The JEM-EUSO project

Observation of UHE cosmic-rays using a Near-UV Telescope on the Japan Experiment Module of the International Space Station

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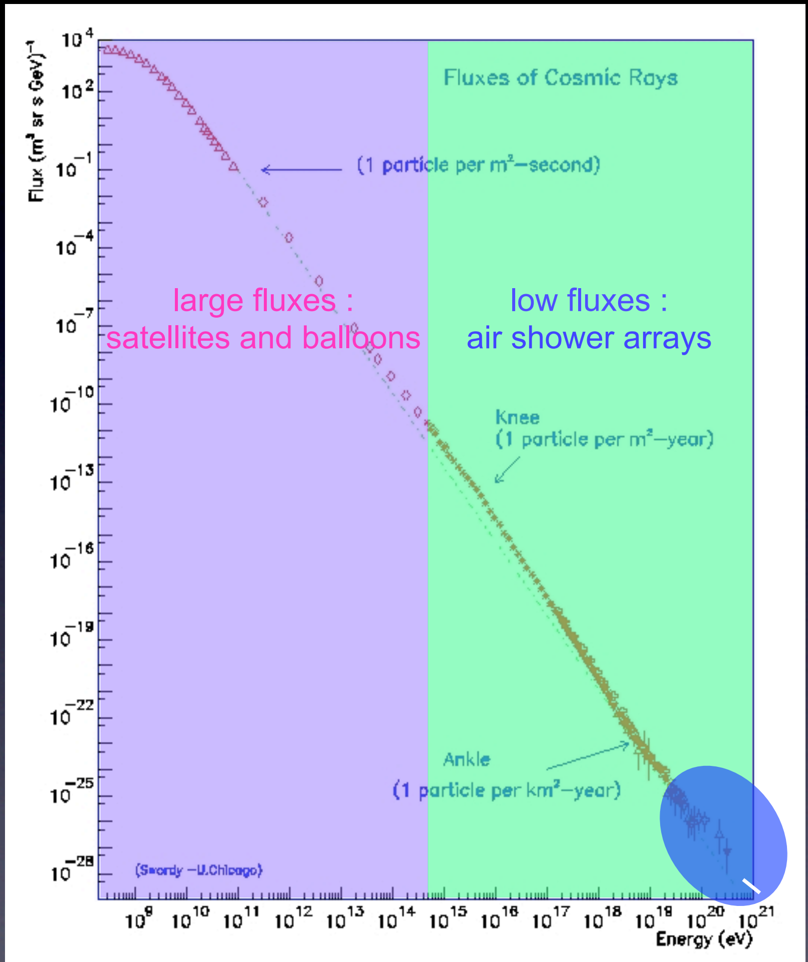
The cosmic spectrum : a 50 years old mystery



Spectrum measured on 12 orders of magnitude in energy and 32 in flux

- At low energy ($<10^{14\text{-}15}$ eV) the fluxes are large -> domain of satellite and atmospheric balloons

- At high energies (low fluxes) one uses air shower properties to detect cosmic-ray -> domain of air shower arrays and fluorescence detector

- At the highest energies ($\sim 10^{20}$ eV), extremely low fluxes (<1 CR.km^{-2}.century^{-1}) -> domain of giant air shower detectors

Should we come back to satellites at the highest energies?

Expected cut-off at the highest energies

Above a few 10^{19} eV, protons and nuclei are expected to interact strongly with photon backgrounds (IR-CMB)

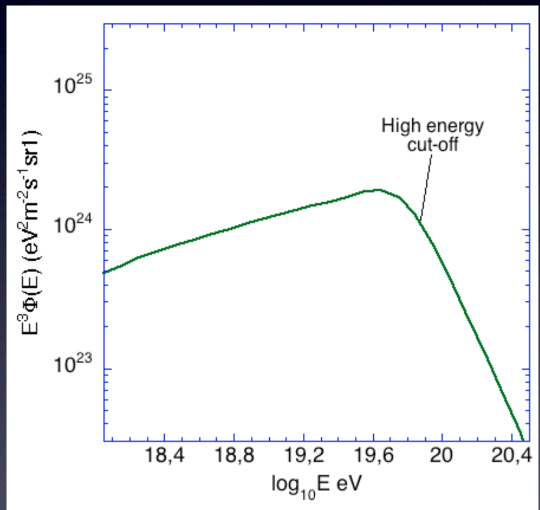
• protons lose energy through the pion production process

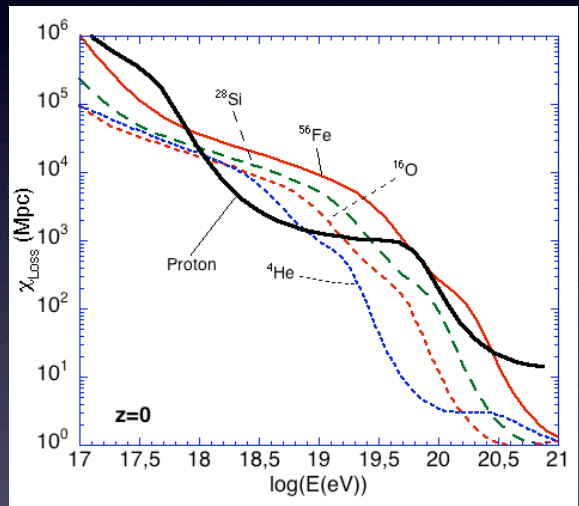
• nuclei are photo-disintegrated through the giant dipole resonance process

