Development of the NIM Mass spectrometer for Exploration of Jupiter’s Icy Moons Exospheres

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JUICE/ PEP

- JUICE*: Jupiter Icy Moons Explorer
  - Investigation of Jupiter and its environment
  - Characterisation of Jupiter’s icy moons Ganymede, Europa and Callisto

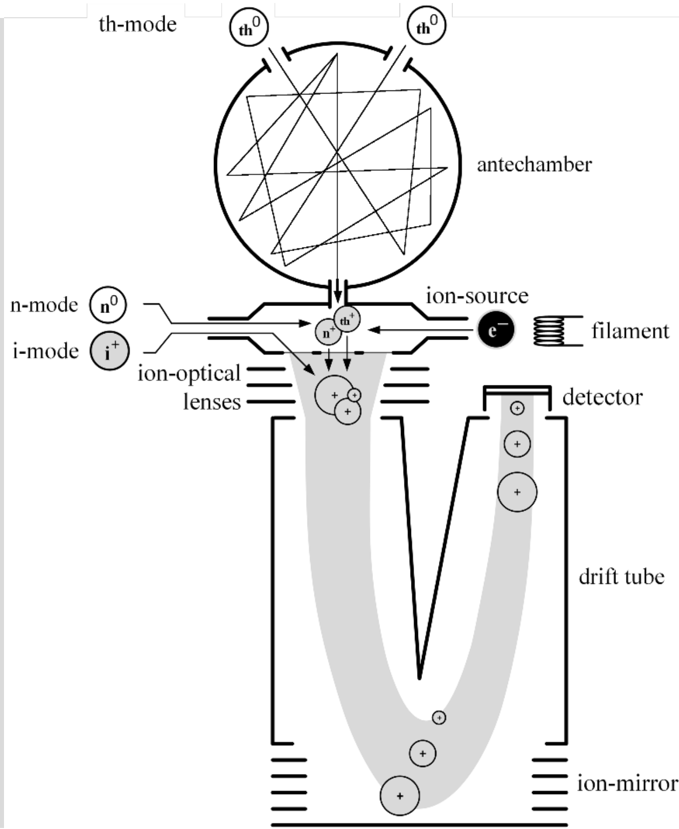
- PEP: Particle Environment Package
  - Investigation of the icy moons’ atmospheres and plasma environment
  - Determine global surface composition and chemistry

*http://sci.esa.int/juice

Neutral Gas and Ion Mass Spectrometer (NIM)

- 3 modes: **th**ermal-, **n**eutral- and **i**on-mode
  - Closed source: Thermalisation of neural gas. FoV of 10/3 π sr
  - Open source: Ions and neutral gas enter ion-source directly. FoV of 300° azimuthal direction and 10° elevation

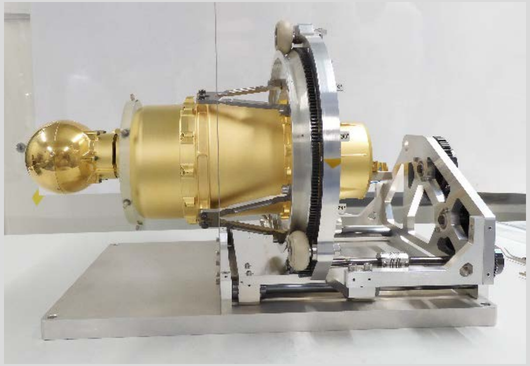
- Electron ionisation
- Ion mirror to increase the flight distance

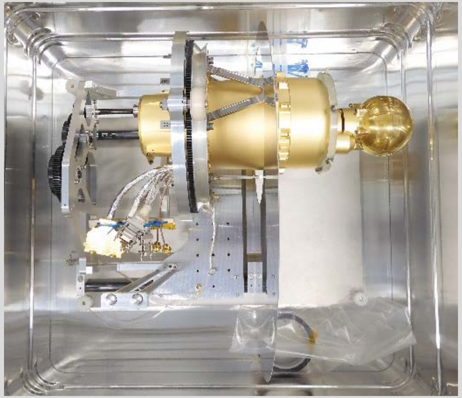


NIM ProtoFlight Model (PFM)

