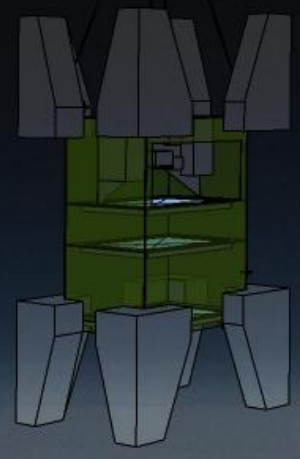


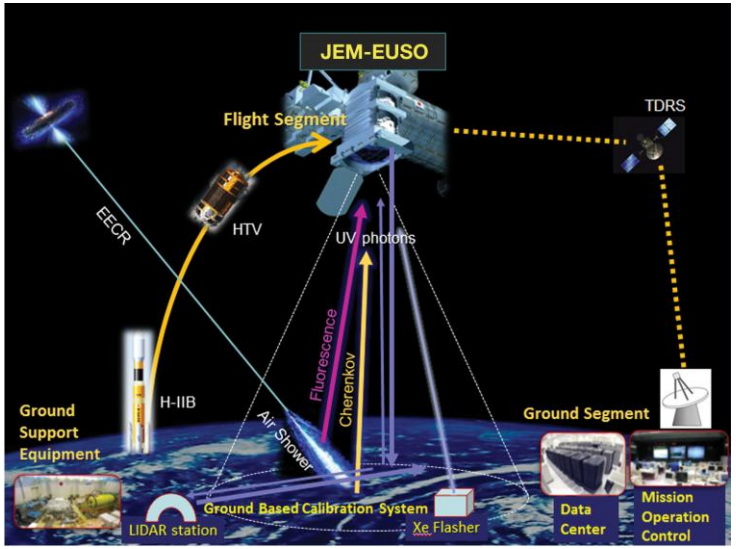
# Euso Balloon a pathfinder mission for the JEM-EUSO experiment

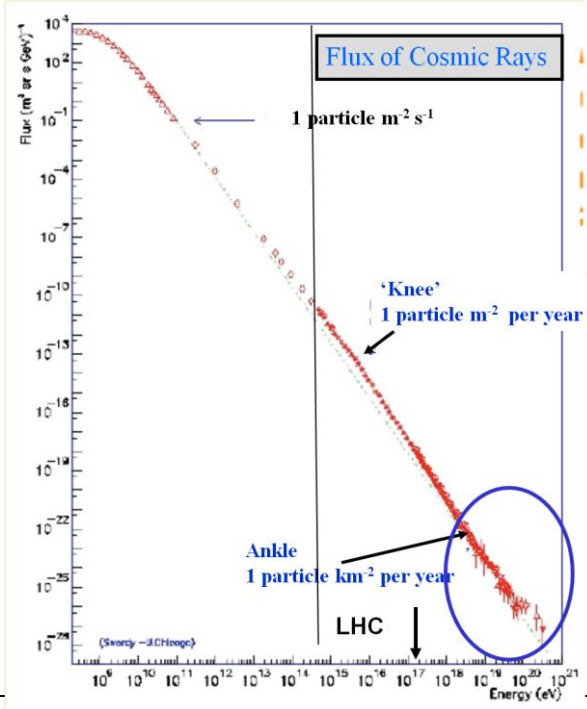
Giuseppe Osteria
INFN Naples, Italy

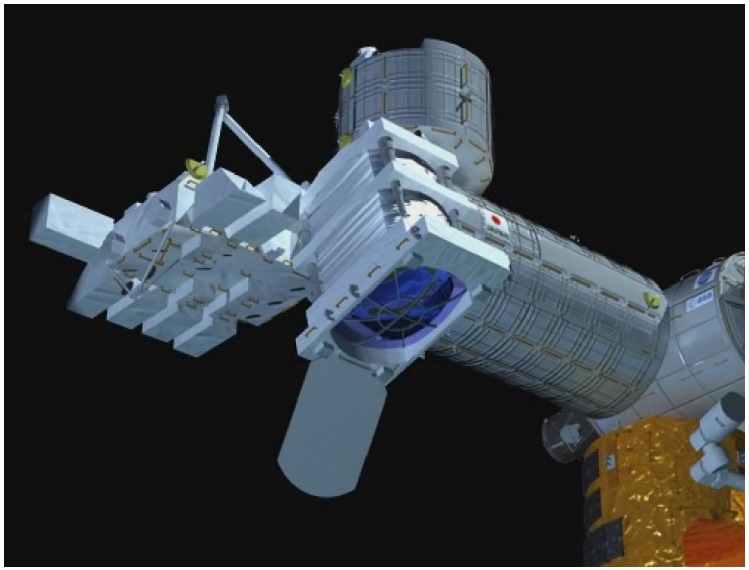
- Reminder on JEM-EUSO mission
-EUSO BALLOON
    -Main objectives
    -Instrument description
    -Status and planning
    -Simulation
    -Conclusion

# The JEM EUSO mission

The **E**xtreme **U**niverse **S**pace **O**bservatory onboard the International Space Station (ISS) **J**apanese **E**xperiment **M**odule is a new type of observatory which observes transient luminous phenomena occurring in the earth's atmosphere. The main objective of JEM-EUSO is to investigate the nature and origin of the Ultra High Energy Cosmic Rays, UHECRs ($E > 5\times10^{19}$ eV), which constitute the most energetic component of the cosmic radiation.

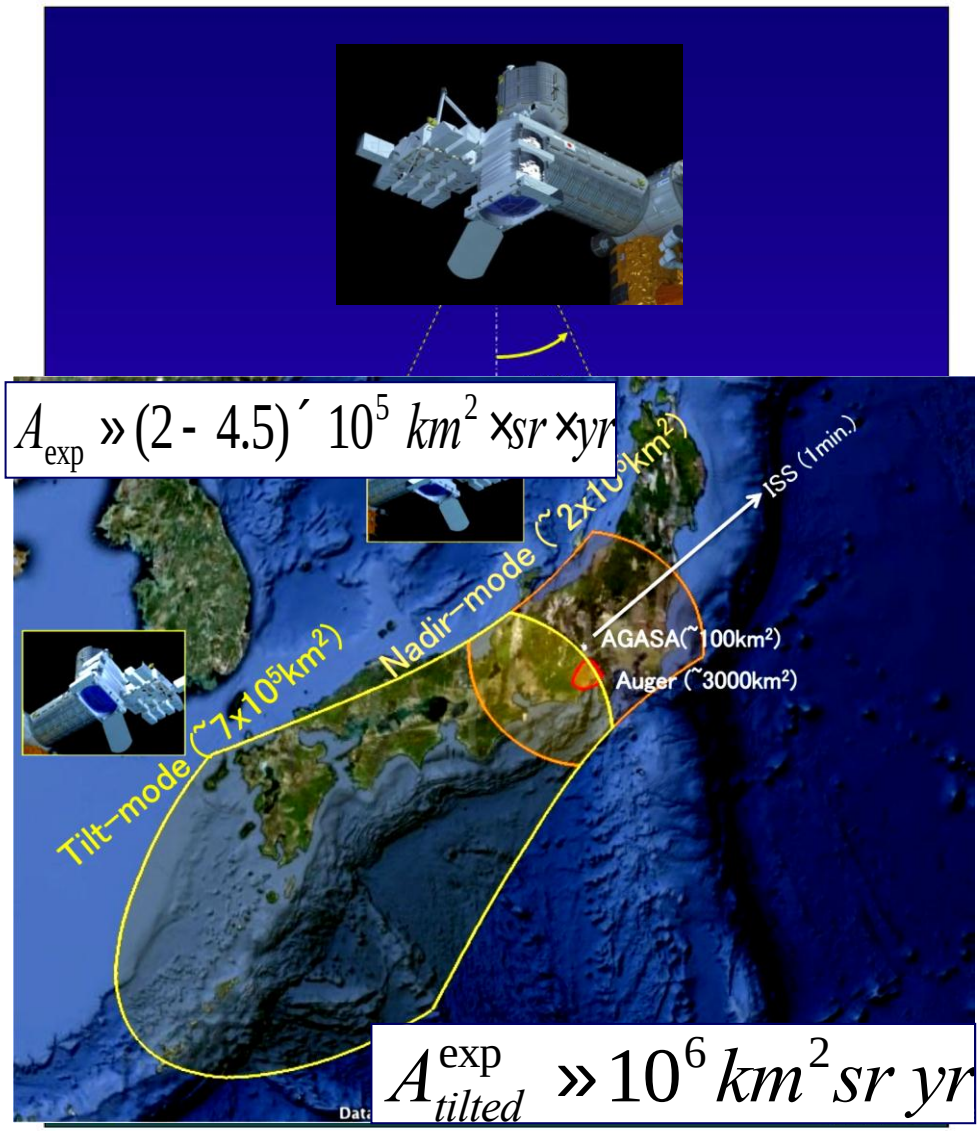


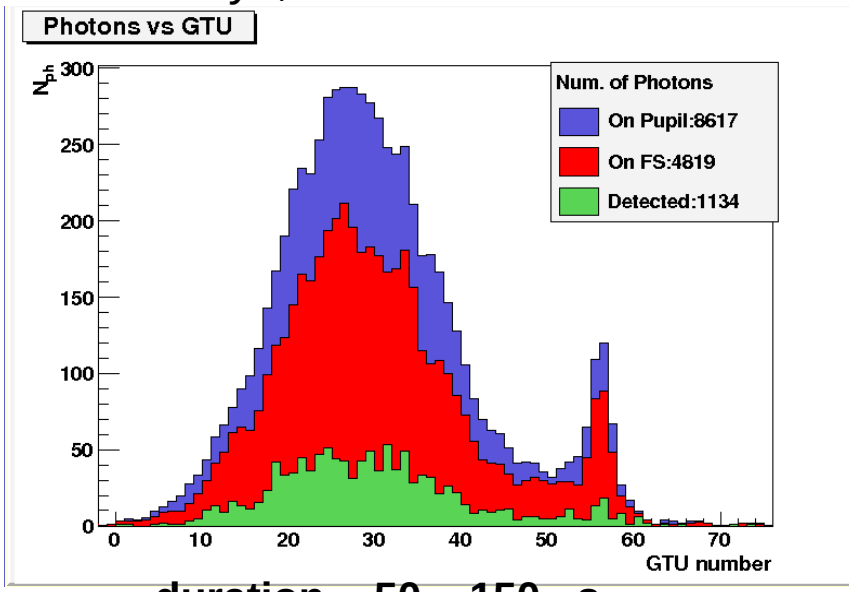



The instrument is planned to be attached to JEM/EF of ISS during the first half of 2017 for a three years long mission

