Status of RIKEN SC-ECRIS

T. Nakagawa (RIKEN)

1. ***Introduction***
   RIKEN RIBF project
2. ***RIKEN SC-ECRIS***
   Structure of Sc-coils, cryostat
3. ***Experimental results***
   Effect of magnetic field gradient and ECR zone size
   Field gradient limitation?
4. ***Preparation for 28GHz operation***
5. ***Schedule***

ECRIS2010 *August 23-26 2010 Grenoble*

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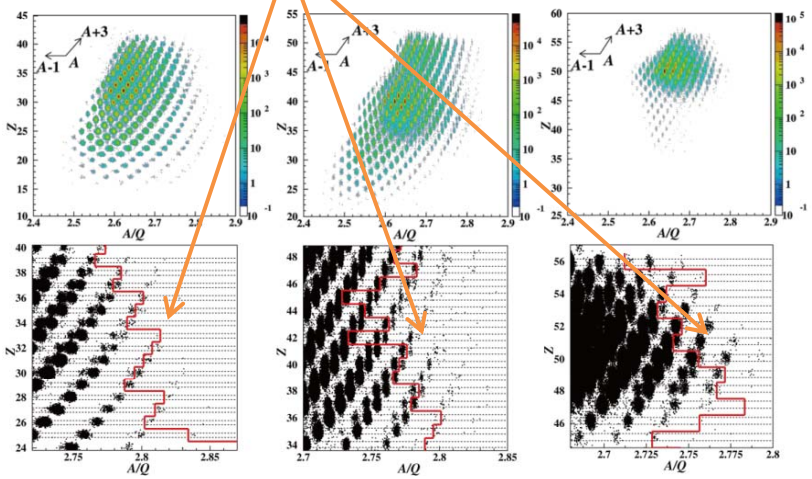
New isotopes production with in-flight fission reaction

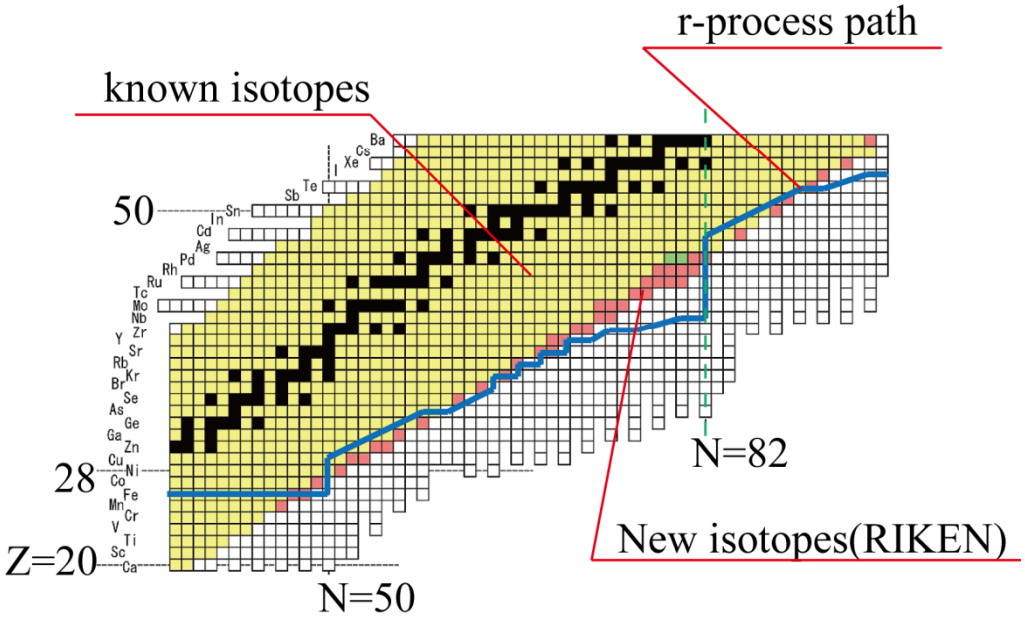
New isotopes



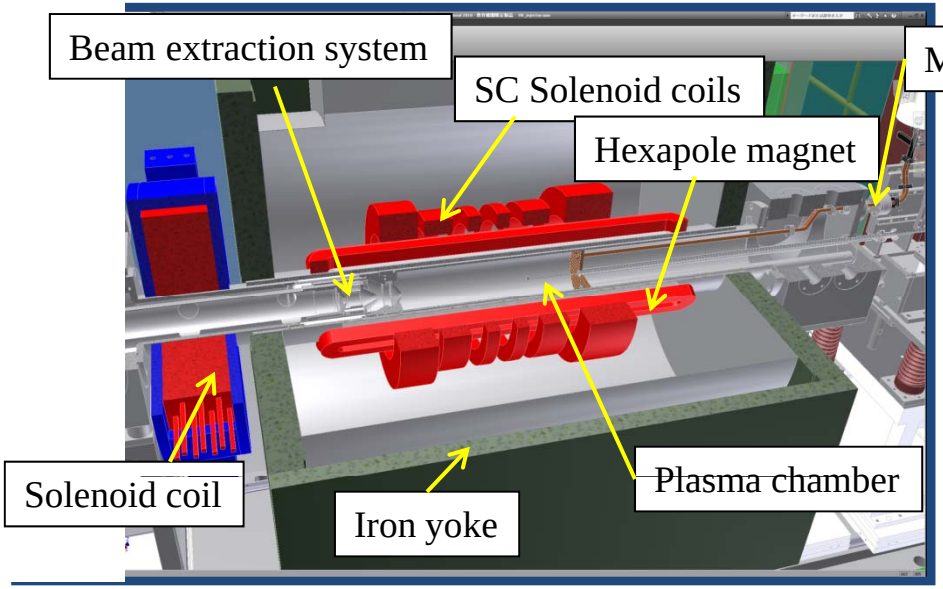
>40 new isotopes were produced
by in-flight fission reaction
(4 days experiments)

18GHz ECRIS ~60pnA(2eμA)

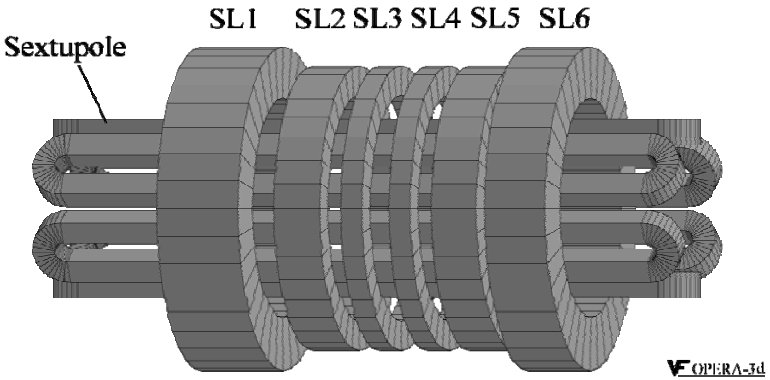
on target ~0.4pnA(345MeV/u)



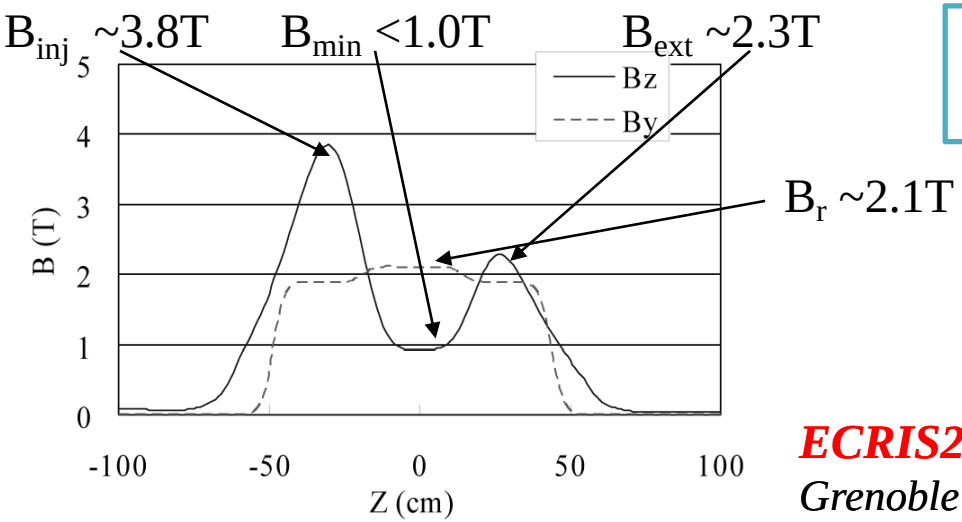
Structure of ion source



SC-coils



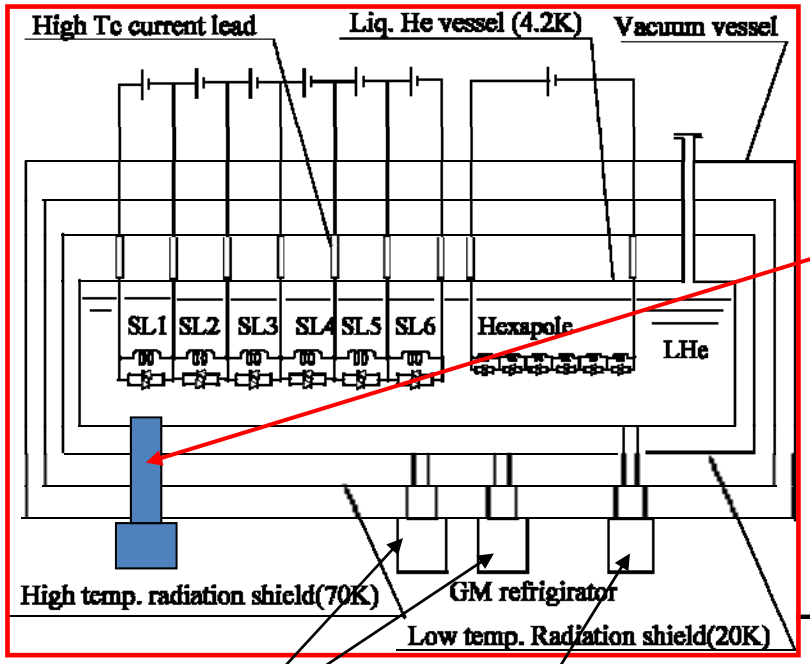
For 28GHz operations



Detailed infromation
RSI 81(2010)02A320

ECRIS2010 *August 23-26 2010*
Grenoble

Cryostat



2009 GM-JT was installed

CG310SC(SUMITOMO)***(GM-JT refrig.)***

Cooling capacity
4.2W/5.0W@4.2K(50/60Hz)
Electric power consump. 5.1/6.1kW(50/60Hz)
Electric power AC200V 3 phase
Weight ~220kgr
Dimension 700Wx520Dx1095H

