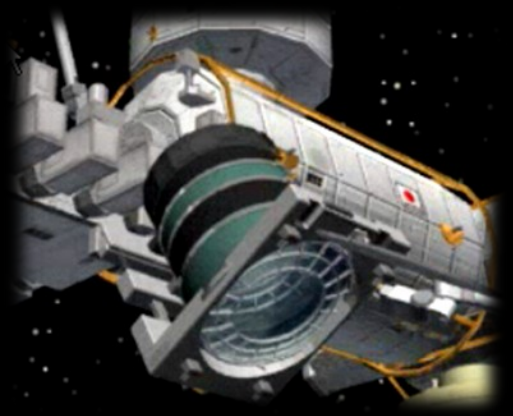


Extreme **U**niverse **S**pace **O**bservatory
on **J**apanese **E**xperimental **M**odule

JEM-EUSO Mission to explore Extreme Universe

Kenji Shinozaki
RIKEN (Wako, Japan)
for the JEM-EUSO Collaboration

TeV Particle Astrphysics 2010, Paris

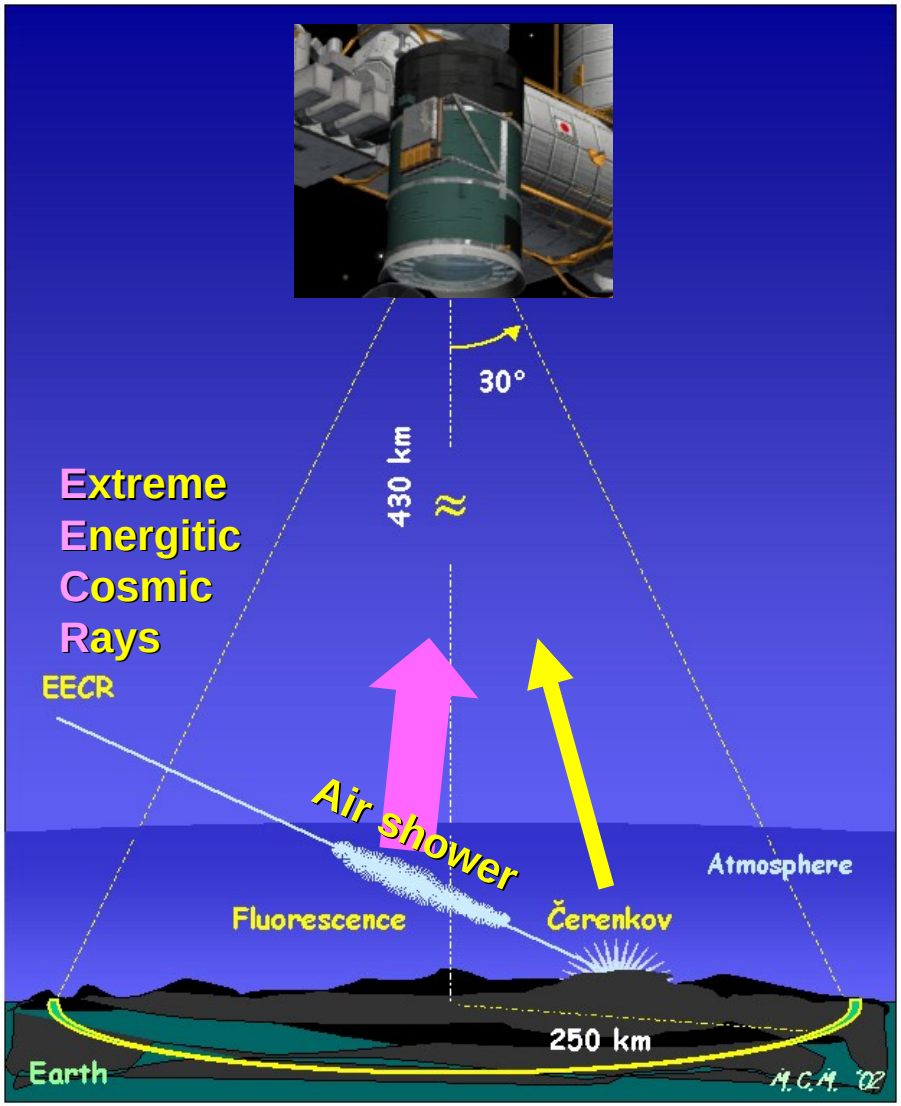
20 July, 2010

JEM-EUSO Collaboration

12 countries, 62 institutions, 170 members + New members

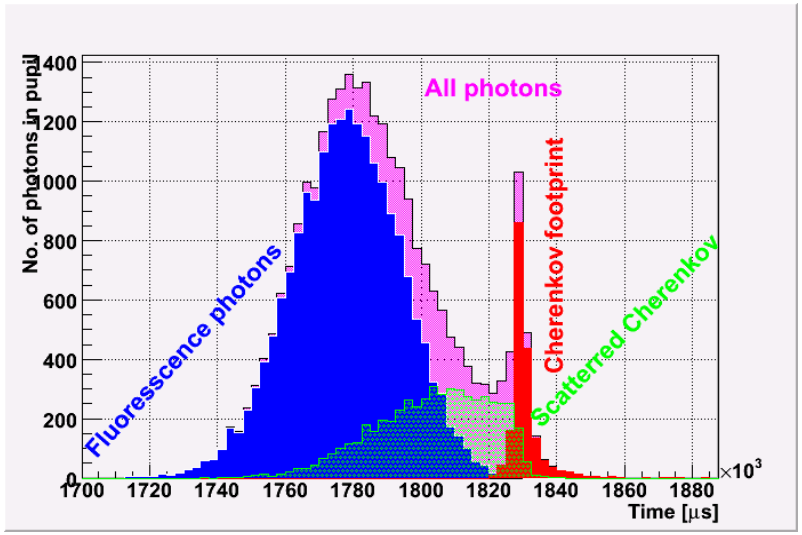
- **Japan** : T. Ebisuzaki, Y. Uehara, H. Ohmori, Y. Kawasaki, M. Sato, Y. Takizawa, K. Katahira, S. Wada, K. Kawai, H. Mase (*RIKEN*), F. Kajino, M. Sakata, H. Sato, Y. Yamamoto, T. Yamamoto, N. Ebizuka, (*Konan Univ.*), M. Nagano, Y. Miyazaki (*Fukui Inst. Tech.*), N. Sakaki, T. Shibata (*Aoyama Gakuin 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)

JEM-EUSO Observation Principle



JEM-EUSO is a new type of observatory for EECRs (extreme energy cosmic rays~10^{20}eV) on board the International Space Station (ISS)

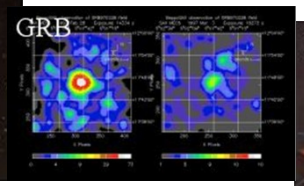
The JEM-EUSO telescope has a super wide field-of-view (60°) and a large aperture (~2.5m diameter)

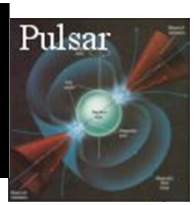


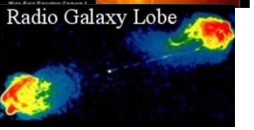
JEM-EUSO telescope observes fluorescence and Cherenkov photons generated by air showers

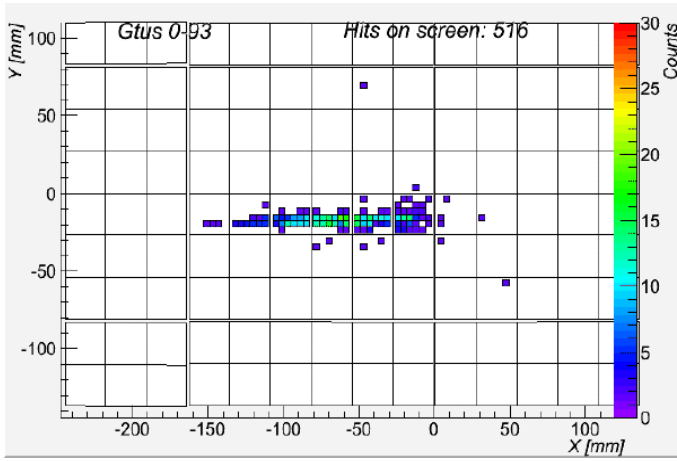
JEM-EUSO

an Astronomical Observatory and Earth Observatory









Typical shower image of FS

EECRs (p,N,g)

