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Numerical Simulation Of RE Deconfinement Experiment Using Local Magnetic Field Perturbation In ADITYA Tokamak

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Abstract

- In this work, an attempt has been made to numerically model the runway electron extraction experiment using LVF coil in ADITYA. All coil systems to generate magnetic field configuration and the runway electron dynamics without radiation loss of the RE has been taken into consideration in the numerical simulation to explain the experimentally observed extraction of the RE in ADITYA tokamak.
- The magnetic field generated by all coil systems of ADITYA are numerically modeled and calculated by EFFI code and plasma equilibrium field is obtained from IPREQ code. The field calculated by the EFFI code and IPREQ then used by the PARTICLE3D code to track the runway electrons following relativistic dynamics without radiation loss.
- Simulation results suggests prior de-confinement of runway electrons (RE) under the influence of local vertical magnetic field perturbation in ADITYA tokamak which is in agreement with the experimental observation. As RE mitigation is of great concern for the ITER, the discussed RE de-confinement simulation technique has the potential to be one of the RE mitigation simulation method which could be adopted for ITER and DEMO like reactors.

Introduction and Background :

- Runway electrons [1] carries significant amount of plasma energy of several MeV can severely damage the first wall and in-vessel components of the tokamaks [2] as well as can interfere with the complex plasma phenomena like plasma equilibrium, MHD instabilities and plasma disruption. Therefore the control of REs are of great concern for reliable operation of any tokamak irrespective of it's size including ITER and DEMO like reactors.
- While Several techniques [3 - 5] exists for runway electron suppression and extraction in several tokamaks viz., MGI, RMP field, additional gas-puff, ECH heating and LHCD, in the ADITYA tokamak experiment local magnetic field perturbation technique has been applied for RE extraction.
- In ADITYA local vertical field coils (LVF coils) to generate local magnetic field perturbation has been successfully applied to extract runway electrons during early phase of discharge time (0.5 – 15 ms) which improved the plasma performance as reported in ref [6].
- An attempt has been made to numerically model the runway electron extraction experiment using LVF coil in ADITYA. All required coil systems of ADITYA and plasma equilibrium have been used to generate magnetic field configuration and study the RE extraction dynamics without its radiation loss in ADITYA tokamak.

ADITYA Experiment Set-up [6]

- LVF coils are at one toroidal location having configuration of Helmholtz like coils placed at the top and the bottom of the machine.
- Coils are connected in series to produce LVF perturbation in opposite direction to the actual equilibrium field with its magnitude varying from 150 to 260G at R_0.

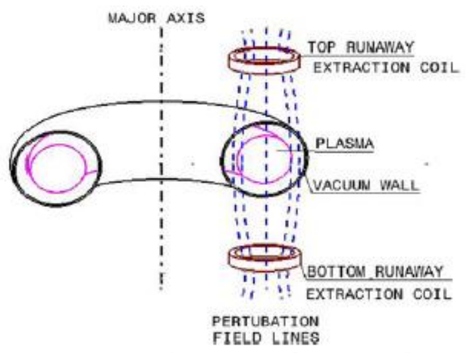

FIG. 1 Schematic of LVF coil integration with the ADITYA Tokamak.

Experimental Observations [6]

- Experiment is carried out in the initial phase of breakdown(0 – 15 ms) and in the ramp-up phase by applying the LVF perturbation.
- With the application of LVF perturbation significant reduction (~5 times) of hard x-rays is observed in both initial and ramp-up phase.

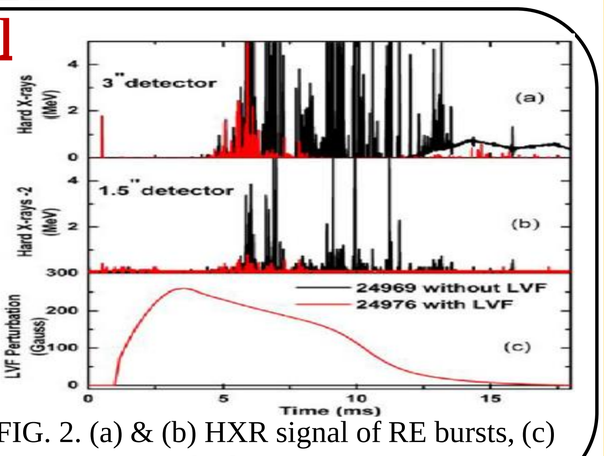

FIG. 2. (a) & (b) HXR signal of RE bursts, (c) Applied LVF currents.

