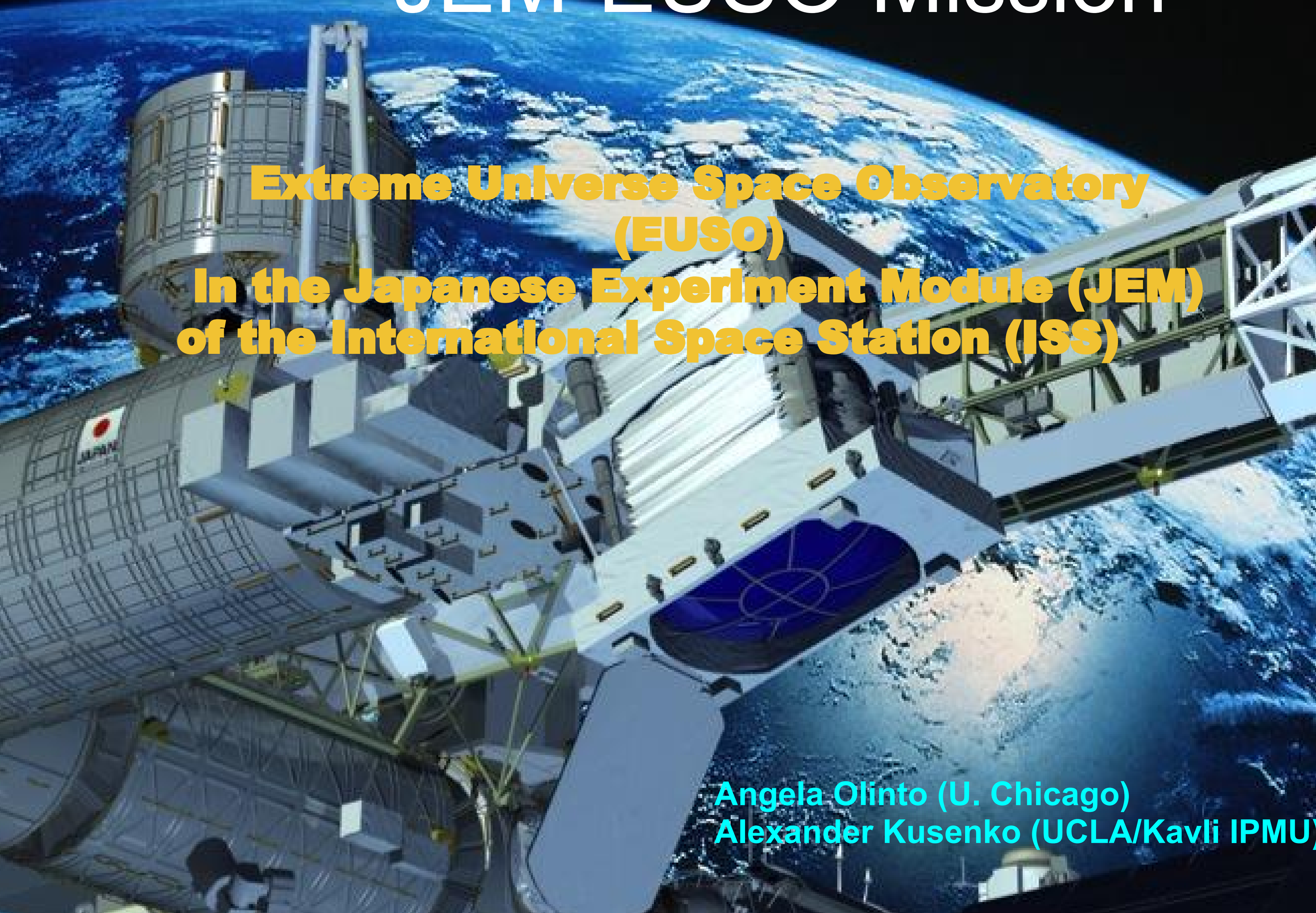
JEM-EUSO Mission



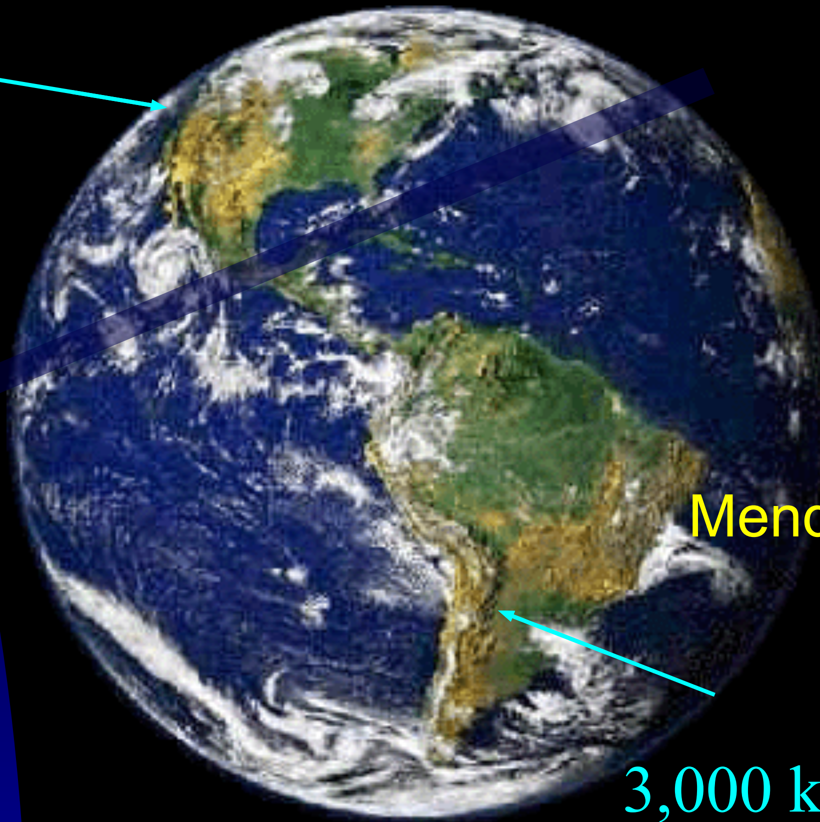
Extreme Universe Space Observatory (EUSO) In the Japanese Experiment Module (JEM) of the International Space Station (ISS)

Angela Olinto (U. Chicago)
Alexander Kusenko (UCLA/Kavli IPMU)

Current Observatories of Ultrahigh Energy Cosmic Rays

Telescope Array
Utah, USA
(5 country collaboration)

