Ion measurements with the Mass Spectrum Analyzer onboard Bepi Colombo MMO

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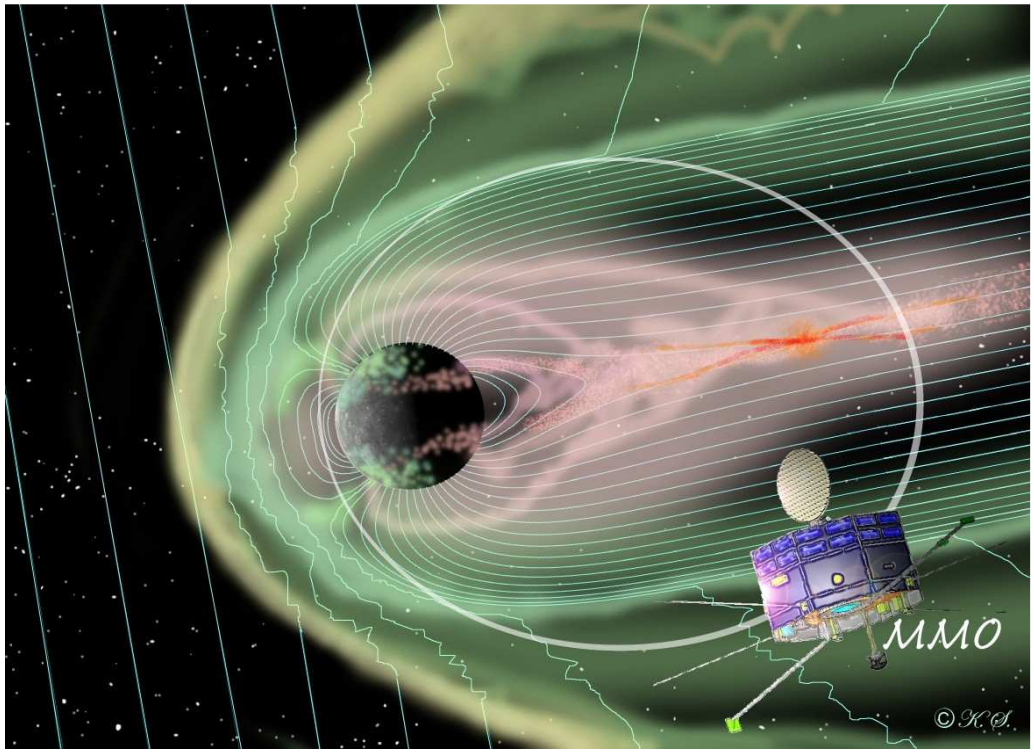
Bepi Colombo mission to Mercury
(MPO/ESA – MMO/JAXA) :
- launch 2014
- arrival 2020

MSA is the Mass Spectrum Analyzer onboard Bepi Colombo MMO.



⇒ MSA has ***three types of scientific objectives*** :

(1) magnetospheric plasma physics
- *investigation of ion sources and sinks*
- *analysis of mechanisms that control the ion transport and acceleration*
- *characterization of current carriers*

(2) planetology
- *identification of material of planetary origin*
- *analysis of magnetospheric recycling*

(3) inner heliosphere
- *characterization of "minor" ions in the solar wind*
- *analysis of pick-up ions from the inner source*

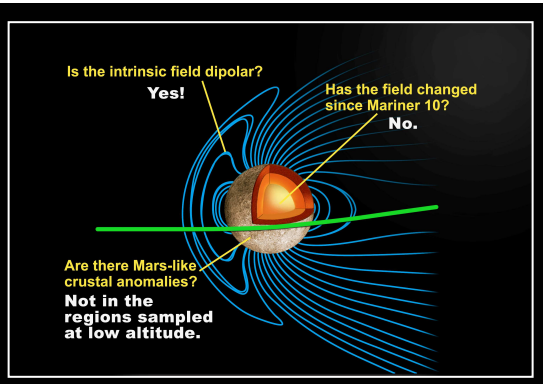
MESSENGER flybys :

14/01/2008 (M1) – 06/10/2008 (M2) – 29/09/2009 (M3)

MESSENGER orbit insertion :

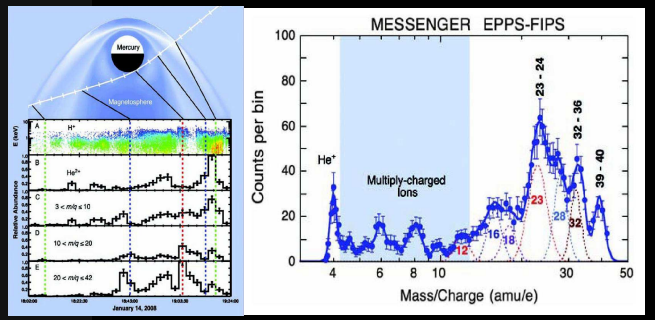
18/03/2011

M1



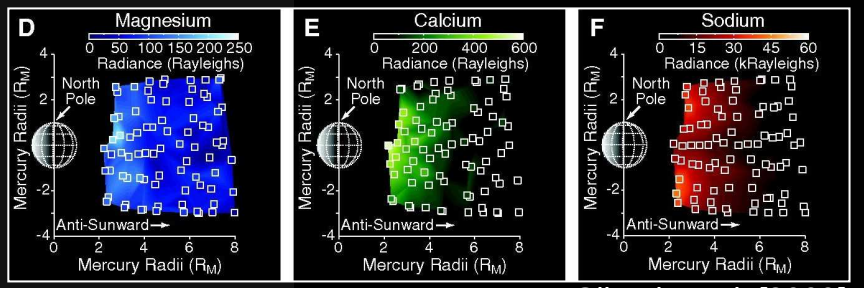
Anderson et al. [2008]

M1



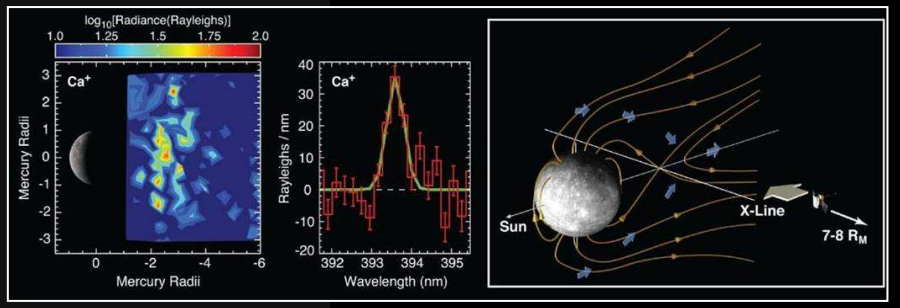
Zurbuchen et al. [2008]

M2



McClintok et al. [2009]

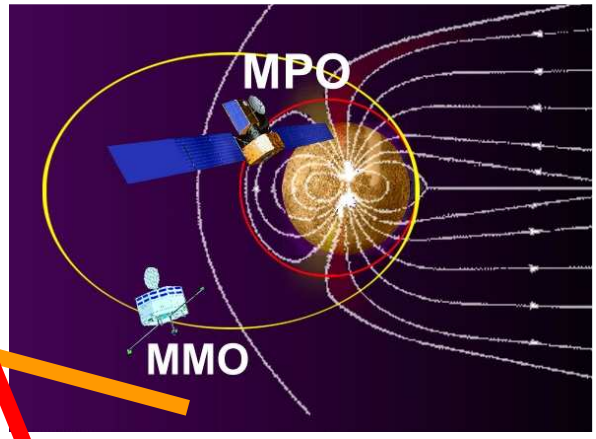
M3



Vervack et al. [2010]

The particle consortium (MPPE) onboard Bepi Colombo MMO

PI : Y. Saito, ISAS



MAST

MEA-1

HEP-e

HEP-ion

(CESR)

(Tokyo Univ.)

