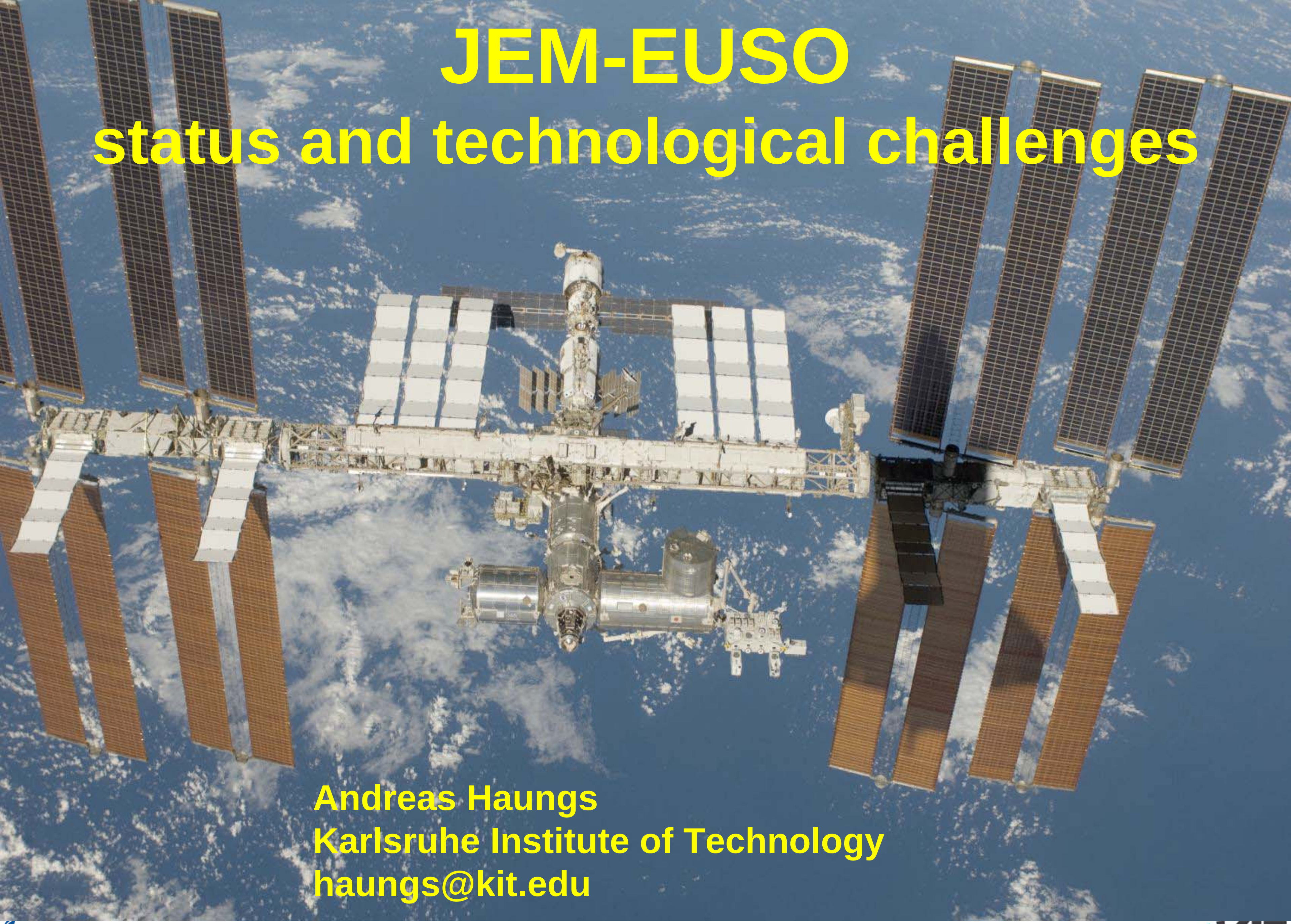
JEM-EUSO
status and technological challenges



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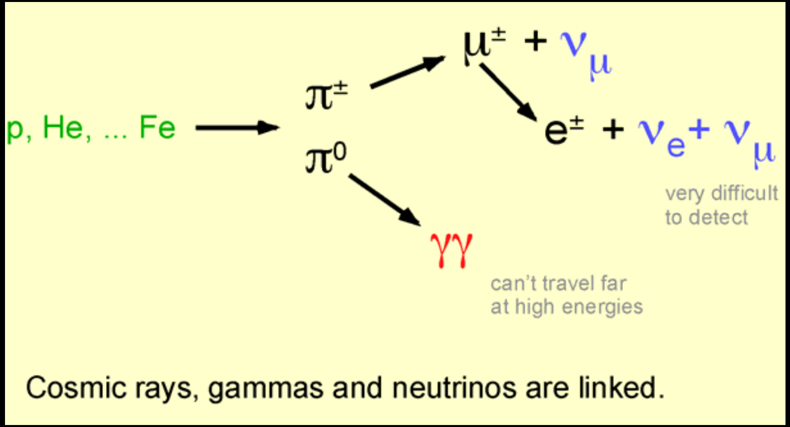
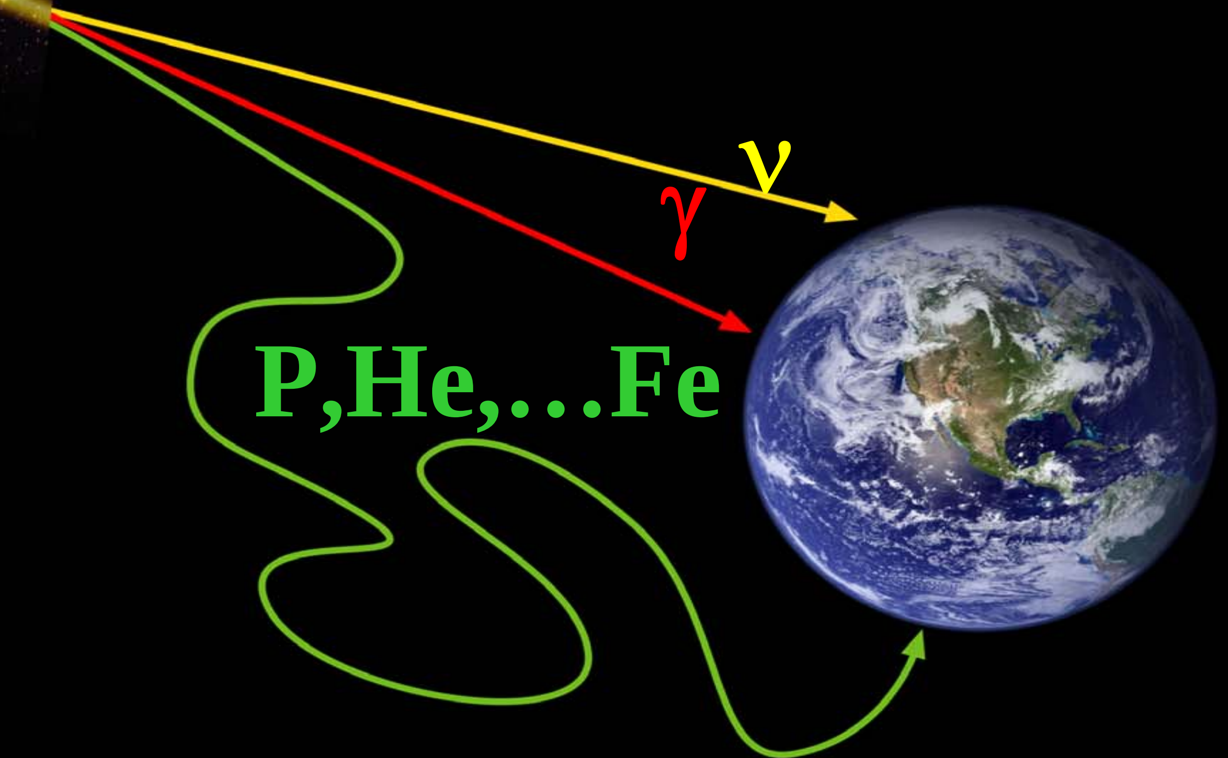
Multi-messenger Approach in Astroparticle Physics

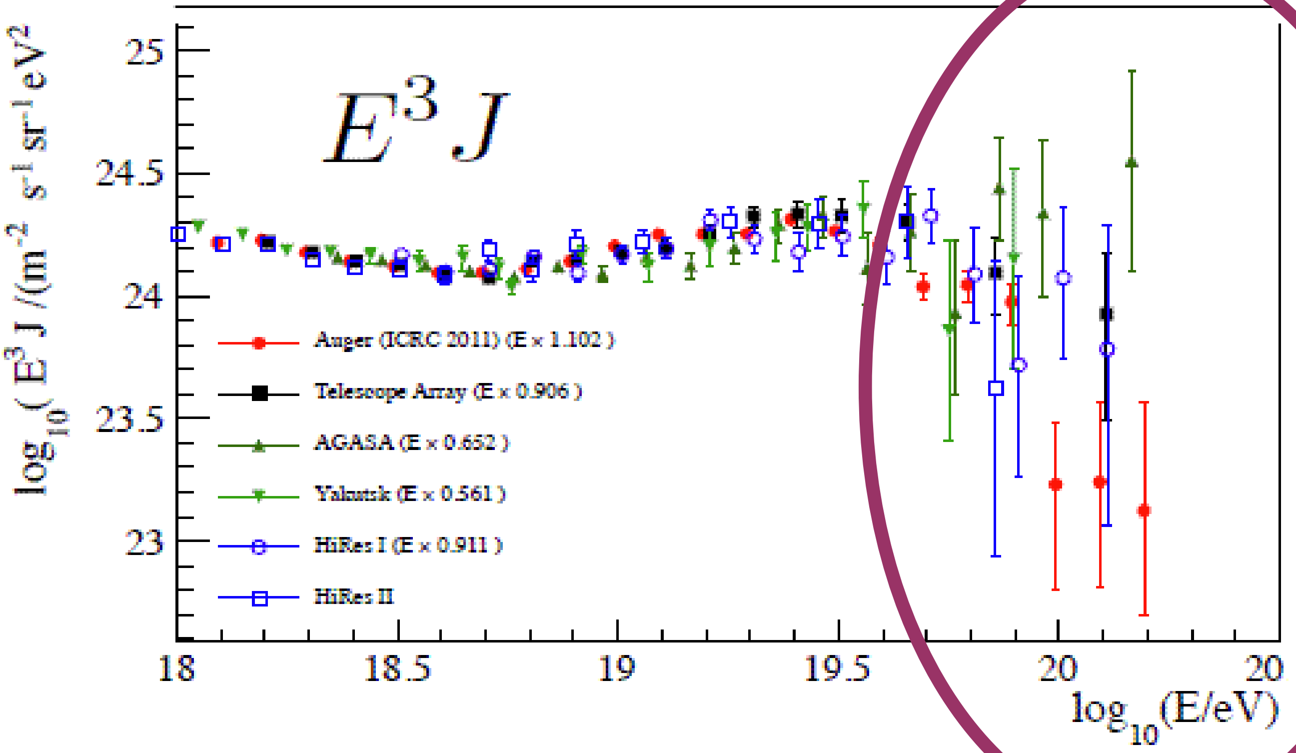
Source:



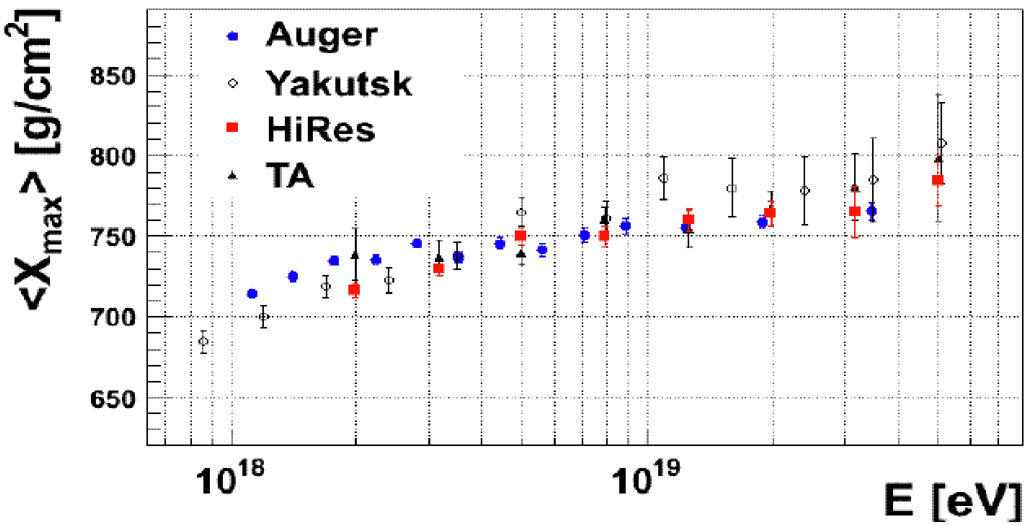


Transport, GZK:

$$p+\gamma_{2.7K} \rightarrow \Delta^{+}(1232)$$
$$\rightarrow p+\pi^{0} \rightarrow p\gamma\gamma$$
$$\rightarrow n+\pi^{+} \rightarrow pe^{+}\nu$$



➔Energy range of particle Astronomy
(if these are at least partly protons)

