Report on experimental results for metal-ion beams

Report: JRA01-ARES-MS84

1) Oven development
2) Sputter development
3) MIVOC development
4) Hot liner
5) New innovations
6) Production efficiency with different methods

Deliverable D7.3 WP7– *JRA01 – ARES*
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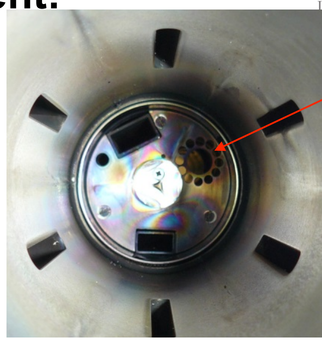
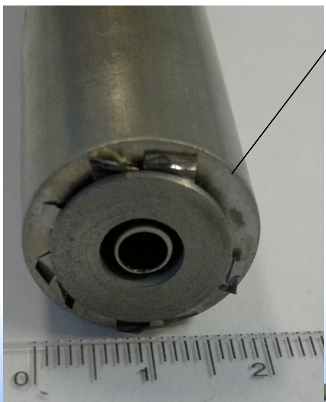
1) Oven development:

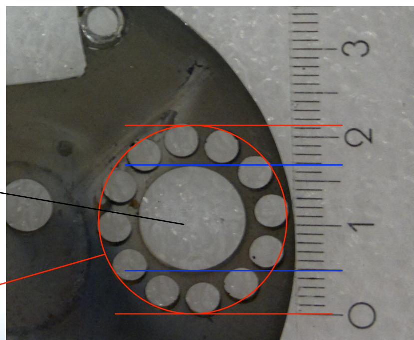
Foil oven:

- The original plan was to have tests with the movable oven. This plan was cancelled after the demagnetized permanent magnets (radial sputtering experiments). The reason can be seen from figure (oven very close to the permanent magnets as soon as it is inserted into the plasma chamber).





Oven is 1-2 mm behind this plate. Metal vapor comes out tough the aperture (12 mm in diameter).



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Foil oven modifications

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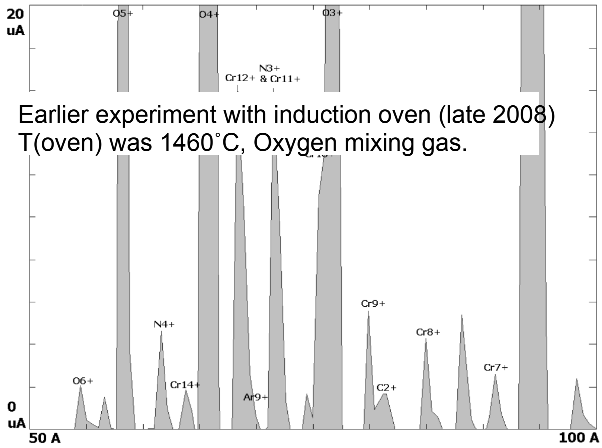
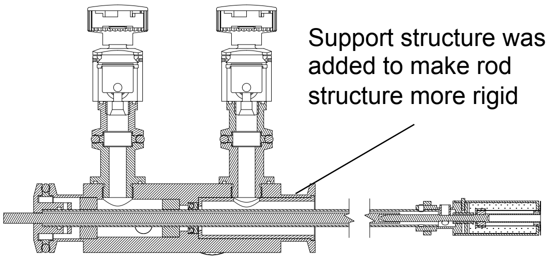
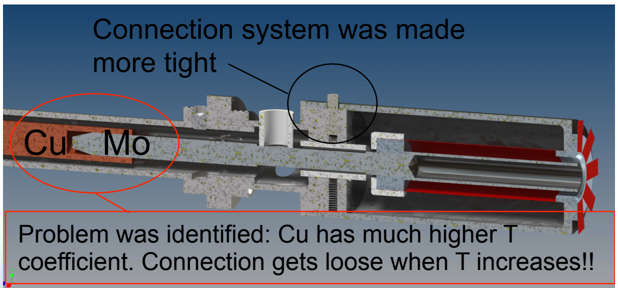


Earlier experiment with induction oven (late 2008)
T(oven) was 1460˚C, Oxygen mixing gas.





