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Radiation-hard Electron Monitor (RADEM) for ESA JUICE mission

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Agenda

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3. RADEM build and models
4. Silicon detector qualification
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6. Data center
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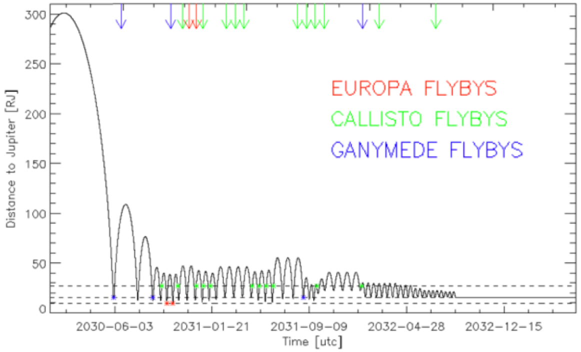
1. Introduction

JUpiter ICy moons Explorer (JUICE) is a part of ESA's Cosmic Vision programme.

It's a large-class spacecraft dedicated for observations of Jupiter and it's three largest moons: Ganymede, Callisto and Europa.

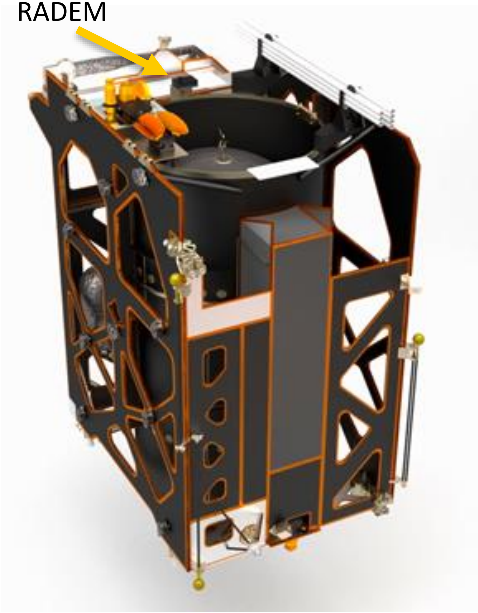
JUICE will explore the conditions of the planet formation, life emergence and mechanisms of the Solar System.

Launch of JUICE is planned for 2022. With 7 years of transfer, it will spend 3 years studying Jovian system.



Jupiter Galilean Moons [www.deography.com] and planned flybys during the mission

1. Introduction



RADEM location onboard the satellite

RADiation-hard Electron Monitor (RADEM) is an instrument designed for ESA JUICE mission.

Development based on long-term experience at PSI with radiation monitors (REM, SREM, NGRM).

Onboard the spacecraft RADEM will serve two functions:

– Contributing to the JUICE science packages,
– Being a part of mission health monitoring system.

The instrument will provide information on electron, proton and heavy ion fluxes, spectra and incoming directions.

2. RADEM requirements and properties

Main scientific goals for RADEM are:

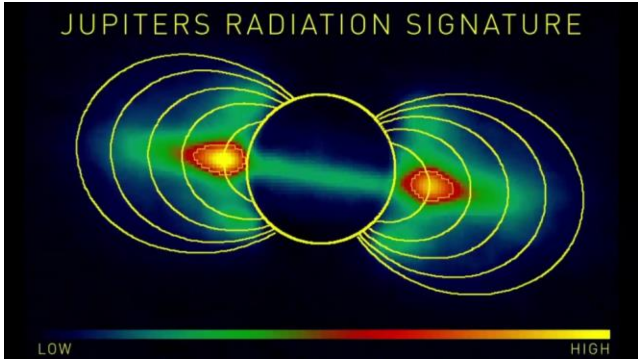
– Characterization of Jupiter's harsh radiation environment,

