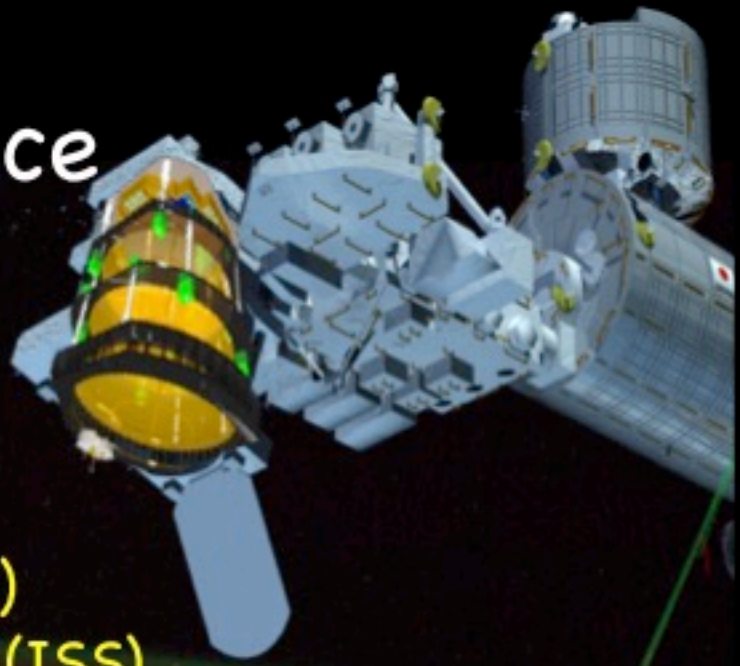
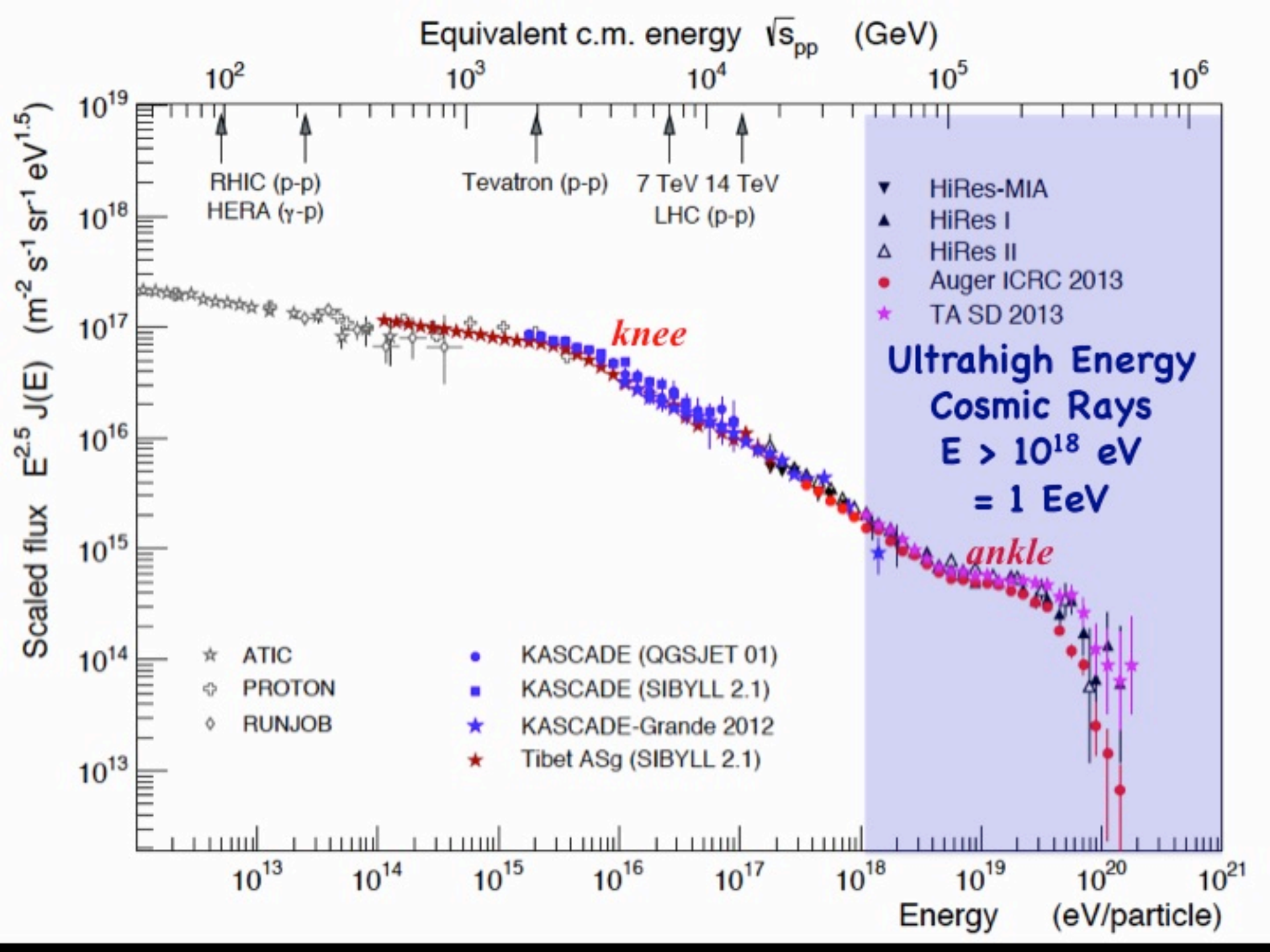
JEM-EUSO Science

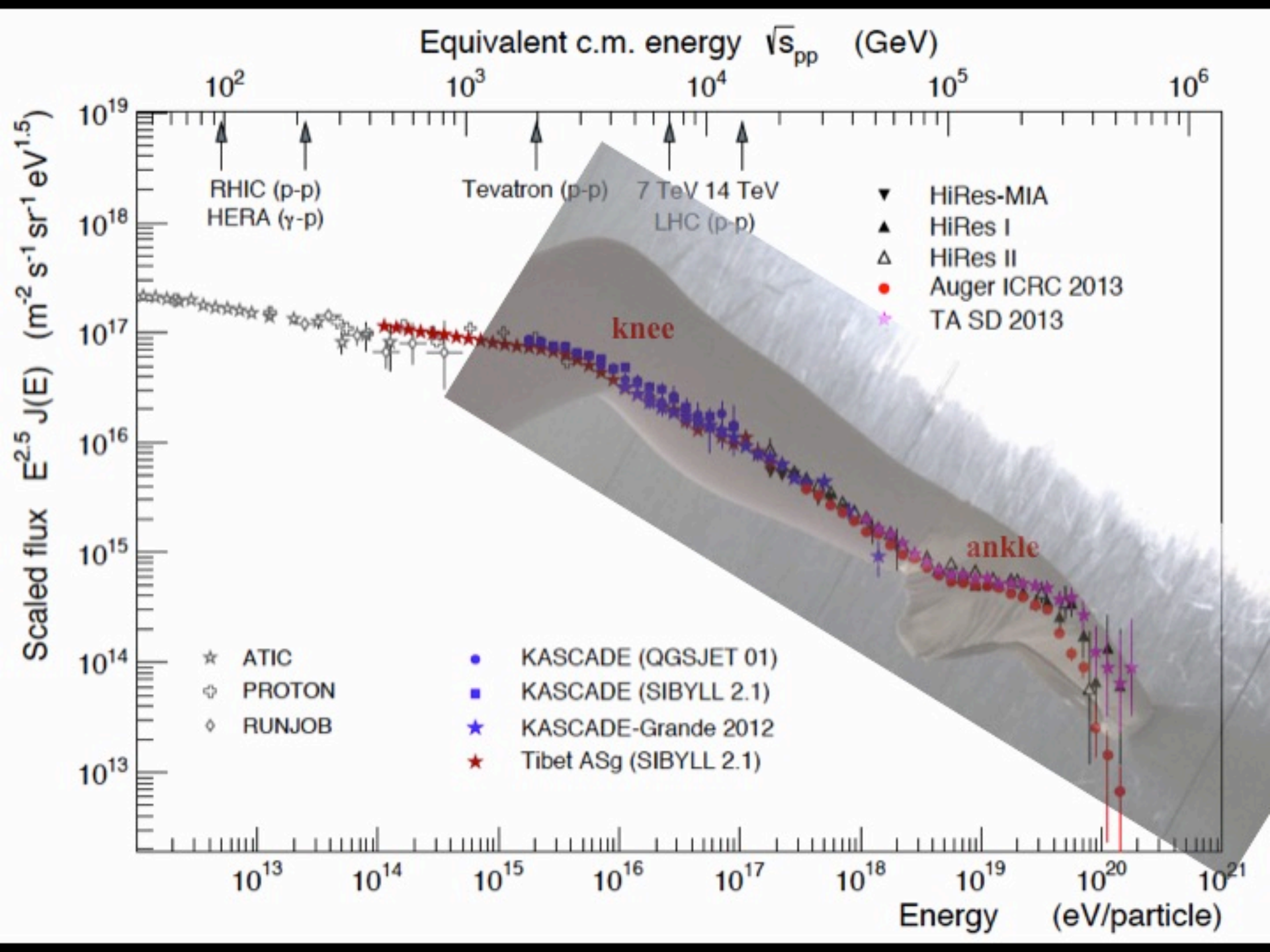


Extreme Universe
Space Observatory
(EUSO)

in the
Japanese Experiment Module (JEM)
of the International Space Station (ISS)

Angela V. Olinto
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)
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 2013
TA SD 2013
knee
Ultrahigh Energy
Cosmic Rays
E > 10^18 eV
= 1 EeV
ankle
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)


Equivalent c.m. energy √s_pp (GeV)
10^2
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RHIC (p-p)
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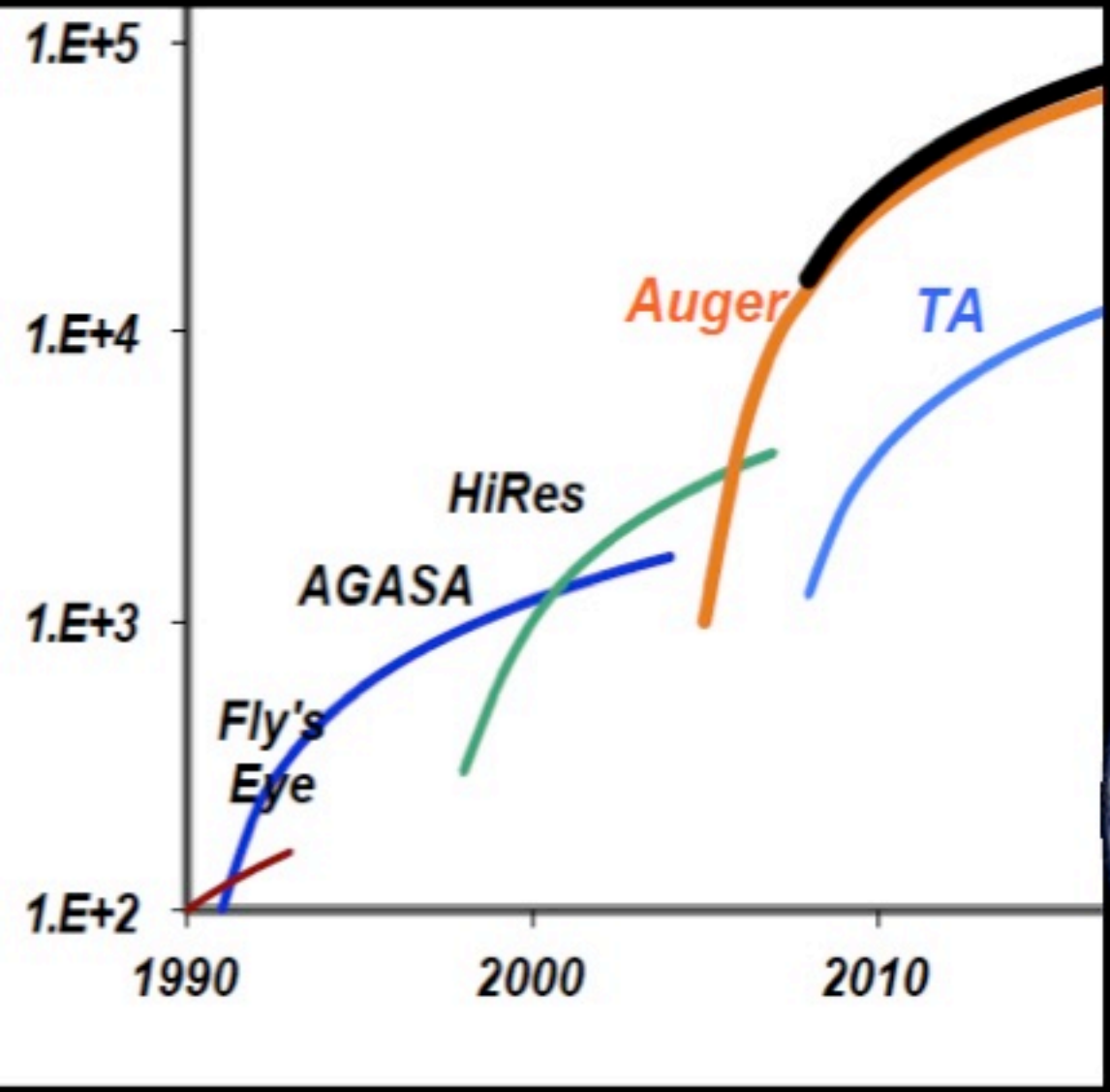
10^13
10^14
10^15
10^16
10^17
10^18
10^19
10^20
10^21
Energy (eV/particle)

