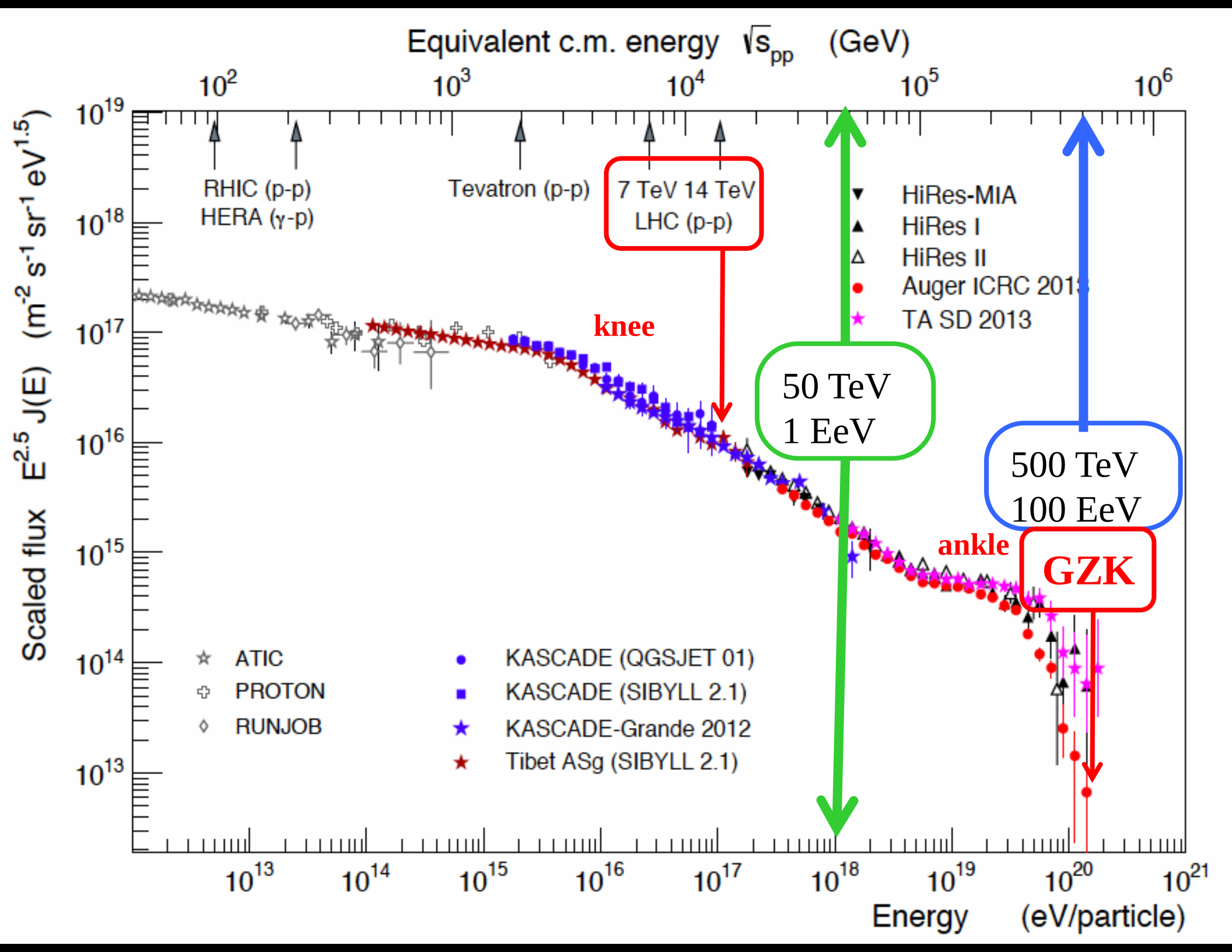
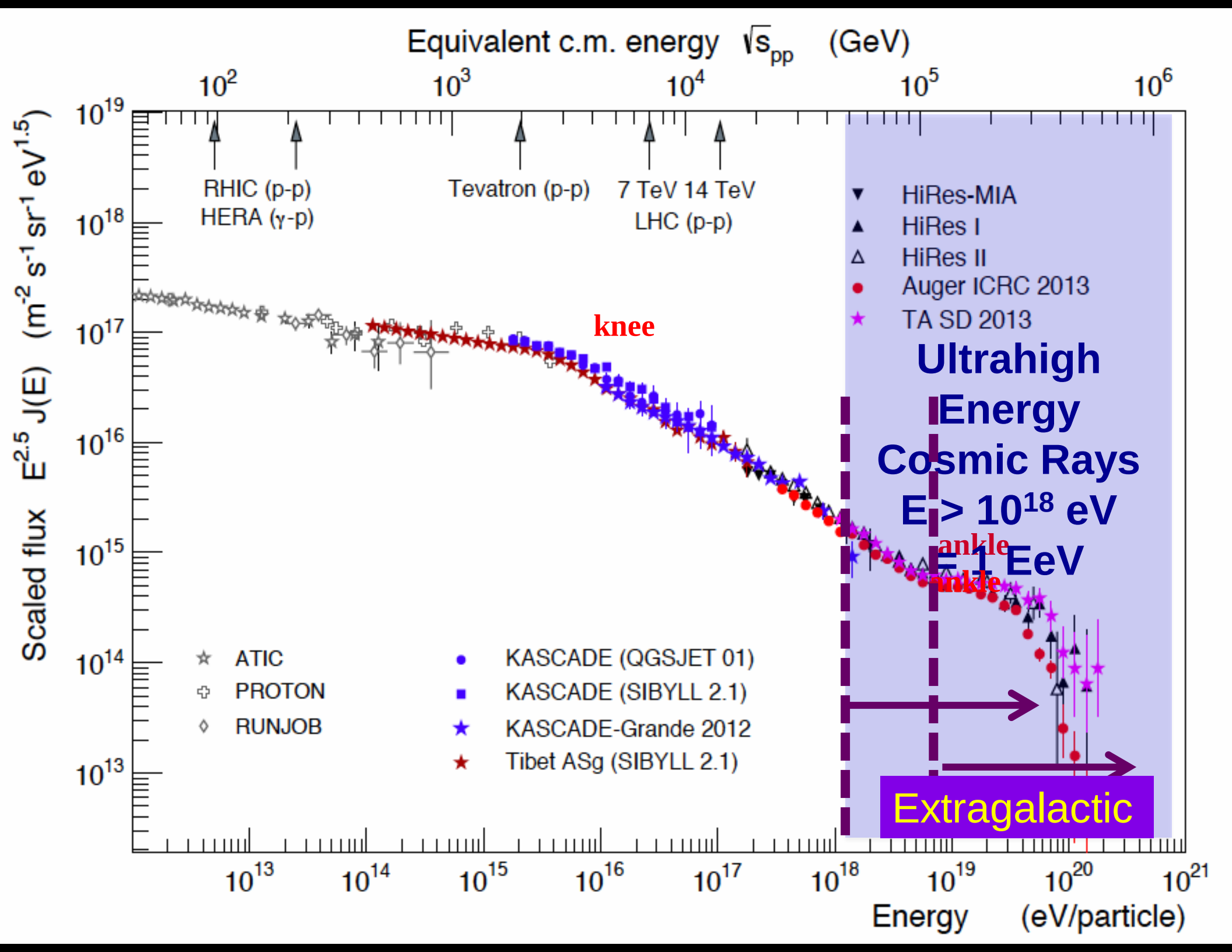
JEM-EUSO Mission

Angela V. Olinto
The University of Chicago


Equivalent c.m. energy √s_pp (GeV)
10^2
10^3
10^4
10^5
10^6
RHIC (p-p)
HERA (γ-p)
Tevatron (p-p)
7 TeV 14 TeV
LHC (p-p)
knee
50 TeV
1 EeV
500 TeV
100 EeV
ankle
GZK
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 2013
TA SD 2013
ATIC
PROTON
RUNJOB
KASCADE (QGSJET 01)
KASCADE (SIBYLL 2.1)
KASCADE-Grande 2012
Tibet ASg (SIBYLL 2.1)
Scaled flux E^2.5 J(E) (m^-2 s^-1 sr^-1 eV^1.5)
10^19
10^18
10^17
10^16
10^15
10^14
10^13
10^13
10^14
10^15
10^16
10^17
10^18
10^19
10^20
10^21
Energy (eV/particle)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RHIC (p-p)
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7 TeV 14 TeV
LHC (p-p)
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 2013
TA SD 2013
knee
Ultrahigh
Energy
Cosmic Rays
E > 10^18 eV
ankle
E 1 EeV
ankle
Extragalactic
Scaled flux E^2.5 J(E) (m^-2 s^-1 sr^-1 eV^1.5)
10^19
10^18
10^17
10^16
10^15
10^14
10^13
ATIC
PROTON
RUNJOB
KASCADE (QGSJET 01)
KASCADE (SIBYLL 2.1)
KASCADE-Grande 2012
Tibet ASg (SIBYLL 2.1)
10^13
10^14
10^15
10^16
10^17
10^18
10^19
10^20
10^21
Energy (eV/particle)

Current Observatories of Ultrahigh Energy Cosmic Rays

Telescope Array

Utah, USA

(5 country collaboration)

700 km^2 array

3 fluorescence telescopes

Pierre Auger Observatory

Mendoza, Argentina

(19 country collaboration)

3,000 km^2 array

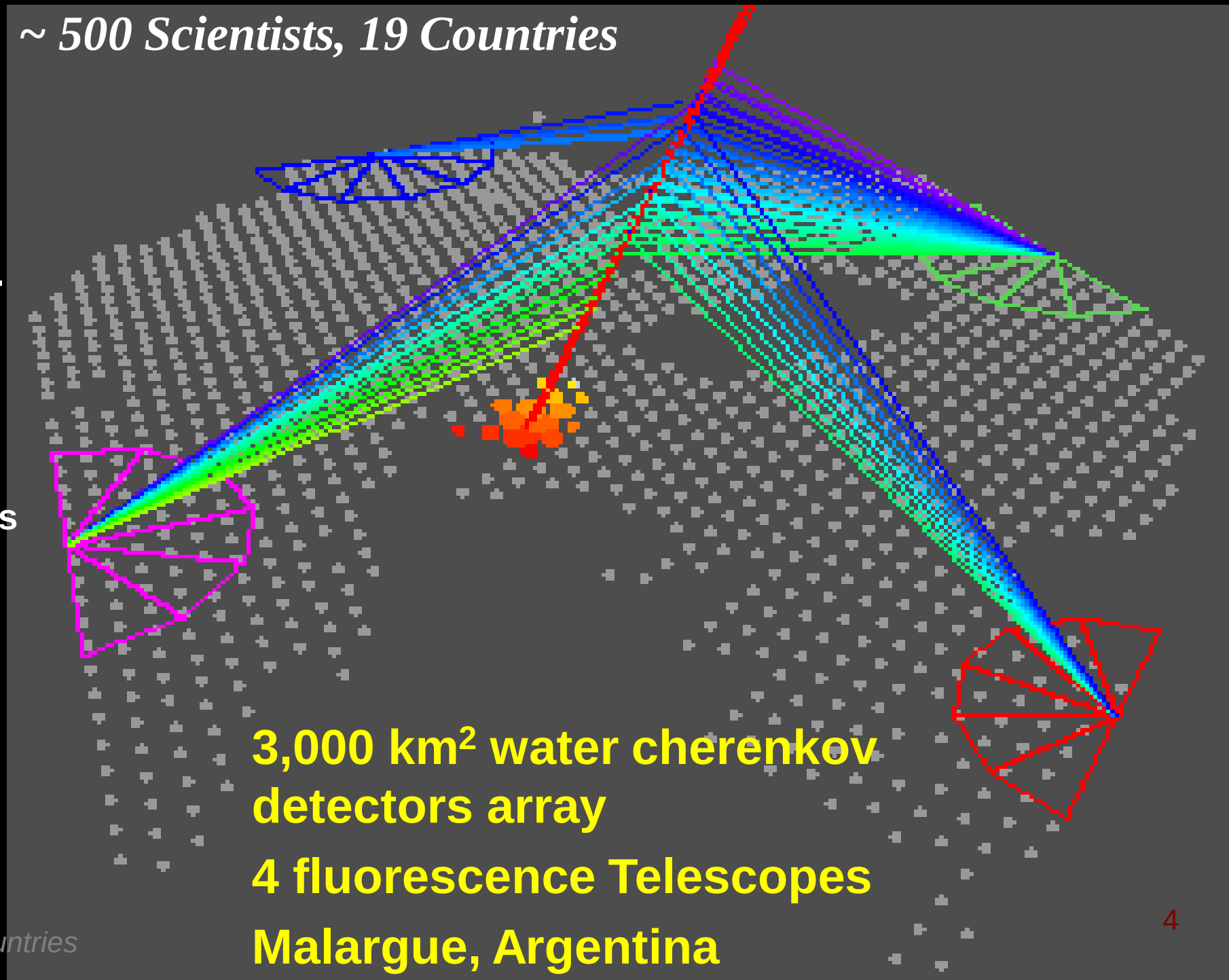
4 fluorescence telescopes

The Pierre Auger Observatory

Argentina
Australia
Brasil
Bolivia*
Croatia
Czech Rep.
France
Germany
Italy
Mexico
Netherlands
Poland
Portugal
Romania*
Slovenia
Spain
UK
USA
Vietnam*

