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BEPICOLOMBO

MERCURY PLANETARY ORBITER (MPO)

BERM Experiment-to-Archive ICD (EAICD)

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CHANGE LOG

Reason for change	Issue	Revision	Date
Global update of the document in the context of the contract BARD – Expert support of the BERM and RADEM instruments	2	0	12/12/2022

CHANGE RECORD

Issue 2	Revision 1		
Reason for change	Date	Pages	Paragraph(s)
Updated data organisation and products. Change of data products format from fits to CDF.	12/12/2022		All
Issue 3	Revision 1		
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Section 5. Table 11 added with data structure/s and label metadata in tabular form, specifying name of fields, data type and description, in	06/06/2023		

order to help the selection of variables to be included in new CDF files.			
Issue 4	Revision 1		
Reason for change	Date	Pages	Paragraph(s)
3.4 Science Data Quality Control and Annex A added to establish the scientif data quality control procedures and tag time periods of scientific data not to be released as public as a result of any issue during acquisition	06/07/2023		

Table of Contents

1. Introduction

1.1 Purpose and Scope

This Experiment-to-Archive Interface Control Document (EAICD) describes the format and content of the BepiColombo Environment Radiation Monitor (BERM) archived data. It includes descriptions of the data products and associated metadata, including the data format, content, and generation pipeline. The specifications described in this EAICD apply to all BER products submitted for archive to ESA's BepiColombo Science Ground Segment (SGS), for all phases of the BepiColombo mission. This document includes descriptions of archive products that are produced by both the BERM support team and by the SGS.

1.2 Applicable Documents

The following documents, of the issue given here-under, are pertinent to the extent specified herein and impose requirements to the SGS or the SGS schedule. They are referenced in the form [AD.XX]:

[AD.01] BC-SGS-PL-014, BepiColombo Science Data Generation, Validation and Archiving Plan
[AD.02] BC-SGS-TN-026, BepiColombo Archiving Guide
[AD.03] PDS4 Standards Reference (SR)
[AD.04] PDS4 Data Dictionary (DDDB)
[AD.05] PDS4 Information Model Specification (IM)

1.3 Reference Documents

The following documents, of the issue given here-under, although not part of this document, amplify or clarify its contents. If no issue given, the most recent issue should be used. They are referenced in the form [RD.XX]:

[RD.01] BC-SGS-TN-042, BepiColombo Data Handling and Archiving Concept
[RD.02] BC-SGS-ICD-xxx, BERM Data Processing Agreement
[RD.03] PDS4 Data Providers Handbook (DPH)
[RD.04] PDS4 Concepts
[RD.05] BC-SGS-LI-014, SGS Glossary
[RD.06] BC-EFA-TR-00028m, BERM PFM-PFM Spare Radiation Calibration Test Report II
[RD.07] BC-EFA-UM-00001 05G, BERM - Equipment User Manual & Handling Procedures
[RD.08] BARD-LIP-TR 0001 02 Analysis-Industrial-BERM-Data, Industrial Data Calibration Report
[RD.09] Pinto M., et al. 2022, The BepiColombo Environment Radiation Monitor, BERM, Space Science Reviews (2022) 218:54, https://doi.org/10.1007/s11214-022-00922-2
[RD.010] BERM Pipeline Description document
[RD.011] Huovelin, J., Vainio, R., Kilpua, E. *et al.* Solar Intensity X-Ray and Particle Spectrometer SIXS: Instrument Design and First Results. *Space Sci Rev* **216**, 94 (2020). https://doi.org/10.1007/s11214-020-00717-3
[RD.012] I.G. Mitrofanov, A.S. Kozyrev, et al, The Mercury Gamma and Neutron Spectrometer (MGNS) on board the Planetary Orbiter of the BepiColombo mission, Planetary and Space Science, Volume 58, Issues 1–2 (2010) pp 116-124, https://doi.org/10.1016/j.pss.2009.01.005.
[RD.013] BSRD-LIP-TR 0002 01 Verification-BERM-Response-Matrix, 2023-12-28

1.4 Abbreviations and Acronyms

See BepiColombo online Glossary [RD.05].

ASIC	Application Specific Integrated Circuit
FOV	Field of View
PCB	Printed Circuit Board
RADFET	Radiation Sensitive Field Effect Transistor

2. BERM Instrument Description

2.1 Science Objectives

The primary objective of BERM onboard the Mercury Planetary Orbiter (MPO) is to provide continuous measurements of the radiation environment of the spacecraft in order to collect regular data on the amount of highly energetic particles, discriminating by type (electrons, protons, heavy ions) and energy level. These measurements will provide information on the radiation doses that the spacecraft and its electronics encounter over the course of the mission. The radiation levels and characteristics derived from BERM data will allow the impact of the radiation environment on the scientific payloads to be derived.

In addition, the data from BERM will be used to augment and extend the in-situ particle measurements of the SIXS-P sensor also on board of BepiColombo, that is detailed described here [RD.06], by extending the measurement range for electrons, protons and heavy ions. Also, the radiation data collected by BERM provides a valuable reference measurement for the MGNS instrument [RD.06], also on board of BepiColombo, allowing for a better discrimination of radiation sources in the MGNS data

2.2 Instrument Description

The BERM instrument (Fig 1a) is an adaptation of the MFS (Multi-Functional Spectrometer) unit flown on Alphasat, from which it has inherited most of its functional features. A noteworthy difference is a re-designed circuit board and an updated ASIC chip which performs the particle recognition and energy reconstruction process.

The so-called *Frontend* (the actual detector) of the instrument consists of a stack of 11 separate thin (300µm) silicon detector layers with variable absorber layers of aluminium and tantalum between the individual detector layers (see Fig 1b for schematic and [RD.07] for technical details). The effective FOV is ~40deg around the -Y axis, pointing out of the radiator panel, close to the baffle of the PHEBUS instrument (Fig.2) of the Mercury Planetary Orbiter (MPO/BepiColombo).

The instrument is designed to discriminate between electrons, protons and heavy ions (mostly alpha particles) and record them in three different particle type channels. It can detect electrons in the range of 0.3-10 MeV, separated into 5 spectral bins; protons between 1-205 MeV, separated into 8 spectral bins and heavy ions in the range of 1-50 MeV/mg/cm2, separated into 5 spectral bins. Table 1 displays BERM expected energy bins per particle type. These values were revisited in the analysis of the industrial data performed in the context of the BARD contract, that can be found in [RD.06] and [RD.09]. The revaluated proton and electron energy bins, including the cross contaminations of electrons to proton channels and of protons to electrons channels are shown in Table 2. The Heavy ion energy bins are still to be verified in the context of the on going work.

