NSTX

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XP-902: The Ongoing Search For the n=3 EF Source in NSTX

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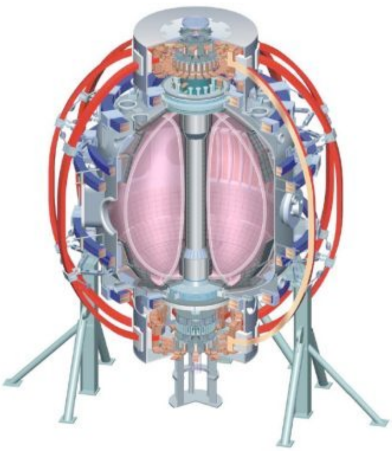
S.P. Gerhardt

J.E. Menard, J.K. Park, R. Bell, B. Le Blanc, D. Gates, S. Sabbagh

NSTX Results Review, 2009



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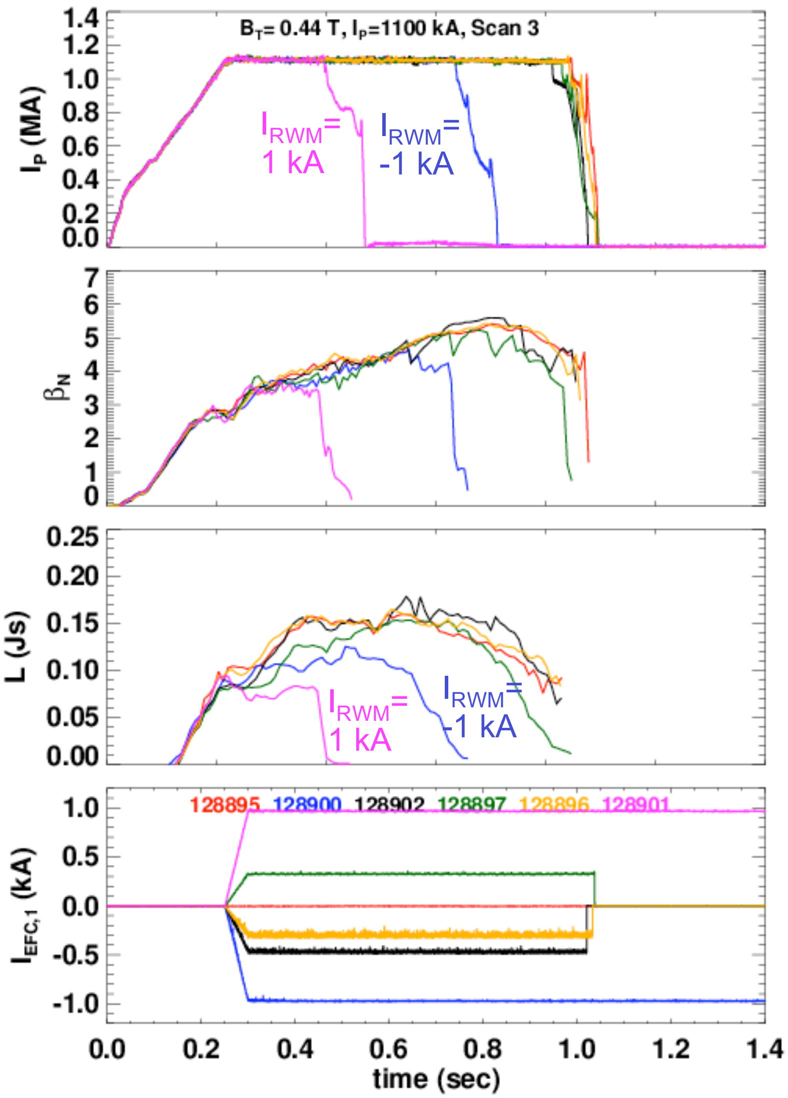
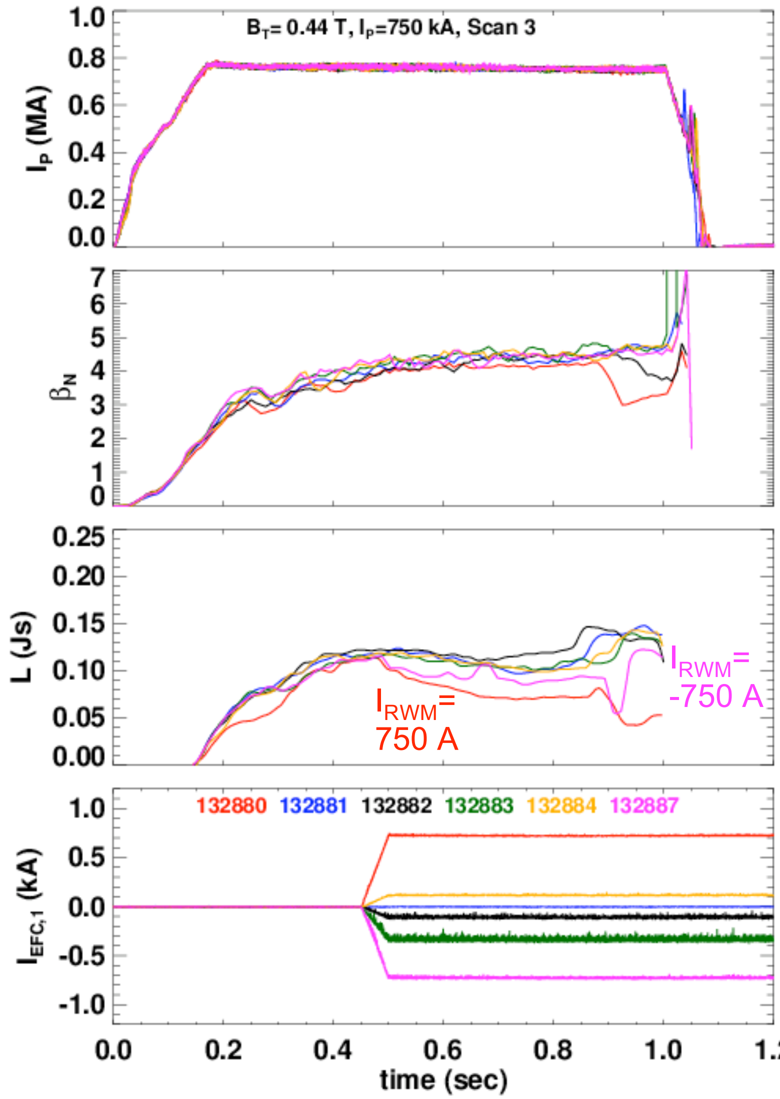
n=3 Error Field Inferred From Asymmetric Response of Plasma Rotation and Sustainment to n=3 Fields