PFM

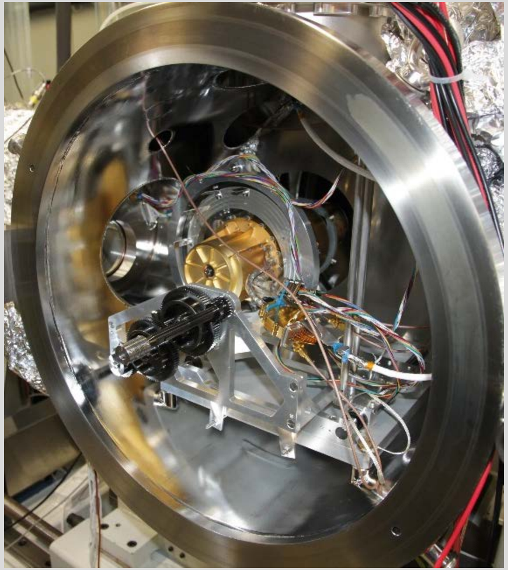
PFM integrated in the test setup





Transport to the vacuum chamber

Integration into the test chamber



Ion Storage Capability of NIM

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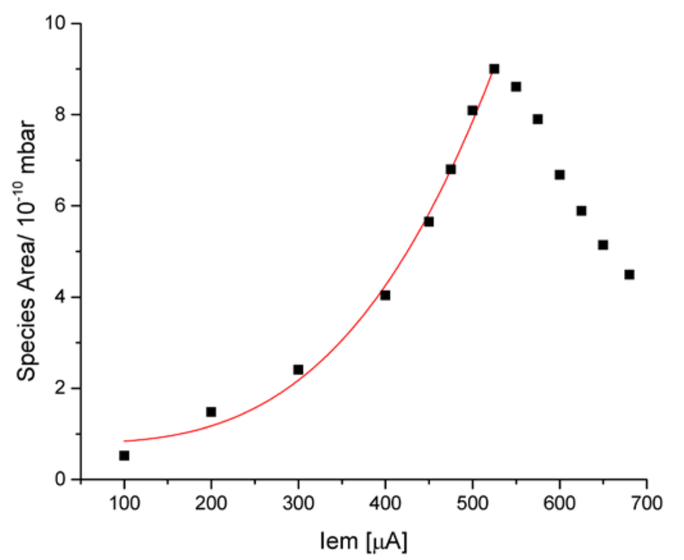
Objective

- Investigation of the NIM ion storage capability

Conclusions

- $S \sim I_{em}^{3.2} \rightarrow$ Ion storage capability is very good of this source. Usual storage values, $S \sim I_{em}^{2}$ (Abplanalp, 2009)
- Signal decrease for I_{em} > 500 µA due to space charge effects



Signal height depends on the electron emission current (I_{em}). Red curved is a fit with the function : $S = a + b \cdot I_{em}^{c}$

Density enhancement behaviour of Antechamber

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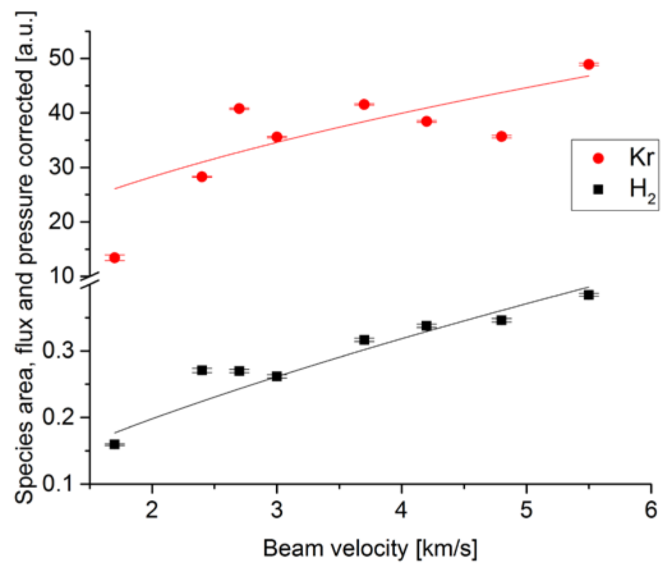
Objective

