EPHIN/COSTEP

Level-2 Data Format Specification

for SOHO Archive

Prepared by : Reinhold Müller-Mellin
Holger Boll

March 1998

Contact address : Institut für Experimentelle und Angewandte Physik
Olshausenstr. 40, D-24118 Kiel, Germany

Reinhold Müller-Mellin
Phone: (49-431) 880 3227 Fax: (49-431) 85660
e-mail: mueller-mellin@kernphysik.uni-kiel.de

Holger Boll
Phone: (49-431) 880 2486 Fax: (49-431) 85660
e-mail: boll@kernphysik.uni-kiel.de

1. Data Product

The EPHIN instrument (Electron Proton Helium INstrument) forms part of the COSTEP experiment (COmprehensive SupraThermal and Energetic Particle Analyser) within the CEPAC collaboration on bord of the SOHO spacecraft (SOlar and Heliospheric Observatory). For a detailed description of the SOHO mission and the COSTEP experiment see *Solar Physics*, **162**, 1995.

The EPHIN instrument produces scientific data at a constant rate of 172 bit/s or 15 megabit per day and housekeeping data at a rate of 0.25 megabit per day (Level Zero data). This data set is processed at the University of Kiel in two steps yielding Level 1 and Level 2 products. The Level 2 data set is organized in files per day, primarily counting rate information (~ 0.36 megabyte per day) and pulse height analysis information (~ 15 megabyte per day) together with their detached header files. Furthermore a correction file (~0.16 megabyte per day) is included which can be used to correct the counting rates for instrumental effects (e.g. gamma ray and neutron produced background, contamination of one particle species by the other) and to separate isotopes. The distribution medium is CD-ROM. Together with the LION/COSTEP data set one CD-ROM is produced per month. AAREADME and CAVEAT text files are included which can be read by WORD (Text only) or other suitable editors.

Data Files:

File Contents	Name Convention
EPHIN counting rates	EPHyydoy.RL2
EPHIN pulse height analysis (PHA)	EPHyydoy.PL2
EPHIN rate correction	EPHyydoy.KOR

Detached Header Files:

File Contents	Name Convention
File header for rate data file	EPHyydoy.MR2
File header for PHA data file	EPHyydoy.MP2

- Counting rates are given as intensities in units of counts/cm^2 s sr MeV, a subset of counting rates is given as counting results per accumulation interval of 59.953 seconds. The factors which were used to convert counting results into intensities are given in chapter 5.
- Pulse height words are given as energy deposits in units of MeV. The conversion factors which were used to convert ADC value of a pulse height into MeV are given in chapter 6.
- Rate correction data are given as counts, from which the correction factor can be derived.
- Time resolution for all 3 data sets is 1 minute (exact accumulation period is 59.953 seconds).

2. Data Format Description

2.1 Counting rates file: EPHyydoy.RL2

Item	Label:	Data Type	Data Contents	Units
1	PB5 Year	integer	year	year 4 digits
2	DOY	integer	day of year	day 1 ... 366
3	MS	integer	milliseconds of day	ms 0 ... 86,400,000
4	S/C Epoch	float (double)	ms since year 0	ms 14 digits
5	Status Word part 1	Integer	bits 0 to 31	binary
6	Status Word part 2	Integer	bits 32 to 39 see chapter 3	binary
7	E150	float (E-Fmt)	intensity	/cm^2 s sr MeV
8	E300	float (E-Fmt)	intensity	/cm^2 s sr MeV
9	E1300	float (E-Fmt)	intensity	/cm^2 s sr MeV
10	E3000	float (E-Fmt)	intensity	/cm^2 s sr MeV
11	P4	float (E-Fmt)	intensity	/cm^2 s sr MeV
12	P8	float (E-Fmt)	intensity	/cm^2 s sr MeV
13	P25	float (E-Fmt)	intensity	/cm^2 s sr MeV
14	P41	float (E-Fmt)	intensity	/cm^2 s sr MeV

