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JUICE-JAPAN WG 木星氷衛星探査計画
—JUICE-PEP/JNA 高速中性粒子計測装置 —

Development of low-energy energetic neutral atom analyzer to be onboard JUICE spacecraft

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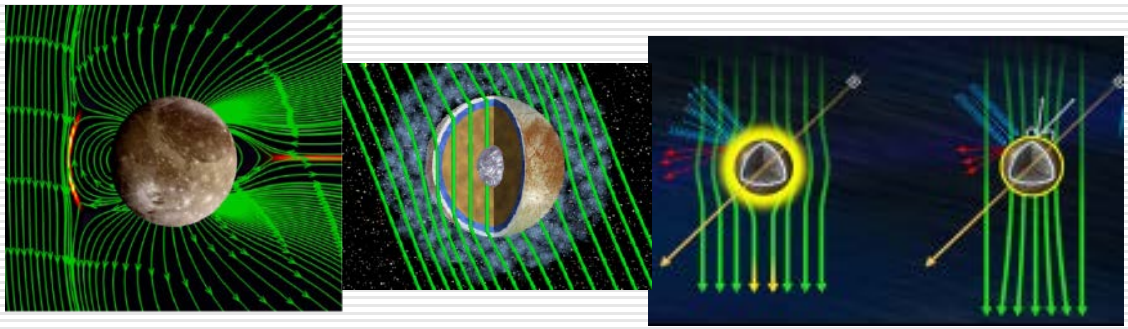
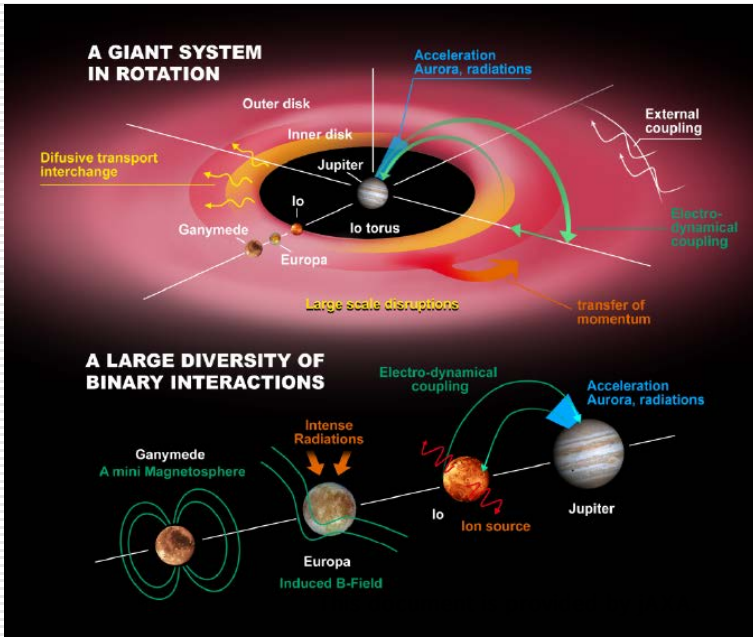
JUICE

- Launch (expected): 2022-2023
- Jupiter orbit insertion (expected): 2030-2031
- Scientific objective:
  - Investigation of Jovian icy satellite (Ganymede, Europa, Callisto) to understand the potential of an environment to support life.
  - Investigation of Jupiter system as an archetype for gas giants



Ganymede Europa Callisto



PEP (Particle Environment Package)

Name		Energy range	Unit to be installed
JEI	Ion / electron energy analyzer	1eV/q – 25keV/q	ZU
JoEE	High energy electron energy analyzer	10keV – 1MeV	ZU
JDC	Ion energy mass analyzer	1eV/q – 25keV/q	NU
NIM	Thermal neutral / ion mass analyzer	thermal	NU
JNA	ENA energy mass analyzer (low-energy)	10eV – 3300eV	NU
JENI	ENA / ion mass analyzer (high-energy)	3keV – 300 keV	EU

NU: Nadia Unit
ZU: Zenith Unit
EU: Energetic particle Unit

Scientific objectives of PEP/JNA

PEP/JNA (Particle Environment Package / Jovian Neutral Analyzer) will perform a direct measurement of:

- Back-scattered particle
- Sputtered particle

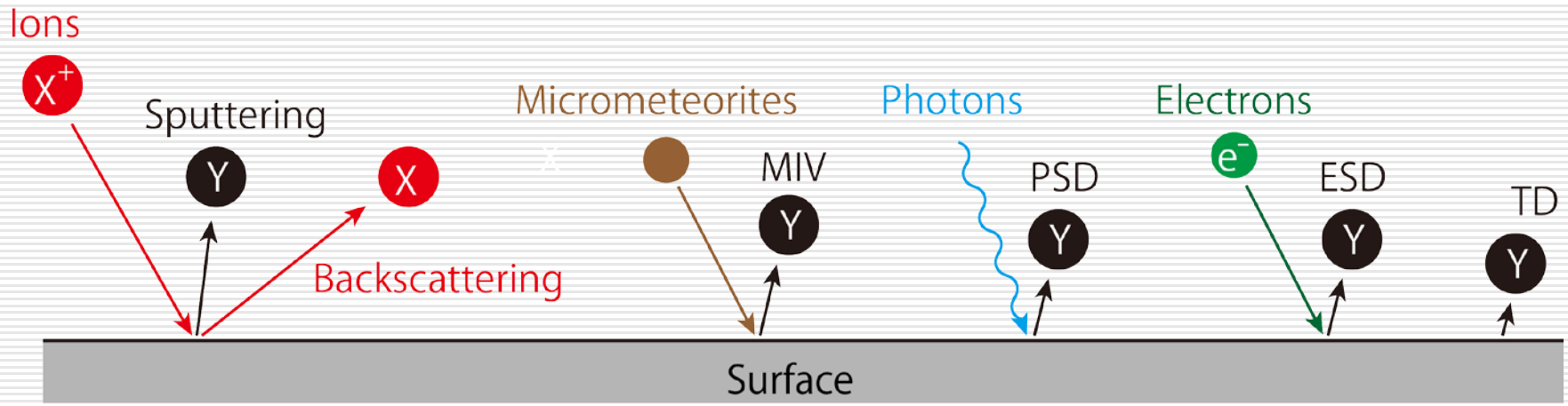
coming from satellite surface.

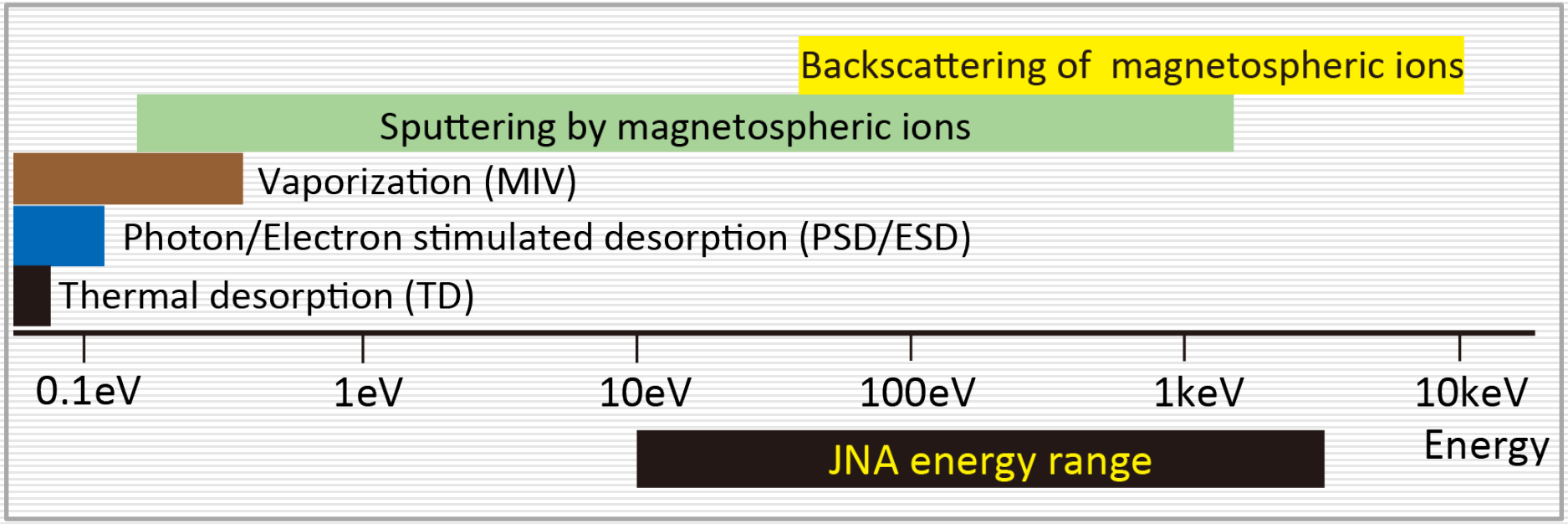
- Neutral particles draw ballistic trajectories because of no effects due to electric / magnetic fields.
- Remote-imaging will be possible and it provides us large-scale characteristics of plasma particles precipitating from Ganymede's magnetosphere toward the satellite surface.