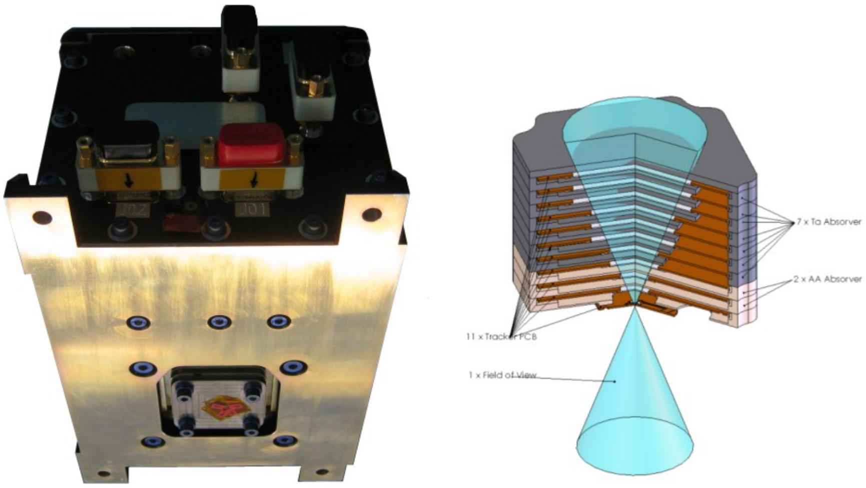

Figure 1 (a) BERM flight unit and (b) Frontend/Detector stack schematic overview

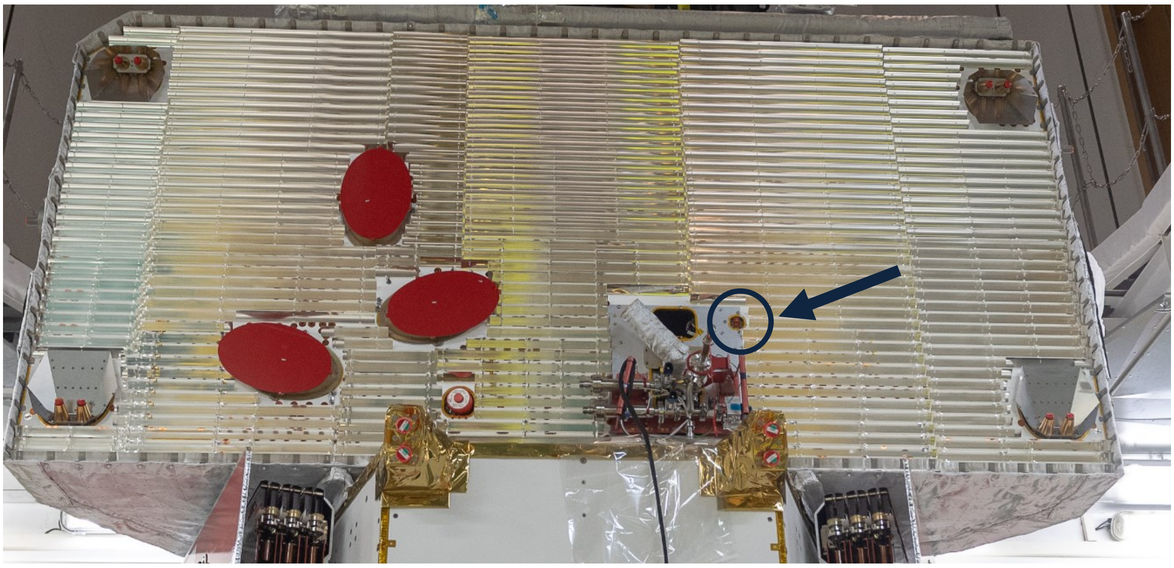

Figure 2 Location of the BERM aperture on the spacecraft radiator panel

Table 1 BERM Energy bins per particle type, prior to the review of BERM calibration.

Channel/Bin	1	2	3	4	5	6	7	8
Electrons [Mev]	0.3-0.62	0.62- 1.26	1.26- 2.54	2.54- 5.1	5.1- 10.22			
Protons [Mev]	1- 1.8	1.8- 3.4	3.4- 6.6	6.6- 13.0	13.0- 25.8	25.8- 51.4	51.4-102.6	102.6-205
Heavy Ions [Mev/mg/cm^2]	1- 2.2	2.2- 4.8	4.8- 10.5	10.5- 22.9	22.9- 50			

Table 2 BERM energy bins per particle type both for the Electron and Proton signal bins obtained after the analysis of the calibration data (described in [RD.06]), including the expected cross-contamination of electrons to proton channels and protons to electron channels.

Bin	Electron energy (MeV)	Proton energy (MeV)
Electron Bin 1	0.17	100–∞
Electron Bin 2	0.3	1.35–1.55; 100–∞
Electron Bin 3	0.5–∞	100–∞
Electron Bin 4	1.1–∞	100–∞
Electron Bin 5	2.6–∞	100–∞
Proton Bin 1	0.44–∞	1.5–5.9; 103–∞
Proton Bin 2	0.33–∞	9.1–13; 103–∞
Proton Bin 3	NA	5.9–9.1
Proton Bin 4	1.1–∞	13–20.7
Proton Bin 5	1.3–∞	20.7–31.4; 95.6–109.2
Proton Bin 6	6.5–∞	31.4–59.1; 100–117
Proton Bin 7	NA	59.1–130
Proton Bin 8	NA	80.1–160

In order to maintain a low data volume, the unit flight unit cannot report individual particle detection signatures, but has been limited to identifying the three measured particle types and their approximate energy ranges on-board and group them into the pre-defined bins, generating a science frame which integrates the measured particle statistics over a fixed interval of 30 seconds. A more in-depth technical description of BERM can be found in [RD.09].

