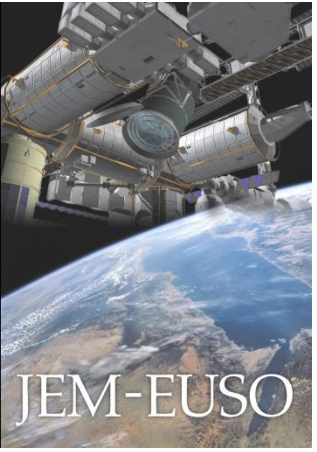
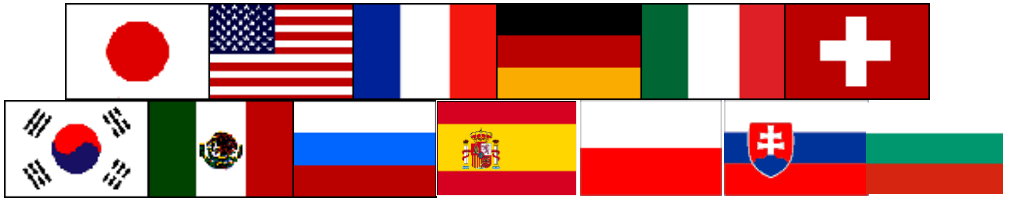




"Doing astronomy by looking downward"

JEM-EUSO Program

Cosmic Rays at Extreme Energies

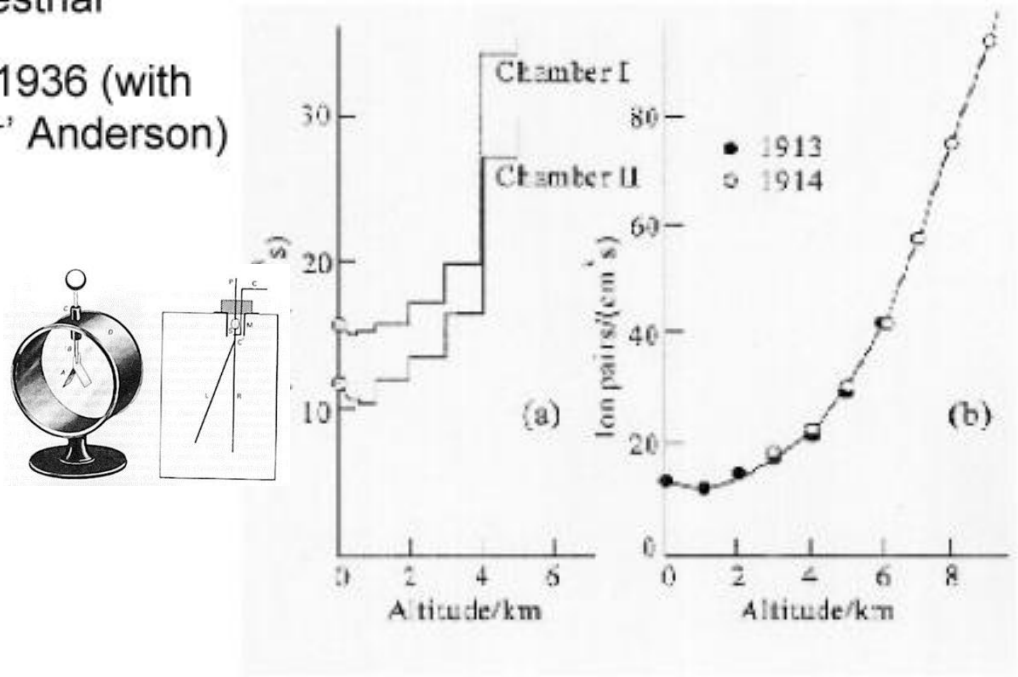
Piergiorgio Picozza
INFN and University of Rome Tor Vergata

AMS DAYS AT CERN - The Future of Cosmic Ray Physics and Latest Results

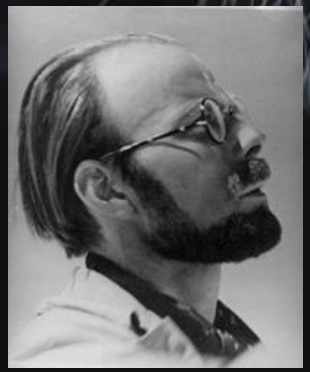
CERN, April 15-17, 2015

The Discovery of Cosmic Rays

- Victor Hess ascended to 5000 m in a balloon in 1912
- Noticed that his electroscope discharged more rapidly as altitude increased
- Not expected as background radiation was thought to be terrestrial
- NPP 1936 (with Carl 'e+' Anderson)

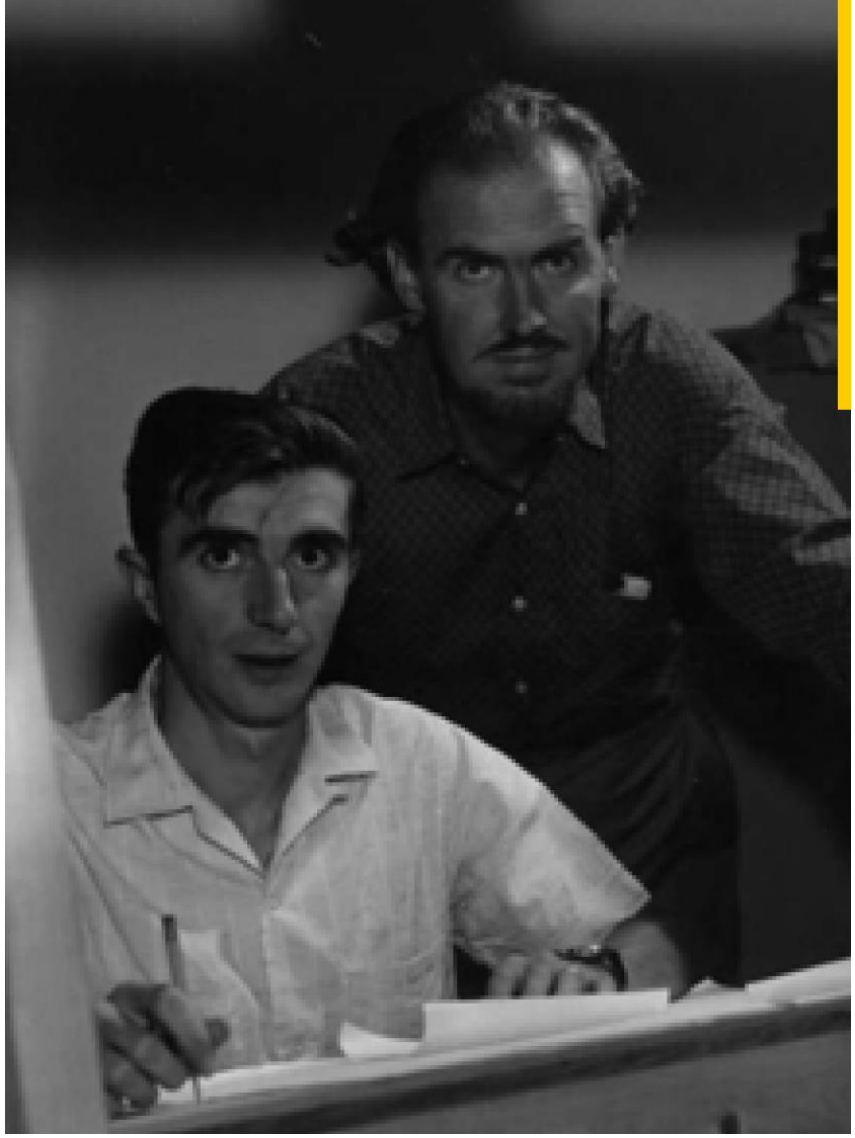


Extensive Air Showers



1937: Pierre Auger $E \sim 10^{15}$ eV

25 years: 7 o.o.m.



John Linsley and Livio Scarsi, early sixties at Volcano Ranch

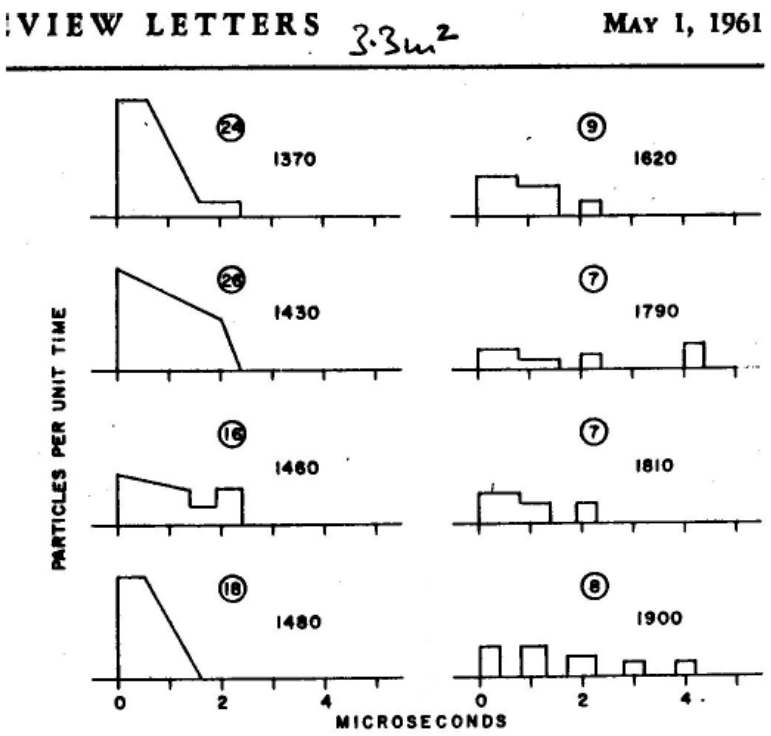
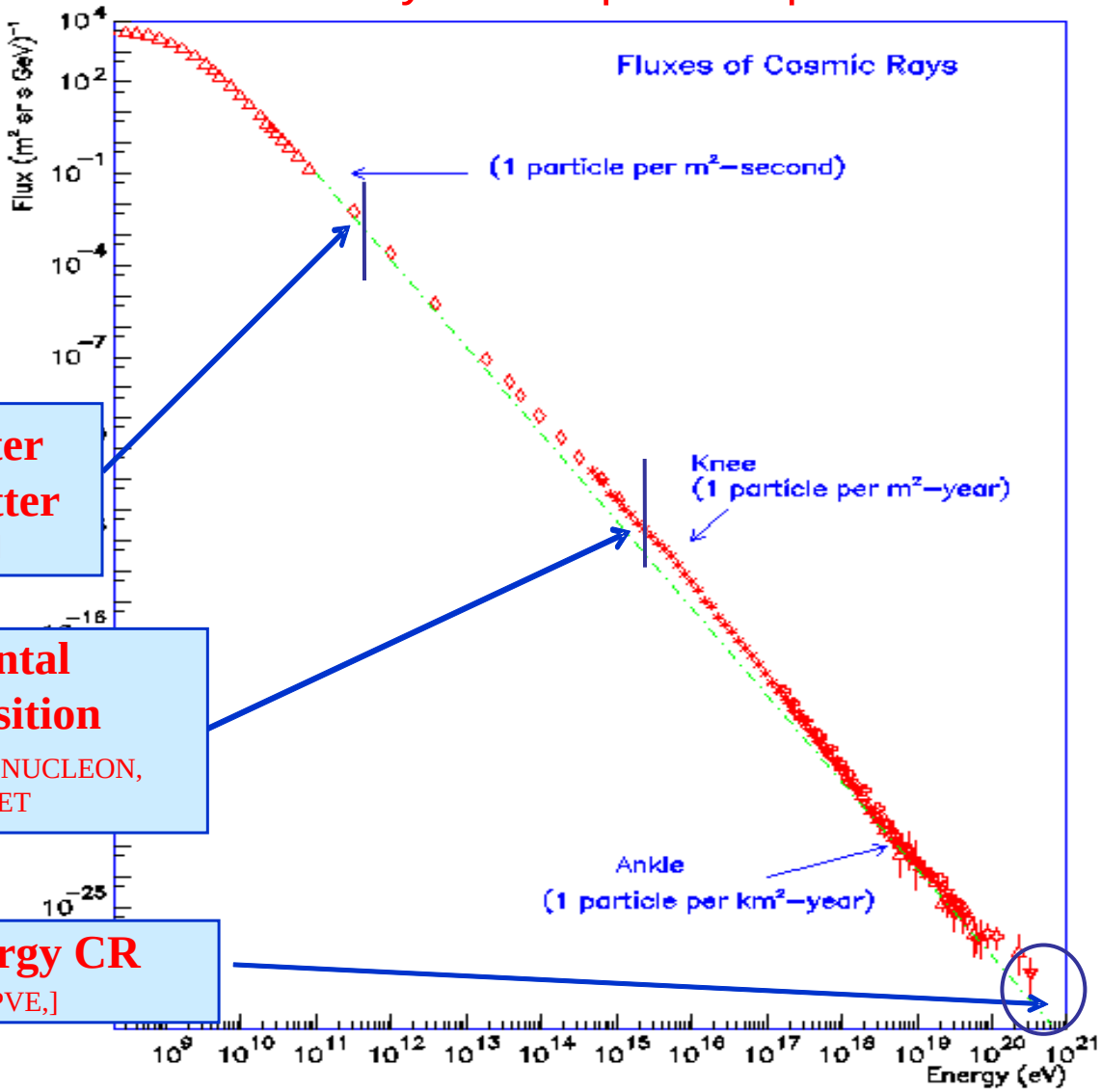


FIG. 3. Distributions in arrival time of shower particles at the eight detectors furthest from the shower axis. The number of particles included in each distribution (to which the areas have been normalized) is shown circled. Distances from the shower axis are also given.

24 years: 5 o.o.m

Event at 6x10^{19} eV; Linsley, Scarsi & Rossi, PRL (1961) 5

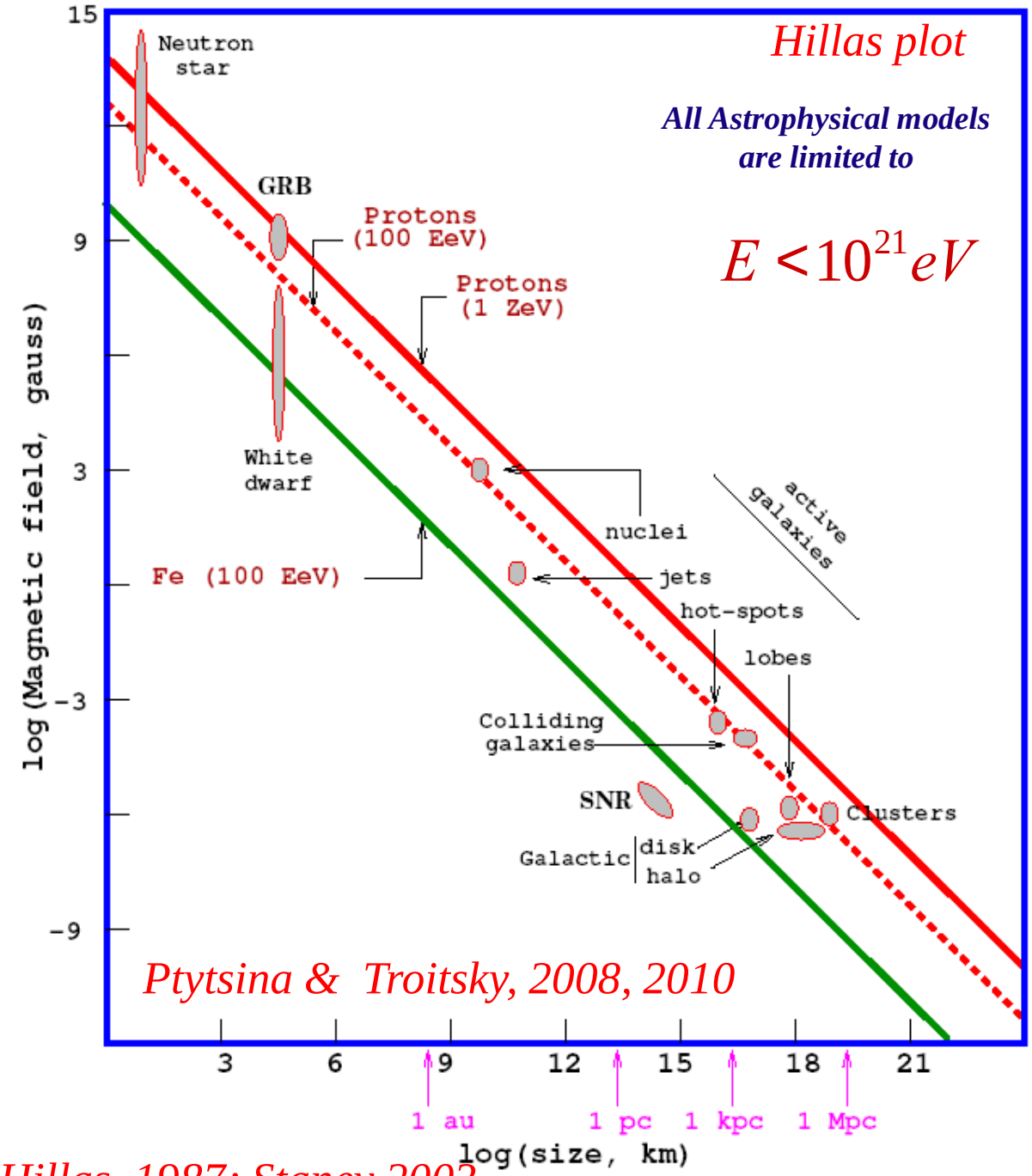
Cosmic Rays and Space Experiments



Antimatter
Dark Matter
[PAMELA, AMS]

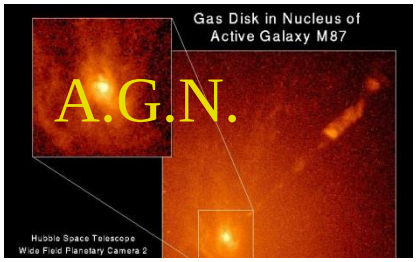
Elemental Composition
ISS-CREAM, NUCLEON, CALET

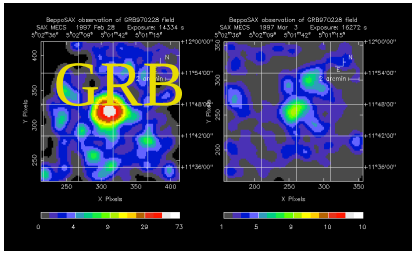
Extreme Energy CR
EM-EUSO, TUS, KLYPVE,]

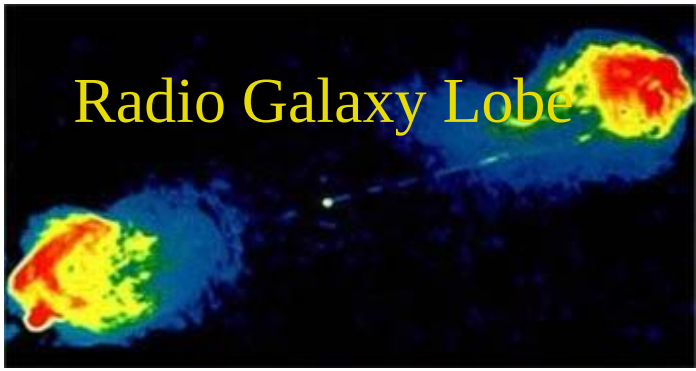


Hillas, 1987; Stanev 2003

Pulsar





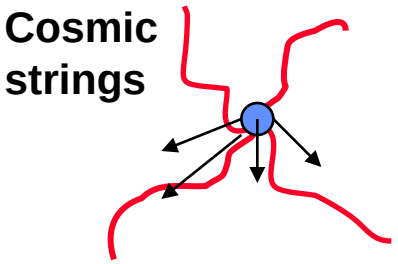


Torres & Anchordoqui, 2004

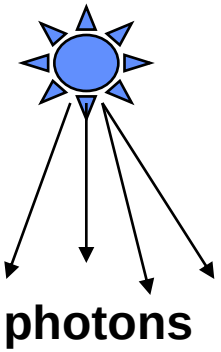
What can originate such cosmic rays?

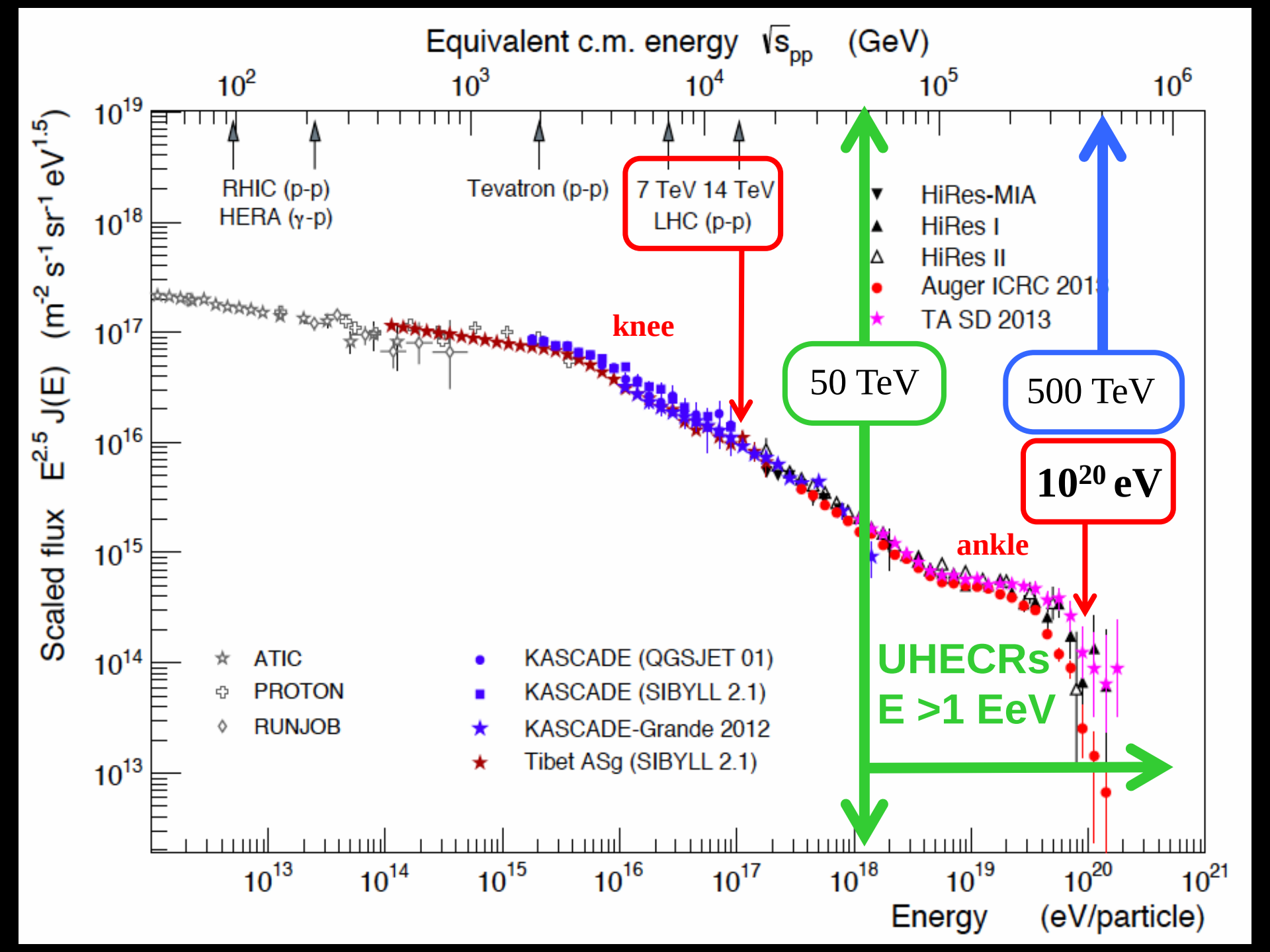
- **"Top-Down" scenario:**

Produced by early universe symmetry breaking, decay of cosmic supermassive background particles, violation of Lorentz invariance……



E or $M_X \approx 10^{21}$ eV




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
ankle
50 TeV
500 TeV
10^20 eV
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 201
TA SD 2013
UHECRs
E >1 EeV
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)

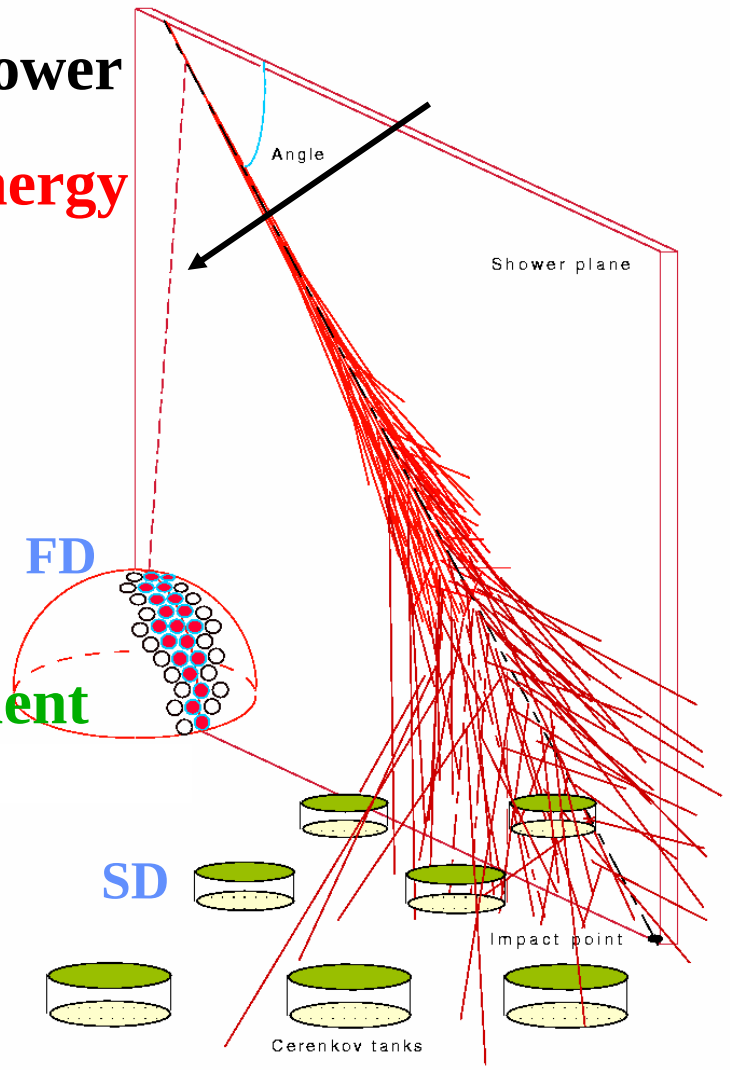
Current Observatories

Fluorescence Detectors (FD)

- Longitudinal development of the shower
- Calorimetric measurement of the energy
- 12% duty cycle

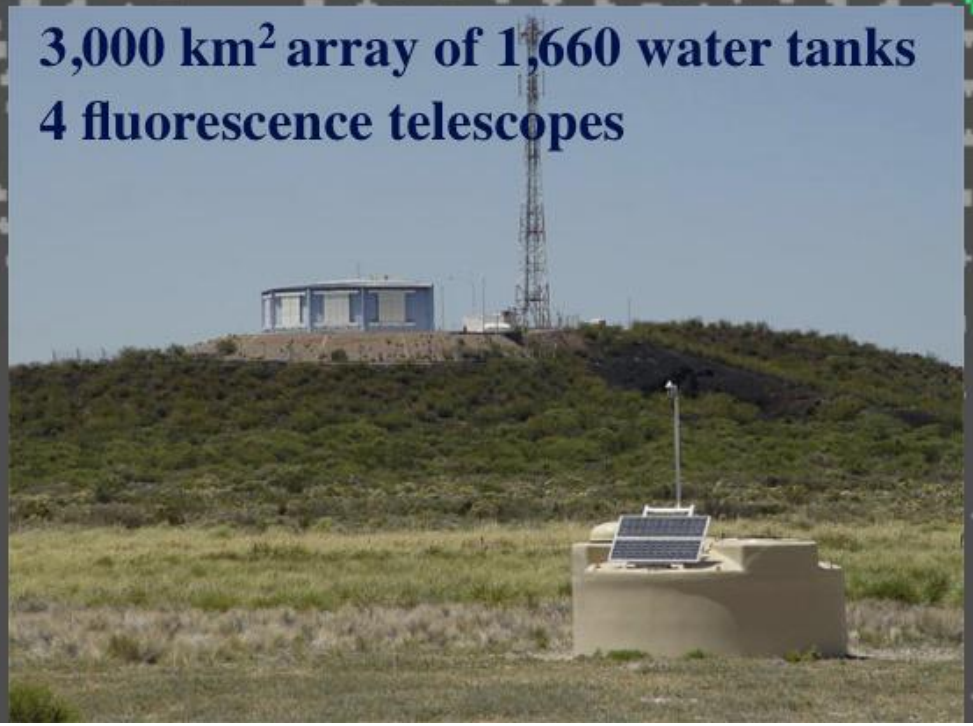
Surface Detectors (SD)

- On ground shower measurement
- Model dependent energy measurement
- ~ 100% duty cycle (High Statistics)



The Pierre Auger Observatory

3,000 km^2 array of 1,660 water tanks
4 fluorescence telescopes



Current Observatories of Ultrahigh Energy Cosmic Rays

Telescope Array

Utah, USA

(5 country collaboration)

700 km^2 array

3 fluorescence telescopes

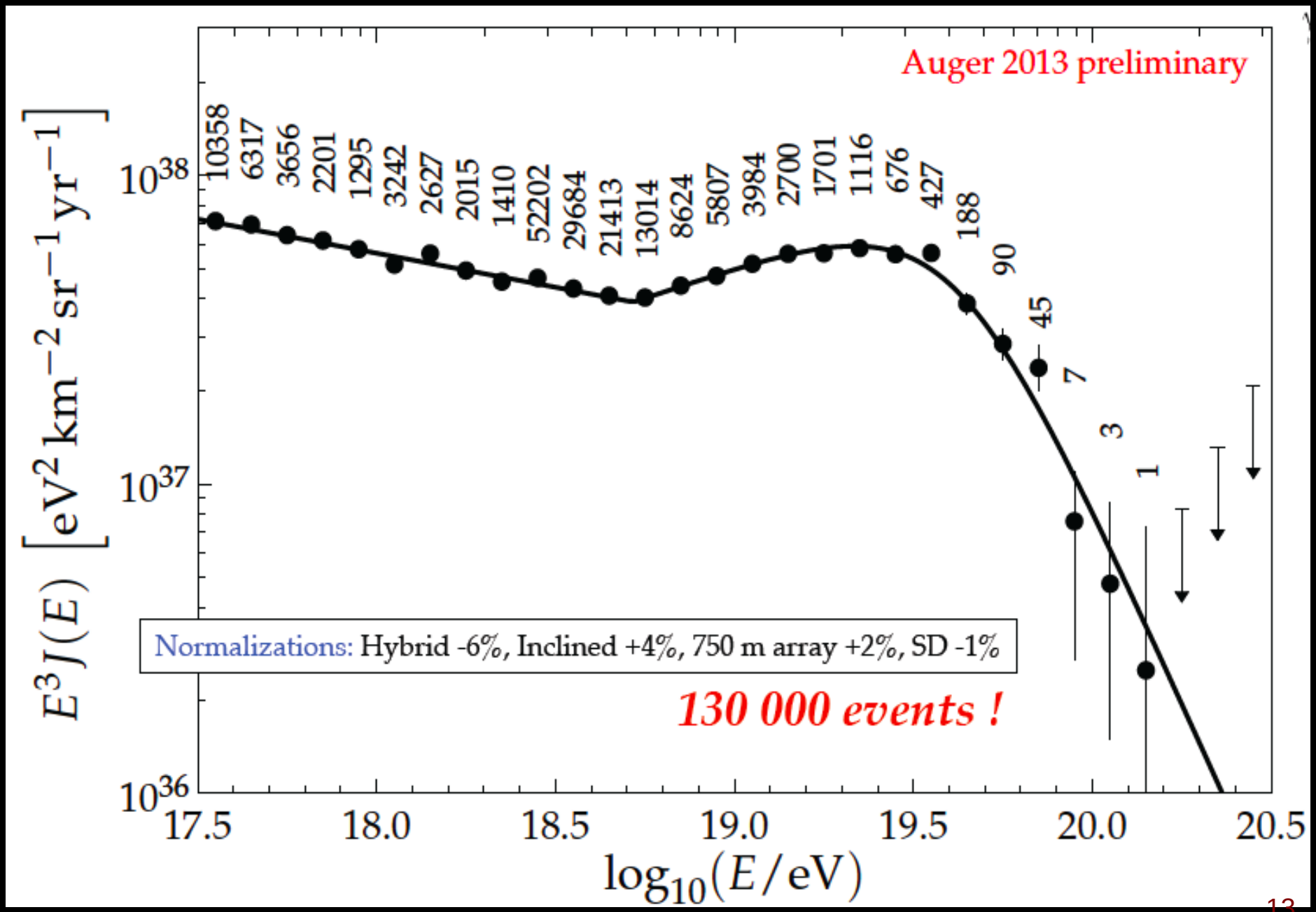
Pierre Auger Observatory

Mendoza, Argentina

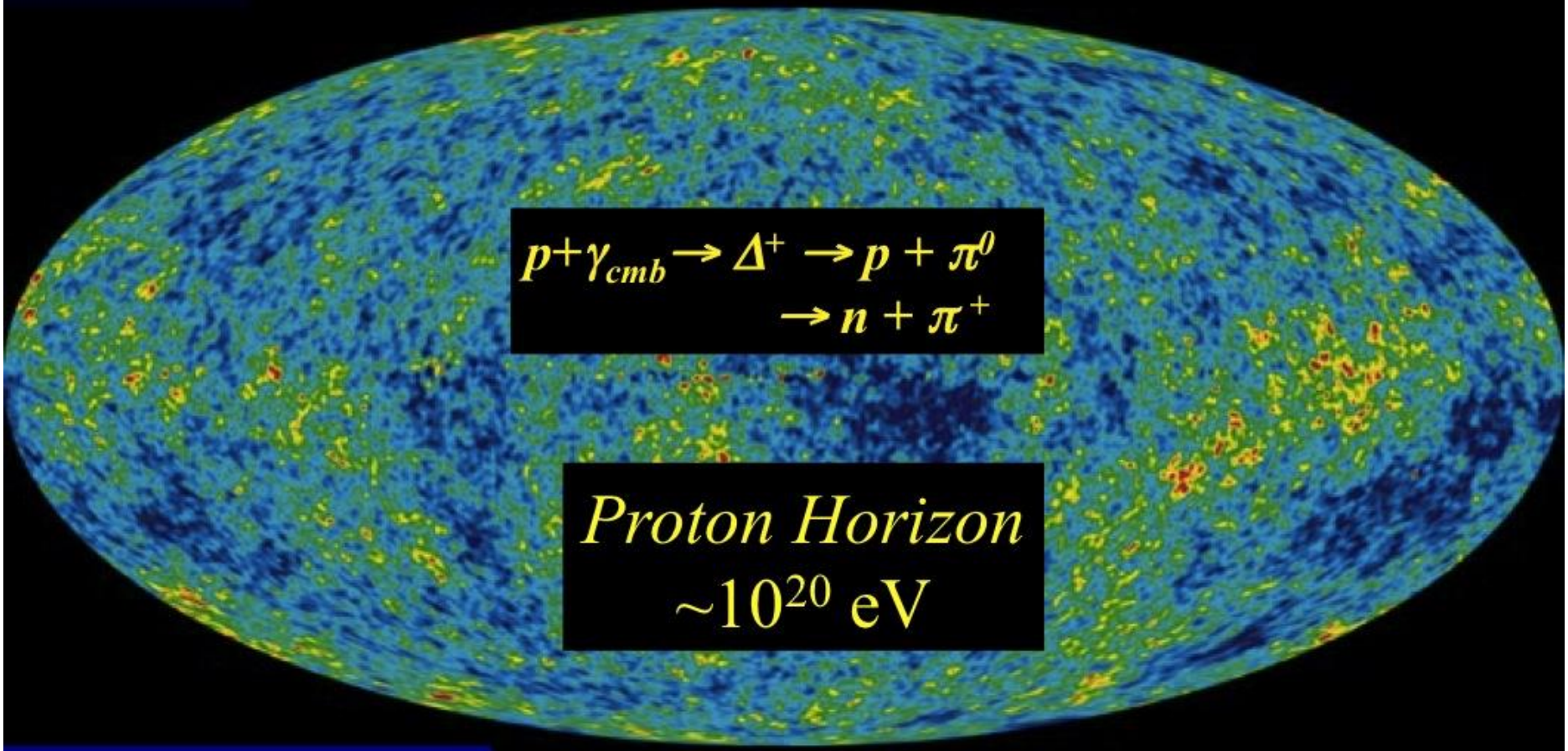
(19 country collaboration)

3,000 km^2 array

4 fluorescence telescopes


Auger 2013 preliminary
10358
6317
3656
2201
1295
3242
2627
2015
1410
52202
29684
21413
13014
8624
5807
3984
2700
1701
1116
676
427
188
90
45
7
3
1
10^{38}
10^{37}
10^{36}
$E^3 J(E)$ $\left[\mathrm{eV}^2\,\mathrm{km}^{-2}\,\mathrm{sr}^{-1}\,\mathrm{yr}^{-1}\right]$
Normalizations: Hybrid -6%, Inclined +4%, 750 m array +2%, SD -1%
130 000 events !
17.5
18.0
18.5
19.0
19.5
20.0
20.5
$\log_{10}(E/\mathrm{eV})$

"Cosmologically Meaningful Termination"



GZK Cutoff

Greisen, Zatsepin, Kuzmin

1966

$p+\gamma_{CMB} \rightarrow p + e^+ e^-$

Does GZK exist?