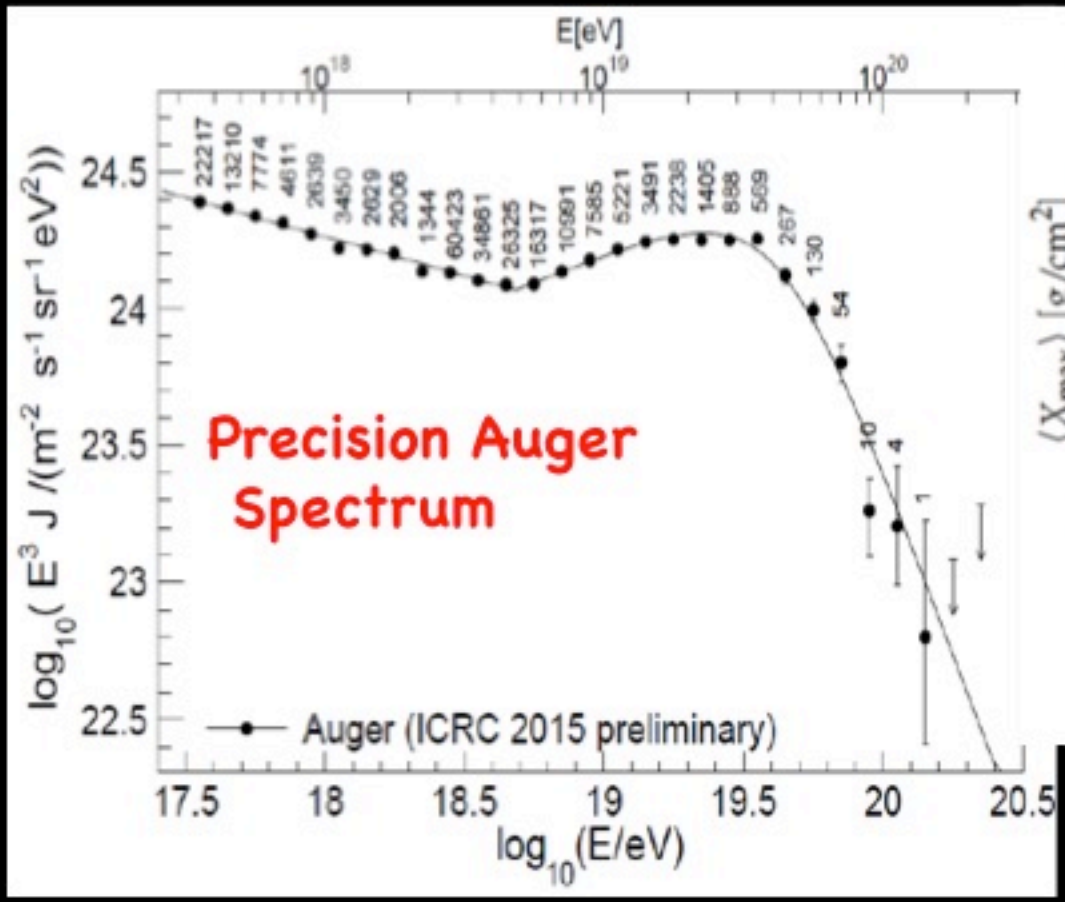
Last Significant Increase in Exposure

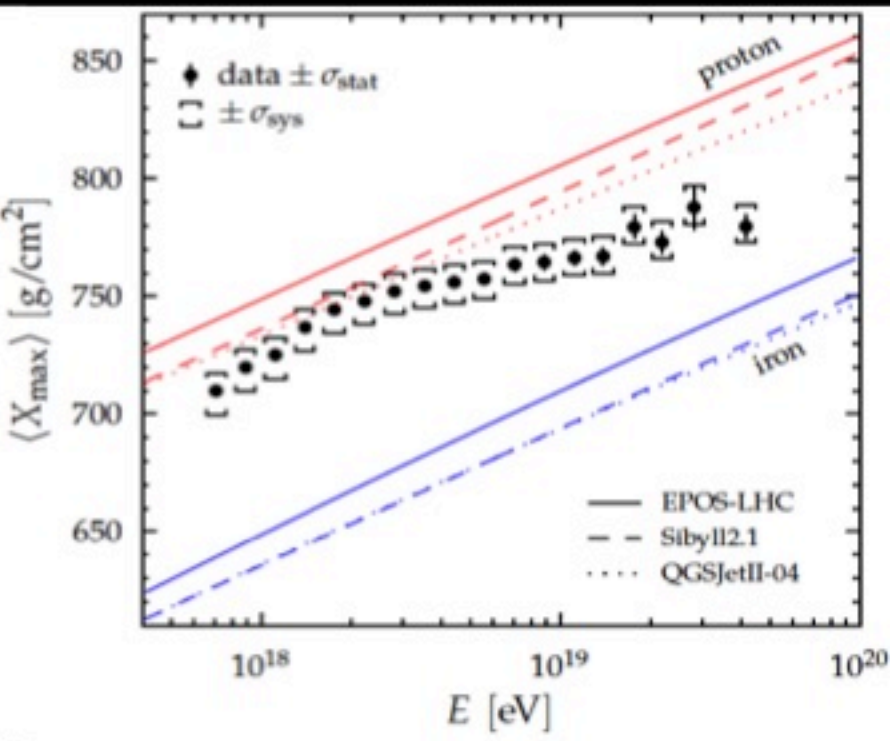


Pierre Auger Observatory
3,000 km², Argentina

Telescope Array
700 km², Utah

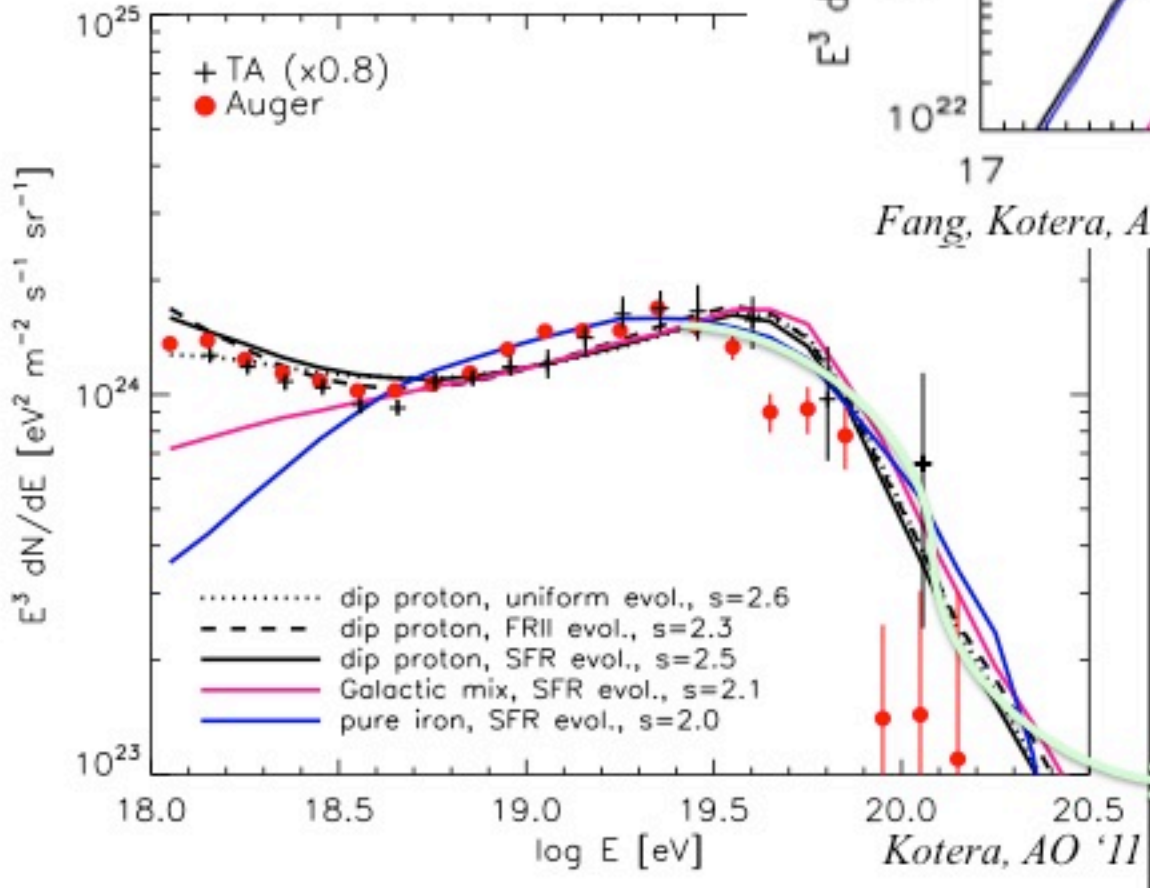
Last Significant Increase in Exposure

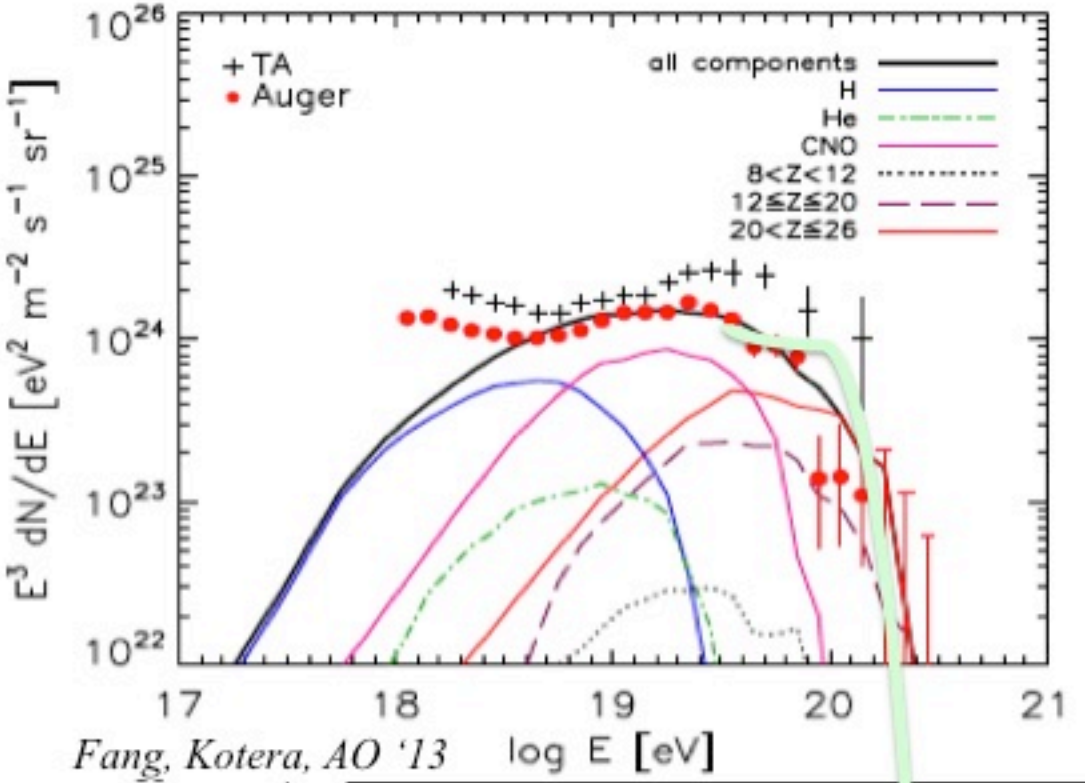




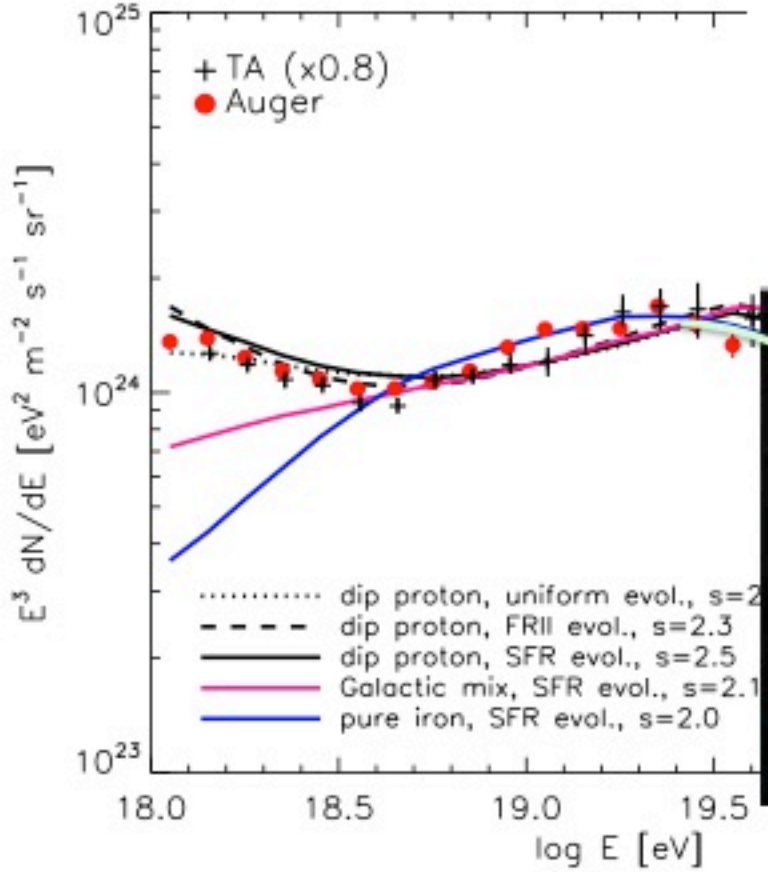
Surprising (to some)
Composition
Trends (Auger)

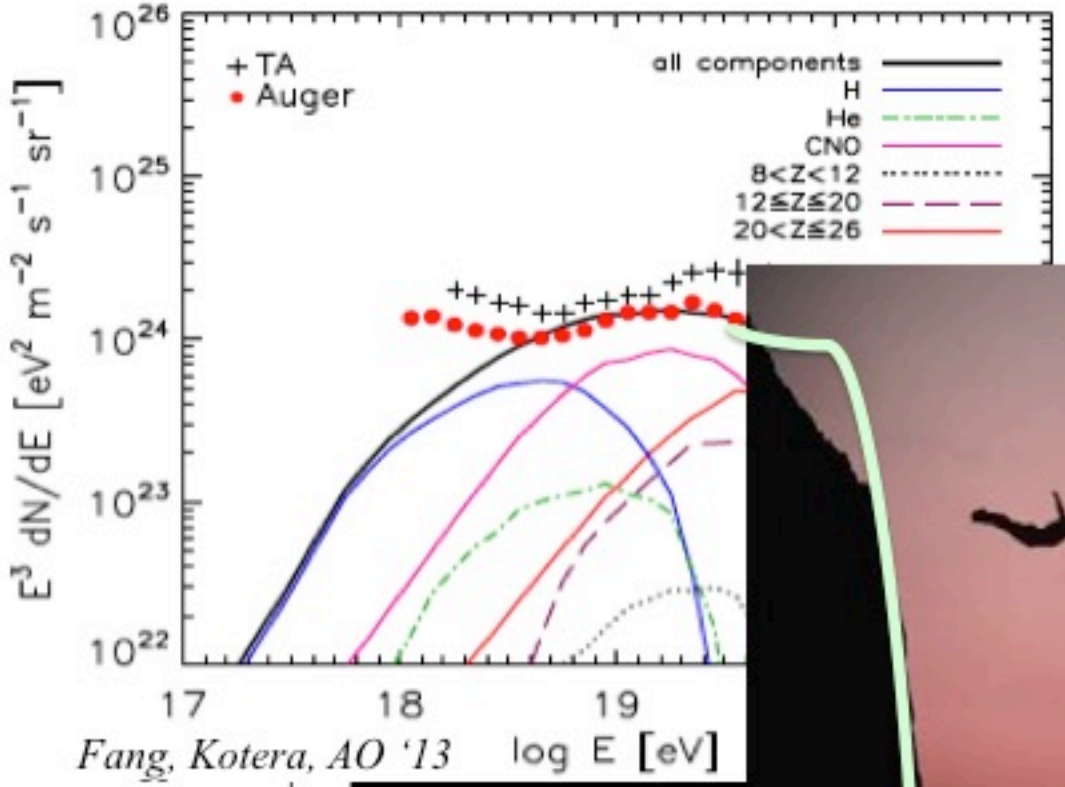
GZK vs E_{max}

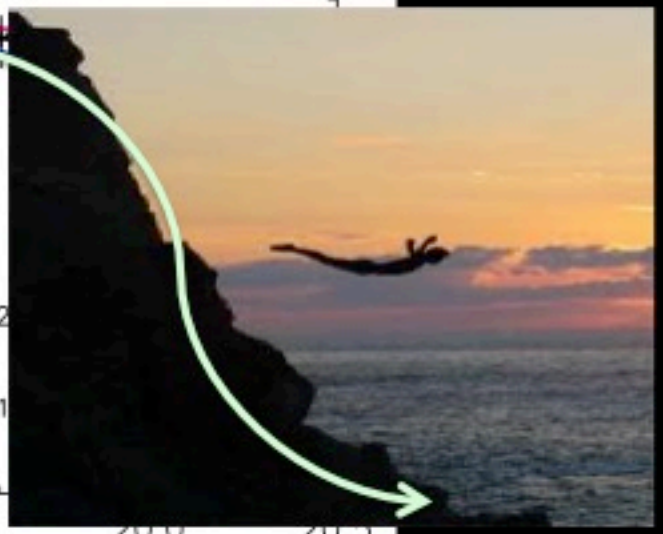

+ TA (x0.8)
Auger
dip proton, uniform evol., s=2.6
dip proton, FRII evol., s=2.3
dip proton, SFR evol., s=2.5
Galactic mix, SFR evol., s=2.1
pure iron, SFR evol., s=2.0
E^3 dN/dE [eV^2 m^{-2} s^{-1} sr^{-1}]
log E [eV]
Kotera, AO '11


+ TA
Auger
all components
H
He
CNO
8<Z<12
12≦Z≦20
20<Z≦26
E^3 dN/dE [eV^2 m^{-2} s^{-1} sr^{-1}]
log E [eV]
Fang, Kotera, AO '13

GZK vs E_{max}

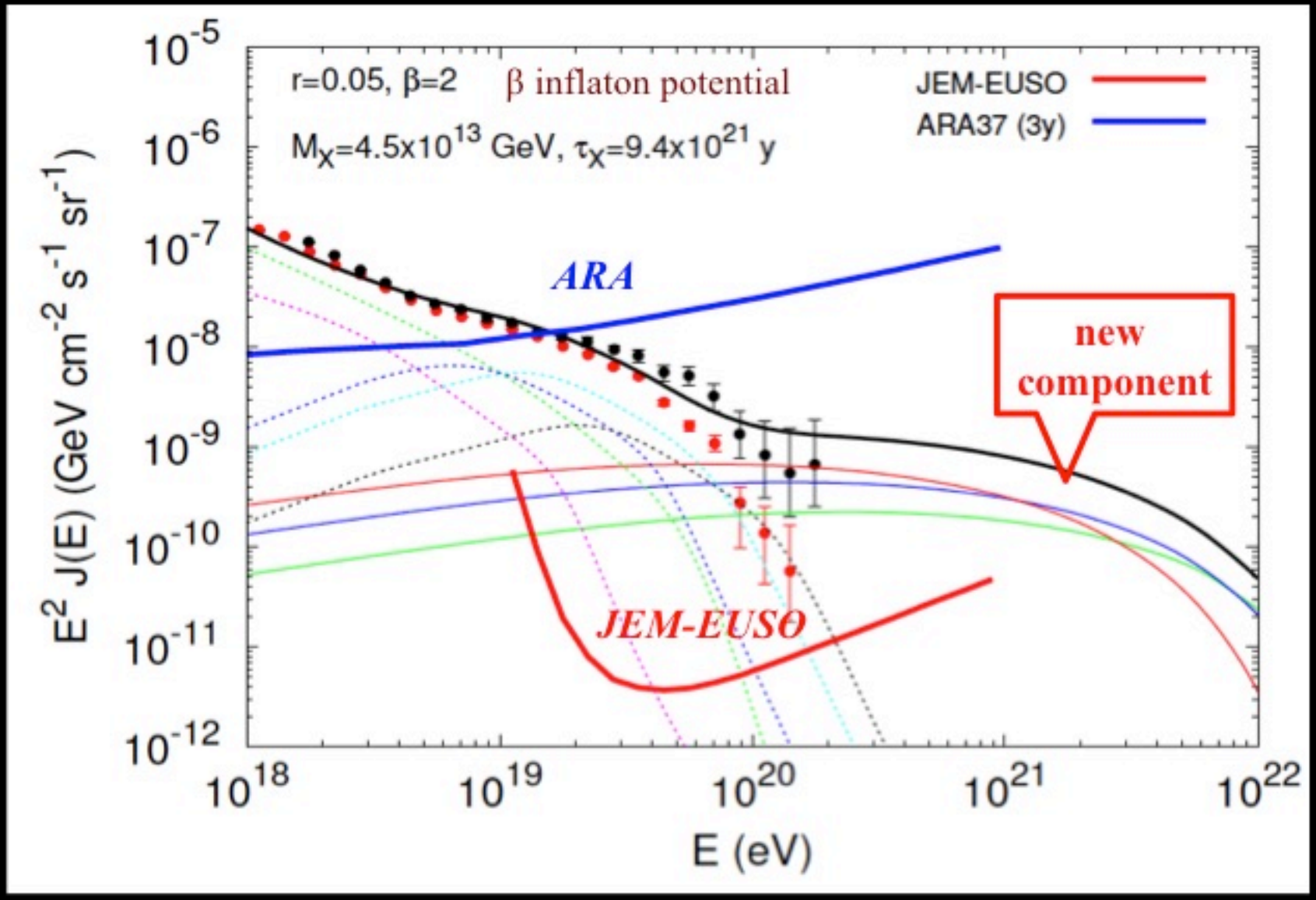

+ TA (x0.8)
Auger
dip proton, uniform evol., s=2
dip proton, FRII evol., s=2.3
dip proton, SFR evol., s=2.5
Galactic mix, SFR evol., s=2.1
pure iron, SFR evol., s=2.0
E^3 dN/dE [eV^2 m^{-2} s^{-1} sr^{-1}]
log E [eV]
Kotera, AO '11


+ TA
Auger
all components
H
He
CNO
8<Z<12
12≦Z≦20
20<Z≦26
E^3 dN/dE [eV^2 m^{-2} s^{-1} sr^{-1}]
log E [eV]
Fang, Kotera, AO '13

