unknown phenomena:
  - Is Lorentz invariance valid? Has the Universe a preferred direction?
  - String physics

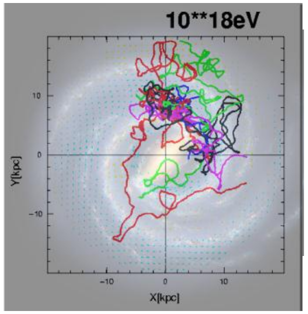


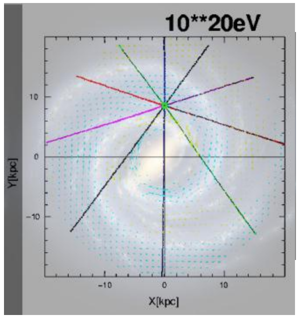
A3. Astronomy with charged cosmic rays

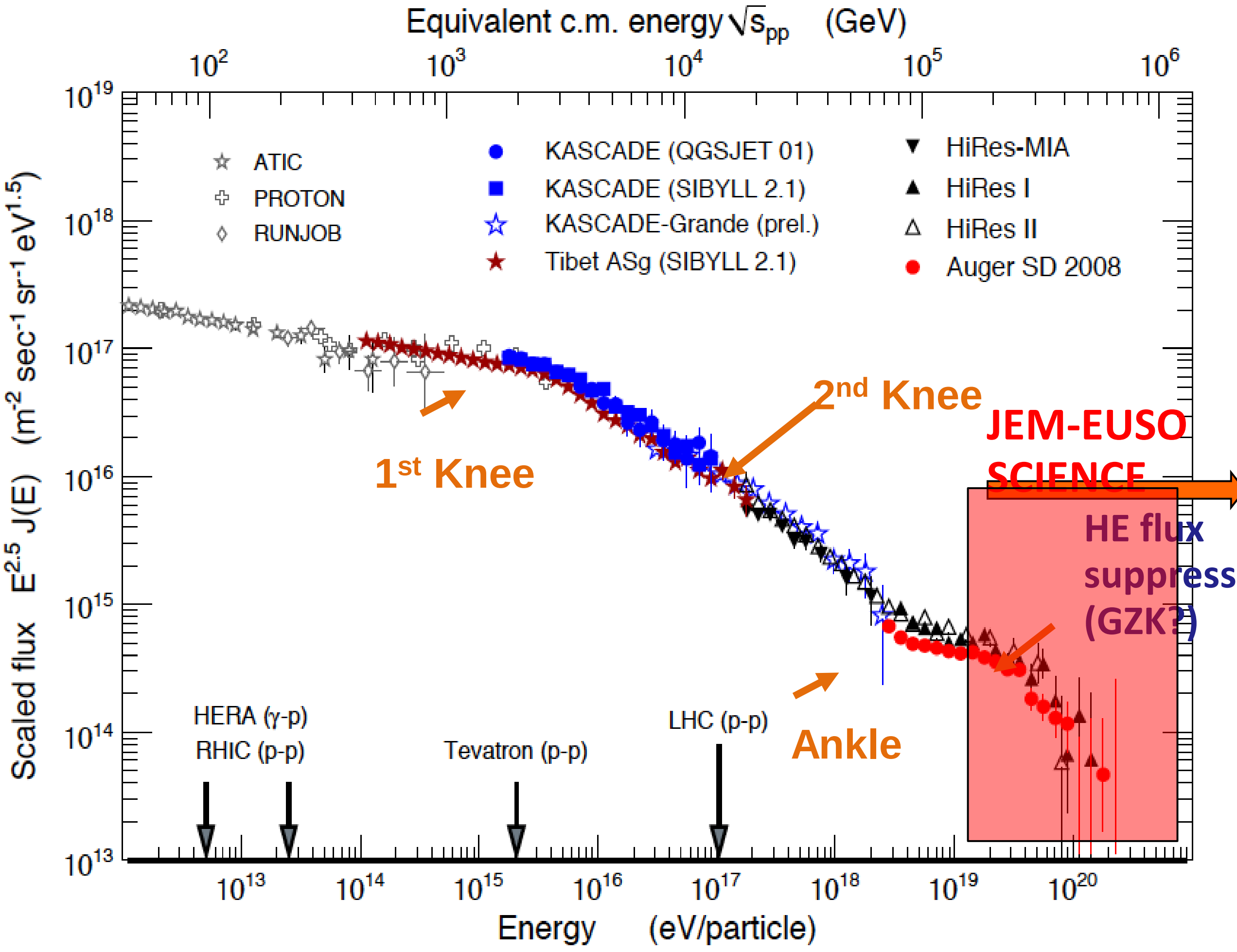
Extragalactic Astronomy

Cosmic rays are not bent by magnetic fields

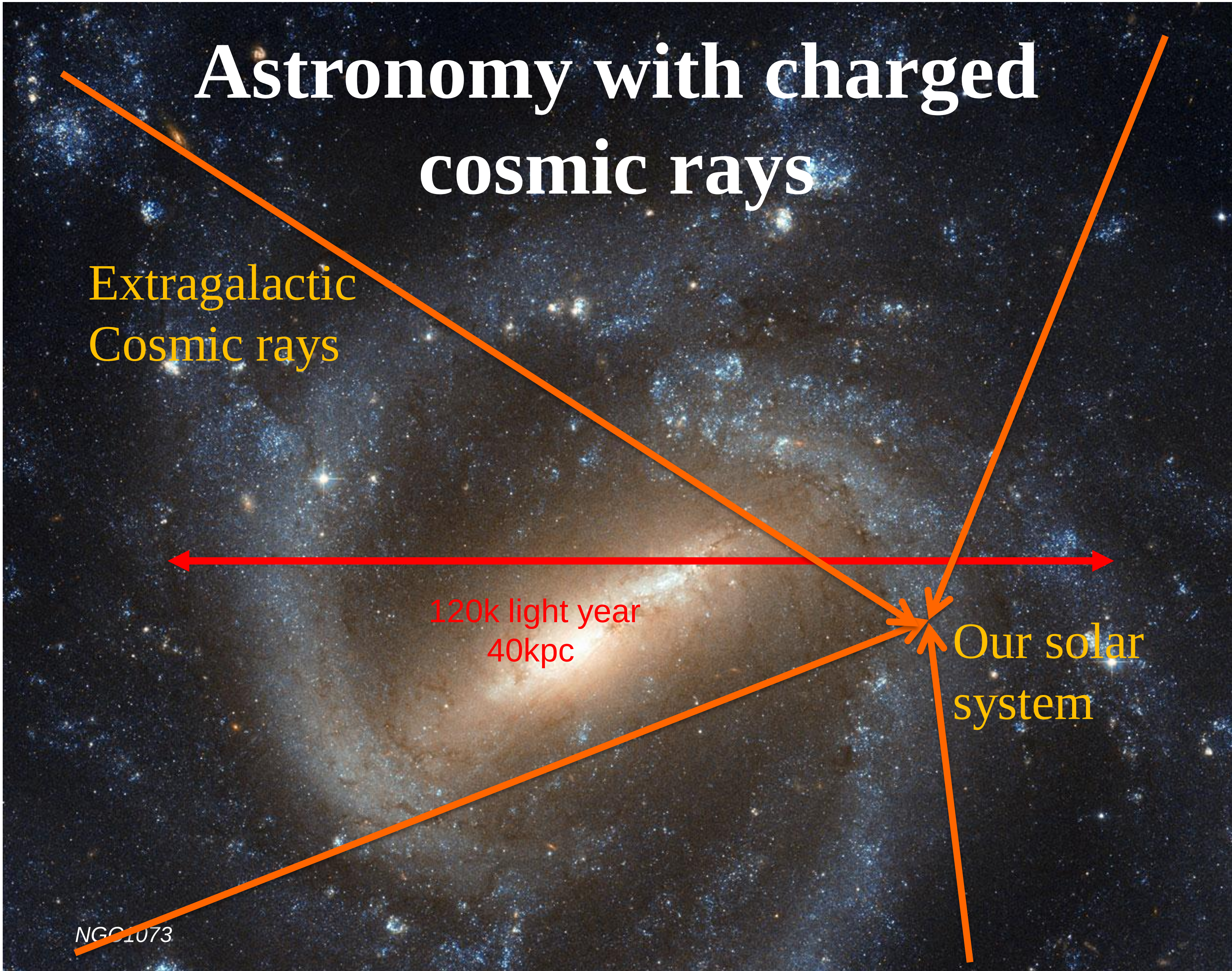
- Where do Ultra-high energy cosmic rays come from?
- How are they produced^
- Is there a difference between Southern (auger) and Northern (Telescope array) hemispheres?



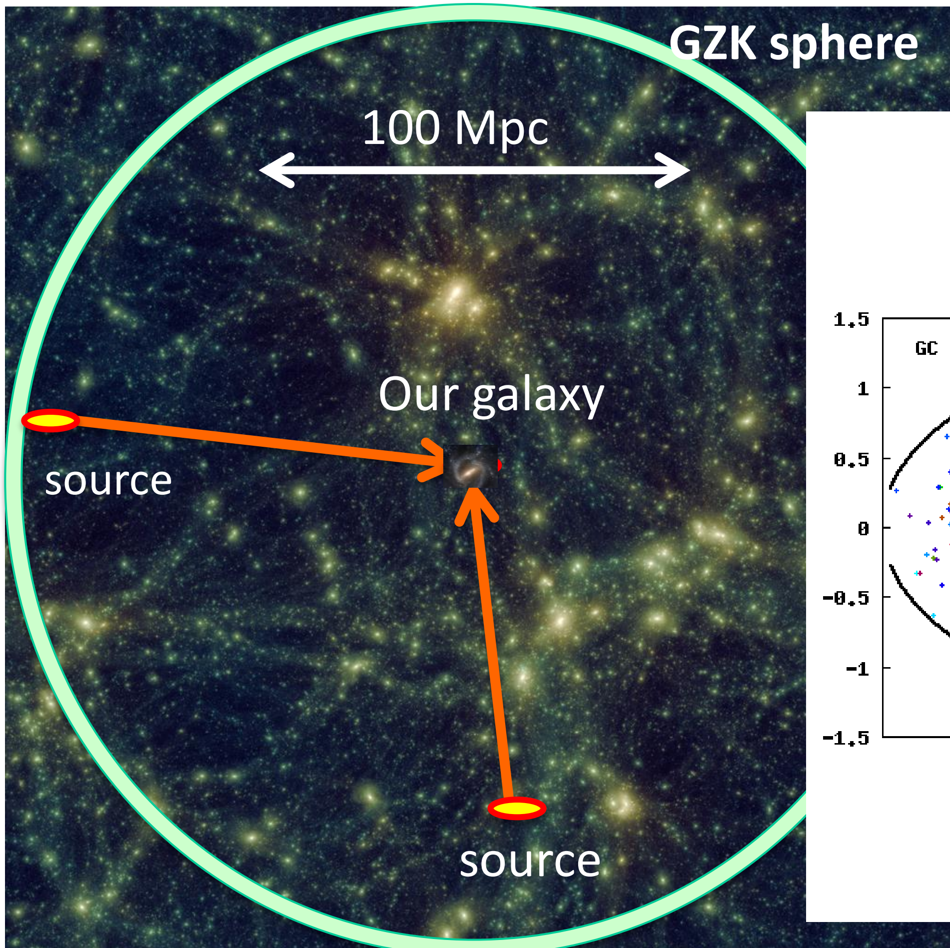


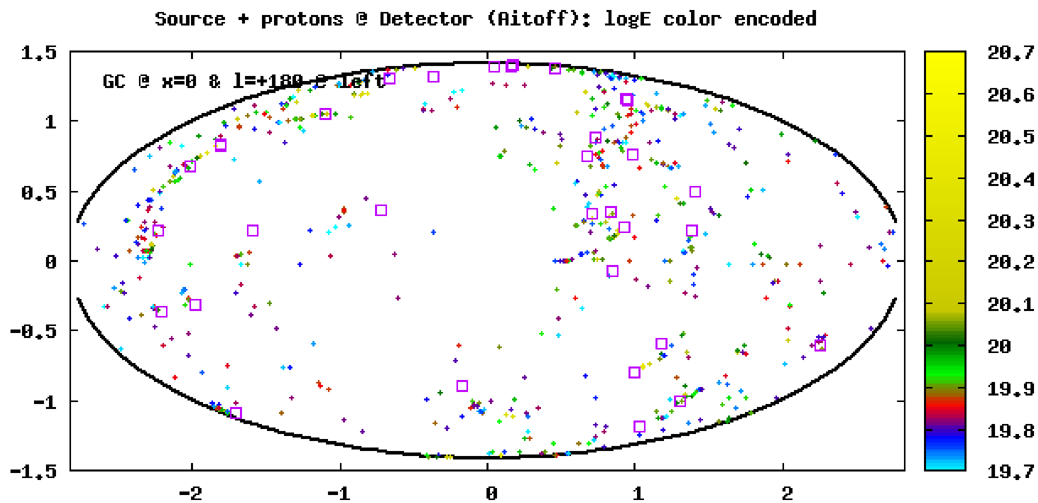


Astronomy with charged cosmic rays



Observation range





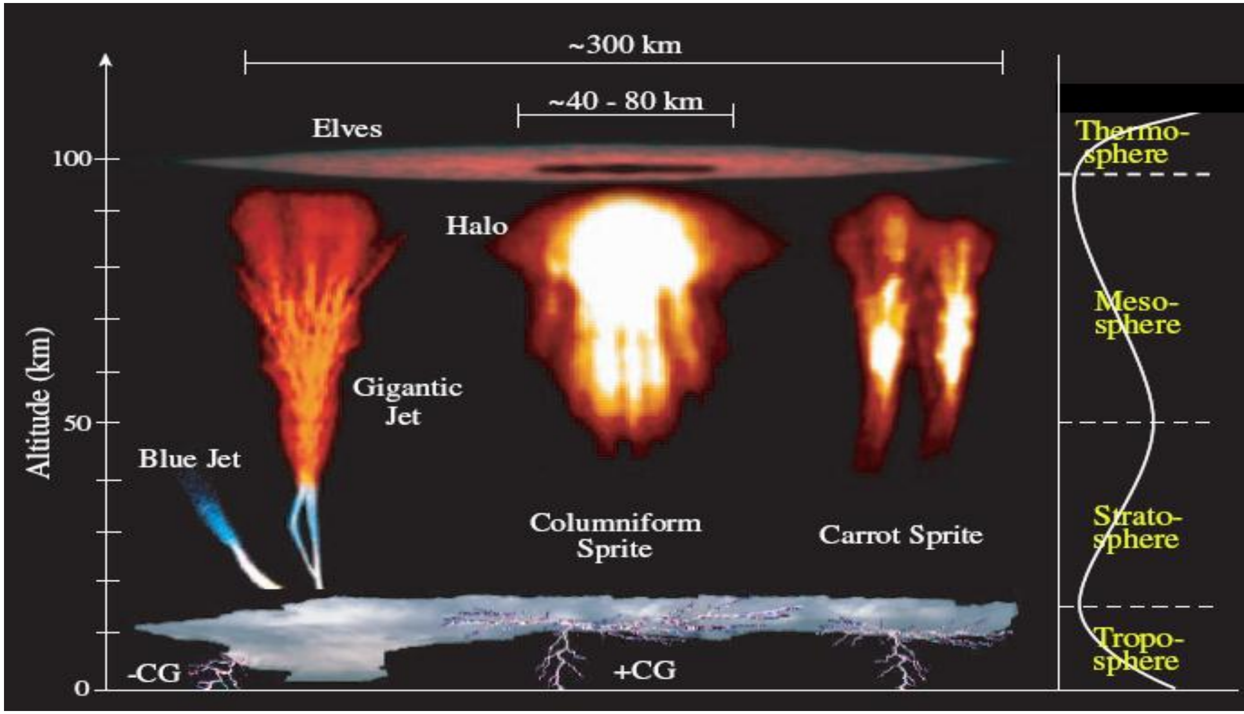
A4. Study and monitor of atmospheric phenomena

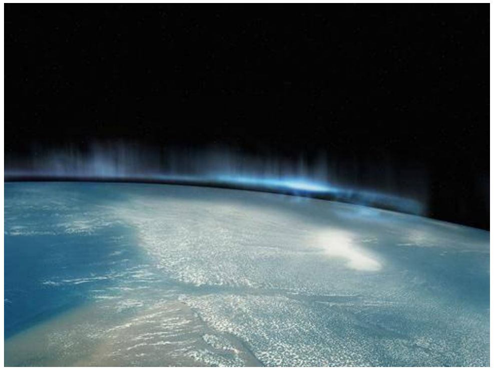
- Transient luminous effects
- Lighting, auroae

- What are the formation processes on time scale of micro-milliseconds?