# The observation principle of JEM-EUSO




JEM-EUSO telescope observes fluorescence and Cherenkov photons generated by air showers created UHE Cosmic Rays,




**duration ~ 50 – 150 μs**

**Simulation of the light profile observed at the entrance pupil (above) and through the instrument using the ESAF code**

The target volume is far greater than possible from the ground

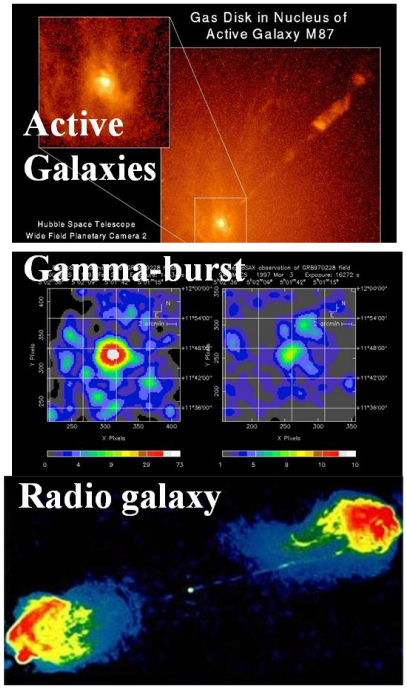
## Astrophysics and Cosmology:

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 neutrinos
- •discovery of UHE Gamma-rays
- •study of the galactic and local extragalactic magnetic field

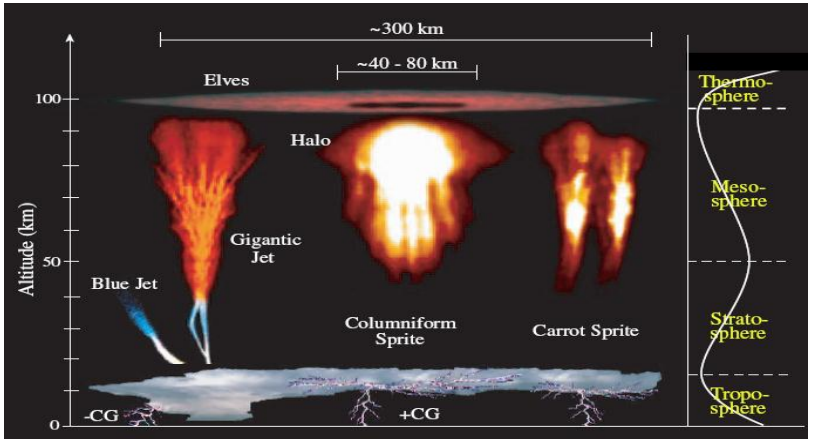



## Atmospheric Science

Nightglow

the transient luminous events (TLE)

meteors and meteoroids



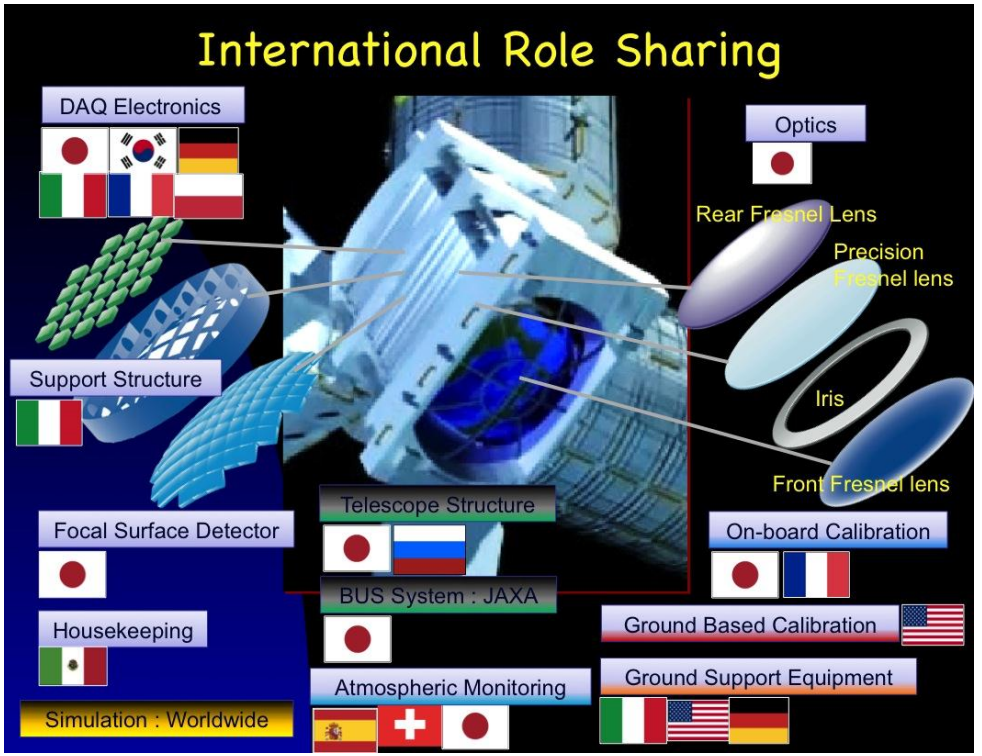
# JEM-EUSO Collaboration

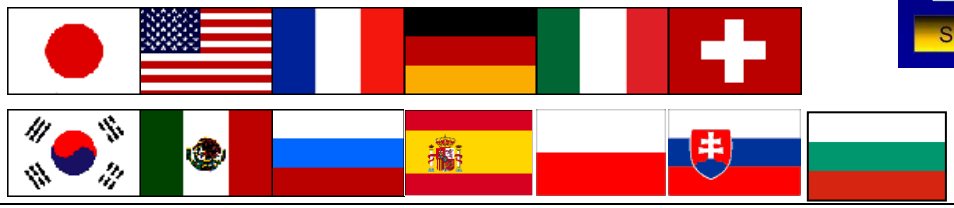
Japan, USA, Korea, Mexico, Russia

Europe: Bulgaria, France, Germany, Italy, Poland, Slovakia, Spain, Switzerland

13 Countries, 80 Institutions,
290 researchers

RIKEN: Leading institution



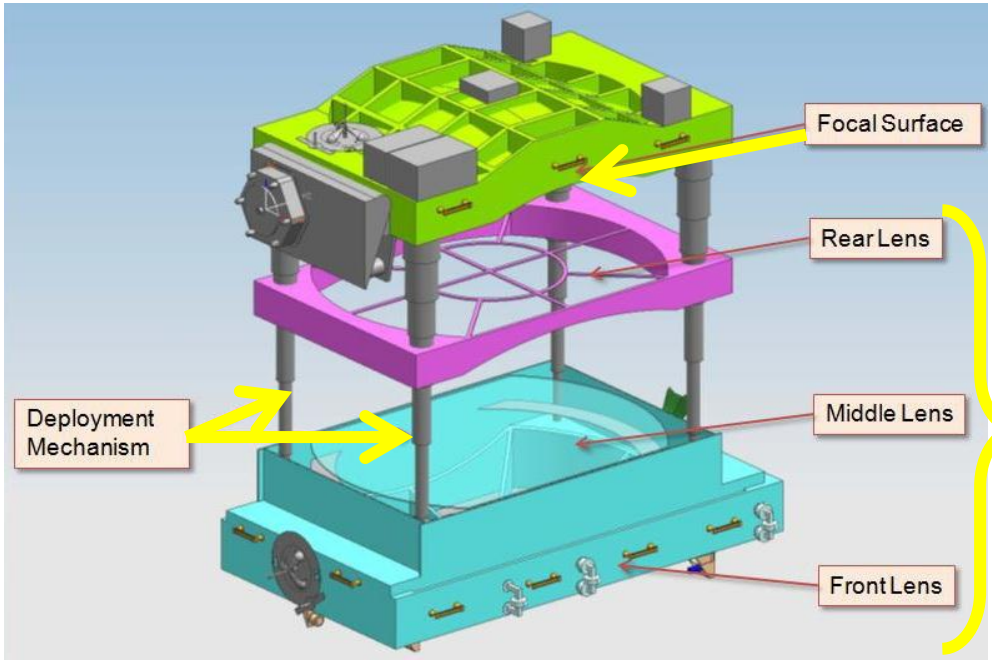



# The JEM EUSO instrument

The telescope is an extremely-fast and highly-pixelized (~$3x10^5$ pixels) digital camera with a large diameter (2.35 m) and a wide-FoV (±30°). It works in near-UV wavelength (330-400 nm) in single-photon counting mode.

The telescope consists basically of four parts:

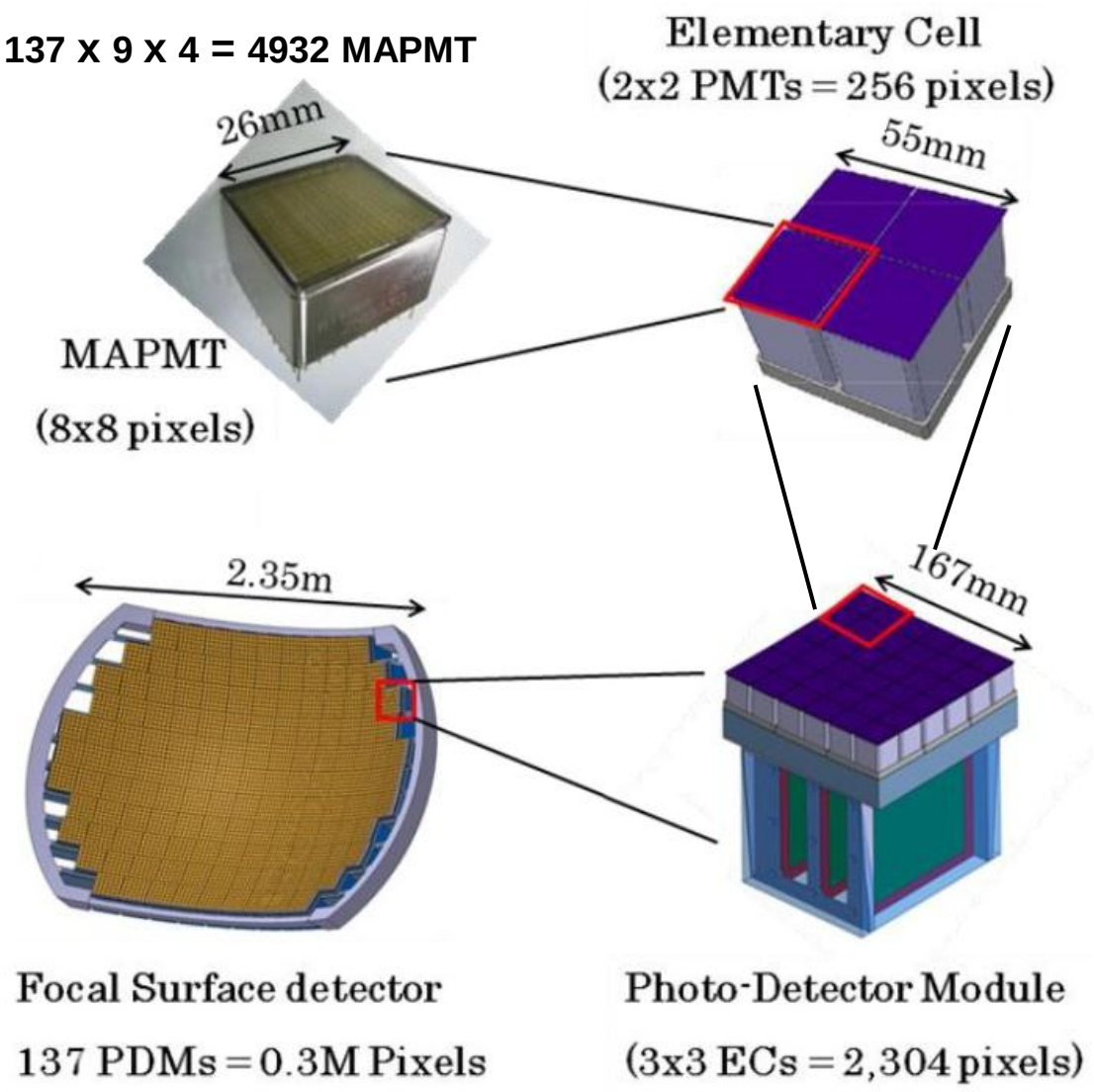
- **optics**: 3 high transmittance optical Fresnel lenses focusing the arriving UV photons onto the FS
- **FS detector**: ~5000 MAPMTs of 64 pixels;
- **FS electronics**: trigger, data acquisition and controls;
- **mechanical structure**.




