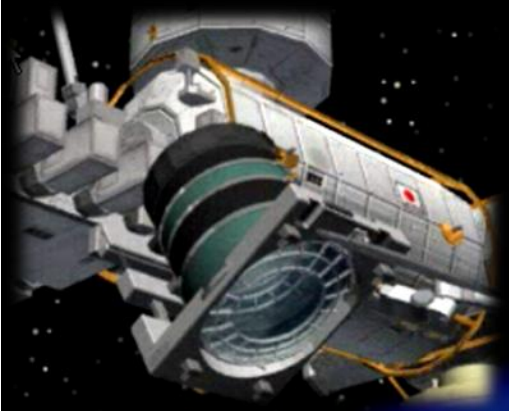


Extreme Universe Space Observatory

Status of the JEM-EUSO Mission

Naoto Sakaki
Aoyama Gakuin University
for the JEM-EUSO Collaboration

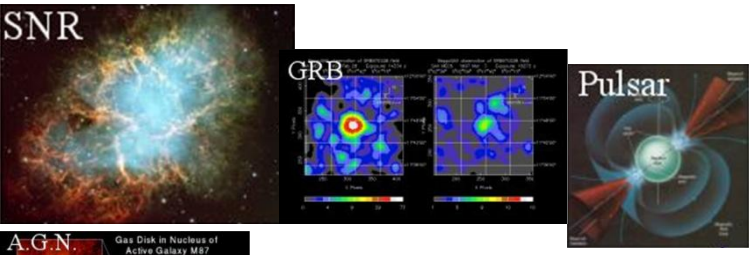
7th Fluorescence Workshop
September 22-24, 2010, Coimbra, Portugal

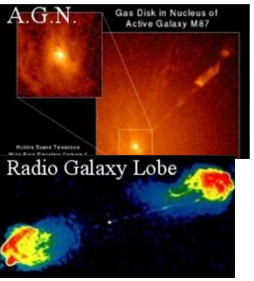
JEM-EUSO collaboration

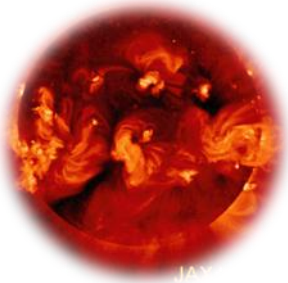
12 countries, 75 Institutions, 225 members

- **Japan** T.Ebisuzaki, H.Ohmori, Y.Kawasaki, Y.Takizawa, Y.Hachisu, N.Tone, K.Katahira, S.Wada, T.Ogawa, K.Kawai, H.Mase, K.Shinozaki, N.Tajima, N.Tone, I.Kaneko *(RIKEN)* F.Kajino, T.Yamamoto, M.Sakata, Y.Yamamoto, H.Sato, N.Ebizuka *(Konan Univ.)* M.Nagano, Y.Miyazaki *(Fukui Tech. Univ.)* T.Shibata, N.Sakaki *(Aoyama Gakuin Univ.)* N.Inoue *(Saitama Univ.)* Y.Uchihori *(NIRS)* K.Nomoto *(Univ. Tokyo)* Y.Takahashi *(Tohoku Univ.)* M.Takeda *(ICRR, Univ. Tokyo)* H.M.Shimizu, Y.Arai, Y.Kurihara, J.Fujimoto *(KEK)* S.Yoshida, K.Mase *(Chiba Univ.)* Y.Mizumoto, J.Watanabe, T.Kajino *(NAOJ)* H.Ikeda, M.Suzuki, H.Yano *(ISAS/JAXA)* T.Murakami, D.Yonetoku *(Kanazawa Univ.)* N.Sugiyama *(Nagoya Univ.)* Y.Itoh *(STE Lab., Nagoya Univ.)* S.Nagataki *(Yukawa Inst., Kyoto Univ.)* S.Inoue, A.Saito *(Kyoto Univ.)* S.Abe, M.Nagata *(Kobe Univ.)* M.Chikawa *(Kinki Univ.)* F.Tajima *(Hiroshima Univ.)* M.Sato, S.Watanabe *(Hokkaido Univ.)* K.Asano *(Tokyo Inst. Tech.)*
- **USA** J.H.Adams Jr., S.Mitchell, R.Young, M.J.Christl, J.Watts Jr., A.English *(NASA/MSFC)* Y.Takahashi, D.Gregory, M.Bonamente, P.J.Reardon, V.Connaughton, S.K.Pitalo, J.Hadaway, J.Geary, R.Lindquist, T.Blackwell, S.N.Zhang, R.Miller *(Univ. Alabama)* H.Crawford, C.Pennypacker, E.G.Judd *(LBL, Univ. California, Berkeley)* K.Arisaka, D.Cline, V.Andreev *(UCLA)* T.Weiler, S.Csorna, A.Berlind *(Vanderbilt Univ.)* R.Chipman, S.McClain *(Univ. Arizona)*
- **France** D.Allard, J-N.Capdevielle, J.Dolbeau, P.Gorodetzky, E.Parizot, T.Patzak, D.Semikoz, F.Dorigo, G.Prevot *(APC-Paris 7)* S.Dagoret-Campagne, D.M.Ragaigne, M.Urban, B.Kegl, C.Taille, S.Ahmad, S.Blin, P.Barrillon, F.Dulucq, J.N.Albert *(LAL, IN2P3-CNRS)*
- **Germany** M.Teshima, T.Schweizer, H.Miyamoto, H.Takami *(MPI Munich)* A.Santangelo, E.Kendziorra, T.Schanz, F.Fenu, T.Mernik *(Univ. Tuebingen)* P.Biermann *(MPI Bonn)* J.Wilms, I.Kreykenbhom *(Univ. Erlangen)* T.Tajima *(LMU & MPQ)* G.Sigl *(Univ. Hamburg)* K.Mannheim, O.Tibolla *(Univ. Würzburg)*
- **Italy** P.Spillantini *(Univ. Firenze)* A.Zuccaro Marchi, L.Gambicorti, V.Bratina *(CNR-INO Firenze)* A.Anzalone, O.Catalano, M.C.Maccarone, B.Sacco, G.La Rosa *(IAS-PA/INAF)* D.Tegolo *(Univ. Palermo)* M.Casolino, M.P.De Pascale, A.Morselli, P.Picozza, R.Sparvoli *(INFN and Univ. Rome "Tor Vergata")* P.Vallania *(INAF-IFSI Torino)* P.Galeotti, C.Vigorito, M.Bertaina, C.Cassardo, S.Ferrarese, R.Cremonini *(Univ. Torino)* F.Isgro, F.Guarino, D.D'Urso, S.Russo *(Univ. "Federico II" di Napoli)* G.Osteria, D.Campana, M.Ambrosio, C.Aramo, G.De Rosa, L.Valore *(INFN-Napoli)* M.Ricci, A.Franceschi, T.Napolitano *(INFN-Frascati)* A.Insolia, R.Caruso *(INFN and Univ.Catania)* A.Cellino, M.Di Martino *(INAF-OATO)*
- **Mexico** G.Medina Tanco, J.C.D'Olivo, J.F.Valdés-Galicia, D.Supanitsky, C.De Donato, L.S.Cruz, A.Zamora, H.H.S.Lopez *(UNAM)* H.Salazar, O.Martinez *(BUAP)* L.Villaseñor *(UMSNH)*
- **Republic of Korea** J.Lee, J.W.Nam, S.Nam, I.H.Park, J.Yang, J.H.Park, H.Lim, A.Jung *(Ehwa W. Univ.)* S.W.Kim *(Yonsei Univ.)* S.U.Kim, J.S.Kim *(KASI)* C.H.Lee *(Pusan National Univ.)* J.S.Chai *(Sungkunkwan Univ.)* Y.K.Kim *(Hanyang Univ.)* Y.Yi *(Chungnam National Univ.)* S.H.Ko *(KAIST)*
- **Russia** G.K.Garipov, B.A.Khrenov, P.A.Klimov, M.I.Panasyuk, I.V.Yashin *(SINP MSU)* D.Naumov, L.Tkachev *(Dubna JINR)*
- **Switzerland** A.Maurissen, V.Mitev *(Neuchatel)* T.Peter *(ETHZ)* A.Neronov, R.Walter *(ISDC)*
- **Spain** M.D.Rodriguez Frias, L.del Peral, E.Colombo, J.A.M.de los Rios, H.Prieto, G.Sáez *(Univ. Alcalá)* M.D.Sabau, T.Belenguer *(INTA)* F.López, A.J de Castro, S.Briz, J.F.Cortés *(Univ. Carlos III)*
- **Poland** T.Batsch, B.Szabelska, J.Szabelski, T.Wibig *(IPJ)* T.Tymieniecka *(Podlasie Univ.)* M.Rybczyński, Z.Włodarczyk *(Kielce Univ.)* G.Siemieniec-Oziębło *(Jagiellonian Univ.)* H.Rothkaehl, J.Błęcki, P.Orleański *(CBK)*
- **Slovakia** K.Kudela, R.Bucik, P.Bobik, M.Slivka *(Inst. Experimental Physics, KOSICE)*

JEM-EUSO is the Astronomical Earth Observatory







EECR s

Dust and Meteors

Charged Particles

Ultraviolet photons

UV, X, γ,ν p, n, e

X, γ,ν,p, e

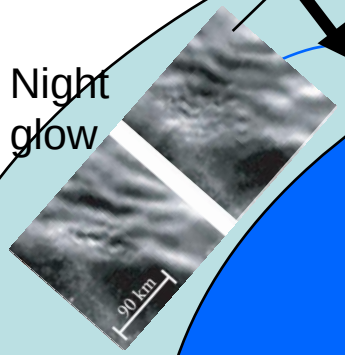
Air shower

Air shower

Atmosphere

Solar wind

Night glow

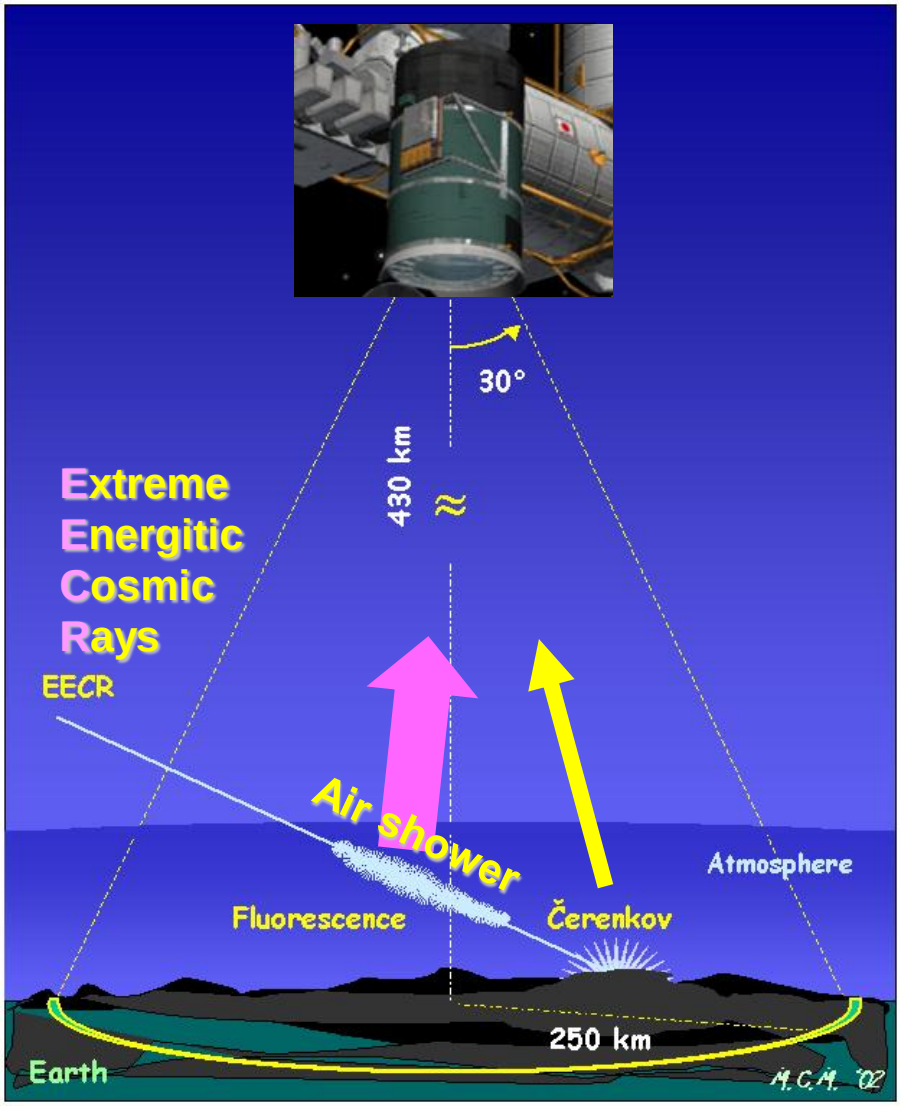


The Earth

Plasma Discahrge

EHE Neutrinos

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).

