Experimental study of ECRIS beam current oscillations

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Content

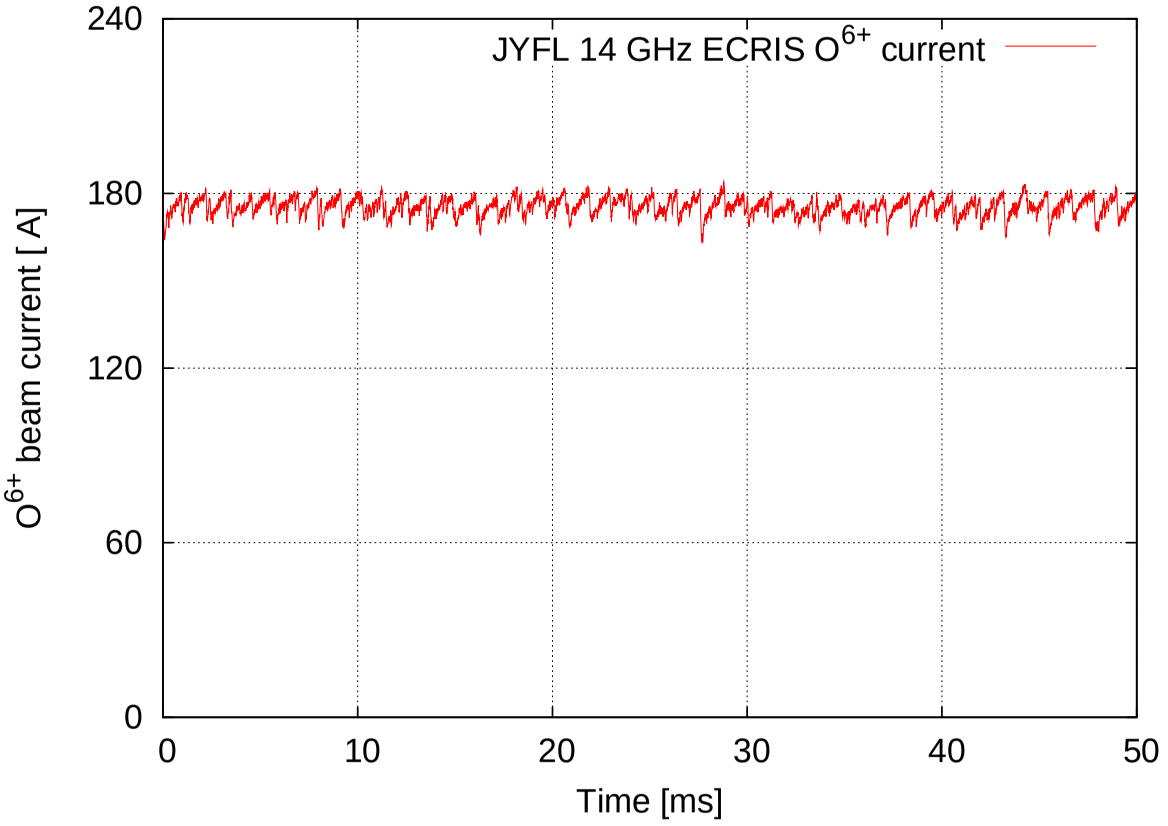
- Stability of ECRIS beams
- Experimental setup and data analysis
- Results
- Discussion - the origin of beam current oscillations

Stability of ECRIS beams

- Stability is especially important for
  - High power accelerators
  - Medical applications
  - Industrial applications
- Different types of stability
  - Long-term droop / increase of the current
  - Rapid oscillations in ~ kHz range

Stability of ECRIS beams

- This work focuses on the rapid oscillations presumably driven by plasma mechanisms



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Previous work

- Magnetic field topology

  Geller's book

  T.A. Antaya and S. Gammino, Rev. Sci. Instrum., 65 (5), (1994), p. 1723.

- Biased disc

  G. S. Taki, P. R. Sarma, A. G. Drentje, T. Nakagawa, P. K. Ray and R. K. Bhandari, High Energ. Phys. Nuc., Vol. 31, Supp. I, (2007), p. 170.

- Gasdynamic ECRIS

  A. Sidorov et al. in this workshop

- Plenty of anecdotal information

  "I know the old LBL ECR could play whale songs by amplifying the signal from a collimator and messing with the first stage" – C. Lyneis

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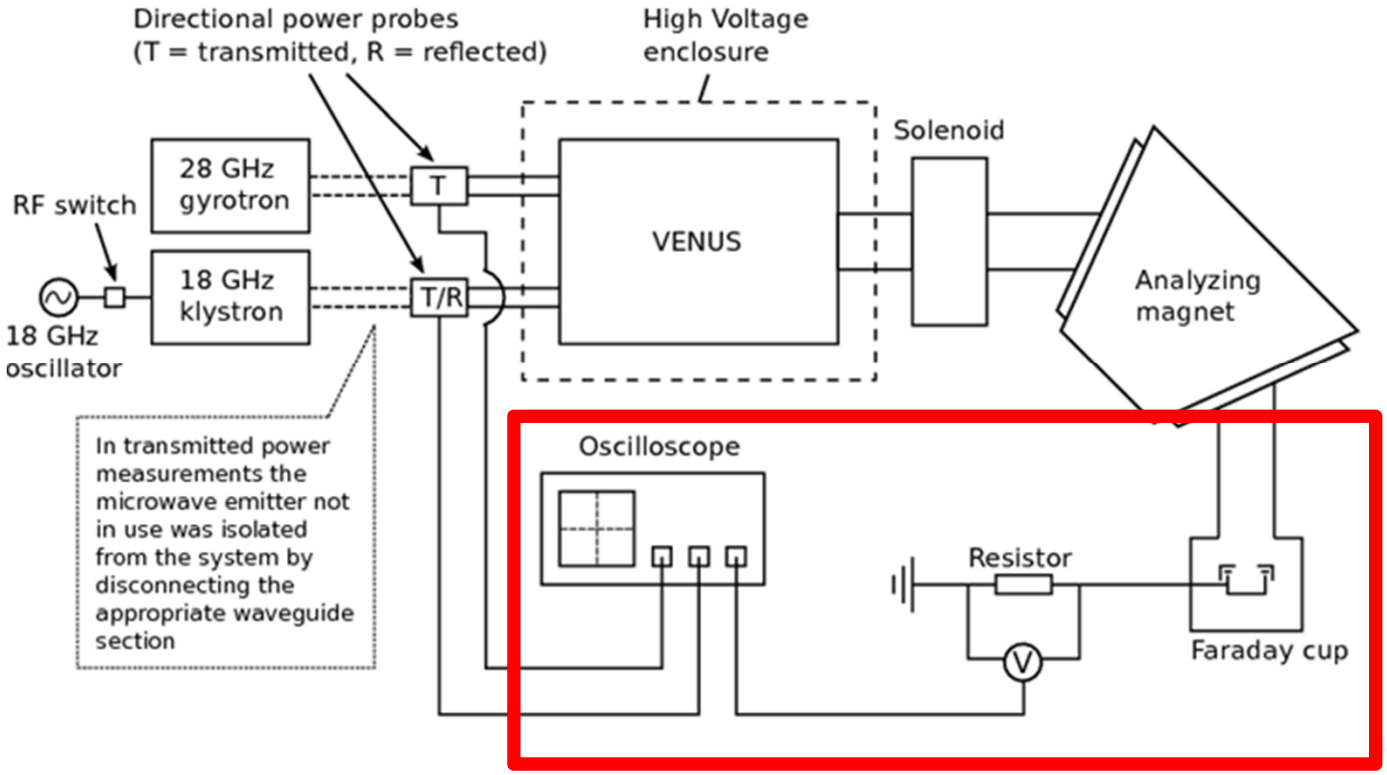
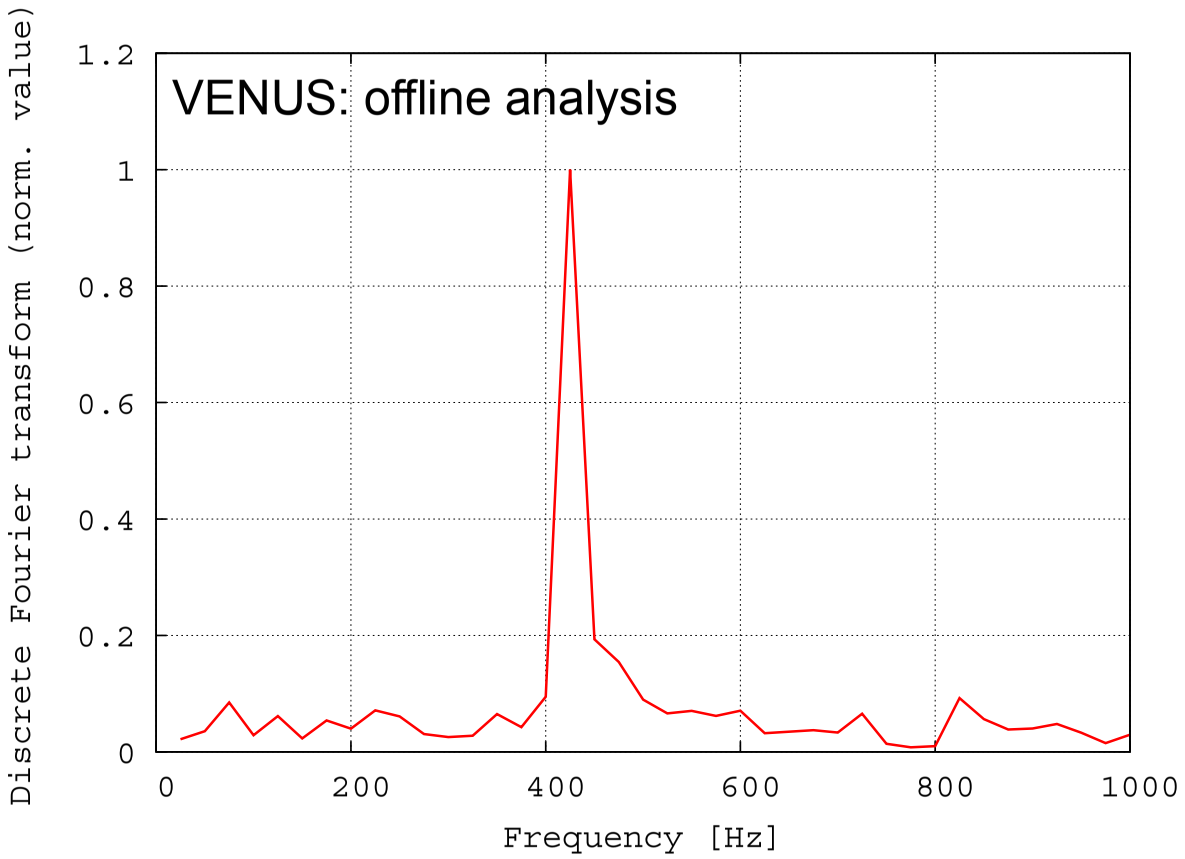
Experimental setup