Meteors

Ultraviolet photons

Air shower

Air shower

EHE Neutrinos

Atmosphere

Night glow

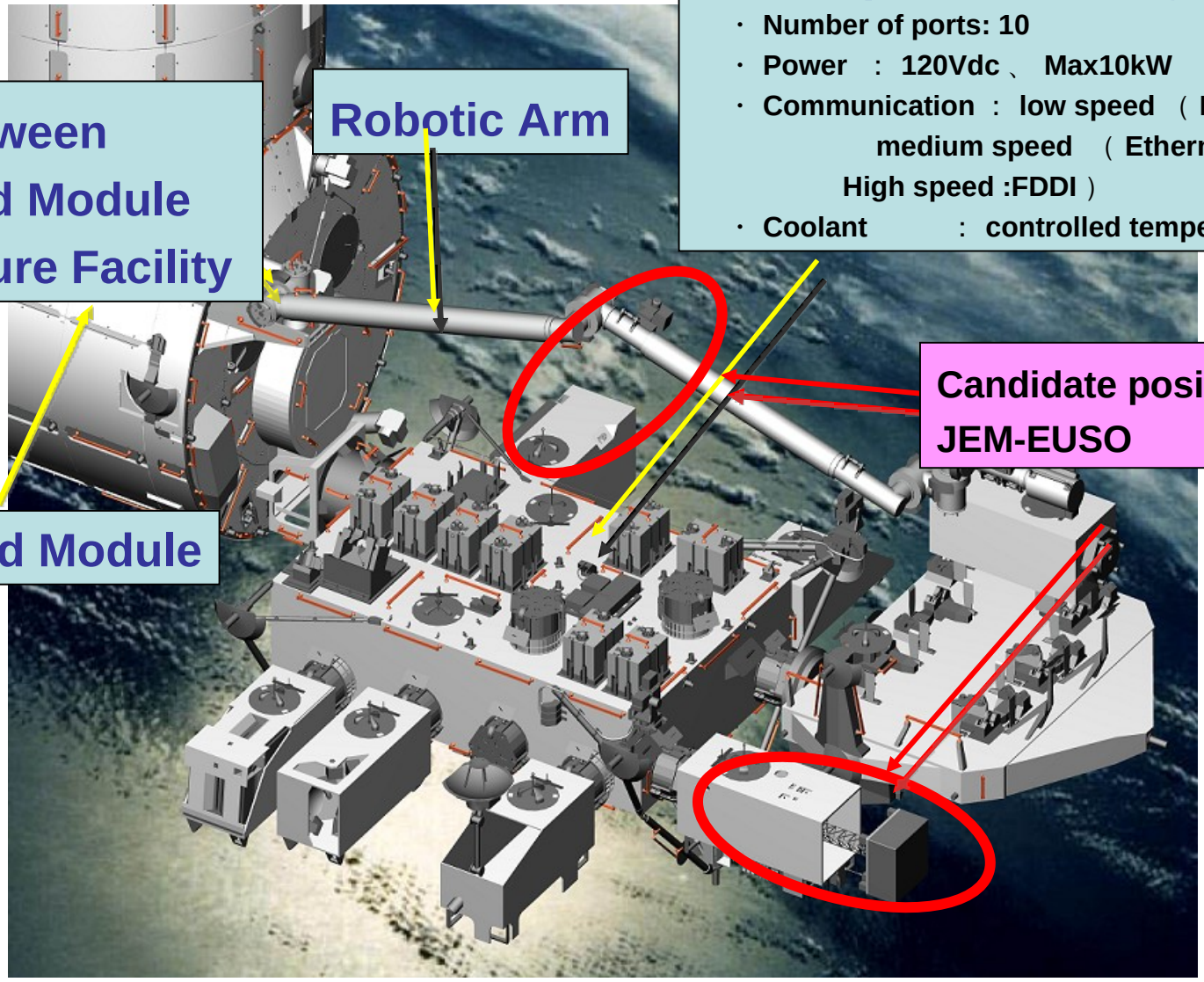
Earth

Plasma Discahrge

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°C

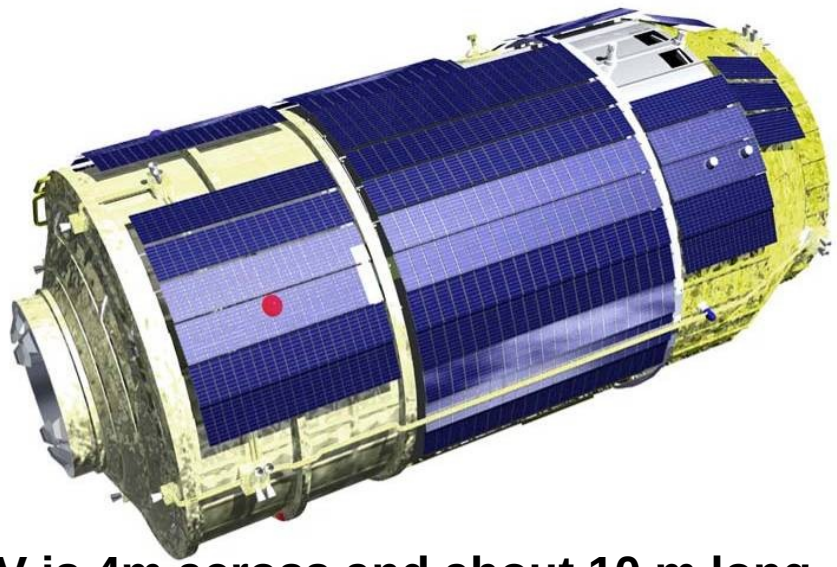
Airlock between Pressurized Module and Exposure Facility

Robotic Arm

Candidate position for JEM-EUSO

Pressurized Module

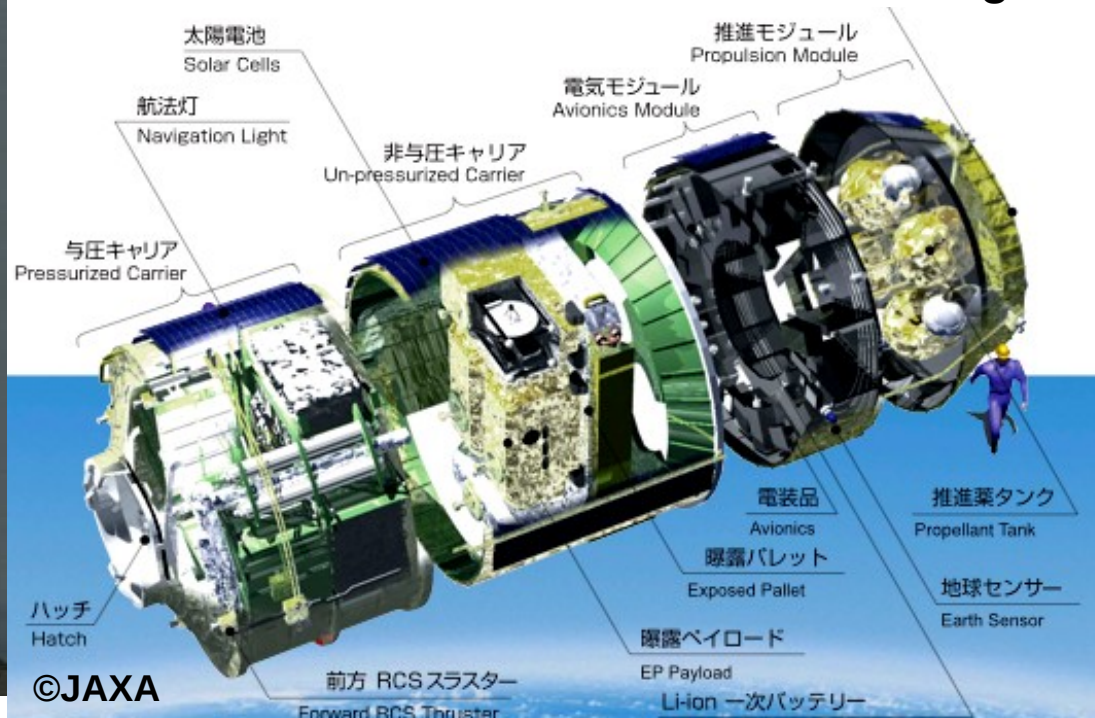
H-II Transfer Vehicle (HTV)



