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Conceptual Design of a Detector of Relativistics Electrons and Protons on Van Allen Belt for a CubeSat Platform

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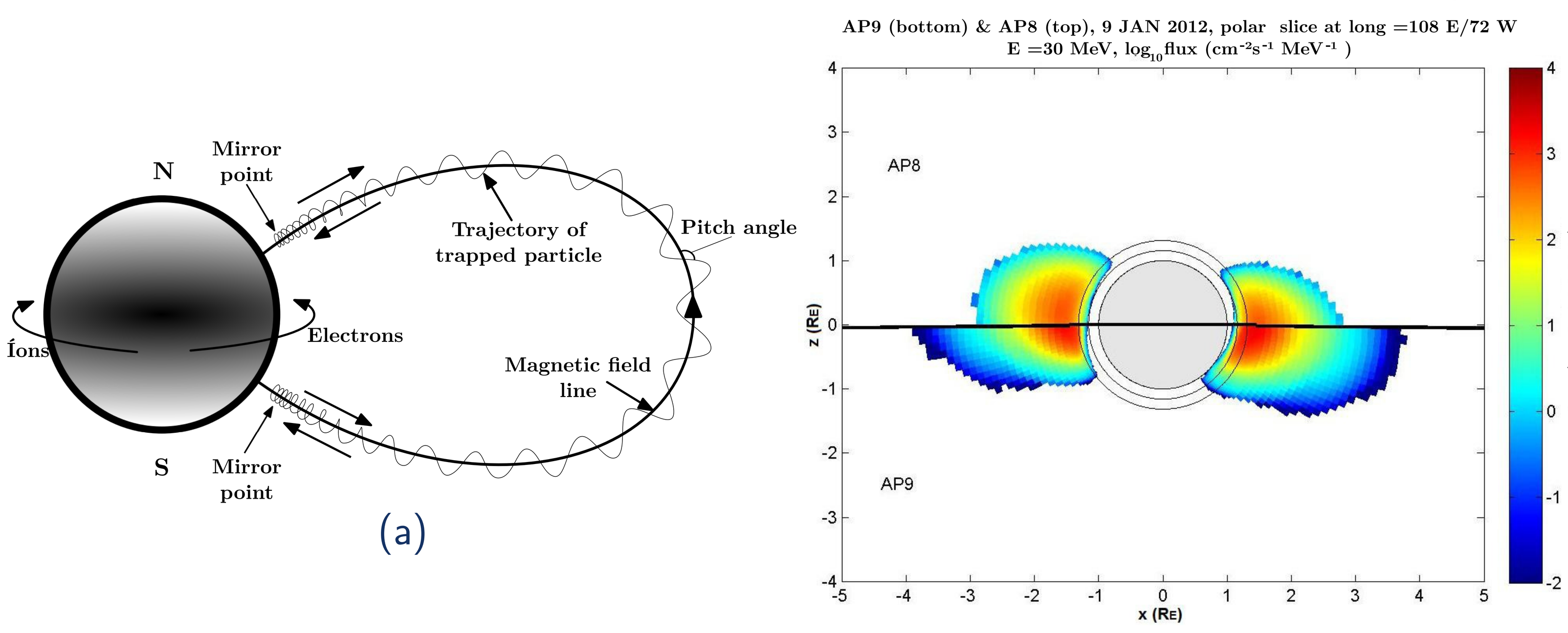
Abstract