2.3 Operational Modes

The operational modes of BERM are defined as follows (Modes are identified in the BERM data with a corresponding mode number):

- IDLE (Mode number = 0)
- SCIENCE (Mode number = 2)

- TEST_BACKEND (Mode number = 3)
- TEST_FRONTEND (Mode number = 4)

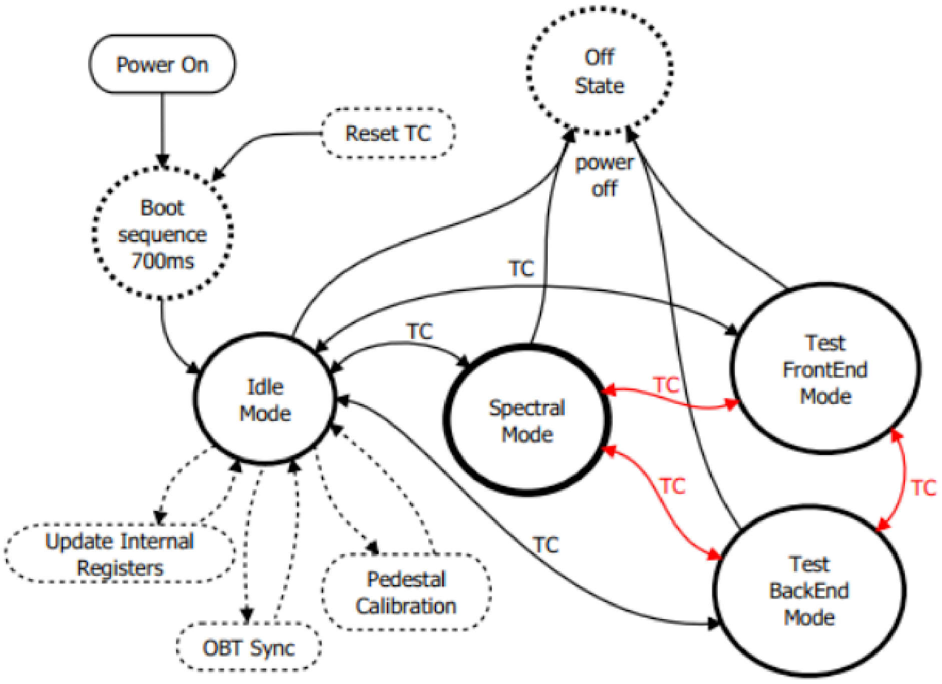

Figure 3 BERM Mode Transition Diagram

In its role as spacecraft infrastructure, BERM Is supposed to continuously operate in the "SCIENCE" mode (also referred to as “Spectral” mode in some documents), in which every 30s the total number of counts in each pre-defined particle/energy range bin is reported as a histogram. In case of maintenance activities, the instrument can be cycled through an "IDLE" mode (equivalent to an instrument standby mode) to either "Test Frontend" or "Test Backend" modes, which allow for the insertion of pre-defined test signals into different parts of the signal processing chain, allowing diagnosis of the health status of the unit. The “Test FrontEnd” (TFE) mode is designed to check the detector stack of BERM by applying pre-defined bursts of voltages at specific frequencies and of variable energy levels. Data from the TFE mode are reported in dedicated frames with different content than the normal science data and are thus archived separately from these. The “Test BackEnd” (TBE) mode feeds a set of artificial detector readings into the signal processing chain, in order to check for the proper functioning of the particle recognition and energy reconstruction algorithm as described in the BERM user manual [RD.07]. Data from the TBE mode is currently not archived in a dedicated product, as the mode was not foreseen to be used during flight. Therefore the mode number should be consulted to identify the data collected in the TBE mode.

2.4 Calibration

The on-ground calibration for BERM have been reported in the Radiation Calibration Report [RD.06], reviewed in [RD.06]]. The in-flight calibration activities consist of:

1) Long-baseline observation of the radiation environment and monitoring of drifts in the instrument response;

2) Periodic fine tuning of the bias voltage for each readout channel to minimise instrument noise and compensate for ageing effects;

3) Cross-calibration with SIXS-P;
4) Use of the front- and backend test modes during regular instrument check-outs.

3. BERM Data Processing Workflow

The BERM science products are produced under the responsibility of the BARD project team in cooperation with the BepiColombo MPO Science Ground Segment (SGS). The data generation, analysis and archiving processes are described in this section.

Science data resulting from the BERM instrument are made available to the scientific community through ESA´s Planetary Science Archive (PSA) following the policies described in the BepiColombo Archiving Plan [AD.01].

3.1 Overview of the Science Data Flow

This section provides an overview of the data flow for the BERM data, from on-board acquisition by the BERM instrument through to ingestion into the ESA's Planetary Science Archive (PSA). All science archive products resulting from BepiColombo comply with version 4 of the Planetary Data System (PDS) standards, a.k.a. PDS4, as specified in the BepiColombo Archiving Guide [AD.02]. An overview of the BERM archive products can be found in section 3.2.
A detailed description of the data generation, calibration and analysis process for the BERM data can be found in section 3.3.

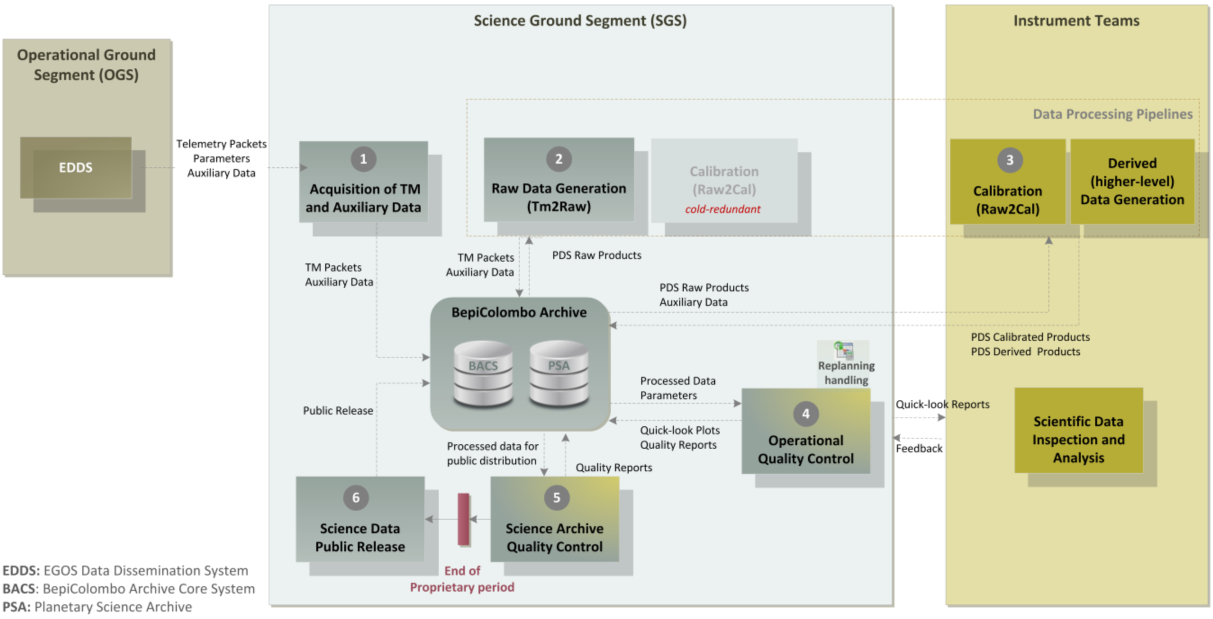

Figure 4 - Science Data Flow.