	Power E_{break}前	E_{break} (eV)	Power E_{break}後	E ½ (eV)	E ½ (ratio)
HiRes	-2.81	$10^{19.75}$	-5.1	$10^{19.77}$	1.12
Auger	-2.59	$10^{19.46}$	-4.3	$10^{19.52}$	0.63
TA	-2.72	$10^{19.75}$	-4.7	$10^{19.78}$	1.15
GZK 計算 (Berezinsky 1988)				$10^{19.72}$	1.00

Fukushima (2011)

UHECR status in just one word

Previous to Auger / HiRes :

$$\frac{1 \text{ particle}}{100\ km^2\ yr\ sr}$$

Key Auger / HiRes result:

$$\frac{1 \text{ particle}}{\cancel{100}\ 1000\ km^2\ yr\ sr}$$

How many EECRs > 60 EeV?

Auger w/ 3,000 km^2

~20 events > 55 EeV/ yr

Telescope Array w/ 700 km^2

~4.6 events > 55 EeV/ yr

TOTAL ~30 events/yr

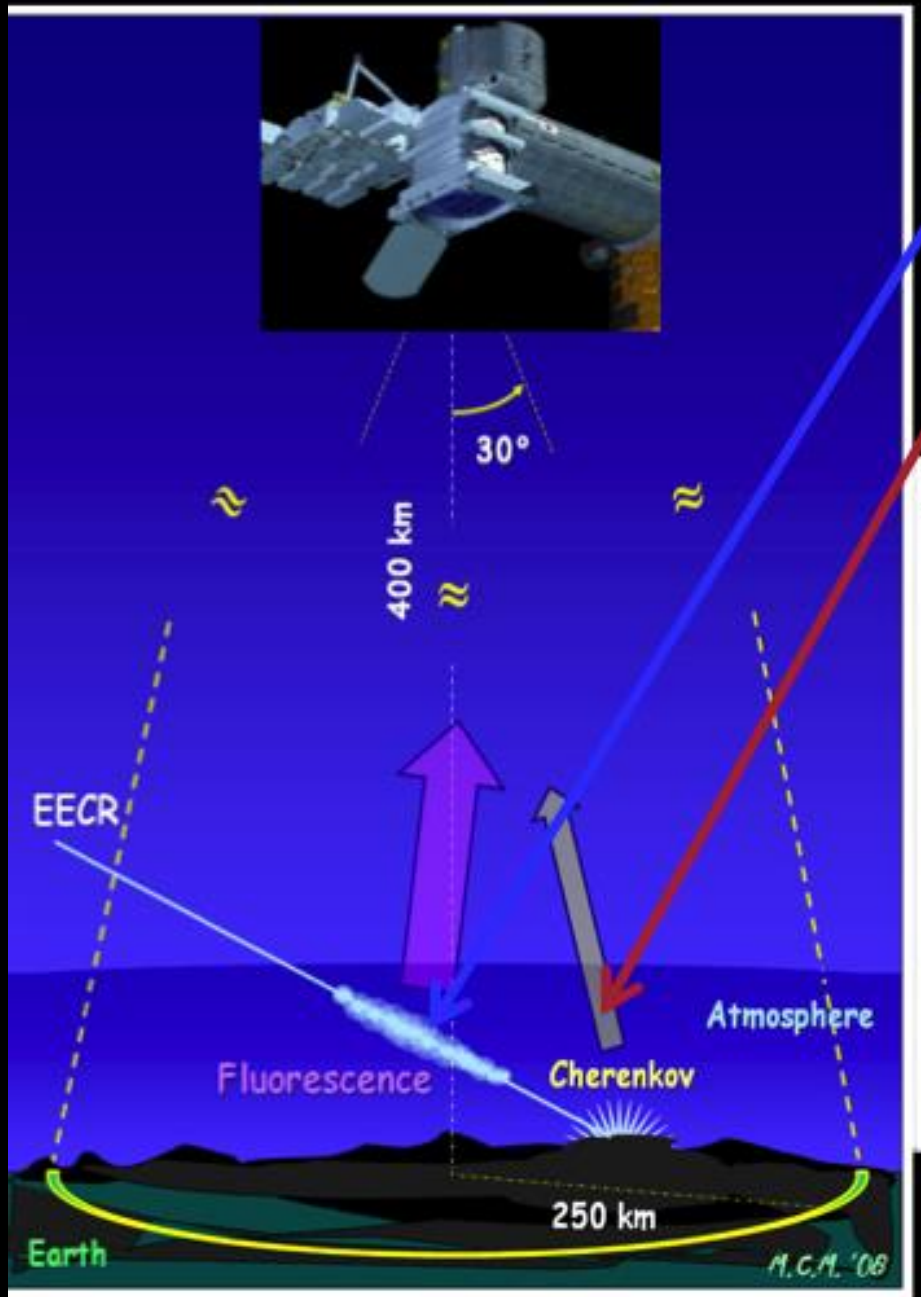
Earth - surface ~ 5 10^8 km^2

~3.4 10^6 events/yr

Go to SPACE!

To look down on the Atmosphere!

Fluorescence from SPACE

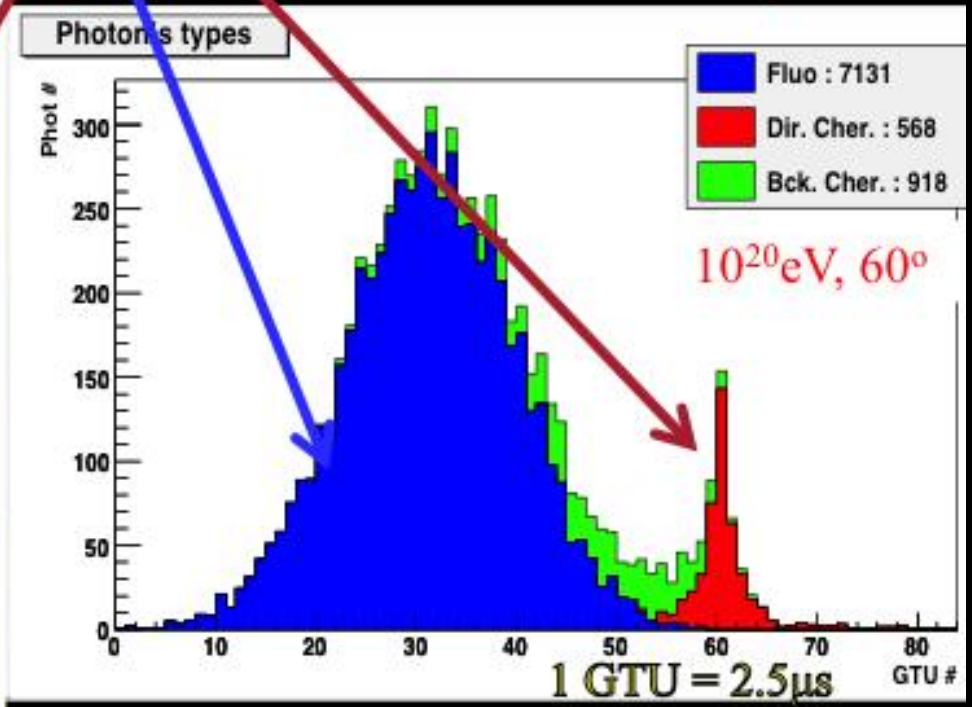


Fast Signal: 50 -150 μs

a) Fluorescence

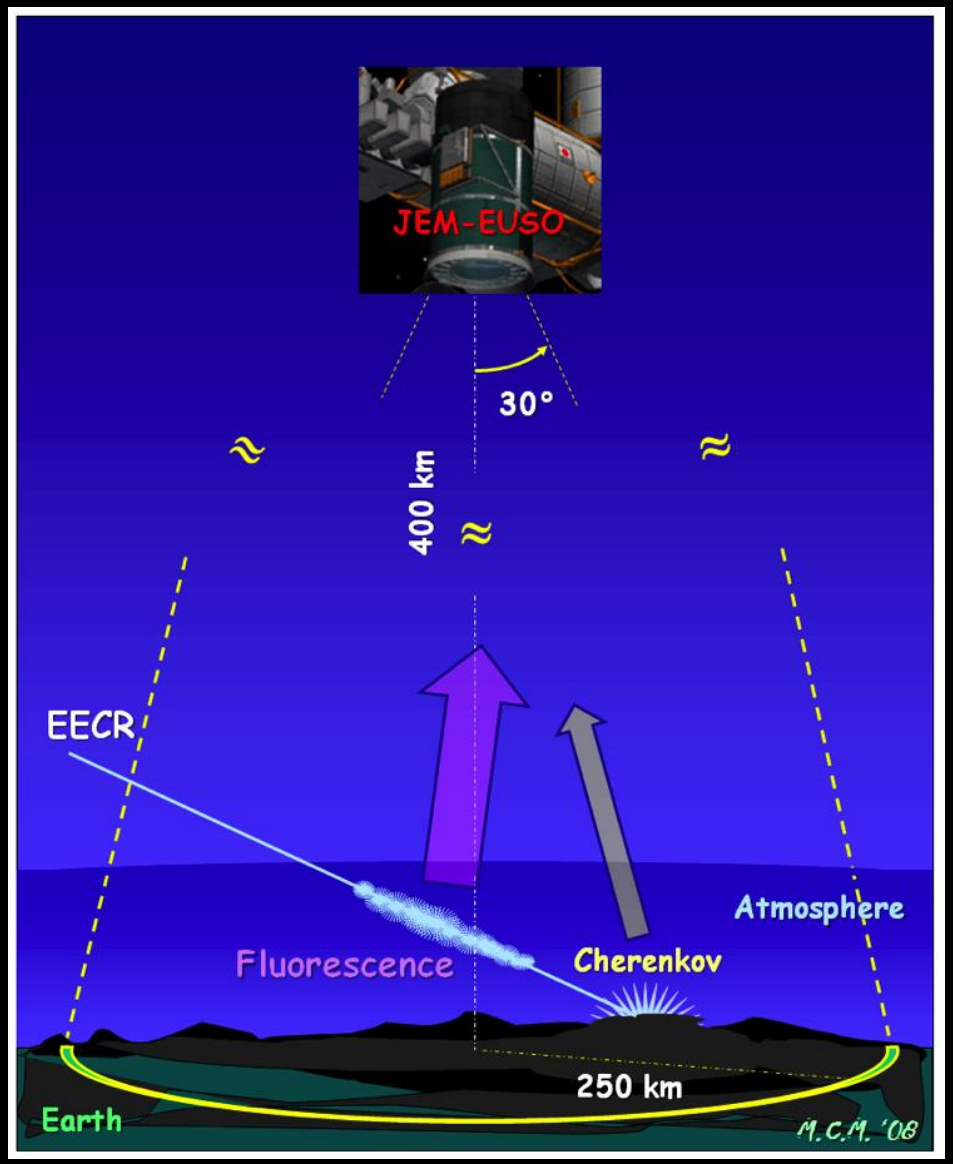
b) Scattered Cherenkov

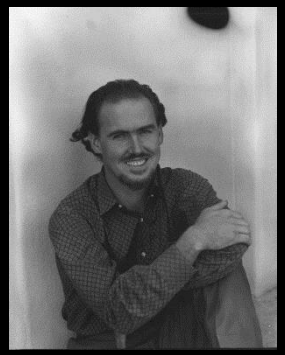
c) Direct (reflected Cherenkov)



Background: 500 /m^2 sr ns

Fluorescence from Space





J. Linsley

Y. Takahashi

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

In 1995 Yoshi Takahashi of UHA rediscovered the original idea and proposed the MASS program wich later became a reality with the OWL and EUSO studies

2000-2004 EUSO on Columbus (ISS)

EUSO

Vincent Van Gogh, "The starry night"

The EUSO submitted to ESA in Oct. 1999 (as F2-F3 missions) was re-oriented to a payload for the ISS

Extreme Universe Space Observatory

2000-2001 Preliminary Accomodation study by D/MSM and D/SCI

ESA Phase A studies March 2002-2003

The EUSO Phase A studie(s) at ESA

The two studies were jointly reviewed by an ESA appointed Panel in July 2004 (Co-chaired by D-SCI and D-MSM)

The Panel considered the EUSO Phase A Study successfully concluded:
…"With the completion of Mission and Instrument Phase A Extension, the EUSO Project could technically proceed to Phase B"…

Shuttle Problems

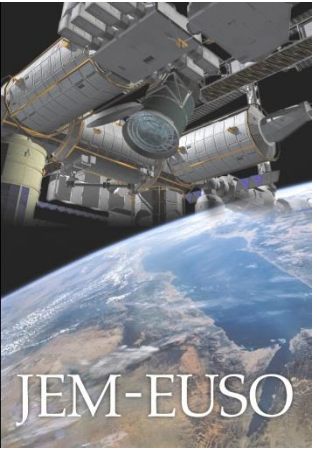
The Turning Point

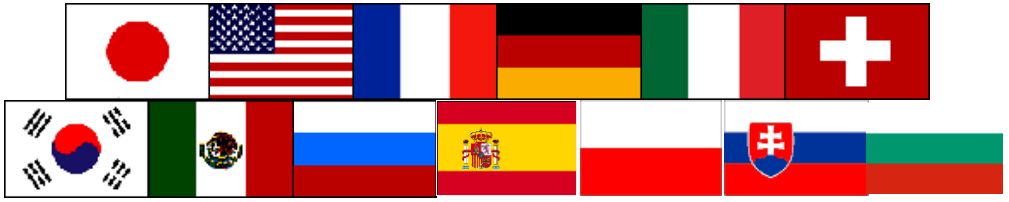
JEM-EUSO Kick-off Meeting
RIKEN, Tokyo, June 6-8 2007

JEM-EUSO Mission

Japanese Experiment Module (JEM)

きぼう, Kibo = Hope





"Doing astronomy by looking downward"

JEM-EUSO Program

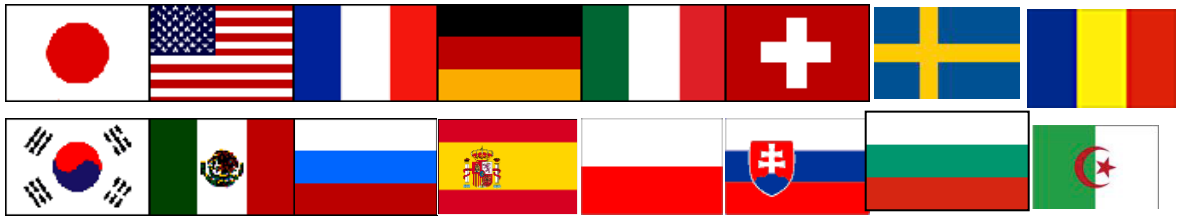
Cosmic Rays at Extreme Energies

JEM-EUSO Collaboration

- Japan, USA, Korea, Mexico, Russia, Algeria

- Europe: Bulgaria, France, Germany, Italy, Poland, Romania, Slovakia, Spain, Sweden, Switzerland

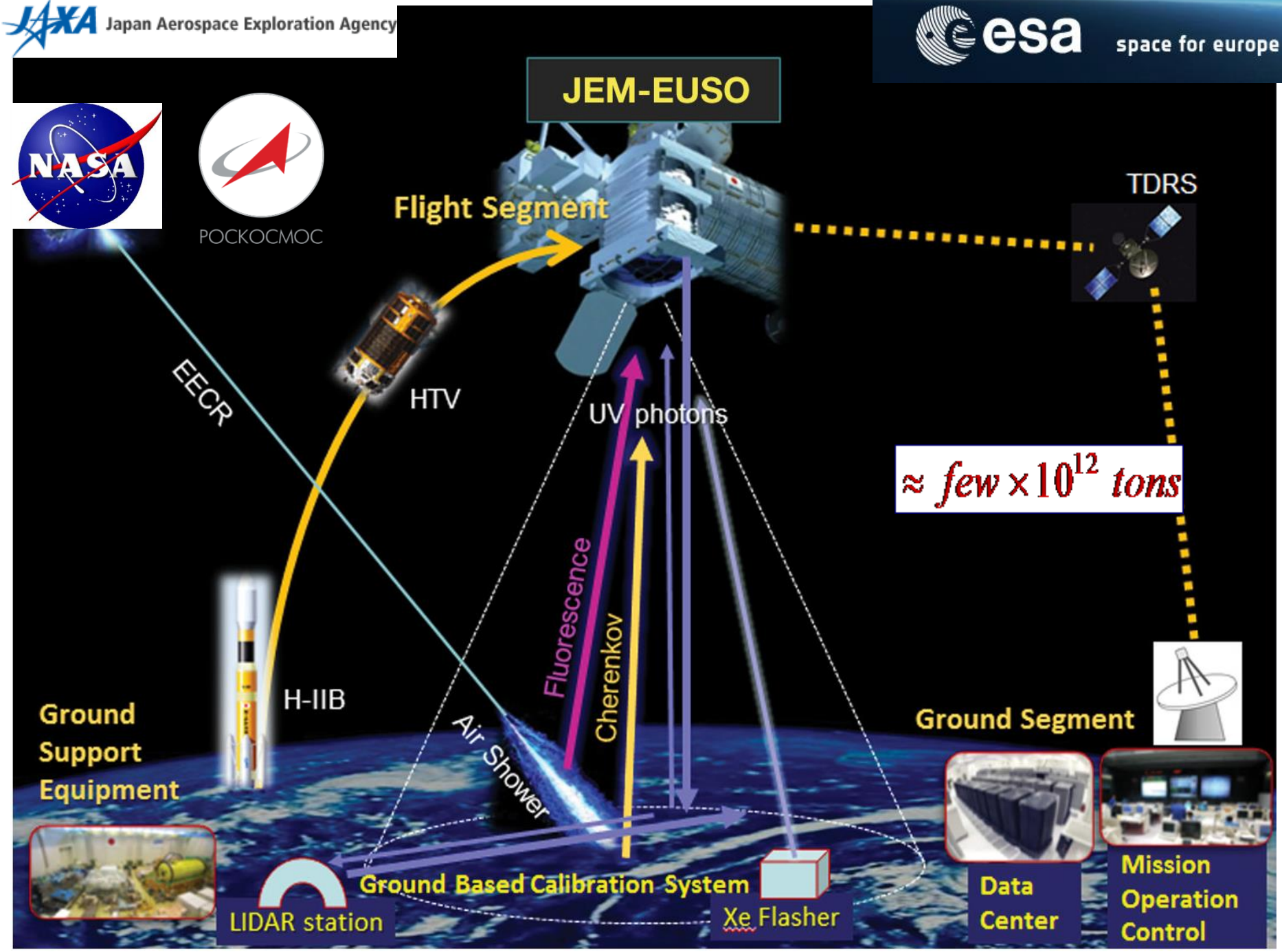
- 16 Countries, 80 Institutions, more than 300 researchers



Space Agencies

- JAXA
- ESA
- NASA
- Roscosmos

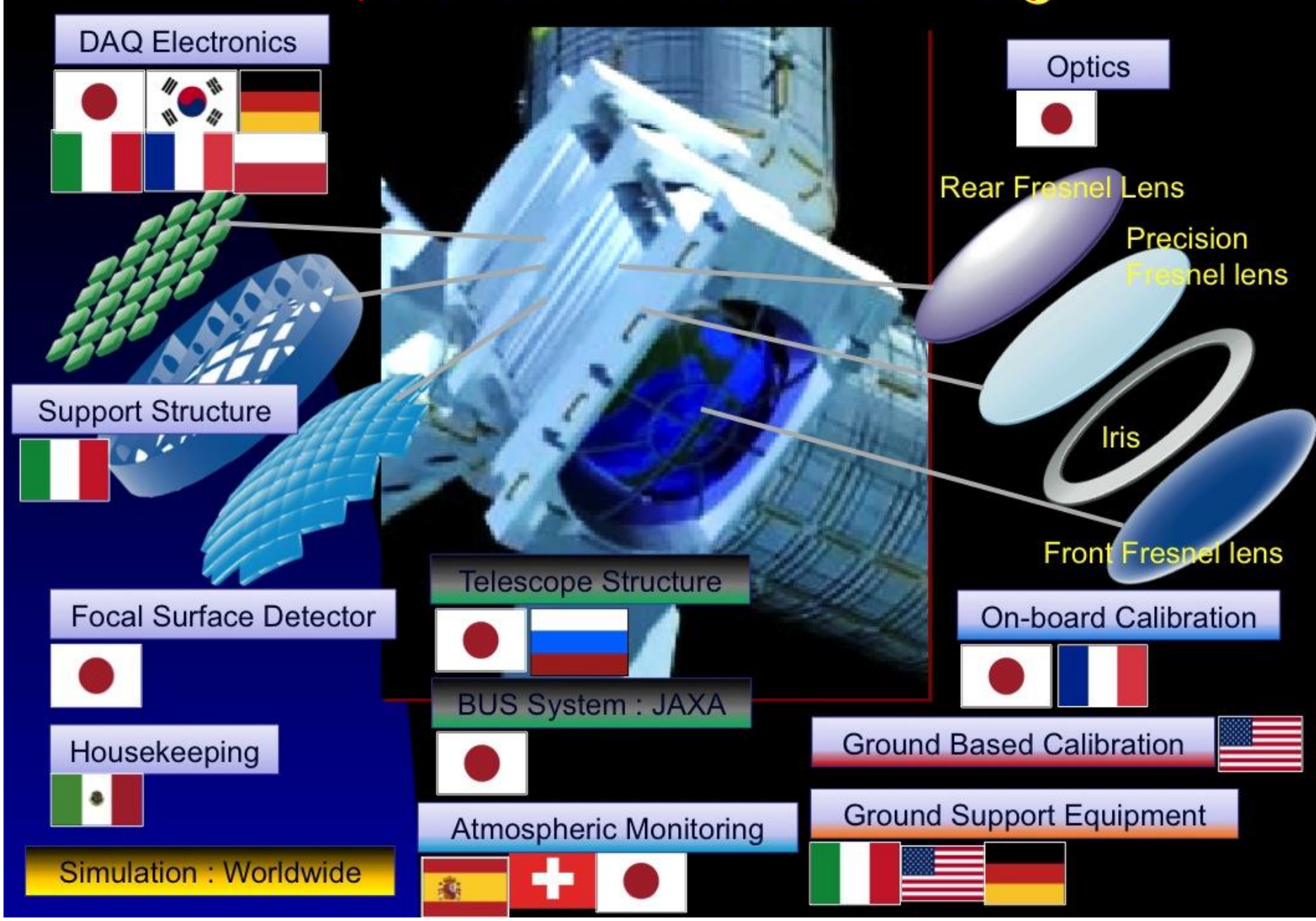
- National Space Agencies


Japan Aerospace Exploration Agency
esa
space for europe
JEM-EUSO
NASA
POCKOCMOC
Flight Segment
TDRS
EECR
HTV
UV photons
≈ few × 10^12 tons
Fluorescence
Cherenkov
Air Shower
H-IIB
Ground Support Equipment
Ground Segment
Ground Based Calibration System
LIDAR station
Xe Flasher
Data Center
Mission Operation Control

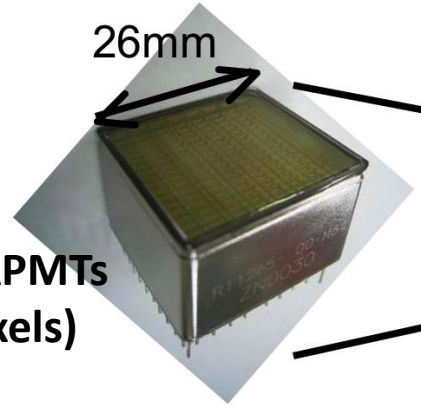
Mission aspects have been successfully studied by JAXA and RIKEN

Parameter	Value
Launch date	2020?
Mission Lifetime	3+2 years
Rocket	H2B
Transport Vehicle	HTV
Accommodation on JEM	EF#2
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°

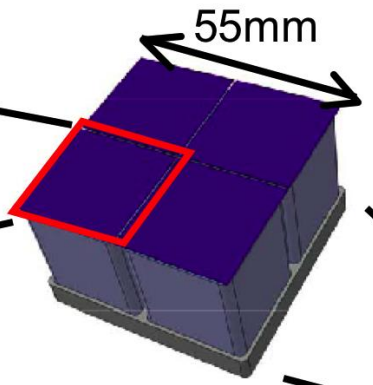
Conceptual view of the telescope



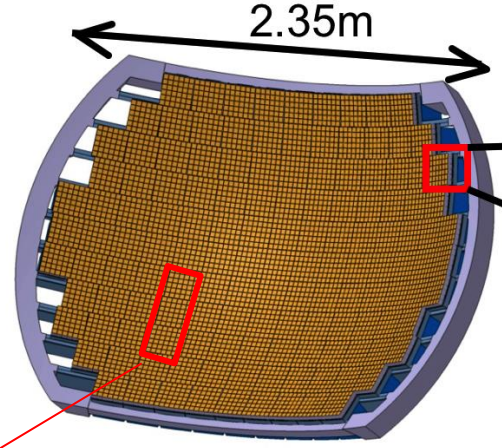
Focal Surface Detector

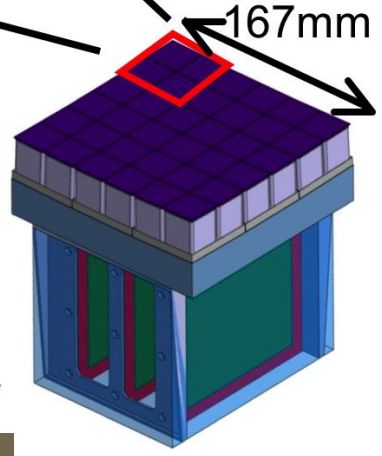


4932 MAPMTs
(8x8 pixels)



Elementary Cell (EC)
(2x2 PMTs = 256 pixels)





Focal Surface detector
137 PDMs
= 0.3M Pixels

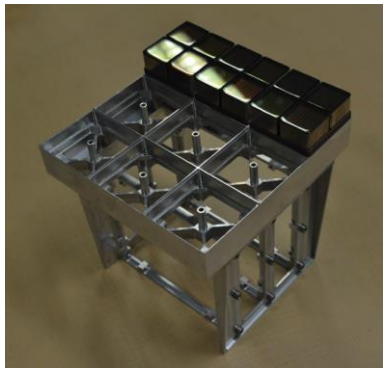


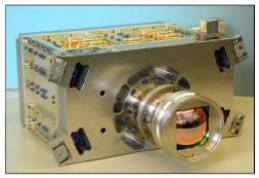
Photo-Detector Module (PDM)
(3x3 ECs = 36 PMTS
2,304 pixels)

1 High Voltage / PDM

The 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
Spatial resolution	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%
Detection Efficiency	≥20%

Atmospheric Monitoring System



- IR Camera **Spain**

  Imaging observation of cloud temperature inside FOV of JEM-EUSO

- Lidar **Switzerland Japan**

  Ranging observation using UV laser

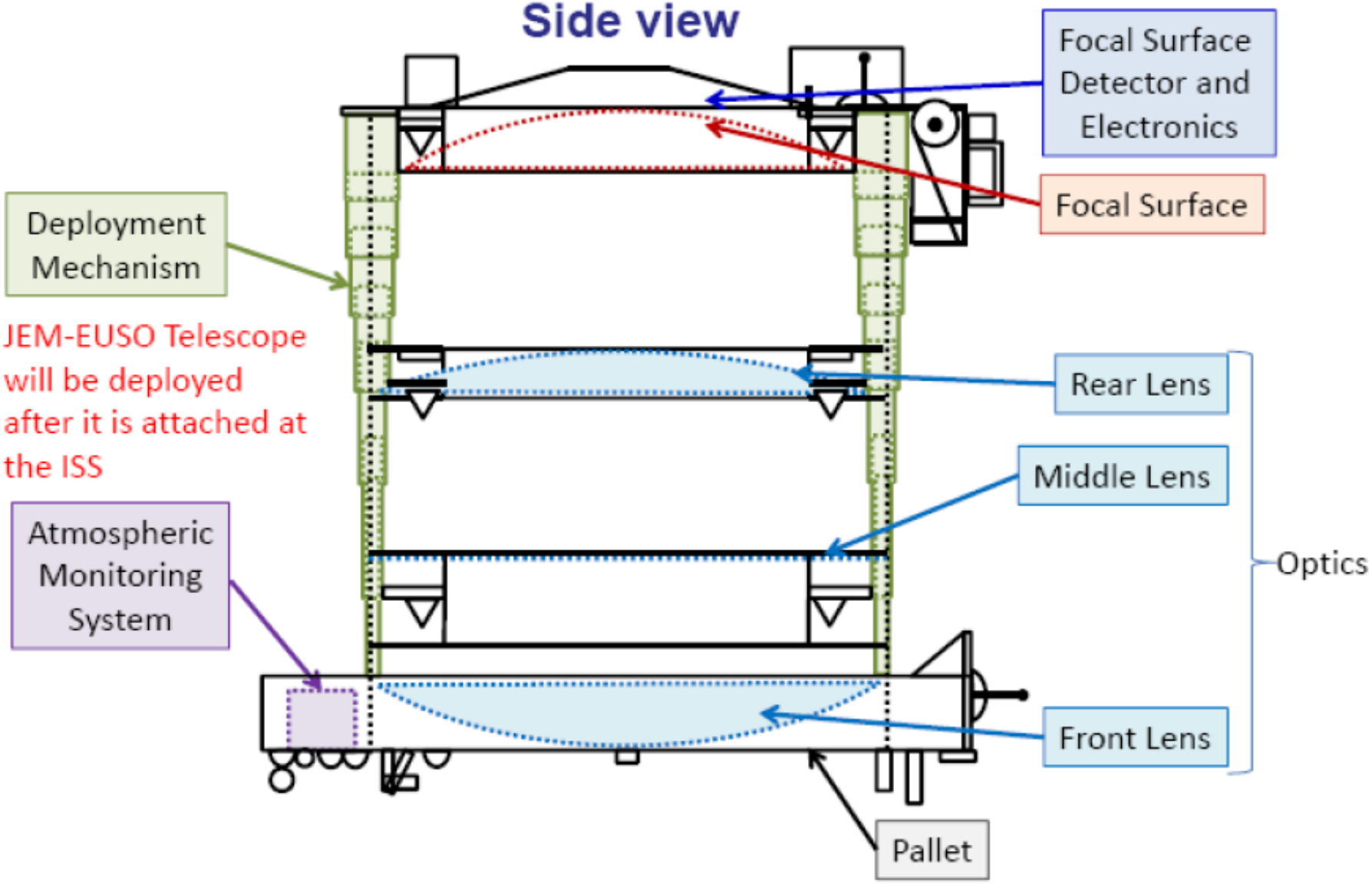
- JEM-EUSO "slow-data"

  Continuous background photon counting

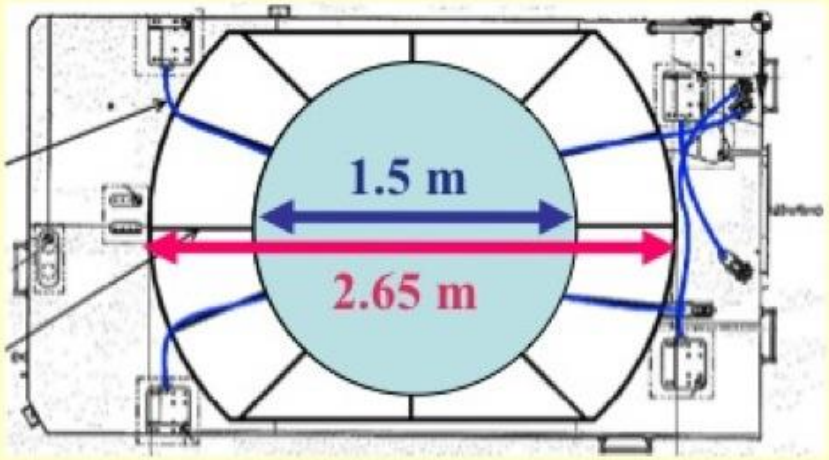
- *Cloud amount, cloud top altitude*: (IR cam., Lidar, slow-data)
- *Airglow*: (slow-data)
- *Calibration of telescope*: (Lidar)

Science Instrument

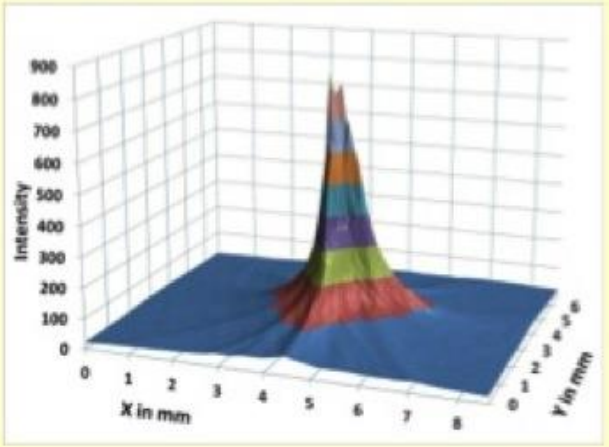
Side view

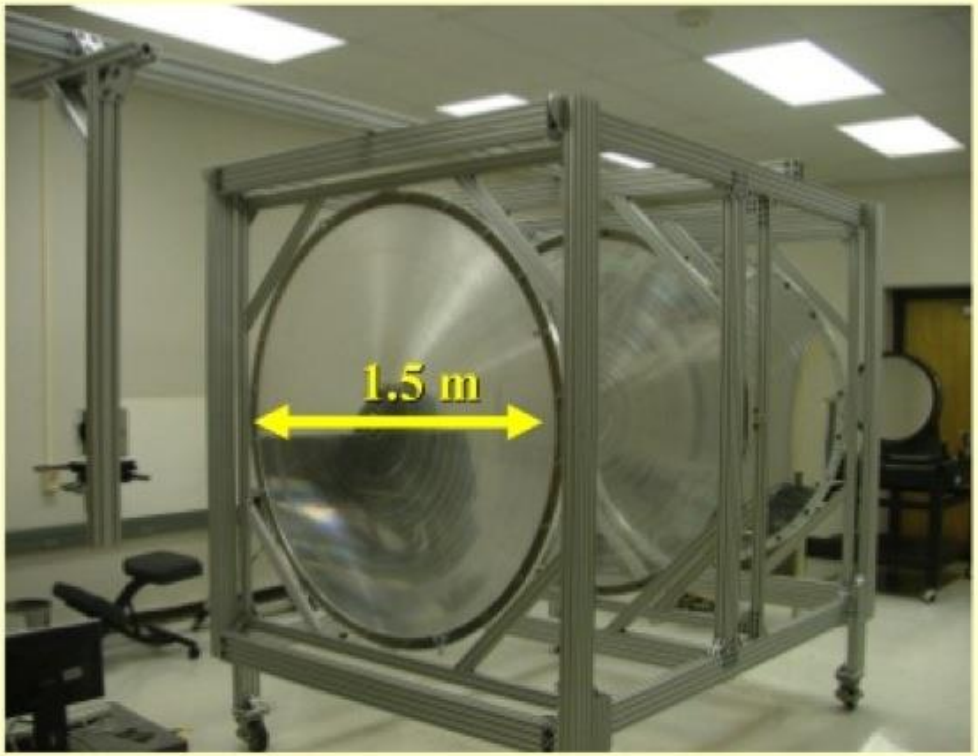


Test of Breadboard Model Lenses



3 Breadboard Model (BBM) Fresnel lenses (1.5m ϕ) are manufactured and tested.





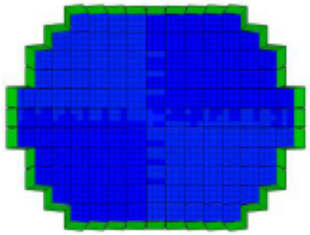
Tested performances meet the requirements or are close to it.

