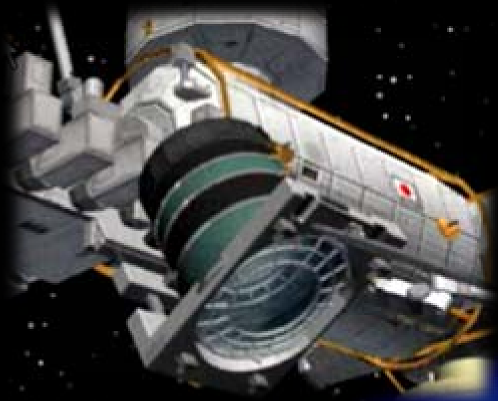


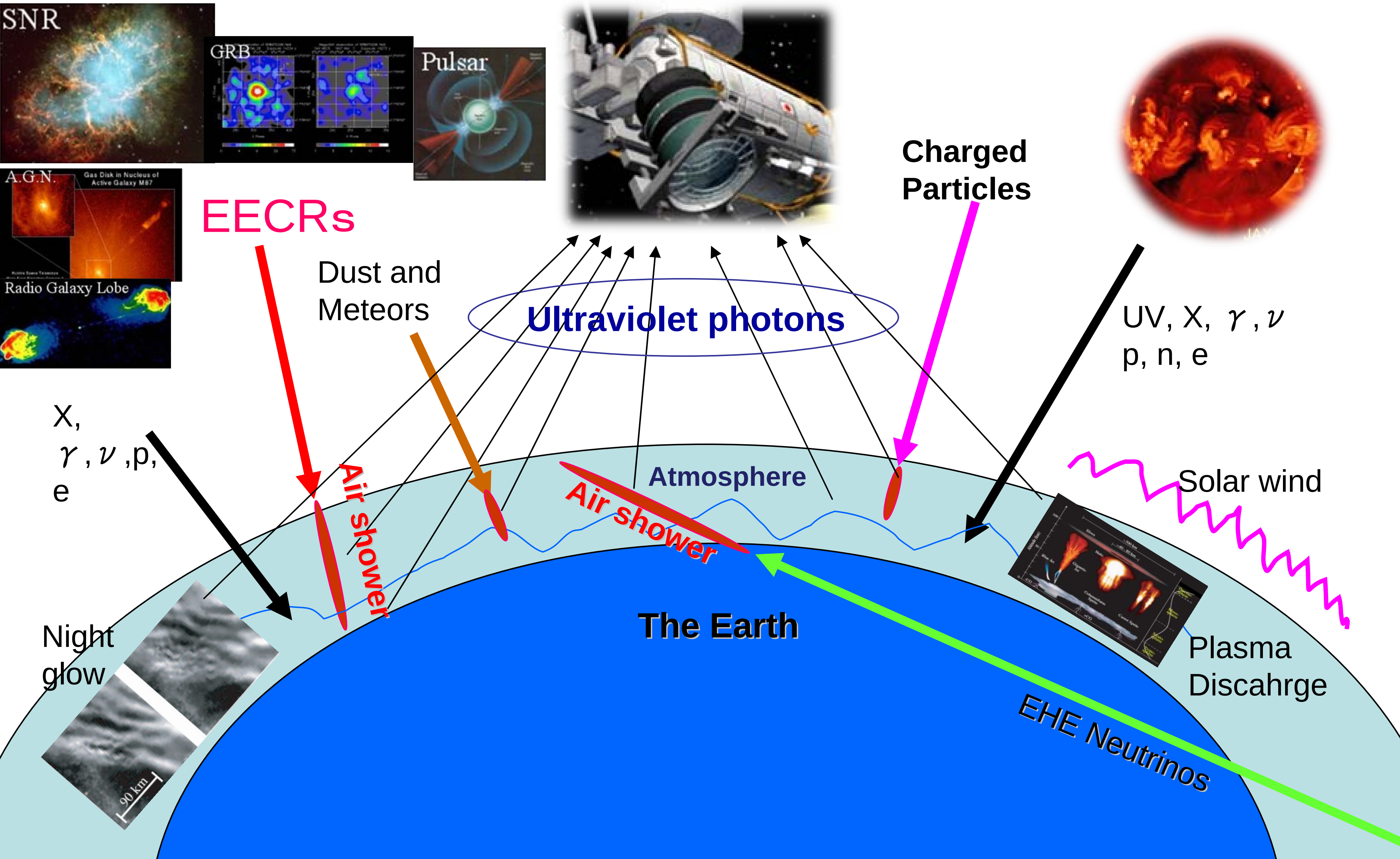
Extreme Universe Space Observatory

The JEM-EUSO Mission

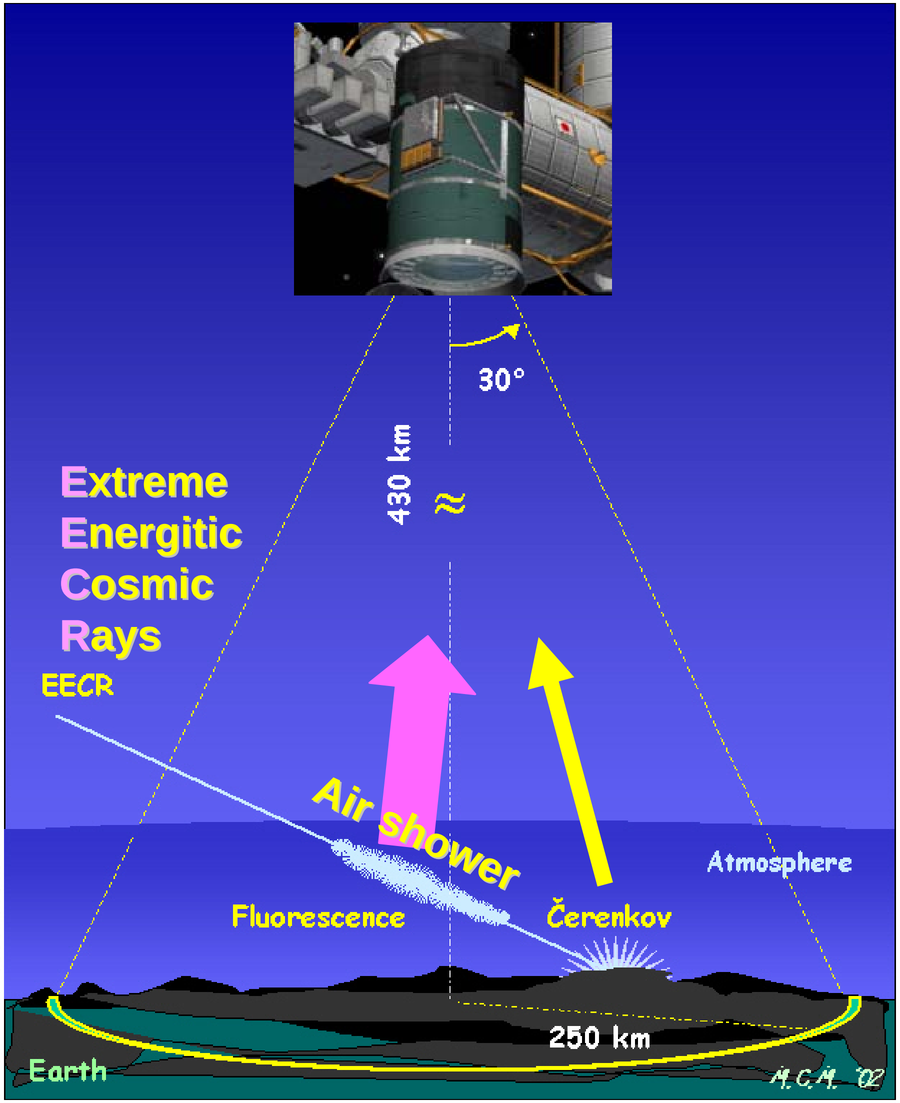
Toshikazu Ebisuzaki
RIKEN
for the JEM-EUSO Collaboration

The Symposium on the Recent Progress of UHECR Observation
Dec. 12, 2010, Nagoya Congress Center, Nagoya

JEM-EUSO is the Astronomical Earth Observatory



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).

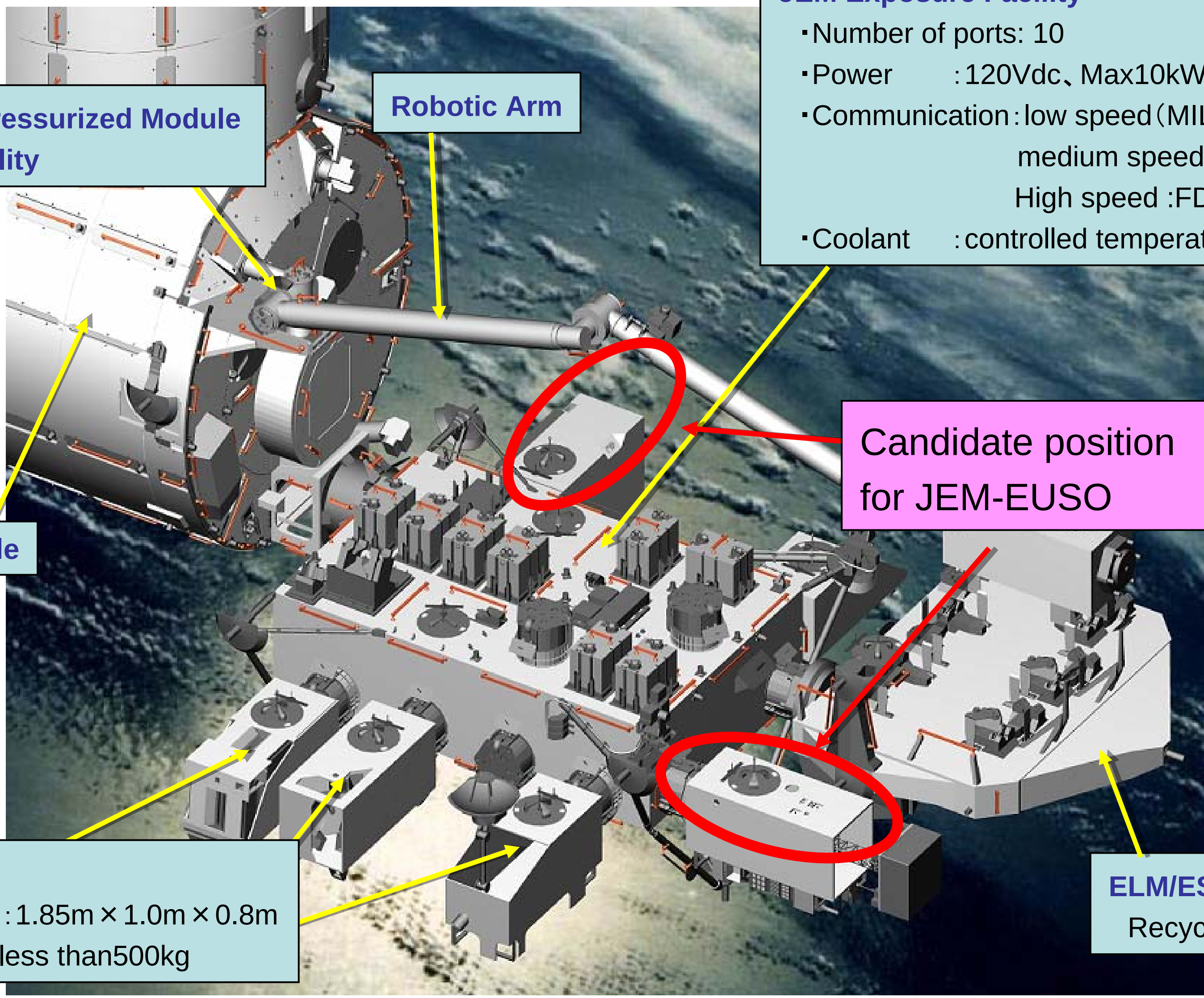
JEM-EUSO mission will initiate particle astronomy at ~10^{20}eV.

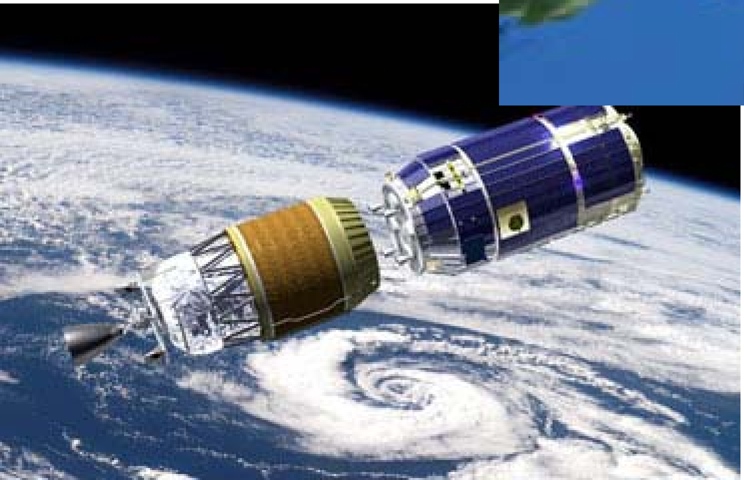
JEM-EUSO telescope observes fluorescence and Cherenkov photons generated by air showers created by extreme energetic cosmic rays

Japanese Experiment Module "Kibo": July 2009

S127E011186

Outline of JEM Exposure Facility

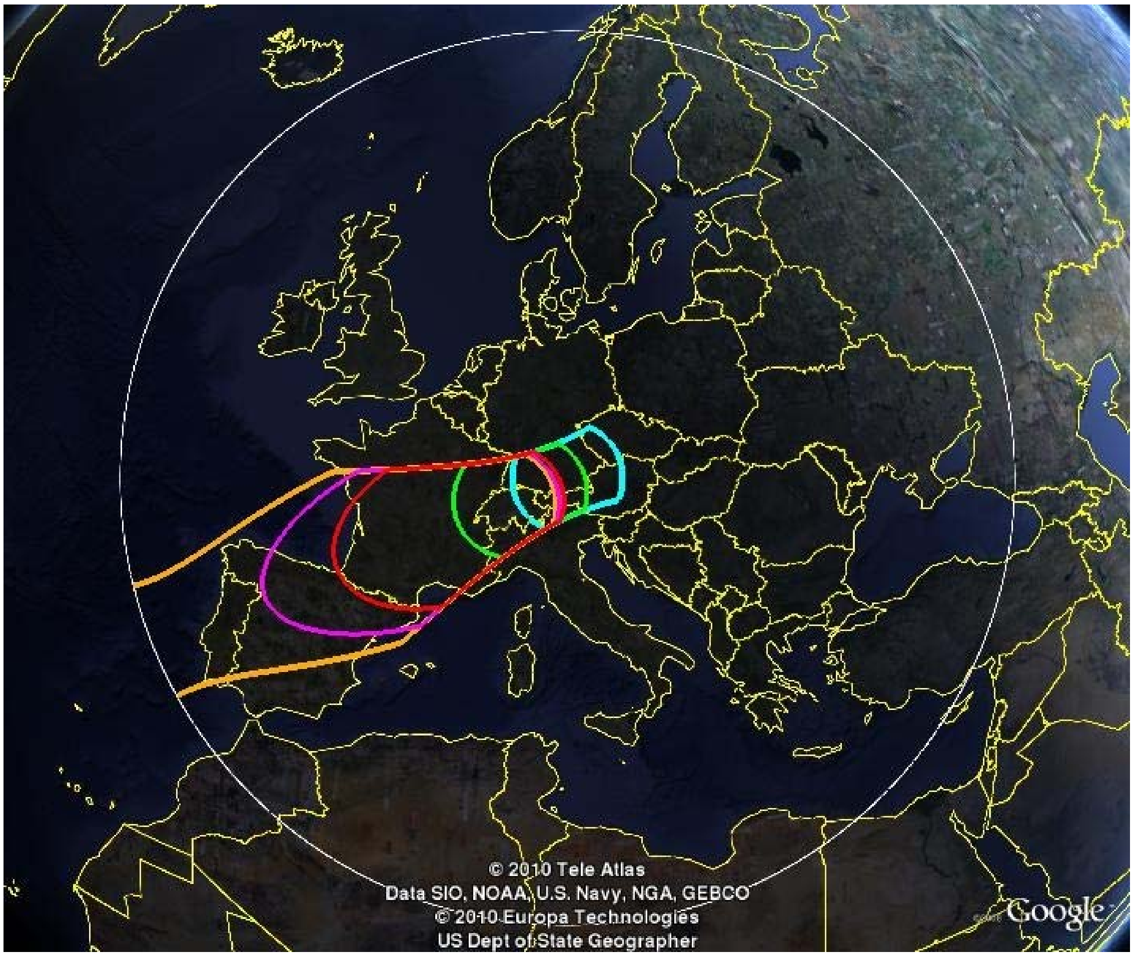


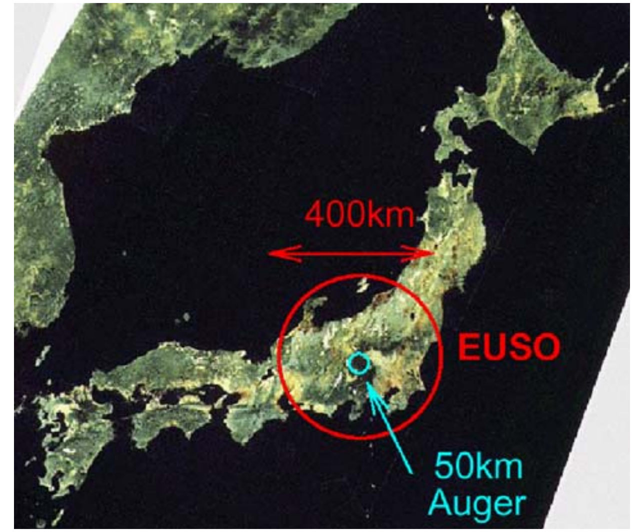


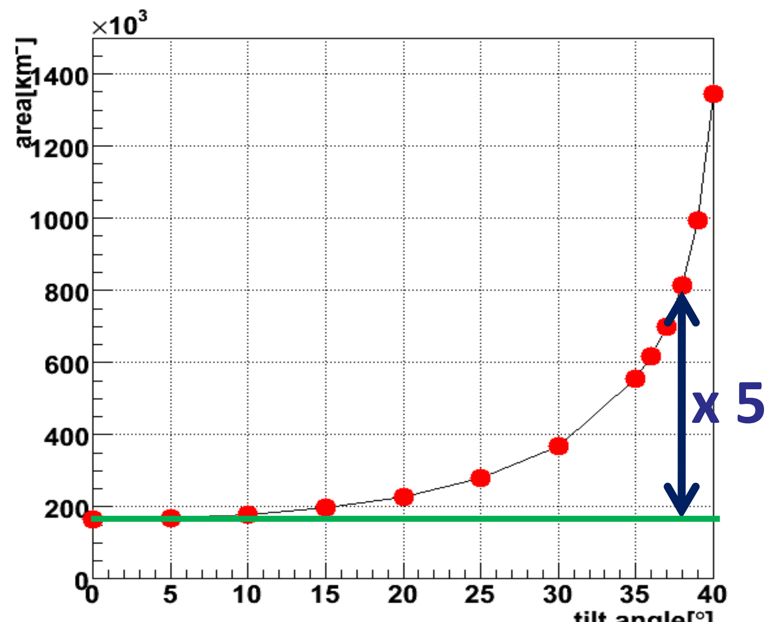
Successful Launch of HTV

September 11, 2009

Field of View



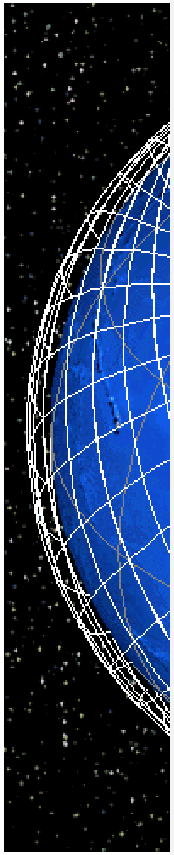


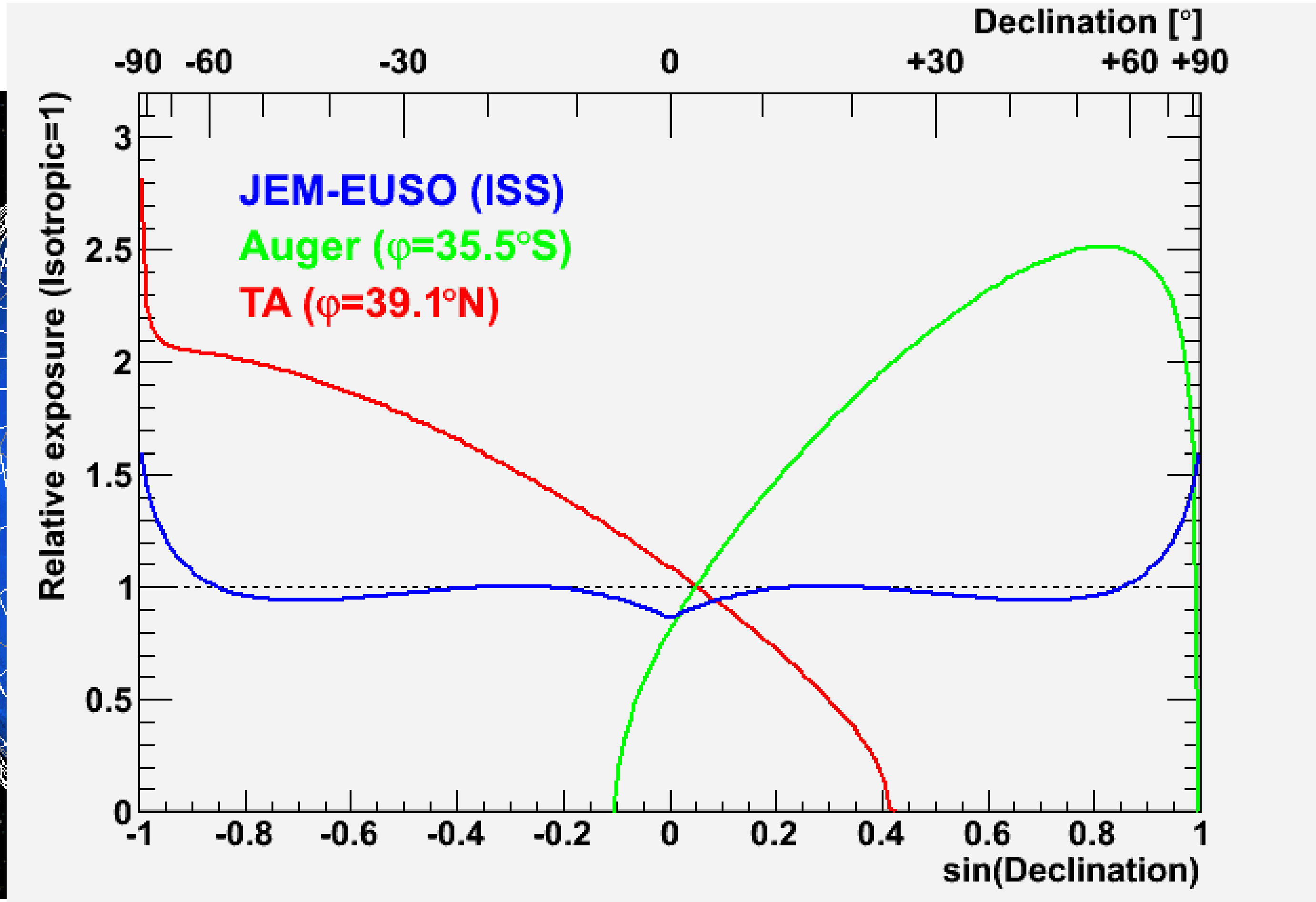


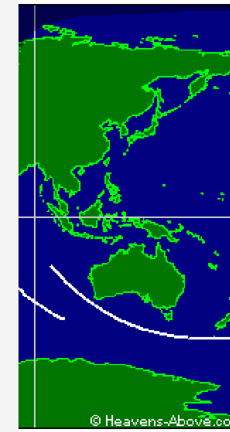
Mission Parameters

• Time of launch:	FY2016
• 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

ISS Orbit







http://www.nlsa.com/

e
ery
ure
of the ISS orbit.

