LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

JUICE RADEM Experiment to Archive Interface Control Document (RADEM EAICD)

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1 INTRODUCTION

1.1 Purpose and Scope

This document (RADEM EAICD) is a user manual for the scientific community to understand and work with the archived data acquired by the RADiation–hard Electron Monitor (RADEM) instrument on board of the ESA JUpiter ICy moons Explorer (JUICE) space mission. A detailed description of the instrument and the data pipelines is included with enough information so that scientists can use the data independently. It includes descriptions of the data products and associated metadata, the data format, content, and generation pipeline. The specifications described in this EAICD apply to all RADEM products submitted for archive to ESA's RADEM Science Ground Segment (SGS), for all phases of the JUICE mission. This document includes descriptions of archive products that are produced by both the RADEM support team and by the SGS.

1.2 Applicable Documents

[AD.01] PDS4 Standards Reference (SR)
[AD.02] PDS4 Data Dictionary (DDDB)
[AD.03] PDS4 Information Model Specification (IM)

1.3 Reference Documents

[RD.01] JUICE Acronyms - JUICE - Cosmos (esa.int)
[RD.02] "JUICE assessment study report (Yellow Book)", ESA/SRE(2011)18, Jan. 2012. URL: https://sci.esa.int/web/juice/-/49837-juice-assessment-study-report-yellow-book
[RD.03] W. Hajdas, P. Gonçalves, M. Pinto, et al., "The JUICE Radiation Environment Monitor, RADEM", Space Sci. Rev. vol. 221, a.43, May 2025. DOI: https://doi.org/10.1007/s11214-025-01163-9
[RD.04] D. J. Williams, R. W. McEntire, S. Jaskulek and B. Wilke, "The Galileo energetic particles detector", Space Sci. Rev., vol. 60, no. 1, pp. 385-412, May 1992. DOI: https://doi.org/10.1007/BF00216863
[RD.05] "Development of a Directionality Detector and Radiation Hardness Assurance for RADEM, the ESA JUICE mission Radiation Monitor", PhD by Marco Pinto (2019) in Institute Superior Técnico – University of Lisbon, Portugal. URL: https://scholar.tecnico.ulisboa.pt/records/sNhvANSmqamJBZqnprN5dWTiSwm-FtNlwW_4

[RD.06]	T. A. Stein et al., "Front-end readout ASIC for charged particle counting with the RADEM instrument on the ESA JUICE mission", Proc. SPIE, vol. 9905, Jul. 2016. DOI: https://doi.org/10.1117/12.22319014
[RD.07]	M. Pinto et al., "Development of a Directionality Detector for RADEM, the Radiation Hard Electron Monitor Aboard the JUICE Mission", IEEE Transactions on Nuclear Science, vol. 66, i. 7, pp: 1770 – 1777, Jul. 2019. DOI: https://www.doi.org/10.1109/TNS.2019.2900398
[RD.08]	“Qualification of the RADEM instrument for the ESA JUICE mission”, PhD by Patryk Socha (2021) in ETH Zurich, Switzerland. URL: https://www.research-collection.ethz.ch/bitstream/handle/20.500.11850/489155/1/Patryk_Socha_thesis.pdf
[RD.09]	M. K. Georgoulis et al., “Analysis and interpretation of inner-heliospheric SEP events with the ESA Standard Radiation Environment Monitor (SREM) onboard the INTEGRAL and Rosetta Missions”, J. Space Weather Space Clim., vol. 8, a.40, Sep. 2018. DOI: https://doi.org/10.1051/swsc/2018027

1.4 Abbreviations and Acronyms

ASIC	Application Specific Integrated Circuit
BIST	Built-In Self-Test
CEU	Central Electronics Unit
DAC	Digital-to-Analog Converter
DD	Directionality Detector
DDDB	Data Dictionary Data Base
DDH	Directional Detector Head
DN	Digital Numbers
EDDS	EGOS System Data Dissemination System
EGOS	European Space Agency Ground Operation System
EDH	Electron Detector Head
EPD	Energetic Particle Detector
FOV	Field of View
GCR	Galactic Cosmic Rays
HG	High-Gain
HGHT	High-Gain High Threshold
HGLT	High-Gain Low Threshold
HIDH	Heavy Ion Detector Head
HK	Housekeeping (also: hk)
IM	Information Model
JUICE	JUpiter ICy moons Explorer
LG	Low-Gain
MBIAS	External Reference Bias Current
MOC	Mission Operations Centre

MRAM	Magnetoresistive Random-Access Memory
NASA	National Aeronautics and Space Administration
OGS	Operational Ground Segment
PDH	Proton Detector Head
PDS	Planetary Data System
PSA	Planetary Science Archive
RADEM	RADiation–hard Electron Monitor
SC	Science (also: sc)
SEL	Single-Event Latch-Up
SEP	Solar Energetic Particle
SGS	Science Ground Segment
SOC	Science Operations Centre
SPICE	Spacecraft, Planet, Instrument, C-matrix, Events
SR	Standard Reference
SRAM	Static Random-Access Memory
SREM	Standard Radiation Environment Monitor
TA	Trigger Analyzer
TC	Telecommand
TM	Telemetry
VA	Voltage Analyzer

Check [RD.01] for the full JUICE acronyms list.

2 SCIENTIFIC OBJECTIVES

The ESA JUICE mission is only the fourth mission to orbit the Jovian system after Galileo, Juno, and Europa Clipper (currently in cruise phase). Other missions such as the Pioneers, Voyager and Ulysses performed gravity assist maneuvers of the planet and therefore had small observation windows.

JUICE will encounter a harsh and complex radiation environment composed of galactic cosmic rays (GCRs), solar energetic particles (SEPs), and the Jovian radiation belts that largely surpass the terrestrial Van Allen belts in both energy and flux [RD.02]. For this reason, it carries RADEM on its +X panel (see Figure 1) [RD.03]. RADEM is a relatively low mass (~5 kg with shielding) and low power (3.2 W) radiation monitor that is responsible for measuring the space radiation environment in-situ, during the entire mission including the cruise to Jupiter.

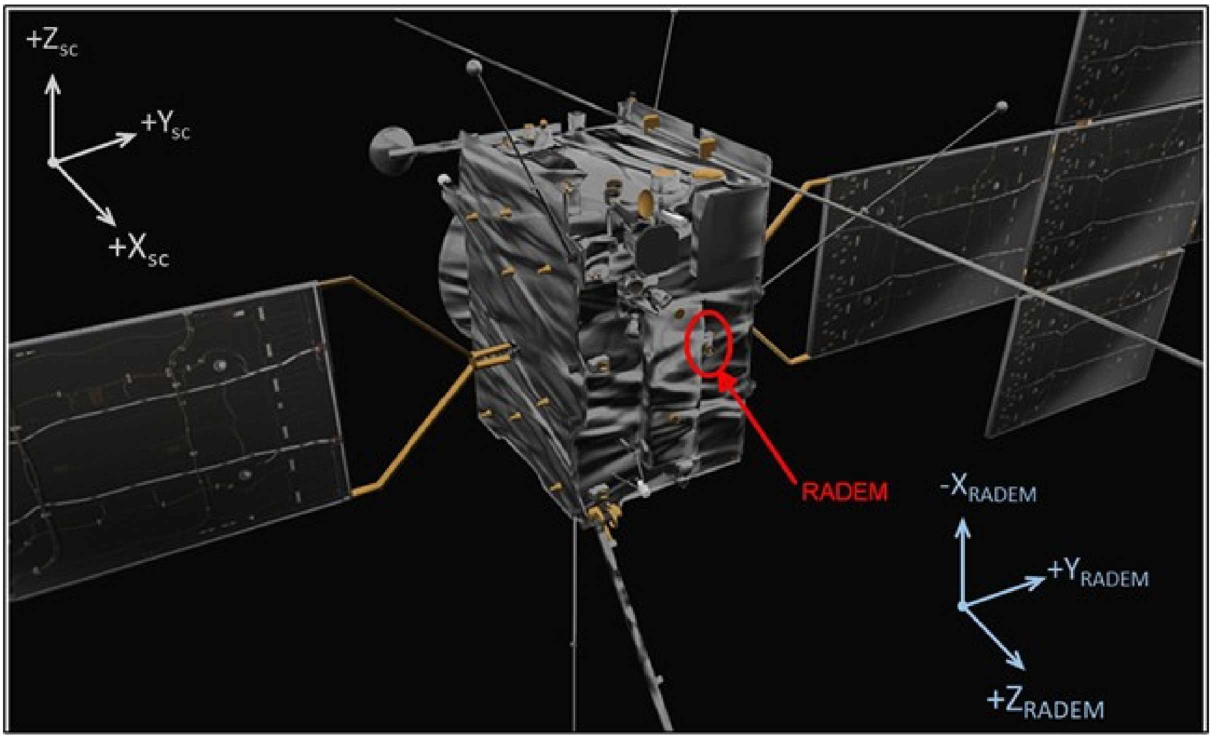

Figure 1 JUICE spacecraft visualization with marked location of RADEM [RD.03]. Also indicated are the spacecraft (SC) and RADEM reference frames used throughout this document. These frames correspond to Spice frames JUICE_SPACECRAFT and JUICE_RADEM. The location of JUICE_RADEM in the JUICE_SPACECRAFT reference frame is: X_{SC}= 1.1853 m, Y_{SC} = 0.4624 m, Z_{SC} = 1.7822 m.