- Data taken on VENUS at LBNL and 14 GHz A-ECR at JYFL
- Oxygen plasmas

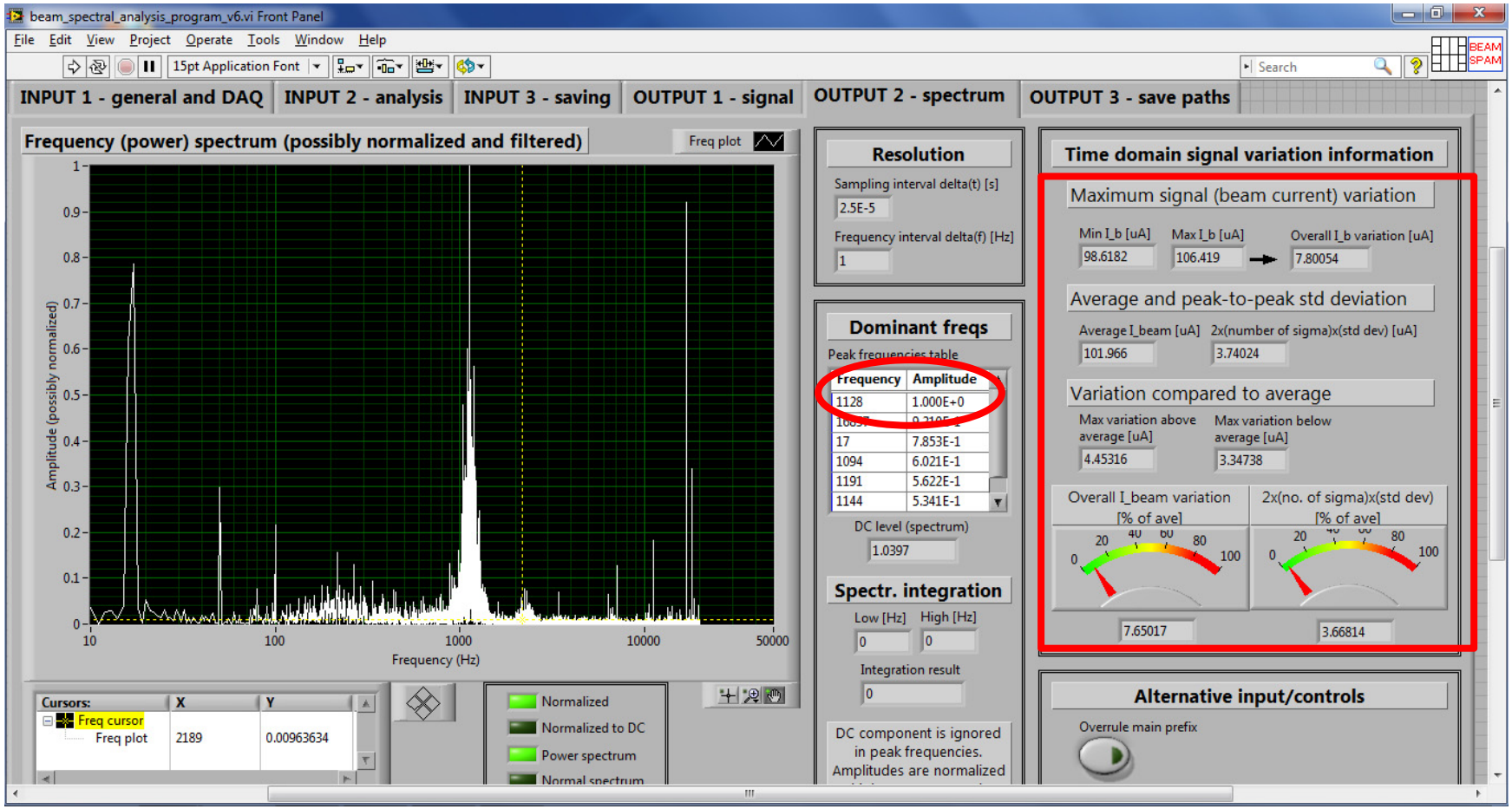


Data analysis

- Discrete Fourier Transform (DFT) to frequency domain



Online data analysis with LabView



Beam current oscillations at frequencies on the order of kHz are filtered and averaged during conventional tuning procedure

