Cavity Tuning Experiments with the JYFL 14 GHz ECRIS

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JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

Content

- Frequency tuning vs. cavity tuning

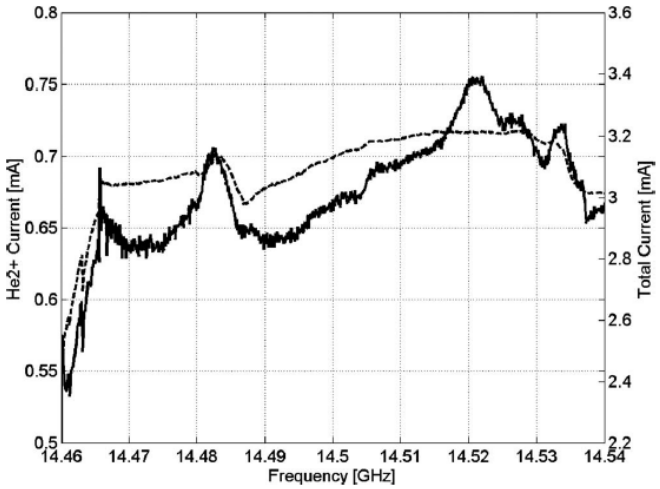
(fine) Frequency tuning effect (FFTE)

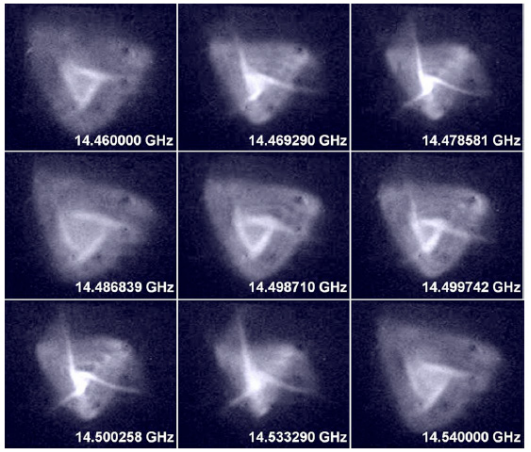
AIP | Review of Scientific Instruments

Observations of the frequency tuning effect in the 14 GHz CAPRICE ion source

L. Celona, G. Ciavola, F. Consoli, S. Gammino, F. Maimone, D. Mascali, P. Spädtke, K. Tinschert, R. Lang, J. Mäder, J. Roßbach, S. Barbarino, and R. S. Catalano

Citation: Review of Scientific Instruments **79**, 023305 (2008); doi: 10.1063/1.2841694





Remarkable variations have been observed depending on the source and the beamline operating parameters, confirming that a frequency dependent electromagnetic distribution is preserved even in the presence of plasma inside the source.

FFTE experiments at JYFL

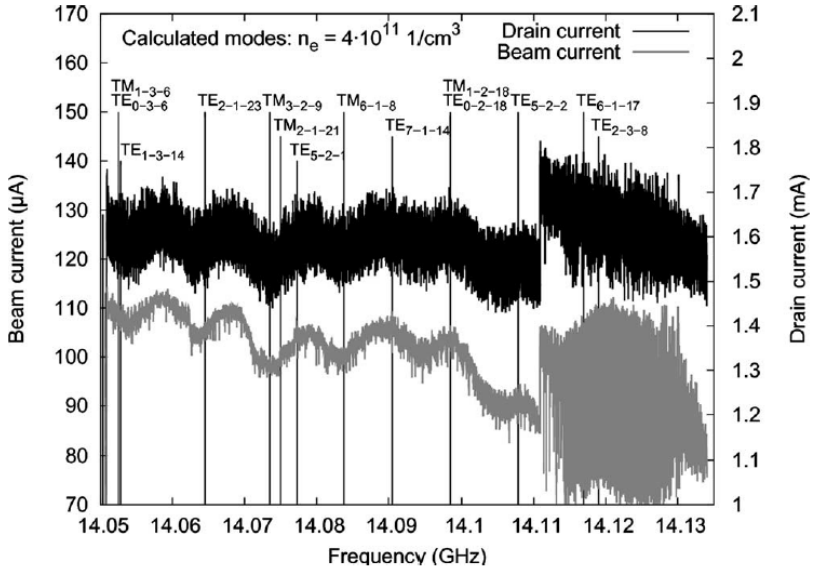
AIP | Review of Scientific Instruments

Effect of electron cyclotron resonance ion source frequency tuning on ion beam intensity and quality at Department of Physics, University of Jyväskyläa)

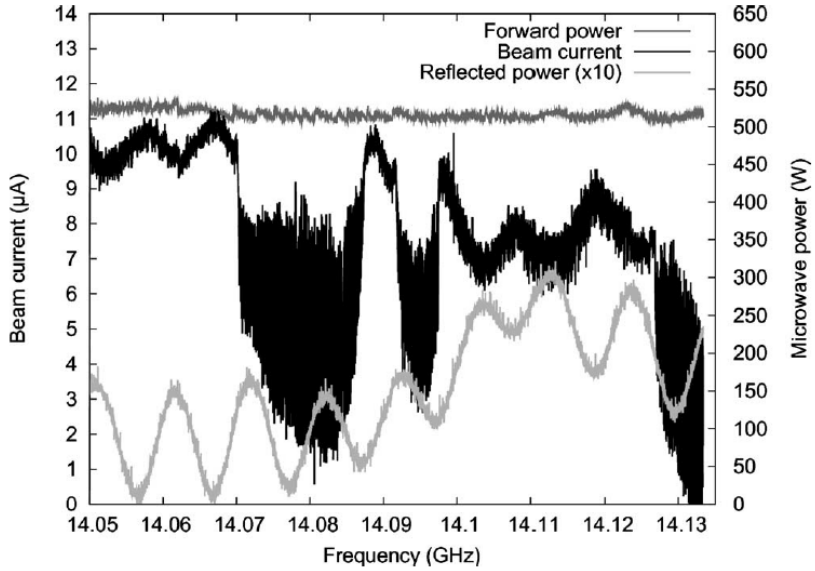
V. Toivanen, H. Koivisto, O. Steczkiewicz, L. Celona, O. Tarvainen, T. Ropponen, S. Gammino, D. Mascali, and G. Ciavola

Citation: Review of Scientific Instruments **81**, 02A319 (2010); doi: 10.1063/1.3267287

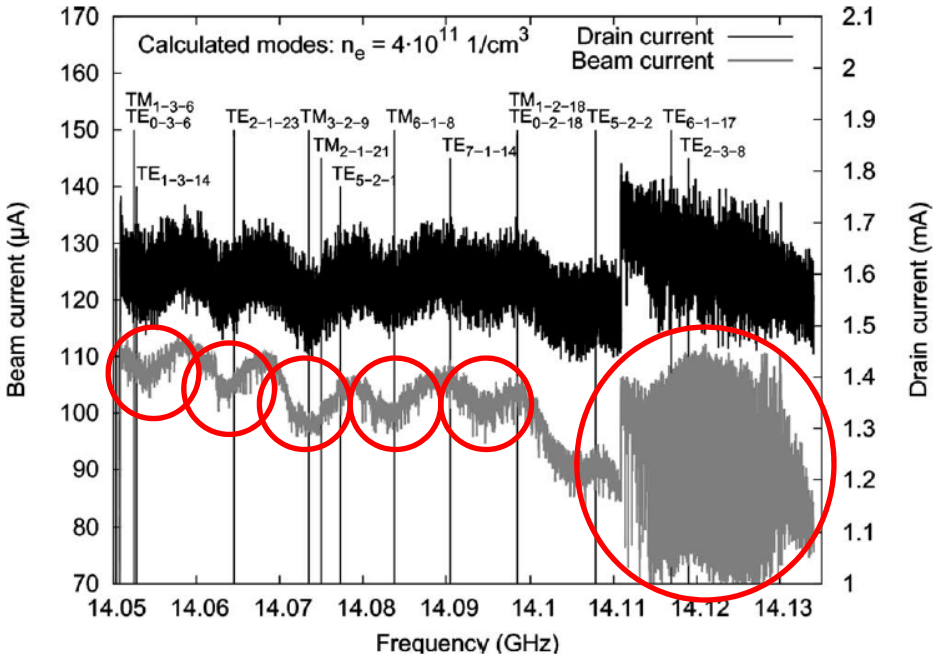
Ar^{9+}



Ar^{12+}



FFTE experiments at JYFL



Periodic ripple

Fluctuating beam current

Cavity modes?

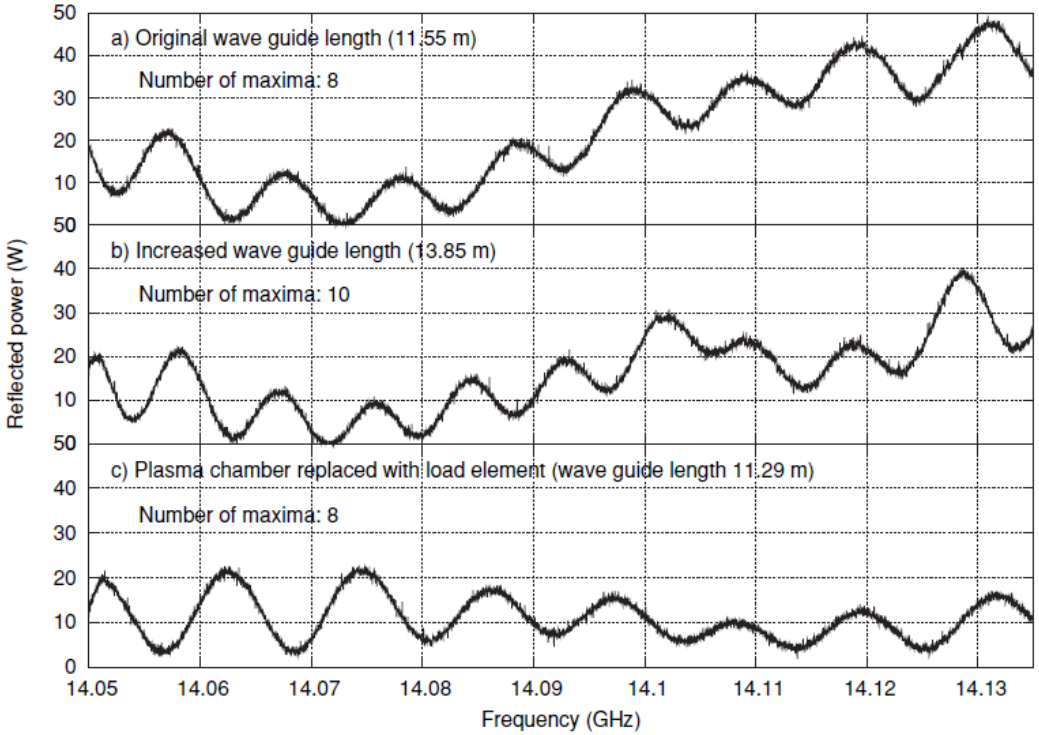
FFTE experiments at JYFL

AIP | Review of Scientific Instruments

Erratum: "Effect of electron cyclotron resonance ion source frequency tuning on ion beam intensity and quality at Department of Physics, University of Jyväskylä" [Rev. Sci. Instrum. 81, 02A319 (2010)]

V. Toivanen, H. Koivisto, O. Steczkiewicz, L. Celona, O. Tarvainen, T. Ropponen, S. Gammino, D. Mascali, and G. Ciavola

Citation: Review of Scientific Instruments **82**, 029901 (2011); doi: 10.1063/1.3541812



Waveguide modes!