Counting rates file: EPHyydoy.RL2 (continued)

Item	Label	Data Type	Data Contents	Units
15	H4	float (E-Fmt)	intensity	/cm^2 s sr MeV/n
16	H8	float (E-Fmt)	intensity	/cm^2 s sr MeV/n
17	H25	float (E-Fmt)	intensity	/cm^2 s sr MeV/n
18	H41	float (E-Fmt)	intensity	/cm^2 s sr MeV/n
19	INT	float (E-Fmt)	intensity	/cm^2 s sr
20	P4 GM	integer	particle count	counts
21	P4 GR	integer	particle count	counts
22	P4 S	integer	particle count	counts
23	P8 GM	integer	particle count	counts
24	P8 GR	integer	particle count	counts
25	P8 S	integer	particle count	counts
26	P25 GM	integer	particle count	counts
27	P25 GR	integer	particle count	counts
28	P25 S	integer	particle count	counts
29	P41 GM	integer	particle count	counts
30	P41 GR	integer	particle count	counts
31	P41 S	integer	particle count	counts
32	H4 GM	integer	particle count	counts
33	H4 GR	integer	particle count	counts
34	H4 S1	integer	particle count	counts
35	H4 S23	integer	particle count	counts
36	H8 GM	integer	particle count	counts
37	H8 GR	integer	particle count	counts
38	H8 S1	integer	particle count	counts
39	H8 S23	integer	particle count	counts
40	H25 GM	integer	particle count	counts
41	H25 GR	integer	particle count	counts
42	H25 S1	integer	particle count	counts
43	H25 S23	integer	particle count	counts
44	H41 GM	integer	particle count	counts
45	H41 GR	integer	particle count	counts
46	H41 S1	integer	particle count	counts
47	H41 S23	integer	particle count	counts
48	Status Flag	integer	see chapter 4	binary
49	Spare			
50	Spare			
51	Spare			

GM = Particles incident parallel to sensor axis, passing through both center segments: A0 and B0 (0° ... 21°)

GR = Particles incident parallel to sensor axis, passing through corresponding ring segments: A1 and B1 or ... or A5 and B5 (0° ... 28°)

S1 = Particles incident at oblique angle through one center segment and one ring segment: A0 and B1 or ... or A5 and B0 (0° ... 34°)

S23 = Particles incident at oblique angle through ring segments: A1 and B2 ... or A1 and B3 (0° ... 42°)

2.2 PHA file: EPHyydoy.PL2

Item	Label	Data Type	Data Contents	Units/Values
1	S/C Epoch	float (double)	ms since year 0	ms 14 digits
2	Co	integer	coincidence type	0 ... 12
3 4 5	Aseg Bseg Pri	integer integer integer	segment det. A segment det. B priority flag	0 ... 5 0 ... 5 0 or 1
6	PHA_A	float (F-Fmt)	energy loss in det. A	MeV
7	PHA_B	float (F-Fmt)	energy loss in det. B	MeV
8	PHA_C	float (F-Fmt)	energy loss in det. C	MeV
9	PHA_D	float (F-Fmt)	energy loss in det. D	MeV
10	PHA_E	float (F-Fmt)	energy loss in det. E	MeV
11	E_tot	float (F-Fmt)	total energy loss	MeV
12 13 14 15	spare spare spare spare			

Coincid. type	0	1	2	3	4	5	6	7	8	9	10	11	12
Channel	E150	E300	E1300	E3000	P4	P8	P25	P41	H4	H8	H25	H41	INT