An atmosphere monitoring system ( IR camera and Lidar) and a calibration system complete the apparatus.

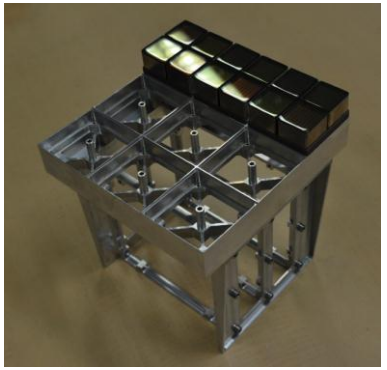
# The Focal Surface detector

**137 X 9 X 4 = 4932 MAPMT**

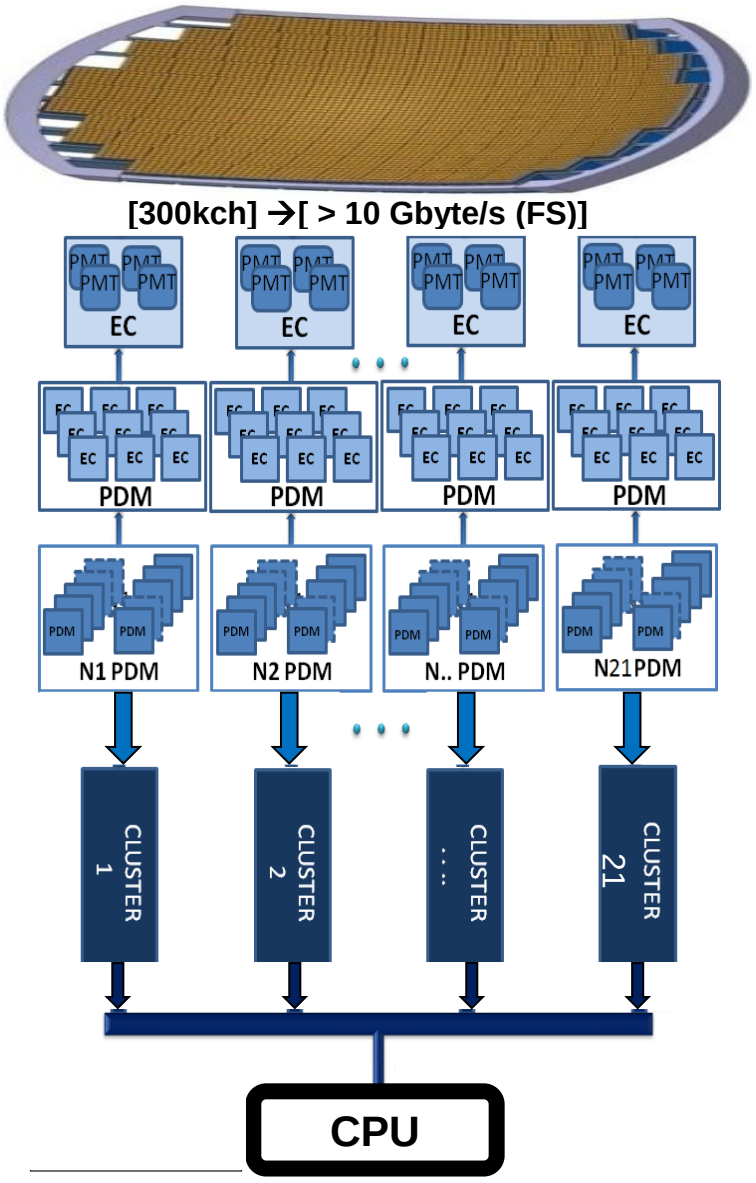



The FS detector has a curve surface of about 2.35 m, totally covered by MAPMT.

- •137 Photo-Detector Modules on the Focal surface
- •9 Elementary Cell on a PDM
- •4 MAPMT on a Elementary cell
- •4932 MAPMT on FS



# The data acquisition chain




Photons coming from EASs are converted into electric pulses by MAPMTs.

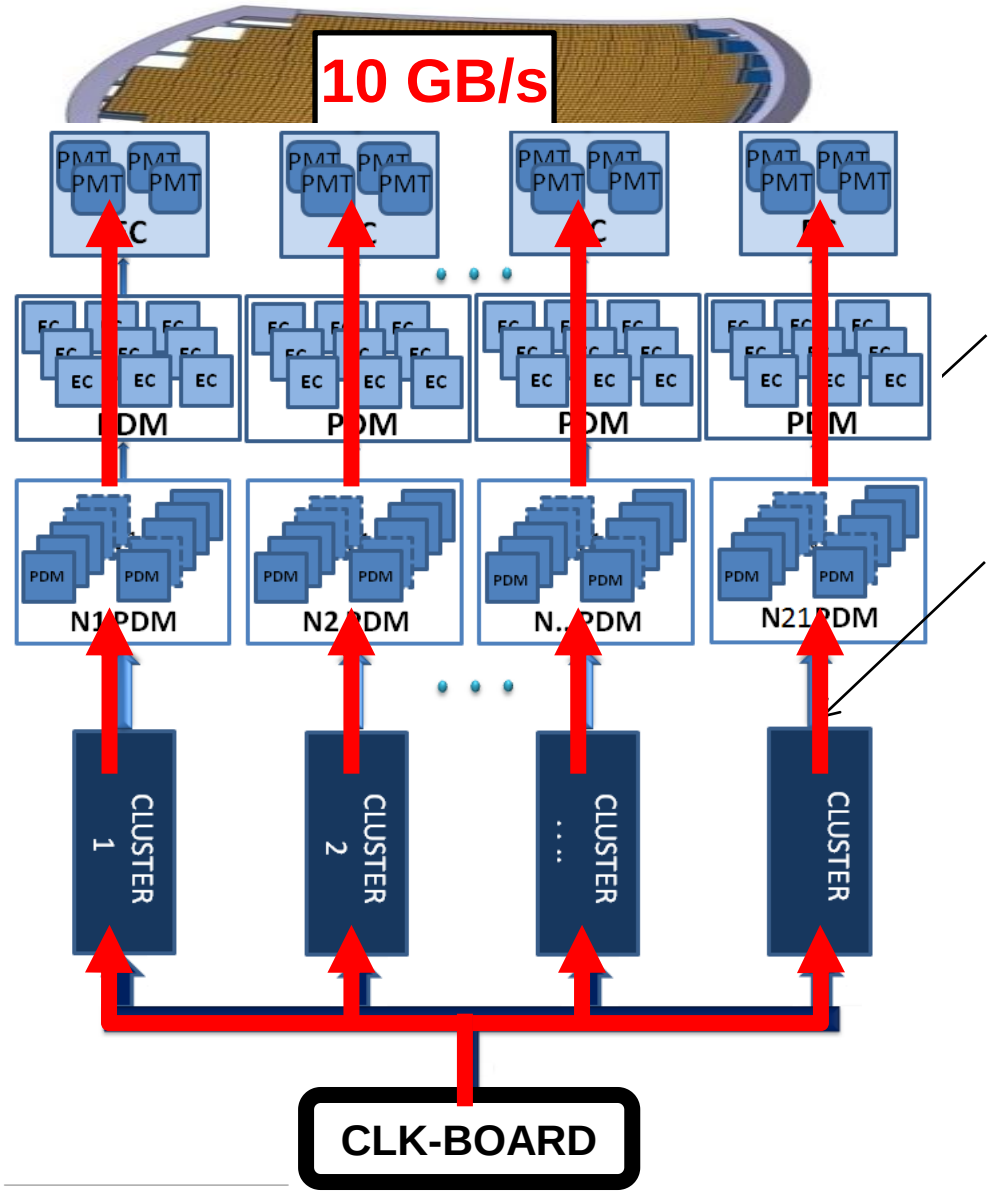
Signals from every MAPMT are discriminated from noise and digitalized by a front-end ASIC.

The ASIC counts the number of photo-electrons produced in a fixed time window for each pixel (Gate Time Unit, 2,5 μs).

The data electronics issues a trigger for EAS event and sends data to the ground for further analysis.

300 Kchannels, 4392 MAPMT
4392 FE ASIC, ~300 FPGA

# Trigger




Since the total number of pixels is very large, a multi-level trigger scheme has been developed.

The 1st level trigger is implemented in a dedicated PDM board, connected to 36 MAPMTs. The output from each PDM board is transmitted to a CCB.

Every CCB collects data from 9 PDM and transmits pixels information to the CPU for event passing the 2nd level trigger conditions only.

