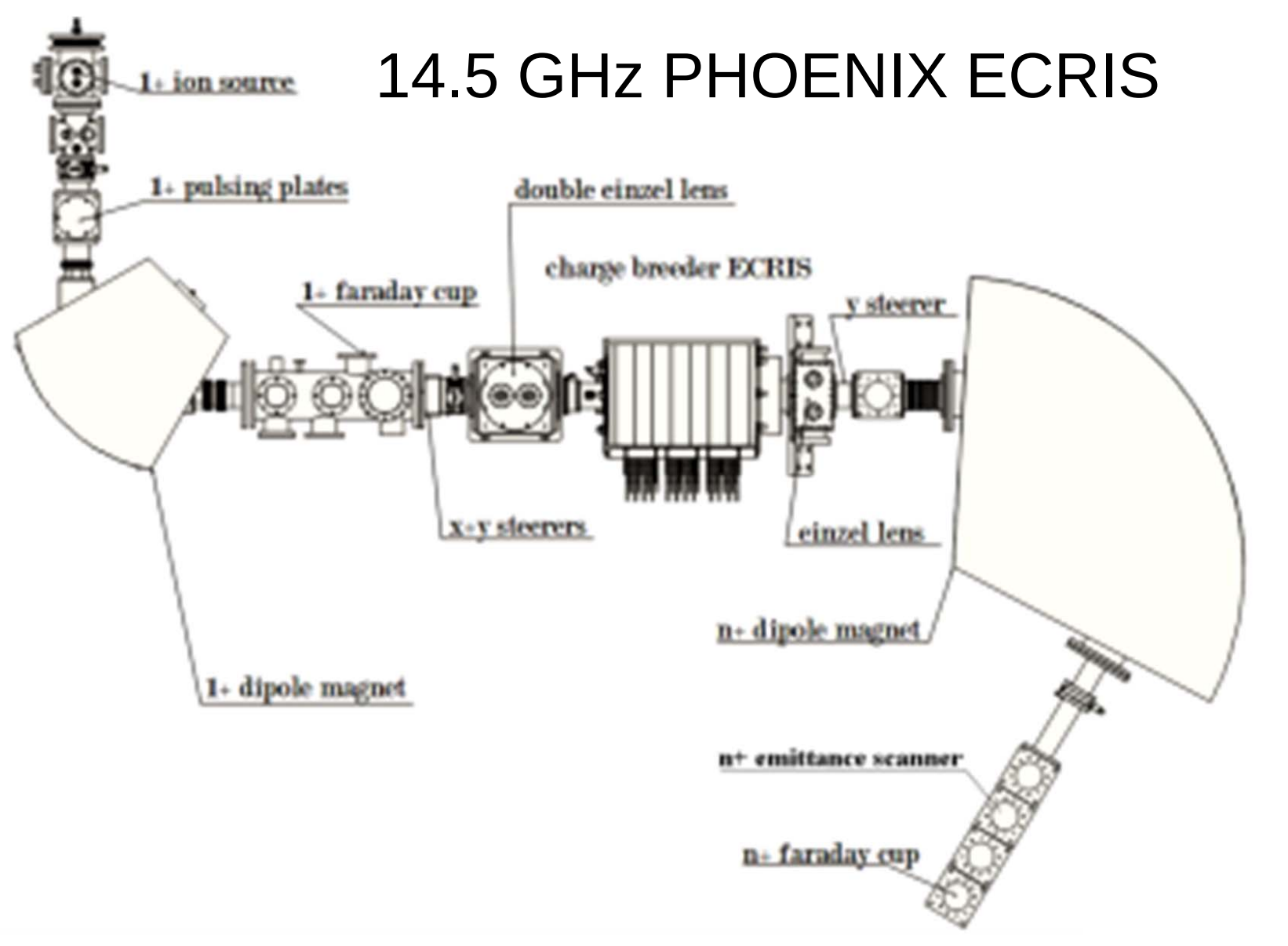
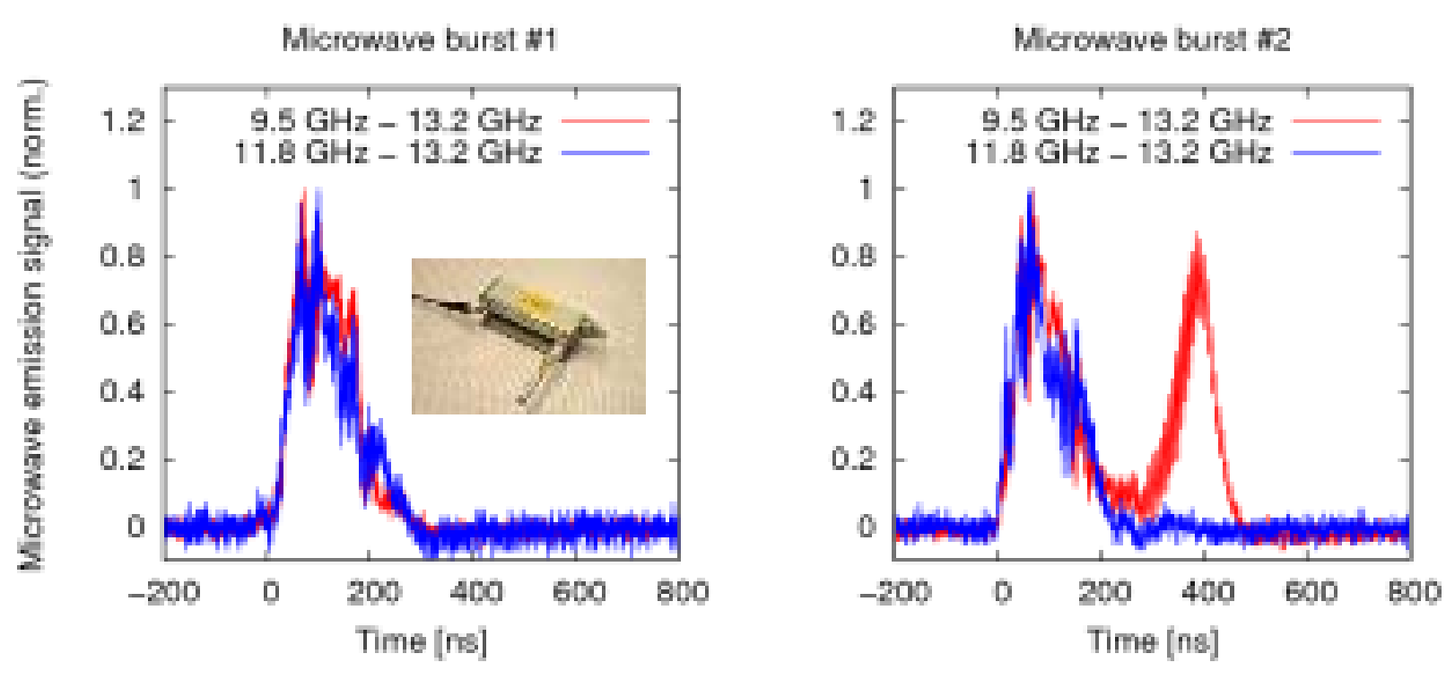
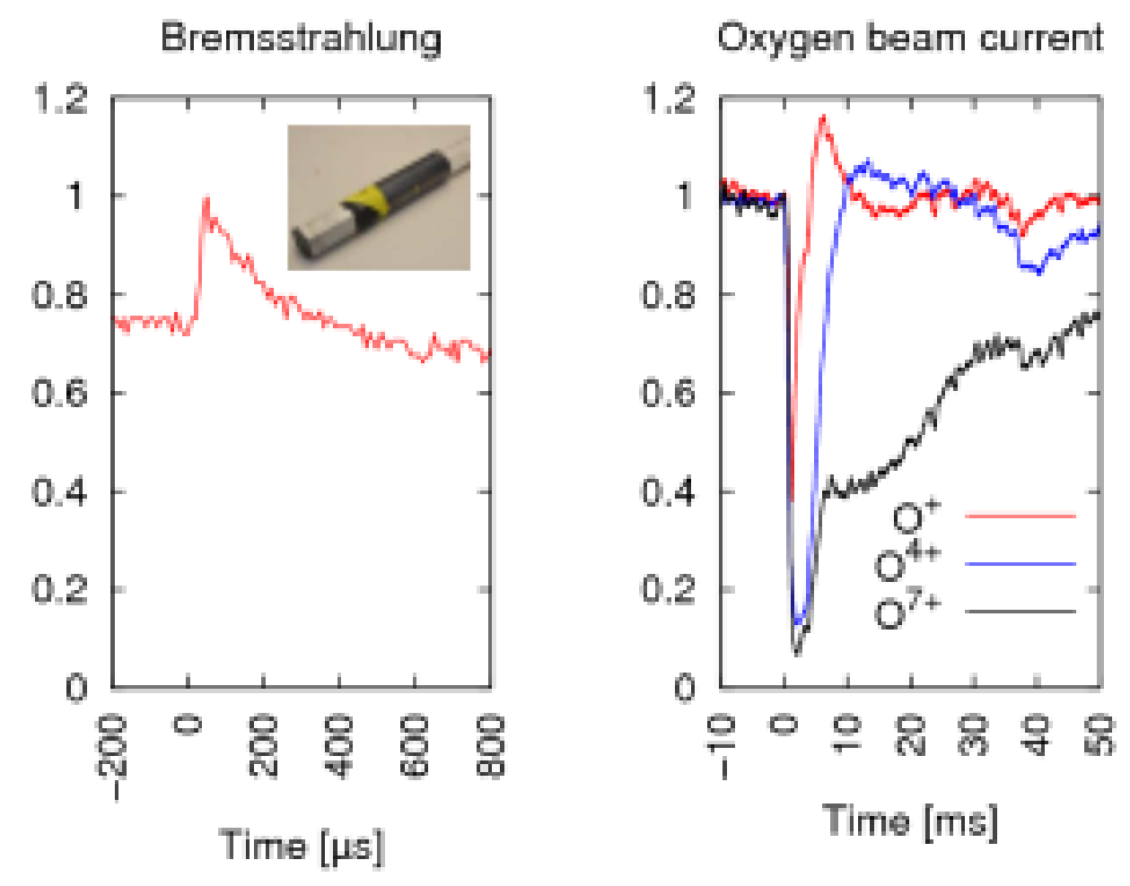
The effect of plasma instabilities on the background impurities in charge breeder ECRIS

