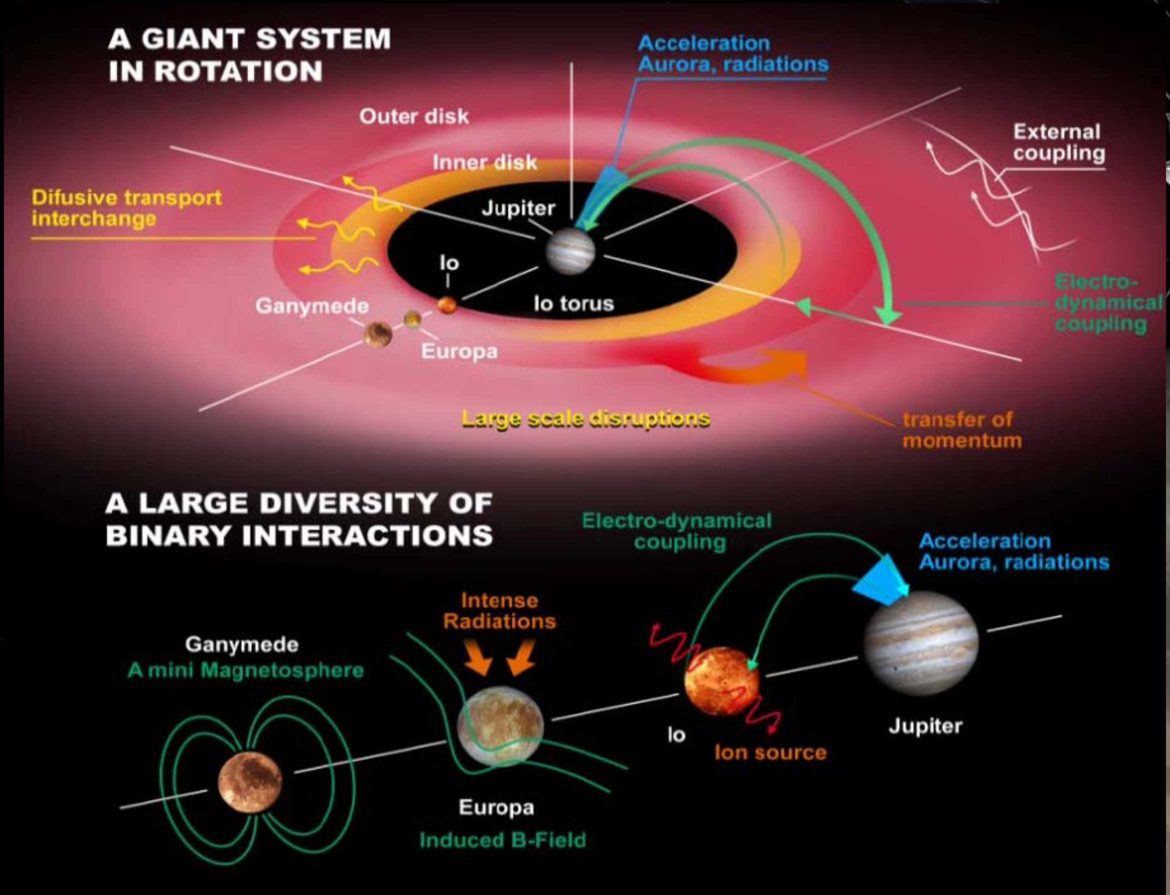
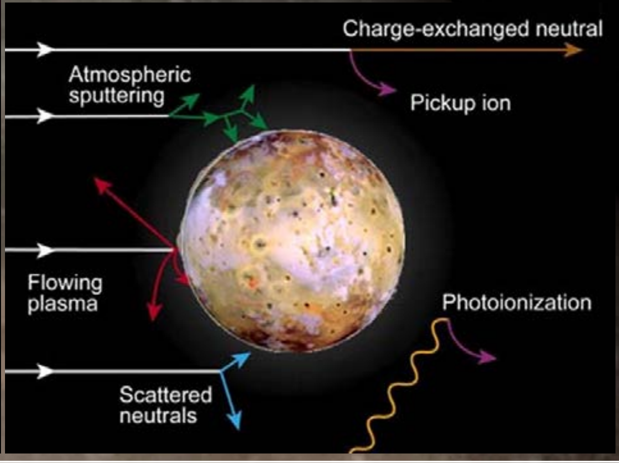
Radiation Measurements with JUICE

