HHFW Status and Plans

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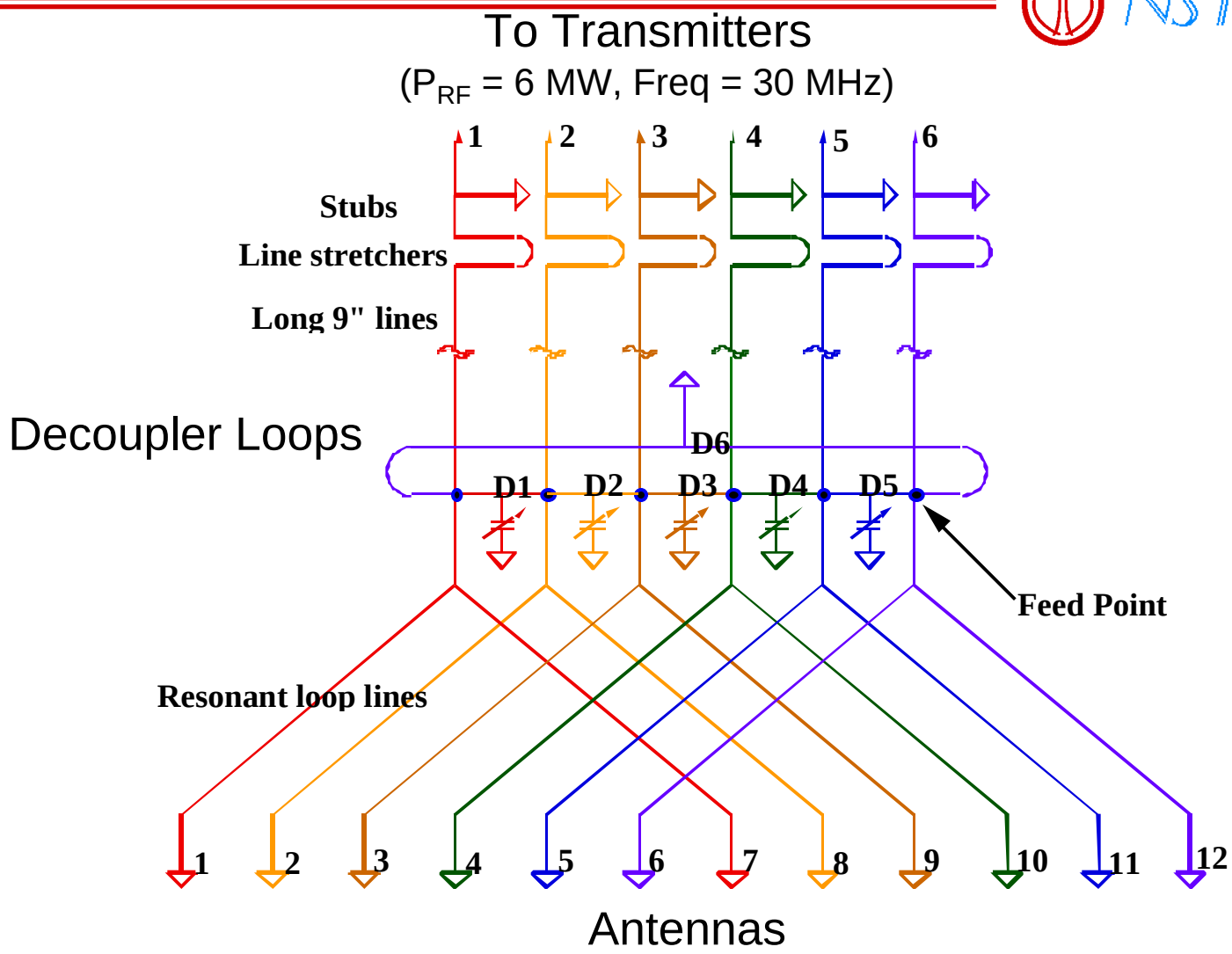
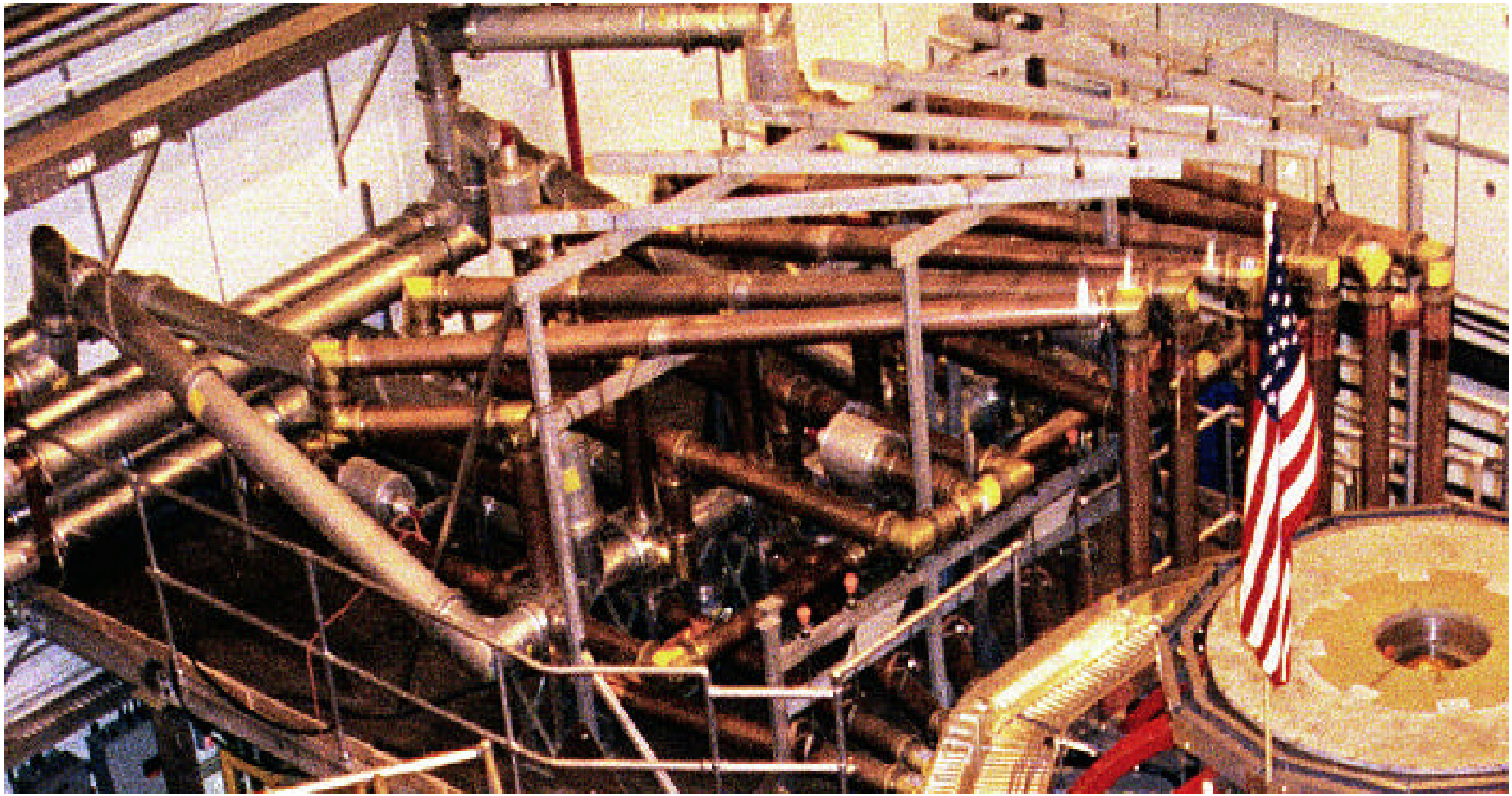
STATUS OF HHFW RESEARCH

