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Investigation of Field-Null and 2D Map of Loop Voltage for Initial KSTAR Operation*

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이화여자대학교, 서울

배 영순, 조 무현, 남궁 원
(포항공과대학교)
김 재현, 김 진용
(한국기초과학지원연구원)

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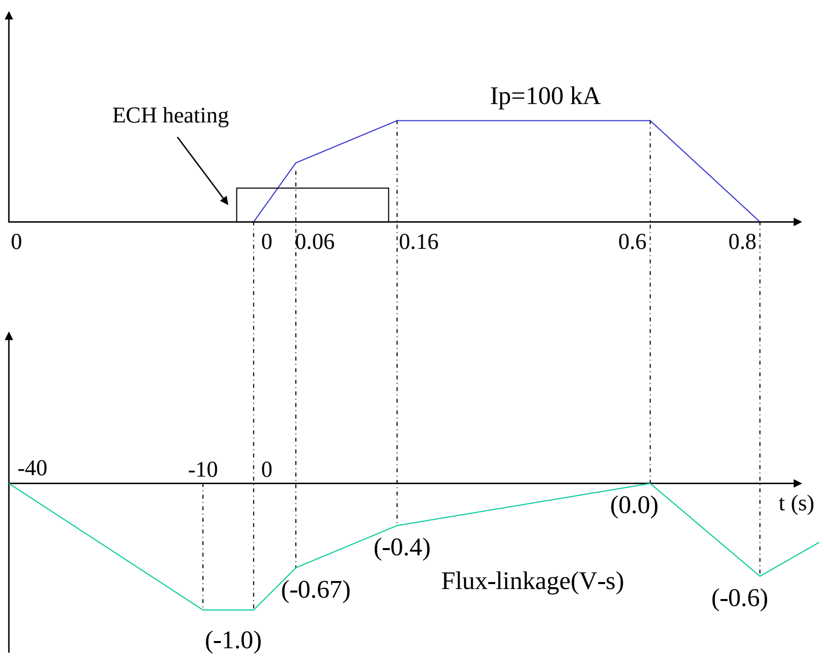
Abstract

- The field-null configuration is an important and essential condition of the ECH pre-ionization for the successful breakdown and reduction of the required loop-voltage in the initial KSTAR operation phase.
- The proper conditions of each PF-coil current are under investigation for the field-null structure and for prompt ramp-up of the plasma current with the ECH-assisted start-up. Recently, a few proper waveforms of PF-coil current are reported using a dump-resistor system in order to obtain the field-null at R = 1.6 m and 5 V loop voltage [1].
- Also, the required values of dump resistors for each PF-coils are found to obtain plasma equilibrium. One may note that dump resistors are being considered as a possible option to replace MG set in the initial KSTAR operation phase.
- In this paper, we present a more detailed study on 2-D field lines and 2-D map of the loop voltage inside the vacuum vessel for the PF-coil currents given in ref. 1. For this we use the POISSON code, which is a 2-D electrostatic solver using finite element method, and a comparison is made with the result in ref. 1, which is obtained from TSC code.

A 5 V loop voltage scenario (TSC code results)



	I_{PF} (kA/turn) (t=0 ms)	I_{PF} (kA/turn) (t=60 ms)	V_{PF}(kV)	P_{PF}(MW)	Modified weighting factor	* Normal weighting factor
PF1	1.75	1.28	1.50	2.62	0.9726	0.9726
PF2	3.01	2.07	1.51	4.53	1.5	1.2157
PF3	2.28	1.55	0.79	1.80	2.4315	2.4315
PF4	5,21	3.54	1.21	6.33	1.2	1.6210
PF5	0.57	0.38	1.58	0.90	2.5	0.7815
PF6	0.18	0.12	1.76	0.32	7.0	1.3677
PF7	0.43	0.17	1.52	0.56	3.0	2.4315
ψ (Wb)	−1.0	−0.67				
total				16.25		

Plasma position: R = 1.6 m, z = 0 m
Plasma radius: a = 0.2 m
Plasma current: Ip = 50 kA at t = 60 ms
Volt-sec: $d\Psi/dt$=[-0.67 – (-1.0)]/60 ms=5.5 V

Ref. J. Y. Kim, Technial Report, "New Start-up Scenarios for the KSTAR Plasma," T730-AT1-PH2-040316/JYKIM-E1-D01.