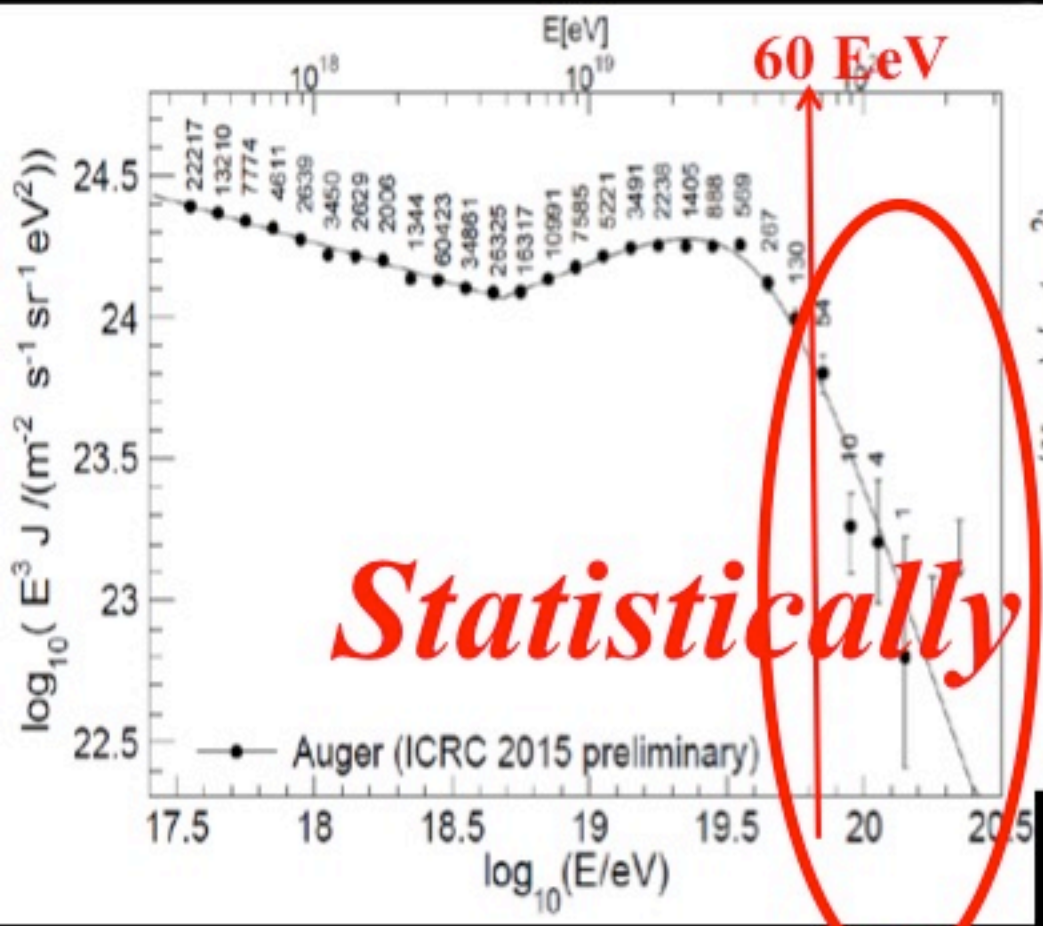


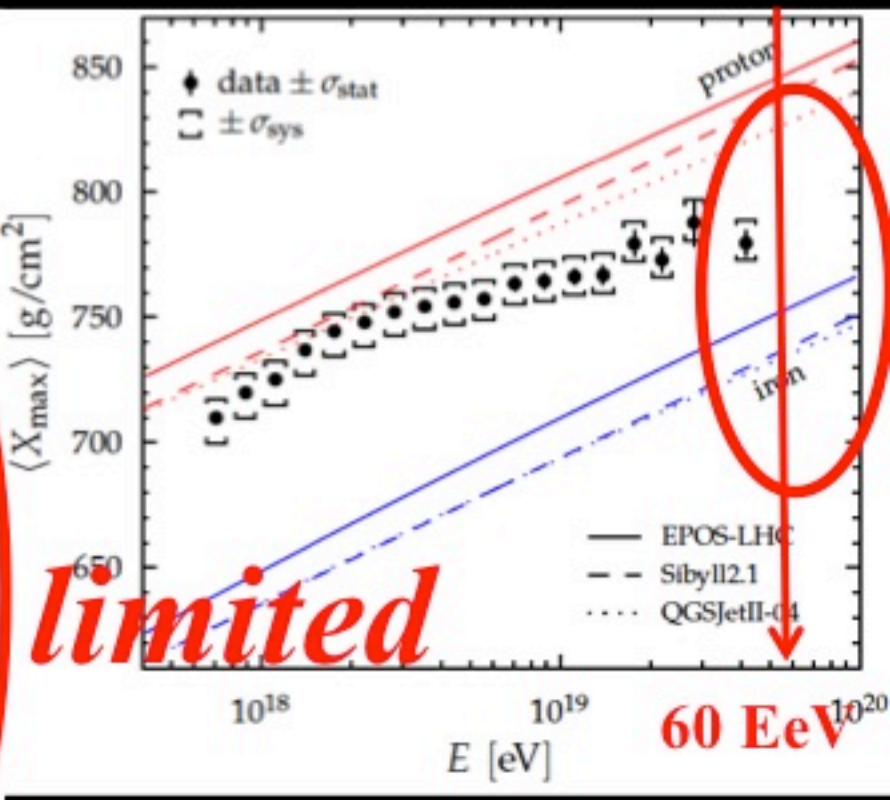
Super Heavy Dark Matter

Aloisio, Matarrese, AO '15



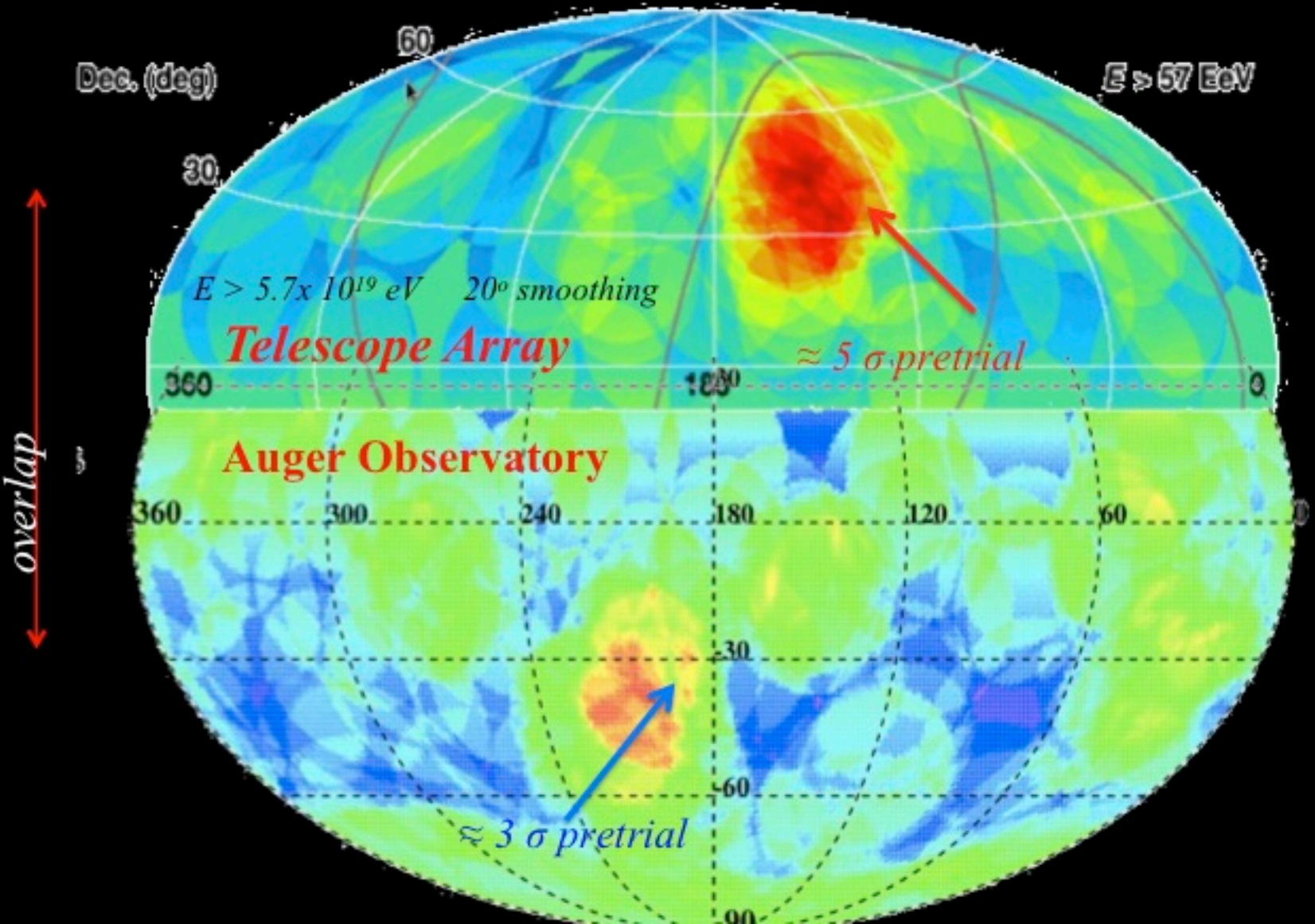
Last Significant Increase in Exposure



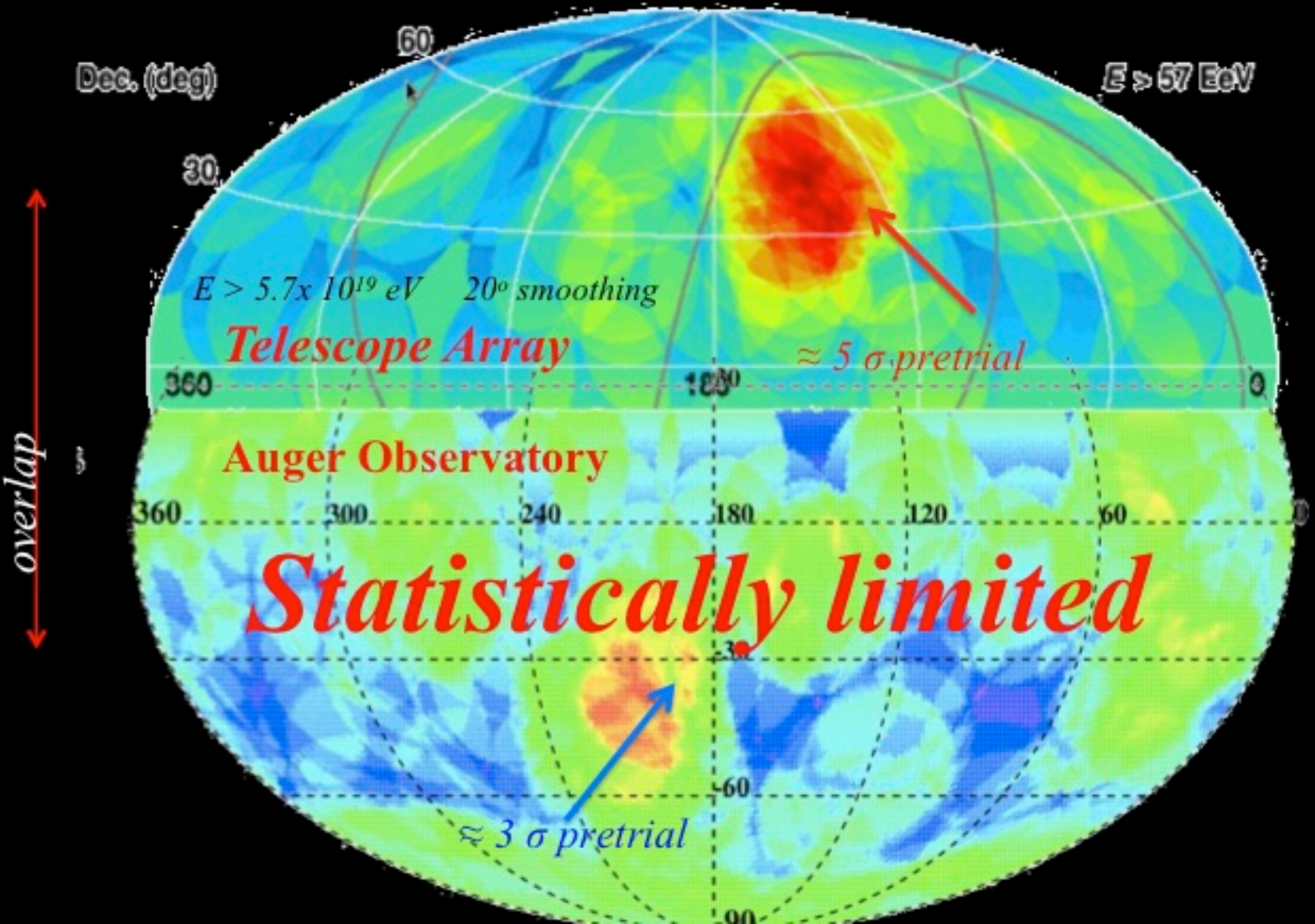


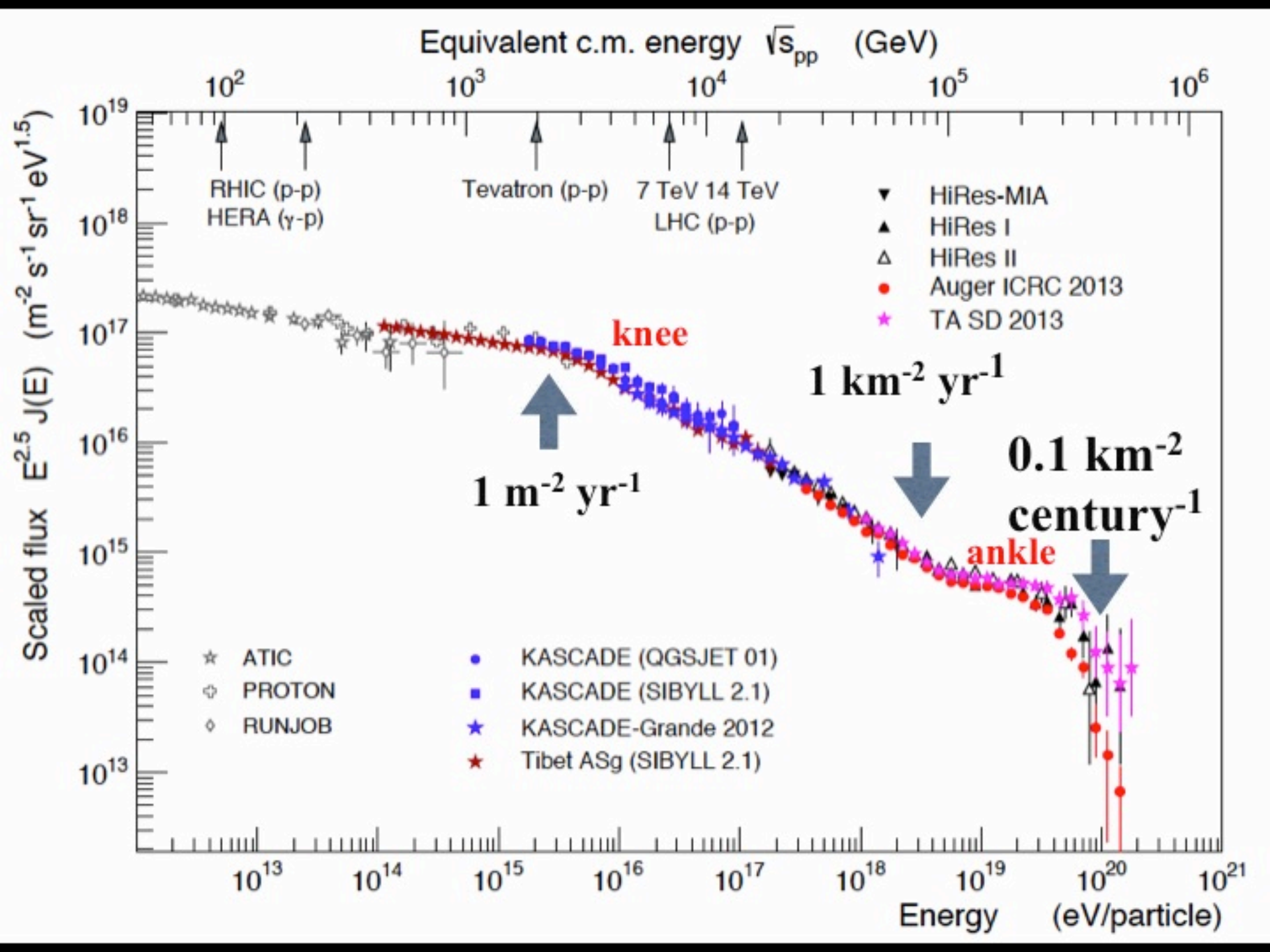
Statistically limited

Anisotropy Hints > 60 EeV



Anisotropy Hints > 60 EeV

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HiRes I
HiRes II
Auger ICRC 2013
TA SD 2013
knee
1 km^-2 yr^-1
1 m^-2 yr^-1
0.1 km^-2 century^-1
ankle
Scaled flux E^2.5 J(E) (m^-2 s^-1 sr^-1 eV^1.5)
10^19
10^18
10^17
10^16
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10^13
10^14
10^15
10^16
10^17
10^18
10^19
10^20
10^21
Energy (eV/particle)

Off the Extreme Energy Cliff

Leading Observatories of Ultrahigh Energy Cosmic Rays

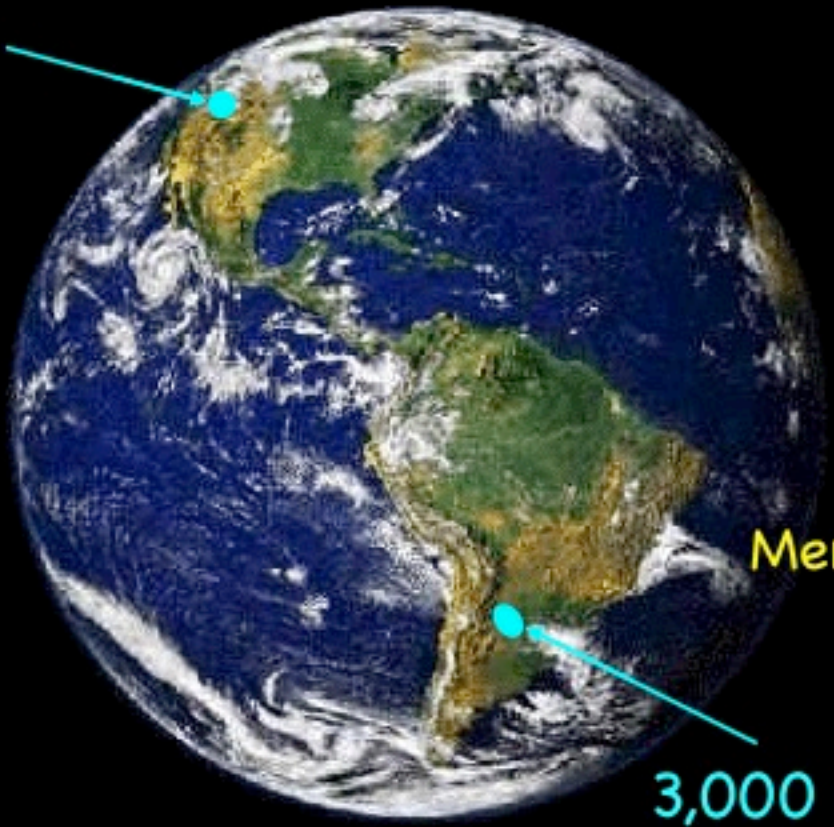
Telescope Array

Utah, USA

(5 country collaboration)