It will provide us:

- Understanding of plasma structure of Ganymede magnetosphere
- Understanding of a role of satellite for mass transport in Jovian magnetosphere

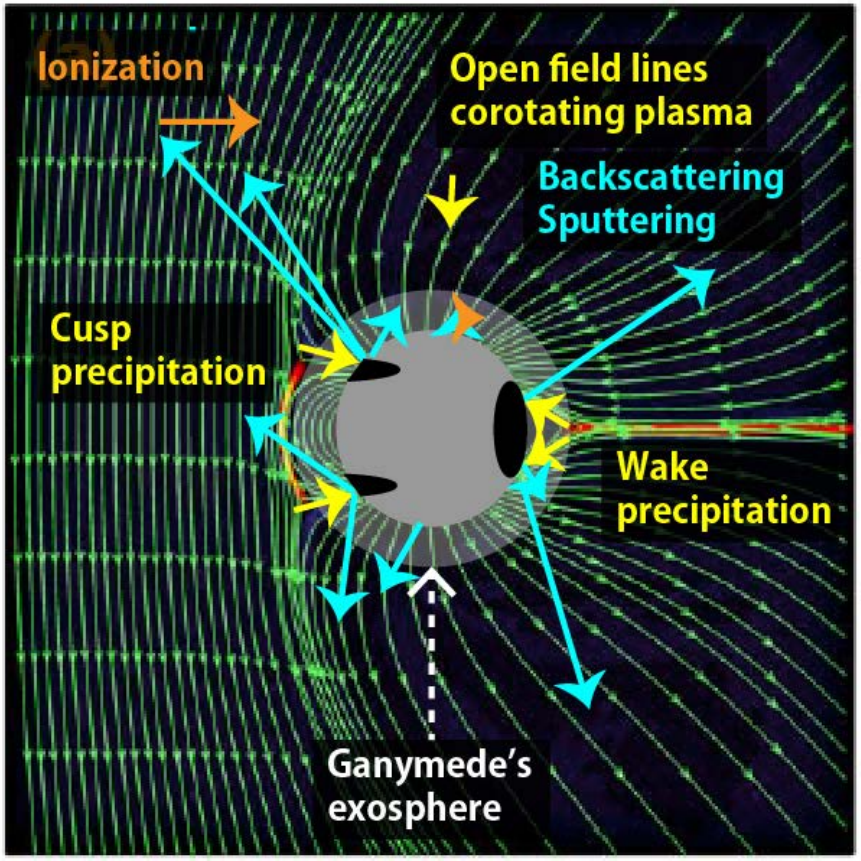
Processes of particle emission from the satellite surface





- Only backscattering / sputtering processes can generate high-energy neutrals.

Structure of Ganymede ‘s magnetosphere
Source/loss/transport processes due to the satellite



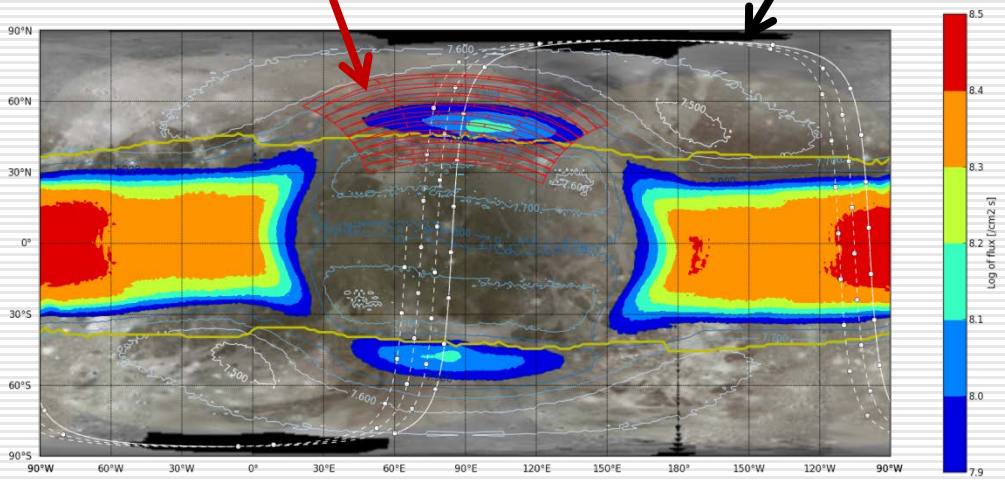
[Jia et al., 2008, modified]

