Investigating Direct Plasma Current Coupling to the Diamagnetic Measurement Using Reversed B_T

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Diamagnetic Flux Yields Plasma Perpendicular Energy

Basic equilibrium relation *[e.g. Lao et al., Nucl.Fusion **25** (1985) 1421]*

$$W_\perp = \int_\Omega p_\perp dV = \int_\Omega \frac{B_{tv}^2 - B_t^2}{2\mu_0} dV + \int_\Gamma \frac{B_p^2}{2\mu_0} [(R - R_t)\mathbf{e}_R + Z\mathbf{e}_Z] \cdot d\boldsymbol{S}$$

$$= I_t \phi_d \gamma_d + \tfrac{1}{4} \mu_0 R_p I_p^2 \gamma_p$$

where

$W_\perp$, $p_\perp$: plasma energy and pressure perpendicular to the toroidal field

B_{tv}, B_t: vacuum and actual toroidal field in the plasma region

B_p: poloidal field;

Ω, dV: plasma volume and its element

Γ, $d\boldsymbol{S}$: plasma bounding surface and its vector element

$\mathbf{e}_R$, $\mathbf{e}_Z$: unit radial (R) and major axial displacement (Z) vectors;

R_t: curvature weighted average major radius

I_t, I_p: toroidal field coil threading current and plasma current

ϕ_d: toroidal flux displaced by the plasma from an encircling loop

R_p: representative plasma major radius

γ_d, γ_p: coefficients; $\gamma_d, \gamma_p \to 1$ for high aspect-ratio circular plasma

In NSTX, use TF coil itself to measure flux displaced by plasma

$$N_{TF}\phi_d = -\int_0^t V_{TF}\,dt' + L_{TF}I_{TF} + \int_0^t R_{TF}I_{TF}\,dt' + \sum_j M_{TF:j}I_j + \sum_{PF} M_{TF:PF}I_{PF}$$

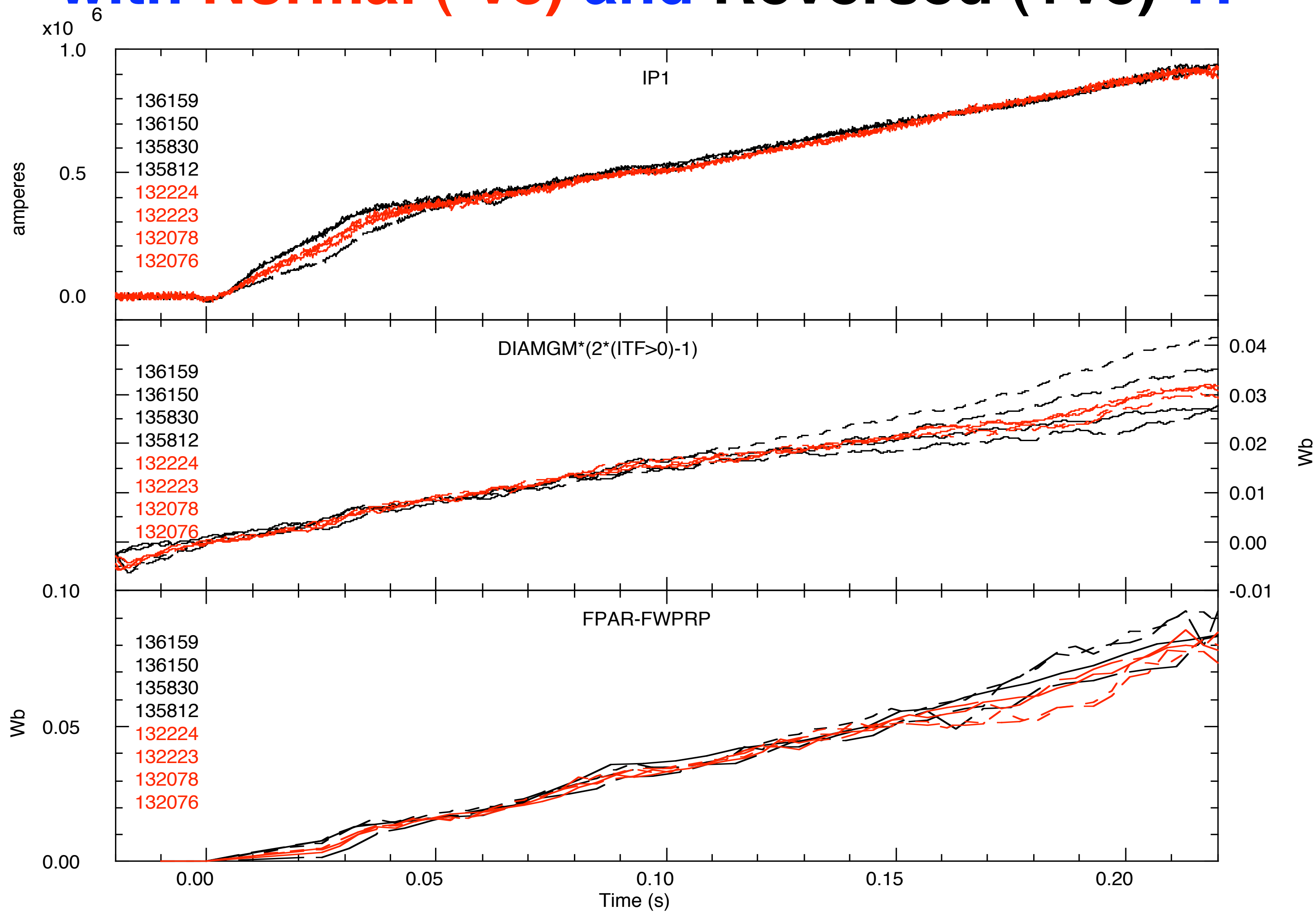
N_{TF}:	number of turns in TF coil (36)
V_{TF}, I_{TF}:	coil terminal voltage and current
L_{TF}, R_{TF}:	coil inductance and resistance (as functions of time)
$I_{PF}, M_{TF:PF}$:	PF coil currents and their mutual inductances to the TF, including plasma current direct coupling
$I_j, M_{TF:j}$:	eddy currents in structure and mutual inductances

- Model effects of TF resistive heating and calibrate in TF shots
- Measure external PF couplings by energizing each coil
- Direct I_p coupling occurs through TF coil interconnections and out-of-radial-plane misalignments
- Measure direct I_p coupling to TF by reversing I_p/I_{TF}

$$\Delta\phi_{TF} = -\phi_d + M_{TF,p}I_p/N_{TF} = \left[\tfrac{1}{4}\mu_0\left(\gamma_p/\gamma_d\right)R_pI_p^2 - W_\perp/\gamma_d\right]/I_t + (M_{TF,p}/N_{TF})I_p$$

- Use low-β ($W_\perp << {}^1/_4\,\mu_0 R_p I_p^2$) so effect of changing γ_d, γ_d minimized

Compare Similar Shots in Early Low-β Phase with Normal (-ve) and Reversed (+ve) TF



- From overlap of normal and reversed TF traces conclude that direct I_p coupling is small: probably below quoted ±3mWb uncertainty