MonRAt: a compact telescope for atmospheric radiation

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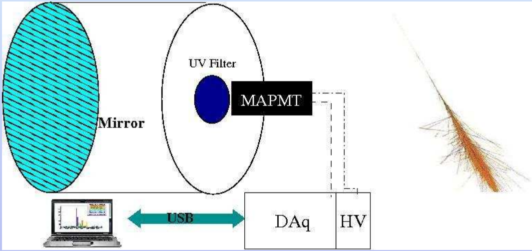
Outline

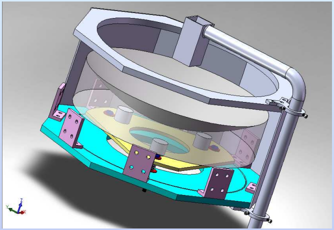
- MonRAt;
- Ray tracing;
- Project;
- Ray tracing;
- Simulations;
- DAq system;
- Software;
- SPE/Gain;
- Future.

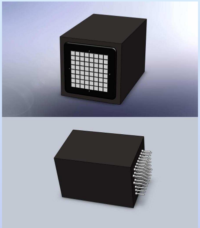
Monitor de Radiação Atmosférica (MonRAt)



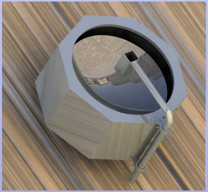
The MonRAt concept.

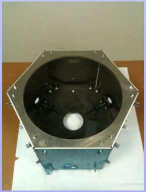
Project and assembled structure

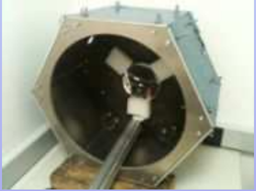




Solid Works models for the telescope and the MAPMT.

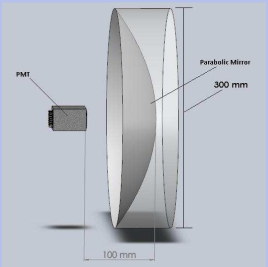


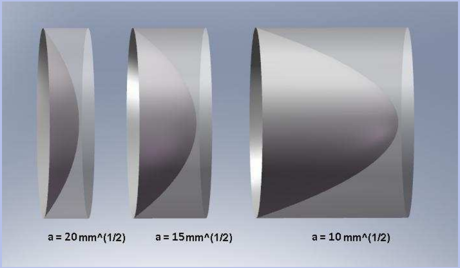




An artistic view of MonRAt and photographies of the assembled strucuture.

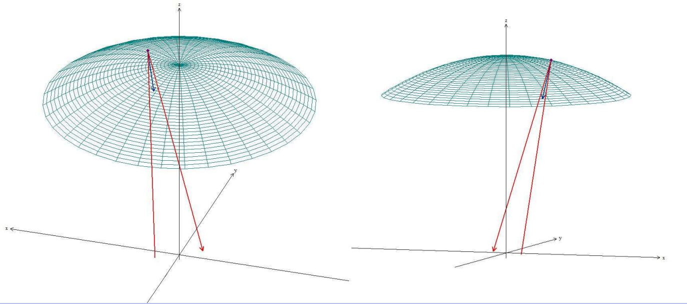
Optics geometry





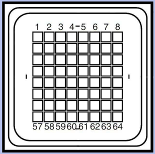
We simulated parabolic mirrors with equation $a^2 z = (x^2 + y^2)$, where the chosen concavity factor was: $a = 20\sqrt{mm}$

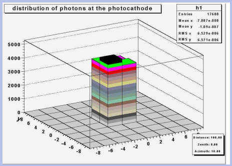
Ray tracing



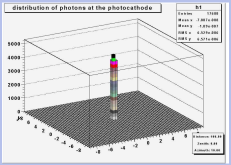
A object-oriented software with 3 classes: mathematics, geometry and optics.

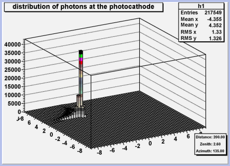
Ray tracing





Map of pixels (8 $\times$ 8).

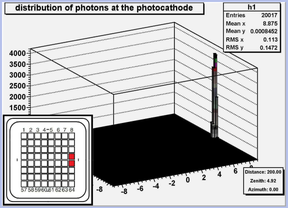




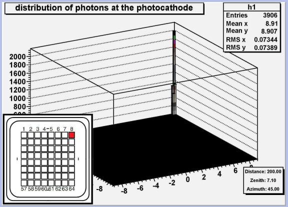
Arbitrary resolution (spot area $\ll 2 \times 2\text{mm}^2$).