1) **Acquisition of Telemetry and Auxiliary Data.** Real-time telemetry received on-ground from the MPO spacecraft is relayed from the ground stations to the Operational Ground Segment (OGS) at ESOC during ground station contacts. The MPO spacecraft has two radio-frequency (RF) bands for downlink (X-band and Ka-band). The X-band channel is used to return near real-time non-science telemetry, mostly for spacecraft health, as well as high-priority science data; telemetry is transmitted packet-by-packet. The Ka-band channel is used to return nominal science data; telemetry is transmitted as a file, using the Generic File Transfer Service (GFTS).

   During each ground station contact, the OGS processes all telemetry frames acquired via X-band into packets, containing instrument and spacecraft data as originally generated on-board, and stores all science telemetry files received via Ka-band as files. Telemetry packets and files are made available in the EGOS Data Dissemination System (EDDS) along with status and auxiliary information generated on-ground by the OGS.

   Immediately after the data becomes available in the EDDS, telemetry packets, Ka-band telemetry files, housekeeping parameters and any additional information relevant for data processing and analysis (e.g. spacecraft trajectory, attitude and time correlation packets) are retrieved by the Science Ground Segment (SGS) via the EDDS and stored in the BepiColombo Operational Archive (a.k.a. BOA), for further processing and long-term preservation. Ka-band telemetry files are decomposed into packets as part of this process.

2) **Raw Data Generation.** Telemetry packets resulting from all instruments are systematically converted into PDS4 raw data products (un-calibrated) by the SGS.

3) **Partially Processed Data**. Additionally, PDS4 raw products may be converted to partially processed products (e.g. converted to physical/engineering units) by either the PI teams or by the SGS. For the BERM instrument, the TM2RAW pipeline is run by SGS and performs the data conversion up to engineering units (equivalent of TM2RAW + RAW2ENG usual pipeline split).

4) **Calibrated Data Generation**. PDS calibrated products are generated based on the best current calibration factors and analysis routines, and using as input the PDS raw products generated in the previous step. This is done by either the SGS or by the PI team, with a prime-redundant configuration, i.e. the prime calibration runs at the PI team site while the SGS hosts a backup of the calibration software (for redundancy). When generated by the PI team, calibrated products are routinely delivered to the SGS for ingestion into the archive.

5) **Higher-level Data Generation**. Derived data products are generated by the PI teams, and delivered to the SGS only when the scientific processing is complete.

6) Data transfer to the Archive. All PDS products generated by the SGS or delivered by the PI teams to the SGS are validated for PDS4 compliance (using the NASA's PDS4 validate tool). Once validated, the products are packaged into a delivery package and transferred to the ESA's Planetary Science Archive (PSA) for ingestion.

   As part of the PSA ingestion process, science products are automatically organised into the so-called PDS4 bundles. For BepiColombo, there is one mission bundle and eleven instrument bundles, one per MPO instrument. Bundles grow incrementally as new (or updated) products are delivered to the PSA.

   The mission bundle contains products generated and maintained by the SGS with information of the BepiColombo mission. This includes all mission level supplementary products required in the instrument bundles to comply with PDS4 (e.g. XML schemas).

   Instrument bundles contain science data along with supplementary information specific to an instrument. All bundles are sub-divided into collections. There is one collection for each data processing level plus supplementary collections for calibration, browse, schema, context, documentation etc.

7) **Operational Quality Control.** Science quick-look products are generated from the PDS4 raw, partially processed and calibrated products, and are made available through a dedicated web-based interface. Using this interface, SGS and PI teams monitor the deviations between the planned and the executed observations, check the instrument and spacecraft health, provide a first assessment of the generated science data products. The interface is also aimed at defining reduced data sets to be downlinked via the Selective Downlink if applicable. PI teams feedback

the result of this analysis to the SGS. In addition, SGS performs regular completeness and integrity checks on the data.

8) **Science Data Quality Control.** Archive products are validated through routine use. PI teams routinely assess archive products as part of the operational quality control. In addition, PI teams use archive products for their analysis throughout the mission lifetime. This enables rapid detection and correction of issues in the archive data. In addition, and prior to the release of the data to the public, formal science reviews are organised by the SGS, in coordination with the Project Scientist.
9) **Science Data Public Release**. All science data resulting from BepiColombo is subject to a maximum proprietary period of six months after which the data is made publicly available through the PSA. In routine operations it is expected that PDS4 data processed at least up to calibrated level will be available to the public after the six-month period. Explicit permission may be given by a PI to reduce this period.

3.2 Overview of the BERM Archive Products

The BERM archive products consist of housekeeping data and science data. BERM science data contains spectra and flux data as well as the instrument response (ARF), redistribution matrix (RMF) and background (BKG) data necessary for spectral fitting.

3.3 Data Generation, Calibration and Analysis

This section will describe in detail the generation, calibration and analysis of the BERM data, with focus on the calibration, and including:

- A detailed description of the calibration inputs (and how these were/are derived)
- Recommended software to calibrate and analyse the data

During the pipeline design and development phase, this information is documented in the BERM Pipeline Description Document [RD.010]. Once the pipeline and calibration algorithms are consolidated, relevant information will be copied into this section.

3.4 Science Data Quality Control

This section describes the different processes by which the archive data products are validated.

3.4.1 Data Generation, Calibration and Analysis

Validation Prior to the delivery of the data to the archive, every data product is validated to check that it conforms to a basic set of requirements, as defined in the BepiColombo Archiving Guide [AD.02]. This is done using the NASA's PDS4 validate tool, and a set of XML Schema and Schematron files. In addition, the SGS performs completeness and integrity checks on the BERM science data to ensure that they comply with the specifications described in this EAICD. Visual inspection is used as necessary to check the content.

3.4.2 Instrument Team Validation

Instrument Team Validation In parallel to SGS archive validation activities, PI teams routinely assess archive products as part of the operational quality control. In addition, PI teams use archive products for their analysis throughout the mission lifetime. This enables rapid detection and correction of issues in the archive data. This section will include details of the validation performed by the PI team on the science data, as part of the routine operational quality control.

3.4.3 Science Reviews

Formal science reviews of the data will be organised by the SGS, in coordination with the Project Scientist. These are the so-called Peer Reviews. The Peer Review committee will include independent planetary scientists knowledgeable in each discipline to assess the quality of the data against well-defined scientific criteria. A preliminary schedule of the reviews can be found in the BepiColombo Archiving Plan [AD.01]. Additional review will be organised as necessary. Data periods to the be tagged as not to be released to the public due to any irregular condition during their acquisition that compromise their scientific value are specified in Annex A.

