



NOVEL CONCEPT FOR DISRUPTION MITIGATION IN THE ADITYA-U TOKAMAK BY INDUCTIVELY DRIVEN IMPURITY PELLET INJECTOR (IPI)



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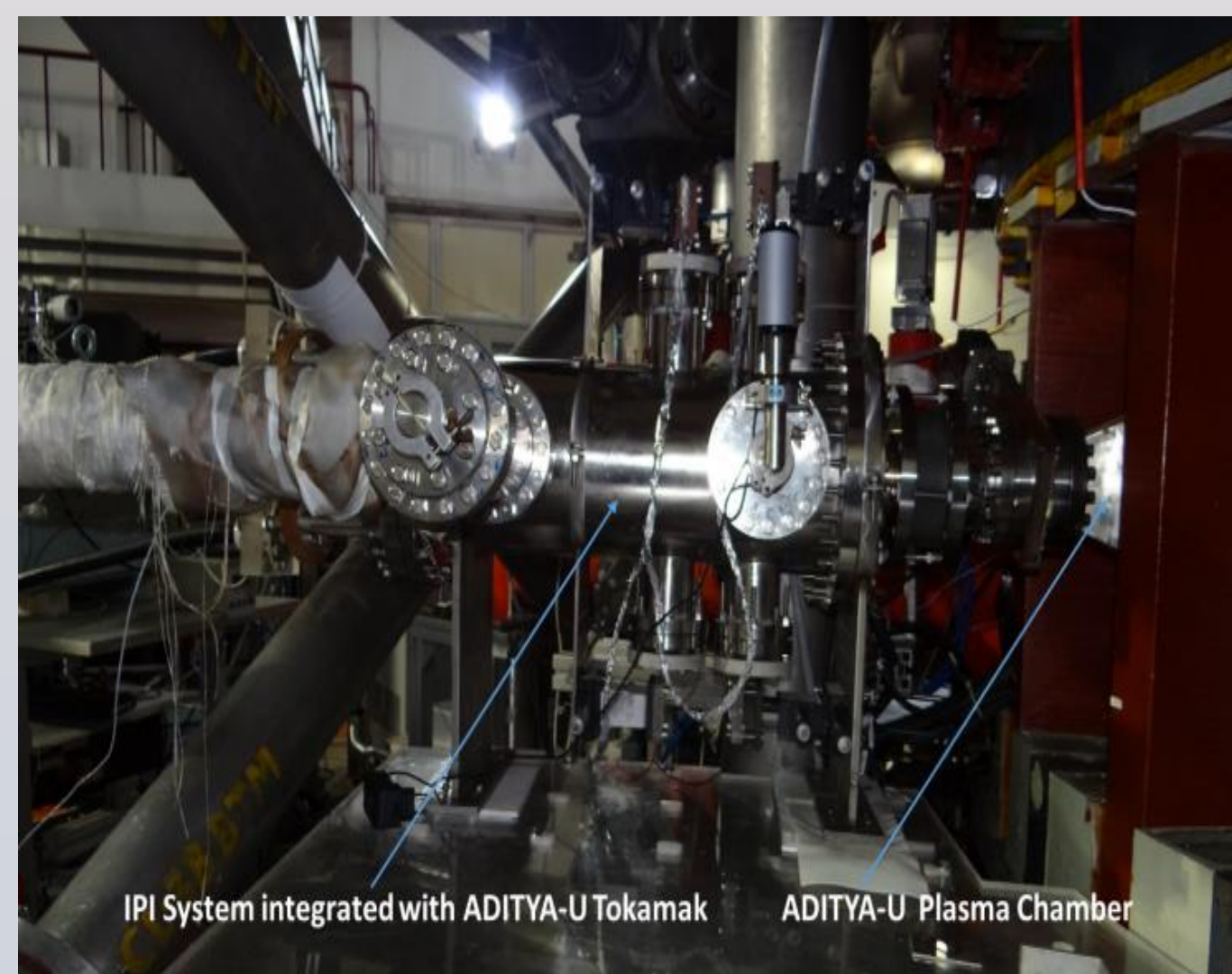
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Abstract

The ADITYA Upgrade (ADITYA-U) is a medium sized ($R_0 = 75$ cm, $a = 25$ cm) Ohmically heated toroidal limiter tokamak, capable of producing circular as well as shaped plasma with single and double null open divertor configuration. A novel concept of inductively driven particle injector (IPI), having fast time response than pneumatic injectors, has been developed and operated successfully during ADITYA-U circular plasmas operation which can ably address the critical need for a suitable disruption control mechanism in ITER and future tokamak. In this technique, Lithium Titanate / Carbonate (Li_2TiO_3 / Li_2CO_3) impurity dust projectile containing a radiative payload weighing $\sim 50 - 200$ mg is injected with velocities of the order of ~ 200 m/s in ADITYA-U tokamak. Lithium Titanate / Carbonate (Li_2TiO_3 / Li_2CO_3) dust particles (pellet) injected into the ADITYA-U plasmas during current plateau disrupted the discharge within $\sim 3 - 4$ ms. It has been observed that the injected impurities radiate the plasma energy and disrupt the discharge. The current quench time has been found to be dependent on the amount of impurity injected and also on the compound, as Li_2TiO_3 injection induces faster current quench than Li_2CO_3 injection as more power radiated in case of Li_2TiO_3 . The Bolometer array shows radiation starts from the plasma core and the Soft X-ray array shows complete plasma core collapses at once.