HTV is 4m across and about 10 m long

Sucessfully launched

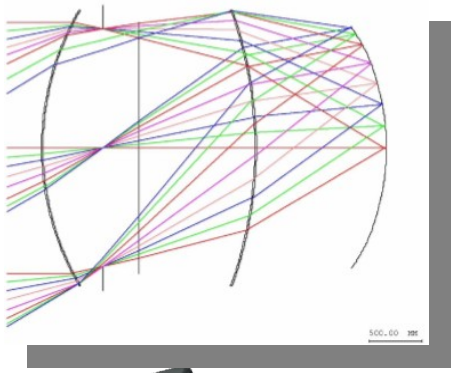
September 2009

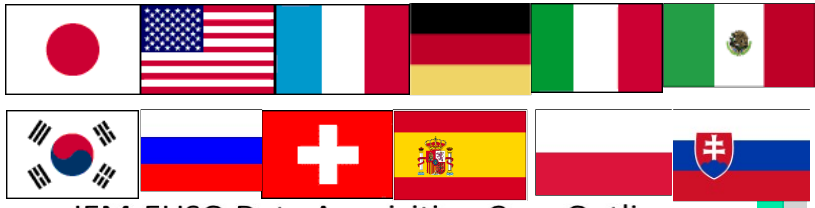


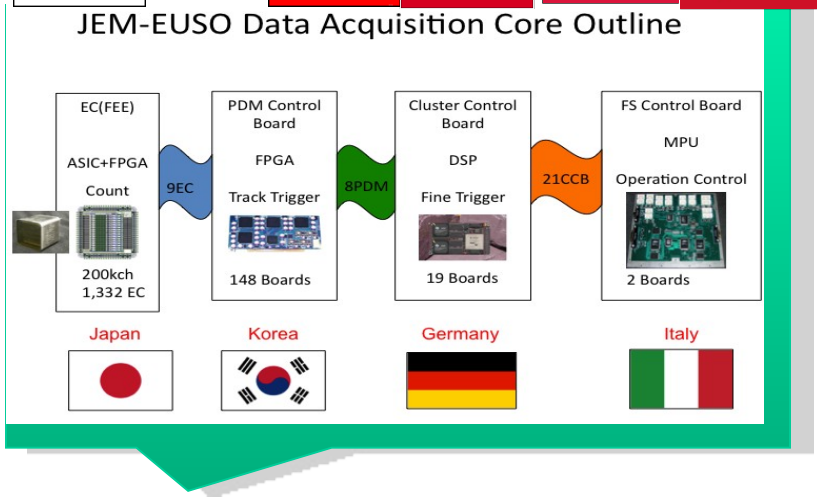
©JAXA

International Role Sharing

Optics: |
USA + Japan



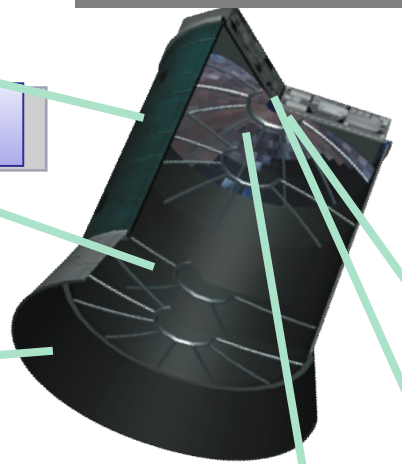




Rear Fresnel Lens

Middle lens

Iris



Front Fresnel lens

DAQ Electronics

Support Structure: Italy + France

Calibration: France & Japan

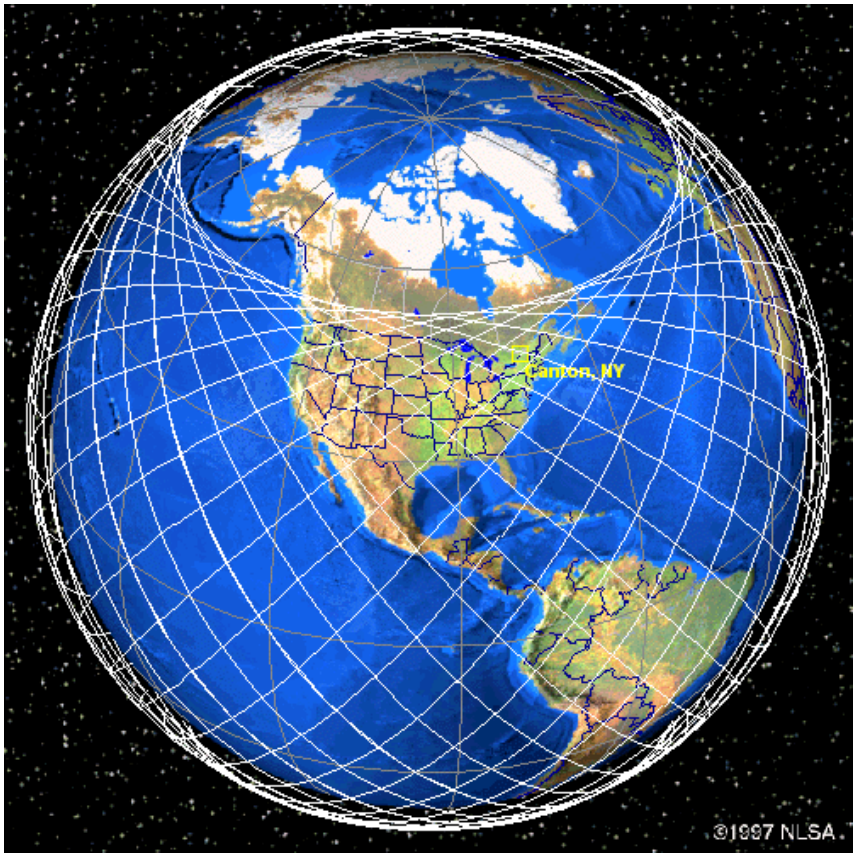
Focal Surface: Japan

Simulation: International

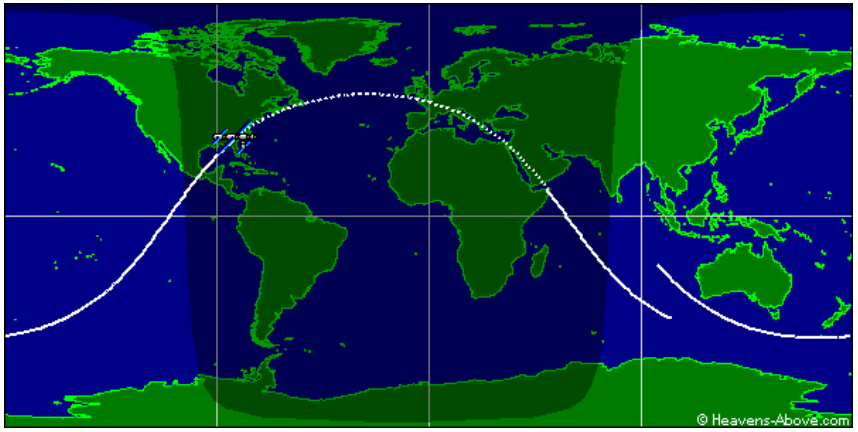
Mission Parameters

- **Date of launch:** Year 2015
- **Operation Period:** 5 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

Space Station Orbit



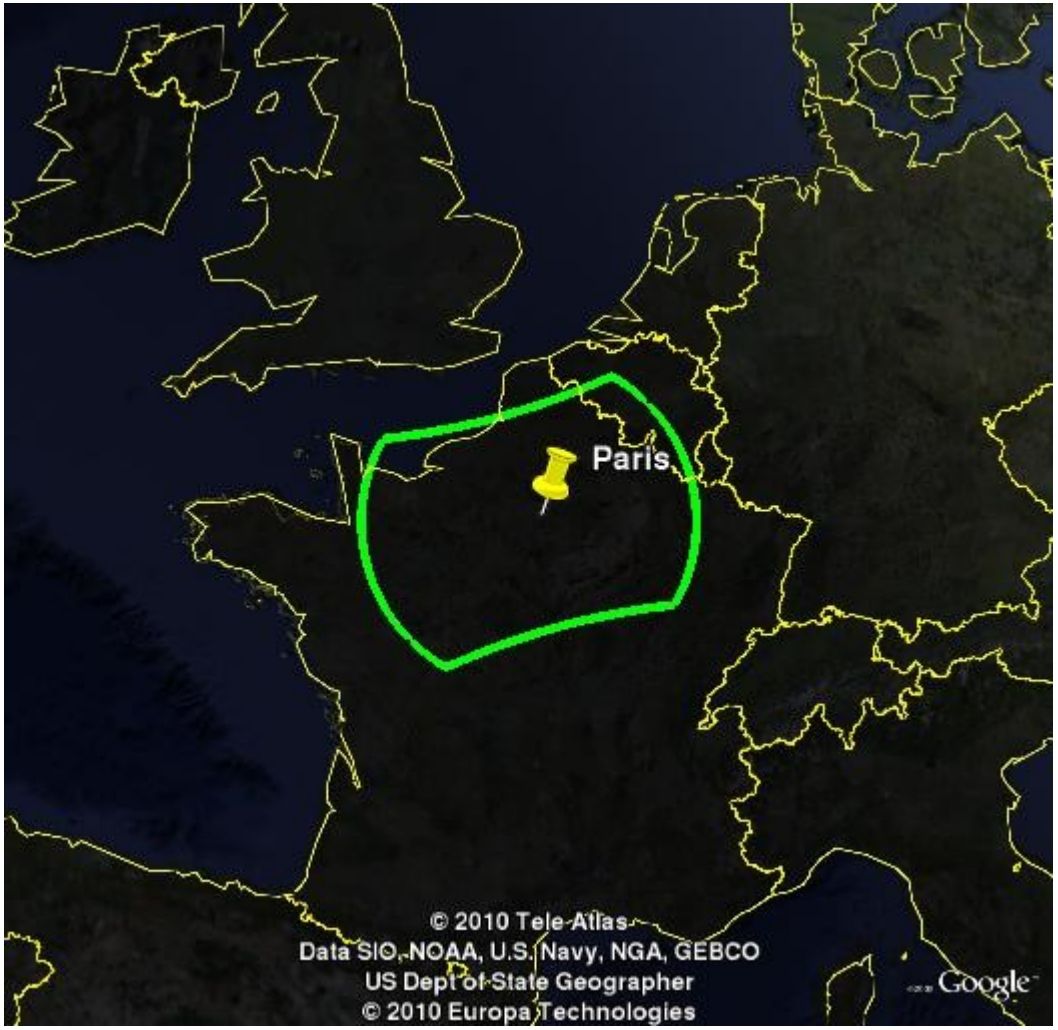
http://www.nlsa.com/

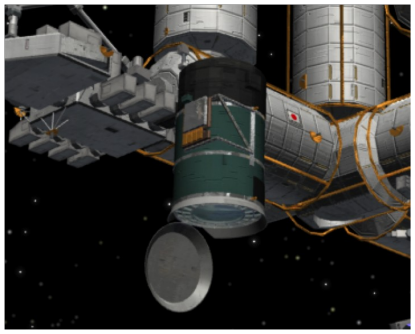


Inclination: 51.6°
Height: ~400km

JEM-EUSO can survey the arrival direction of EECRs from the all direction in Celestial Sphere

Field of View (nadir mode)



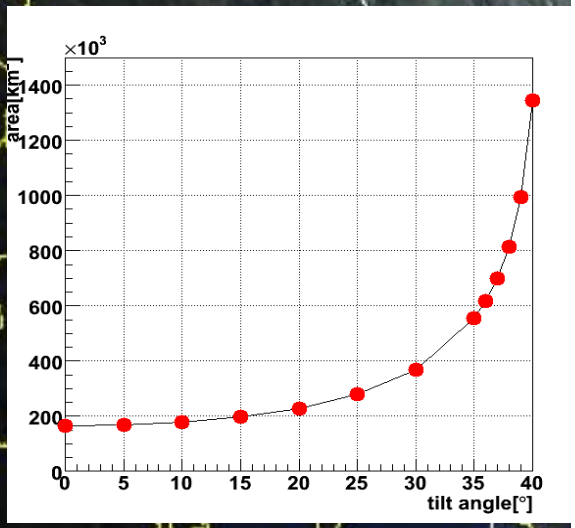


Nadir mode: Operation with telescope directing to nadir (first period)

