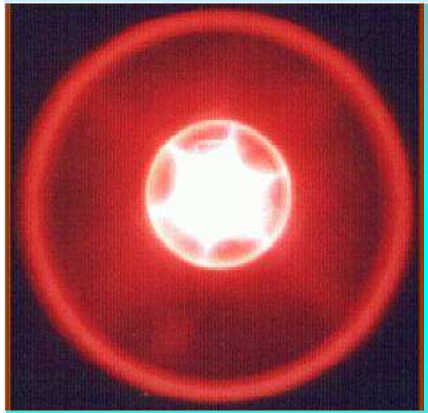
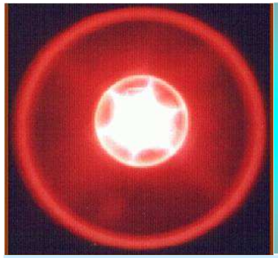


Optimized extraction conditions from high power-ECRIS by dedicated dielectric structures.

L. Schachter[1], K. E. Stiebing[2], S. Dobrescu[1]

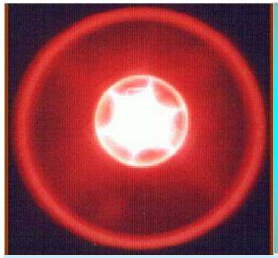
1) National Institute for Physics and Nuclear Engineering, Bucharest - Romania
2) Institut für Kernphysik der J. W. Goethe Universität, Frankfurt/ Main - Germany



Starting points:

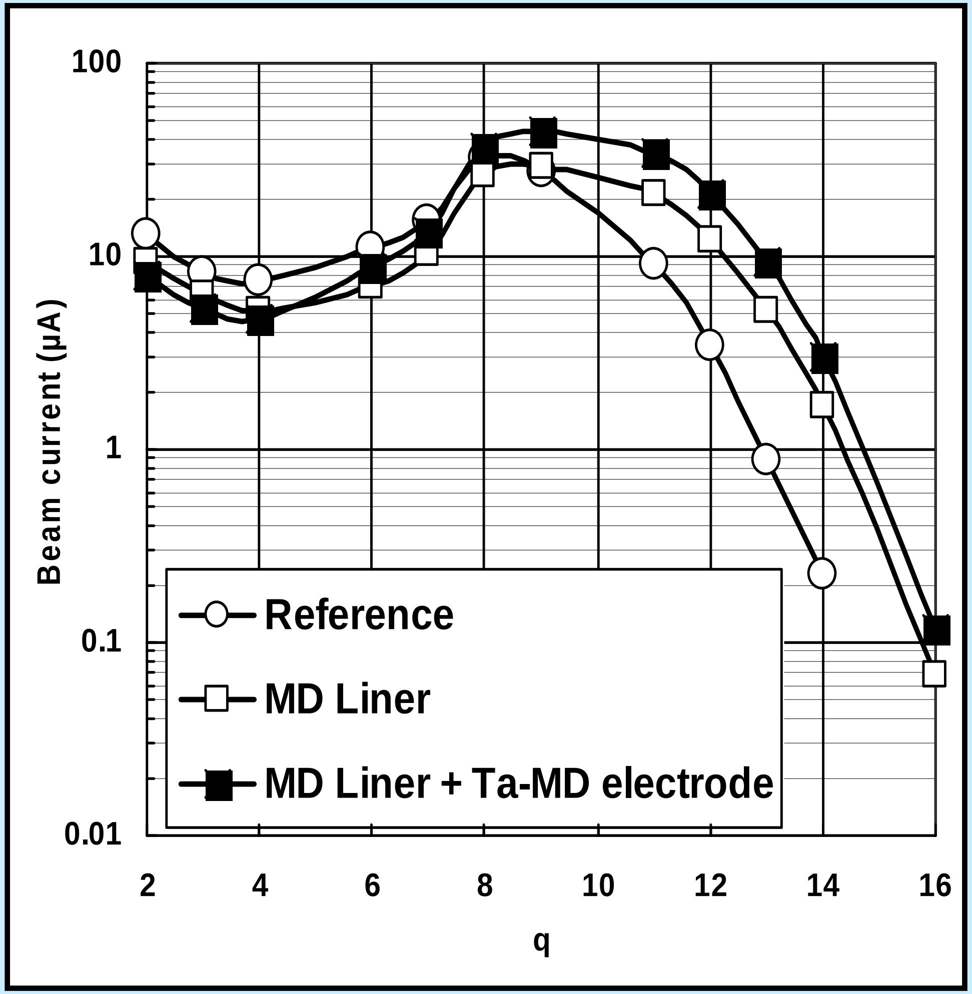
The MD-method of enhancing the ion output from ECR ion sources is well established and basically works via two mechanisms, the regenerative injection of cold electrons from an emissive dielectric layer on the plasma chamber walls and via the cutting of compensating wall currents, which results in an improved ion extraction from the plasma.