http://users.jyu.fi/~vialtoiv/shared/beam-n-spectr/

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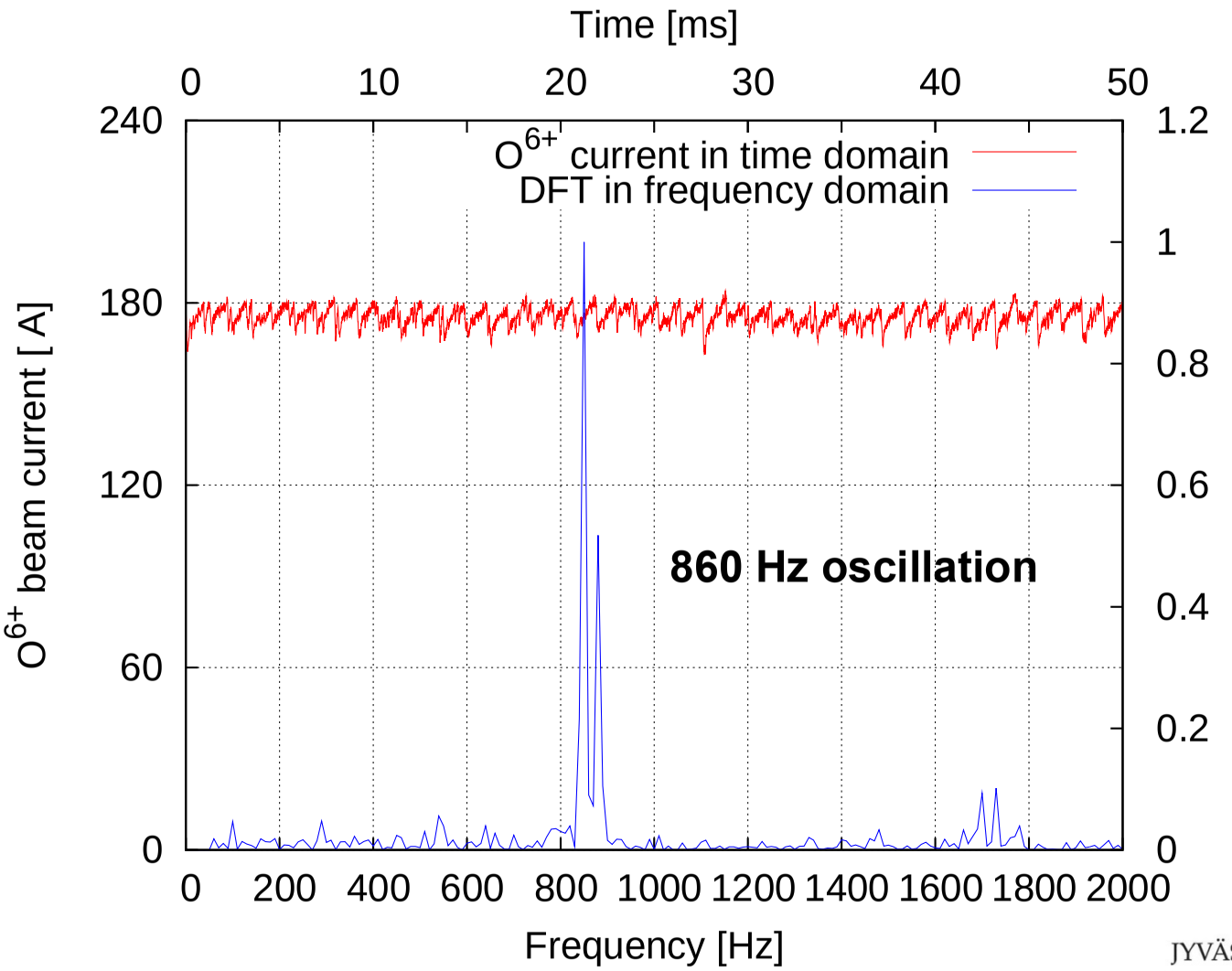
Online data analysis with LabView