*Associate Countries

~ 500 Scientists, 19 Countries



3,000 km² water cherenkov detectors array

4 fluorescence Telescopes

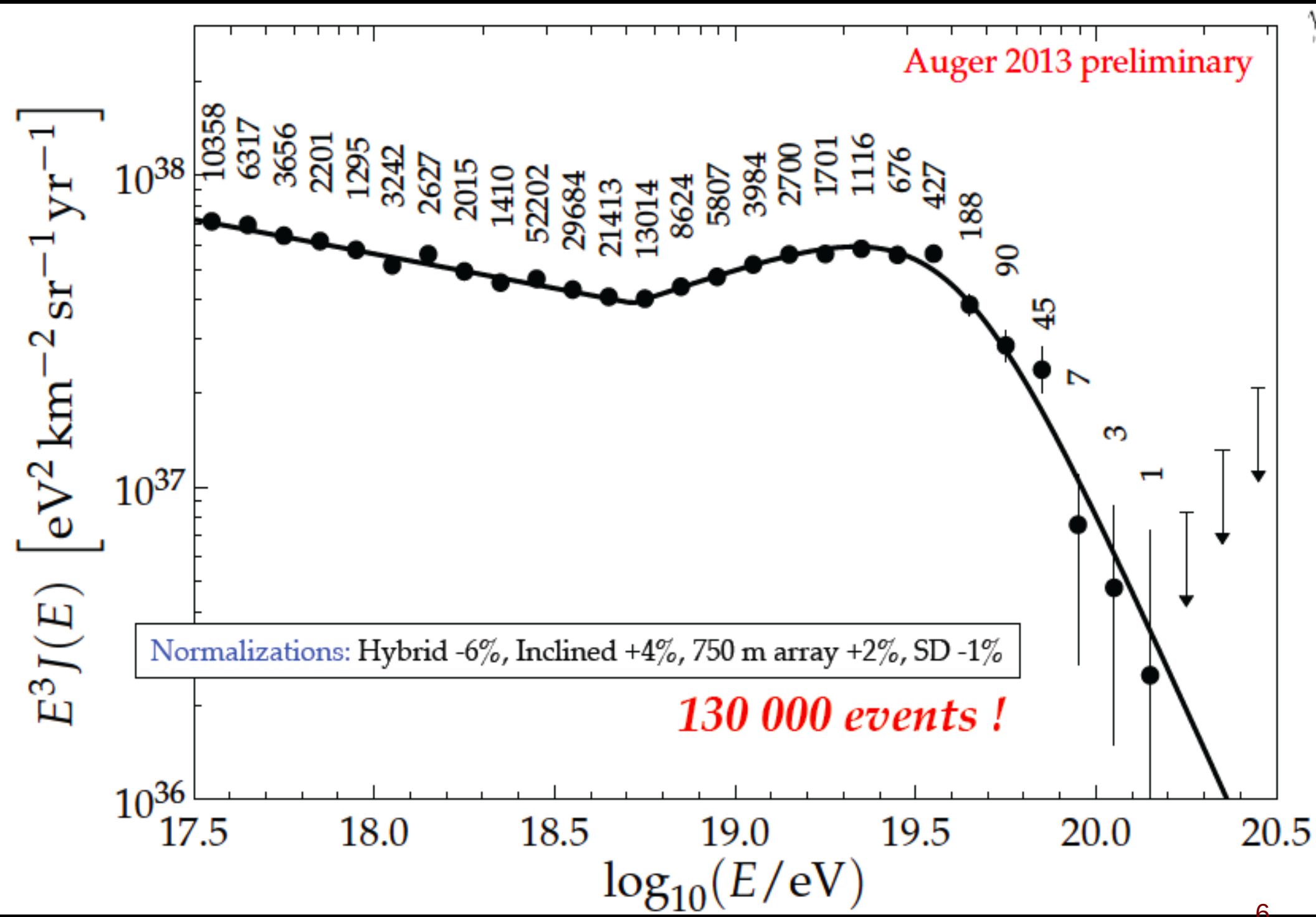
Malargue, Argentina

Telescope Array

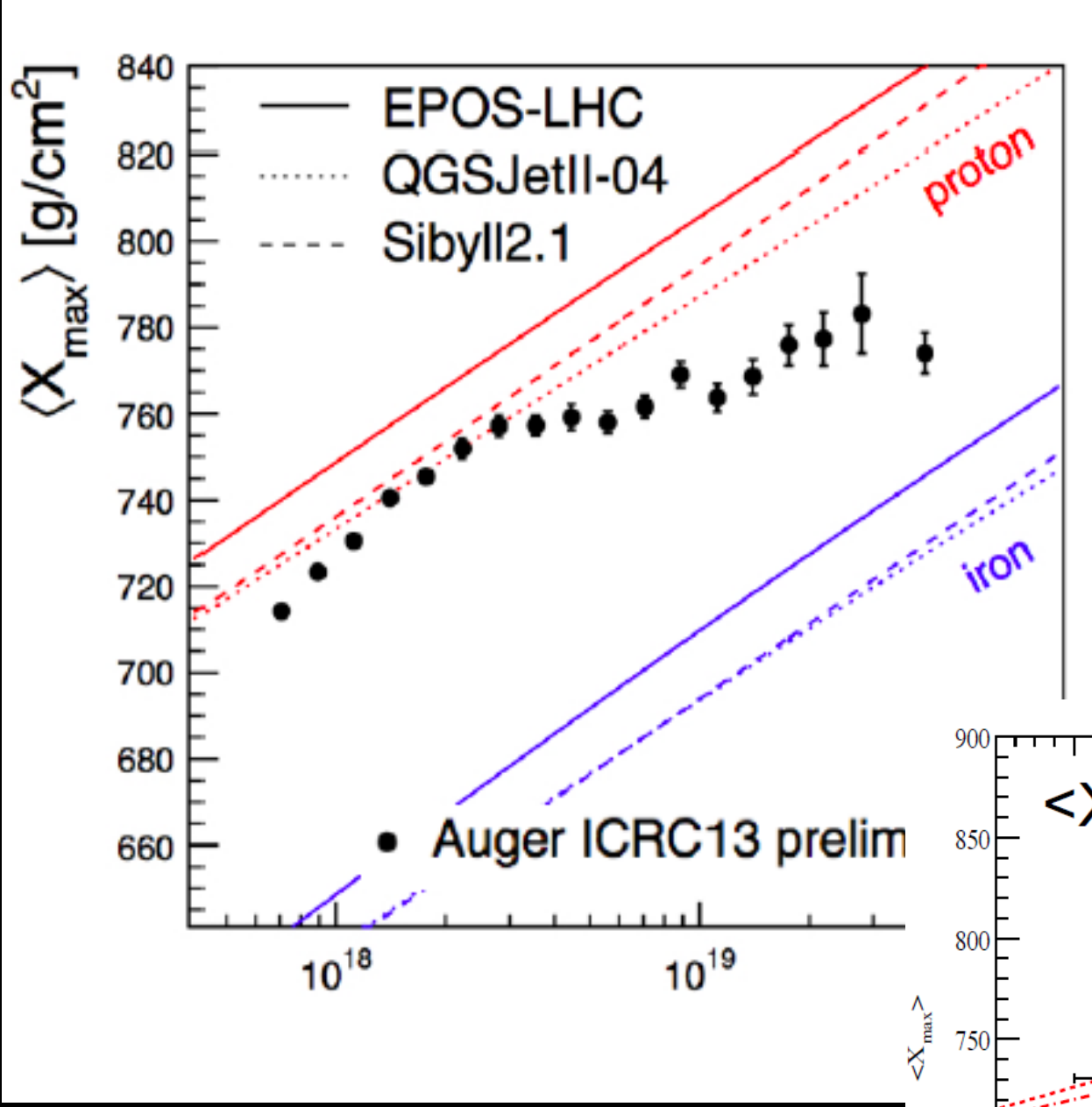
Belgium
Japan
Korea
Russia
USA

Area: 700 km^2

3 FD stations overlooking an array of 507 scintillator surface detectors (SD) complete and operational as of ~1/2008.

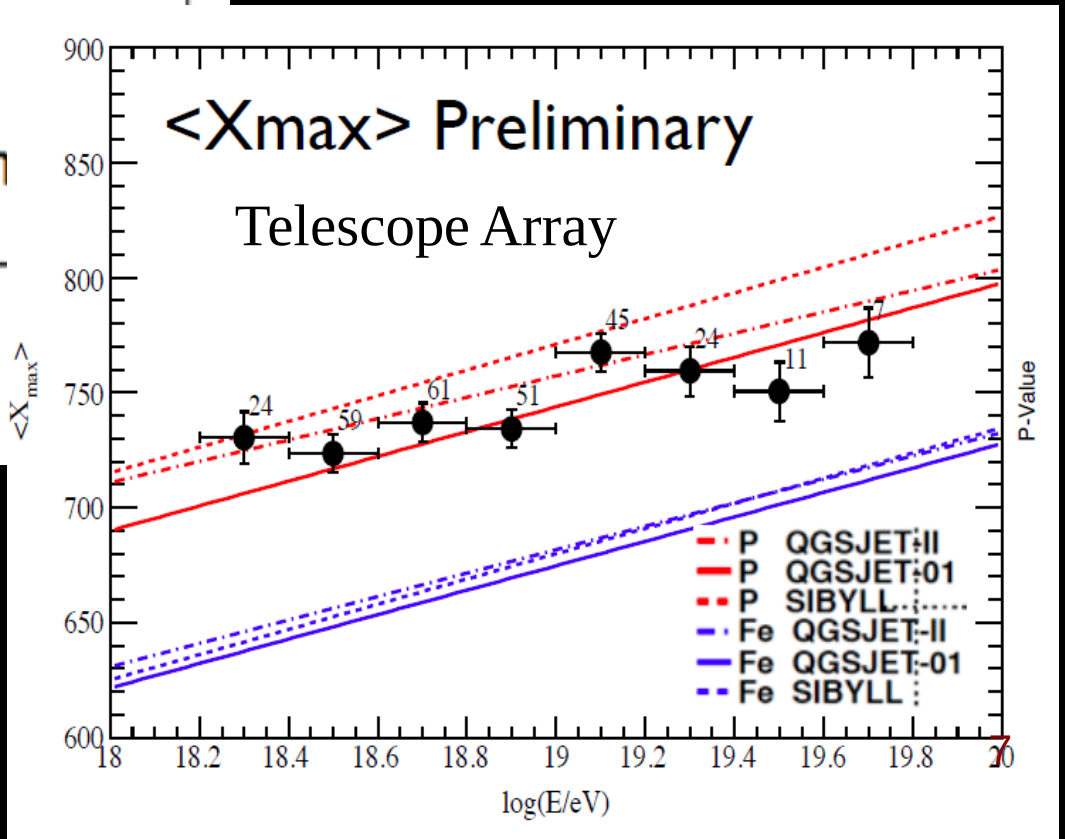


See Dembinski



Auger sees change slope: Change in Composition or interactions

TA: does not confirm

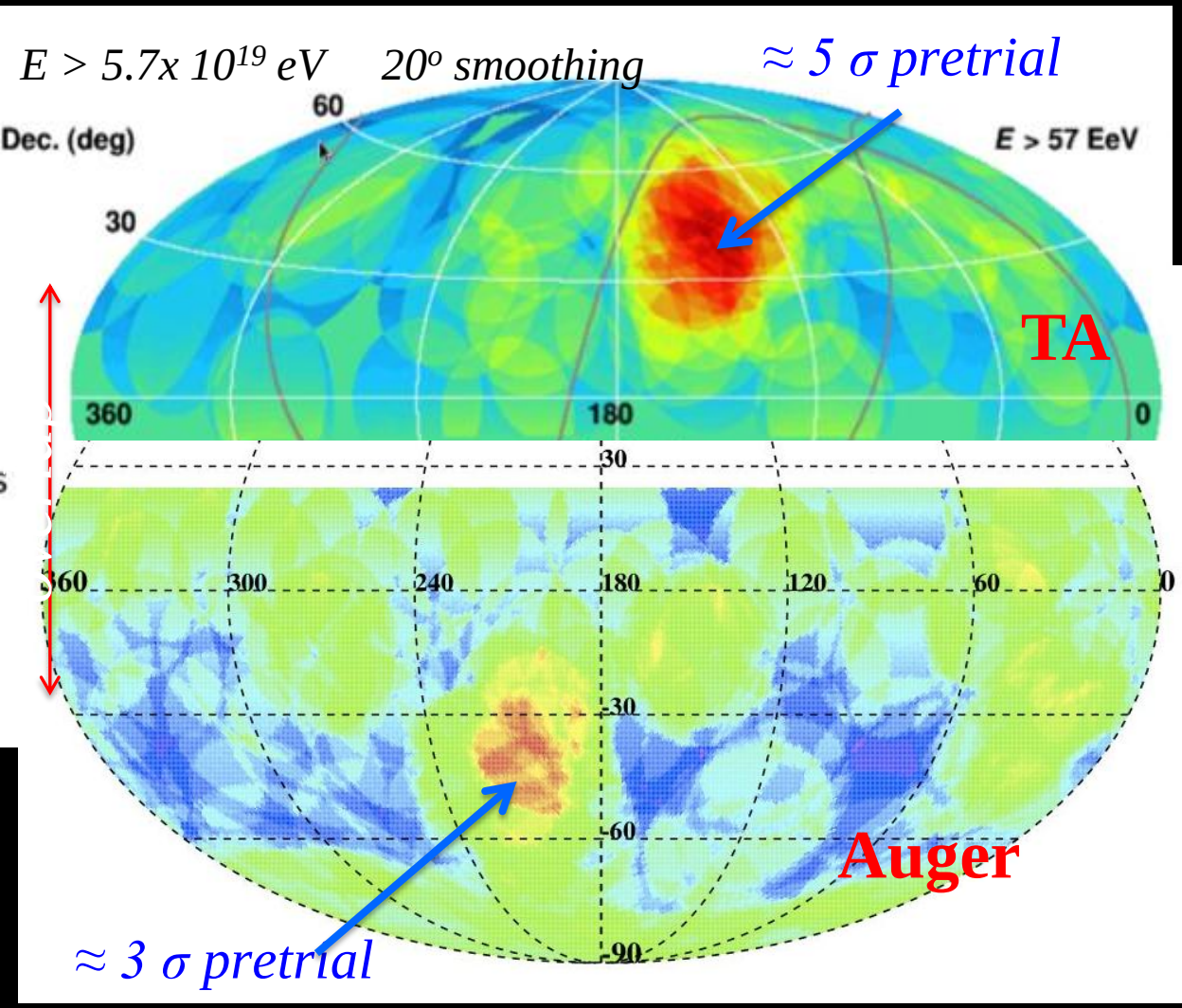



Where do UHECRs
come from?

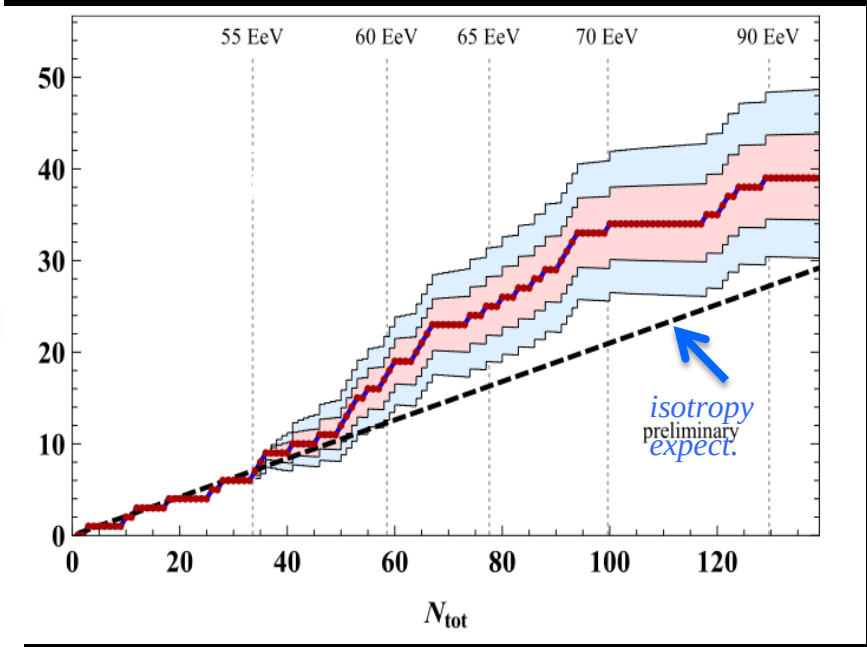
Where do UHECRs come from?

UHECR Anisotropy Hints >60 EeV

Statistically limited evidence for Comic Ray Anisotropy above 5.7x 10^{19} eV in the North and South



# of events correlating with AGN, ordered in energy (integral plot)



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 < 30 events/yr

30+ years to reach 1,000

Earth - surface ~ 5 10^8 km^2

~3.4 10^6 events/yr

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 < 30 events/yr

5 o.o.m to go!

Earth surface ~ 5 10^8 km^2

~3.4 10^6 events/yr

Go to SPACE!

To look down on the Atmosphere!

How many UHECRs > 60 EeV?

Auger + TA ~30 events/yr

JEM-EUSO

~200 events > 60 EeV/yr

Earth - surface ~ 5 10^8 km^2

~3.4 10^6 events/yr

How many UHECRs > 60 EeV?

Auger + TA ~30 events/yr

JEM-EUSO

~200 events > 60 EeV/yr

40.0.m to go!

Earth surface ~ 5 10^8 km^2

~3.4 10^6 events/yr

JEM-EUSO Mission

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

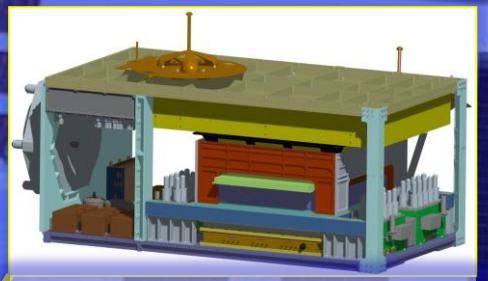
JEM-EUSO

Japan, USA, Korea, Mexico, Russia, Algeria
Europe: Bulgaria, France, Germany, Italy, Poland, Slovakia, Spain, Switzerland, Sweden
15 Countries, 300 researchers
Leading institution: RIKEN

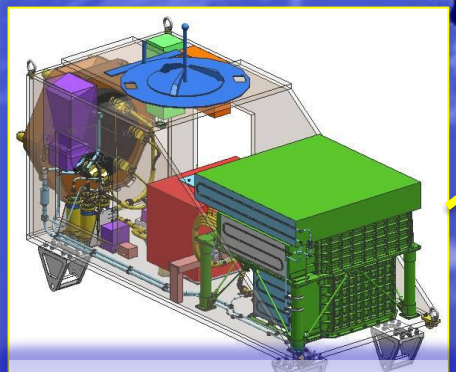
PI: Piergiorgio Picozza

View from NASA: “Cosmic Ray Observatory on the ISS”

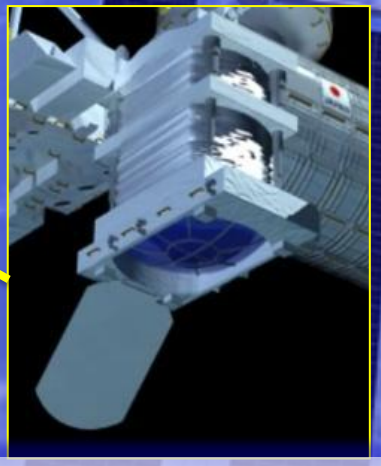
AMS Launch
May 16, 2011



ISS-CREAM
Sp-X Launch 2014



CALET on JEM
HTV Launch 2014

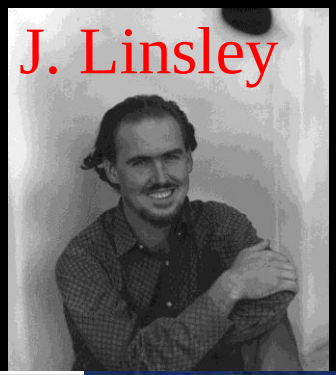


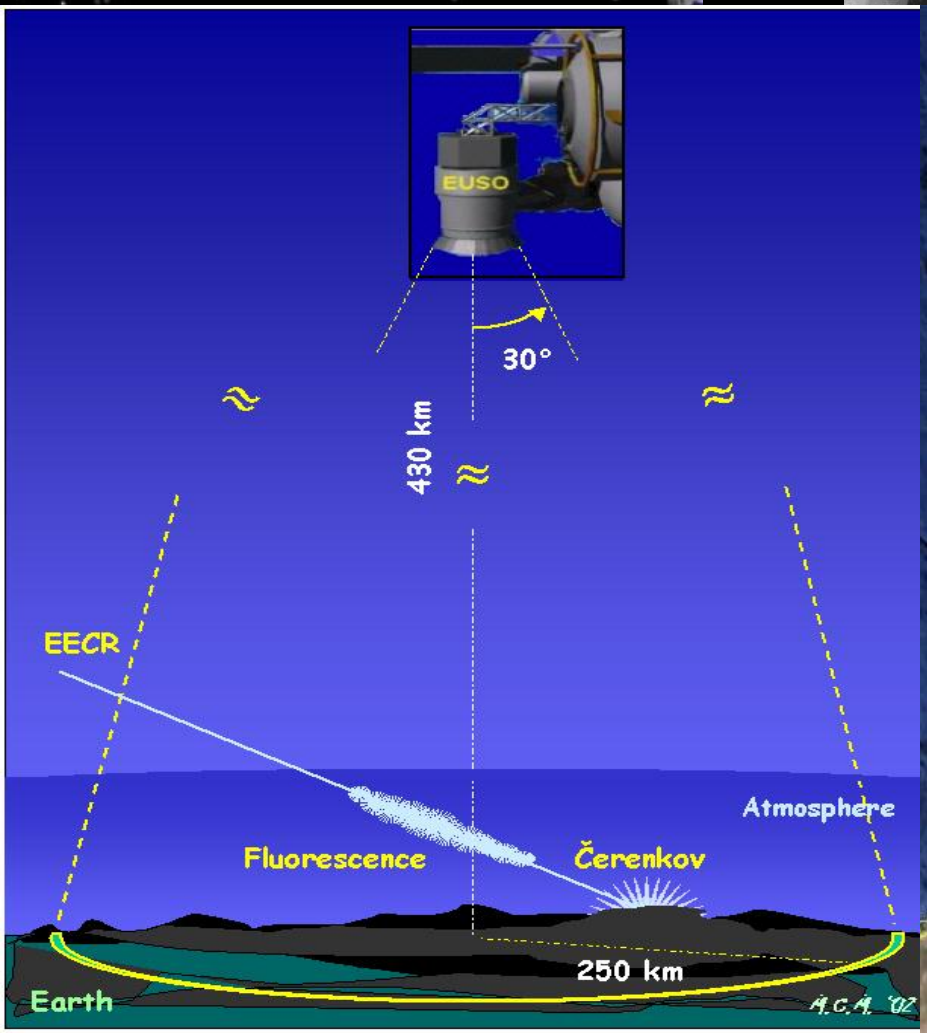
JEM-EUSO
Launch
Tentatively
planned for 2017

