March 30, 2015

The hitchhiker's guide to the scintillating tile

1. Introduction

The SiPM kit allows to perform cosmic ray and β particle detection using a plastic scintillating tile. The tile (model SP5602) has a sensitive volume of 150 x 150 x 10 mm^3 and two loops of embedded wavelength shifting (WLS) fiber to collect and deliver the light to the SiPM sensors. The standard set-up for the use of the tile is shown in fig. 1.

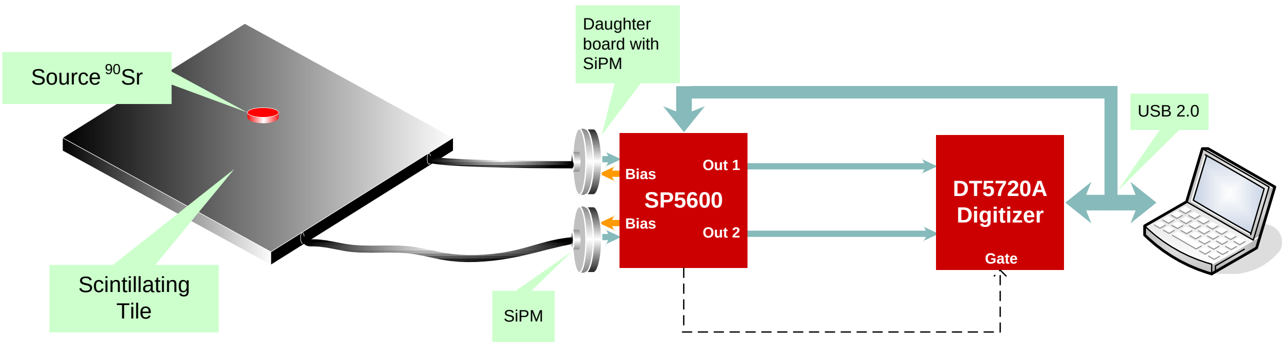

Fig. 1: The CAEN set-up for the use of the scintillating tile.

Cosmic rays are high-energy charged particles; by interacting with the terrestrial atmosphere, they mainly produce pions, kaons and electromagnetic showers. At sea level most cosmic rays are muons; their mean energy is about 4 GeV and their flux for horizontal detectors is ≈ 1 cm^{-2} min^{-1} at energies higher than 1 GeV [1].

The expected rate of muons across the scintillating tile is about 4 particles per second, requiring a fine tuning of the system in order to achieve a significant reduction of the random coincidence rate and enhance the system sensitivity.

This document is intended to be a step-by-step guide to the commissioning and use of the tile.

2. Preliminary measurements

2.1 Check of the fiber integrity

A simple check of the fiber integrity can be performed illuminating one end of the WLS fiber and verifying that the light is transmitted to the opposite end. As a side result, it can be verified that the spectrum of the transmitted light is peaking on green as expected by a WLS fiber.

2.2 Check of the amplification gain of the PSAU channels

The amplification of the two channels of the SP5600 (Power Supply and Amplification Unit, PSAU hereafter) is supposed to be equal. However since the equalization of the gain of the two sensors is crucial, we suggest performing a quick and simple test:

- Mount the holder with one sensor on channel 0;
- Start the PSAU;
- Switch on channel 0 and bias the SiPM to the nominal operating voltage (in this example the sensor in use is MPPC S10362-11-100C biased at 70.4 V at 24°C);
- Set the PSAU gain (in this example is 40 dB);
- As an indication of the sensor gain measure the peak-to-peak distance at the oscilloscope;
- Switch off channel 0;
- Unmount the sensor from channel 0 and mount it on channel 1;
- Switch on channel 1 and set the same values of bias voltage and PSAU gain;
- Check the peak-to-peak distance at the oscilloscope and if required tune the PSAU gain to obtain the same peak-to-peak distance.

3. SiPM Gain equalization

In order to maximize the homogeneity of the response of the tile, the photon detection efficiency (PDE) of the two sensors shall be equalized. Assuming to have two sensors of the same family, differences in the PDE are possibly due to a variation of the triggering efficiency. Since the latter is a function of the overvoltage, equalization can be presumed when the gains of the sensors are equal. This can be achieved as follows:

- Mount the sensors on both channels ;
- Start the PSAU ;
- Start the Digitizer;
- Switch on the channels, set the bias voltage to the nominal values;
- Tune the voltages to equalize the peak-to-peak distance at the oscilloscope (fig. 2).