During Oct. 2013 – Jan. 2014 foil oven was slightly modified to improve the reliability (not inserted into the chamber). The intensity of 7.6 μA for Cr^{8+} was obtained with the helium mixing (I_{oven} was 59 A). If the earlier T calibration can be trusted after these small modifications the oven temperature was slightly higher than 1500˚C. This oven has potential to go remarkably higher in T.

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MoO_3 with oven

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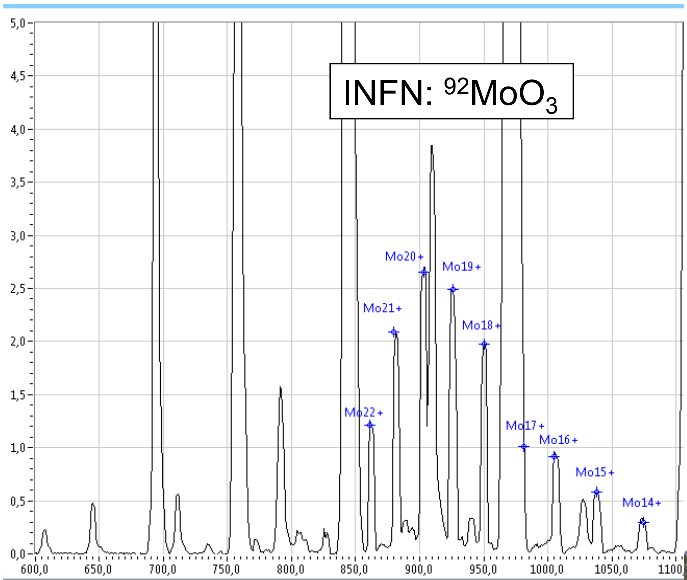
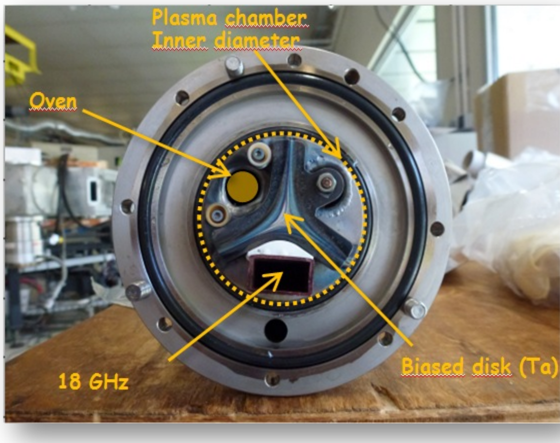
- MoO_3 has the vapor pressure of 1 mbar at 800˚C
- Has several isotopes (^{92}Mo: 14.84 %, ^{94}Mo: 9.25 %, ^{95}Mo: 15.92 %, ^{96}Mo: 16.68 %, ^{97}Mo: 9.55 %, ^{98}Mo: 24.13 %, ^{100}Mo: 9.63 %)

EU classification Carc. Cat. 3
Harmful (**Xn**)
Irritant (**Xi**)



Oven experiments at GANIL:

- Oven capable of covering evaporation temperatures from Ca to Ni
- Movable (any tests?)
- Strong heating by RF/plasma. Limiting the performance for high charge state Ca beams (Ca^{16+})
- He vs O_2 vs N_2 has negligible effect on total ionization efficiency (which is ≈ 5 %)



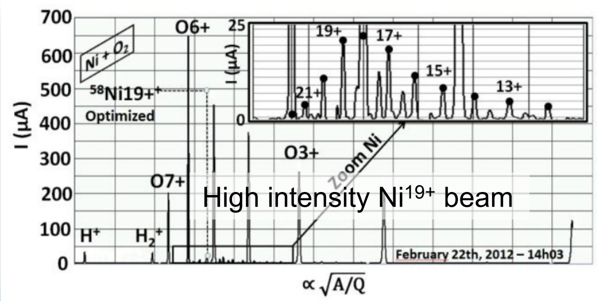


FIG. 2. Best spectrum optimized on $^{58}Ni^{19+}$ (20 µA). RF power: 1.7 kW, oven position : 0 mm, oven electrical power: 71 W (oven temperature 1450°C off line), biased disk: −36 V / 0.5 mA, extraction : 40 kV / 4.7 mA, coils current: 1130 A / −1180 A / 1290 A, FC slits : 10 mm, extraction: 1.4 10^{-8} mbar.