2.3 Rate correction file: EPHyydoy.KOR

Item	Data contents	Data type	Units
1 2 3	year day of year ms of day	integer integer integer	year: 4 digits day: 1...366 ms: 0...86,400,000
4	ms since year 0	float (double)	ms: 14 digits
 5 6 7 8 9	P4 Ptota total # of particles in P4 PHA, arbitrary incidence p+d # particles in proton & deuterium box, arb. incidence Ptotp total # of particles in P4 PHA, parallel incidence p # of particles in proton box, parallel incidence d # of particles in deuterim box, parallel incidence	 integer integer integer integer integer	 counts counts counts counts counts
 10 11 12 13 14	P8 Ptota total # of particles in P8 PHA, arbitrary incidence p+d # particles in proton & deuterium box, arb. incidence Ptotp total # of particles in P8 PHA, parallel incidence p # of particles in proton box, parallel incidence d # of particles in deuterim box, parallel incidence	 integer integer integer integer integer	 counts counts counts counts counts
 15 16 17 18 19	P25 Ptota total # of particles in P25 PHA, arbitrary incidence p+d # particles in proton & deuterium box, arb. incidence Ptotp total # of particles in P25 PHA, parallel incidence p # of particles in proton box, parallel incidence d # of particles in deuterim box, parallel incidence	 integer integer integer integer integer	 counts counts counts counts counts
 20 21 22 23 24	P41 Ptota total # of particles in P41 PHA, arbitrary incidence p+d # particles in proton & deuterium box, arb. incidence Ptotp total # of particles in P41 PHA, parallel incidence p # of particles in proton box, parallel incidence d # of particles in deuterim box, parallel incidence	 integer integer integer integer integer	 counts counts counts counts counts
 25 26	H4 Ptota total # of particles in H4 PHA, arbitrary incidence ^{3}He + ^{4}He # particles in ^{3}He + ^{4}He box, arb.incidence	 integer integer	 counts counts

27	Ptotp total # of particles in H4 PHA, parallel incidence	integer	counts
28	^{3}He # of particles in ^{3}He box, parallel incidence	integer	counts
29	^{4}He # of particles in ^{4}He box, parallel incidence	integer	counts
	H8		
30	Ptota total # of particles in H8 PHA, arbitrary incidence	integer	counts
31	^{3}He + ^{4}He # particles in ^{3}He + ^{4}He box, arb.incidence	integer	counts
32	Ptotp total # of particles in H8 PHA, parallel incidence	integer	counts
33	^{3}He # of particles in ^{3}He box, parallel incidence	integer	counts
34	^{4}He # of particles in ^{4}He box, parallel incidence	integer	counts
	H25		
35	Ptota total # of particles in H25 PHA, arbitrary incidence	integer	counts
36	^{3}He + ^{4}He # particles in ^{3}He + ^{4}He box, arb.incidence	integer	counts
37	Ptotp total # of particles in H25 PHA, parallel incidence	integer	counts
38	^{3}He # of particles in ^{3}He box, parallel incidence	integer	counts
39	^{4}He # of particles in ^{4}He box, parallel incidence	integer	counts
	H41		
40	Ptota total # of particles in H41 PHA, arbitrary incidence	integer	counts
41	^{3}He + ^{4}He # particles in ^{3}He + ^{4}He box, arb.incidence	integer	counts
42	Ptotp total # of particles in H41 PHA, parallel incidence	integer	counts
43	^{3}He # of particles in ^{3}He box, parallel incidence	integer	counts
44	^{4}He # of particles in ^{4}He box, parallel incidence	integer	counts

Energetic particles can undergo several processes in the EPHIN telescope, which lead to inaccurate particle classification: e.g. electrons can be scattered by large angles, reducing their penetration depth in the detector stack and thus mimicking nuclei, nuclei can pass through insensitive matter like detector mounts, depositing less observable energy, or suffer from nuclear interaction in the silicon detector. This is to a large degree unavoidable, but can be corrected to some degree by pulse height analysis. Using ground data from accelerator calibration and flight data from the first 8 months of SOHO operation, calibration curves for the various nuclei species were established. Boxes around these curves allow elemental and isotopic separation for protons, deuterium, helium-3 and helium-4. Restriction to only particles incident parallel to the optical axis of the telescope decreases the path length variation, thereby increasing the isotopic resolution at the expense of statistical accuracy. To improve on statistics, averaging over longer time periods may be carried out. Owing to multiple scattering there is no easy correction available for electron channels.

