Witnessing a Forbush Decrease with a Microscintillator Ionisation Detector over the Atlantic Ocean - EGU23-13801

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A novel ionisation detector was brought aboard the NRP Sagres during the 2021 SAIL campaign, which saw the ship sail the Atlantic Ocean. On 4th November 2021, a coronal mass ejection resulted in a rapid decrease in the observed cosmic ray intensity - known as a Forbush decrease. We present the response of the PiN detector during the Forbush decrease and compare it with that of Dourbes neutron monitoring station. Composed of a 1x1x0.8 cm^3 CsI(Tl) scintillator coupled to a PiN photodiode, the PiN detector demonstrates agreement in the count rate of select energy regions when compared to neutron monitoring data - a capability afforded by its ability to retrive energy and count rate information.

1. Microscintillator Ionisation Detector

The PiN detector employs scintillation as the method of particle detection. The detection and measurement process is detailed below in Figure 1, previous deployment can be found in [1,2].

- **Incident radiation** produces a **light pulse**
- Light pulse produces a **current pulse**
- I-V converter produces voltage pulse
- Voltage pulse is amplified
- Schmitt trigger activates beginning the measurement process
- Valley subcircuit holds the minimum value of the voltage pulse
- Microcontroller timestamps the **reference** and **valley** voltages
- Pulse height **dV** is proportional to energy of incident radiation

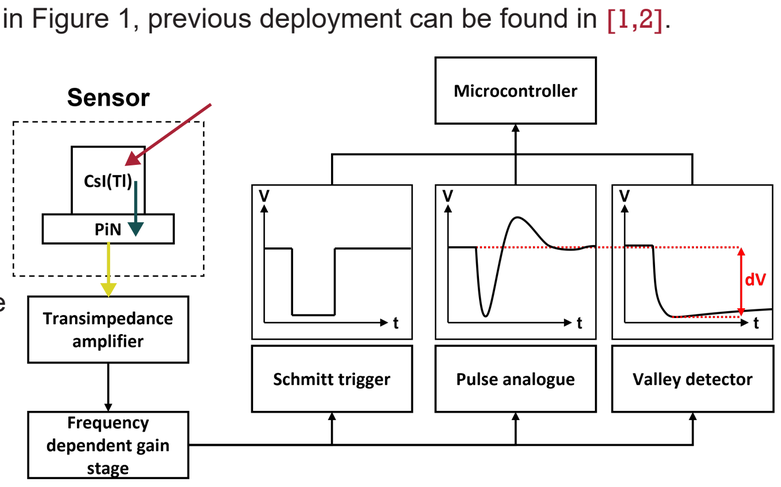

Figure 1: PiN Detector measurement process. A pulse height is determined by the difference between a reference value in the pulse analogue and the valley detector minimum.

By binning pulse height values, a pulse height spectrum can be obtained; which can be converted into an energy spectrum - seen in Figure 2.

In the pulse height spectrum, events are grouped by energy, however, events can additionally be grouped by time, and further by energy and time.

For example, Figure 4 displays the normalised count rate behaviour of all events, but Figure 6 displays the count rate behaviour from counts in specific energy bins.

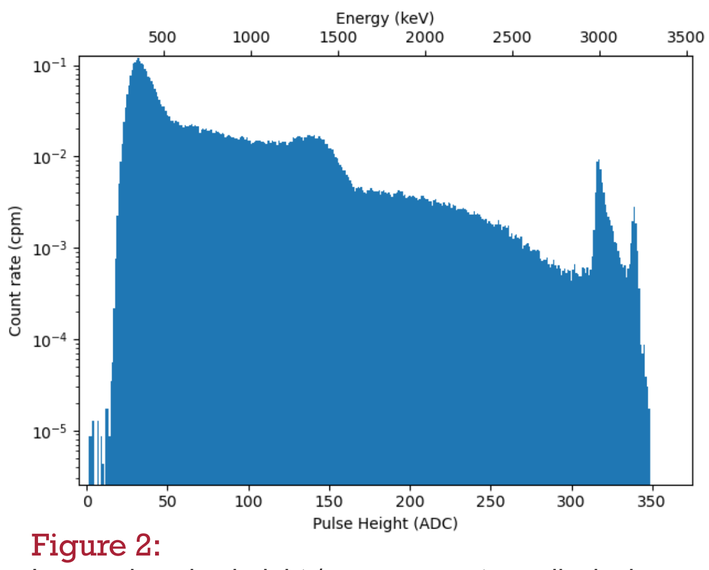

Figure 2: Log-scale pulse height / energy spectrum displaying the count rate for each energy bin, over a 160 day period.

