Experiments to improve the performance of the GTS-LHC ECR ion source

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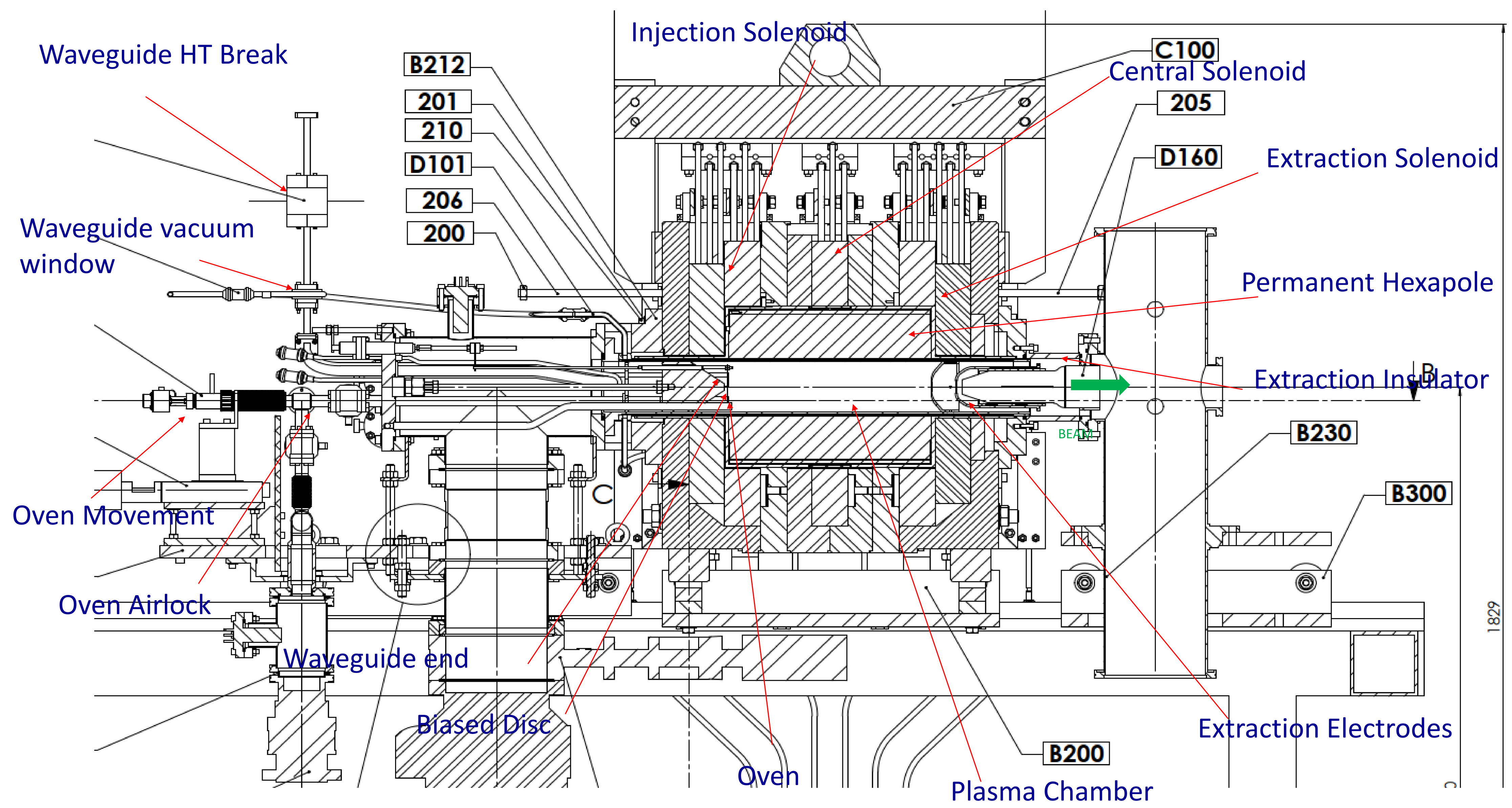
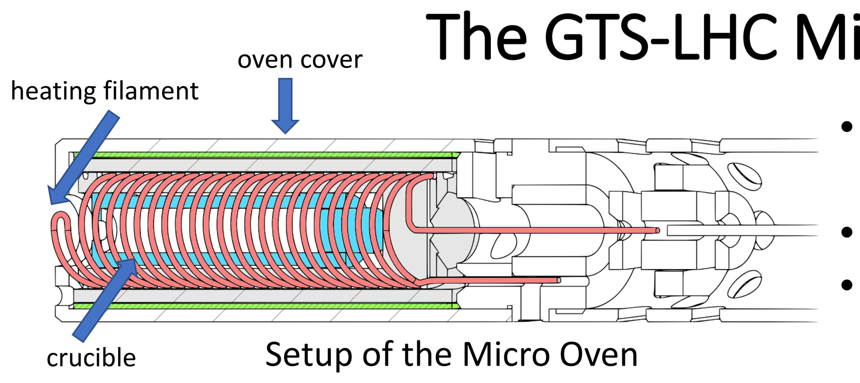
Abstract. The GTS-LHC 14.5 GHz ECR ion source provides the ion beam, which after acceleration in the ion injector complex, is injected into the LHC, as well as being sent to fixed target experiments at CERN. Two experiments have been performed on the source. The stainless steel plasma chamber has been sputter-coated with a rather thick layer of aluminium on the surface facing the plasma; and the lead micro-oven has been modified to avoid the build-up of lead-oxide on the oven outlet. Details of the changes will be given, and results of beam measurements will be shown, with particular attention on how the stability and oven-refill schedule is impacted by these changes