Full-Sky Coverage

Science

Science Objectives

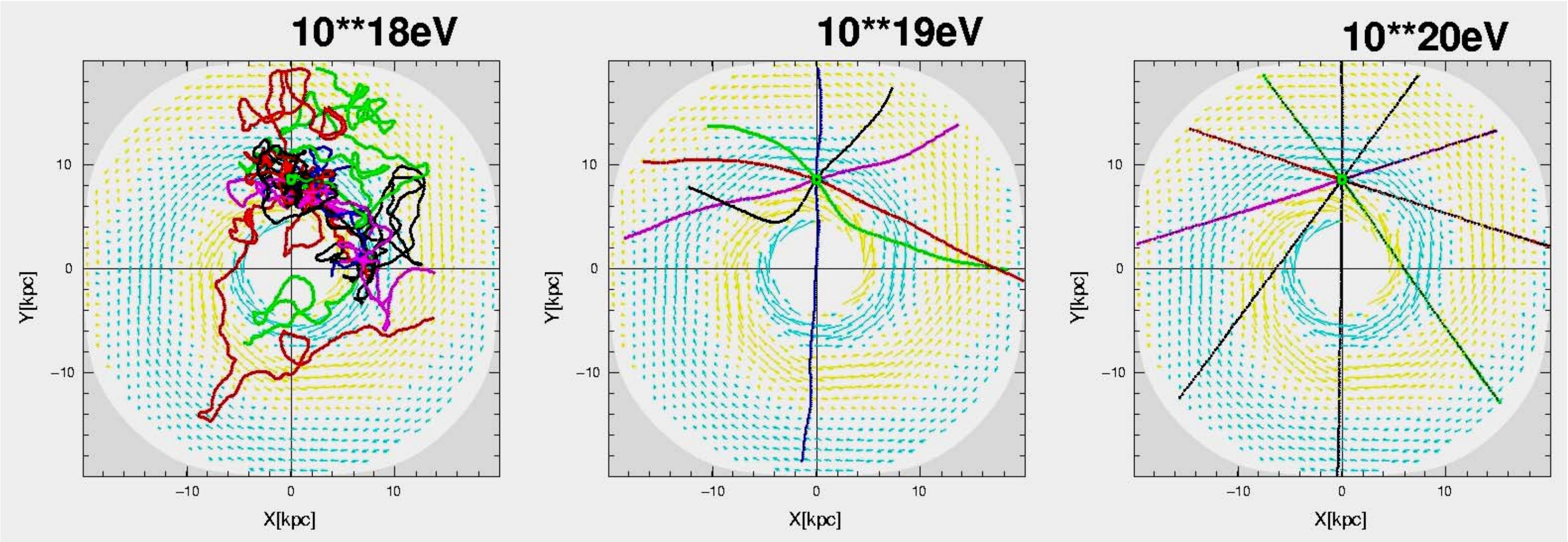
- **Fundamental Objective**

  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

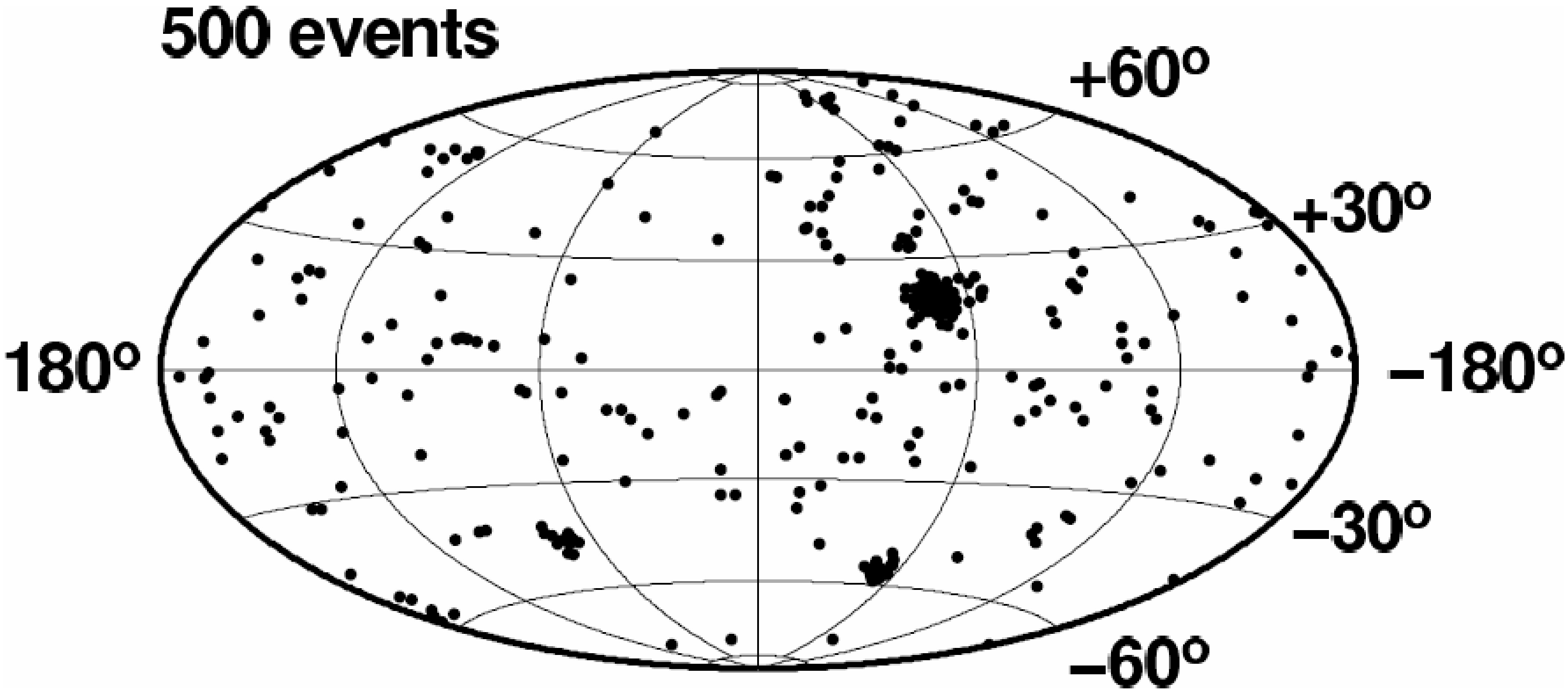


銀河内の伝播シミュレーション

We can specify origin of EECRs by arrival direction

Three years after launch:

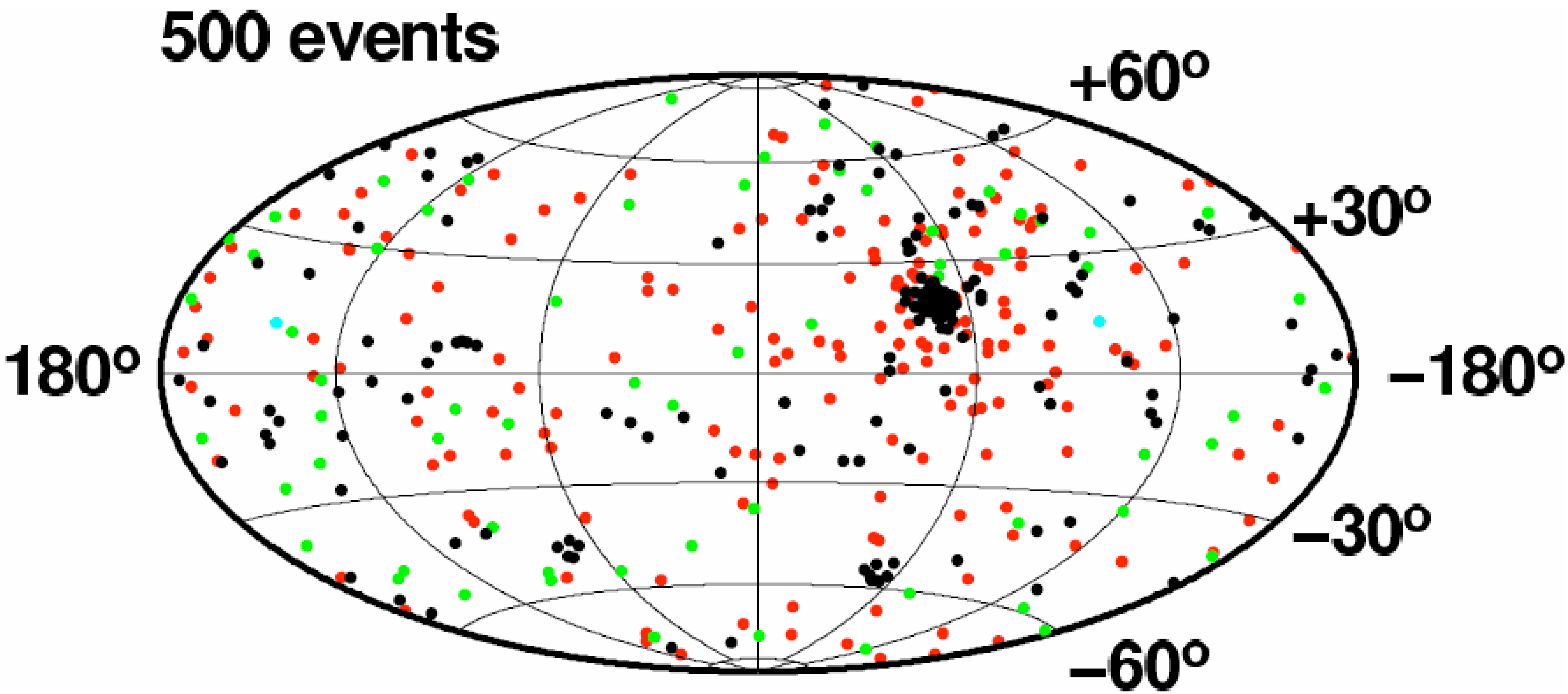
500events (proton)



Takami et al 2010

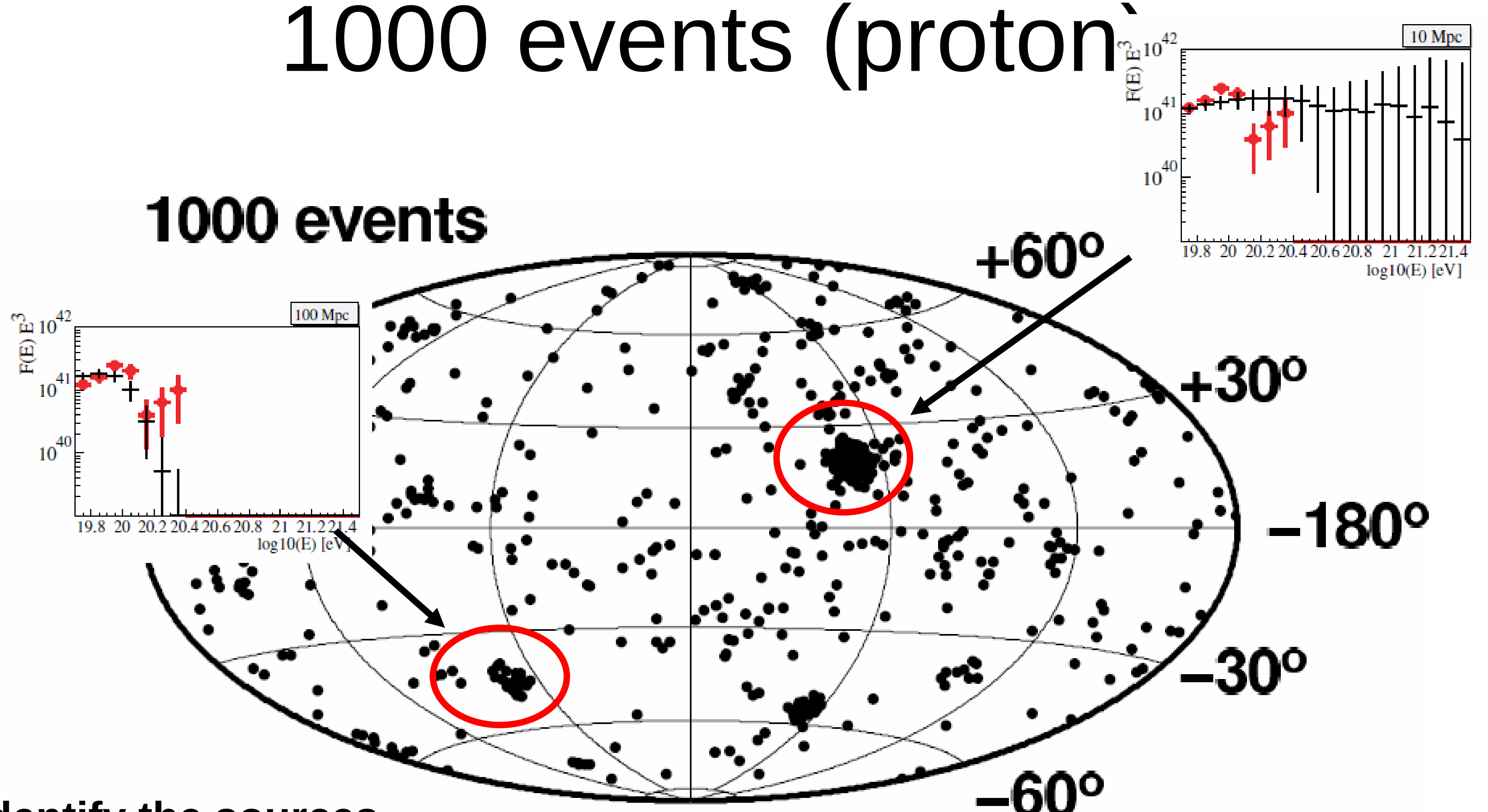
Three years after Launch

500 events（proton : iron=1 : 1）



Takami et al 2010

Five years after launch: 1000 events (proton`



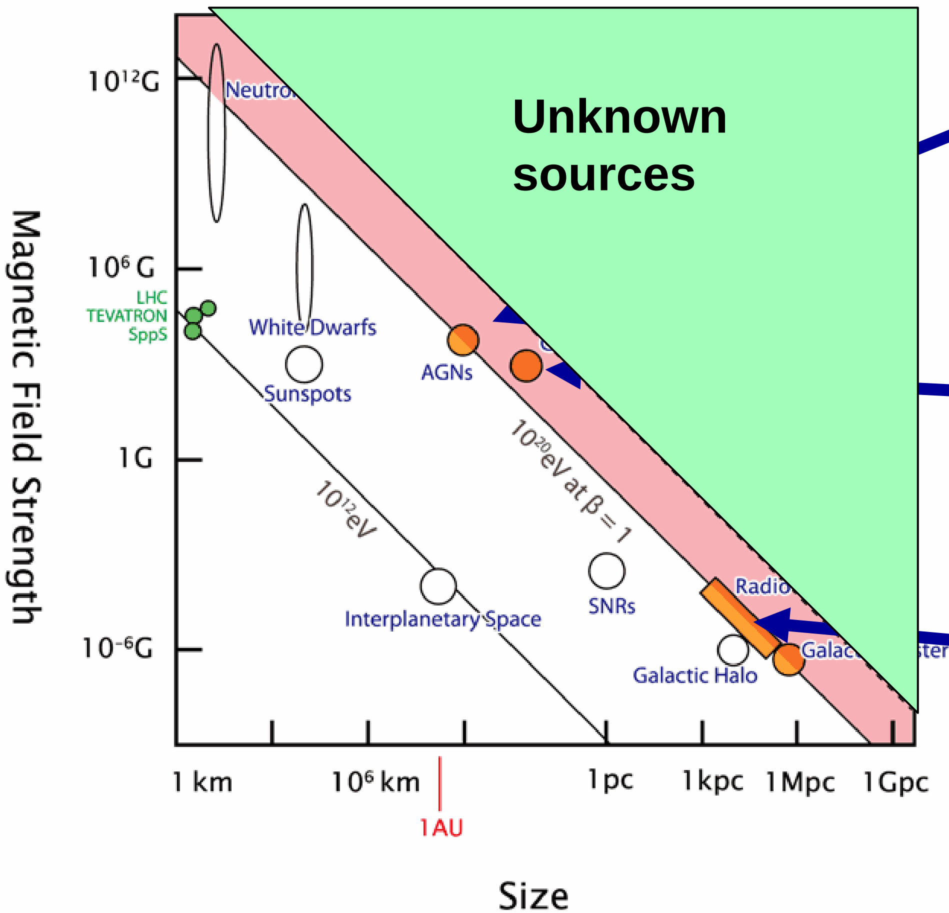
- Identify the sources
- Confirmation of GZK
- Clarify acceleration mechanism

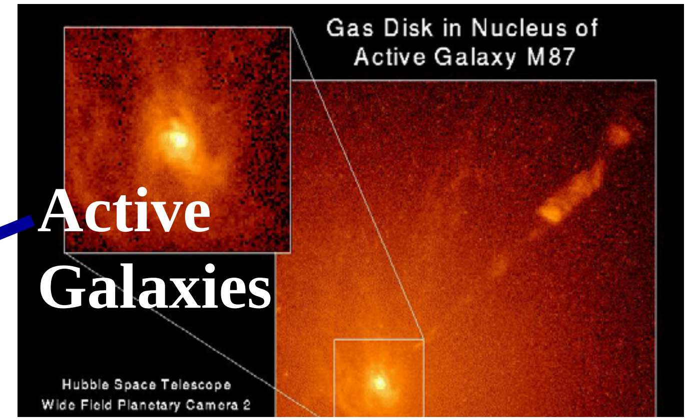
Takami et al 2010

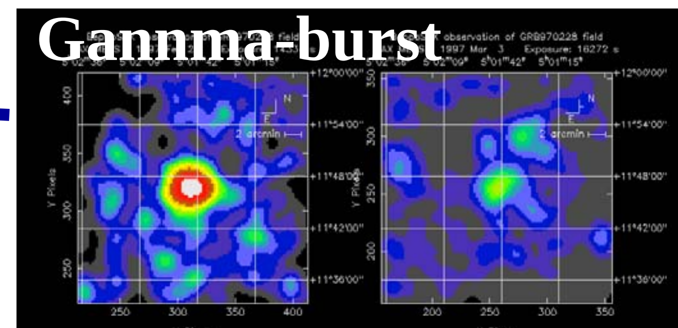
Possible Sources

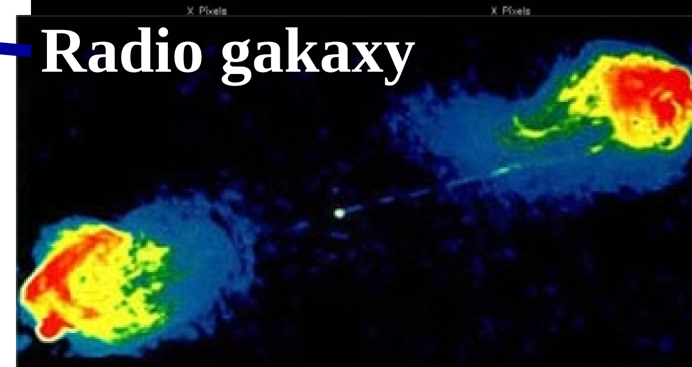
Blackhole related objects

New mechanism of acceleration



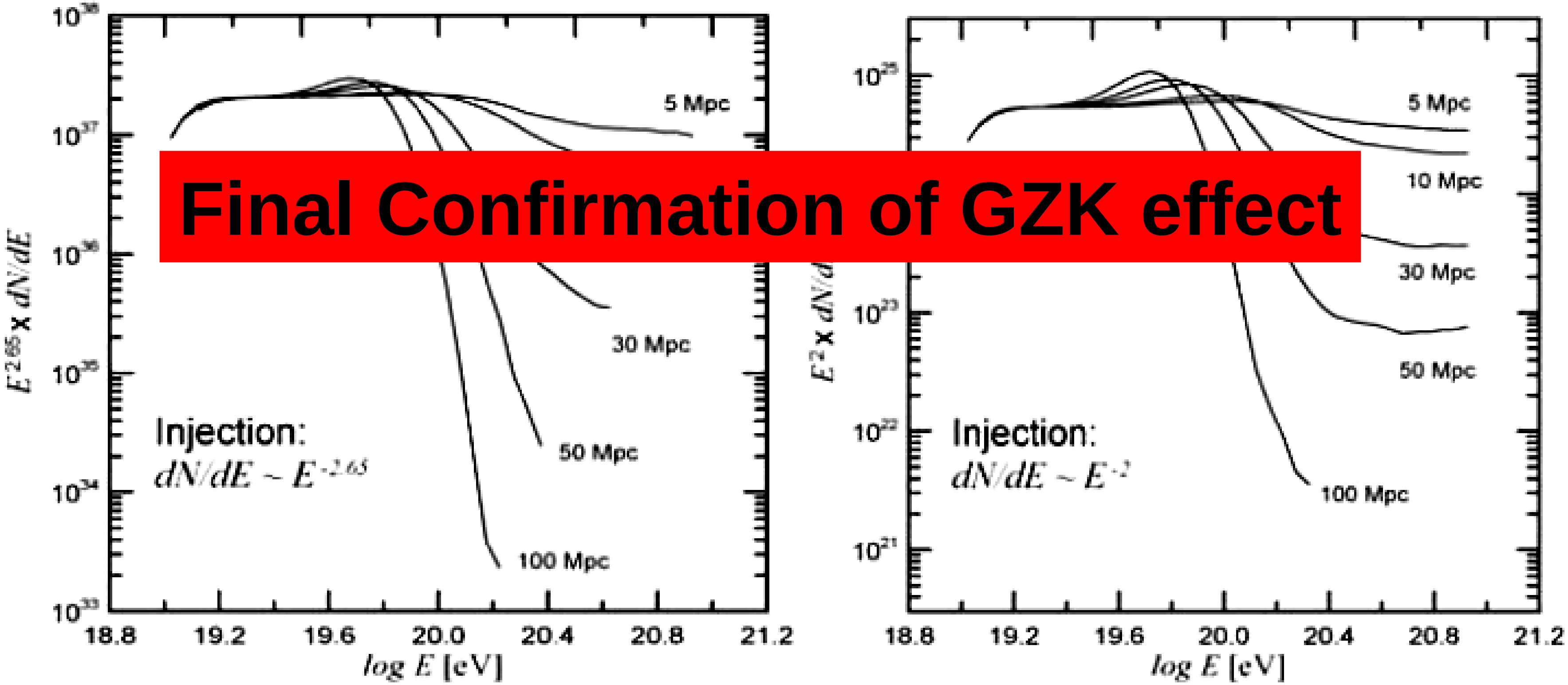






EECR Energy Spectra for Various Source Distance

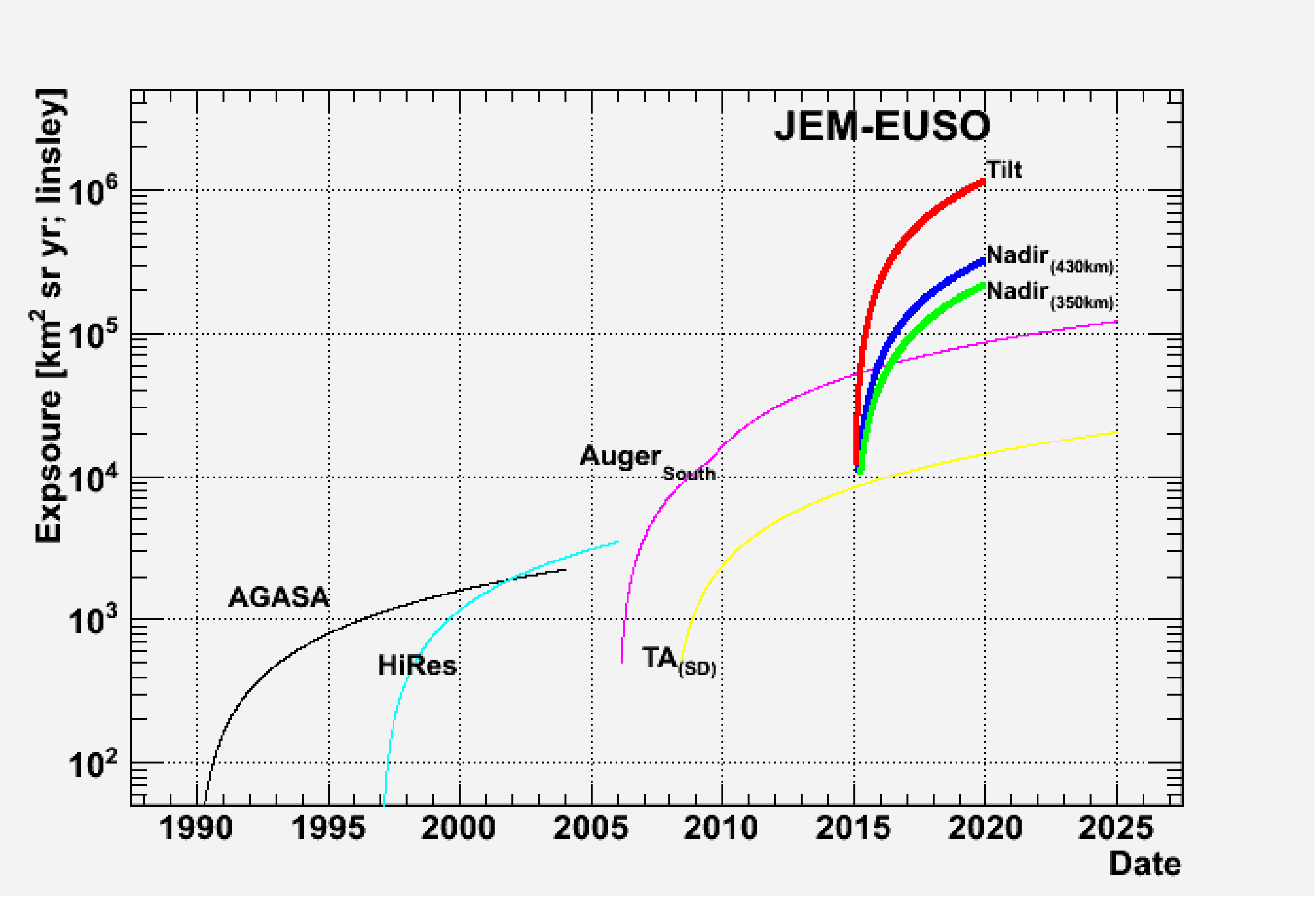
The energy spectra at around 10^{20} eV differs for different source distances affected by the GZK process.