3 THE INSTRUMENT

The main drivers of the mission and its instruments are the Jovian radiation belts [RD.02], and the distance between Jupiter, Earth and the Sun which greatly constrain the spacecraft mass, power and communication. Table 1 summarizes RADEM's requirements and operational conditions. To comply with them, RADEM has four detector heads, the Electron Detector Head (EDH), the Proton Detector Head (PDH), the Heavy Ion Detector Head (HIDH), and the Directional Detector Head (DDH) as shown in Figure 2. The latter is essential to keep RADEM's mass and power consumption low, removing the need to have a rotational platform such as the one used in the Energetic Particle Detector (EPD) aboard Galileo [RD.04].

Table 1 RADEM requirements and operation conditions. Adapted from [RD.03].

Property	**Requirement**
Electron energy range	0.3-40 MeV
Max. detectable electron flux	10^9 particles/cm^2/s
Proton energy range	5-250 MeV
Max. detectable proton flux	10^8 particles/cm^2/s
Detectable ion species	Helium-Oxygen
Ion Linear Energy Transfer range	0.1-10 MeV.cm^2.mg^{-1}
Max. detectable heavy ion flux	≥4.33x 10^5 particles/cm^2/s
Dose outside S/C	1 Mrad
Dose limit on electronics	0.1 Mrad
Total volume	1 dm^3
Total mass	5 kg
Power consumption	3.2 W

3.1 Instrument design

The EDH and the PDH consist of two separate silicon stack detectors with eight sensors each (see Figure 3). The HIDH is composed of only two sensors. Stack detectors rely on both total energy and deposited energy measurements to identify particle species and energy. They measure a particle's energy based on how far in the stack it travelled before stopping and identify the particle type depending on how much energy it deposited (electrons deposit less energy than protons which, in turn, deposit less energy than alpha particles, etc) – usually in the last detector. Their main caveats are relatively low energy resolution, high energy contamination on the first detector (penetrating particles can go through the collimator and deposit energy in it), and approximately infinite upper energy limit in the last detector.

The DDH is a completely new design that is responsible for measuring electron angular distributions from 300 keV to 2 MeV [RD.05].

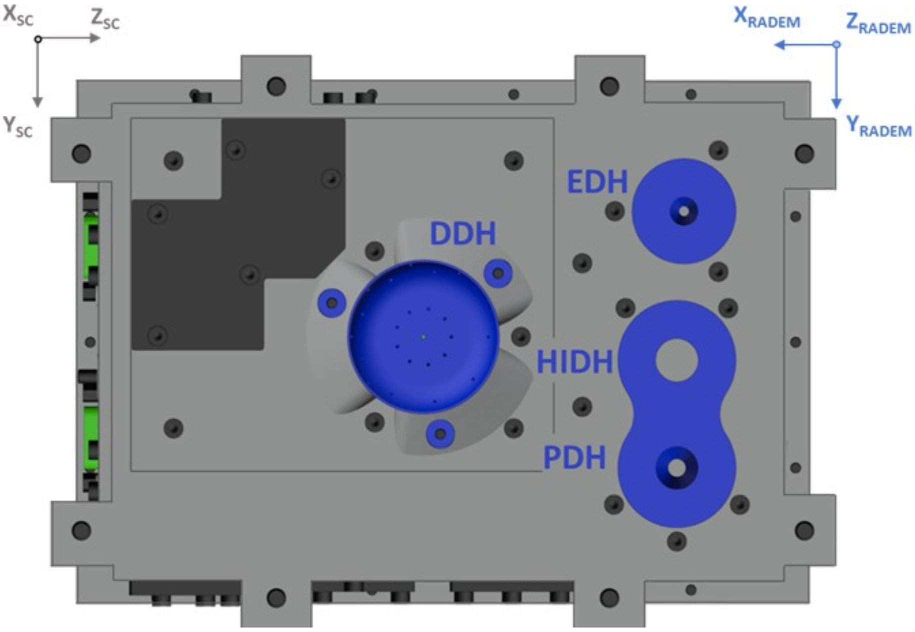

Figure 2 RADEM: The four detector heads: EDH (Electron Detector Head), PDH (Proton Detector Head), HIDH (Heavy Ion Detector Head) and DDH (Directional Director Head).

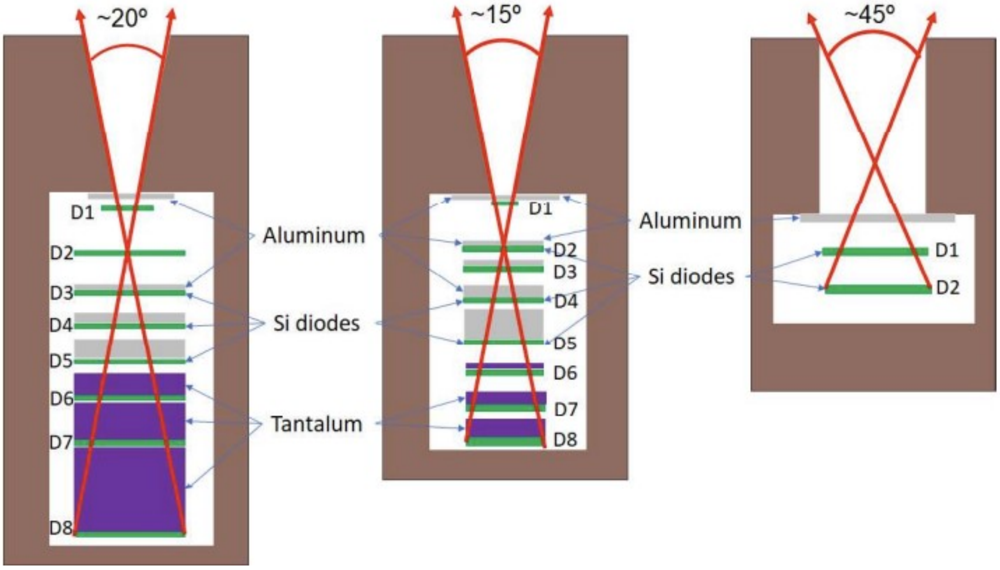

Figure 3 From left to right schematic of the PDH, EDH and HIDH (from [RD.05]). The sizes are not to scale but the PDH is larger than the EDH which in turn is larger than the HIDH (see [RD.03]). Brown represents the copper collimator, gray aluminum absorbers, green silicon sensors, and purple tantalum absorbers.

3.2 Electron Detector Head

EDH is the most crucial subunit of RADEM from the mission safety point of view. It was designed to measure electrons with energies between 0.3 and 40 MeV. The extended energy range, as compared with the sensitivity of monitors placed on satellites orbiting the Earth such as the Standard Radiation Environment Monitor (SREM) which measures electrons from ~300 keV to ~10 MeV [RD.09], is adjusted to the intense and highly energetic electron environment of Jupiter. Particles of this energy range are predicted to be responsible for the majority of the total ionizing dose effects on the JUICE spacecraft during the mission [RD.02][RD.05].

The EDH has eight silicon sensors, identified as D1, D2, ..., D7, D8 (or EDH D1, EDH D2, ..., EDH D8) from top (aperture side) to bottom, interleaved by aluminum and tantalum absorbers as shown in Figure 3. EDH D1 and D2-D8 have diameters of 3 mm and 6 mm, respectively. All dimensions of the telescope elements are described in [RD.03][RD.05]. The detector is surrounded by an 8 mm copper collimator with a 15º field-of-view (FOV). The thickness and material of the absorbers is based on the energy range that it is intended to measure. Each sensor is connected to an individual High-Gain (HG) channel of an VATA466 Application Specific Integrated Circuit (ASIC) – EDH_ASIC [RD.06]. The ASICs are described in more detail in Section 3.6. This way the signals are collected independently from every sensor.

Further pre–processing inside of the ASIC includes detection threshold for signal acceptance and pre–selected coincidence logic between detector inputs. The EDH theoretical electron energy channels are: 0.35-0.5 MeV; 0.5-1.0 MeV; 1.0-2.0 MeV; 2.0-4 MeV; 4.0-7.0 MeV; 7-17.5 MeV; 17.5-35 MeV; and >35 MeV. These values are based on the continuous stopping power approximation which is not an exact solution since it does not consider the stochastic nature of radiation interaction with matter and does not account for electronic effects. For this reason, the real energy channels require calibration to be determined.

3.3 Proton and Heavy Ion Detector Heads

The Proton Detector Head (PDH) and Heavy Ion Detector Head (HIDH) consist of two connected but independent collimators with circular openings sharing the same VATA466 ASIC – PIDH_ASIC (see Section 3.6 for more detail) [RD.06]. The PDH is designed to measure protons of the energy between 5 and 250 MeV. The heavy ion part is optimized for the detection of ions between Helium and Oxygen in the energy range from 8 to 700 MeV.