ENA

(IRF)

MIA

(ISAS)

MEFISTO-S

(CESR)

MDM

MEA-2

MSASI

(LPP)

MSA

WPT-S

MPPE Sensors

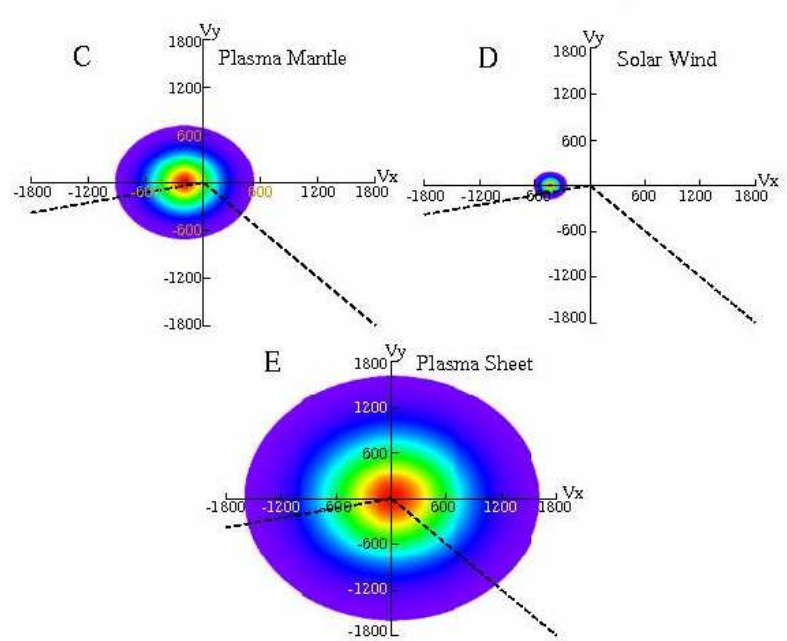
MEA:	Mercury Electron Analyzer	
	energy spectrum of electrons	3eV-30keV
MIA:	Mercury Ion Analyzer	
	energy spectrum of solar wind ions	100eV/q-30keV/q
	energy spectrum of Mercury ions	5eV/q-30keV/q
MSA :	Mass Spectrum Analyzer	
	energy mass spectrum of ions	5eV/q - 40keV/q mass: 1-60
HEP-ion:	High Energy Particle-ion	
	energetic ions	30keV-1.5MeV
HEP-ele:	High Energy Particle-electron	
	energetic electrons	30keV-700keV
ENA:	Energetic Neutral Atom	
	low-energy energetic neutral atoms	<25eV-3.3keV

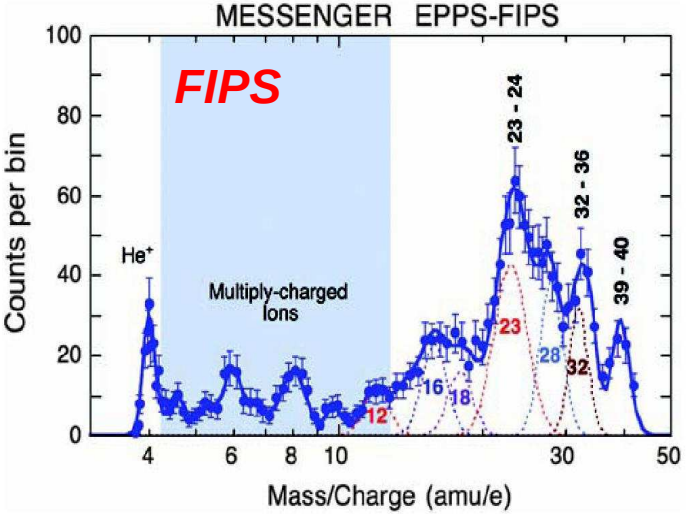
⇒ MSA will provide ***unprecedented information*** on Mercury's magnetized environment with :

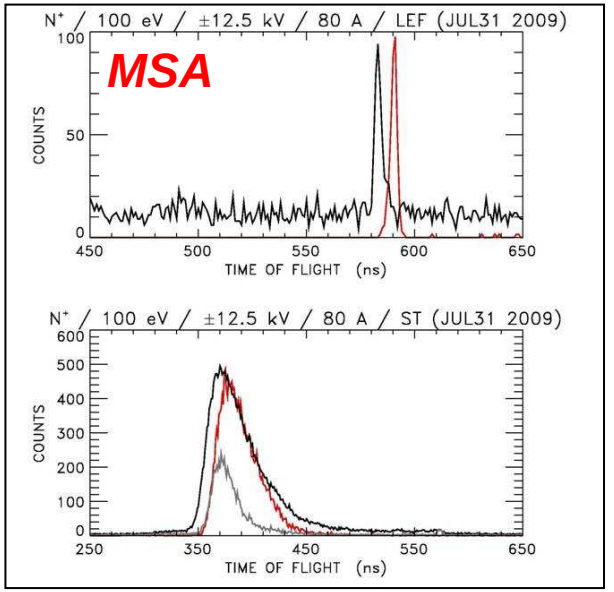
(1) ***3-D ion distributions*** taking advantage of MMO spin

(MESSENGER is 3-axis stabilized

⇒ limited FOV of FIPS analyzer)





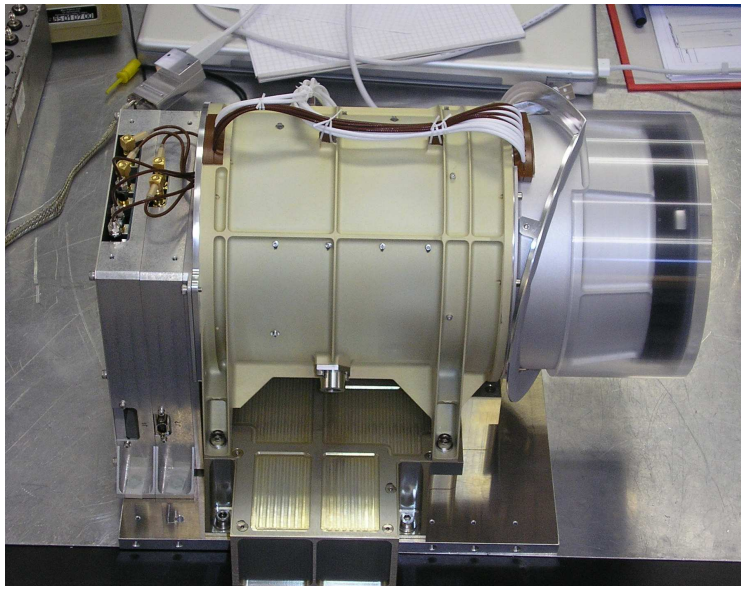


(2) ***high mass resolution*** (m/Δm ≈ 40)

using "reflectron" principle

(FIPS analyzer is equipotential)

MSA characteristics



MSA is a Time-of-Flight spectrometer
(heritage CASSINI-CAPS-IMS) that
will measure ***mass-resolved ion distributions***

⇒ FOV : 6° x 270°

⇒ mass range : 1 - 60 amu

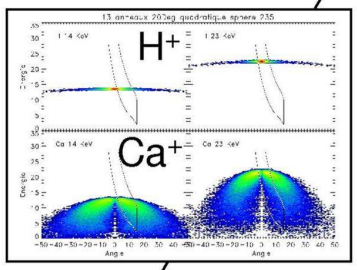
⇒ energy range : 1 eV/q - 40 keV/q ($\Delta E/E \approx 10\%$)

⇒ angular resolution (max) : 11.25° x 11.25°

⇒ time resolution : 3-D ion distribution in 4 s (32 energies)

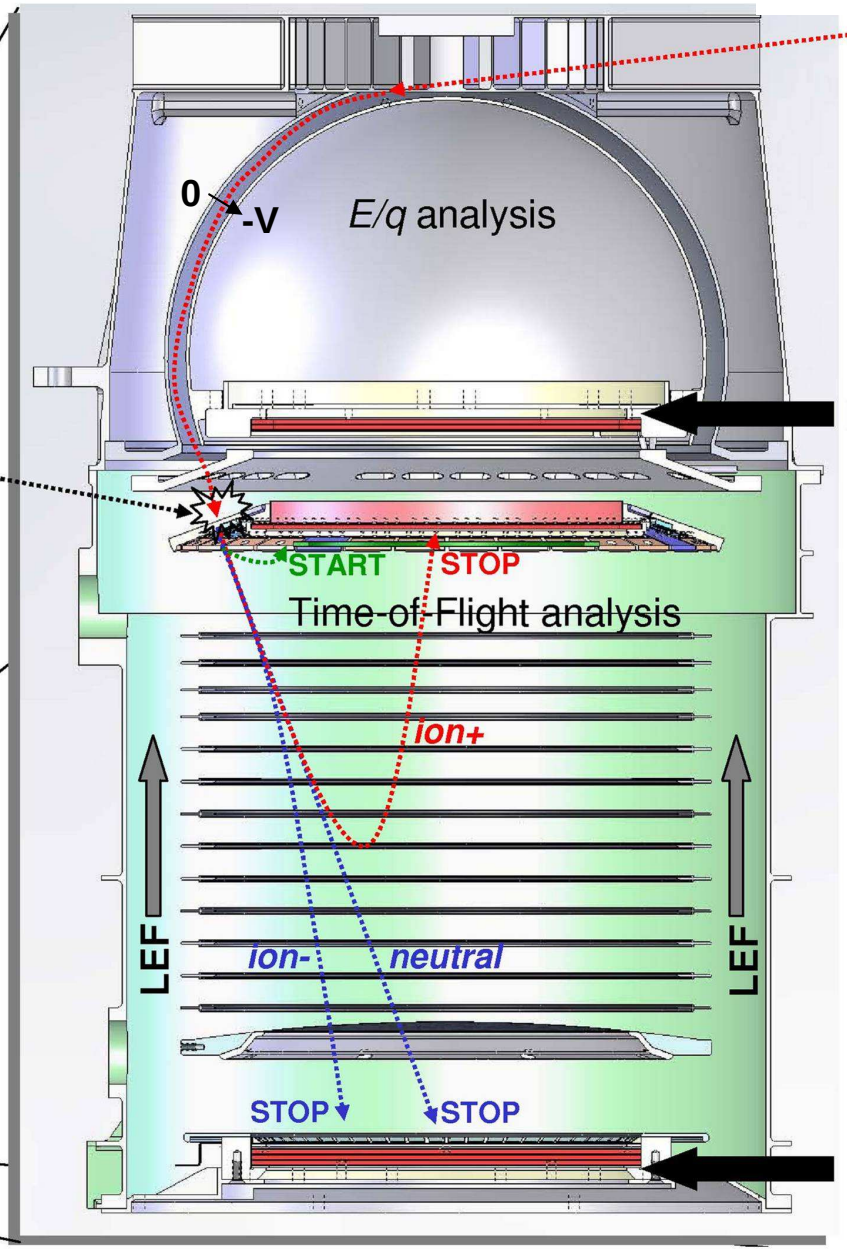
⇒ G-factor (electrostatically controlled using "spoiler") : ~1.5 10^{-3} cm^2 sr

