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Spontaneous Formation of Spherical Tokamak by ECH on LATE

H.Tanaka, Y.Abe, K.Hayashi, J.Yamada, T.Matsumoto,
T.Yoshinaga, M.Uchida, S.Yamaguchi*, T.Maekawa,
S.Maebara**, T.Imai***

Graduate School of Energy Science, Kyoto University
*Graduate School of Science, Kyoto University
**Japan Atomic Energy Research
***Tsukuba University

Contents

Study on Formation of Initial Closed Flux Surfaces

Formation of Spherical Tokamak by ECH only without Ohmic Heating

Vertical field is essential to generate plasma current.

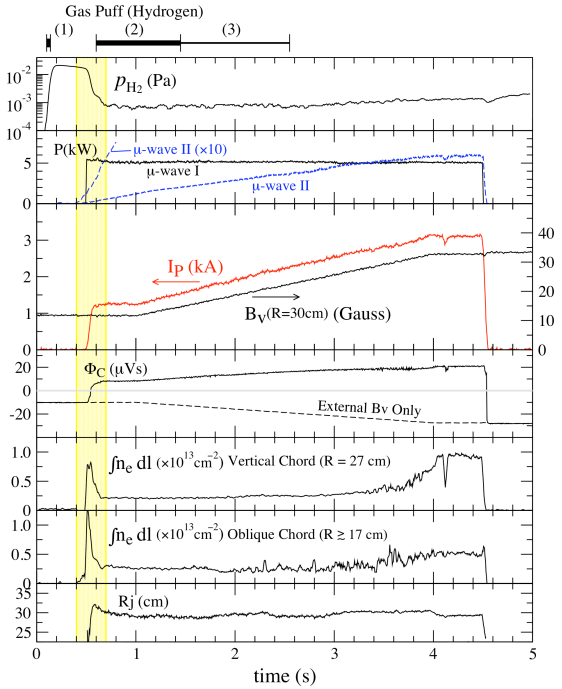
Change of topology:

Open field configuration ==> Formation of initial closed flux surfaces

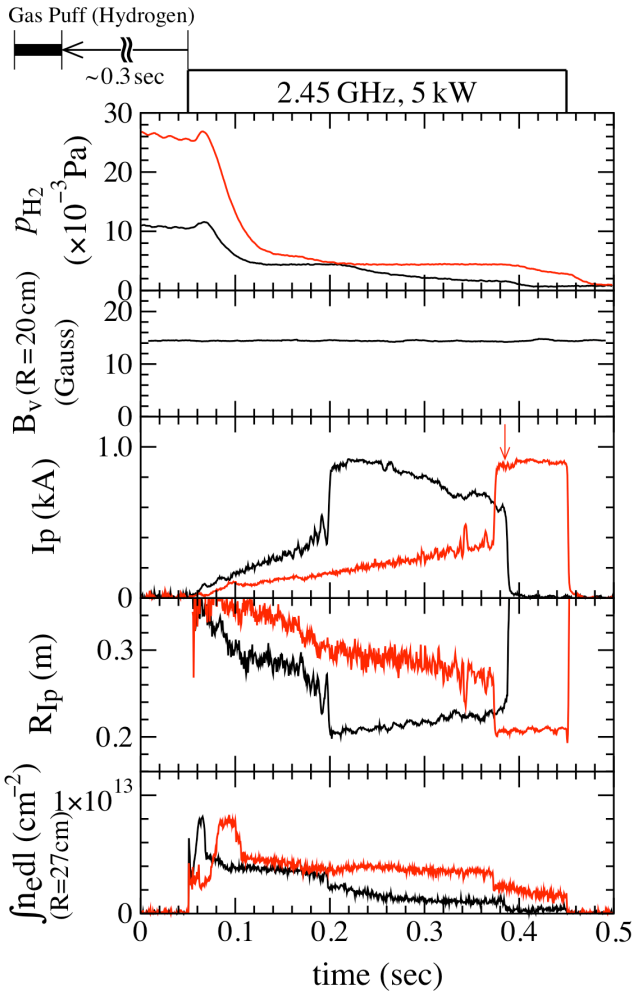
* How does it occur?

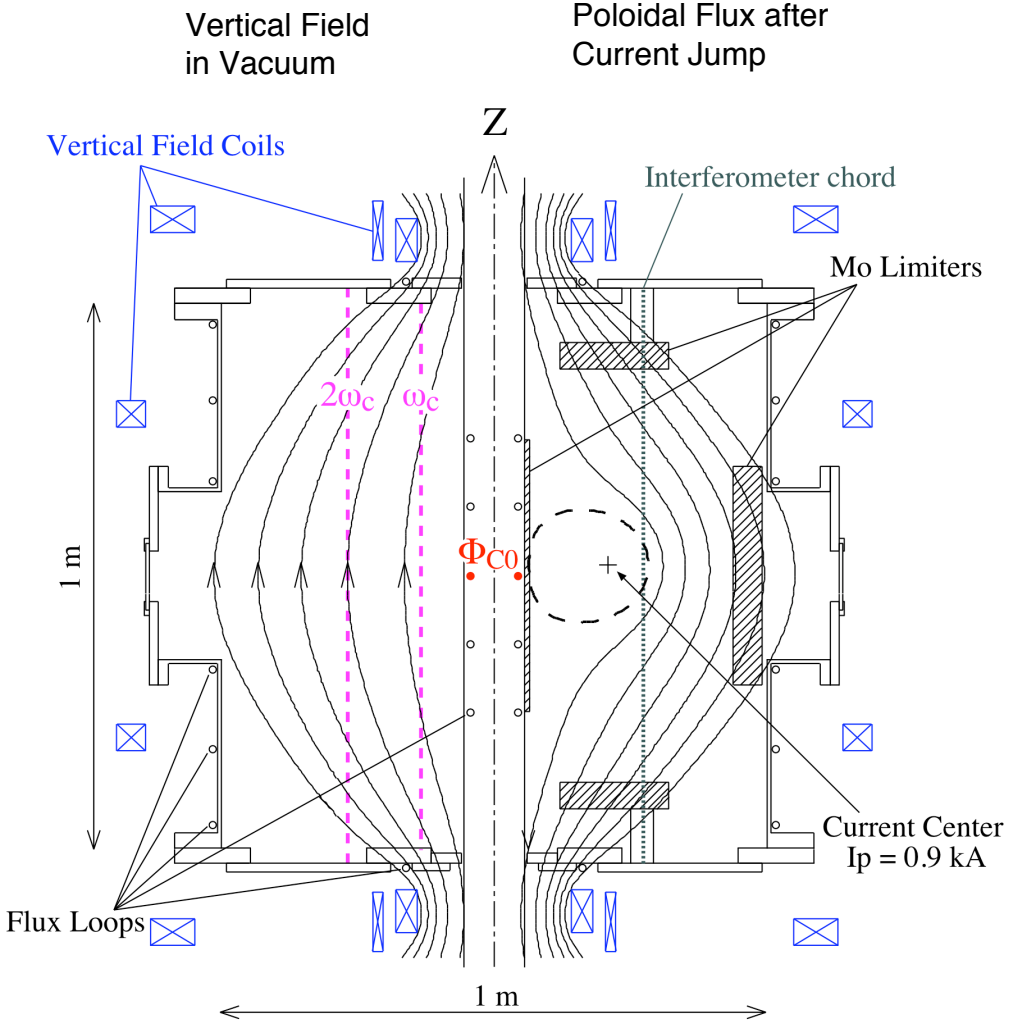
* What is the difference with the Ohmic case?