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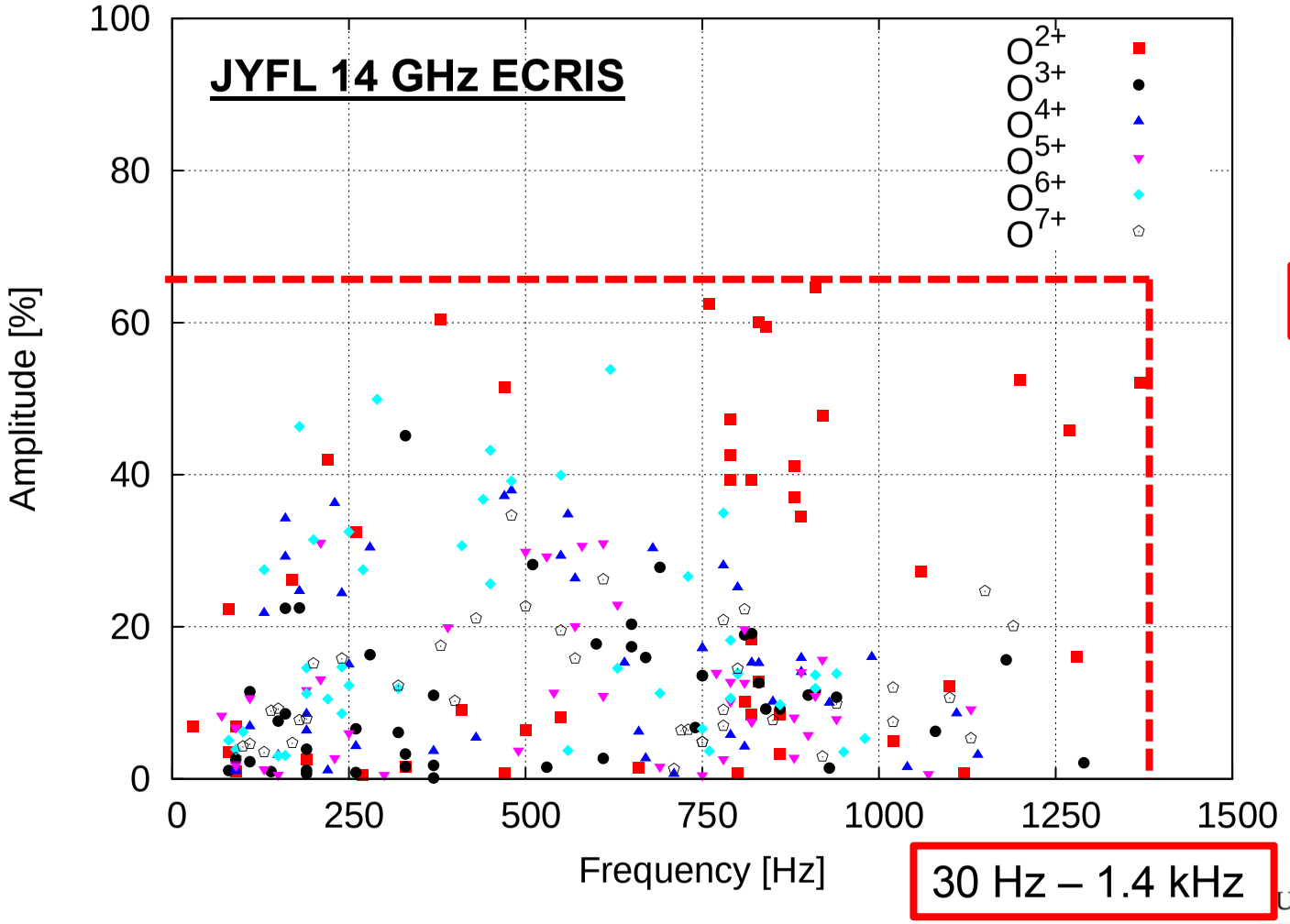
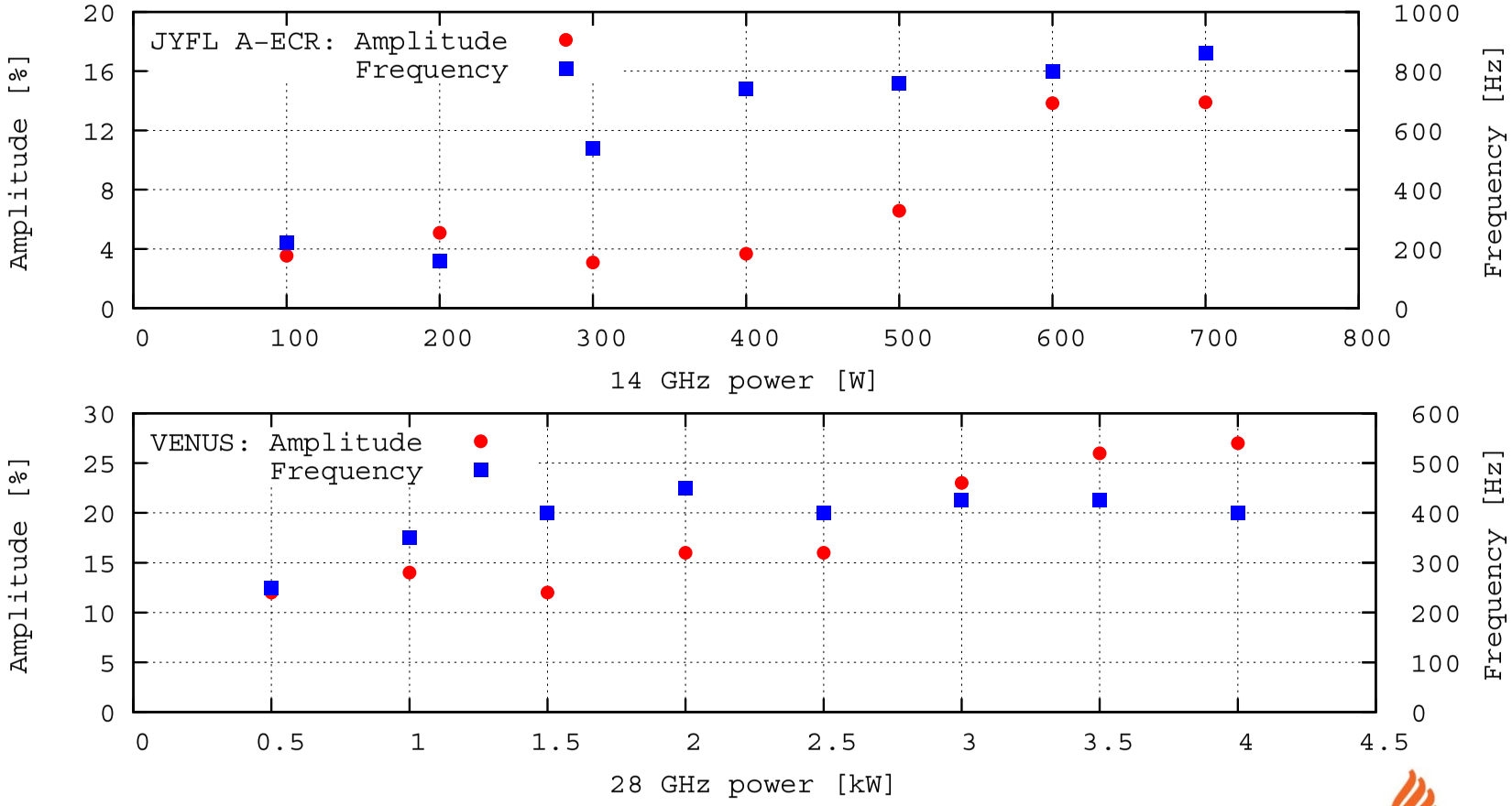
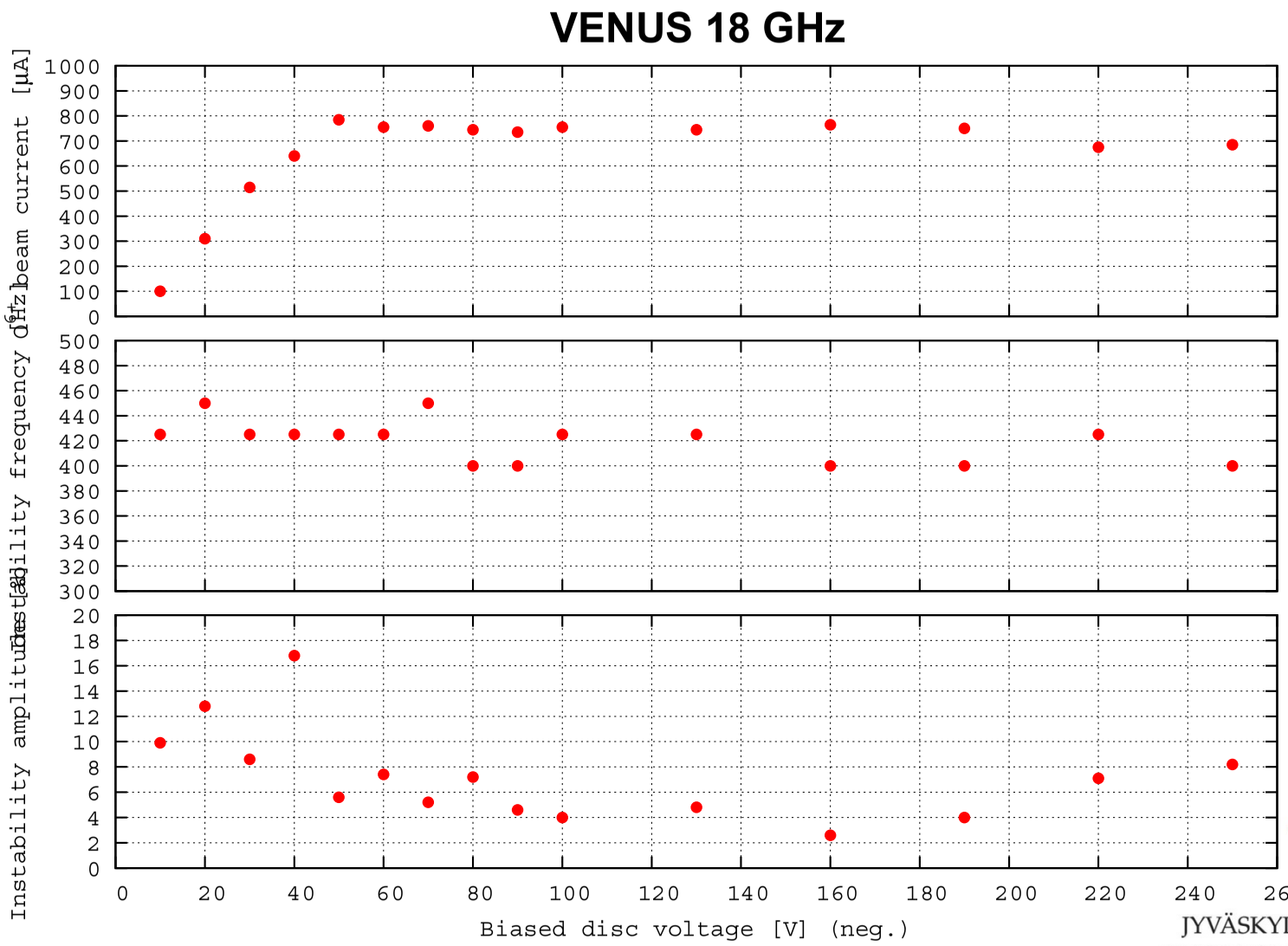
Range of oscillation frequencies and amplitudes