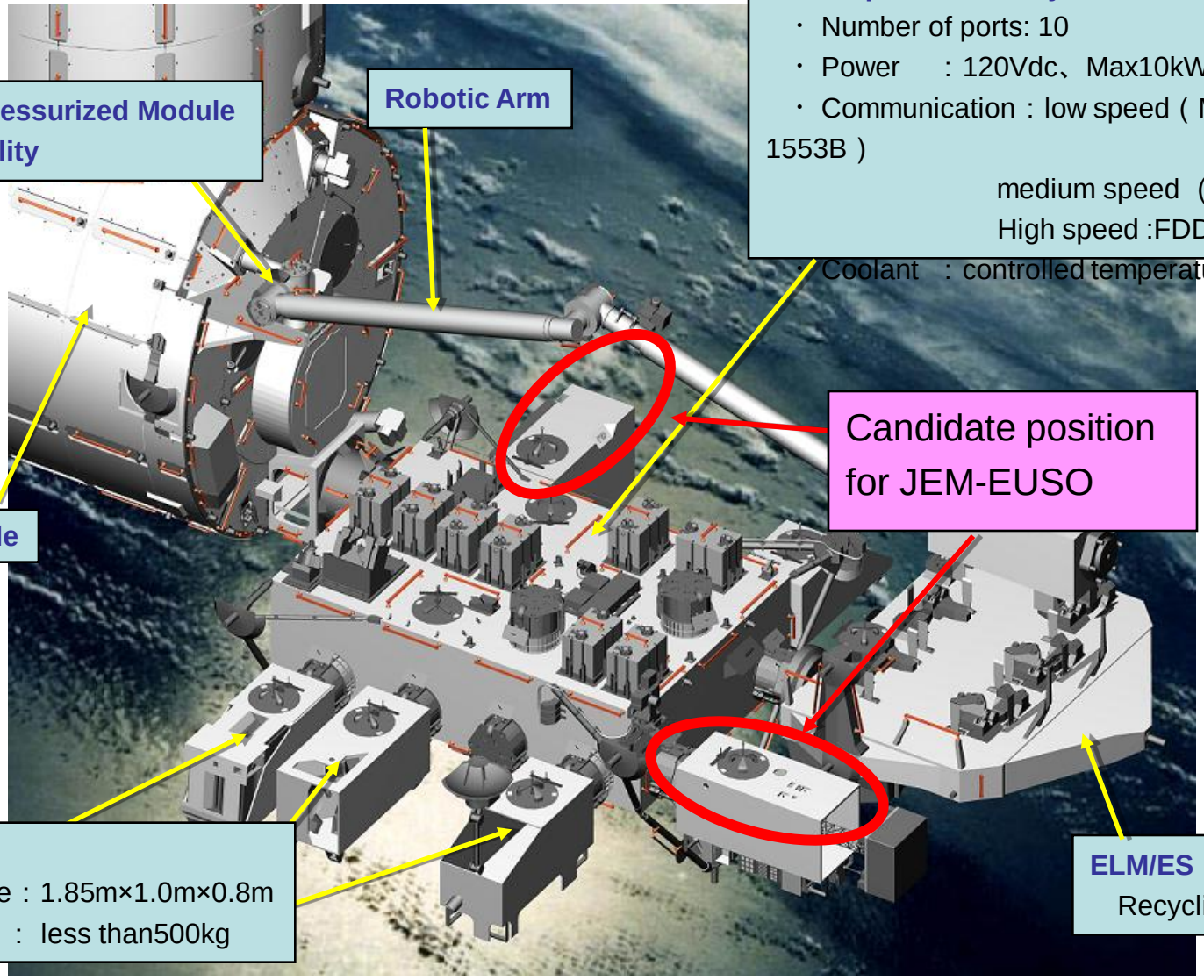
JEM-EUSO mission will initiate particle astronomy at ~10^{20}eV.