Experiments under steady vertical field

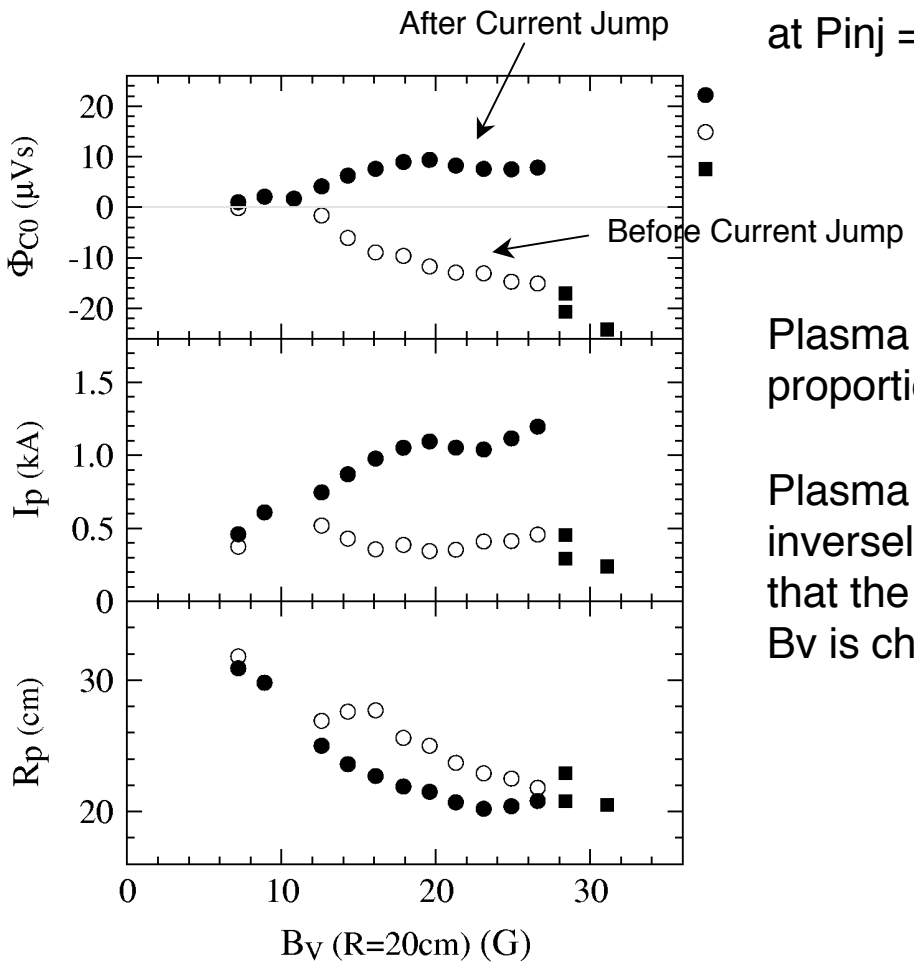


Current Jump and Spontaneous Formation of Closed Flux Surfaces under Steady Vertical Field





Dependence on the Vertical Field Strength



Current jump occurs 11 G =< Bv =< 28 G at Pinj = 5 kW

Φ_{C0} is inverted after current jump

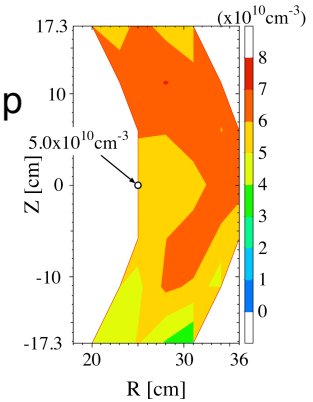
Plasma current after the jump is nearly proportional to Bv.

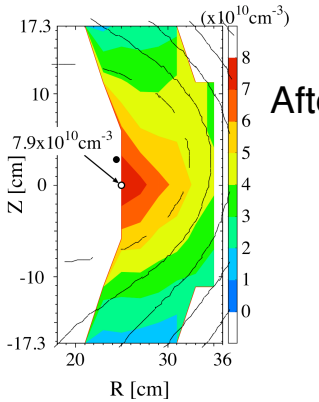
Plasma current before the jump is not inversely proportional to Bv, suggesting that the plasma pressure is changed as Bv is changed.

Change of ne, Vs, Te Profile after Current Jump

Before Current Jump

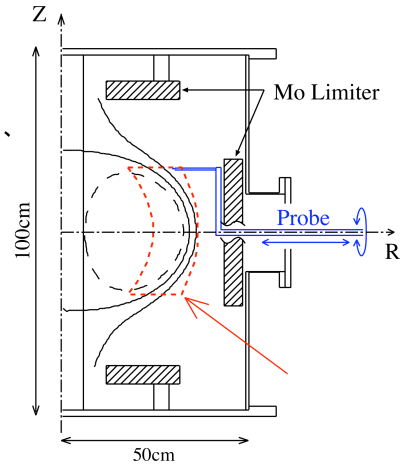
n_e (R,z)



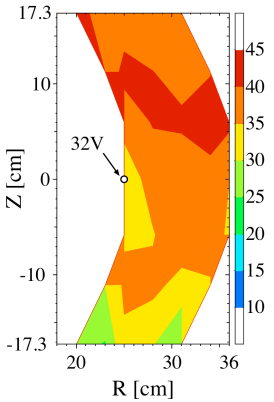


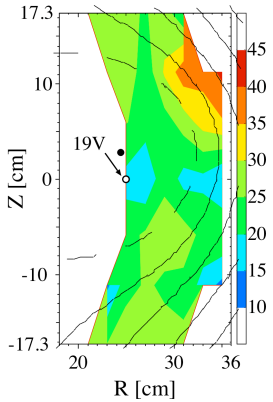
After Current Jump

The contor lines of poloidal flux and n_e profile almost coincide each other.