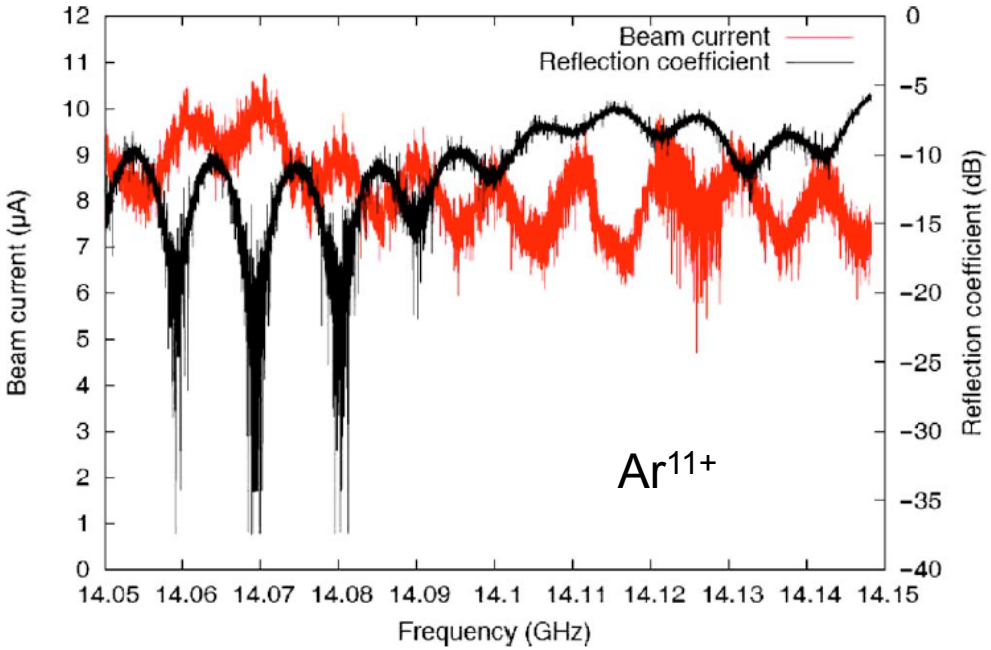
FFTE experiments at JYFL

AIP | Review of Scientific Instruments

Microwave to plasma coupling in electron cyclotron resonance and microwave ion sources (invited)a)

L. Celona, S. Gammino, G. Ciavola, F. Maimone, and D. Mascali

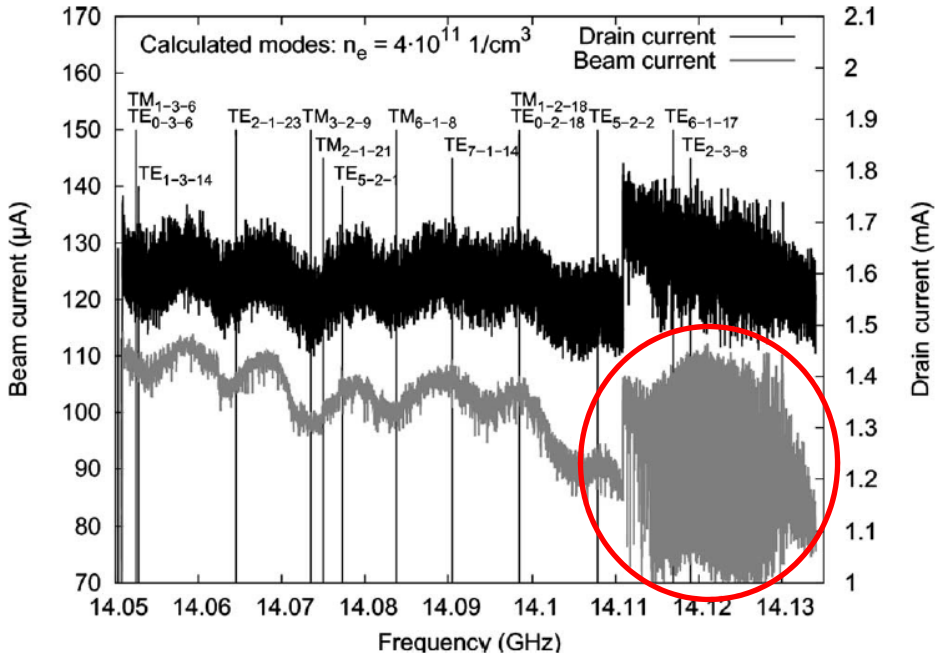
Citation: Review of Scientific Instruments **81**, 02A333 (2010); doi: 10.1063/1.3265366



The periodic ripple first ascribed to electromagnetic field pattern over the resonance surface was later confirmed to be a waveguide effect.

FFTE experiments at JYFL

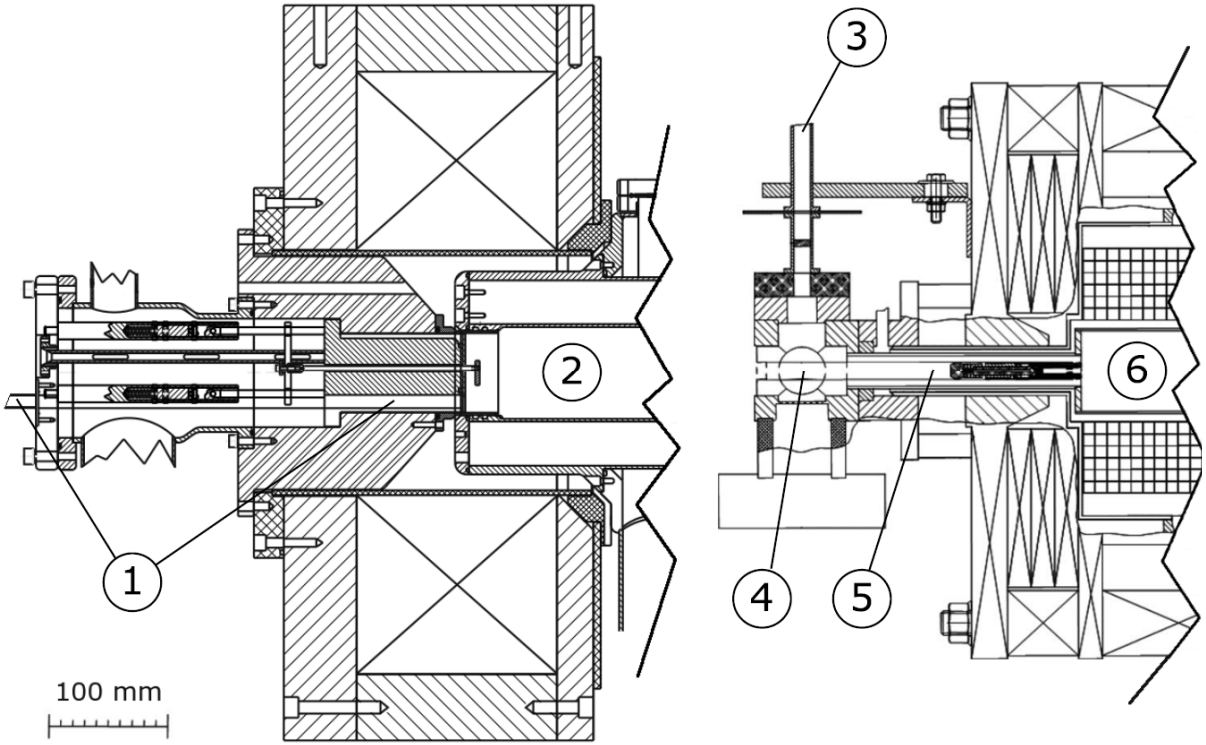
Two questions remain (at least)



What is causing this?

Why is the Caprice source more sensitive to frequency tuning than the A-ECR?

Caprice vs. A-ECR



DEPARTMENT OF PHYSICS
UNIVERSITY OF JYVÄSKYLÄ
RESEARCH REPORT No. 6/2013

STUDIES OF ELECTRON CYCLOTRON RESONANCE ION SOURCE BEAM FORMATION, TRANSPORT AND QUALITY

BY

VILLE TOIVANEN

Academic Dissertation
for the Degree of
Doctor of Philosophy

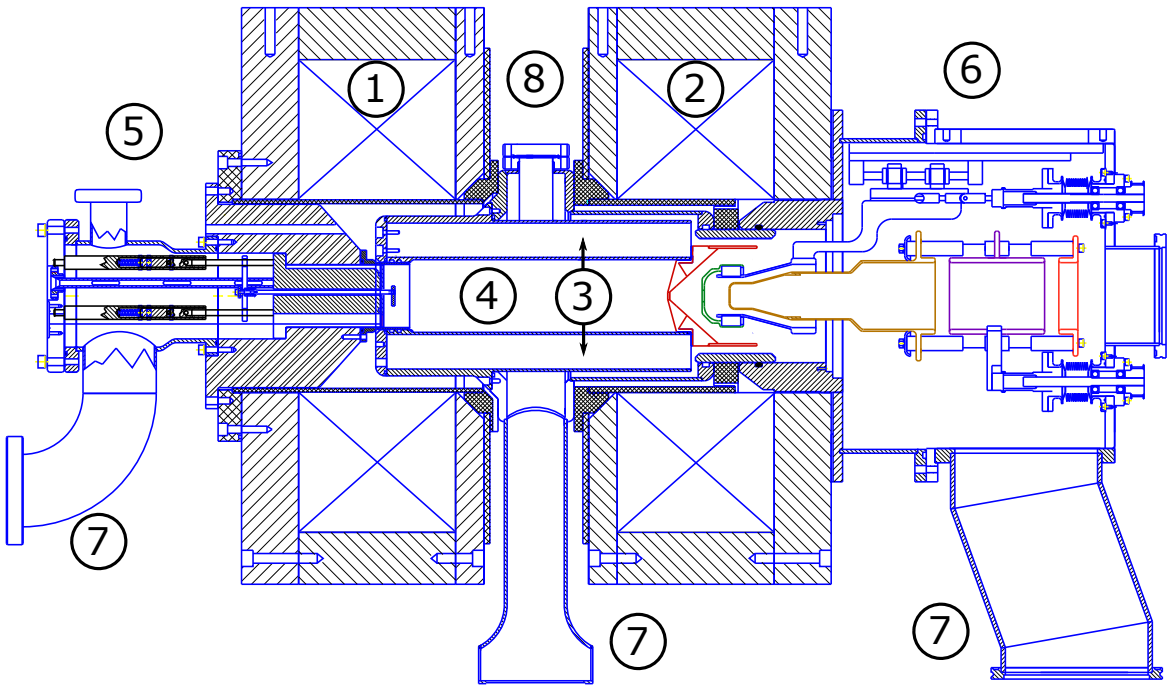
The microwave coupling system affects the frequency response of the ECRIS

How to decouple the effect of the microwave launching system and plasma chamber electric field distribution on ECRIS performance?