➡ above the interaction threshold, the particles horizon is reduced

➡ only nearby sources can contribute at the highest energies

➡ a cut-off is expected in the spectrum (whatever the composition at the sources)





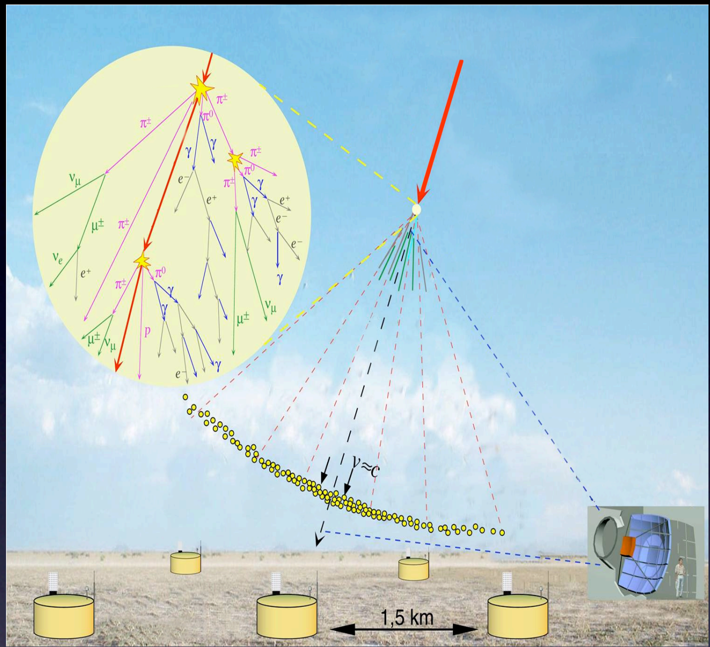
- Energy loss processes isolate the nearby Universe at the highest energies, the sky is supposed to be anisotropic if the sources are somehow correlated with the local matter
- Magnetic deflections are expected to be small at such high energies

➡ if protons are present they should point back to their sources

Drawback : the fluxes are extremely low

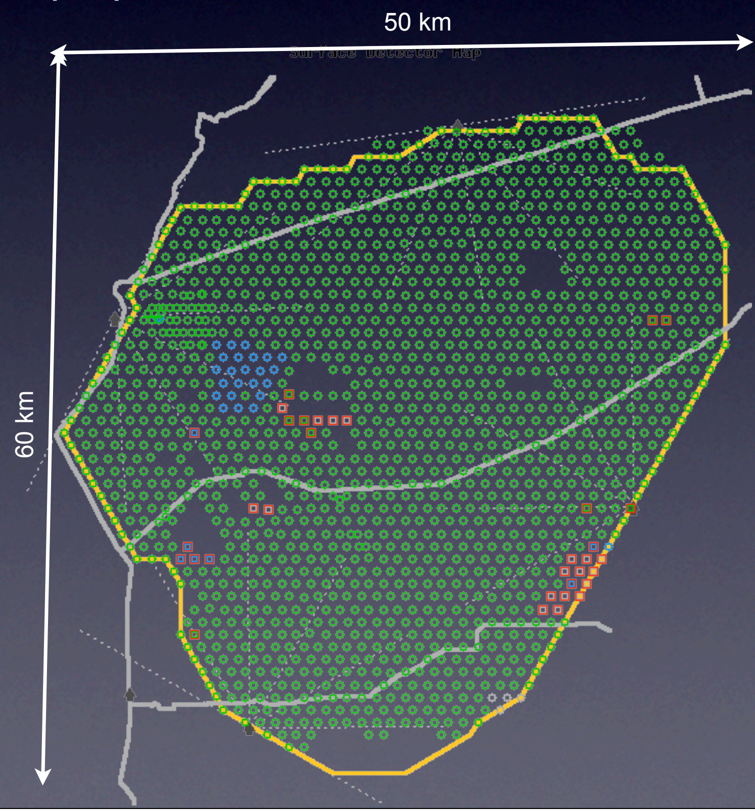
➡ Huge aperture experiments are needed to accumulate statistics

The Pierre Auger observatory : a giant hybrid air shower detector



- Southern hemisphere observatory built in Argentina
- Surface detector : sample the lateral development of the shower at the ground
- Fluorescence detector : measure the longitudinal development of the shower