$700\ \text{km}^2$ array
3 fluorescence telescopes

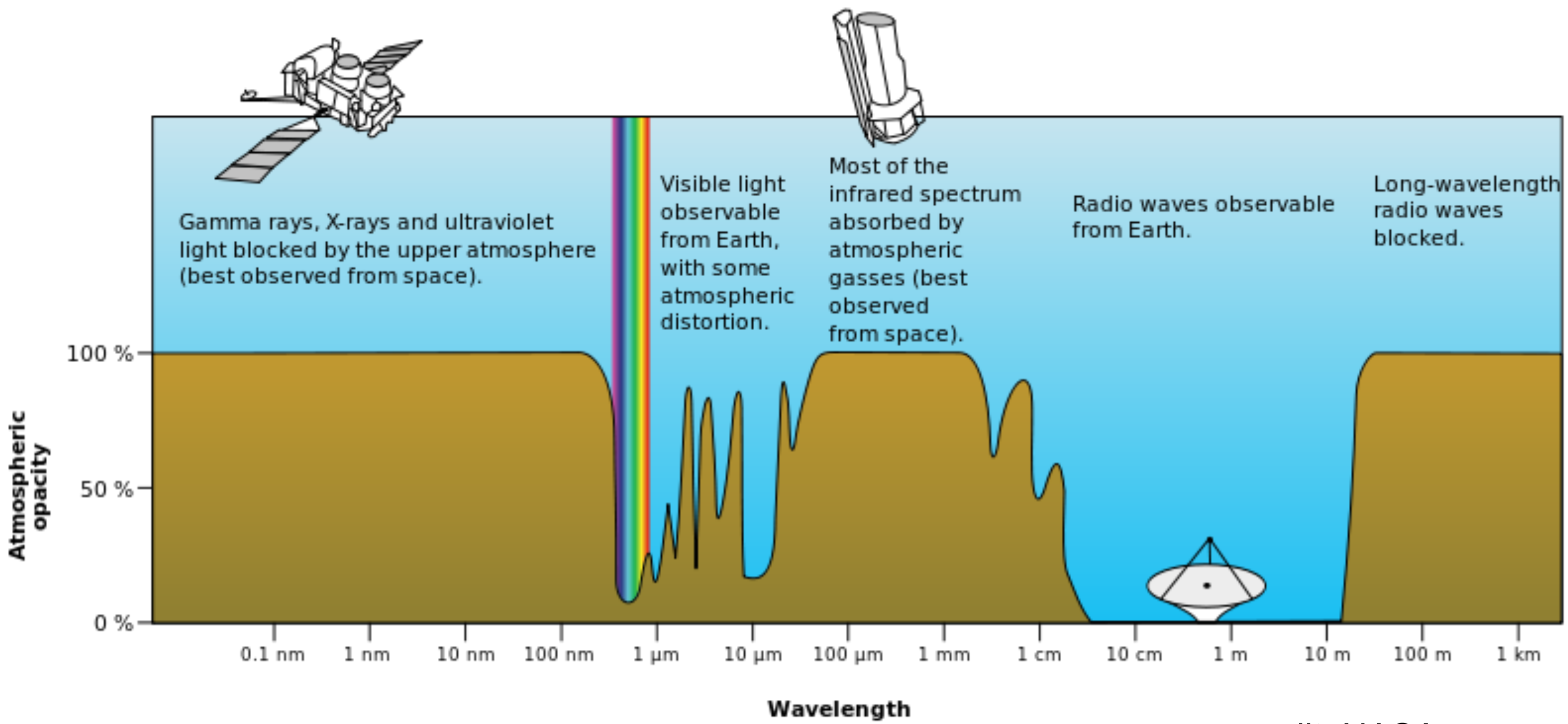


Pierre Auger Observatory
Mendoza, Argentina
(19 country collaboration)

$3{,}000\ \text{km}^2$ array
4 fluorescence telescopes

The era of particle astronomy begins

Prior to space exploration, astronomy relied on atmospheric transparency windows:



credit: NASA

The era of particle astronomy begins

Charged particle astronomy transparency window

Lower bound: deflection by magnetic fields

Upper bound: GZK cutoff

Magnetic fields

- **galactic: microgauss** [Vallée, New Astron Rev., 48, 763]
- **intergalactic (in clusters): nanogauss**
- **intergalactic (in voids): femtogauss** [Essey et al., Astropart.Phys. 35 (2011) 135]

Deflections can interfere at energies below 10 EeV,

even for relatively nearby extragalactic sources.

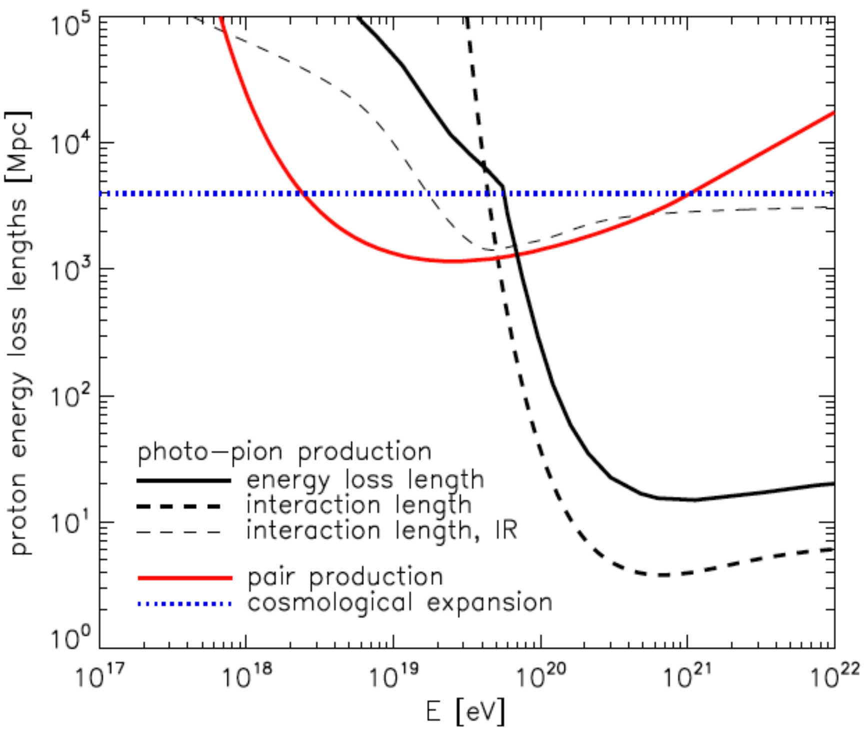
Need to go beyond HiRes, PAO, and TA.

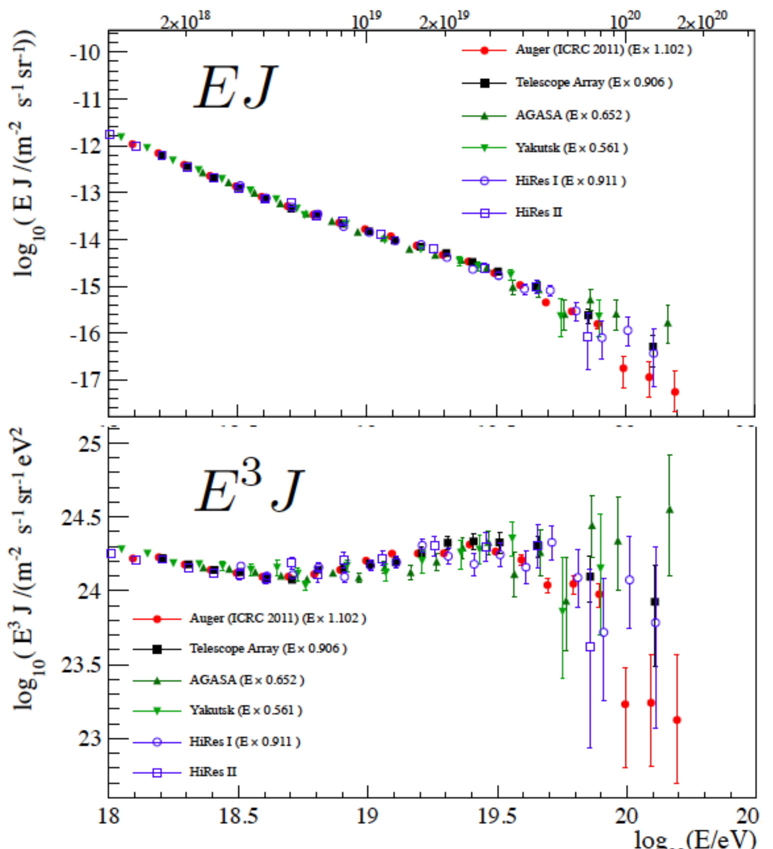
The era of particle astronomy begins

Charged particle astronomy transparency window

Lower bound: deflection by magnetic fields

Upper bound: GZK cutoff (?)





