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XMP: Intrinsic Error Field Investigation
XP: Early and Later Error Field Correction in Reduced Density Advanced Scenarios

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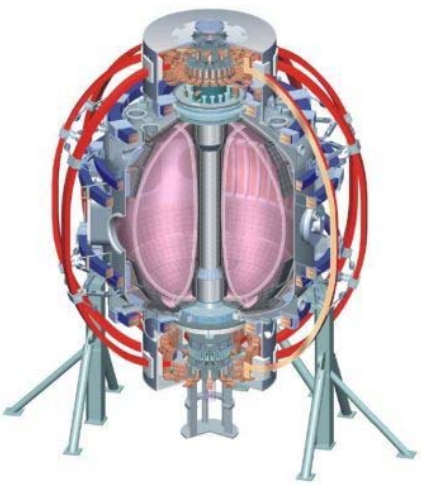
and the NSTX Research Team

NSTX Research Forum for 2011-2012 Campaign
B318, PPPL
March 15-18, 2011



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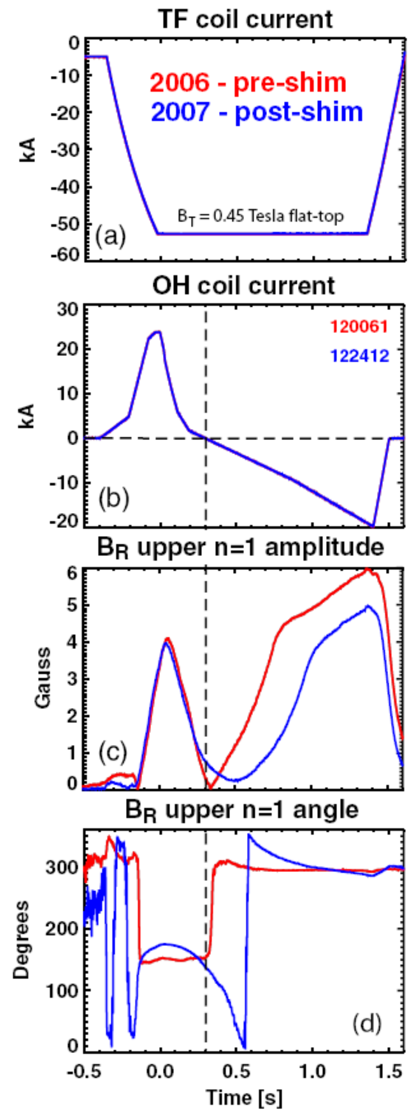
Motivation

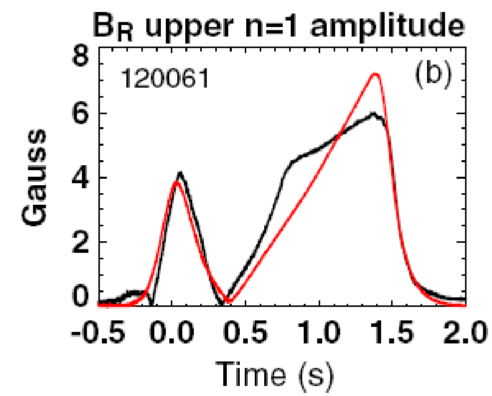
- Intrinsic error field by OH-TF joint movements may be now different after many operations in years
  - Previous one is from 2007, and may need an update
- Early OH-TF error field correction (XP1004) will be more important in reduced density scenario due to locking
  - Further test is needed to maximize its benefits
- Later OH-TF error field correction is typically not pre-programmed due to strong plasma response effects, but plasma responses can be predicted
  - **This also includes the early flat-top phase, where DEFC or RWM feedback is also not reliable**

OH-TF distortion can be modeled by magnetic measurements in vacuum

- OH-TF distortion can be modeled by n=1 shifts and tilts for 12 TF centre rods, which should reproduce measurements in sensors
- Jon's model reproduced measured amplitudes and phases very well
  - Error ~ $I_{OH} \times I_{TF}$
- However, error field is now possibly different by many operations in years, so new XMP is desired



→ **Measurement**
Model



[Menard, NF 50 (2010) 045008]

Early error field correction is needed due to large error fields in early phase (XP1004)

- Error field is very large in the early phase, and thus correction is important to reduce locking and rotational damping
- XP1004 addressed this, but should be revisited

3. Experimental run plan

A. Reproduce increased rotation w/ n=1 early EFC using fiducial or 700kA shot 135779 (4 shots)

B. Scan EFC turn-on time, amplitude, phase to optimize EFC

a. Timing scan: -30, -20, -10, 0, +20, +40ms (5-7 shots)

b. Amplitude scan: ×0.6, 0.8, 1, 1.2, 1.4 (4-6 shots)

c. Phasing scan: -30, -15, 0, 15, 30° (4-6 shots)