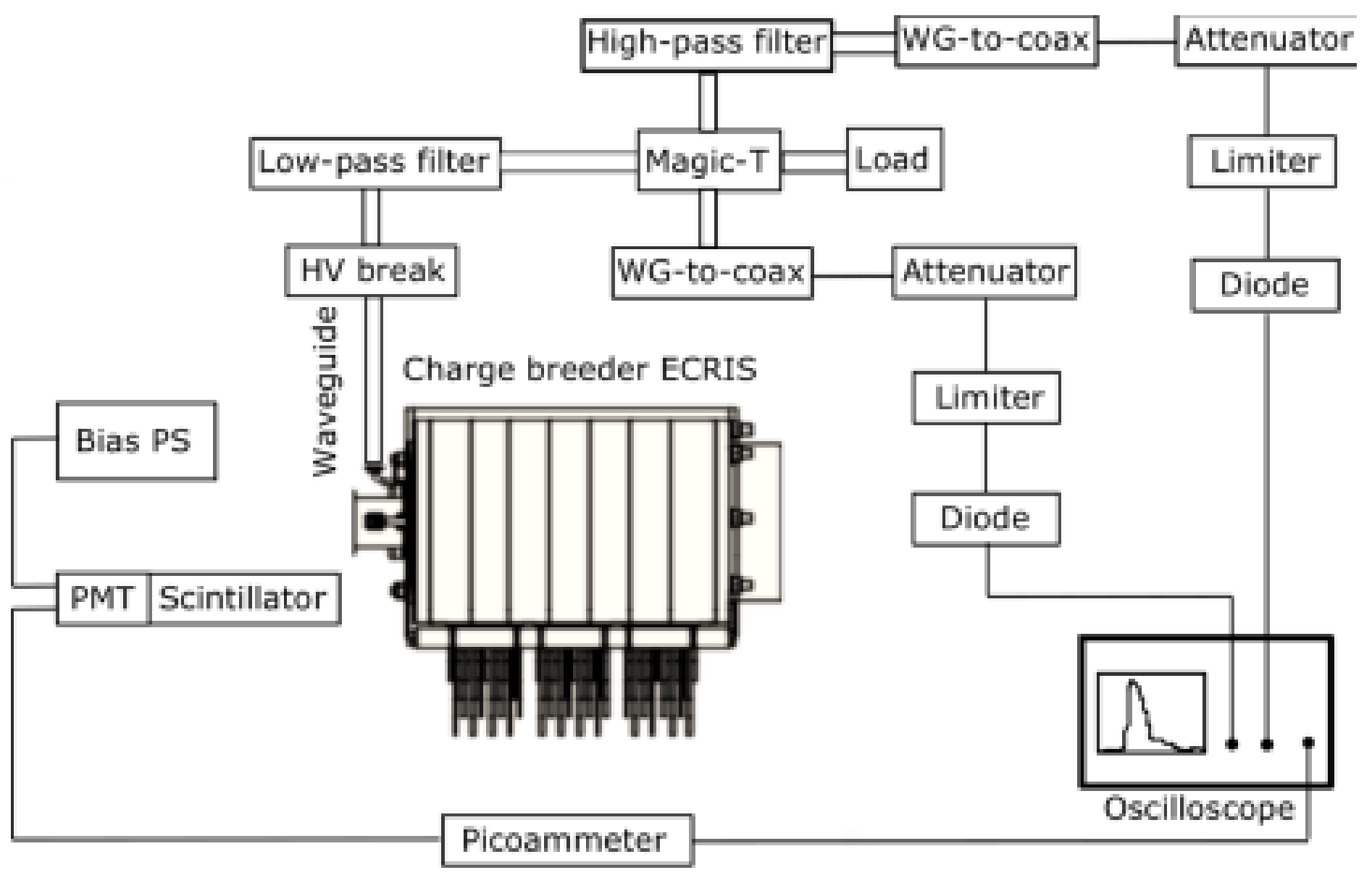
O. Tarvainen[1], J. Angot[2], I. Izotov[3], V. Skalyga[3], H. Koivisto[1], T. Thuillier[2] , T. Kalvas[1] , V. Toivanen[4], R. Kronholm[1] and T. Lamy[2]
1 University of Jyväskylä, Department of Physics, Accelerator Laboratory
2 Université Grenoble-Alpes, CNRS, IN2P3-LPSC, 53 avenue des martyrs 38026 Grenoble Cedex,
3 Institute of Applied Physics, RAS, 46 Ul`yanova St., 603950 Nizhny Novgorod, Russian Federation
4 Grand Accélérateur National d'Ions Lourds (GANIL), 14076 Caen Cedex 5, France
UNIVERSITY OF JYVÄSKYLÄ
LPSC Grenoble Laboratoire de Physique Subatomique et de Cosmologie

