Leading Observatories of Ultrahigh Energy Cosmic Rays

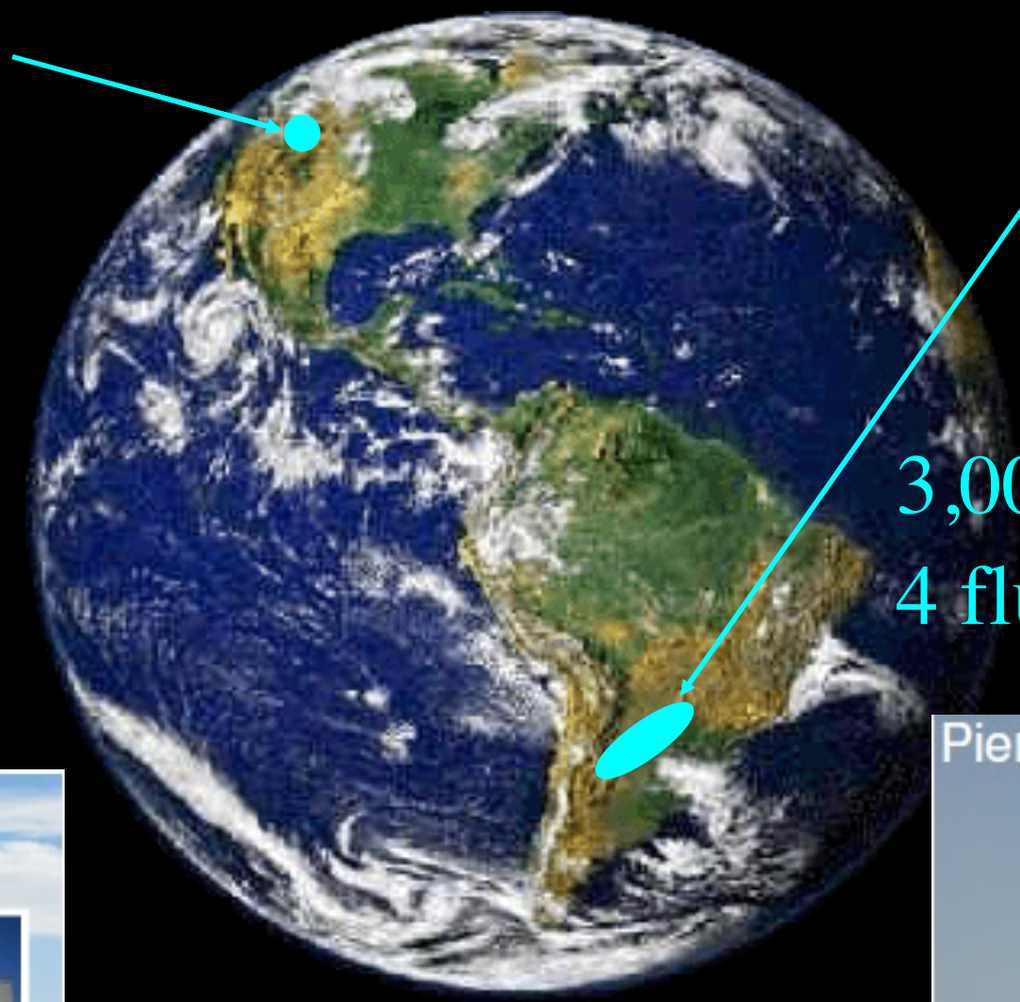
Telescope Array

Utah, US

(5 country collaboration)