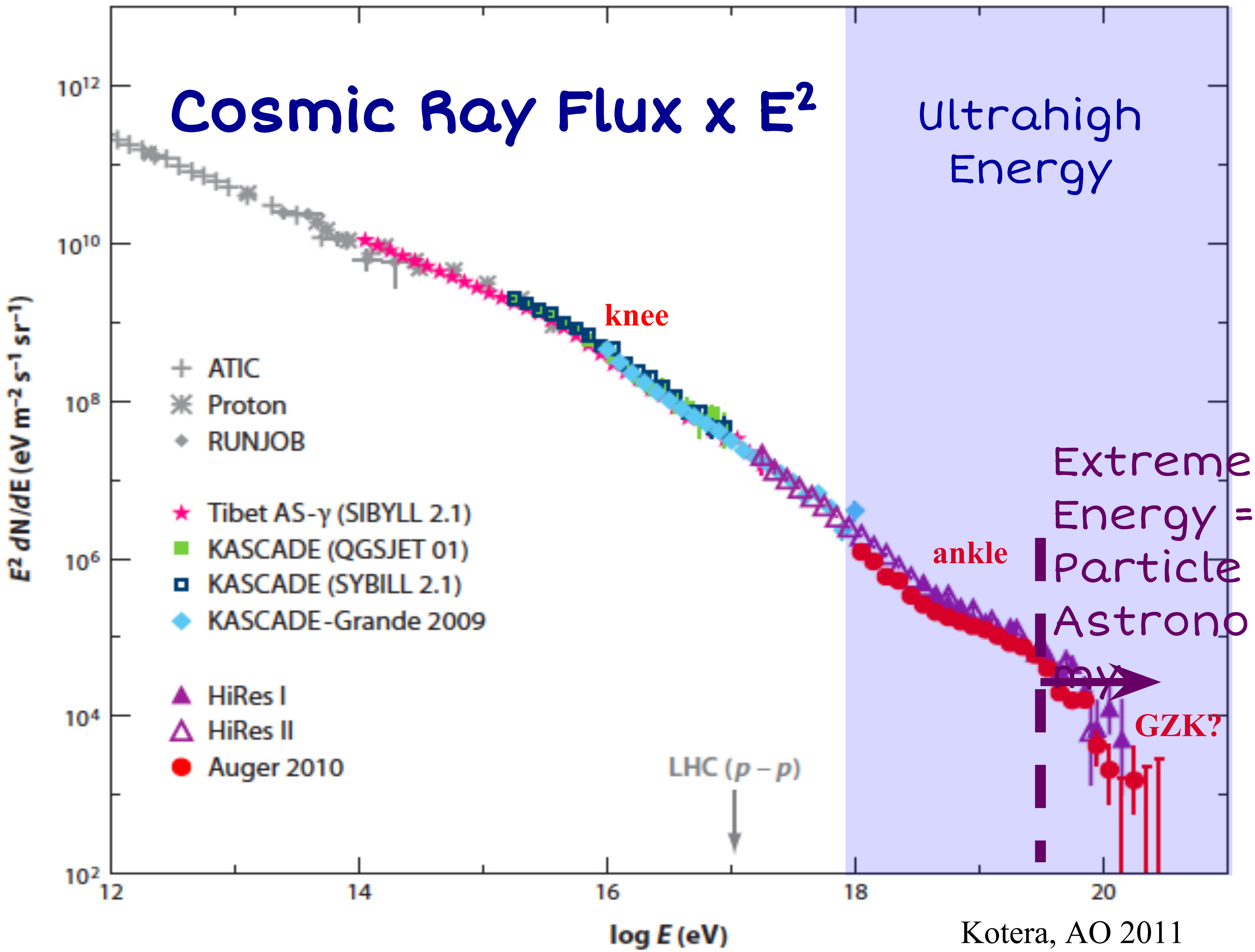
The era of particle astronomy begins

Charged particle astronomy transparency window

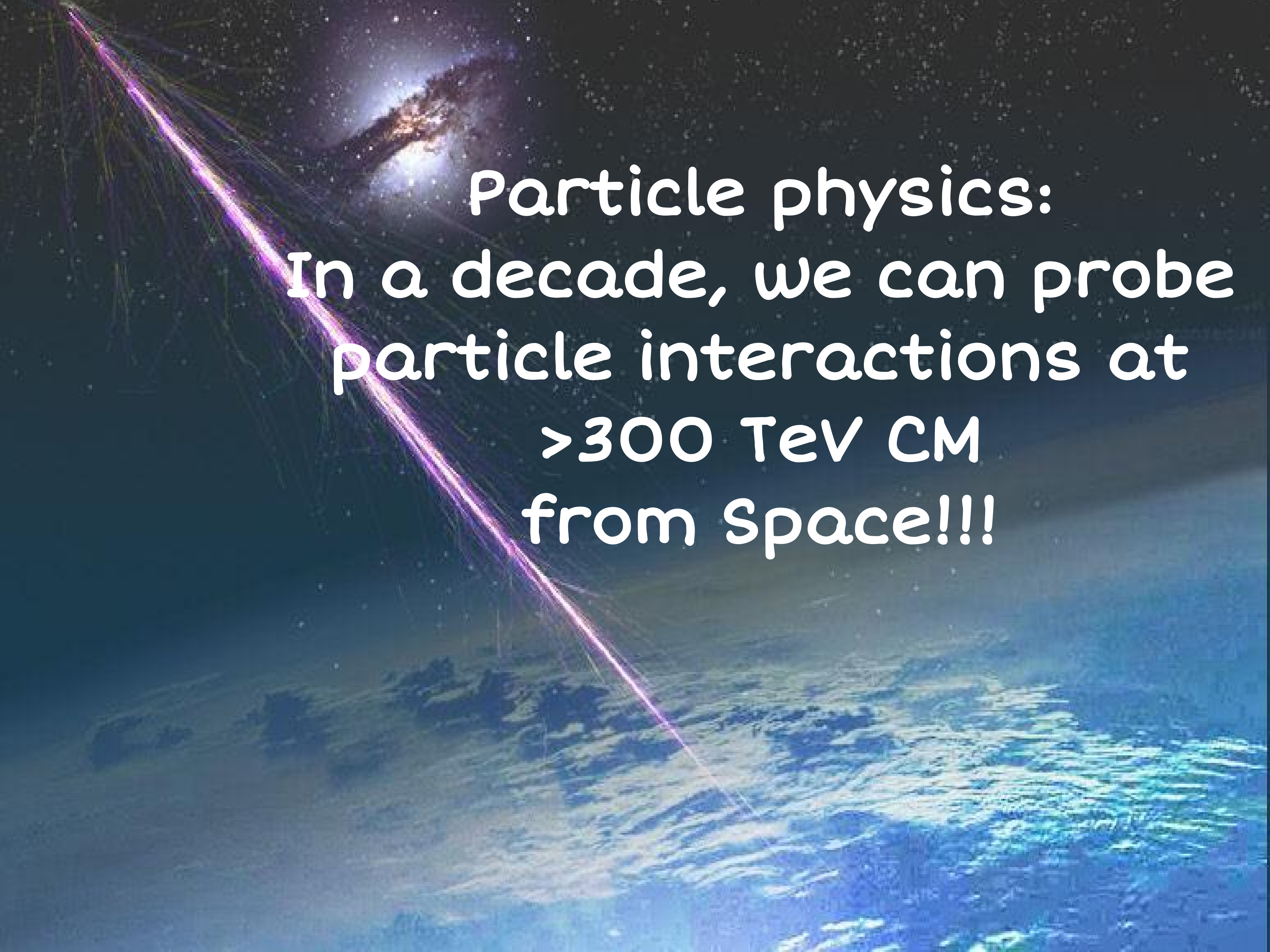
Lower bound: deflection by magnetic fields
Upper bound: GZK cutoff

Transparency window:
tens of EeV, for nearby sources

Need many events at tens of EeV energies!