Experimental setup and instability signals

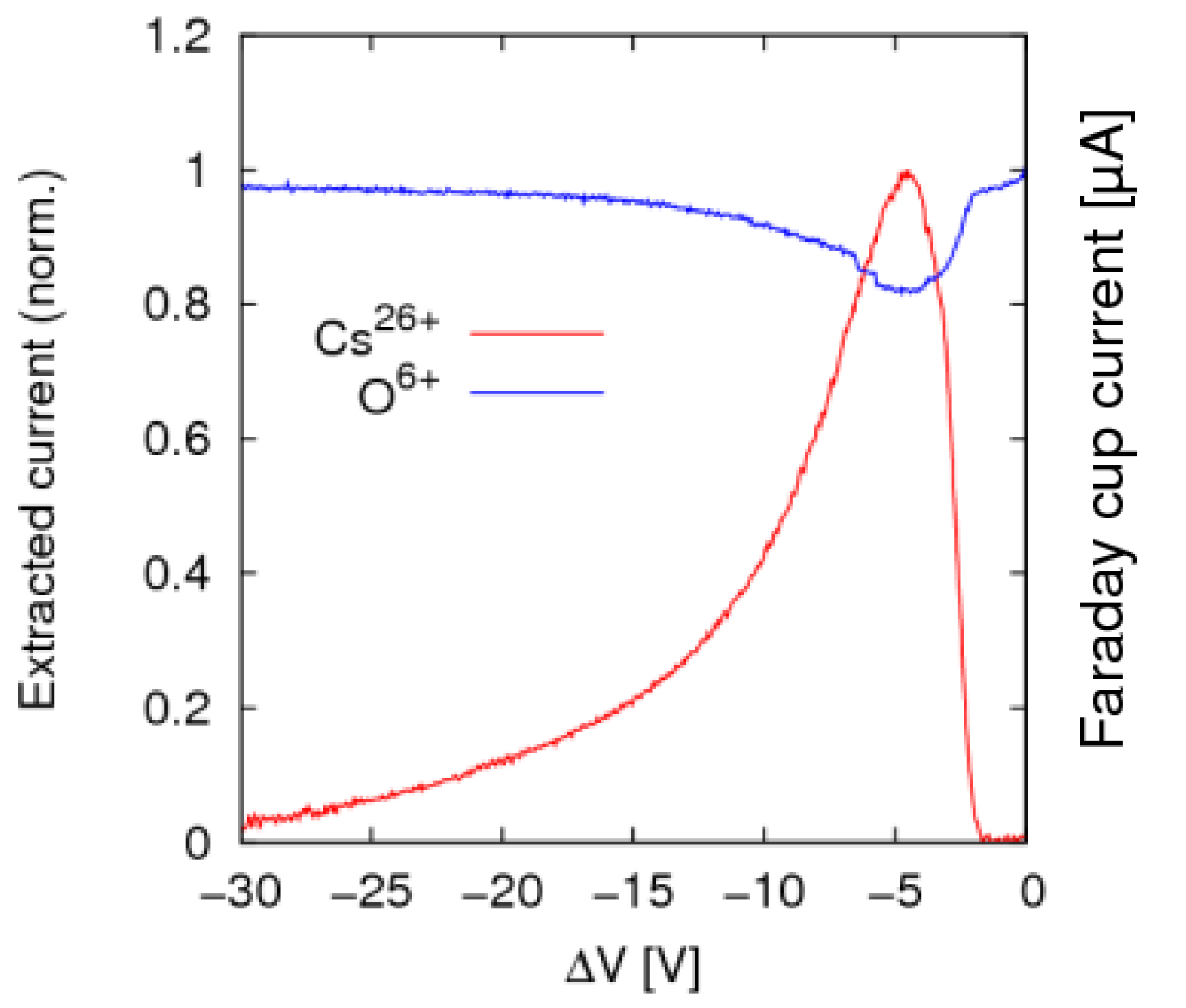


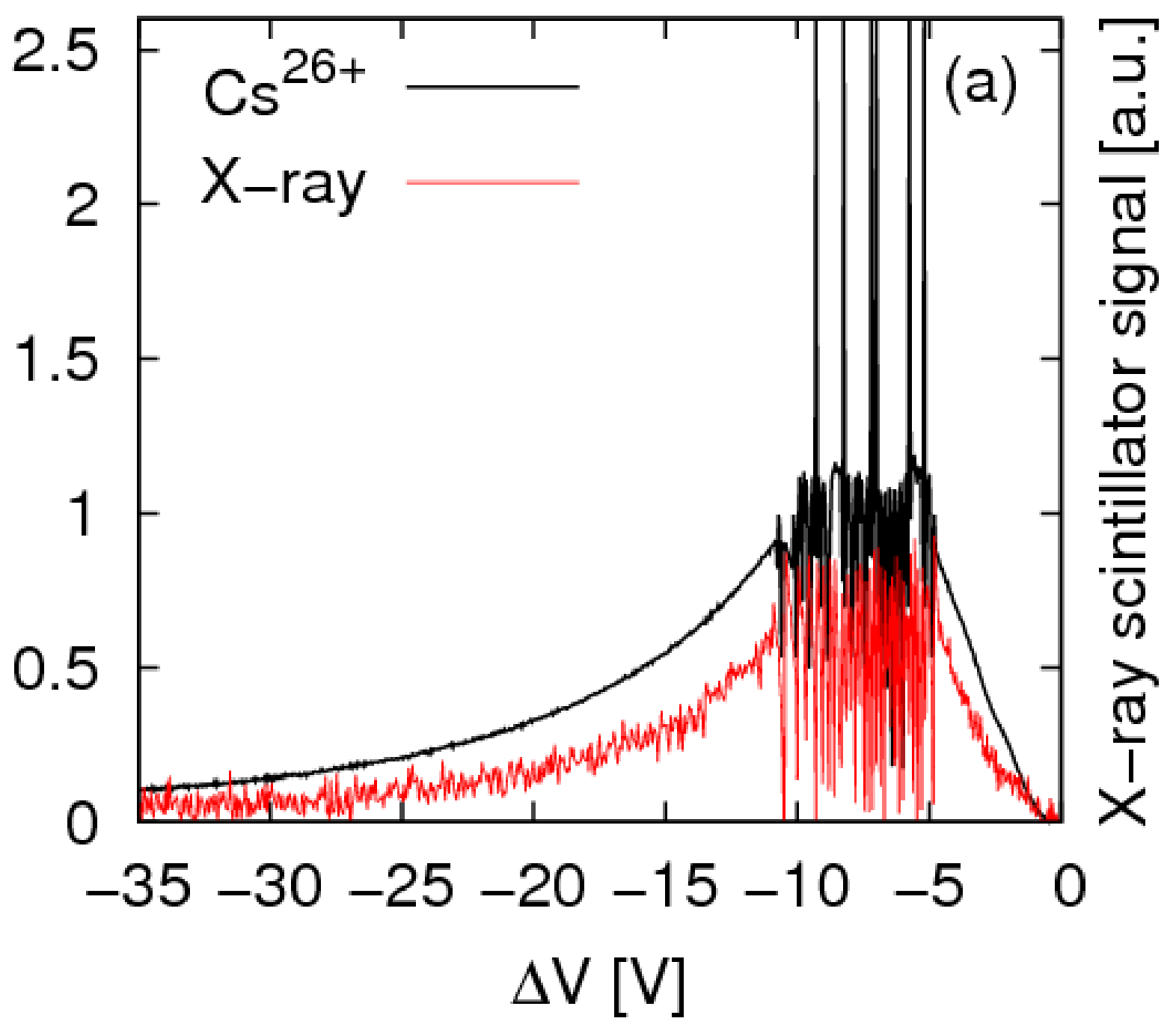






The effect of 1+ injection on the charge breeder plasma

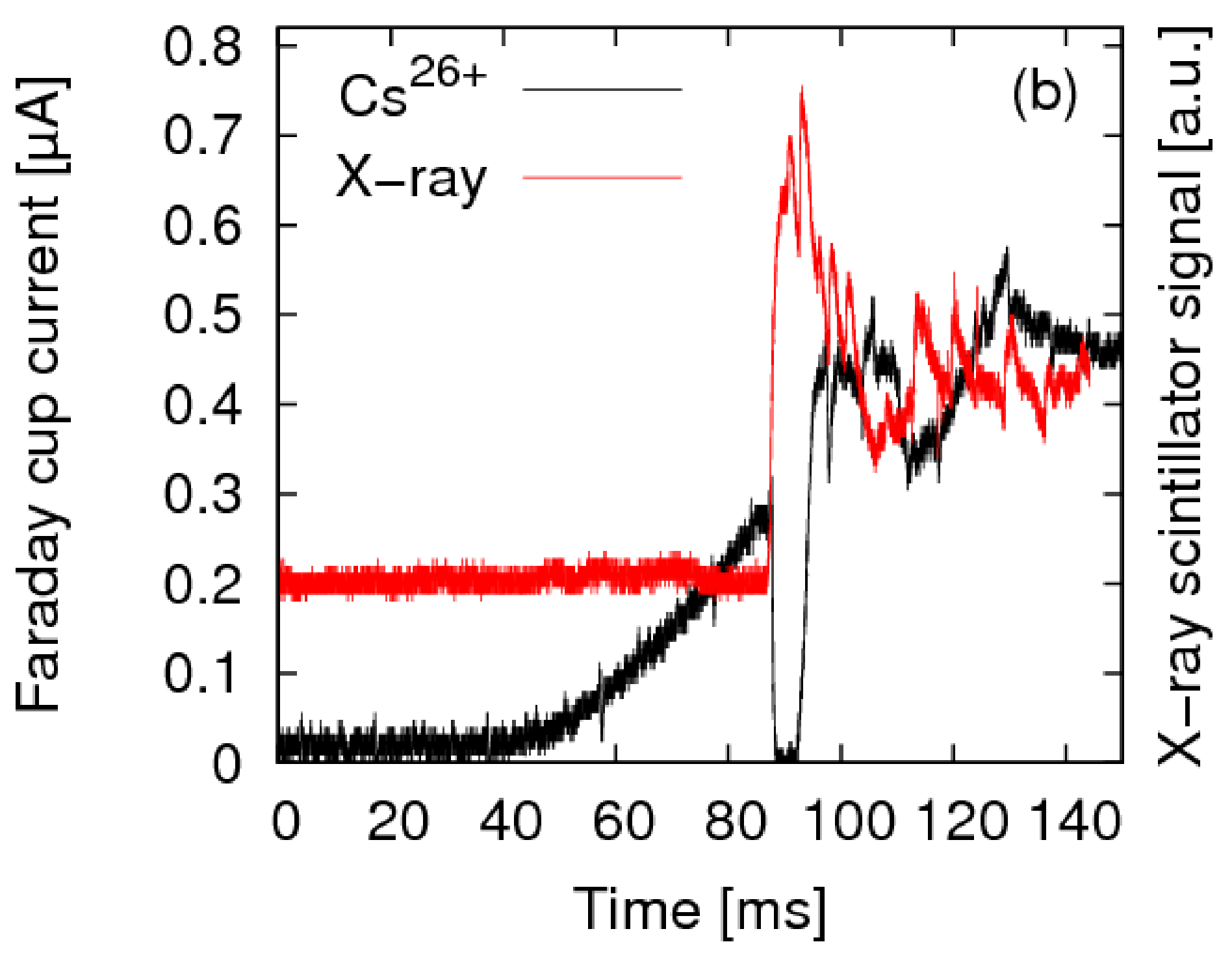