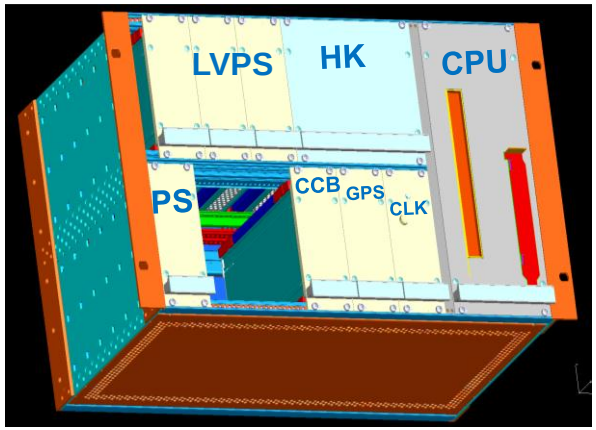
- hierarchical and highly parallel structure
- intrinsically redundant

Also the clock distribution network has a hierarchical structure

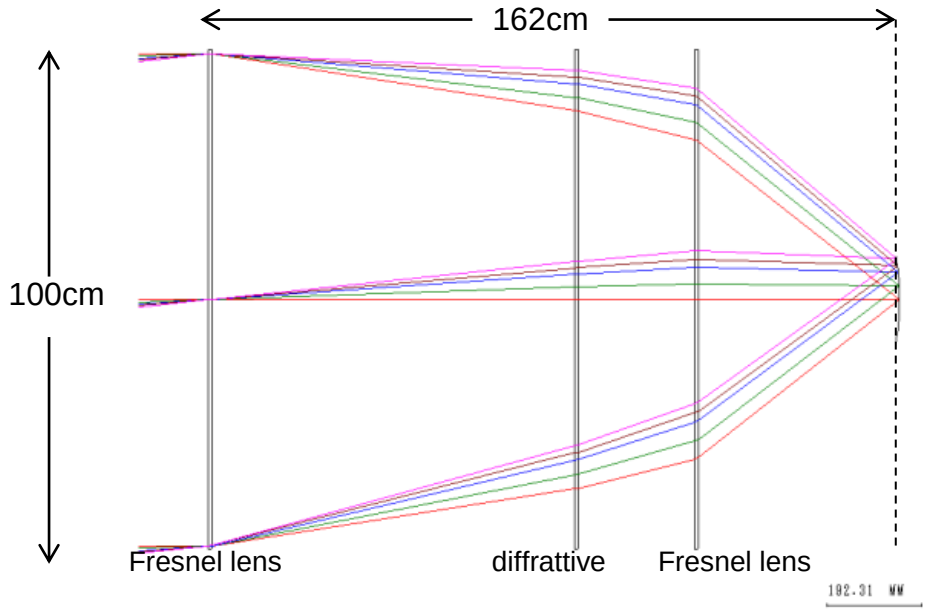
# EUSO BALLOON instrument

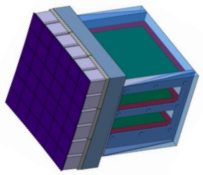
The EUSO BALLOON instrument consists of:

- 1 Optical system (3 flat-type lenses)
- 1 PDM
- 1 Data Processor
- 1 Telescope structure

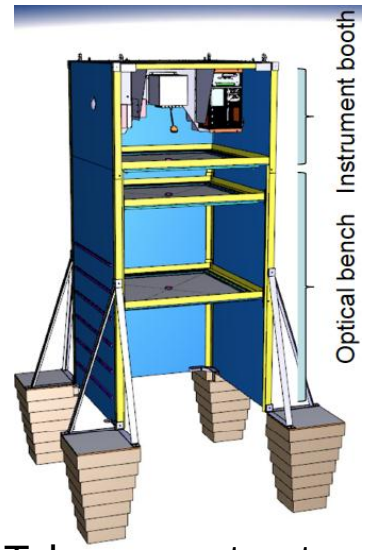



Data Processor

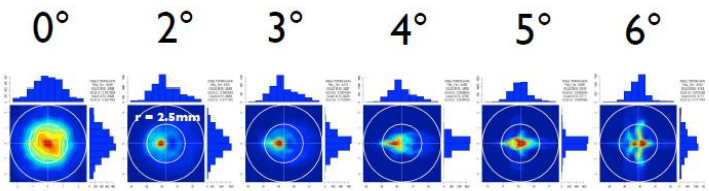


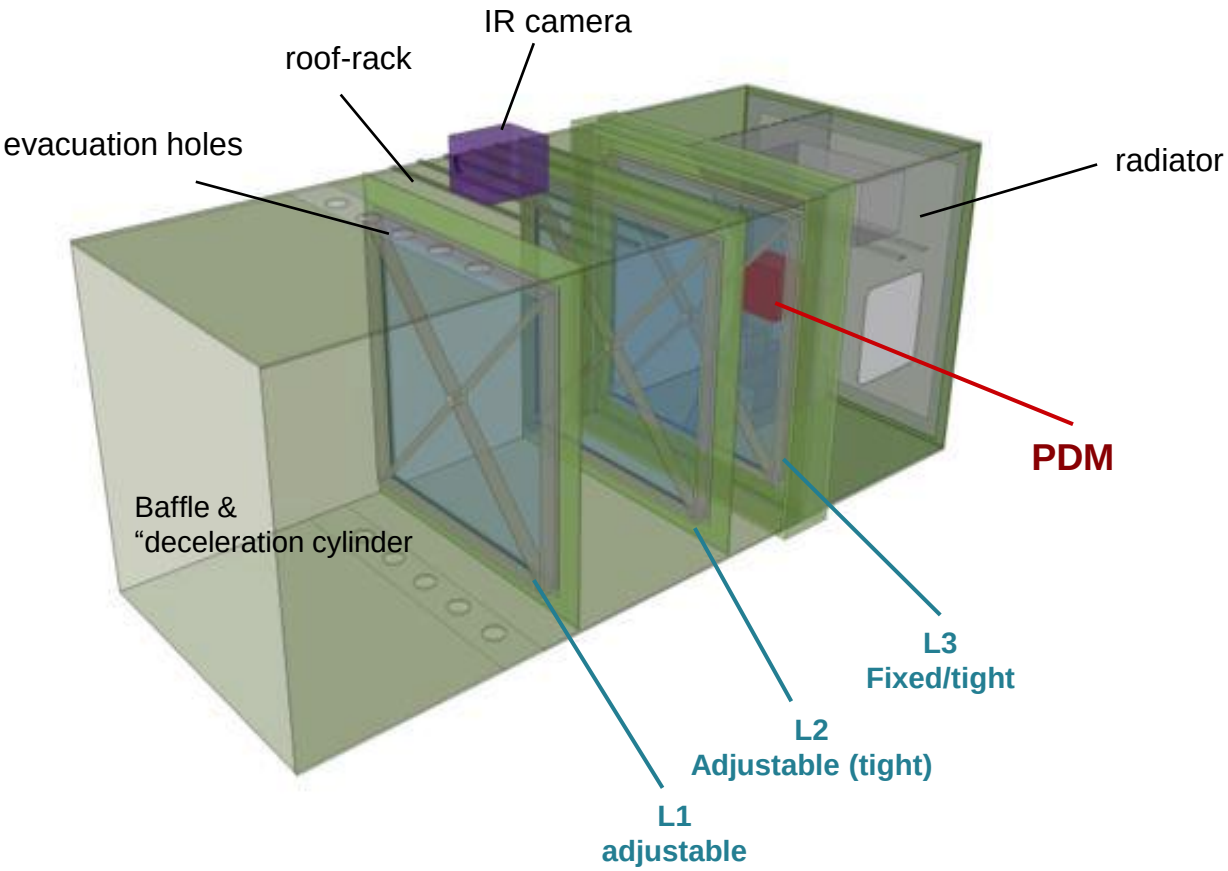
PDM
(2304 pixels)



