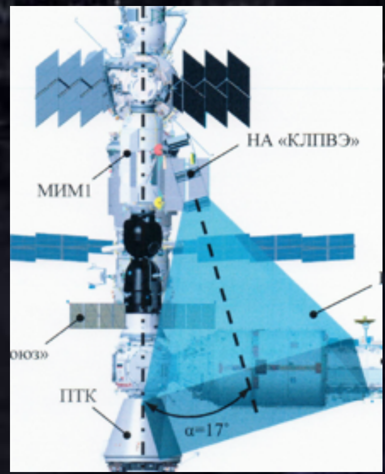
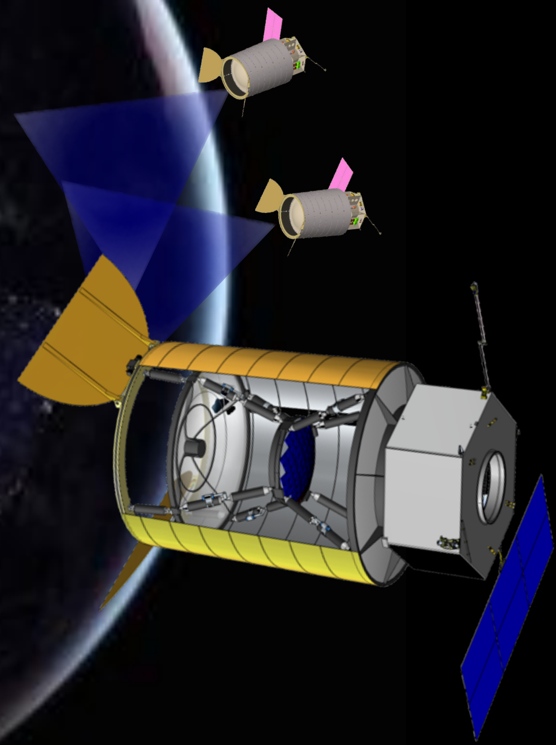
Observation of ultra high energy cosmic rays from space (K-EUSO and POEMMA)

Mini-EUSO (2019-)

K-EUSO (2023+)



POEMMA (2029+)

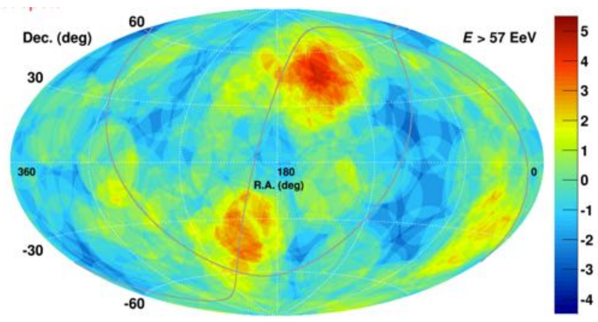


Y. Takizawa (RIKEN)

for the JEM-EUSO collaboration

CRPHYS2020 (2020.12.09)

Science of the space missions



- All sky survey with the world's largest exposure
  - Find sources of UHECRs.
    - Find new hotspots in the equatorial region of the sky.
      - TA and Auger are low sensitivity in this region.
  - We expected to find new UHECR sources (about ten).
    - If we observed sources, we can study acceleration mechanism by comparison with spectrum of each source.
      - Confirmation of GZK steeping (comparison with each spectrum)
      - Acceleration limit (in case of source distance is in GZK horizon)
        - Possibility of new acceleration mechanism (Japan team)
          - Bow wake field acceleration (T. Ebisuzaki and T. Tajima, 2014a and 2014b)
  - Observation of up-going τ neutrino from space (POEMMA)
    - Pioneer space observations of astrophysical neutrinos and,
    - Discover cosmogenic neutrinos

Possibility of new acceleration mechanism

Astronomical ZeV Acceleration in the relativistic jet from an accreting supermassive blackholes

Toshikazu Ebisuzaki and Akira Mizuta
(RIKEN)
Toshiki Tajima (UC Irvine)

T. Ebisuzaki and T. Tajima, “Astrophysical Wake Acceleration Driven by Relativistic Alfvenic Pulse Emitted from Bursting Accretion Disk”, (arXiv:1905.04506)

Difficulties of Fermi acceleration in UHECR

1. Bending is inevitable

   →synchrotron loss

2. Confinement is difficult

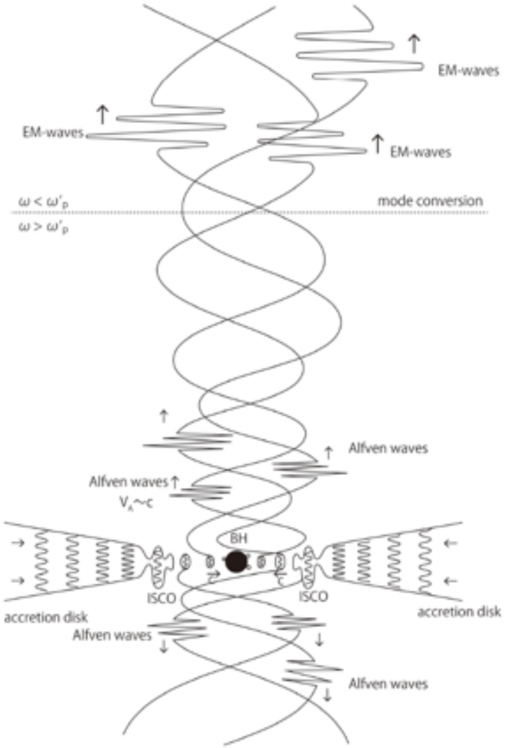
   →no acceleration

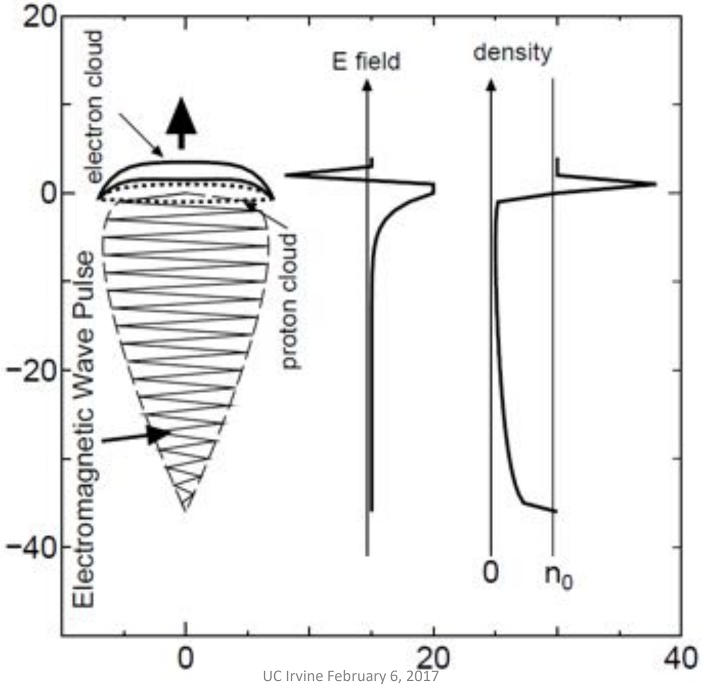
3. Escape problem

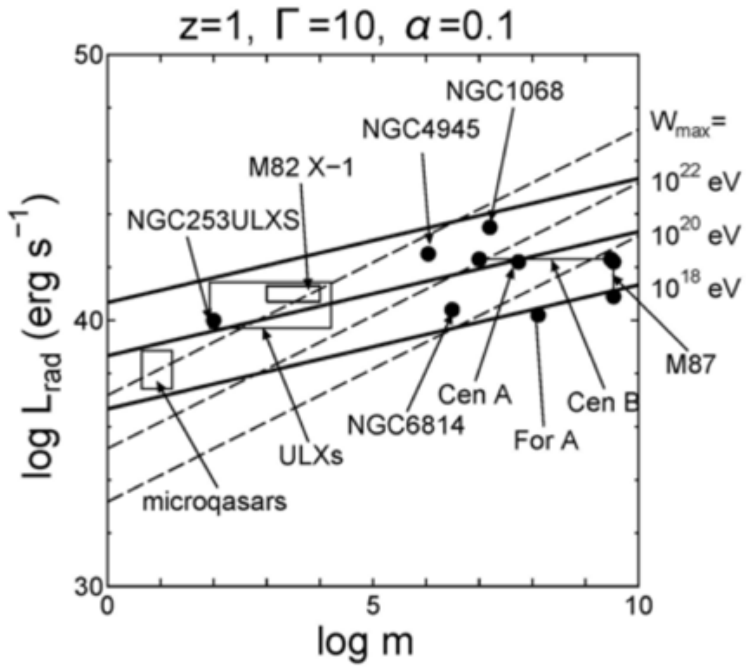
   →magnetic field does not disappear without adiabatic loss

Wakefield acceleration

Bow wake field acceleration in the relative jet

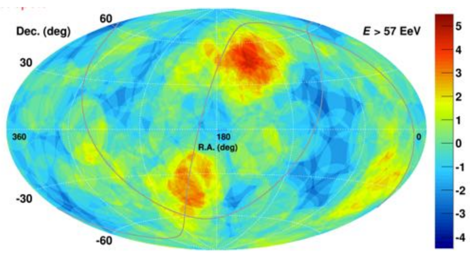






Black hole mass

T. Ebisuzaki and T. Tajima, "Astrophysical Wake Acceleration Driven by Relativistic Alfvenic Pulse Emitted from Bursting Accretion Disk", (arXiv:1905.04506)



Accretion disk at the inner edge makes many transitions between a strongly magnetized state and a weakly magnetized state.
These transitions excite strong pulses of EM disturbance.
These disturbances convert into strong EM wave pulses to accelerate particles in jets.

Wakefield/pondermotive acceleration

1. No bending: linear acceleration

   →No synchrotron loss

2. No Confinement is necessary

   →just push

3. No escape problem

   →Wake will naturally disappear

4. Prediction: it must be gamma-ray sources

Science of the space missions

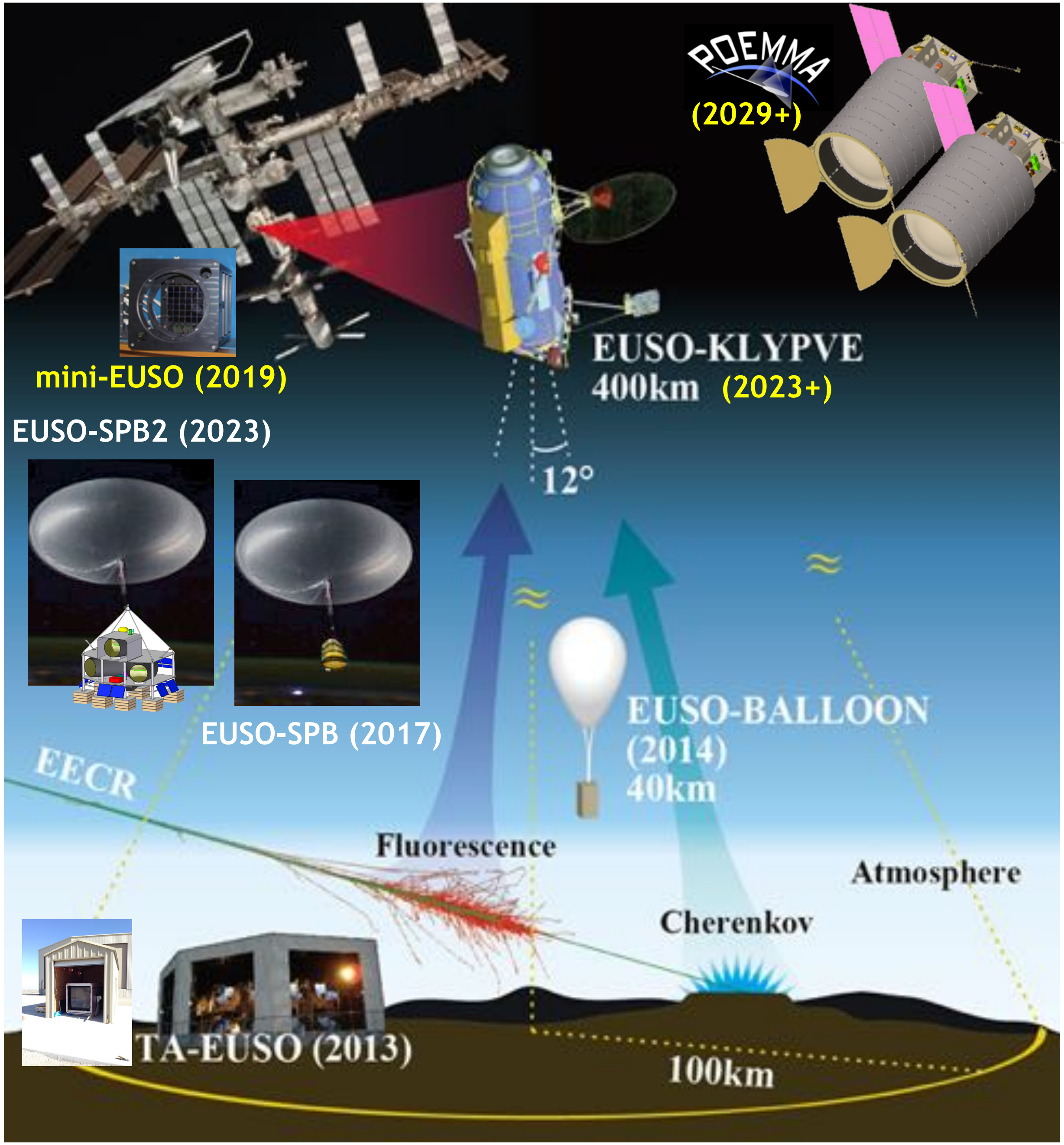
The JEM-EUSO Japan would like to examine the bow wake filed acceleration theory by K-EUSO and POEMMA.

