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XP503: Locked Mode and Error Field Physics in NSTX

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NSTX Results Review
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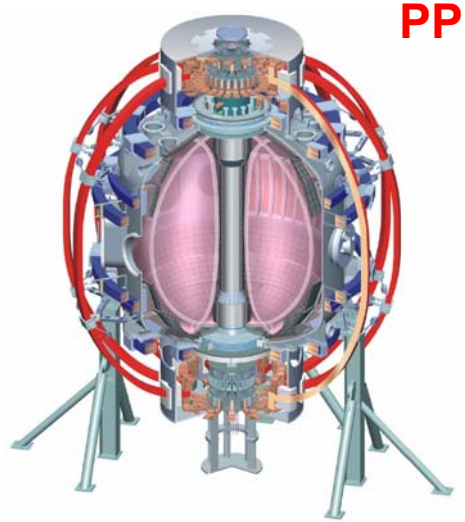

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Goals of experiments

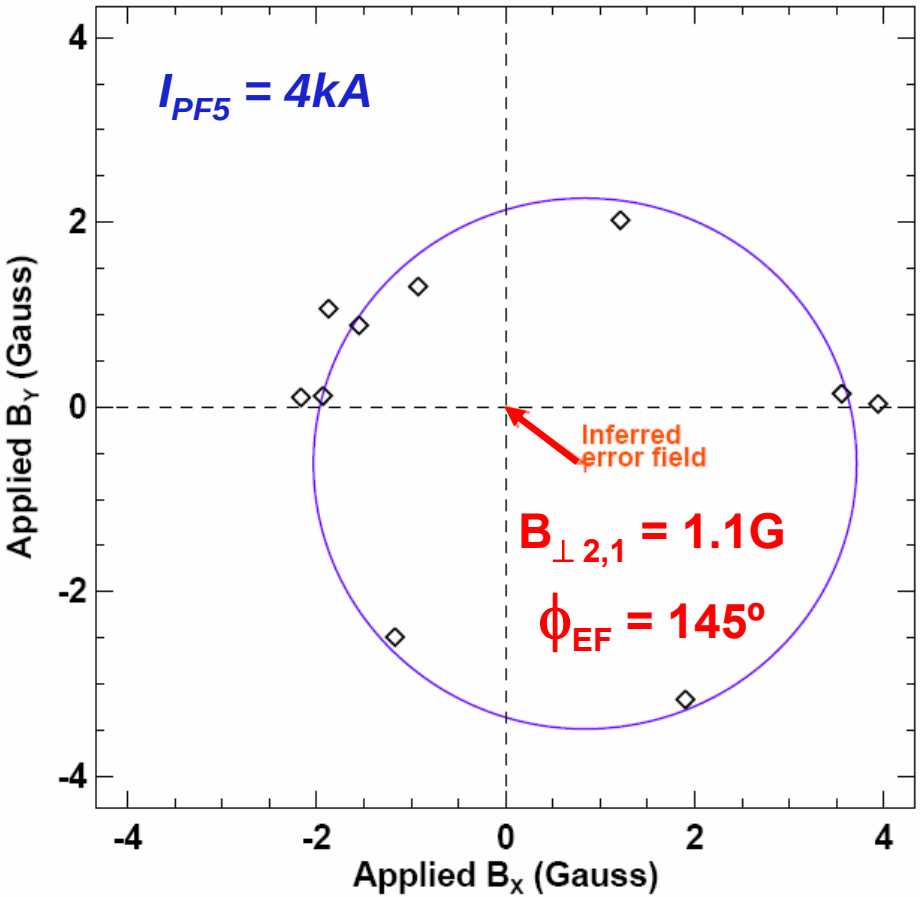
- Study low-β locked-mode threshold during I_P flat-top
  - Contribute low-A data to scaling studies:
    - $\alpha_n \approx 1$, $\alpha_B \approx -1$, **$\alpha_q \approx 0.8 - 1.6$, $\alpha_A \approx 0.4\text{-}0.8$ (MAST)**

$$\frac{b_{pen}}{B_t} \propto n^{\alpha_n} B^{\alpha_B} q^{\alpha_q} (R/a)^{\alpha_A}$$