700 km^2 array

3 fluorescence telescopes



Pierre Auger Observatory

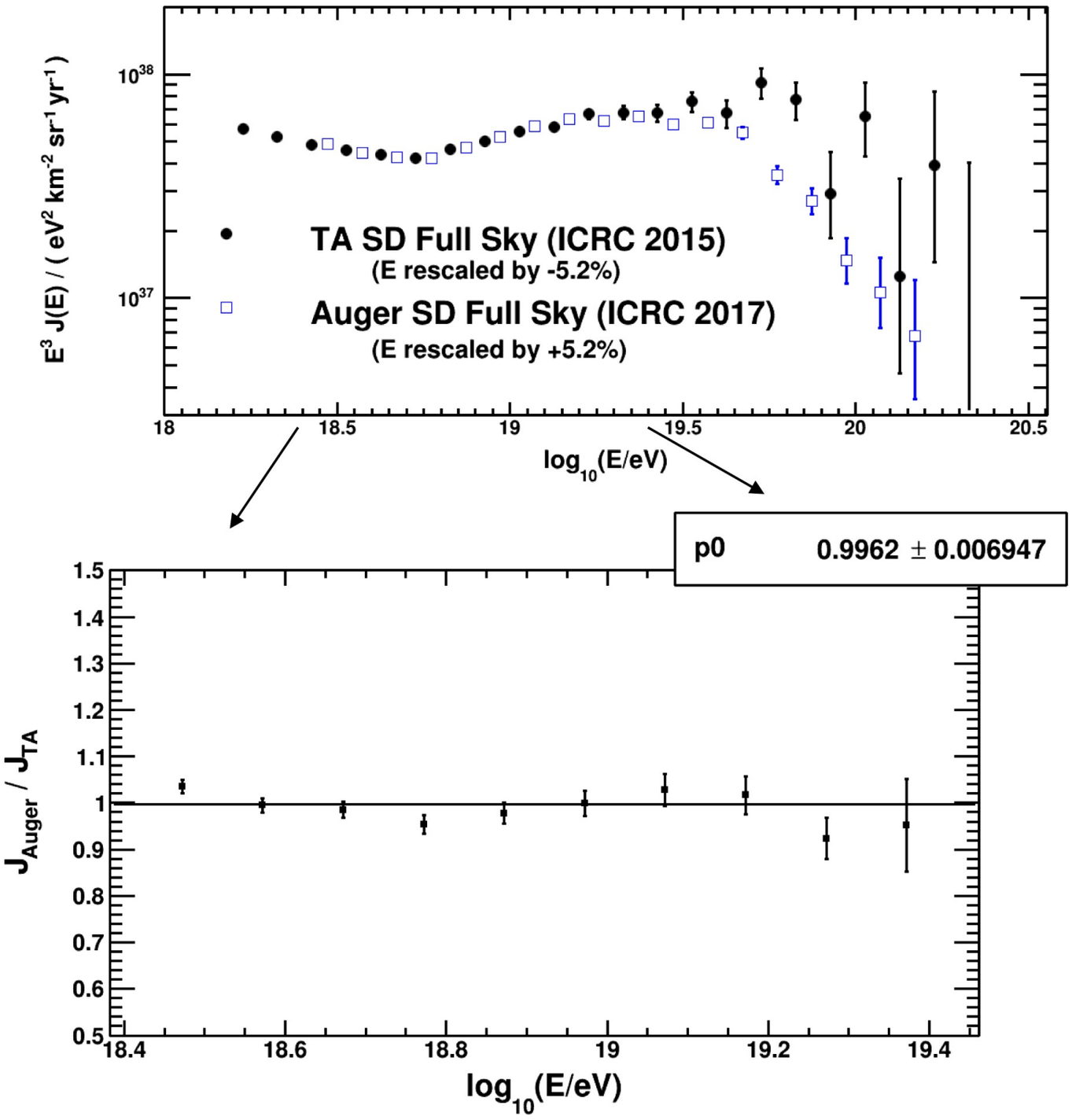
Mendoza, Argentina

(19 country collaboration)

3,000 km^2 array

4 fluorescence telescopes

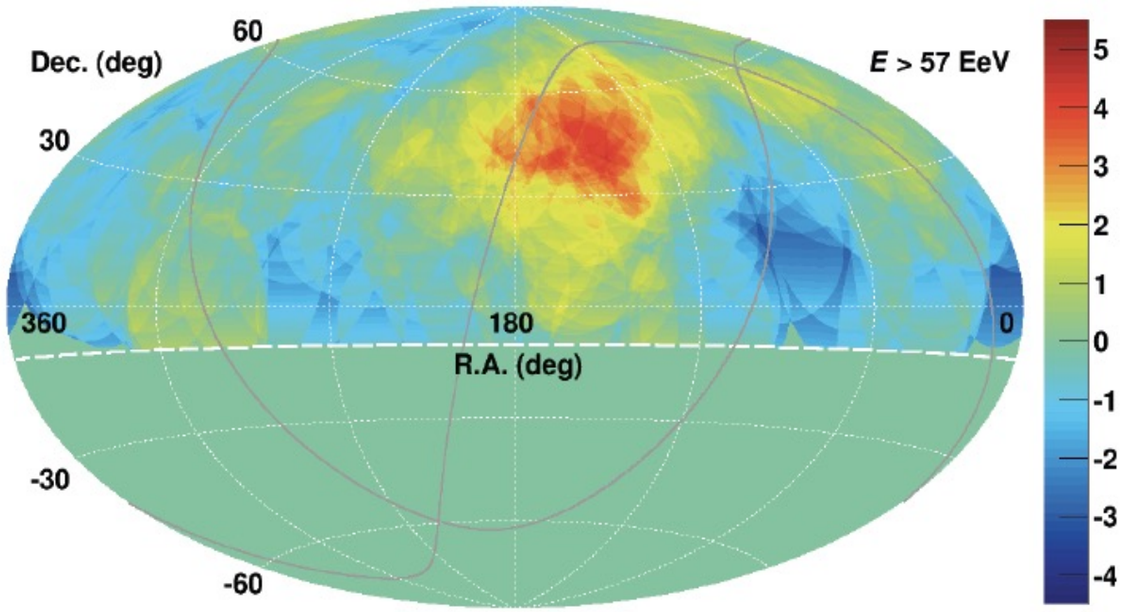
Rescale Auger and TA energies



- Constant rescaling factor of **5.2%**
  - From fitting ratio of fluxes Auger/TA into a unity in the ankle region
  - Auger energies *raised* by 5.2%
  - TA energies *lowered* by 5.2%
- Agree in the ankle region $10^{18.4}$ eV < E < $10^{19.4}$eV after rescaling
- **Difference above $10^{19.4}$ eV persists after locking energy scales of experiments**

8

TA "Hot Spot" 2017 ($E > 57$ EeV, $\sim 3\,\sigma$)