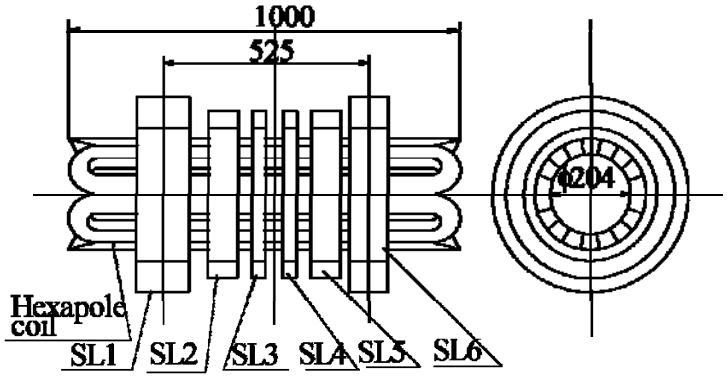
GM refrig. 35W(45K), 6.3W(10K)

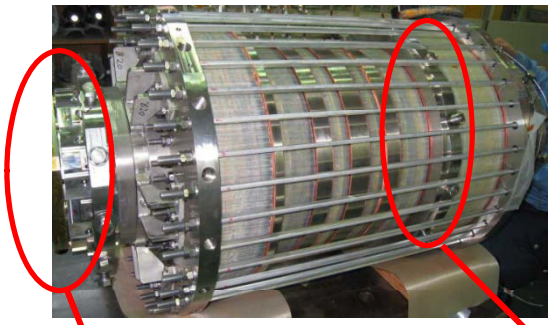
GM. Refrig. 50W(43K), 1.0W(4.2K)

(W)

Item	Helium vessel	Low temp. radiation shield	High temp. radiation shield
Design temp.	4.2 K	20 K	70K
Radiation	0.005	5.5	40
Conduction			
Support	0.005	0.3	4
Port	0.06	1.5	20
Current lead	0.07	10	64
Total heat load	0.14	17.3	128

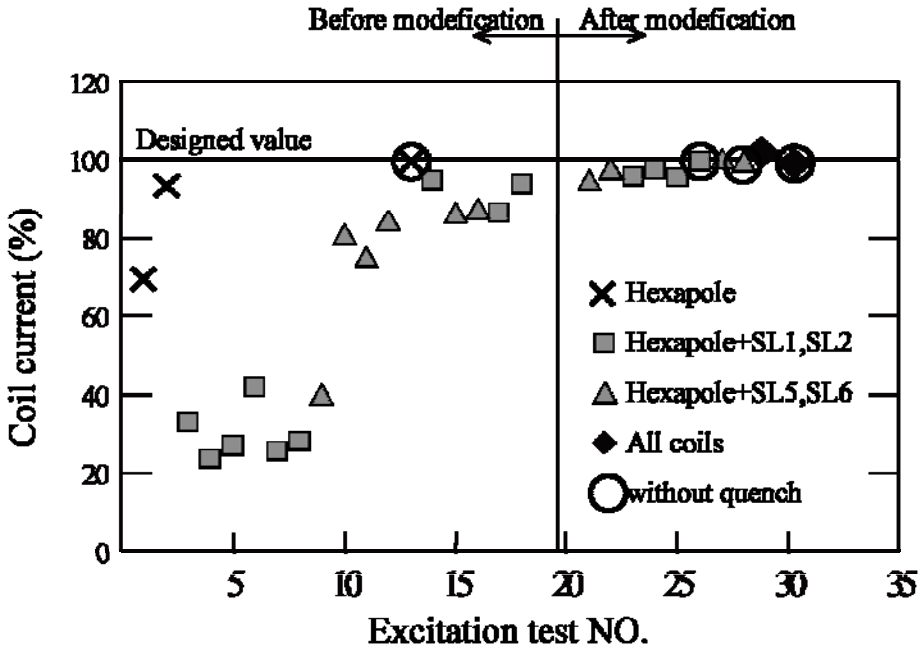
SC-coils and excitation test





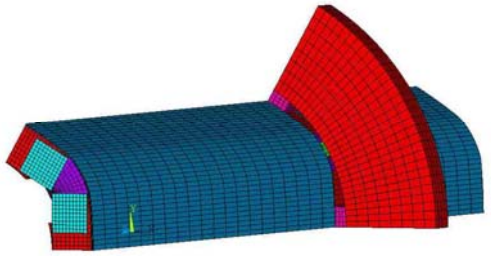
First trial

Hexapole magnet support

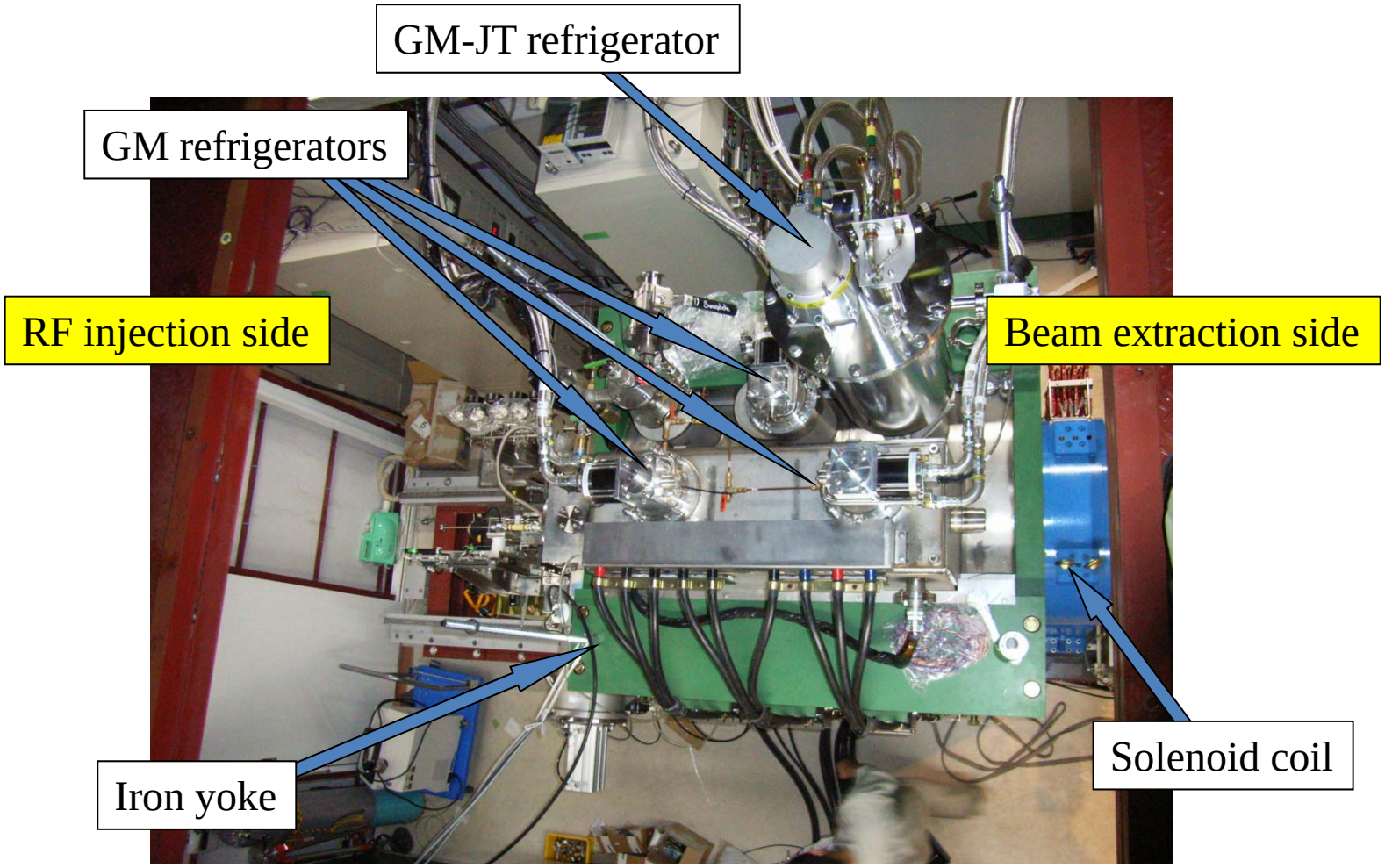


Second trial

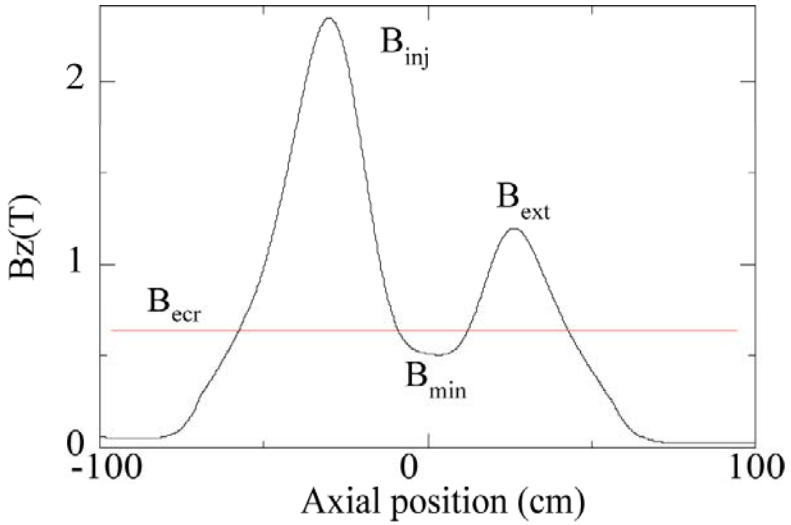
Modification of Hexapole edge support



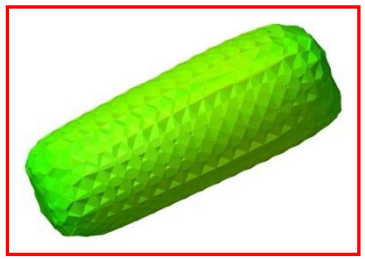
Picture of SC-ECRIS



Magnetic field distribution

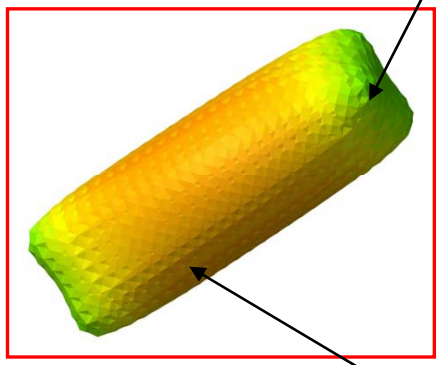


ECR zone shape (B_{min}=0.51T)