Once the gain is equalized the Dark Count Rate (DCR) on the two sensors is likely to be similar. This can be checked on the "PSAU counting" tab setting the discriminator at 0.5 and 1.5 photoelectron thresholds (fig.3).

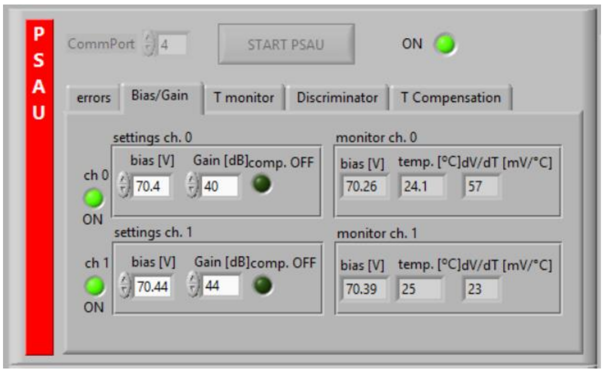

Fig.2: The PSAU set-up.

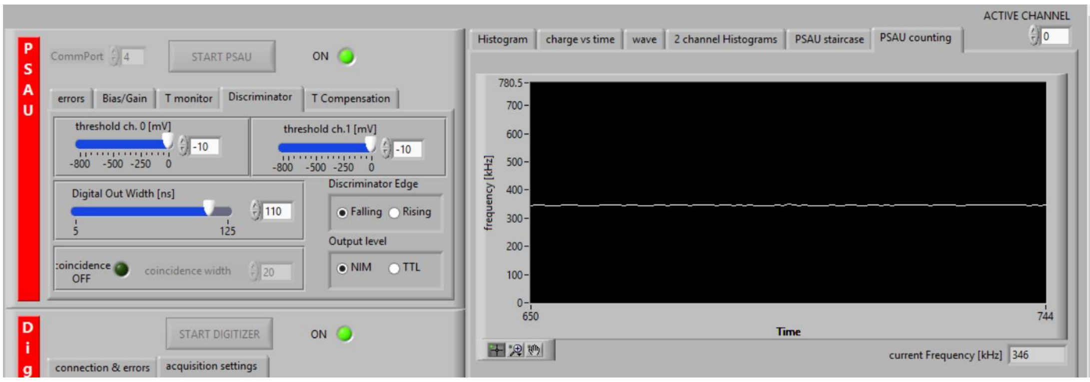

Fig.3: “PSAU counting” tab.

4. Optimization of the discriminator thresholds

Because of the DCR, the system has to be made sensitive to the cosmic ray flux relying on the time correlation of the signals by the two sensors. This is implemented requiring the coincidence of the output of the leading edge discriminators on each channel. The thresholds shall be set to reduce the random coincidence rate below the Hertz level, proceeding as follows:

- Click on the “PSAU StairCase” tab and run the two staircases clicking on “REFRESH” button;

