A Radiation Monitor for space applications - #268

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Abstract

The Radiation Monitor (RadMon) consist of a telescopic arrangement of high Z absorbers and plastic scintillators coupled with silicon photomultipliers (SiPMs). The SiPM signals are processed and digitized with the BETA ASIC, which was specifically designed for SiPM readout in space applications. The monitor will output proton detection rates in a set of integral energy channels with expected thresholds ranging from 70 MeV to 1GeV. Here, I describe the design of the prototype built and the preliminary results of the performance evaluation from dedicated beam tests and ad hoc MonteCarlo simulations made in the framework of my PhD project research.

Some spacecraft failures can be directly attributed to intense radiation exposure ($10^8 - 10^7$ $protons\ cm^{-2}$ in 1 year between 100 and 500 MeV), which affects the on-board electronics by causing radiation damage or spacecraft charging. A monitor of the radiation environment becomes essential to understand and calibrate the impact on human activities in space. **Radiation Monitor (RadMon) main objectives**:

- ❑ Measure the integral proton flux with a reasonable statistical error within ~1 hour.
- ❑ Have modest energy resolution to distinguish SEPs from CR spectral shapes.
- ❑ Monitor protons with energies higher than tens of MeV.

Prototype and readout electronics

- The RadMon

  The prototype built consist of:
  - Four 2x2 cm^2 scintillator tiles, 3mm width.
  - Three tungsten blocks of width 1,2 and 4 cm in telescopic arrangement.
  - 6 mm of copper before the first tile.
  - 2 3x3 mm^2 FBK NUV-HD RH SiPMs per Tile, solded with a PCB ensuring the connection with the readout electronics.

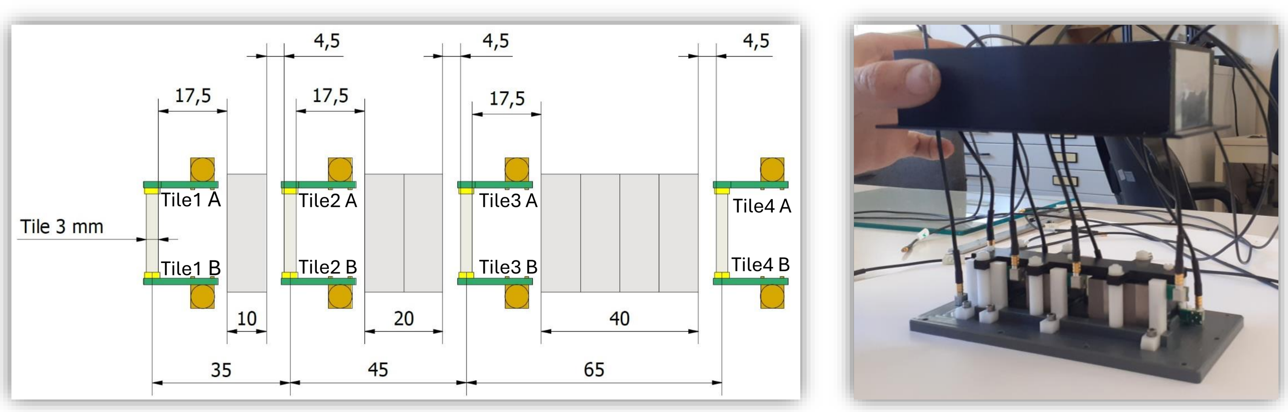

Figure 1. RadMon schematic (left). All the sizes are expressed in millimeters. Photo of the RadMon (right).

Except for the copper block, all the prototype was mounted in a 3D printed box functioning both as support and black-box.

- The BETA readout

  Developed at ICCUB (Institut de Ciències del Cosmos Universitat de Barcelona), it is in charge of:
  - ❑ Signal processing and shaping with multi-gain system .
  - ❑ Triggering, max trigger rate ~ 10kHz.
  - ❑ Digitization.

  It's features, like low power consumption or high channel density per ASIC, are optimized for SiPM readout in space applications.

Beam Test at CNAO

The CNAO (National Centre for Oncological Adrotherapy) is a facility for hadron therapy for treating solid tumors located in Pavia. Beam properties:

- High intensity beams of proton (60-250 MeV) and carbon ions (120-400 MeV/u).
- Beam transverse size ~ 5 mm.