700 km^2 array

3 fluorescence telescopes



Pierre Auger Observatory

Mendoza, Argentina

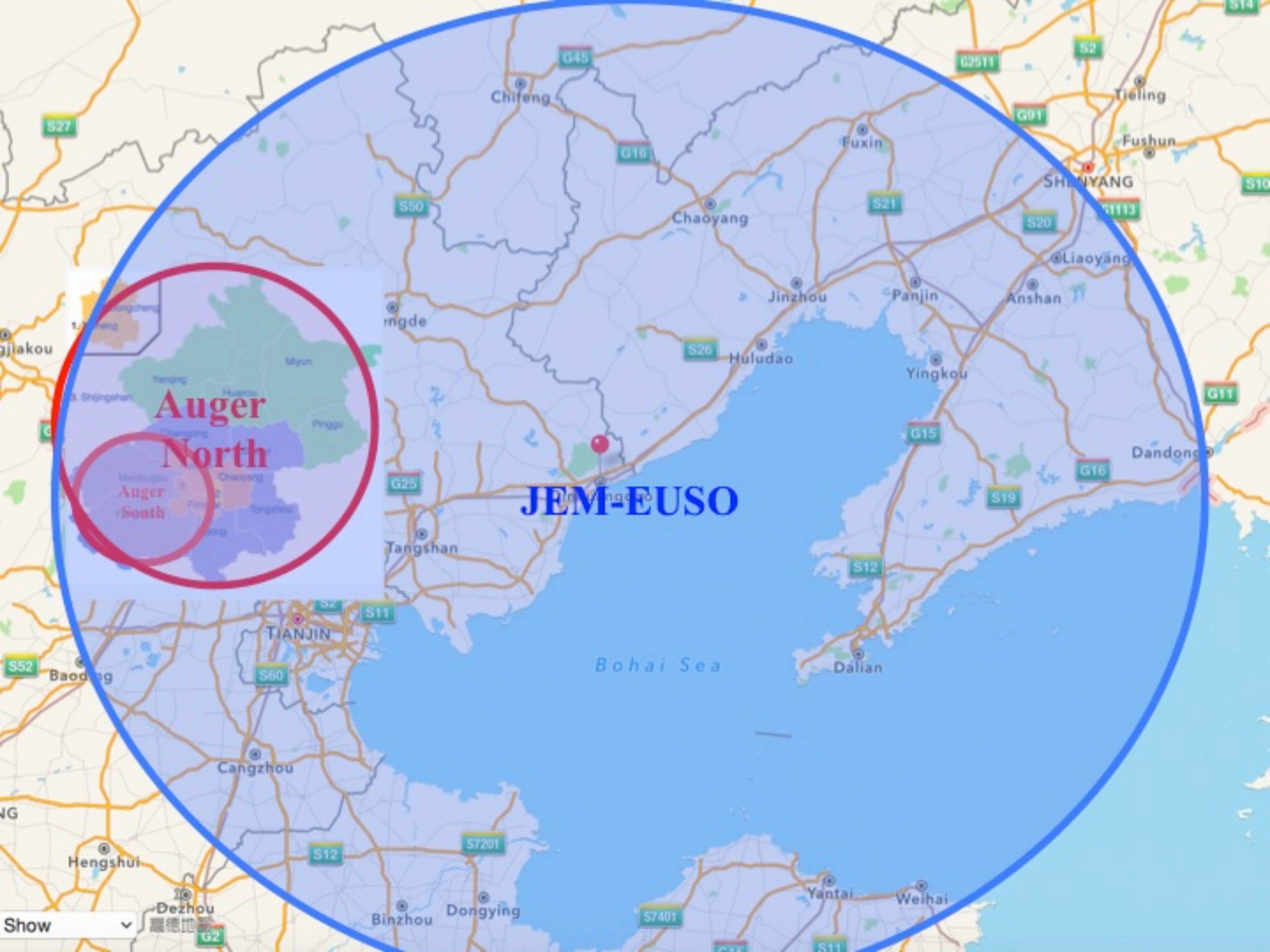
(19 country collaboration)

3,000 km^2 array

4 fluorescence telescopes

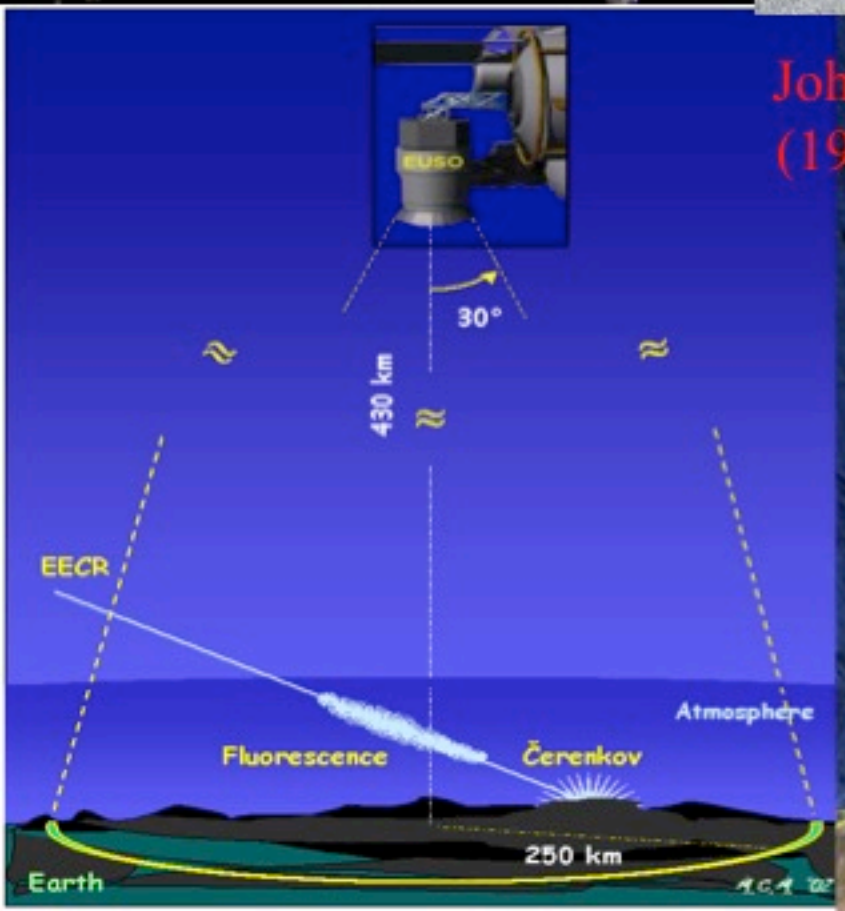

Beijing Municipality
21 M people
16.4 k km²
2. Dongcheng
1. Xicheng
3. Shijingshan
Yanqing
Huairou
Miyun
Pinggu
TA
700km²
Changping
Shunyi
Auger South
3,000 km²
Haidian
Mentougou
Chaoyang
3
1
2
Fengtai
Fangshan
Tongzhou
Daxing

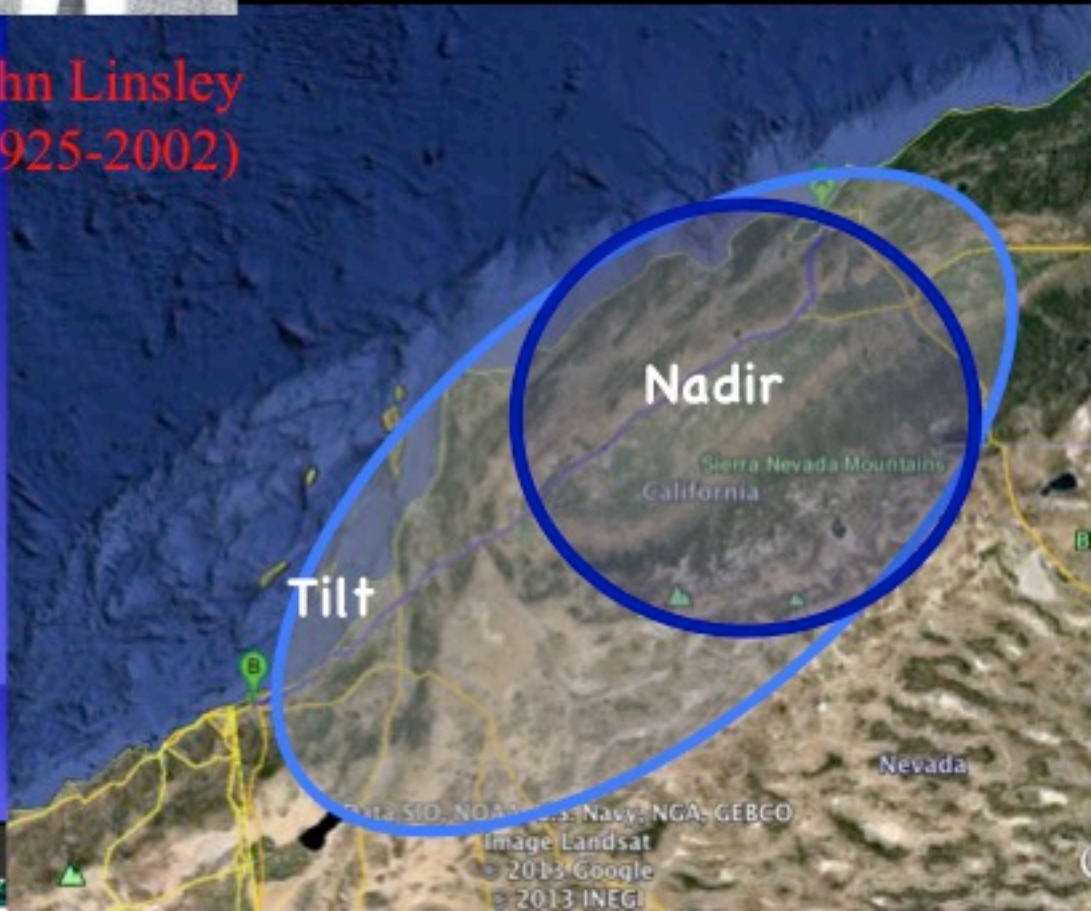

Beijing Municipality
21 M people
16.4 k km²
2. Dongcheng
1. Xicheng
3. Shijingshan
Yanqing
Huairou
Miyun
Pinggu
Changping
Auger North
20,000 km²
Shunyi
Haidian
Mentougou
Chaoyang
3
1
2
Auger South
Fengtai
Fangshan
Tongzhou
Daxing


Auger North
Auger South
JEM-EUSO
Bohai Sea
Chifeng
Fuxin
Tieling
Fushun
SHENYANG
Chaoyang
Liaoyang
Jinzhou
Panjin
Anshan
Huludao
Yingkou
Dandong
Tangshan
TIANJIN
Dalian
Cangzhou
Hengshui
Dezhou
Binzhou
Dongying
Yantai
Weihai
Show

Fluorescence from SPACE

John Linsley
(1925-2002)





JEM-EUSO Collaboration

Scientists from 16 countries

Piergiorgio Picozza, PI

JEM-EUSO

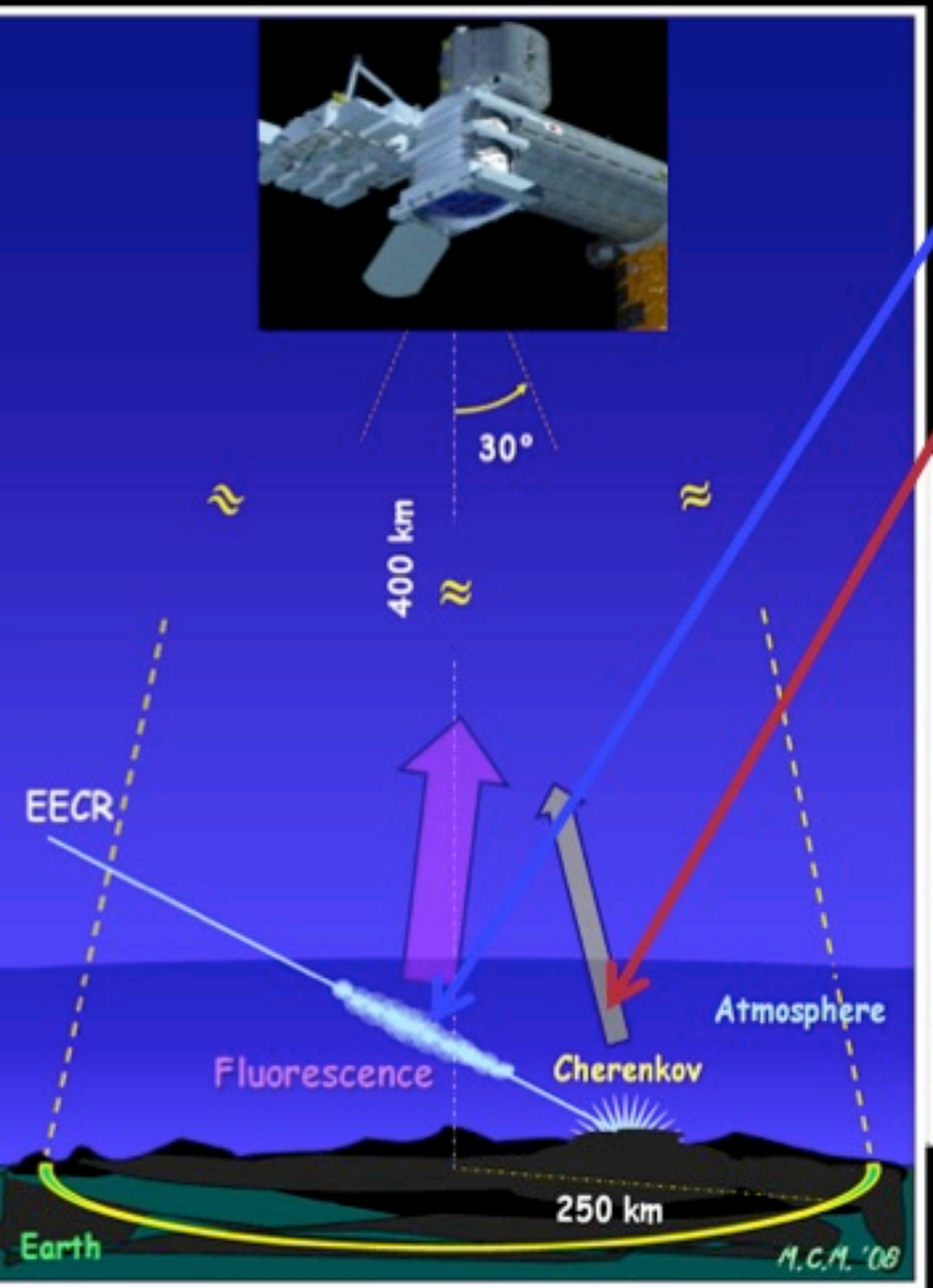
Main Science Goal

To discover the **most extreme** sources, i.e., Ultrahigh Energy Cosmic rays (UHECRs) sources

through a **significant** (1 o.o.m) increase in exposure to EECRs

*EECR: E > 60 EeV

Fluorescence from SPACE

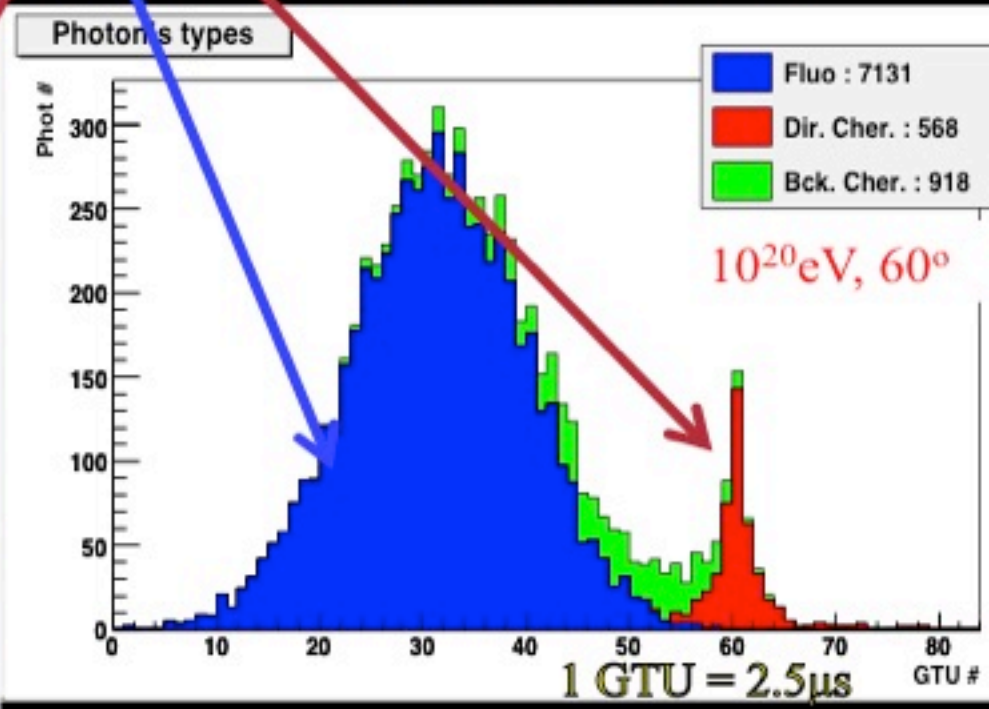


Fast Signal: 50 -150 μs

a) Fluorescence

b) Scattered Cherenkov

c) Direct (reflected Cherenkov)



Background: 500 /m^2 sr ns

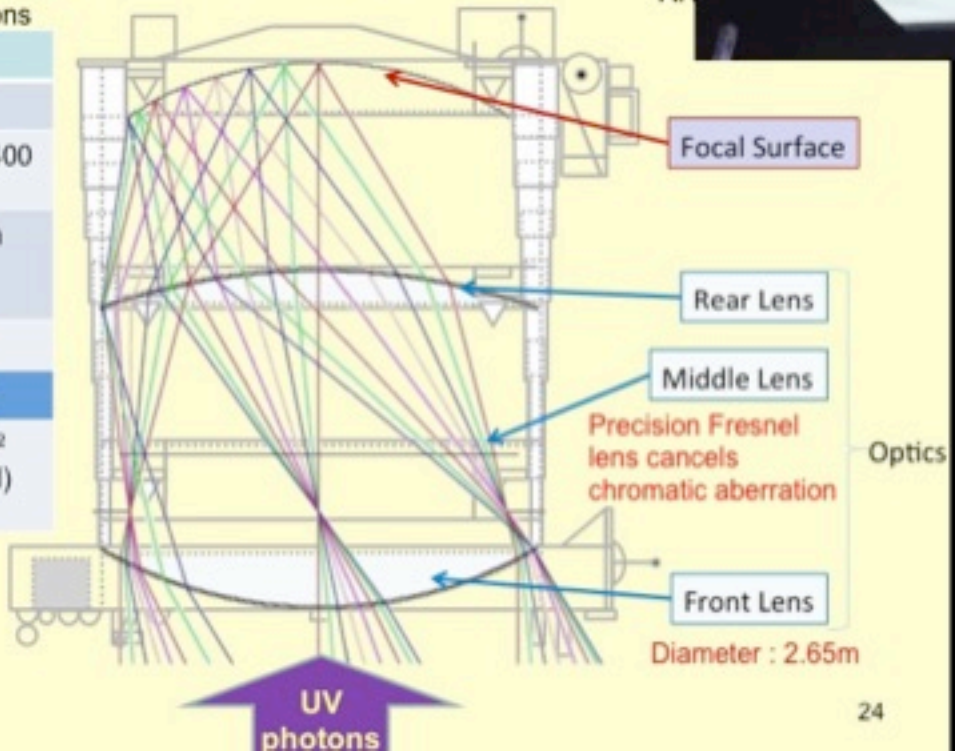
JEM-EUSO
Fresnel Lens Refractor
60 deg FOV

Optics design by ray tracin

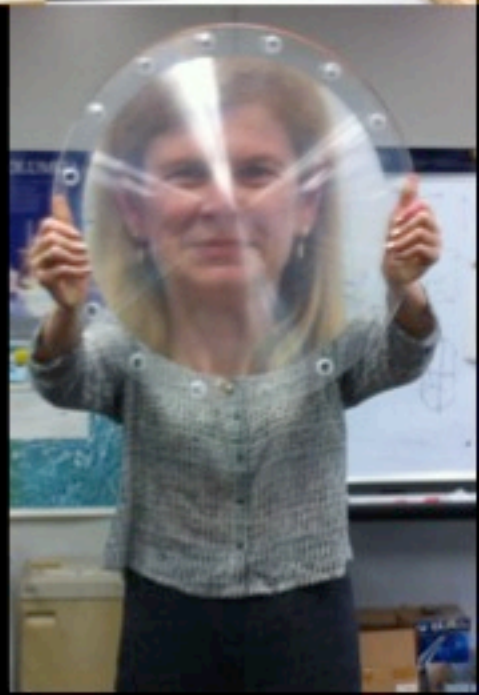
A.

