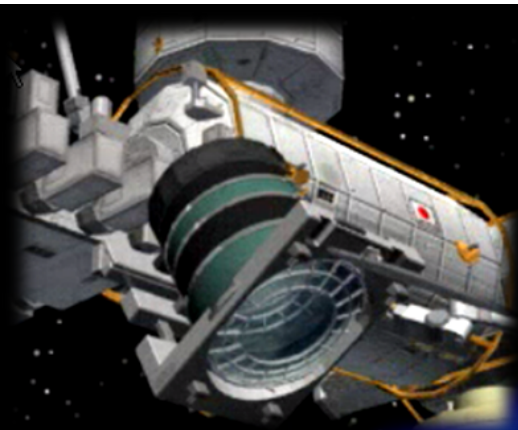




Extreme Universe Space Observatory

RENATA, Barcelona, 02/11/2011

The JEM-EUSO Space Mission: Spanish Scientific & Technological Contribution

**M. D. Rodríguez Frías
for JEM-EUSO-Spain
spas.uah.es**



A mi RENATA,

a la que he sentido como una hija... y como una madre...

*y a la que ahora como colega, le animo a impulsar y
consolidar las Astropartículas Españolas en el
panorama nacional e internacional.*

Overview

- ✓ Scientific Motivation of this Space Mission.
- ✓ JEM-EUSO main instrument & Mission parameters.
- ✓ Scientific & Tecnological contribution of Spain.
- ✓ Spanish Consortium involved in JEM-EUSO.
- ✓ Infrared Camera of JEM-EUSO.
- ✓ Conclusion & Further Steps.

ARRIVAL DIRECTIONS ANISOTROPY ?

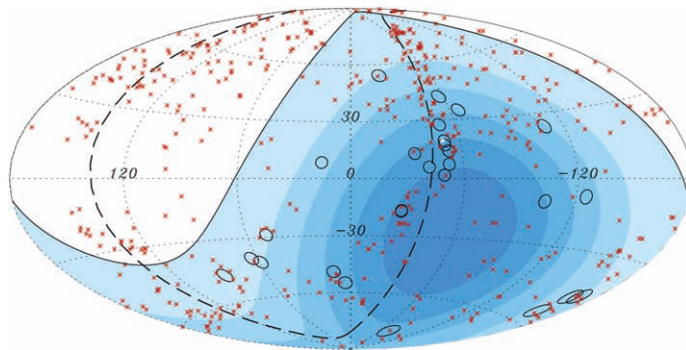


The Pierre Auger Collaboration
SCIENCE, 2007.

○ : Arrival direction ($>57\text{EeV}, <3.1\text{degrees}$)

Red points: AGN($< 75\text{Mpc}$);

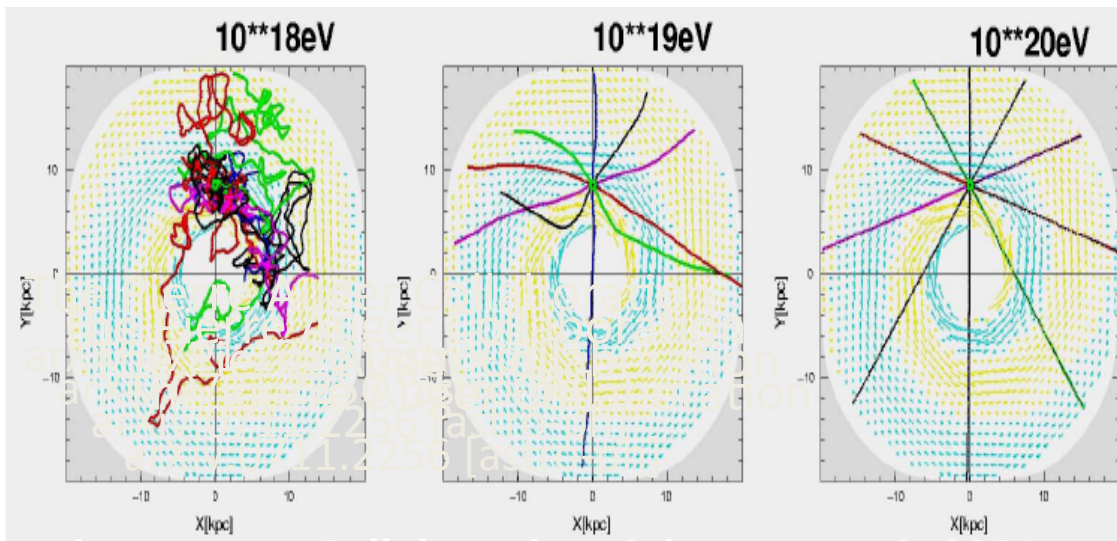
White * is CEN-A



Anisotropy of the arrival directions of UHECRs and their extragalactic origin.

Circles of radius 3.1° centered at the arrival directions of the 27 CRs with $E_p \geq 5.7 \cdot 10^{19}$ eV. Red asterisks indicate the positions of the 472 AGN (318 in the FoV of the Observatory) with redshift $z \leq 0.018$ ($D < 75$ Mpc) . Véron-Cetty catalog.

The number UHECR events recorded corresponds to **1.2 years** of operation of the complete southern array.



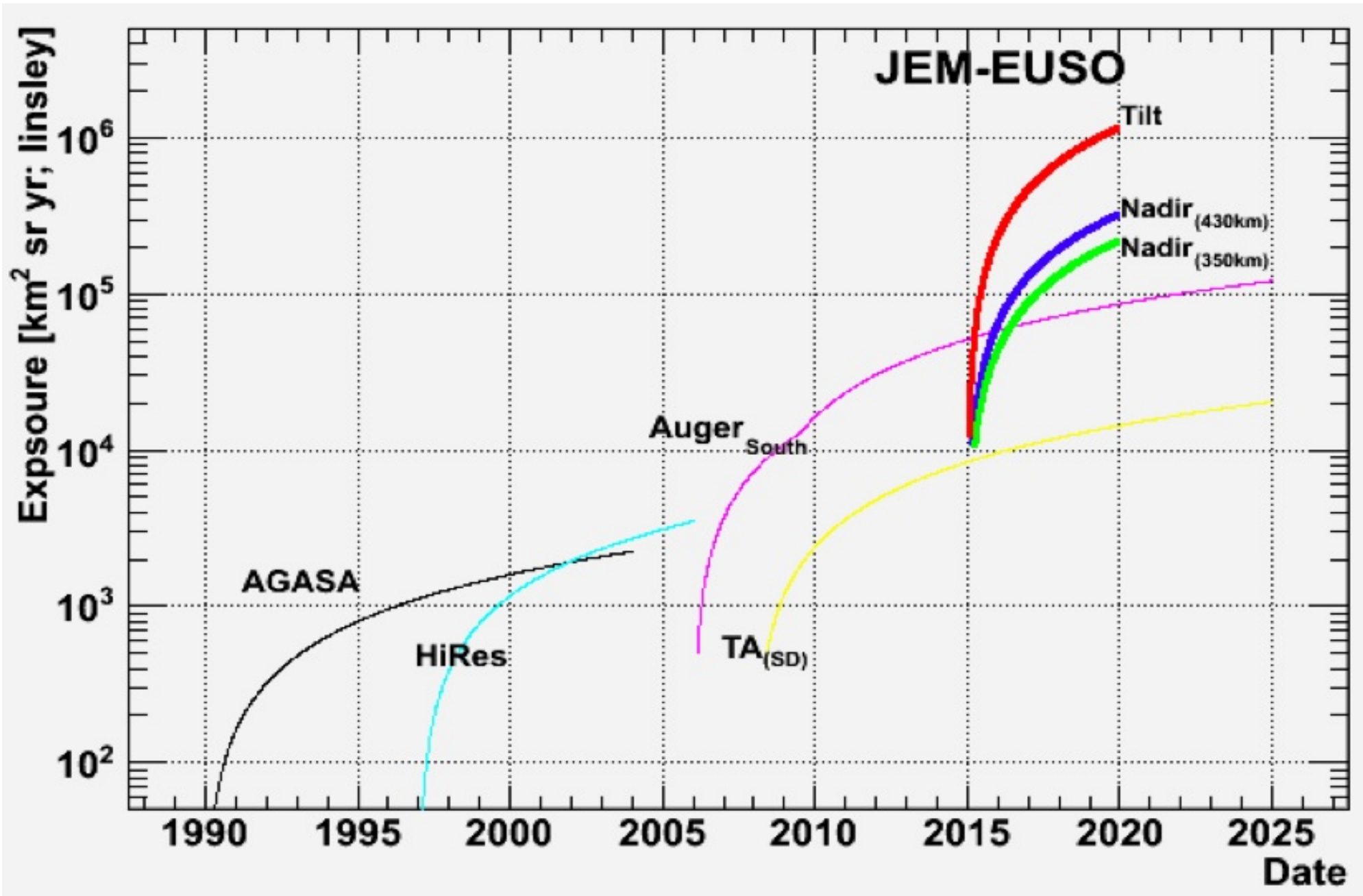
Due to magnetic deflections in EGMF & GMF, very high statistics @ EHECR are crucial to identify sources and established
“Charged-Particle-Astronomy”
@ $E > 10^{20}$ eV

Why a space-based experiment for CR's detection ?

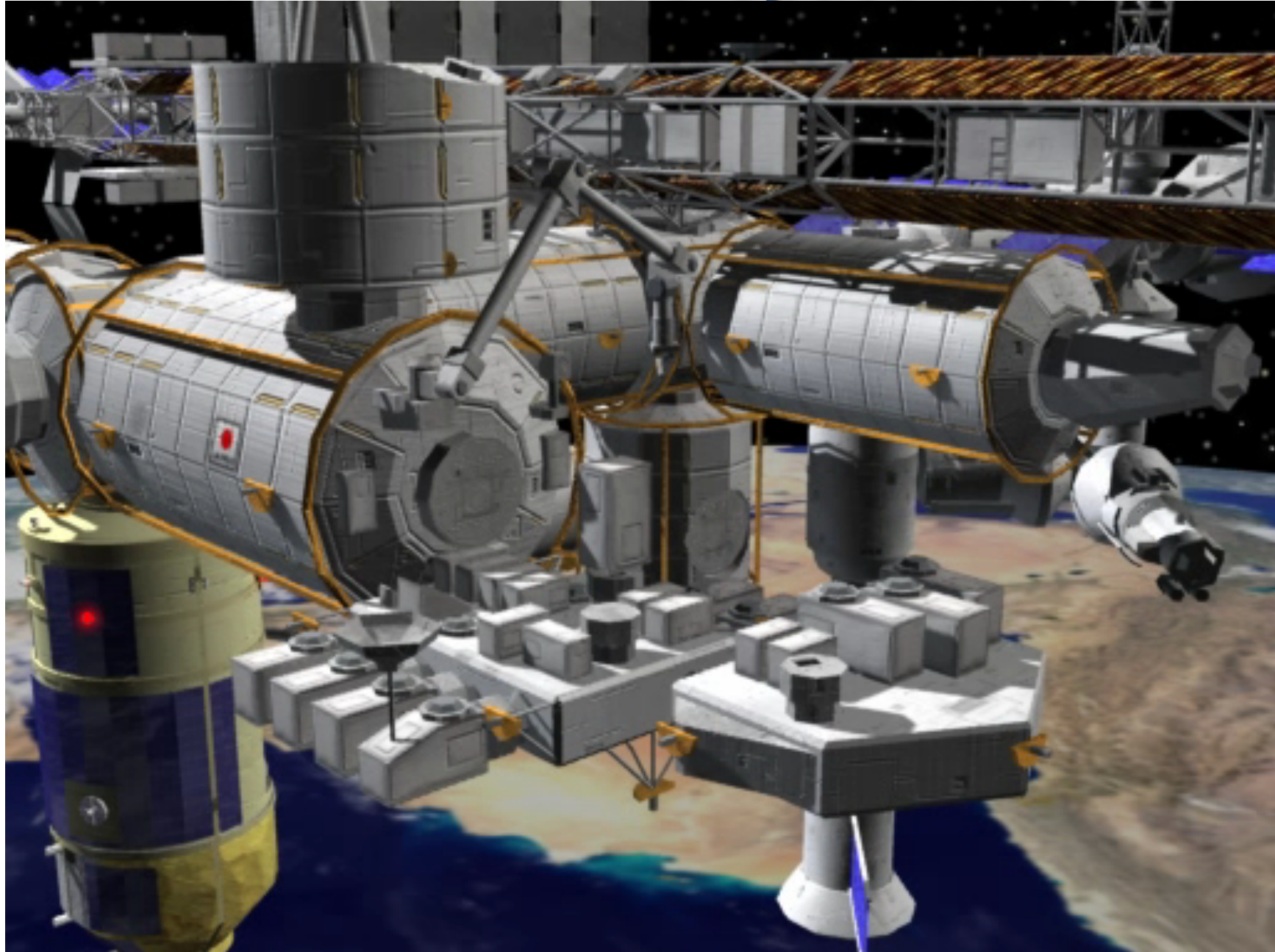
Increase Exposure to increase statistics
& full sky coverage

Experiment	Acceptance (km ² sr)	Operational Period	Operational Life (years)	Observational Efficiency (%)	Exposure (km ² sr year)	Relative Exposure
Auger SD FD=Hybrid	7,000 7,000	2006-2015 2006-2015	10+ 10+	100 10	7.0 ×10 ⁴ 7.0 ×10 ⁴	1 0.1
Telescope Array SD FD	1,400 6,700	2008-2015	10 10	100 10	1.4×10 ⁴ 6.7×10 ³	0.2 0.1
TUS	30,000	2009-2014	5	20	3.0×10 ⁴	0.5
JEM-EUSO nadir tilted Total	520,000 2,580,000	2016-2017 2018-	2 3+(5) 5+(5)	20 20 20	2.1×10 ⁵ 1.5 ×10 ⁶ 1.7 ×10 ⁶	4 in two years 25+(42) 30+(42)

Why a Space-based experiment for CR's detection ?