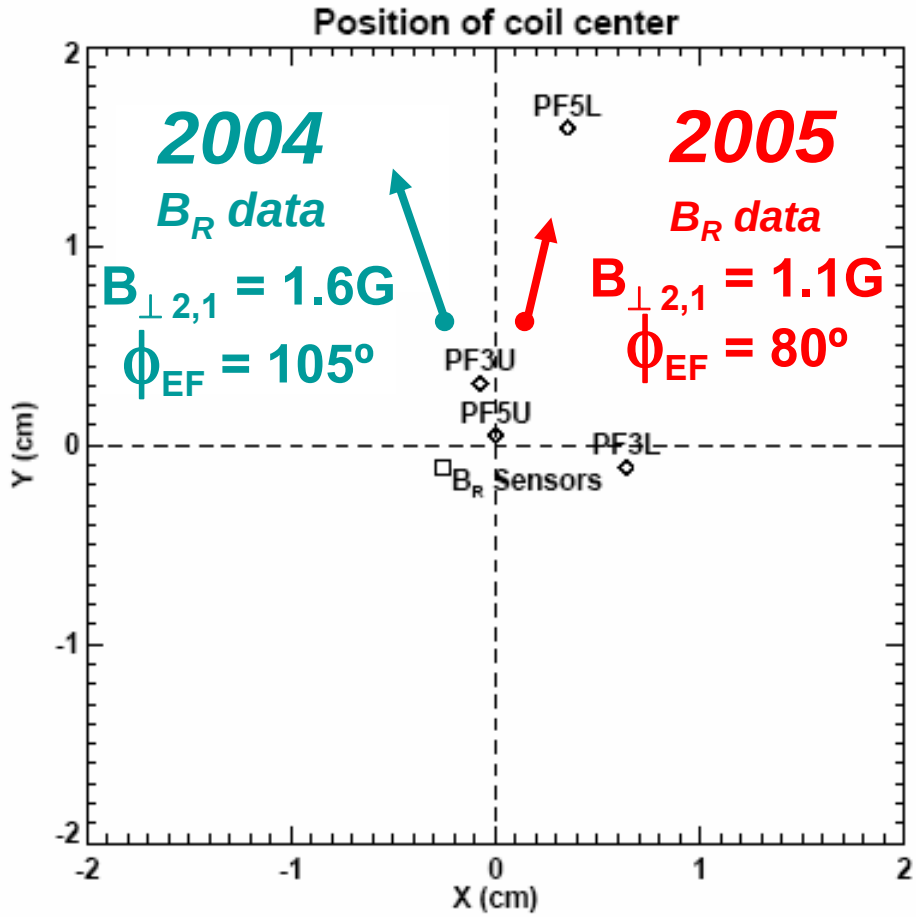
  - Measure threshold for locking vs. phase at fixed *n*, *B*, shape
    - **"Measure" any static intrinsic error field, and correct for it**
  - Determine density scaling of thresholds
  - Determine B scaling of penetration threshold
  - Determine elongation scaling of threshold
    - Scan range of κ from 1.6 for MDC-6 LSN to typical NSTX κ=2
  - Determine q* and q_{95} (triangularity) scaling of threshold

Measured EF amplitude is consistent with PF5 shift model, but EF directions disagree by 35-60º

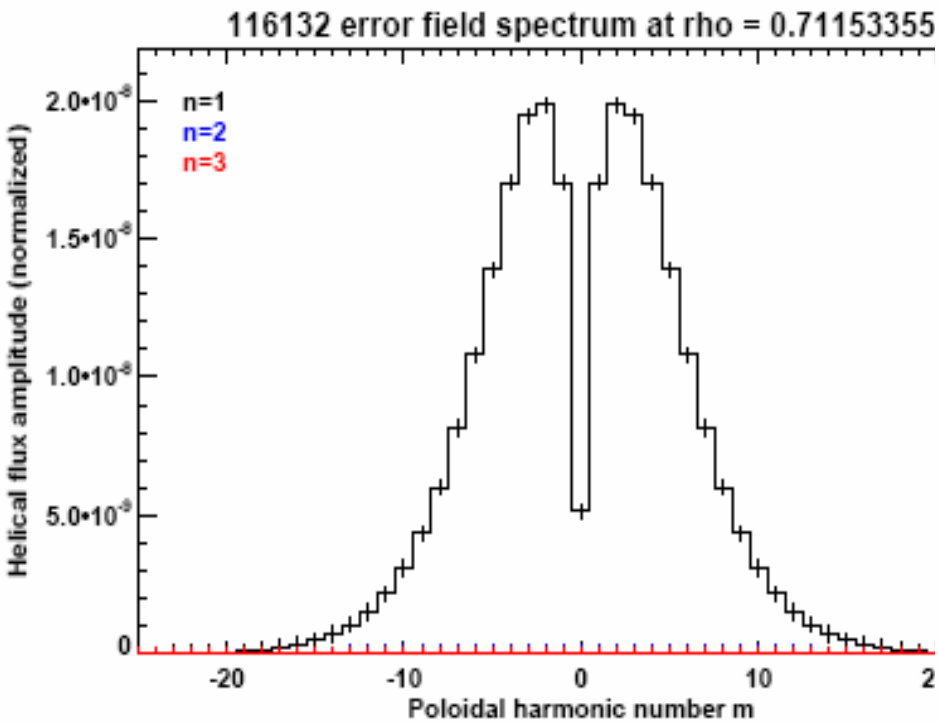
Error field measurements including data at higher density:

