SEP fluxes in GEO measured with ESA's Multi-Functional Spectrometer

Filipe Carvalho[1,2]

[1]LIP, Laboratório de Instrumentação e Física Experimental de Partículas, [2]IST, Instituto Superior Técnico

maximo@lip.pt

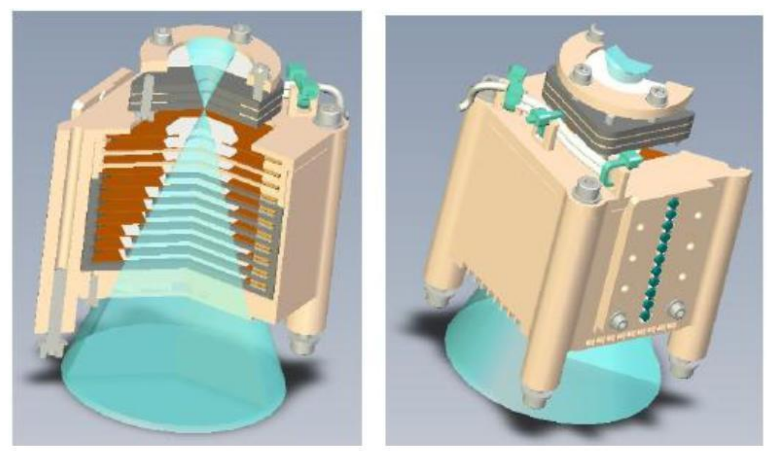
Supervisor: Patrícia Gonçalves

Co-supervisor: Luísa Arruda

MFS and AlphaSat

AlphaSat is a telecomunications satellite, orbiting in GEO since 2013.

It includes several payloads and experiments, one of which is MFS, a spectrometer with the purpose of characterizing the GEO environment regarding ionizing particles.



MFS overview

MFS is composed of a stack of 11 silicon detectors interleaved by layers of shielding material, as well as a collimator made of tantalum that allows the spectrometer to operate under high particle fluxes.

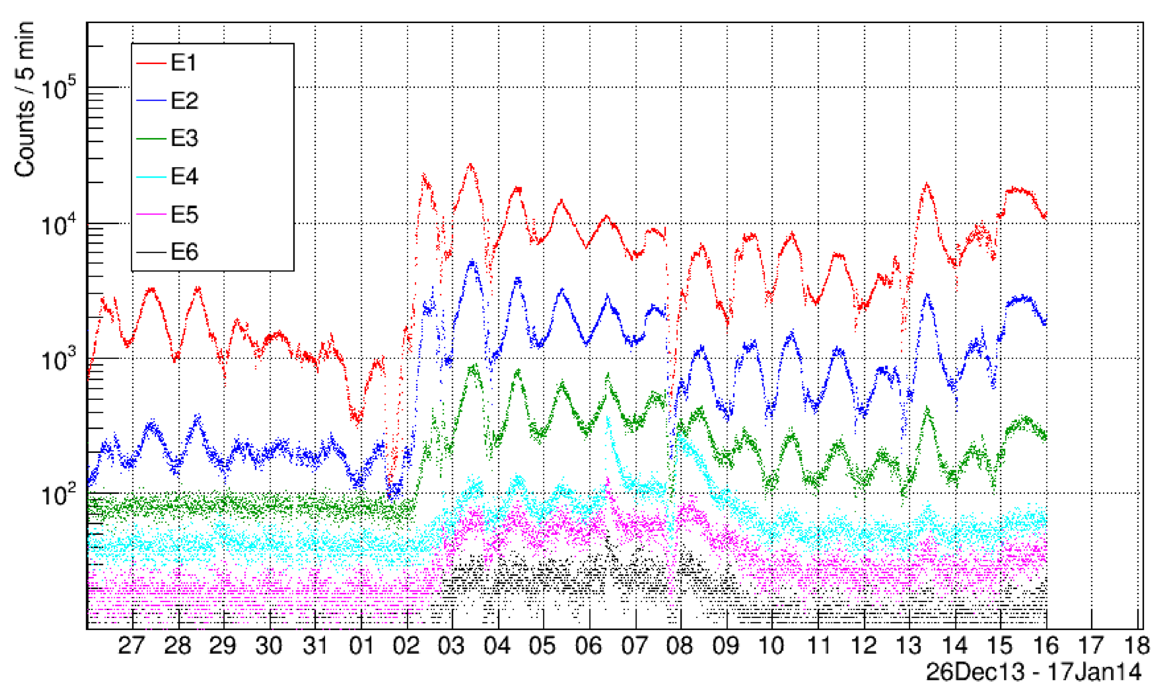
Ionizing particles interact electromagneticaly with the detector's materials and lose energy to the medium, creating a signal processed by the associated electronics.

