

Measurement and Modelling of the Atmospheric Radiative Environment

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Context

Extensive Air Shower (EAS):

- Protons and ions from outer space
- Create secondary particles → the earth radiative environment

Hazards in electronic devices:

- Single Event Effect (SEE)
- Neutrons and protons
- Cellphones, planes, drones, balloons, ...

Needs :

- Quantify the population of particles in the Atmosphere
- **Why ?** → Risk calculations and design equipment protected against radiation hazard

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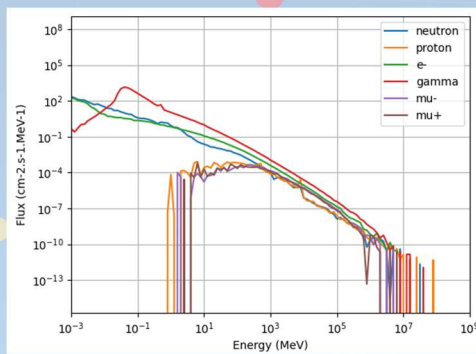
Modelling

EAS complex phenomenon :

- Billions of secondary particles
- Neutrons, electrons, photons, muons, pions, ...
- From atomic scale to planetary scale
- Primary energy from 10⁶ to 10¹⁸ eV

Difficult to modelize:

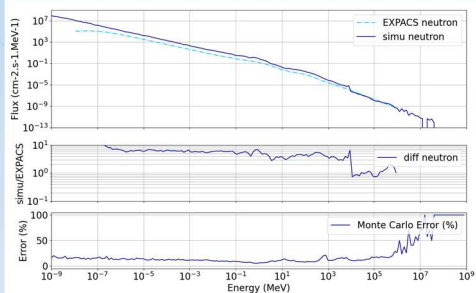
- Colossal Monte Carlo simulation of the Atmosphere
- Between Newtonian and relativistic physics



Simulation at 18 km with our model

Model results :

- Good correlation with exact → less than a factor 10
- Good Monte Carlo Error → around 10%



Comparison at 18 km of our simulation and EXPACS

Measurement

2021 – Creation of an instrument :

- BRAD (Balloon Radiation Analysis Device)
- Interface various radiation experiments with CNES balloons gondolas.

2022 – Addition of PIX particle detector :

- Used alone → PIX-SOLO
- Or embedded in BRAD → BRAD-PIX

Both instruments flew on stratospheric Balloons up to an altitude of 35 km.



BRAD-PIX on table

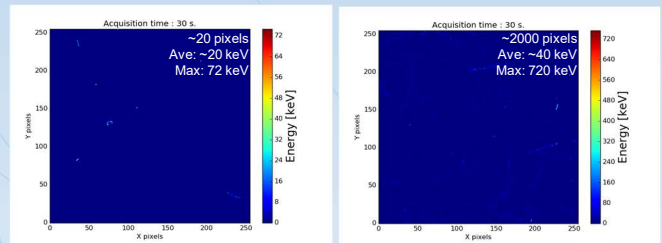
PIX-SOLO in its box

BRAD-PIX and PIX-SOLO integrated on Hamera3

Hamera3 launch © CNES

2000 spectrometer images collected:

- Data analyze still ongoing
- Two PIX images at different altitudes 0 and 25 km
 - Left : 20 pixels activated, max 72 keV
 - Right : 2000 pixels activated, max 720 keV



PIX image at 0 km

PIX image at 25 km

Perspectives

The measurement from the flights in Timmins (Canada) in August 2022 allowed us to collect more than 2000 spectrometer images with different time frames at different altitudes.

From them, we plan to extract an energy spectrum of particles below 35 km.

The final step will be the comparison of measurements with the model results.