The main cause of failures in space missions is due to radiation. The higher the energy, the greater the damage. Around the Earth there are regions with different densities of high energetic particles. A more concentration is observed in a specific region called the Van Allen belt. Continuous monitoring of the radiation belt can provide a better understanding of the dynamics of some phenomena not yet fully explained, such as the balance between the mechanisms of loss and acceleration of charged particles in the medium. This also allows the refining of spaceweather models useful in the analysis of risks in space missions. This paper presents the conceptual design of a system of detection of high energetic particles to be applied in space environment in regions of the radiation belt. It is proposed an instrument model capable of measuring the flow of electrons and protons in the energy range of (1-10) MeV and (15-30) MeV, respectively, suitable for a CubeSat platform. Compact and cost-effective solutions were chosen to make up the detection subsystems. The topology, idealized from examples in the literature, was segmented into three classes: sensing unit, based on the association of a scintillating crystal of CsI (Tl) with a photodiode; formatting unit, through a load amplifier and a 10-bit resolution and 10 MHz sample rate A/D converter; and signal analysis unit, done digitally with neural classifier algorithm. It was created two virtual models, a mechanic highlighting the format and arrangement of the elements of the instrument, and a functional one that simulated its response to being stimulated by a beam of particles characteristic of the environment in question. Finally, a dimensional analysis of the proposed model is presented, as well as its efficiency of energy estimation, counting rate and particle classification.

Introduction

The study and monitoring of the energetic particles fluxes in the Earth's radiation belts has been shown in many scientific and tchnological works in the last 30 years. More recently, the expressive numbers of satellites orbits in this region, it has been even more necessary to correctly describe the characteristics of such environment to mitigate and prevent possible failures and faults in these technological systems. With a better understanding of the radiation belt, is possible to improve models for estimation of radiation and its damage to electronic devices in the space environment.(fig. 1) This contributes to the project of new spacecraft missions, i.e. the design parameters for radiation protection are better fitted. The energeticle particles fluxes are the key parameter to better describe the dynamics of the radiation belts. For this it is needed to discriminate the particle species, their energy and, also the angle of the helical movement around the field line (pitch angle) of each species (mostly electrons and protons). Therefore, in the development of new measurement technologies, the following requirements for the instrument must be met: (i) To discriminate at least two types of particle's species (in general, electrons and protons); (ii) Measure the flow of protons with energy above 10 MeV and (iii) electrons with energy above 1 MeV; (iv) Estimate *pitch angle*. Owing these parameters, it is possible to observe events of acceleration and loss of particles in this region.



(a) (b)

Figure 1: (a)Trajectories of particles trapped on closed field lines (adapted from (BAUMJOHANN; TREUMANN, 1996)).(b)Comparison of AP8(top) and AP9(bottom) on a meridional cut throug the radiation belts, 30 MeV proton fluxes (adapted from(JOHNSTON et al., 2014))

Objectives

In this work it is proposed the electronics topology to built a electron-proton detector able to meets the requirements enumerated above. Also, the proposed solution have to be suitable for a CubeSat platform. The results will provide subisides for the assesment of the feasibility to develop these equipments for the space weather activities.

Methodology

The conceptual design of a electron-proton detector is based on a simplified and low cost conceptual topological solution. The innovative aspect is to implement a neural network to evaluate the signal analysis and sinal-to-noise ratio (under construction). Our solution bennefits from the examples founded in the literature related to the electronics functional elements in detection systems. Such elements are identified as: a sensing unit, a signal formatting unit and a measured signal analysis unit. The preliminary results are presented for the main parameters related to these units, i.e., the estimative of the detector parameter is calculated considering the virtual model of this topology, together with the proposed mechanical(fig. 2) and eletronical (fig. 3) solutions. The results for the electronical and mechanical concepts are presented at (table 1) and the signal analysis unit is shown at (fig. 4).