Using information from simulations, the signals can be interpreted, resulting in the identification of the incoming particle and corresponding energy.

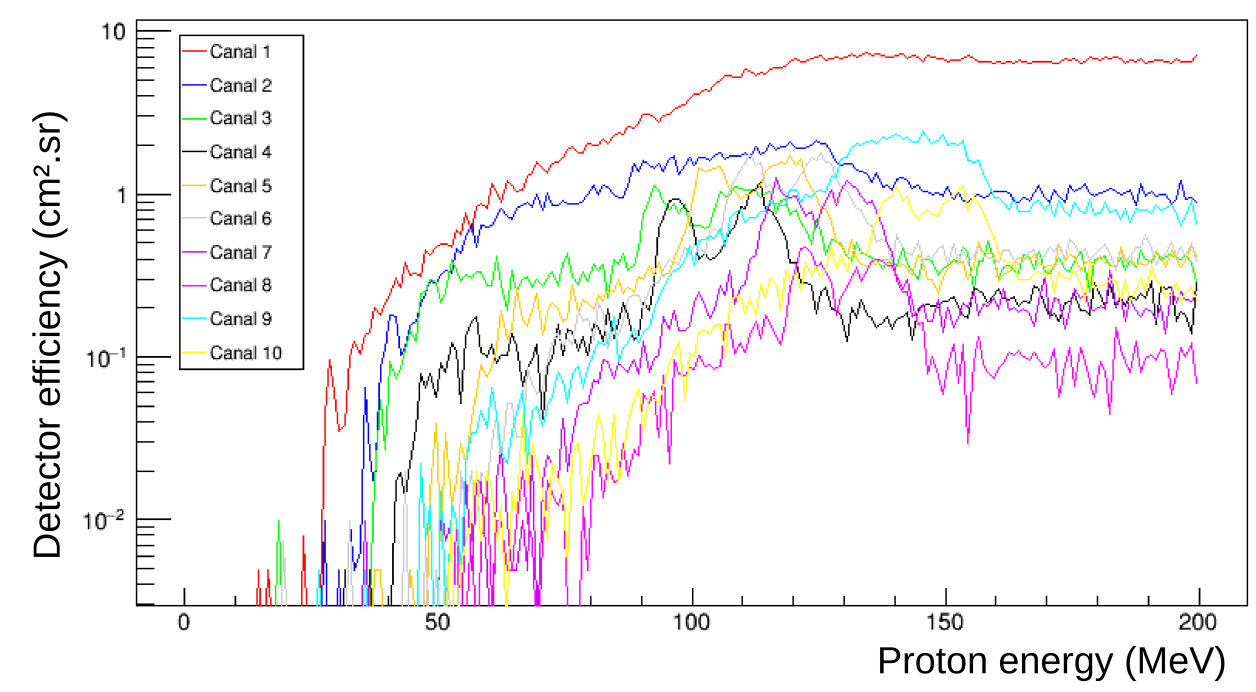
MFS data

Once MFS identifies the incoming particles and corresponding energies, this information is organized in energy channels (10 for protons, 7 for electrons) and presented as the number of counts registered for a given time period for each channel.