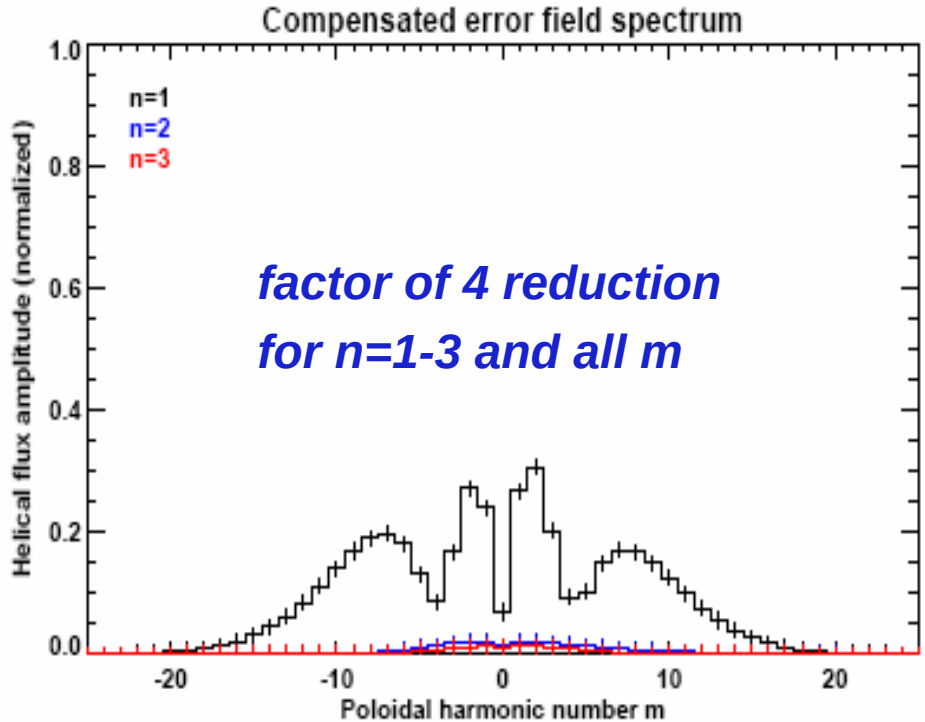


Error field predictions from shifted PF5L model



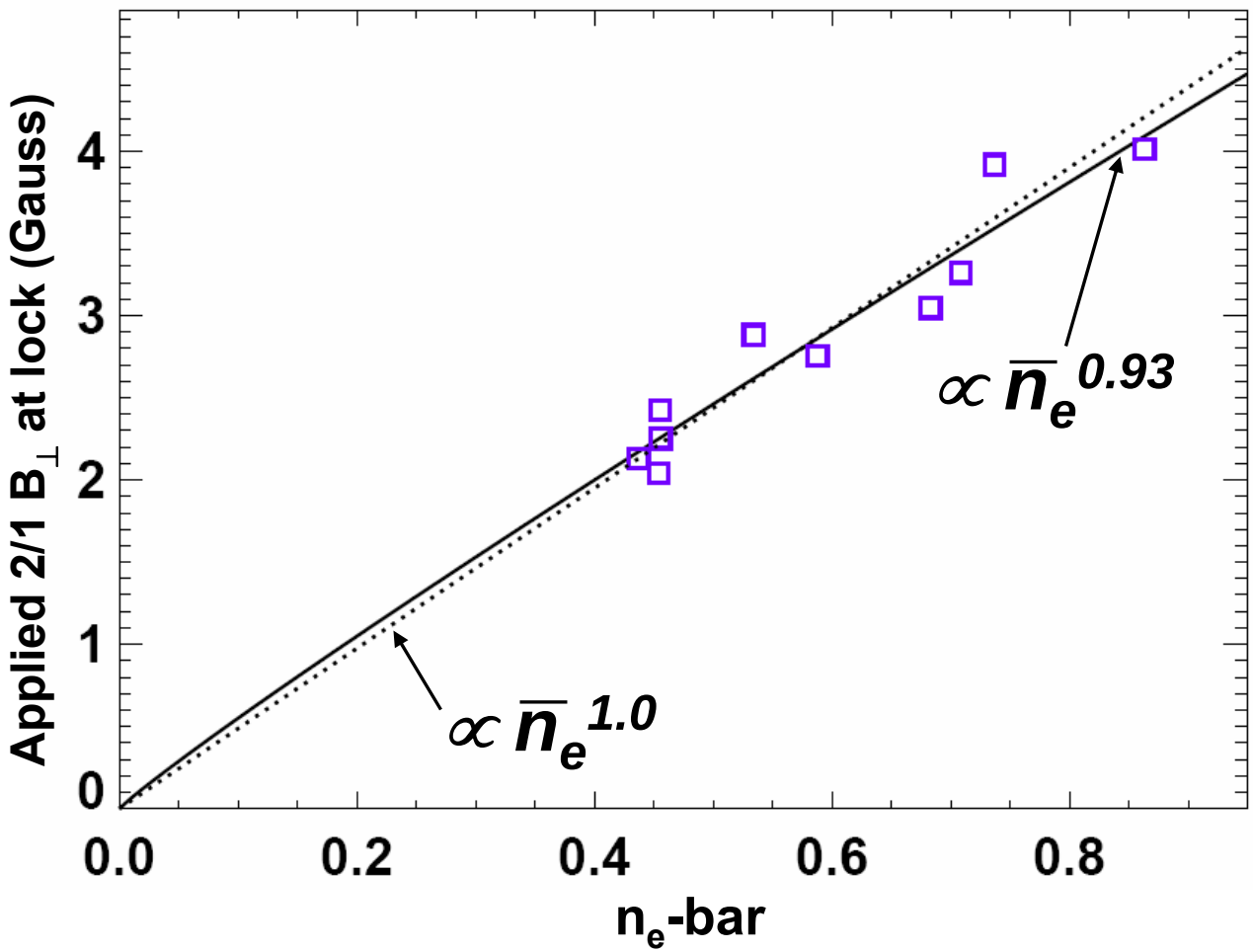
Proximity of EF correction coils to PF5 allows good cancellation of PF5 n=1 error fields