Results

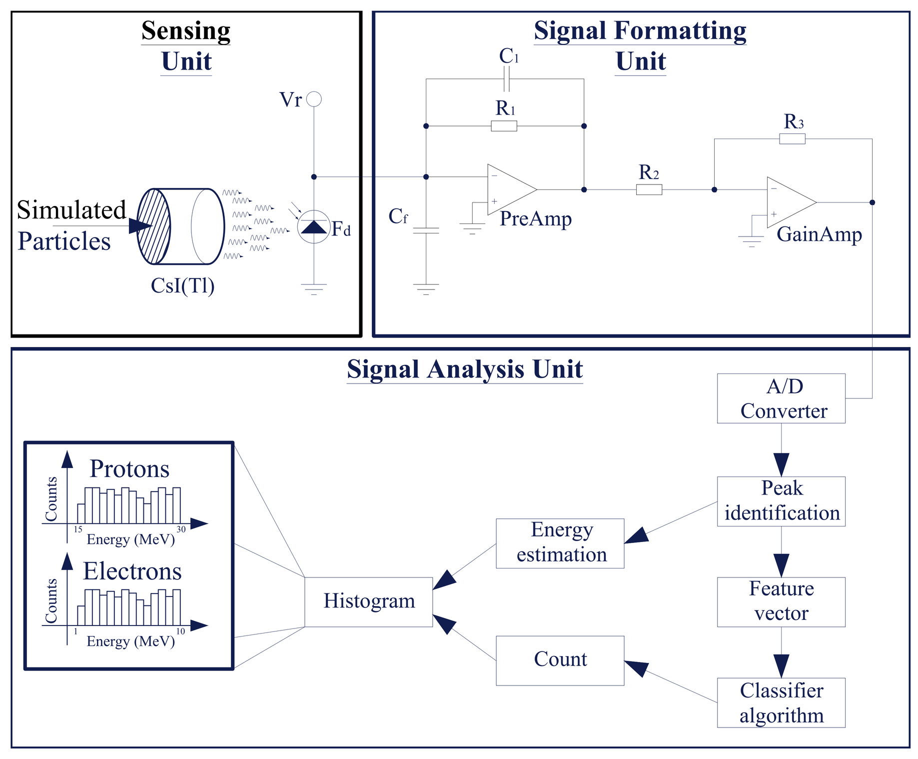


Figure 2: Electronic model

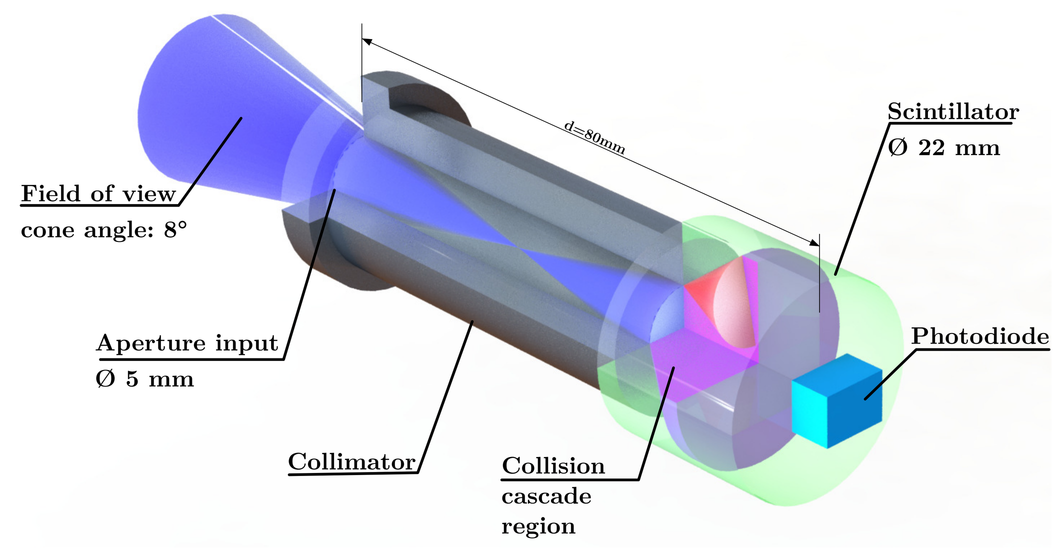
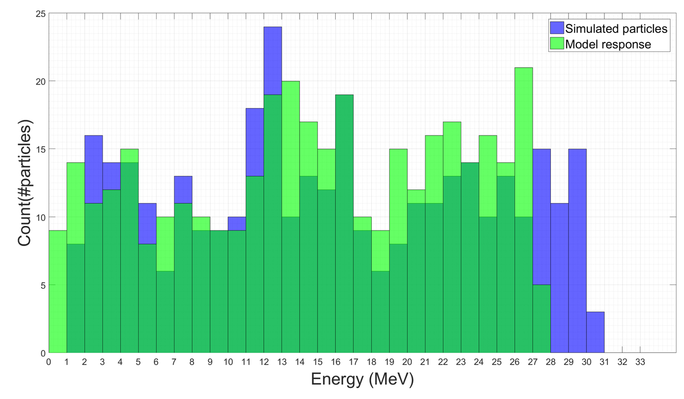