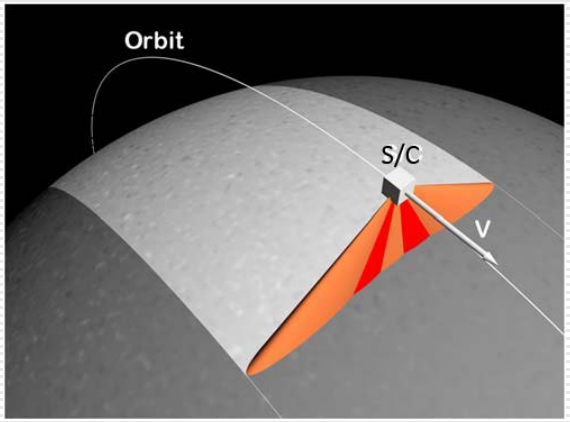
- Ganymede has an intrinsic magnetic moment.
- Ganymede’s magnetosphere is generated in Jovian co-rotating plasmas. Its characteristics are different from those of terrestrial magnetosphere.
- Localized precipitation of plasma particles, which reflects magnetospheric structure (Loss of magnetospheric plasmas)
- Emission due to back-scattering / sputtering
- Exosphere / ionosphere / torus
- Ionization of neutrals (source of plasmas for the magnetosphere)

Precipitating region (numerical simulation)

PEP/JNA FOV

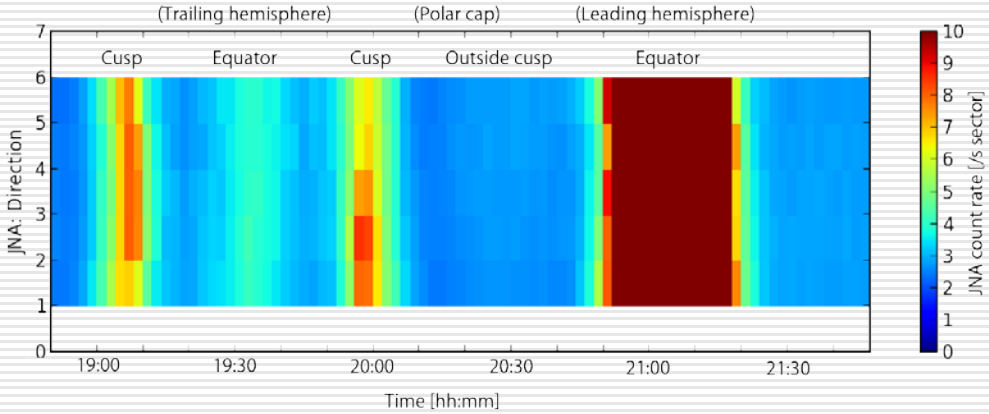
JUICE trajectory (500km x 500km)





- Cusp
- Precipitation at low latitude which corresponds to magnetic reconnection above the leading hemisphere

PEP/JNA estimated count rate



Complemental point to in-situ plasma measurements

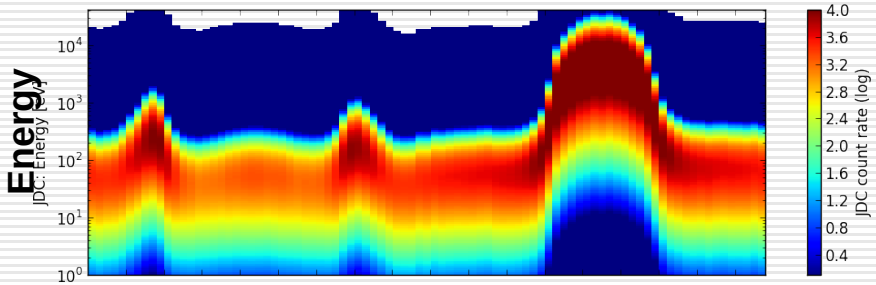
Measurement of L-ENAs

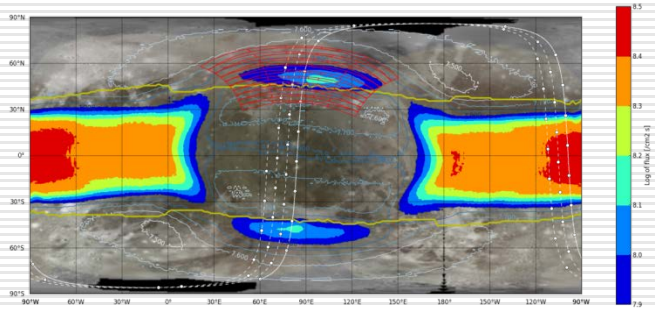
- Remote imaging is possible. It reflects plasma distribution on magnetically connected region to the satellite surface which is inside FOV of the instrument.
- It is difficult to reproduce energy distribution, pitch-angle distribution etc. clearly.

