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Initial Analysis of XP-950: Long-Pulse Development at High β_T.

S. P. Gerhardt, D.A. Gates, J.E. Menard, S.A. Sabbagh, R. Bell, B. LeBlanc

and the NSTX Research Team

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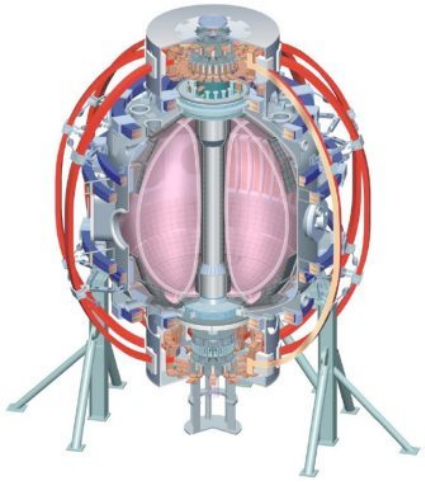


Goal is to Achieve Long Pulse With $\beta_T \geq 25\%$

- Spherical torus might make for attractive facility for nuclear component testing:

** More recent ST-FNSF designs are more "conservative"*

	ST-CFT, Phase 1 (Peng 2005, PPCF)	ST-CFT, Phase 2 (Peng 2005, PPCF)	ST-CFT, Phase 3 (Peng 2005, PPCF)	ST-CTF, (Wilson 2004, IAEA)
Wall Loading (MW/m^2)	0.1	1	2	1.5
Elongation	3.1	3.1	3.1	2.5
β_T	14	18	28	22
β_N	3.8	3.8	5.9	3.5
f_{BS} (%)	0.58	0.49	0.5	0.4
f_{NI} (%)	1.	1.	1.	1.
$I_N=I_P/aB_T$ (MA/mT)	3.8	4.7	5.8	6.1
$H_{98y,2}$	1.5	1.5	1.5	1.3

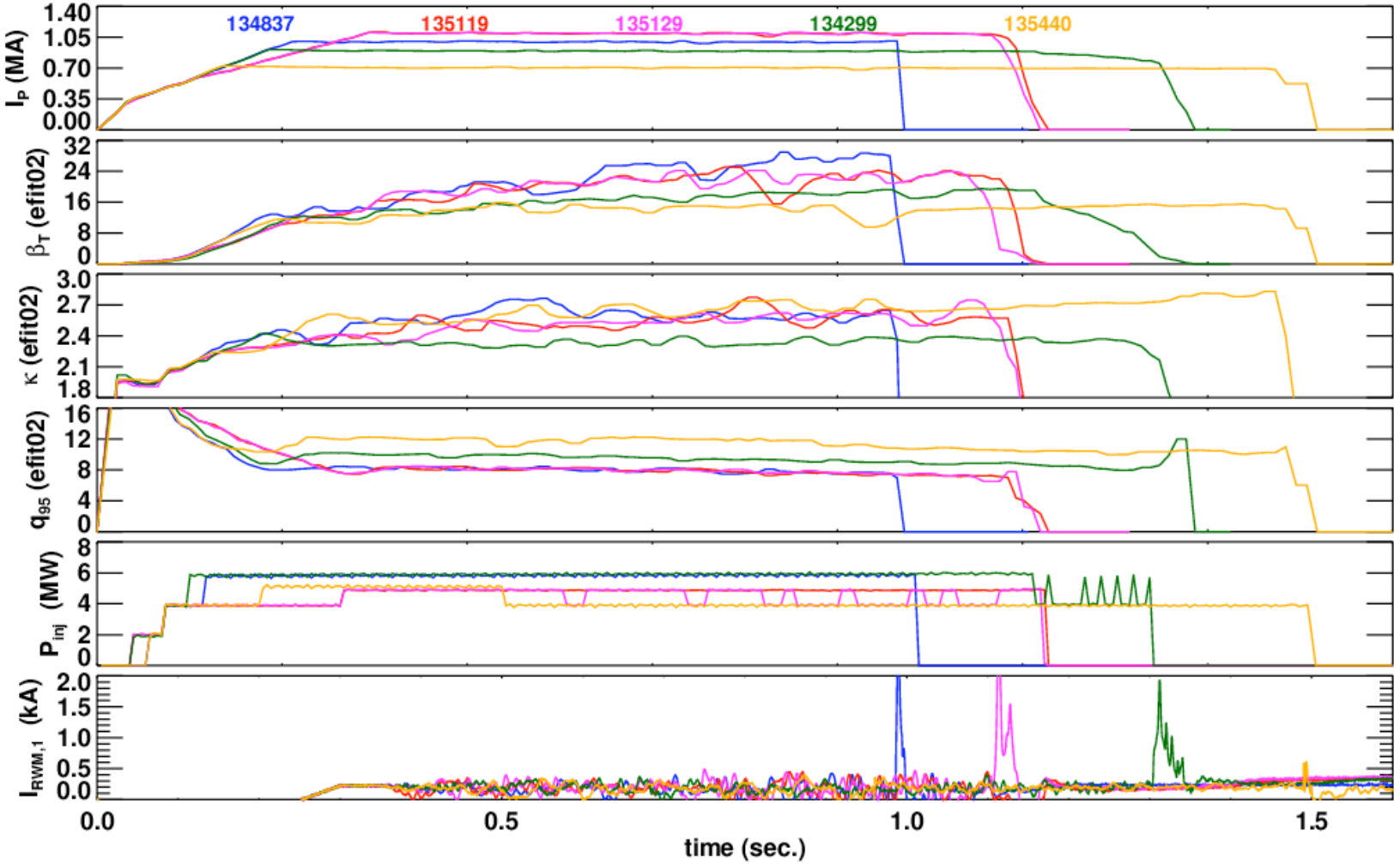
- Goal of this XP: study discharges with parameters as close to these values as possible.
  - However, clear that 100% non-inductive operation is unavailable without additional current drive.
- Method: Operate at highest $I_N=I_p/aB_T$, κ, & β_N, consistent with long pulse.

