JEM-EUSO Extreme Universe Space Observatory onboard Japan Experiment Module

KEK HEAP09

2009/11/11@Tsukuba

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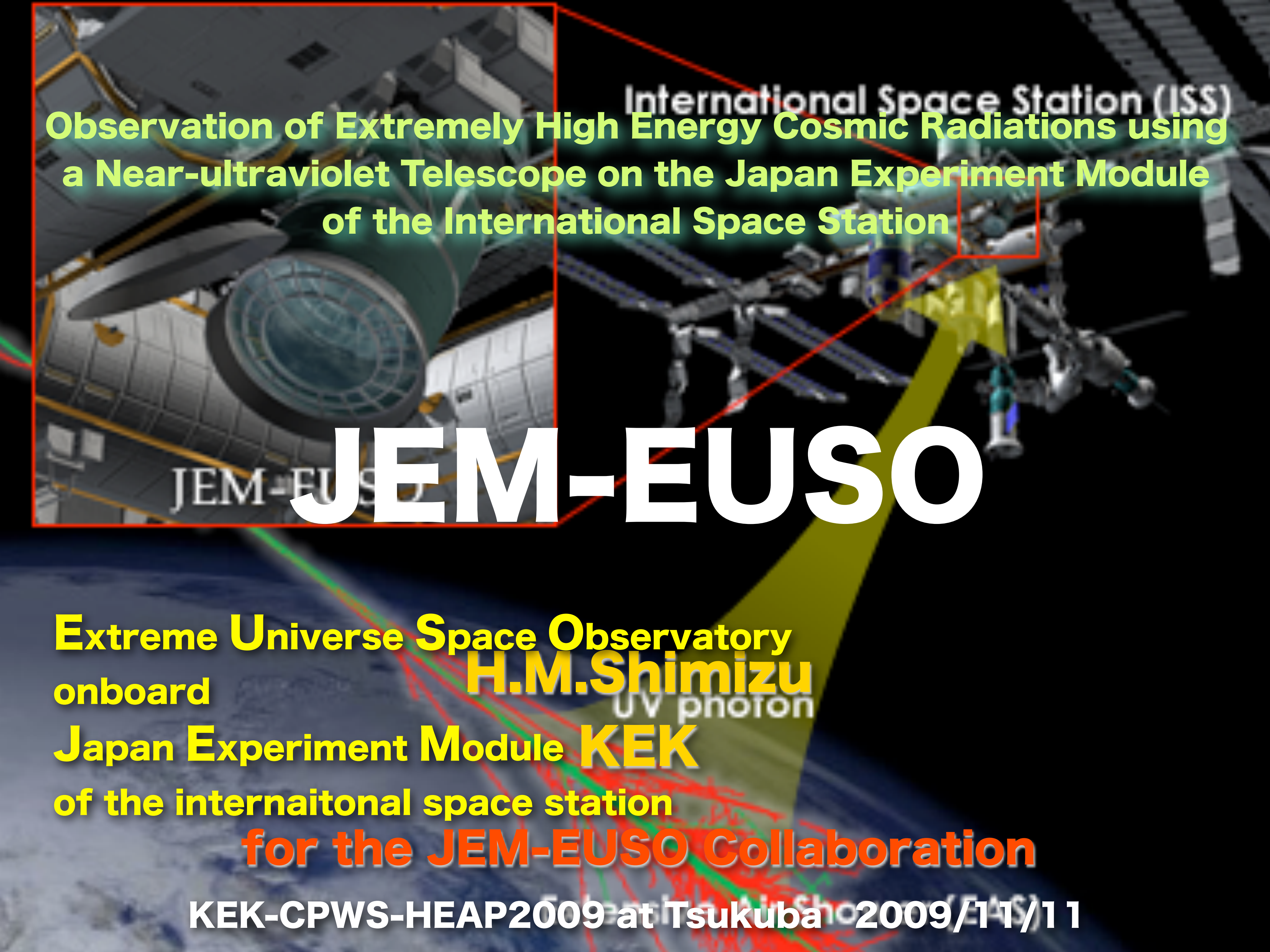


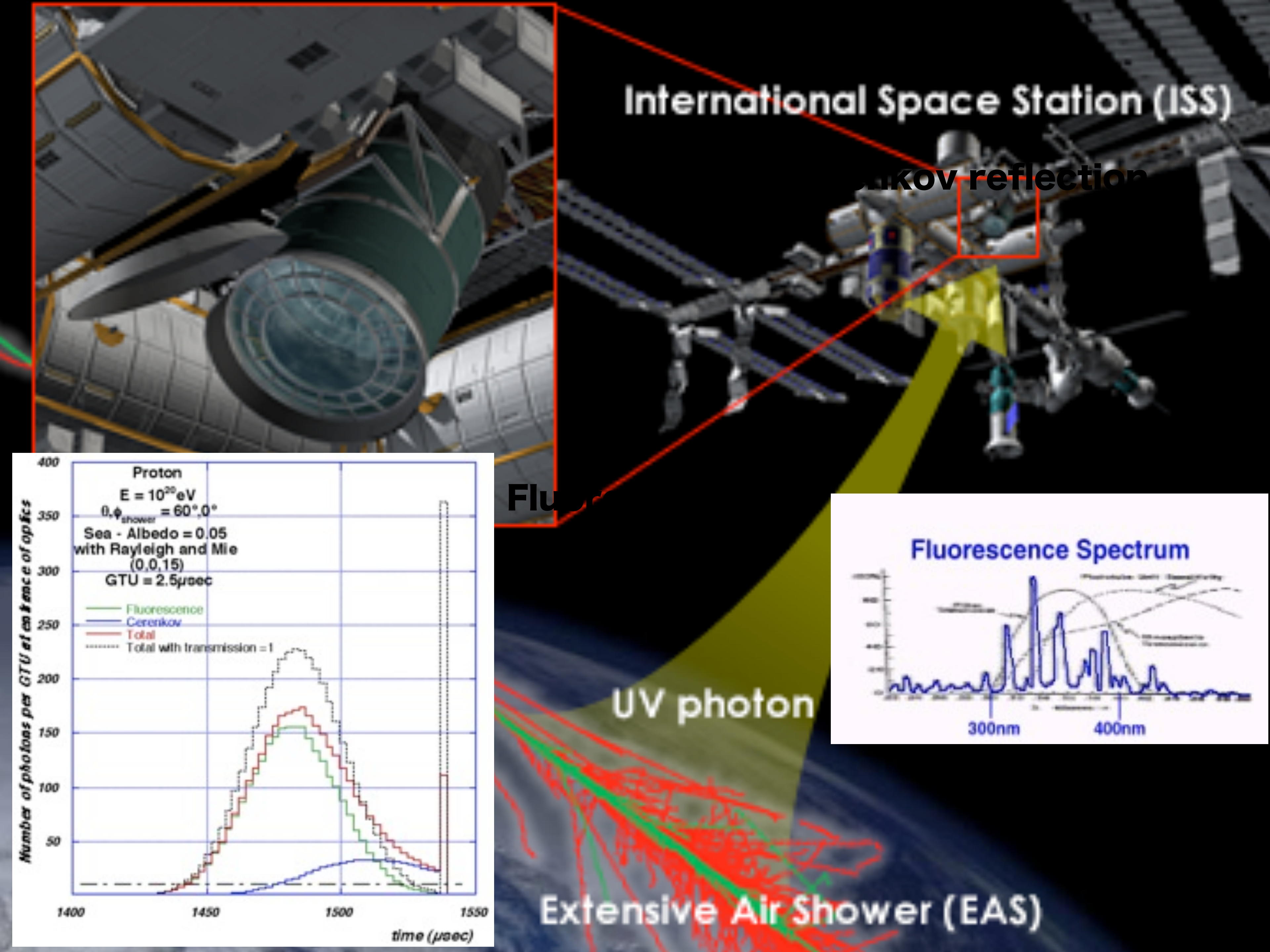
Observation of Extremely High Energy Cosmic Radiations using a Near-ultraviolet Telescope on the Japan Experiment Module of the International Space Station

JEM-EUSO

Extreme Universe Space Observatory
onboard
Japan Experiment Module
of the internaitonal space station

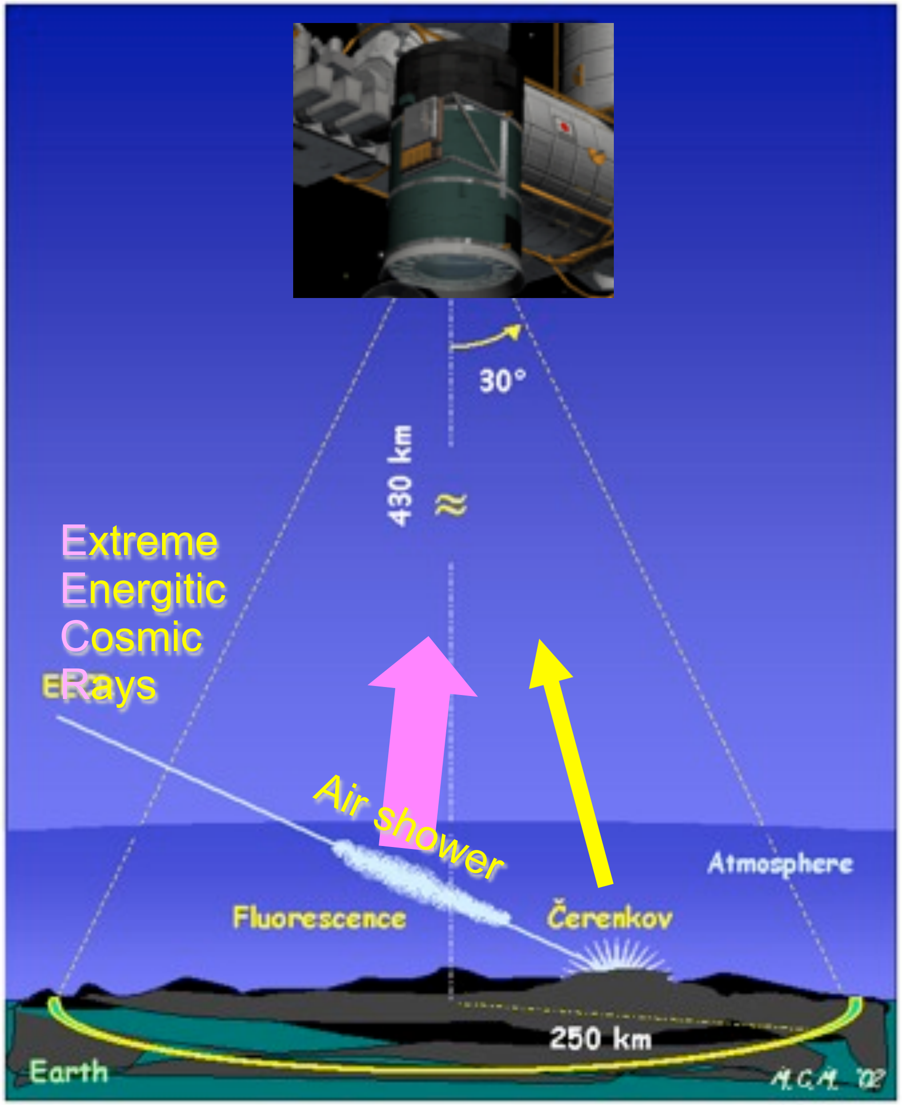
H.M.Shimizu
KEK
for the JEM-EUSO Collaboration

KEK-CPWS-HEAP2009 at Tsukuba 2009/11/11



International Space Station (ISS)
kov reflection
Flu
Proton
E = 10^20 eV
θ,φ_shower = 60°,0°
Sea - Albedo = 0.05
with Rayleigh and Mie
(0,0,15)
GTU = 2.5μsec
Fluorescence
Cerenkov
Total
Total with transmission = 1
Number of photons per GTU at entrance of optics
400
350
300
250
200
150
100
50
1400
1450
1500
1550
time (μsec)
Fluorescence Spectrum
300nm
400nm
UV photon
Extensive Air Shower (EAS)

JEM-EUSO Observational Principle



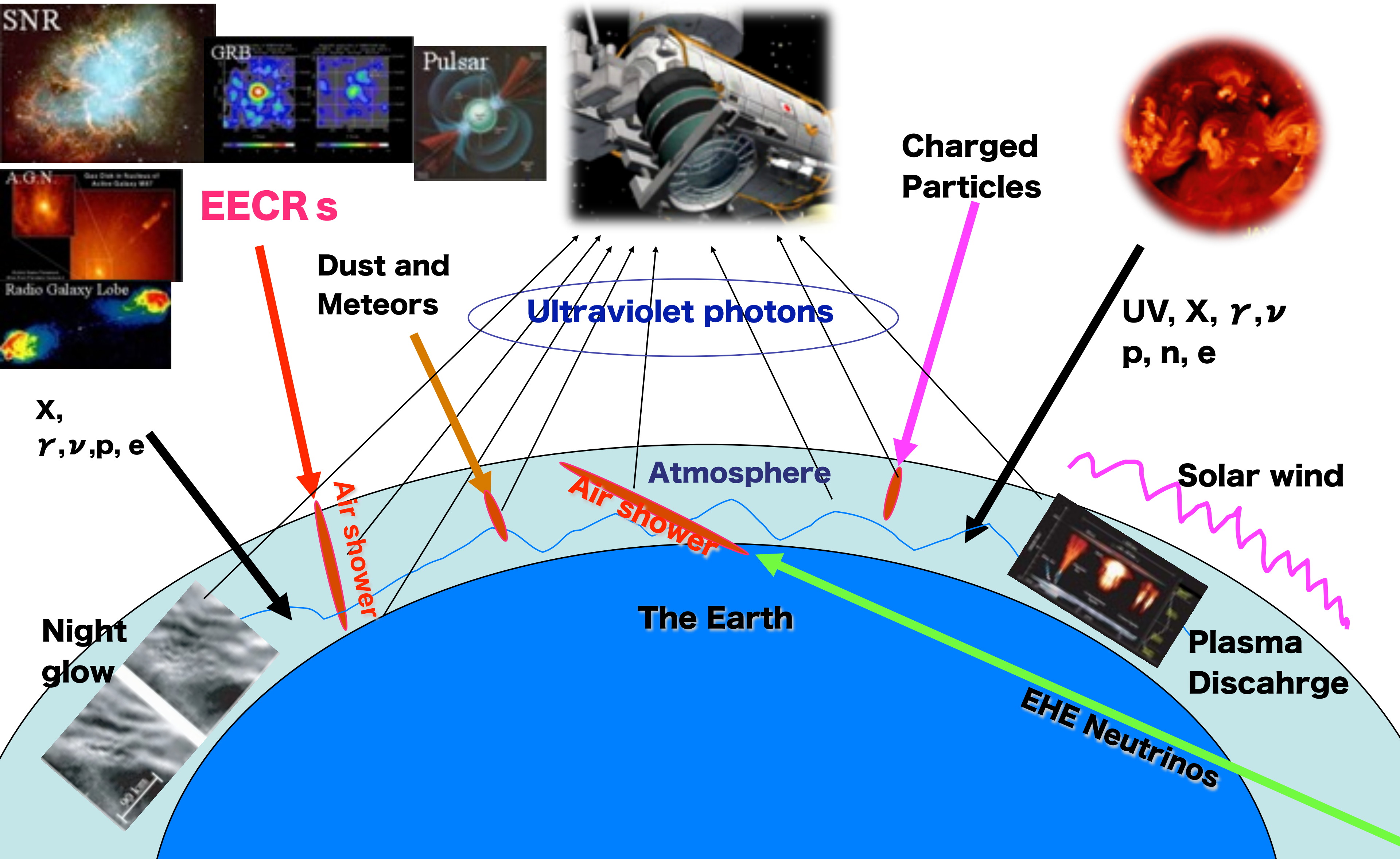
JEM-EUSO is a new type of observatory on board the International Space Station (ISS), which observes transient luminous phenomena occurring in the earth's atmosphere.

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

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

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

JEM-EUSO is the Astronomical Earth Observatory



Science Objectives

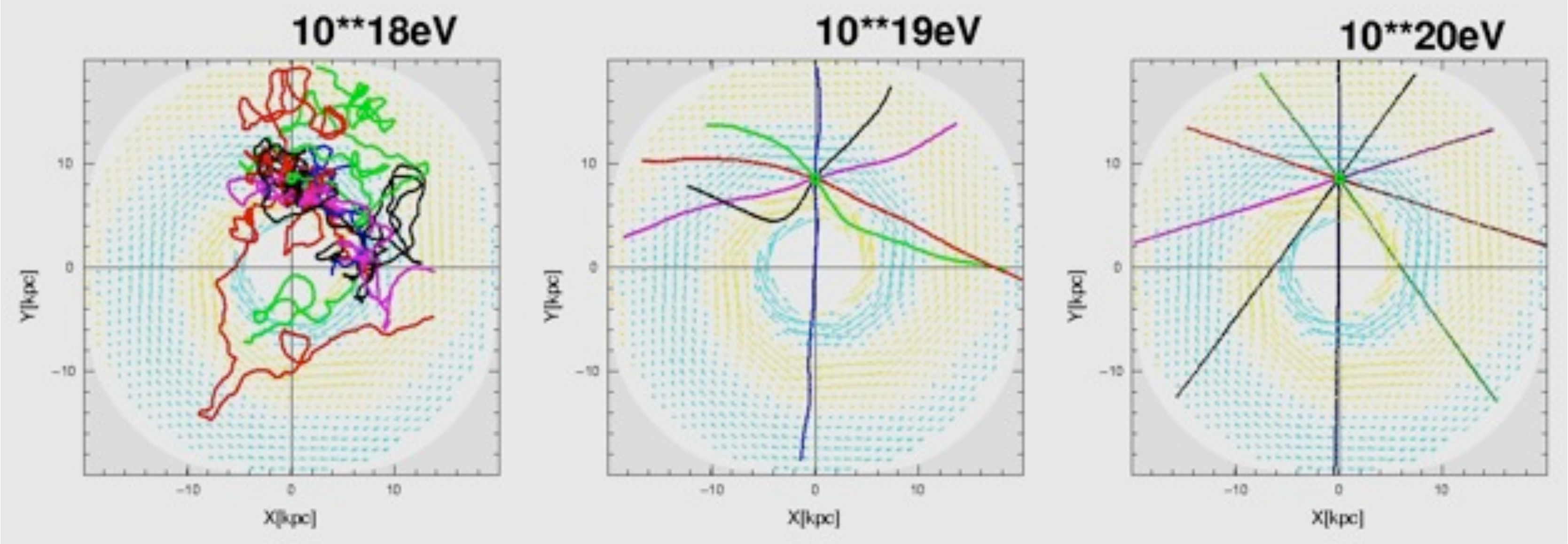
- **Primary Objective**

  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

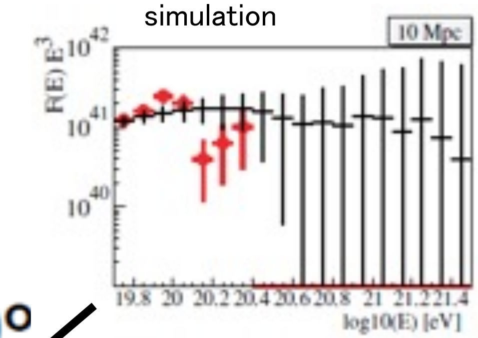
10^{20}eV proton can be traced back to its source.

