Timepix and Cosmic Radiation

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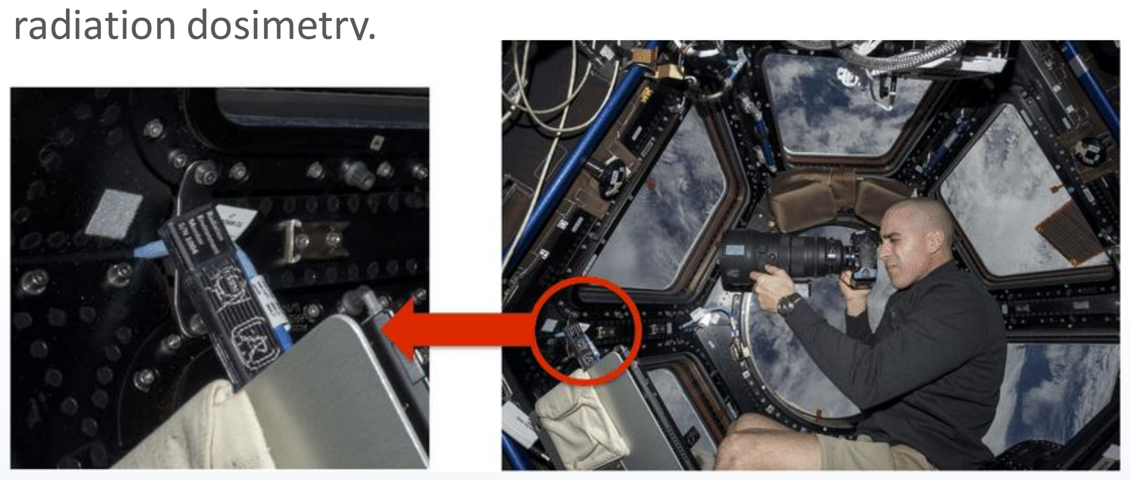
Introduction

The cosmos is filled with charged particles traveling at high speeds and in all directions. These particles are so small and carry so much energy, that it can break the DNA of a cell or mutate it, which may lead to cancer in the long run. On earth, we are protected from these particles due to the magnetic field and hundreds of kilometers of atmosphere that block these particles. Astronauts however are the ones constantly exposed to this harmful radiation. Radiation monitoring is important because although we may not be able to shield the astronauts from all cosmic radiation, we can study cosmic radiation and solar rays in order to limit the time the astronaut spends in space to reduce risk.

Timepix

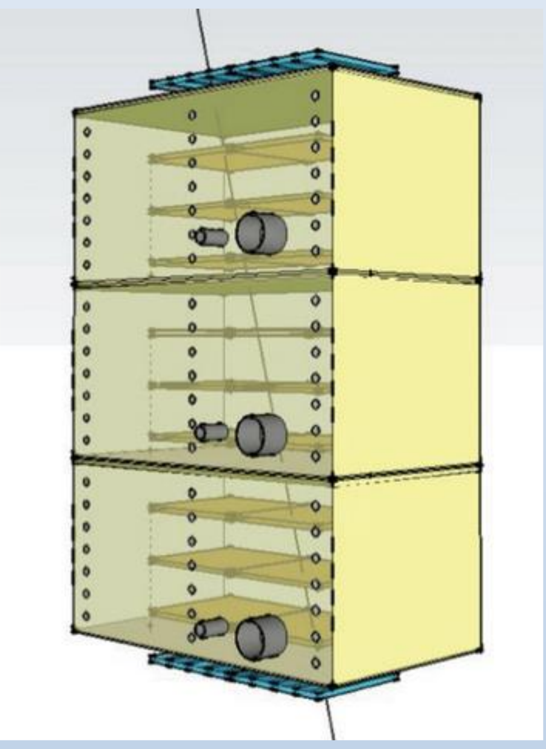
The Timepix is a pixilated radiation detector, designed to count and measure high energy particles that are present. It was designed at CERN, and since 2012 Dr. Pinsky's group at the University of Houston have been flying these detectors on the International Space Station. As of 2017, NASA has been using them as their main system for radiation dosimetry.