Content

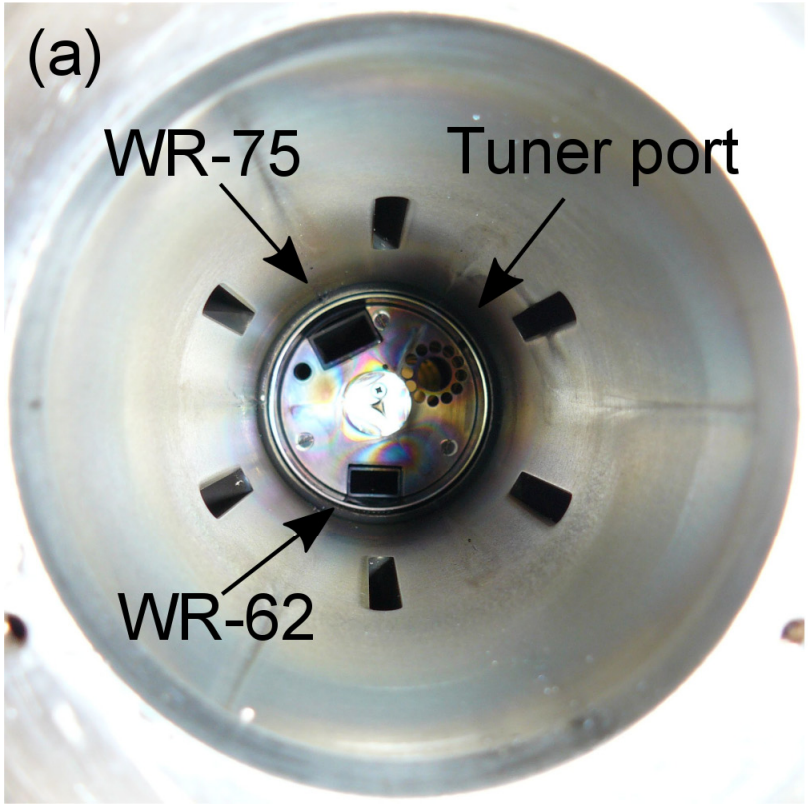
- Frequency tuning vs. cavity tuning
- Experimental setup
- Experimental results and discussion

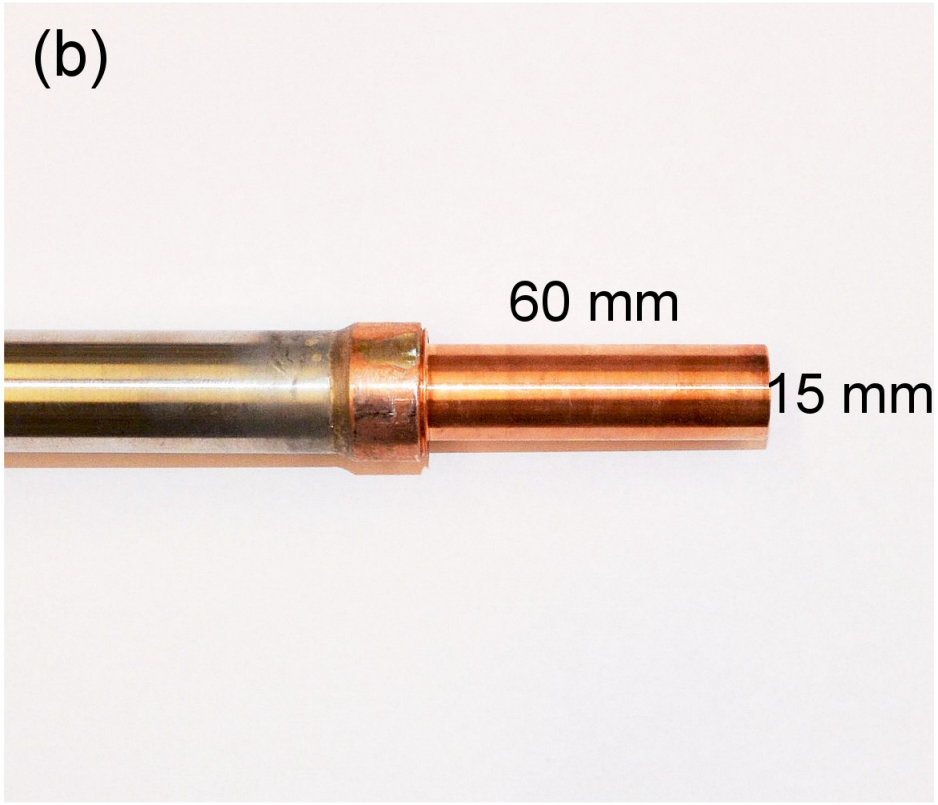
JYFL 14 GHz ECRIS (A-ECR)



1. Injection coil
2. Extraction coil
3. PM hexapole
4. Plasma chamber
5. Waveguides
6. Extraction
7. Pumping
8. Radial viewport

How to tune the cavity properties?





WR-62: 14.00 – 14.15 GHz klystron

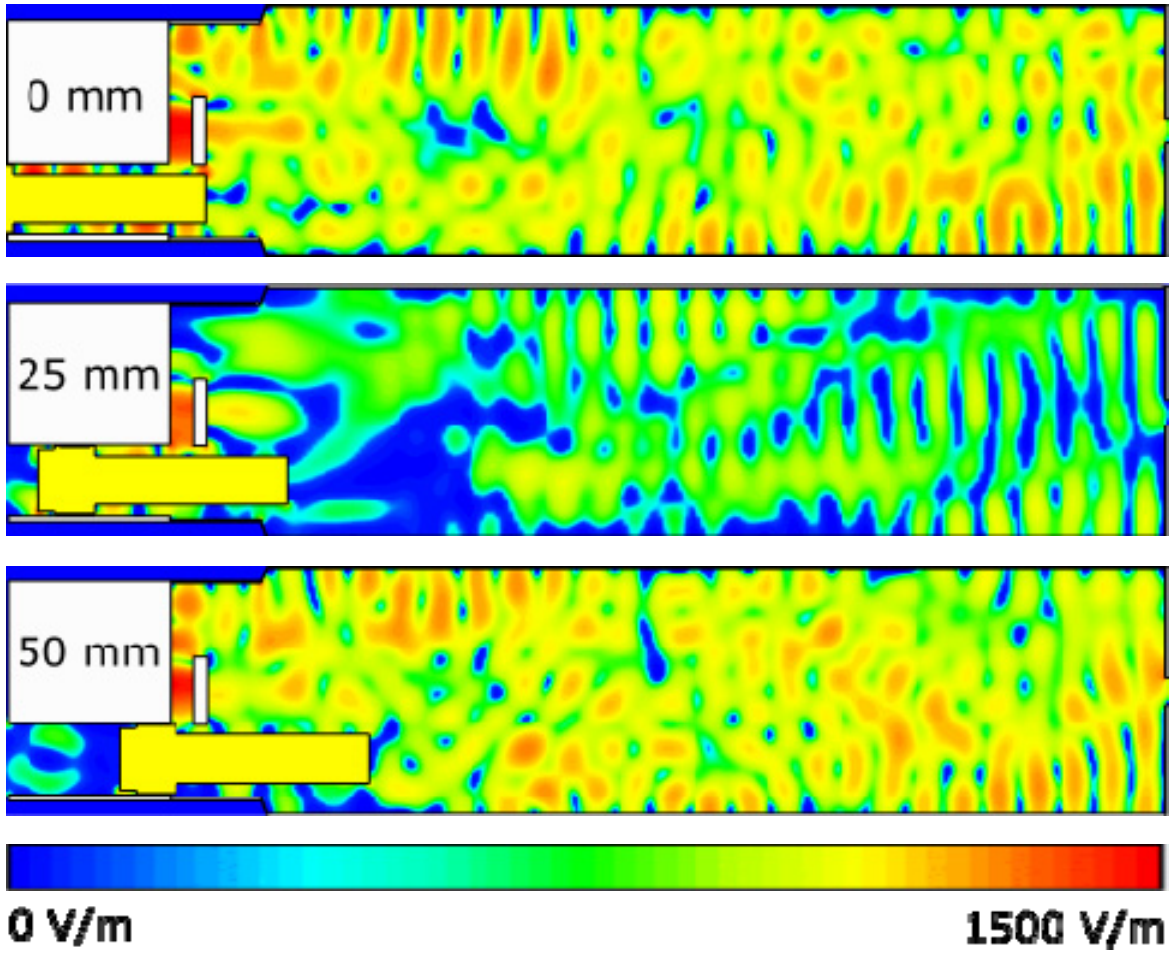
WR-75: 10.75 – 12.75 GHz TWTA

Copper plunger inserted 0 – 50 mm inwards through the oven port

Position adjusted without breaking the vacuum or disconnecting the HV

CST Microwave studio simulation

The effect of the tuner position on empty cavity rms electric field at 14.053 GHz



Plasma affects the field strength and distribution!