PF coil currents, eddy current, plasma current

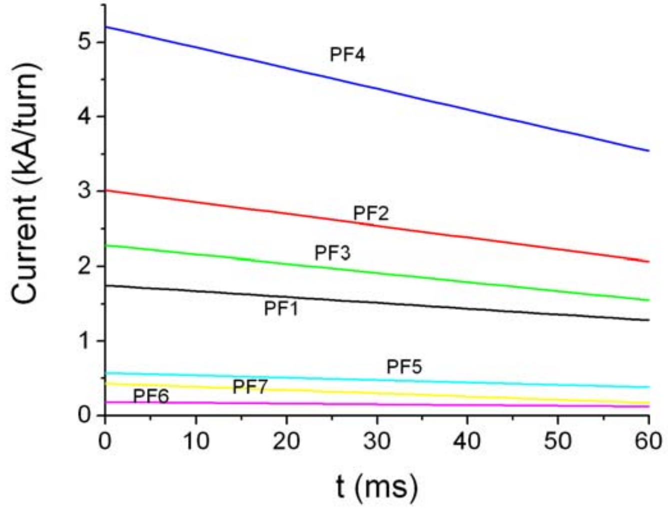


Fig. 1

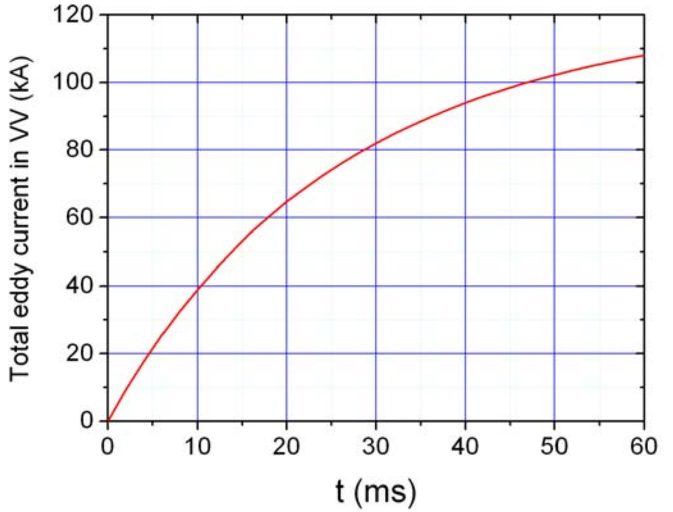


Fig. 2

