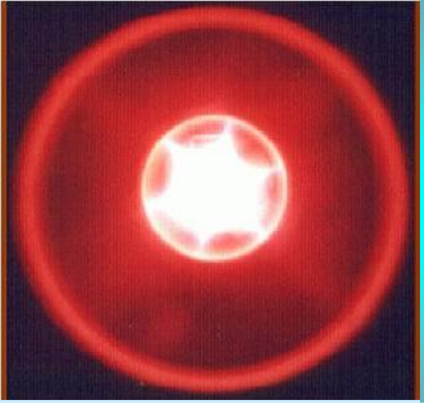

ENSAR-ARES CONTRIBUTIONS

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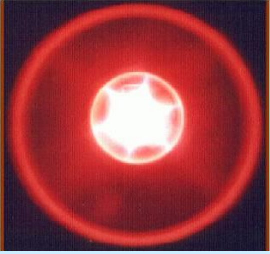
Institut fur Kernphysik der J. W. Goethe Universitat, Frankfurt/ Main- Germany

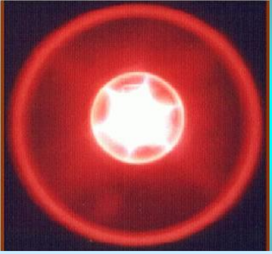


Starting points:

Developing the MD method it was our first goal to increase the performance of ECR ion sources in the range of high-charge-state(HCS) ion beam formation

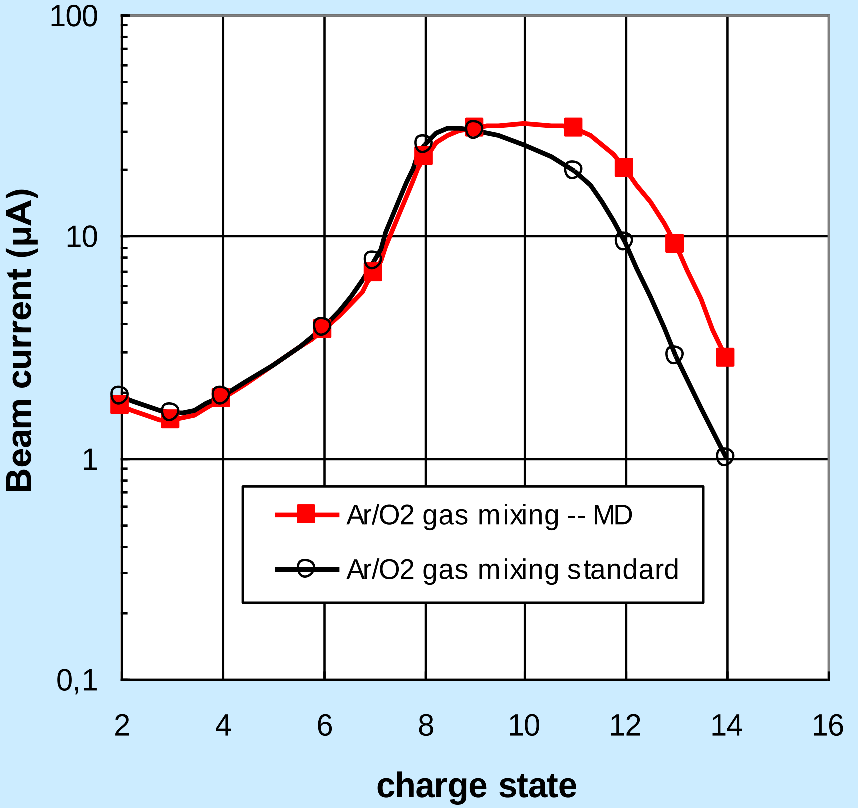
Experiments with MD configurations have been realized at the 14 GHz ECRIS of the Institut fur Kernphysik of the Goethe Universitet in Frankfurt/Main(IKF-ECRIS), at the 14 GHz CAPRICE type ECRIS in Groningen and at the PHOENIX 18 GHZ ECRIS in Grenoble. In all experiments the high enhancement rates for the HCS ion intensities as compared to the standard configuration have been demonstrated. A similar experiment in LNS Catania was only partially successful due to a technologically non adequate MD liner. In the frame of ARES collaboration our efforts were focused onto the use of MD as a tool of investigation of the physical propeties and processes of the ECR plasma.

- *The influence of the plasma- wall interaction on the gas mixing in ECRIS was studied, revealing a decrease of the source's efficiency.*
- *An influence of the extraction voltage on the high energy slope of Bremsstrahlung radiation spectra has been reported. This was the subject of a dedicated study at the IKF –ECRIS.*
- *Most of the new generation ECRIS installations use Double Frequency Heating(DFH) to increase the very high charge states intensities. We have carried out a series of dedicated experiments to study the influence of an enhanced EEDF, created by using the MD method, onto the perforfomance of DFH.*
- *In our last studies we have performed two new rxperiments at the IKF- ECRIS, which I intend to present here.*



Mixing gas in the plasma chamber :

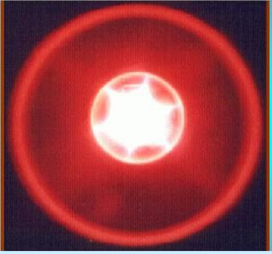
20/80)% gas mixing for the stainless steel (standard) and metal dielectric (MD) configuration of the ECRIS.
(beam transport optimized for Ar^{14+}, P_{RF}= 800 Watt



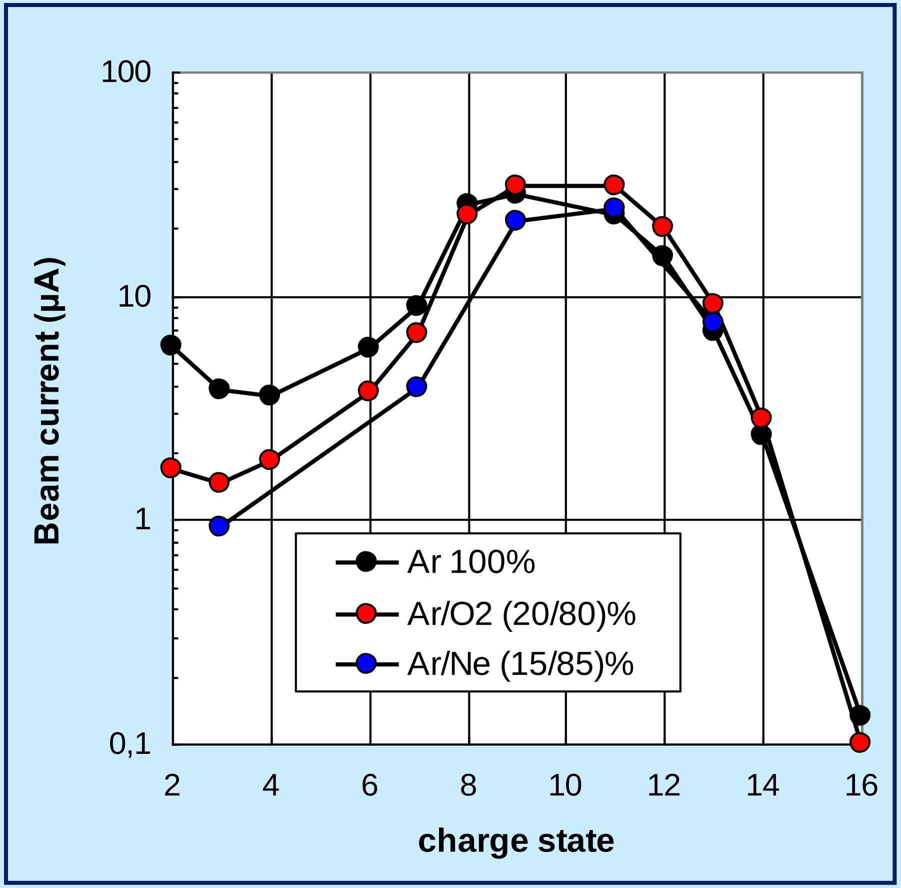
Starting point:

Comparing the intrinsic performances

- *The intrinsic perormances with gas mixing for the standard (stainless steel) configuration and the MD configuration are compared*
- The ***intrinsic*** performance with gas mixing is significantly higher for the high-charge-state-ion production for the source with ***MD configuration*** than the one for the standard configuration.
- The behavior at the low-charge-states regime is not significantly changed



GAS Mixing in the MD plasma chamber



<u>The GM effect in the MD source:</u>

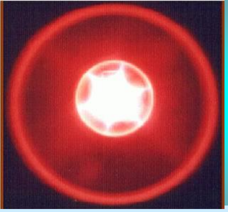
Comparing mixing gas (Ar/O_2 and Ar/Ne) with pure Argon.

It is observed that the gas-mixing efficiency for the production of highly charged ions is strongly reduced in the presence of an MD-liner (e.g. the intensity of Ar^{13+} for Ar/O_2 gas mixing is now only 35% higher compared to the pure Argon case).

The intensities of low charge states are strongly suppressed as in the case of the standard source.

- <u>Conclusion:</u>

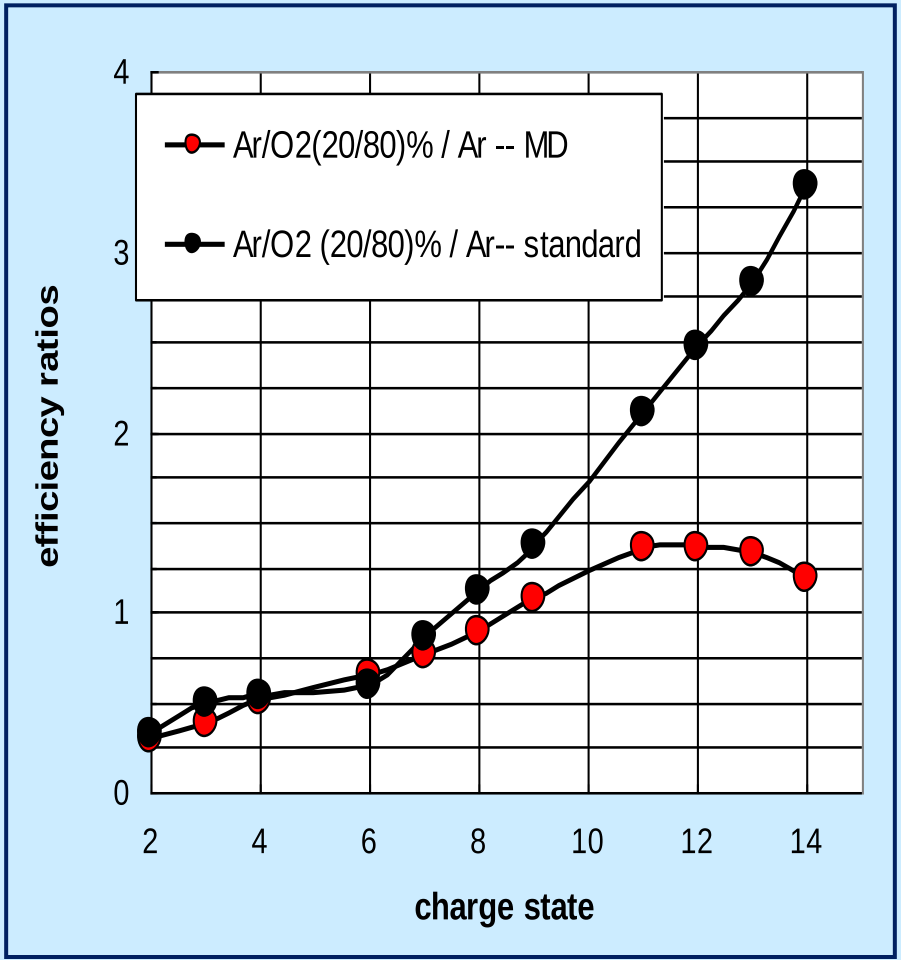
- MD and GM are basically different effects!



Influence of plasma-wall interaction on the mixing gas efficiency :

