Observation Of Electrostatic Confinement Of Runaway Electrons Using A Biased Electrode In ADITYA-U Tokamak

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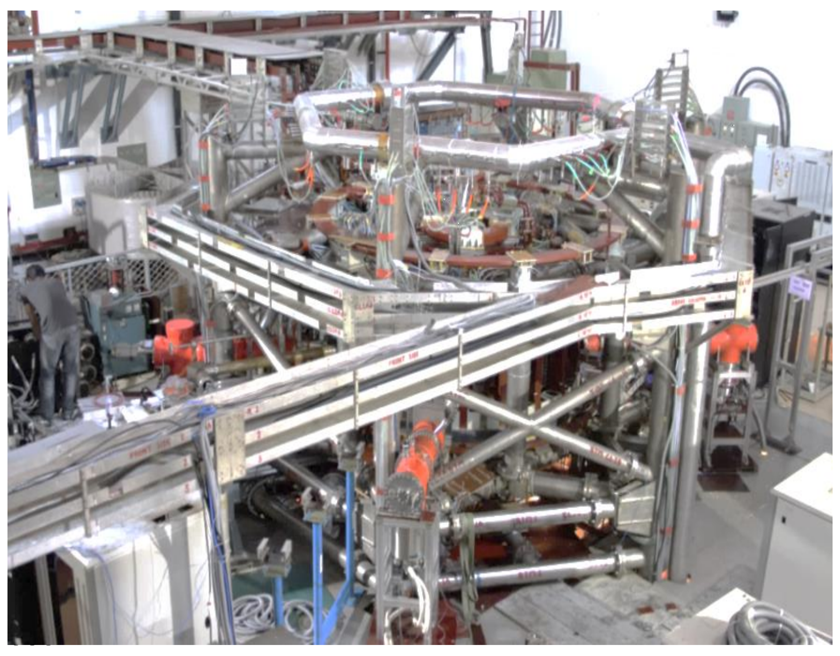
ABSTRACT/ INTRODUCTION

- Control and/or mitigation of runaway electrons (REs) is necessary for the operation of larger fusion devices including ITER
- ADITYA-U: REs are observed by monitoring the hard X-rays (HXR) produced when they interact with the limiter tiles, usually in low density discharges.
- In general, the REs are lost as soon as the plasma disrupts (~ 1 ms).
- However, in the discharges performed by placing a biased electrode inside the last closed flux surface (LCFS), the HXR flux is observed to persist even after plasma disruption.
- The REs are confined due to the $E_r \times B_\varphi$ rotation induced by the external radial electric field.

ADITYA-U Tokamak

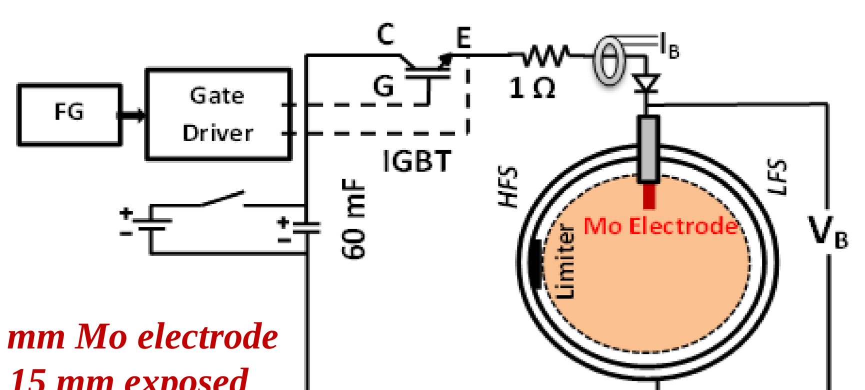
- R = 0.75 m; a = 25 cm
- Toroidal belt limiter
- 2 poloidal quarter ring limiters
- Toroidal field B_T : 1.28T
- q_{edge} ~ 3.5 – 4.0
- Plasma current Ip: 100 - 130 kA
- Plasma duration: 50 - 100 ms
- Electron density ne: 1.0 - 2.0x10^{19}
- Electron temperature Te: 200 - 300 eV