- *Are they caused by cosmic rays?*

- Multi-wavelength
- Multi detector observation





A5. Crew protection and planetary defense

Need to extend the near-Earth metereoid and space debris inventory and size distribution from space, to overlap the data on the smallest bodies observed by ground-based Near Earth Object programs, filling missing data between 10^3 - >10^6 kg

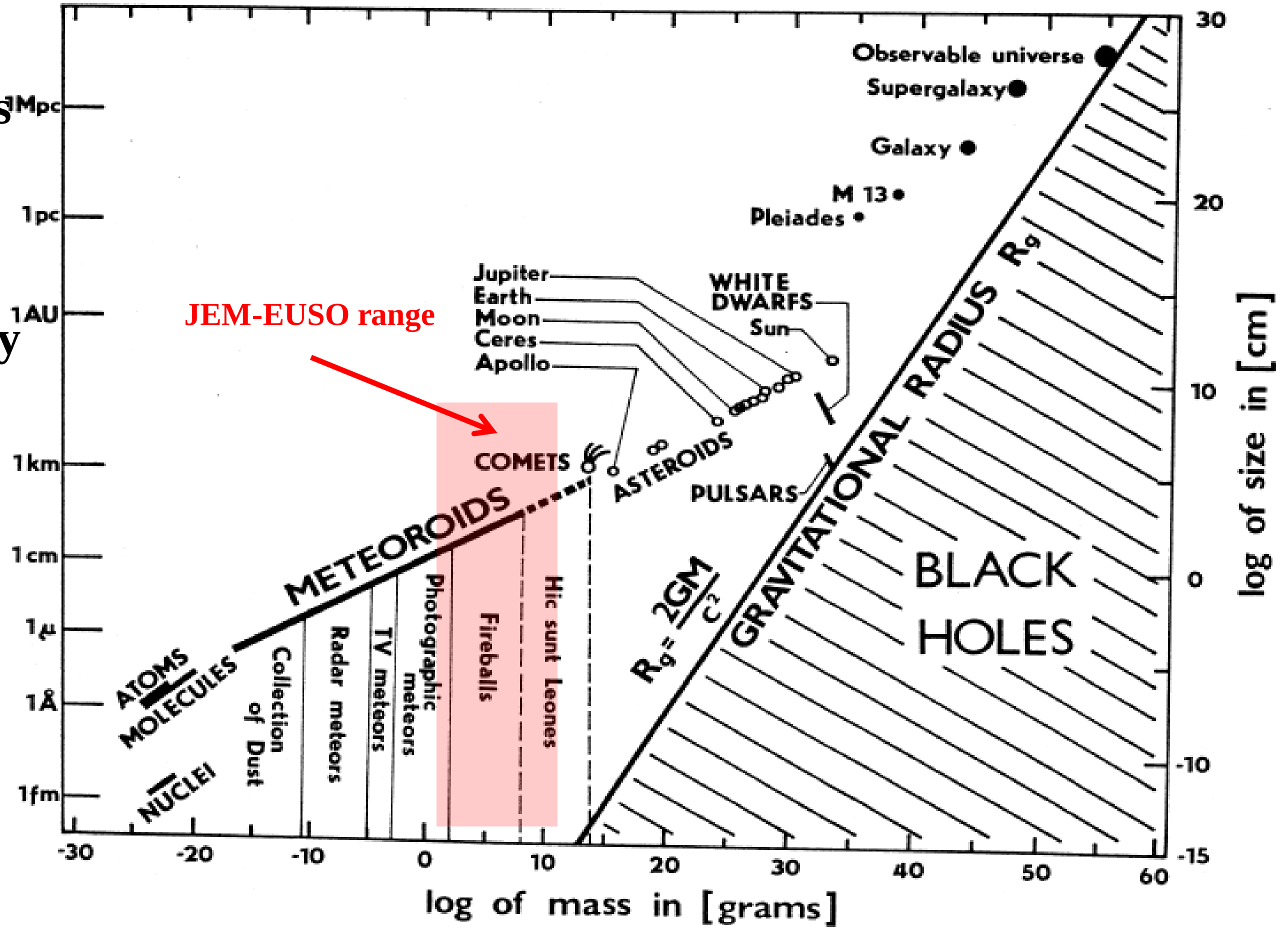
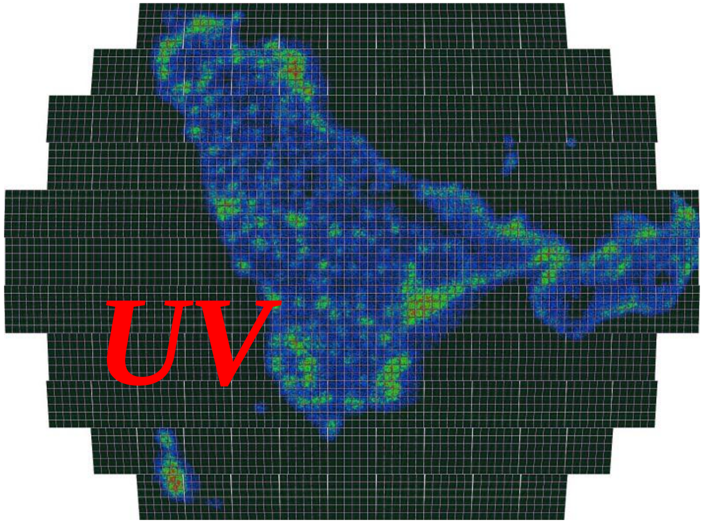


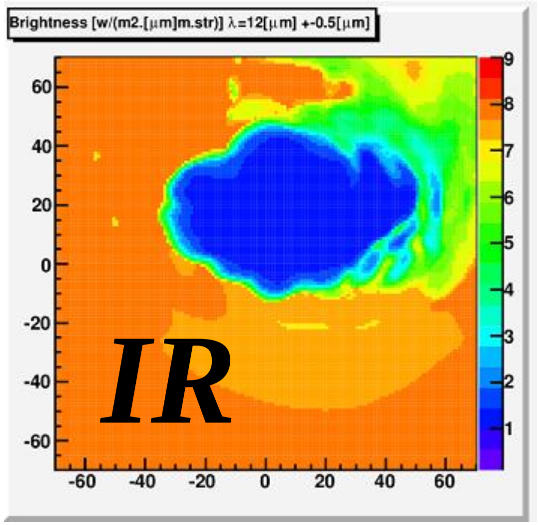
Figure 1. Diagram of size versus mass contains some known objects of the observable universe and shows the significance of the meteoroid complex. Meteoroids with sizes of tens and hundreds of meters are the least known bodies of the solar system.

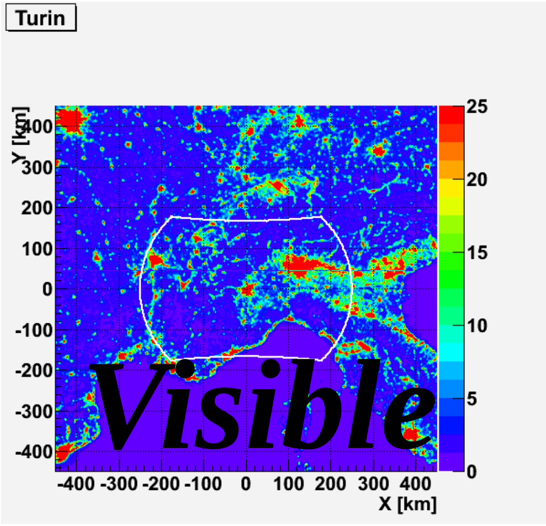
A. Cellino et al. – Planetary Defense Conference, Bucharest, May 9-12, 2011

A6. Earth observation and environmental monitoring

- Multi-wavelength monitoring of the Earth
- High spatial and temporal resolution
- Night UV map since Apollo and OGO-4 times, micros precision
- Detect cloud, oil spills, plankton population, pollution, ozone layer, cloud cover…
- Cross-correlation with other devoted detectors (GLIMS)

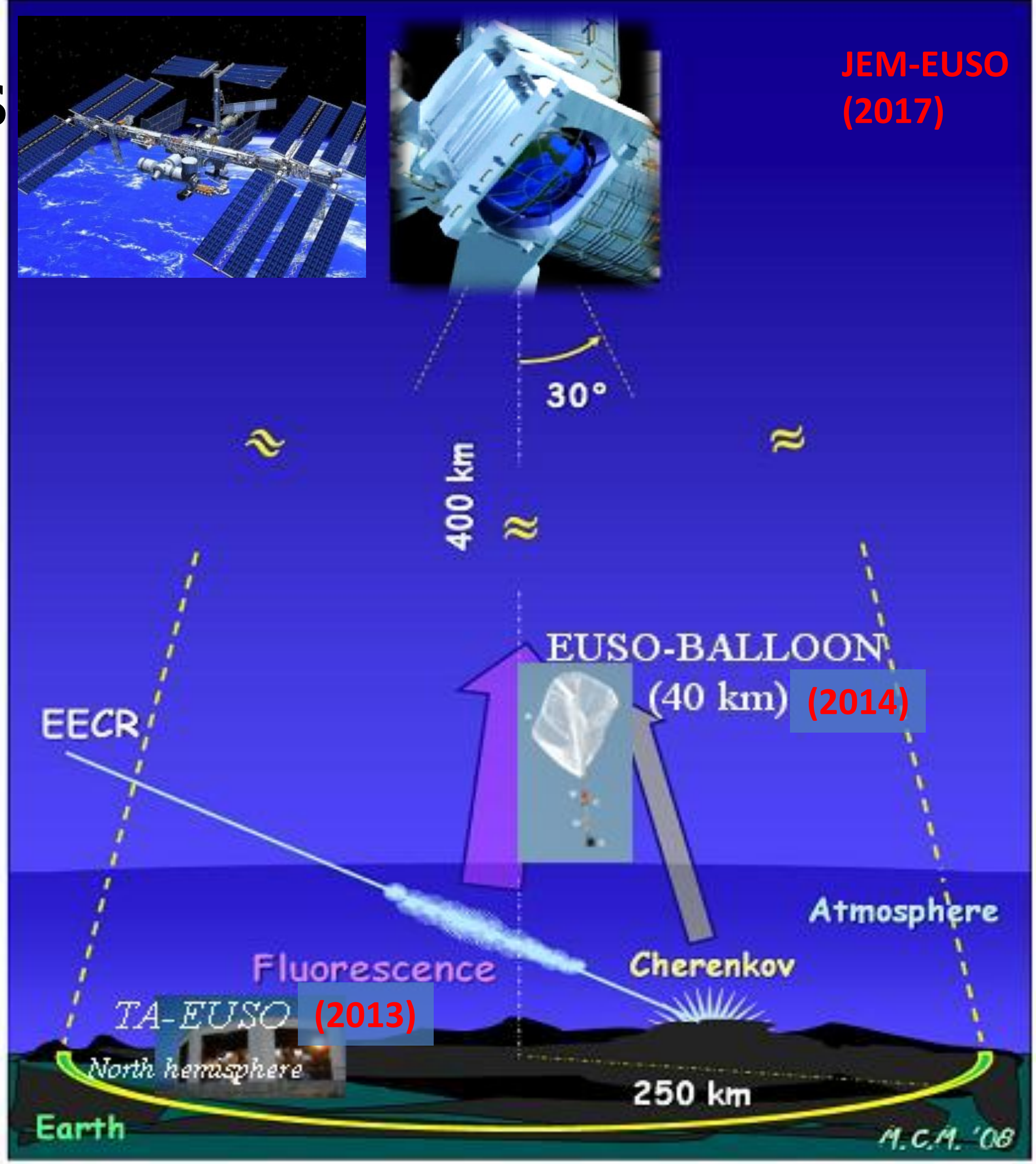






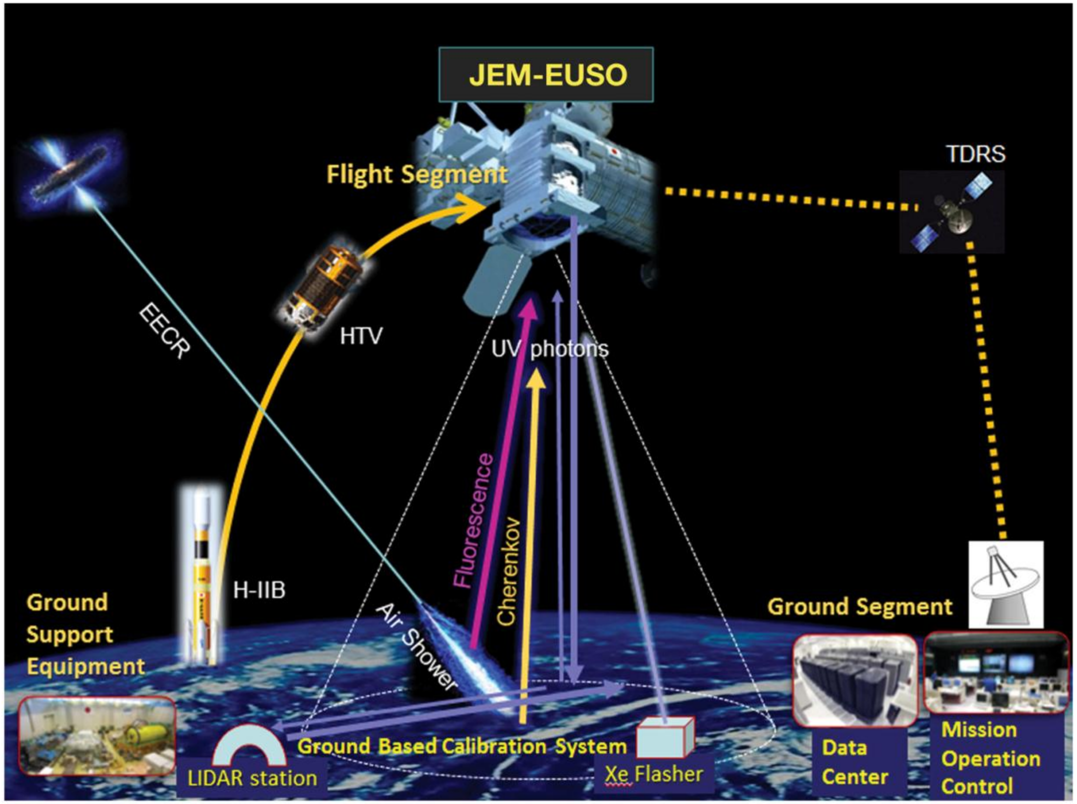
B. Instruments

1. JEM-EUSO (2017)
2. Ground Test at Telescope Array site. (2013)
3. Balloon flights (3) from Canada (French Space Agency CNES) 2014-
4. Prototype from ISS: Micro-UVT



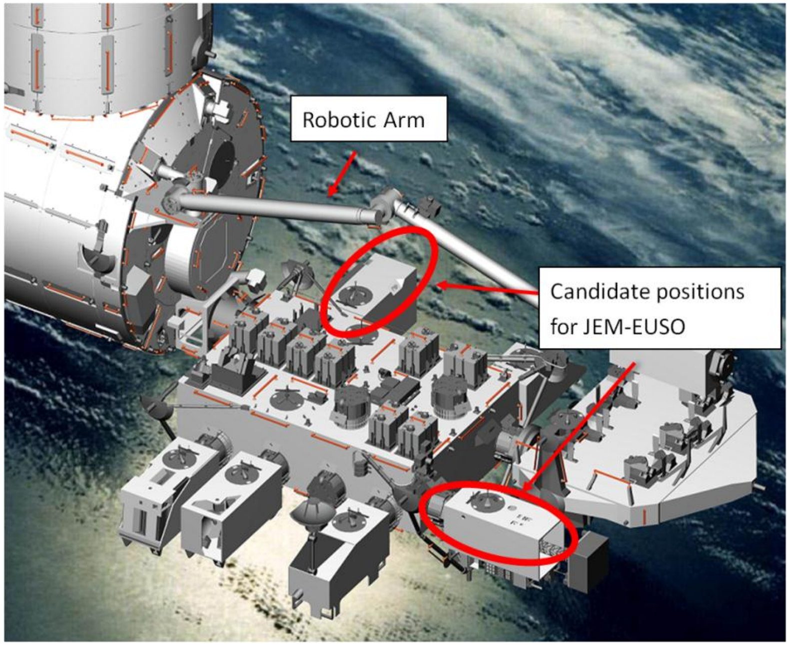
B1. JEM-EUSO: refractor tel. from ISS

JEM-EUSO Concept of Operations



JEM-EUSO will be the first instrument to make a nearly uniform all-sky survey of extremely energetic cosmic rays. JEM-EUSO will measure the energies and arrival directions of these cosmic rays, then map them onto the celestial sphere so that correlations with local extragalactic matter distributions and possibly nearby sources can be made. Using a collecting power nearly 10 times larger than any existing experiment, JEM-EUSO will enable an investigation of the nearest cosmic accelerators and possibly the identification of individual acceleration sites.