Final Confirmation of GZK effect

Medina-Tanco 2008

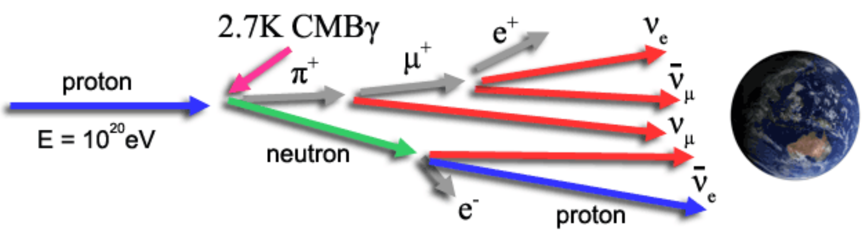
JEM-EUSO exposure



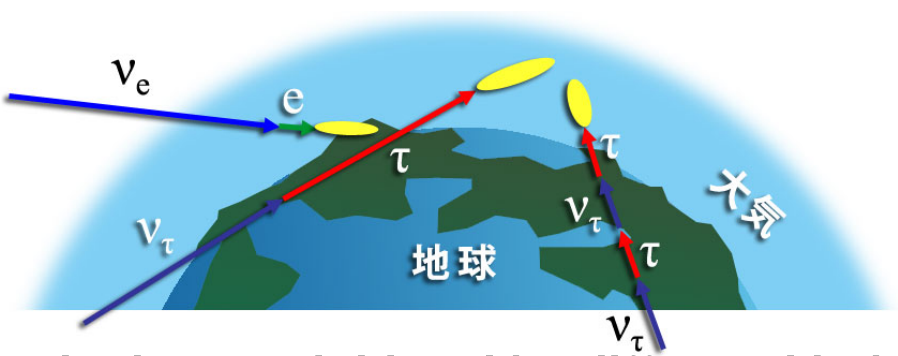
JEM-EUSO as gamma ray & neutrino observatory

- **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

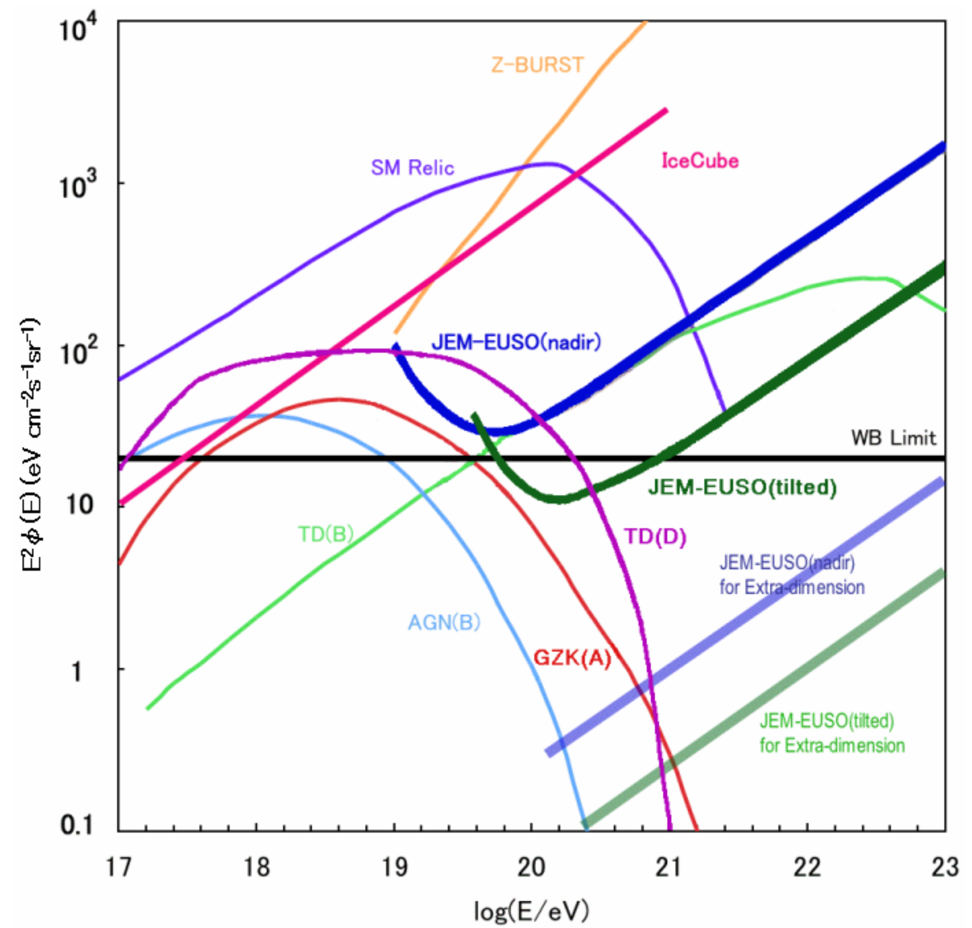
Extreme Energitic Cosmic Neutrinos



Neurino production by the GZK process

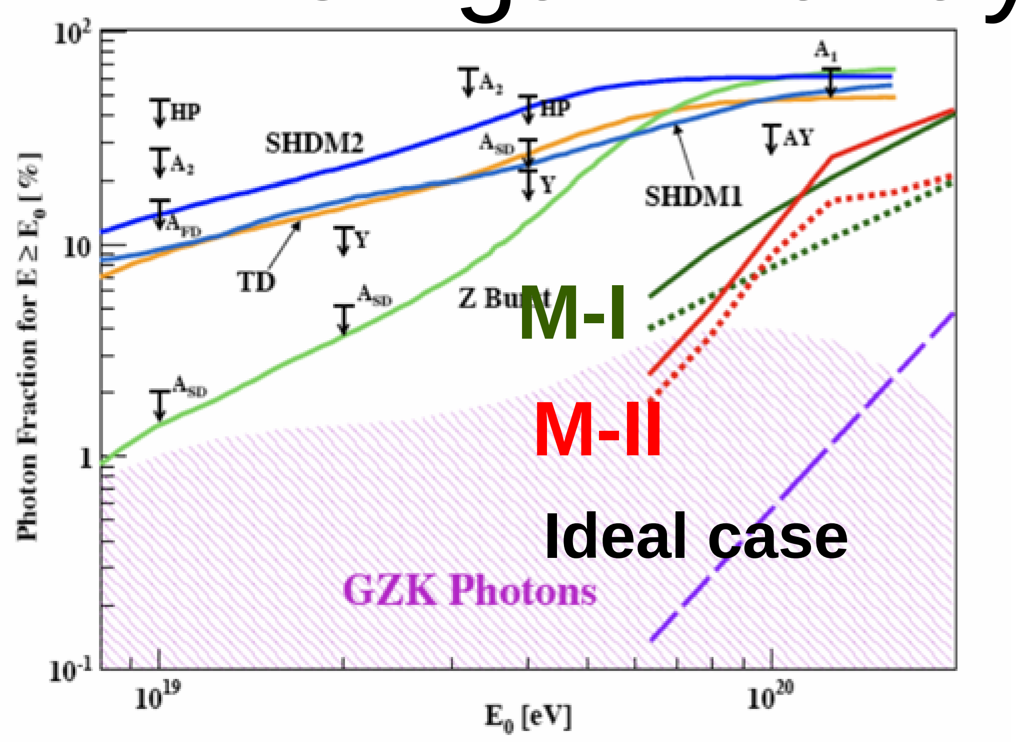


Air showers initiated by different kind of neutrinos



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

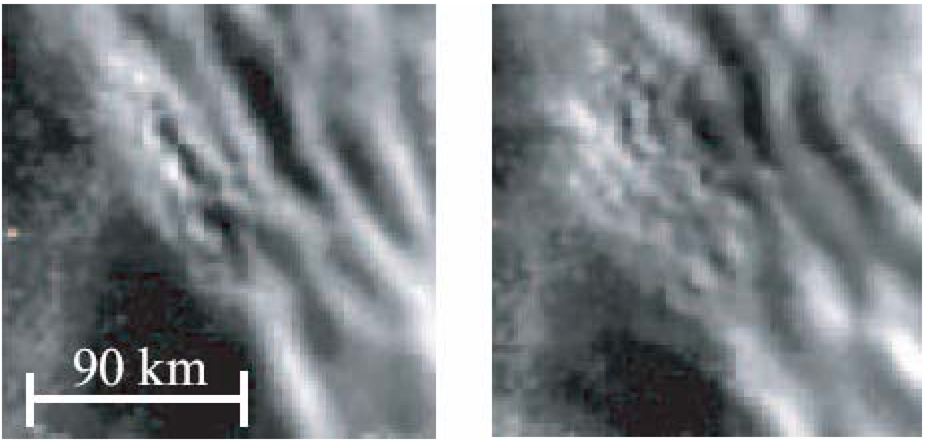
Expected sensitivity on gamma ray fraction



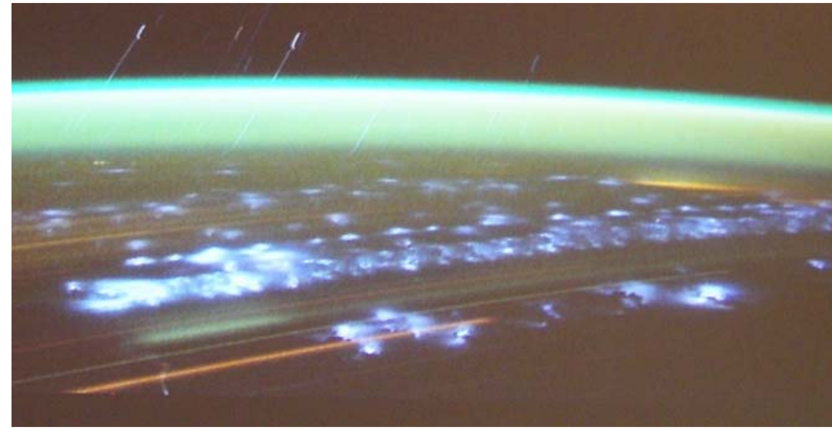
Expected limit by 5 year mission compared with upper limits set by existing experiments (95%CL)

- 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

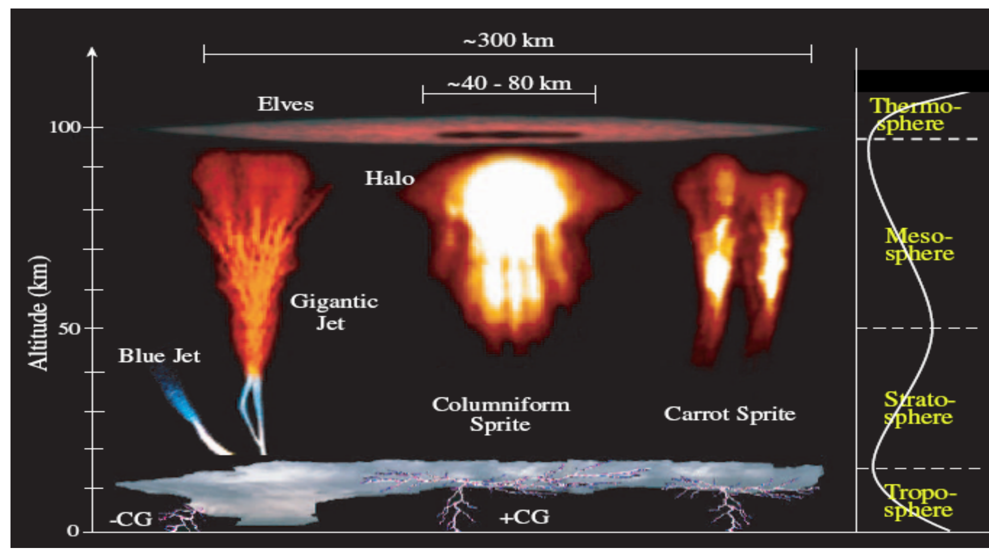


OH airlow observed from ground



Lightning picture observed from ISS

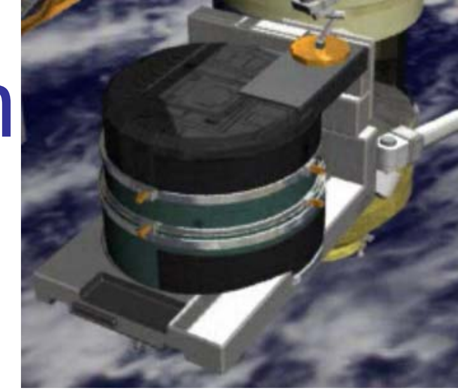
Leonid meteor swarm in 2001 taken by Hivison



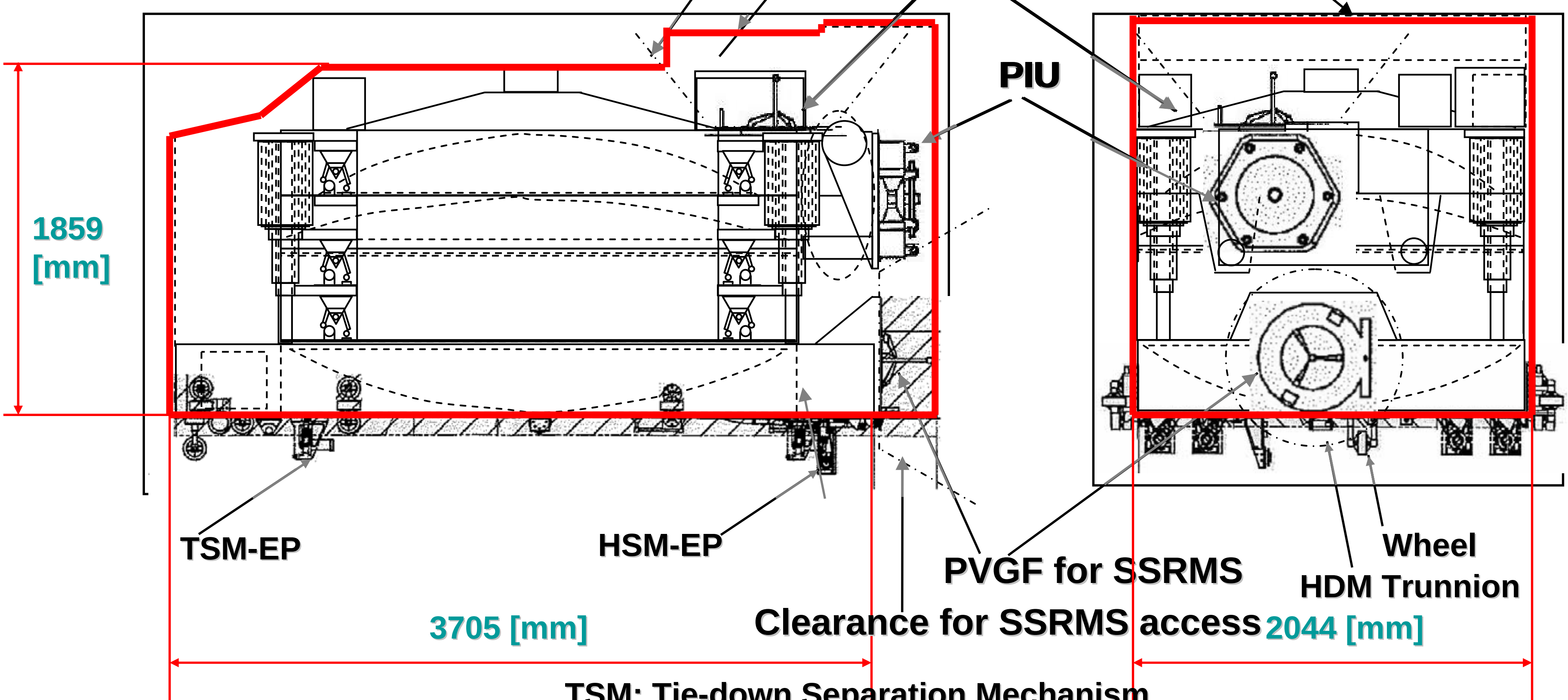
Various trangent airglows

Instrument

JEM-EUSO Launch Configuration

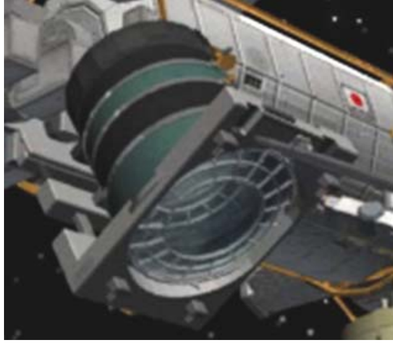


JEM-EUSO telescope will be squeezed at launch.

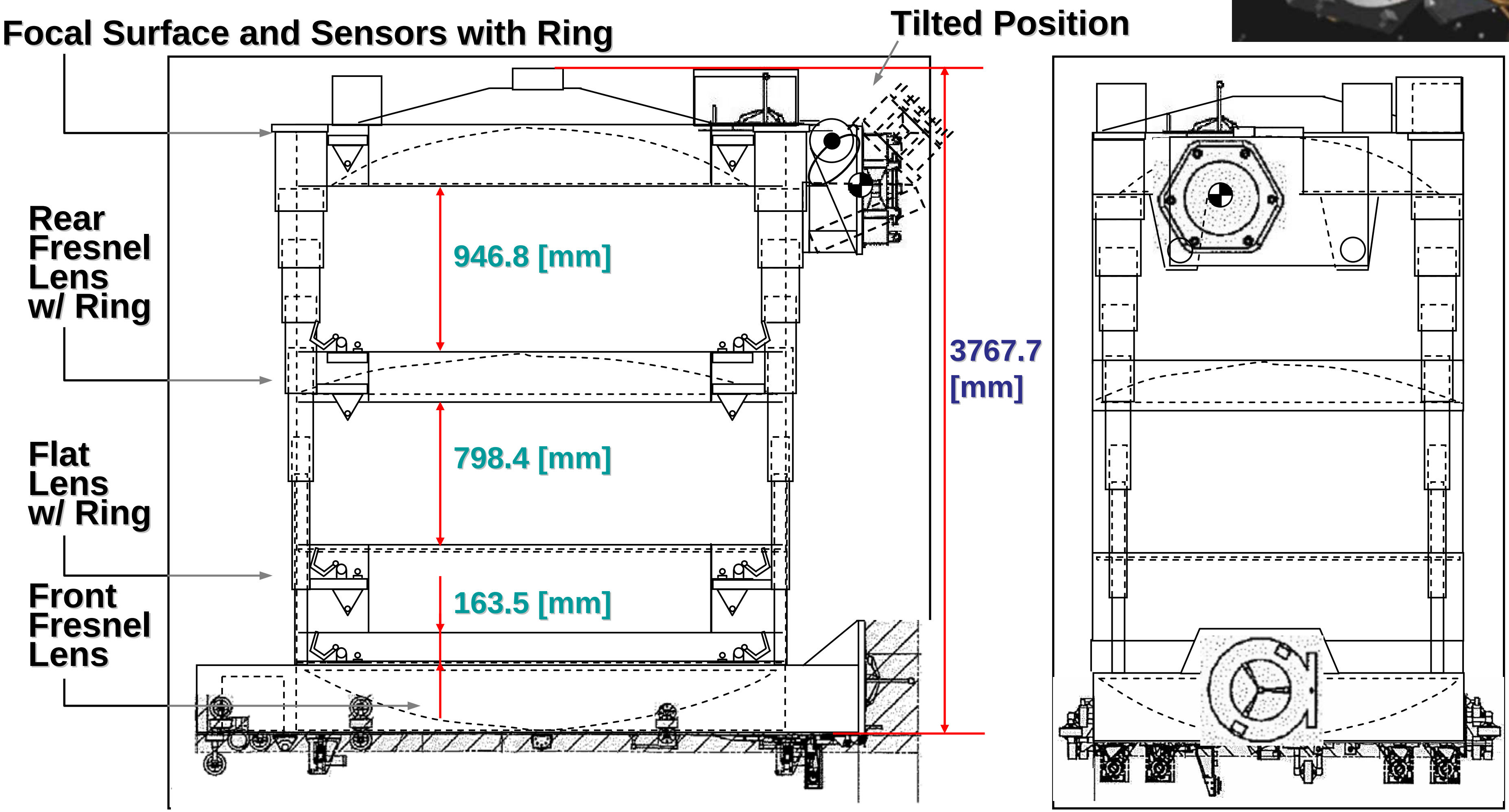


TSM: Tie-down Separation Mechanism
HSM: Harness Separation Mechanism
HDM: Hold Down Mechanism
SS: Space Station

JEM-EUSO On-orbit Configuration

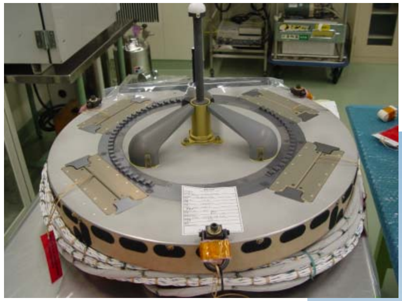


JEM-EUSO telescope will be elongated on orbit.

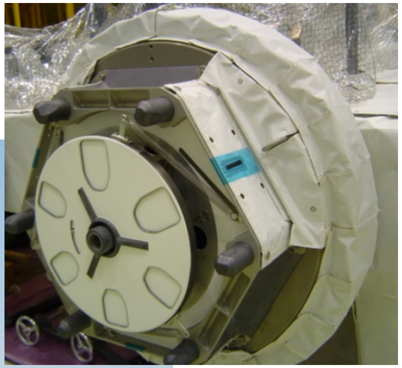


Telescope Barrel is not shown.

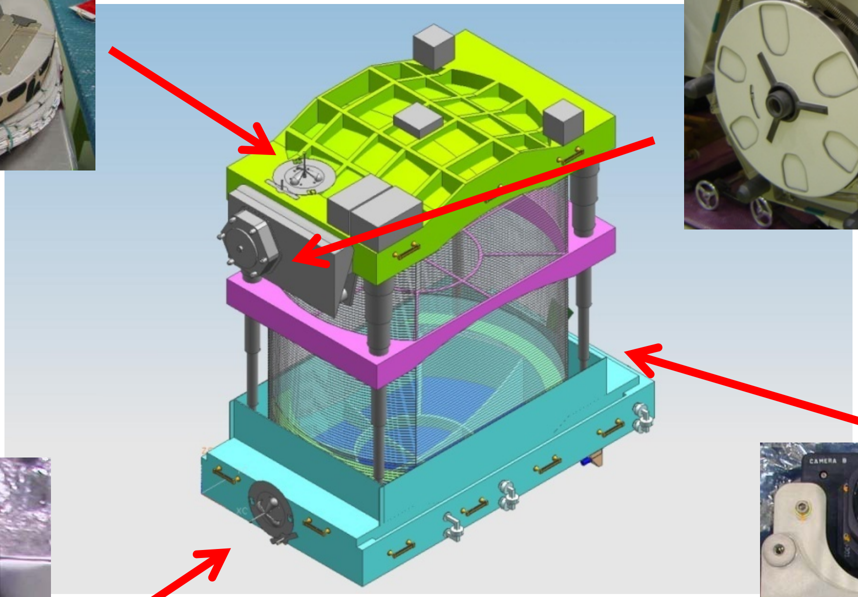
Telescope Structure



PVGF Overview



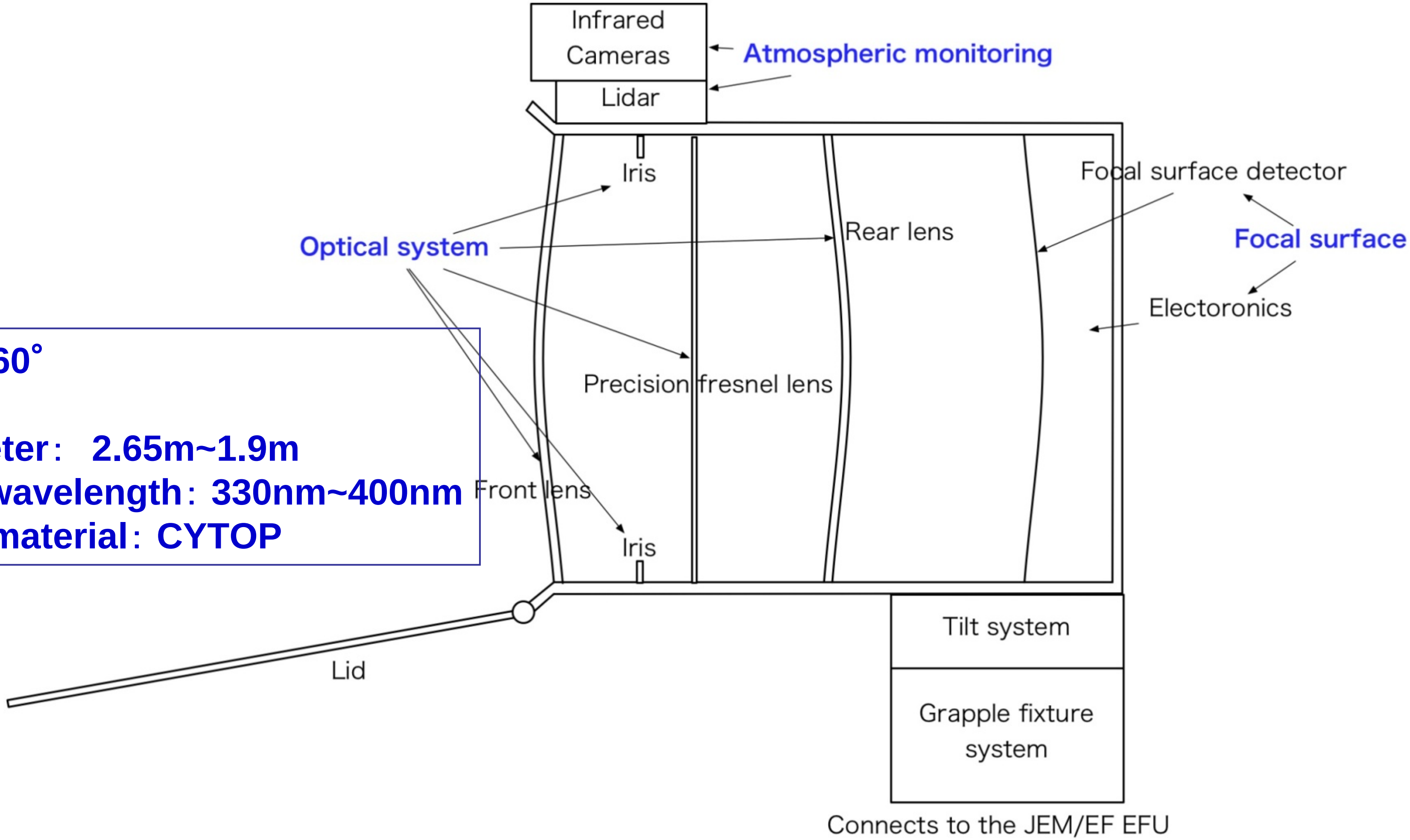
PIU Overview



FRGF Overview

HBCS Overview

Conceptual View of JEM-EUSO Telescope



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

Two Material Candidate for lens
PMMA000 and CYTOP

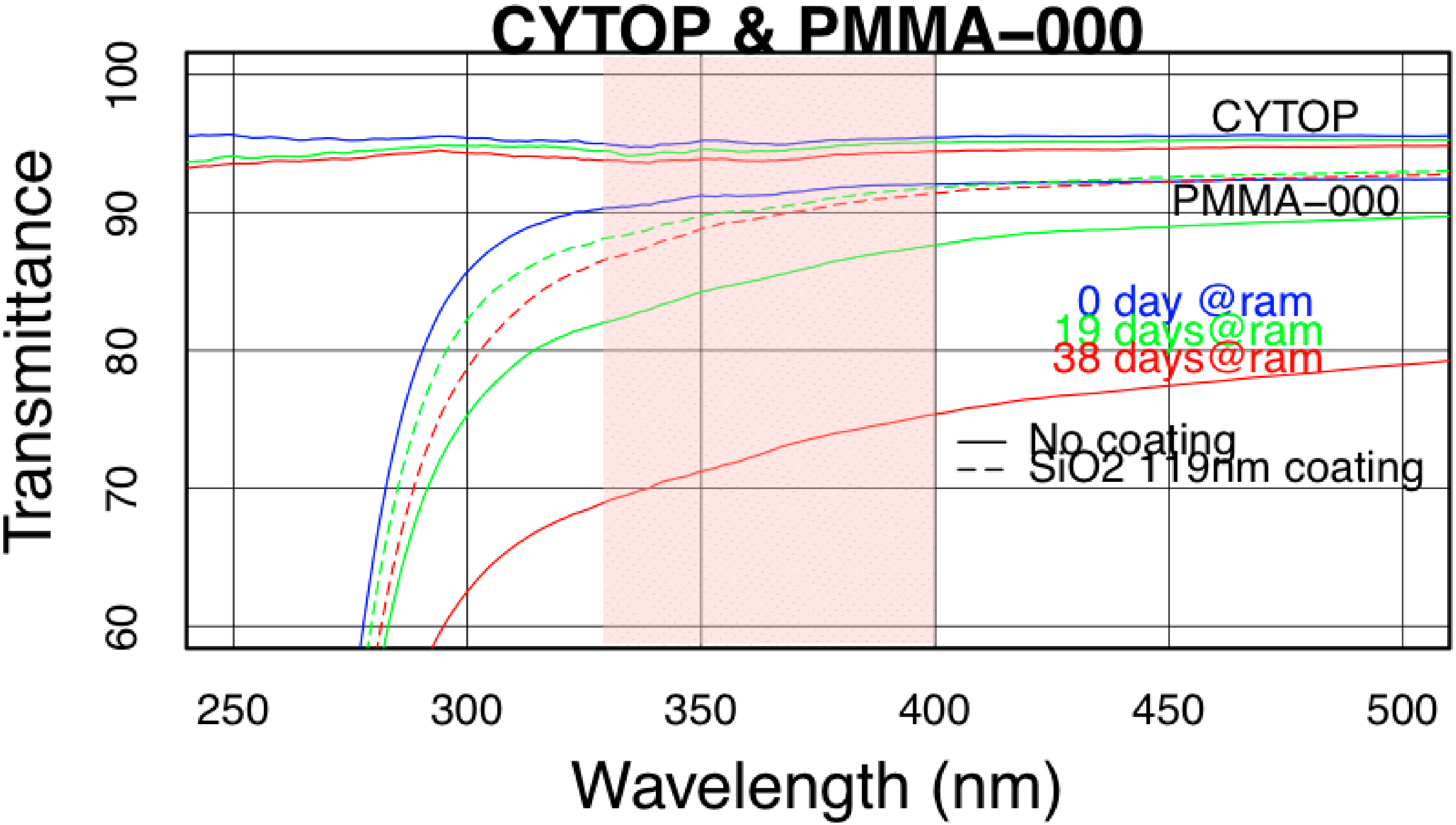
PMMA000

- Mitsubishi Layon
- Refraction index~1.5
- Large color aberration
- Low density：1.2
- No tolerance against Atomic Oxygen
- Cheap
- Aquarium
- Many space experiment
  - →Baseline