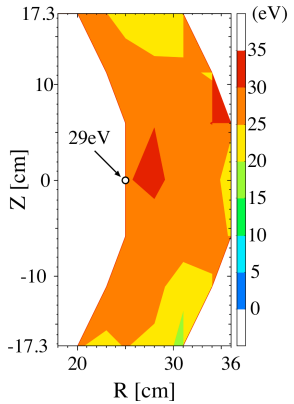
V_s (R,z)

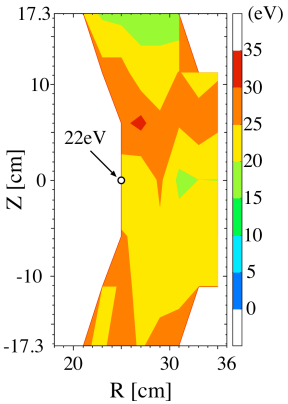




Space potential decreased, suggesting that the confinement of electrons is improved by the formation of the closed flux surfaces.

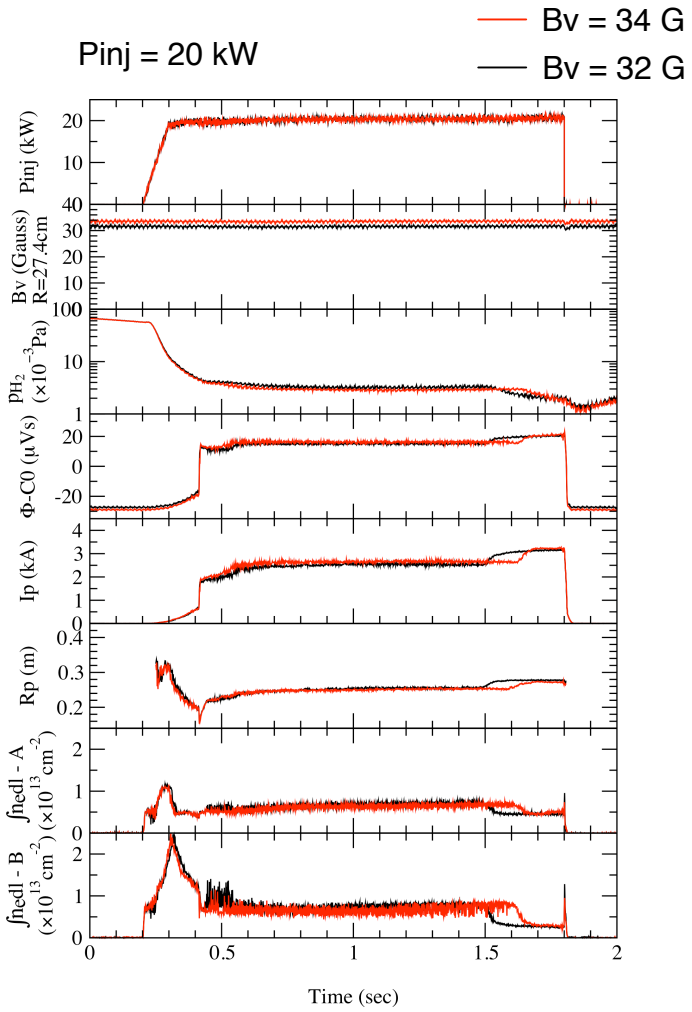
T_e (R,z)