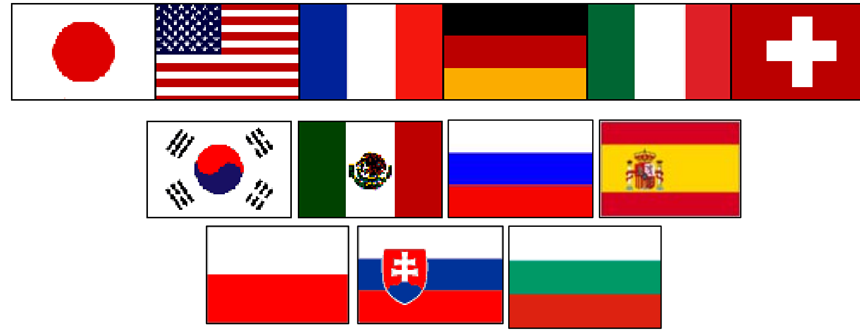


Need for the future

➔more statistics at highest energies

M.Fukushima: CERN Symp, Feb2012

JEM-EUSO Collaboration



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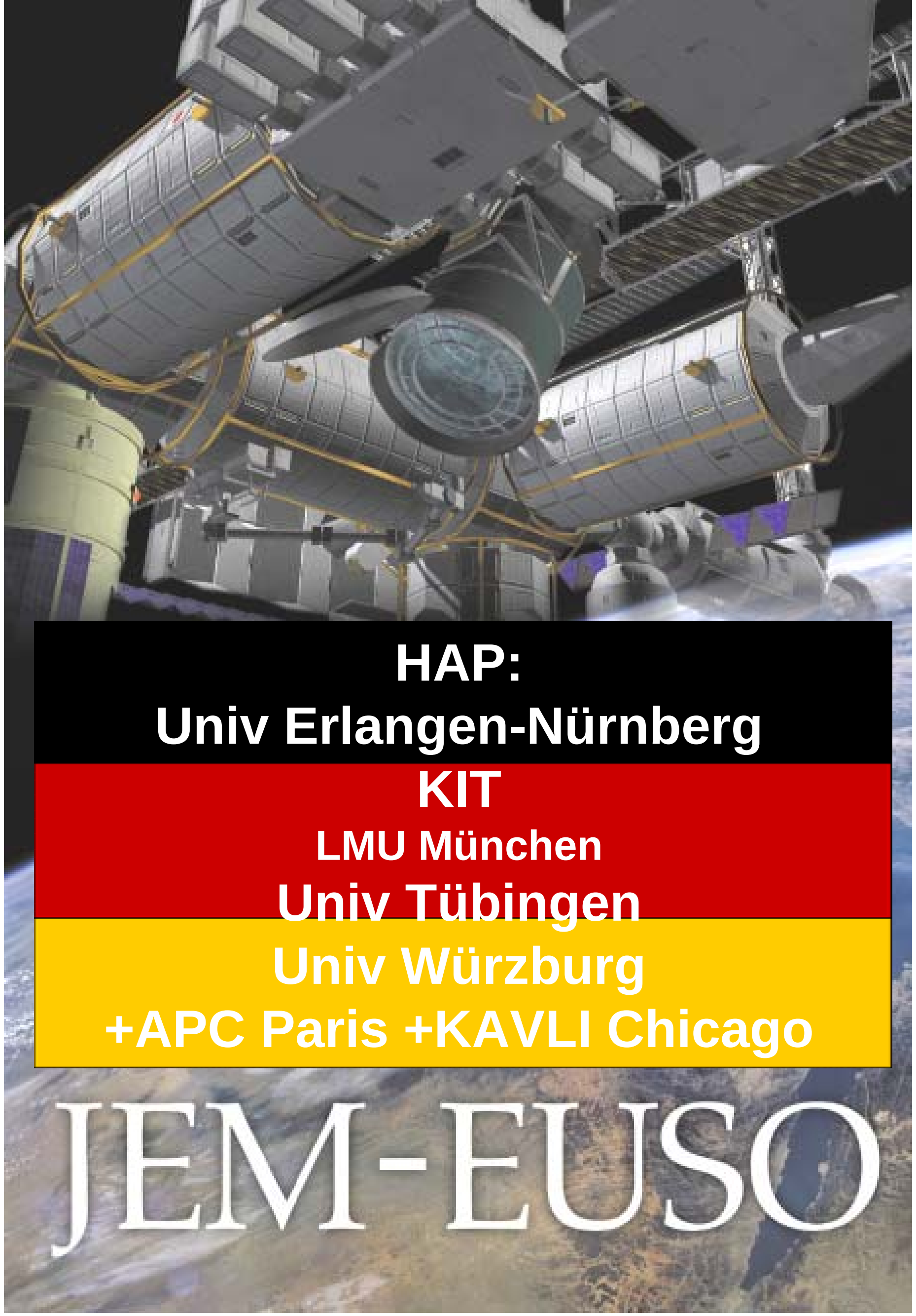
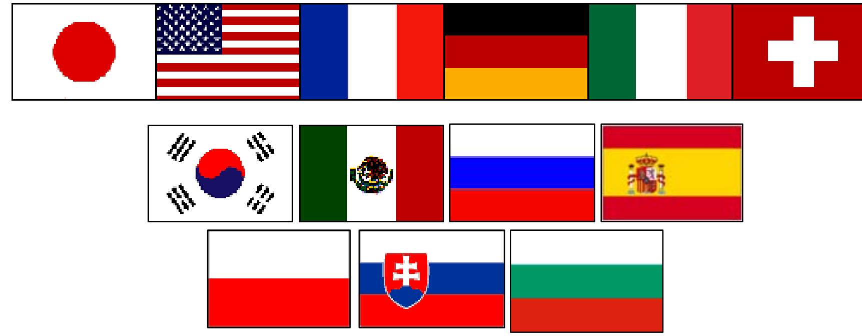
13 countries

78 institutes

267 members



JEM-EUSO Collaboration



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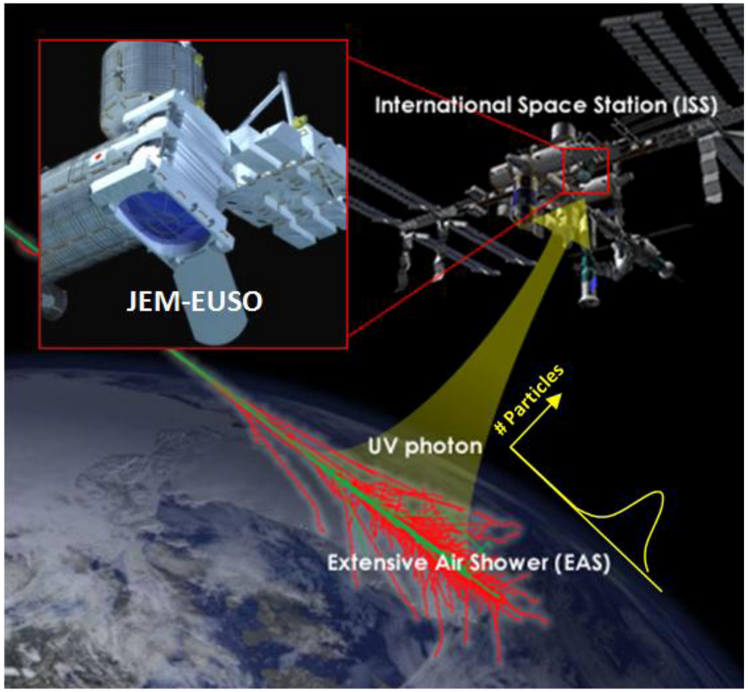
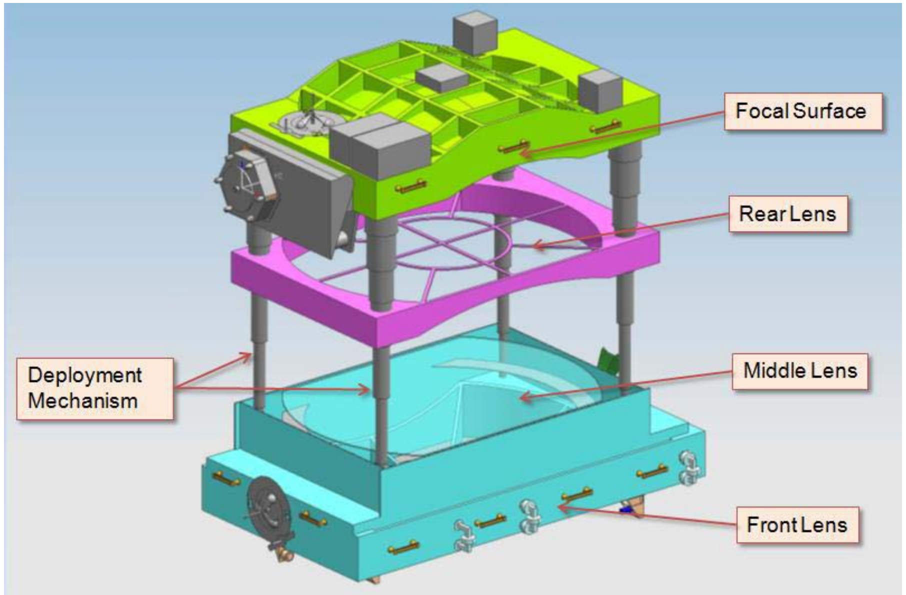
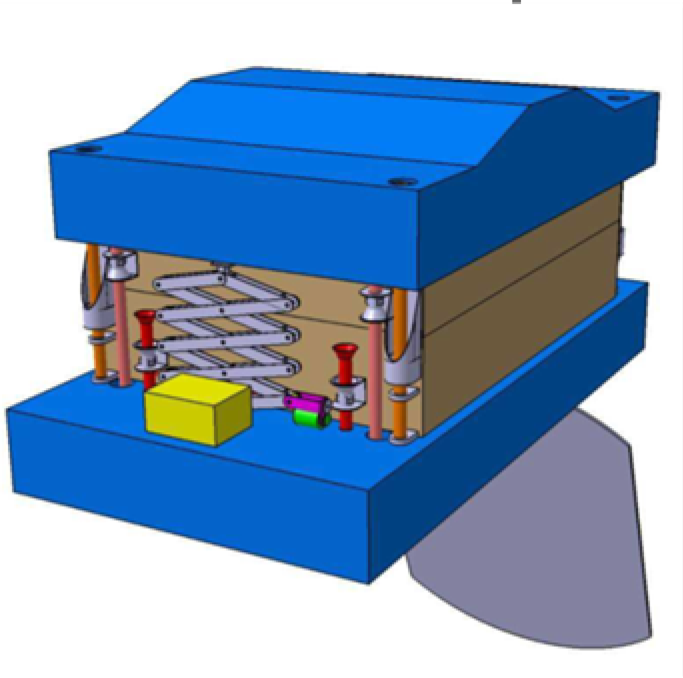
JEM-EUSO main features

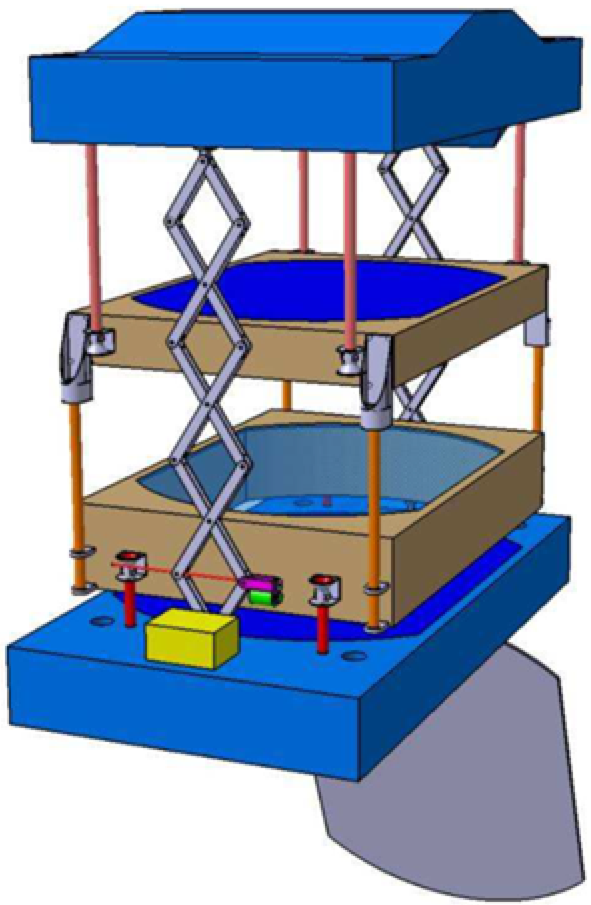
Method:	**fluorescence (full calorimetric)**
Large field of view:	**± 30° thanks to double sided spherical Fresnel lenses**
At 400 km (ISS):	**2 10^5 km^2 (nadir mode) up to 10^6 km^2 (tilted mode)**
No need for stereo:	**400 km >> shower length (TPC with a drift velocity = c)**





technical aspects (examples) : telescope

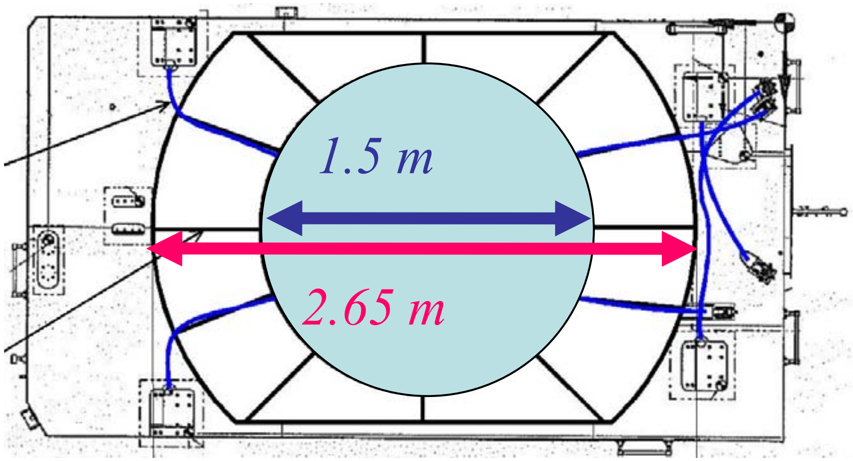


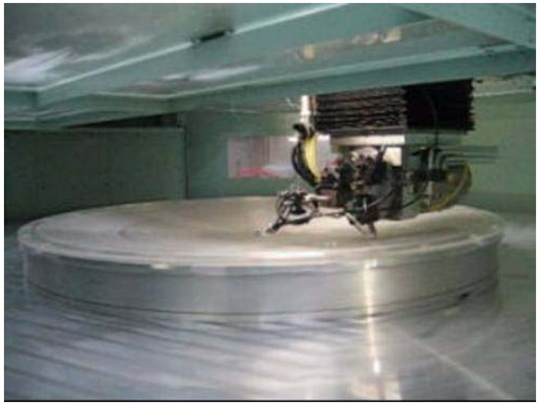


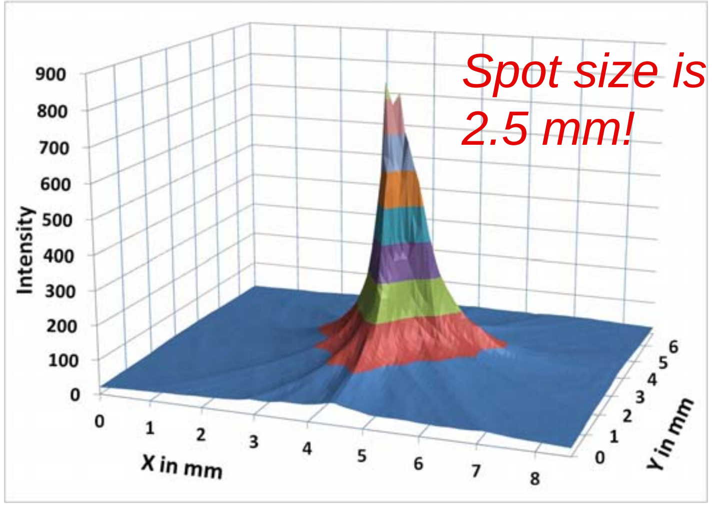
Parameter	Value
Launch date	JFY 2016
Mission Lifetime	3+2 years
Rocket	H2B
Transport Vehicle	HTV
Accommodation on JEM	EF#2
Mass	1938 kg
Power	926 W (op.) 352 W (non op.)
Data rate	285 kbps (+ on board storage)
Orbit	400 km
Inclination of the Orbit	51.6°
Operation Temperature	-10° to 50°