As this extraction from the plasma becomes a more and more challenging issue for modern ECRIS installations with high microwave power input, a series of experiments was carried out at the 14 GHz ECRIS of the Institut für Kernphysik in Frankfurt/Main, Germany (IKF). In contrast to our earlier work, in these experiments emphasis was put on the second of the above mechanisms namely to influence the sheath potential at the extraction by structures with special dielectric properties. Two different types of dielectric structures, Tantalum-oxide and Aluminum oxide (the latter also being used for the MD-method) with contrastingly different electrical properties were mounted on the extraction electrode of the IKF-ECRIS, facing the plasma. For both structures an increase of the extracted ion beam currents for middle and high charge states by 60-80 % was observed. The method is able to be applied also to other ECR ion sources for increasing the extracted ion beam performances.



MD in the plasma chamber:

partial restoration of the plasma ambipolarity
⟶ *Increase of ion-confinement time*



- ***<u>Secondary electron emission</u>*:**

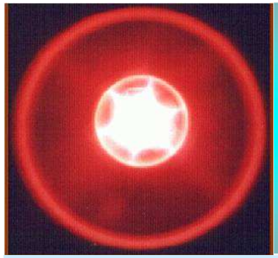
→ Increase of:

- ➢ electron density by a factor of 2.5
- ➢ electron temperature by a factor of 1.7