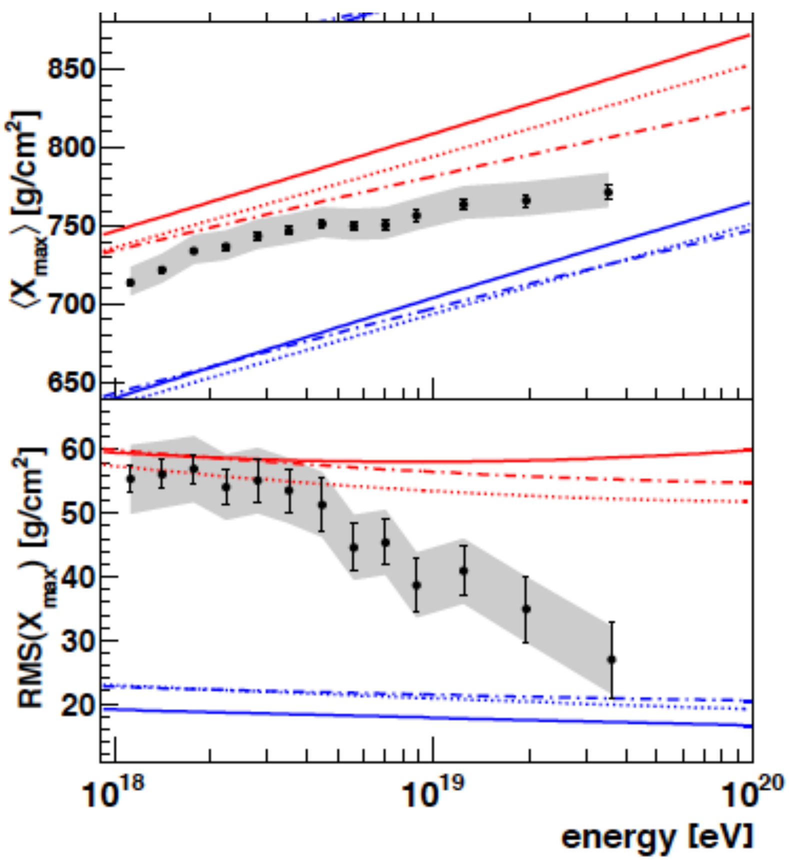


Kotera, AO 2011

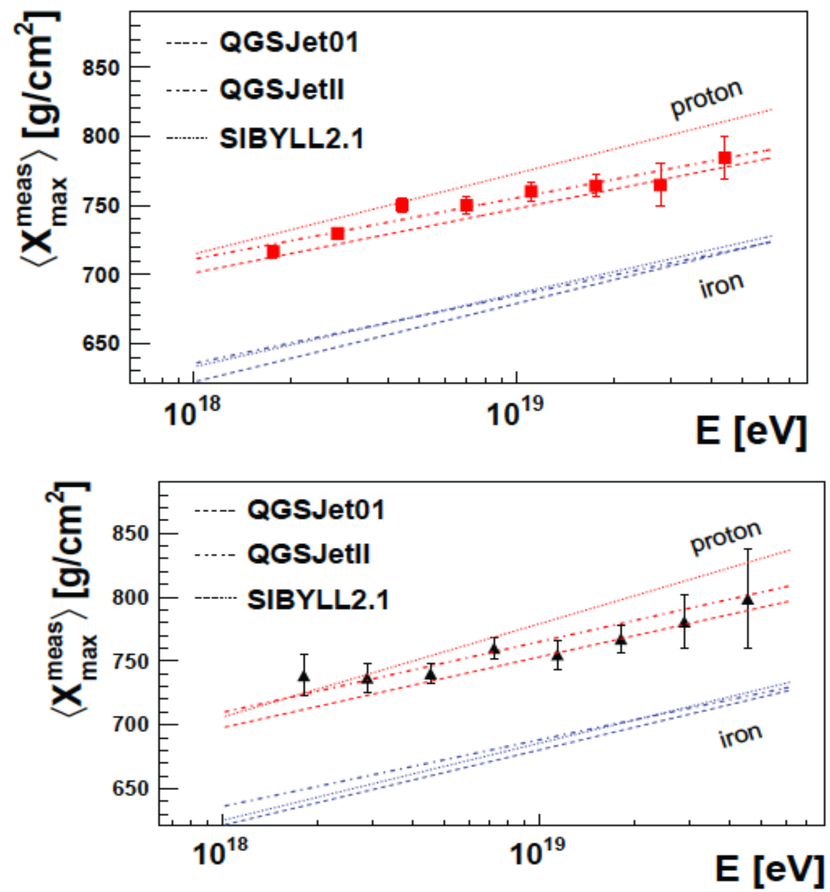

Particle physics:
In a decade, we can probe
particle interactions at
>300 TeV CM
from Space!!!

Composition mystery

Pierre Auger



HiRes and TA



How many EECRs > 60 EeV?

Before we see the sources?

1,000 is a good o.o.m. estimate

Dipole from direction of Cen A in Auger >60 EeV:

(a posteriori) right ascension harmonic analyses

$$\alpha_d \, \hat{d} = \frac{3}{\mathcal{N}} \int J(\hat{u}) \, \hat{u} \, d\Omega$$

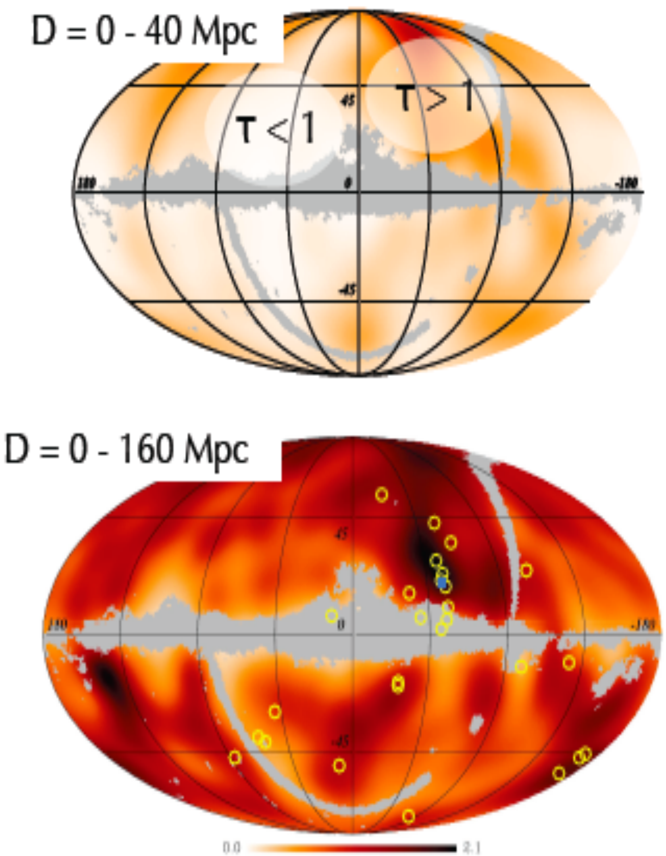
$\alpha_d = 0.25$

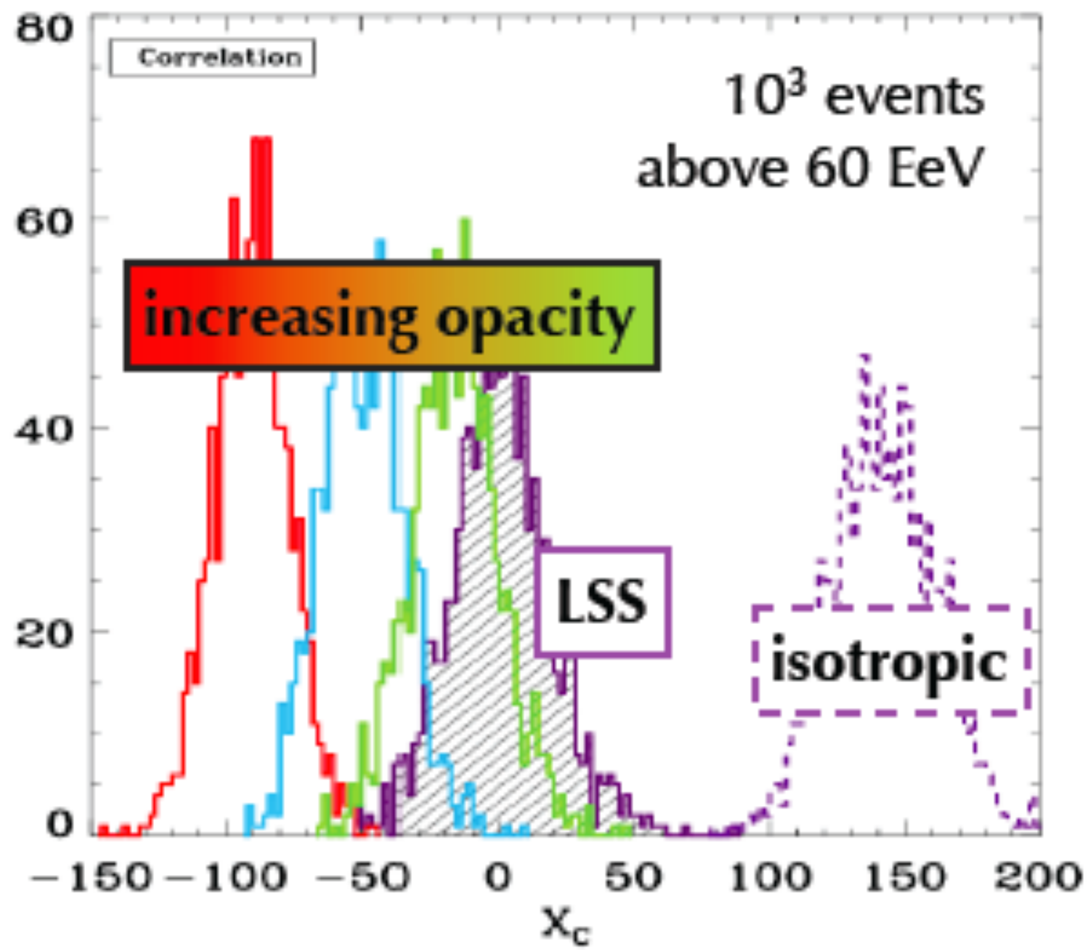
Anchordoqui, Goldberg & Weiler '11

5σ discovery requires 1,000 events

(with whole sky coverage)