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

Japanese Experiment Module “Kibo” : July 2009

S127E011186

Outline of JEM Exposure Facility



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±4℃

Airlock between Pressurized Module and Exposure Facility

Robotic Arm

Candidate position for JEM-EUSO

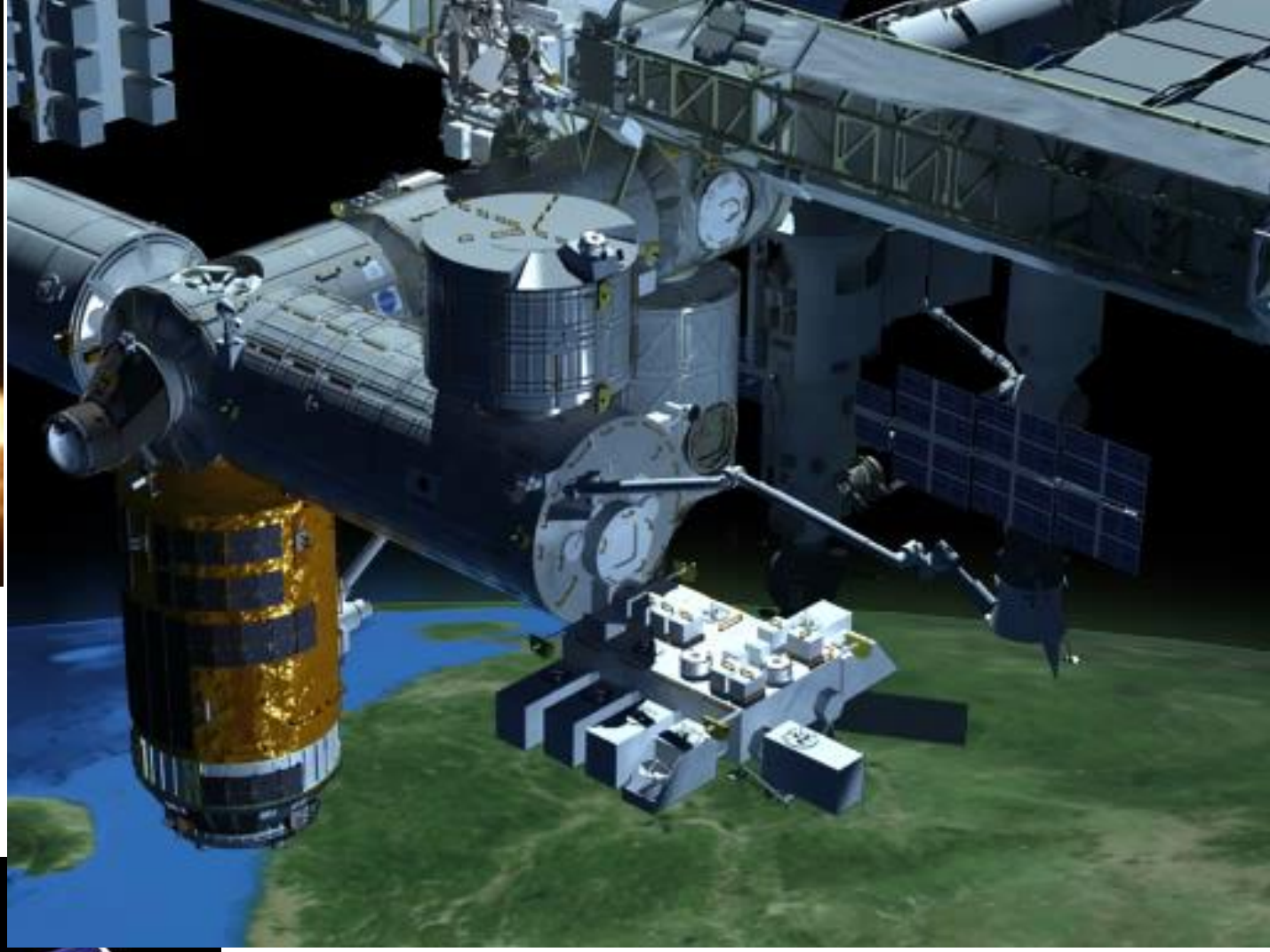
Pressurized Module

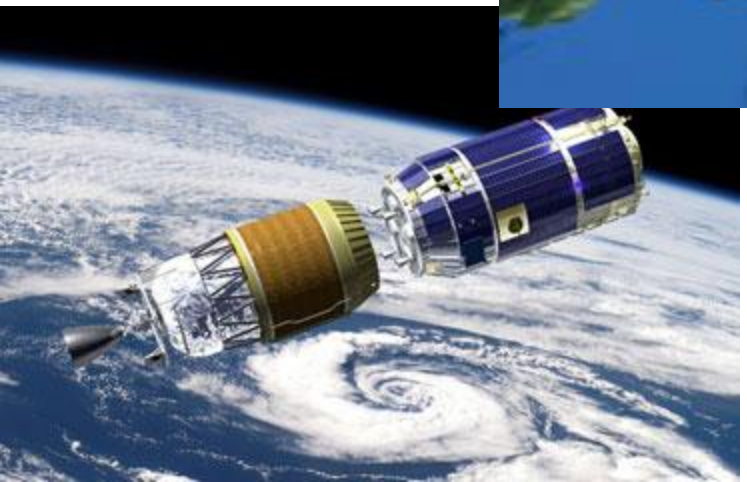
Payload

standard envelope：1.85m×1.0m×0.8m
mass : less than500kg

ELM/ES

Recycling of payload

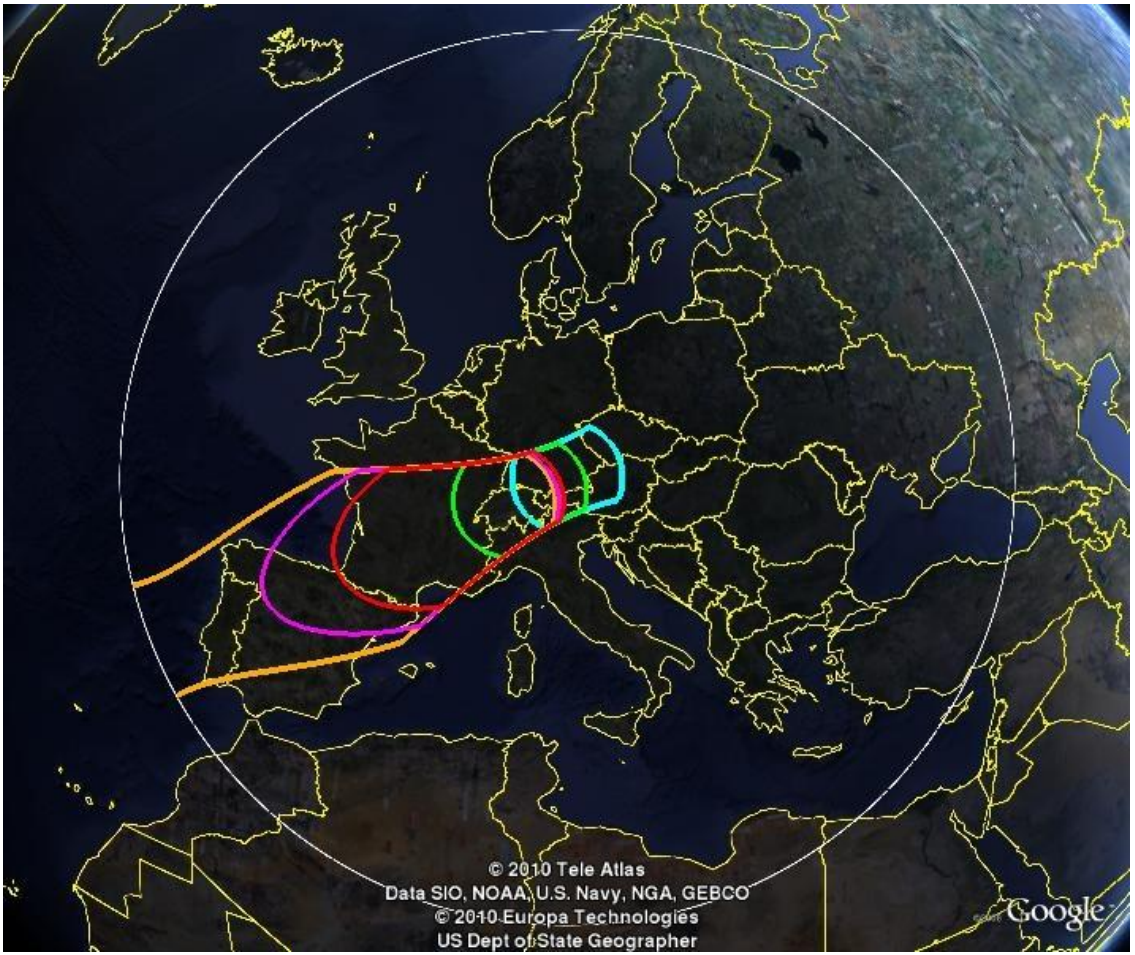


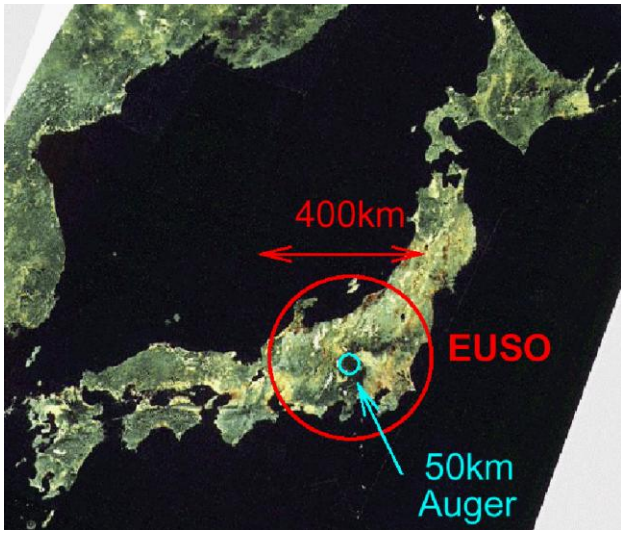


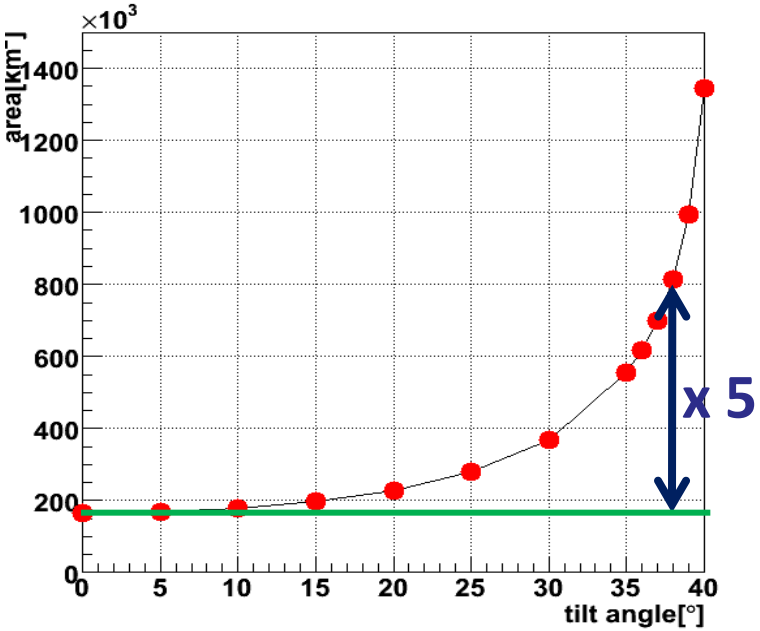
Successful Launch of HTV

September 11, 2009

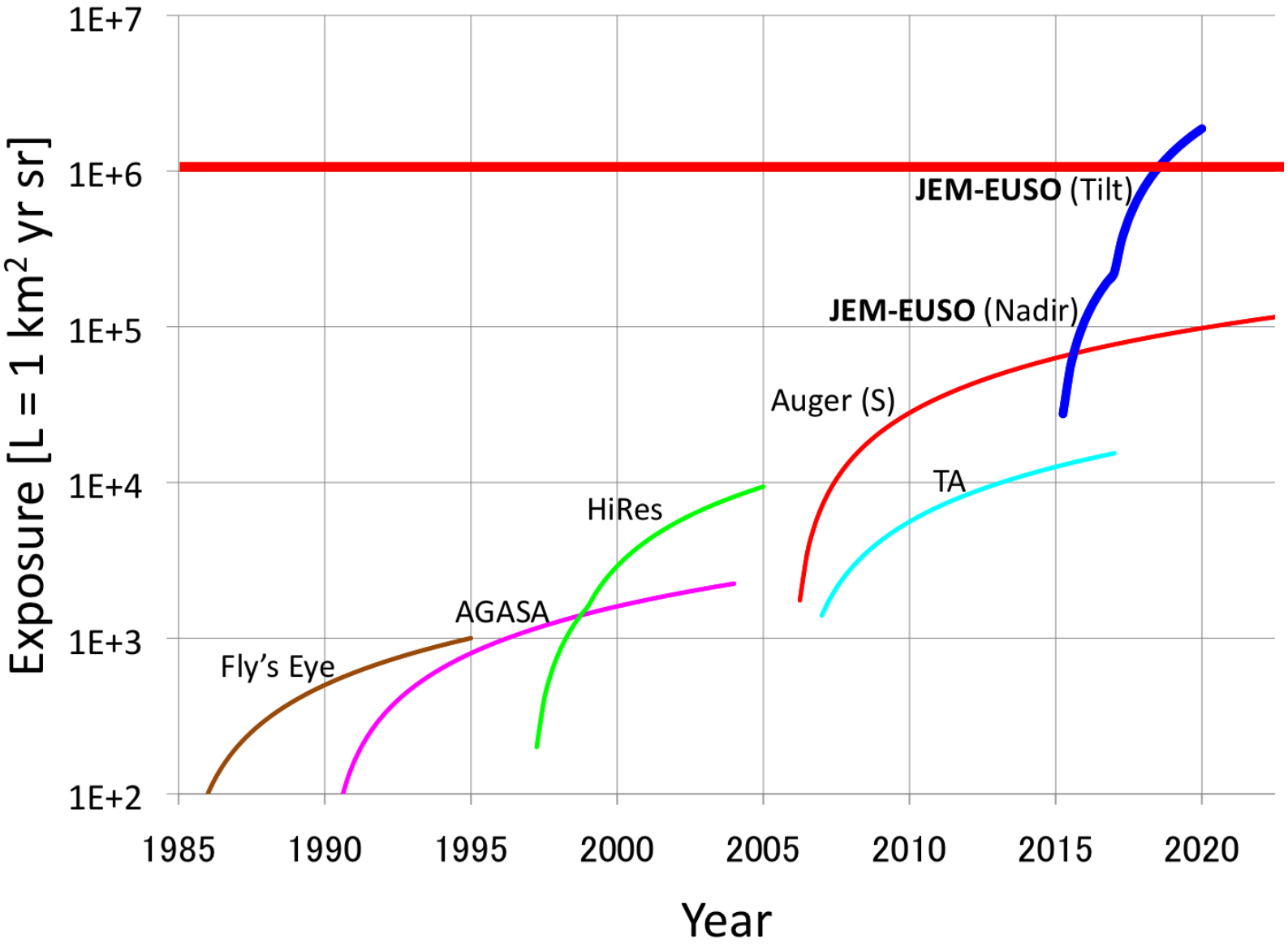
Field of View







Exposure Evolution



Mission Parameters

- Time of launch: year 2015
- Operation Period: 3 years (+ 2 years)
- Launching Rocket : H2B
- Transportation to ISS: un-pressurized Carrier of H2 Transfer Vehicle (HTV)
- Site to Attach: Japanese Experiment Module/ Exposure Facility #2
- Height of the Orbit: ~400km
- Inclination of the Orbit: 51.64°
- Mass: 1983 kg
- Power: 926 W (operative), 352 W (non-operative)
- Data Transfer Rate: 285 kpbs

Science Objectives

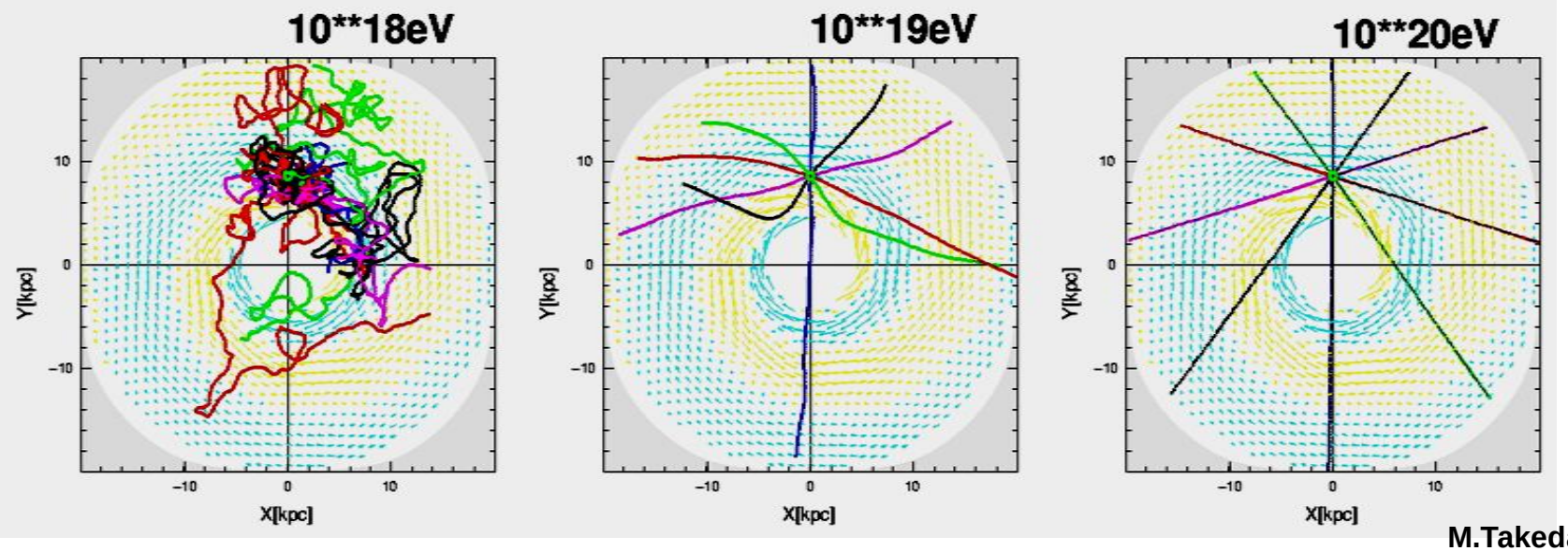
- **Fundamental Objective**

  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

$E>10^{20}$ eV particles do not bent

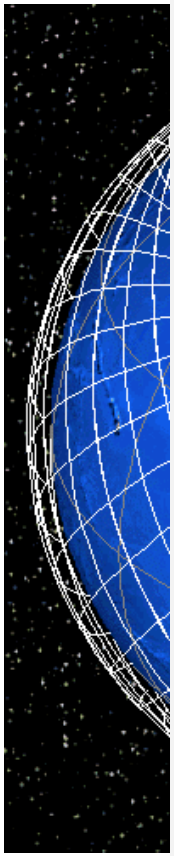


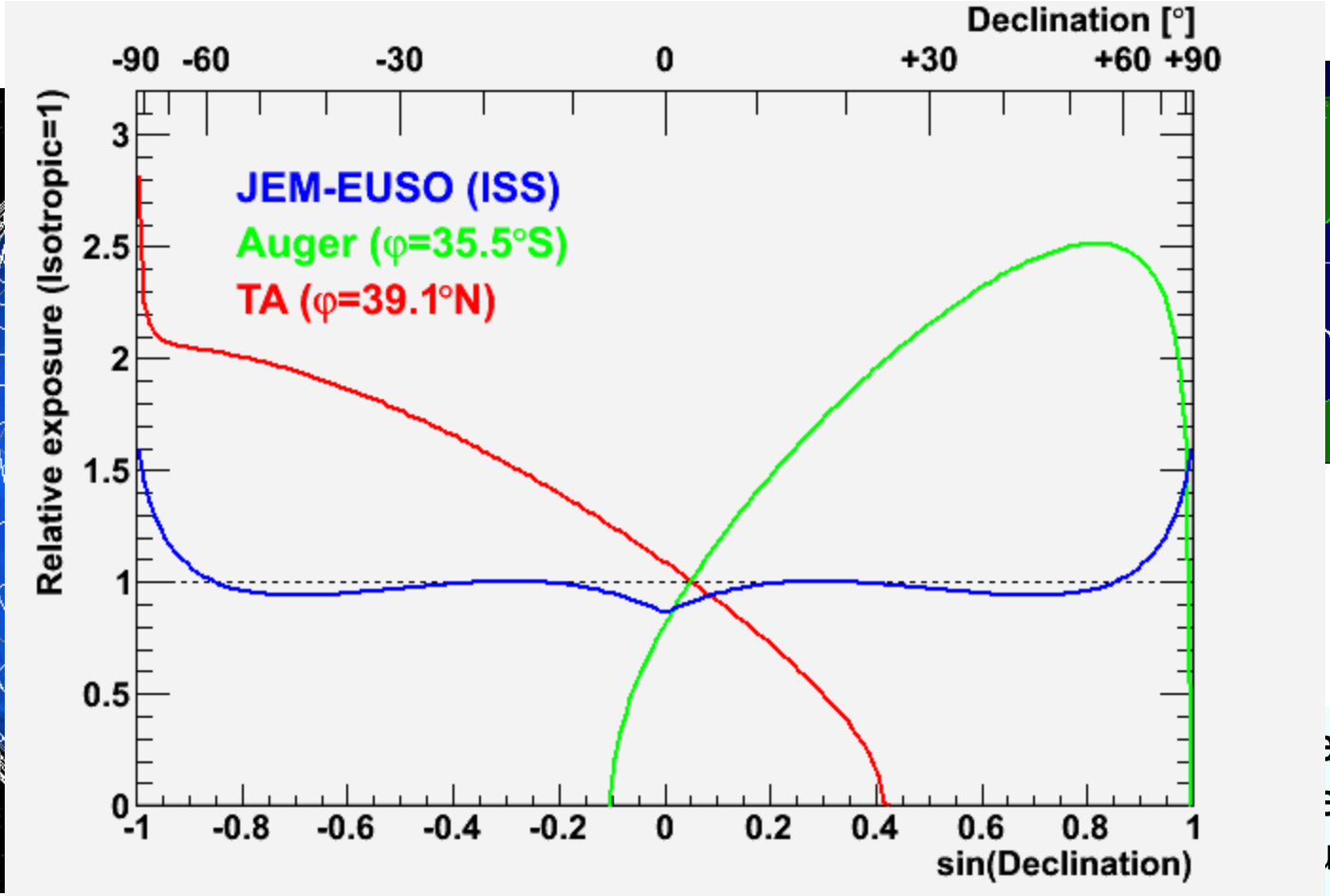
M.Takeda

銀河内の伝播シミュレーション

We can specify origin of EECRs by arrival direction

ISS Orbit



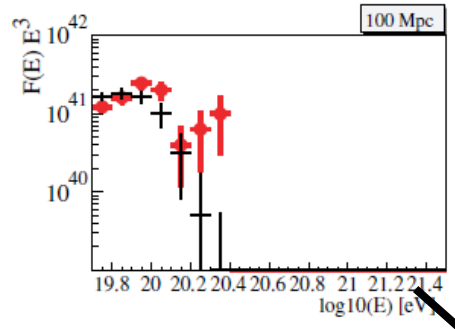


http://www.nlsa.com/

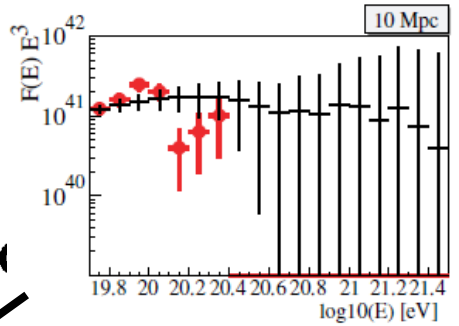
of the ISS orbit.