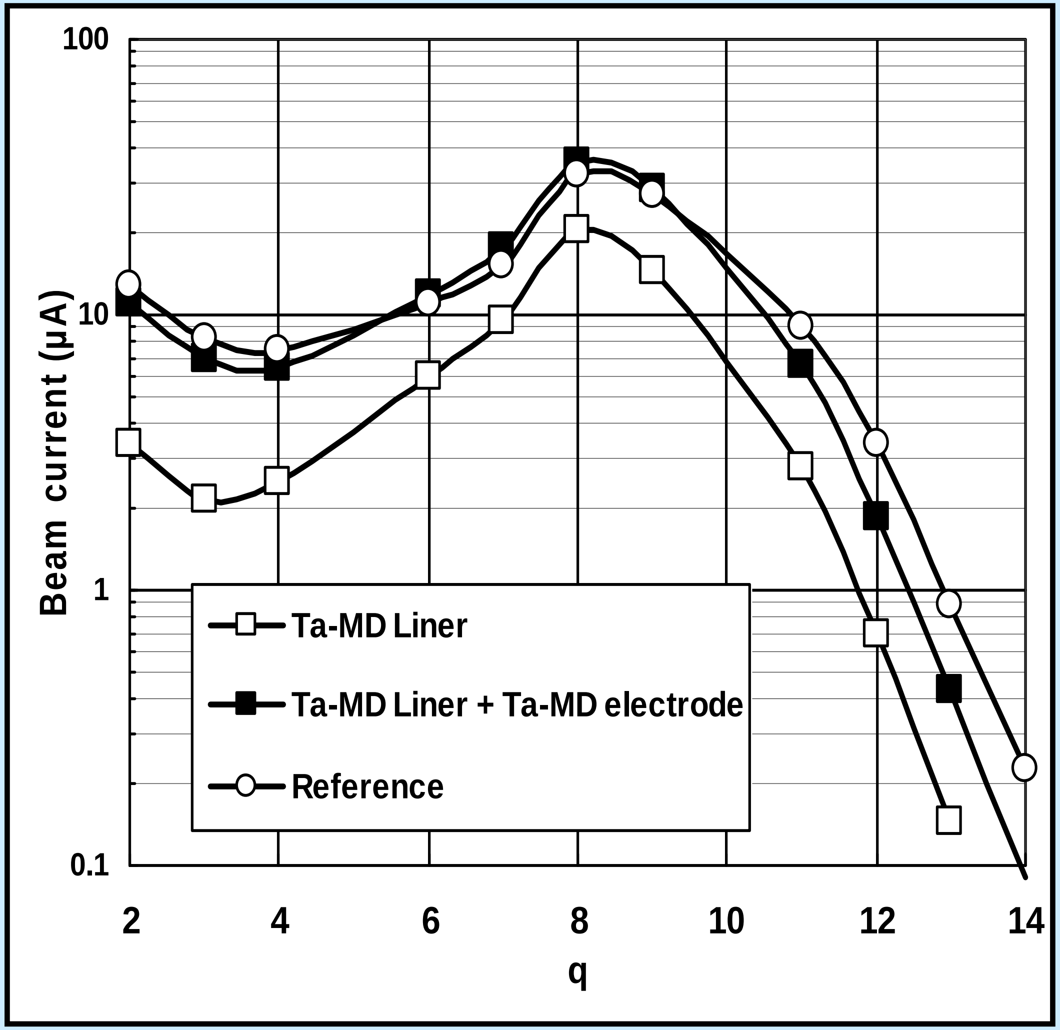
<u>Figure 1:</u> Charge state distributions (CSD) of argon ions extracted from the ECRIS. Plasma and ion transport optimized for the extraction of Ar^{14+} ions. Rf-power 1KW.

⟶ **All intermediate and high charge states are enhanced between 400-800 %**

While the Al- MD liner changes the shape of the CSD considerably, the additional Ta-MD-structure clearly enhances the extracted ion currents in the region of intermediate and high charge states considerably.



MD in the plasma chamber:



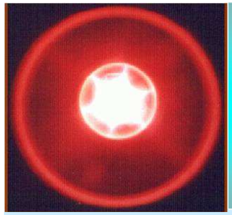
T

Tantalum MD disk effect

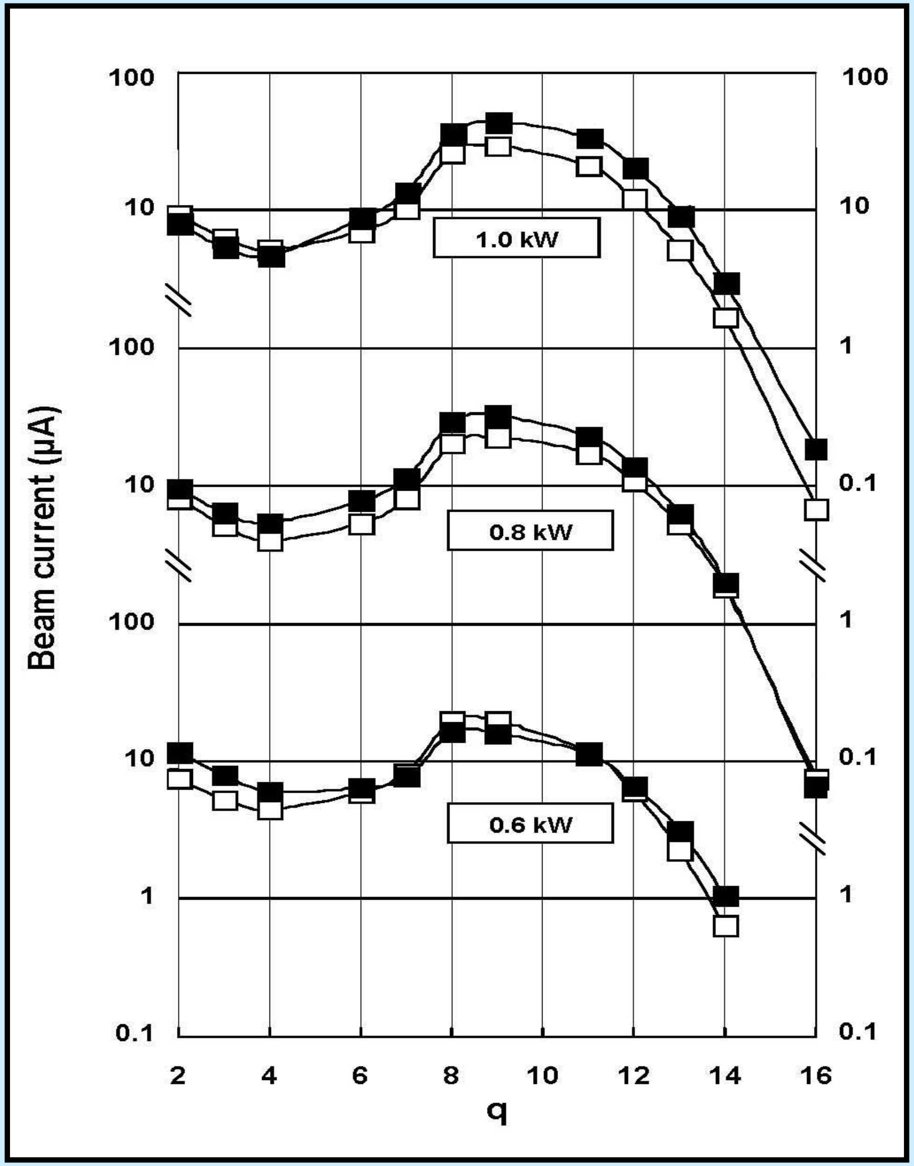
<u>Figure 2:</u> CSD for a source configuration where the Al-MD liner was substituted by a Ta-MD liner (same geometry). Plasma and ion transport optimized for the extraction of Ar^{14+} ions. Rf-power 1KW.

The installation of a Ta-MD liner instead of an Al-MD liner results obviously in a strongly reduced output from the source. The Ta-MD liner is just an insulator without markable emission of secondary electrons and, in contrast to the Al-MD liner (fig.1), obviously does not change the shape of the CSD.

→ Also in this scenario, the Ta-MD electrode serves to considerably improve the extraction of the ions from the plasma by the suppression of ion losses by wall currents at the extraction hole.



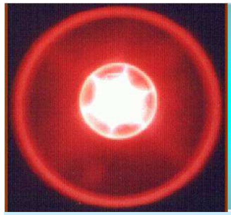
RF-power effect by MD:



It is well known that the careful shaping of the extraction conditions becomes more and more important the higher the source performance in terms of plasma density and temperature is.

Figure 3: **Comparison of CSD with (solid symbols) and without (open symbols) Ta-MD electrode for three different microwave powers. Plasma and ion transport optimized for the extraction of Ar^{14+} ions.**

⟶ A "shifts" towards higher charge states with increasing microwave power. While at 600 Watt some enhancement at the low-charge state-end of the CSD can be identified, at 1000 Watt clearly the range of intermediate and high charge states is enhanced, demonstrating that this method works the better, the higher the microwave power and hence the plasma parameters are.



Role of the dielectric properties of the MD-structure at the extraction electrode

