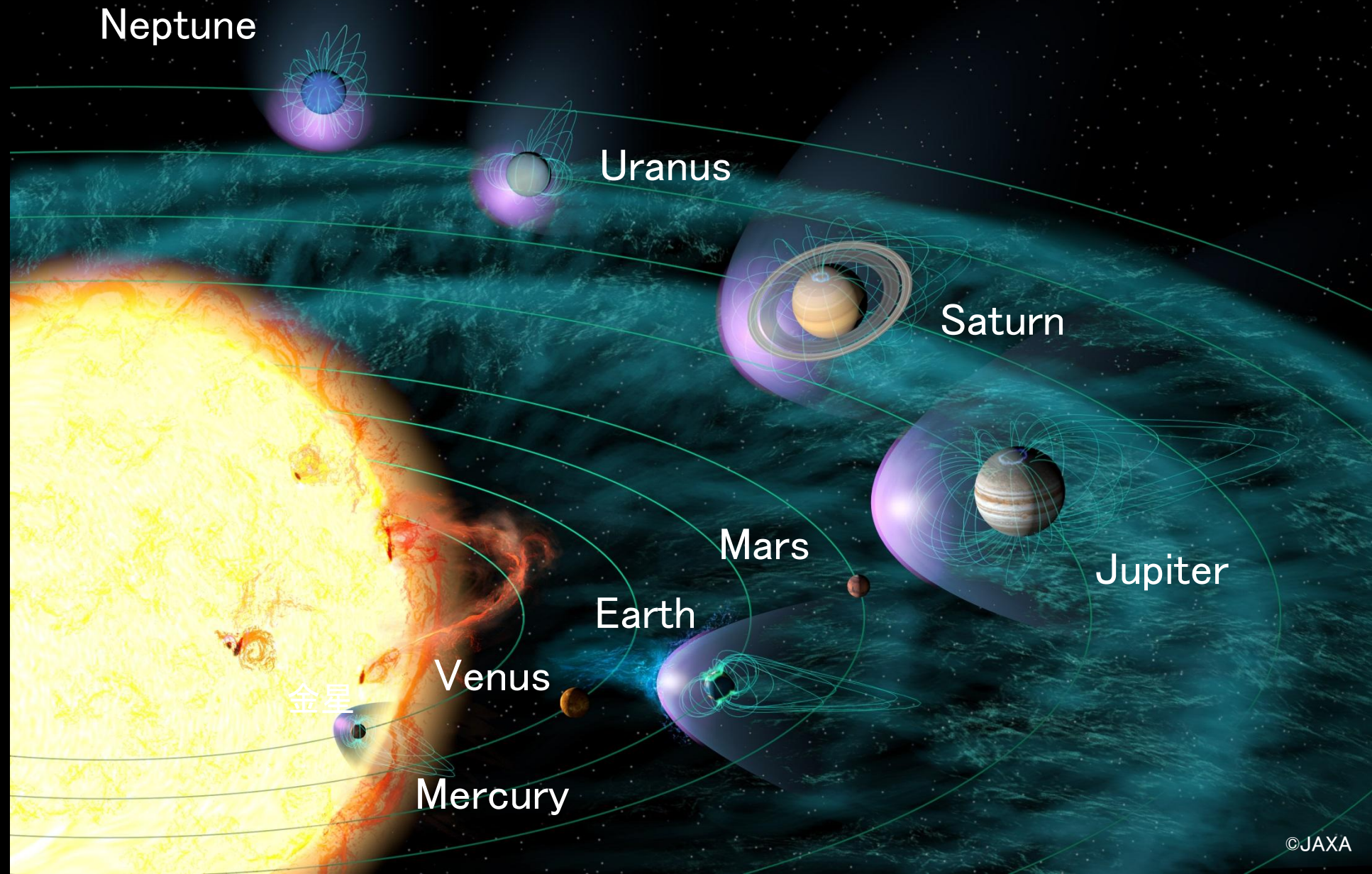


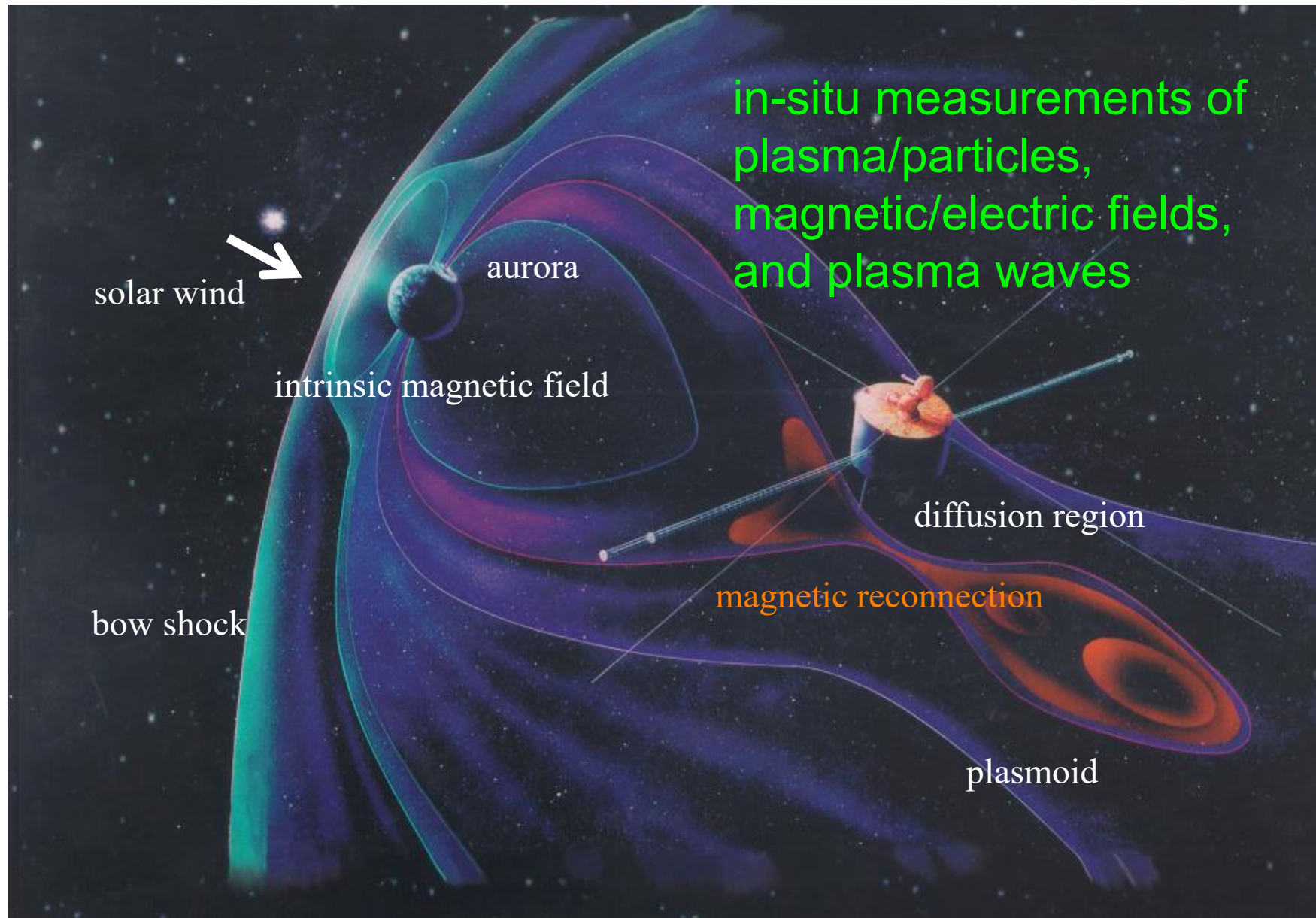
In-situ plasma particle measurements in current and future planetary exploration