Some Unique Discharges Were Made

134837, 135119, 135129 : Good Shots from XP-948

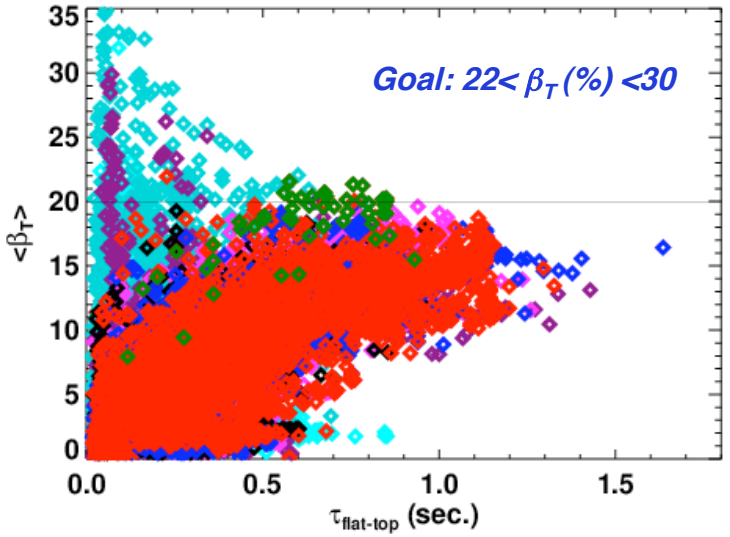
134299: Excellent Morning Fiducial

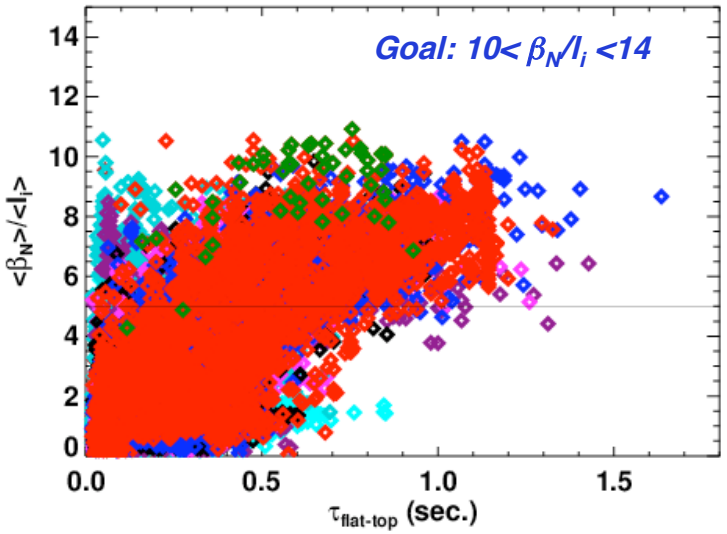
135440: Longest Shot of the Year, from XP-836