Full-Sky Coverage

Arrival Map



シミュレーション



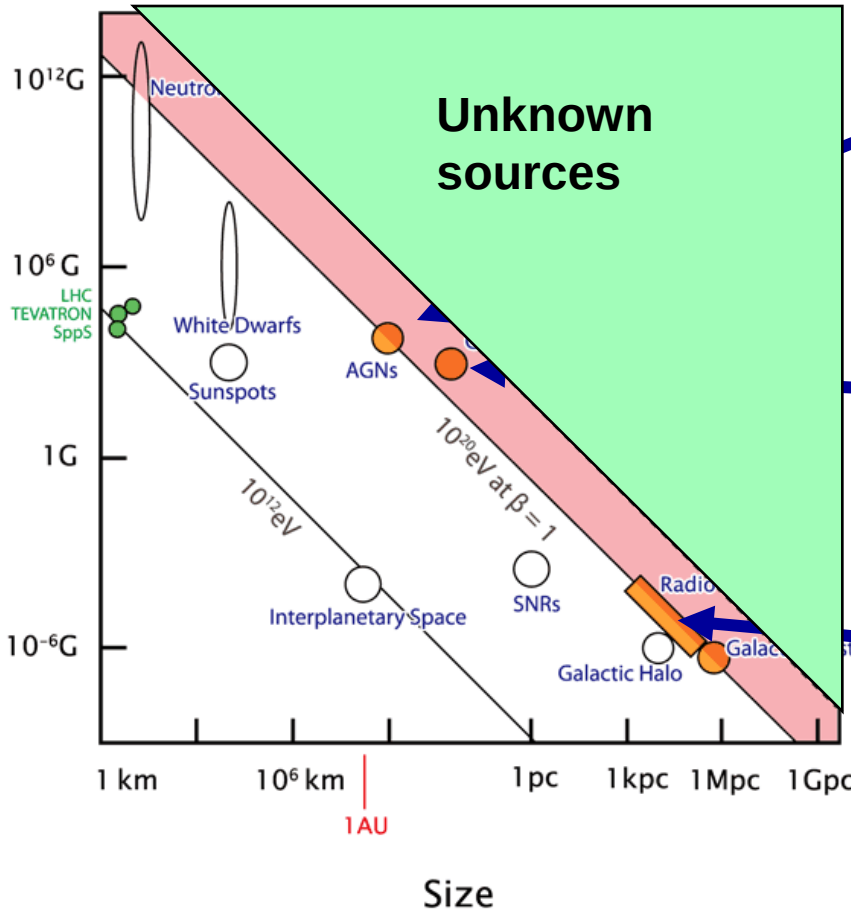
- Identify the sources
- Confirmation of GZK
- Clarify acceleration mechanism

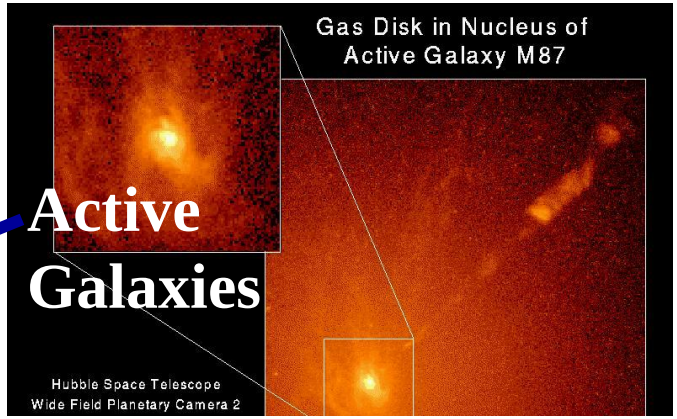
STAR Burst Galaxies

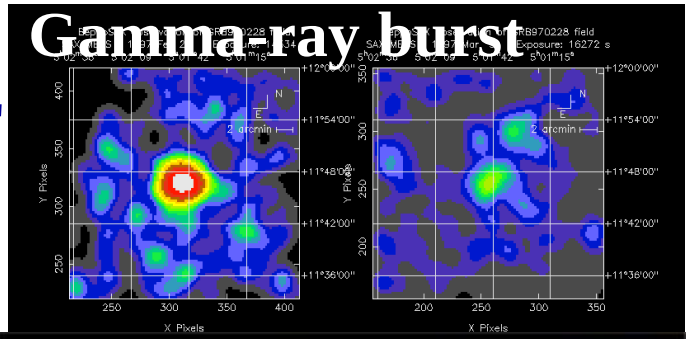
Possible Sources

Blackhole related objects

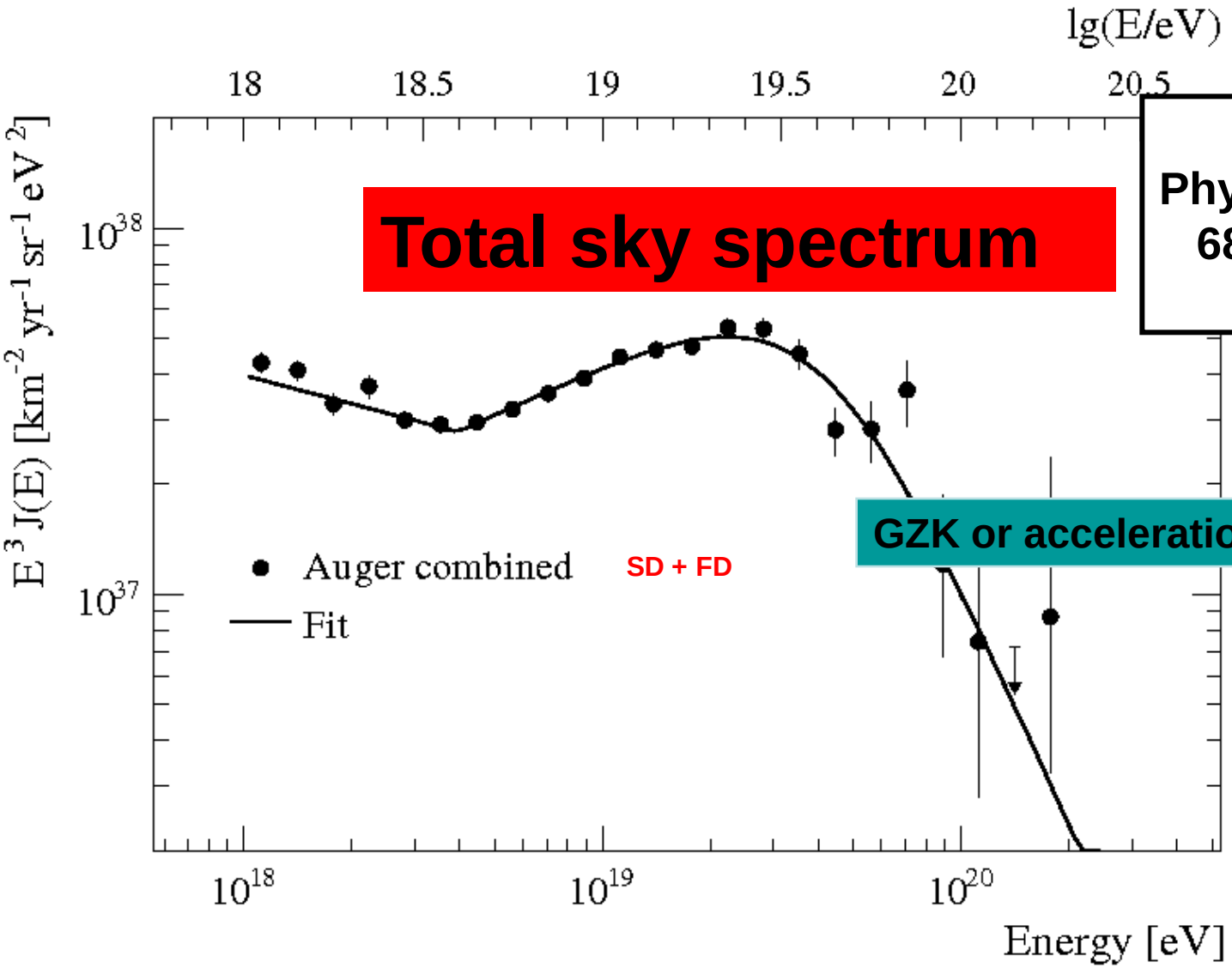
New mechanism of acceleration







Energy Spectrum from Auger Observatory



Total sky spectrum

Physics Letters B
685 239 2010

GZK or acceleration limit?

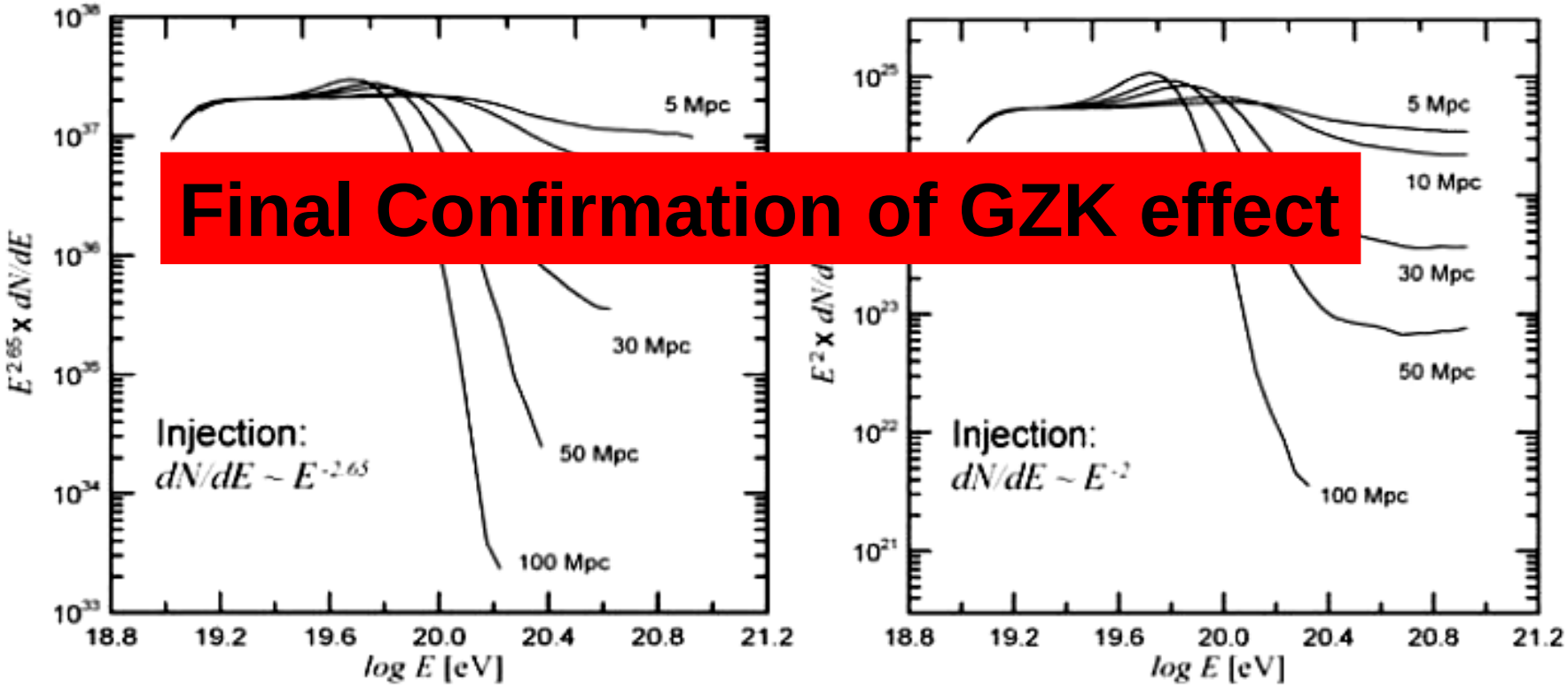
Schuessler

HE 0114

Above 3 x 10^{18} eV, the exposure is energy independent: 1% corrections in overlap region

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.



Final Confirmation of GZK effect

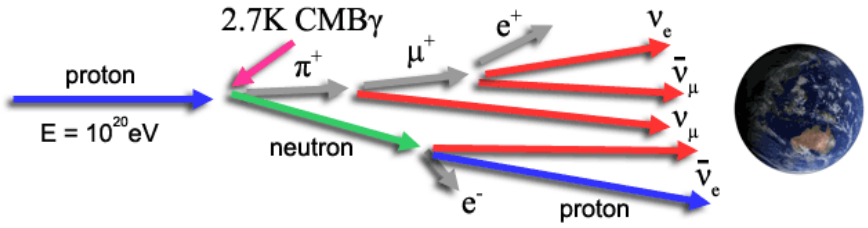
Medina-Tanco 2008

JEM-EUSO as gamma ray & neutrino observatory

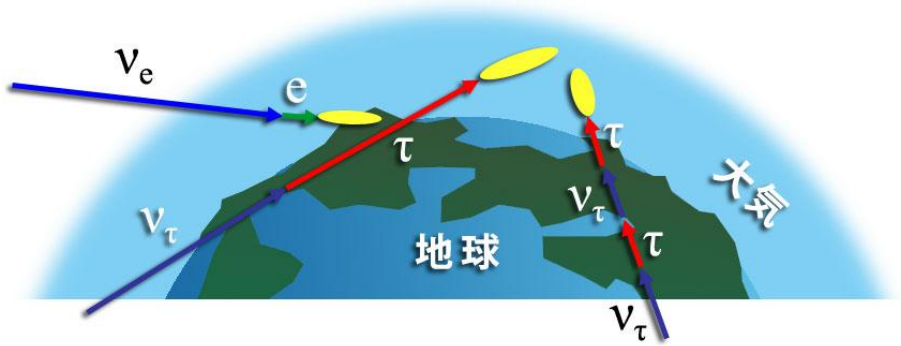
- **International Space Station-aboard EECR observatory**
  - Orbiting at ~400 km in ±51.6 degrees latitudes
  - Flight in varying geomagnetic field (~0.6 gauss) around orbit