The JEM-EUSO program

EUSO-TA (2013-)
EUSO-Balloon (2014)
EUSO-SPB (2017)

EUSO-SPB2 (2023)

Mini-EUSO (2019)
K-EUSO (2023+)
POEMMA (2029+)



Space missions

We start space missions for observing UHECRs from 2019.

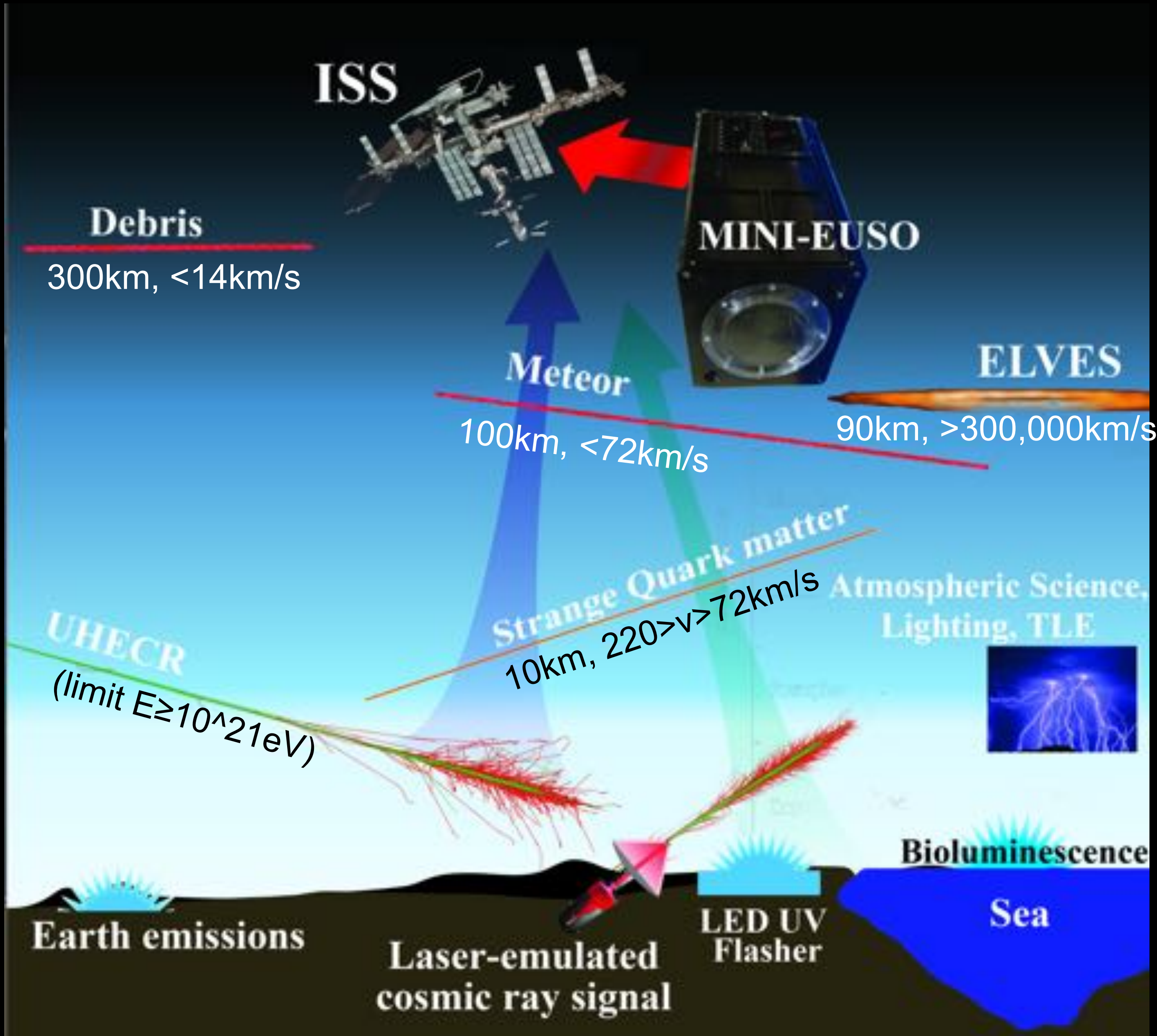
Mini-EUSO

Mini-EUSO is a Joint mission of Russian and Italian team with the JEM-EUSO corroboration.

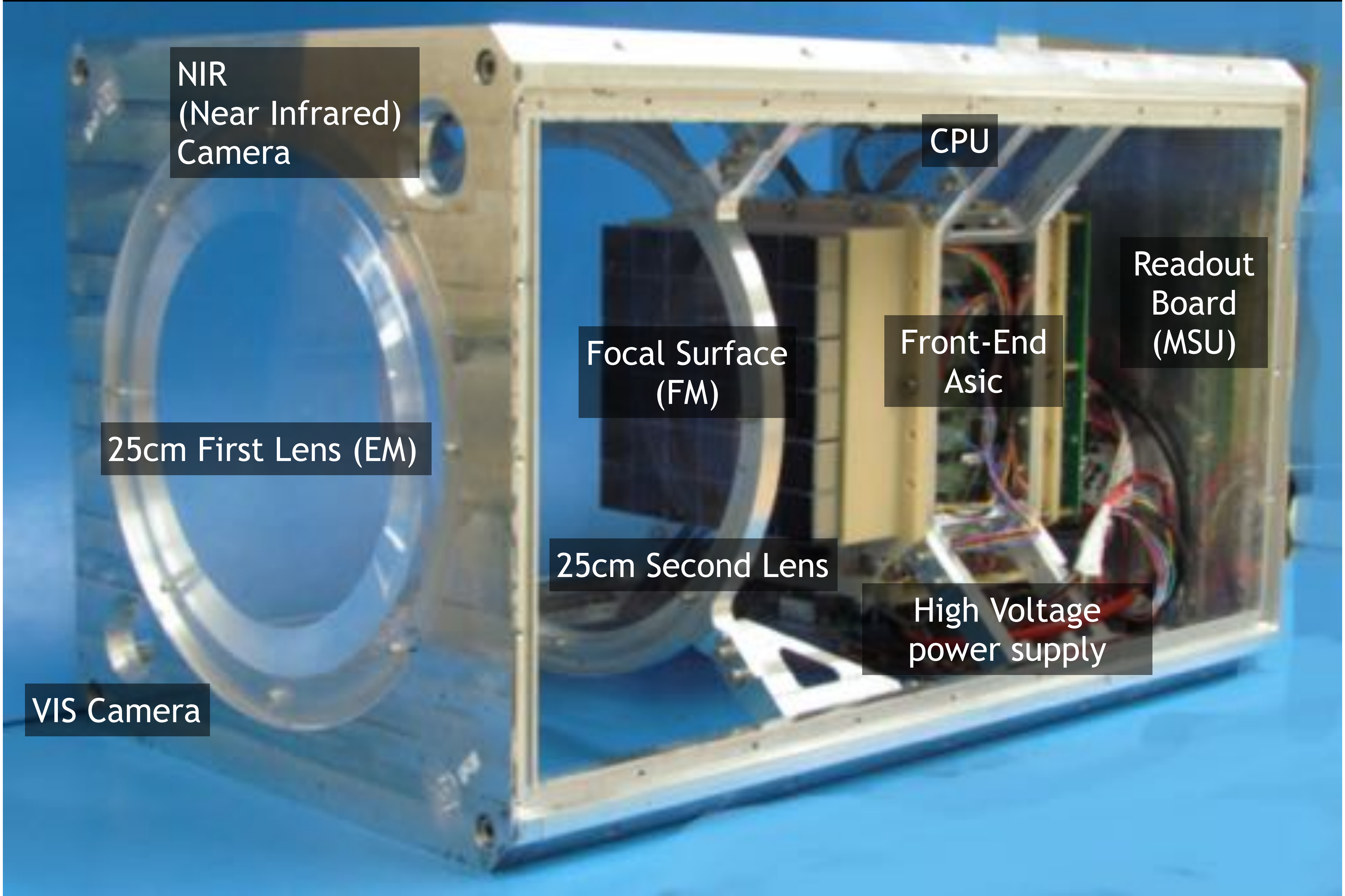
Main purpose is measurement of the near UV region background from space for future space missions such as K-EUSO and POEMMA.

Science Objectives

Main purpose is to observe near UV background level and cloud environment for future missions such as K-EUSO and POEMMA.



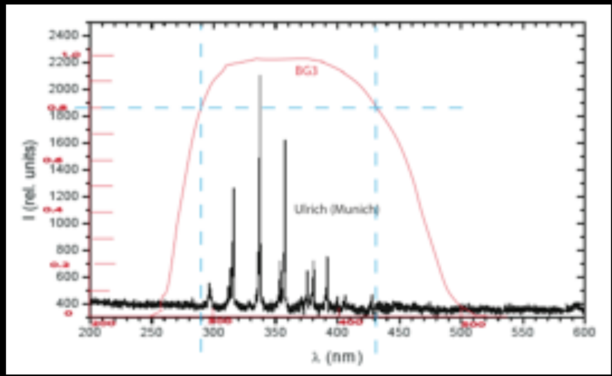
MINI-EUSO EM in clean room

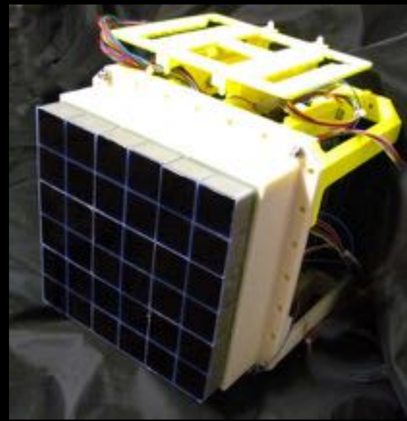


Sensors

East Japan and Tokyo bay

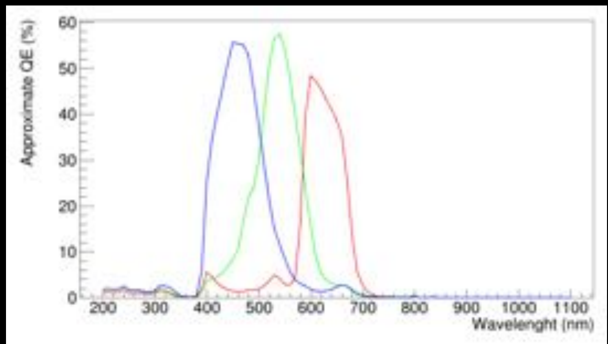
UV main camera
48*48 pixels
40 deg 243km 5km/pix
2.5mus and above



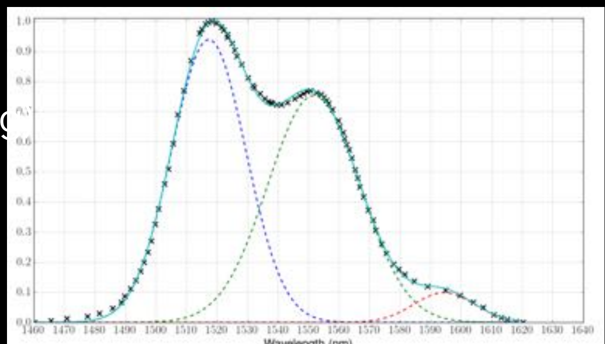


This photo detector module design will be used for K-EUSO and POEMMA.