The JEM-EUSO Space Mission

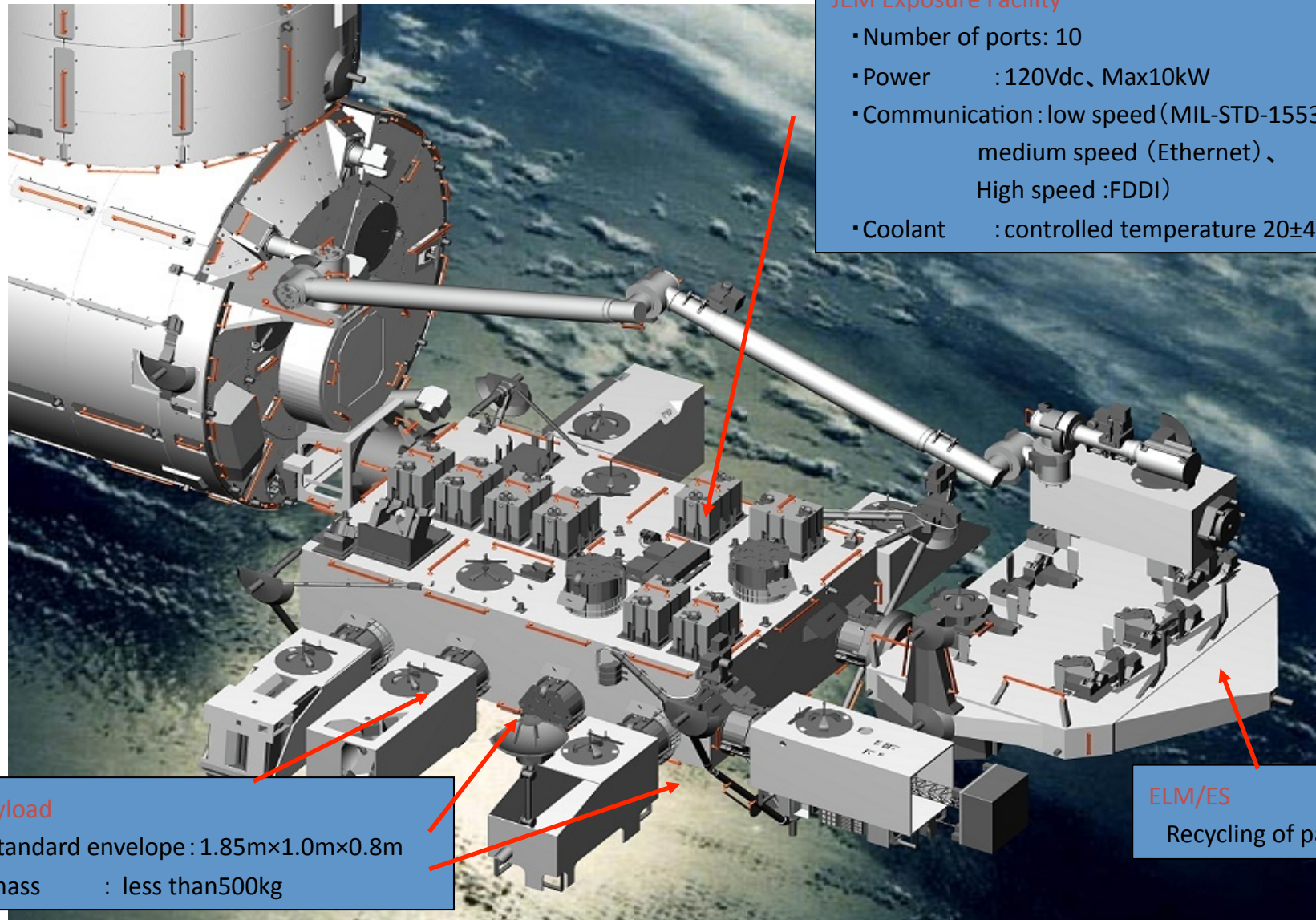


JEM-EUSO Collaboration



- ▶ **Japan** : T. Ebisuzaki, Y. Uehara, H. Ohmori, Y. Kawasaki, M. Sato, Y. Takizawa, K. Katahira, S. Wada, K. Kawai, H. Mase (*RIKEN*), F. Kajino, M. Sakata, H. Sato, Y. Yamamoto, T. Yamamoto, N. Ebizuka, (*Konan Univ.*), M. Nagano, Y. Miyazaki (*Fukui Inst. Tech.*), N. Sakaki, T. Shibata (*Aoyama Gakuin Univ.*), N. Inoue (*Saitama Univ.*), Y. Uchihori (*NIRS*), K. Nomoto (*Univ. of Tokyo*), Y. Takahashi (*Tohoku Univ.*), M. Takeda (*ICRR, Univ. Tokyo*), Y. Arai, Y. Kurihara, H.M. Shimizu, J. Fujimoto (*KEK*), S. Yoshida, K. Mase (*Chiba Univ.*), K. Asano, S. Inoue, Y. Mizumoto, J. Watanabe, T. Kajino (*NAOJ*), H. Ikeda, M. Suzuki, T. Yano (*ISAS, JAXA*), T. Murakami, D. Yonetoku (*Kanazawa Univ.*), T. Sugiyama (*Nagoya*), Y. Ito (*STEL, Nagoya Univ.*), S. Nagataki (*YITP, Kyoto Univ.*), A. Saito (*Kyoto Univ.*), S. Abe, M. Nagata (*Kobe Univ.*), T. Tajima (*KPSI, JAEA*), M. Chikawa (*Kinki Univ.*), and M. Tajima (*Hiroshima Univ.*)
- ▶ **USA** : J. H. Adams Jr., S. Mitchell, M.J. Christl, J. Watts Jr., A. English, R. Young (*NASA/ MSFC*), Y. Takahashi, D. Gregory, M. Bonamente, K. Pitalo, J. Hadaway, J. Geary, R. Lindquist, P. Reardon, T. Blackwell (*Univ. Alabama in Huntsville*), H. Crawford, E. Judd, C. Pennypacker (*LBL, UC Berkeley*), K. Arisaka, D. Cline, J. Kolonko, V. Andreev (*UCLA*), A. Berlind, T. Weiler, S. Csorna (*Vanderbilt Univ.*), R. Chipman, S. McClain (*Arizona*)
- ▶ **France** : D. Allard, J-N. Capdevielle, J. Dolbeau, P. Gorodetzky, J. J. Jaeger, E. Parizot, T. Patzak, D. Semikoz, J. Waisbard (*APC-Paris 7*)
- ▶ **Germany** : M. Teshima, T. Schweizer (*Max Planck Munich*), A. Santangelo, E. Kendziorra, F. Fenu (*Univ. Tuebingen*), P. Biermann (*MPI Bonn*), K. Mannheim (*Wuerzburg*), J. Wilms (*Univ. Erlangen*)
- ▶ **Italy** : M. Focardi, E. Pacce, P. Spillantini (*Univ. Firenze*), V. Bratina, L. Gambicorti, A. Zuccaro (*CNR-INO, Firenze*), A. Anzalone, O. Catalano, M.C. Maccarone, P. Scarsi, B. Sacco, G. LaRosa (*IAS-PA/INAF*), G. D'Alì Saiti, D. Tegolo (*U. Palermo*), R. Battiston (*Perugia*), M. Casolino, M.P. De Pascale, A. Morselli, P. Picozza, R. Sparvoli (*INFN and Univ. Rome "Tor Vergata"*), P. Vallania (*INAF-IFSI Torino*), P. Galleotti, C. Vigorito, M. Bertaina (*Univ. Torino*)
- ▶ **Mexico** : G. Medina-Tanco, J.C. D'Olivo, J.F. Valdes (*Mexico UNAM*), H. Salazar, O. Martinez (*BUAP*), L. Villasenor (*UMSNH*)
- ▶ **Republic of Korea** : S. Nam, I. H. Park, J. Yang (*Ehwa W. Univ.*)
- ▶ **Russia** : Garipov G.K., Khrenov, B.A., Klimov P.A., Panasyuk M.I., Yashin I.V. (*SINP MSU*), D. Naumov, Tkachev. L. (*Dubna JINR*)
- ▶ **Switzerland** : A. Maurissen, V. Mitev (*Neuchatel, Switzerland*) :
- ▶ **Spain** : M.D. Rodriguez-Frias, L. del Peral, J.A. Morales de los Ríos, G. Sáez, H. Prieto, N. Pacheco, J. H-Carretero (*UAH*), M.D. Sabau, T. Belenguer, C. González-Alvarado, M. Reina (*NTA*), F. López, S. Briz, A. J. de Castro, F. Cortés (*UC3M*), J. Licandro, E. Jóven, M. Serra, V. Ali, O. Vaduvescu (IAC).

Outline of JEM Exposure Facility-KIBO



JEM Exposure Facility

- Number of ports: 10
- Power : 120Vdc、Max10kW
- Communication : low speed (MIL-STD-1553B)
medium speed (Ethernet)、
High speed :FDDI)
- Coolant : controlled temperature $20\pm4^{\circ}\text{C}$

Payload

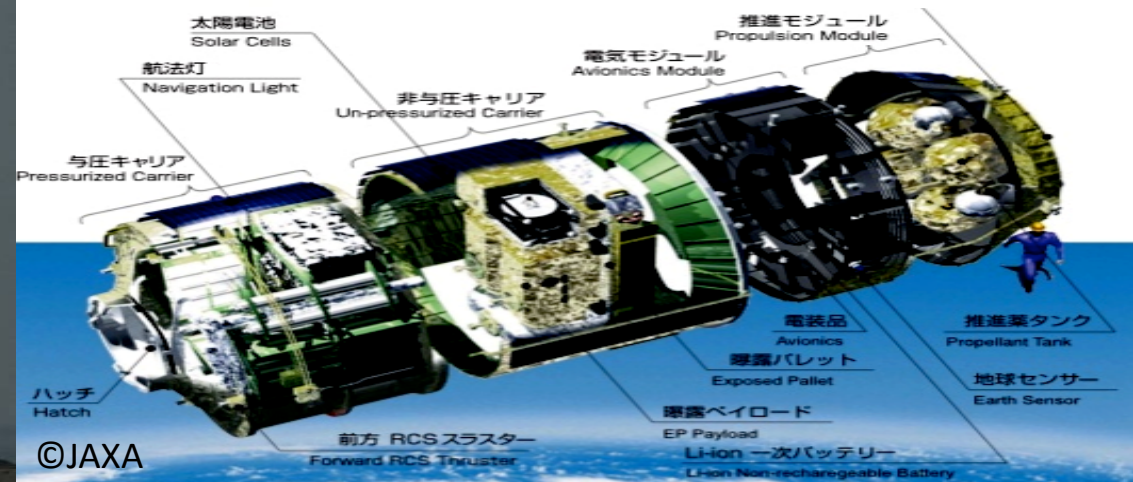
standard envelope : 1.85m×1.0m×0.8m
mass : less than 500kg

ELM/ES

Recycling of payload

H-II Transfer Vehicle (HTV)

On September 18, 2009 the first Japanese HTV module was successfully docked to the ISS, transferring material and leaving the ISS safely. Have a look at the film @ www.nasa.gov.