- 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

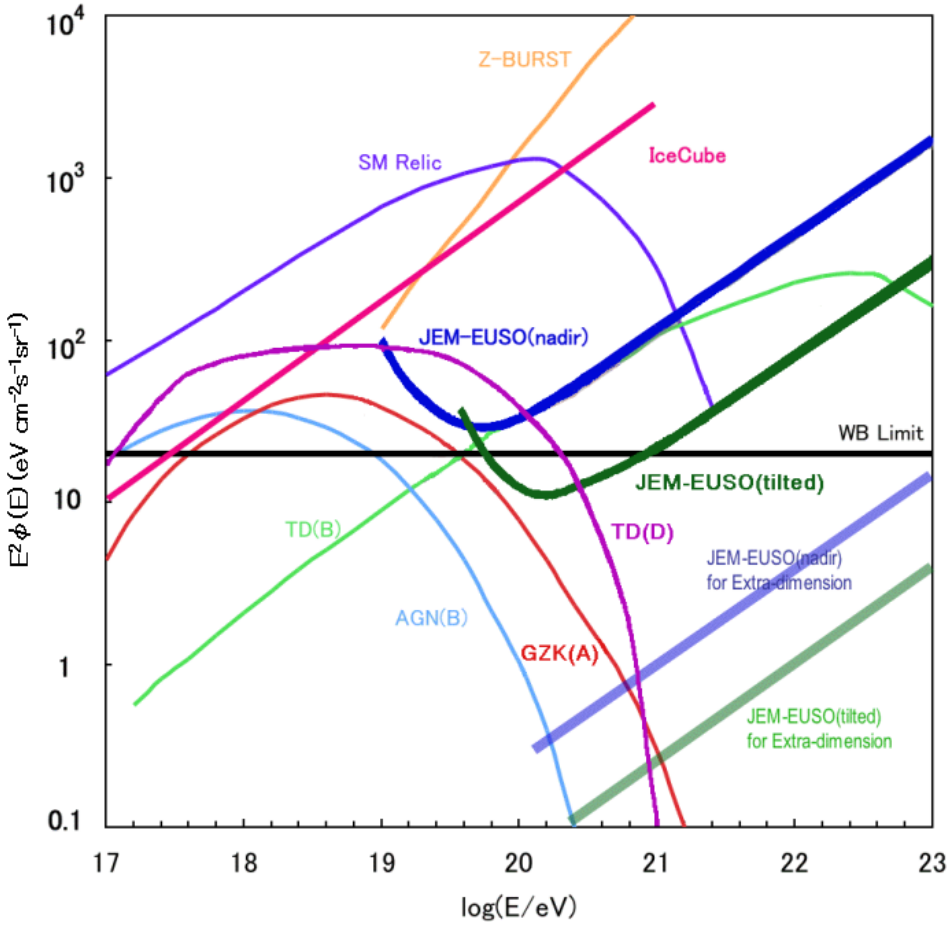
Extreme Energitic Cosmic Neutrinos



Neurino production by the GZK process

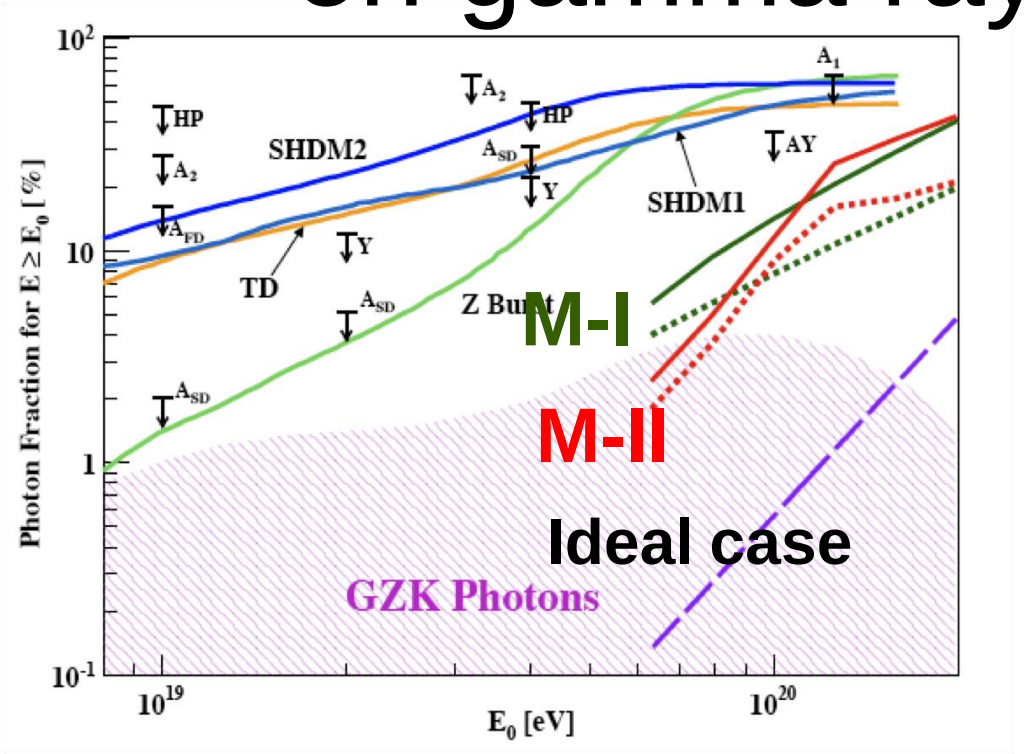


Air showers initiated by different kind of neutrinos



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

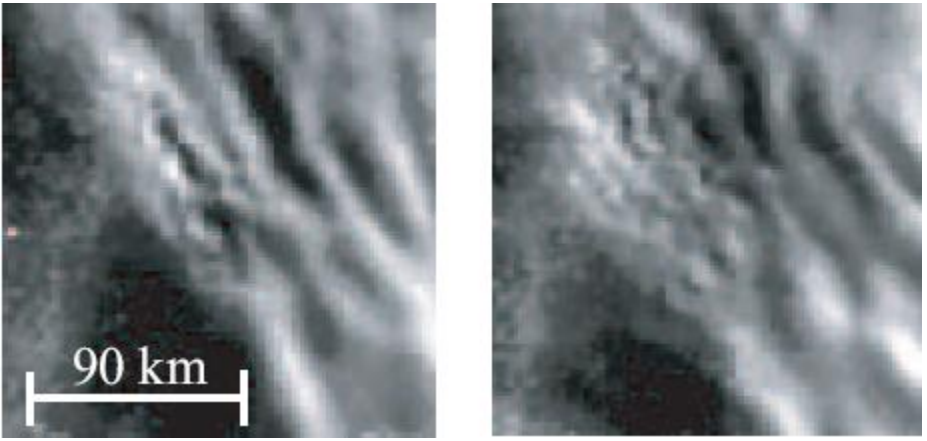
Expected sensitivity on gamma ray fraction



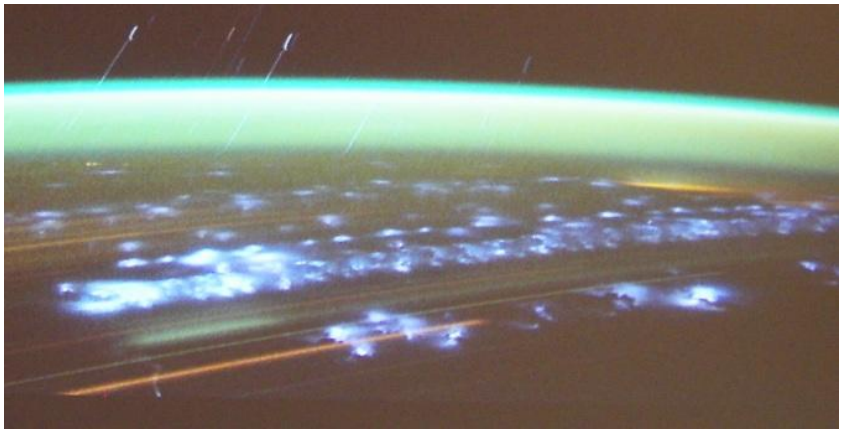
Expected limit by 5 year mission compared with upper limits set by existing experiments (95%CL)

- Ideal case (only statistics): Xmax strong discriminator for gamma ray
- More realistic estimate (assumed experimental errors in *X*max) using 2 different approaches to evaluate flux limit
  → New and stringent limit expected @ the highest energies (~10^{20}eV)
  - Possible detection of GZK photons during the Mission

Atmospheric Luminous Phenomena

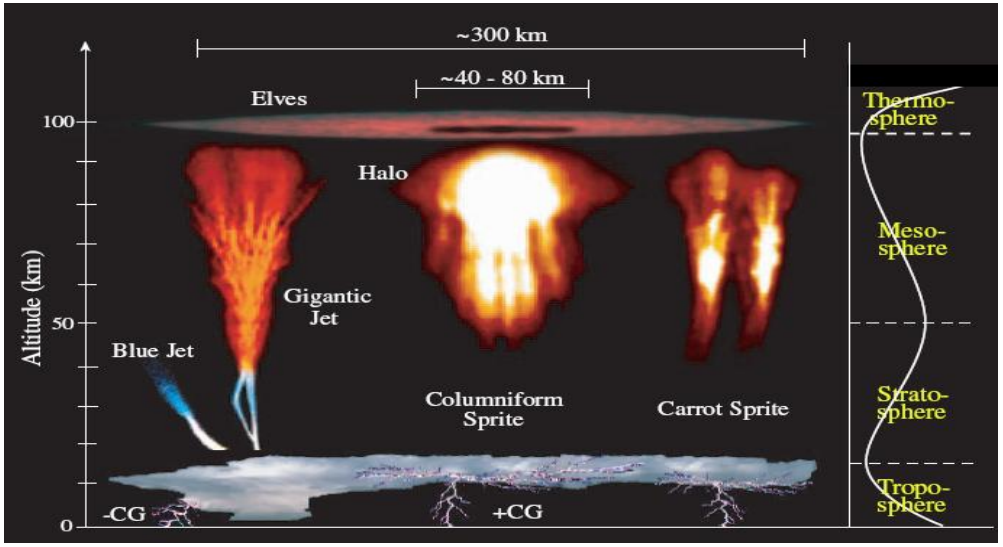


OH airlow observed from ground



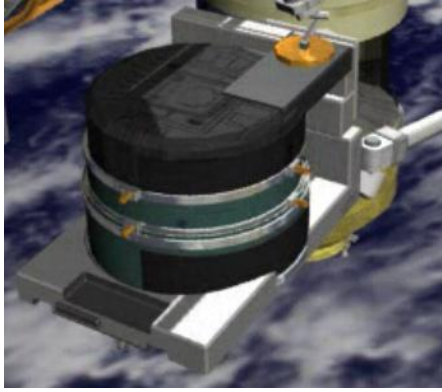
Lightning picture observed from ISS

Leonid meteor swarm in 2001 taken by Hivison

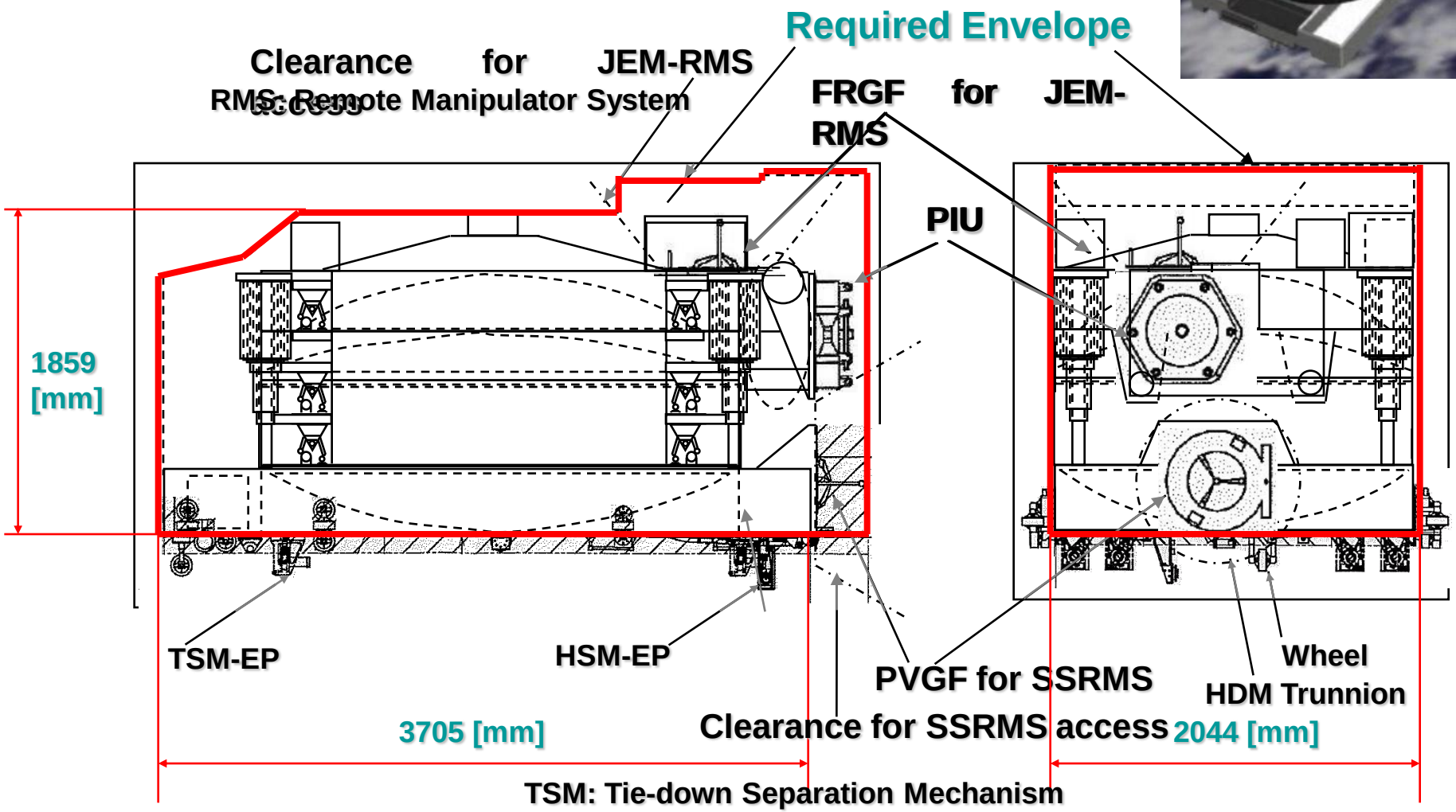


Various trangent airglows

JEM-EUSO Launch Configuration

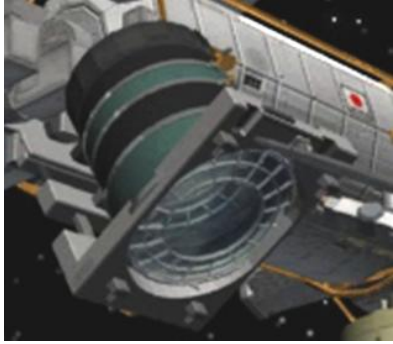


JEM-EUSO telescope will be squeezed at launch.

