NSTX

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XP-1006: Increasing the Non-Inductive Fraction in High-κ NB Heated H-mode

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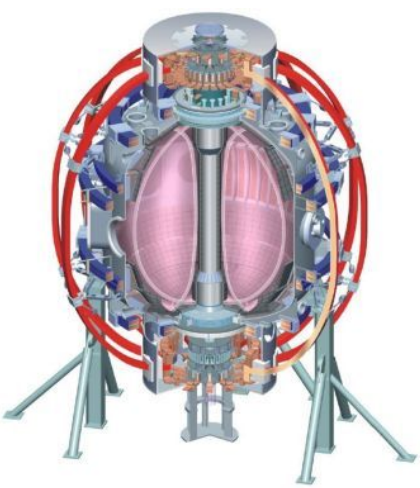

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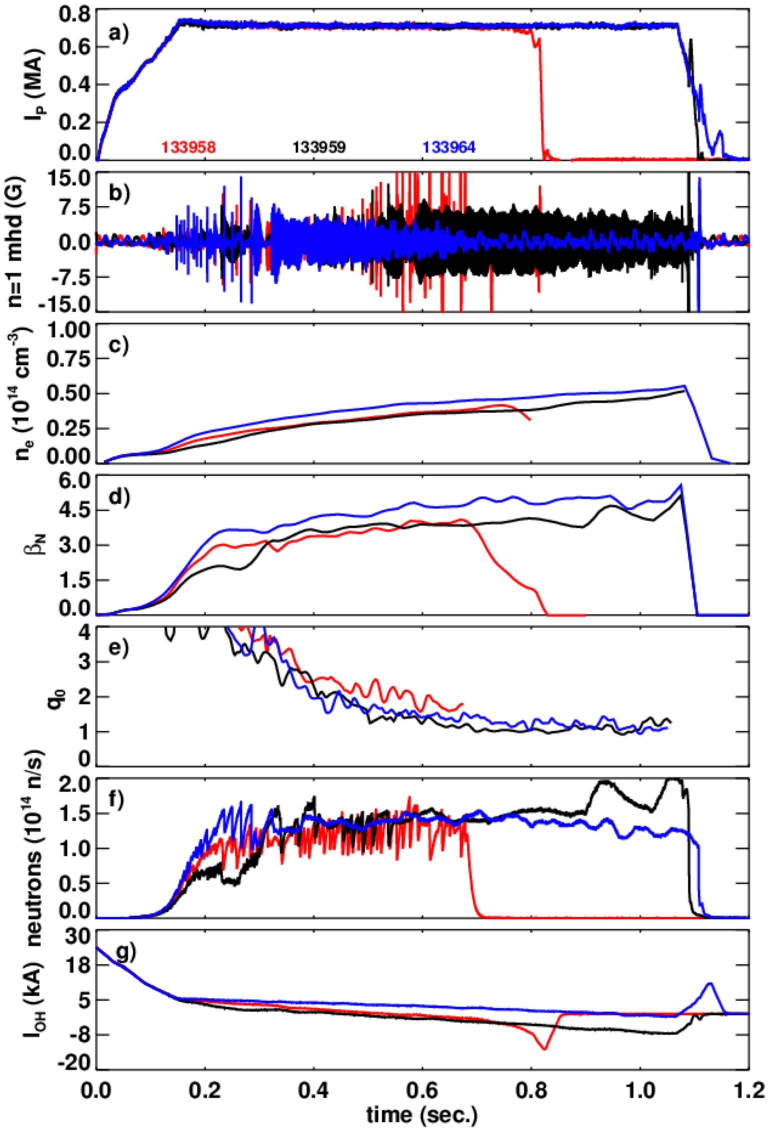
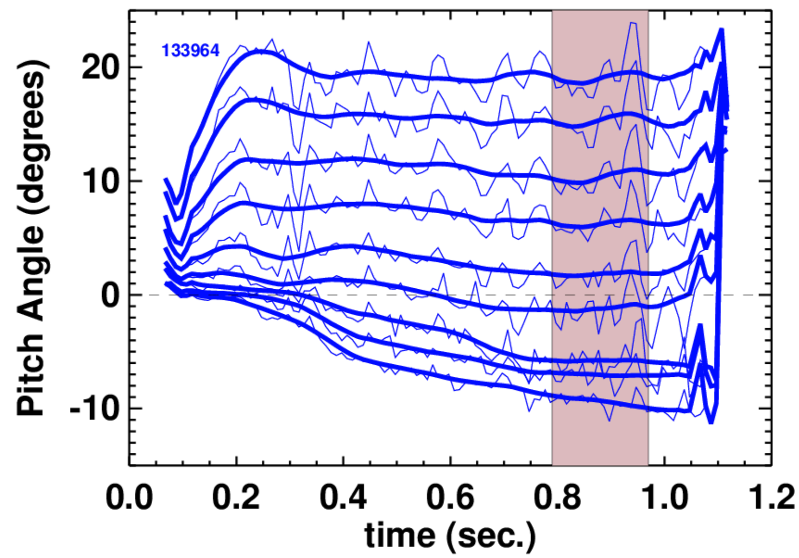
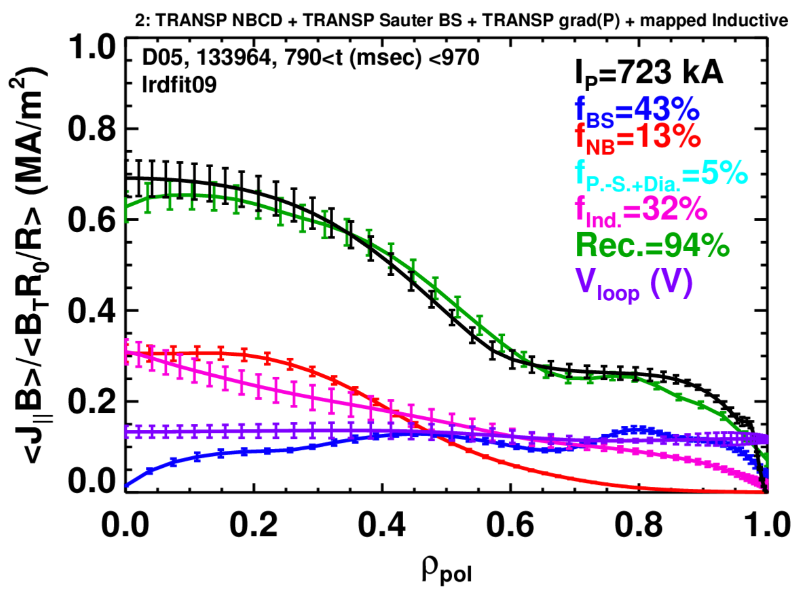
Summary