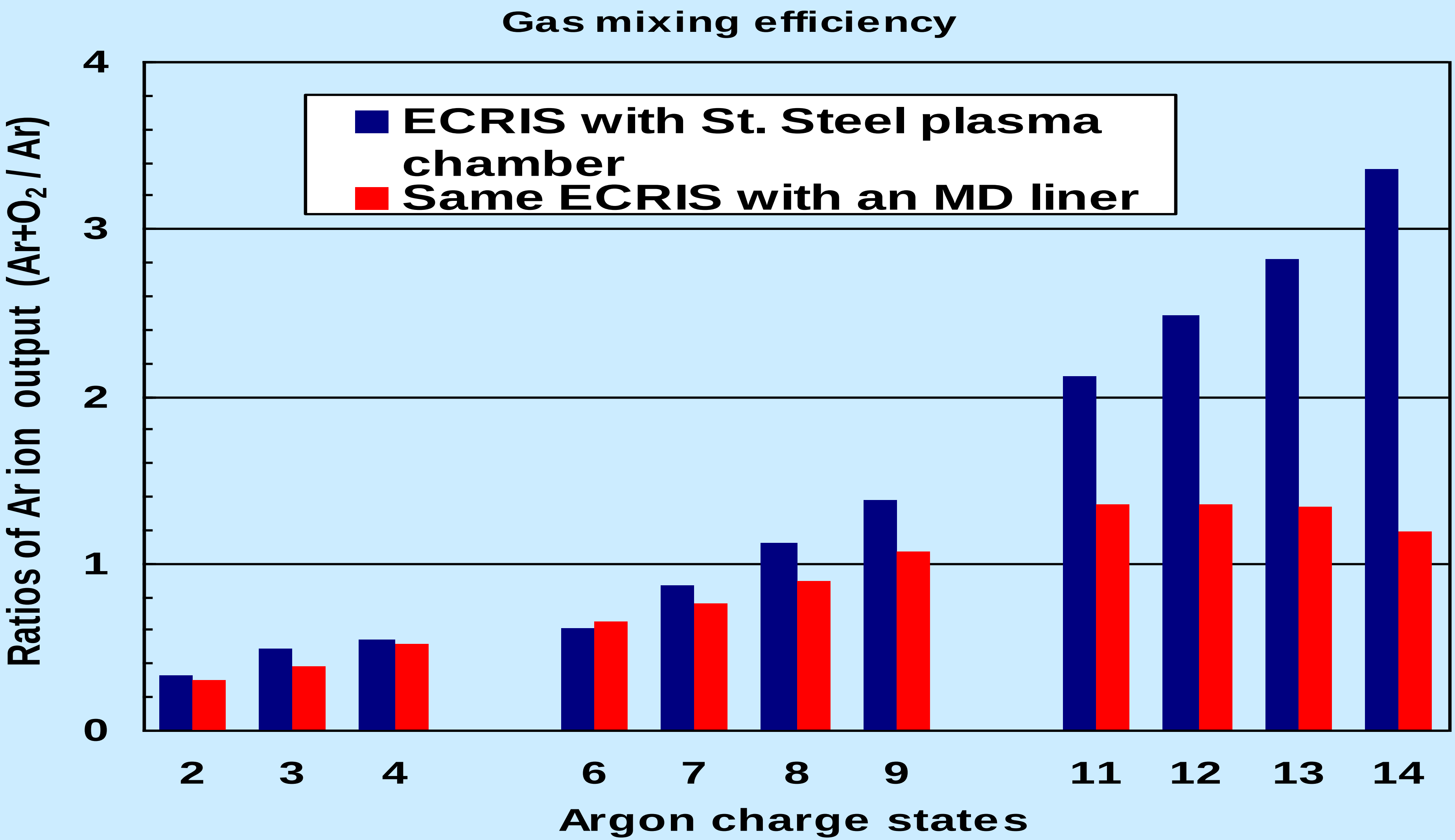
Efficiency-ratios

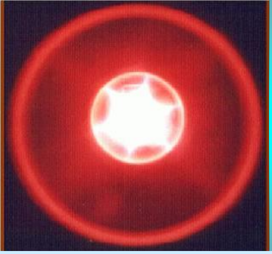
$$\varepsilon^{GM} = I(q)^{GM} / I(q)^{\text{pure gas}}$$



A MD liner turns the ECRIS into a higher performing source. The basic gas mixing mechanism should act in this configuration as well, however, the experiment pointed out that the changed configuration, which implies a significant plasma-wall interaction, is much less efficient. Now, the gas mixing physics is changed: the mass effect continues to increase the high charge states ion production; however, the dilution effect by its strong reduction of the average plasma charge reduces the diffusion of plasma electrons to the wall which is responsible for the MD effect. Thus, the efficiency of the gas mixing method, when plasma-wall interaction is significant, is reduced in our experiment to 35% versus the standard ECRIS gas mixing efficiency.

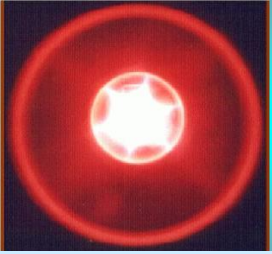
Conclusion on plasma –wall influence on gas mixing



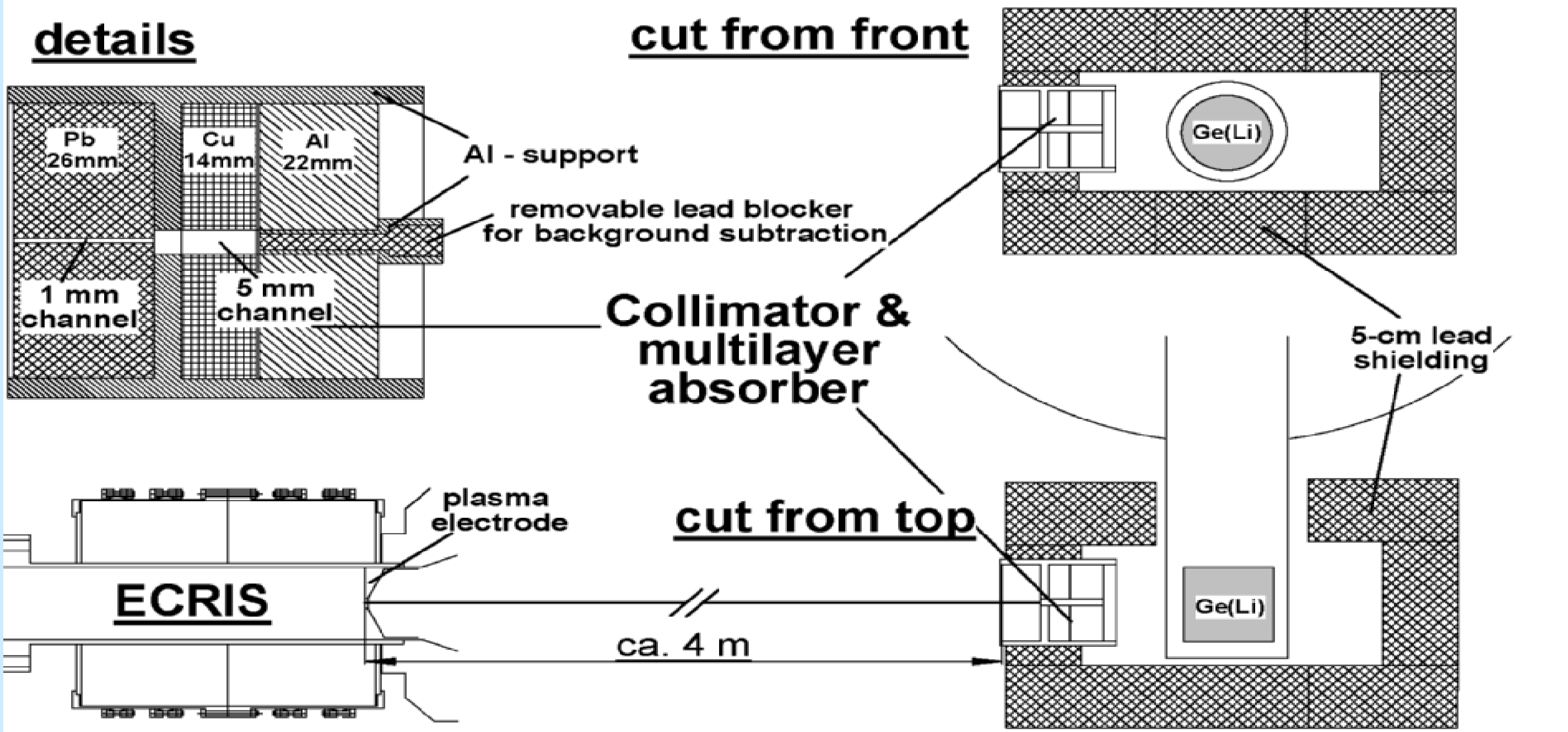


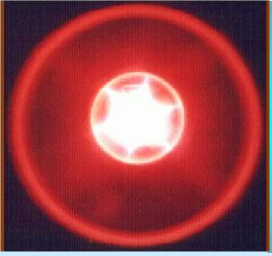
Starting idea:

- **An influence of the extraction voltage on the high energy slope of Bremsstrahlung radiation spectra has been reported in ECRIS experiments, which is not well understood so far. In order to provide more detailed data on this effect, we have measured Bremsstrahlung radiation spectra accompanying especially the evolution of highly charge ions (i.e. by monitoring the Ar14+ charge state) as the extraction voltage is changed from zero to 20 kV, in dedicated experiments at the Frankfurt 14 GHz-ECRIS.**
- **The Experiment permitted to clarify the problem of a possible Extraction voltage influence on the energetic plasma electron population.**
- **For this Bremsstrahlung and Charge State Distribution(CSD)spectra Were measured and correlated for different extraction voltage values.**
- **The experiments were performed at the 14 GHz ECRIS of the Institut für Kernphysik, University of Frankfurt/Main, Germany**

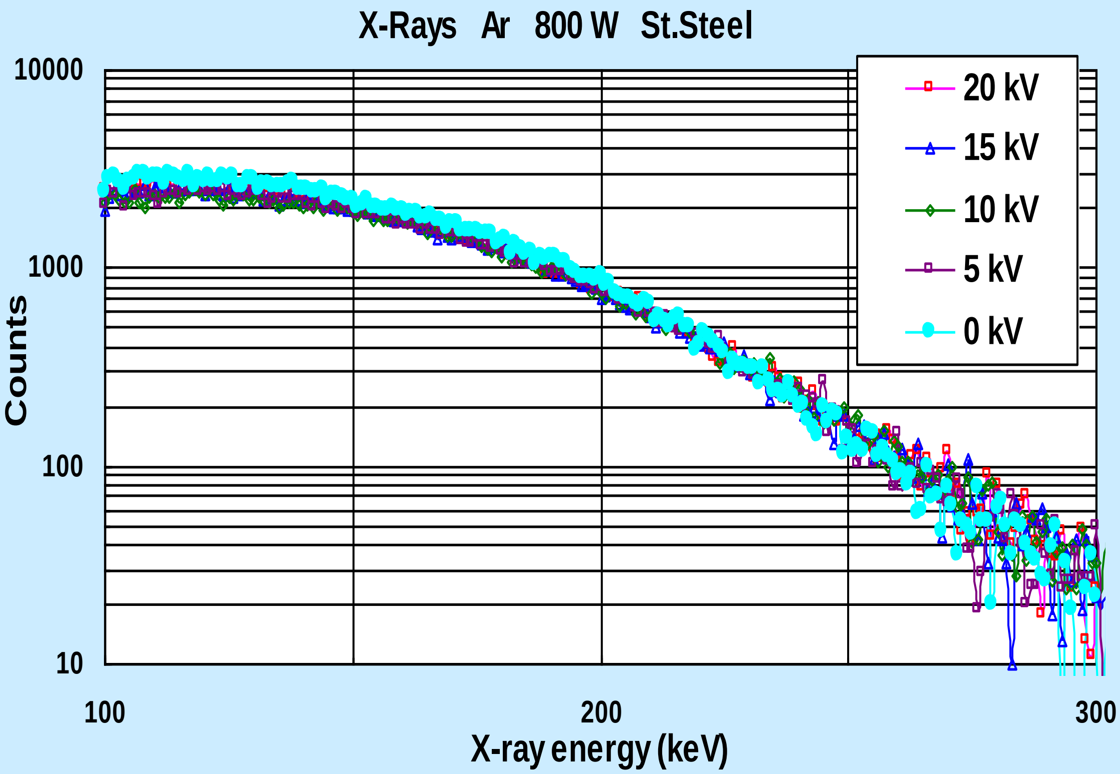


Bremsstrahlung measurements set-up sketch:

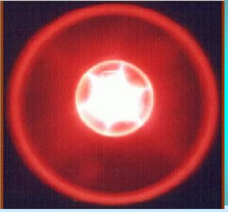




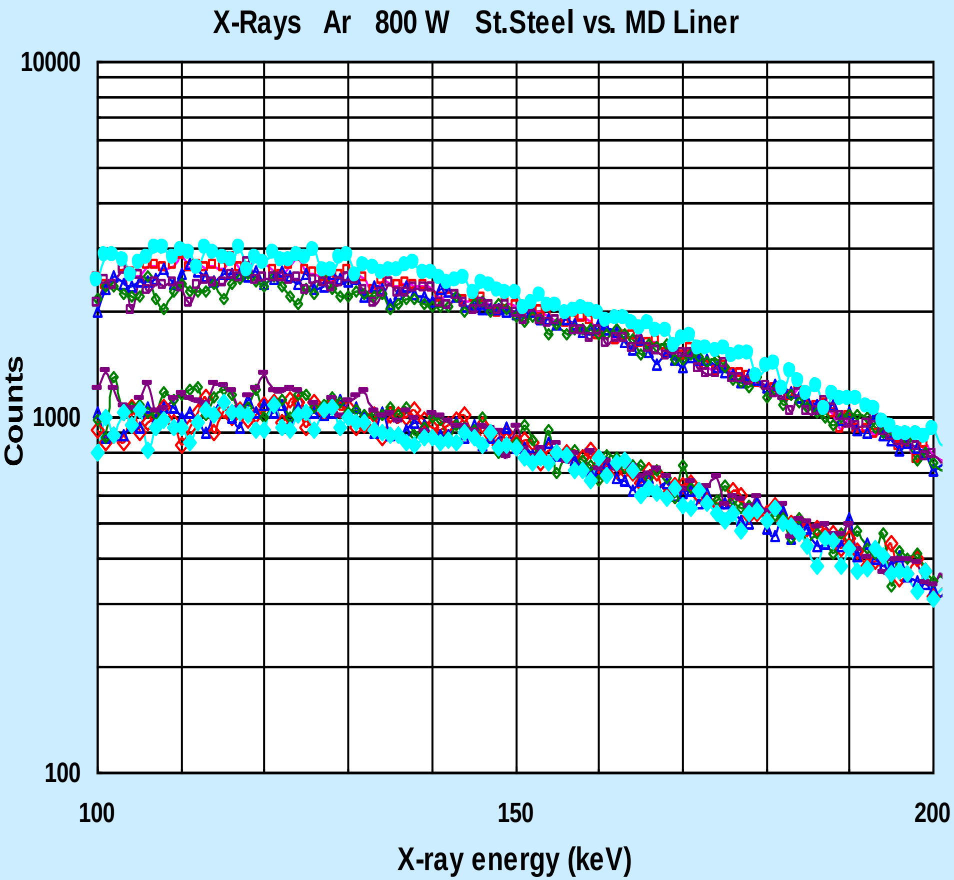
Extraction voltage influence on Stainless steel plasma chamber Bremsstrahlung:



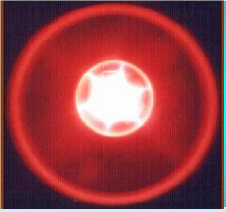
It's observable that the spectra are practically the same for the total yields as well as for the spectral shapes. An interesting aspect is that the highest yields are obtained at 0 extraction voltage(no extraction of ions), probably due to the fact hat in absence of an extraction voltage a higher number of electrons are stopped inside the source.