Earlier experiments

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Nuclear Instruments and Methods in Physics Research B 226 (2004) 392–400
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Beam Interactions with Materials & Atoms
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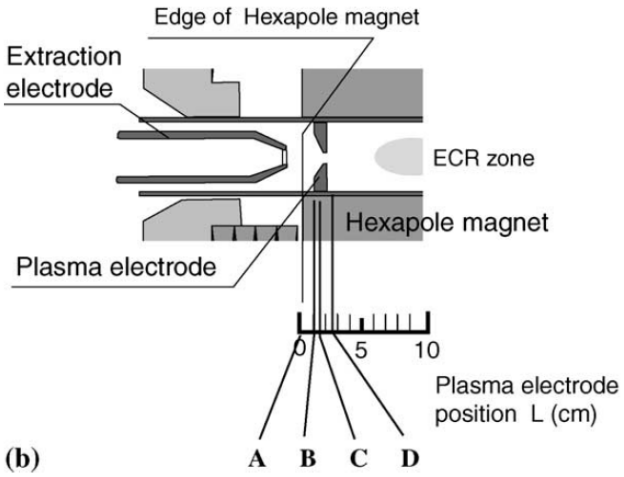
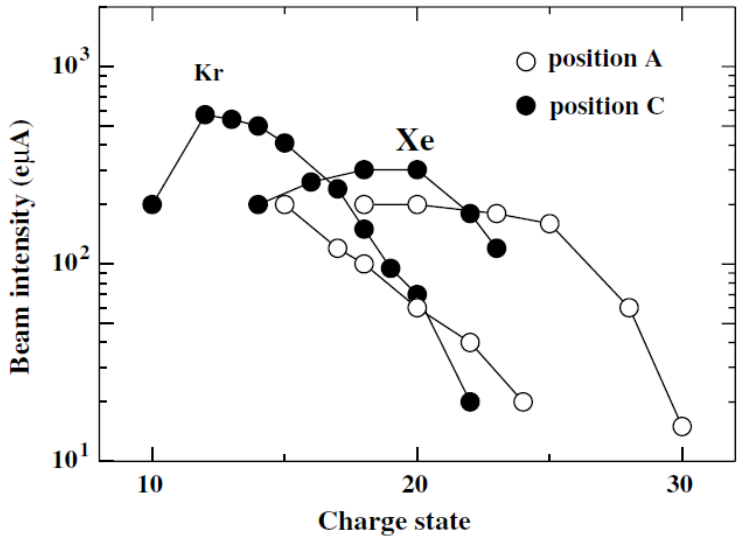
Production of multi-charged ions in the RIKEN 18 GHz ECRIS

T. Nakagawa [a,*], Y. Higurashi [a], M. Kidera [a], T. Aihara [b], M. Kase [a], Y. Yano [a]

[a] *RIKEN, Hirosawa 2-1, Wako, Saitama 351-0198, Japan*
[b] *SHI, Accelerator Service Ltd., Kita-shinagawa 5-9-11, Shinjuku-ku, Tokyo 141-0001, Japan*

Movable plasma electrode





Earlier experiments

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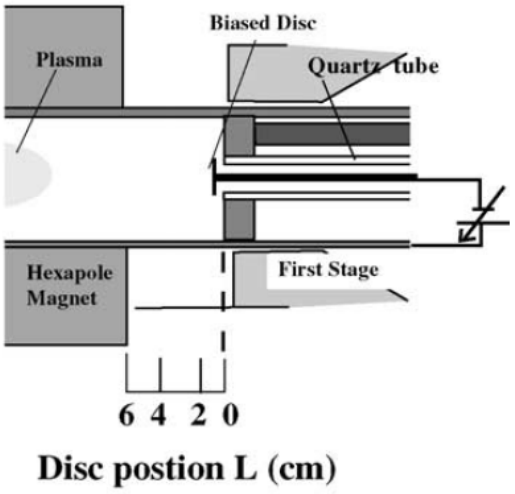
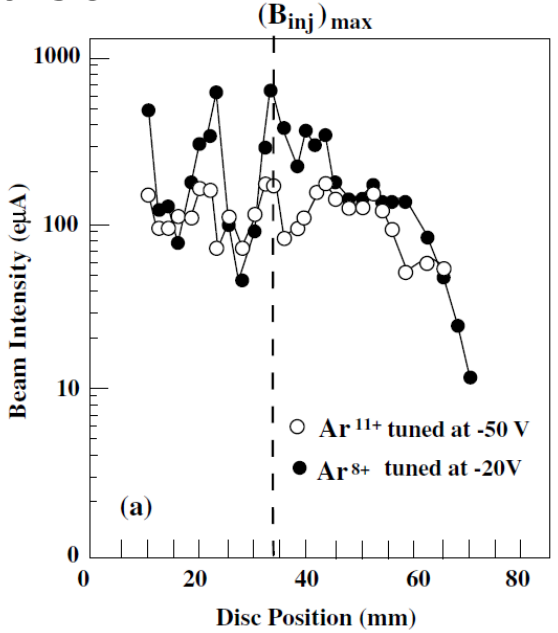
Movable biased disc





Earlier experiments

Nuclear Instruments and Methods in Physics Research A 726 (2013) 41–46

Contents lists available at SciVerse ScienceDirect

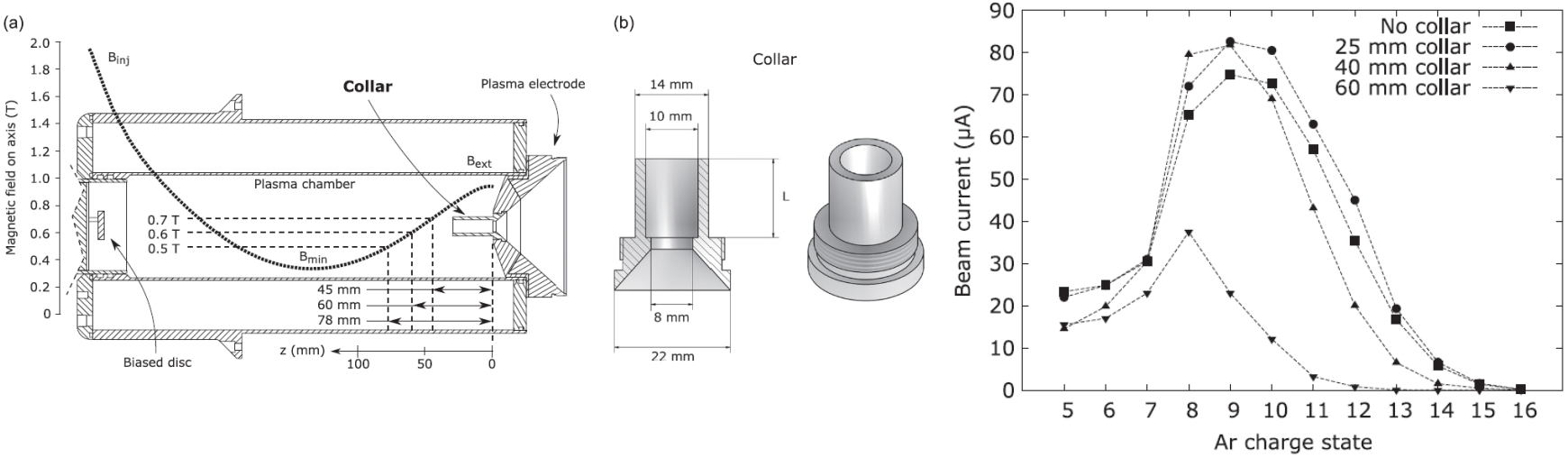
Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

The effect of plasma electrode collar structure on the performance of the JYFL 14 GHz electron cyclotron resonance ion source

V. Toivanen *, O. Tarvainen, J. Komppula, H. Koivisto

University of Jyväskylä, Department of Physics (JYFL), P.O. Box 35, FI-40014, Finland



Earlier experiments

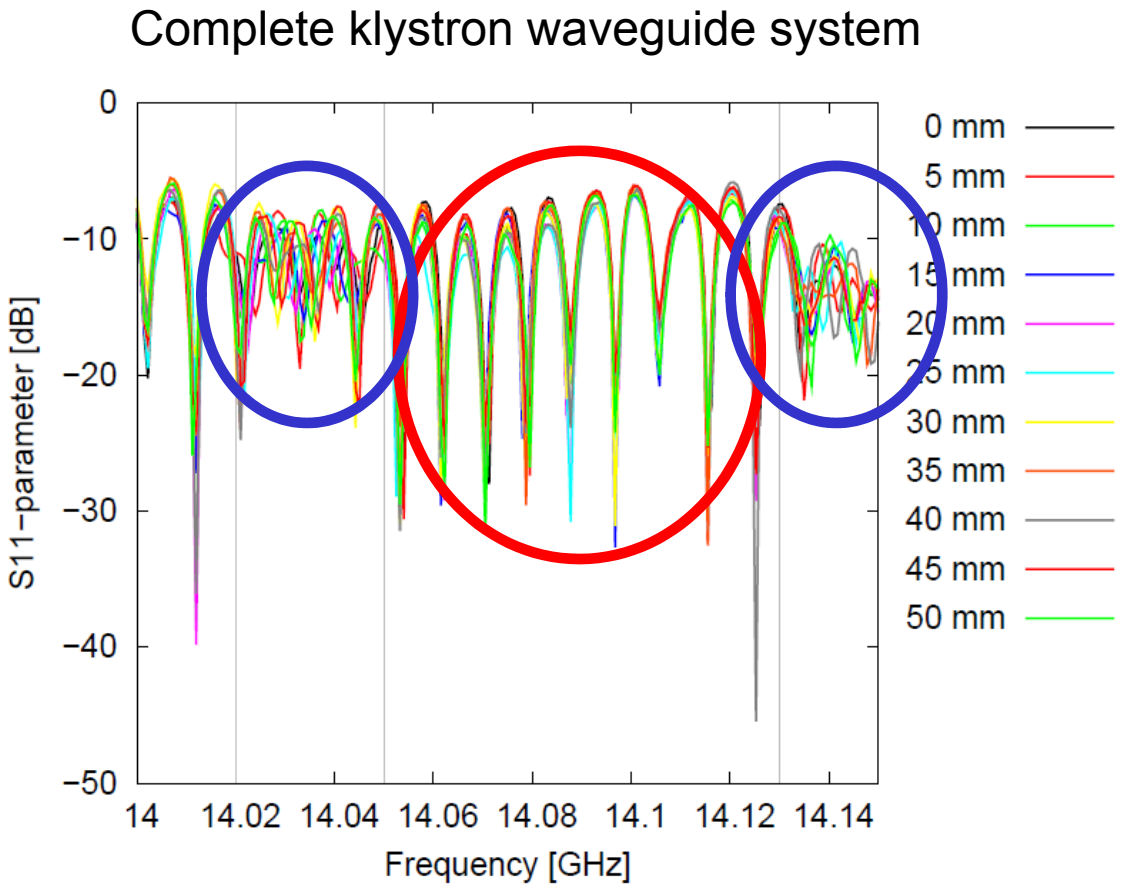
- Not a comprehensive list (ovens, sputter targets etc.)
- Earlier experiments were not focused on the effect of cavity properties
- Required venting and pumping the source in between data points (collar) or…
- … the plasma confinement properties were affected (movable electrodes)