- XP-836, run in both 2008 & 2009, developed a nice high-kappa scenario with 65-70% non-inductive fraction.
  - 133964: 700 kA, 0.48 T, κ=2.6-2.7
- TRANSP "predicts" two ways to further increase f_{NI}:
  - Decrease Z_{eff} at fixed n_e.
  - Reduce I_P further.
- This XP:
  - Apply impurity reduction techniques to discharge 133964
  - Potentially reduce I_P, maybe down to I_P=500 kA
  - Time permitting, do some beam modulations and a κ scan.

Shot 133964 is the Template Shot For this XP.







TRANSP Simulations Of Two Scenarios to Increase f_{NI}

1) **Decrease Z_{eff} at Fixed I_P, T_e, n_e**

2) **Decrease I_P and P_{inj}**

Rescale profiles with cutting edge transport model…

….guessing!

$$T_{e,i,new}(\rho)=C^{1/2}T_{e,i,new}(\rho)$$

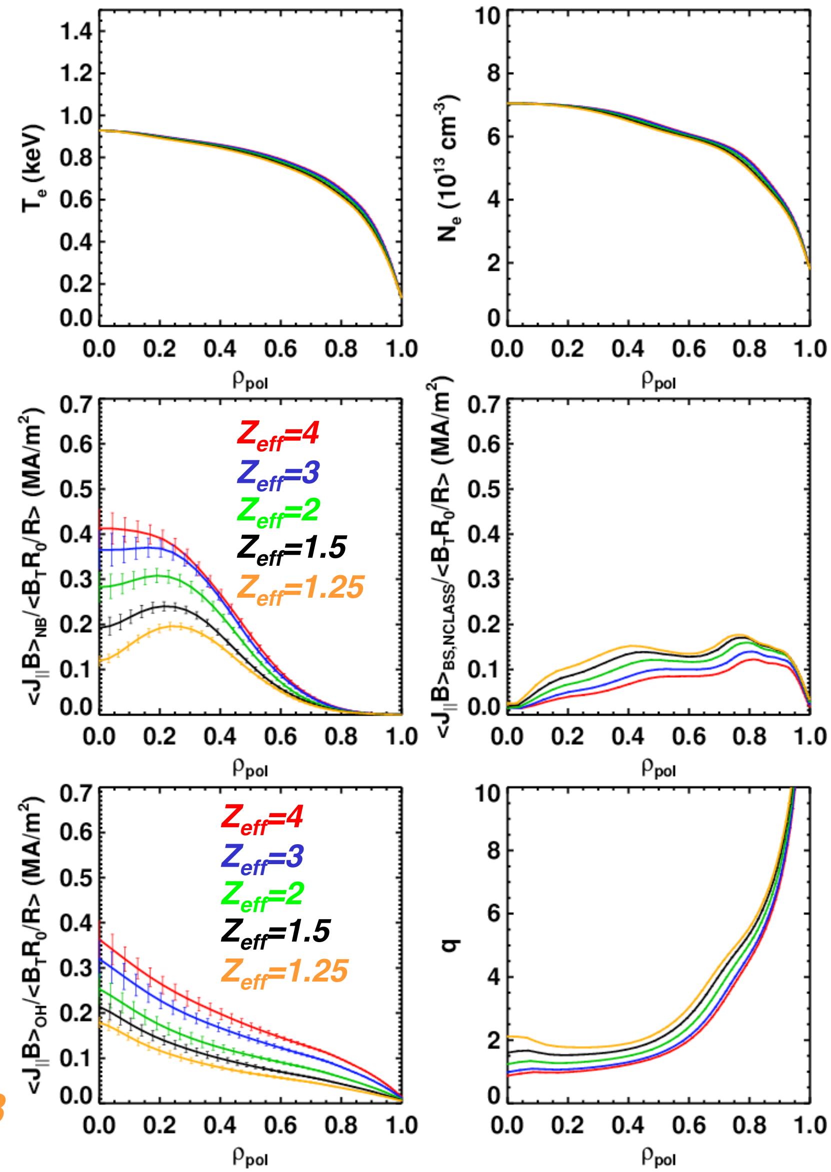
$$n_{e,C,new}(\rho)=C^{1/2}n_{e,C,new}(\rho)$$

$$C=(I_{P,new}/I_{p,old}) \times (P_{inj,new}/P_{inj,old})^{1/3}$$

Not self consistent, but approximately preserves H_{98}

TRANSP Shows that Reducing Z_{eff} Can Increase The Non-Inductive Fraction

- Fix:
  - Electron Density
  - Electron and ion temperatures
- Vary:
  - Z_{eff}, but with flat profile, assuming carbon is the impurity.
  - Ion density is adjusted to achieve quasi-neutrality.
- Decreasing Z_{eff}:
  - Decreases beam current drive.
  - Increases bootstrap current.
  - Raises q_{min}



