Apollo 14 CPLEE Electron and Ion Count Rates and Fluxes Data Collection Description

H. K. Hills, 25 July 2019

Overview

This collection contains fixed-width ASCII tables of raw counts and derived fluxes of electrons and ions in the energy range of 40 to 20,000 eV observed at the Apollo 14 ALSEP site [7] by the two analyzers of the Charged Particle Lunar Environment Experiment (CPLEE), one looking in the local vertical direction and one at 60 degrees from vertical toward lunar west. Although most data were acquired by the automatic voltage stepping sequence that required 19.2 seconds to complete a 15-point (channel) spectrum over the energy range, some data were also acquired in the manual mode that sampled various subsets of the energy channels in 2.4 seconds. Data include housekeeping measurements and the necessary time and mode identification information. The time span is from 05 February 1971 through 02 March 1973 and includes observations of the large solar flare event of 04 August 1972.

These data are the ASCII transformation of the Common Data Format (CDF) files in NASA Space Science Data Coordinated Archive (NSSDCA) dataset SPHE-00885, "Apollo 14 CPLEE, 2.4-s and 19.2-s spectra of 0.04-23 keV Electrons and Protons in Two Directions on the Lunar Surface" [1]. The CDF files are reformatted data extracted from the NSSDCA original binary dataset SPHE-00017 on tape, "Apollo 14 CPLEE Count Rate Data" [11].

The user should read [9] which describes the CPLEE instrument in detail and provides initial results; [10] explains the design and operation of Switched Proton Electron Channeltron Spectrometers such as CPLEE. The user should also look at the details of the operation of CPLEE provided in [2] and in section 11 of [3]. For additional engineering and operations information on the Apollo 14 ALSEP station (also known as Array 4) and its experiments, see [3], [4], and [5]. For detailed operational history of the individual ALSEP experiments, see [6]. For a brief description of CPLEE together with a summary of its operational history and its data content, formats, and availability, see [8]. [12] analyzes the plasma clouds produced by the impact of the Apollo 14 Lunar Module that occurred 66 km away from CPLEE.

Data Products

This collection contains two types of data products, where each type consists of an ASCII fixed-width tabular data file (.tab) and a detached PDS label (.xml) that defines the format and contents of the data file:

1. Science Data: 203 daily products of raw electron and ion counts and derived fluxes along with housekeeping data. The file naming convention is apollo14_cplee_YYYYMMDD.tab/.xml, where YYYYMMDD specify the observational year, month, and day.
2. Support Data: One product containing a) the calibration conversion factors used to compute the fluxes from observed counts and b) the various electron and ion channel energies associated with raw counts and derived fluxes in the science data products. These center energies and counts-to-flux conversion factors can also be found in Table 1 of Appendix A. The file naming convention is apollo14_cplee_support_data.tab/xml.

Science Data Products

Each daily science data table consists of 35-column records, following two header records that provide labels for the columns. Each record contains data from one CPLEE sequence. The table columns and their contents are shown below. All counts are given in units of "data number" and all fluxes in units of "/centimeter-squared second steradian electron-volt". Appendix A summarizes the calibration of the CPLEE instrument and provides the center energy values for electron and ion channels and the calibration factors used to compute the fluxes, which can also be found in the Support Data file.

Column 1: Epoch, universal time formatted as yyyy-mm-ddThh:mm:ss
Column 2: Mode/Step, mode and step indicator: 8 is automatic stepping mode; otherwise it is manual mode and the value (0-7) is the 'step' that specifies the analyzer(s) and energy channels to be sampled.

Column 3 contains 15 consecutive data points for E_flux_A, the derived electron flux from analyzer A. These are for detector energy channels 1 through 5 for each of three deflection voltage steps -35, -350, and -3500 volts, respectively, for electrons. The center energy values of the 15 electron channels for analyzer A are given in the Energy_EA column of the Support Data file. Then column 4 continues similarly with 15 consecutive points for E_flux_B, the derived electron flux from analyzer B. Next, column 5 contains 15 consecutive data points for P_flux_A, the derived proton (ion) flux from analyzer A for detector energy channels 1 through 5 for each of three deflection voltage steps +35, +350, and +3500 volts, respectively, for protons. The center energy values of the 15 proton channels for analyzer A are given in the Energy_PA column of the Support Data file. This pattern of 15 data points for five energy channels in each of three deflection voltages (-35, -350, and -3500 volts for electrons; or +35, +350, and +3500 volts for ions) continues through column 10 as shown, where "E" or "P" in the column name specify electron or proton (ion); "A" or "B" indicate analyzer A or B; and the superscript [1] denotes a column in the Support Data file:

Column Description
- 3 E_flux_A, at 15 energy values given by Energy_EA[1], e.g., 40, 50, 65, 94, 200, 500, 600, 750, 1100, 2000, 4800, 5800, 7200, 10000, and 20000 eV, respectively.
- 4 E_flux_B, at 15 energy values given by Energy_EB[1]
- 5 P_flux_A, at 15 energy values given by Energy_PA[1], e.g., 60, 70, 84, 170, 300, 500, 600, 750, 1100, 2000, 4800, 5800, 7200, 10000, and 20000 eV, respectively.
- 6 P_flux_B, at 15 energy values given by Energy_PB[1]
- 7 E_counts_A, raw counts at 15 energy values given by Energy_EA[1]
- 8 E_counts_B, raw counts at 15 energy values given by Energy_EB[1]
- 9 P_counts_A, raw counts at 15 energy values given by Energy_PA[1]
- 10 P_counts_B, raw counts at 15 energy values given by Energy_PB[1]

Columns 11 through 16 contain the observed wideband (WB) counts and derived fluxes for analyzers A and B at the three deflection voltages:
- 11 WB_E_flux_A, at three energy values given by WB_ENERGY_EA[1]
- 12 WB_E_flux_B, at three energy values given by WB_ENERGY_EB[1]
- 13 WB_counts_PA, at three energy values given by WB_CHAN[1]

[1] A column in the support data table.

14 WB_counts_PB, at three energy values given by WB_CHAN[1]
15 WB_counts_EA, at three energy values given by WB_ENERGY_EA[1]
16 WB_counts_EB, at three energy values given by WB_ENERGY_EB[1]

Columns 17 and 18 contain the calibration counts for both analyzers from a signal generator (nominally 3.93 x 10**5 counts) when the deflection voltages are zero:
17 CAL_A, at five detector (energy) channels
18 CAL_B, at five detector (energy) channels

Columns 19 and 20 contain the derived electron fluxes observed by the wideband channel of both analyzers at each of three deflection voltages for electrons, -35, -350, and -3500 volts, respectively. Columns 21 and 22 provide the counts observed by the wideband channel of both analyzers.
19 WB_BKG_flux_EA, at three electron wideband energy values given by WB_ENERGY_EA[1]; calculated by applying the electron wideband flux conversion factor for analyzer A to the counts in WB_BKG_A[1].
20 WB_BKG_flux_EB, at three electron wideband energy values given by WB_ENERGY_EB[1]; calculated by applying the electron wideband flux conversion factor for analyzer B to the counts in WB_BKG_B[1].
21 WB_BKG_A, one value of wideband background counts for analyzer A, zero deflection voltage
22 WB_BKG_B, one value of wideband background counts for analyzer B, zero deflection voltage

Columns 23 and 24 contain observed background counts for both analyzers:
23 BKG_A, one value for each of detectors 1-5 of analyzer A, zero deflection voltage
24 BKG_B, one value for each of detectors 1-5 of analyzer B, zero deflection voltage

Columns 25 through 28 contain background electron and ion fluxes computed for both analyzers. Each column follows the same pattern described for Columns 3 through 10, where each column contains 15 data points for five energy channels in each of three deflection voltages (-35, -350, and -3500 volts for electrons; or +35, +350, and +3500 volts for ions):
25 P_BKG_flux_A, at three deflection voltage values of ENERGY_PA[1] and five detector (energy) values; calculated from counts in P_BKG_A[1]
26 P_BKG_flux_B, at three deflection voltage values of ENERGY_PB[1] and five detector (energy) values; calculated from counts in P_BKG_B[1]
27 E_BKG_flux_A, at three deflection voltage values of ENERGY_EA[1] and five detector (energy) values; calculated from counts in E_BKG_A[1]
28 E_BKG_flux_B, at three deflection voltage values of ENERGY_EB[1] and five detector (energy) values; calculated from counts in E_BKG_B[1]