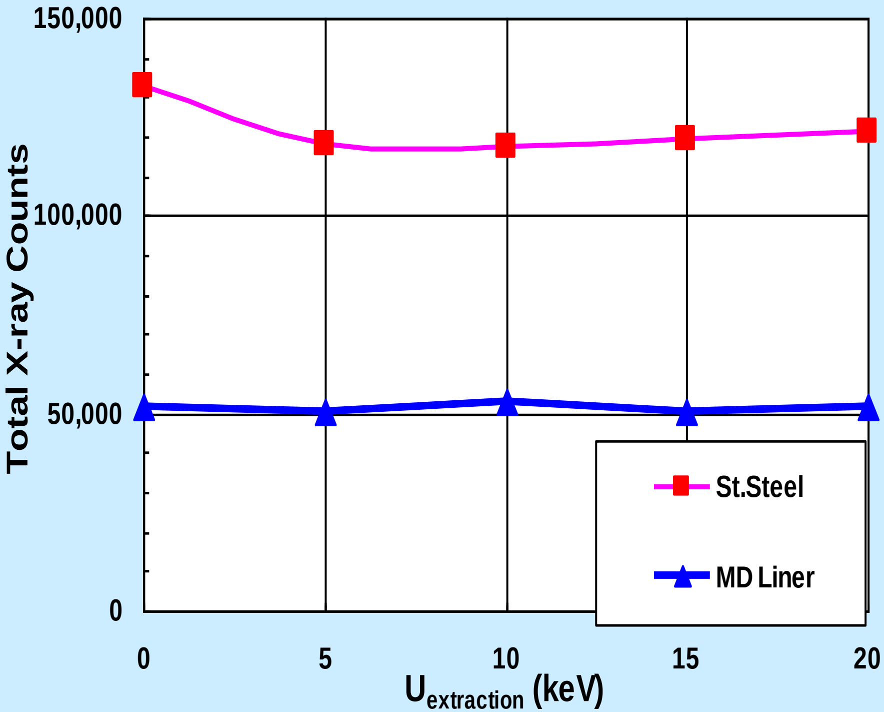
Comparison: Bremsstrahlung for Stainless Steel and MD configurations



In order to provide supplementary information, a 90 mm length MD liner was introduced in the plasma chamber covering the inner walls. Due to the higher confinement of this configuration a possible effect of an extraction voltage influence should be more pronounced.
A comparaison of both configuration is presented for the same range of voltages. The shape of the spectra are identical, however, the total yields for the MD configuration are in average three times lower(as expected for the configuration) . It's interesting that this time the spectrum for extraction voltage is lower than the spectra with extraction voltage, which certainly is due to the better confinement introduced by the MD liner.0

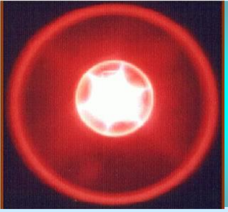


Total X-ray counts detected (140 - 200 keV) in function of the extraction voltage

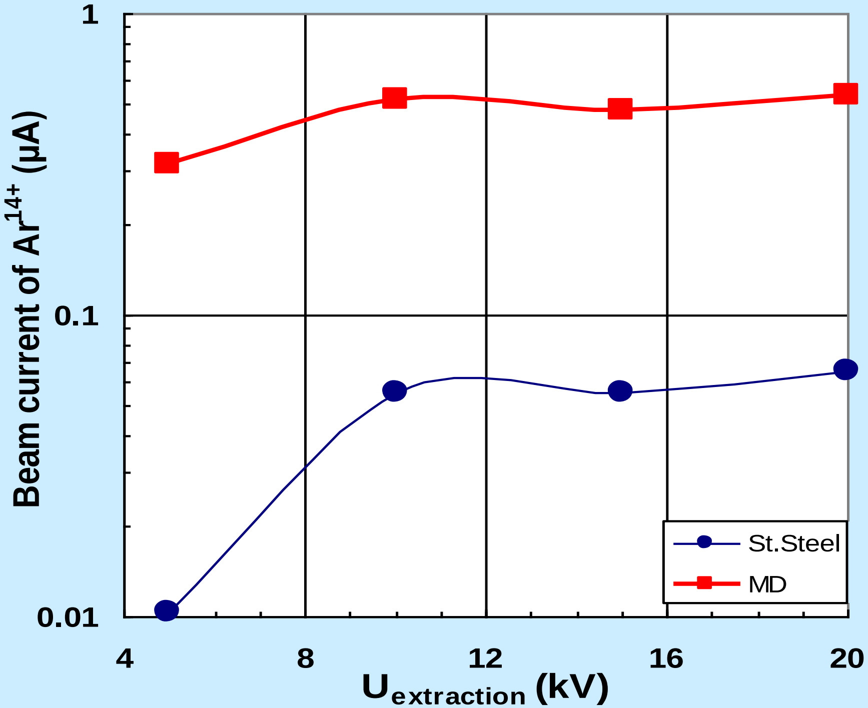


The total X-ray yields (detected in the range 140-200 keV) monitored as a function of the extracted voltage confirm that the extraction voltage does not change the rate of x-rays.

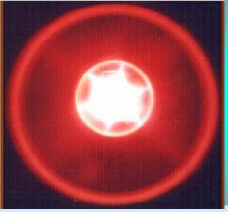
We can conclude that the Bremsstrahlung measurements did not put in evidence a change concerning the plasma energetic electron population.