Z_{eff}=4: f_{BS}=40%, f_{NB}=17%, f_{NI}=62%, β_N=4.3

Z_{eff}=3: f_{BS}=45%, f_{NB}=16%, f_{NI}=67%, β_N=4.7

Z_{eff}=2: f_{BS}=55%, f_{NB}=15%, f_{NI}=76%, β_N=5.0

Z_{eff}=1.5: f_{BS}=62%, f_{NB}=13%, f_{NI}=81%, β_N=5.2

Z_{eff}=1.25: f_{BS}=66%, f_{NB}=12%, f_{NI}=84%, β_N=5.3

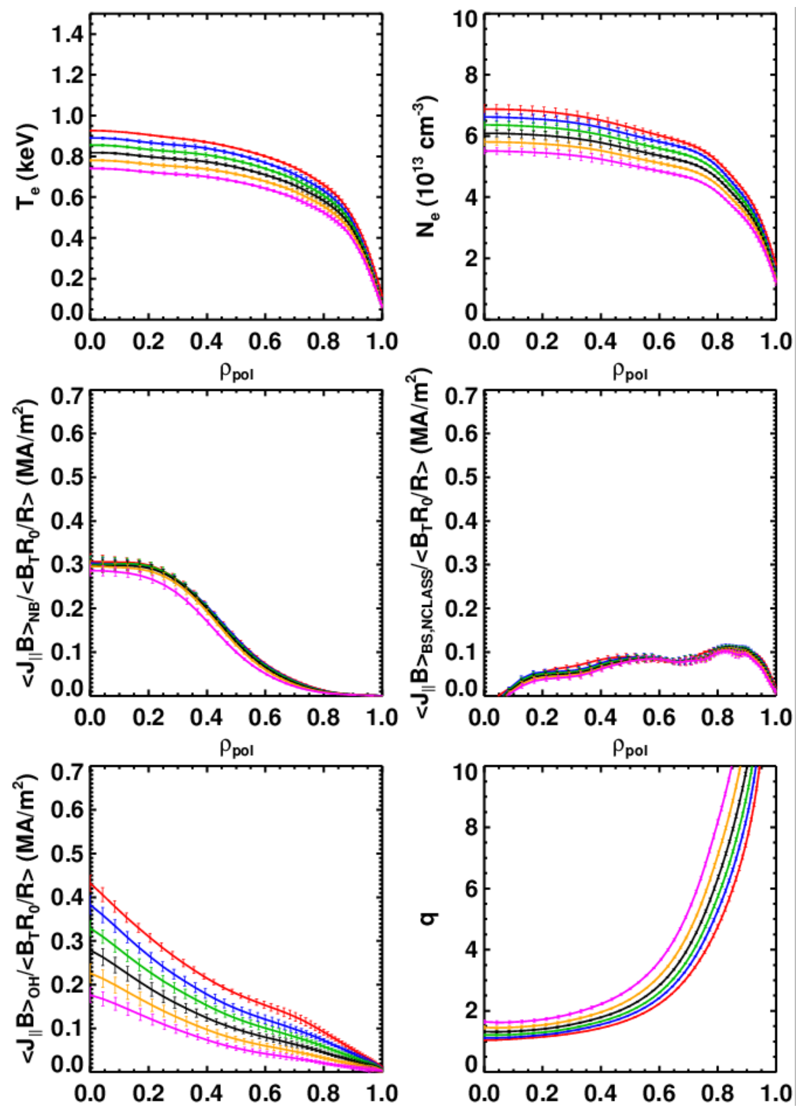
TRANSP Shows That Reducing I_P May Also Increase f_{NI}

6 MW Input Power

I_p	f_nbcd (%)	f_bscd (%)	betaN	H98	ploss (MW)
700	15	39	5.1	1	1.3
650	16	43	5.14	1.02	1.5
600	17	46	5.14	1.06	1.8
550	18	51	5.15	1.09	2
500	18	55	5.14	1.13	2.3
450	18	62	5.1	1.19	2.7

- ***H_{98} increases because density dependence of confinement was not properly considered in modifying profiles.***
- ***Loss powers >2MW are probably unacceptable.***
  - ***Dropping to 4MW at 500 kA drops NBCD to ~13%, p_{loss}~1.5 MW***
  - ***CX and BO loss are comparable.***
- ***Presents an alternate scenario for increasing f_{NI}.***

