11. PEPSSI INSTRUMENT DESCRIPTION

11.1 Overview

11.1.1 PEPSSI Investigation

PEPSSI (Pluto Energetic Particles Spectrometer Science Investigation) is a particle telescope and a time-of-flight (TOF) spectrometer that 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 (but not all species are uniquely separated) and for electrons from ~30 keV to 700 keV.

The PEPSSI instrument traces its heritage back to the MESSENGER Energetic Particle Sensor (EPS) instrument. EPS/PEPSSI was developed with the support of a NASA Planetary Instrument Definition and Development (PIDDP) grant aimed at designing a low-mass, low-power sensor that can measure energetic pickup ions produced near planets and comets (Andrews *et al.,* 1998; McNutt *et al.,* 1996). The overall PEPSSI instrument weighs 1.5 kg and uses maximum power of 1.4 W.

Figure 11-1 shows the placement of PEPSSI on the spacecraft and the PEPSSI fields-of-view (FOV).

The science goals of the PEPSSI instrument are:

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

11.1.2 PEPSSI Sensor Description

PEPSSI is a compact particle telescope with a time-of-flight (TOF) section and a solid-state detector (SSD) array (see Figure 11-2). A mechanical collimator defines the acceptance angles for the incoming ions and electrons. A cutaway view of the assembly is shown in Figure 11-3. The TOF section is axially symmetric; entrance and exit apertures are 6 mm wide with an azimuthal opening angle of 160°. The entry and exit apertures are covered by thin (~7 $\mu g/cm^2$) polyimide/aluminum and (~10 $\mu g/cm^2$) palladium/carbon foil mounted on high-transmittance stainless-steel grids, respectively. The foil thickness and composition is a compromise to minimize the energy threshold, secondary electron production, and scattering of particles in the foil while blocking UV from the direct Sun and Lyman-α background. PEPSSI measures the ion TOF using secondary electrons generated as the ion passes through the entrance and exit foils in the spectrometer. Total energy is measured by the SSD array. Each of the six SSDs has two pixels, three of the SSDs are dedicated for ion measurement. The other three have one pixel covered with ~1 μm Al absorber, to block low energy ions and permit measurements of electrons. The fan-like collimator together with the internal geometry defines the acceptance angles. The FOV is 160° by 12° with six angular sectors of 25° each; the total geometric factor is ~0.15 cm^2sr. As an ion passes through the sensor, it is first accelerated by the potential of ~3 kV on the front foil prior to hitting it. The ion generates secondary electrons at the foils, which are then electrostatically steered to well-defined separate regions on a single micro channel plate (MCP), providing “start” and “stop” signals for the TOF measurements (from 1 ns to 320 ns). The segmented MCP anode, with one start segment for each of the six angular entrance segments, allows determination of the direction of travel even for lower-energy ions that do not give an SSD signal above threshold.

The combination of measured energy and TOF provides unique particle identification by mass and particle energy depending on the range: for protons from ~30 keV to ~1 MeV; for heavy (CNO) ions from

~80 keV to ~1 MeV. Lower-energy (>3 keV) ion fluxes are measured by TOF only, but without the SSD signal, providing velocity spectra at these energies as well. Molecular ions, expected from Pluto's atmosphere, will break up in the foil prior to their full detection, but will be detected as high-mass events. Internal event classification electronics determine the mass and produce an eight-point energy spectrum for each of four species for six arrival directions. Energetic electrons are measured simultaneously in the dedicated electron pixels in the range from ~30keV to 700 keV. Only protons with energies > 300 keV (expected to be very rare at Pluto) can penetrate the absorbers on these pixels, and even those would be eliminated by on-board MCP coincidence requirements and ground comparisons with the simultaneously measured ion flux.

11.1.3 PEPSSI Electronics Description

Extensive uses of miniaturization and custom electronic in the design allow PEPSSI to weigh less than 1.5 kg and consume less than 1.4 W. PEPSSI is made up of six modular 4"x4" slices. They consist of:

1) Energy board;
2) High Voltage Power Supply (HVPS);
3) TOF board;
4) Digital processing board;
5) Common event processor board; and
5) Low Voltage Power Supply (LVPS) board.

Figure 11-4 shows the exploded view of PEPSSI with each board labeled. A brief description of the functionality of each board is highlighted below.

Energy board:

The energy board is the interface between the SSDs and the signal conditioning electronics. It houses the sensor, MCP anodes, charge amplifiers, pulse shapers, etc. In addition, it also outputs the pulse signal from the 6 start anodes and 1 stop anode.

HVPS board:

The HVPS board contains the high voltage (HV) drive circuitry, HV transformer, and its control circuitry. It provides HV up to -2900 V for the sensor electrostatic lens and MCP bias. In addition, the HVPS also needs to provide bias voltage over the range of 0 to -200 V with <10 mV ripple.

Digital processing board:

The digital processing board provides valid event logic functions, which include channel enables, programmable coincidence window, event packet generation and rate counters for event statistics. It provides the logic to distinguish between electrons, ions and directionality.

Common event processor board:

This board contains PEPSSI's main processor (RTX2010RH), the Filed Programmable Gate Array (RT54SX72S), and various memory modules (SRAM, EEPROM, PROM).

LVPS board:

This board converts primary spacecraft power into multiple low voltage outputs used by PEPSSI. It provides highly efficient power conversion into two digitals (+5, +2.5V) and four analogs (+5, -5, +15, and -15) outputs.

11.2 Introduction to PEPSSI Data

The PEPSSI instrument can operate in two modes: Normal and Diagnostic. On the spacecraft, each event generates a PHA record. This record is classified by event type: Electron, High-Energy Ion (or "Hi-Ion" or "Triple"), or Low-Energy ion (or "Low-Ion," "Double," or "TOF-only"). In diagnostic mode, events are not classified; alternatively, all events are "diagnostic events". Events of a given type are further classified into "Rate Boxes" by their energy and/or time of flight (TOF). Thus each event has a type, a rate box, and a detector in which it occurred. Instead of detector number, we will often use arrival direction (or sector) since there is a one to one relation between them (see Figure 11-5). A six character string is used to specify each possible classification (or Rate) of an event. The construction of this string is (type)(rate box)S(arrival sector). The arrival sector numbering is shown in Figure 11-5. The "type" string is:

B – Hi-Ions (possesses Energy and TOF)

R – Electrons (energy only, no TOF)

L – Low-Ions (TOF-only, no-energy).

For High Energy Ions, the "Rate Boxes" are determined by areas in the TOF vs Energy plane (see Figure 11-6). These correspond to different particle species and different energies.

For Electrons, the "Rate Boxes" are determined by energy ranges.

For Low Energy Ions, the "Rate Boxes" are determined by TOF ranges *and* by which heavy ion discriminators fired. The definition of Low-Ion "Rate Boxes" has been changed for the post-Jupiter phases of the mission. Note that because of the way the PEPSSI electronics work, frequently the arrival sector is unknown or uncertain for the Low-Ion measurements.

Some examples:

B02S04 – High-Energy Rate Box #2, arriving from the sector 4 direction. Protons with deposited energy in channels 95-169 , in analog-to-digital units(ADUs).

L06S03 – Low-Ions Rate # 6 arriving from the sector 3 direction. Ions with TOF indices from 45-79 ADUs and for which the heavy ion discriminator H0 fired but H1 didn't.

R00S05 – The 0^{th} electron rate, arriving from the sector 5 direction. Electrons with Energy channels in the range 720-1023 ADUs .

There are two counters for each Rate that are incremented whenever a corresponding event occurs. The N2 counter is accumulated for a certain time interval (programmable down to 1 second during the Pluto encounter but typically 15-60 seconds during cruise), then recorded and zeroed. The N1 counter is accumulated for some multiple of the N2 interval (usually 10 minutes during cruise), then recorded and zeroed. A certain number of PHA events are kept according to a complex priority scheme and telemetered along with the Rate data. (Note: if the multi-hit, i.e. anti-coincidence, flag is set for an event, the event is *not* counted. This is programmable, but the "don't count multi-hit events" rule was true outside of Bad Time Intervals for the whole Jupiter phase).

Various housekeeping and status data and certain global hardware and software counters are also present in the data at Levels 1 and 2.

PEPSSI Level 1 and PEPSSI Pre-Level 2 data are internal formats that are not used outside the SOC.

PEPSSI Level 2 data represents, with 3 exceptions, the raw data taken from the spacecraft telemetry. It has merely been reformatted for ease of use. No data has been added, removed or altered with the following 3 exceptions:

a. Instrument Status information has been calibrated to physical units where applicable (see discussion in section 11.4 below).
b. For clarification, a “DT” column has been added to the Rate tables to indicate the integration time over which the count data was accumulated. This information is not available in the spacecraft telemetry and must be calculated from the available timestamps. This “DT” value may be inaccurate during Bad Time Intervals (BTIs), see below.
c. For ease of use, we have added a column giving the deduced “Rate Box” of High-Ion PHA and Electron PHA events to the Level 2 PHA data. While this can, in principle, be calculated from the raw Level 2 quantities and the RATEBOXDEFINITIONPLANES.FIT file available in the CALIB/ directiory of the PDS archive, the procedure is complex enough that we have found it convenient to perform this calculation in advance and include the information in the Level 2 files.

PEPSSI Level 3 data presents the data in a format that should be convenient for scientific analysis. All of the calibration parameters needed to convert Level 2 data to Level 3 data are present in the headers of the Level 3 data files. The formulas used to calculate the calibrated quantities are also present in the Level 3 headers.

Rate data is presented in physical flux units with uncertainties as well as counts per second.

PHA data is presented with calibrated TOF and deposited energy. Further calibrated incident energies are given for assumed ion species. Only PHA data telemetered with the N2 rates is present in Level 3 as discussed below. There are also some “quick look” PHA images and Rate spectrograms in the Level 3 data to allow for a simple overview of each “day's” (see below) observations.

No “multi-hit” events are present in Level 3 PHA data. No diagnostic mode data is present in the Level 3 data. BTI data *is* present in the Level 3 data but should be ignored. Level 3 data for the “Launch” phase is present for quick-look purposes, but, apart from the deposited energy calibration (which is well known), the calibrations are performed with dummy values, as will be evident from examination of the header information.

Note: End users of PEPSSI data (i.e. those outside the instrument team and the SOC) will probably not find much useful information in the Level 1 and Pre-Level 2 documentation which follows and are encouraged to skip directly to section 11.4.3, Level 2 Data.

11.2.1 Effect of Spacecraft Spin

Because New Horizons is not a pure “spinning” spacecraft, PEPSSI data does not have specific adaptations available for data taken while the spacecraft is spinning. For event data, the timestamp and sampling period are too coarse to accurately correlate any given event with a specific spacecraft attitude.

For rate data, since the data accumulation periods rarely "line up" precisely with the start and end of a spin, there will typically be some spin-modulation of the measured rates due to sample aliasing.