Numerical Modeling of the Experiment:

- The integrated PARTICLE3D-EFFI-IPREQ code has been developed which uses field calculated by the EFFI code [7] from the coil sets and plasma equilibrium fields by IPREQ [8] code to track the runway electrons following relativistic dynamics without radiation loss using PARTICLE3D code [9]. Code has the capability to track particle orbits under the influence of any combination of symmetric and asymmetric fields in tokamaks.
- OT, TFC, BV and LVF coil systems of ADITYA are numerically modeled and analyzed by EFFI code , which is then used by PARTICLE3D code to track the runway electrons started from R, Z grid points in the plasma region.
- Initial conditions used for REs : Energy: 1 to 3 MeV, Pitch Angle = 0^o, V_φ direction in -ve B_φ, B_φ = - 0.824 T, LVF Field |Bz| = 255e-4 T at R=0.75 m.

Simulation Results:

Using Coil Generated B field

-ve LVF

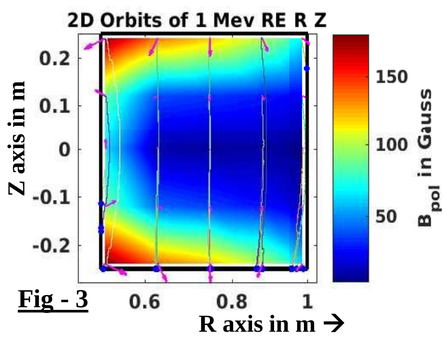

Fig - 3

No LVF

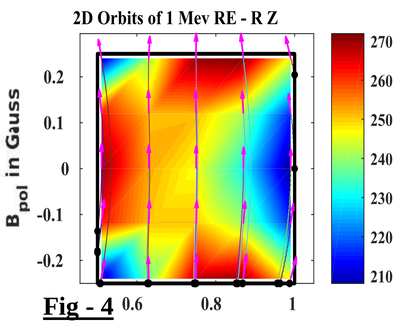

Fig - 4

+ve LVF

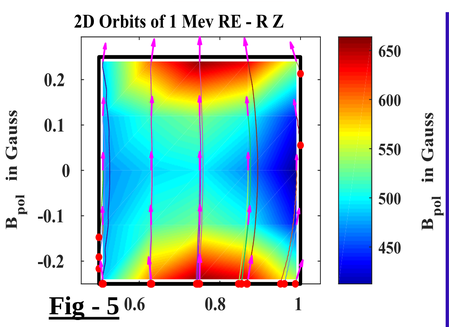

Fig - 5

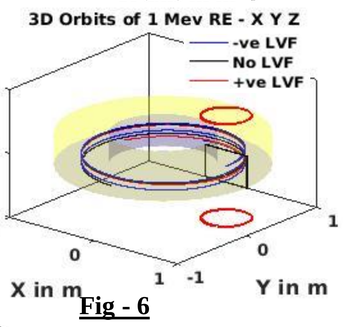

Fig - 6

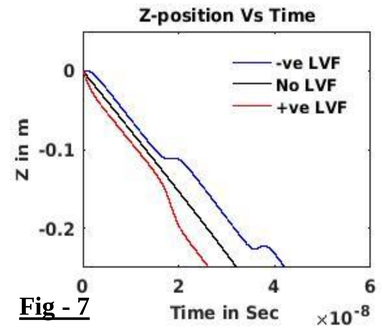

Fig - 7

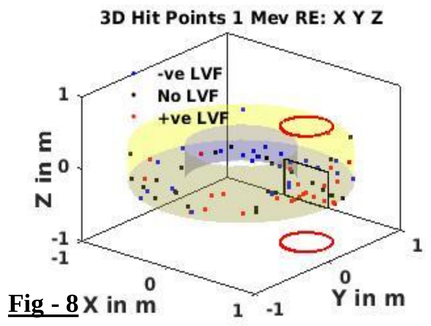