The last seven columns provide single-valued housekeeping values:
29 WB_CAL_A, wideband calibration count for analyzer A
30 WB_CAL_B, wideband calibration count for analyzer B
31 HV_A, detector high voltage for analyzer A
32 HV_B, detector high voltage for analyzer B
33 DC_DC_V, DC-to-DC converter voltage; column name in table header is DC_DC
34 T_cpa, temperature of the curved plate analyzers in degrees Celsius
35 T_elect, temperature of the electronics in degrees Celsius

Each detached PDS label (.xml) specifies the data file structure so that PDS-compatible software can properly read the corresponding data. Users who prefer to read the data files directly can use this Fortran-based FORMAT statement, which specifies the 35-column data record layout:

```
FORMAT ( 19A, 2X, I1, 1X, 15(1X, E11.4), 1X, 15(1X, E11.4), 1X, 15(1X, E11.4), 1X, &
  &15(1X, E11.4), 1X, 15(1X, E12.5), 1X, 15(1X, E12.5), 1X, 15(1X, E12.5), 1X, &
  &15(1X, E12.5), 1X, 3(1X, E11.4), 1X, 3(1X, E11.4), 1X, 3(1X, E12.5), 1X, &
  &3(1X, E12.5), 1X, 3(1X, E12.5), 1X, 3(1X, E12.5), 1X, 5(1X, E12.5), 1X, &
  &5(1X, E12.5), 1X, 3(1X, E11.4), 1X, 3(1X, E11.4), 2X, E12.5, 2X, E12.5, 1X, &
  &15(1X, E12.5), 1X, 15(1X, E12.5), 1X, 15(1X, E11.4), 1X, 15(1X, E11.4), 1X, &
  &15(1X, E11.4), 1X, 15(1X, E11.4), 2X, E12.5, 2X, E12.5, 2X, F8.2, 2X, F8.2, 2X, &
  &F5.2, 2X, F7.2, 2X, F5.2 )
```

Example of a Science Data Product

Here is one example to show how the 15-data-point columns are set up and how each value is associated with a specific deflection voltage, detector, and center (channel) energy. This example is for Column 3 (E_flux_A, the 15 electron fluxes for analyzer A) of the first data row in the science data file, /data/1971/apollo14_cplee_19710205.tab.

E_flux_A Repetition Number	E_flux_A Data Value	Deflection Voltage Step (V)	Detector Number	Center Energy (eV)
1	1.1800E+04	-35	1	40
2	0.0000E+00	-35	2	50
3	5.6400E+03	-35	3	65
4	5.3000E+02	-35	4	94
5	4.0000E+02	-35	5	200
6	3.1300E+02	-350	1	500
7	2.1000E+02	-350	2	600
8	7.0800E+02	-350	3	750
9	1.3000E+02	-350	4	1100
10	3.9000E+02	-350	5	2000
11	8.8400E+03	-3500	1	4800
12	2.4800E+02	-3500	2	5800
13	2.7400E+03	-3500	3	7200
14	1.0100E+03	-3500	4	10000
15	1.5300E+03	-3500	5	20000

This pattern is nearly identical for Column 5 (P_flux_A, the 15 ion fluxes for analyzer A) except the deflection voltage steps are +35, +350, and +3500 and the center energies are 60, 70, 84, 170, 300, 500, 600, 750, 1100, 2000, 4800, 5800, 7200, 10000, and 20000 eV.

Support Data Product

The support data file that contains a single 14-column record, which follows two headers that provide labels for the columns. The columns and their contents are shown below. Most of the contents in this file can also be found in Table 1 of Appendix A.

Columns 1 through 6 provide the electron and ion channel energies, in units of eV, associated with the columns in the science data tables.