Torgeir Paulsen - ESA/Estec

26/04/2018

Jovian Magnetosphere

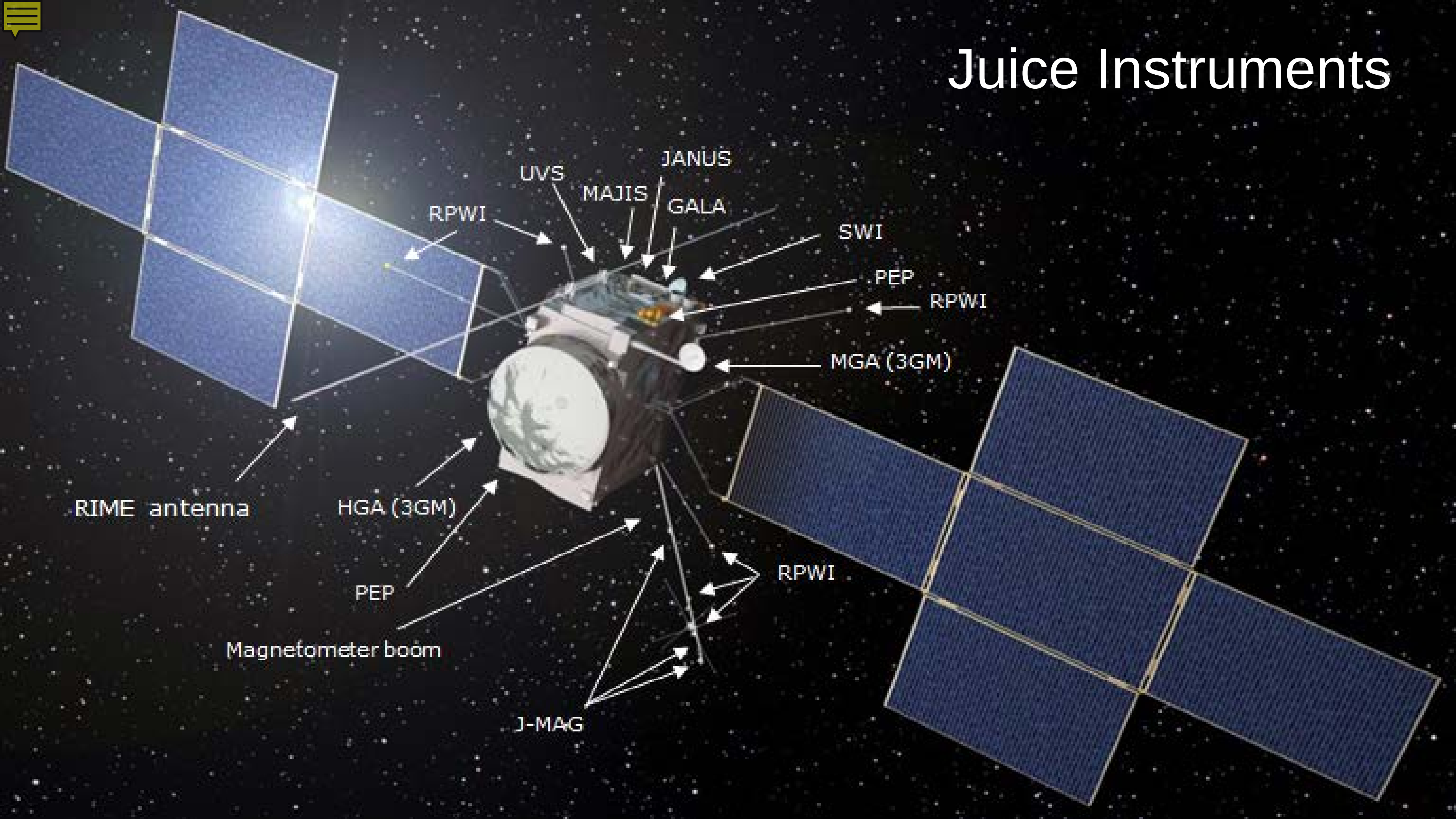




Plasma Experiments in Past and Future Missions

Spacecraft	Arrival	Type of instruments
Pioneer 10 & 11	1973/74 flyby	Helium Vector Magnetometer, Plasma Analyzer, Charged Particle Instrument, Geiger Tube Telescope, Trapped Radiation Detector
Voyager 1 & 2	1979 flyby	Triaxial Fluxgate Magnetometer, Plasma Spectrometer, Low Energy Charged Particle Instrument, Cosmic Ray System
Galileo	1995 – 2003 orbiter 1995, 2003 atmospheric	Magnetometer, Energetic Particles Detector, Heavy Ion Counter, Plasma Subsystem, Plasma Wave Subsystem
Ulysses	1992, 2004 gravity assist	Solar wind plasma experiment, Solar wind ion composition experiment, Magnetic fields experiment, Energetic-particle composition/neutral gas experiment, Low-energy charged-particle composition/anisotropy experiment, Cosmic rays and solar particles experiment, Radio/plasma waves experiment, Solar x-rays and cosmic gamma-ray bursts experiment
Cassini–Huygens	2000 gravity assist	Cassini Plasma Spectrometer, Ion and Neutral Mass Spectrometer, Dual Technique Magnetometer (Helium Vector and Fluxgate), Magnetospheric Imaging Instrument, Radio and Plasma Wave Science
New Horizons	2007 gravity assist	Time of flight ion and electron sensor, electrostatic analyzer and retarding potential analyzer
Juno	2016 orbiter	Fluxgate Magnetometer (supported by star sensors), Jovian Auroral Distributions Experiment, Jovian Energetic Particle Detector Instrument, Radio and Plasma Wave Sensor
Rosetta	2004 gravity assist	Spectrometer for Ion and Neutral Analysis, Cometary Secondary Ion Mass Analyser

Juice Instruments



Particle Experiment Package (PEP)

JNA: Low energy Energetic Neutral Atom (ENA) imager

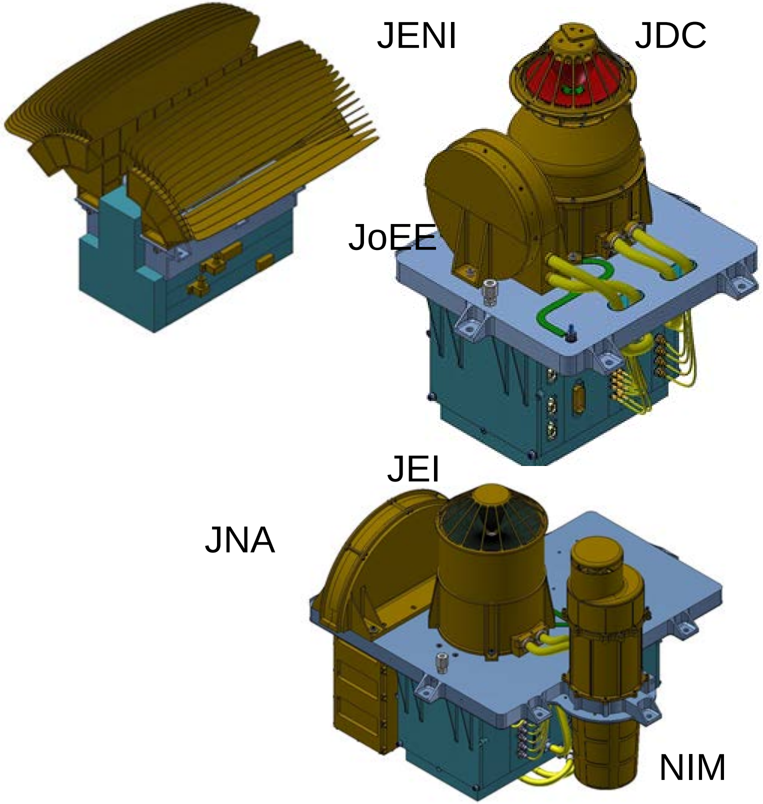
JENI: Energetic ion spectrometer and ENA imager

NIM: Neutral gas and ion mass spectrometer

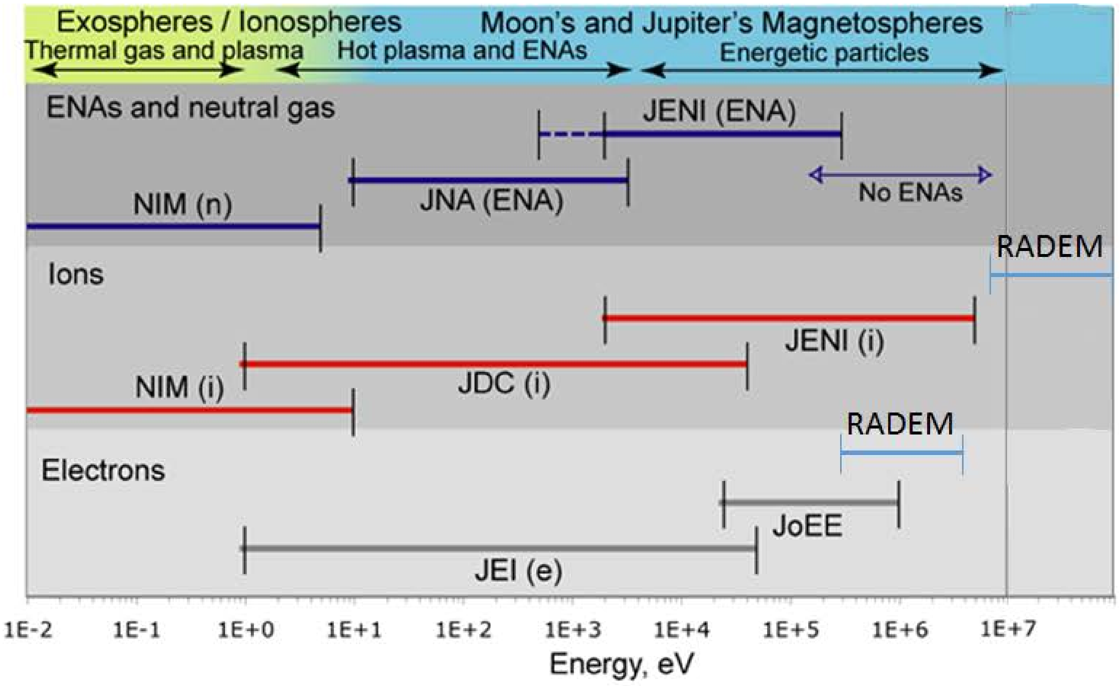
JDC: Plasma dynamics & composition analyser