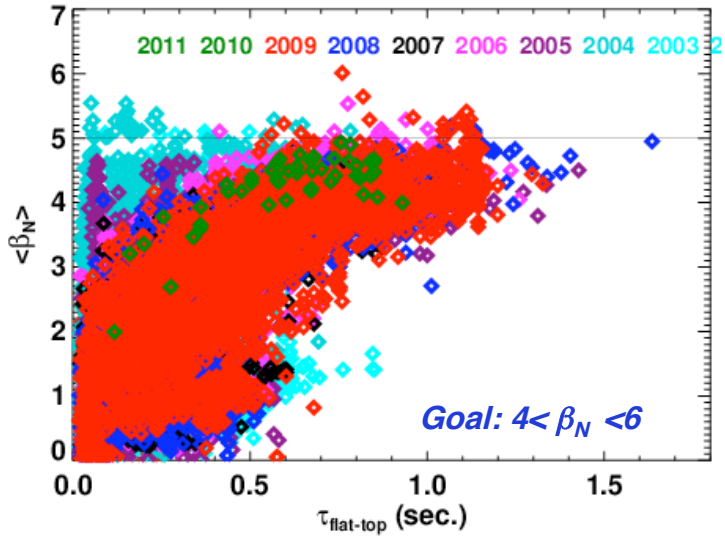


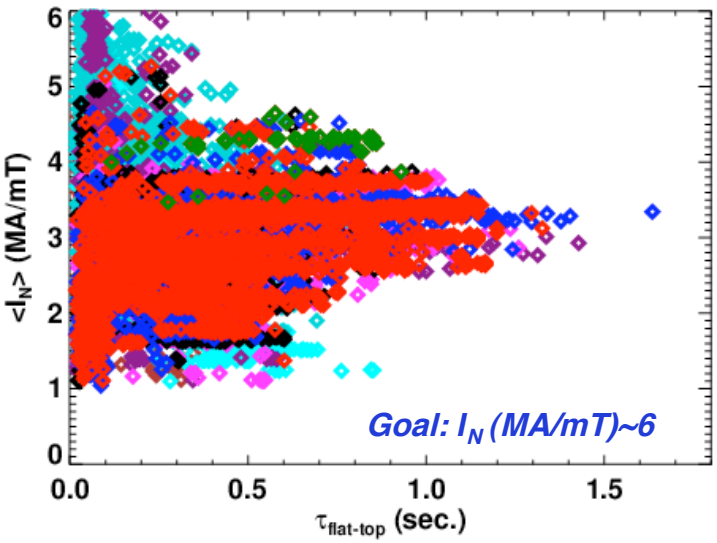
Achieved Discharges Push the Boundary of NSTX High-β_T, Long-Pulse Operating Space

XP-948 2009 2008 2007 2006 2005 2004 2003-02 2001









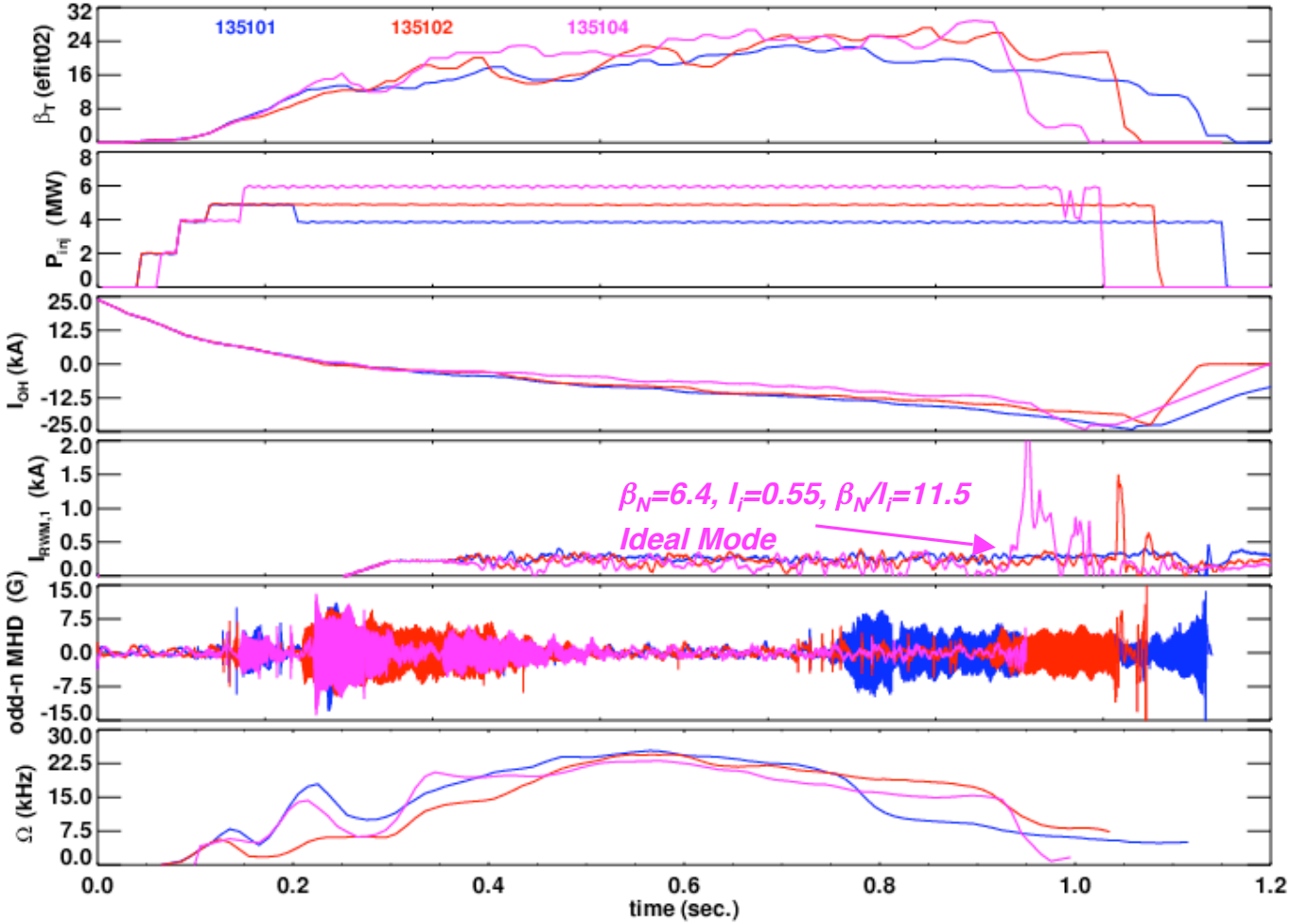
Too much power→Ideal MHD
Too little power→Rotating MHD.