ADITYA-U tokamak

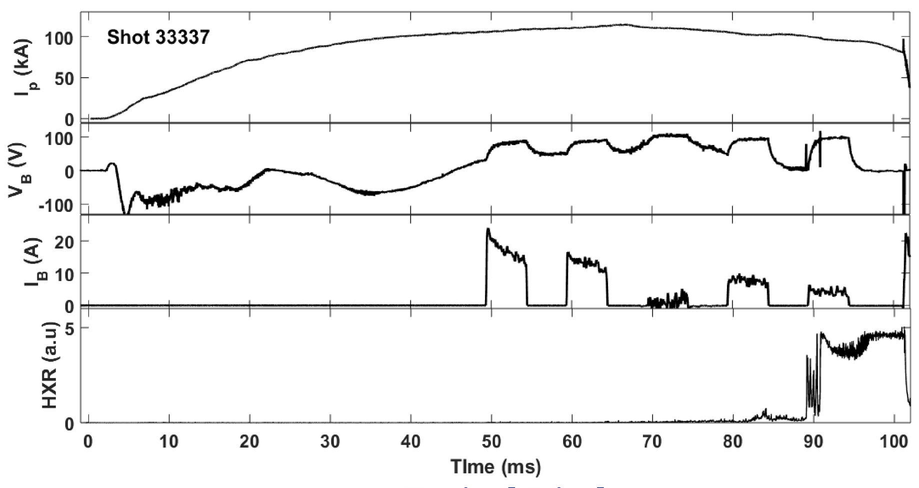
EXPERIMENTAL SET UP

- A set of 15 Langmuir probes (LP): measure the edge plasma n_e, T_e.
- Two arrays of Rake LP (each consisting seven equidistant LP) measure the floating potential and its fluctuations.
- $E_r = \Delta V_p/\Delta r$ – Radial electric field
- 3 inch NaI (Tl) scintillator detector; minimum energy 221 keV
- Plastic scintillator detector; measures HXR flux