https://cern.ch/go/6fct



Source Characteristics	
Ion	Pb29+ (highest intensity)
Ion Intensity	150 µA (Pb29+)
Support Gas	Oxygen
Frequency	14.5 GHz
Microwave Power	< 2000 W
Mode	Afterglow
Magnets – Long.	3x Normal Solenoids
Magnets – Radial	Permanent Hexapole
Voltage	19 kV
Biased disc	<400 V - pulsed

The GTS-LHC Micro Oven



Setup of the Micro Oven

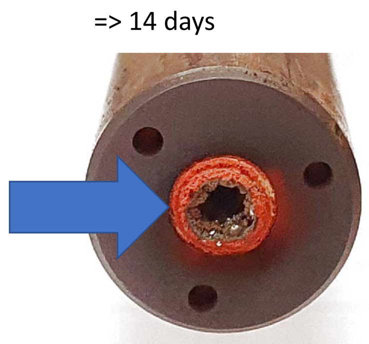
- Lead for evaporation is inside a crucible
- Capacity of around 1.5 g of Pb
- Resistively heated with a tantalum filament wound as a double helix

Limitation: In 2018 and before the oven needed a refill and cleaning every two weeks, even though the crucible still contained almost half the lead sample

Blockages of lead oxide

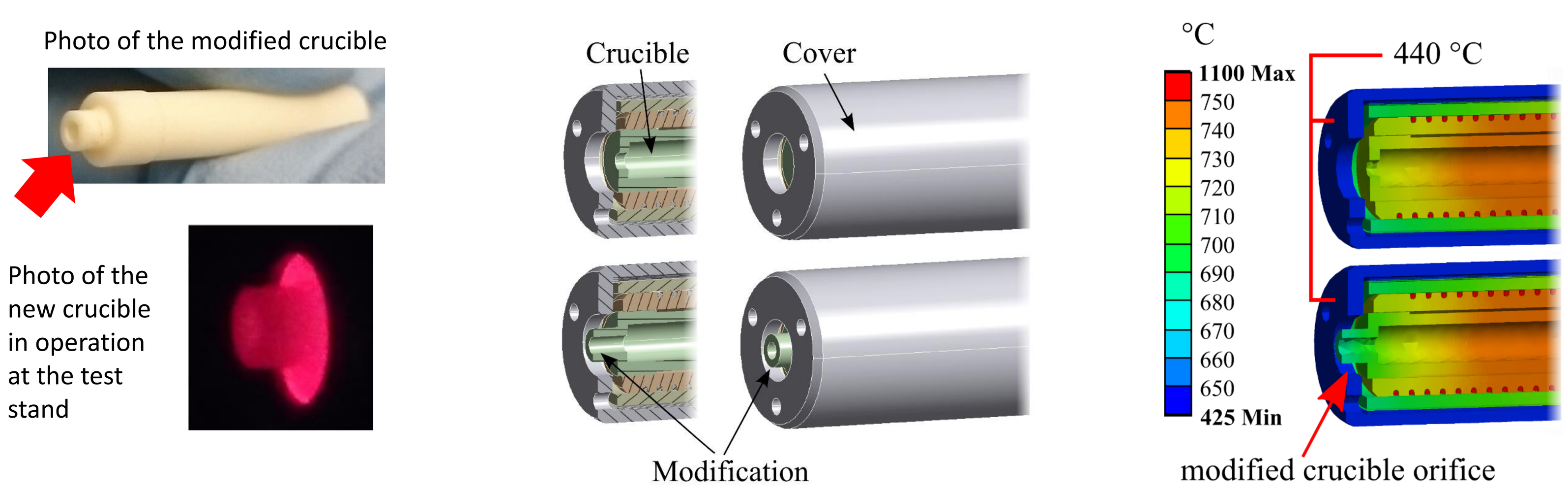
- Oxygen is used as a buffer gas in the source
- Lead condensate can react with the oxygen and form lead oxide
- From test stand: Lead oxide starts forming at outer oven cover
- Eventually complete orifice of oven gets blocked
- One of the main limiting factors for the oven runtime

