Probing Cosmic Ray Detection at GHz Frequencies using IAR 30m Radiotelescope

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Ultra High-Energy Cosmic Rays (UHECR)

- Messengers from the most energetic objects in the universe.
- Only way to test the p-p cross section above LHC energies.
- Very low flux(1part/km^2/yr) due to the interaction of UHECRs with CMB.
- A Challenge to do Particle Astronomy!

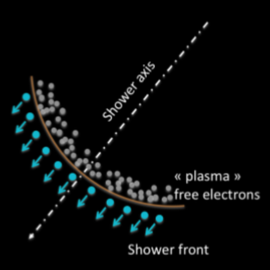
Argentinian Low-cost Atmospheric Molecular Bremsstrahlung Radiation Experiment

Limitations of Current Techniques

- The Pierre Auger Observatory and Telescope Array currently lead the Field.
- Design based on surface particle detectors and fluorescence telescopes.
- Surface detectors are expensive, and difficult to deploy over large areas.
- Fluorescence telescopes are very expensive, and require clean moonless nights to operate reducing their duty cycle to 10%.
- Research is underway for low-frequency (MHz) radio detection. This technique is promising but requires a high number of stations and relies on simulations or cross calibration with other techniques to estimate the UHECR energy.

The Molecular Bremsstrahlung Radiation (MBR) Promise

- Free electrons interact with air molecules giving MBR at microwave (GHz) frequencies.
- Unpolarized, isotropic emission that scales with the number of particles and thus the energy in the cascade.
- Initial lab measurement at SLAC T471 experiment by Gorham [1] detected a strong signal @ 1.5-6 GHz, and ensued a series of experiments to detect this radiation on the field with inexpensive satellite communications hardware.

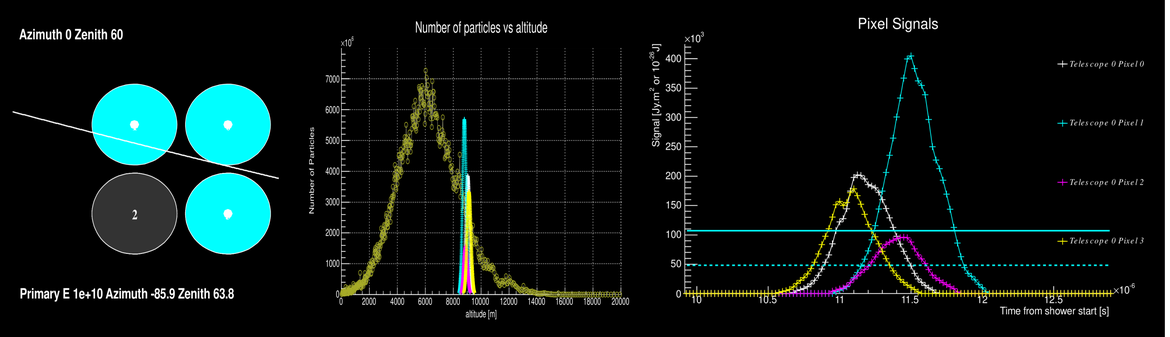


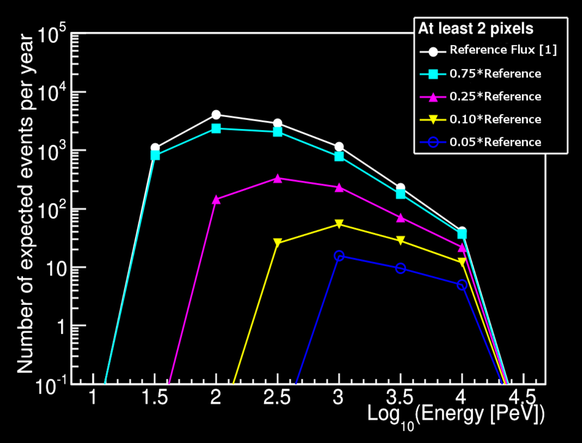
- None of them could make an unambiguous detection!. Sensitivity too low?
- Independent measurements in other accelerators gave controversial results.

The Experimental Design

- Use IAR 30m dish to achieve unprecedented sensitivity.
- Use a Multi-Pixel array feed based on Digestif/Apertif design at ASTRON [2].
- Test Initially with a 4-pixel/dual polarization camera to scale up to 100 pixel.
- Detector based on Software Defined Radio technology (See our posters [3] [4]).

Expected Results from Simulations





Could we detect it?

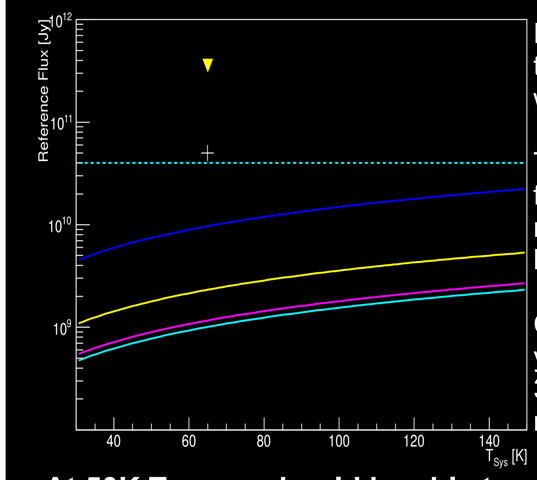


Figure shows the no-detection limit that could be set to the MBR emission from cascades that could be set with the 4-pixel ALAMBRE as a function of the T_{sys}

The dotted line represents the emission level derived from Gorham [1] beam measurement , the triangle the no detection limit set by MIDAS and cross the hypothetical limit set by 1 year of MIDAS operation

Colored lines indicate the limit that could be set by 1 year of ALAMBRE operation for 1 (cyan), 2 (magenta), 3 (yellow) and 4 (blue) simultaneous pixel triggers if no detection is made

At 50K T_{sys} we should be able to see some events even if the emission is 100 times less intense than reported in [1] !

References

[1] P.W. Gorham et al., Phys. Rev. D 78, 032007 (2008)

[2] https://www.astron.nl/general/apertif/apertif

[3] Gancio et al. “Pulsar radio observations using SDR”, this conference

[4] Gancio et al, “Hydrogen Observations using SDR and the IAR1”, this conference