Timepix and ALTEA

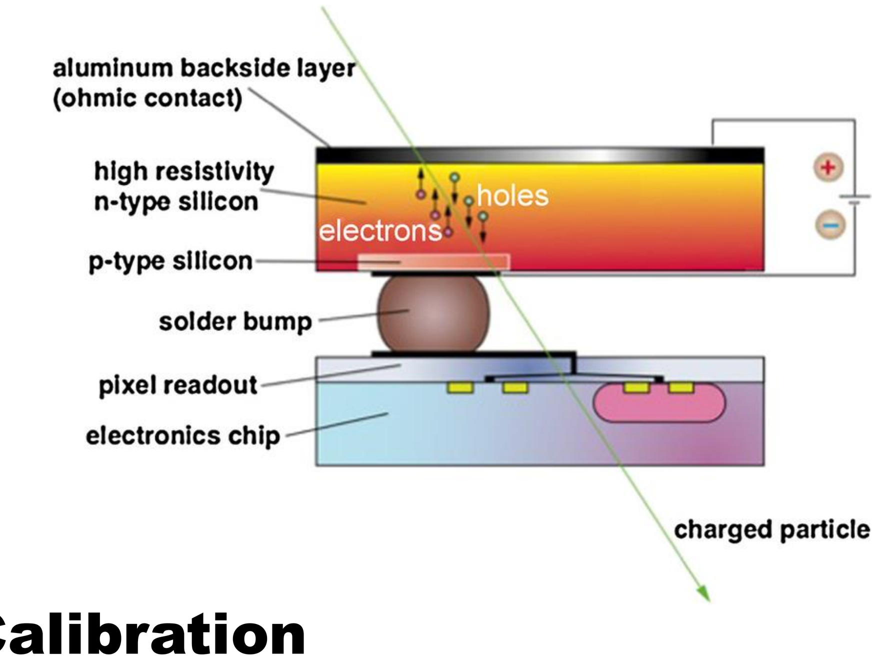
The Timepix's success at NASA has led other space agencies to become interested in its use, including the Italian Space Agency for their ALTEA program. ALTEA is a program to study the long term effects of space radiation on astronauts. They want to integrate the Timepix into their ALTEA-LIDAL experiment. An experiment using three monolithic silicon detector units in order to extend ALTEA's detection capabilities to lower mass elements. The Timepix will be used to cross calibrate the response of the detectors.

I worked at Tor Vergata University in Rome, Italy in the summer of 2017, to introduce the Timepix to the ALTEA-LIDAL team as well as to set up and calibrate the detector so that it can be used in conjunction with the apparatus.
When the detector is optimally set up and calibrated, it can be used with ALTEA systems to check and enhance the measurements made.



How It Works

The Timepix is made up of 256 by 256 separate pixels. When a particle enters the silicon sensor, the interaction between the particle and material create a signal. This signal will travel down to a counter in the bottom due to an applied voltage on the silicon sensor.
The counter in each pixel will time the duration of the signal, we call it ADC(analog to digital converter). This is just a measure of time, and fortunately: the duration of the signal is proportional to the energy that is being deposited by the particle.



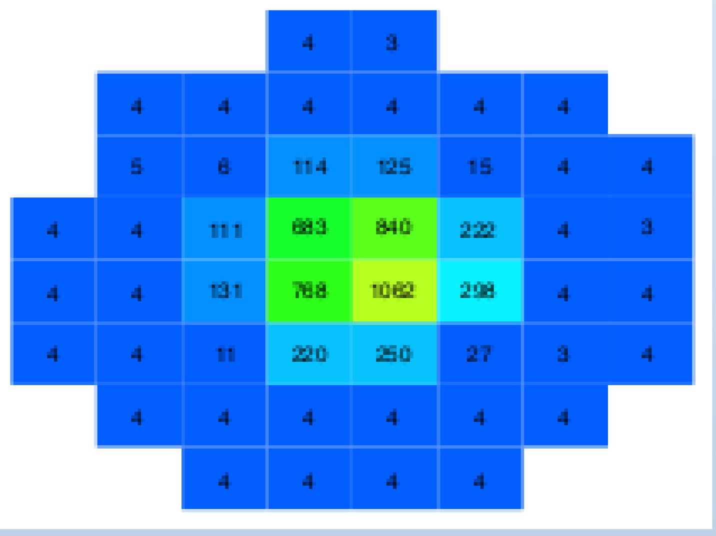
Calibration

Calibrating the detector means translating measurements made by the detector into units we understand and normally use. The Timepix can be calibrated using a few radioactive sources, and observing how the detector responds to the emitted radiation. If we know properties of this specific source, we can translate the measurements from the detectors into units we know to expect.
There are many complications that can come into play when calibrating the detector: each pixel may have a different response and must be calibrated individually, or multiple particles may be hitting the detector at a similar position in a short period of time and affecting the measurement.

Method

Compared to the standard calibration procedure, we investigated an easier and faster way to calibrate the Timepix response. This method uses only two radioactive sources. We used an alpha source (Americium 241) and a beta source (Sodium 22) to make a calibration that works for the ALTEA-LIDAL system.