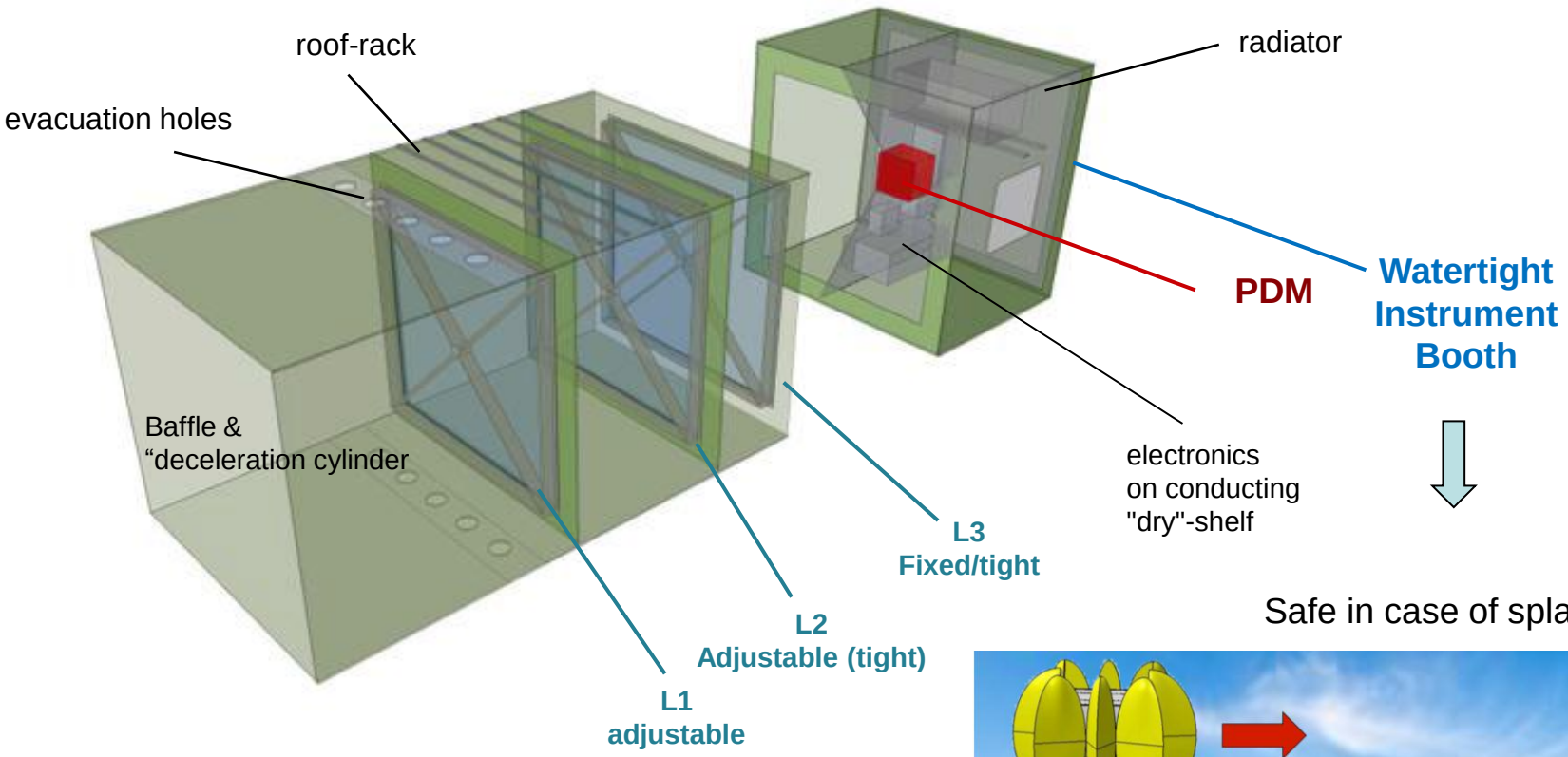

Telescope structure



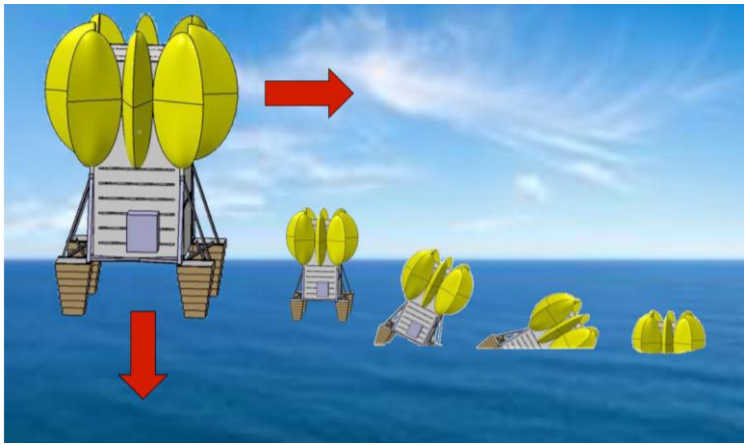
# Assembled instrument w/o floaters & crash pads



# Optical Bench (OB) Instrument Booth (IB)




Safe in case of splashdown



# Objectives for EUSO BALLOON

**A-level (technology demonstrator)**

Full scale end-to-end test of the JEM-EUSO's key technologies and instrumentation:

- the entire PDM, its ASIC's, the FEE, Trigger, HV power supplies, HV switches
- onboard hard- and software algorithms for triggering and shower-recognition

**B-level (cosmic ray acquisition and background study)**

- experimental confirmation of the effective background below 40 km
- test and adjust trigger and switching algorithms, observational modes
- testing of the acquisition capability of the IR camera

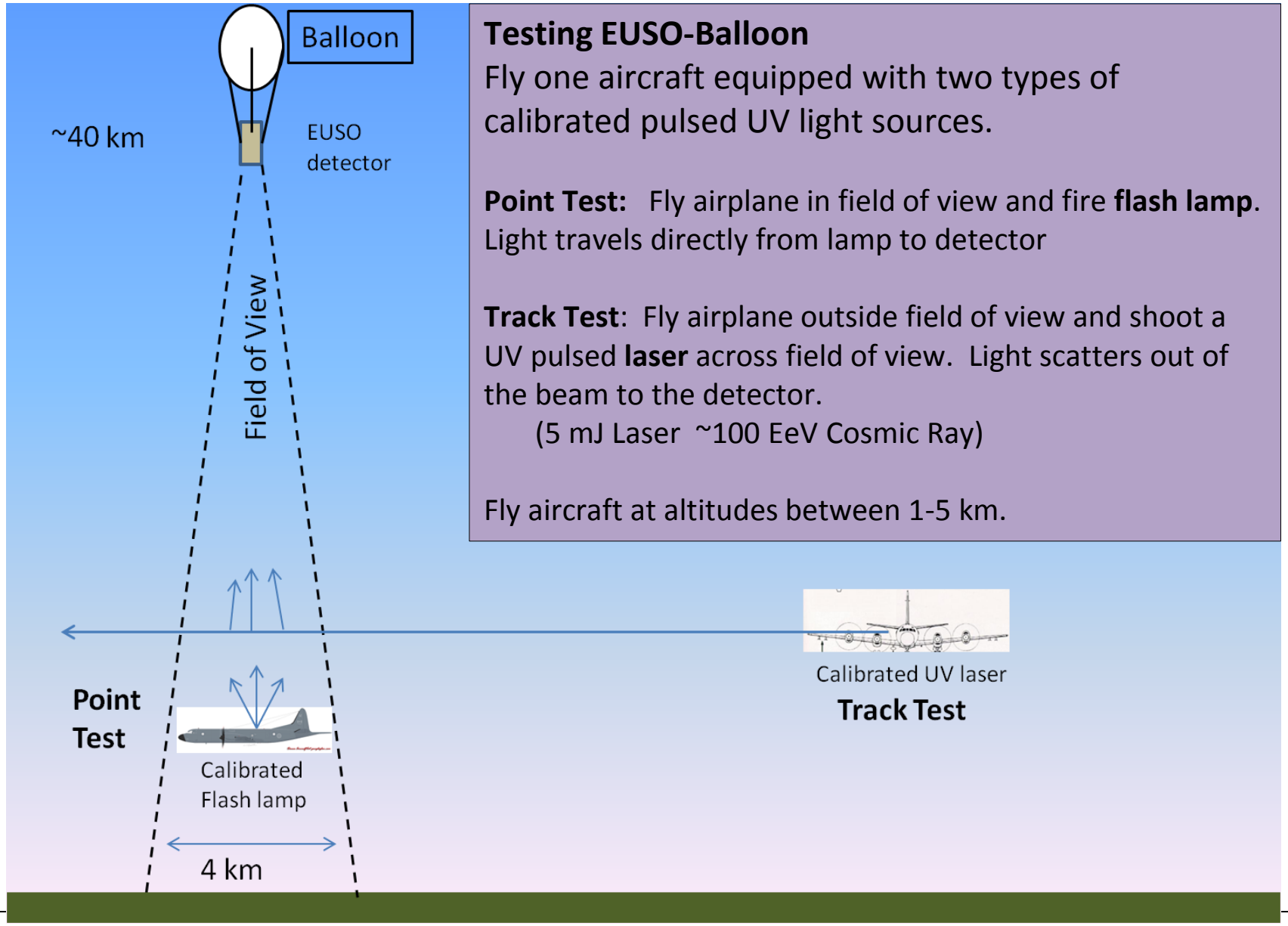
**C-level (precursor mission) :**

- 1st detection of air-showers by looking down from the edge of space
- detection of laser induced events from space …

"fringe benefits" of EUSO-BALLOON

- balloon triggers decisive steps in TRL levels in JEM-EUSO subsystems

# 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.

# EUSO-BALLOON vs. JEM-EUSO

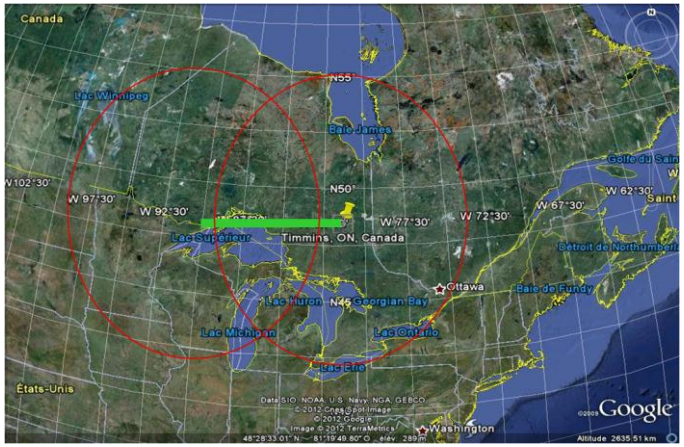
| | JEM-EUSO | EUSO-Balloon |
|---|---|---|
| Height(km) | 420 | 40 |
| Diameter(m) | 2.5 | 1 |
| FoV/pix(deg) | 0.08 | 0.25 |
| Pixel@ground(km) | 0.580 | 0.175 |
| FoV/PDM(deg) | 3.8 | 12 |
| PDM@ground(km) | 28.2 | 8.4 |
| Signal Ratio | 1 | 17.6 |
| BG Ratio | 1 | 0.9-1.8 |
| S/√N | 1 | 20-10 |
| $E_{thr}$(eV) | $3x10^{19}$ | $1.5\text{-}3x10^{18}$ |
| Number of PDM | 143 | 1 |

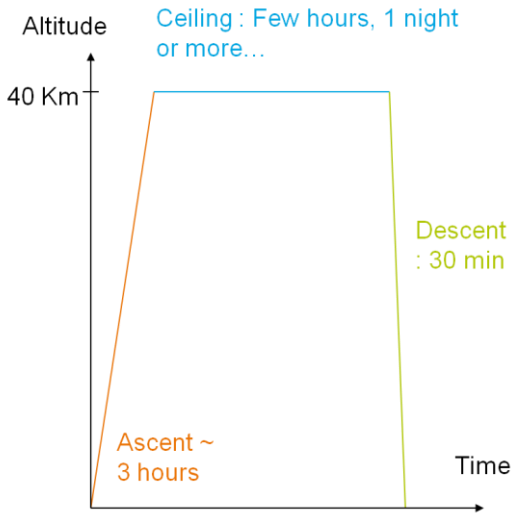
Maximize performance of EUSO-Balloon keeping parameters as close as possible to JEM-EUSO

# EUSO BALLON mission

**Three flights mission (recently approved by CNES)**

First flight : 2014 Timmins.