135101: 4 MW Early Rotating Mode

135102: 5MW, Delayed Rotating mode

135104: 6 MW, Ideal Mode

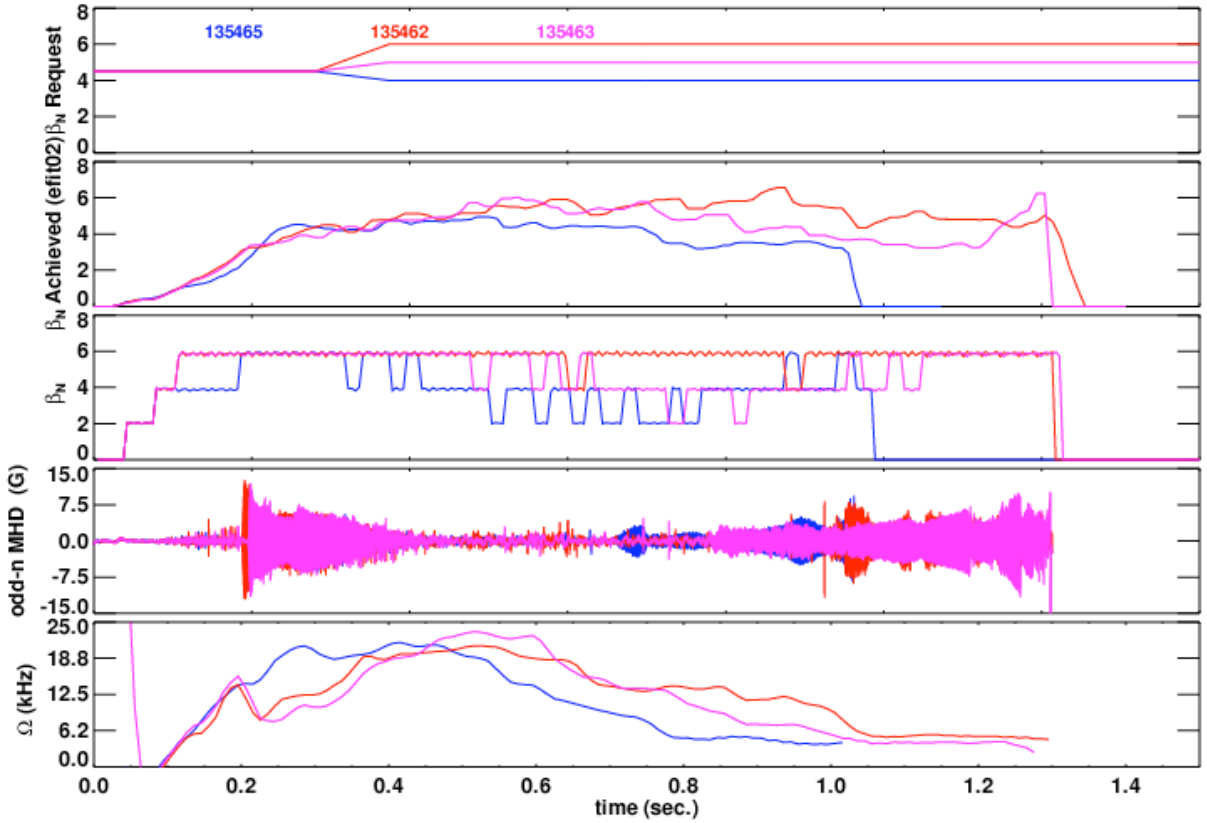
All I_P=1MA, B_T=0.4 T



Actively working on computing creditable MSE/T_e constrained equilibria for these high-κ shots.