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°



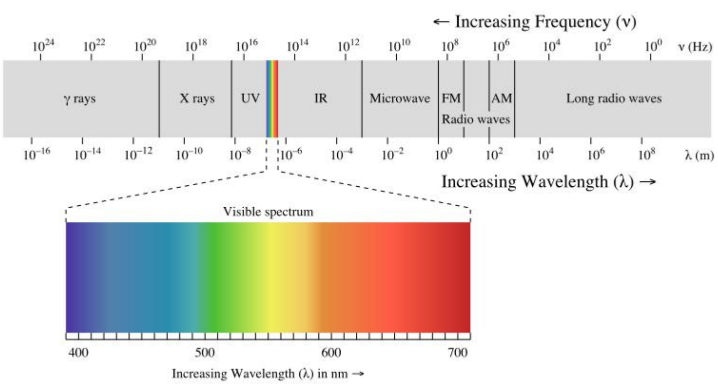
Potential JEM-EUSO instrument locations on ISS Kibo module

JEM-EUSO

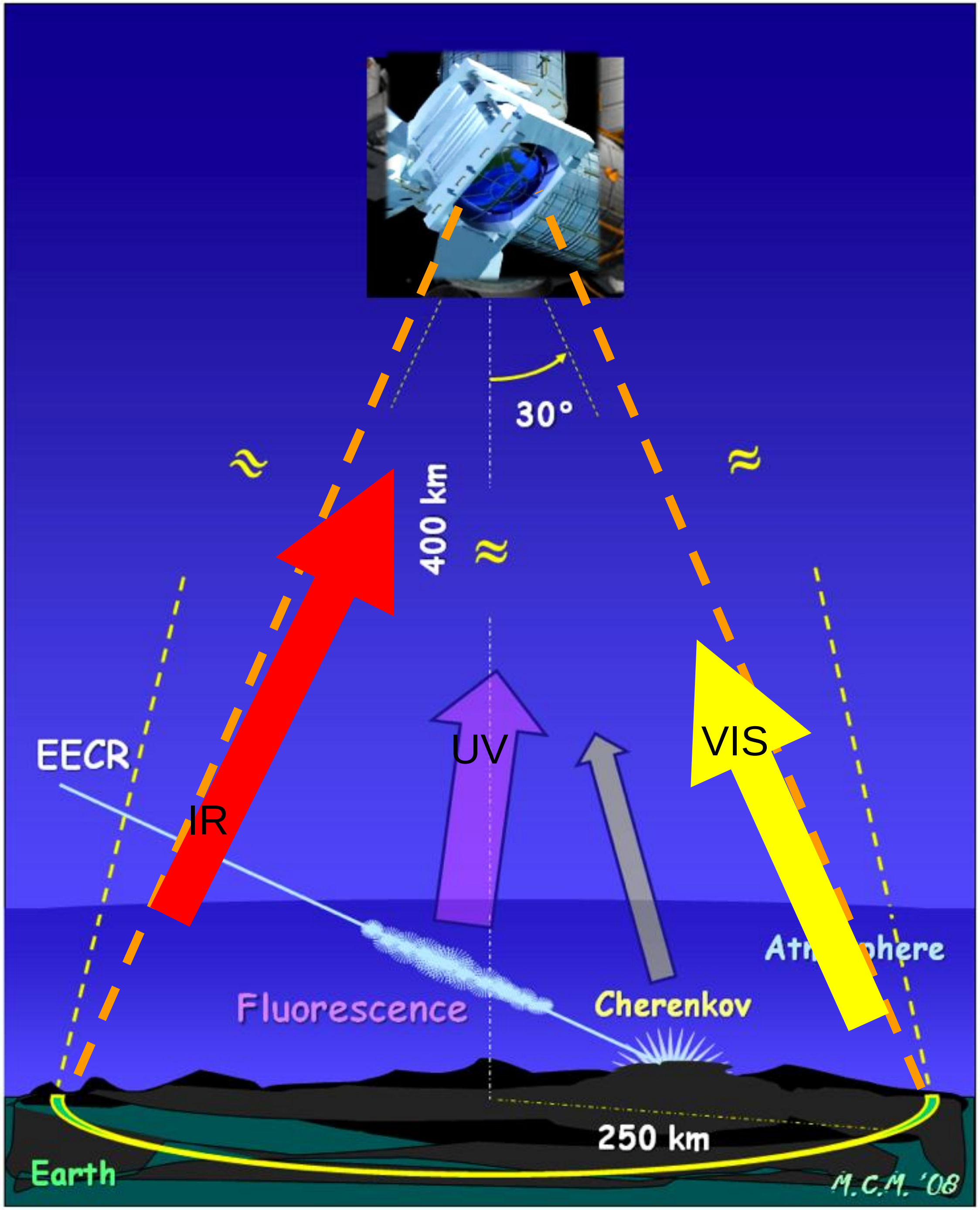
an instrument with unprecedented characteristics:

2 tons, 2.5m lenses

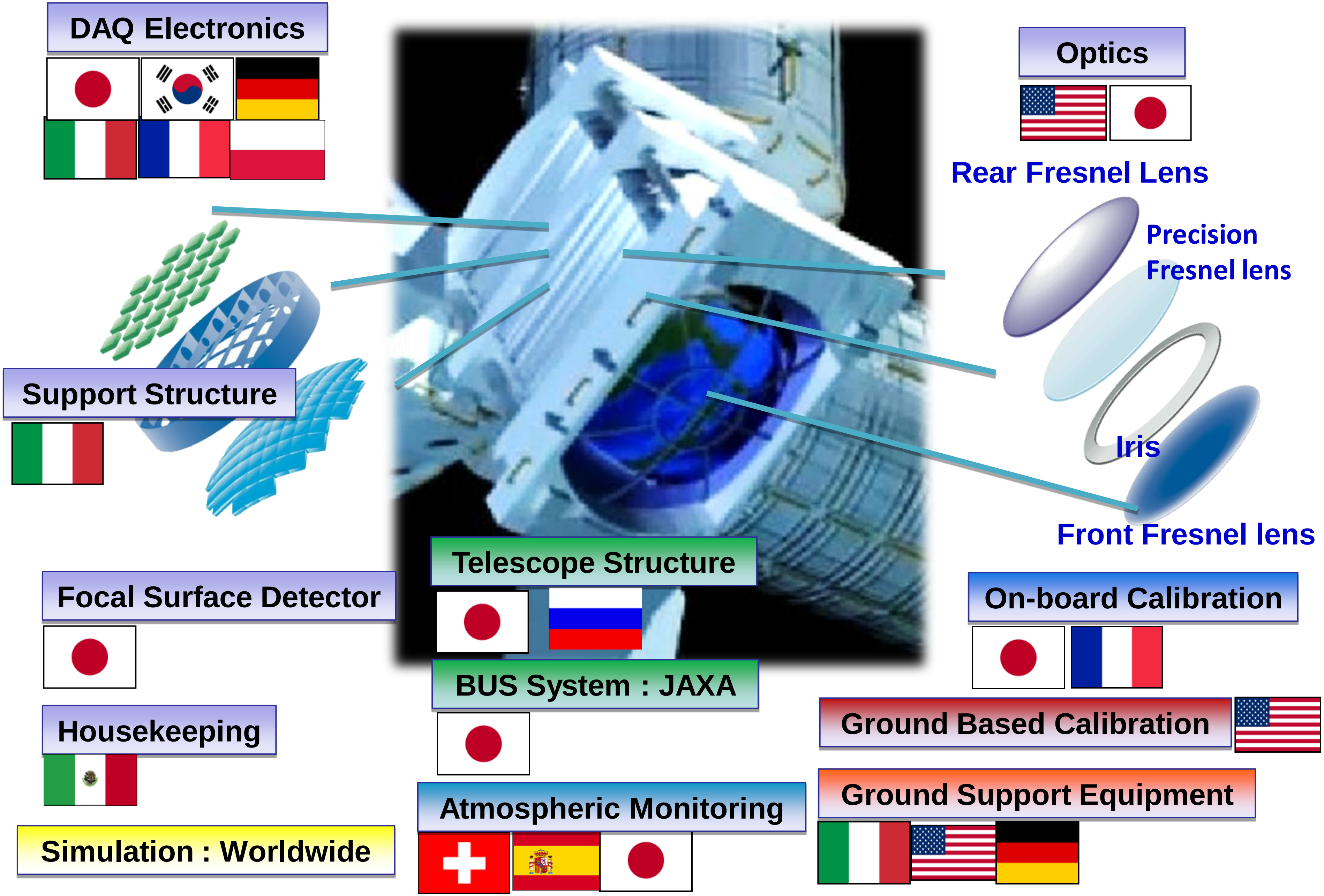
I. Detector size $\mathbf{10^{12}}$ ton
II. Aperture: $\mathbf{10^{6}}$ km^2 tilt
II. Energy of acceptance ($\mathbf{10^{20}}$ - $\mathbf{10^{21}}$ eV)
III. Multi-band field of view:
UV Focal surf: 330-400 nm
Visible camera: 700, 530, 470+-50 nm
Infrared camera: 1008+-10 nm



UV: 300kch VIS:300kch*2 IR: 300kch*2



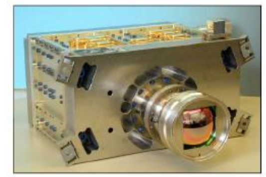
Instrument breakdown and International role sharing



Atmospheric Monitoring System

- <u>IR Camera</u> ***Spain***

  Imaging observation of cloud temperature inside FOV of JEM-EUSO

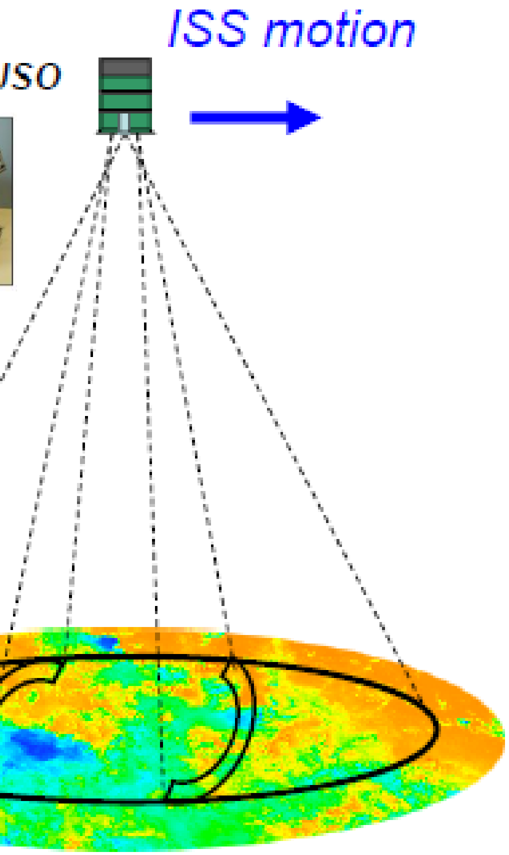


- <u>Lidar</u> ***Switzerland Japan***

  Ranging observation using UV laser

- <u>JEM-EUSO "slow-data"</u>

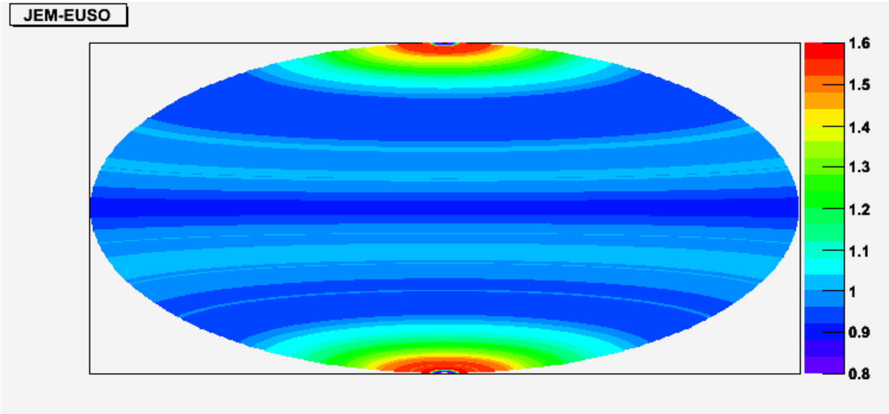
  Continuous background photon counting

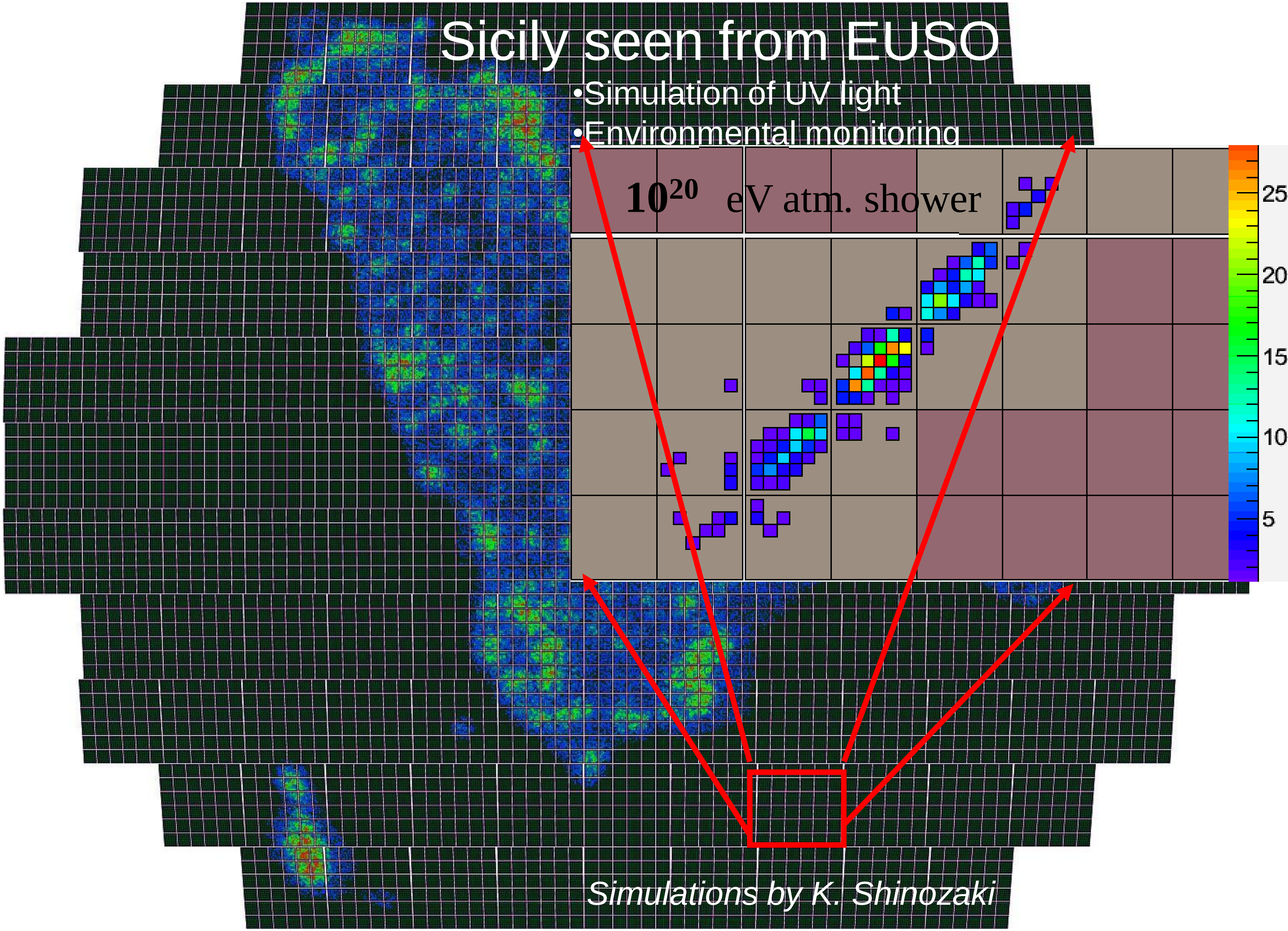


- *Cloud amount, cloud top altitude*: (IR cam., Lidar, slow-data)
- *Airglow*: (slow-data)
- *Calibration of telescope*: (Lidar)

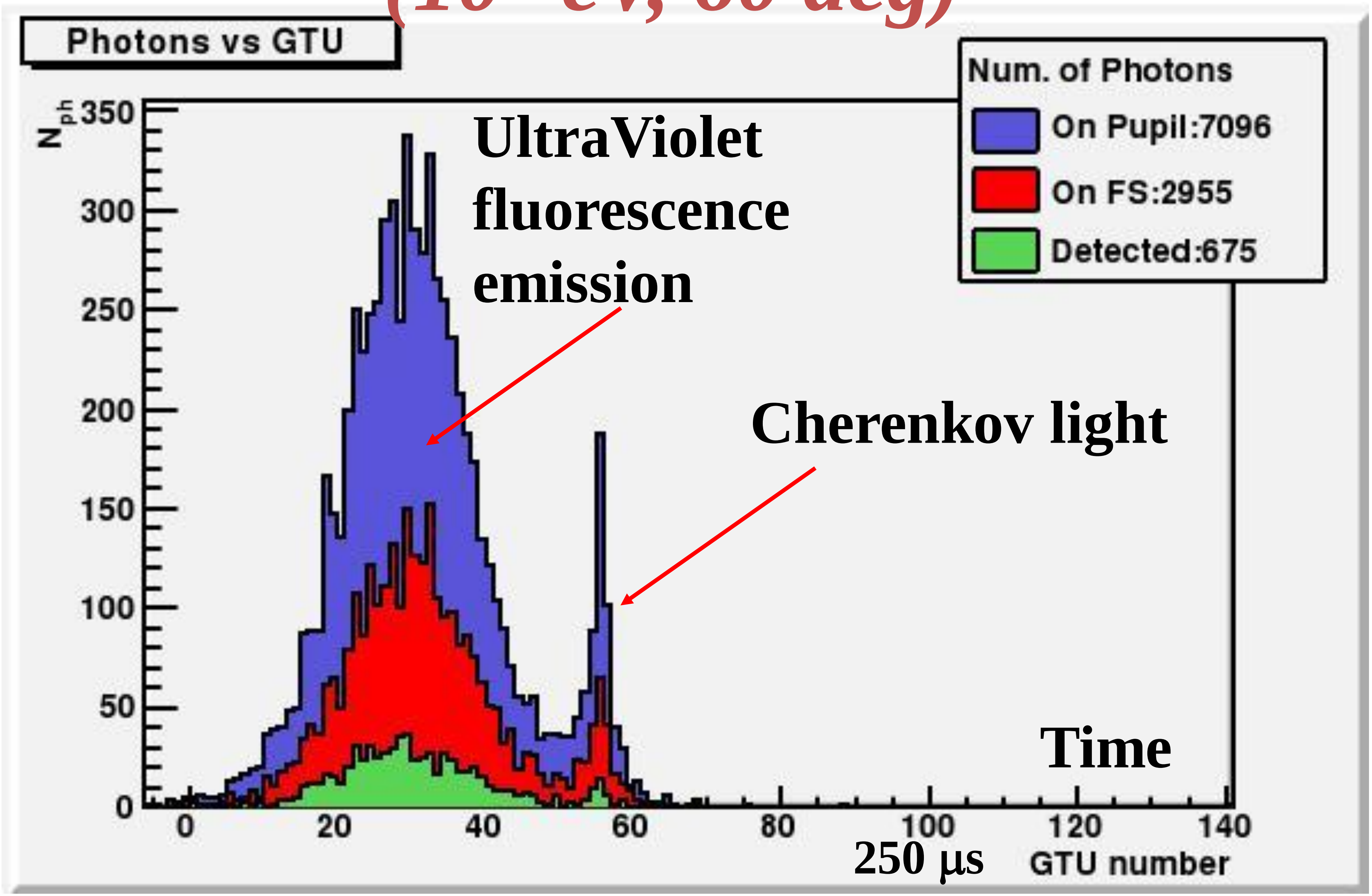
JEM-EUSO Field of view in Nadir and Tilt Mode