CYTOP

- Asahi Glass
- Refraction index 1.35
- Small Color aberration
- High density=2.0
- Strong tolerance against Atomic Oxygen
- Expensive
- Coating, Medical Instruent, and UV fiber
- No space experiment
  - →Advanced option

Atomic Oxygen :vertical



Telescope cross section

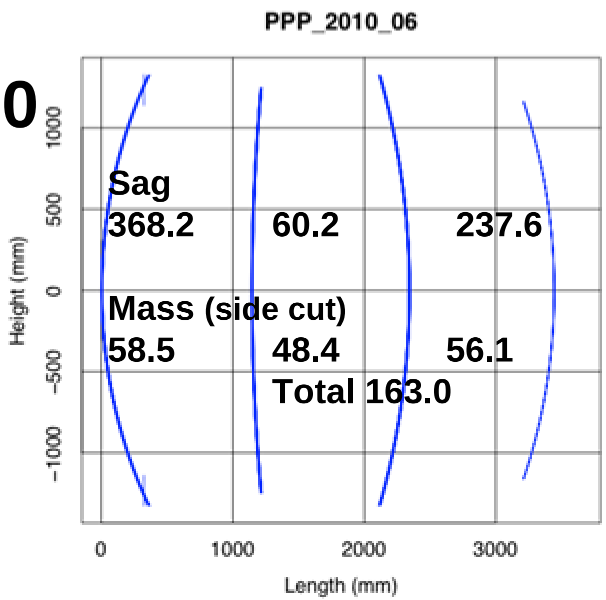
Baseline optics

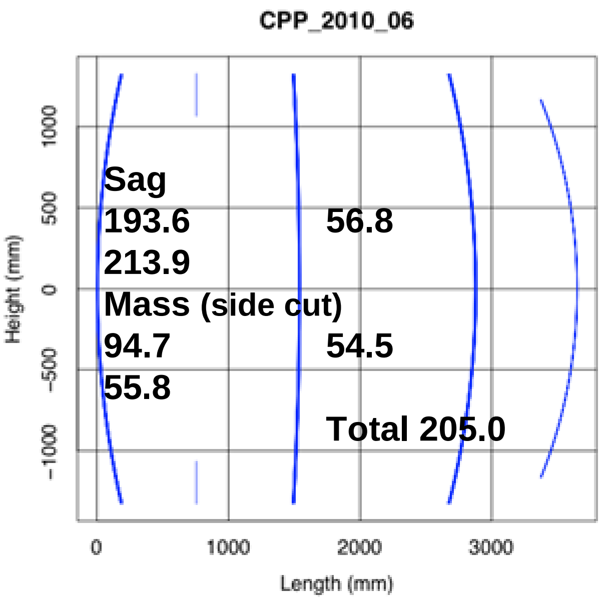
Advanced optics

PPP 2010

FS spherical
Radius of curvature
2997.33933073

Diameter 2330





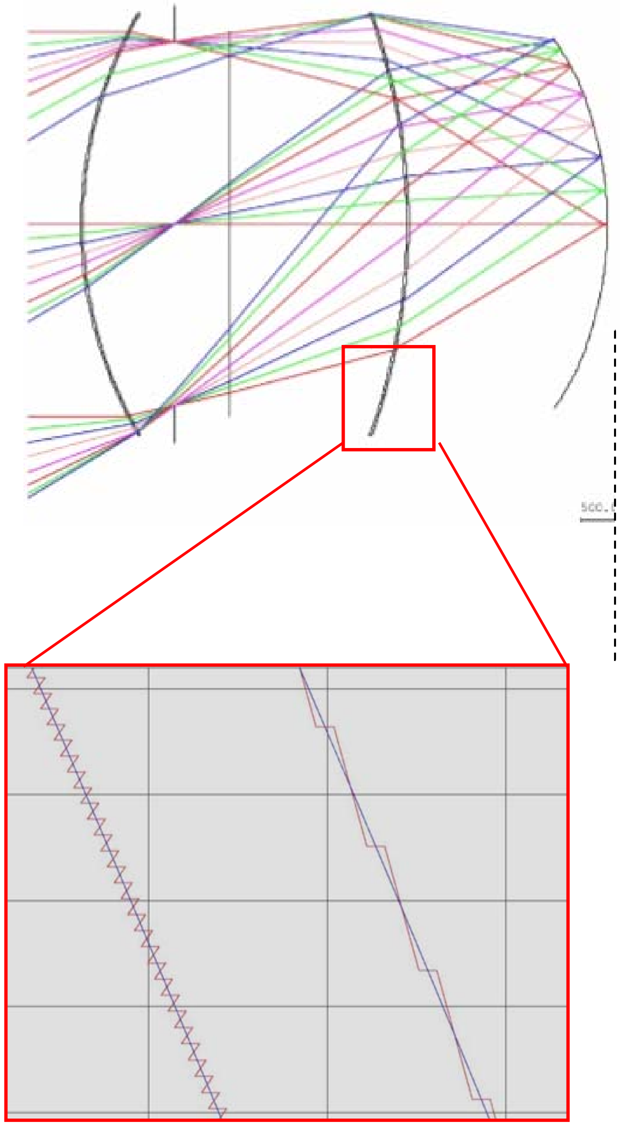
CPP 2010

FS spherical
Radius of curvature
2592.01405949

Diameter 2340

JEM-EUSO
OPTICS.GR.JP

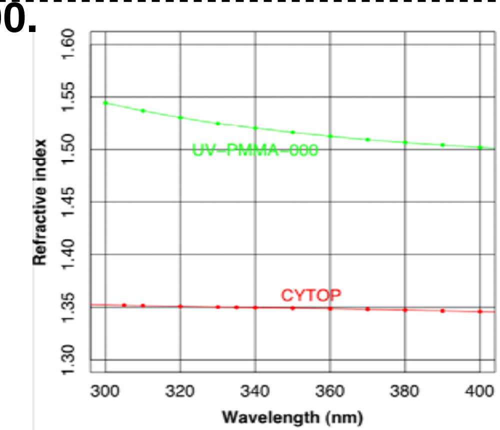
JEM-EUSO Optics



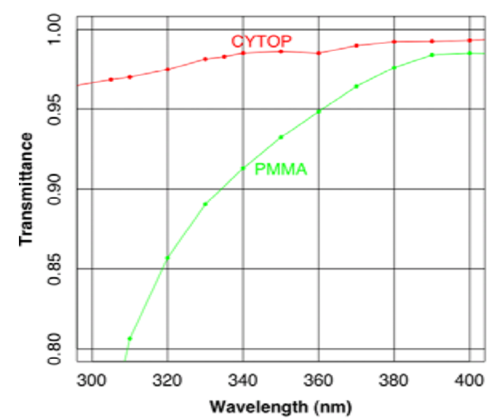
Lens diameter	2650mm
Field of view	60°
Wavelength	330nm≤ λ ≤ 400nm
Lens material	PMMA - 000, CYTOP

CYTOP

Transmittance is 95% between UV and near IR.
In addition, the refractive index dispersion of CYTOP is smaller than PMMA-000,therefore, CYTOP reduces the color aberration effect as compared with PMMA-000.The optical characteristics of CYTOP are superior to PMMA-000.



Refractive indexes of the two materials CYTOP and PMMA-000 in the near UV region

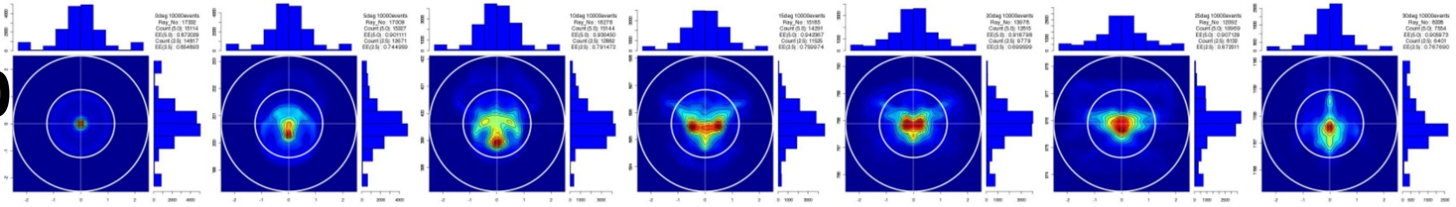


Transmittance of CYTOP and
PMMA-000 (15mm thckness)

Spot Diagram

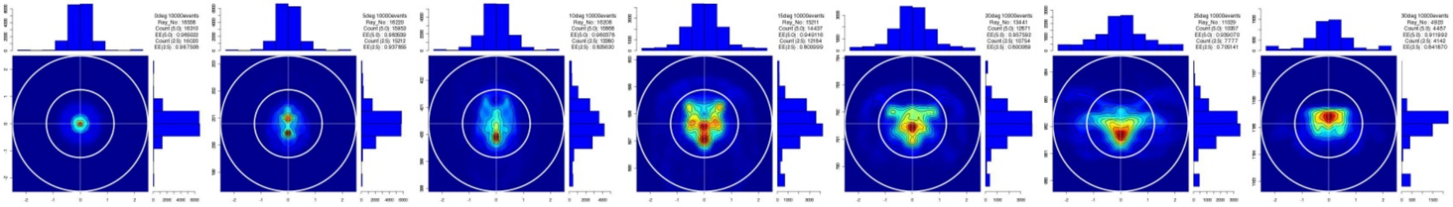
Baseline optics

PPP 2010



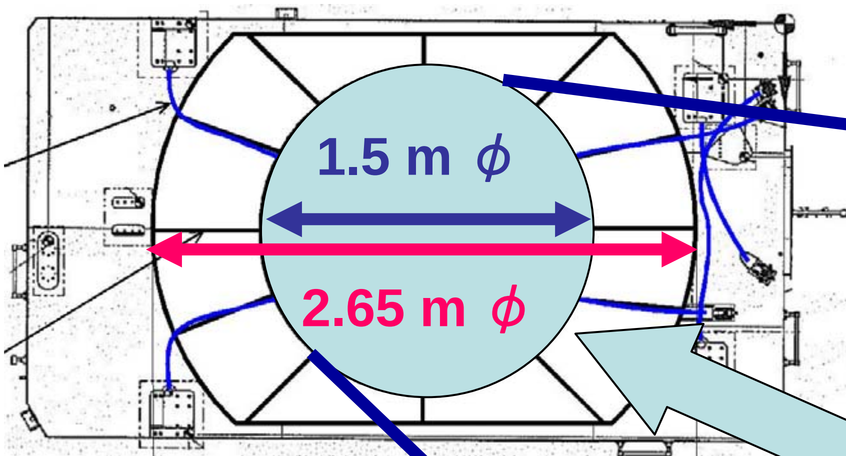
Advanced optics

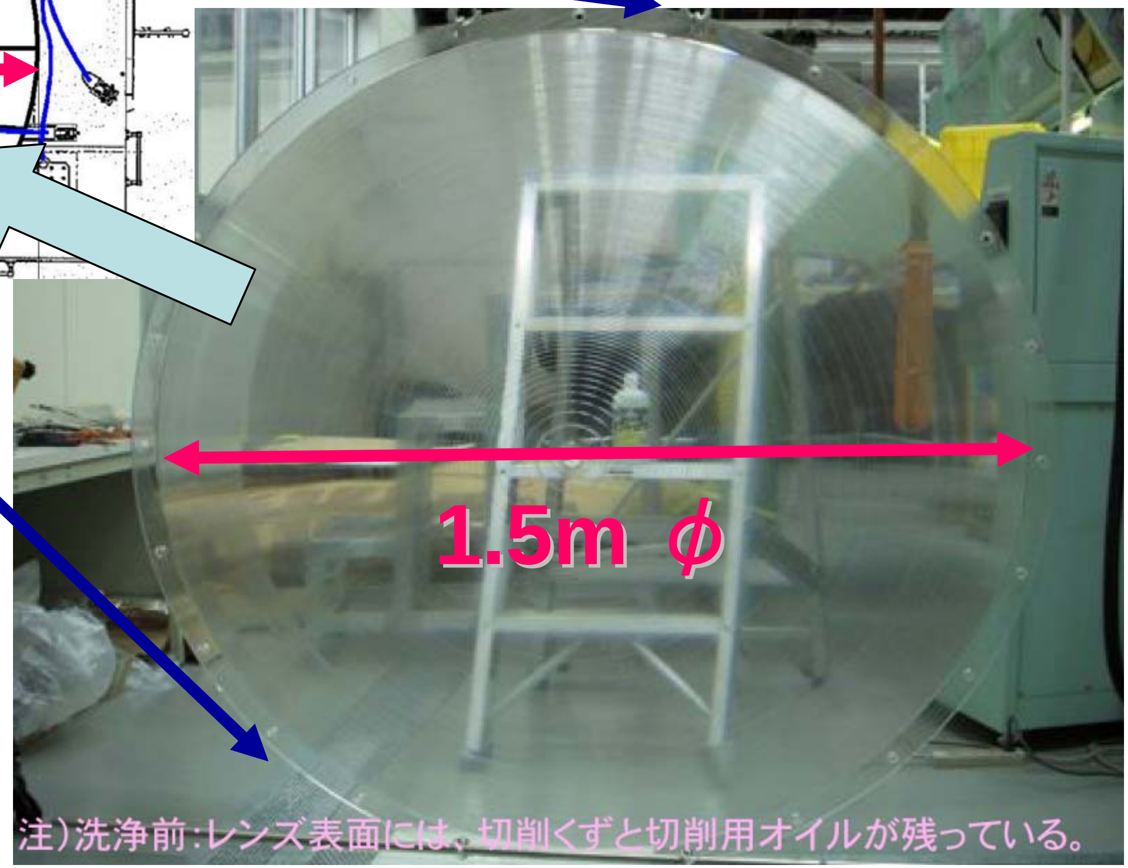
CPP 2010



Optics

Manufacturing large diameter Fresnel Lens





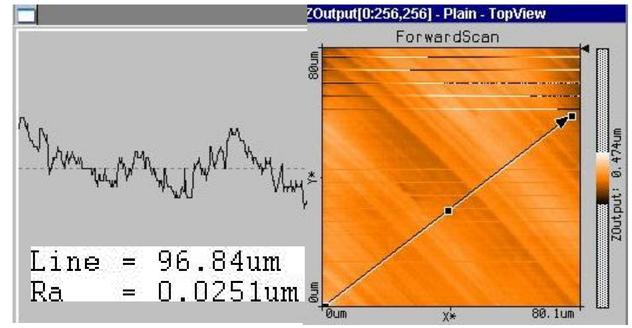
We obtained a cutting machine with a 3.4m dia. turn table to make a 2.65m dia. Fresnel Lens.

Results of processing Convex surface（remediation）〔1st lens〕

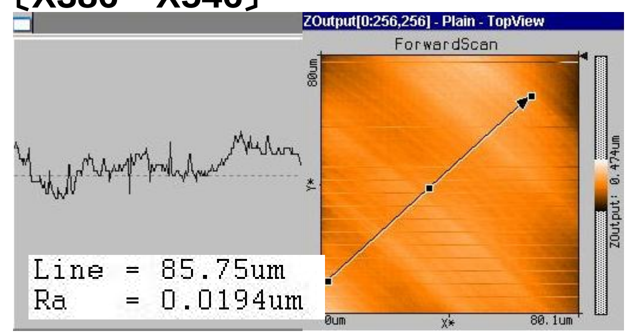
Measurement results by AFM are shown below. We measured at the 3 different points, and all the measurement results in these 3 parts were almost the same. Therefore, we would like to indicate the measured data of the first lens for instance.

outline view

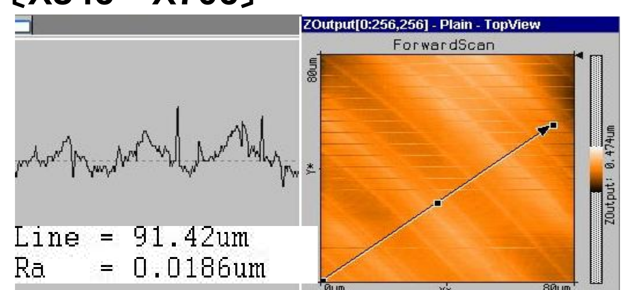
〔X216～X386〕



〔X386～X546〕



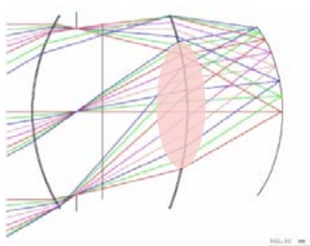
〔X546～X706〕

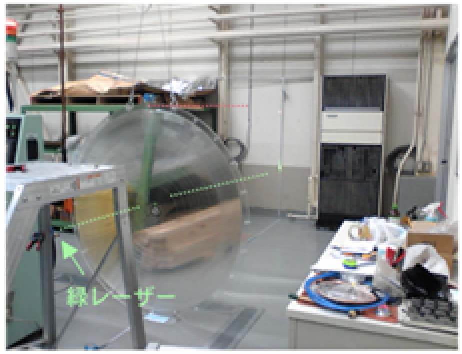


The related data with optical measurement shows that the roughness was under RMS 20nm