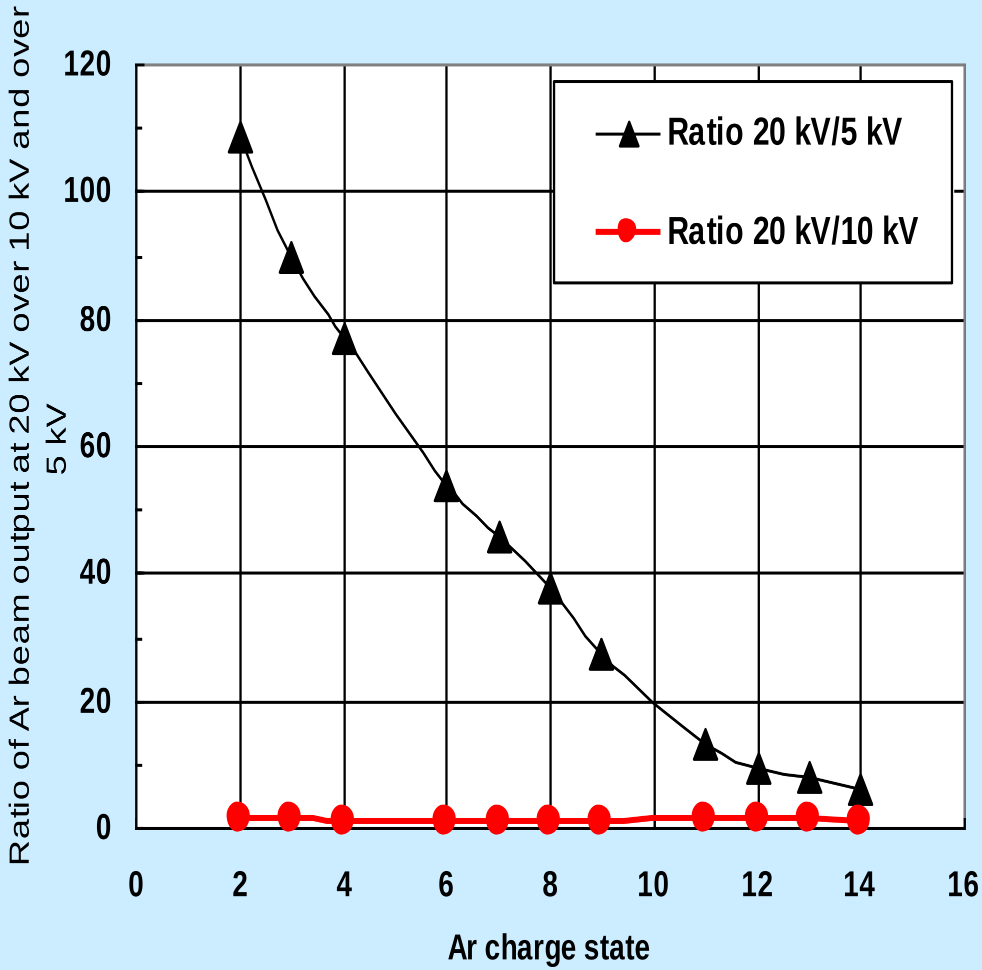
Argon 14+ monitorization of extraction voltage influence



The results of the Ar14+ intensity monitoring of changes are presented for the both configurations. Only very small variations due to different extraction voltages which are inherent are observed.



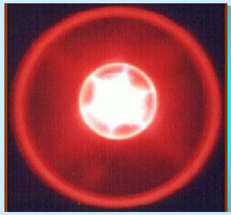
CONCLUSION



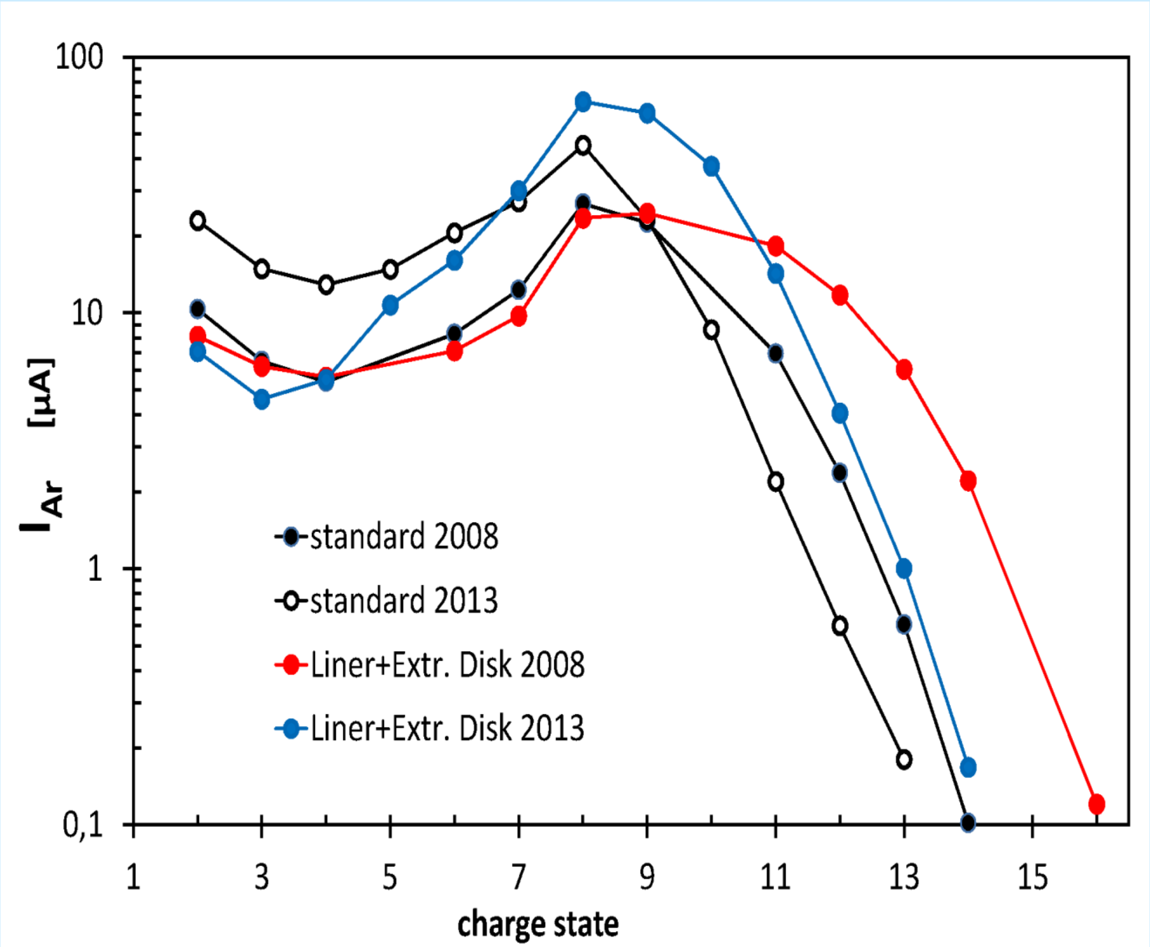
- •The ratio 20 KV/10 KV on the graphs it's a very clear answer for our experiment . The experiment did not proof any evidence for some influence of the extraction voltages on the energetic electron population of the plasma. The influence of the extraction voltage is limited only by the properties of the beam extraction. This is illustrated in figure by the 20KV/5 KV ratio.

On the Role of Electron Energy Distribution Function in Double Frequency Heating

In order to gain information on the DFH-mechanism and on the role of the lower injected frequency we have put emphasis on the creation of a discrete resonance surface also for this lower frequency. Our established method of inserting an emissive MD (metal-dielectric) liner into the plasma chamber of the source is used in these experiments as a tool of investigation. In this way the electron temperature and density for both ECR zones is increased in a controlled manner, allowing conclusions on the role of the change of the EEDF with and without DFH.