- **2.65m x 1.90m x 3.50m ; 2 tons**
- **have to fit into the rocket**
- **expansion at the ISS**

technical aspects (examples) : Fresnel lenses

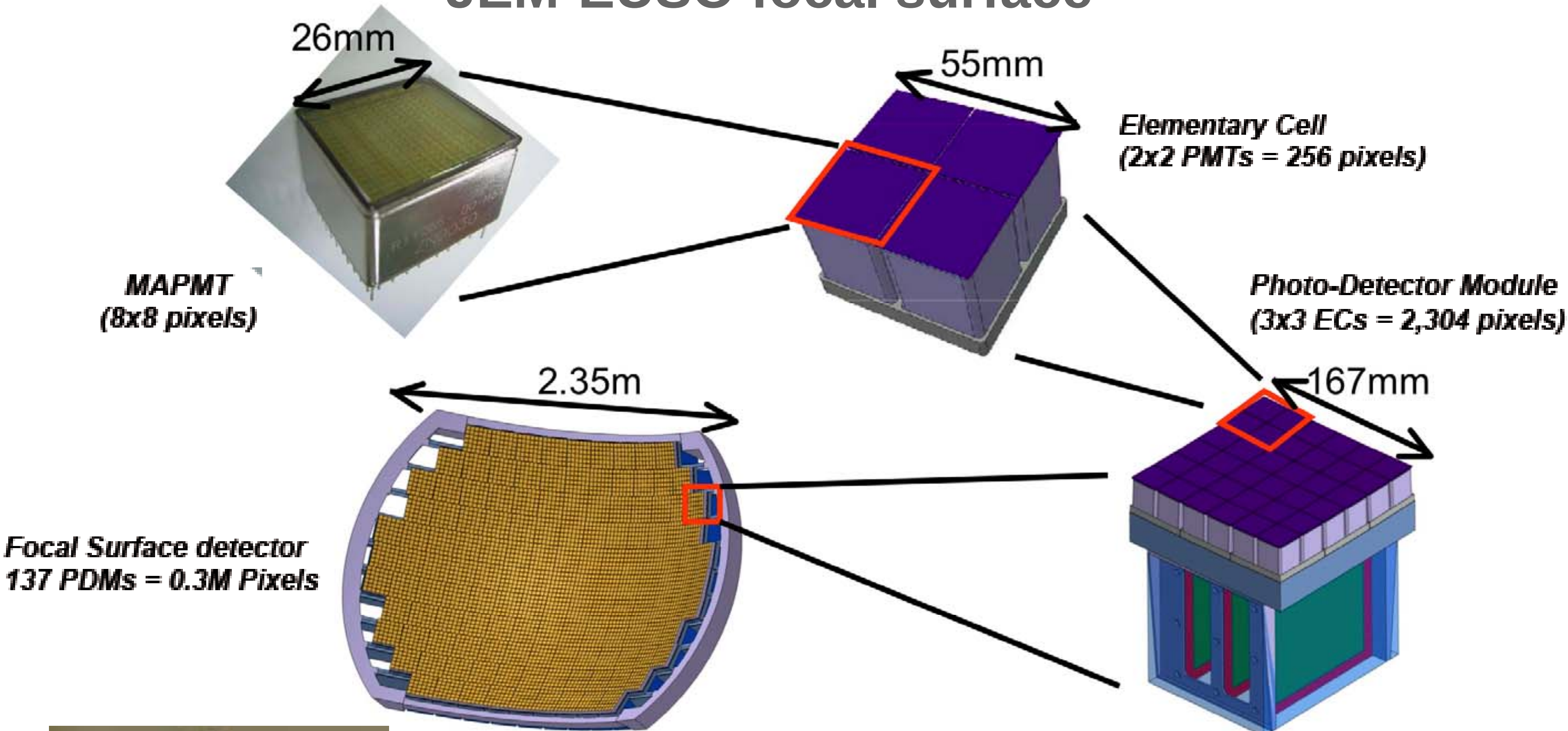






- Tested performances meet already the requirements
- two month production time per lense

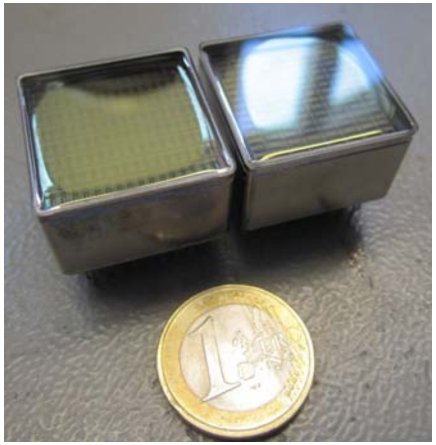
JEM-EUSO focal surface



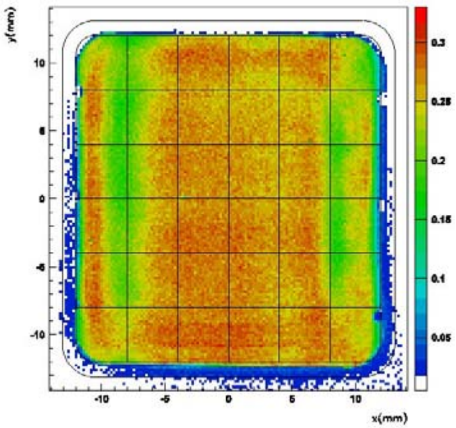
Focal surface:

- prototypes of PDM in preparation
- FoV of 1 PDM = 27 x 27 km^2

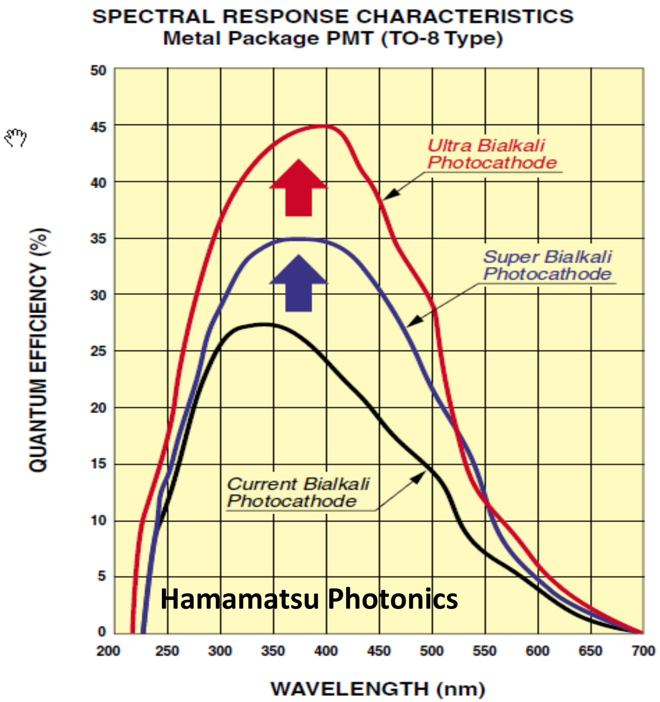
technical aspects (examples) : MAPMT



+UV Filter



Ultra Bialkali ZB0765
Average: (24.4 ± 1.8)%

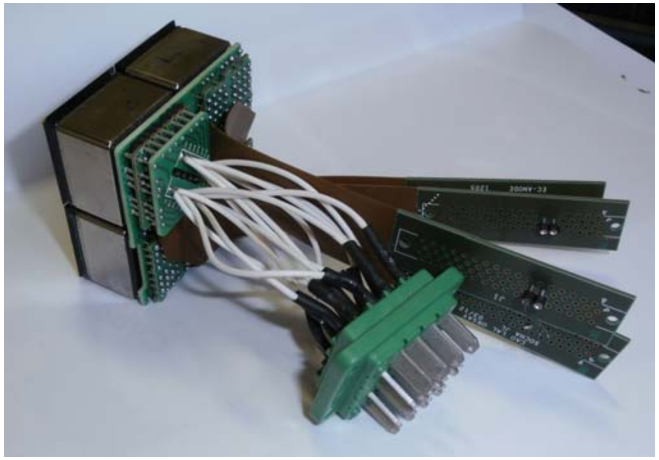


- 23.04mm * 23.04mm effective area
- 8*8 Channels 2.88mm * 2.88mm
- Ultra bi-alkali photo-cathode
- 12 dynodes + 1 guard ring
- Gain of ~ 10^6
- Photon detection efficiency ~ 30%
- Near-ultraviolet wavelength region
- Clearly separated pixels
- No crosstalk

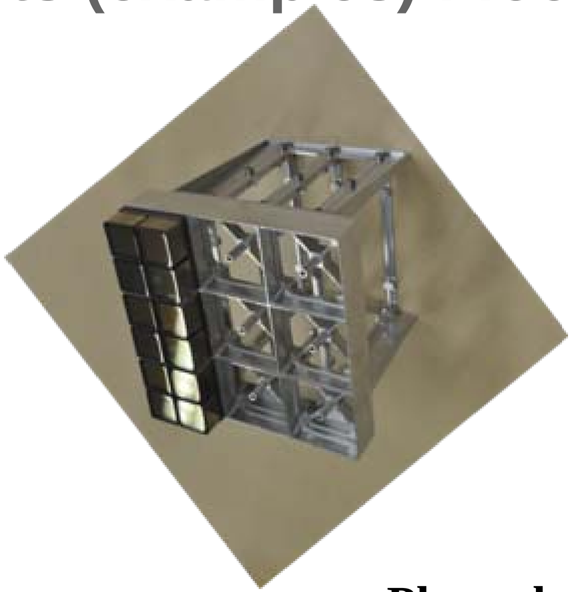
- Collaboration with Hamamatsu
- Reduction of size,
- increase of anode number
- Improvement of Quantum efficiency
- Improvement of uniformity of response

?? Use of SiPMs ??

technical aspects (examples) : focal surface



Elementary Cell (EC)



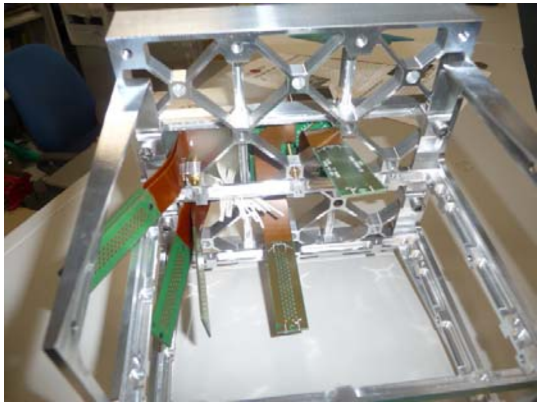
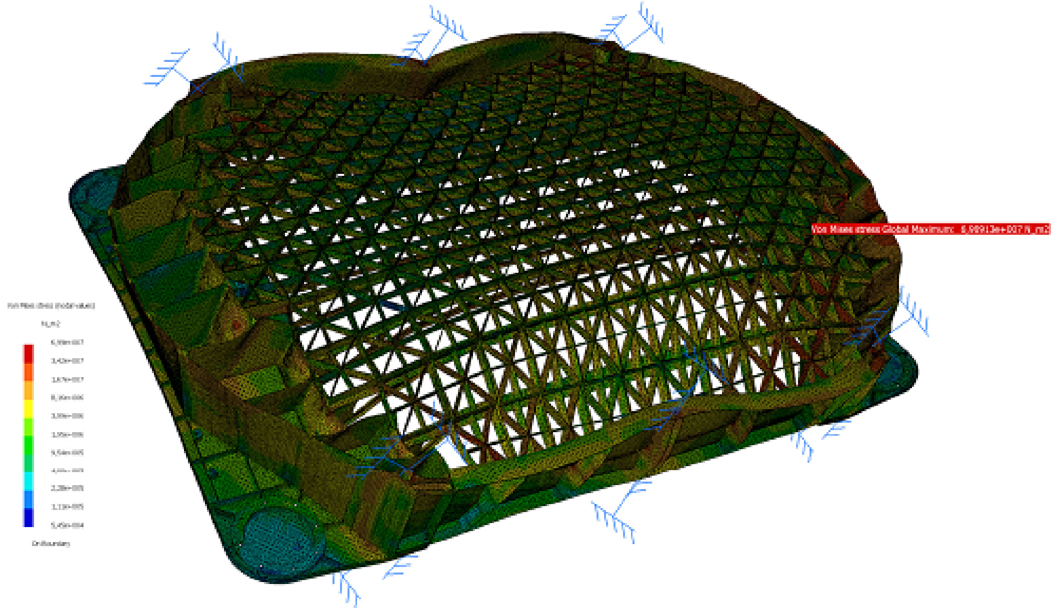


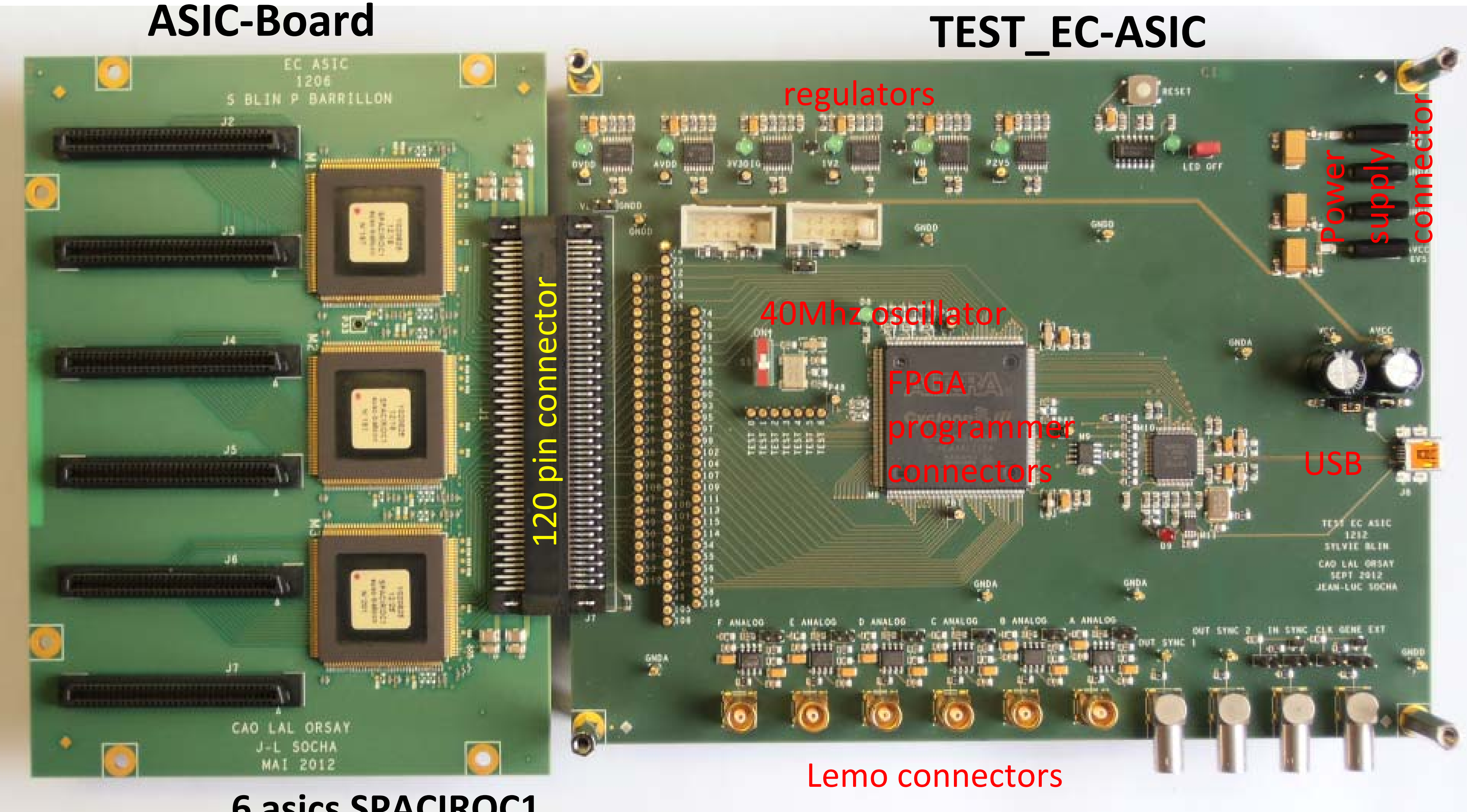
Photo detection module (PDM)