Column Description

1 ENERGY_EA, center energies of the 15 electron channels (detectors 1 through 5 for each of three deflection voltage steps -35, -350, and -3500 volts) for analyzer A
2 ENERGY_EB, center energies of the 15 electron channels for analyzer B
3 ENERGY_PA, center energies of the 15 ion channels (detectors 1 through 5 for each of three deflection voltage steps +35, +350, and +3500 volts) for analyzer A
4 ENERGY_PB, center energies of the 15 ion channels for analyzer B
5 WB_ENERGY_EA, center energies of the three wideband channels for electrons for analyzer A
6 WB_ENERGY_EB, center energies of the three wideband channels for electrons for analyzer A

Columns 7 through 14 provide the calibration factors to convert observed counts to flux in units of "# particles/cm**2 s sr eV" and the detector numbers:

7 CF_EA, One conversion factor for each of the 15 electron channels for analyzer A
8 CF_EB, One conversion factor for each of the 15 electron channels for analyzer B
9 CF_PA, One conversion factor for each of the 15 ion channels for analyzer A
10 CF_PB, One conversion factor for each of the 15 ion channels for analyzer B
11 CF_WB_EB, One conversion factor for each of the three wideband electron channels for analyzer B
12 CF_WB_EA, One conversion factor for each of the three wideband electron channels for analyzer A
13 WB_CHAN, center energies, in keV, of the three wideband channels for protons for analyzers A and B
14 DETNUM, specifies the five detectors (channel electron multipliers [2]), numbered 1 through 5.

Data Gaps and Quality

The CPLEE instrument operated continuously from 5 February 1971 until 6 June 1971 at which time a partial failure in one the of high voltage supplies forced intermittent operations [6]. The science data products cover this five-month period of continuous operation. After this failure, principal investigator D. L. Reasoner selected and provided data only for periods of interest (e.g., solar flares, lunar impacts, and magnetic storms) for which CPLEE operation was stable and good quality data were received. Therefore science data products after 6 June 1971 are intermittent.

There is a case where it appears that the instrument is in mode 4 and the counting rate is increased noticeably during the exact time interval that the instrument is in mode 4. However, the data provider, Dr. H. K. Hills (NSSDCA), determined this increased counting rate was caused by some unknown spurious effect going on at that time: the voltage on the A/D converter is zero, which apparently leads to an unexpected (and unpredicted), unreliable result for the particle counts for that frame.

While producing the ASCII data products for this collection, the data provider confirmed values for raw counts and fluxes should be represented in exponential format with four decimal places preserved, which is the format specified in the source CDF files [1].

References

[1] "Apollo 14 CPLEE, 2.4-s and 19.2-s spectra of 0.04-23 keV Electrons and Protons in Two Directions on the Lunar Surface", Dataset id. SPHE-00885, NASA Space Science Data Coordinated Archive, Goddard Space Flight Center, 2007. (Dataset description, https://calypso.gsfc.nasa.gov/dsc/DSC_0226.pdf)

[2] "Apollo 14 Charged Particle Lunar Environment Experiment (CPLEE)" in "Apollo 14 Document Collection", Document Product id. urn:nasa:pds:apollodoc:a14doc:a14a_cplee_overview, NASA Planetary Data System, 2019.

[3] Apollo Lunar Surface Experiments Package Systems Handbook, ALSEP 4, Unnumbered, Flight Control Division, NASA Manned Spacecraft Center, Houston, Texas, 1970. (https://www.lpi.usra.edu/lunar/ALSEP/pdf/31111000675122.pdf)

[4] Apollo Lunar Surface Experiments Package, ALSEP Flight System Familiarization Manual, Revision B, ALSEP-MT-03, NASA CR-99604, The Bendix Corporation for [10] NASA Manned Spacecraft Center, published 1 August 1967, revised 15 April 1969. (https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19710014816.pdf or https://repository.hou.usra.edu/handle/20.500.11753/238)

[5] Apollo Lunar Surface Experiments Package, ALSEP Flight System Familiarization Manual, Revision B / Change 1, ALSEP-MT-03, NASA CR-99604, The Bendix Corporation for NASA Manned Spacecraft Center, Houston, Texas, 18 March 1970. (https://repository.hou.usra.edu/handle/20.500.11753/45)

[6] Bates, J. R., et al., ALSEP Termination Report, NASA Reference Publication 1036, April 1979. (https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19790014808.pdf)

[7] Davies, M. E., and T. R. Colvin, Lunar coordinates in the regions of the Apollo landers, Journal of Geophysical Research, Volume 105, Issue E8, pages 20,227-20,280, 2000. (doi:10.1029/1999JE001165)

[8] Lauderdale, W. W., and W. F. Eichelman, Apollo Scientific Experiments Data Handbook, NASA, TM-X-58131, Houston, Texas, August 1974, updated August 1976. (https://repository.hou.usra.edu/handle/20.500.11753/17 or https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19760007062.pdf)

