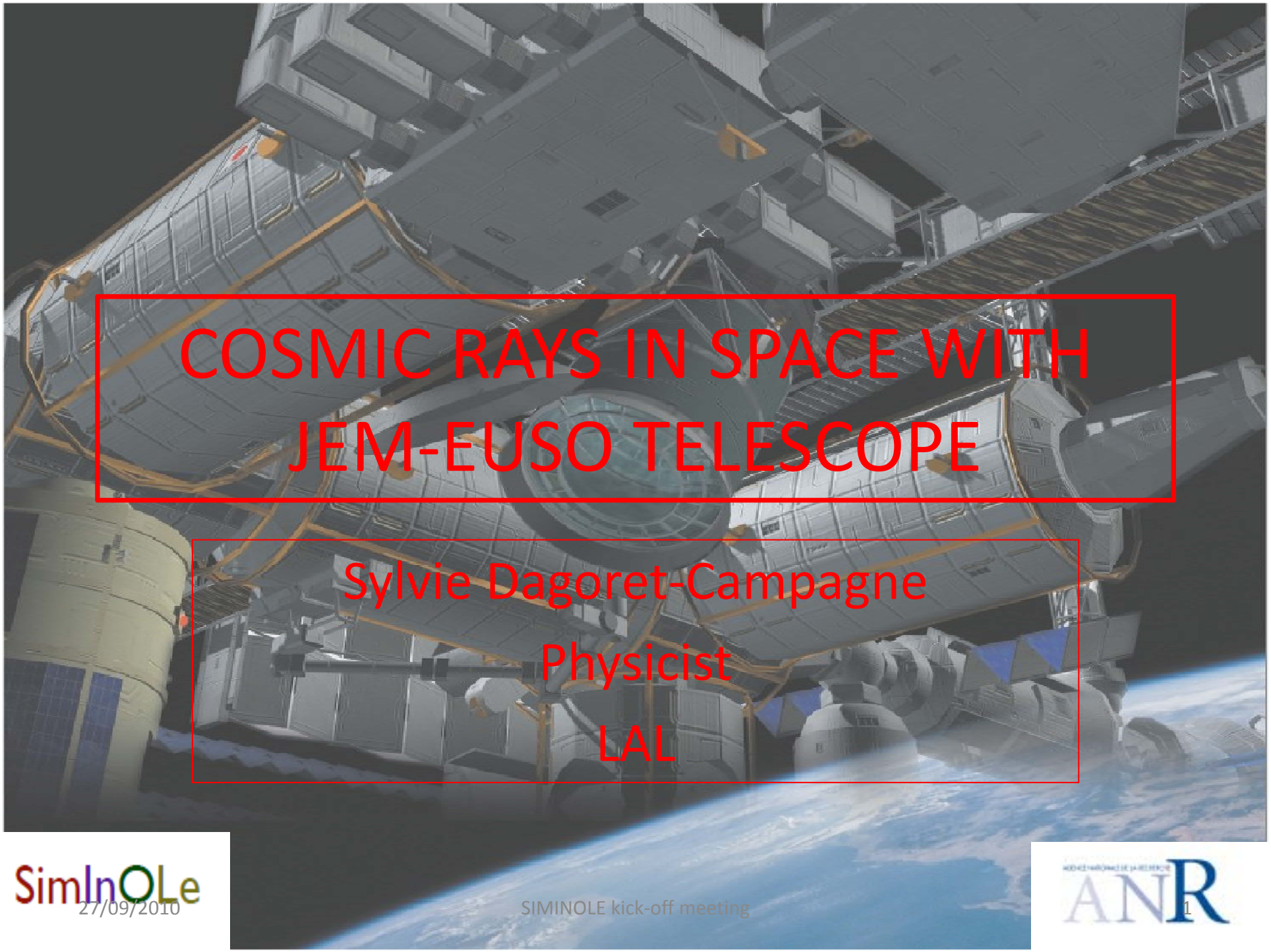
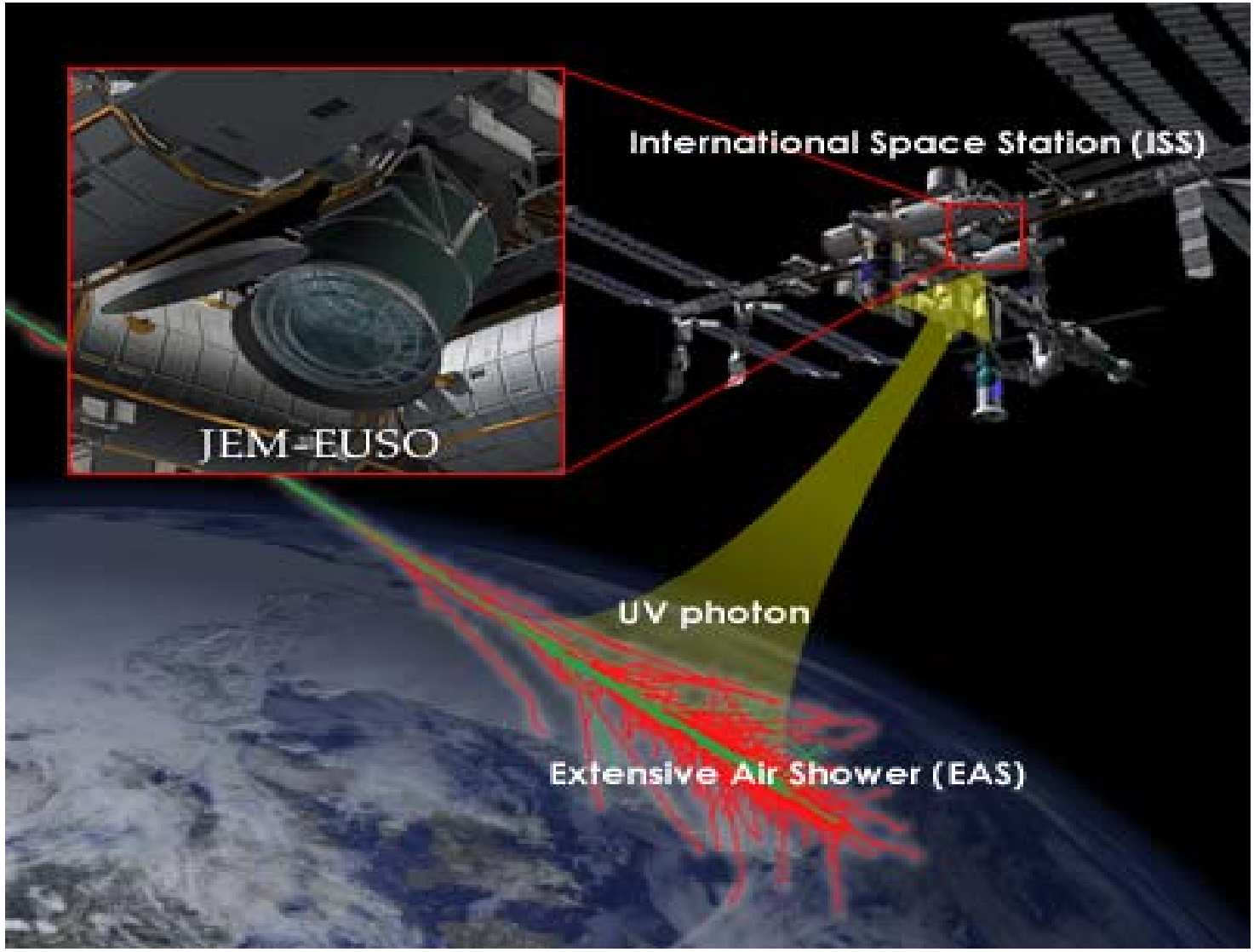