MFS data: electron counts for each channel



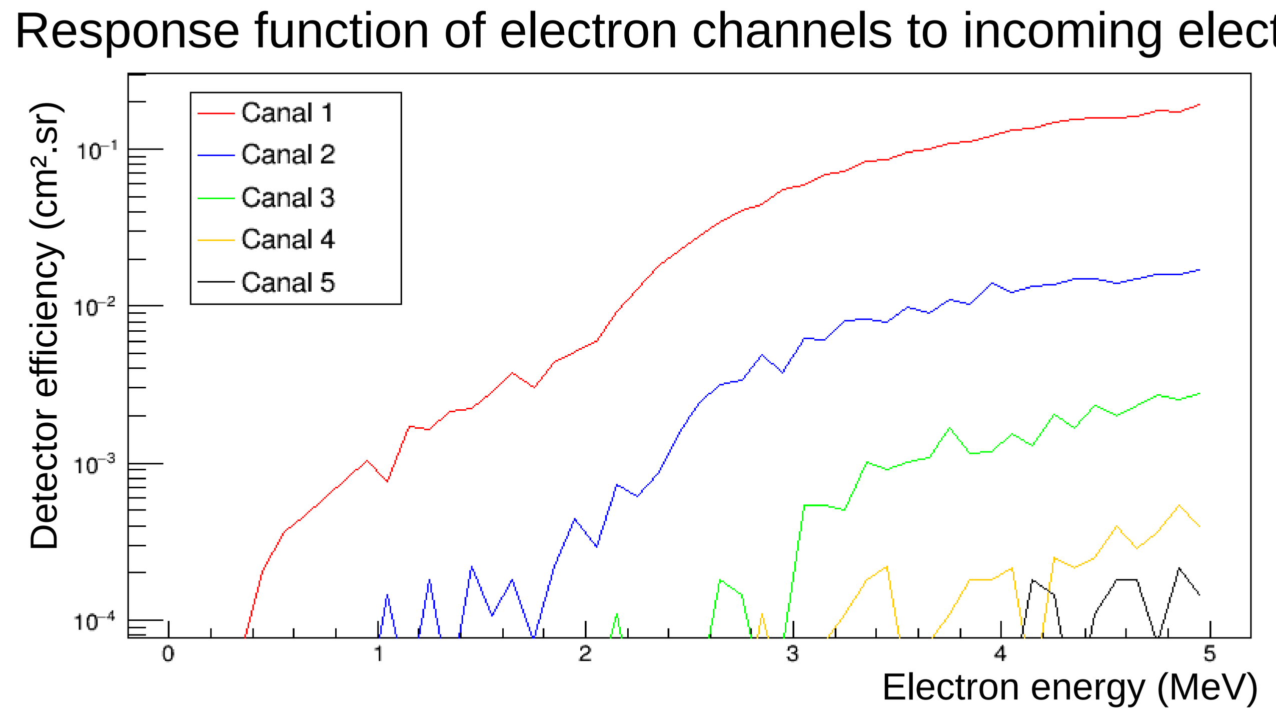
Response function of proton channels to incoming protons



MFS response functions

To quantify the detector's efficiency to the incoming particles, simulations of MFS were made using Geant4 tool. This information was available as histograms of each channel's efficiency (cm².sr) to each incoming particle as a function of its energy.

Response function of electron channels to incoming electrons



MFS flux spectra reconstruction method

MFS counts, for a given time Δt, are expressed as:

$$C = \Delta t \int_{\Delta E} \sum_{\alpha} F_{R_\alpha} . \Phi_\alpha(E) dE$$

Where the flux $\Phi(E) = kE^{-\alpha}$ [1] has units of #/(MeV.s.sr. cm²).

F_R is the channel's response function to incoming particles and obtained from simulation.

To find the best pair of parameters (k,α) a maximum likelihood estimate method was used. The number of counts the various MFS channels register follows a Poisson distribution:

$$P(X = x) = \frac{\lambda^x e^{-\lambda}}{x!}$$

$$\lambda = \Delta t \int F_R . kE^{-\alpha} dE$$

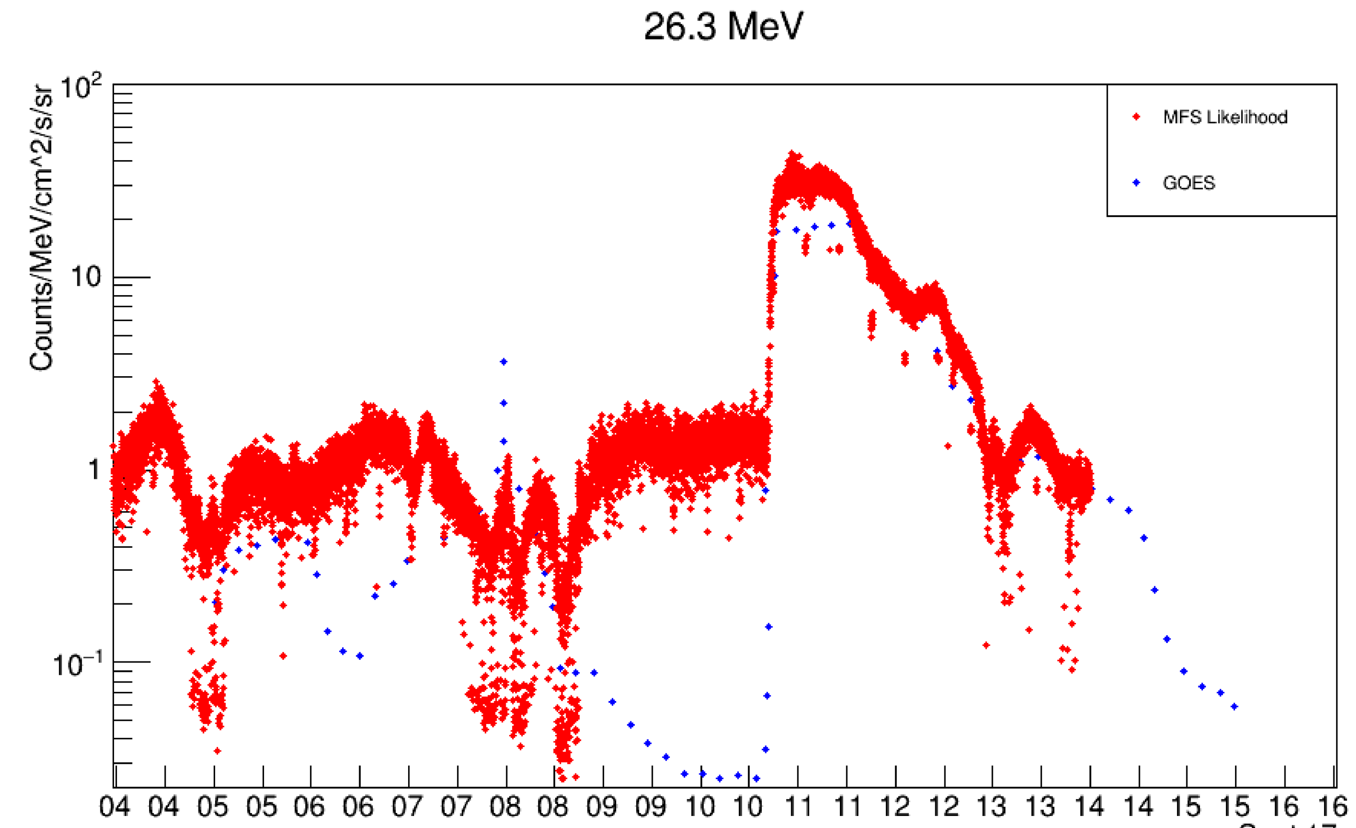
The method consists on maximizing the likelihood function [2]:

$$logL(k, \alpha | C) = \sum_{i=1}^{10} \left[C_i log\left(\Delta t \int F_{R_i} kE^{-\alpha} dE \right) - \Delta t \int F_{R_i} kE^{-\alpha} dE - log\left(C_i!\right) \right]$$

Root's TMinuit minization tool was used to find it's maximum by changing the parameters k and α. Once the best pair (k, α) is found, the flux can be plotted.