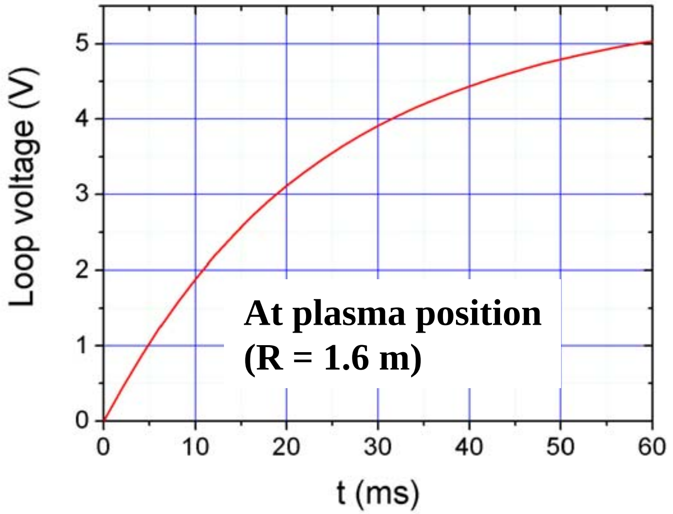


Fig. 3

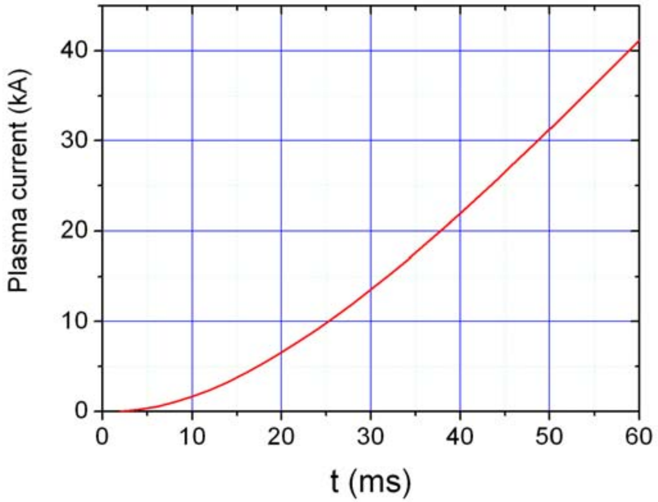
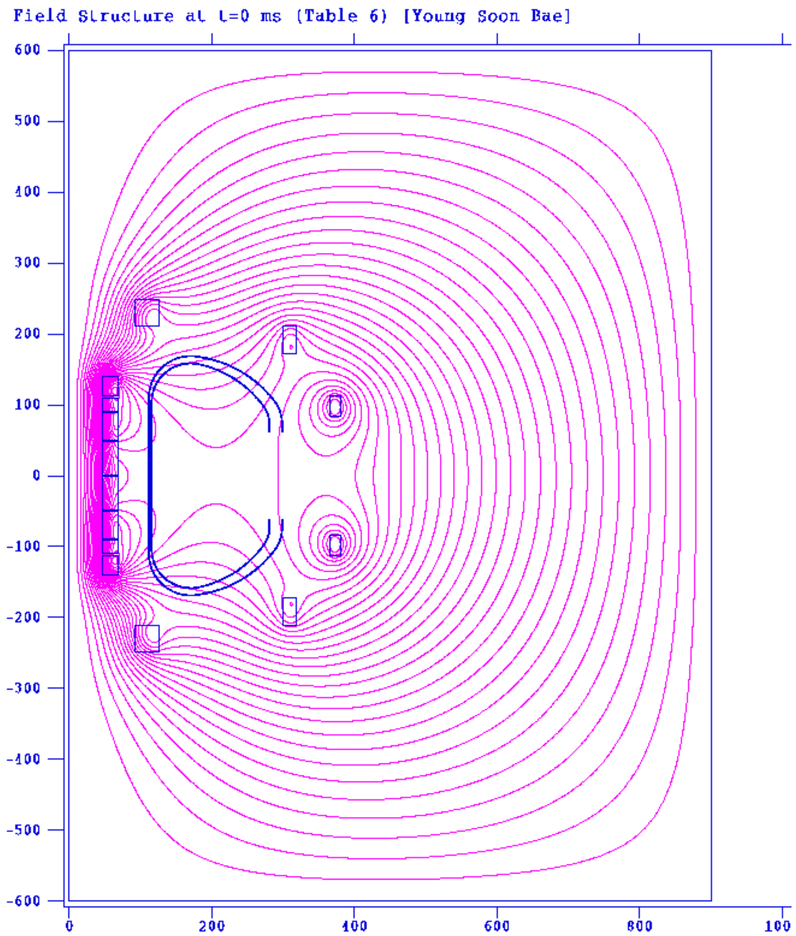
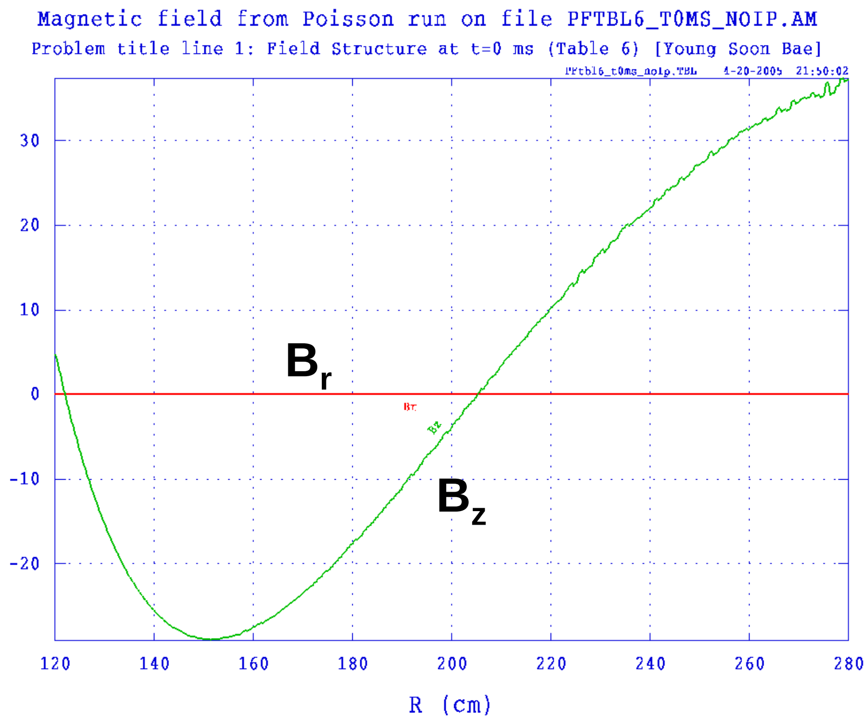