Nadir mode covers ~2 x 10^5 km^2 area (FOV: 380 km x R500 km) for 430 km altitude (~5.5x10^5 km^2 sr)

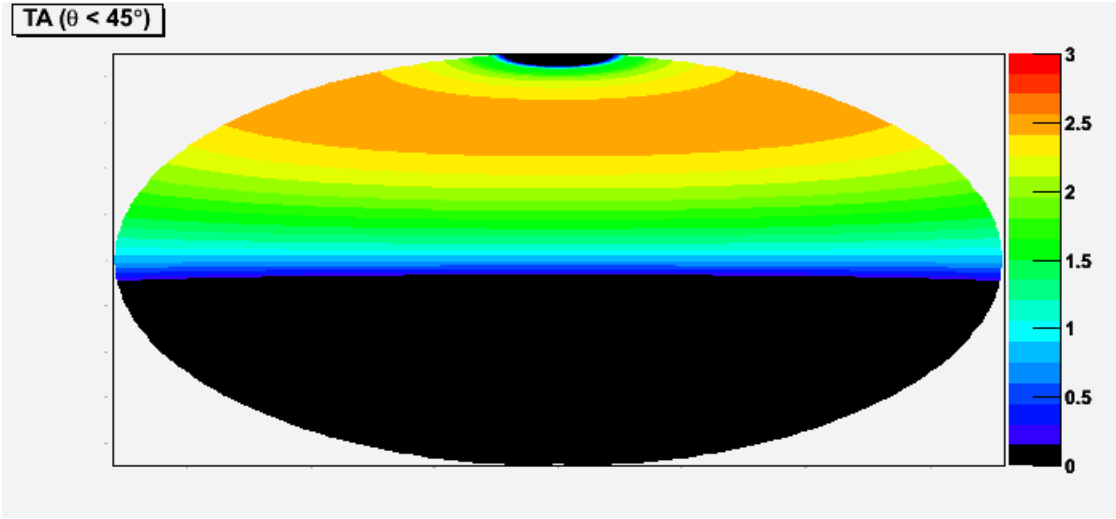
Tilt mode FOV

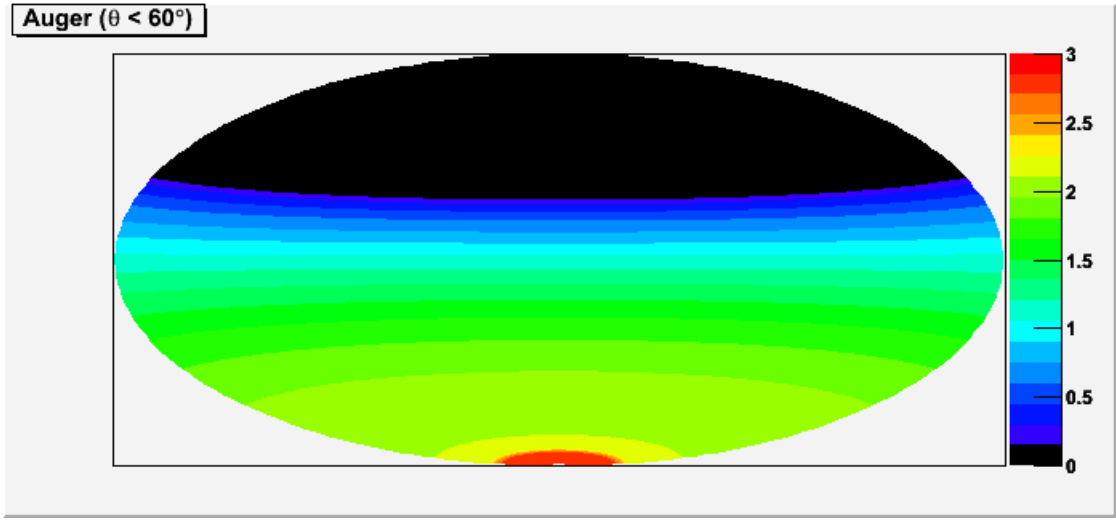
40 38 30 20 deg. tiling



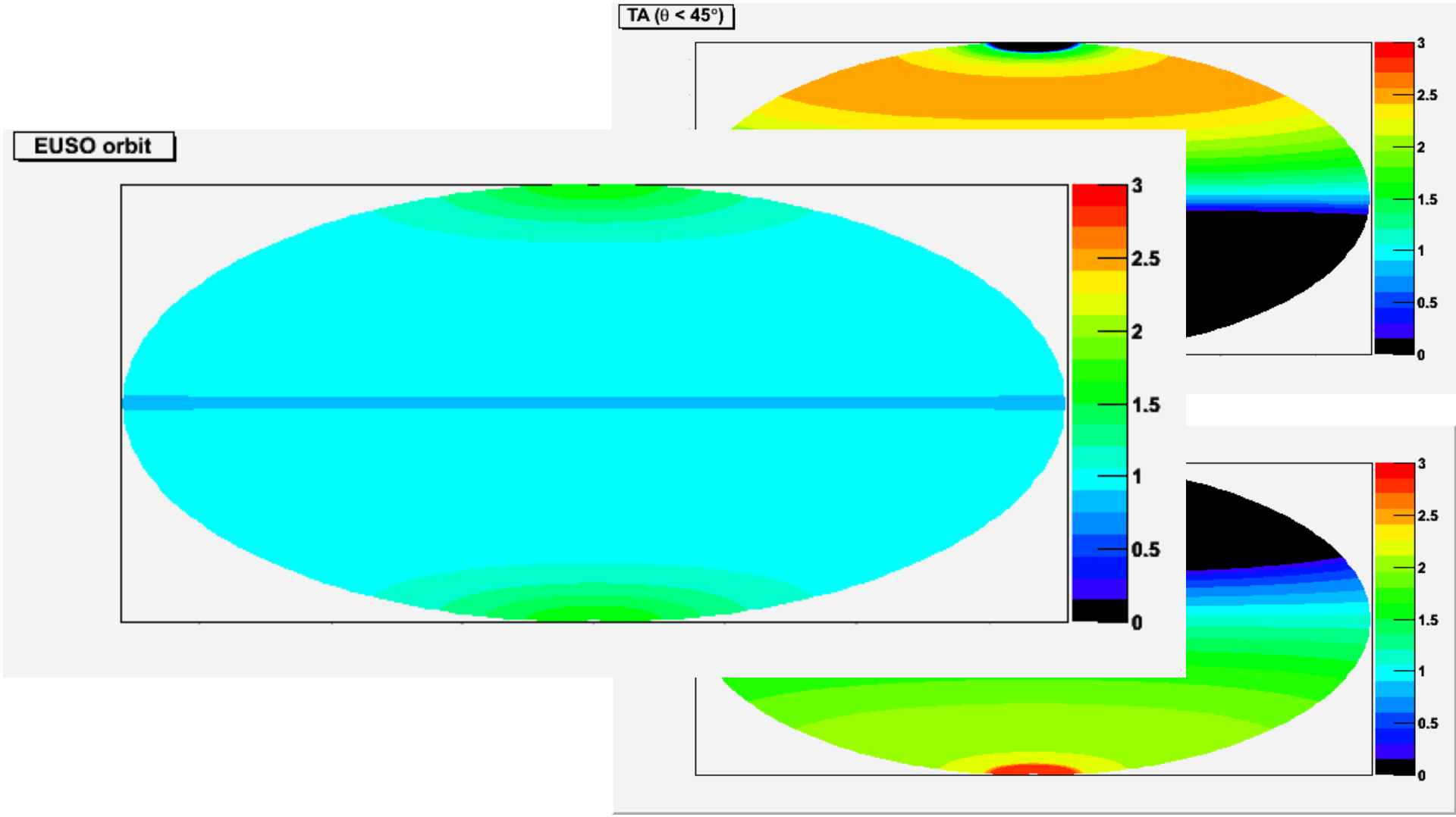
Several times increase of instantaneous observation area