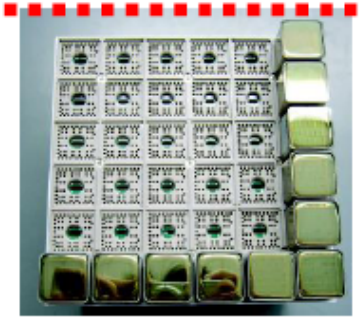
Result: ~3mm RMS

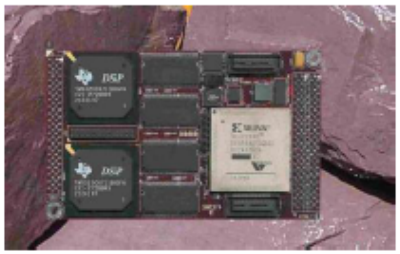
Req. : 4.6mm RMS

JEM-EUSO DAQ – Data reduction block scheme

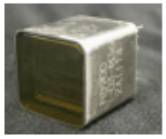
9.6 GB/s (FS) $4*10^{-3}$ compression 10^{-3} compression 297 kbps 3 Gbyte/day

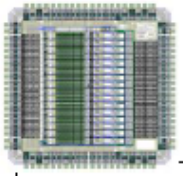






Storage on SSD will give factor 3, up to 10 Gbyte/day Return with Soyuz





FEE

ASIC+ FPGA

Count

9EC

PDM Control Board

FPGA

Track Trigger

8PDM

PhotoDetector Modules

Cluster Control Board

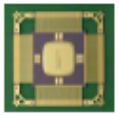
DSP

20CCB

FS Control Board

MPU

Operation Control



200kch 1,476 EC

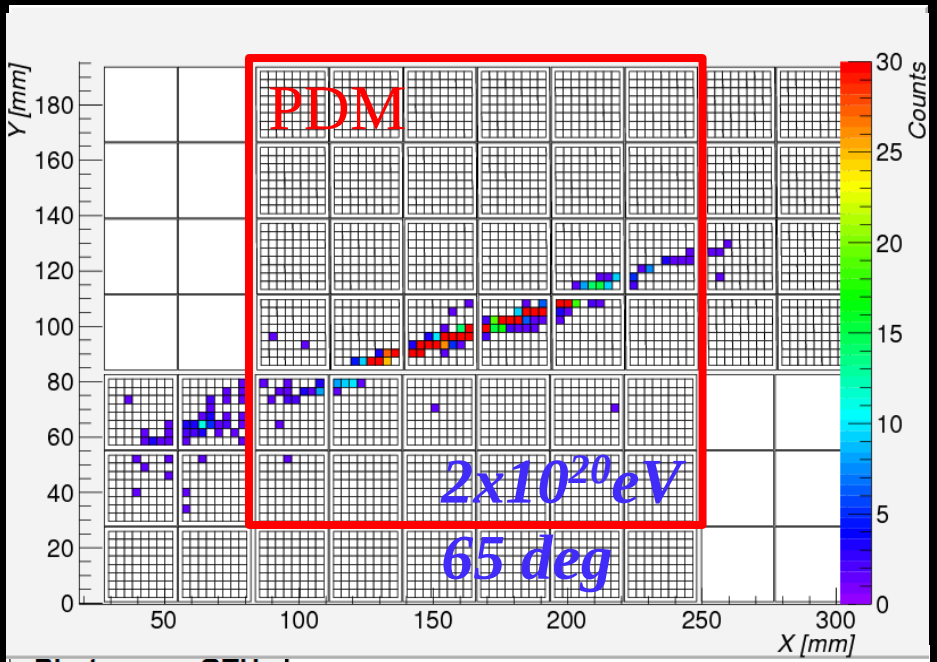
160 Boards

20 Boards

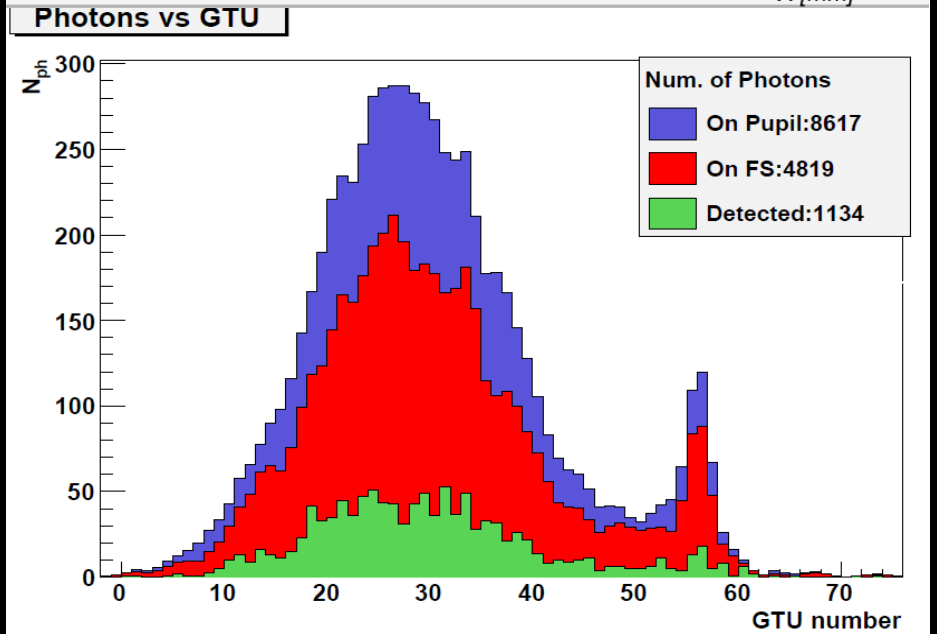
2 Boards

LVDS with SpaceWire (ECSS-E-50-12A)

Shower Simulation

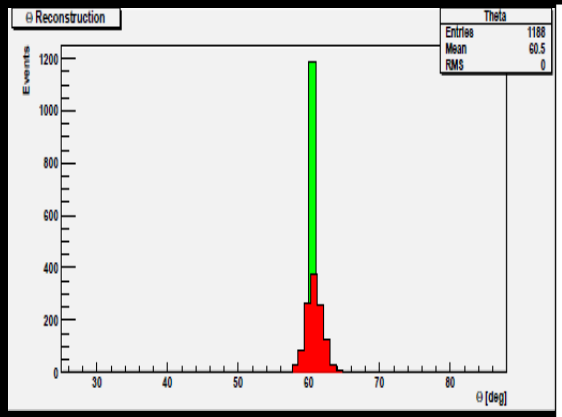


Simulated air shower image on the focal surface detector.

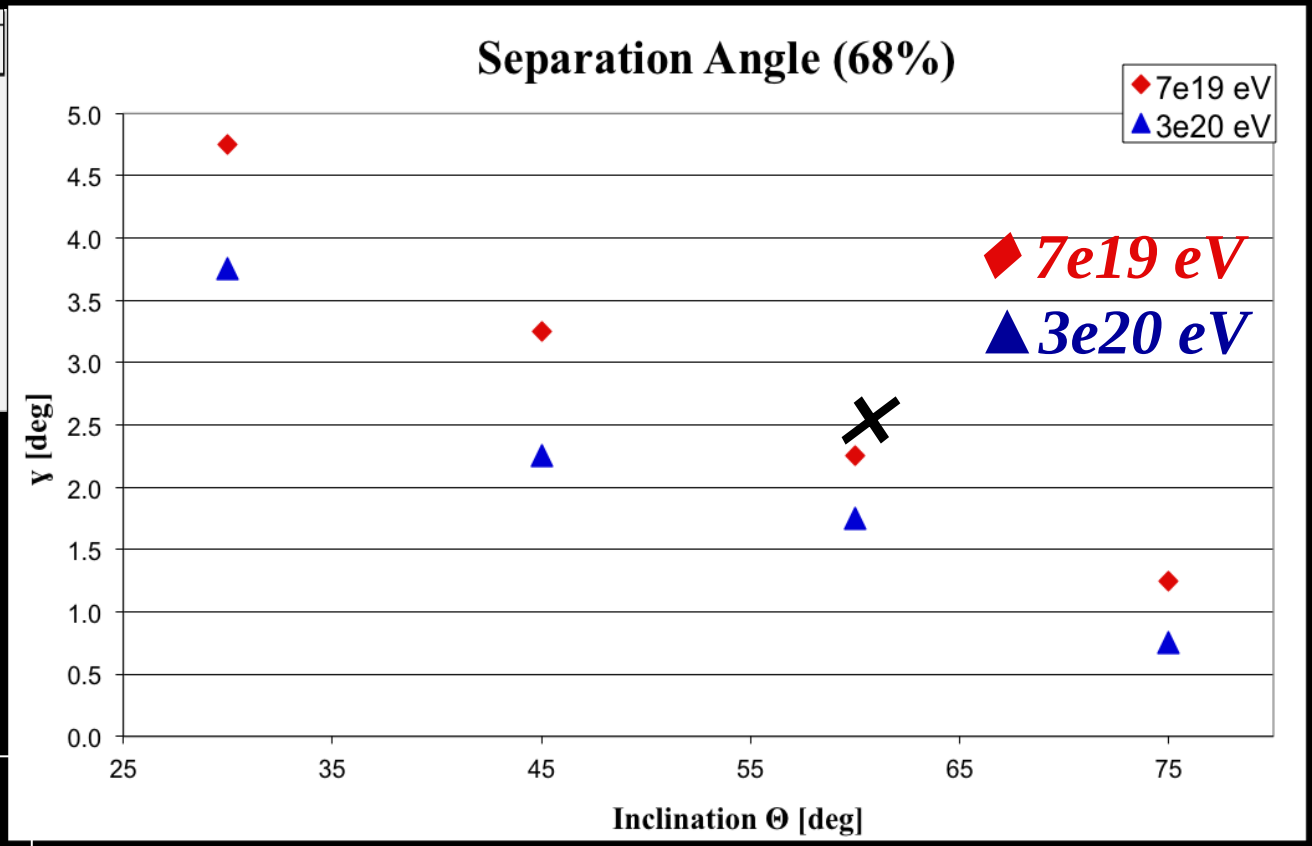


Detected photoelectrons are recorded every Gate Time Unit (GTU) of 2.5μs continuously.

Angular Resolution



α(deg)



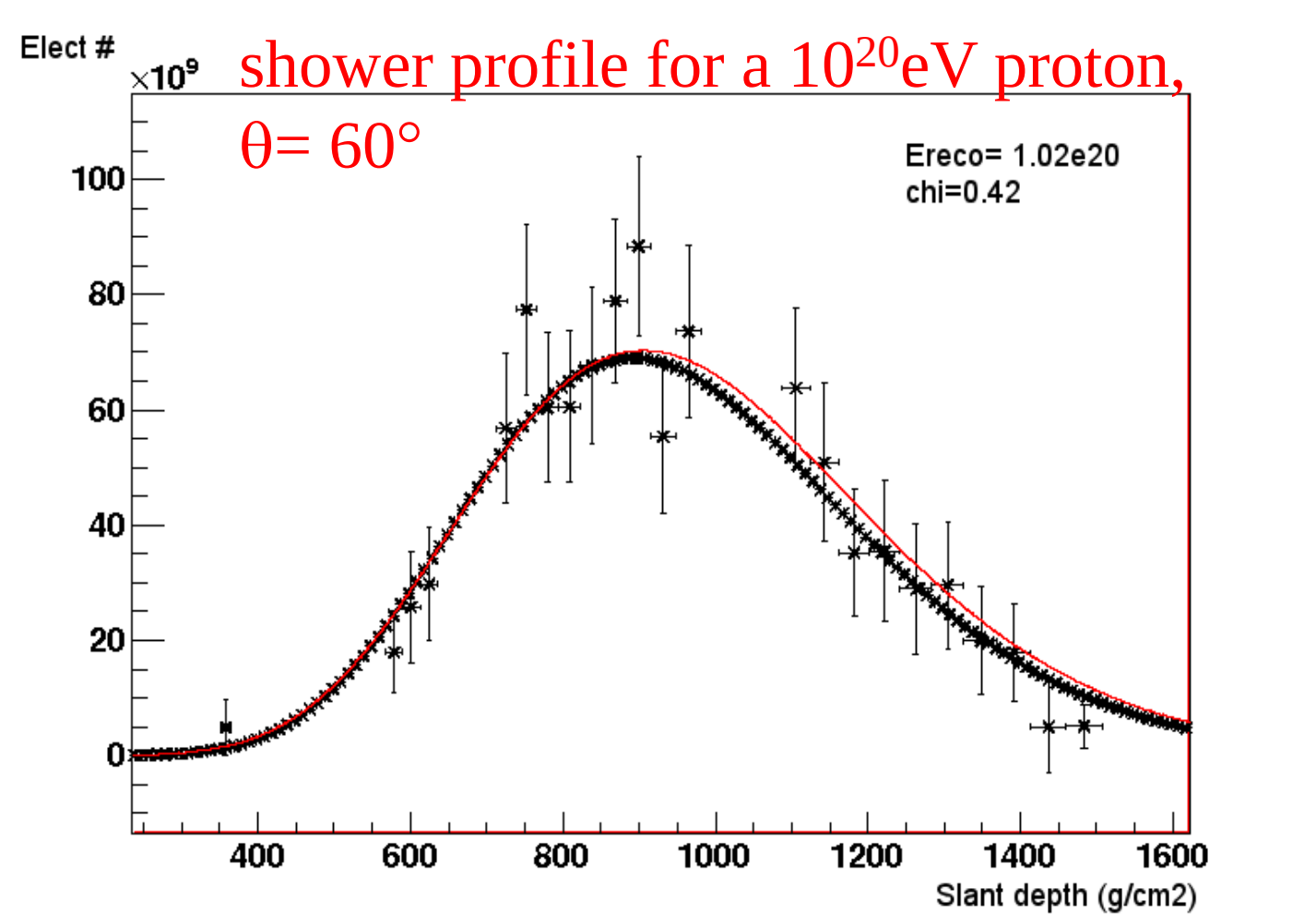
× **Requirement**
α<2.5˚ @
E=10^{20}eV, θ=60˚

Zenith Angle θ(deg)

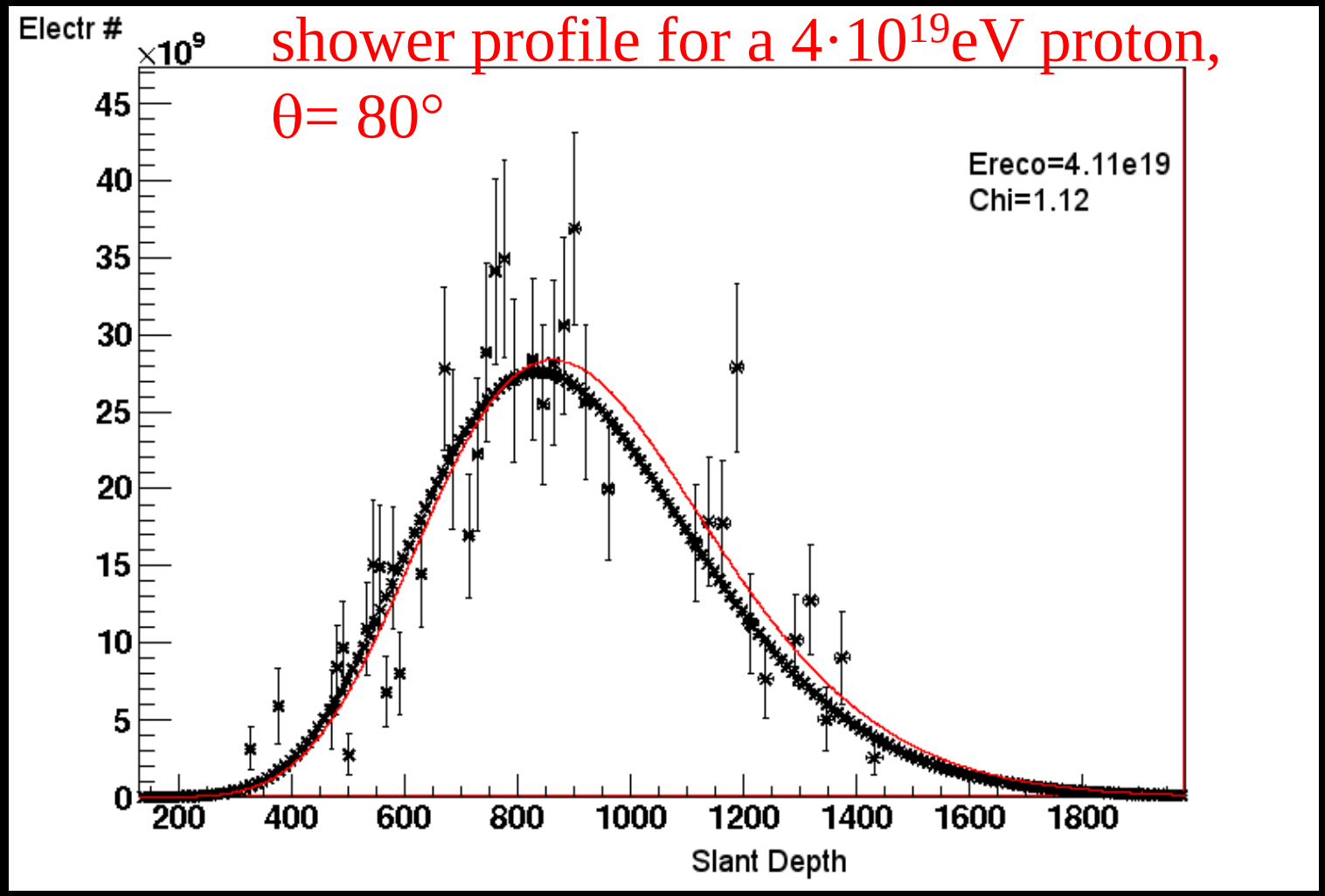
End to end simulations show that the requirement is met.