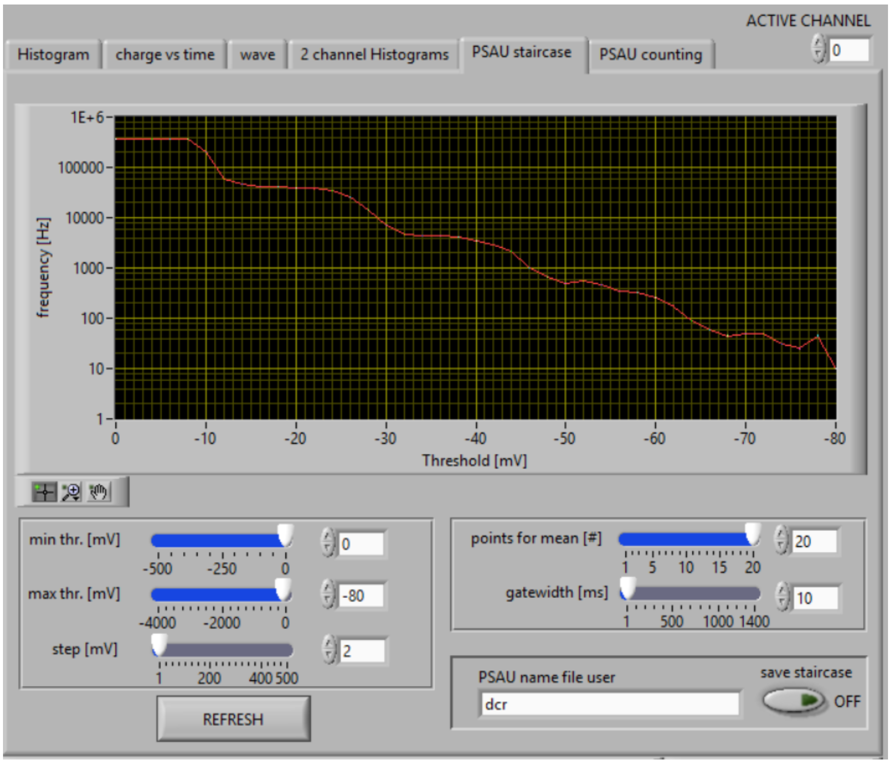

Fig.4: DCR measurement on channel 0 with “PSAU staircase” tab.

- For both channels, estimate the thresholds in mV corresponding to 0.5, 1.5, 2.5 and 3.5 photoelectrons;
- For every threshold value (set in the PSAU “Discriminator” tab for each channel), measure the DCR in the “PSAU counting” tab;
- Switch on the coincidence in the PSAU panel and set the coincidence width (τ) to 20ns. The corresponding logical signal will appear on Ch0 digital output.
- Measure the random coincidence rate and tune the thresholds until it drops below the Hertz level.
- Cross check the measurement with what can be expected according to the formula

$$\textit{Coincidence rate} = 2\,\tau\,N_0\,N_1$$

N_0 = dark counting rate sensor 0

N_1 = dark counting rate sensor 1

5. Cosmic rays and radioactivity detection

By now, the system shall be properly set-up and ready to go. As a final step before the real experiment starts, the scintillator tile shall be connected. Before doing that it is strongly advised:

- to power off the sensor bias, to prevent any damage to the detectors
- to use optical grease on the fiber tips for index matching and optimal light transmission.

After having restarted the system and set the proper parameters as outlined above, the simplest possible way to verify something has changed and the system is detecting particles across the scintillator is to measure the coincidence rate, possibly scanning the values of the threshold. An exemplary outcome is reported in Fig.5, reporting as well the counting rate for a ^{90}Sr source (3 kBq activity) positioned on the tile. The measured cosmic ray rate at 3.5 p.e. threshold is 2.5 Hz, corresponding to an efficiency ~62%. Fair enough for designing and performing a series of measurements and intrigue your students….

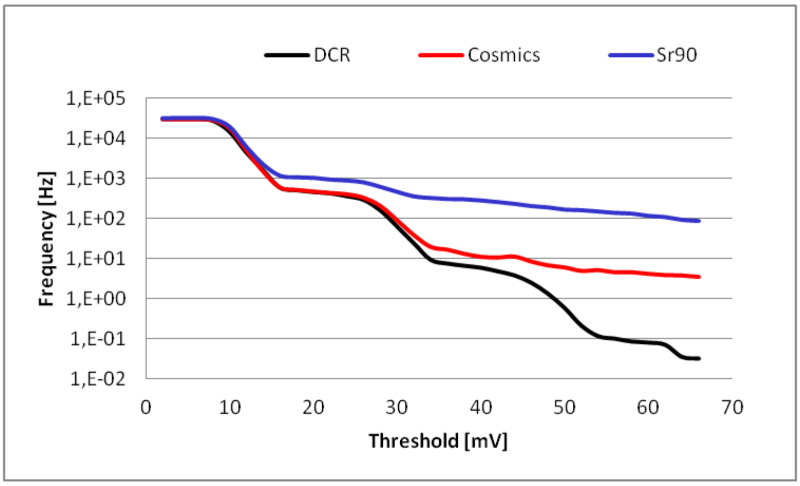

Fig.5: Frequency of the coincidence between the sensor output vs the discriminator threshold. The dark count rate is staircases of DCR, cosmic rays and Sr^{90}.

[1] K.A. Olive *et al.* (Particle Data Group), Chin. Phys. C, **38**, 090001 (2014).

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