MSA principle (1/2)



ion interaction with carbon foil

EQM optics



high mass resolution
Linear Electric Field detector

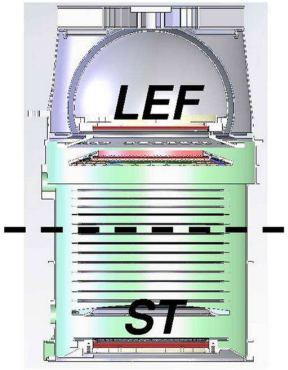
high sensitivity
Straight-Through detector

MSA principle (2/2)

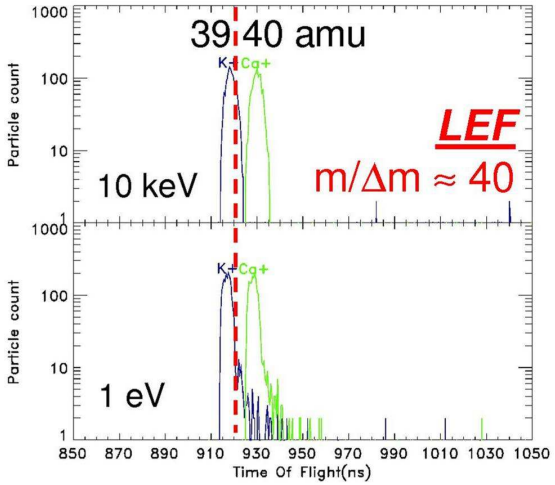
Two instruments in one
(high resolution LEF and high sensitivity ST)
operating simultaneously.

LEF : harmonic oscillator
($d^2Z/dt^2 = - qkZ/m$)

$\Rightarrow$ ***$m/q = kT^2/\pi^2$***
(isochronous ToF)

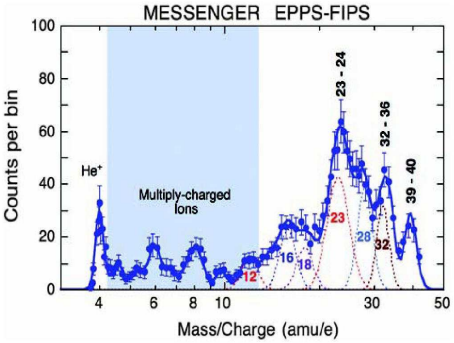


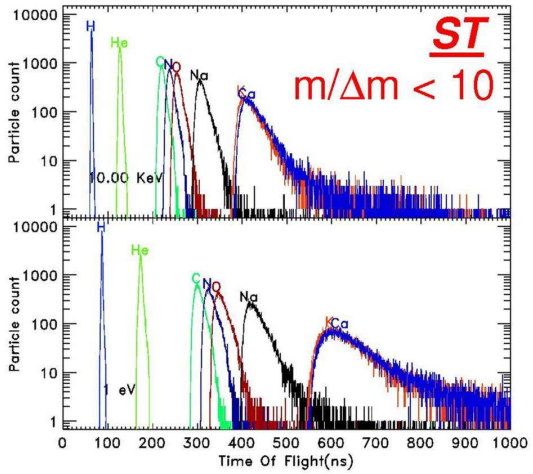
simulations



ST : accumulation of particles with distinct energies and path lengths

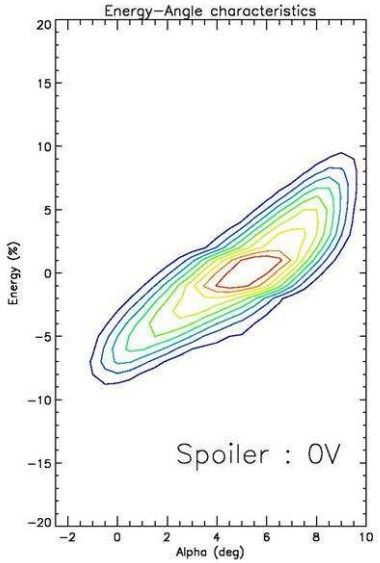
$\Rightarrow$ ***$m/q = 2(E/q)T^2/L^2$***



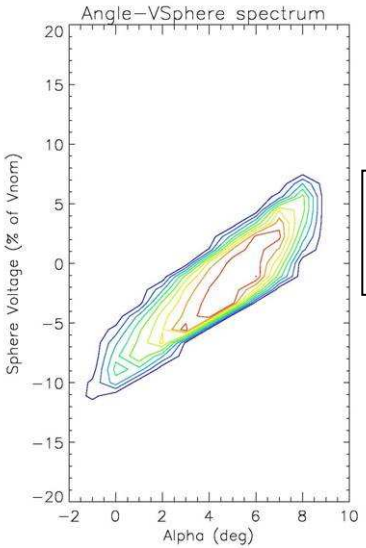


Energy-elevation response

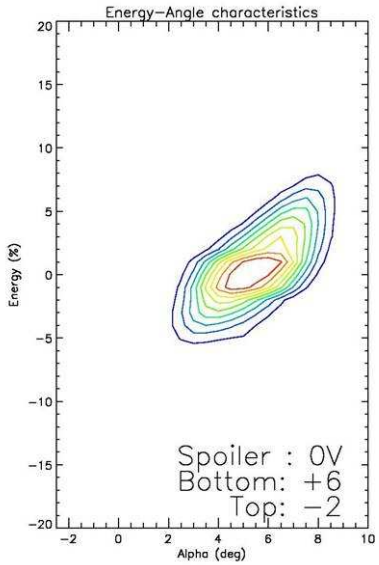
simulation

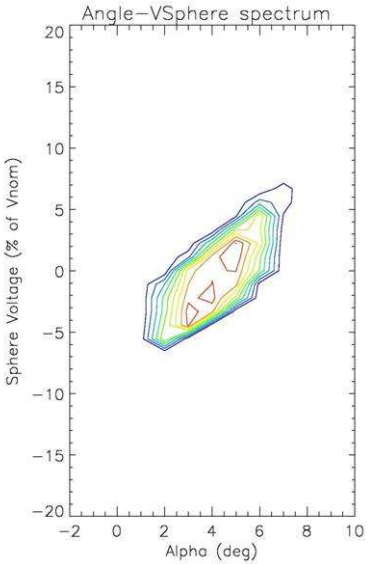


EM data



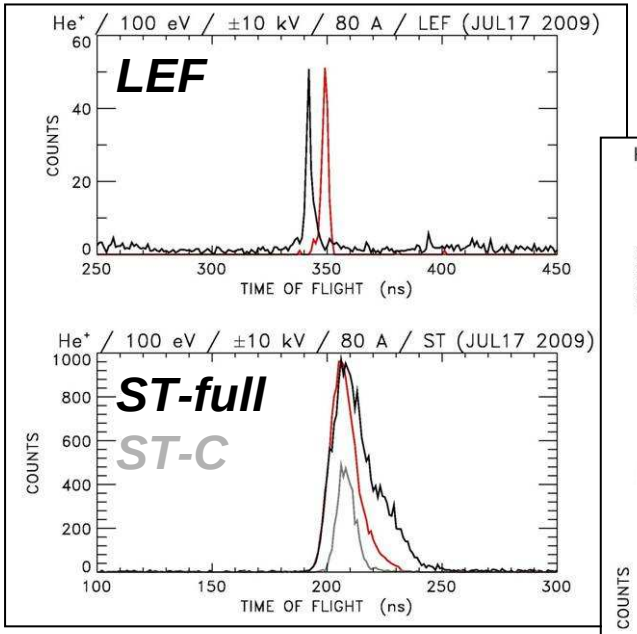
nominal window
(16 mm entrance height)