- **International Space Station**
- Orbiting at ~400 km in ±51.6 degrees latitudes
  - –Covers both northern and southern hemispheres
  - –Flight in varying geomagnetic field (~0.6 gauss) around orbit
- Viewing night atmosphere in ~500 x 400 km area (nadir mode)
  - –Wide FOV allows to measure entire slowly developing showers
  - –Target volume exceeding an order of 10^{12} tons

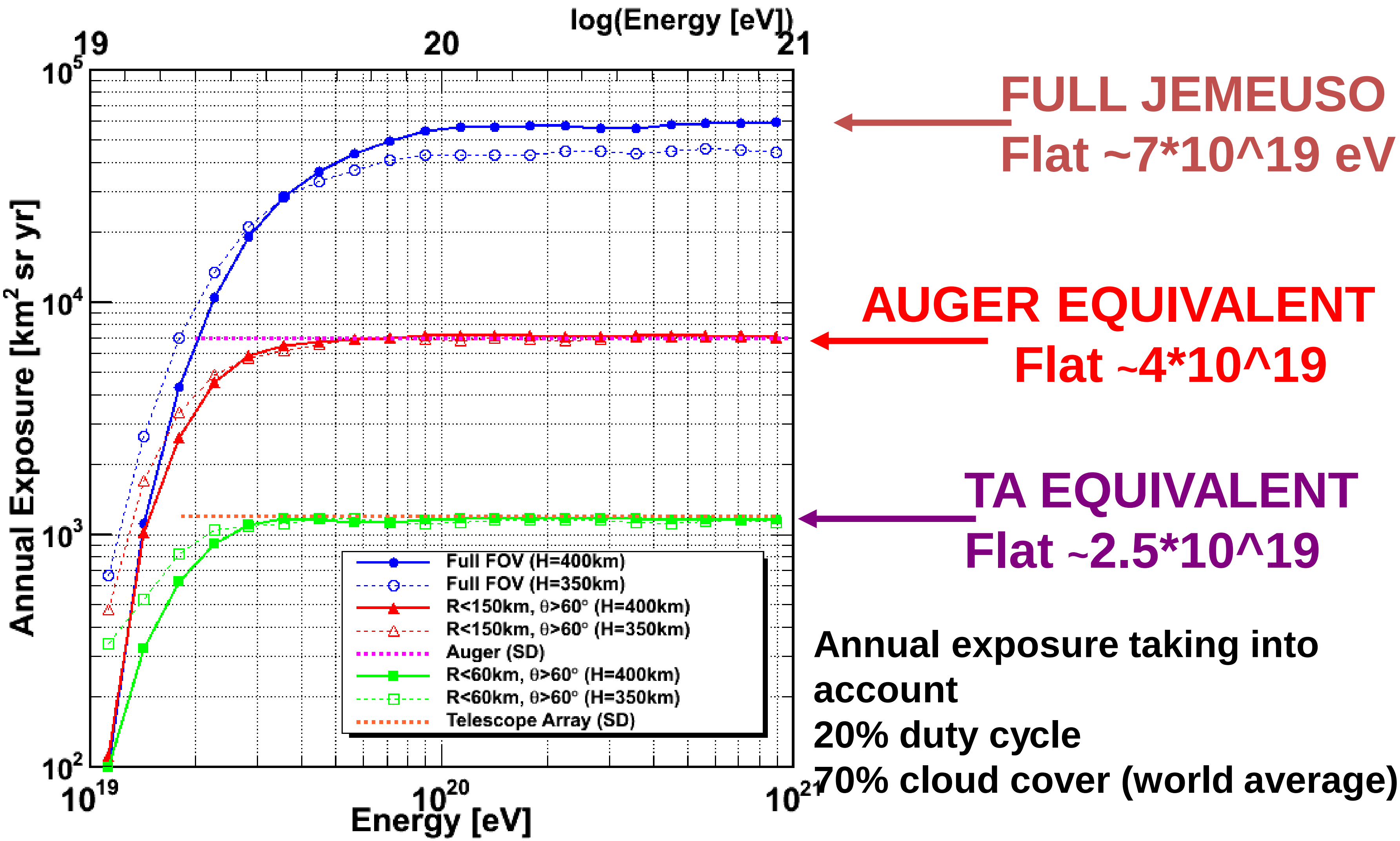



Sicily seen from EUSO
•Simulation of UV light
•Environmental monitoring
10^20 eV atm. shower
25
20
15
10
5
Simulations by K. Shinozaki

UV Signal of a proton shower (10^{20}eV, 60 deg)

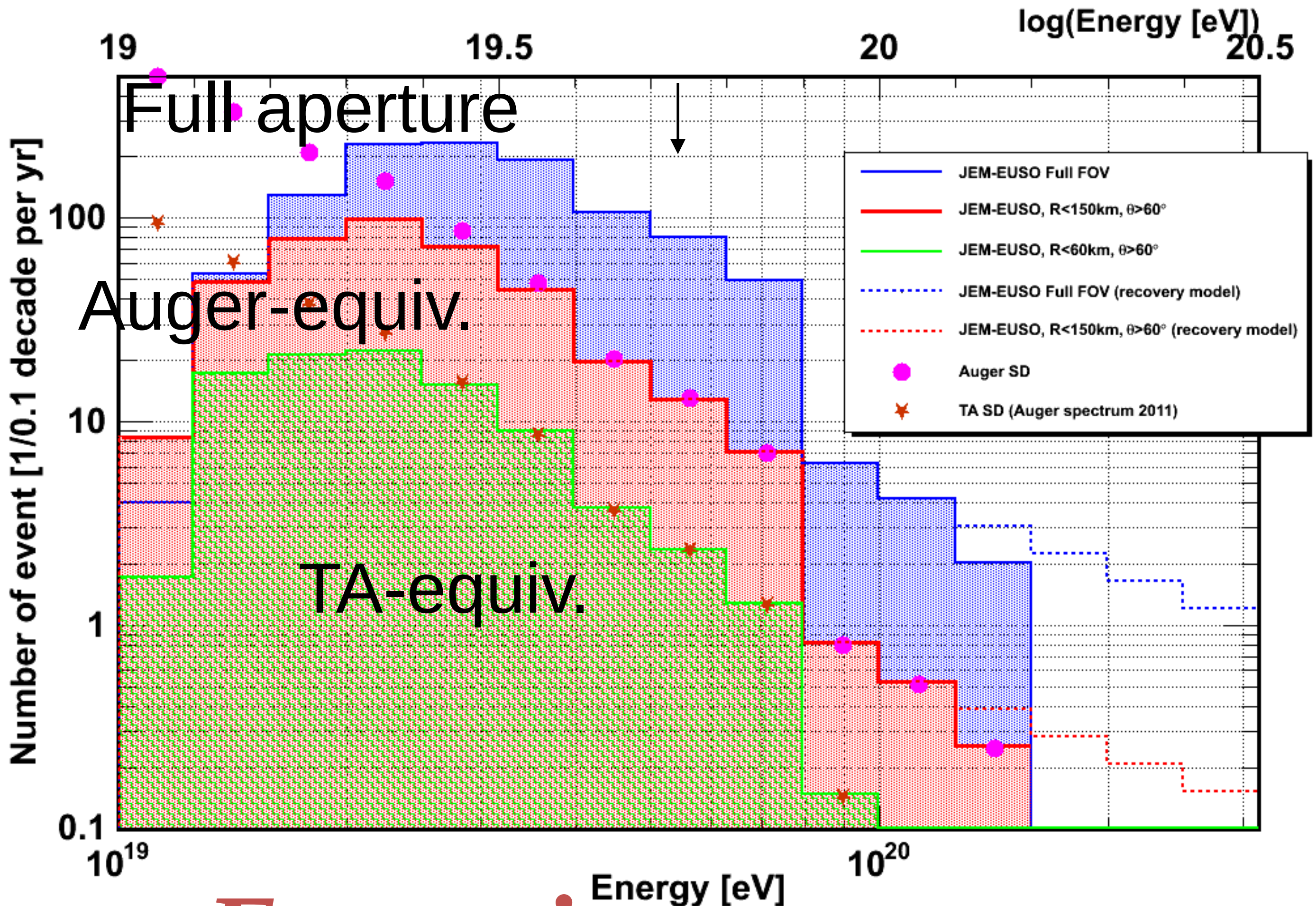


Fiducial volumes and "golden events" for overlap at low energies



Annual exposure taking into account
20% duty cycle
70% cloud cover (world average)

Overlap and match spectra with Auger and TA

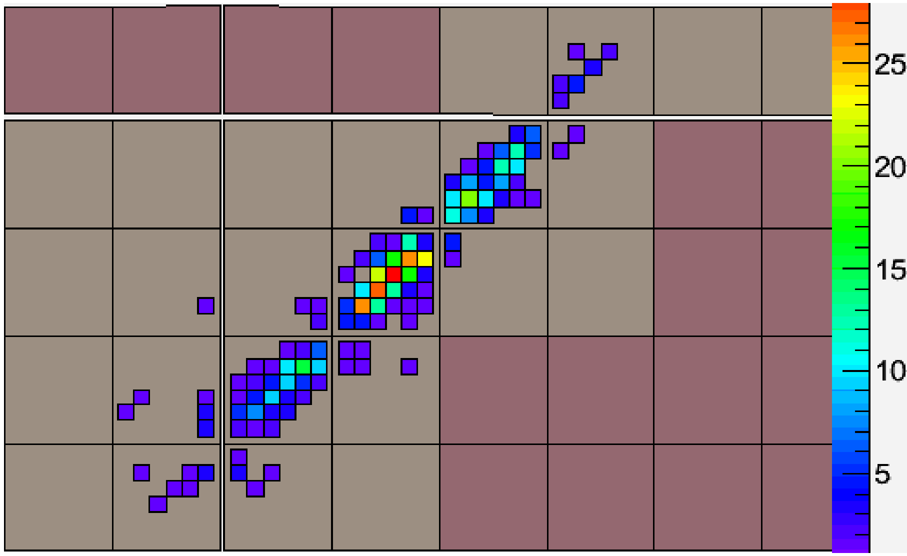


Events in one year

Comparative exposure with ground observatories

Observatory	Aperture km^2 sr	Status	Start	Lifetime	Duty cycle	Annual Exposure km^2 sr yr	Relative to Auger
Auger	7,000	Operations	2006	4 (16)	1	7000	1
TA	1,200	Operations	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

Cosmic-Ray and Earth Observation modes

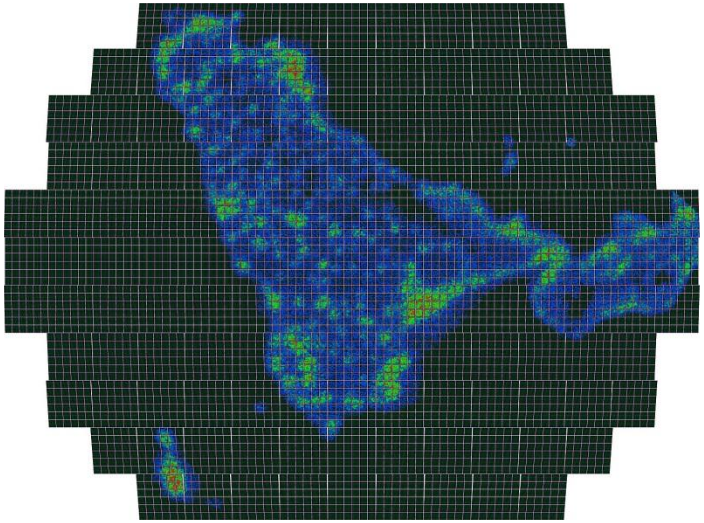


Cosmic Rays

- Need dark (<20-25 moon), no big towns
- Duration <300 mus
- Few photons

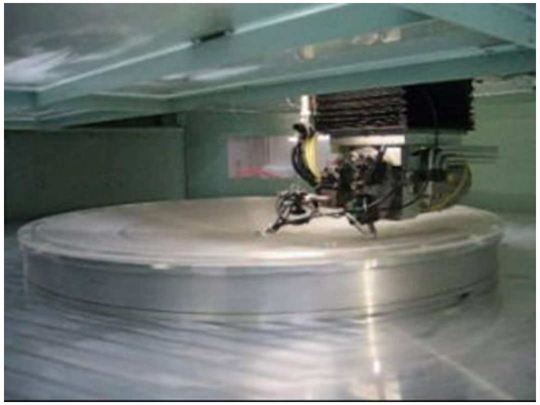
Atmospheric and Earth Observation Sciences

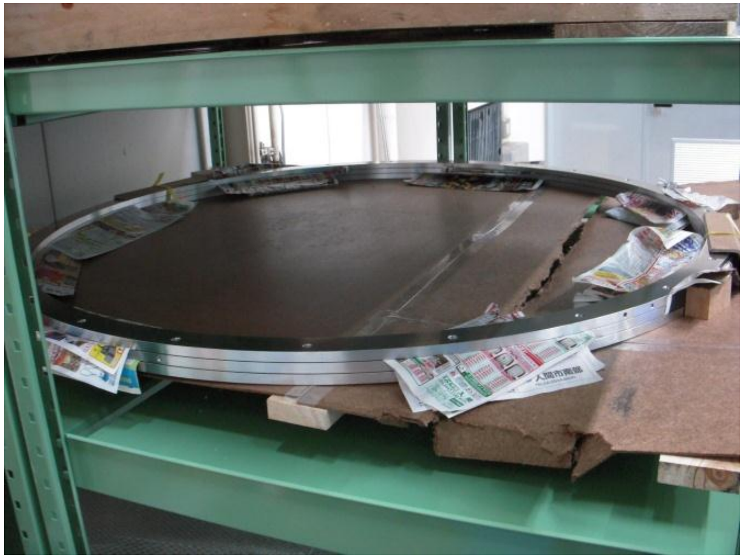
- Tolerate more background
- Duration >300 mus
- >100 photons

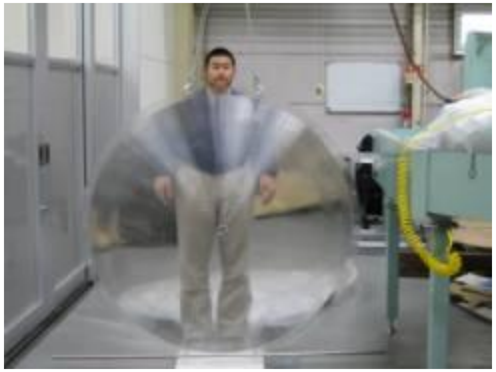


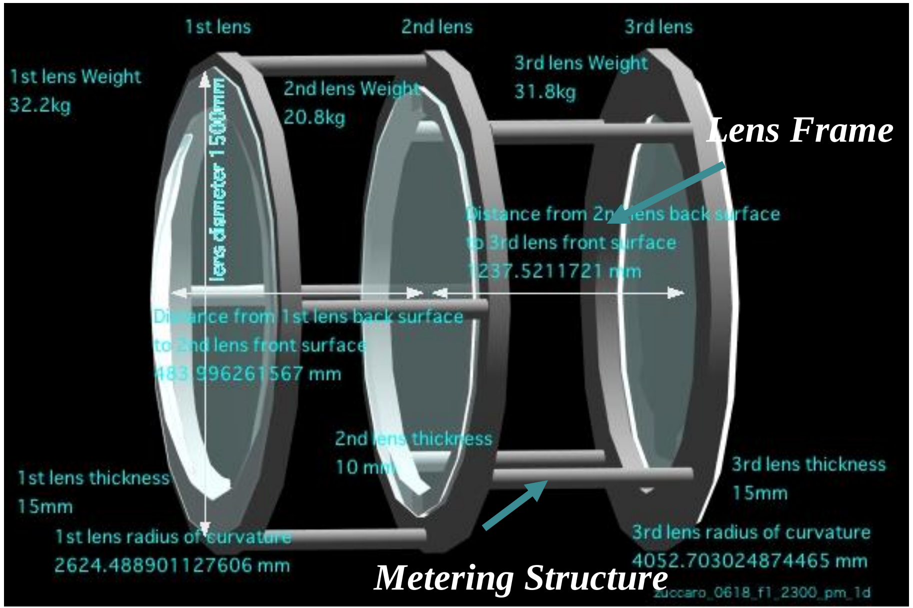
JEM-EUSO mock-up model

Optical system:1.5m model (Japan- USA)

