Novel Approach To Estimate Plasma Current Density Profile With Magnetic Probes In Aditya-U

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ABSTRACT

- Tokamak plasma shows a radial variation of current density J(r), which is responsible for several plasma phenomena, like several instabilities, plasma transports etc. [1,2]
- For the better understanding of a tokamak plasma, estimation of current density profile is required
- This work first time attempts and successfully estimates the radial current density profile of Aditya-U plasma using spatial profile of magnetic fields

ADITYA-U TOKAMAK

R_0 = 75 cm; a = 25 cm;
Loop voltage: 20-22 V;
Toroidal Field: 1.3-1.5 T;
I_P = 150-213 kA $\pm$10%;
Plasma duration ~ 300 - 400 ms;
T_e = 250-500 eV $\pm$30%;
n_e = 3-4 $\times 10^{19} m^{-3}$ $\pm$10%.

CHOICE OF MAGNETIC PROBES IN ADITYA-U: MIRNOV PROBES [3]

- Two sets of Mirnov [2,3] garlands, as shown in Fig. 1.
- Data are taken from Mirnov garland 1 only.

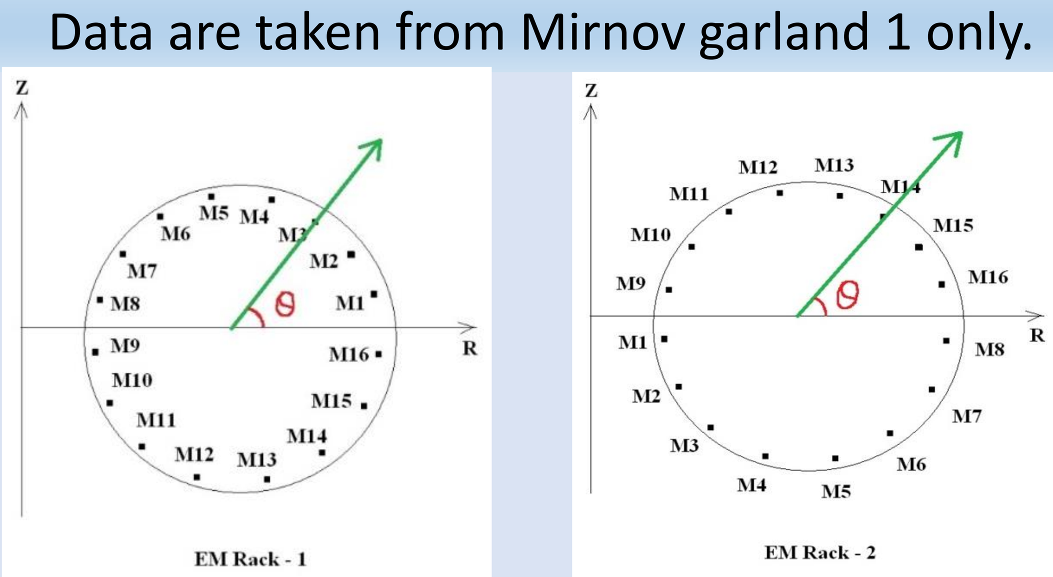

FIG 1: Schematic of Mirnov Garland 1 (left) and 2 (right).

GENERATION OF CURRENT DENSITY PROFILE AND HENCE MAGNETIC FIELD AT PROBE LOCATIONS

- The toroidal peaked current density profile generated using:

$$J(r) = J_0\left(1 - \frac{r^2}{a^2}\right)^{\gamma},$$

where J_0 = the density at the column centre, r = distance along minor radius, a = minor radius = 25 cm, γ = exponent

- Resultant density profiles plotted in Fig 2
- Corresponding spatial profile of magnetic field at Mirnov probe locations given in Fig 3 – only three profiles chosen for plot to avoid clumsiness