Yoshifumi SAITO
ISAS / JAXA

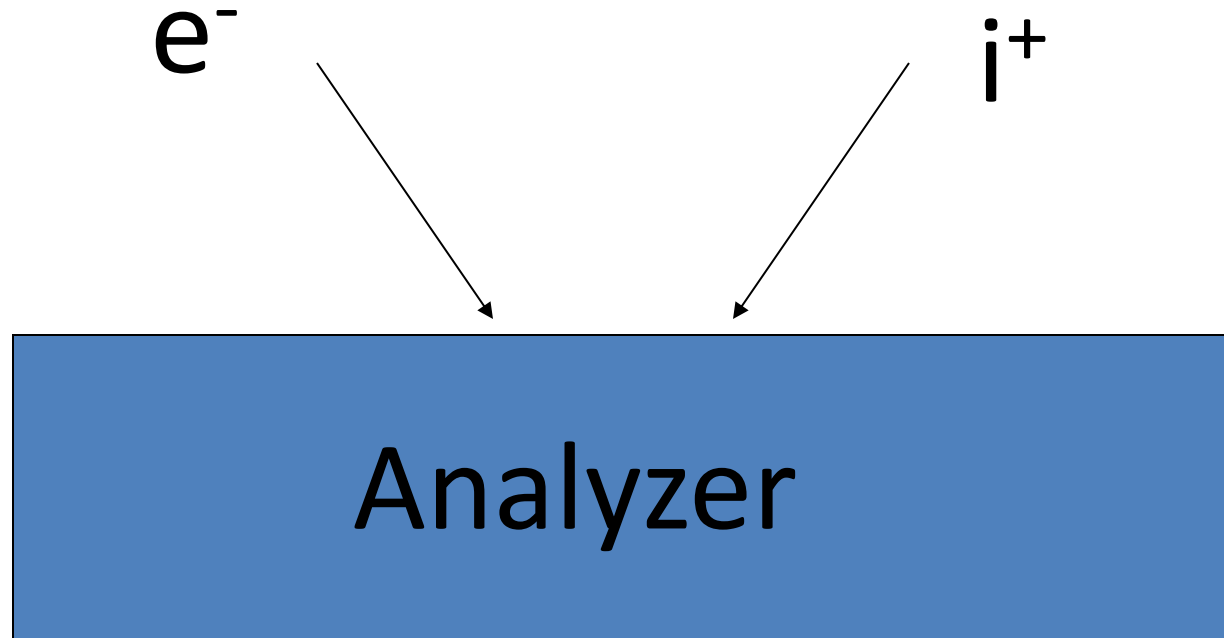
Heliosphere



Structure and Dynamics of the Terrestrial and Planetary Magnetospheres



Charged Particle Measurement

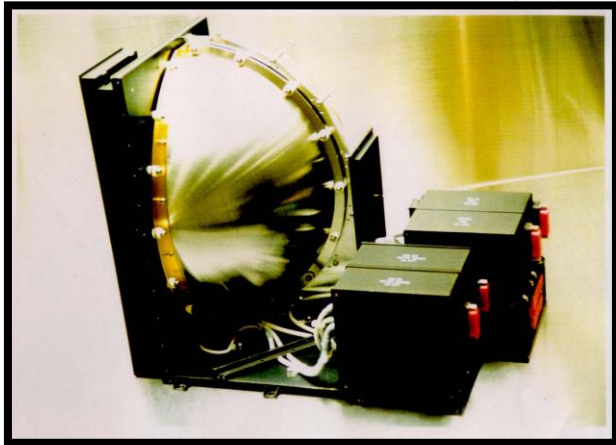
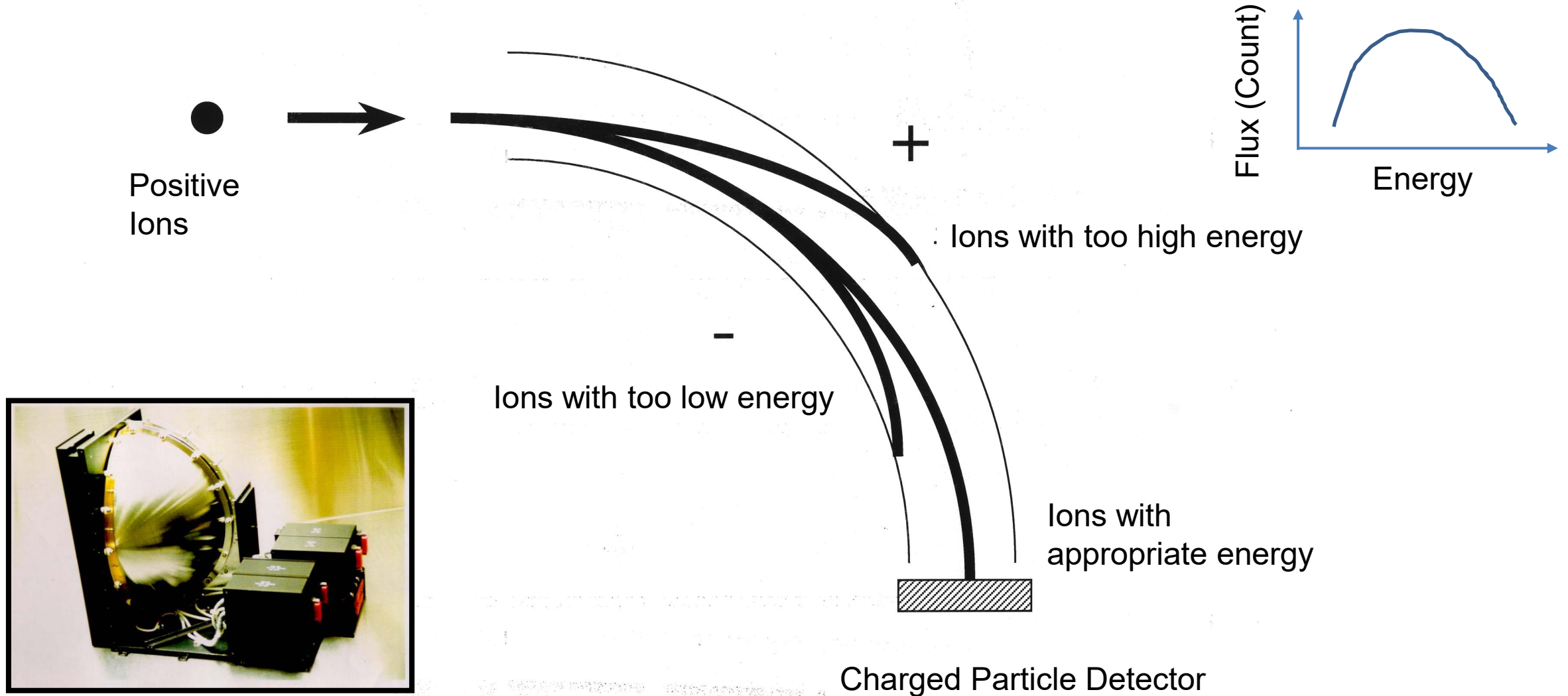


Charged particle analyzers measure the current or number of the electrons / ions entering the analyzer.

The measurements are made with a fixed sampling time discriminating the energy, direction, mass and charge state of the charged particles.