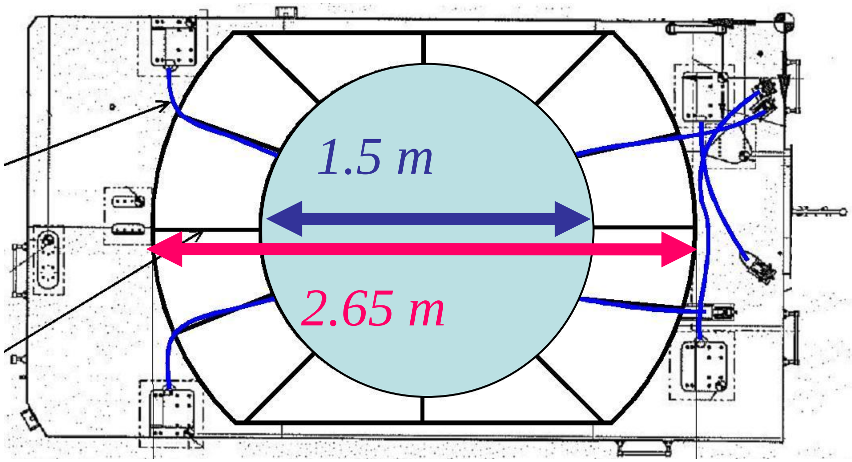




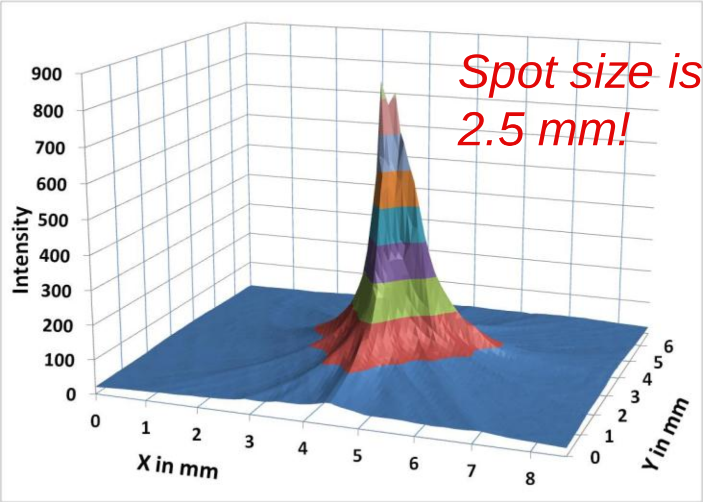




Optical system protoype



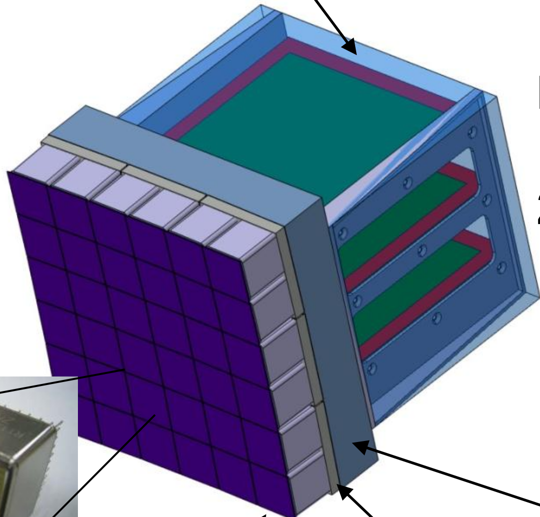
large diameter Fresnel lenses manufactured in Japan and tested in the US at the University of Alabama (Huntsville) and at MSFC (NASA)

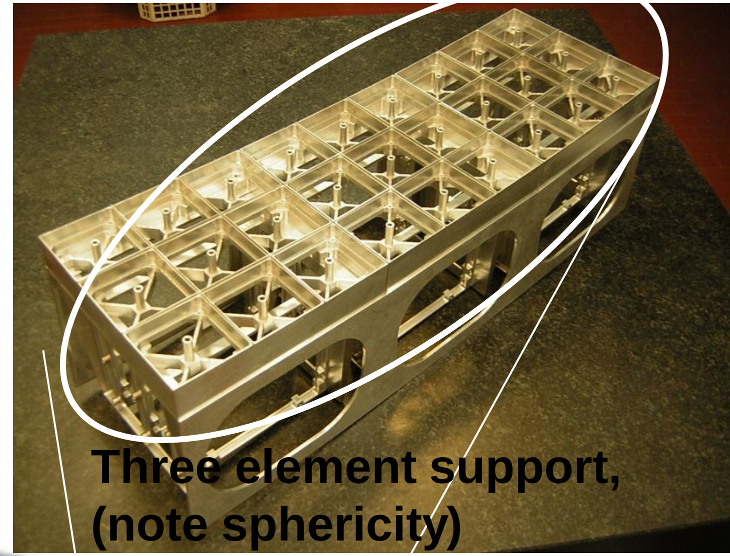


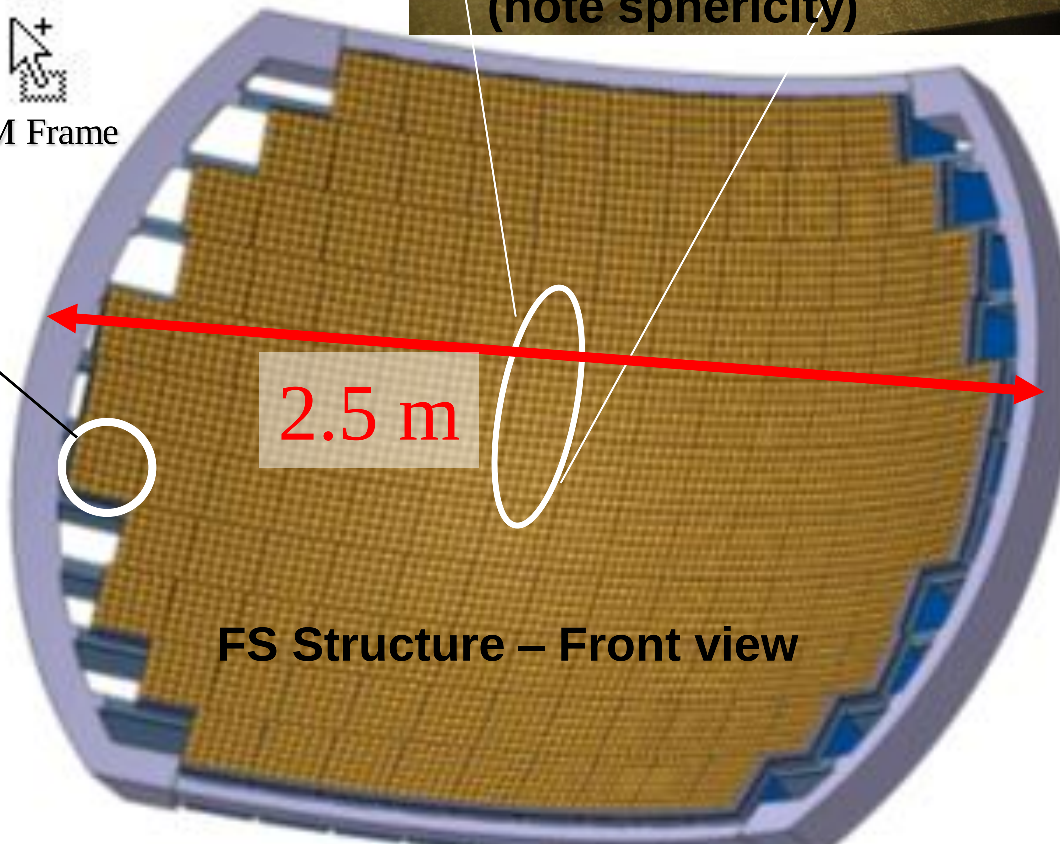
Tested performances meet already the requirements (or are close to it)

Focal Surface Mechanics

Photo Detector Module
2304 channels



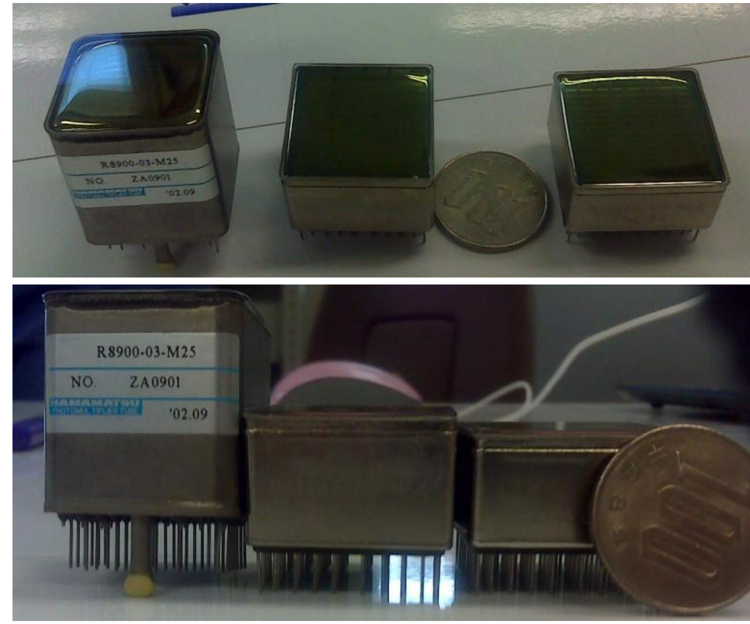




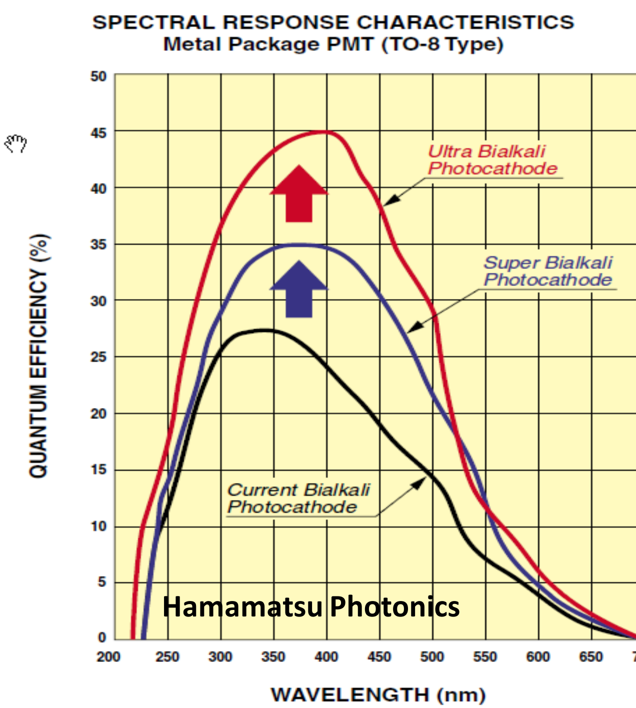
137 PDMs in the FS – 315 kchannels

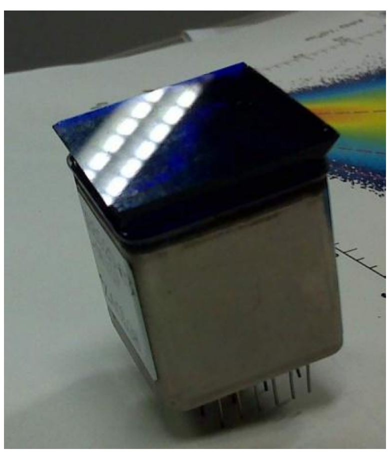
PMT development

- Collaboration with Hamamatsu
- Reduction of size, increase of anode number
- Improvement of Quantum efficiency
- Improvement of uniformity of response
- Each of the 137 PDM boxes houses 36 PMTs, 64 channels each

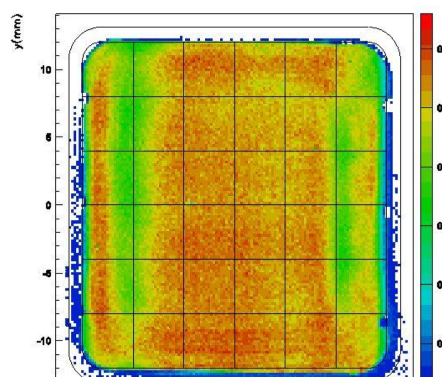


Miniaturization of dynodes



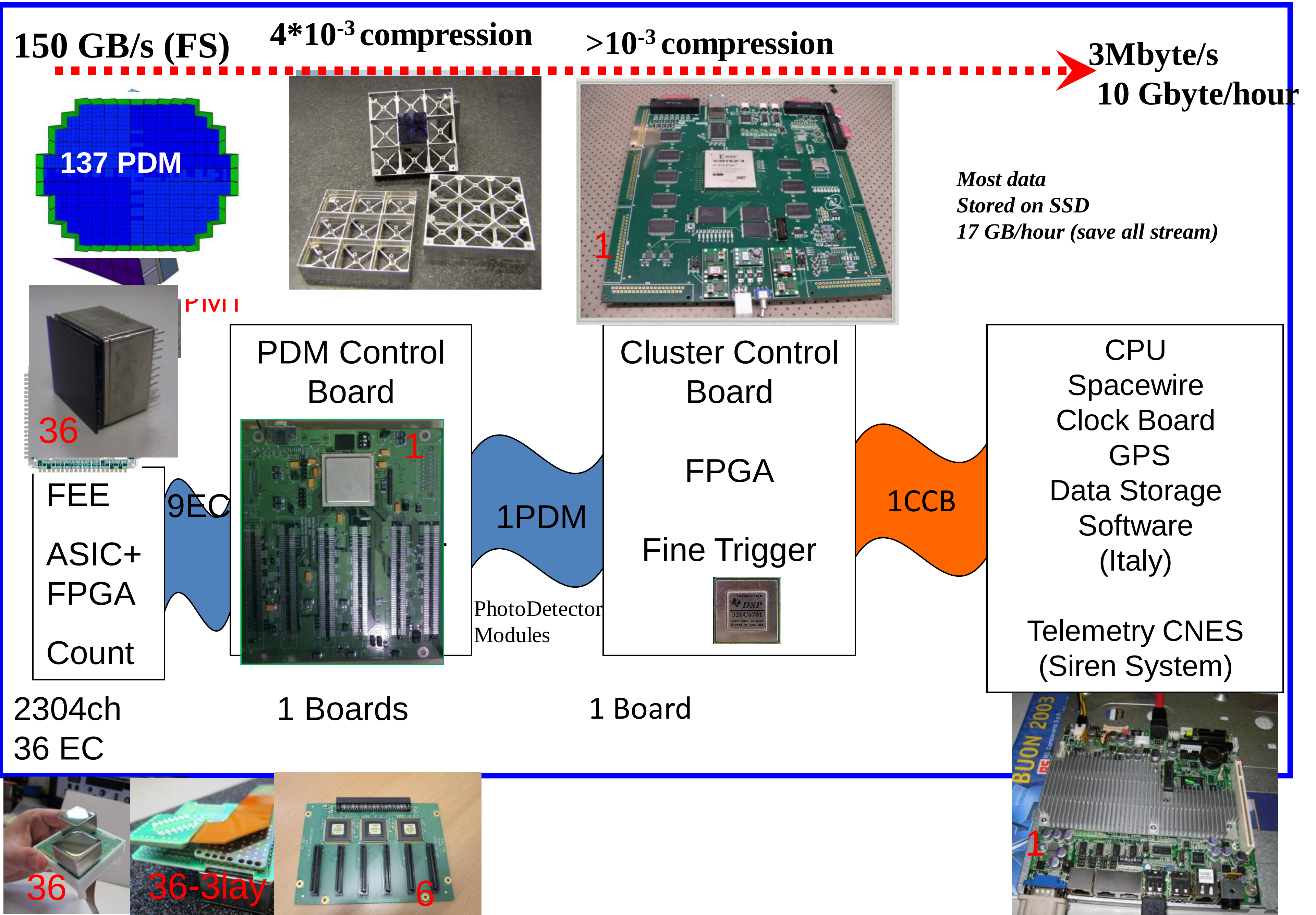


UV Filter



Ultra Bialkali ZB0765
Average: (24.4 ± 1.8)%

JEM-EUSO DAQ – Electronic System scheme



TA-EUSO

Calibration tests at Telescope Array site Utah

- Collaboration with ICRR, Institute of Cosmic rays, Tokyo University, Kashiwa campus → Installation march 2013

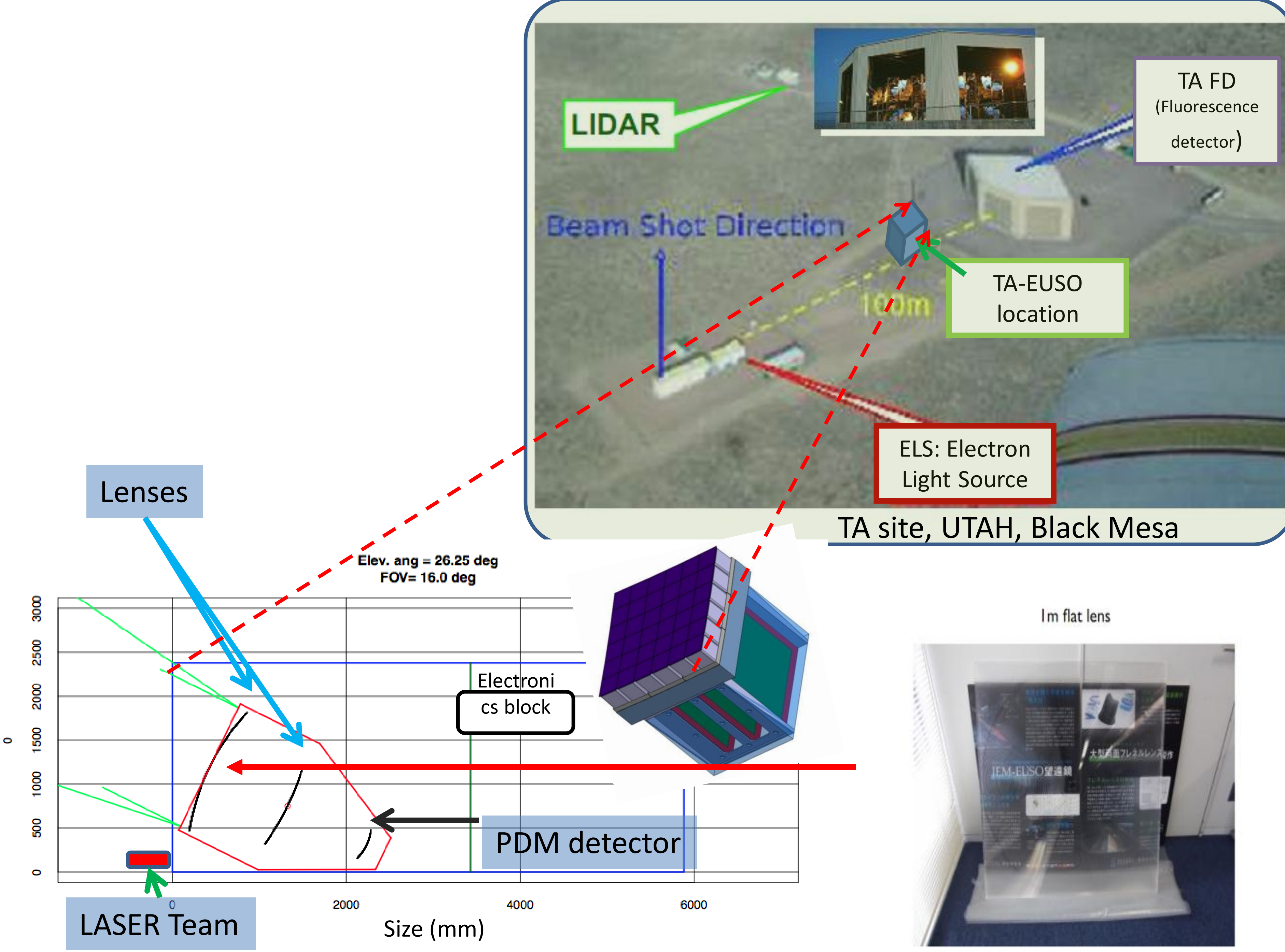
- Main purpose: calibration:

a) Cross calibration with TA FD through Noise comparison.