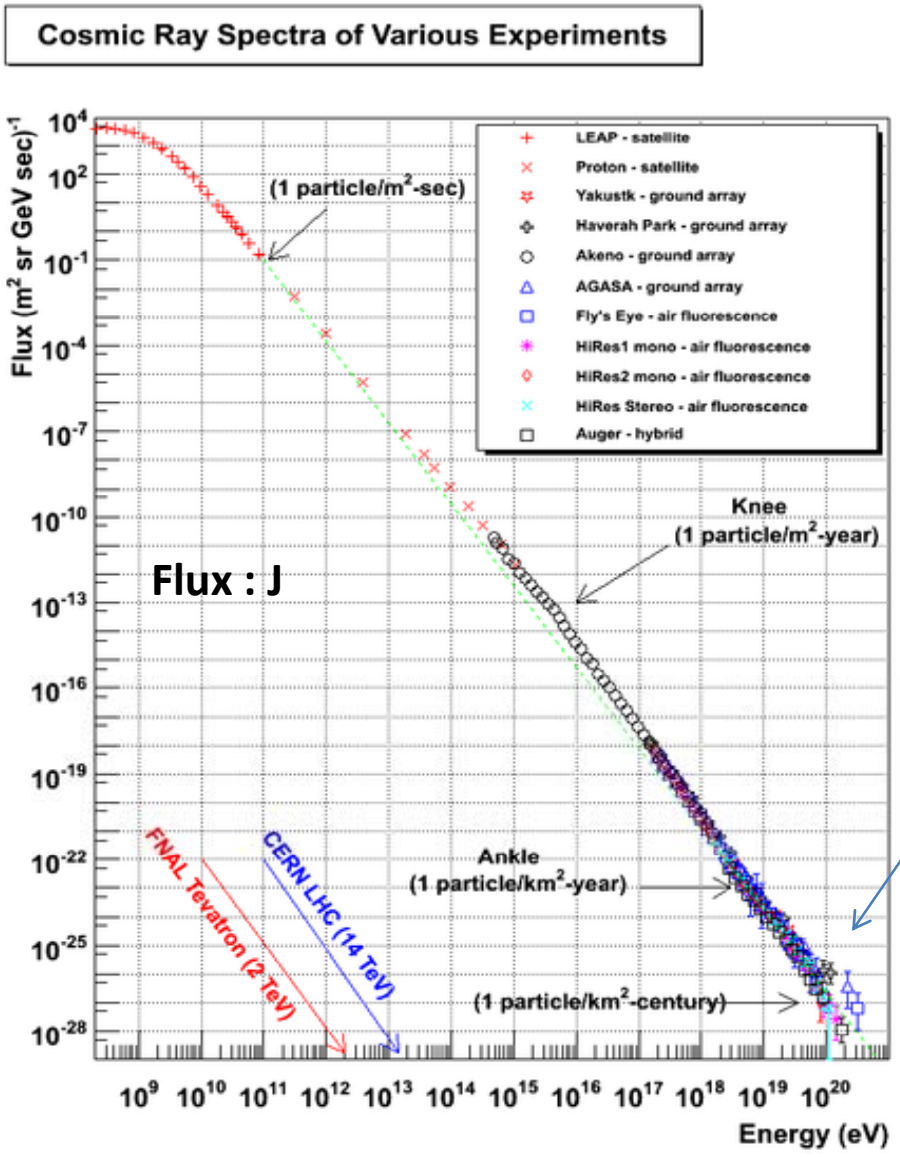
# COSMIC RAYS IN SPACE WITH JEM-EUSO TELESCOPE