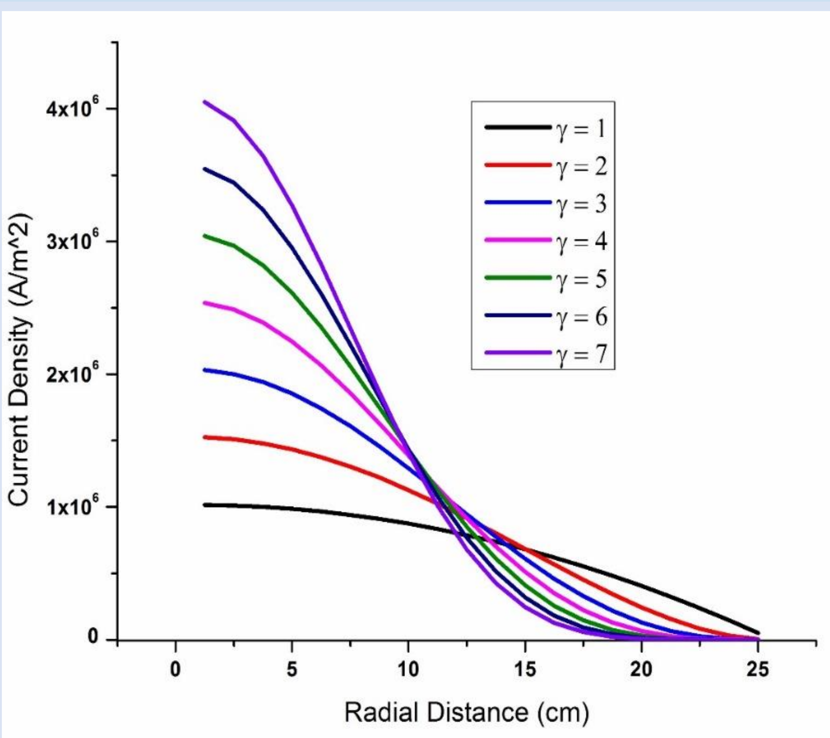

FIG 2. Toroidal current density profile, generated, for different values of γ, with total current to be 100 kA.

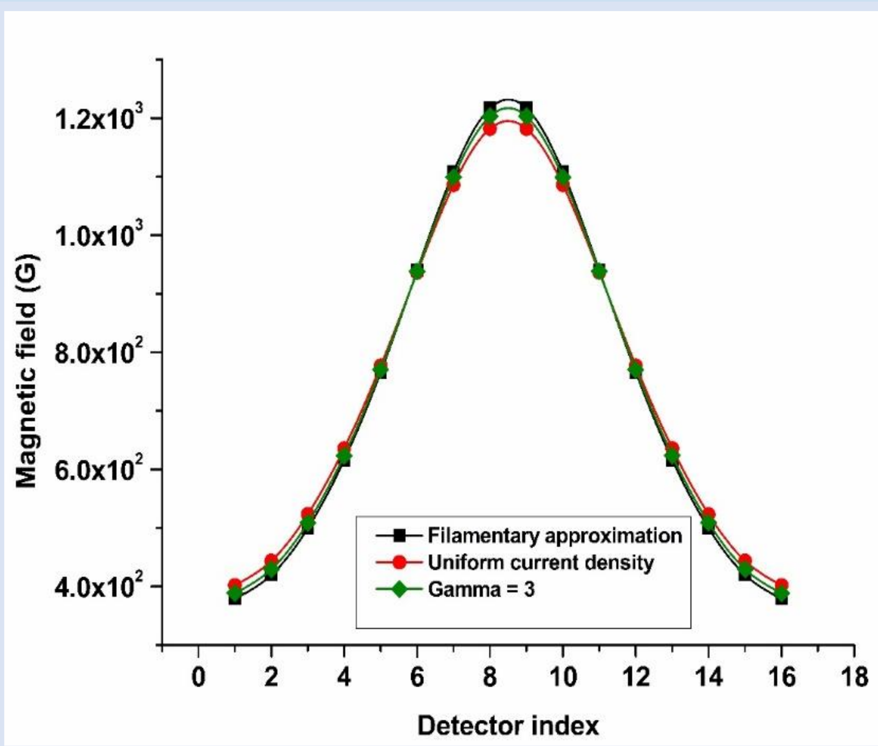

FIG. 3. Spatial profile of magnetic field at all Mirnov probes due to 100 kA of toroidal current.