C3 Case: Von Mises Stress



- **vibration safe**
- **HV switches**
- **fast switch-off of PDMs**
- **trigger logic**

technical aspects (examples) : focal surface

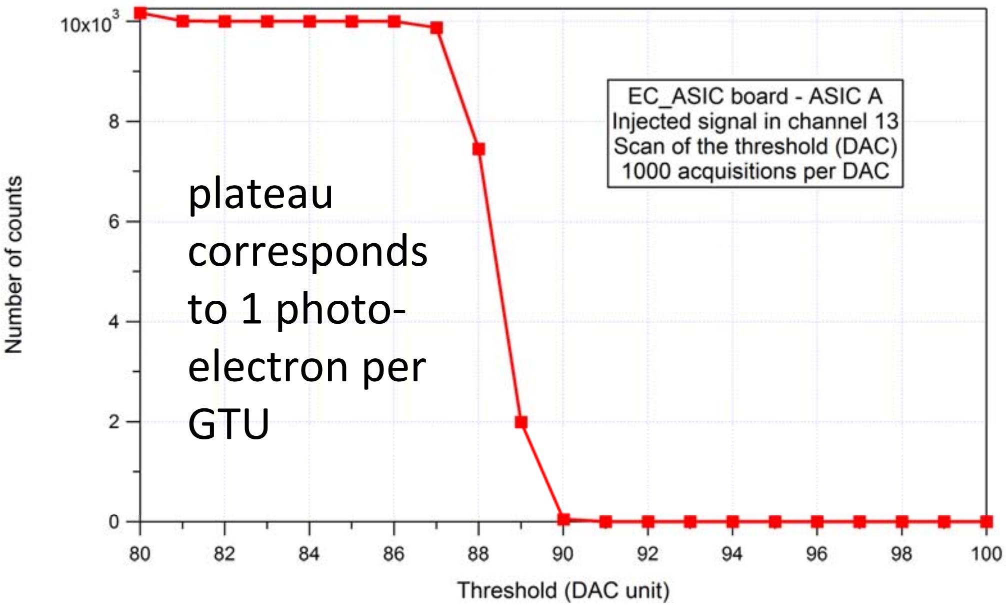


6 asics SPACIROC1

Packaging:CQFP160 pins

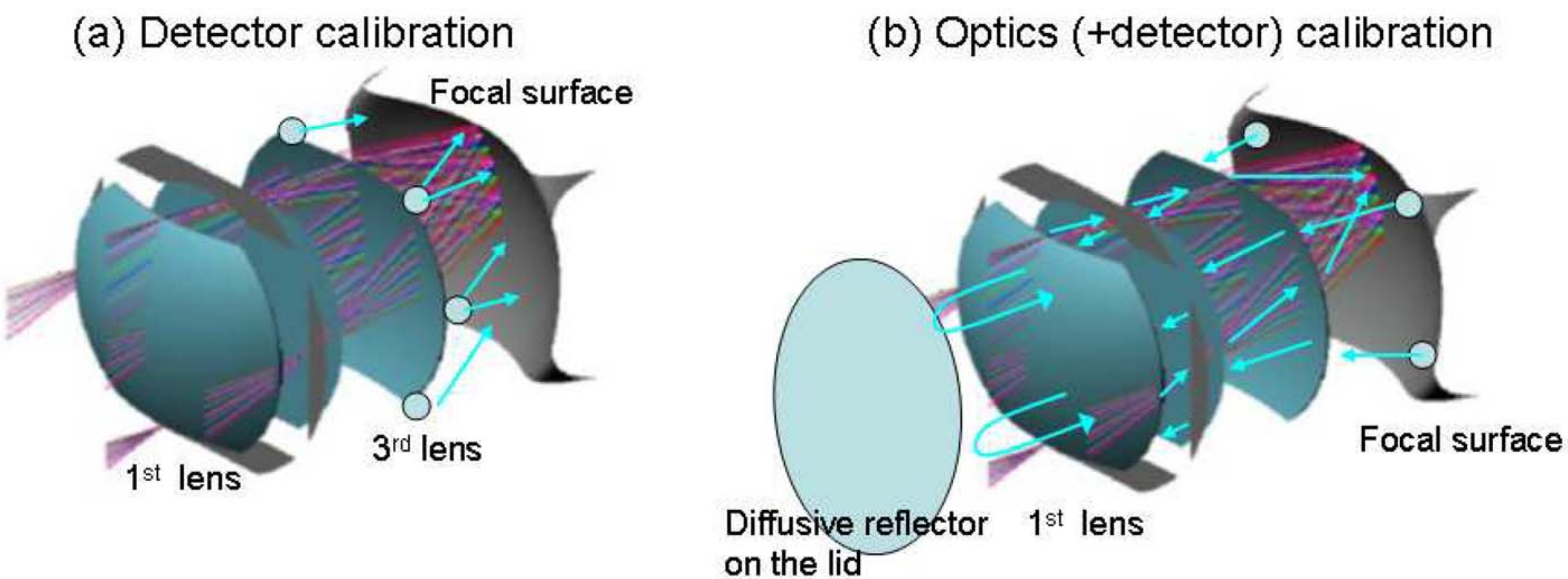
technical aspects (examples) : calibration

- **Efficiency dominated by electrostatics of the cathode**
- **Gain dominated by the dynodes and HV**
- **On ground Calibration in *single photon mode***
  - **Good photon shielding (black box)**
  - **Number of photons coming from light source**
  - **Every single pixel by itself Confined spot size of light source**
  - **Measure single photo-electron spectra & s-curves**



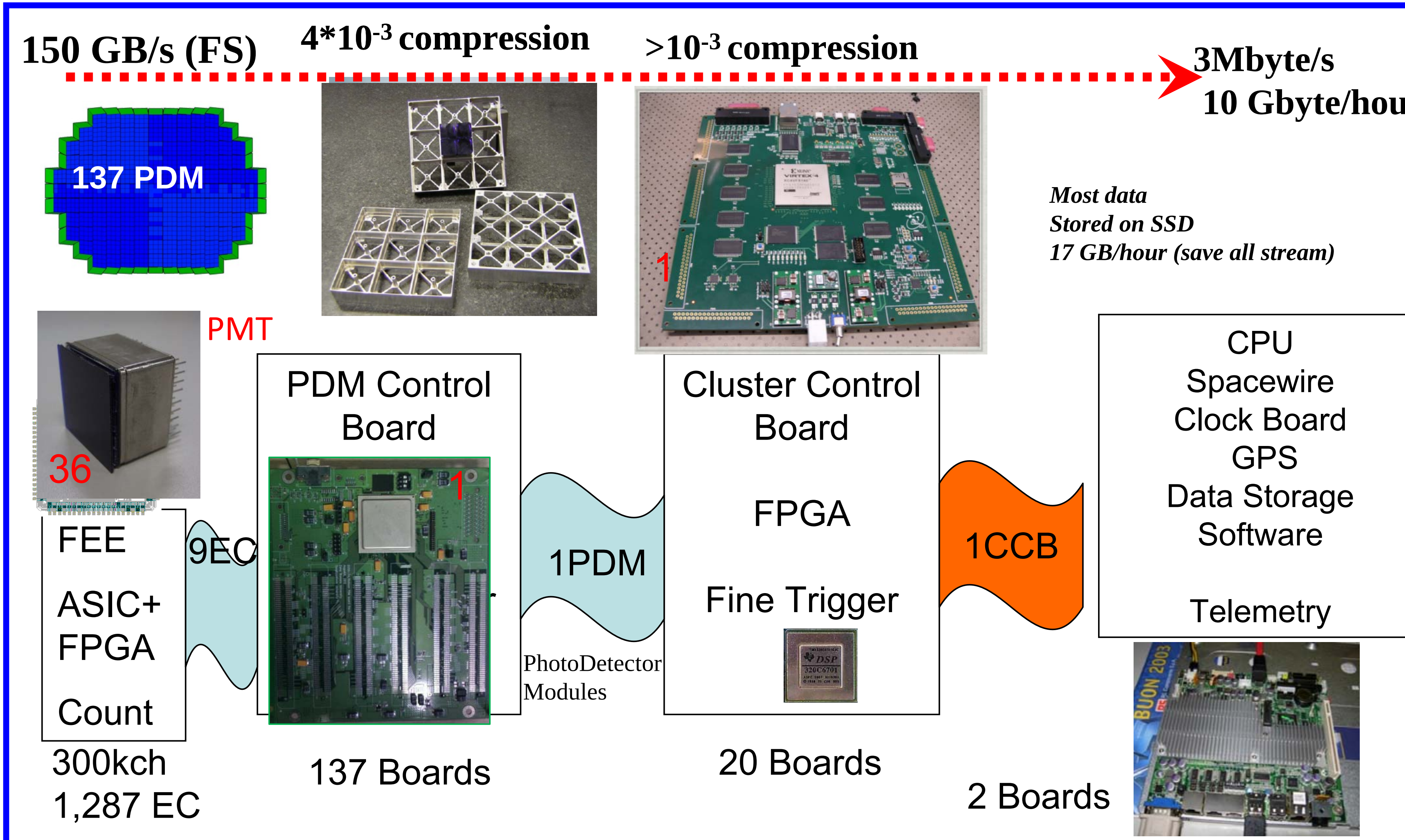
also: LIDAR + Xe-flasher from ground….

technical aspects (examples) : calibration



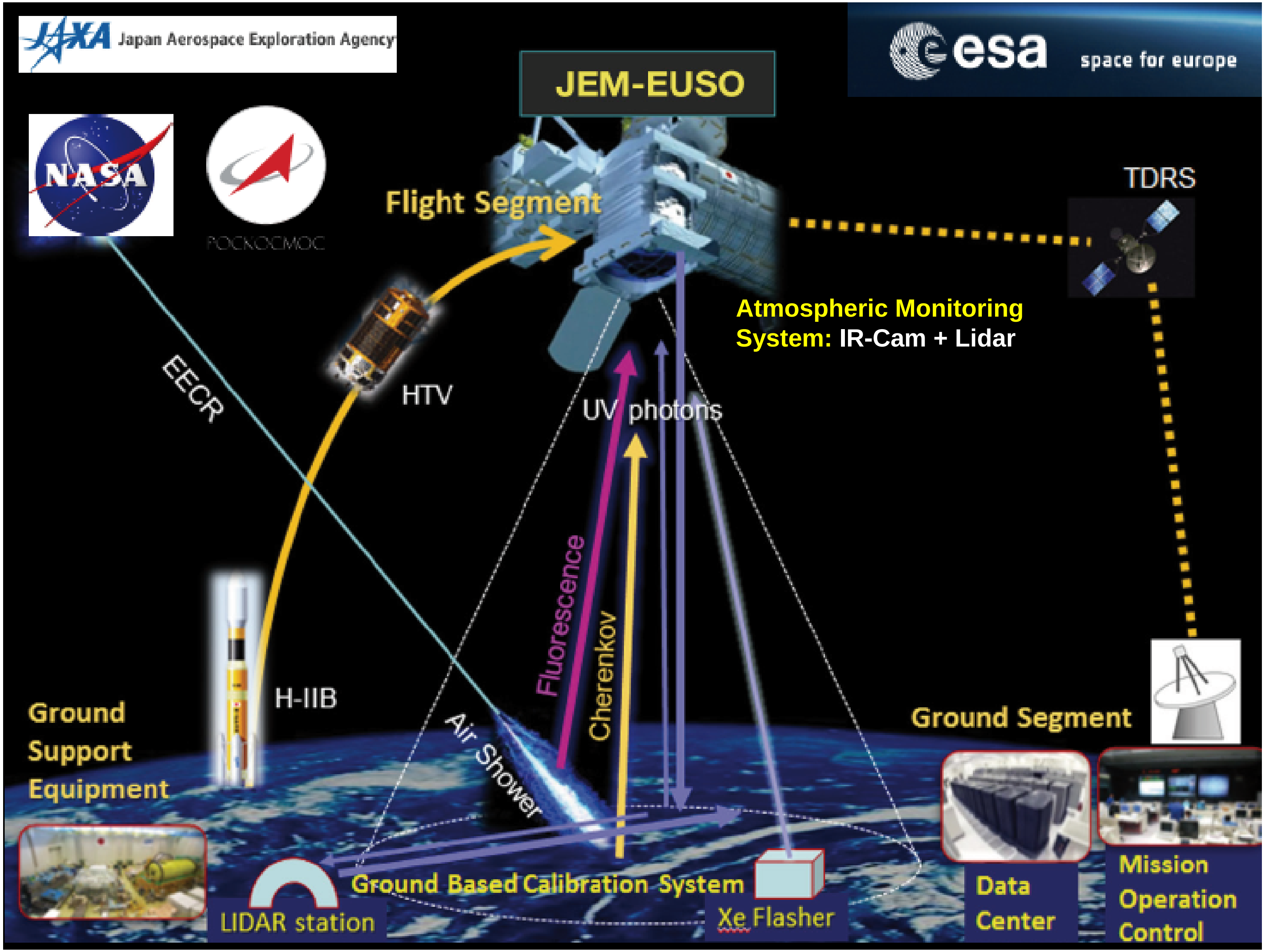
- in-flight calibration
- absolute, homogenous light source needed
- illumination of whole focal surface
- optics + detector calibration
- applied during day (lid closed, every 45 mins)

technical aspects (examples) : DAQ



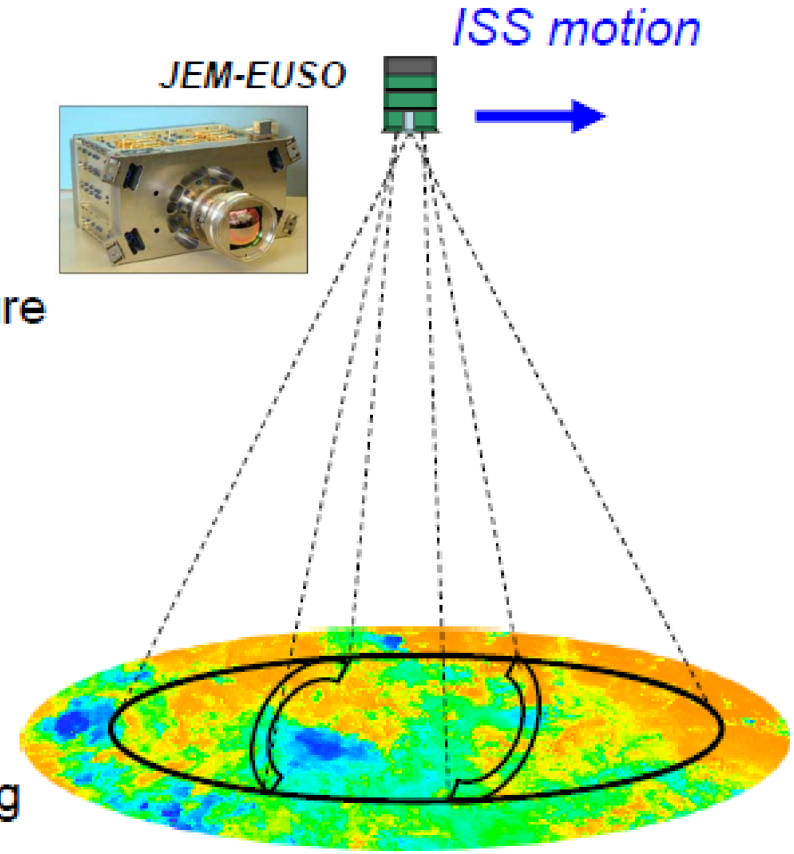
JEM-EUSO mock-up model

JEM-EUSO: the full machine



technical aspects (examples) : Atmospheric Monitoring

Atmospheric Monitoring System



- **IR Camera**

  Imaging observation of cloud temperature inside FOV of JEM-EUSO

- **Lidar**

  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)