Measurement of plasmas

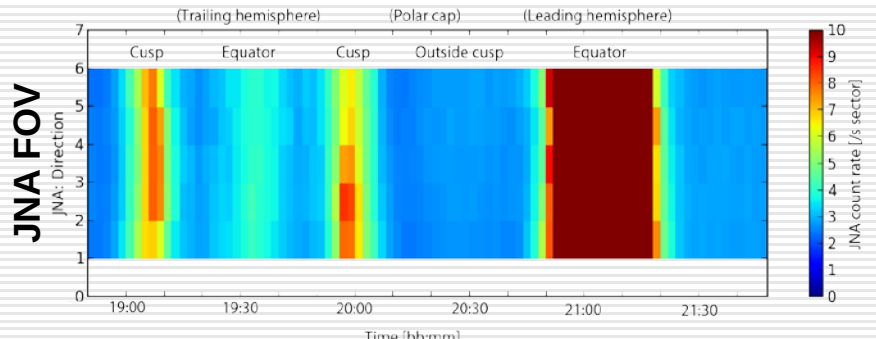
- In-situ observation in principle. Remote imaging is difficult.
- Measurements of plasma structures with better resolution (resolution provided by the instrument) are possible.

Ion (JDC)



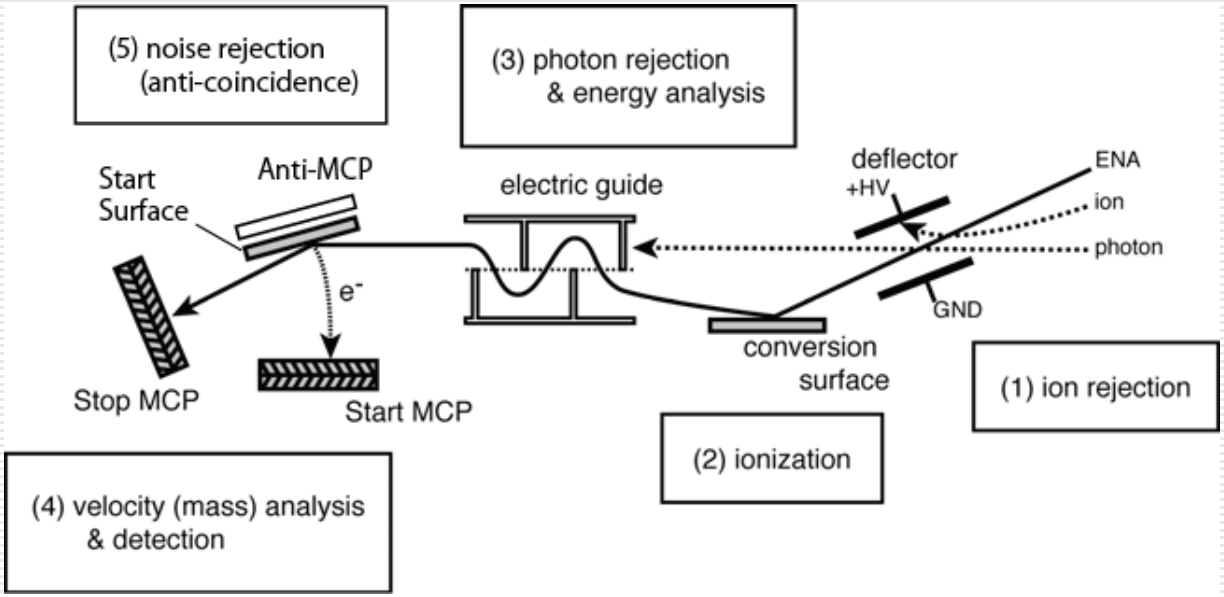


L-ENA (JNA)