4. Data Organisation and Contents

This section describes the basic organisation of a BERM bundle, and the naming conventions used for the products, collections and bundle, and basic product filenames.

4.1 Format and Conventions

BERM data are compatible with version 4 of the NASAs Planetary Data System (PDS) standards, so-called PDS4 [RD.04], and follow the organisation, format, content and documentation requirements described in the BepiColombo Archiving Guide [AD.02].

All data from the BERM experiment for the entire mission are stored in a top-level structure (root directory) called **bundle**. This bundle is stored in the PSA as a single entity.

Science, calibration products and housekeeping data can be in the same collection, for example data_raw; their lids will tell the difference. For the instrument science data, for each processing level, this is standardised by PDS4 to four levels: raw, partially processed, calibrated and derived.

BERM currently produces raw science data only. It is foreseen to add partially processed data (fluxes per area) in the near future and arrive at a fully calibrated product (flux per energy per area) eventually.

The structure of the bundle is outlined in figure:

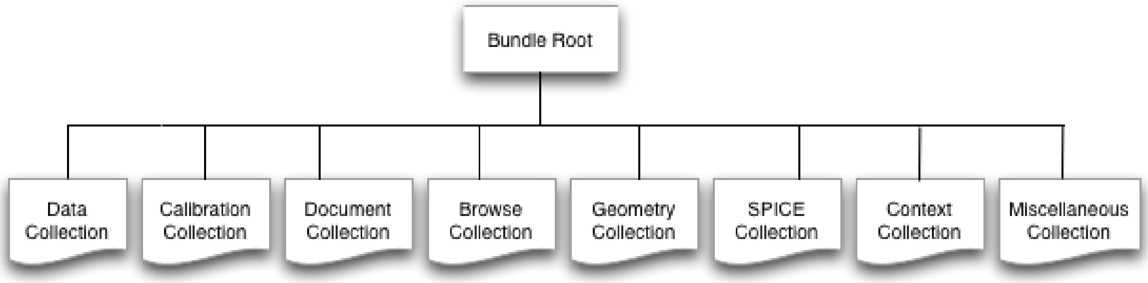

Figure 5 BepiColombo data bundle structure.

Details of the structure and content of the BERM bundle are provided in the following sections.

4.2 Bundle Content and Structure

The complete set of BERM data is archived in one single instrument bundle (root directory). A top-level description of the bundle is provided below. A more detailed description of its contents and format is provided in the following sub-sections.

Table 3 – BERM instrument bundle

Bundle Title	Bundle Logical Identifier (LID)	Description
BERM bundle	urn:esa:psa:bc_mpo_berm	This bundle contains the data collected by the BERM experiment on-board the BepiColombo Mercury Planetary Orbiter (MPO) spacecraft, along with the documents and other information necessary for the interpretation of the data.

The following files are contained in the root directory of the bundle:

- bundle_bc_mpo_berm.xml (this is an inventory file for the bundle)
- readme_bc_mpo_berm.txt (this is a README file for the bundle; it contains a table of contents)

Inside the bundle, the data are organised in a directory structure as follows:

Table 4 BERM collections

Collection Name	Collection Logical Identifier (LID)	Description
data_raw	urn:esa:psa:bc_mpo_berm:data_raw	BERM channel contents and housekeeping products; units are digital numbers (DNs), counts or milliseconds, no conversion applied. Product is the XML label with the data product that is in CDF format. See section 4.5.1
data_partially_processed	urn:esa:psa:bc_mpo_berm:data_partially_processed	This shall contain the BERM fluxes per unit area.

		Product is the XML label with the data product that is in CDF format. See section 4.5.2 To be implemented
data_calibrated	urn:esa:psa:bc_mpo_berm:data_calibrated	BERM spectra (particle fluxes per channel, per unit energy, per unit area) and housekeeping products, in engineering/physical units. Product is the XML label with the data product that is in CDF format. To be implemented.
calibration_raw	urn:esa:psa:bc_mpo_berm:calibration_raw	This shall contain all data acquired through Frontend Tests, Backend tests and Triggering tests (Backend and Trigger data to be separated manually)
browse_partially_processed	urn:esa:psa:bc_mpo_berm:browse_partially_processed collection	To be implemented later. The partially processed fluxes shall be used for this.
document	urn:esa:psa:bc_mpo_berm:document	Documents related to the bundle; necessary for the use and interpretation of the data. See section 4.6.6.
spice_kernels (S)	urn:esa:psa:bc:spice	SPICE kernels.
xml_schema (S)	urn:esa:psa:bc:xml_schema	XML Schemas used in the bundle.

4.3 Collection Naming Convention

4.4 File Naming Convention

All files generated for BERM shall follow the general conventions described in section 3.3 of the BepiColombo Archiving Guide [AD.02].

4.5 BERM Science Data Organisation

4.5.1 Raw Data directory (data_raw)

The structure of the 'raw data' collection is as follows:

data_raw/

- collection_data_raw.xml
- collection_data_raw.csv
- <mission_phase>/
  - sc/
  - hk/

Where <mission_phase> (which can be found by consulting the mission_phases.[xml/tab] product in the BepiColombo mission bundle) is:

- near-earth: Near Earth Commissioning Phase (NECP)
- cruise: Interplanetary Cruise phase (ICP)

  - vgaN: Venus Gravity Assist, with N=1-2
  - mgaN: Mercury Gravity Assist, with N=1-6
  - egaN: Earth Gravity Assist
- commissioning: Mercury Orbit Commissioning Phase (MOCP)
- science: Mercury Science Nominal and Extended Phase (MSP)

The sc and hk directories are further sub-divided in months or range of orbits as follows:
<YYYYMM>/ (during NECP, Cruise and Mercury commissioning phases)
<ORBIT_NNNNN_MMMMM>/ (used during the Mercury Science Phase)

Where YYYYMM is year and month, NNNNN start orbit and MMMMM end orbit.

The lowest level sub-directories contain the following types of data products:

Table 5 - BERM 'science raw' data and housekeeping product types.