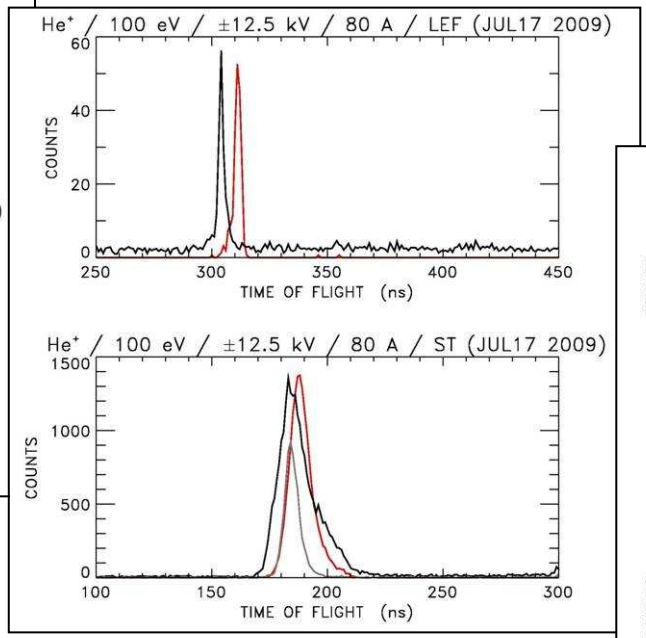


reduced window
(8 mm entrance height)