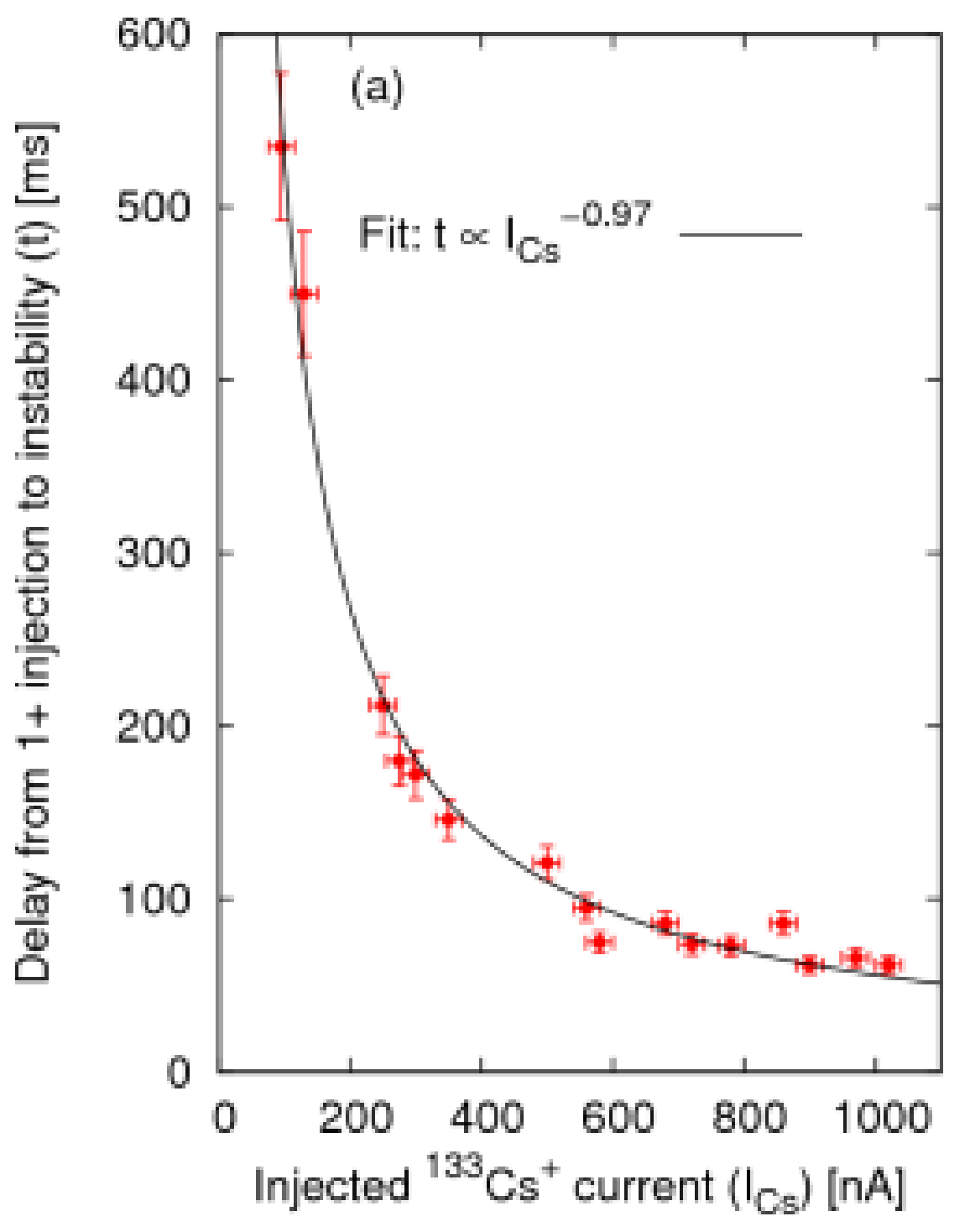
The injection and capture of the 1+ beam affects the charge breeder plasma properties and can induce kinetic instabilities depending on the magnetic field strength, microwave power and capture efficiency of the 1+ ions.