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

Fluorescence from SPACE



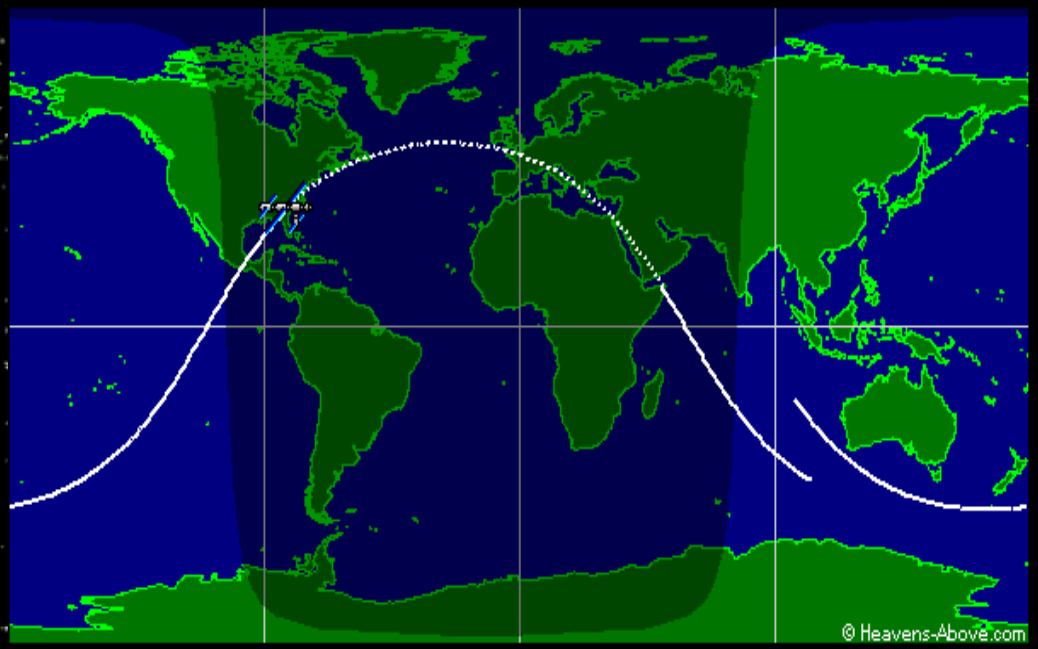


JEM-EUSO Mission

Parameter	Value
Launch date	2018
Mission Lifetime	3+2 years
Rocket	H2B or Falcon9
Transport Vehicle	HTV or Dragon
Accommodation on JEM	EF#9
Mass	~1200 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°

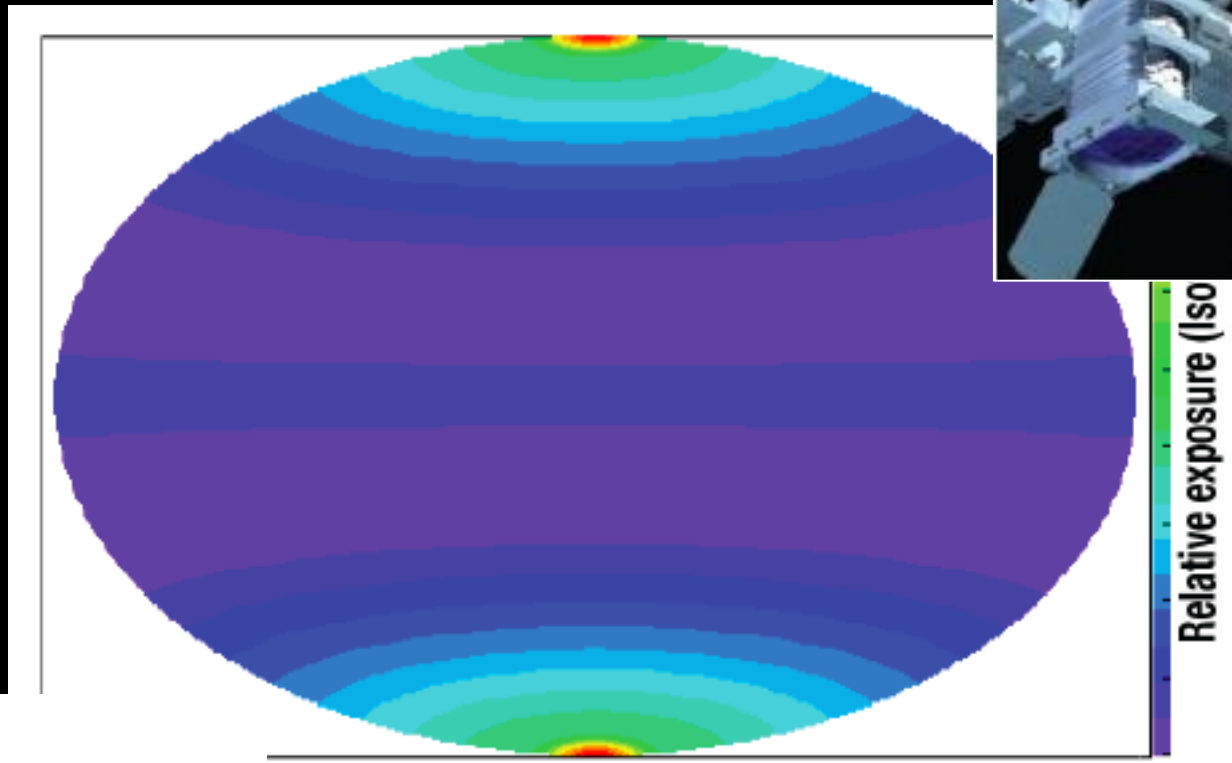
Full Sky Coverage
with nearly uniform exposure

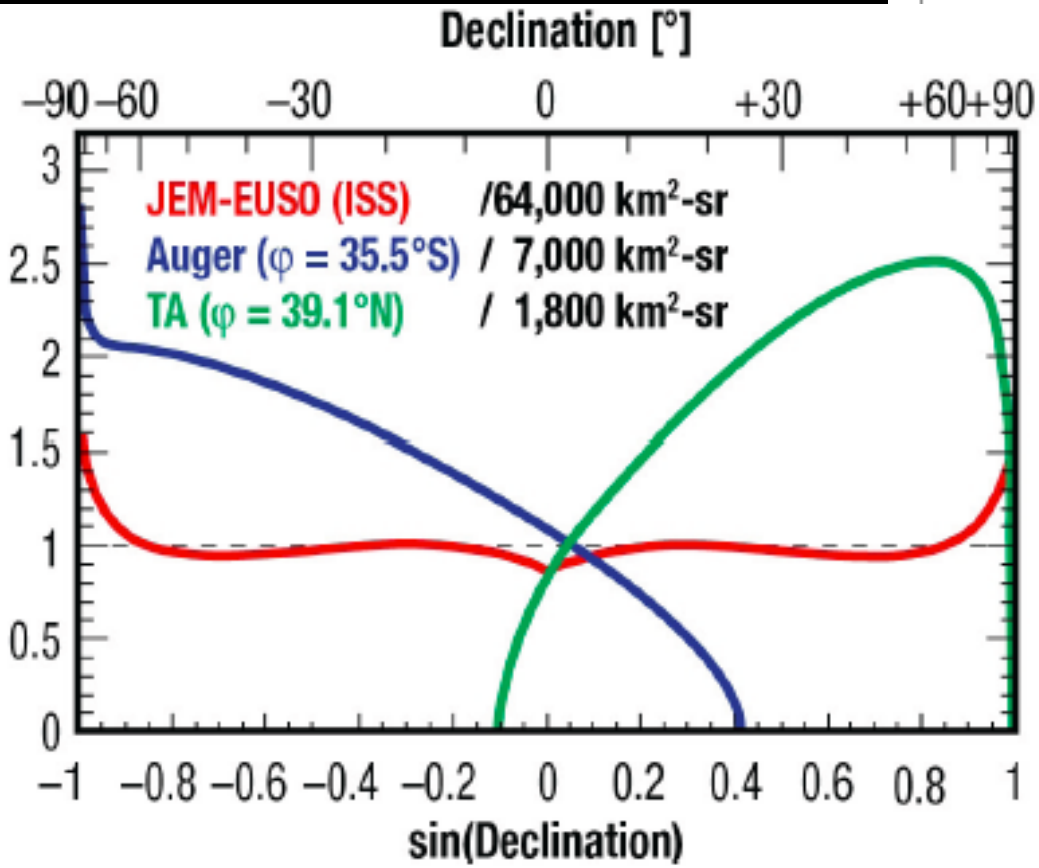
The ISS ORBIT

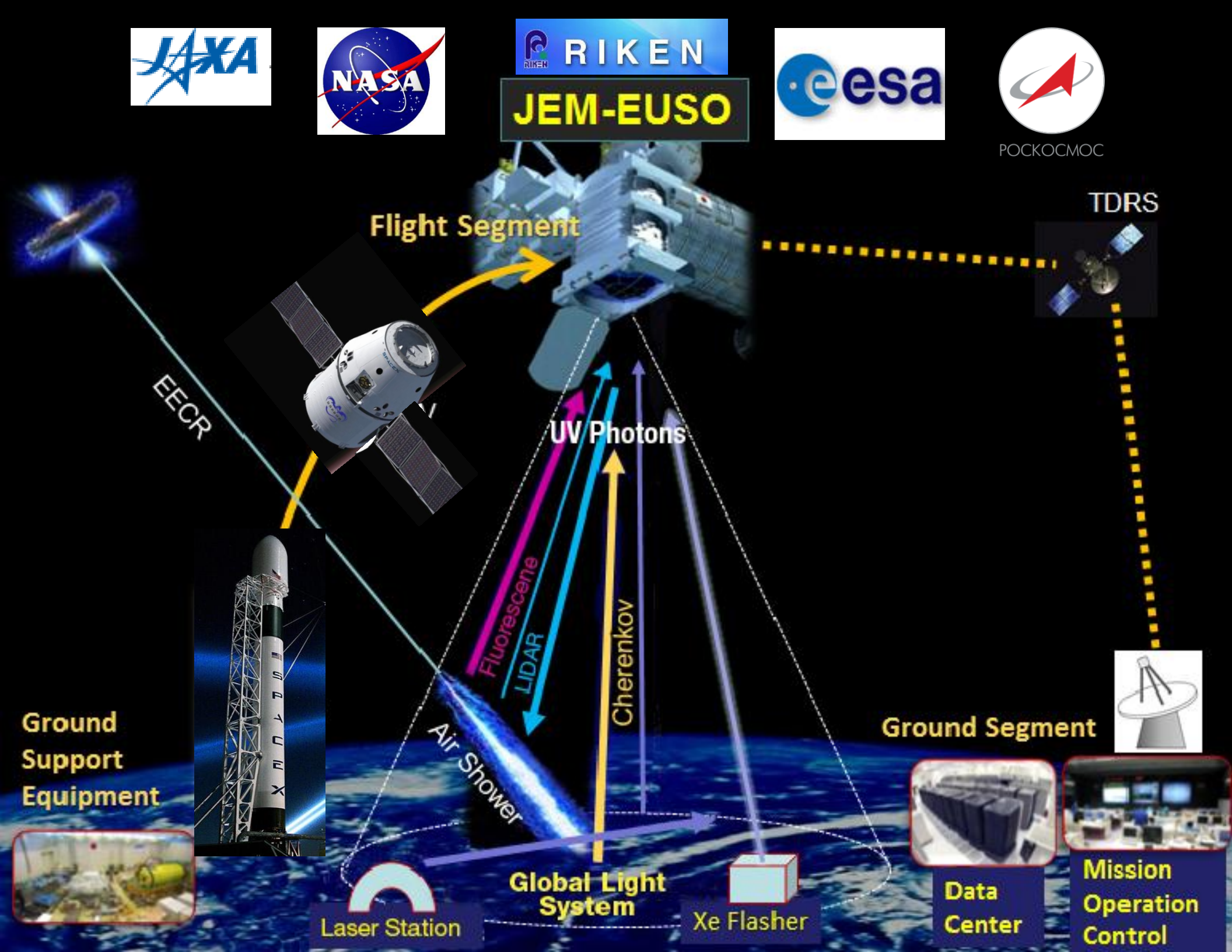


Inclination: 51.6˚
Height: ~400km

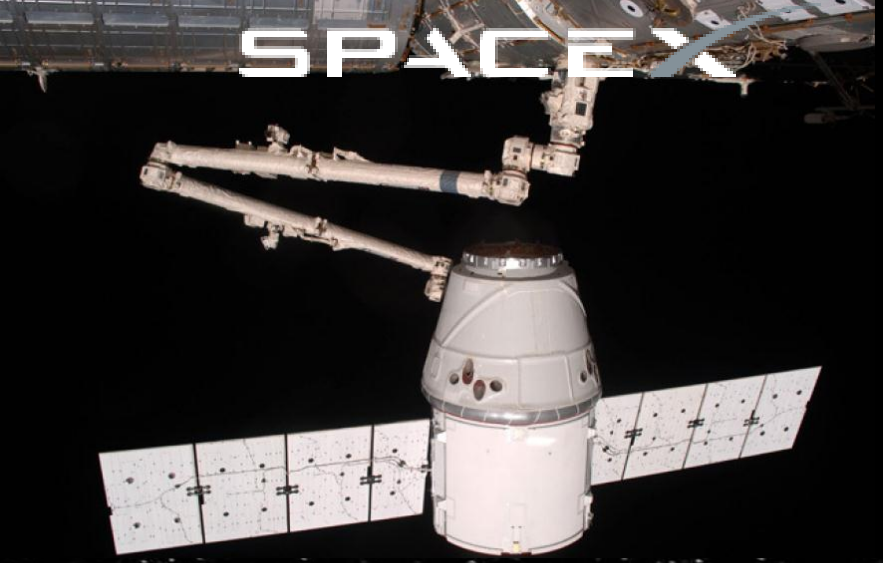
JEM-EUSO
Sky Coverage



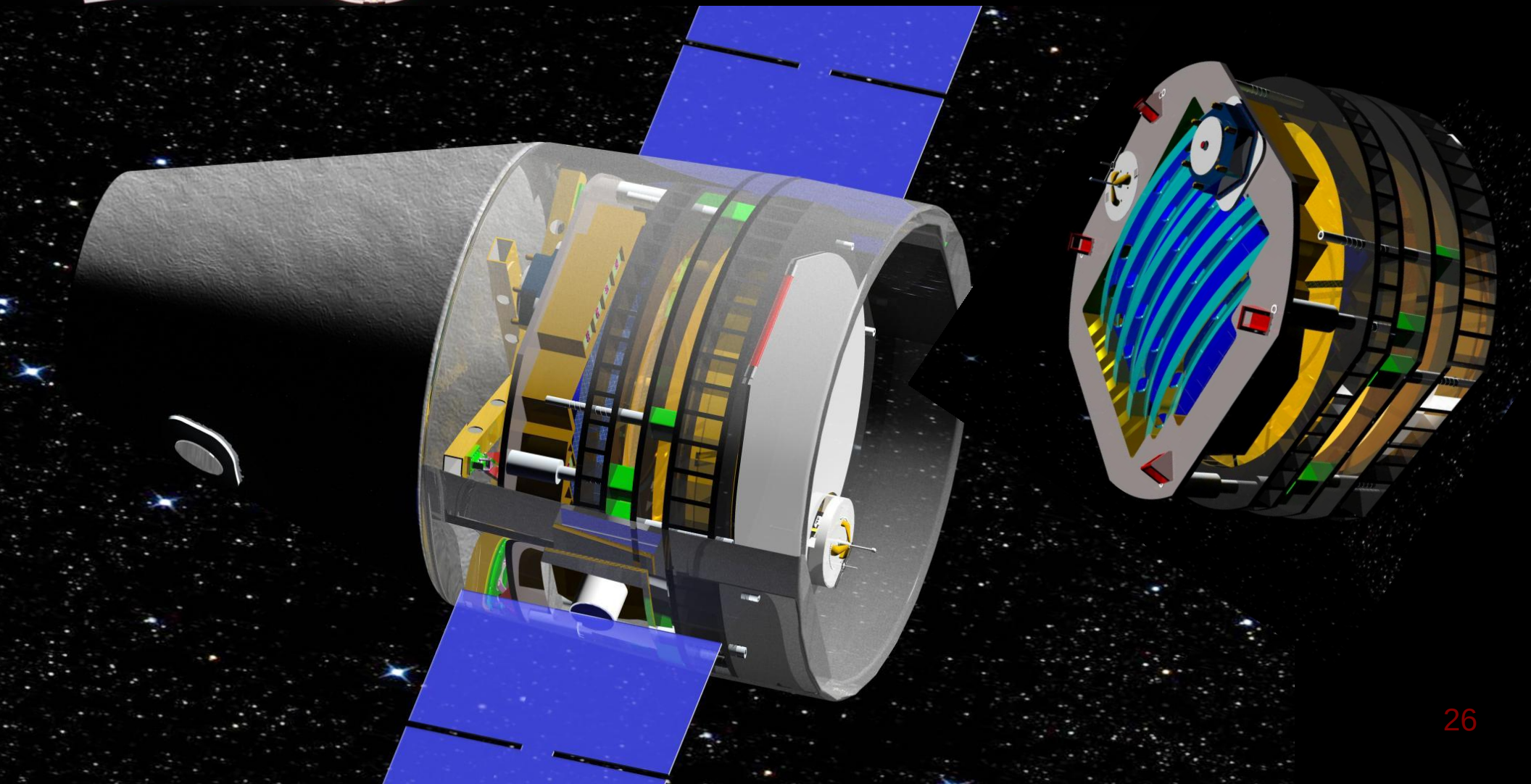


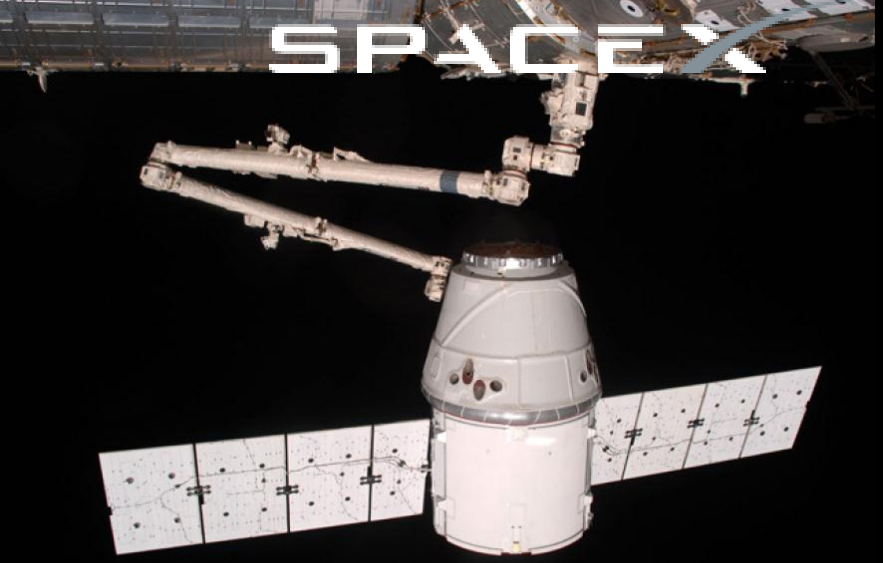

JAXA
NASA
RIKEN
JEM-EUSO
esa
POCKOCMOC
TDRS
Flight Segment
EECR
UV Photons
Fluorescene
LIDAR
Cherenkov
Air Shower
Ground Support Equipment
Ground Segment
Global Light System
Laser Station
Xe Flasher
Data Center
Mission Operation Control