リアレンズ（第3レンズ）（2008年末完成）

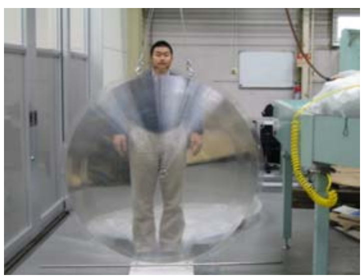
簡易集光テスト（緑レーザー 532nm）

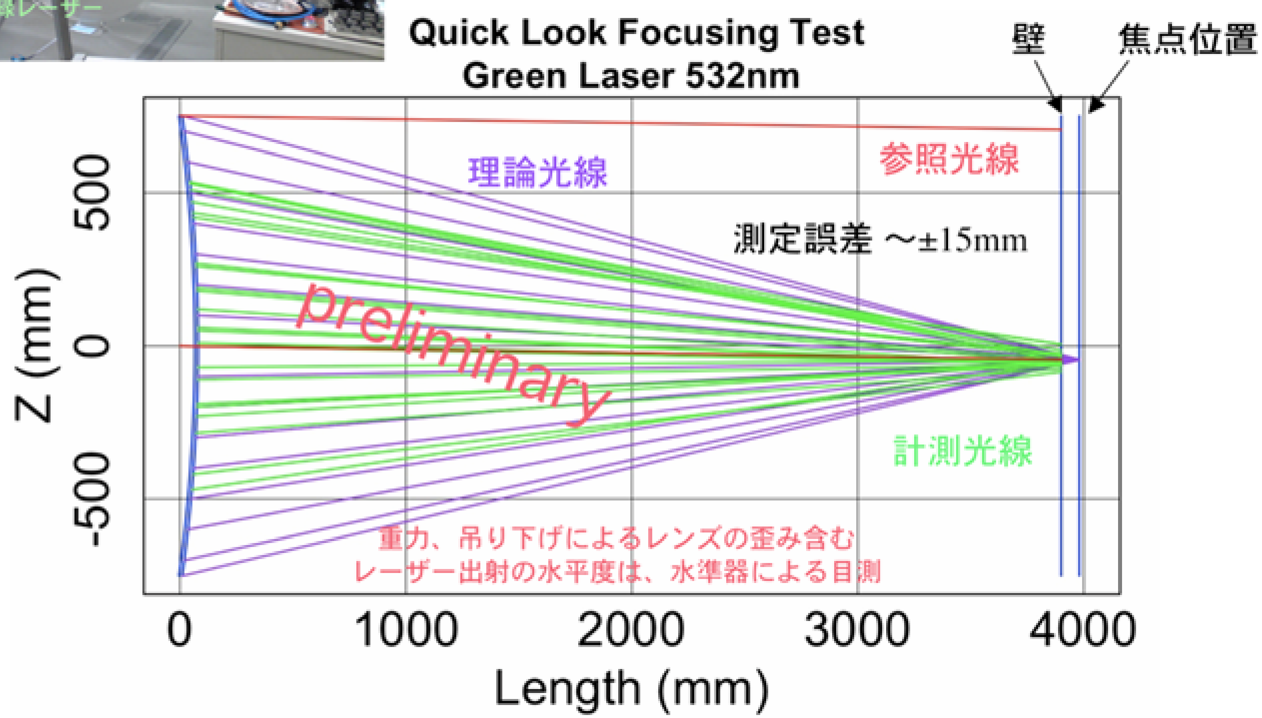




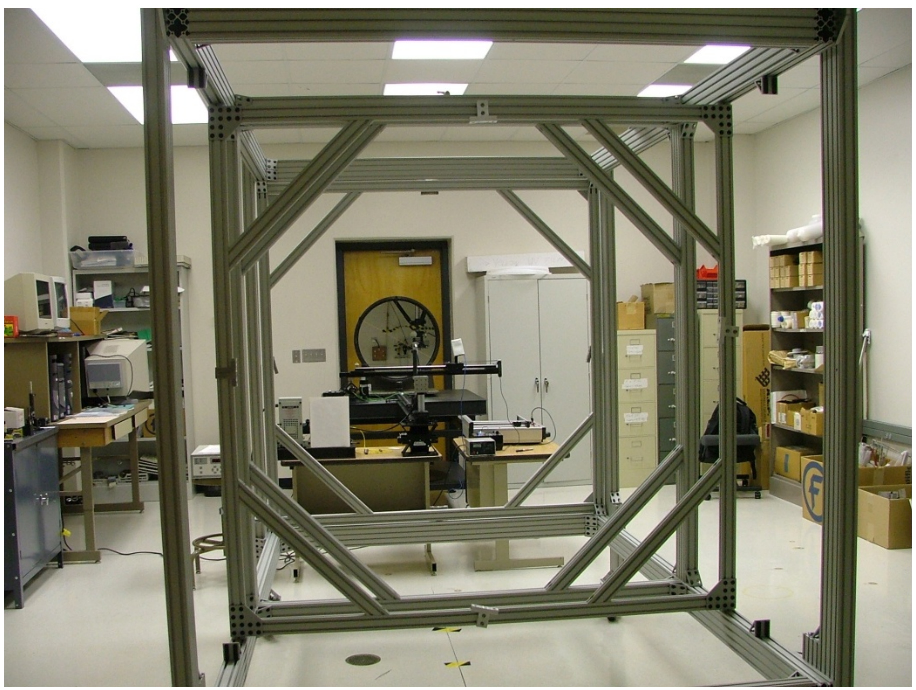
NASAでの詳細光学テストに備え簡易確認

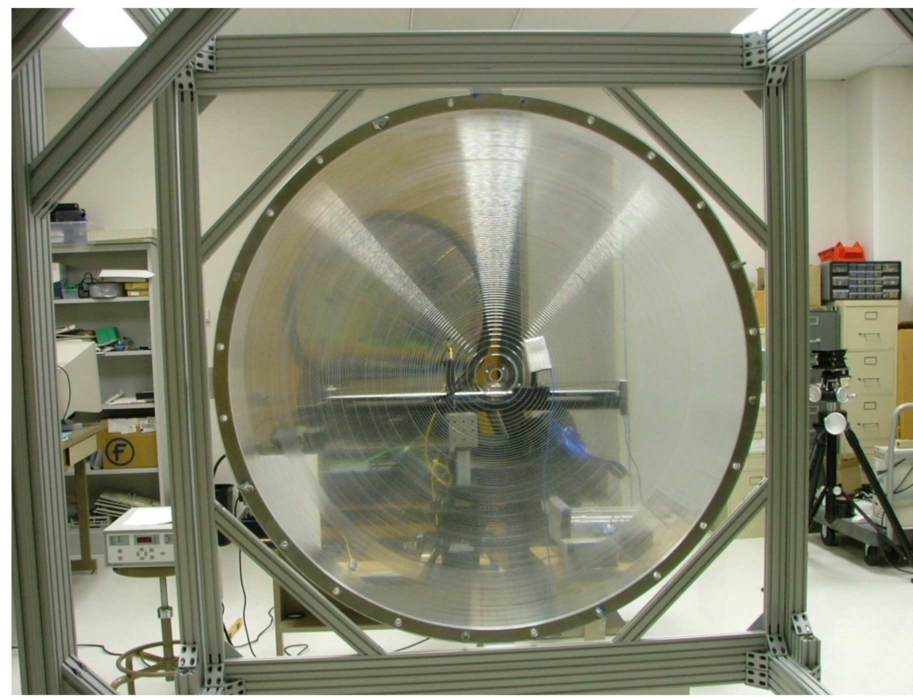
製作パラメタの確認（データの符号など）



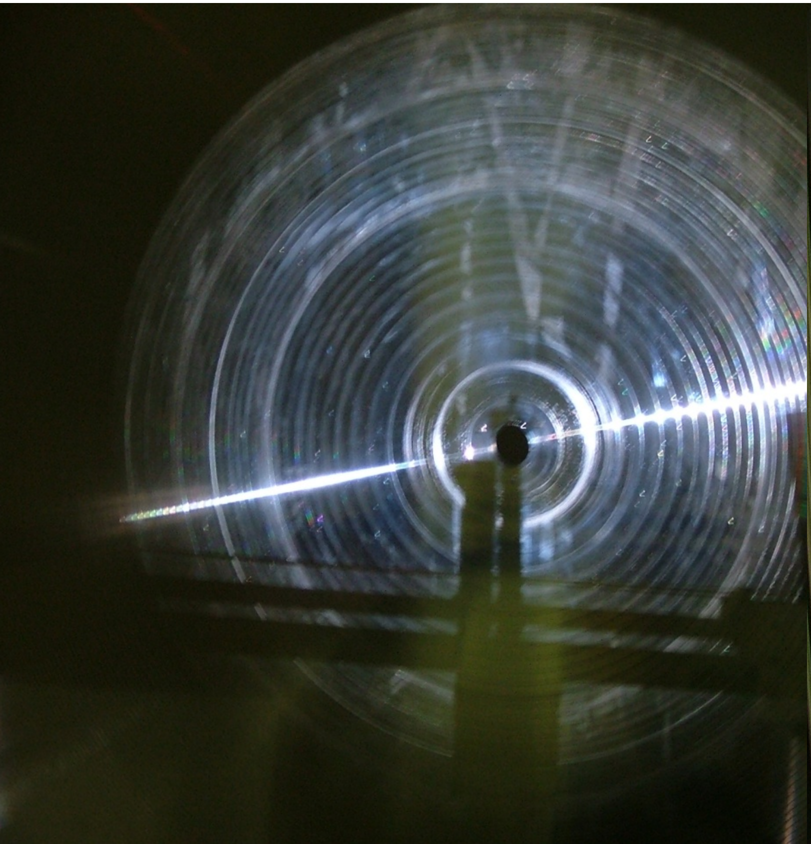


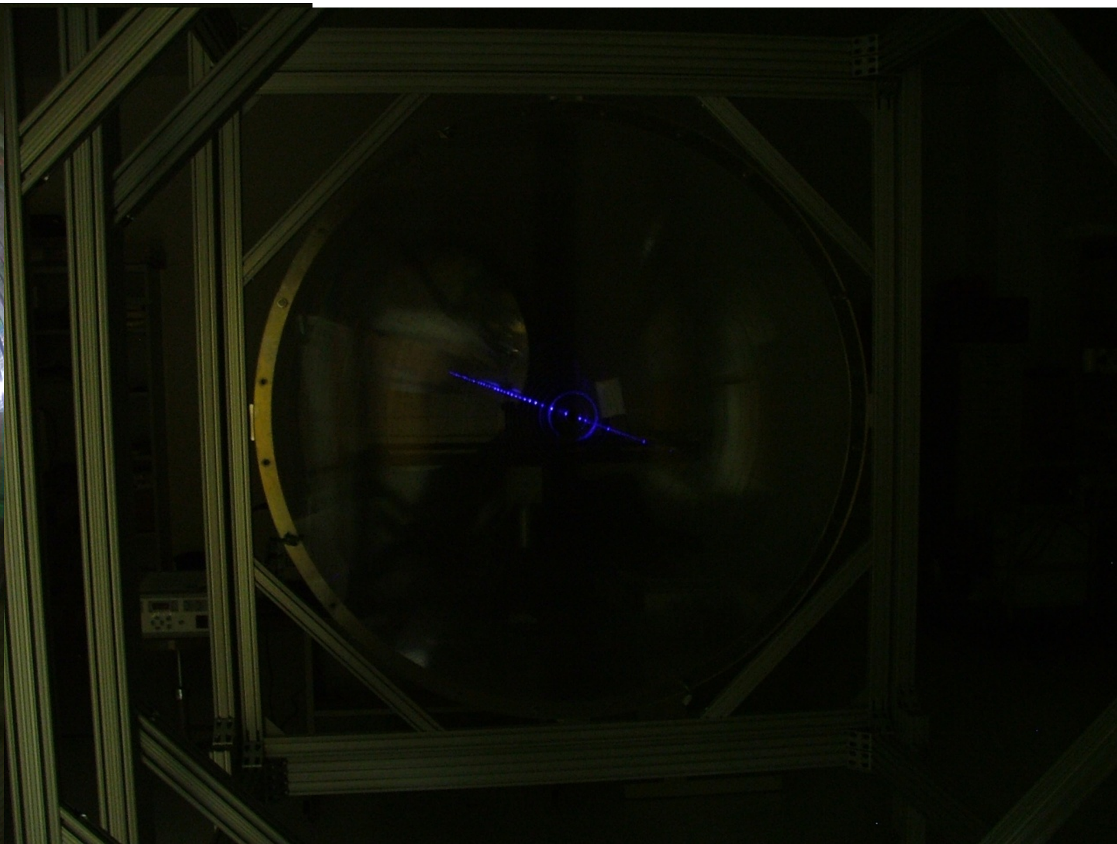
Optical Test at UAH



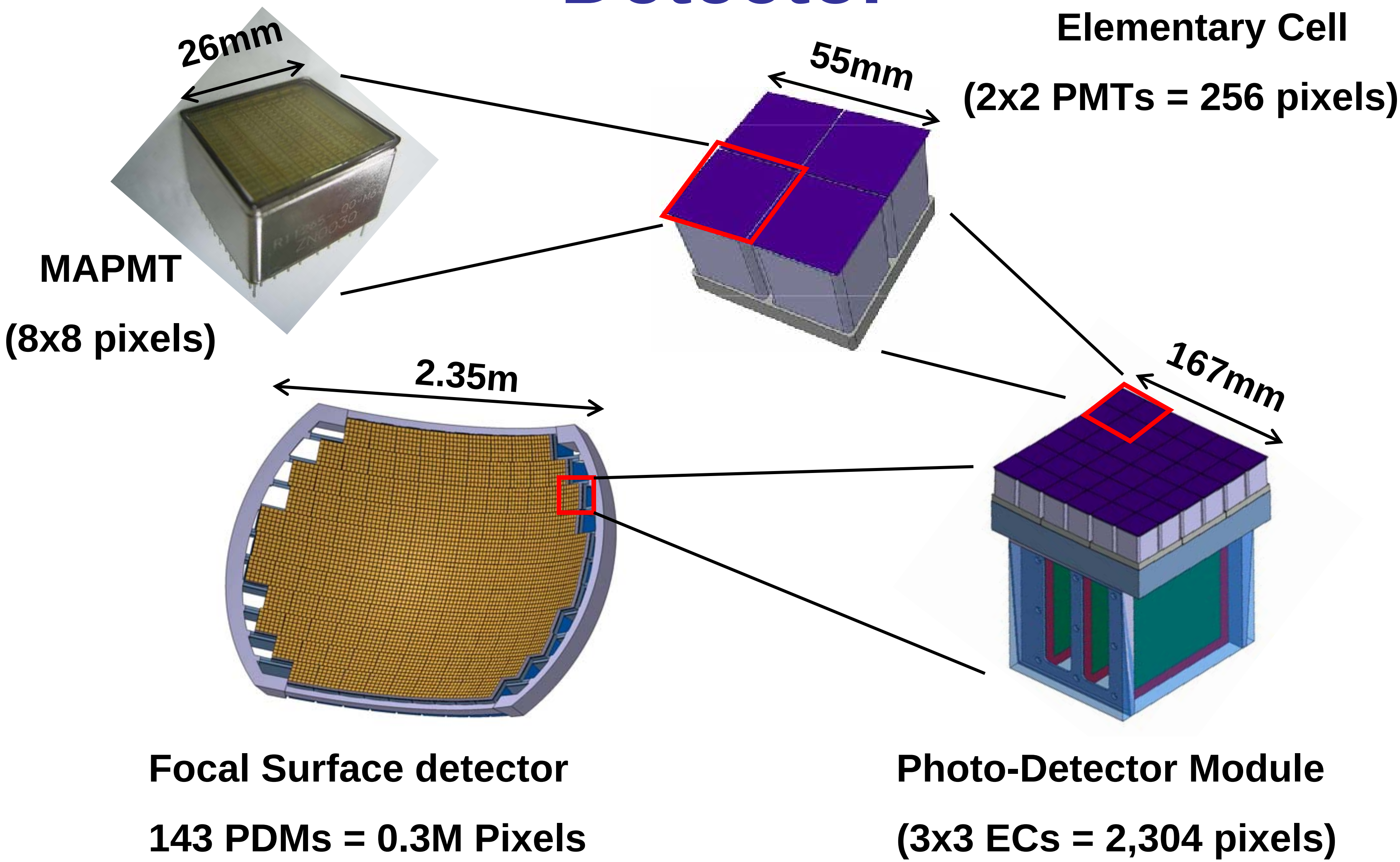


Optical Test at UAH

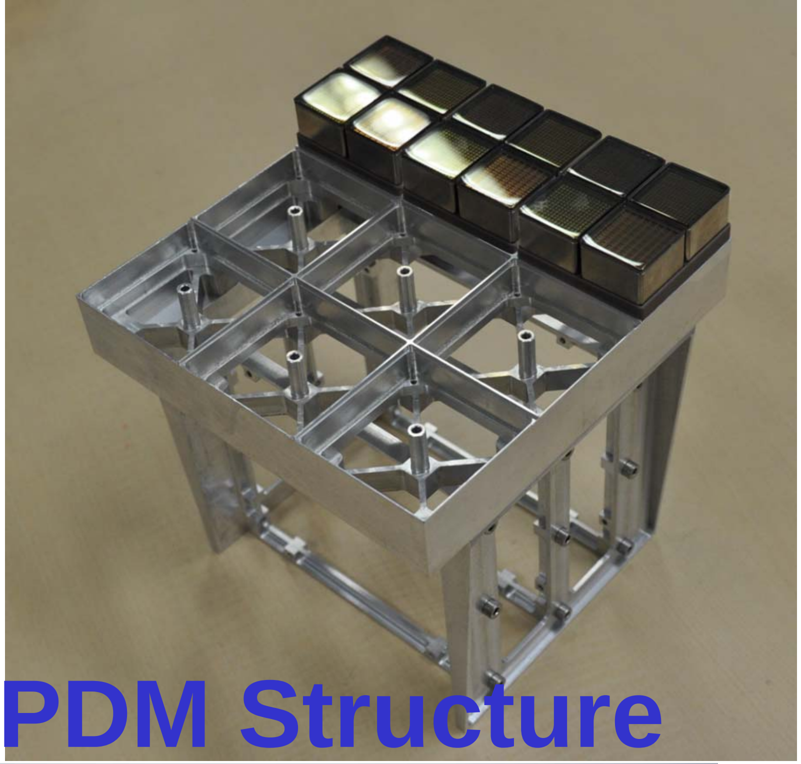




JEM-EUSO Focal Surface Detector



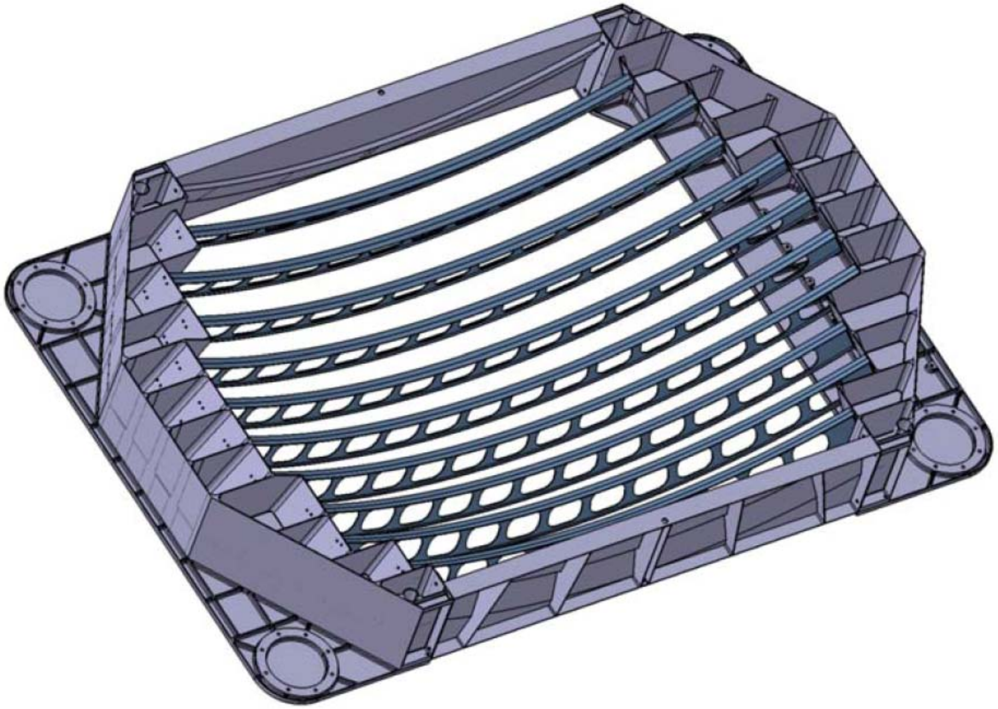
New MAPMT M64
and PDM structure

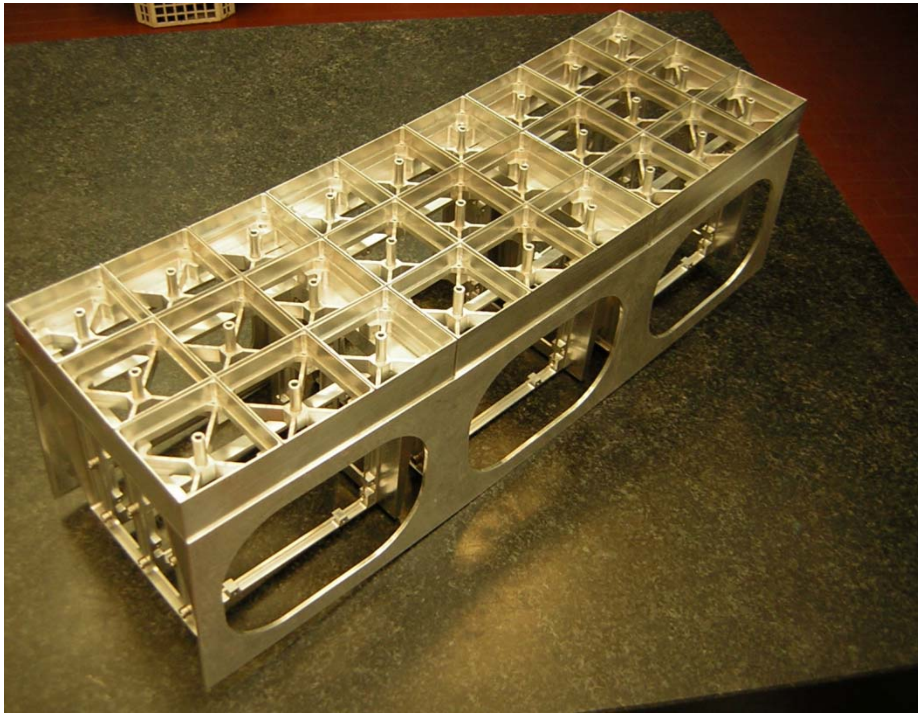


New PDM Structure

New M64

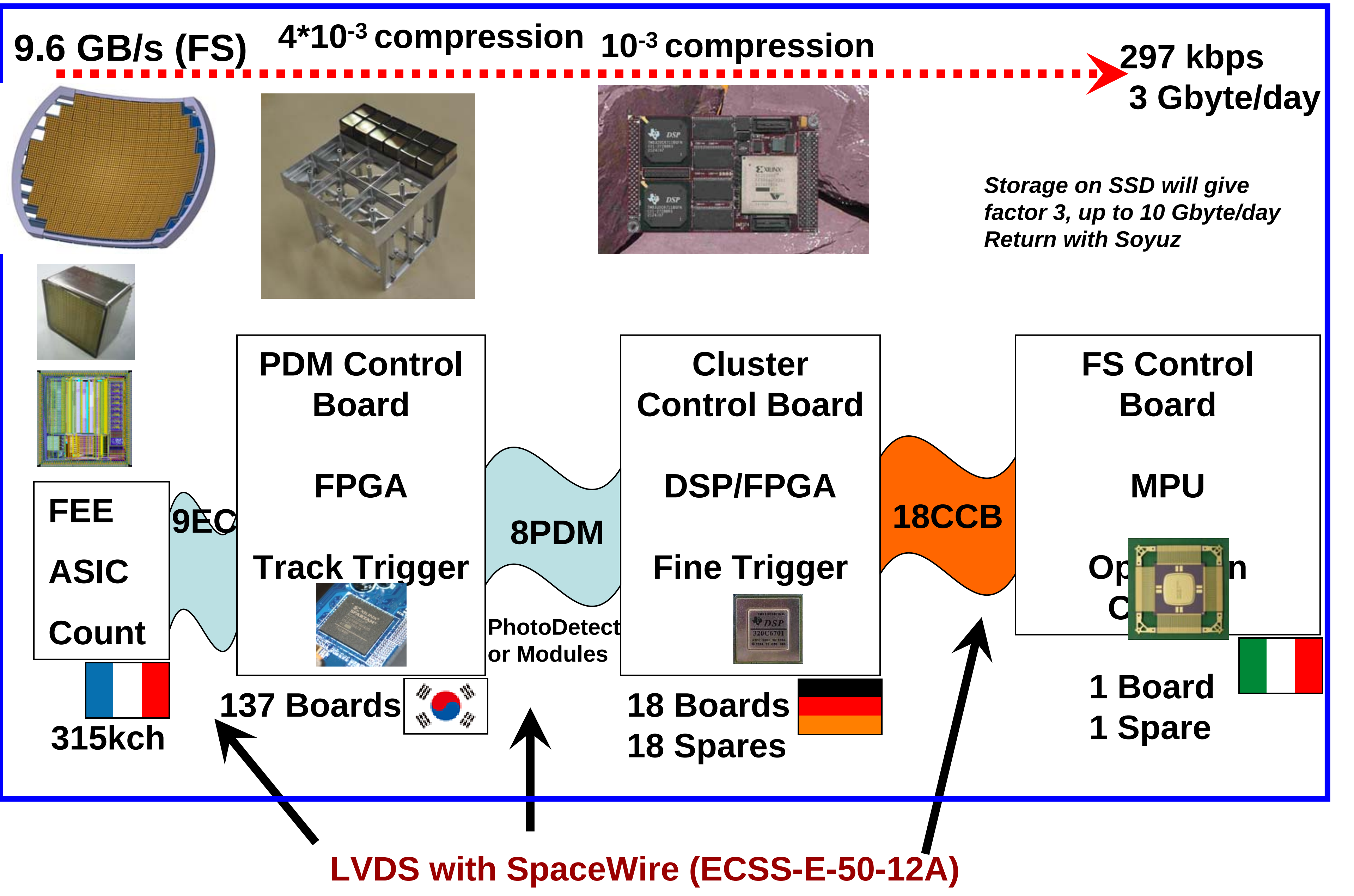
FS Support Structure



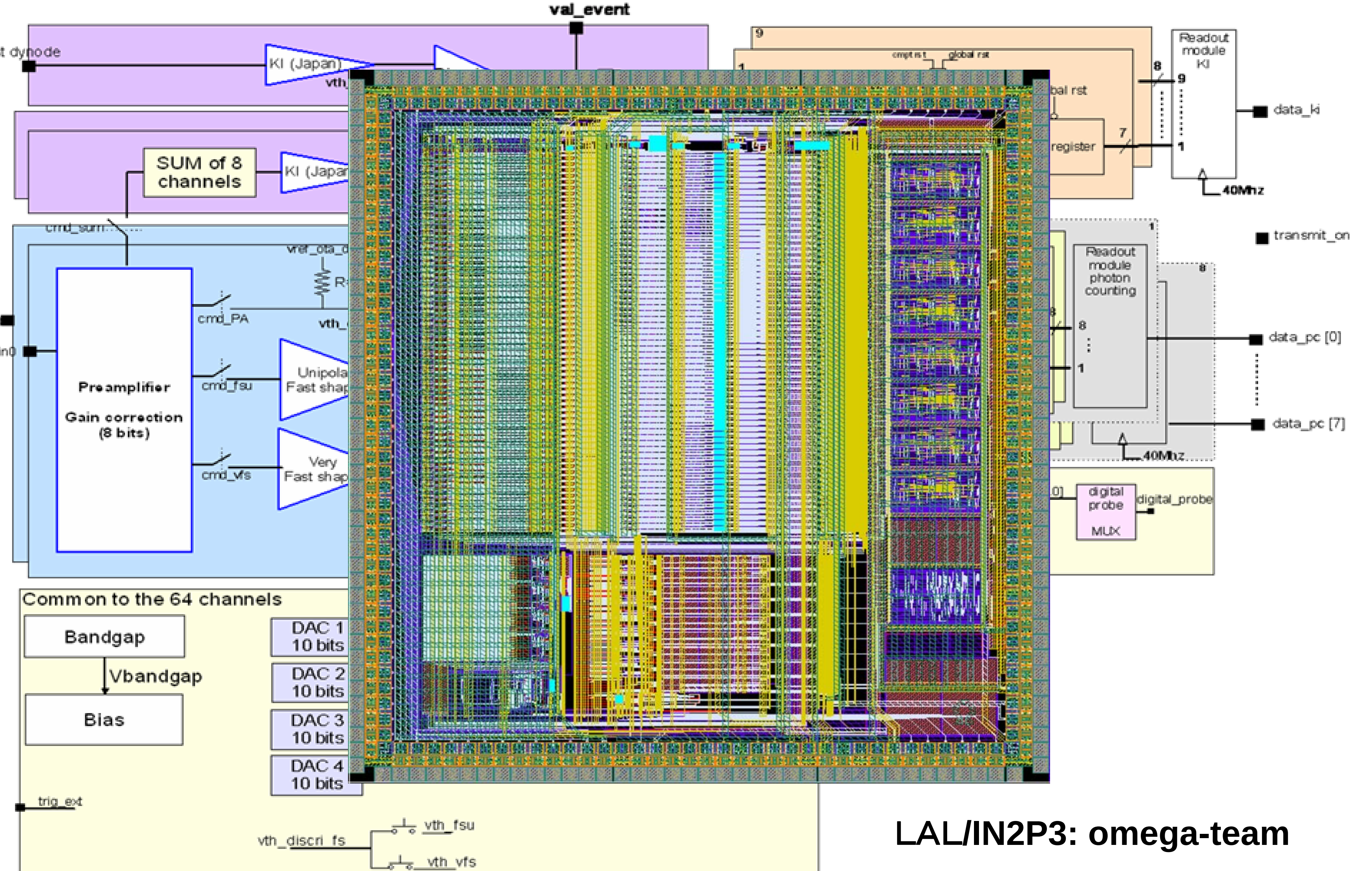


The prototype of the rib structure and 3 PDM stru

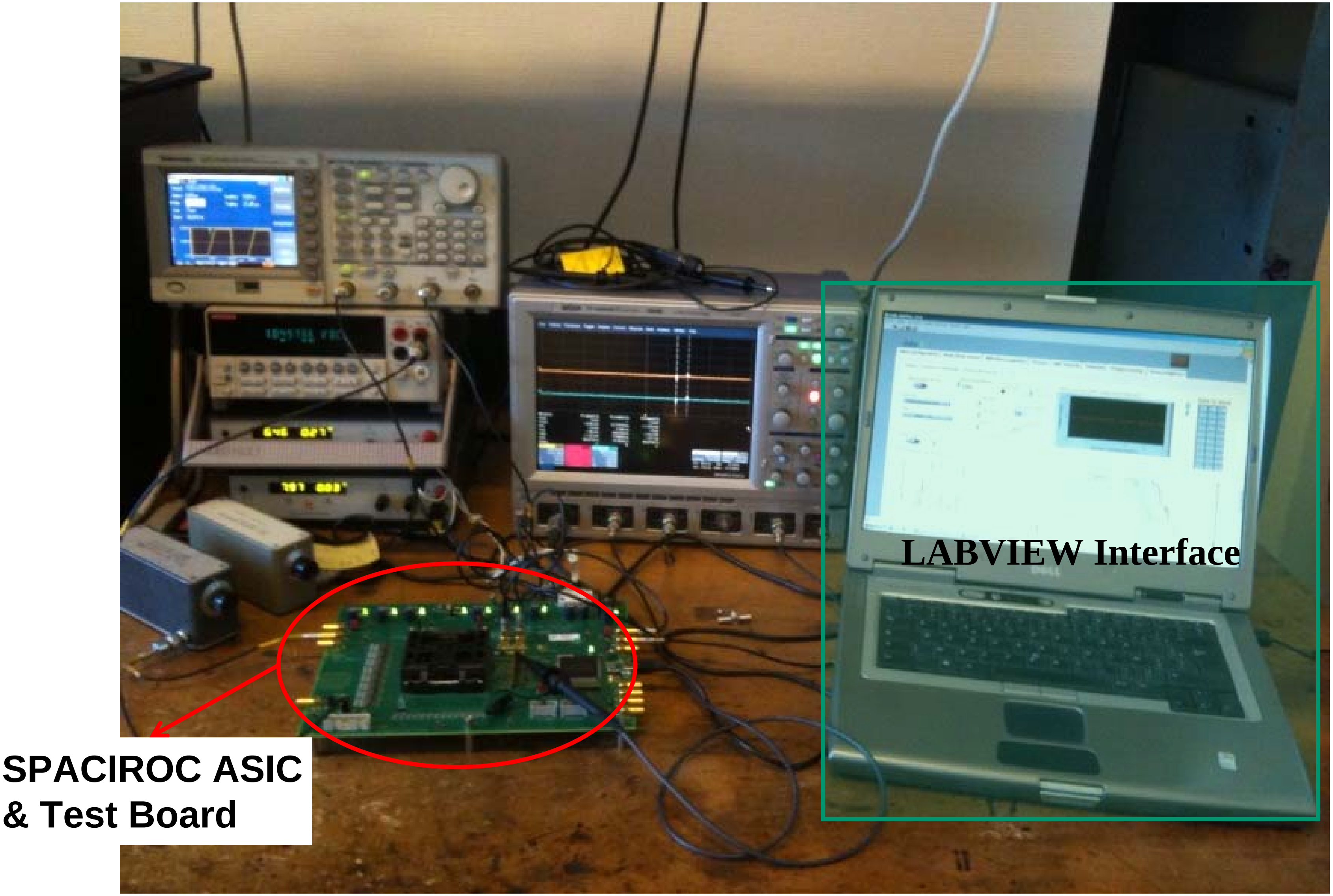
JEM-EUSO DAQ – Data reduction block scheme