How to correct the counting rates:

1. divide the number of PHA counts in the box by the total number of PHA counts
2. apply this correction factor to the associated counting rate

Example for arbitrary incidence:

$$P4_{\text{corrected}} = P4_{\text{uncorrected}} \text{ (= item 11 of EPHyydoy.RL2)} \bullet \frac{\text{item 6 of EPHyydoy.KOR}}{\text{item 5 of EPHyydoy.KOR}}$$

Example for parallel incidence:

$$P4_{\text{corrected}} = \frac{\text{item 20 + item 21 of EPHyydoy.RL2}}{59.953 \bullet 1.02 \bullet 3.5} \bullet \frac{\text{item 8 + item 9 of EPHyydoy.KOR}}{\text{item 7 of EPHyydoy.KOR}}$$

Note: for parallel incidence the counting results must be converted into intensities. The geometric factor for the sum of six segments (P4GM+P4GR) is about 5 % less than 6 times the geometric factor for the center segments (Ring A/B OFF, see chapter 5).

How to average corrected fluxes over n minutes:

$$\text{Average} = \frac{1}{n} \sum_{i=1}^{n} \text{(counting rate} \bullet \text{correction factor)}$$

2.4 Header for Rate Data File: EPHyydoy.MR2

Example:

University of Kiel, Extraterrestrial Physics Group
PI: Horst Kunow
Program: GENSCIL2, Author: Holger Boll, Jan-97
Program_Version: 1.0
Data_Version: V01
Project: SOHO-COSTEP
Instrument: EPHIN
Data_Type: Rates
Data_File_Name:EPH97001.RL2
Data_File_Type: ASCII
Generation_Date: Tue Feb 18 16:48:43 1997
Data_Period_Start: 1997-01-01 00:01:10
Data_Period_End : 1997-01-01 23:59:02
Parameter_File_Name: EPH_IFAC.PRO

2.5 Header for PHA Data File: EPHyydoy.MP2

Example:

University of Kiel, Extraterrestrial Physics Group
PI: Horst Kunow
Program: GENPHAL2, Author: Holger Boll, Jan-97
Program_Version: 1.0
Data_Version: V01
Project: SOHO-COSTEP
Instrument: EPHIN
Data_Type: Pulse Height Analysis
Data_File_Name: EPH97001.PL2
Data_File_Type: ASCII
Generation_Date: Thu Feb 13 14:15:58 1997
Data_Period_Start: 1997-01-01 00:01:10
Data_Period_End : 1997-01-01 23:59:02
Parameter_File_Name: PHA_BIN_ENERG.PRO

3. EPHIN Status Word

The EPHIN status word in words 5 and 6 of the counting rate file is implemented by hardware in the onboard EPHIN electronics and telemetered to ground. Its unrestricted use requires detailed knowledge of the EPHIN hardware. For data evaluation by scientists less familiar with the hardware, an EPHIN status flag in word 48 of the counting rate file has been implemented by software (see chapter 4).

Label	**Bit**	**EPHIN Status Information**								
	Position	**MSB**							**LSB**	**Comment**
Status part 1	31 – 24	N/U	FMB	FMB5	FMB4	FMB3	FMB2	FMB1	FMB0	Fail. mode
default		0	1	1	1	1	1	1	1	Det. B
Status part 1	23 – 16	Ring	FMA	FMA5	FMA4	FMA3	FMA2	FMA1	FMA0	Fail. mode
default		0	1	1	1	1	1	1	1	Det. A
Status part 1	15 – 8	N/U	Reset	Wdog	PROM	SRAM	RAM	Dwnld	Upld	CPU status
default		0	0	0	1	1	1	0	0	
Status part 1	7 – 0	Op Mode		SIO Fr	SIO Ovr	SIO Par	Minute Counter			mode, error,
default		0	1	0	0	0	X	X	X	frame count
Status part 2	31 – 8	N/U								
default		0								
Status part 2	7 – 0	Det.G	Det.A-F	An.Pow	FMG	FMF	FME	FMD	FMC	Power and
default		1	1	1	1	1	1	1	1	Fail. mode