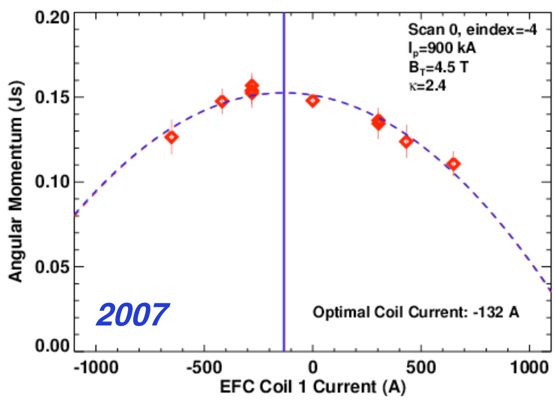


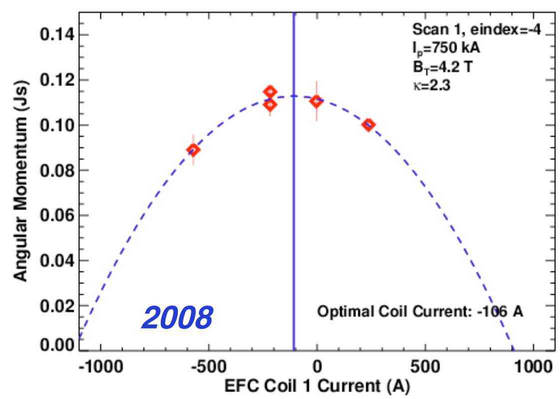


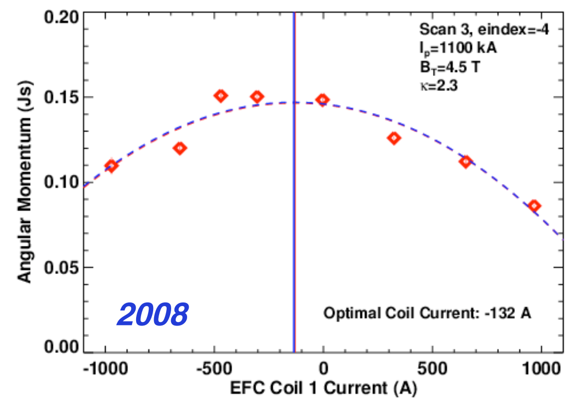
XPs 701, 823, and 902 Combined To Provide the Optimal n=3 Correction Current as a Function of I_P, B_T

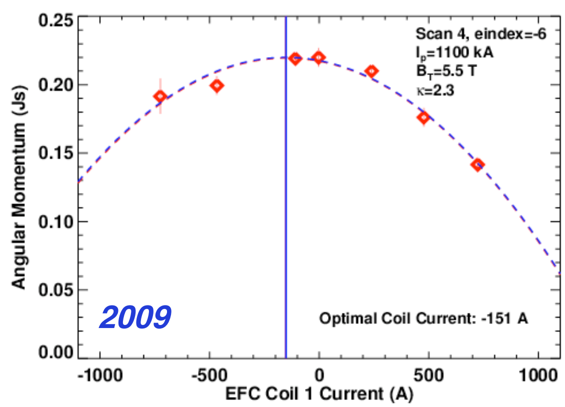
For a given combination of I_P, B_T, and κ, compute the "optimal" n=3 correction by maximizing the angular momentum.

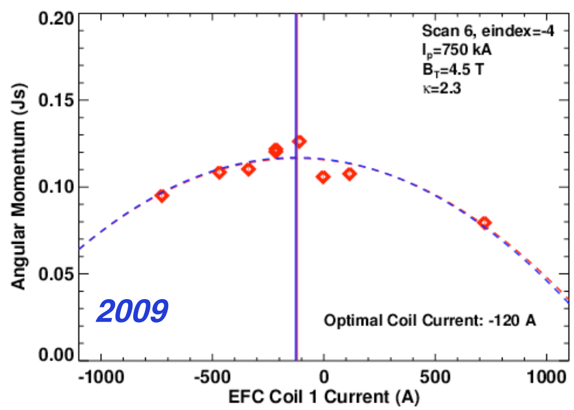
These control parameters map directly to potential EF sources: $I_P \rightarrow I_{PF5}, I_{PF3}$, $B_T \rightarrow I_{TF}$, $\kappa \rightarrow I_{PF3}$