Measurement Principle of Ion / Electron Energy Spectrum

Spherical Electrostatic Analyzer



90deg. Spherical Electrostatic Analyzer

BepiColombo/Mio

Mercury Magnetospheric Orbiter

Launched in October 2018



BepiColombo mission plan



Launch:
20 Oct. 2018

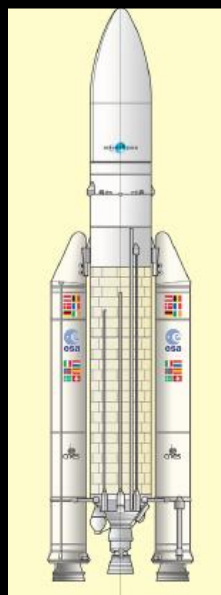
Earth swing-by x 1
Venus swing-by x 2
Mercury swing-by x 6

Arrival: Nov. 2026

Interplanetary Cruising

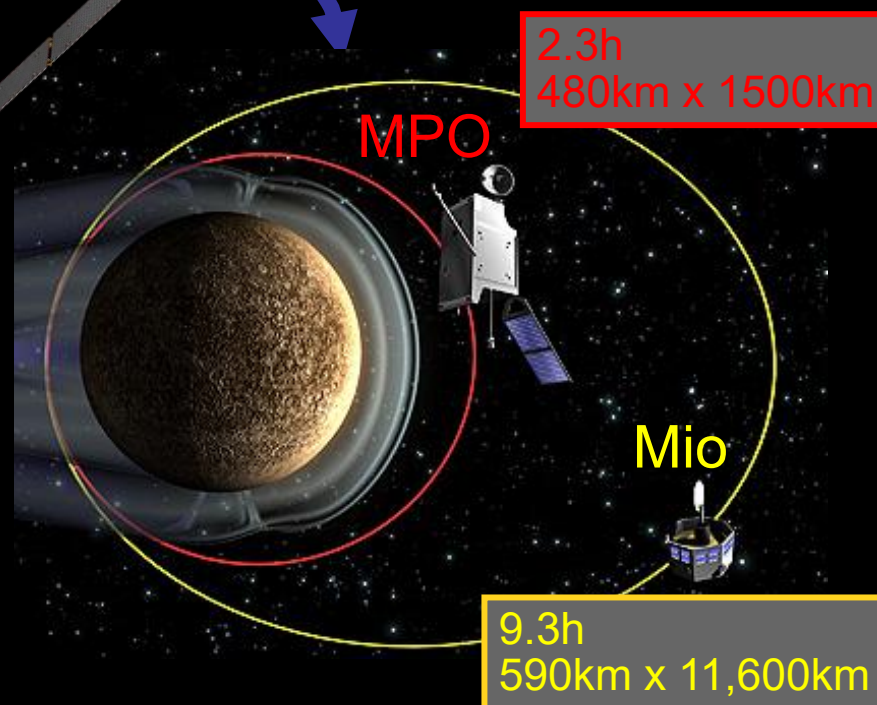
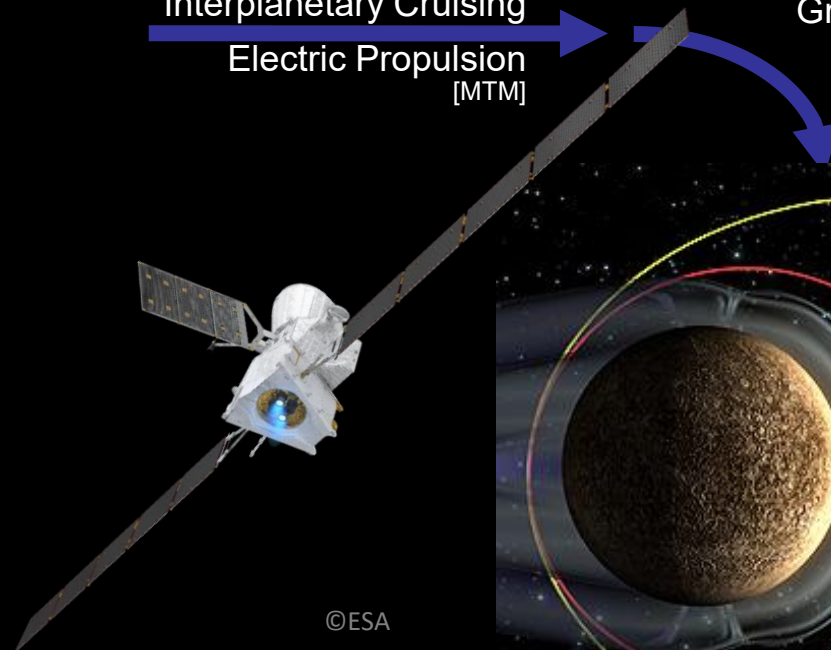
Electric Propulsion
[MTM]

Mercury Orbit Insertion
Gravitational Capture



Ariane-5:
MPO+MMO

Yellow: JAXA
Red: esa



2.3h
480km x 1500km

MPO

Mio

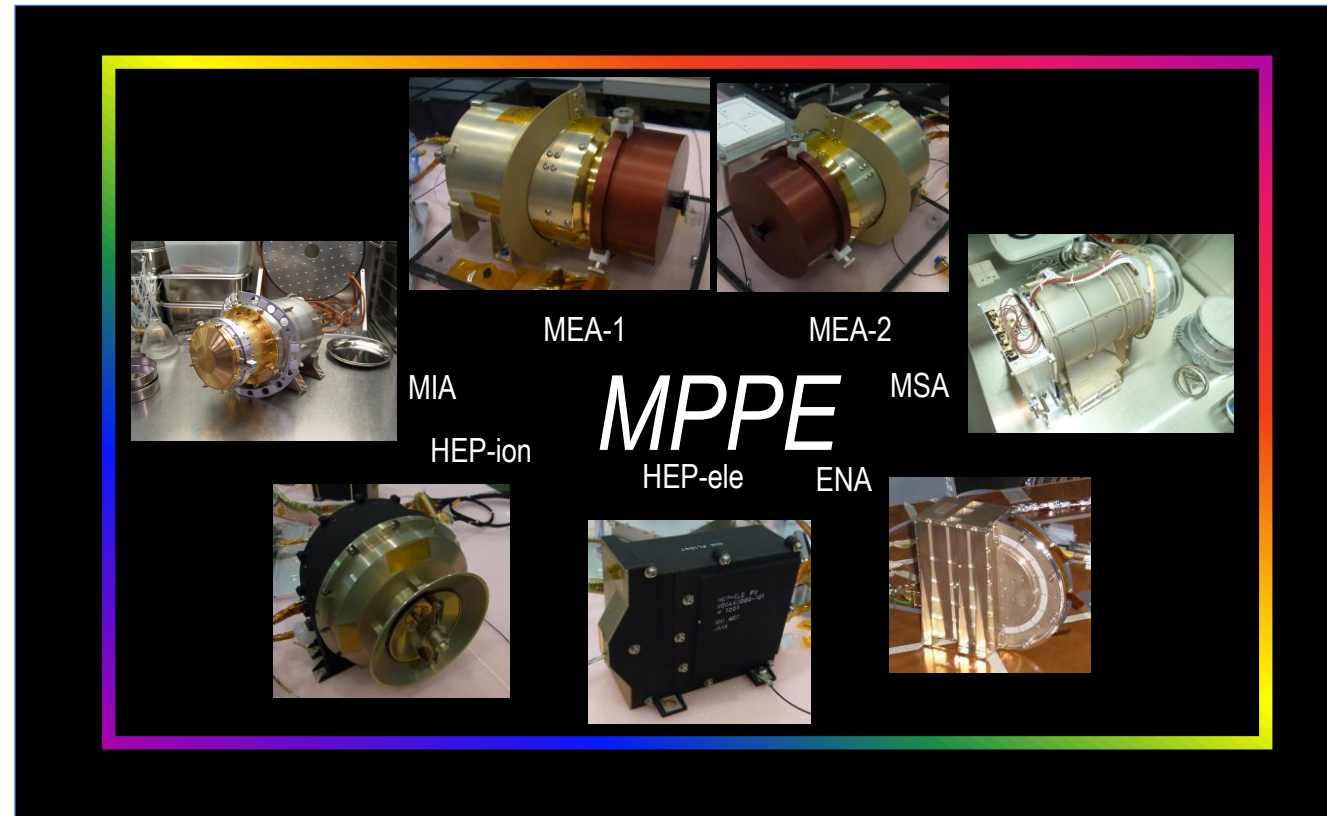
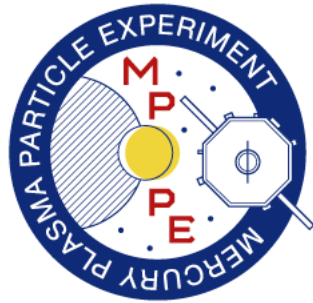
9.3h
590km x 11,600km