N/U = not used SIO Fr, Ovr, Par = Serial Input Output framing error, overrun error, parity error
X = don't care Wdog = watchdog event
Op mode 00 = standby, 01 = nominal operation, 10 = calibration, 11 = not allowed

4. EPHIN Status Flag

The EPHIN status flag shall facilitate the use of the EPHIN data set without detailed knowledge of the EPHIN hardware status bits and their effects. The status flag is generated by ground software. It is located in word 48 of the counting rate file. The contents of the status flag is a decimal code which results from the summation of the flag bit values.

Flag Bit Value	**Remarks**
0	Nominal observation, i.e. High Voltage ON, no failure mode, ring segment switching disabled
1	Failure mode E
2	Ring A/B OFF
4	E patch uploaded
8	Commissioning
16	Standby or maintenance, i.e. High Voltage OFF
32	Calibration, i.e. test mode
64	Ring segment switching enabled
128	TBD

4.1 Status Flag History

A status flag history is given from first switch-on in December 1995 until February 1998. The status flag is valid from the time indicated until a new status flag is listed. An updated list of the status flag is included on the Level 2 distribution medium (see CAVEAT.TXT).

Year	Month	Day	Hour	Minute	Status Flag	Change
1995	12	07	17	28	16	EPHIN ON (standby or maintenance)
1995	12	07	17	35	0	Nominal observation
1995	12	09	17	03	8	Commissioning
1995	12	10	05	15	0	Nominal observation
1996	10	31	14	47	1	Failure mode E
1996	12	12	16	42	3	Ring A/B OFF (for check-out only)
1996	12	18	14	45	1	Ring A/B ON (back to normal)
1997	02	15	10	25	-1	EPHIN OFF (no data)
1997	02	16	16	37	16	EPHIN ON (standby or maintenance)
1997	02	16	16	45	0	Nominal observation
1997	02	19	14	57	1	Failure mode E
1997	03	13	14	41	5	Upload E patch (salvage PHA_E)
1997	04	23	16	19	37	Calibration
1997	04	23	16	28	5	End calibration
1997	08	22	13	10	5	Upload histogram patch (parallel incidence)
1997	10	10	14	39	69	Enable ring segment switching

Note:
- The code -1 (no data) is dummy. It will not show up in L2 data records as it is only introduced for the purpose of machine reading above table.
- The first table or software upload after EPHIN ON will set bit 2^2 (value 4). It can only be cleared by power cycling or by a reset command. A second upload will not be recognizable as a status change (see e.g. histogram patch on 22-AUG-97).

4.2 Example

In order to select data which are taken with EPHIN in observation mode (not always nominal !) the flag shall have the following contents:

Start	Stop	Status Flag	Remarks
07-DEC-95	09-DEC-95	0	Nominal observation
10-DEC-95	31-OCT-96	0	Nominal observation
31-OCT-96	12-DEC-96	1	Failure mode E Rates: E3000, P41, H41 show zero counts, corresponding events are counted together with E1300, P25, H25, hence use larger energy window. PHA: no PHA words for E3000, P41, H41, corresponding events are pulse height analyzed as E1300, P25, H25, pulse heights for E (PHA_E) are lost.
12-DEC-96	18-DEC-96	3	Failure mode E with ring A/B OFF Rates: as in failure mode E above but use small geometry factor PHA: as in failure mode E above
18-DEC-96	19-FEB-97	1	Failure mode E (see above)
19-FEB-97	10-OCT-97	5	Failure mode E with upload of E-patch, i.e. recovery of PHA_E Rates: as in failure mode E above PHA: no PHA words for E1300, P25, H25 events corresponding events are pulse height analyzed as E3000, P41, H41. PHA_E = zero for true E1300, P25, H25 events PHA_E > zero for true E3000, P41, H41 events.
10-OCT-97	> FEB-98	69	Failure mode E with upload of E-patch and automatic ring segment switching enabled Irregular status changes may occur automatically: "RING A/B OFF", i.e. bit value 2 is added (flag =71). This status change is event driven, it switches to the low geometric factor during high fluxes. On detection of low fluxes, the ring segments are switched back on again. The occurrence is not recorded in this table.