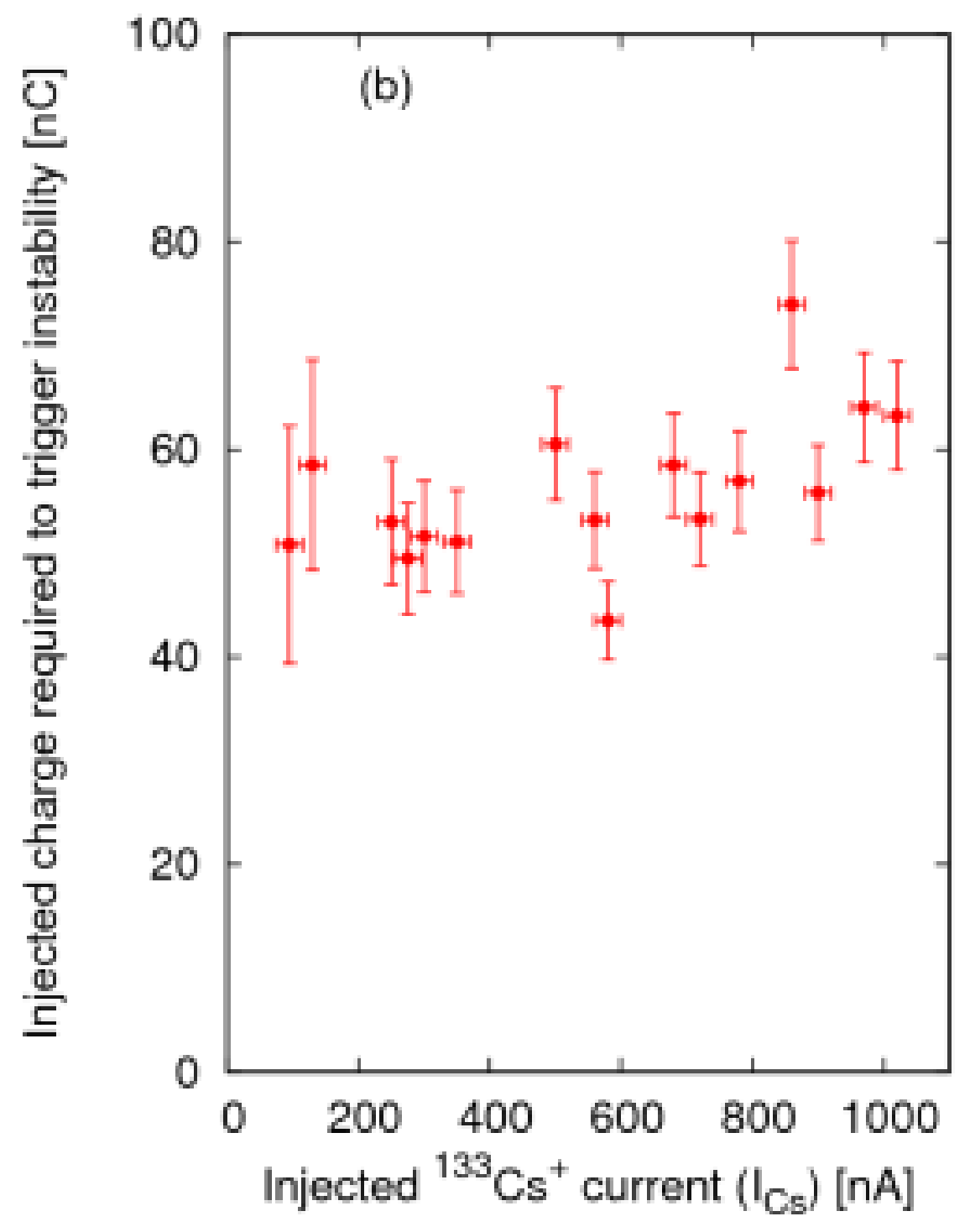
The plasma is more sensitive to Cs than Rb injection implying a mass effect.

Delayed effect or prompt interaction – what are the consequences?