Simulation conditions

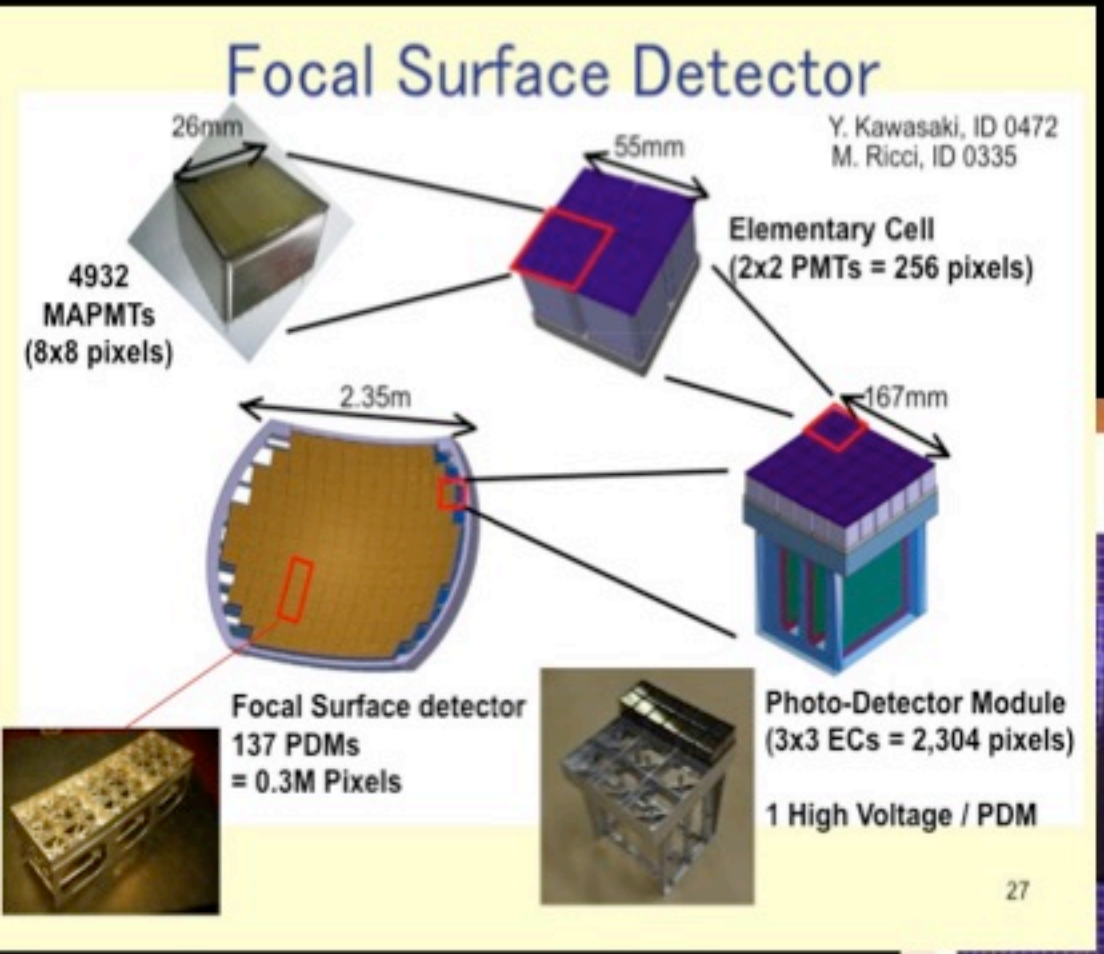
Optics	
FOV	±30
Optical bandwidth	330 ÷ 400 nm
Entrance Pupil Diameter	≥ 2.3 m
F/number	≤1
Focal surface	
Focal surface area	~4.5 m² (curved)

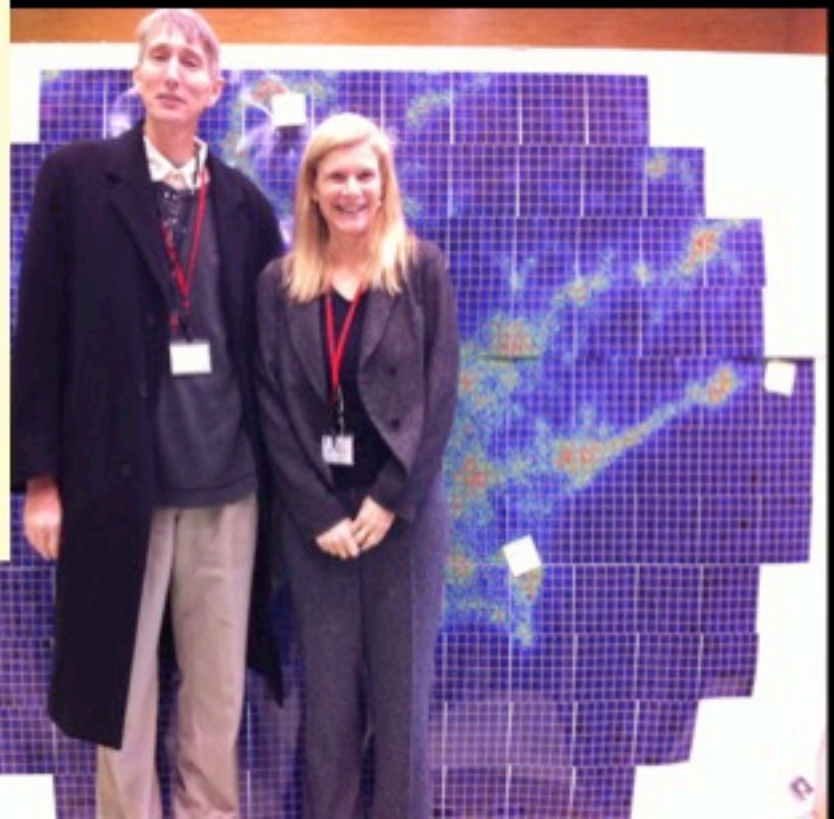


24

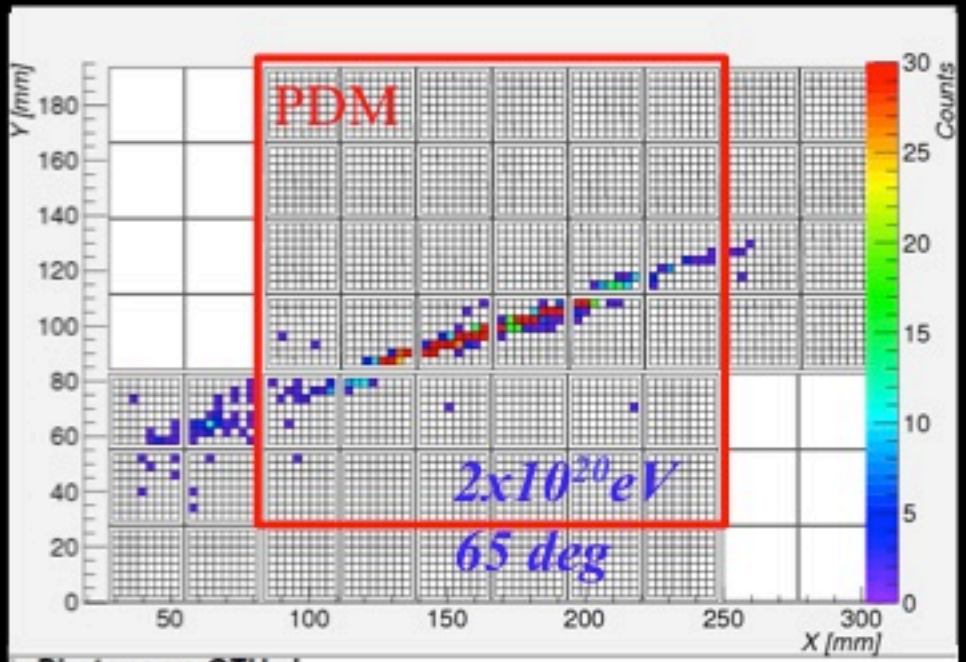


JEM-EUSO
0.3M pixel MAPMT ultrafast camera

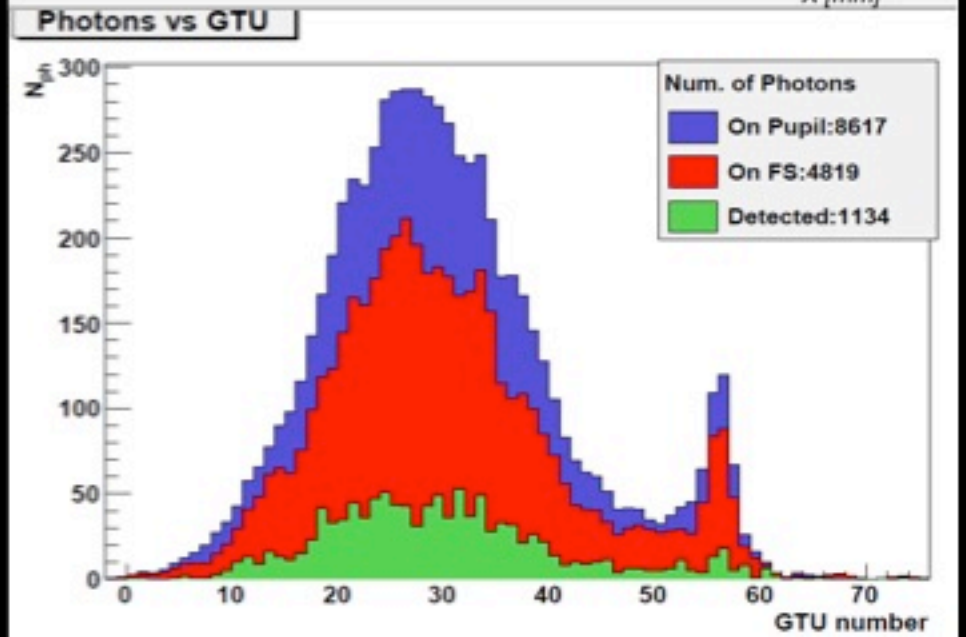




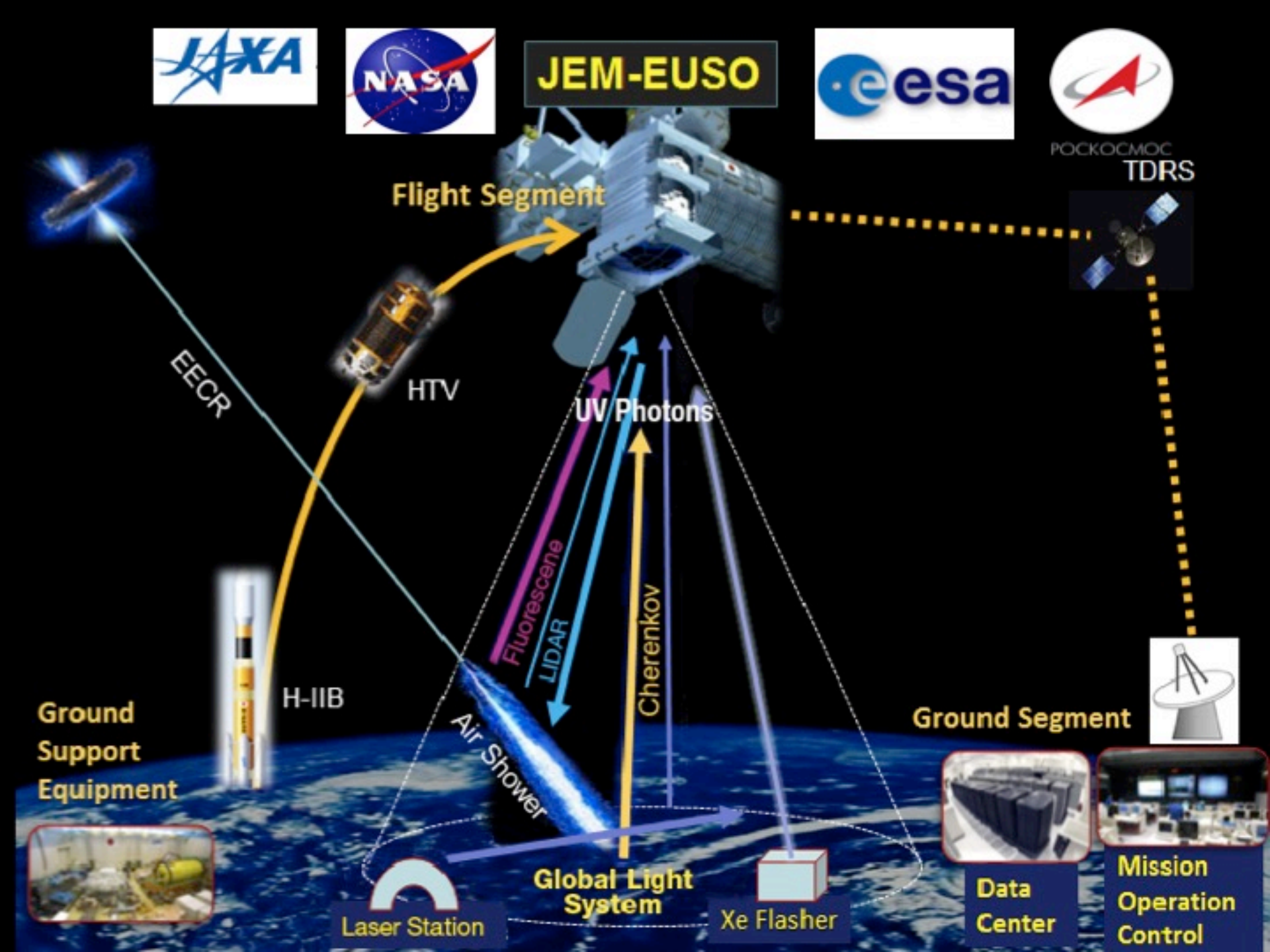
Shower Simulation

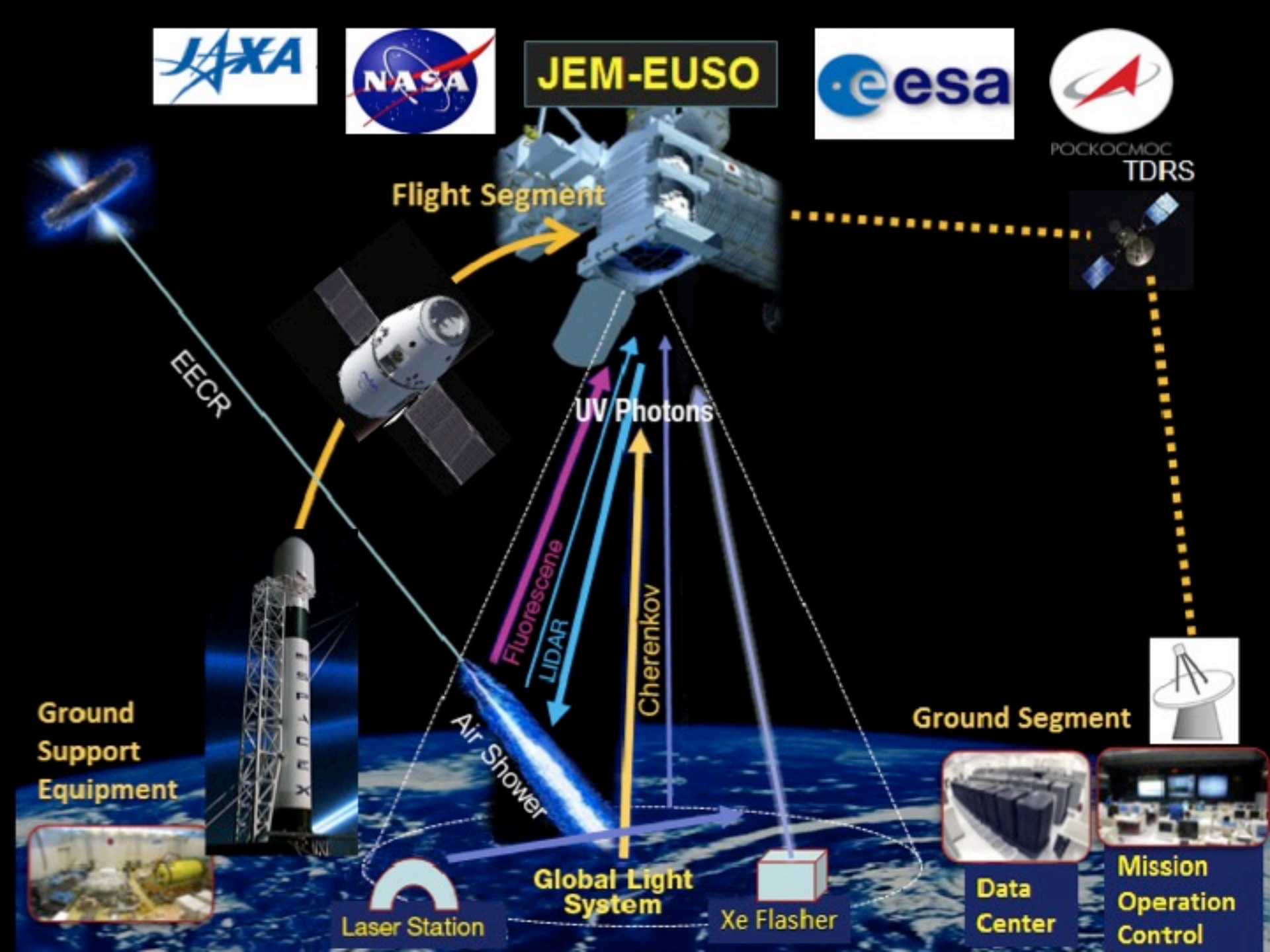


Simulated air shower image on the focal surface detector.



