Data Introduction: New Horizons Spacecraft, PEPSSI Instrument

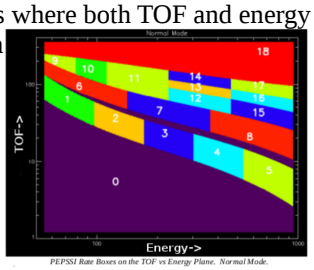
This is an abbreviated guide to the main elelements of this [instrument] data set to provide an overview and a quick path to viewing the data. Many details and subtleties regarding these data have been excluded here tfor the sake of brevity and clarity; those who plan to perform scientific analysis on these data must read the documentation referenced by or provided in this data set.

PEPSSI science goals: 1) determine the escape rate of Pluto's atmosphere; 2) measure the interaction of the solar wind with Pluto's ionosphere; 3) determine the source and nature of energetic particles found near Pluto.

Instrument: PEPSSI (Pluto Energetic Particles Spectrometer Science Investigation) is a compact particle telescope with a time-of-flight (TOF) section and a solid-state detector (SSD) array with twelve detectors arranged in a 12° x 160° swath in six 25°-wide angular sectors and 2° between sectors, with one TOF start anode and two SSDs per sector. Sectors 0,2,5 each have one ion detector and one electron detector; sectors 1,3,4 each have two ion detectors. PEPSSI measures ions and electrons over a broad range of energies and pitch angles. Particle composition and energy spectra are measured for H to Fe from ~ 30 keV to ~1 MeV and for electrons from ~30 keV to 700 keV.

Operations and *measurements*: 1) A mechanical collimator defines the acceptance angles for incoming ions and electrons, directing them to one of the six sectors. 2) PEPSSI measures the ion ***TOF*** using secondary electrons generated as the ion passes through entrance and exit foils; entrance foil secondary electrons hit the sector's start anode flagging the TOF start and ***identifying the sector*** and therefore the incoming ion direction; exit foil electrons hit the stop anode flagging TOF stop. 3) PEPSSI measures the ***total ion energy***, above a threshold, when ions hit the SSD array. Energies below the SSD thresholds may be measured via secondary electron pulse height on a micro-channel plate (MCP) above the TOF anodes, which provides a coarse indication of low-energy particle mass.

Event data, selection, accumulation and classification: (N.B. this section is greatly simplified to keep this introduction within a set page limit; refer to data set documentation for a more complete understanding.) Each event generates TOF and/***or*** energy on-board measurements in Analog-to-Digital Units (ADUs) i.e. raw data counts; ADU values are log-compressed with 5 bits each of mantissa and exponent. For events with a TOF detection, there is the sector(s) of the start anode(s) (N.B. multiple start anodes may detect secondary electrons from an event). For events with energy detection only, there is the sector (0-5 for ion SSDs) or electron SSD (0-2). Due to bandwidth limitations, all (Pulse Height Analysis; PHA) data for all events are not stored; instead, PHA data for only a subset of events are chosen, according to a round-robin priority scheme, and stored on-board. Further, the timestamps of individual events are not recorded, rather all events over an interval (typically 10s to 600s) are passed from the instrument to spacecraft storage as a group, with a single timestamp for the start of the group interval. PHA data are separated into three event types: High-Energy Ion (also High-Ion or Triple) events where both TOF and energy detections were measured; Electron events where only electron SSD detections were measured; Low-Energy Ion (also Low-Ion, Double or TOF-Only) events where only TOF detections were measured. Finally, although full PHA data for all events are not recorded, all events are classified by event type, sector, and [TOF+energy] Rate Box, and a count (rate) of each classification is recorded over each time interval. The classifications are represented by 6 character strings, with one character for event type (B = Hi-Ion; L = Low-Ion; R = Electron); a two-digit rate box (00-18; see the 19 colored regions in the figure to the right); and an S (Sector) followed by a two-digit sector designator (00-05 for Hi-Ion events; 00-02 for Electron events). For example: a rate labeled B02S04 represents a particle arriving from the sector 3 direction (Start Anode 4; N.B. anode and detector numbering are reversed), which deposited energy between 94 and 169 ADUs (see orange region 2 in the figure) onto one of the SSDs. There are additional classifications (HK for housekeeping; C for software counters, etc.); refer to the data set documentation for more detail.



PEPSSI Rate Boxes on the TOF vs Energy Plane. Normal Mode.