β_N Control Commissioned as Part of XP-948

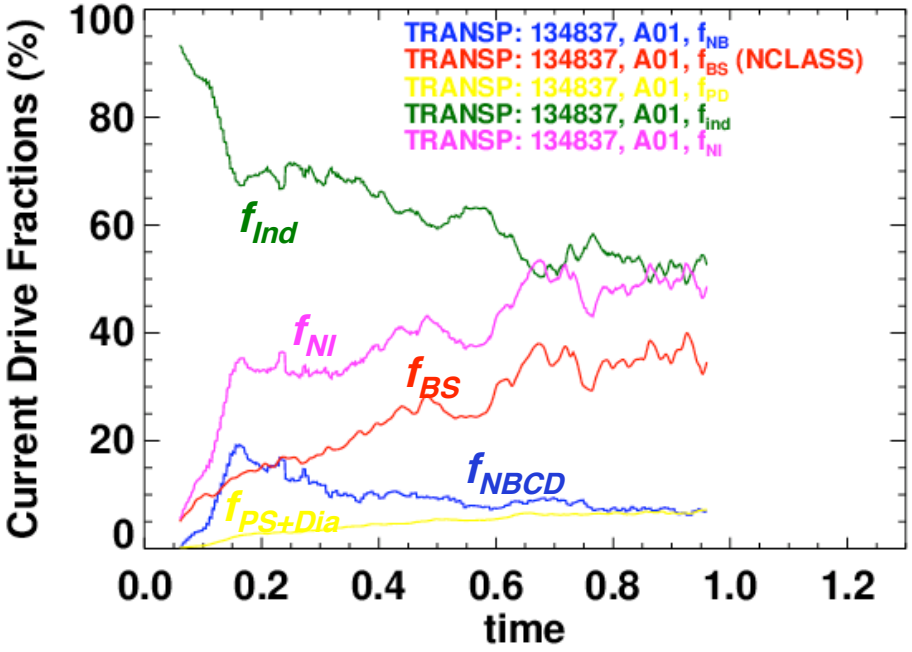
- β_N control was a substantial background effort during the FY-09 run.
  - Main effort by S.P. Gerhardt, D. A. Mastrovito, and D.A. Gates
- β_N control was commissioned as part of XP-948, used in XP-943.
- Gains not fully optimized…need to do some modeling during break and revisit.
  - Improved rtEFIT basis vectors implemented after these shots, should be very helpful.
- Once again, turning down the NB power causes core-MHD



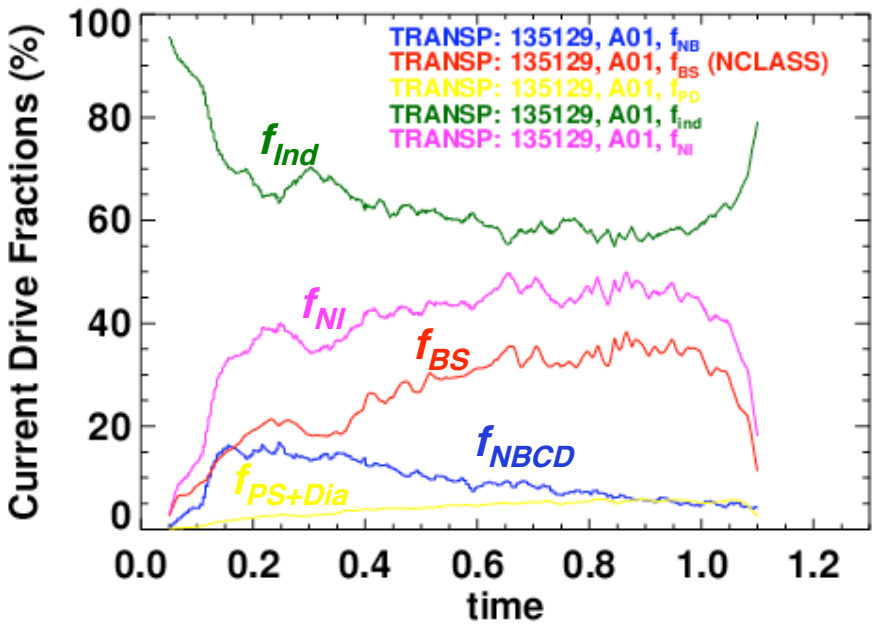
- Shots from XP-934, RWM feedback and no magnetic braking. Feedback gains changed between shots.
- β_N requests of 4, 5, and 6
- Reconstructed β_N evolution follows the requests of the trends
- Rotating MHD comes earliest when the beams (and torque) are reduced.
- Core MHD leads to a similar low rotation state in all cases