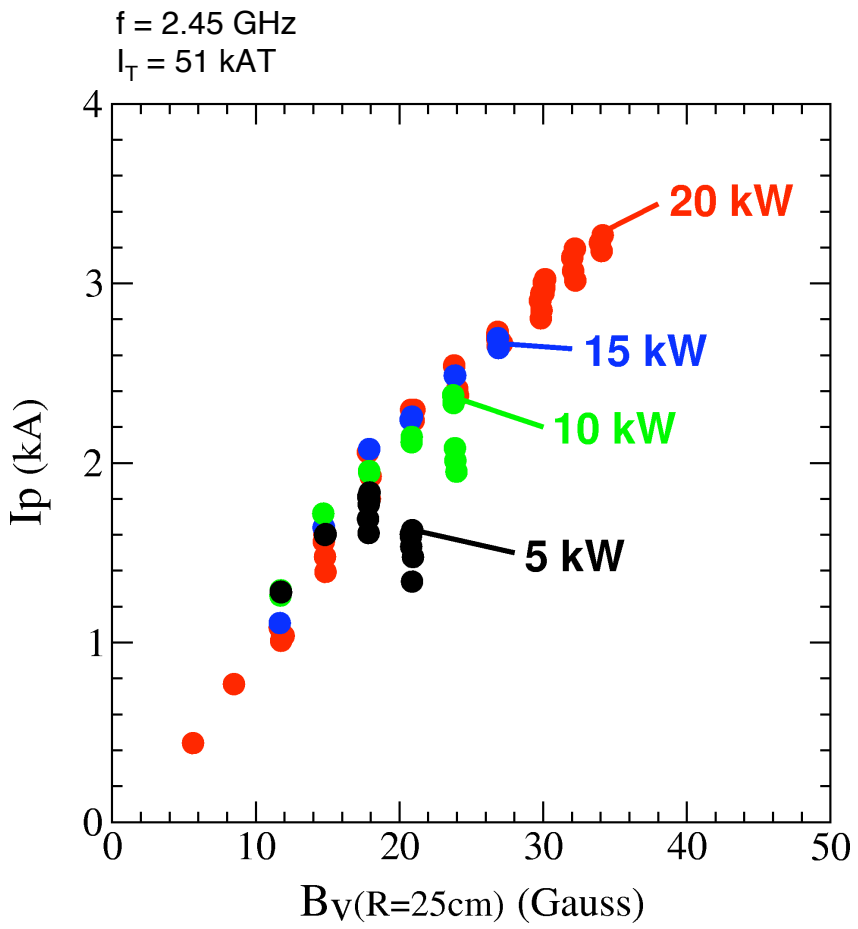




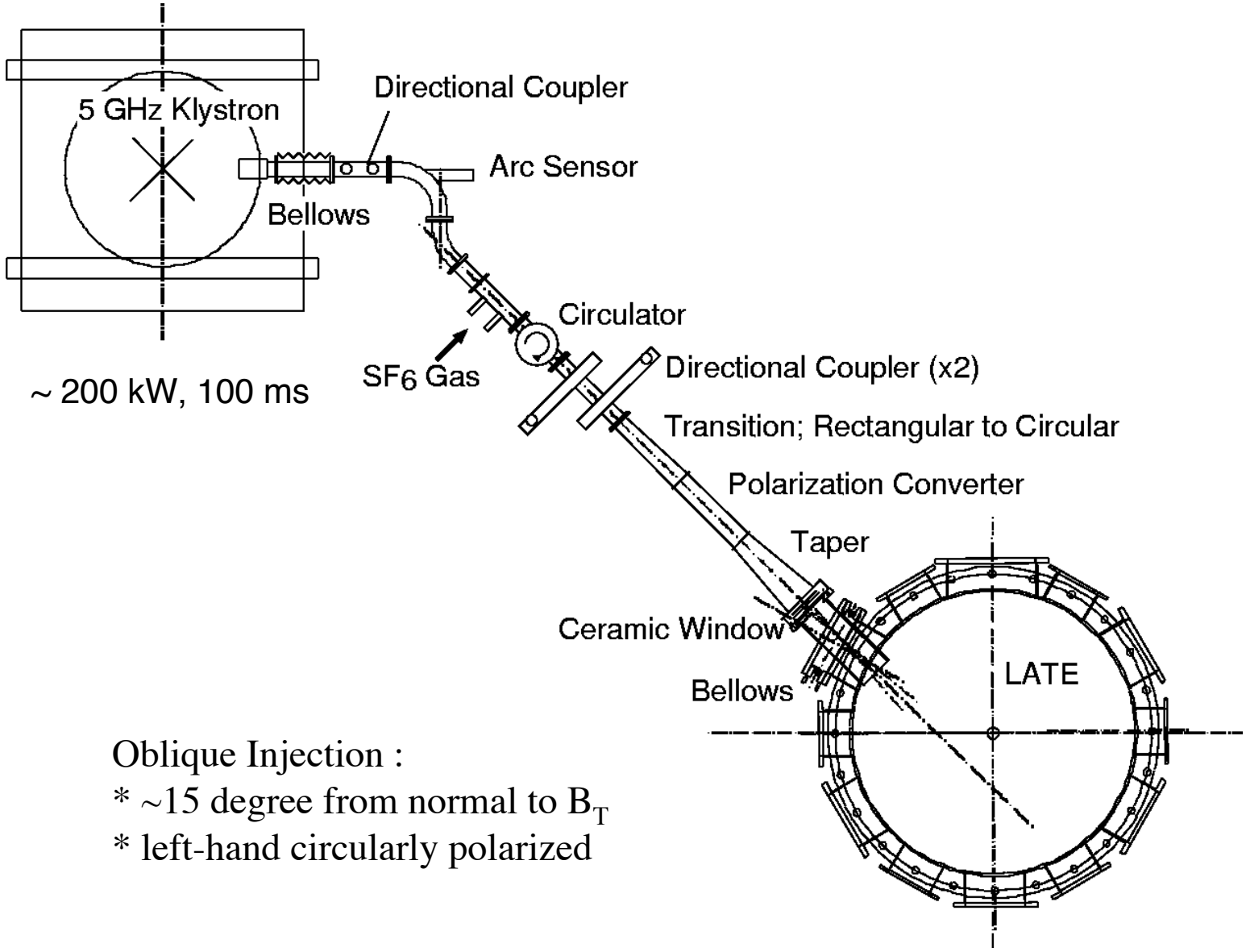
Te is 20 - 30 eV and the profile is broad and do not have any apparent structures corresponding to the closed flux surfaces.

Maximum Ip Increases with Bv and Pinj





5 GHz ECH System Setup

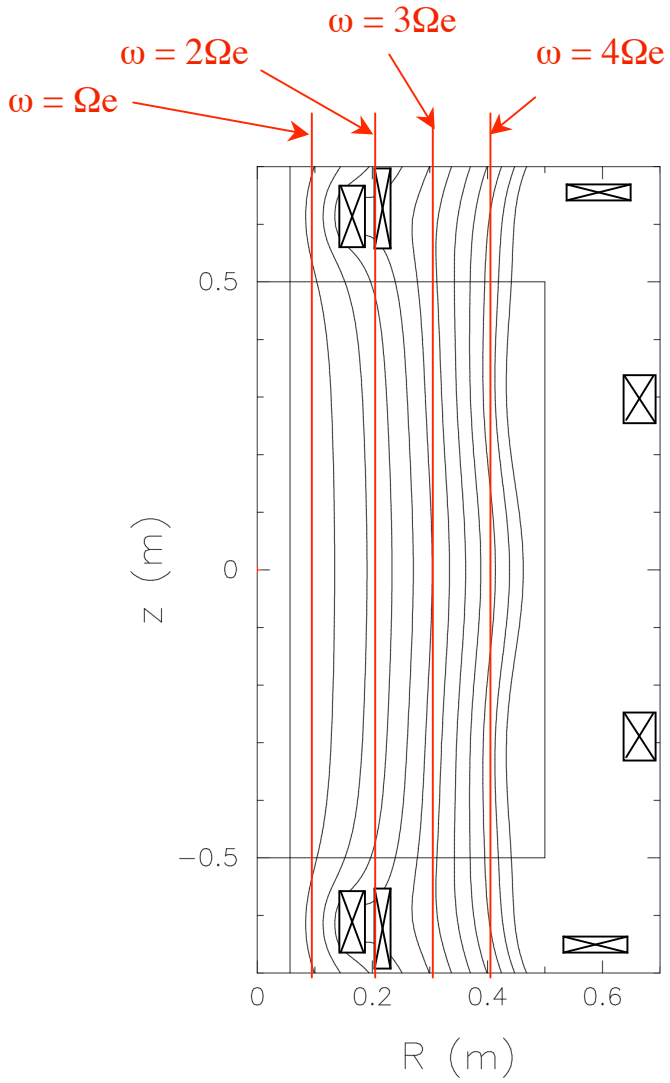


Oblique Injection :