For example, N2 counter accumulation data timestamped at 15s sampling intervals while the spacecraft is spinning at ~12s per revolution (5RPM) would sample the same 90 degrees of sky (3s of a revolution) twice per sampling interval, but would sample the other 270 degrees of sky only once per sampling interval.

11.3 Level 1 Specifics

The SOC Level 1 data product is a FITS format data file and all data is contained in FITS extension Header Data Units (HDUs). Each HDU contains a PEPSSI science data telemetry block which is described in depth in the PEPSSI Flight Software Specification. Level 1 files are not present in the PDS archive. There are

File Type	HDU Type
N1	Primary HDU: High Priority Telemetry Block Extension 1: PHA Telemetry Block Extension 2: Status Telemetry Block
N2	Primary HDU: Medium Priority Telemetry Block Extension 1: PHA Telemetry Block Extension 2: Status Telemetry Block
N3	Primary HDU: Low Priority PHA Telemetry Block

11.3.1 Data Sources (High/Low Speed, CCSDS, ITF)

PEPSSI is low-speed only. Data will be from CCSDS (Consultative Committee for Space Data Systems) packets.

11.3.2 Definition of an "Observation"

PEPSSI doesn't make specific "Observations".

11.3.3 Header with Keywords

This section has intentionally left blank as of early 2014, but may be filled in at a later date.

11.3.4 Spacecraft Housekeeping Needed in Level 1 Files (for Calibration)

Spacecraft attitude is necessary to calculate PEPSSI pointing in the ecliptic coordinate system, and with respect to Jupiter, Pluto, and Charon. An accuracy of 1 degree is adequate.

11.3.5 Raw Science Data and/or Housekeeping Requirements

No special requirements

11.4 Level 2 Specifics

11.4.1 Algorithm for Pipeline

11.4.1.1 IDL L1 to Pre-L2 step

The PEPSSI pipeline conversion from Level 1 (L1) to Level 2 (L2) data has two steps. The first uses an IDL program to rearrange the Raw L1 data into single-rowed vector-valued FITS tables. These "Pre-L2" files are temporary and not in the final PDS archive. Multiple Pre-L2 files will be combined in the next processing step into final L2 files; see section 11.4.2.2 below.

The base routine PEPSSI_LEVEL2_PIPELINE reads from the input file the following variables:

Filein

dir_cal

temp_dir

status_file

fileout

and generates in the output files one of more of the corresponding HDUs

N1

N1_STATUS

N2

N2_STATUS

D_N1

D_N2

PHA_ELECTRON

PHA_LOW_ION

PHA_HIGH_ION

PHA_DIAG

STATUS

Decoding of the level 1 data stream follows two steps: first blocks are read into the 7 structures:

```
N1 = {   $
    met:lonarr(blockcnt), $
    high_ions:lonarr(6,19,blockcnt), $
    electrons:lonarr(3,3,blockcnt), $
    low_ions:lonarr(7,16,blockcnt), $
```

```
        rates:lonarr(32,blockcnt), $
        housekeeping:fltarr(33,blockcnt)      }

    N2 = {   $
        met:lonarr(blockcnt), $
        high_ions:lonarr(6,19,blockcnt), $
        electrons:lonarr(3,3,blockcnt), $
        low_ions:lonarr(7,8,blockcnt), $
        rates:lonarr(24,blockcnt)       }

    PHA_ELECTRON={  $
            met:lonarr(ele_cnt) , $
            energy:fltarr(ele_cnt) , $
            multi:intarr(ele_cnt) , $
            chann:intarr(ele_cnt) }

    PHA_LOW_ION={  $
            met:lonarr(low_cnt) , $
            tof:fltarr(low_cnt) , $
            heavy1:intarr(low_cnt) , $
            heavy0:intarr(low_cnt) , $
            startseg:intarr(low_cnt) }

    PHA_HIGH_ION={  $
            met:lonarr(hig_cnt) , $
            energy:fltarr(hig_cnt) , $
            tof:fltarr(hig_cnt) , $
            multi:intarr(hig_cnt) , $
            heavy1:intarr(hig_cnt) , $
            heavy2:intarr(hig_cnt) , $
            chann:intarr(hig_cnt) , $
```

```
        startseg:intarr(hig_cnt) }

    PHA_DIAG={  $
        met:lonarr(dia_cnt) , $
        energy:fltarr(dia_cnt) , $
        tof:fltarr(dia_cnt) , $
        start:intarr(dia_cnt) , $
        stop:intarr(dia_cnt) , $
        fired:intarr(dia_cnt) , $
        multi:intarr(dia_cnt) ,  $
        heavy1:intarr(dia_cnt) , $
        heavy0:intarr(dia_cnt) , $
        chann:intarr(dia_cnt) , $
        startseg:intarr(dia_cnt) }

    STATUS = { $
      MET:lonarr(nsta), $
      STATINT:lonarr(nsta), $
      MACBLCKS:lonarr(nsta), $
      TLMVOL:lonarr(nsta), $
      WTCHADDR:lonarr(nsta), $
      WTCHMEM:bytarr(nsta), $
      WTCHDATA:lonarr(nsta), $
      PEPSWVER:bytarr(nsta), $
      ALARMID:bytarr(nsta), $
      ALARMTYP:bytarr(nsta), $
      ALARMCNT:bytarr(nsta), $
      CMDEXEC:bytarr(nsta), $
      CMDREJCT:bytarr(nsta), $
      MACEXEC:bytarr(nsta), $
      MACREJCT:bytarr(nsta), $
```

```
        MACROID:bytarr(nsta), $
        MACROLRN:bytarr(nsta), $
        MONRESP:bytarr(nsta), $
        WRITEENB:bytarr(nsta), $
        HVPSCURR:fltarr(nsta), $
        HVPSVOLT:fltarr(nsta), $
        BIASCURR:fltarr(nsta), $
        BIASVOLT:fltarr(nsta), $
        PEPSTAT:lonarr(nsta), $
        DVOLTP5:fltarr(nsta), $
        AVOLTN5:fltarr(nsta), $
        VOLTP2:fltarr(nsta), $
        VOLTN5:fltarr(nsta), $
        VOLTP15:fltarr(nsta), $
        VOLTN15:fltarr(nsta), $
        DCURRP5:fltarr(nsta), $
        ACURRP5:fltarr(nsta), $
        CURRP2:fltarr(nsta), $
        CURRN5:fltarr(nsta), $
        CURRP15:fltarr(nsta), $
        CURRN15:fltarr(nsta), $
        PRIMCURR:fltarr(nsta), $
        LVPSTEMP:fltarr(nsta), $
        ENGYTEMP:fltarr(nsta), $
        HVPSTEMP:fltarr(nsta), $
        ADDR12C:lonarr(nsta), $
        RSLT12C:lonarr(nsta) $
      }
```

where blockcnt is the number of blocks present in the level 1 file (i.e. the number of sample periods), ele_cnt is the number of electron pha events, and similarly for low_cnt, hi_cnt, and dia_cnt. nsta is the number of sample periods for the status quantities. See the full L2 file description for the meaning of the status quantities.

Example: n1.low_ions(3,4,6) corresponds to the number of time_of_flight only events (low_ions) coming from anode 3, 4th velocity bin, collected during the 6th time interval.

11.4.1.2 MIDL L1 to Pre-L2 step

A Java program derived from the MIDL analysis program is used to convert the Pre-L2 files into L2 files. With rare exceptions, each L2 file contains data from exactly 86,400 contiguous spacecraft seconds (about one day). So the Times-of-Day (TODs), in UTC, of the start and stop times of data coverage from successive days both will drift with respect to UTC with the clock on the spacecraft, and will jump by about one second on days that have leap-seconds. Through 2010, the typical clock drift rate through 2010 is of order 1ms/d, and the TOD of the start and stop times for each file are within a few seconds of midnight on each day.

The exceptions to the 86,400 spacecraft seconds rule are days when new Rate Box definitions are loaded to the spacecraft, in which case there will be a “before” file and an “after file” (such load-days are very rare).

The DataConverter program essentially “flattens out” the Pre-L2 structure. In the L2 files, each row is a separate sampling period or PHA event (i.e. the blockcnt, hi_cnt, lo_cnt, etc. axis is now the row structure of the FITS binary table). Each “Rate Box” or hardware count is a separate column in the N1 or N2 FITS table. So, for example, each row of the N1 rates extension represents a separate sampling period (usually 600 seconds) and each column is a different rate, listed in alphabetical order by rate name, so the columns would be:

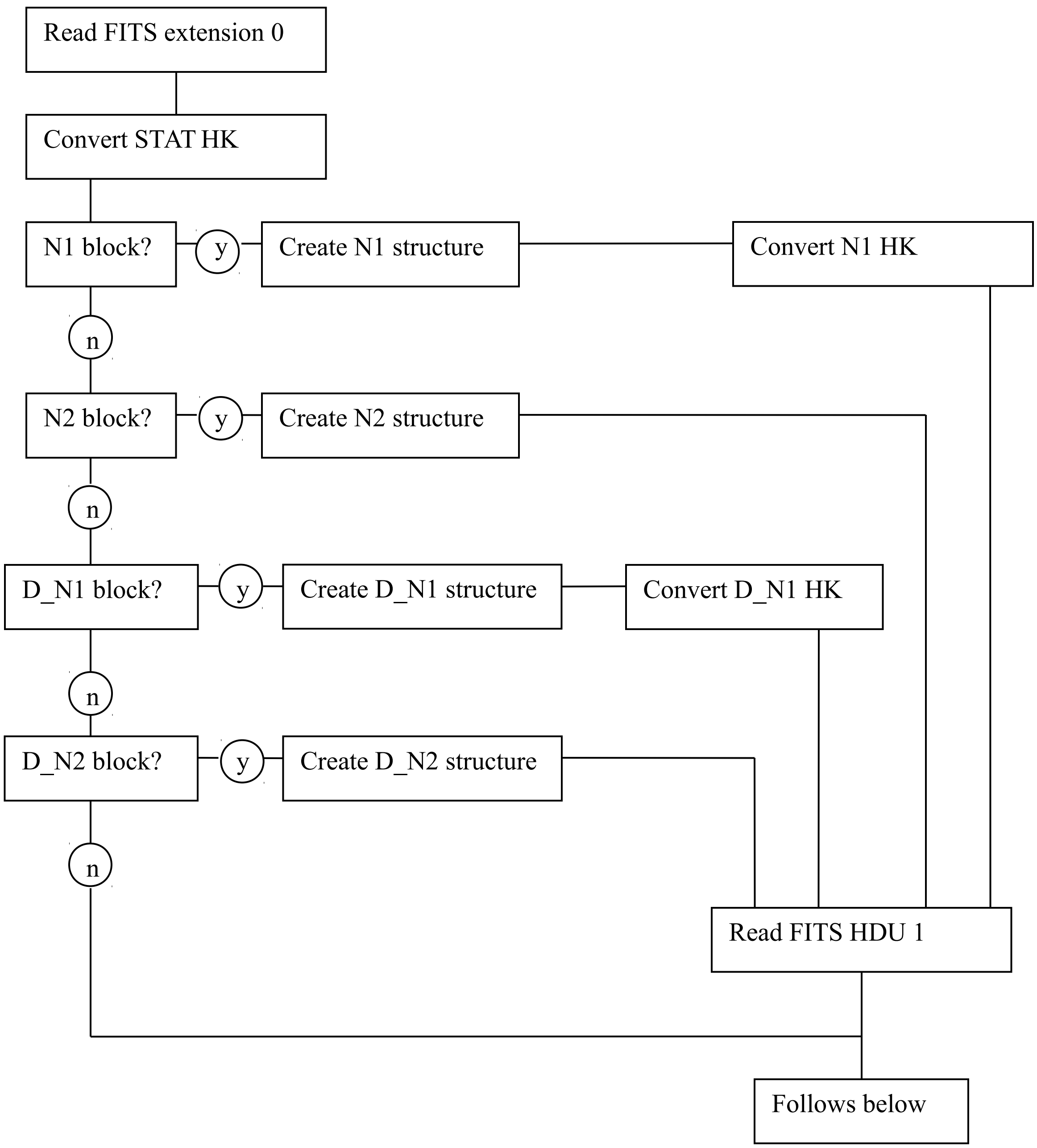
ET, MET, B00S00, B00S01, …, B18S05, C00D00, C01D01, …, C23, C24, HK00, HK01, …,HK34, J00, J01, …, J06, L00S01, L00S02, …, L15S05, L15SUnknown, R00S00, …, R02S05