- System operated in full configuration
  - All 6 transmitters, Full decoupling and matching system
  - Power level up to 4 MW , routine 2-3 MW
- Electron heating observed
- Use of HHFW as tool begun
  - Early heating to modify l_i and q(0)
  - Used for β limit studies

HHFW SYSTEM DESIGN: 12 STRAPS, 6 TRANSMITTERS, 6 DECOUPLERS

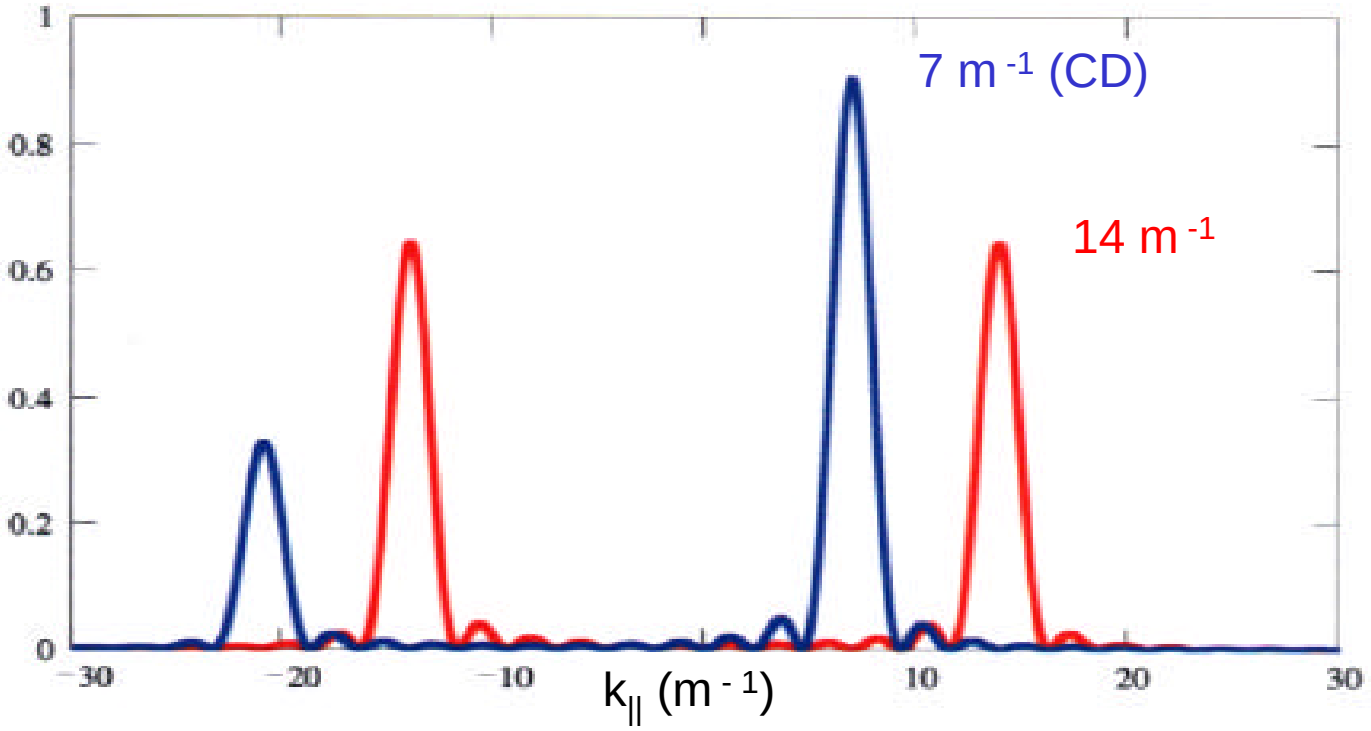


DECOUPLING AND FEED NETWORK



POWER SPECTRUM OF ANTENNA IS PROGRAMMABLE OVER A WIDE RANGE OF $k_{||}$ (~ 2 to ~ 14 m^{-1})