SpaceX Dragon

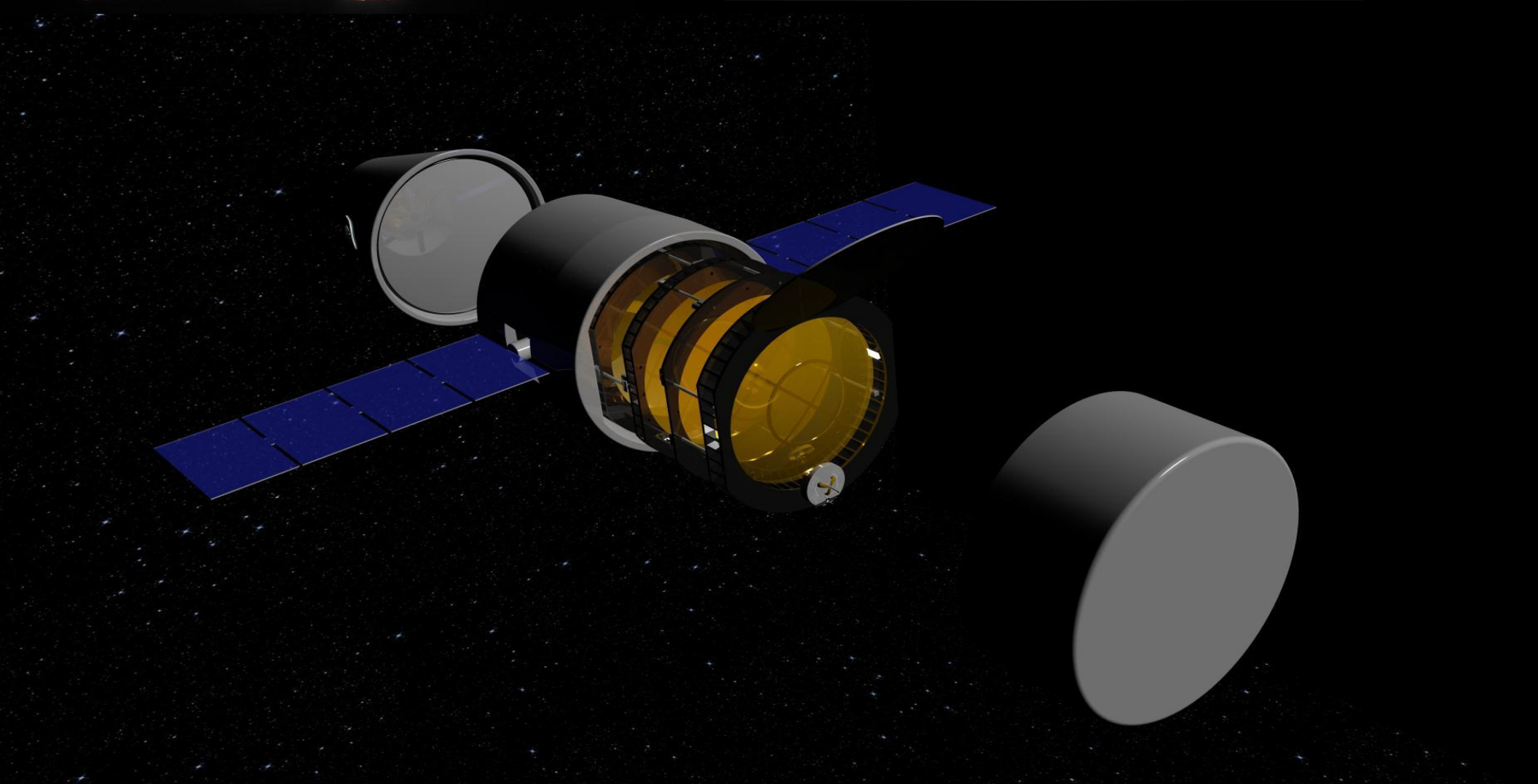

SPACEX


DRAGON




SPACEX


DRAGON



UV Telescope Parameters

Parameter	Value
Field of View	±30°
Monitored Area	>1.3×10^{5}km^2
Telescope aperture	≥2.5 m
Operational wavelength	300-400 nm
Resolution in angle	0.075°
Focal Plane Area	4.5 m^2
Pixel Size	<3 mm
Number of Pixels	≈3×10^5
Pixel size on ground	≈560 m
Time Resolution	2.5 μs
Dead Time	<3%
Photo-detector Efficiency	≥20%

Payload

DAQ Electronics

Optics

Rear Fresnel Lens

Precision Fresnel lens

Iris

Front Fresnel lens

Support Structure

Telescope Structure

Focal Surface Detector

On-board Calibration

BUS System : JAXA

Housekeeping

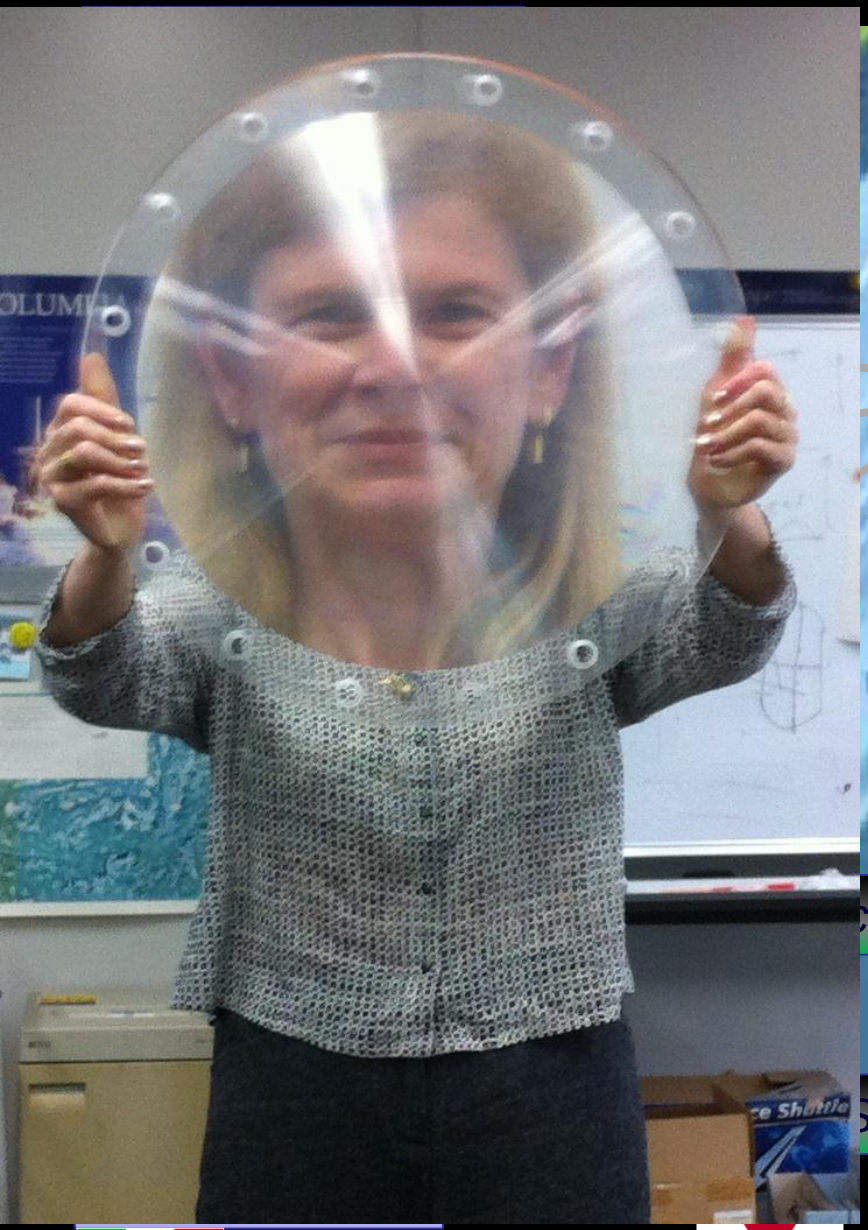
Ground Based Calibration

Atmospheric Monitoring

Ground Support Equipment

Simulation : Worldwide

Payload



Optics

Rear Fresnel Lens

Precision Fresnel lens

Iris

Front Fresnel lens

cope Structure

On-board Calibration

System : JAXA

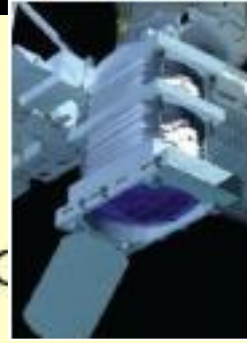
Ground Based Calibration

Ground Support Equipment

Atmospheric Monitoring

Simulation : Worldwide

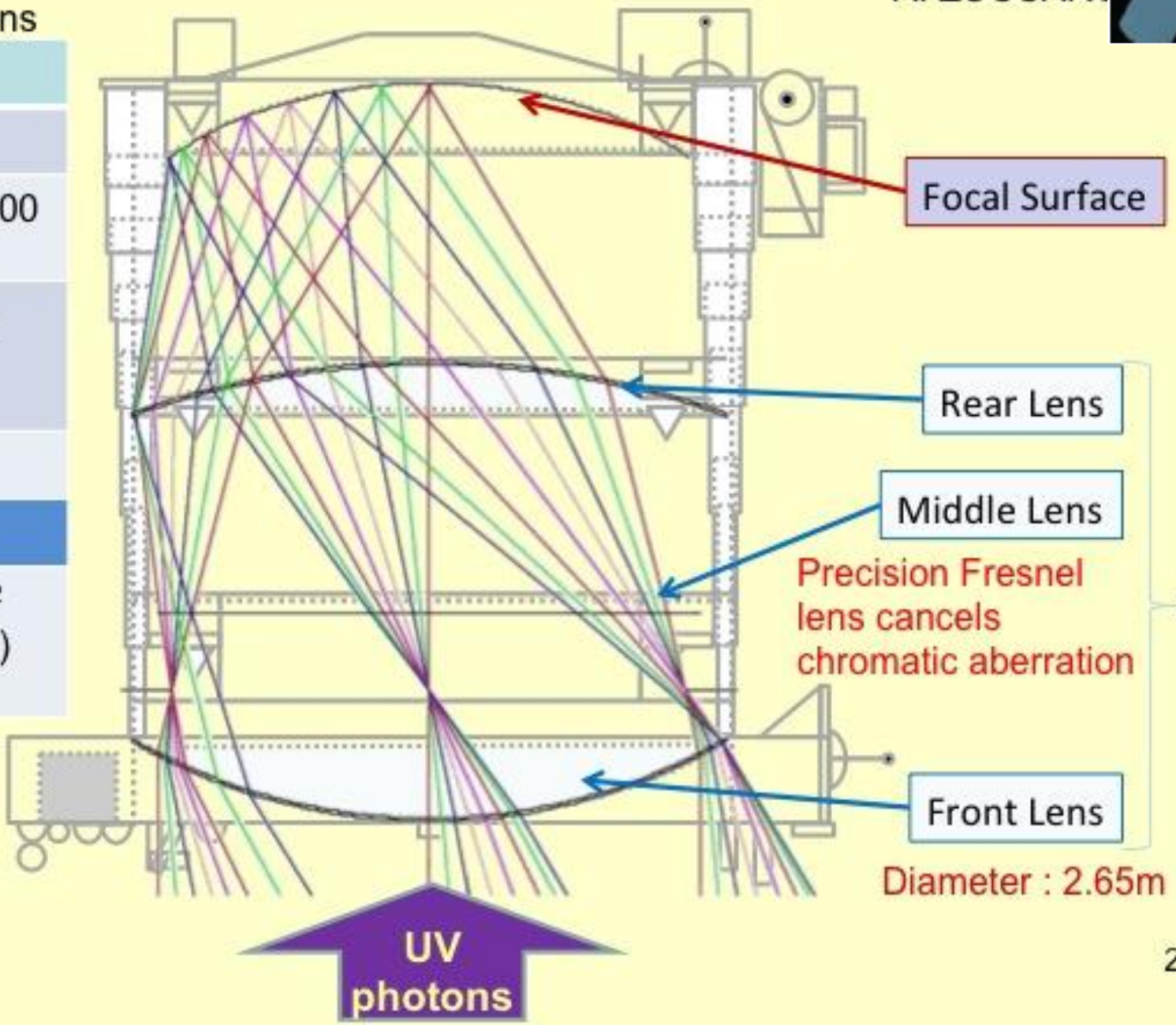
Optics design by ray tracing



A. ZUCCARO

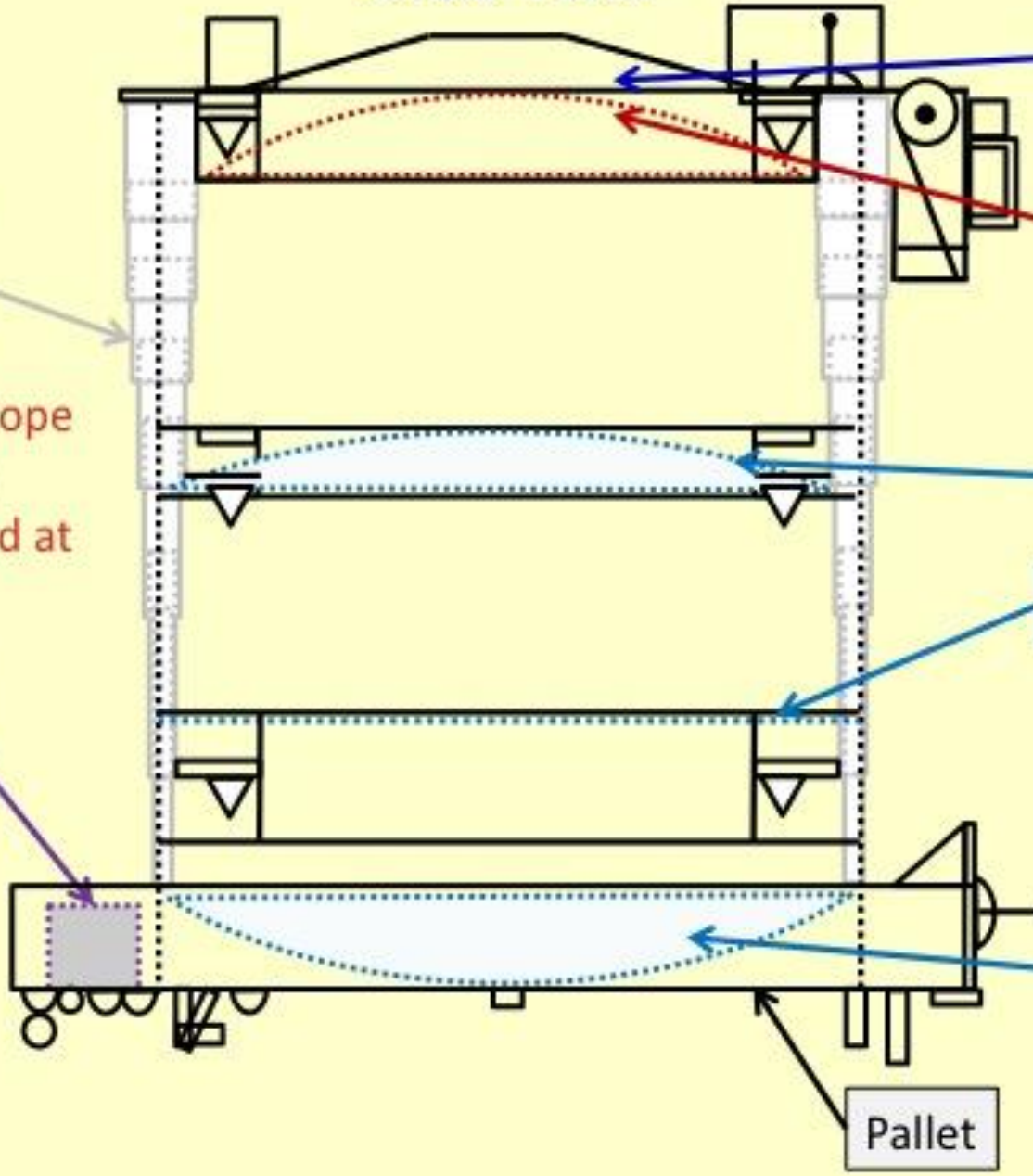
Simulation conditions

Optics	
FOV	±30
Optical bandwidth	330 ÷ 400 nm
Entrance Pupil Diameter	≥ 2.3 m
F/number	≤1
Focal surface	
Focal surface area	~4.5 m² (curved)



Science Instrument

Side view



Telescope Scale

Focal Surface Detector

493
MAP
(8x8 p

le
ls

UV Telescope Parameters

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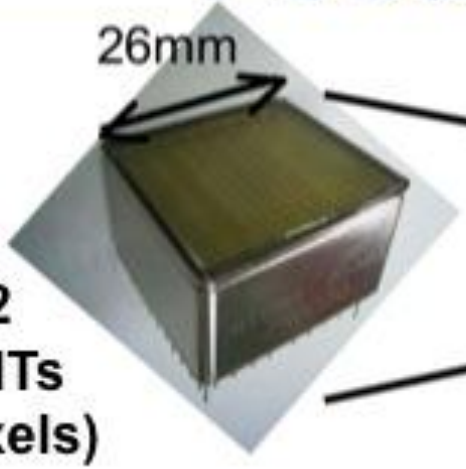
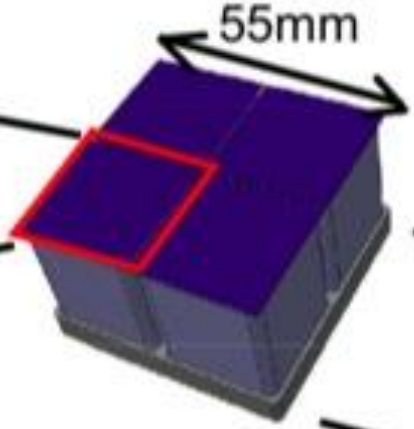
Time Resolution	2.5 μs
Dead Time	<3%
Photo-detector Efficiency	≥20%