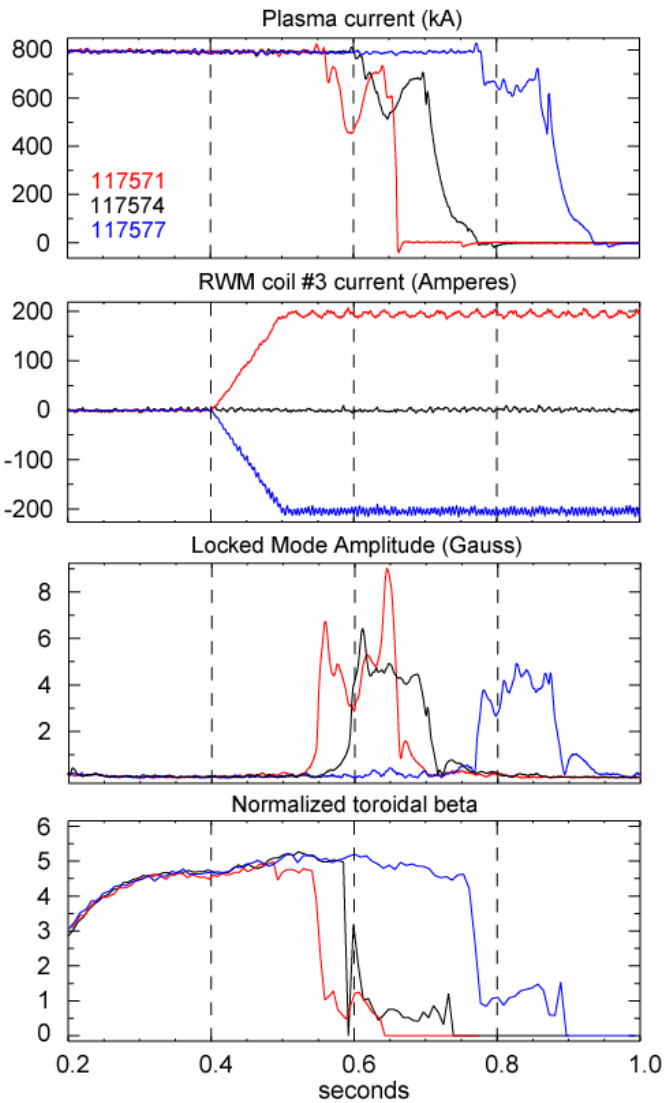
Choose range of m's and n's to minimize vacuum EF helical flux

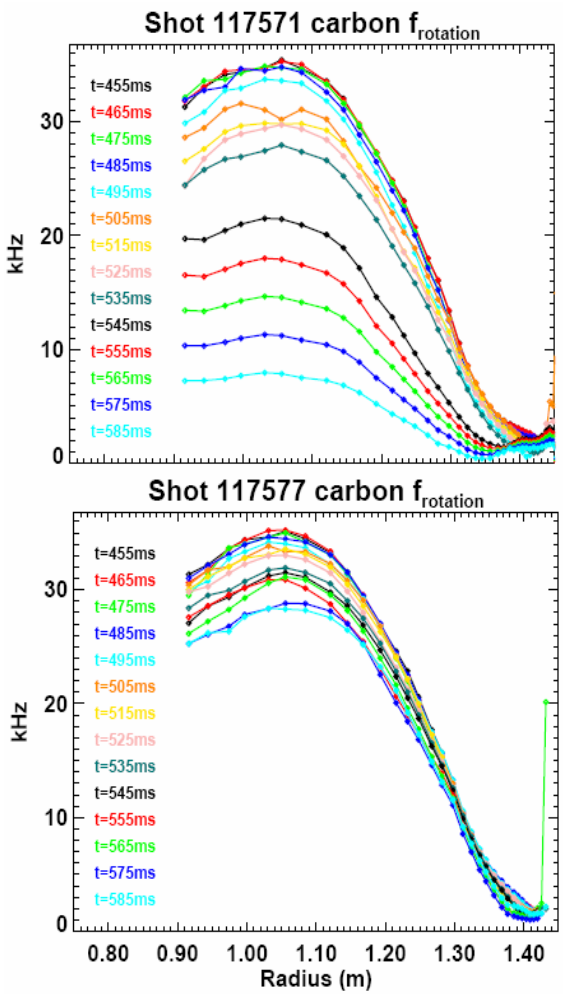
Preliminary density threshold scaling results