- Verification of the functionality of the antechamber by measuring the density enhancement behaviour of the antechamber



Conclusion

- Signal increase with increasing beam velocity as expected according to (Wurz et al., 2007)

Mass Range

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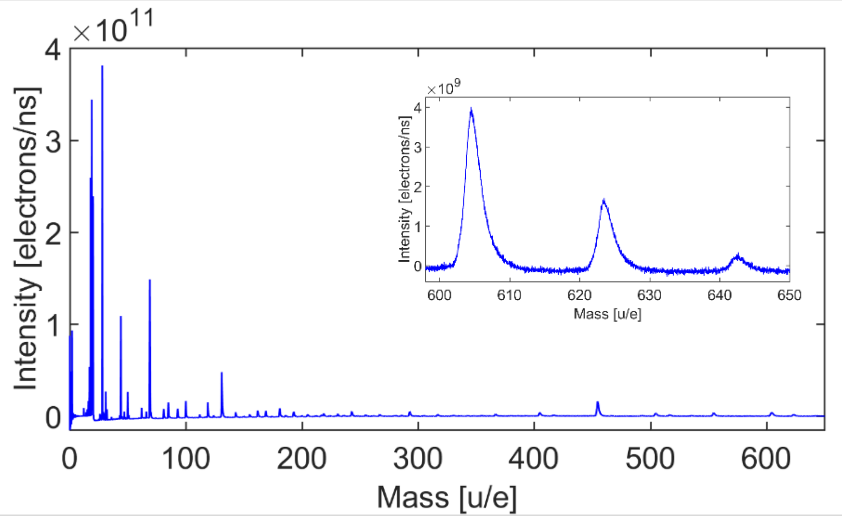
Objective

- NIM is designed to measure masses up to 1’000 u. Expected masses up to ~100 u
- FC5311 was used as a test sample because it has tabulated masses up to 624 u. This was the sample with the highest mass range available.

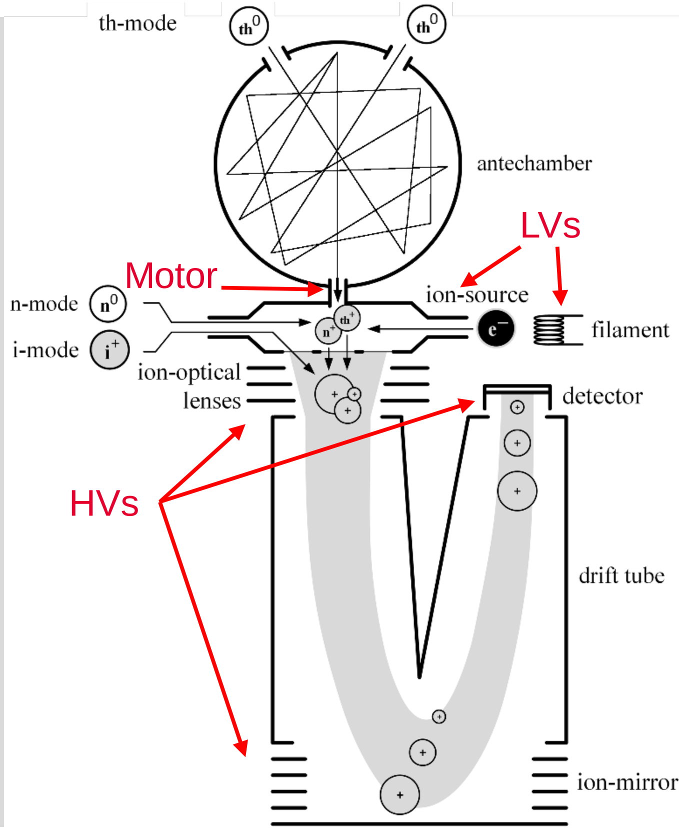


Conclusion

- Masses visible up to 642 u which is even higher than the highest mass tabulated (624 u) of this test sample