* ~15 degree from normal to B_T
* left-hand circularly polarized

5 GHz ECH System (Photograph)

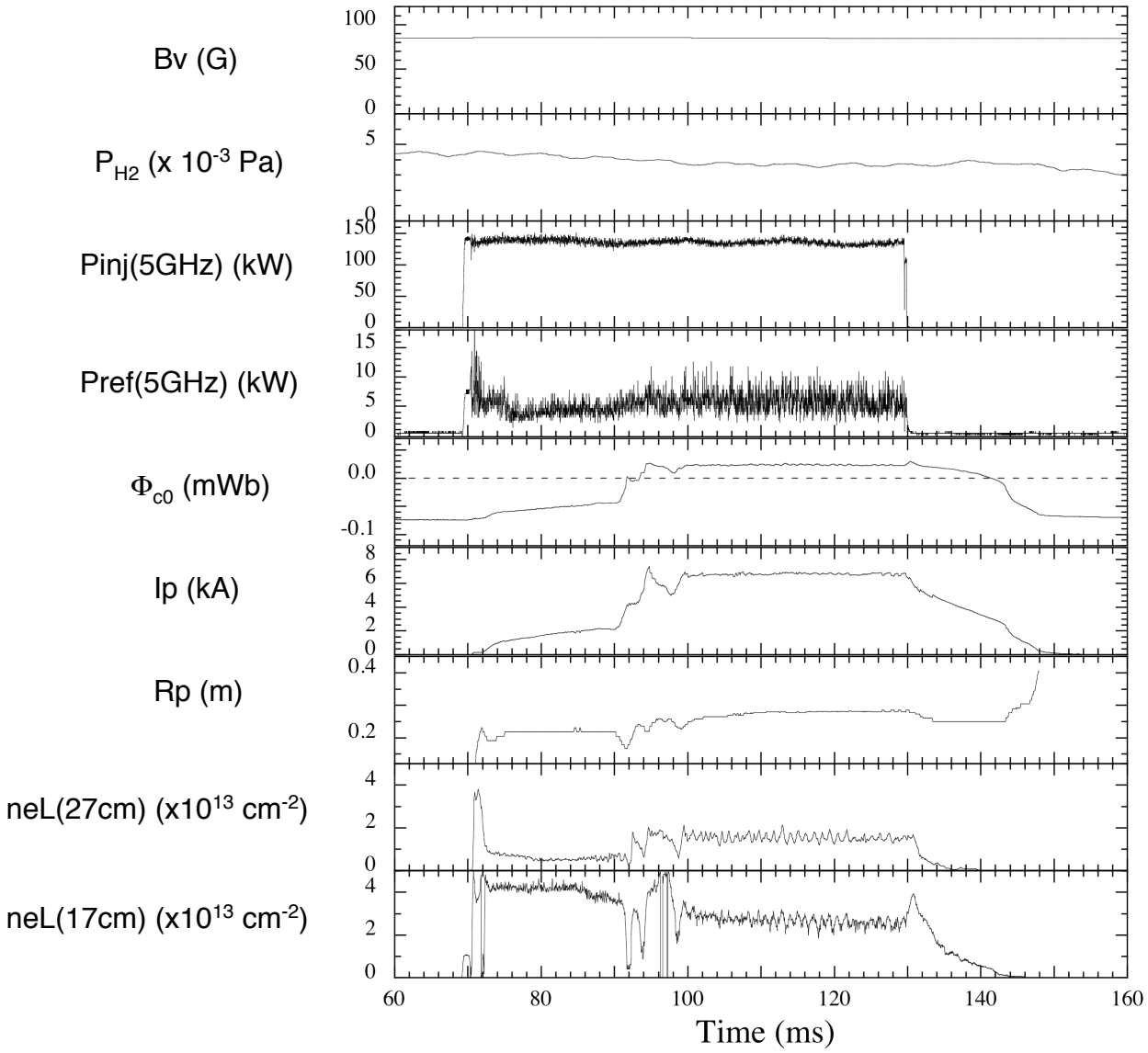
Magnetic Field Configuration



I_T = 90 kAT
f = 5GHz

R(ω = Ωe) = 10.1 cm
R(ω = 2Ωe) = 20.2 cm
R(ω = 3Ωe) = 30.2 cm
R(ω = 4Ωe) = 40.3 cm

Waveform of Discharge (5GHz, 130 kW, 60 ms)



I_T = 90 kAT
Bv = 85 G (@R = 27.4cm)