Population Separation needs
1,000 events above 60 EeV

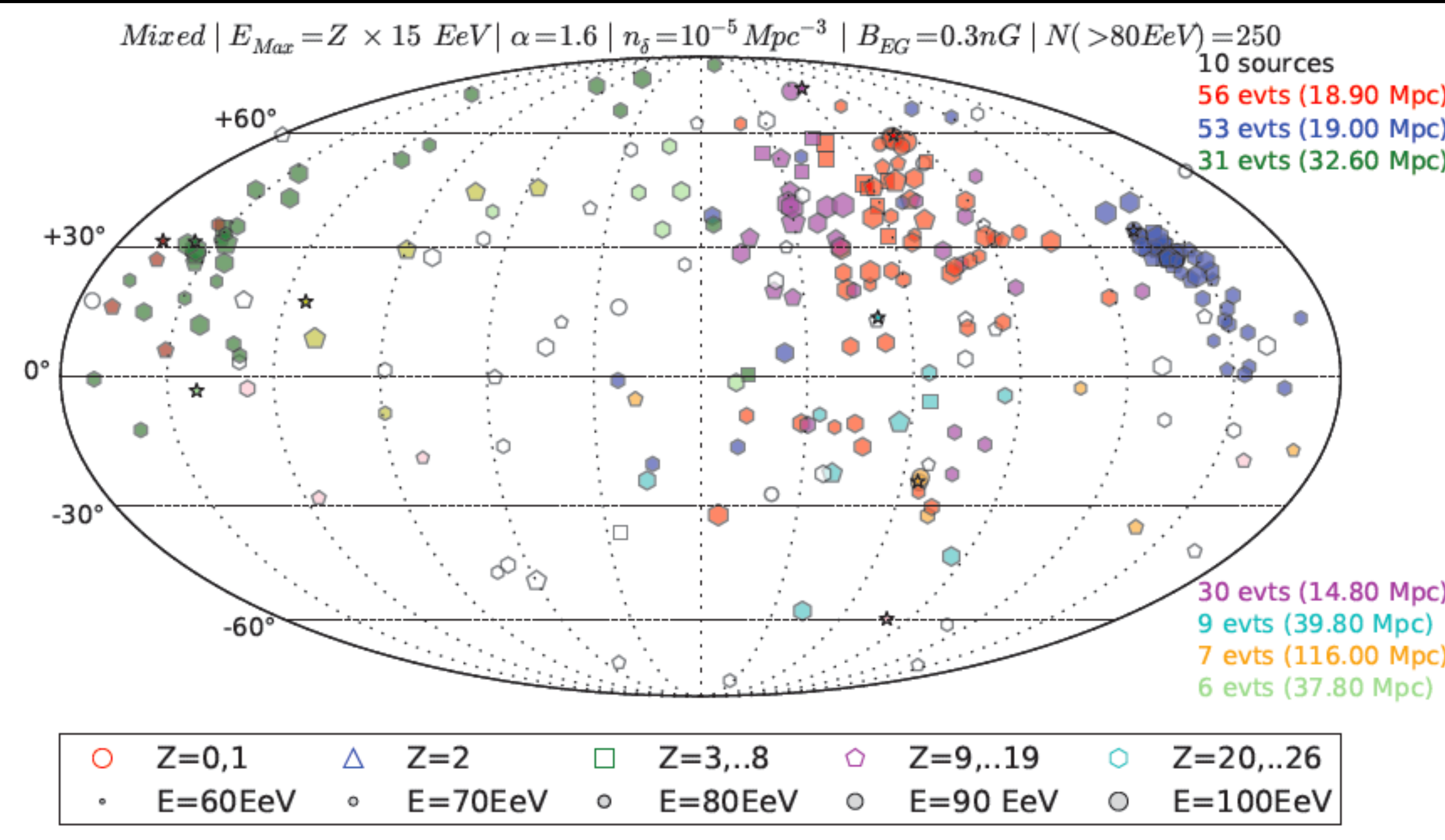




Kalli, Lemoine, Kotera '10

$$X_C = \sum_{i=1}^{N_{tot}} \frac{(N_i^{T} - \langle N_{i,\mathrm{LSS}}\rangle)(\langle N_{i,\mathrm{iso}}\rangle - \langle N_{i,\mathrm{LSS}}\rangle)}{\langle N_{i,\mathrm{LSS}}\rangle}$$

or >250 events E>80 EeV mixed



Protons cut exponentially > 15 EeV
heavier nuclei dominate > 80 EeV

Rouille D'Orfeil et al '13

How many EECRs > 60 EeV?

Auger w/ 3,000 km^2

~20 events > 60 EeV/ yr

Telescope Array w/ 700 km^2

~5 events > 60 EeV/ yr

Auger + TA ~ 25 events/yr > 60 EeV

40 years to reach 1,000

How many EECRs > 60 EeV?

Auger w/ 3,000 km^2

~20 events > 60 EeV/ yr

Telescope Array w/ 700 km^2

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Auger + TA ~ 25 events/yr

40 years to reach 1,000

Earth - surface ~ 5 $10^8 km^2$

~3.4 10^6 events/yr

JEM-EUSO Mission

Japan, USA, Korea, Mexico, Russia, Europe: Bulgaria, France, Germany, Italy, Poland, Slovakia, Spain, Switzerland

13 Countries, 73 RIKEN tions, 250 researchers

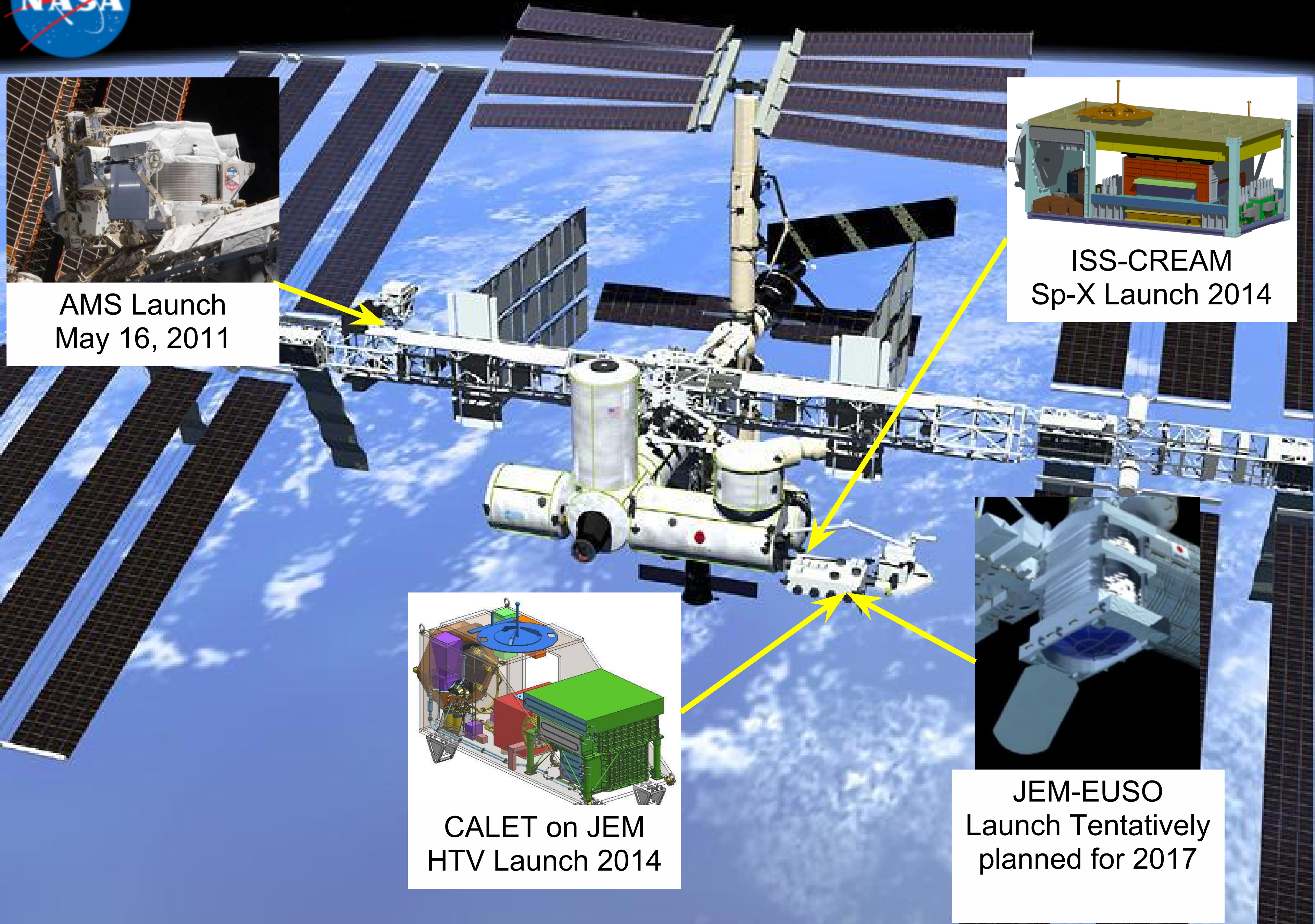
NASA

JAXA

esa

РОСКОСМОС

View from NASA: "Cosmic Ray Observatory on the ISS"