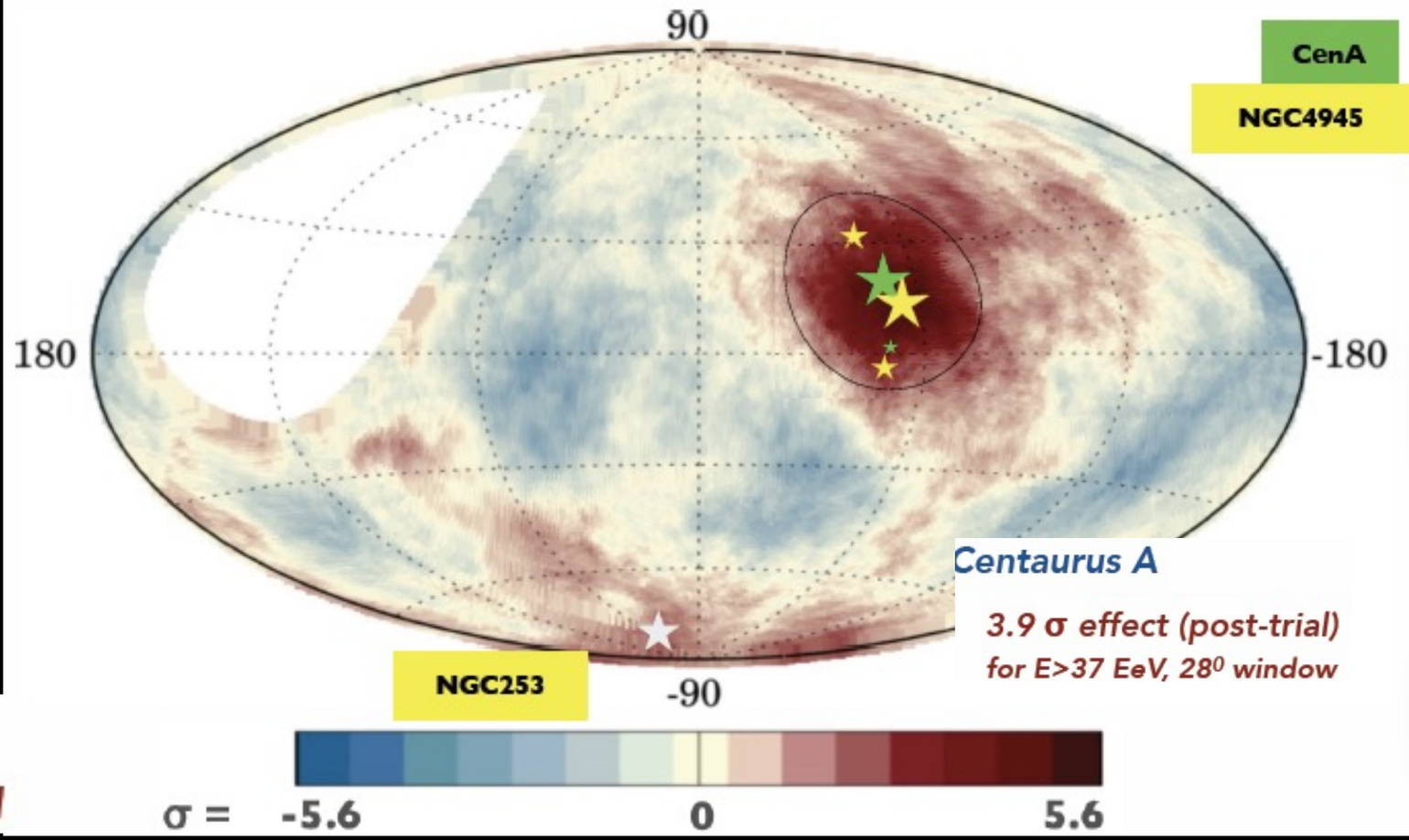
TA

Anisotropy hints
@ E > 40 EeV

Auger

Total SD events with E>32 EeV : 2157

Total exposure 101,400 km² sr yr



ICRC2019 *4.5 σ for SBGs*

[Jan 2004-Aug 2018] *3.1 σ for γ-AGN*

How many UHECRs > 60 EeV?

- Auger w/ 3,000 km^2
- ~25 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

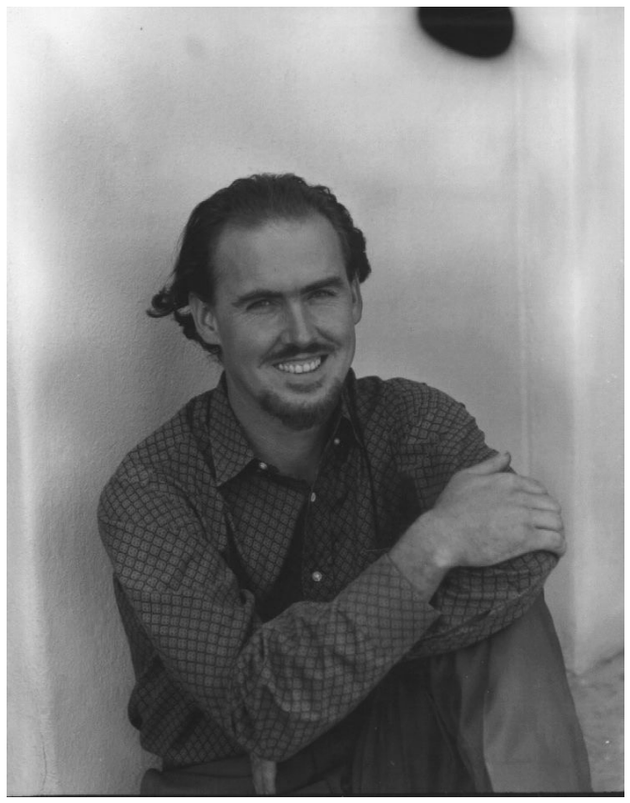
- **POEMMA**
- **~300 events > 60 EeV/y**

4 o.o.m to go!

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

~3.4 10^6 events/yr

1979, An idea* of John Linsley



John Linsley in 1979 in the Field Committee Report of NASA “Call for Projects and Ideas in High Energy Astrophysics for the 1980s”

The concept to observe, by means of Space Based devices looking at Nadir during the night, the fluorescence light produced by an EAS proceeding in the atmosphere