T.Mernik et al., ID633

Energy Resolution



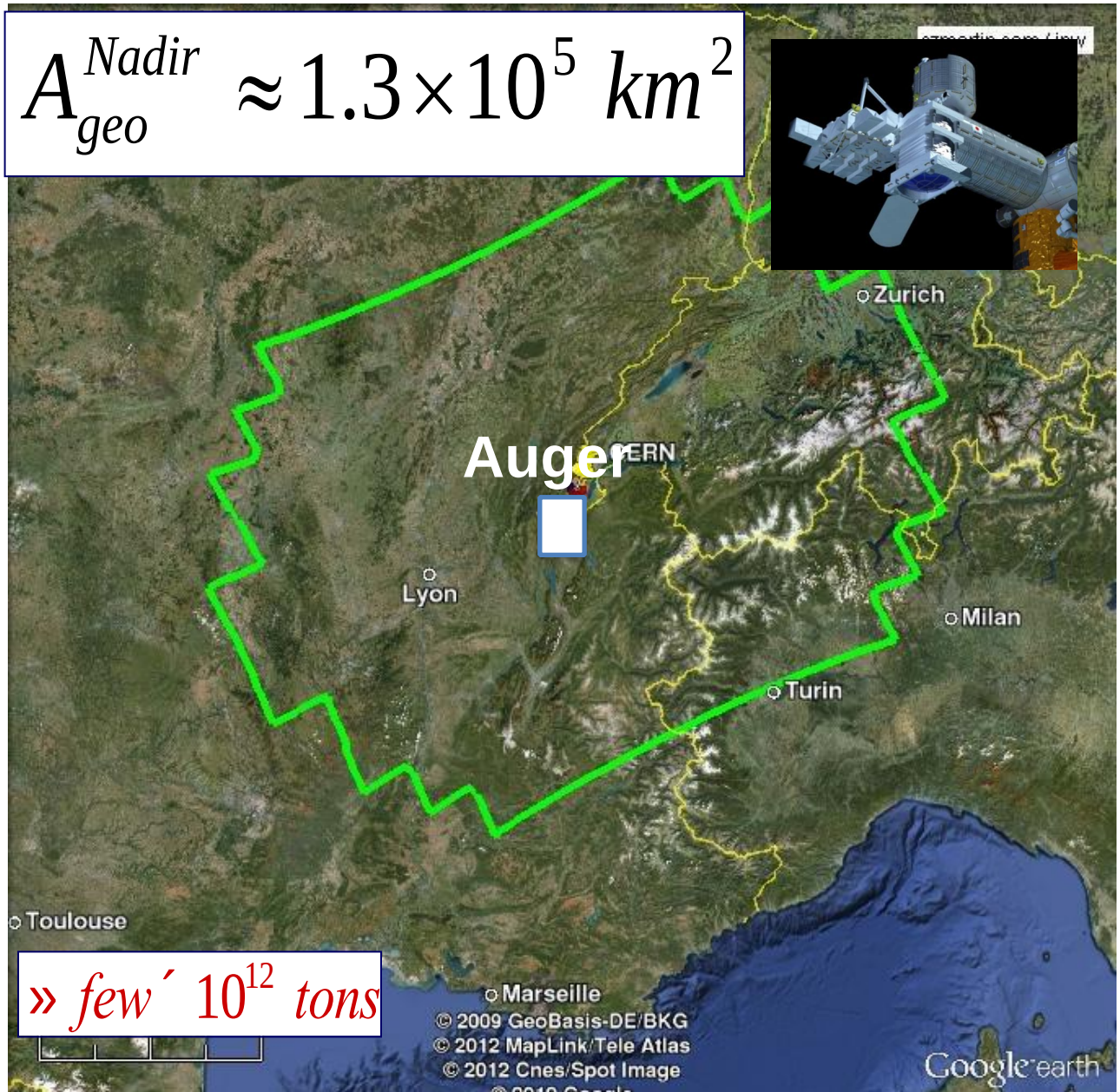
ΔE/E < 30% for ~90% of events



ΔE/E < 30% for ~ 90% of events

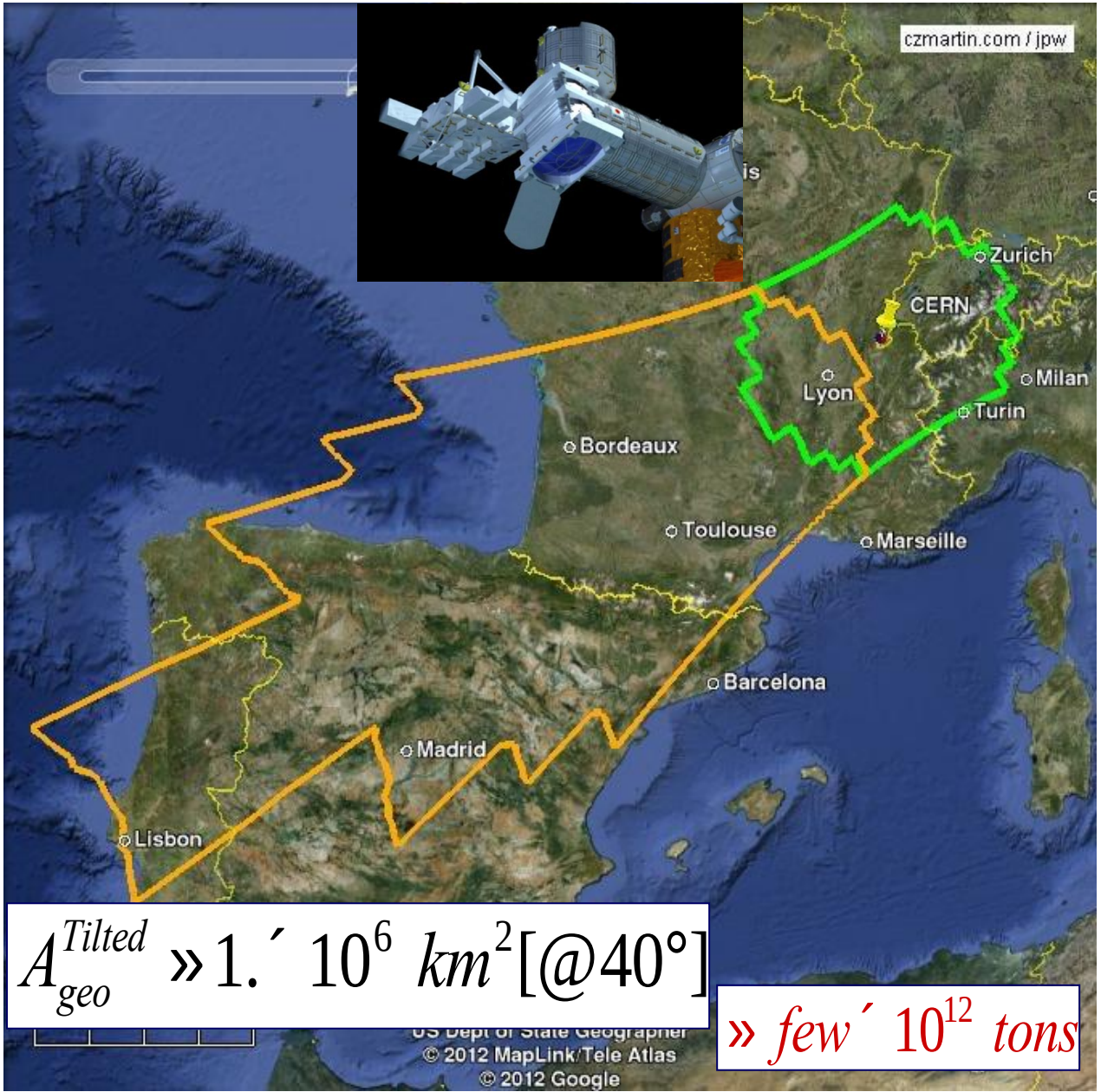
Monitored Area

$$A_{geo}^{Nadir} \approx 1.3 \times 10^5 \ km^2$$



» few´ 10^{12} tons

Monitored Area

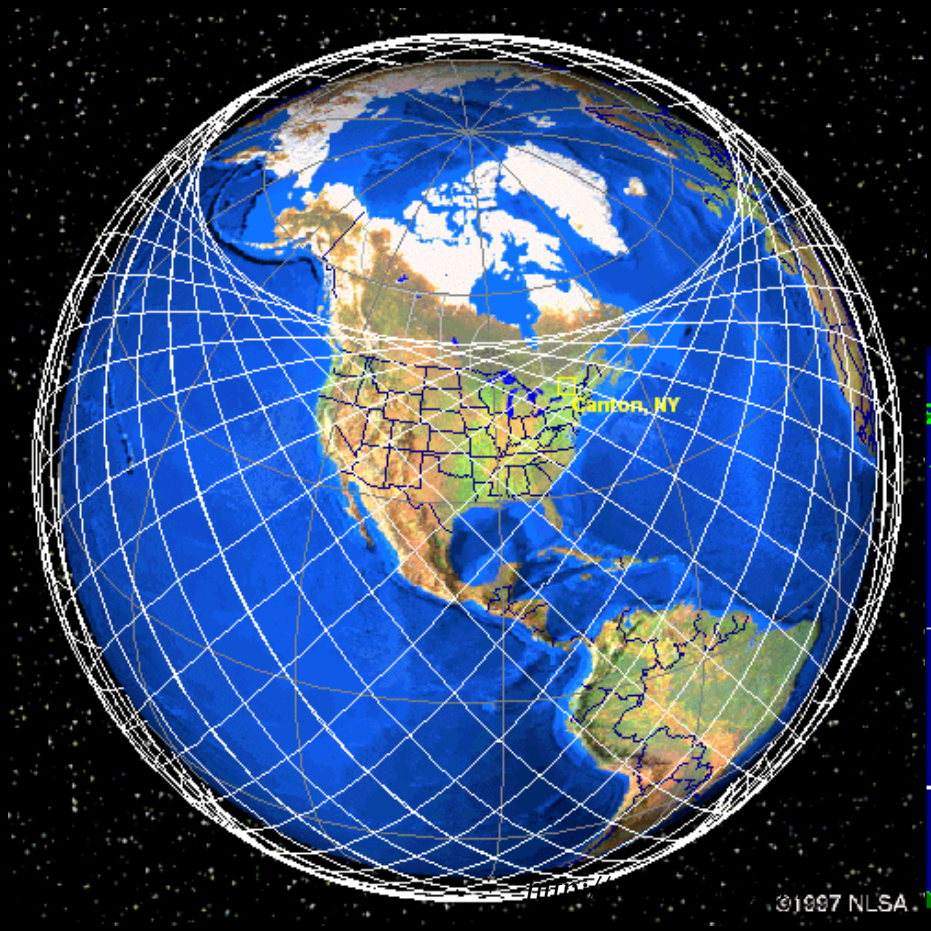


$$A_{geo}^{Tilted} \gg 1.\acute{}\ 10^{6}\ km^{2}[@40°]$$

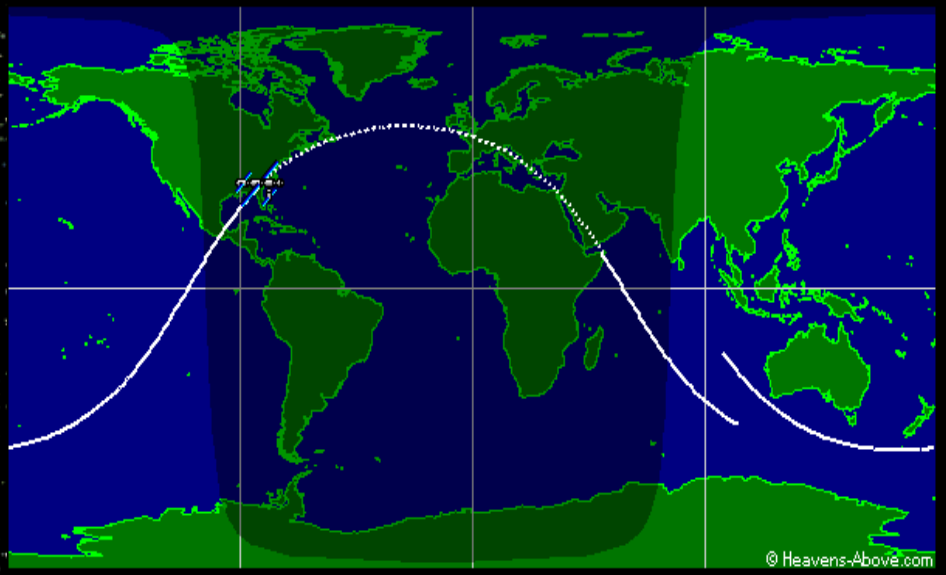
$$\gg few\acute{}\ 10^{12}\ tons$$

Full Sky Coverage

with nearly uniform exposure



The ISS ORBIT

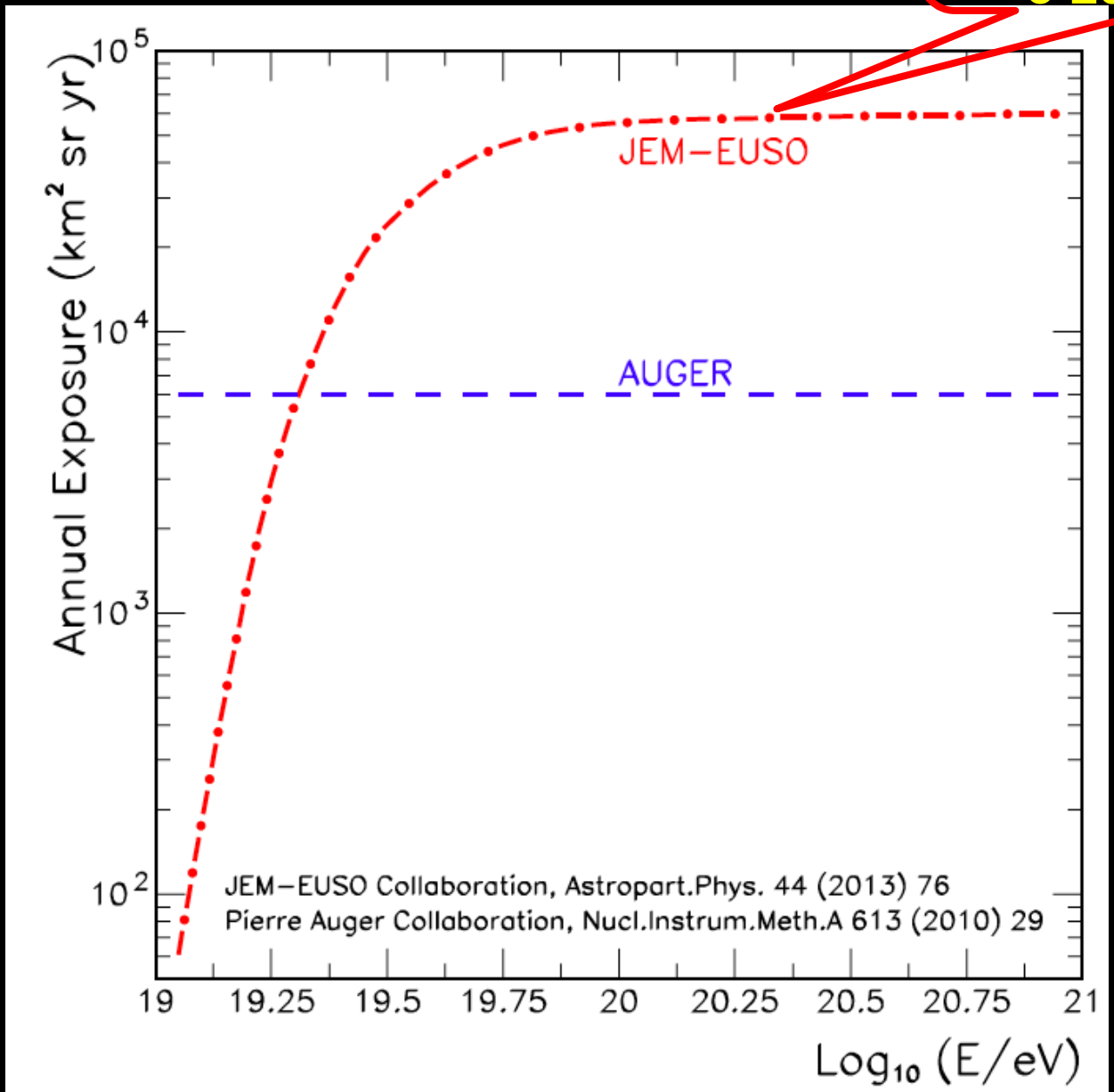


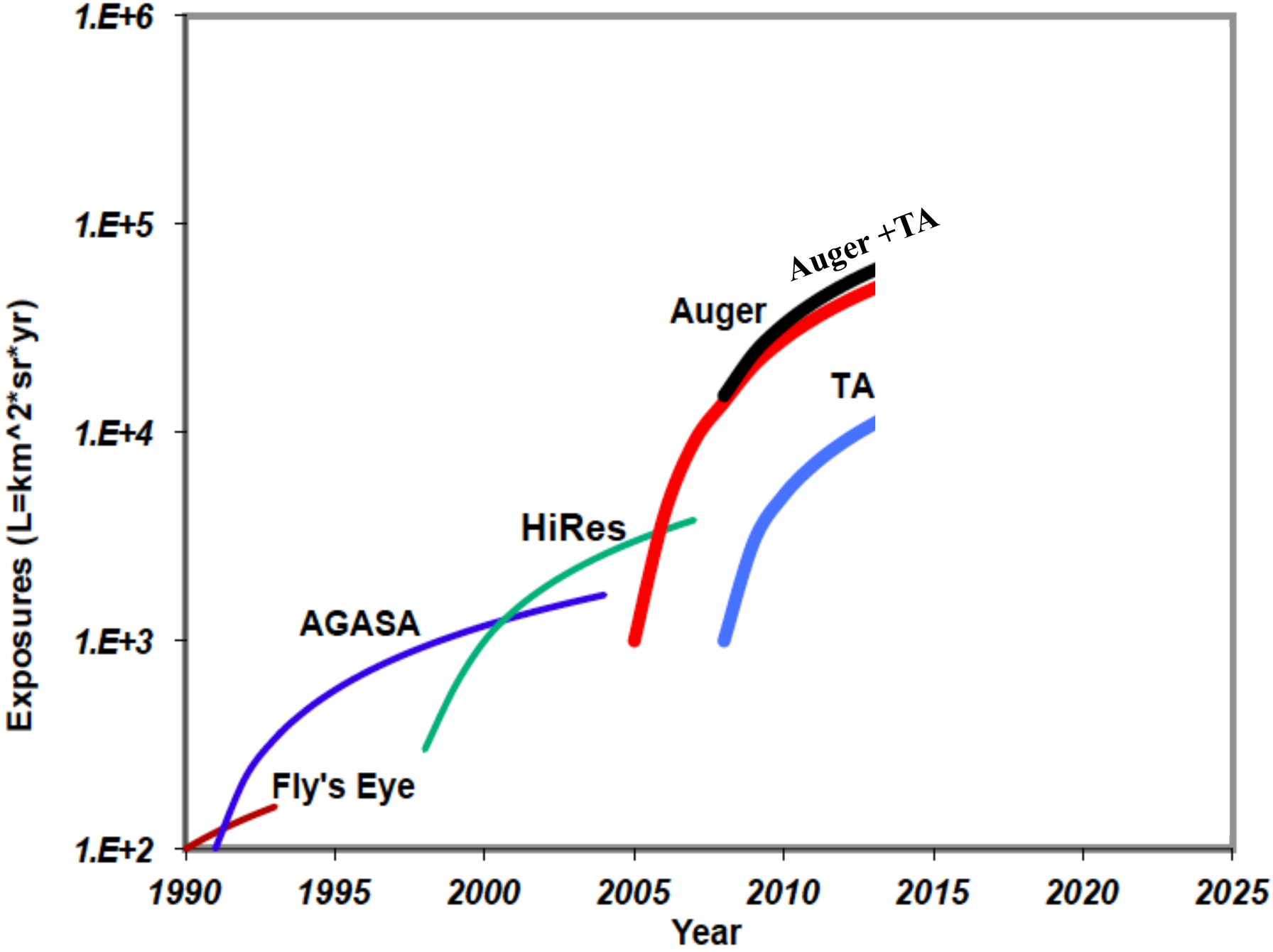
Inclination: 51.6°

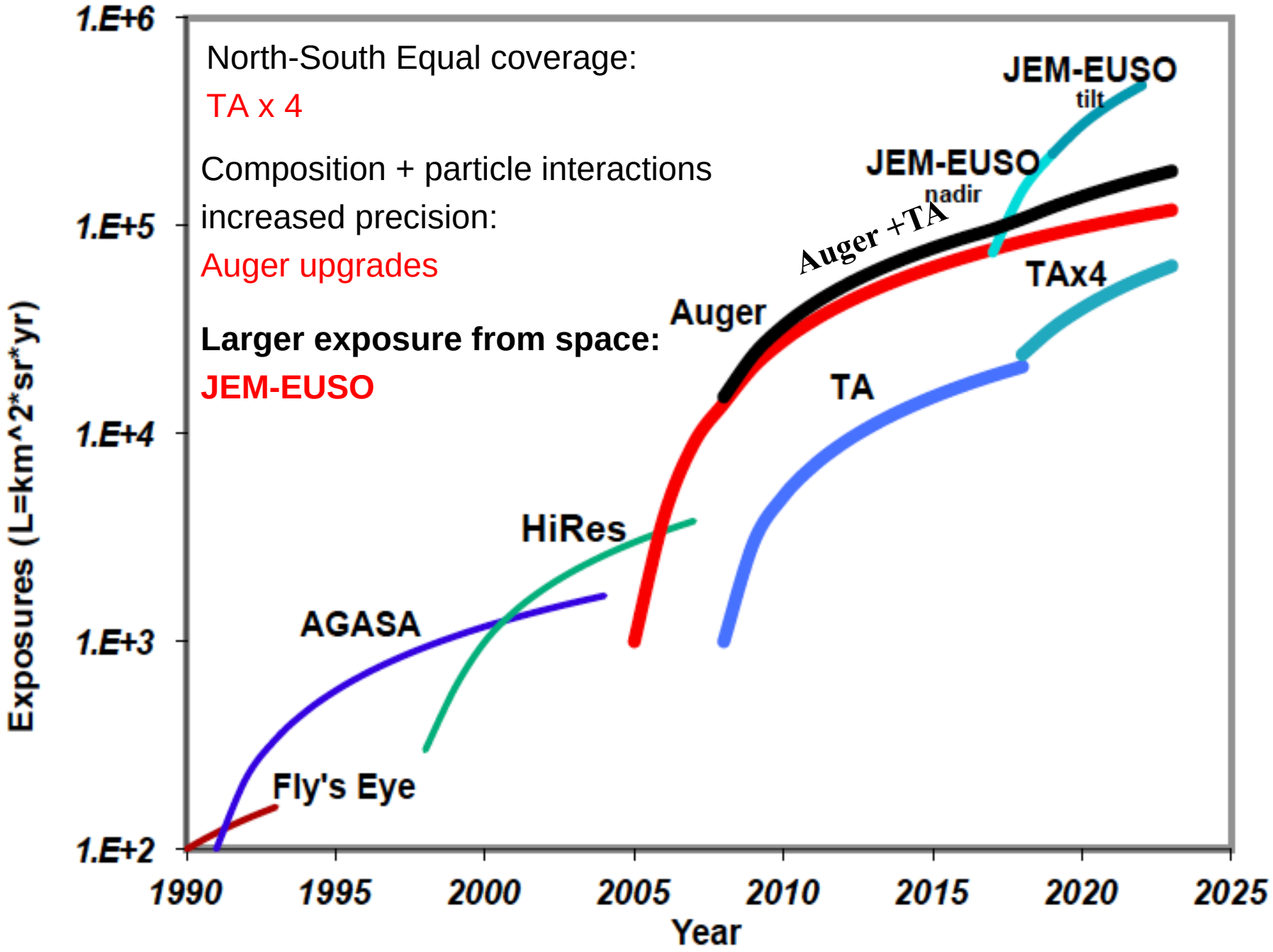
Height: ~400km

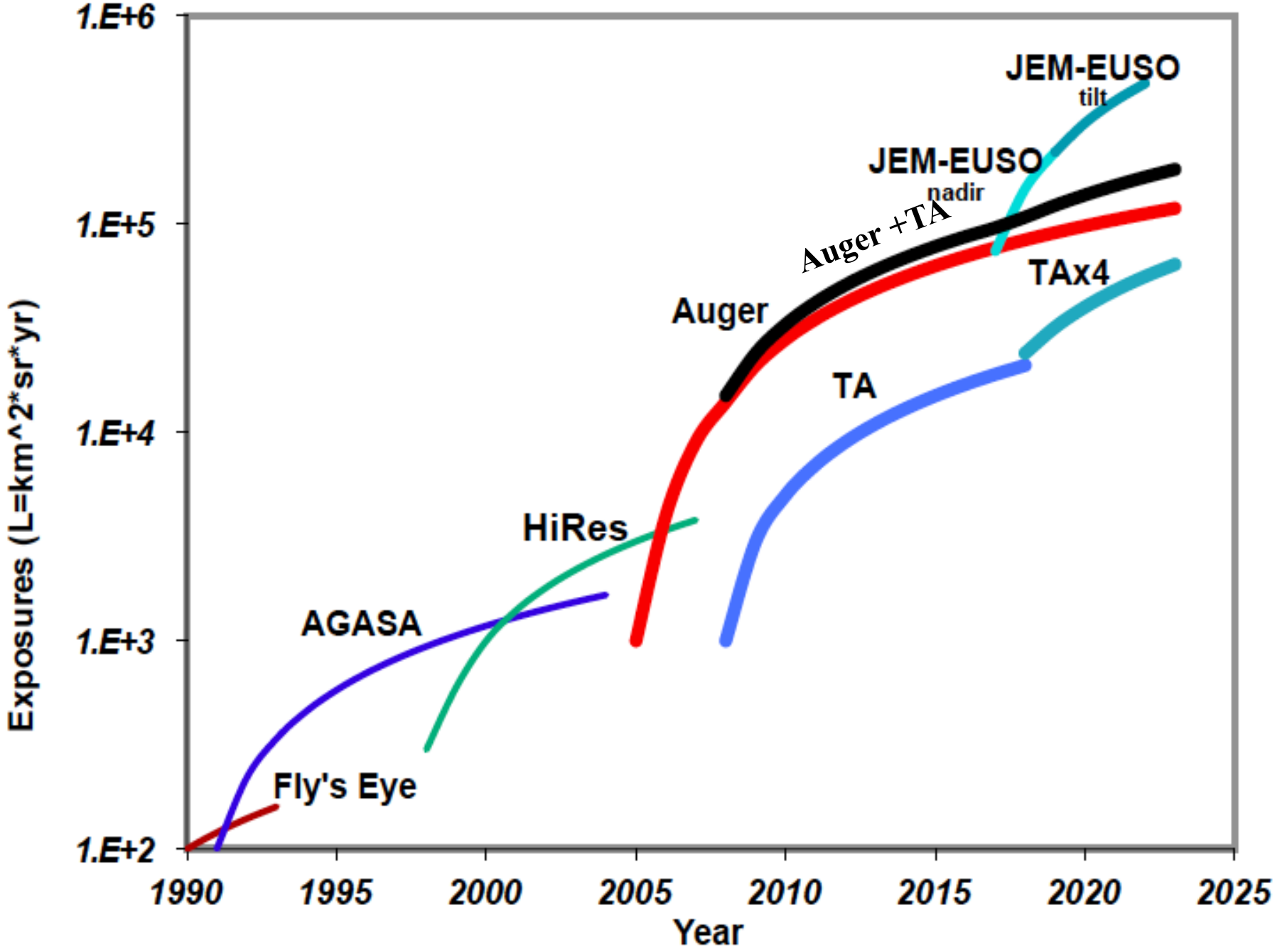
JEM-EUSO

annual exposure =
10 x Auger
$6\ 10^4$ km^2 sr yr

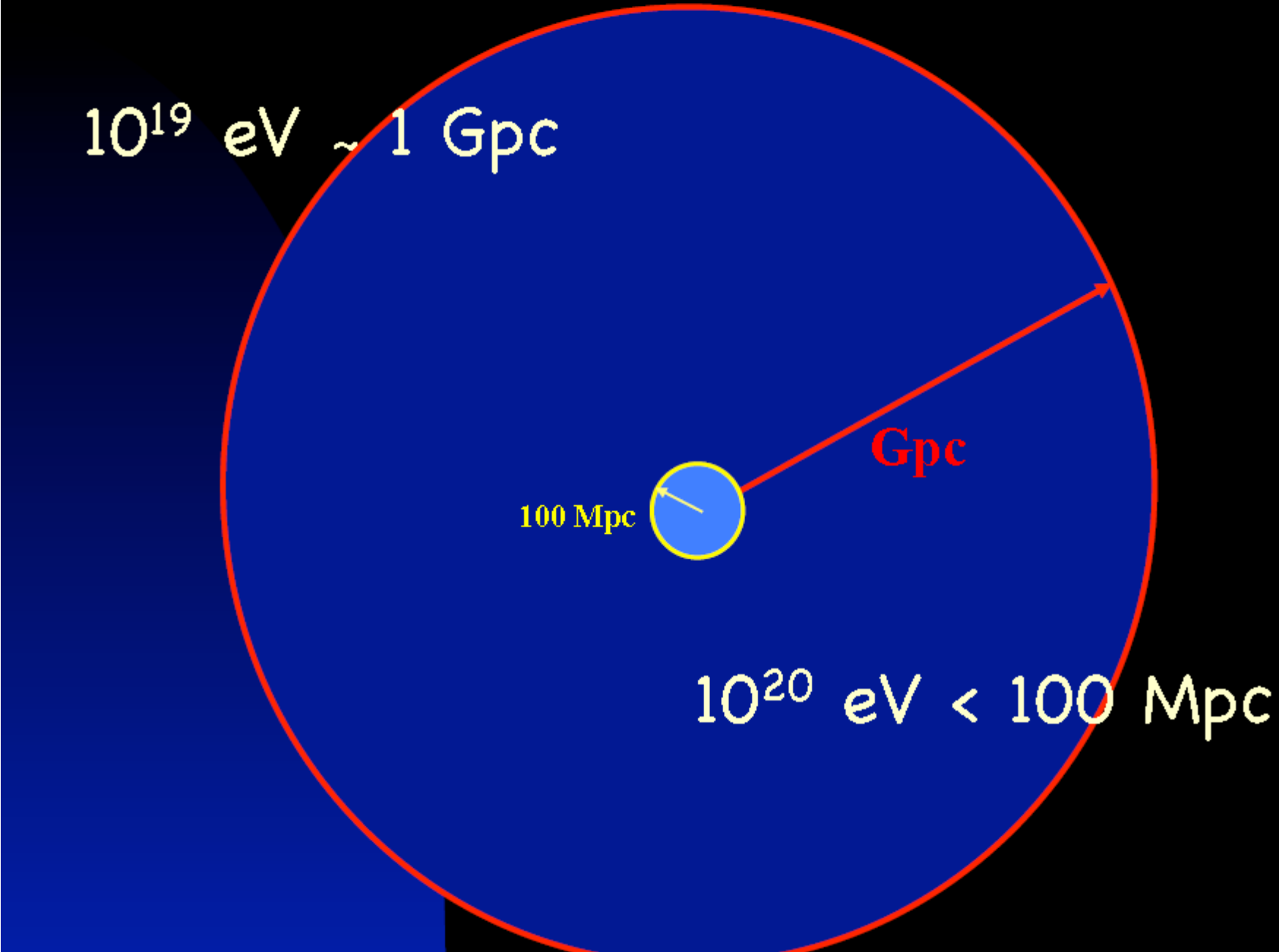


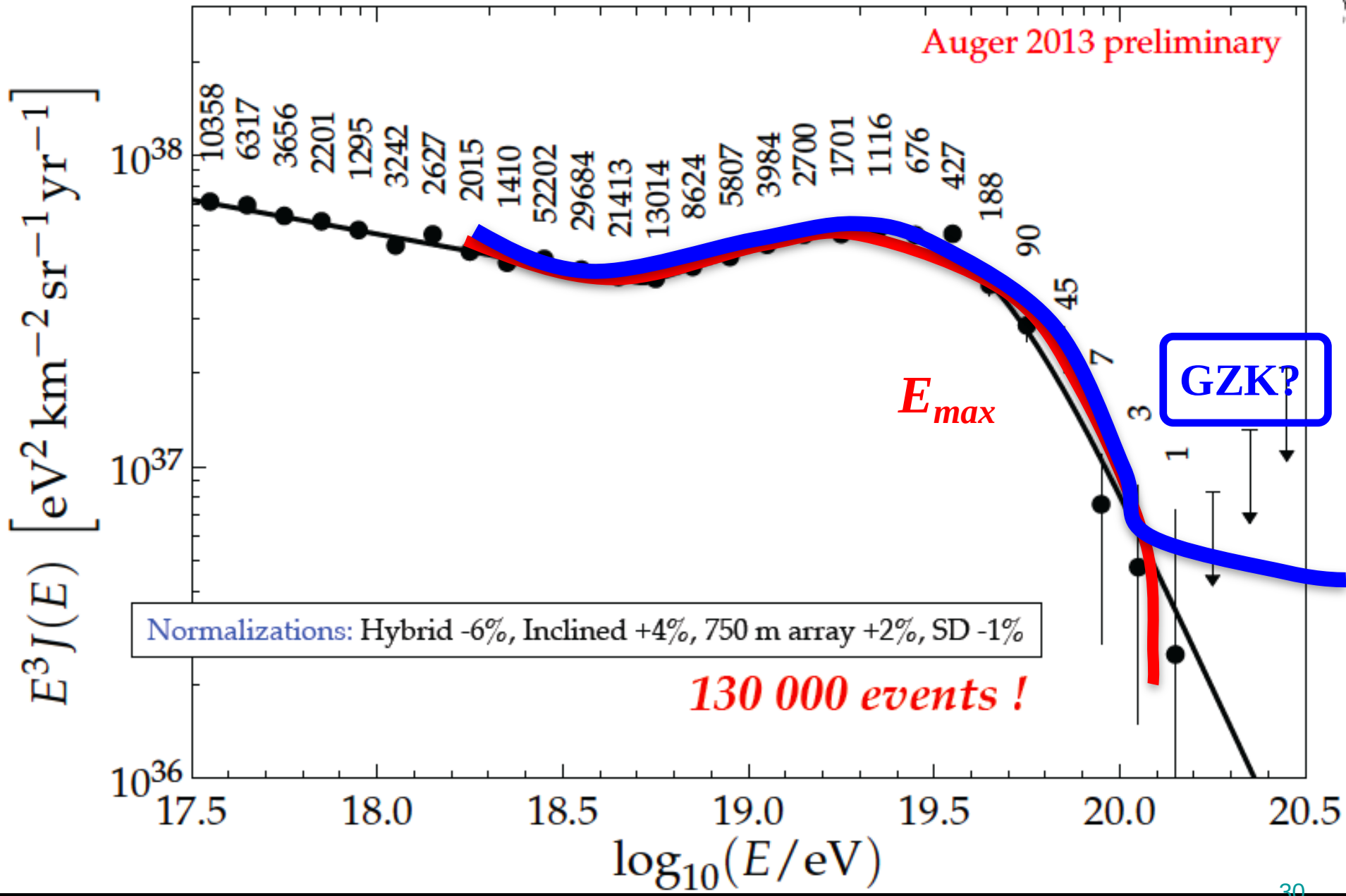

1.E+6
1.E+5
1.E+4
1.E+3
1.E+2
Exposures (L=km^2*sr*yr)
1990
1995
2000
2005
2010
2015
2020
2025
Year
Auger +TA
Auger
TA
HiRes
AGASA
Fly's Eye


North-South Equal coverage:
TA x 4
Composition + particle interactions
increased precision:
Auger upgrades
Larger exposure from space:
JEM-EUSO
JEM-EUSO
tilt
JEM-EUSO
nadir
Auger +TA
TAx4
Auger
TA
HiRes
AGASA
Fly's Eye
1.E+6
1.E+5
1.E+4
1.E+3
1.E+2
Exposures (L=km^2*sr*yr)
1990
1995
2000
2005
2010
2015
2020
2025
Year


1.E+6
1.E+5
1.E+4
1.E+3
1.E+2
Exposures (L=km^2*sr*yr)
1990
1995
2000
2005
2010
2015
2020
2025
Year
JEM-EUSO
tilt
JEM-EUSO
nadir
Auger +TA
TAx4
Auger
TA
HiRes
AGASA
Fly's Eye

Horizons:




Auger 2013 preliminary
10358
6317
3656
2201
1295
3242
2627
2015
1410
52202
29684
21413
13014
8624
5807
3984
2700
1701
1116
676
427
188
90
45
7
3
1
E_{max}
GZK?
Normalizations: Hybrid -6%, Inclined +4%, 750 m array +2%, SD -1%
130 000 events !
10^{38}
10^{37}
10^{36}
17.5
18.0
18.5
19.0
19.5
20.0
20.5
$E^3 J(E)$ $\left[\mathrm{eV}^2\,\mathrm{km}^{-2}\,\mathrm{sr}^{-1}\,\mathrm{yr}^{-1}\right]$
$\log_{10}(E/\mathrm{eV})$

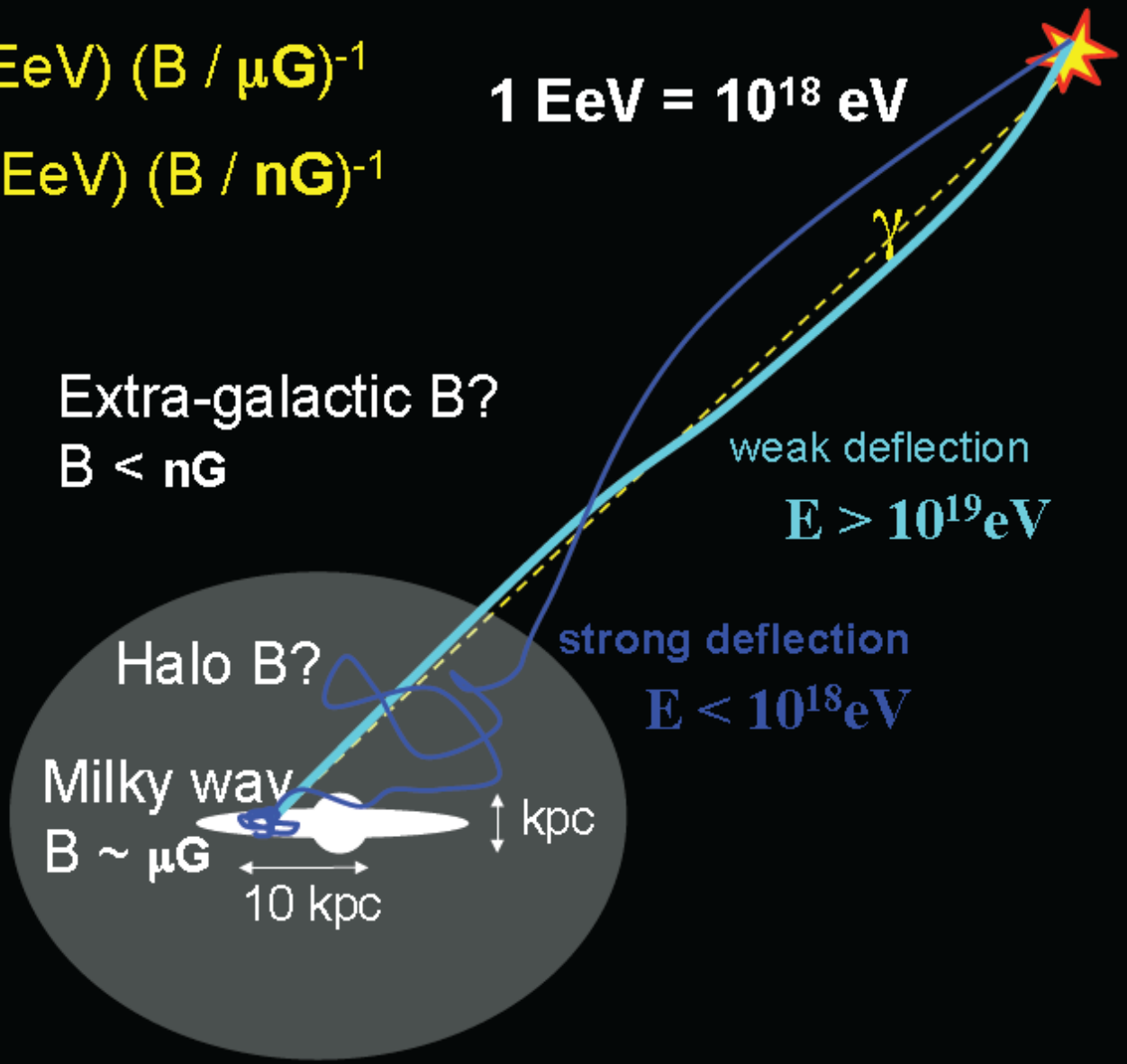
Known unknown"

Cosmic Magnetic Fields

R_L = **kpc** Z^{-1} (E / EeV) (B / **μG**)$^{-1}$

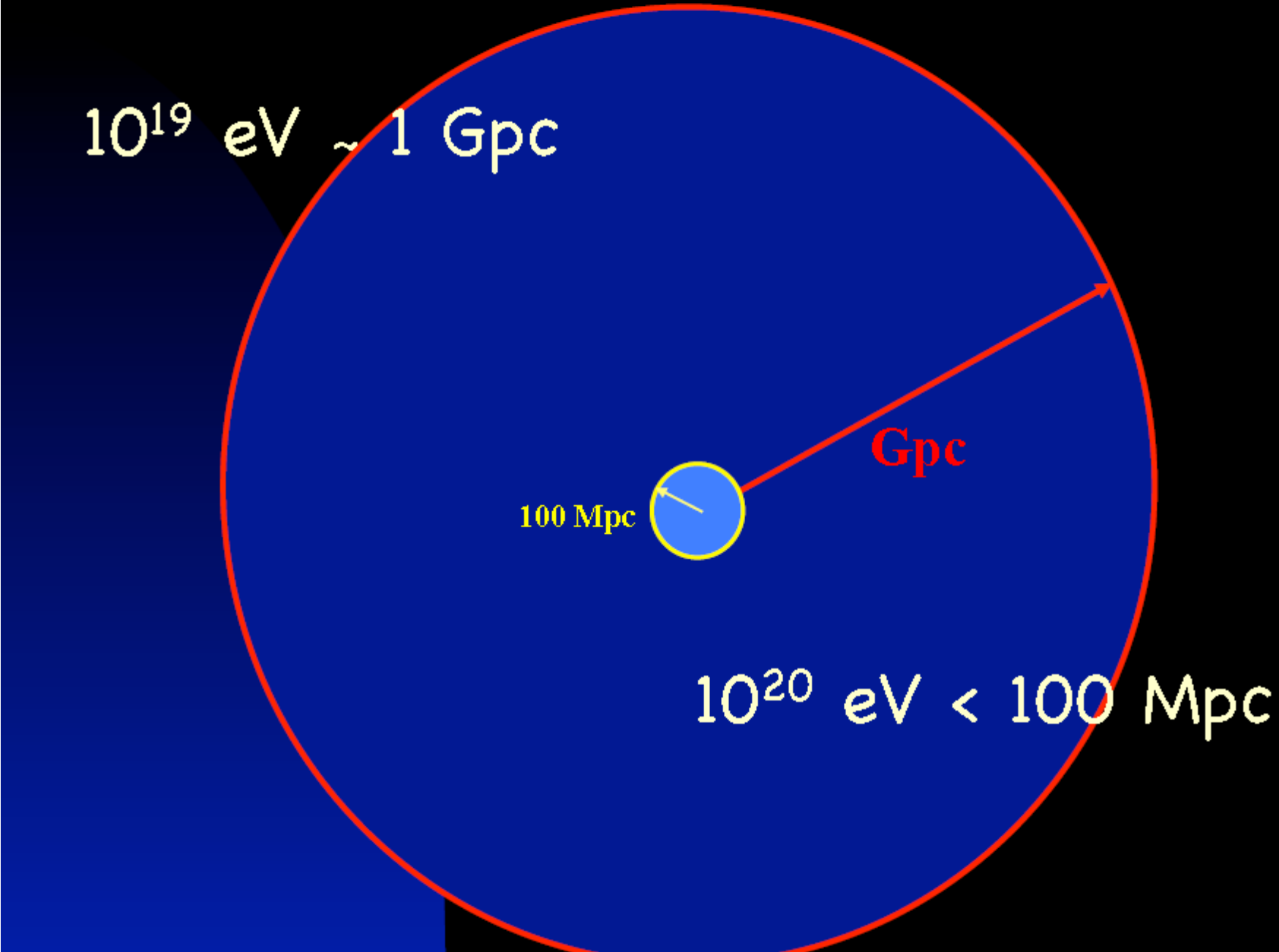
R_L = **Mpc** Z^{-1} (E / EeV) (B / **nG**)$^{-1}$

1 EeV = 10^{18} eV

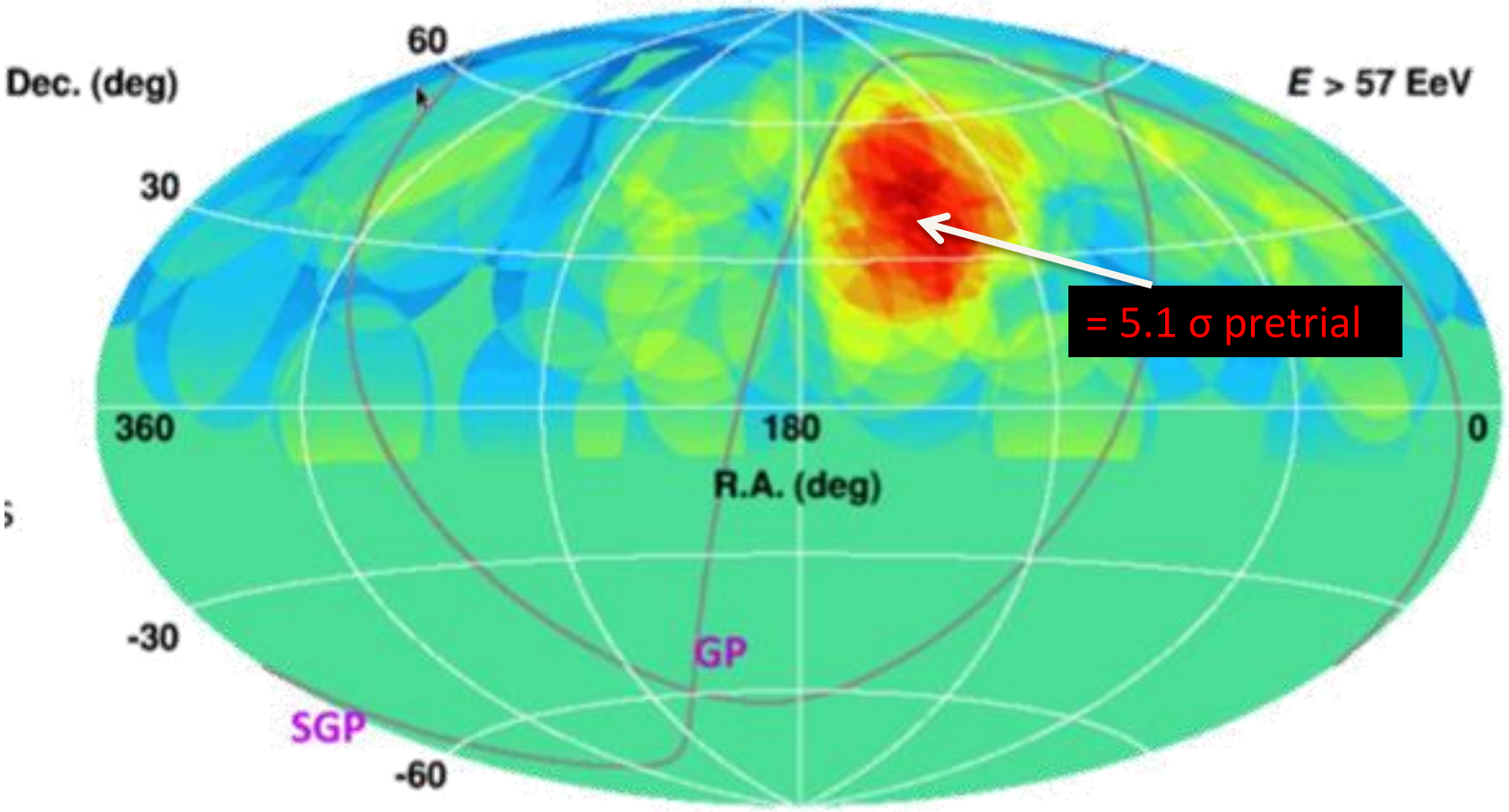


alactic B deflection
< 10° Z (40 EeV/E)
nisotropic in sky

Horizons:



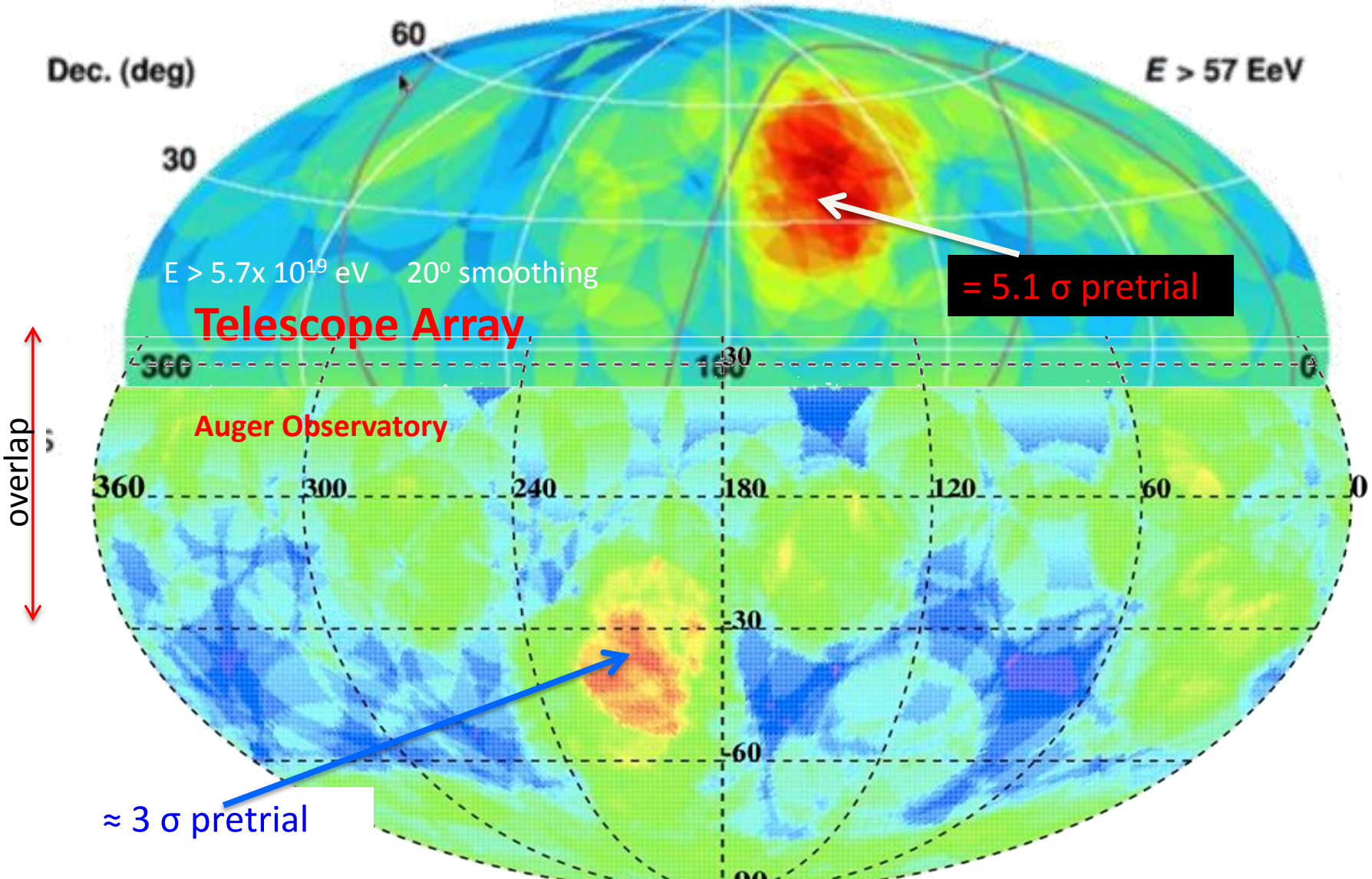
Telescope Array Hotspot > 60 EeV



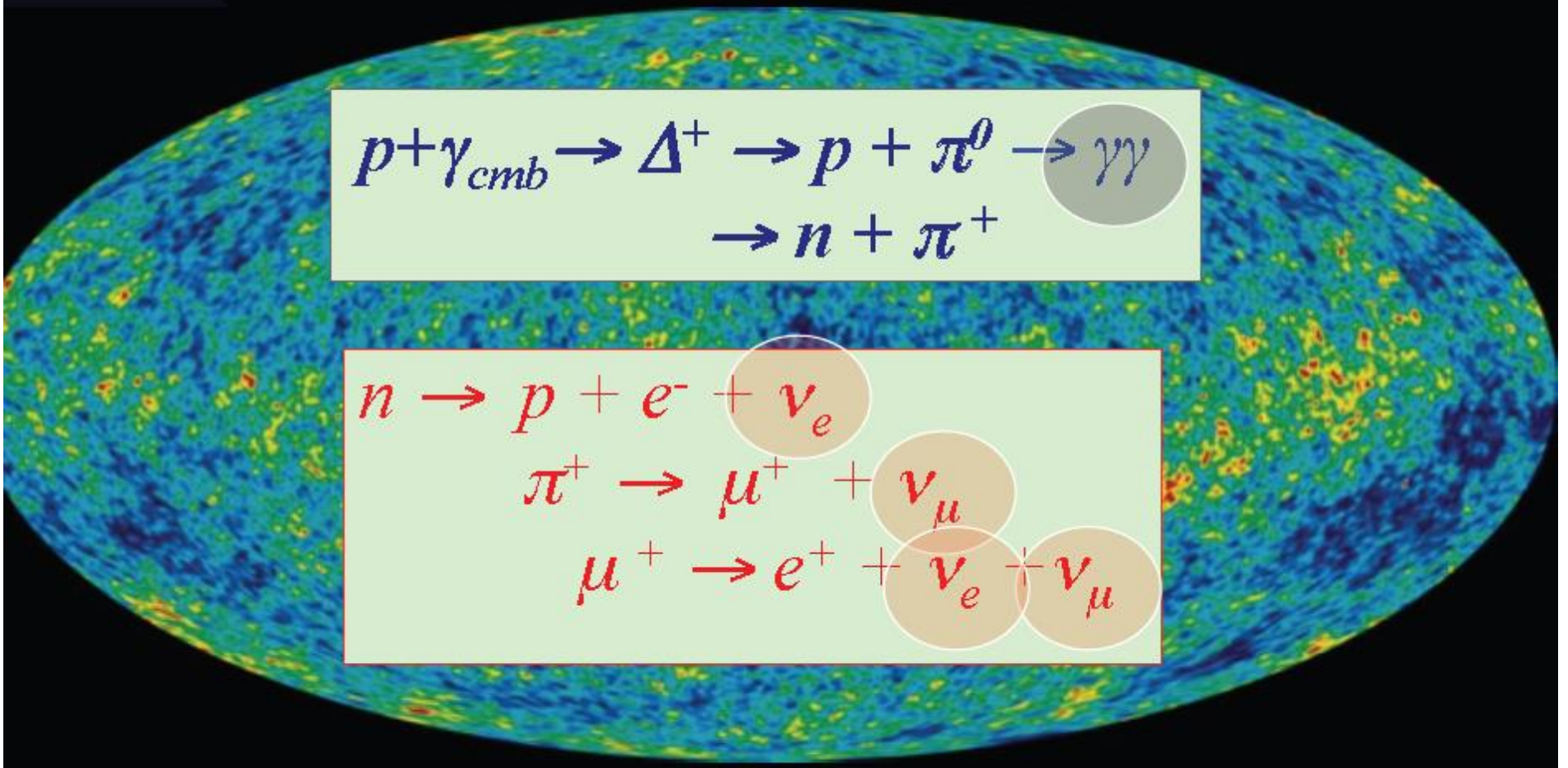
Abbasi et al. 2014

Anisotropy Hints > 60 EeV

arxiv.1404.5890



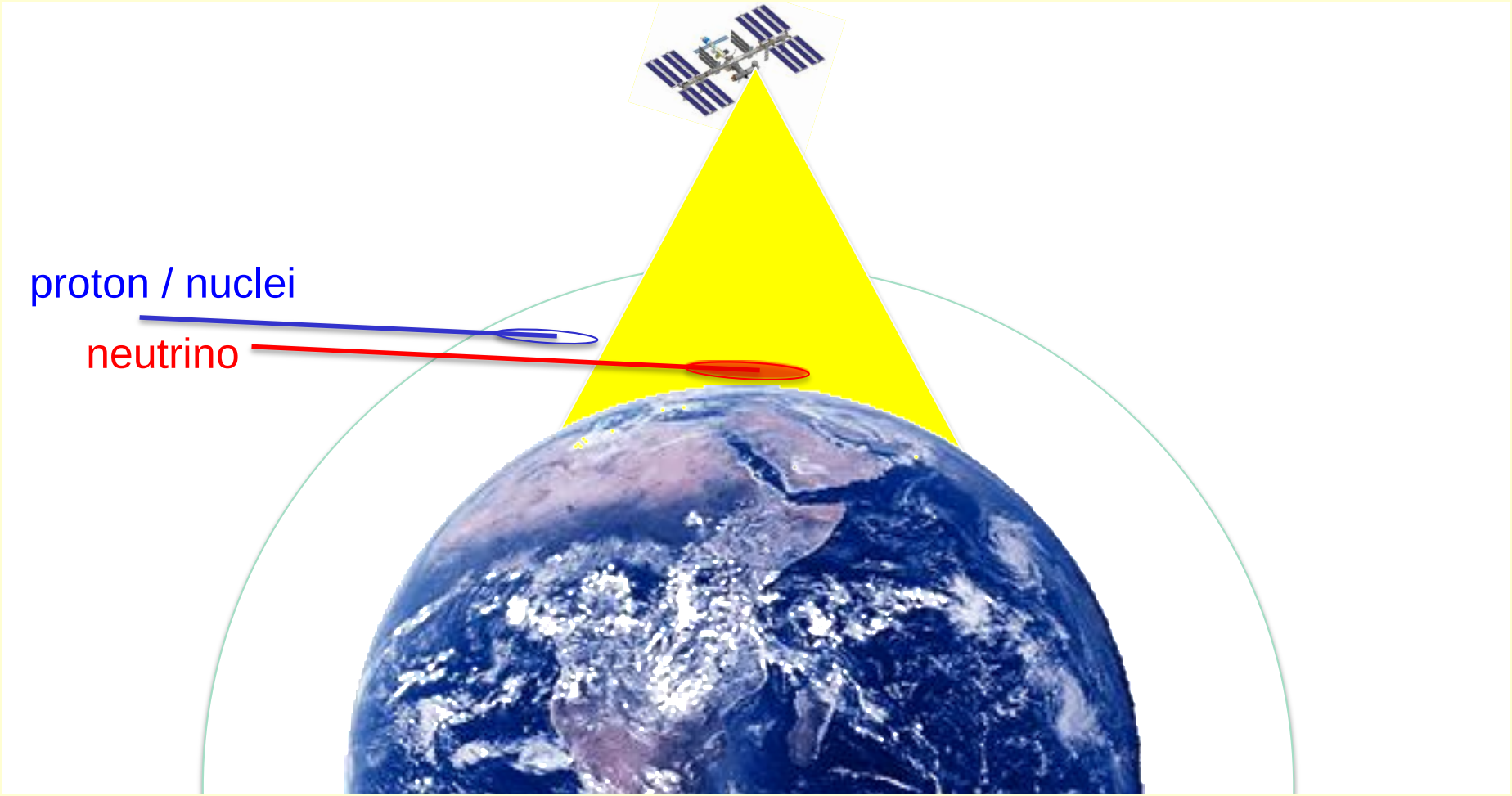
Cosmogenic (GZK) Neutrinos & Photons



$$p + \gamma_{cmb} \rightarrow \Delta^{+} \rightarrow p + \pi^{0} \rightarrow \gamma\gamma$$
$$\rightarrow n + \pi^{+}$$

$$n \rightarrow p + e^{-} + \nu_{e}$$
$$\pi^{+} \rightarrow \mu^{+} + \nu_{\mu}$$
$$\mu^{+} \rightarrow e^{+} + \nu_{e} + \nu_{\mu}$$