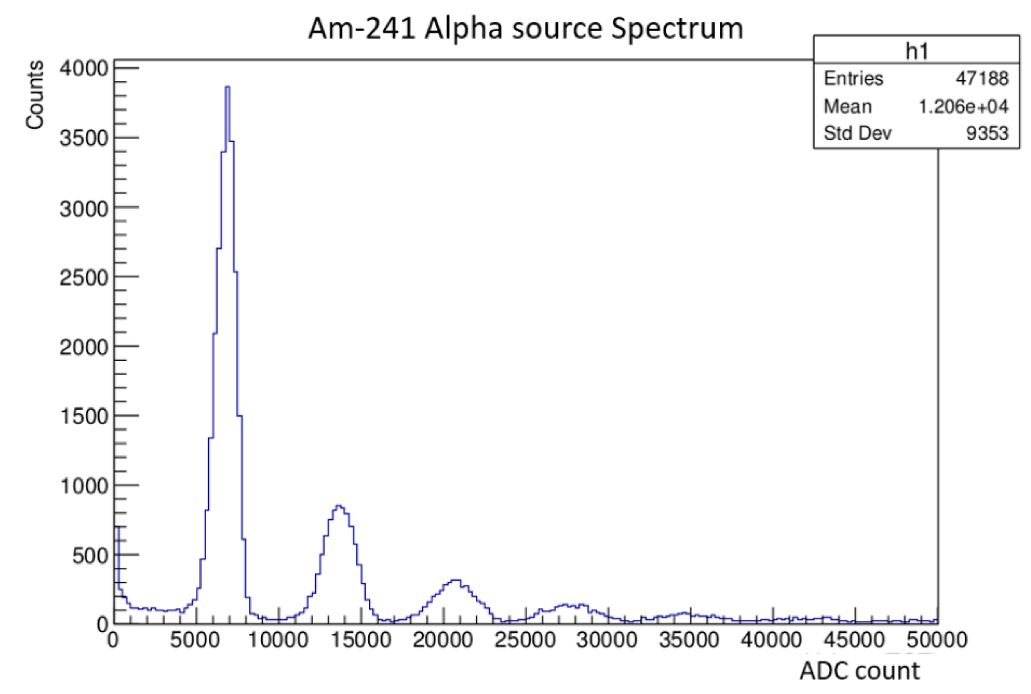
When an alpha particle for example, hits the detector, the signal spreads out, and many signals are received over multiple neighboring pixels forming a cluster(as shown to the right). If we add up all of the signals or ADC counts over all the affected pixels, and knowing how much energy the particle should deposit, we can figure out in average how much energy is deposited by each ADC count.