DISTINGUISHING CURVES

- To distinguish the peaked curves of Fig3, curves are fitted using Lorentzian function:

$$B(x) = B_0 + \frac{2A}{\pi}\frac{w}{4(x-x_c)^2 + w^2} ,$$

where B_0 = offset value, A = the area under the curve, w = full width at half maximum, x_c = abscissa at which the peak appears

- Among these parameters, w found to be most appropriate to distinguish between two source current profiles
- Table 1 provides values of w for different current density profiles

TABLE 1. VALUE OF w FOR DIFFERENT TOROIDAL CURRENT DENSITY PROFILES

Uniform Current	γ							Filamentary Current
	1	2	3	4	5	6	7	
8.6471	8.4903	8.4312	8.3849	8.3643	8.3404	8.3319	8.3197	8.2409

EXPERIMENTAL RESULTS

- Magnetic fields for plasma column only, found at Mirnov probe locations during plasma flat-top, when column movement is almost zero
- Such a plot for a typical discharge given in Fig. 5, along with the related temporal profiles in Fig. 4
- Averaged experimental value of the fitting parameter $\boldsymbol{w \sim 6.871}$, different from that in Table 1

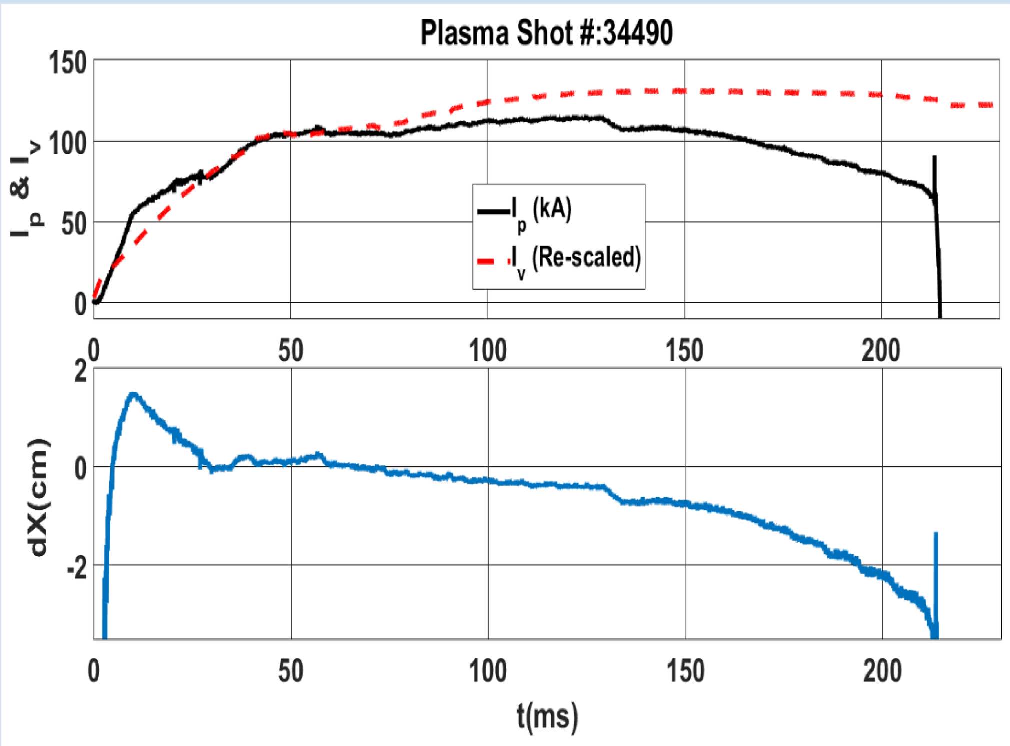

FIG 4: Temporal profile of plasma and vertical field currents (I_P & I_V) and horizontal position (dX) for the plasma discharge #34490.