Moving the tuner does not require compromizing the vacuum, it does not affect the plasma confinement and it is not in contact with the plasma

Content

- Frequency tuning vs. cavity tuning
- Experimental setup
- Experimental results and discussion

The effect of the tuner position on the empty cavity output return loss (S11)

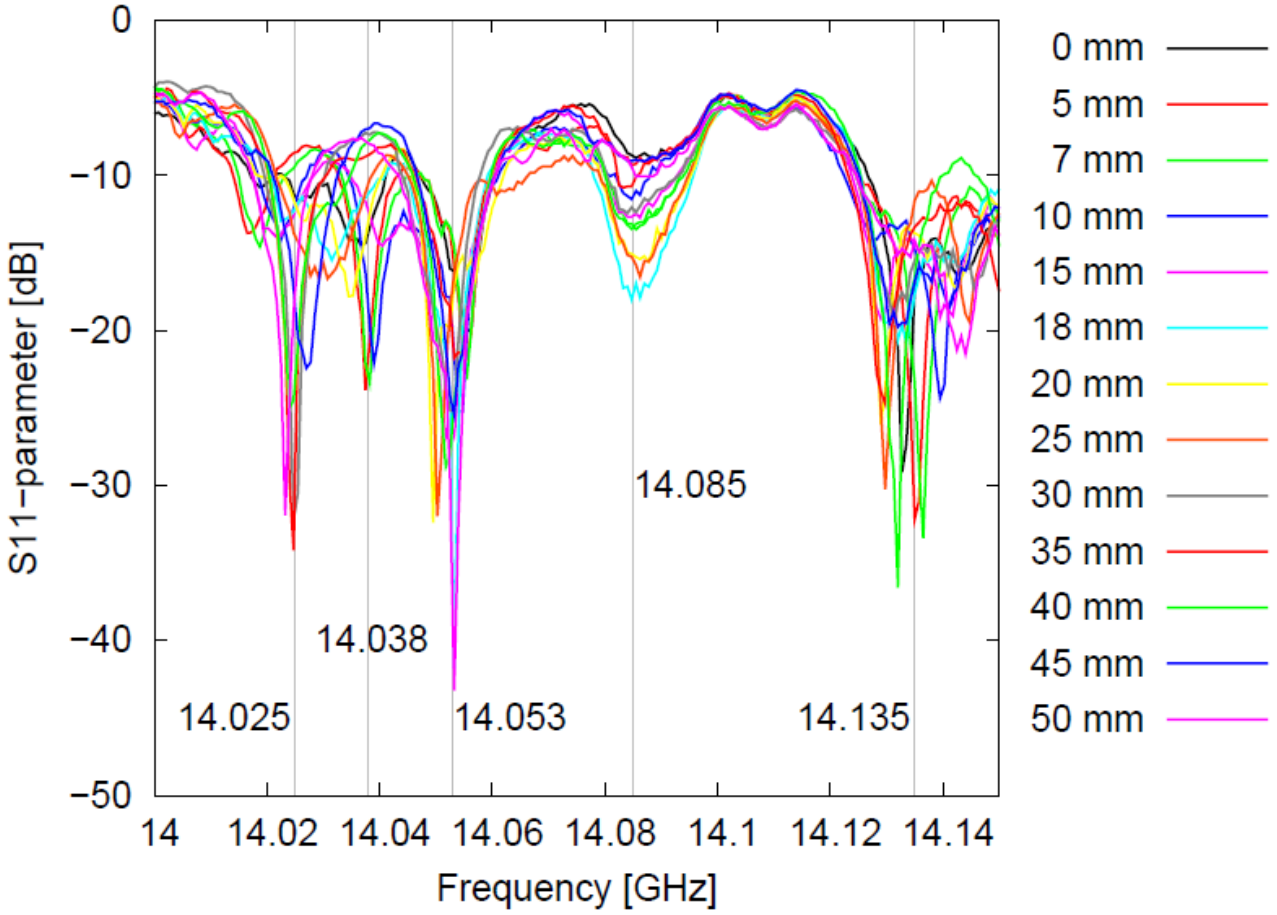


Dominating periodic ripple corresponding to waveguide modes

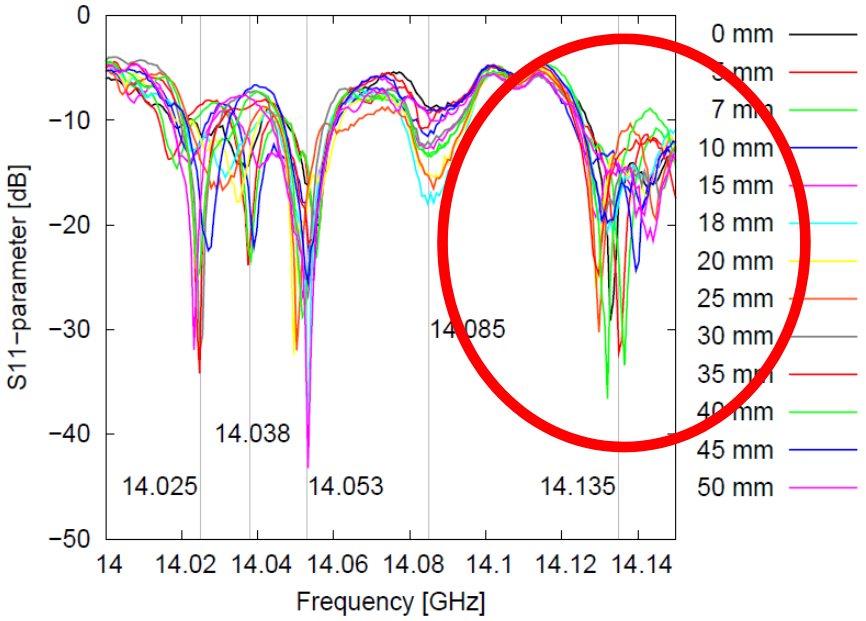
Cavity effect in narrow frequency bands?

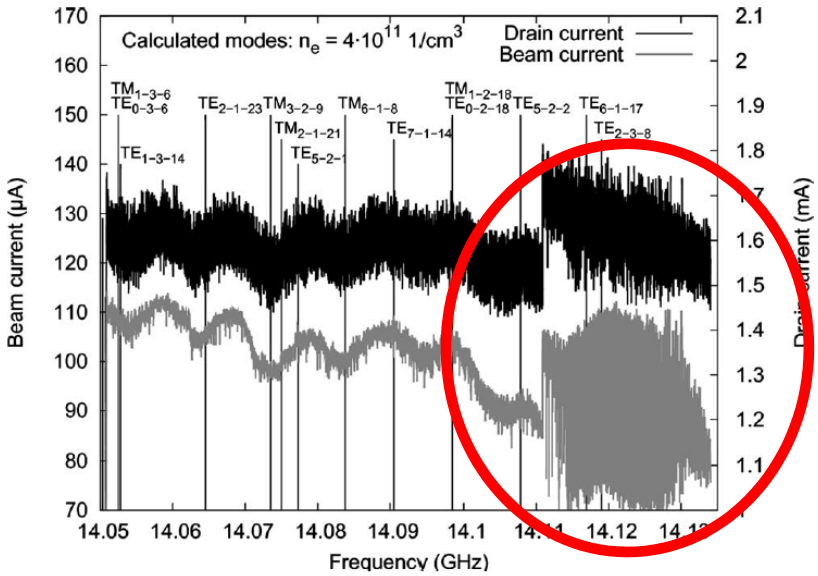
The effect of the tuner position on the empty cavity output return loss (S11)

Waveguide and HV-break removed



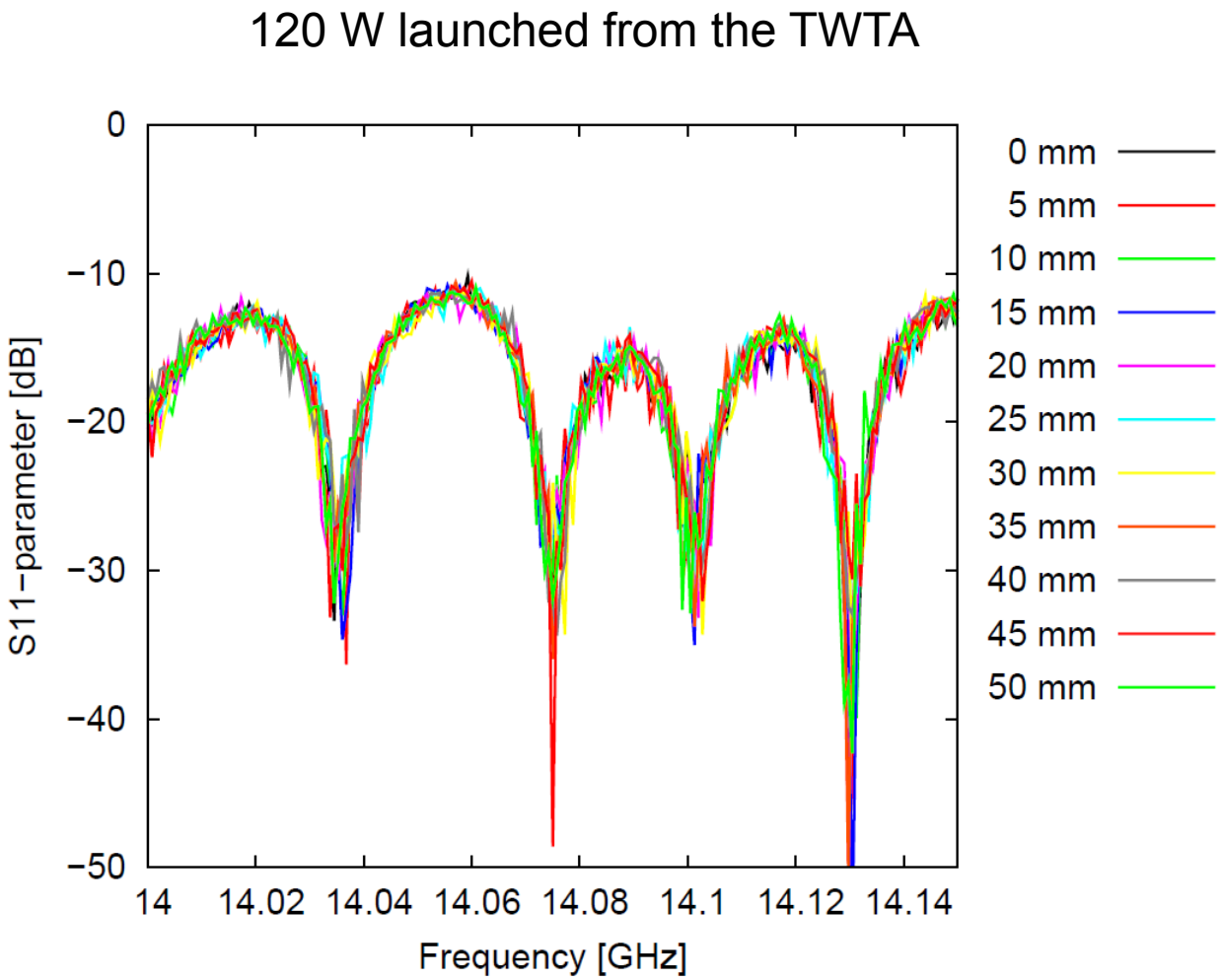
Maybe there is something?