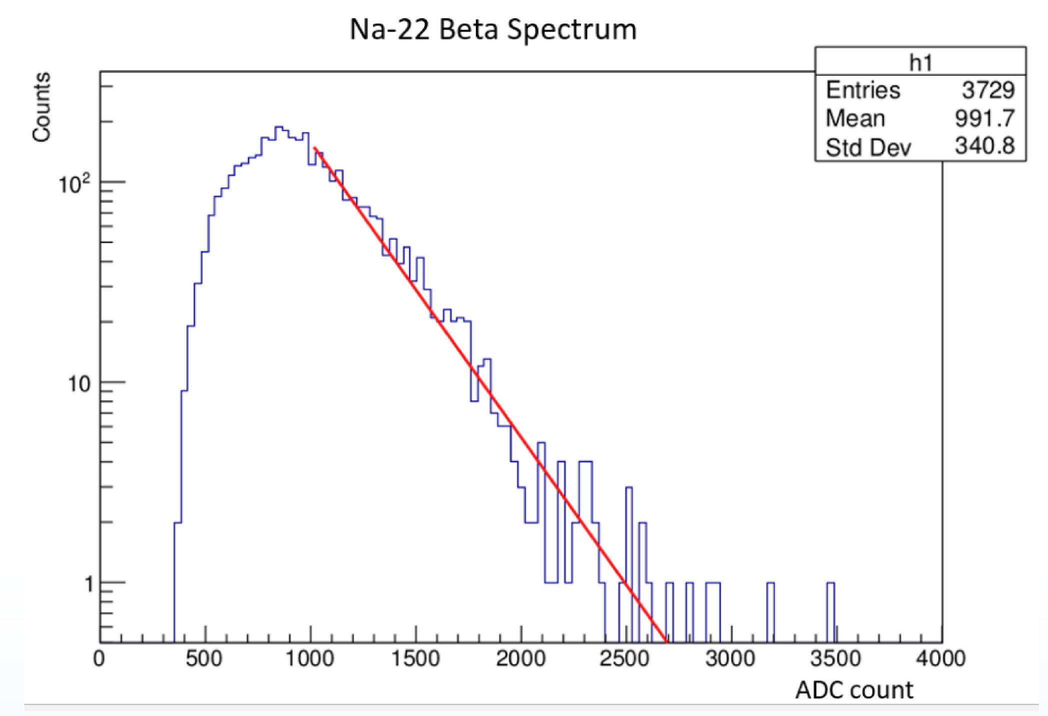


Results

Alpha from Americium 241

Multiple alpha hits in a short period of time will multiply the ADC counts by the integer number of particles. If we know the energy of each particle, we can use that to estimate a translation of ADC to energy. Using each multiple of a hit as a new data point.
Each peak in the histogram to the right represents a multiple of alpha particles that hit the detector, the first peak is a single alpha particle, the second one is a double hit which clearly has about twice the ADC counts of the first hit.
We can use the ADC count for each multiple with respect to the expected energy for each particle to make a linear calibration.



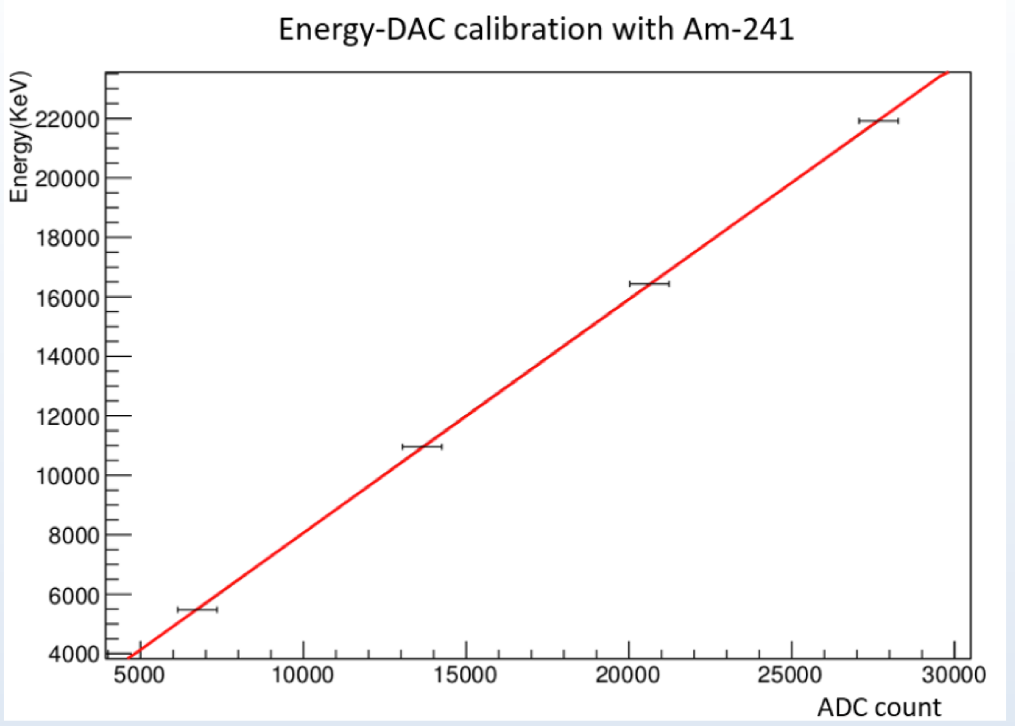


Beta from Sodium 22

Beta sources emits a spectrum of energies instead of a single particle energy like alpha. However, they have a known maximum possible energy. If we have the response from many particles, we can see what is the maximum response received (as shown to the left). We assume the maximum measured response corresponds to the maximum possible energy. Again we have a correlation between an energy and a detector response that we can use to enhance our calibration of DAC to energy or use it to check the calibration done with alpha particles.

Linear Calibration

Knowing that the alpha source deposits 5.48 MeV of energy per particle, and the beta source has a maximum deposition energy of 2.33 MeV per particle. We can fit our calibration accordingly and come up with a translation of 208 KeV + 0.785 KeV/DAC. But it does not take into account lower energy particles, or minor differences in each individual pixel.



Conclusion

We developed a new method of calibration for the Timepix pixel detector with scientists at the Italian Space Agency using alpha and beta particle sources. This method is quicker and easier to use than existing methods and is being used at the Italian Space Agency to help integrate the Timepix detector into the existing ALTEA-LIDAL system.