The PDH has eight silicon sensors, identified as D1, D2, ..., D7, D8 (or PDH D1, PDH D2, ..., PDH D8) from top (aperture side) to bottom, interleaved by aluminum and tantalum absorbers as shown in Figure 3. PDH D1 and D2-D8 have a diameter of 6 mm and 12 mm respectively. All dimensions of the telescope elements are described in [RD.03][RD.05].The detector is surrounded by an 8 mm copper collimator with a 20º aperture. The thickness and material of the absorbers is based on the energy range that is intended to measure. Each sensor diode is connected to an individual HG channel of a VATA466 ASIC (see Section 3.6 for more detail) [RD.05]. This way the signals are collected independently from every sensor.

Further pre–processing inside of the ASIC includes detection threshold for signal acceptance and pre–selected coincidence logic between detector inputs. The PDH theoretical electron energy channels are: 4-7 MeV; 7-12.5 MeV; 12.5-20 MeV; 20-35 MeV; 35-50 MeV; 50-80 MeV; 80-125 MeV and >125 MeV. These values are based on the continuous stopping power approximation which is not an exact solution since it does not consider the stochastic nature of radiation interaction with matter and does not account for electronic effects. For this reason, the real energy channels require calibration to be determined.

The HIDH only has two silicon sensors, with a FOV of 45º as shown in Figure 3. D1 and D2 both have a diameter of 12 mm. All dimensions of the telescope elements are described in [RD.03][RD.05]. The two sensors are connected to the Low-Gain (LG) channels of the VATA466 ASIC (see Section 3.6 for more detail) [RD.06]. Unfortunately, the first sensor is unresponsive since launch.

3.4 Directional Detector Head (DDH)

The DDH is significantly different from the other detectors both in its design and purpose. It was developed specifically for RADEM to compensate for the lack of a rotating mechanism such as the used by the EPD in the Galileo mission [RD.04]. Rotating mechanisms are heavier and require power that RADEM constraints do not allow. Therefore, the development of a different solution, the DDH, was necessary. The DDH consists of a semi-torus with 4 mm inner radius and 8 mm outer radius, united with a central cylinder with 12 mm radius and 8 mm height, copper collimator, with 28 holes, or entrances, each with a radius of 0.5 mm and 8 mm of length [RD.05][RD.07]. The holes point to four zenithal directions, 0º, 22.5º, 45º and 67.5º, and 2x9 azimuthal directions interleaved by 40º for each zenithal direction. Due to spacing constraints, the 67.5º sensors are azimuthally phased by 20º from the 22.5º and 45º directions. By definition, there is only one zenith-pointing sensor. A schematic of the geometrical form is shown in Figure 4.

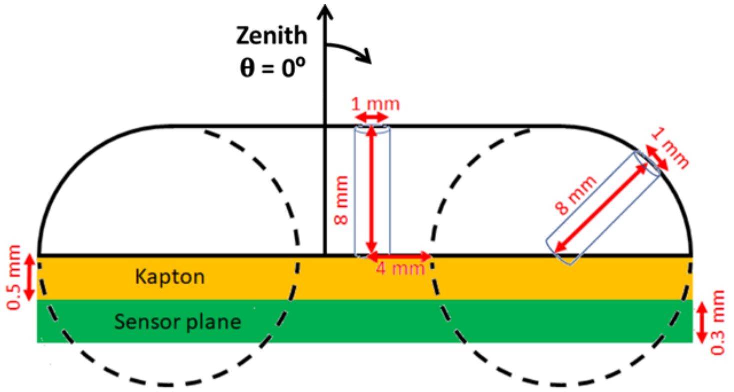

Figure 4 Directional Detector Head concept cut view (from [RD.07]). The 28 collimator apertures, in gray, corresponding to each direction have approximately the same length, 8 mm, and the same diameter, 1 mm. Figure dimensions are not to scale. The Zenith origin corresponds to the one in Table 4.

A thin, 0.5 mm thick kapton absorber separates the semi-torus collimator and a custom-made, 31-pixel, 0.3 mm thick, 30 mm in diameter, n-well silicon diode. 28 of the pixels are disposed below the FOV of one of the collimator holes, with a geometrical area corresponding to its projection on the plane (see Figure 5). Three extra pixels (29, 30, 31 in Figure 5) also exist in the silicon wafer. They do not have an opening to the sky. Their main purpose is measuring the background of the other sensors, which consists of particles able to pass through the collimator. The three extra pixels have different areas (Sensor 29 - 0.80 mm^2, Sensor 30 - 1.20 mm^2, Sensor 31 - 2.18 mm^2). These areas correspond to the areas of the other 28 pixels described in Table 2, to allow for a direct removal of the noise.

Each pixel is isolated and connected to one of the HG channels of a VATA466 ASIC – DDH_ASIC (see Section 3.6 for more detail) [RD.06]. The thickness of the kapton absorber matches the range of electrons of 300 keV in that material. The energy cutoff, however, differs in different directions, since the linear path length of particles coming from steeper angles is larger. The same is true for protons which have an energy cutoff of 7 MeV. Table 2 summarizes the main characteristics of DDH directions.

Table 2 DDH direction characteristics. Adapted from [RD.07].

Zenithal Direction (º)	# of sensors (azimuthal directions)	Sensor Area (mm^2)	Energy Threshold (MeV)	
			Electrons	Protons
0	1	0.79	0.39	7.00
22.5	9	0.80	0.30	7.00
45	9	1.20	0.35	8.50
67.5	9	2.18	0.50	12.5

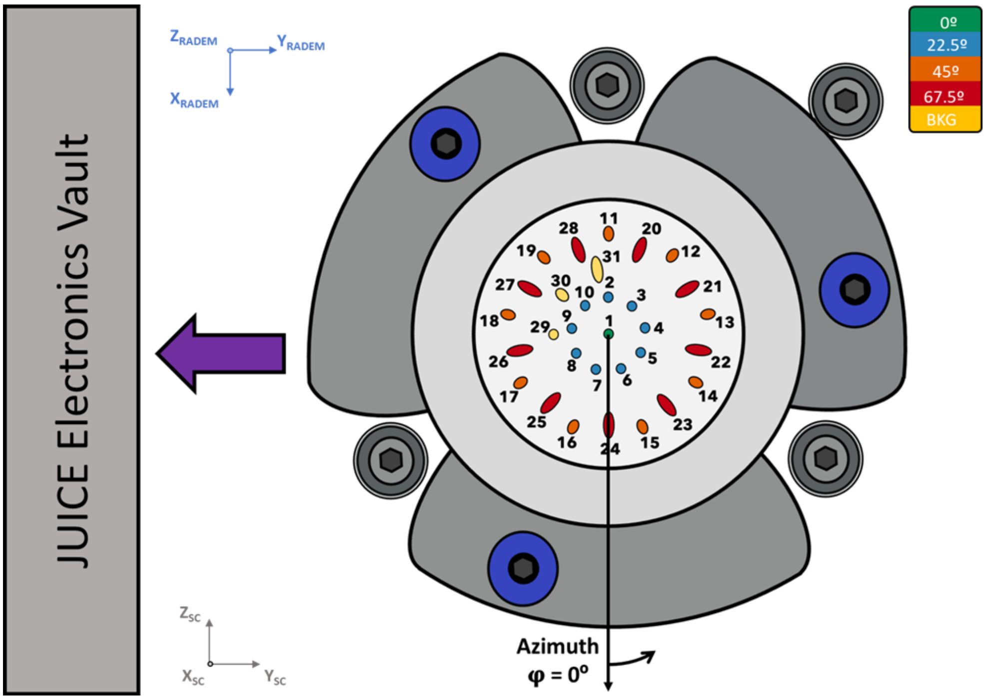

Figure 5 DDH pixelated silicon sensors. Each color (green, yellow, orange and red) corresponds to a different zenithal direction. Numbers correspond to the DD bins in the science raw data (see Section 3.7 details). The Azimuth origin corresponds to the one in Table 4. The JUICE Electronics Vault relative location in the DDH plane is also shown. The vault obscures a number of DDH sensors as described in Section 3.8.

3.5 Active sensors

All detector heads sensors are 300 µm thick, n-doped silicon diode sensors custom-designed by the Paul Scherrer Institute for RADEM and manufactured at SINTEF [RD.08] There are four different diode-diameters in RADEM: 3 mm, 6 mm, 12 mm for EDH, PDH, and HIDH, and 30 mm for DDH, with 28 individual sensors for direction and three for background measurements [RD.05]. Full depletion was found to occur with a bias voltage of −35 V [RD.08]. To minimize radiation damage effects, which will likely increase the diodes' dark-current, and ensure their full depletion until the end of the mission, the bias voltage of all diodes is set to −80 V [RD.08].

3.6 Front-End Electronics

RADEM's front-end electronics incorporate three VATA466 ASICs, developed by IDEAS in Norway [RD.06]. Each detector is connected to a dedicated ASIC unit except for the PDH and HIDH which share a unit. The ASIC features 36 input channels with charge-sensitive pre-amplifiers—four LG and 32 HG (see Figure 6). All sensors on RADEM are connected to

HG channels. The only exception is the two HIDH sensors which are connected to the LG channels since ions deposit more energy than protons and electrons, and therefore, the signal they generate requires less amplification. Although the ASIC supports pulse-height analysis, this feature is not implemented in RADEM due to its slow timing response.