– Study of dynamics in Jovian radiation belts,

– Understanding of trapped particle energy gain and loss,

– Space weather monitoring across the Solar System,

– Comparison between Jupiter and Earth radiation environment



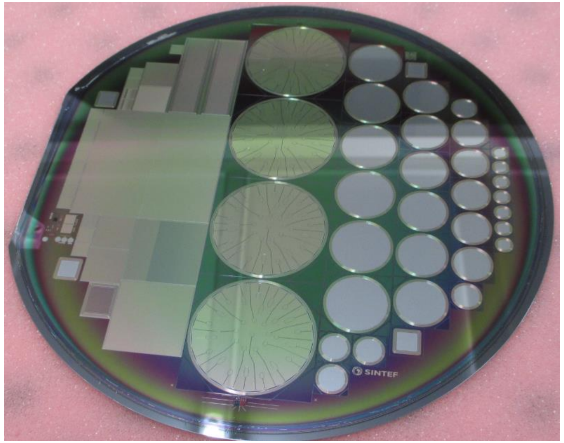
Jupiter's radiation belts [www.missionjuno.swri.edu]

2. RADEM requirements and properties

RADEM will inform spacecraft on particle fluxes, spectra and total radiation dose.

RADEM most important functional requirements are:

– Discrimination between electrons, protons and heavy ions,
– Energy coverage:
  - 0.3 – 40 MeV for electrons,
  - 5 – 250 MeV for protons,
  - 8 – 670 MeV for heavy ions,
– Peak fluxes:
  - 10^9 #/cm²/s (E > 100 keV) for electrons,
  - 10^8 #/cm²/s (E > 1 MeV) for protons
– Radiation dose on rad-hard components: 100 krad,
– Information on dose rate and total dose.



Wafer with RADEM diodes, designed at PSI

3. RADEM build and models

RADEM consists of:

– Electron Stack Detector (ESD),

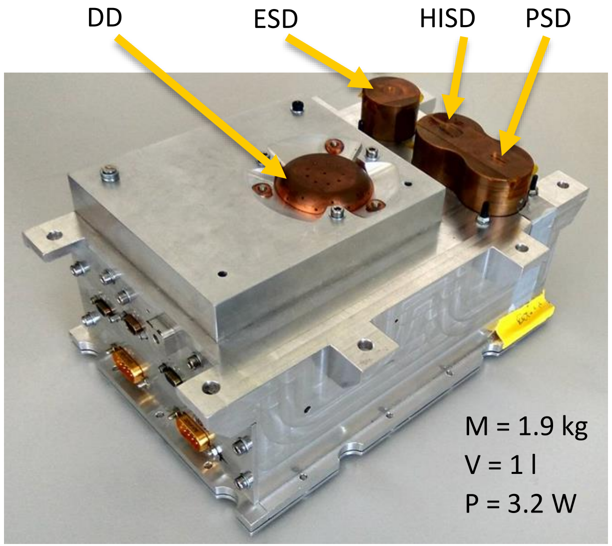
– Proton Stack Detector (PSD),

– Heavy Ion Stack Detector (HISD),

– Directional Detector (DD),

– three Application-Specific Integrated Circuits (ASIC) designed especially for RADEM on JUICE.

<u>PSI contributed to design of all listed components.</u>



RADEM Engineering Model

RADEM models:

– Bread-Board (BBM) – developed and tested 2017,

– Engineering (EM) – developed and tested 2019,

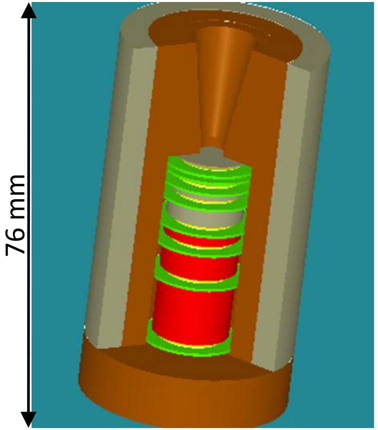
– Engineering Qualification (EQM) – tests currently undergoing,

– Proto-Flight (PFM) – currently under development.