Need to widen density scan, and test at other *B* and *q*

Pulse-lengths have been extended at high β_N using newly installed error-field correction coils



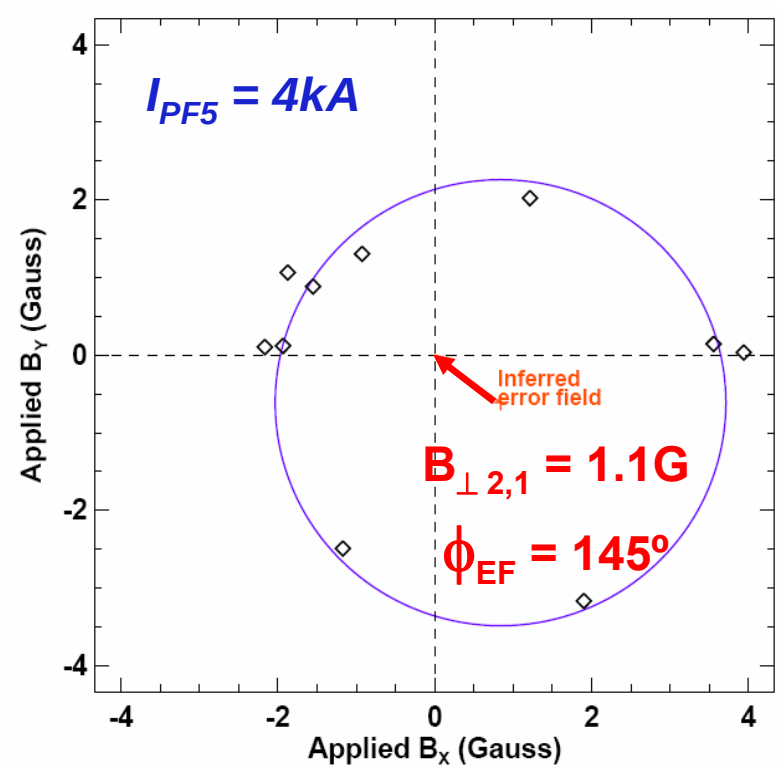


- Rotation is damped in "non-correcting" directions and leads to earlier island locking and/or RWM formation
- Central rotation is sustained & near-edge rotation locking is avoided in "correcting" direction - extending pulse length at high-β

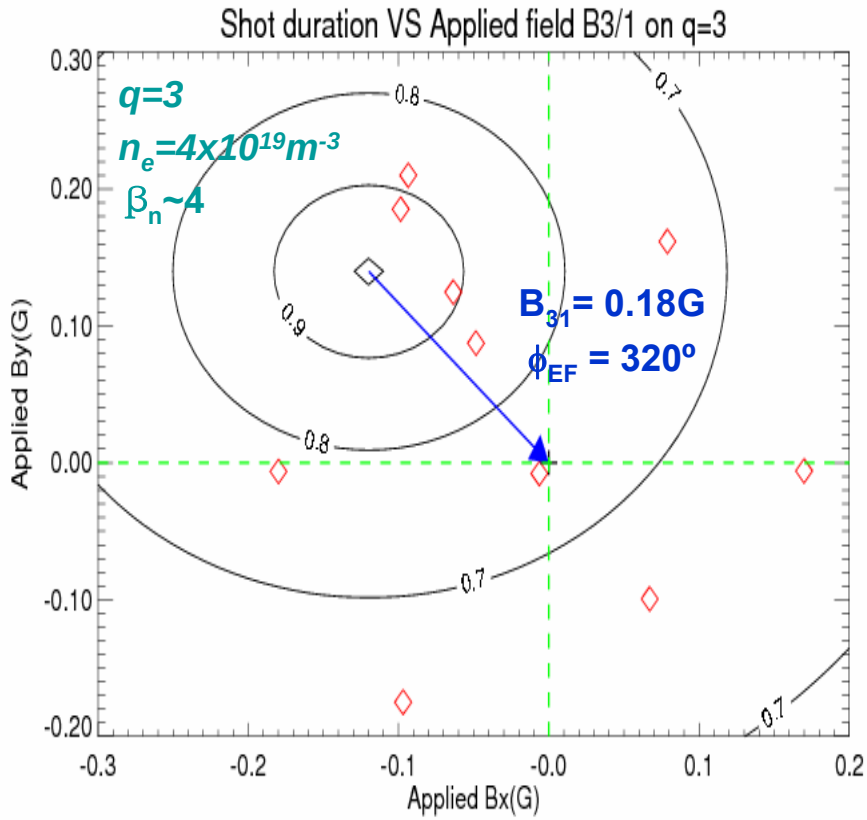
Experiments indicate error field cannot be the result of a single coil's static error field