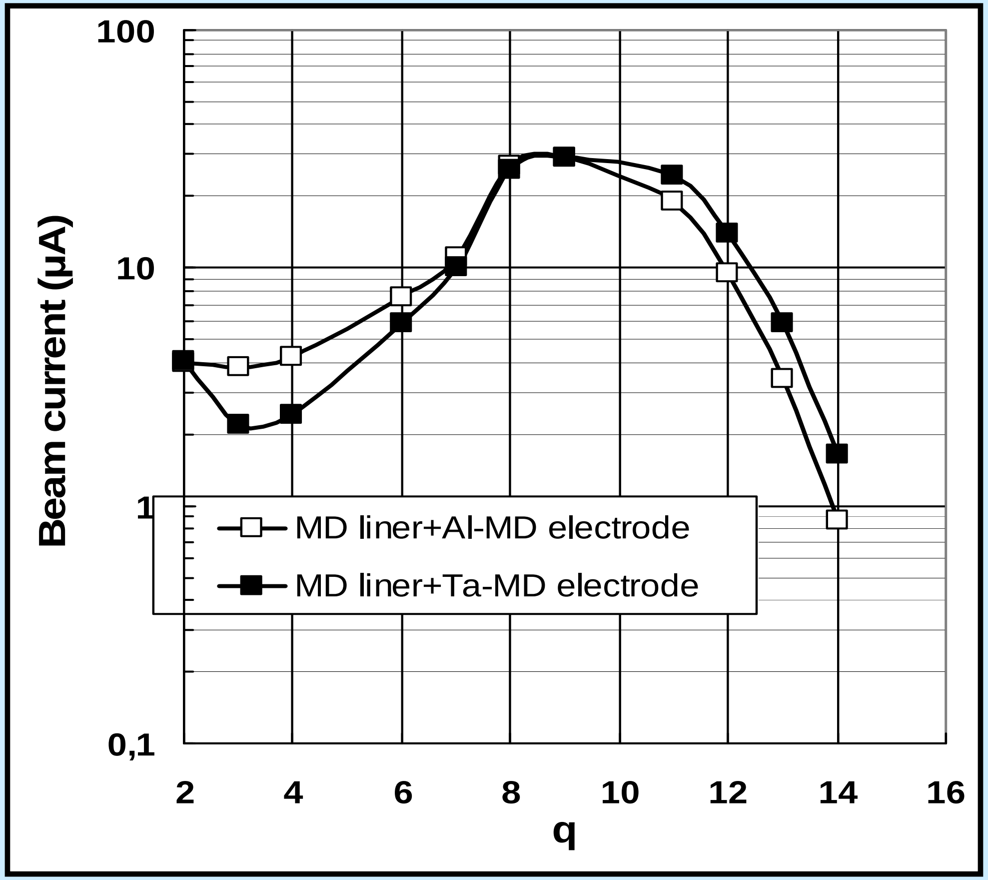
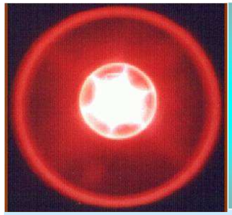


Figure 4: Comparison of CSD with Al-MD-electrode (open symbols) and Ta-MD-electrode (full symbols). Plasma and ion transport optimized for the extraction of Ar^{14+} ions. RF- power 1kW.

→ **Whereas the AL-MD structure works better at low charge states,**
the Ta-MD structure outmatches the Al-MD-structure at high charge states.