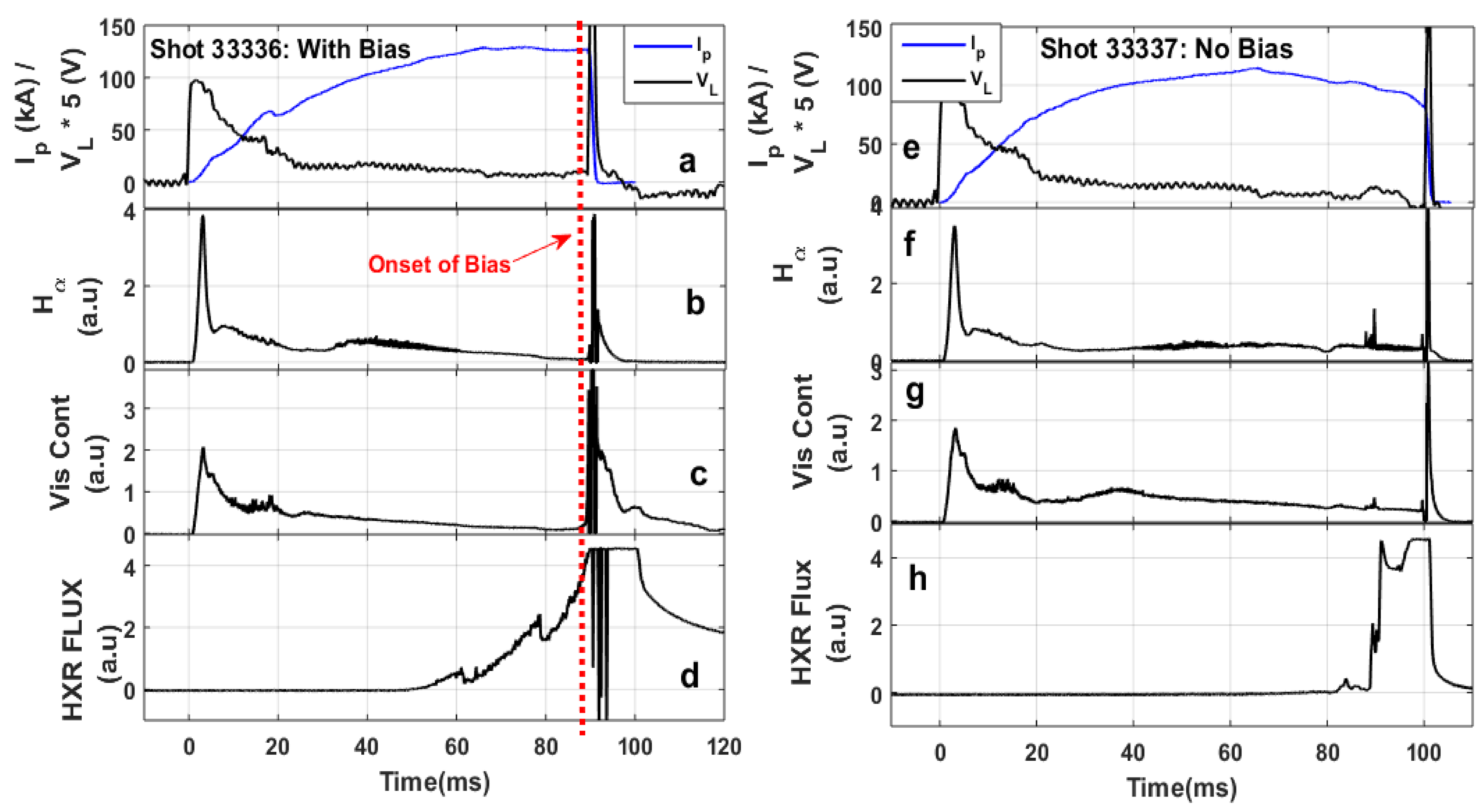
5 mm Mo electrode 15 mm exposed length

Electrode Bias Circuit

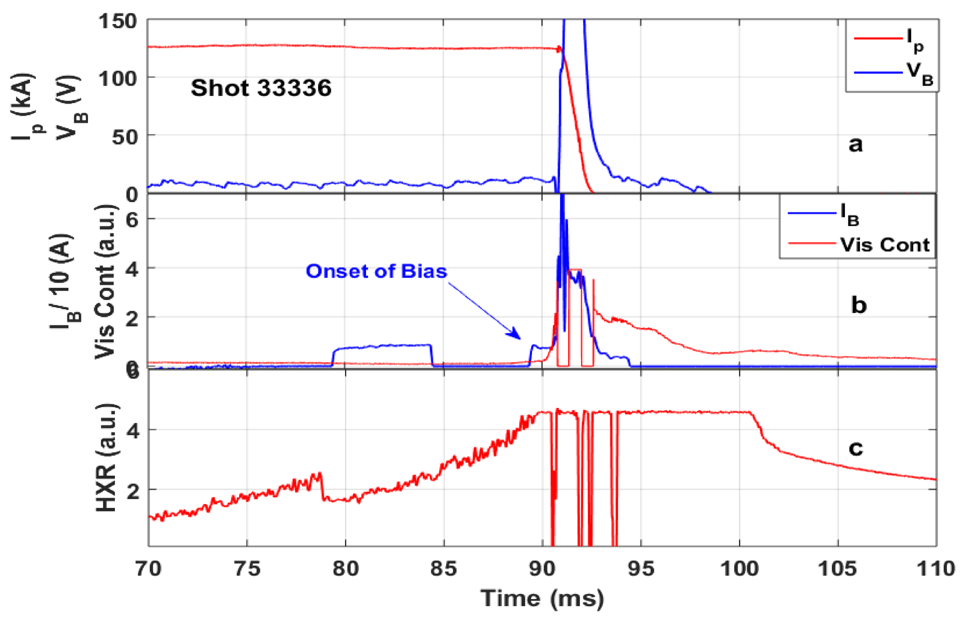


Typical Discharge

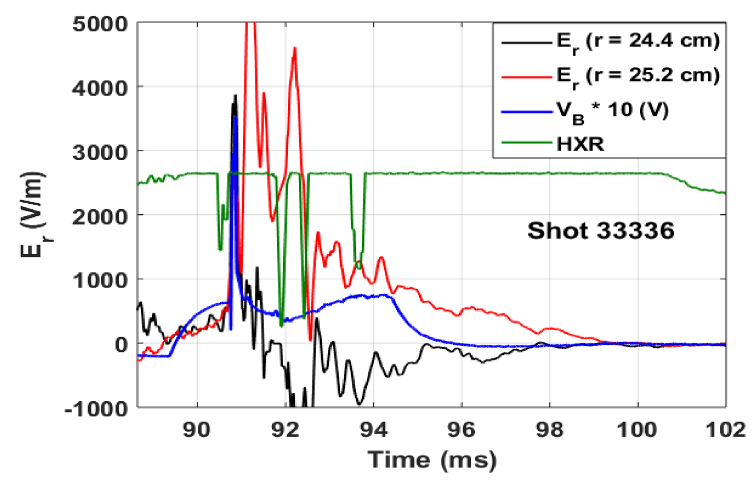
EXPERIMENTAL OBSERVATIONS



EXPERIMENTAL OBSERVATIONS



HXR flux persists after disruption; Bias voltage ~ 100 V



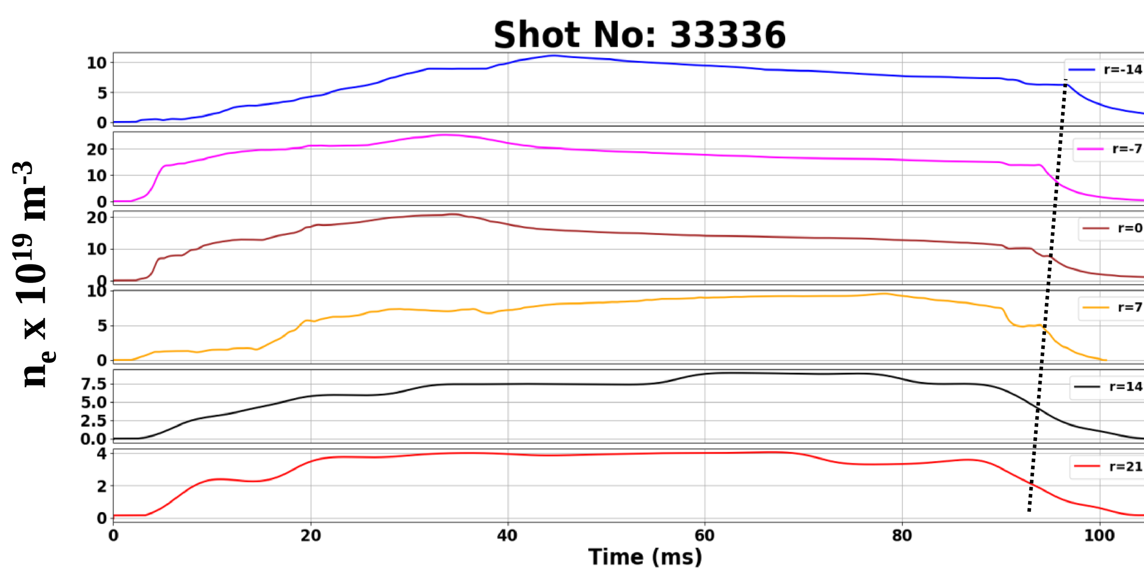
Radial Electric Field measured with LP

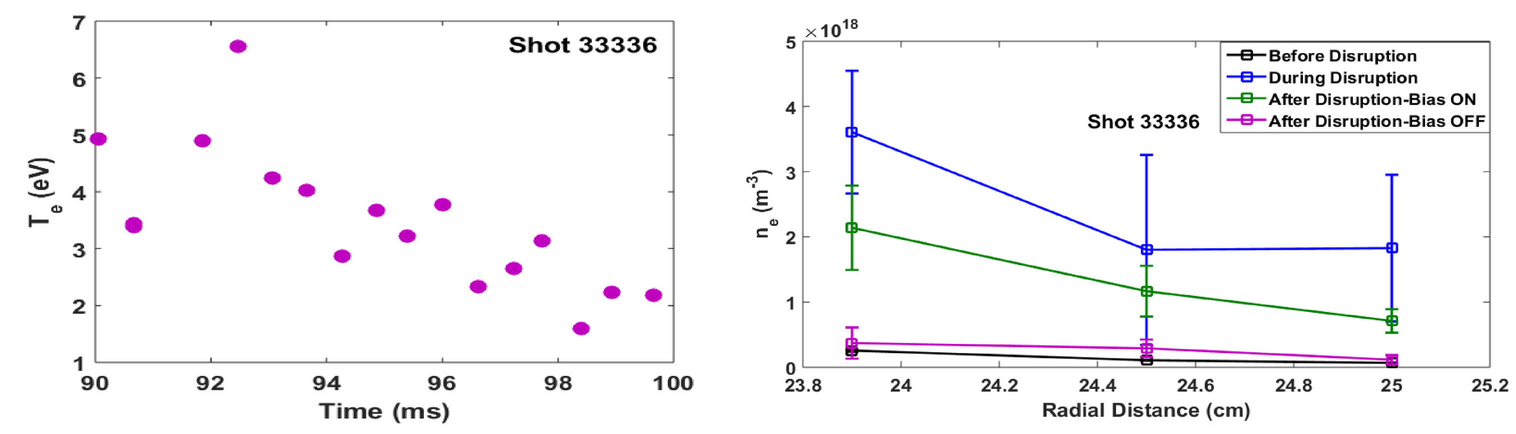
How are REs confined?

- *I_p falls but RE flux persists*
- *Bias ON during disruption*
- *Main plasma disrupted*
- *Role of E_r?*
- *E_r x B_φ causes RE to rotate?*
- *Central n_e do not change substancially*
- *Why no I_p?*