[9] O'Brien, B. J. and D. L. Reasoner, 10. Charged-Particle Lunar Environment Experiment (CPLEE), Apollo 14 Preliminary Science Report, NASA SP-272, pages 193-213, NASA, Washington, D.C., 1971. (https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19710021477.pdf)

[10] O'Brien, B. J., F. Abney, J. Burch, R. Harrison, R. LaQuey, and T. Winiecki, SPECS, a Versatile Space-Qualified Detector of Charged Particles, Review of Scientific Instruments, 38, 1058, 1967. (doi:10.1063/1.1720966)

[11] Reasoner, D. L., "Charged Particle Lunar Environment Experiment (CPLEE)" in Data Set Catalog 226 for "Apollo 14 CPLEE Count Rate Data", Dataset id. SPHE-00017, NASA Space Science Data Coordinated Archive, Goddard Space Flight Center, 1972. (Dataset description, https://calypso.gsfc.nasa.gov/dsc/DSC_0226.pdf)

[12] Reasoner, D. L. and B. J. O'Brien, Brief Reports: Measurement of the Lunar Surface of Impact-Produced Plasma Clouds, Journal of Geophysical Research, Volume 77, Issue 7, pages 1292-1299, 1972. (doi:10.1029/JA077i007p01292)

Source

Dr. K. H. Hills, NSSDCA staff scientist, provided this data description, including the explanations of the science data products and the CPLEE calibration.

Appendix A. Apollo 14 CPLEE Calibration

This appendix is a reproduction of the printed hardcopy of the CPLEE Calibration section in [11].

In Table 1 below, the center energies of the various channels and the numbers to convert from counts/cycle (1 cycle = 1.2 seconds) to flux in particles/cm^2 second steradian eV are given. Negative deflection voltages (-35, -350, -3500) for channels (detectors) 1-5 are electron channels, while positive deflection voltages for channel 6 are electron channels. Conversely, positive deflection voltages for channels 1-5 and negative deflection voltages for channel 6 are ion channels. The calibrations for the lowest energy ion channels (+35 volts, channels 1-5) are estimated as there was no low-energy ion source available for calibration; these estimates are enclosed by parentheses.

The deflection voltage step labeled +0 (positive zero) is a background measurement. At the -0 (negative zero) deflection voltage step, a test oscillator with frequency of about 375 kHz is connected to the amplifiers to verify operation of the entire data link.

Figures 1 and 2 show the actual CPLEE energy passbands for electron. Here are plotted *GF (E)* vs. *E*, where *GF* is the geometric factor and *E* is the energy. The area under a curve is $GF_O \times \Delta E$, or the effective geometric factor in units of (cm^2 steradian eV counts)/particle. The conversion numbers in Table I were obtained by the formula:

$$N = \frac{1}{GF_o \times \Delta E} \times \frac{1}{1.2}$$

The factor of 1.2 accounts for the 1.2 second accumulation time. Figures 1 and 2 are also provided as separate high-resolution images in PDF/A format to aid researchers.

Table 1:
CPLEE Counts to Differential Flux (Counts/1.2 sec to #/cm^2 second steradian eV)

Voltage Step	Center Energy (eV)		Flux units/counts	
(V), Detector	Analyzer A	Analyzer B	Analyzer A	Analyzer B
-35, 1	40	45	5900	4350
-35, 2	50	54	2780	2560
-35, 3	65	70	1410	1430
-35, 4	94	100	530	532
-35, 5	200	200	100	74
-35, 6				
-350, 1	500	500	313	351
-350, 2	600	600	210	266
-350, 3	750	750	118	143
-350, 4	1100	1100	65	81
-350, 5	2000	2300	15	15
-350, 6				
-3500, 1	4800	5000	68	70