➡ two independent detector that measure different properties of air showers



•1600 surface detector spread over 3000 km^2

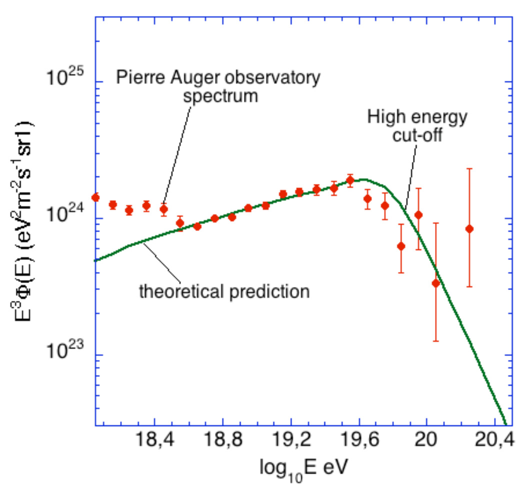
•4 fluorescence telescope

➡by far the largest observatory in the world

➡will provide unprecedented statistics at the highest energies

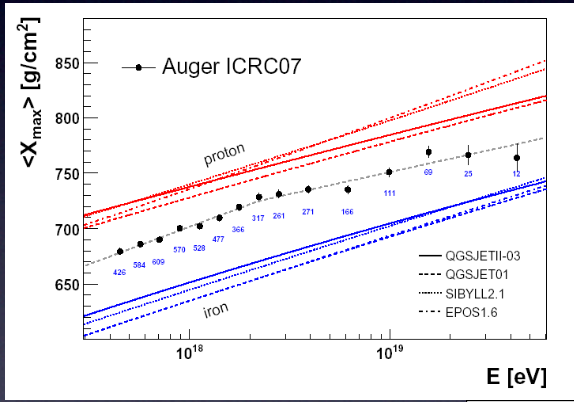
➡hybrid detection for a better understanding of air shower properties

Recent results of the Pierre Auger observatory : is CR astronomy possible?



Auger Collaboration ICRC 2007

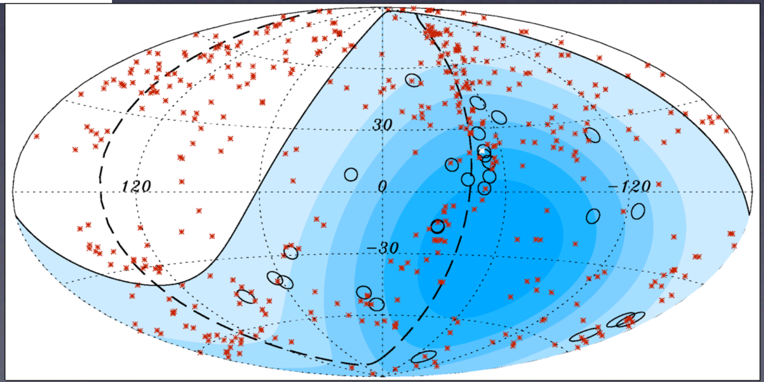
Auger spectrum exhibits a cut-off at the highest energies
This cut-off is expected theoretically



Auger Collaboration ICRC 2007

Composition measurement favor a mixed composition maybe getting heavier at the highest energies

Auger Collaboration science 2007



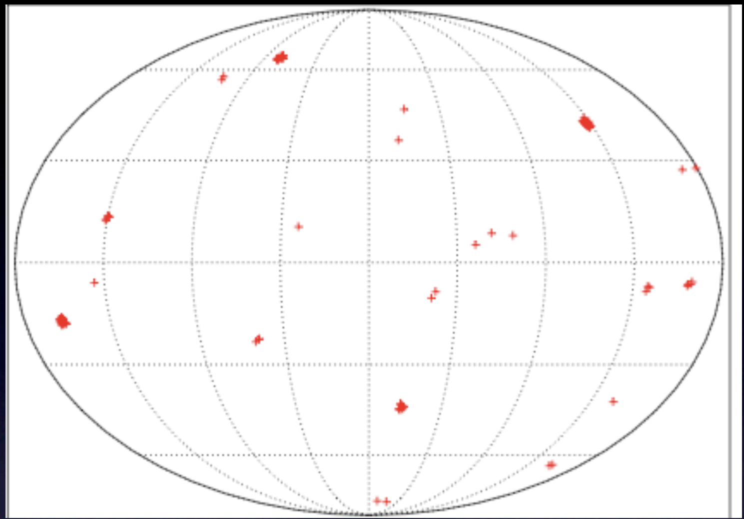
A significant correlation between the arrival directions of the highest energy events and nearby AGN has be shown

➡ the sky is anisotropic at the highest energies

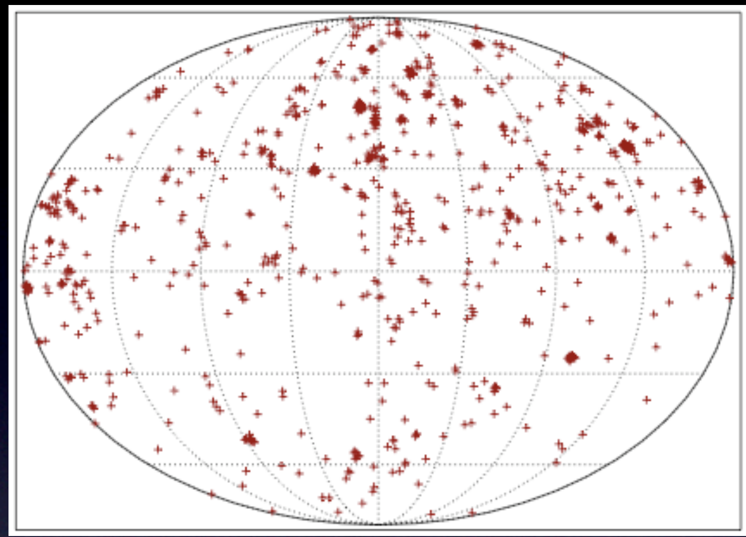
➡ favors CRs coming from extragalactic sources

➡ starting point of the CR astronomy?