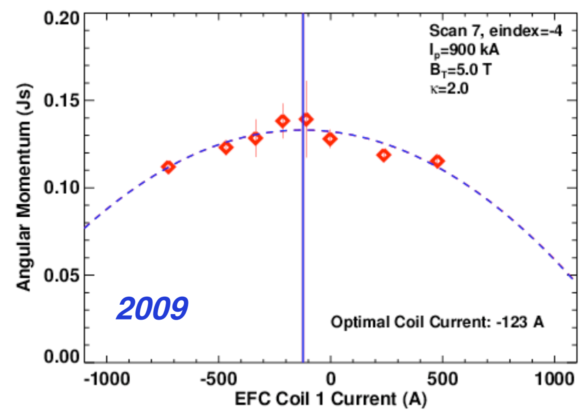




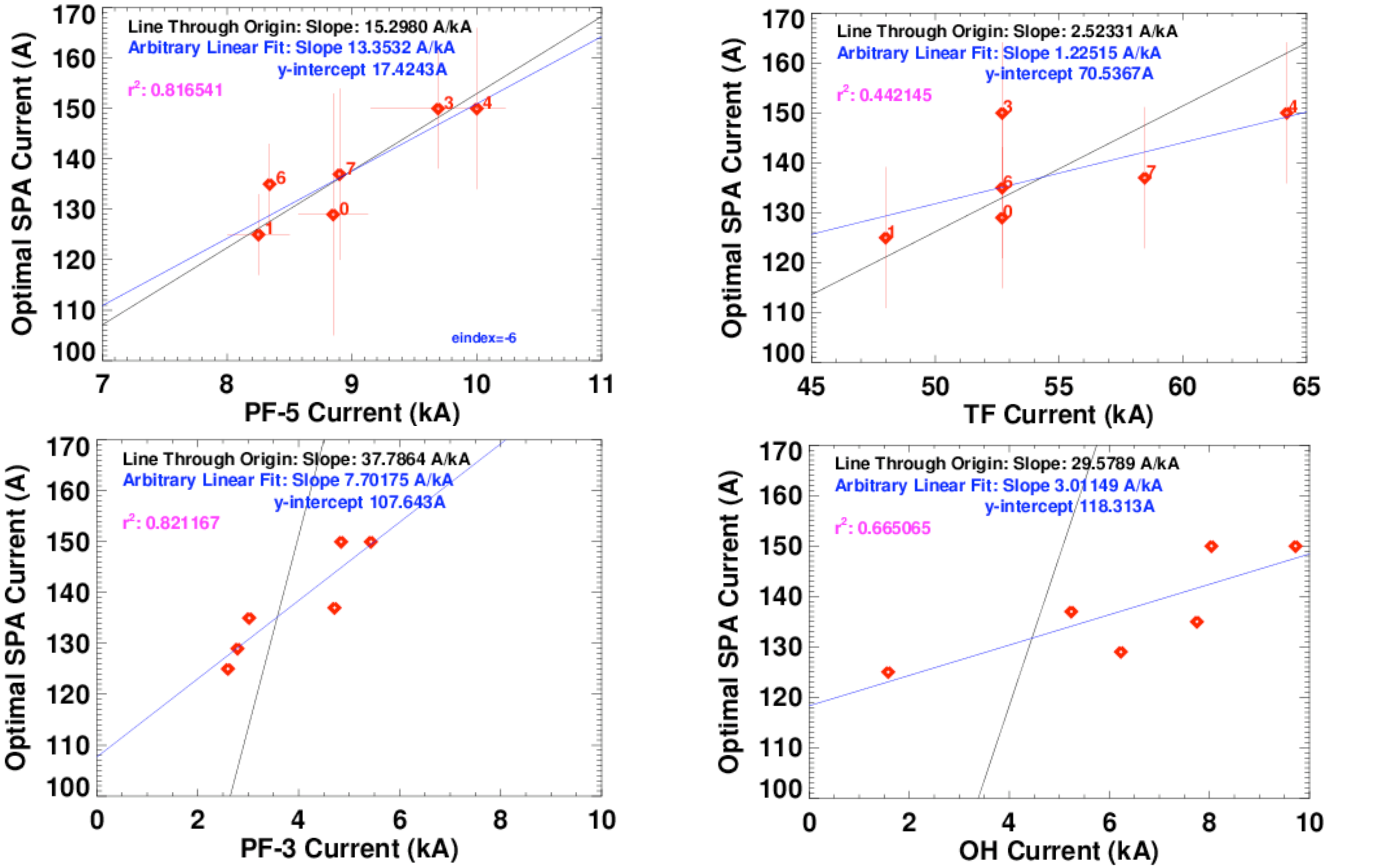






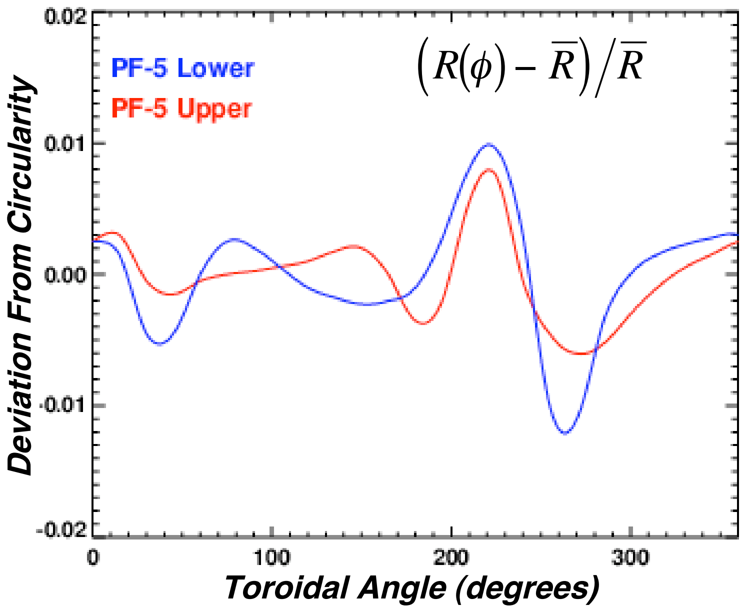


Optimal Correction Correlates Best With The PF-5 Current



Limited Scan in Reversed B_T (Not Plotted) Showed That the Optimal Correction Did Not Change Sign

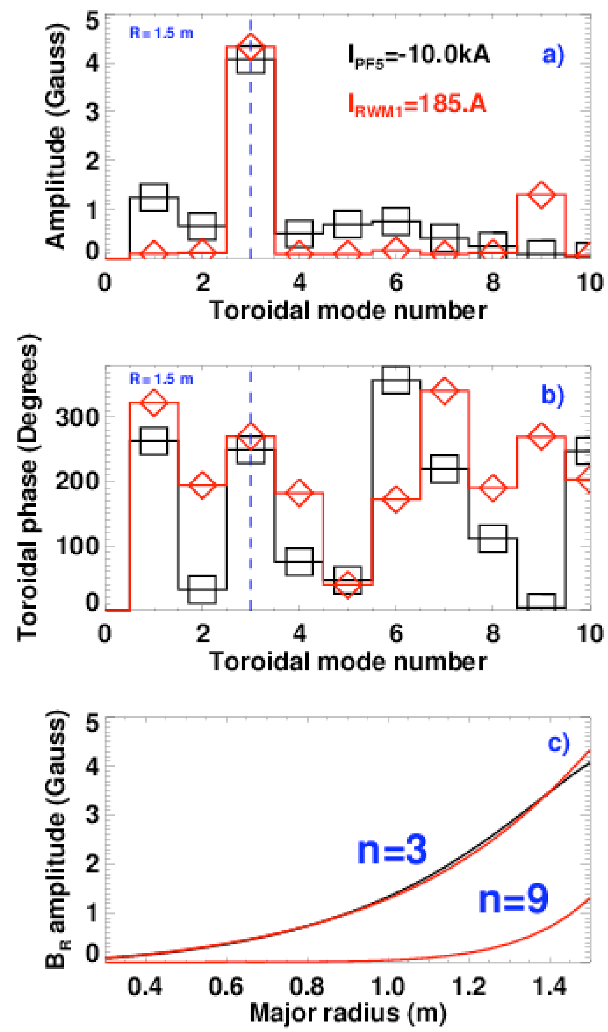
Out of Round PF-5 Is The Likely Source of the EF



- PF-5 Coils are out of round, with a significant n=3 component.

- Vacuum calculation predicts that 185A of SPA current can cancel the error field.
- Phase between applied field and EF is reasonably (fortuitously) good.
- Consistent with XP-805 observation that n=2 EFs are small.

Calculation By JEM



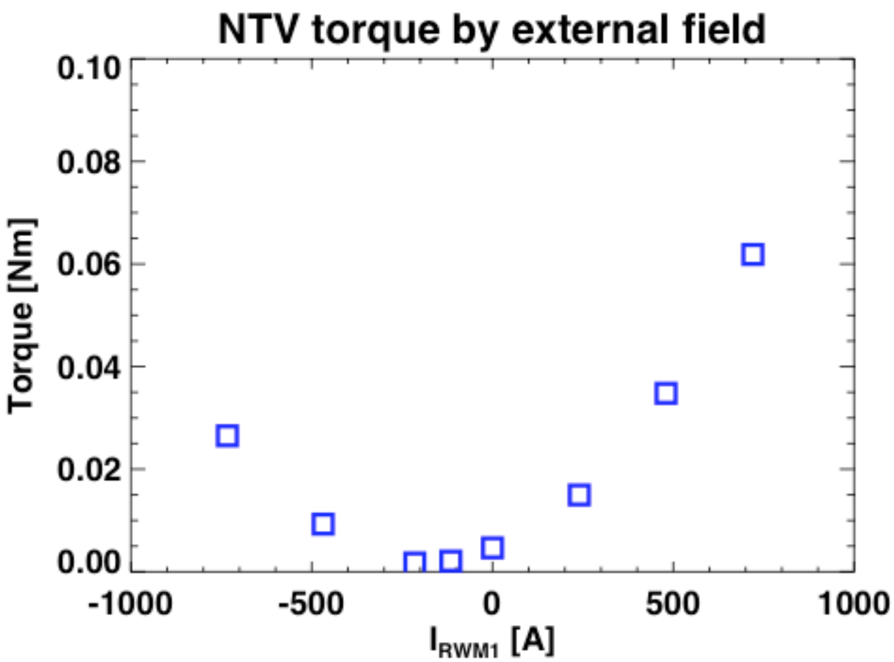
NTV Calculations Including the Plasma Response Indicated Correction Magnitudes Comparable to That in Experiments