Observation: 1 Earth year (+Extension)

MPPE: MERCURY PLASMA PARTICLE EXPERIMENT

comprehensive instrument package :

ions and electrons in the solar wind and in the Mercury's magnetosphere, neutral particles from Mercury surface



>100 members (Japan, Europe, USA, Taiwan, China, Russia)



Pre-flight Calibration and Near-Earth Commissioning Results of the Mercury Plasma Particle Experiment (MPPE) Onboard MMO (Mio)

Yoshifumi Saito · Dominique Delcourt · Masafumi Hirahara · Stas Barabash · Nicolas André · Takeshi Takashima et al. [full author details at the end of the article]

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Abstract

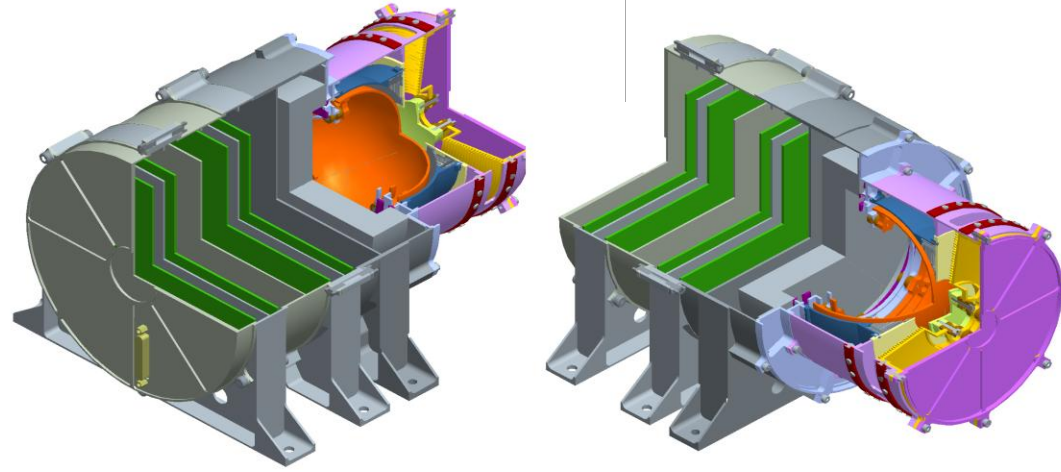
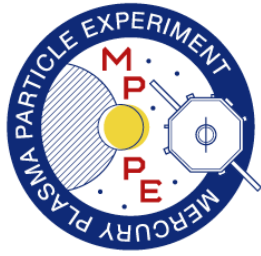
BepiColombo Mio (previously called MMO: Mercury Magnetospheric Orbiter) was successfully launched by Ariane 5 from Kourou, French Guiana on October 20, 2018. The Mercury Plasma/Particle Experiment (MPPE) is a comprehensive instrument package on-board Mio spacecraft used for plasma, high-energy particle and energetic neutral atom measurements. It consists of seven sensors including two Mercury Electron Analyzers (MEA1 and MEA2), Mercury Ion Analyzer (MIA), Mass Spectrum Analyzer (MSA), High Energy Particle instrument for electron (HEP-ele), High Energy Particle instrument for ion (HEP-ion), and Energetic Neutrals Analyzer (ENA). Significant efforts were made pre-flight to calibrate all of the MPPE sensors at the appropriate facilities on the ground. High voltage commissioning of MPPE analyzers was successfully performed between June and August 2019 and in February 2020 following the completion of the low voltage commissioning in November 2018. Although all of the MPPE analyzers are now ready to begin observation, the full service performance has been delayed until Mio's arrival at Mercury. Most of the fields of view (FOVs) of the MPPE analyzers are blocked by the thermal shield surrounding the Mio spacecraft during the cruising phase. Together with other instruments on Mio including Magnetic Field Investigation (MGF) and Plasma Wave Investigation (PWI) that measure plasma field parameters, MPPE will contribute to the comprehensive understand-

Authors and Affiliations

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✉ Y. Saito
saito@stp.isas.jaxa.jp

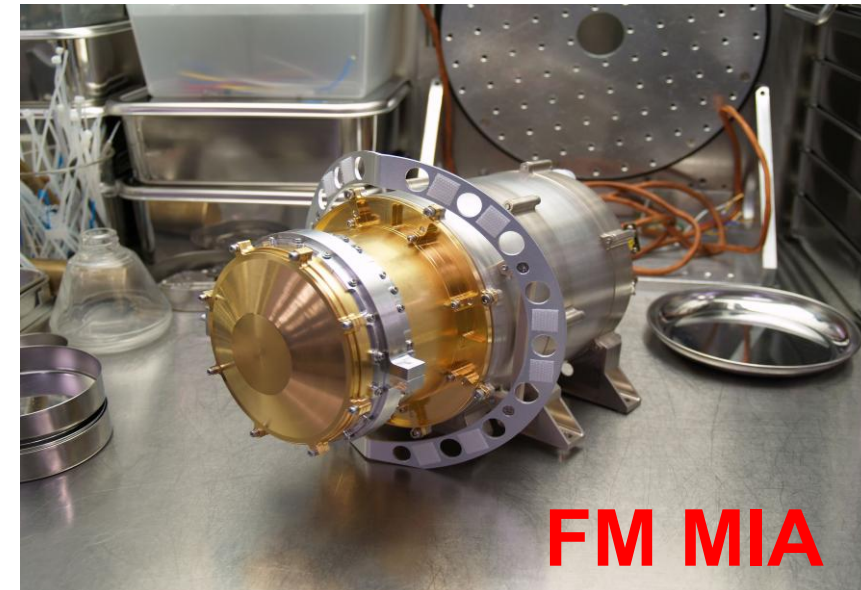
¹⁴ Faculty of Mathematics and Physics, Charles University, V Holešovičkách 2, 180 00 Prague 8, Czech Republic