Main Physics Program

Main scientific objectives

- Measurement of Ultra-high energy Cosmic Rays

➔ Astronomy and Astrophysics through the particle channel

= Physics and Astrophysics at $E > 5.\times10^{19}$eV

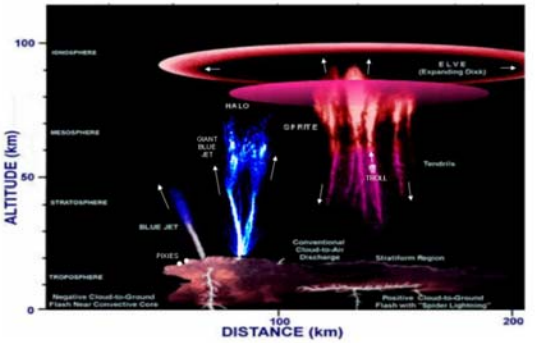
Exploratory scientific objectives

- Exploratory Objectives: new messengers
  - Discovery of UHE neutrinos
    discrimination and identification via X_0 and X_{max}
  - Discovery of UHE Gammas
    discrimination of X_{max} due to geomagnetic and LPM effect

- Exploratory Objectives: magnetic fields

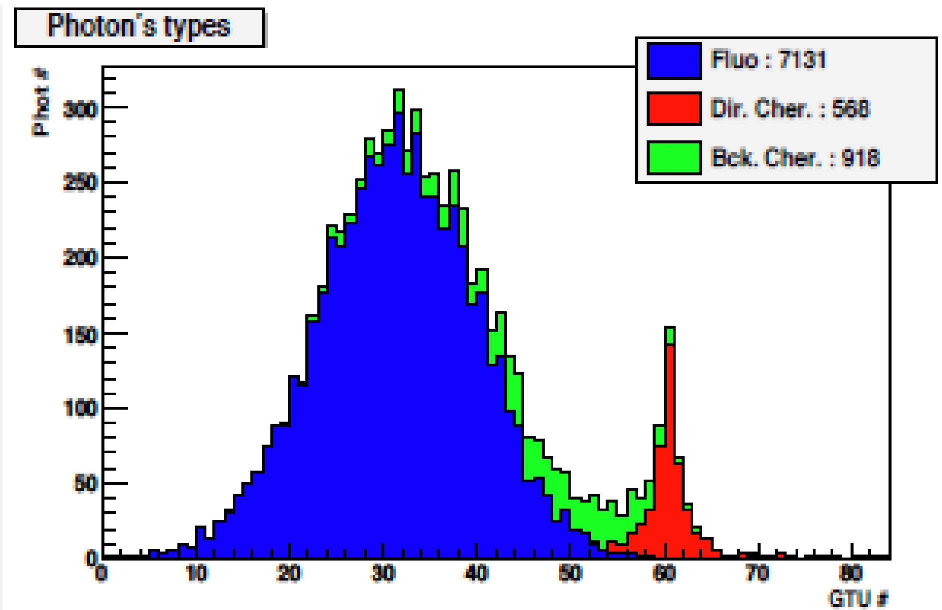
- Exploratory Objectives: Atmospheric science
  - Nightglow
  - Transient luminous events
  - Space-atmosphere interactions
  - climate change

  ← with the fast UV monitoring of the Atmosphere



(Elaboration of figure by Lyons et al. 2000)

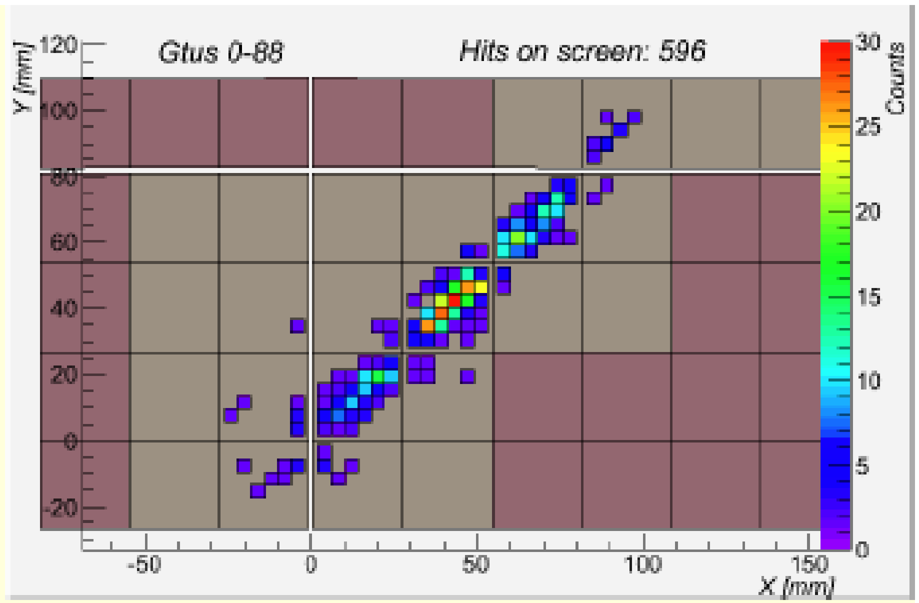
The observation technique



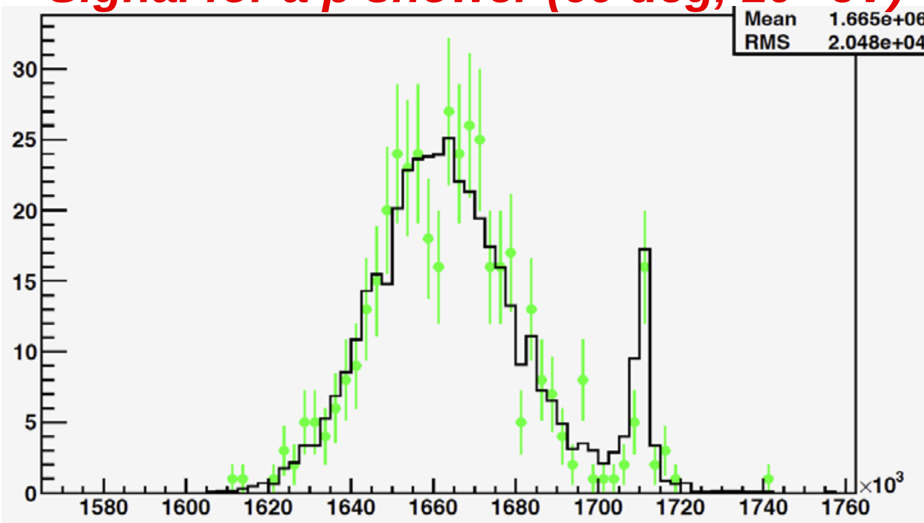
1 GTU = 2.5µs

Background = 500 ph / m^2 sr ns (from Tatiana satellite)

Fast signal: ~50-150µs



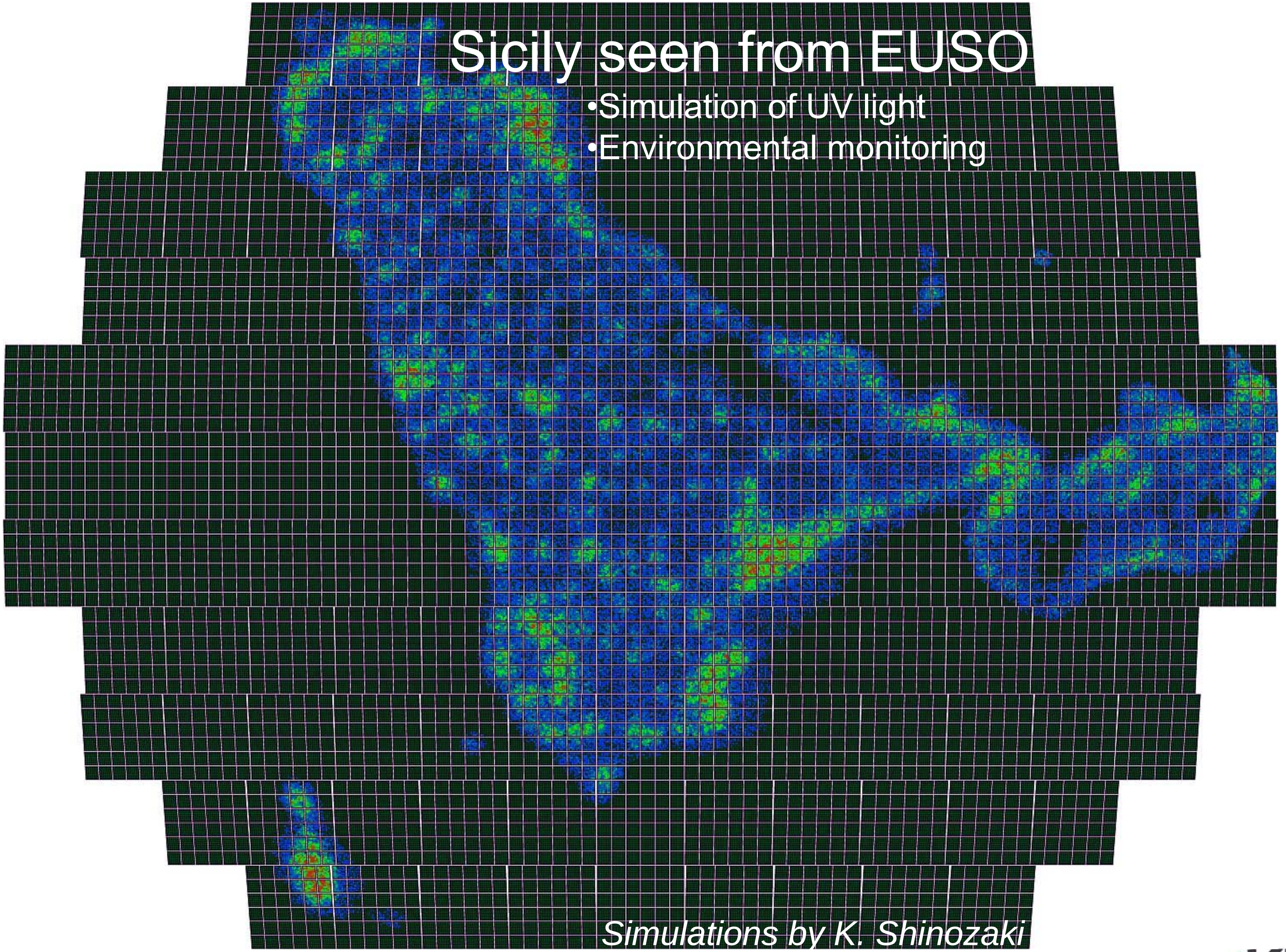
Signal for a p shower (60 deg, 10^{20}eV)



ΔE/E < 30% for ~90% of events

Sicily seen from EUSO

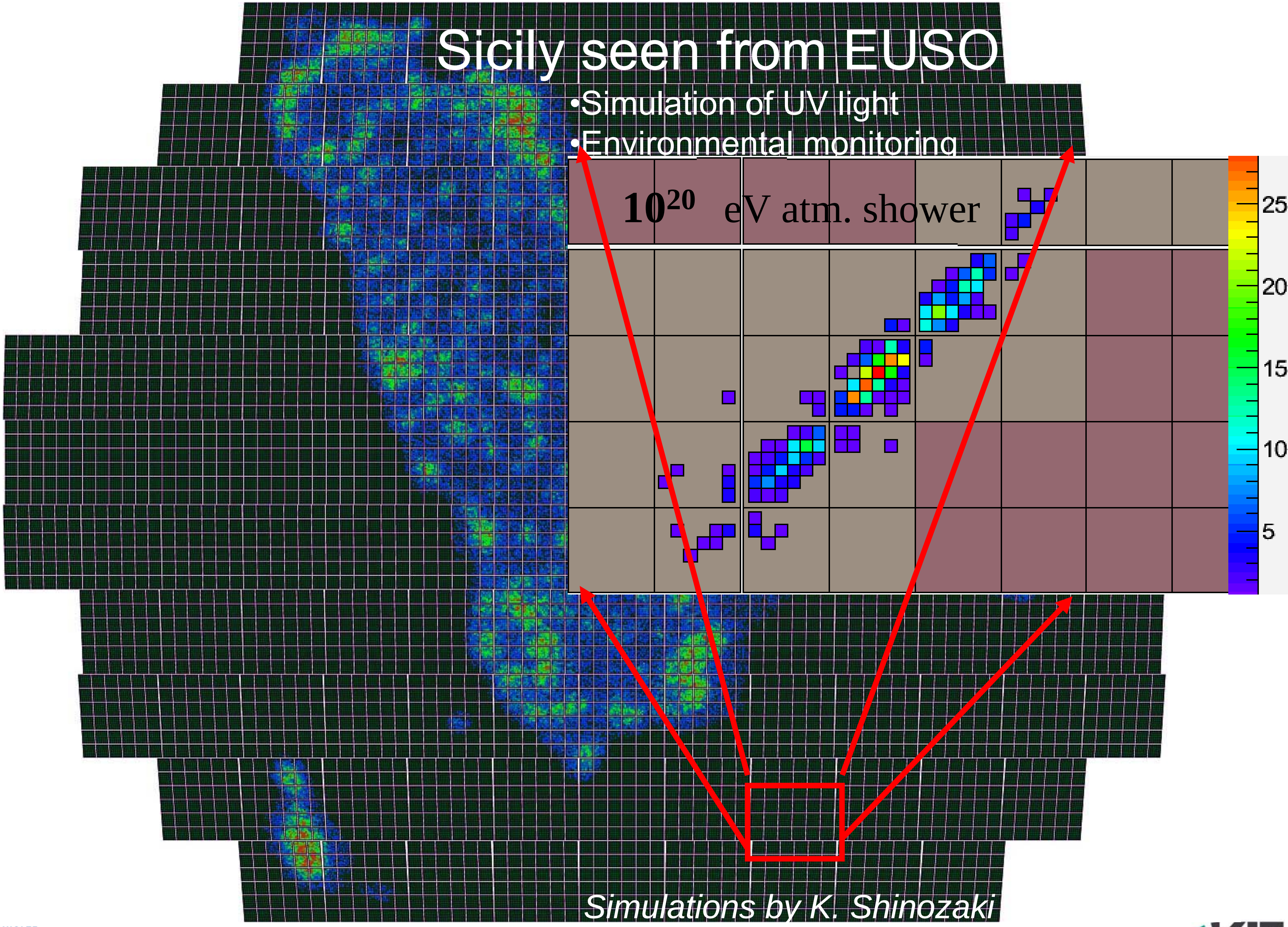
- Simulation of UV light
- Environmental monitoring