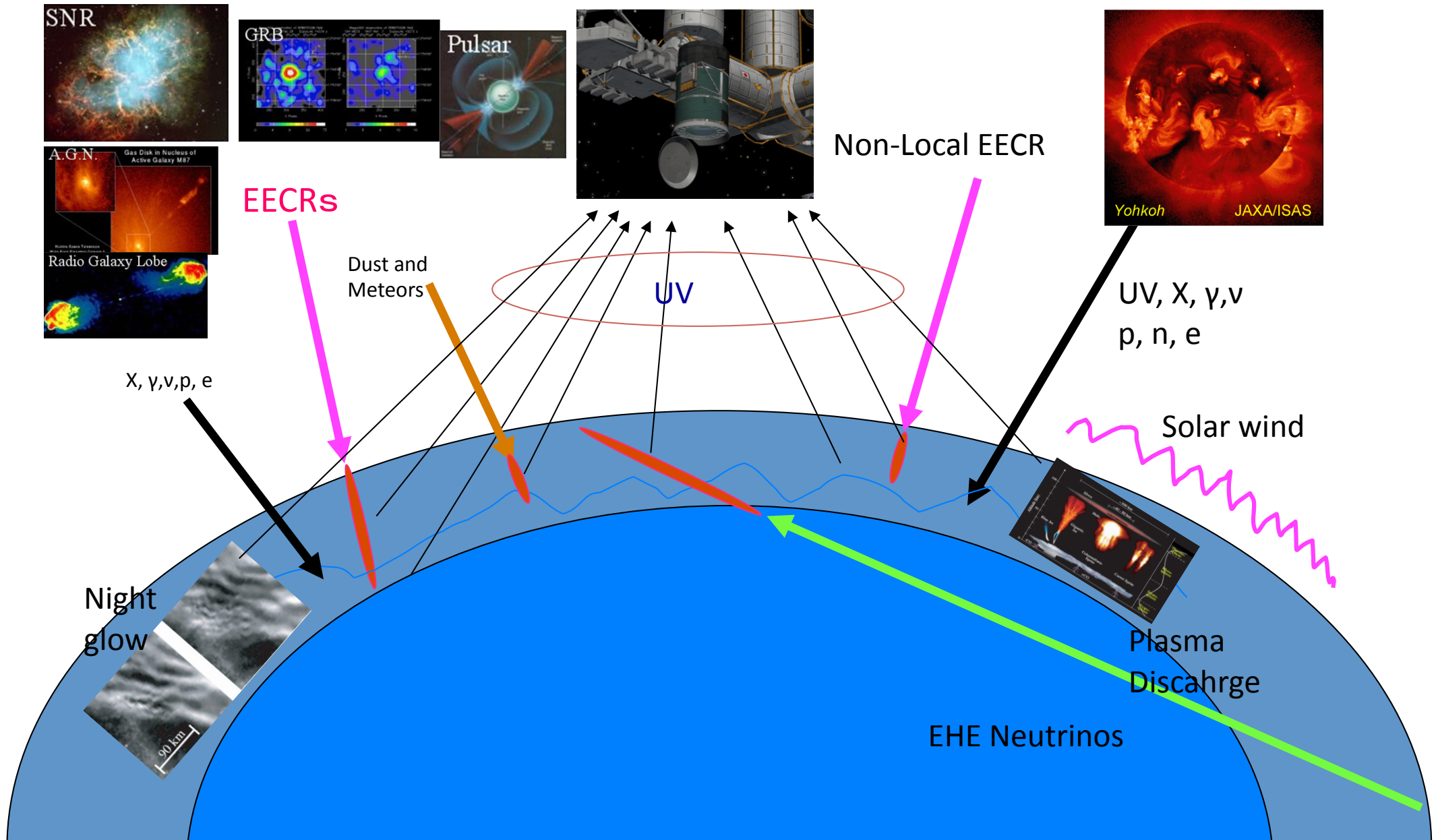


©JAXA

Parameters of Mission

- **Time of launch:** year 2016
- **Operation Period:** 3 years (+ 2 years)
- **Launching Rocket :** H2B
- **Transportation to ISS:** non pressurized Carrier of H2 Transfer Vehicle (HTV)
- **Site to Attach:** Japanese Experiment Module/ Exposure Facility #2
- **Height of the Orbit:** ~430km
- **Inclination of the Orbit:** 51.6°
- **Mass:** 1983 kg
- **Power:** 926 W (operative),
352 W (non-operative)
- **Data Transfer Rate:** 285 kbps

Extreme Universe Space Observatory JEM-EUSO



Science Objectives

- **Main Objective :**

Astronomy and astrophysics through particle channel with extreme energies

- Possible identification of the particle and energy sources based on the analysis of the arrival direction
- Possible identification of the acceleration and radiation mechanisms with the measurement of energy spectrum from individual sources

- **Exploratory objective :**

- Measurement of Extreme High Energy Gamma Rays (EHEGR).
- Detection of extreme high energy neutrinos
- Estimation of the structure of galactic and extragalactic magnetic fields and its intensity
- Identification of relativity, quantum gravitational effect & Dark Matter.
- Study of atmospheric luminous phenomena: night-glows plasma discharges & lightings.

Criteria from Scientific Requirements

(Success Criteria)

- Full Success :

Number of Events >1000 (above 7×10^{19} eV)

Minimum Success: >500

- Extra Success

Achieve one or all of three exploratory objectives

- **Arrival direction < 2.5 degrees**
- **Energy resolution $< 30\%$**
- **Hadron/Photon/neutrino: $\Delta X_{\text{max}} < 120$ g /cm²**

Flujo de los rayos cósmicos que detectará jem-euso

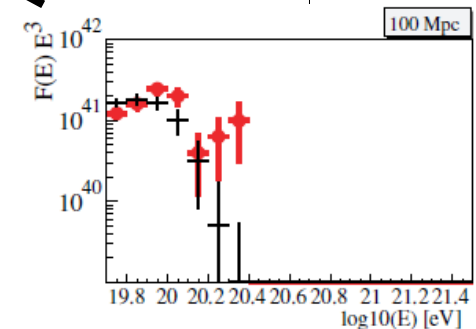
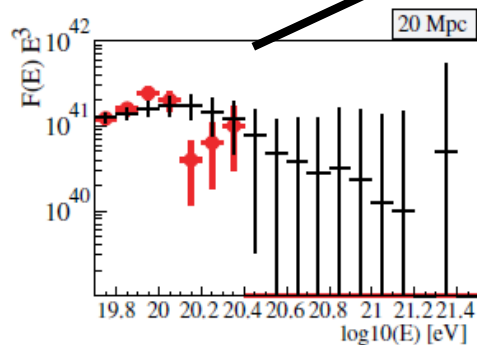
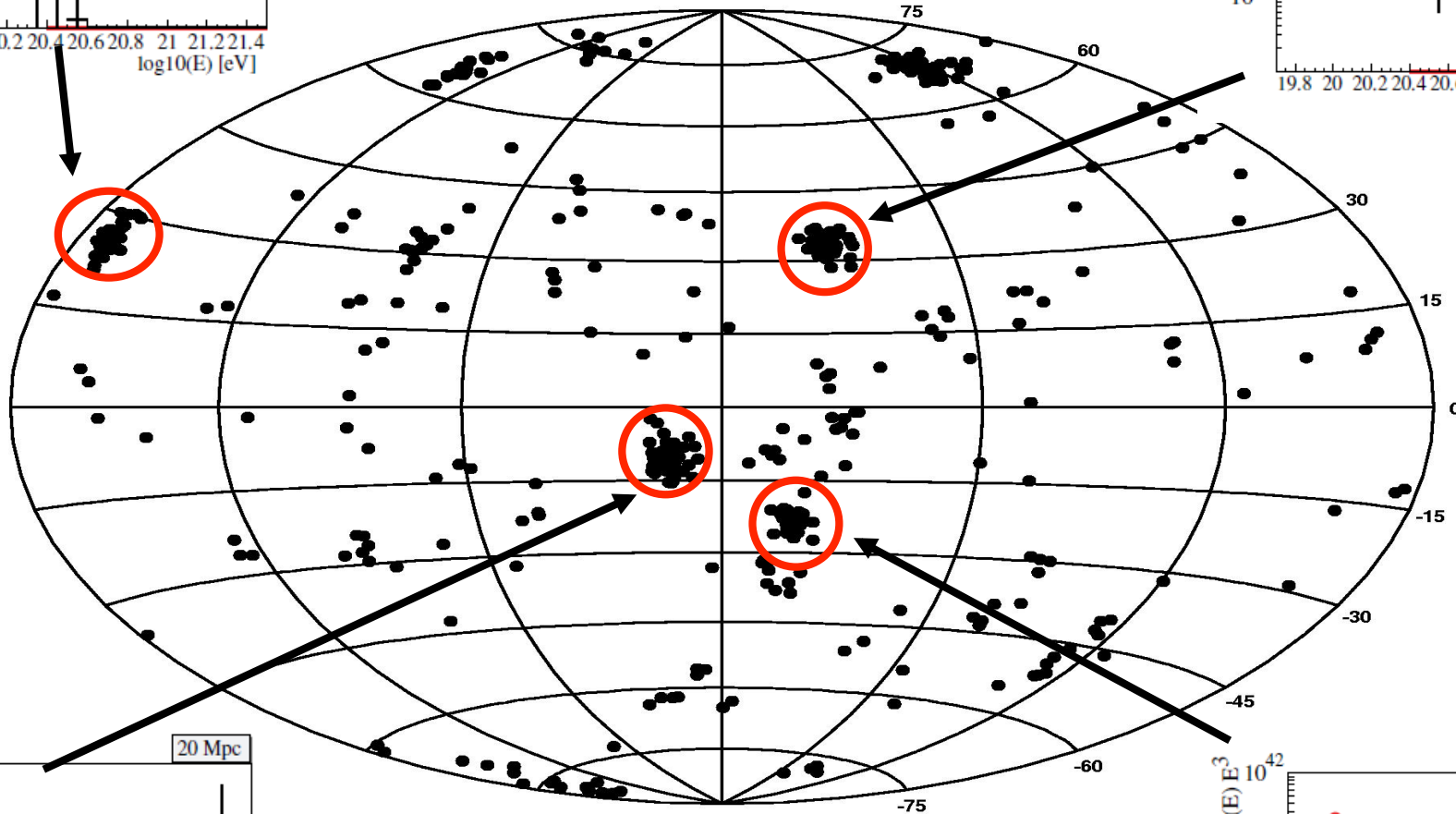
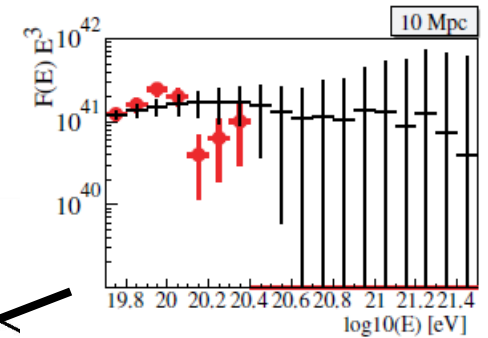
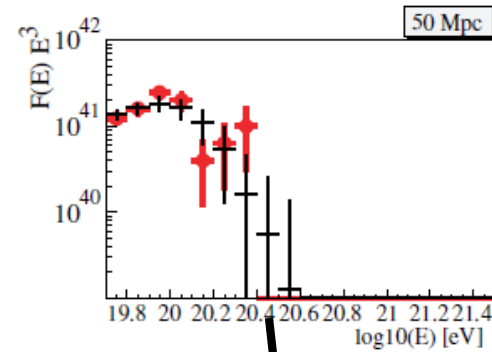
Consideraciones:

- El tiempo de observación como $\sim 20\%$ del día
 - Área del modo nadir: $2,5 \cdot 10^5 \text{ km}^2$
 - Área del modo tilted: $\sim 10^6 \text{ km}^2$