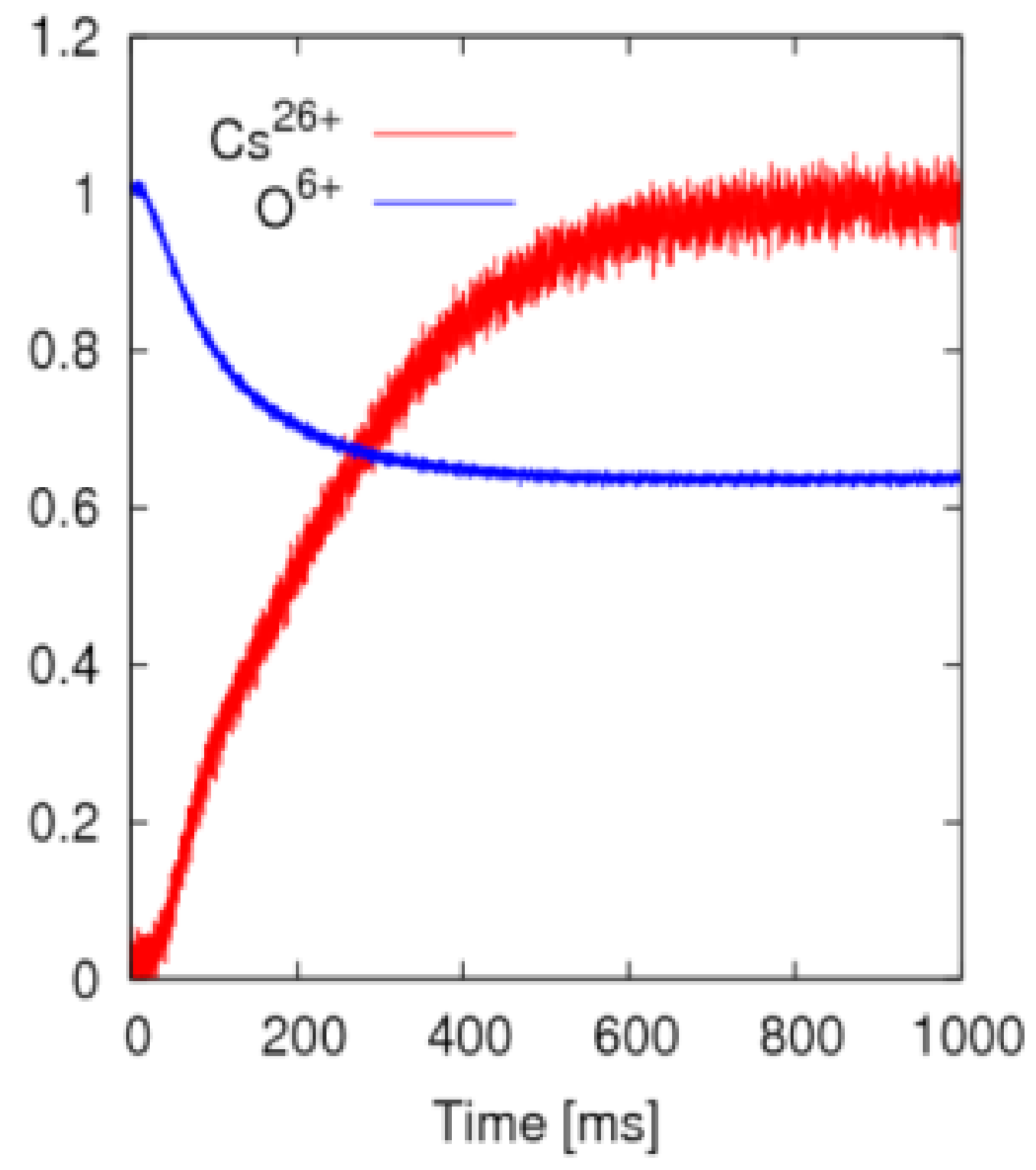
Instabilities are triggered with a delay which excludes a prompt interaction of the 1+ beam and the charge breeder plasma





The length of the delay depends on the injected current / captured charge

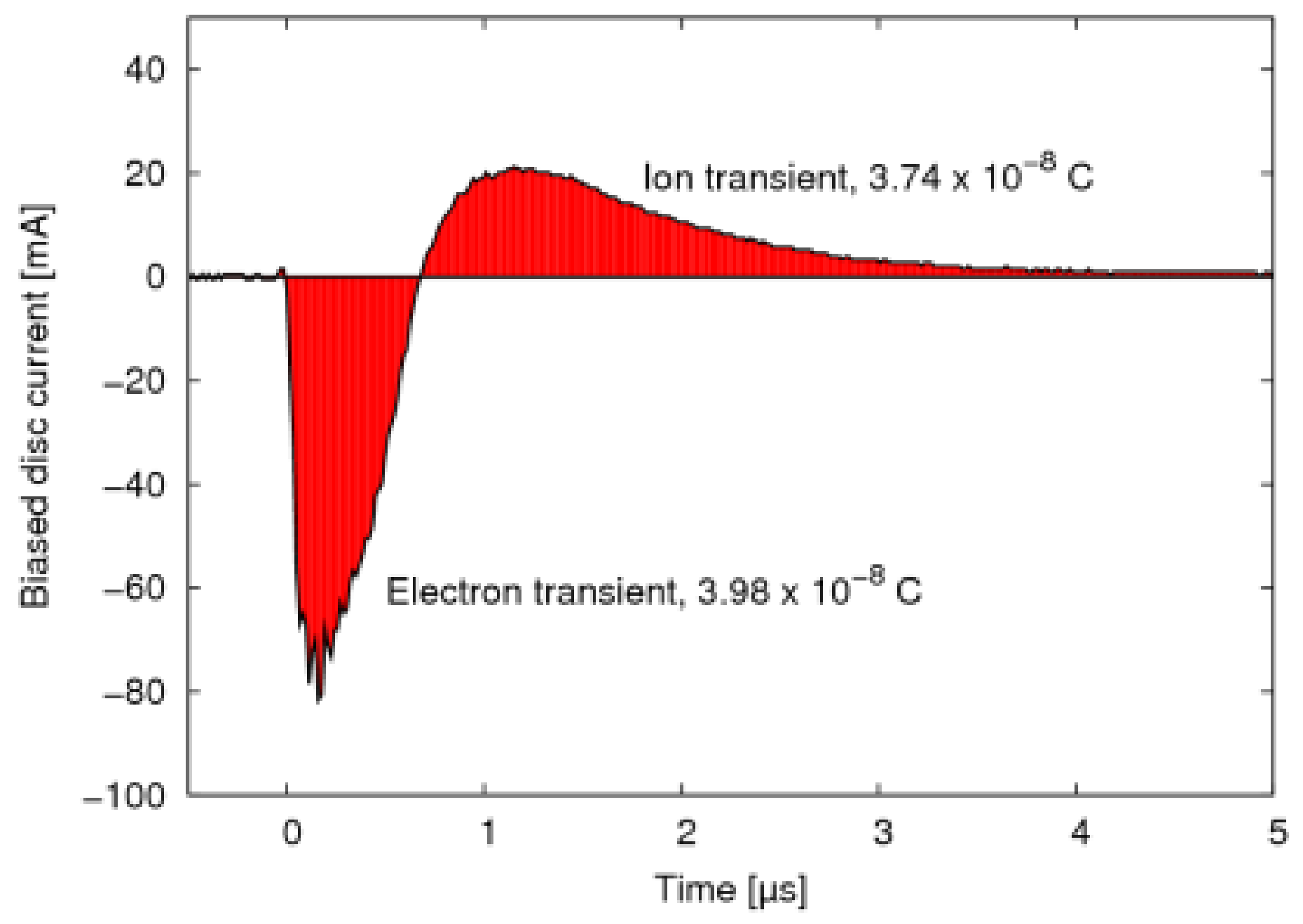
The appearance of instabilities with the 1+ injection is caused by the variation of the discharge parameters in a time-scale similar to the 90 % rise times (breeding times) of the high charge state ion currents