C. Assess stability at low density with and without optimized n=1 EFC

a. Reduce density in 20% steps until LM disruption with n=1 EFC (8 shots)

D. Increase flat-top I_P and assess/optimize n=1 EFC

a. Scan EFC amplitude: ×0.8, 1.2, etc. for 0.9MA, 1.1MA (6 shots)

E. Assess impact of early EFC on breakdown by turning on EFC during OH pre-charge (2 shots)

Used fiducial

Varied timing

Varied amplitude

Did not vary phasing

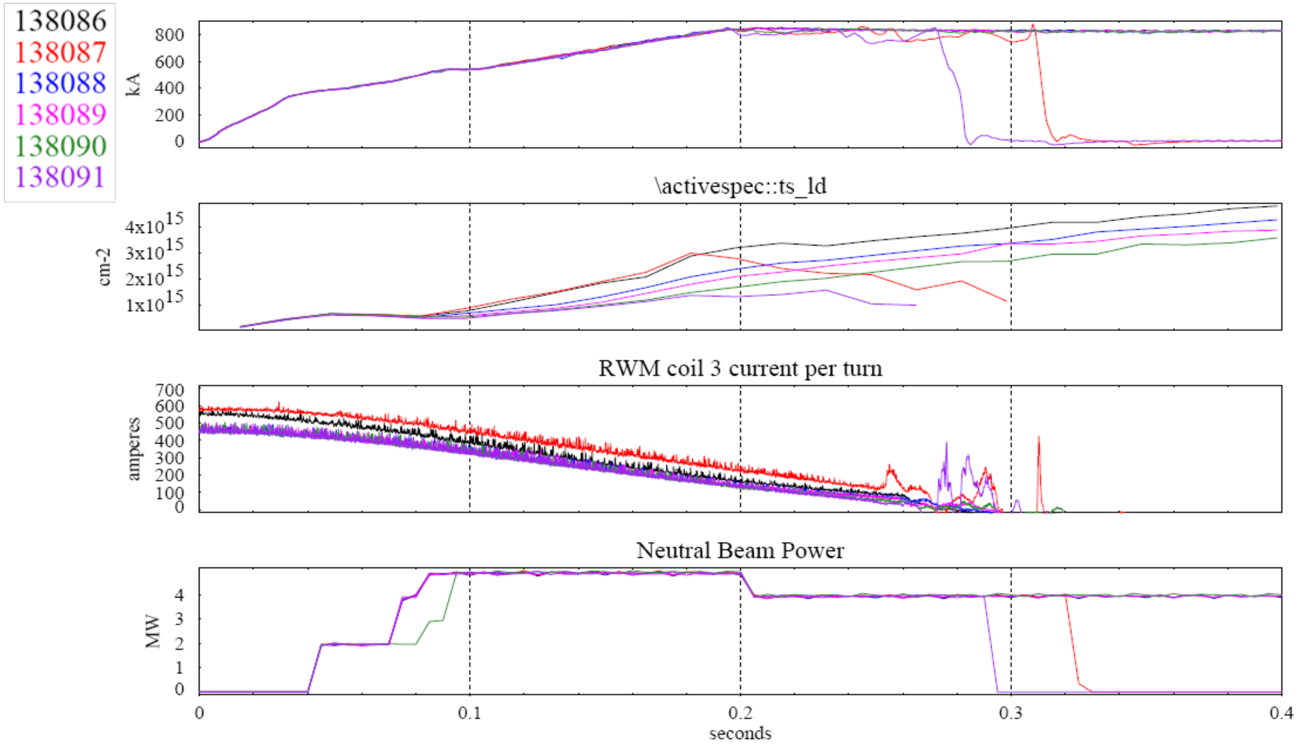
Scanned density with and without EFC

Did not vary I_P

Applied EFC during break-down for many shots

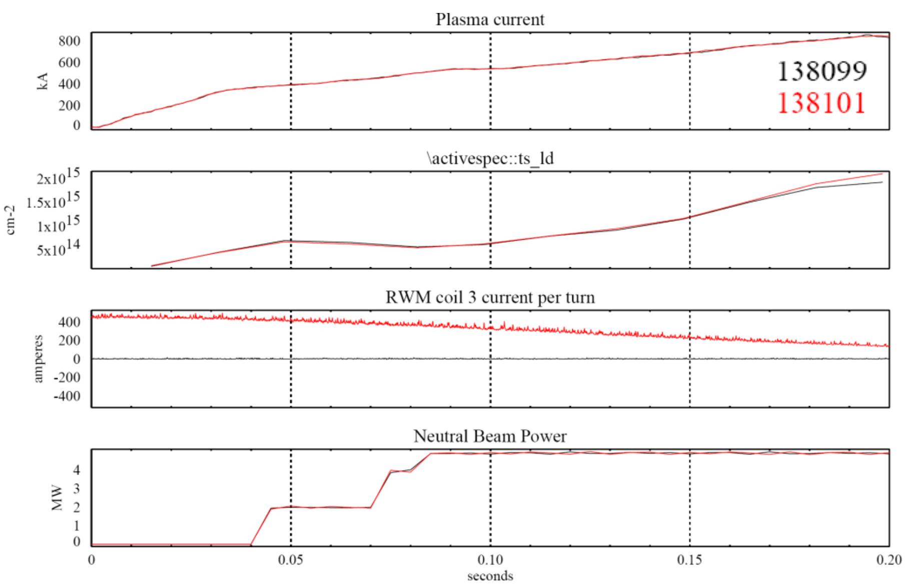
Early error field correction will be more important in reduced-density scenario

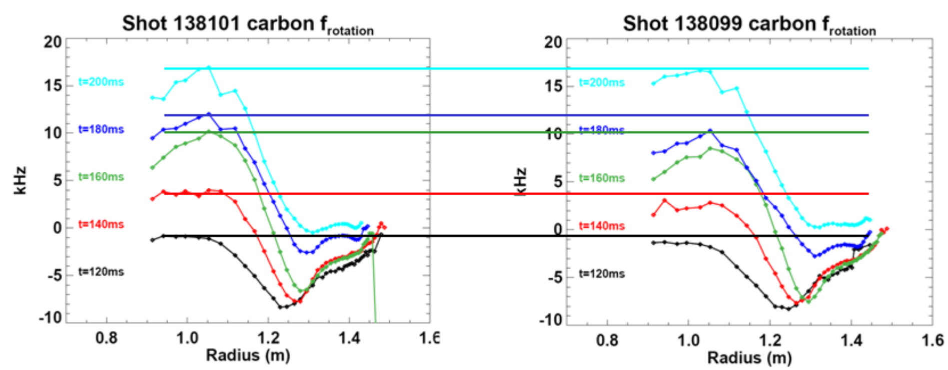