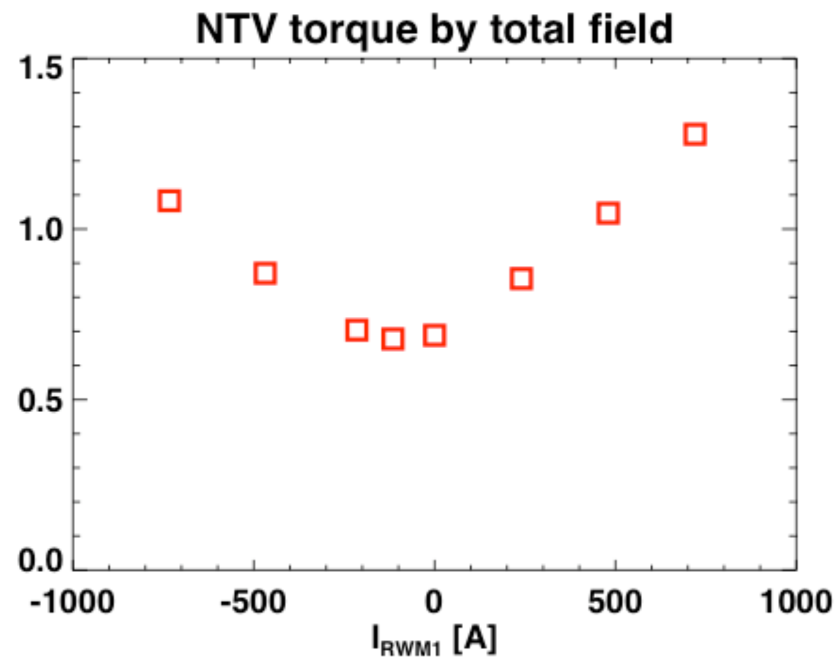
NTV Calculations: EF+Applied Field

Trend is right, but magnitudes are all wrong.

NTV Calculations: EF+Applied Field+Plasma Response

Magnitudes are about correct: T=dL/dt~.05/.1





Calculations By J.-K. Park

Conclusions And Next Steps

- Conclusions
  - There is an n=3 EF.
  - The n=3 EF is observed to scale with the PF-5 coil current.
  - The phase and amplitude of the correction is consistent with that expected from the known coil distortion.
- Next Step:
  - APS contributed talk, Mode Control Workshop invited talk, both on EFs in NSTX.
  - PPCF paper on non-resonant EF measurements and correction.
  - Implement n=3 correction dynamically tied to the PF-5 coil current?

XP-930: Shot Development

- XP-930: RFA measurements as a test of proximity to MHD stability limits.
  - Didn't actually do this XP.
- Roger showed ~0.6 days for XP-930 shot development.
  - Low-δ (0.4), high-κ shot diverting with PF-2 only.
- This development was quite productive.
  - Was used for S.P. control development Kolemen XP.
    - This was then used for the J. Kallman LLD XP.
    - This was used for A. Sontag ELM XP.
- We should consider actually running XP-930 next year.

Eight Total Scans Attempted, Though Only Five are Useful

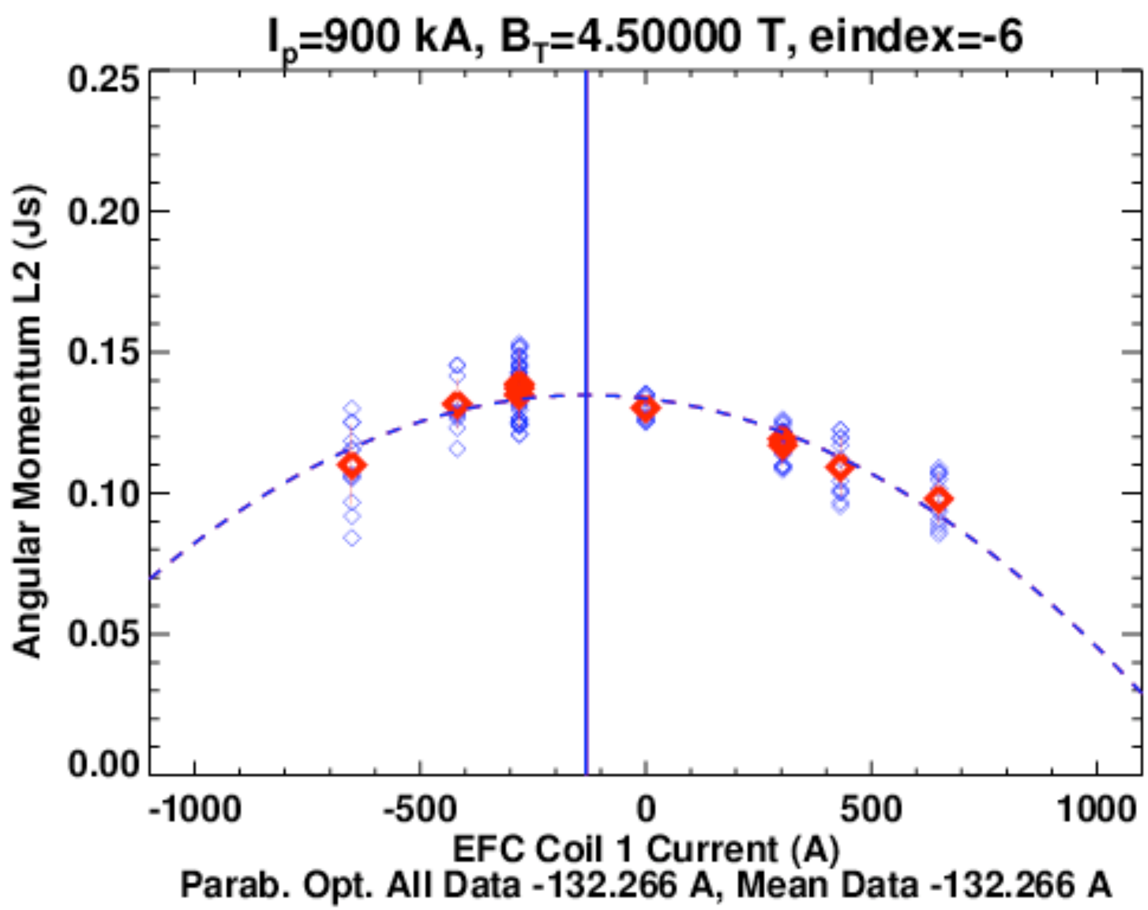
Scan	Ip	BT	κ (lrdfit06)	# Shots	XP
0	**800**	**0.45**	**2.24**	**7**	**701**
1	750	0.42	2.36	5	823
2	900	0.45		4	823
3	**1130**	**0.45**	**2.36**	**8**	**823**
4	**1111**	**0.55**	**2.26**	**8**	**902**
5	750	0.45	2.22	4	902
6	**750**	**0.45**	**2.26**	**8**	**902**
7	**900**	**0.45**	**2.18**	**8**	**902**

