Calibration and First Data from UCLA's Electron Losses and Fields Investigation (ELFIN) Dual CubeSat Mission

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1. Abstract

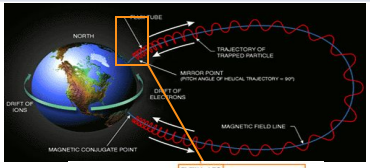
The Electron Losses and Fields Investigation, ELFIN, is a duo of active student-built 3U+ CubeSats successfully launched by UCLA in September 2018 into a 460 km circular polar orbit. ELFIN will measure the local pitch angle-resolved energy spectrum of relativistic electrons and ions precipitating from the radiation belts into Earth's atmosphere. ELFIN's primary science objective is to assess to what extent Electromagnetic Ion Cyclotron (EMIC) waves drive such scattering events. ELFIN's secondary objective is to investigate plasma sheet phenomena such as the location of the Isotropic Boundary Layer (IBL). There are four nominal science zones per orbit, spanning the geomagnetic range including L=3 to L=12 (outer radiation belts and plasma sheet).

ELFIN's instrument suite consists of an Energetic Particle Detector (EPD) and a Fluxgate Magnetometer (FGM). The EPD is comprised of two collimated solid-state detector stacks to measure the incident flux of energetic electrons from 50 keV to >4.5 MeV and ions from 50 keV to >4.5 MeV. ELFIN is unique in that it couples a wide energy range with a narrow field (FWHM) of view (<22°) with high differential energy resolution (dE/E < 0.5 with 16 energy channels). ELFIN spins perpendicular to the geomagnetic field to provide 16 pitch-angle particle data sectors per revolution (nom. 3 seconds), providing high time resolution (~200 ms/spin sector). Pitch angles are determined using the FGM.

This presentation focuses on the testing and performance of the ELFIN electron EPDs (EPD-E), which were ground calibrated prior to launch using radioactive isotope testing and Geant4 simulation. The ELFIN-A EPD-E has recently completed its preliminary on-orbit commissioning and cross-mission calibration with POES. Selected calibration data and first science-quality data are presented.

2. EPD at a Glance

Each ELFIN EPD will sweep through the loss cone to look for energetic particles that have been scattered by Electromagnetic Ion Cyclotron (EMIC) waves.

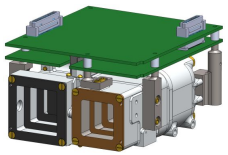


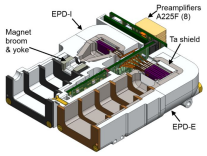
Engineering Specifications

- Volume < 1U
- Mass ~ 700 g
- Micron MSX Silicon Detectors (500um, 1000um, 2000um)
- Tantalum Shielding
- Two apertures (ion, electron)

Instrument Specification

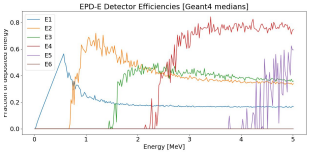
- 50 keV – >4.5 MeV (electrons)
- 50 keV – >4.5 MeV (ions)
- Capable of 0.2 – 150,000 cps
- 8 ADCs, 2 FPGAs distributed between 2 PCBs
- Anti-coincidence logic
- Pulse height analysis and summing (16 energy bins)

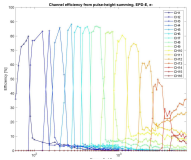


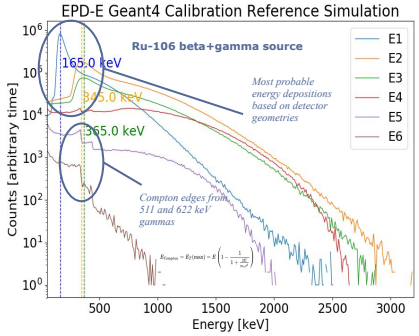


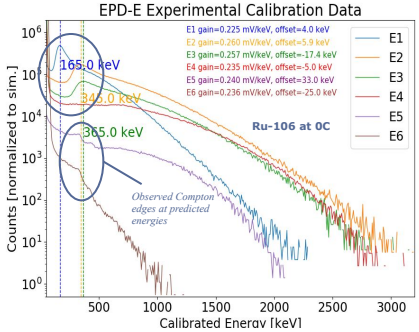
3. ELFIN-A Electron Detector Calibration

Laboratory calibration was performed using a number of radioactive isotopes including Ru-106, Am-241, Sr-90, and Ba-133. Observations were compared with Geant4 simulations of the same inputs. A range of temperatures were covered in testing.