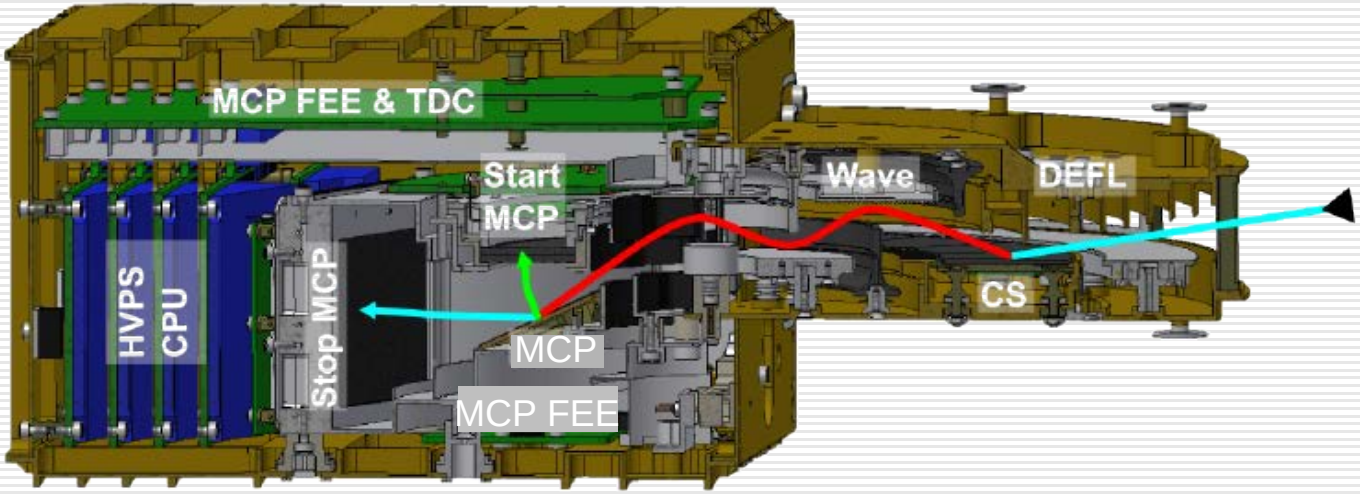


- Time evolution of large-scale plasma structure can be obtained by L-ENA imaging.

PEP/JNA measurement principle



①Rejection of ions
②Ionization
③Energy analysis
+ photon rejection
④Time-of-flight
analysis
⑤Anti-coincidence



PEP/JNA design

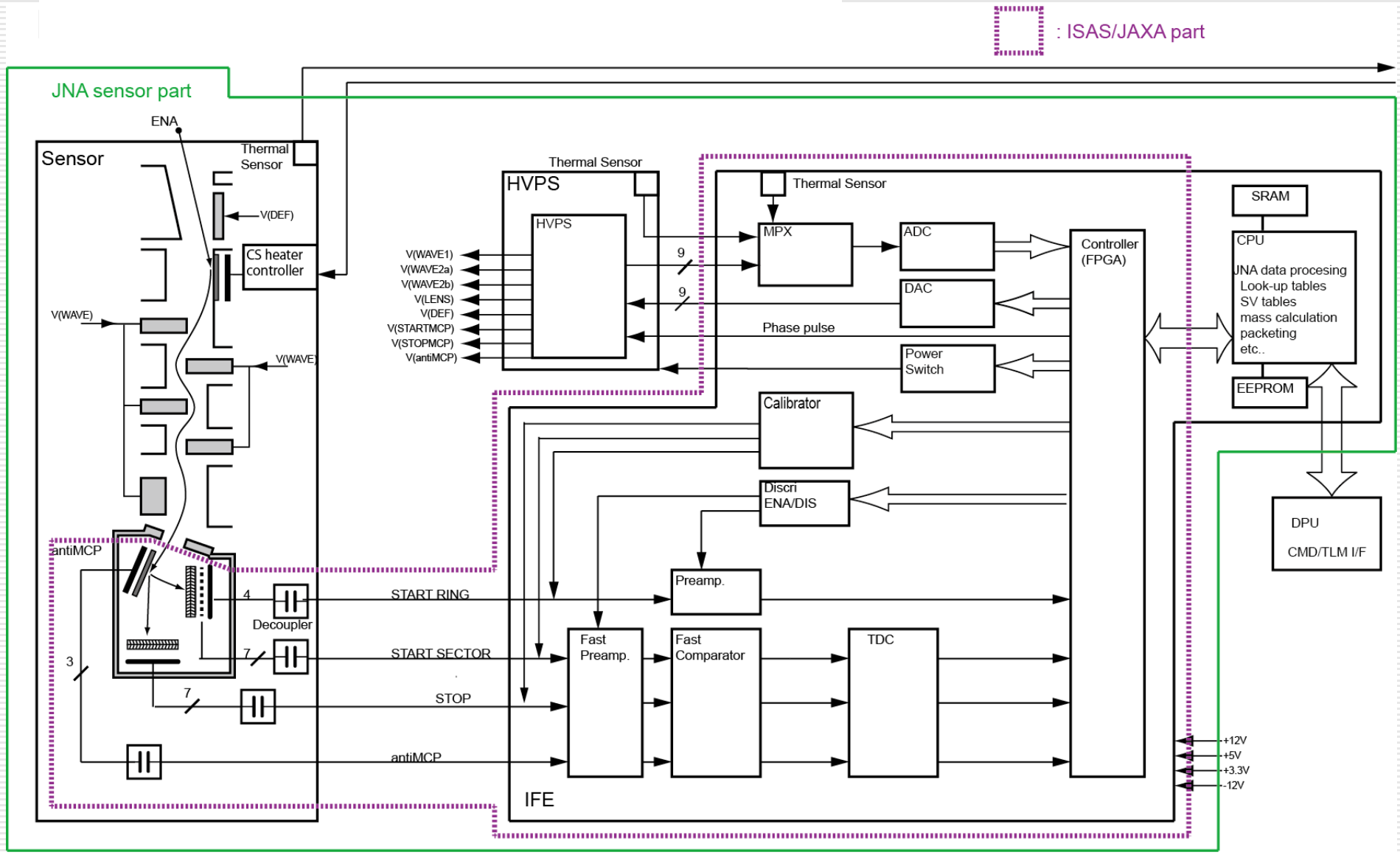
Target	Energetic neutral atoms
Energy range	10eV – 3300eV
Energy resolution	1 (ΔE/E)
Mass resolution	1, >16
Angular resolution	7x25 deg
FOV(total)	15x150 deg
Sensitivity	$2x10^{-6}$ [cm^2 str eV/eV /sector] (including efficiency)
Time resolution	15s (nominal)