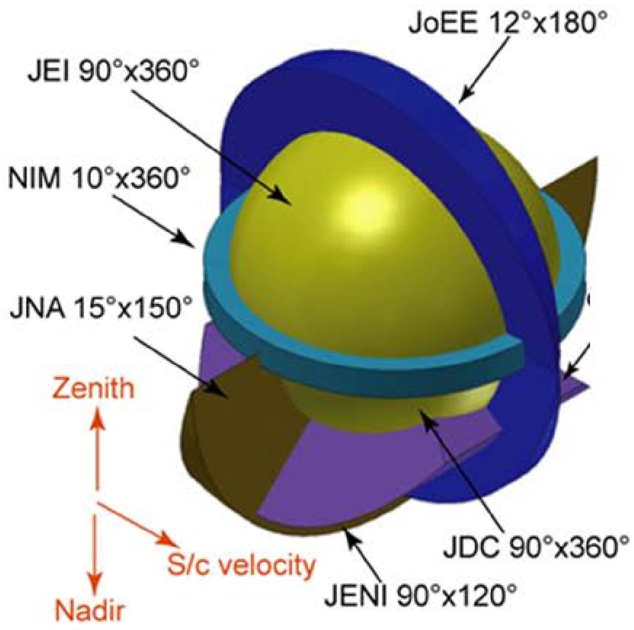
JEI: Electron and ion sensor

JoEE: Energetic electrons spectrometer

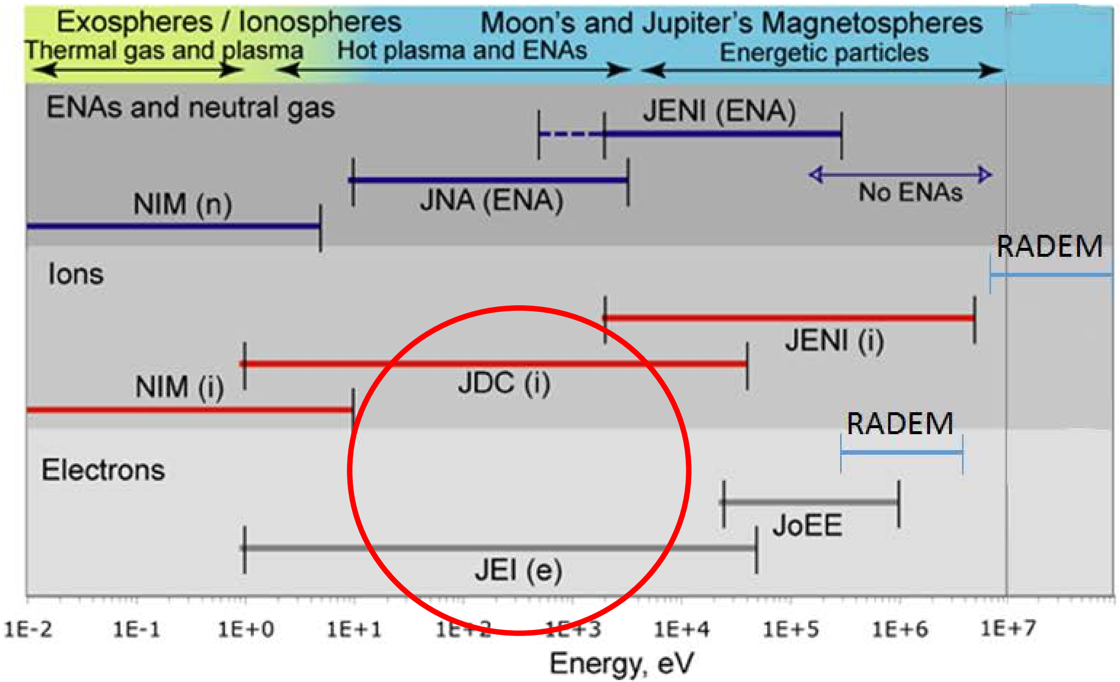


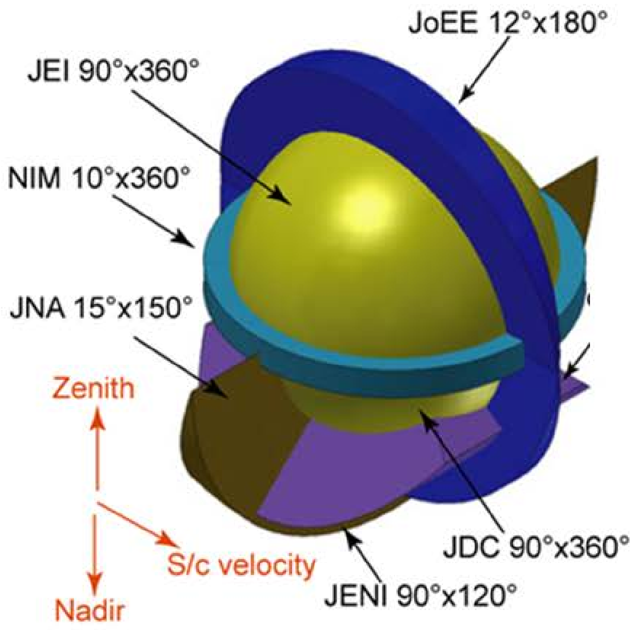
Particle vs Energy / Field of View





JDC/JEI Particle vs Energy / Field of View





JDC: Plasma Dynamics & Composition Analyser
JEI: Electron & Ion spectrometer

Jovian Dynamics and Composition (JDC)

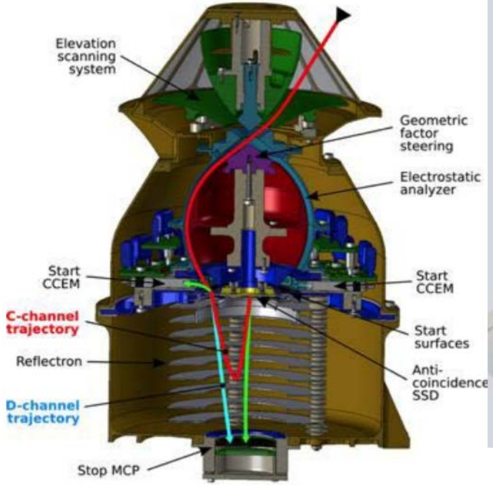
The Swedish Institute of Space Physics, Kiruna

Plasma ions and electrons

1 eV – 41 keV, ΔE/E=12%

M/ΔM=30

Hemispheric, 5.5˚x19.5˚ resolution



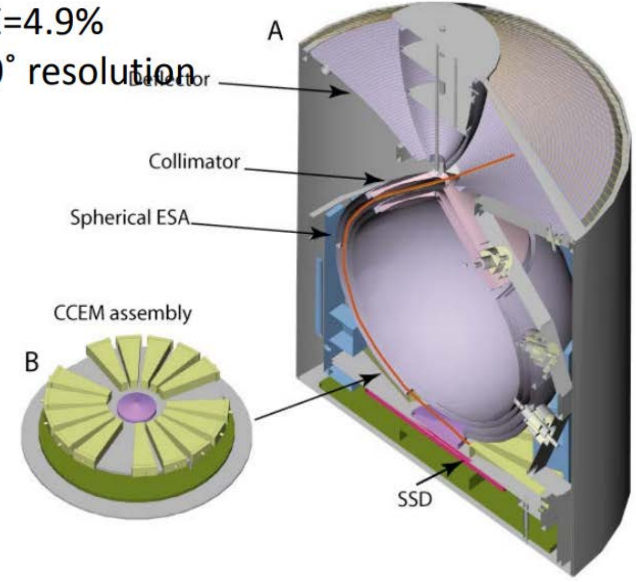
Jovian Electrons and Ions (JEI)