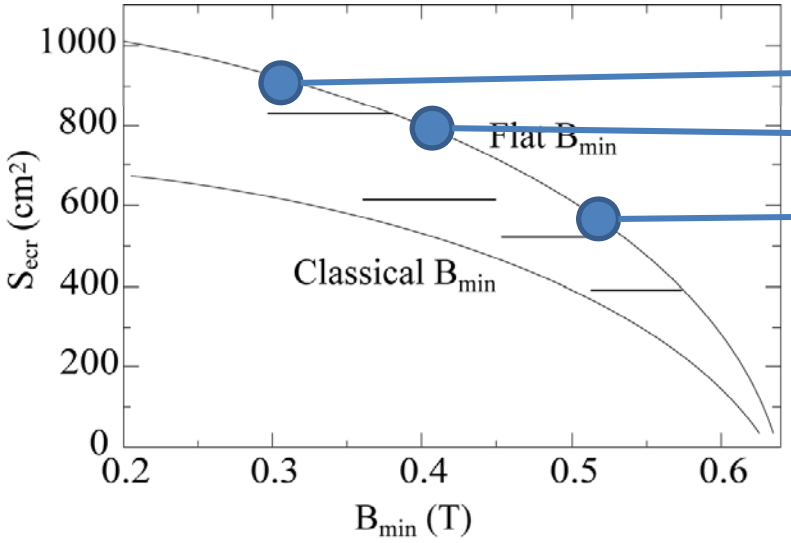


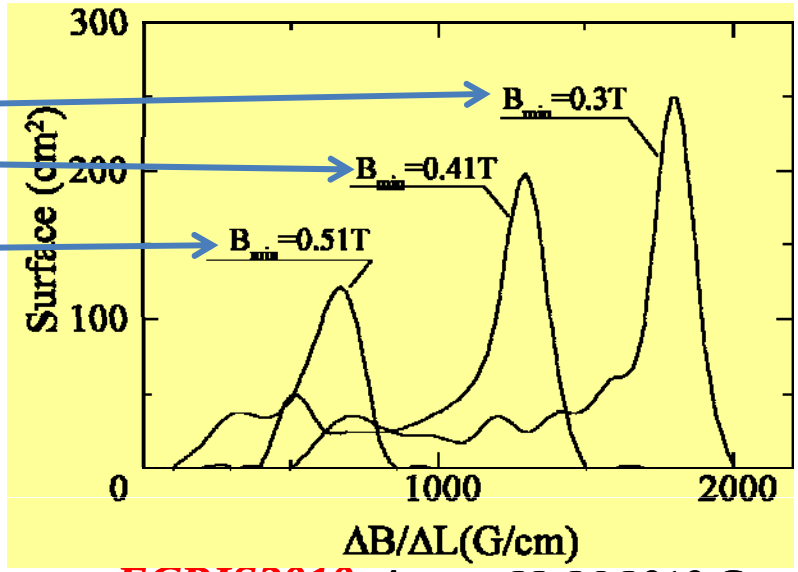
ECR zone shape (B_{min}=0.3T)

Gentler

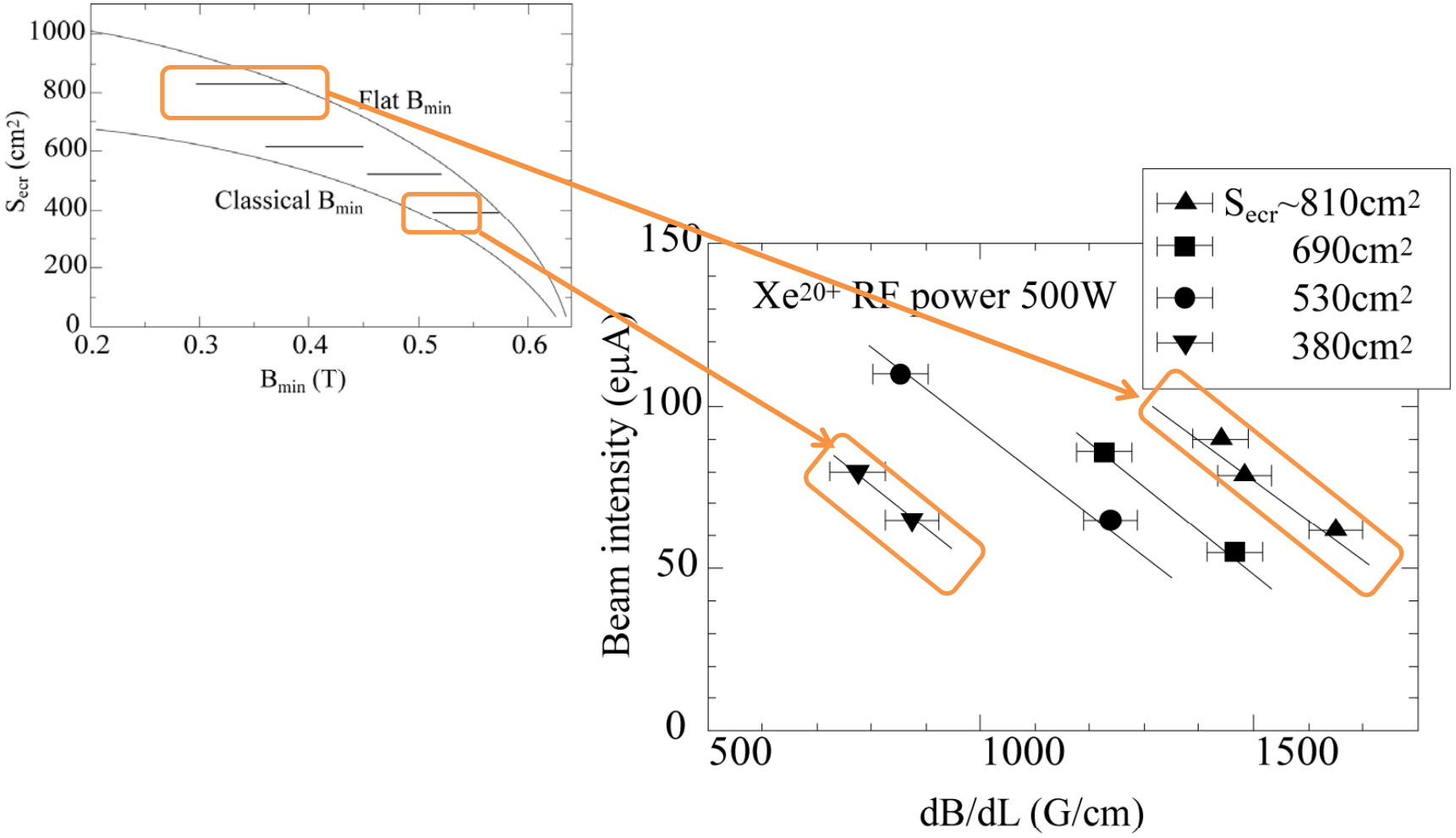


Steeper

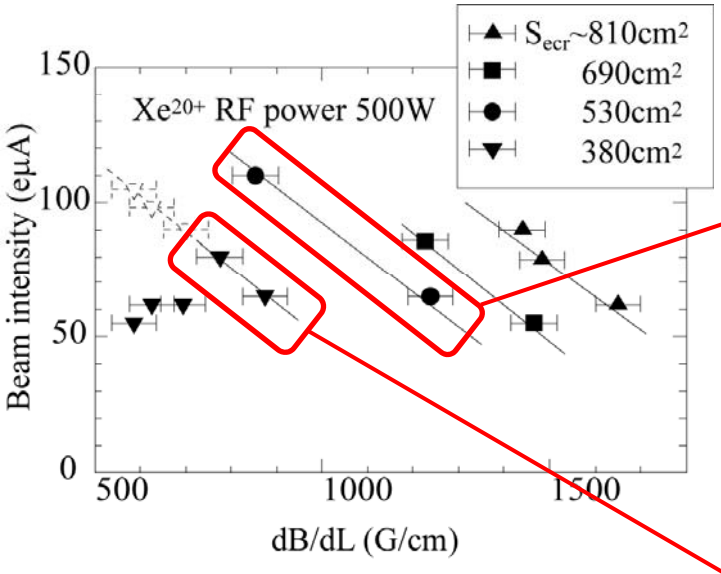




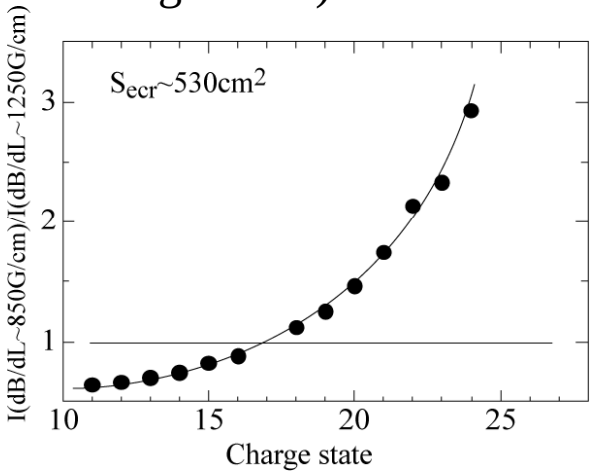
Field gradient, ECR zone size (I)