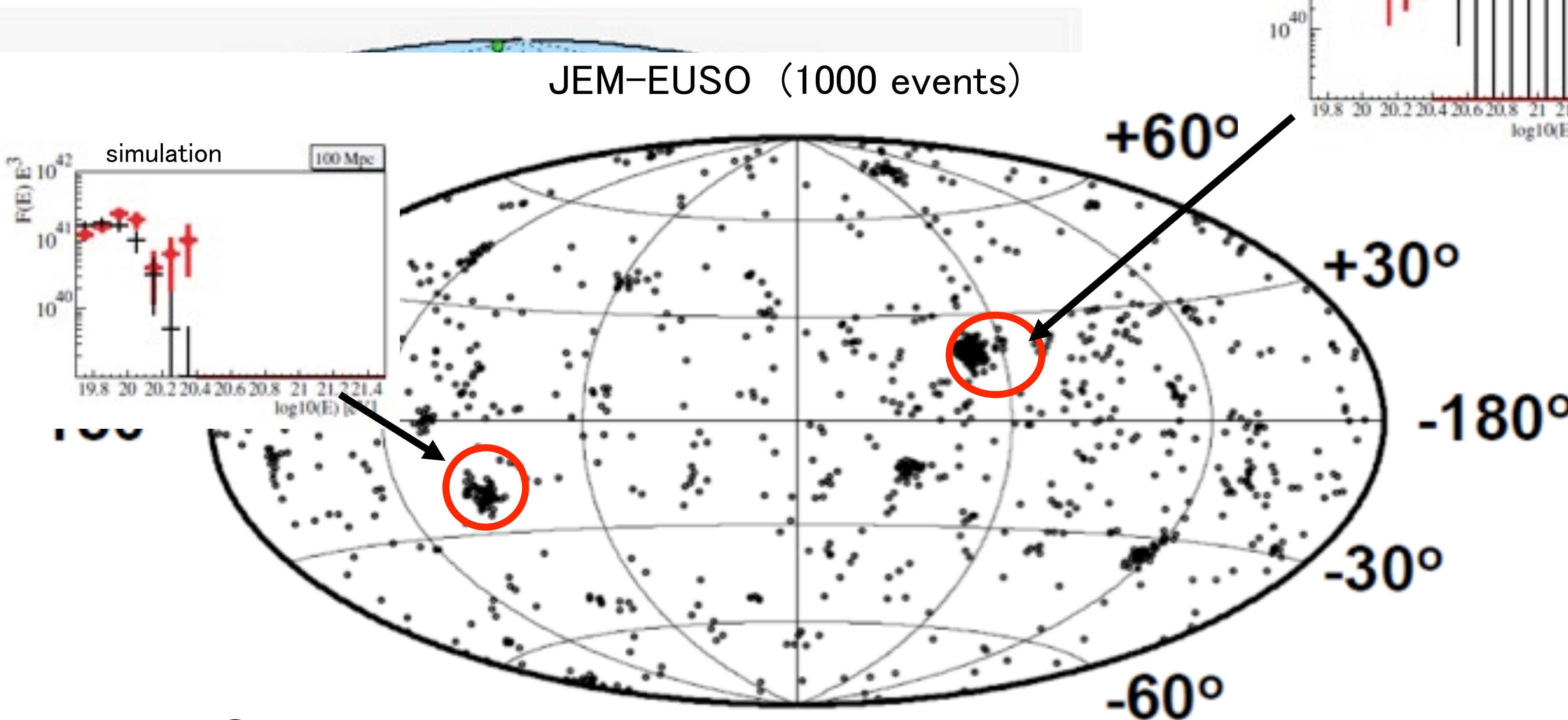


Proton Propagation in Galactic Magnetic Field

Identification of source objects is possible from the arrival direction distribution → Particle Astronomy

Arrival Map

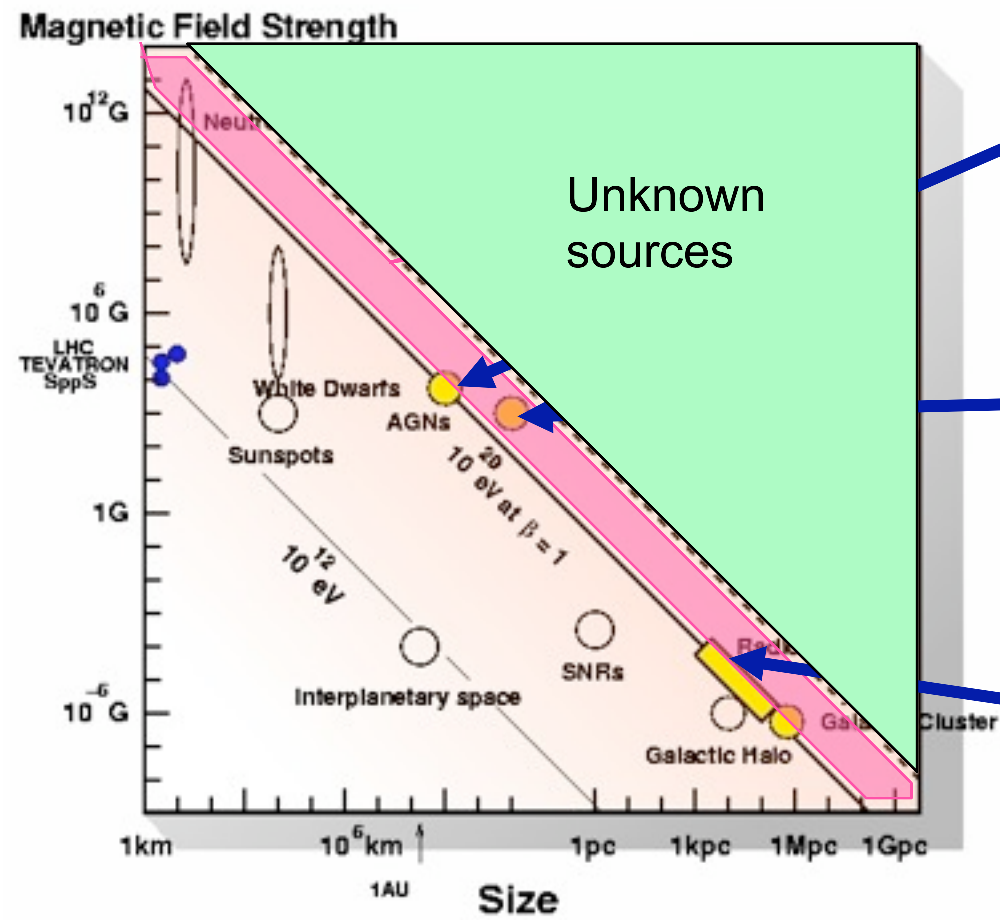




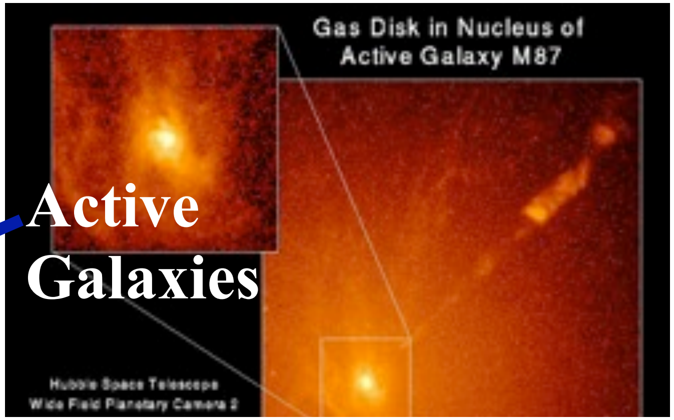
- Identify the sources
- Confirmation of GZK
- Clarify acceleration mechanism

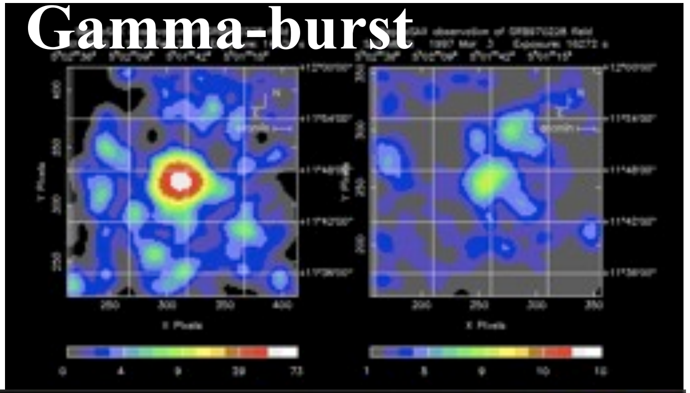
Possible Sources

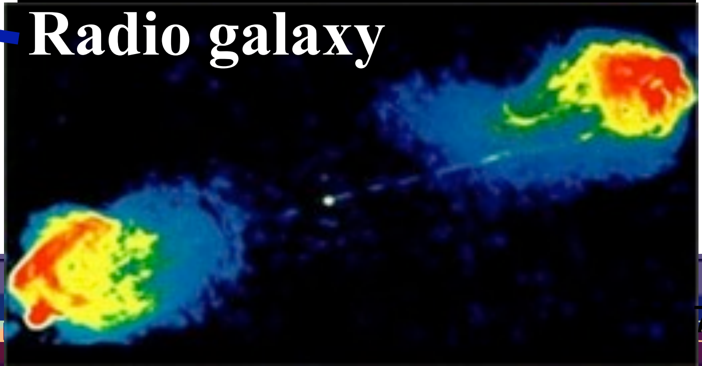
New mechanism of acceleration



Blackhole related objects

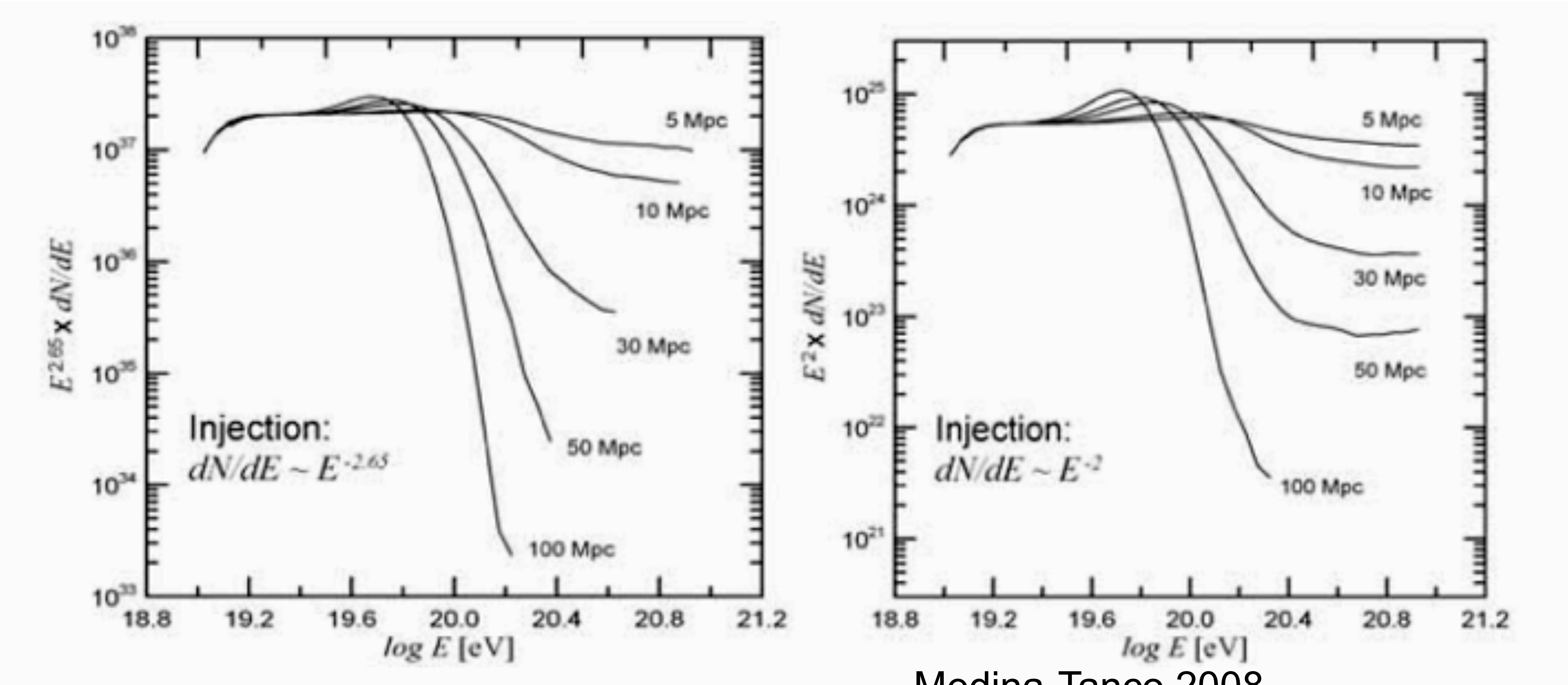






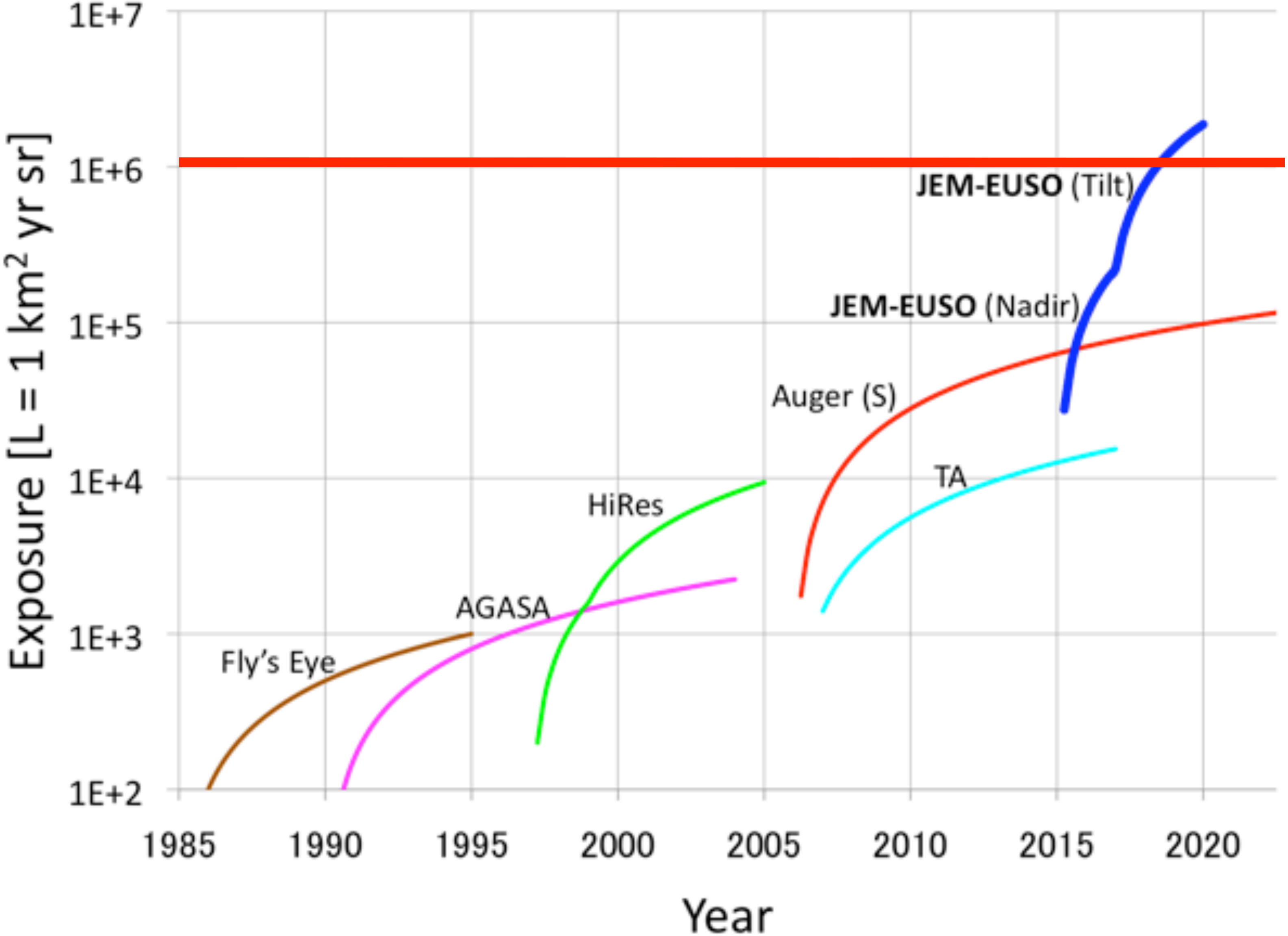
EECR Energy Spectra for Various Source Distance

The energy spectra at around 10^{20} eV differs for different source distances affected by the GZK process.