Exposure uniformity





Exposure uniformity



Rather uniform full-Sky Coverage

Science Objectives

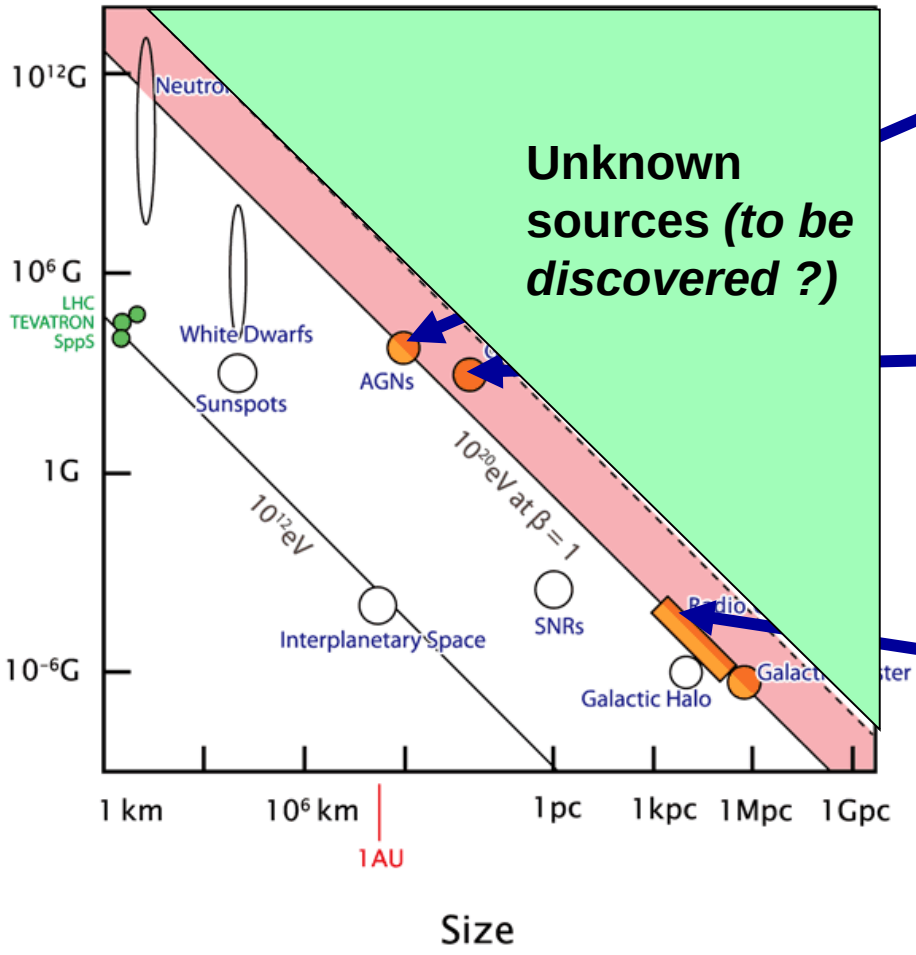
- **Fundamental Objective**

  Extreme energy astronomy by particle channel

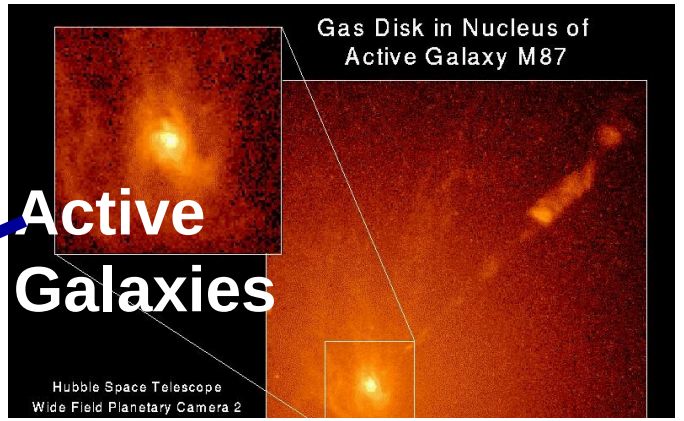
  Determine their origin and the acceleration mechanism

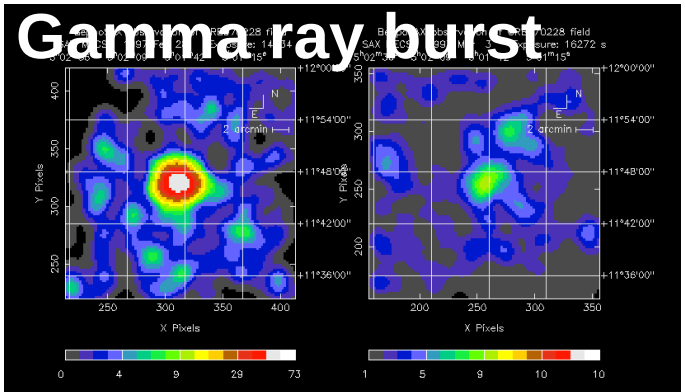
- **Exploratory Objectives**
  - **Detection of extreme energy gamma rays**
  - **Detection of extreme energy neutrinos**
  - **Study of the galactic magnetic field**
  - **Verification of the relativity and the quantum gravity effect in extreme energy**
  - **Global observations of nightglows, plasma discharges and lightning**

Possible Sources

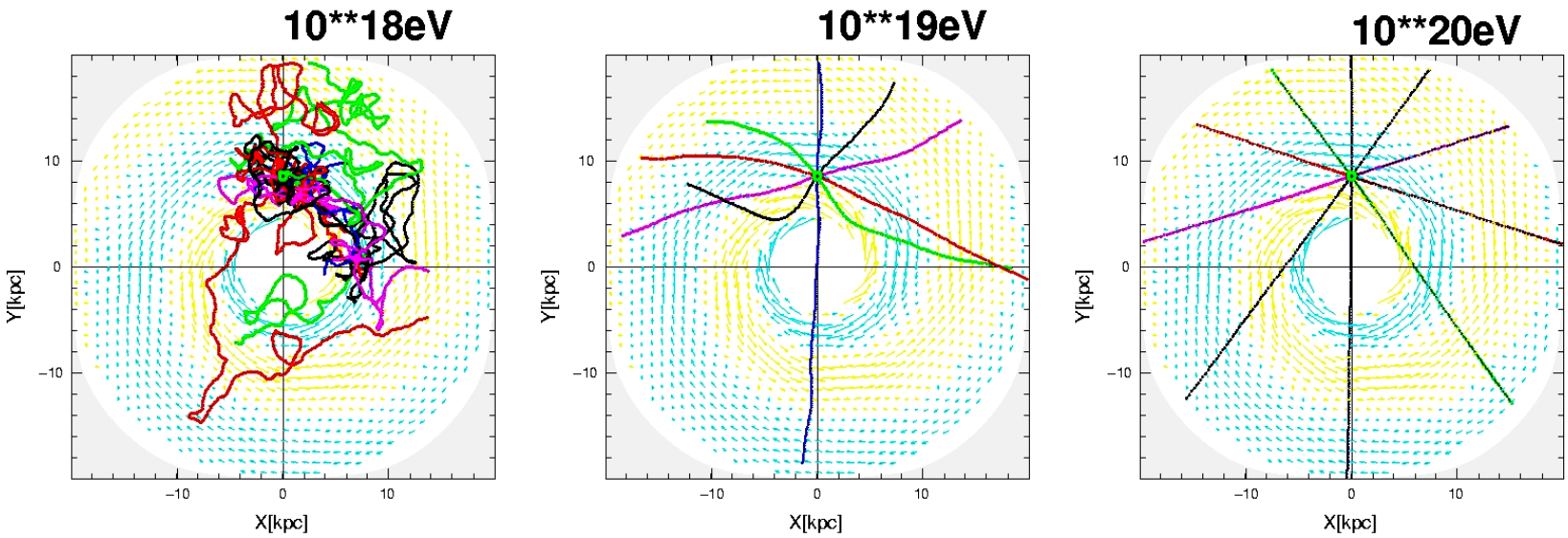


Black hole related objects



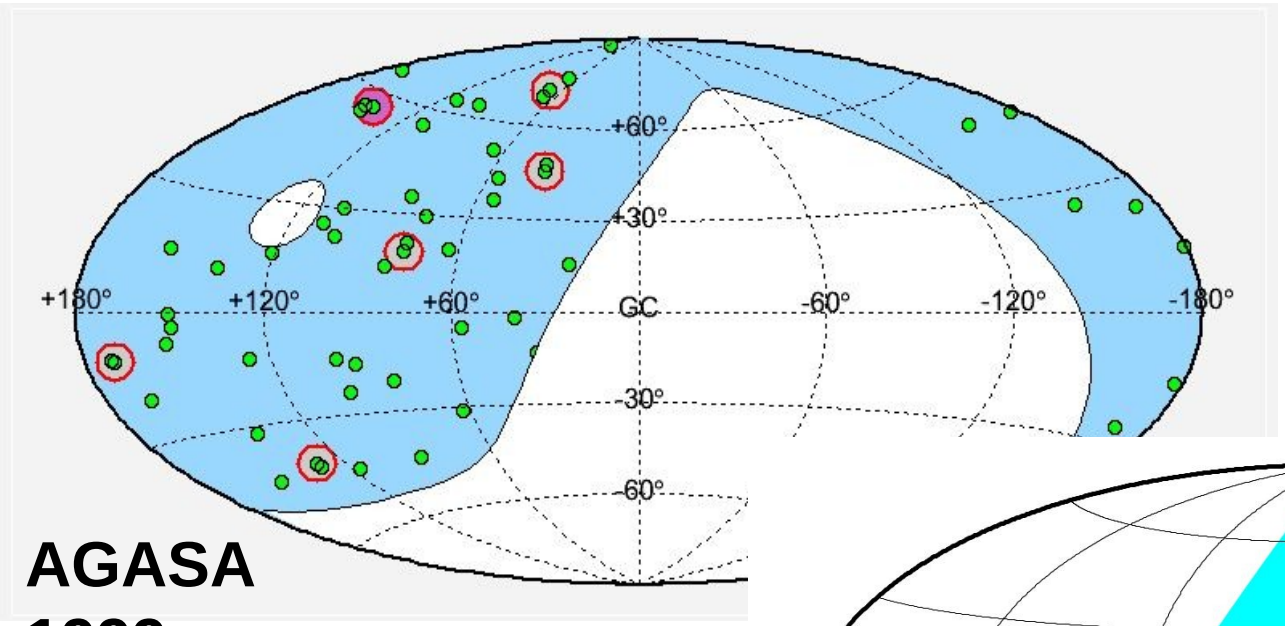


E>10^{20} eV particles travel 'straight'