Starting point: Status of the IKF 14GHz ECRIS



Modified magnetic field configuration of the IKF-ECRIS: to extract higher ion currents of intermediate q for injection into the RFQ post-accelerator

New quadrupoles in the LEBT for doublets 100%

Modified magnetic field configuration of the IKF-ECRIS: 10GHz RF-system (Pmax = 100W) installed at the second RF-port

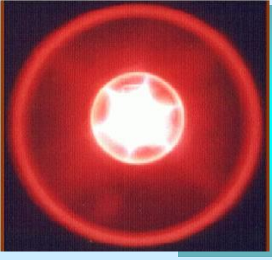
The MD-structure: specially processed Al-Al2O3 interface (1mm) thickness) installed symmetrically to the hexapole

change of EEDF of the plasma by enhancing:e--density by **2.5** / e--temperature by **1.7**

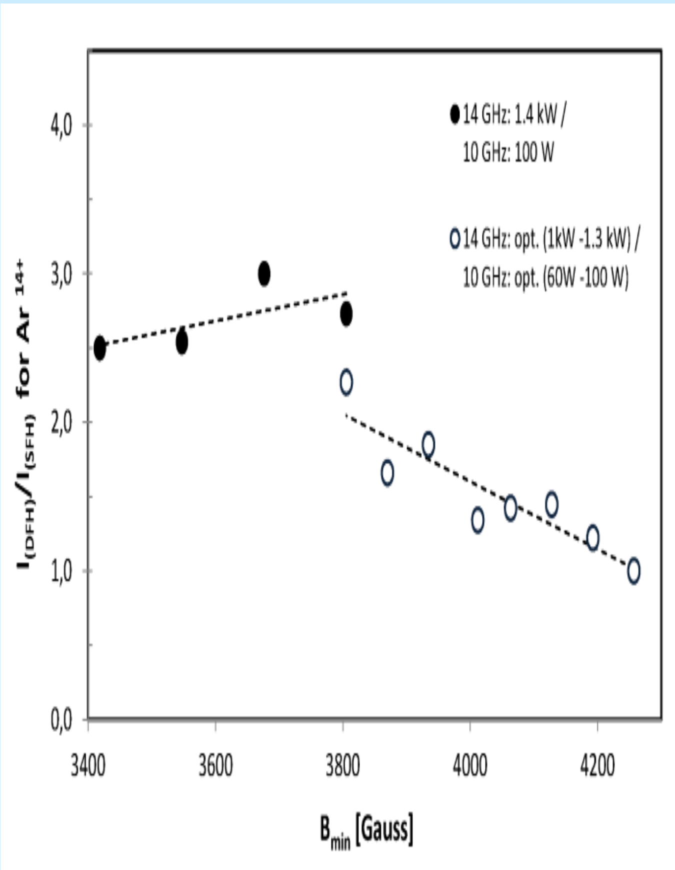
Source parameters:

Extraction voltage:15 kV.

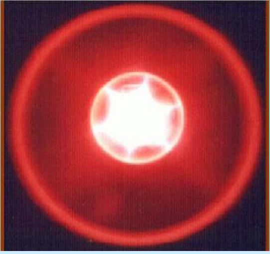
- Working gas: pure Argon
- Source pressures:
- Injection: 1. 0 - 5.0) x10-7 mbar
- Extraction: 7.0 - 8.0 x 10-8 mbar
- Beam optics optimized for Ar14+ transport
- Biased disk (position and voltage):
- used to optimize extracted currents
- Beam optics optimized for Ar14+ transport



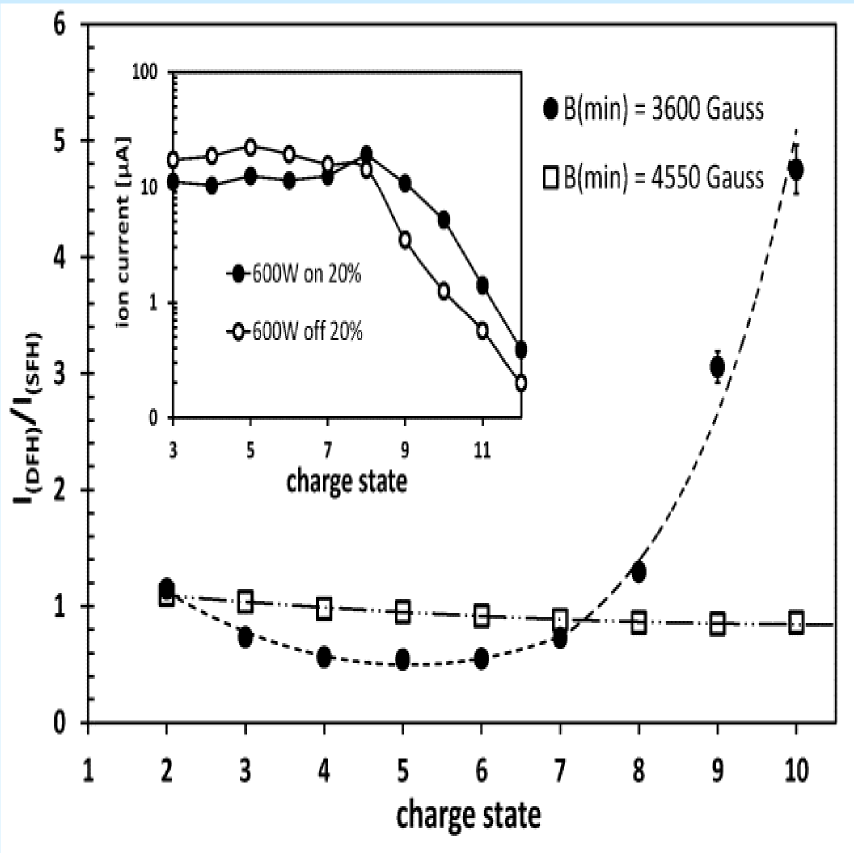
Experiment



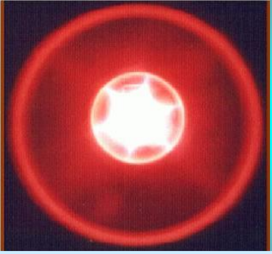
As DFH is most effective at the highest charge states we concentrate our experiments to the observation of Ar14+. In order to monitor the transition from the regime of "off resonance" heating, where no separate 10 GHz zone is formed, to resonance heating, we have carried out a series of measurements reducing the current of the middle coil in smaller steps. The results of a series of experiments are given in Fig. 1. Increasing performance as a function of the reduction of the current on the middle coil is obvious (open dots). The data saturate at values around 2.7 when the 10 GHz surface starts to form (full dots). At the given configuration of the IKF ECRIS, the injection of high RF powers (1,4 kW) was necessary to carry out this study for the 14+ charge state of argon. The measured enhancement by DFH of 2.7, therefore, may be obscured by the fact that this high power level also leads to a loss of electrons. With higher confinement the obtained DFH/SFH ratio for Ar14+ would certainly be significantly higher



Tacking in account the current status of the 14 GHz IKF Source



Because the magnetic field configuration of the IKF-ECRIS was recently modified to extract higher ion currents of intermediate charge states for the injection into the RFQ post accelerator higher enhancement factors and the shift of CSD towards high charge states has been observed in this experiment at conditions more appropriate, i.e., at intermediate charge states. For this purpose 14 GHz RF-power levels of 300–600 W are sufficient. The shift in CSD is clearly visible. In this region the trend that DFH helps to boost higher charge states is evident. This is also clearly visible in the insert of figure for two values of Bmin. The results demonstrate that the extraction of very highly charged ions in resonant DFH mode can be significantly improved by optimizing the plasma EEDF.