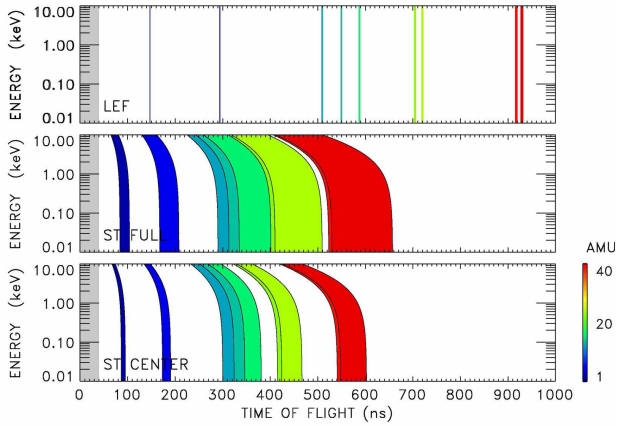
TOF spectra

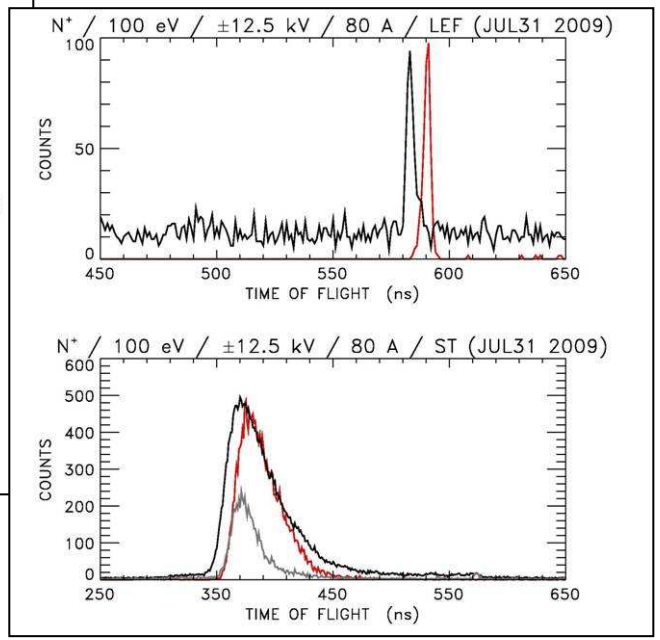


100 eV **He+**
VHV = 10 kV



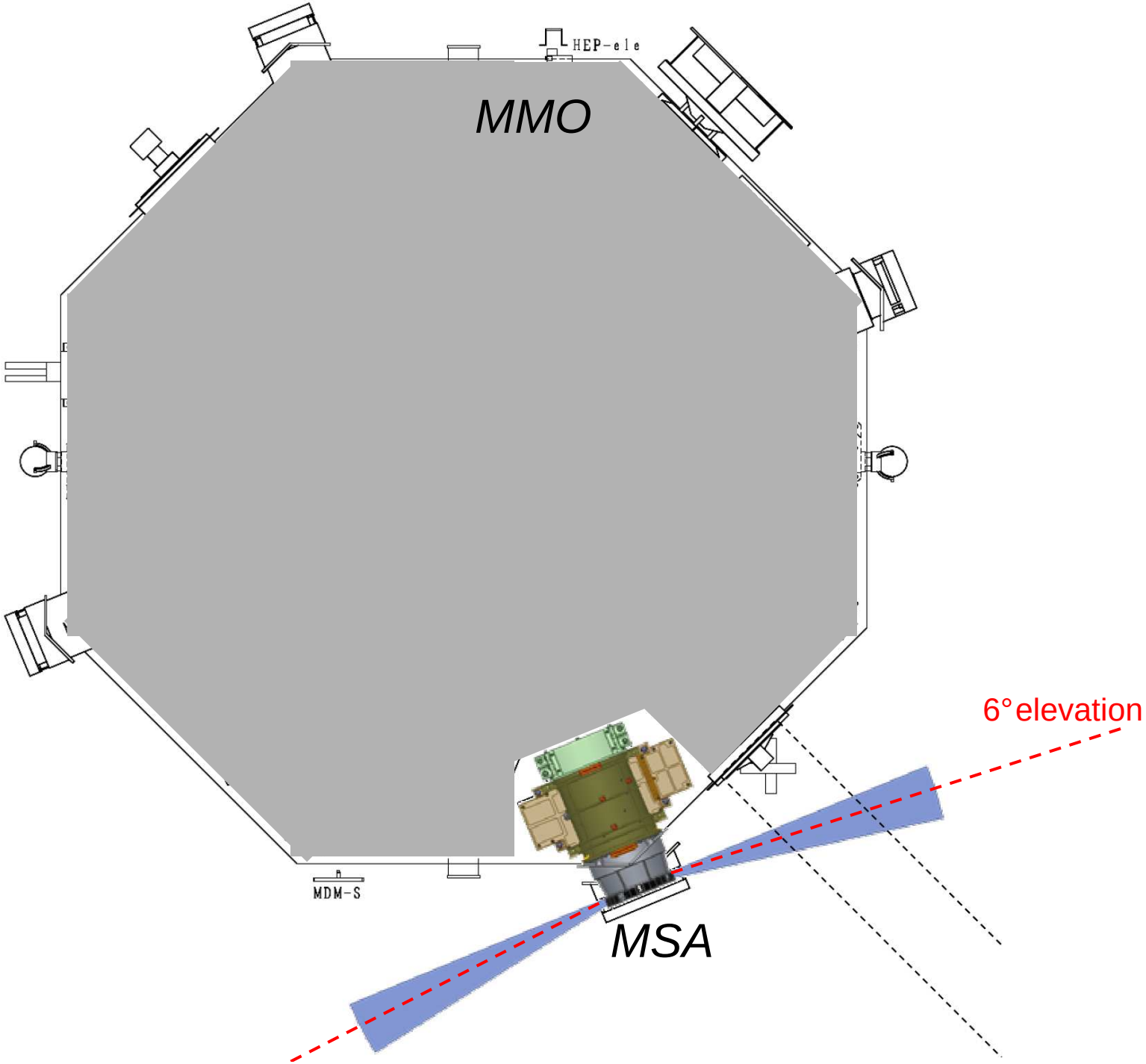
100 eV **He+**
VHV = 12.5 kV

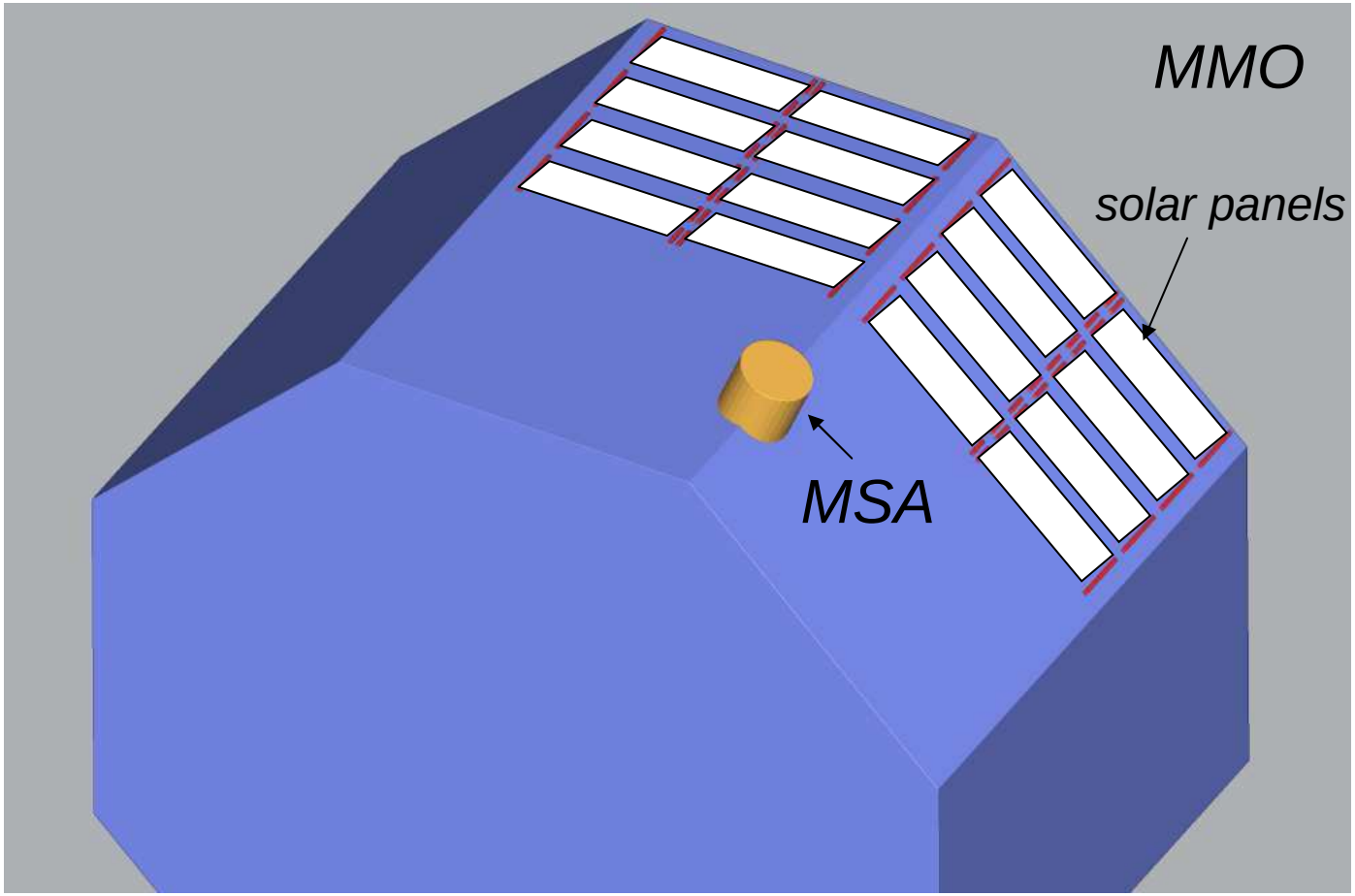


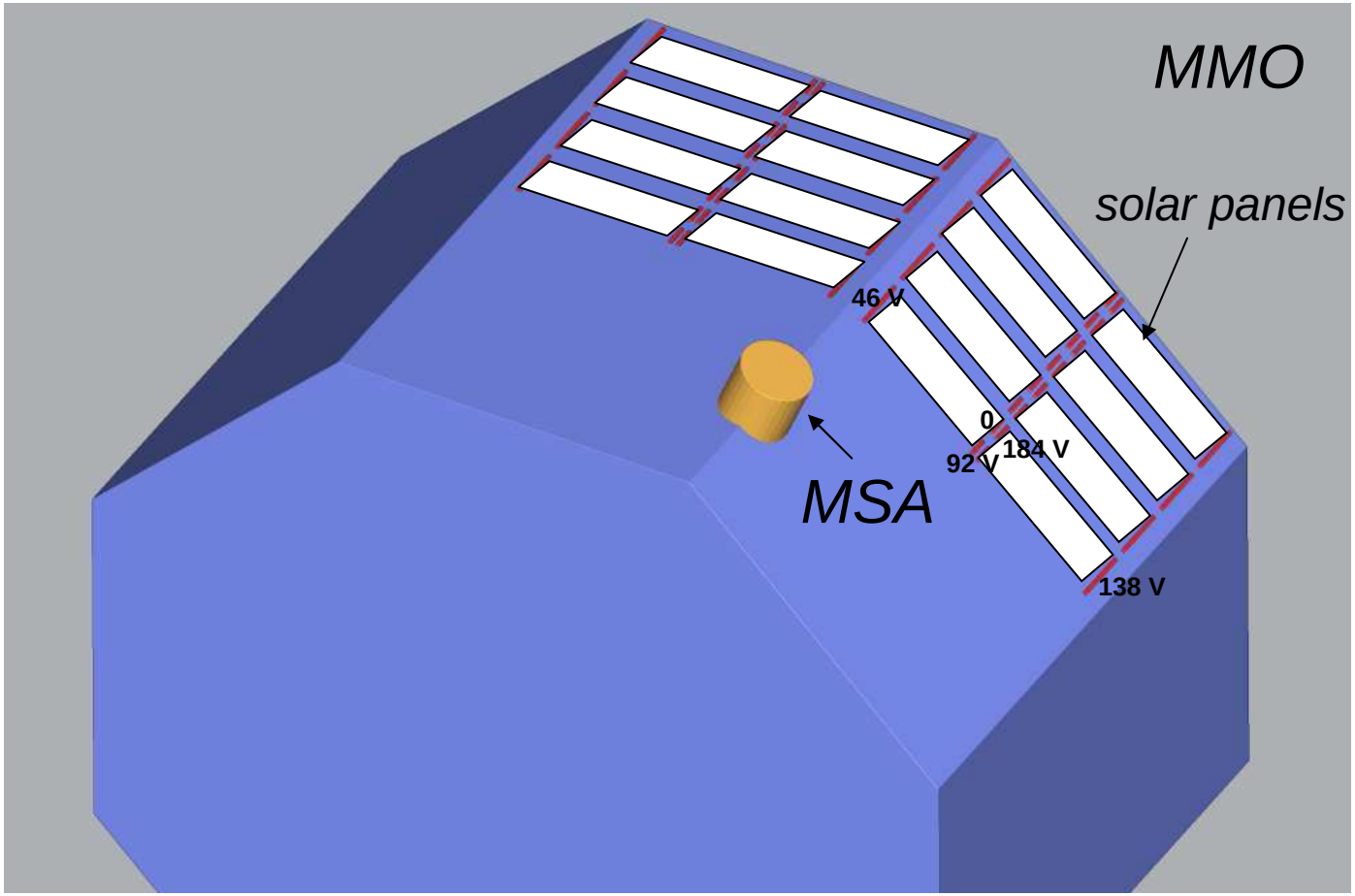


100 eV **N+**
VHV = 12.5 kV

red = numerical simulations

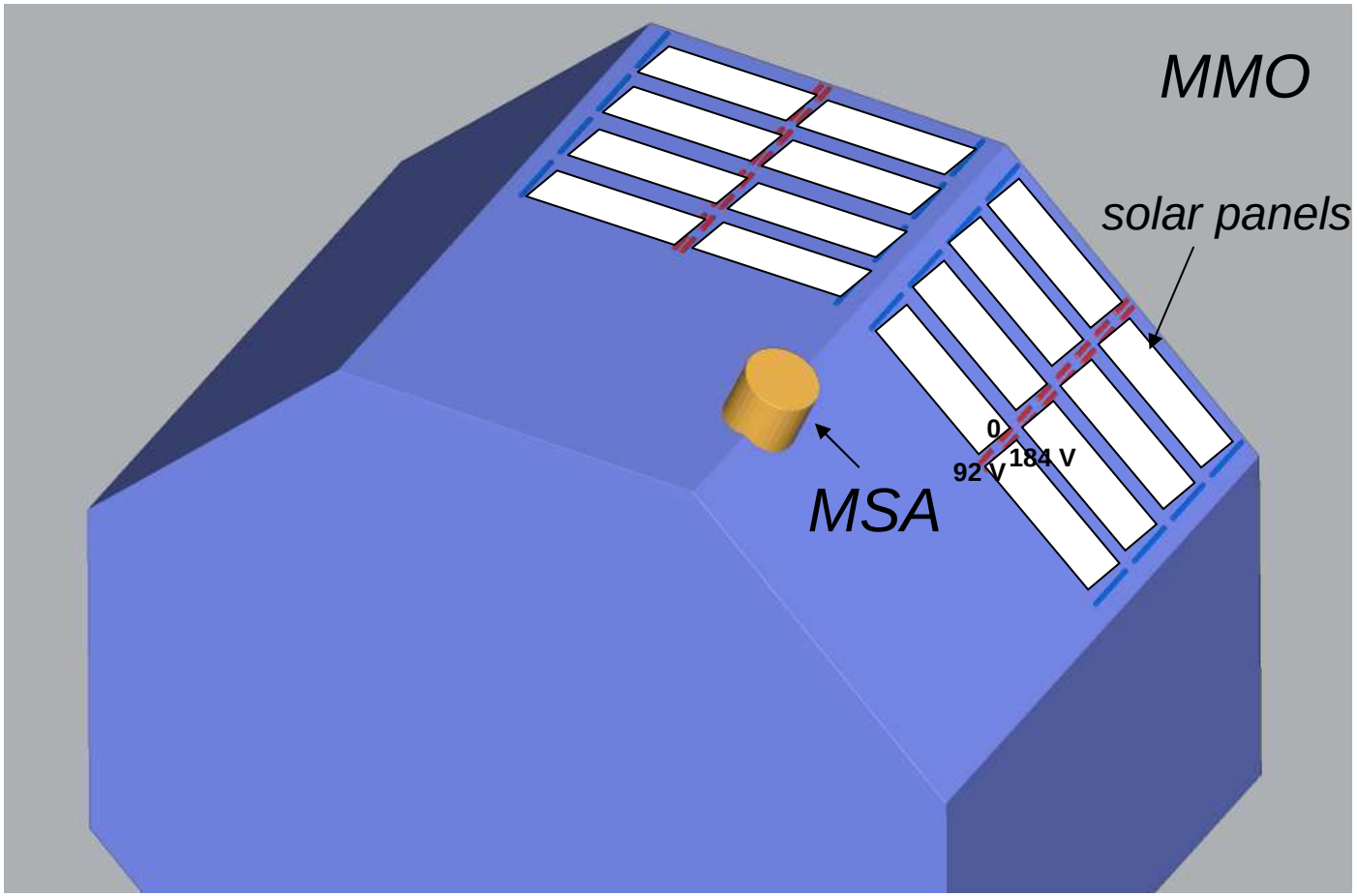

HEP-ele
MMO
MDM-S
MSA
6° elevation


MMO