- Inferred Error Fields are observed to have **opposite** directions in low & high-β plasma with assumption of a **static** error field

Inferred EF in Low-β



Inferred EF in High-β

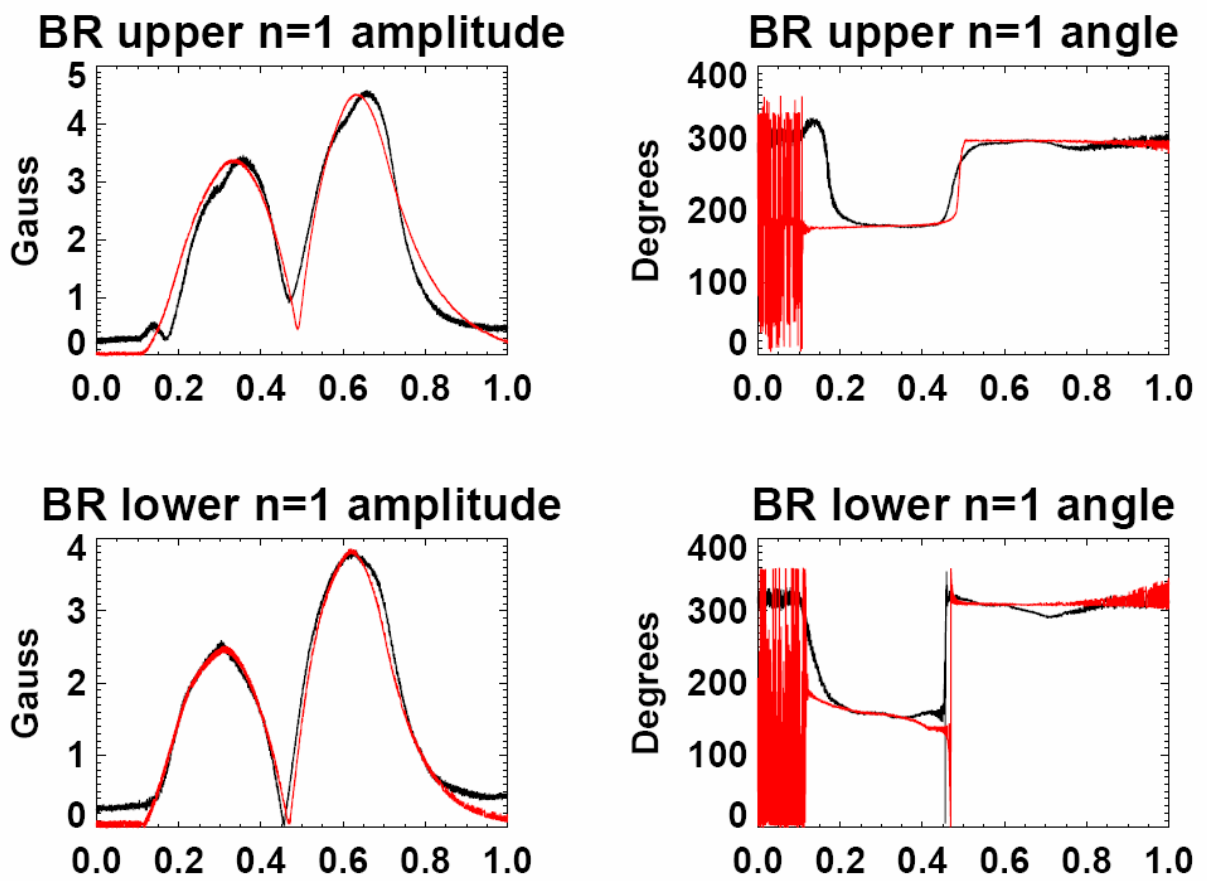


Vacuum shots indicate TF coil motion ∝ $I_{OH} \times I_{TF}$

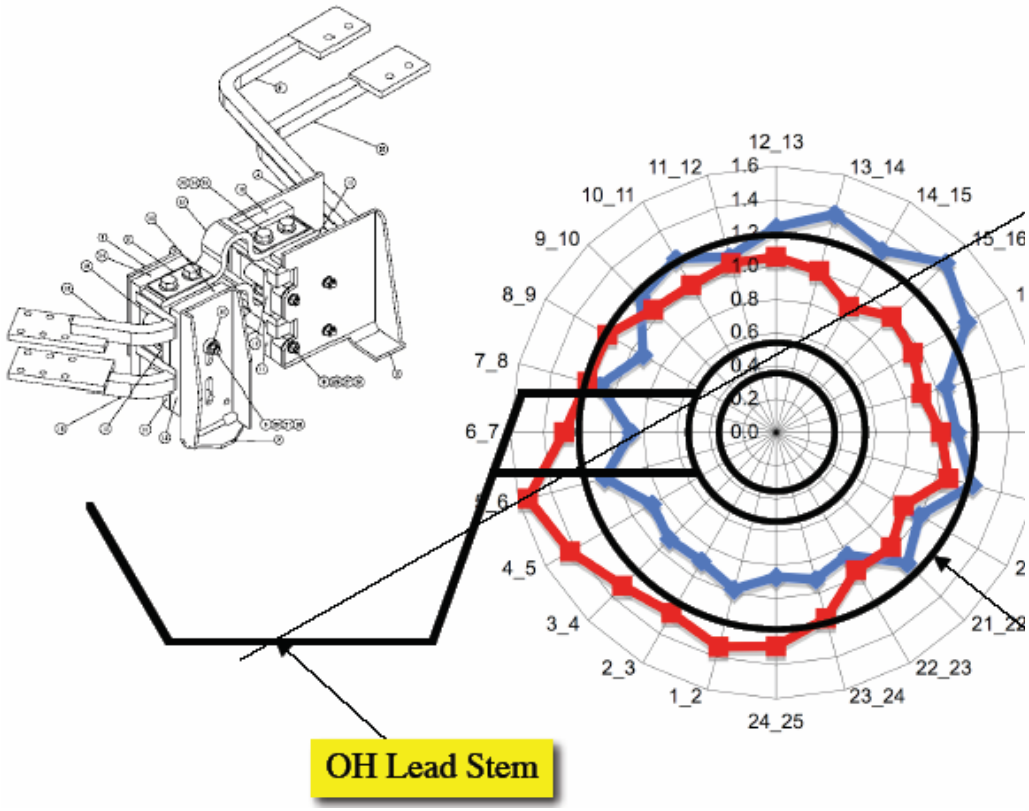
n=1 B_R exhibits time lag (50-100ms), polarity dependence, up/down asymmetry