Simulations by K. Shinozaki

Sicily seen from EUSO

- Simulation of UV light
- Environmental monitoring



Simulations by K. Shinozaki

JEM-EUSO Performance: Annual Exposure

Depends on zenith angle and energy …

and is determined by four factors:

$$TA \times \eta \times k \times l$$

$$TA \rightarrow Trigger\ Aperture$$

Determined by the trigger efficiency

$$\eta \rightarrow duty\ cycle$$

Determined by the background (and operation)

$$\kappa \rightarrow cloud\ impact$$

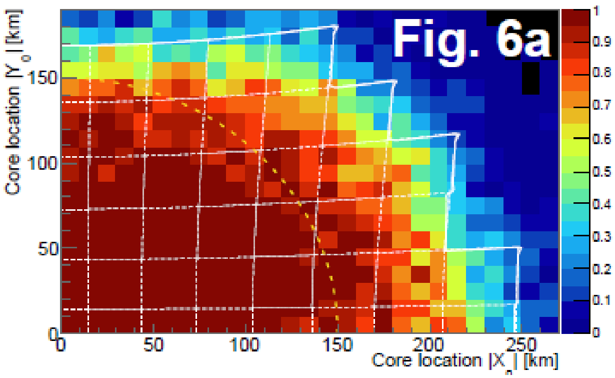
Determined by the cloud coverage

$$l \rightarrow citylights\ \&\ lightnings$$

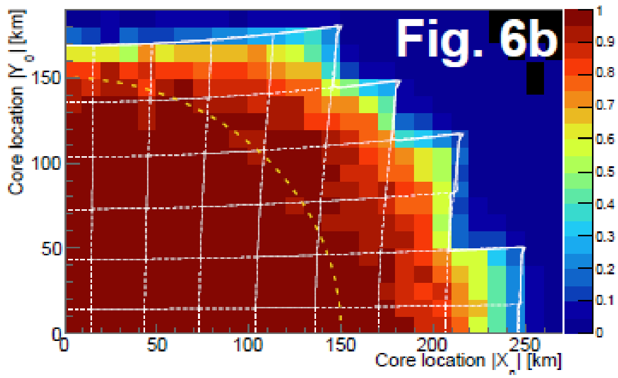
Local effects which limit the aperture

JEM-EUSO Performance: Efficiency

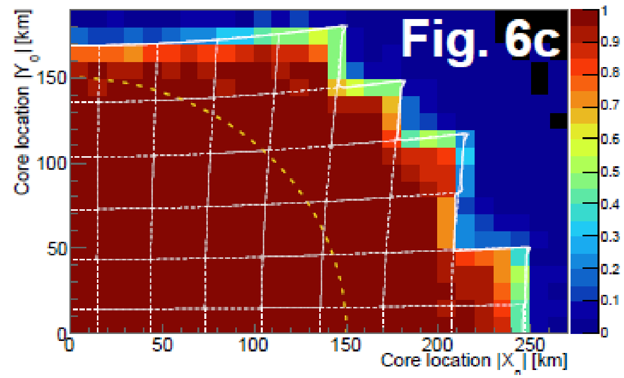
$E > 4 \cdot 10^{19}$eV; $\Theta > 60^o$

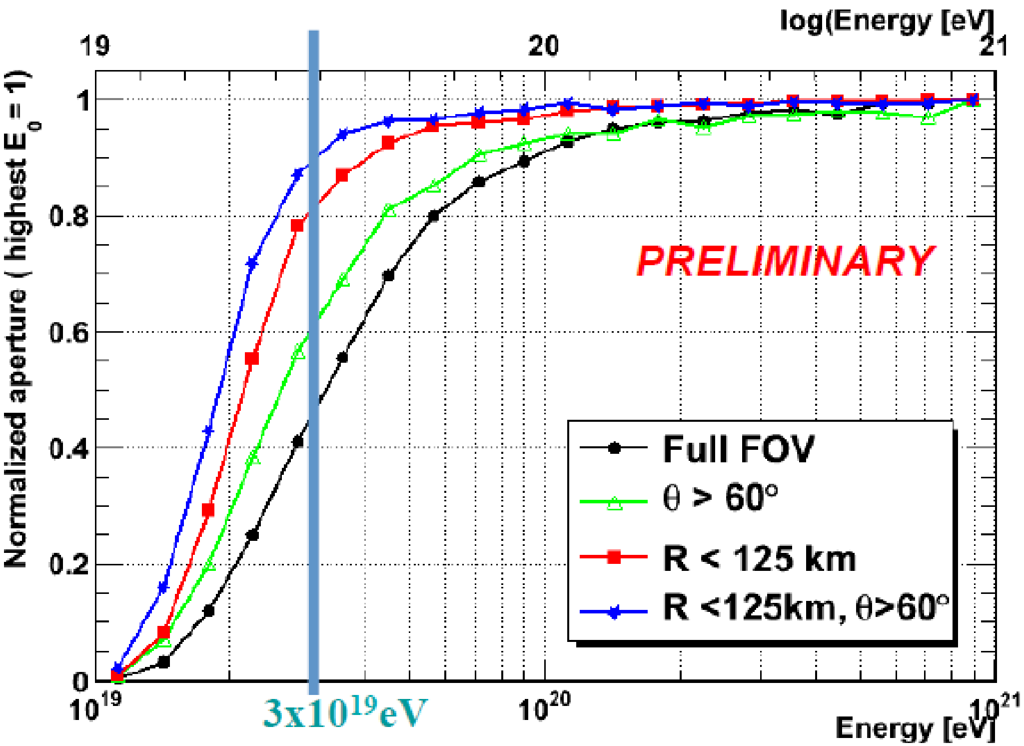


$E > 5.5 \cdot 10^{19}$eV



$E > 10^{20}$eV



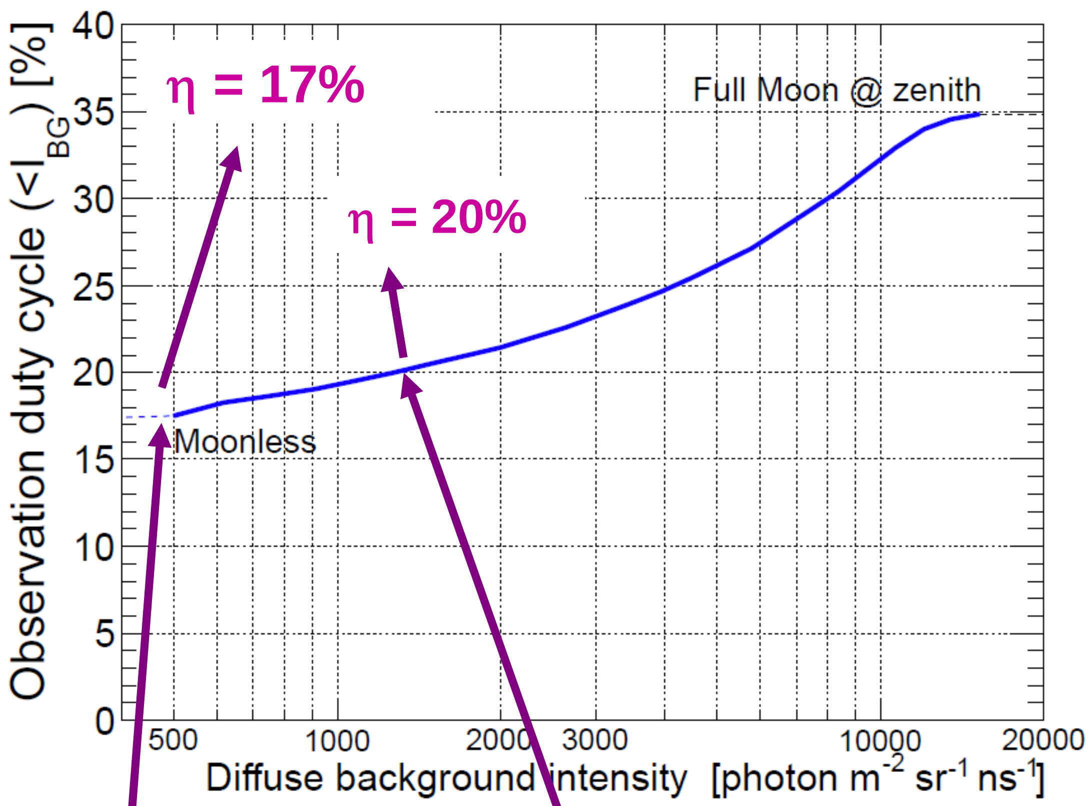


Trigger Efficiency

- 100% at $E = 4 \cdot 10^{19}$eV when $\Theta > 60^o$ and R < 150 m
- 90% at $E = 10^{20}$eV when full FoV

Including bg = 500 ph / m² sr ns (Tatiana satellite)

JEM-EUSO Performance: duty cycle



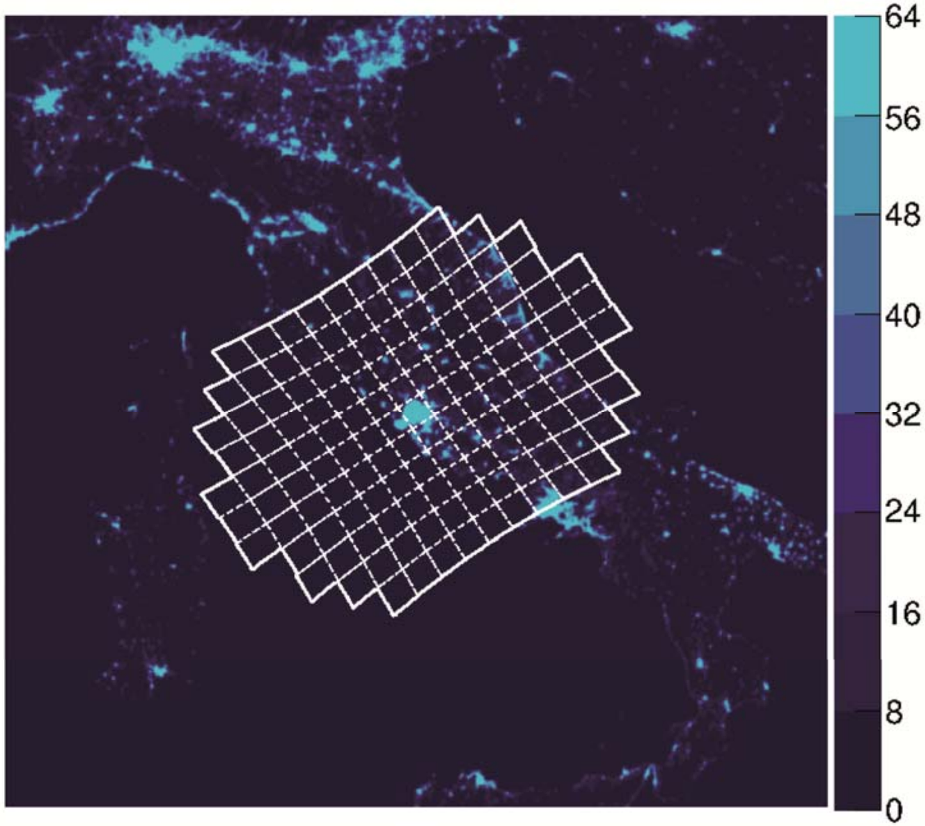
acceptable moon background:
1500 ph / m² sr ns

Night glow background:
500 ph / m² sr ns

Duty Cycle

- **No moon: ~17%**
- **Accepting little moon light: ~20.5%**
  (from analytical calculations)

JEM-EUSO Performance: city lights & lightnings



CITY LIGHTS:

~ 7% (DMSP data)

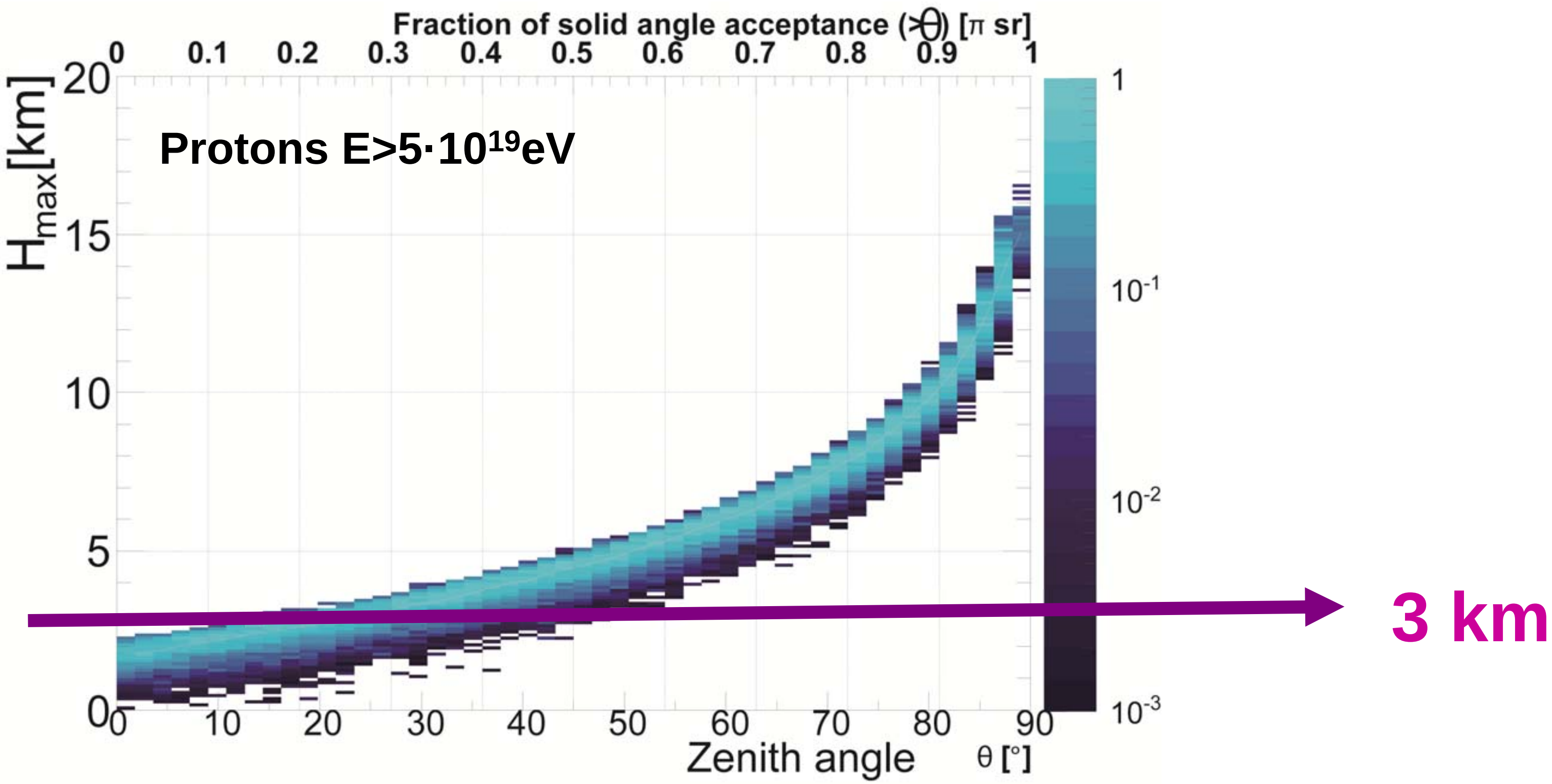
LIGHTNINGS:

~ 2% (Tatiana data)