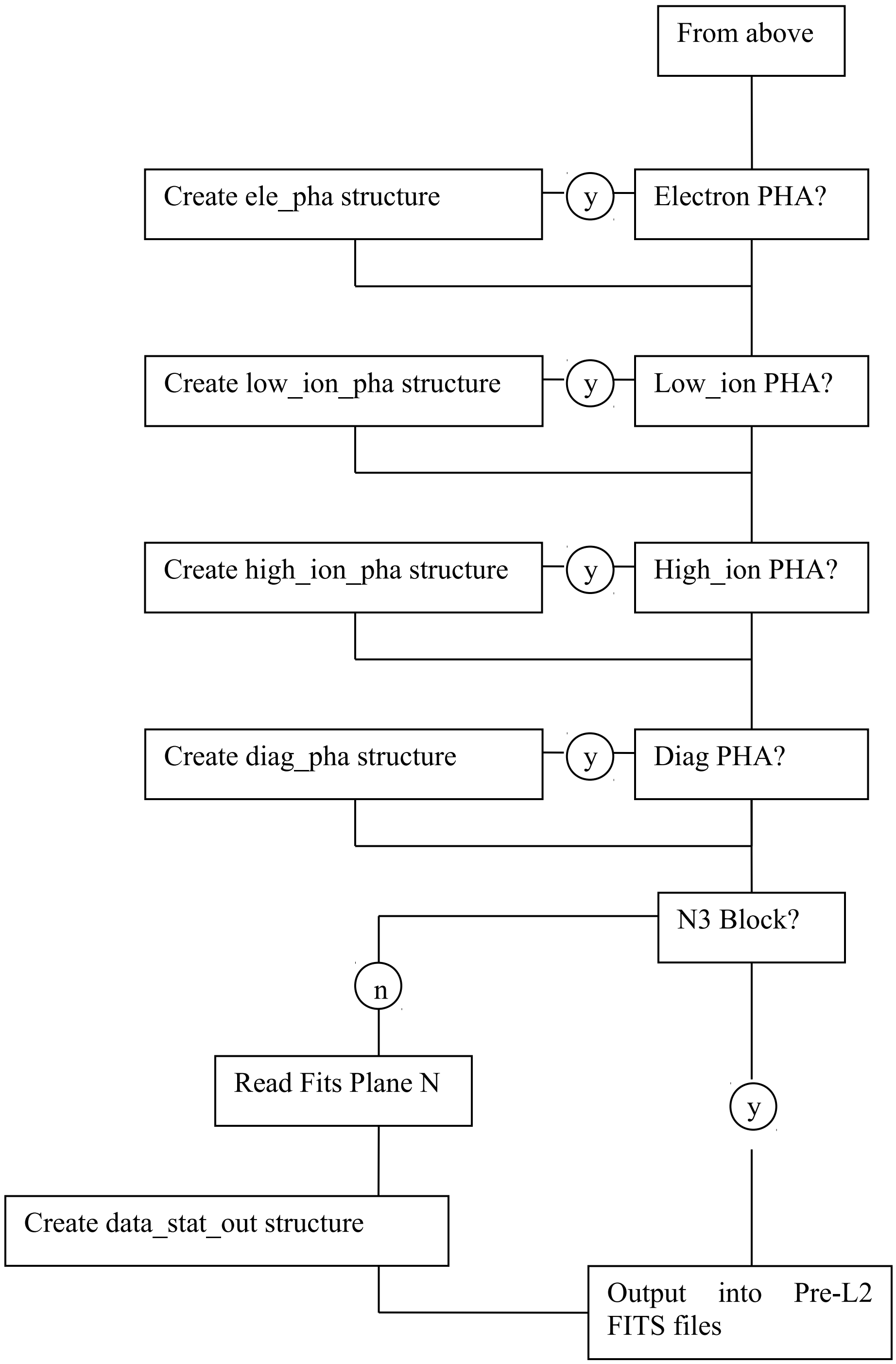
The meaning of the individual Rate Labels will be discussed below, or see the comments in the corresponding FITS header. As another example, the PHA_ELECTRON extension is another simple 2D table of values; each row represents a separate PHA event, the columns are:

ET, MET, ApID (packet Application Process IDentifier; also Application ID), Cross_Talk_Indicator, Electron_Channel, Raw_Energy

11.4.2 Dataflow Block Diagram

11.4.2.1 L1 to Pre-L2




From above
Create ele_pha structure
y
Electron PHA?
Create low_ion_pha structure
y
Low_ion PHA?
Create high_ion_pha structure
y
High_ion PHA?
Create diag_pha structure
y
Diag PHA?
N3 Block?
n
Read Fits Plane N
y
Create data_stat_out structure
Output into Pre-L2 FITS files

11.4.2.2 Pre-L2 to L2 processing

There is no data-flow diagram for Pre-L2 to L2 processing.

11.4.3 L2 Data Format

The contents of the L2 files are detailed in the following sections. The ordering of the extensions is *not* guaranteed, programs accessing the data should search for the desired extension by name (in the EXTNAME keyword). There will always be only one extension of each type (EXTNAME) and not all types will be present. An extension will only be present if there is data of that type taken during the time period covered by that file. The coverage of a single L2 "daily" file begins at an integer multiple of 86,400 ephemeris (TDB, Barycentric Dynamical Time) seconds from a time near a nominal midnght UTC time at launch (January, 2006). All events and rate measurements with timestamps in that file occur before the 86,400th TDB second following. All event records in the file occur ***between*** those two TDB times, but there are rarely if ever event records with timestamps ***at*** those times. The values and keyword values in the FITS header dealing with time are as follows:

ET – N.B. not in the FITS header or PDS label. The ephemeris time of the beginning of coverage of this file. This corresponds to a time near 00:00:00 (midnight) UTC at the start of the mission (January, 2006), but slides back with respect to 00:00:00 UTC as the mission progresses through UTC leapsecond events.

MET,METEND – Integer MET values approximating the beginning and ending of the coverage period of this file, expressed in terms of the spacecraft clock. Since these values are truncated to the previous integer value and do not include spacecraft clock partition information, they should be used with caution, if at all. The filename contains a truncated version of the beginning MET keyword value. Note that, because the integer MET values are rounded *down*, the beginning MET usually represents a time *not* actually contained in this file. Usually, two consecutive-in-time files have beginning MET values that differ by a multiple of 86,400; however, because the spacecraft clock runs slower (MET seconds are longer) than TDB seconds, sometimes that [difference modulo 86,400] will be 86,399s. The PDS keyword values START_TIME and STOP_TIME are millisecond-rounded UTC times based on these rounded MET values, and the PDS keyword values SPACECRAFT_CLOCK_START_COUNT and SPACECRAFT_CLOCK_STOP_COUNT are in turn based on START_TIME and STOP_TIME, and include sub-millisecond artifacts of the sequence of roundoffs.

STARTMET,STOPMET – Floating-point MET values of the first and last record (in any EXTENSION) in this file. These values may be useful for quickly answering data availability questions. STARTMET ≥ MET and STOPMET < METEND.

Other time related keywords in the header are artifacts from the processing pipeline and should be considered as "for instrument team use in validation only".

The Primary HDU contains no data, only informational header keywords identifying mission info, observational start time, and information about the file creation (date, software version, etc.).

The available extensions are:

D_N1, D_N1_STATUS, D_N2, D_N2_STATUS, N1, N1_STATUS, N2, N2_STATUS, PHA_DIAG, PHA_ELECTRON, PHA_LOW_ION, PHA_HIGH_ION

The different extensions are described below. For detailed information such as the data-type of different columns see the FITS header in the data file.

Extension names beginning with "D_" (and the PHA_DIAG extension) represent data taken in diagnostic mode. Diagnostic data is taken for purposes of calibration and understanding the instrument at a very low level. Diagnostic data is complex and often taken under unusual conditions. It is unlikely that the general user will be able to use diagnostic data in any meaningful way. In diagnostic mode, a PHA event is generated whenever any of the instrument detectors sees an event. All events are counted except for those with the multi-hit flag set (by default, the multi-hit setting can be changed). This means that there are no "Low-Ion" events because, by definition, these events are required to have no SSD fire, which is mutually exclusive with the diagnostic mode requirement that every diagnostic event is initiated with an SSD fire. Many of the columns will contain "fill values" for certain types of events. The "Fill" values for invalid Energy and TOF PHA data are: Energy – 1023 and TOF – 2047. In the PHA_DIAG extension, what would normally be an electron event, for instance, will have a Time of Flight value of 2047.

11.4.3.1 PHA_HIGH_ION

When an ion enters the PEPSSI detector, if it has enough energy, we measure an Energy and a Time of Flight (TOF). Since we don't have enough bandwidth to telemeter all of our events, we use a round robin priority scheme to decide which PHA events to discard and which to telemeter. All of the events are counted in the N1 and N2 Rate data. The Rate data can be used to remove the priority group effects (to a large extent) from the PHA data by weighting events by their respective rates. See the L3 documentation below for more on rate-weighting.