Data readout is managed through level triggers (thresholds) and processed via 36 programable pattern units; each linked to one of the 36 counters. Additional ASIC circuits, including the internal pulser, are detailed in [RD.06]. Each channel is divided into a Voltage Analyzer (VA) and a Trigger Analyzer (TA); RADEM utilizes only the TA section.

The TA consists of:

- One Low Threshold (LT) discriminator for LG channels.
- One Low Threshold (HGLT) and one High Threshold (HGHT) discriminator for HG channels.

Each threshold type has a distinct dynamic range, programmable via a 10-bit Digital-to-Analog Converter (DAC). However, in-flight calibration showed that these values are not representative of the full system (ASIC + detectors). In fact, other properties such as capacitance and intrinsic noise are also critical to the threshold requiring individual calibration of each sensor and associated ASIC channel.

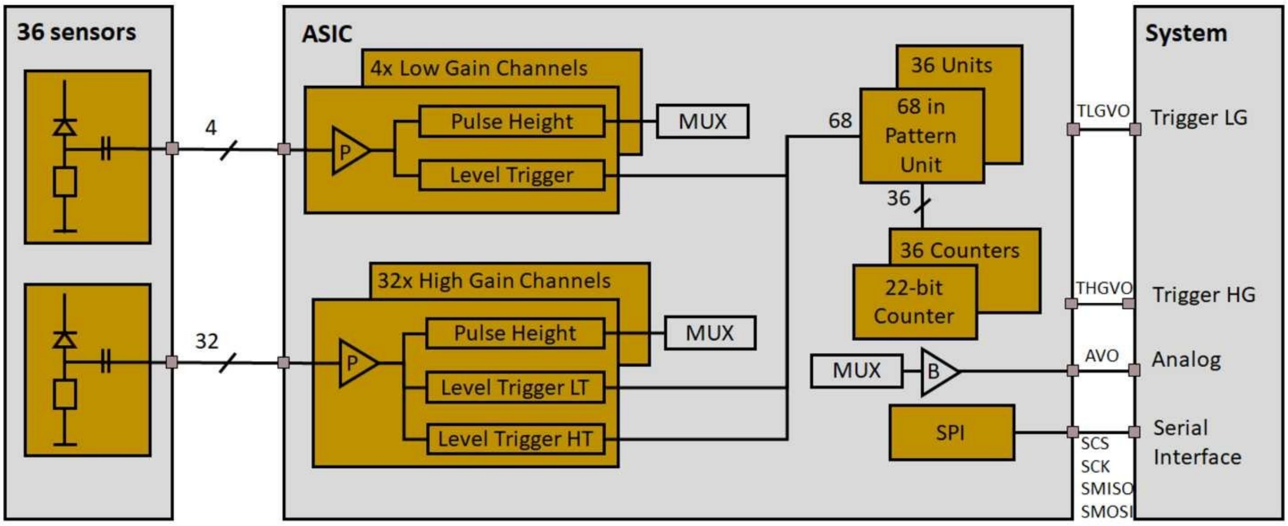

Figure 6 Block diagram of the VATA466 ASIC with radiation sensors (left), the integrated circuit (ASIC, center), and the readout system (right).

3.7 Counters (Detection Channels)

While each detector head's ASIC has 36 pattern units and counters, only a sub-set of them are sent to Earth. This can be seen in the science raw data where eight counters (or detection channels) from the PDH are assigned to the PROTONS variable, two counters (or detection channels) from the HIDH are assigned to the HEAVY_IONS variable, eight counters (or detection channels) from the EDH are assigned to ELECTRONS variable, and 31 counters (or detection channels) from the DDH are assigned to DD variable individually according to Table 4. The counters are read periodically. The time between the read outs is equivalent to the integration time and is defined by the variable INTEGRATION_TIME. The standard value for INTEGRATION_TIME is 60s but can be as low as 10s or much higher.

Data from 12 additional counters (or detection channels), are sent to Earth. However, since they are not necessarily needed to fulfil RADEM's requirements, we decided to store these in a CUSTOM variable. The variable has counters from both EDH (CUSTOM 1-5 and 12) and PDH (CUSTOM 6 and 11). Due to the software configuration CUSTOM 11 and 12 are the sum of five EDH and PDH counters, respectively, and the CUSTOM 7-9 channels are a sum of all channels in the PROTONS, ELECTRONS, and DD variables respectively.

3.8 Instrument Performance

The main objective of RADEM is to measure high energy electrons (>300 keV) and protons (> 5 MeV) separately. However, RADEM's capabilities are highly dependent on its configuration of its detector heads. These objectives were not met with the initial RADEM configuration (Configuration 1) and therefore, a large reconfiguration was done (Configuration 2). Annex A outlines the configuration, calibration, and operational periods. Annex B shows the energy sensitivities of each configuration and Annex C the thresholds of each detector and the coincidence logic of each counter (detection channel).

A list of all critical events and reconfigurations are shown in Table 3. Future reconfigurations are being planned to adapt to the different mission phases.

Table 3 Critical events and reconfigurations.

Date	Event
14-04-2023	HIDH D1 is not responsive. A critical failure seems to have occurred.
30-08-2023	Beginning of operations. Configuration 1 setup.
10-07-2024	Major Reconfiguration. Configuration 2 setup.

Table 4 Viewing directions corresponding to each DD bin in RADEM's referential frame (see Figure 5 for their physical location).

DD_XX	Zenith θ (º) – ref. RADEM	Azimuth φ (º) - ref RADEM
1	0	0
2	22.5	180
3	22.5	140
4	22.5	100
5	22.5	60
6	22.5	20
7	22.5	340
8	22.5	300
9	22.5	260
10	22.5	220
11	45	180
12	45	140
13	45	100
14	45	60
15	45	20
16	45	340
17	45	300
18	45	260
19	45	220
20	67.5	160
21	67.5	120
22	67.5	80
23	67.5	40
24	67.5	0
25	67.5	320
26	67.5	280
27	67.5	240
28	67.5	200
29	22.5	N.A. (background)
30	45	N.A. (background)
31	67.5	N.A. (background)

3.9 Known issues and Caveats

Most caveats in the RADEM data are specific to each configuration. However, there are four general issues/caveats, two related to its location in the spacecraft, on the side of the electronics vault:

1. The following DDH sensors (bins) are partially shadowed by the electronic vault (see Figure 5): ‘DD Bin 8’, ‘DD Bin 9’, ‘DD Bin 16’, ‘DD Bin 17’, ‘DD Bin 18’, ‘DD Bin 19’, ‘DD Bin 25’, ‘DD Bin 26’, ‘DD Bin 27’, ‘DD Bin 28’. This situation is persistent and will last for the entire mission.
2. During cruise phase, RADEM is pointing anti-sunward (away from the Sun). This is mandatory during the JUICE mission hot phase but could be relaxed during the rest of the cruise phase.
3. The HIDH D1 (top sensor) has been unresponsive since launch. It is not expected to recover.
4. There is a software issue since launch related to memory scrubbing that is not correcting single event upsets. This issue has no implications for the science data outside of a possible accumulation of errors leading to an instrument reboot.

3.9.1 Configuration 1

All RADEM channels in configuration 1 are sensitive to both proton and electrons. However, the proton sensitivity is higher meaning that during SEPs it is more likely to measure protons.

3.9.2 Configuration 2

The main caveat is the contamination from high energy protons in the electron channels, and from low energy protons in the first electron channel – see Annex B. PROTONS bin 8 is an integral channel sensitive to similar energies and can be used to monitor this contamination. If its count rate is equal or higher than the electron channels, then there might be contamination.

3.10 Operational modes

RADEM has the following operational modes:

1. Safe/Service Mode
2. Normal/Science Mode
3. Test/Calibration Mode with three types of calibration tests

Figure 7 flowchart explains their relation.

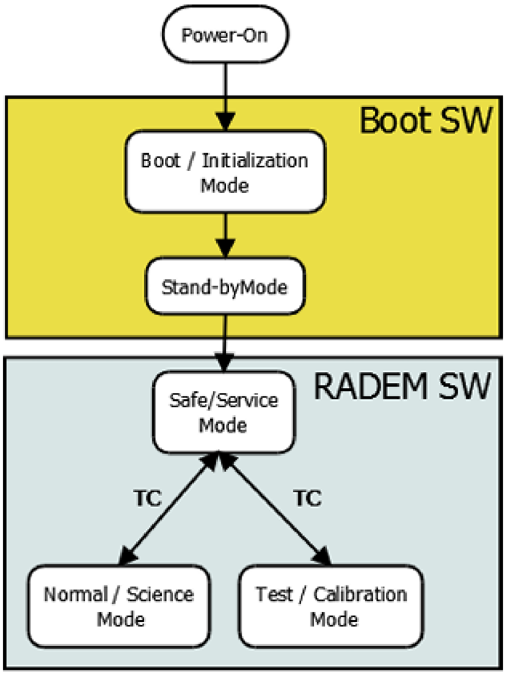

Figure 7 – RADEM software (SW) modes diagram. TC stands for telecommand.