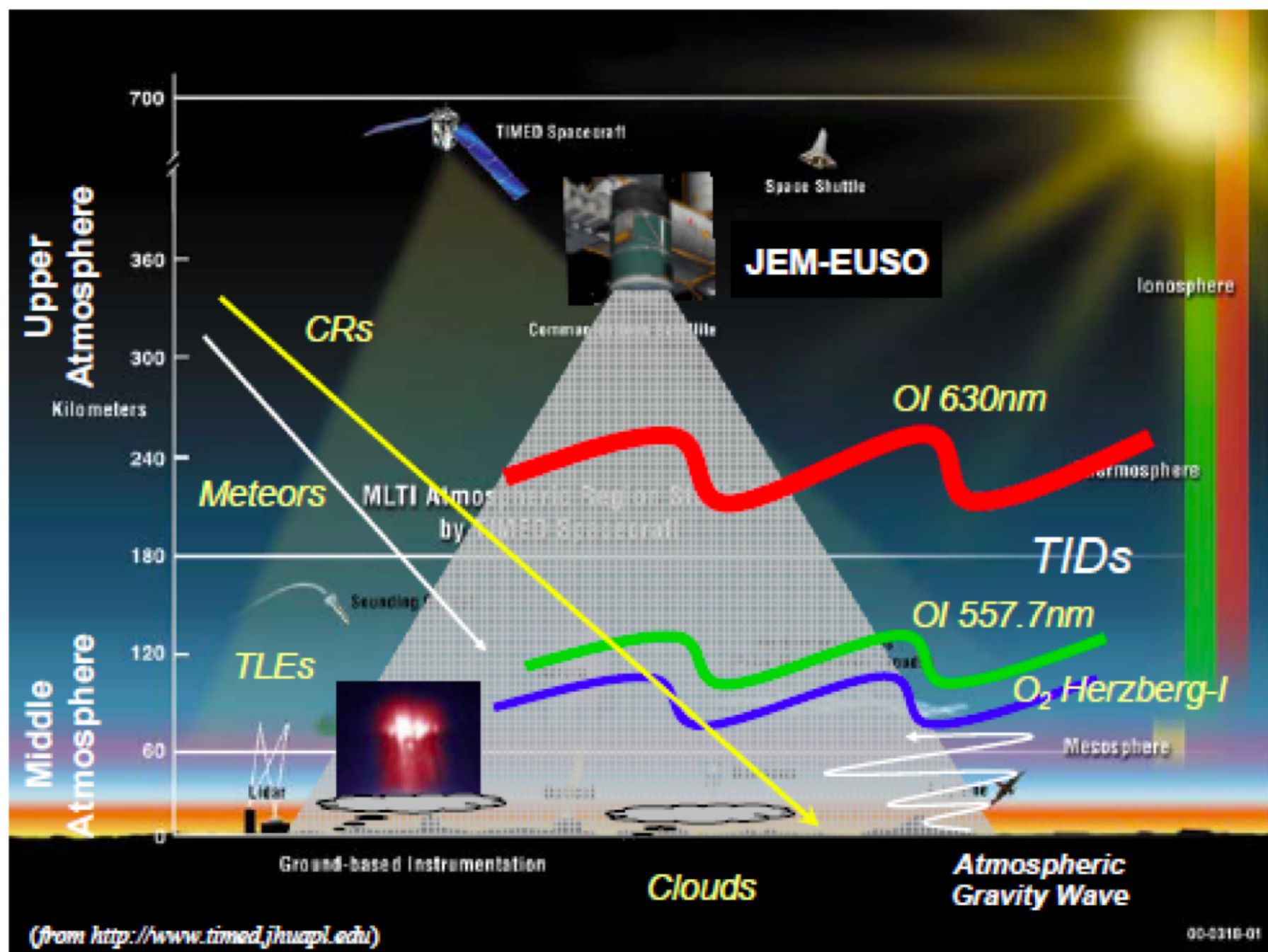
ENERGÍA (eV)	FLUJO ($E^{-2.7}$)	MODO NADIR	MODO TILTED
$5 \cdot 10^{18}$	6,5 part/ km^2yr	37eventos/hora	148eventos/hora
10^{19}	1 partícula/ km^2yr	6 eventos/hora	23 eventos/hora
10^{20}	0,002 part/ km^2yr	0,3 partículas/día	1,1 partículas/día
10^{21} ¿?	$4 \cdot 10^{-6}$ part/ km^2yr	0,2 partículas/año	0,8 partículas/año

Particle Astronomy

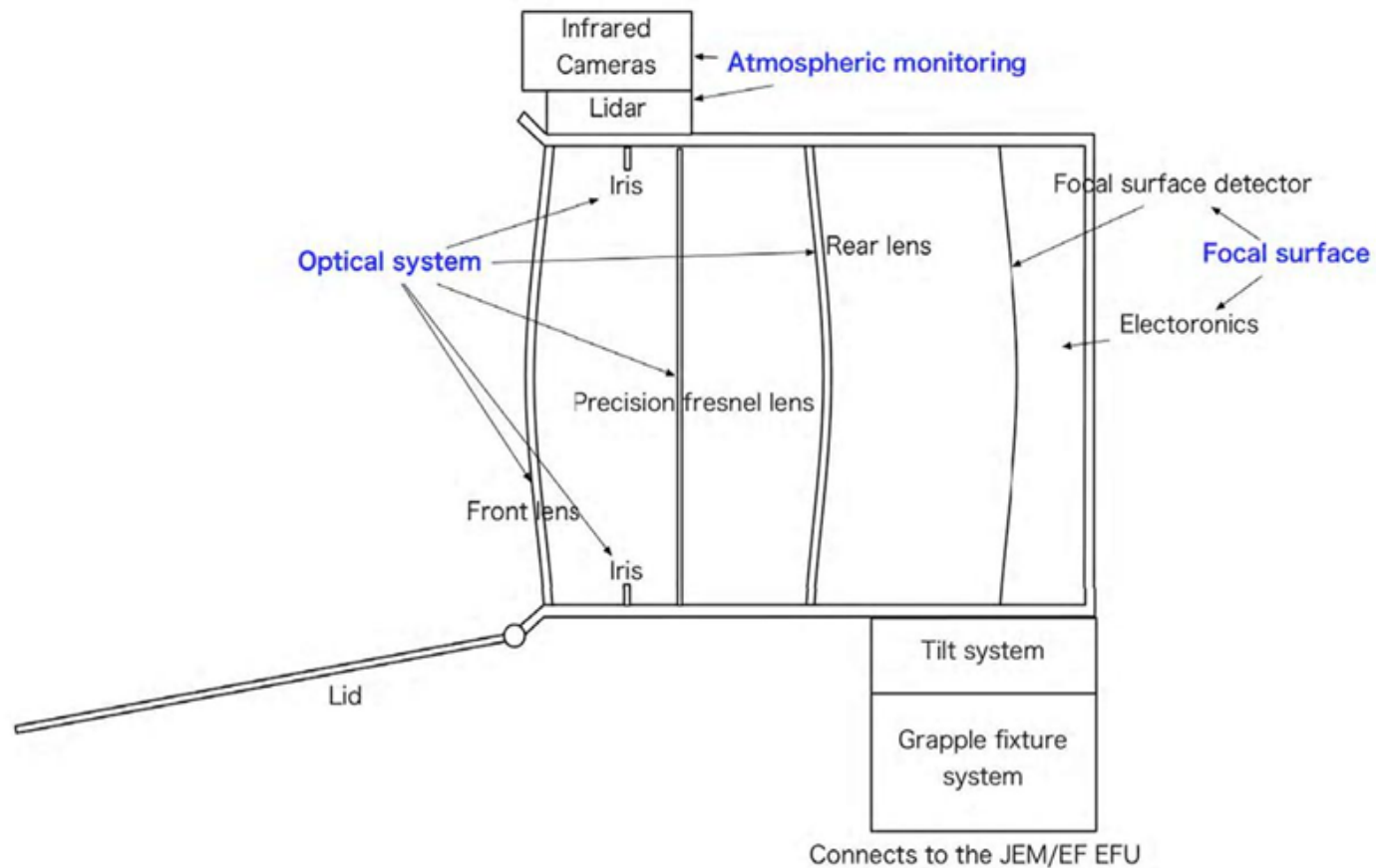
If we get >1,000 events,



- 1,000 events : $E > 7 \times 10^{19} \text{ eV}$
- Several dozen clusters are expected with full sky coverage



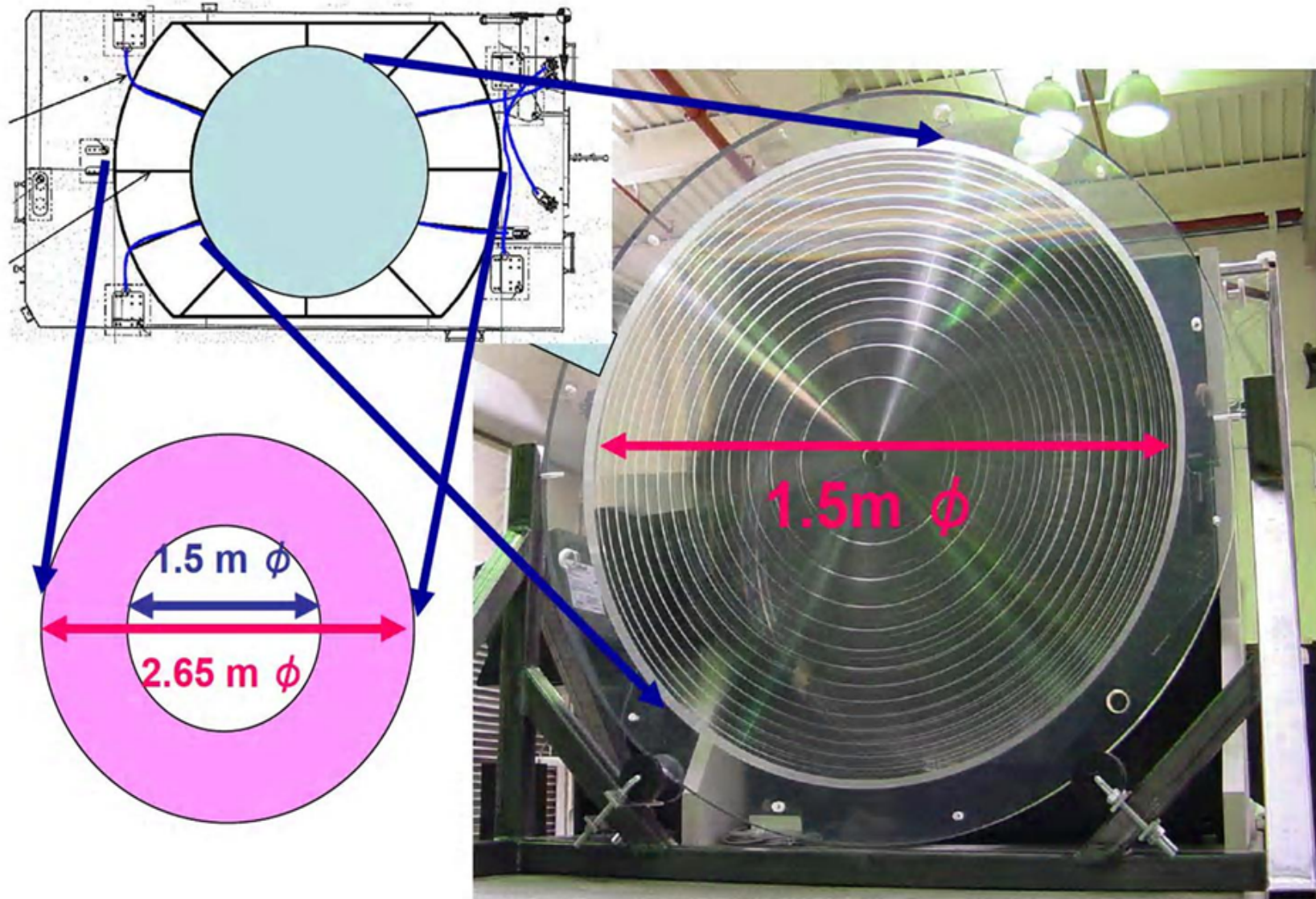
JEM-EUSO telescope



Providers of Instrument

subsystems	Providers (nations)
Optics	USA
Detector	Japan, Germany, France
Electronics	Japan, Italy, Korea, Germany
Atmospheric Monitor	Switzerland, Japan, USA, Spain
Calibration	Germany, France, Japan, USA
System Software	Japan, Italy
Logistics	Japan
Ground Segments	Japan, Italy, Mexico, Spain
Interface Software	Japan, Italy, Mexico, Spain
Analysis Software	all
Analysis	all