2. SAIL Campaign and Dourbes Neutron Monitoring Station

The PiN detector was deployed onboard the NRP Sagres as part of SAIL - an atmospheric and oceanographic monitoring campaign. In July 2021, NRP Sagres left Lisbon for a trip through the Açores, running until September 2021. The PiN detector was operational during this period and beyond, during the latter period, there was an occurance of a Forbush decrease.

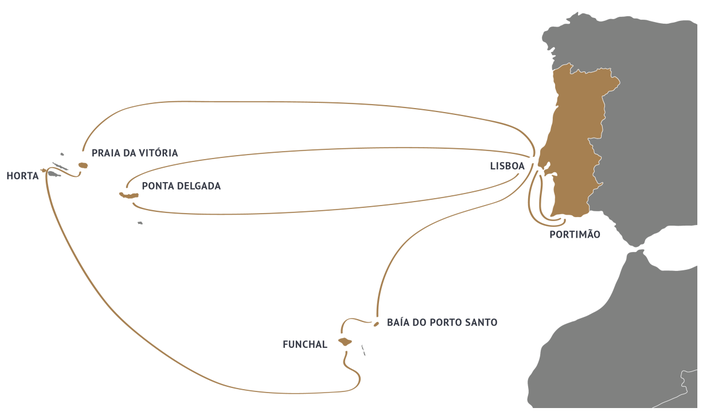

Figure 3: NRP Sagres sailing trajectory from the July - September period 2021 [3].

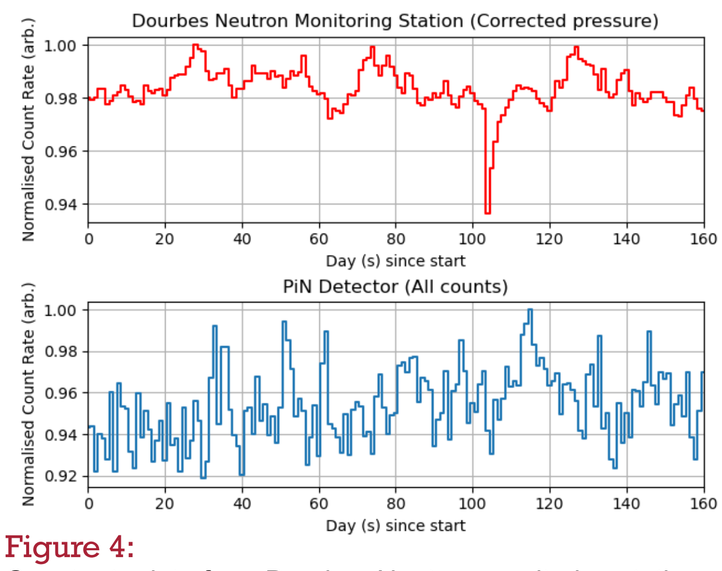

Figure 4: Count rate data from Dourbes Neutron monitoring station. Day 104 (4th Nov 2021) displays a Forbush decrease event [4]. PiN count rate over the same period, for the full energy range.

The Forbush decrease was observed by the Dourbes (Belgium) Neutron Monitoring Station. The Forbush event caused a 3.5% decrease in the measured neutron count rate, persisting with a recovery period of 6 days.
In the PiN detector, a 2.13 % decrease was observed across all counts.

Table 1: Count rates in respective detector systems around the Forbush decrease

Detector	Count rate (cpm)
Dourbes (Before)	6740 ± 20
Dourbes (During)	6500 ± 60
Dourbes (After)	6700 ± 40
PiN (Before)	4.22 ± 0.04
PiN (During)	4.13 ± 0.02
PiN (After)	4.25 ± 0.02

Due to the PiN detector being sensitive to particles from 80-3000 keV, there is a lot of variability in the count rate of all particles. Therefore, the pulse height (energy) of some events would follow the Forbush behaviour more closely than others.