ADITYA-U Tokamak

Machine and Plasma Parameters	
Major radius (R)	0.75 m
Minor radius (a)	0.25 m
Plasma Shape	Circular / Shaped
Toroidal Field	1.3 T
Plasma Current	120-130 kA $\pm 10\%$
Plasma Duration	~ 110 ms
Electron Density	$1.5 - 2.0 \times 10^{19} \text{ m}^{-3} \pm 10\%$
Electron Temp.	200 eV – 250 eV $\pm 30\%$



Micron size particle injector for Disruption studies

Disruption in Tokamak

Disruptions in Tokamaks:

- An abrupt termination of a tokamak discharge
- Sudden loss of plasma stored energies
- The force and heat loads damage the plasma facing components

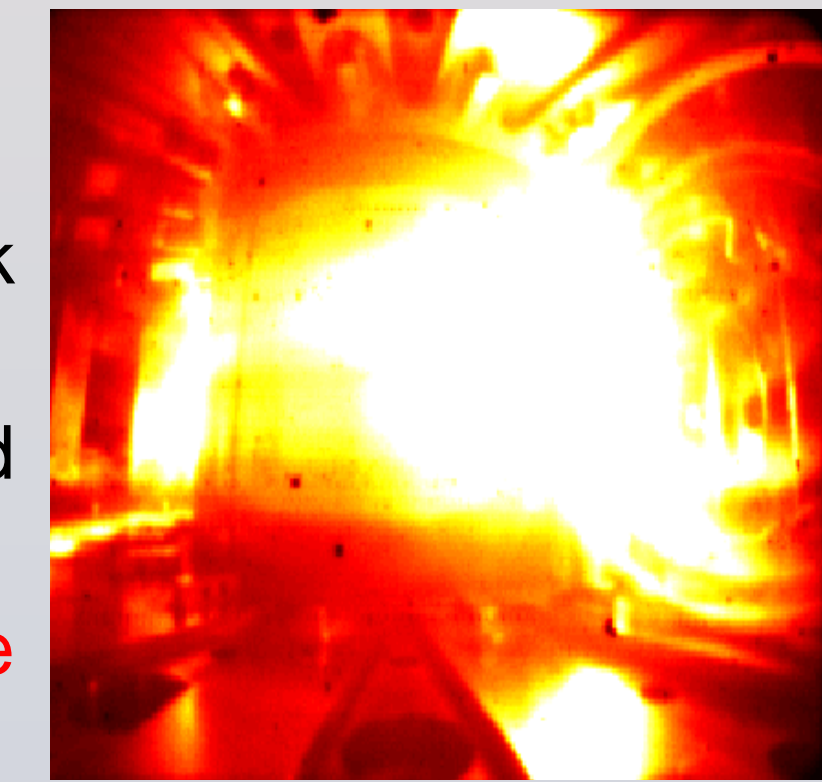


Image of ADITYA-U Disruption

Mitigation Techniques: Need of the hour

→ Existing technique: Massive Gas injection

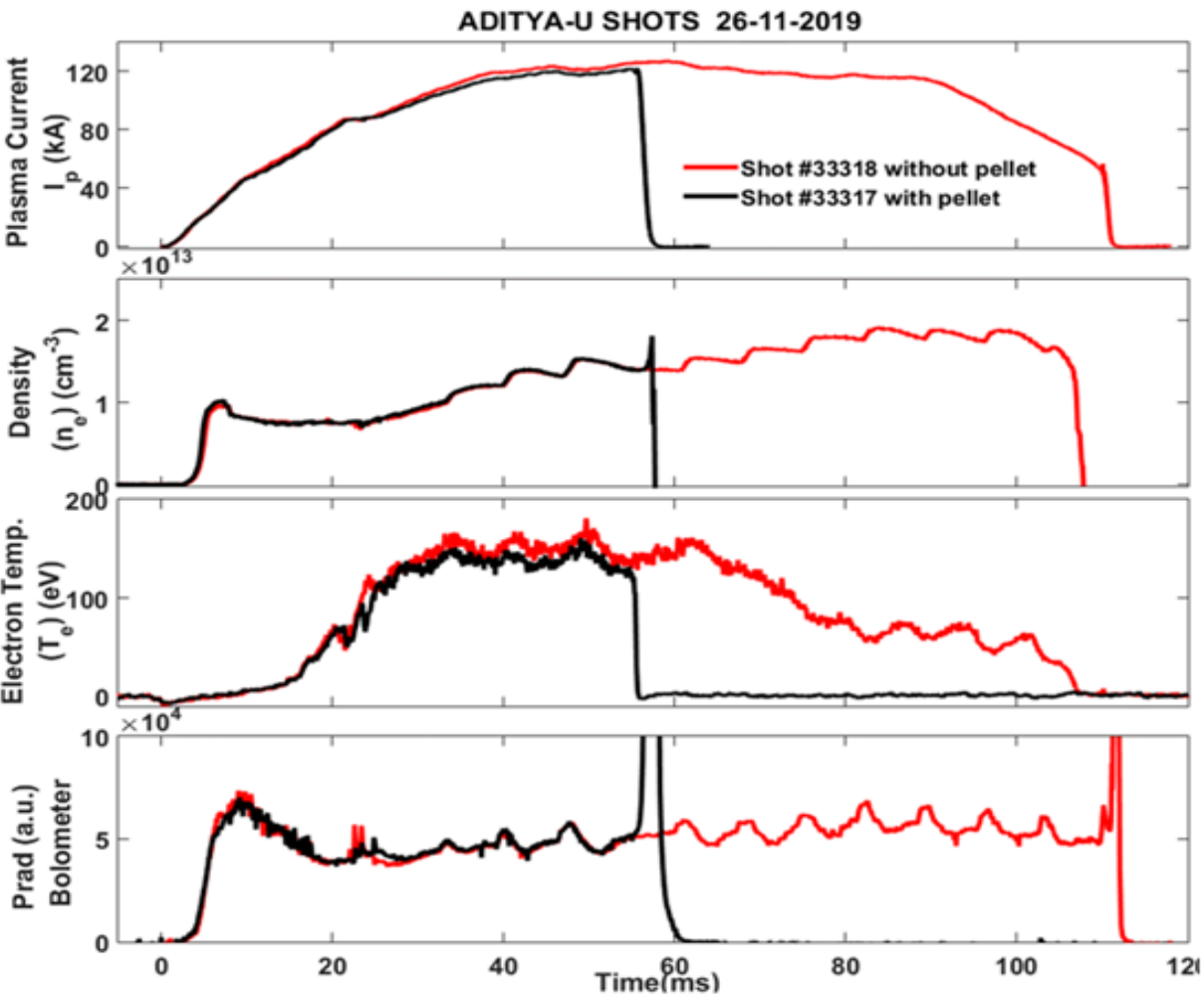
→ Problems: Slow penetration to the core of the plasma, Massive loads on pumps