Sylvie Dagoret-Campagne
Physicist
LAL

# The physics Theme

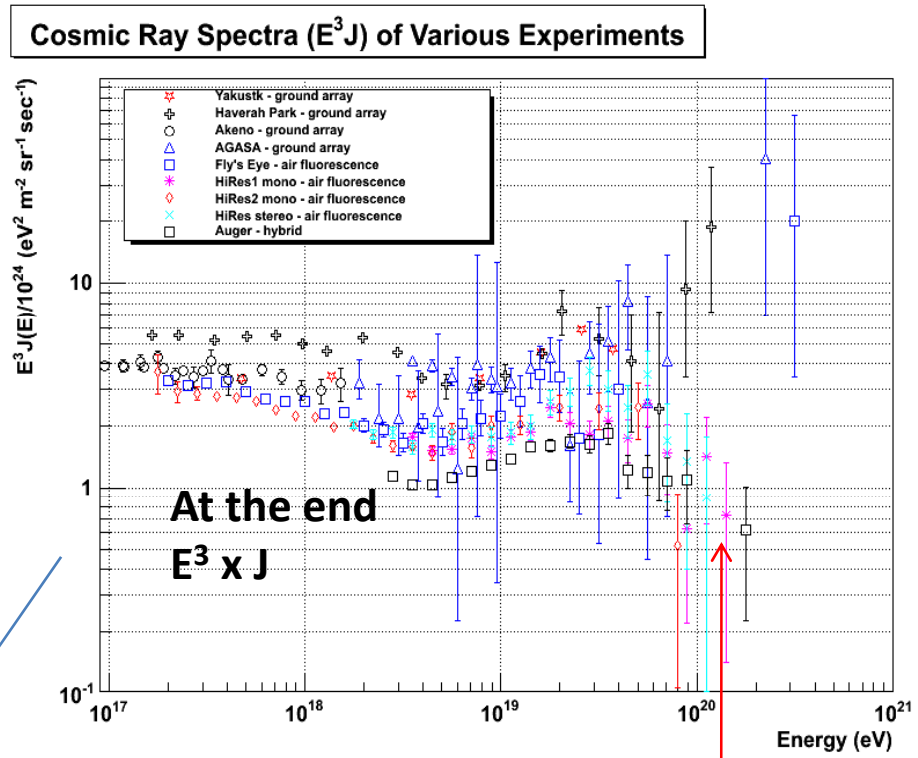


# SCIENTIFIC KNOWLEDGE ON COSMIC RAYS



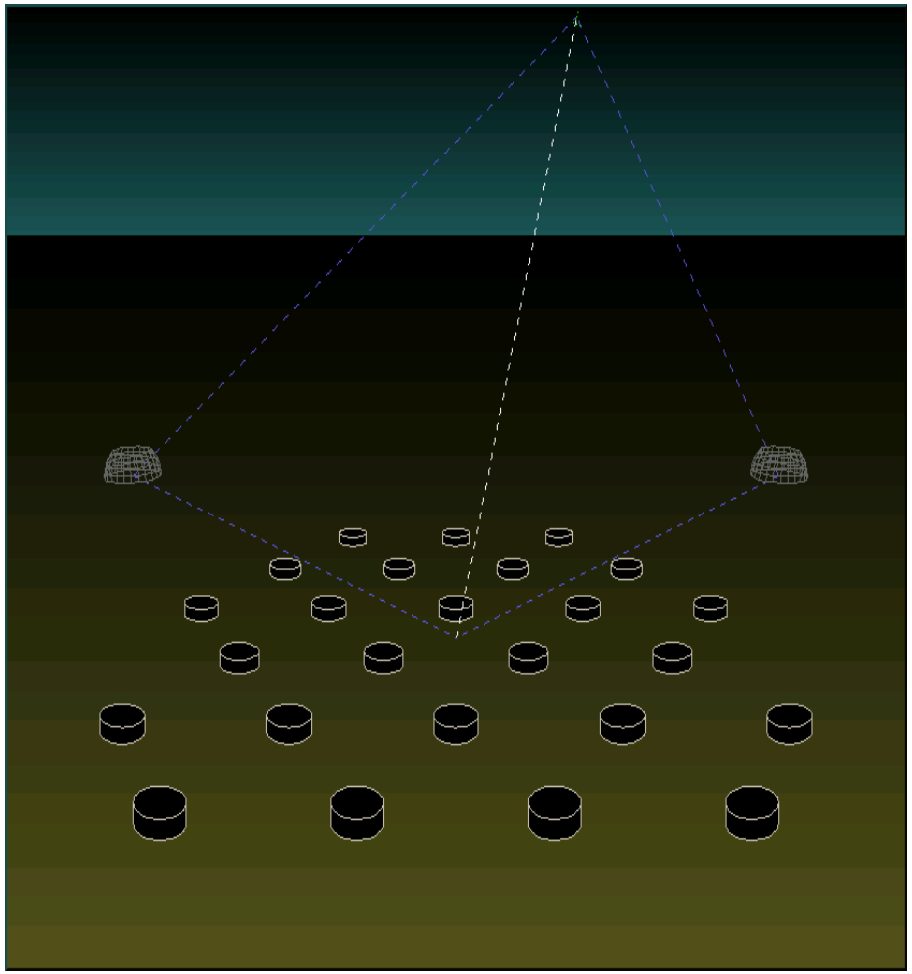

## End of Spectrum measurement

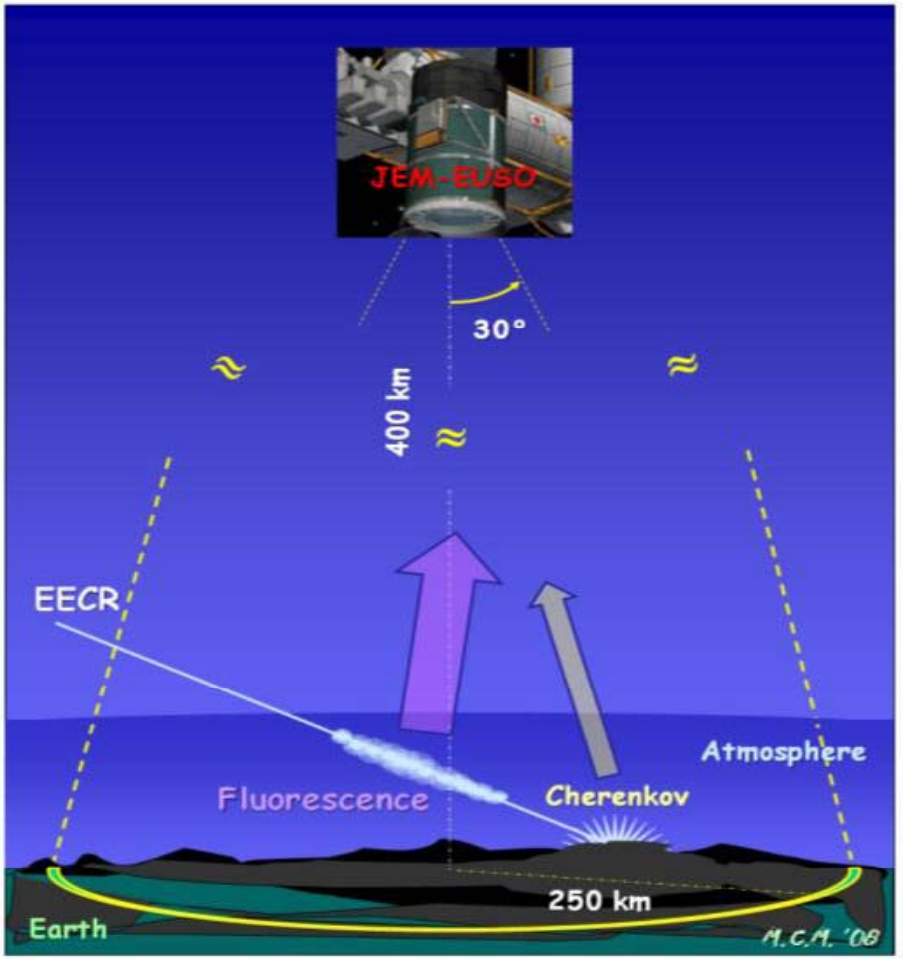
(J : defined by nb of CR per surface, solid angle, time,energy unit )




**Cutoff « GZK»**
**Main physical interest**

# Why Going in Space : the size of the observatory






**P. Auger Observatory at ground: Surface of 3000 km$^2$**

**JEM-EUSO in Space : Surface 5.2 10$^5$ – 1.2 10$^6$ km$^2$**

# Lower priority physics : Non cosmic rays studies

Slow phenomena !, large timescale

**Meteor detection** down to the micro-gram

- Bright luminosity in the UV range
- Statistic poorly known at low mass

**Bright atmospheric phenomena-lightning**

- Huge light background
- opportunity to correlate them with CR

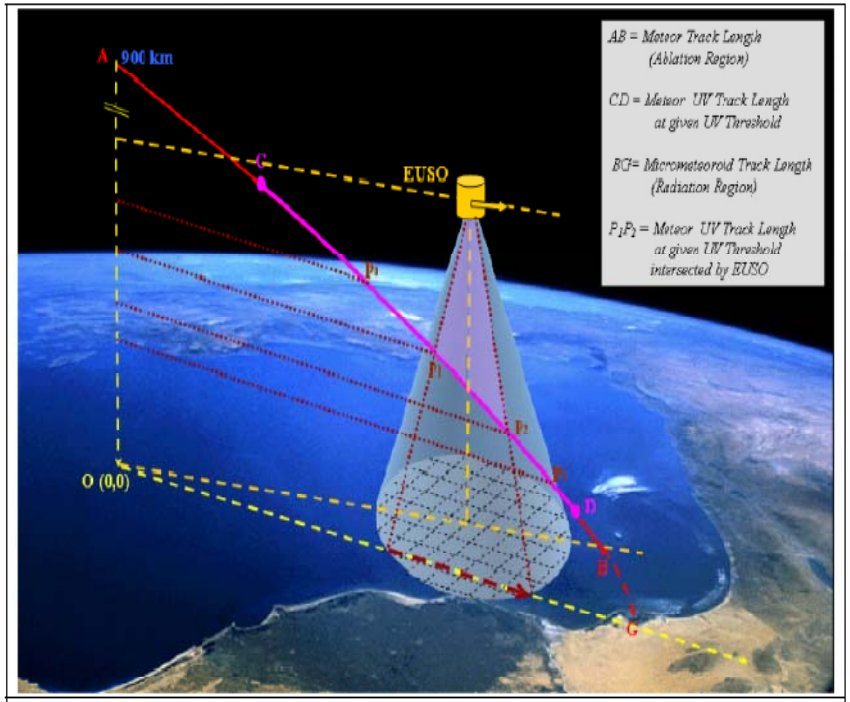
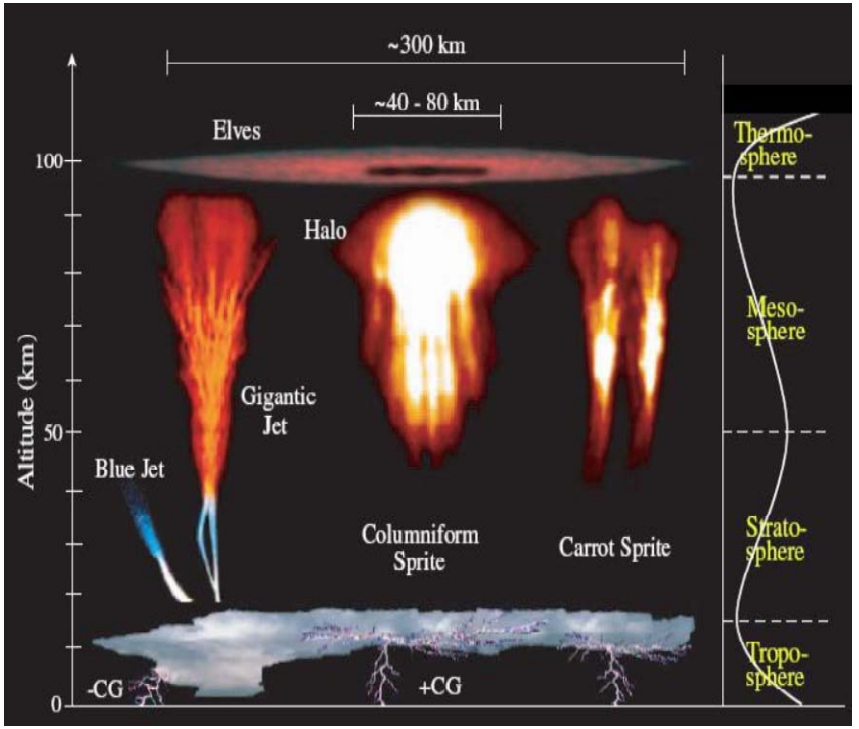