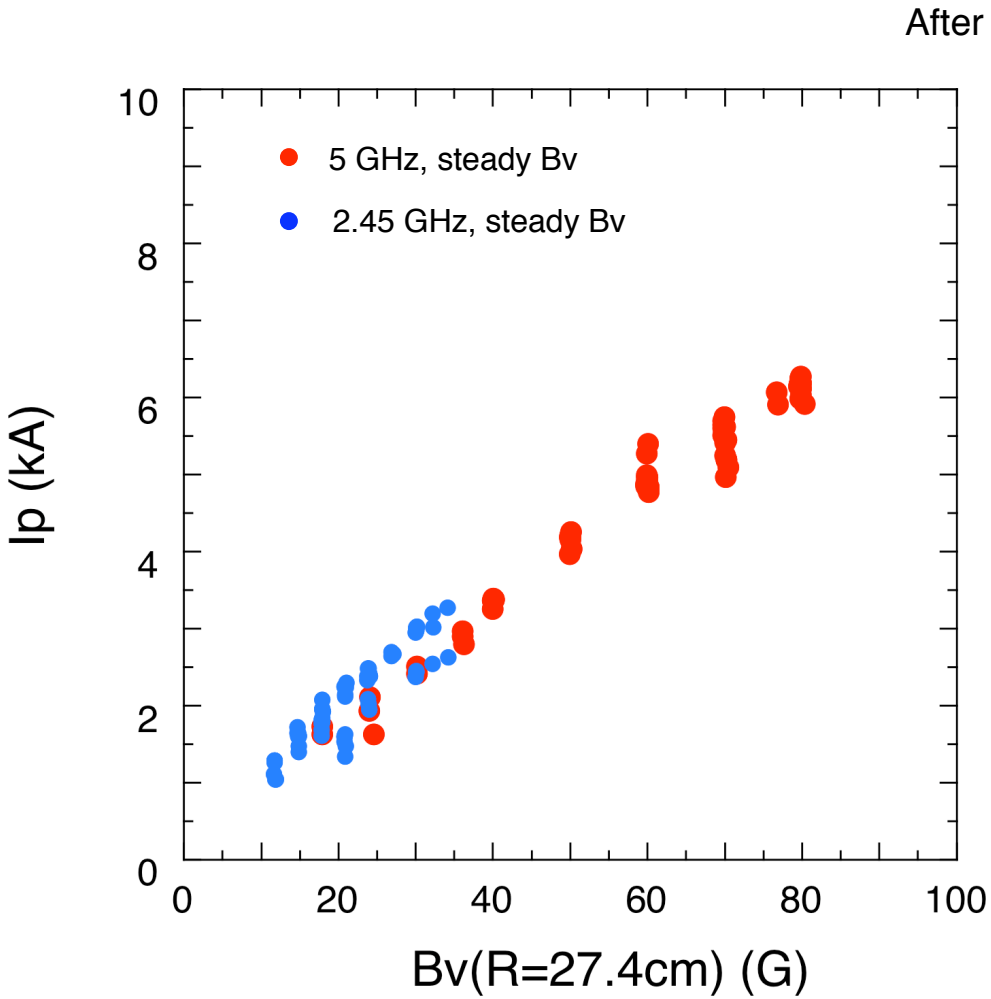
P_{inj} ~ 130 kW, 60 ms

$\Phi_{c0} > 0$: Field Reversal

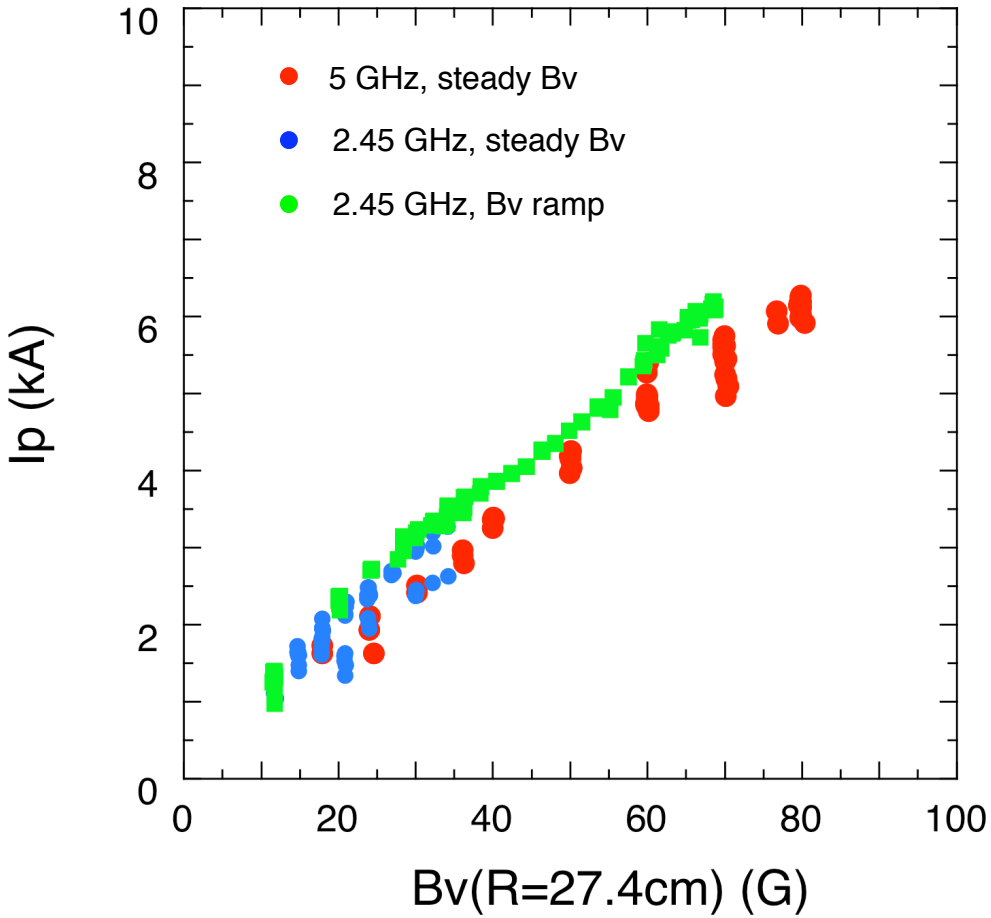
Ip ~ 6.5 kA

$n_eL = 3 \times 10^{13} cm^{-2}$

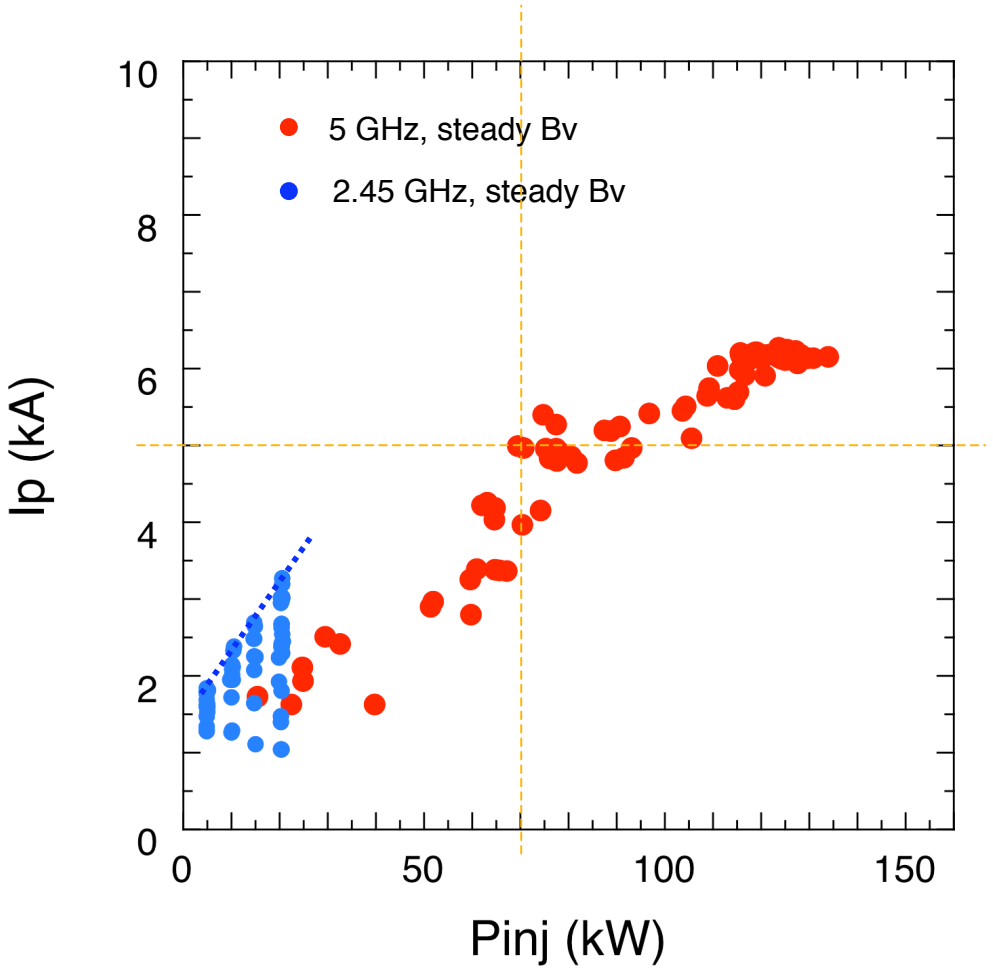
Maximum Ip Increases with Bv (5GHz)



Maximum Ip Increases with Bv (5GHz & 2.45 GHz)