→ Remedy: Fast injection of solid particles

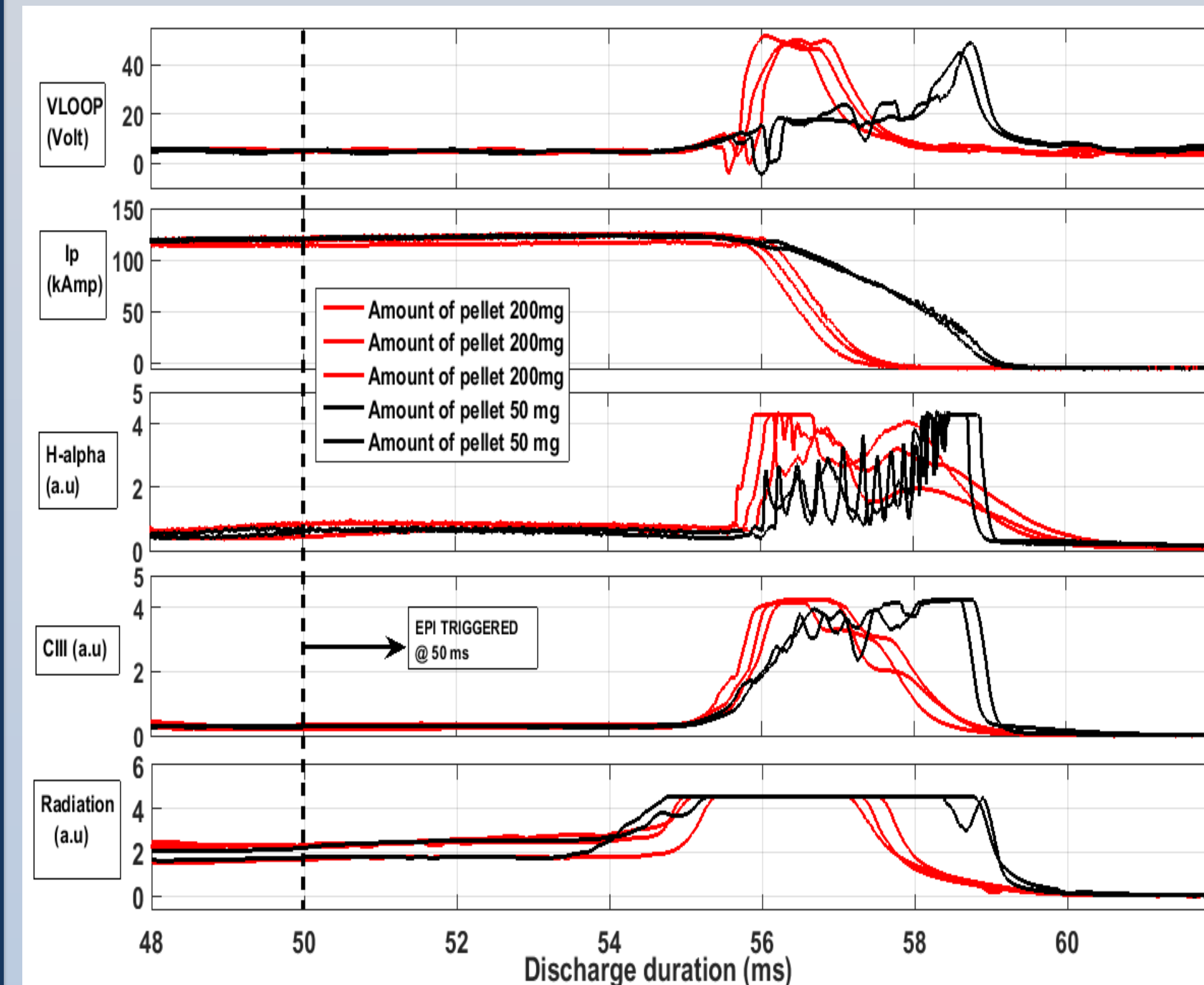
Inductively-Driven Pellet accelerator and Injector in ADITYA-U

Injected Particles: Lithium Titanate / Carbonate
Particle size ~ 50 micron
Particle velocity ~ 200 m/s
Particles reached ADITYA-U core in ~ 4 ms
Amount injected $\sim 50 - 200$ mg
Particle Injected causes fast Disruption of Plasma Current
(Red Curve: No Injection)
(Black Curve: With injection)
Density, temperature terminate very rapidly due to increased radiation after the injection

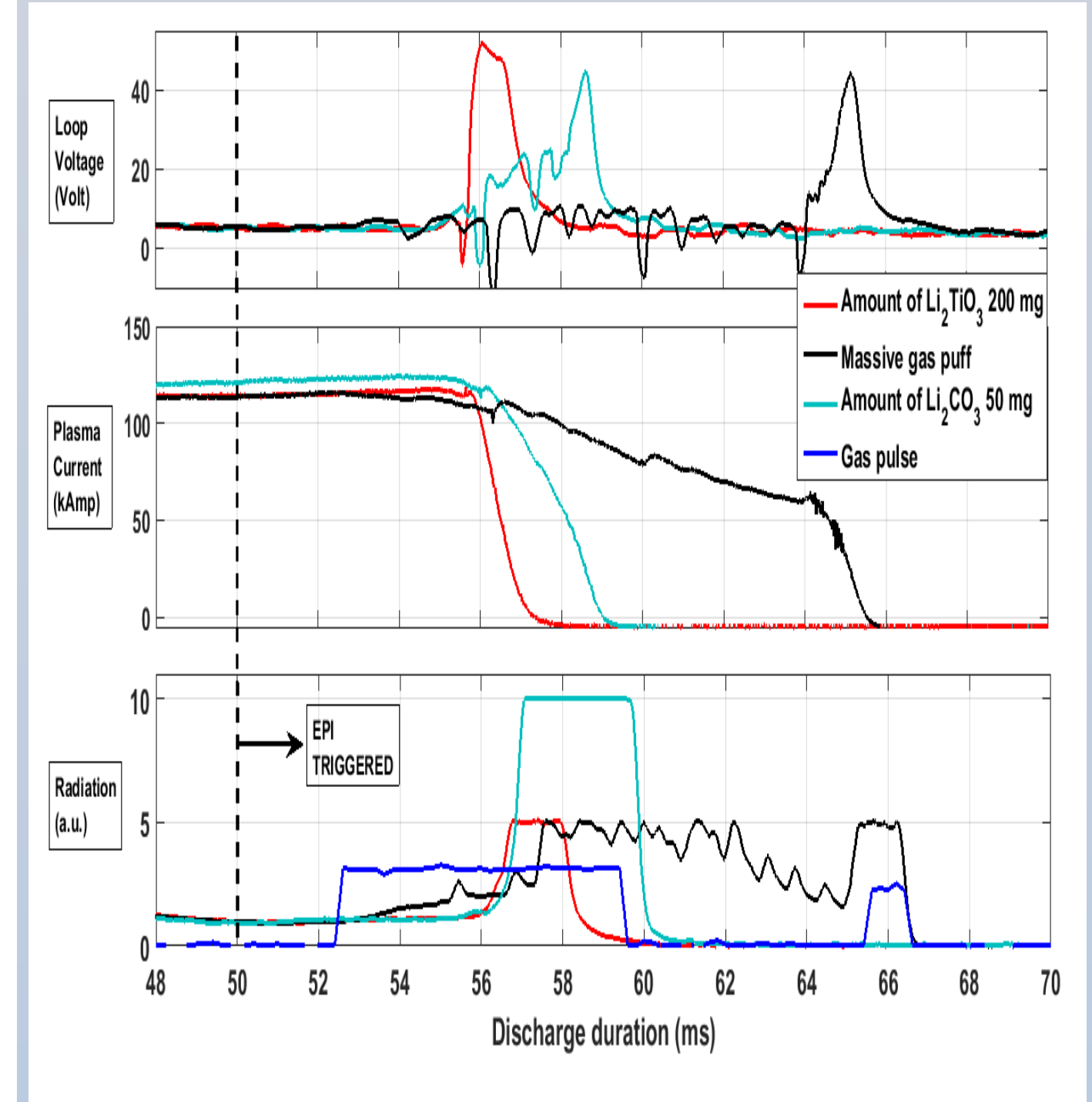
First time an electromagnetic pellet injector used to fire the pellets into the tokamak
Significant development towards ITER disruption control
ADITYA-U SHOTS 26-11-2019