Y. Takahashi (1995): MASS: Maximum Energy Auger (Air Shower Satellite Italian Mission)

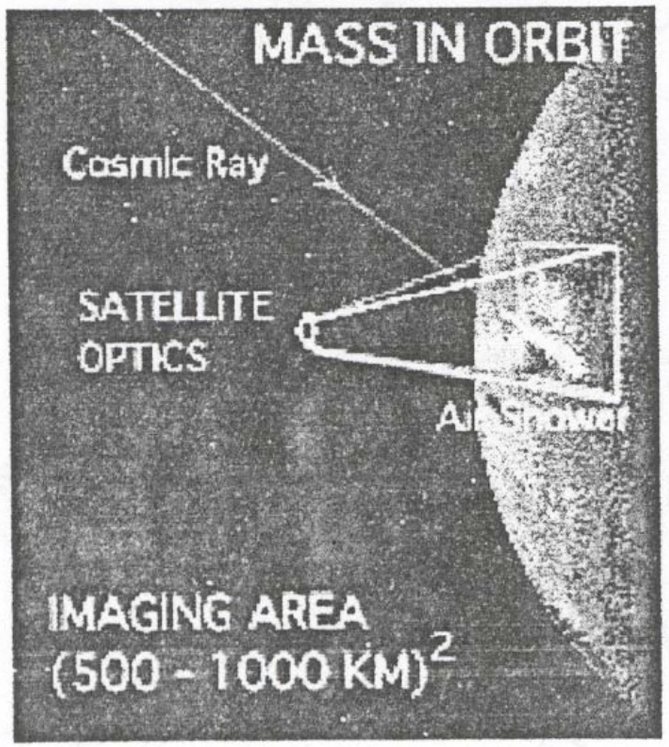
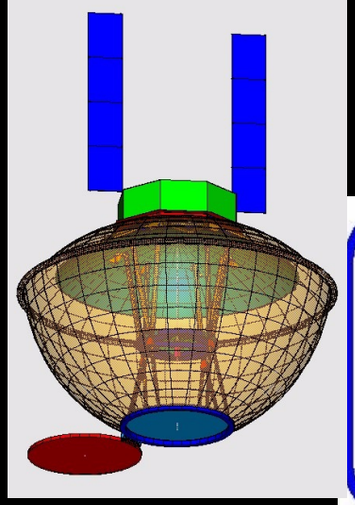


Fig. 3 Artist view of the MASS on orbit.