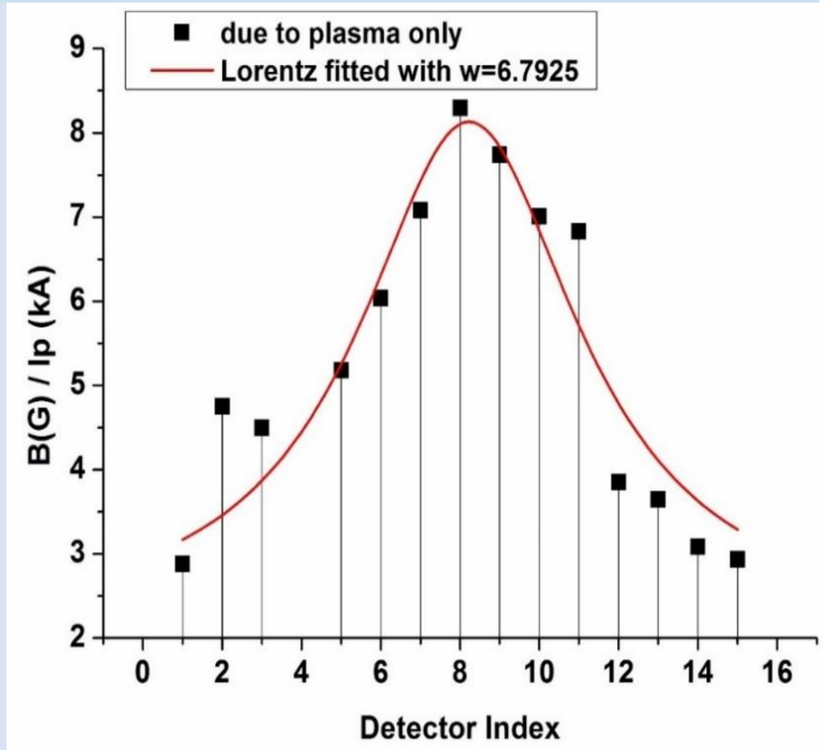

FIG 5: Spatial profile of experimental magnetic field at Mirnov probes, at 63 ms of discharge #34490.

ESTIMATION OF ADDITIONAL MAGNETIC FIELDS

- To discard the mismatch between experimental and expected *w*, unwanted eddy magnetic fields at probe locations found, and given in Table 2
- These eddy magnetic fields are present at plasma flat-top when the positional movement of the column is negligibly small

TABLE 2. AVERAGED EDDY MAGNETIC FIELDS (G) AT DIFFERENT MIRNOV PROBES

1	2	3	5	6	7	8	9	10	11	12	13	14	15
1.064	1.429	0.543	1.355	2.592	2.939	4.383	4.205	3.341	2.797	1.430	0.699	0.233	0.755

ESTIMATION OF PLASMA CURRENT DENSITY PROFILE

- Magnetic field (numerically achieved) at Mirnov probe are corrected for eddy magnetic fields and fitted with Lorentzian function
- These fitting parameters are in good agreement with experimental one, as given in Table 3

TABLE 3. VALUE OF w FOR DIFFERENT TOROIDAL CURRENT PROFILES WITH EDDY CORRECTIONS

Uniform Current	γ							Filamentary Current
	1	2	3	4	5	6	7	
6.9564	6.9071	6.8924	6.8761	6.8703	6.8618	6.8602	6.8571	6.8334

CONCLUSIONS

- At plasma flat-top, with minimal movement of the plasma column, current density profile follows **γ~ 3-4.**
- Contributions from unknown eddy currents to the Mirnov signals are successfully figured out.

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