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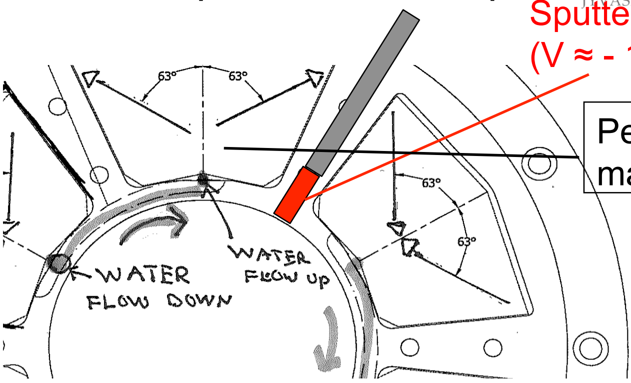
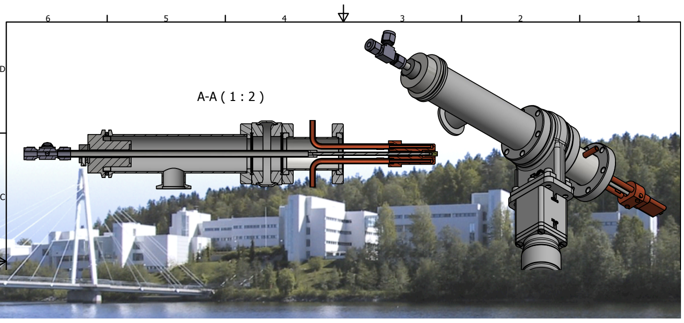
2) Sputter development: Radial sputtering

High intensity Ti^{11+} ion beam was obtained using radial sputtering. Caused the damage of PM structure. New cooled design was constructed.

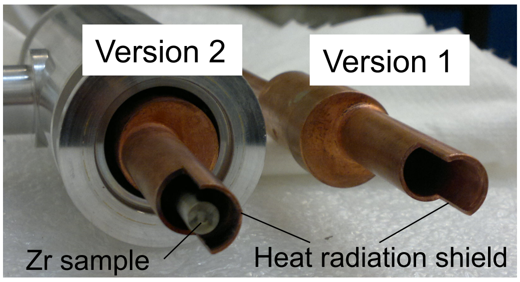


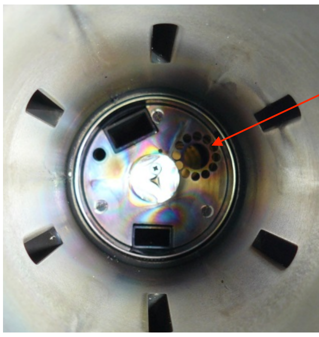
New design: Intensities were lower than earlier (Ti^{11+} : ≈ 20 µA → less than 10 µA). This indicates that we have had sputtering + heating. The question comes up: can we arrange this resonant heating safely?



2) Axial sputtering

Axial sputtering: two versions, two separate experimental weeks, **not yet successful.**





Version 1: Heat shielding is very close to the wall when sputter sample is inserted into the plasma chamber. To avoid any contact (possibly causes a local heat load on permanent magnet) we decided to limit insertion to 15 mm. We saw some tens of nA of Zr^{12+} beam (without high confidence!)

Axial sputtering

Version 2: we were able to get up to 0.5 μA of Zr^{12+} beam. During the short time we see more (close to 2 μA) but we were not able to get it back. The intensity is far behind the requested (≈ 20 μA).