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


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

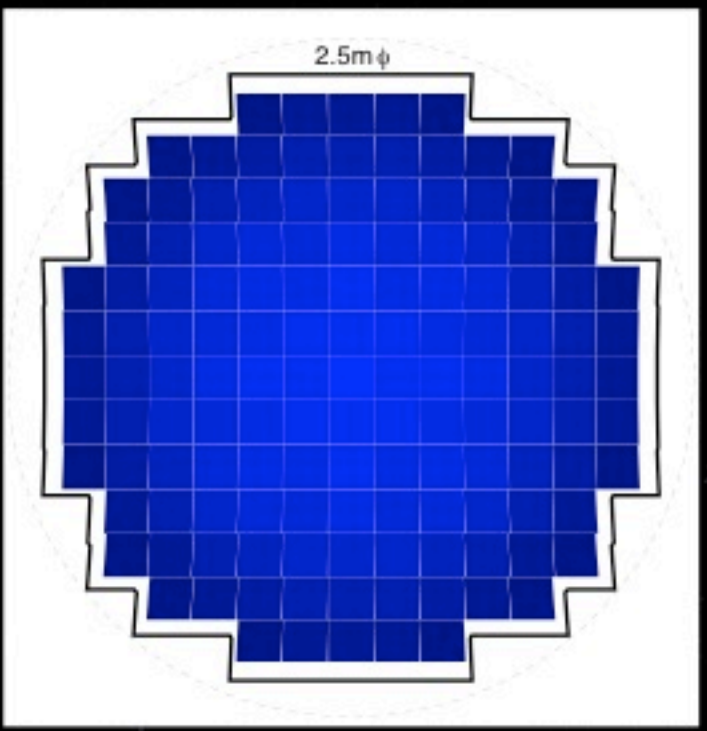

JAXA
NASA
JEM-EUSO
esa
РОСКОСМОС
TDRS
Flight Segment
EECR
UV Photons
Fluorescene
LIDAR
Cherenkov
Air Shower
Ground Support Equipment
Ground Segment
Laser Station
Global Light System
Xe Flasher
Data Center
Mission Operation Control

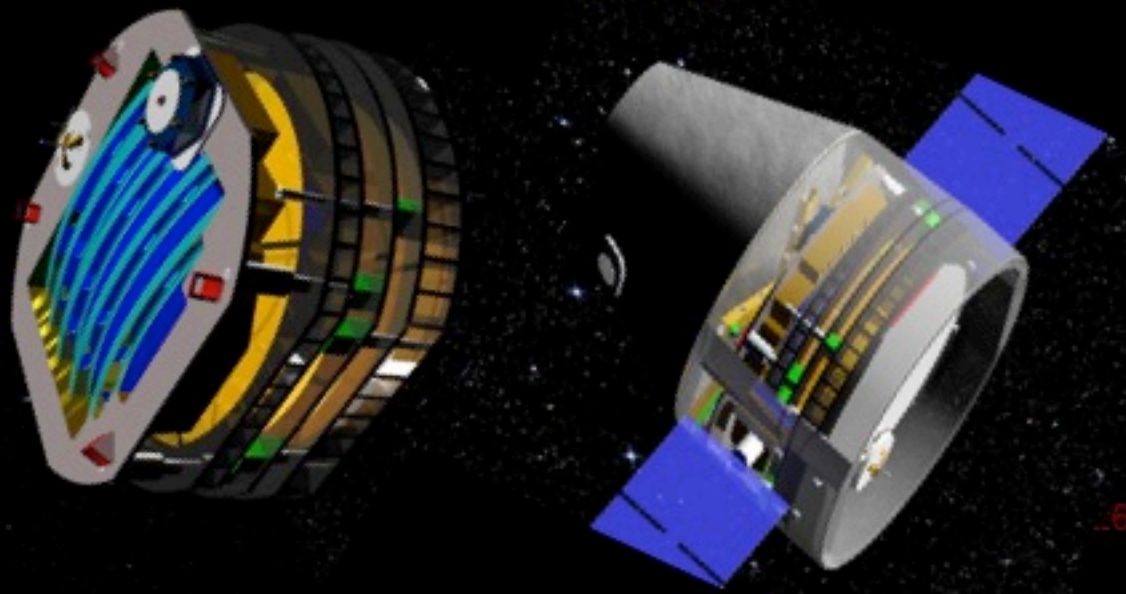
Improved
Energy resolution:
Requirements:
30% for E > 80 EeV
Central region
20% for E > 50 EeV;
5 to 10% for E > 300 EeV

SPACEX

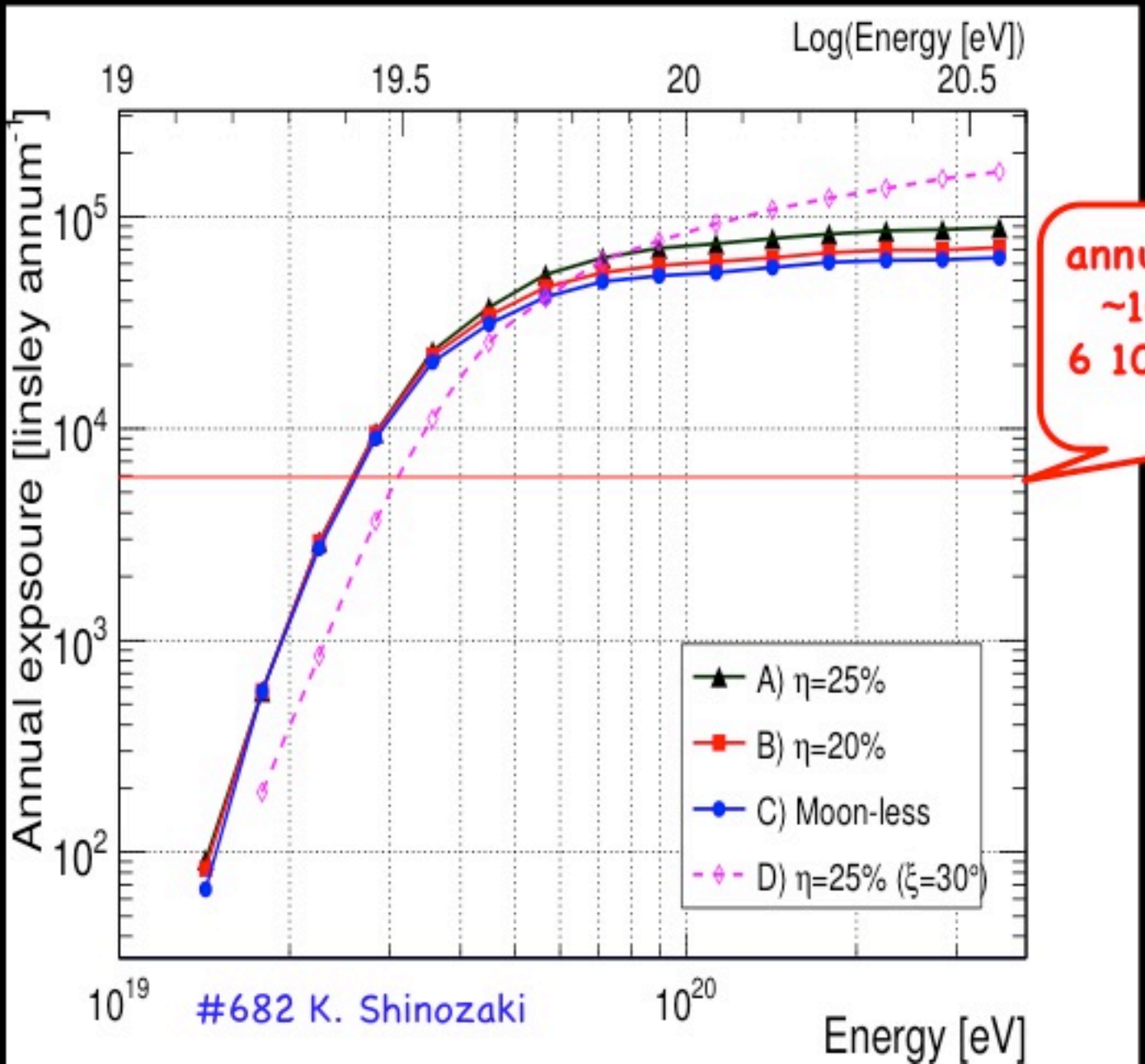
DRAGON

X_{max} resolution
Requirements: 120 g/cm^2 for 200 EeV
Central region
100 g/cm^2 for E> 50 EeV;
50 g/cm^2 for E > 300 EeV





JEM-EUSO Annual Exposure



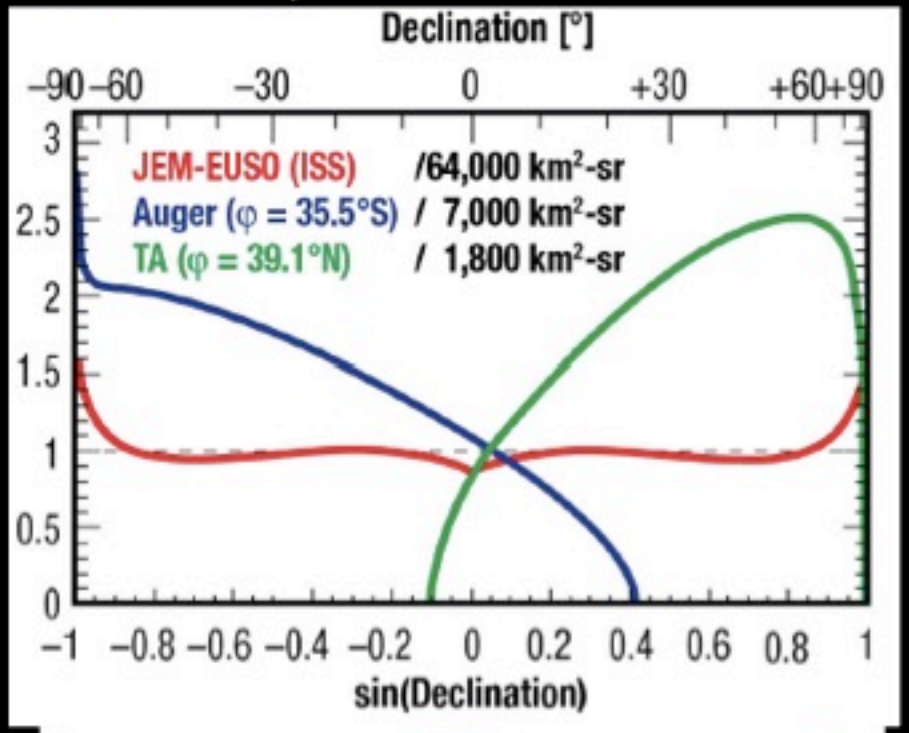
annual exposure
~10 x Auger
6 10^4 km^2 sr yr

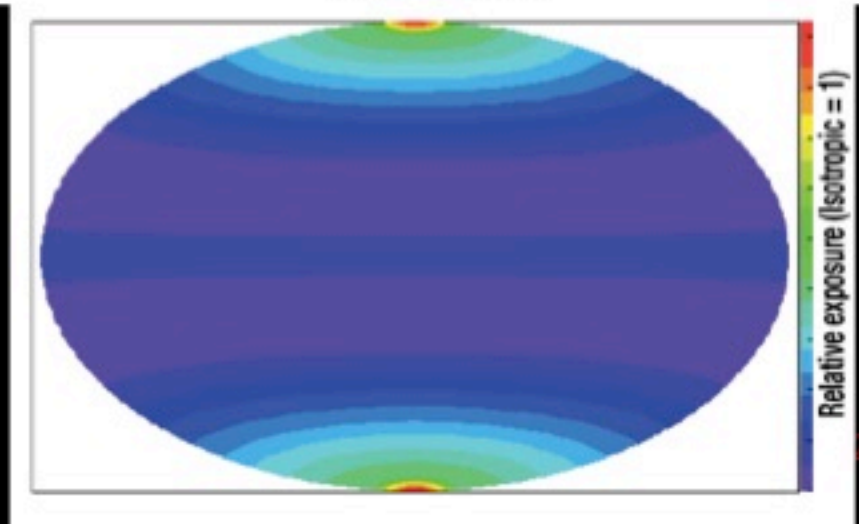
JEM-EUSO Full Sky Coverage
with nearly uniform exposure

