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The Jovian Dynamics and Composition Analyzer on JUICE

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Abstract

The Jovian Dynamics and Composition Analyzer (JDC), a new instrument design currently developed and built by the Swedish Institute of Space Physics, as part of the Particle Environment Package (PEP), will explore the Jovian system on board of the JUICE spacecraft. The sensor's science objective is to study the Jovian moons and Jupiter's magnetosphere. In the development process the functionality and performance were simulated. These results will be compared to the behavior of the manufactured sensor in the second half of 2018.

1. Introduction

The Jovian Dynamics and Composition Analyzer (JDC), a new instrument design, built at the Swedish Institute of Space Physics, is included as one of six sensors into the Particle Environment Package (PEP)[1]. PEP is one of the scientific payloads on the JUpiter ICy moons Explorer (JUICE) which is part of ESAs cosmic vision 2015 - 2025 program. JUICE will be launched in 2022 with its mission goal to explore the Jovian system with a focus on the moons Europa, Callisto and Ganymede. JDC will measure the 3D distribution functions of positive and negative ions, including electrons, in an energy range from 1 eV to 40 keV.

2. JDCs scientific Objectives

The scientific objectives of JDC can be split into two parts, (1) studying the structure, creation and maintenance of the Jovian magnetodisc and (2) studying properties of the four Galilean moons, like (2a) the interaction of the Jovian magnetosphere with the moons; (2b) the study of the exospheric composition for Ganymede, Callisto and Europa; (2c) the precipitating plasma populations on the surfaces of Ganymede and Callisto; (2d) and 3D continuous plasma moment measurements to investigate the interior of Ganymede.

3. Instrument

The JUICE payloads will be exposed to a high flux of penetrating electrons in the harsh Jovian radiation environment. While electronics are most affected by the Total Ionization Dose (TID), degradation of the detectors depends on the peak instantaneous flux. Appropriate shielding is reducing the amount of penetrating electrons, to ensure the required performance over the complete mission of electronics and detectors. The electrons absorbed by the shielding produce Bremsstrahlung, which affects the detectors. Therefore, the shielding is optimized to reduce the impact of the Bremsstrahlung on the measurements.
The sensor with its different subsystems is shown in Figure 1.

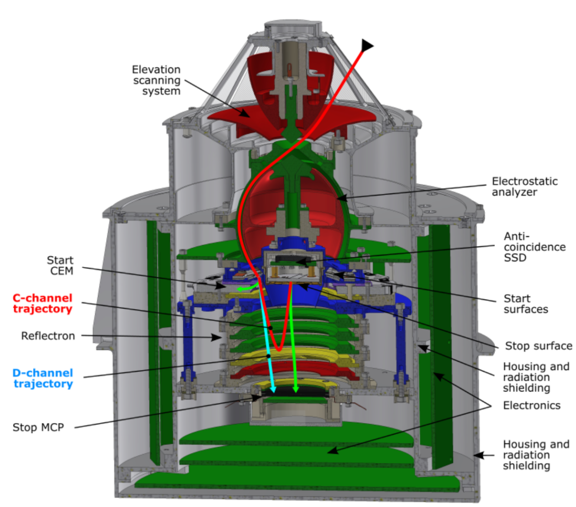

Figure 1: cross section of JDC with typical particle trajectories indicated

Following a typical trajectory, particles will enter JDC through the elevation scanning system on top of the sensor. This subsystem consists of two electrodes between which an electric field is applied. By adjusting this electric field 12 elevation steps are covered. The field-of-view is further divided into 16 azimuthal sectors. With this a hemispherical field-of-view is obtained.

Subsequently particles pass through the electrostatic analyzer, which has a compact wedge shaped form[2]. In the electrostatic analyzer the particles are separated according to their energy per charge. The polarity of the voltages in the electrostatic analyzer can be switched, to measure positive and negative particles, including electrons.

Table 1: Expected performance of JDC

Parameter	Performance
Particle species	(i+),(i-),(e)
Energy range	$1\,\mathrm{eV}$ - $40\,\mathrm{keV}$
Energy resolution	12%
Mass range	$1\,\mathrm{amu}$ - $70\,\mathrm{amu}$
Mass resolution	2 - 3 (D-channel) $\geq$ 20 (C-channel)
Field of view	$90°$ x $180°$ ($< 25\,\mathrm{keV}$) $< 90°$ x $180°$ ($> 25\,\mathrm{keV}$)
Angular resolution	$5.5°$ x $19.5°$
Time resolution	2D per $0.8\,\mathrm{s}$ 3D per $11\,\mathrm{s}$
G - Factor	Total: $8 \times 10^{-3}\ \frac{\mathrm{cm^2 sr eV}}{\mathrm{eV}}$ Pixel: $5.6 \times 10^{-4}\ \frac{\mathrm{cm^2 sr eV}}{\mathrm{eV}}$

The exit of the electrostatic analyzer leads the particle to one of 16 azimuthal start surfaces. The particle produces secondary electrons upon scattering on the start surface, changing its charge state to either positive, negative or neutral - with the neutral particles being dominant. The before mentioned secondary electrons are guided into start Channel Electron Multipliers (CEMs), to create the start signal for the time-of-flight measurement. Depending on the new charge state of the particle, different trajectories are possible: The neutral particles propagate on straight lines, without any further interaction inside the reflectron until they hit the stop Multi Channel Plate (MCP). Positive ions are reflected in the linear electric field of the reflectron and will hit the stop surface guarded by an anti-coincidence Solid State Detector (SSD). During this interaction additional secondary electrons are produced which are focused into the center part of the stop MCP. Negative ions are accelerated inside the linear electric field and their trajectory is slightly bent compared to the trajectory of the neutrals. The stop MCP anode is divided into three separate regions: The center region for the electrons, the outer region, where negative ions and neutrals are detected and a ring in between where particles from both particle populations can be detected. With this setup it is possible to get a high sensitivity for neutrals and negative ions in the D(ynamics)-channel and a high mass resolution for positive ions in the C(omposition)-channel. The performance values are shown in Table 1.

The detectors are placed in the center of JDC, surrounded by an onion shaped radiation shielding: The innermost shell is built out of aluminum, followed by the electronic boards and the outermost layer out of tungsten alloy.

The mechanical assembly of the technological model is currently ongoing and first light of JDC is in the second half of 2018. A first glimpse on the mechanical parts of the entrance system of JDC can be seen in Figure 2. After first light the sensors performance will be compared with the predicted properties, shown in Table1.

Figure 2: JDC TM deflector mechanical parts assembly

References

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