RGB camera
1280*960 pixels
33.2*24.8 degrees
231*174 km 180 m/
pixel
1s



NIR camera
(BW with phosphor coating
1280*960 pixels
33.2*24.8 degrees
231*174 km 180 m/pixel
4s

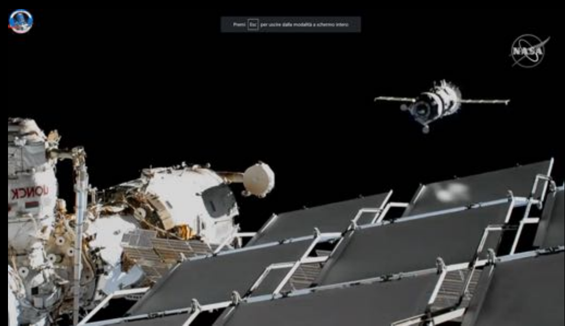


Roll-out of Soyuz MS-14, 19/8/2019

Launch, 2/8/2019

First docking, 24/8/2019 unsuccessful

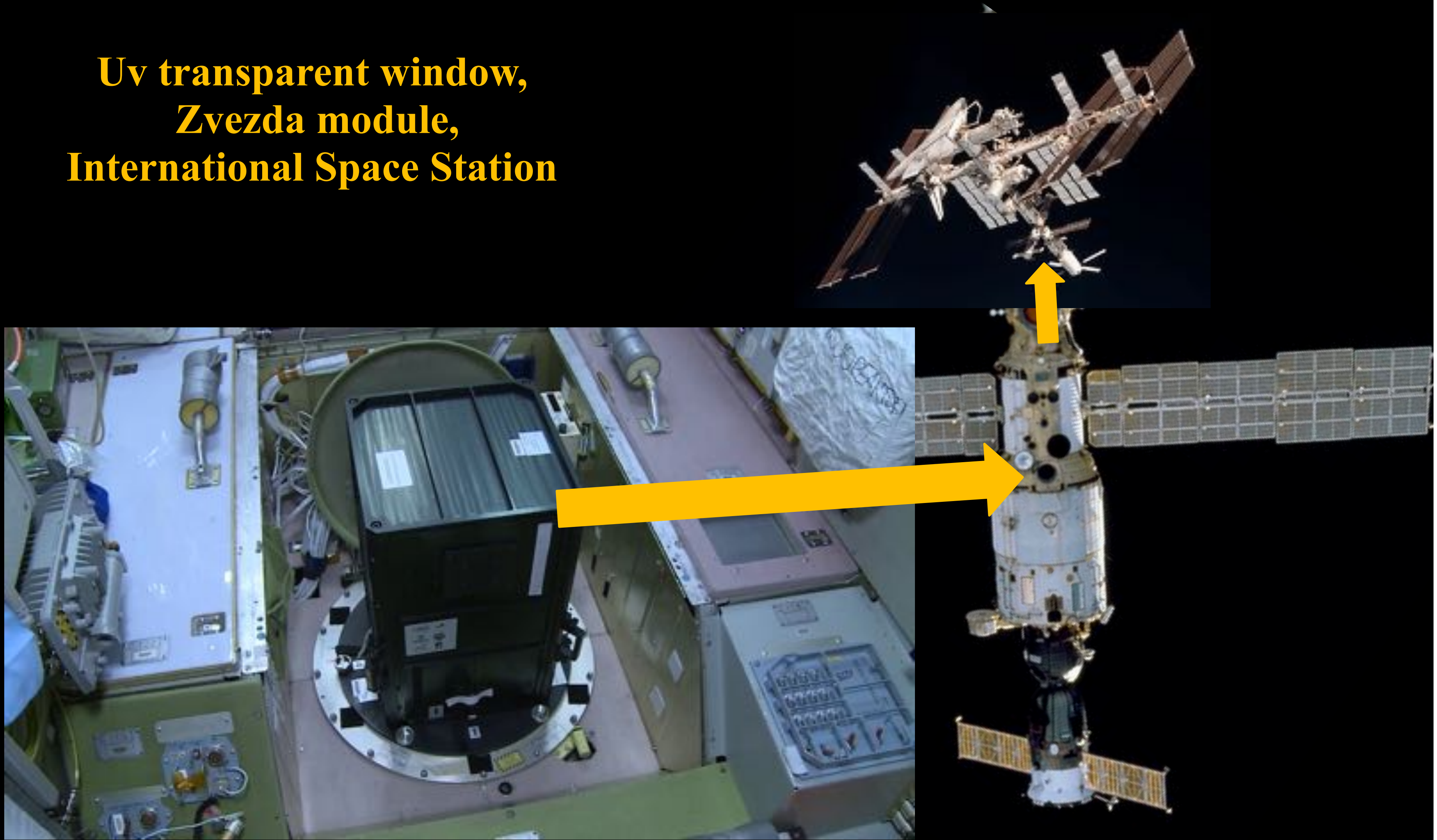
Relocation of MS-13 from Zvezda to Poisk



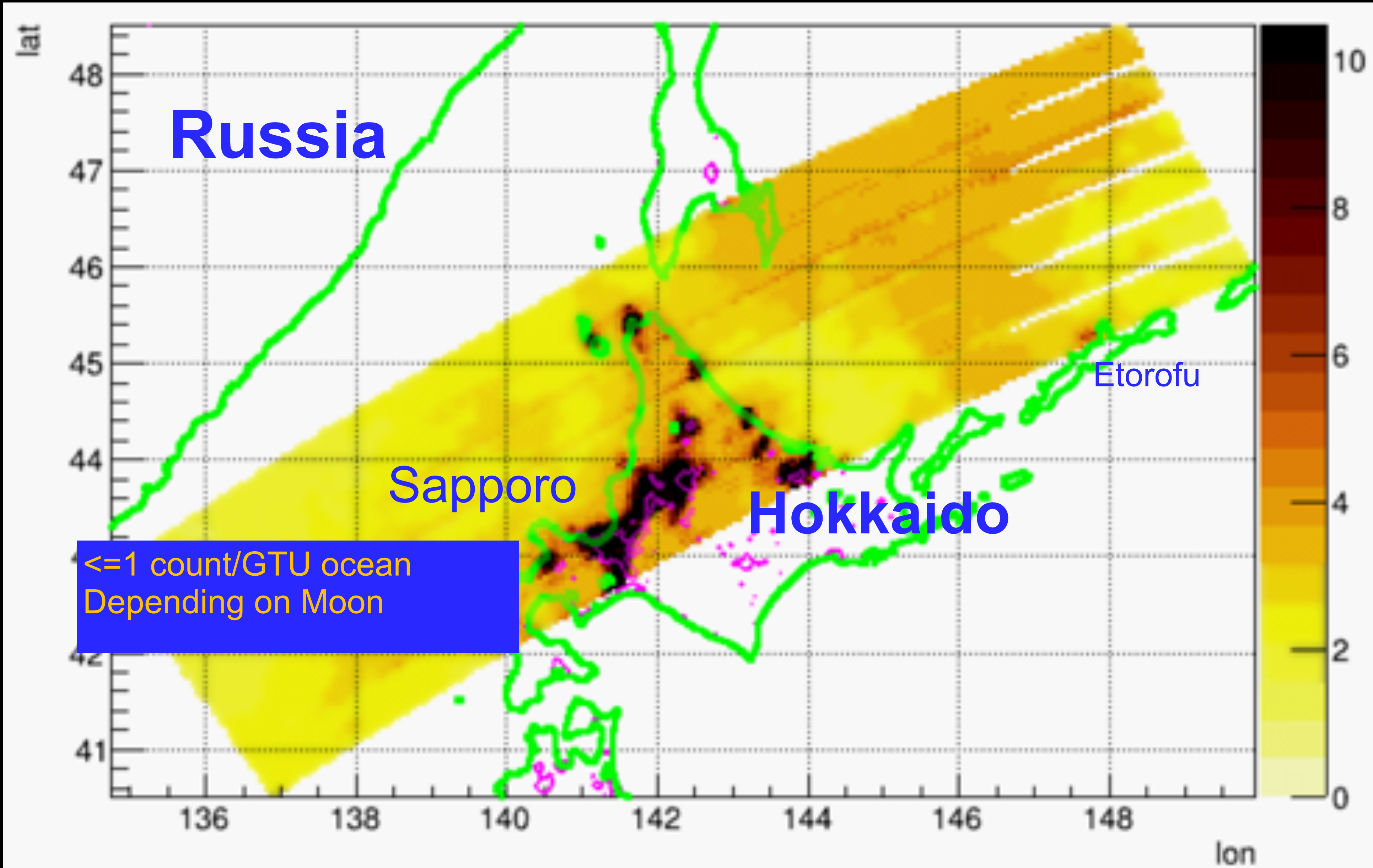
Second docking, 27/8/2019 successful

Mini-EUSO installation

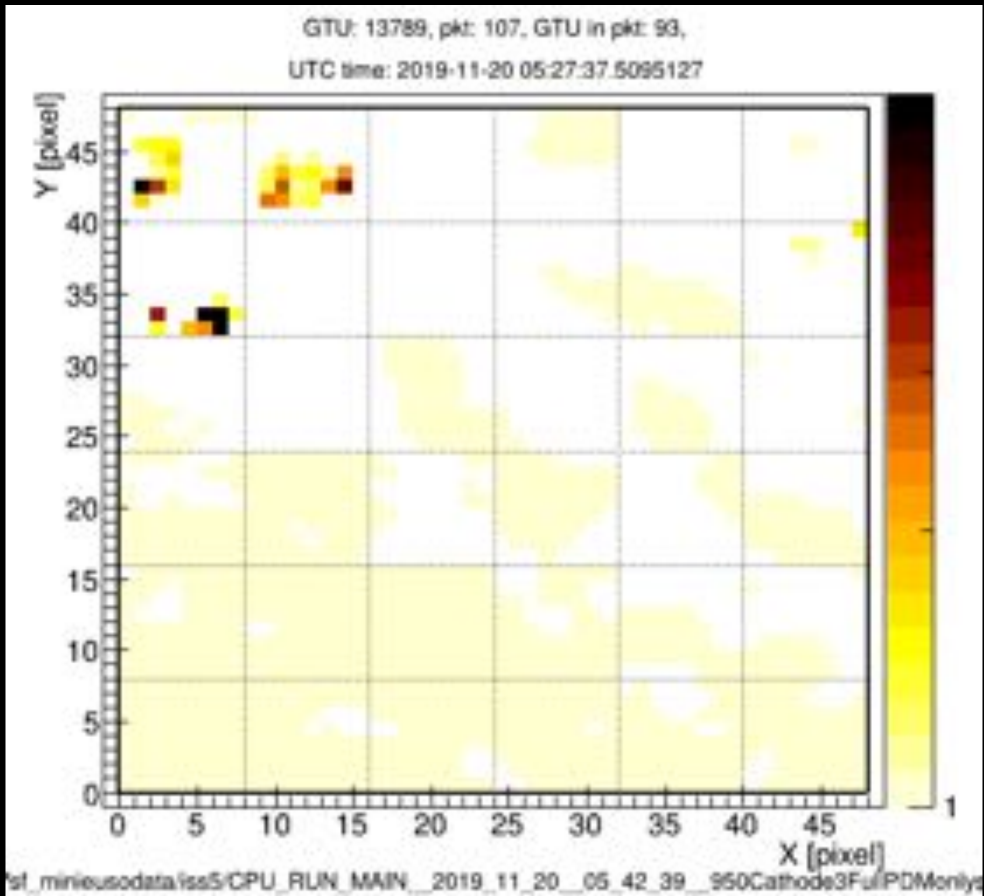
Uv transparent window,
Zvezda module,
International Space Station