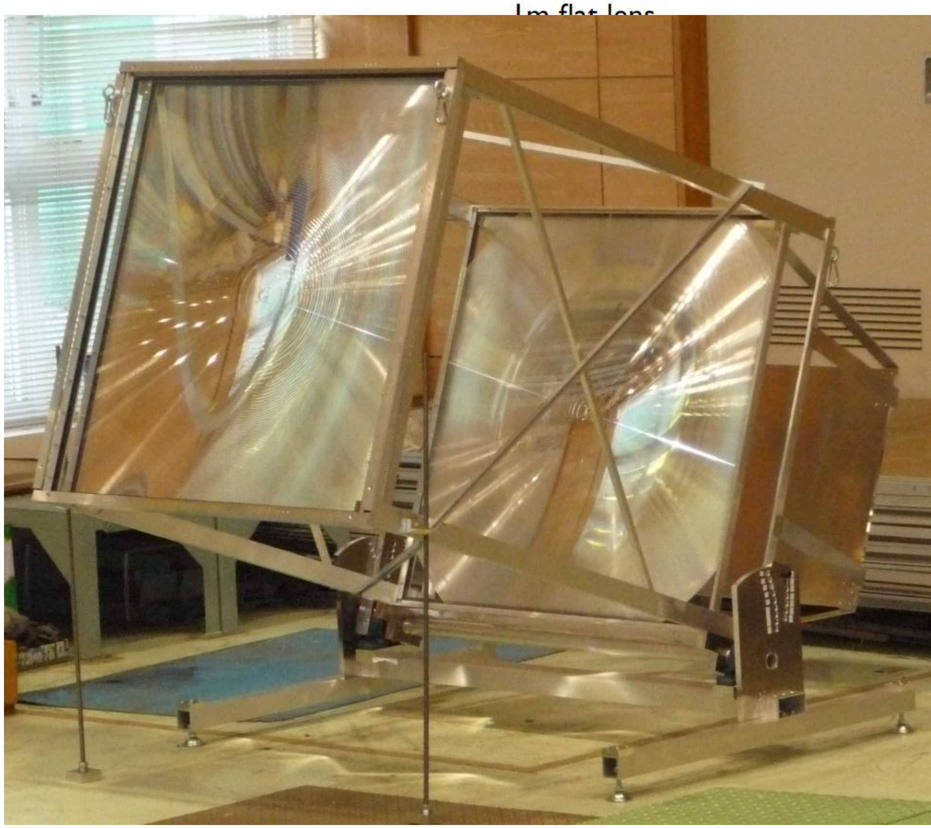
b) Measurement of background in various conditions

c) When lidar or electron beam shots, store the data to have an absolute calibration.

d) Observe few showers in coincidence with TA.


LIDAR
TA FD
(Fluorescence
detector)
Beam Shot Direction
100m
TA-EUSO
location
ELS: Electron
Light Source
TA site, UTAH, Black Mesa
Lenses
Elev. ang = 26.25 deg
FOV= 16.0 deg
Electroni
cs block
PDM detector
LASER Team
0
500
1000
1500
2000
2500
3000
0
2000
4000
6000
Size (mm)
1m flat lens
JEM-EUSO望遠鏡

Objectives of the EUSO system at TA site

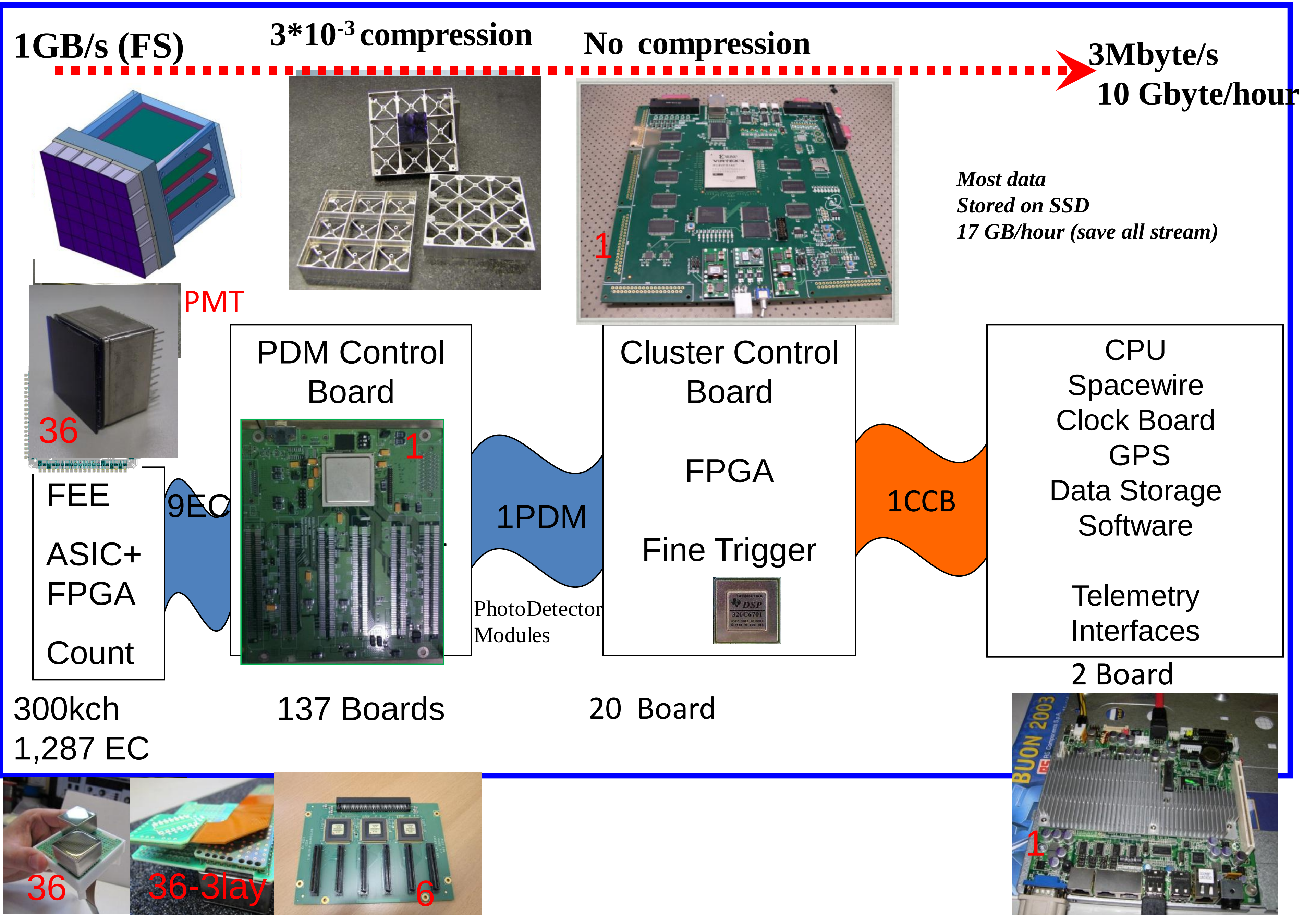


Engineering test of the detector using one PDM and two lens system.

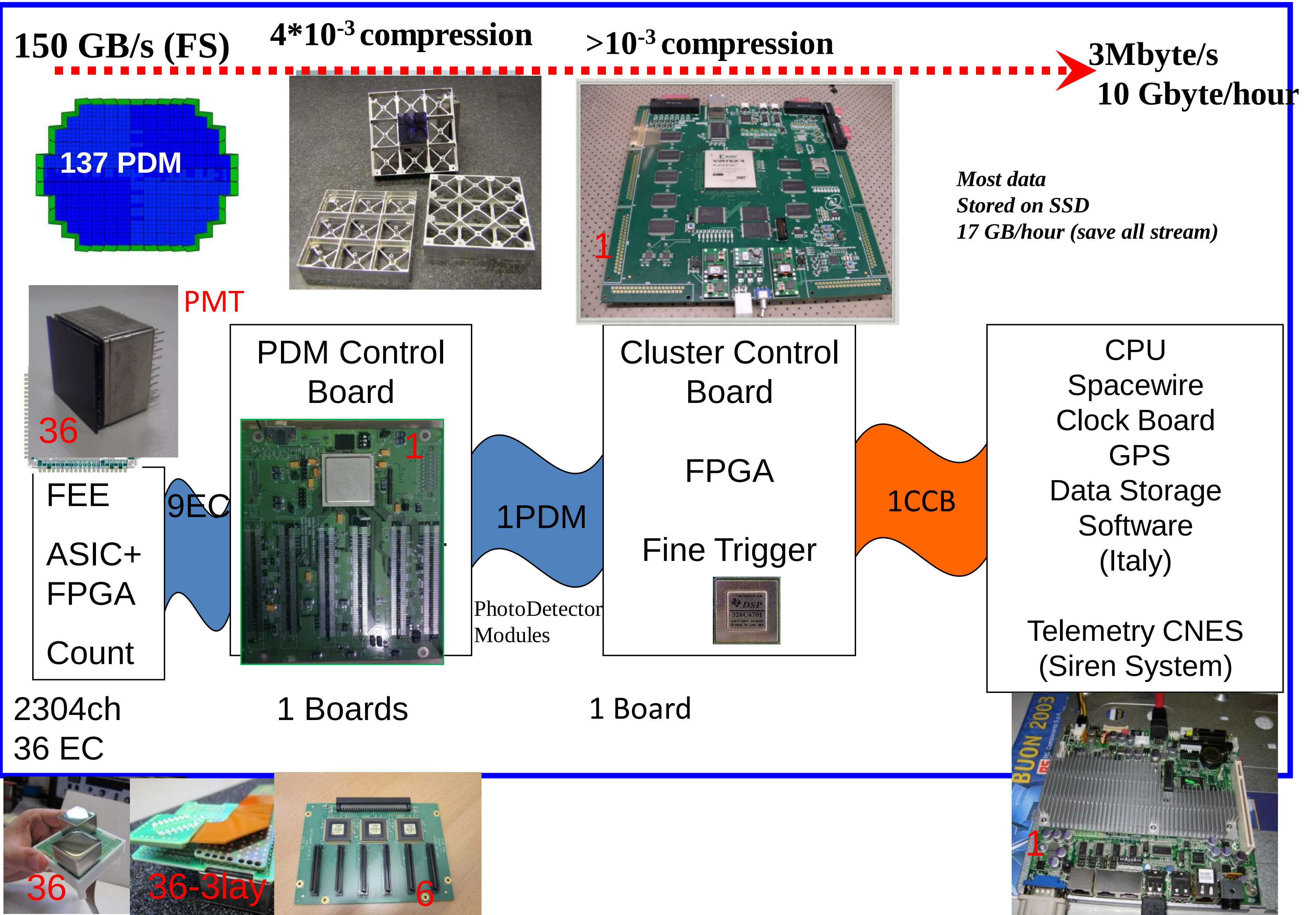
Field calibration with TA FD

a) With Laser (CLF)
b) With electron beam (ELS)
c) With the observation of several (10s/yr) in coincidence with TA.

Balloon/TA EUSO DAQ – Electronic System scheme



JEM-EUSO DAQ – Electronic System scheme



Location： Black Rock Mesa

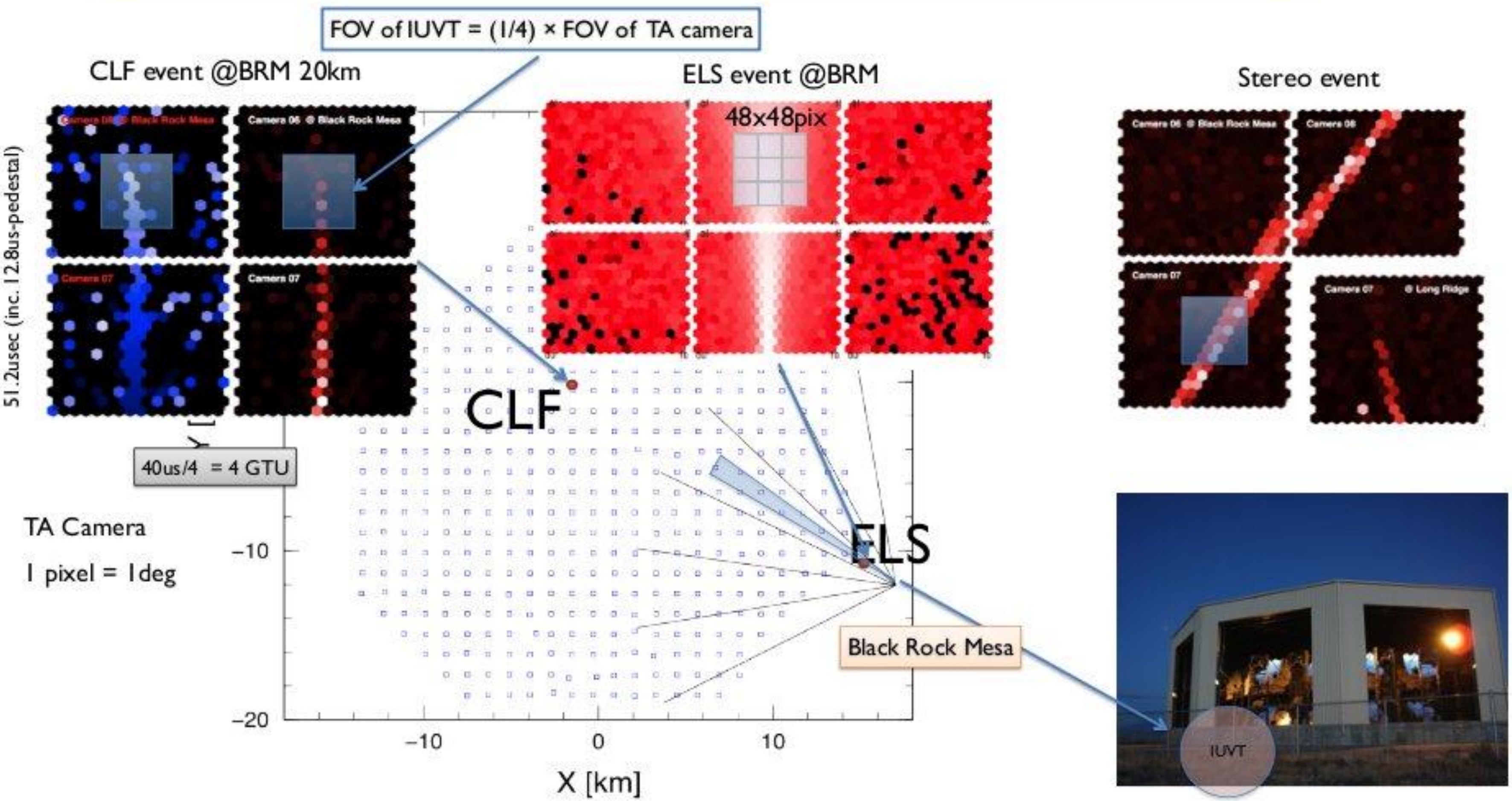
IUVT is able to observe CLF and ELS.

Time: March. 2012～ → The second half of 2012

Synchronize between TA and IUVT: GPS time

(If possible, we want to use Trg. Signal from TA elec.)

IUVT should have a mechanism to change its elevation.