The PHA_HIGH_ION extension contains one row for each high energy ion event that was not discarded by the priority scheme. The columns are:

ET	Ephemeris Time (s past J2000 epoch) of start of accumulation interval
MET	Mission Elapsed Time
ApID	Which ApID was this event telemetered in: N1 – 0x691, N2 – 0x692, N3 – 0x693
Cross_Talk_Indicator	Did more than one detector fire?
H0	Did Heavy Ion Descriminator 0 fire?
H1	Did Heavy Ion Descriminator 1 fire?
Ion_Channel	Detector Channel (0-8)
Raw_Energy	Energy deposited (ADU)
Raw_TOF	Time of Flight (ADU)
Start_Anode	Bits 0-5 are set if that start anode fired.

Notes for PHA High Ion data:

- **IMPORTANT NOTE:** The timing of a PHA event is, in general, *not* known to 1 second precision. The "time tag" of a PHA event only represents the start time of the accumulation interval of the Rate packet with which it was telemetered. So, in normal cruise operation, for example, "N1 PHA" event arrival times are known only to the nearest 10 minutes, N2 events to the nearest minute, and N3 events to within 2 hours. See discussion of Level 3 PHA data for more details.

- See Figure 11-5 for a diagram of the detector numbering. 9 of the 12 detectors are dedicated to Ions (the other 3 are dedicated to electrons) and are configured accordingly.
- Mission Elapsed Time starts about 19-JAN-2006-18:09:05.184.
- The H0 and H1 ion discriminators were found to be of limited usefulness.
- Events with the Cross_Talk_Indicator value set are discarded from the rate counters and are not usually used in analysis.
- The Start Anode column consists of a single byte. The individual bits 0-5 indicate whether the corresponding Start Anode (0-5) registered an event. See Figure 11-5 for start anode layout. Note that, unfortunately, the numbering of the anodes is reversed from the numbering of the incoming angle sectors.
- Energy and TOF are given in raw "Analog to Digital Units" (ADU).
- The electronics of the Start Anodes are such that, while a given event may have a known TOF, the exact Start Anode information may be uncertain or completely unknown. Thus, a valid event may show more than one Start Anode, or none.

11.4.3.2 PHA_ELECTRON

The PHA_ELECTRON data is very similar to the PHA_HIGH_ION data except that the TOF-related values aren't present since electrons aren't detected by that part of the instrument (i.e. they only have solid state detector (SSD)-related values:

ET	Ephemeris Time (s past J2000 epoch) of start of accumulation interval
MET	Mission Elapsed Time
ApID	Which ApID was this event telemetered in
Cross_Talk_Indicator	Did more than one detector fire?
Electron_Channel	Detector Channel (0-2)
Raw_Energy	Energy deposited solid state detector (ADU)

Notes for PHA_ELECTRON data:

- Only Sectors 0, 2, and 5 have electron detectors (0,1, and 2, respectively) associated with them.
- See PHA_HIGH_ION notes for other relevant info.

11.4.3.3 PHA_LOW_ION

The PHA_LOW_ION events are from low energy ions that register in the TOF part of the detector but do not trigger the SSDs. Hence "Low Ions" have TOF data (and associated quantities like Start Anode) but no Energy data:

ET	Ephemeris Time (s past J2000 epoch) of start of accumulation interval

MET	Mission Elapsed Time
ApID	Which ApID was this event telemetered in
H0	Did Heavy Ion Descriminator 0 fire?
H1	Did Heavy Ion Descriminator 1 fire?
Raw_TOF	Time of Flight (ADU)
Start_Anode	Bits 0-5 are set if that start anode fired.

See PHA_HIGH_ION notes for other relevant info.

11.4.3.4 PHA_DIAG

In diagnostic mode, the following columns are present:

ET	Ephemeris Time (s past J2000 epoch) of start of accumulation interval
MET	Mission Elapsed Time
ApID	Which ApID was this event telemetered in?
Cross_Talk_Indicator	Did more than one detector fire?
Fired	0 - electron event 1 - ion event
H0	Did Heavy Ion Descriminator 0 fire?
H1	Did Heavy Ion Descriminator 1 fire?
Ion_Channel	Detector Channel (0-8) or (0-2 if electron)
Raw_Energy	Energy deposited solid state detector (ADU)
Raw_TOF	Time of Flight (ADU)
Start	Did a start anode fire?
Start_Anode	Bits 0-5 are set if that start anode fired.
Stop	Did the stop anode fire?

Notes for Diagnostic PHA Data:

- The “Fired” flag indicates whether the event is an Ion or an Electron event. This determines which Rate counter gets incremented as well.
- Raw Energy frequently has the 1023 fill value in diagnostic mode.
- Raw TOF frequently has the 2047 fill value in diagnostic mode.

11.4.3.5 N1 and D_N1

The N1 and N2 (and D_N1 and D_N2) extensions contain several types of “Rate” data. The Rate data is accumulated in histograms which are then dumped at set intervals. During cruise: 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. These values will be different during the Pluto encounter or certain testing events. The DT column will indicate the accumulation time for a given row or Rate data. The DT column may not be accurate during BTIs.

B Rates: The number of high energy ion events in the various Hi-Ion "Rate Boxes".

C Rates: The contents of various hardware counters

HK Rates: Various housekeeping quantities such as power levels and descriminator thresholds

J Rates: Software counters that represent overall quantities like total number of Electron Events.

L Rates: The number of low energy (TOF-only) ion events in the various Lo-Ion Boxes.

R Rates: The number of electron events in the various electron "Rate Boxes".

The N1 and D_N1 data are identical in format; the D_N1 data is taken when the instrument is in diagnostic mode. The definitions of some of the Rate Boxes are different in diagnostic mode and normal mode (i.e. the Rate Box number is the same, but its definition is different depending on the mode). The events being counted are triggered with different rules, as well, see the discussion of PHA_DIAG data for more detail.

We describe some of the rates in more detail below. A detailed description of each rate is also available in the FITS header as a comment to the keyword defining a Rate column. Example:

```
TTYPE12 = 'B01S03  ' / B01S03: Protons (60-94) Energy ADUs Sector: 3
```

means that column 12 contains rate B01S03 which is nominally Protons with energy between 60 and 94 ADUs incident from Sector 3.

B Rates: The TOF vs Energy plane is divided into 19 "Rate Boxes" as shown in Figure 11-6. Each high energy ion is classified into a Rate Box and further its incident sector is used to classify it, resulting in a Rate, or histogram cell designation of the form BnnSnn. The B boxes in normal mode for the Jupiter encounter were:

Rate Box	Species	Low Energy (ADU)	High Energy (ADU)
B00	Ions (Low TOF)	0	1023
B01	Protons	60	94
B02	Protons	95	169
B03	Protons	170	299
B04	Protons	300	534
B05	Protons	535	1023
B06	Helium	60	139
B07	Helium	140	364
B08	Helium	365	1023
B09	Oxygen	60	74
B10	Oxygen	75	110
B11	Oxygen	111	227
B12	Oxygen	228	463

B13	Sulfur	228	463
B14	Heavy Ions	228	463
B15	Oxygen	464	1023
B16	Sulfur	464	1023
B17	Heavy Ions	464	1023
B18	Ions (High TOF)	60	1023

In diagnostic mode, the boxes were:

Rate Box	Species	Low Energy (ADU)	High Energy (ADU)
B00	Ions (Low TOF)	0	1023
B01	Protons	55	94
B02	Protons	95	170
B03	Protons	171	299
B04	Protons	300	534
B05	Protons	535	1023
B06	Helium	55	138
B07	Helium	139	363
B08	Helium	364	1023
B09	Heavy Ions	55	138
B10	Heavy Ions	139	363
B11	Heavy Ions	364	1023
B12	Ions (No TOF)	55	86
B13	Ions (No TOF)	87	137
B14	Ions (No TOF)	139	227
B15	Ions (No TOF)	228	363
B16	Ions (No TOF)	364	585
B17	Ions (No TOF)	588	1023
B18	Ions (High TOF)	0	1023

C Rates:

C00D00	Detector 00 Singles
C01D01	Detector 01 Singles
C02D02	Detector 02 Singles
C03D03	Detector 03 Singles
C04D04	Detector 04 Singles
C05D05	Detector 05 Singles
C06D06	Detector 06 Singles
C07D07	Detector 07 Singles
C08D08	Detector 08 Singles
C09D09	Detector 09 Singles
C10D10	Detector 10 Singles
C11D11	Detector 11 Singles
C12S05	Anode 00 Singles Sector: 5
C13S04	Anode 01 Singles Sector: 4

C14S03	Anode 02 Singles	Sector: 3
C15S02	Anode 03 Singles	Sector: 2
C16S01	Anode 04 Singles	Sector: 1
C17S00	Anode 05 Singles	Sector: 0
C18	Electron Events	
C19	Ion Events	
C20	H0 Singles	
C21	H1 Singles	
C22	Starts	
C23	Stops	
C24	Valid TOFs	

Notes:

-"Singles" means single events on the named detector.

HK Rates:

These are various housekeeping values:

HK00	Peak Discriminator Level 0
HK01	Peak Discriminator Level 1
HK02	Peak Discriminator Level 2
HK03	Peak Discriminator Level 3
HK04	Peak Discriminator Level 4
HK05	Peak Discriminator Level 5
HK06	Peak Discriminator Level 6
HK07	Peak Discriminator Level 7
HK08	Peak Discriminator Level 8
HK09	Peak Discriminator Level 9
HK10	Peak Discriminator Level 10
HK11	Peak Discriminator Level 11
HK12	HVPS Level
HK13	BIAS Level
HK14	Start Constant Fraction Discriminator Power
HK15	Stop Constant Fraction Discriminator Power
HK16	Stop Constant Fraction Discriminator Threshold
HK17	Start Constant Fraction Discriminator Threshold
HK18	Start Anode 0
HK19	Start Anode 1
HK20	Start Anode 2
HK21	Start Anode 3
HK22	Start Anode 4

HK23	Start Anode 5
HK24	Heavy Discriminator 0
HK25	Heavy Discriminator 1
HK26	Command word A mirror
HK27	Command word B mirror
HK28	Event parameter A mirror
HK29	Event parameter B mirror
HK30	Event parameter C mirror
HK31	Bus read address (from most recent bus read)
HK32	Bus read value (resulting data value)
HK33	Unknown0
HK34	Unknown1

Notes:

- HK33 and HK34 are only retained because they're present in the telemetry. They're just spare values.