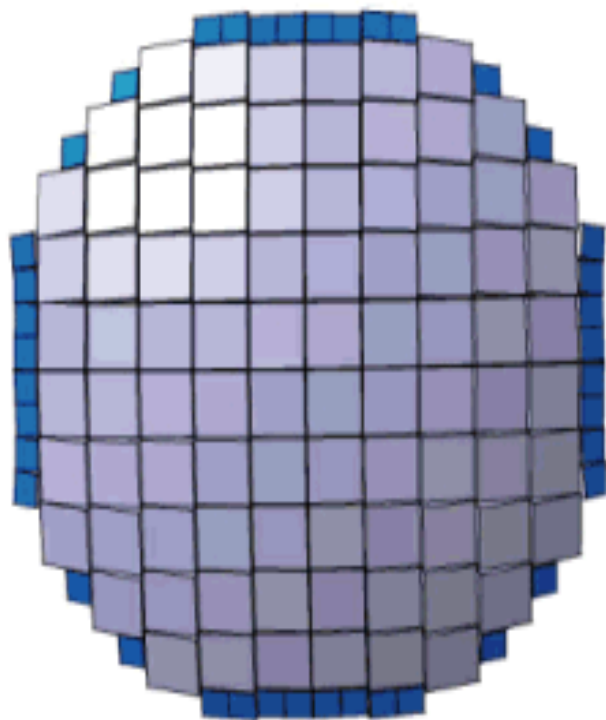
Fresnel lens: central + annals



JEM-EUSO Focal Surface

Focal Surface detector

150 PDMs = 0.2M pixels)



Elementary Cell

(2x2 PMTs = 144 pixels)

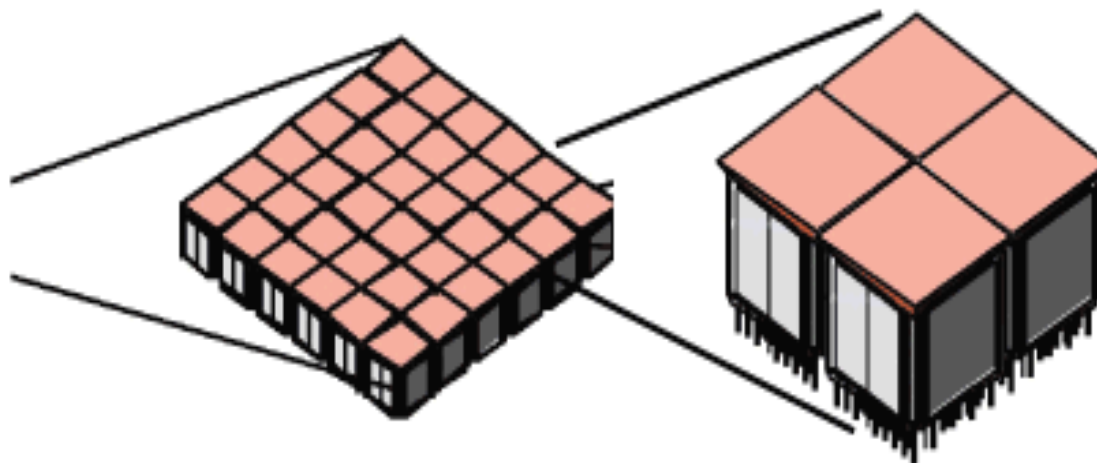
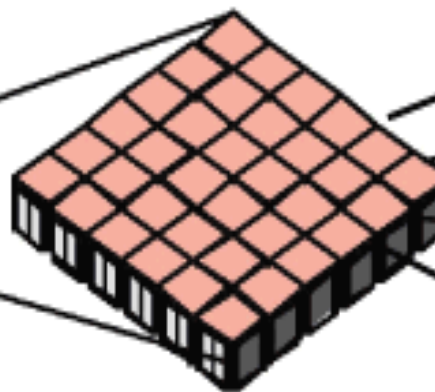
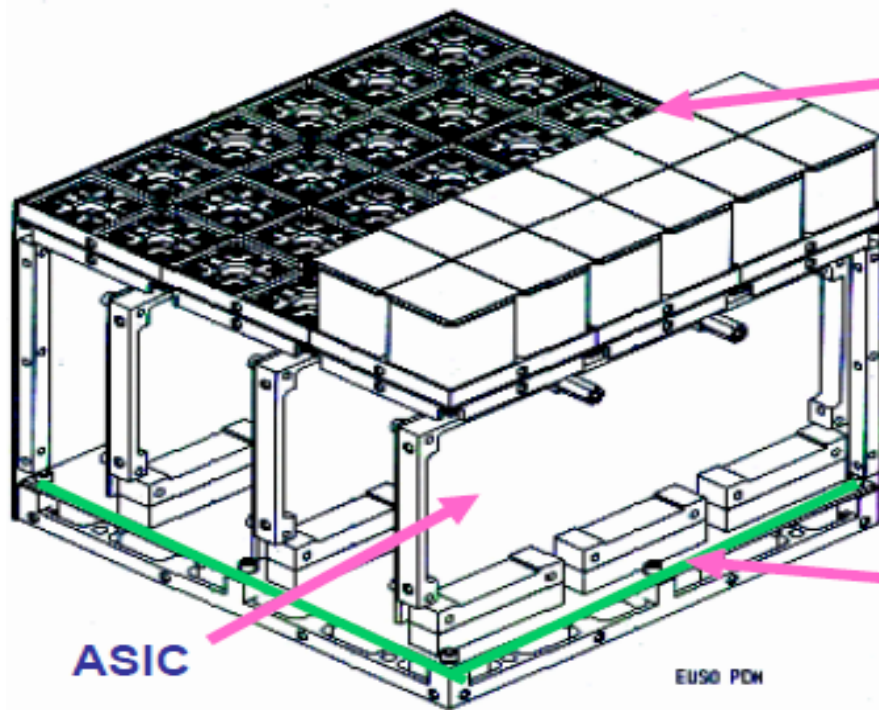


Photo-Detector Module

(3x3 ECs = 1296 pixels)

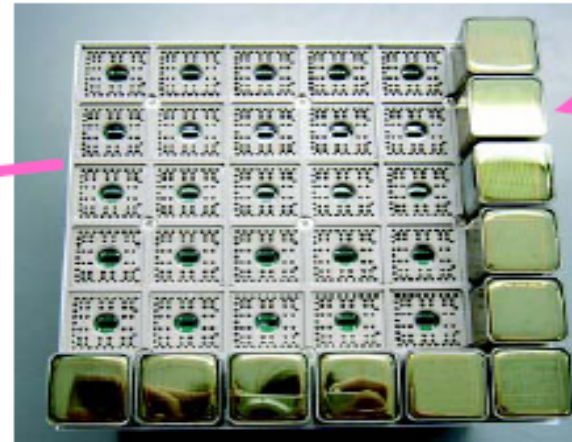


PDM and HVPS module board

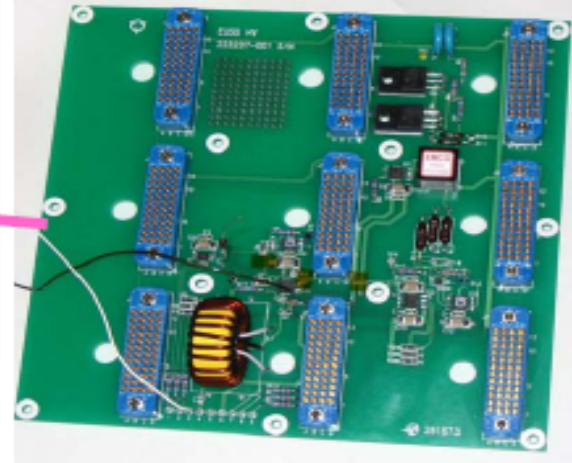


ASIC

Photodetector Module
(PDM)



36 MAPMT
with 36
anodes



HVPS module board

JEM-EUSO: Status & Prospects

- Approved Phase A 2007-mid 2009 by JAXA.
- Phase B1: SRR. mid 2009-2011.
- Phase B2: PDR+BBM by 2012.
- Pre-Calibration & Background measurements: Balloon Flight (French Space Agency, CNES), 2013.
- Phase C: CDR 2013-2014.
- Construction, Assembly & Verification: 2015-2016.
- Launch by HIIB-HTV & Commissioning 2016-2017.
- Operation period:
2017-2018 (Nadir mode). 2018- ... (Title mode).
- Resources:
90.000 k€-26.000 k€ Europe (33% Europe, 66% Others).

TUS: JEM-EUSO pathfinder

- TUS will be launched by Lomonosov satellite (Roscosmos Russia Agency) by 2012.
- When we joined JEM-EUSO, TUS was already defined and the contribution of countries to TUS had been defined very well in advance.
- The contributions to Space projects use to be closed in the earliest phases of the Space Mission design & it does not remain opened during later phases of development.
- Spain is NOT contributing to TUS & has ANY responsibility to the JEM-EUSO pathfinder.

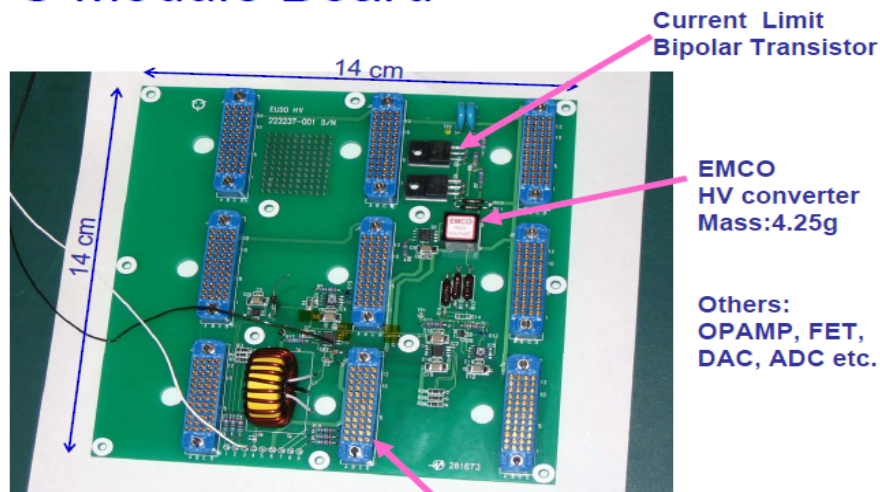
JEM-EUSO ESA positive outcomes

- ✓ 2010: ESA: “Fundamental Physics Roadmap Advisory Team (FPR-AT)”
- ✓ 2010 ESA “Astronomical Working Group (AWG)”.
- ✓ 2010 Program ELIPS (European programme for Life and Physical sciences and applications) accepted by the ESA committee for “Human Spaceflight, Microgravity and Exploration on ISS”.
- ✓ June 2010 The Science Unit of The European Space Foundation (ESF) has informed positively the JEM-EUSO space mission.
- ✓ April 2011 ESA Topical Team for Coordination of the European Involvement in JEM-EUSO.