Finding the Data: Archival data are stored in directories with names of the form ***yyyymmdd_kkk*** where ***yyyy***, ***mm***, and ***dd*** are the year, month, and day on which data taking started and ***kkk*** is the 6-digit mission elapsed time (MET) prefix. Data filenames have the form ***pep_mmm_0xaaa_nnn.fit***, where ***mmm*** is the 10-digit spacecraft clock time suffix, ***aaa*** is the telemetry application identifier (ApID), ***nnn*** is the processing level identifier. An additional version number suffix, ***_v,*** follows the processing level in some data sets.

0xaaa = ***0x691*** *(High Priority);* ***0x692*** *(Medium);* ***0x693*** *(Low, < 501 PHA);* ***0x694*** *(Low, > 500 PHA)*
0x695 *(Diag "); ***0x696*** (Diag "); ***0x697*** (Diag "); ***0x698*** (Diag ")*
nnn = ***eng*** *(raw data);* ***sci*** *(calibrated)*

Searching for data: There is a brief summary of the types of observations in the data set catalog (***catalog/dataset.cat)***. There is also a table of the sequences in the data set documentation (***document/seq_pepssi_...)***. Each row in that table provides 1) a sequence ID that matches NEW_HORIZONS:SEQUENCE_ID keywords in data product PDS labels, 2) a time, in UTC & SCLK, just before all observations of that sequence, 3) a brief prose description of the observations. Refer to the sequence table label (***document/seq_pepssi_*.lbl)*** for more detail.

Reading the data: Each file typically contains data from one day (86,400s) of observations. All data files are in FITS format and are readable with standard FITS viewers and software libraries. All FITS files have records with 2880 bytes. Refer to the NASA FITS Support Office (currently http://fits.gsfc.nasa.gov/) for FITS standard details. All sections in FITS files start on 2880-byte boundaries and are padded to a 2880-byte boundary with spaces or nulls. A detached PDS label file named ***pep_mmm_0xaaa_nnn_v.lbl*** accompanies each FITS data file and describes its structure; a selectively edited example label fragment for a raw data file is shown below. The black section describes the entire file as comprising 262 2880-byte records. The red section has pointers locating five sections in the file: three headers and two tables; tables contain data; FITS HEADERs describe the data sections and contain ancillary information, but are generally redundant with information in the PDS label (not shown here).

```
PDS_VERSION_ID          = PDS3
RECORD_BYTES            = 2880
FILE_RECORDS            = 262
^HEADER = "PEP_0299310715_0X691_ENG.FIT"
^EXTENSION_N1_HEADER = ("PEP_0299310715_0X691_ENG.FIT", 8)
^EXTENSION_N1_TABLE = ("PEP_0299310715_0X691_ENG.FIT", 26)
^EXTENSION_PHA_ELECTRON_HEADER = ("PEP_0299310715_0X691_ENG.FIT", 213)
```

```
^EXTENSION_PHA_ELECTRON_TABLE = ("PEP_0299310715_0X691_ENG.FIT", 214)
```

The yellow section below starts the description of the N1 binary table (the pointer to this table is above), describing the numbers of rows, of columns per row, and of bytes per row in the table. The blue and green extracted sections describe columns 1 and 19 in this table, providing details of where to find the content of each column.

```
OBJECT                         = EXTENSION_N1_TABLE
  INTERCHANGE_FORMAT             = "BINARY"
  ROW_BYTES                      = 1224
  ROWS                           = 11
  COLUMNS                        = 305
  DESCRIPTION                    = "FITS EDU number:  1; FITS EDU name: N1; Rate Data from APID 691, Normal Mode"
  OBJECT         = COLUMN
    NAME           = "ET"
    BYTES          = 8
    COLUMN_NUMBER  = 1
    DATA_TYPE      = "IEEE_REAL"
    START_BYTE     = 1
    DESCRIPTION    = "Ephemeris Time"
  END_OBJECT     = COLUMN
  OBJECT         = COLUMN
    NAME           = "B02S03"
    BYTES          = 4
    COLUMN_NUMBER  = 19
    DATA_TYPE      = "MSB_INTEGER"
    START_BYTE     = 77
    DESCRIPTION    = "B02S03: Protons (86-139) Energy ADUs Sector: 3"
  END_OBJECT     = COLUMN
```

Summary of the raw data files: Each table contains a different type of data, there is only one table of each type, and a table will only be present if data of that type were taken during the time of that file. The primary science tables are: PHA_ELECTRON; PHA_LOW_ION; PHA_HIGH_ION; N1; N2. Measured values are raw ADUs. Data set documentation contains additional table descriptions.