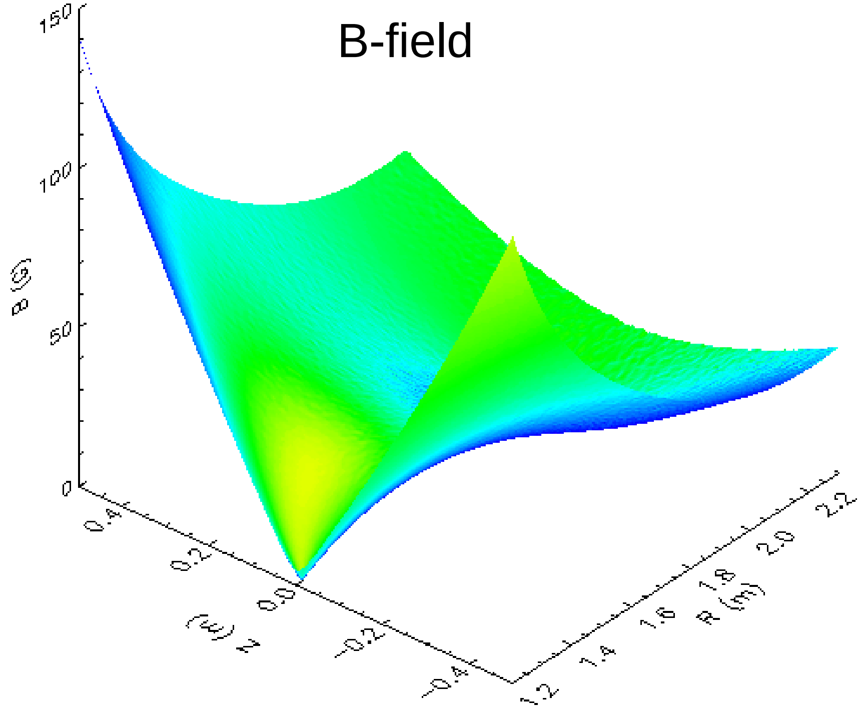
Fig. 4

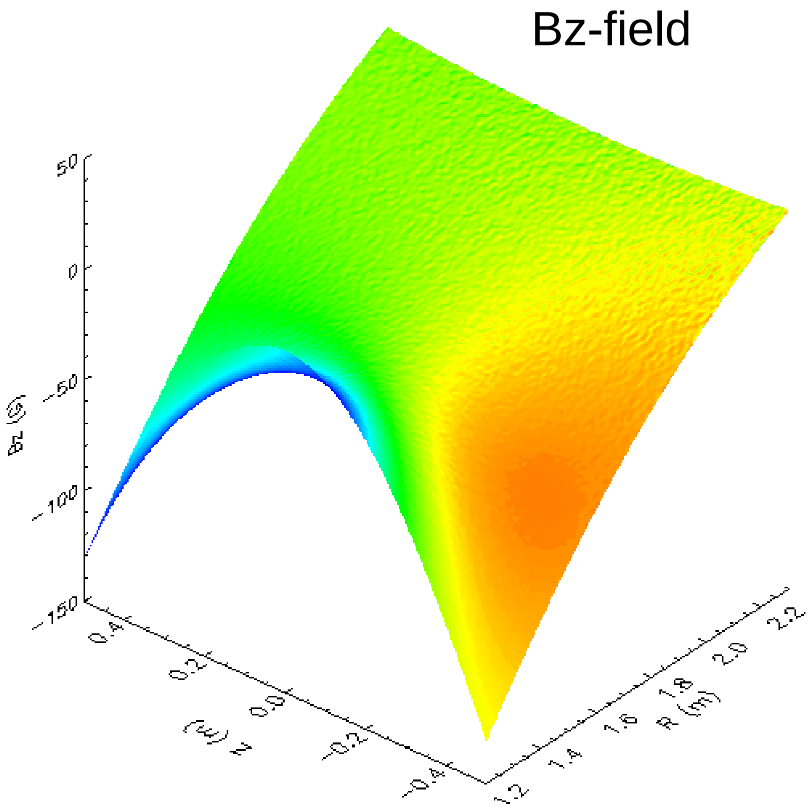
Field-Null at t = 0 ms





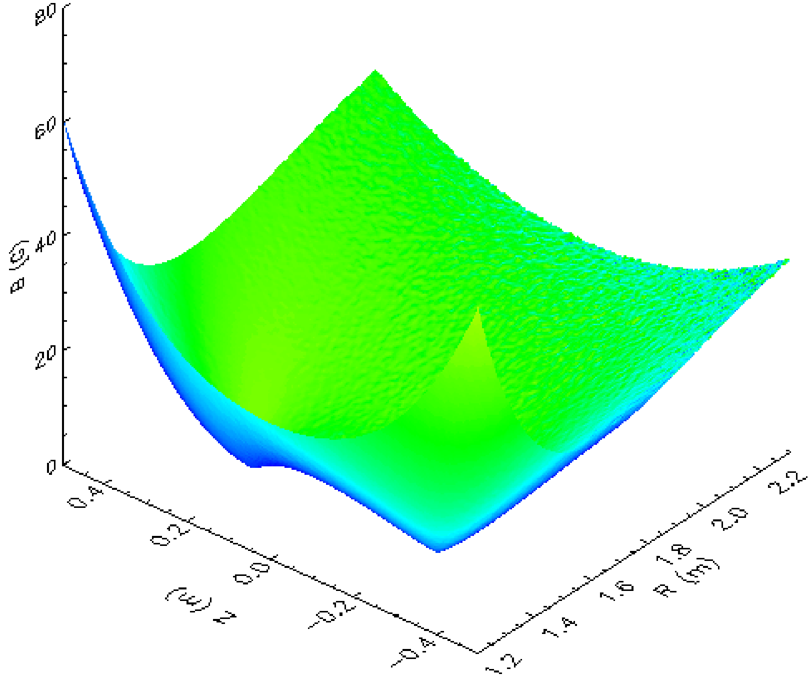
2D B-field Distribution for field-null (t = 0 ms)