Max-Planck Institute,

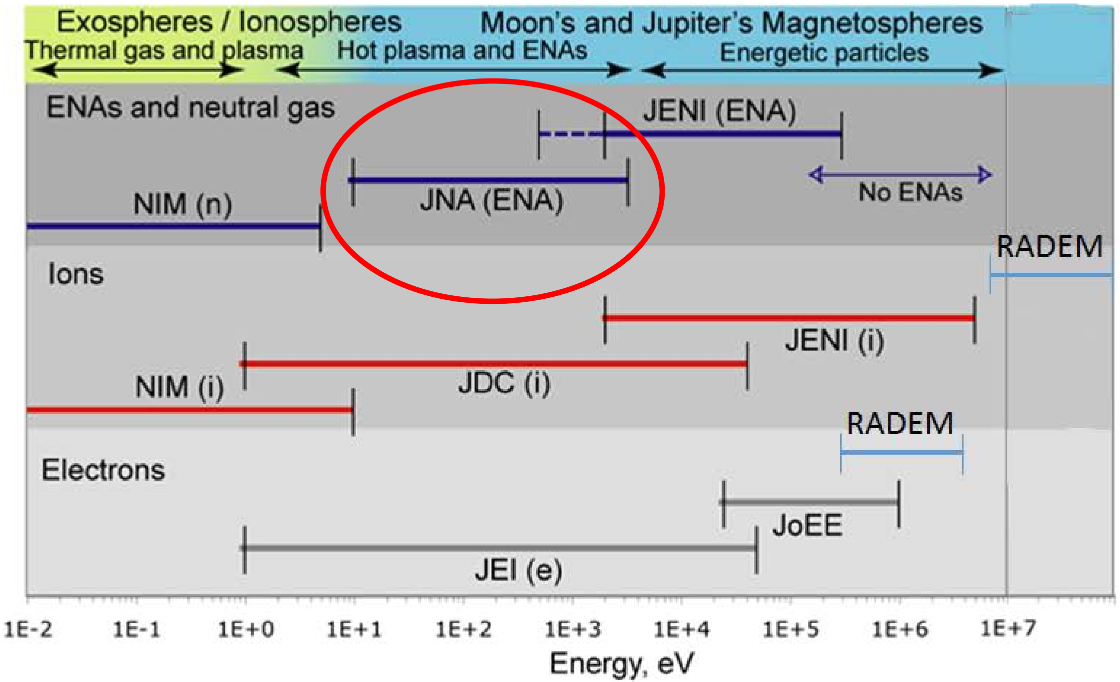
Plasma electrons and ions

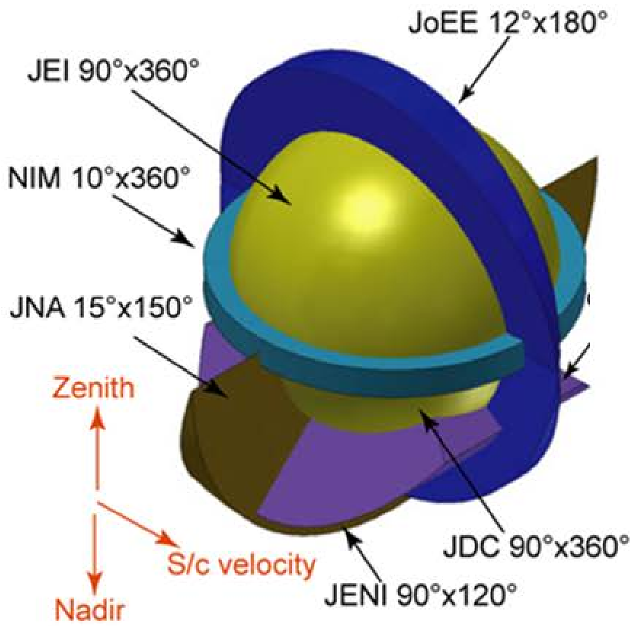
~1 eV – 50 keV, ΔE/E=4.9%

Hemispheric, 20˚x10˚ resolution



JNA Particle vs Energy / Field of View





JNA: Jovian Neutral Atoms Analyser

Jovian Neutral Atoms (JNA)

The Swedish Institute of Space Physics, Kiruna

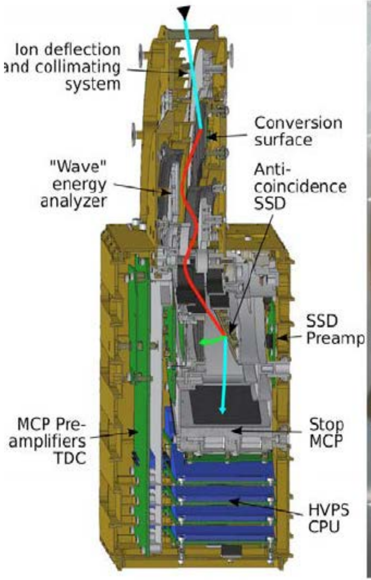
Low-energy ENA
10 eV – 3 keV (H)
7°x25° resolution

JNA will quantify low energy ENA fluxes from Ganymede and to create ENA maps of the surface.

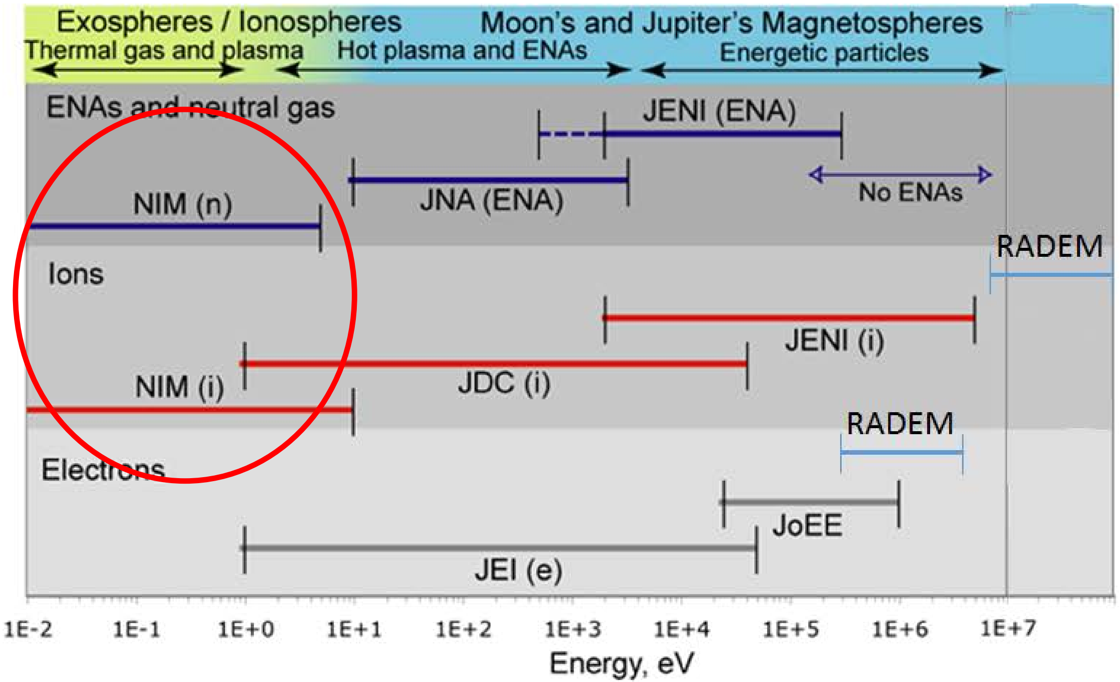
Nearly identical to flight-tested and successfully operated instruments (Chandrayaan-1)