MIA

Mercury Ion Analyzer

**Toroidal Electrostatic Analyzer
with electrical sensitivity control
Ion energy spectra**



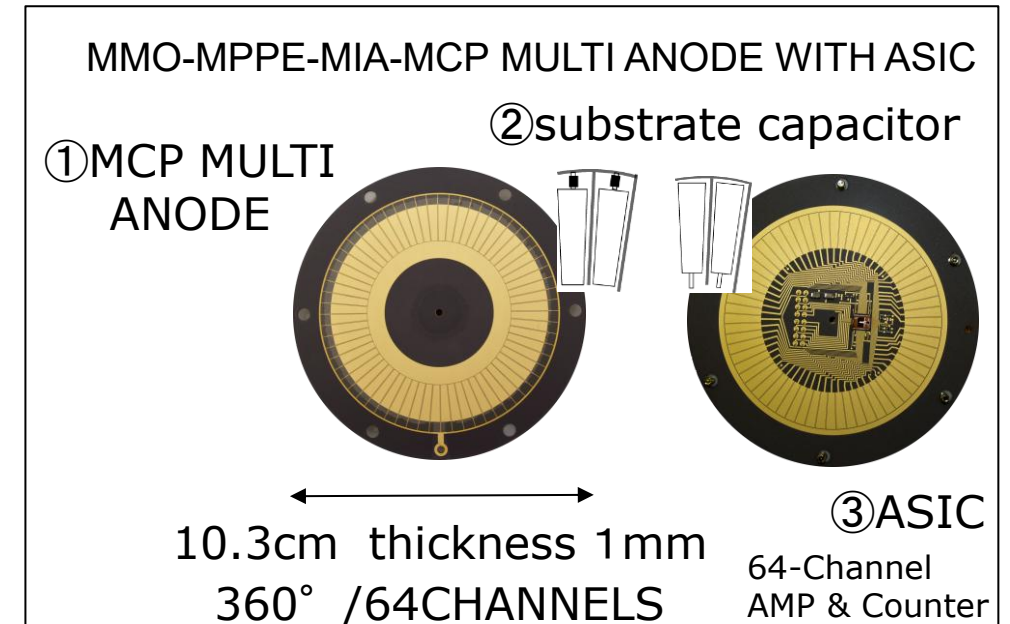
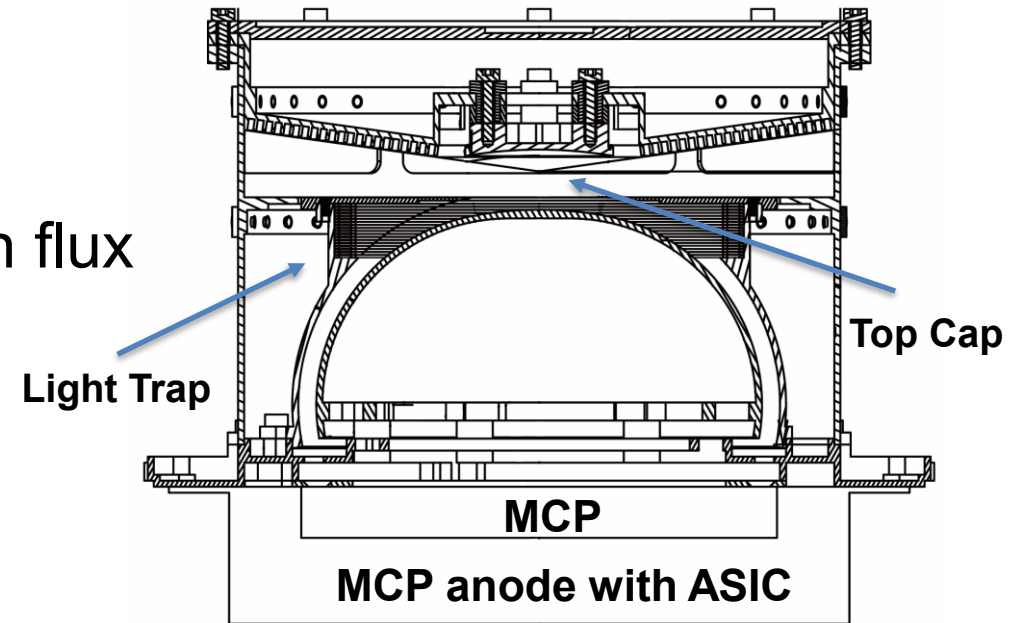
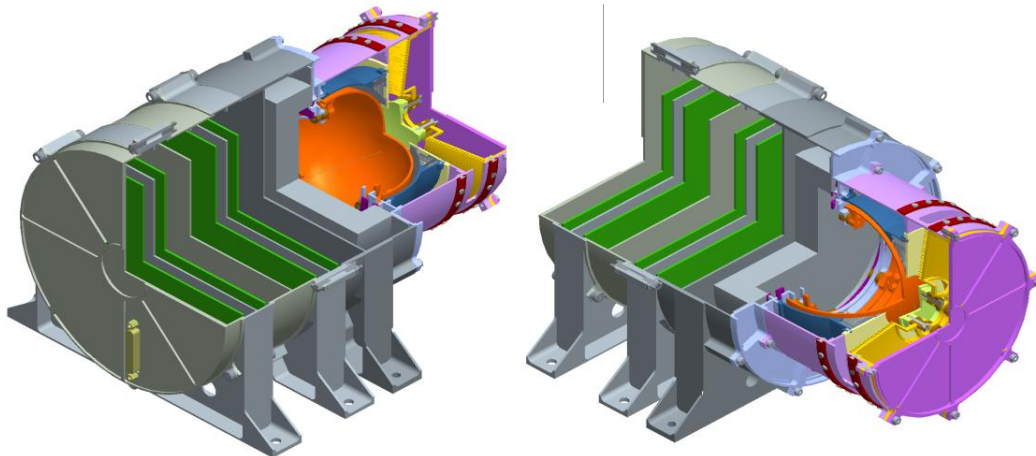
FM MIA