X-ray spectra at 1000 W RF Power

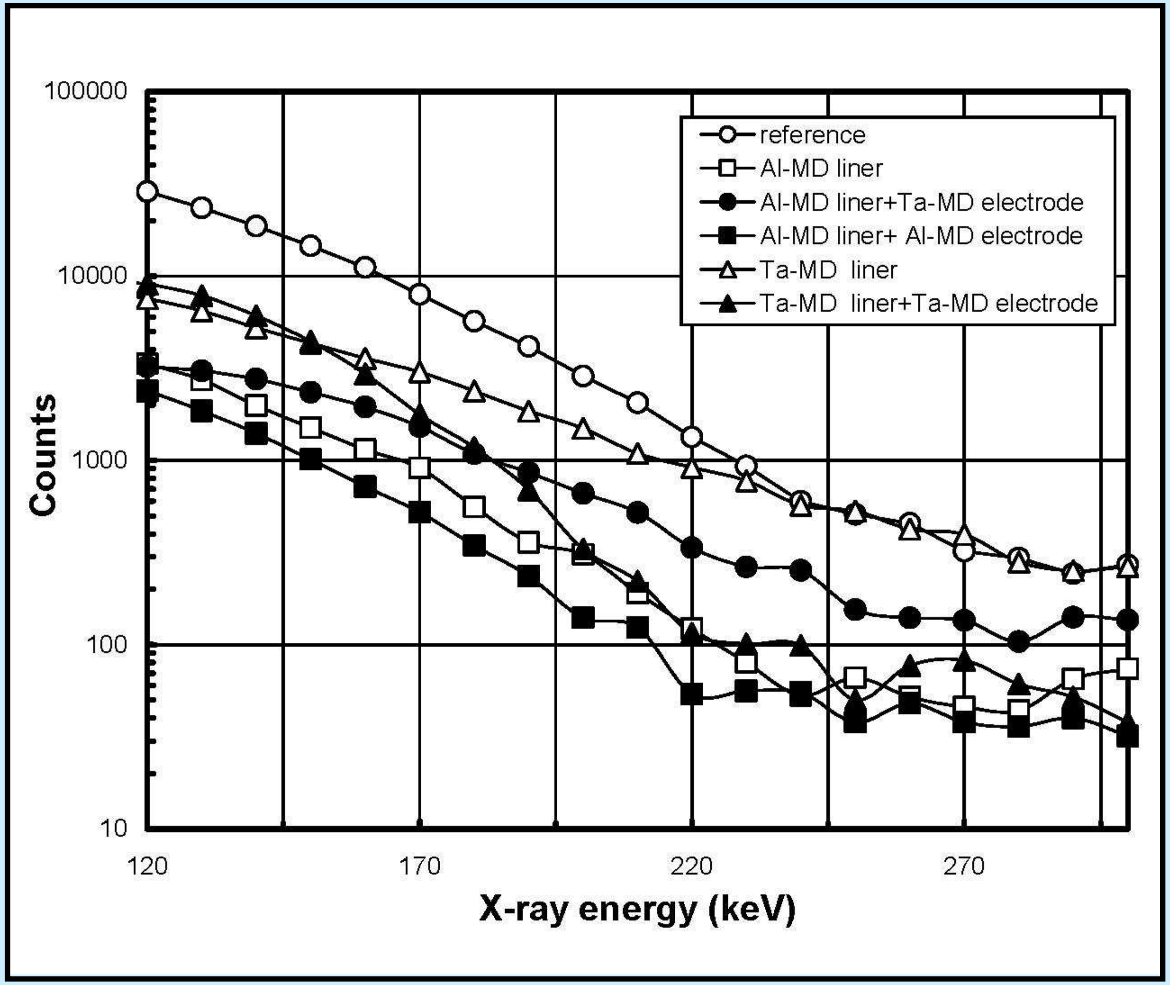


Figure 5: X-ray spectra at 1kW RF Power for different source configurations.