Energy range: PEP/JENI can cover energies larger than 2000eV.

Energy resolution: Back-scattering and sputtering particles will be able to be discriminated even if ΔE/E ～ 1 by analyzing obtained energy spectra.

Angler resolution: Instrumental resolution of 30 deg corresponds to 6-8 deg on satellite surface (referred to center of Ganymede, JUICE is on 500km circular orbit)

JNA block-diagram



Background noise due to high-energy particles

Followings are countermeasures:

- Passive shield
- Anti-coincidence due to SSD
- Coincidence with time-of-flight method

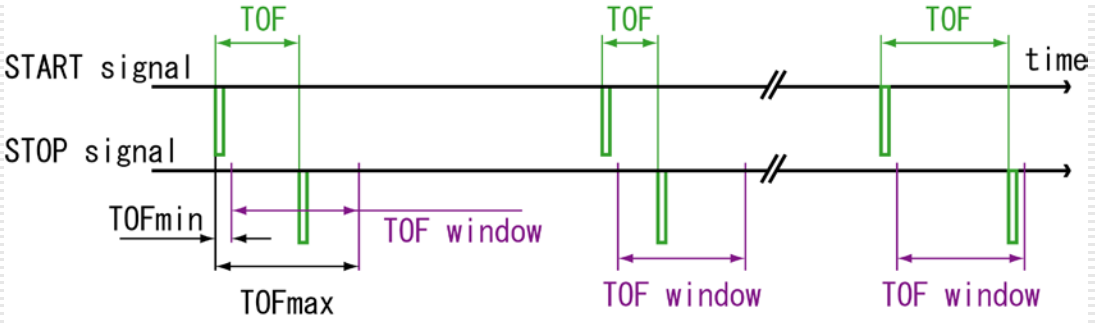
$C_{false} = C_{START}\ C_{STOP}\ \Delta t$