-3500, 2	5800	6000	31	33
-3500, 3	7200	7500	18	24
-3500, 4	10000	10000	9.5	11.5
-3500, 5	20000	23000	6.5	6.5
-3500, 6				
+35, 1	(60)	(55)	(2×10^5)	(1.2×10^5)
+35, 2	(70)	(65)	(50000)	(50000)
+35, 3	(84)	(85)	(19000)	(20000)
+35, 4	170	(100)	2000	(4000)
+35, 5	300	220	230	240
+35, 6	75	85	4.8	4.5
+350, 1	500	500	630	615
+350, 2	600	600	380	475
+350, 3	750	750	170	242
+350, 4	1100	1100	70	105
+350, 5	2000	2200	12	11
+350, 6	750	800	0.74	0.83
+3500, 1	4800	5000	35	35
+3500, 2	5800	6000	13.4	14.3
+3500, 3	7200	7500	6.9	8.0
+3500, 4	10000	10000	2.7	3.3
+3500, 5	20000	22000	1.5	1.5
+3500, 6	9000	8000	0.31	0.60

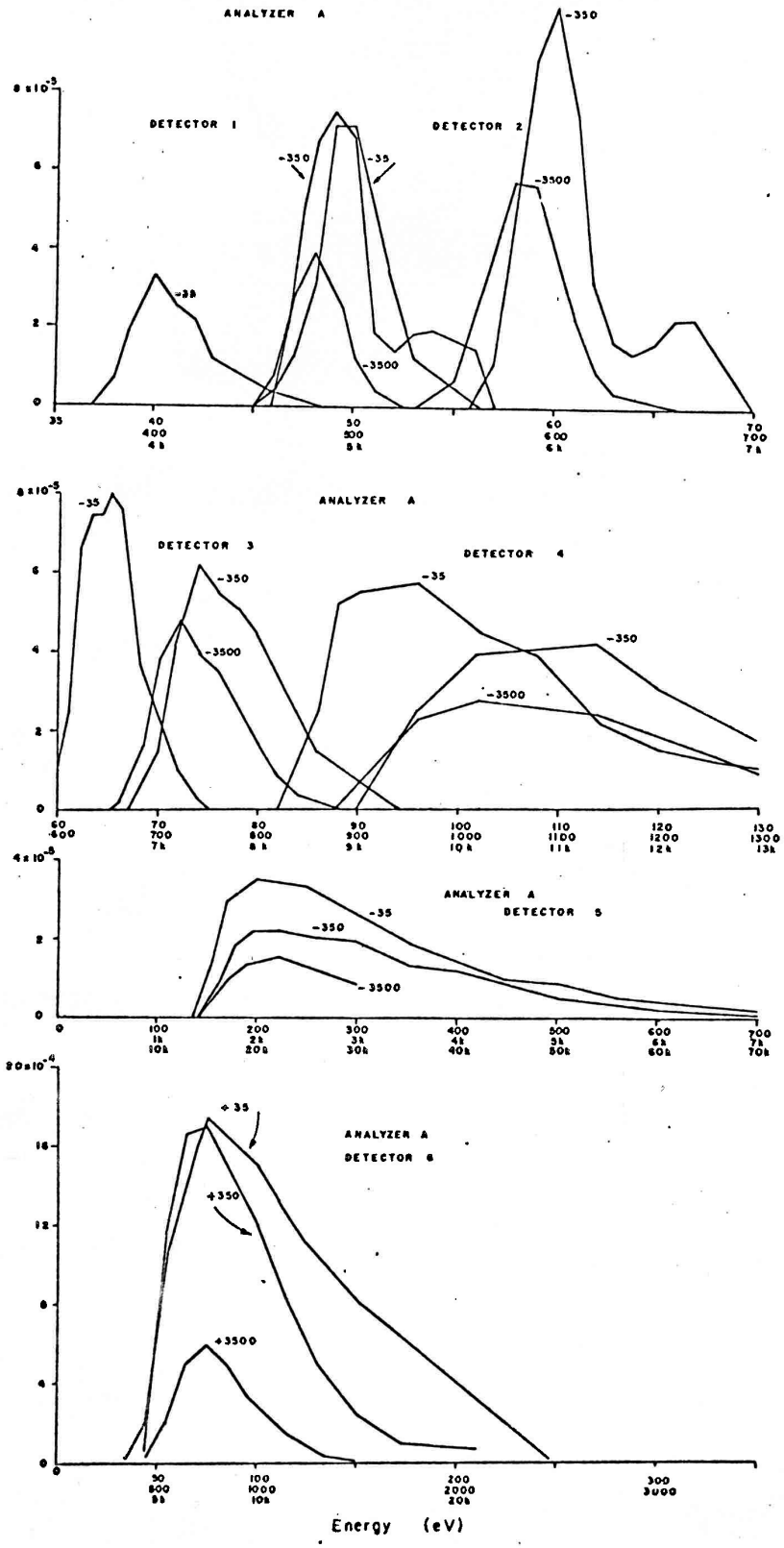

Figure 1: Energy passbands for CPLEE Analyzer A

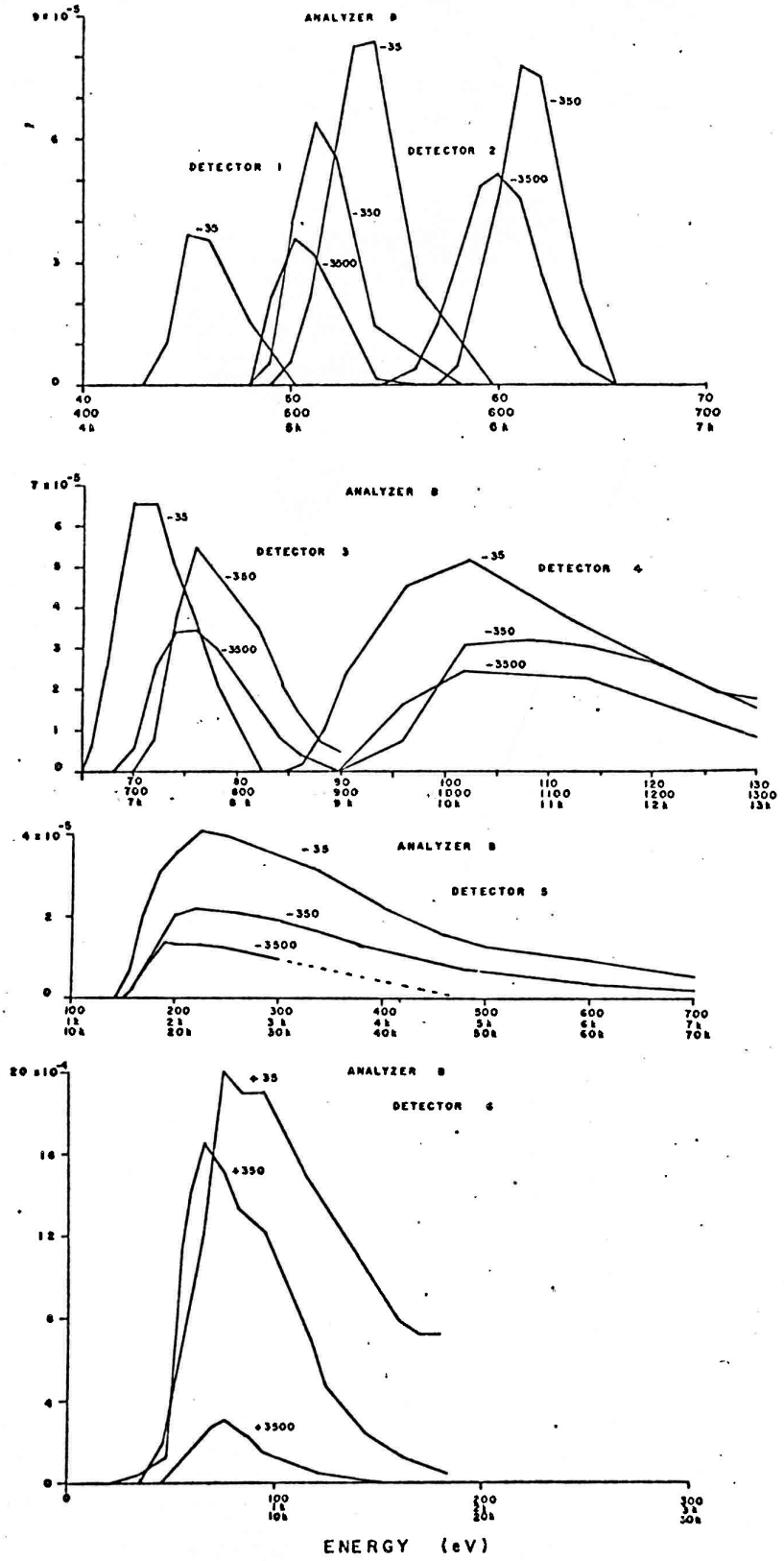

Figure 2: Energy passbands for CPLEE Analyzer B