- ***Dark blue* rows are good scans**
- ***At least 6 discharges with a large range of n=3 levels required for a good fit.***
- ***Range of I_P, B_T, and κ allow the different sources to be decoupled.***

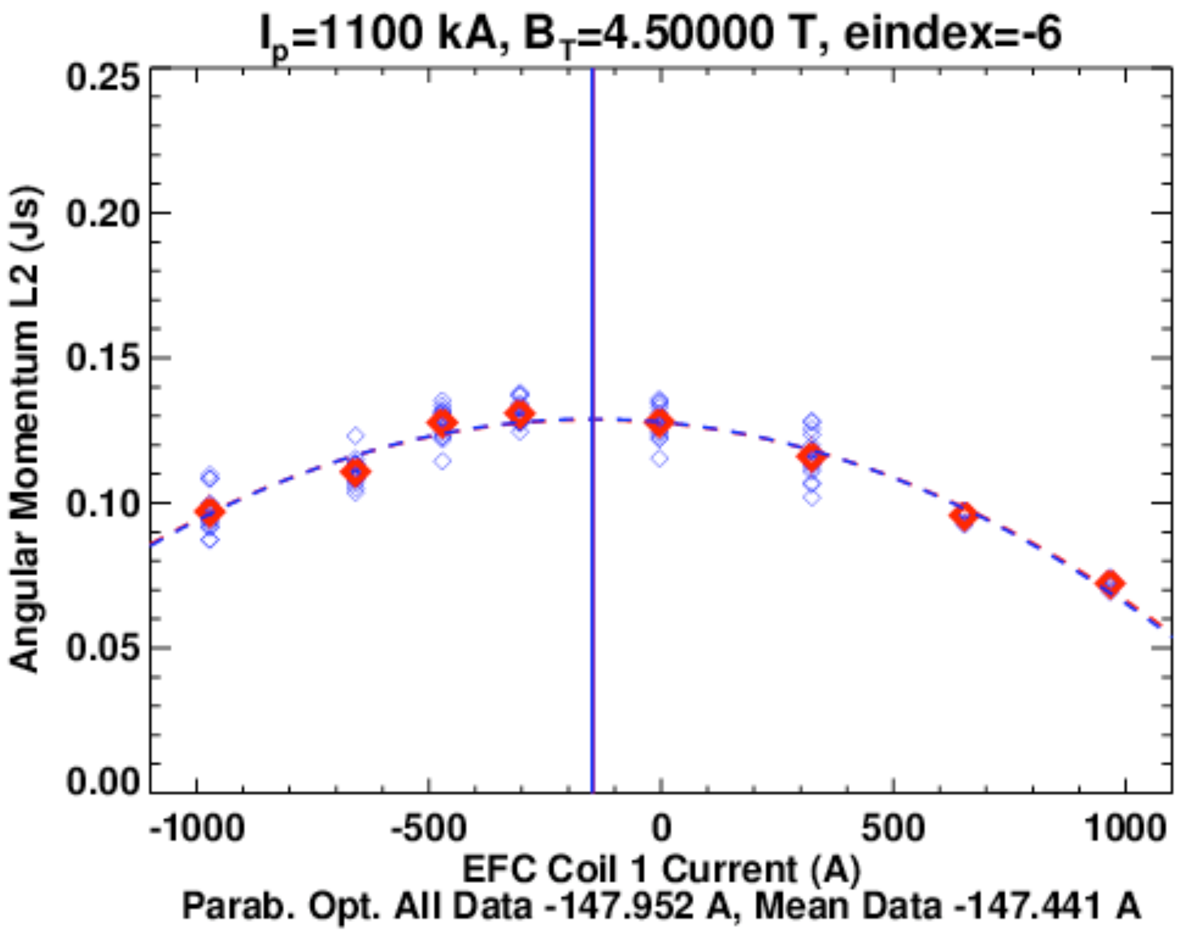
Determine the Optimal Correction By Scanning the Applied n=3 Field

- Pick a discharge scenario with given values of $\{I_P, B_T, \kappa\}$.
- Apply n=3 fields of various amplitudes and phase.
- Determine the amplitude and phase which maximizes the plasma angular momentum.
- Repeat for different values of $\{I_P, B_T, \kappa\}$ to determine scaling of correction with coil currents.