The future of cosmic-ray observations at the highest energies



Auger North+South 2014; 10^{-5} source.Mpc^3



Auger North+South 2030; 10^{-3} source.Mpc^3 (source Auger North Design Report)

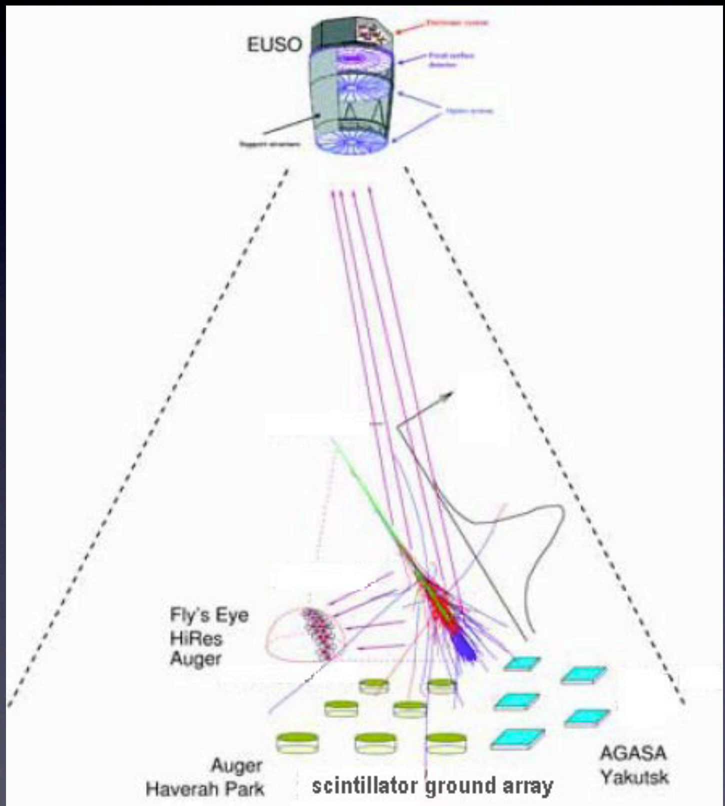
The Pierre Auger observatories, south (3000 km^2) and north (20000 km^2 in colorado) should improve our knowledge of the UHE cosmic-rays origin by :

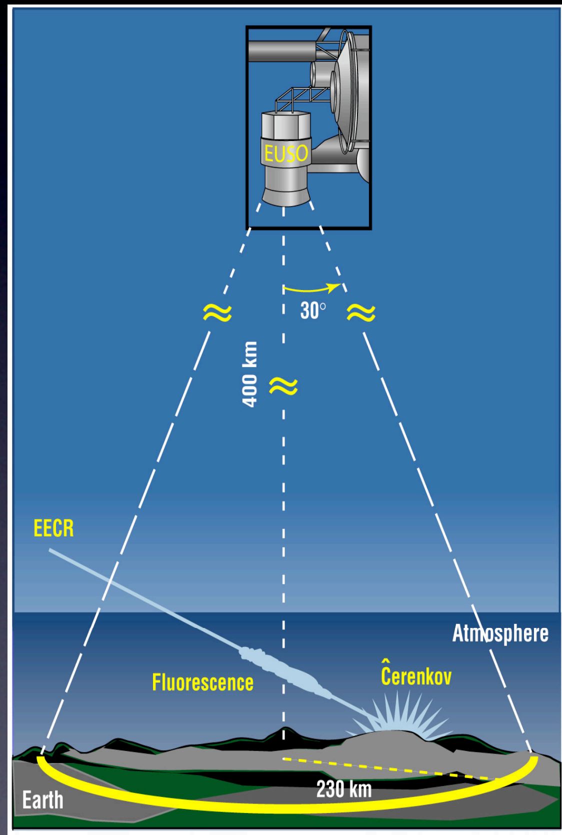
- measuring the CR spectrum up to a few 10^{20} eV
- measuring the CR composition
- constrain air shower physics
- draw detailed sky maps
- maybe estimate individual spectra for a few very bright sources

But Auger certainly represents the limit of what can be done with Air shower arrays
To go further one way is to go back to space