Electronic Board Tests

- Low Voltages (LVs)
  - Used in the ion-source and around the electron emitting filament
- High Voltages (HVs)
  - Used for the focusing lenses in the ion-source, for the ion-mirror and the detector
- Shutter Motor
  - Located between the antechamber and the ion-source. Used when measuring in n-Mode to block particles coming from the antechamber



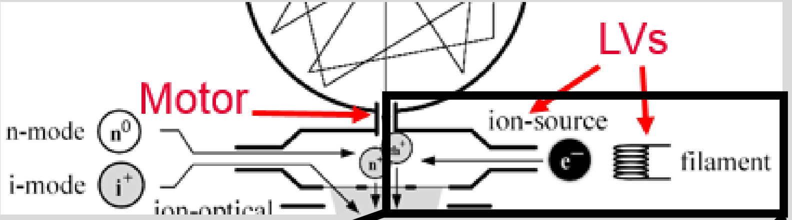
Low Voltage Board

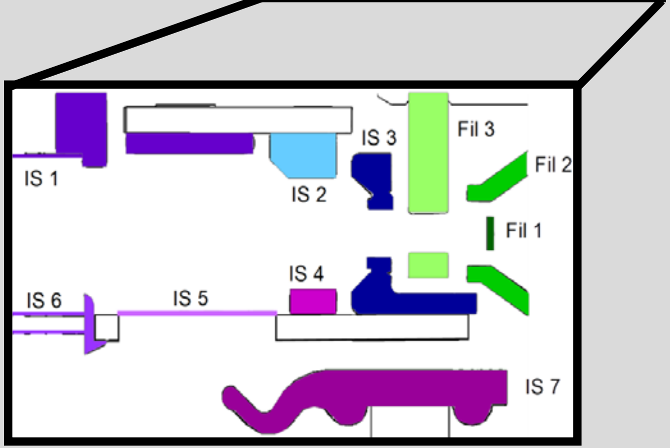
Electronic Board Tests

Measurement configurations

- Lab electronics: all voltages were provided by lab electronics. In case separate electrodes are listed, the voltages of these electrodes are provided by the flight low voltage board

Configuration	m/Δm				SNR			
	O_{16}	F_{19}	N_2	CO_2	O_{16}	F_{19}	N_2	CO_2
Fil1	90 ±3	174 ±10	419 ±47	471 ±47	35	498	243	116
Lab electronics	103 ±4	156 ±8	419 ±47	448 ±43	62	838	544	263
Fil 1, 2, 3, IS 1, 2, 4	93 ±3	174 ±10	419 ±47	448 ±43	36	471	182	94
Lab electronics	105 ±4	164 ±9	419 ±47	471 ±47	74	789	654	325
IS 1, 2, 4	107 ±4	164 ±9	419 ±47	471 ±47	75	771	679	339





Ion-Source (IS) and Filament (Fil) electrodes

Conclusion

- Same mass resolution for all different configurations
- LV board not calibrated → lower SNR