➔ l = 91%

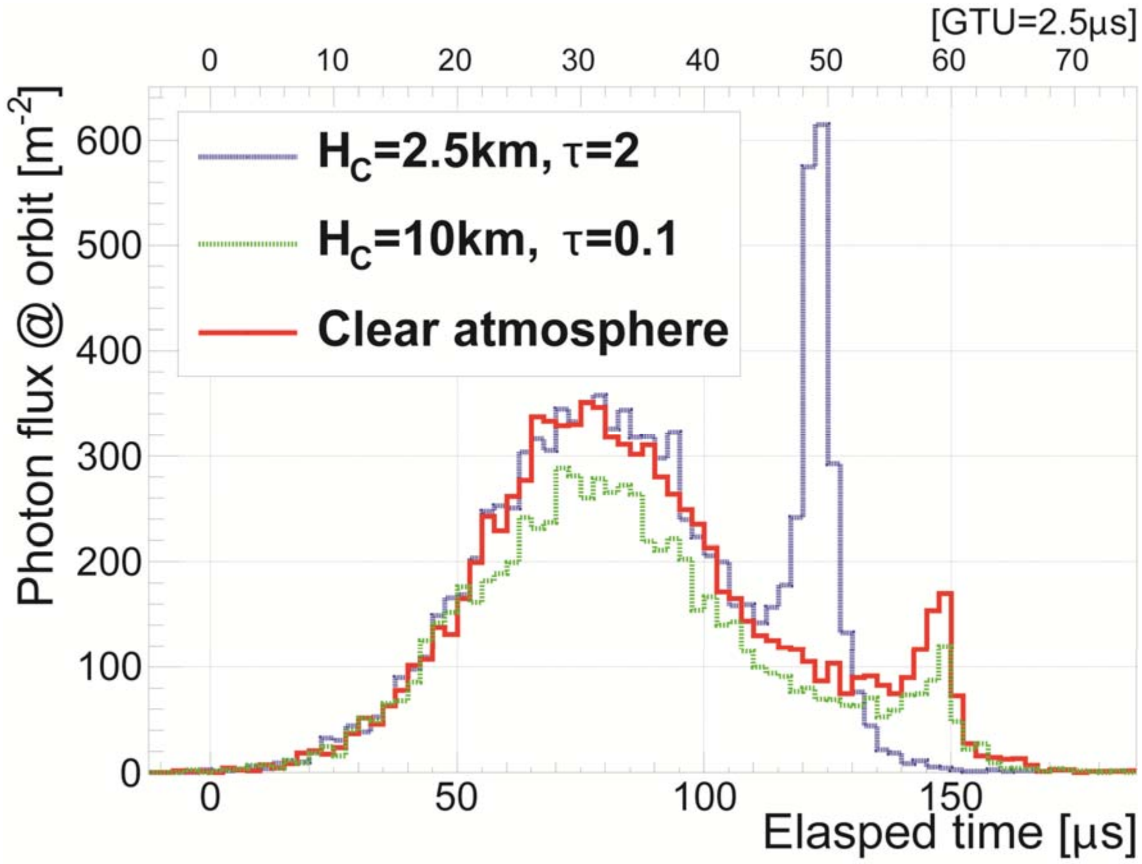
$$l \rightarrow citylights \,\&\, lightnings$$

JEM-EUSO Performance: cloud impact



➔ Most EAS relevant for JEM-EUSO reach maximum above the typical cloud altitudes!

JEM-EUSO Performance: reconstruction with clouds



- **shower profiles are attenuated for optically thin clouds (eg. cirri).**
- **optically thick clouds (eg. strati) block photons emitted below cloud**
- **cloud reflected Cherenkov light improves the reconstruction**

JEM-EUSO Performance: cloud coverage

Clear sky ~ 31%
Green band ~ 60%

Cloud top

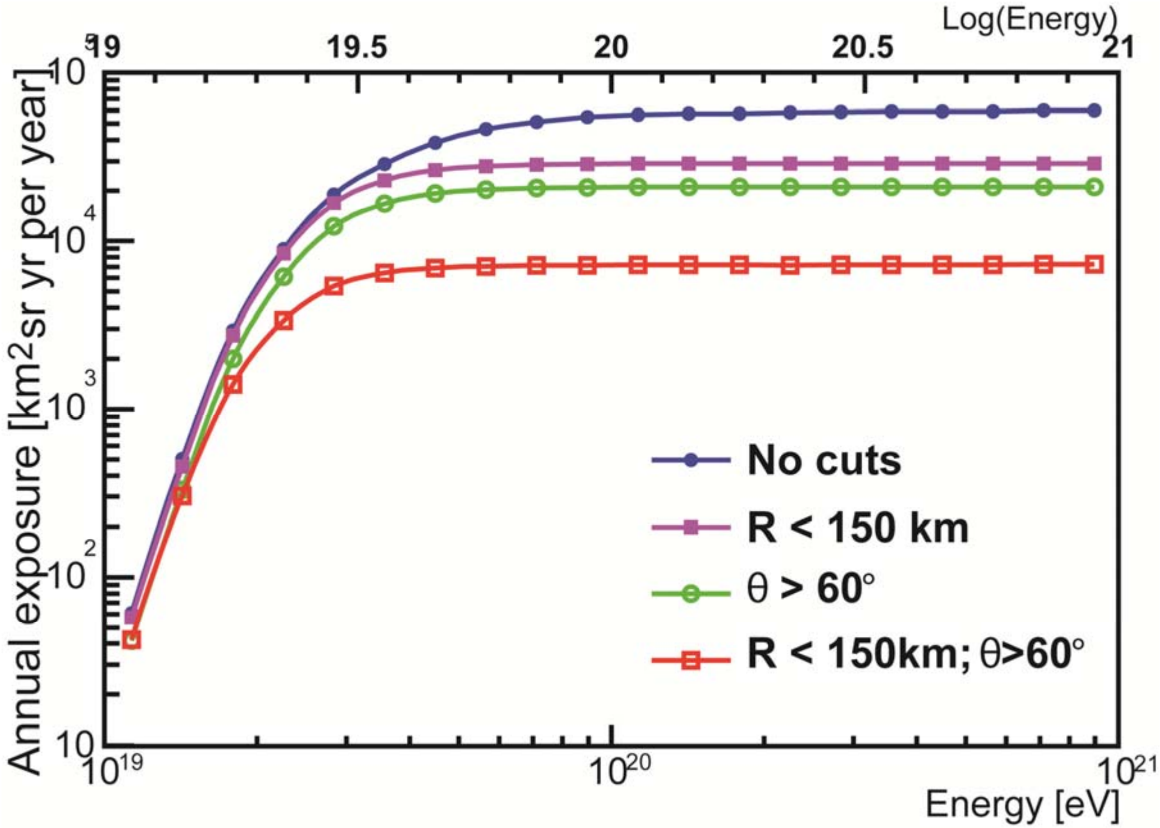
Optical Depth

	<3.2 km	3.2-6.5 km	6.5-10 km	>10 km
OD>2	16	5.9	8.6	5.0
OD:1-2	6.0	3.0	4.2	2.5
OD:0.1-1	6.5	2.0	3.2	5.0
OD<0.1	31	<0.1	<0.1	1.2

- **Occurrence of clouds (in %) between 50° N and 50° S on TOVS database (Confirmed by ISCCP,CACOLO & MERIS database)**

➔ In ~72% of the cases the UV track including X_{max} is observable

JEM-EUSO Exposure (…Nadir mode)



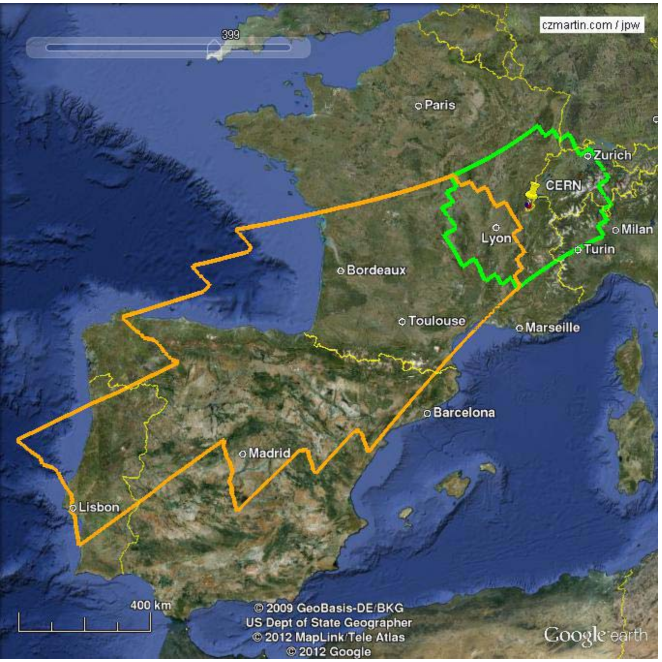
60,000 km²sr yr

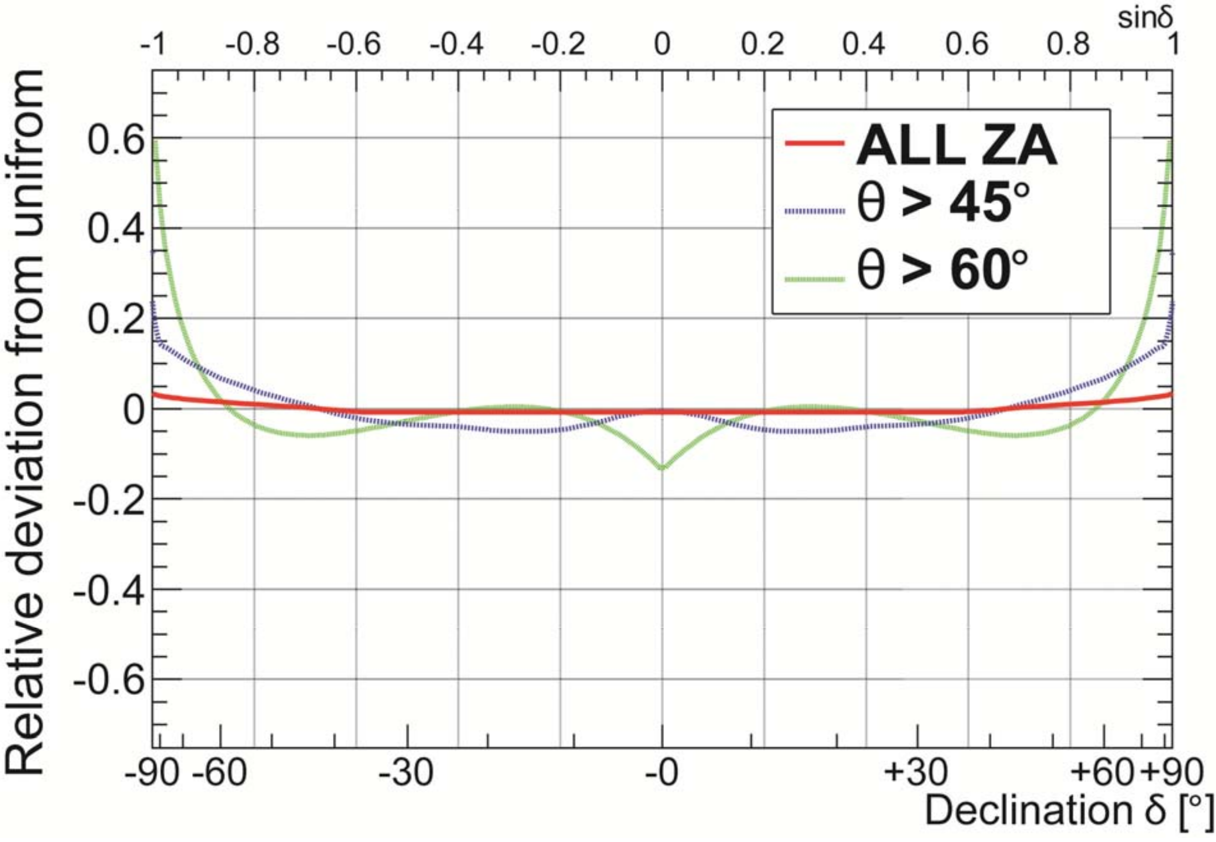
7,000 km²sr yr

$$TA \times \eta \times k \times l$$

- With tight geometrical cuts a direct comparison with ground-based observatories possible
- full FOV provides about one order higher exposure than Auger at higher energies
- When accepting higher BG level improvements possible

JEM-EUSO: aperture





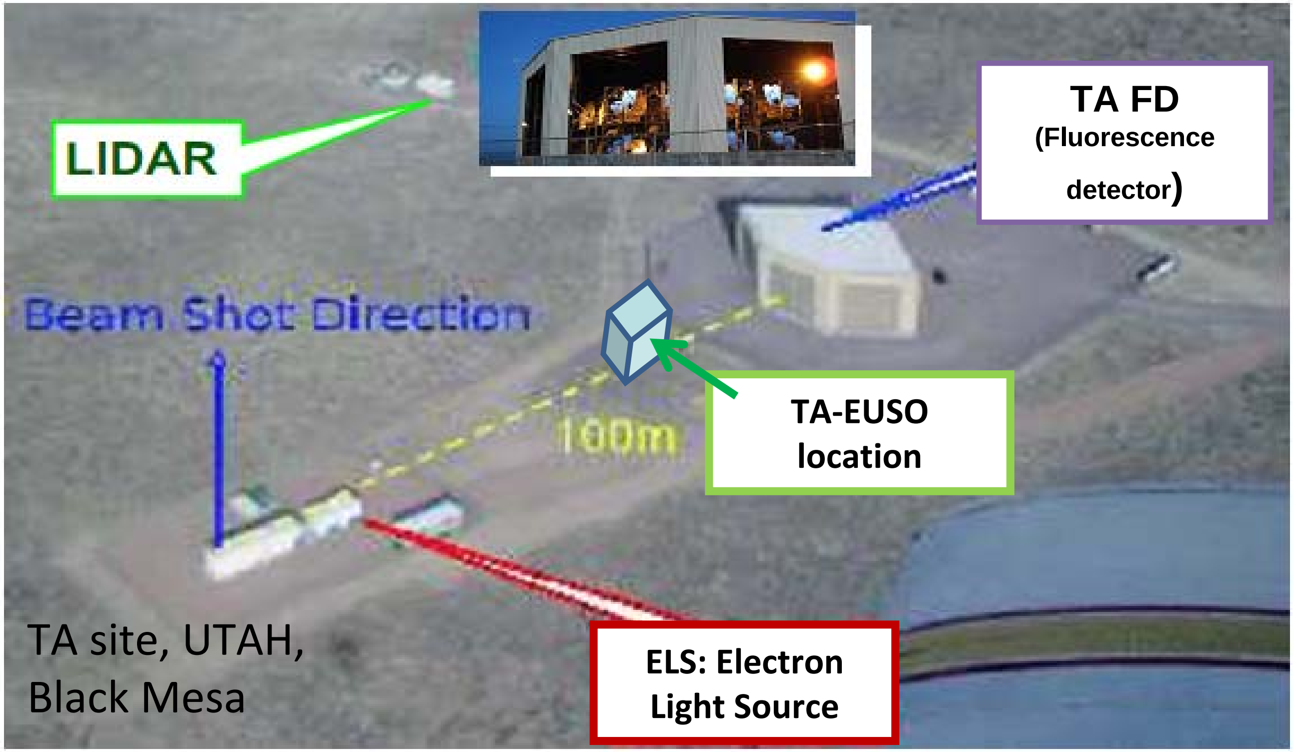
- **Uniform coverage of both hemispheres!**

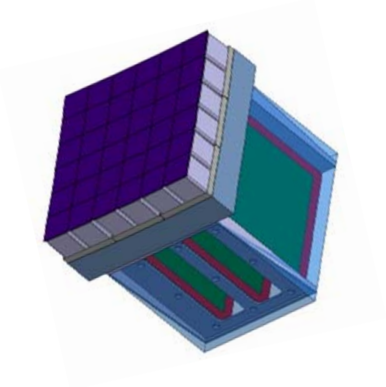
TA-EUSO
Cross-calibration tests at Telescope Array site, Utah

<u>Main purpose: calibration using existing FD telescope</u>

- **Lidar and electron beam ➔ absolute calibration**
- **Few showers in coincidence with TA**
- **Later repeat also at the Pierre Auger Observatory**

Operation early 2013!