Balloon size for EUSO :

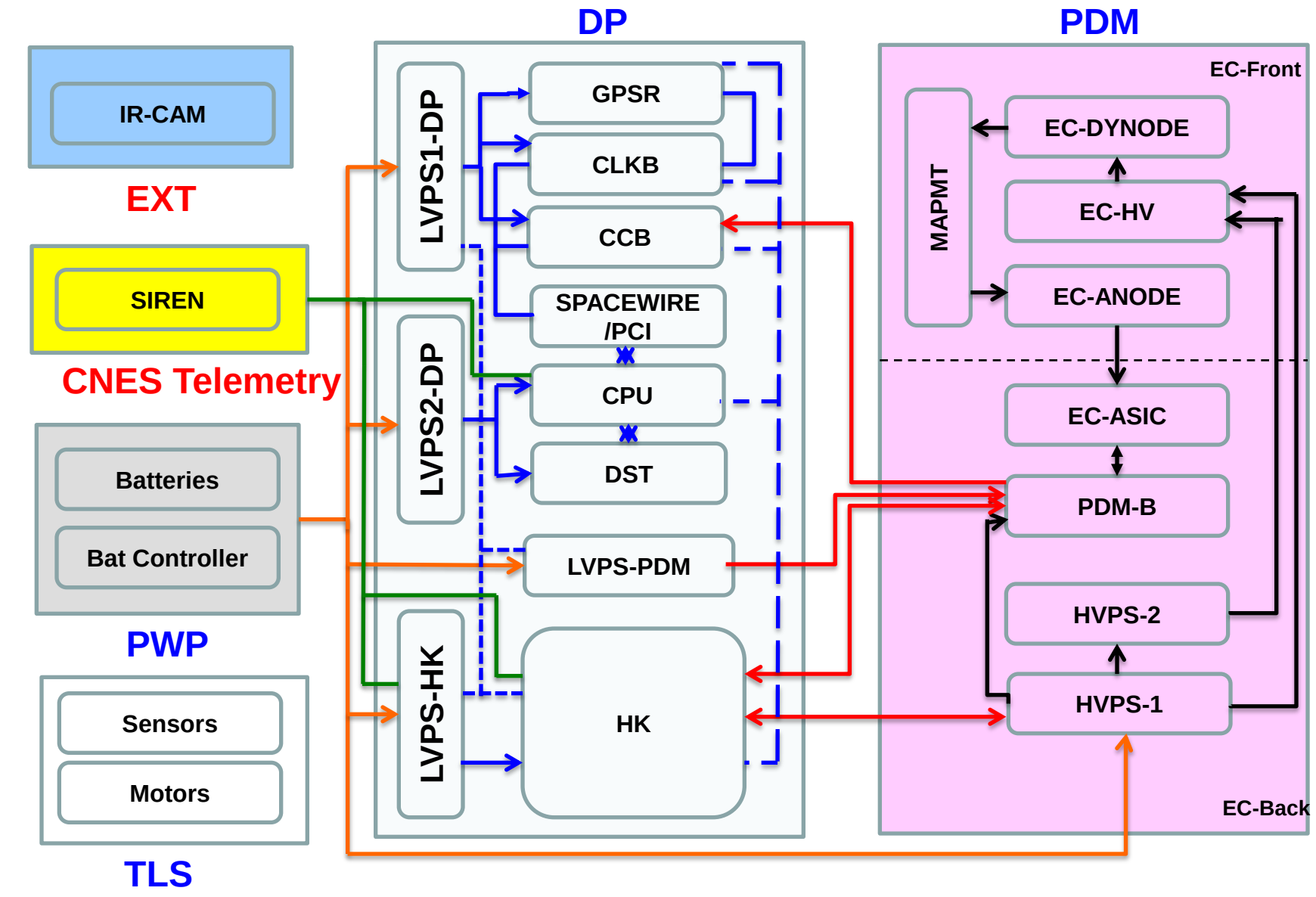
400 000 $m^3$ -> 40 Km altitude


Second flight : 2015 Kiruna?

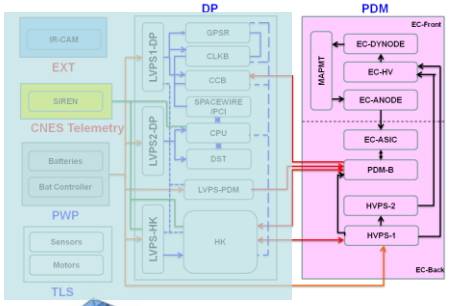

Third flight : 2016 Aire sur l'Adour?

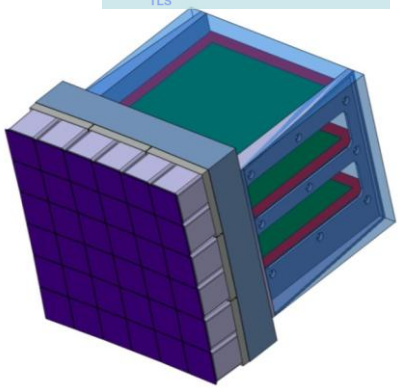

Environmental constrain:
Low pressure (3 mbar)
Thermal range: -30°C +50°C

# EUSO BALLOON subsystems

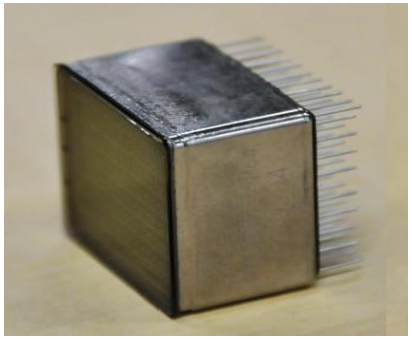


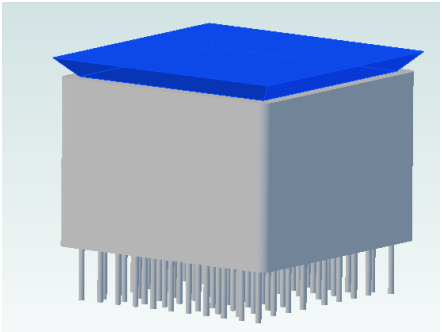
# Global view of the PDM



- The PDM consists in an assembly of several components:
  - 1 mechanical structure
  - 9 Elementary Cell (EC) front units
    - Multi-Anode Photomultipliers (MAPMTs): 36 in total
    - Front end electronic
  - 6 ASIC boards (EC_ASIC)
  - 2 High Voltage Power Supplies (HVPS)
  - 1 PDM board (also called FPGA board)
- It has to detect the UV photons coming from the optic
- Its size is given by the mechanical structure: 167 x 167 x 160 mm
- Its weight will be around 3.6 kg
- Its power budget will be 20 W



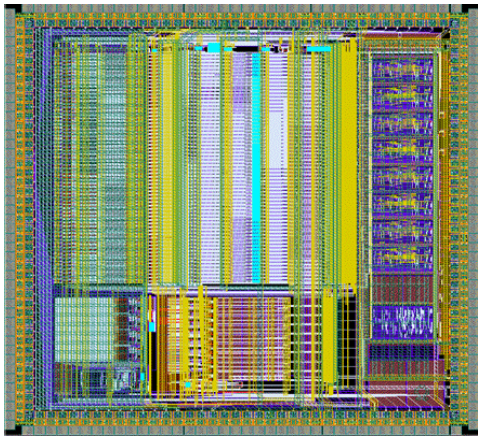


# The MAPMT

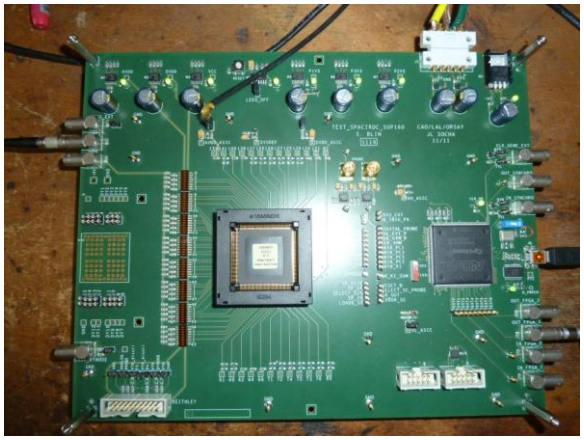
**The main specifications of R11265-03-M64 are as follows:**

| | |
|---|---|
| •pixels side | 2.88 mm |
| •maximum sensitive area | 23.04 mm × 23.04 mm. |
| •physical dimension of the MAPMT | 26.2 mm × 26.2 mm (length is 20.25 mm). |
| •weigth | 27.3 g. |
| •photo-cathode | ultra-bialkali |
| •window material/thikness | UV glass/ 0.8 mm |
| •quantum efficiency | higher than 35% (maximum 40%) for wavelengths from 330 nm to 400 nm. |
| •dynode structure | metal channel with 12 stages, |
| •gain | $10^6$ at 0.9 kV with a tapered voltage divider. |
| •anode pulse rise-time I | 1.5 ns. |
| •transit time spread | about 0.3 ns. |
| •cross talk | about 1%. |
| •gain non-uniformity (anodes) | 1:3. |
| •gain non-uniformity (MAPMT) | within 1:2. |
| •anode dark curr. (30 min. storage) | 1 nA. |

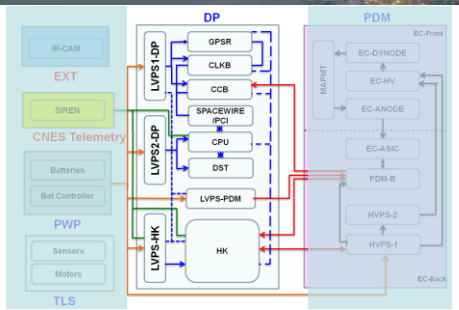
# SPACIROC ASIC



- 64 channels ASIC in AMS 0.35 µm SiGe technology designed by Omega group at LAL
- Requirements:
  - ✓ Readout of MAPMT (charge or current input)
  - ✓ Gain adjustment (preamplifier)
  - ✓ Photo-electron counting (Fast Shaper + discriminator)
  - ✓ Estimation of the charge (Q to T converter)
  - ✓ Radiation hardness
  - ✓ Low consumption (<1 mW/ch)
- All achieved with the first version of the ASIC



# Data Processor functional requirements




**The Data Processor sub system has to:**

- Control of the front-end electronics (configuring)
- Perform Second level trigger filtering
- Tag the events with arrival time (UTC) and payload position (GPS)
- Manage the Mass Memory for data storage
- Measure live and dead time of the instrument
- Provide signals for time synchronization of the event
- Perform housekeeping monitor
- Handle interface to tele-commands and to telemetry system

Budgets:

- Mass < 20 kg
- Power < 50 W
- Data acquisition: 2304 channels → 330 kbytes/event

# Description of the DP and its components

The DP functionality is obtained by connecting different specialized items which form a complex system.