April 2024 beam test setup:

- ➢ Scintillating Fiber tracker (SciFi).
- ➢ Trigger module (TRG) with two 10x10 cm^2 tiles. The first as trigger tile and the second one, with a 3 cm diameter hole in the center, used as veto.
- ➢ RadMon.

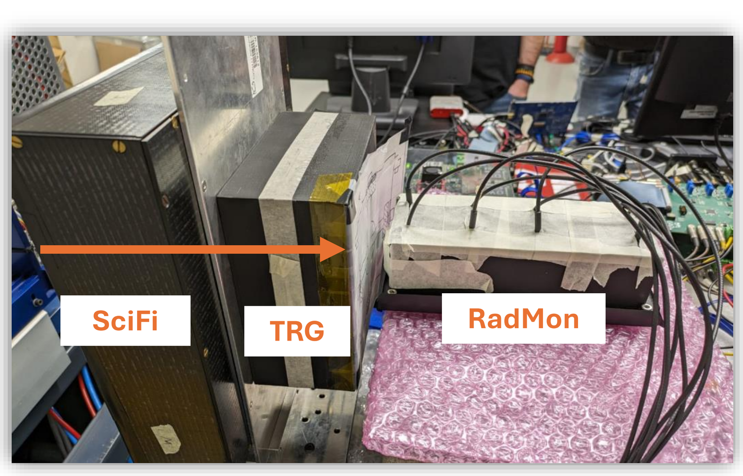

Figure 2. CNAO beam test setup. The RadMon was placed immediately afterwards the trigger module.

Acknowledgements

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Test results and Simulation

The beam test at CNAO has been carried out as follows:

- ✓ Optimization of the working point with a BETA gain configuration scan.
- ✓ Energy scan from the maximum proton energy available 227 MeV down to 70 MeV.

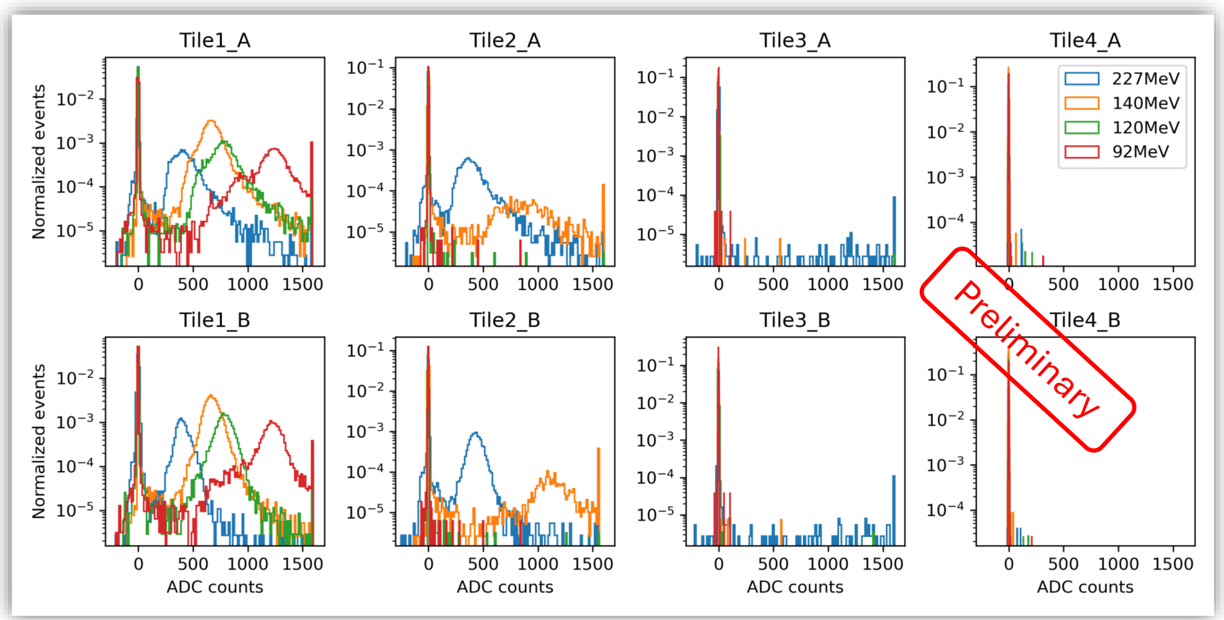

Figure 3. ADC count spectrum of the RadMon channels at different proton energies. The order of the tiles and SiPMs is the same shown in Figure 1.