The ISS ORBIT

http://www.nlsa.com/

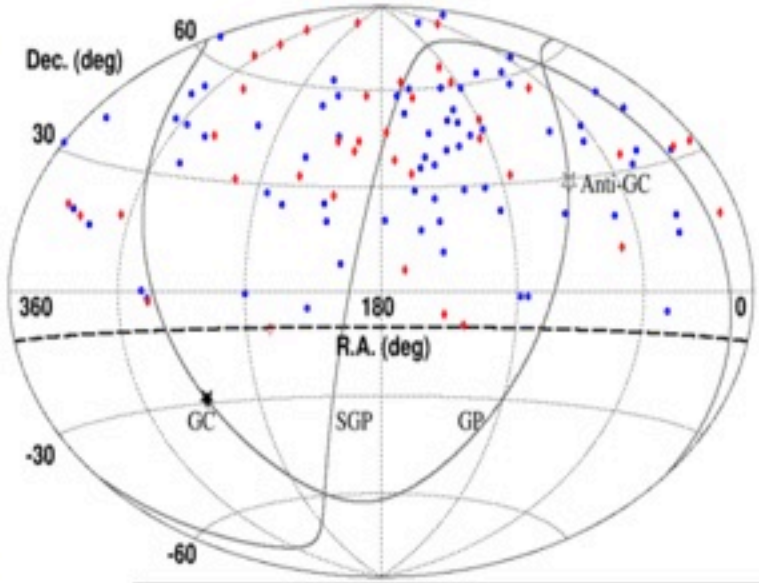
Inclination: 51.6°
Height: ~400km

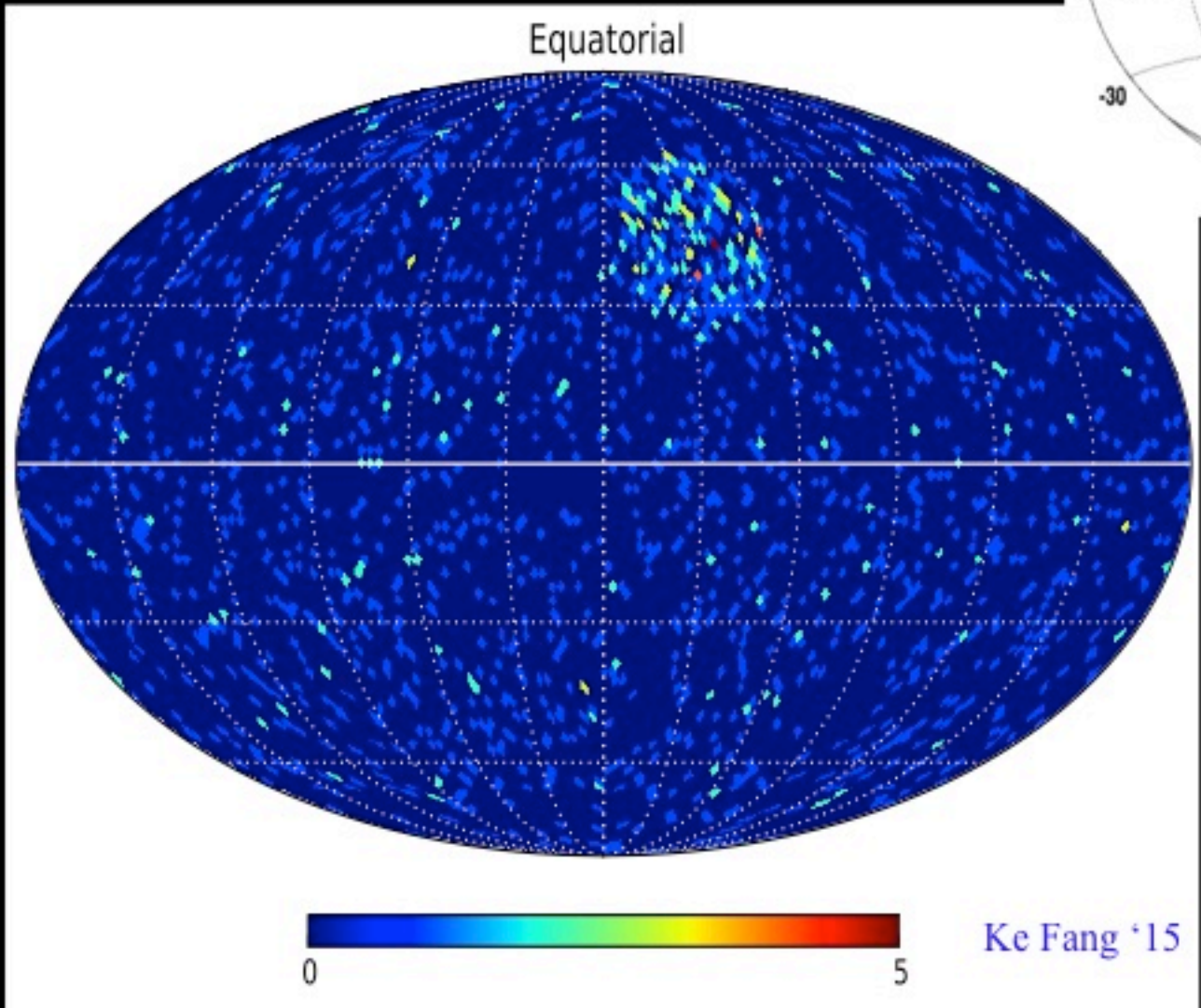




JEM-EUSO Source Identification

2620 events > 57 EeV over the entire sky
240 events > 57 EeV from HotSpot

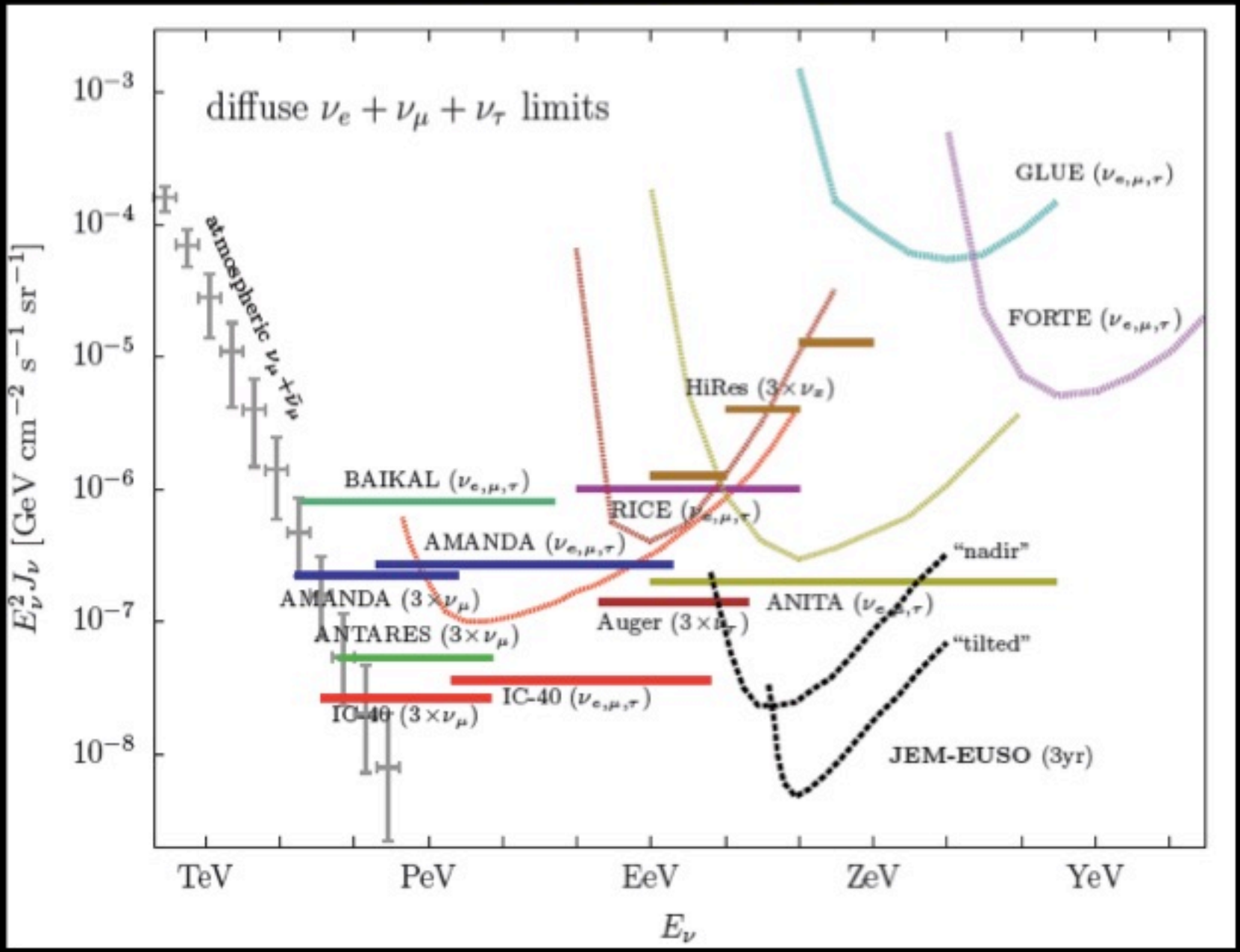




Ke Fang '15

5 yr Mission
using TA 7yr numbers
(1 JE yr = 40 TA yr
= 10 TAx4 yr)

ZeV neutrinos?



JEM-EUSO Science objectives

Study of Cosmic Particles at the Highest Energies

Main Science Objectives:
Identify **UHE sources**
Measure energy spectra of individual sources
Measure the trans-GZK spectrum

Exploratory objectives:
Discover UHE Gamma-rays
Discover UHE neutrinos
Study Galactic and Extragalactic Magnetic Fields
Discover Relics from the Early Universe (e.g., SHDM)

Atmospheric Science
Nightglow
Transient luminous events (TLE)
Meteors and meteoroids

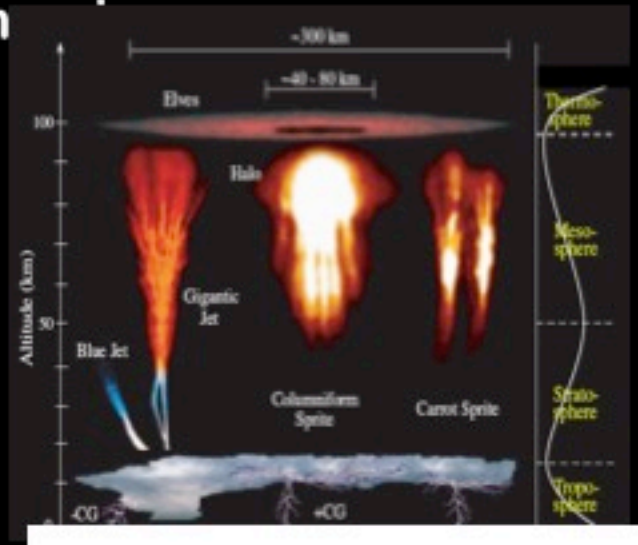
JEM-EUSO Science objectives

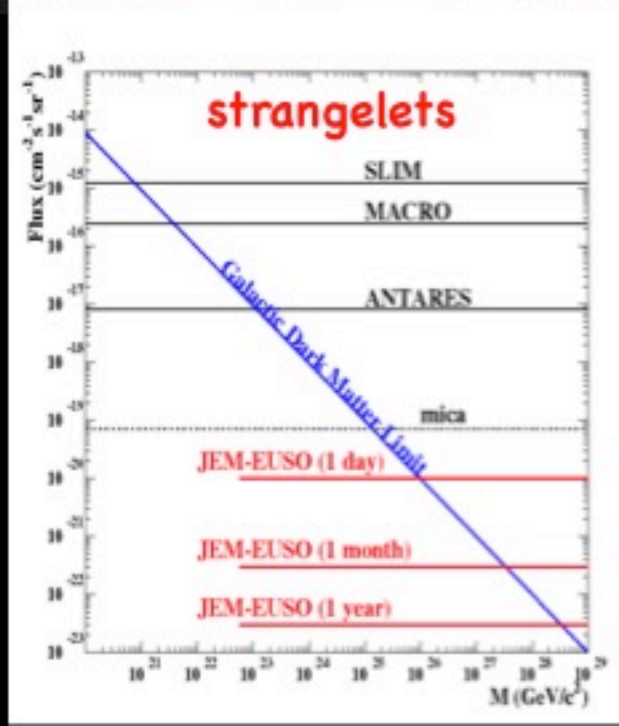
Study of Cosmic Particles at the Highest En

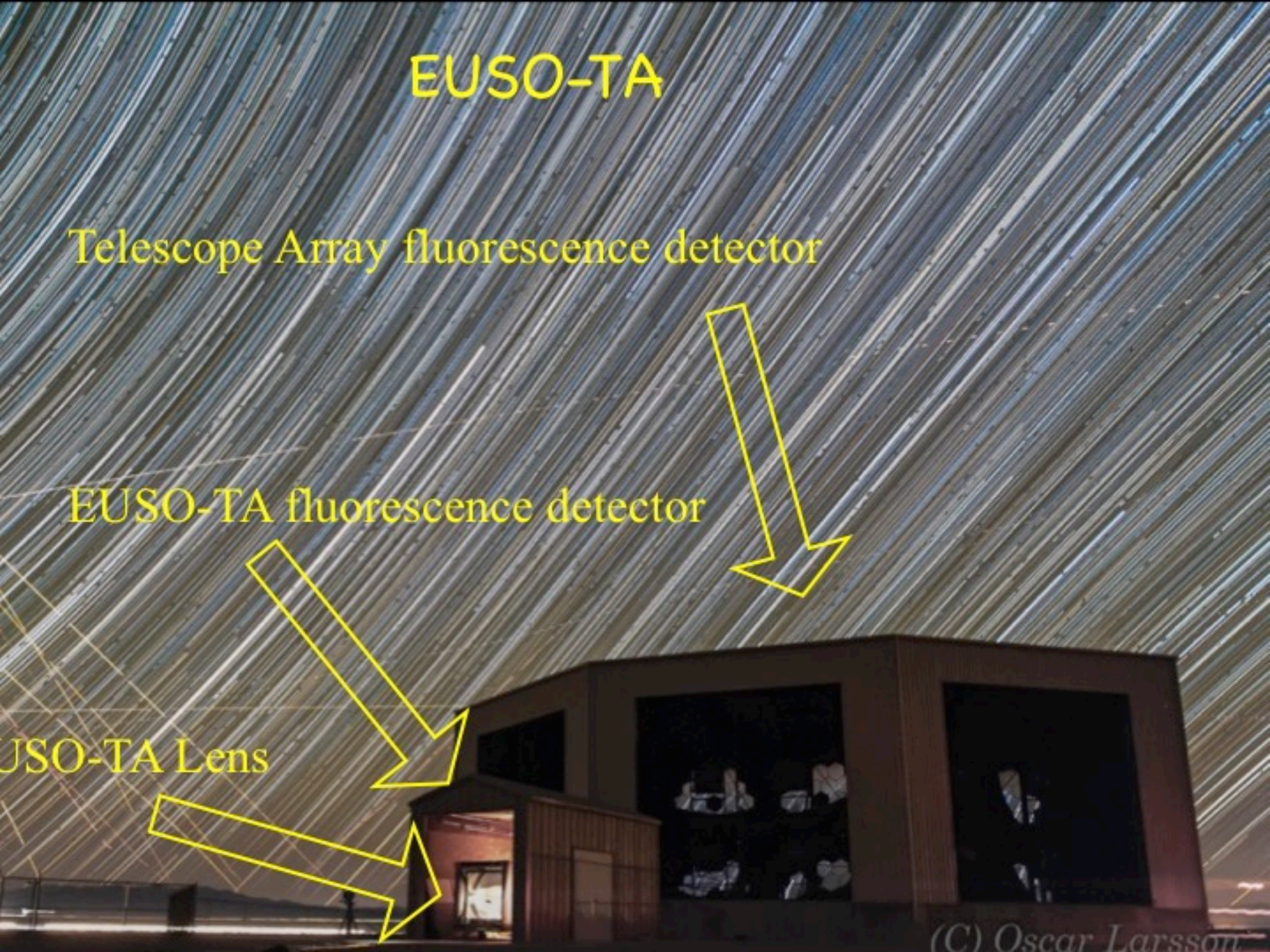
Main Science Objectives:
Identify **UHE sources**
Measure energy spectra of individual sources
Measure the trans-GZK spectrum

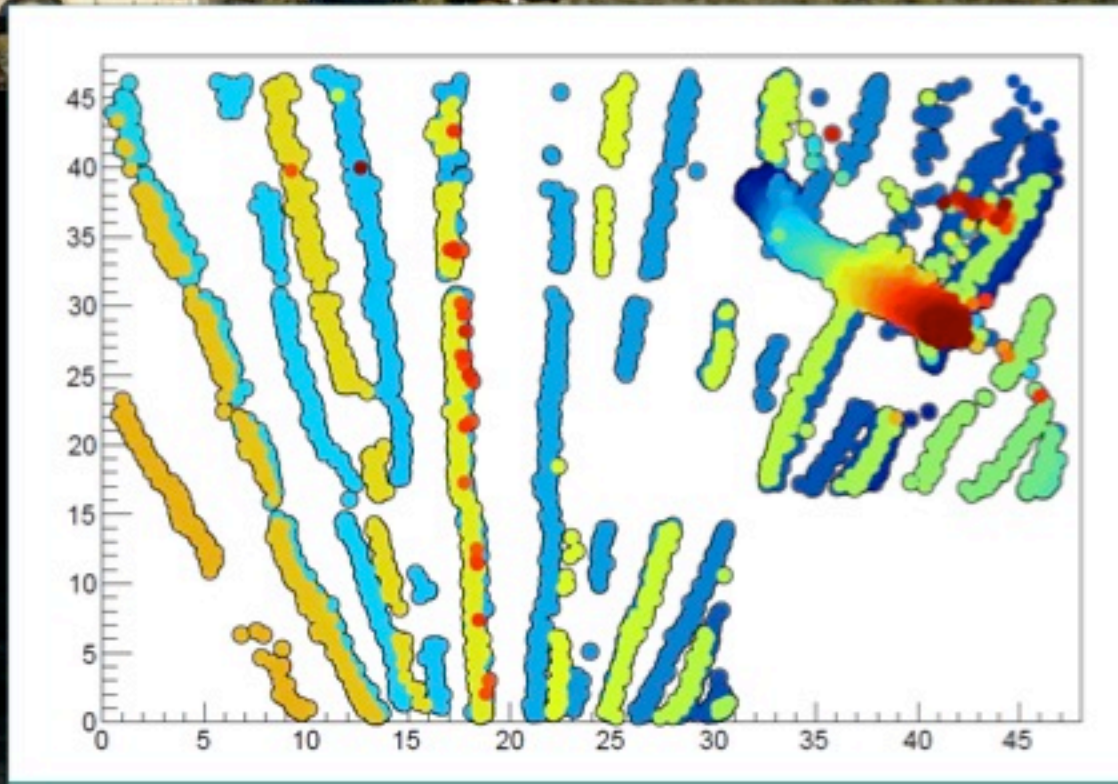
Exploratory objectives:
Discover UHE Gamma-rays
Discover UHE neutrinos
Study Galactic and Extragal. Magnetic Fields
Discover Relics from the Early Universe
(e.g., SHDM)

Atmospheric Science
Nightglow
Transient luminous events (TLE)
Meteors and meteoroids



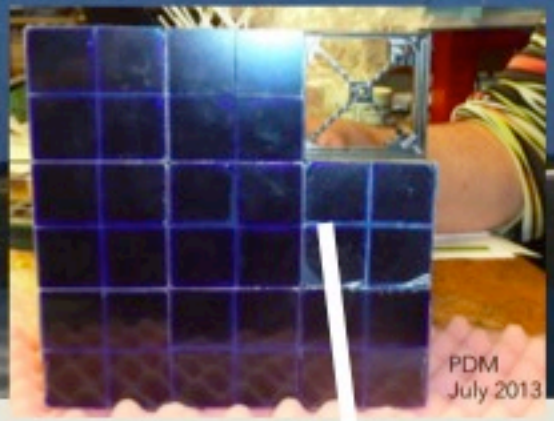


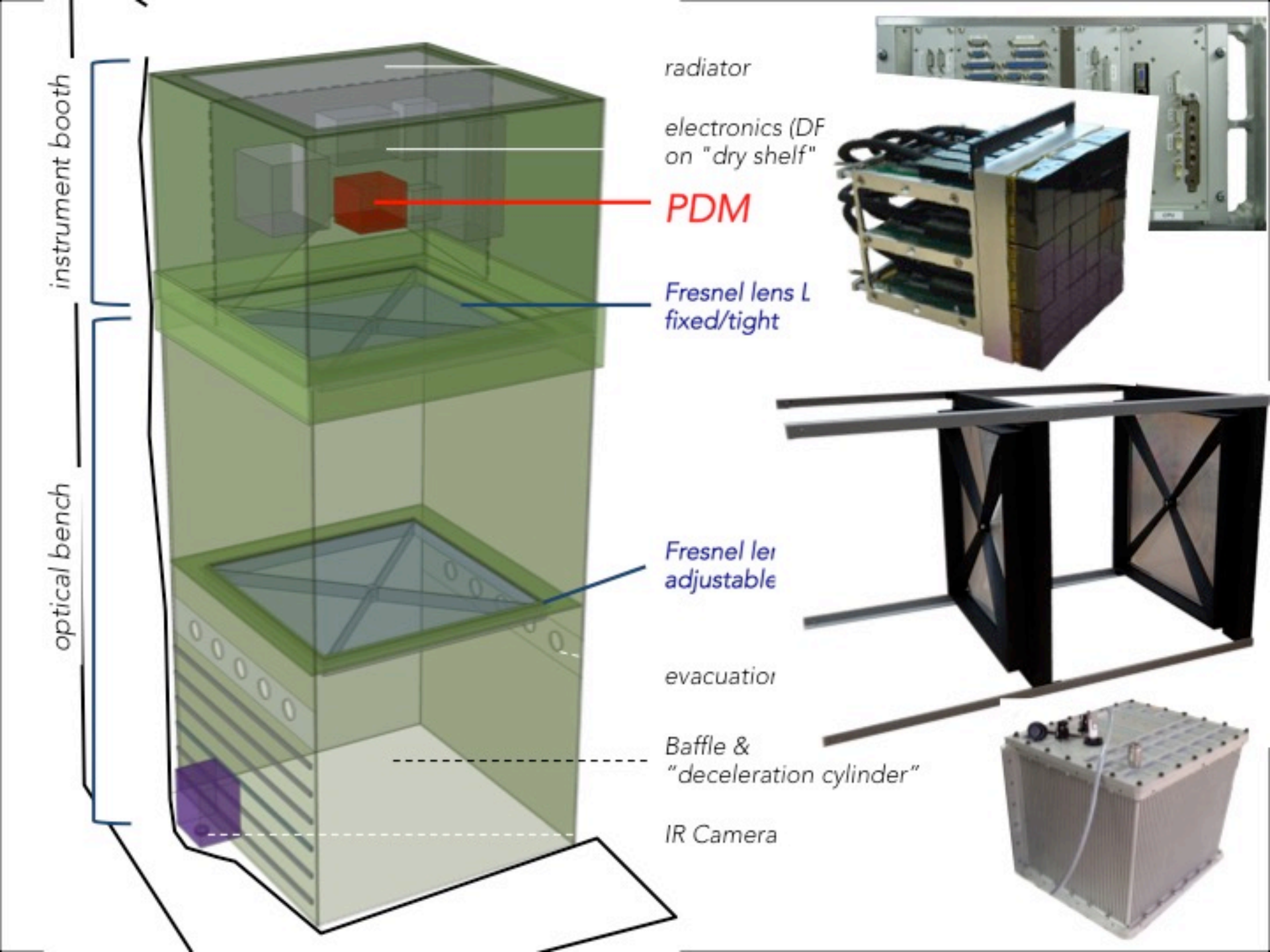

EUSO-TA
Telescope Array fluorescence detector
EUSO-TA fluorescence detector
USO-TA Lens
(C) Oscar Larsson