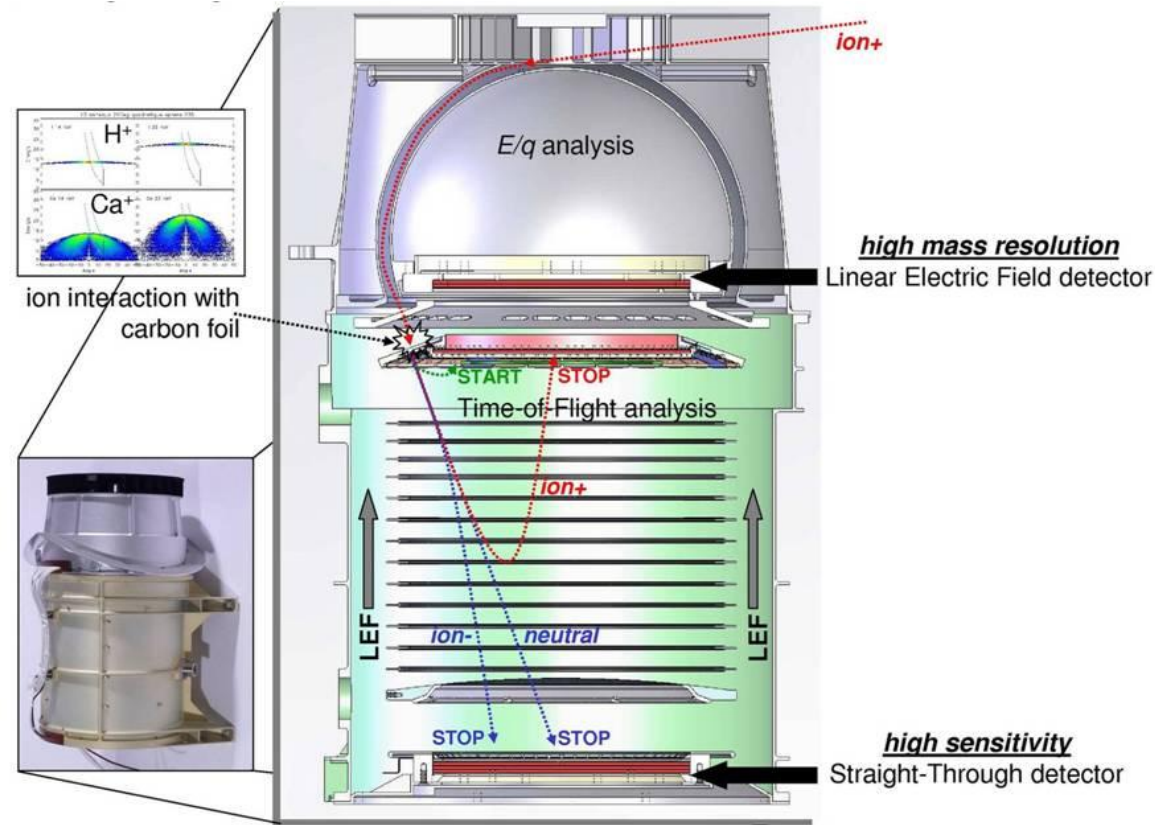
Mercury

- high solar wind ion flux & low magnetospheric ion flux
--- > wide dynamic range
- power consumption should be reduced