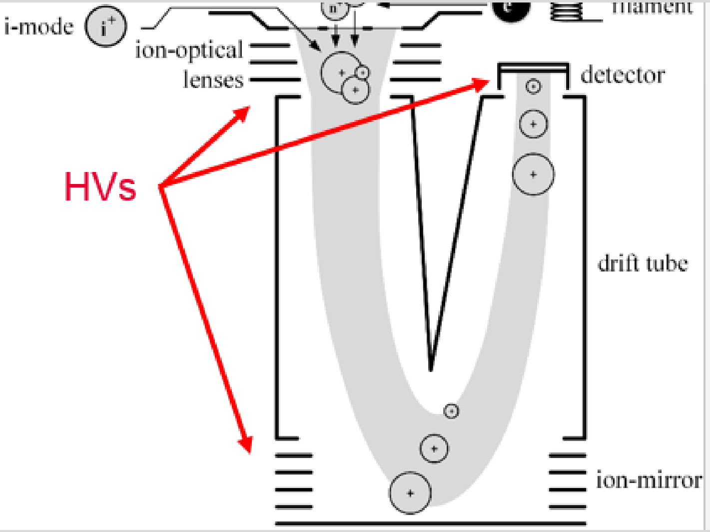
High Voltage Board

Electronic Board Tests

Measurement configurations

- Lab electronics: all voltages were provided by lab electronics. In case separate electrodes are listed, the voltages of these electrodes are provided by the flight high voltage board. Tested electrodes were electrodes from the ion-mirror
- R2 reaches -7 kV, R15 is a bipolar high voltage electrode reaching up to +2.3 kV

Configuration	m/Δm				SNR			
	N_2	CO_2	^{129}Xe	^{132}Xe	N_2	CO_2	^{129}Xe	^{132}Xe
R15	307 ± 25	330 ± 23	361 ± 16	365 ± 16	422	266	383	385
Lab electronics	295 ± 23	330 ± 23	396 ± 17	365 ± 16	350	225	310	313
R2	295 ± 23	330 ± 23	361 ± 16	373 ± 17	250	159	227	229
R2, R15	295 ± 23	330 ± 23	361 ± 16	373 ± 17	293	189	268	269
Lab electronics	295 ± 23	319 ± 21	369 ± 17	373 ± 17	316	204	287	289



Conclusion

- Same mass resolution and signal-to-noise ratio for the different configurations

Motor Boards

Electronic Board Tests

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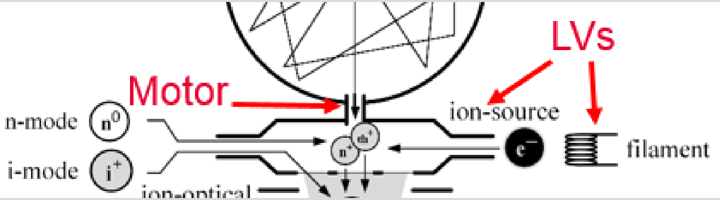
Measurement configurations

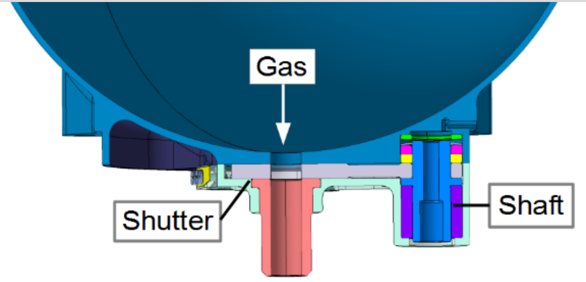
- Shutter open/ closed: neutral particle beam enters the ion source through the antechamber;
- Background: neutral particle beam points on the antechamber outer wall and scatters into the ion-source
- N_2 and CO_2 are residual gas and not part of the beam



Configuration	m/Δm				SNR			
	N_2	CO_2	^{129}Xe	^{132}Xe	N_2	CO_2	^{129}Xe	^{132}Xe
Shutter open	307 ±25	330 ±23	361 ±16	373 ±17	550.8	309.9	735.7	740.2
Shutter close	307 ±25	330 ±23	361 ±16	365 ±16	540.3	315.4	120.8	121.6
background	307 ±25	330 ±23	353 ±15	357 ±16	631.6	360.2	85.4	84