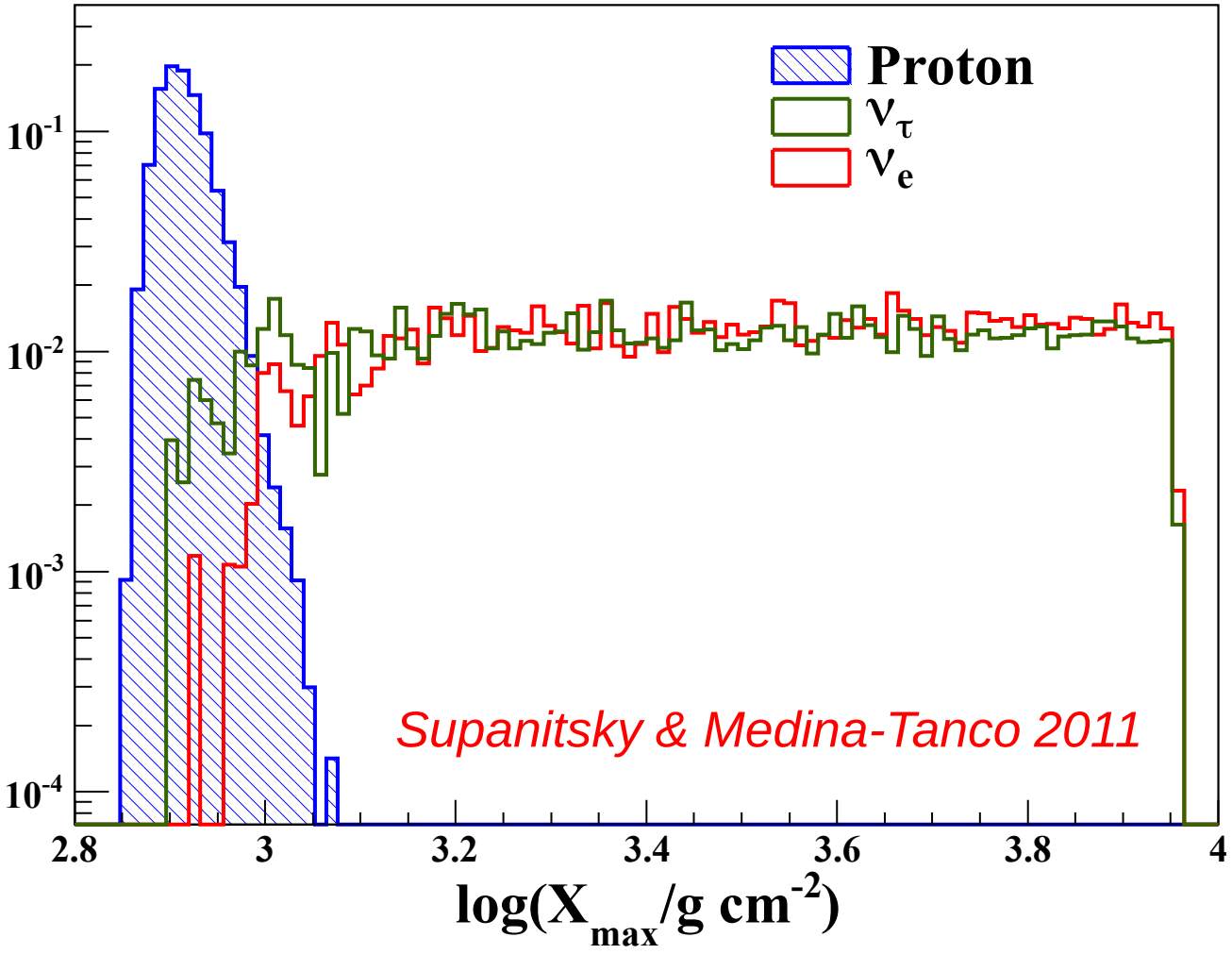
The key concept



$$(CC)\ n_l N \rightarrow l + hadrons$$

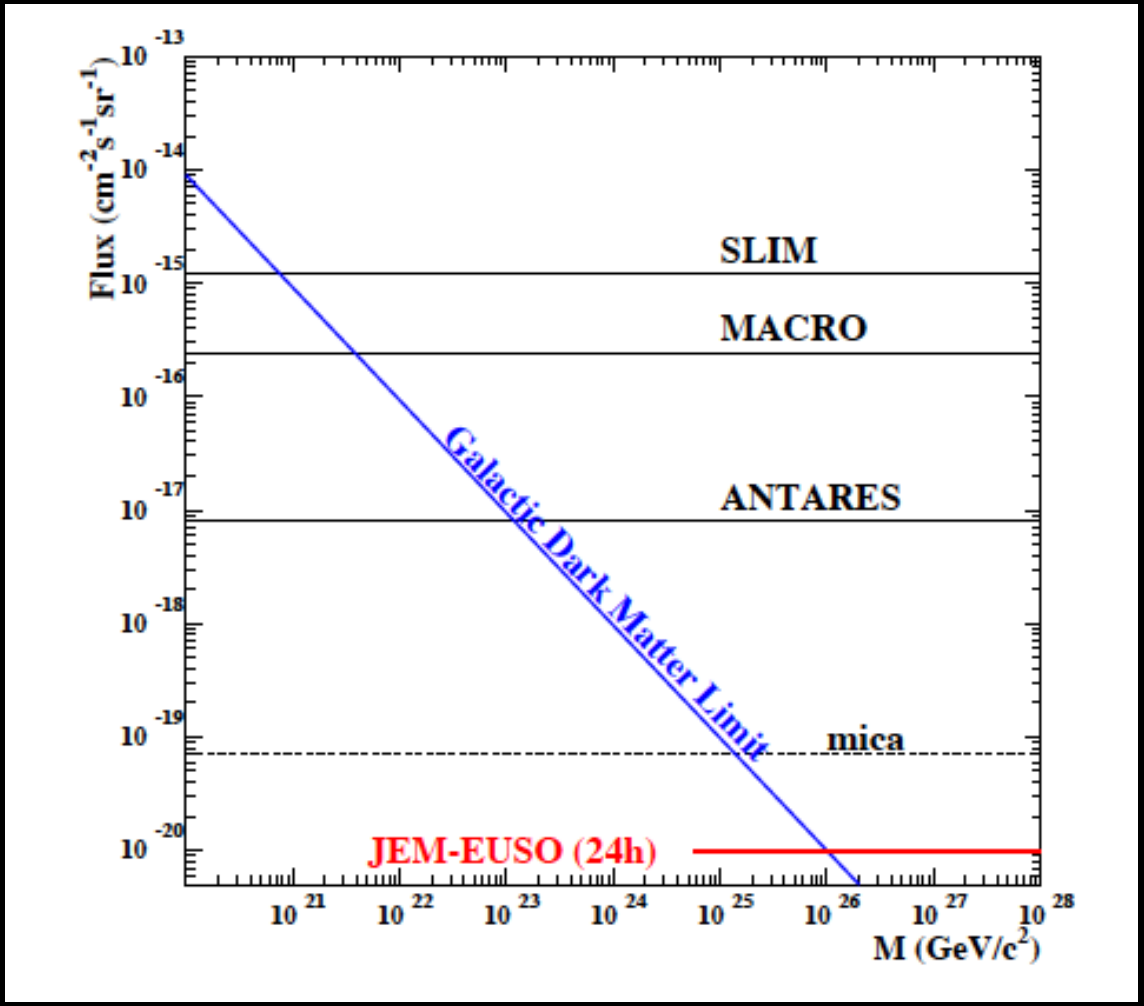
$$(NC)\ n_l N \rightarrow n_l + hadrons$$

Neutrinos vs. Protons: X_{max}

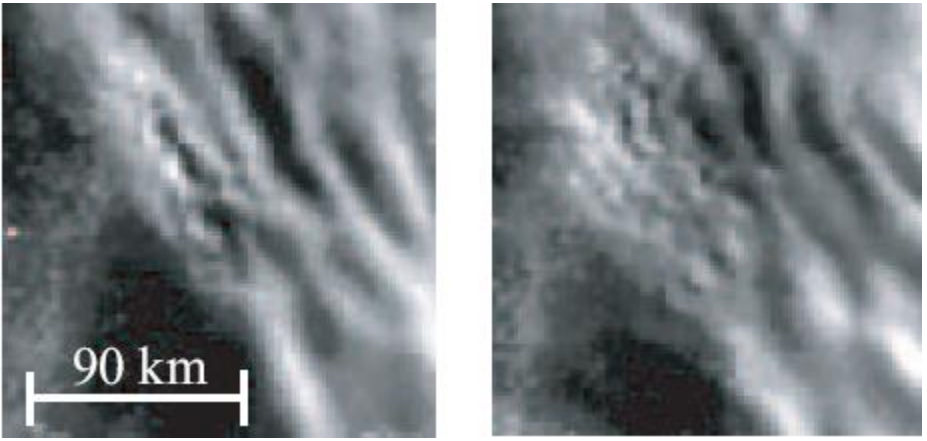


Distribution of X_{max} for protons and neutrinos for $E=10^{20}$ eV and $\theta=85^\circ$ (First Peak of the shower profile)

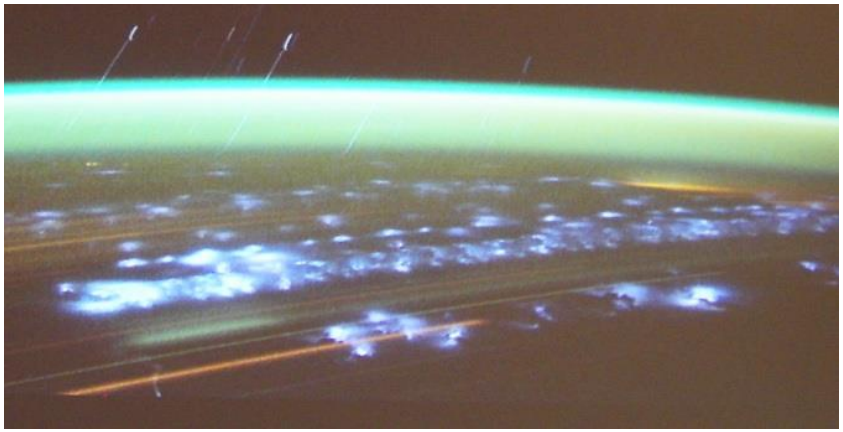
Nuclearites of Strangelets sensitivity



Atmospheric Luminous Phenomena

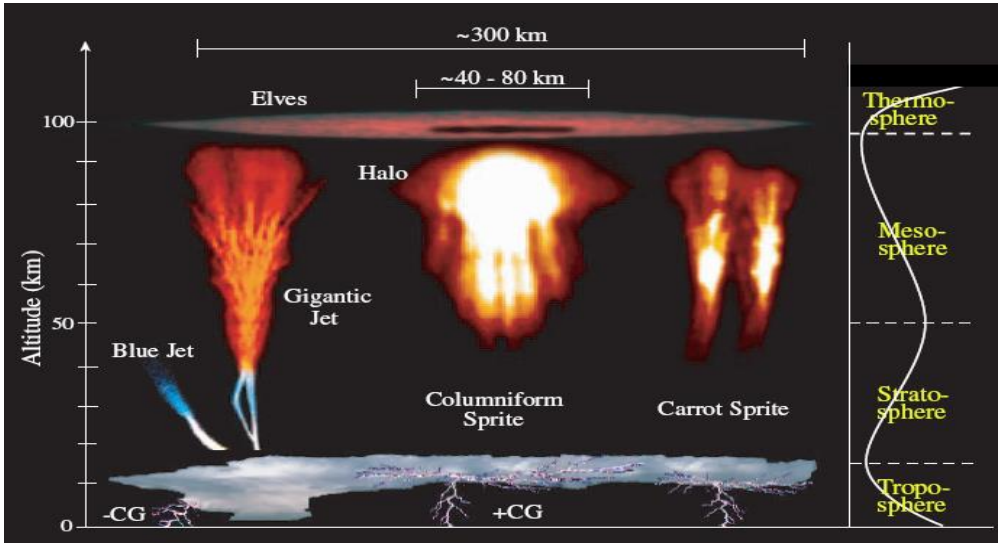


OH airglow observed from ground



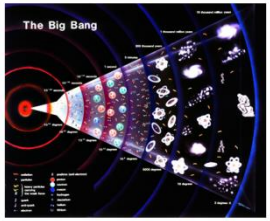
Lightning picture observed from ISS

Leonid meteor swarm in 2001 taken by Hivison



Various transient airglows

JEM-EUSO Science



- **Astrophysics and Cosmology**:

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

  - Exploratory objectives:
    - *discovery of UHE Gamma-rays*
    - *discovery of UHE neutrinos*
    - *study of the galactic and local extragalactic magnetic field*
    - *"Top-Down" scenario*

- **Atmospheric Science**
  - *Nightglow*
  - *the transient luminous events (TLE)*
  - *meteors and meteoroids*

Recommendation of FPRAT

esa Science & Technology — Science Programme, European Space Agency

- The Roadmap has been presented to the Community
- JEM-EUSO science recognized and a *very positive recommendation has been given*

Work with the Pierre Auger Observatory has shown that an instrument with a much greater aperture is required. This can come from a Mission of Opportunity (JEM-EUSO) which will take forward the astrophysical connections and also meet some fundamental physics objectives.

- The Advisory Team supports the active participation of the European community in ultra-high energy cosmic rays in the Japanese mission JEM-EUSO on the Japanese module of the ISS. This is an excellent opportunity to test the possibility of detecting such cosmic rays from space. If successful, this would open the road to an even higher statistics of cosmic rays of the highest energy.

C.2 Priorities for the space program

- Mission of opportunity: JEM-EUSO

It is our pleasure to inform you that your proposal indicated in the table below received a favourable scientific and technical review and its selection for inclusion in the ELIPS research pool was approved by the ESA Programme Board for Human Spaceflight, Microgravity and Exploration.

„ It is our pleasure to inform you that your proposal ... received a favourable scientific and technical review and its selection for inclusion in the ELIPS research pool was approved by the ESA Programme Board for Human Spaceflight, Microgravity and Exploration“

We wish to express our appreciation to you for your interest in this research announcement. We congratulate you on the success of your proposal in this competitive forum.

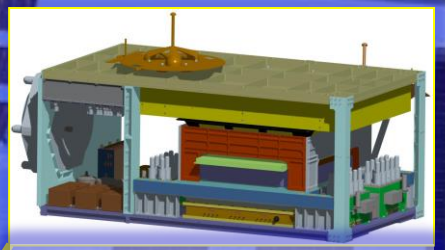
Sincerely,

pp

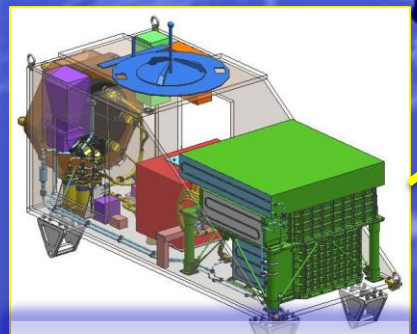
C. Fuglesang
Head ISS Science and Applications Division

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

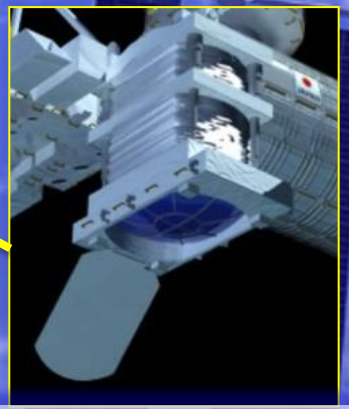
AMS Launch
May 16, 2011



ISS-CREAM
Sp-X Launch 2015

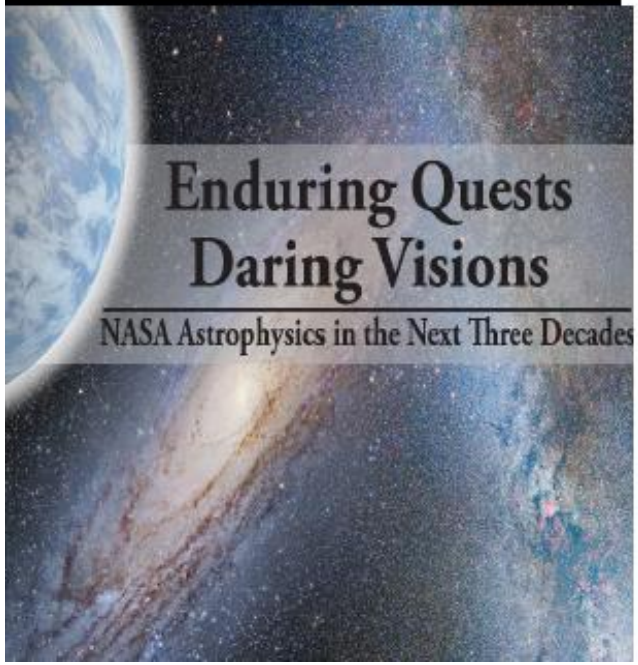


CALET on JEM
HTV Launch 2015

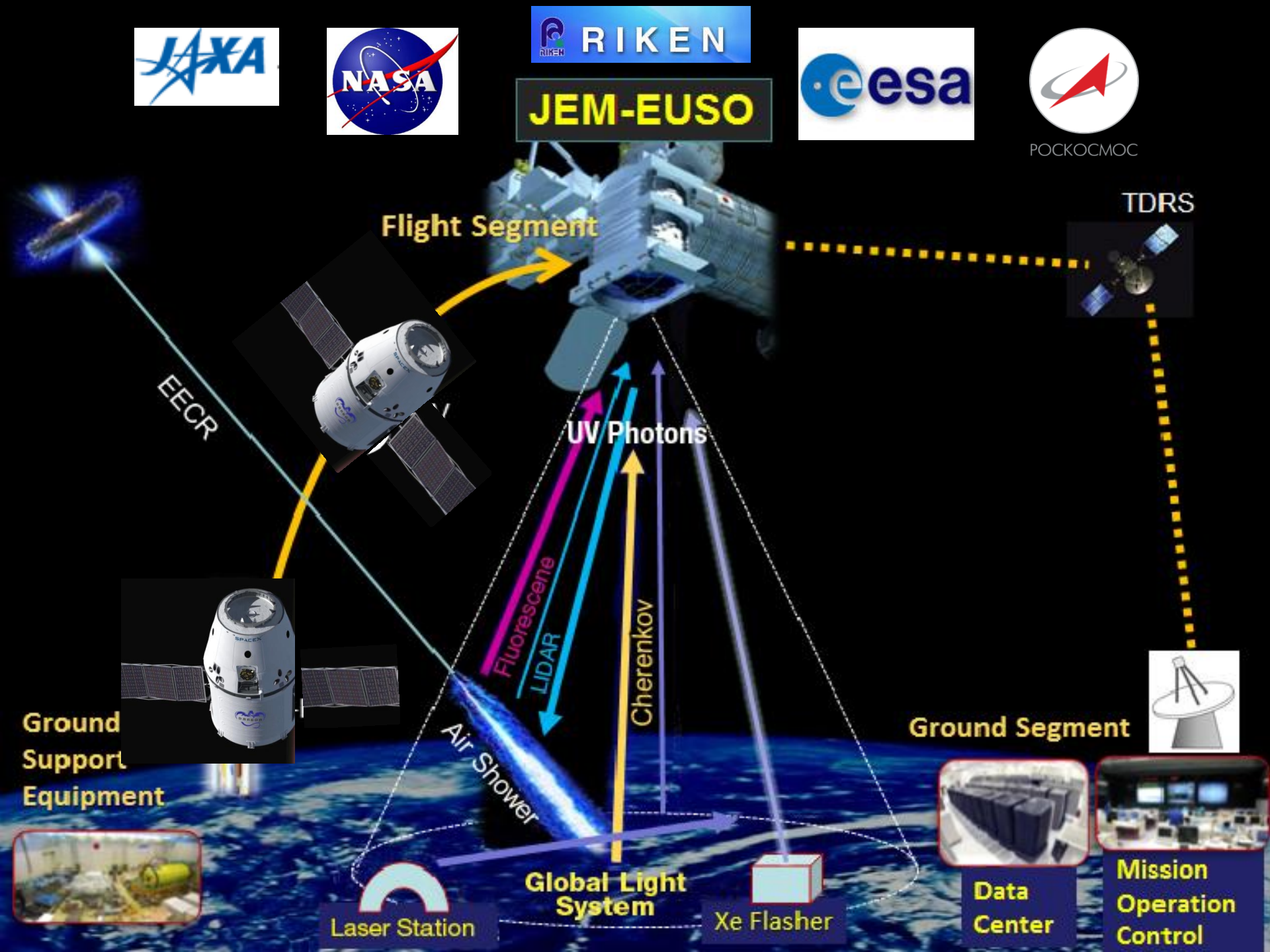


JEM-EUSO

NASA Astrophysics Roadmap 2014

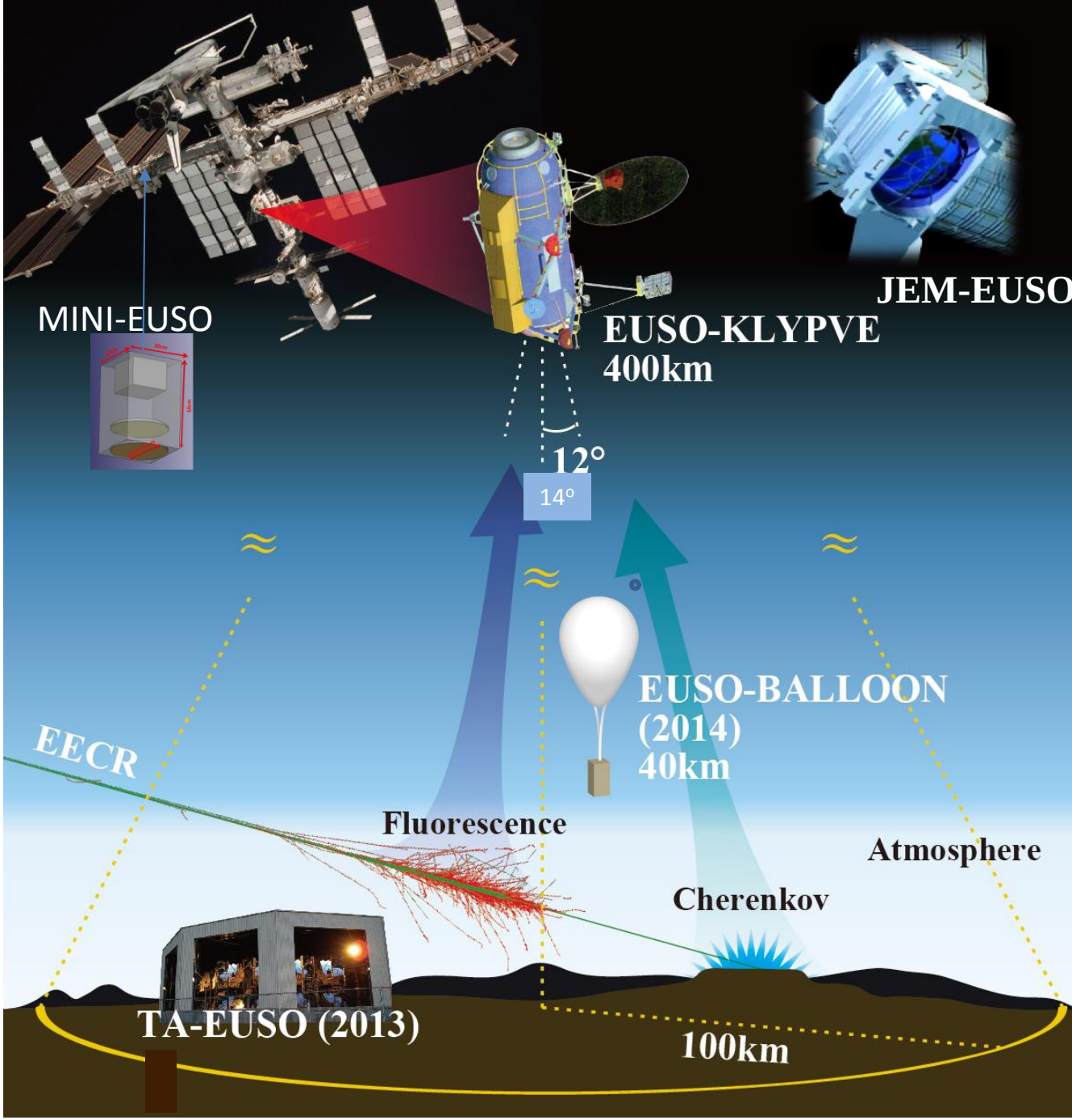


	Near-Term	Formative	Visionary
Gravitational Waves		Gravitational Wave Surveyor	Gravitational Wave
Cosmic rays	JEM-EUSO		
Radio			Cosmic Dawn Ma
Microwaves		CMB Polarization Surveyor	
Infrared	JWST	Far IR Surveyor	
	WFIRST-AFTA, Euclid	LUVOIR Surveyor	ExoEarth Mapp
Optical	TESS, Gaia		
Ultraviolet			
X-rays	NICER, Astro-H		


JAXA
NASA
RIKEN
JEM-EUSO
esa
POCKOCMOC
Flight Segment
TDRS
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

The JEM-EUSO program

1. **EUSO-TA: Ground detector at Telescope Array site: 2013-**
2. **EUSO-BALLOON: 1st balloon flight Aug 2014**
3. **EUSO-SPB (2017)**
4. **MINI-EUSO (2017)**
5. **K-EUSO (2019)**
6. **JEM-EUSO (>2020)**



The JEM-EUSO program

1. TA-EUSO: Ground detector at Telescope Array site: 2013-

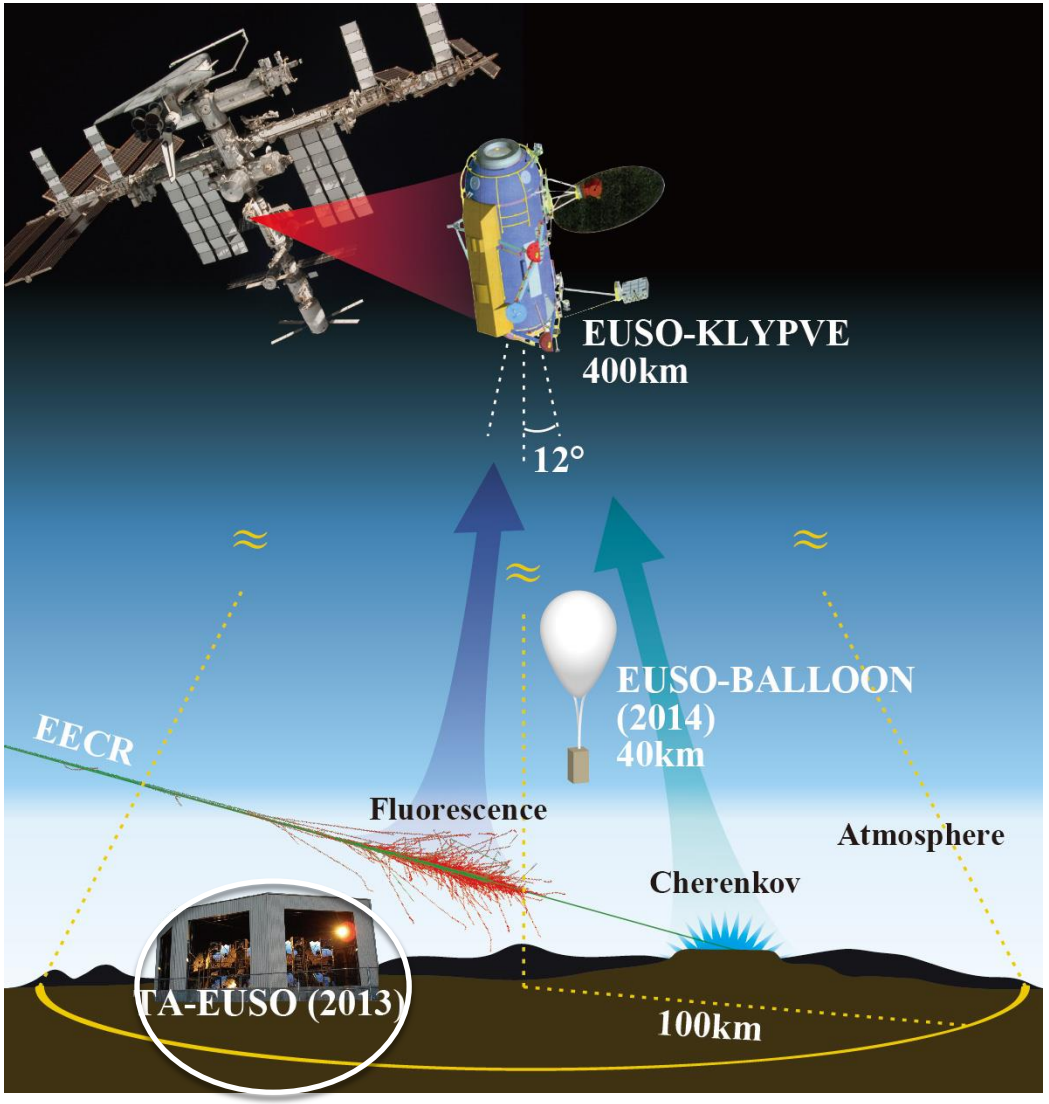
2. EUSO-BALLOON: 1st balloon flight from Timmins, Canada (French Space Agency CNES) 2014

3. EUSO-SPB (2017)

4. MINI-EUSO (2017)

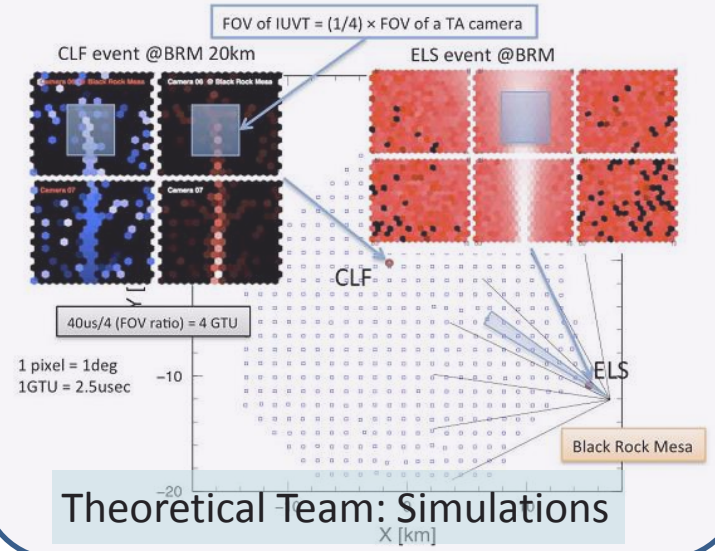
5 K-EUSO (2019)

6. JEM-EUSO (>2020)

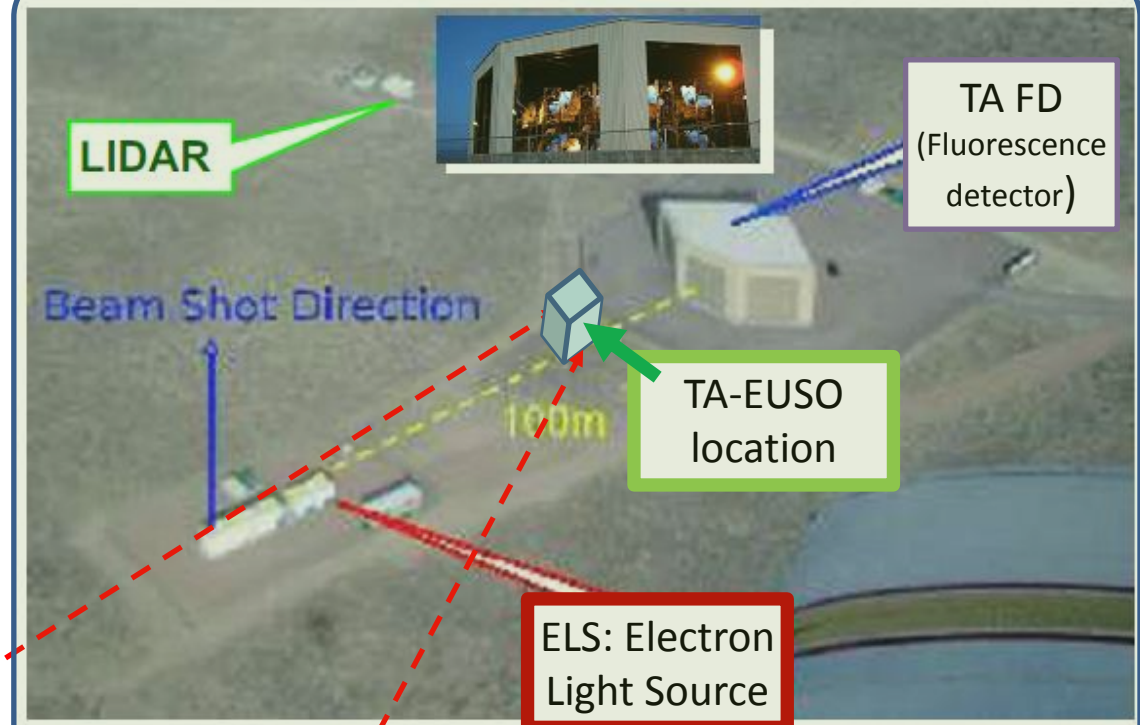


EUSO @ Telescope Array

EUSO-TA 1 PDM
=1 PDM of EUSO-Balloon and two Fresnel lenses.
FoV of ± 4 degrees triggered by the fluorescence detectors of TA

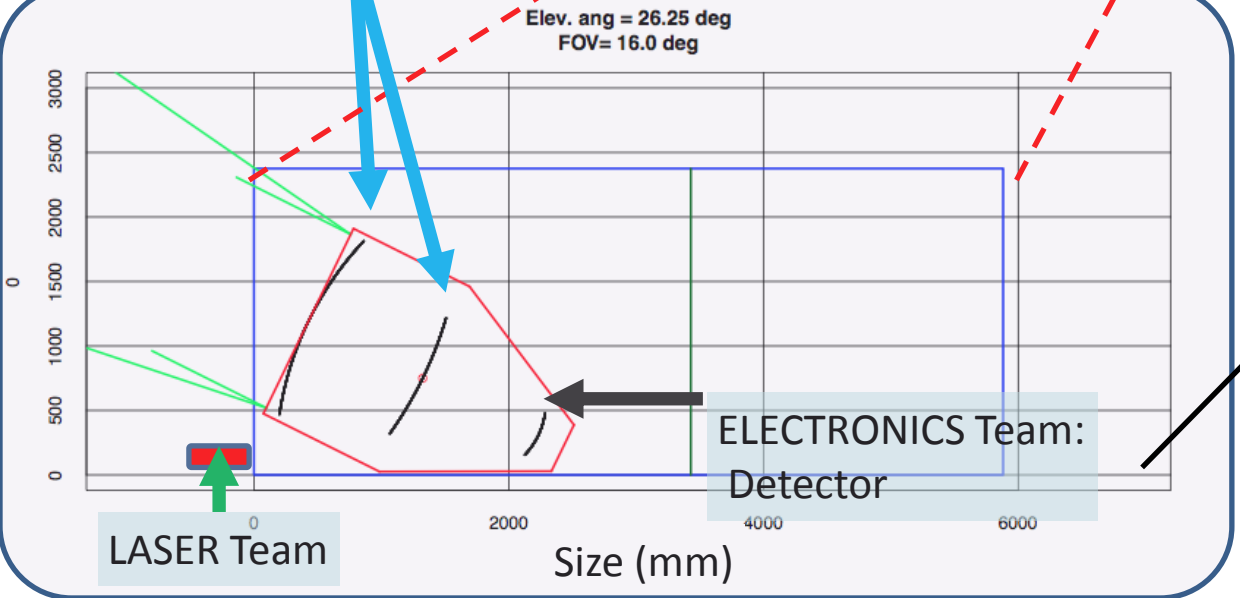


Theoretical Team: Simulations



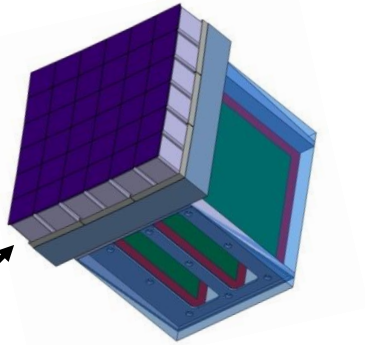
TA site, UTAH, Black Mesa

OPTICS Team: Lenses



ELECTRONICS Team: Detector

LASER Team

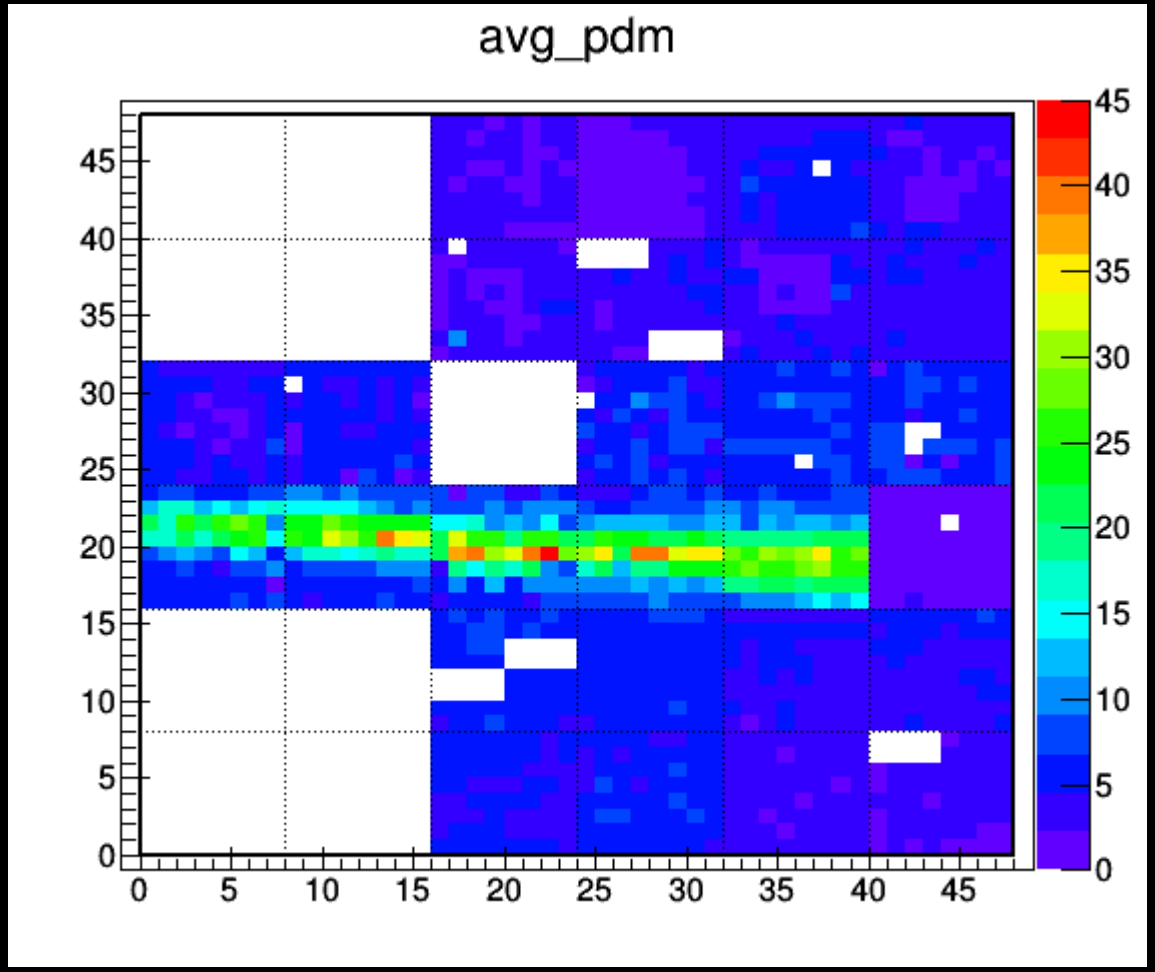


PDM detector block

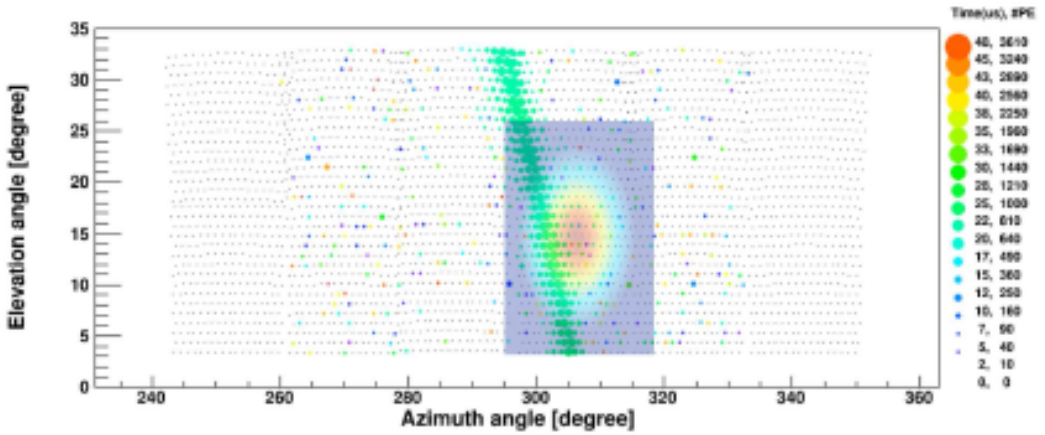
Objectives of EUSO-TA

- Engineering Test TRL 4
- Absolute calibration by lidar and electron beam shots
- Cross calibration with TA FD
- Take few showers in coincidence with TA.
- In operation: January 2015

