Particle Energy Spectra Reconstruction of the Multi-Functional Spectrometer In-flight Data using Machine Learning Techniques

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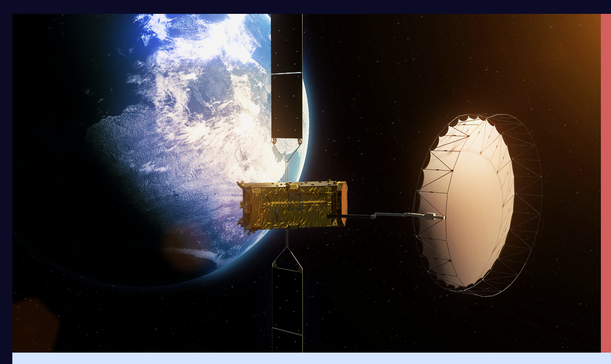


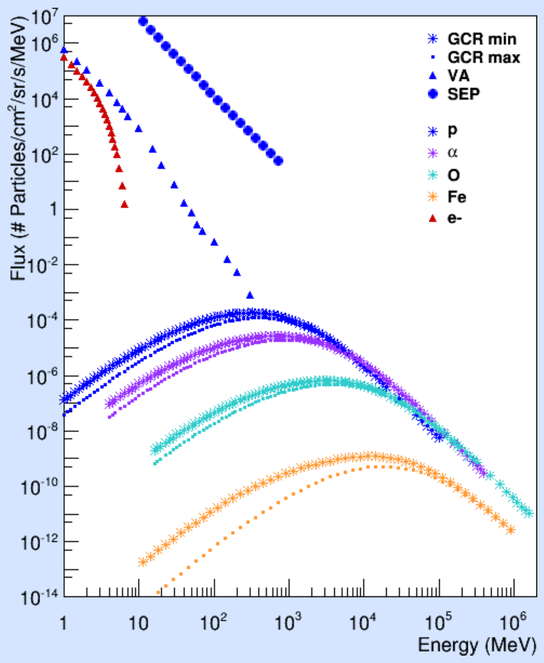
Abstract:

The MFS (Multi-Functional Spectrometer) is a radiation monitor hovering in geostationary orbit aboard the Alphasat satellite launched in July 2013. A Geant4 simulation was developed with the manufacturer's CAD geometry. Particle identification and kinetic energy reconstruction is done in 37 channels following the scheme in place. The main goal of this thesis is to explore and develop efficient methods both in speed and accuracy for differential energy flux prediction based on measured count rates.

1. MFS technical overview

Environment in GEO[1]

- cosmic rays
- solar energetic particles
- Van Allen outer belt



Detection principle

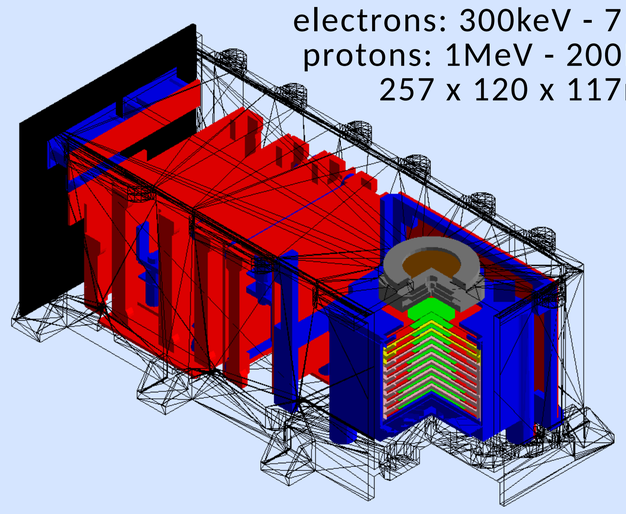
- energy deposits
  via collisional stopping power
- stack of 11 silicon wafers
- 9 absorbers between detectors

E_{kin} reconstruction

- comparison of energy deposits with predetermined thresholds
- assignment to one of 37 channels (7 for electrons, 10 for protons, etc)

2. Simulation

electrons: 300keV - 7MeV
protons: 1MeV - 200MeV
257 x 120 x 117mm³

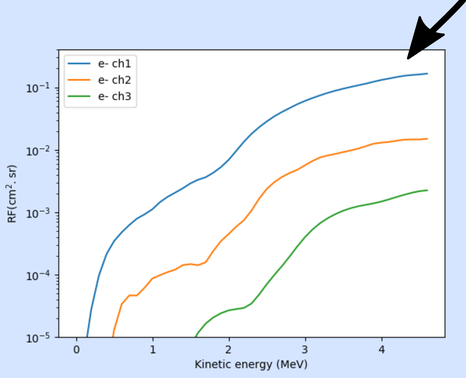


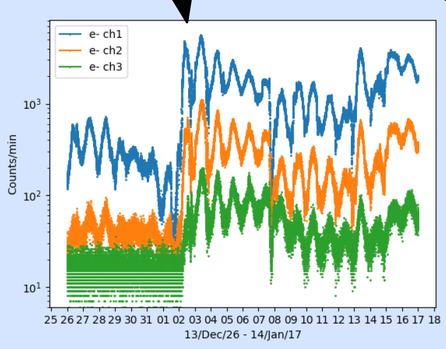
CAD geometry → GUIMesh[2] → GDML format → Geant4 ← particle source
Geant4 → trackers energy deposits → trackers calibration ← ground test data
trackers calibration → trackers ADC levels → threshold comparison → E_{kin} reconstruction