Figure 6.5.8-2 *The path of a meteor in the EUSO FoV*



# The Instrument

Collection surface:

$S_{coll} = 5m^2$ (2m x 2.6m)

Field of View:

FOV ~ ±30° x ±30°

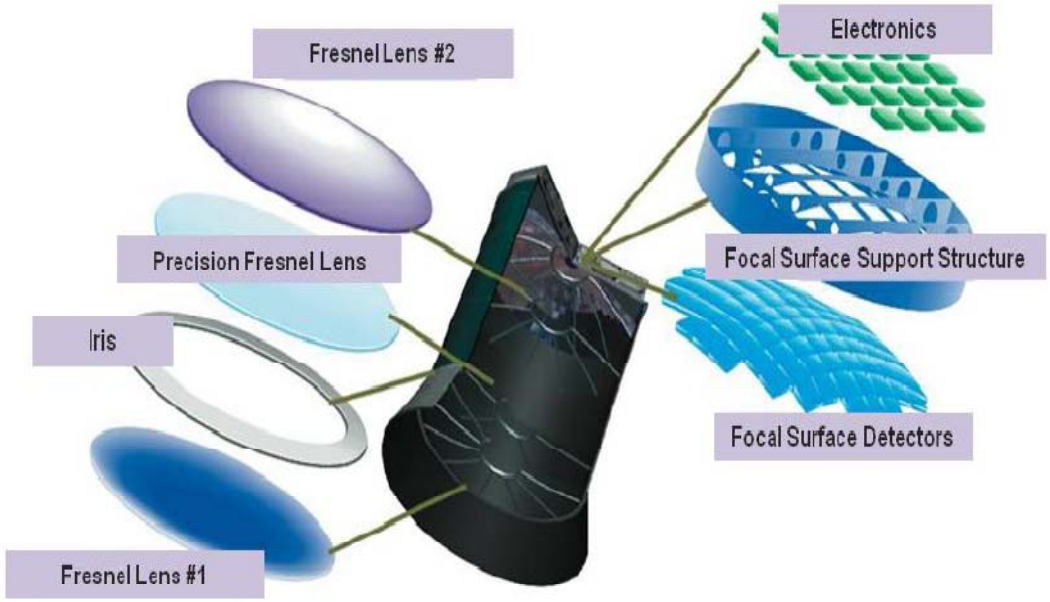
Pixels:

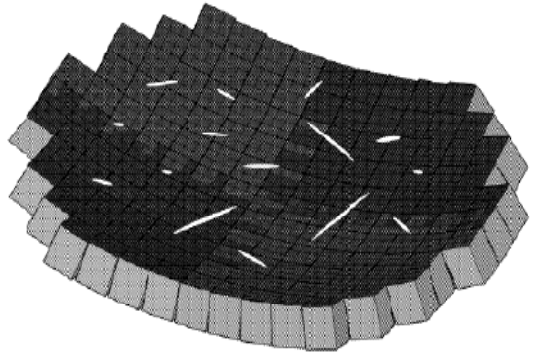
~ $3.5 \times 10^5$ pixels

FOV(pixel) =0.1° (~700 m)

Collection time sampling:

$\tau_{coll}$= 2.5 µs (~700 m)

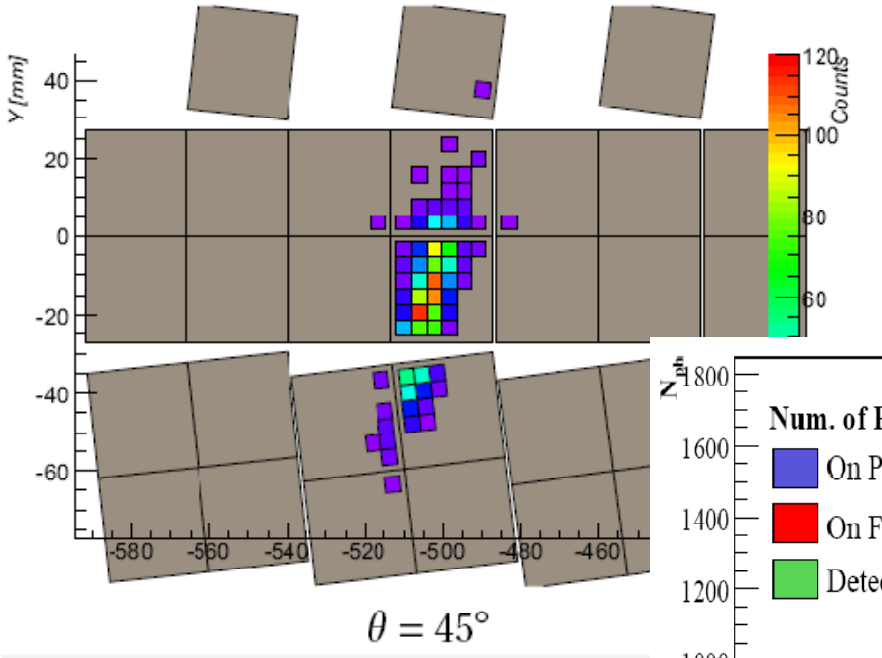


Actual Focal surface shape

# How an Air Shower Event looks like in our detector ?

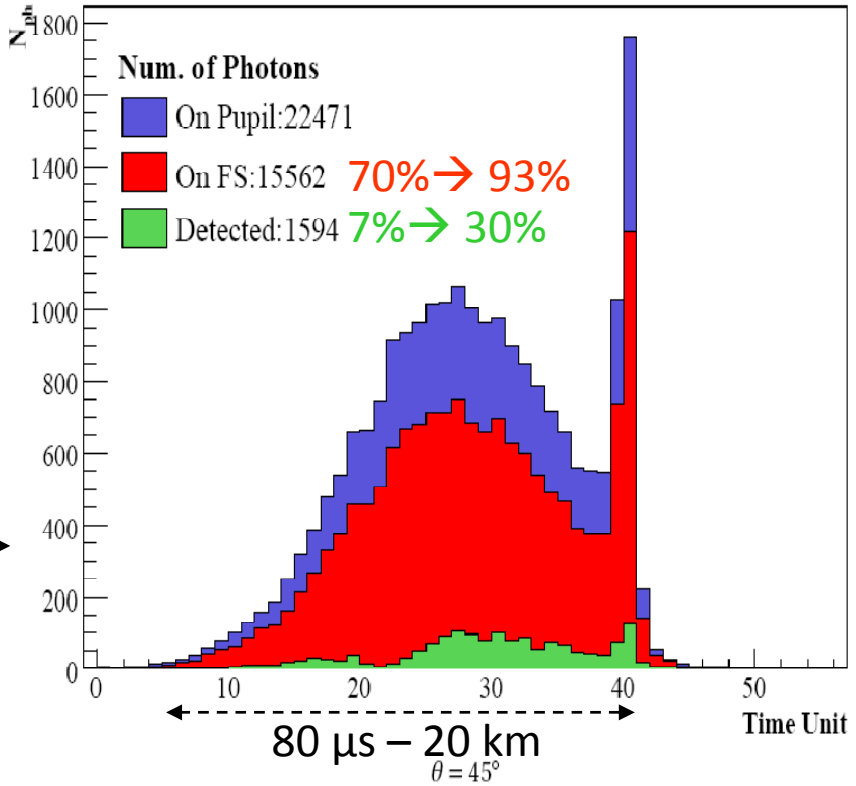
JEM-EUSO sees a factor $10^{-3}$ photons less than in Auger telescopes !