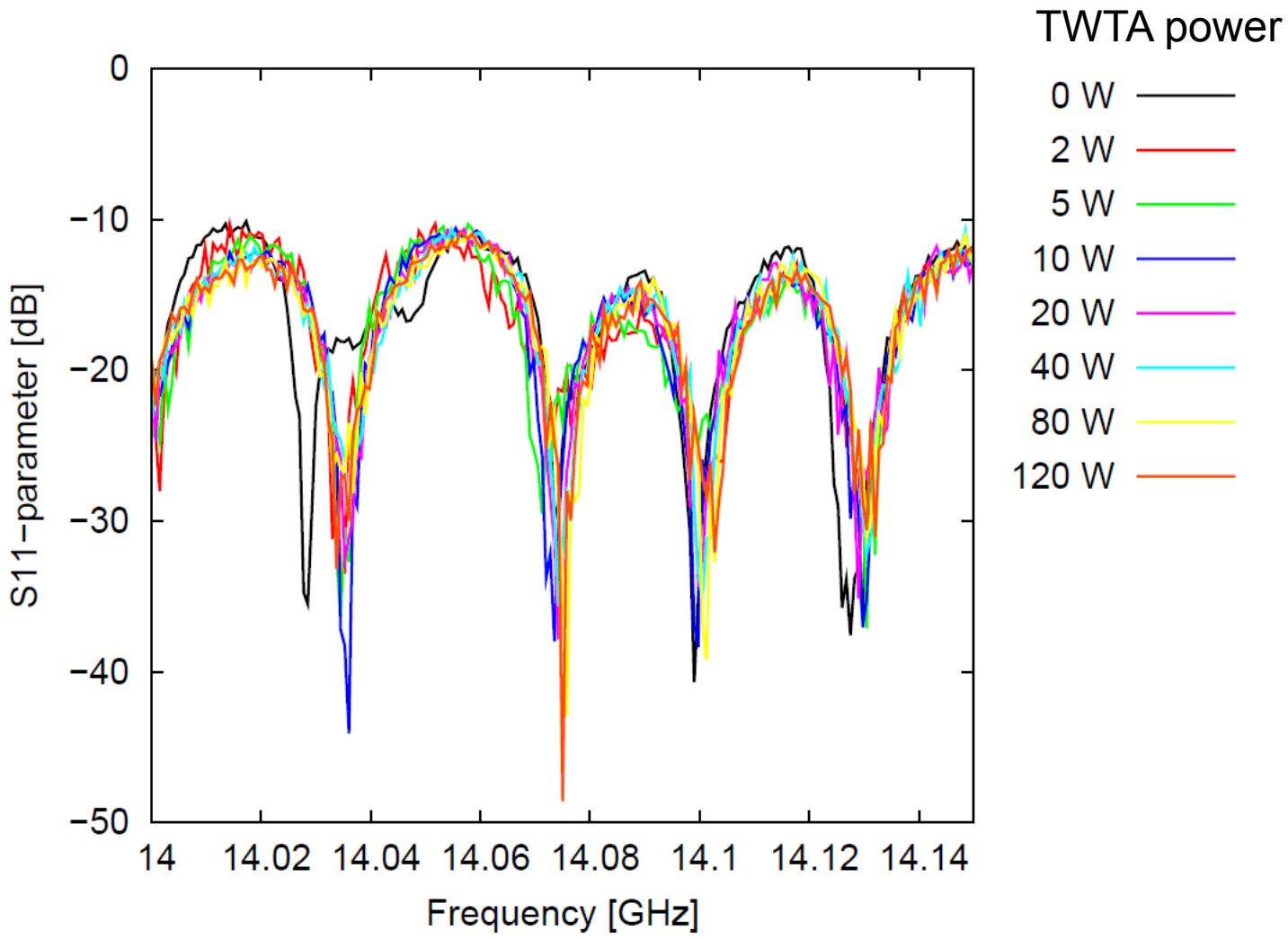


What is the effect of the plasma?

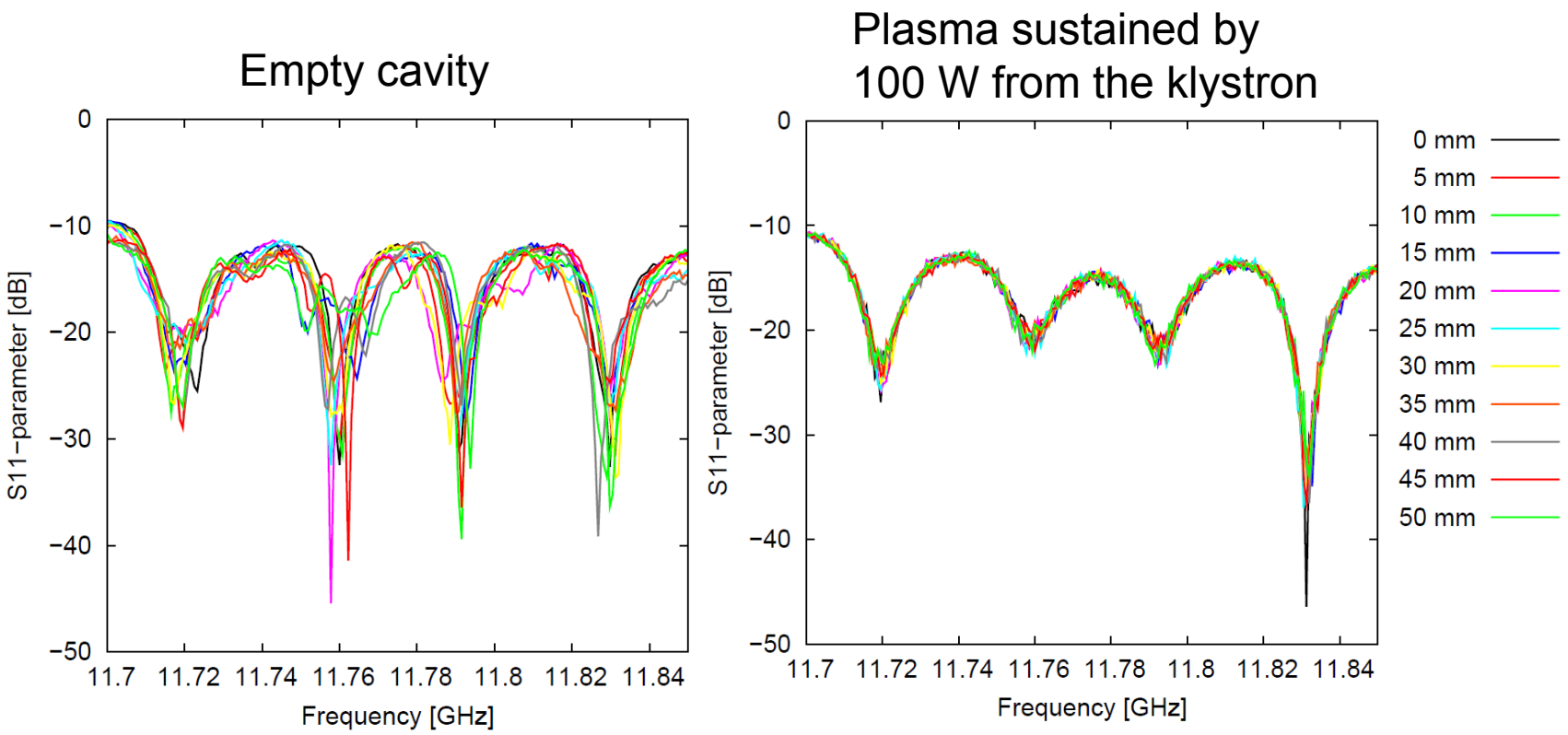
S11-parameter with plasma



S11-parameter with plasma



Similar observation in the TWTA frequency band



Similar effect throughout the TWTA frequency range of 10.75-12.75 GHz

?