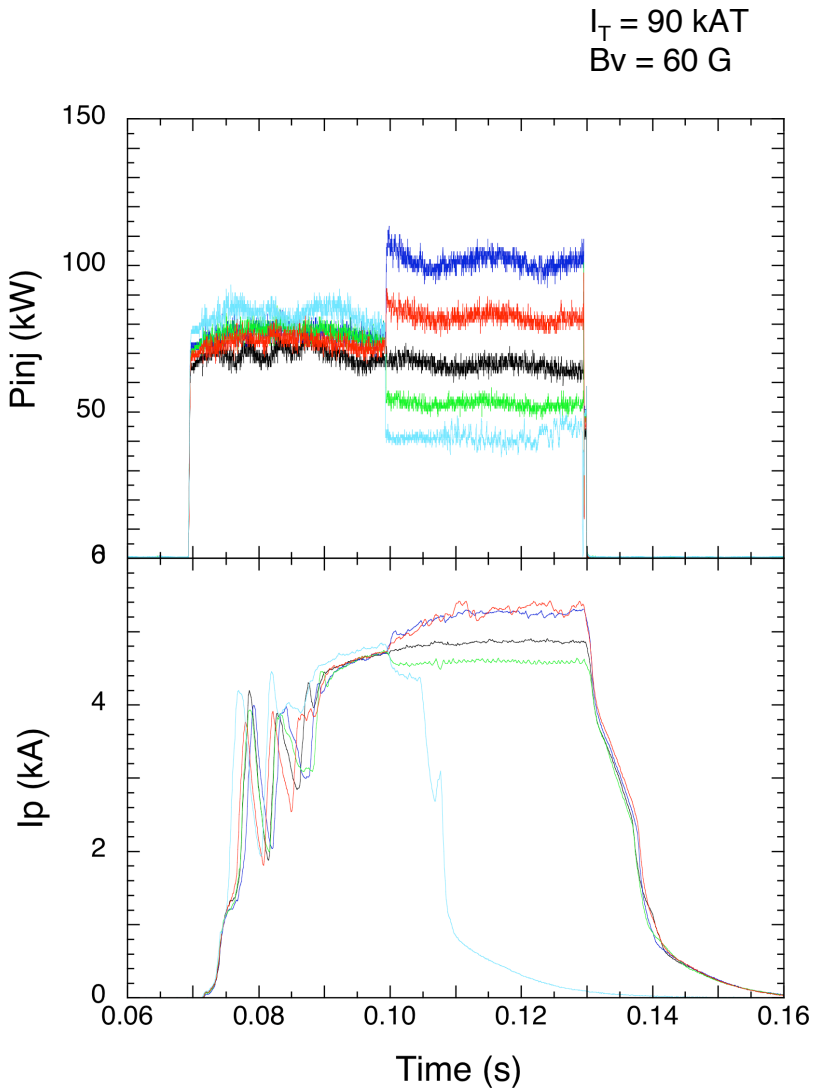


Maximum Ip Increases with Pinj (5GHz)

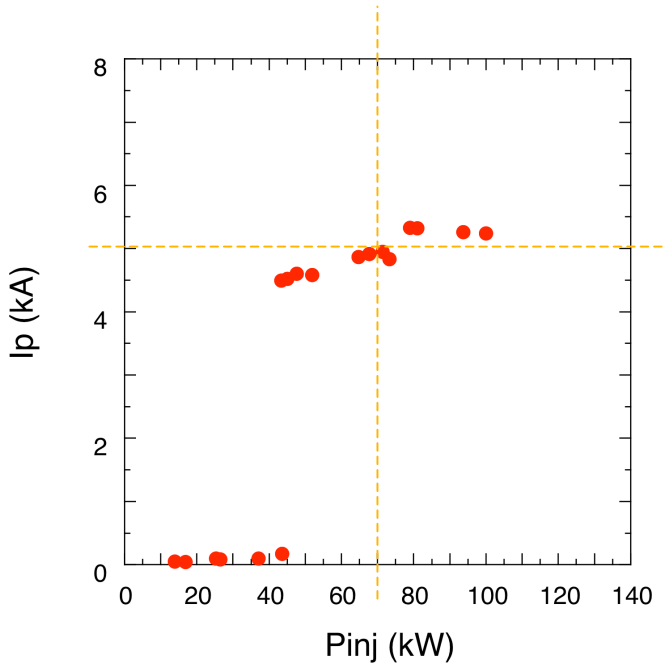


There needs a minimum power for occurrence of current jump.

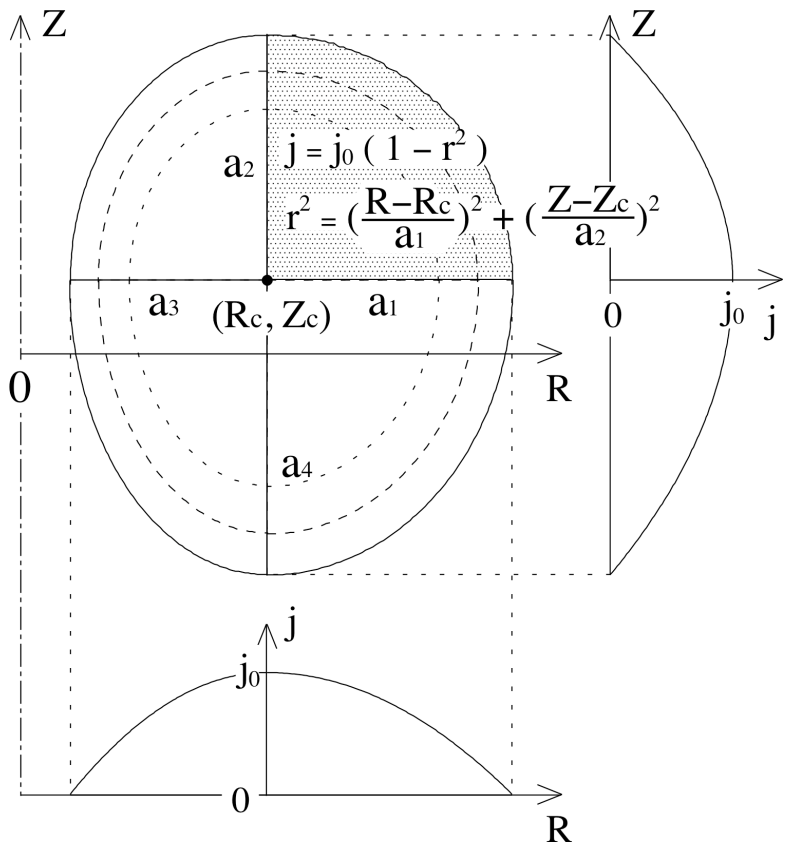
Pinj Dependence after Current Jump



Once the current jump has occurred and the closed flux is formed, microwave power necessary for drive current becomes small.