solar panels
MSA



*Simulations of **positive** ion paths until MSA entrance in vacuum approximation (large Debye length)*

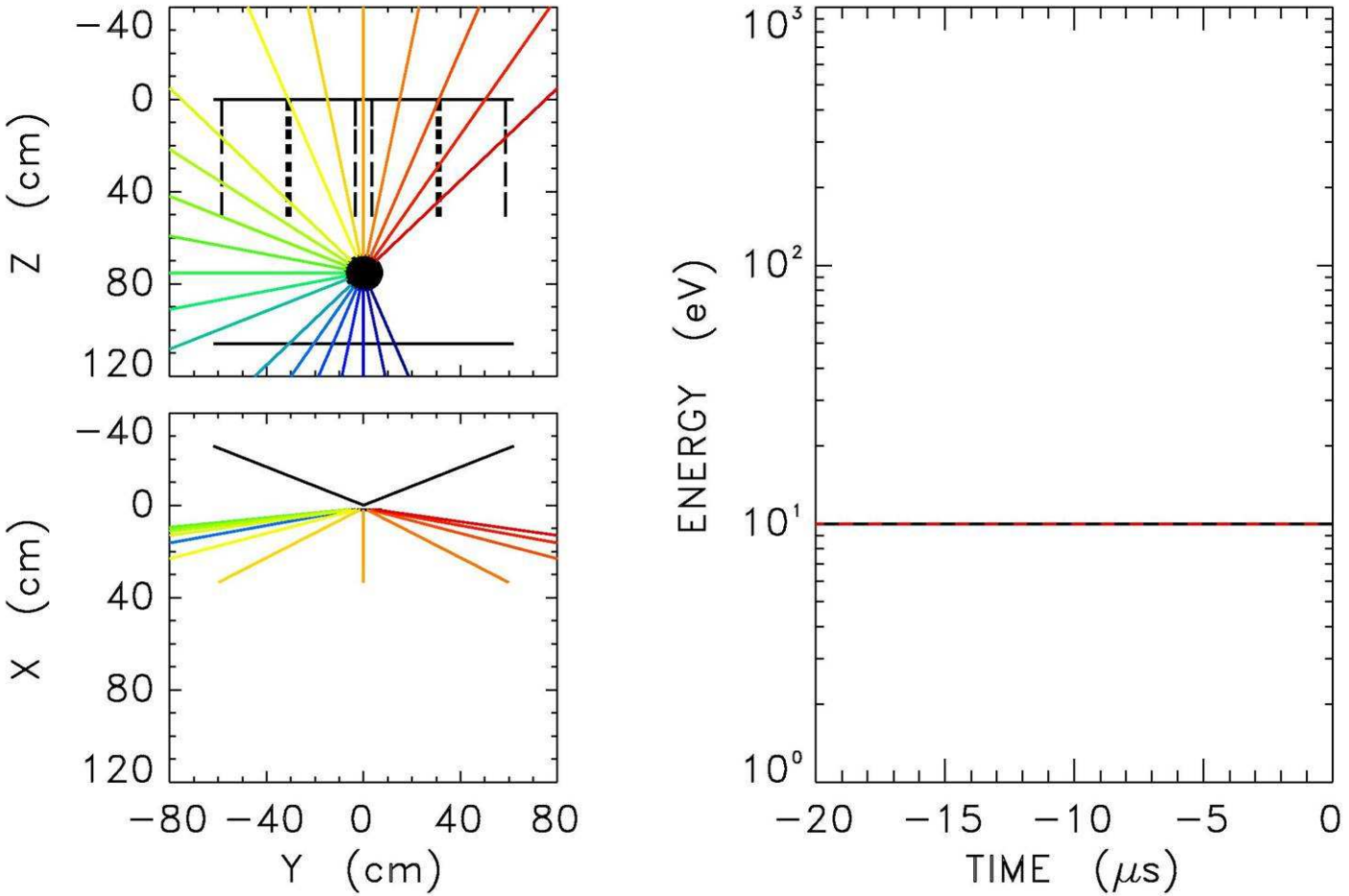
1. no shielding

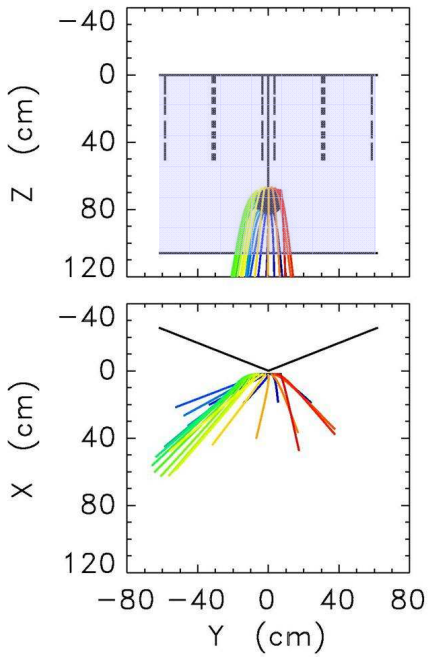


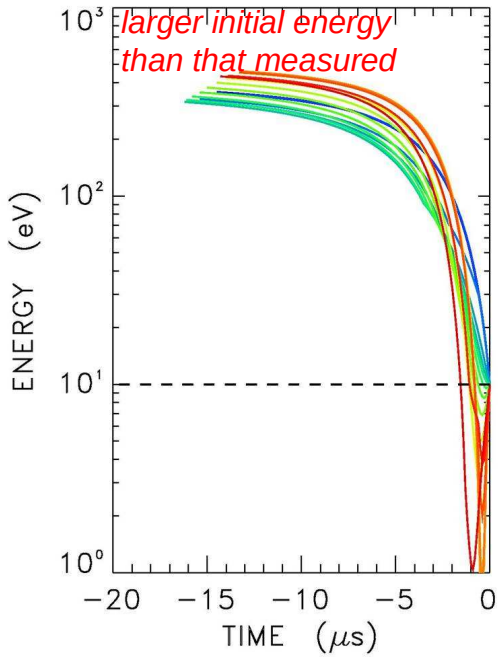
*Simulations of **positive** ion paths until MSA entrance in vacuum approximation (large Debye length)*

2. shielded S/C edges -

no S/C charging (10 eV ; 6° elevation)