Microwave power



Biased disc voltage



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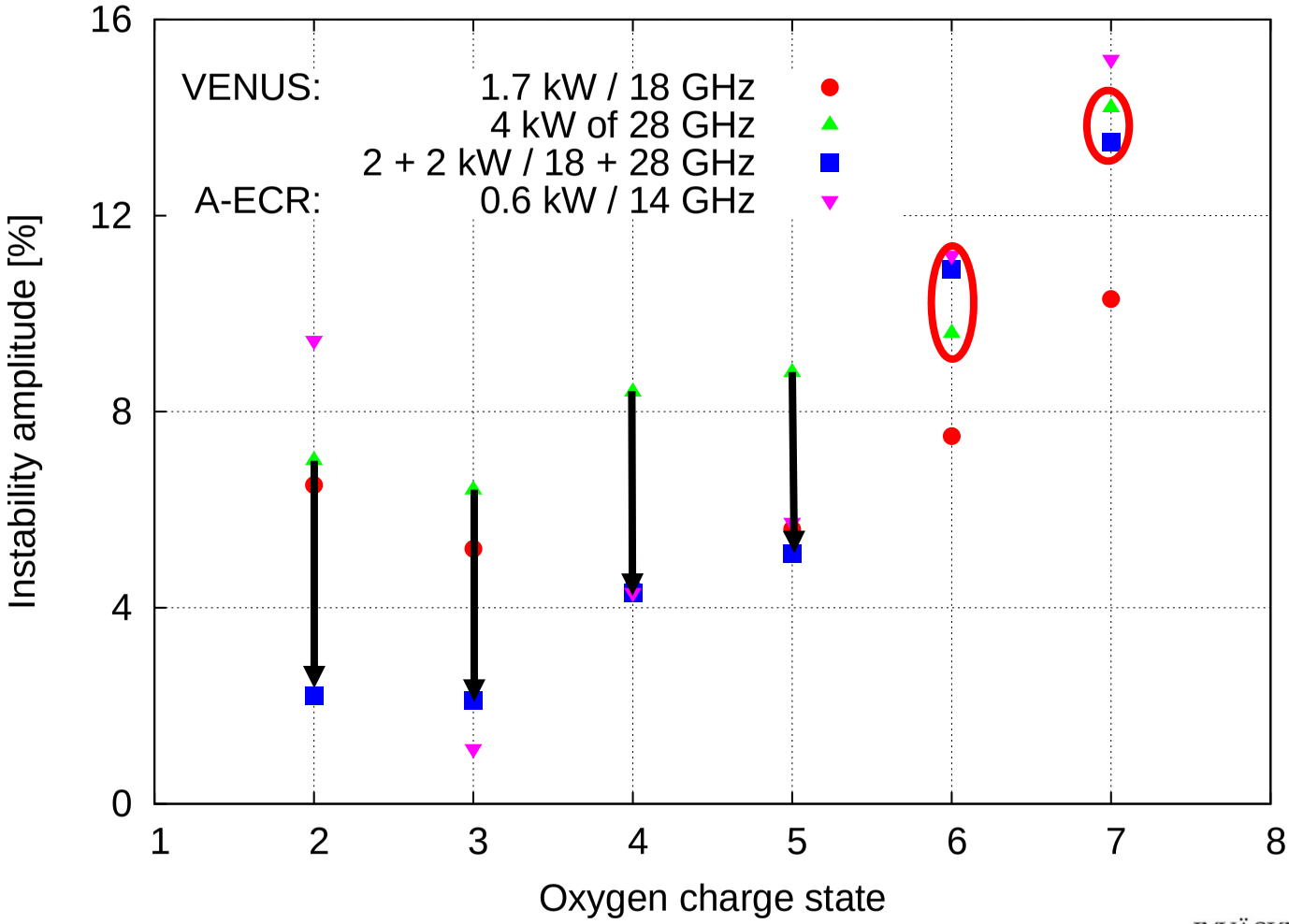
Typical charge state dependence



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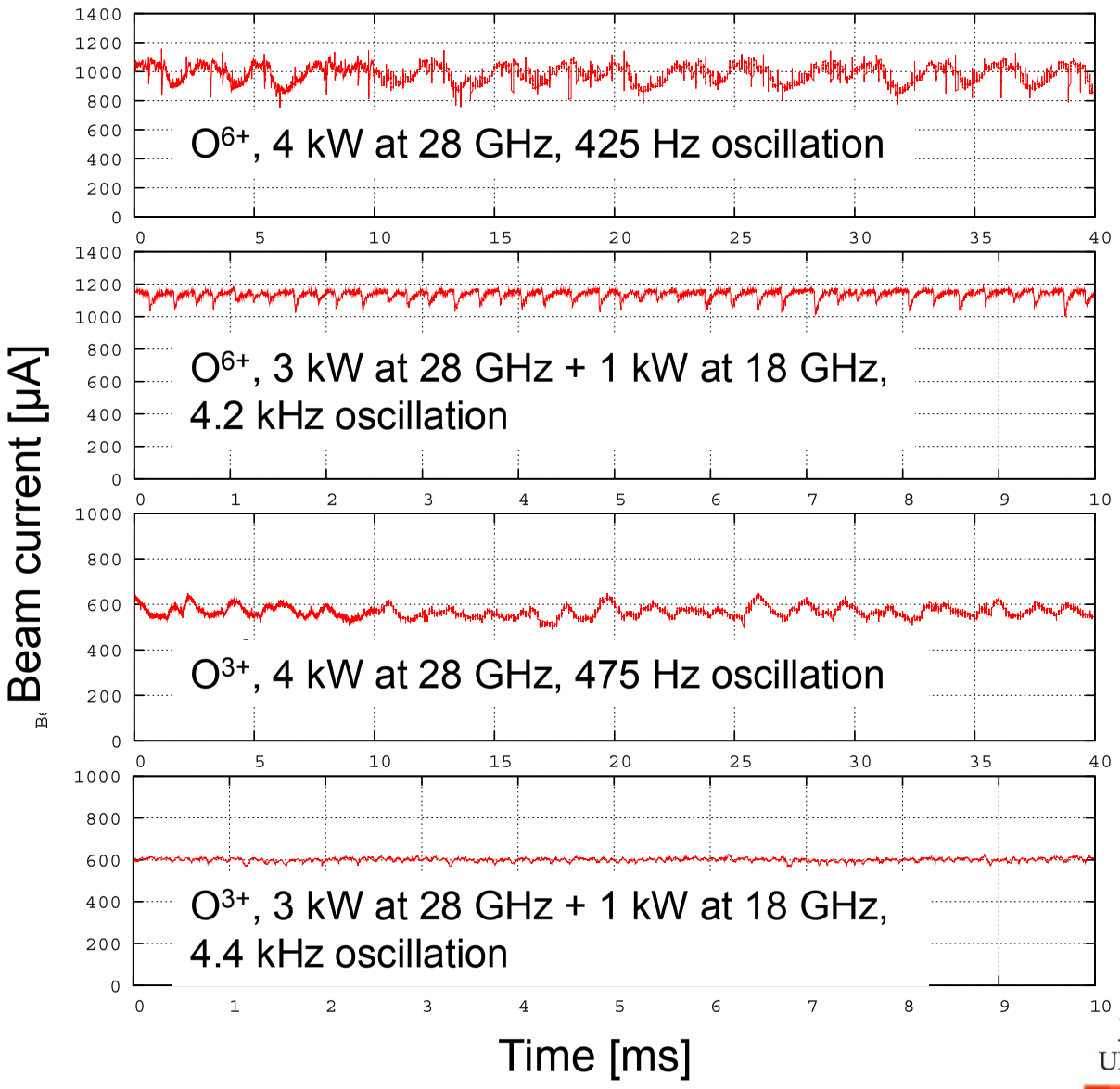
Double frequency heating