Read-out ASIC : SPACIROC



LAL/IN2P3: omega-team


LABVIEW Interface
SPACIROC ASIC
& Test Board

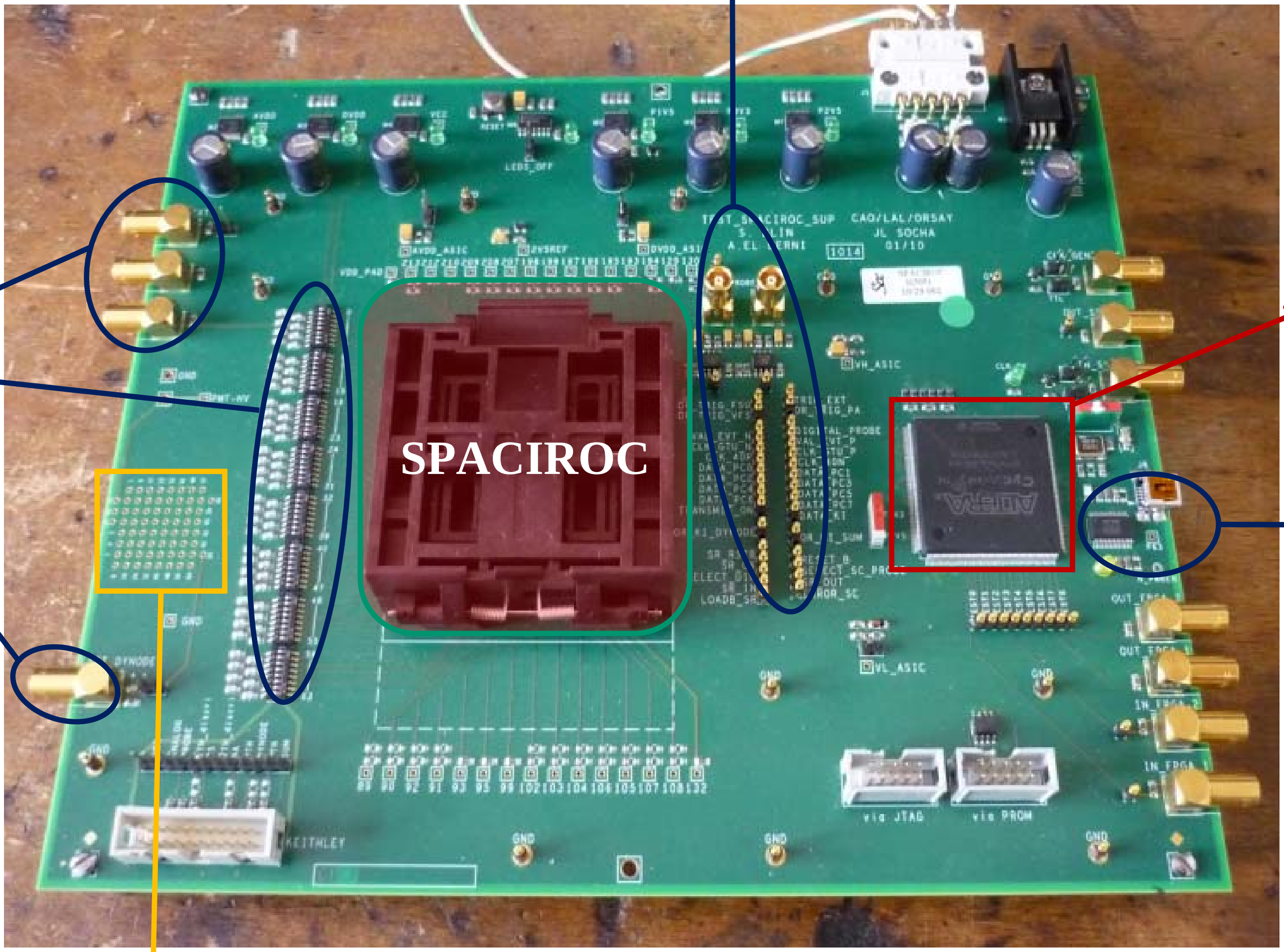
SPACIROC Test Board

Monitoring

Charge Input & Switching

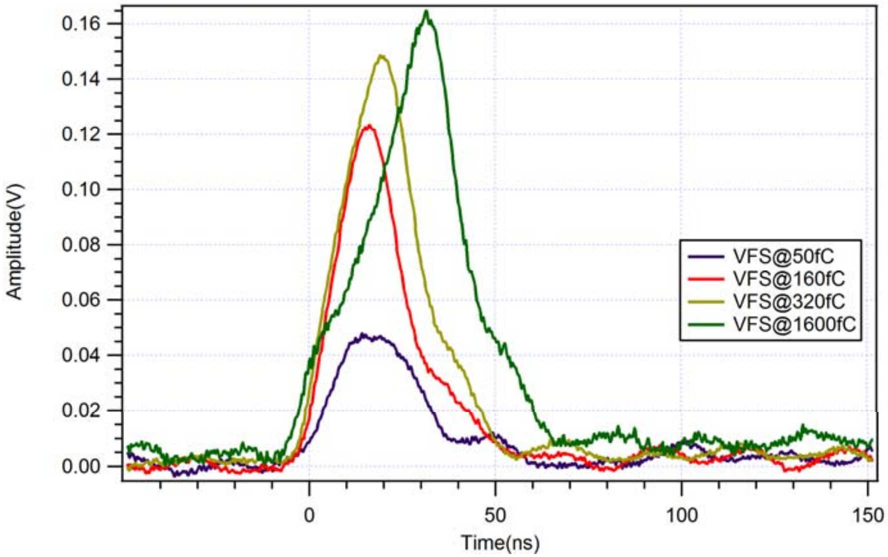
FPGA

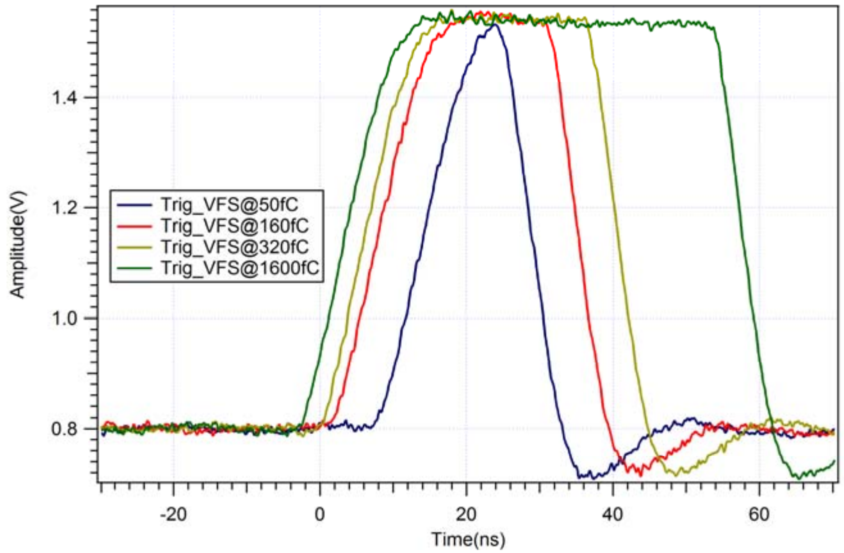
USB Interface



MAPMT Footprint

• VFS : Analog signal responses

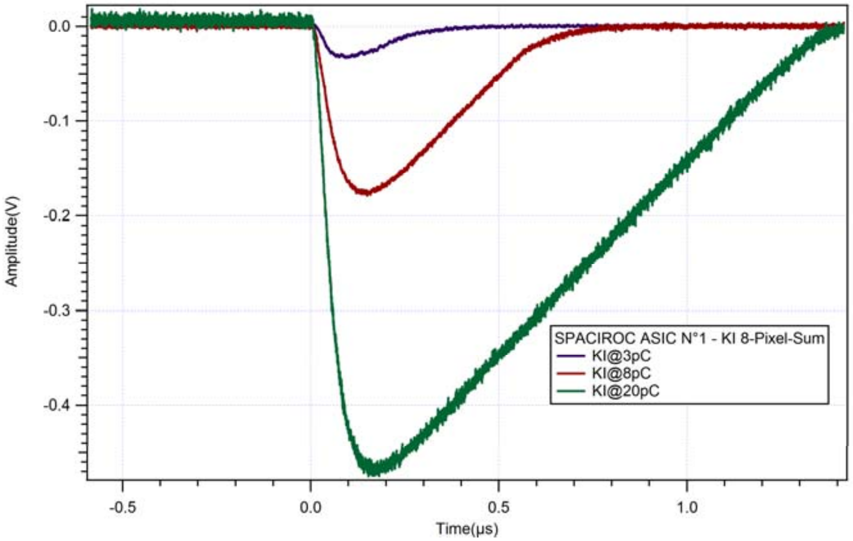


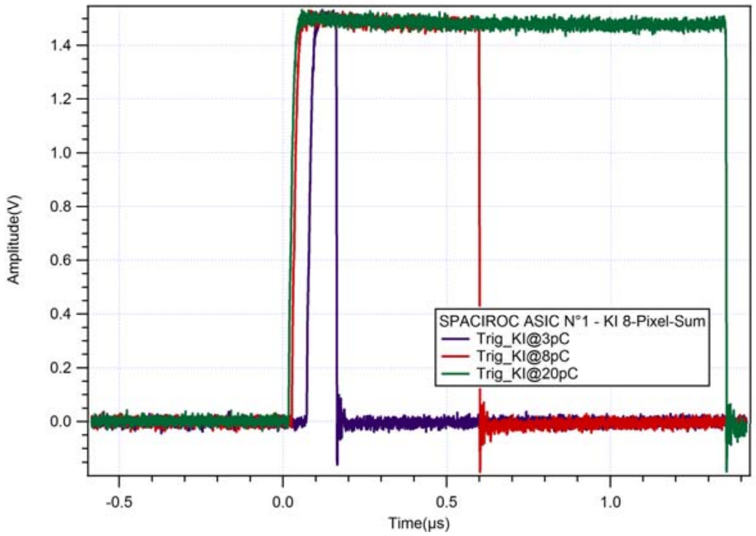


Fixed-gain shaper. Experimental design.
•Injected charges: 50fC,160fC,320fC & 1.6pC (1/3 to 10 p.e)
•Smallest trigger pulse width measured ~ 15ns (from analog signal monitori

Preliminary Results

• KI : Analog signal responses





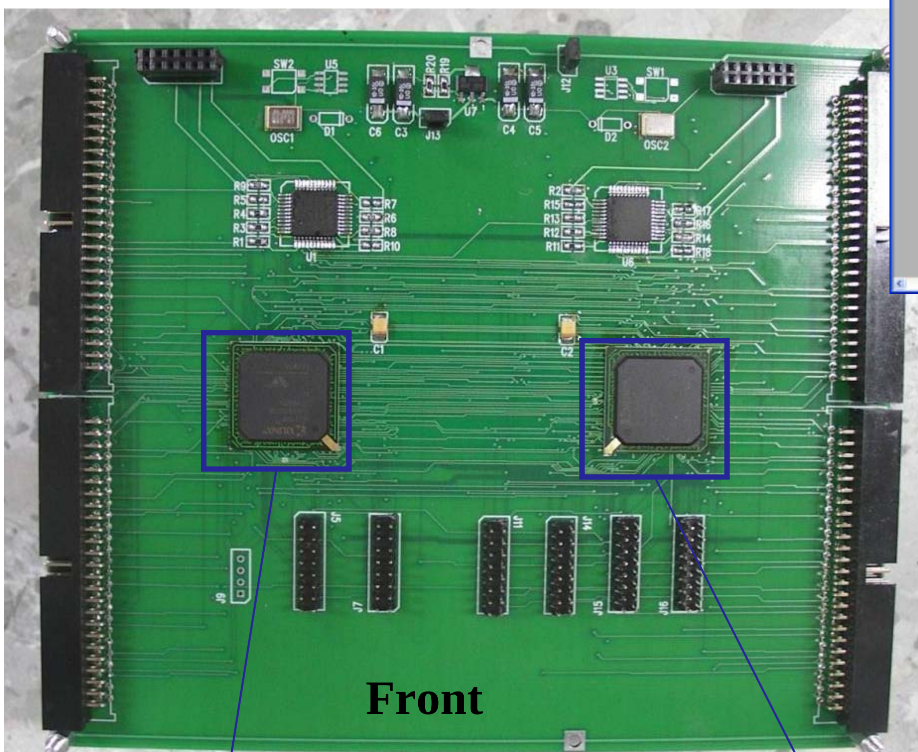
KI early analysis.

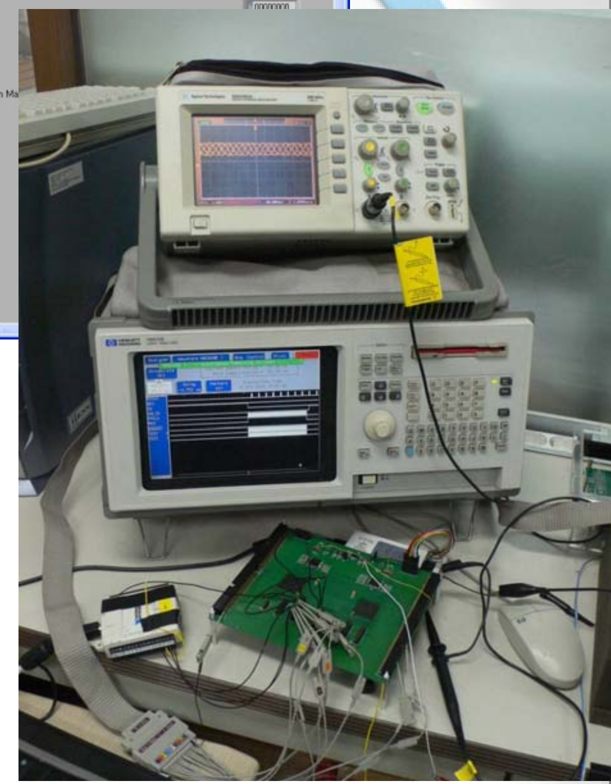
- **Injected charges: 3pC,8pC & 20pC (~ 20 to 125 p.e)**
- **Trigger pulse width measured starting from 73ns (from analog signal monitoring**
- **KI system working correctly (pulse width adjustement, current absorber, …)**

Preliminary Results

Ewha DAQ board

EWHA TEST BOARD





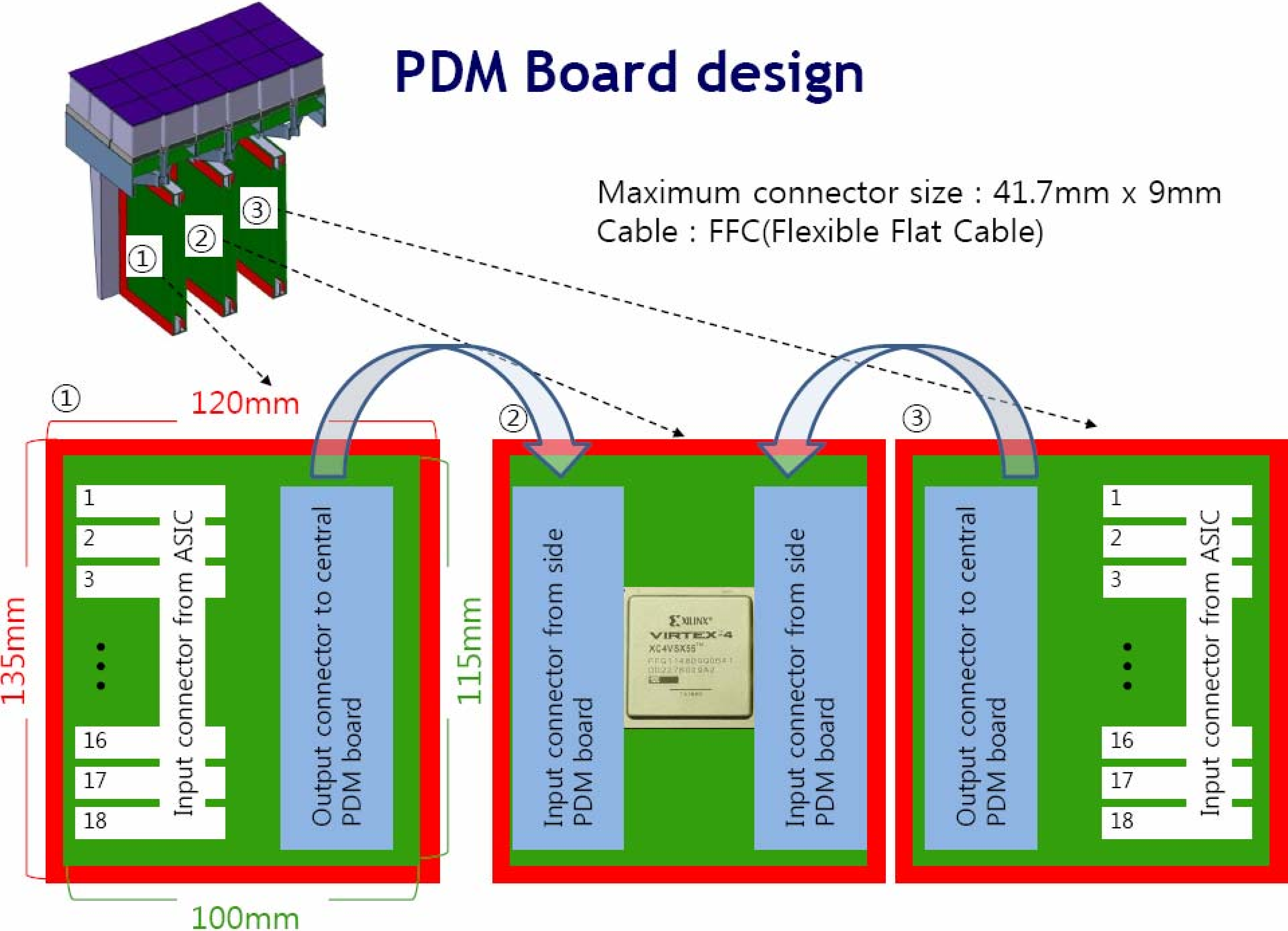
Set up for Lab test

PC interface chip

JEM EUSO trigger FPGA chip

PDM Board design

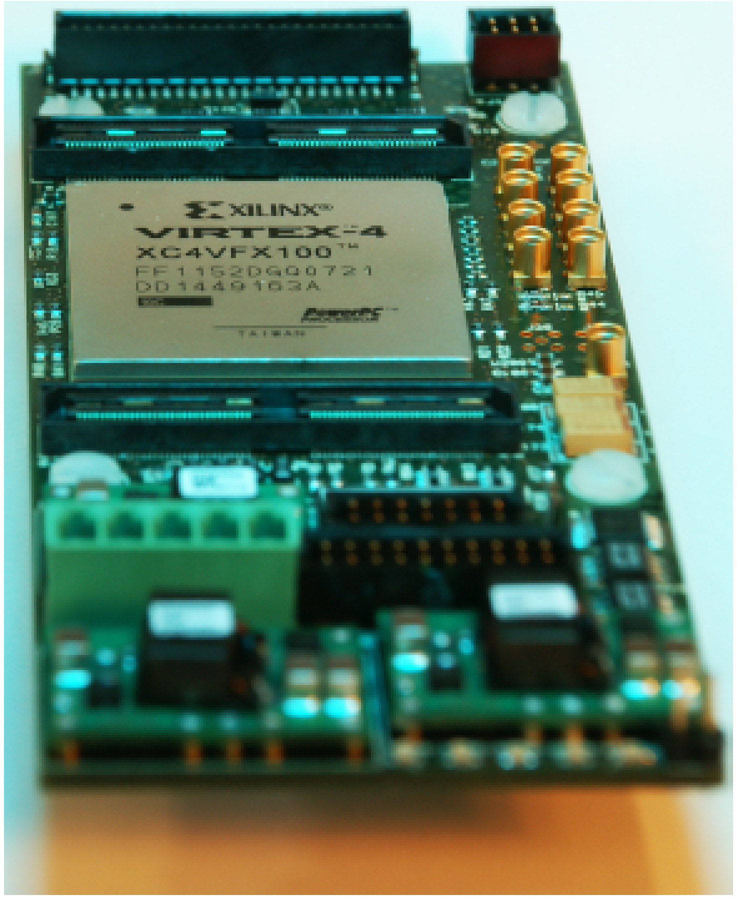
Maximum connector size : 41.7mm x 9mm
Cable : FFC(Flexible Flat Cable)



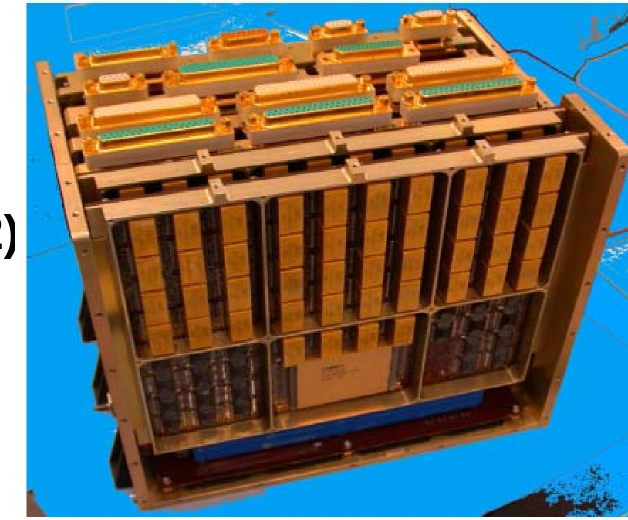
Hardware of the Cluster Control Board (CCB)

FPGA instead of DSP:

- for the current L3-Trigger
  - ⇒ no need for floating point operations
  - ⇒ only integer sums (but a lot)
  - ⇒ a lot of internal RAM
  - ⇒ dedicated for parallel processing
- interfaces:
  - ⇒ main I/O standard is LVDS
  - ⇒ main datapath (PDM→CCB): ≈300 I/Os
  - ⇒ no need for external I/O expansion
  - ⇒ no need for external LVDS drivers



Main CPU



⇒ Processor (TSC695F-ERC32 or AT697F-LEON2)

7 daughter-boards:

- **Power Supply mmodule**
- **Supervisor module**
- **2 housekeeping module**
- **1 IDAQ module**
- **1 Input/outtput Interface moduel**
- **1 Memory Module**
- **1553 Interface module**

•Thales AleniaSpace

•Heritage of PAMELA CPU

Monitoring: Serial Digital, Bi-level, Contact Closure, Analogue, Thermistor inputs.

Housekeeping: HL14/26V Cmd, Memory Load

Primary Power: 21¸35VDC unregulated.