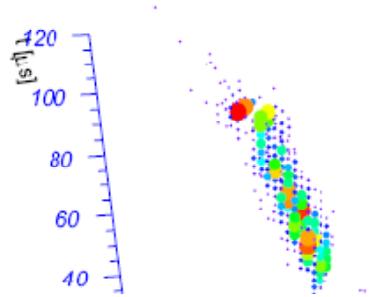



Event view in Focal Plane

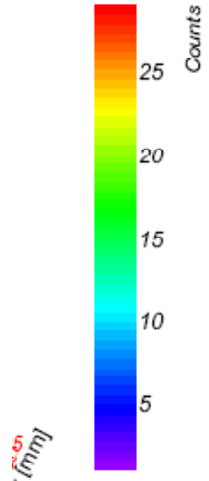
- pixel size δ=0.1°

Number of photoelectrons Detected versus time →



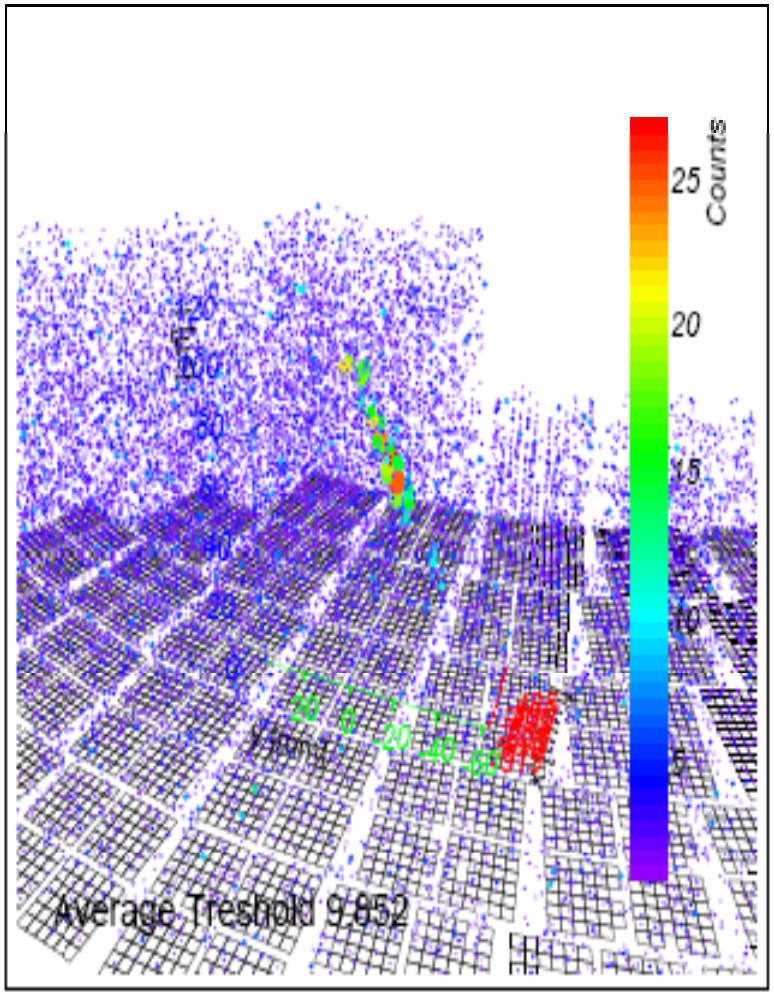




Nb photo electrons



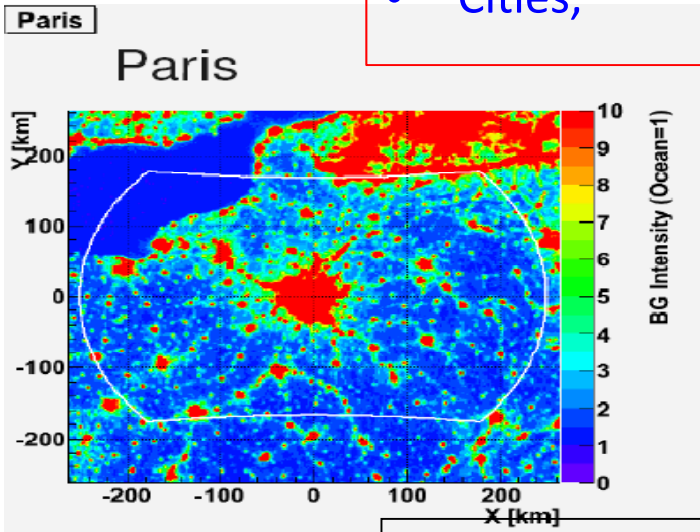

e Unit)

# Main night Background




**Sky background:**

- Nightglow,
- Zodiacal light,
- Stars, planets,
- Moon,
- Cities,




Irreducible background:
40 MHz/pixel
100 pe/PMT/GTU
1.5 pe/pixel/GTU

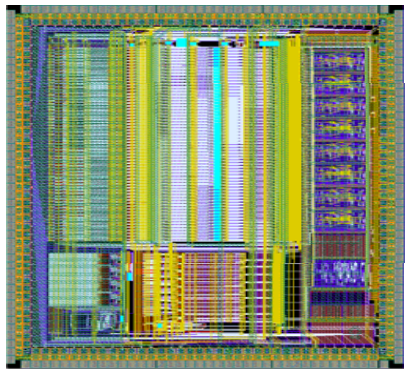
**Need a trigger with high background rejection factor**

# Trigger hierarchy to filter out the background

Level 0

1 to 2 pe per pixel
per GTU
400 kHz/channel

Sky background,
**LAL ASIC SPACIROC**
output



Level 1&2

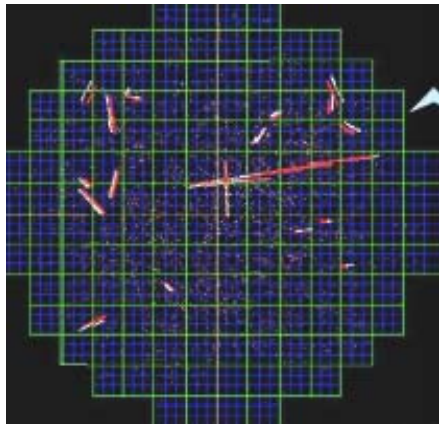
7Hz/PDM
(3. $10^{-3}$ Hz/channel)
BG Rejection factor $10^{8}$

FPGA/PDM Logic
Track search
Algorithm over
2300 pixels during 9 GTU
(EWHA/Italy)

Level 3

**0.1 Hz/Full detector**
**6 $10^{-4}$ Hz/PDM**
**BG rejection factor**
**~ 10000**

DAQ
**Shower Pattern**
**recognition**
**based on**
**Statistical algorithm**
**(LAL**,Germany)