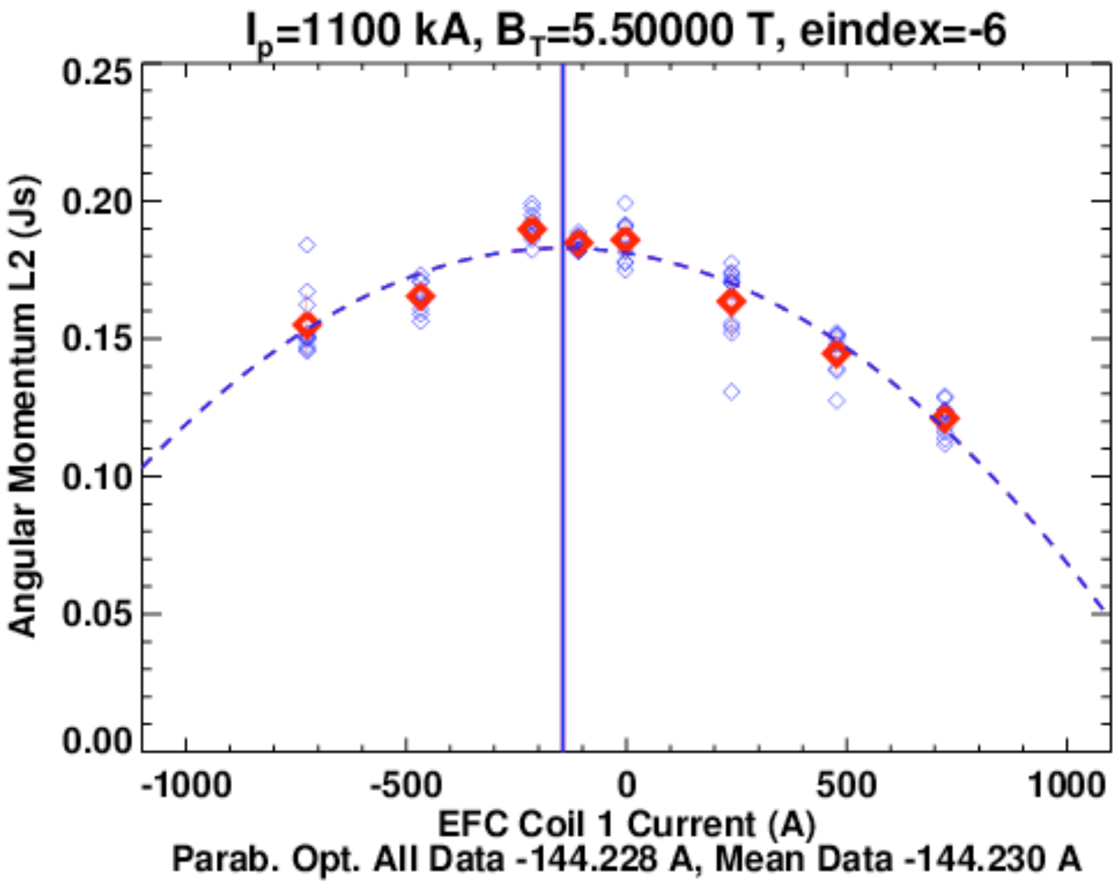
Scan 0: XP 701, I_P=800 kA, B_T=0.44 T



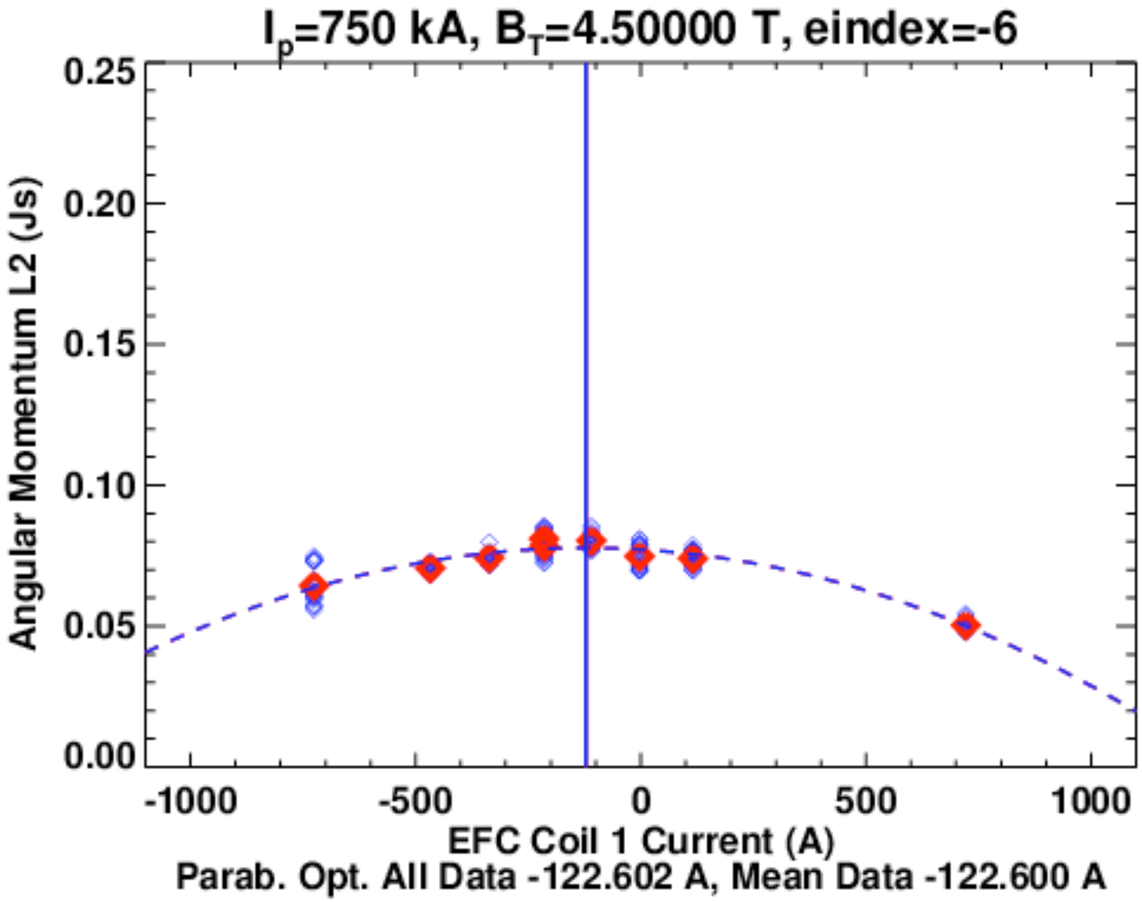
Scan 3: XP 823, I_P=1100 kA, B_T=0.45 T (I)