JEM-EUSO : observing UHE cosmic-rays from space

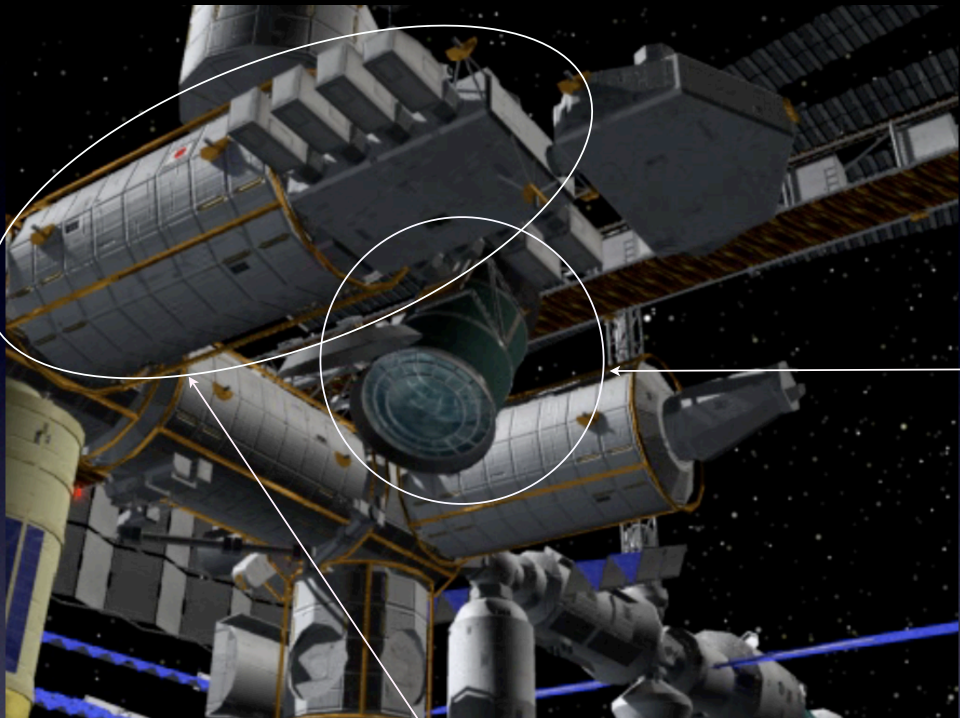
Principle : observing the fluorescence light, emitted during the longitudinal development, from space





Keep the advantage of the fluorescence detection : calorimetric measurement of the energy
Huge field of view