After a successful boot test, the RADEM enters the Safe/Service Mode. In this mode only communications and housekeeping/monitoring functions are enabled. All frontend interfaces are disabled. After receiving the specific telecommand (TC), RADEM changes to normal mode where frontend managers are enabled. Housekeeping and communications are also available. This is the default operating mode of RADEM unit, as it is the mode where all the scientific measurements and/or calibration will be performed and stored.

After receiving specific TCs, RADEM may change from Safe/Service Mode to Test Mode, where the Frontend managers are enabled. In this mode one detector head is enabled and tested, while all the others are disabled. Housekeeping (hk) and communications are also available when the software is running in this mode. There are three calibration tests:

- Gain/Offset – In this test a known energy pulse is generated, and the detected value is read with analogue readout.
- Pedestal – This test verifies which thresholds need to be defined for each channel
- Readout – This test verifies each channel analogue readout value for 50 detected particles and returns the values according to detector head in test.

3.11 Calibration

The RADEM on-ground calibration was performed during the development of the instrument [RD.03]. The in-flight calibration activities consist of:

- Long-baseline observation of the radiation environment and monitoring of drifts in the instrument response.
- Periodic fine tuning of the bias voltage for each readout channel to minimize instrument noise and compensate for ageing effects.
- Cross-calibration with the Particle Environmental Package instrument onboard JUICE.
- Use of the front- and backend test modes during regular instrument check-outs.

4 RADEM DATA GENERATION AND ANALYSIS

This section provides an overview of the data flow for the RADEM data, from on-board acquisition by the RADEM instrument until ingestion into the ESA's Planetary Science Archive (PSA).

- **Acquisition of Telemetry and Auxiliary Data**. Telemetry and Auxiliary Data are made available via European Space Agency Ground Operation System (EGOS) Data Dissemination System (EDDS) by the Mission Operations Centre (MOC). The Science Operations Centre (SOC) retrieves the telemetry (TM) and auxiliary data from the EDDS
- **Raw Data Generation**. Telemetry packets resulting from all instruments are systematically converted into PDS4 raw data products by the SGS.
- **Calibrated Data Generation**. PDS4 calibrated products are generated based on the best current calibration factors and analysis routines, and using as input the PDS4 raw products. This is done automatically by the raw2cal pipeline.
- **Derived Products**. No derived products exist so far. In the future, spectral, dose-depth curves and pitch angle distribution will be added.
- **Notes**:
  - Near-Earth Commissioning Phase Data will not be included in the foreseeable future.
  - Threshold scans are in the raw data but not in the calibrated data. They will be added as calibration raw.
  - No spice kernels are used.

An overview of the RADEM archive products can be found in Section 5.

- **Data transfer to the Archive**. All PDS4 products generated by SGS are validated for PDS4 compliance (using NASA's PDS4 validation 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 organized into PDS4 bundles. For JUICE, there is one mission bundle and instrument bundles.
- **Science Data Quality Control**. Archive products are validated through routine use. RADEM team assesses archive products as part of the operational quality control.
- **Science Data Public Release.** RADEM has no proprietary period. In routine operations it is expected that PDS4 data processed at least up to the calibrated level will be available immediately to the public.

5 DATA ORGANISATION AND CONTENTS

This section describes the basic organization of a RADEM bundle, and the naming conventions used for the products, collections and bundles, and basic product filenames.

5.1 Format and Conventions

RADEM data are compatible with version 4 of the NASAs Planetary Data System (PDS) standards, the so-called PDS4. All data from the RADEM 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.

The bundle is subdivided into a set of collections (sub-directories) to separate different types of data and information into an easy-to-navigate manner. Thus, the bundle contains separate collections for instrument science data, housekeeping data, calibration products, documentation, etc. For the instrument science data, there are separate collections for each processing level and this is standardized by PDS4 to four levels: raw, partially processed, calibrated and derived.

RADEM currently produces raw science data only. It is foreseen soon to arrive at a fully calibrated product (flux per energy per area per steradian per second).

5.2 Bundle Content and Structure

The complete set of RADEM data is archived in one single instrument bundle (root directory) – see Table 5. 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 5 RADEM instrument bundle

Bundle Title	Bundle Logical Identifier (LID)	Description
RADEM bundle	urn:esa:psa:juice_radem	This bundle contains the data collected by the RADEM experiment on-board the JUICE 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_juice_radem.xml (this is an inventory file for the bundle)
- readme_juice_radem.txt (this is a README file for the bundle; it contains a table of contents)

Inside the bundle, the data is organized in a directory structure as shown in Table 6.

Table 6 RADEM collections.

Collection Name	Collection Logical Identifier (LID)	Description
data_raw	urn:esa:psa:juice_radem:data_raw	RADEM channel contents and housekeeping products; units are digital numbers (DNs), counts or milliseconds, no conversion applied. Products are CDF files with the corresponding lblx labels. See Section 5.3.1 for more details on this data collection structure, where subfolders based on the mission phase will be introduced.
browse_raw	urn:esa:psa:juice_radem:browse_raw	This contains a collection of products that are .png with .lblx labels. In these products are representative plots with the raw data fluxes for different particle types and for housekeeping parameters. See Section 5.3.2 for more details on this data collection structure.
data_calibrated*	urn:esa:psa:juice_radem:data_calibrated	RADEM spectra (particle fluxes per channel, per unit energy, per unit area, per second) and housekeeping products, in engineering/physical units. Products are CDF files with corresponding lblx labels. To be implemented.
browse_calibrated*	urn:esa:psa:juice_radem: browse_calibrated	This contains a collection of products that are .png with.lblx lablels. In these products are represented plots with the calibrated data fluxes for different particle types and for housekeeping parameters. To be implemented.
miscellaneous	urn:esa:psa:juice_radem:miscellaneous	Contains miscellaneous products including any additional information and documentation products not easily classified as one of the other collections.
documents	urn:esa:psa:juice_radem:document	Documents related to the bundle, necessary for the use and interpretation of the data. See Section 5.3.4.
context (S)	urn:esa:psa:juice:context	Text files describing the agency, mission, spacecraft, instrument and targets. These files refer to the full descriptions in the document collection.
spice_kernels (S)	urn:esa:psa:juice:spice	SPICE ancillary data files “kernels” products used for geometry computations (instrument kernels).
xml_schema (S)	urn:esa:psa:juice:xml_schema	XML Schemas and related products used for generating and validating the products used in the bundle (PSA dictionaries in use).

*not yet available.

(S) This is a “secondary member” collection i.e. this is a collection associated to the bundle by reference to a collection in the mission bundle. Products inside this collection are prepared and maintained by the SGS and are not part of instrument data deliveries to the SGS. For completeness, this collection is included in the instrument bundle when accessed and downloaded from the PSA.

5.3 RADEM Science Data Organization

5.3.1 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 Juice mission bundle) are:

- near_earth_commissioning: Near Earth Commissioning Phase
- cruise: Interplanetary Cruise phase
- payload_checkout: Payload Checkout (not applied to RADEM)
- planetary_flybys/:
    - lunar_earth_flyby: Lunar Earth Gravity Assist
    - venus_flyby: Venus Gravity Assist
    - earth_flyby: Earth Gravity Assist

The sc and hk directories are further sub-divided in months as <YYYYMM>, where YYYYMM is year and month. The lowest level sub-directories contain the data products shown in Table 7. <YYYYMMDD>: date and UTC time of the measurements in the product X and Z correspond to the data version of the file.

Table 7 RADEM science raw data product types.

Directory Name	File Naming Convention	Description
sc	radem_raw_sc_<YYYYMMDD>__X_Z.lblx/.cdf	Proton, electron, heavy ion, DD, event counts per integration interval of measurements, sorted by energy bins, see section 6.1.1.
hk	radem_raw_hk_<YYYYMMDD>__X_Z.lblx/.cdf	Accompanying information about voltages, temperatures and other relevant data for the health status of the instrument, recorded without units, see section 6.1.2 (SID 7).

5.3.2 Browse raw directory (browse_raw)

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

browse_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 Juice mission bundle) are:

- near_earth_commissioning: Near Earth Commissioning Phase
- cruise: Interplanetary Cruise phase
- payload_checkout: Payload Checkout (not applied to RADEM)
- planetary_flybys/:
  - lunar_earth_flyby: Lunar Earth Gravity Assist
  - venus_flyby: Venus Gravity Assist
  - earth_flyby: Earth Gravity Assist

The sc and hk directories are further sub-divided in months or range of orbits as <YYYYMM>, where YYYYMM is year and month.

The lowest level sub-directories contain the data products shown in Table 8. <YYYYMMDD>: date and UTC time of the measurements in the product, and X and Z correspond to the data version of the file.

Table 8 RADEM browse products.

Directory Name	File Naming Convention	Description
raw	radem_raw_sc_browse_<YYYYMMDD>__X_Z.lblx/.png radem_raw_hk_browse_<YYYYMMDD>__X_Z.lblx/.png	Proton, electron and ion count rates/ Housekeeping parameters plots.