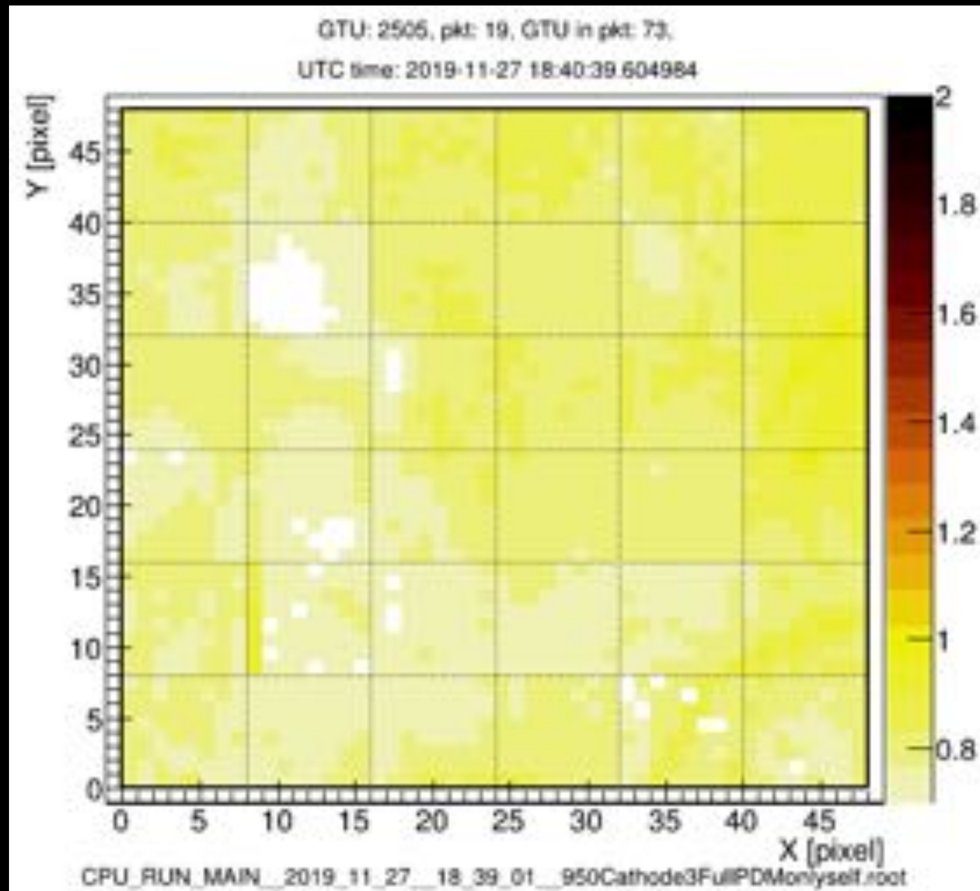
UV maps: Northern Japan



Meteor 2019-11-27



Meteor 2019-11-20

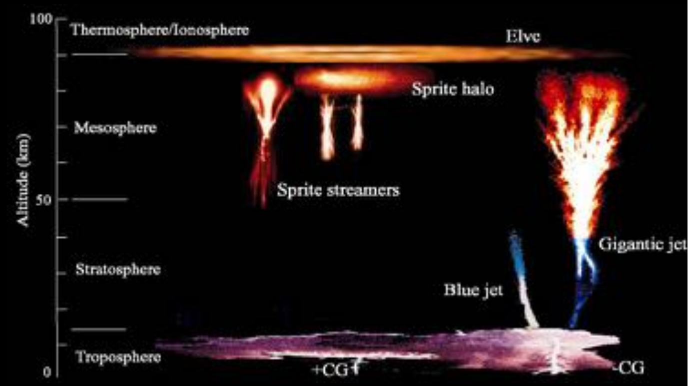


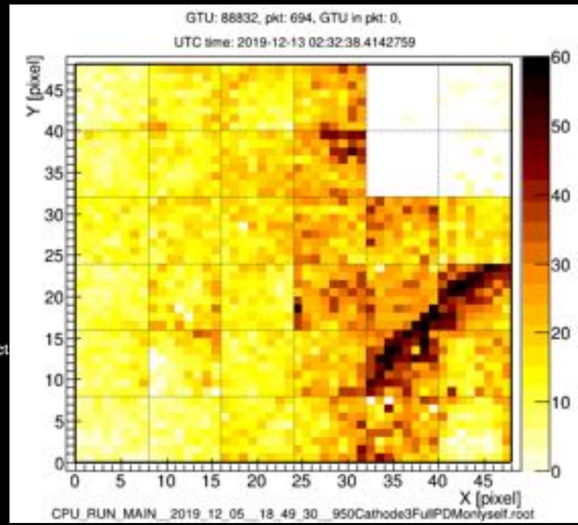
ELVES (transient luminous events)

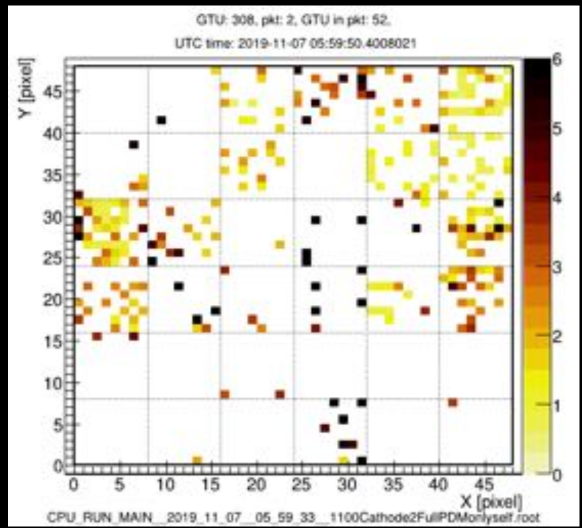
Superluminal rings
100km+ radius

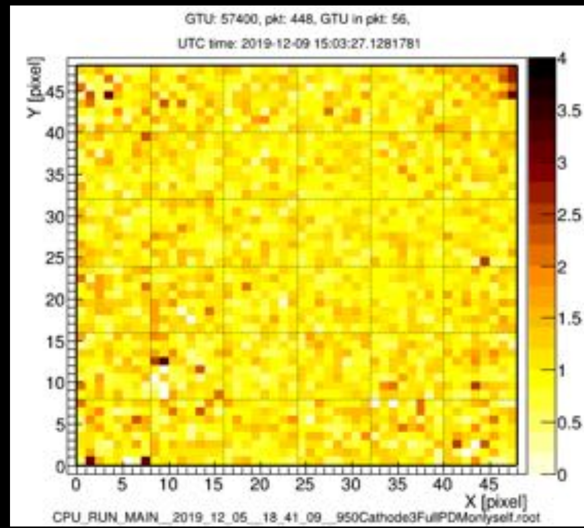
Upper atmospheric lighting releases e.m. wave which heats the ionosphere
Transient Gamma Flash relationship

About 400mus
Overall duration









2.5μs
GTU

K-EUSO mission

K-EUSO is a Joint mission of Russian and Japanese team with the JEM-EUSO corroboration.

K-EUSO will be launched 2023 or after.
Phase A study in Russia will be finished by May 2019.

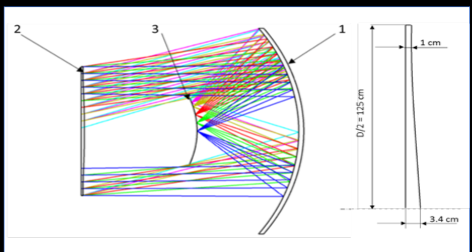
K-EUSO mission

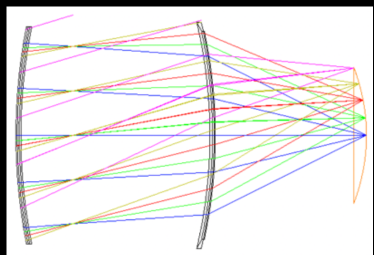
Russia, Japan and the JEM-EUSO corroboration

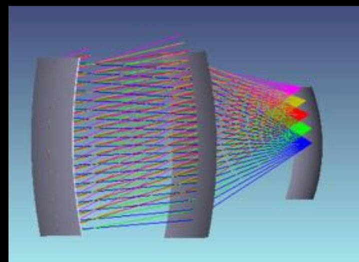
Phase A study in Russia has finished May 2019 with conditions attached.

Condition: ROSCOSMOS requests to redesign the telescope with reducing EVA[extra-vehicular activity].

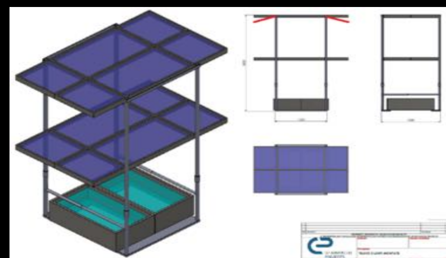
→ Alignment of segment mirrors needs huge EVA by astronauts.







FOV 20° x 15°、RMS spot size < 3mm



Russian, Italy and Japanese team is estimating performance of new telescope.

Japanese task : manufacturing of K-EUSO lens.