- Electrical sensitivity control
- Mechanical attenuation grid

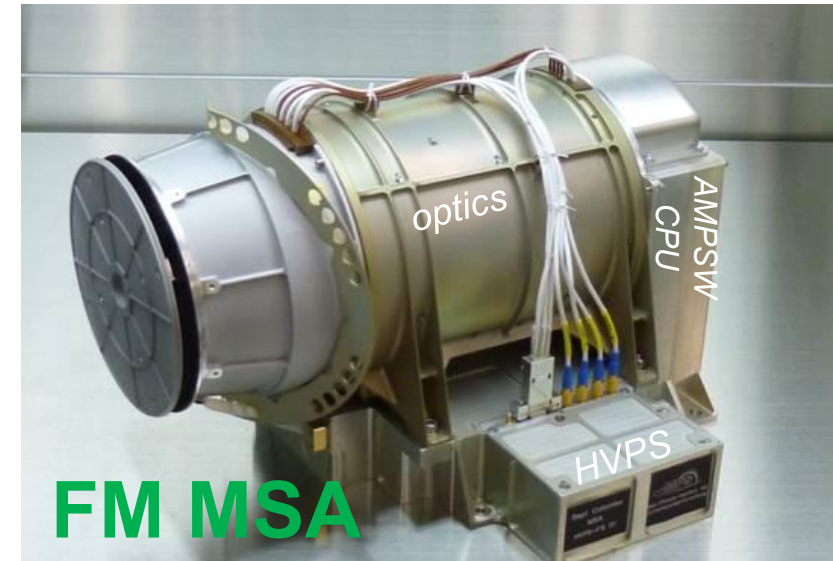


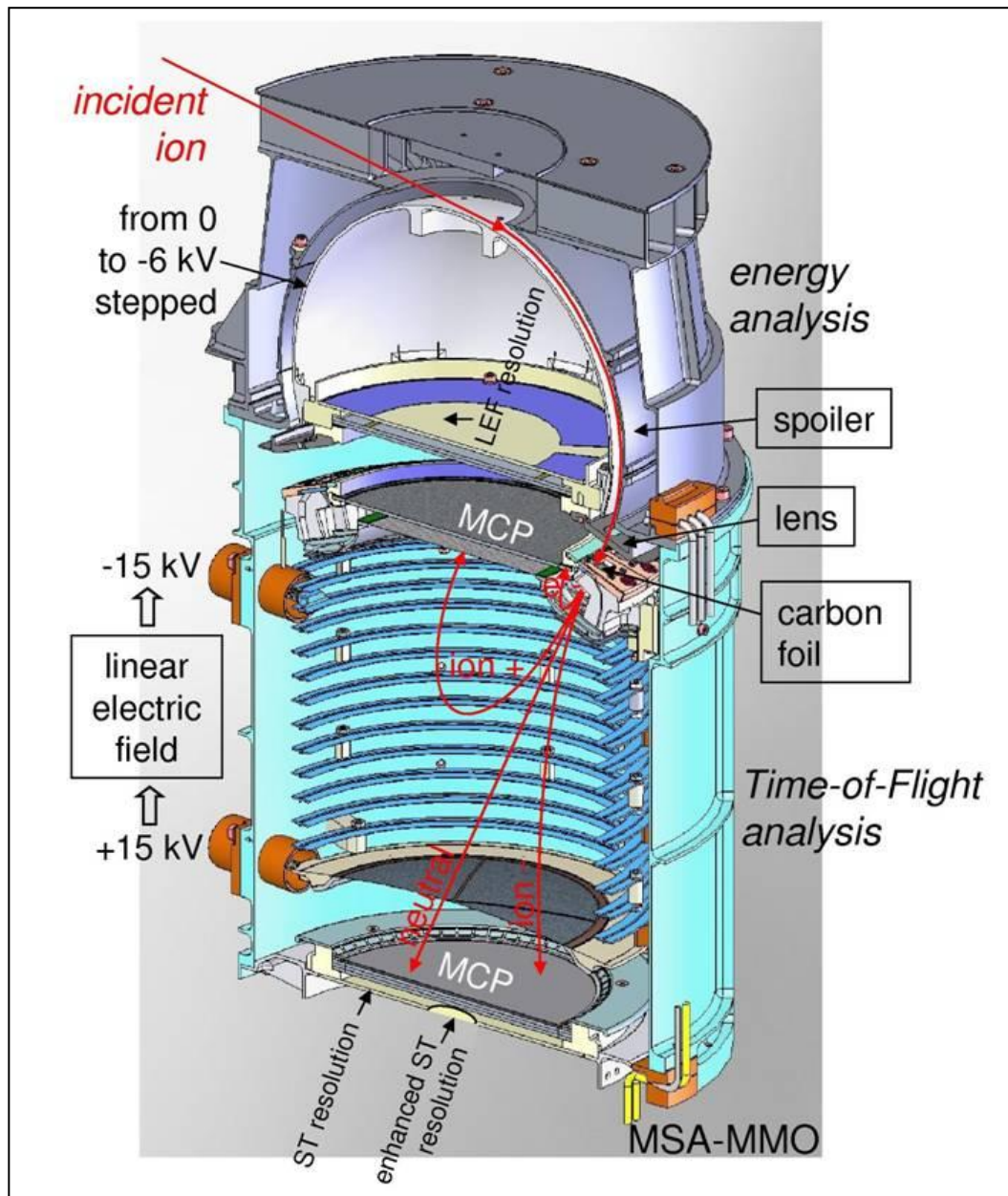


MSA

Mass Spectrum Analyzer

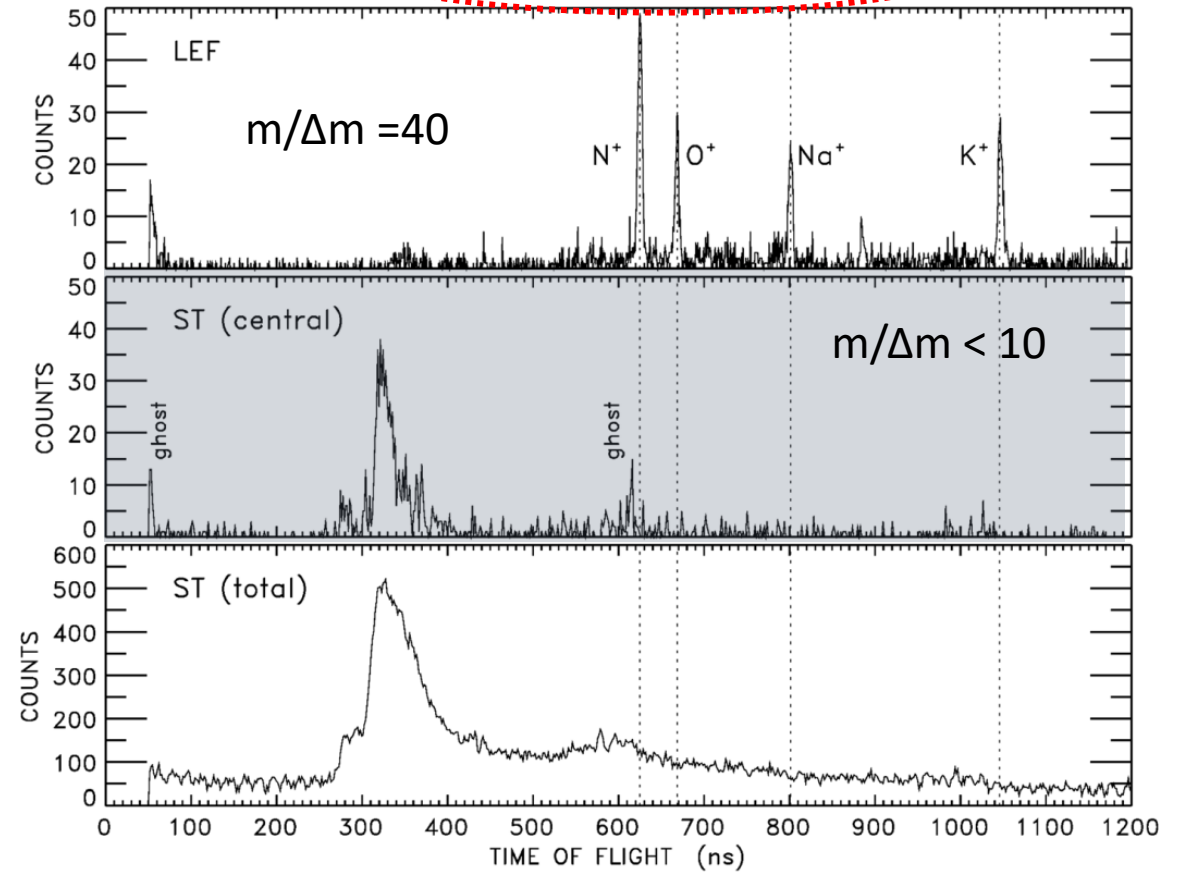
**Toroidal Electrostatic Analyzer
+ LEF-TOF Mass Spectrometer
with electrical sensitivity control
Mass identified Ion energy spectra**





MSA FM performances

LEF : high mass resolution

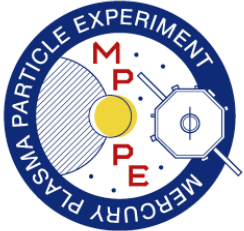


ST : moderate mass resolution

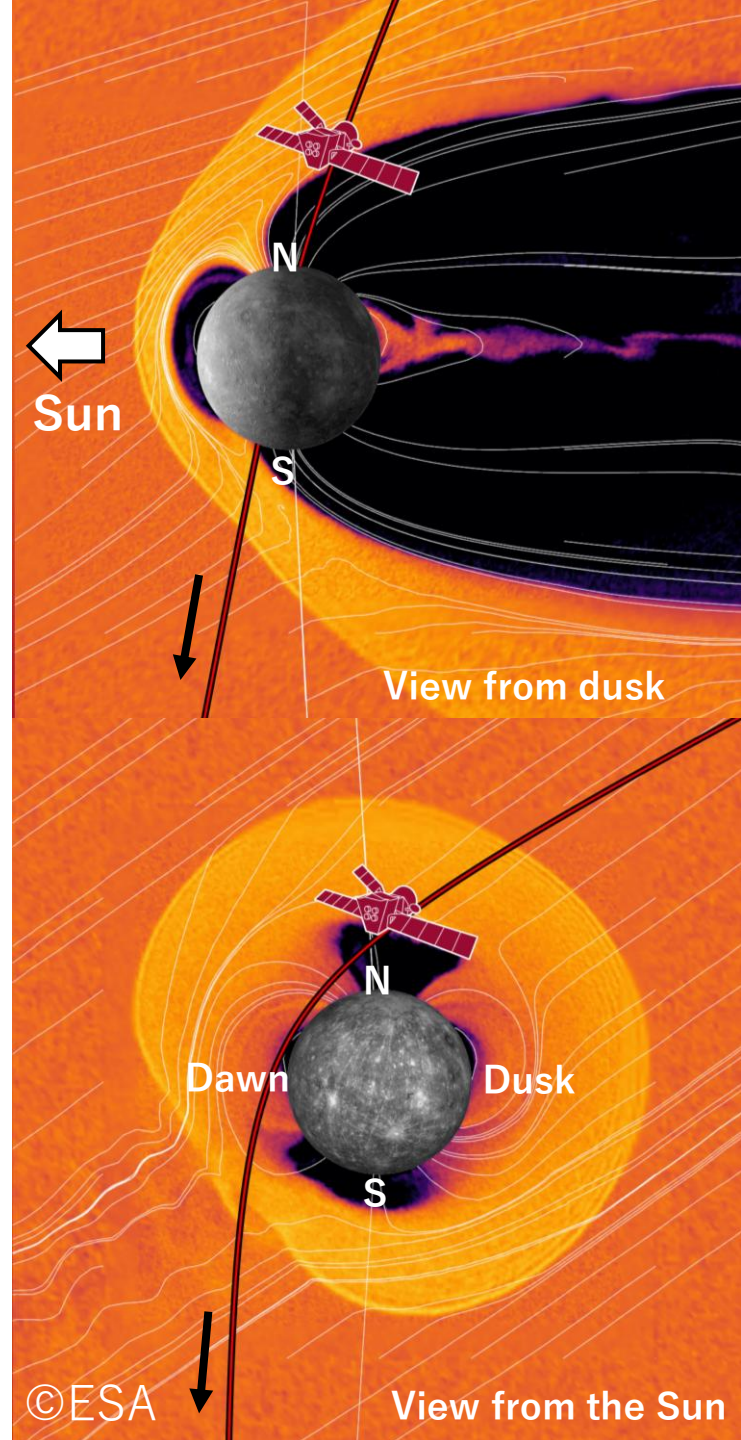
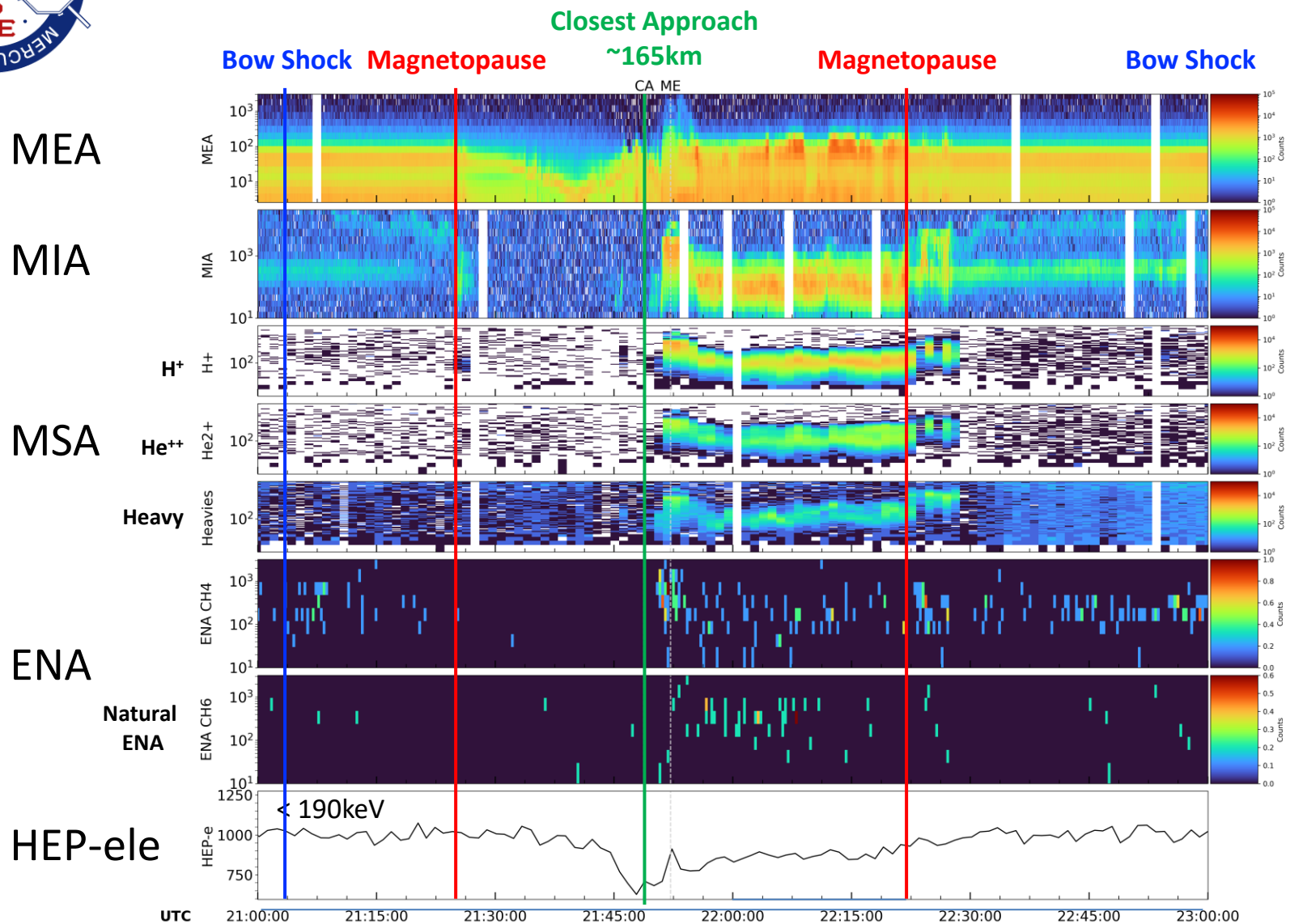