Let’s see with the beam

Experimental procedure

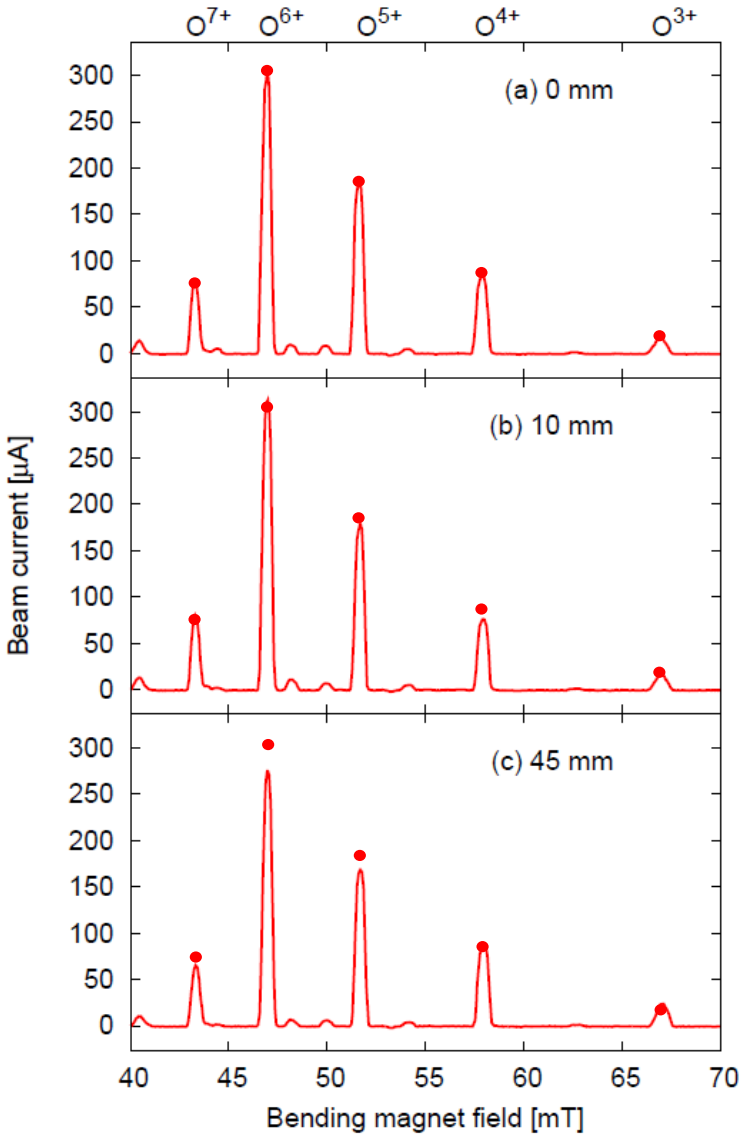
- Step #1: select frequencies of interest from the klystron and TWTA frequency ranges
- Step #2: tune for O^{6+} with the tuner at 0 mm
- Step #3: fix neutral gas pressure, power, biased disc voltage
- Step #4: move the tuner
- Step #5: make small adjustments of $< \pm 1\%$ to the magnetic field strength if necessary to stabilize the plasma
- Step #6: record m/q-spectrum
- Step #7: goto #4

The effect of the tuner position on oxygen beams – 14.053 GHz

Baseline

Maximum

Minimum



O^{6+}: +2 %

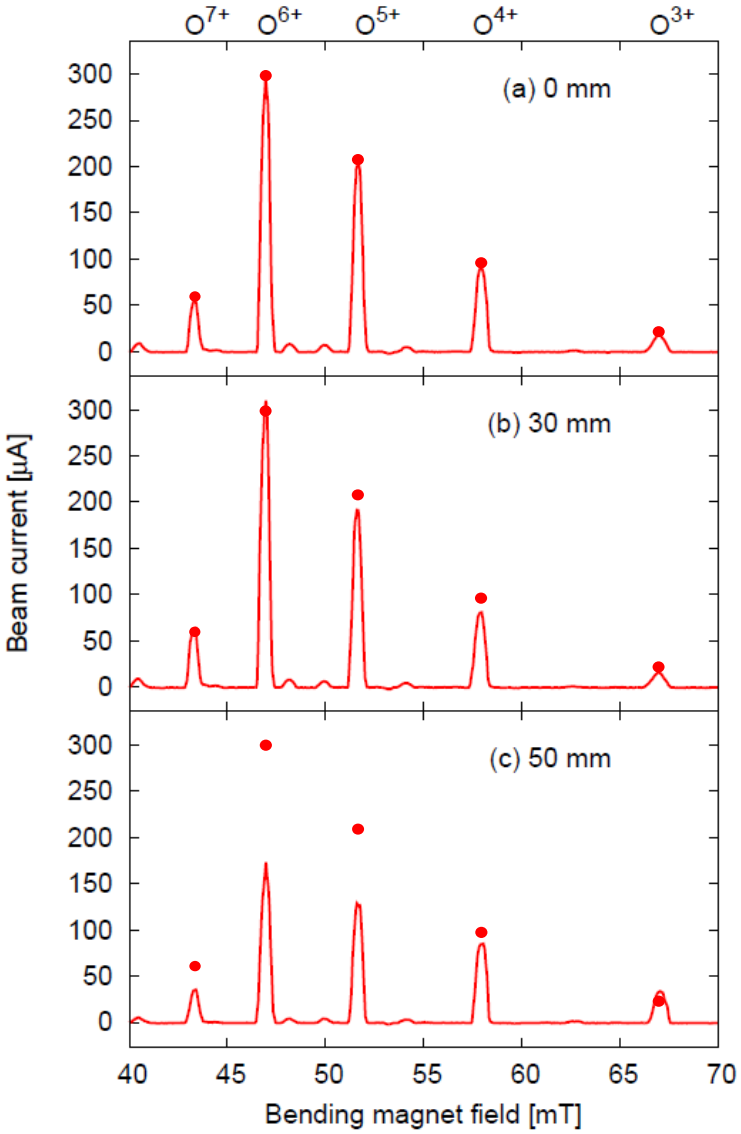
O^{6+}: -10 %

The effect of the tuner position on oxygen beams – 14.135 GHz

Baseline

Maximum

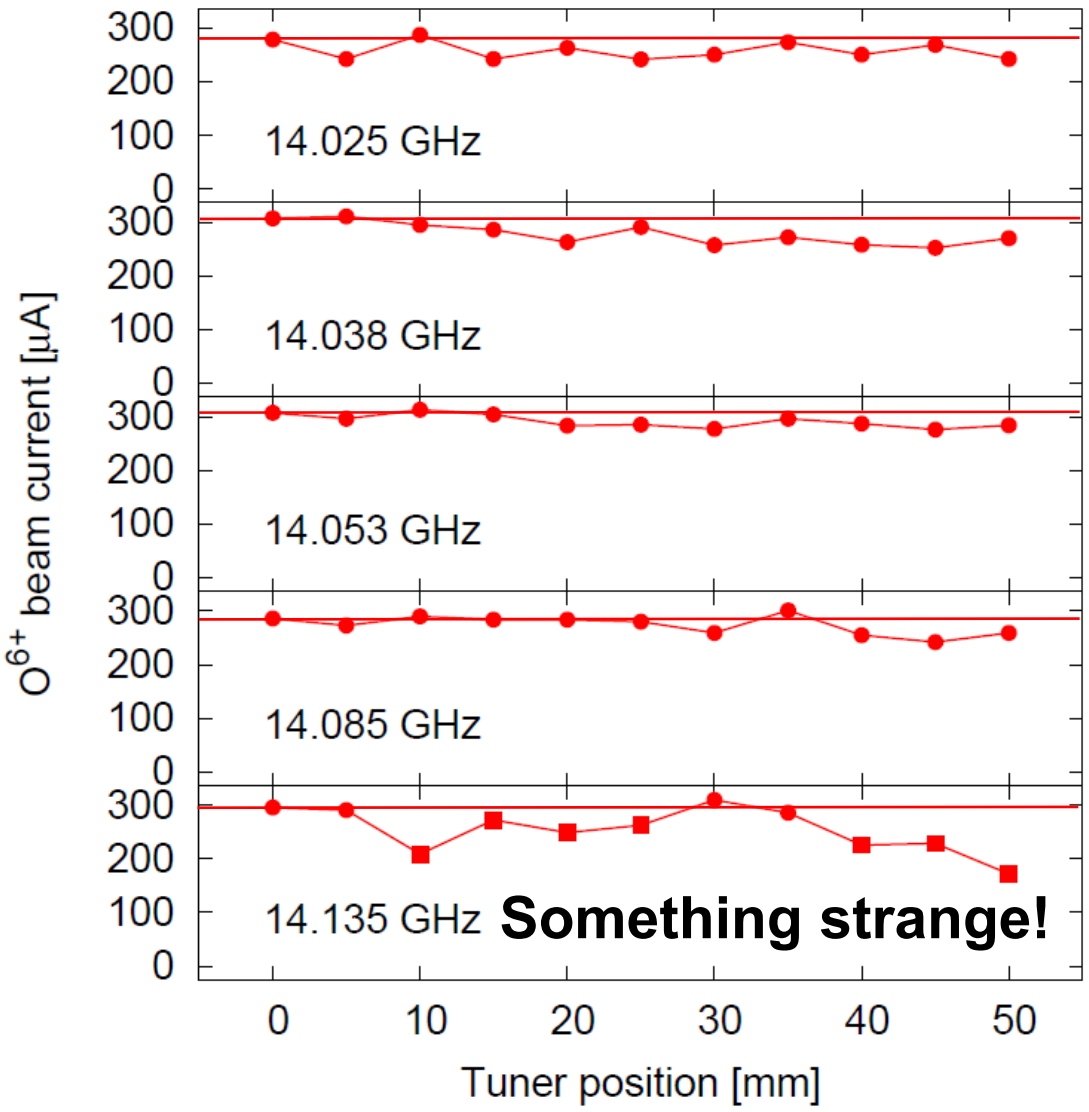
Minimum



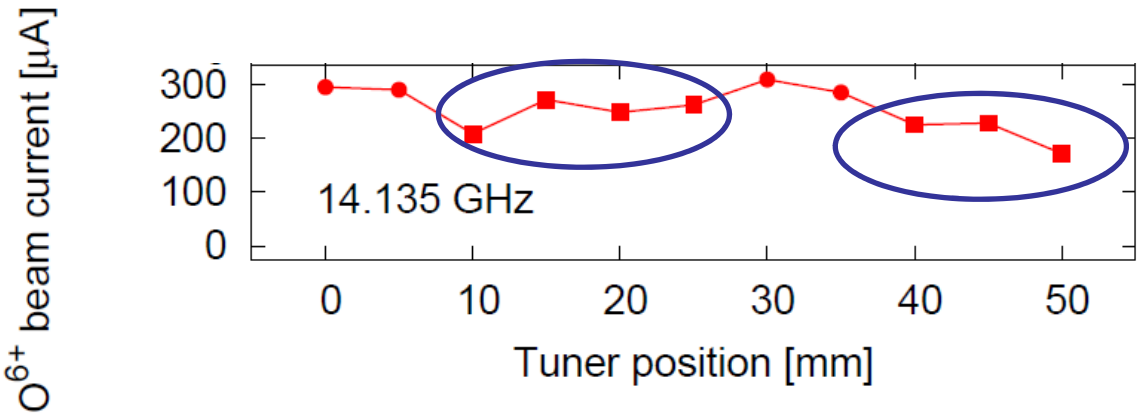
O^{6+}: +5 %

O^{6+}: -42 %

The effect of the tuner position on the beam current of O^{6+}

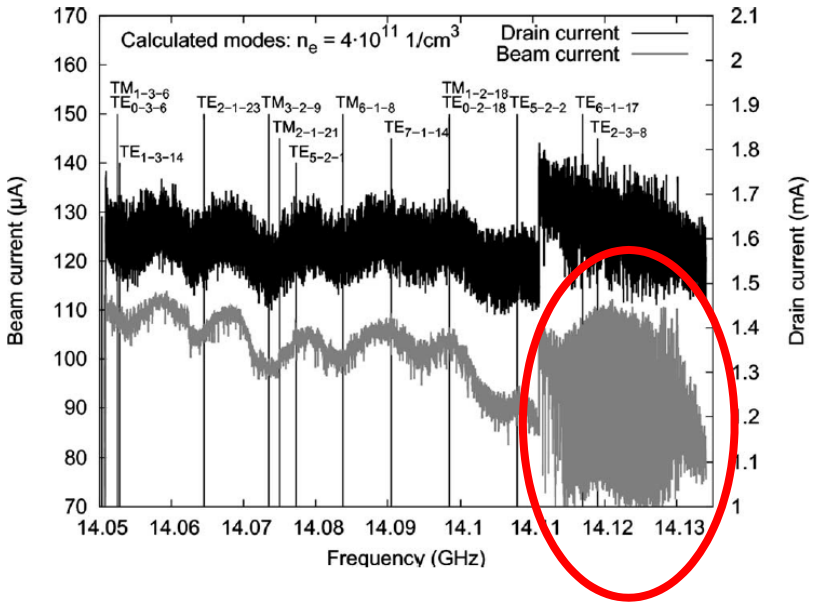


’Mode-hopping’