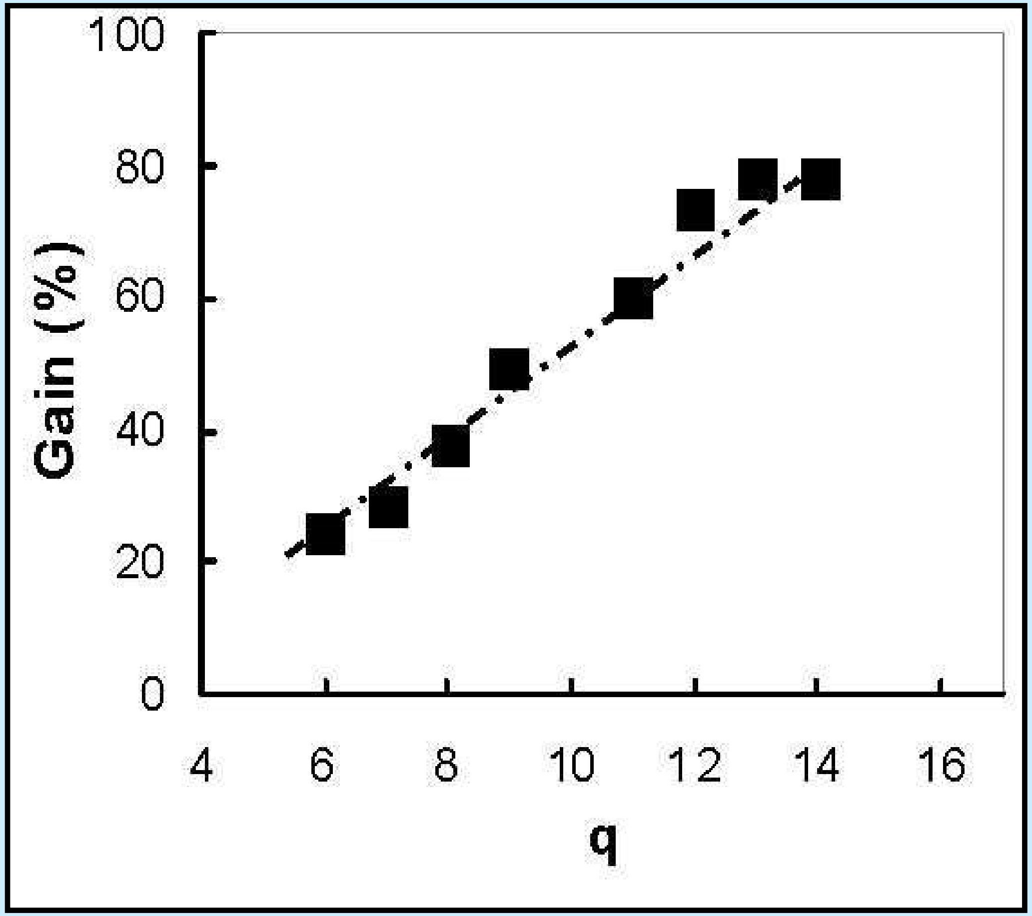
The control of x-ray emission is an important issue in develpment of new high power ECRIS

→ **The Ta-MD electrode increases the x-ray emission compared to the configuration with only am Al- MD liner**

→ **The Al-MD electrode further reduces the x-ray emission.**

→ **For both configurations, the x-ray emission is much lower compared to the reference (standard stainless steel ECRIS).**

Tantalum net contribution



<u>Figure 6:</u> net contributions from the Ta-structure: the gain factor G is defined as :