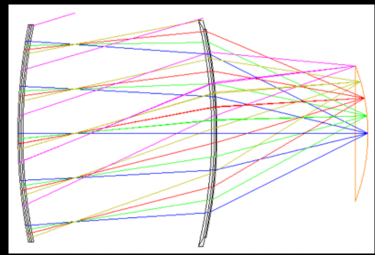
K-EUSO lens manufacturing

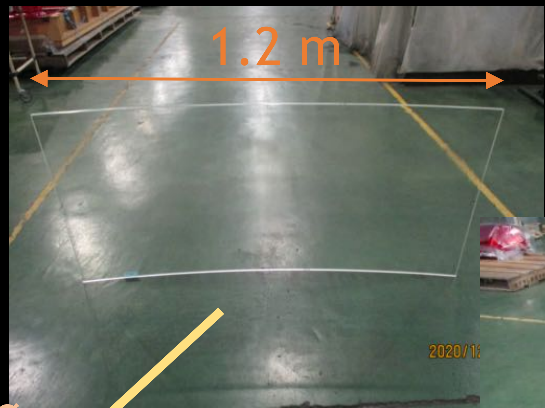
Production of slumping molds

27th November

Concave mold

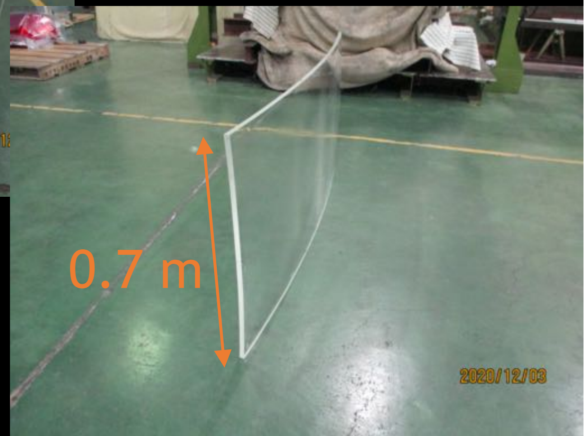
Convex mold





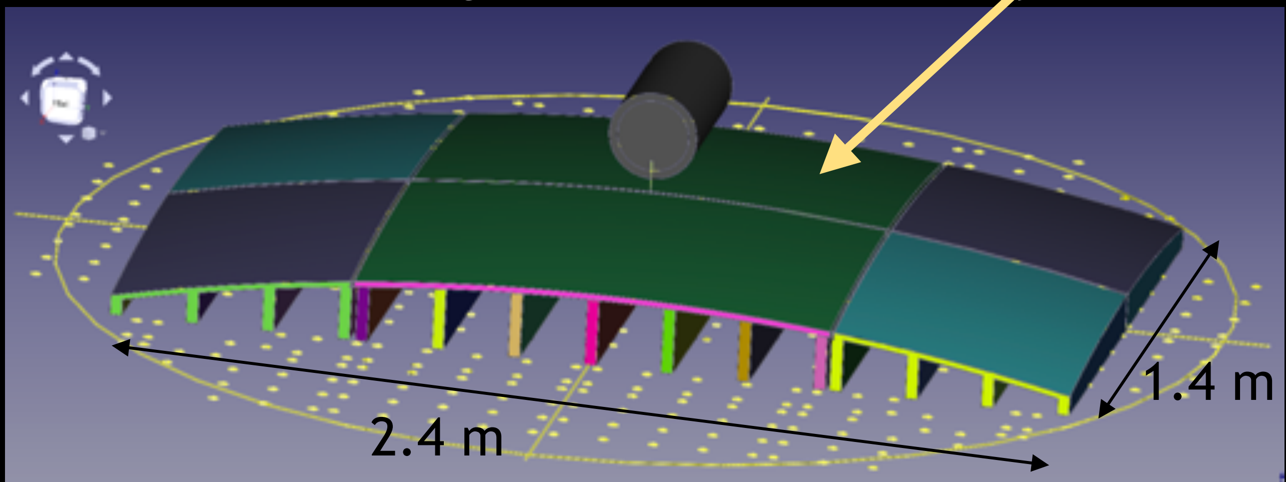
UV transparent PMMA

3rd December

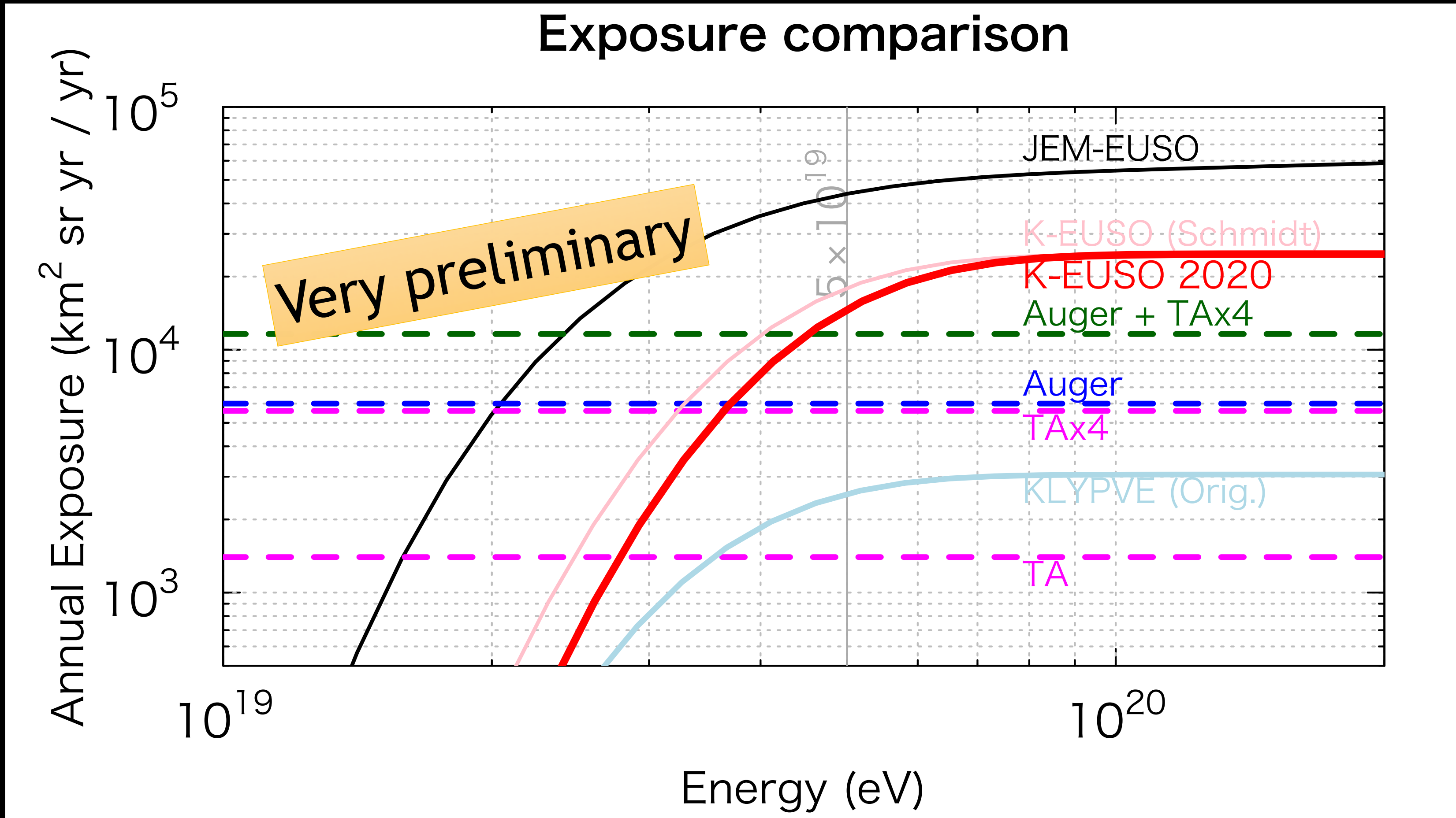


A CAD image of lens manufacturing

Lens manufacturing will start from January 2021.



Annual Exposure by Y. Takizawa
Rough estimation from S/N ration
(K-EUSO 2020)



KEUSO has 4 times of Auger and 4.4 times of TAx4 exposure.

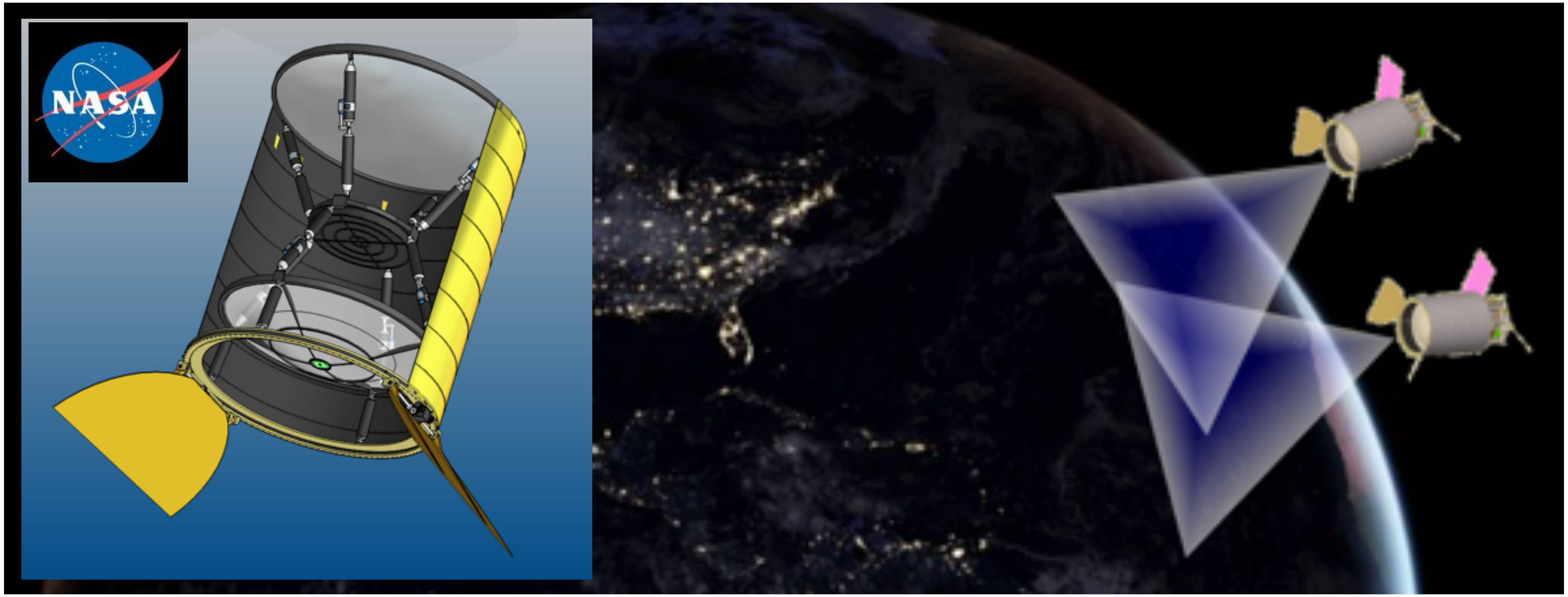
K-EUSO will observe, in three years,

about 8000 events over 10^{19} eV,

about 500 events over 5.7×10^{19}eV.

POEMMA mission

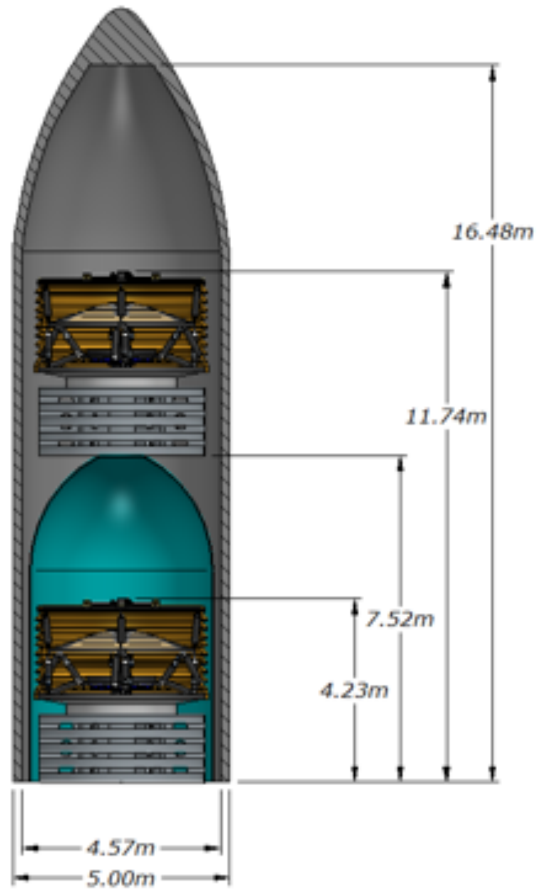
Stereo observation



POEMMA team is working on a conceptual design for selection of the 2020 Astronomy and Astrophysics Decadal Survey .

POEMMA mission

Mission Lifetime:	3 years (5 year goal)
Orbits:	525 km, 28.5° Inc
Orbit Period:	95 min
Satellite Separation:	~25 km – 1000+ km
Satellite Position:	1 m (knowledge)
Pointing Resolution:	0.1°
Pointing Knowledge:	0.01°
Slew Rate:	8 min for 90°
Satellite Wet Mass:	3860 kg
Power:	2030 W
Data:	1 GB/day
Data Storage:	7 days
Communication:	S-band (X-band if needed)
Clock synch (timing):	10 nsec



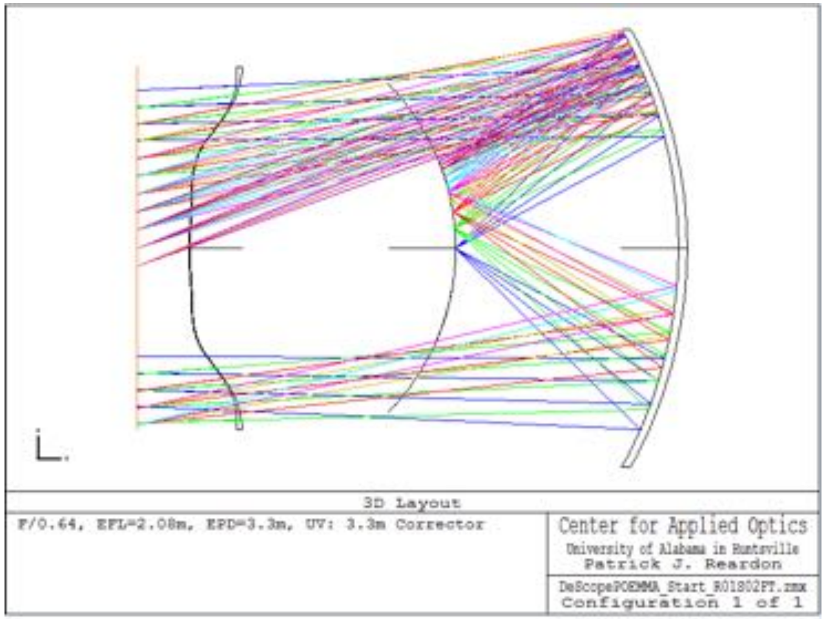
Dual Manifest Atlas V

Operations:

- Each satellite collects data autonomously
- Coincidences analyzed on the ground
- View the Earth at near-moonless nights, charge in day and telemeter data to ground