B3. EUSO Balloon

EUSO Balloon campaign

–Look down from the balloon with an UV telescope (PDM + 3 lens system)

–Engineering test

–UV-Background measurement

–Airshower observations from 40 km altitude

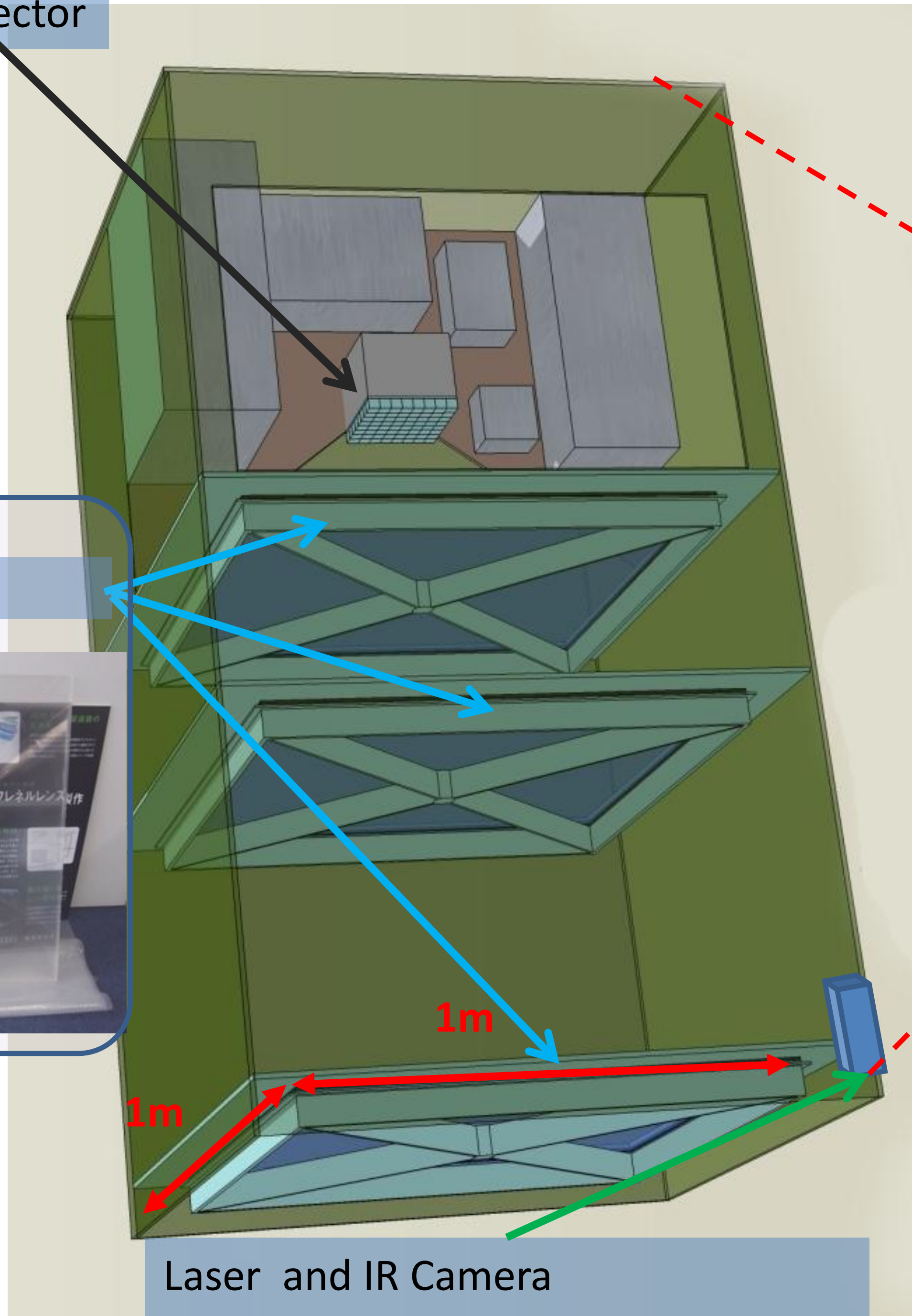
2011/6 Approved by CNES

2014, March , first of three annual launches

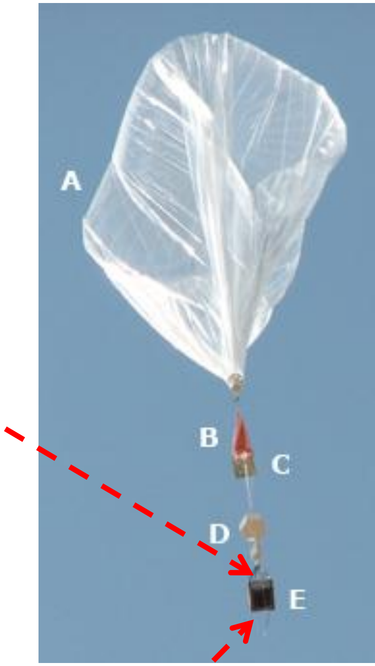
Electronics Detector

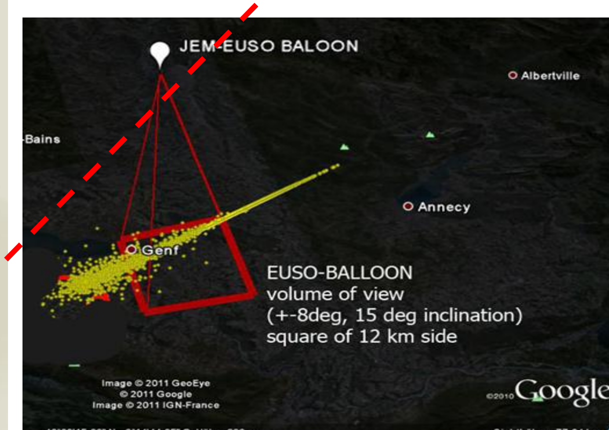
EUSO Balloon

Lenses



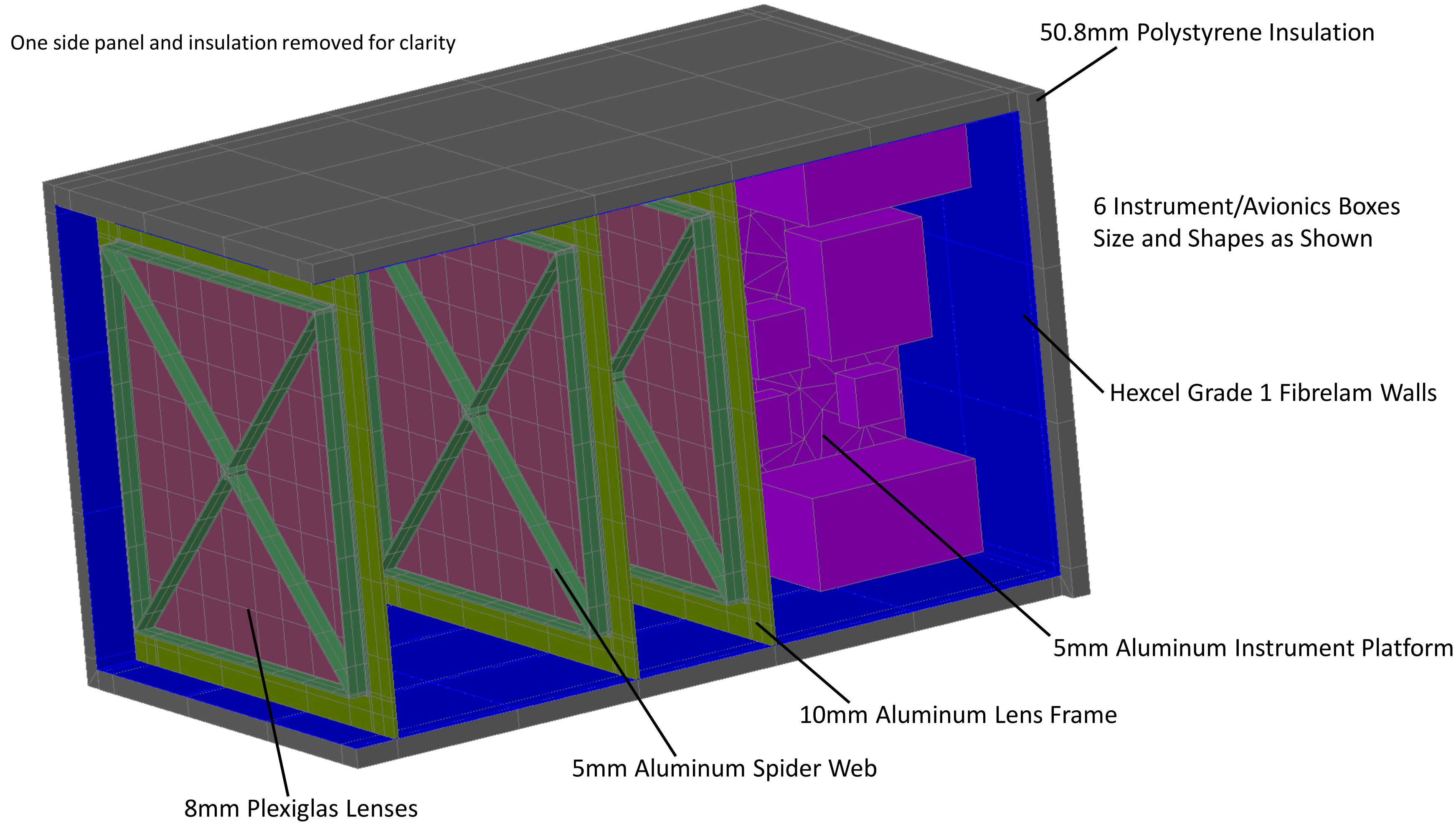
Laser and IR Camera

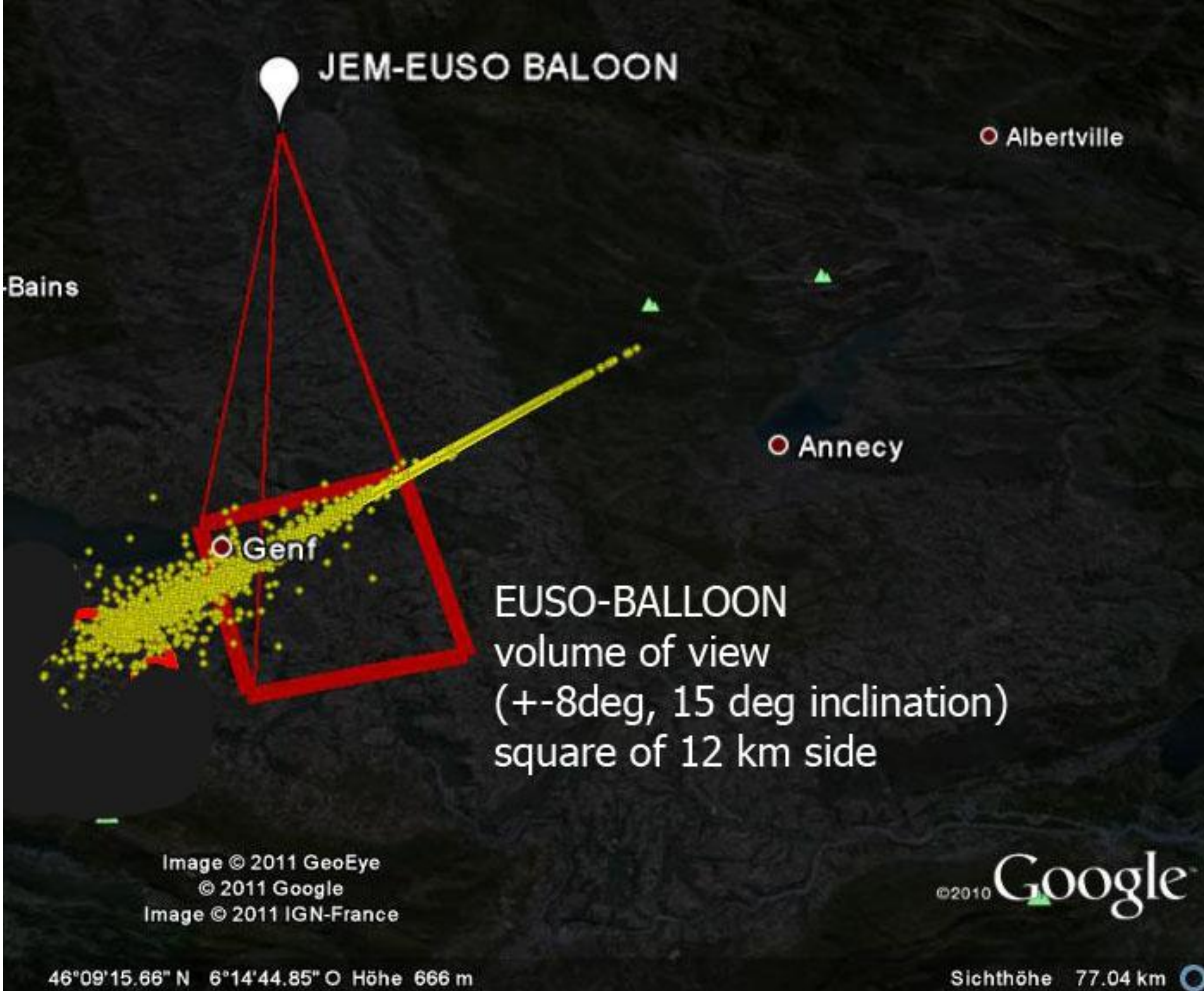




Simulations

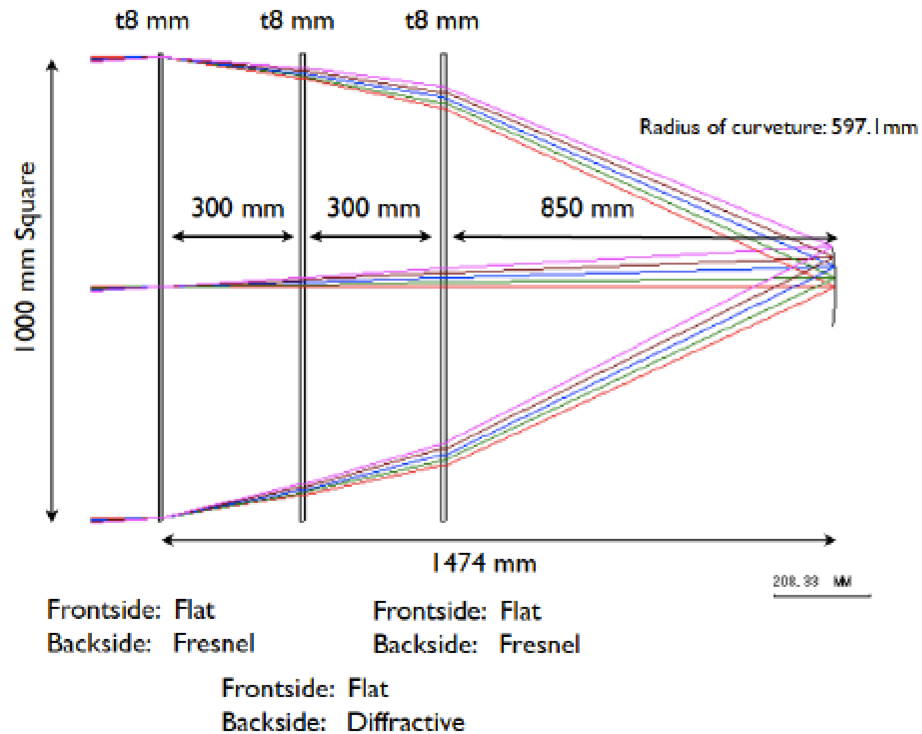
Thermal Model

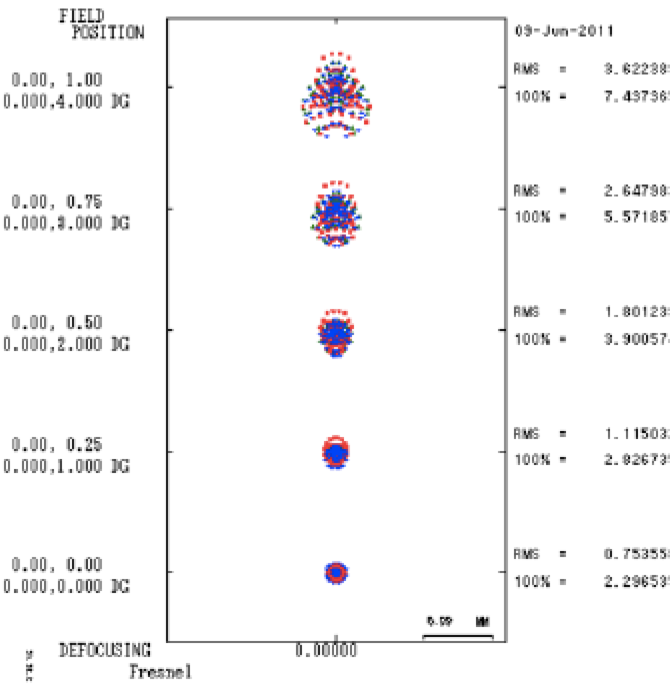



JEM-EUSO BALOON
Albertville
-Bains
Annecy
Genf
EUSO-BALLOON
volume of view
(+-8deg, 15 deg inclination)
square of 12 km side
Image © 2011 GeoEye
© 2011 Google
Image © 2011 IGN-France
©2010 Google
46°09'15.66" N 6°14'44.85" O Höhe 666 m
Sichthöhe 77.04 km

Payload architecture - driven by optical design

Objective : as representative as possible for JEM-EUSO
the present design (Y. Takizawa, 6.2011) is charactized by
a short focal lenght, 1.47 m and
a fairly large FOV of 8° (see talk Bertaina-Gorodetzky)