Focal Surface Detector

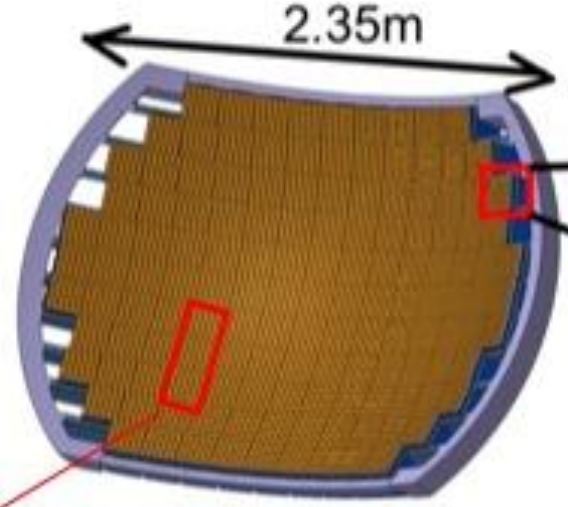
Y. Kawasa
M. Ricci, II

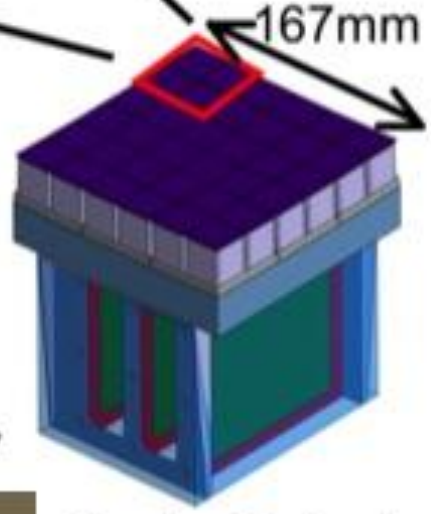


4932 MAPMTs (8x8 pixels)



Elementary Cell (2x2 PMTs = 256 pixels)





Focal Surface detector
137 PDMs
= 0.3M Pixels

Photo-Detector Module
(3x3 ECs = 2,304 pixels

1 High Voltage / PDM

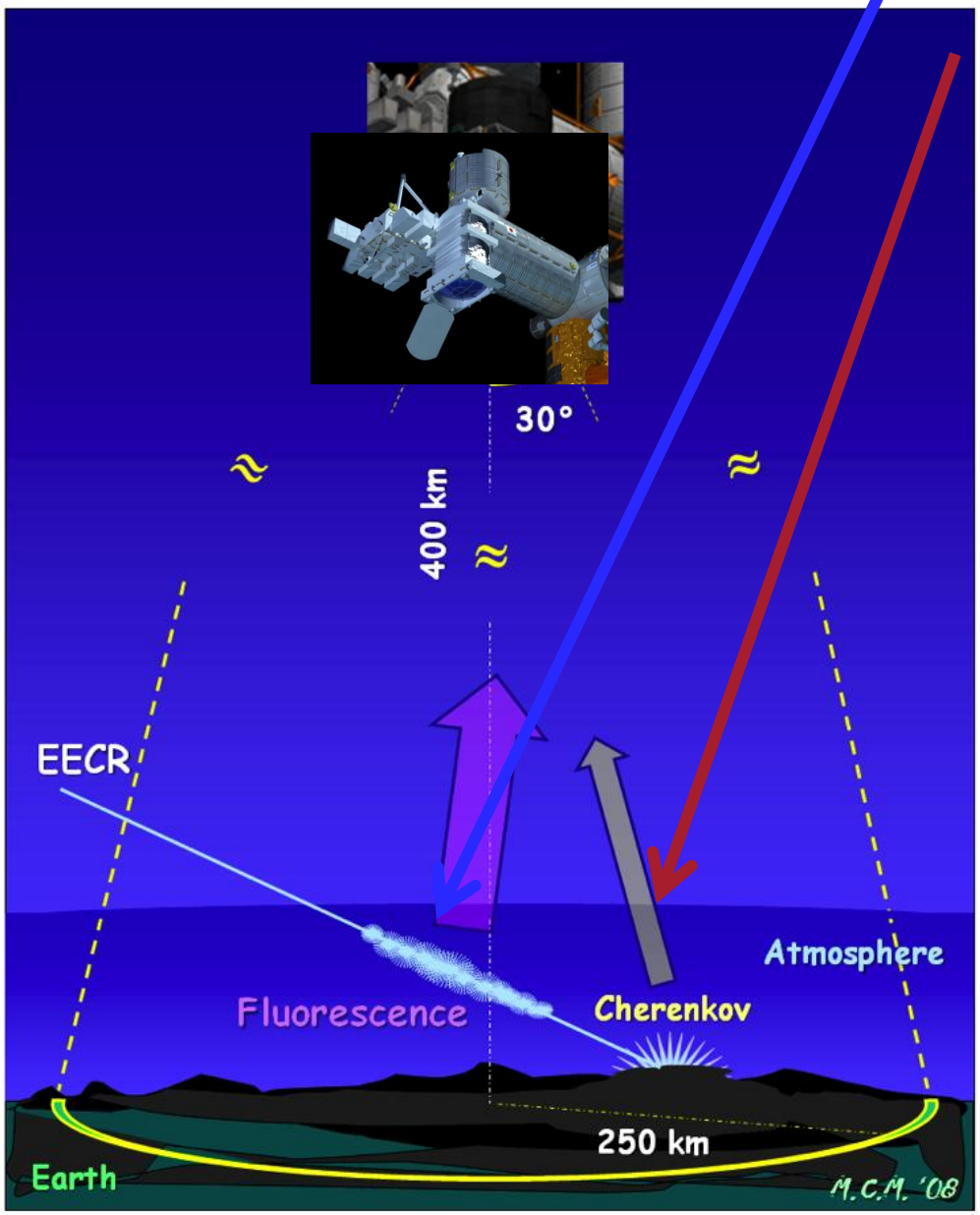
FAST SIGNAL

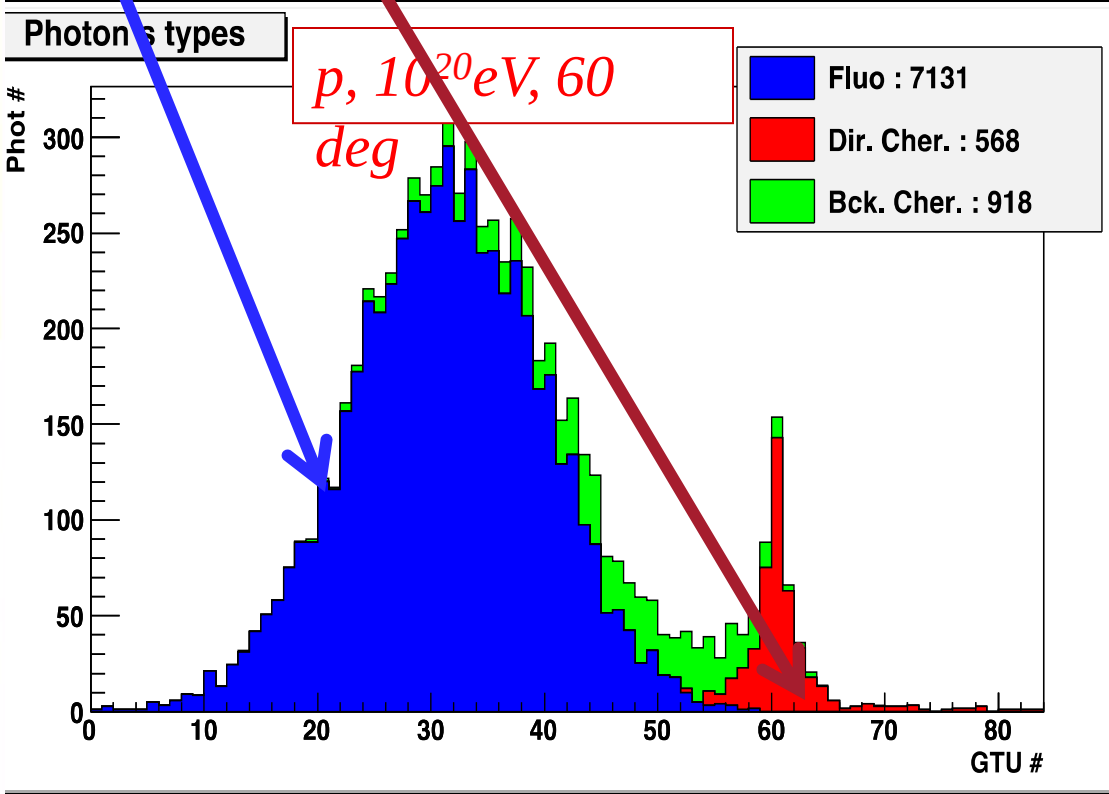
duration 50 -150 μs

a) Fluorescence

b) Scattered Cherenkov

c) Direct (diffusively reflected Cherenkov

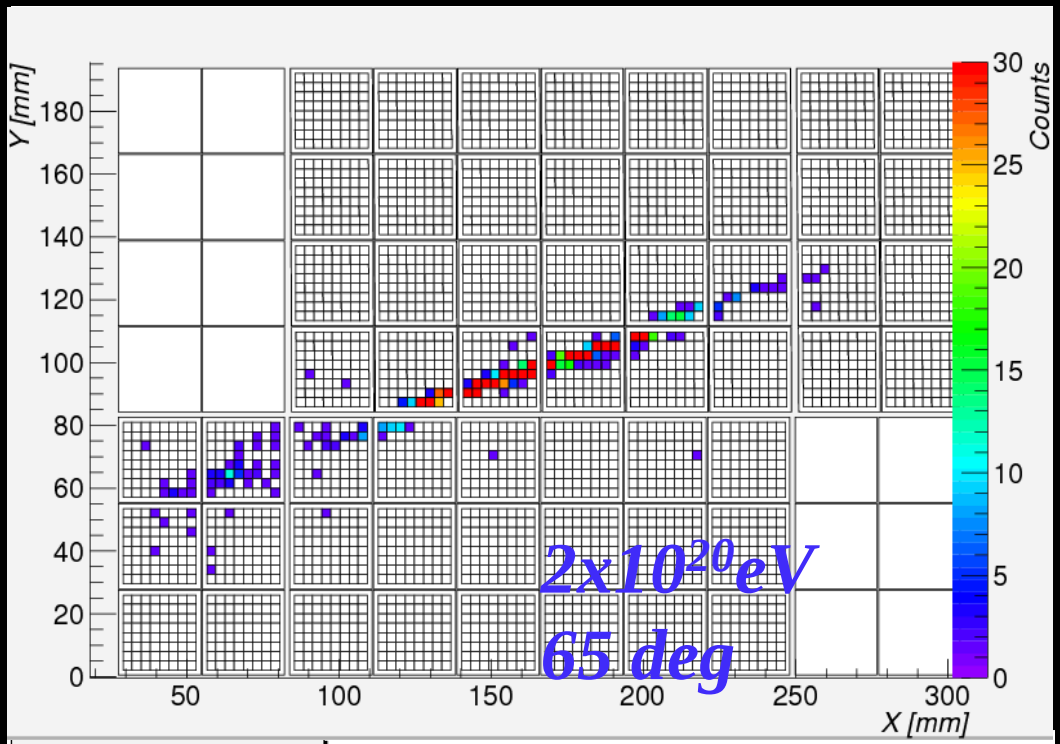




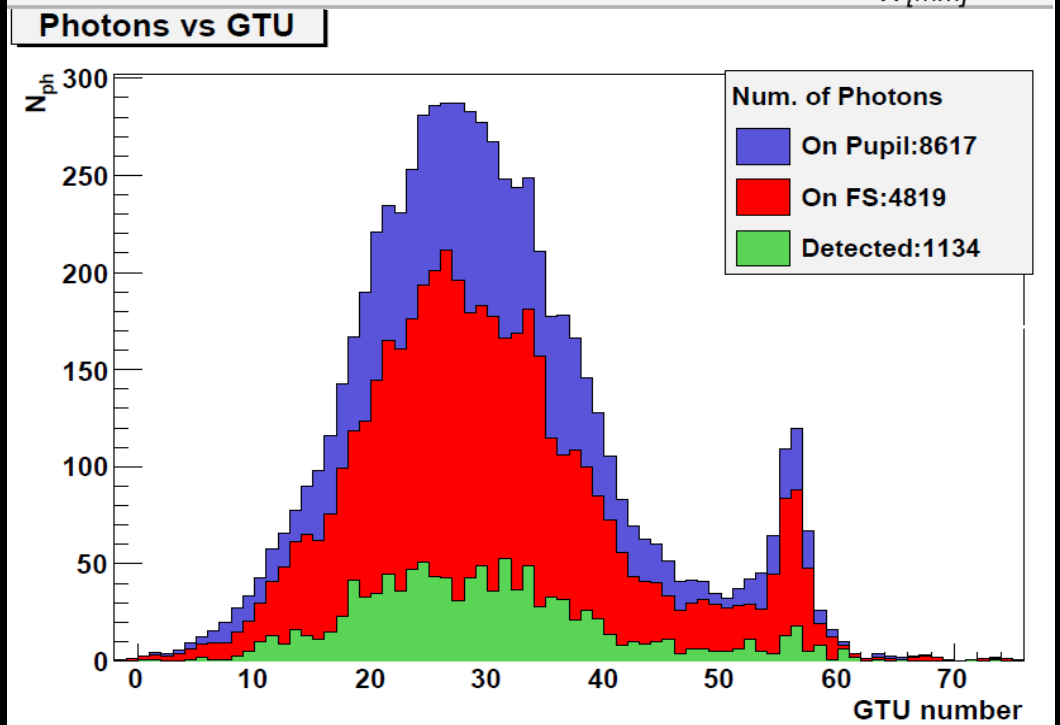
1 GTU gate time units = 2.5 μs

Background: 500 /m^2 sr ns

Shower Simulation



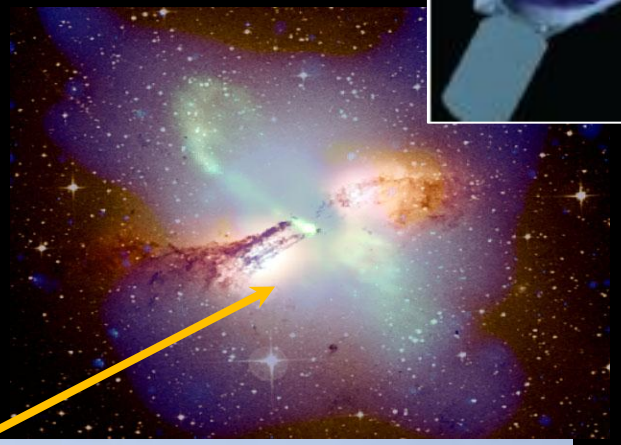
Simulated air shower image on the focal surface detector.



Detected photoelectrons are recorded every Gate Time Unit (GTU) of 2.5μs continuously.