6 MW Input Power



Proposed Impurity Reduction Methods

Divertor Gas Puff

ELM Pacing

dr_{sep} optimization

Divertor Gas Puffing Has Helped Reduce Impurities

Reference Shots

138768: 2500 Torr

t_{start}=150 msec

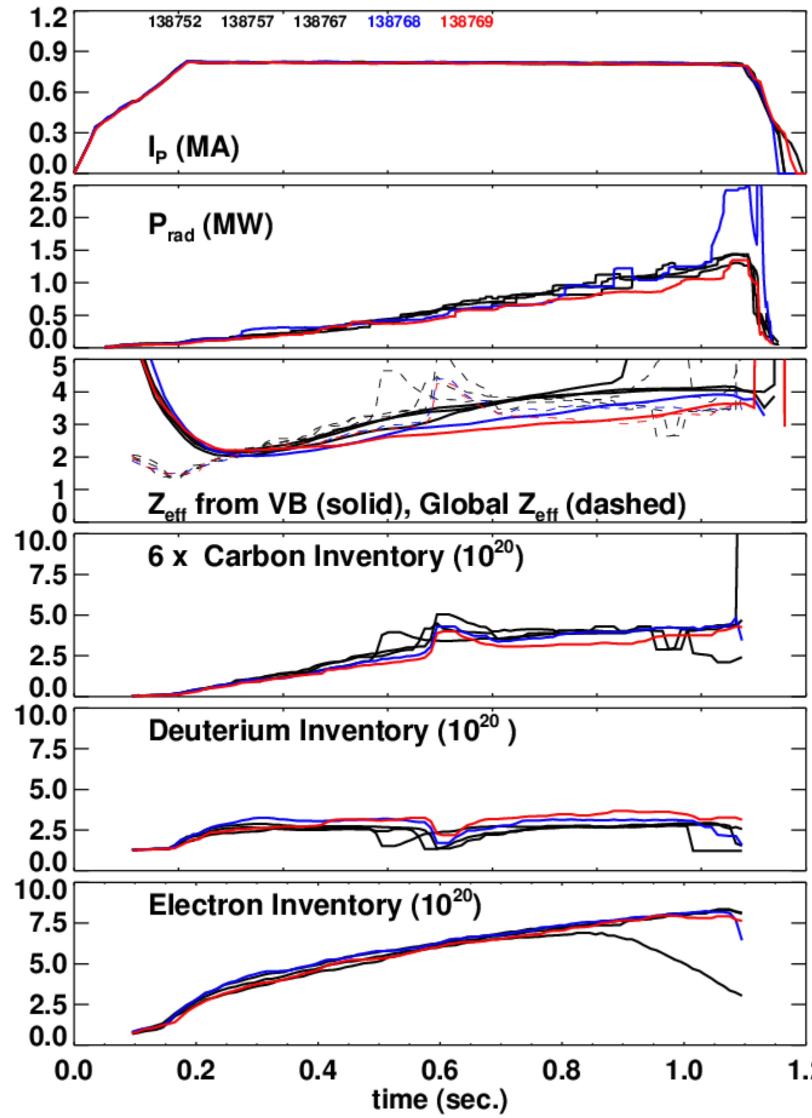
duration=100 msec

138769: 3000 Torr

t_{start}=300 msec