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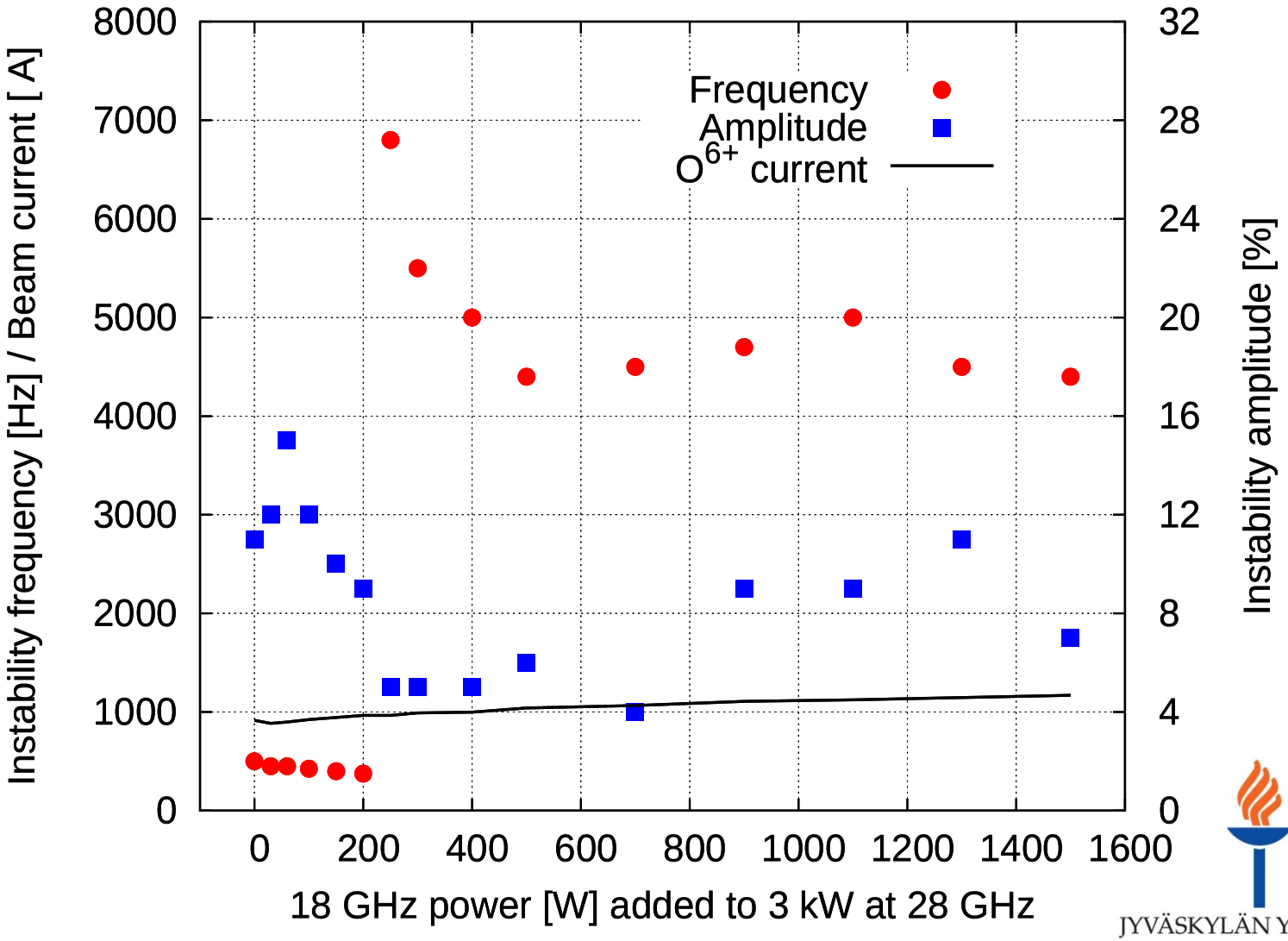
Double frequency heating



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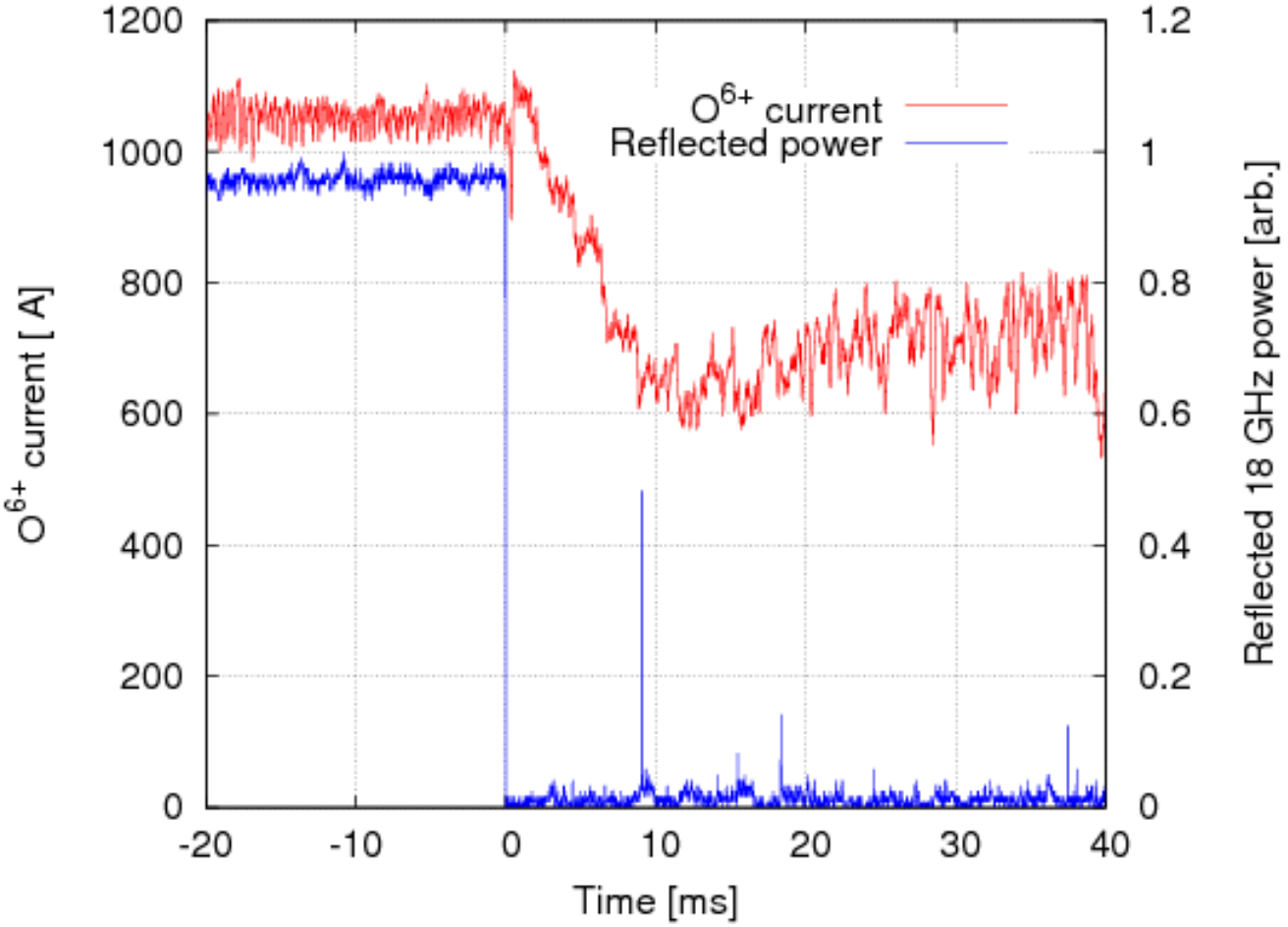
Double frequency heating



Magnetic field

Description	$R_{inj}/R_{ext}/R_{rad}$	O^{6+} amplitude [%]
VENUS 1.7 kW / 18 GHz	3.4 / 2.3 / 2.0	7.5
VENUS “high-B” 2 kW / 18 GHz	5.3 / 3.3 / 3.5	2.2
JYFL A-ECR 300 W / 14 GHz	4.2 / 2.0 / 2.2	12.1
JYFL A-ECR 300 W / 14 GHz	3.7 / 1.7 / 2.2	3.8
JYFL A-ECR 300 W / 11.5 GHz	4.3 / 2.0 / 2.7	3.1

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Where do the beam current oscillations come from?