5.3.3 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> (which can be found by consulting the mission_phases.[xml/tab] product in the Juice mission bundle) are:

- near_earth_commissioning: Near Earth Commissioning Phase
- cruise: Interplanetary Cruise phase
- payload_checkout: Payload Checkout (not applied to RADEM)
- planetary_flybys/:
  - lunar_earth_flyby: Lunar Earth Gravity Assist
  - venus_flyby: Venus Gravity Assist
  - earth_flyby: Earth Gravity Assist

The sc and hk directories are further sub-divided in months or range of orbits as <YYYYMM>, where YYYYMM is year and month.

The lowest level sub-directories contain the data products shown in Table 9. <YYYYMMDD>: date and UTC time of the measurements in the product and X and Z correspond to the data version of the file.

Table 9 RADEM 'calibrated data' data product types

Directory Name	File Naming Convention	Description
sc	radem_cal_sc_<YYYYMMDD>__X_Z.lblx/.cdf	[Not currently produced] TBD: Proton, Electron and Heavy Ions calibrated fluxes sorted by energy bins.
hk	radem_cal_hk_<YYYYMMDD>__X_Z.lblx/.cdf	Accompanying information about voltages, temperatures and other relevant data for the health status of the instrument, as recorded by the instrument calibrated to appropriate units: K, C, V, mA, etc. (SID 7).

5.3.4 Document directory (document)

The structure of the ‘document’ collection is as follows:
document/

- collection_document.xml
- collection_document.csv
- < Documents; see Table 10>

Table 10 RADEM document list.

Document	File Naming Convention
Ref JUI-LIP-RDM-ICD-001	This document.

5.3.5 Miscellaneous directory (miscellaneous)

The structure of the ‘miscellaneous’ collection is as follows:
document/

- collection_document.csv/lblx
- configuration_table__X_Z.csv/lblx
- target_visibility_windows__X_Z.csv/lblx

configuration_table__X_Z.[csv/lblx] contains the time intervals during which each configuration (0 – calibration, 1, 2, etc) was used (see Section 3.7 for more details about each configuration).

target_visibility_windows__X_Z.[cvs/lblx] product includes the information on the RADEM target visibility windows which contains the Target_LID, Target_Name, Target_Type, Visibility_Start and Visibility_End since launch until the current mission moment. X and Z correspond to the data version of the files. This file should be used to identify data from different scientific targets such as Earth or Venus during the JUICE gravity assists or the solar wind during the rest of the cruise.

6 DATA PRODUCT FORMATS

RADEM data products are formatted in accordance with the PDS4 specifications (see [AD.01]). This section provides details on the formats used for each of the products included in the RADEM science and housekeeping data.

6.1 Raw data products

6.1.1 Science raw data

Science raw data is given in CDF format with the naming convention described in Section 5.3.1. Its parameters and their respective limit values are given in Table 11.

In the Science raw data eight counters (or channels) are assigned to the PROTONS variable and two counters are assigned to the HEAVY_IONS variable (PIDH_ASIC), eight counters are assigned to ELECTRONS variable (EDH_ASIC), and 31 counters are assigned to DD variable (DDH_ASIC). 12 channels are also assigned to a CUSTOM variable which has counters from both EDH_ASIC (CUSTOM 1-6 and 12) and PIDH_ASIC (CUSTOM 10 and 11). Due to the software configuration CUSTOM 11 and 12 are the sum of five EDH_ASOC and PIDH_ASIC channels respectively. Due to software implementation, channels CUSTOM 7-9 are a sum of channels in the PROTONS, ELECTRONS, and DD variables respectively, but it should be changed in a future software update.

6.1.1.1 Science raw data particle measurement uncertainties

The counts values stored in variables Protons, Electrons, Heavy Ions, CUSTOM and DD, let's call them generically $NCounts_i$, have an uncertainty value associated with its measurements that are related on the statistics acquired by each channel. Therefore, the data uncertainty of each of these values can be simply calculated by $\sqrt{(NCounts_i)}$.

Table 11 Science raw data format.

Item	Units	Size [bytes]	Limits	Description
TIME_UTC	ms	24 (CHAR)		UTC timestamps of the data.
TIME_OBT	s	18 (CHAR)		S/C clock at observation time.
PROTONS	counts	32 (UINT4[8[)	0-(2^{32}-1)	Array of time series for each proton energy bin. The

				protons detector contains 8 bins in total.
ELECTRONS	counts	32 (UINT4[8])	$0-(2^{32}-1)$	Array of time series for each electron energy bin. The electron detector contains 8 bins in total.
HEAVY_IONS	counts	8 (UINT4[2])	$0-(2^{32}-1)$	Array of time series for each high energy ion, energy bin. The heavy Ion detector contains 2 bins in total.
DD	counts	124 (UINT4[31])	$0-(2^{32}-1)$	Directionality detector with 31 bins/sensors each corresponding to one direction.
CUSTOM	counts	48 (UINT4[12]	$0-(2^{32}-1)$	Array of time series of unclassified particle and energy bins.
INTEGRATION_TIME	s	2 (UINT2)	0-6534	All Detector Heads integration time.
CONFIGURATION_ID	N.A.	1 (BYTE)	0-99	Science configuration ID used.
LABEL_PROTONS	N.A.	1 (BYTE)	N.A.	Labels for each PROTONS bin.
LABEL_ELECTRONS	N.A.	104 (CHAR[8])	N.A.	Labels for each ELECTRONS bin.
LABEL_HEAVY_IONS	N.A.	104 (CHAR[8])	N.A.	Labels for each HEAVY_IONS bin.
LABEL_DD	N.A.	26 (CHAR[2])	N.A.	Labels for each DD bin.
PROTON_BINS	N.A.	279 (CHAR[31])	1-8	PROTONS bin number.
ELECTRON_BINS	N.A.	8 (UINT1)	1-8	ELECTRONS bin number.
HEAVY_ION_BINS	N.A.	8 (UINT1)	1-2	HEAVY_IONS bin number.
DD_BINS	N.A.	8 (UINT1)	1-31	DD bin number.
CUSTOM_BINS	N.A.	8 (UINT1)	1-12	CUSTOM bin number.

Note: Order of data fields in data file is different than in science data packet TM(140,2)

6.1.2 Housekeeping raw data

The housekeeping raw data is given in CDF format. The raw HK values are recorded onboard as numeric readouts of digital encoders in unitless numbers, referred to as DN 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 12 for more details of the housekeeping parameters and their respective limit values.

Table 12 Housekeeping (SID7) raw data format.

Item	Units	Size (bytes)	Limits	Description
TIME_UTC	ms	24 (CHAR)	N.A.	UTC timestamps of the data.
TIME_OBT	s	18 (CHAR)	N.A.	S/C clock at observation time.
HK_PACKET_TYPE	N.A.	4 (CHAR)	N.A.	ID of the HK report.
RADEM_MODE	N.A.	1 (UINT1)	1-15	RADEM working mode (15 - Calibration, 5 - Safe and 10 - Normal).
SYSTEM_ERRORS	N.A.	8 (UINT4[2])	0-(2^{32}-1)	System Errors: Central Electronics Unit Software Status and Parametric Errors.
LABEL_SYSTEM_ERRORS	N.A.	34 (CHAR [2])		SYSTEM_ERRORS label.
BIST_STATUS	N.A.	1 (UINT1)	0-(2^{6}-1)	Built-In Self Test Status procedure, responsible for performing the RADEM self-test, where RADEM Detector Heads and Power Supply Health are evaluated.
CPU_WORK_LOAD	ADC	4 (UINT4)	0-(2^{32}-1)	uProcessor Watchdog reload margin.
DETECTOR_HEADS_ STATUS	N.A.	6 (UINT1[6])	0-(2^{6}-1)	PDH and HIDH Detector Status, EDH Detector Status, DDH Detector Status (ON/OFF), PIDH ASIC Status, EDH ASIC Status, DDH ASIC Status – Single Latch-Up (SEL) detected and internal Errors.
LABEL_DETECTOR _HEADS _STATUS	N.A.	150 (CHAR[10])	N.A.	VOLTAGES labels.
VOLTAGES	ADC	40 (UINT4[10])	0-(2^{6}-1)	System voltages. Parameters under control are PCU +92.5V and +4.3V, Detector 90V, CEU 3.3V and the ASICs supply voltage of 3.3V and 1.8V.
LABEL_VOLTAGES	N.A.	150 (CHAR[10])	N.A.	VOLTAGES labels.
CURRENTS	ADC	6 (UINT2[3])	0-(2^{16}-1)	PIDH_ASIC, EDH_ASIC, and DDH_ASIC External Reference Bias Current (MBIAS).
LABEL_CURRENTS	N.A.	45 (CHAR[3])		CURRENTS labels.
TEMPERATURES	ADC	10 (UINT2[5])	0-(2^{16}-1)	System Temperatures: PCU, CEU, PDH and HIDH, EDH, DDH.
LABEL_ TEMPERATURES	N.A.	160 (CHAR[10])	N.A.	TEMPERATURES labels.