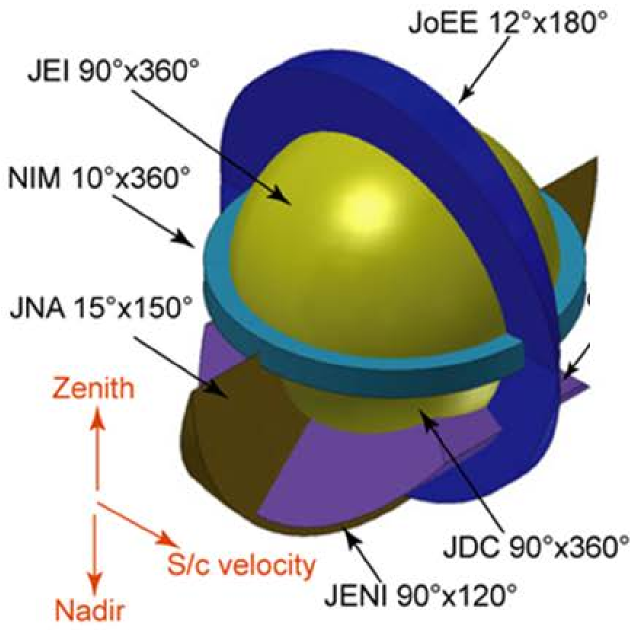
Uses triple coincidence

Based on the particle – surface interaction principle

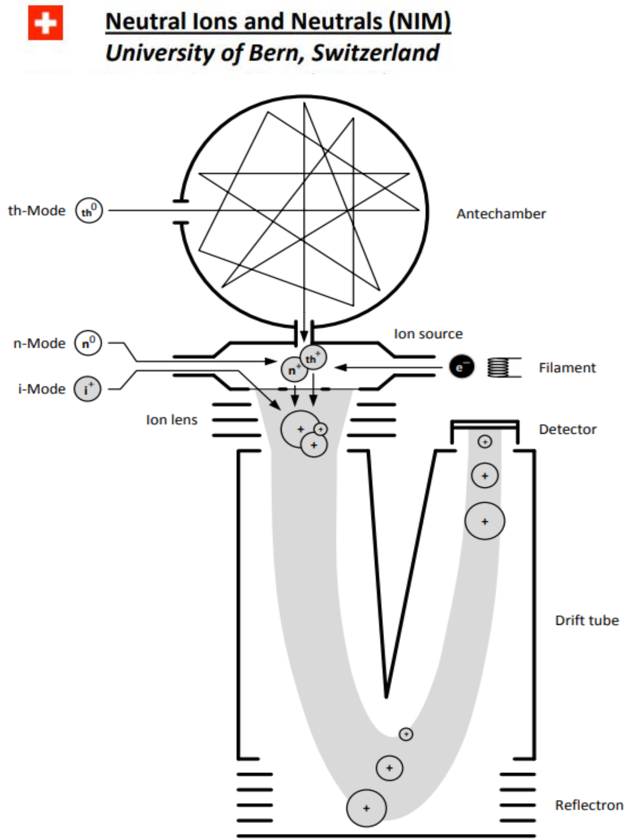


NIM Particle vs Energy / Field of View





NIM: Neutral Gas & Ion Mass Spectrometer

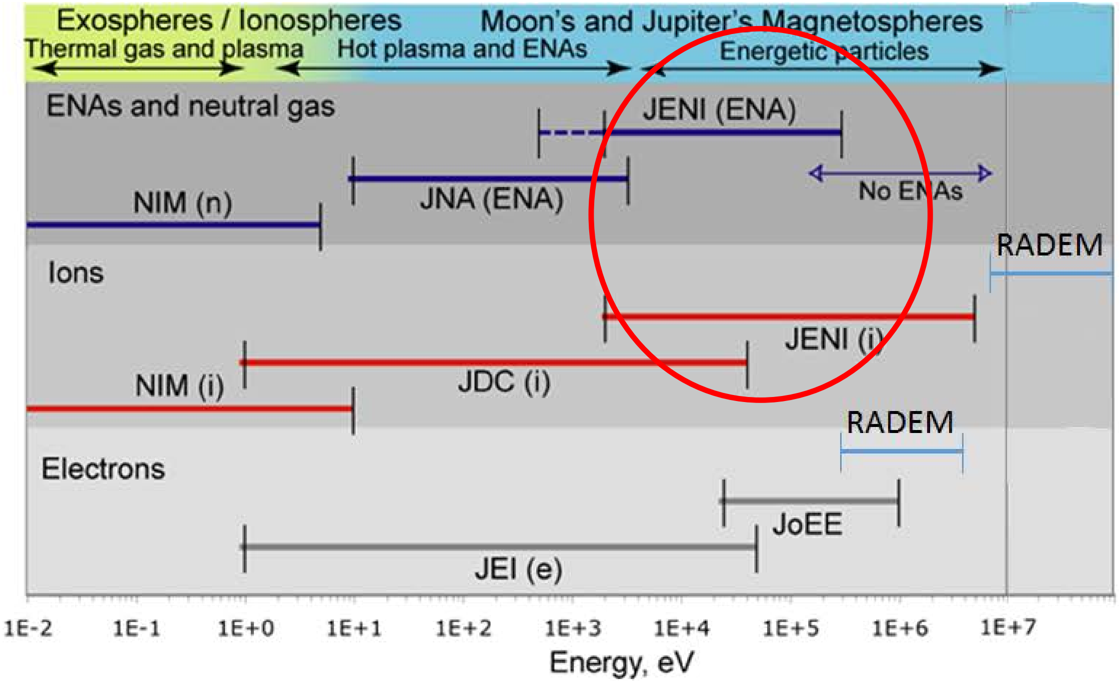


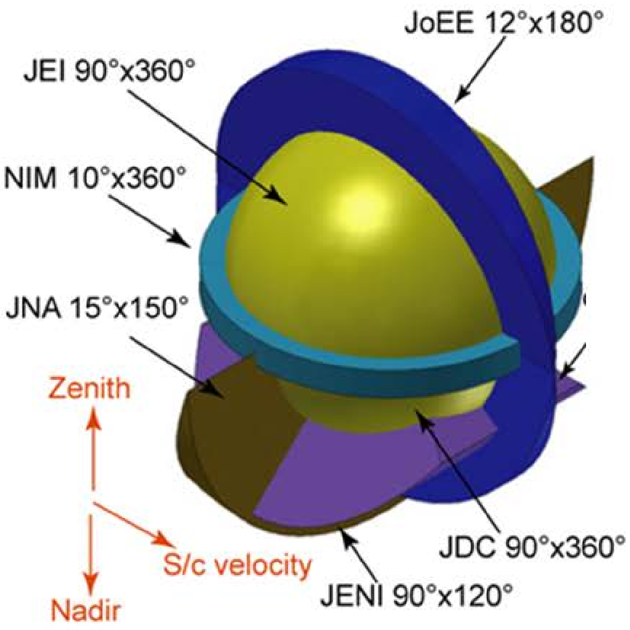
NIM is a Time of Flight (ToF) mass spectrometer with a ToF reflectron and can work in either neutral mode and ion mode.