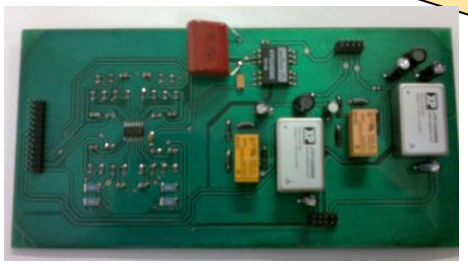
The main subassembly items are:

- Control Cluster Board (CCB)
- Main processing unit (CPU)
- Data Storage (DST)
- Housekeeping system (HK)
- Clock Board (CLKB)
- GPS receiver (GPSR)
- Data Processor Power Supplies (DP-LVPS1-2-3)
- PDM Power Supply (PDM-LVPS)

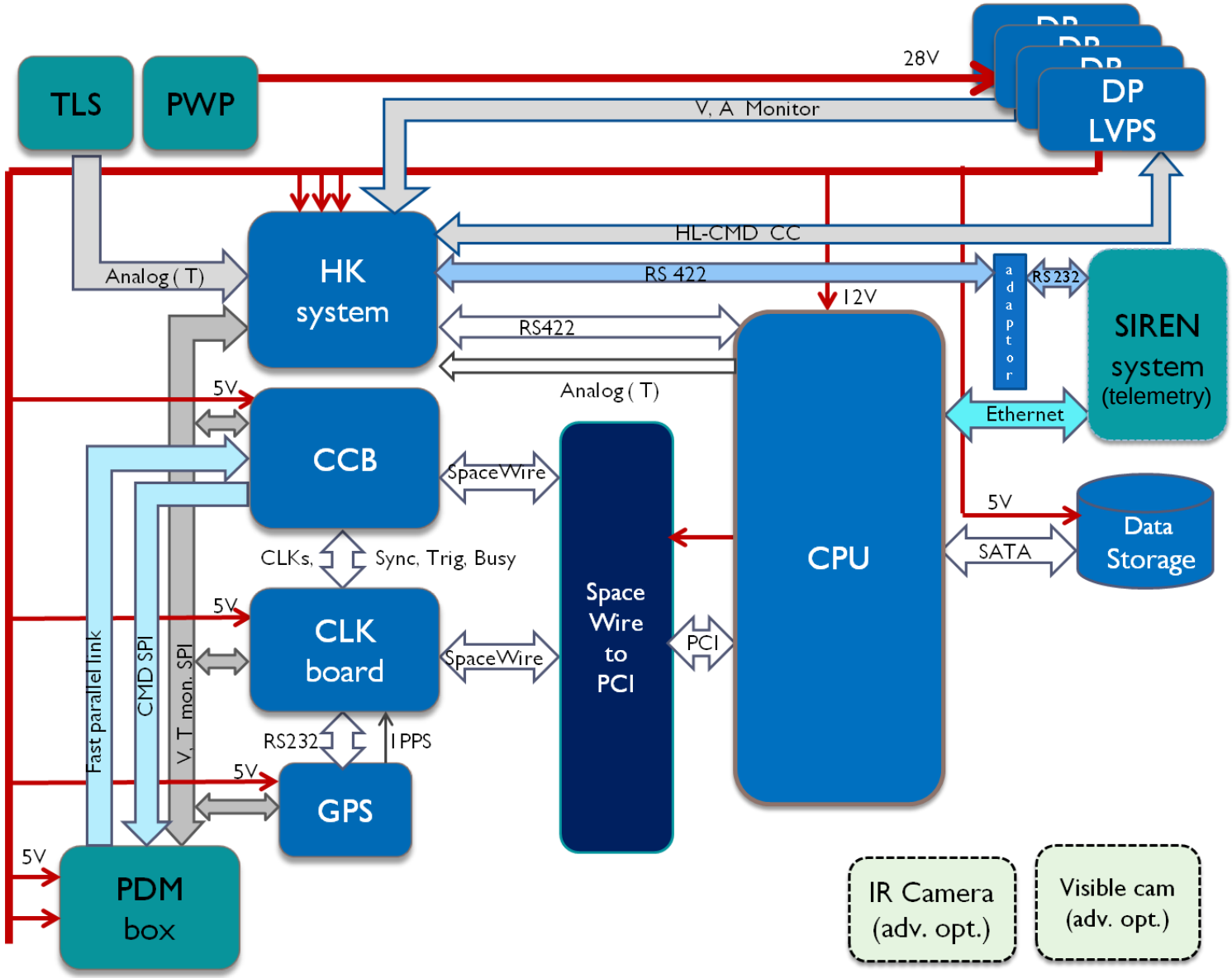
Arbor iTX-i2705

2 x OCZ 512 GB SSD disk

SpaceWire PCI Mk2



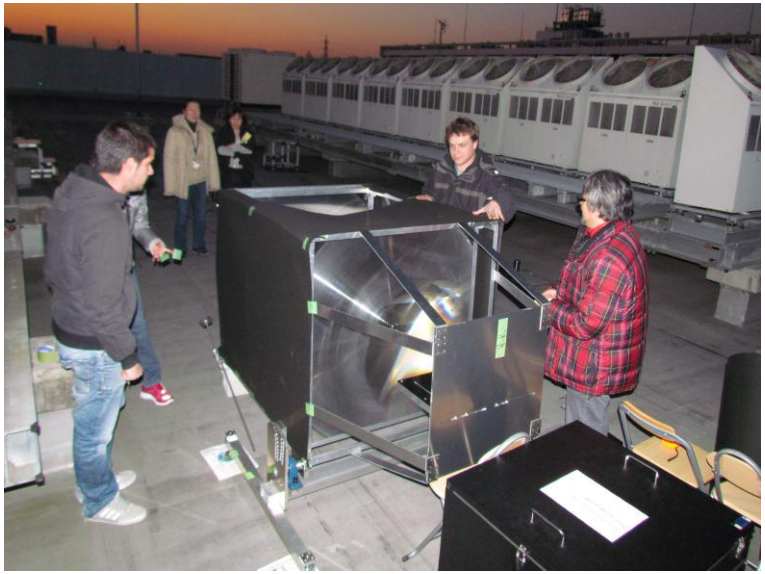
# Data Processor block diagram

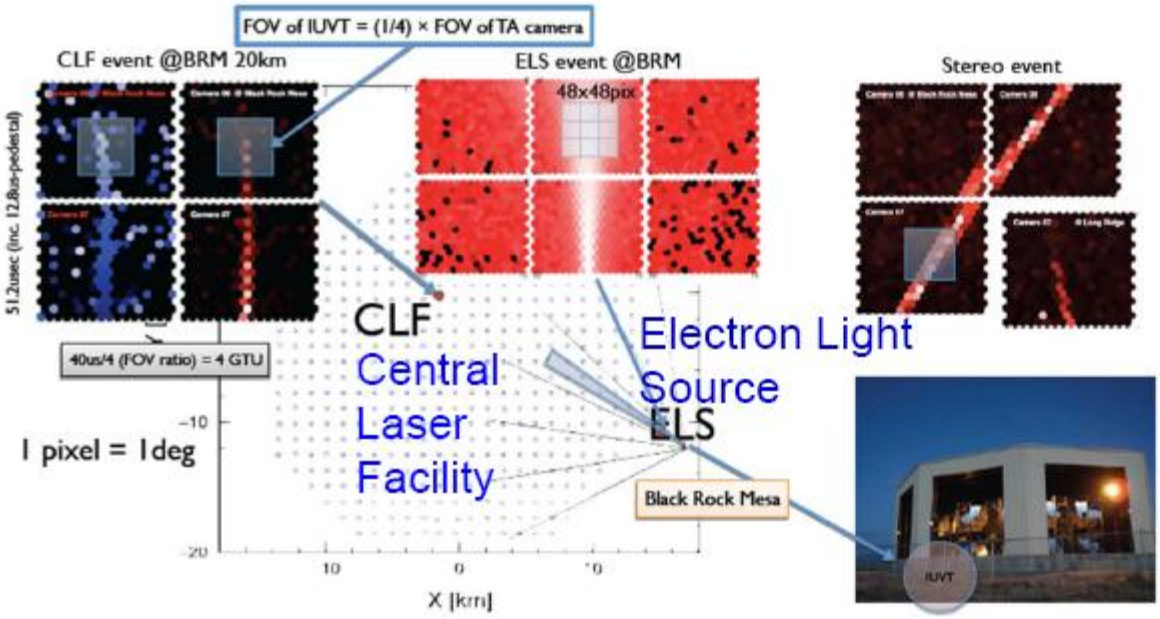


# Status

A full prototype of the instrument has been realized and integrated at Riken.

The prototype will be installed in the Telescope Array site in Utah






Light from Electron Light Source (ELS) and LIDAR of TA can be observed besides cosmic ray events.