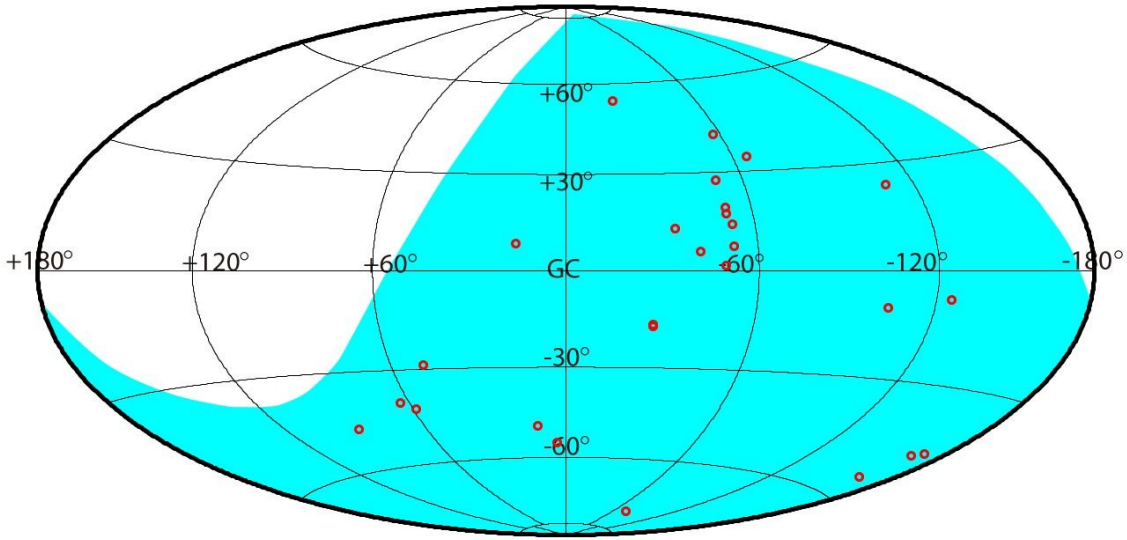
We can specify origin of EECRs by their arrival direction