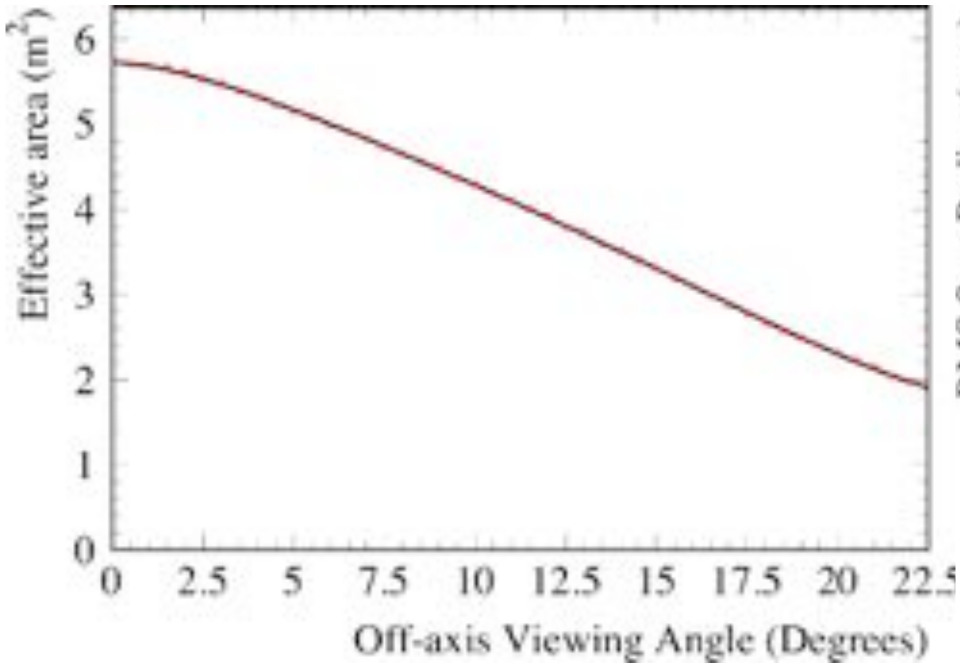
John Krizmanic, UHECR2018

POEMMA optics design

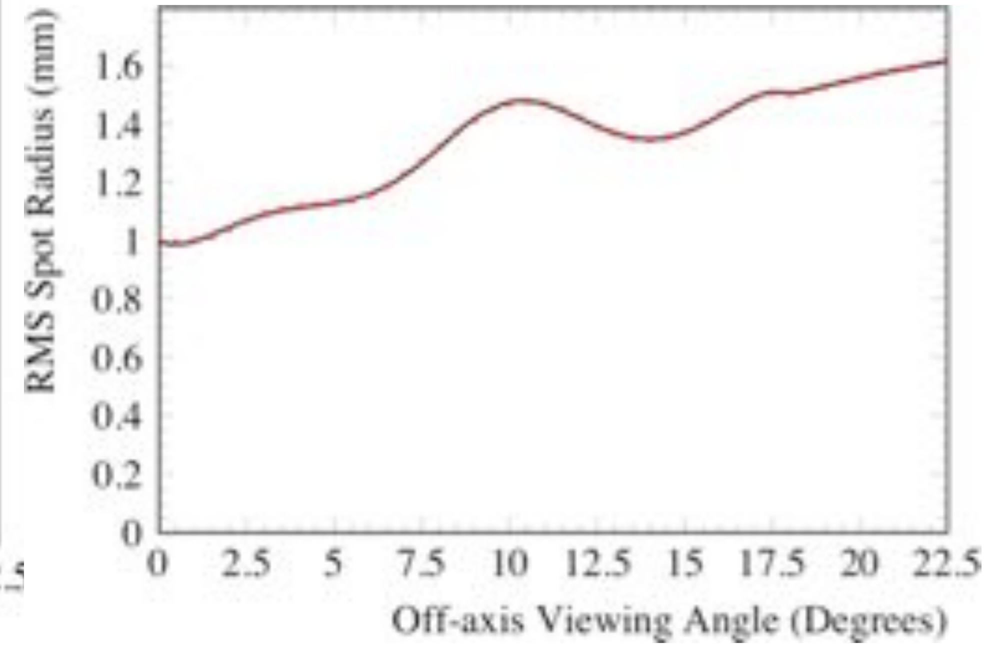


Mirror: 4.0m diameter spherical
Corrector lens: 3.3m, aspherical、UV-PMMA
Focal surface: 1.6m diameter
FOV: 45°
F# : 0.64
Spot size: ～3mm diameter
Angular resolution： 1°/pixel
Effective area：6～2 m^2 (JEM-EUSO: 2 m^2)
Orbit altitude: 525 km

Effective area

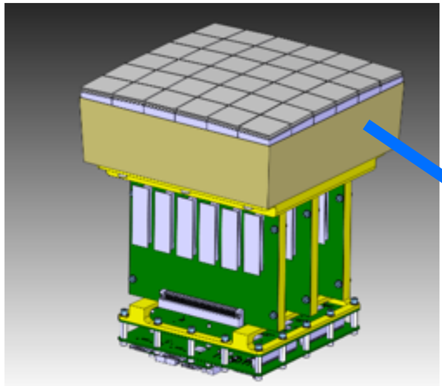


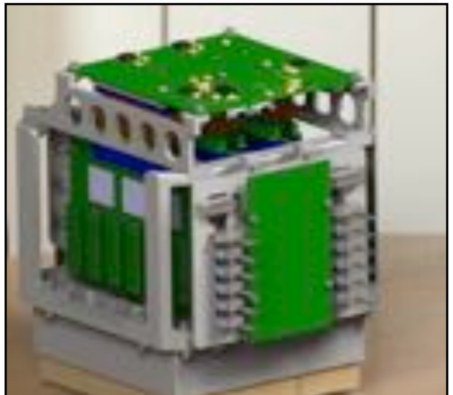
Spot size（radius, mm)

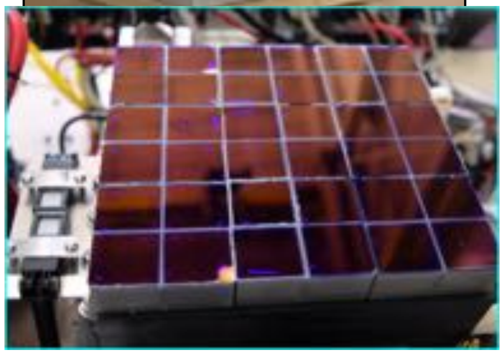


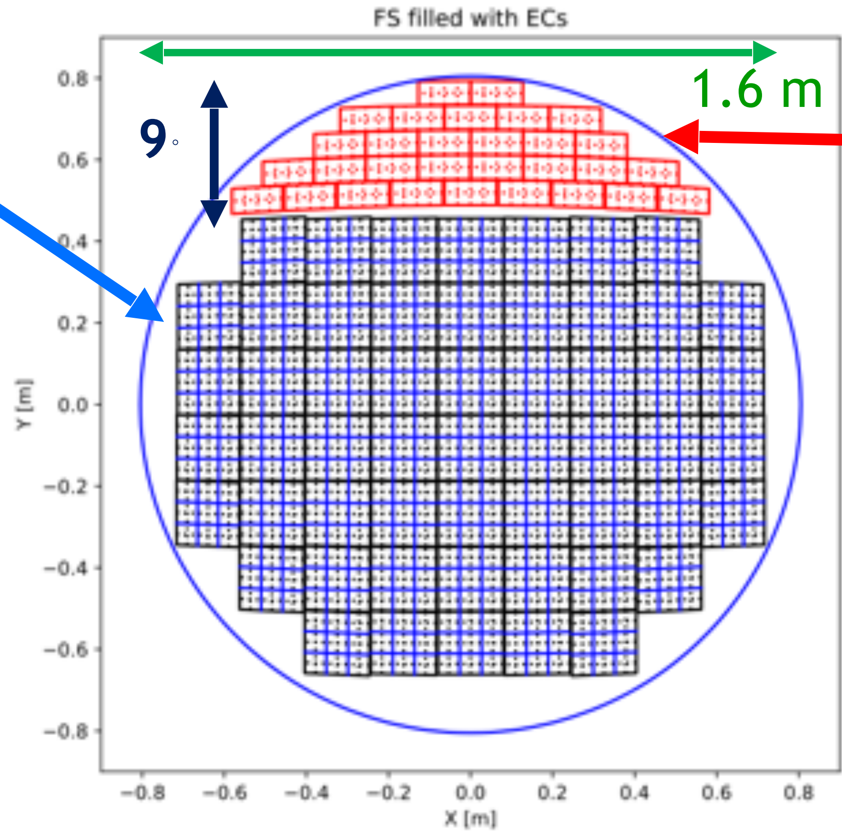
Hybrid focal surface detector

UV Fluorescence Detection using MAPMTs with UV filter: developed by JEM-EUSO: 1 usec sampling



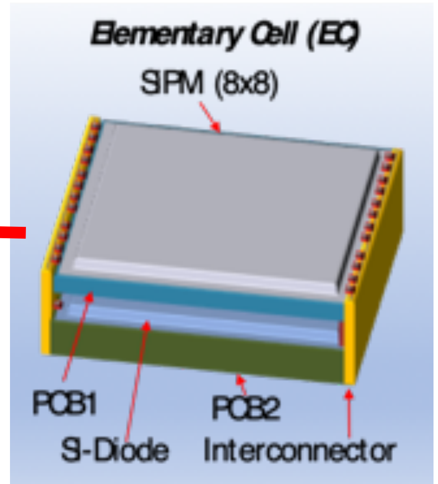






55 Photo Detector Modules (PDMs)= 126,720 pixels
1 PDM = 36 MAPMTs = 2,304 pixels

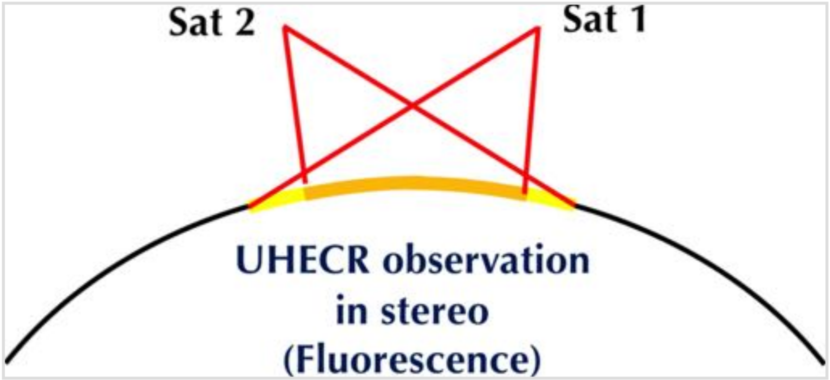
Cherenkov Detection using SiPMs:
20 nsec sampling



30 SiPM focal surface units
Total 15,360 pixels
512 pixels per FSU (64x4x2)

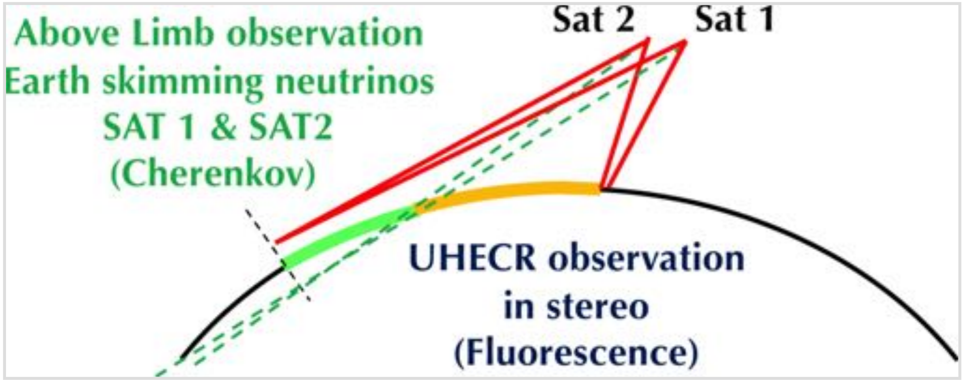
POEMMA observation modes

Nadir mode (UHECR)

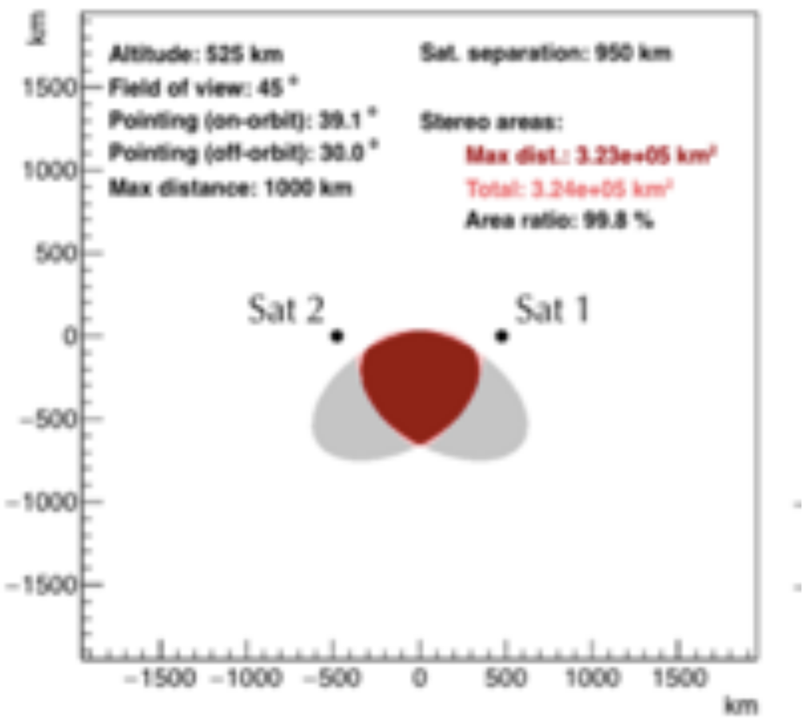


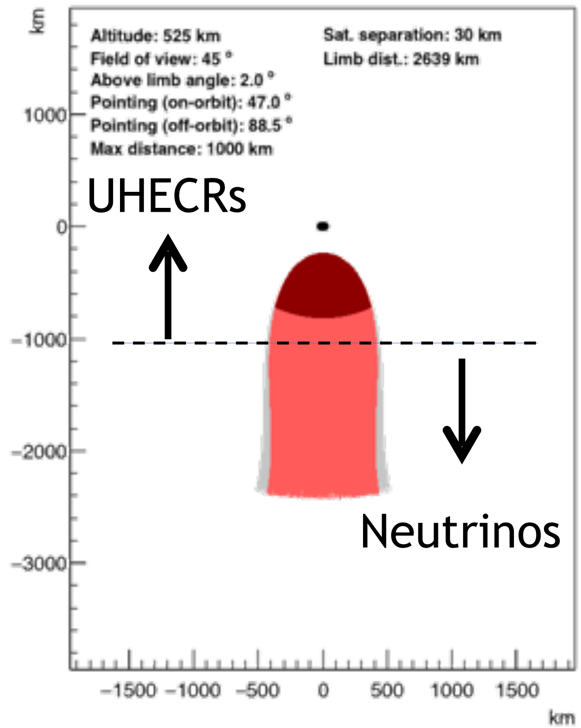
Satellite Separation ~300 km

Limb-viewing mode (UHECR + neutrino)