Medina-Tanco 2008

Exposure Evolution



JEM-EUSO Scientific Requirements (Success Criteria)

statistics

$\geq$1000 events for $E \geq 7\times10^{19}$eV

full success

$\geq$500 events for $E \geq 7\times10^{19}$eV

minimum success

to conclude the origin from the observed event distribution

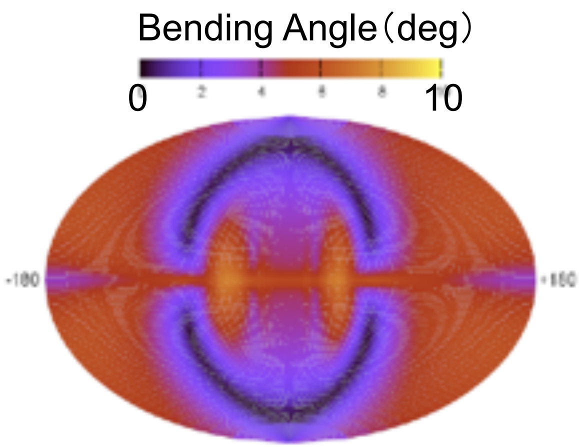
accuracy

arrival direction		$\leq$ 2.5 deg
primary energy		$\leq$ 30%
X_{max}	atmospheric depth at shower maximum	$\leq$ 120 g cm^{-2}

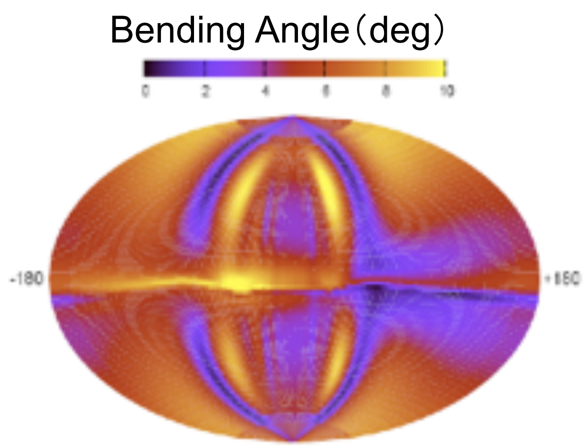
for primary particle identification (hadron, photon, neutrino)

Estimation of the Structure of the Galactic Magnetic Field

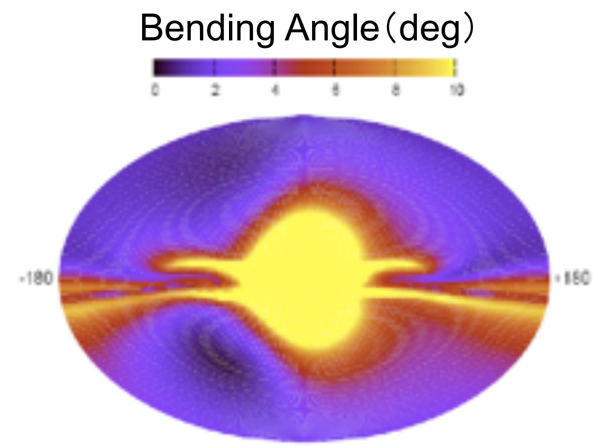
Map of bending angle of cosmic rays with the rigidity of 4×10^{19} eV for different models of the galactic magnetic fields.



Tinyakov and Tkachev (BBS-A)

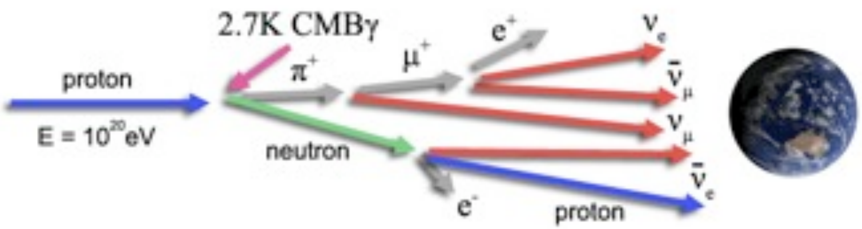


Harari, Mollerach and Roulet(BBS-S)

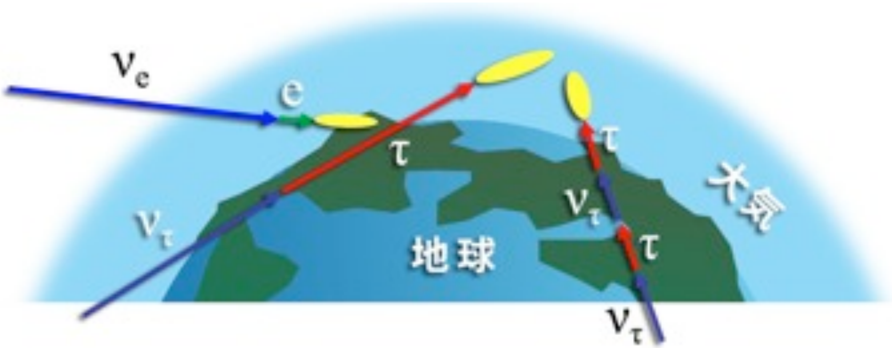


Prouza and Smida(BBS-S)

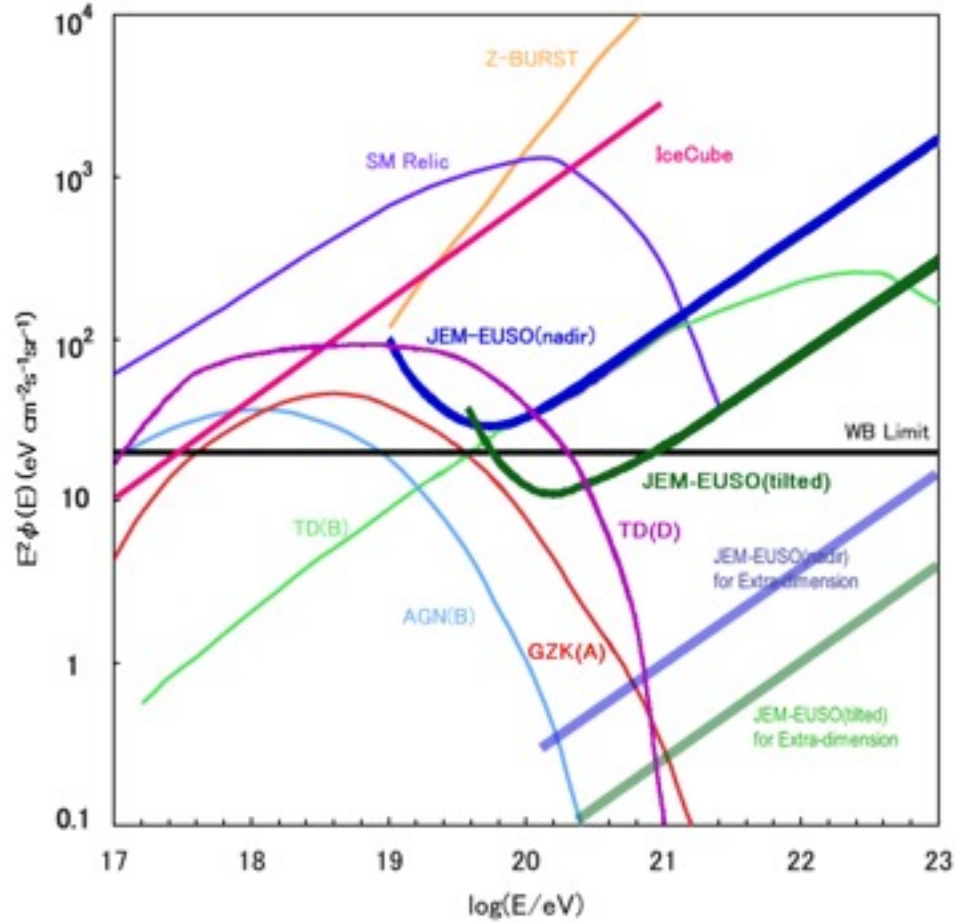
Extreme Energitic Cosmic Neutrinos



Neurino production by the GZK process

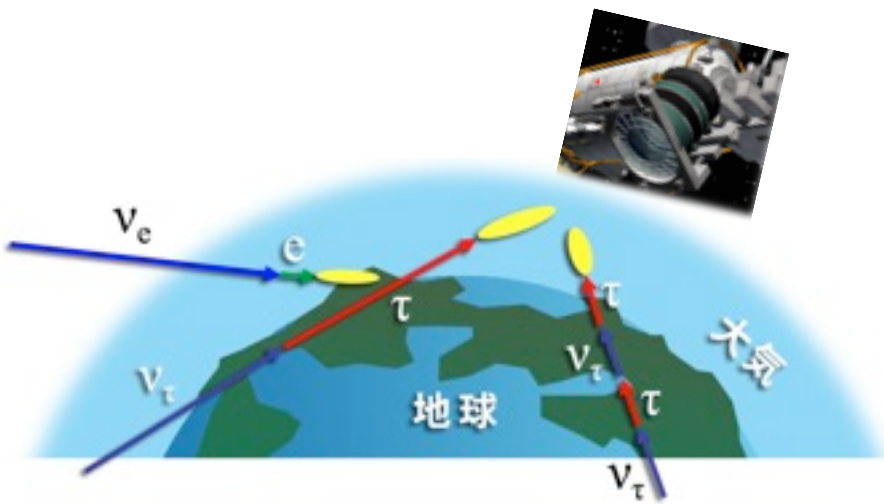


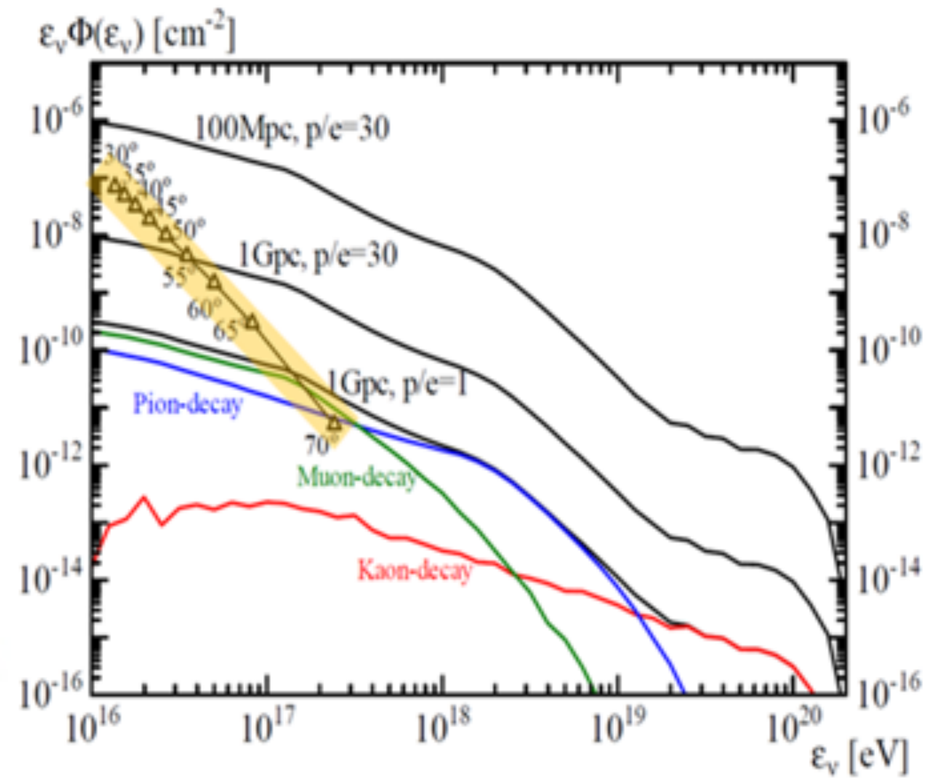
Air showers initiated by different kind of neutrinos



Neutrino fuxes for various models and detection capability of JEM-EUSO

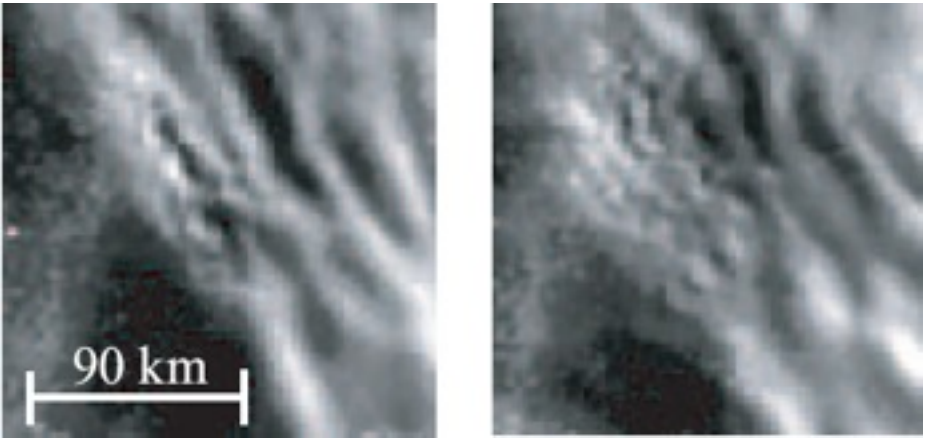
Detection of Extreme Energitic Neutrinos from Gamma-ray Bursts



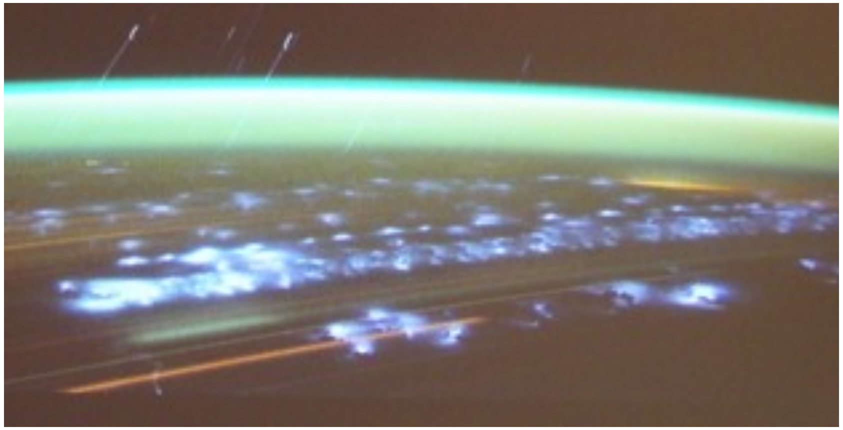


ν_τ with energy 10^{16}-10^{17} eV from γ burst source interact with earth at several 100m - several 1km underground and make upward showers. JEM-EUSO may observe such events by the tilted observational mode.

Atmospheric Luminous Phenomena

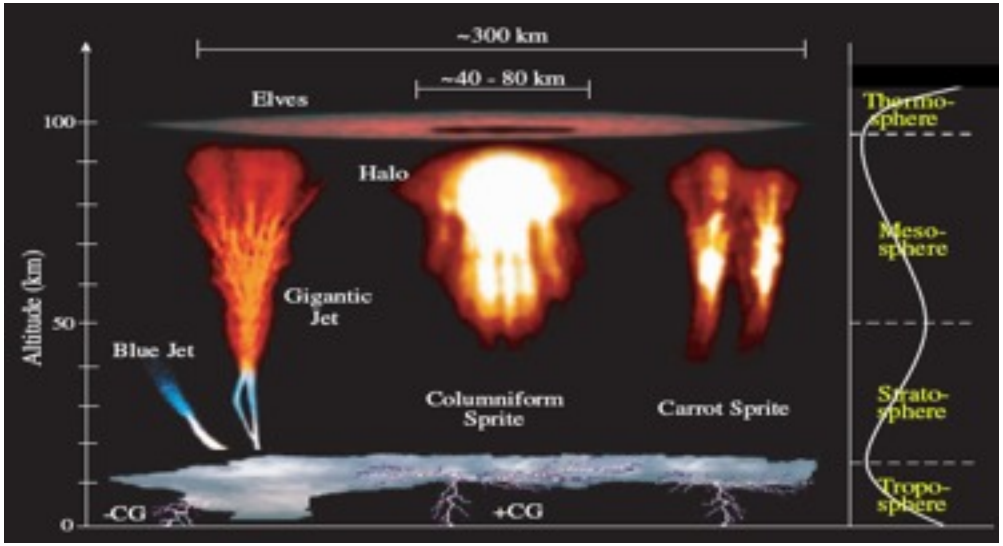


OH airglow observed from ground



Lightning observed from ISS

Leonid meteor swarm in 2001
taken by Hivison camera

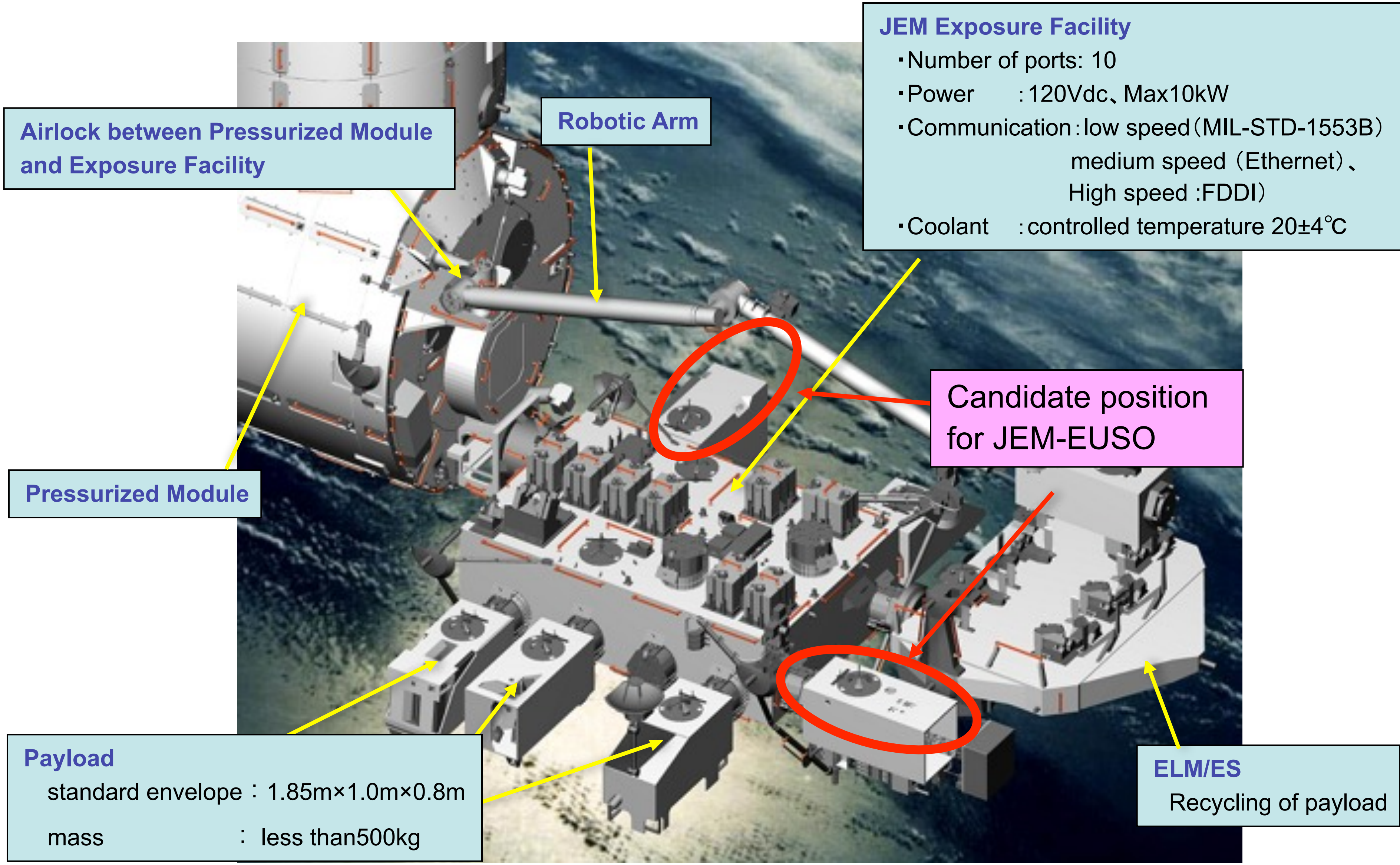


Various transient airglows

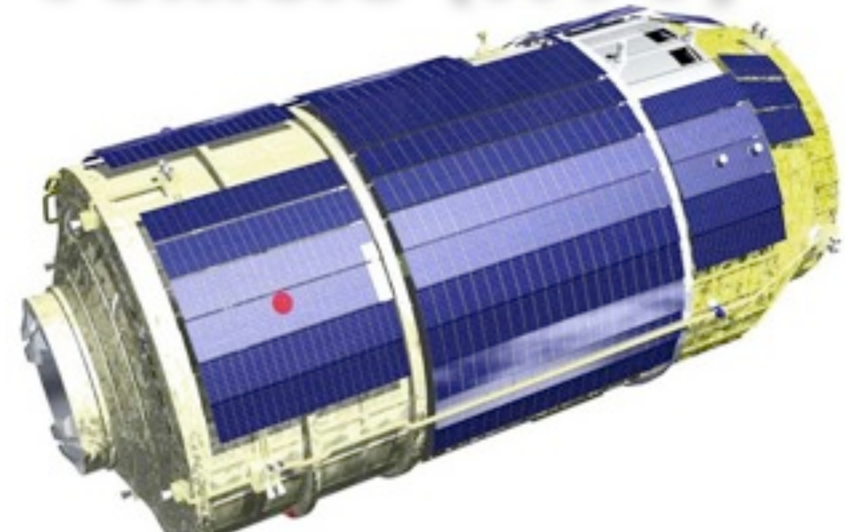
Japanese Experiment Module "Kibo" : July 2009