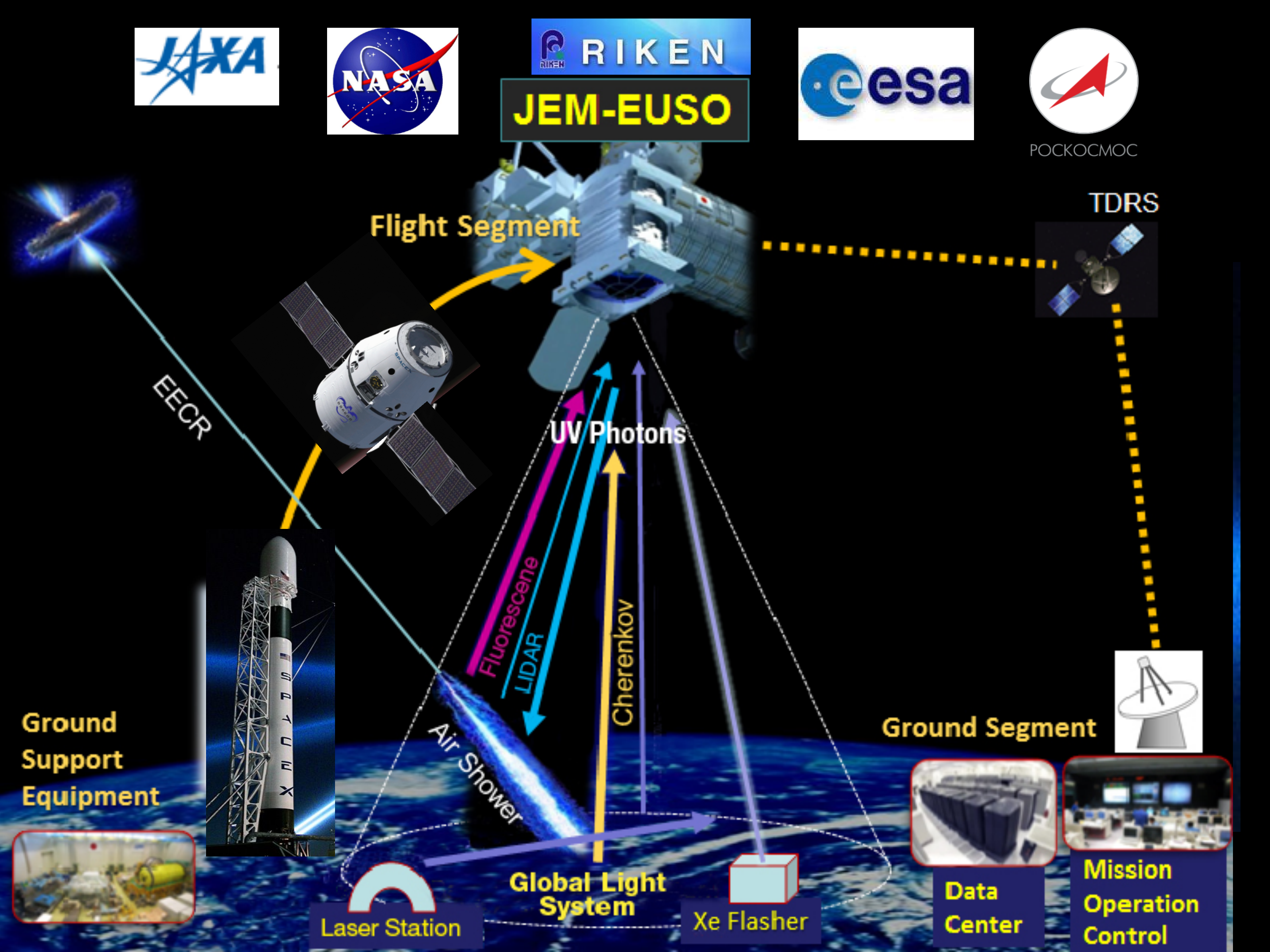
JEM-EUSO goals

- pioneer the study of EECR from Space
- increase exposure to EECR by 1 order of magnitude
- discover the nearby sources of UHECRs

EECR: Extreme Energy CRs > 60 EeV
UHECR: Ultrahigh Energy CRs > 1 EeV = 10^{18} eV

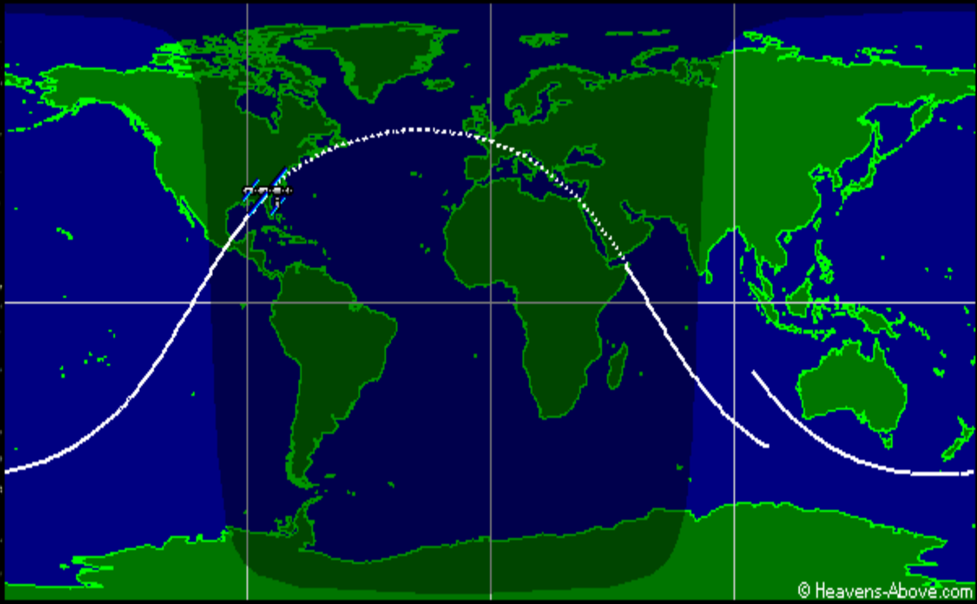
JEM-EUSO Mission

Parameter	Value
Launch date	2017
Mission Lifetime	3+2 years
Rocket	H2B (or Falcon9)
Transport Vehicle	HTV (or Dragon)
Accommodation on JEM	EF#9
Mass	1938 kg
Power	926 W (op.) 352 W (non op.)
Data rate	285 kbps (+ on board storage)
Orbit	400 km
Inclination of the Orbit	51.6°
Operation Temperature	-10° to +50°


JAXA
NASA
RIKEN
JEM-EUSO
esa
РОСКОСМОС
TDRS
Flight Segment
EECR
UV Photons
Fluorescene
LIDAR
Cherenkov
Air Shower
Ground Support Equipment
Ground Segment
Laser Station
Global Light System
Xe Flasher
Data Center
Mission Operation Control

Full Sky Coverage
with nearly uniform exposure

The ISS ORBIT



Inclination: 51.6°
Height: ~400km

Duty Cycle

Universitetsky Tatiana: satellite (Moscow State Univ) – operated January 2005 -March 2007, altitude 950 km, FOV 15° atmospheric surface of 250km in diameter UV (310-400nm) light