JEM-EUSO in USA

Global Light System



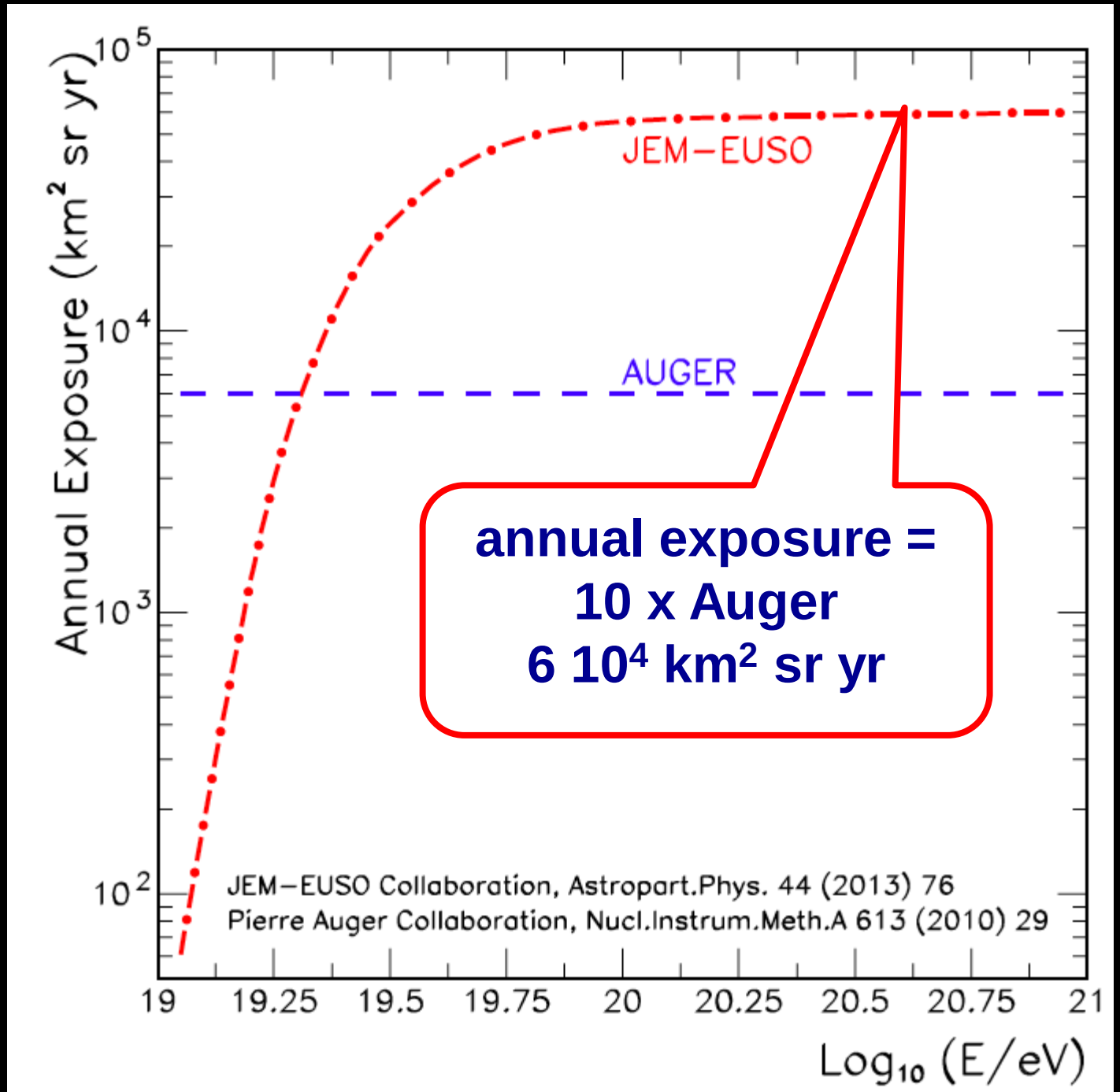
JEM EUSO GLS Some Candidate Locations

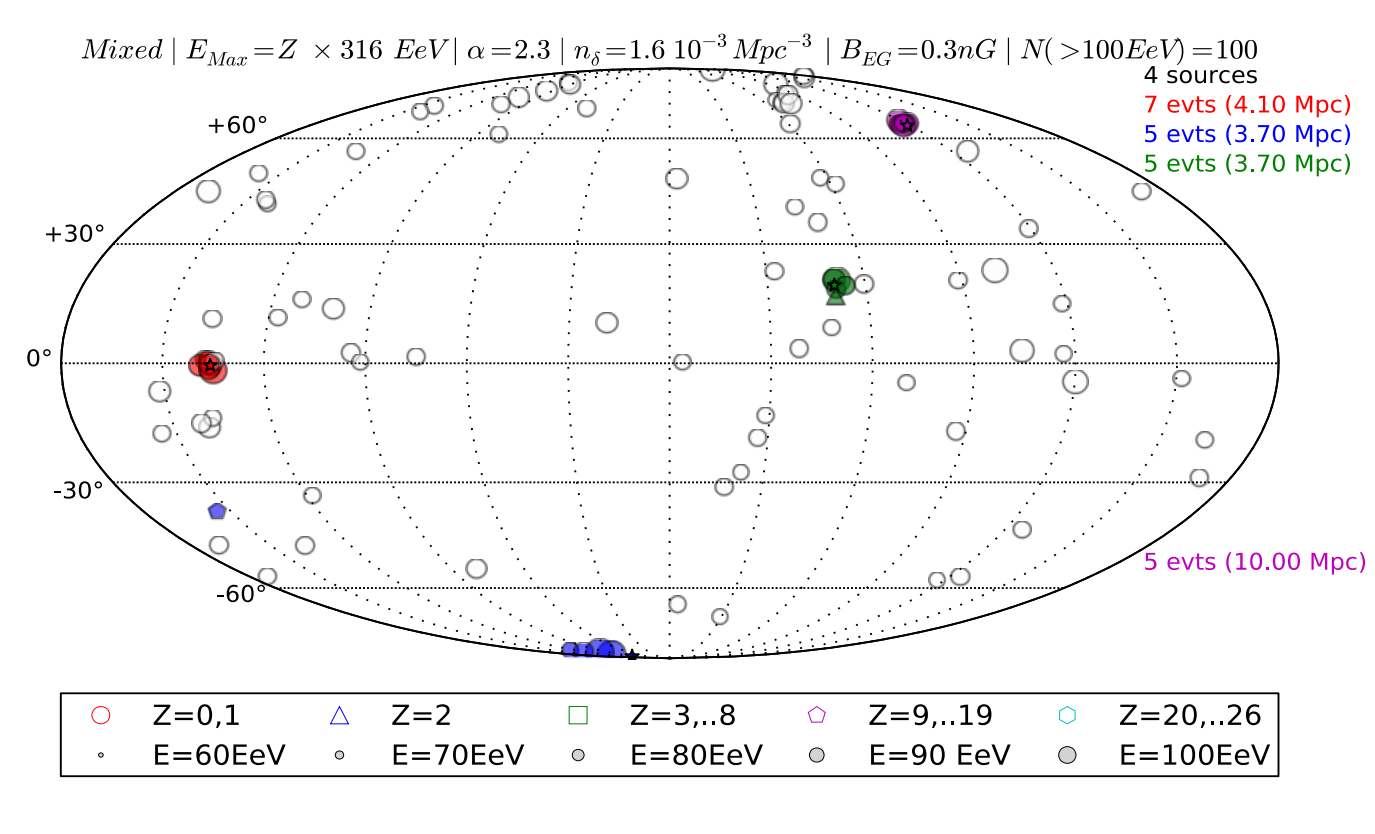
Location	Latitude	Elevation	Location	Latitude	Elevation
Jungfraujoch (Switzerland)	47°N	3.9 km	Chacaltaya (Bolivia)	16° S	5.3 km
Mt. Washington (NH, USA)	44° N	1.9 km	La Reunion (Madagascar)	21° S	1.0 km
Alma-Ata (Kazakhstan)	44° N	3.0 km	Cerro Tololo (Chile)	30° S	2.2 km
Climax (CO, USA)	39° N	3.5 km	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			

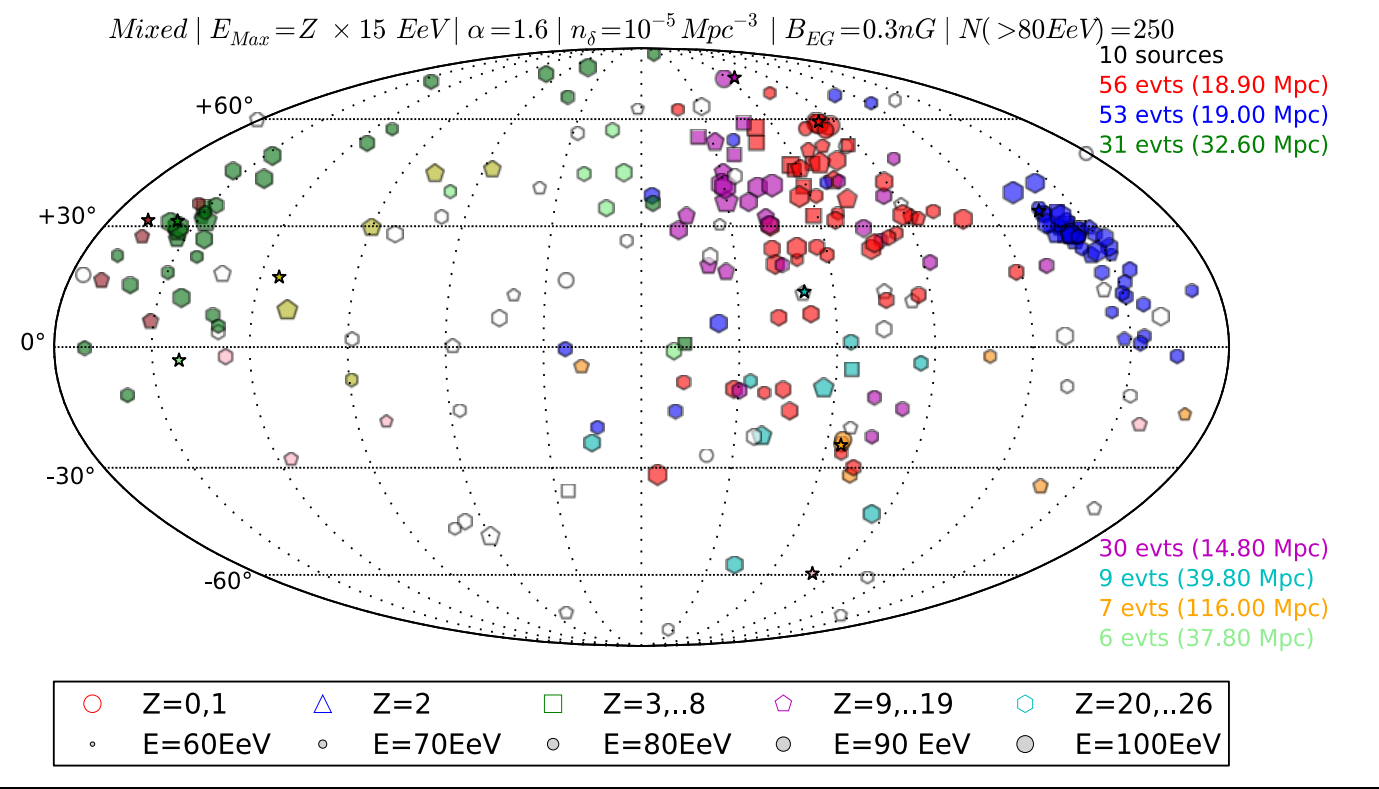
JEM-EUSO goals

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

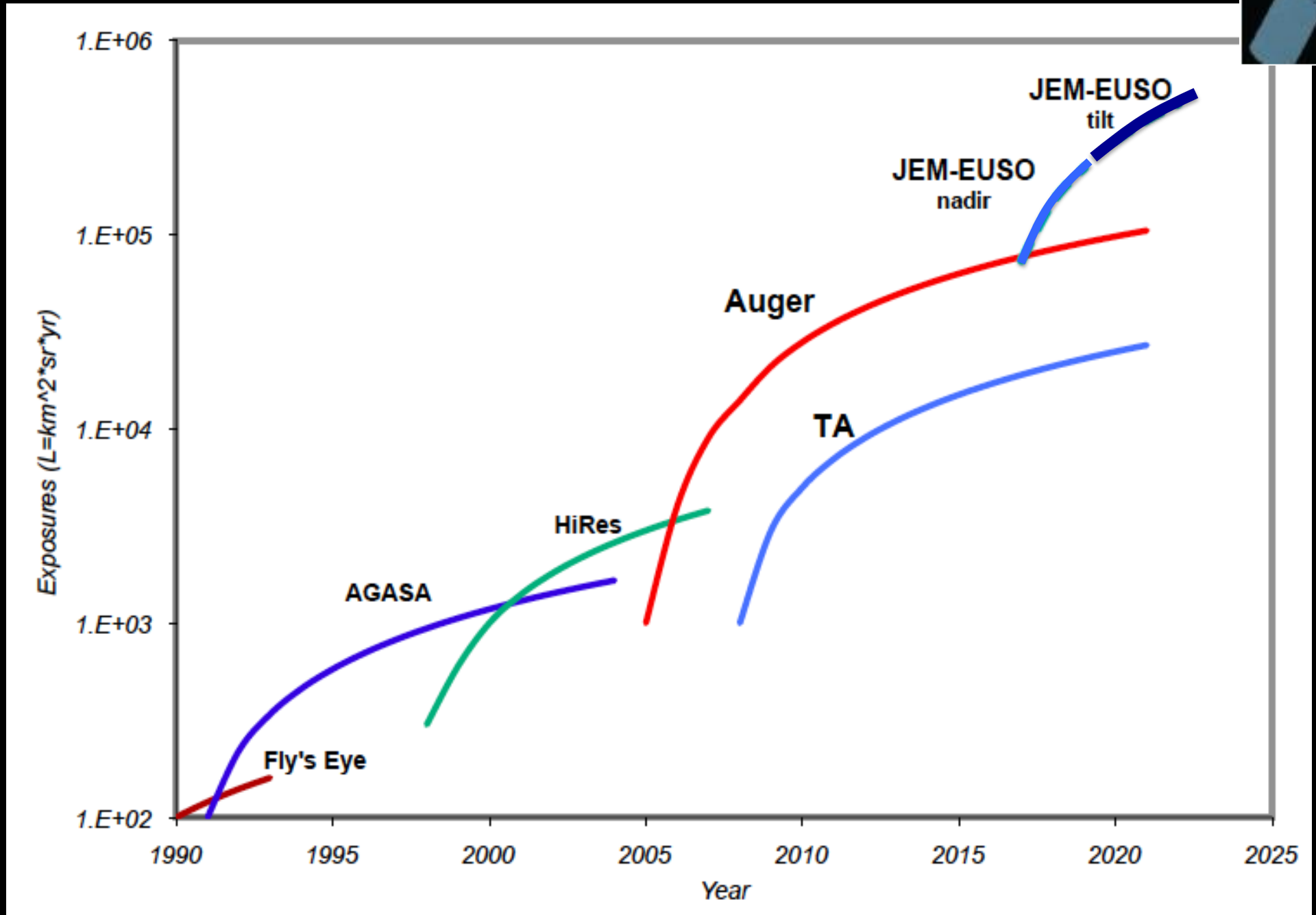
JEM-EUSO


Annual Exposure (km² sr yr)
10⁵
10⁴
10³
10²
JEM−EUSO
AUGER
annual exposure =
10 x Auger
6 10⁴ km² sr yr
JEM−EUSO Collaboration, Astropart.Phys. 44 (2013) 76
Pierre Auger Collaboration, Nucl.Instrum.Meth.A 613 (2010) 29
19
19.25
19.5
19.75
20
20.25
20.5
20.75
21
Log₁₀ (E/eV)

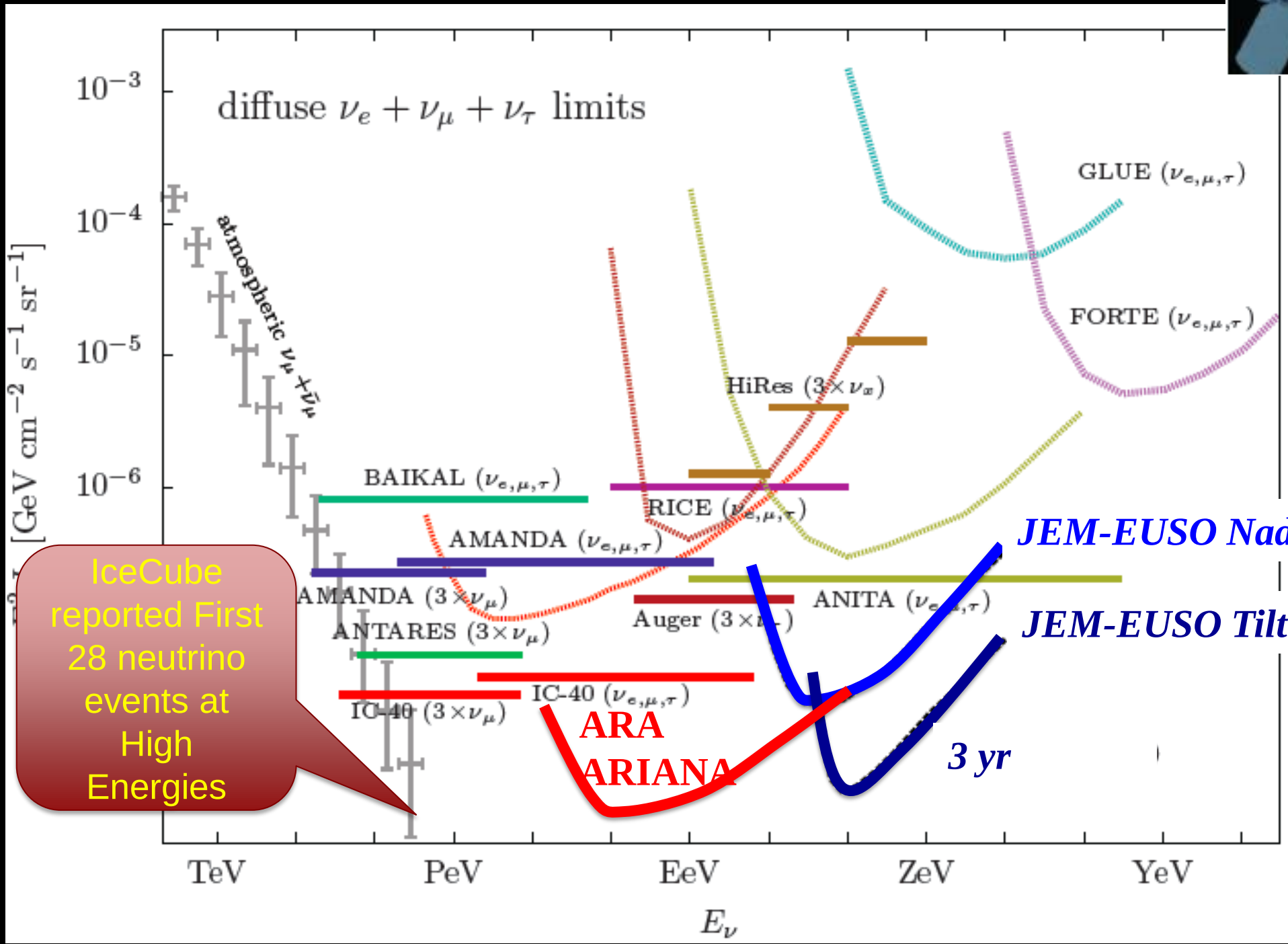

$Mixed \mid E_{Max} = Z \times 316\ EeV \mid \alpha = 2.3 \mid n_\delta = 1.6\ 10^{-3}\ Mpc^{-3} \mid B_{EG} = 0.3nG \mid N(>100EeV) = 100$
4 sources
7 evts (4.10 Mpc)
5 evts (3.70 Mpc)
5 evts (3.70 Mpc)
5 evts (10.00 Mpc)
+60°
+30°
0°
-30°
-60°
Z=0,1
Z=2
Z=3,..8
Z=9,..19
Z=20,..26
E=60EeV
E=70EeV
E=80EeV
E=90 EeV
E=100EeV


$Mixed \mid E_{Max} = Z \times 15\ EeV \mid \alpha = 1.6 \mid n_\delta = 10^{-5}\ Mpc^{-3} \mid B_{EG} = 0.3nG \mid N(>80EeV) = 250$
10 sources
56 evts (18.90 Mpc)
53 evts (19.00 Mpc)
31 evts (32.60 Mpc)
30 evts (14.80 Mpc)
9 evts (39.80 Mpc)
7 evts (116.00 Mpc)
6 evts (37.80 Mpc)
+60°
+30°
0°
-30°
-60°
Z=0,1
Z=2
Z=3,..8
Z=9,..19
Z=20,..26
E=60EeV
E=70EeV
E=80EeV
E=90 EeV
E=100EeV