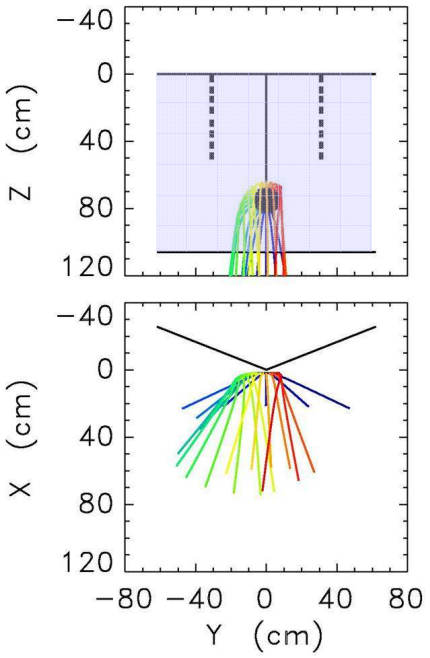


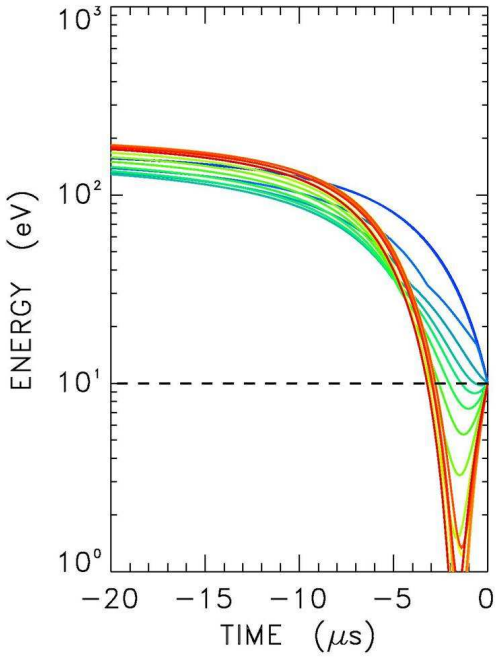




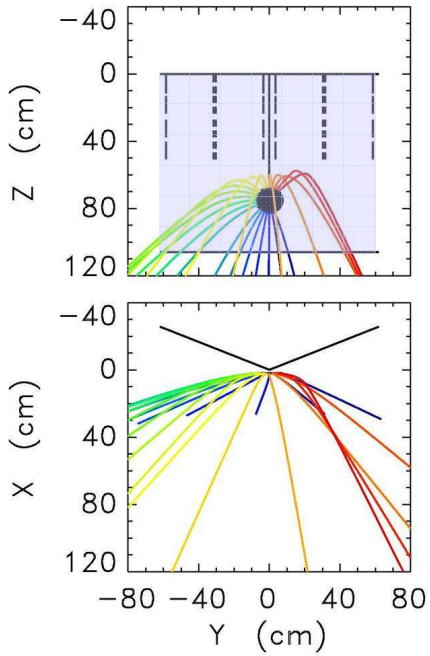
10 eV and 6° elevation

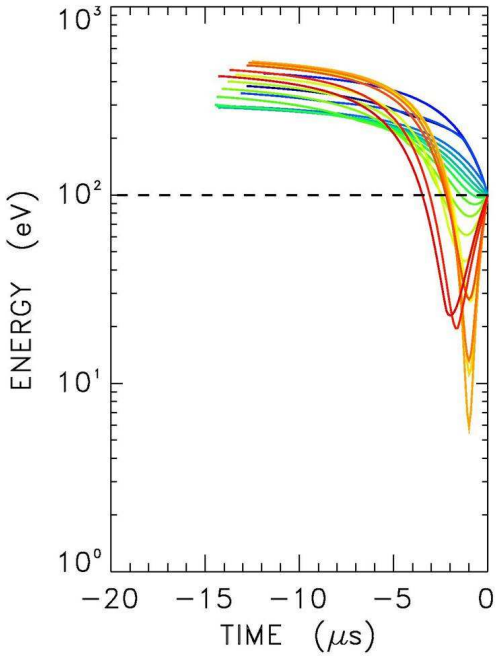
no shielding





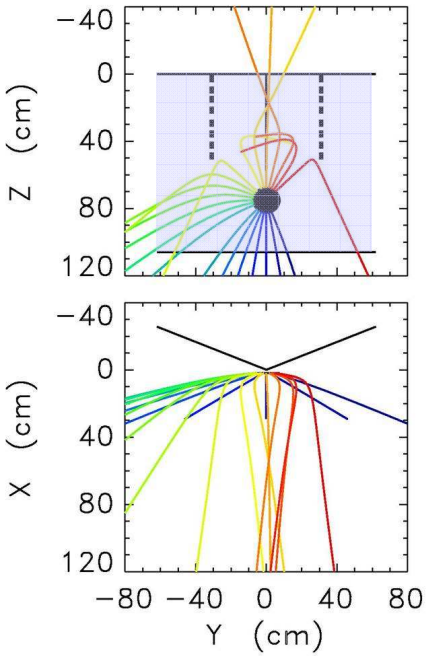
shielded S/C edges

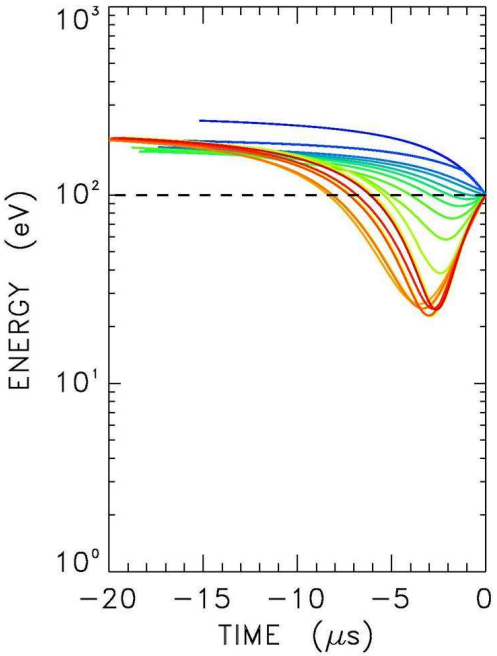




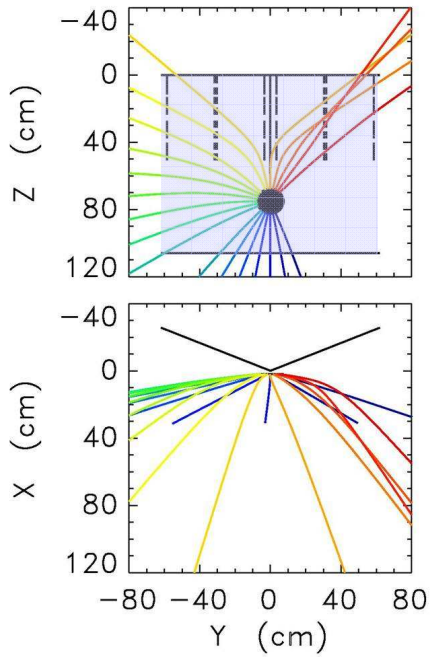
100 eV and 6° elevation

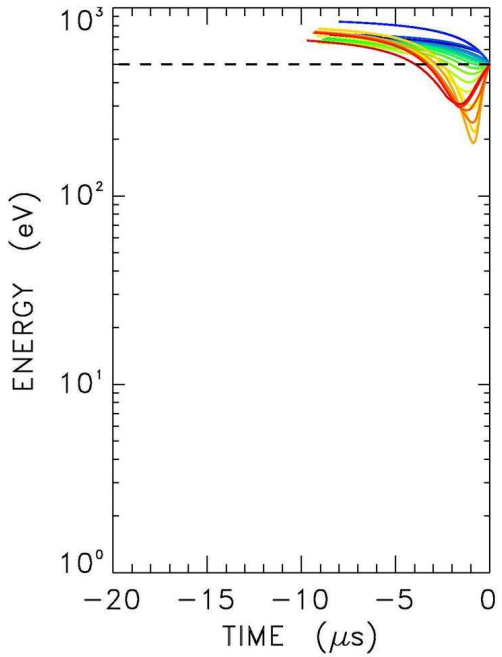
no shielding





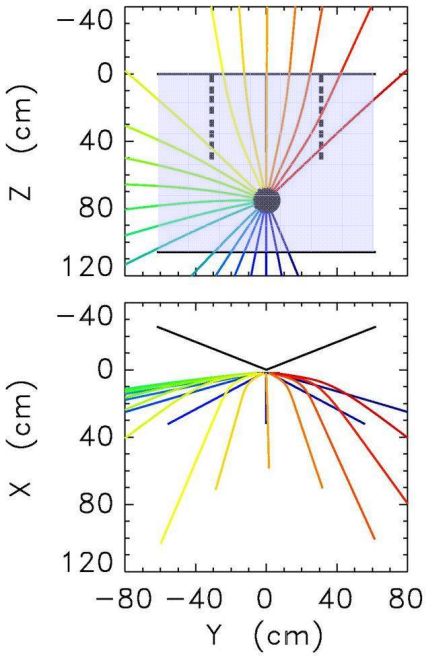
shielded S/C edges

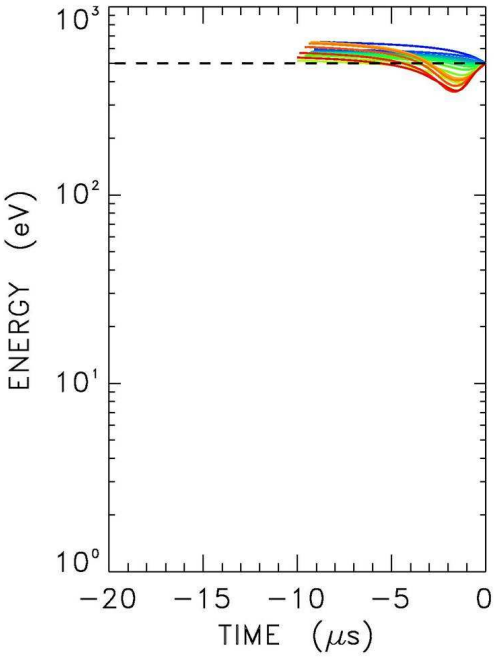




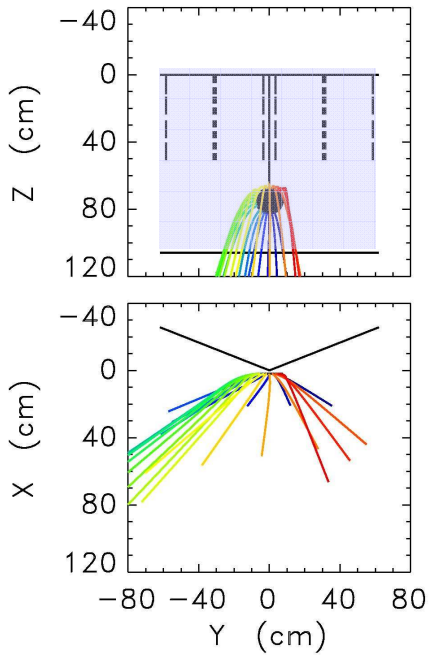