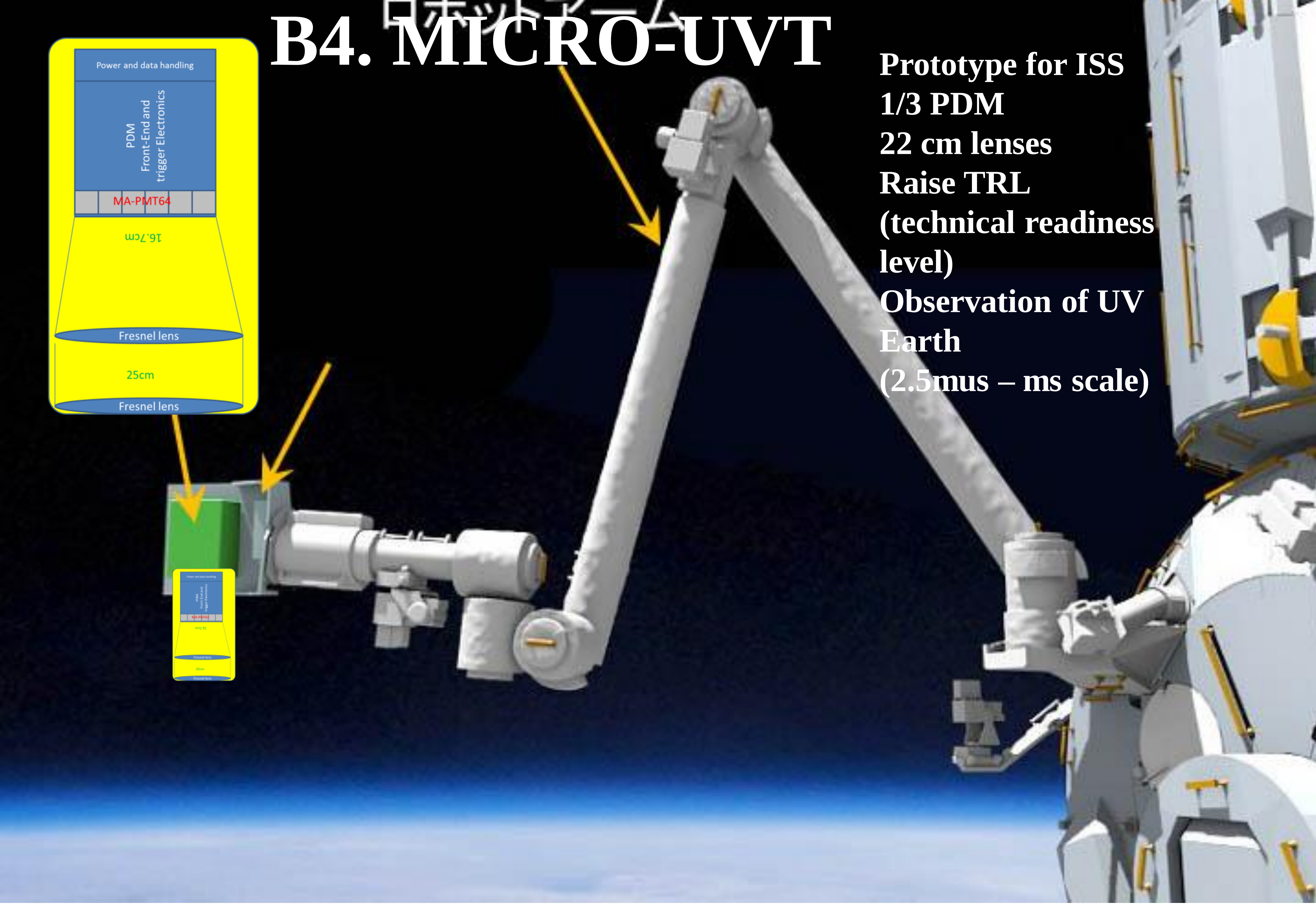


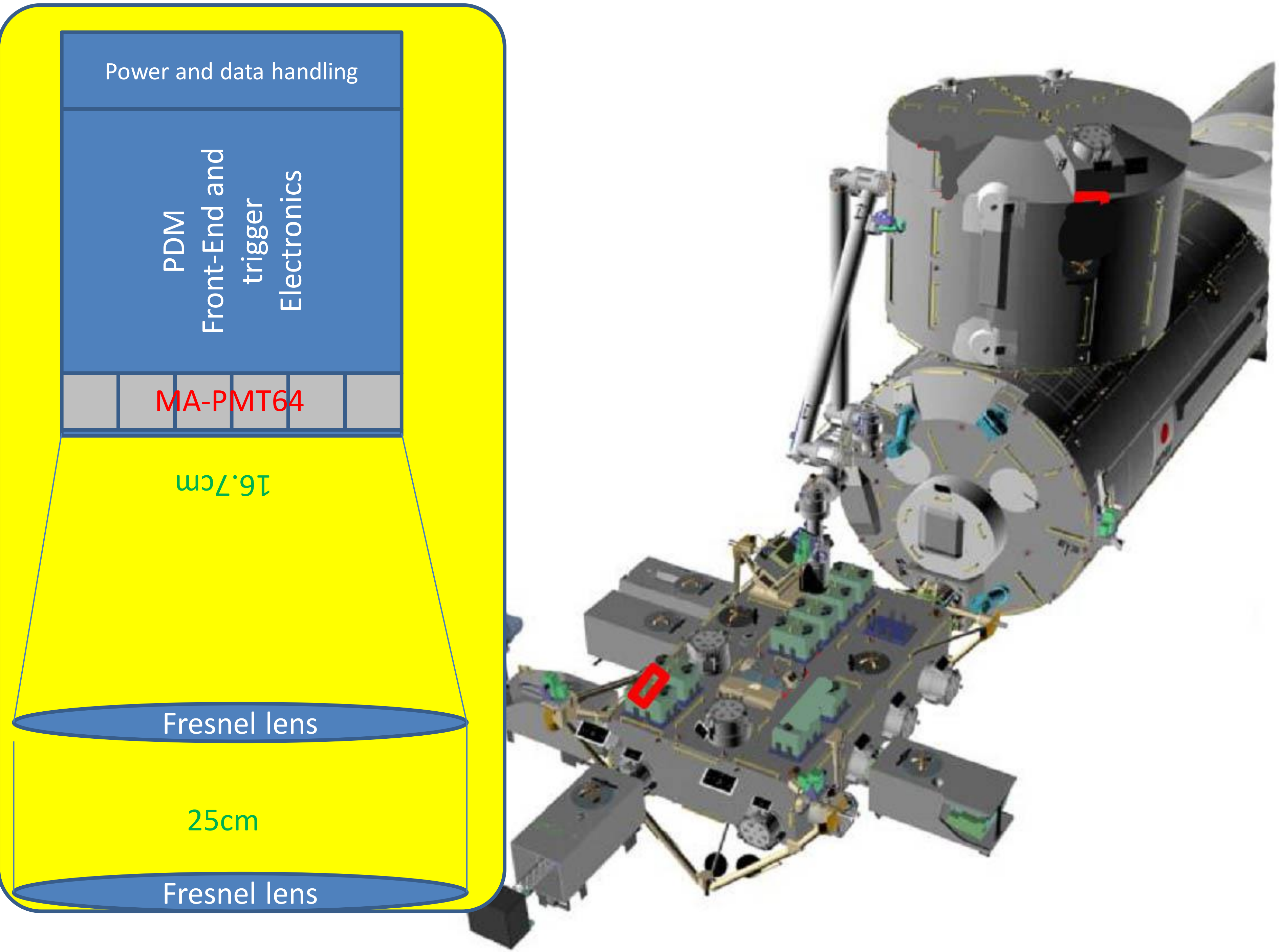


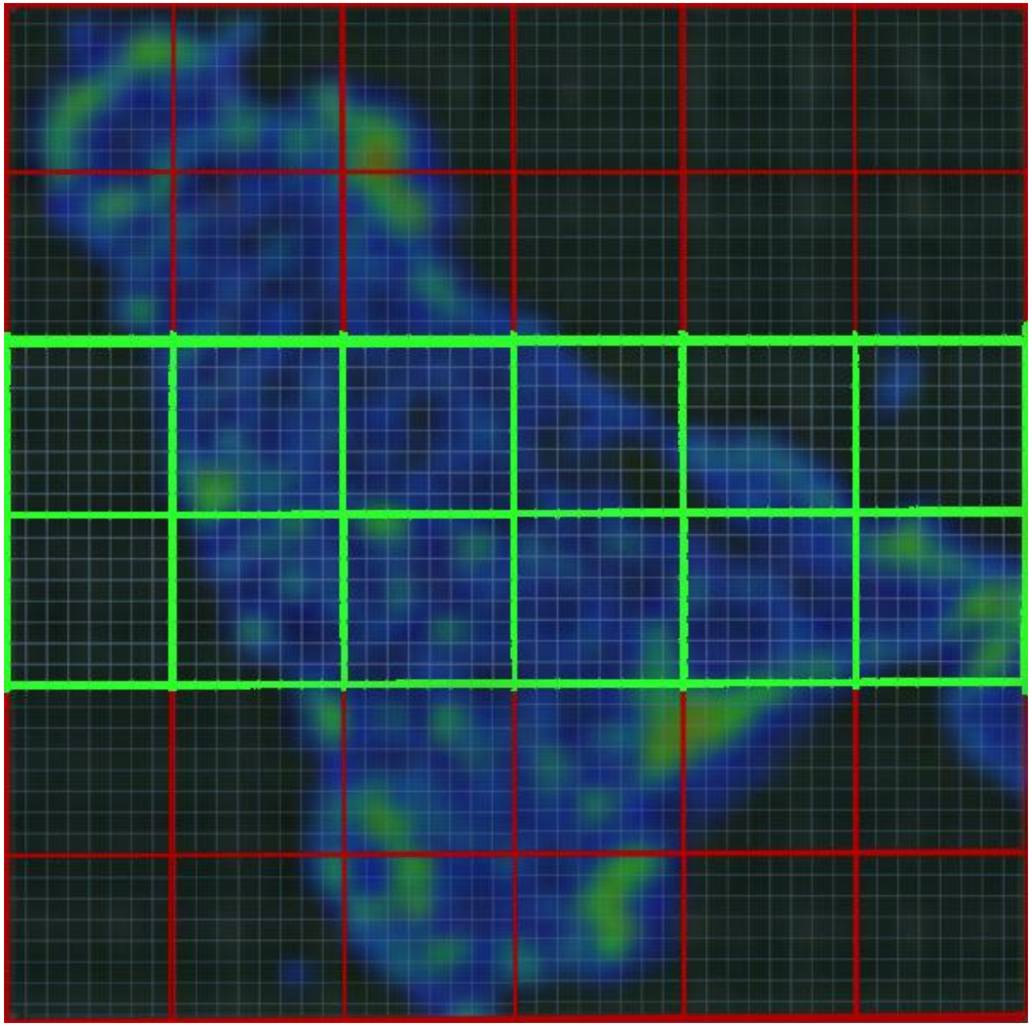
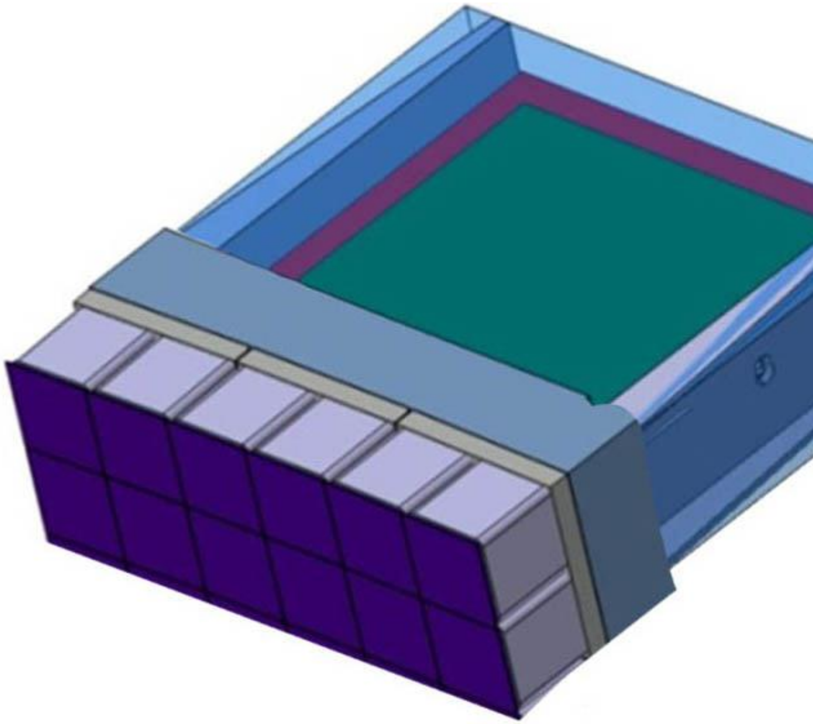
=> mass of FRESNEL lenses : 9.6 kg
=> rough dimension of telescope : 1 x 1 x 1.8 m

B4. MICRO-UVT

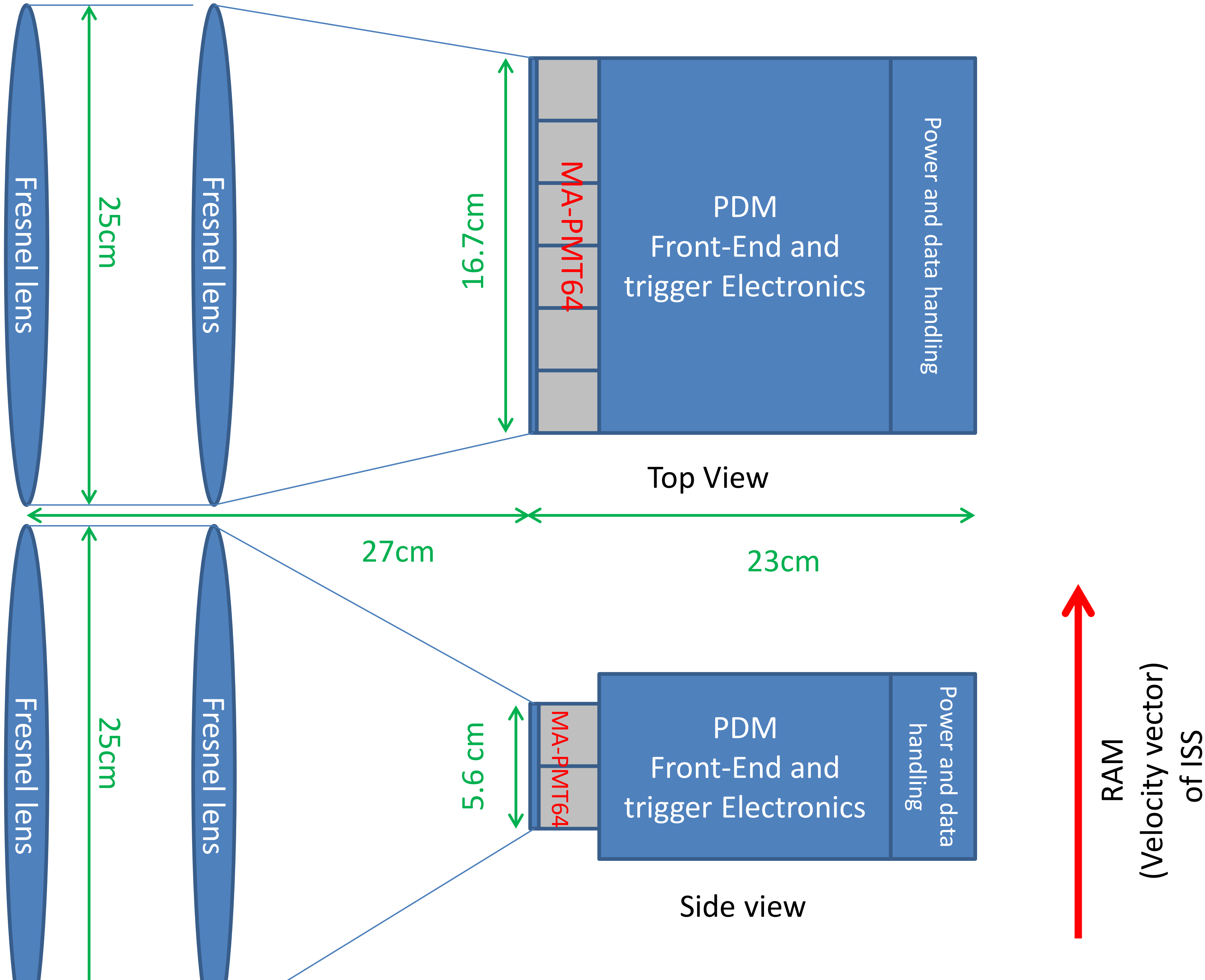
Prototype for ISS
1/3 PDM
22 cm lenses
Raise TRL
(technical readiness level)
Observation of UV Earth
(2.5mus – ms scale)




Power and data handling
PDM
Front-End and
trigger
Electronics
MA-PMT64
16.7cm
Fresnel lens
25cm
Fresnel lens

Montecarlo simulation (Geant4) of Micro UVT response. In green the instantaneous field-of view, in red the area covered in a swath of a few minutes. There are 768 pixels divided in 12 phototubes (1/3 of a PDM). PMTs are places orthogonal to the scanning (velocity) vector. Data are acquired every i 2.5 microseconds and can be processed on board or on ground. The image shown has a smoothing algorithm applied.


Fresnel lens
25cm
Fresnel lens
16.7cm
MA-PMT64
PDM
Front-End and
trigger Electronics
Power and data handling
Top View
27cm
23cm
Fresnel lens
25cm
Fresnel lens
5.6 cm
MA-PMT64
PDM
Front-End and
trigger Electronics
Power and data
handling
Side view
RAM
(Velocity vector)
of ISS

Micro UVT yearly plan

2012
Laboratory prototype
Ground test

2013
Flight Model construction
Calibration

2014
Qualification tests
Launch
Operations in WORF and outside

2015
Cont. Operations
Data analysis
Retrieval of data

Conclusions

- **JEM-EUSO is a novel mission concept to study Ultra-High-Energy Cosmic rays as well as Atmospheric and Earth Science**

- **A number of side projects and experiments using this technology are being developed and installed**

- **Measurements beginning in a few months.**