J Rates:

These are software counter totals:

J00	Electron Events
J01	Hi-E Ion Events
J02	Low-E Ion Events
J03	Electron Discards
J04	Hi-E Ion Discards
J05	Diagnostic Events
J06	Diagnostic Discards

L Rates:

Rate Box	Type	Lower TOF (ADU)	Upper TOF (ADU)
L00	Unused	0	0
L01	Light Very Fast	6	13
L02	Light Fast	14	31
L03	Light Slow	32	75
L04	Light Very Slow	76	179
L05	Unused	0	0
L06	Medium Very Fast	45	79
L07	Medium Fast	80	141
L08	Medium Slow	142	252
L09	Medium Very Slow	253	449
L10	Unused	0	0
L11	Heavy Very Fast	90	159
L12	Heavy Fast	160	283
L13	Heavy Slow	284	505

L14	Heavy Very Slow	506	899
L15	Dump Bin	0	1024

Notes:

- Since the heavy ion discriminators appear to be of limited usefulness, the L Rate Boxes were reprogrammed after the Jupiter observing phase and are substantially different for the next observing phase of the mission.
- Light events – neither heavy ion discriminator fired.
- Medium events – H0 fired, H1 didn't
- Heavy events – both discriminators fired.

R Rates:

R rates represent electron events.

Rate Box	Lower Energy (ADU)	Upper Energy(ADU)
R00	0,720	57,1023
R01	57	202
R02	203	719

Notes:

- R00 nominally includes both low and high energies, but this is only a complication early in the Jupiter phase (days 6 – 22 of 2007), after which the electron detector threshold was raised so that only the high energies received valid events. This is why the L3 spectrograms put the electron pixels in the order: R01, R02, R00
- There are only 3 (out of 12) detectors dedicated to electrons (see Figure 11-5). We number sectors the same way we do in the other rates, so electron rates only come from sectors: S00, S02, and S05..
- For a discussion of designations R00A, R00B and SAll in L3 PHA data, see section 11.4.5.4.

11.4.3.5.1 Rate Box Definitions

For Electrons and Low-Ions, the rate box definitions are simple ranges in Energy and TOF in ADUs which can be found in the Level 2 headers. For Hi-Ions, the Rate Boxes are regions in the TOF-Energy plane (see Figure 11-6). The precise specification of the rate boxes is complex and this is why we include rate box classifications in the Level 2 PHA data. However, we also provide the file RATEBOXDEFINITIONPLANES.FIT in the CALIB/ directory of PDS data sets.

Through the Jupiter mission phase and into the Pluto Cruise mission phase, PEPSSI has had three sets of Rate Box definitions. There are separate rate box definitions for Normal and Diagnostic mode. The

RateBoxDefinitionPlanes.fit file contains 6 extenstions (3 sets x 2 modes). The Rate Box classification data is presented as an image containing the Rate Box id number (0-18) in the Time of Flight (TOF) vs Energy plane. TOF and Energy are presented in raw analog to digital units (ADUs). Thus, TOF ranges from 0-2047 and Energy from 0-1023. The Rate Box classification of any event can be determined by looking up the corresponding pixel in the classification image. In diagnostic mode, Energy-only detections have a fill value of 2047 for TOF, and the Rate Box classification image assumes that. The time range for each set is given in the header of the respective HDU. The ranges are:

Set 0	Before 2006-07-07
Set 1	2007-07-07 through 2007-05-24
Set 2	After 2007-05-24

11.4.3.6 N2 and D_N2

N2 (and D_N2) are identical to their N1 counterparts except that they are typically sampled much more frequently (every 15 or 60 seconds) and only some of the L and C rates are present:

- Only L01,02,03,04,08,09,13,14 are present
- Only C00,02,03,05,06,07,08,09,10,13,14,15,16,17,22,23,24 are present

11.4.3.7 (D)_N(1/2)_STATUS

All the STATUS extensions contain the same quantities for their respective coverage periods.

STAT00	STATINT	Status interval (seconds)
STAT01	MACBLCKS	Number of macro blocks fre
STAT02	TLMVOL	Telemetry volume produced
STAT03	WTCHADDR	Memory watch address
STAT04	WTCHMEM	Watched memory (pg. no)
STAT05	WTCHDATA	Watched memory
STAT06	PEPSWVER	Software version number
STAT07	ALARMID	Latest Alarm Id
STAT08	ALARMTYP	Latest alarm type
STAT09	ALARMCNT	Count of alarms
STAT10	CMDEXEC	Commands executed
STAT11	CMDREJCT	Commands rejected
STAT12	MACEXEC	Macro commands executed
STAT13	MACREJCT	Macro commands rejected
STAT14	MACROID	Id of most recent macro executed
STAT15	MACROLRN	Macro learn mode
STAT16	MONRESP	Monitor response
STAT17	WRITEENB	Memory write enable
STAT18	HVPSCURR	HVPS current

STAT19	HVPSVOLT	HVPS voltage
STAT20	BIASCURR	Bias current
STAT21	BIASVOLT	Bias voltage
STAT22	PEPSTAT	PEPSSI status word
STAT23	DVOLTP5	+5V digital voltage
STAT24	AVOLTN5	+5V analog voltage
STAT25	VOLTP2	+2.5V voltage
STAT26	VOLTN5	-5V voltage
STAT27	VOLTP15	+15V voltage
STAT28	VOLTN15	-15V voltage
STAT29	DCURRP5	+5V digital current
STAT30	ACURRP5	+5V analog current
STAT31	CURRP2	+2.5 volt current
STAT32	CURRN5	-5V current
STAT33	CURRP15	+15V current
STAT34	CURRN15	-15V current
STAT35	PRIMCURR	Primary current
STAT36	LVPSTEMP	LVPS temperature
STAT37	ENGYTEMP	Energy temperature
STAT38	HVPSTEMP	HVPS temperature
STAT39	ADDR12C	I2C read command address
STAT40	RSLT12C	I2C read command result

11.4.4 Bad Time Intervals (BTIs)

Various instrument conditions can make the PEPSSI data difficult or impossible to use for scientific purposes. Powering down, ramping the high voltage power up or down, running in diagnostic mode, etc. will all make the PEPSSI data unusable for standard analysis. The "PEPSSI_BTI.txt" file, when present, contains a tab-separated list of "Bad Time Intervals" (BTIs), which should be used to exclude data that are unsuitable for science analysis. It should be noted that the entire "Launch" phase of PEPSSI data is classified as a BTI.

While not actually a BTI, the period between 2007 day 144 and day 178 should be treated with caution as well. The PEPSSI Rate Box tables were changed on day 144 and calibration and analysis of this period is still preliminary.

11.4.5 L3 Data Format

The L3 Files contain calibrated scientific data in an easily accessible form. There are three basic types of data in the L3 files: Quick-Look, flux-calibrated Rate Data, and calibrated PHA data. As with the L2 files, each file contains one UTC day's worth of data. No Diagnostic mode data is present in the L3 files. No "multi-hit" data is present in L3 files. Only N2-telemetered PHA data is present in L3 files.

The Level 3 files are meant to be, as much as possible, self-documenting. All calibration constants, calibration formulas, and physical units should be present in the FITS header in an easily readable format. It should be possible, albeit with a lot of work, to reproduce the Level 3 files independently from the Level 2 files using the information in the Level 3 headers.

11.4.5.1 Primary HDU: Rate Weighted 2-D Histogram

The image in the primary array of the L3 file is a rate-weighted 2-D histogram of the PHA data for that day binned in calibrated deposited energy. It represents a "best available" overview of the day's most detailed high energy ion data.

The priority scheme distorts ion abundances, so we correct for that by using a "rate-weight" rather than a single count. For each period of 600 seconds, we divide the counts reported in the N2 rate box by the number of PHA events observed in that rate box. This is the weight those events are then assigned in constructing the histogram (see Figure 11-7 and Figure 11-8 for comparison of weighted and unweighted histograms). The two axes: energy deposited in the SSD and time of flight, are simple linear calibrations of the measured values. The calibration parameters are reported in the primary FITS header.

11.4.5.2 Quick Look Spectrograms

The extensions: SPEC_Protons, SPEC_Helium, SPEC_Heavies, SPEC_Electrons, and SPEC_LowIon, 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 (i.e. "Sectors"). During cruise, 60 seconds is, except for the first hour of the day, the default accumulation interval of N2 data (Before 2007 day 42, the default N2 accumulation interval was 30 seconds). The x-axis of the spectrograms is hour of day. On the y-axis each pixel represents a different rate (e.g. B00, L01, R02, etc.). Nominal deposited energies of the rate boxes (or, in the case of Low-Ions, nominal time of flight bins) are given in the FITS header.

11.4.5.3 FLUX

This HDU contains calibrated fluxes, uncertainties, and raw counts/sec 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.

IMPORTANT NOTE: The UTC **YEAR** and **DAY_OF_YEAR** columns are only included for convenience in plotting. DO NOT USE THEM for precise timing as there could be leap-second ambiguities in them. Use the ephemeris time (**ET**) column if precision is important.

For some Rate Boxes, the exact particle species is undeterminable. They contain both Oxygen and Sulfur. Separate calibrations are supplied for Oxygen and for Sulfur. The Rate Box name is modified by appending an "O" or an "S" respectively in the FITS table column name.

All of the quantities used in the calibration of the flux measurement, including their uncertainties are included in keywords in the FITS header. A description of the calibration procedure follows.

IMPORTANT NOTE: Calibration work on the PEPSSI instrument is ongoing. Uncertainties in some quantities (particularly efficiency) are still very large.

11.4.5.3.1 FLUX Calibration Procedure

We calculate the differential intensity j (1/cm²sr-s-keV) in terms of the counts C, time coverage T (s), geometric factor G (cm²sr), upper and lower energy bounds E_{hi} and E_{lo} (keV), and detection efficiency η:

$$j = \frac{C/T}{G\Delta E\eta} ,$$

where $\Delta E \equiv E_{hi} - E_{lo}$. We assume Poisson statistics for C, no error in T, absolute errors in G, E_{hi}, E_{lo} and relative error in η. So, formally we quote the counts as $C = C \pm \sqrt{C}$, the energies as $E = E \pm \delta E$, and the geometry factor is $G = G \pm \delta G$. We could also write $\eta' = \eta' \pm \delta\eta'$ but choose instead to define the relative error $\varepsilon \equiv \frac{\delta\eta}{\eta}$. Starting with the minimum and maximum efficiencies that describe a two sigma confidence band, η_{lo} and η_{hi}, we determine our best efficiency using the geometric mean $\eta = \sqrt{\eta_{hi}\eta_{lo}}$ and subsequently determine the relative error $\varepsilon = \sqrt{\frac{\eta_{hi}}{\eta_{lo}}}$. So, we can quote the efficiency and relative error as $\eta = \eta \overset{\times}{\div} \frac{\delta\eta}{\eta}$, or $\eta = \eta \overset{\times}{\div}\varepsilon$, meaning that the actual efficiency is between η/ε and $\eta\varepsilon$, to one sigma confidence.