Raw PHA tables: PHA_ELECTRON; PHA_LOW_ION; PHA_HIGH_ION. These contain columns for the end time of the accumulating interval, the uncalibrated Energy and Time of Flight values and the detectors involved in measuring a given event (e.g. which solid state energy detector fired and/or which start anode fired). Each row represents a separate charged particle event. N.B. the time columns in each row are the ***time of the interval*** during which event of the row occurred, ***not the time of the event*** itself.

Raw Rate tables: The N1 and N2 (and D_N1 and D_N2) extensions contain several types of Rate data. The Rate data are accumulated in histograms which are then dumped at set intervals. For N1 data, usually the histograms are accumulated for 600 seconds. For N2 data, the accumulation time is usually 60 seconds except for the first hour of the day when it is 15 seconds. During the Pluto encounter shorter accumulation times were used. The specific accumulation time for any observation should be obtained from the **DT** column. These tables have a column containing the counts for each interval for every type of event. For example, The PDS COLUMN OBJECT with **`NAME = "B02S03"`** and **`COLUMN_NUMBER = 19`** in the label extract above describes a column containing counts of High-Ion (**`B`**) events with [TOF+Energy] values that land in Rate Box **`02`** (see the figure above) that came from the direction of Sector 2 (Start Anode **`03`**).

Summary of the calibrated data files: The calibrated data are a scientifically useful subset of the raw data. As with the raw data, each calibrated data file covers all of a single day of observation. There are three basic types of data in the calibrated files: Quick-Look; flux-calibrated Rate Data; calibrated PHA data. No Diagnostic mode data are present in the calibrated files. The calibrated files are meant to be, as much as possible, self-documenting. All calibration constants, calibration formulas, and physical units are present in the FITS headers in an easily readable format. In addition, PEPSSI PDS data sets contain, under the CALIB/CALPARS/ subdirectories, ASCII tables extracted from those FITS headers; this was done at the request of PDS peer reviewers and as a convenience to save the user extracting the FITS headers, which do not have per-line termination.

Calibrated quick-look image: The image in the primary array of the calibrated file is a rate-weighted 2-D histogram of the PHA data for that day binned in calibrated deposited energy. The priority scheme distorts ion abundances, so we correct for that by using a "rate-weighted," rather than a single count, histogram.

Calibrated quick-look spectrogram images: The SPEC_Protons, SPEC_Helium, SPEC_Heavies, SPEC_Electrons, and SPEC_LowIon tables contain quick-look spectrograms of their respective species. These spectrograms present counts/second N2 data, averaged over 60 second intervals and summed over all incidence directions.

Calibrated FLUX table: The FLUX table contains calibrated fluxes ($cm^{-2}\ sr^{-1}\ s^{-1}\ keV^{-1}$), flux uncertainties, and raw counts/s rates for all of the High Energy Ion and Electron N2 Rate data. There is also an accumulation time column (DT) and three timing columns. Separate calibrations are given for different ion species for some of the rate boxes if the composition in that rate box is complicated (e.g. both oxygen and sulfur in a single box).

Calibrated PHA tables: The three PHA tables (PHA_ELECTRON, PHA_LOW_ION, PHA_HIGH_ION) contain the PHA event data telemetered in the N2 data. Each row represents a single PHA event. Cross-talk events are excluded. Quantities of limited usefulness (such as Heavy Ion Discriminator triggers) are excluded. Calibrated Deposited Energy and/or Time of Flight values are given in scientific units (keV and/or ns, respectively). The linear calibration constants and formulas are in the FITS headers. A Speed (km/s) column is calculated from the Time of Flight. The Rate Box classification for each event is given in the Rate_Box column. The PHA_HIGH_ION table contains additional columns: H_Incident_Energy; He_Incident_Energy; O_Incident_Energy; S_Incident_Energy. These columns contain the calculated Incident energy assuming that the event is of that (H, He, O, or S) species. The Rate_Normalized_Weight column has removed Priority Group artifacts from the PHA data. This column is usually used in making histograms of the High Energy Ion PHA data.