In the ion mode it collects ions from the ambient plasma.

In the neutral mode ambient neutral gas entering the instrument is ionized by electron impact and the resulting ions are stored.

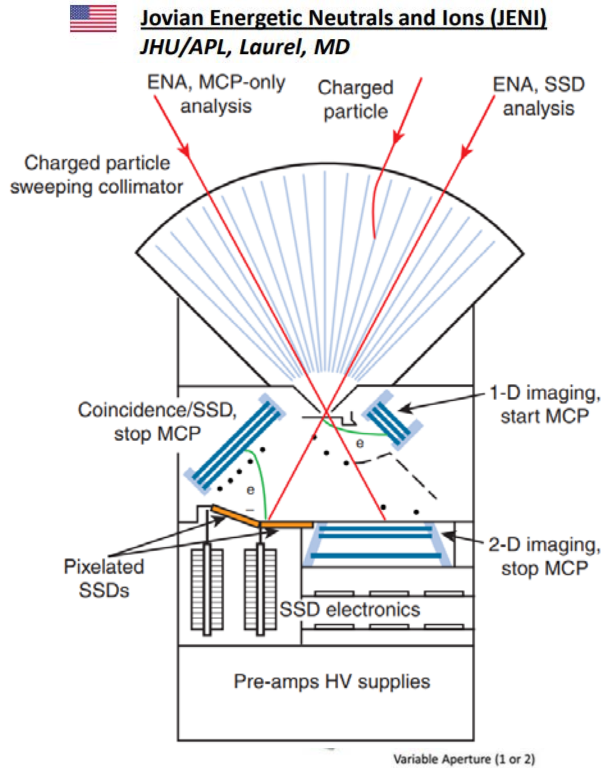
JENI Particle vs Energy / Field of View





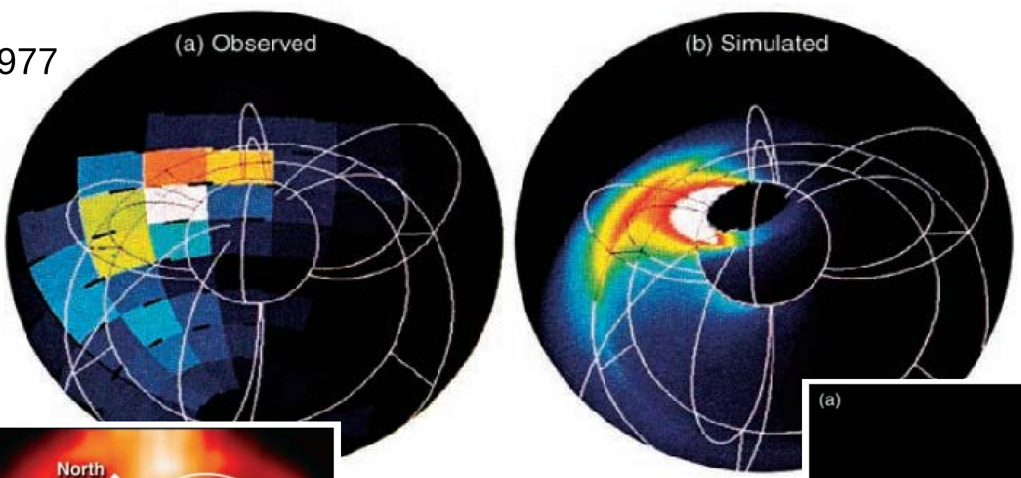
JENI: Neutral Gas & Ion Mass Spectrometer

- Combined high-resolution, high sensitivity ENA camera and energetic ion and electron imaging Spectrometer.
- A foil-based TOF system provides triple coincidences to operate in Jupiter’s harsh environment.
- Global imaging of hot plasma (energetic particles) energization critical to understanding the creation and stability of magneto-discs
- Global imaging of neutral gas torus to constrain Europa’s and Io’s surface release to space