- XP1004 : Density scan shows plasma is sensitive to EFC amplitude between t=100-200ms when density is reduced
- Density threshold for locking decreases by up to factor of 2 from over-compensated EFC → to near optimal EFC



Plasma sensitivity by early error field correction may be due to rotation

- XP1004: Very carefully matched low density plasmas with and without EFC show EFC increases rotation 10-20% for t=120-180ms
- **Additional EFC <u>phase</u>, amplitude scans might be able to further increase rotation at reduced density**



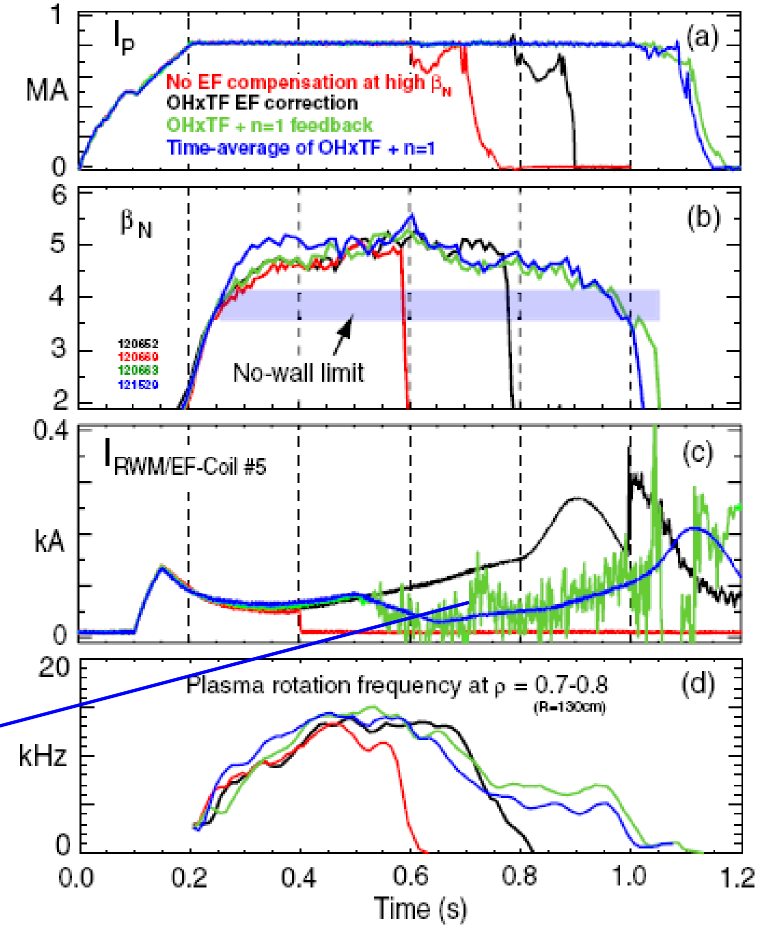


Preprogrammed EFC can be extended to later phase by including response effects

- Study showed preprogrammed EFC (PEFC) is not good in the later phase due to strong plasma response and dynamic EFC (DEFC) or RWM feedback is much better