Extensive Air-shower Fluorescence from SPACE

Orbiting Wide-angle Light-collectors

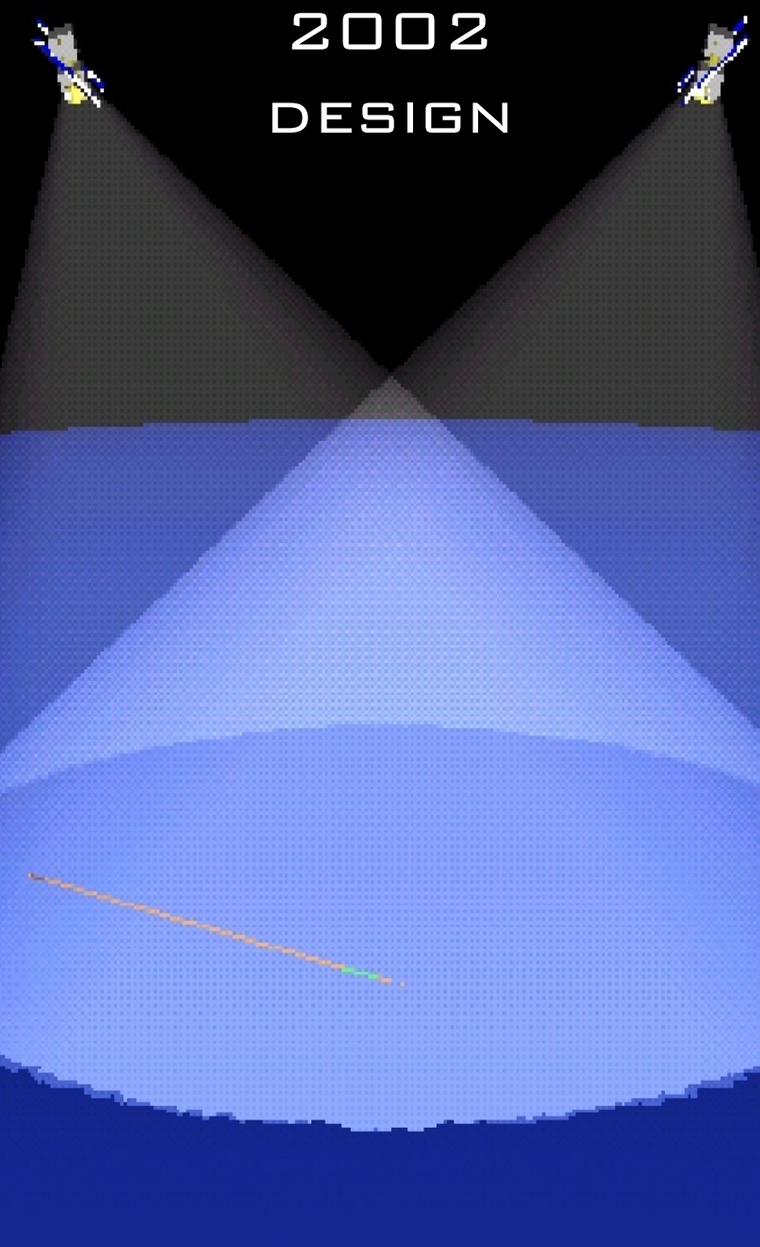
EUSO

2002

OWL

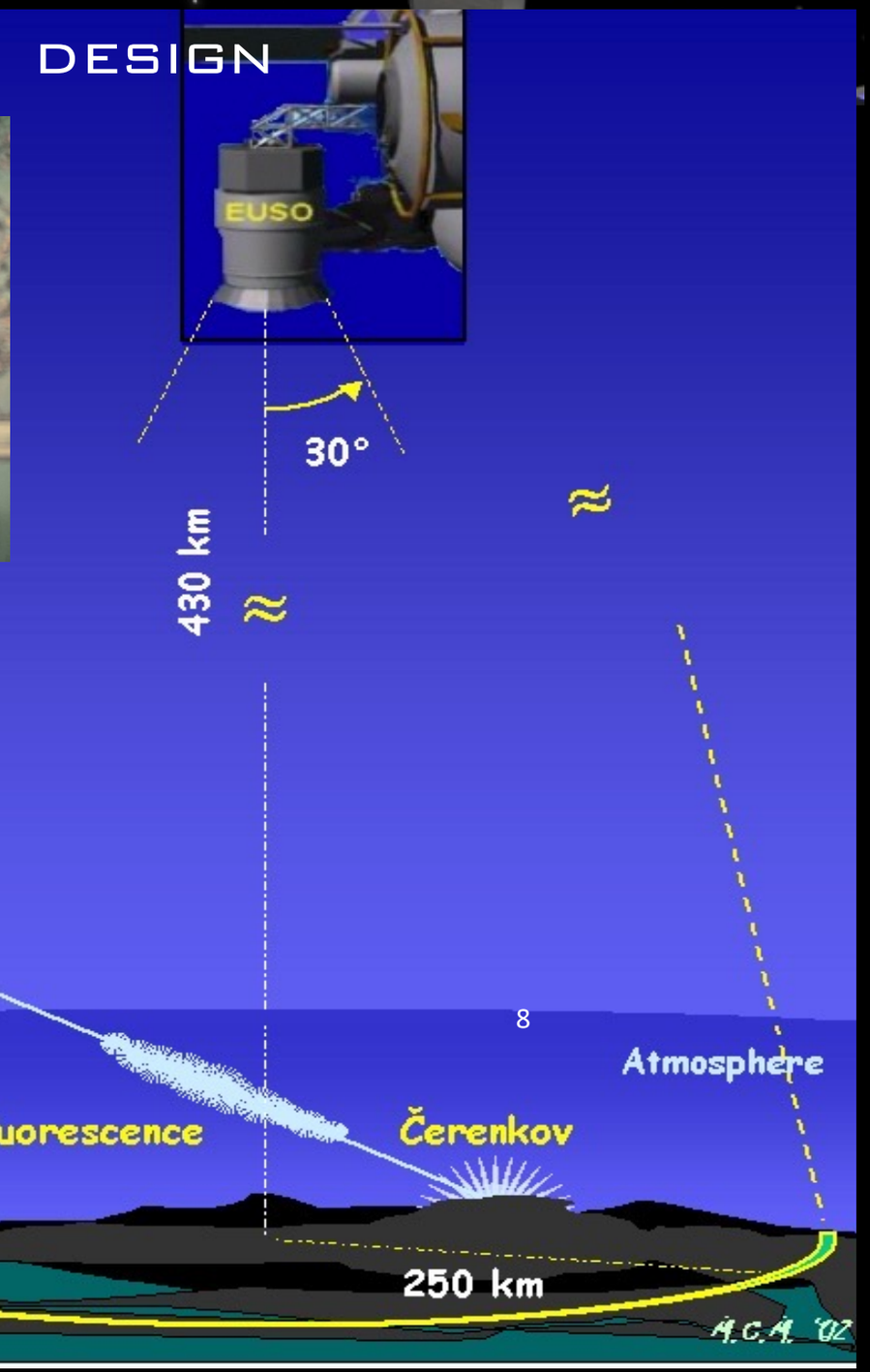
2002

DESIGN

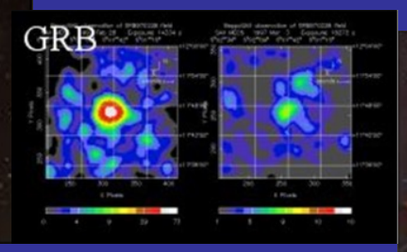


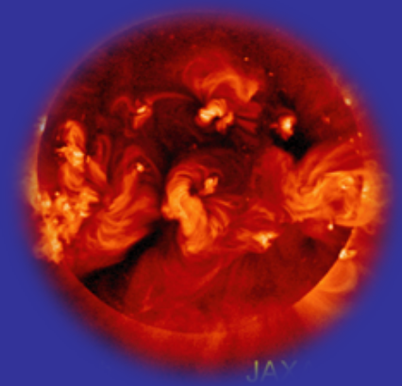
L. Scarsi

DESIGN



JEM-EUSO is an Astronomical Earth Observatory from Space





EECR s

Dust and Meteors, Space Debris, Nuclearites

Charged Particles

ltraviolet photons

UV, X, γ, ν
p, n, e

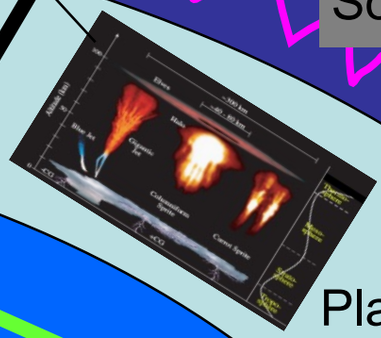
$X, \gamma, \upsilon, p, e$

Air shower

Air shower

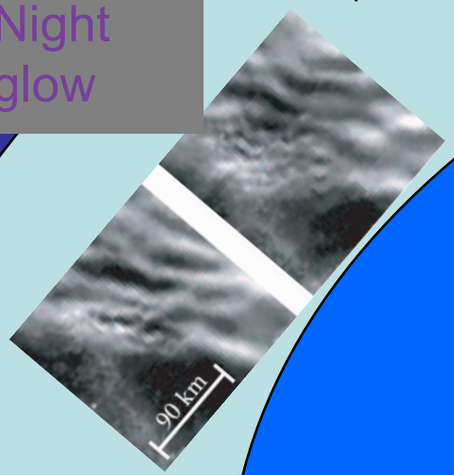
Atmosphere

Solar wind



Plasma Discahrge

Night glow



The Earth

EHE Neutrinos

Atmosphere in JEM-EUSO FoV
O(10^3 km^3 H_2O equivalent)

JEM-EUSO PROGRAM

EUSO-TA (2013-)

EUSO-Balloon (2014)

TUS (2016)