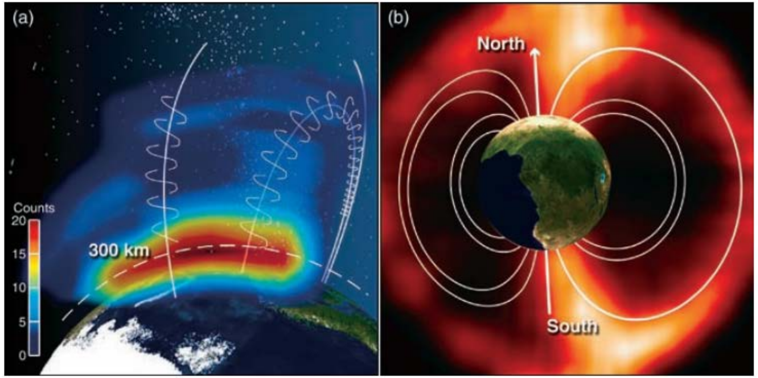


JENI/JNA ENA Instruments

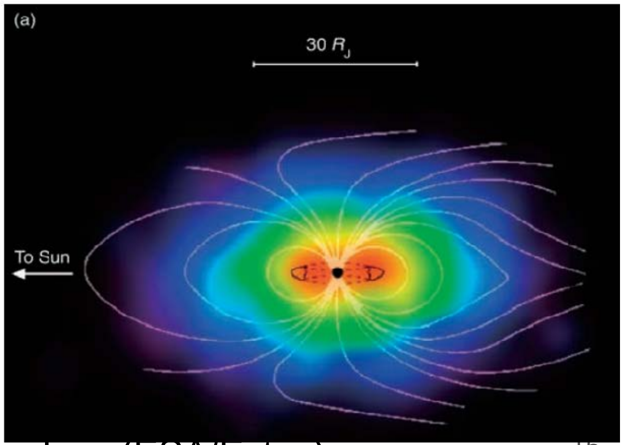
ISEE-1 1977



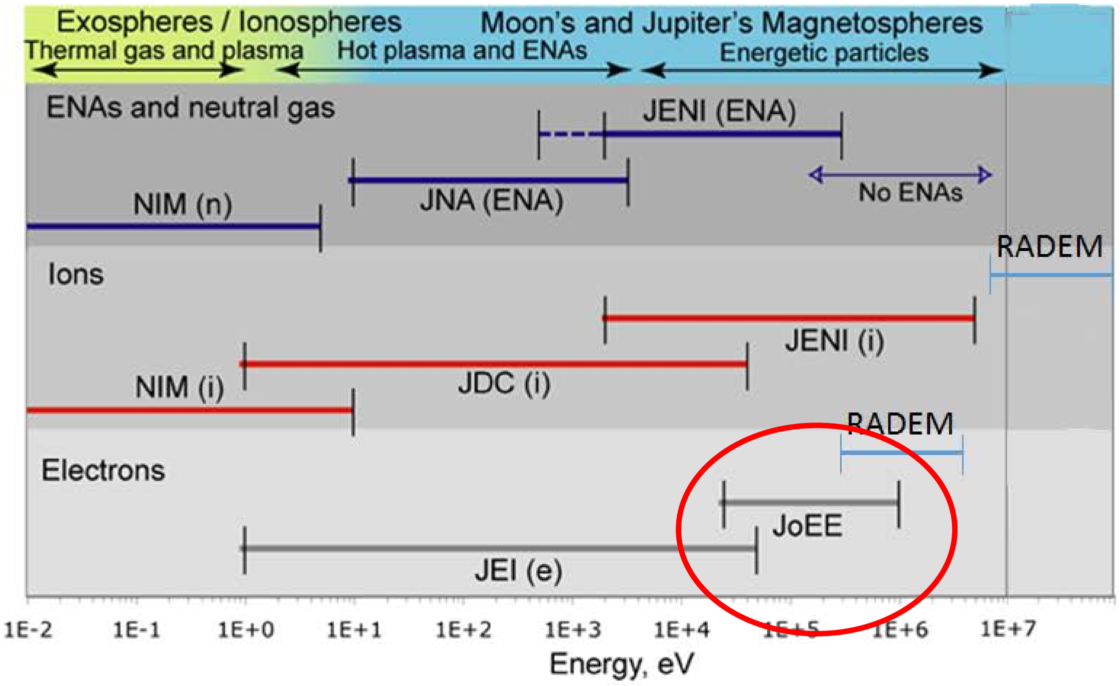
ASTRID 1995

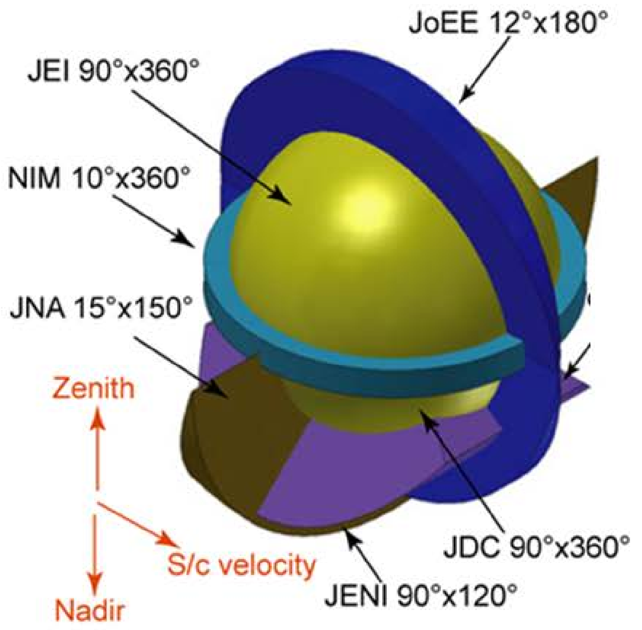


Cassini 2004



JoEE Particle vs Energy / Field of View





JoEE: Energetic Electrons Spectrometer

- JoEE measures an energy spectrum near simultaneously in eight different directions using a self-closing magnets to separate electrons of different energies on to SSD pixels for spatial coincidences.
- Built on Galieo/EPD background rejection techniques proven at Jupiter
- Uses double coincidence to mitigate radiation

Jovian Energetic Electrons (JoEE)