Field gradient effect

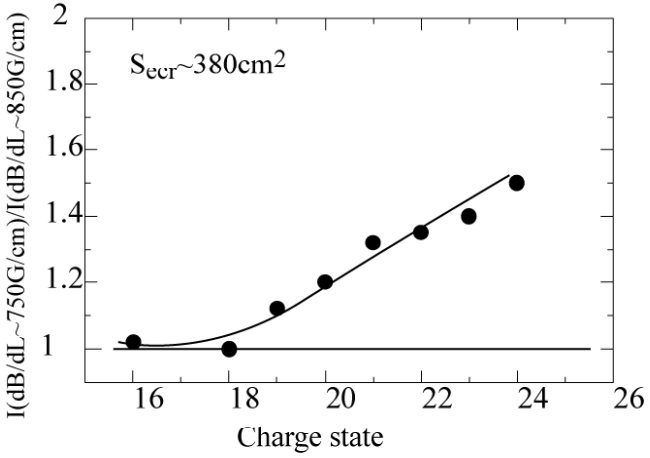


Ratio of the beam intensity between two conditions (different field gradient)



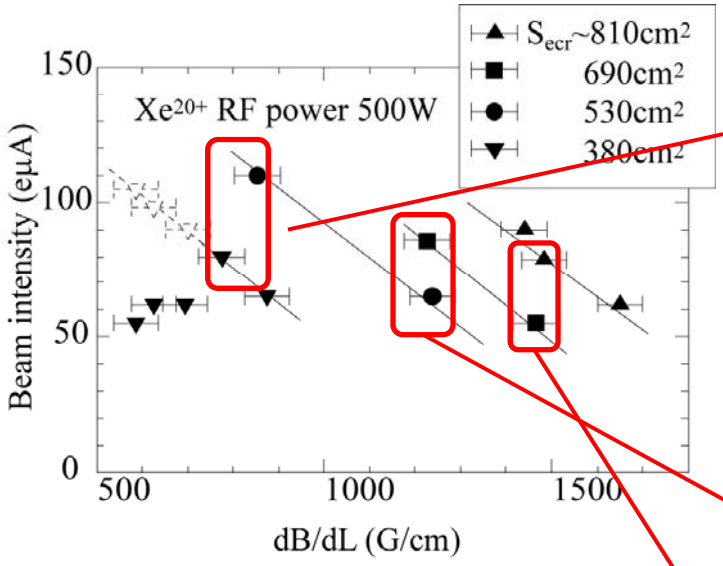
The ratio increases with increasing charge state

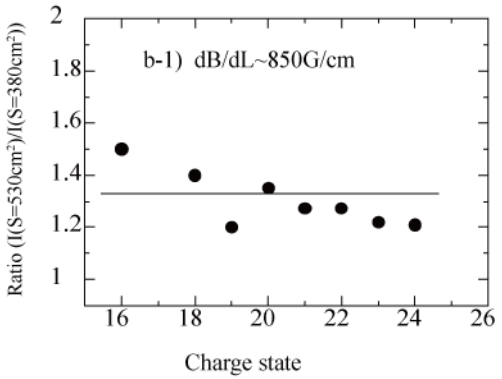
Electron temperature effect

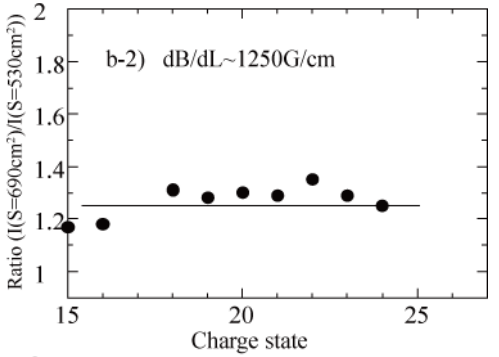


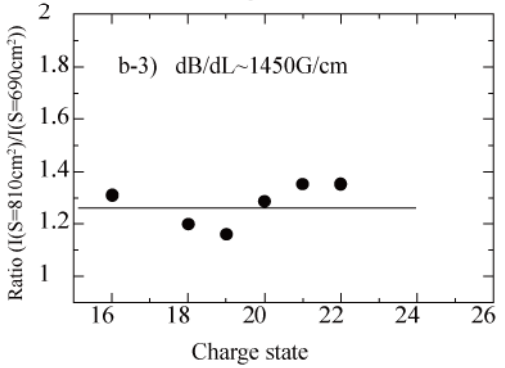
ECR zone size effect

Ratio of the beam intensity between two conditions (different ECR zone size)





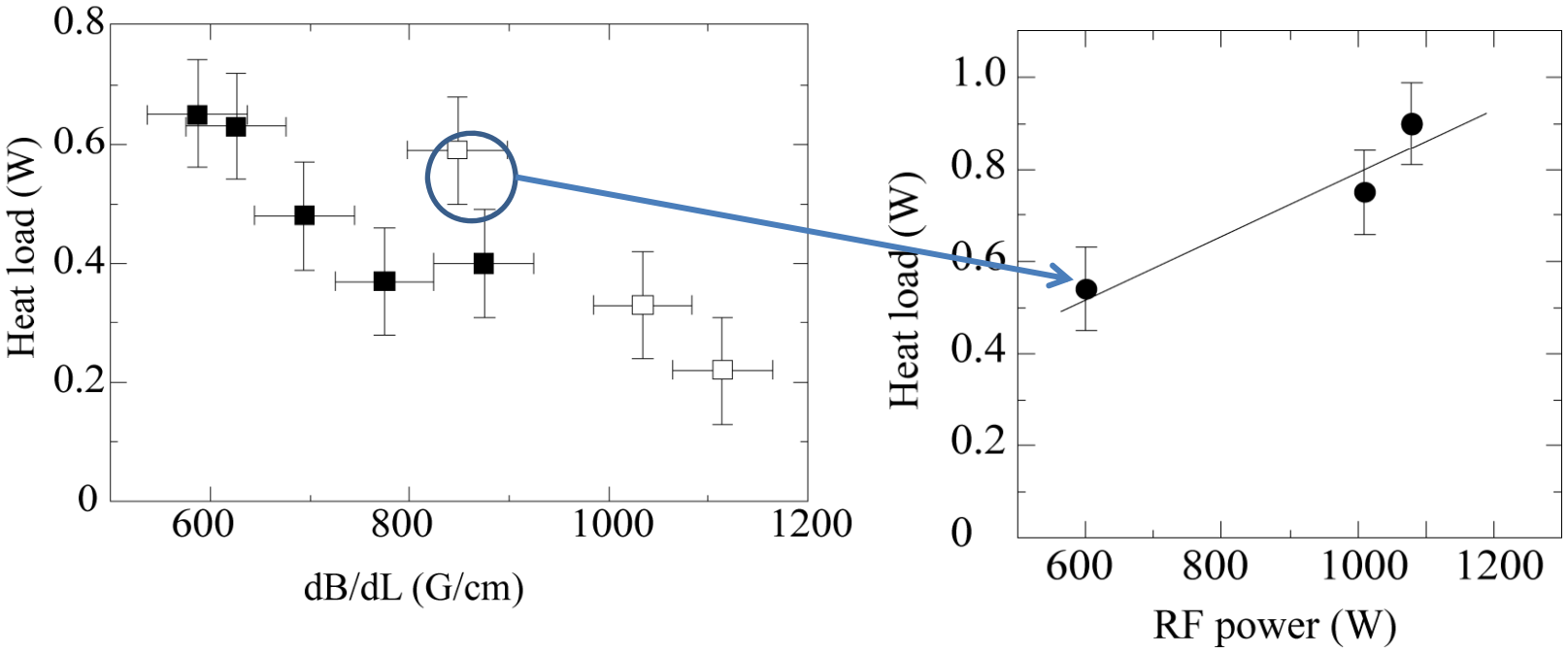




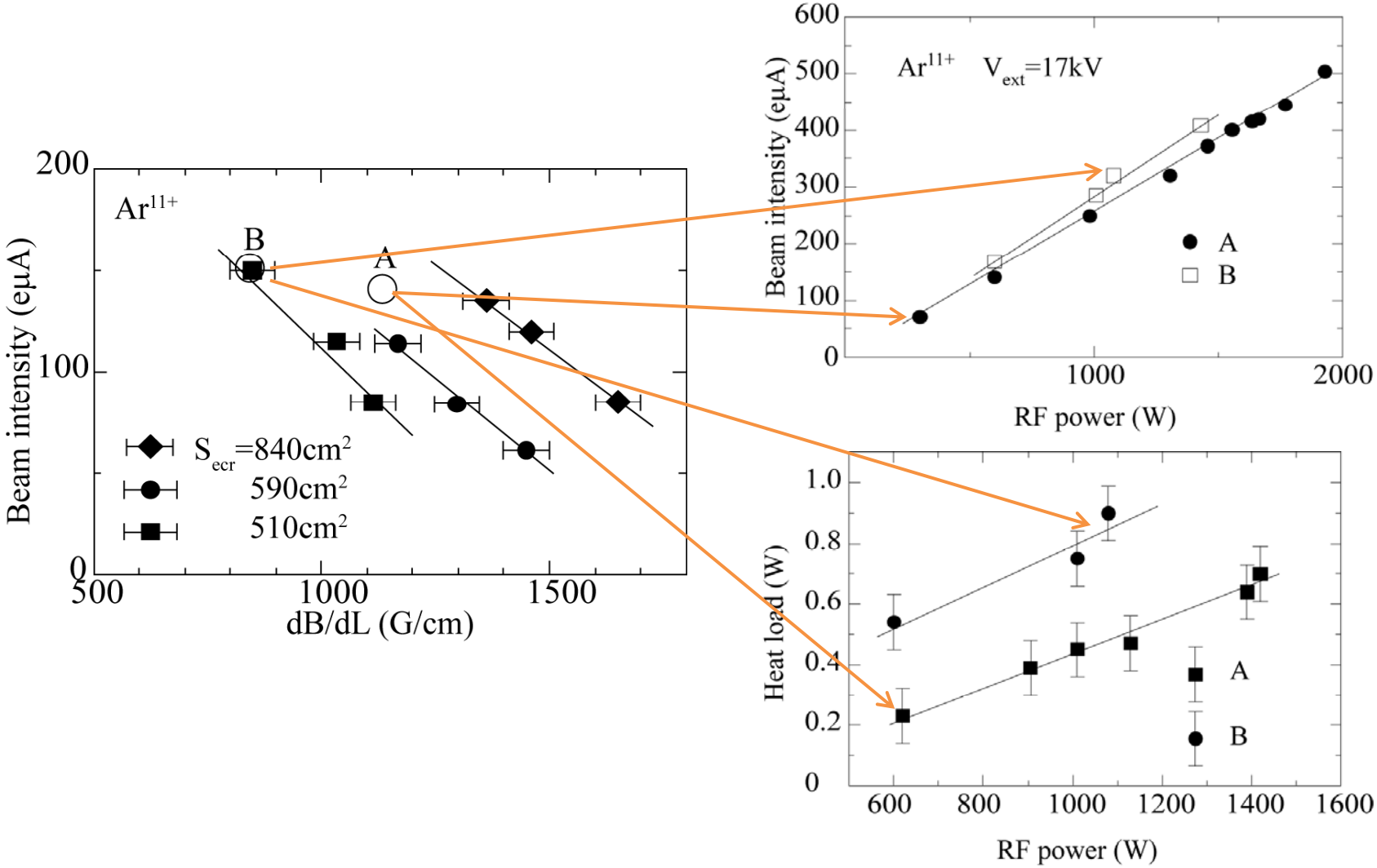
The ratio was almost constant and independent on the charge state