3. RADEM build and models

Stack Detectors

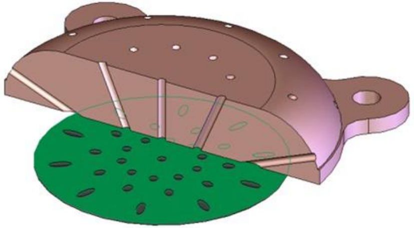
- 0.3 mm thick Si diodes arranged in stacks
- Single collimated entry
- 8 diodes for ESD and PSD, 2 for HISD
- Al and Ta absorbers between diodes



Proton Stack Detector

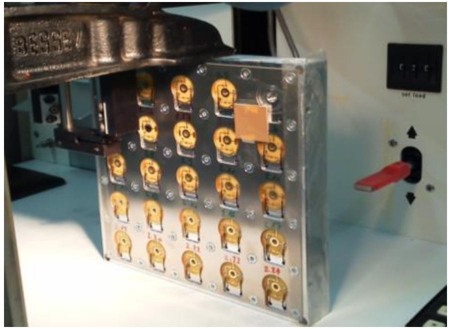
Directional Detector

- Single 0.3 mm thick Si diode with 28 sensitive areas
- 28 collimator holes with Kapton entrance windows
- Theta angle: 70^0

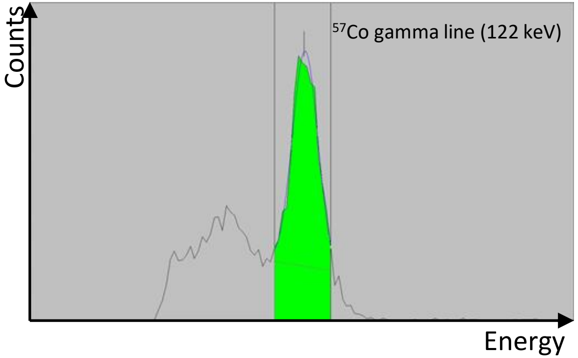

Directional Detector

Both designs based on Monte Carlo simulation results done by PSI

4. Silicon detector qualification



Die shear test setup



Electronic resolution measurement plot

PSI was responsible for development and qualification of Si detector assemblies. PSI developed the ground support equipment for ASIC test and data acquisition.

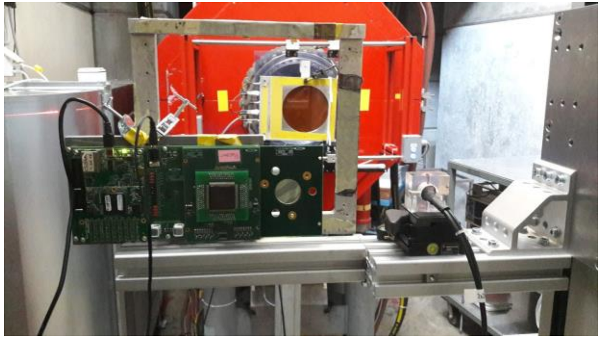
Tested detectors were used in EQM and PFM.

Required tests can be grouped into three categories:

– Physical properties (Thickness, Pull-Wire, Die Shear),
– Electrical properties (Resistivity, Forward Voltage, Full Depletion, Leakage Current),
– Performance (Displacement Damage, Energy Resolution).

5. RADEM performance tests

RADEM BBM and EM performance was tested to verify:
– Response to different ionizing radiation sources,
– Threshold gain factor of Low and High Gain channels,
– Linearity of flux scaling,
– Coincidence logic mechanism,
– Alignment of Directional Detector pixels.



RADEM BBM at PiM1 beamline

Instrument was tested with proton beam at Proton Irradiation Facility (PIF), electrons at PiM1 and different radioactive sources.

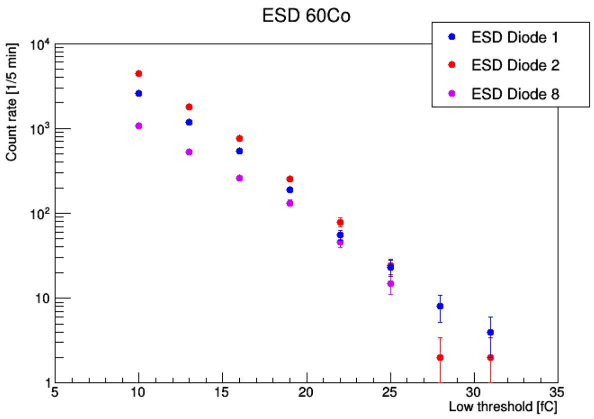
Measurements were followed by Geant4 Monte Carlo simulations to compare and verify obtained results.