In case of
- Ganymede orbiting phase
- AL equivalent shield thickness
  = 20mm

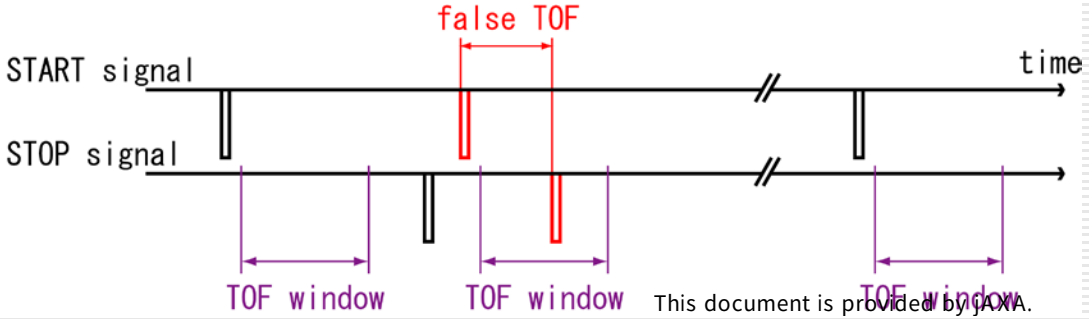
C_{START} = 4000cps
(rejection due to anti-coincidence is included.)
C_{STOP} = 7000cps

C_{false} = 1.8cps (Δt = 64ns)

Real signal

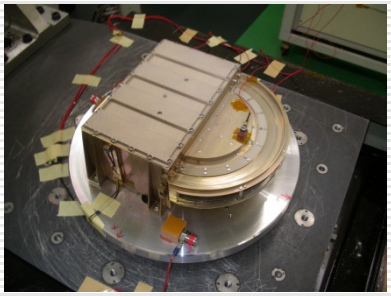


Noise signal (appeared in randomly)



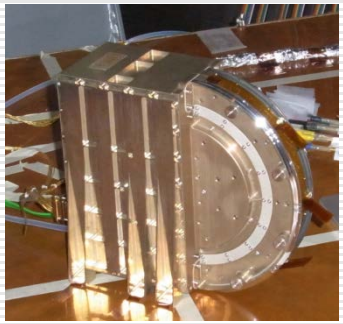
Development of L-ENA instrument

Chandrayaan-1/SARA/CENA (Indian moon mission)



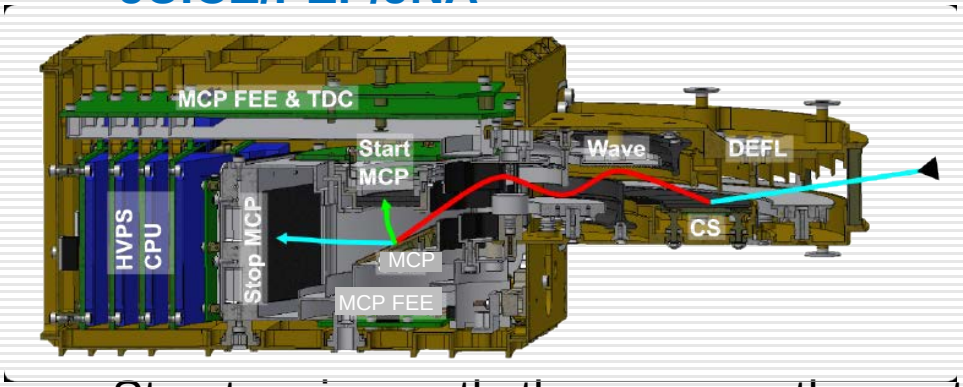
- Launched in 2008.
- Energy spectra of back-scattered particles from the moon surface is obtained. Scattered efficiency is 20% (Wieser et al., 2009)
- Scattering function for back-scattering is deduced (Schaufelberger et al., 2011).
- Magnetic anomaly on the moon surface affects precipitation of plasma partciles. (Wieser et al., 2010)

MMO/MPPE/ENA



- To be launched in 2015
- Development of the instrument is mostly completed.

JUICE/PEP/JNA



Structure is mostly the same as the past instruments except for the following:

- On-board CPU
- SSDs for anti-coincidence

We do not know the instruments which have better performance than PEP/JNA, if we consider the instruments with similar weight.

Summary

- PEP/JNA will perform the direct measurements of the back-scattering / sputtering neutral particles coming from the satellite surface. It will provide:
  — Understanding of large-scale structure of Ganymede's magnetosphere
  — Understanding of a role of satellite for mass transport in Jovian magnetosphere

- Neutral particles draw ballistic trajectories because of no effects due to electric / magnetic fields. Remote-imaging will be possible and it provides us characteristics of plasma particles precipitating from Ganymede's magnetosphere toward the satellite surface.

- Measurements of L-ENAs are complementary to in-situ plasma measurements.

- 20mm of AL-equivalent shield thickness will be necessary. Optimization of shield structure is necessary.

- We do not know the instruments which have better performance than PEP/JNA, if we consider the instruments with similar weight.