Spanish Consortium @ JEM-EUSO

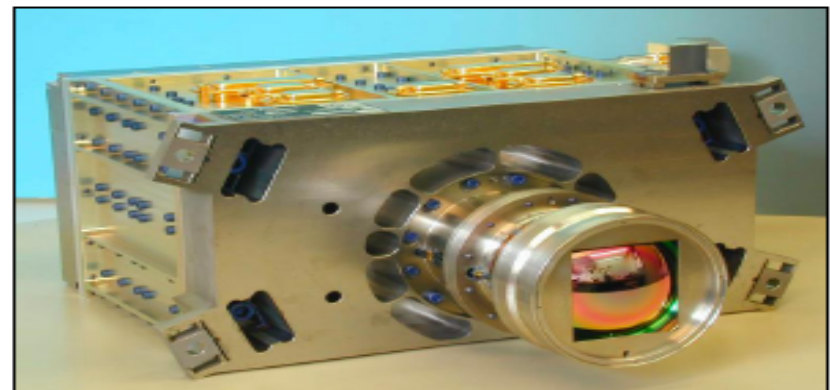
- I. Sept 2007, Valencia. We presented the project for the first time to the RENATA community and invited potential interested members to join.
- II. Dec 2007 MOU signed between UAH-RIKEN.
- III. JEM-EUSO meeting @ Spain hosted by the SPAS group @ UAH (October 24, 2008) with attendance of the PI of JEM-EUSO Prof. Toshikazu Ebisuzaki, where the Spanish contribution to JEM-EUSO: decided:

HVPS Module Board



Size: 14cm × 14cm
Mass: 251 g

9 Connectors to connect
with Elementary Cells



IAS

- Sc
- Se

Spanish consortium @ JEM-EUSO

IV. 09-02-2009: JEM-EUSO Kick-off meeting @ Madrid for the IR camera design study.

3 main goals:

- Identify and set up a JEM-EUSO Consortium @ Spain.
- Define the work packages for the IR camera.
- Try to define an alternative design to the IR-camera baseline.

JEM-EUSO Consortium @ Spain.



V. June 10, 2009: Formal Establishment of the JEM-EUSO Consortium & sign of NDAs (Non Disclosure Agreements).

VI. June 2009: RENATA meeting @ Alcala. JEM-EUSO was presented and invitation to join as well.

VII. July 31, 2009: JEM-EUSO funded for the first time in Spain. Positive outcome of the MICINN Complementary Action:

"Spanish Contribution to the IR Camera of the JEM-EUSO Space Mission.", 300 k€ for 2009.

JEM-EUSO_SPAIN Consortium @ Present

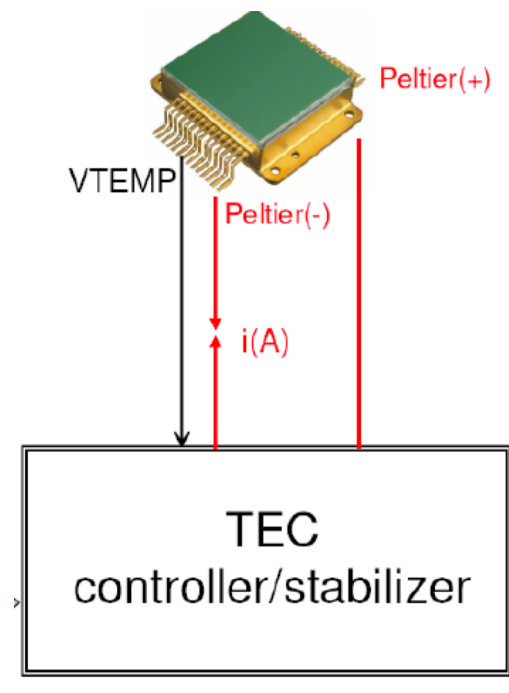
- Spanish contribution since 2007 (MOU: UAH-RIKEN).
- JEM-EUSO funded in Spain (2009-2012) from MICINN+CAM+MULTIDARK+UAH: 2.15 M€ for the Feasibility Study delivered to Japan in Dec 2009 & Phase A delivered to Japan in Aug 2010. Phase B1 & SRR (ongoing) will be delivered to Japan by Dec 2011.
- Spain is involved in the JEM-EUSO Executive Committee since Oct2011.
- Just approved for the first time a coordinated MICINN project for Phase B2 (BBM & PDR) to be delivered to Japan by Dec 2012.
- 4 research centers: UAH, INTA, UC3M & IAC.
- 4 Space companies: SENER, LIDAX, SENSIA & ARQUIMEA

mid-IR Camera

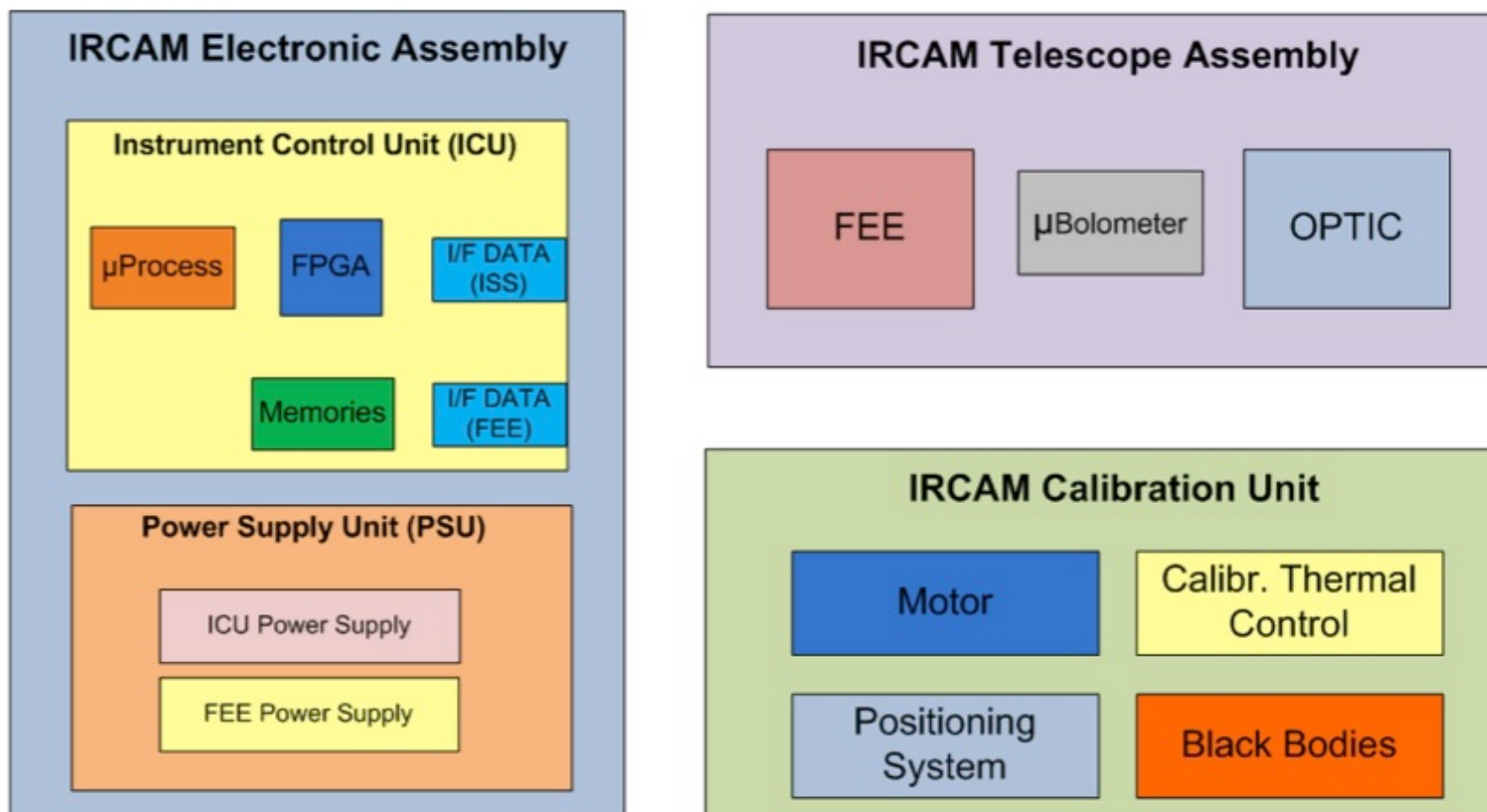
Item	Value	Reason
Wavelength	10 – 13 μm	Atmospheric transmission, S/N
FOV	> 60°	Same FOV as JEM-EUSO
Spatial Resolution	0.25°	1.8 kmx2.2km/pix @ nadir
Observation Temperature Range	200 – 320 K	Cloud top temperature in Troposphere
Absolute Temperature Resolution	< 3 K	Altitude resolution < 500m
IR Sensor	Uncooled Microbolometer Array	Mass, Power Pixel size 340 x 240
Exposure Time	33 ms	ISS motion within ½ -pix of IR camera
Observation Interval	30 s	ISS motion of JEM-EUSO ½ FOV

Detector: Si- α & Ge window

- The detector in the actual baseline is the uncooled μ Bolometer of the ULIS French company (640x480 pixels). The working operative temperature is around 30°C and it needs of a dedicate TEC to guarantee on the FPA a very stable temperature.



JEM-EUSO IRCAM Block Diagram

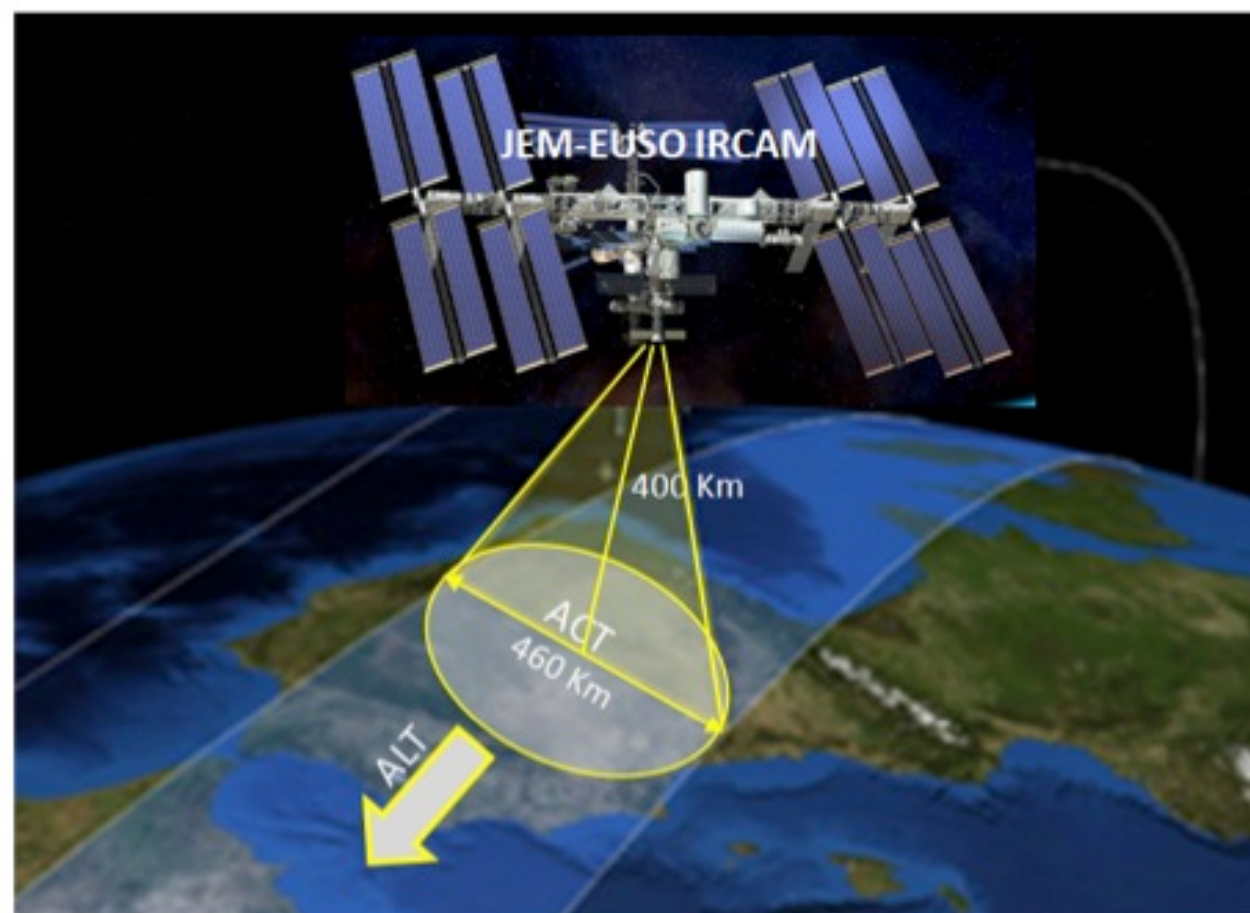


JEM-EUSO IRCAM MISSION PARAMETERS

Acquisition Type: "IMAGING" Detector (640x480 pixels)