Mercury Flyby Events

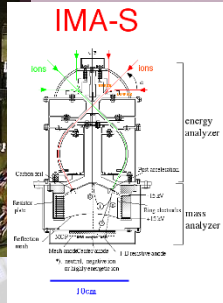
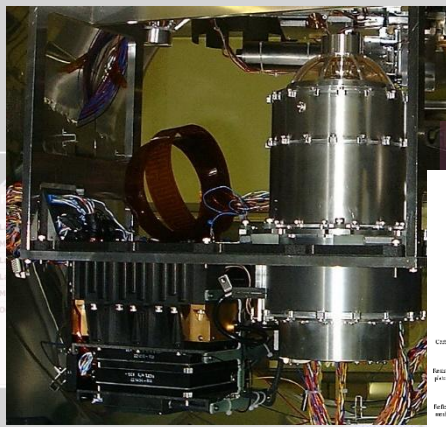
10/2021	1st Mercury Flyby
6/2022	2nd Mercury Flyby
6/2023	3rd Mercury Flyby
9/2024	4th Mercury Flyby
12/2024	5th Mercury Flyby
1/2025	6th Mercury Flyby
11/2026	BepiColombo arrival at Mercury



Mercury Flyby #4 20240904 Mio MPPE Summary Plot



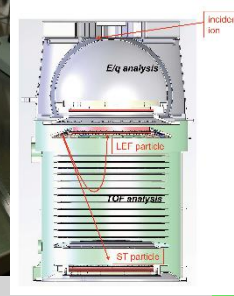
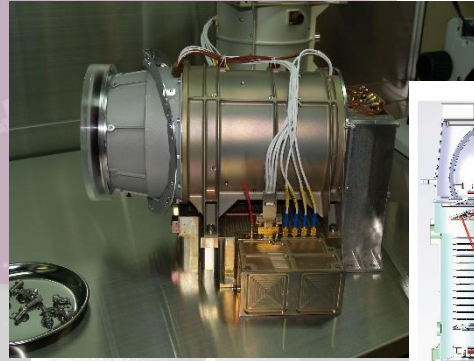
$m/\Delta m = 15$



Energy Mass Spectrometer
Moon Plasma 2007
Kaguya

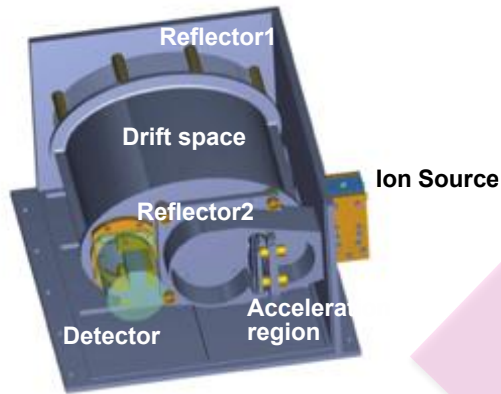
mass spectrometer is one of the key instruments for planetary exploration

Reflectron-type Mass Spectrometer for Planetary Exploration



$m/\Delta m = 40$

Energy Mass Spectrometer
Mercury Plasma 2018
BepiColombo/Mio

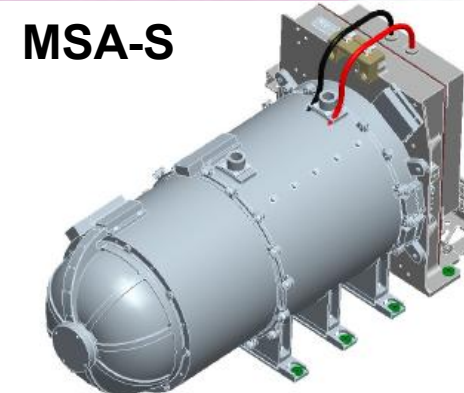


$m/\Delta m > 200$

REIWA-TRITON
Neutral Mass
Spectrometer
for **LUPEX** Moon Rover
~2027

Development of
Neutral Mass
Spectrometer

Energy Mass Spectrometer
Phobos plasma environment
MMX ~2026



$m/\Delta m = 100$

Development of
Energy-Mass
Ion Spectrometer

Summary

- In order to understand the structure and dynamics of the terrestrial and planetary magnetospheres, we are making in-situ measurements of plasma/particles.
- One of the missions we have our instrument for measuring plasma/particles onboard is BepiColombo. BepiColombo will arrive at Mercury in November 2026.
- We have an instrument suite for plasma/particle measurement MPPE on BepiColombo/Mio.
- Instruments for measuring plasma/particle for future missions including ion energy mass spectrometers with higher mass resolution and neutral particle analyzers are under development.
- It is our great pleasure to collaborate with Czech researchers in the current and future space missions.

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