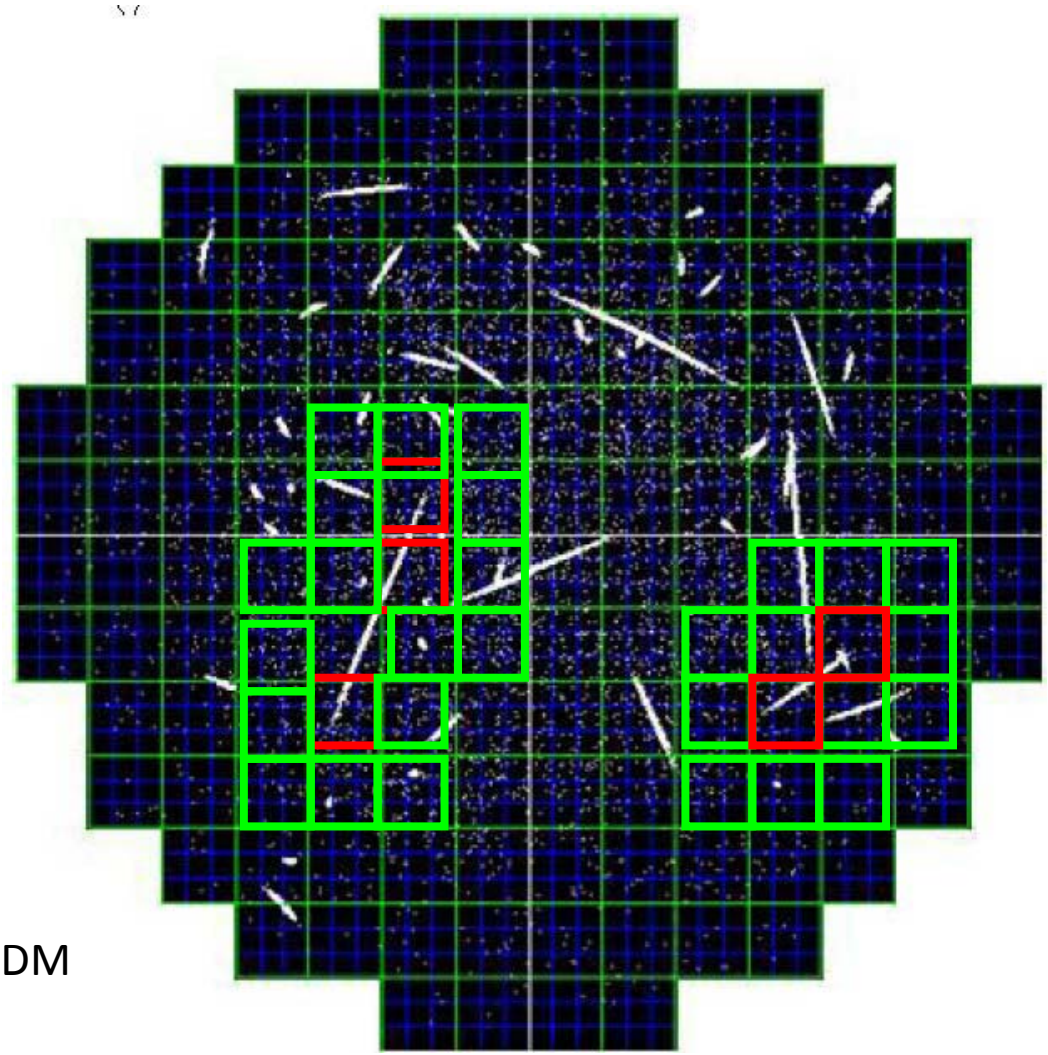


**Air Shower rate $10^{-3}$ Hz**

# Trigger Algorithm to be developed in SIMINOLE framework

A **digital processor (DSP)** handles 8 PDM (a square of 48 x 48 pixels) for the trigger (kind of pattern recognition in space and time)

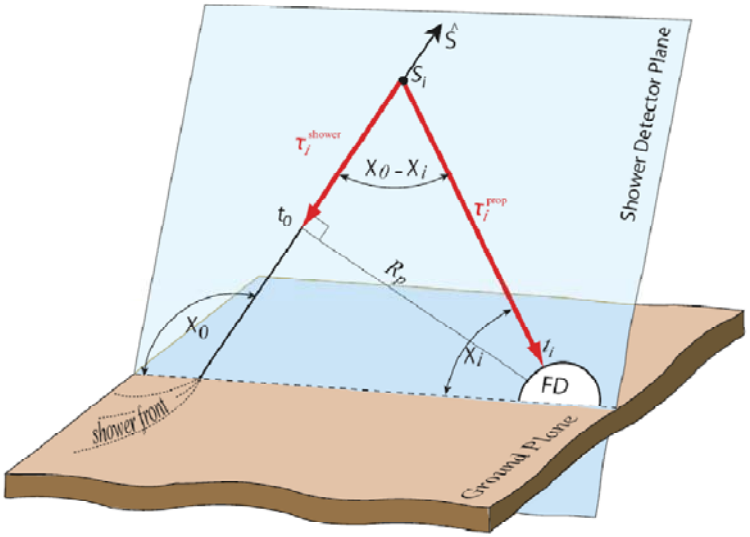
- Input rate : 56 Hz
- **Output rate : 5x 10 $^{-3}$ Hz**
- **background rejection : 10 $^{4}$**
- selection efficiency ~ 100% above 5 $10^{19}$ eV