Order of magnitue increase in Exposure

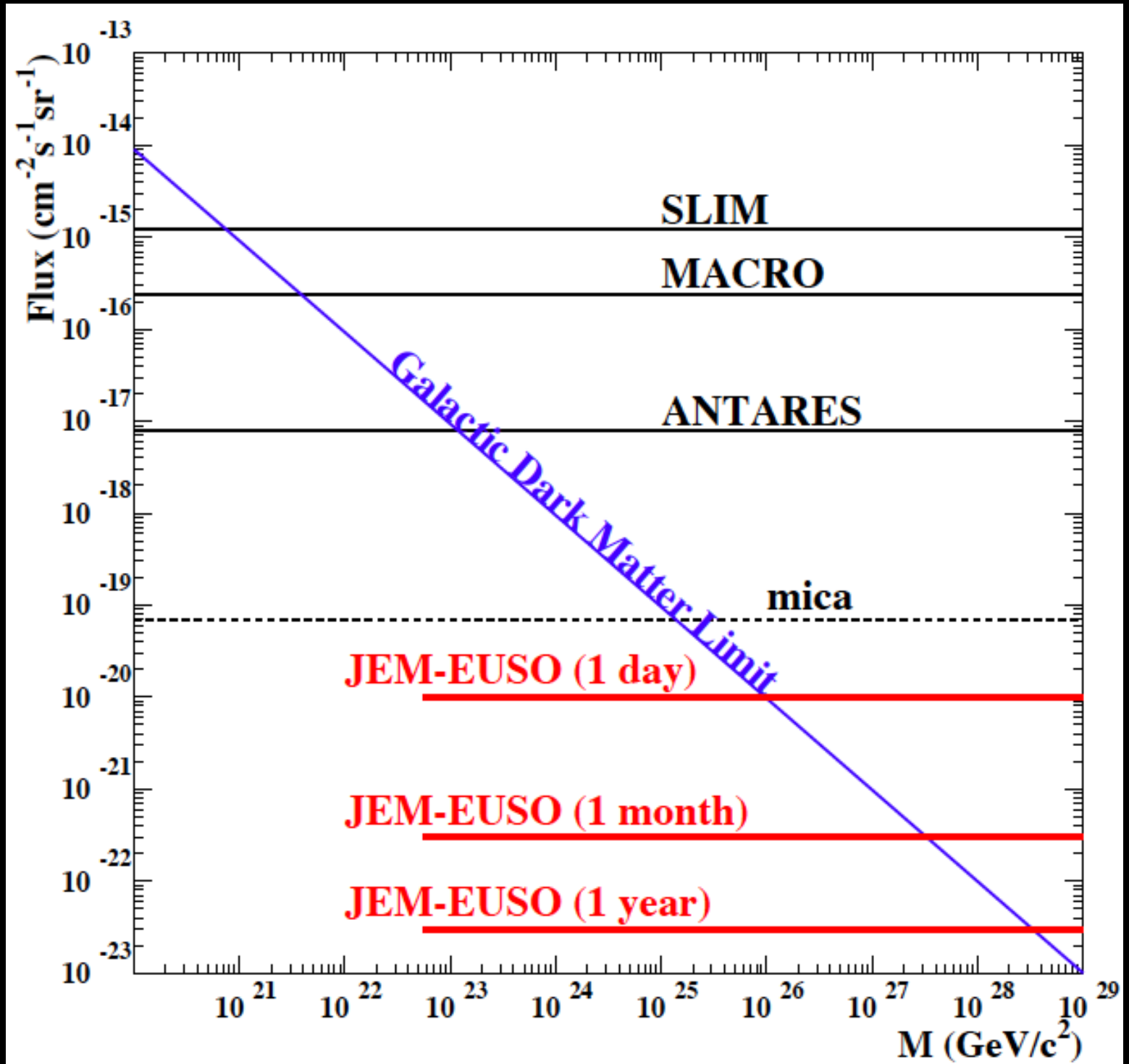


ZeV neutrino sensitivity

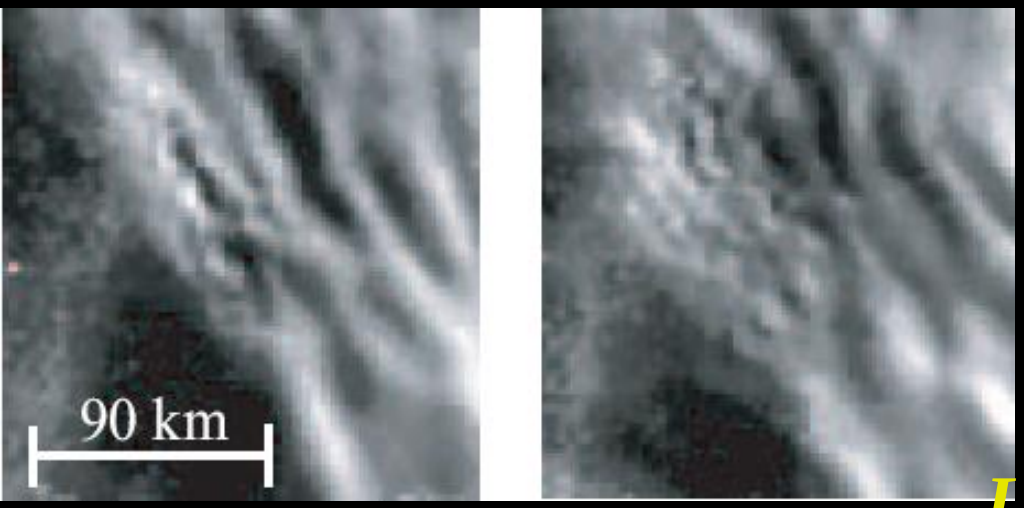


IceCube reported First 28 neutrino events at High Energies

Strangelet Limits



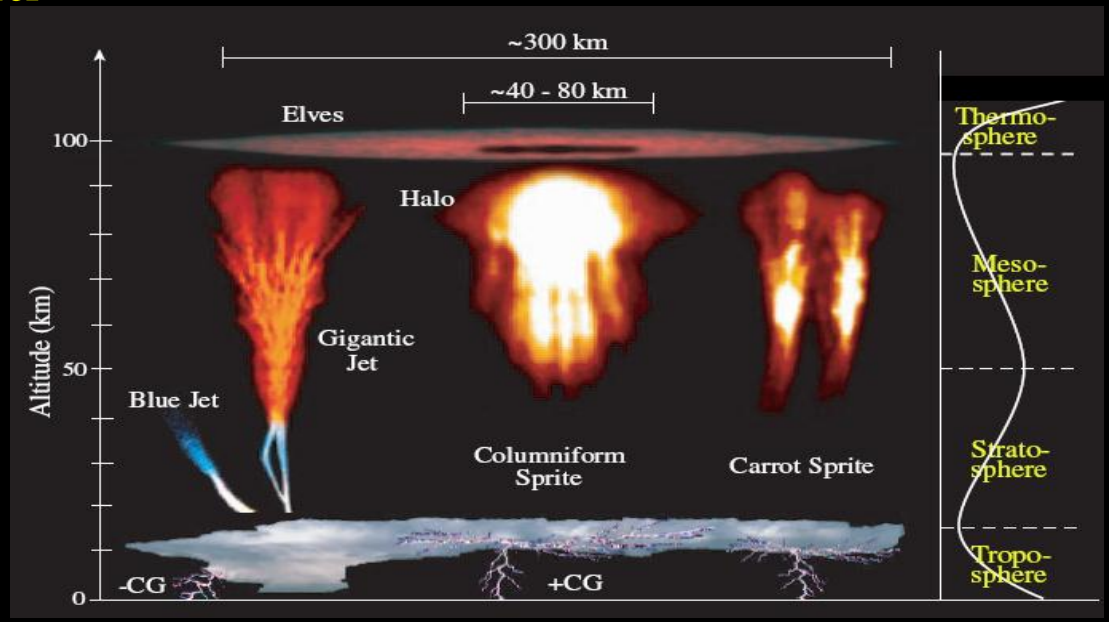
Atmospheric Luminous Phenomena



OH airglow observed from ground

Lightning picture observed from ISS

Leonid meteor swarm in 2001 taken by Hivison camera



Various transient airglows

EUSO PATHFINDERS

EUSO-Balloon (First flight Fall 2014)
EUSO-TA (commissioning Spring 2014)
Mini-EUSO (2015-16)

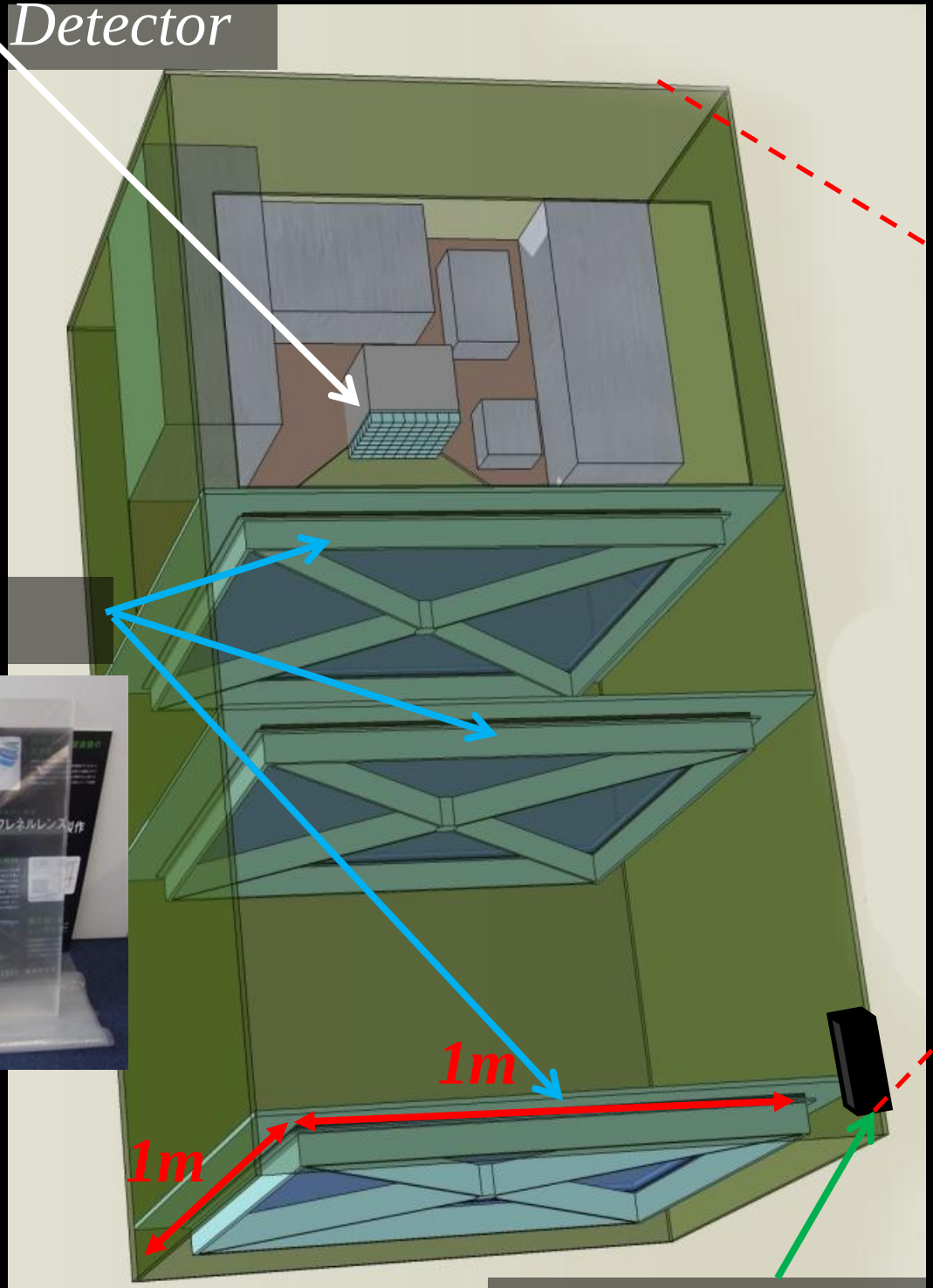
EUSO Balloon - pathfinder

Scheduled for flight Fall 2014

PI: P. von Ballmoos

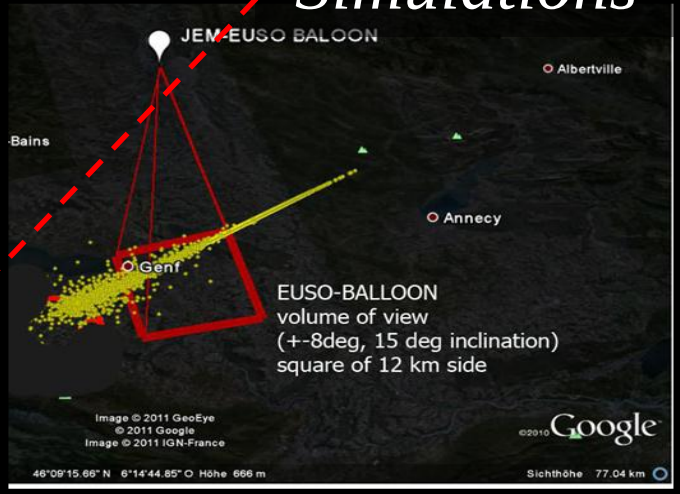
EUSO Balloon

Electronics Detector



Lenses

Simulations



Laser and IR Camera

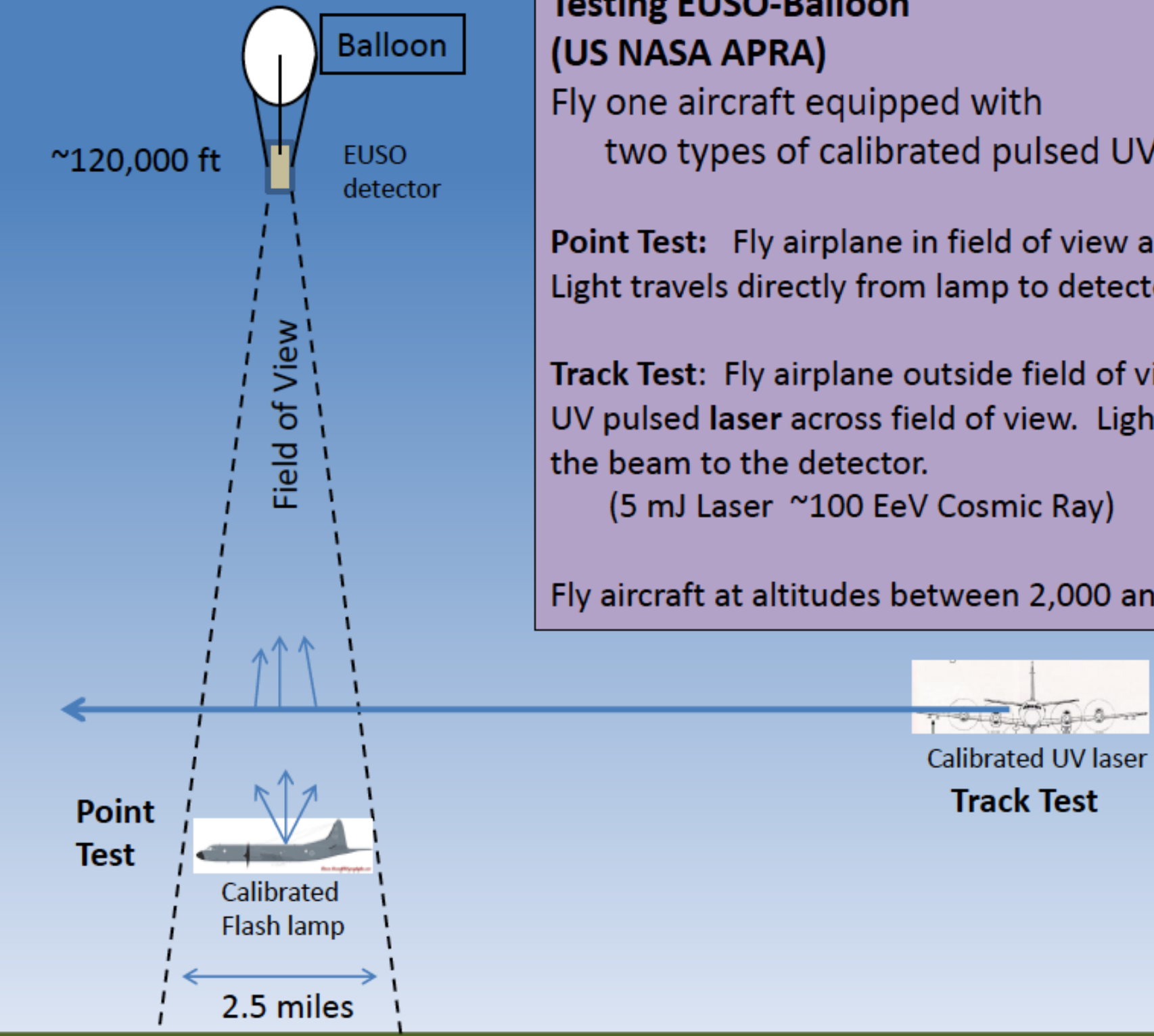
Testing EUSO-Balloon
(US NASA APRA)

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

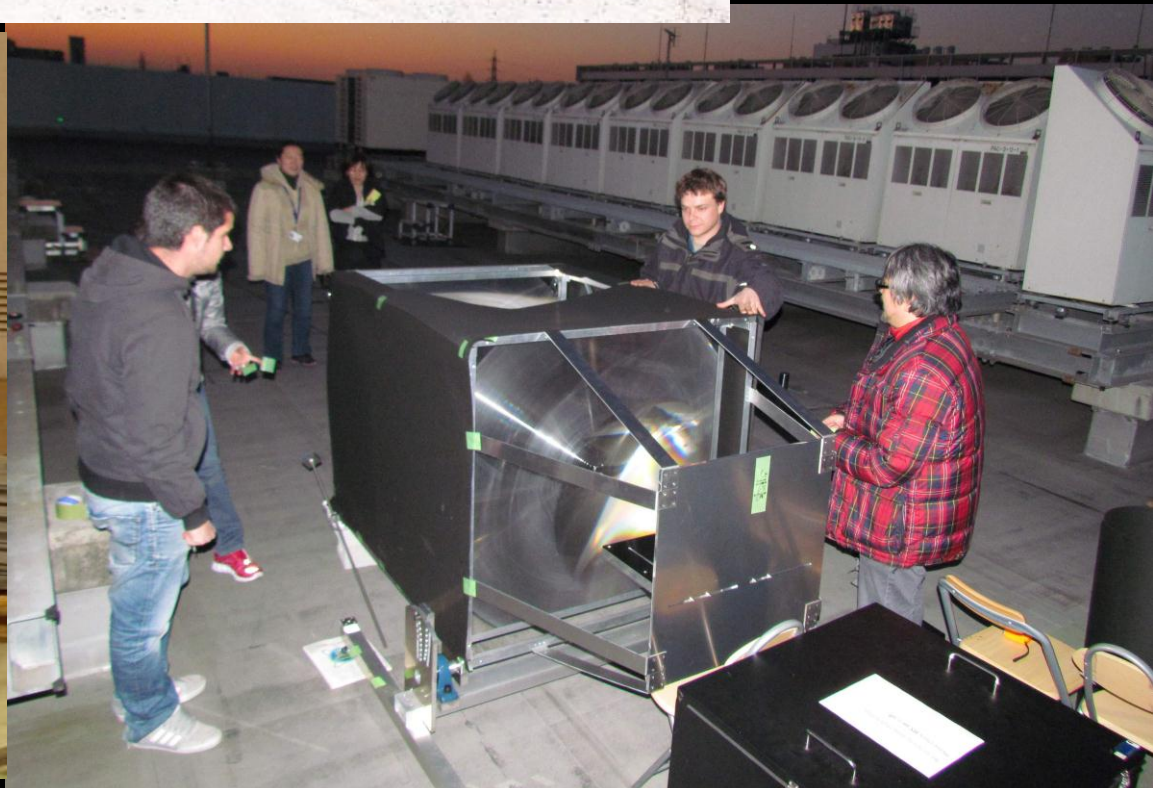
Point Test: Fly airplane in field of view and fire **flash lamp**. Light travels directly from lamp to detector

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.