JEM-EUSO : on the ISS



Launch expected in 2013

EUSO

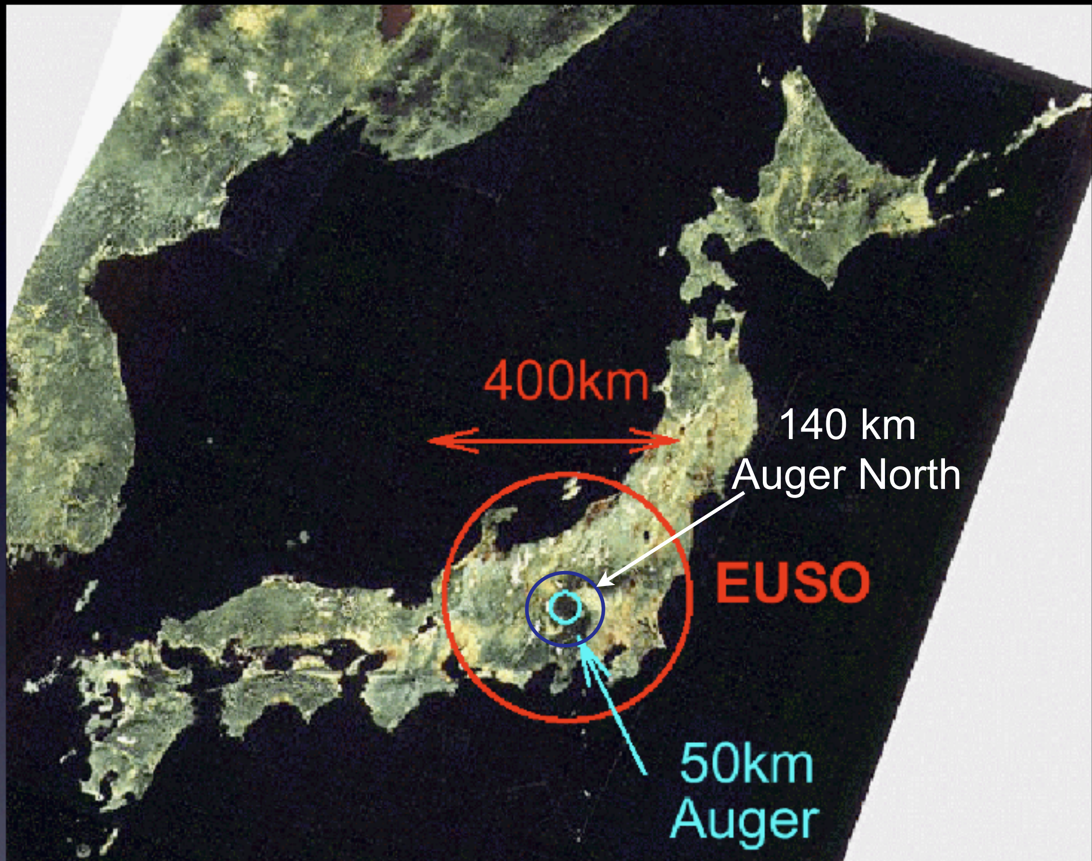
Extreme Universe Space Observatory

accommodated on **JEM** of **ISS**

Japanese Experiment Module

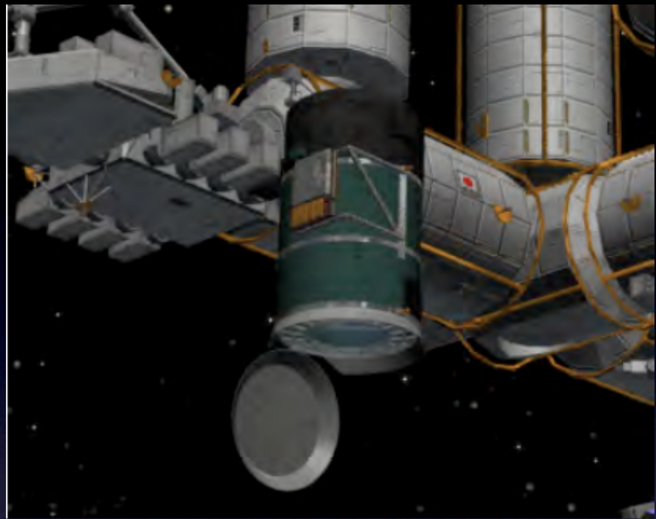
International Space Station

A huge collection area



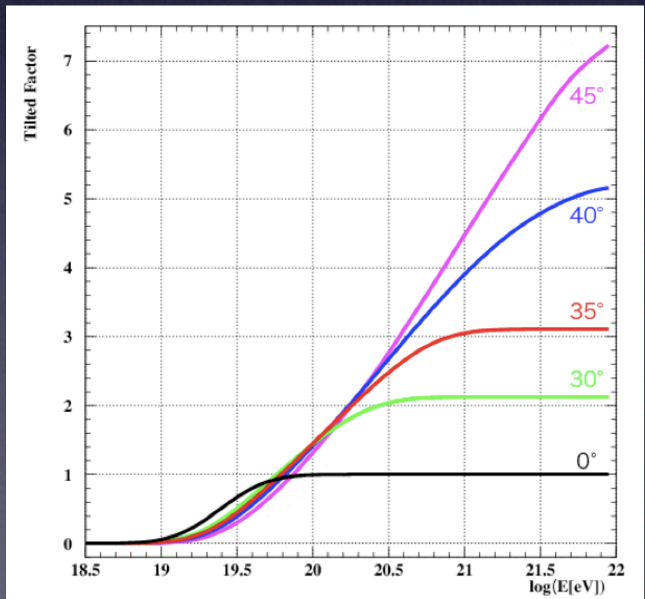
~10 times bigger than Auger South+North
~20% of duty cycle
fully efficient above 10^{20} eV
➡ twice more event per year (20 times for the fluorescence detector)

A tilted mode to increase the statistics



nadir mode

tilted mode



Significant increase of the statistics above 10^{20} eV could be crucial to accumulate statistics at the highest energies

JEM-EUSO : science objectives

- Astronomy and astrophysics of charged cosmic-rays
  - large statistics measurement of the high energy cut-off
  - source identification, individual spectra measurement
  - constraints on acceleration mechanisms
  - composition

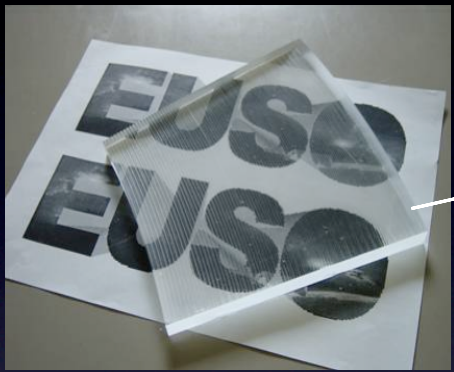
- Identification of photons and neutrinos showers

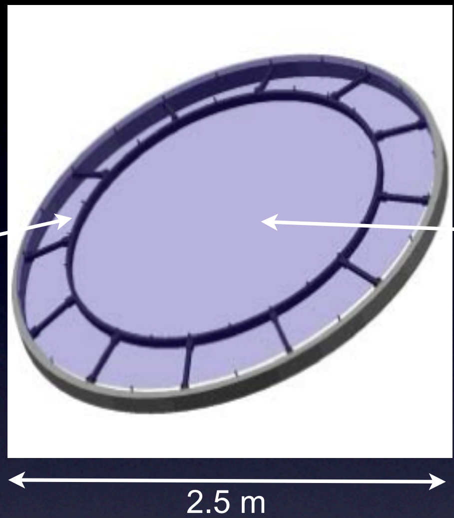
- Constraints on extra-dimensions and quantum gravity

