Solar Orbiter HET/BGO Single-Counter Data Retrieval

SPEARHEAD project note

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1 Purpose

This note summarizes the Solar Orbiter High Energy Telescope (HET) in the context of the SPEARHEAD deliverables D3.2 and D5.3. The emphasis is on the Level-1 EPT-HET single-counter products that provide HET/BGO detector counts for SPEARHEAD data retrieval and cross-calibration work.

2 Solar Orbiter HET

HET is part of the Energetic Particle Detector (EPD) suite on Solar Orbiter. The EPD suite combines several sensors covering suprathermal to relativistic particle populations; HET is the high-energy telescope within this system and is used for energetic electrons, protons, helium, heavier ions, and penetrating high-energy particles. Its measurements are particularly relevant for solar energetic particle events and for the comparison of particle fluxes between spacecraft and long-term reference data sets.

The EPT-HET unit is compact and combines the Electron Proton Telescope (EPT) and HET electronics. The HET sensor head is a double-ended telescope. It consists of four passivated implanted planar silicon detectors arranged around a central scintillation detector. The silicon detectors provide the energy-loss and coincidence information needed for event classification, while the central scintillator is a bismuth germanate detector, BGO ($Bi_4Ge_3O_{12}$), with high stopping power for energetic particles. The entrance silicon detectors have two segments, and the inner silicon detectors have three segments, including guard-ring regions that help reject particles that entered through unintended paths or scattered inside the telescope. This segmentation supports trajectory checks, background rejection, and the definition of different geometric factors.

The telescope apertures are covered by thin foils that suppress low-energy particles and protect the detector system from direct solar illumination. The detector signals are processed through charge-sensitive preamplifiers, shapers, analog-to-digital conversion, and FPGA-based trigger logic. The on-board processing applies threshold, coincidence, and anti-coincidence conditions to classify events into detector counters. For SPEARHEAD, the relevant practical point is that the BGO/scintillator-related information is taken from the Level-1 single-counter CDF variables.

3 Archive Products

For Solar Orbiter HET/BGO single-detector counts, the relevant source products are the EPD Level-1 single-counter products. The data are obtained from the UAH EPD Data Portal and are also available through the ESA Solar Orbiter Archive (SOAR):

https://espada.uah.es/epd/data/
https://espada.uah.es/epd/data/api
https://soar.esac.esa.int/soar/

The relevant Solar Orbiter EPD/HET Level-1 products are listed in Table 1. For HET/BGO single-detector counts, these Level-1 EPT-HET single-counter products should be used.

Table 1: Level-1 EPD/HET single-counter products relevant for SPEARHEAD retrievals.

Product or search name	Description
epd_epthet1_sc	Level-1 EPT-HET1 single counters, Sun / anti-Sun
epd_epthet2_sc	Level-1 EPT-HET2 single counters, south / north

The Level-1 EPT-HET single-counter products include detector count variables for the corresponding viewing directions. For a retrieval of BGO detector counts, the CDF variable metadata for the chosen Level-1 EPT-HET product should be inspected and the HET detector count variables whose labels and descriptions correspond to the BGO/scintillator channel used in the SPEARHEAD processing should be selected.

4 Retrieval from the EPD Data Portal and SOAR

The HET/BGO single-detector counters are obtained from Solar Orbiter EPD Level-1 EPT-HET single-counter CDF products. The product epthet1-sc provides the ecliptic unit, covering Sun and anti-Sun directions, while epthet2-sc provides the polar unit, covering south and north directions. The UAH EPD Data Portal and ESA SOAR should be cited as the archive sources, and the product name, file name, time interval, version information, and access date should be recorded for traceability in D3.2 and D5.3.

For users who need the already extracted HET/BGO single-detector counts rather than the original CDF products, the practical data source is the Zenodo delivery file SOLO_HET-Single-Counter.txt. The EPD Data Portal and SOAR should be cited for archive provenance, and the Zenodo file should be cited as the ready-to-use single-counter data product used in the SPEARHEAD deliverables.

Within the archive search, the relevant product descriptors are summarized in Table 2. The single-detector counters are provided separately for the two EPT-HET units: the ecliptic unit covers the Sun and anti-Sun viewing directions, while the polar unit covers the south and north viewing directions.

Table 2: Archive descriptors relevant for HET/BGO single-counter retrieval.

Need	Product / descriptor	Direction or unit
HET single detector counters	epd-epthet1-sc	Ecliptic unit: Sun / anti-Sun
HET single detector counters	epd-epthet2-sc	Polar unit: south / north

Inside the CDFs, the single-counter variables are counts, for example A11H, A11L, B11H, B11L, C1H, and C1L. The support variable ACC_TIME gives the accumulation time in seconds. A count rate can therefore be derived approximately as

$$R = \frac{N}{\texttt{ACC_TIME}},$$

where N is the counter value and `ACC_TIME` is in seconds. For `epthet1-sc`, the DPDD describes the product as EPT-HET1 Level-1 single detector counters for the ecliptic unit, with HET A/B/C single-count variables for the Sun and anti-Sun directions. For `epthet2-sc`, the analogous product is EPT-HET2 Level-1 single detector counters for the polar unit, with south/north HET detector variables and the same 60 s cadence and `ACC_TIME` structure.