$$G(q) = [I_{Ta\text{-}str}(q) - I_{std}(q)] / I_{std'}(q),$$

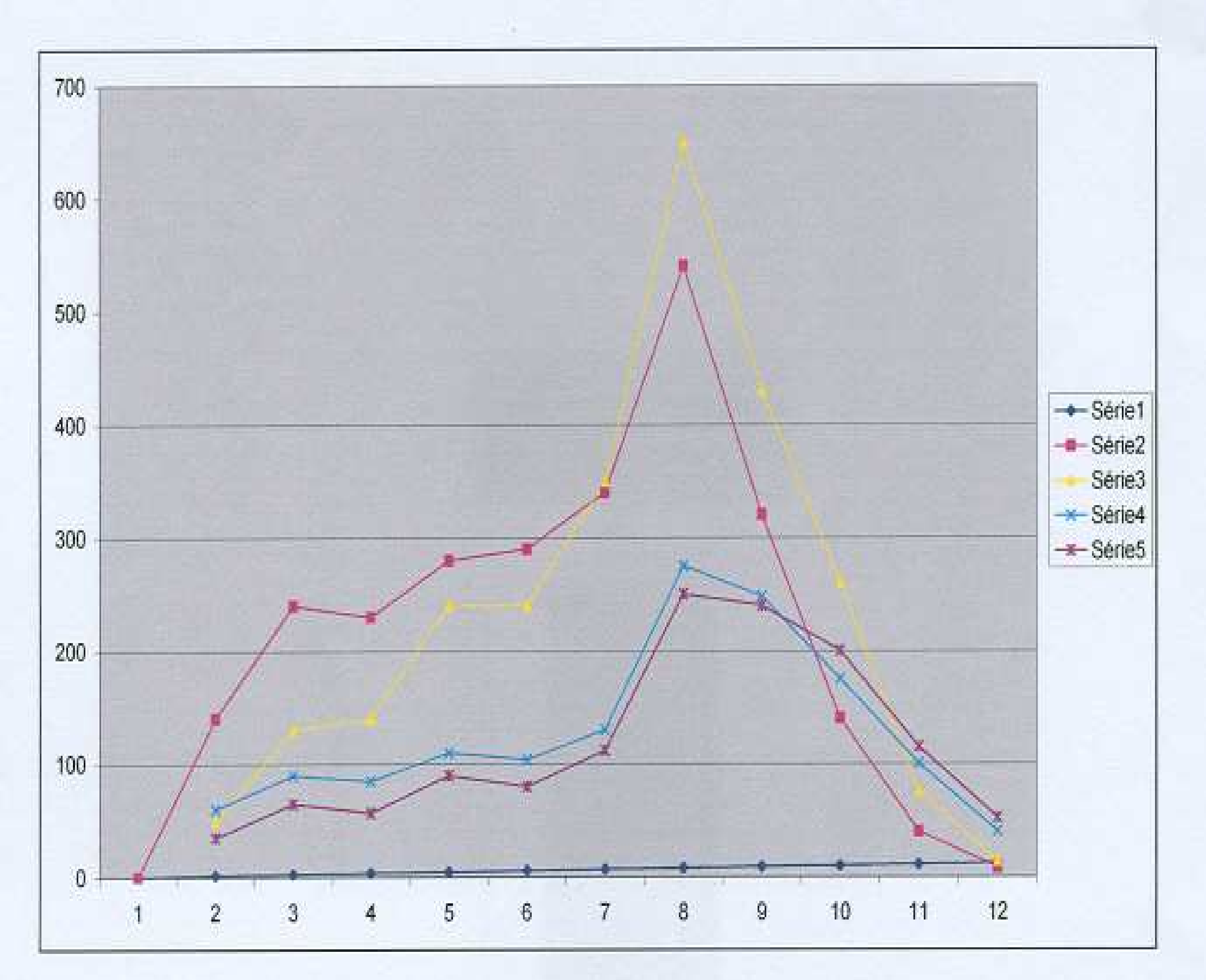
$I_{std}(q)$ is the ion current per charge state q for the source with stainless steel electrode and Al-MD-liner;
$I_{Ta\text{-}str}(q)$ is the configuration with a Ta-MD electrode in addition to the configuration of $I_{std}(q)$.

→ **A gain of 70-80%, relative to the standard source with Al-MD-liner and stainless steel electrode, is observed for the range of intermediate and high-charge-state Ar-ions.**

→ **This is due to the positive charging of the plasma-facing surface of the structure under electron bombardment.**

→ **The degree of this charging, and hence the improvement factor, depends on the dielectric constant of the layer.**

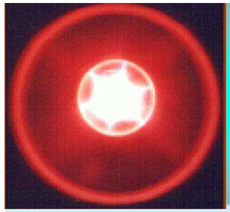
MD Aluminum dielectric structure
on PHOENIX-V2 extraction



MD Aluminum dielectric structure inserted in the plasma chamber on the plasma electrode
For 8+ and 12+ optimizations and 500 W microwave power at 18 GHz

For 8+ optimization:
Serie2- St. Steel Extr. El.
Serie3- MD Extr. El.

For 12+ optimization:
Serie4- St. Steel Extr. El.
Serie5- MD Extr. El.



CONCLUSIONS

MD dielectric extraction structures in the plasma chamber

- **stronger output of high charge state ions: 80% higher Ar14+**

lower X-rays emission

The results demonstrate that dielectric structures on the extraction electrode introduce a new feature, which is not present in the standard ECRIS with stainless steel plasma electrode. An isolating structure at this position not only serves to cut the wall currents at the extraction, avoiding ion losses at this point, but also serves to improve the extraction conditions of ions by optimizing the sheath potentials at this point in such a way that a considerably higher amount of ions can be extracted through the extraction hole.