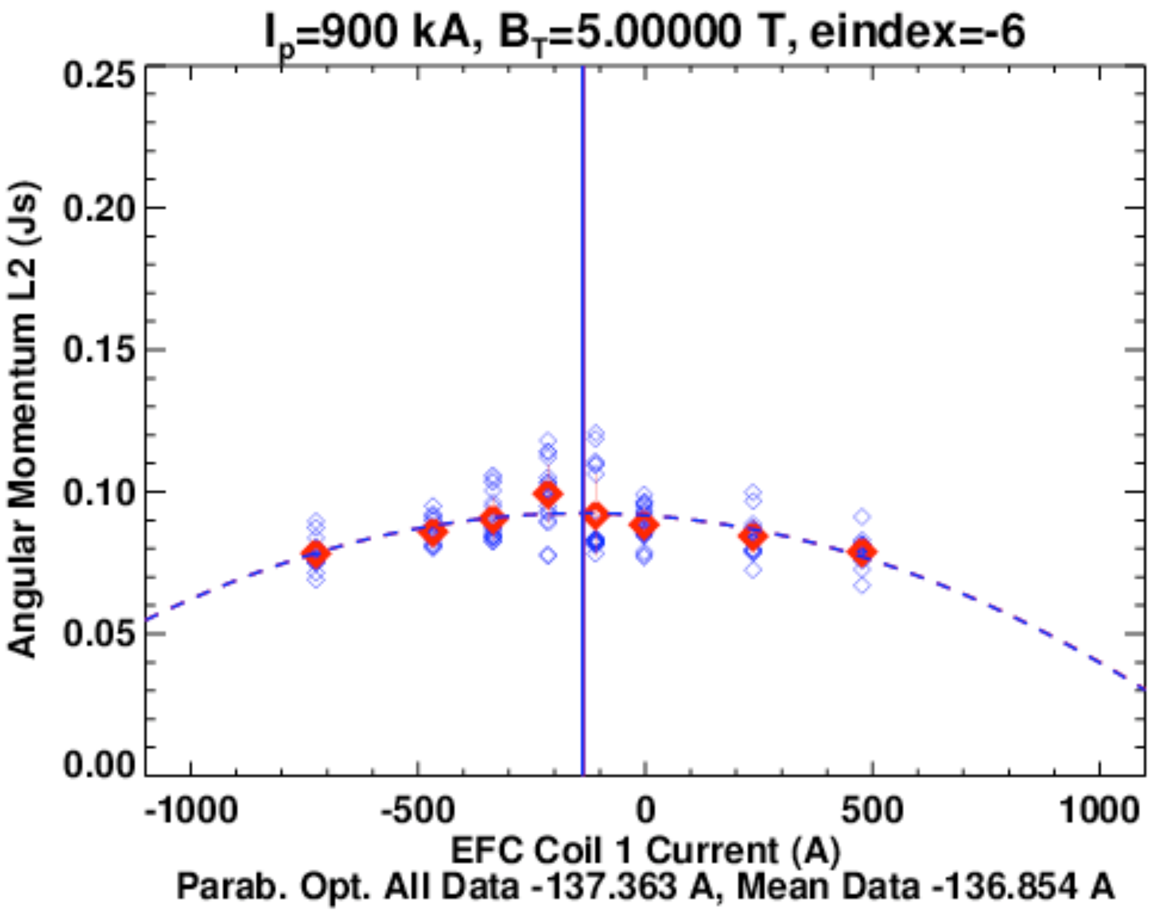
Scan 4: XP 902, I_P=1100 kA, B_T=0.55 T



Scan 6: XP 902, I_P=750 kA, B_T=0.45 T

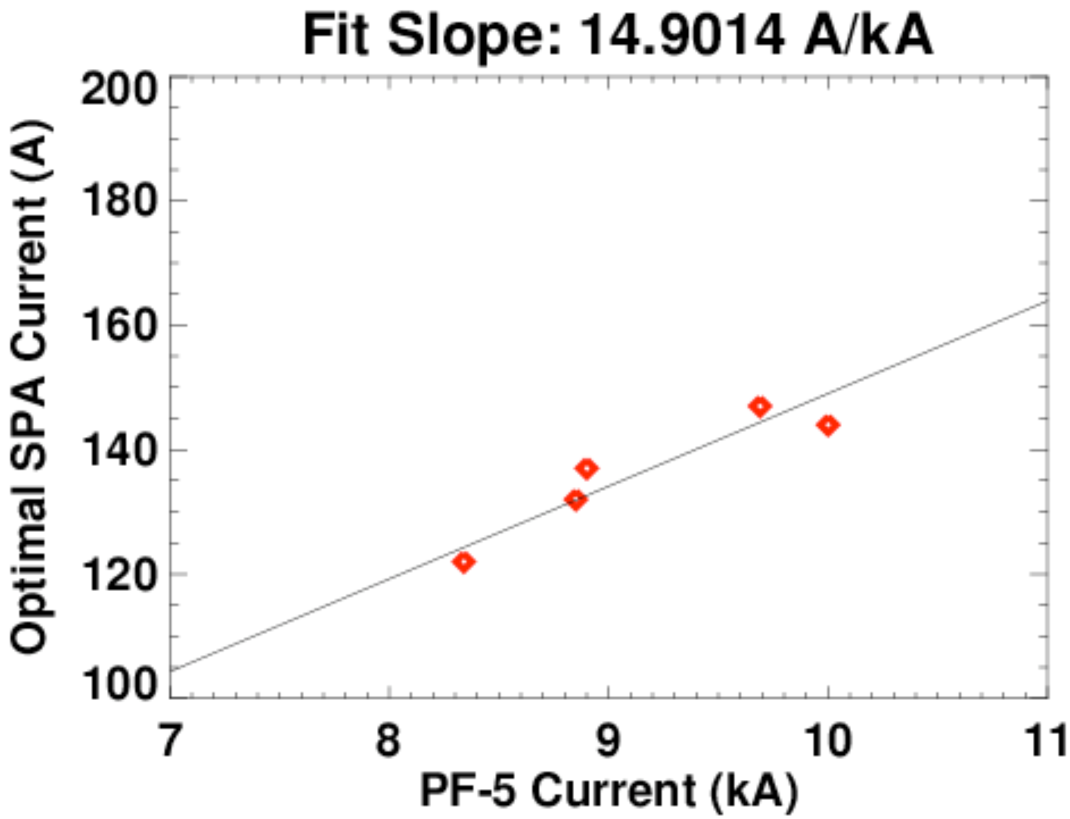


Scan 7: XP 902, I_P=900 kA, B_T=0.5 T

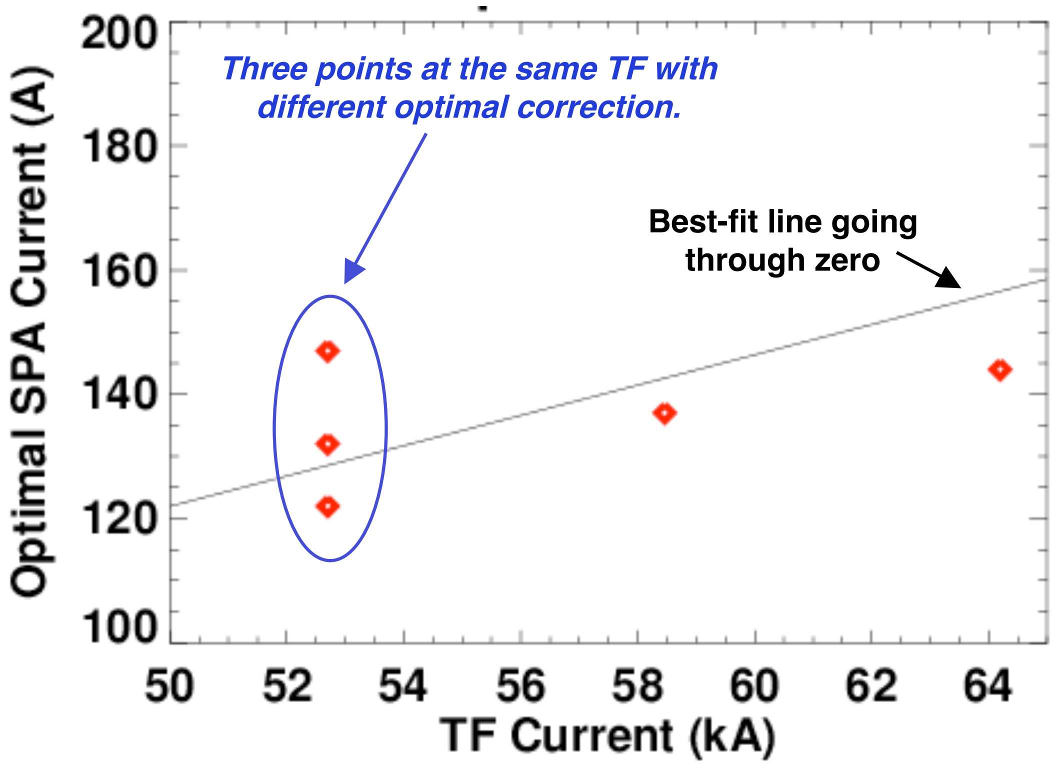


Optimal Correction Correlates Well With the PF-5 Coil Current

- Optimal correction is apparently ~15 A n=3 per 1kA PF5.