Comparison with other DFH earlier experiments results

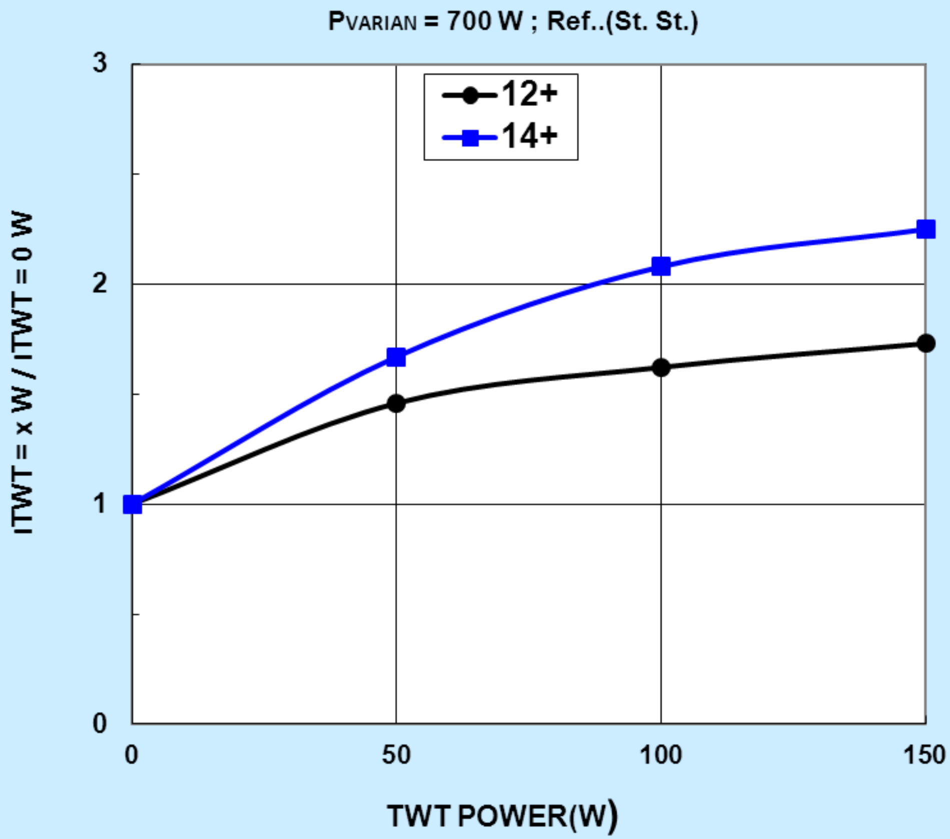
- The reported results demonstrate that the extraction of very highly charged ions in resonant DFH mode can be significantly improved by optimizing the plasma EEDF

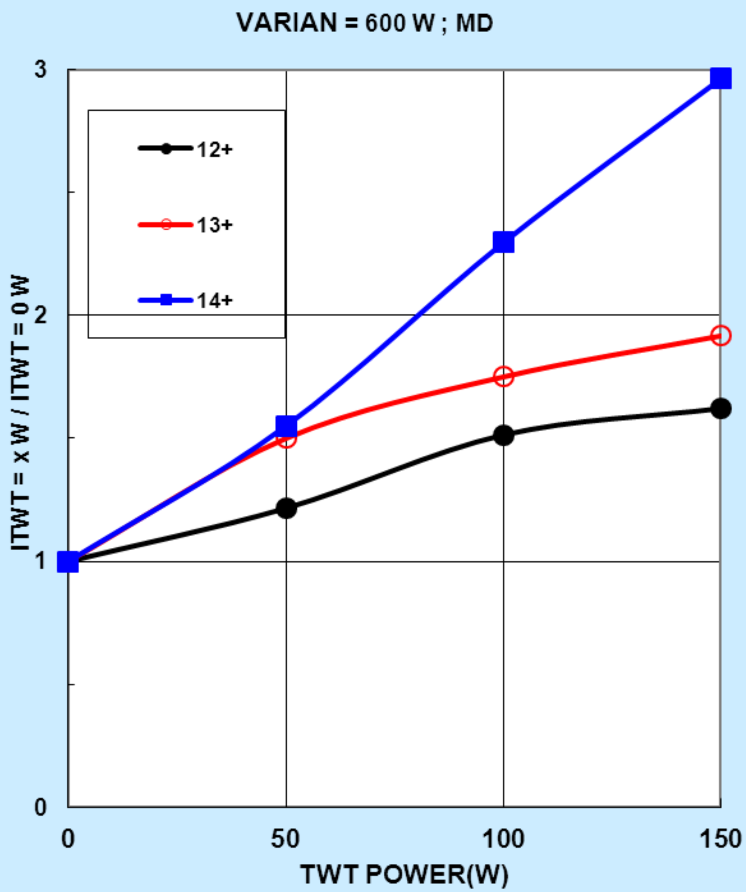
ion	LBNL-AECR 14+10 GHz	ANL-ECR1 10.5 +12 GHz	IKF 14.3 +10 GHz
Ar^{12+}		1.7	
Ar^{13+}	1.1	2,0	
Ar^{14+}	1.37		2.7
Ar^{16+}	1.6		

The Double Close Frequency Heating and the EEDF Influence

The injection of two, well separated RF-frequencies with still overlapping resonance zones has been used to substantially improve the high-charge state performance of the 14.GHz ECRIS of the Institut für Kernphysik, Goethe University Frankfurt, Germany (IKF.) This method, denoted here as "Double Close Frequency Heating" (DCFH) has been applied by using the 2^{nd} RF transmitter, launched to the standard IKF ECRIS installation (a TWT of a comparatively small band width. Frequencies of 14,33GHz (Klystron) and 13,5GHz (TWT) were injected into the source. To gain insight onto the role of EEDF of the plasma, these measurements have been performed with the standard (all stainless steel) source and the source equipped with an emissive (MD) liner.

Some Results





ENSAR- ARES CONTRIBUTIONS

THANK YOU FOR YOUR PATIENCE !