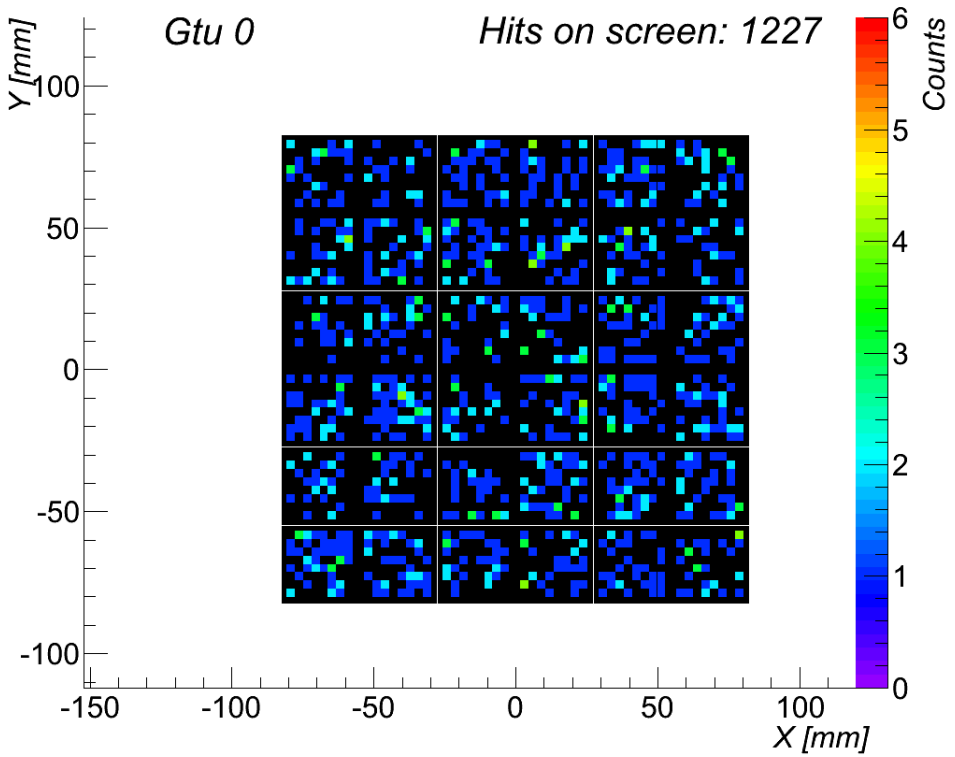
# Simulation

An example of background observation

*250 photons / $m^2$ ns sr*

*Uniform distribution*

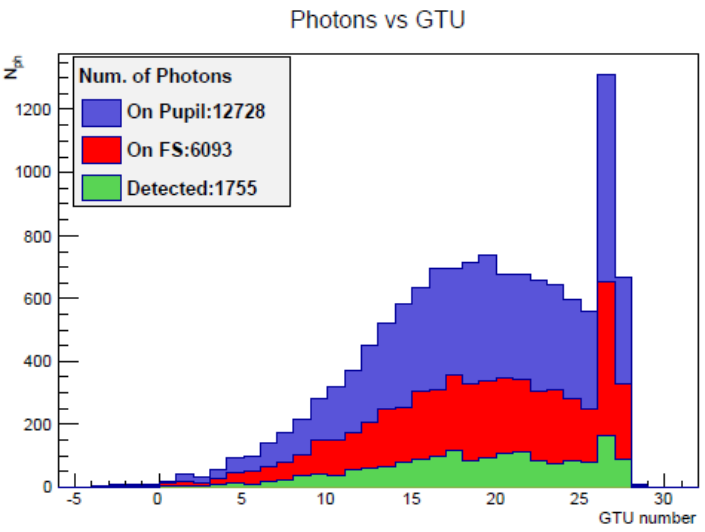
Simulated at electronics level

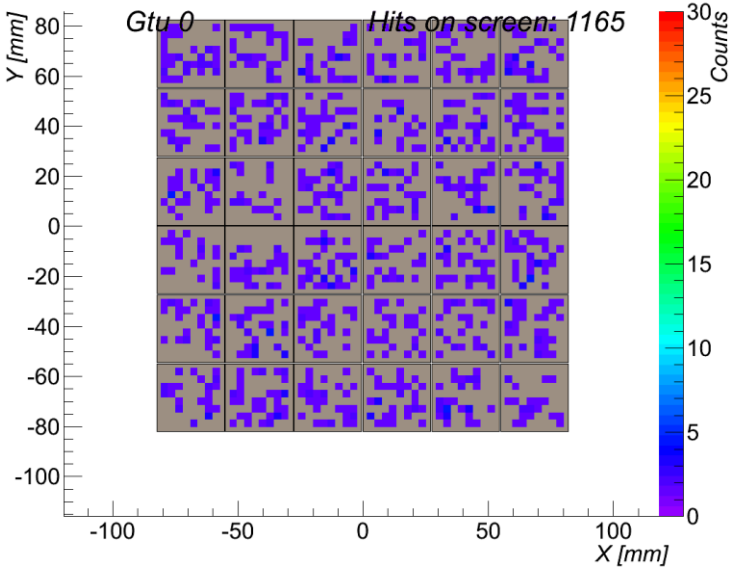


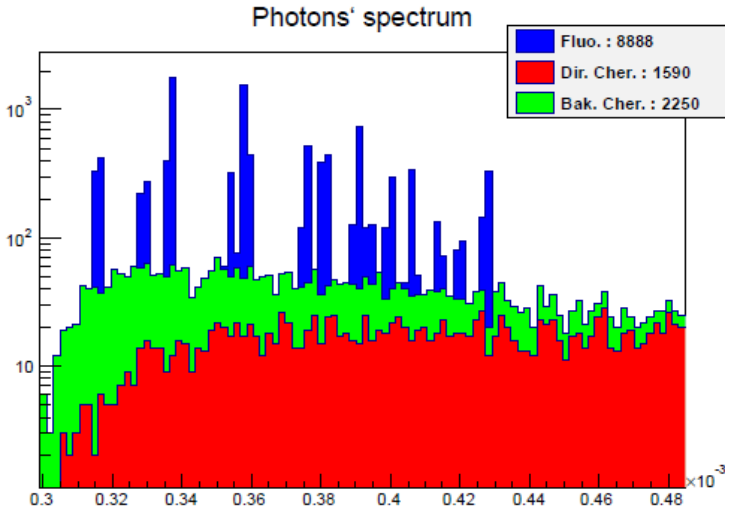

*The EUSO Simulation and Anlaysis Framework has been used for the simulation*

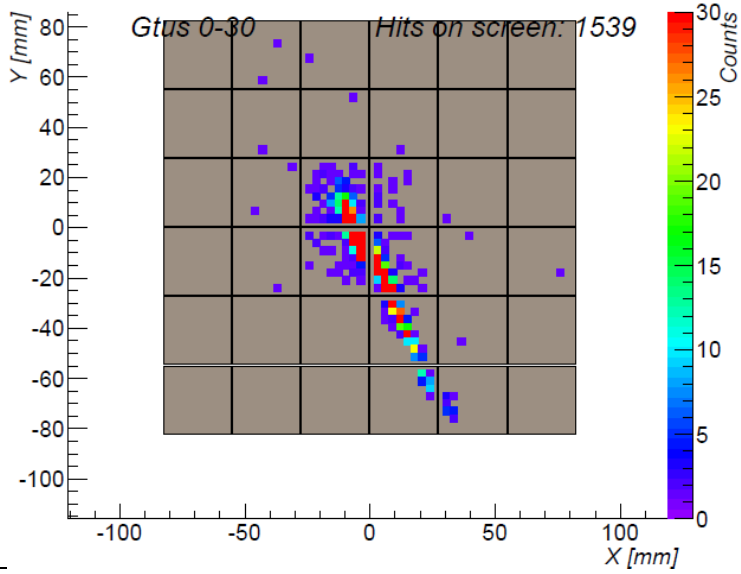
# Example Signal Track

- *Proton*
- *1e19 eV*
- *Theta= 20°*
- *Phi= 135°*

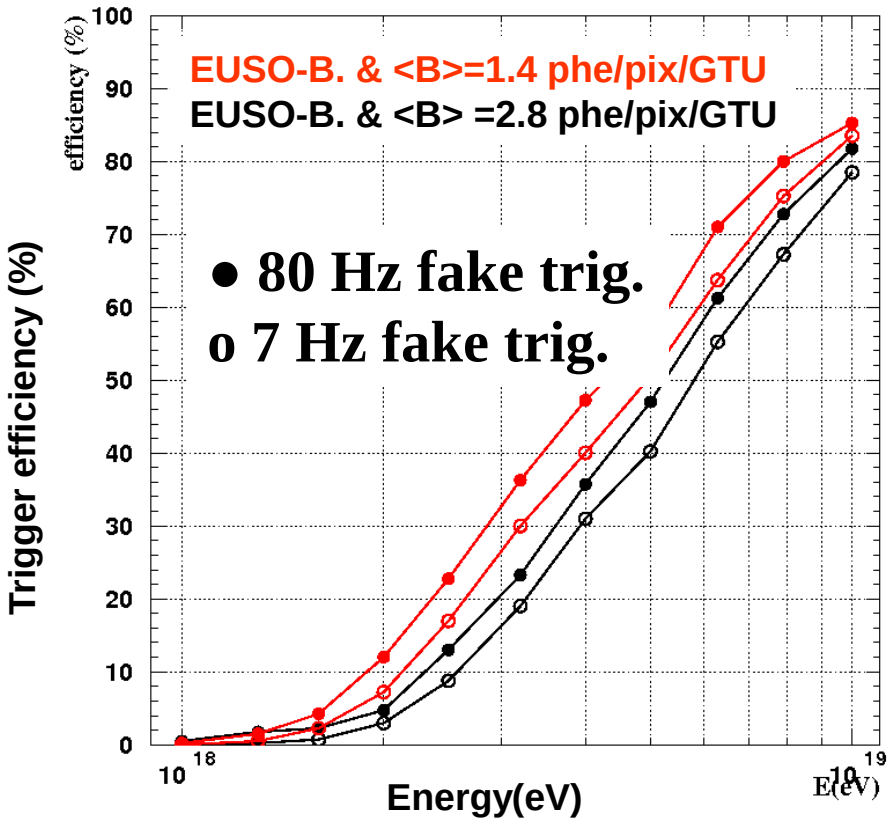


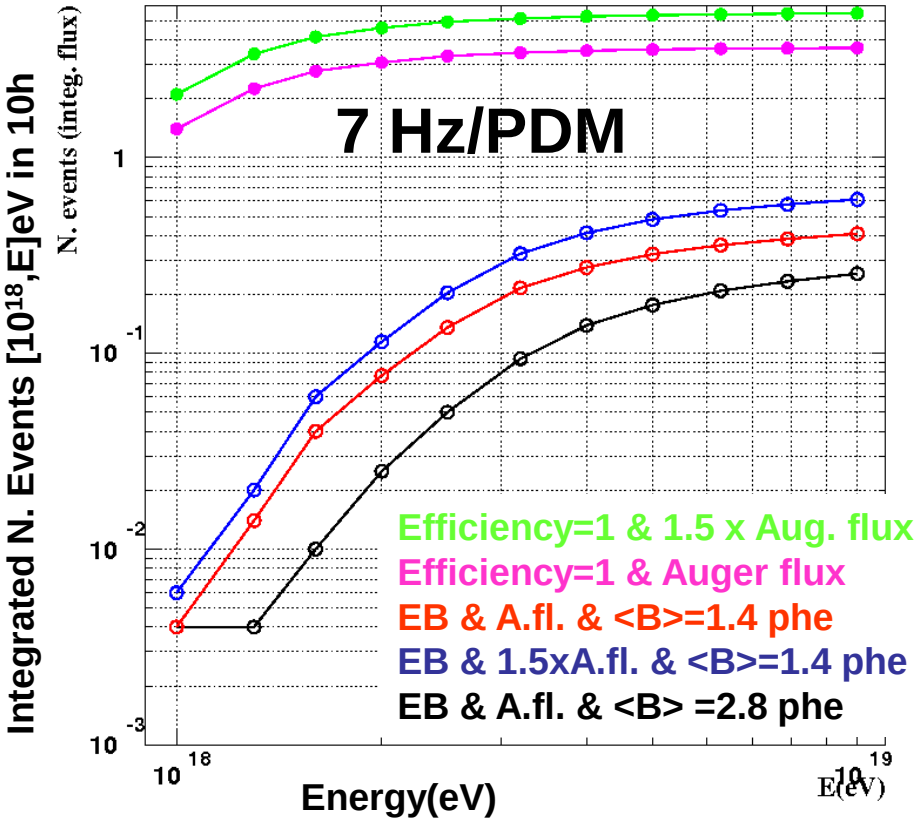



# Trigger Efficiency




LEFT PLOT: *Trigger efficiency curve for events with impact point inside FoV*.
RIGHT PLOT: Black, red and blue curves *give preliminary results on the performance from a 10 h duration flight* for different assumptions of background and cosmic ray flux.

# Conclusions

EUSO-Balloon *will IMAGE the UV sky background* (star light, airglow, TLEs, artificial lights) in the bandwidth used by the JEMEUSO mission.

*All key components and the relative sub-assembly items will be tested* according to the configuration foreseen for the JEM-EUSO mission: in particular *the trigger scheme and its capability to cope with the variable sky conditions*.

*Simulation studies have been performed* to understand the structure of the expected signal and the effective energy threshold of EUSO-Balloon and its possibility to detect Extensive Air Showers. *Results confirm the capability of the instrument of detecting primary cosmic rays of energy* $E>10^{18}$ *eV.*

Due to the low cosmic ray *flux the detection of a couple of events will require few days exposure time* → therefore the detection of the first air shower from the edge of the space will most probably require more than one flight.

Everything is on schedule for the first flight from Timmins (spring 2014)

Thanks