3. Energy Discrimination

By looking at the count rate of specific energy bins, the energies which demonstrate Forbush behaviour (CR-before>CR-during, CR-after>CR-during, CR-before>CR-after) can be idenitified, and their percentage change quantified. Figure 5 shows the average percentage difference scaled by the number of counts in that energy bin.

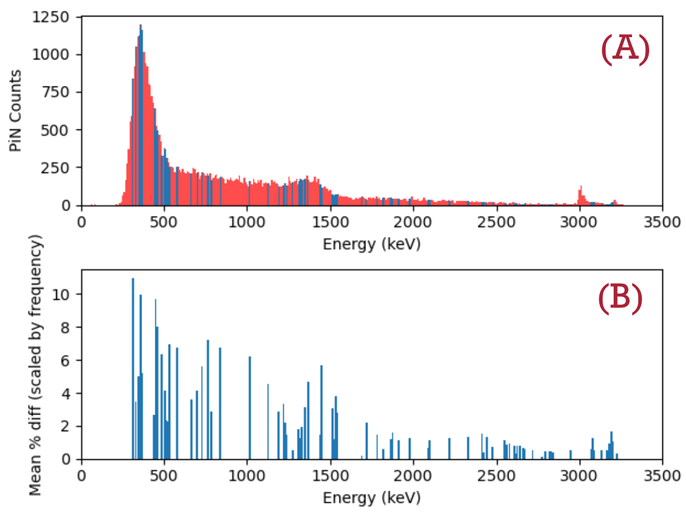

Figure 5:
(A) Energy spectrum for the days over the Forbush period; bins which displayed Forbush behaviour are marked in blue.
(B) Where Forbush behaviour was seen, the mean percentage difference, scaled by the counts in the bin, are displayed. The shape distribution of the percentage difference does not follow exactly the shape of the pulse height spectrum, suggesting the change is not homogenous across the energy spectrum.

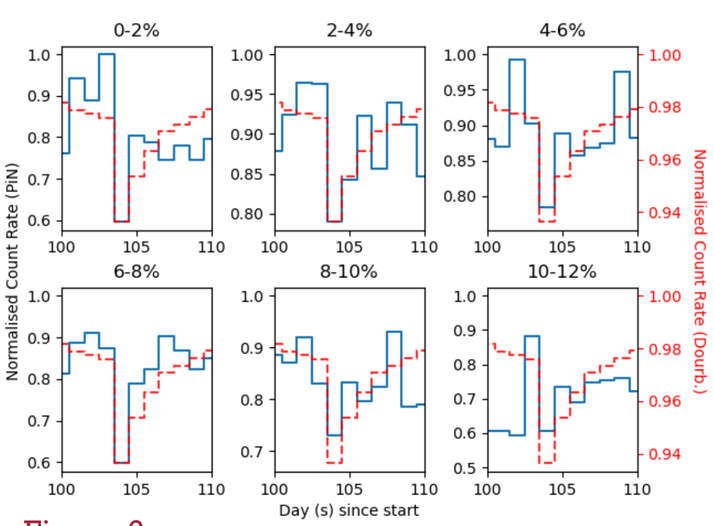

Figure 6: By grouping the idenitified counts in Figure 5 by their percentage difference, it can be seen that some energy groups follow neutron data more closely than others - quantified in Table 2.

Table 2: Correlation coefficient, p-value, and median energy for groups identified in Figure 5.

% Diff	R^2, p-value	Median E
0-2	0.825, 0.043	2570
2-4	0.872, 0.024	1200
4-6	0.805, 0.054	710
6-8	**0.966, 0.002**	**580**
8-10	0.803, 0.054	400
10-12	0.397, 0.436	311

Of the counts which display Forbush behaviour, where the scaled percentage difference is 6-8%, demonstrate the most agreement with Dourbes data. Within this group, consisting of seven energy bins, the 530±20 keV and 580±20 keV most closely correlate with neutron data.

Conclusions

- During a Forbush decrease, events detected by the PiN detector displayed varying levels of agreement with cosmic ray neutron monitoring stations.
- For events which demonstrated Forbush behaviour, counts with lower energy agreed more than higher.
- The two energy bins which displayed the most correlation were 530±20 keV and 580±20 keV.
- Gamma events in these regions could be attributed to 511 keV annihilation, Tl^{208} (583 keV), and Bi^{214} (609 keV).
- 511 keV annhilation peak is a prominent feature in the cosmic gamma ray spectrum [5].

References

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