Mass: 12Kg. Power consumption: 68W (peak)

Dimension: 280x253x251mm (LxWxH) Memory: 64 Gbit

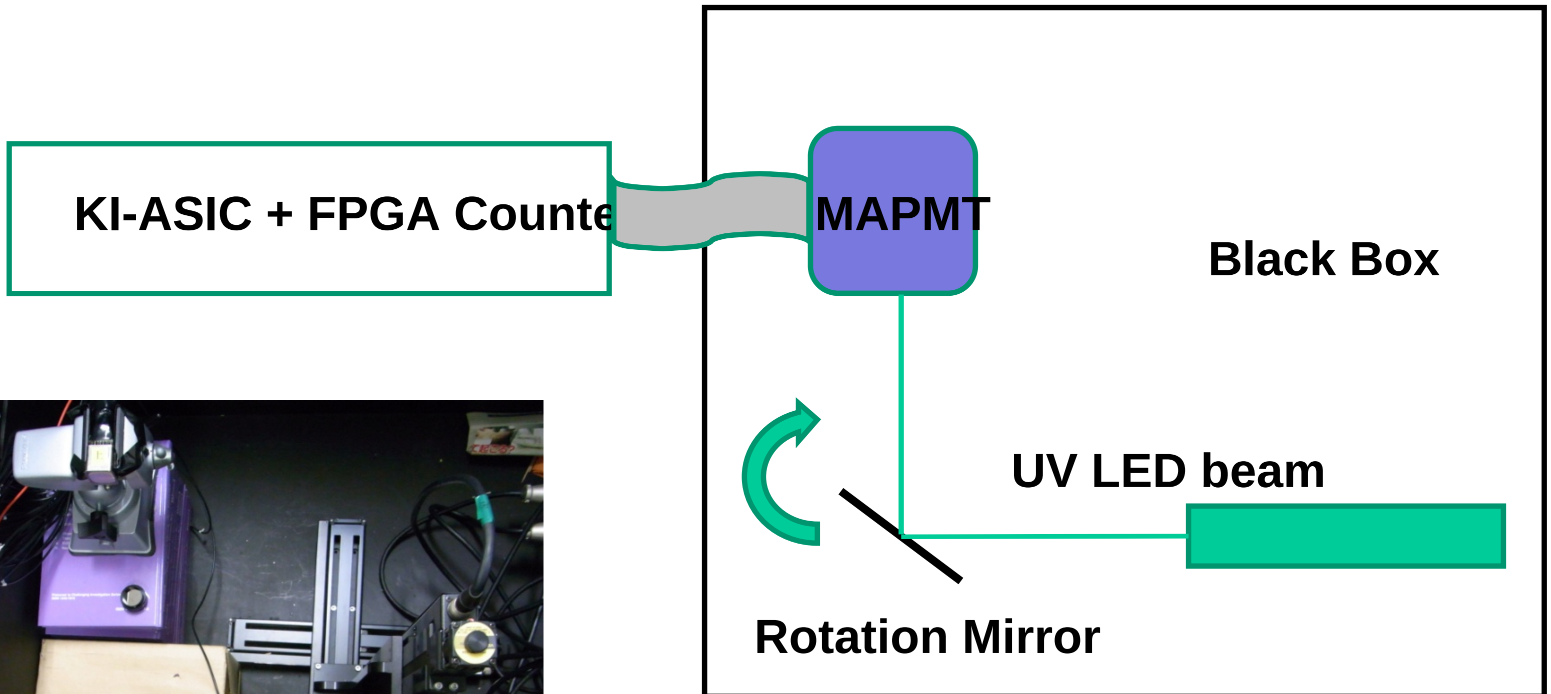
Radiation: latch-up protection with no loss of data. ECC (Error correction Circuit) against single bit and burst errors.

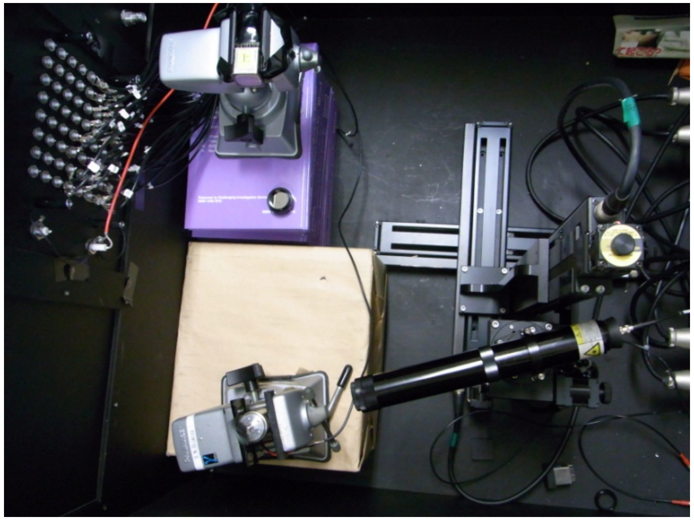
Performance along indefinite period: TID>40kRad.

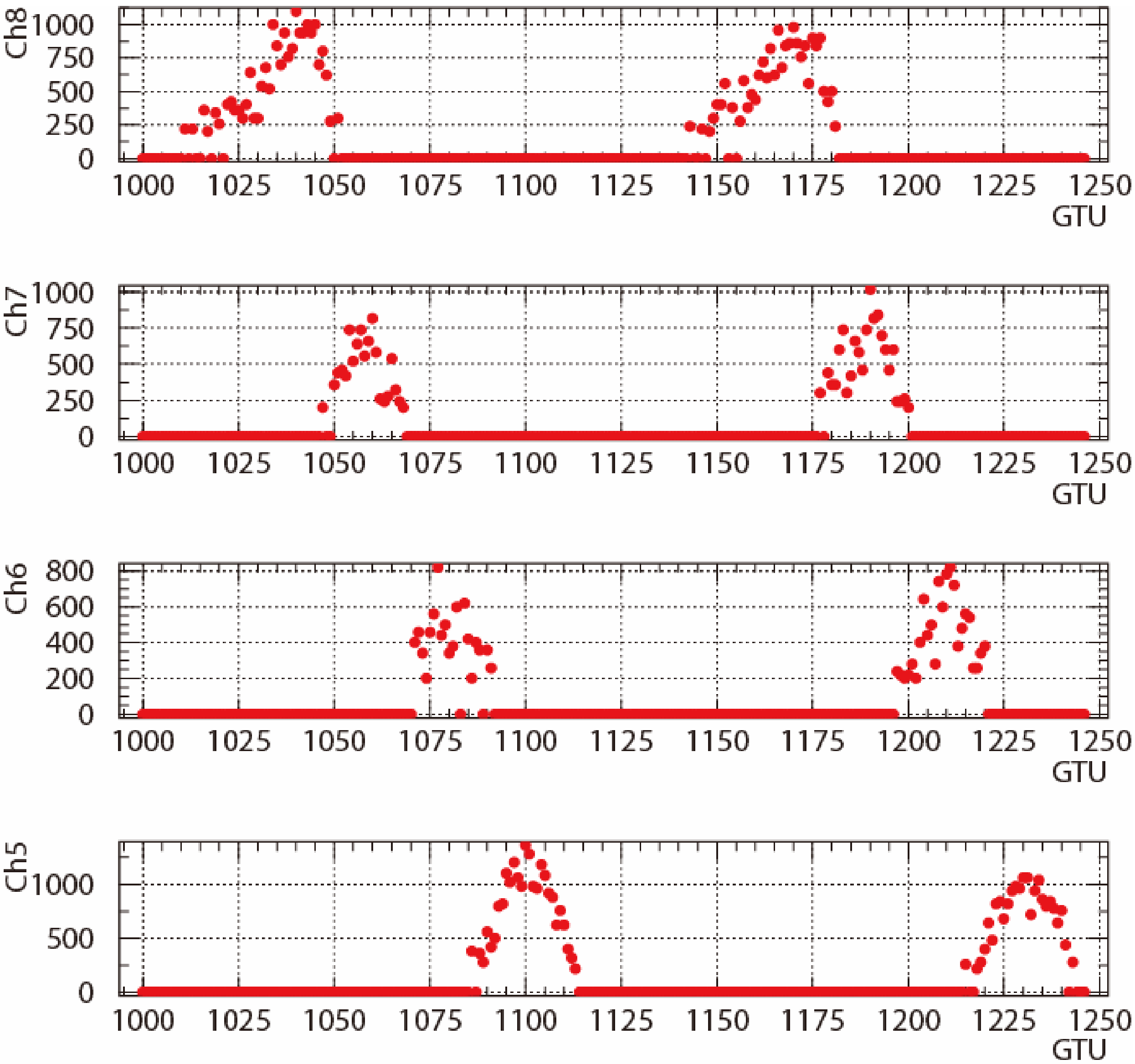
Basic memory devices: 256Mbit SDRAM (Synchronous Dynamic RAM)

Memory technology: MCM, 3D packaging (10 bit – redundancy), TSOP plastic DRAMs.

Test of PMT and AISC with the scanning UV



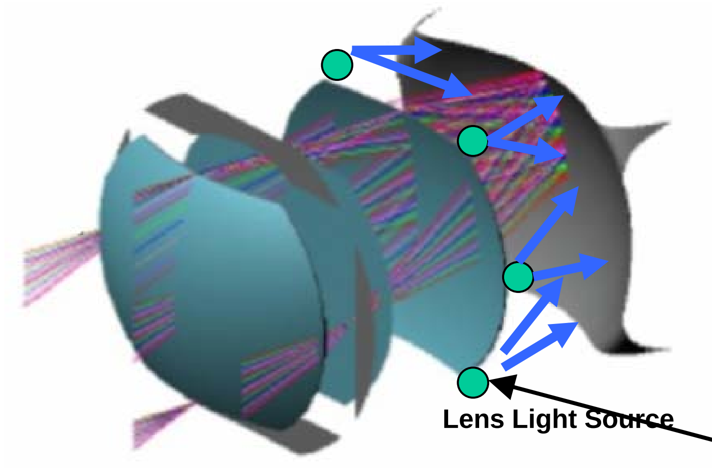




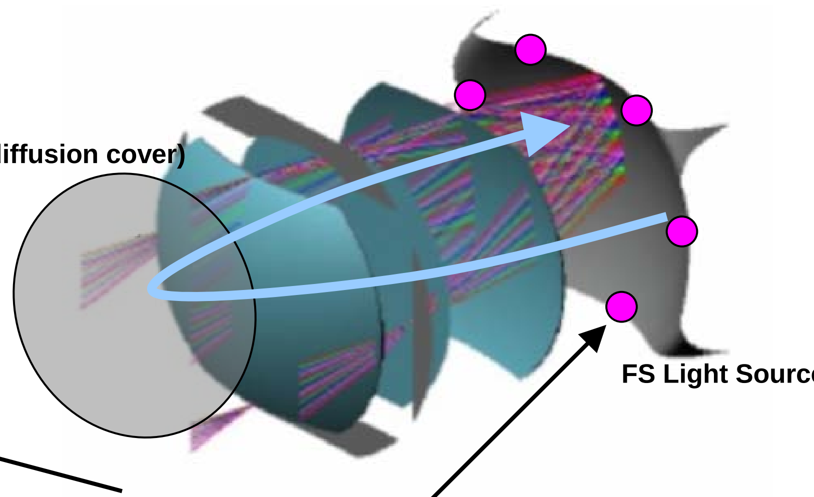
鏡の回転速度より算出される光点の移動速度83.8m/sに対して、19GTU/画素(84.2m/s)で光点が移動している

Onboard calibration

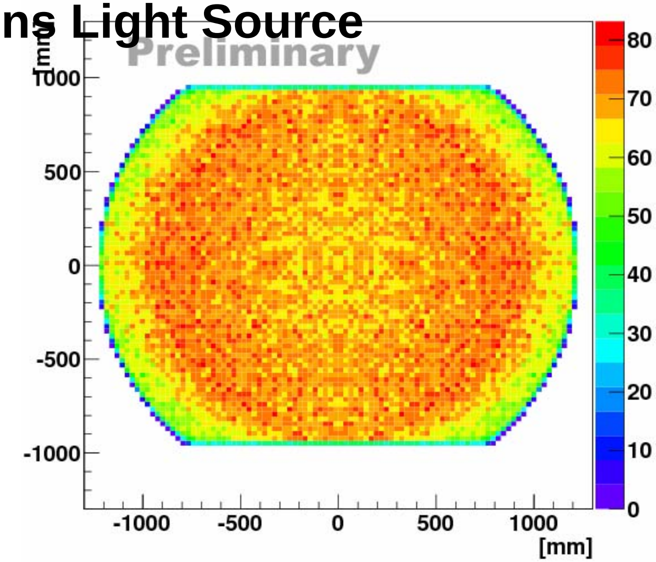
Detector calibration

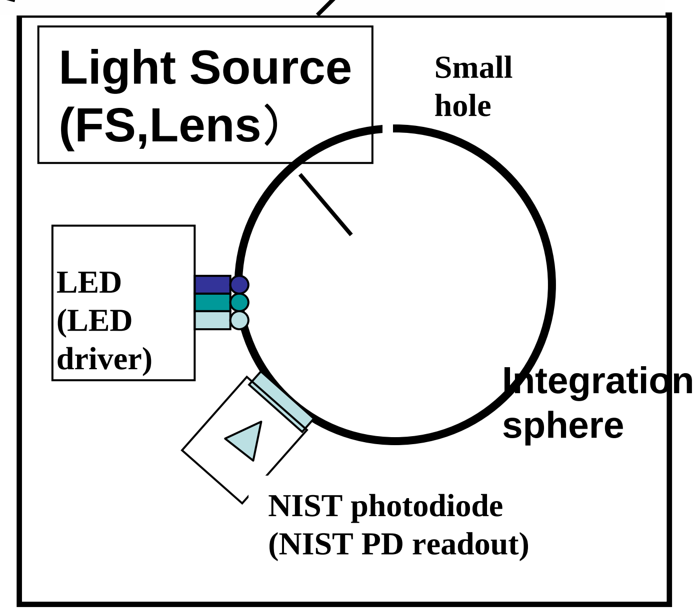


Optics (+detector) calibration



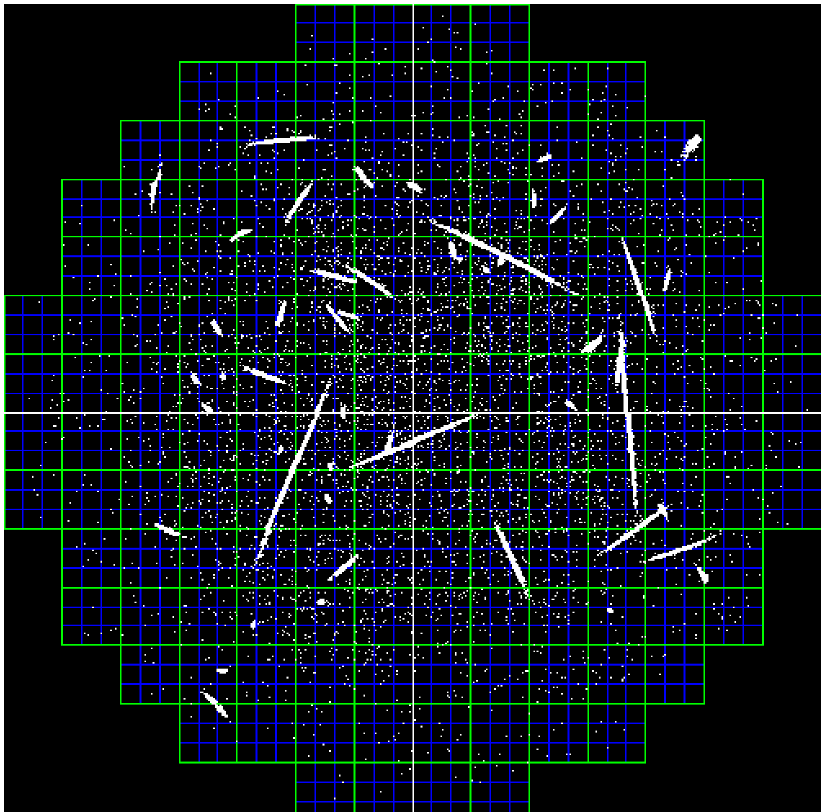
Brightness distribution by four Lens Light Source



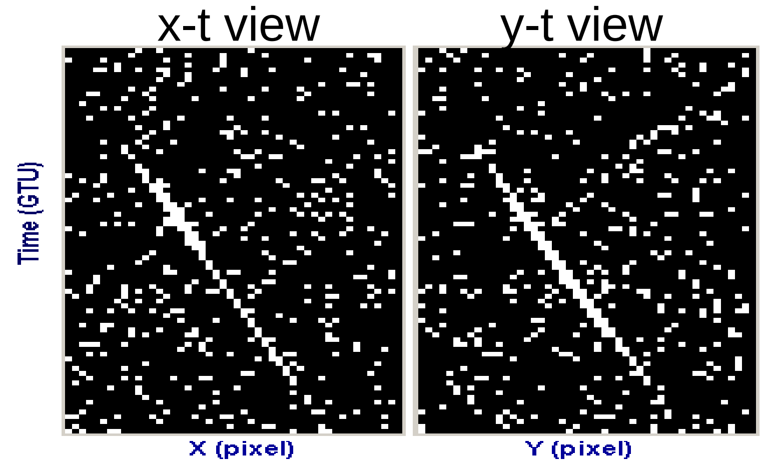


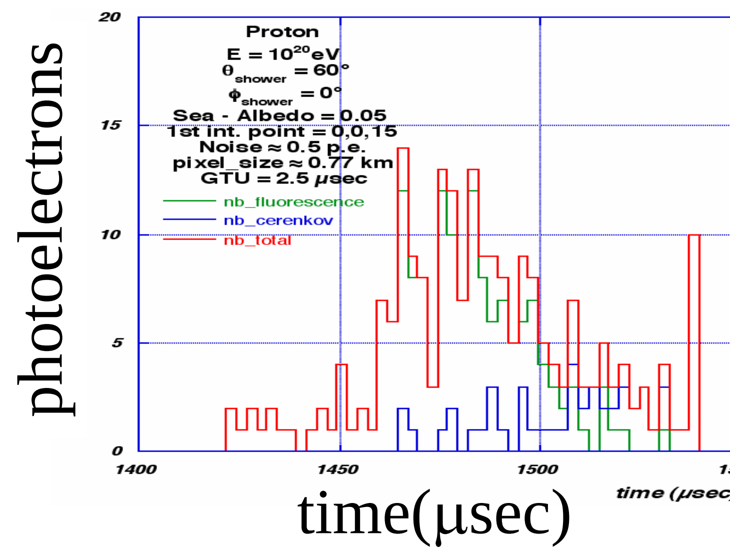
Air shower Image on the Focal Surface

simulation



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





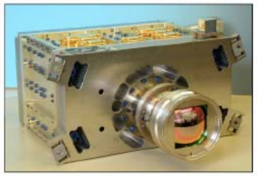
Proton E=10^{20}eV, θ=60°
GTU = 2.5 μsec

Atmospheric Monitoring System

Atmospheric Monitoring System

- IR Camera

  Imaging observation of cloud temperature inside FOV of JEM-EUSO

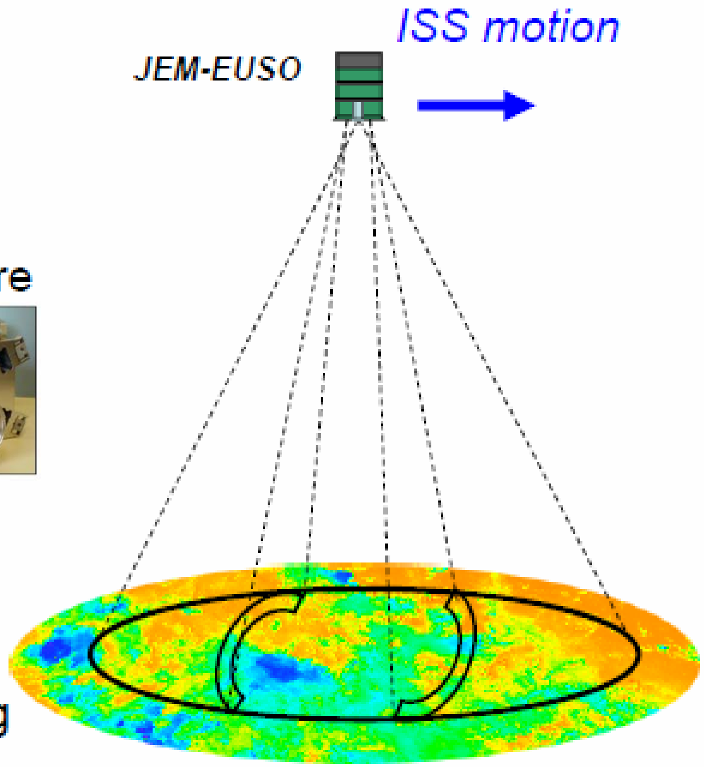


- Lidar

  Ranging observation using UV laser

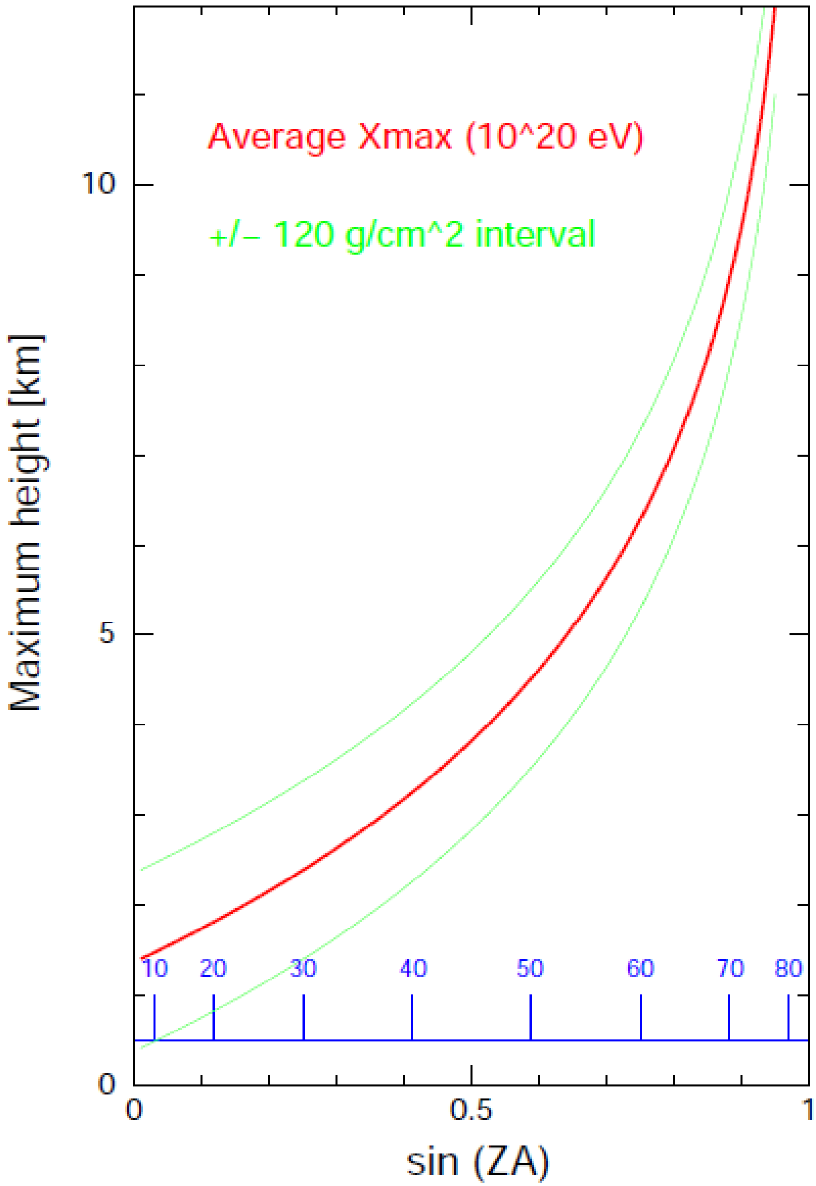
- JEM-EUSO "slow-data"