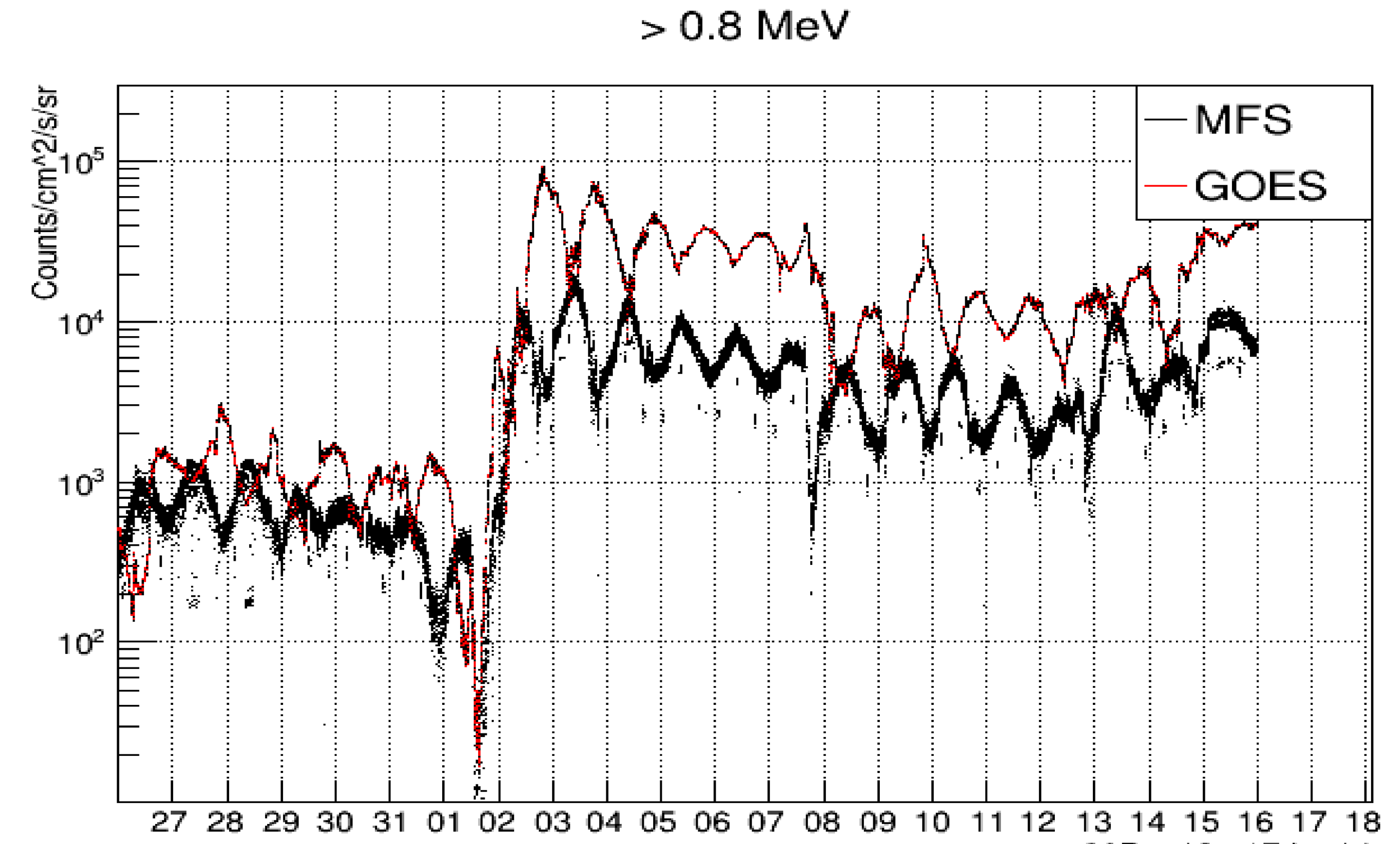
Proton differential flux: MFS vs GOES (September 2017)

26.3 MeV



Electron integral flux: MFS vs GOES (Dec. 2013 – Jan. 2014) [3]

> 0.8 MeV



References

[1] Mewalt, R, et. al., *Proton, helium and electron spectra during the large solar particle events of October-November 2003*, Journal of Geophysical Research, Vol. 110, 2005.

[2] Cowan, G, *Statistical Data Analysis*, Oxford University Press, 1998.

[3] Arruda, L., Gonçalves, P., Carvalho, F., et. al., *SEP Electrons in GEO measured with the ESA MultiFunctional Spectrometer*, submitted to IEE TNS, under review, TNS-00806-2017