Arrival direction map

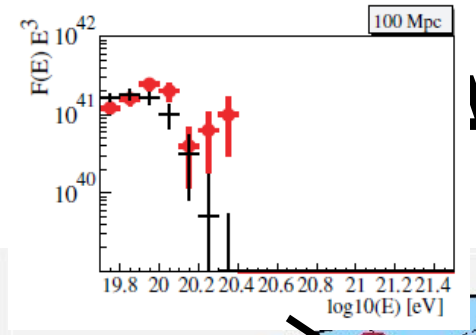


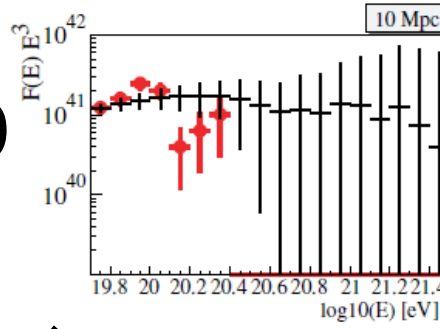
AGASA 1999

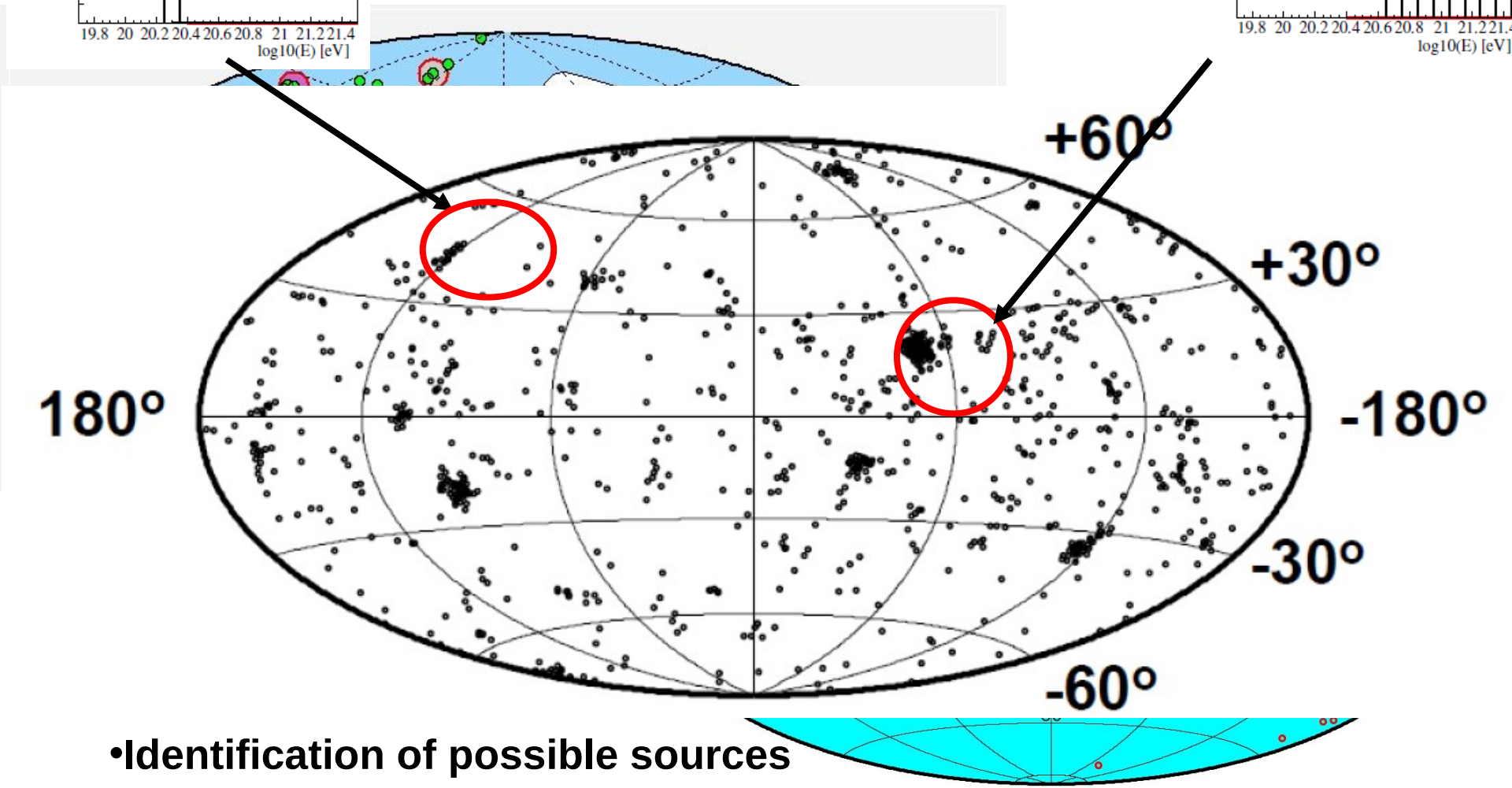
Auger 2007



Arrival direction map



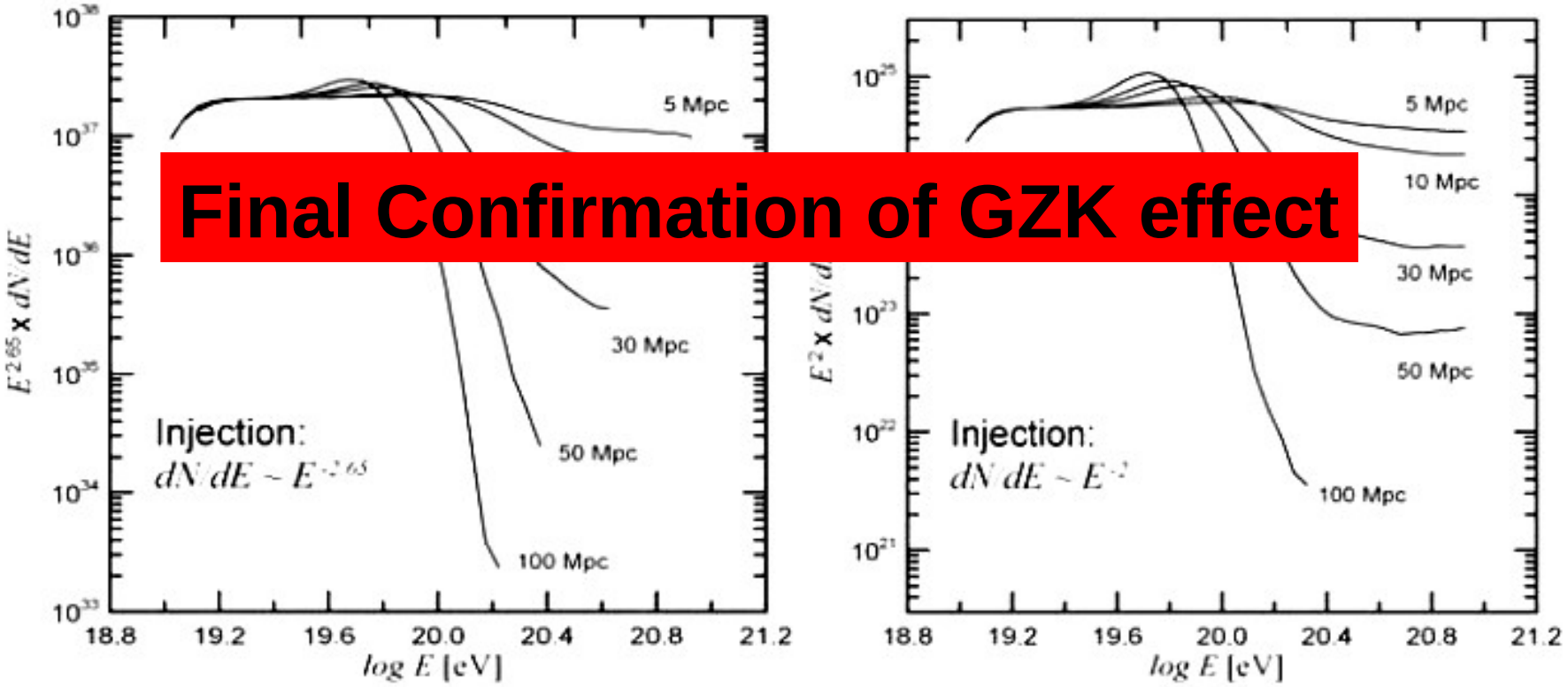




- Identification of possible sources
- Confirmation of GZK

EECR Energy Spectra for Various Source Distances

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



Final Confirmation of GZK effect

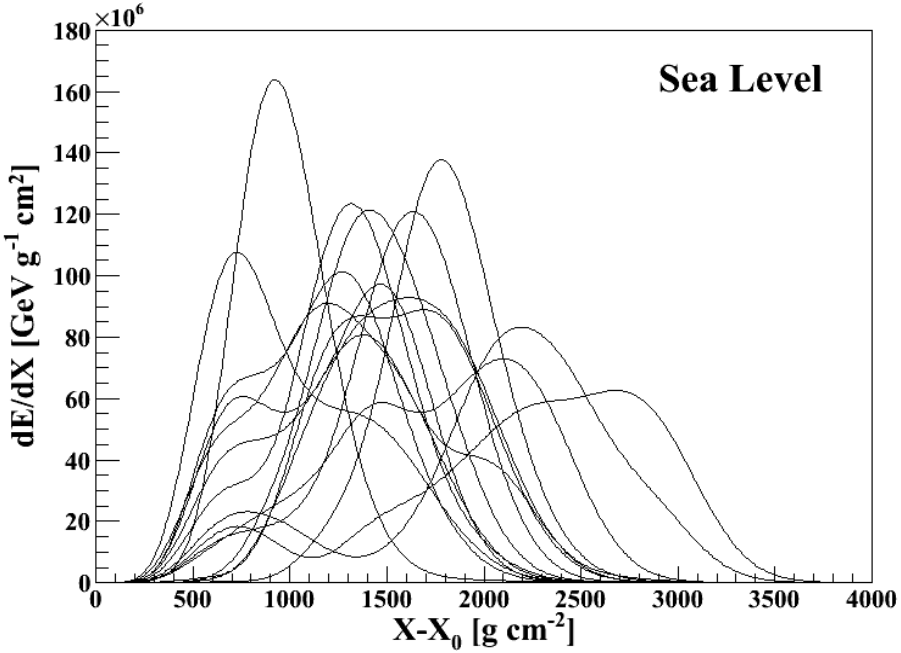
Medina-Tanco 2008

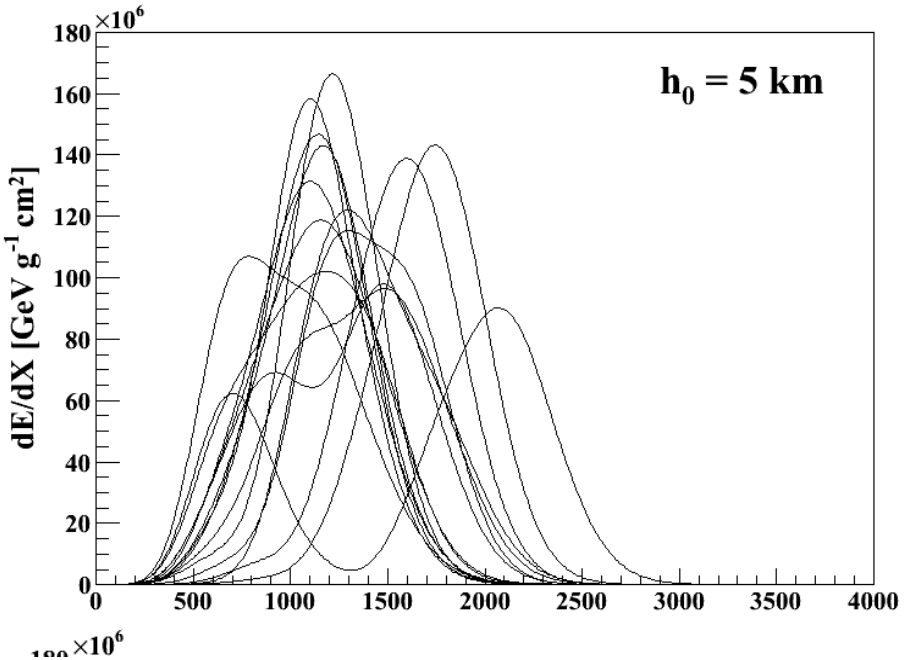
JEM-EUSO as gamma ray & neutrino observatory

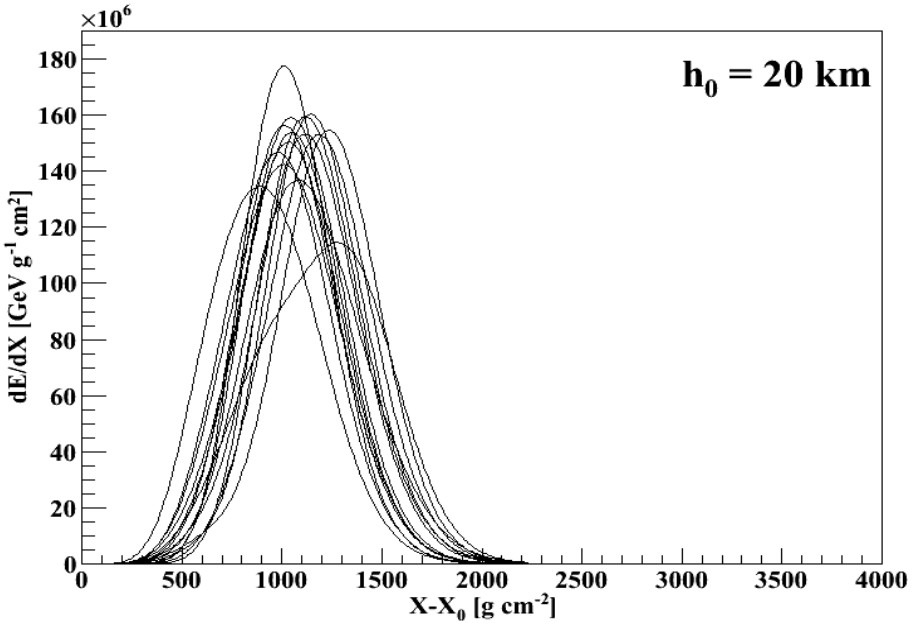
- International Space Station-aboard EECR observatory
  - Orbiting at ~400 km in ±51.6 degrees latitudes
  - Flight in varying geomagnetic field (~0.6 gauss) around orbit