Beginning Analysis of Non-Inductive Current Drive (I)

134837: I_P=1000 kA and B_T=0.4T
Max β_T=30% f_{NI}~50%



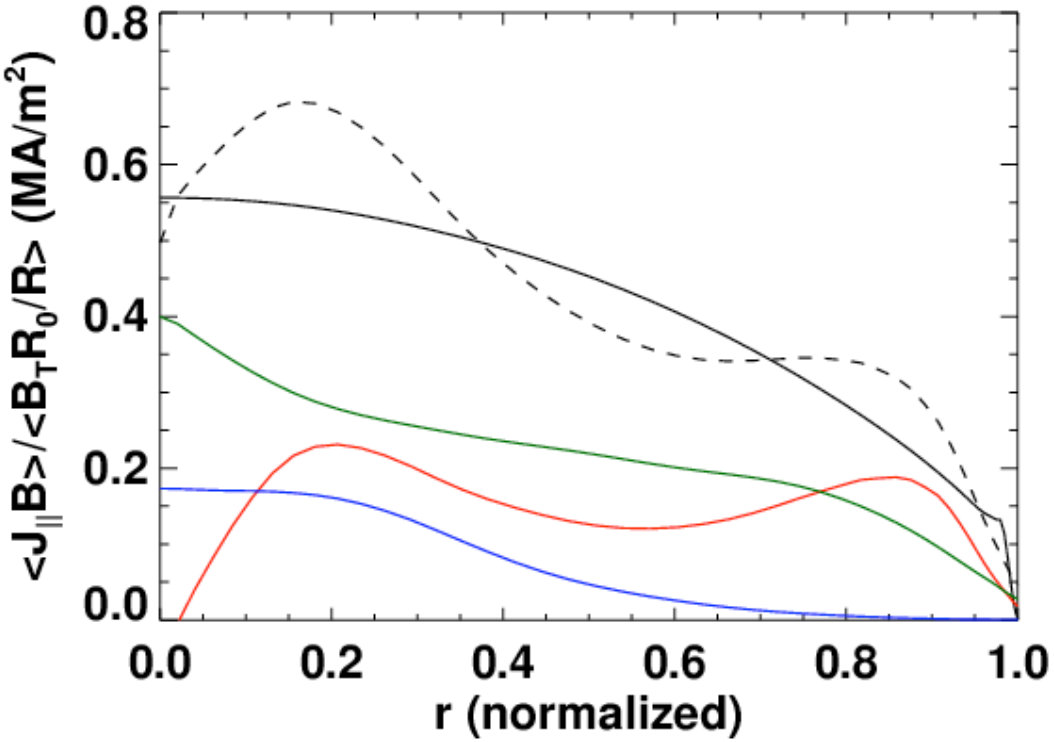
135129: I_P=1100 kA and B_T=0.45T
Max β_T=25% f_{NI}~45%



Preliminary!

Beginning Analysis of Non-Inductive Current Drive (II)

- Preliminary results
  - Reasonable agreement in the total current.
  - 50% inductive, 50% non-inductive
  - Using “homegrown” Sauter B.S. model reduces total current to 90% of reconstruction.
- Detailed radial structures don’t match well.
  - Reconstruction may be too smooth (though match to PA data is reasonable)
  - Need to refine kinetic profile mapping, different ways of determining Z_{eff}