Run 16.11 - 30.11.2020
=> 14 days



Prevent the blockage with a beak

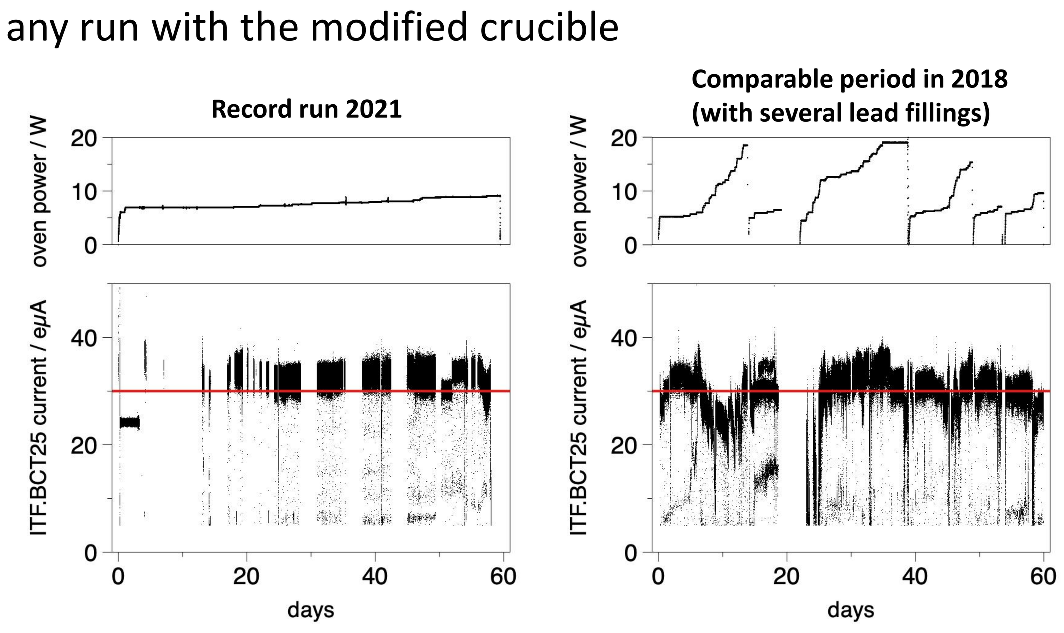
- When the crucible orifice is elongated with a "beak", no lead is deposited onto the colder oven cover => No condensate => No lead oxide blockage
- The beak itself remains hot enough to prevent condensation of lead on itself