- Global observations of plasma phenomena in the atmosphere

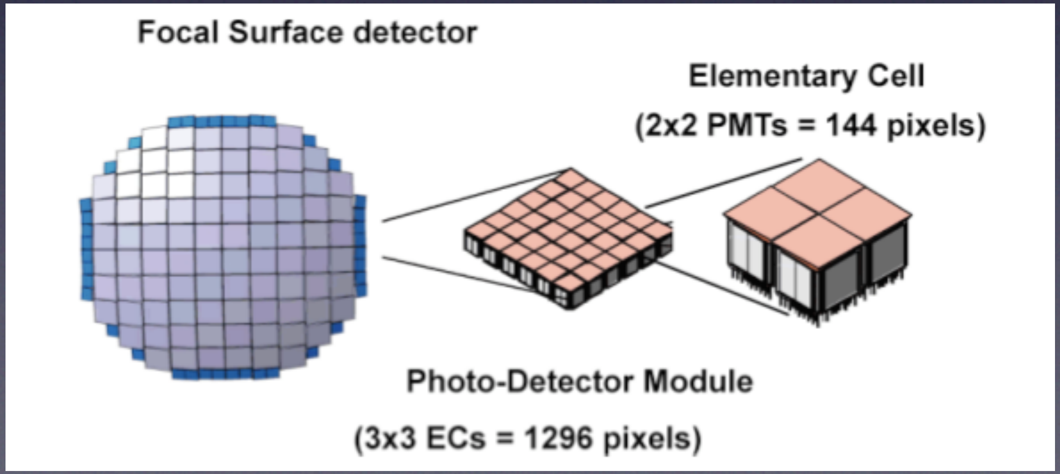
JEM-EUSO : the instrument

Optics : Fresnel lenses; 330-400 nm bandwidth; D=2.5; R=0.1 deg; f=2.5 m





Focal surface detectors : 2.5 m diameter curved surface



Convert the incoming fluorescence photons into electric signals

1 Elementary Cell contains 4 Multi-Anode photomultipliers (MAPMTs) manufactured by Hamamatsu
1 Photo-Detector Module (PDM) contains 9 EC

The focal surface detector is made of about 160 PDMs -> ~6000 MAPMTs

JEM-EUSO : atmosphere and clouds monitoring

- LIDAR :

  - light weight and low power consumption

  - used for cloud monitoring, estimate of the detector efficiency and sea albedo estimates

- IR camera :

  - monitors the temperature of the the top-clouds

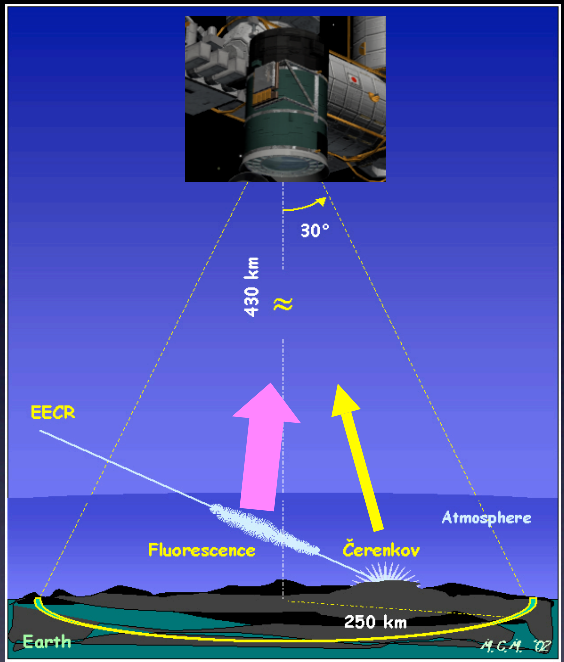
  - combined with LIDAR data to estimate the cloud coverage

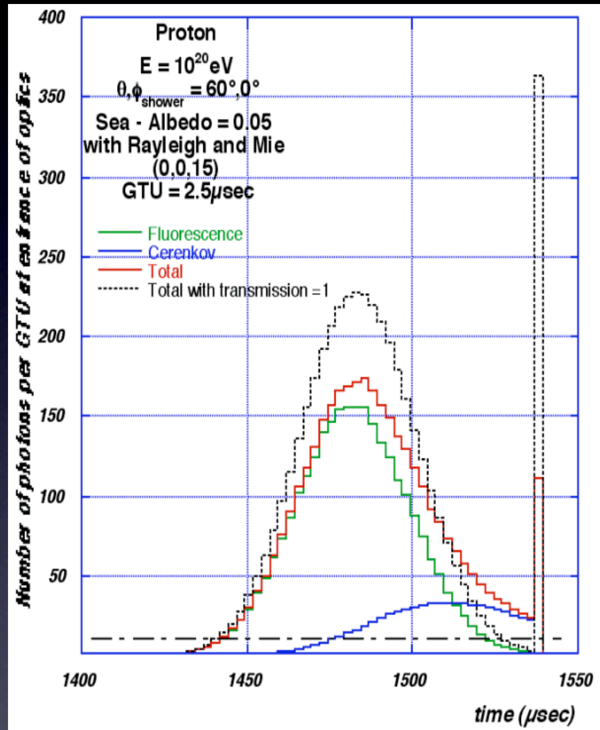
- Slow data

  - photon counting rate each 3.5s can be used to monitor starlight scattering and reflexion by the top-clouds

Expected performances

A typical event :





Resolution :