Ray tracing

Field of view



$$\theta \leq \pm 4.9^{\circ} \Longrightarrow \Omega_{pixel} = 1.44 \times 10^{-4}\ sr$$



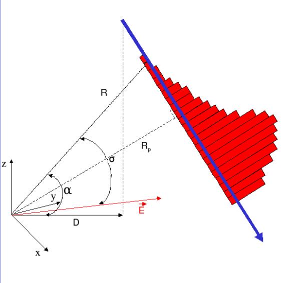
$$\theta \leq \pm 7.1^{\circ}$$

CORSIKA simulations:

We simulated proton-induced showers with:

- Energies: 10^{17}, $10^{17.5}$,10^{18}, $10^{18.5}$, 10^{19}, $10^{19.5}$, 10^{20} eV ;
- Zenith angle $0^o < \theta < 60^o$;
- Thinning factor of 10^{-5};
- Longitudinal (vertical) steps of 5 g/cm^2.

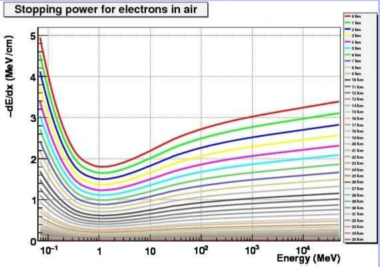
10^3 showers for each energy



Mirror and shower geometries ($D \leq 10$ km).

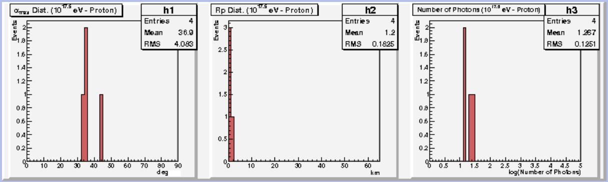
Energy deposit and fluorescence light generation

- The number and the energy of electrons and positrons have been read for each longitudinal step;
- A standard parameterization of the atmosphere has been used;
- For each particle a Bethe-Bloch equation is used to calculate the deposited energy:

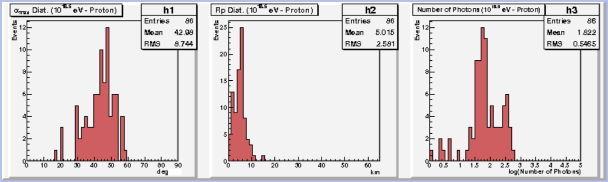


- The fluorescence photons yield is calculated though Nagano parameterization;
- Number of photons impinging the telescope: $N_{\gamma}^{tel} = N_e \cdot FY(K_e, \rho, T, \lambda) \cdot \Delta x \cdot T^m \cdot T^a \cdot \frac{\Omega_{mirr}}{4\pi}$.

Results

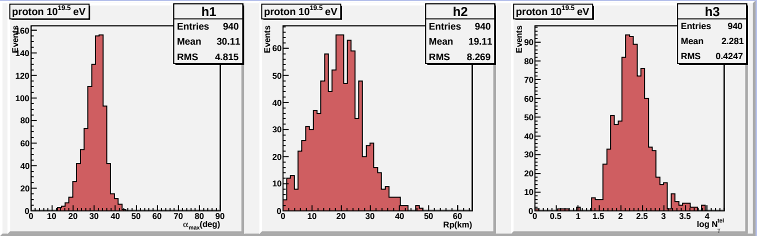


Distributions for 10^3 proton showers of $10^{17.5}$ eV.



Distributions for 10^3 proton showers of $10^{18.5}$ eV.

Results



Distributions for 10^3 proton showers of $10^{19.5}$ eV.