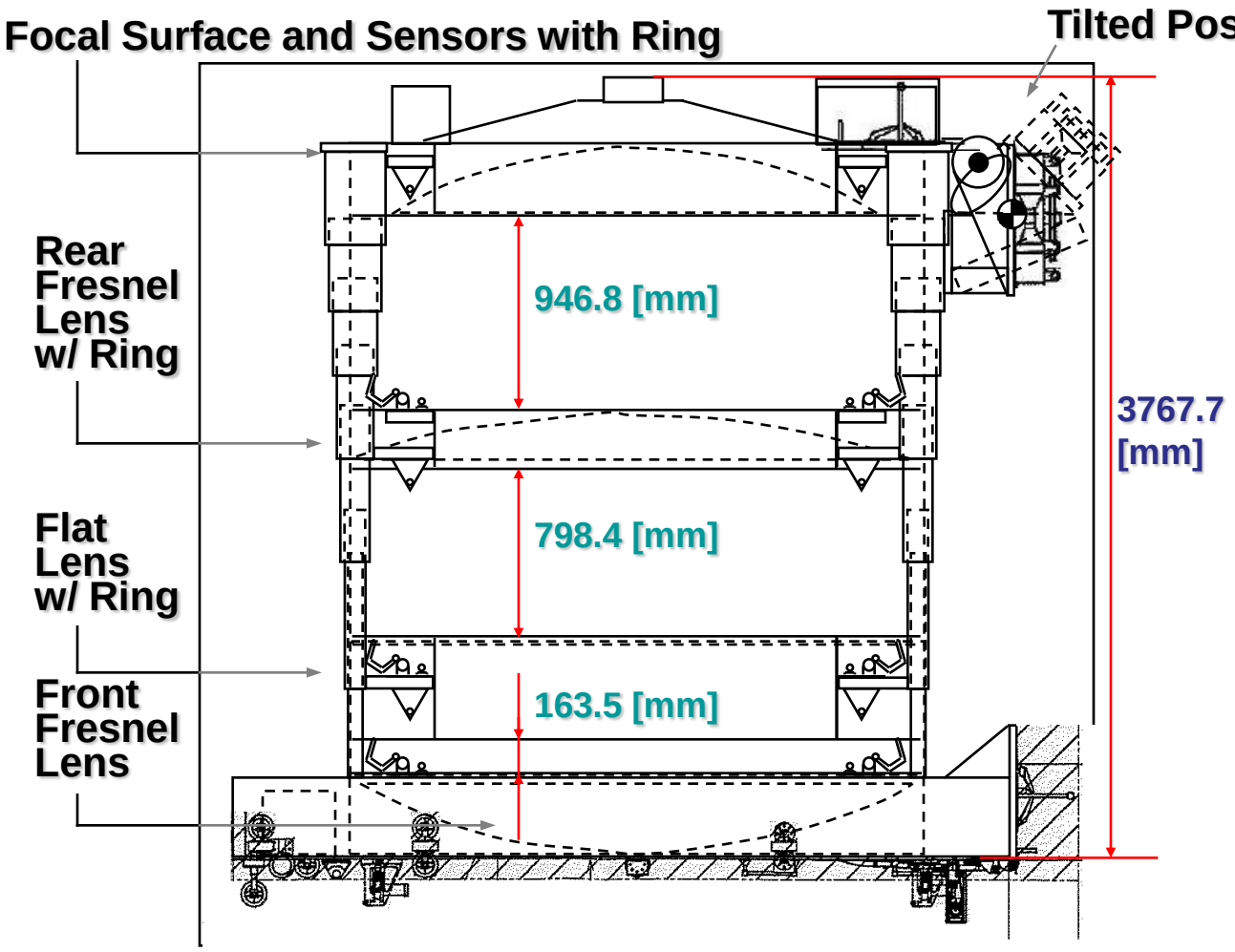


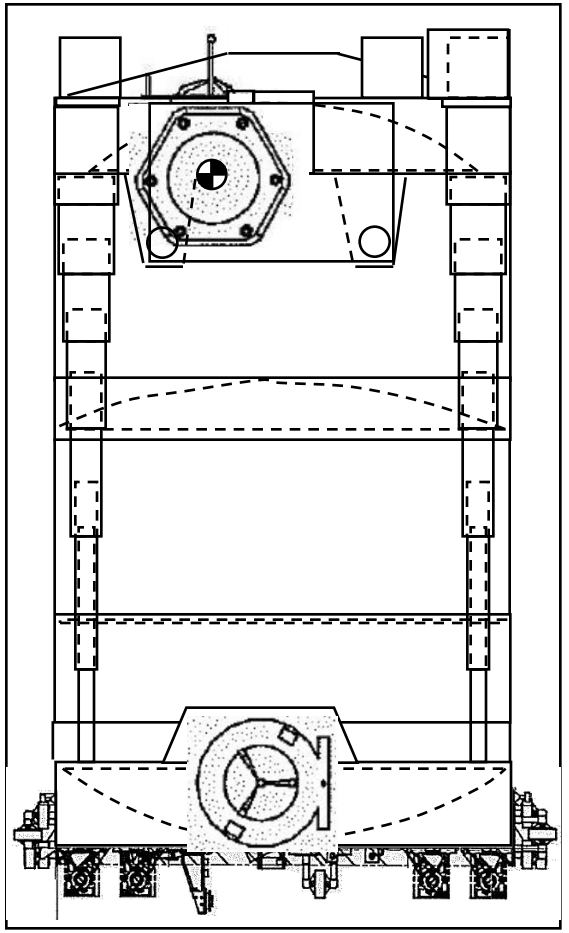
TSM: Tie-down Separation Mechanism
HSM: Harness Separation Mechanism
HDM: Hold Down Mechanism
SS: Space Station

JEM-EUSO On-orbit Configuration



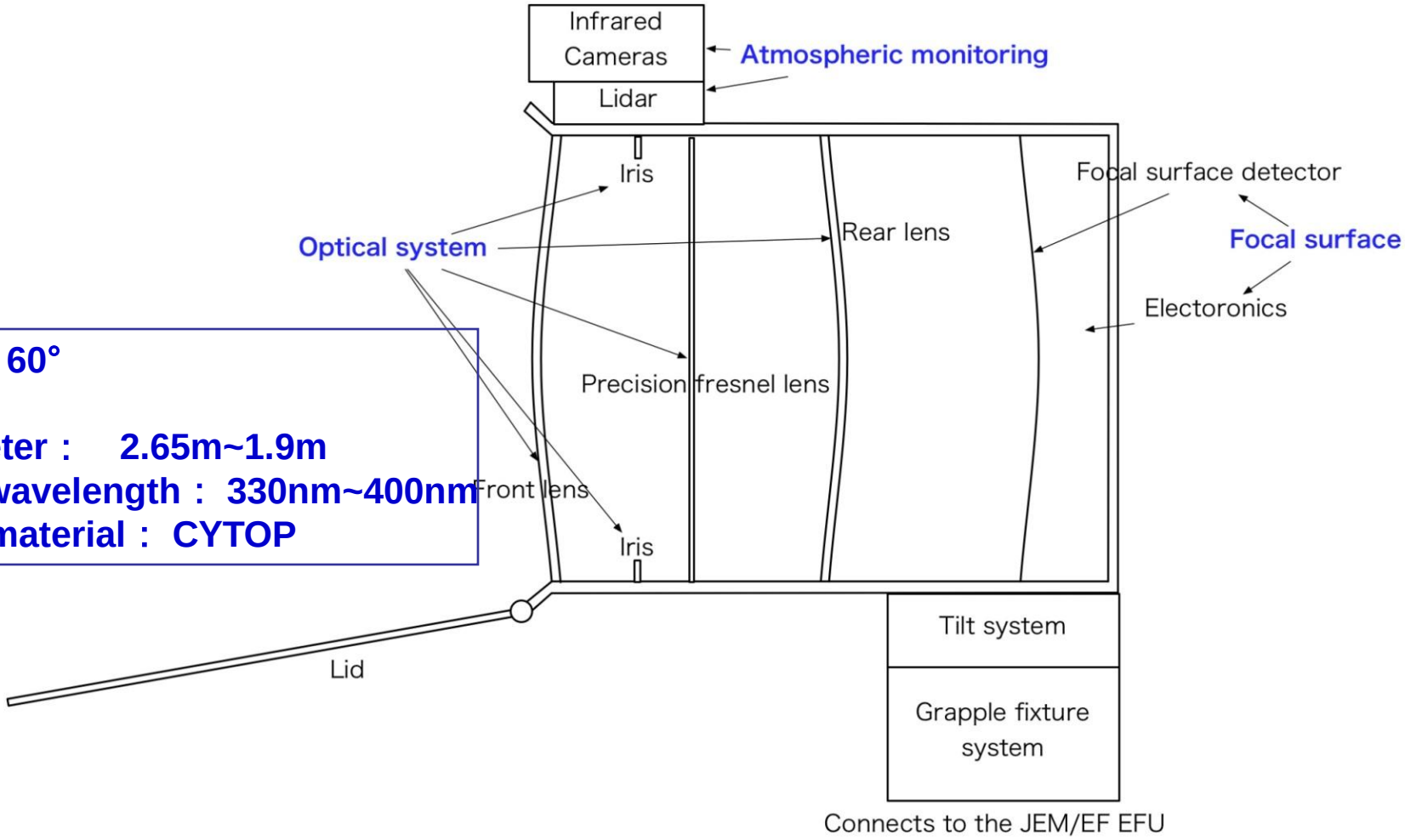
JEM-EUSO telescope will be elongated on orbit.





Telescope Barrel is not shown.