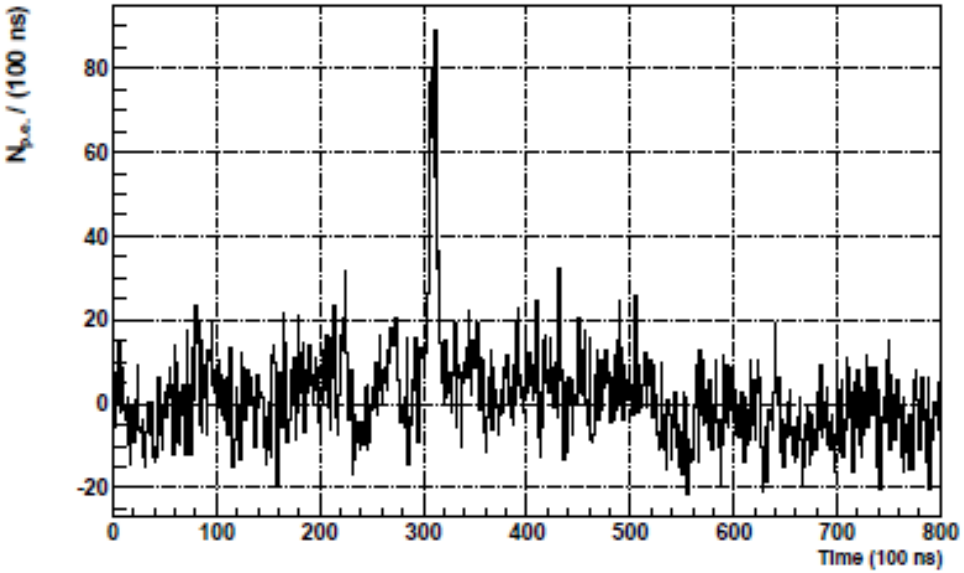
Laser (vertical) 60 m distance



Shower 10^{18} eV at FAST @ EUSO-TA



(a)



The JEM-EUSO program

1. TA-EUSO: Ground detector at Telescope Array site: 2015-

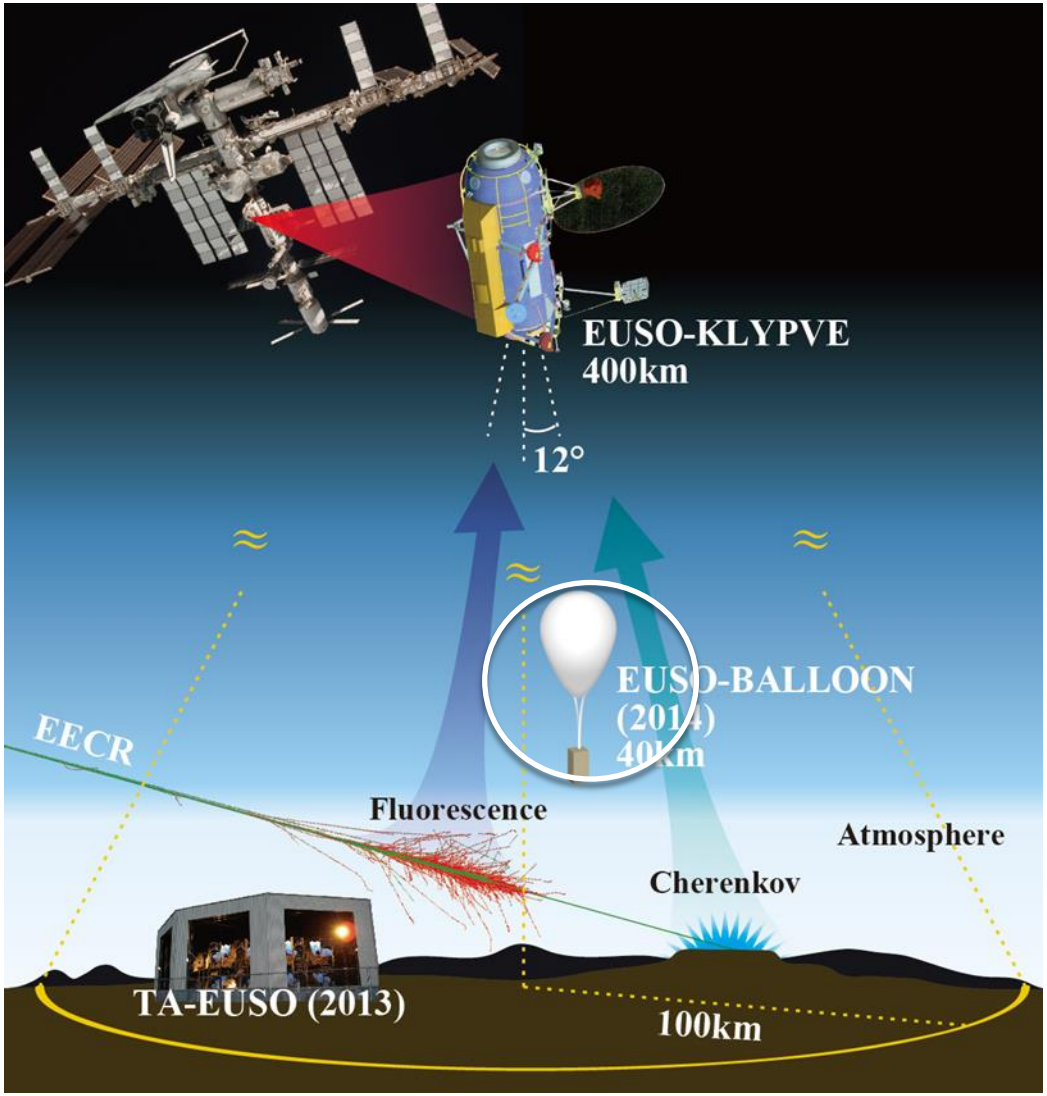
2. EUSO-BALLOON:
1st balloon flight from Timmins, Canada (French Space Agency CNES) 2014

3. EUSO-SPB (2017)

4. MINI-EUSO (2017)

5. K-EUSO (2019)

6. JEM-EUSO (>2020)



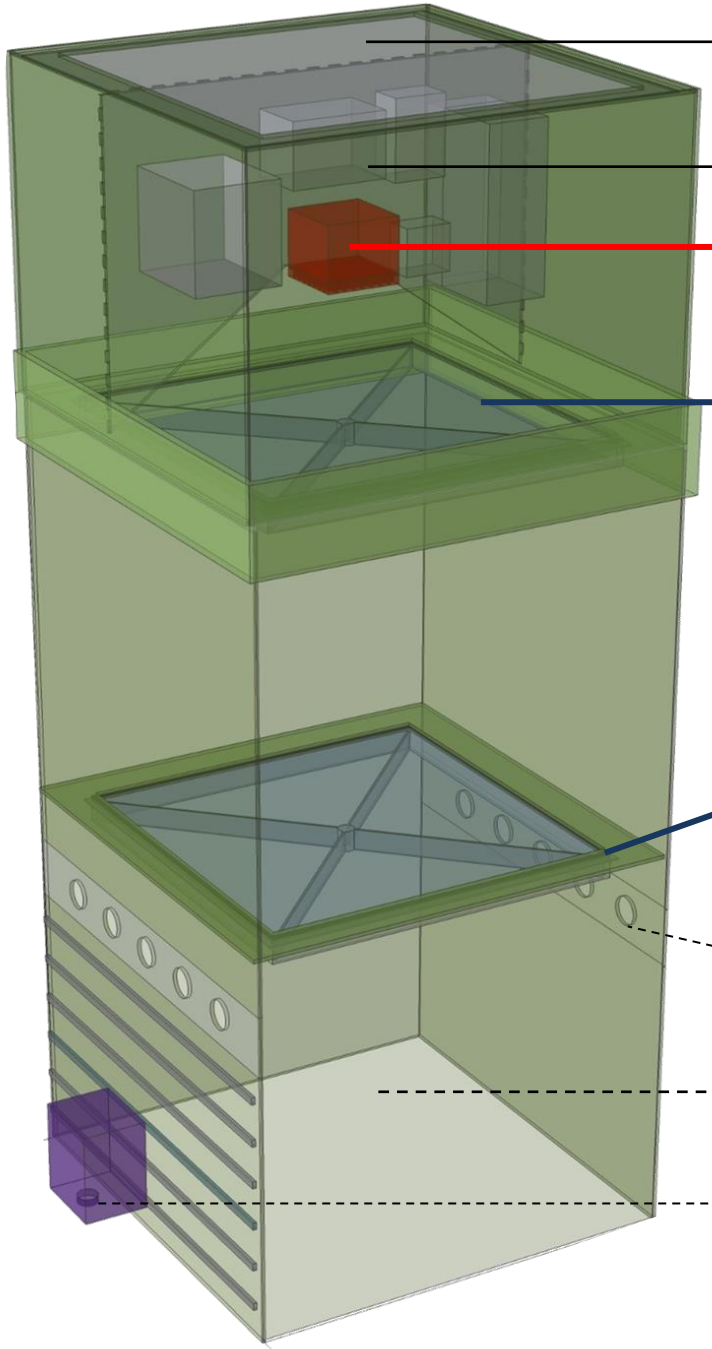
EUSO Balloon

EUSO Balloon objectives

- Engineering test TLR 5
- Look down from the balloon with an UV telescope (PDM + 2 lens system)
- UV-Background measurement
- Airshower observations from 40 km altitude

instrument booth

optical bench

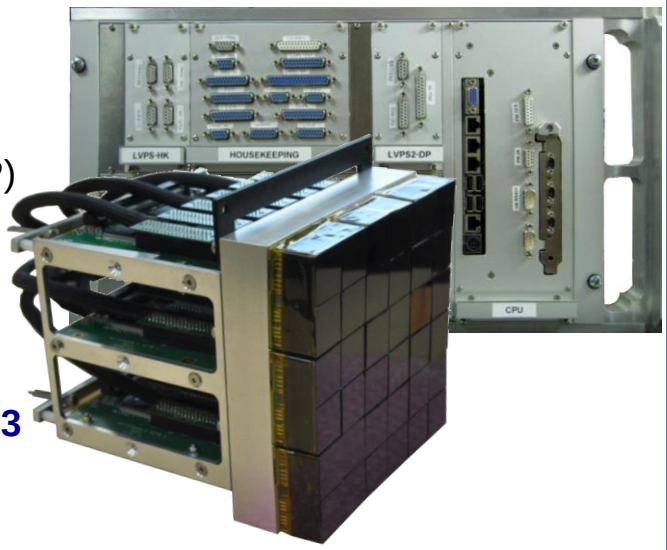


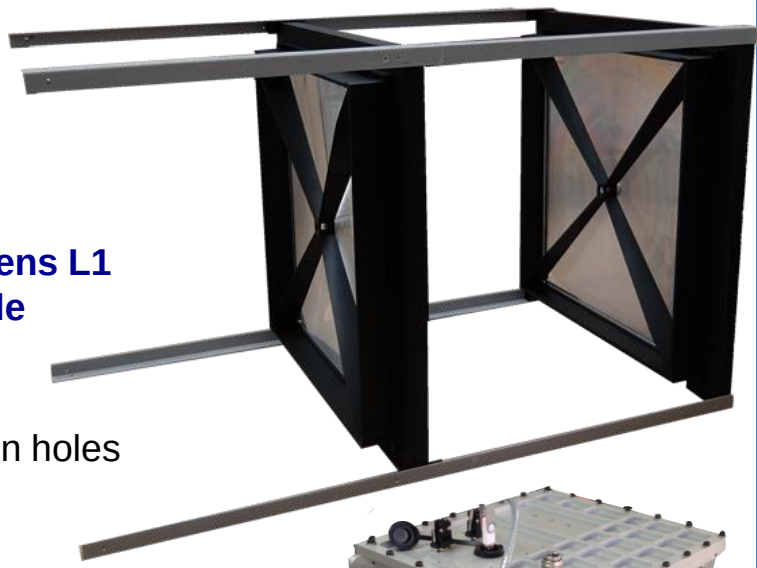
radiator

electronics (DP)
on "dry shelf"

PDM

Fresnel lens L3
fixed/tight





Fresnel lens L1
adjustable

evacuation holes

Baffle &
“deceleration cylinder”

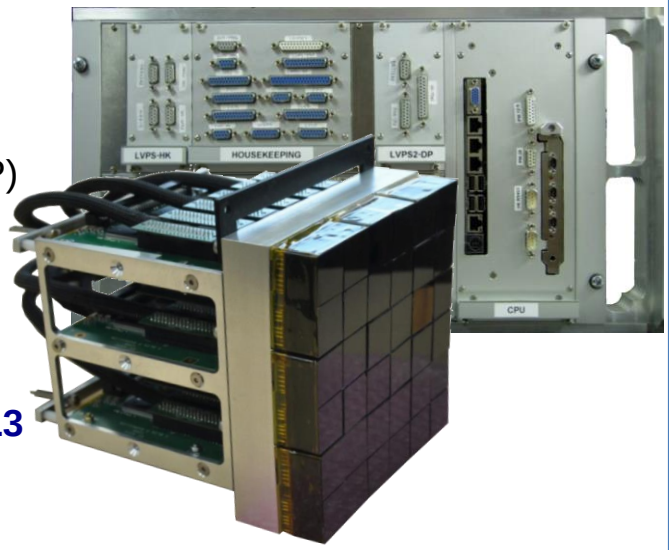
IR Camera

instrument booth

optical bench

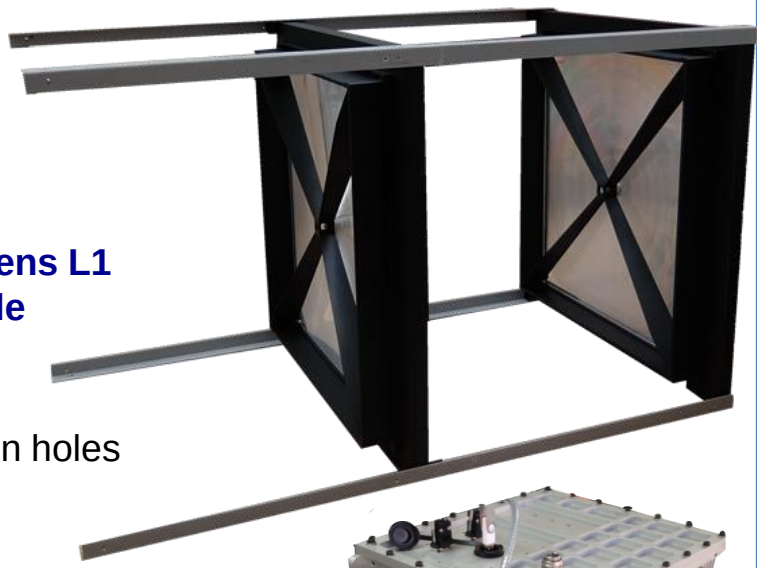
radiator

electronics (DP)
on "dry shelf"



PDM

Fresnel lens L3
fixed/tight



Fresnel lens L1
adjustable

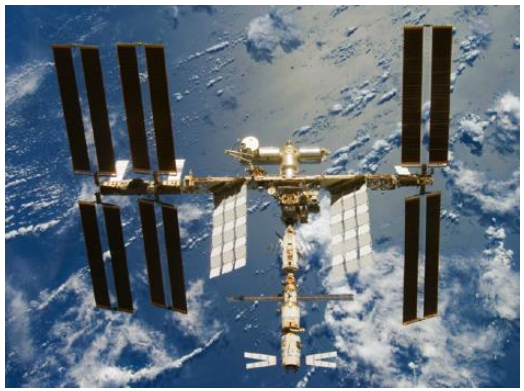
evacuation holes

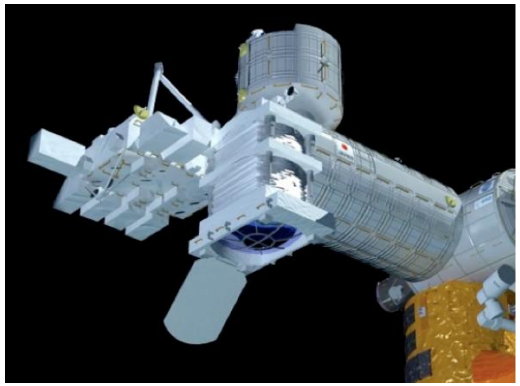
Baffle &
“deceleration cylinder”

IR Camera

JEM-EUSO vs EUSO-Balloon

- **EUSO-Ballon: A path-finder project of JEM-EUSO**

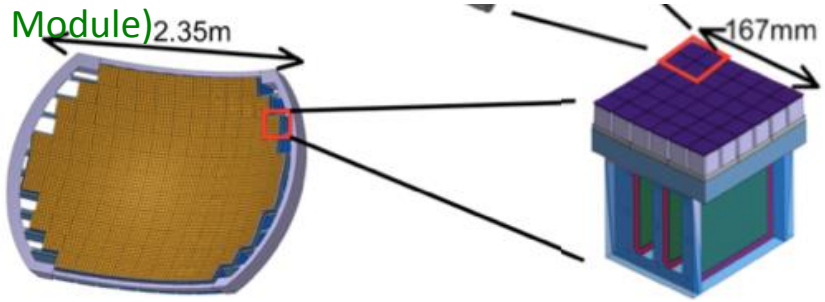


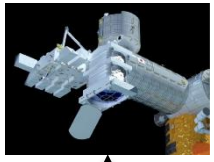


JEM-EUSO

137 PDM
(Photo Detector
Module)

1 PDM





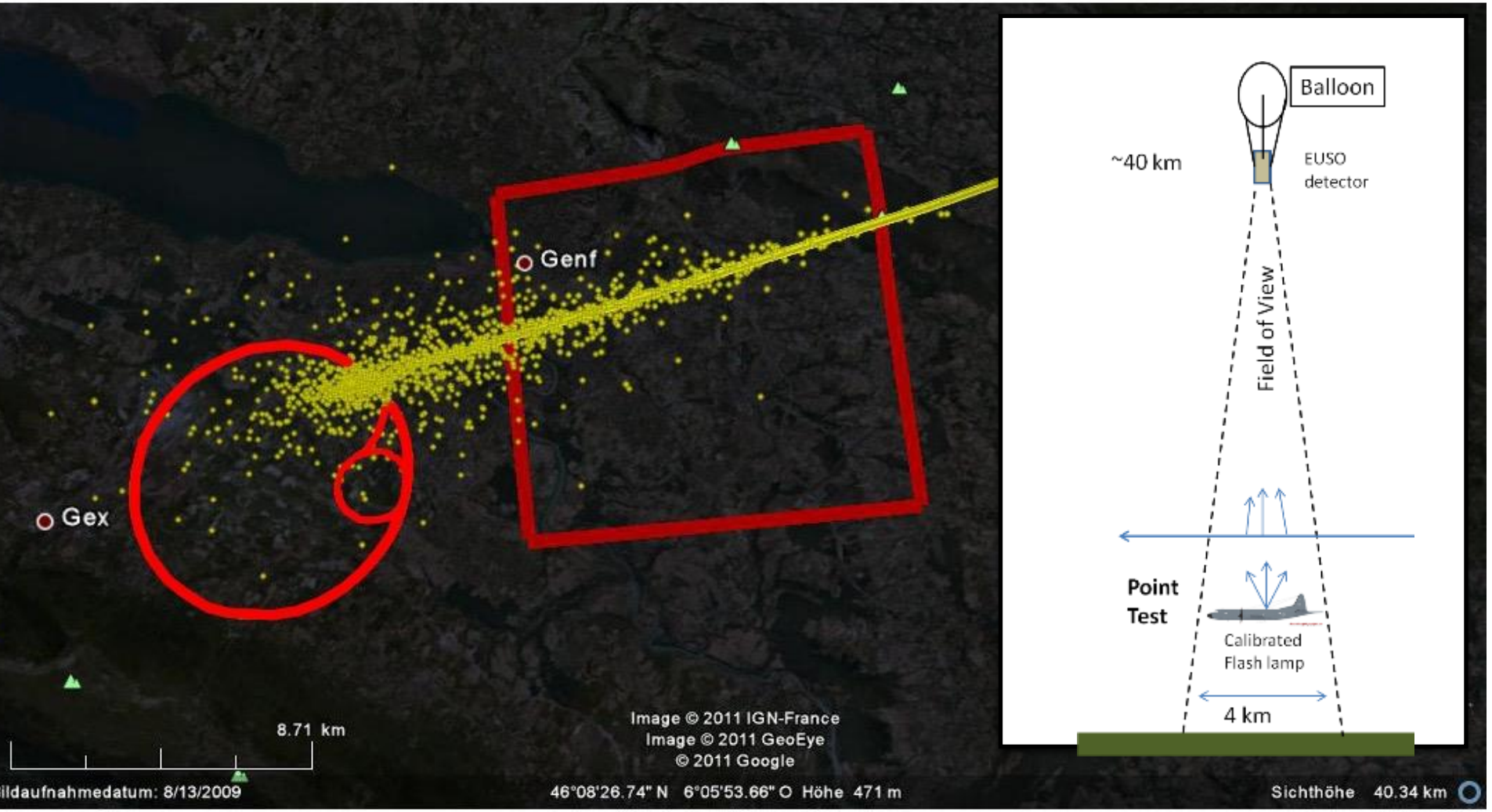
~400km

~40km

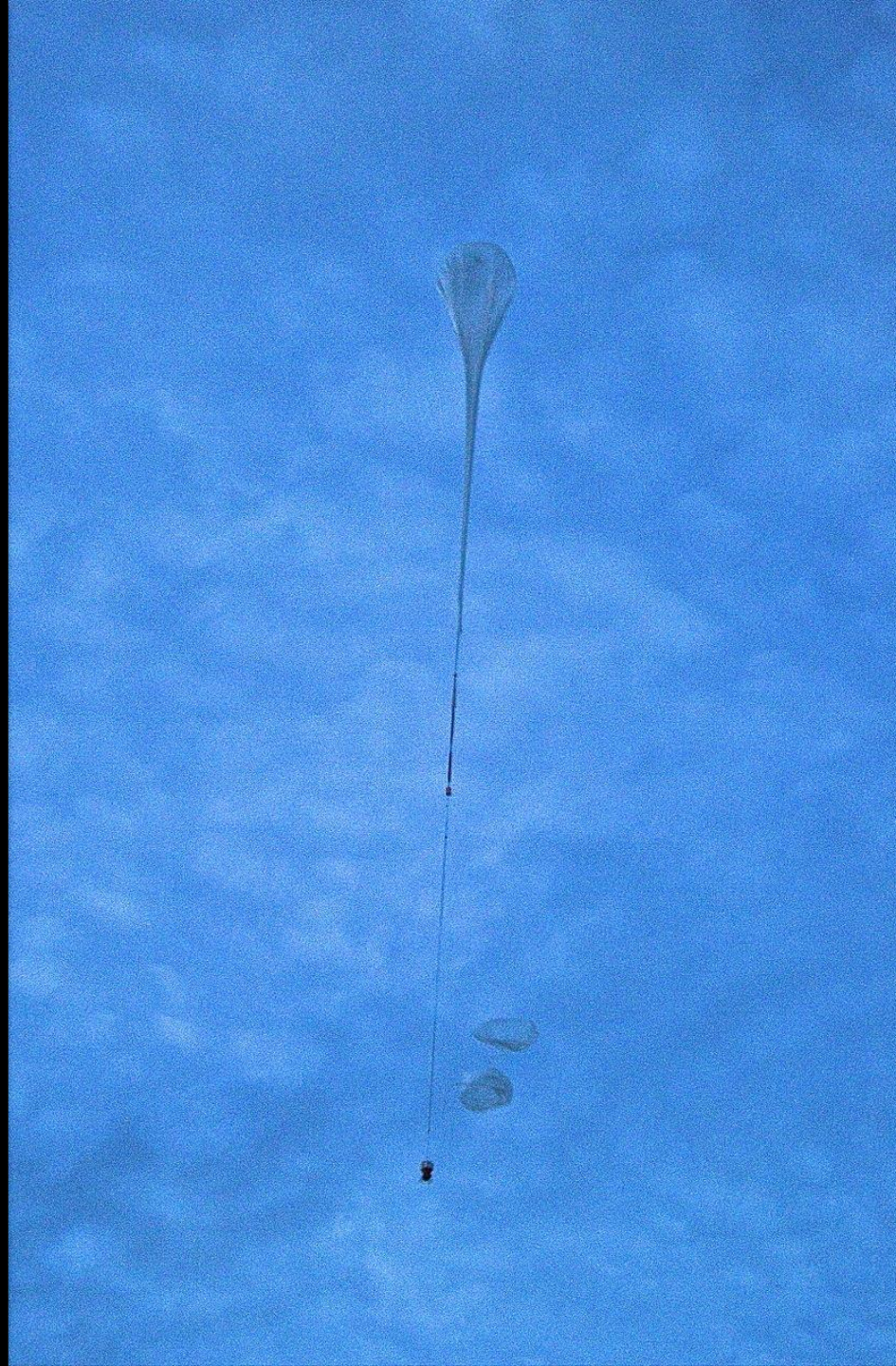
Earth

EUSO-
Balloon

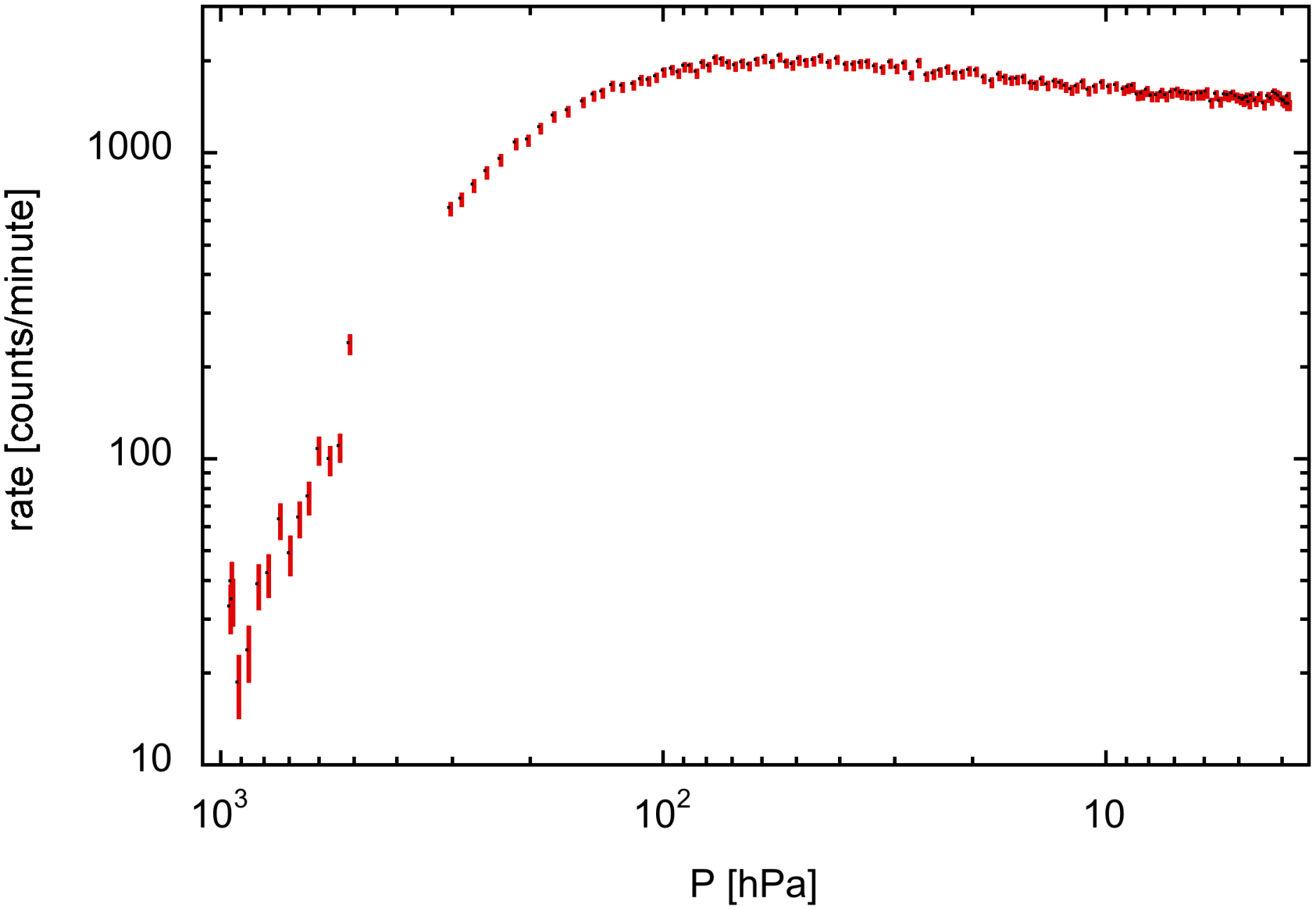
FoV (± 3°) of EUSO-Balloon compared with LHC



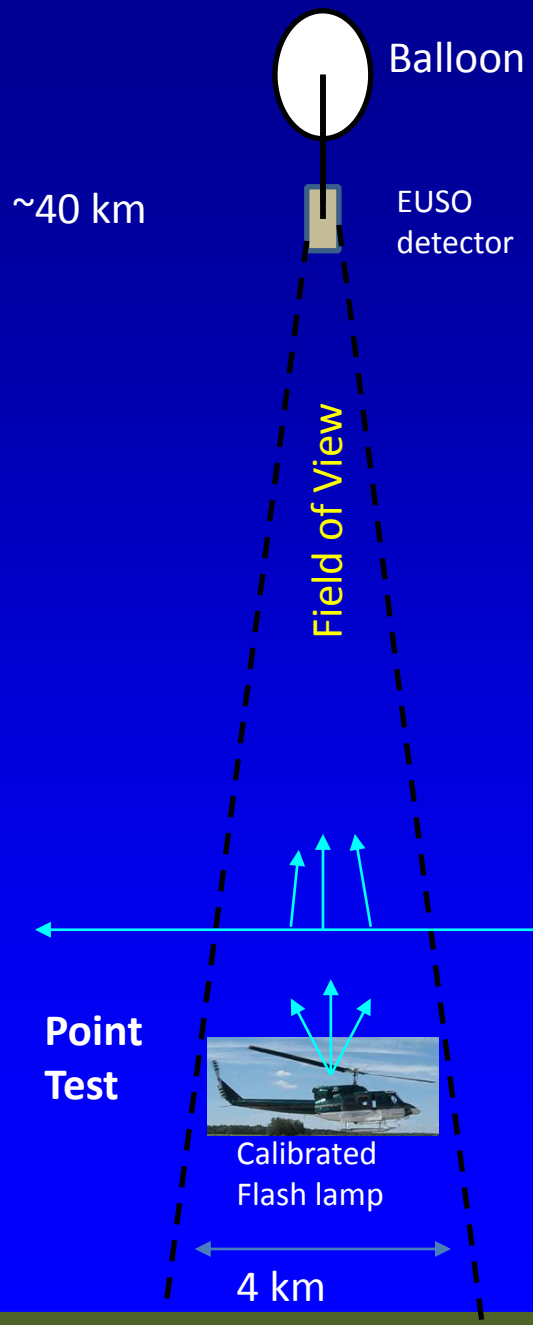

24.8.2014 20:53 LT



BALLOON ASCENT



EUSO-BALLOON ‘‘in flight’’ calibration



Testing EUSO-Balloon

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

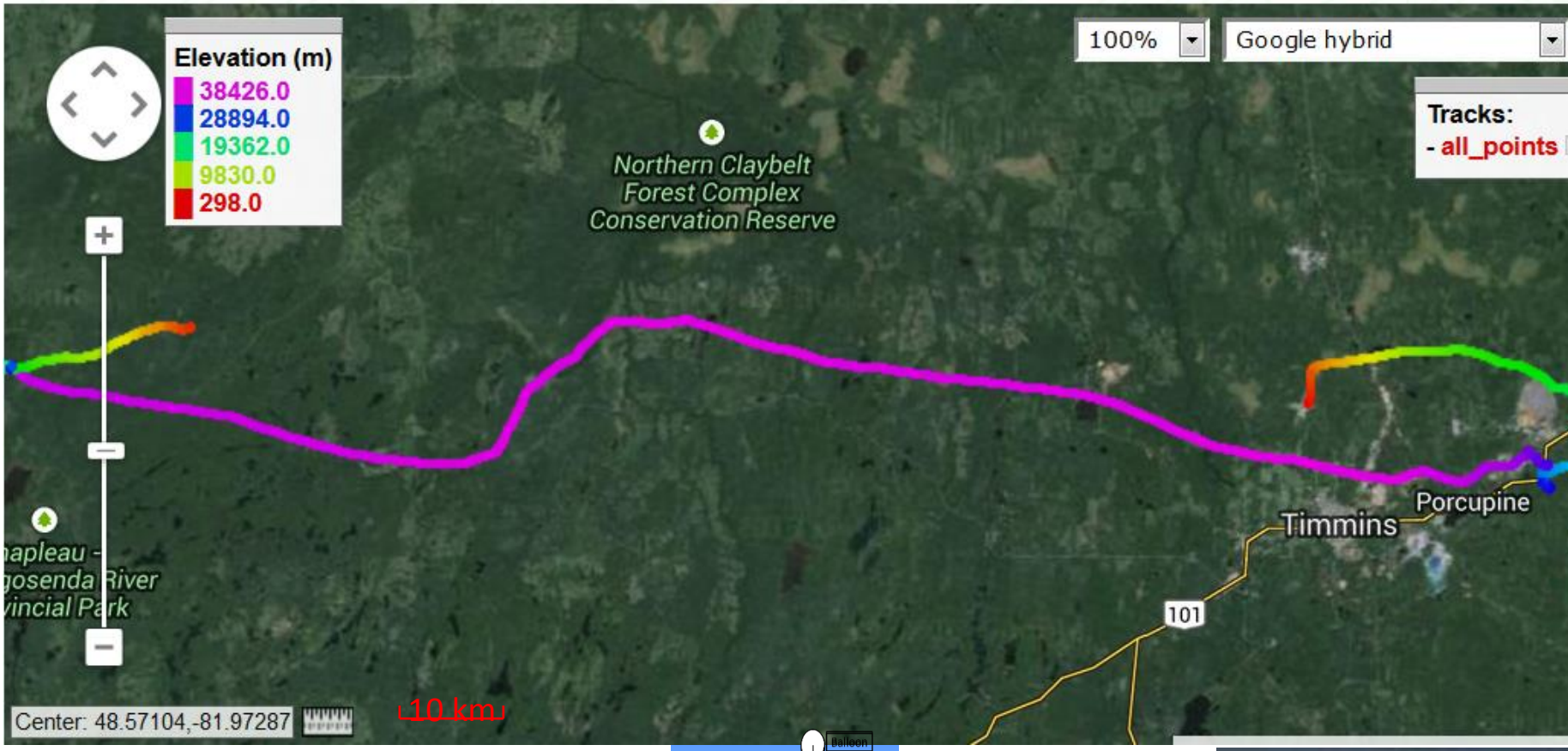
Point Test: Fly airplane in field of view and fire **flash lamp**. Light travels directly from lamp to detector

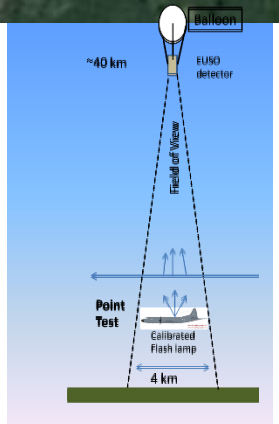
Track Test: Fly airplane outside field of view and shoot a UV pulsed **laser** across field of view. Light scatters out of the beam to the detector.
(5 mJ Laser ~100 EeV Cosmic Ray)

Fly aircraft at altitudes between 1-5 km.