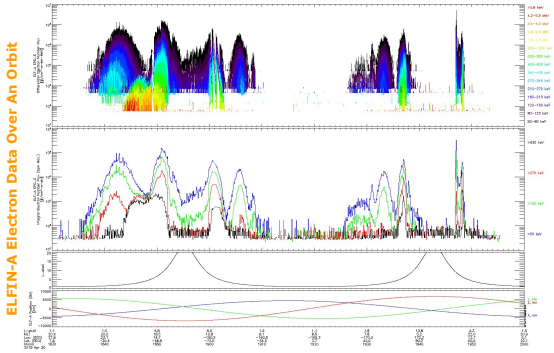




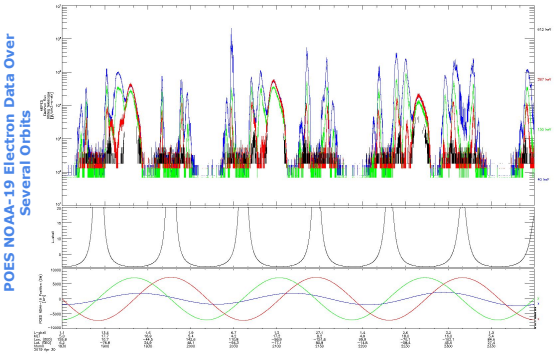
Energy channel	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Minimum energy $E_{min,i}$ [keV]	~50	80	120	160	210	270	345	430	630	900	1300	1800	2500	3350	4150	≥5800
Bin width ΔE_i [MeV]	0.03	0.04	0.04	0.05	0.06	0.075	0.085	0.2	0.27	0.4	0.5	0.7	0.85	0.8	1.65	N/A
Characteristic energy E_i [keV]	75	113	151	197	259	326	413	562	767	1068	1516	2150	3333	3794	5182	N/A
$\Delta E_i / E_i$	0.37	0.44	0.18	0.33	0.22	0.23	0.24	0.36	0.28	0.36	0.34	0.37	0.49	0.22	0.51	N/A
Channel efficiency Γ_i	0.74	0.8	0.85	0.86	0.87	0.87	0.87	0.87	0.82	0.8	0.75	0.6	0.5	0.45	0.25	0.05
Threshold gain correction T_i	5	1	1	0.8	1	1	1	1	1	1	1	1	1	1	1	1
Flux coef. $F_{i,j\neq 15}$ [1/cm^2-str-keV]	45.0	8.3	6.2	7.7	7.7	7.7	7.7	7.7	8.1	8.3	8.9	11.1	13.3	14.8	26.7	133.3

Table: ELFIN-A EPD-E nominal energy bins and flux conversion coefficients. The energies $E_{min,i}$ represent the lowest energy in the bin necessary to be counted in that bin, but less than $E_{min,i+1}$.

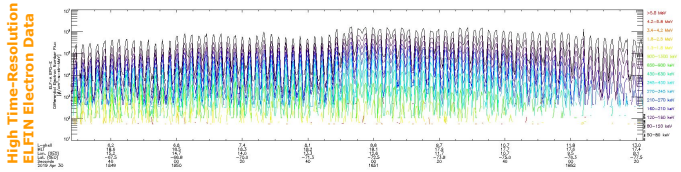
4. Cross-Calibration and First Science-Quality Data



Top figure: ELF-A EPD-E data over the span of an orbit (top) showing two polar crossings. The first crossing is indicative of an extended auroral oval with 50-120 keV electron fluxes. The second panel from top shows the maximum integral flux observed over a single spin period (a measure of trapped and precipitating flux; not spin averaged). Inner and outer radiation belt crossings are evident, as is possibly the duskward edge of the plasma sheet near L~8. The spin maxima integral flux is directly comparable to the POES electron data below.



Middle figure: POES NOAA-19 MEPED integral electron fluxes show several polar crossings in the same time window as the ELFIN data (although different MLT). Similar features and flux levels are observed, providing a measure of validation for the ELFIN electron data. The 90 degree telescope measures primarily trapped fluxes in ELFIN's science regions.



Bottom figure: Zoomed in timespan of the top figure revealing ELFIN's high time resolution electron data at roughly 200 ms/spin sector sampling. Periodic fluxes are clearly observed every ½ spin period, along with variations in the field-aligned populations. Pitch-angle information will be available upon completion of commissioning of the FGM instrument.

5. Conclusion and Future Work

The ELFIN electron data is nearly science ready. Once the on-orbit calibration of the EPD-I and FGM are complete, data will begin public release. Please visit https://elfin.igpp.ucla.edu/ for more information.

Jet Propulsion Laboratory, California Institute of Technology