Conceptual View of JEM-EUSO Telescope



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

International Role Sharing

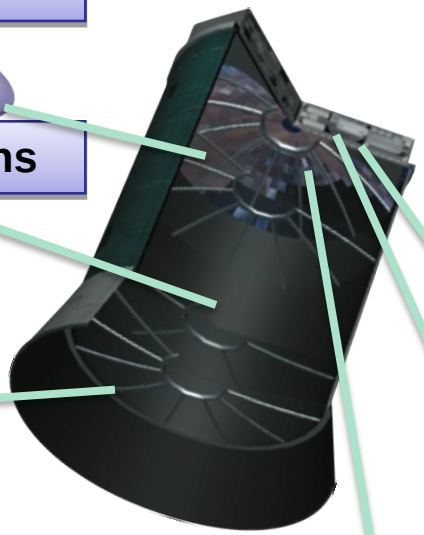
Optics: USA + Japan

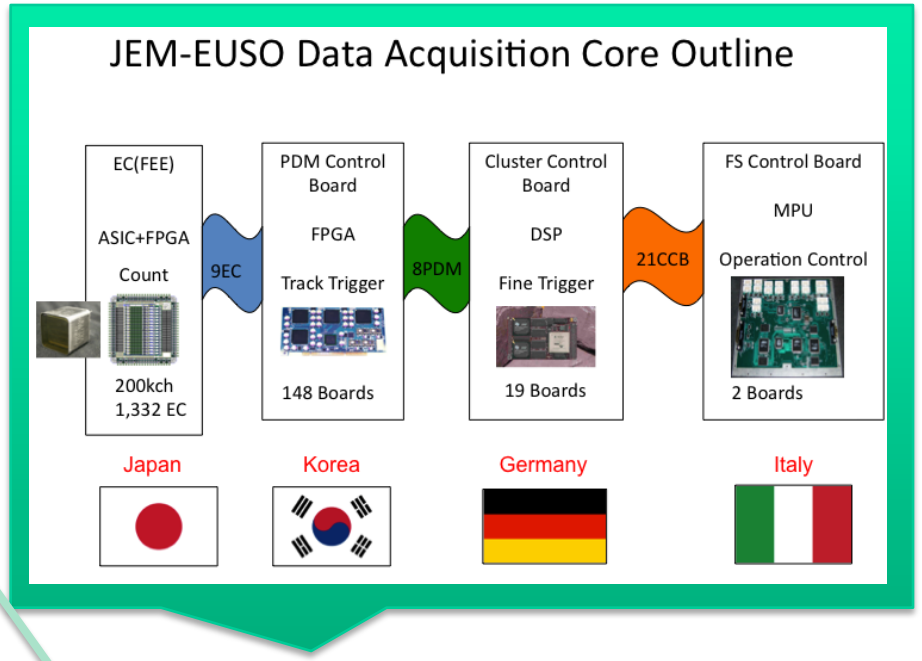
Fresnel Lens #2

Precision Fresnel lens

Iris

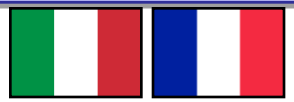
Fresnel lens #1





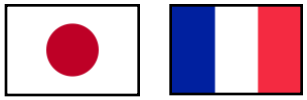
DAQ Electronics

Support Structure: Italy + France



Focal Surface: Japan

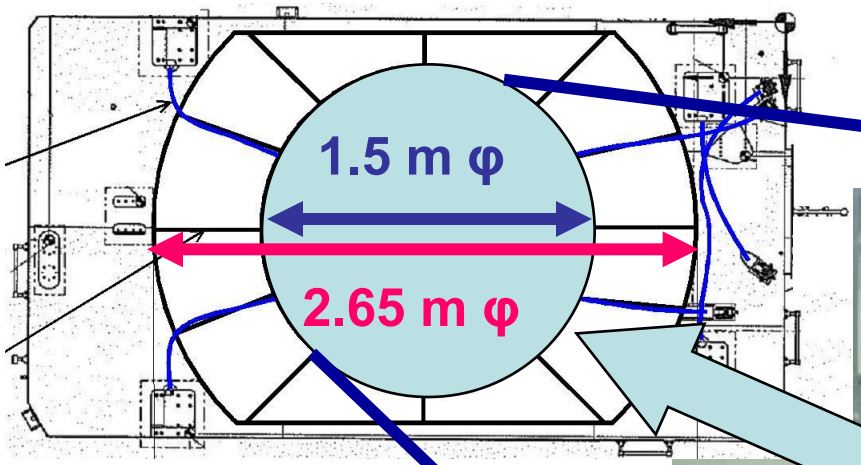
Calibration: Japan + France

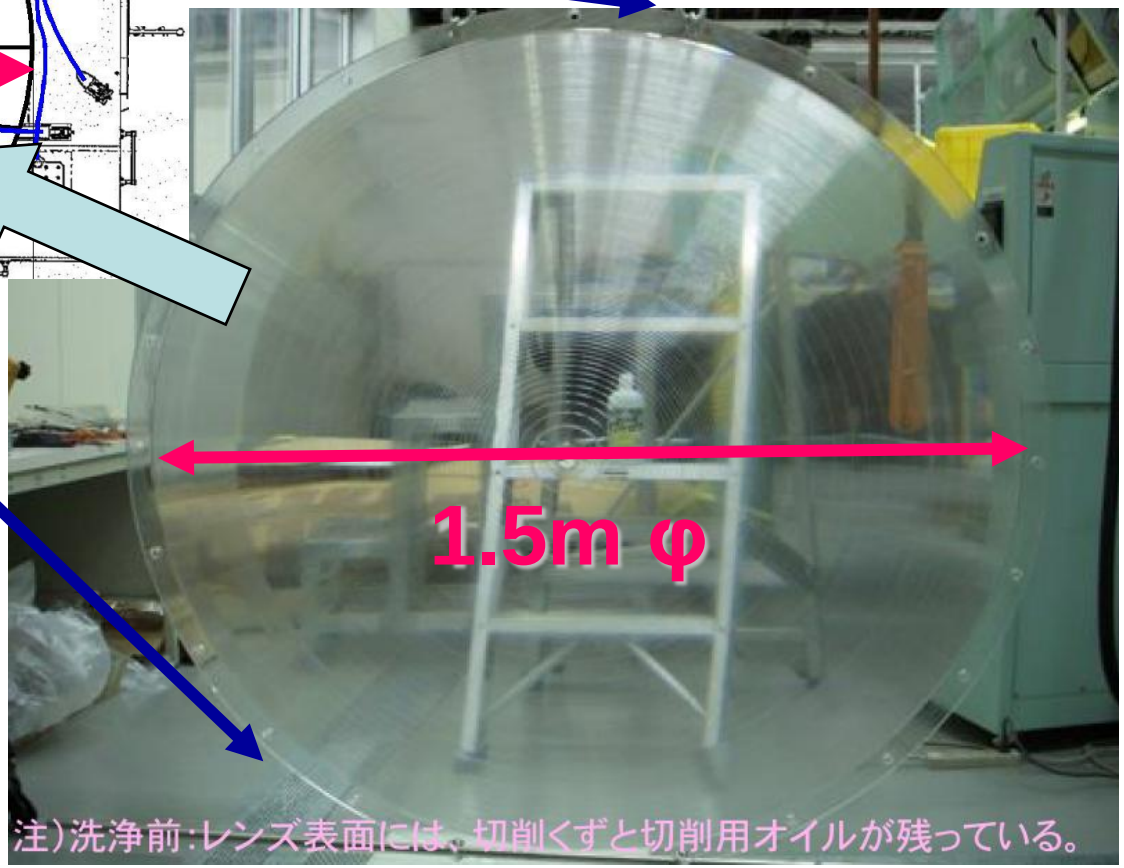


Simulation: Worldwide

Optics

Manufacturing large diameter Fresnel Lens

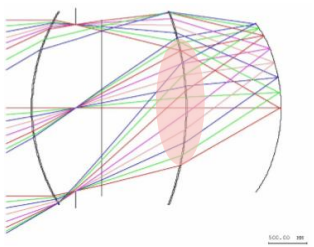


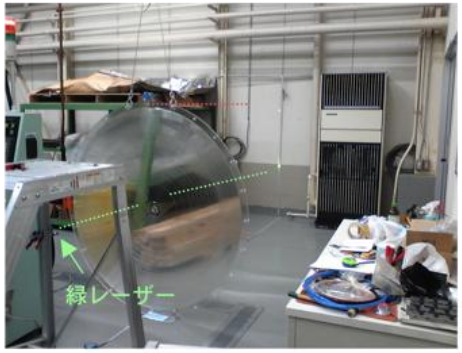


We obtained a cutting machine with a 3.4m dia. turn table to make a 2.65m dia. Fresnel Lens.