EUSO - Telescope Array



Mini EUSO

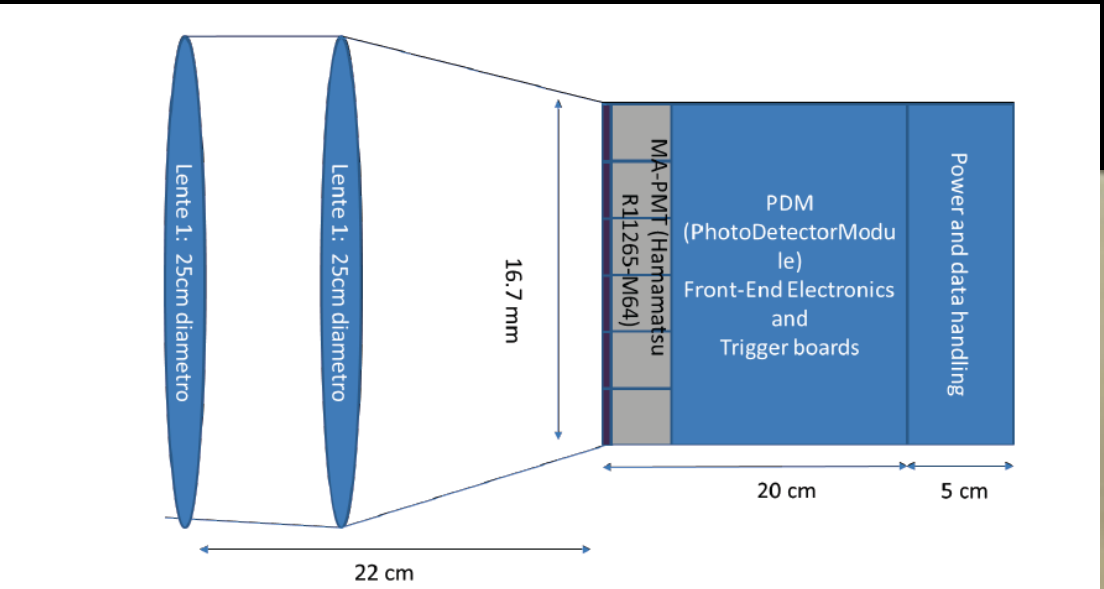
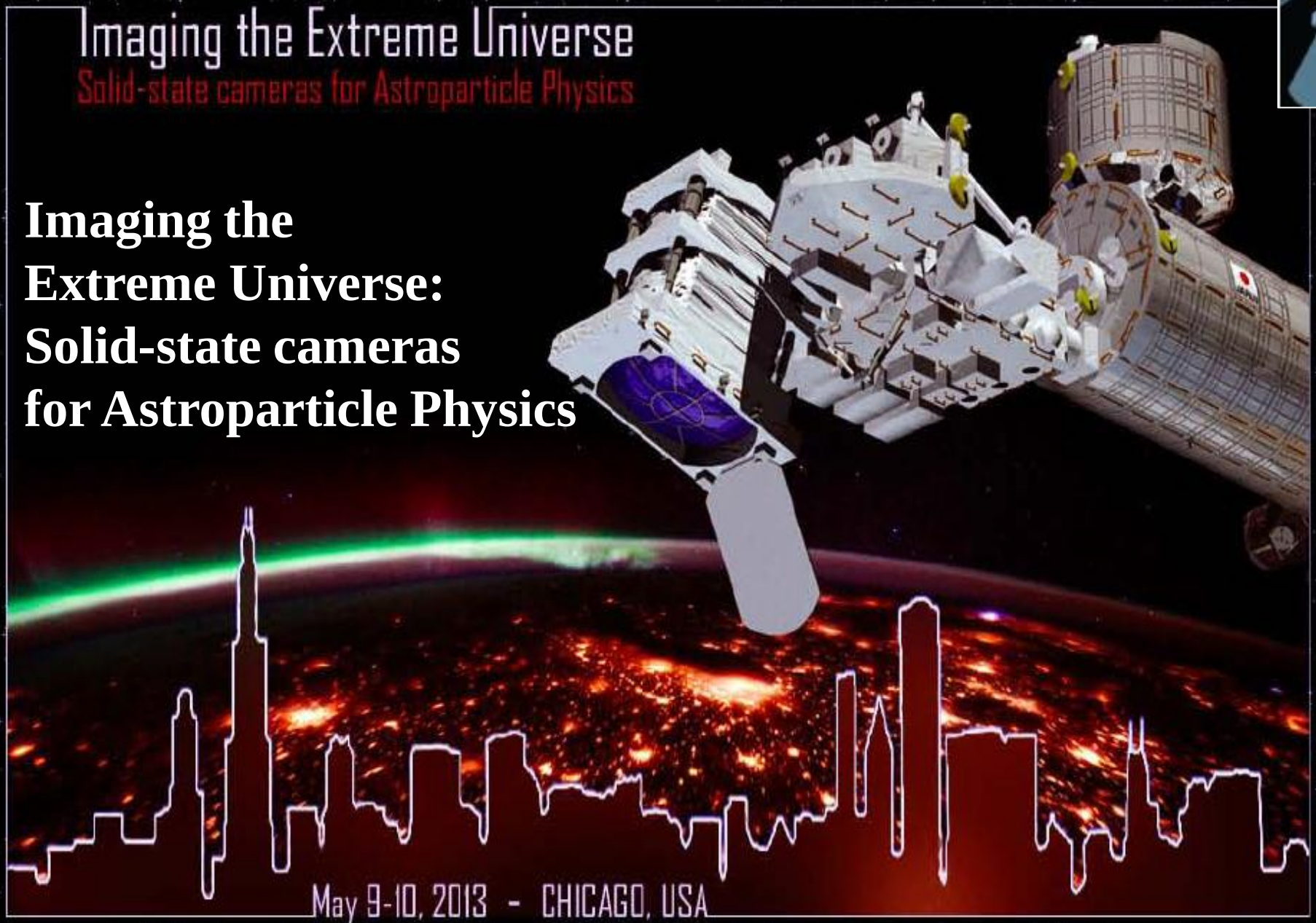


Figure 1 MINI-EUSO block scheme: Optical system with two Fresnel Lenses (25 cm diameter) focalizes UV light on a focal surface of 1 PDM, 36 multi-anode PMTS, total 2304 pixel

American window

Russian window

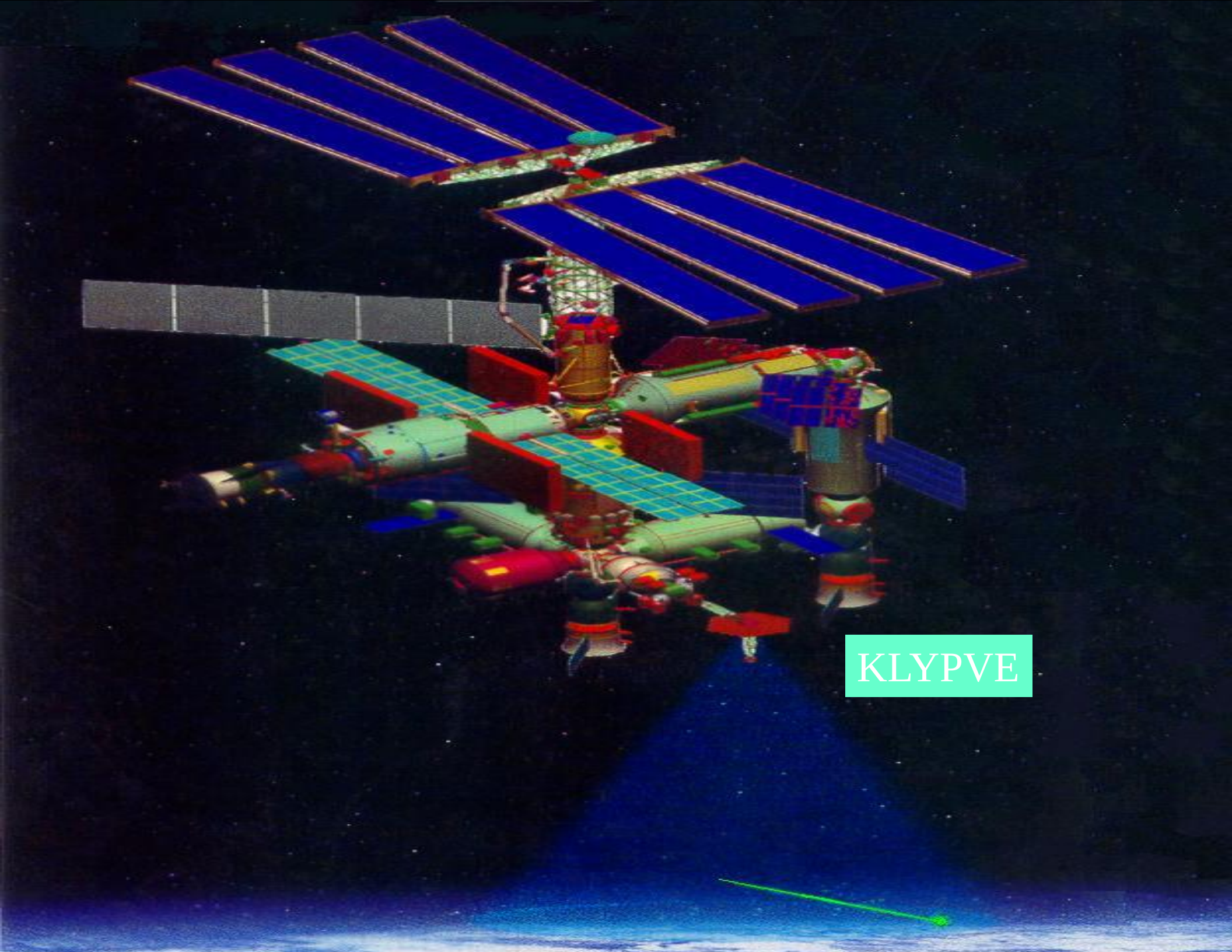
Focal Surface R&D



Imaging the Extreme Universe: Solid-state cameras for Astroparticle Physics

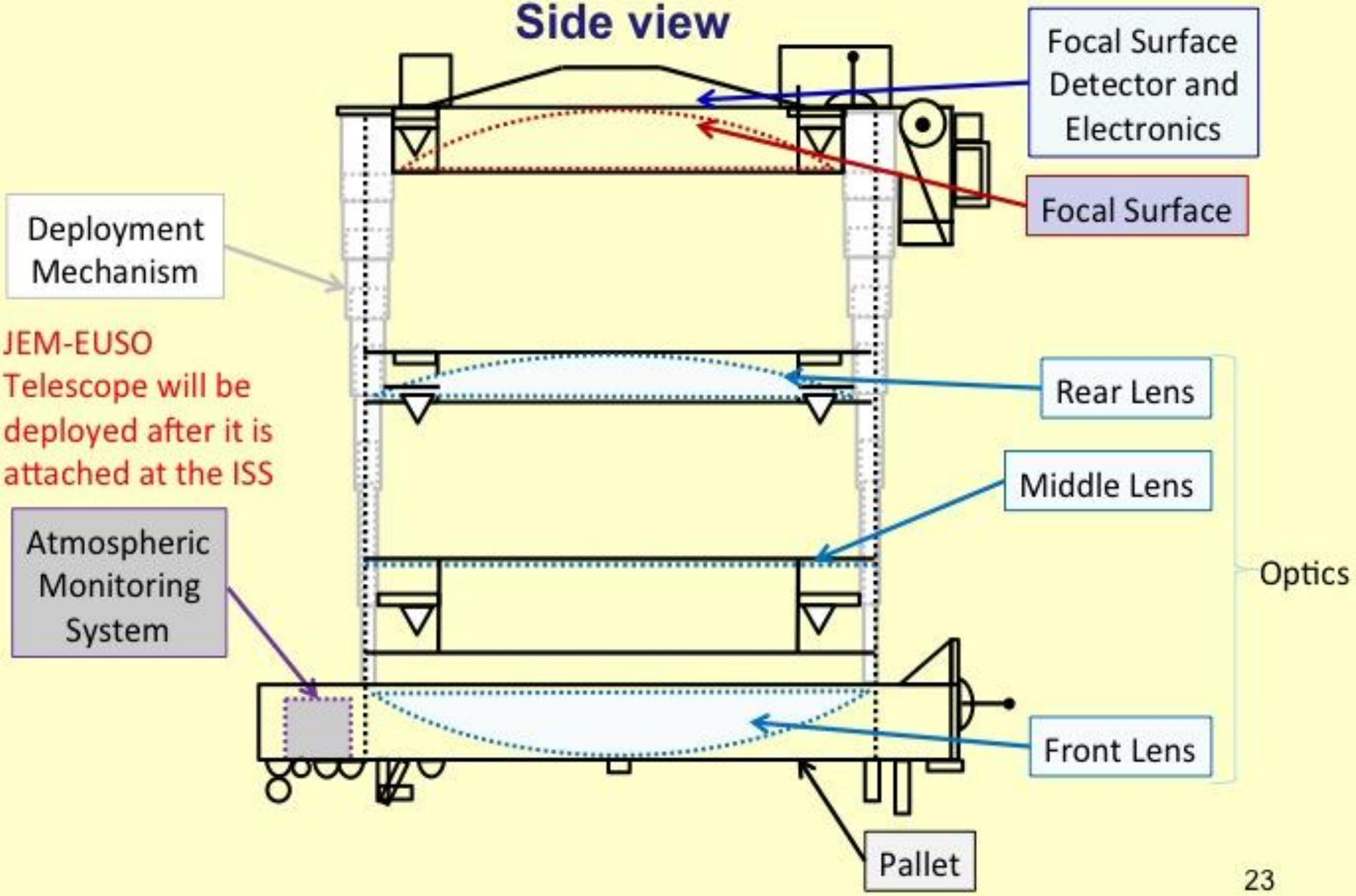
In the next decade, we can find the Sources of UHECRs from Space!!!


Thanks!

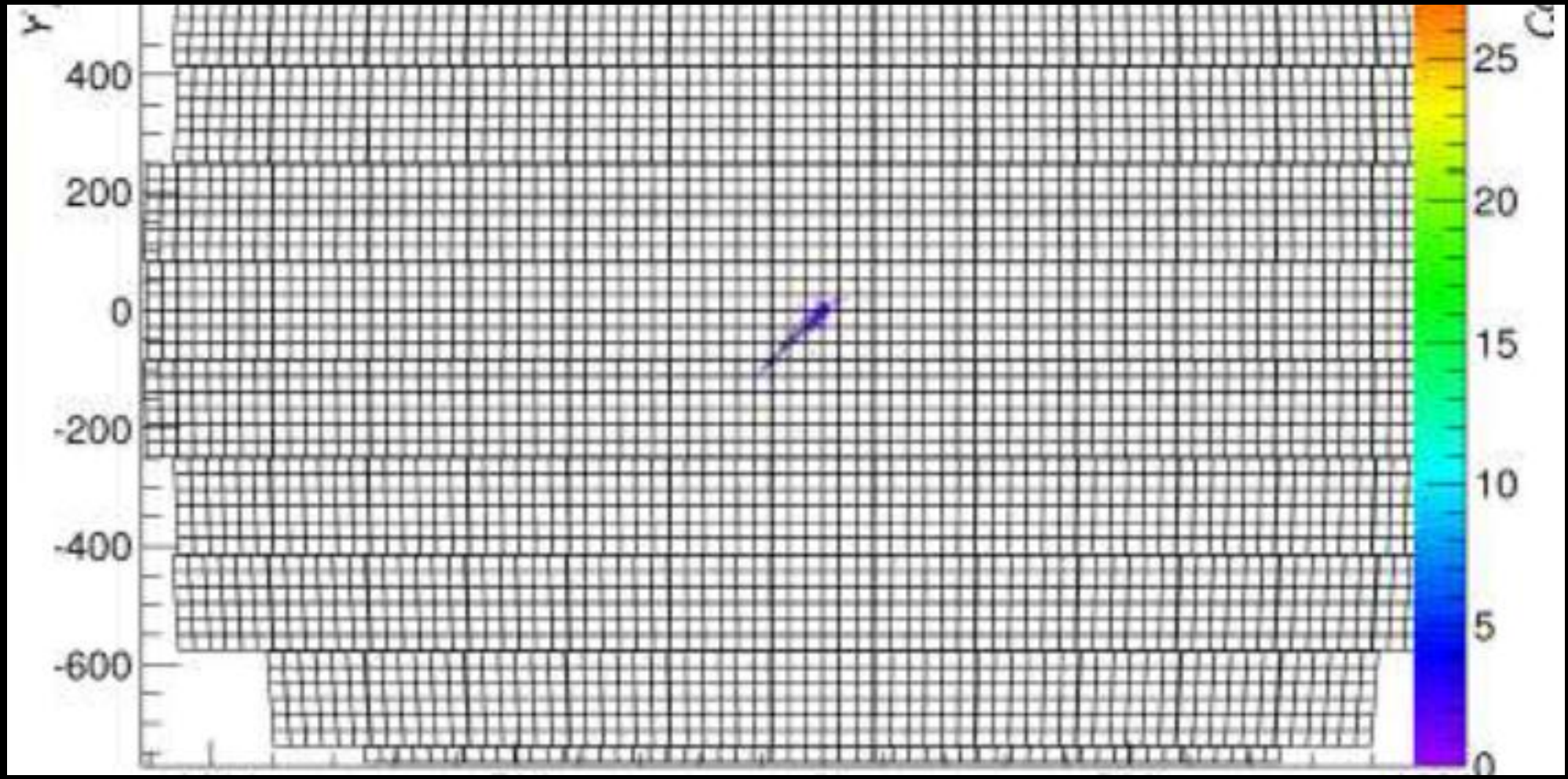

KLYPVE

Science Instrument

Side view



Showers in ~1 PDM



Next Generation GZK Neutrino Detectors

Current Limits

Flux Lower Limit