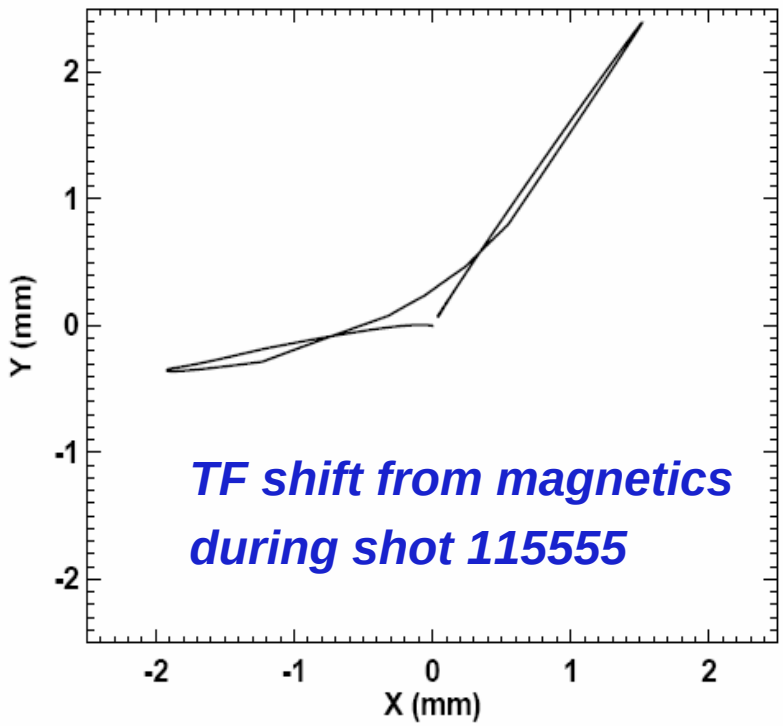
- Developed TF model allowing **both shift and tilt**
- Multiple filter time-constants needed to capture time lags
- **Accurate prediction of EF at sensor → hope for predicting EF in plasma**

Measured & Simulated error field at sensors



TF flag-joint resistance variation direction consistent with direction of translation/shift inferred from magnetics