Results with the modified crucible at the GTS-LHC

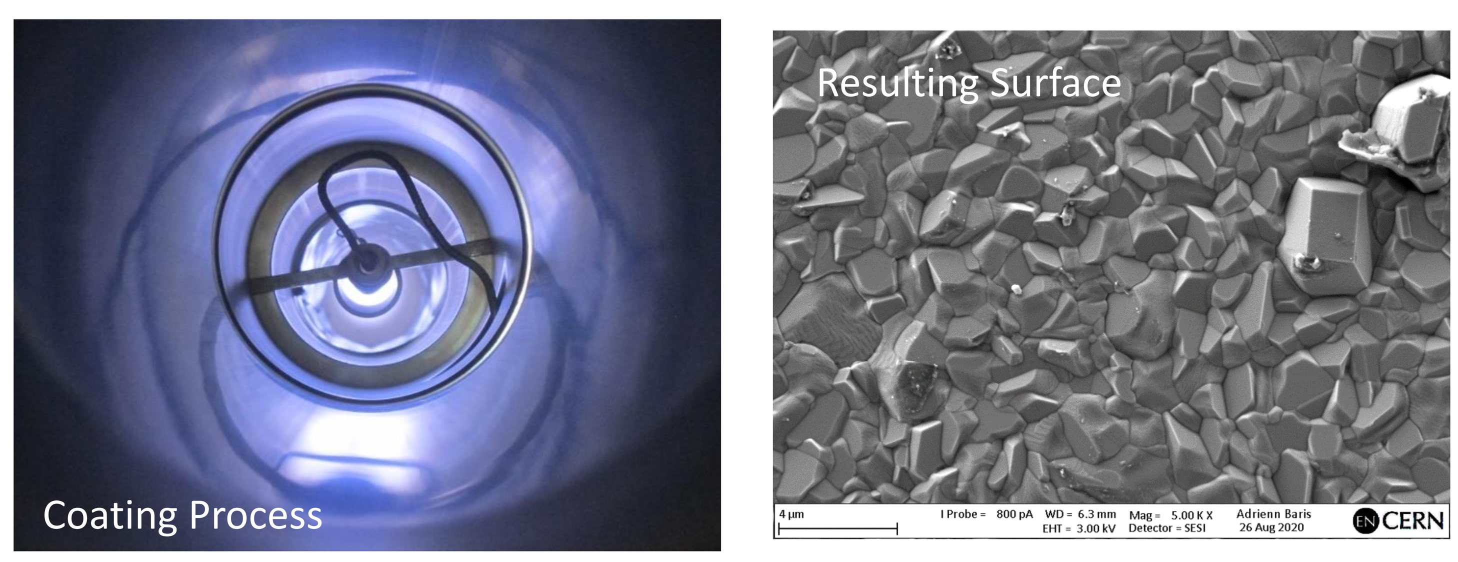
- The modified crucible was tested at the GTS-LHC in 2021 in all runs so far
- No lead oxide visible after any run with the modified crucible

Photo after 59 days of continuous operation



- A record run for 59 days was achieved with more than 30 days of beam delivery to the subsequent accelerator LEIR
- Results are promising for a LHC heavy ion run without oven refill (usually 4 weeks)
- Still in testing (run as long as possible) and new refill schedule needs to be decided

Aluminium Coated Plasma Chamber



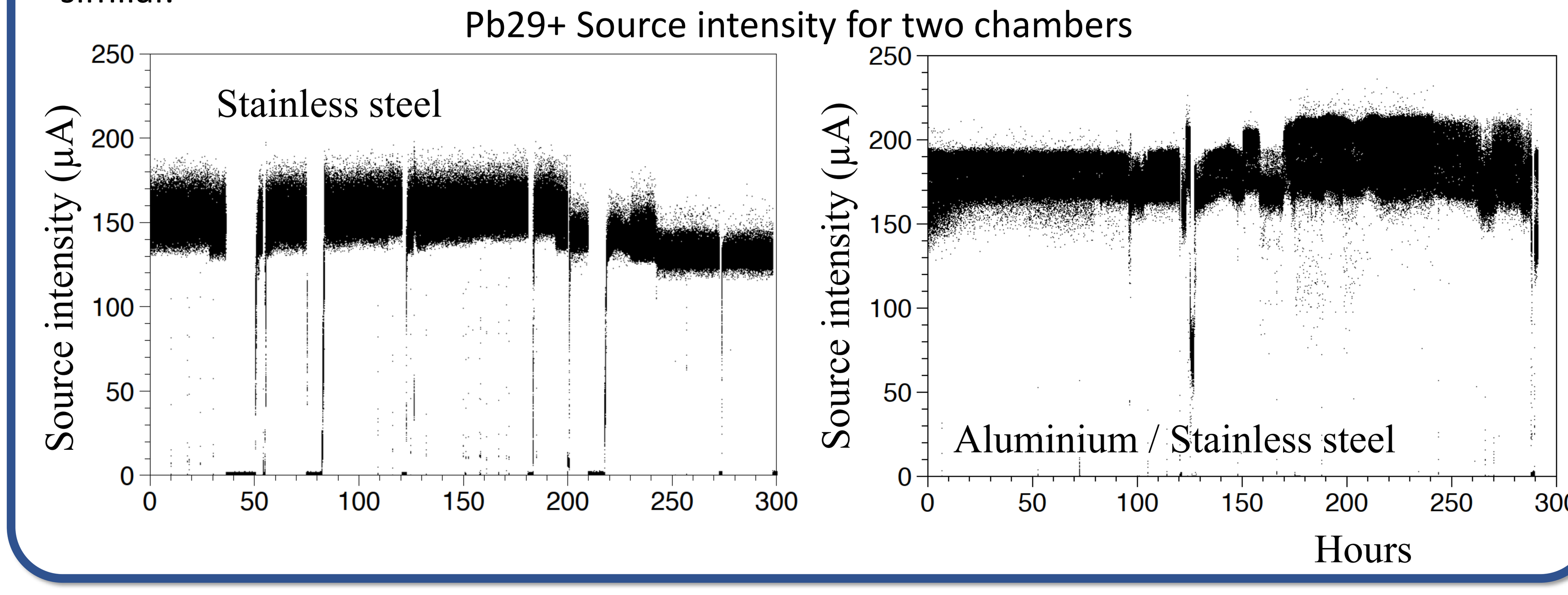
Stainless steel (SS) plasma chamber with a 20 µm thick coating of aluminium along the plasma facing surface, produced by dc magnetron sputtering in argon (Al/SS chamber).