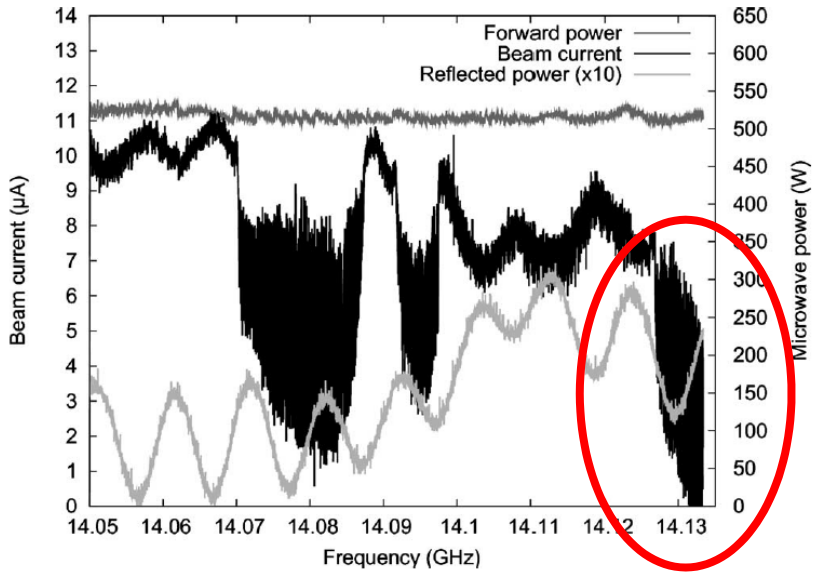


Random hopping between two plasma states

Ar9+

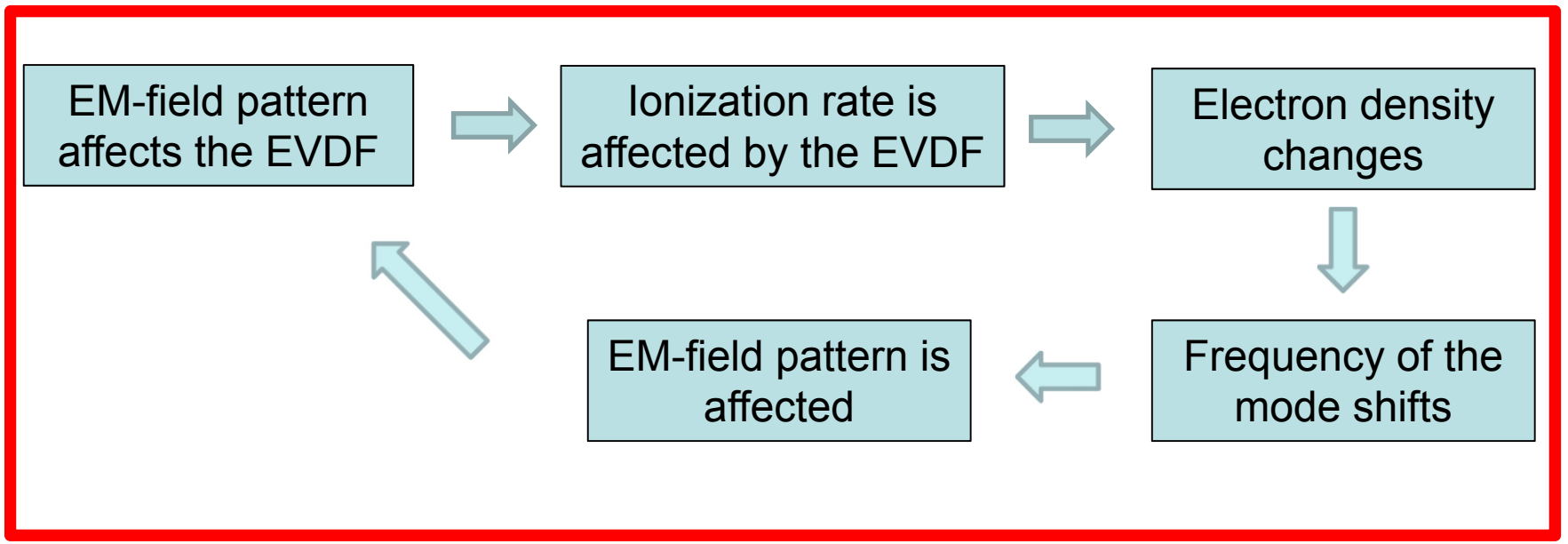


Ar12+



Is the ’mode-hopping’ related to cavity modes?

Mode-hopping?

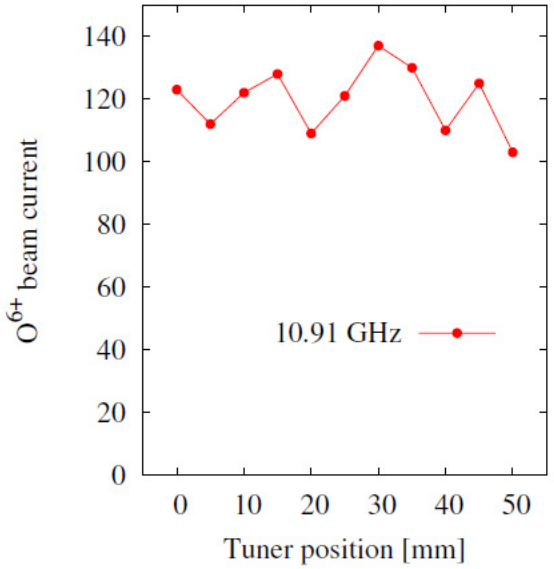


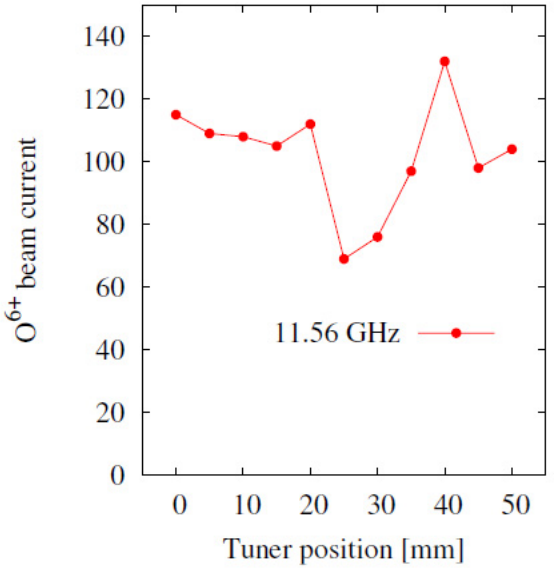
Speculation!

Is the klystron bandwidth wide enough to observe the cavity tuning effect?

The effect of the tuner position on oxygen beams – results with TWTA

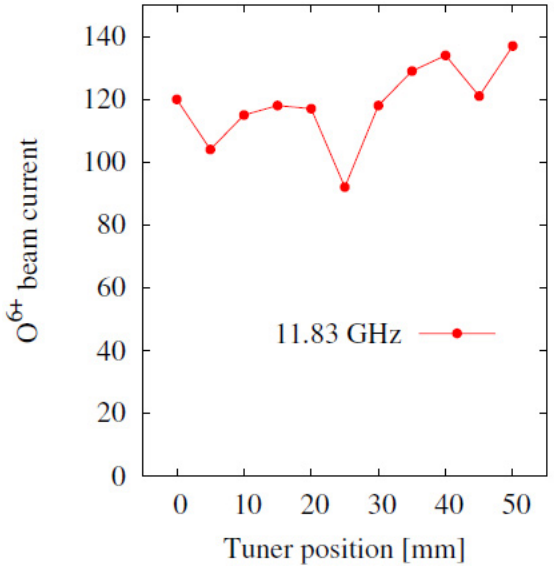
+11 / -16 %

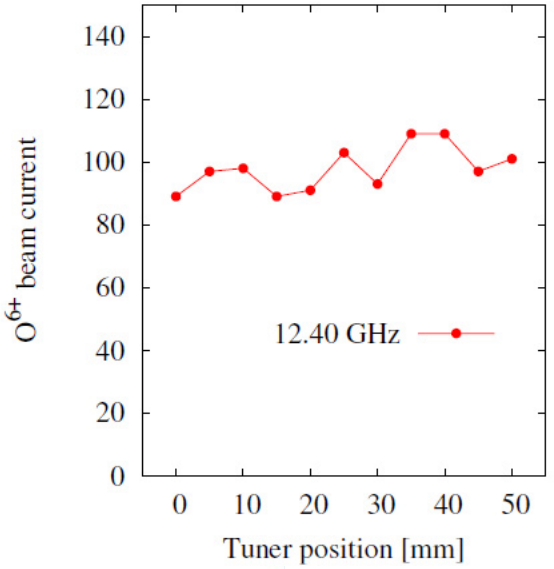




+15 / -40 %

+14 / -23 %





+22 %

Conclusions

- The charge state distribution of oxygen is affected by the tuner position
- The optimum tuner position depends on the microwave frequency
- In the frequency range of the klystron the extracted currents can be increased only moderately (< 10 %) by optimizing the tuner position
- In the frequency range of the TWTA the effect is more significant BUT is it only because lower performance?
- At certain tuner positions the plasma exhibits mode hopping which explains the reduced beam currents
- S11-parameter can not be considered as a good indicator of the source performance

Thank You
for your attention!