5 Zenodo Single-Counter File

The file `SOLO_HET-Single-Counter.txt`, distributed through Zenodo, contains the HET/BGO single-detector counts prepared for the SPEARHEAD data release. It was produced from Solar Orbiter EPD Level-1 single-counter data obtained from the UAH EPD Data Portal and SOAR, but it is the better source for users who want the derived single-counter data directly. The file contains one header line followed by time-binned count data. The time stamp is stored in six integer columns, `year`, `month`, `day`, `hour`, `minutes`, and `seconds`. The `ACC_TIME` column gives the actual accumulation time in seconds used for the counts in that row. The four counter columns are `C1H`, `C2H`, `C1L`, and `C2L`. The suffixes `H` and `L` denote high- and low-threshold count channels, respectively, while `C1` and `C2` denote the two channel groups delivered in the derived file.

The inspected file covers the period from 2026-01-15 00:00 to 2026-01-29 23:59. It contains 21 594 data rows, has a nominal cadence of one minute, and contains no duplicate time stamps. Three short gaps were identified: from 2026-01-16 23:59 to 2026-01-17 00:02, from 2026-01-22 23:59 to 2026-01-23 00:01, and from 2026-01-24 23:59 to 2026-01-25 00:03. The count values range from approximately 8.4×10^2 to 2.3×10^6, indicating both quiet count levels and enhanced intervals within the selected archive time span.

6 Python Generation Script

The file `SOLO_HET-Single-Counter.txt` can be regenerated with the Python script `generate_solo_het_single_counter.py`, written for this SPEARHEAD documentation and data-preparation task [5]. The script obtains Level-1 EPT-HET single-counter CDF files from the UAH EPD Data Portal API, reads the CDF variables with `cdflib`, and writes an ASCII table with the columns

`year month day hour minutes seconds ACC_TIME C1H C2H C1L C2L`.

By default the script uses `epthet1-sc`, corresponding to the EPT-HET1 ecliptic unit, and writes 60-second count bins. The polar unit can be processed by selecting `-product epthet2-sc`. The default variables are `C1H`, `C2H`, `C1L`, and `C2L`, but other CDF counter variables can be requested with the `-variables` option. The option `-acc-time` selects the output accumulation time in seconds; counts are summed into those bins and `ACC_TIME` stores the summed accumulation seconds actually used for each row.

A typical command is:

```
python generate_solo_het_single_counter.py \
  --start 2026-01-15 \
  --end 2026-01-29 \
  --acc-time 60 \
  --output SOLO_HET-Single-Counter.txt
```

The default output contains raw counts summed over the requested accumulation bins. If count rates are required, the option `-rates` writes $N/$`ACC_TIME` instead, using the summed accumulation time for each output row. The option `-cache-dir` controls where downloaded

CDF files are stored, so repeated processing can be performed without downloading the same files again.

The script was tested by regenerating the interval 2026-01-15 to 2026-01-29 from `epthet1-sc`. For all 21 594 time stamps present in the inspected original file, the regenerated values of `C1H`, `C2H`, `C1L`, and `C2L` were identical. The direct archive regeneration contained six additional minutes that were absent from the inspected original file: 2026-01-17 00:00–00:01, 2026-01-23 00:00, and 2026-01-25 00:00–00:02. Thus the code reproduces the original file exactly for all common time stamps, while retaining the complete minute cadence available from the current archive download.

7 Use in SPEARHEAD D3.2 and D5.3

For D3.2, the UAH EPD Data Portal and SOAR provide the archive provenance needed to document Solar Orbiter high-energy particle data. For D5.3, the BGO/scintillator-related Level-1 HET single counters and the Zenodo file `SOLO_HET-Single-Counter.txt` can be used as high-energy detector-count channels for comparison with other spacecraft data sets, event lists, and quiet-time or Forbush-decrease studies. The retrieval should preserve the original CDF timing information, accumulation time, quality flags, product version, viewing direction, and the exact variable names used. If the counts or rates are converted to a derived SPEARHEAD ASCII or CSV product, the header should state the source product, selected variables, units, time coverage, processing date, accumulation time, and any averaging or quality-selection criteria. For the public ready-to-use single-counter product, the file name and Zenodo record should be cited in addition to the EPD archive provenance.

Acknowledgement

The Solar Orbiter EPD data used for this documentation and for the derived single-counter file were generated and maintained by the EPD team and distributed through the UAH EPD Data Portal, with the products mirrored in the ESA Solar Orbiter Archive (SOAR). Solar Orbiter is a space mission of international collaboration between ESA and NASA, operated by ESA. Users should read the EPD release notes and instrument caveats, acknowledge the EPD team and the archive source, and additionally cite the Zenodo data release containing `SOLO_HET-Single-Counter.txt` when using the ready-to-use HET/BGO single-detector counts.

References

[1] UAH EPD Data Portal: `https://espada.uah.es/epd/EPD_data.php`.

[2] UAH EPD Data Browser, Level-1 archive tree: `https://espada.uah.es/epd/data/archive?path=%2Fl1%2F`.

[3] UAH EPD Data Browser API help: `https://espada.uah.es/epd/data/api_help`.

[4] ESA Solar Orbiter Archive (SOAR), web interface: `https://soar.esac.esa.int/soar/`.

[5] OpenAI Codex, `generate_solo_het_single_counter.py`, Python script generated for the SPEARHEAD Solar Orbiter HET/BGO single-counter data preparation, 2026-06-22.

[6] R. Elftmann, doctoral thesis excerpt on the Solar Orbiter HET design and GEANT4 response modelling, local SPEARHEAD source material.