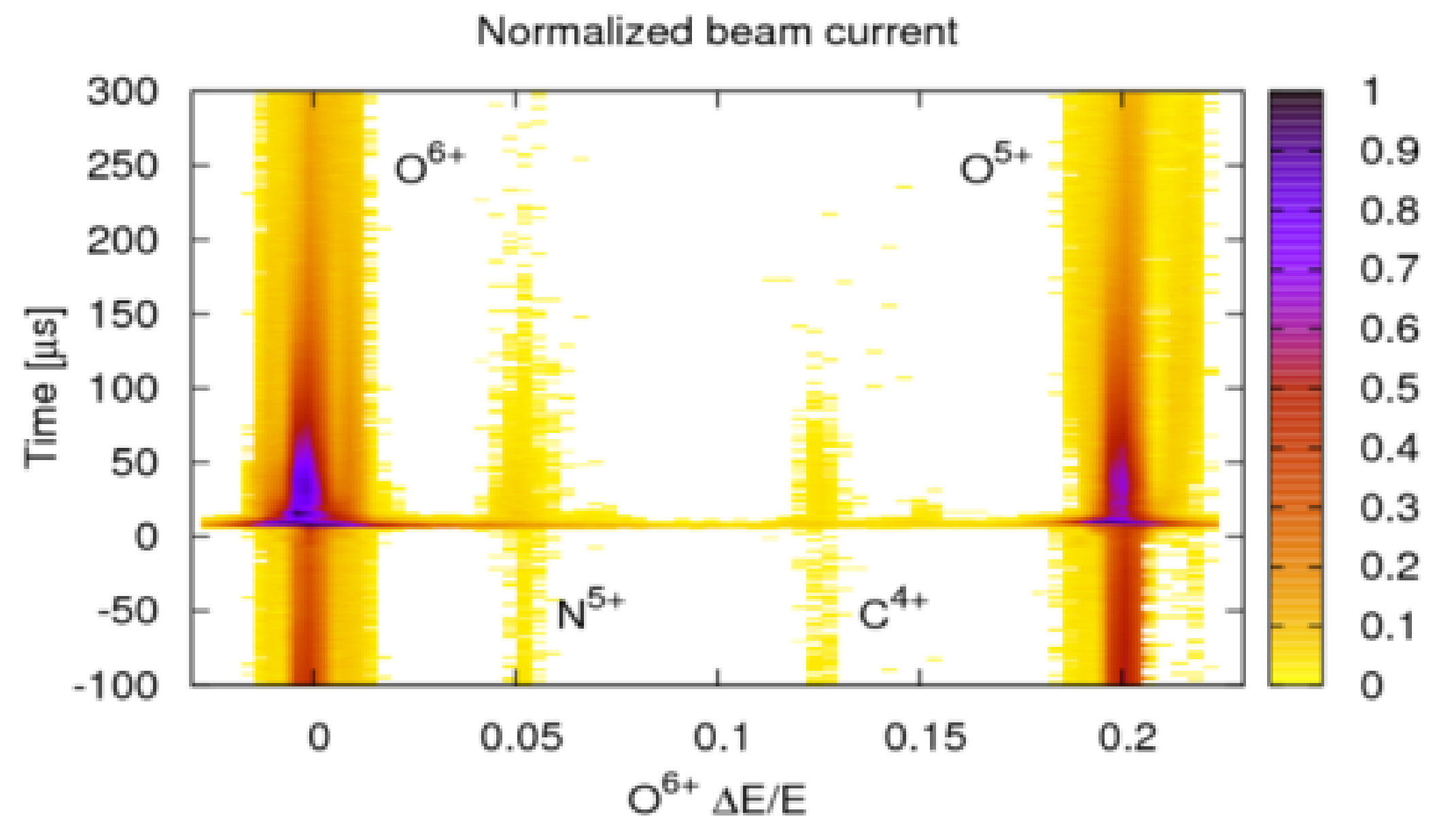


Should the breeding times be measured by pulsing the 1+ injection ?

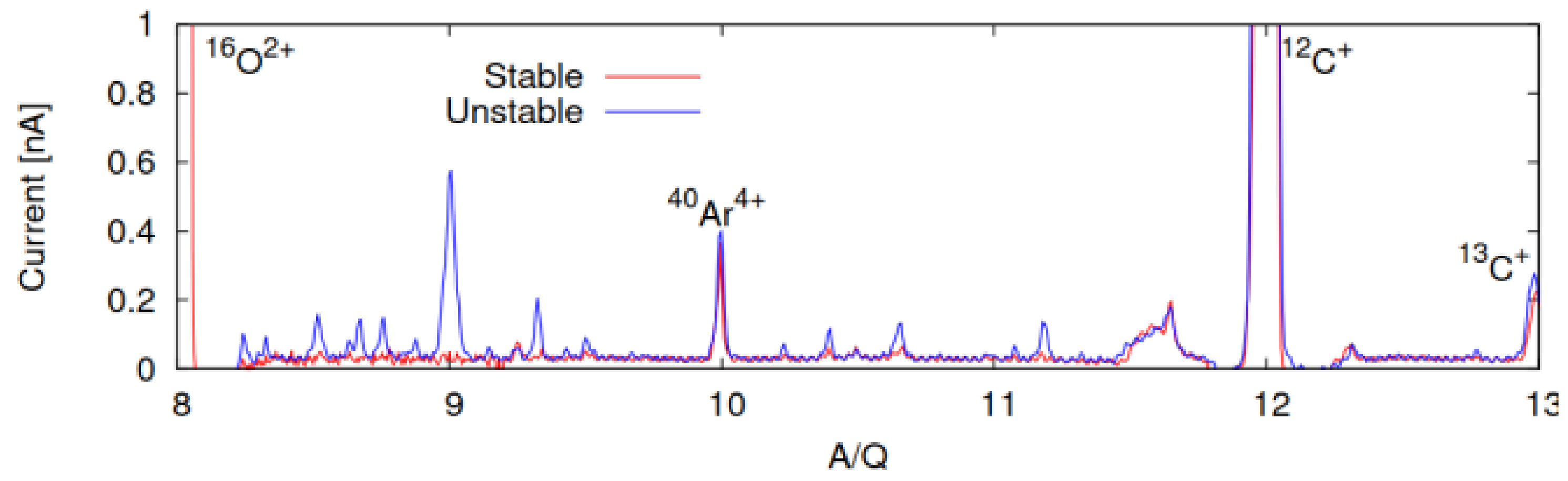
The effect of the instabilities on the impurity background of the extracted n+ beams

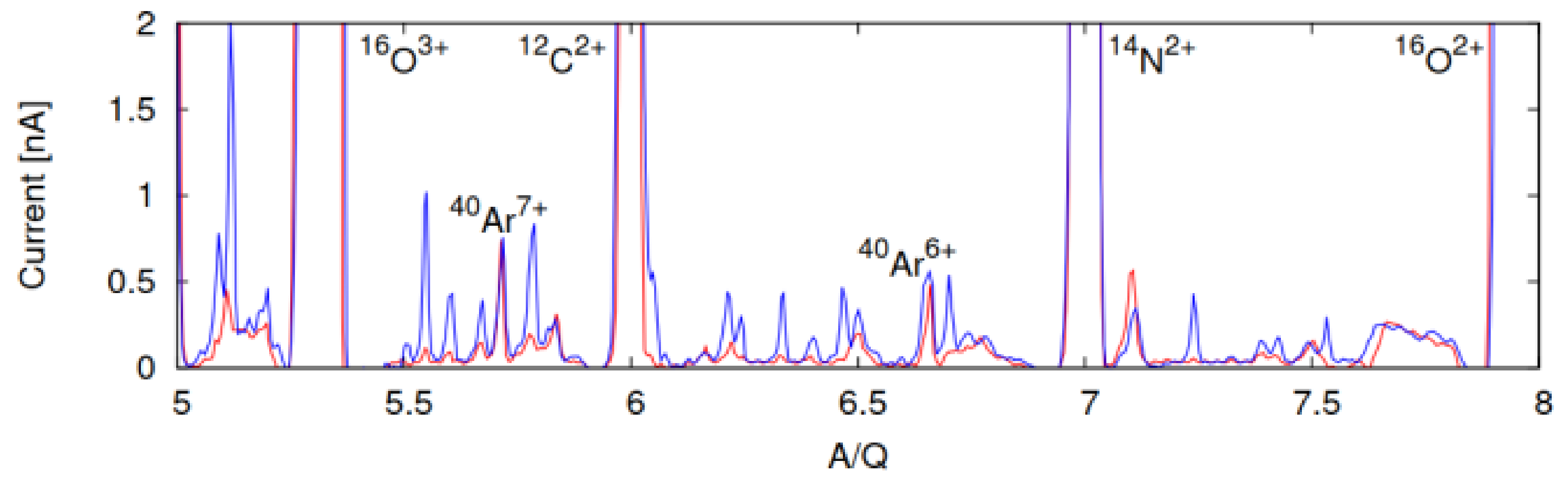
The instabilities first expel electrons which results to > 1 kV transient plasma potential