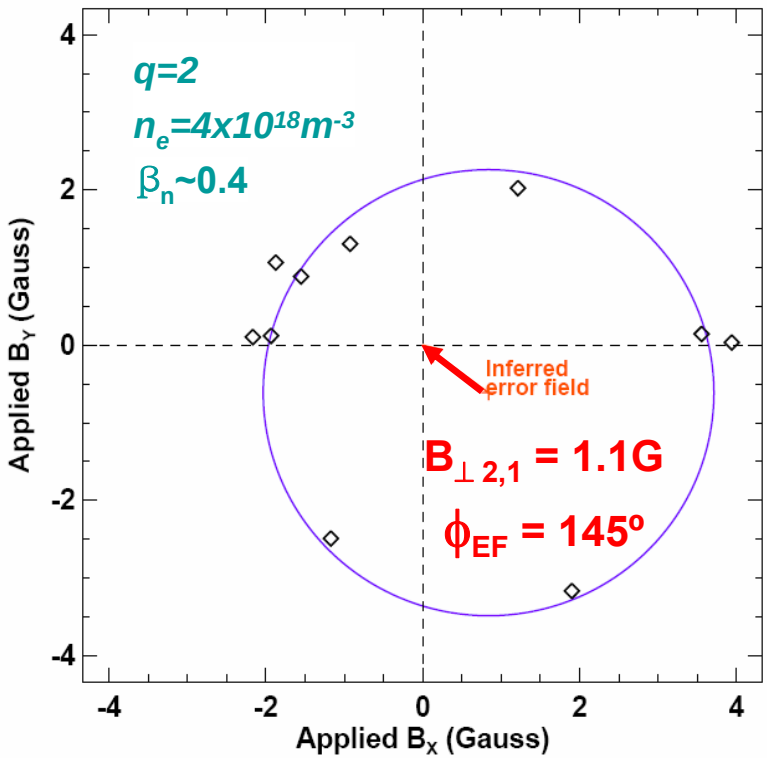




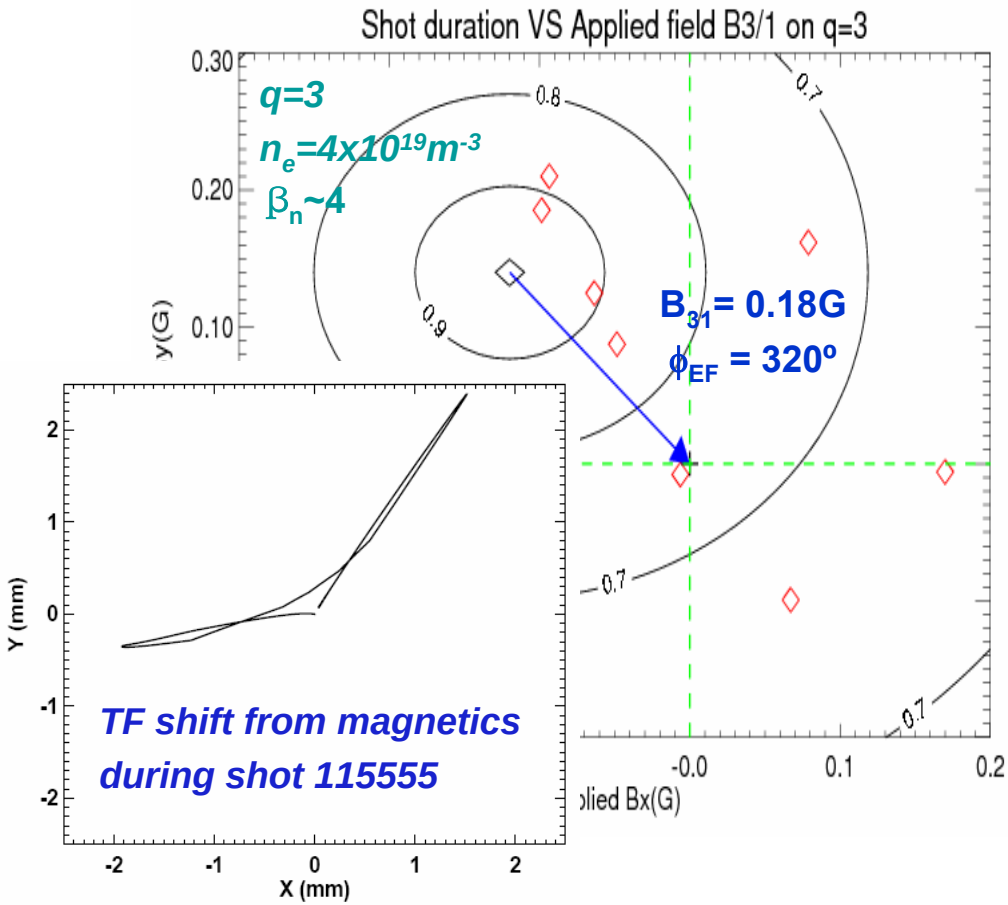
Accumulated data strongly suggests OH/TF interaction creates error field which varies throughout shot even with constant plasma parameters

Error field from TF shift should be orthogonal to shift direction, in reasonable agreement with measurements

Inferred EF in Low-β



Inferred EF in High-β



Low and high-β shots DO lock with different OH polarities… Working on signs/magnitudes

Summary

– Measured threshold for locking vs. applied error field phase at fixed *B*, shape with varied density
  - Find $\alpha_n \approx 1$
  - Inferred intrinsic error field at low density
  - Inferred intrinsic error field at high-β and high density

– Low β and high β EFC currents have opposite directions
  - PF5 and $I_{OH} \times I_{TF}$ error fields are largest and likely dominate
  - $I_{OH} \times I_{TF}$ EF from TF translation/motion during discharge

Future work

- Expand parameter space for locked mode
  : n_e, q, B_T and shaping scaling
  : Low β and High β behavior with sideband effects
- Study sideband effects and mode structure theoretically
  : DCON/VACUUM & MARS-F code as simulation tools
- Consider multiple resonant and non-resonant EF identification and correction on various surfaces
  : Multiple EF effects on global plasma behavior
- Implement & test pre-programmed EF correction
  : Tracking EF during operation by several representative cases such as low/high β
- EF feedback control for locked mode and RWM