5. EPHIN Intensity Factors

Part of the Level-2 counting rates are already converted into intensities [counts/(cm^2 s sr MeV/n)] by dividing the counting rates [counts/s] through the intensity factor:

Intensity Factor = Geometry Factor • Energy Window [cm^2 sr MeV/n]

The factors vary with observation modes of EPHIN. The following observation modes with influence on the intensity factor have been in use during the SOHO prime mission:

Observation Mode	Description
nominal mode	High voltage on, all detectors logically on
failure mode E	High voltage on, detector E logically off
ring A/B off	High voltage on, segments A1 … A5 and B1 … B5 logically off and respective preamplifier power off

Geometry Factor: **units: cm^2 sr**

Geometry factor: nominal observation mode				
0.25	1.78	2.01	1.58	E150, E300, E1300, E3000
5.14	5.14	4.77	3.8	P4, P8, P25, P41
5.14	5.14	4.77	3.8	H4, H8, H25, H41
6.85				INT

Geometry factor: failure mode E				
0.25	1.78	1.8	1.	E150, E300, E1300, E3000
5.14	5.14	4.29	1.	P4, P8, P25, P41
5.14	5.14	4.29	1.	H4, H8, H25, H41
7.84				INT

Geometry factor: ring A/B off and failure mode E				
0.01	0.14	0.11	1.	E150, E300, E1300, E3000
0.18	0.18	0.18	1.	P4, P8, P25, P41
0.18	0.18	0.18	1.	H4, H8, H25, H41
0.36				INT

Note: The combination ring A/B off without failure mode E will probably never occur.

Energy Window: **units: MeV or MeV/n**

Energy window: nominal observation mode				
0.45	2.3	3.6	5.2	E150, E300, E1300, E3000
3.5	17.2	16.	12.	P4, P8, P25, P41
3.5	17.2	16.	12.	H4, H8, H25, H41
1.				INT

Energy window: failure mode E				
0.45	2.3	7.4	1.	E150, E300, E1300, E3000
3.5	17.2	28.	1.	P4, P8, P25, P41
3.5	17.2	28.	1.	H4, H8, H25, H41
1.				INT

Note:
- No energy window is given for the integral counter INT. The geometry factor given is twice the forward incident factor assuming an idealized response for forward and backward incident particles. The actual factor is somewhat lower due to absorption in the spacecraft matter.
- Switching ring segments off does not change the energy window

6. EPHIN PHA conversion factors

The Level 2 data in the PHA files are given in units of MeV. The following conversion factors were used to convert the telemetered channel number TLM_i, i.e. the analog-to-digital converter result of a pulse height, into energy deposit PHA_i in MeV for detector i:

$$\mathbf{PHA_i} = \frac{\mathbf{TLM_i}}{\mathbf{1023}} \bullet \mathbf{Factor_i}$$

where $Factor_i$ can be either the low range factor or high range factor, depending on the Low/High flag of the telemetered pulse height word.

Detector pulse height	Low range factor	High range factor
PHA_A	3.00	30.00
PHA_B	3.00	45.00
PHA_C	16.07	166.7
PHA_D	20.00	225.00
PHA_E	20.00	225.00