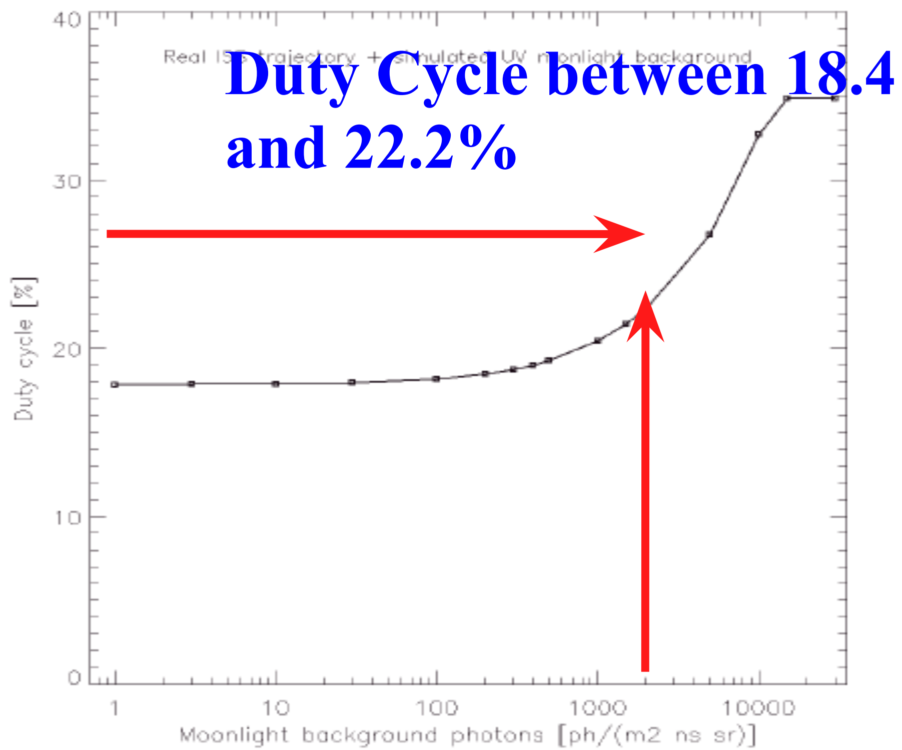
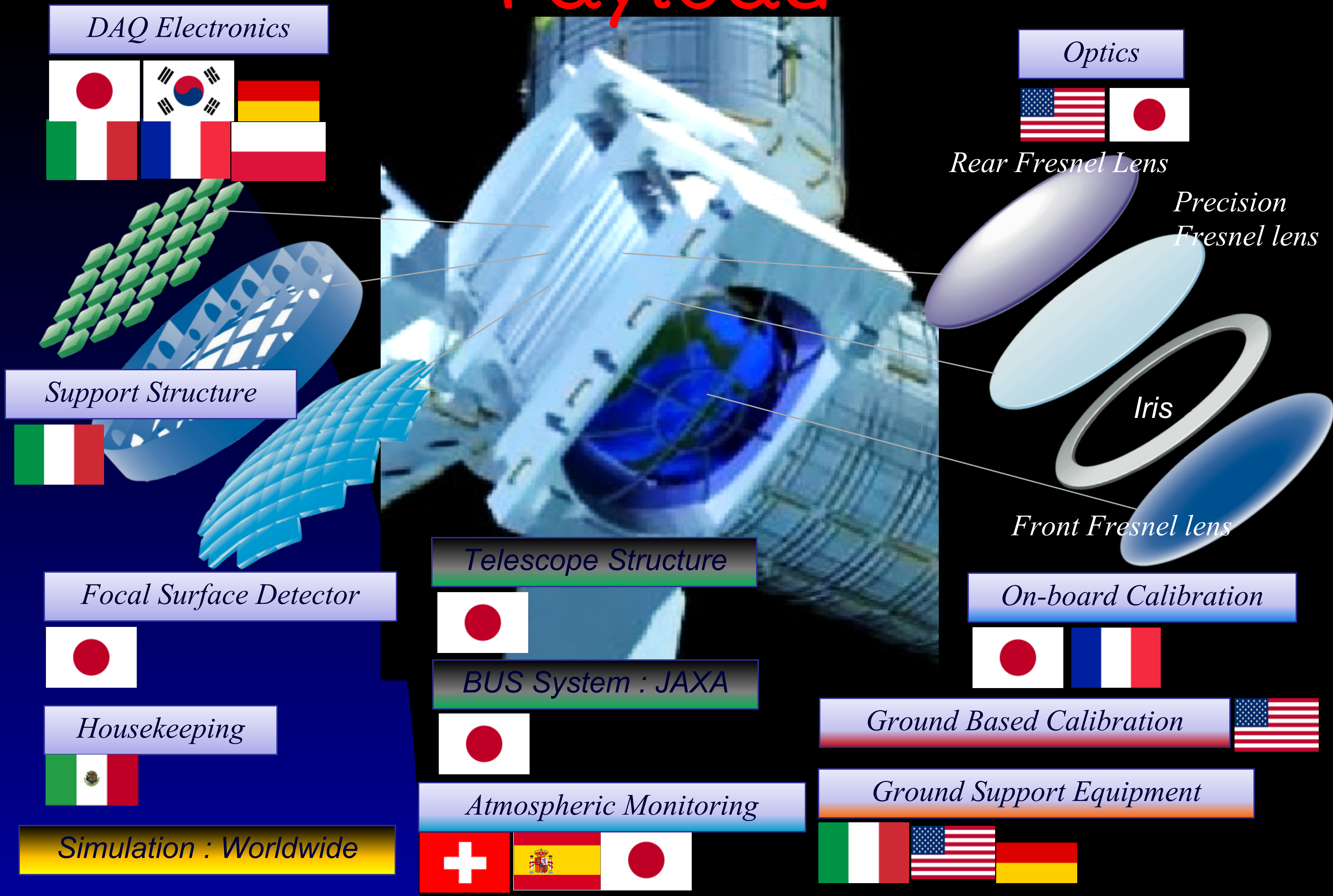


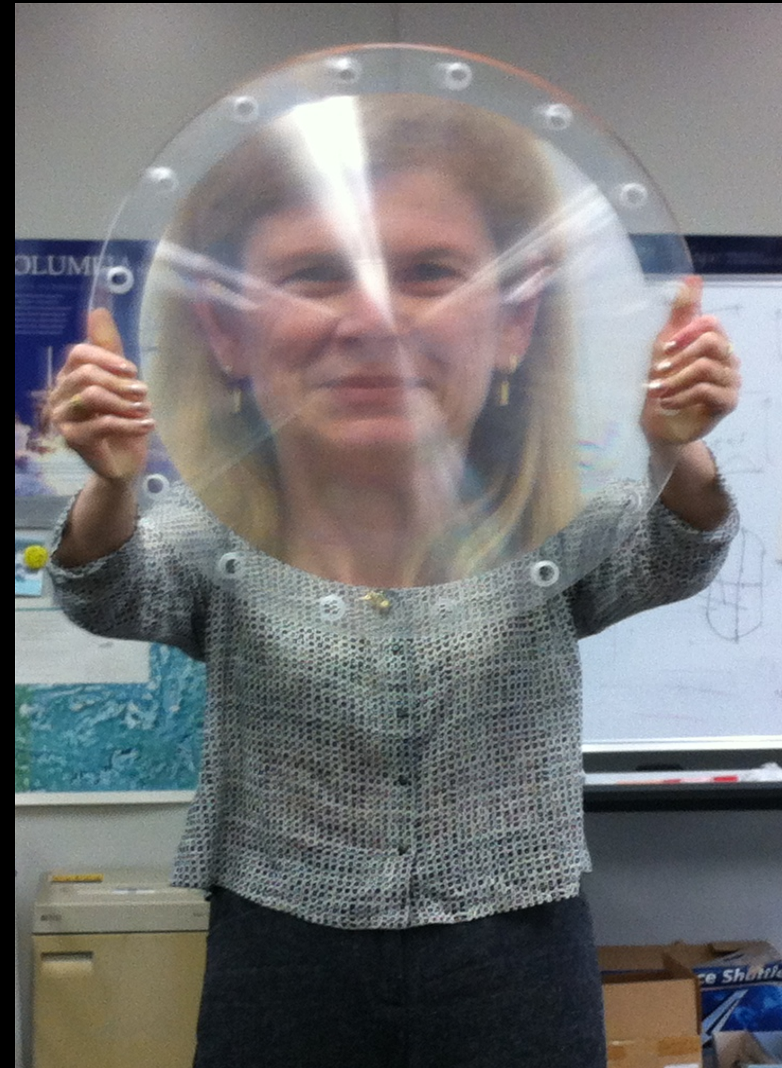
Figure 1. Duty cycle evaluated from real ISS trajectory in years 2005 till 2007 and simulated moonlight BG light.

Solar zenith angle (deg.)	Duty cycle (%
108	22.2
109	22.1
110	21.9
111	21.7
112	21.5
113	21.3
114	21.0
115	20.6
116	20.3
117	19.9
118	19.5
119	19.0
120	18.4

Payload



DAQ Electronics
Optics
Rear Fresnel Lens
Precision Fresnel lens
Iris
Front Fresnel lens
Support Structure
Telescope Structure
Focal Surface Detector
BUS System : JAXA
On-board Calibration
Housekeeping
Ground Based Calibration
Atmospheric Monitoring
Ground Support Equipment
Simulation : Worldwide