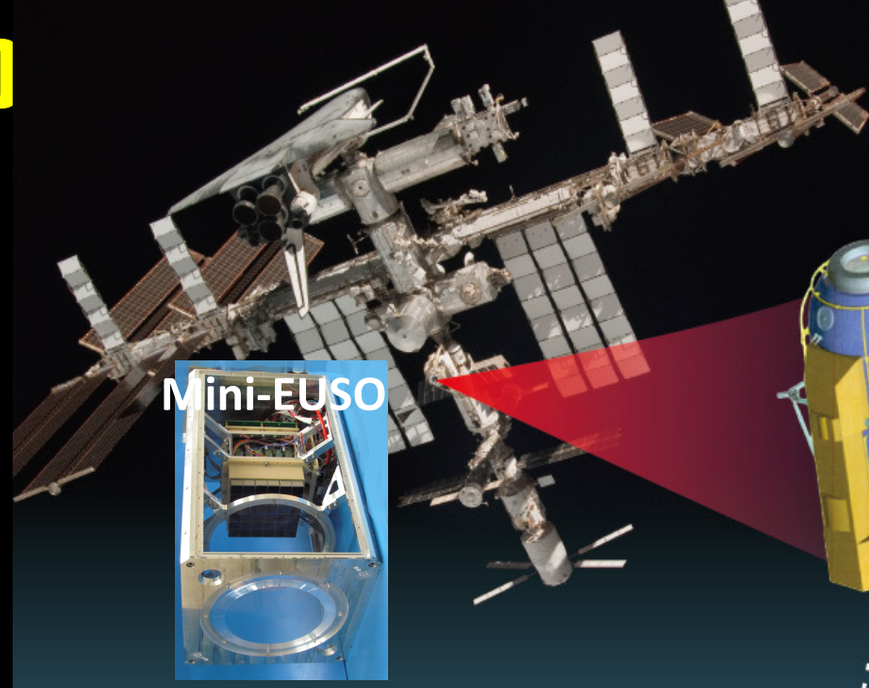
EUSO-SPB1 (2017)

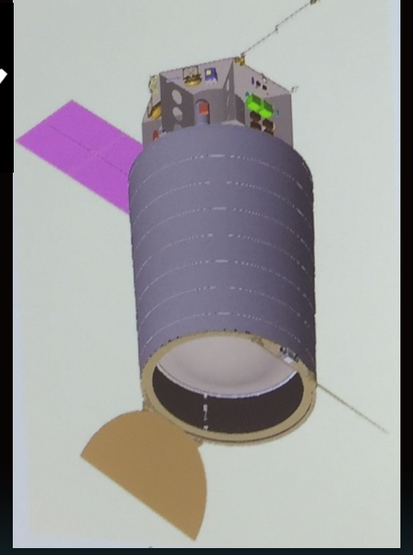
Mini-EUSO (2019)

EUSO-SPB2 (2023)

K-EUSO (2024+)

POEMMA (2028+)





EUSO-KLYPVE
400km

20°

EUSO-BALLOON
(2014)
40km

EECR

Fluorescence

Cherenkov

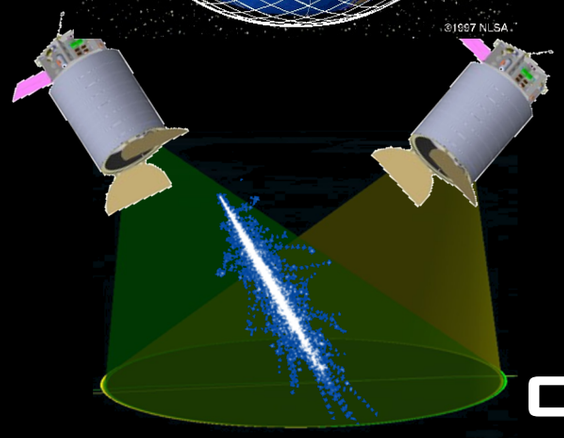
Atmospher

TA-EUSO (2013)