NSTX 134837, lrdfit06, TRANSP, A01

Bootstrap Model: TRANSP A01, NCLASS

I_{BS}=339723, f_{BS}=35%

I_{PD}=79394, f_{PD}=8%

I_{NB}=73913, f_{NBCD}=7%

I_{Ind}=440582, f_{Ind}=46%

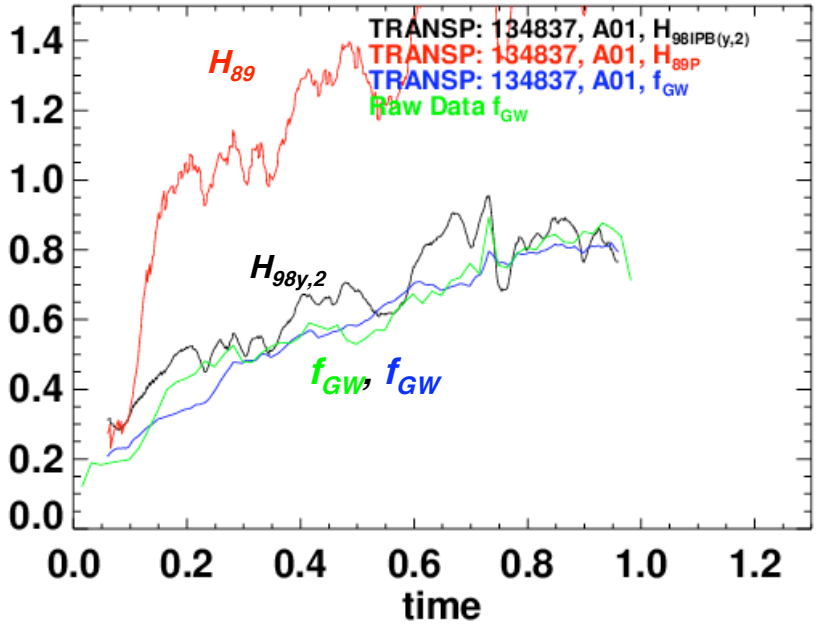
f_{NI}=51%

$f_{rec.}$=97%

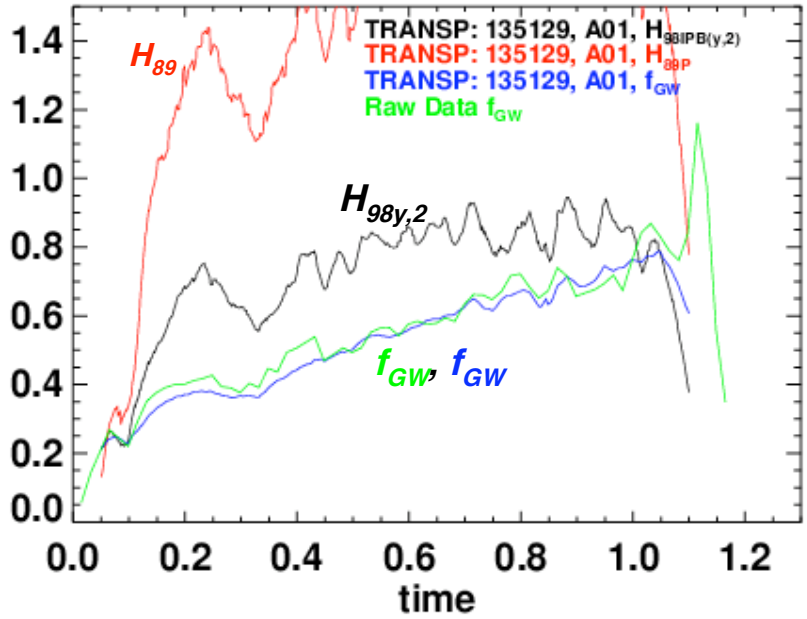
Preliminary!