- Plasma
  - Kinetic instabilities
  - MHD instabilities
- Plasma – beam boundary (meniscus)
  - Potential fluctuations
- Beam line
  - Charging of extraction elements
  - Fluctuating space charge compensation
- Environment
  - Background pressure, DFT

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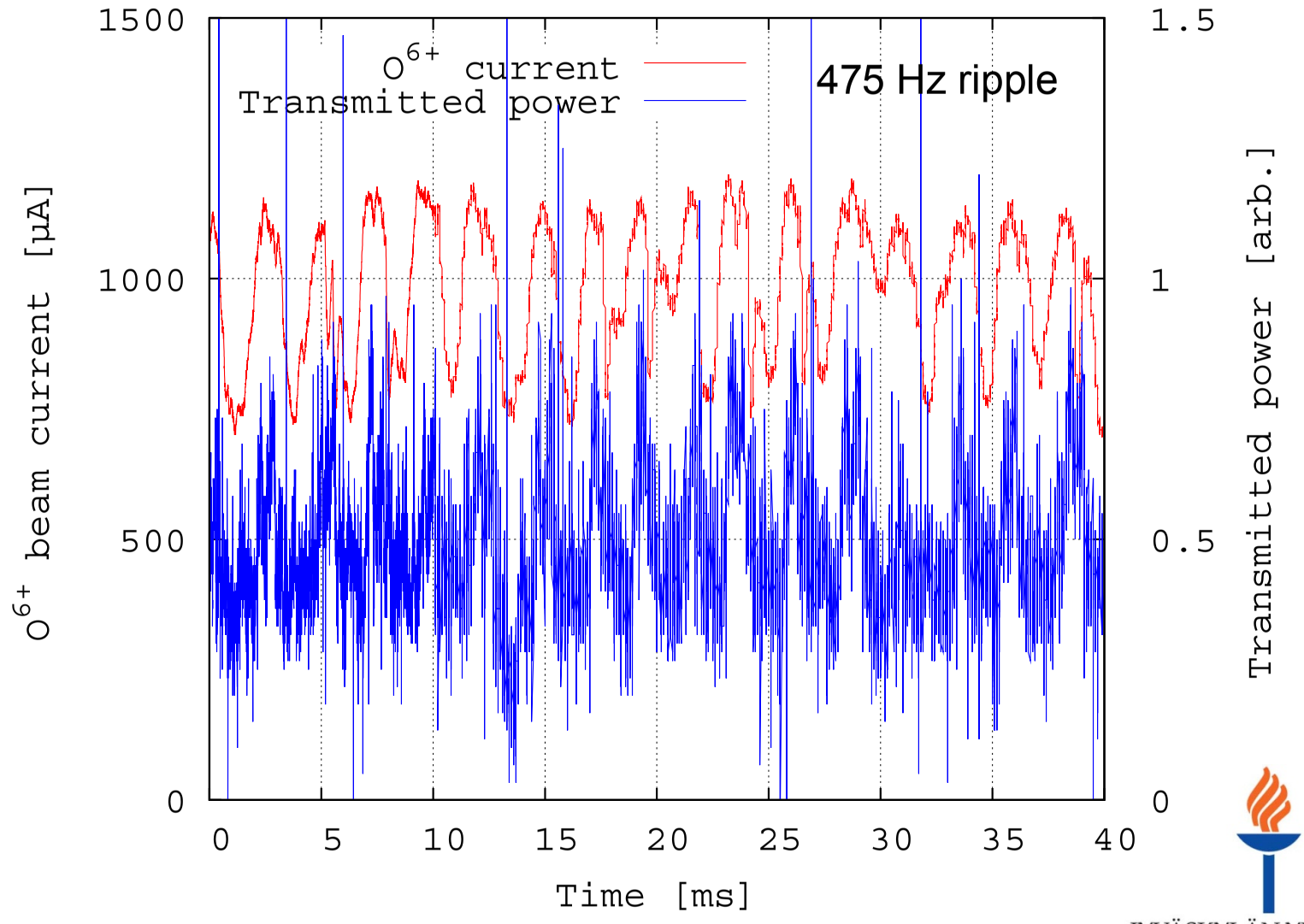
Plasma effect?



Forward power ripple at ~ 40 kHz

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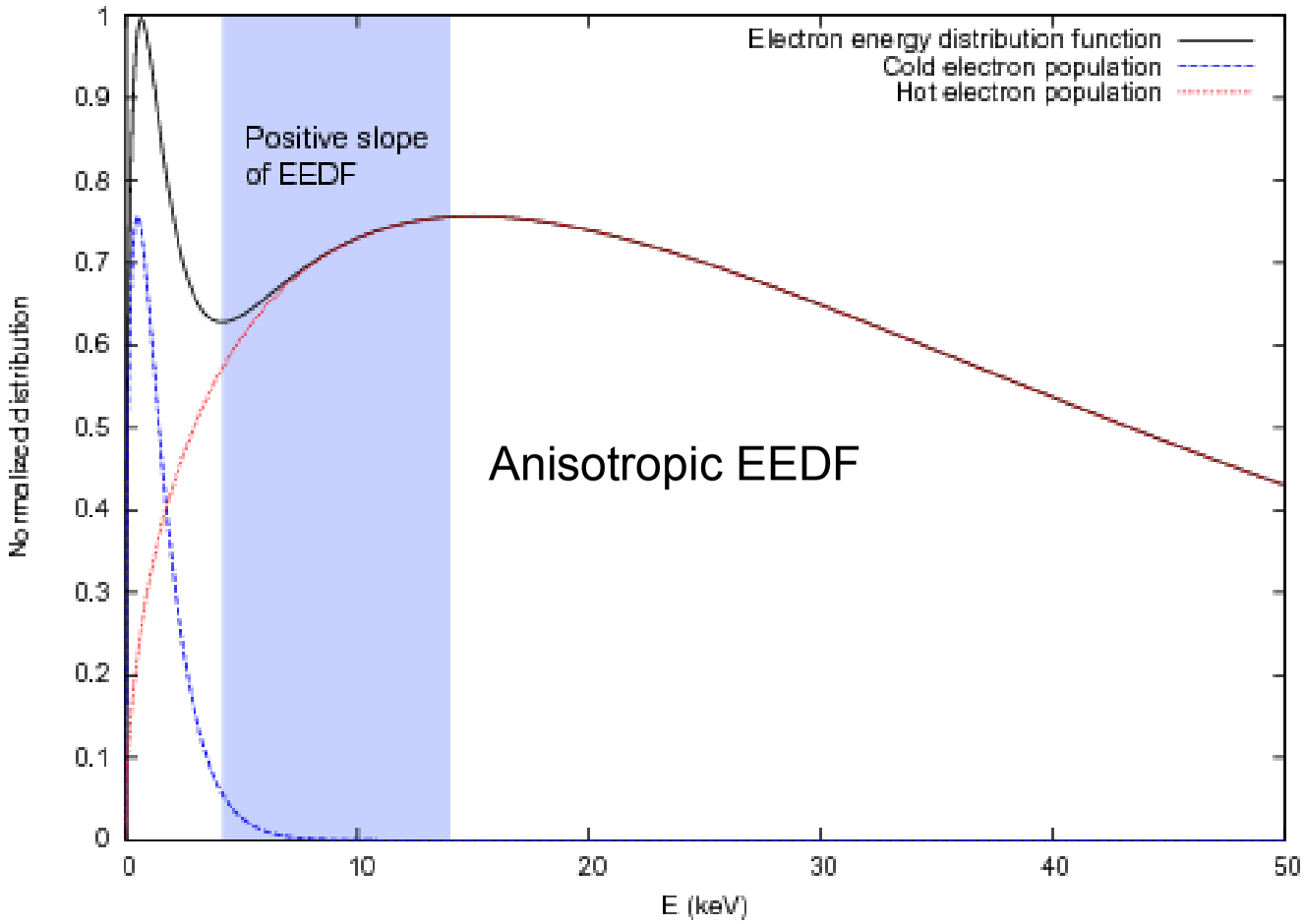
Kinetic plasma instabilities



Kinetic (cyclotron) instabilities are observed in afterglow plasma – see the poster by I. Izotov et al.