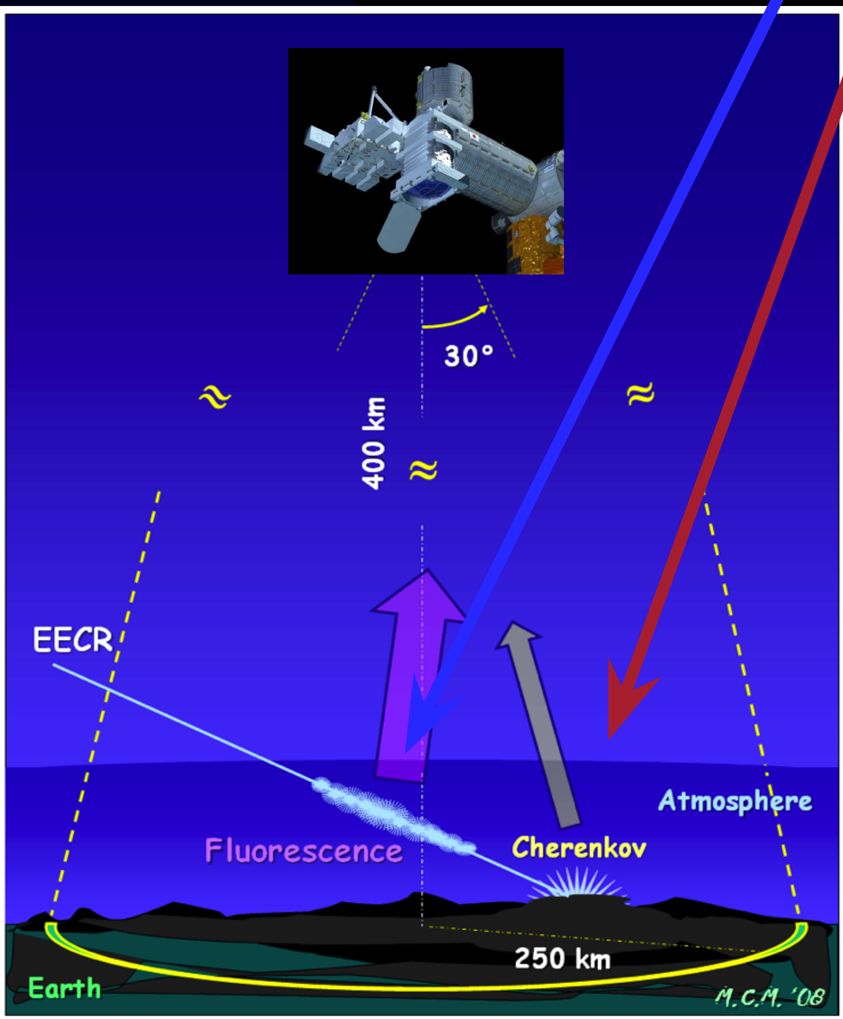
FAST SIGNAL

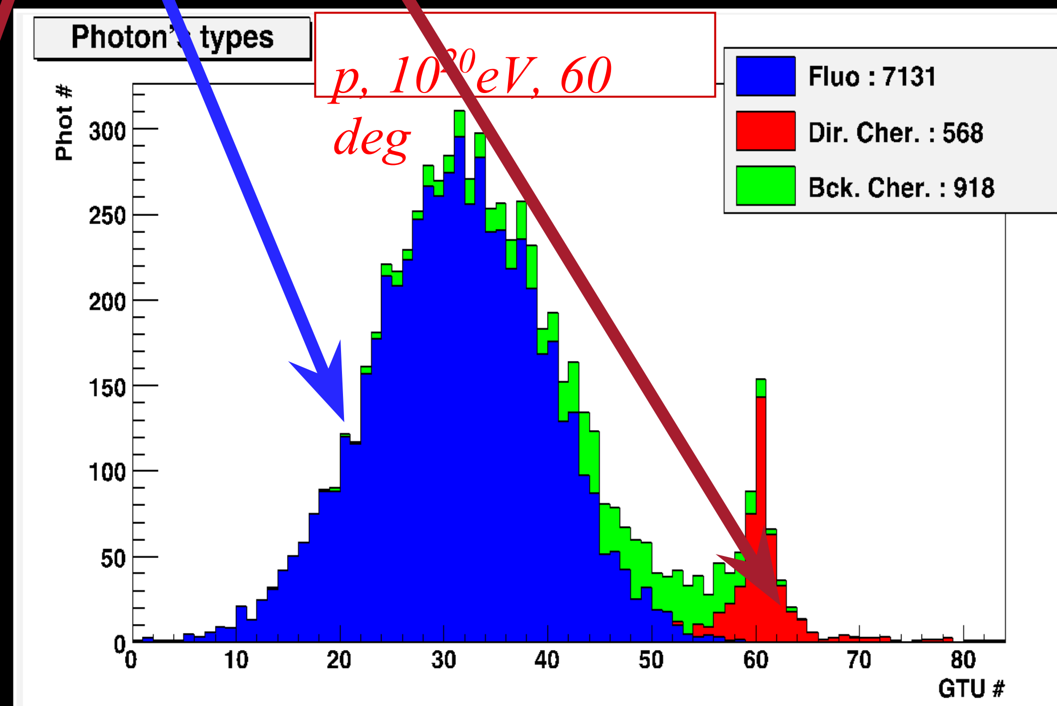
duration 50 -150 μs

a) Fluorescence

b) Scattered Cherenkov

c) Direct (diffusively reflected Cherenkov)





1 GTU gate time units = 2.5 μs

Background: 500 /m^2 sr ns

JEM-EUSO Balloon

- Look down from the balloon with an UV telescope
  (3 lenses system + 1 PDM EM)
- Engineering test
- Background test
- Airshower from 40 km altitude

2009 Proposal submitted to CNES (France)

2011/6 Approved by CNES

2012/2 Approved to go to Phase B

→ 2014 spring, first launch from Canada or Sweden

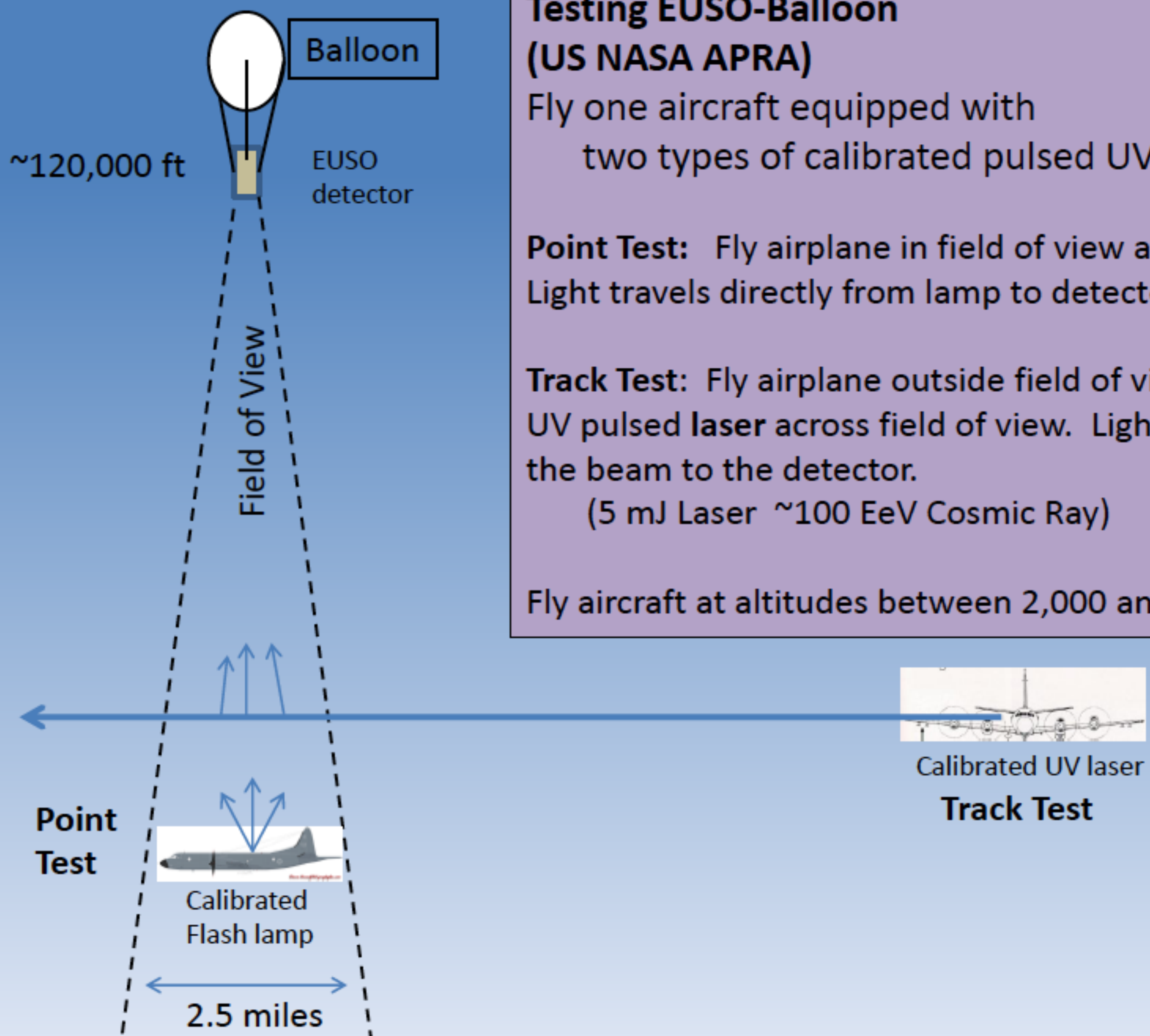
Testing EUSO-Balloon
(US NASA APRA)

Fly one aircraft equipped with
two types of calibrated pulsed UV light sources.

Point Test: Fly airplane in field of view and fire **flash lamp**.
Light travels directly from lamp to detector

Track Test: Fly airplane outside field of view and shoot a UV pulsed **laser** across field of view. Light scatters out of the beam to the detector.
(5 mJ Laser ~100 EeV Cosmic Ray)

Fly aircraft at altitudes between 2,000 and 10,000 feet.



JEM-EUSO in USA

Global Light System

JEM EUSO GLS Some Candidate Locations

Location	Latitude	Elevation	Location	Latitude	Elevation
Jungfraujoch (Switzerland)	47°N	3.9 km	Chacaltaya (Bolivia)	16° S	5.3 km
Mt. Washington (NH, USA)	44° N	1.9 km	La Reunion (Madagascar)	21° S	1.0 km
Alma-Ata (Kazakhstan)	44° N	3.0 km	Cerro Tololo (Chile)	30° S	2.2 km
Climax (CO, USA)	39° N	3.5 km	Sutherland (South Africa)	32° S	1.8 m
Frisco Peak (UT, USA)	39° N	2.9 km	Pierre Auger (Argentina)	35° S	1.4 km
Mt Norikura (Japan)	30° N	4.3 km	South Island (New Zealand)	43° S	1.0 km
Mauna Kea (HI, USA)	20° N	>3.0 km			
HAWC Site (Mexico)	19° N	3.4 km			

JEM-EUSO Mission