Satellite Separation ~30 km



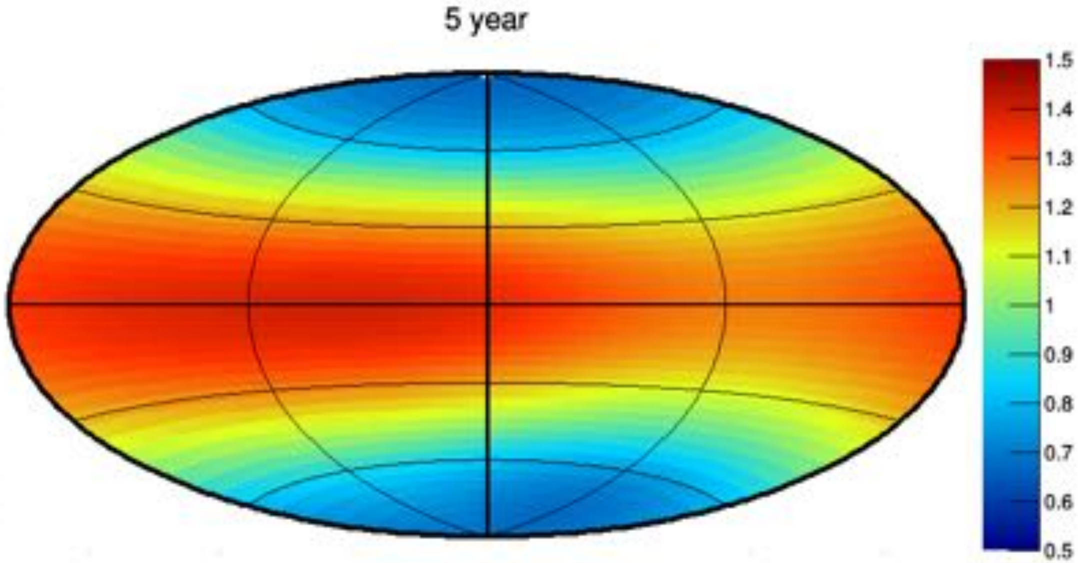


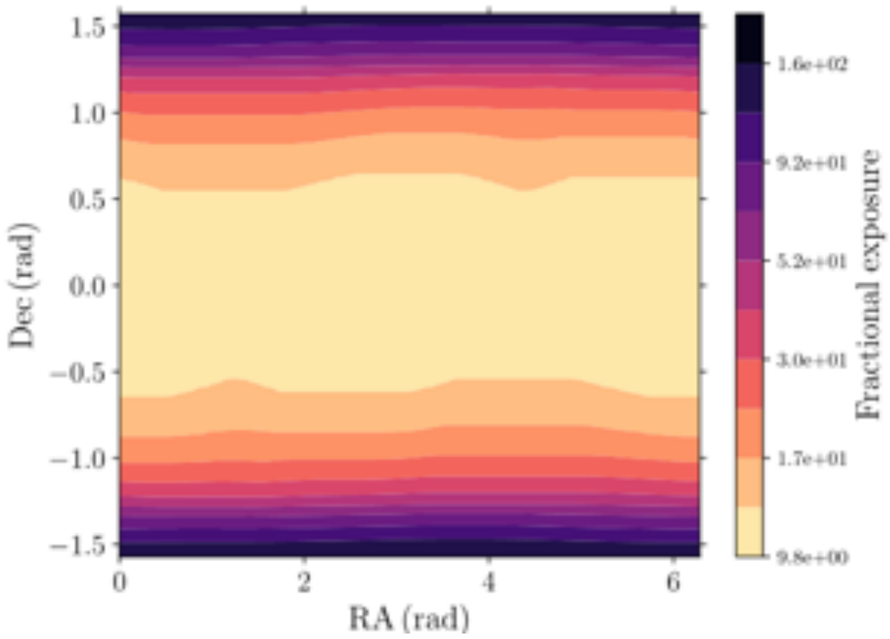
Sky Coverage

Nadir mode (UHECR)

Limb-viewing mode (neutrino+UHECR)

One year with re-orientations

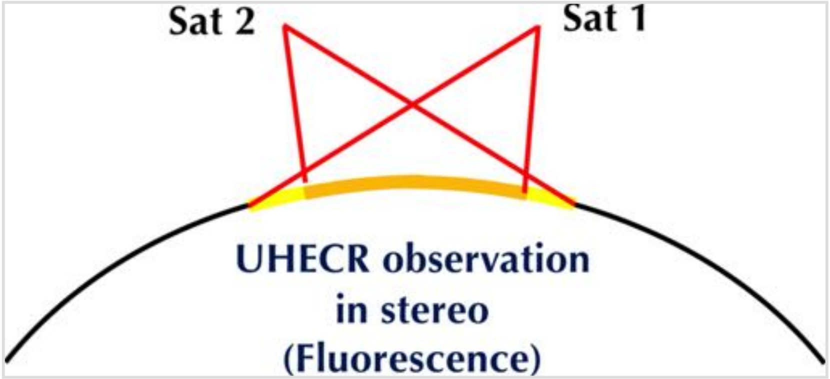




Calcs & plots by K. Shinozaki

Calcs & plots by C. Guépin & F. Sarazin

UHECR observation (Nadir)

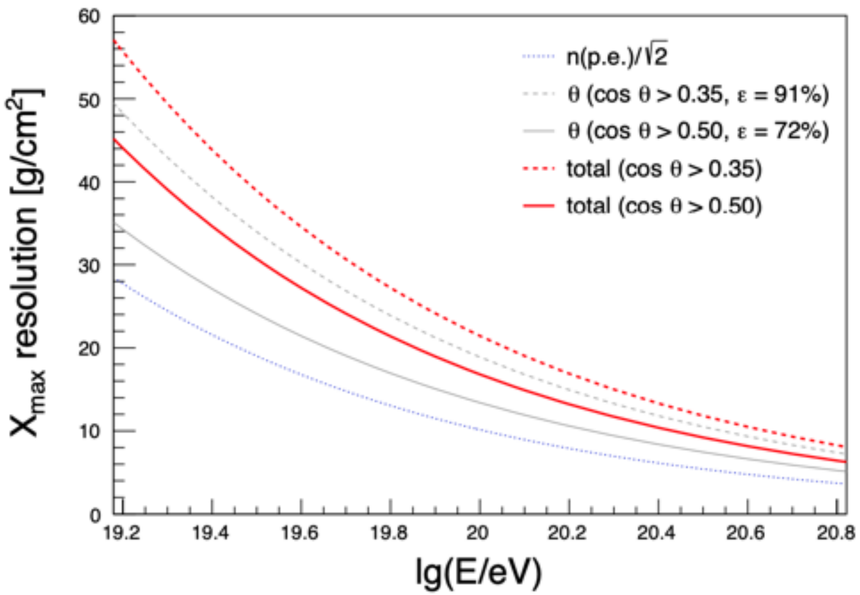


Satellite Separation ~300 km

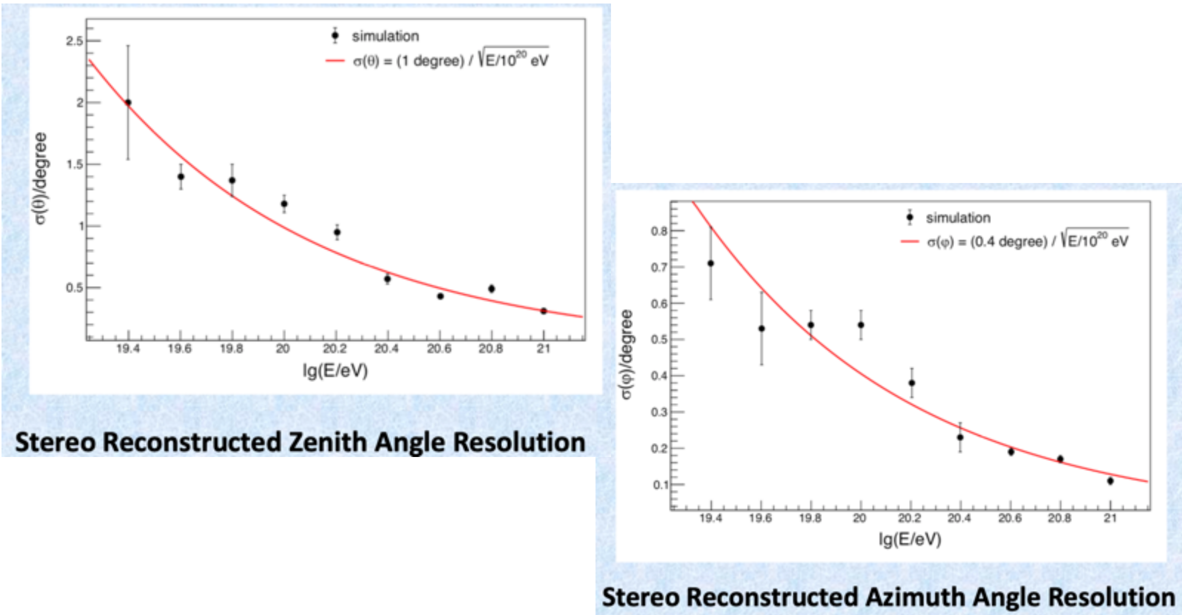
Energy resolution: < 20%
JEM-EUSO requirement < 30%