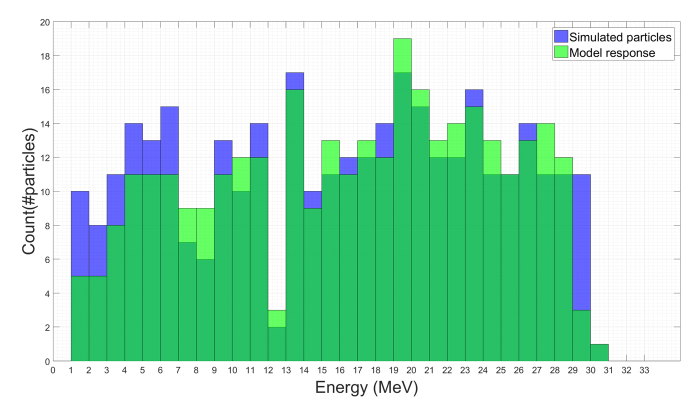
Figure 3: Mechanical model

		Simulated classes			Total(%)
		electron	proton	alfa	
Estimated classes	electron	355	12	3	95.9
	proton	0	320	5	98.5
	alfa	0	9	296	97.0
Total(%)		100	93.8	97.4	97.1

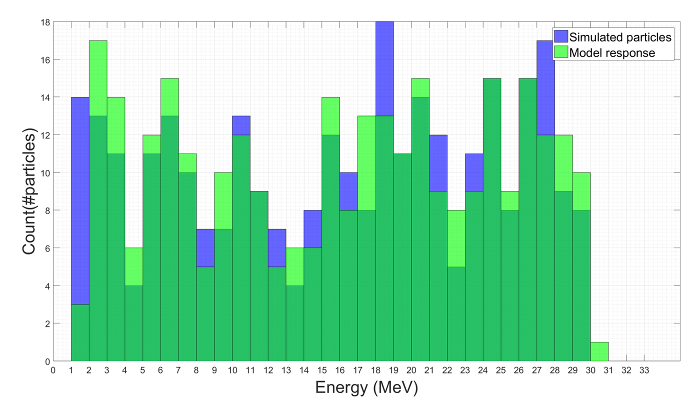
(a)



(b) 370 electrons 1 to 30 MeV



(c) 325 protons 1 to 30 MeV



(d) 305 alpha 1 to 30 MeV

Figure 4: (a)Particles classification, (b) counting and estimation of energy in a simulation of the proposed detector model of 1000 particles (electrons (b), protons (c) and alpha (d)) with a collision interval of $20\mu s$. Note that each bin has a range of 1 MeV.

	Name	Measurements	Estimate
Parameter	Dimension	diameter x length	25mm x 80mm**
	Fiel of View	Degrees	8°
	Massa	Miligrama (mg)	TBD*
	Power	Wats	TBD*
Signal response	Count rate	Particle per seconds	10^5 #/s
	Energy resolution	range of each channel	1 MeV
	Count Energy error	Mean squared error	(e:26.6) (p:5) (α:7.5)
	Classification efficiency	True positive	96%

Table 1: Parameters and responses of the proposed detection topology.
*To be defined
** without electronics

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