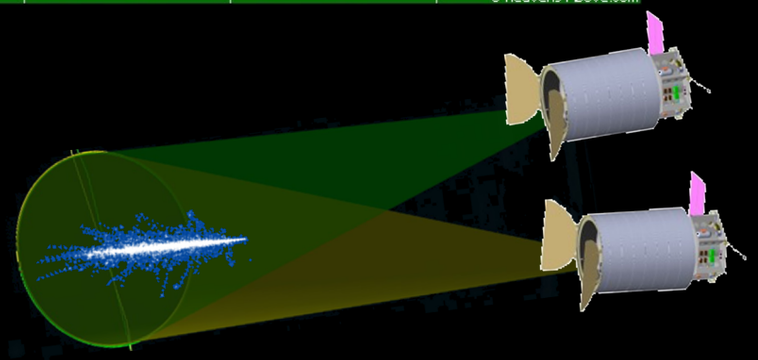
100km

Science Instrument

tics

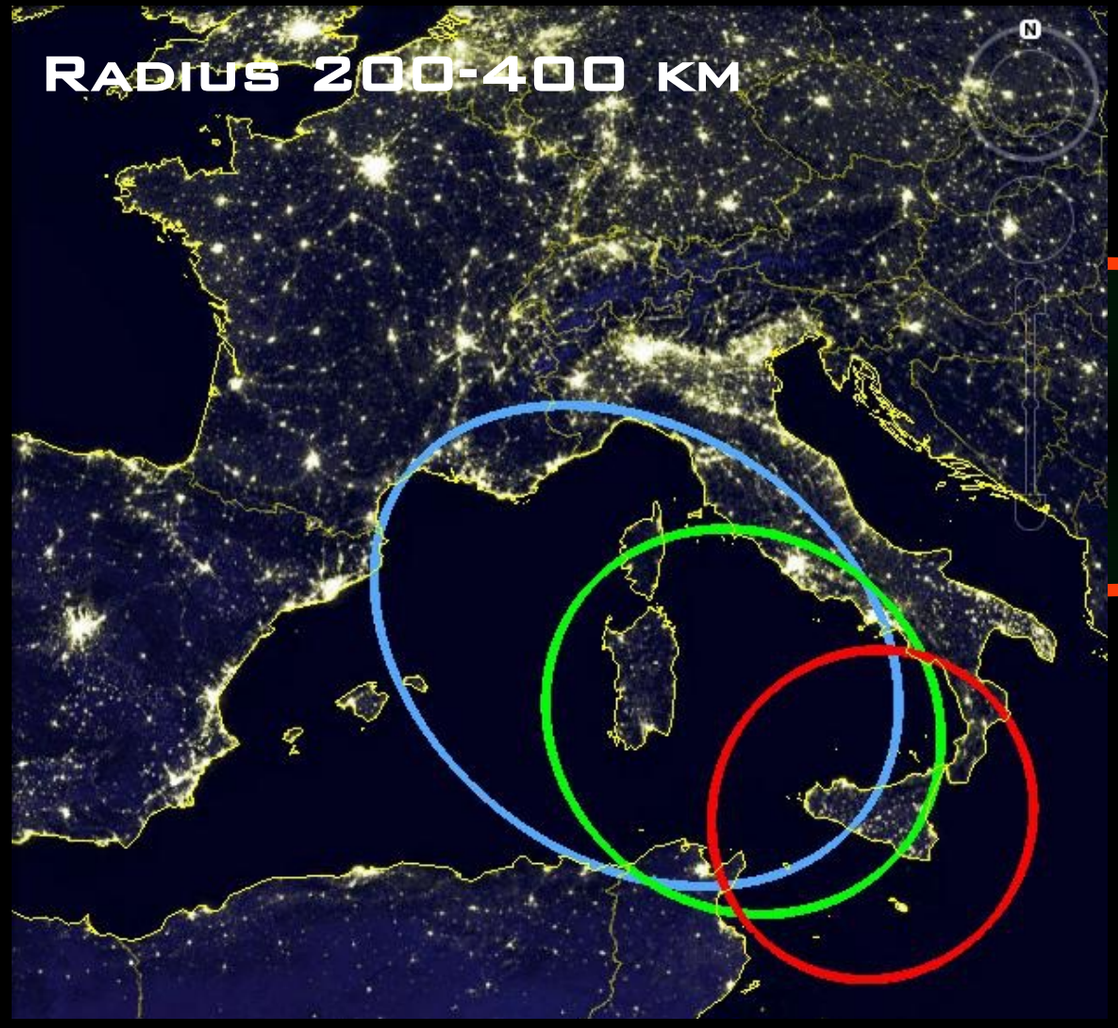


POEMMA



Observing Modes

Nadir for UHECR:



Limb for Neutrinos & UHECRs

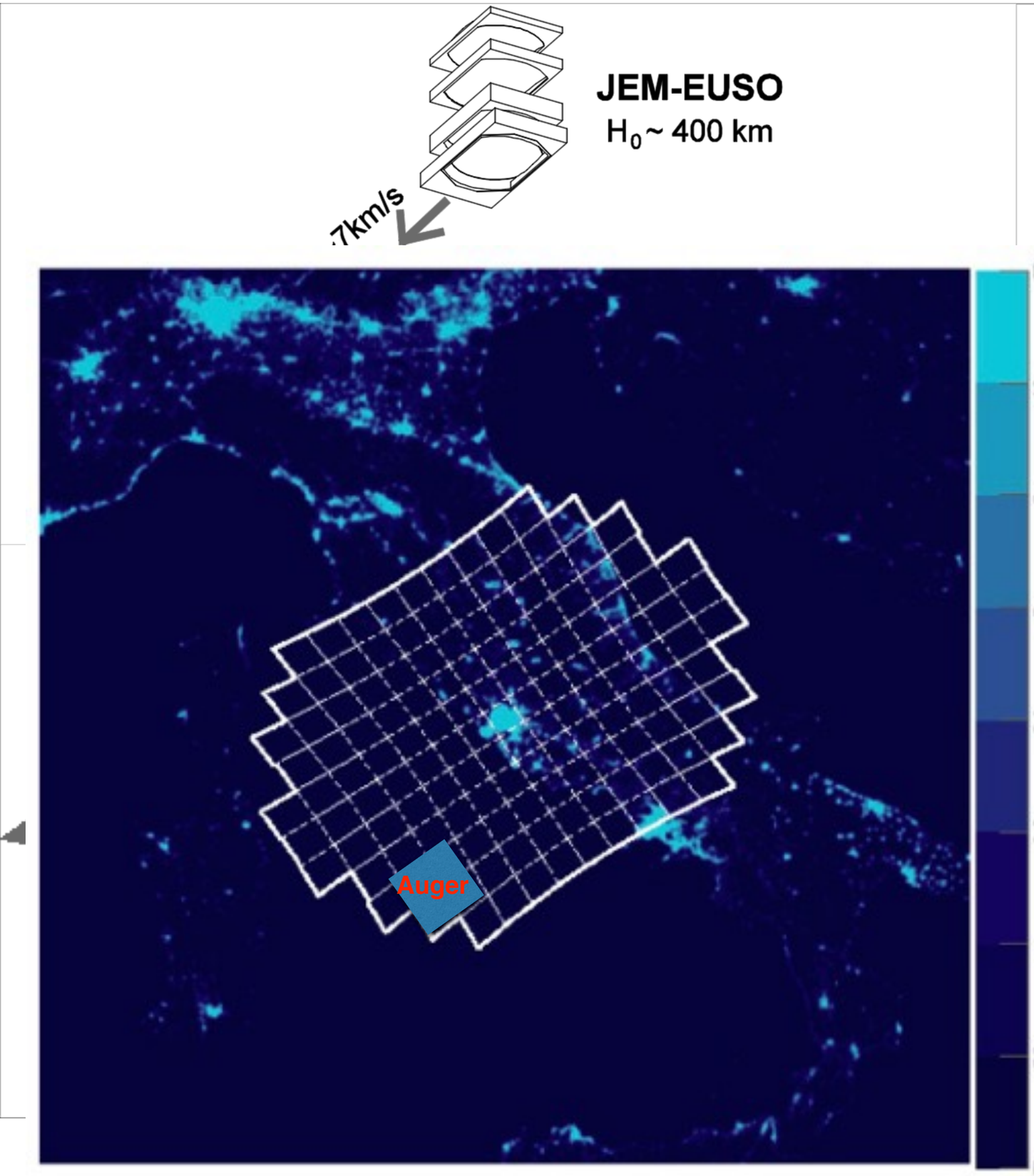
Scientific challenges:

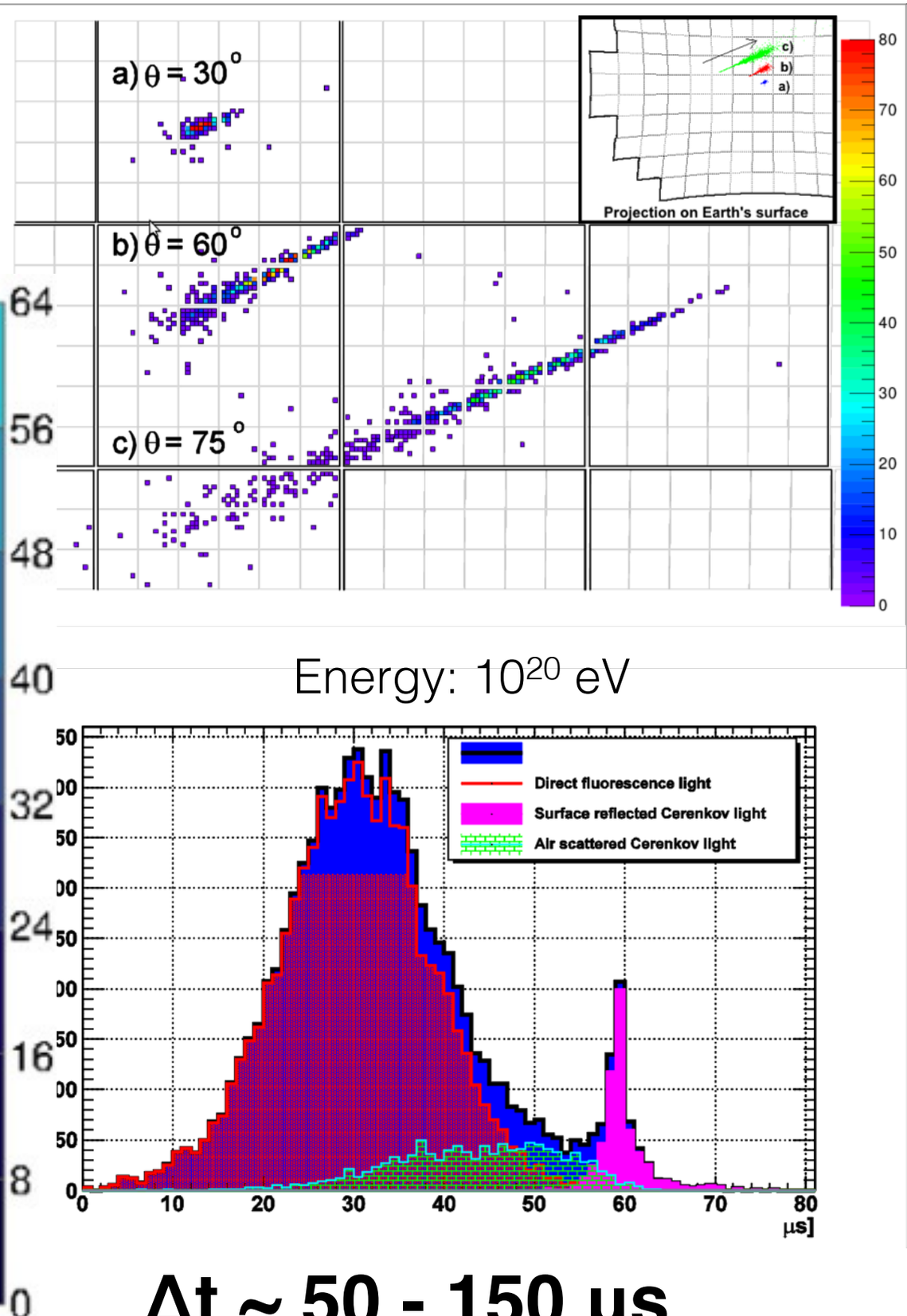
- » Energy threshold below GZK cutoff (a factor of 2 higher energies means very few statistics and no inter calibration with ground experiments).
- » Light conditions continuously varying (ISS speed 7.5 km/s —> night/day change every 45 minutes).
- » Atmospheric conditions (clear sky, clouds, lightning, cities and anthropic light) continuously changing.
- » We need to test the capability of the instrument to adapt its working conditions to the different situations.
- » We need to record and recognise the different atmospheric and anthropogenic conditions.

Technological challenges:

- » Low power consumption (<1kW for POEMMA single tel. - >10^5 pixels)
- » Low mass (~1.5 tons for POEMMA single tel.))
- » Low telemetry (1 GB/day for POEMMA single tel.)
- » Radiation hard instrumentation
- » Space-qualified instrumentation (need to increase TRL)

JEM-EUSO Observation Principle





Energy: 10^{20} eV

Δt ~ 50 - 150 μs

Exposure for ToO Observations