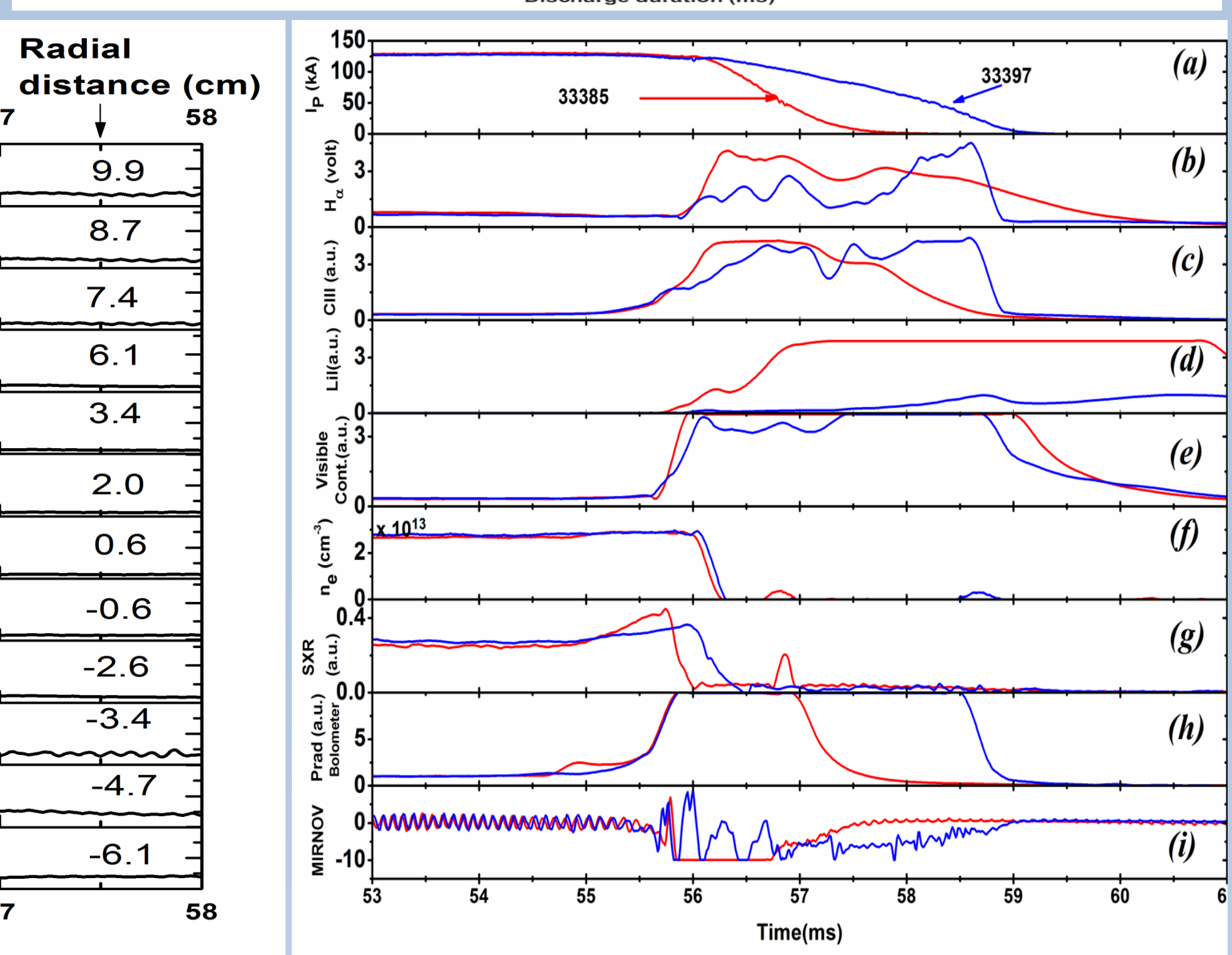
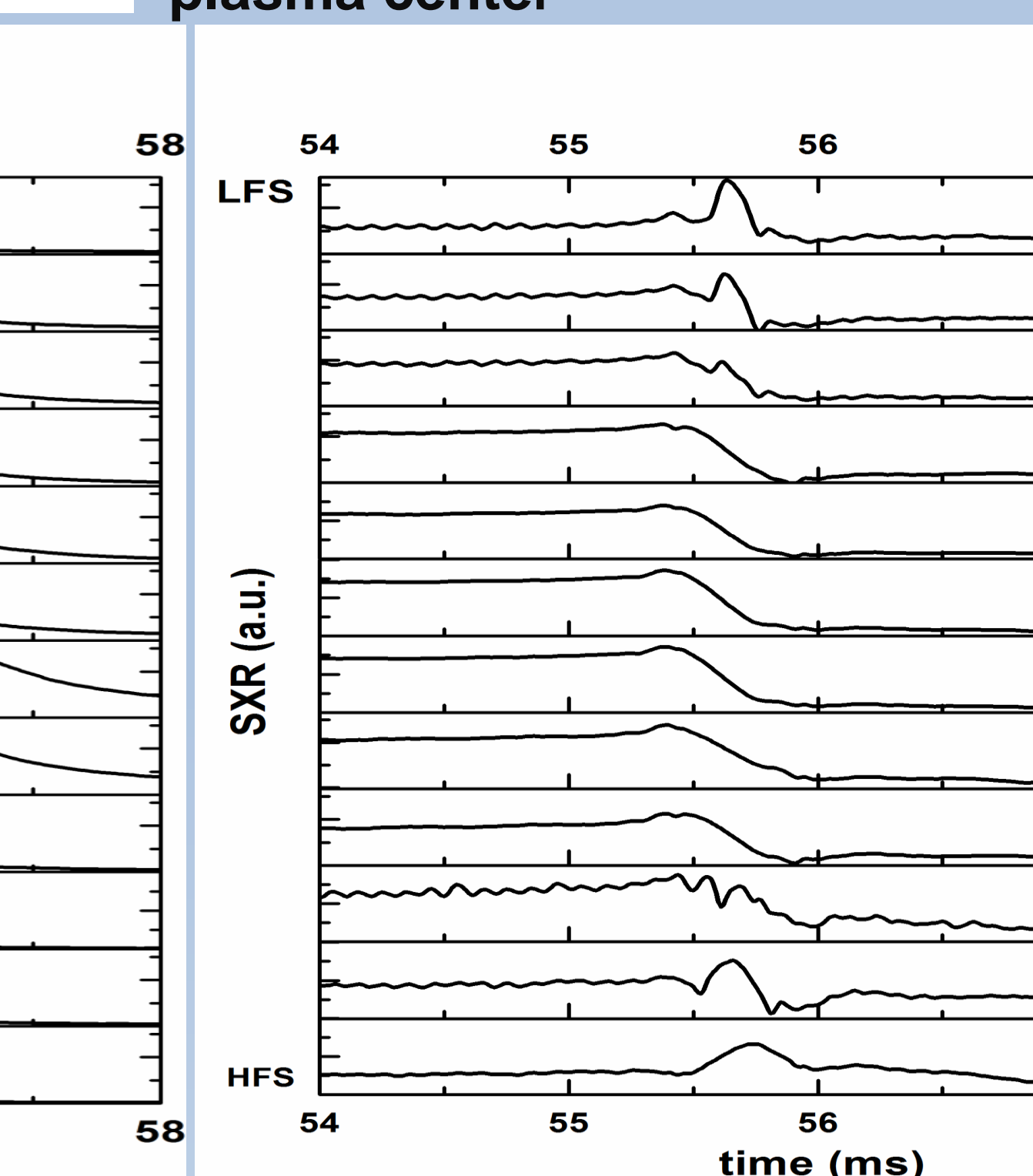
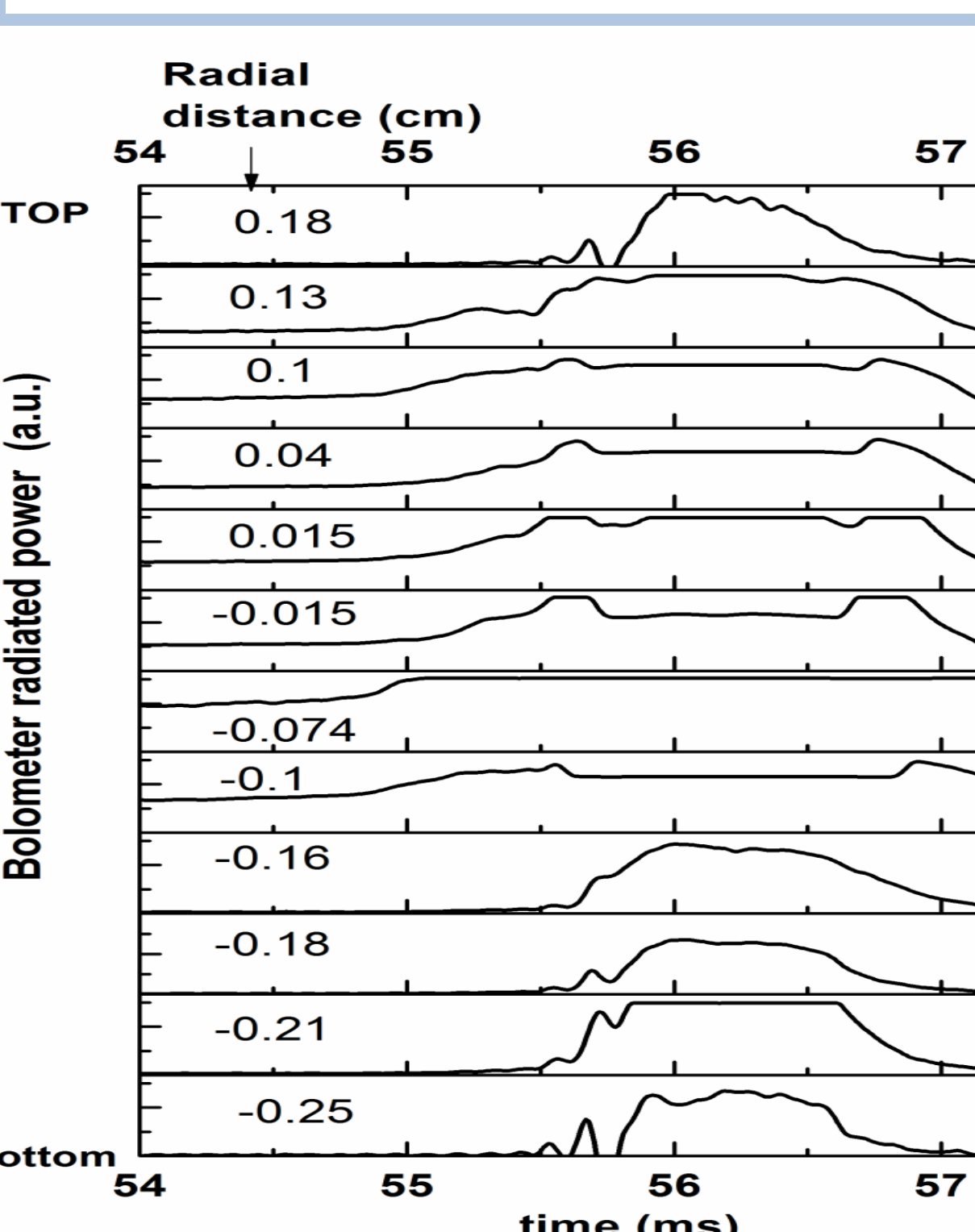
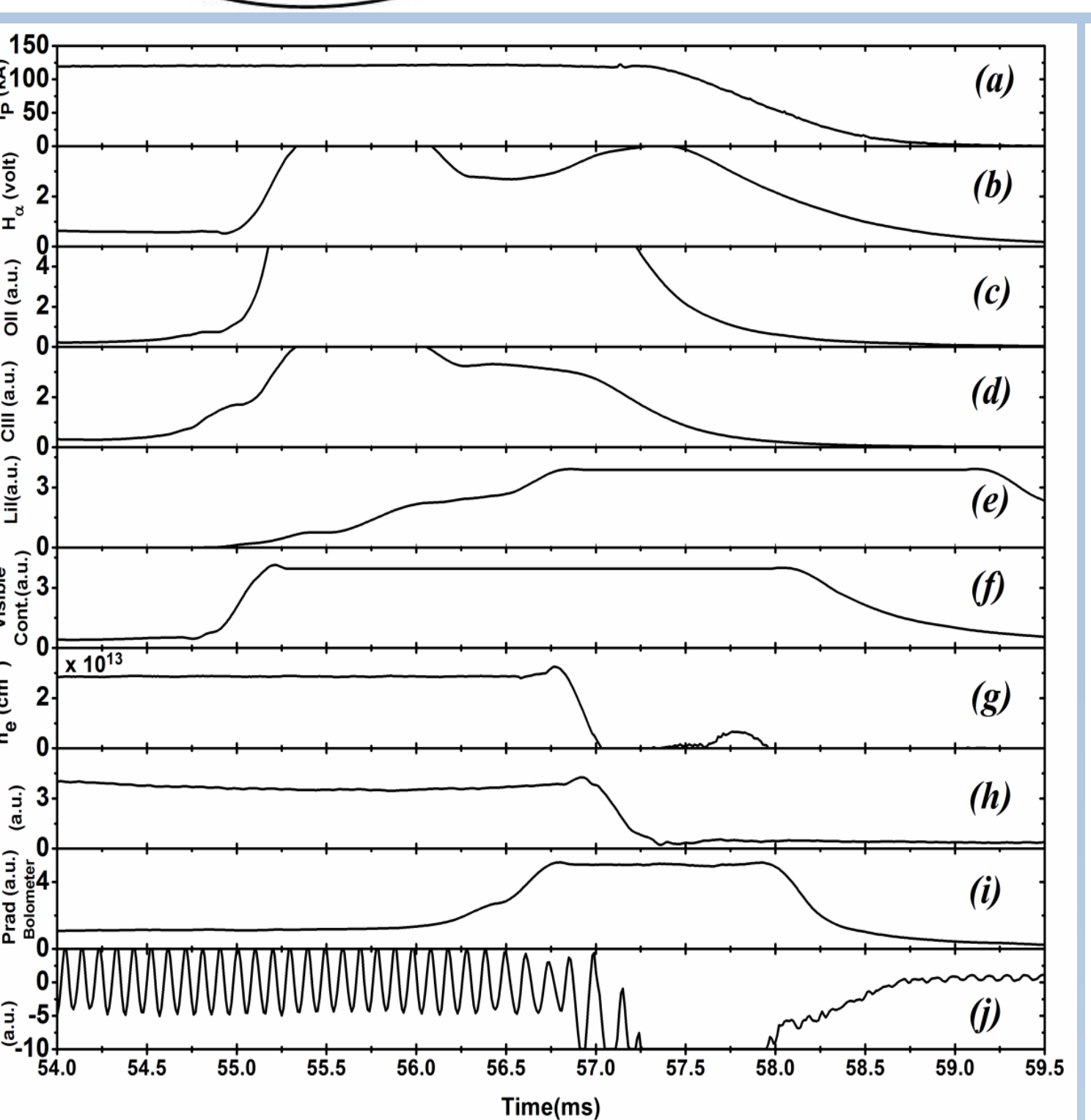
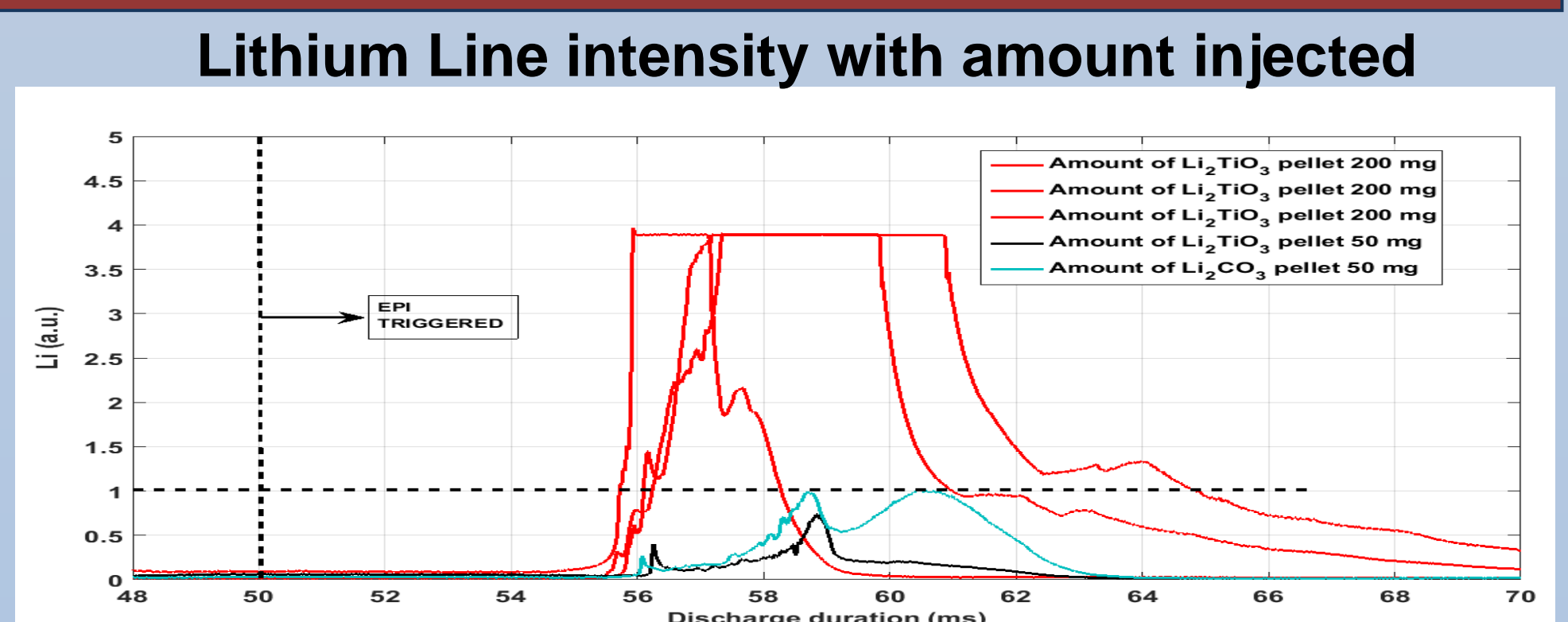
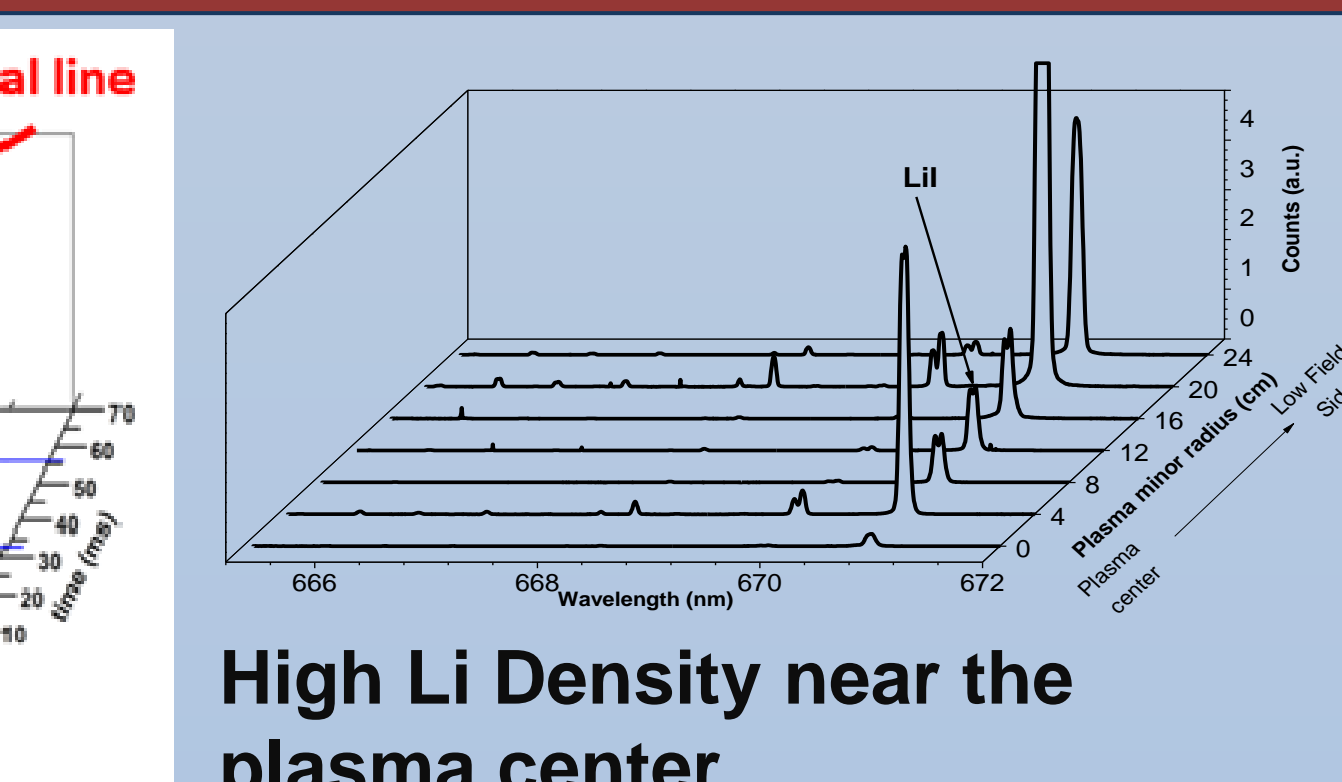