Conclusion

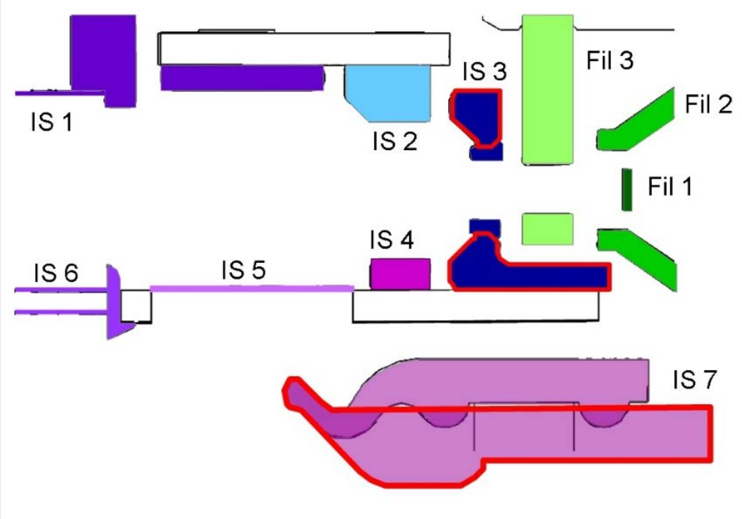
- Same mass resolution for all different configurations
- Shutter performance lower than expected due to differences between laboratory and flight environment



Redesign of IS

Objective

- Redesign of ion-source due to mechanical failure during vibration test
- New design:
  - ring to narrow the entrance hole of the electron beam had to be removed due to mechanical reasons
  - IS 7 was shifted to increase its distance to the entrance (IS 3) to increase high voltage stability
  - In red the redesigned electrodes IS 3 and IS 7



Redesign of Ion Source

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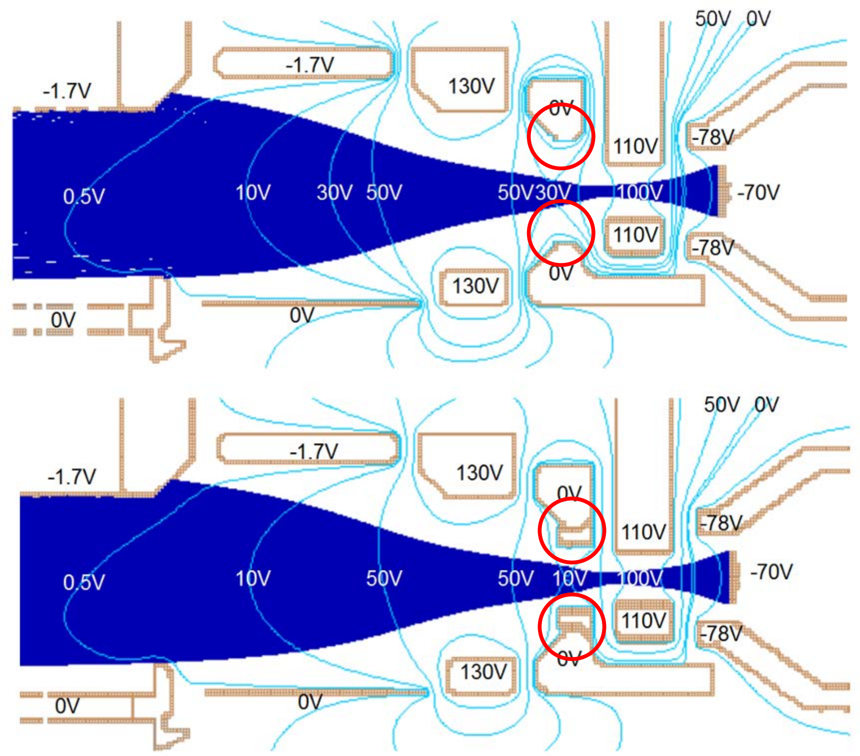
Objective

- Simulations to evaluate the impact of the redesign on the performance of the ion source