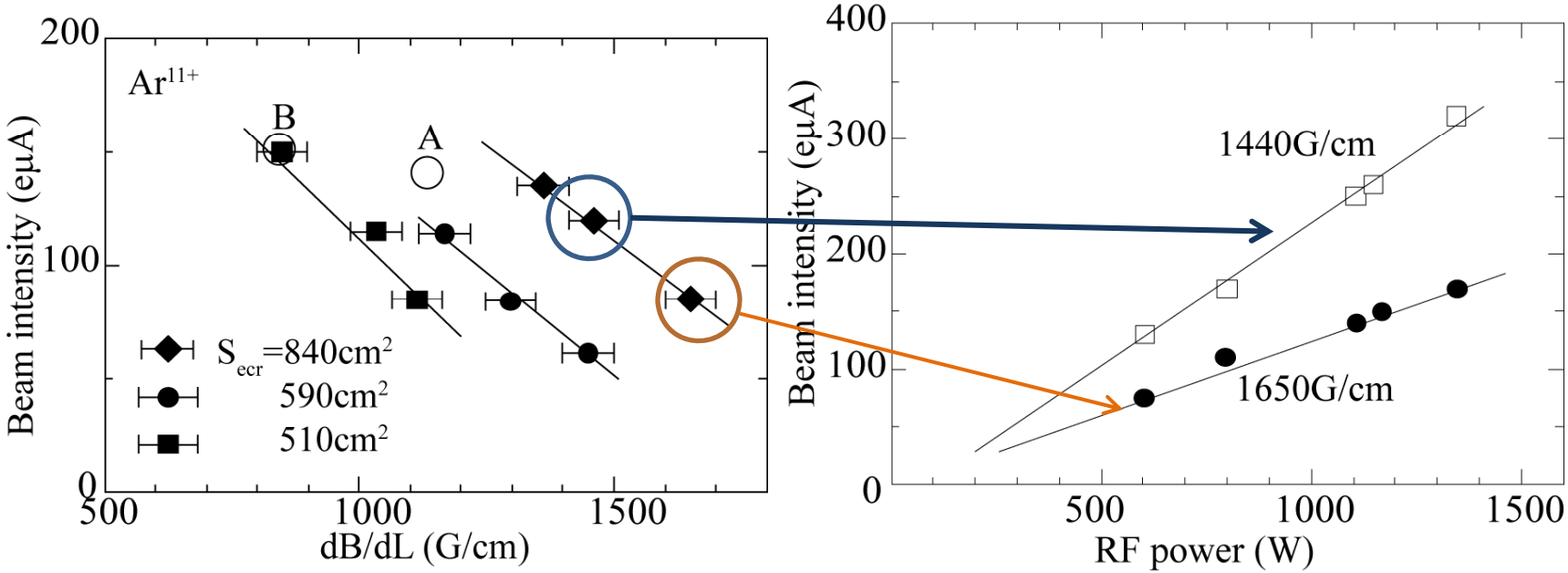
Heat load (X-ray)

18GHz Microwave

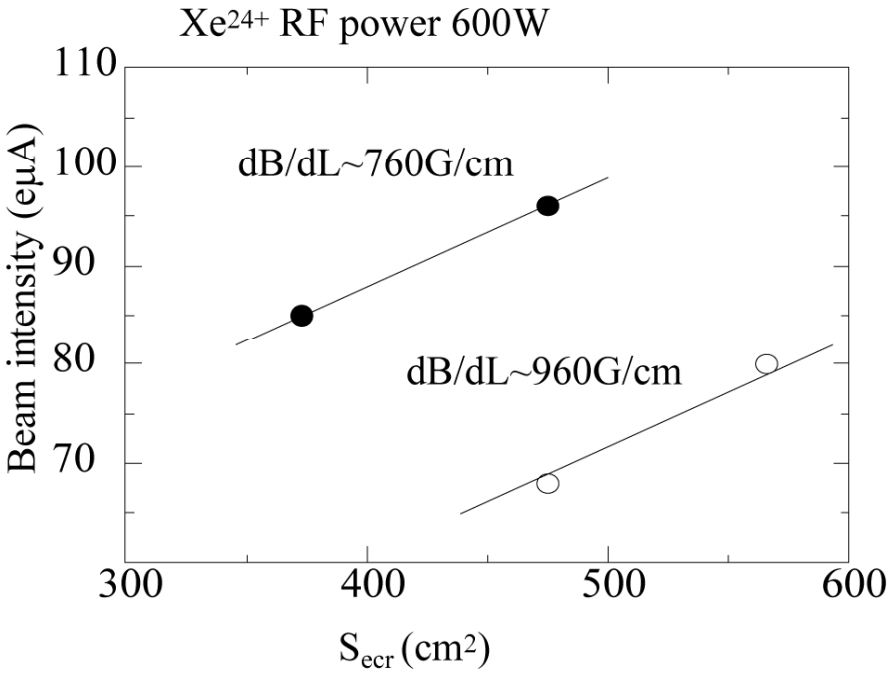


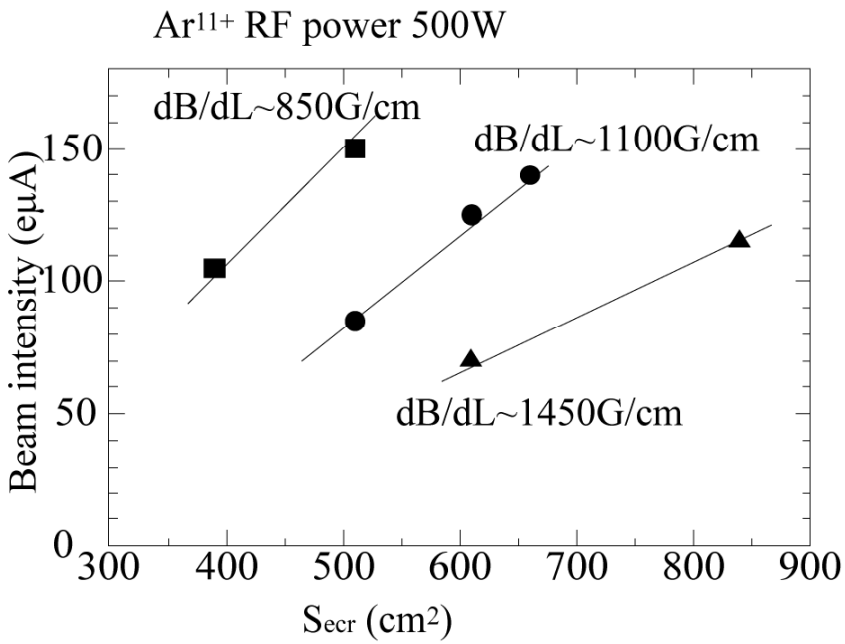
RF power dependence (beam intensity, heat load)