S127E011186

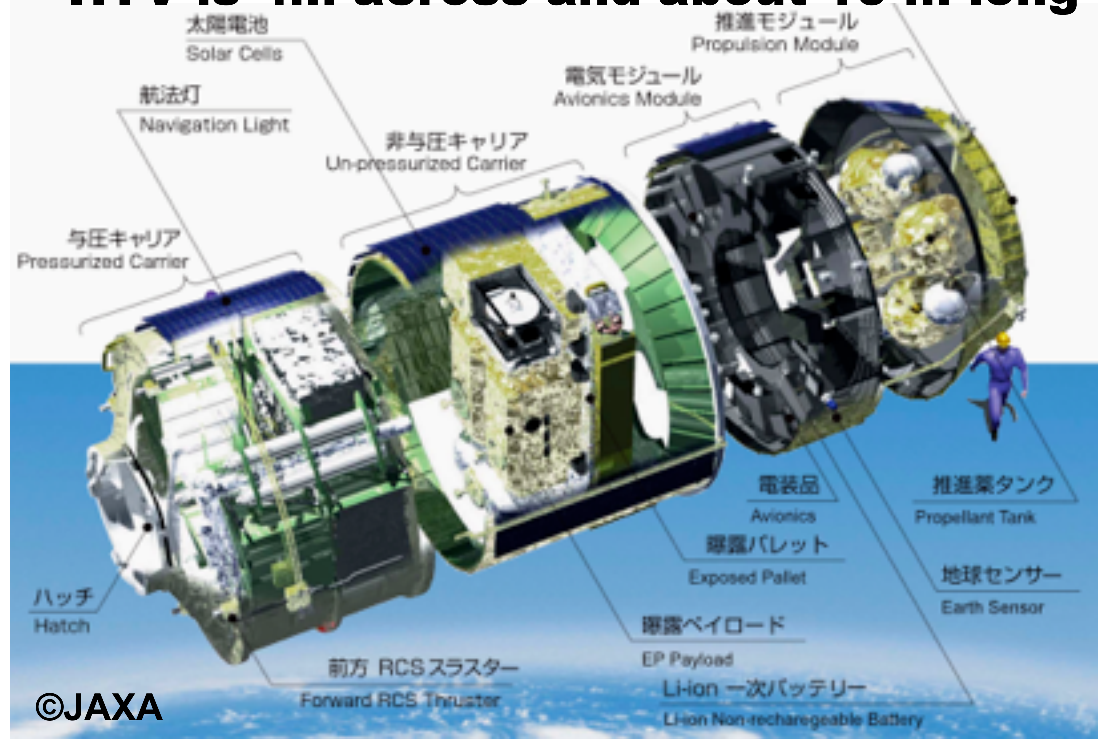
Outline of JEM Exposure Facility

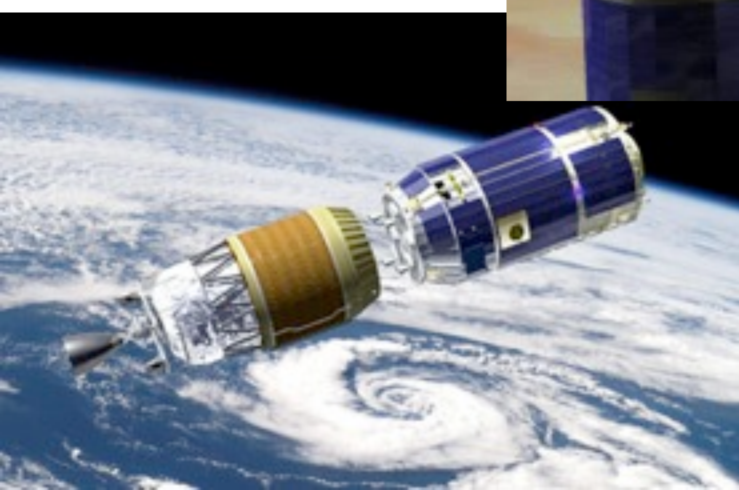


H-II Transfer Vehicle (HTV)



HTV is 4m across and about 10 m long



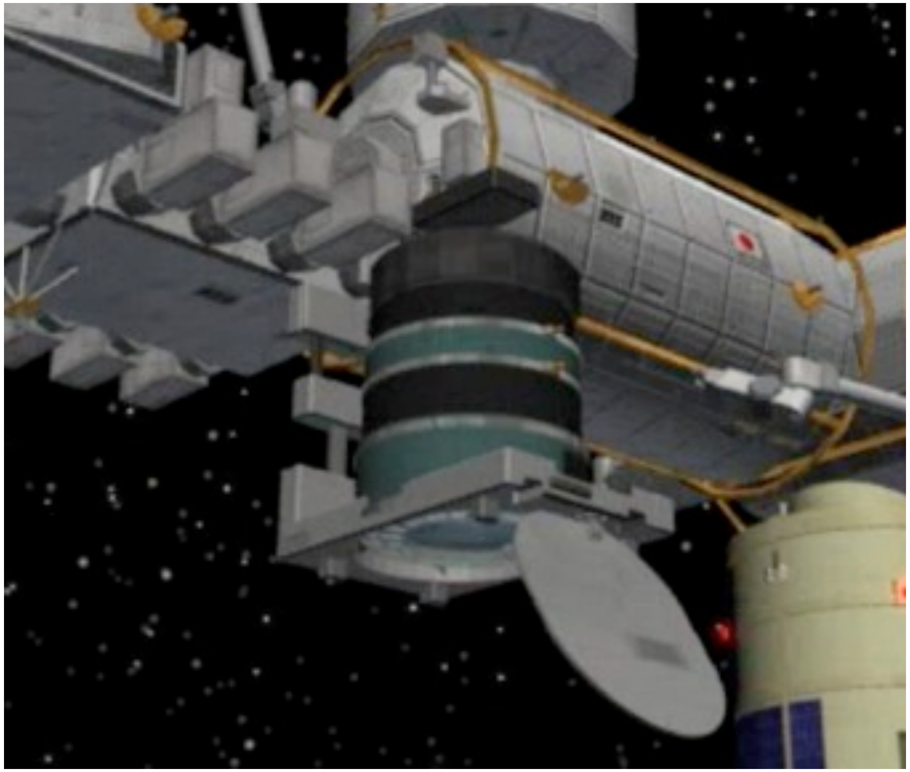


Successful Launch of HTV

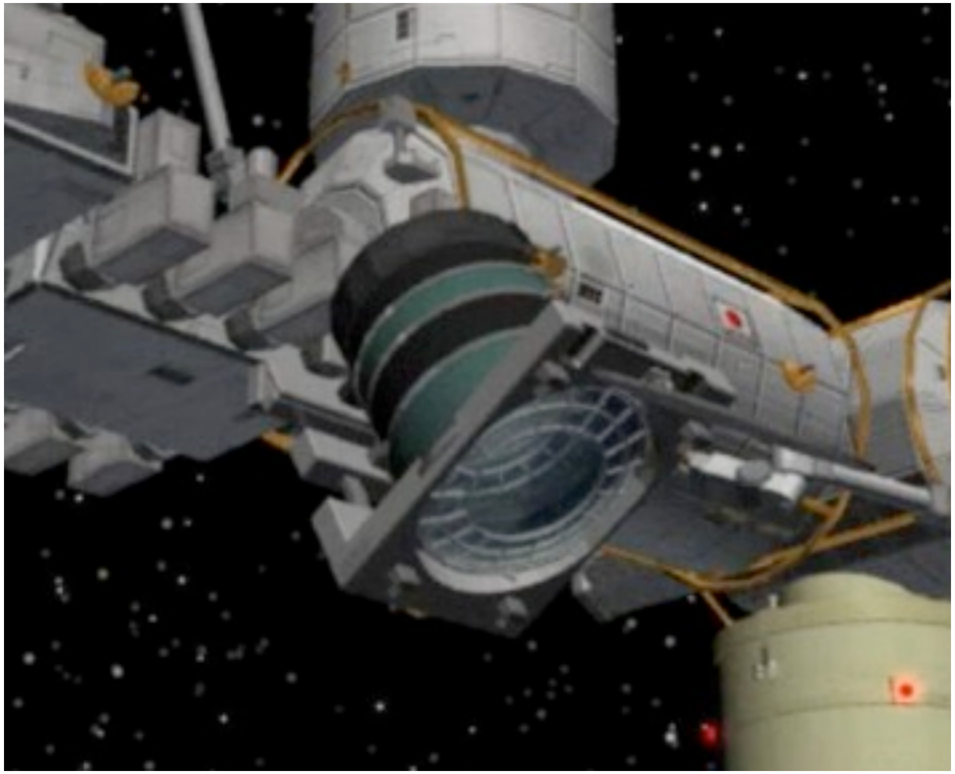
September 11, 2009

Observation mode of JEM-EUSO

To be launched in 2015 and attached to ISS JEM/EF



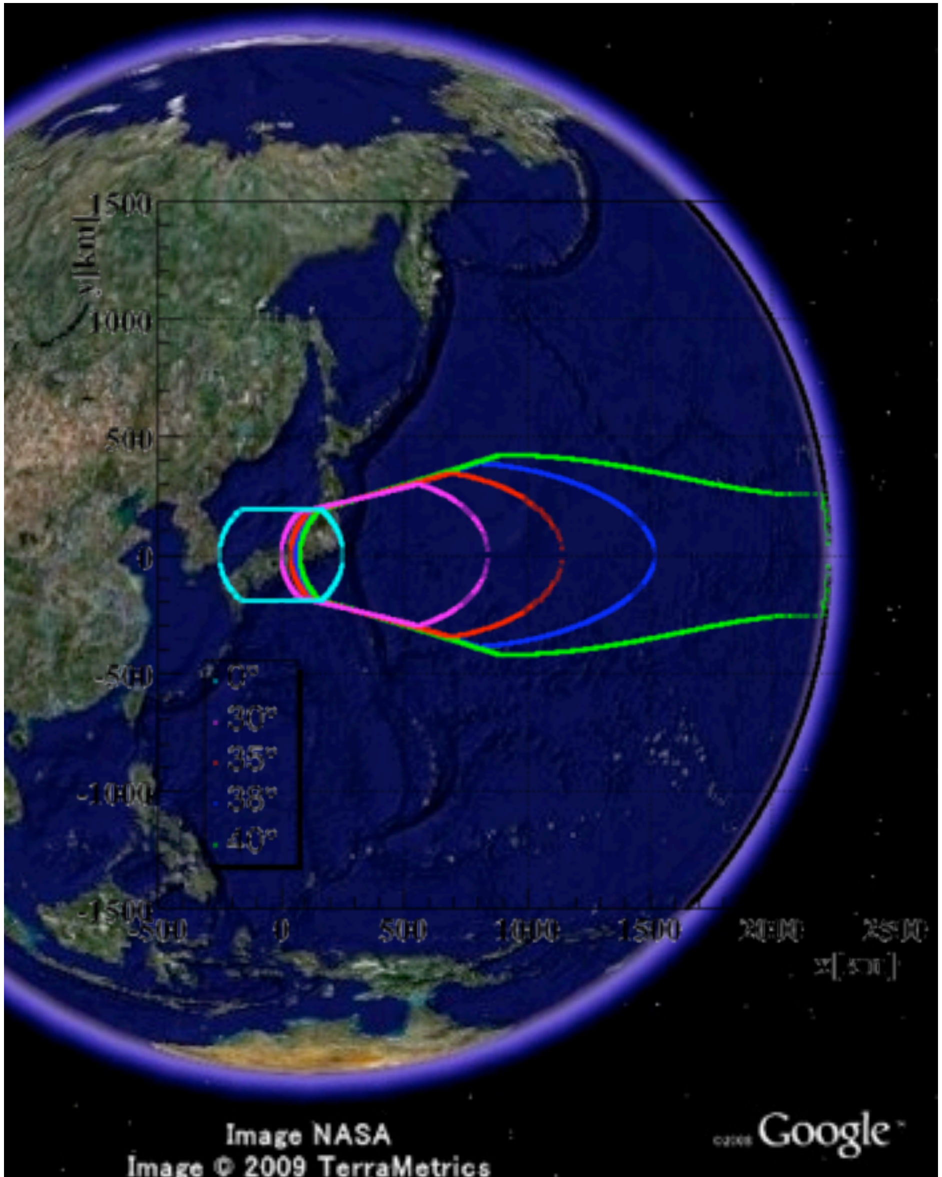
Nadir Mode

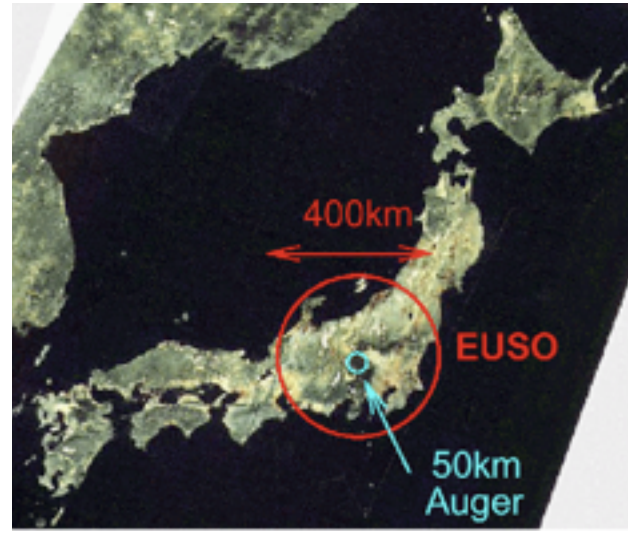


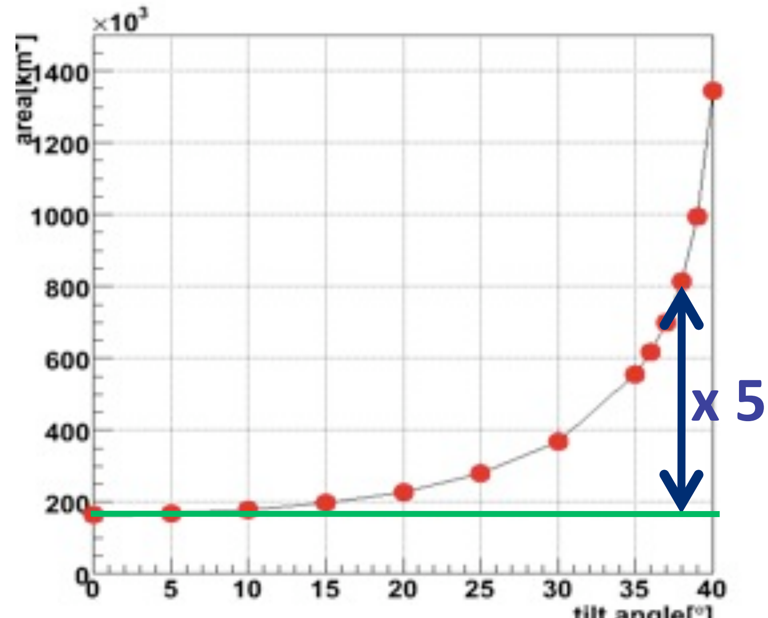
Tilted Mode

Larger exposure can be obtained

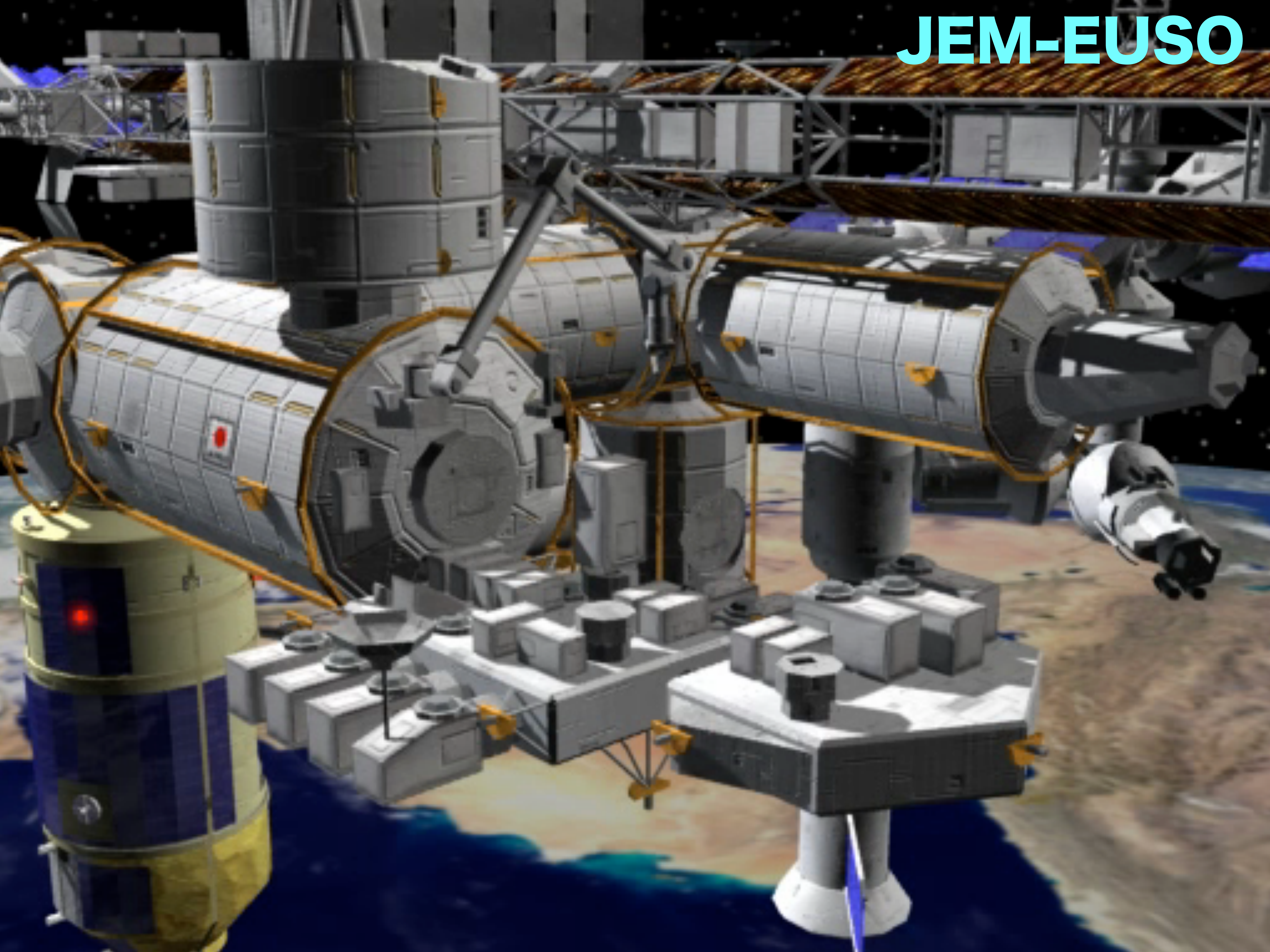
Field of View







JEM-EUSO



Mission Parameters

Launch	2015
Operation Period	3 years (+2 years)
Launch Vehicle	H2B
Transpotation to ISS	un-pressurized carrir of HTV (H2 Transfer Vehicle)
Site to Attach	Japan Experiment Module / Exposure Facility #2
Height of the Orbit	~400km
Inclination of the Orbit	51.64°
Mass	1983 kg
Power	926W (operation) 352W (non-operation)
Data Trasfer Rate	285 kpbs