CEU_MEMORY_ERROR _COUNTERS	ADC	8 (UINT2[4])	0-(2^{16}-1)	System Memory Error Counters: Static Random-Access Memory (SRAM) Single Error, SRAM Double Error, Magnetoresistive Random-Access Memory (MRAM) Double Error and MRAM Double Error.
LABEL_CEU_MEMORY _ERROR_COUNTER	N.A.	116 (CHAR[4])	N.A.	CEU_MEMORY_ERROR_COUNTERS labels.
CEU_MEMORY_ERROR _ADDRESSES	address	16 (UINT4[4])	0-(2^{32}-1)	CEU Memory Error Addresses
LABEL_CEU_MEMORY _ERROR_ADDRESSES	N.A.	116 (CHAR[4])	N.A.	Labels of the CEU memory error addresses vector
ASIC_ERROR_COUNTERS	Counts	6 (UINT2[3])	0-(2^{16}-1)	PIDH_ASIC, EDH_ASIC, and DDH_ASIC Error Counters.
LABEL_ASIC_ ERROR_COUNTERS	N.A.	63 (CHAR[3])	N.A.	ASIC_ERROR_COUNTERS labels.
ASIC_LATCHUP_MONITOR	bits	3 (UINT[3])	0-(2^{6}-1)	ASIC Latchup Monitor: PIDH_ASIC, EDH_ASIC, DDH_ASIC Bit 0 error status.
LABEL_ ASIC_ LATCHUP_MONITOR	N.A.	39 (CHAR[3])	N.A.	ASIC_LATCHUP_MONITOR label.
ASIC_SCRUBBING _ERROR_STATUS	bits	3 (UINT[3])	0-(2^{6}-1)	ASIC Scrubbing: PIDH_ASIC, EDH_ASIC, DDH_ASIC Bit 0 error status (Units: bits).
LABEL_ ASIC_SCRUBBING_ ERROR_STATUS	N.A.	45 (CHAR[3])	N.A.	ASIC_SCRUBBING_ERROR labels.
ASIC_TABLES	bits	6 (UINT[6])	0-(2^{6}-1)	ASIC configuration in use including coincidence logic (Coincidence Tables) and thresholds (Register Table).
LABEL_ASIC_TABLES	N.A.	6 (CHAR[6])	N.A.	ASIC_TABLES labels.

Annex A. Operational Periods

Table 13 Operational periods including settings configuration number, calibration runs and other tests/operations. Calibrated data is only generated for configurations 1 and 2.

Start	End	Operational Condition
2023-04-14T00:00:00.000Z	2023-08-29T23:59:59.999Z	NECP
2023-08-30T00:00:00.000Z	2024-03-04T13:33:24.406Z	Configuration 1
2024-03-04T13:33:24.407Z	2024-03-06T12:52:51.096Z	Switch Off
2024-03-06T12:52:51.097Z	2024-04-30T11:10:59.999Z	Configuration 1
2024-04-30T11:11:00.000Z	2024-04-30T13:11:59.999Z	Mapping Tests
2024-04-30T13:12:00.000Z	2024-05-21T07:59:59.999Z	Configuration 1
2024-05-20T08:00:00.000Z	2024-05-27T23:24:59.999Z	Calibration Run
2024-05-27T23:25:00.000Z	2024-07-09T11:05:59.999Z	Configuration 1
2024-07-09T11:06:00.000Z	2040-08-31T00:00:59.999Z	Configuration 2

Annex B. Energy Sensitivities

Configuration 1

Table 14 Energy sensitivity of each channel with Configuration 1 settings.

Variable	Entry	Detector ASIC	Electron Energy Interval (MeV)	Proton Energy Interval (MeV)	Alpha Energy Interval (MeV)
PROTONS	1	PIDH	>0.32	>5.2	20.7-24.0 & >54.5
	2	PIDH	>0.36	>8.43	33.6-37.4 & >65.5
	3	PIDH	>0.81	>14.3	>93.9
	4	PIDH	>1.02	>22.6	>114
	5	PIDH	>1.02	>36.3	>162
	6	PIDH	>1.02	>57.4	>254
	7	PIDH	>1.02	>68.0	>254
	8	PIDH	>1.02	>68.0	>254
ELECTRONS	1	EDH	>0.40	>7.65	30.6 & > 85.0
	2	EDH	>0.74	>12.8	>104
	3	EDH	>1.15	>20.7	>145
	4	EDH	>1.15	>30.8	>191
	5	EDH	>1.15	>47.4	>191
	6	EDH	>1.15	>54.5	>191
	7	EDH	>1.15	>65.0	>191
	8	EDH	>0.82	>65.0	>191
HEAVY_IONS	1	PIDH	Unresponsive	Unresponsive	Unresponsive
	2	PIDH	Not sensitive	10.0 & >49.0	30.9-90 & >100
DD	0	DDH	>0.30	>7.00	>28.0
	22.5	DDH	>0.30	>7.00	>28.0
	45	DDH	>0.35	>8.50	>34.0
	67.5	DDH	>0.50	>12.5	>50.0
	bkg	DDH	>2.00	>30.0	>120
CUSTOM	1	EDH	Undefined	Undefined	Undefined
	2	EDH	Undefined	Undefined	Undefined
	3	EDH	Undefined	Undefined	Undefined
	4	EDH	Undefined	Undefined	Undefined
	5	EDH	Undefined	Undefined	Undefined
	6	PIDH	Undefined	Undefined	Undefined
	7	Sum PIDH	All	All	All
	8	Sum EDH	All	All	All
	9	Sum DDH	All	All	All
	10	PIDH	Undefined	Undefined	Undefined
	11	PIDH	Undefined	Undefined	Undefined
	12	EDH	Undefined	Undefined	Undefined

Configuration 2

Table 15 Energy sensitivity of each channel with Configuration 2 settings.

Variable	Entry	Detector ASIC	Electron Energy Interval (MeV)	Proton Energy Interval (MeV)	Alpha Energy Interval (MeV)
PROTONS	1	PIDH	>20.0	5.70-8.90 & >70.0	20.4-35.5
	2	PIDH	Not sensitive	8.90-14.2 & 80.0-173	32-65
	3	PIDH	Not sensitive	14.7-22.7	56.9-55-60 & >90
	4	PIDH	Not sensitive	22.7-31.5	>105
	5	PIDH	Not sensitive	37.5-45.0	>135
	6	PIDH	Not sensitive	58.0-70.0	>215
	7	PIDH	Not sensitive	70.0-78.0	>265
	8	PIDH	>10.0	>56.0	>100
ELECTRONS	1	EDH	>0.47	7.65-7.95 & >45.0	Not sensitive
	2	EDH	>0.88	>45.0	Not sensitive
	3	EDH	>1.70	>45.0	Not sensitive
	4	EDH	>2.00	>55.0	Not sensitive
	5	EDH	>2.00	>65.0	Not sensitive
	6	EDH	>2.00	>70.0	Not sensitive
	7	EDH	>2.00	>70.0	Not sensitive
	8	EDH	>2.00	>70.0	Not sensitive
HEAVY_IONS	1	PIDH	Not sensitive	> 105	39.2-49.5
	2	PIDH	Not sensitive	10.0 & >49.0	30.9-90 & >100
DD	0	DDH	>0.30	>50.0	Not sensitive
	22.5	DDH	>0.30	>50.0	Not sensitive
	45	DDH	>0.35	>40.0	Not sensitive
	67.5	DDH	>0.50	>40.0	Not sensitive
	bkg	DDH	>2.00	Same as zenith	Not sensitive
CUSTOM	1	EDH	0.95-1.90 & >13.0	7.70-13.2 & > 87.0	30.5-53.0 & >348
	2	EDH	Not sensitive	13.2-20.2 & 116-144	53.0-81.0 & 464-576
	3	EDH	Not sensitive	20.2-34.5 & 116-144	81.0-125 & 464-576
	4	EDH	>20.0	>70.0	>280
	5	EDH	>3.00	>70.0	>280
	6	PIDH	>0.42	5.10-5.70 & >19.0	20.5-22.5 & >105
	7	SumPIDH	All	All	All
	8	SumEDH	All	All	All
	9	SumDDH	All	All	All
	10	PIDH	Undefined	Undefined	Undefined
	11	PIDH	Not sensitive	>105	>420
	12	EDH	>7.00	>65.0	>420

Annex C. ASIC Settings

Configuration 1

Table 16 PIDH_ASIC Coincidence 1 scheme (C: Coincidence, AC: Anti-Coincidence).

Channel	**Low Gain**		**High Gain**																
	HIDH D1	**HIDH D2**	**PDH D1**		**PDH D2**		**PDH D3**		**PDH D4**		**PDH D5**		**PDH D6**		**PDH D7**		**PDH D8**	
	LG1	LG2	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT
HEAVY_IONS 1	**C**	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HEAVY_IONS 2	X	**C**	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PROTONS 1	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PROTONS 2	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X	X	X
PROTONS 3	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X
PROTONS 4	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X
PROTONS 5	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X
PROTONS 6	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X
PROTONS 7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X
PROTONS 8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**
CUSTOM 6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CUSTOM 7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CUSTOM 11	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 17 DDH_ASIC Coincidence 1 scheme (C: Coincidence, AC: Anti-Coincidence).