A spectrum in ADC counts at different proton energies and for all the SiPMs has been obtained. A and B are used to distinguish the side of the tile where the SiPM is mounted.

From this spectrum it can be noted:

- The pedestal is due to the inefficiency of the TRG system. It can be reduced taking into account also the Fiber Tracker information (TBD).
- No proton reach the last tile, regardless of the energy.
- 227 MeV protons fire the third tile.
- 92 MeV protons are stopped in the first tungsten block.

At the lowest energy tested, 70 MeV, only 2% of the total events deposited energy in the first tile since they are absorbed in the 6 mm copper absorber.

To verify these results, a dedicated simulation has been set up with the GEANT4 toolkit. From the simulation, the minimum energy for the protons to reach the first tile is 60 MeV.

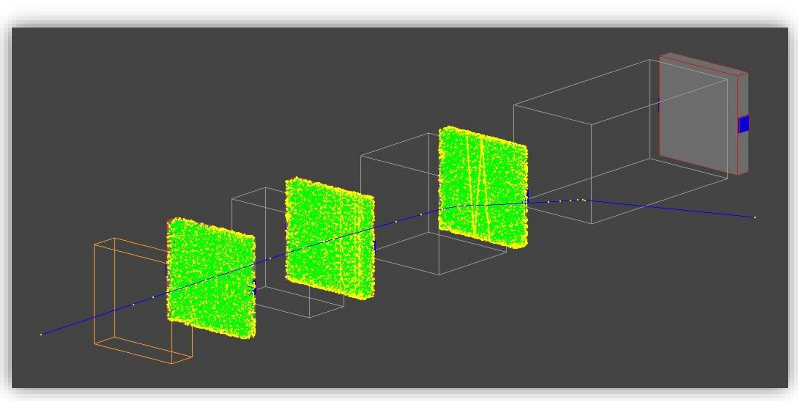

Figure 4. Simulation of a 400 MeV proton impinging on the RadMon along the beam line. The fired tiles stand out because of the green lines representing the scintillating photon trajectories.

Considering the energies tested:

- ❑ The maximum peaks in the ADC counts spectrum have been fitted. Results shown for the front tile SiPMs (orange and blue dots).
- ❑ The simulated deposit energy spectrum in the first scintillator has been fitted (green triangles).

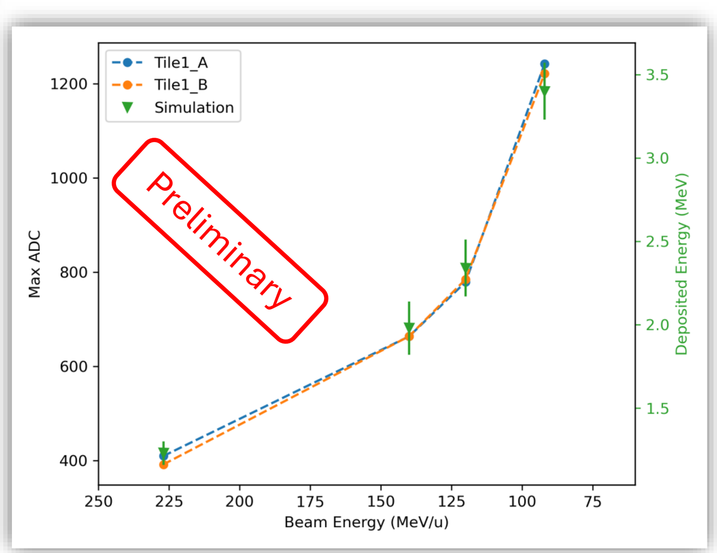

Figure 5. Most probable deposit energy for the first tile, from beam test and from simulation. Dotted lines are just connecting data points to guide the eye.

As shown in Figure 5, the experimental results are in agreement with simulations which could be useful to calibrate the RadMon.

Conclusion and Next Steps

We have built the RadMon prototype and performed a first test at CNAO. In parallel, a simulation of the prototype has been developed and the outcome compared with the beam test results. The next steps are to upgrade and exploit the simulation to calibrate the RadMon response and to fully understand the energy spectrum shapes.