- **However, PEFC is still tracking DEFC, indicating that PFEC can be extended continuously to the later phase by adding 'plasma response factor'**

Difference between black and blue is likely due to different plasma response for the inboard and outboard perturbation

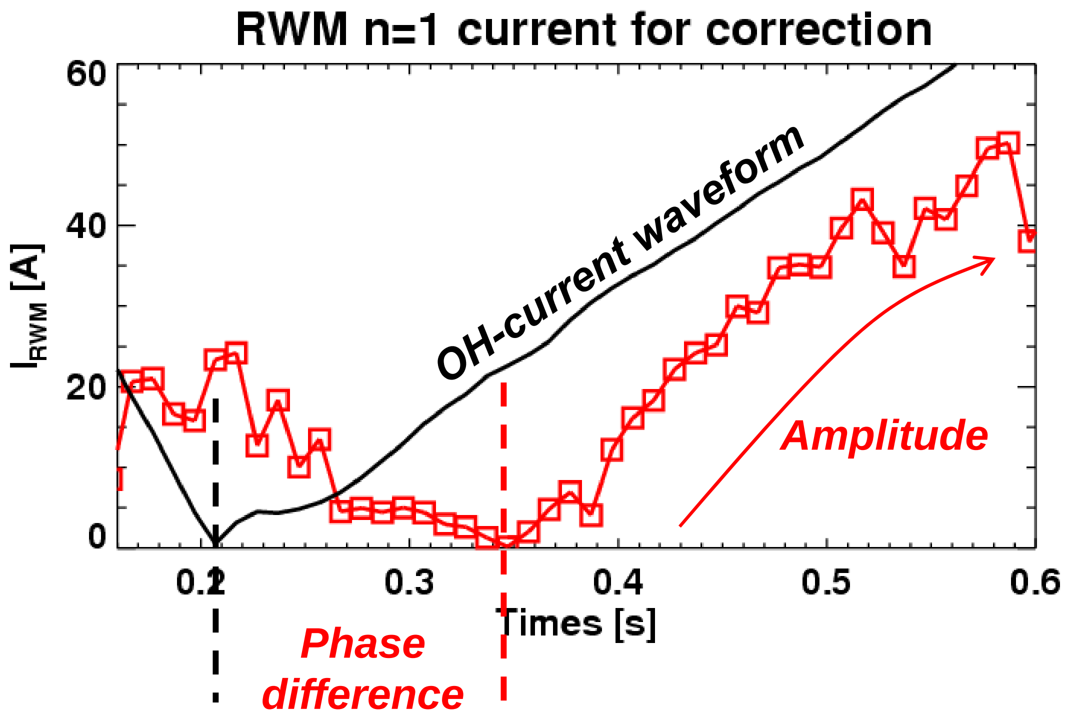


[Menard, NF 50 (2010) 045008]

Initial calculations show both amplitude and phase in PEFC should be modified

- Initial plasma response calculations by IPEC show PEFC may need the delay of phase by ~100ms, and the smaller amplitudes
  - Need more analysis for a longer shot

#130217, β_N<4, IPEC to minimize 7 resonant fields in the core



Shot plan (0.5 day XMP, 1~2.5 day for XP)

- XMP (0.5 day)
  - Road OH-TF waveforms (#115555, #120061) and detect error field

- Early error field correction (0.5~1.5 day)
  - Reproduce increase in rotation with n=1 early EFC
    - Refine/scan EFC phase and amplitude to optimize EFC to increase early rotation, reduce mode-locking activity
    - Phasing scan: -90,-60, -30, 0, 30, 60, 90, 135, 180 degrees
    - Amplitude scan: 0.6, 0.8, 1, 1.2, 1.4 relative to best previous
  - Vary IP ramp-rate and/or flat-top IP to assess EFC robustness

- Later error field correction (0.5~1.0 day)
  - Extend PEFC to later phase with pre-calculated damping factors
    - Extension and damping factor scans will be performed
  - Use PEFC+DEFC or PEFC+RWM for comparison