Xmax resolution

30 g/cm^2 above 50 EeV
20 g/cm^2 above 100 EeV



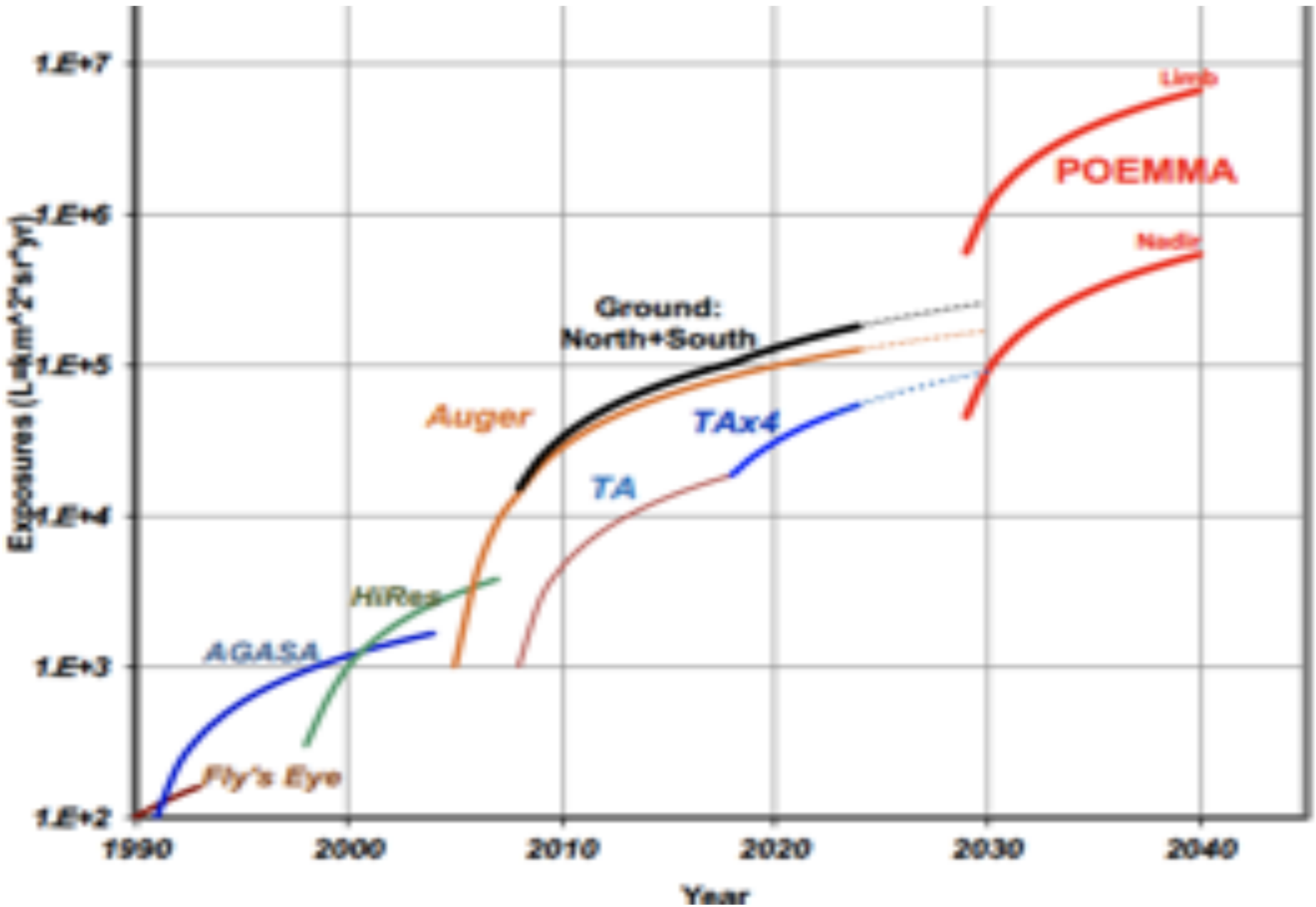
Angular resolution



JEM-EUSO requirement : < 2.5°

JEM-EUSO requirement : < 120 g/cm^2

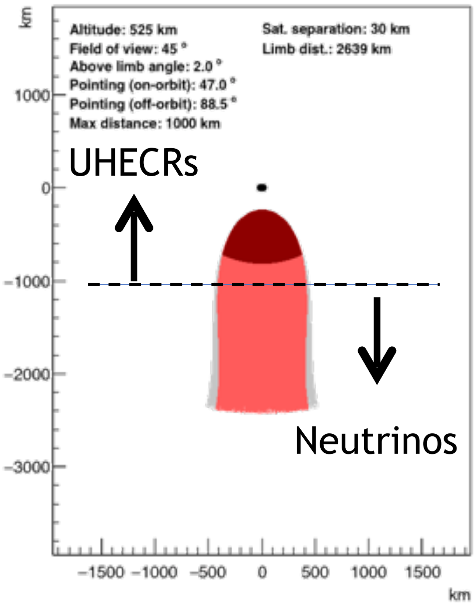
Integral exposure

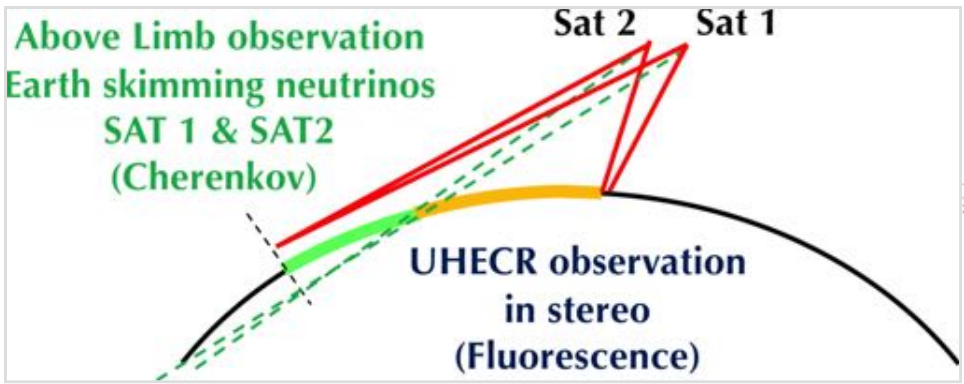


John Krizmanic, UHECR2018

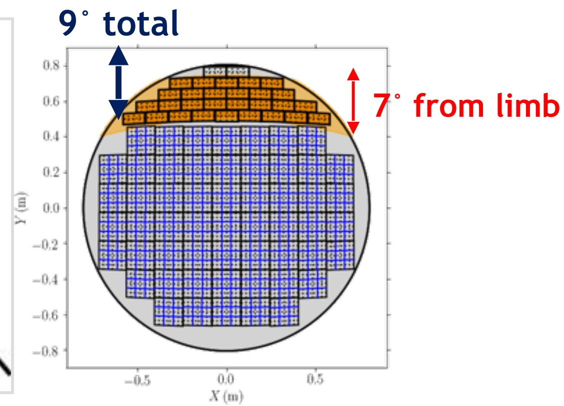
Cosmic neutrino observation from 20 PeV through the EeV scale

Limb-viewing mode (UHECR + neutrino)

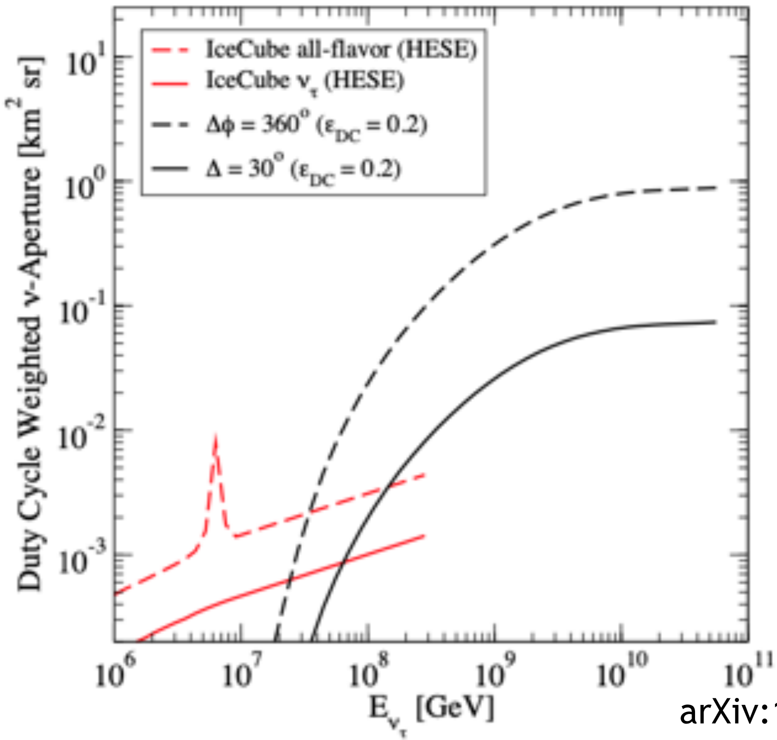




Satellite Separation ~30 km



POEMMA diffuse-flux neutrino sensitivity



- 20% duty cycle
- 10 PE threshold with time coincidence to reduce air glow background ‘false positives’
- Viewing to 7° away from Limb

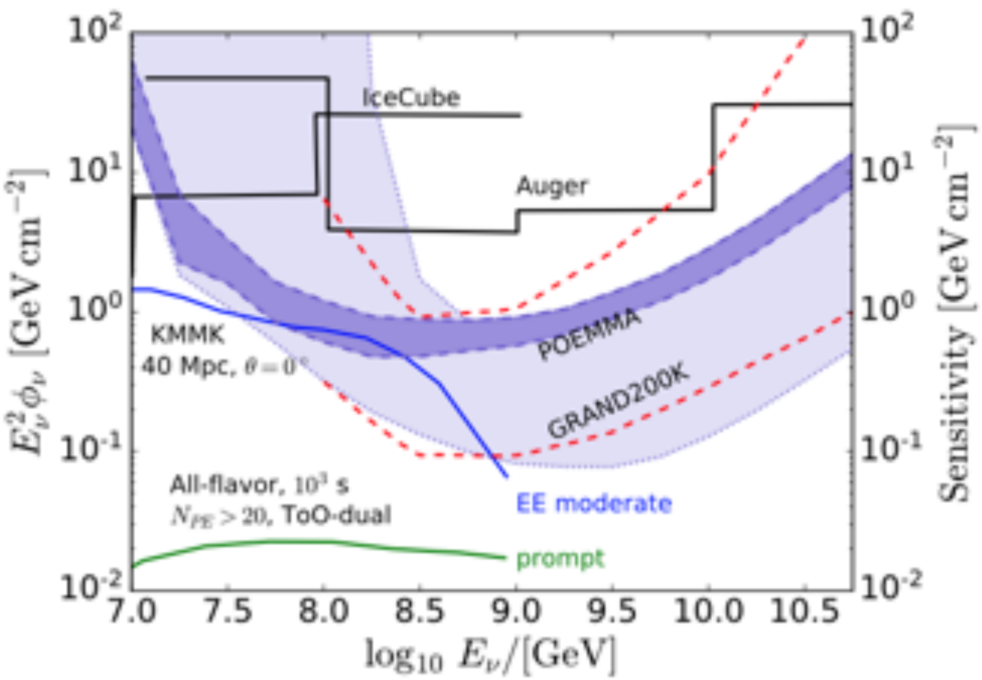
arXiv:1906.07209

Highly energetic cosmic neutrinos from astrophysical transient events,

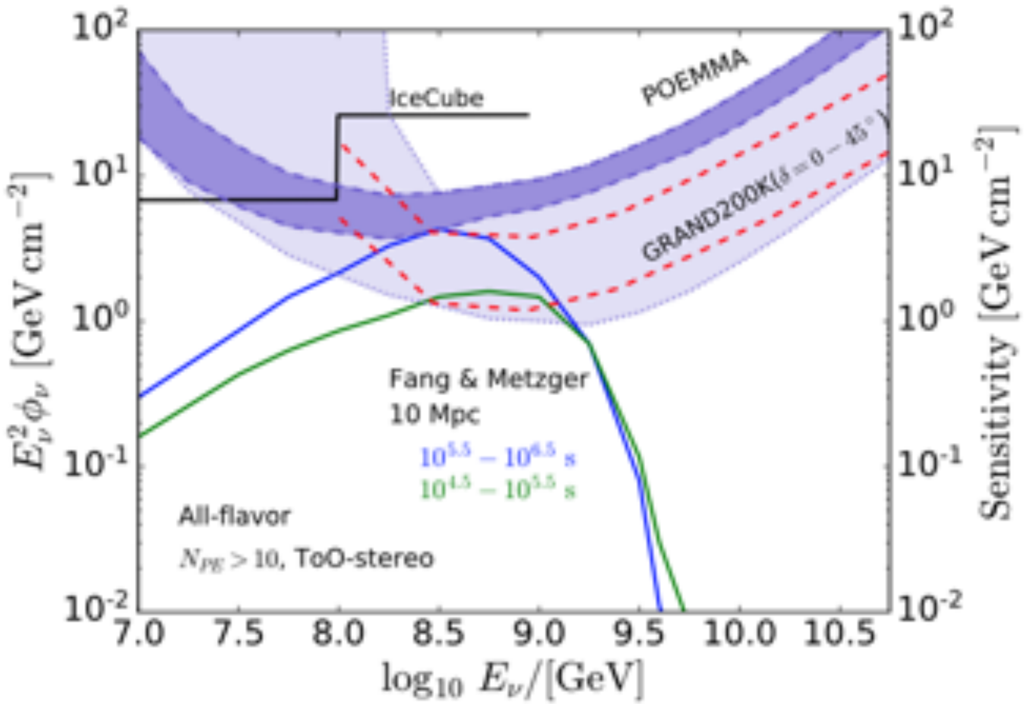
such as

- gravitational wave events from compact object merge,
- short and long gamma-ray burst,
- the birth of pulsars and magnetars,
- etc

POEMMA sensitivity to short burst (1000s)



POEMMA sensitivity to long burst (> 1day)



arXiv:1906.07209

Summary

The JEM-EUSO corroboration is moving to space missions from 2019.

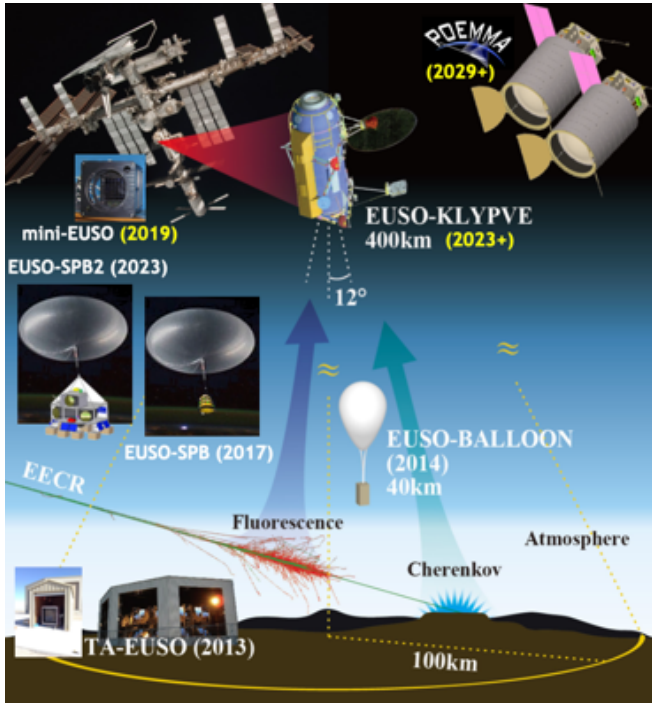
mini-EUSO(2019), K-EUSO(2023+), POEMMA(2029+)

What's your targeted physics in next decades?

The JEM-EUSO Japan would like to examine the bow wake filed acceleration theory by K-EUSO and POEMMA.

What we need to accomplish?

I (we) need to study more about the bow wake filed acceleration theory to find its clear signs from observation data of K-EUSO and POEMMA.



Thank you