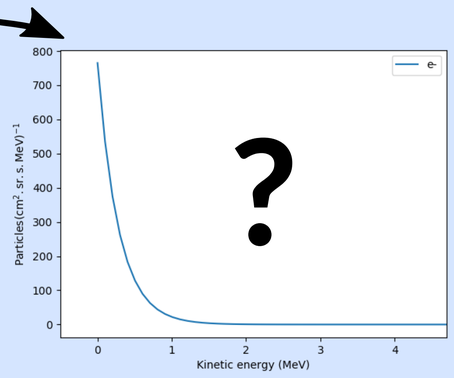
3. Observed count rates[3]

$$C = \sum_{q=e,p} \int_0^{\infty} f_q(E).\, RF_q(E).\, dE$$

- C: observed count rates
- $f_q(E)$: unknown energy spectra
- $RF_q(E)$: response functions taken from simulation

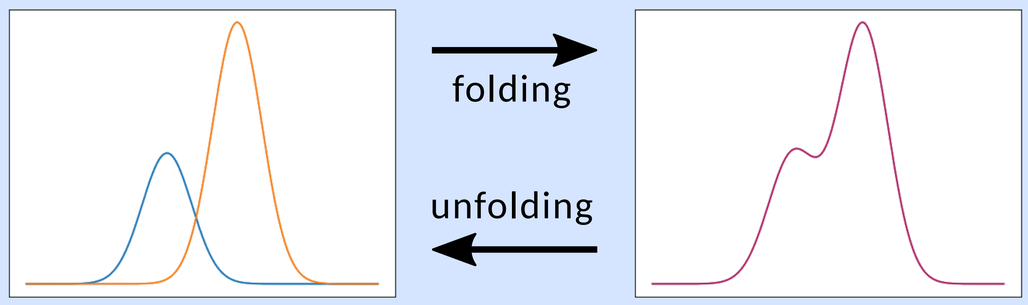




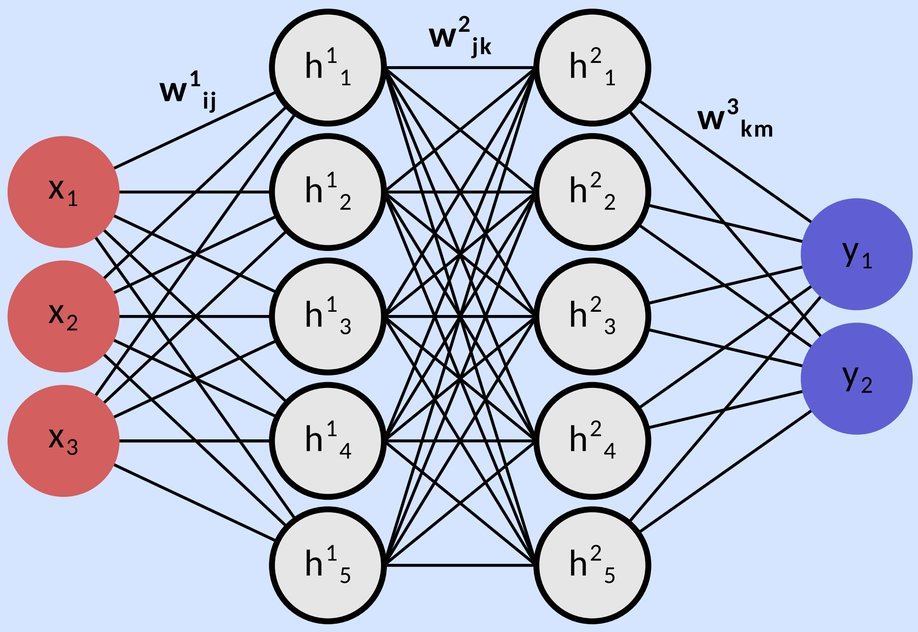


4. Data unfolding

Requires the inversion of the previous equation
(Fredholm integral equation of first kind)



5. Neural networks



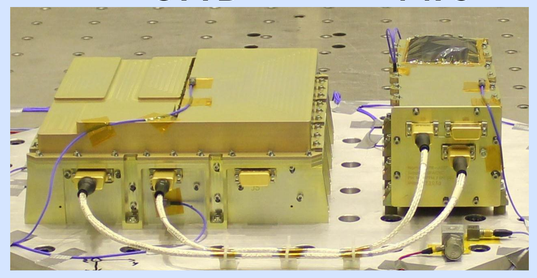
6. Some approaches to try

	Standard	NNPDF[4]
architecture	dense feedforward	
inputs	channel count rates	energy
outputs	differential energy flux bins	particles differential flux
training	once	for every set of count rates
training error	compare predictions with simulated differential energy flux	convolute predicted NN with RF and compare with count rates data

7. Further work

- comparison of predictions with other GEO radiation monitors such as GOES
- correlation with components failure data in twin experiment CTTB[5] (Component Technology Test-Bed)

CTTB MFS



References

[1] A. L. Casimiro et al, *Assessment of radiation exposure in manned missions to Mars for three mission profiles*, Radiation and Applications Journal (RAD Journal), RAD 2017, Budva, Montenegro, 12-16 June 2017
[2] M. Pinto et al, *GUIMesh: A tool to import STEP geometries into Geant4 via GDML*, Computer Physics Communications, Vol. 239, June 2019,c pp. 150-156
[3] L. Arruda et al, *Electrons in GEO measured with the ESA Multi-Functional Spectrometer during the January 2014 SEP*, IEEE Transactions on Nuclear Science, Volume: 65 , Issue: 8, July 2019, pp. 1540 - 1545
[4] arXiv:1410.8849 [hep-ph]
[5] J. Sampaio, L. Sintra et al, *Dose measurements and simulations of the RADFETs response onboard the ALPHASAT CTTB experiments*, submitted to IEEE Transactions on Nuclear Science