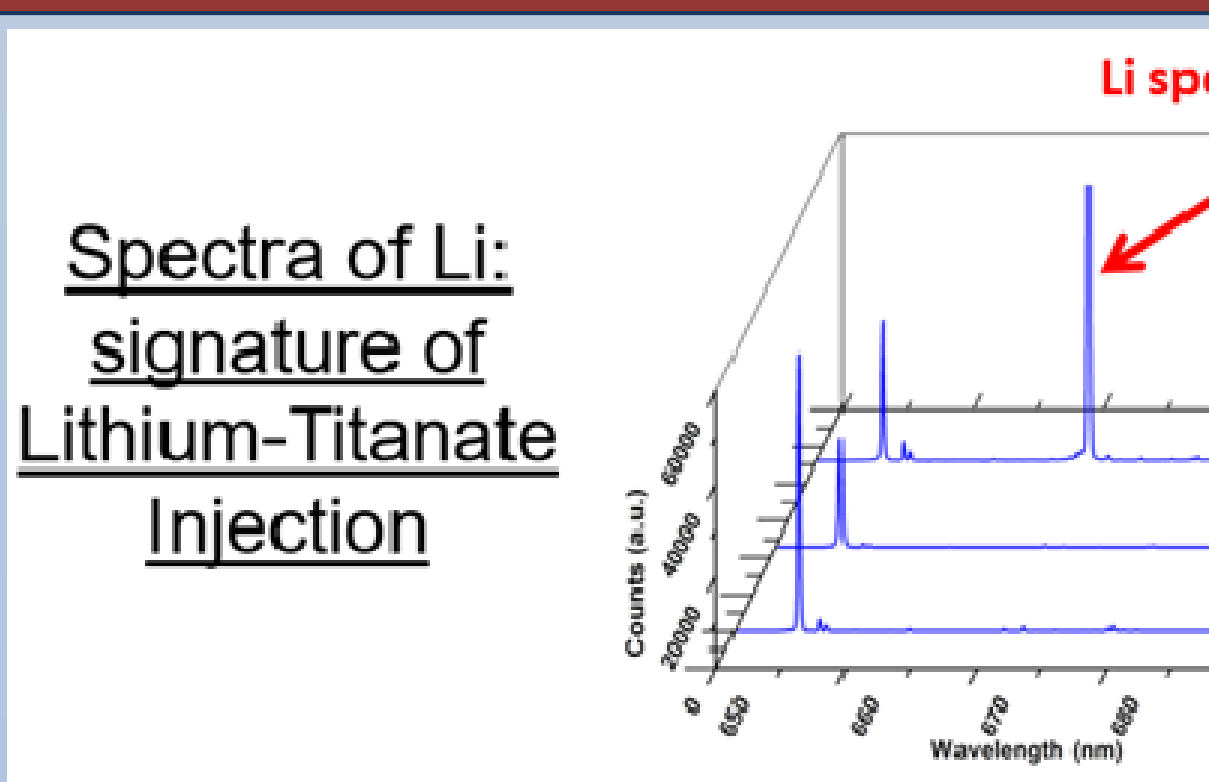
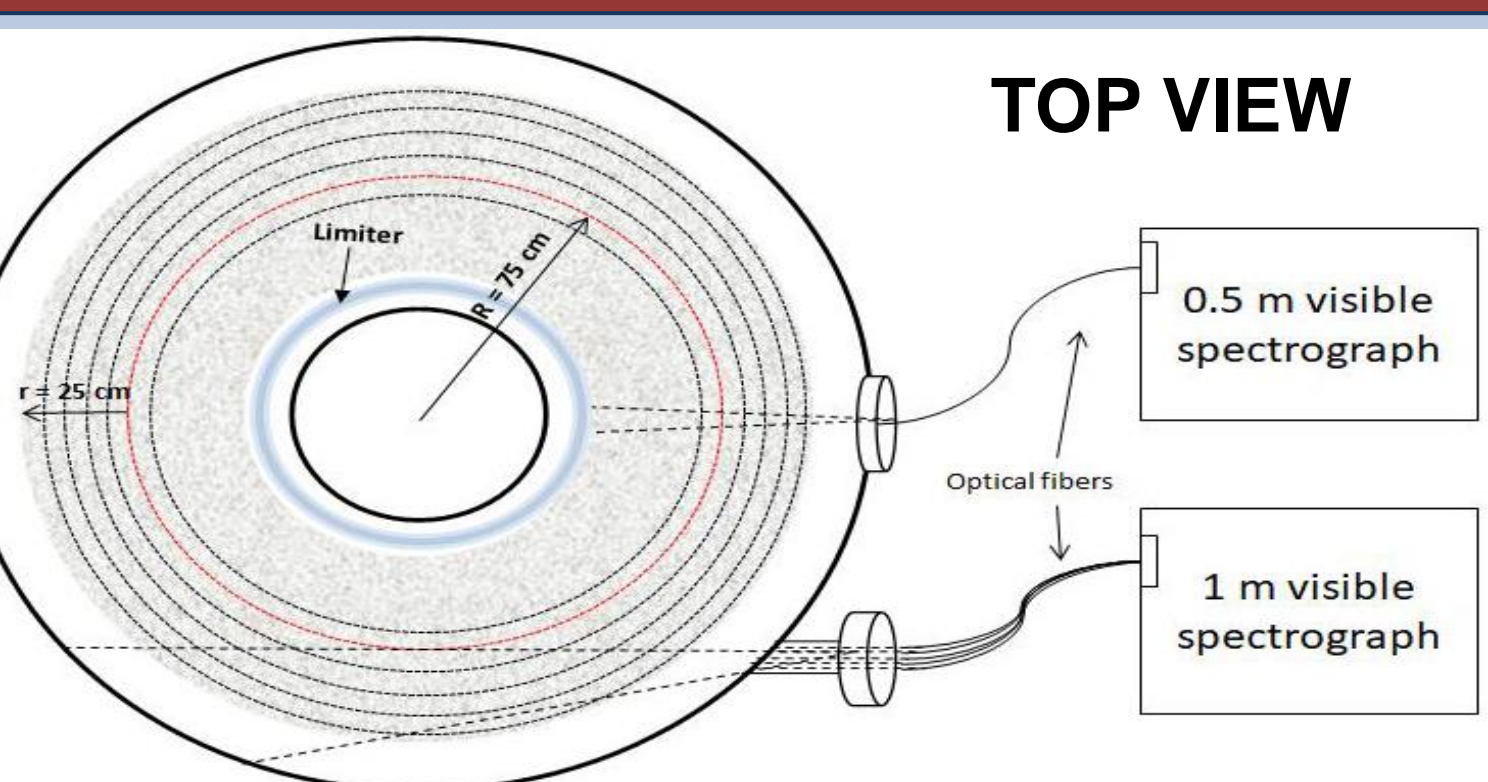
Control of I_p (Plasma Current) Fall rate



Slower Decay with Massive Gas Puff



Observations



Temporal Evolution of Plasma Parameters with Particle Injection

Radiated power profile shows plasma core radiates first

Soft X-ray emission intensity profile shows complete core plasma collapses at once

Lithium Titanate (Li_2TiO_3) works better than Lithium Carbonate (Li_2CO_3)

Summary

- ✓ Particles injected using an Inductively-Driven Pellet accelerator and Injector
- ✓ Pellets reached hot plasma core in a few milliseconds
- ✓ Radiated away its thermal energy, causing a rapid quench of plasma current.
- ✓ Injected Particles: Lithium Titanate/Carbonate
- ✓ Particle size ~ 50 micron, Amount (50-200 mg)
- ✓ Particle Velocity ~ 200 m/s
- ✓ Lithium Titanate induces faster current quench time
- ✓ Bolometer Array shows radiation starts from the center
- ✓ Soft X-ray Array shows complete plasma core collapses at once