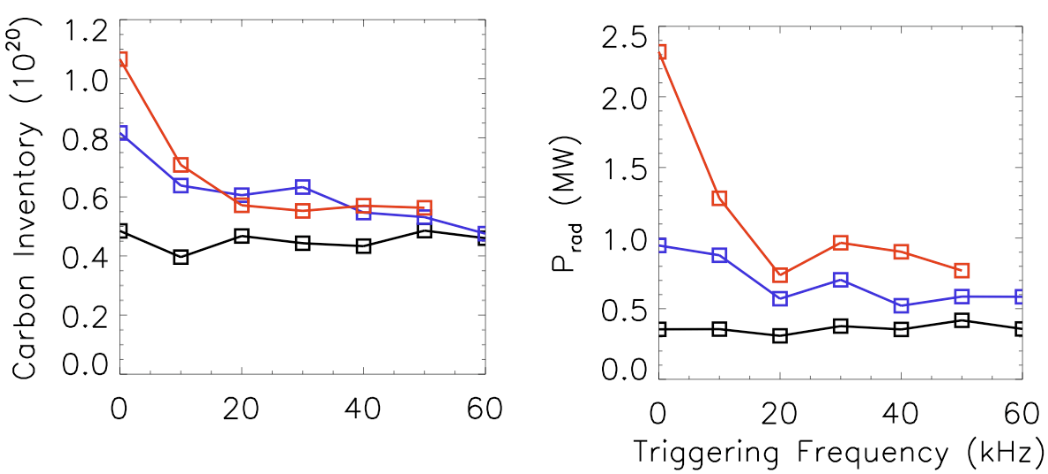
duration=100 msec

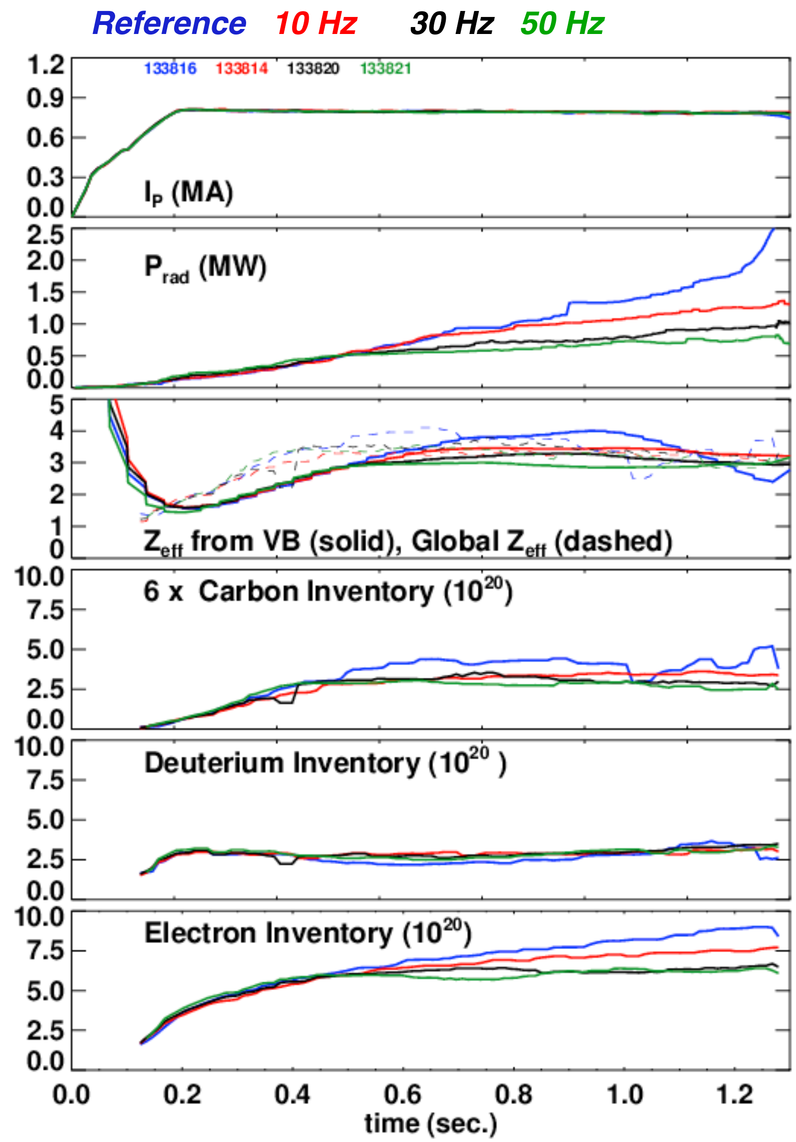
- *Discharge is an 800 kA fiducial shape plasma.*
- *~100 msec delay between command to fire and appearance of gas.*
- *Many other combinations of plenum pressure, start times, and puff durations were applied.*