MHD-instabilities

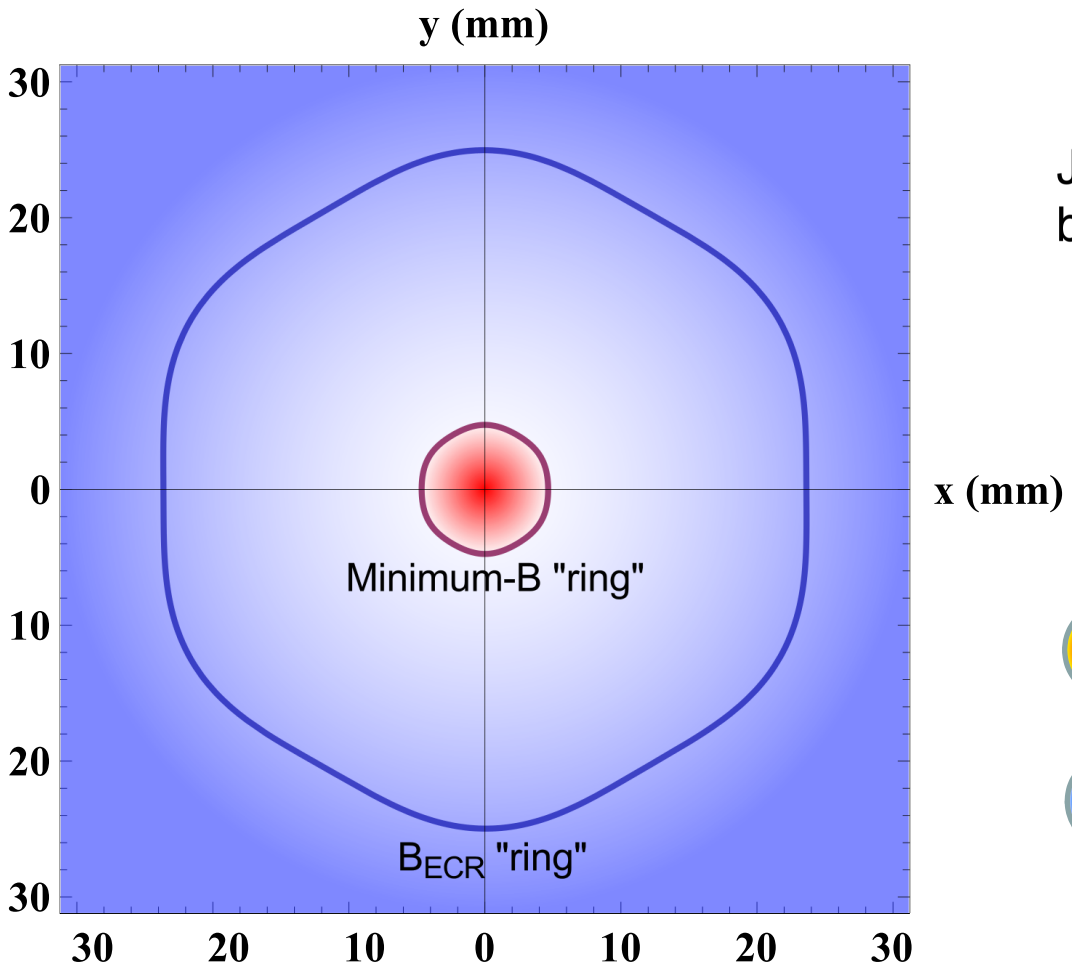
- Driven by the topology of the magnetic field
- Effectively supressed in minimum-B in comparison to simple mirror machines
- Condition for suppressing MHD-instabilities

$$\partial B/\partial r \geq 0$$

- Magnetohydrodynamically “quiet” plasma when *particle pressure* << *magnetic pressure*

$$n_e k T_e << B^2/2\mu_0$$

MHD-instabilities



JYFL 14 GHz ECRIS
between the coils

$\partial B/\partial r < 0$

$\partial B/\partial r \geq 0$

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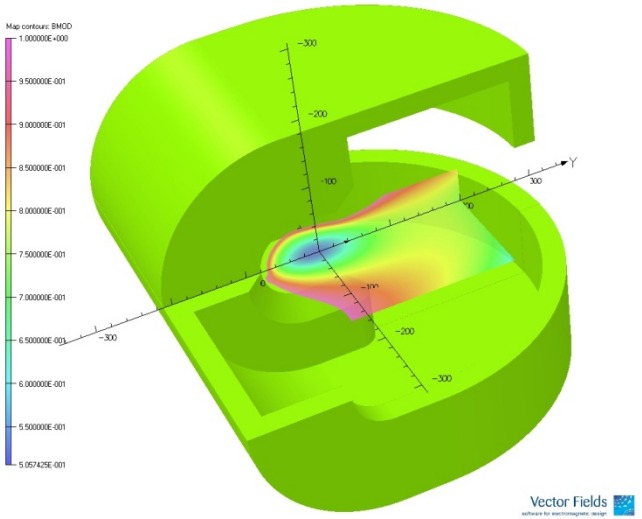
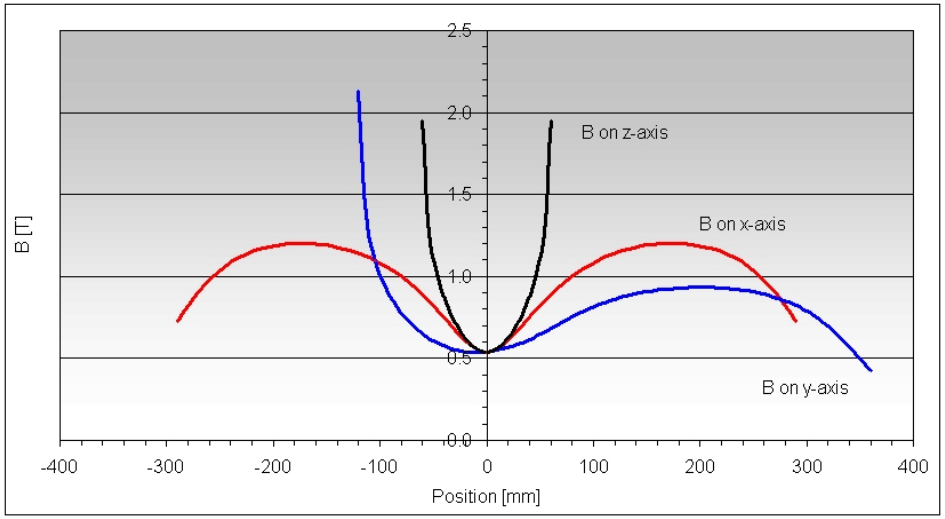
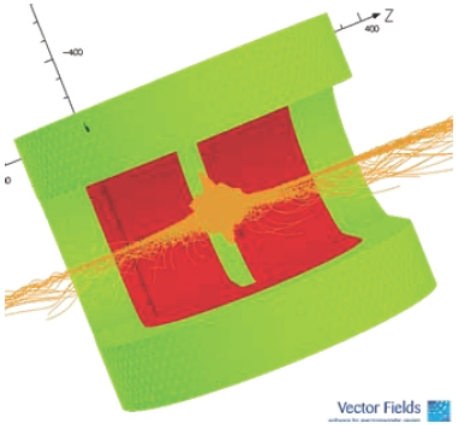
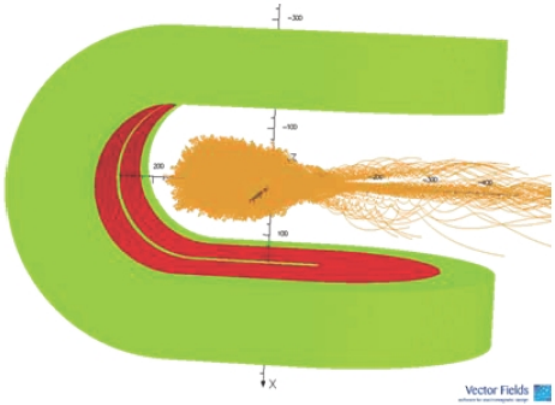
True minimum-B: ARC-ECRIS









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Further diagnostics

- Sector Faraday Cup
- Bremsstrahlung emission (scintillation detector)
- Plasma-microwave coupling
- Bias disc current
- Escaping electron flux

Stay tuned!

Thank You!

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