The simulations showed:

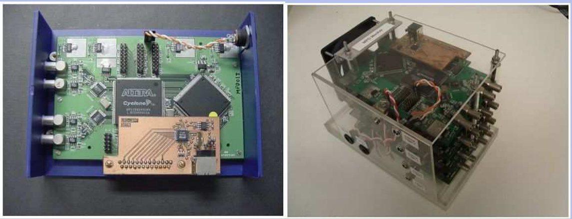
- Threshold: $E > 10^{17.5}$ eV;
- Range: ~ 40 km;
- Set the dynamic range to $\sim 10^2$ of photons;
- For $-4{,}9^\circ < \theta < 4{,}9^\circ$ the solid angle viewed by one pixel is $\Omega_{pix} = 1.44 \times 10^{-4}$ $srad$;
- One pixel views a shower with maximum depth 1 km away developing in 71.2 ns and 21.35 m.

Data Acquisition System

The DAq consists of sets of pre-amplifiers in the front-end of the MAPMT:

Pre-amplifiers set.

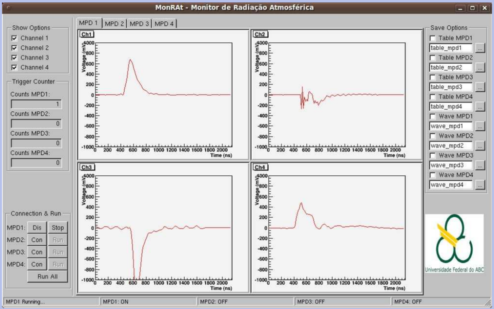
and FPGA-based boards (called MPDs) able to record trigger times and waveforms from each channel and send the data to a computer by USB ports:



Left: a photography of 1 FPGA-board. Right: the setup for 16 channels.

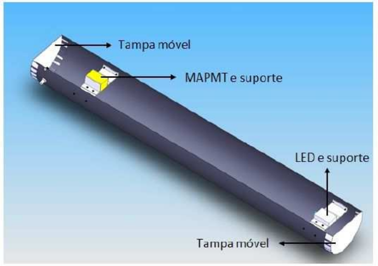
Software

- A object-oriented software developed using the ROOT framework and the library for the USB transceivers;
- Event counters for each device are shown on the screen and a status bar displays terms of connections and messages to the user;
- Options for displaying graphics and writing to files (waveforms or tables), chosen by the user via checkboxes;
- Data generated in these output files will be used to reconstruct the events.

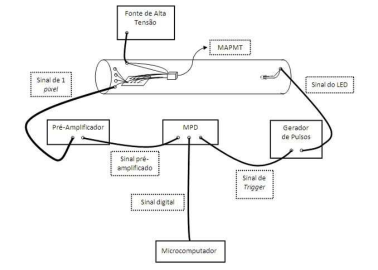


Graphical interface of the data acquisition software.

Setup for measuring the single photoelectron spectra and the gain



(a) Dark chamber.

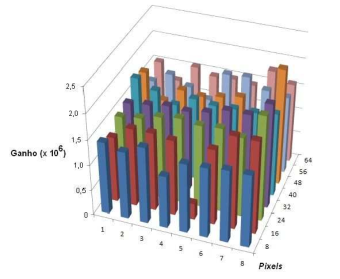


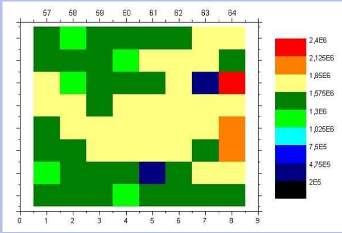
(b) Setup for characterization of the MAPMT.

SPE/Gain

Gain of MAPMT's pixels

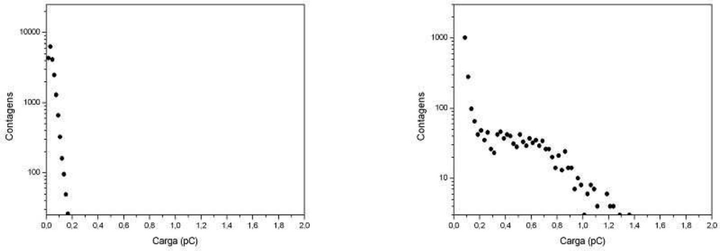
$$G = \frac{Q_{sig}}{Q_{1pe}} = \frac{\int i(t)dt}{1{,}6\times 10^{-19}\ \mathrm{C}}$$





Map of the gains of individual pixels.

Single photon spectra



(a) *Pixel* 47 (b) *Pixel* 48

Single photon spectra of 2 representative pixels.

Future

- Complete the DAq system by the end of this year;
- Start taking data in Brazil in 2012;
- Take it to Malargüe in 2012.

Brazilian dark nights