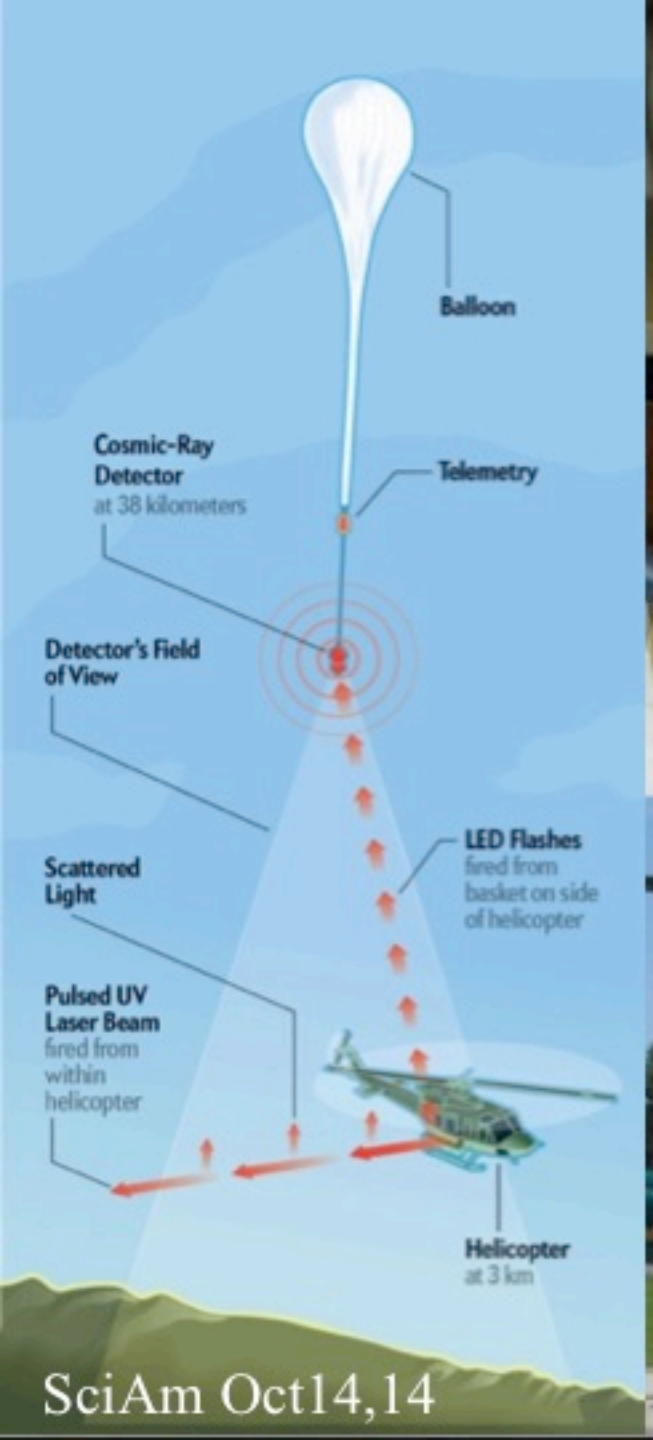

0
5
10
15
20
25
30
35
40
45

EUSO Balloon:

1st flight and first light on 24-25.8.2014

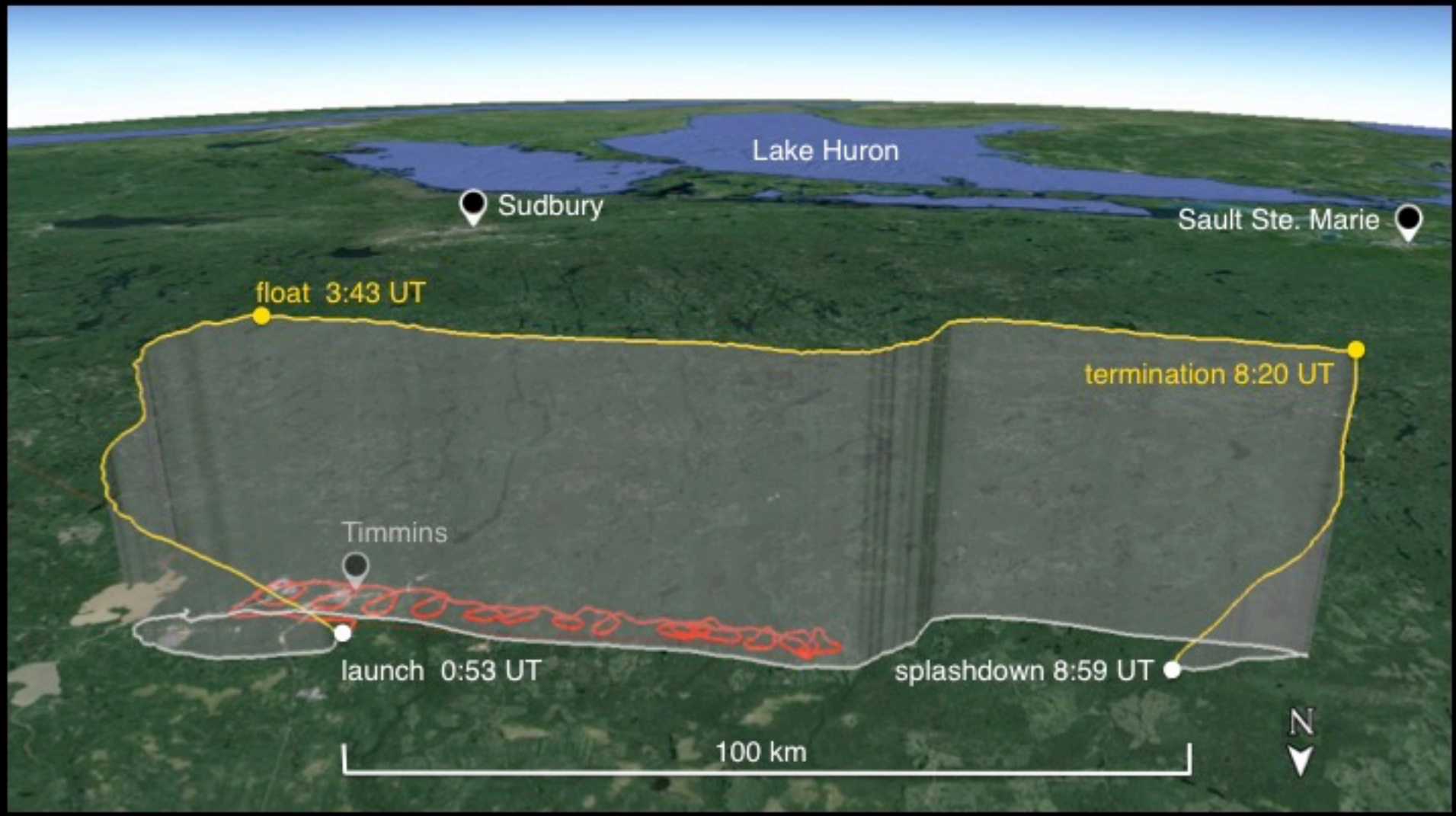



instrument booth
optical bench
radiator
electronics (DF
on "dry shelf"
PDM
Fresnel lens L
fixed/tight
Fresnel le
adjustable
evacuatio
Baffle &
"deceleration cylinder"
IR Camera



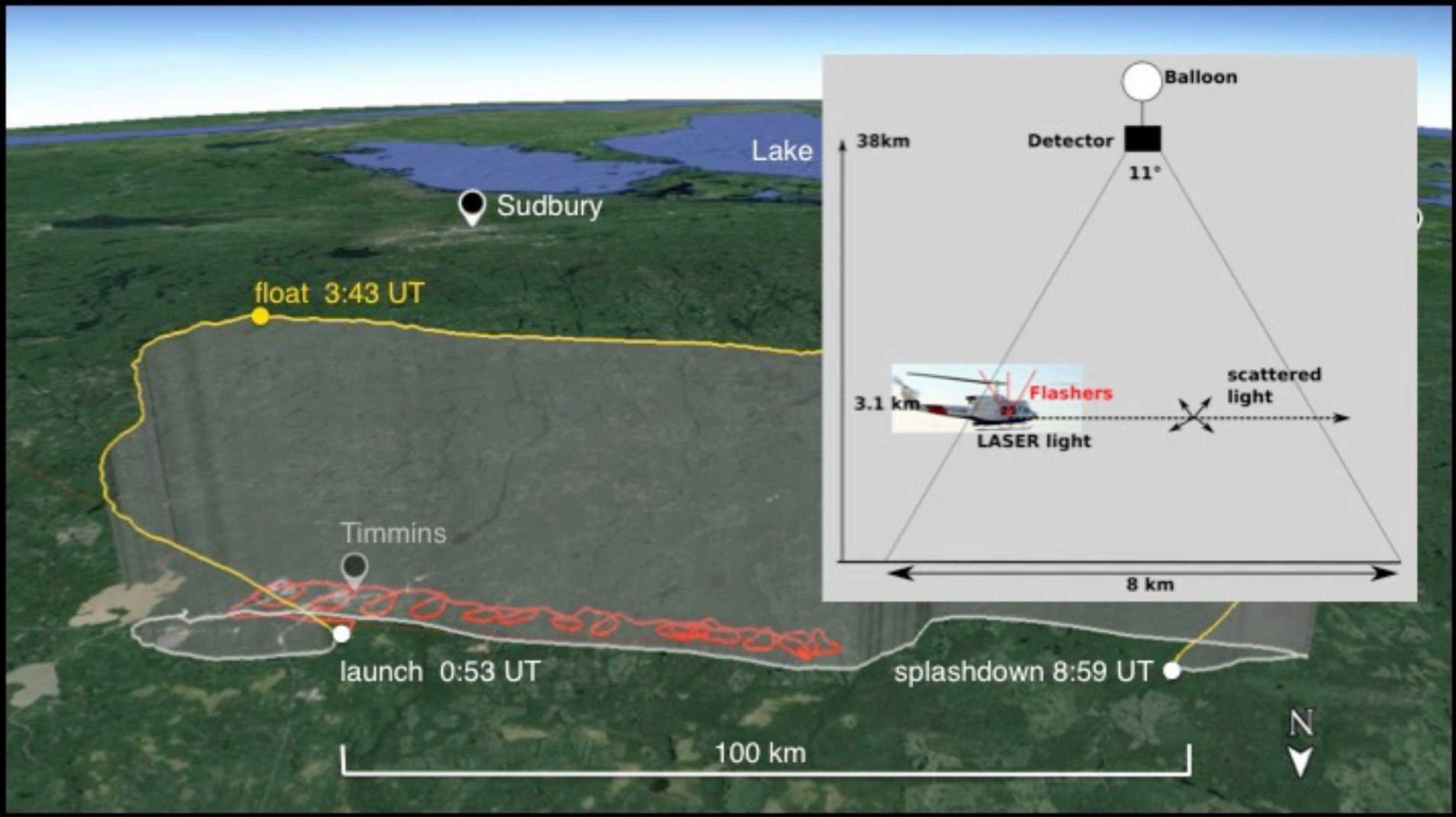
SciAm Oct14,14

EUSO Balloon first flight



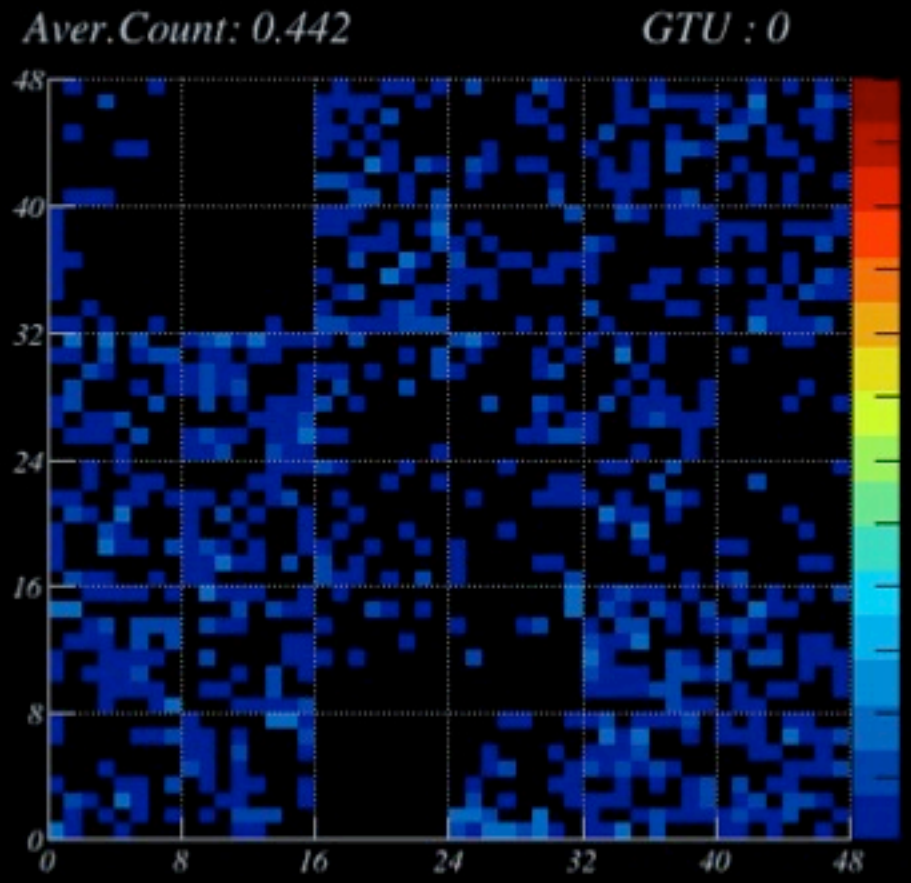
EUSO-Balloon: was launched on August, 24 2014 from Timmins, (Canada)

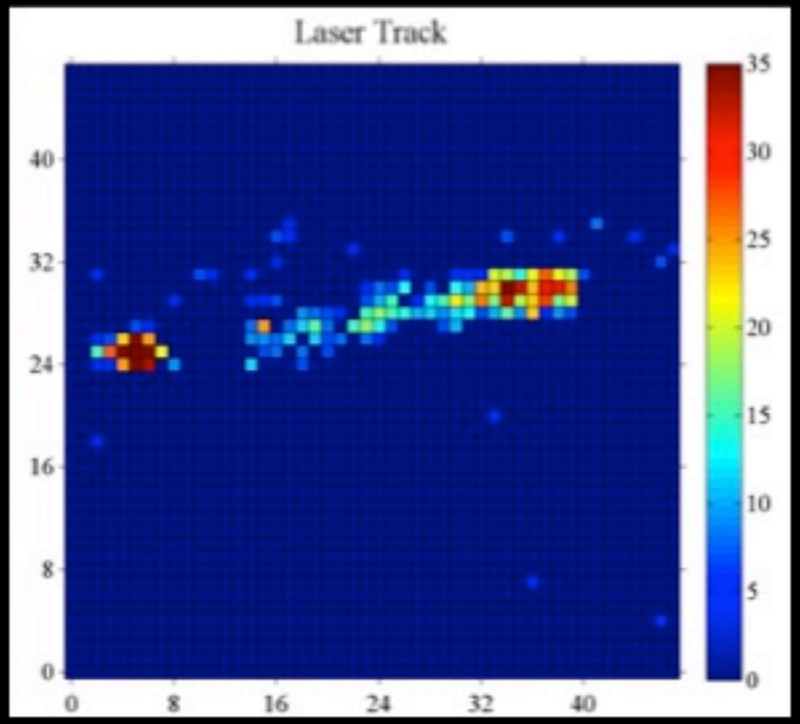
EUSO Balloon first flight



EUSO-Balloon: was launched on August, 24 2014 from Timmins, (Canada)

Flasher & Laser shot





EUSO-SPB mission

Super Pressure Balloon = SPB

On average, 1 event/night in March/April
Possibility to fly for several weeks

EUSO-SPB

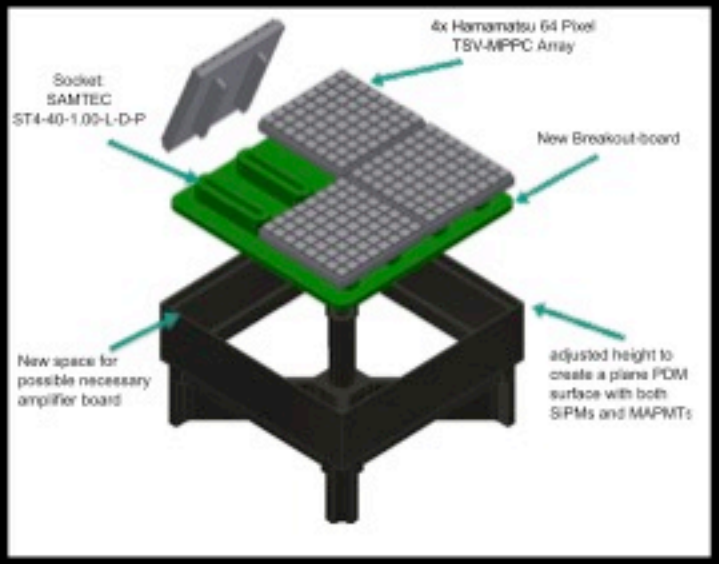
Super Pressure Balloon (SPB)
Ultra Long Duration flight
2017 Spring Campaign

First observations of UHECRs from near space: 20 nights

Photon Threshold	Events/ hour	Events/ dark period
200	0.42	50
300	0.18	21
400	0.09	11

Path of the successful 2015 flight by NASA, from Wanaka NZ

SPB Flight under NASA leadership (2017)



SPB-flight: Different Background conditions, transient atm. events

Test of a SiPM based detection element (a subset of the PDM)

A key development of the JEM-EUSO program

Path of the successful 2015 flight by NASA, from Wanaka NZ

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

40.0m to go!

Earth surface ~ 10^8 km²

~3.4 10^6 events/yr


Reach out to the Cosmos to study
the Highest Energies!
謝謝
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