ALT = Along Track

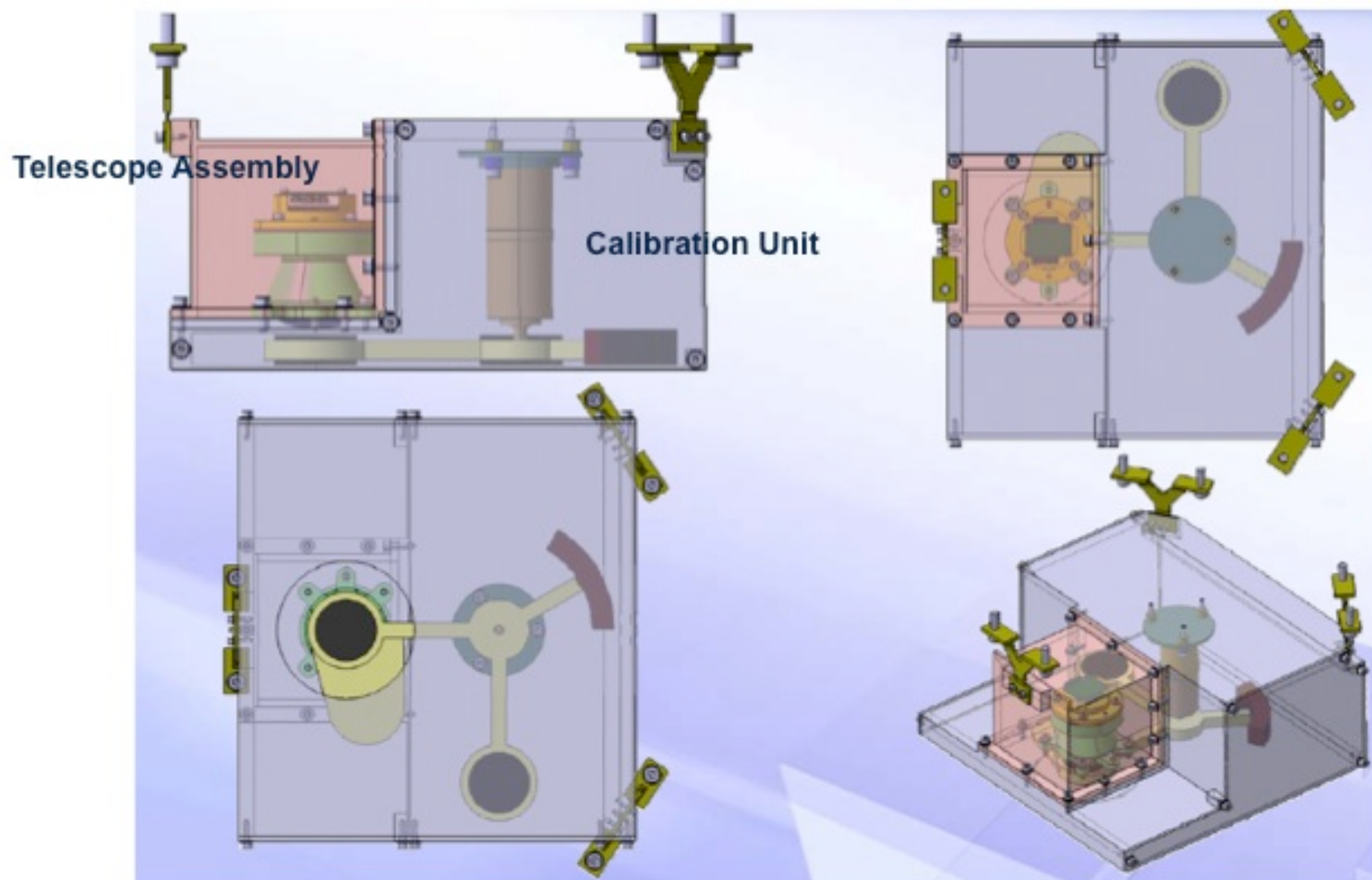
ACT = Across Track



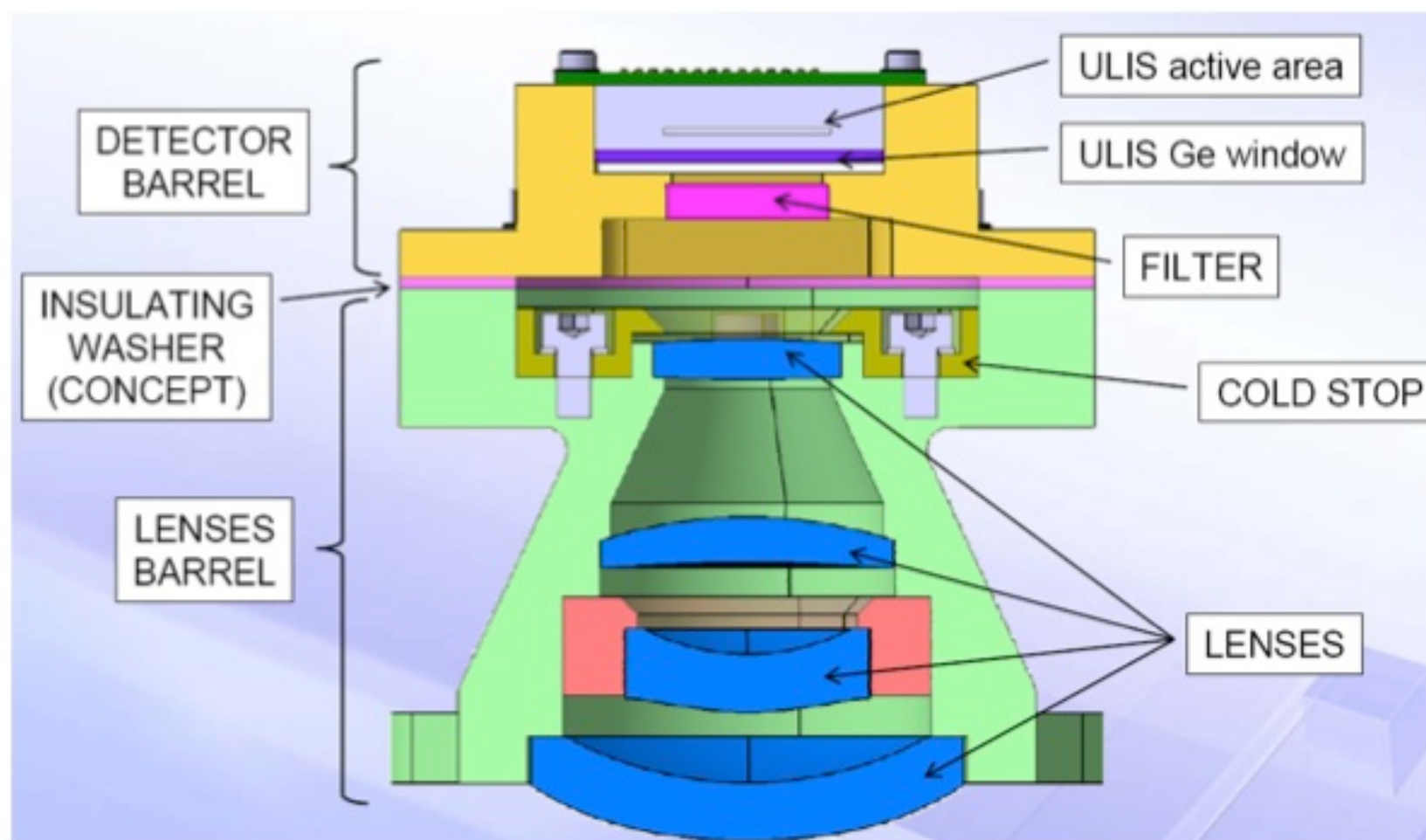
ISS Height (Km)	400,00
FoV (Deg)	60,00
ISS Speed (Km/s)	7,20
Time Snapshot (s)	30,00
Pixels ACT	640,00
Pixels ALT	480,00

Swath (Km)	461,88
Drift (Km)	216,00
Pix Res (Km)	0,7217
IFoV	0,1034

JEM-EUSO IRCAM Telescope Assembly and Calibration Unit

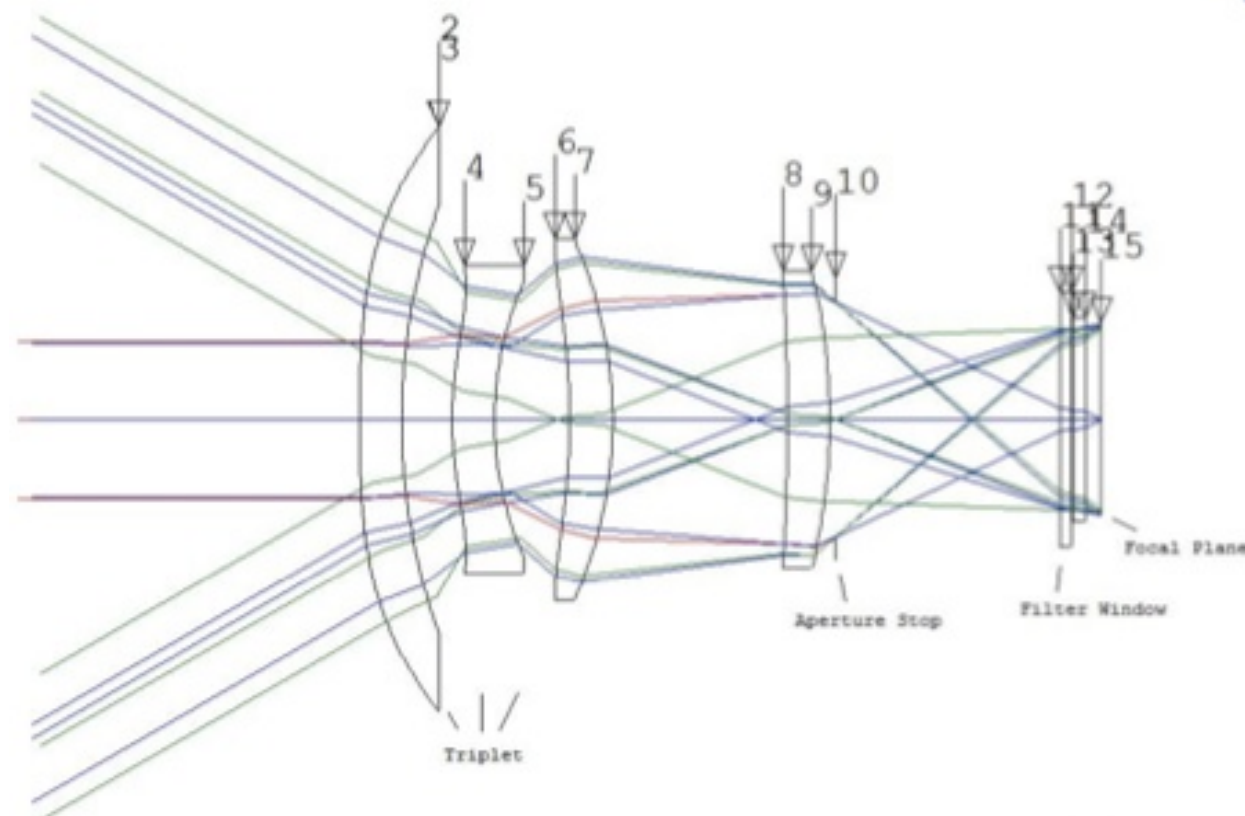
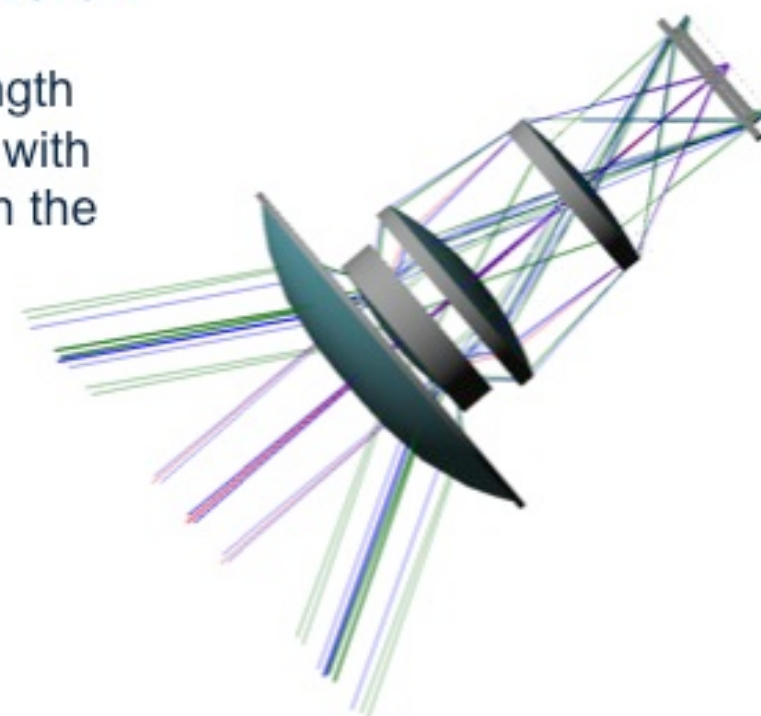