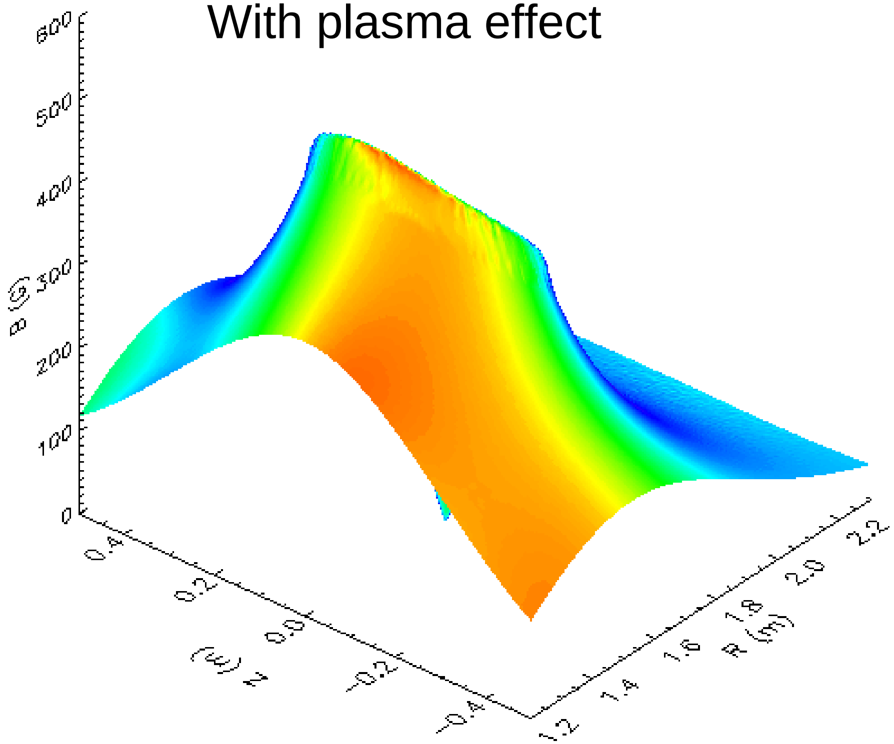


2D B-field distribution at t = 60 ms

Without plasma effect

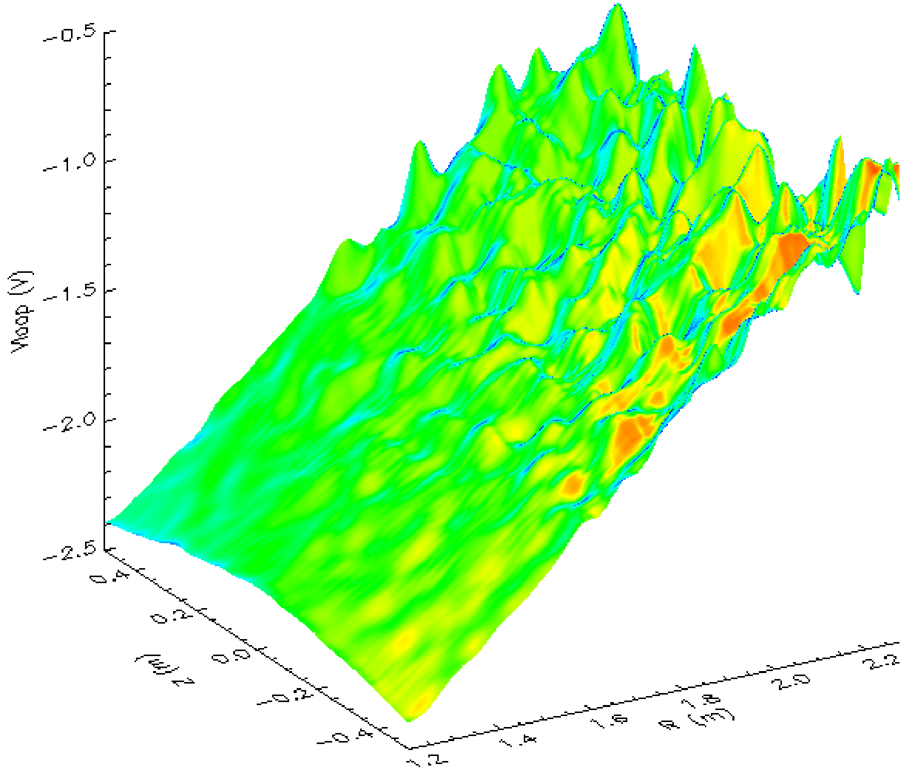


With plasma effect

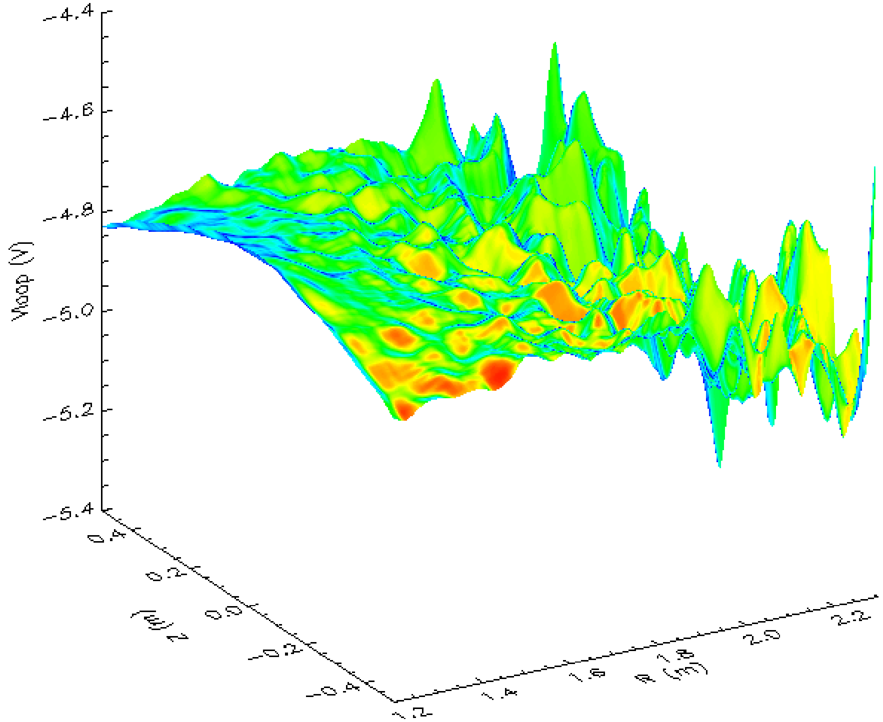


Loop voltage without effect of plasma current

t = 10 ms

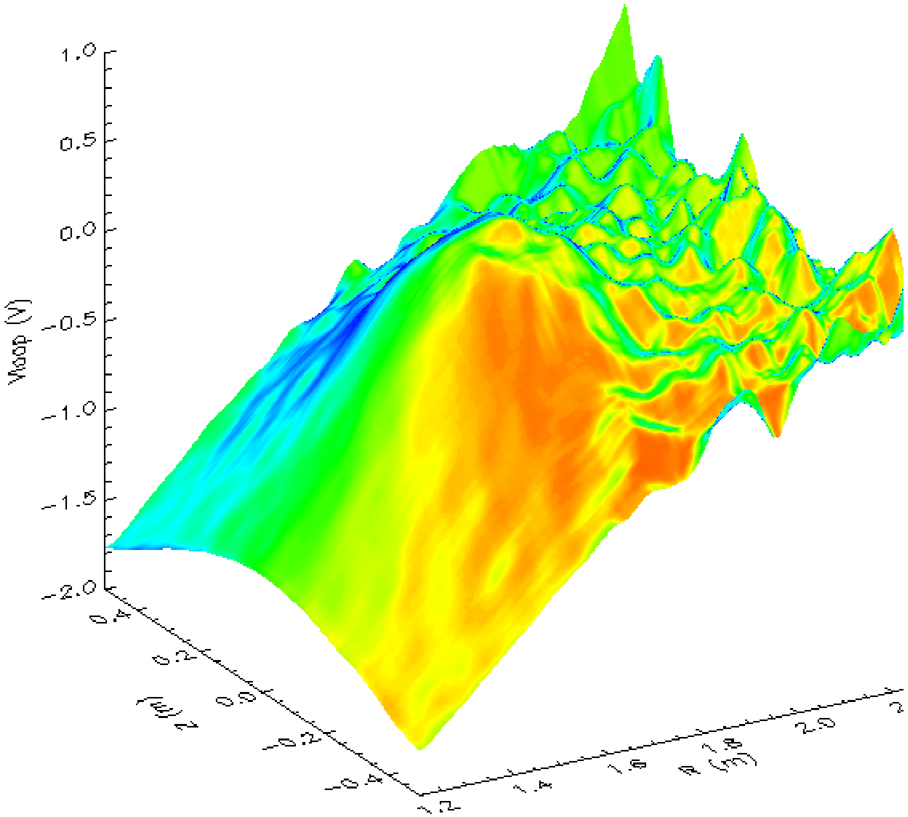


t = 60 ms

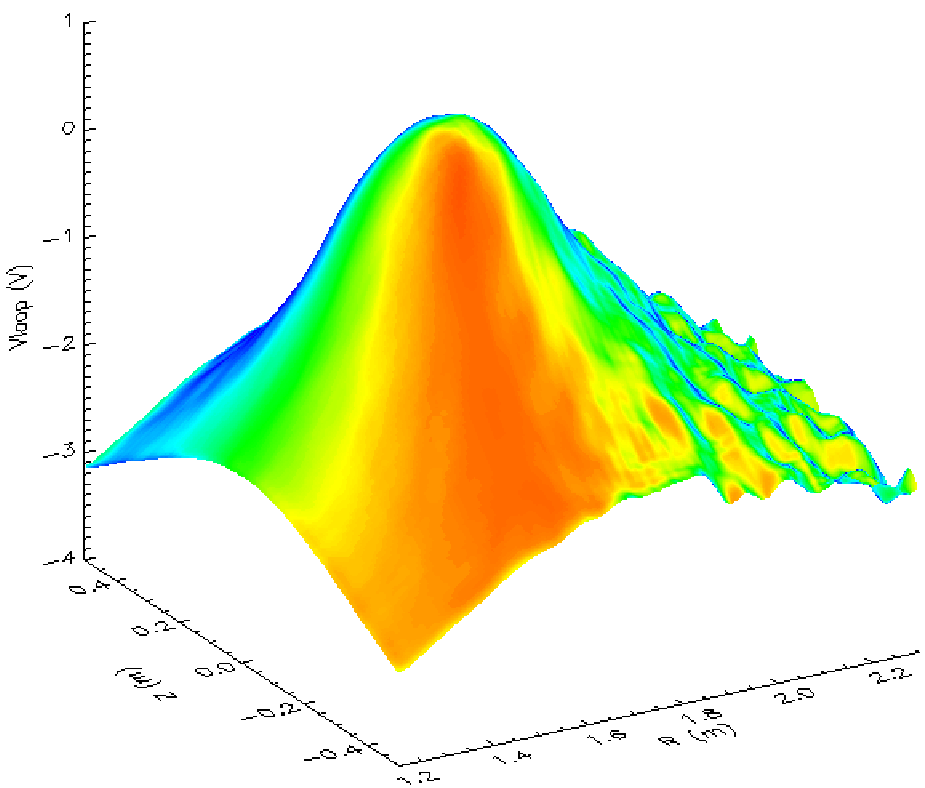


Loop voltage with effect of plasma current