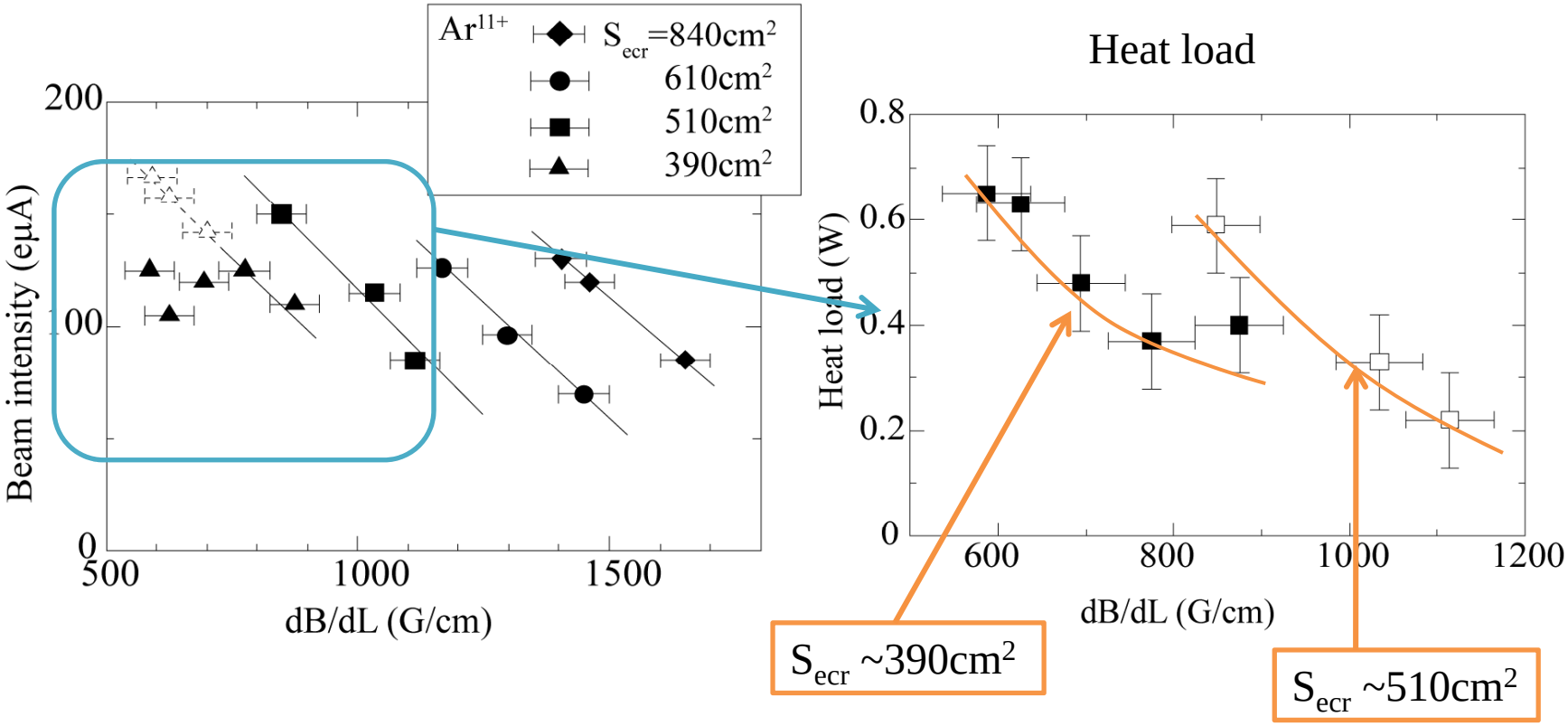

Ar11+
B
A
Secr=840cm2
590cm2
510cm2
Beam intensity (eμA)
dB/dL (G/cm)
1440G/cm
1650G/cm
RF power (W)

ECR zone size effect



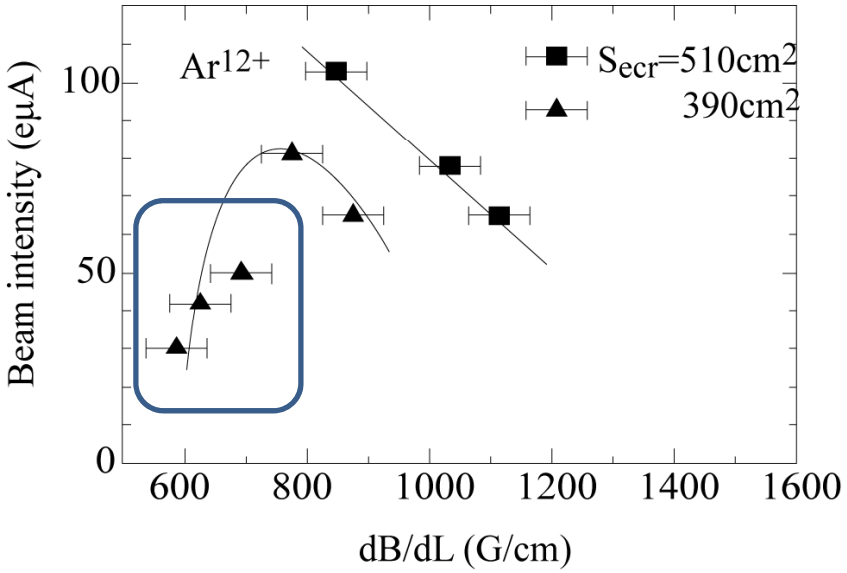


Field gradient limit ? (I)

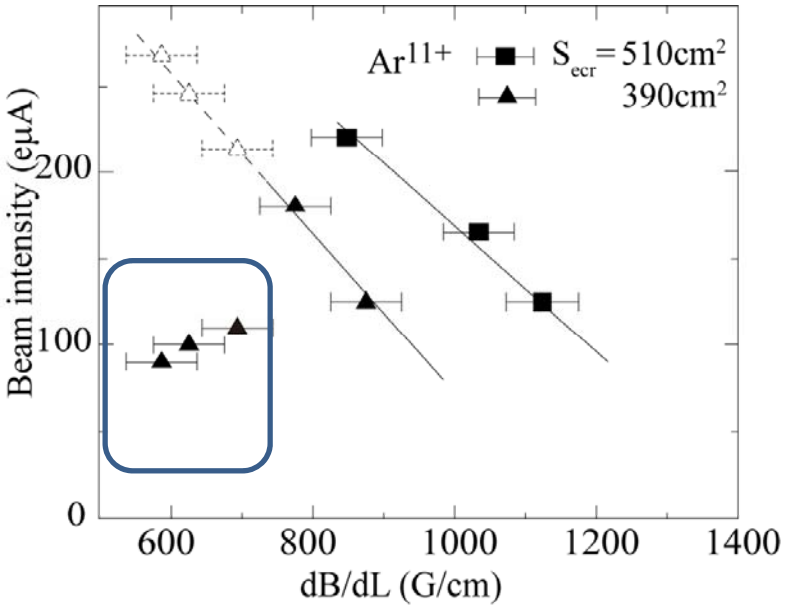


Field gradient limit ? (II)