JEM-EUSO Scientific Requirements (Success Criteria)

statistics

$\geq$1000 events for $E \geq 7\times10^{19}$eV

full success

$\geq$500 events for $E \geq 7\times10^{19}$eV

minimum success

to conclude the origin from the observed event distribution

accuracy

arrival direction		$\leq$ 2.5 deg
primary energy		$\leq$ 30%
X_{max}	atmospheric depth at shower maximum	$\leq$ 120 g cm^{-2}

for primary particle identification (hadron, photon, neutrino)

ISS Orbit

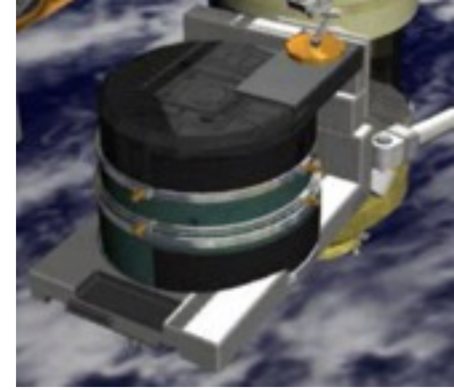
http://www.nlsa.com/

Inclination: 51.6°
Height: ~400km

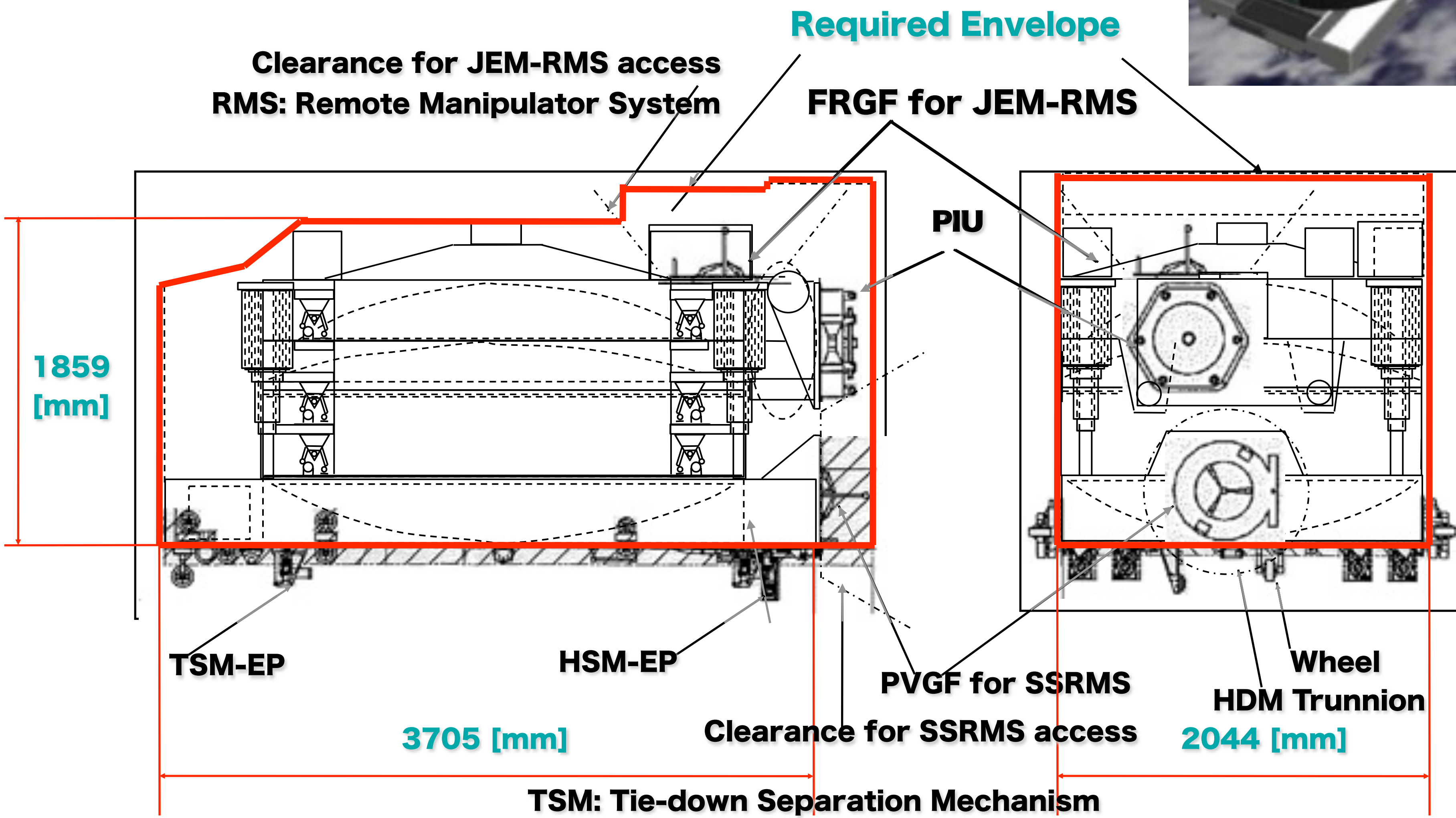
JEM-EUSO can observe the arrival direction of EECR very uniformly owing to the nature of the ISS orbit.

Full-Sky Coverage

JEM-EUSO Launch Configuration

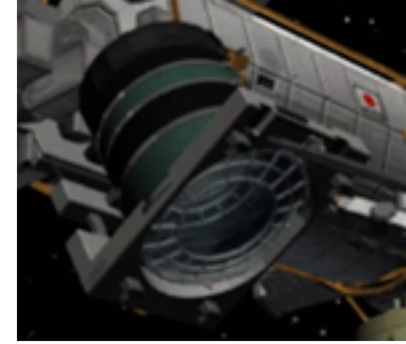


JEM-EUSO telescope will be squeezed at launch.

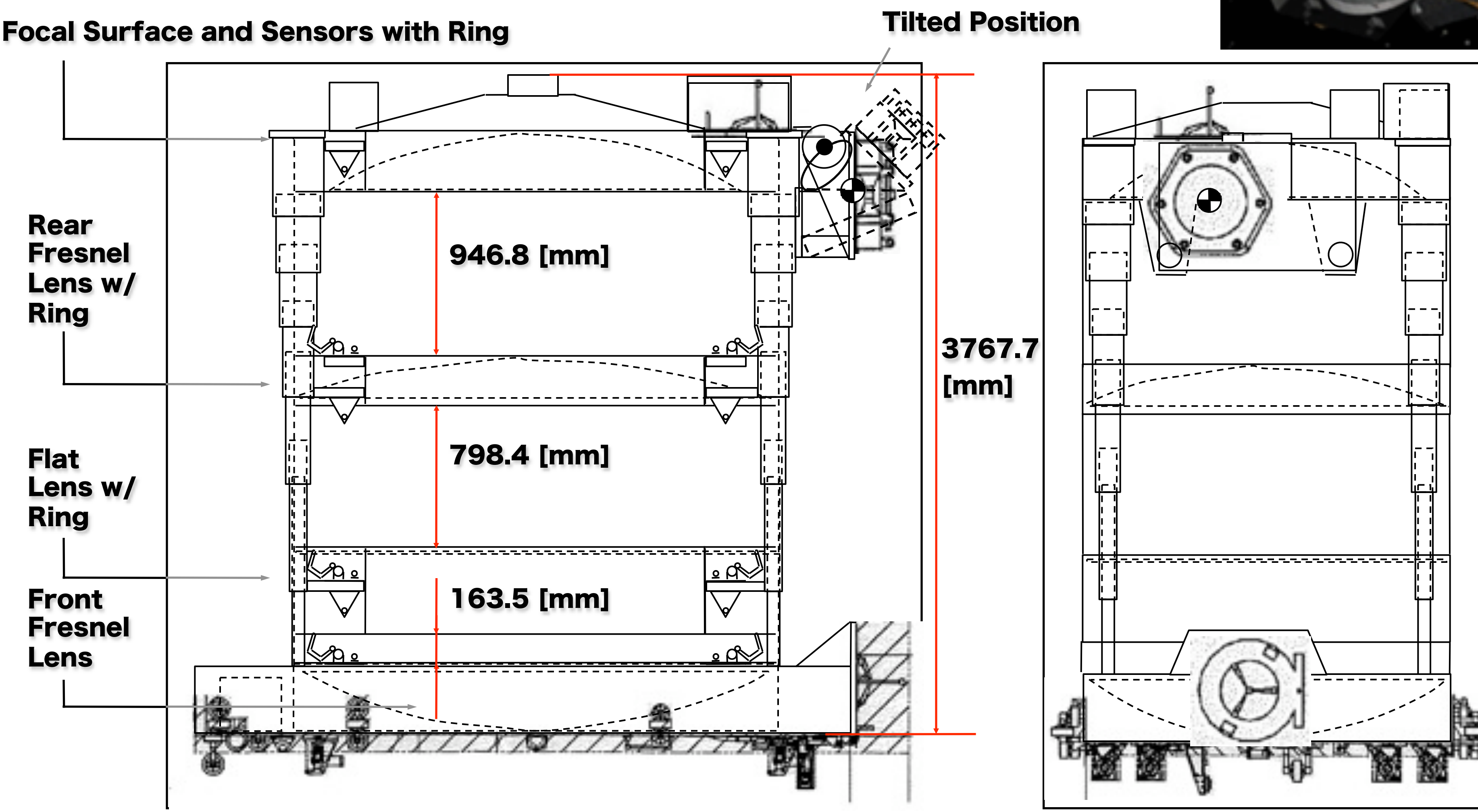


TSM: Tie-down Separation Mechanism
HSM: Harness Separation Mechanism
HDM: Hold Down Mechanism
SS: Space Station

JEM-EUSO On-orbit Configuration

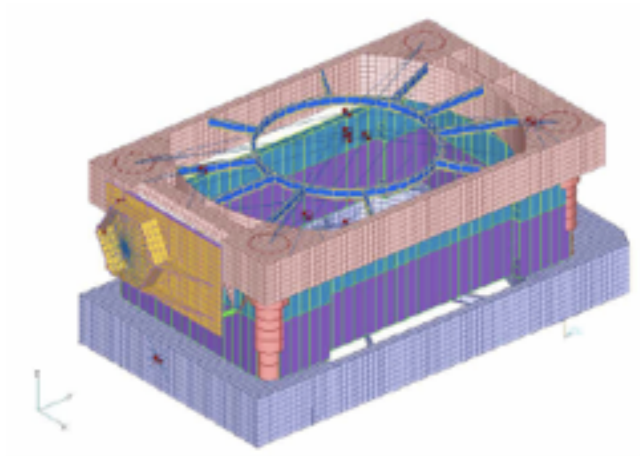


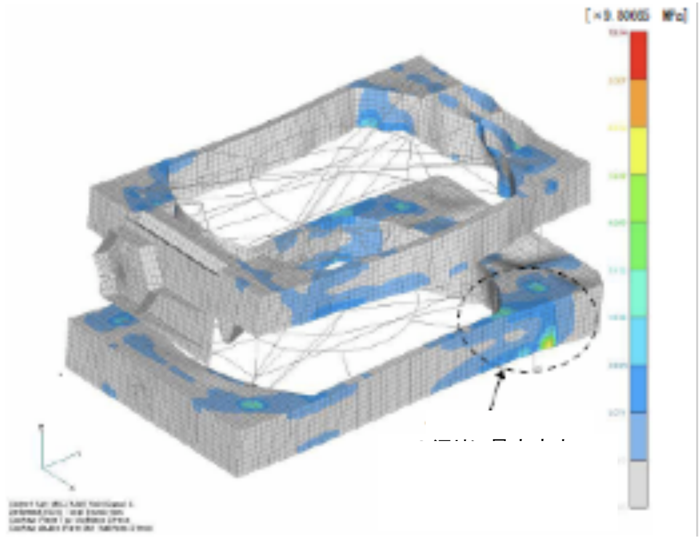
JEM-EUSO telescope will be elongated on orbit.

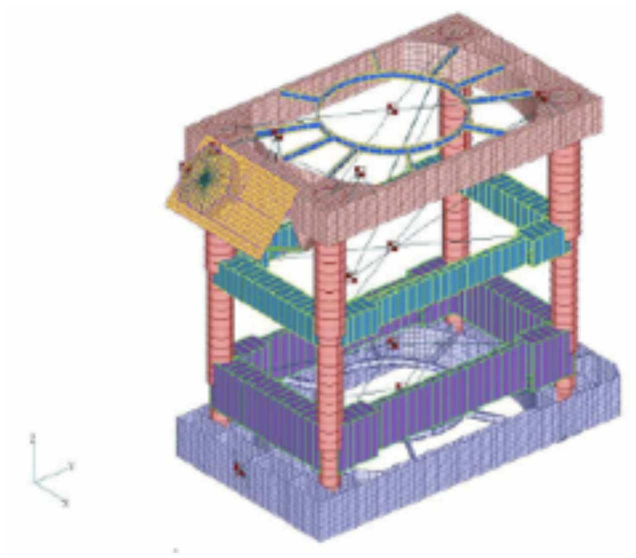


Telescope Barrel is not shown.

Structural Analysis





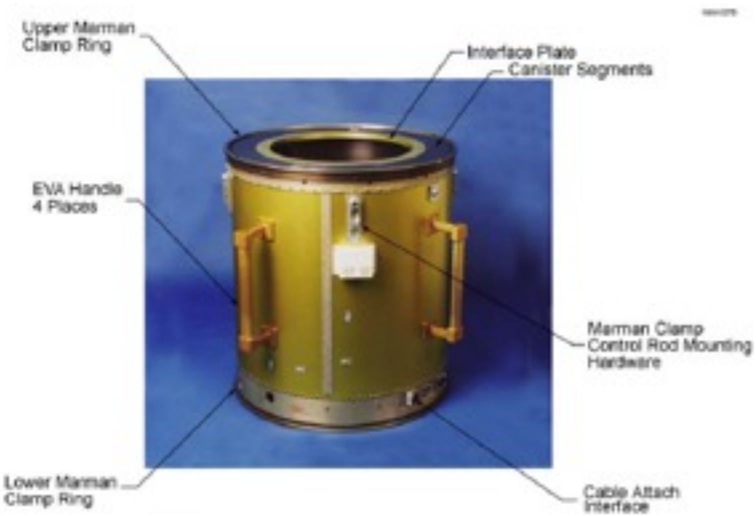


Lowest order characteristic frequency at launch is 25.6Hz

Lowest order characteristic frequency while the observation is 1.7Hz

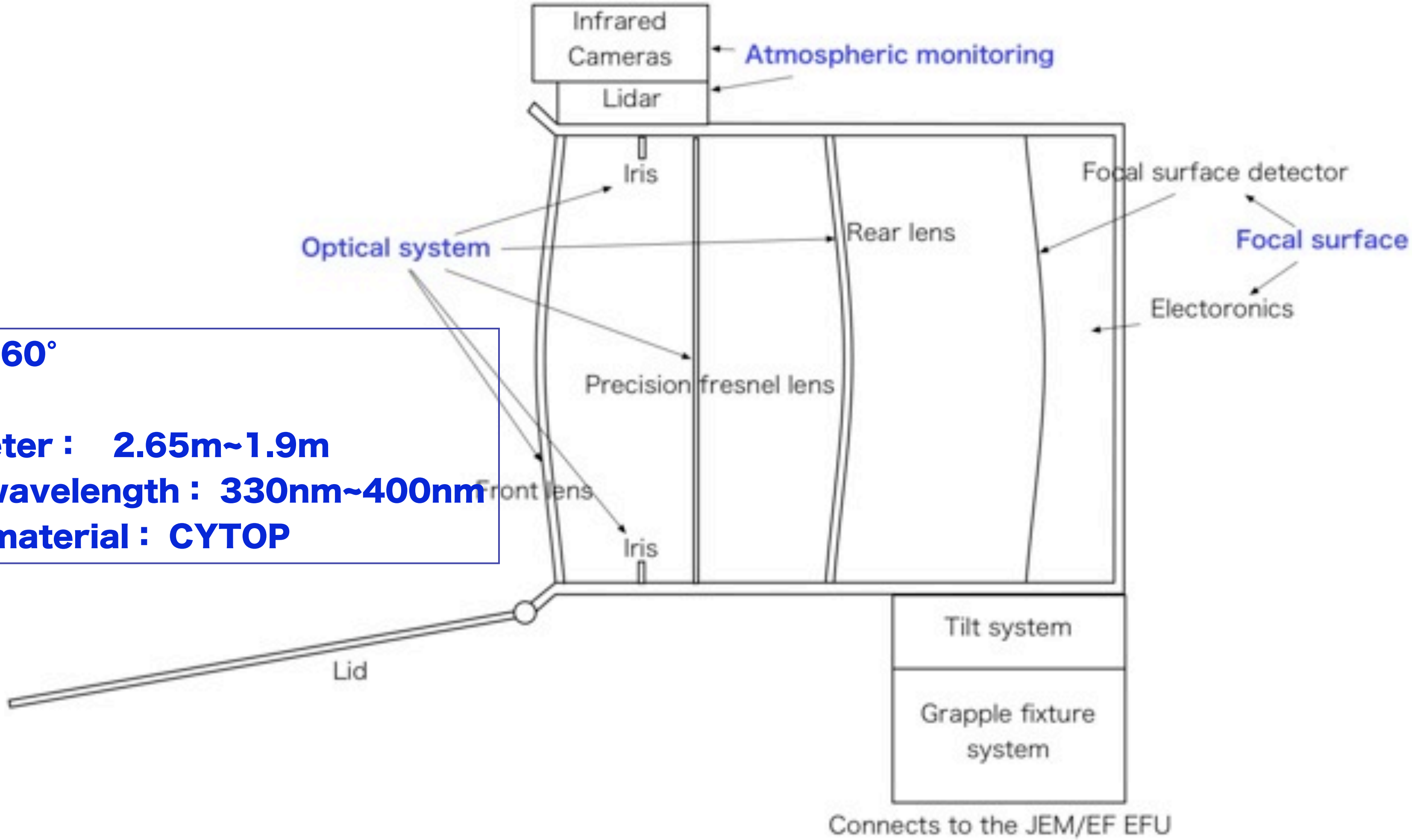
We cleared the minimum requirement value of 1Hz.