The ions expelled by the plasma potential cause sputtering of the plasma facing materials which results to significant impurity background of the extracted n+ beam





A/Q	Ion(s)	I_U/I_S	A/Q	Ion(s)	I_U/I_S
26.99–27.02	$^{54}Fe^{2+}$, $^{27}Al^{1+}$	2.1	6.23–6.25	$^{50}Cr^{8+}$, $^{100}Mo^{16+}$	14
25.98–26.02	$^{52}Cr^{2+}$	2.5	6.21–6.23	$^{56}Fe^{9+}$	3.7
18.58–18.62	$^{56}Fe^{3+}$	7.1	5.87–5.89	$^{53}Cr^{9+}$, $^{100}Mo^{17+}$	3.6
11.09–11.11	$^{100}Mo^{9+}$	2.5	5.77–5.79	$^{52}Cr^{9+}$	4.8
11.19–11.21	$^{56}Fe^{5+}$	6.2	5.67–5.68	$^{85}Rb^{15+}$	3.1
10.66–10.68	$^{96}Mo^{9+}$	3.4	5.59–5.61	$^{56}Fe^{10+}$	6.8
10.40–10.45	$^{94}Mo^{9+}$, $^{52}Cr^{5+}$	4.1	5.52–5.55	$^{133}Cs^{24+}$, $^{61}Ni^{11+}$	11
10.22–10.25	$^{92}Mo^{9+}$	3.2	5.49–5.50	$^{66}Zn^{12+}$	2.4
9.50–9.52	$^{57}Fe^{6+}$, $^{95}Mo^{10+}$	4.2	5.19–5.23	$^{52}Cr^{10+}$	5.3
9.33–9.34	$^{56}Fe^{6+}$	6.0	5.12–5.13	$^{133}Cs^{26+}$	5.4
9.17–9.20	$^{92}Mo^{10+}$	3.0	5.09–5.11	$^{56}Fe^{11+}$	6.8
8.99–9.01	$^{54}Fe^{6+}$, $^{27}Al^{3+}$	55	4.93–4.95	$^{133}Cs^{27+}$	4.4
8.85–8.90	$^{98}Mo^{11+}$, $^{62}Ni^{7+}$, $^{133}Cs^{15+}$	5.5	4.86–4.88	$^{68}Zn^{14+}$	5.7
8.72–8.76	$^{96}Mo^{11+}$, $^{61}Ni^{7+}$	7.1	4.84–4.86	$^{58}Ni^{12+}$	4.2
8.66–8.68	$^{52}Cr^{6+}$	11	4.75–4.76	$^{133}Cs^{28+}$	4.8
8.62–8.64	$^{95}Mo^{11+}$	5.1	4.73–4.75	$^{52}Cr^{11+}$	6.0
8.50–8.52	$^{17}O^{2+}$	7.8	4.59–4.60	$^{133}Cs^{29+}$	3.4
8.32–8.34	$^{52}Cr^{6+}$	6.3	4.57–4.59	$^{55}Mn^{12+}$	4.7
8.26–8.29	$^{58}Ni^{7+}$	3.3	4.53–4.55	$^{50}Cr^{11+}$, $^{68}Zn^{15+}$	8.7
8.23–8.25	$^{66}Zn^{8+}$	7.4	4.48–4.50	$^{27}Al^{6+}$, $^{54}Fe^{12+}$	2.6
7.54–7.57	$^{98}Mo^{13+}$	13	4.40–4.42	$^{53}Cr^{12+}$	8.7
7.43–7.45	$^{52}Cr^{7+}$	3.7	4.33–4.35	$^{52}Cr^{12+}$	3.9
7.38–7.40	$^{133}Cs^{18+}$	2.5	4.31–4.33	$^{56}Fe^{13+}$	7.3
7.23–7.26	$^{58}Ni^{8+}$	20	4.27–4.29	$^{60}Ni^{14+}$	16
6.74–6.76	$^{27}Al^{4+}$, $^{54}Fe^{8+}$	2.2	4.25–4.27	$^{64}Zn^{15+}$	3.0
6.71–6.73	$^{94}Mo^{14+}$	8.5	4.15–4.17	$^{50}Cr^{12+}$, $^{133}Cs^{32+}$	9.5
6.60–6.63	$^{53}Cr^{8+}$	3.1	3.79–3.80	$^{57}Fe^{15+}$, $^{53}Cr^{14+}$	3.0
6.50–6.52	$^{13}C^{2+}$	2.1	3.77–3.79	$^{68}Zn^{18+}$	5.6
6.49–6.51	$^{52}Cr^{8+}$	22	3.73–3.75	$^{56}Fe^{15+}$	5.7
6.39–6.41	$^{64}Zn^{10+}$, $^{96}Mo^{15+}$	6.0	3.71–3.73	$^{52}Cr^{14+}$	2.4
6.32–6.34	$^{57}Fe^{9+}$	13	3.30–3.32	$^{56}Fe^{17+}$	3.3

The impurities are a major drawback of ECRIS charge breeders and operation under unstable condition should be avoided or the instabilities should be suppressed e.g. by double frequency heating

O. Tarvainen, I. Izotov, D. Mansfeld, V. Skalyga, S. Golubev, T. Kalvas, H. Koivisto, J. Komppula, R. Kronholm, J. Laulainen and V. Toivanen, *Beam current oscillations driven by cyclotron instabilities in a minimum-B electron cyclotron resonance ion source plasma*, Plasma Sources Sci. Technol. 23, 025020, (2014).

O. Tarvainen, J. Angot, I. Izotov, V. Skalyga, H. Koivisto, T. Thuillier, T. Kalvas and T. Lamy, *Plasma instabilities of a charge breeder ECRIS*, Plasma Sources Sci. Technol. 26, 105002, (2017).

V. Skalyga, I. Izotov, T. Kalvas, H. Koivisto, J. Komppula, R. Kronholm, J. Laulainen, D. Mansfeld and O. Tarvainen, *Suppression of cyclotron instability in Electron Cyclotron Resonance ion sources by two-frequency heating*, Phys. Plasmas 22, 083509 (2015).