- ***E_r reduces after bias turned off; How does it sustain after bias?***
- ***Non-neutral plasma? Confinement improvement due to E_r? [1]***

- *Density exists but no I_p?*
- *Density decreases rapidly after bias is turned off*
- *A clear lag in the fall of density in subsequent chords observed.*
- *Inward propagation of RE after bias OFF?*





(a) Edge temperature measured at r = 25 cm, (b) Density profile before, during and after disruption

- *T_e measured with LP: decreases from 5 eV at the end to disruption to 2 eV at t ~ 100 ms*
- *The corresponding density profile show:*
- *During disruption: Sharp profile*
- *After disruption: Profile still sharp when bias is ON: Confinement of REs*
- *After disruption: Profile becomes flat as soon as bias is turned off : RE loss*

CONCLUSION

- *REs confined using an induced radial electric field by biasing an electrode in the tokamak edge.*
- *E_r x B_φ rotation of the RE helps in the confinement?*
- *Confinement as long as biasing is ON.*
- *Non-neutrality measurement important for the physics understanding.*
- *Parametric variation with B_T, I_p, biased voltage important*

ACKNOWLEDGEMENTS / REFERENCES

1. *Sarasola X, Pedersen T S, First experimental studies of the physics of plasmas of arbitrary degree of neutrality, Plasma Phys. Control. Fusion 54 (2012) 124008*