Extension Mechanism



- NGST Inc. ISIS mast

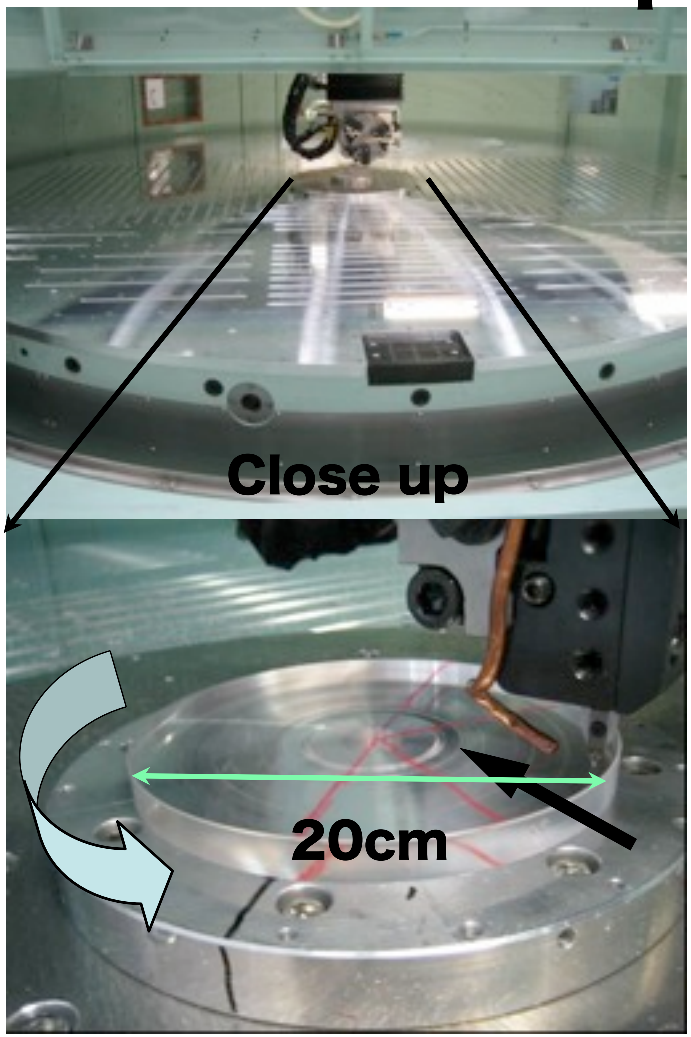
Conceptual View of JEM-EUSO Telescope



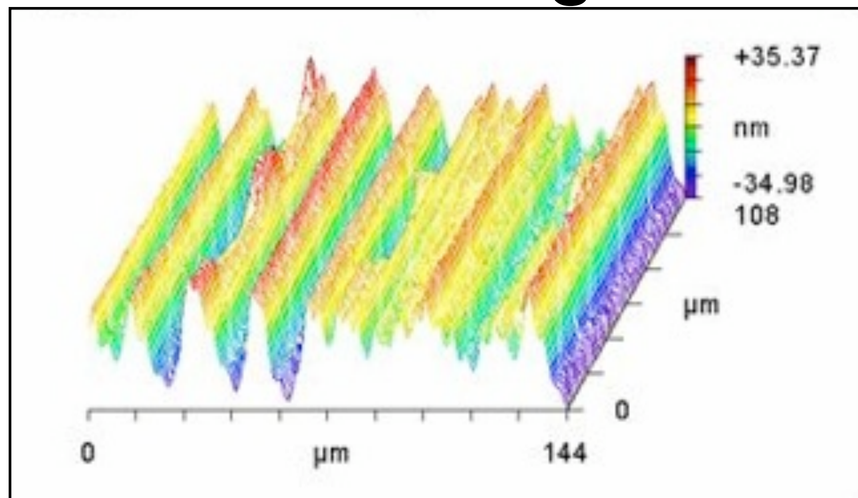
FoV： 60°
F/1.0
Diameter： 2.65m~1.9m
Obs. wavelength： 330nm~400nm
Lens material： CYTOP

Optics

Sample cutting test



Surface roughness



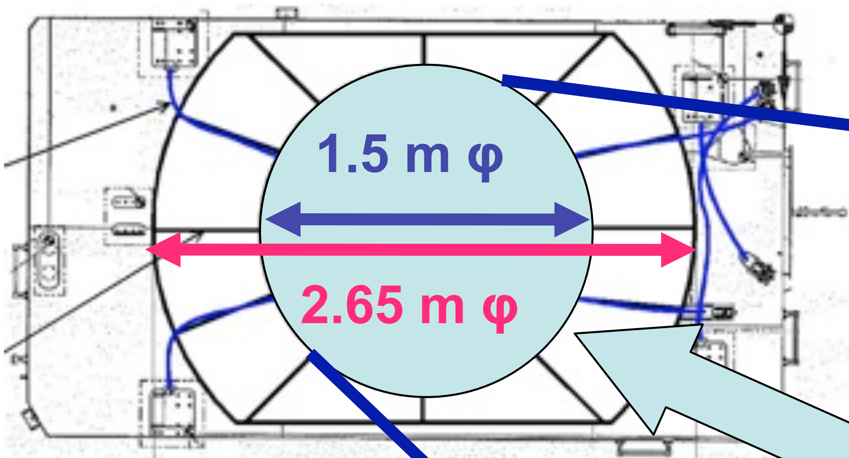
PV	62.174	nm	Ra	11.583	nm
rms	13.809	nm	Rz	51.29	nm

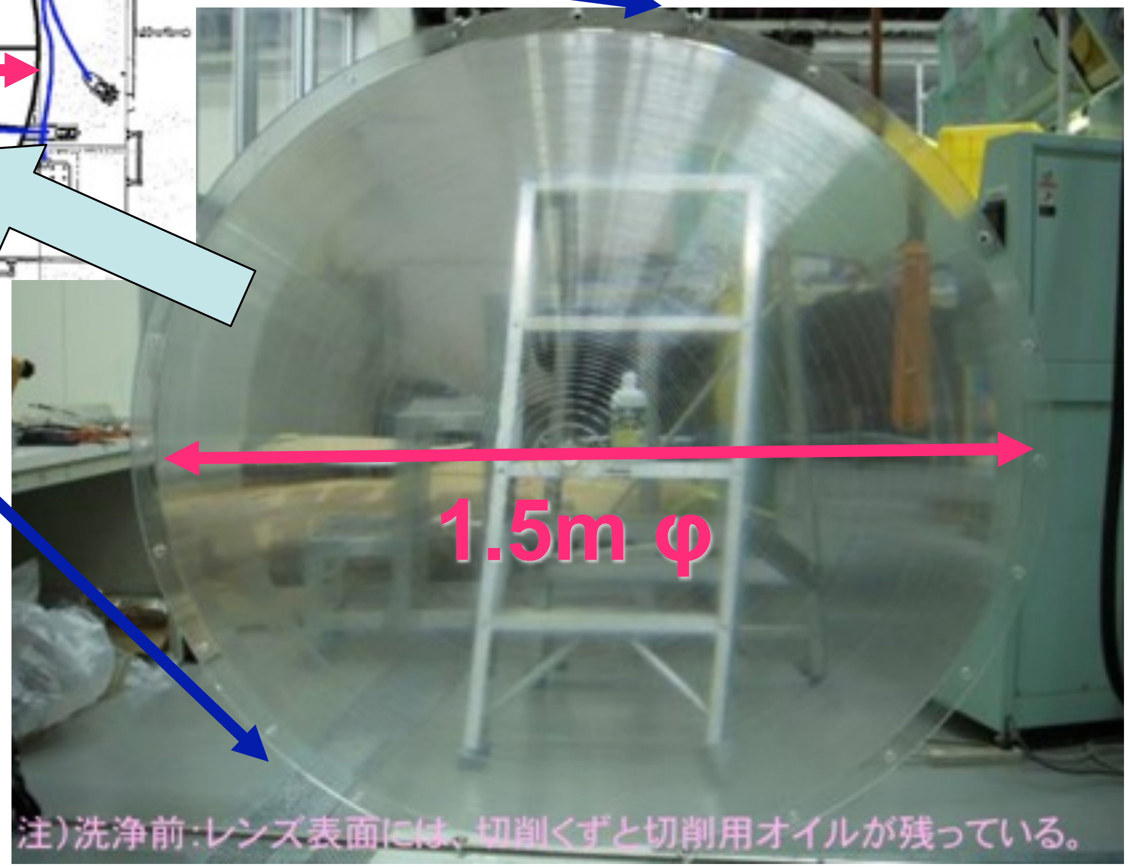
Surface roughness < 20nmRMS

(Requirement : ±72 nm)

Optics

Manufacturing large diameter Fresnel Lens



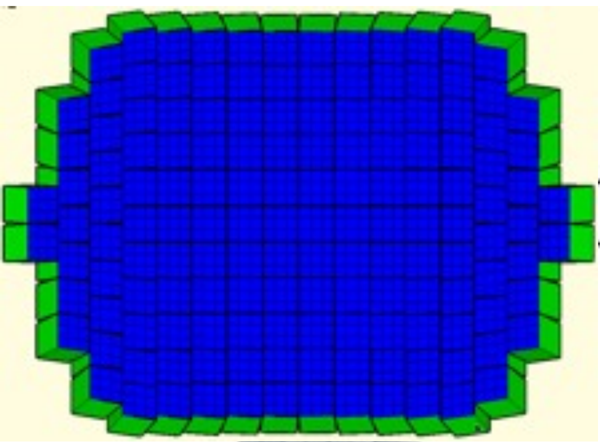


We obtained a cutting machine with a 3.4m dia. turn table to make a 2.65m dia. Fresnel Lens.

Focal Surface Detector

Focal Surface detector

(148PDMs = 0.2M pixels)



2.6 m max

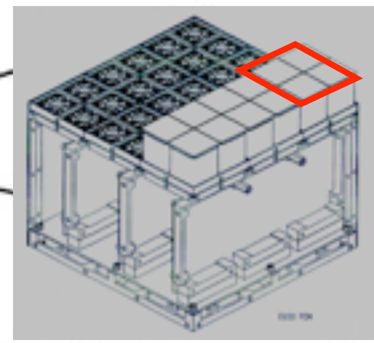
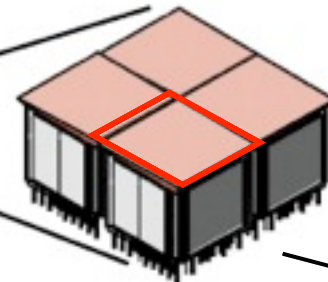


Photo-Detector Module

(3x3 ECs = 1296 pixels)

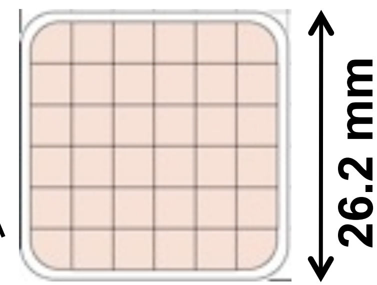
Elementary Cell

(2x2 PMTs = 144 pixels)

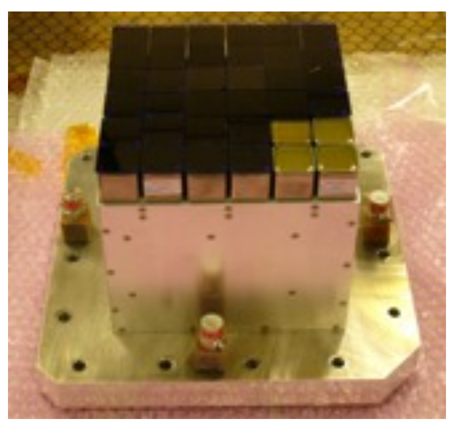


MAPMT

(6x6 pixels)

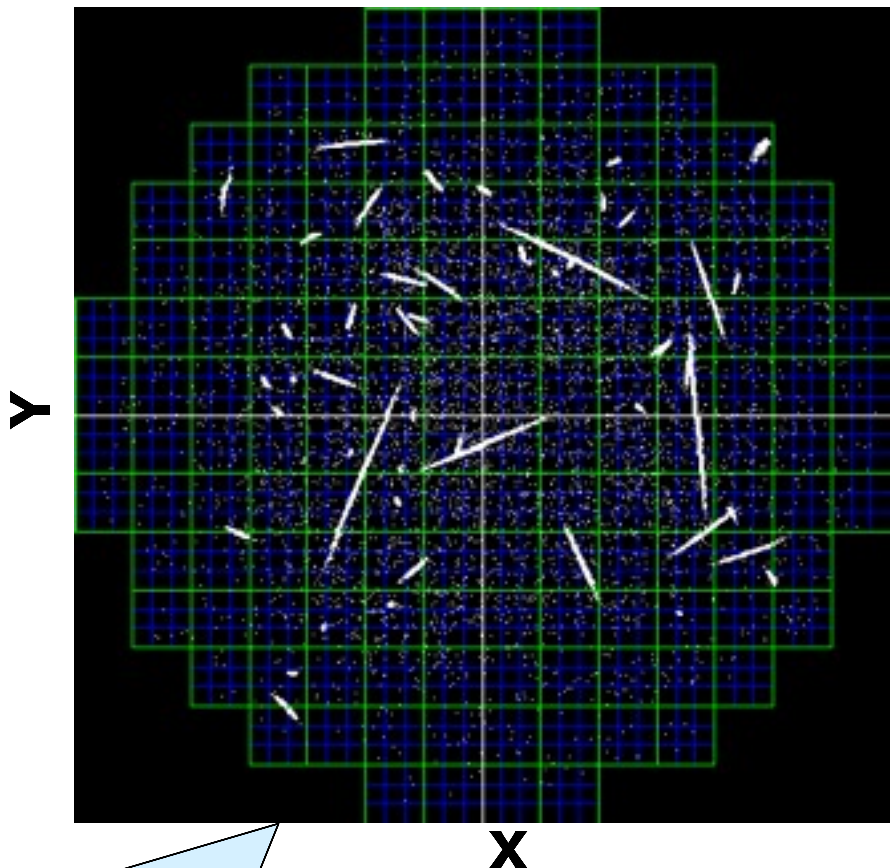


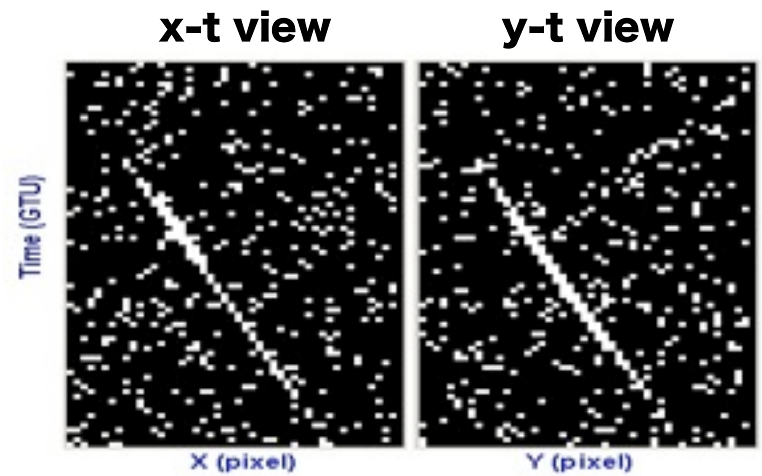
Radiation test and Vibration test has been done