E~30%

$\Delta\theta$~1-2 deg

ΔX_{MAX}~40-80 $g.cm^2$

International collaboration

March 2008 : 10 countries; 51 institutions; ~130 scientists

- Japan : T. Ebisuzaki, Y. Uehara, H. Ohmori, Y. Kawasaki, M. Sato, Y. Takizawa, K. Katahira, S. Wada, K. Kawai, H. Mase (*RIKEN*), F. Kajino, M. Sakata, H. Sato, Y. Yamamoto, T. Yamamoto, N. Ebizuka, (*Konan Univ.*), M. Nagano, Y. Miyazaki (*Fukui Inst. Tech.*), N. Sakaki, T. Shibata (*Aoyama Gakuin Univ.*), N. Inoue (*Saitama Univ.*), Y. Uchihori (*NIRS*), K. Nomoto (*Univ. of Tokyo*), Y. Takahashi (*Tohoku Univ.*), M. Takeda (*ICRR, Univ. Tokyo*), Y. Arai, Y. Kurihara, H.M. Shimizu, J. Fujimoto (*KEK*), S. Yoshida, K. Mase (*Chiba Univ.*), K. Asano, S. Inoue, Y. Mizumoto, J. Watanabe, T. Kajino (*NAOJ*), H. Ikeda, M. Suzuki, T. Yano (*ISAS, JAXA*), T.Murakami, D. Yonetoku (*Kanazawa Univ.*), T. Sugiyama (*Nagoya*), Y. Ito (*STEL, Nagoya Univ.*), S. Nagataki (*YITP, Kyoto Univ.*), A. Saito(*Kyoto Univ.*), S. Abe, M. Nagata (*Kobe Univ.*), T. Tajima (*KPSI, JAEA*)、M. Chikawa (*Kinki Univ.*), and M. Tajima (*Hiroshima Univ.*)
- USA : J. H. Adams Jr., S. Mitchell, M.J. Christl, J. Watts Jr., A. English, R. Young (*NASA/ MSFC*) , Y. Takahashi, D. Gregory, M. Bonamente, K. Pitalo, J. Hadaway, J. Geary, R. Lindquist, P. ReardonT. Blackwell (*Univ. Alabama in Huntsville*), H. Crawford, E. Judd, C. Pennypacker (*LBL, UC Berkeley*), K. Arisaka, D. Cline, J. Kolonko, V. Andreev (*UCLA*), A. Berlind, T. Weiler, S. Csorna (*Vanderbilt Univ.*), R. Chipman, S. MaClain (*Arizona*)
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- Republic of Korea : S. Nam, I. H. Park, J. Yang (*Ehwa W. Univ.*)
- Russia : Garipov G.K., Khrenov, B.A., Klimov P.A. Panasyuk M.I., Yashin I.V. (*SINP MSU*), D. Naumov, Tkachev. L (*Dubna JINR*)
- Switzerland : A. Maurissen, V. Mitev (*Neuchatel, Switzerland*)
- Spain : D.Rodriguez-Frias, L.Peral, J.Gutierrez, R.Gomez-Herrero (*Univ. Alcala*)

Proposed contribution of the French collaboration

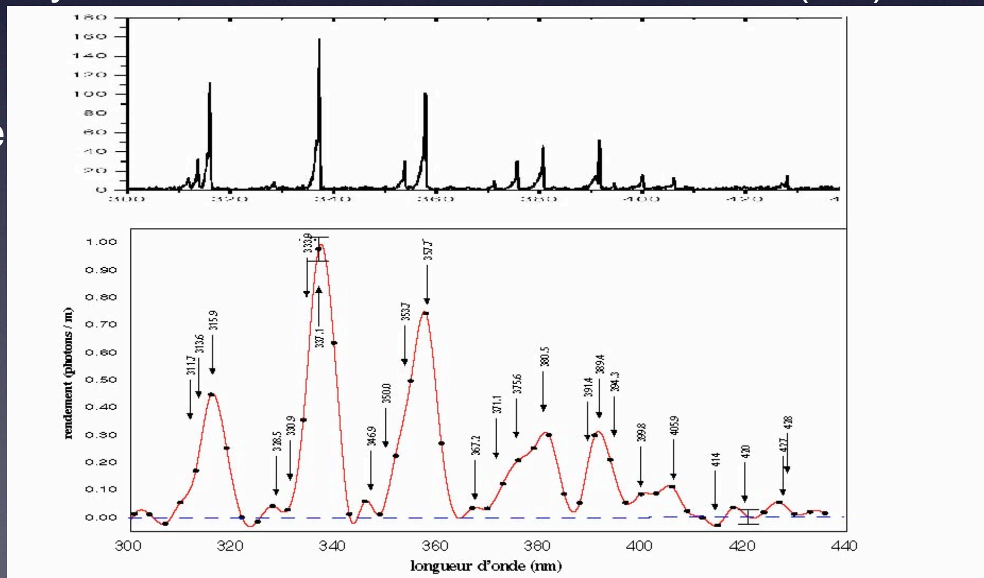
✳Estimate of the UV fluorescence yield :

- Number of fluorescence photons emitted by a relativistic electron in the air per unit path length -> proportionality between the number of fluo. photons and number of electrons in the shower

- Main source of systematics on the energy for fluorescence based experiments

- Patented method to calibrate the photodetectors (at 1.5%) is used (Lefeuvre and Gorodetsky 2006) -> lowest claimed systematics measurement in the market (5%)

- A measurement for different conditions of pressure, temperature and humidity is proposed



Proposed contribution of the French collaboration

✴Calibration of the focal surface detector pixels

✴ PMTs High voltage distribution

✴ Purchase of the infra-red camera

✴ Software :

- State of the art transport code of CRs (proton, nuclei, neutrinos)
-> contribution to the science case and interpretation of the data

- Theory of hadronic interaction and dedicated air shower simulations for EUSO

- Participation to the end-to-end simulation

Outline

- Observing giant air shower from space is a promising technique to accumulate statistics at the highest energies and do CR astronomy
- JEM-EUSO represents a pathfinder for this technique and should improve our knowledge of UHECR origin
- France has to be part of it !