With these given errors the formal error in j is given by:

$$\delta j = j\sqrt{\frac{1}{C} + \left(\frac{\delta G}{G}\right)^2 + \frac{(\delta E_{hi})^2 + (\delta E_{lo})^2}{\Delta E^2} + \left(\frac{\delta\eta}{\eta}\right)^2} = j\sqrt{\frac{1}{C} + \left(\frac{\delta G}{G}\right)^2 + \frac{(\delta E_{hi})^2 + (\delta E_{lo})^2}{\Delta E^2} + \varepsilon^2}$$

Here we have assumed that all errors $\delta x_1,\ldots,\delta x_N$, are uncorrelated and have used the general expression for the error in a function $f = f(x_1,\ldots,x_N)$:

$$(\delta f)^2 = \sum_{i=1}^{N}\left(\frac{\partial f}{\partial x_i}\delta x_i\right)^2$$

A "pseudo-code" version of the actual calculation code used is given in **COMMENT** keywords in the FITS header.

Note on the correlation of the errors in E_{lo} and E_{hi}:
To zeroth order, we can treat the errors on E_{lo} and E_{hi} as uncorrelated. One pragmatic reason is that it is a conservative assumption; if we are wrong then we are *overstating* the errors (at most by a factor of √2). Also, there are times when the uncertainty in E_{lo} or E_{hi} will be quite uncorrelated. For example the E_{lo} could depend on our understanding of the SSD threshold, while the E_{hi} could depend on our estimate of how fast the spectrum will be falling, both very different things. The most problematic case (from an error propagation point of view) would be where we believe we know the passband width ΔE very well but we are not sure of the absolute energies. We think most of these potential cases are taken care of in the channel-to-$E_{deposit}$ calibration (which establishes the scale) whereas most of the potential cases of uncorrelated errors in E_{lo} and E_{hi} occur in the $E_{deposit}$-to-$E_{incident}$ calibration.

11.4.5.3.2 Derivation and Explanation of Calibration Table Values

In the headers of the L3 files, we have supplied values to convert the instrument specific data (e.g., count rates) into physical instrument-independent units (e.g., differential intensity), as well as computing the physical quantities themselves. It must be stressed that these are preliminary values and calibration work by the instrument team is ongoing.

The calibration quantities are energy pass-band ($\Delta E \equiv E_{hi} - E_{lo}$, lower and upper limit of the energies of the particles measured), measurement efficiency (η, the fraction of valid incident particles that are actually measured), the geometry factor (G, the measurement of the physical detector size and solid angle subtended by the field of view). These values are all given and applied with uncertainties in the Level 3 files.

The energies are incident energies. Incident energy is the energy the particle has just before entering the instrument aperture absent the effect of the ~3 kV accelerating potential, which would induce a charge dependent energization. These energies were determined using a Monte Carlo technique that includes the energy loss as the particles trace through the entire system: start foil, free time-of-flight area, stop foil, dead layer, and energy defect. Losses through the foils are simulated and traced, as well as trajectory aberrations due to angular scattering. The energy defect for every particle and energy is also estimated by the SRIM code and checked with real data, where available. Some ground calibration of protons was also included. The uncertainties were not quantitatively determined from this modeling and measurements but are rather estimated from the known differences between various techniques. The geometry factors are derived from the same technique with similarly non-quantitative errors. These calibration values, although the uncertainties have not been estimated quantitatively, we consider appropriate to use for scientific study.

The largest uncertainty in the calculated PEPSSI fluxes in the Level 3 data is due to the efficiency determination. PEPSSI, like most particle instruments (excluding sensors that rely only on solid state detectors and measure relative high ~> 1 MeV/nuc particles), is far from 100% efficient. This is due in large part to the "foil efficiency," which is the fraction of incident ions that result in secondary electrons that are detected by the micro channel plate (MCP). This efficiency is dependent on the voltage established across the MCP. So there are at least two primary physical processes involved (a) the probability that there are any secondary electrons emitted from the foil and (b) the probability that any resulting electrons are steered towards the MCP and multiplied to a sufficient current conducted to the anodes and that this signal triggers the start or stop discriminators.

We can determine this through a combination of ground measurements, through analysis of the in-flight calibration alpha-particle source, modeling, and through intercalibration with known measurements. Before we can confidently report absolute fluxes, we must do all of these things. Currently we have only employed the final method, which has the obvious drawback of not providing an independent determination of the absolute flux. Therefore the fluxes provided in the Level 3 data should not be used as is to conduct science that is relying on absolute fluxes for scientific interpretation unless the user determines the fluxes independently and with full knowledge of the care that must be taken.

In addition to these issues, a further consideration must be taken into consideration. The PEPSSI instrument was specifically engineered to make low rate measurements. This means that whenever there was a trade off between engineering effort, electronic components, power usage, mass, and volume, and ability to make high rate measurements, the later was given relatively low priority. For example, the CPU was selected for it's low power consumption, which means that there is an upper limit to the total number of events that can be processed. Therefore the user has to be aware that saturation of the rates can take place and that the saturation does not have to be uniform across different rates. It is possible during high rate periods for a large number of triple coincidence ions, for example, to impeded the processing of electrons.

It is for this reason that it is very difficult to provide a single set of calibration values for this phase of the mission. We have provided what we have now and intend to continue to improve our knowledge and deliver the improved calibration information with subsequent updates to the PDS archive

11.4.5.4 PHA Data

The three PHA extensions: PHA_ELECTRON, PHA_LOW_ION, and PHA_HIGH_ION contain the PHA event data. As in the L2 data, each row represents a single PHA event. Events with the multi-hit (cross talk) flag set have been excluded. Quantities of limited usefulness (such as Heavy Ion Discriminator triggers) have been excluded. Because of the difficulty of removing priority scheme biases from non-N2 PHA data, only N2 (ApID == 0x692) PHA data is present in the L3 files.

Calibrated Deposited Energy and/or Time of Flight values are given. The linear calibration constants and formulas are in the FITS headers. A **Speed** column is calculated from the Time of Flight assuming a 6.0cm flight path.

The Rate Box classification for each event is given in the **Rate_Box** column. Special cases follow:

- **R00A and R00B**: R00 was originally the "dump bin" channel for electrons. Early in the mission it had a low-energy and a high energy band ("A" and "B" respectively). Since we raised the threshold, there is now only the high energy band in practice, that is, we will never see electrons in the R00A band. "R00A" and "R00B" are used in the L3 PHA data column ("Rate_Box") that indicates how the flight software categorized the event. The actual channel in N1 or N2 (L2) or FLUX (L3) extensions only exists as "R00".
- **SAll:** SAll means all Sectors (0-5) averaged together.

The PHA_HIGH_ION extension contains additional columns:

The **H_Incident_Energy, He_Incident_Energy, O_Incident_Energy,** and **S_Incident_Energy** 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 by the procedure described in the Primary HDU section above. This column is usually used in making histograms of the High Energy Ion PHA data.

11.4.6 Memory Required

1 GB memory and a 3 GHz Pentium is sufficient for processing.

11.4.7 Temporary File System Space Needed

The Pre-Level 2 files require up to 50MB per day's worth of data.

11.4.8 Predicted Size of Output File(s)

Level 2 files are in the range 1MB – 30MB. Level 3 files are typically 5-6 times larger than the corresponding Level 2 file, but only range up to a maximum of around 50MB.

11.4.9 Predicted Execution time

Less than a minute per file, typically. The L1 to Pre-L2 conversion takes a few seconds per file. The entire Jupiter phase takes 40 minutes to convert from Pre-L2 to L2 and L3 files on a Red Hat Linux machine with 4 4GHz Xeon processors. It's not known how much parallelization was actually responsible for the speed.

11.4.10 Contact/Support Person(s)

Stefano Livi, Matthew Hill, Martha Kusterer, Larry Brown and Reid Gurnee

11.4.11 Maintenance Schedule (Code/Data Updates, Documentation)

As calibration data is collected during flight, the level 2 pipeline code will require updates either to calibration files or to code for bug fixes or enhancements.

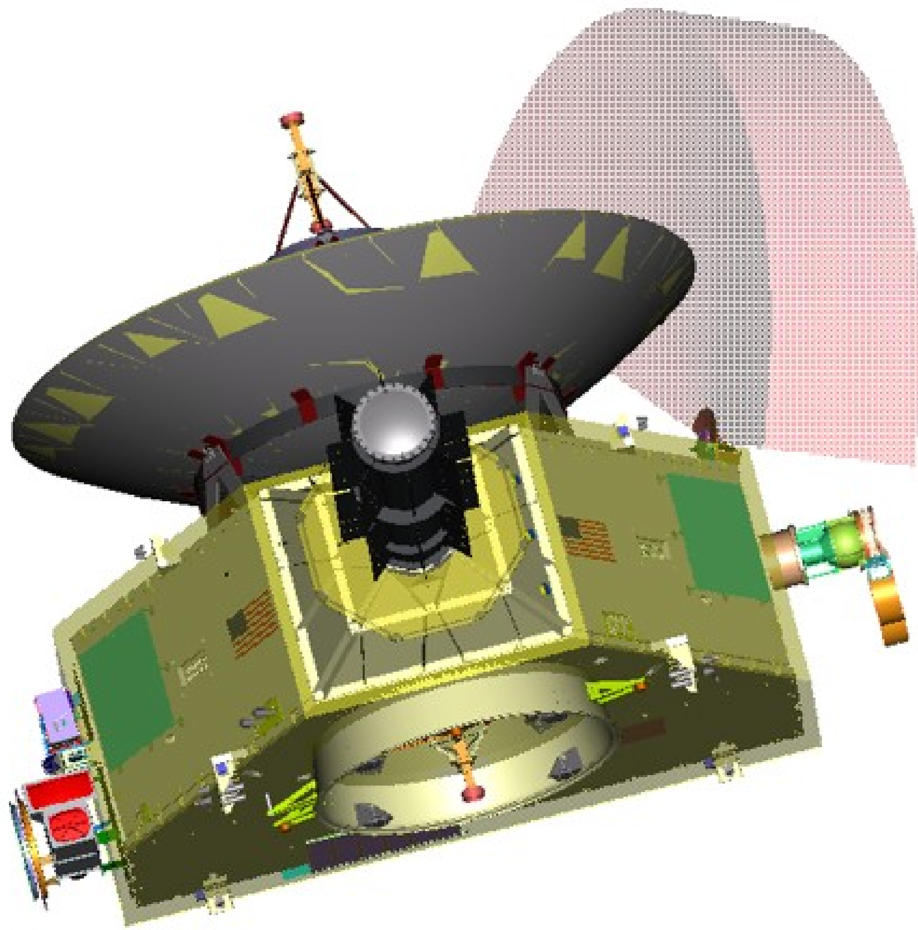


Figure 11-1: Location of PEPSSI on the New Horizons spacecraft. The lightly shaded area denotes PEPSSI Field-of-View (FOV)