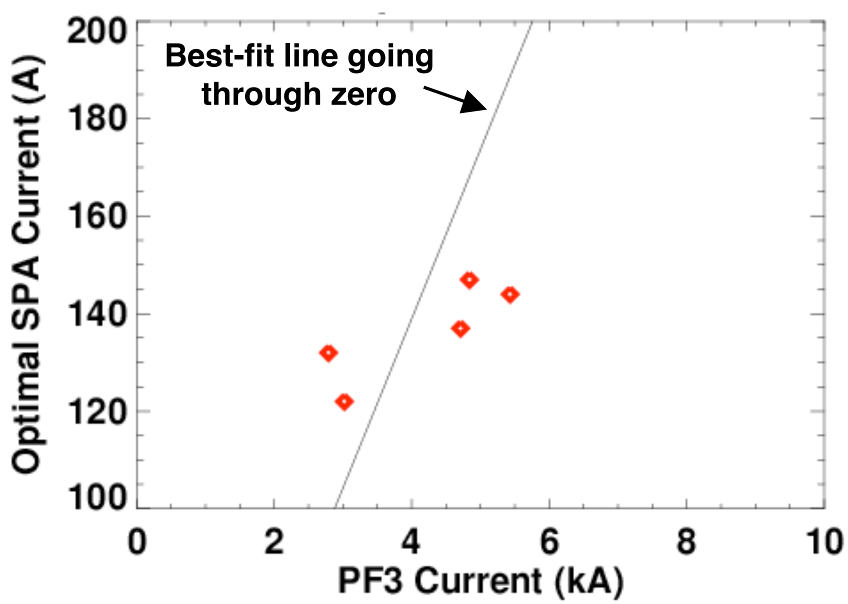


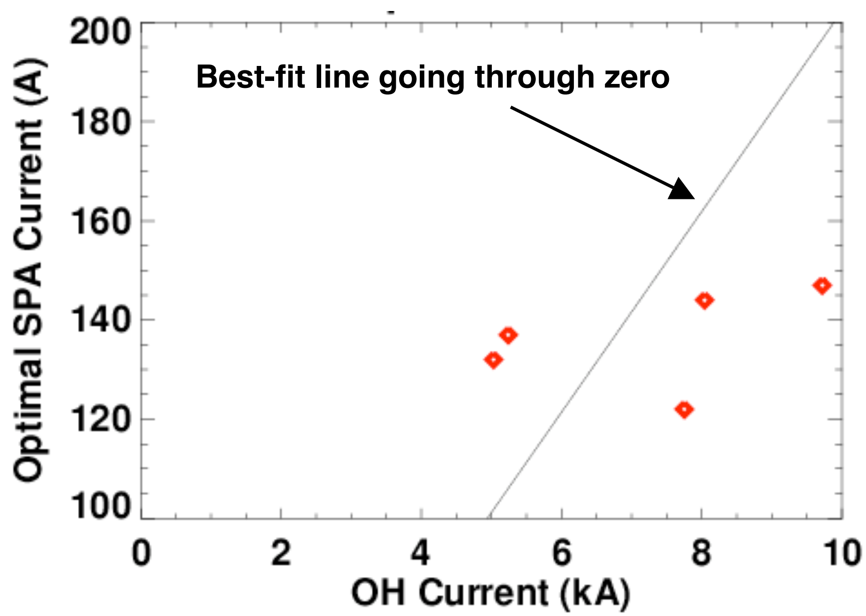
Correction Essentially Uncorrelated with the TF Current



No Correlation of Correction With PF-3 or OH

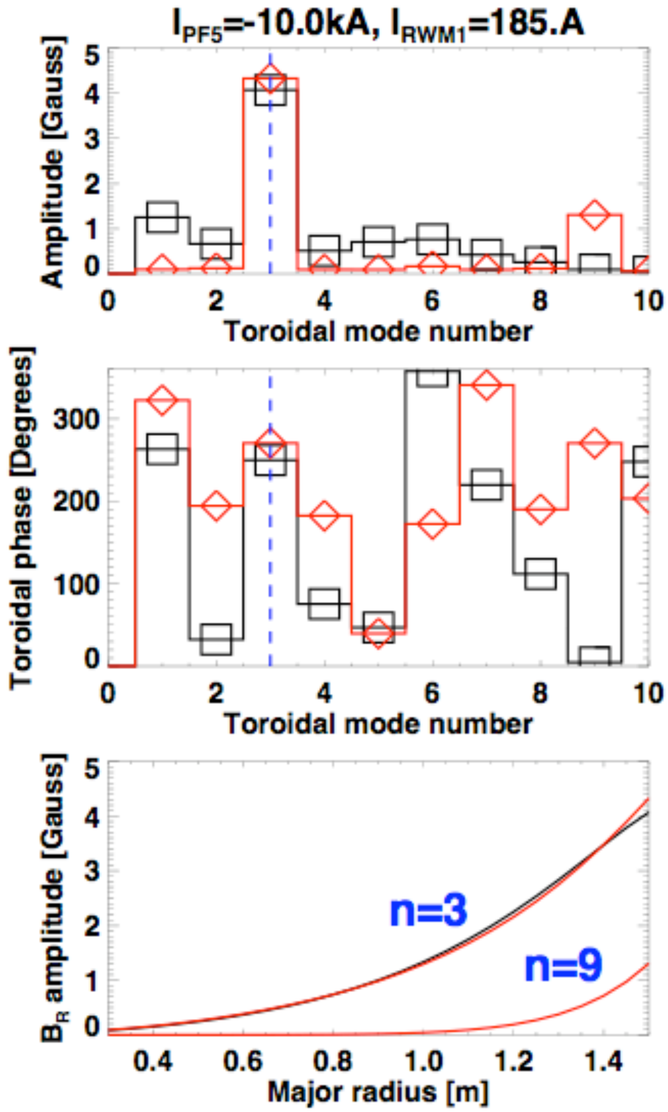
- PF-2 coil not used in these discharges.
- Both PF-3 and OH value at end of flat-top scale (roughly) with I_P.
- Best fit lines through zero don't reveal any trend.





Experimental Correction Consistent With Prediction Based on PF Coil Shape

- PF-5 coil known to have a slightly triangle shape



Part 2 Shot List: Testing of Optimized Correction

- Reference: Optimal I_P, B_T pair from previous scans.
  - Looks now like $[I_P,B_T]$=[1100kA, 0.45T] is a good configuration.
- Choose the PF5/SPA gain coefficients as:

$$G_{PF5,SPA1} \approx -15 \times f \quad (A/kA)$$
$$G_{PF5,SPA2} \approx -15 \times f \quad (A/kA)$$
$$G_{PF5,SPA3} \approx +15 \times f \quad (A/kA)$$

- 8 (or less) shot scan of the Gain Multiplier "f", verifying that realtime correction works.

SPA 1 Optimal Gain	SPA 2 Optimal Gain	SPA 3 Optimal Gain	Gain Multiplier	SPA 1 Gain	SPA 2 Gain	SPA 3 Gain	Shot Number
-15	-15	15	**-1**	15	15	-15	
-15	-15	15	**-0.5**	7.5	7.5	-7.5	
-15	-15	15	**0**	0	0	0	
-15	-15	15	**0.5**	-7.5	-7.5	7.5	
-15	-15	15	**1**	-15	-15	15	
-15	-15	15	**1.5**	-22.5	-22.5	22.5	
-15	-15	15	**2**	-30	-30	30	
-15	-15	15	**2.5**	-37.5	-37.5	37.5	