- 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

Profiles of neutrino induced showers

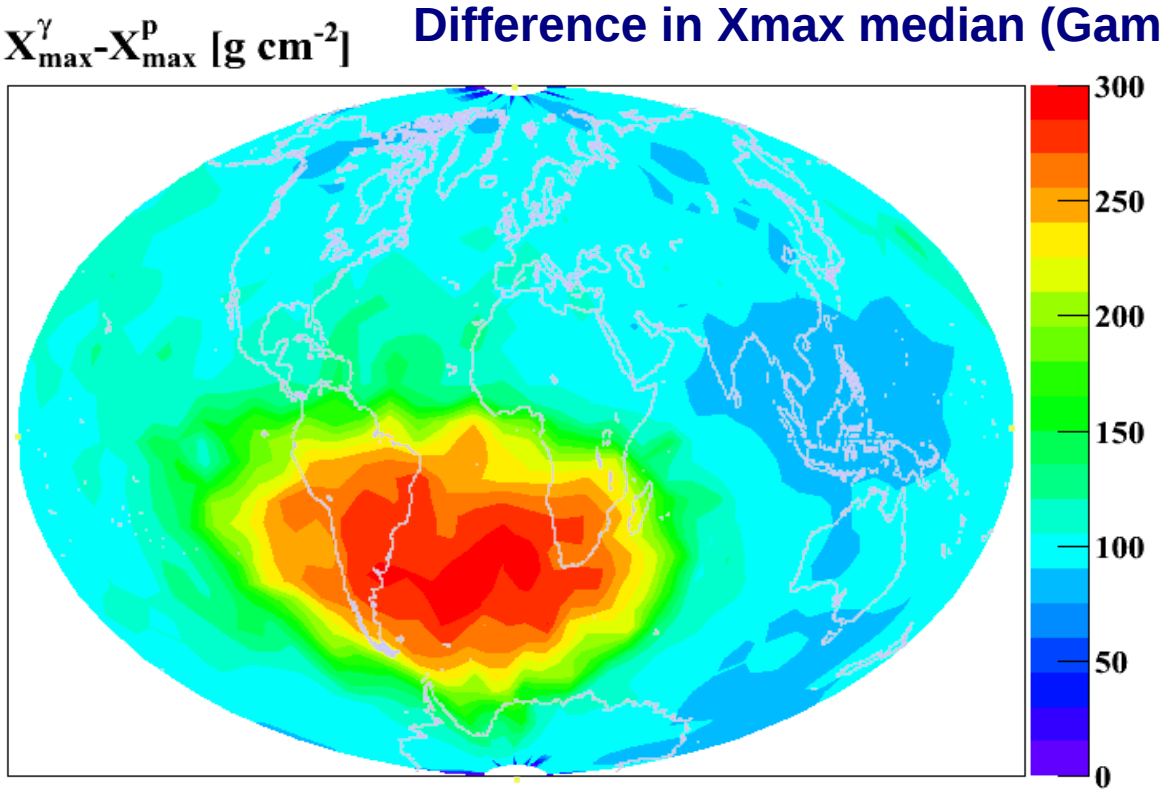






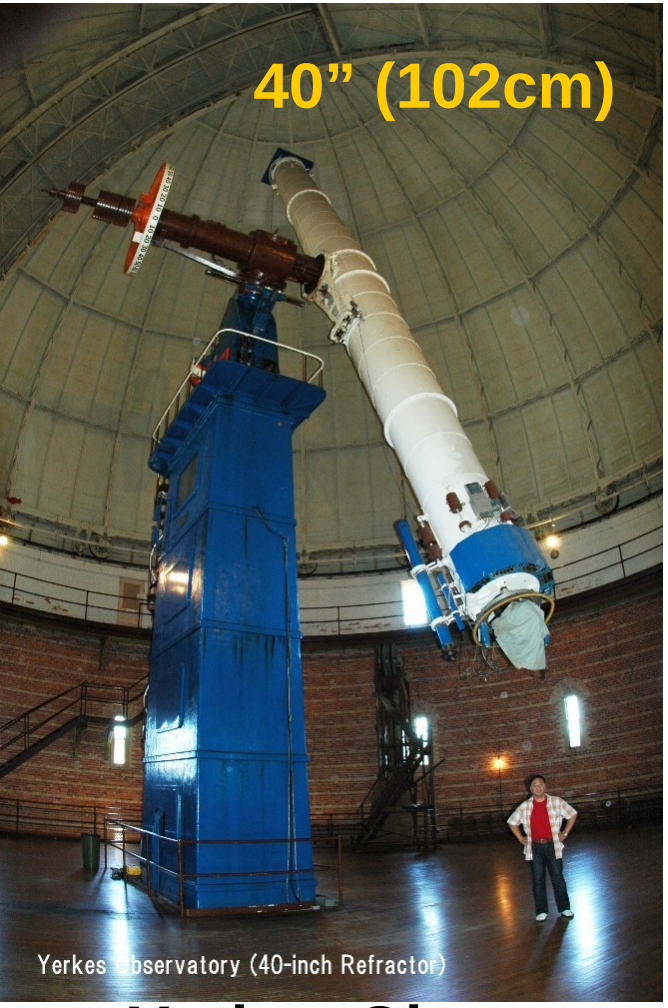
- First peak resulted from hadronic part of shower
- Second and following peaks from electromagnetic part
  - LPM effect more significant at lower altitudes

Global map of Xmax dependence for gamma ray induced showers



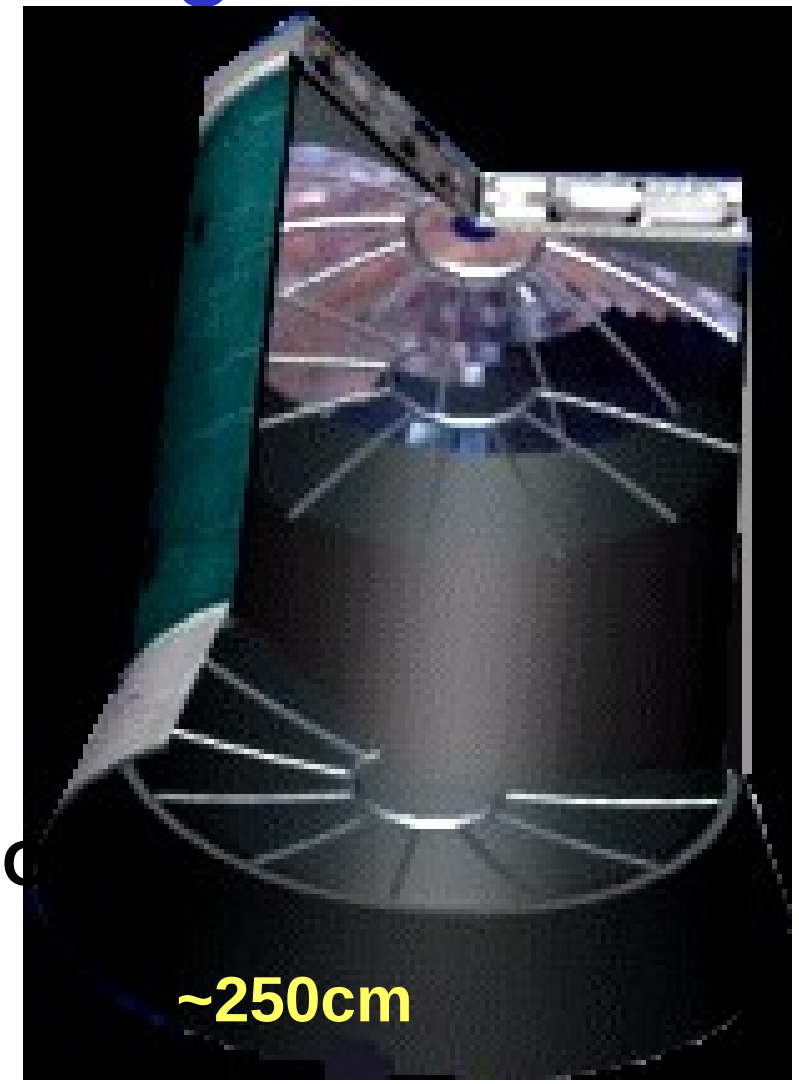
- Shower development significantly slower than proton EAS depending upon local geomagnetic field & energy
- Weak geomanetic field region (eg South Antarctic Anomaly)
  - Window to PRE-SHOWER-free gamma rays (hotspot)

JEM-EUSO
refractive telescope largest ever

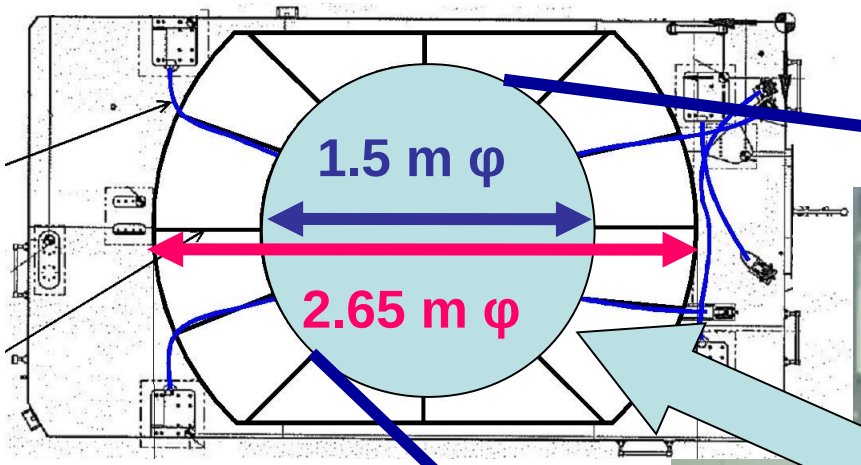


Yerkes Observatory 1897

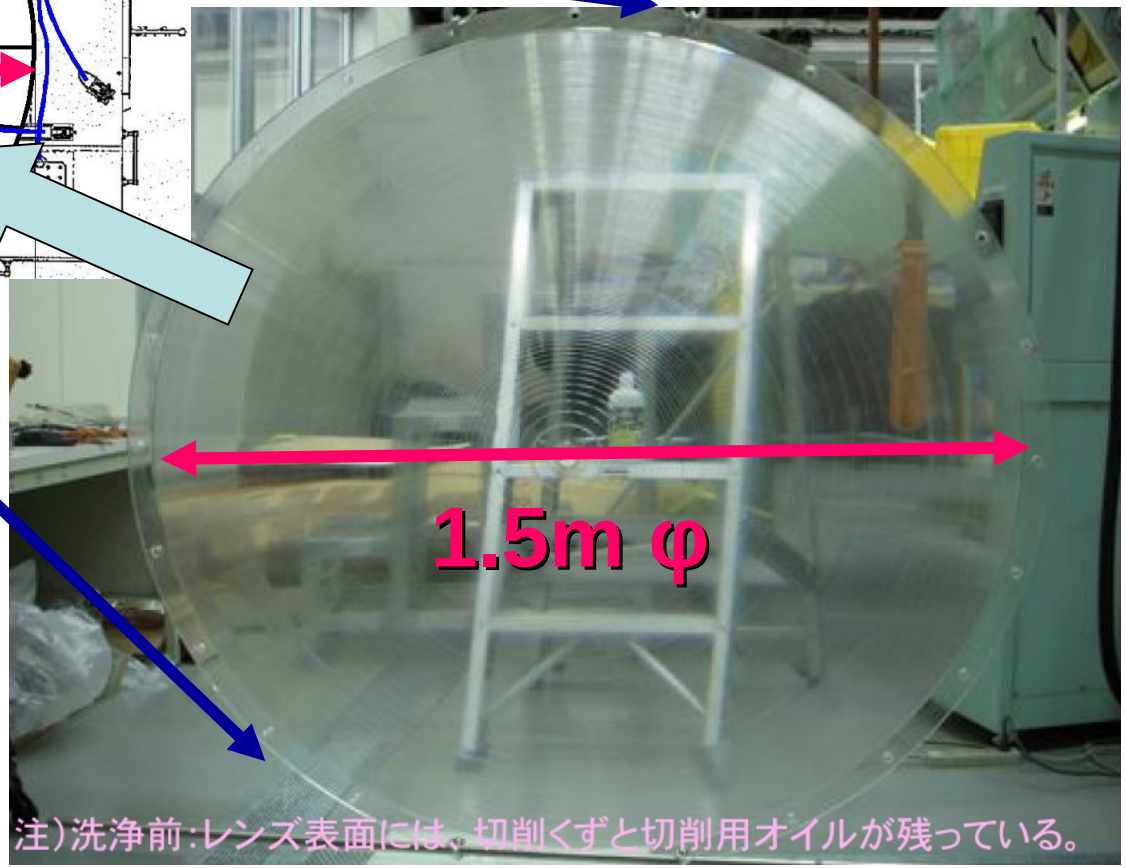
JEM-EUSO
2015



Recent Progress in 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.

Summary
Three Challenges

- **Challenge to Astronomy through Charged Particle**
  - **Identification of Origin of EECR by Arrival Direction**
  - **Determination of EECR acceleration mechanism in the Universe**
- **Challenge to the limit of the Fundamental Physics**
  - **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