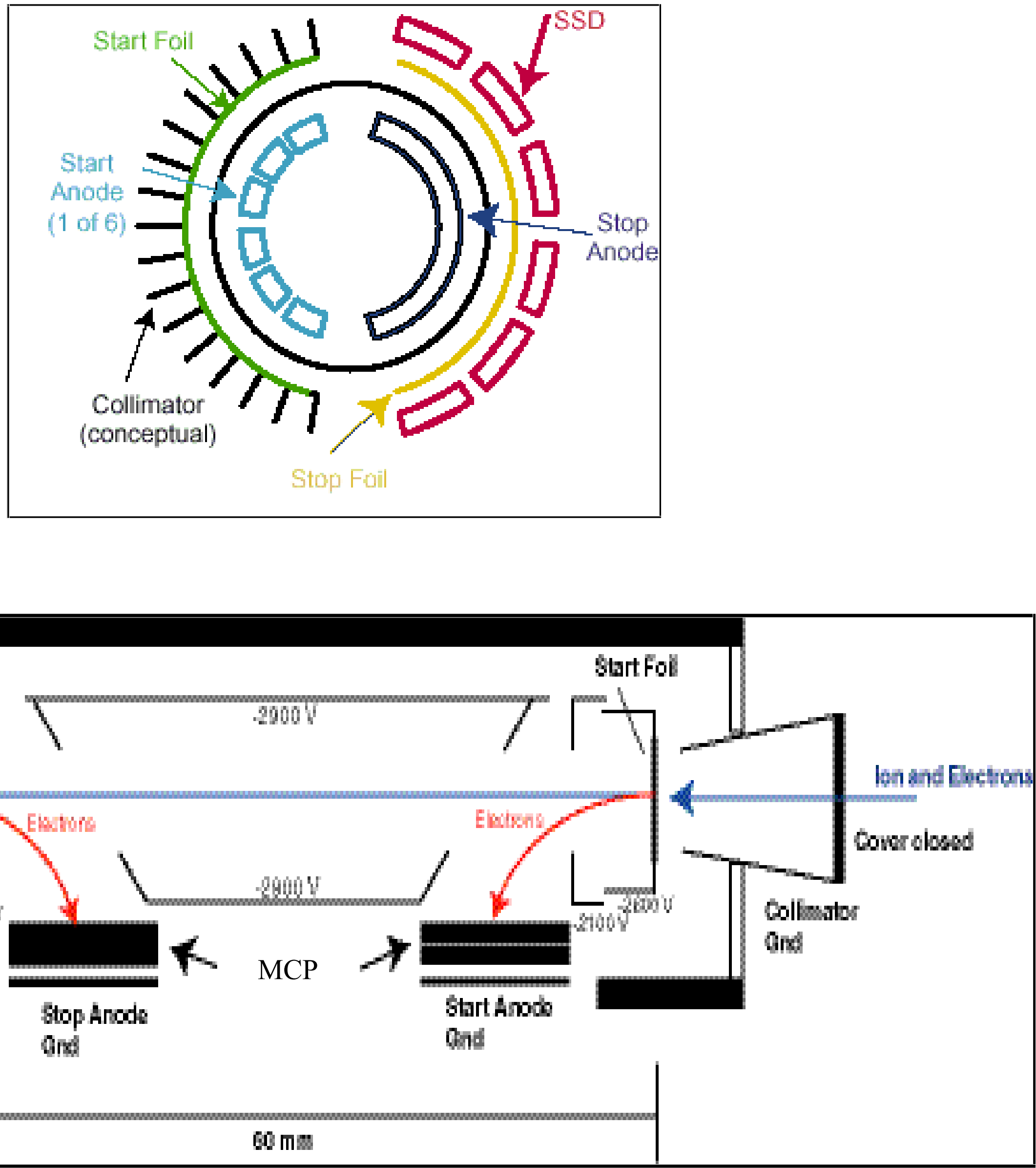


Figure 11-2: Schematic drawings of the PEPSSI sensor

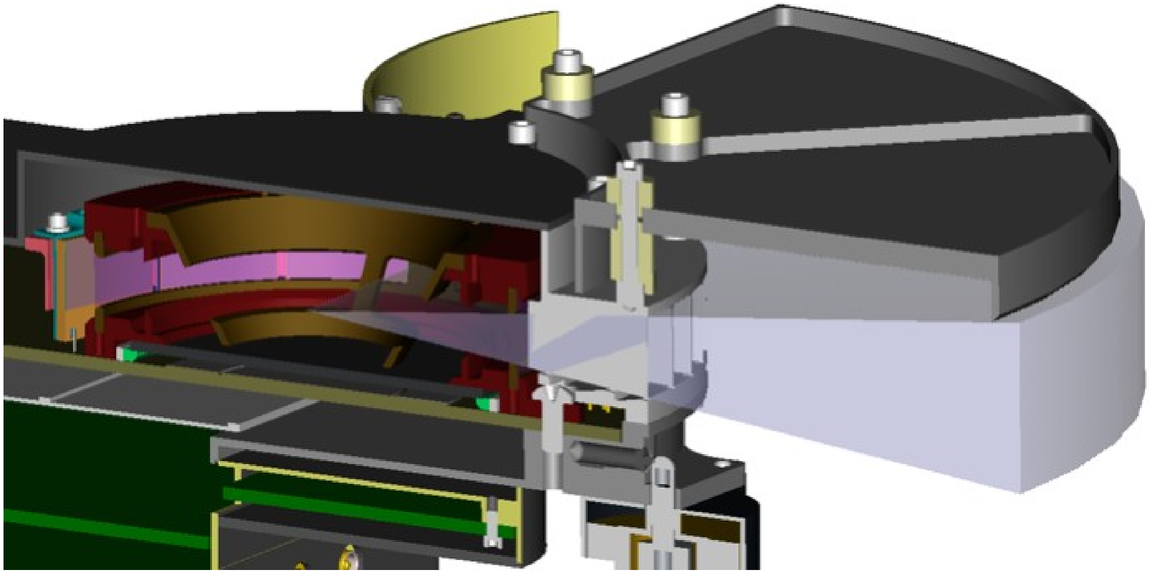


Figure 11-3: A cut-away view of the PEPSSI FOV.

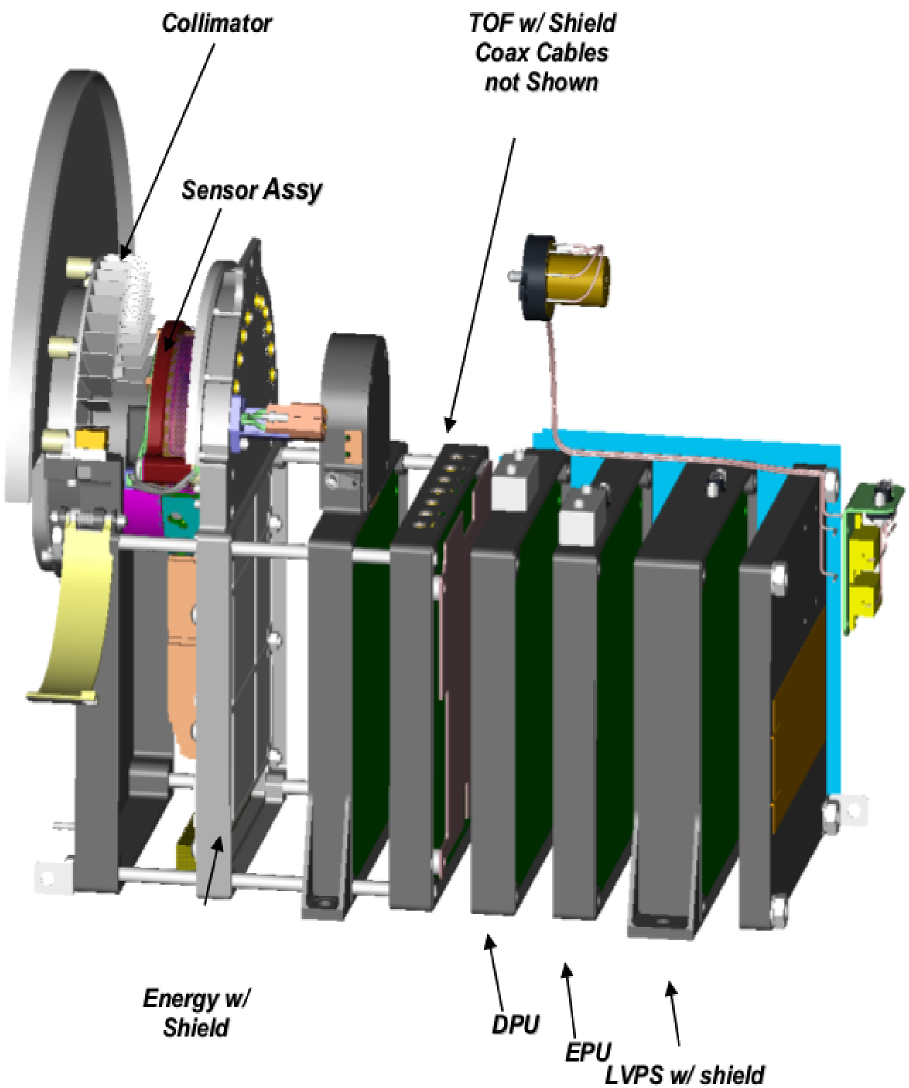


Figure 11-4: Expanded view of the PEPSSI sensor.