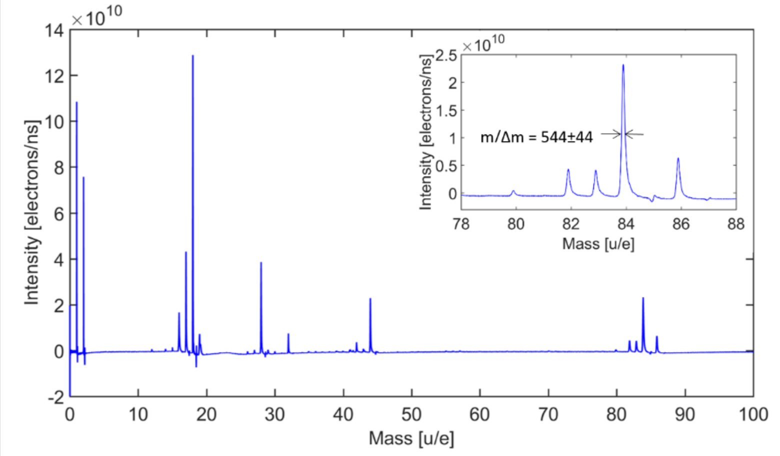
Conclusion

- The redesign did not change the flight path of the electrons significantly, therefore expected performance of the ion source should be the same

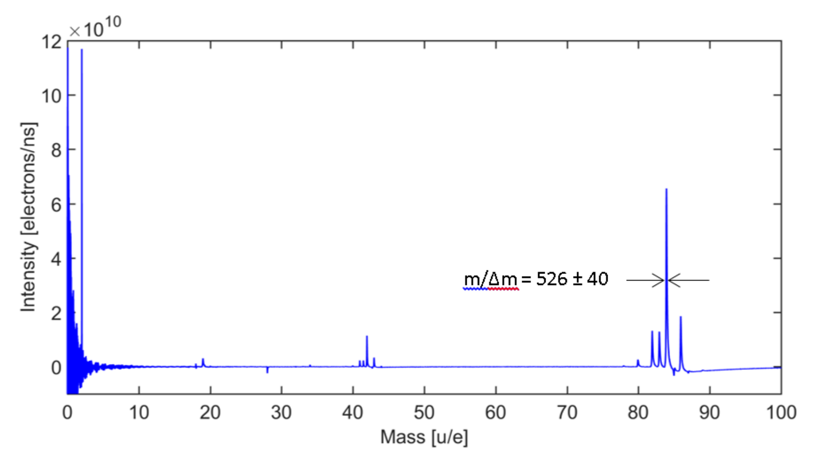


Test Results

thermal Mode



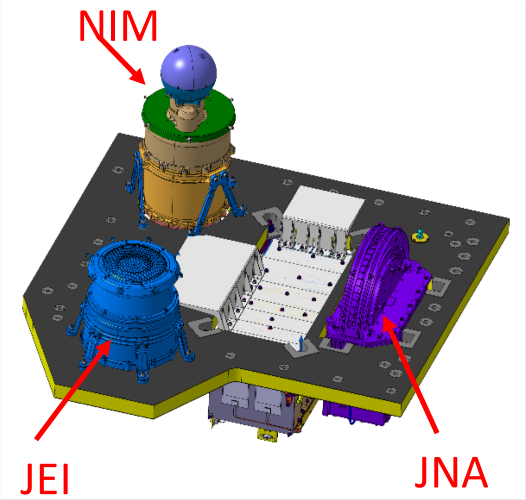
neutral Mode

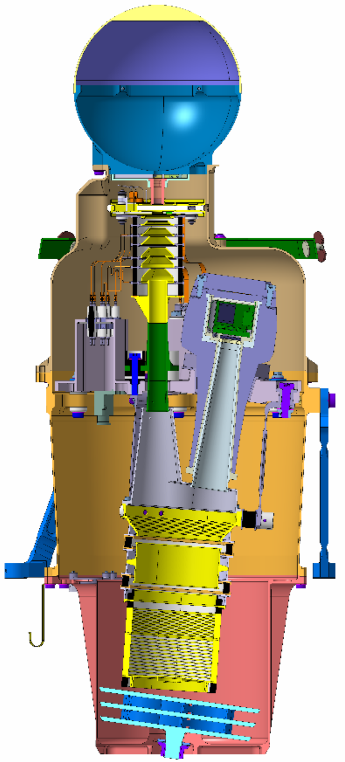


- Mass resolutions could be improved by a redesign of the old source

Next Steps

- Finalise work with PFM
- Commissioning, testing and calibration of the Proto Flight Model (PFM) sensor with flight electronics
- Integration and final testing completed by end of July 2020





Have a nice day