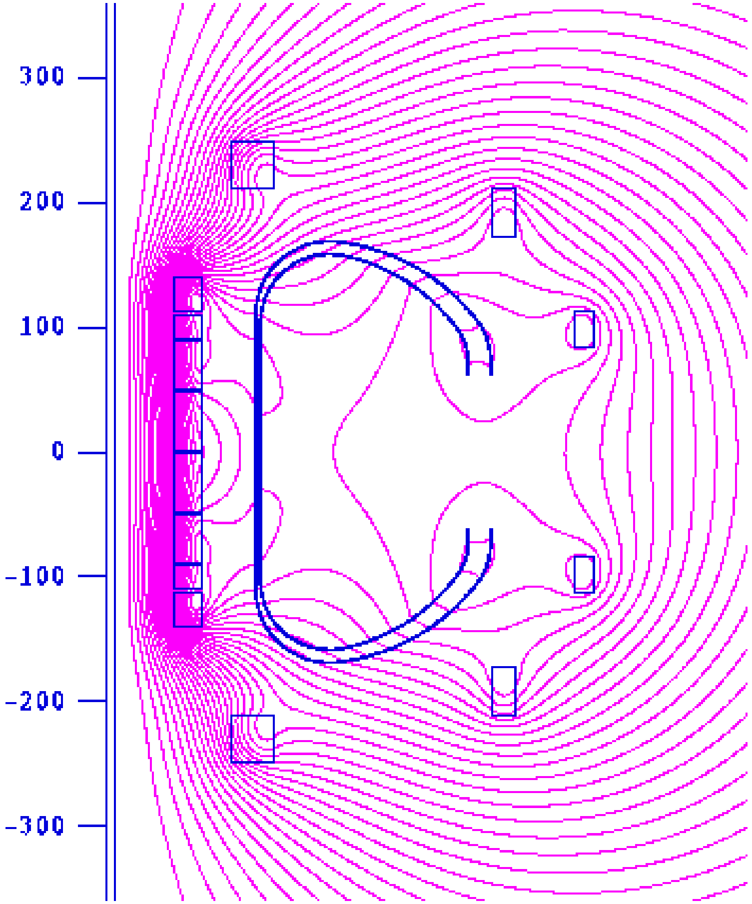
t = 10 ms



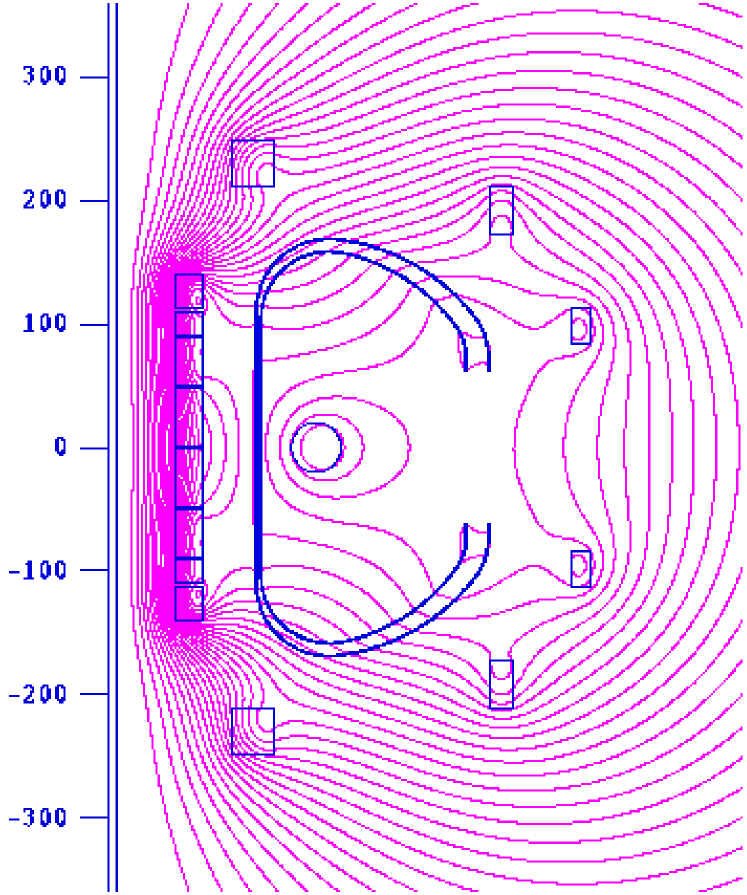
t = 60 ms



Flux-contour at t = 60 ms



Without plasma



With plasma

Summary

- If it is true that the plasma current is increased slowly during blip period (t = 0 ms ~ 60 ms) as shown in Fig. 4, the increasing of loop voltage as shown in Fig. 3 would be modified due to the additional magnetic flux induced by the plasma current.

- The plasma induced flux lowers the loop voltage as seen in the POISSON simulation.

- It is wondered that the plasma current flows before the breakdown. We normally expect the abrupt change of the plasma current at the breakdown. However, Fig. 4 shows the slowly increased plasma current.

- When the circuit equation of the plasma current, $dI_p/dt = (V-R_pI_p)/L_p$, is solved, it is needed to be checked that all kinds of loss effect of the plasma is considered. The loss terms are seen in the energy balance equations describing the plasma temperature and the plasma density. Hence, they are related to the plasma resistivity, R_p.

- Self-consistent code should be developed to find true PF coil current scenario: considering pre-ionization effect by ECH RF power, eddy current effect, plasma current effect, etc.)