Beginning Analysis of Confinement

134837: I_P=1000 kA and B_T=0.4T
Max β_T=30% f_{NI}~50%
H_{98}≈0.8 f_{GW}≈0.8

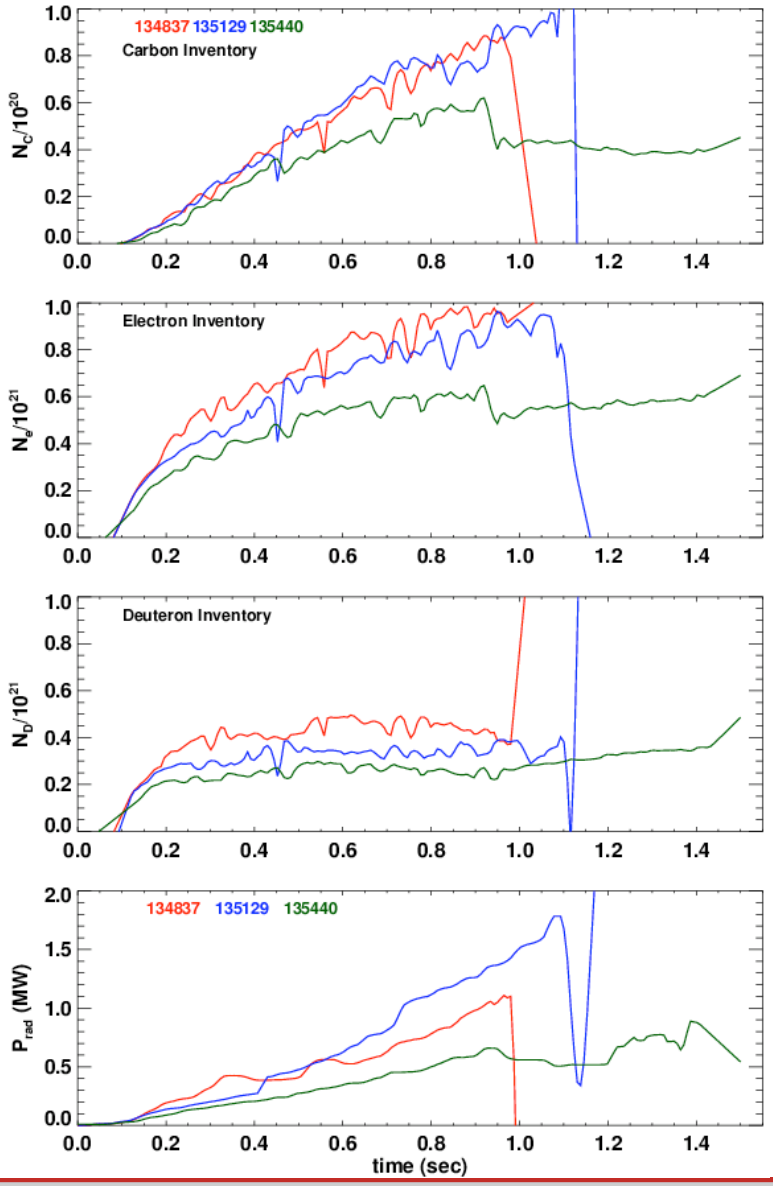


135129: I_P=1100 kA and B_T=0.45T
Max β_T=25% f_{NI}~45%
H_{98}≈0.8 f_{GW}≈0.78

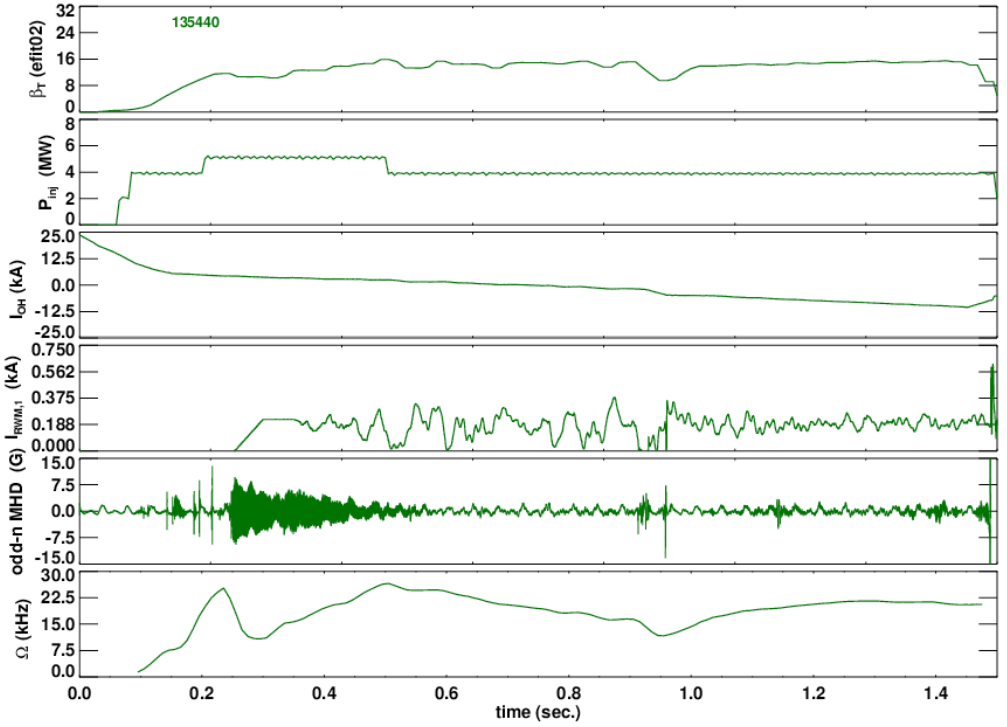


Preliminary!

Increases in Carbon, Radiated Power Remain a Problem in These Discharges



- 134837 (2 *Large* ELMs), 135129 (ELM Free): Good high-β_T Shots from XP-948
  - Deuterium density is clamped, but N_C and P_{rad} increase
- 135440: Longest Shot of the Year, from XP-836
  - Flat electron and carbon density with no ELMs…very interesting case?



Conclusions and Next Steps

- Were successful in producing discharges with high-β_T.
  - Modest extension of the NSTX operating space
- Parameter space appears highly constrained:
  - Too much input power: rapid, ideal-mode disruptions
  - Reduce the input power: too-rapid q evolution leads to rotating core mhd.
- For best shots (*preliminary*):
  - β_T~25%-30%
  - f_{BS}=35%, f_{NI}=50%
  - $H_{98y,2}$~0.8
- Next Steps:
  - Complete confinement and NI-fraction analysis for the full high-κ data set (XP-836 & XP948)
  - Implement X-point height control to enable highest-κ with large I_{OH}.
  - Implement Control tools to allow operation at highest possible β_N.
    - Improved rtEFIT Basis Functions.
    - Further optimization of DEFC and RWM feedback.
    - β_N control to operate near, but not cross, stability boundaries.
  - Reduce the Density with LLD!

Much Analysis To Do

- Presentation of this and other NSTX results at mid-October ITPA IOS meeting.