Current Profile Model

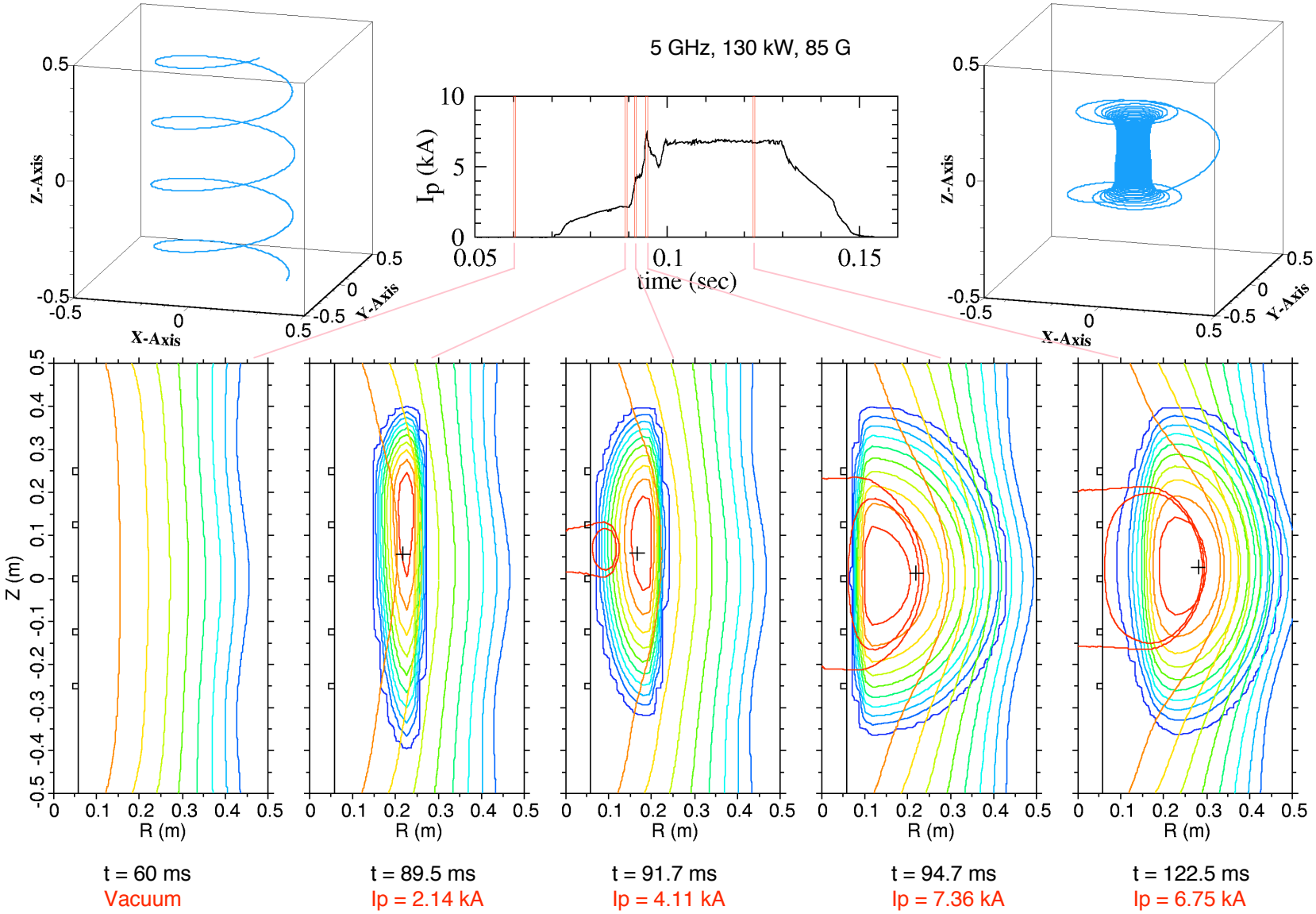


We adopt the following model to express the current profile and obtain 7 values from the measured poloidal flux by least-squares-error fitting method:

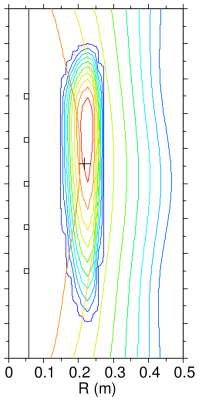
The plasma currrent flows in the area composed of 4 one-quarter-ellipses with parabolic profiles.

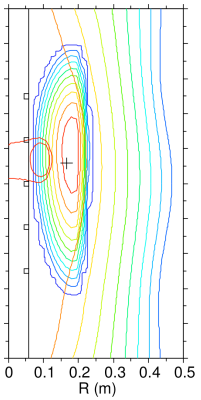
7 fitting parameters:
-positioin of the maximum of current density : Rc, Zc
-the value of the maximum current density : j0
- length of the each axis of ellipse : a1, a2, a3, a4

Model Calculation of Currrent Distribution



A Speculation of Mechanism of Spontaneous Formation





•To start the process of current jump, some amount of plasma current should be made flowing in the open field lines. Such current may enhance the local magnetic mirror and the number of trapped electrons increases. Perpendicular heating by ECH may assist trapping effectively and the plasma pressure will increases, resulting in the increase of pressure-driven current.

•Small closed flux surfaces appear if the enough current are driven. Then the auto-selected current could flow because of the different direction of shift of drift surfaces of passing electrons around the closed flux surfaces. The shift of the drift surface of electrons carrying counter-current is inward and they may escape beyond the separatrix to the wall or hit the inner wall (center stack), while that of electrons carrying co-current is outward and may be effected nothing.

•Such positive feedback mechanism increases plasma current till the initial closed flux surface is formed and balanced by the MHD equilibrium condition

* Contribution of bootstrap current and/or EC driven current is an open question.

Summary

•By injecting microwave power under steady vertical field at low gas pressure, plasma current suddenly increases in the course of slow rise ("current jump"). By this process, initial closed flux surfaces are spontaneously formed.

•The steady value of plasma current after the formation of the closed flux surfaces is proportional to the vertical field strength so as to maintain the MHD equilibrium. Increasing both vertical field strength and injected microwave power, more plasma current can be generated. So far, plasma current up to 6.5 kA is obtained when 5 GHz, 130 kW microwave power is injected at Bv = 85 G.

•By the magnetic measurement and model calculation of current distribution, it is suggested that elongated current distribution in the open field lines enhances the local magnetic mirror, and during the current jump, small closed flux surfaces are formed and become large as the current profile spreads toward outboard side.