Directory Name	File Naming Convention	Description
sc	ber_raw_sc_histogram_<YYYYMMDD>.xml/.cdf ber_raw_sc_histogram_<NNNNN>.xml/.cdf	Particle event counts per 30s interval integration interval of measurements, sorted by particle types and energy bins
hk	ber_raw_hk_<YYYYMMDD>.xml/.cdf ber_raw_hk_<NNNNN>.xml/.cdf	Accompanying information about voltages, temperatures and other relevant data for the health status of the instrument, as recorded by the instrument in in raw digitally encoded numbers (DN) without unit

where:
<YYYYMMDD>: date and UTC time of the measurements in the product (used during NEC and ICP);
<NNNNN>: orbit number of the first measurement in the product (used at Mercury)

4.5.2 Partially processed Data directory (data_partially_processed) [PARALLEL to RAW above]

The structure of the 'Partially processed data' collection is as follows:
data_partially_processed/

- collection_data_partially_processed_raw.xml
- collection_data_partially_processed_raw.csv
- <mission_phase>/
  - sc

where **<mission_phase>** is defined as in section 4.5.1, and the sc and hk directories are further sub-divided in months or range of orbits as follows:

- • <YYYYMM>/ (during NECP, Cruise and Mercury commissioning phases)
- • <ORBIT_NNNNN_MMMMM>/ (used during the Mercury Science Phase)

Where YYYYMM is year and month, NNNNN start orbit and MMMMM end orbit.

The lowest level sub-directories contain the following types of data products:

Table 6- BERM 'partially processed science' data product types.

Directory Name	File Naming Convention	Description
	ber_par_sc_histogram_<YYYYMMDD>.cdf/.xml ber_par_sc_histogram_<NNNNN>.cdf/.xml	Particle event counts per unit area per 30s interval integration interval of measurements, sorted by particle types and energy bins.

where:

<YYYYMMDD>: date and UTC time of the measurements in the product (used during NEC and ICP);
<NNNNN>: orbit number of the first measurement in the product (used at Mercury)

4.5.3 Calibrated Data directory (data_calibrated)

The structure of the 'calibrated data' collection is as follows:

data_calibrated/

- collection_data_calibrated.xml
- collection_data_calibrated.csv
- <mission_phase>/
  - sc/
  - hk/

where **<mission_phase>** is defined as in section 4.5.1, and the sc and hk directories are further sub-divided in months or range of orbits as follows:

<YYYYMM>/ (during NECP, Cruise and Mercury commissioning phases)<ORBIT_NNNNN_MMMMM>/ (used during the Mercury Science Phase)

Where YYYYMM is year and month, NNNNN start orbit and MMMMM end orbit.

The lowest level sub-directories contain the following types of data products:

Table 7 - BERM 'calibrated data' product types.

Directory Name	File Naming Convention	Description
sc	ber_cal_sc_histogram_<YYYYMMDD>.cdf/.xml ber_cal_sc_histogram_<NNNNN>.cdf/.xml	[Not currently produced] ´ TBD: This shall contain the calibrated fluxes based on the values from the raw_sc_histogram product
hk	ber_cal_hk_<YYYYMMDD>.cdf/.xml ber_cal_hk_<NNNNN>.cdf/.xml	Health information as per raw_hk product, but converted into physical units by applying calibration curves.

where:

<YYYYMMDD>: date and UTC time of the measurements in the product (used during commissioning and cruise phase);

<NNNNN>: orbit number of the first measurement in the product (used at Mercury)

4.5.4 Calibration directory (calibration)

At the moment the calibration data are maintained along with the raw dataset. This shall be changed to a dedicated calibration directory, once physical calibration activities are being performed.

The structure of the calibration data' collection is as follows:

calibration/

- collection_calibration.xml
- collection_ calibration.csv
- <mission_phase>/

where **<mission_phase>** is defined as in section 4.5.1, and the sc and hk directories are further sub-divided in months or range of orbits as follows:

- • <YYYYMM>/ (during NECP, Cruise and Mercury commissioning phases)
- • <ORBIT_NNNNN_MMMMM>/ (used during the Mercury Science Phase)

Where YYYYMM is year and month, NNNNN start orbit and MMMMM end orbit.

The lowest level sub-directories contain the following types of data products:

Table 8 - BERM 'science raw' data product types.

Directory Name	File Naming Convention	Description
test_fe	ber_raw_calib_test_fe_<YYYYMMDD>.xml/.cdf ber_raw_calib_test_fe_< NNNNN>.xml/.cdf	Front-end calibration histogram
		Back end- Three products: FEE, Backend, Trigger

where:

<YYYYMMDD>: date and UTC time of the measurements in the product (used during NEC and ICP);

4.5.5 Browse Partially processed directory (browse_partially_processed)

The structure of the ‘browse’ collection is as follows:

browse_partially_processed/

- collection_browse_partially_processed .xml
- collection_browse_partially_processed .csv
- <mission_phase>/
    - sc

where **<mission_phase>** is defined as in section 4.5.1, and the sc directory is further sub-divided in months or range of orbits as follows:

<YYYYMM>/ (during NEC, Cruise and Mercury commissioning phases)

<ORBIT_NNNNN_MMMMM>/ (used during the Mercury Science Phase)

Where YYYYMM is year and month, NNNNN start orbit and MMMMM end orbit.

The lowest level sub-directories contain the following types of data products:

Table 9 - BERM Quick-Look Analysis (QLA) plots of the data products.

Directory Name	File Naming Convention	Description
sc	ber_par_sc_browse_<YYYYMMDD>.xml/.png ber_par_processed_browse_<NNNNN>.xml/.png	Proton, electron and ion spectra count rates

where:

<YYYYMMDDThhmmss>: date and UTC time of the measurements in the product (used during NEC and cruise);

<NNNNN>: orbit number of the first measurement in the product (used at Mercury).

4.5.6 Document directory (document)

The structure of the 'document' collection is as follows:

document/

- collection_document.xml
- collection_document.csv
- < Documents; see table below >

Table 10 BERM Documents

Document	File Naming Convention
BC-SGS-ICD 024_BERM_EAICD.pdf	This document
BC-EFA-TR-00028m BERM PFM.pdf	PFM Spare Radiation Calibration Test Report II
BARD-LIP-TR 0001 02.pdf	Analysis of industrial data
Pinto_2022.pdf	Pinto M., et al. 2022, The BepiColombo Environment Radiation Monitor, BERM, Space Science Reviews (2022) 218:54, https://doi.org/10.1007/s11214-022-00922-2

5. Data Products

BERM data products are formatted in accordance with the PDS4 specifications (see [AD.03], [AD.04] and [AD.05]) following the rules in the BepiColombo Archiving Guide [AD.02]. This section provides details on the formats used for each of the products included in the BERM science data. The PDS4 products are made of an xml label plus a data file, which in the case of BERM is in CDF format. The label contains essential metadata needed to contextualise the specific product.