L2 Triggered PDM

Boundary of a Triggered PDM

# Geometrical Reconstruction similar to that in Auger in mono

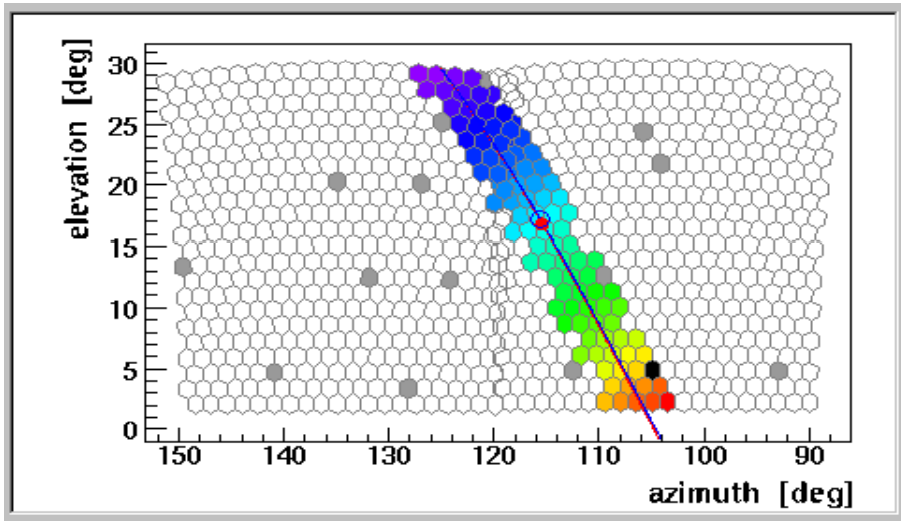


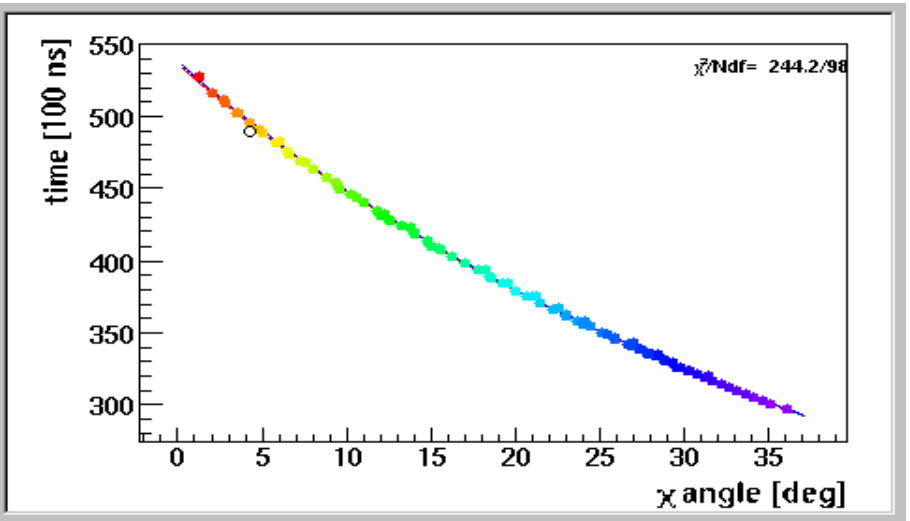

3 unknown parameters $t_0$, $R_p$, $X_0$

$$t_i = t_0 + \frac{R_p}{c} \tan\left[(\chi_0 - \chi_i)/2\right]$$

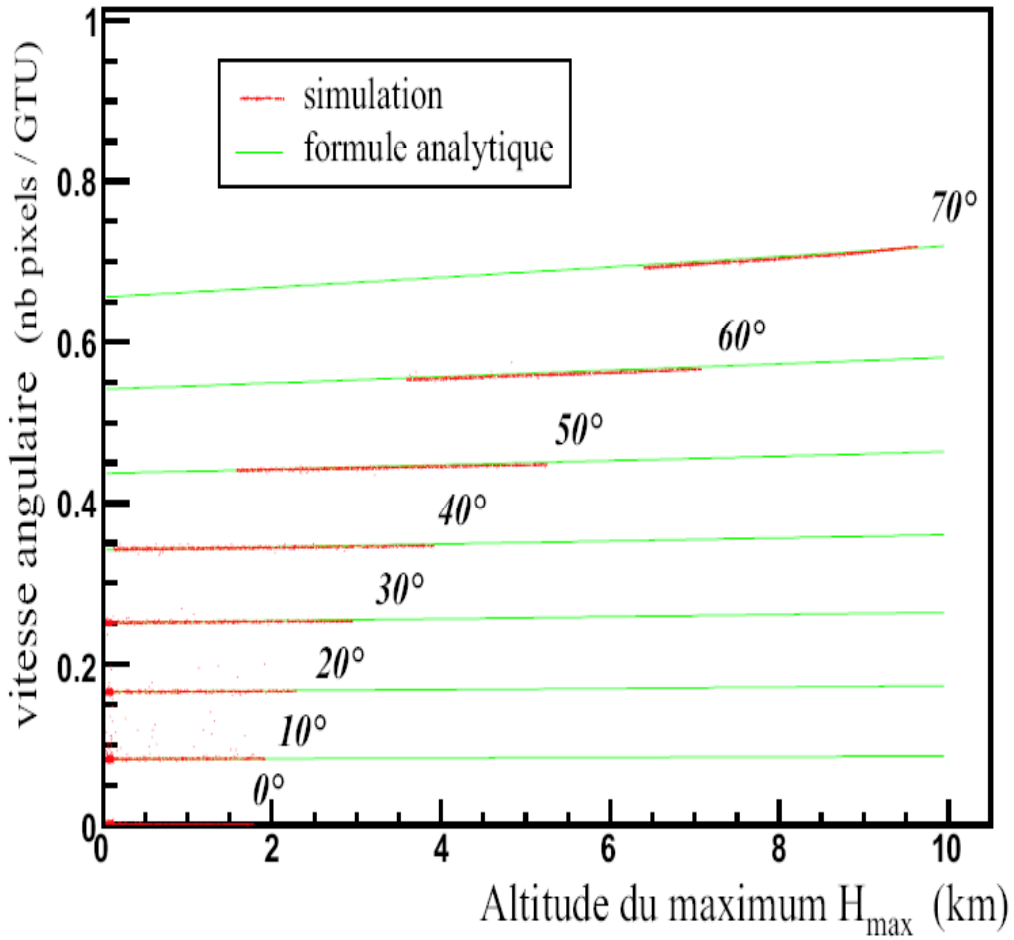
In monocular , need to see the non-linearity of the tan function (sufficient number of pixels)

Measurement of the angular velocity



# Geometrical reconstruction in JEM-EUSO : Measurement of the zenithal angle by the angular velocity in the shower detector plane




$$\frac{\omega}{\omega_0} = \frac{\sin\theta}{1+\cos\theta}\,\frac{1}{1-\dfrac{h_{max}}{h_{jem}}}$$

ω angular speed at maximum (number of pixel crossed during a time unit)