Helicopter equipped with
laser and Xenon flasher

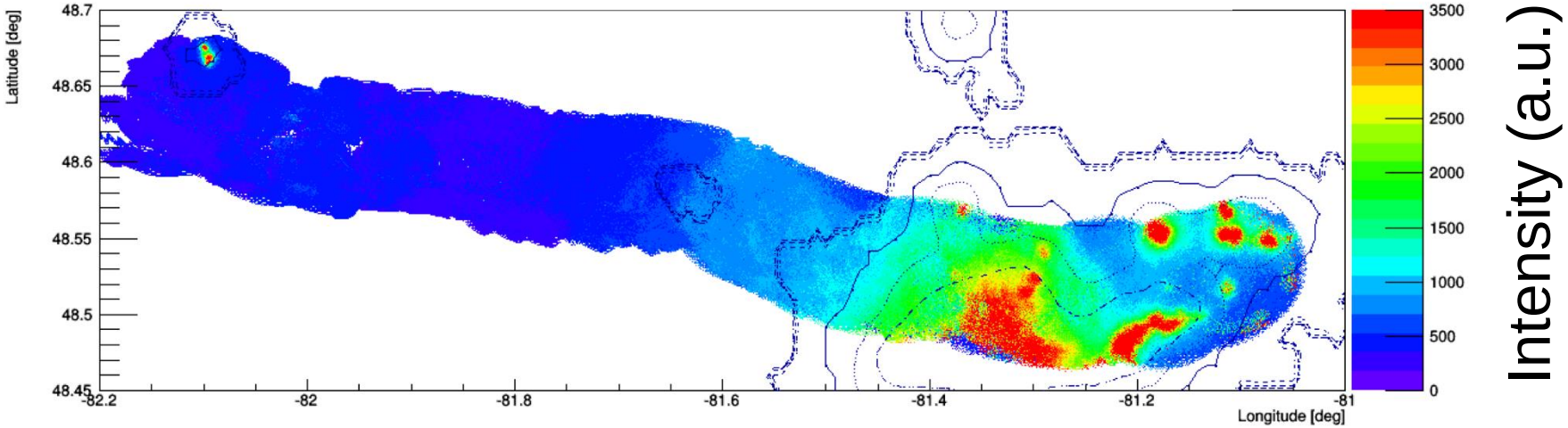
Balloon trajectory

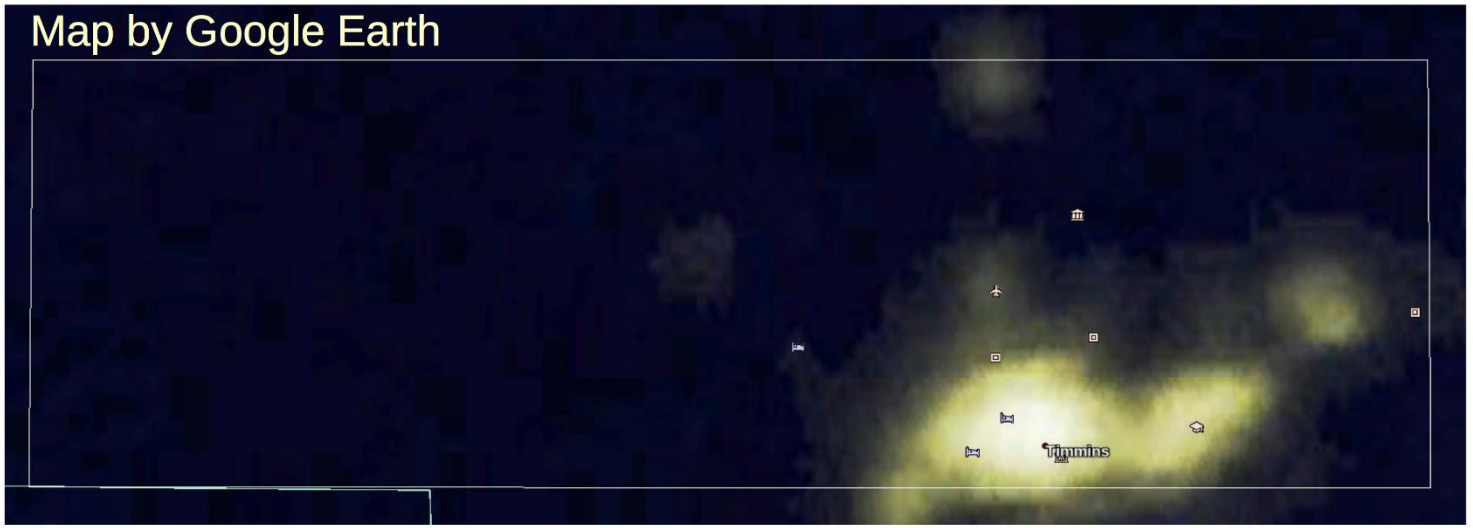


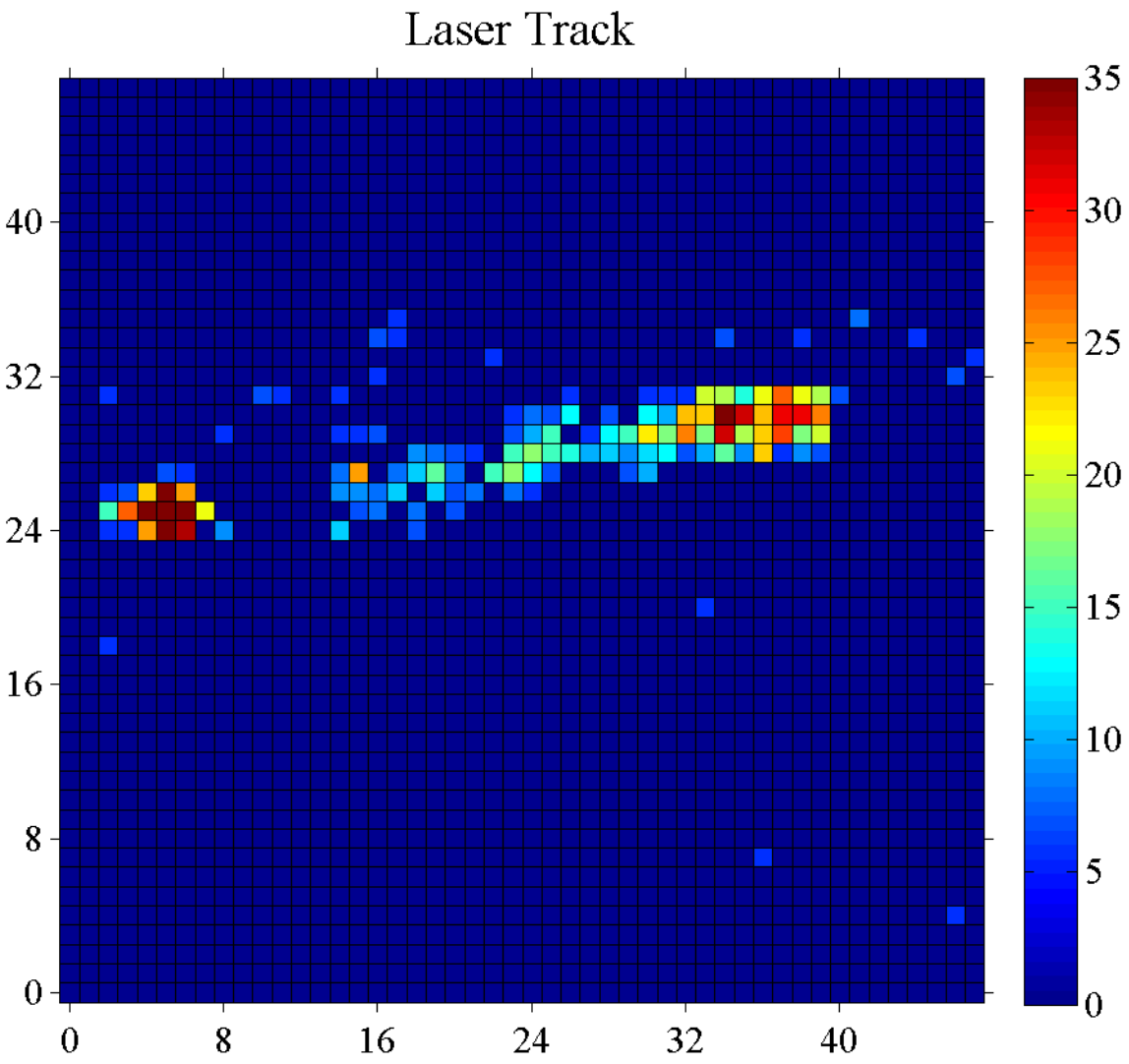


Man-made lights by DMSP

- Positions of man-made lights match lights observed by DMSP satellites

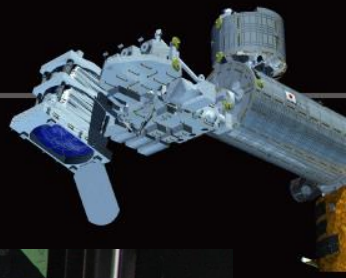


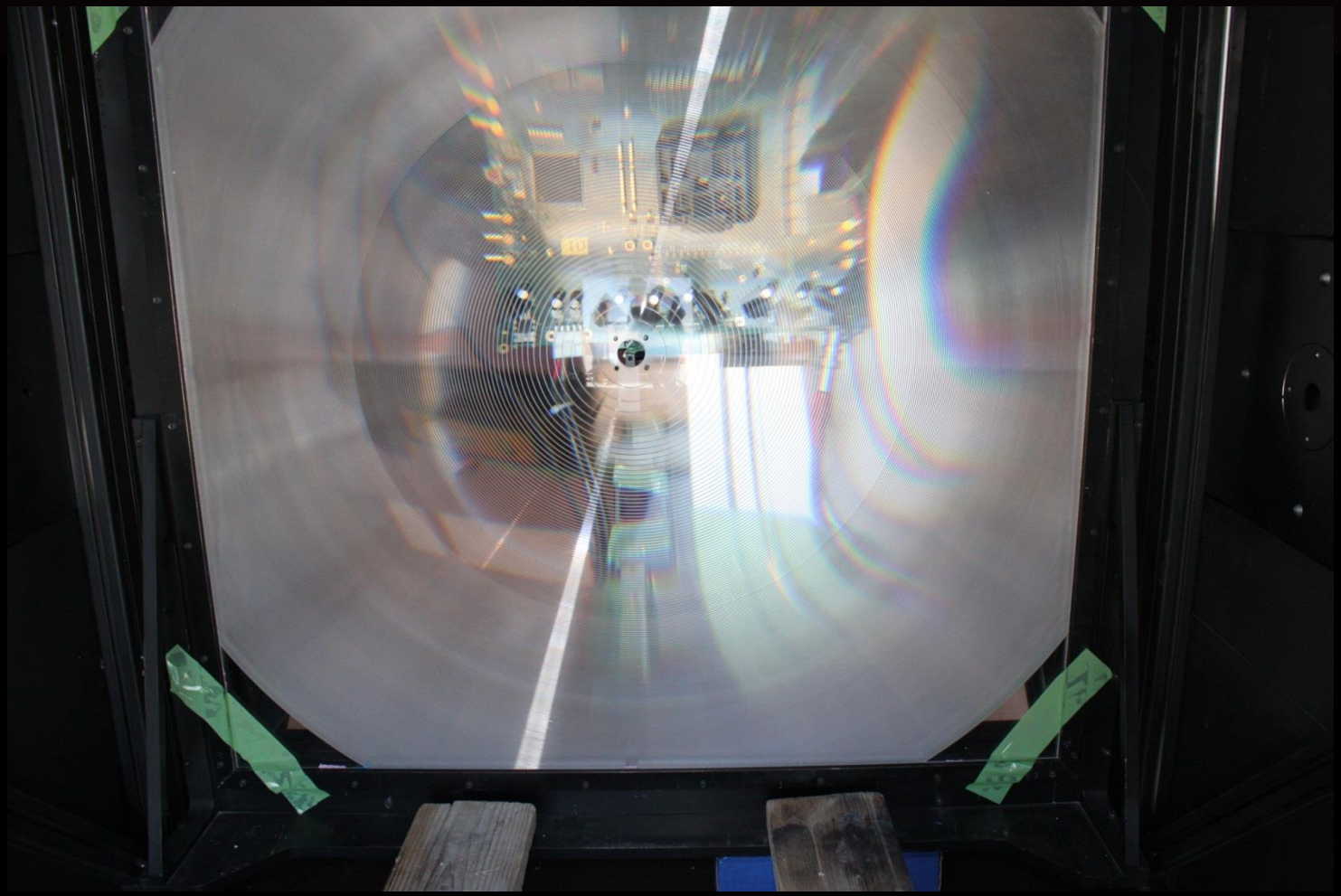


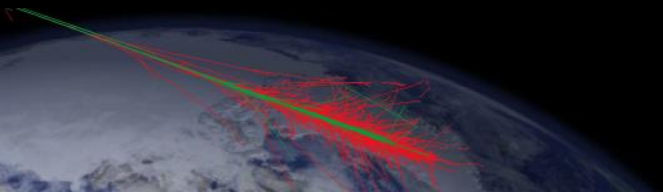

Laser Track
0
8
16
24
32
40
0
5
10
15
20
25
30
35
GTU (2.5μs)


2 km
1 miles

JEM-EUSO on ISS explores the origin of the highest energy particles in the Universe



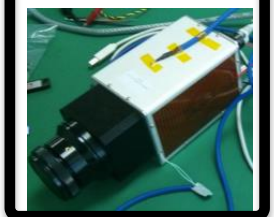




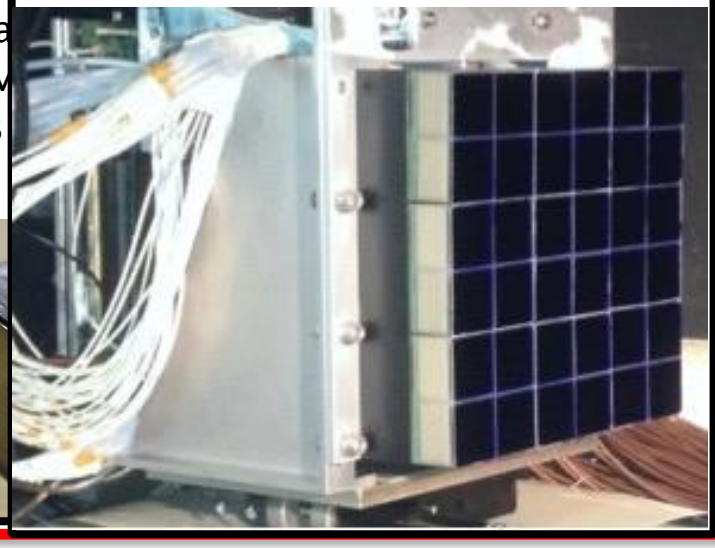
JEM-EUSO collaboration 13 Countries, 80 Institutes as of March, 2013

Data Acquisition (DAQ) Chain

IR camera



PDM
- 9 EC-Units



PMT
- Hma
MAPM
- BG3

Front-end (FE) electronics

EC-ASIC
- 6 x ASICs
- readout
- counter

PDM-Board
- Slow control
- Level 1 (L1, track trigger

Data Processing (DP)

CPU
- Run control, config. FE electronics
- Console & GUI, remote access, etc.
- Data processing
- managing Mass Memory for data storage

CCB
(Cluster Control Board)
- Receive data from 9 PDMs

HK, LVPS

The JEM-EUSO program

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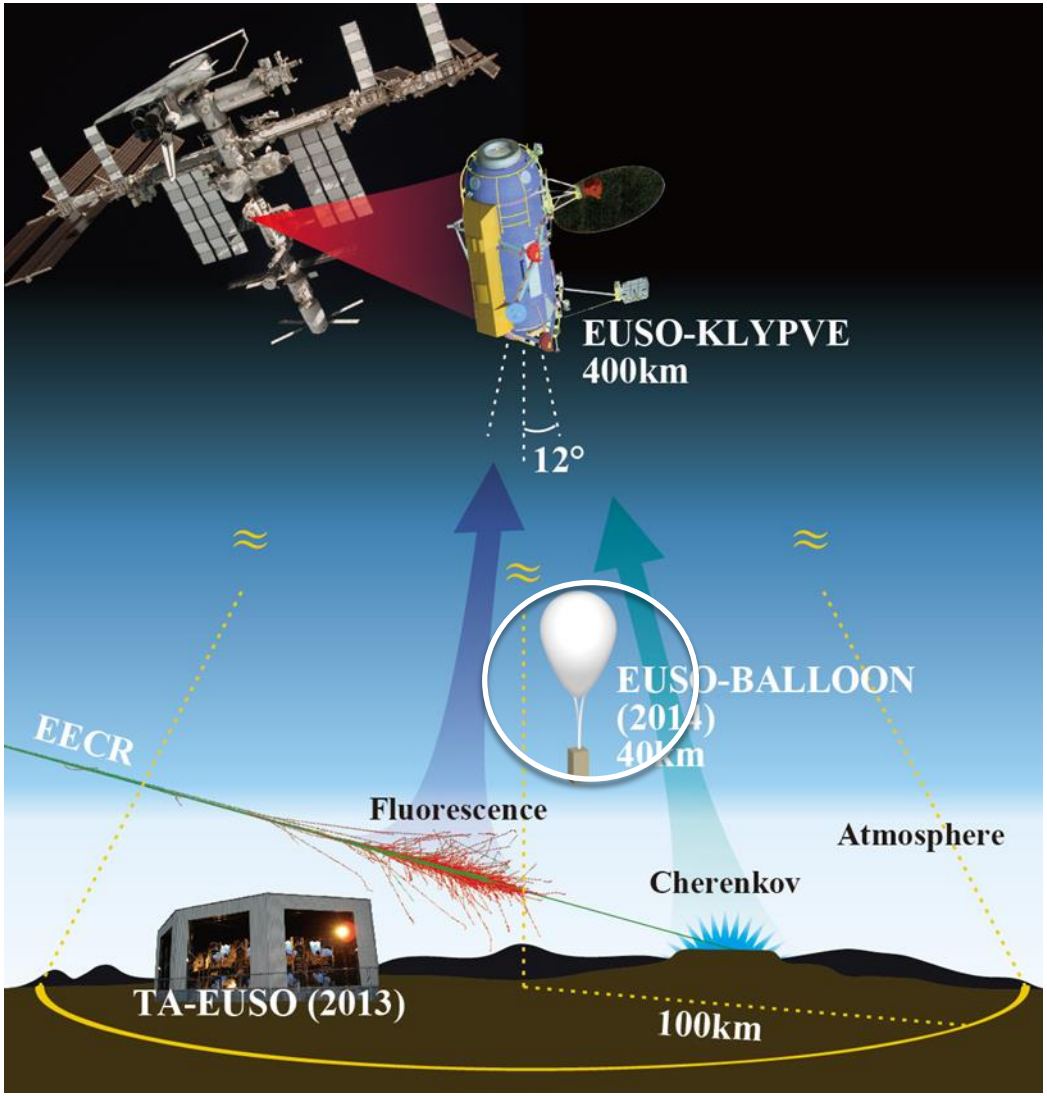
3. EUSO-SPB (2017)

4. MINI-EUSO (2017)

5. K-EUSO (2019)

6. JEM-EUSO (>2020)

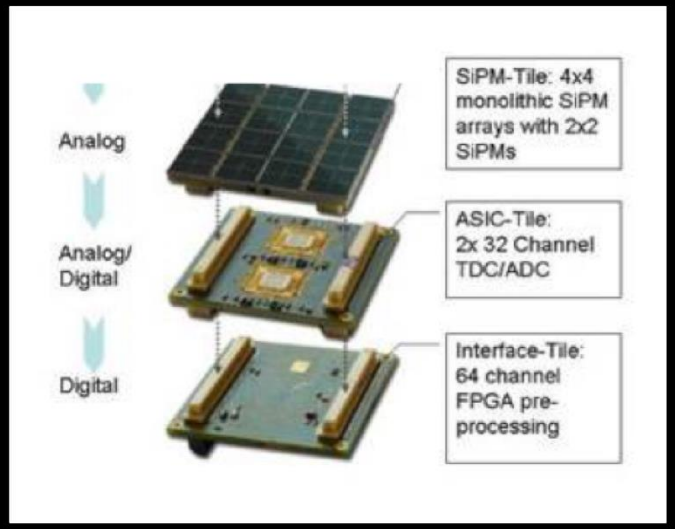


Next steps: **EUSO-SPB** 2017

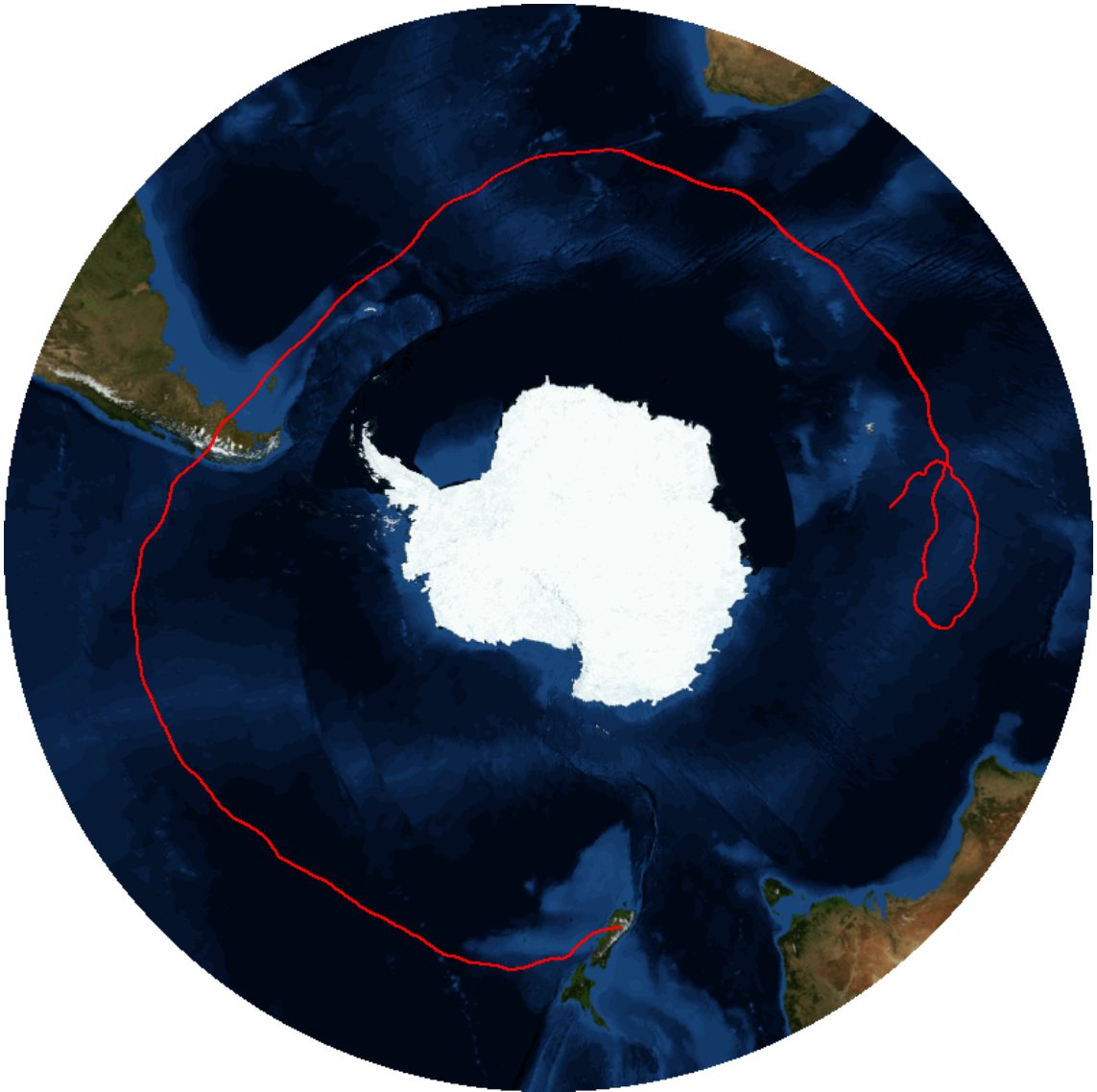
Super Pressure Baloon (SPB)

Ultra Long Duration flight

- first observations of UHECRs from space
- test SiPM focal surface



Columbia Scientific Balloon Facility
SPB - Flight 662NT - LDB Relayed Real Time GPS Data



Aire sur l'Adour, France 2016

The JEM-EUSO program

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3. MINI-EUSO (2017)

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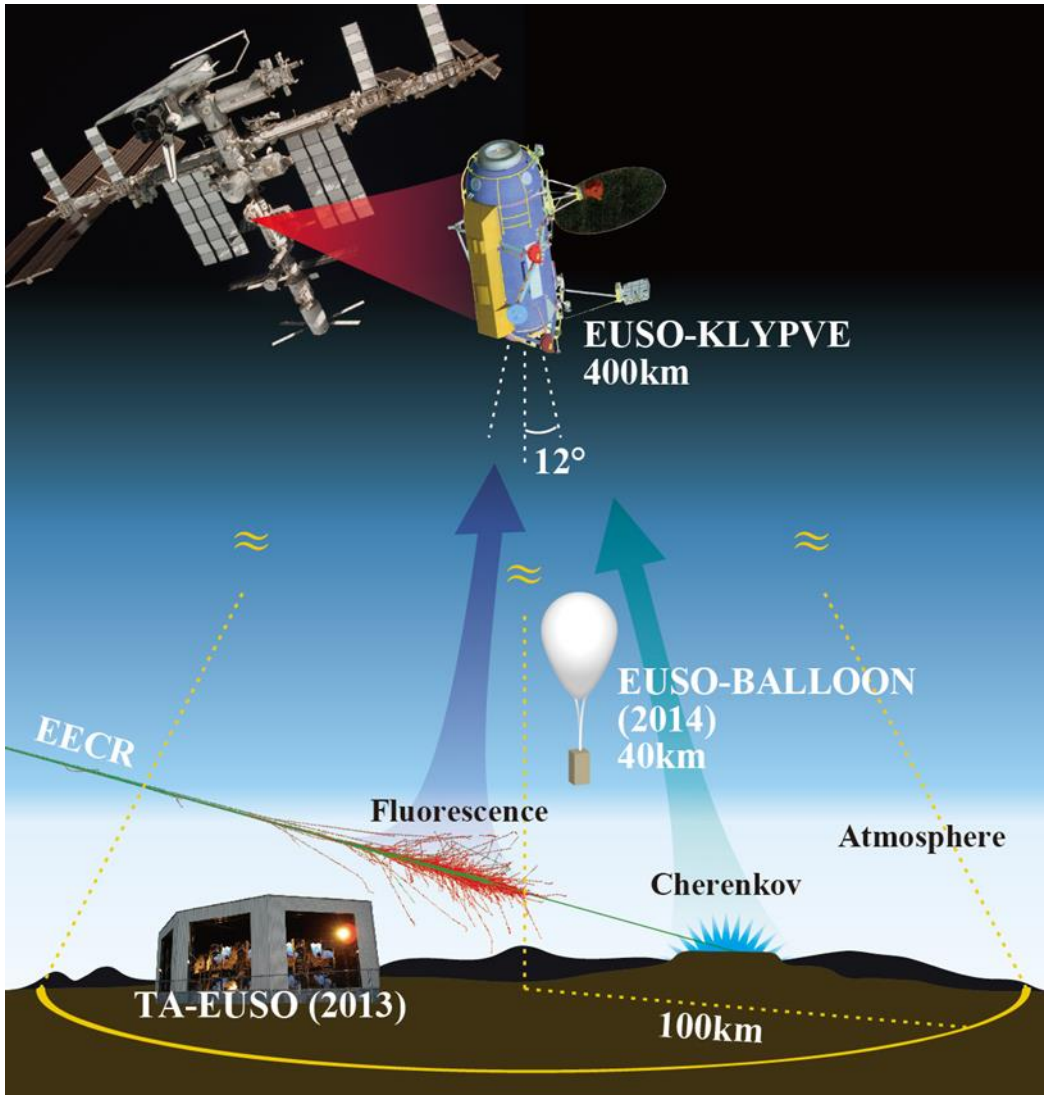
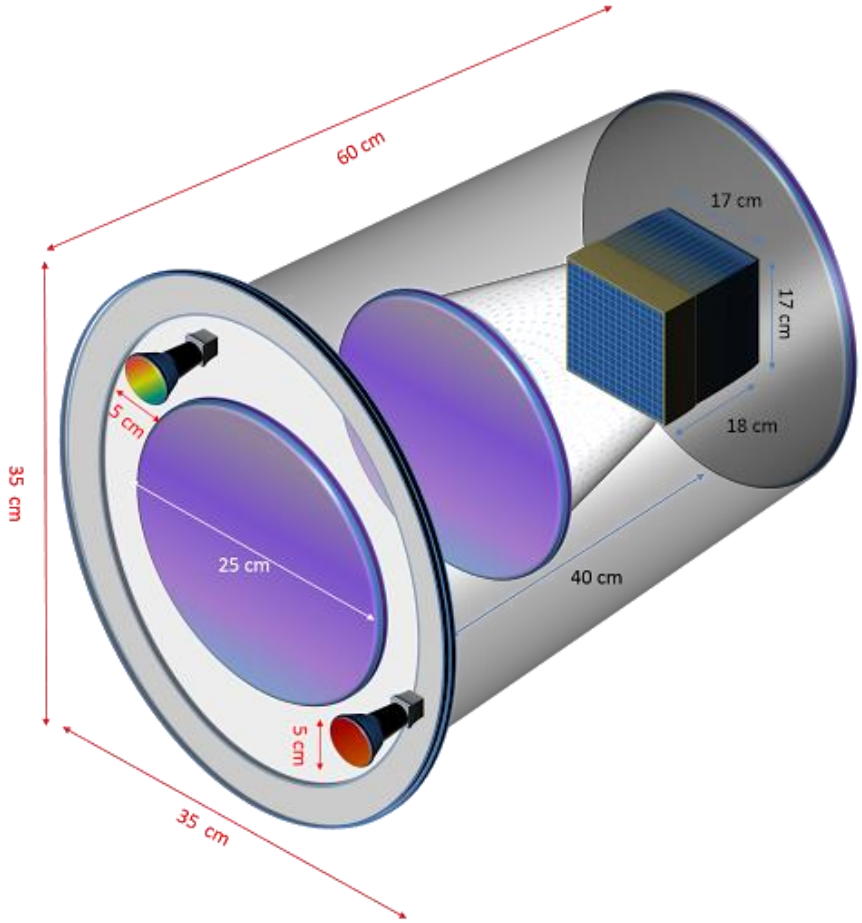
5. JEM-EUSO (>2020+)

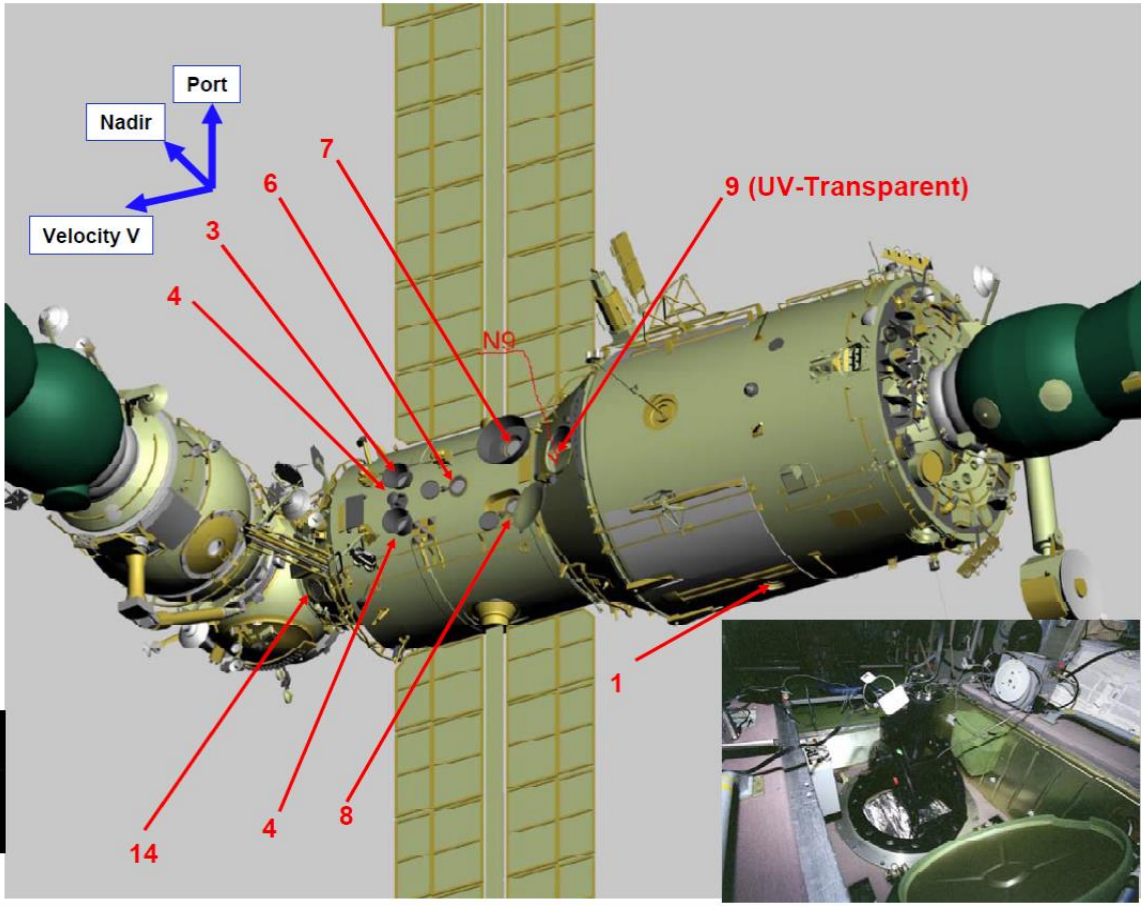


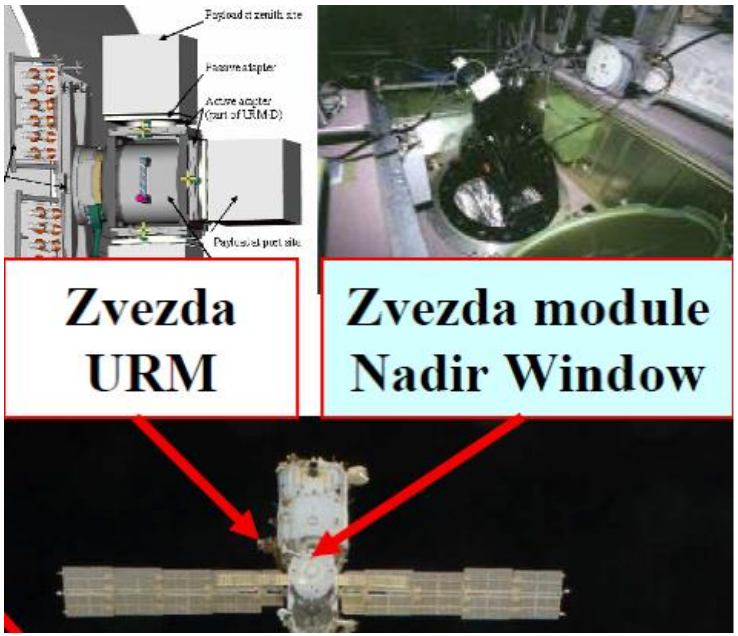
Mini-EUSO
Measurement of UV Background from ISS



The Window of Mini-EUSO

Mini-EUSO


Port
Nadir
Velocity V
7
6
3
4
9 (UV-Transparent)
N9
1
14
4
8

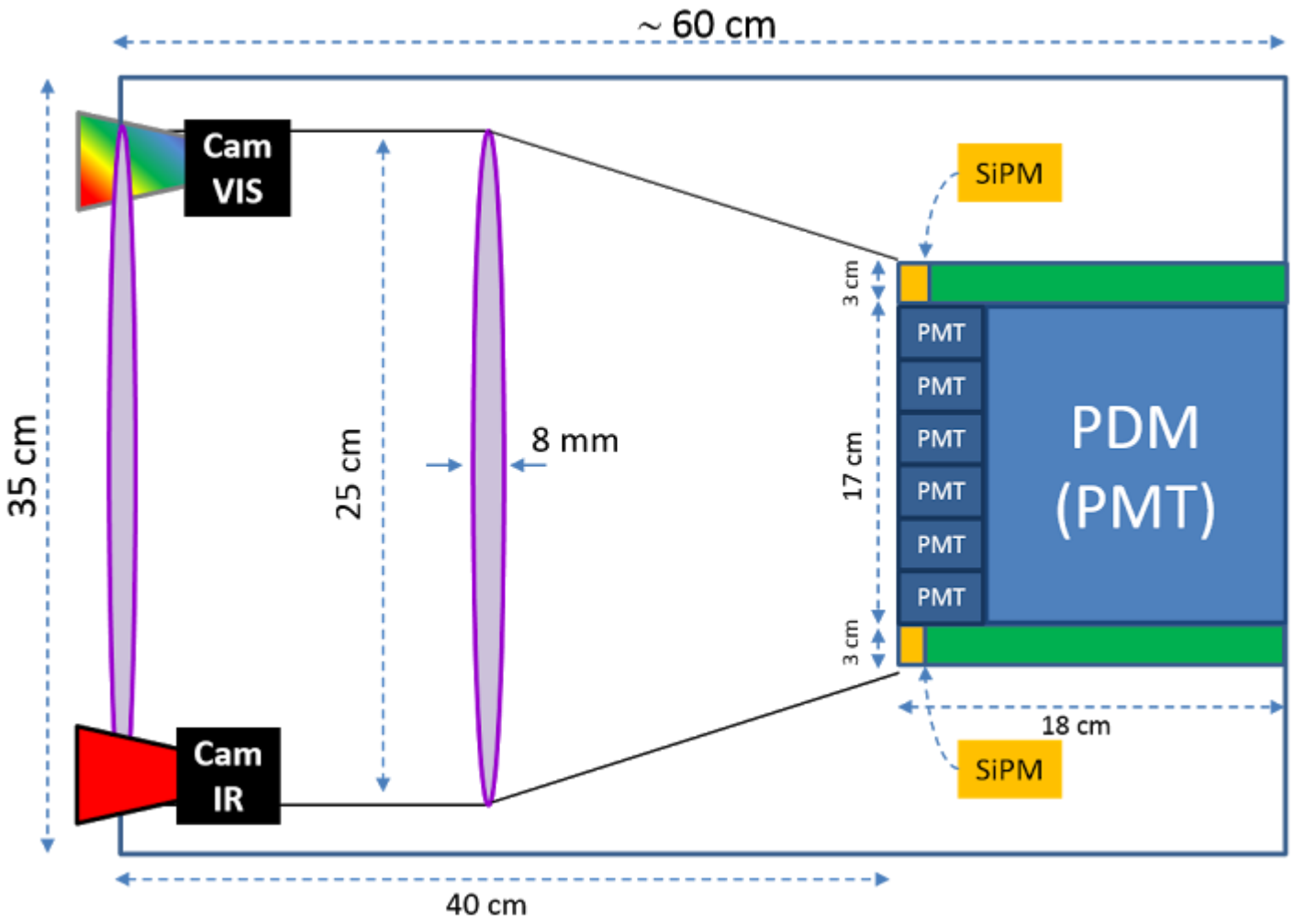

Zvezda
URM
Zvezda module
Nadir Window

Mini-EUSO - UV Atmosphere

- Mini-EUSO is included, with the name UV Atmosphere, into Russian "Stage program of scientific and applied research and experiments".