5.1 Raw Data

5.1.1 Housekeeping Raw Data

[ber_raw_hk_<YYYYMMDD>.cdf / ber_raw_hk_<NNNNN>.cdf]

The raw housekeeping data is a CDF file. The raw HK values are recorded onboard as numeric readouts of digital encoders in unitless numbers, referred to as DN (Digital Number) values **in intervals of 2 minutes**. All voltages used by individual components of the circuit board and electronics, as well as the temperatures for the RADFET and the ASIC are being recorded along with several error flags and counters that allow the instrument health status to be checked. See Table 5 for more details of the housekeeping parameters and their respective limit values.

5.1.2 Science Histogram Raw Data

[ber_raw_ sc_histogram <YYYYMMDD>.cdf / ber_raw_ sc_histogram <NNNNN>.cdf]

The “raw” science histograms are cdf files consisting of already partially reduced data. These contain the overall particle counter value that reports all detected particle events which are compatible with any type of particle having entered the detector stack through the entrance aperture over the interval of 30s and the corresponding particle counts for each particle type and energy bin, for 5 electron bins, 8 proton bins and 5 Heavy Ion bins, as described in Table 11. Additionally, the science data frames also contain a timestamp for the on-board creation time and the instrument mode number (not listed in Table 11). It should be noted that the overall particle counter value may be higher than the sum of all recorded values in the individual bins, as those only count the number of particle events for which a valid identification of particle type and energy range could be determined.

5.1.3 Test Front-End (TFE) Histogram Data

[ber_raw_calib_test_fe_< YYYYMMDD>.cdf / ber_raw_calib_test_fe_< NNNNN>.cdf]

The data from the frontend test mode are largely equivalent in structure to the raw science data, containing a timestamp of the creation time, a mode number, the selected channel and 32 counter values which represent counts of individual bit-mask configurations.

In contrast to the science data, the TFE data are produced by inserting test pulses of pre-defined frequencies (STEP_FEQUENCY) and voltages (STEP) into the detector and reading out the response of the electronics with the particle recognition and energy reconstruction process disabled. The 32 FEE (FEE_BIN1.32) data bins each contain the cumulative counts of one 32-bit digital value from the selected energy range (ADC_BITMASK) and detector number (CH_TEST).

Table 11 - Science data counters and their correspondence to particle bin channels.

Item	Size	Limits	Remarks
Particle counter	32bit	0 to 4294967296	Absolute value for 30s period
Electron BIN1	24bit	0 to 16777216	Estimated range [0.30 – 0.62] MeV
Electron BIN2	24bit		Estimated range [0.62 – 1.26] MeV
Electron BIN3	24bit		Estimated range [1.26 – 2.54] MeV
Electron BIN4	24bit		Estimated range [2.54 – 5.10] MeV
Electron BIN5	24bit		Estimated range [5.10 – 10.22] MeV
Proton BIN1	24bit	0 to 16777216	Estimated range [1.0 – 1.8] MeV
Proton BIN2	24bit		Estimated range [1.8 – 3.4] MeV
Proton BIN3	24bit		Estimated range [3.4 – 6.6] MeV
Proton BIN4	24bit		Estimated range [6.6 – 13.0] MeV
Proton BIN5	24bit		Estimated range [13.0 – 25.8] MeV
Proton BIN6	24bit		Estimated range [25.8 – 51.4] MeV
Proton BIN7	24bit		Estimated range [51.4 – 102.6] MeV
Proton BIN8	24bit		Estimated range [102.6 – 205.0] MeV
Heavy Particle BIN1	24bit	0 to 16777216	Estimated range [1.0 – 2.2] MeV/mg/cm^2
Heavy Particle BIN2	24bit		Estimated range [2.2 – 4.8] MeV/mg/cm^2
Heavy Particle BIN3	24bit		Estimated range [4.8 – 10.5] MeV/mg/cm^2
Heavy Particle BIN4	24bit		Estimated range [10.5 – 22.9] MeV/mg/cm^2
Heavy Particle BIN5	24bit		Estimated range [22.9 – 50] MeV/mg/cm^2
OBT	32bit	0 to 4294967296	Returned in each packet; unit = 1ms
Other BINs	24bit	0 to 16777216	Absolute value for 30s period

Table 12: Science data variables description and corresponding data types

Variable	Data Type	Description	Limits
TIME_UTC	ISO-8601 date format	UTC Time of OBSERVATION: YYYYMM-DDT HH:MM:SS.SSSSSSZ	No limit
TIME_OBT	ISO-8601 date format	S/C-CLOCK AT OBSERVATION TIME: P/SSSSSSSSSS.FFFFF, P: PARTITION OF THE S/C-CLOCK, SSSSSSSSSS: RELATIVE SECONDS AFTER T0, FFFFF: FRACTIONAL NON DECIMAL SECONDS RUNNING UNTIL 65535	No limit
ACQ_TIME	int64	Acquisition Time: time in seconds since BERM is on, incremented each 30s.	0 to 2^{64}
BERM_MODE	int16	BERM Mode (idle=0, science=2)	0 to 2^{16}
PARTICLE_C	int32	Absolut value of particles (/30s)	0 to 2^{32}
E_BIN_1	int32	Particle counts in Electron Bin1 (/30s)	
E_BIN_2	int32	Particle counts in Electron Bin2 (/30s)	
E_BIN_3	int32	Particle counts in Electron Bin3 (/30s)	
E_BIN_4	int32	Particle counts in Electron Bin4 (/30s)	
E_BIN_5	int32	Particle counts in Electron Bin5 (/30s)	0 to 2^{32}
P_BIN_1	int32	Particle counts in Proton Bin1 (/30s)	
P_BIN_2	int32	Particle counts in Proton Bin2 (/30s)	
P_BIN_3	int32	Particle counts in Proton Bin3 (/30s)	
P_BIN_4	int32	Particle counts in Proton Bin4 (/30s)	
P_BIN_5	int32	Particle counts in Proton Bin5 (/30s)	
P_BIN_6	int32	Particle counts in Proton Bin6 (/30s)	
P_BIN_7	int32	Particle counts in Proton Bin7 (/30s)	
P_BIN_8	int32	Particle counts in Proton Bin8 (/30s)	0 to 2^{32}
H_BIN_1	int32	Particle counts in Heavy-Ions Bin1 (/30s)	
H_BIN_2	int32	Particle counts in Heavy-Ions Bin2 (/30s)	
H_BIN_3	int32	Particle counts in Heavy-Ions Bin3 (/30s)	
H_BIN_4	int32	Particle counts in Heavy-Ions Bin4 (/30s)	
H_BIN_5	int32	Particle counts in Heavy-Ions Bin5 (/30s)	0 to 2^{32}

O_BIN_1	int32	Particle counts in Other Particles Bin1 (/30s)	0 to 2^{32}

5.2 Calibrated Data Products

5.2.1 Housekeeping Calibrated Data

[ber_cal_hk_< YYYYMMDD> / ber_cal_hk_<NNNNN>]
The calibrated housekeeping data contain the corresponding data fields to the raw product but all DN values are converted into physical units, applying the transfer functions described in **Error! Reference source not found.** (pp 20 and following), resulting in the intervals displayed in Table 13.