JEM-EUSO IRCAM TELESCOPE ASSEMBLY

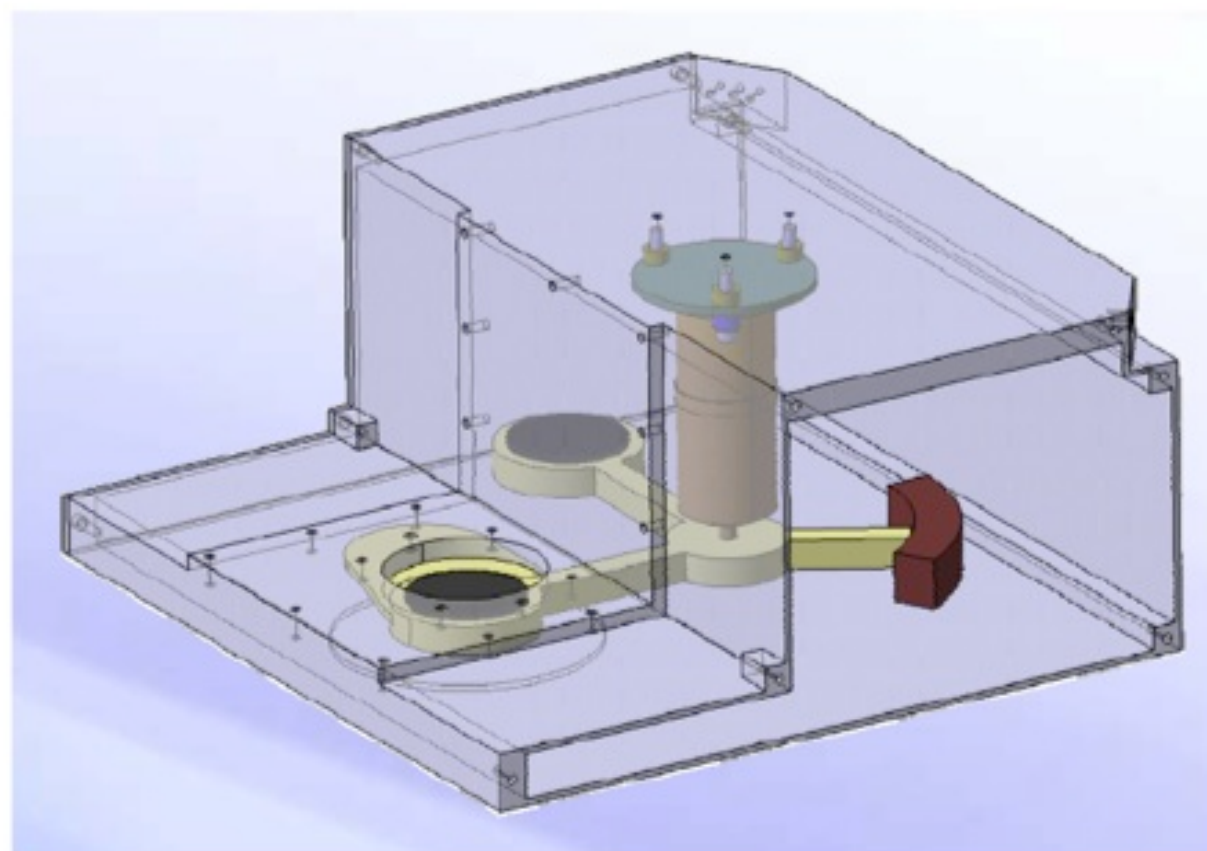


JEM-EUSO IRCAM OPTICAL DESIGN

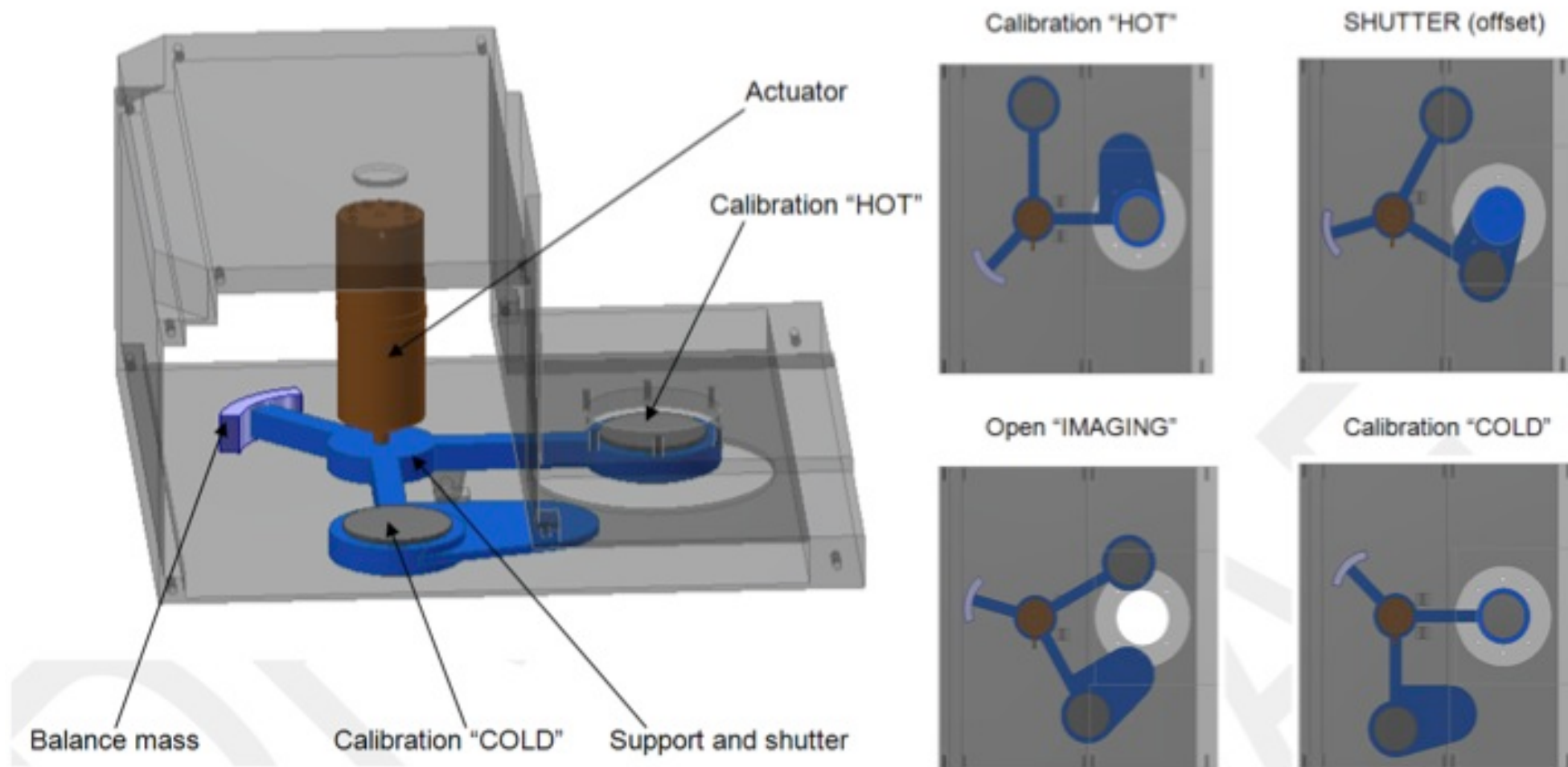
The system, consisting of four lenses, has a focal length of 15.20 mm, and f-number of 1.17, and it shall work with a total field of view of 60°. The overall length between the first surface to the focal plane is 60.00 mm.



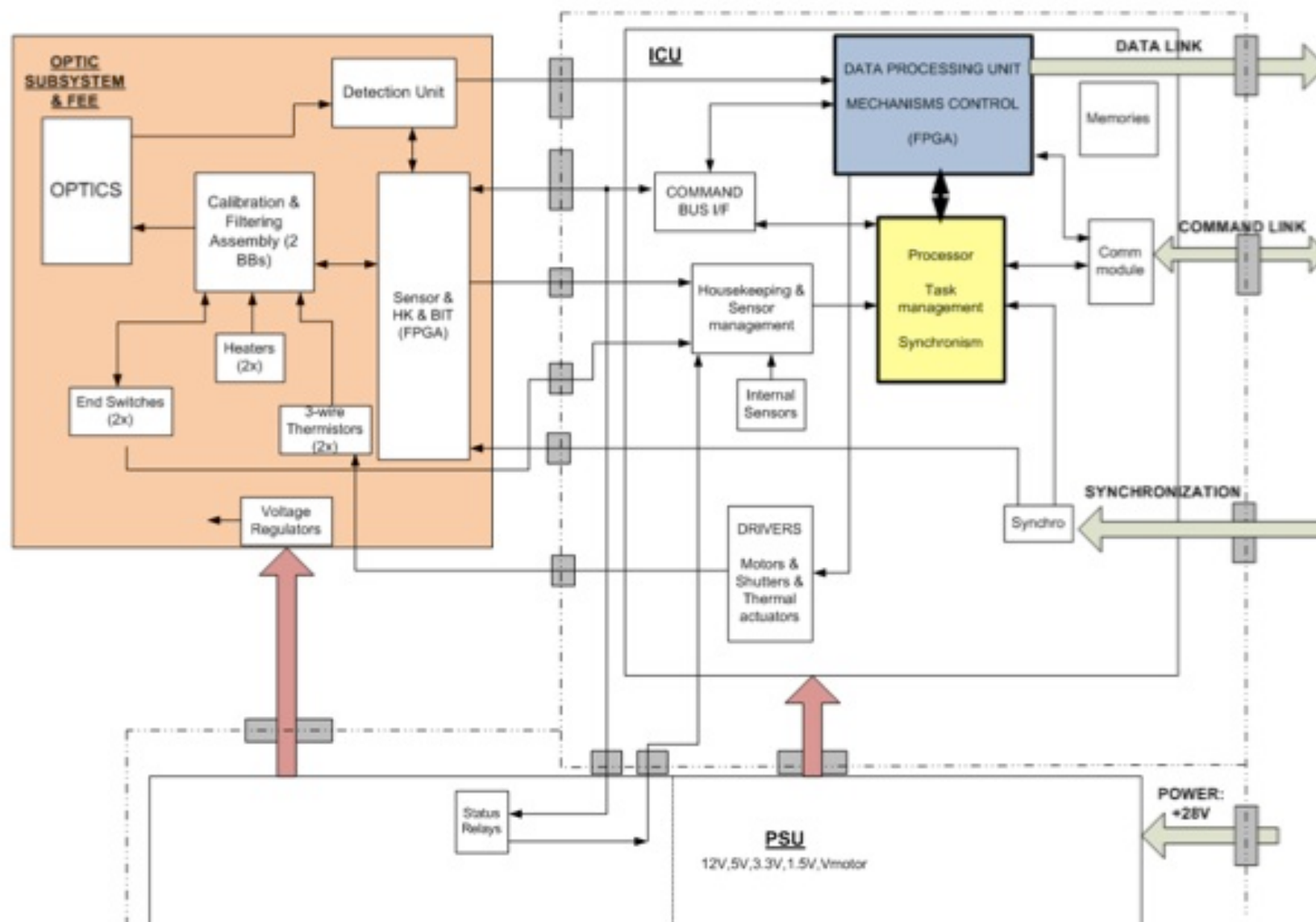
JEM-EUSO IRCAM CALIBRATION UNIT



JEM-EUSO IRCAM CALIBRATION UNIT



JEM-EUSO IRCAM ELECTRONIC ASSEMBLY



JEM-EUSO Space Mission: towards the first EHECR @ ZeV scale from Space...