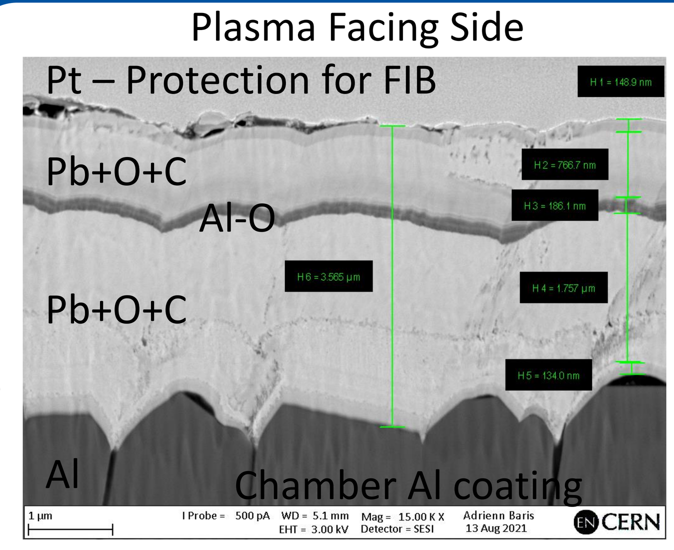
Beam Tests

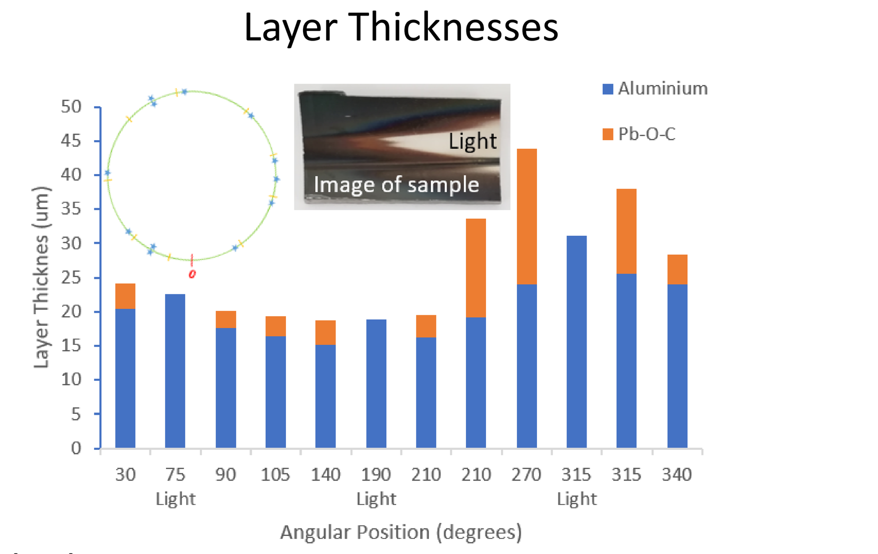
Beam tests made with the two chamber types, with Al/SS run specially for ~1500 hours. Initially, the Al/SS chamber only needed 400-500 W microwave power to deliver a high intensity beam. After some time it became necessary to increase this power. After ~1000 hours of operation, the two chambers performance is very similar.

Plasma Chamber	Year	Start time for data analysis (Hours)	Source Beam Intensity Pb29+ (µA) mean	stdev	RFQ Beam Intensity Pb29+ (µA)
SS	2018	4000	190	9	140
Al/SS (LP)	2021	200	190	14	140
Al/SS (HP)	2021	1000	175	10*	130
SS	2021	200	150	8	115
SS	2021	1000	150	8	115
SS	2021	2000	160	10	130

Pb29+ Source intensity for two chambers







SS/Al chamber analysed with FIB, to dissect the layers.
Most of the chamber has been coated with a porous layer of Pb-O-C, up to 20 µm thick.
The regions corresponding to the electron loss lines have kept the aluminium layer, and there is no Pb coating. The thickness of the P-O-C depends on the angular position.