Table 13: HK fields limits in raw data and their corresponding values in calibrated data.

Name	Description	Low	High	Unit	Min	Max	Unit
P1V5	Secondary Voltage +1.5V	12324	15562	ADC Ch.	1.425	1.575	V
ADC_Vref	ADC Voltage Reference	10434	14120	ADC Ch.	0.76	0.95	V
RadFet	Radfet Delta TID	0	16383	ADC Ch.	-0.45	1.45	V
P2V5	Secondary Voltage +2.5V	11976	15319	ADC Ch.	2.35	2.65	V
Detectors Bias Spectral and Datalog Modes	Secondary Voltage +56V	12627	16330	ADC Ch.	55.9	63.4	V
Detectors Bias Idle, Test Frontend and Test Backend Modes	Secondary Voltage +56V	3849	4273	ADC Ch.	-0.2	2.0	V
P2V	Secondary Voltage +2V	12065	15210	ADC Ch.	1.90	2.10	V
Temperature Sensor 2	Temperature @ Radfet	818	16383	ADC Ch.	-35	+85	ºC
Temperature Sensor 1	Temperature @ ASIC	908	16383	ADC Ch.	-30	+85	ºC
N5V	Secondary Voltage -5V	1012	2024	ADC Ch.	-5.85	-4.75	V
P3V3	Secondary Voltage +3.3V	12529	15753	ADC Ch.	3.15	3.45	V
P4V	Secondary Voltage +4V	11878	14963	ADC Ch.	3.80	4.20	V
P5V	Secondary Voltage +5V	12350	15856	ADC Ch.	4.70	5.30	V
N4V	Secondary Voltage -4V	1244	2083	ADC Ch.	-4.50	-3.85	V
AGND	Internal Analogue Ground	3018	4958	ADC Ch.	-	-	V
P15V	Secondary Voltage +15V	11465	14612	ADC Ch.	14.1	15.9	V
HK_REF	HK Reference Voltage	10473	12482	ADC Ch.	2.45	2.55	V

Table 14 displays the sift and hard limits for the HK variables, where Hard limits are only defined for the maximum absolute rating of the components and consequently shall have as action a BERM switching off following by a switch on, after 1min time (power cycling). No action is associated to values beyond the soft limits of the variables, unless a hard limit is also reached. Crossing soft soft limits only will raise a “yellow” flag indicating that BERM is working with a parameter out of the recommended performance specification. ADC_Vref, Radfet and HK_Ref are outputs and consequently they don’t have associated hard limits.

Table 14: Calibrated HK fields and their limits. The hard limits are predefined to

Name	Description	Soft Limits		Hard Limits		Unit
		Min	Max	Min	Max	
P1V5	Secondary Voltage +1.5V	1.425	1.575		1.7	V
ADC_Vref	ADC Voltage Reference	0.76	0.95			V
RadFet	Radfet Delta TID	-0.45	1.45			V
P2V5	Secondary Voltage +2.5V	2.35	2.65		3.0	V
Detectors Bias Spectral and Datalog Modes	Secondary Voltage +56V	55.9	63.4		65.0	V
Detectors Bias Idle, Test Frontend and Test Backend Modes	Secondary Voltage +56V	-0.2	2.0		5.0	V
P2V	Secondary Voltage +2V	1.90	2.10		2.5	V
Temperature Sensor 2	Temperature @ Radfet	-35	+85	-40	+125	ºC
Temperature Sensor 1	Temperature @ ASIC	-30	+85	-40	+125	ºC
N5V	Secondary Voltage -5V	-5.85	-4.75	-6.0		V
P3V3	Secondary Voltage +3.3V	3.15	3.45		3.6	V
P4V	Secondary Voltage +4V	3.80	4.20		5.0	V
P5V	Secondary Voltage +5V	4.70	5.30		6.0	V
N4V	Secondary Voltage -4V	-4.50	-3.85	-5.0		V
AGND	Internal Analogue Ground	-	-			V
P15V	Secondary Voltage +15V	14.1	15.9		16.4	V
HK_REF	HK Reference Voltage	2.45	2.55			V

5.2.2 Science Histogram Partially processed data

Not yet generated

ber_par_sc_histogram_<YYYYMMDD> / ber_par_sc_histogram_<NNNNN>

The BERM partially processed consist of particle counts per channel per unit area histograms. These are derived from the raw science BERM data, by dividing the count rate in each channel (obtained from the integration of the number of counts in 30s intervals) by the active area of the corresponding channel, computed using instrument simulation and ground-test data. These partially processed data can be used to verify data consistency between the different BERM channels and as a test for sources of noise or unexpected channel behaviour.

5.2.3 Science Histogram Calibrated Data

Not yet generated by the pipeline.

ber_cal_sc_histogram_<YYYYMMDD> / ber_cal_sc_histogram_<NNNNN>

The BERM spectral (particle fluxes per channel, per unit energy, per unit area) data correspond to histograms resulting from the raw science BERM data, consisting on the number of particle counts per 30s intervals in each BERM channel, via the application of BERM channel calibration factors– channel geometric factors –. These are based on ground test data calibration and instrument simulation, and, if necessary, corrected by in-flight calibration analysis.

5.2.4 BERM Response matrix

The most updated response functions are available in document [RD.13] with the new models of cross talk, new response functions were computed using the Bow-Tie method as it was computed in [RD.08].

5.3 Derived Data Products

High level data generation:

Derived data products are generated by the PI teams, and delivered to the SGS only when the scientific processing is complete.

Not yet generated

TBD: Once calibrated science data is available, further service products for other instruments is planned for periods with sufficient data quality.

ANNEX A KNOWN ISSUES

This includes a list of acquisition times where some acquisition problem has happened that the scientific content of data is not viable and therefore is not available.

Initial Time period	Final time period	Issue description
28.12.2022	18.01.2023	SGS has reported an inconsistent BERM behaviour following the pedestal calibration on 28-Dec-22. EFACEC has checked the available data and stated that BERM had a “wrong” behaviour in the science reconfiguration and due to keeping a test bit enabled.

END OF DOCUMENT