Proton Irradiation Facility area

5. RADEM performance tests

^{60}Co γ source

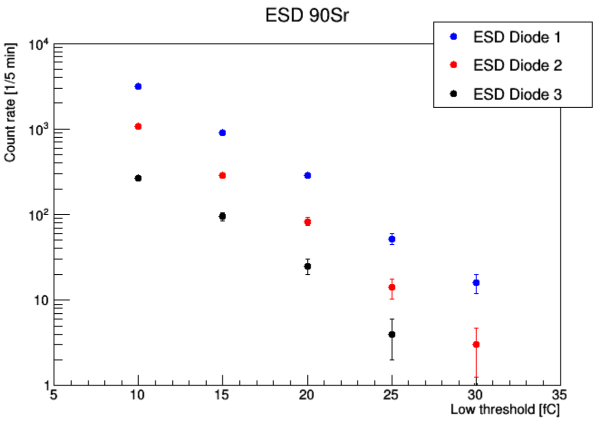
- Can penetrate through RADEM shielding
- Response simultaneously verified in all diodes of the stack



ESD response to 60Co radioactive source

^{90}Sr β^{-} source

- Expected response to electron radiation in first three diodes
- Descending count rate due to geometry factor and energy cut-off



ESD response to 90Sr radioactive source

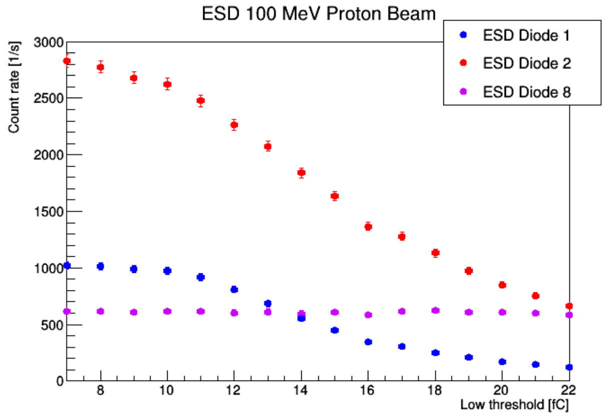
5. RADEM performance tests

High Gain channels response

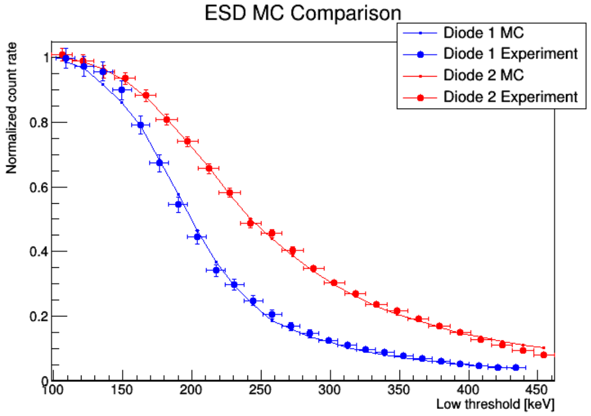
- Low and High Threshold scan of High Gain channels of the ASIC
- 200 and 100 MeV proton beam
- Simultaneous test of all stack diodes

Verification with Monte Carlo simulations

- Detailed geometry and radiation models
- Detector noise impact included in results
- Simulation results in good agreement with experimental data