リアレンズ（第３レンズ）（2008年末完成）

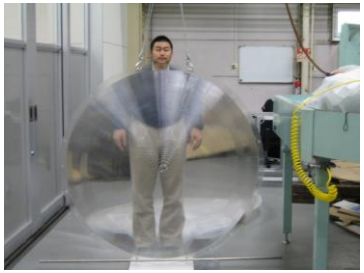
簡易集光テスト（緑レーザー 532nm）

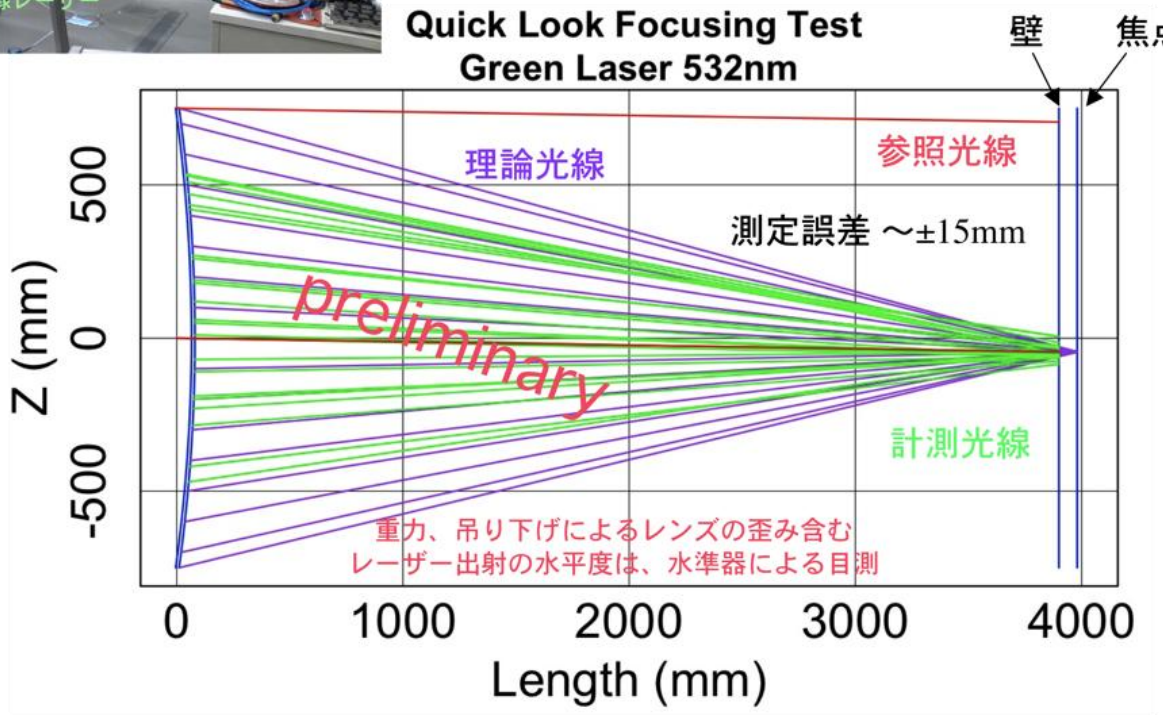




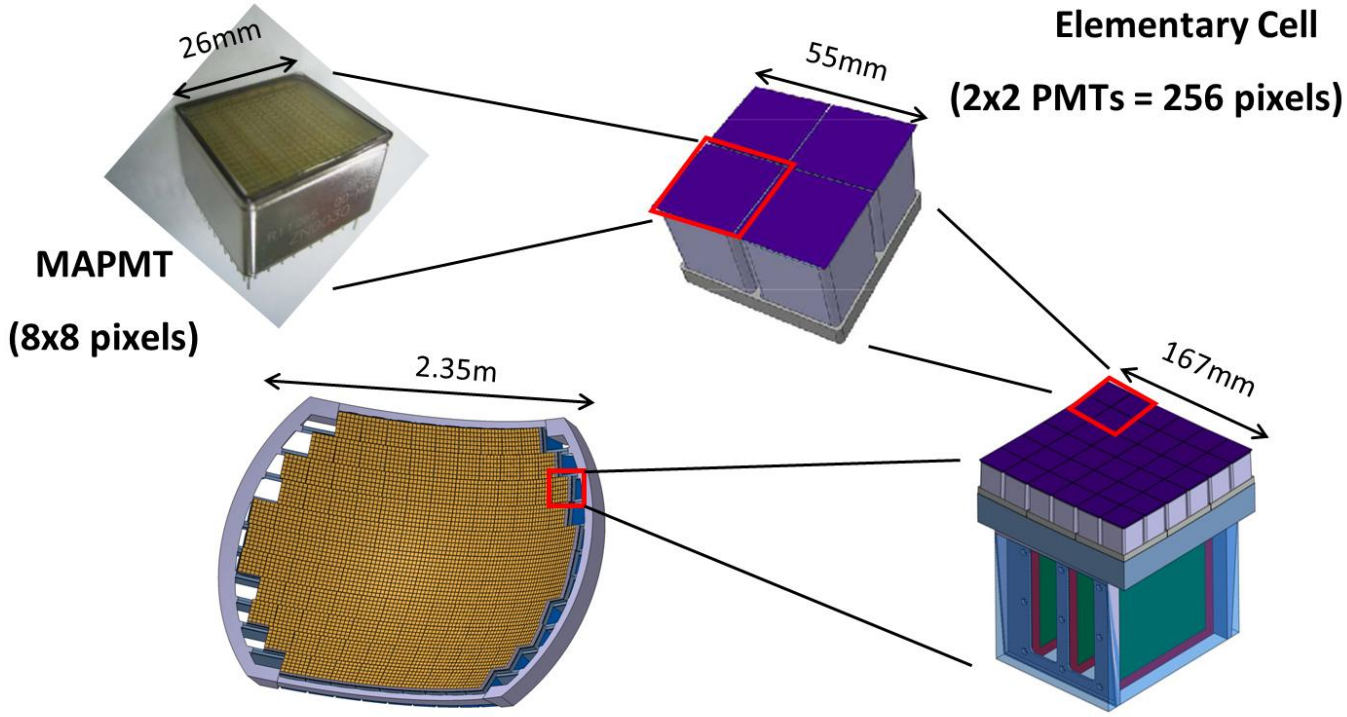
NASAでの詳細光学テストに備え簡易確認

製作パラメタの確認（データの符号など）



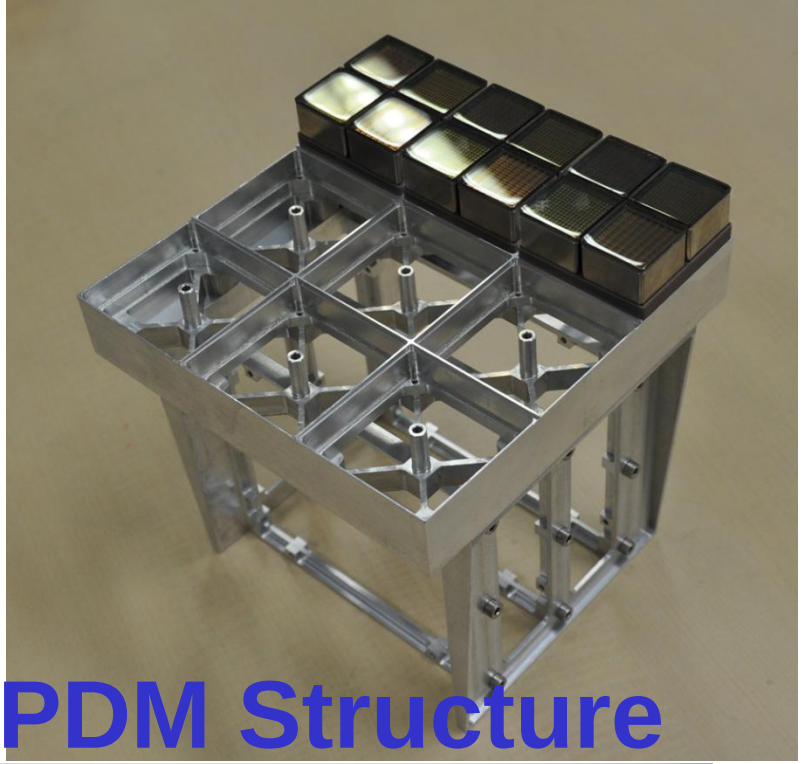


Focal Surface

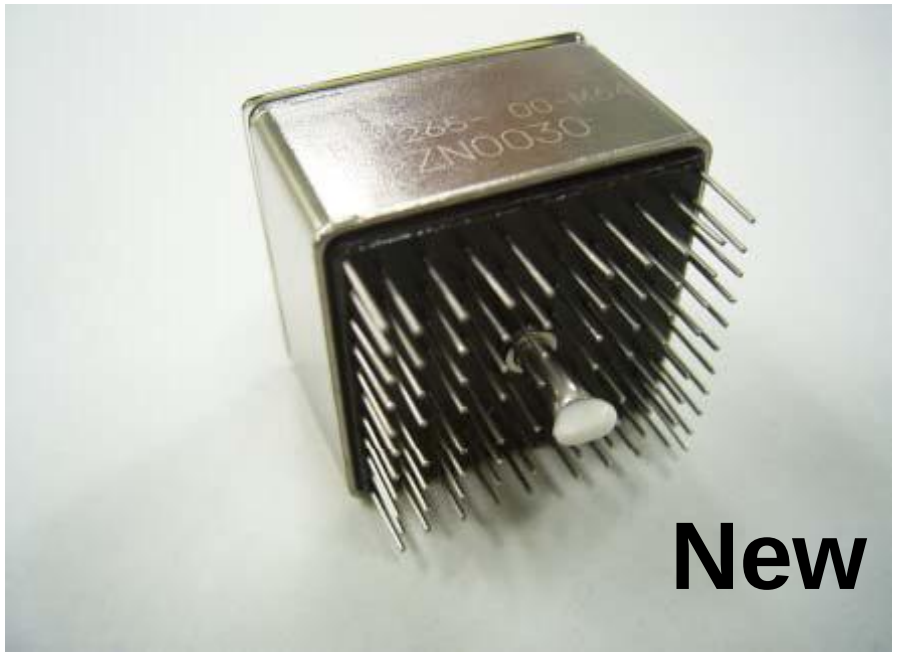


The Module Structure of the Focal Surface Detector

New MAPMT M64 and PDM structure



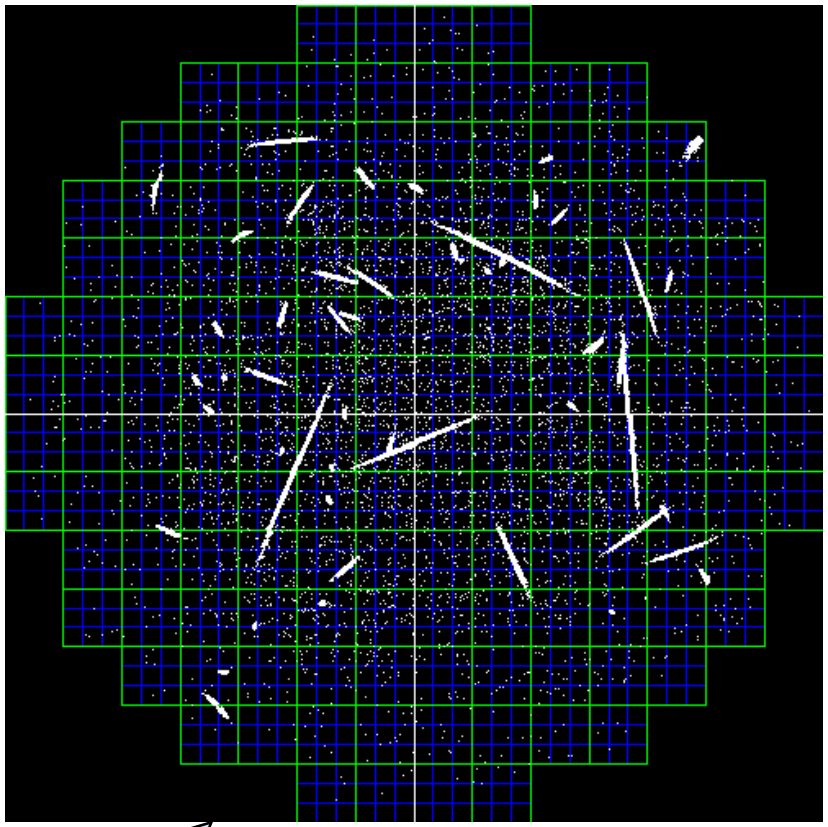
New PDM Structure



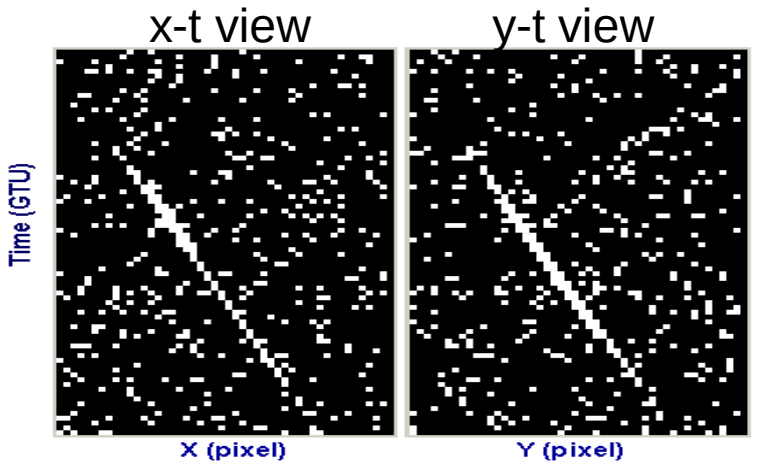
New M64

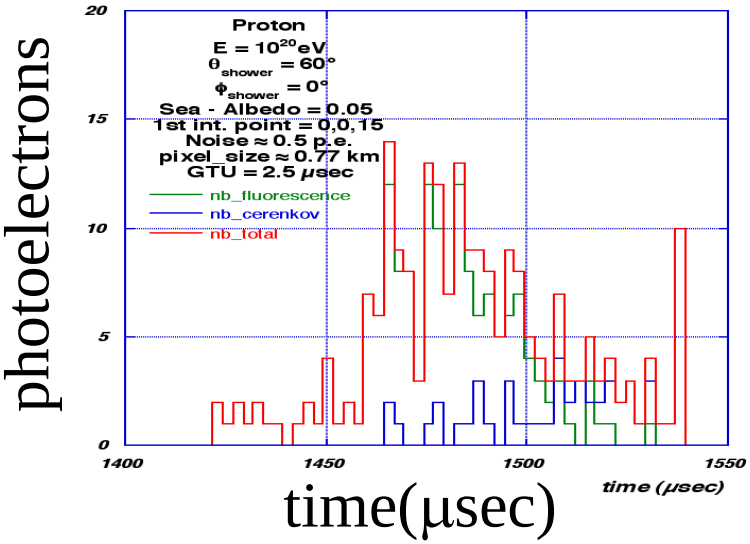
Air shower Image on the Focal Surface

simulation



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

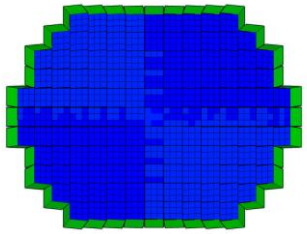


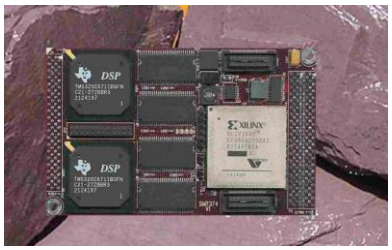


Proton E=10^{20}eV, θ=60º
GTU = 2.5 μsec

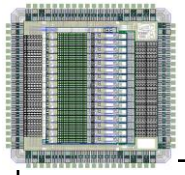
JEM-EUSO DAQ – Data reduction block scheme

9.6 GB/s (FS) — $4*10^{-3}$ compression — 10^{-3} compression → 297 kbps, 3 Gbyte/day





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



FEE

ASIC+ FPGA

Count

200kch
1,476 EC

9EC

PDM Control Board

FPGA

Track Trigger

160 Boards

8PDM

PhotoDetector Modules

Cluster Control Board

DSP

Fine Trigger

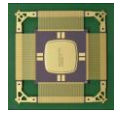
20 Boards

20CCB

FS Control Board

MPU

Operation Control



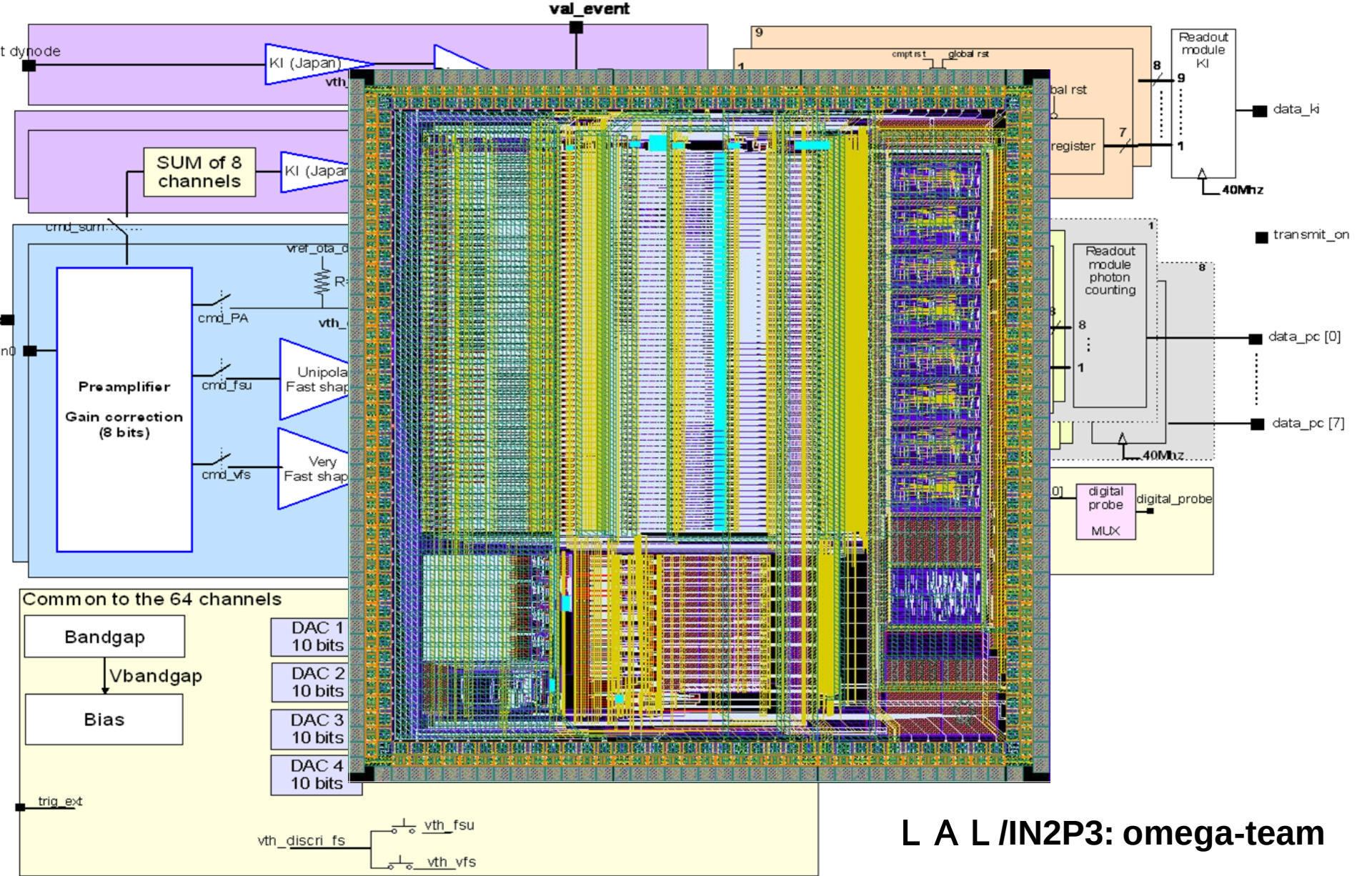
2 Boards

LVDS with SpaceWire (ECSS-E-50-12A)

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

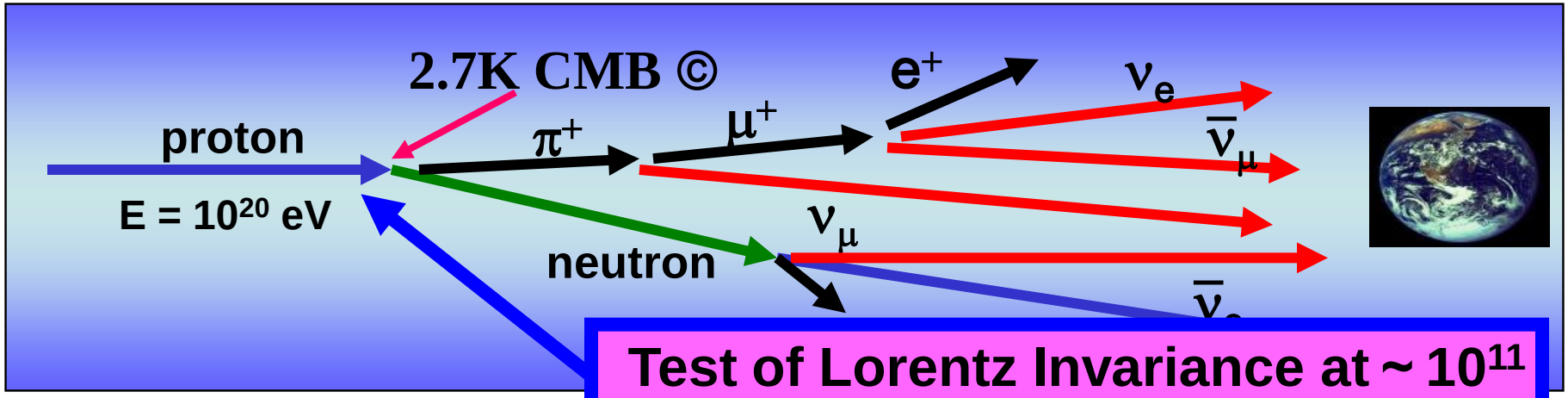
Read-out ASIC : SPACIROC



L A L /IN2P3: omega-team

Greisen-Zatsepin-Kuz'min Process

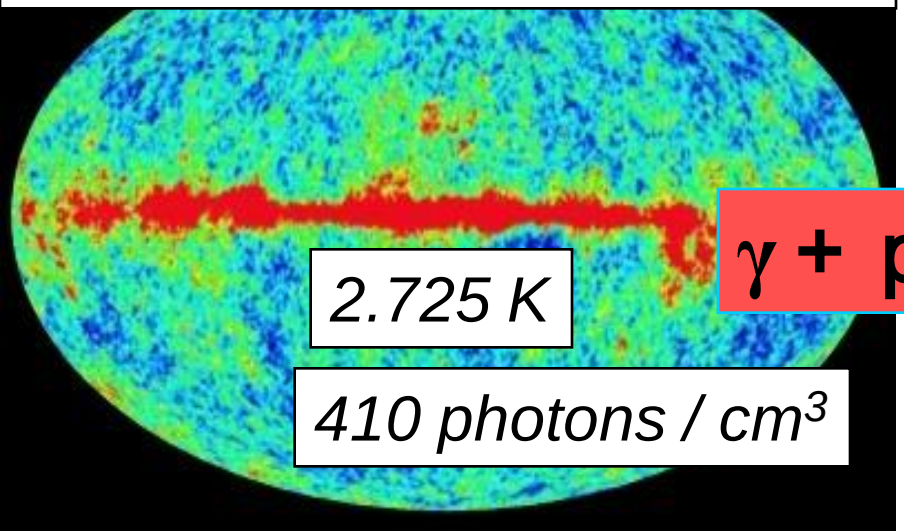
Greisen1966; Zatsepin and Kuz'min1966

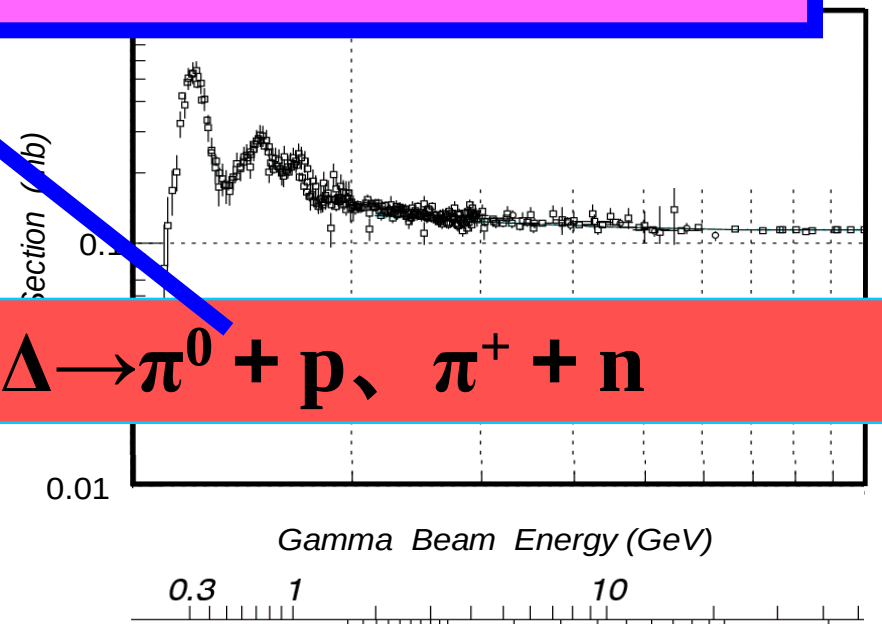


Test of Lorentz Invariance at ~ 10^{11}

Sato and Tati 1972

Microwave Cosmic Backgro
Radiation





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

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 ($\gamma \sim 10^{11}$)
  - Detection of UHE 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 is foreseen in 2015