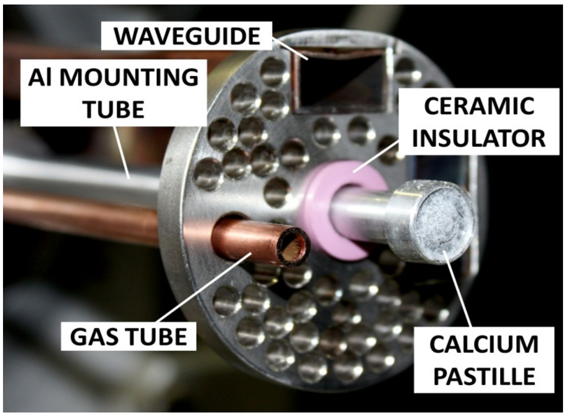
Zero level corresponds to inner surface of pc

Poistion [mm]	Sputter voltage [kV]	Sputter current [mA]
-10	3	0.21
-20	3	0.45
-20	4	0.52
-40	4	1.04

Typical sputter voltage in the case of radial sputtering is 1-2 kV

- The insertion had a big effect as is seen from the current of sputter voltage.
- We should have enough sputtering (sputter current high enough)
- Conclusion: sputter products do not reach the plasma.

Axial sputtering



More axial sputtering experiments were performed at ATOMKI:

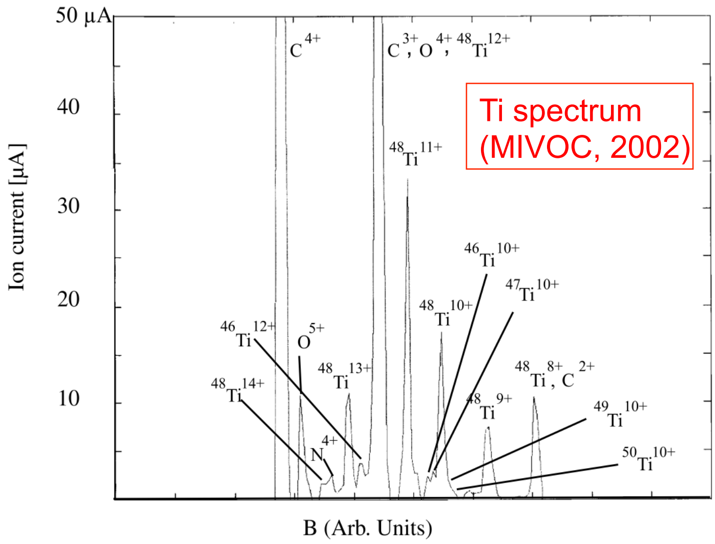
Results: Au^{20+}: 1 μA (very stable, O_2 buffer)
Ca^{8+}: 2 μA
Si^{5+}: 2 μA

This looks more promising!! Has to be on plasma flux area? Closer to plasma? More experiments have to be performed.

3) MIVOC development:

^{50}Ti ion beams

The first Ti ion beams using MIVOC were produced using commercial compound: ((trimethyl)pentamethylcyclo pentadienyltitanium)



Isotope/charge	8+	9+	10+	11+
^{46}Ti 7.9%	3.6*	4.7*	4.8*	4.8*
^{47}Ti 7.3%	3.3*	4.3*	4.4*	4.4*
^{48}Ti 73.9%	33	43	44	45
^{49}Ti 5.5%	2.5*	3.2*	3.3*	3.3*
^{50}Ti 5.3%	2.5*	3.2*	3.3*	3.3*

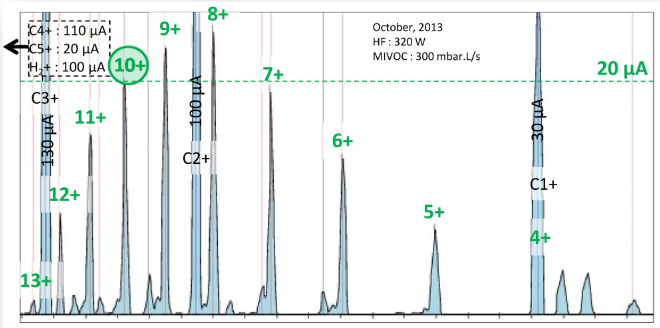
^{50}Titanium beam production at JYFL with the ECRIS2 ion source