High Gain channels response to 100 MeV protons



MC simulation comparison with ESD proton scan

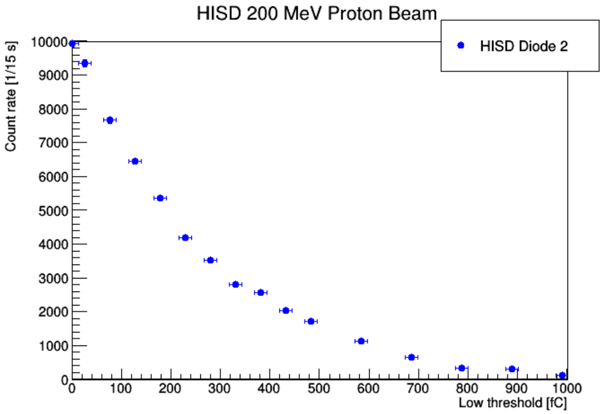
5. RADEM performance tests

Low Gain channels response

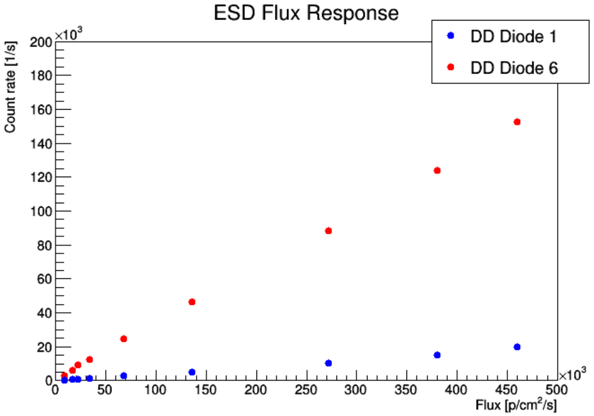
- Low Threshold scan of Low Gain channels of the ASIC
- 200 MeV proton beam
- Energy deposition imitating heavy ions

Flux scaling

- Tests done with 200 MeV proton beam
- Counting rate above 10^5/s
- Linear response to changing flux within tested range



Low Gain channel response to proton beam

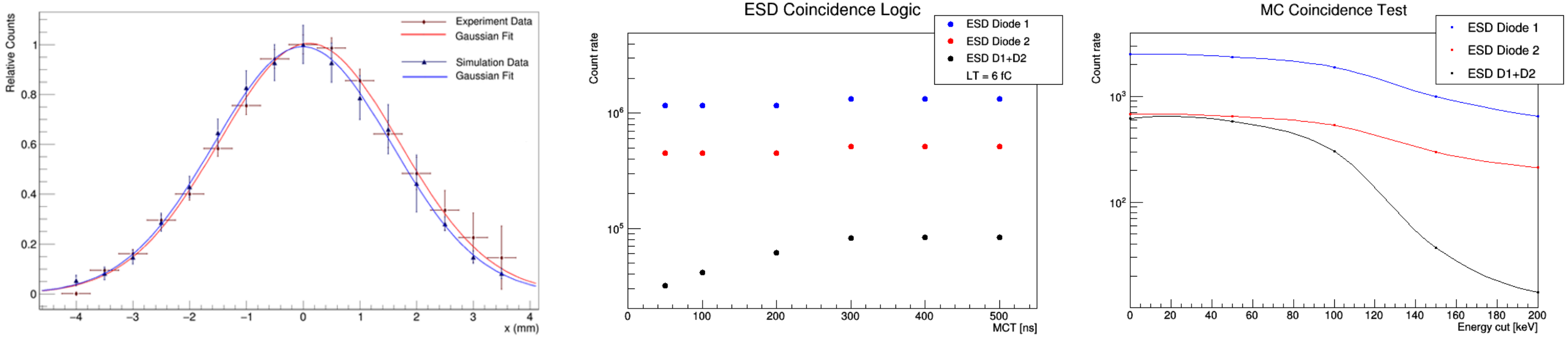


Electron Stack Detector flux test preliminary results

5. RADEM performance tests

Collimated ^{90}Sr source

- Electron detectors were tested with ^{90}Sr source to verify mechanism of coincidence and the alignment of DD sensitive areas
- Coincidence window width was tested on ESD and observed behavior was supported by Monte Carlo simulations
- DD pixel alignment matches the theoretical position within error bars



DD pixel alignment comparison with MC

Coincidence width test of ESD

MC simulation results of coincidence test

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6. Data center

Well organized data center is crucial for scientific outcome of the mission.

JUICE Data Center is planned to be located in Villafranka (Spain) with a copy in Switzerland.

RADEM will be operational and providing data throughout the whole duration of the JUICE mission, including interplanetary transfer phase.

Data center structure and organization is currently under development in collaboration between PSI, LIP and ESA.

7. Summary

- RADEM functionalities were verified and compared with MC simulations
- Final models are currently under development
- The instrument is planned to be delivered by the end of 2020
- RADEM Data Center development is ongoing

My thanks go to

- Klaus Kirch
- Wojtek Hajdas
- Malte Hildebrandt