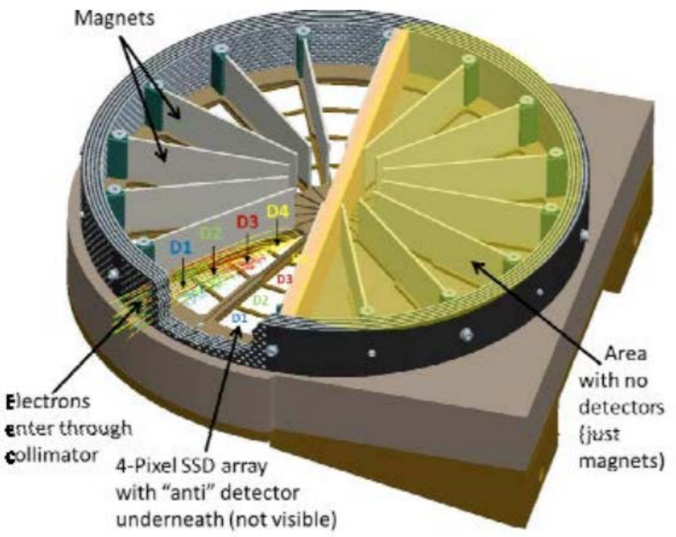
JHU/APL, Laurel, MD

Energetic electrons

25 keV – 1 MeV, ΔE/E≤20%

12˚x180˚, 12˚x22˚ resolution

Δt = 0.3 s

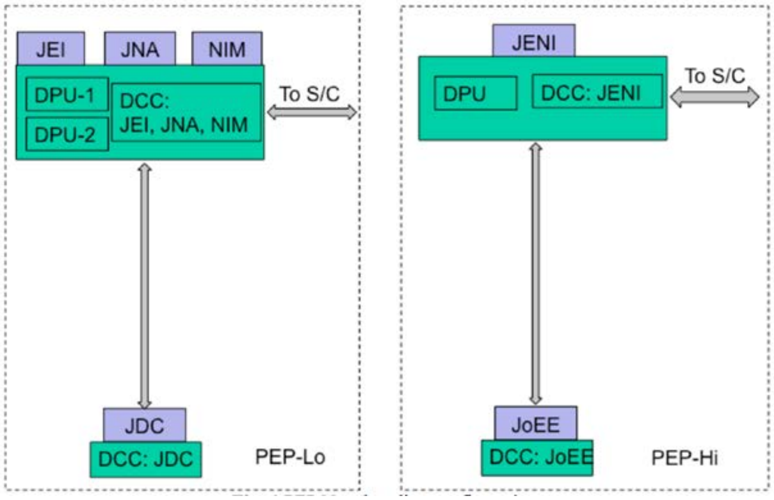


Challenges

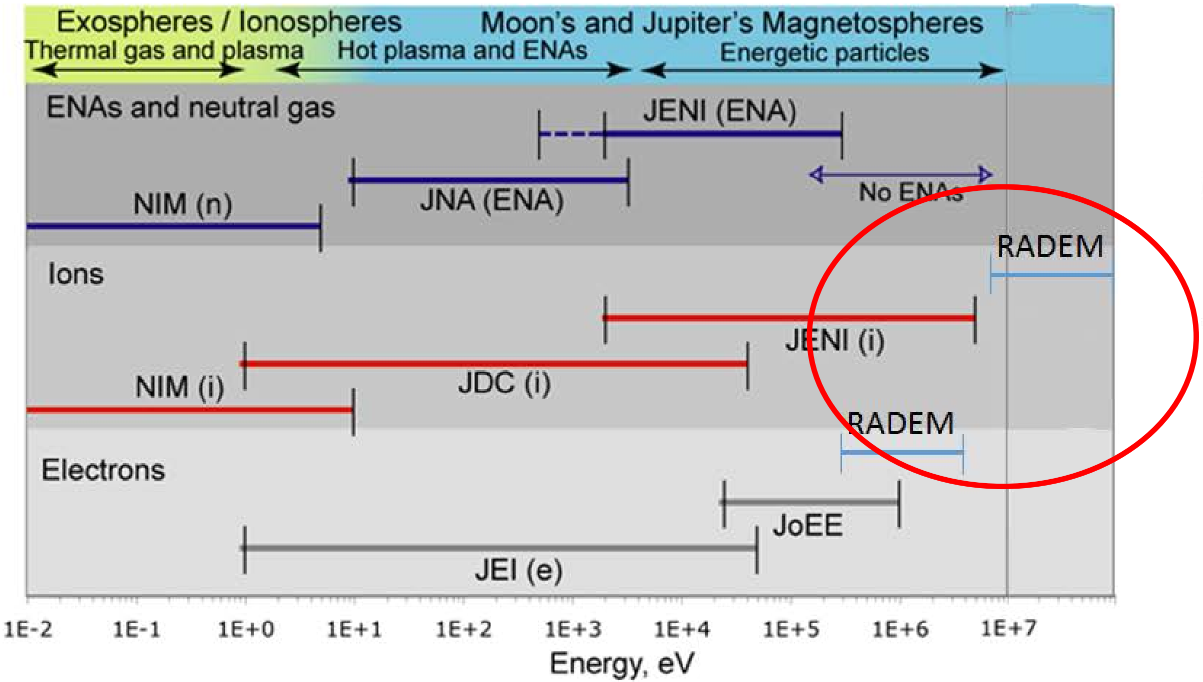
- Usage of robust and proven components.
- Balancing the advantage of new & unproven technology (e.g. FPGA/ASIC) against old & proven
- Usage of front end electronics with very high radiation hardness (better than 200krad)
- Optimise the usage of (usually heavy) radiation shielding material (typically Tungsten Copper alloys)
- Usage of a sensor technique with very high signal to noise ratio to allow simple front end electronics.
- Maintain the instrument mass and power allocation throughout the development cycle.
- Avoiding charging of the S/C. A potential buildup (typically due to UV) will repel ions in the lower energy range (critical for NIM, JDC and JEI instruments)
- Planning for long lead time components, maintaining the development time.
- Ensure younger scientist are motivated and attracted to the project, ensuring continuation and transfer of know-how.

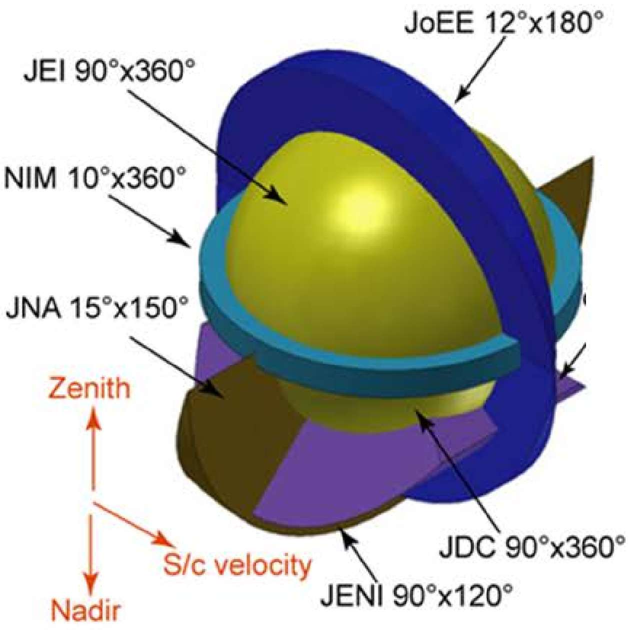
PEP Sensor Organisation

- The PEP sensors are grouped in two separate instruments.
- The European PEP Lo and US PEP Hi (Lo and Hi referring to the energy range)
- The PEP Lo sensor JEI, JNA, NIM and JDC are controlled by a common processor unit and communicating independently with the S/C main computer/memory. Similarly PEP Hi sensors JENI and JoEE has a common control unit.
- Both instruments communicates with the S/C computer via SpaceWire for storage and command
- The SpaceWire bus allows point to point communication with other instruments (i.e. RPWI and JMAG)



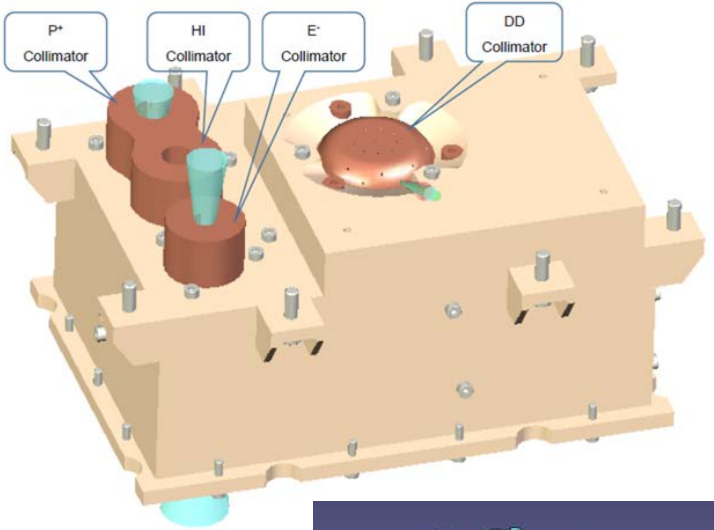
SREM/RADEM Particle vs Energy / Field of View

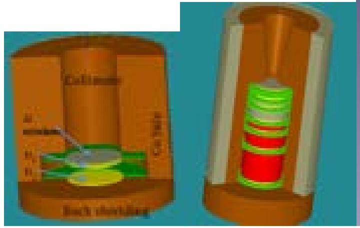


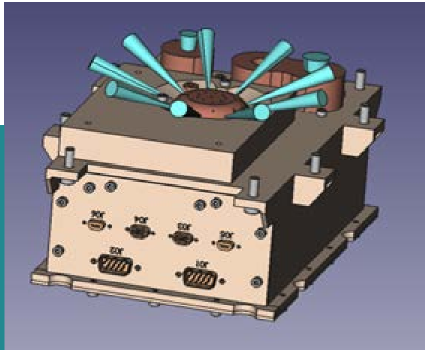


RADEM

- The RADEM is a Space radiation environment monitor and is ta
made for the Jovian environment.
- Its purpose is in-space environment monitoring for detection an
characterisation of the space energetic particles in terms of tota
dose, discrimi-nating types and energy levels as well as
determining the direction of the electrons fluxes.
- The goal is upgrade the radiation environment engineering moc
for Jupiter
- The RADEM is comprised of a single unit containing all the
required hardware.







RADEM Main Performance Drivers

Made up of three RADEM detectors heads, based on Si detectors and interfacing with the ASIC VATA466:

P&IDH (Protons & Heavy Ions Detector Head)
– detect Protons in the range 5 - 250MeV
– be able to count up to a peak proton flux of 10^8 #.cm-2.s-1 for protons with energy above 5MeV
EDH (Electrons Detector Head)
– detect Electrons in the range 300 KeV to 40MeV
– be able to count up to a maximum flux of 10^9 #.cm-2.s-1, for electrons with energy above 300 keV:
DDH (Directional Detector Head)
– detect electrons in the range 0.3 to 10MeV and shall be insensitive to protons with energy below 5MeV
– have a field-of-view with cone half angle of 74.5 degrees (65% of 2πΩ)
– have an angular separation capability of 25º elevation and 45º azimuth
Designed to be always on, also during cruise
Low weight (< 2.5kg), low power (< 2.6W)
SpaceWire interface, very low data rate (< 50 bps)