Channel	**Low Gain**		**High Gain**																
	NA	**NA**	**DDH 1**		**DDH 2**		**DDH 3**		**…**		**…**		**DDH 29**		**DDH 30**		**DDH 31**	
	LG1	LG2	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT
DDH #1	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DDH #2	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X	X	X
DDH #3	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X
…	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X
…	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X
DDH #29	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X
DDH #30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X
DDH #31	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**

Table 18 EDH_ASIC Coincidence 1 scheme (C: Coincidence, AC: Anti-Coincidence).

Channel	**Low Gain**		**High Gain**															
	NA	**NA**	**EDH D1**		**EDH D2**		**EDH D3**		**EDH D4**		**EDH D5**		**EDH D6**		**EDH D7**		**EDH D8**	
	LG1	LG2	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT
ELECTRONS 1	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ELECTRONS 2	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X	X	X
ELECTRONS 3	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X
ELECTRONS 4	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X
ELECTRONS 5	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X
ELECTRONS 6	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X
ELECTRONS 7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X
ELECTRONS 8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**
CUSTOM 1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CUSTOM 2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CUSTOM 3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CUSTOM 4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CUSTOM 5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CUSTOM 12	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 19 Thresholds values for each detector (front-end channel) in Configuration 1.

Sensor	**Low Threshold**		**High Threshold**	
	ADC	MeV	ADC	MeV
HIDH D1	2	Unknown	NA	NA
HIDH D2	2	TBD	NA	NA
PDH D1	347	0.43	977	12.26
PDH D2	265	0.29	411	12.47
PDH D3	347	0.43	666	8.08
PDH D4	378	0.37	565	8.29
PDH D5	368	0.35	707	9.33
PDH D6	337	0.31	852	12.45
PDH D7	378	0.51	817	13.54
PDH D8	368	0.57	783	17.43
EDH D1	153	0.15	422	6.64
EDH D2	153	0.16	449	5.94
EDH D3	143	0.14	460	4.91
EDH D4	153	0.08	351	3.81

EDH D5	143	0.09	335	4.10
EDH D6	143	0.07	405	4.29
EDH D7	122	0.09	322	3.38
EDH D8	112	0.09	389	4.50
DDH D1	102	0.092	345	2.54
DDH D2	102	0.054	345	3.42
DDH D3	102	0.084	345	3.07
DDH D4	102	0.064	345	3.63
DDH D5	102	0.083	345	3.20
DDH D6	102	0.066	345	3.13
DDH D7	102	0.074	345	3.07
DDH D8	102	0.063	345	3.24
DDH D9	102	0.074	345	3.21
DDH D10	102	0.059	345	3.47
DDH D11	102	0.082	345	3.41
DDH D12	102	0.078	345	3.23
DDH D13	102	0.074	345	3.83
DDH D14	102	0.077	345	3.55
DDH D15	102	0.078	345	3.56
DDH D16	102	0.073	345	3.51
DDH D17	102	0.095	345	3.20
DDH D18	102	0.087	345	3.45
DDH D19	102	0.074	345	3.87
DDH D20	102	0.081	345	3.57
DDH D21	102	0.070	345	3.75
DDH D22	102	0.084	345	3.41
DDH D23	102	0.085	345	3.29
DDH D24	102	0.086	345	3.43
DDH D25	102	0.093	345	3.45
DDH D26	102	0.085	345	3.58
DDH D27	102	0.064	345	3.90
DDH D28	102	0.074	345	3.73
DDH D29	102	0.070	345	3.20
DDH D30	102	0.064	345	3.82
DDH D31	102	0.082	345	3.46

Configuration 2

Table 20 PIDH_ASIC Coincidence 2 scheme (C: Coincidence, AC: Anti-Coincidence).

Channel	**Low Gain**		**High Gain**																
	HIDH D1	**HIDH D2**	**PDH D1**		**PDH D2**		**PDH D3**		**PDH D4**		**PDH D5**		**PDH D6**		**PDH D7**		**PDH D8**	
	LG1	LG2	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT
HEAVY_IONS 1	X	X	X	X	X	X	X	X	X	X	X	X	**AC**	X	X	**C**	X	**C**
HEAVY_IONS 2	X	**C**	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PROTONS 1	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X	X	X	X
PROTONS 2	X	X	X	**C**	**C**	**AC**	**AC**	X	X	X	X	X	X	X	X	X	X	X
PROTONS 3	X	X	**C**	X	X	X	**C**	**AC**	**AC**	X	X	X	X	X	X	X	X	X
PROTONS 4	X	X	**C**	X	X	X	X	X	**C**	**AC**	**AC**	X	X	X	X	X	X	X
PROTONS 5	X	X	**C**	X	X	X	X	X	X	X	**C**	**AC**	**AC**	X	X	X	X	X
PROTONS 6	X	X	**C**	X	X	X	X	X	X	X	X	X	**C**	**AC**	**AC**	X	X	X
PROTONS 7	X	X	**C**	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	**AC**	X
PROTONS 8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**AC**	X	**C**	**AC**
CUSTOM 6	X	X	**C**	**AC**	**C**	X	X	X	X	X	X	X	X	X	X	X	X	X
CUSTOM 11_1	X	X	**C**	X	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**
CUSTOM 11_2	X	X	X	X	**C**	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**

Table 21 DDH_ASIC Coincidence 2 scheme.

Channel	**Low Gain**		**High Gain**																
	NA	**NA**	**DDH D1**		**DDH D2**		**DDH D3**		**DDH D4**		**DDH D5**		**DDH D6**		**DDH D7**		**DDH D8**	
	LG1	LG2	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT
DDH #1	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DDH #2	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X	X	X
DDH #3	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X
…	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X
…	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X
DDH #29	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X
DDH #30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X
DDH #31	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**

Table 22 EDH_ASIC Coincidence 2 scheme (C: Coincidence, AC: Anti-Coincidence).

Channel	**Low Gain**		**High Gain**															
	NA	**NA**	**EDH D1**		**EDH D2**		**EDH D3**		**EDH D4**		**EDH D5**		**EDH D6**		**EDH D7**		**EDH D8**	
	LG1	LG2	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT
ELECTRONS 1	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ELECTRONS 2	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X	X	X
ELECTRONS 3	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X
ELECTRONS 4	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X
ELECTRONS 5	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X	X	X
ELECTRONS 6	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X	X	X
ELECTRONS 7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**	X	X
ELECTRONS 8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**C**	**AC**
CUSTOM 1	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X	X	X	X
CUSTOM 2	X	X	X	**C**	X	**C**	**AC**	X	X	X	X	X	X	X	X	X	X	X
CUSTOM 3	X	X	X	**C**	X	X	X	**C**	**AC**	X	X	X	X	X	X	X	X	X
CUSTOM 4	X	X	X	X	X	X	X	X	X	X	X	X	**AC**	X	X	**C**	X	**C**
CUSTOM 5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**AC**	X	**C**
CUSTOM 12_1	X	X	X	X	**C**	**AC**	X	X	X	X	X	X	**C**	**AC**	X	X	X	X

Table 23 Thresholds values for each detector (front-end channel) in Configuration 2.

Sensor	**Low Threshold**		**High Threshold**	
	ADC	MeV	ADC	MeV
HIDH D1	1	Unknown	NA	NA
HIDH D2	2	TBD	NA	NA
PDH D1	280	0.34	120	1.55
PDH D2	800	1.18	600	18.05
PDH D3	800	1.20	600	7.28
PDH D4	800	1.11	600	8.80
PDH D5	800	1.07	600	7.94
PDH D6	800	1.05	600	8.80
PDH D7	800	1.32	600	9.96
PDH D8	800	1.52	600	13.41
EDH D1	180	0.20	40	0.72
EDH D2	180	0.20	40	0.63
EDH D3	180	0.18	40	0.50
EDH D4	180	0.11	40	0.55

EDH D5	180	0.13	40	0.56
EDH D6	180	0.10	40	0.46
EDH D7	180	0.16	40	0.56
EDH D8	180	0.17	40	0.49
DDH D1	120	0.106	40	0.29
DDH D2	120	0.072	40	0.40
DDH D3	120	0.100	40	0.36
DDH D4	120	0.083	40	0.42
DDH D5	120	0.099	40	0.37
DDH D6	120	0.082	40	0.36
DDH D7	120	0.090	40	0.36
DDH D8	120	0.080	40	0.38
DDH D9	120	0.091	40	0.37
DDH D10	120	0.078	40	0.40
DDH D11	120	0.099	40	0.40
DDH D12	120	0.095	40	0.37
DDH D13	120	0.094	40	0.44
DDH D14	120	0.096	40	0.41
DDH D15	120	0.097	40	0.41
DDH D16	120	0.092	40	0.41
DDH D17	120	0.112	40	0.37
DDH D18	120	0.105	40	0.40
DDH D19	120	0.094	40	0.45
DDH D20	120	0.100	40	0.41
DDH D21	120	0.089	40	0.43
DDH D22	120	0.102	40	0.40
DDH D23	120	0.103	40	0.38
DDH D24	120	0.104	40	0.40
DDH D25	120	0.111	40	0.40
DDH D26	120	0.104	40	0.42
DDH D27	120	0.085	40	0.45
DDH D28	120	0.093	40	0.43
DDH D29	120	0.087	40	0.37
DDH D30	120	0.084	40	0.44
DDH D31	120	0.100	40	0.40

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