EPSC Abstracts
Vol. 11, EPSC2017-464, 2017
European Planetary Science Congress 2017

The Jovian Electron and Ion Spectrometer (JEI) for the JUICE mission

M. Fränz, U. Bührke, P. Ferreira, H. Fischer, P. Heumüller, N. Krupp, W. Kühne, and E. Roussos
Max Planck Institute for Solar System Research MPS, Göttingen, Germany. (fraenz@mps.mpg.de / Fax: +49-551-384979240)

Abstract

The magnetosphere of Jupiter is apart from the Sun the strongest source of charged particles in the Solar system. The interaction of these particles with the exospheres of the Jovian moons forms one of the most complex plasma laboratories encountered by human space flight. For this reason the plasma analyzer package forms a crucial experiment of the Jupiter Icy Moon Explorer (JUICE) [1,]. As part of the Plasma Environment Package (PEP, [2]) we here describe a combined electron and ion spectrometer which is able to measure the electron and ion distribution functions in the energy range 1 to 50000 eV with high sensitivity and time resolution. This instrument is called the Jovian Electron and Ion Analyzer, JEI.

Sensor Design

The main design drivers for the Jovian Electron and Ion Analyzer, JEI, are: (1) Usage of robust and proven components to allow stable measurements after 8 years of interplanetary cruise and 2 years in the harsh Jovian environment. (2) Usage of front end electronics with very high radiation hardness (better than 200krad) - more sensitive electronics are located in the PEP common rack. (3) Usage of a sensor technique with very high signal to noise ratio to allow simple front end electronics. (4) Minimize the sensitive area to allow measurements during times of high radiation background (5) Achieving a spatial resolution of at least 22.5 deg in azimuth and polar angle to allow measurement of electron and ion loss cones and spatial extend of ion beams. (6) Achieving an energy resolution of better than 10% to allow detection of local acceleration processes and mass discrimination in cold ion beams. (7) Minimize sensor entrance opening and move all radiation sensitive parts to the bottom of the sensor. (8) To achieve a total geometric factor of better than 10^{-4} cm^{2}sr(eV/eV) to have a high signal to noise ratio .

Sensor Technique

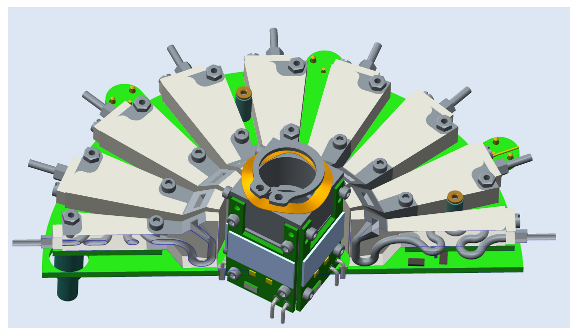

Figure 1: Cut through the JEI detector plane consisting of 16 CEMs .

The considerations listed above did lead to the conclusion that the electron and ion detection should be via Channel Electron Multipliers (CEMs) and not via Micro Channel Plates (MCP). General performance of CEMs and MCPs on previous space mission is discussed in [3]. Both CEMs and MCPs have been shown to survive 11 years of operation in the Earth radiation belts on the Polar Hydra experiment. But we think that CEMs have following advantages for use on the JUICE mission: (1) CEMs have a much higher signal to noise ratio than MCPs. This means that the lower signal produced by penetrating radiation can be easier suppressed by an amplifier threshold for CEMs as it was done for the Galileo PLS sensor [4,]. (2) CEM entrance area can be made significantly smaller than for MCPs reducing the sensitive area for background radiation. (3) CEM electronics are simpler than MCP electronics and have thus lower radiation protection requirements. (4) CEMs use one amplifier per pixel which means that count rates of 1MHz per pixel can be measured without saturation. Usual MCP setups use fewer amplifiers such that maximum count rate per pixel is much lower. (5) CEM design can be adapted in close cooperation with the manufacturer.