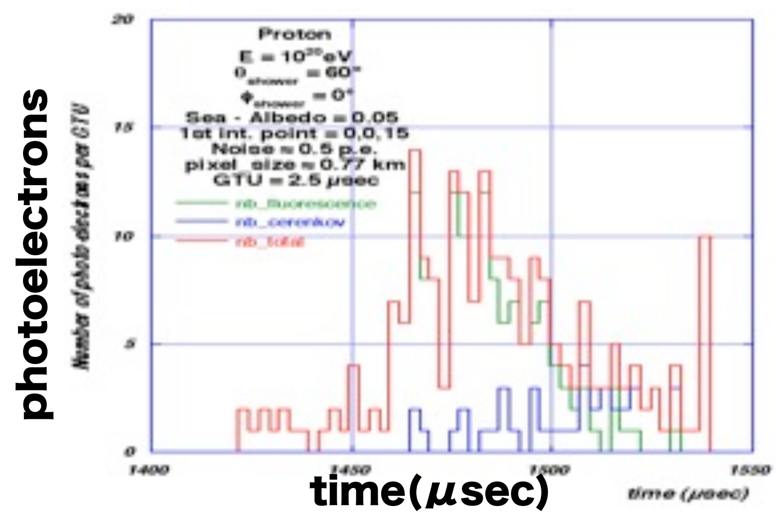


Air shower Image on the Focal Surface

simulation



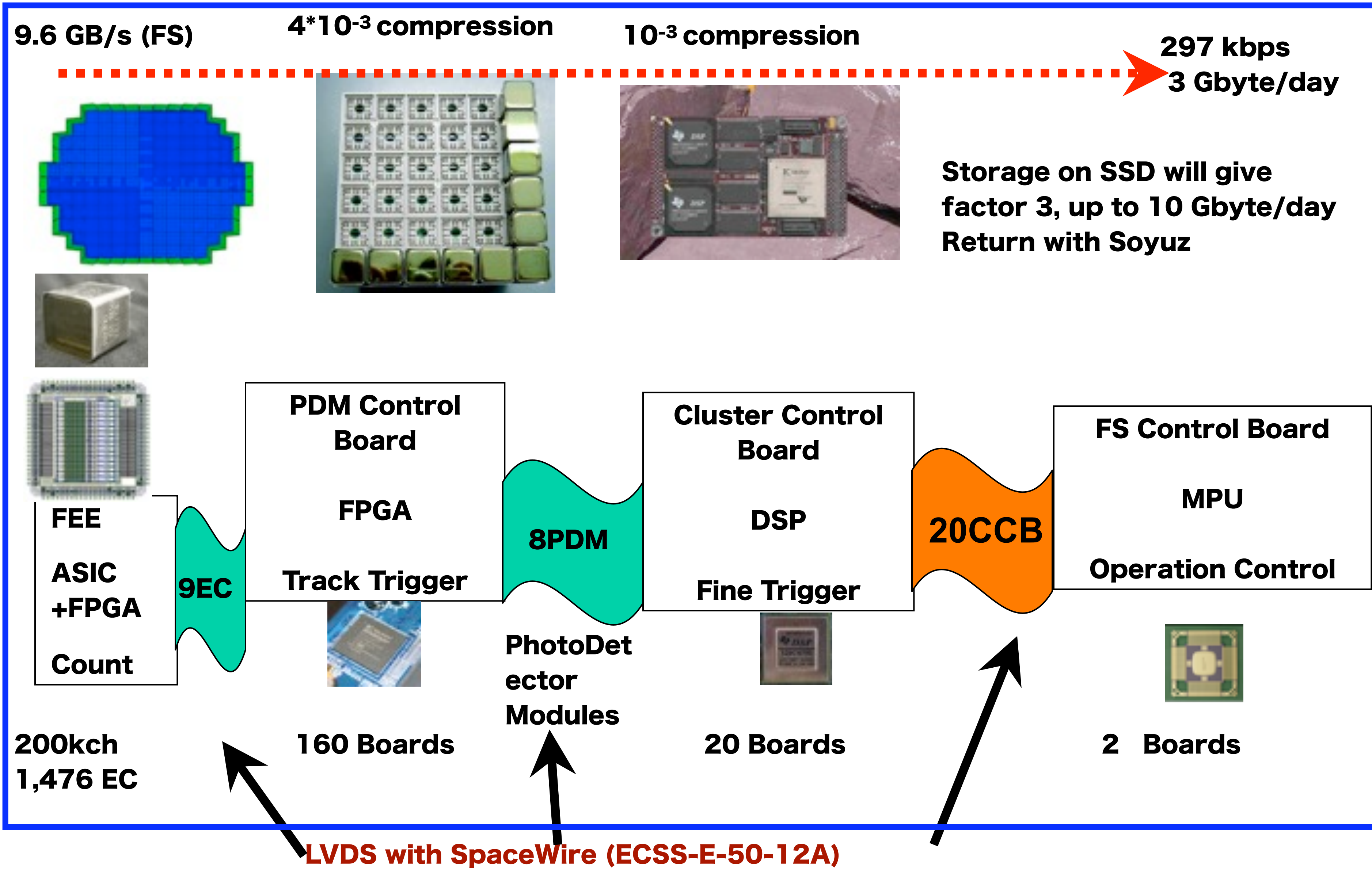




50 events of 10^{20}eV proton showers are superimposed on the EUSO focal surface with 192 k pixels.

Proton E=10^{20}eV, θ=60°
GTU = 2.5 μsec

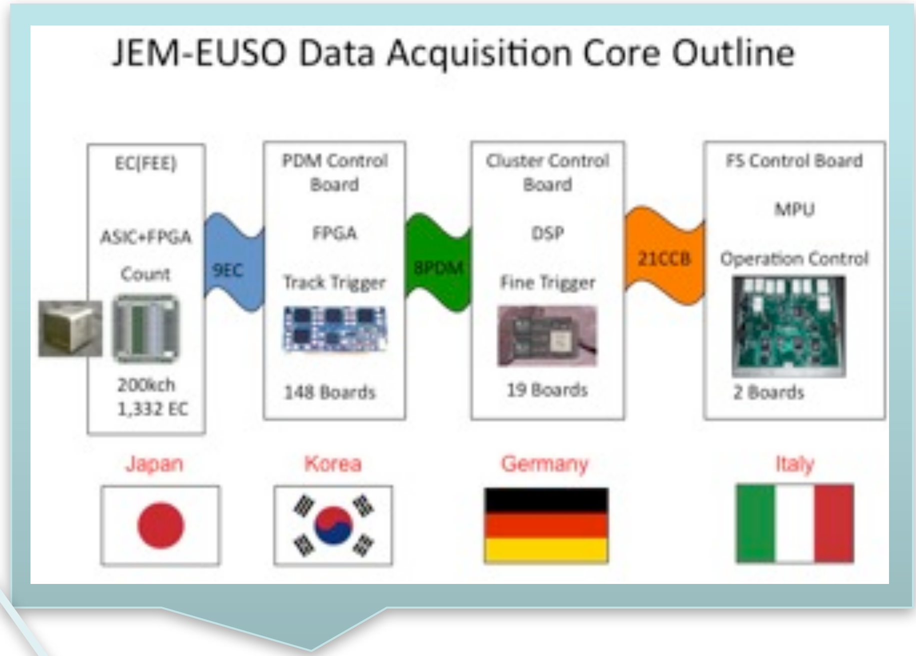
JEM-EUSO DAQ – Data reduction block scheme

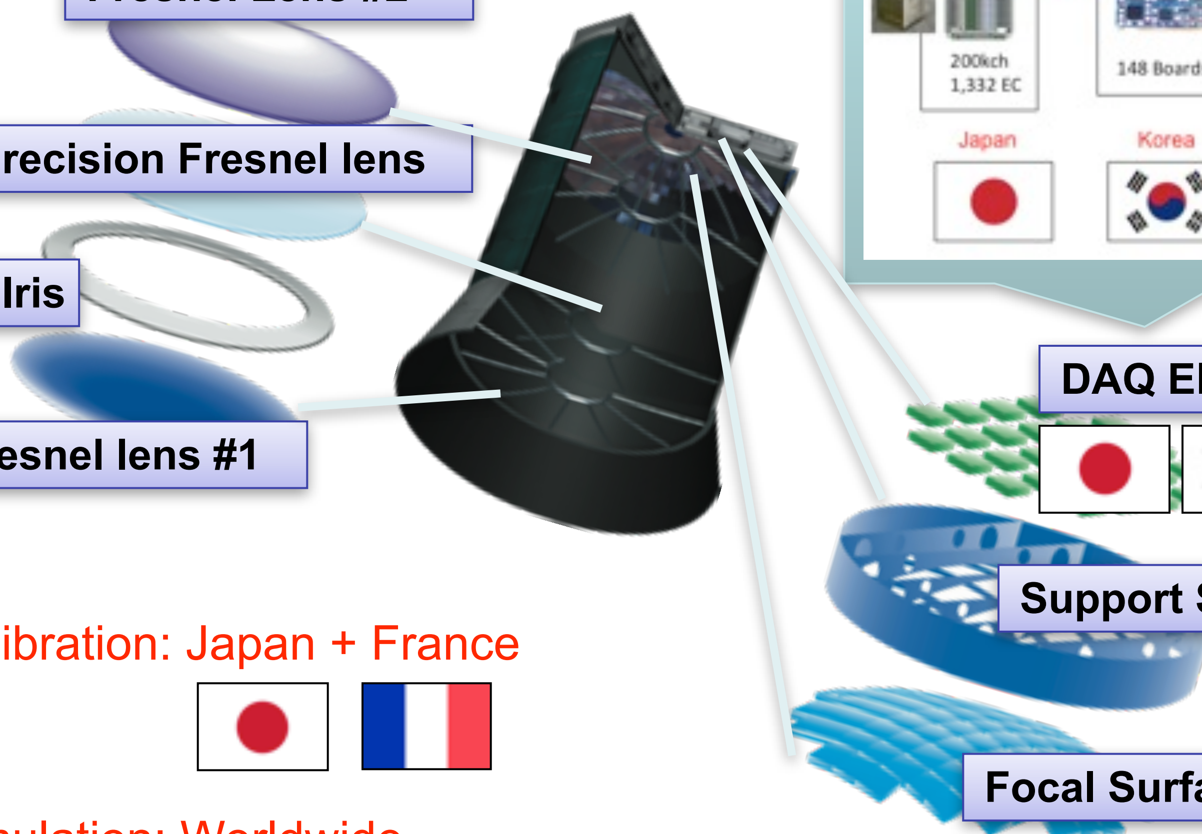


Poster: [143] The trigger system of the JEM-EUSO Telescope, BERTAINA, CATALANO G-12

Oral: [153] The data acquisition and handling system of the Jem-Euso experiment, M. CASOLINO

International Role Sharing





Optics: USA + Japan

Fresnel Lens #2

Precision Fresnel lens

Iris

Fresnel lens #1

DAQ Electronics

Support Structure: Italy + France

Focal Surface: Japan

Calibration: Japan + France

Simulation: Worldwide

Parts and Suppliers

Item	quan.	Supplier
Optics		MSFC
First Lens	1	MSFC
Lens	2	RIKEN
Frame	1	IA/Nippi
Second Lens	1	MSFC
Lens	2	MSFC/RIKEN
Frame	1	IA/Nippi
Third Lens	1	MSFC
Lens	2	MSFC/RIKEN
Frame	1	IA/Nippi
Iris	1	IA/Nippi(TBD)
Filter	4932	Shot (TBD)
Focus Mechanism	1	IA/Nippi
CS		IN2P3-APC
Onboard LD system	5	IN2P3-APC

Item	quan.	Supplier	
FS		RIKEN	
Detector		4932	RIKEN
PMT	4932	Hamamatsu	
EC	1232	IN2P3-LAL/RIKEN	
EC-ASIC	4932	IN2P3-LAL	
EC-B	1232	IN2P3-LAL	
PDM	137	INFN-LNF/RIKEN	
PDM Structure		137	INFN-LNF
PDM-B	137	Ehwa W. Univ.	
HV-B	137	Poland (TBD)	
CCB	36	Univ. of Tubingen	
MDP	2	U. of Rome T.V.	
FS-Structure	1	INFN-LNF	
AMS		RIKEN	
IR camera		1	UAH
Lidar	1	CSEM	
LD	3	TBD	
Laser Head	1	RIKEN	
Power Supply	1	RIKEN	

EUSO :

Ever Largest Refractive Telescope

1897

2015

Principle of Relativity

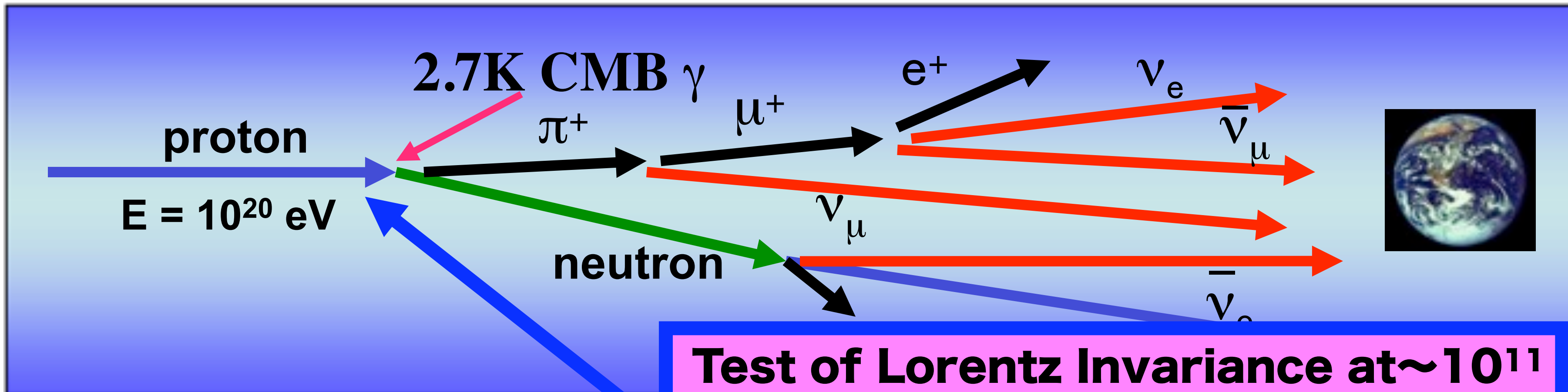
Principle of Relativity:
Galileo Galilei: There are no differences in physical laws at any velocity

Theory of Relativity: Einstein: Lorentz Invariance

Are there realy no limits?

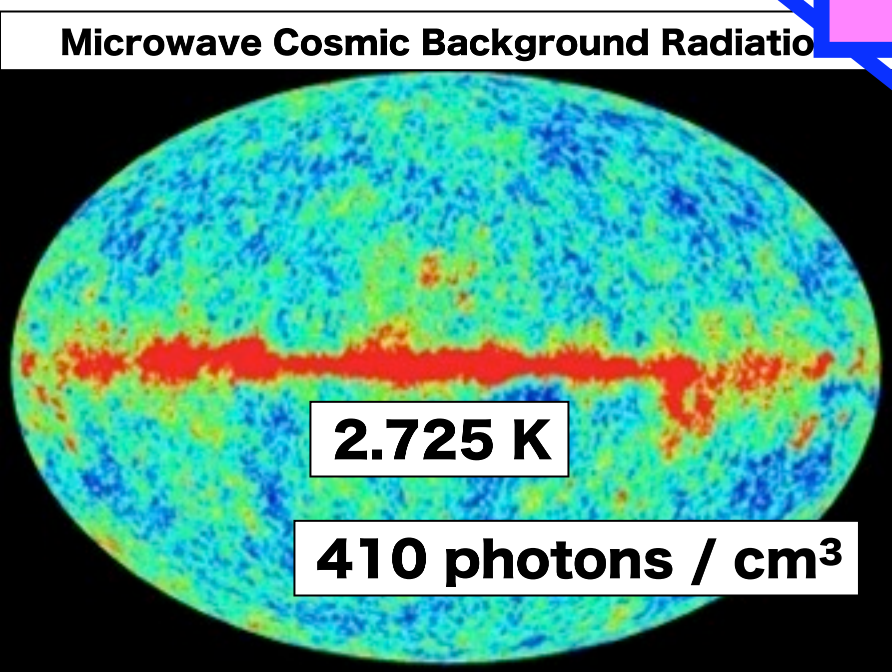
Greisen-Zatsepin-Kuz'min Process

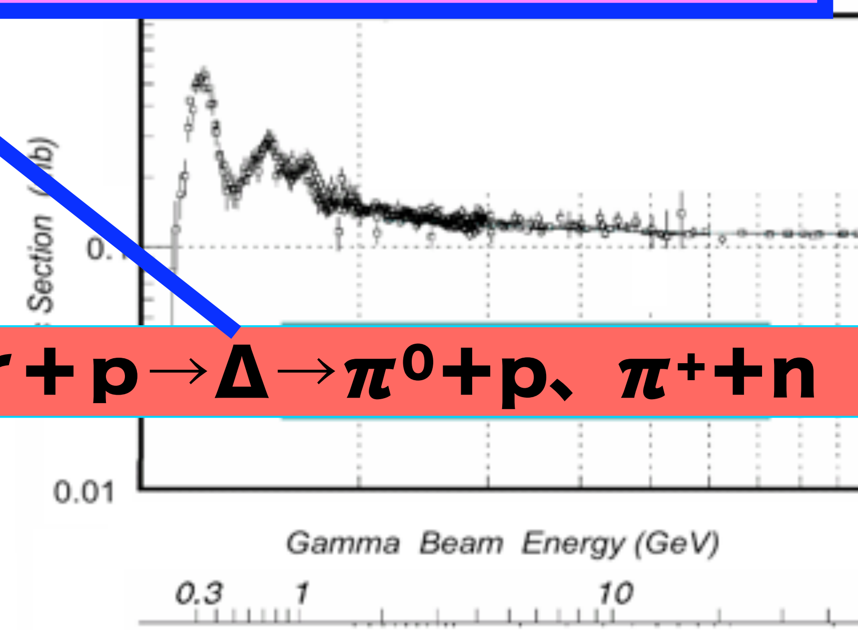
Greisen1966; Zatsepin and Kuz'min1966



Test of Lorentz Invariance at∼10^11

Sato and Tati 1972





$$\gamma + p \rightarrow \Delta \rightarrow \pi^0 + p、\ \pi^+ + n$$

Summary Three Challenges

- Challenge to Astronomy through Charged Particle
  - Clarify Origin of EECR by Arrival Direction
  - Huge Accelerators in the Universe
- Challenge to the limit of the Fundamental Physics
  - Lorentz invariance at the highest extreme (γ~10^{11})
  - Detection of gamma-rays and neutrinos
- Challenge to the Largest Refractive Telescope on orbit
  - Super Light weight Fresnel Lenses
  - Super fast Focal Surface Detectors