ELM Pacing Can Lower Radiated Power and Z_{eff}

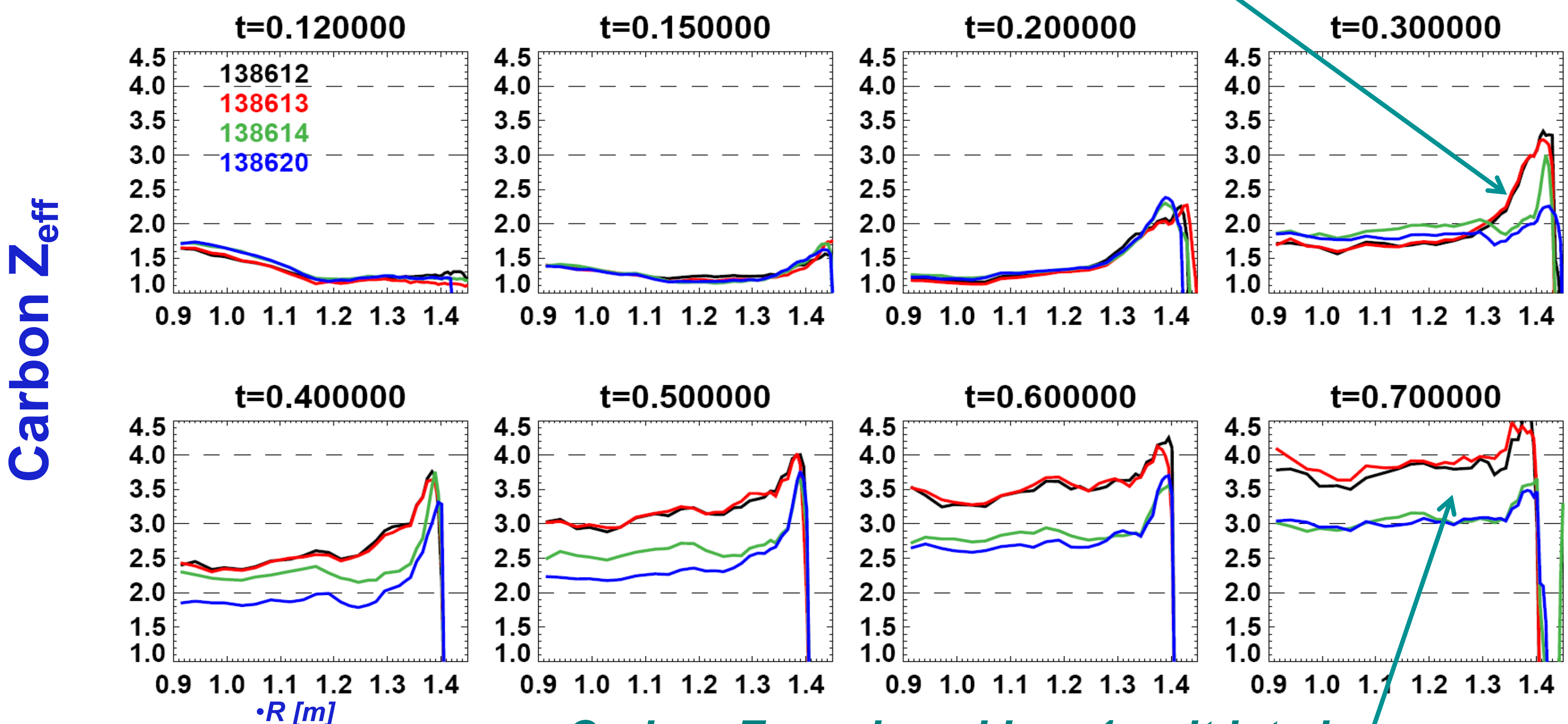
- Reliable ELM triggering demonstrated in 2009.
  - Reductions in both P_{rad} and carbon with low-frequency triggering.
  - Low-frequency (20 Hz.) triggering had minimal performance degradation.
- New "AC Compensations" in the mode-ID algorithms should allow RWM feedback and DEFC during rapid n=1 pulses.
- Low-frequency triggering is likely optimal for this XP.