In the study phase for the JUICE mission we developed with Sjuts Optics, Göttingen, a specific sensor design which allows to arrange 16 CEMs in a circular array (2) with 22.5 degree azimuthal resolution and a total opening area of only 16x0.08cm^2=1.28cm^2. The area of the CEM which is sensitive to penetrating radiation is defined by the CEM entrance cone. It is about 10 times larger than the entrance cross-section. For this reason we will position an anti-coincidence solid state detector (SSD) above the CEM plane.

Sensor Ion Optics Design

The ion optics design of the JEI sensor is driven by points 4 to 8 listed above. To keep the geometry simple and allow measurement of both ions and electrons we decided to choose a pure electrostatic analyzer with a spherical energy analyzer (ELSA) and electrostatic entrance deflectors. The diameter of the analyzer is limited by the diameter of the circular CEM array and by the available sensor mass of about 800g without radiation shielding components. Energy resolu-

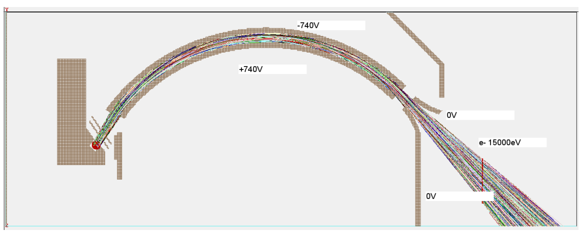

Figure 2: JEI SIMION simulation of ion optics for specific voltage/energy setting.

tion and range are determined by the analyzer constant k=R/ΔR where ΔR is the gap distance between the analyzer spheres and R is the midpoint radius of the analyzer gap. To avoid discharges in non-pure vacuum voltage difference between charged parts of the sensor should be smaller than 2.0kV/mm. For this reason we have chosen a gap distance of ΔR=2mm. This results in an analyzer constant of k=19.75 with an energy resolution of ΔE/E=8.3% and a maximum analyzer voltage of 4.0kV to measure particles up to energies of 40keV/q. In clean vacuum conditions the voltage can be increased to 6kV, allowing a maximum energy of 60keV/q.

Mechanical Design

The mechanical design of the JEI sensor is driven by the mass and volume constraints and by the fact that

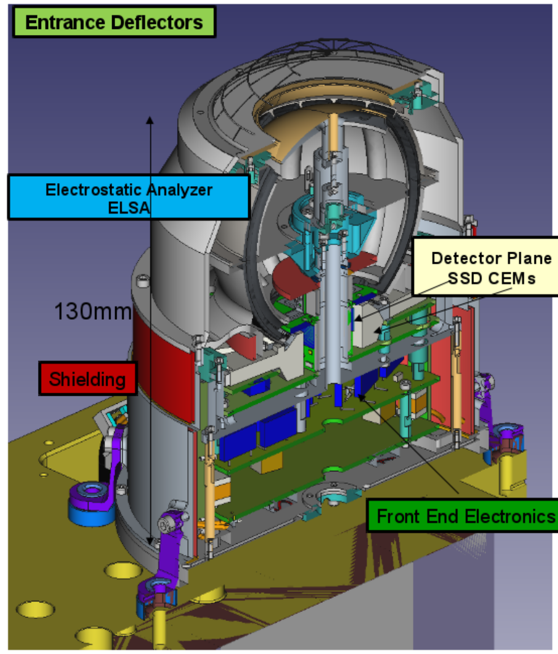

Figure 3: JEI sensor mechanical construction.

part of the electronics must be located close to the detectors to avoid noise from long signal cables. Thus the design follows the cylindical symmetry given by the ion optics. Electronic boards are also circular and added at the bottom of the sensor. All other electronic boards (high voltage supply, channeltron preamplifier, control board) are located in a common rack of the PEP instrument located below the spacecraft panel (not shown here). Radiation shielding elements made from tungsten-copper alloy (red parts in Fig.3) are optimized to reduce the count rates by secondary emission in the detector area.

References

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