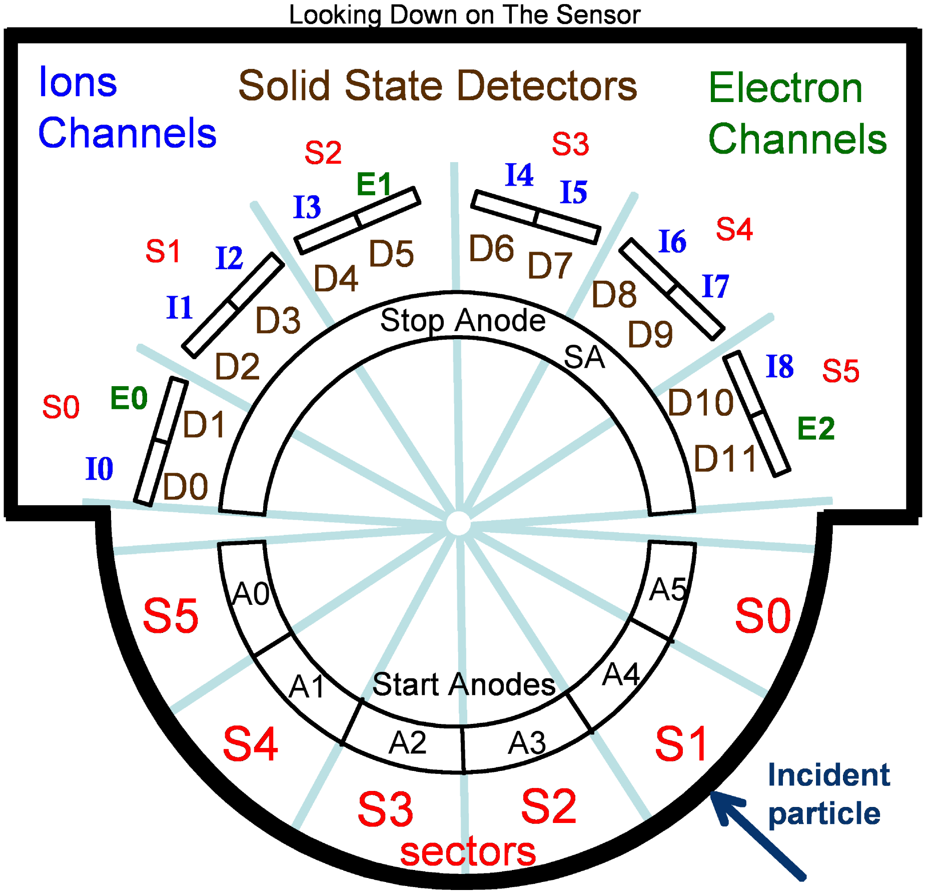


Figure 11-5: Pepssi Layout labeling

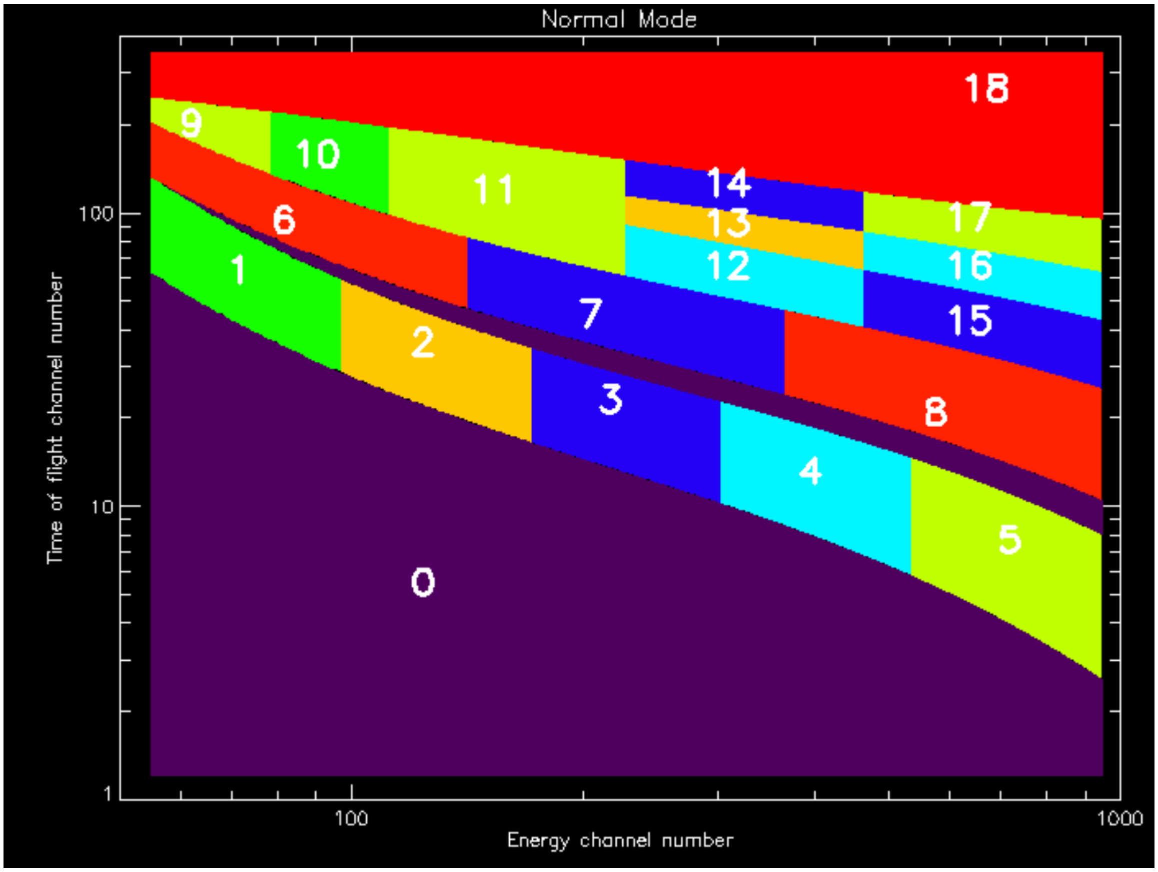


Figure 11-6: PEPSSI Rate Boxes on the TOF vs Energy Plane. Normal Mode.

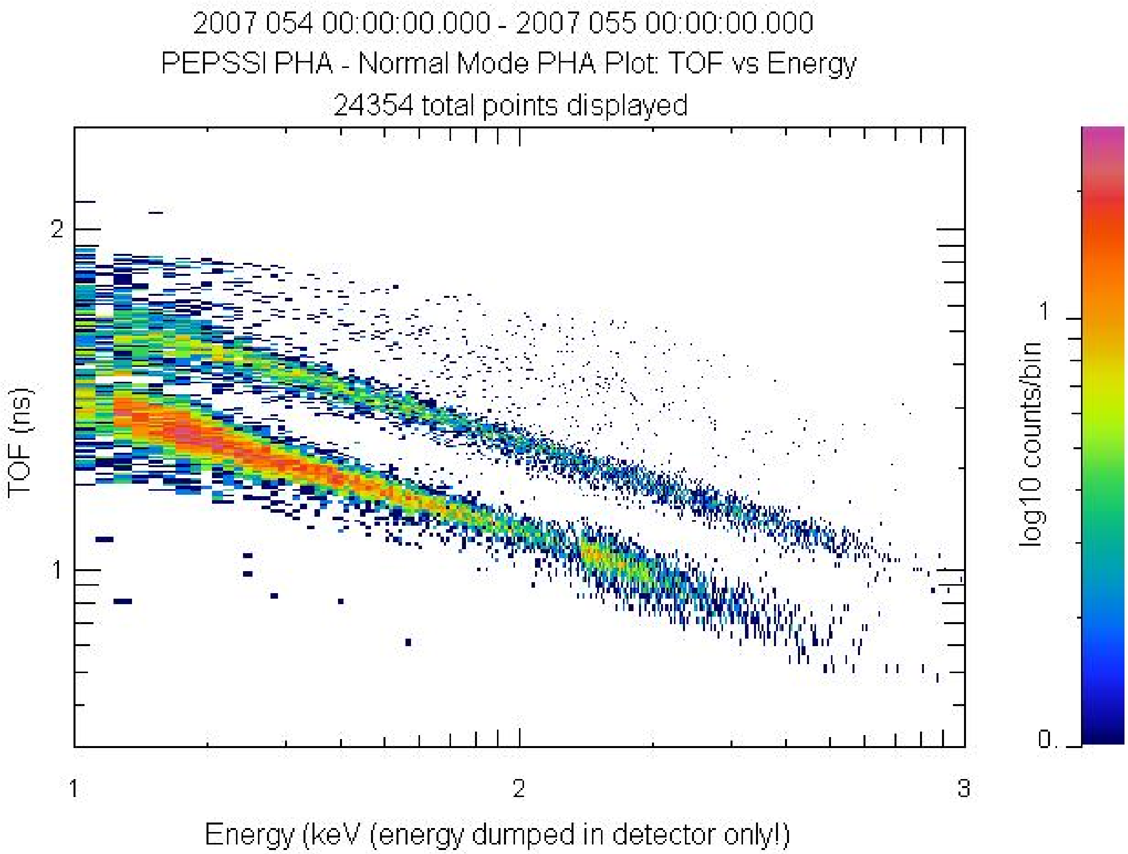


Figure 11-7: 2D PHA Histogram: No weighting. Note artifact in high energy protons (Box B03).

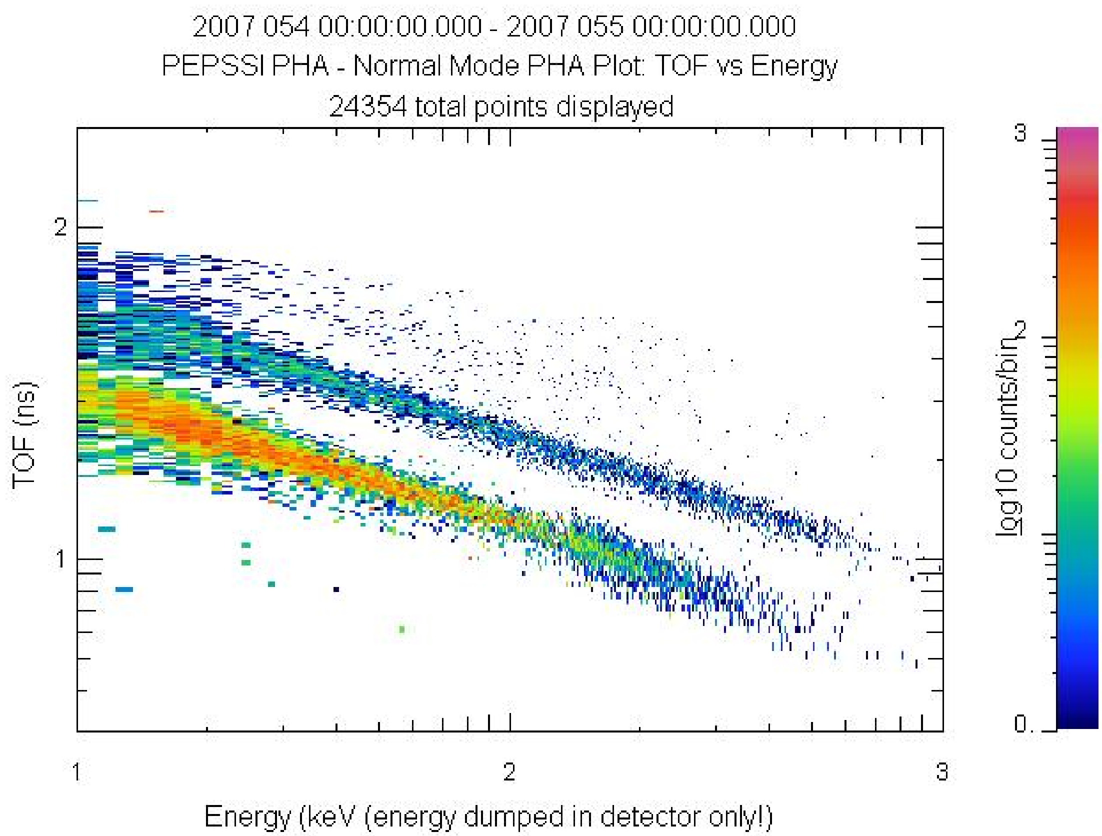


Figure 11-8: 2D PHA Histogram with Rate-Weighting applied.