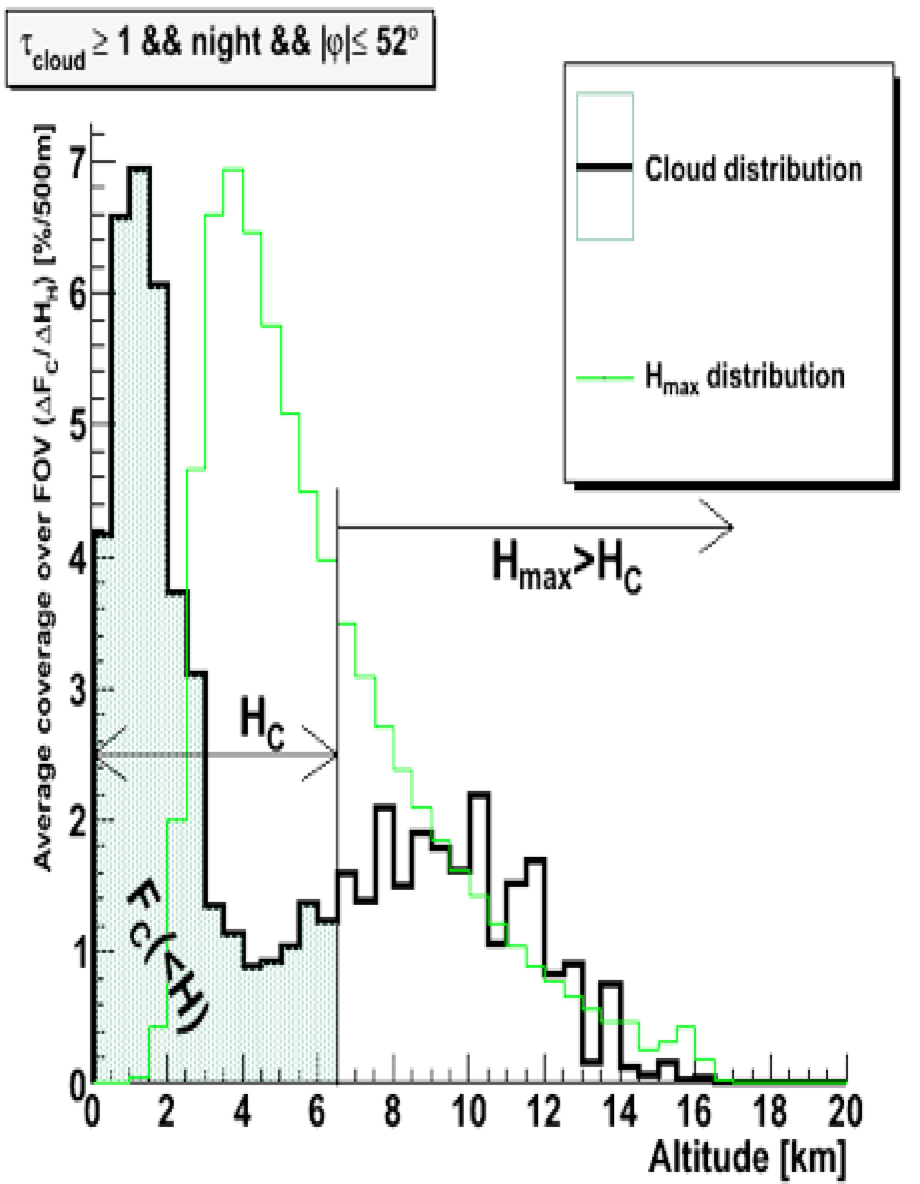
  Continuous background photon counting



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

Cloud Height distribution vs. Hmax

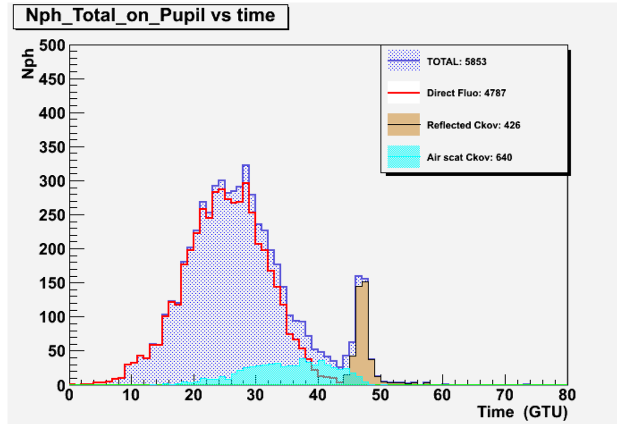


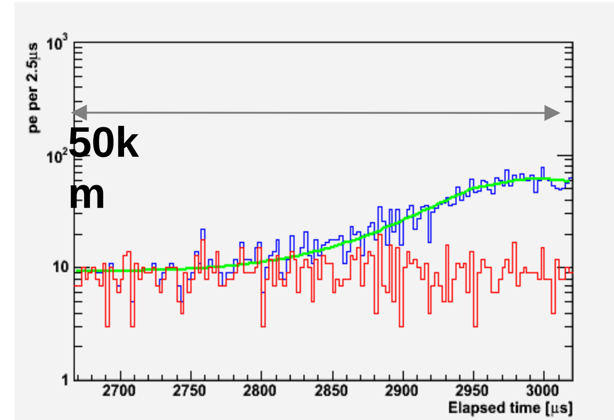


Cloud Simulation

No Cloud

Lidar

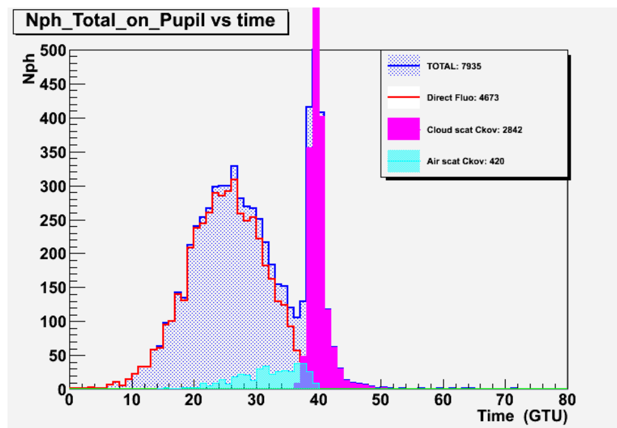


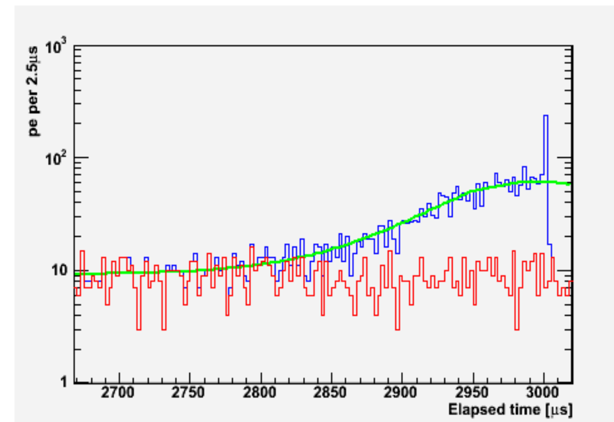


Low cloud

-Strong Cherenkov mark

-





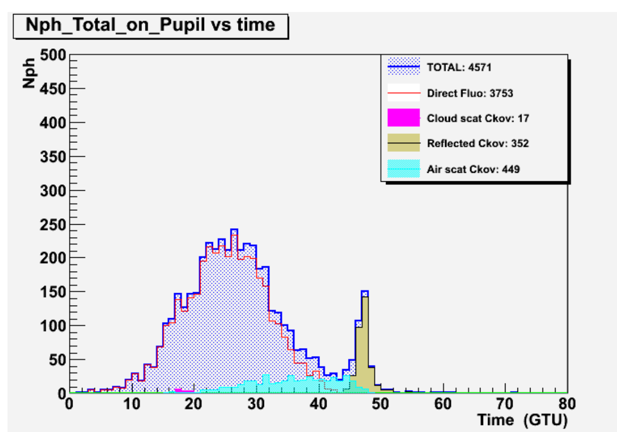
High Thin Cloud

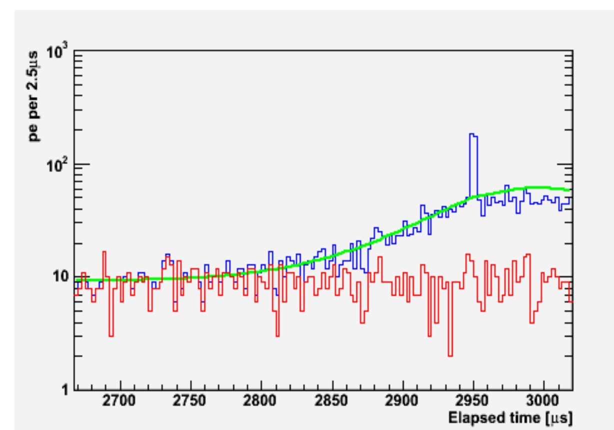
Arrival Direction

Large error in Energy

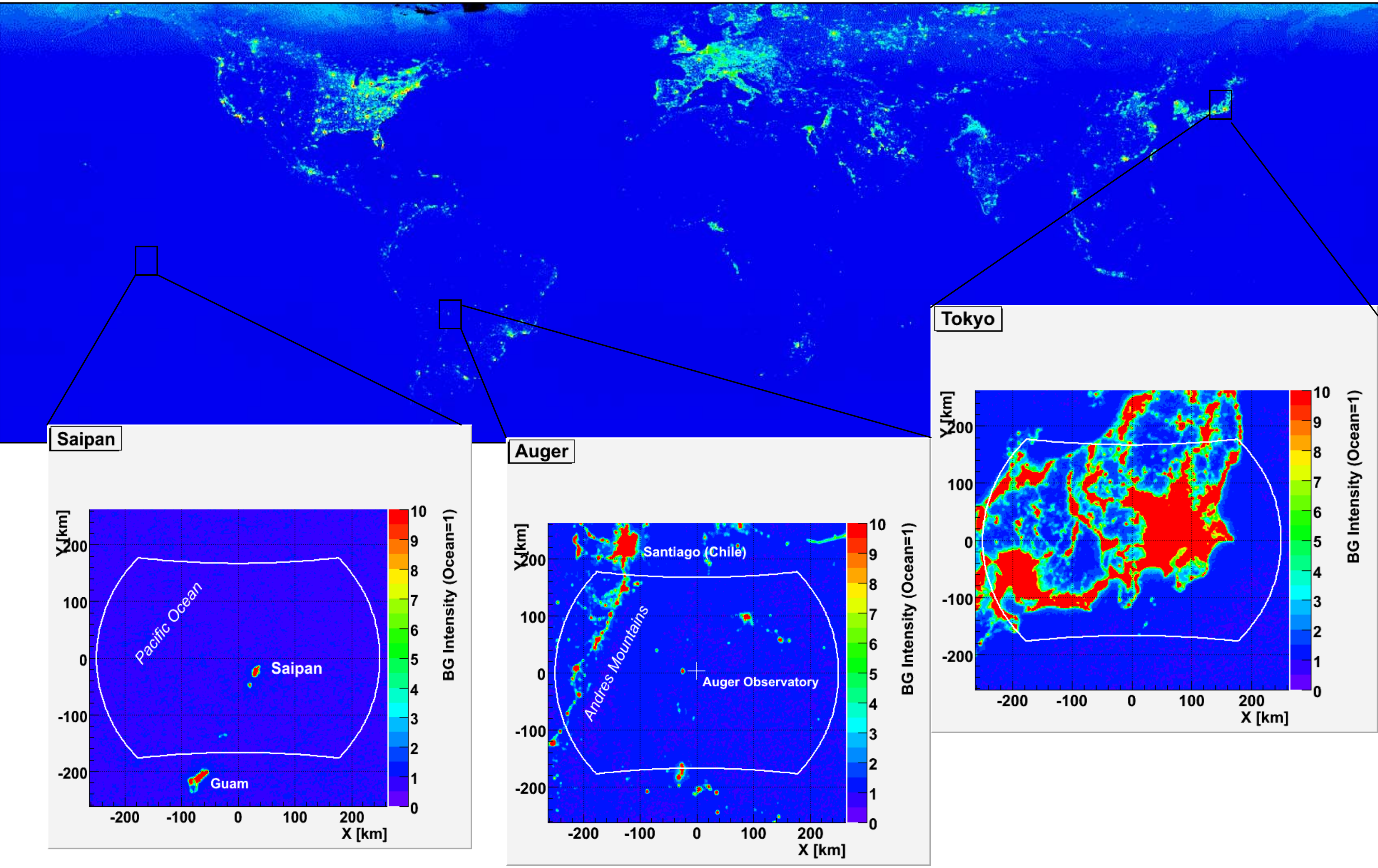
Detection by Lidar

10/10/4





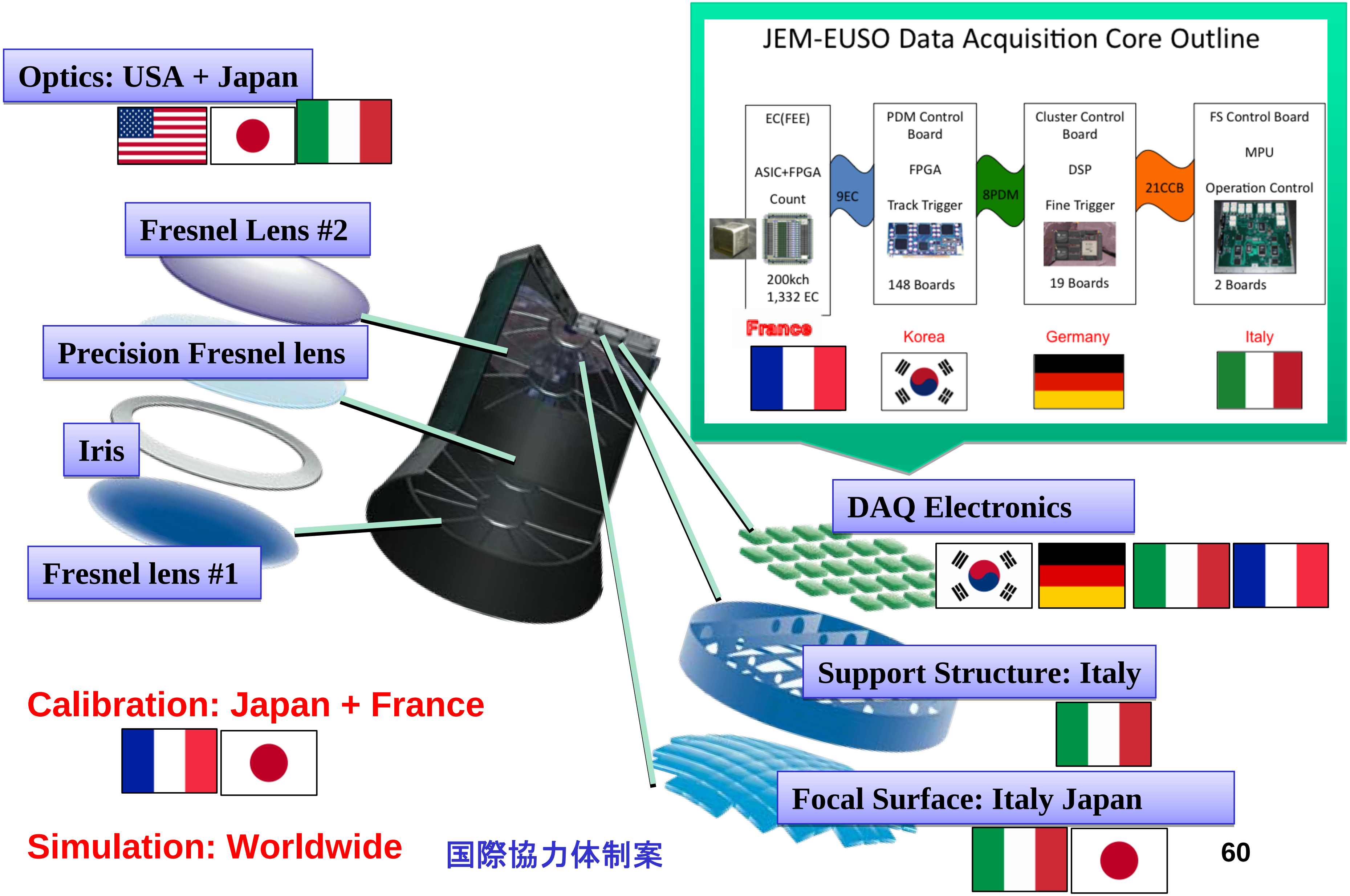
City Light



Saipan
Pacific Ocean
Saipan
Guam
Y [km]
X [km]
BG Intensity (Ocean=1)
Auger
Santiago (Chile)
Andres Mountains
Auger Observatory
Y [km]
X [km]
BG Intensity (Ocean=1)
Tokyo
Y [km]
X [km]
BG Intensity (Ocean=1)

International Collaboration

International Collaboration



Members (12 countries)

Japan	70	23
US	29	6
Italy	47	12
France	22	2
Germany	17	7
Swiss.	6	3
Spain	14	3
Poland	13	5
Slovakia	4	1
Russia	7	2
Korea	16	8
Mexico	11	3
Total	256	75

ATT-1: Flight Hardware Role & Responsibility

JAXA

JEM-EUSO Integration(JAXA)

- Bus System (JAXA)
- Science Instrument System (PI)

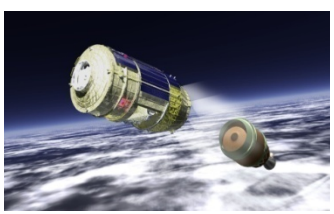
Provide Flight Hardware

RIKEN, working with the JEM-EUSO collaboration

Science Instrument Integration (PI)

- Telescope
- Optics
- Focal Surface
- Mission Drive Processor
- Atmospheric Monitor
- Attitude and Orbit Determination
- Mechanical Drive Controller
- Calibration
- House Keeping

HTV launch & EF Attachment (JAXA)


International PIs

Status in Japan

- Finishing three years Phase-A study
  - JAXA-RIKEN collaboration(Dec. 2009-Jul. 2010)
  - Official review by JAXA ISS project office Positive assesment until now: Technical feasility OK
- Elongation of ISS operation to 2020 and beyond (possiblly 2027)
  - Approved by Japanese government
- Forsee System Requirement Review (March 2010)
  - Technical Readiness
  - Cost assesment and
  - International Role Sharing(Upmass, Power, Downmass)

JAXA-RIKEN agreement

- Scientific Utilization of ISS
- Framework of utilization of JEM/KIBO as National Infrastructure in Japan
- Many Science Fields
    - Bio- and Material Sciences (Pressurized)
    - Earth and Space Sciences (External facility)
        - MAXI and JEM-EUSO
    - International symposium at Wako Riken on 27-28 April
- It has been concluded and approved by Space Advisory Committee of Japanese government on May 12, 2010.

Status in the US

- Proposal to NASA (SALMON CALL) is being prepared:
- NASA/MSFC support
  - Testing the Breadboard Optics
  - Conceptual design work on the lens frames
  - Conceptual design work on the telescoping mechanism

Status in Europe

- *ESA :* Positive recommendations on the science potential from the
  - ESA's Fundamental Physics Roadmap Team
  - European Science Foundation (ESF)
  - The Astronomy Working Group
  - Physics Working Group

EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

Space Sciences Unit
ESF Peer-Review

Panel Report

Proposal Information

Project Number	**AO-2009-1050**
Project Title	A European participation to JEM-EUSO: The Extreme Universe Space Observatory on-board the Japanese Experimental Module of ISS (JEM-EUSO)

1. Overall Scientific/Technical Merit:

This is an excellent proposal worthy of being accepted for further review.

Recommendation of FPRAT

esa Science & Technology Science Programme European Space Agency

- The Roadmap has been presented to the Community
- JEM-EUSO science recognized and a *very positive recommendation has been given*

Work with the Pierre Auger Observatory has shown that an instrument with a much greater aperture is required. This can come from a Mission of Opportunity (JEM-EUSO) which will take forward the astrophysical connections and also meet some fundamental physics objectives.

- The Advisory Team supports the active participation of the European community in ultra-high energy cosmic rays in the Japanese mission JEM-EUSO on the Japanese module of the ISS. This is an excellent opportunity to test the possibility of detecting such cosmic rays from space. If successful, this would open the road to an even higher statistics of cosmic rays of the highest energy.

C.2 Priorities for the space program

- Mission of opportunity: JEM-EUSO

AO-2009-Phys-BIOSR (ELIPS)

- Letter of Intent submitted on the 15th June 2009
- *Full Proposal submitted on the 14th of September*
- *Main requests to ESA: resources on the ISS*

Outcome of the ISS ESA's proposal

esa

estec

European Space Research
and Technology Centre
Keplerlaan 1
2201 AZ Noordwijk
The Netherlands
Tel. (31) 71 5656565
Fax (31) 71 5656040
www.esa.int

Prof. Andrea Santangelo
Kepler Center for Atro and Particle Physics Tuebingen
Eberhard-Karls-Universitaet Tuebingen
Institute for Astronomy and Astrophysics
Sand 1
D-772076 Tuebingen
Germany

T + 31-71-565-6550
F + 31-71-565-3661

Our ref. HSF-US/2010-041

Noordwijk, 1 June 2010

Dear Prof. Santangelo,

We would like to inform you that the review of the proposals submitted in response to the ESA AO-2009 for Biology on Sounding Rockets and Physical Sciences on all platforms has been completed.

It is our pleasure to inform you that your proposal indicated in the table below received a favourable scientific and technical review and its selection for inclusion in the ELIPS research pool was approved by the ESA Programme Board for Human Spaceflight, Microgravity and Exploration.

„ It is our pleasure to inform you that your proposal … received a favourable scientific and technical review and its selection for inclusion in the ELIPS research pool was approved by the ESA Programme Board for Human Spaceflight, Microgravity and Exploration"

We wish to express our appreciation to you for your interest in this research announcement. We congratulate you on the success of your proposal in this competitive forum.

Sincerely,

C. Fuglesang
Head ISS Science and Applications Division

Conclusions

EUSO:
Ever Largest Refractive Telescope

1897

2016

Principle of Relativity

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

↓

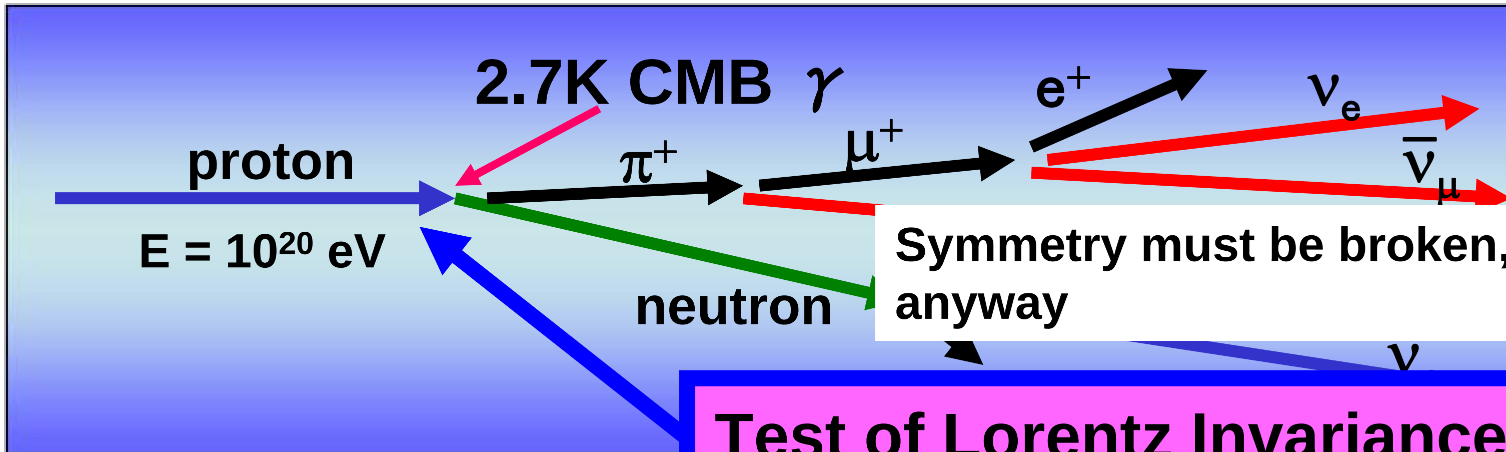
Theory of Relativity: Einstein: Lorentz Invariance

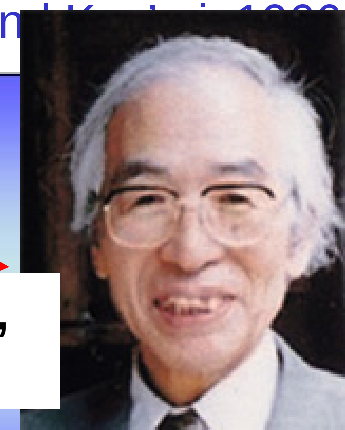
↓

Are there realy no limits?

Greisen-Zatsepin-Kuz′min Process

Greisen1966; Zatsepin an



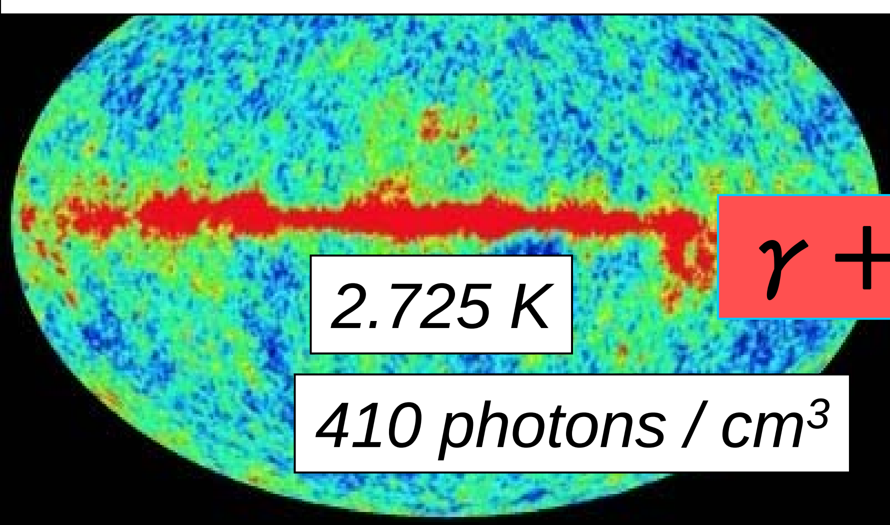


Symmetry must be broken, anyway

Test of Lorentz Invariance at～10^{11}

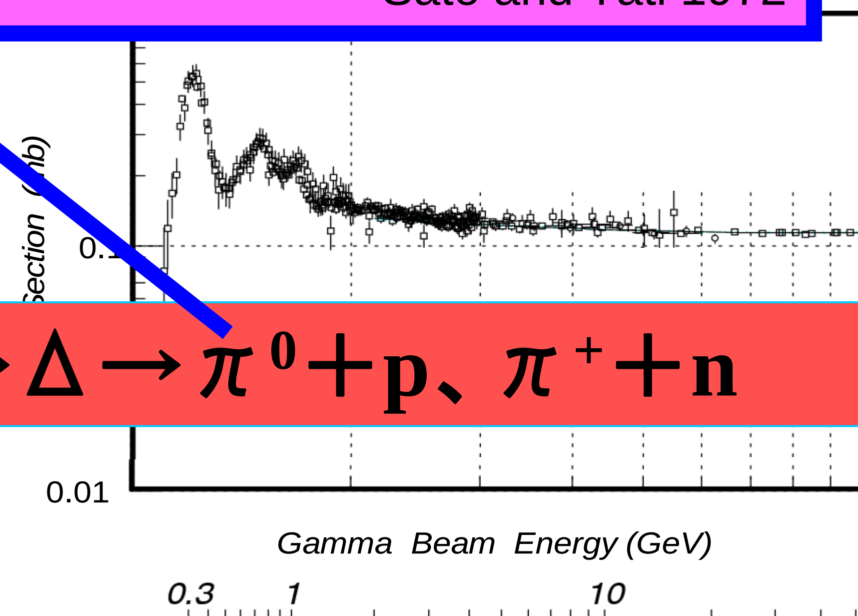
Sato and Tati 1972

Microwave Cosmic Backgro
Radiation



2.725 K

410 photons / cm^3



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

Summary１：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 gamma-rays and neutrinos
- Challenge to the Largest Refractive Telescope on orbit
  - Super Light weight Fresnel Lenses
  - Super fast Focal Surface Detectors

Summary 2：International Collaboration

- US
  - NASA/MSFC Support optical test
  - Apply to SALMON
- Europe
  - Approved as an ELIPSE program
  - Three committees highly recommended
    - Astronomy WG, Fundamental Physics RT, and European Foundation
- Japan
  - Decided extension of ISS operation to 2020 and beyond
  - JAXA-Riken Agreement for ISS utilization

Back-up