- Technical requirements are prepared by RSC "Energia" and should be released soon.

Mini-EUSO - UV Atmosphere



UV from Night-Earth

- Chemistry of the mesosphere. Airglow lights

- Map of the Earth in UV:
  climatic effects, bioluminescence in the oceans and phytoplankton, presence of hot aerosols in the atmosphere, monitoring volcano emissions

- Study of atmospheric phenomena. *TGF and TLE*

- Human activities: UV emissions by agricultural crops, by industrial or civilian facilities

- Security:
  blast or explosion, tracking also the evolution of the explosive shell in time;
  space debris assessment;
  tsunami and airglow coupling

- Study of meteors

- Search for Strange Quark Matter

- Cosmic ray Showers

JEM-EUSO

- NASA MideX Announcement of Opportunity to be released in the Fall 2016 with Mission of Opportunity (MOO) payloads
- US JEM-EUSO team would like to propose to this AO
- 2 payloads selected by Spring-Summer 2017
- Phase A – down select in 2018
- Approved mission is selected –

- M5 at ESA may come at 2017 (?)

The JEM-EUSO program

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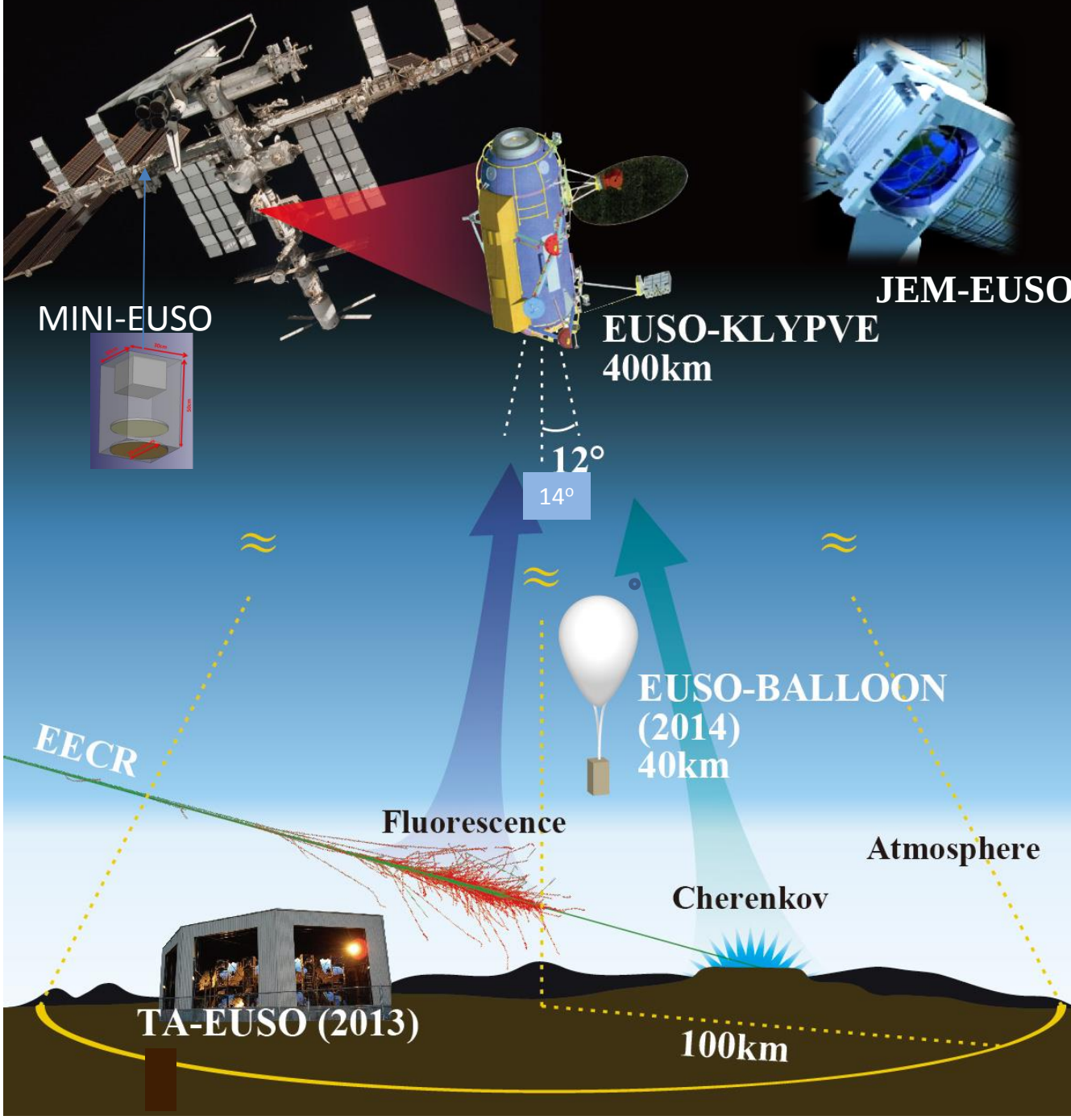
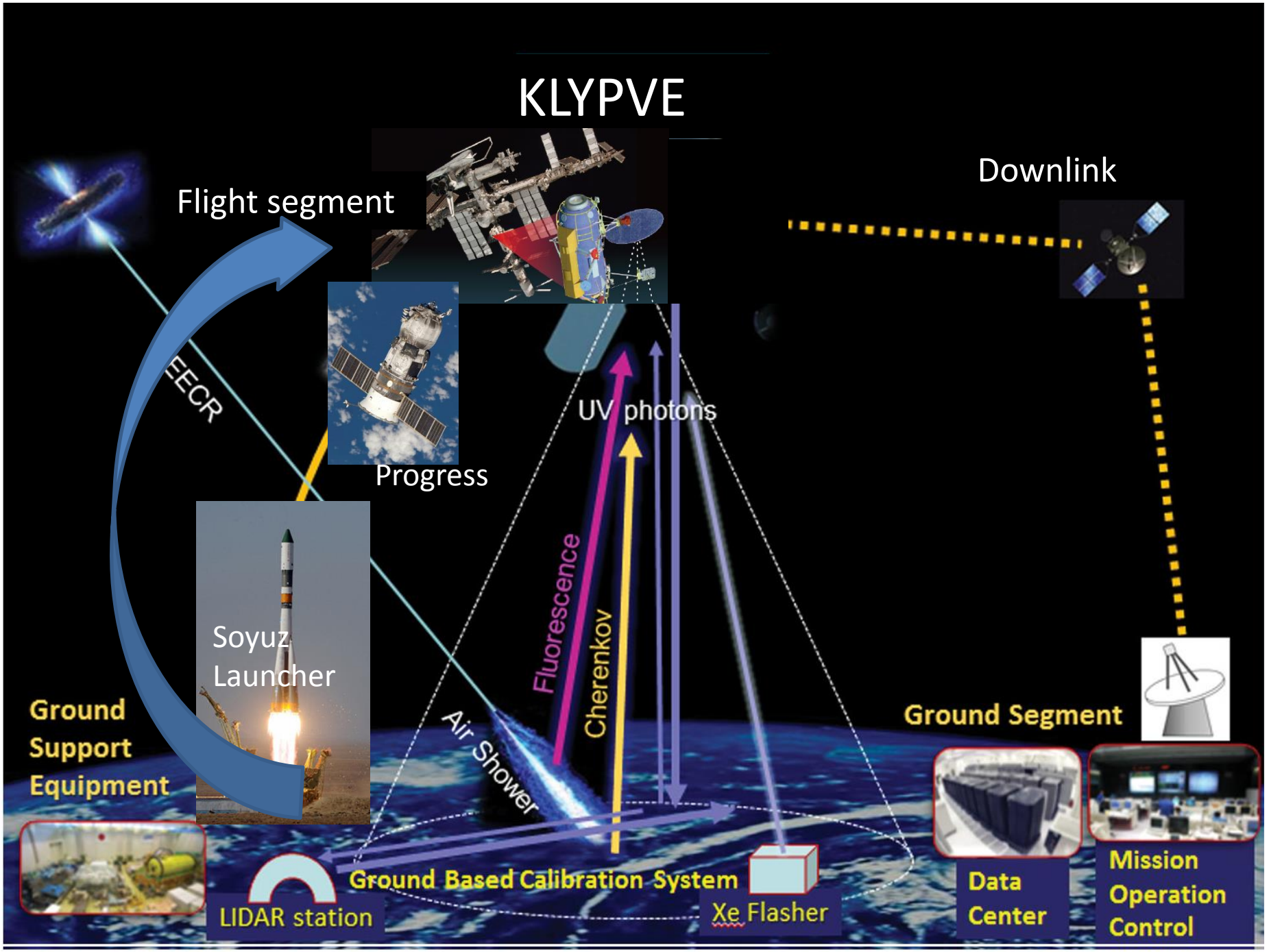
3. MINI-EUSO (2017)

4. **K-EUSO (2019)**

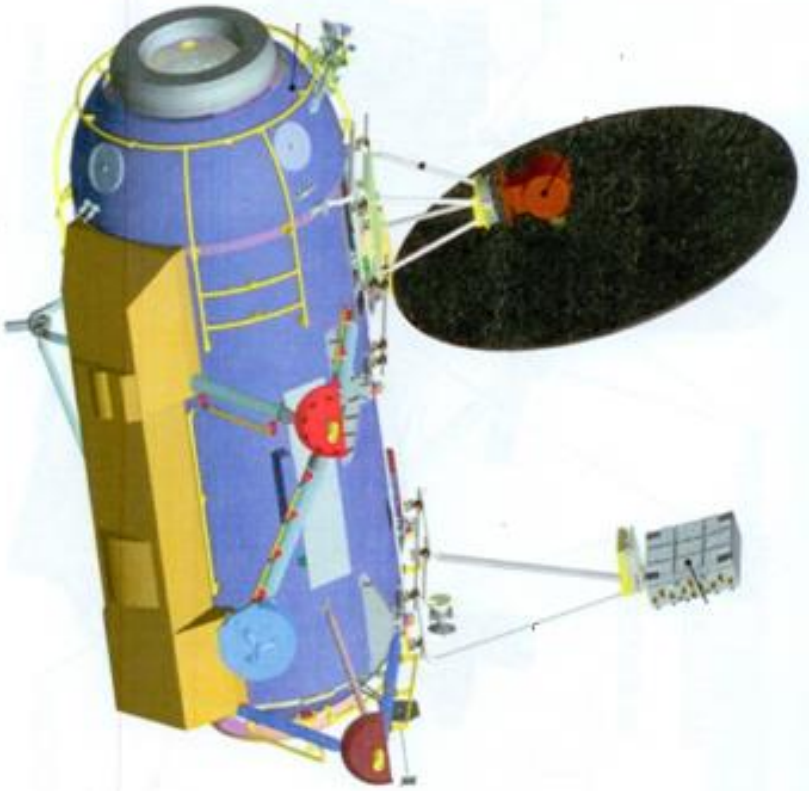
5. JEM-EUSO (>2020)




KLYPVE
Flight segment
Downlink
EECR
Progress
UV photons
Fluorescence
Cherenkov
Air Shower
Soyuz
Launcher
Ground
Support
Equipment
Ground Segment
Ground Based Calibration System
LIDAR station
Xe Flasher
Data
Center
Mission
Operation
Control

KLYPVE on RS ISS

Total mass	< 650 kg (delivery requirement)
Total power consumption	< 600 W (RS ISS limit)
Mirror diameter	3600 mm (< 4000 mm)
Focal distance	4000 mm
Parts size (mirror segments, photo detector clusters)	1200×700 mm (airlock requirement)
Scientific information	>4 TB/year hard disk to ground
Telemetry information	50 Mbytes per day
Focal Surface	1200 mm diameter

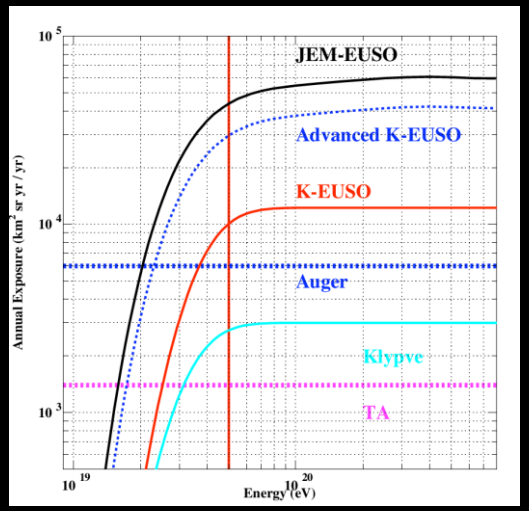


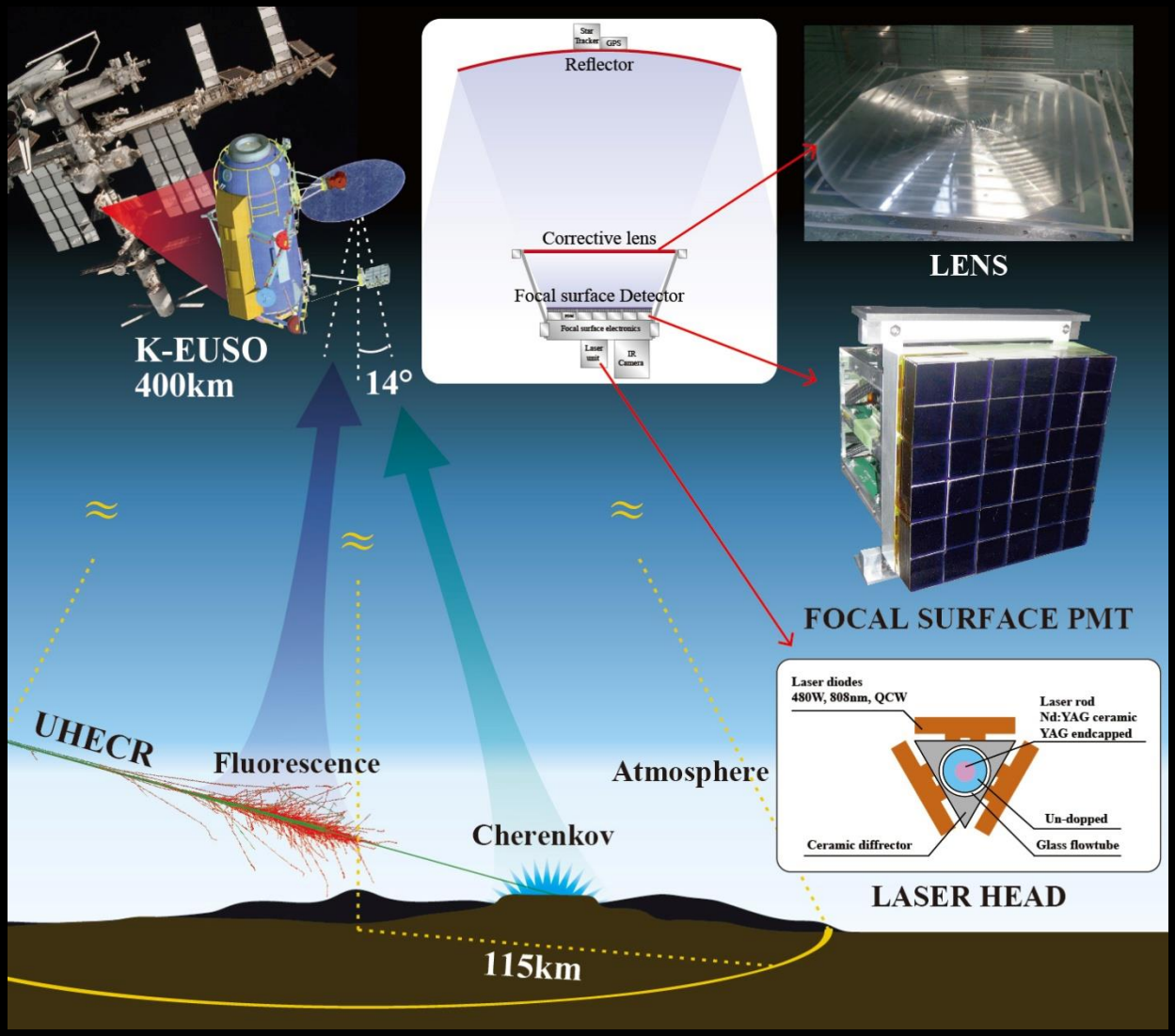
KLYPVE Status

- The experiment is in the Russian Federal Space Program
- It passed the stage of preliminary design (pre-phase A)
- Technical requirements have been signed by RSC “Energia” and MSU
- A contract for the conceptual design stage (2015-2016) is in preparation
- KLYPVE is included into “Stage program of scientific and applied research and experiments”

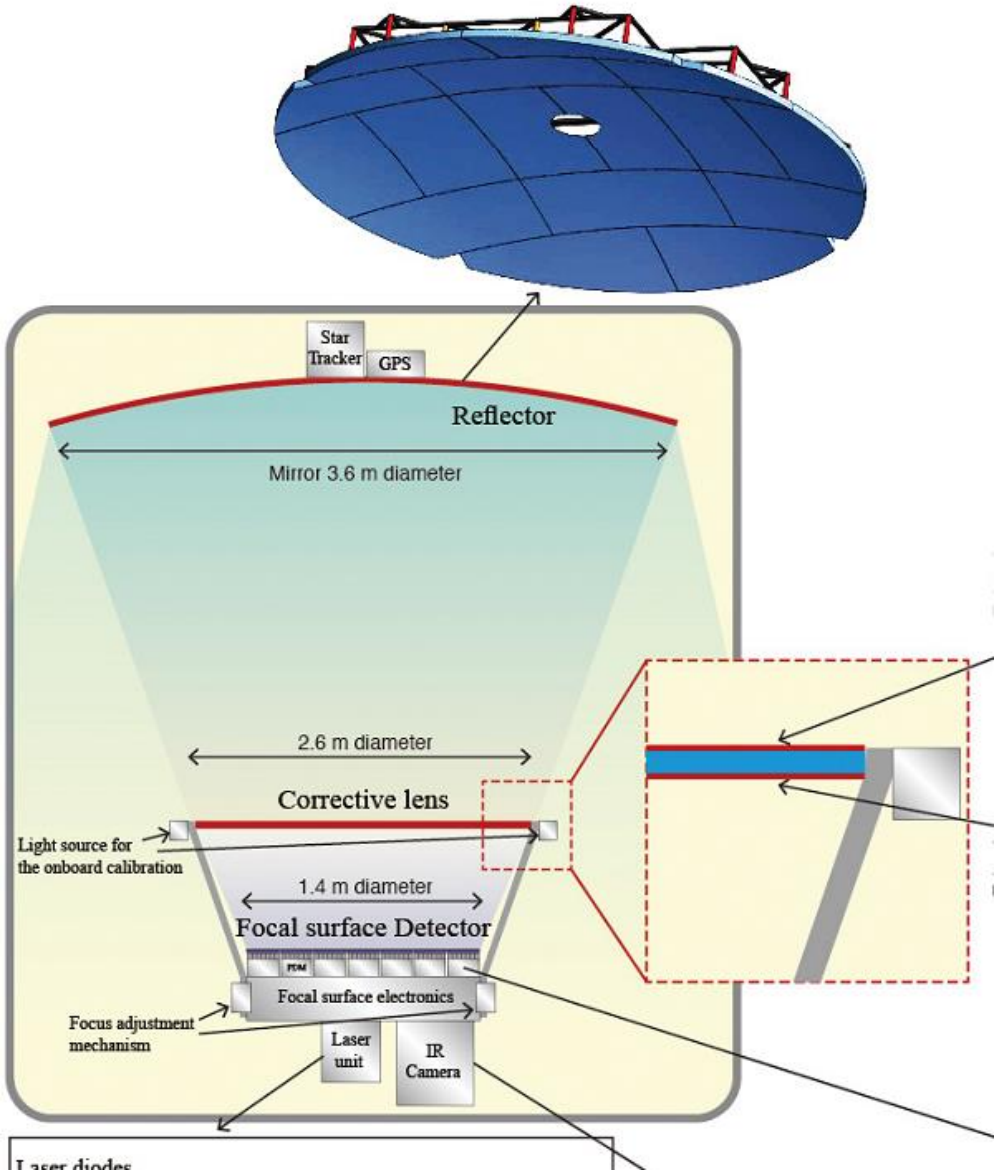
From KLYPVE to K-EUSO

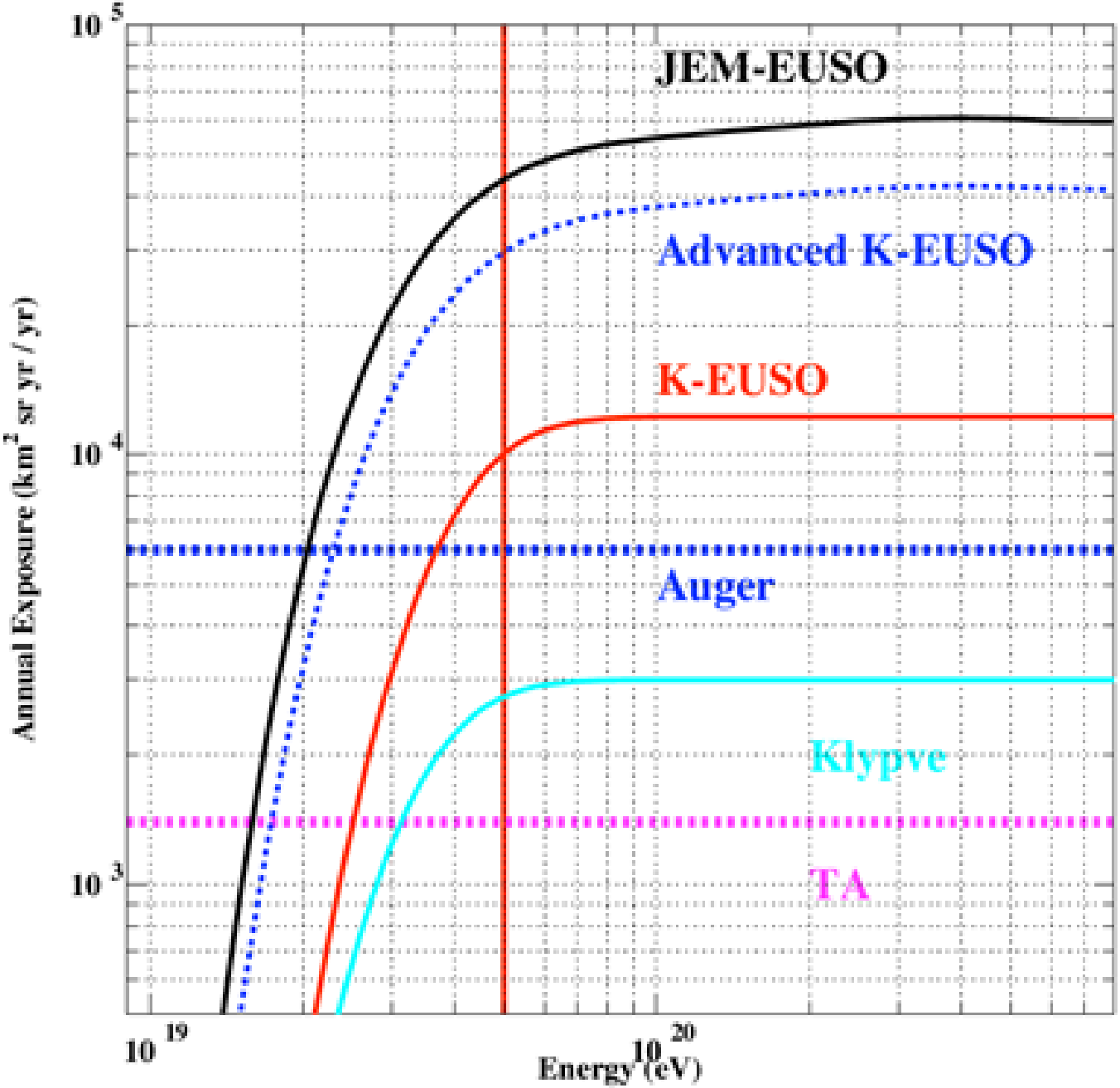
1. Lenses
2. FS electronics
3. Laser head



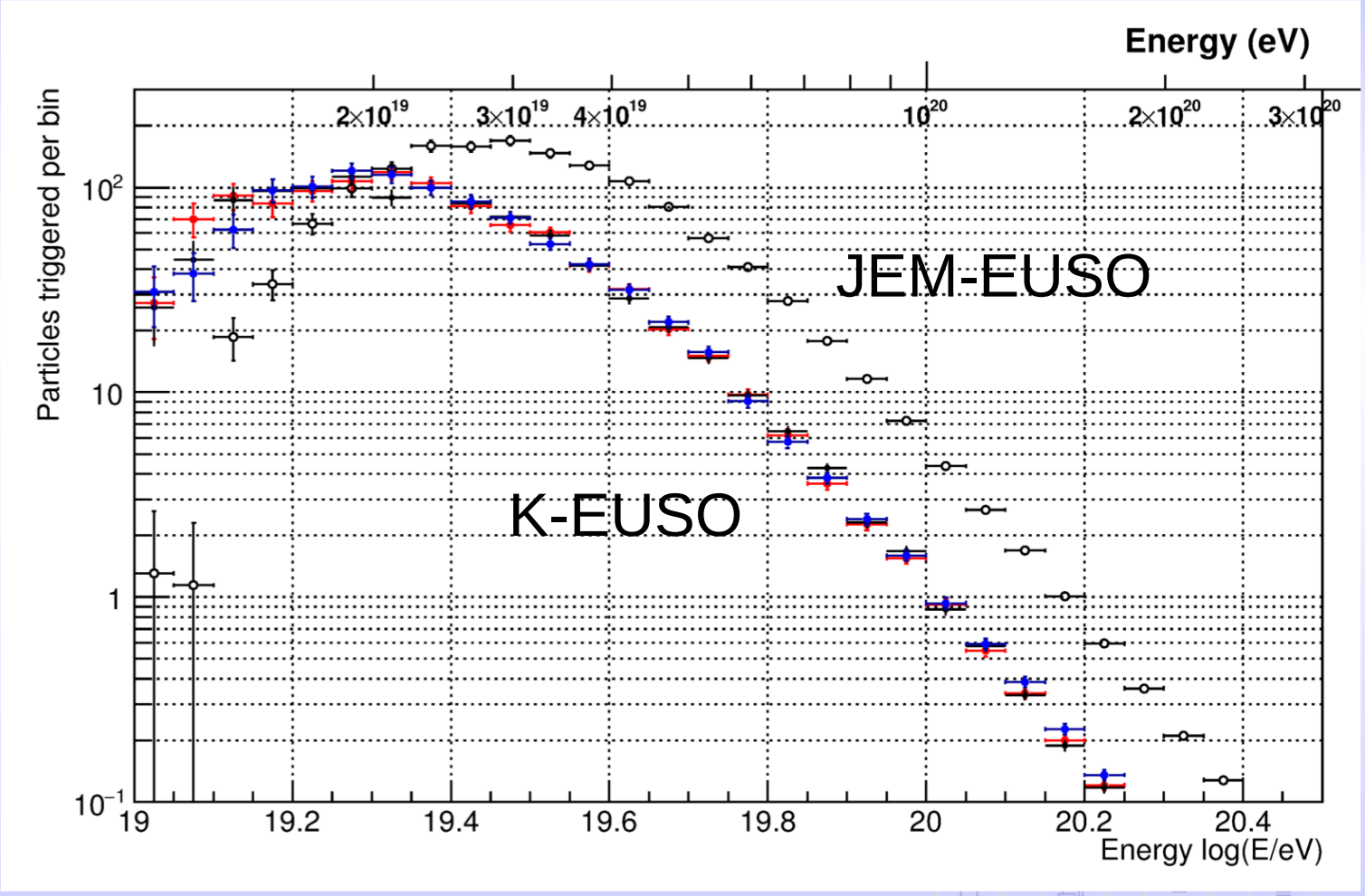


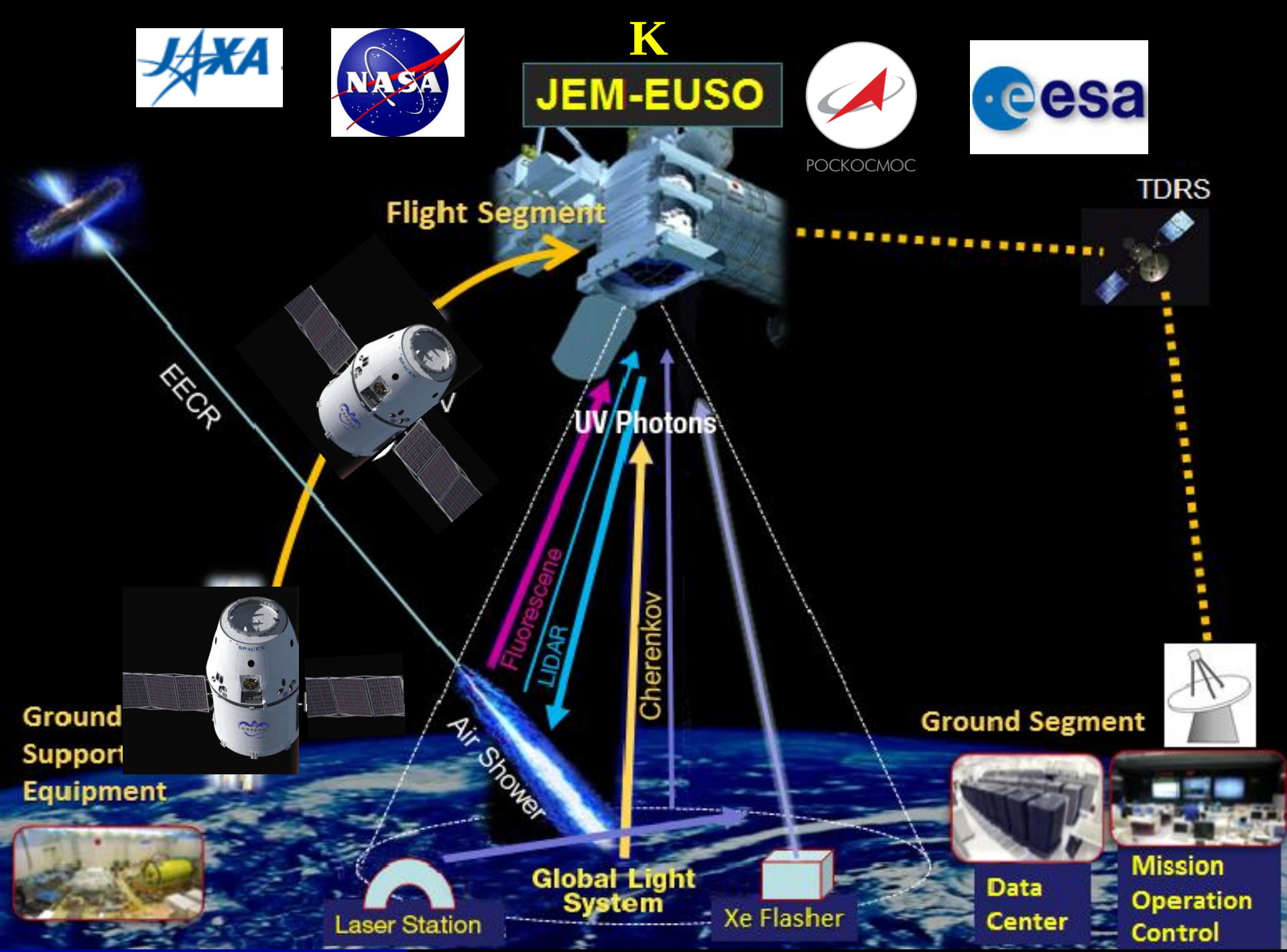
K-EUSO


Star Tracker
GPS
Reflector
Mirror 3.6 m diameter
2.6 m diameter
Corrective lens
Light source for the onboard calibration
1.4 m diameter
Focal surface Detector
Focal surface electronics
Focus adjustment mechanism
Laser unit
IR Camera


JEM-EUSO
Advanced K-EUSO
K-EUSO
Auger
Klypve
TA
Annual Exposure (km^2 sr yr / yr)
Energy (eV)
10^5
10^4
10^3
10^{19}
10^{20}

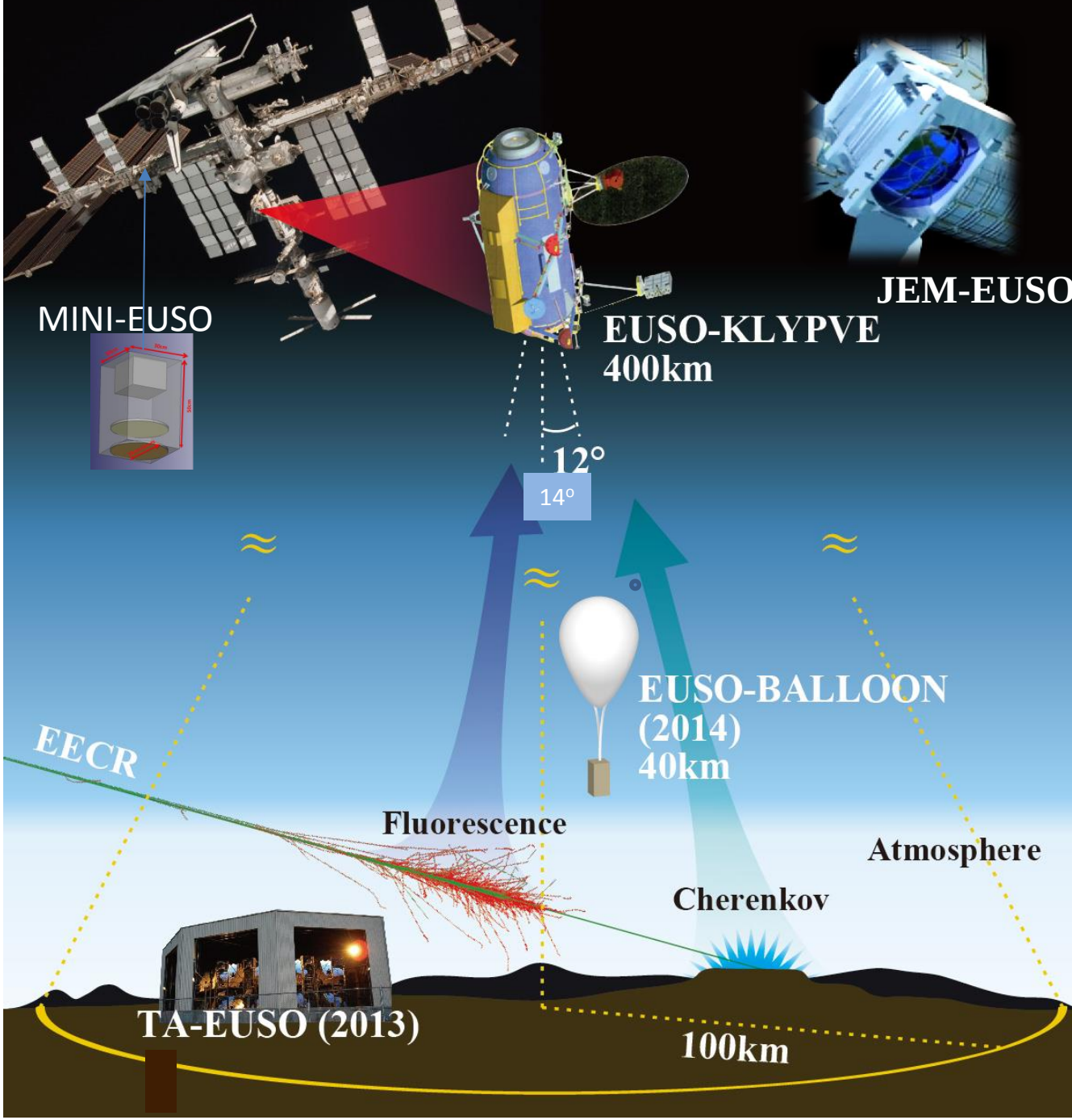
A preliminary estimate of the annual triggered spectrum




JAXA
NASA
K
JEM-EUSO
POCKOCMOC
esa
Flight Segment
TDRS
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

The JEM-EUSO program

1. **EUSO-TA: Ground detector at Telescope Array site: 2013-**
2. **EUSO-BALLOON: 1st balloon flight from Timmins, Canada**
3. **EUSO-SPB (2017)**
3. **MINI-EUSO (2017)**
4. **K-JEM-EUSO (>2020)**



Thanks!

http://jemeuso.roma2.it