- Using $C_5(CH_3)_5$**Ti**$(CH_3)_3$
- $^{50}Ti^{11+}$ beam of 15-20 µA
- Nuclear physics experiment of several weeks

^{50}Titanium beam production at GANIL with the ECR4 ion source

- Using $C_5(CH_3)_5$**Ti**$(CH_3)_3$
- $^{50}Ti^{10+}$ beam of 10-25 µA
- Nuclear physics experiment of 15 days

$^{50}Ti^{q+}$	9+	10+	11+	12+
I [µA]	14.9	16.8	19.4	14.8

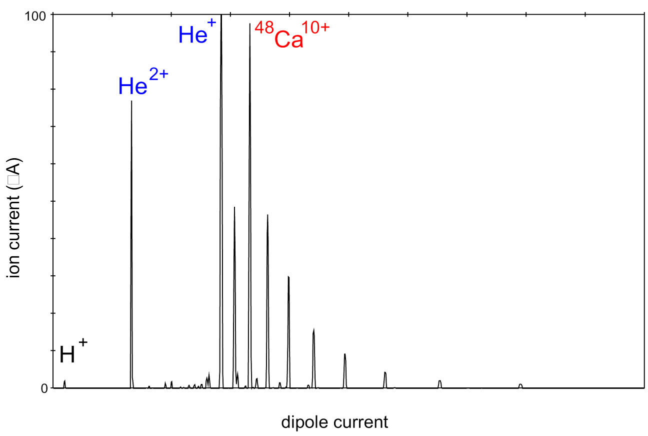


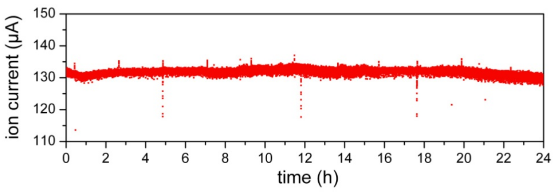
Successful synthesis of Ti compound makes the Ti isotopes of 46, 47 and 49 available.

4) Hot liner R & D

Hot liner at **GSI:**

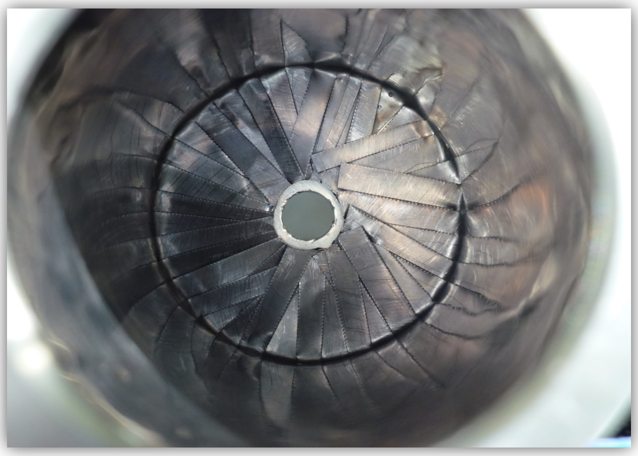
- Passively heated by plasma
- Works nicely for Ca
- Production efficiency similar to gases was reached: 13 % for Ca^{10+}, overall efficiency > 40 % (measured after dipole)
- Long term stability





Hot liner at GANIL:

- **??**



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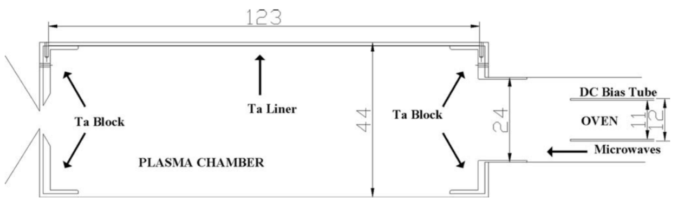
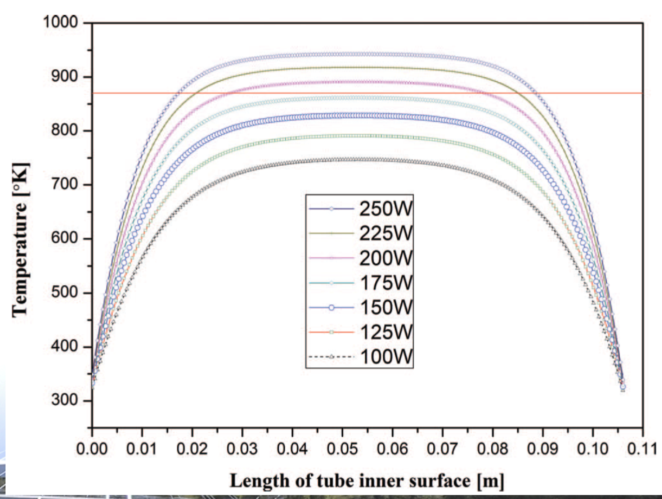
Hot liner at INFN:

- Temperature distribution of liner as a function of microwave power was simulated
- Ca consumption rate decreased ≈ 40 %





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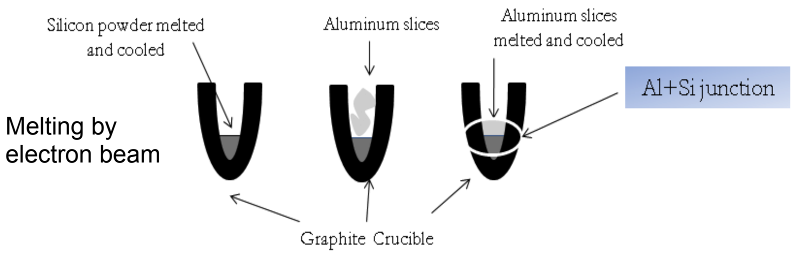
5) New innovations

Production of sputter target from elements available in powder form (especially for refractory elements)

Melting by electron beam



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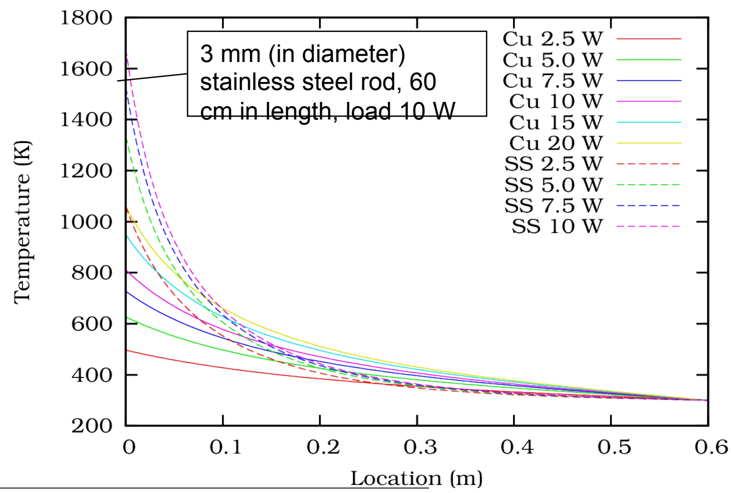
Use of low thermal conductivity

During the development work of axial sputtering we realized that even a low power load can result on substantial increase of T if material has a low thermal conductivity. This might be useful when the geometry has been optimized for this idea.



Material	Depends on T Thermal conductivity @25˚C [W/m/K]	Melting point [˚C]	Thermal expansion E-6 [1/K]
Ti	21.9	1668	8.6
SS	**16**	1510	15
Cu	400	1084	16.5
Zr	**22.7**	1855	5.7
Mo	139	2623	4.8
Ta	**57**	3017	6.3

- Optimal geometry
- Optimal combination of materials

H. Koivisto, JYFL, 9th Oct.2012

6) Production efficiency with different methods

MIVOC method has much higher production efficiency than oven method (JYFL miniature oven):

- Gaseous form (at RT) not condensation on the walls
- Capture of slow molecule (by plasma) might be more efficient