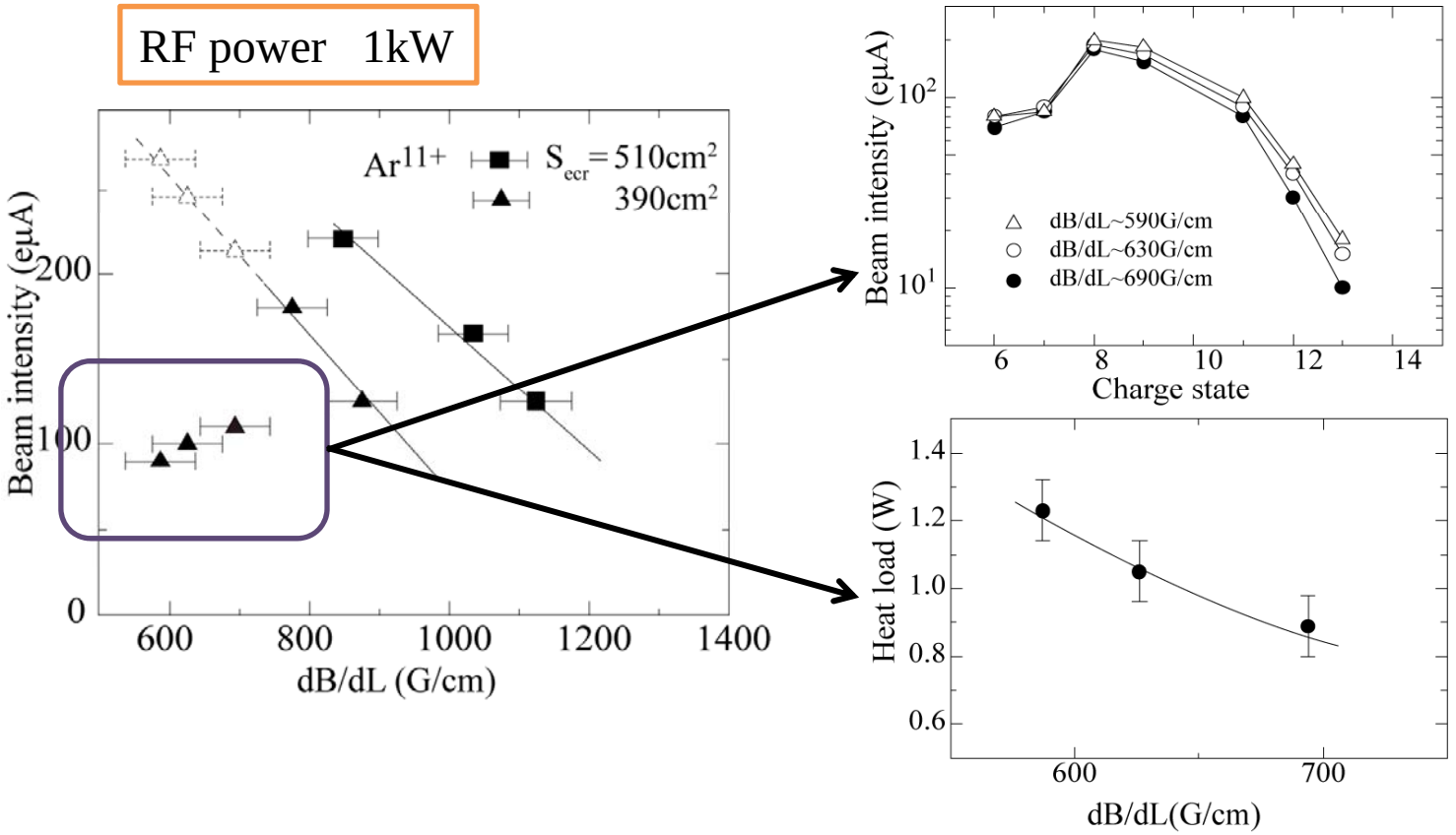
Ar^{12+}



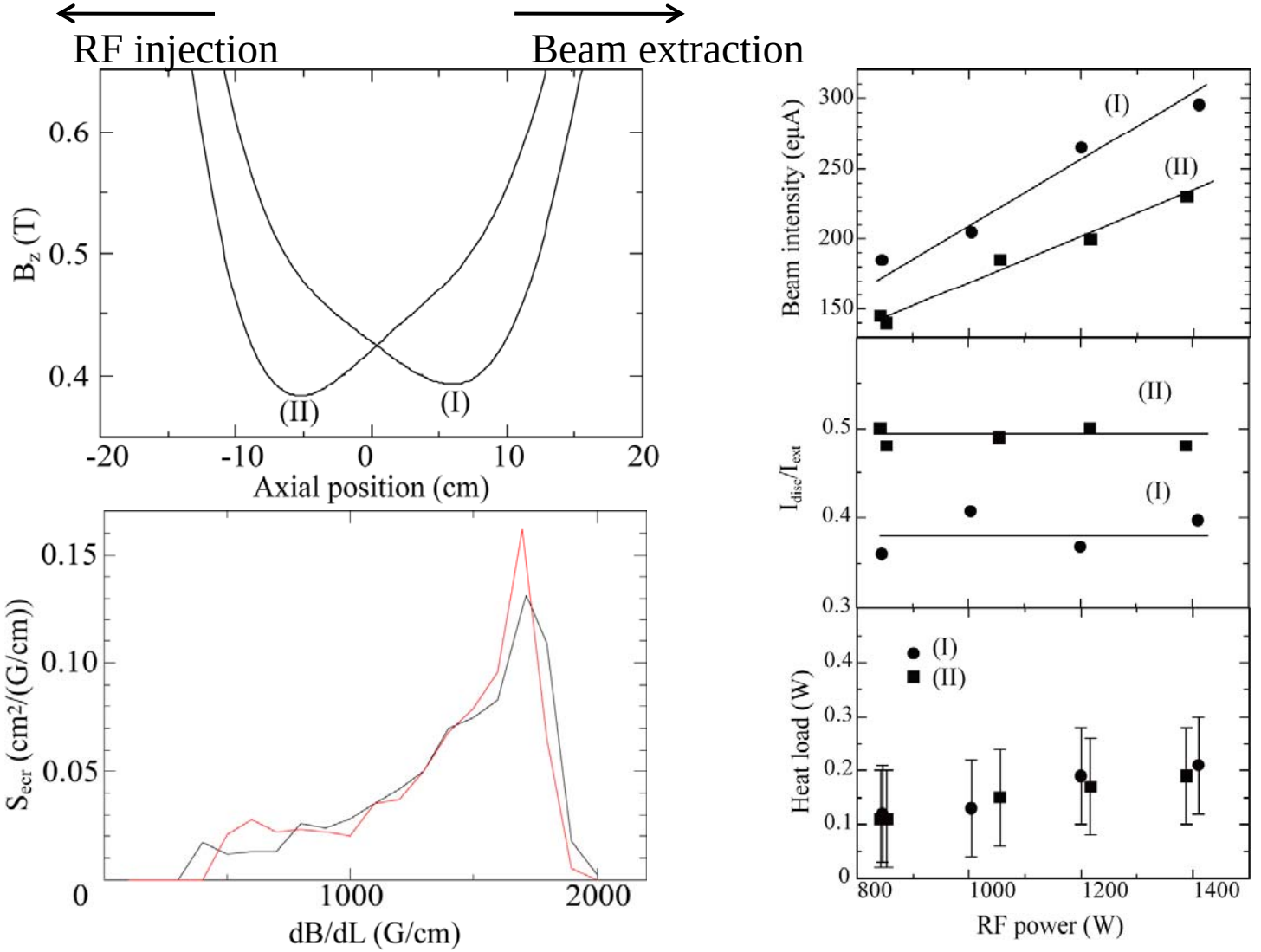
RF power =1kW



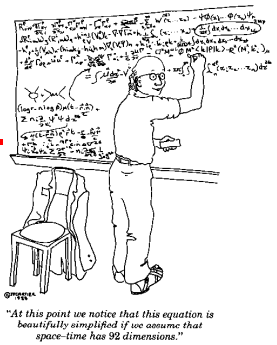
Field gradient limit ? (III)



Shape of B_{min}



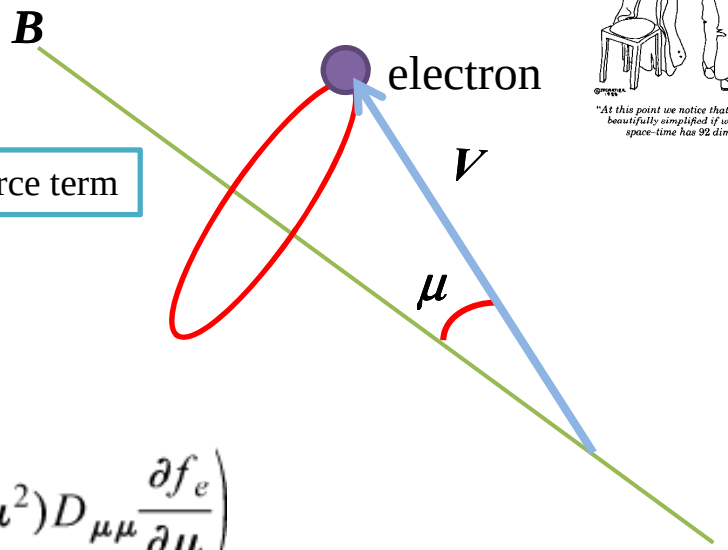
Microwave Frequency effect I



Fokker-planck equation

Collision term | HF term | Source term

$$\frac{\partial f_e}{\partial t} = C(f_e) + Q(f_e) + S(f_e)$$



$$Q = \frac{1}{v^2}\frac{\partial}{\partial v}\left(v^2 D_{vv}\frac{\partial f_e}{\partial v}\right) + \frac{1}{v^2}\frac{\partial}{\partial \mu}\left((1-\mu^2) D_{\mu\mu}\frac{\partial f_e}{\partial \mu}\right)$$

$$D_{vv} = D = \frac{4}{3}\pi\left(\frac{eE}{2m_e}\right)^2 \frac{d}{L\omega}, \qquad D_{\mu\mu} = D\left(\frac{v}{v_{ph}}\right)^2.$$

Strength of electric field (RF power)

Magnetic field gradient (B_{min} effect)

$$\frac{k^2c^2}{\omega^2} \approx -\frac{\omega_p^2}{\omega k v_T}.$$

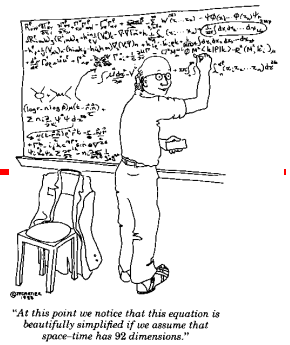
Taking the phase velocity $v_\phi = \omega/k$, we obtain

$$v_\phi^3 \approx \frac{\omega^2}{\omega_p^2} v_T c^2 = \frac{n_c}{n_e} v_T c^2,$$

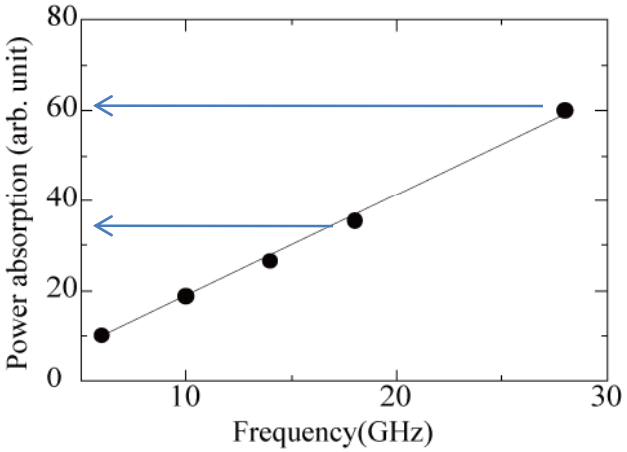
$$n_c = \frac{\omega^2 m_e \epsilon_0}{e^2}$$

A. Girard et al, Phys. Rev. E 62(2000)1182

Microwave Frequency effect II

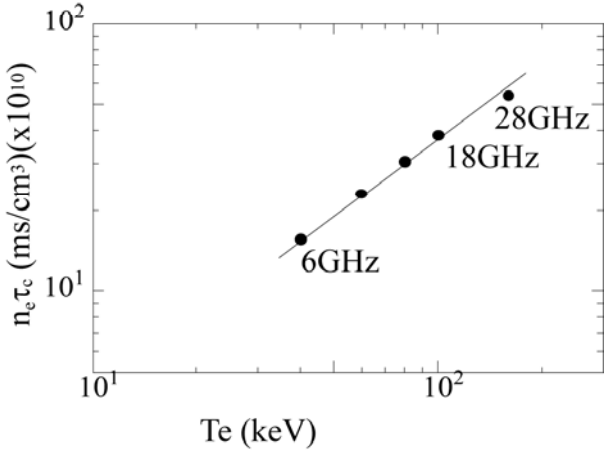


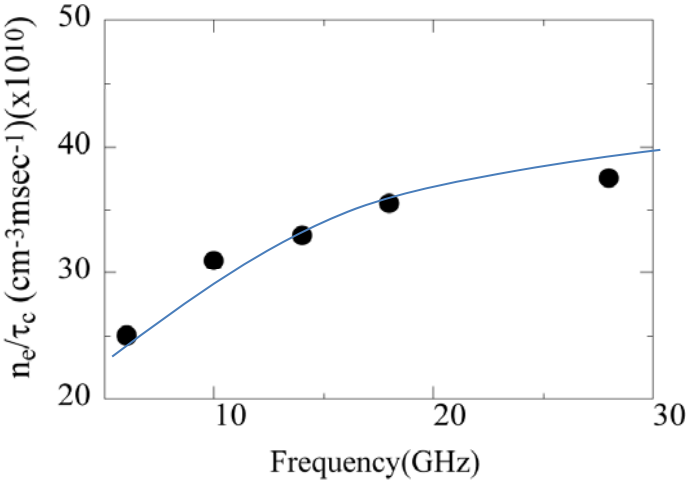
Fokker –planck equation



18GHz ➡ 28GHz

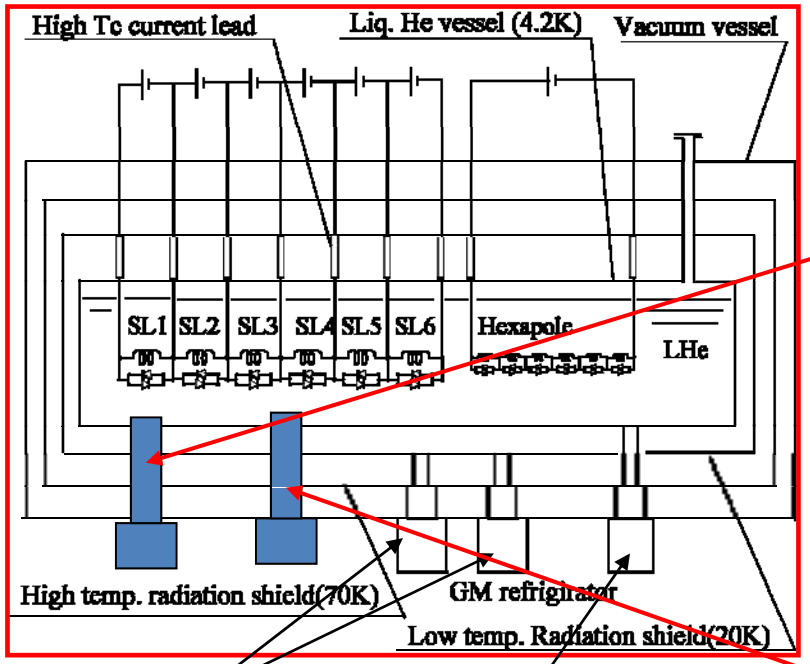
Power absorption ***~factor two***





A. Girard et al, Phys. Rev. E 62(2000)1182

28GHz SC-ECRIS II (Cryostat(2011))