XP1005: ΔR_{SEP} change from -7mm to 0 reduces impurity confinement and/or generation and reduces C Z_{eff} by -1

- *Like 2009 result, size of H-mode C impurity "ear" near t=0.3s influences late Z_{eff}*

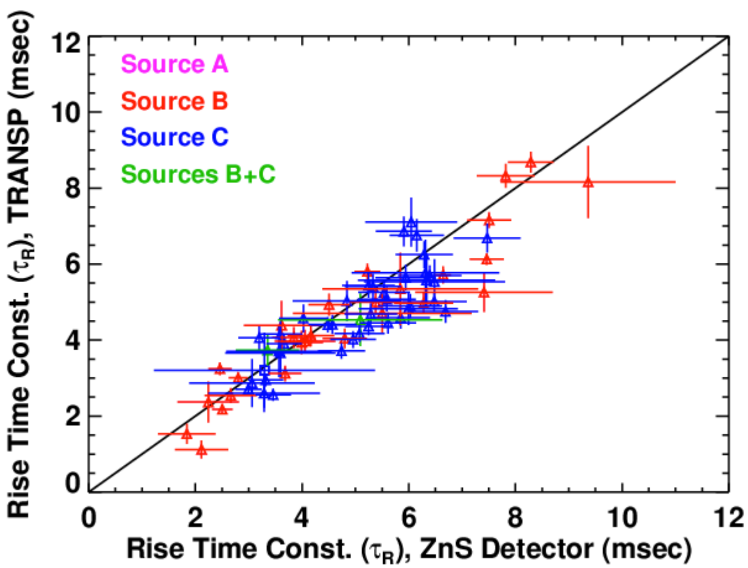


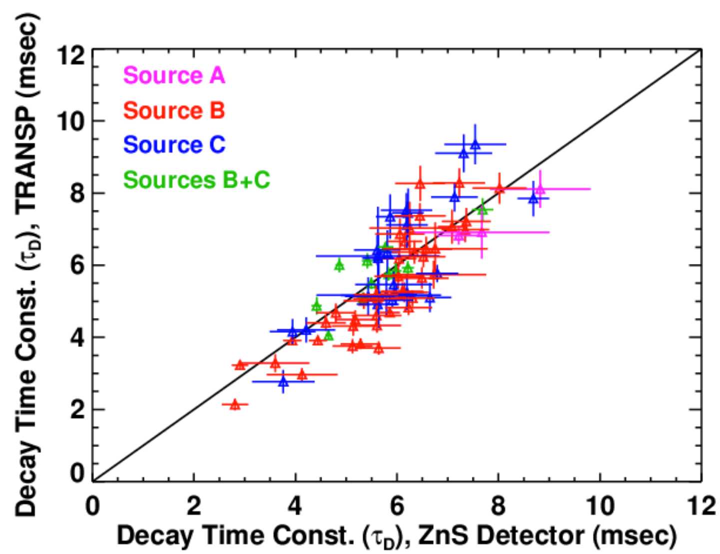
- *Carbon Z_{eff} reduced by ~1 unit late in*

Motivates testing combinations of this + divertor D puff + snowflake + …

Aside: Might be Nice to Have Some NB Modulation Data in This Configuration.

- Can get some nice basic knowledge from NB modulations[1]:
  - Initial slope of the neutron trace after beam turn-on is related to the prompt loss.
  - Longer time-scale evolution is related to the slowing down of high-energy particles.
  - Both can be compared to TRANSP simulations.
- Comparing time-scales eliminates the reliance on absolute calibration of the neutron detector.
- Present database is dominated by irregular modulations of Srcs. B & C from β_N control experiments.
- This target is a nice low I_P plasma for a systematic comparison with TRANSP.





Heidbrink, et al., Nuclear Fusion 2003

Other Notes On XP

- Additional machine improvements to help this year:
  - "new" rtEFIT basis vectors to provide improve outer-gap regulation.
  - New RWM detection, the "miu" algorithm:
    - AC compensations will help reduce braking due to mis-identification of n=1 modes during transients.
    - Don't propose to use B_R feedback, unless it appears absolutely necessary.
  - β_N control system is qualified (but would prefer not to use it).
    - 133964 took all 6 MW, but if β_N increases with impurity reduction, then may need to back down of power.
- Primary NSTX conditions:
  - 6 MW NBI available
  - Dual LITER evaporators
  - Provision for Bay-E gas injection and SGI
  - Full profile diagnostics.