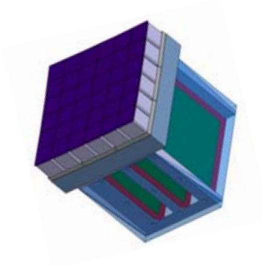


EUSO-Balloon
JEM-EUSO prototype at 40km altitude

Main purpose: Background measurements and engineering tests

- **Engineering test**
- **UV-Background measurement**
- **Air shower observations from 40 km altitude**

First flight: 2014!



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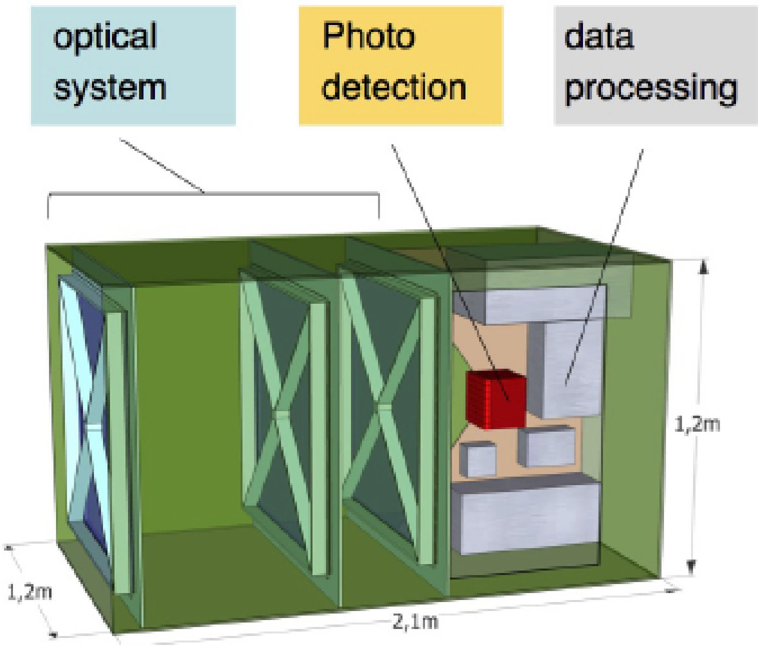
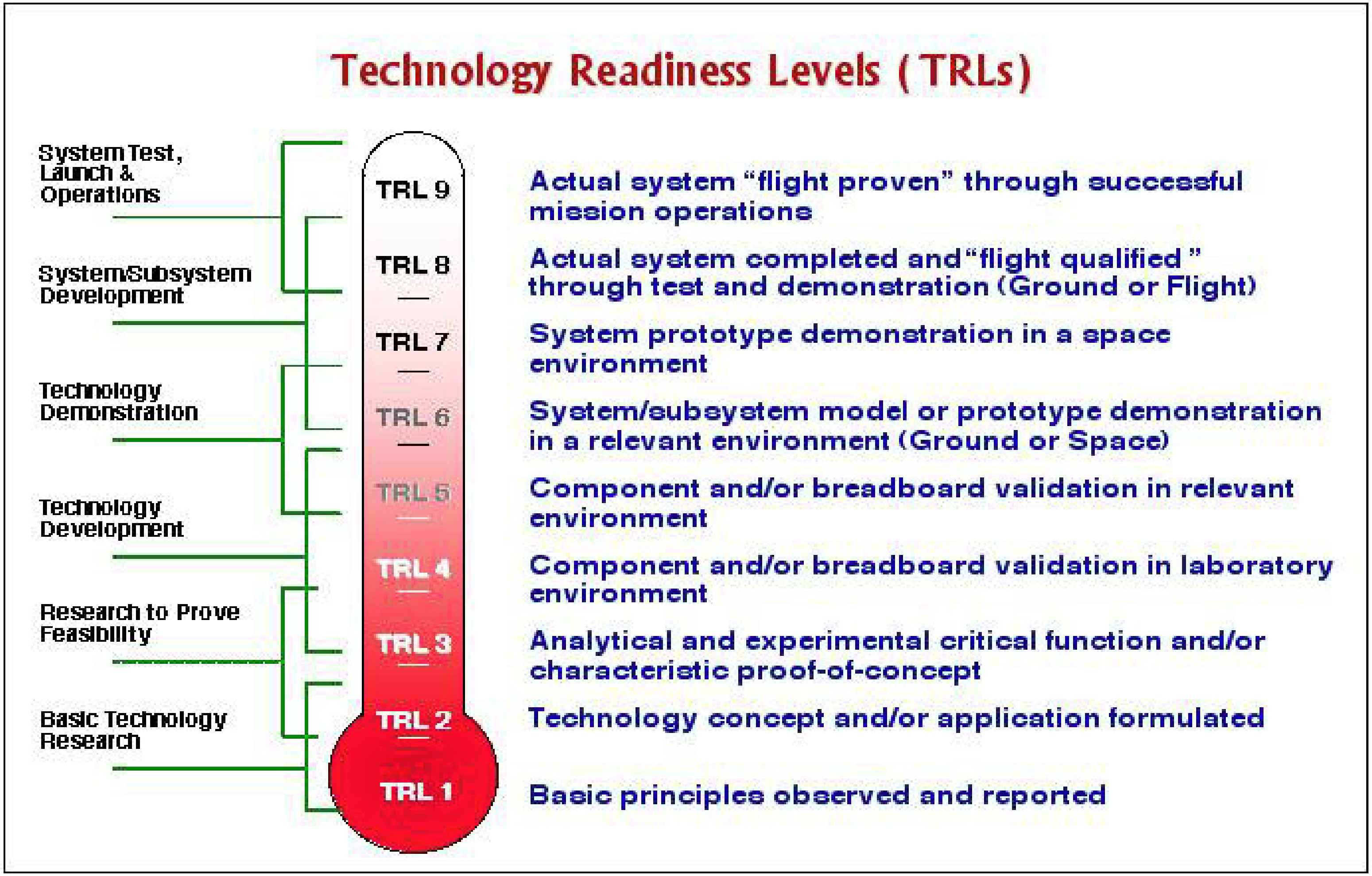
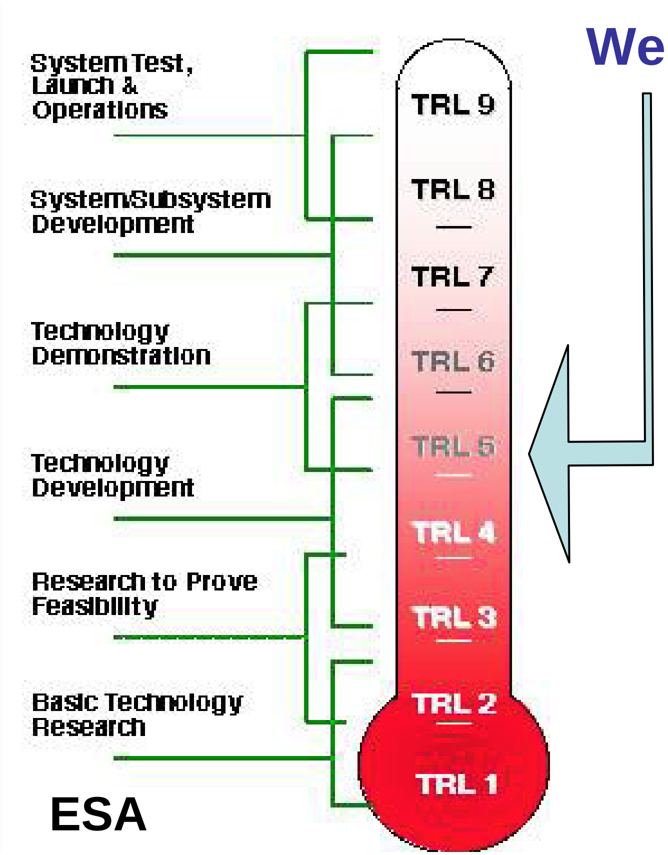


Technical Readiness Level (TRL) – scheme of space agencies



ESA

Technical Readiness Level (TRL) – scheme of space agencies



We are here!!

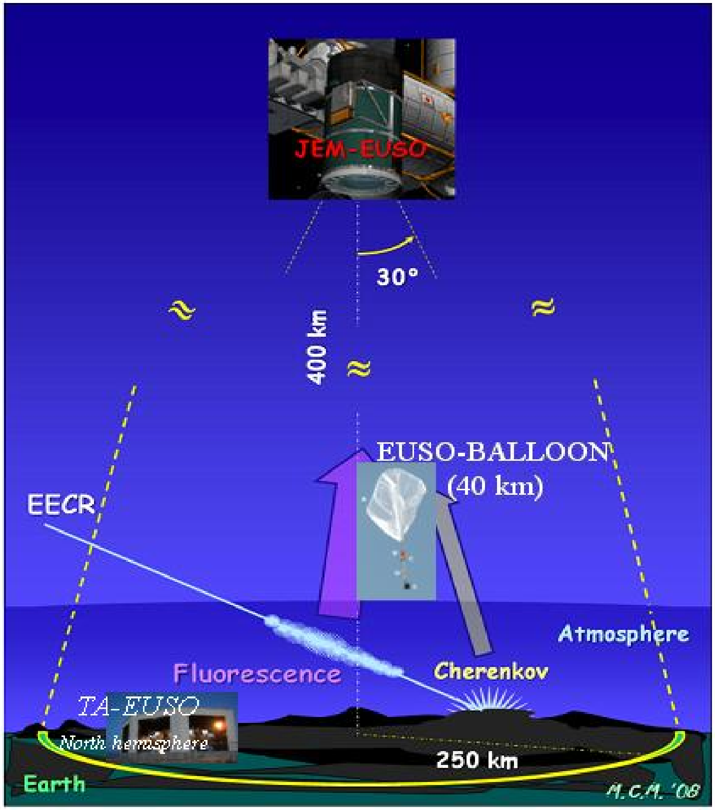
(successful Balloon flights will be TRL5)

space challenge is given by

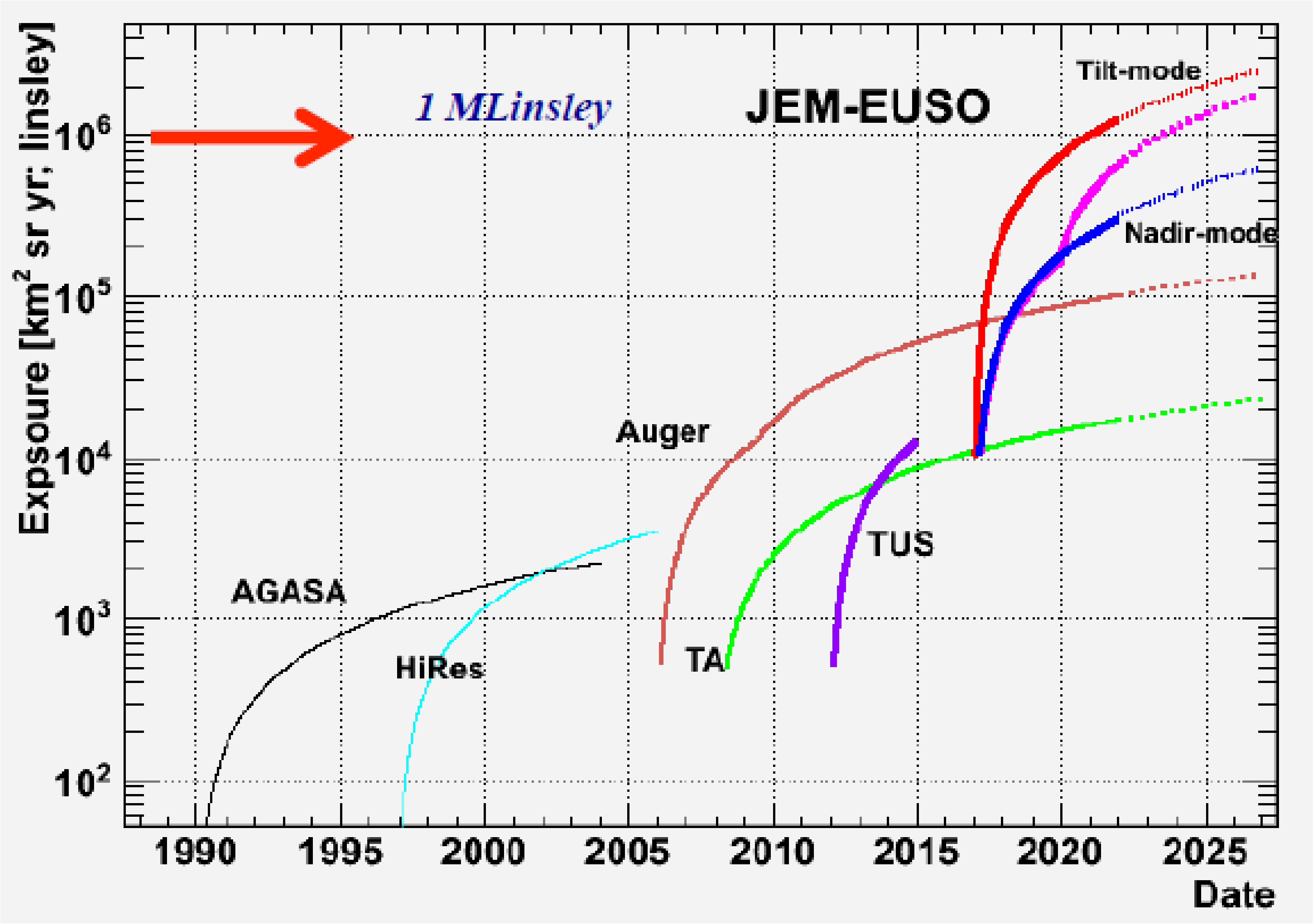
- **a) severe thermal constrains (heat flow through radiation)**
- **b) severe vibration constrains (due to launch and re-enter)**
- **c) radiation hardness issue**
- **d) power limitations**
- **e) ITAR free elements**
- **f) safety issues related to the use on the ISS**

JEM-EUSO

- **Study of EECR from**
  - **Ground (Utah) → early 2013**
  - **Balloon (40 km) → 2014-15**
  - **Space (ISS) → launch 2017**



- **(Advanced) Technologies**
  - **Electronics: large amount on boards, have to be small, have to meet space requirements**
  - **Very tight schedule**


1 MLinsley
JEM-EUSO
Tilt-mode
Nadir-mode
Auger
TUS
AGASA
HiRes
TA
Exposure [km^2 sr yr; linsley]
10^6
10^5
10^4
10^3
10^2
1990
1995
2000
2005
2010
2015
2020
2025
Date