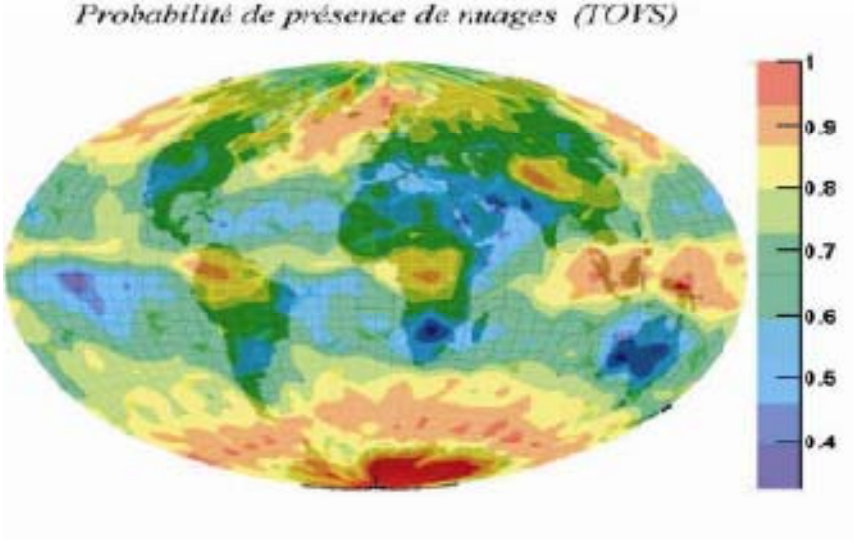
$\omega_0$ idem for a horizontal shower

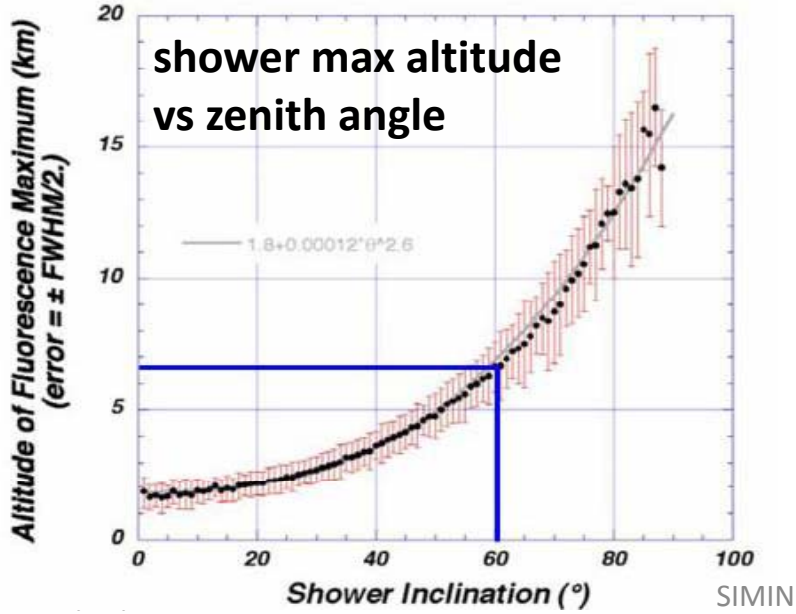
$h_{max}$ altitude of shower max

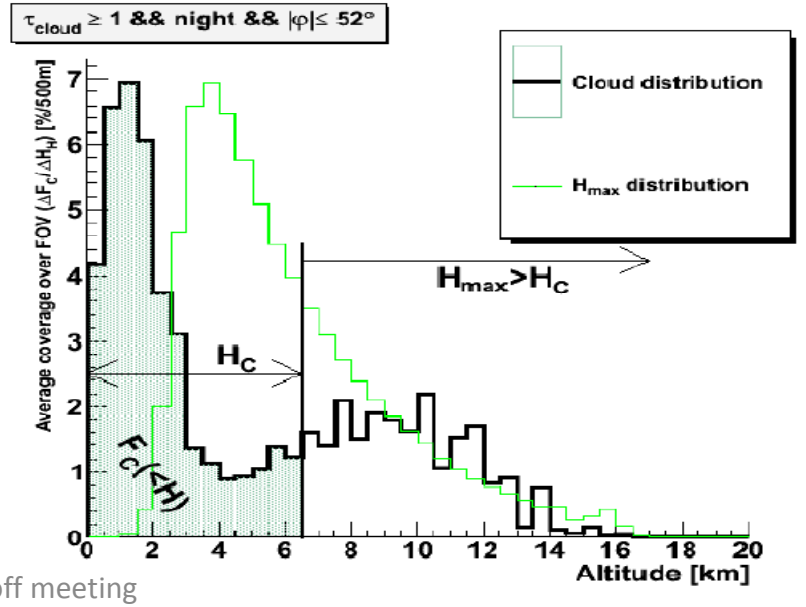
$h_{jem}$ altitude of JEM-EUSO

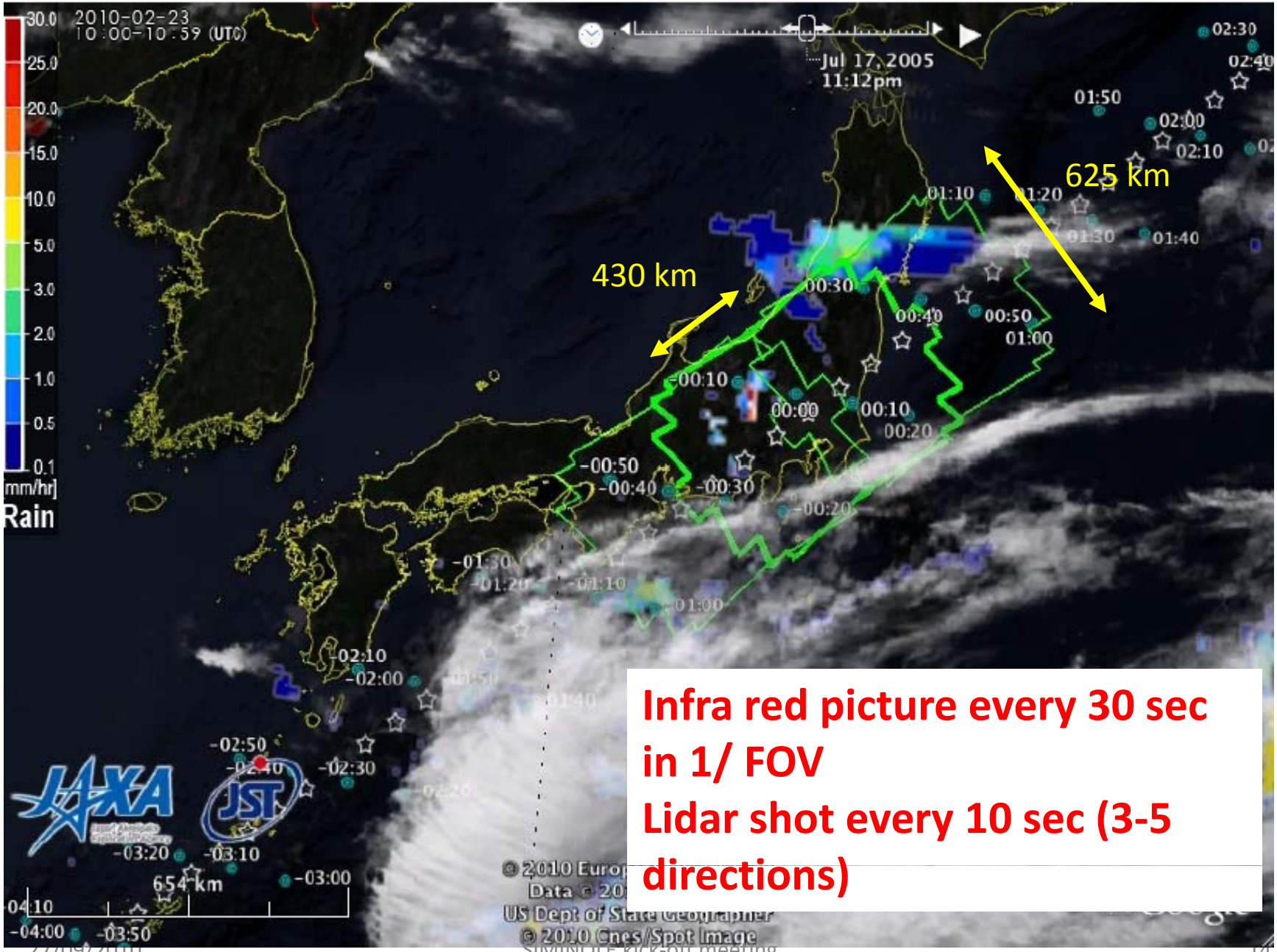
# The acceptance problem

- **Clear sky coverage for JEM-EUSO ~30%**
- **Shower maximum must be above cloud top height,**
- **Clouds reduce the acceptance.**
- **Cloud monitoring is mandatory**




2010-02-23
10:00-10:59 (UTC)
30.0
25.0
20.0
15.0
10.0
5.0
3.0
2.0
1.0
0.5
0.1
[mm/hr]
Rain
Jul 17, 2005
11:12pm
625 km
430 km
654 km
JAXA
JST
Infra red picture every 30 sec in 1/ FOV
Lidar shot every 10 sec (3-5 directions)

# EUSO-BALLOON ~2013

- Flight a 4-PDM (144 MAPMTs, ~10000 pixels in 2013)
- 40 km altitude
- FOV ~ 20° half angle
  - 1pixel has 0.4° and see 280 m
- Short flight (few hours) in Golfe de Gascogne or over Mediterranean See
- Long flight at Kiruna/Sweden

- Goals

1) Test of the embarked electronics : PMT + ASIC +FPGA (trigger)
2) Works in hard conditions of temperature, pressure
3) Background measurements (Airglow)
4) Signal tests with a Lidar
5) Trigger Tests

# Conclusion

- JEM-EUSO need application of utilities that are the subject of SIMINOLE project

1. **3rd level Trigger (on-line)**
   - The background rejection and selection algorithm
   - Shower modeling and atmosphere/clouds modeling
2. **Air shower reconstruction (off-line)**
   - Shower modeling as well as atmosphere , clouds & aerosols modeling
3. **Atmosphere & detector simulations**
4. **Pre-flight balloon experiment for tuning algorithms**
   - Simulation must start now

# JEM-EUSO accomodation on the ISS (~2015-2017)