Completion of Japanese Experiment Module KIBO

Successful Launch of HTV

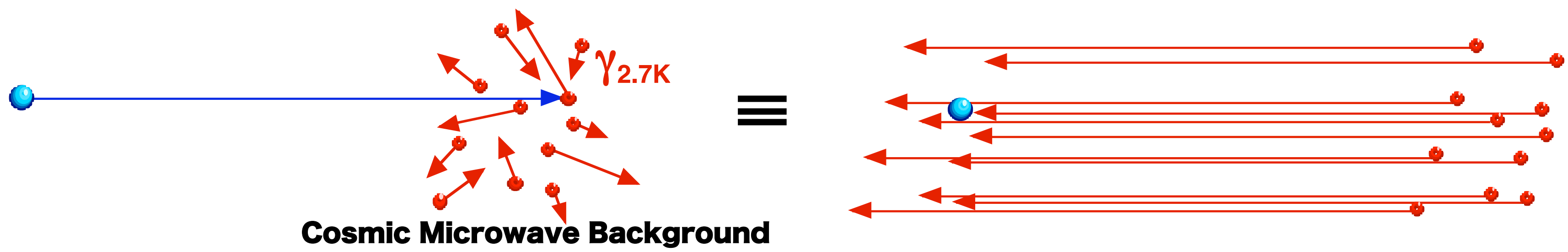
JEM-EUSO Launch in 2015

JEM-EUSO Collaboration

12 countries, 62 institutions, 170 members

- **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, P. Readon, V. Connaughton, K. Pitalo, J. Hadaway, J. Geary, R. Lindquist, P. Readon (***Univ. Alabama in Huntsville***), H. Crawford, C. Pennypacker (***LBL, UC Berkeley***), K. Arisaka, D. Cline, J. Kolonko, V. Andreev (***UCLA***), T. Weiler, S. Csorna (***Vanderbilt Univ***.),
- **France** : J-N. Capdevielle, P. Gorodetzky, D. Allard, J. Dolbeau), T. Patzak, J.J. Jaeger, E. Parizot, D. Semikoz, J. Weisbard (***APC,IN2P3,CNRS***), S. Dagoret-Campagne ***(LAL,IN2P3,CNRS***)
- **Germany**: M. Teshima, T. Schweizer (***MPI, Munich***), A. Santangelo, E. Kendziorra, F. Fenu (***Univ. Tuebingen***), P. Biermann (***MPI Bonn***), K. Mannheim (***Wuerzburg***), J. Wilms (***Univ. Erlangen***)
- **Italy** : E. Pace, M. Focardi, P. Spillantini (***U. Firenze***) V.Bratina, A. Zuccaro, L. Gambicorti (***CNR-INOA Firenze***), A. Anzalone, O. Catalano, M.C. Maccarone, P. Scarsi, B. Sacco, G. La Rosa (***IAS-PA/INAF***), G. D'Ali Staiti, D. Tegolo (***U. Palermo***), M. Casolino, M.P. De Pascale, A. Morselli, P. Picozza, R. Sparvoli (***INFN and Univ. Rome "Tor Vergata"***), P. Vallania (***IFSI-INAF Torino***), P. Galeotti, C. Vigorito, M. Bertaina (***U. Torino***), A. Gregorio (***Trieste***), F. Isgro, F.Guario, D. D'urso, D. Supanifsky (***U. "Federico II" di Napoli***)**,** G. Osteria, D. Campana, M. Ambrosio, C. Aramo (***INFN-Nappli***)
- **Mexico**: G. Medina-Tanco, J.C. D'Olivo, J.F.Valdes (***Mexico UNAM***), H. Salazar, O. Martines (***BUAP***), L. Villasenor (***UMSNH***)
- **Republic of Korea** : S. Nam, I. H. Park, J. Yang (***Ehwa W. Univ***.), T.W. Kim (***Ajou University***), S.W. Kim (***Yonsei University***), K.K. Joo (***Chonnam National University***)
- **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**: D.Rodriguez-Frias, L.Peral, J.Gutierrez, R.Gomez-Herrero (***Univ. Alcala***)
- **Poland**: T. Batsch, B. Szabelska, J. Szabelski, T. Wibig(IPJ), T. Tymieniecka(Podlasie Univ.), Z. Wlodarczyk(Kielce Univ.), G. Siemieniec-Ozieblo(Jagiellonian Univ.)
- **Slovakia**: K. Kudela, R. Bucik, R. Bobik, M. Slivka (Inst. Experimental Physics, KOSICE)

Greisen-Zatsepin-Kuzmin (GZK) effect



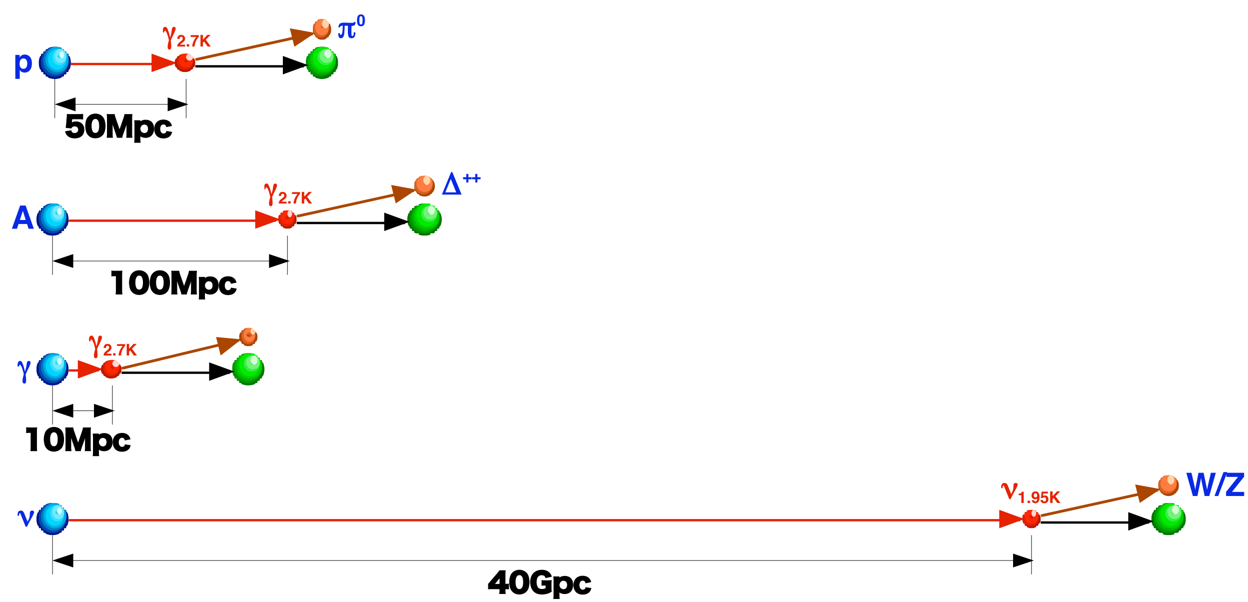
Greisen-Zatsepin-Kuzmin (GZK) cutoff

proton $E \geq 5\times10^{19}$eV

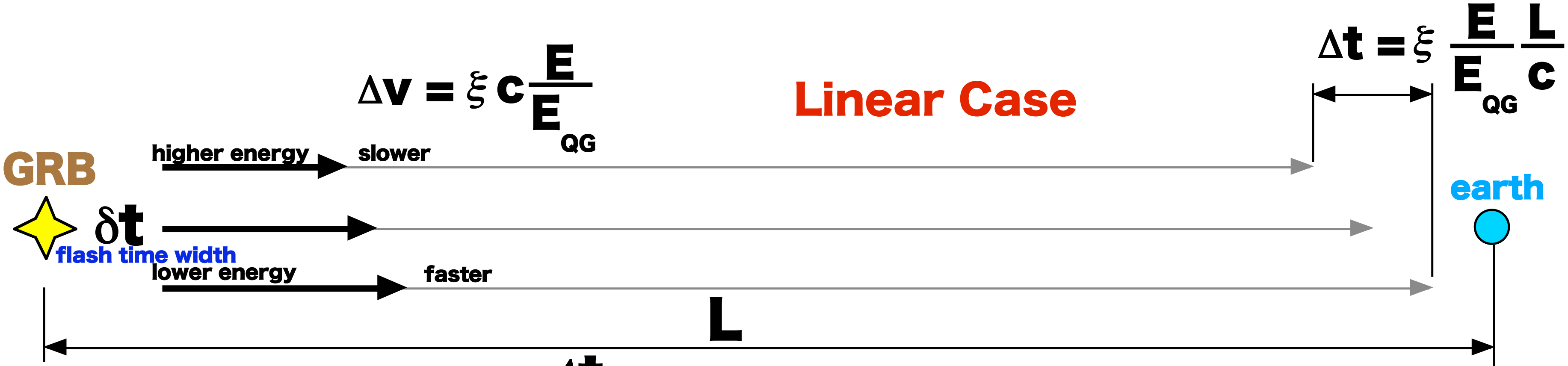
nuclei $E \geq 5\times10^{18}$eV

γ-ray $E \geq 10^{14}$eV

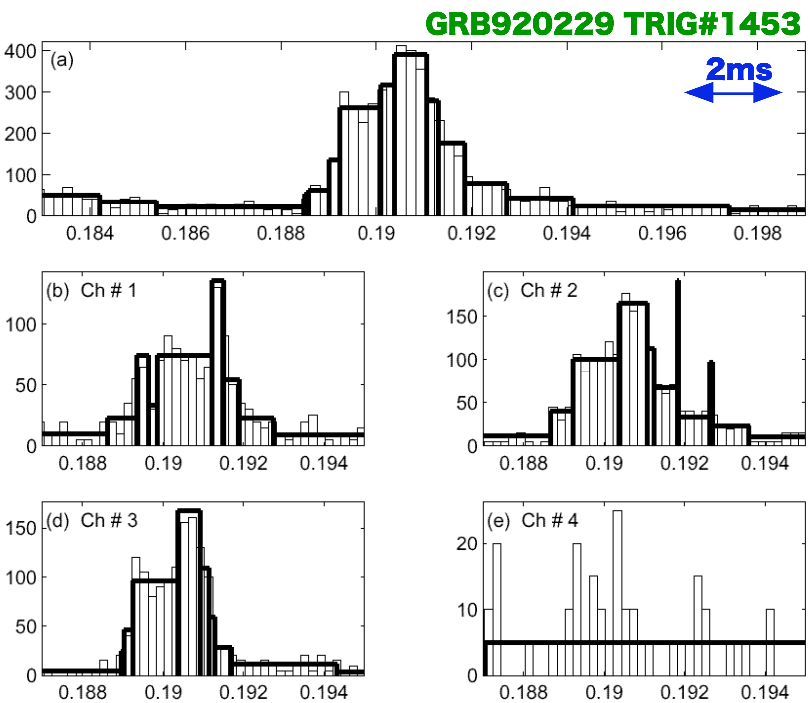
neutrino $E \geq 4\times10^{22}$eV

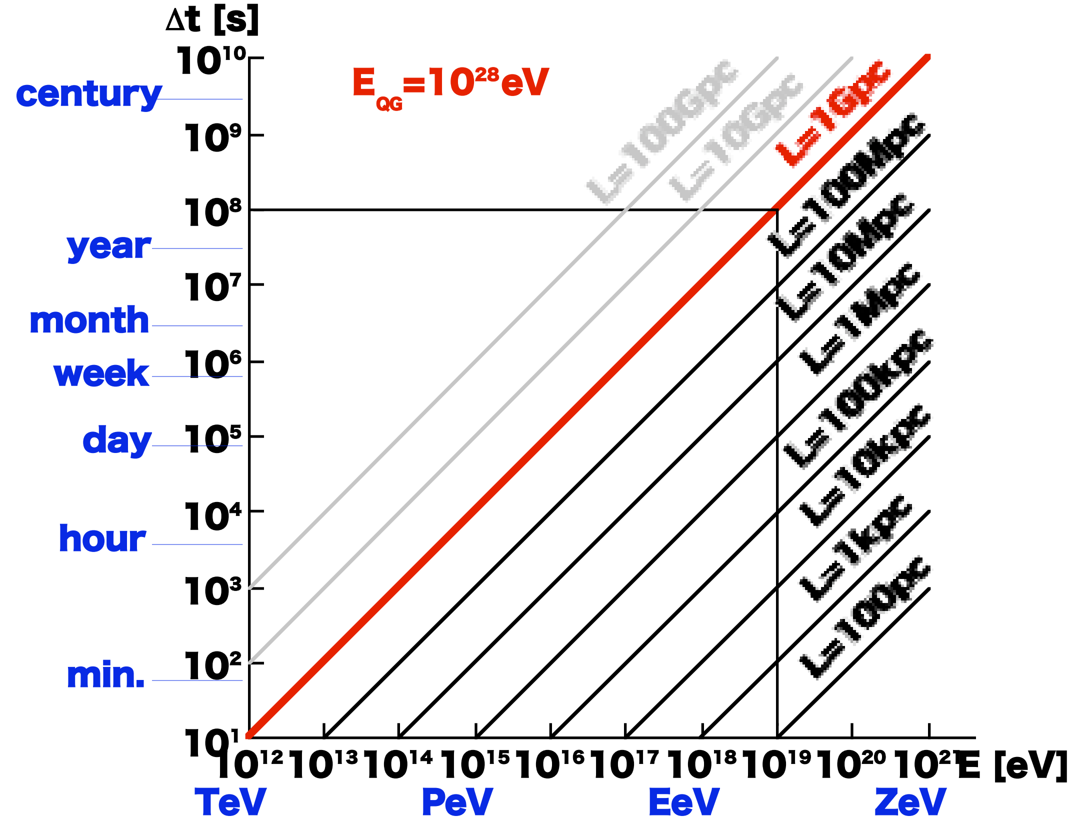


Long Baseline Time-of-flight



sensitivity factor $\eta = \frac{\Delta t}{\delta t}$





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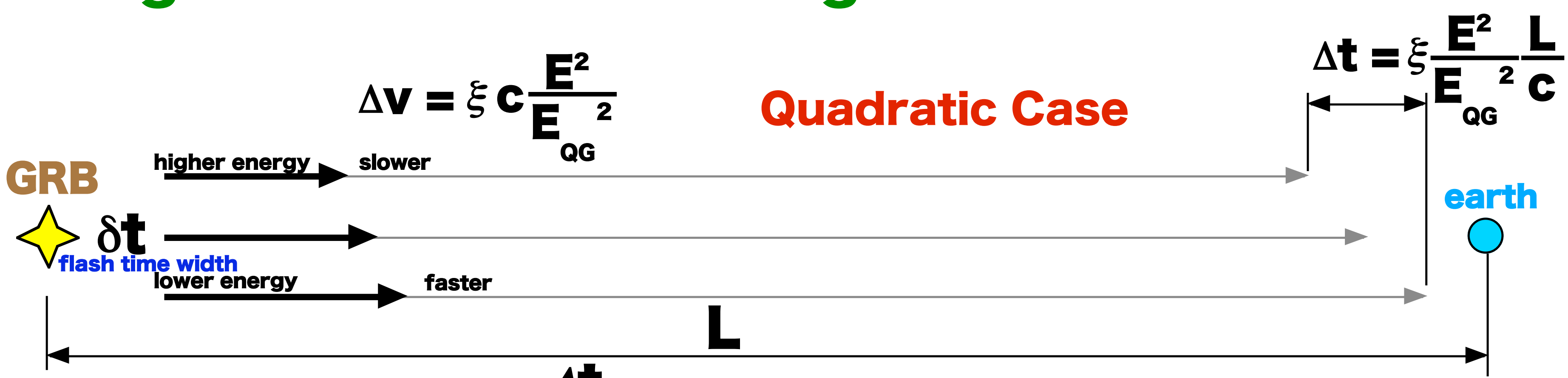
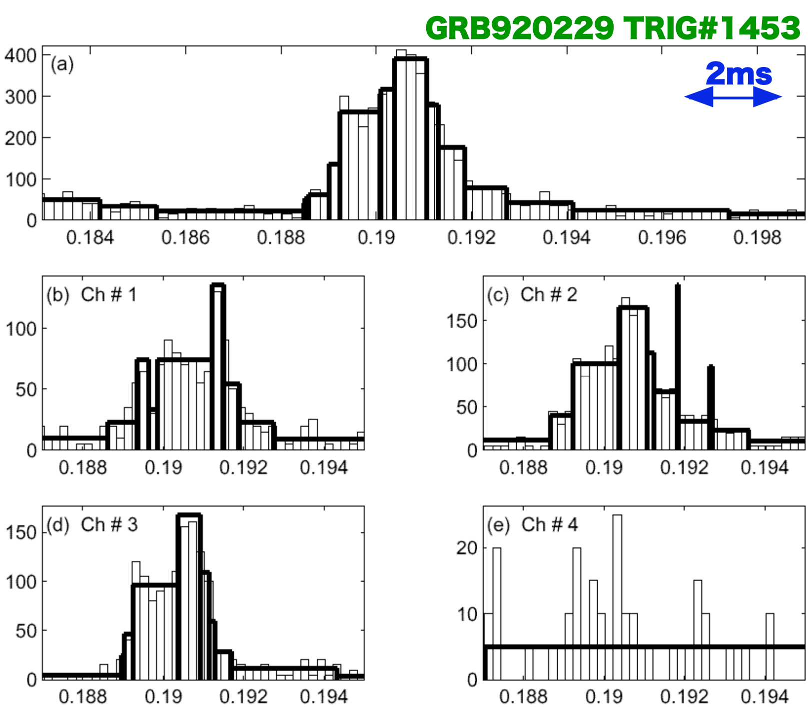
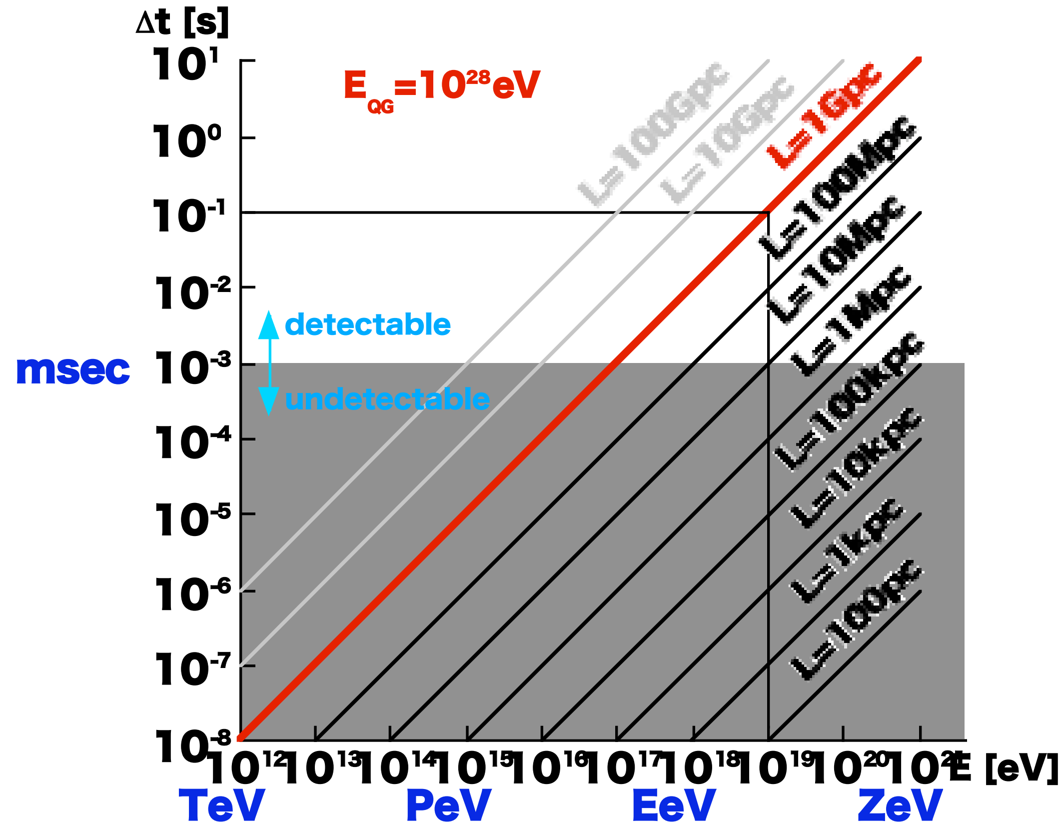


sensitivity factor $\eta = \frac{\Delta t}{\delta t}$





Photon Absorption Mean Free Path under Quantum Gravity