GM refrig. 35W(45K), 6.3W(10K)

GM. Refrig. 50W(43K), 1.0W(4.2K)

2011. April
Total cooling power ~10W

2009. Oct.

CG310SC(SUMITOMO)***(GM-JT refrig.)***

Cooling capacity
4.2W/5.0W@4.2K(50/60Hz)
Electric power consump. 5.1/6.1kW(50/60Hz)
Electric power AC200V 3 phase
Weight ~220kgr
Dimension 700Wx520Dx1095H

2011. March.

CG310SC(SUMITOMO)***(GM-JT refrig.)***

Cooling capacity
4.2W/5.0W@4.2K(50/60Hz)
Electric power consump. 5.1/6.1kW(50/60Hz)
Electric power AC200V 3 phase
Weight ~220kgr
Dimension 700Wx520Dx1095H

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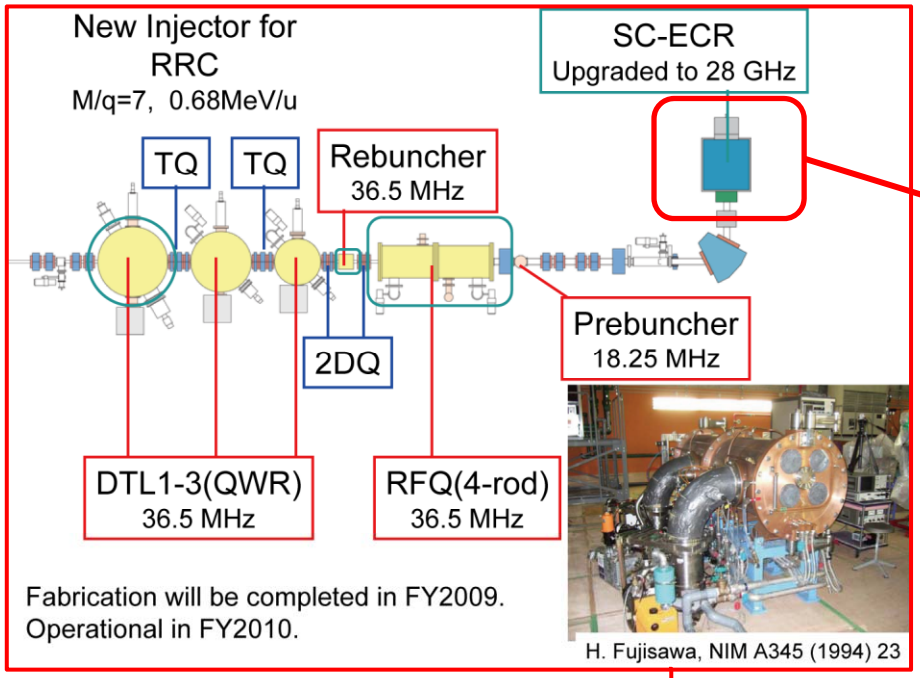
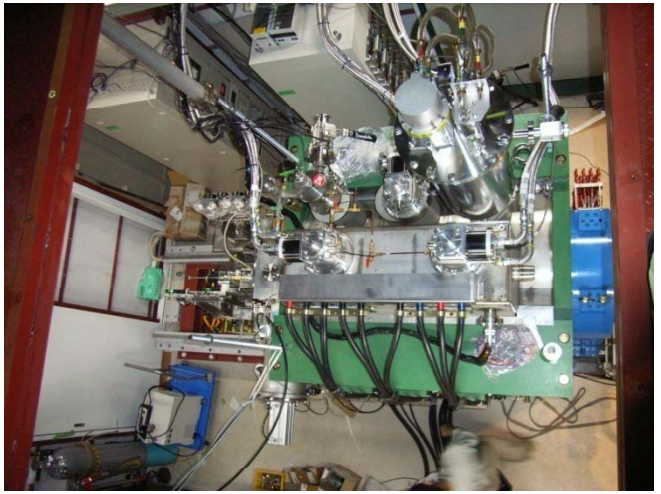
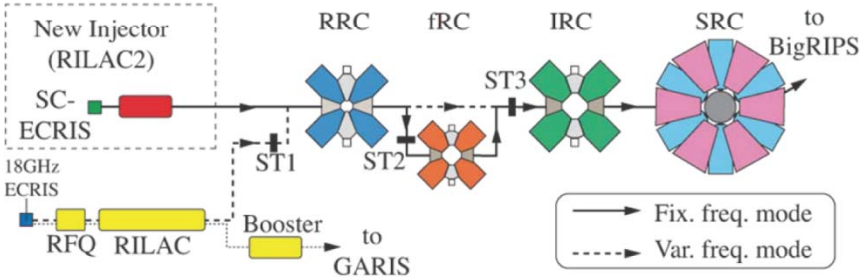
Next step for RIBF (New injector (2011 March~))

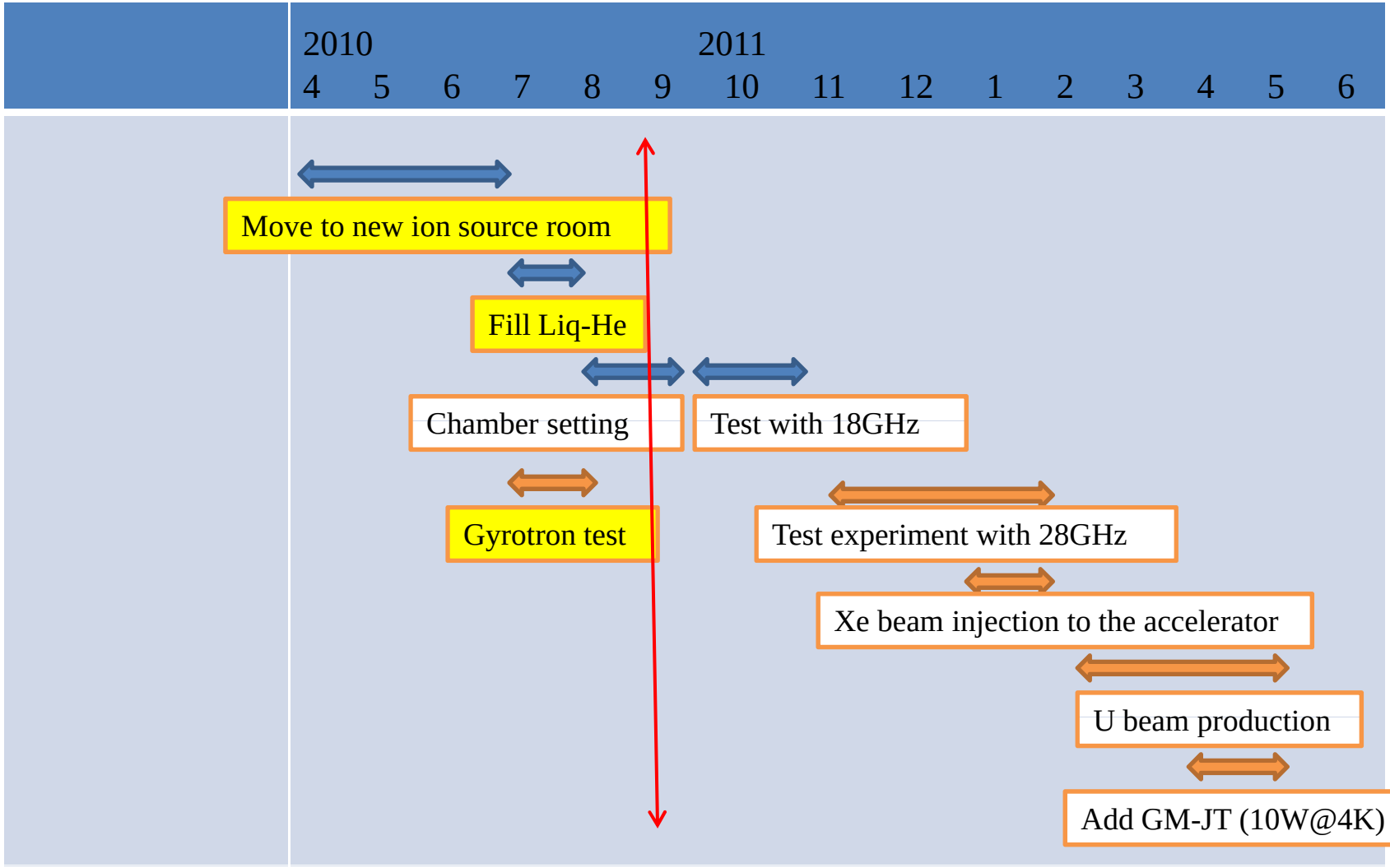




Mar. 2011

~0.6MeV/u U^{35+}, Xe^{20+}



U: 50 - 100 pnA

Schedule for 28GHz