Fig - 8

Equilibrium Generated B field

-ve LVF

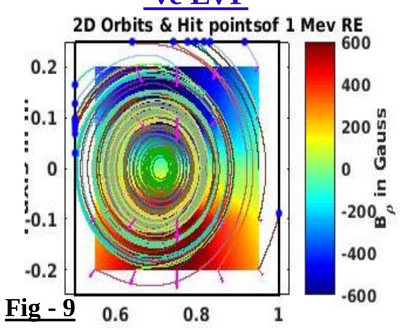

Fig - 9

No LVF

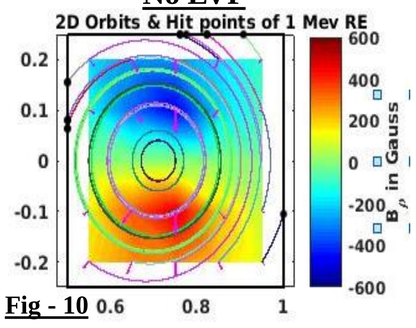

Fig - 10

+ve LVF

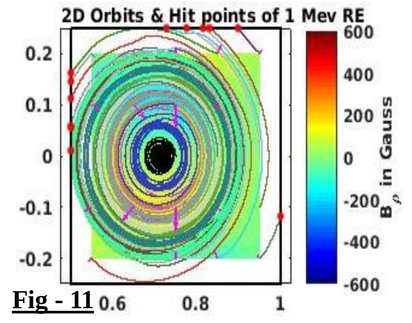

Fig - 11

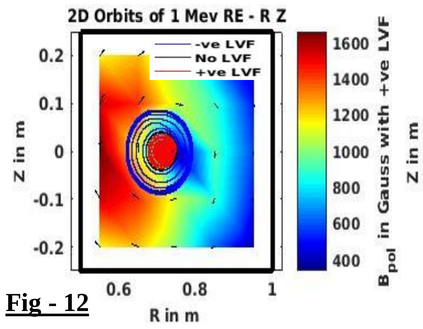

Fig - 12

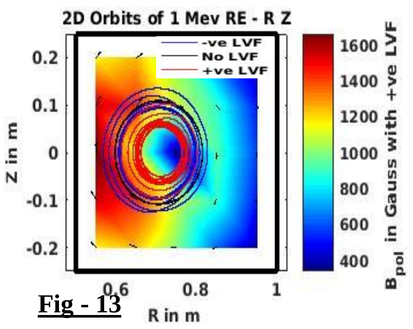

Fig - 13

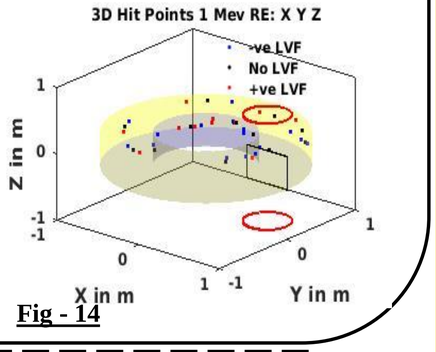

Fig - 14

Conclusions:

- Integrated PARTICLE3D-EFFI-IPREQ code has been developed which uses field calculated by the EFFI code from the coil sets and plasma equilibrium fields by IPREQ [7] code to track the runway electrons following relativistic dynamics.
- RE deconfinement experiment has been numerically modeled by Integrated PARTICLE3D-EFFI-IPREQ code .
- Numerical modeling of the experiments shows RE gets de-confined with the application of suitable LVF. RE gets pulled out when a +ve B_ρ or B_z field applied locally. This is observed in both without (Fig. 3 - 8) and with the plasma equilibrium field (Fig. 9 - 14).
- RE loss fraction and its dependency and characteristics on RE energy, LVF magnitude and other factors will be studied and presented in the future work.

Acknowledgement:

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