500 eV and 6° elevation

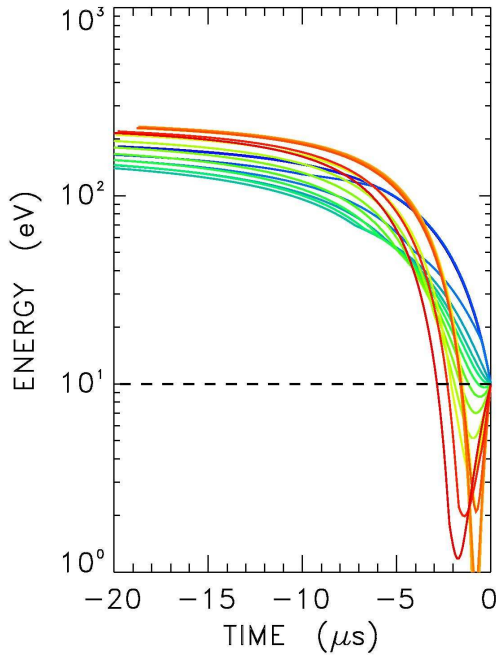
no shielding





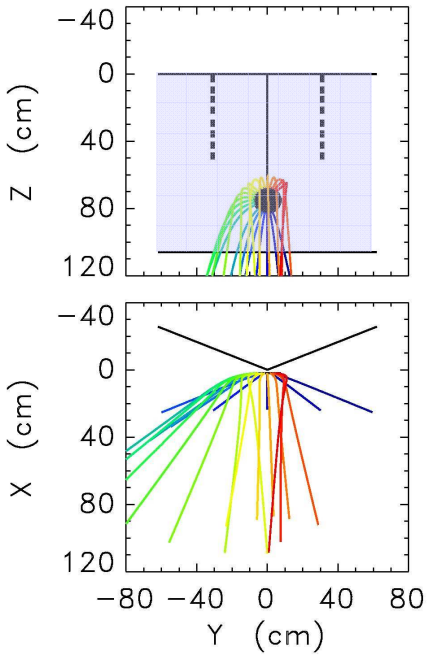
shielded S/C edges

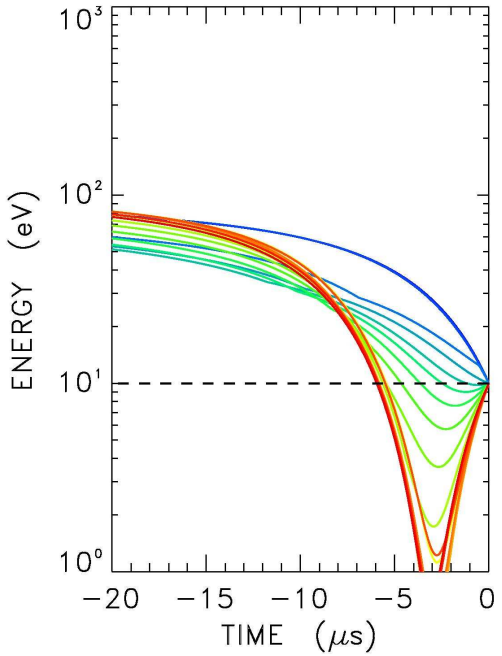




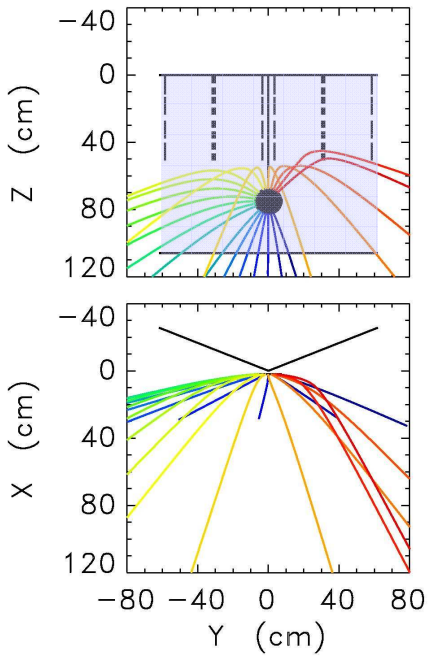
10 eV and 6° elevation (several minutes after eclipse → 50% ΔV)

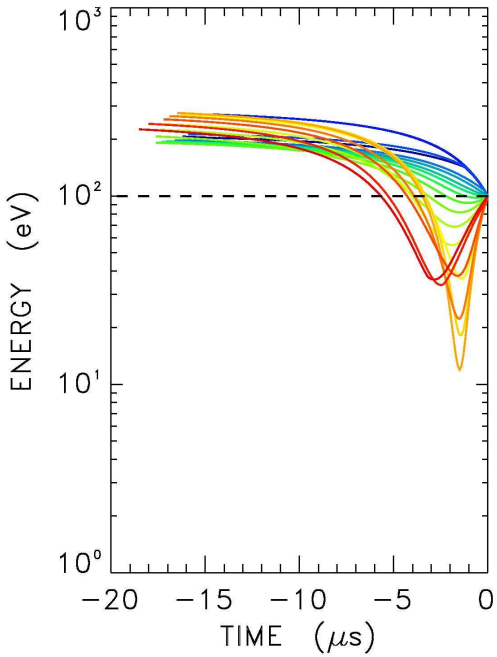
no shielding





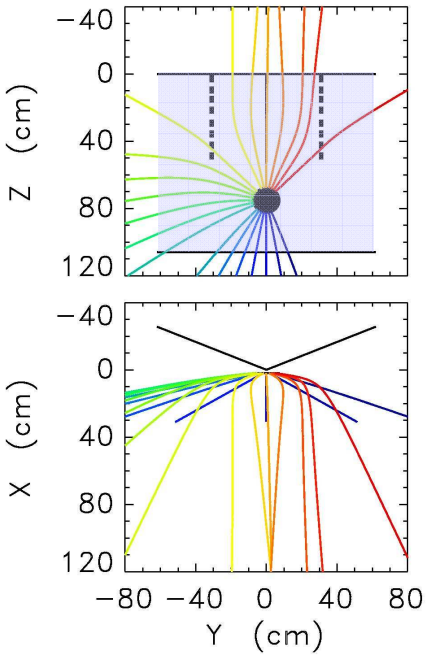
shielded S/C edges

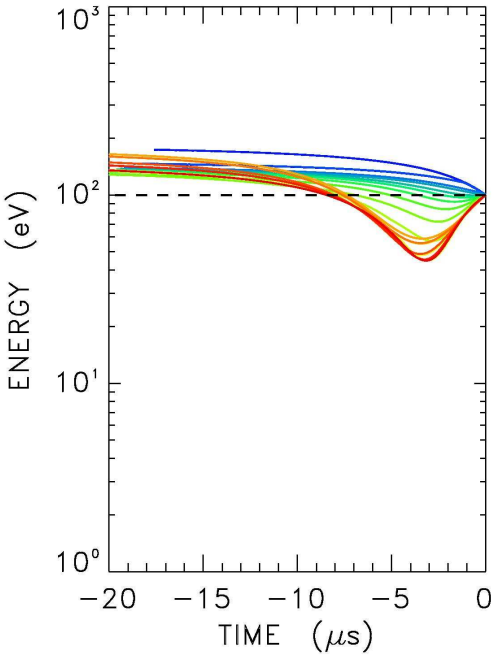




100 eV and 6° elevation (several minutes after eclipse → 50% ΔV)

no shielding





shielded S/C edges