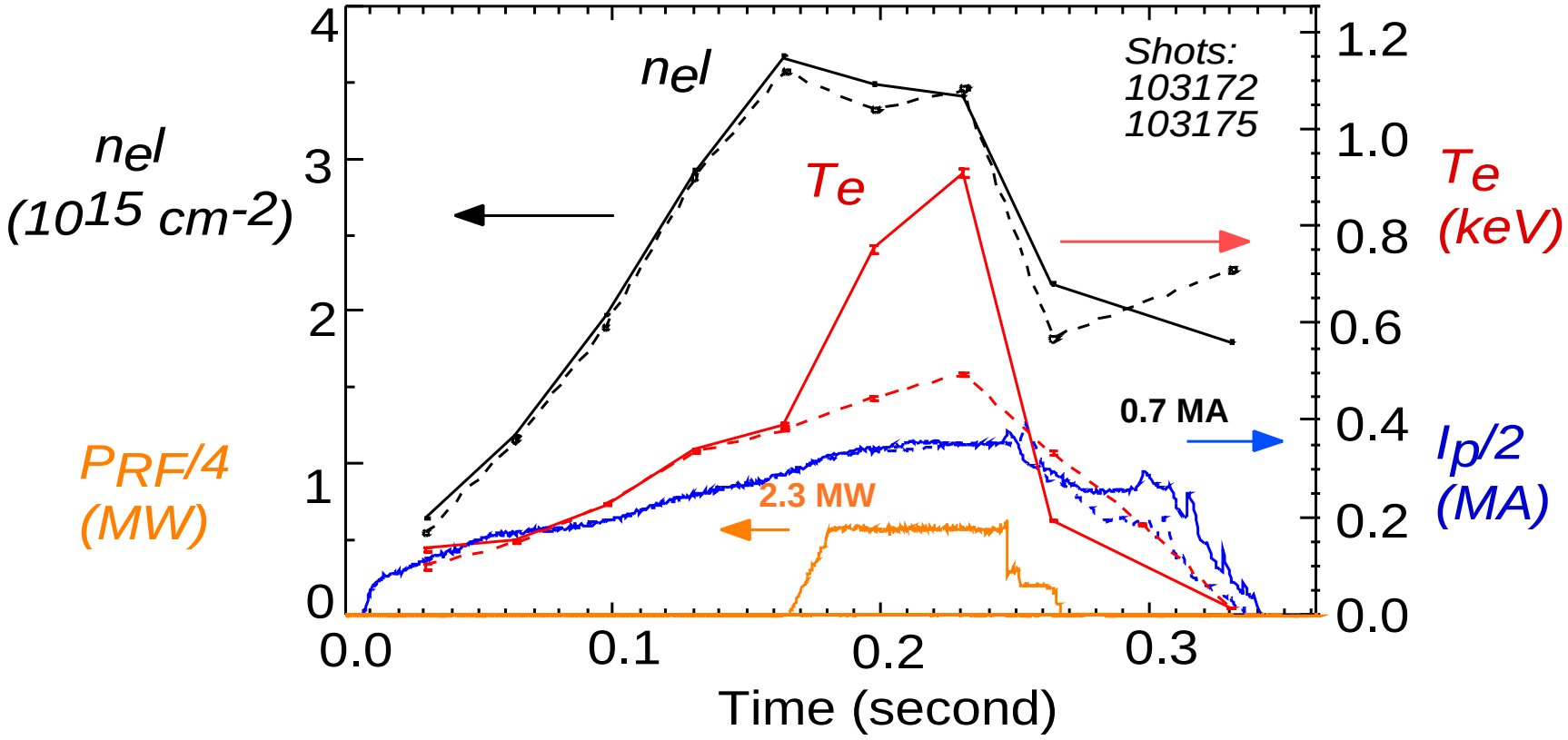
Antenna Power Spectrum



- Programming $k_{||}$ facilitates heating to higher T_e and change to CD phasing
- Decoupling between adjacent straps provided with decoupling loops
  - minimizes mutual effects in vacuum
  - mutual to plasma has small effect on decoupling
- Experiments which follow were conducted with $k_{||}$ ~ 14 m^{-1}

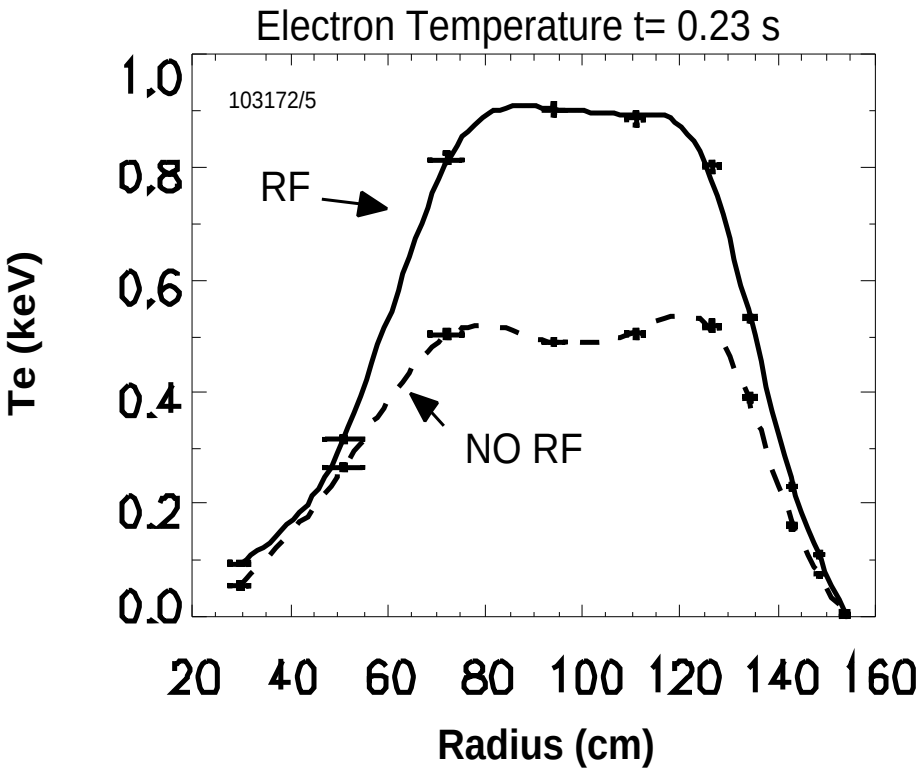
STRONG ELECTRON HEATING HAS BEEN OBSERVED IN HELIUM PLASMAS WITH THOMSON SCATTERING

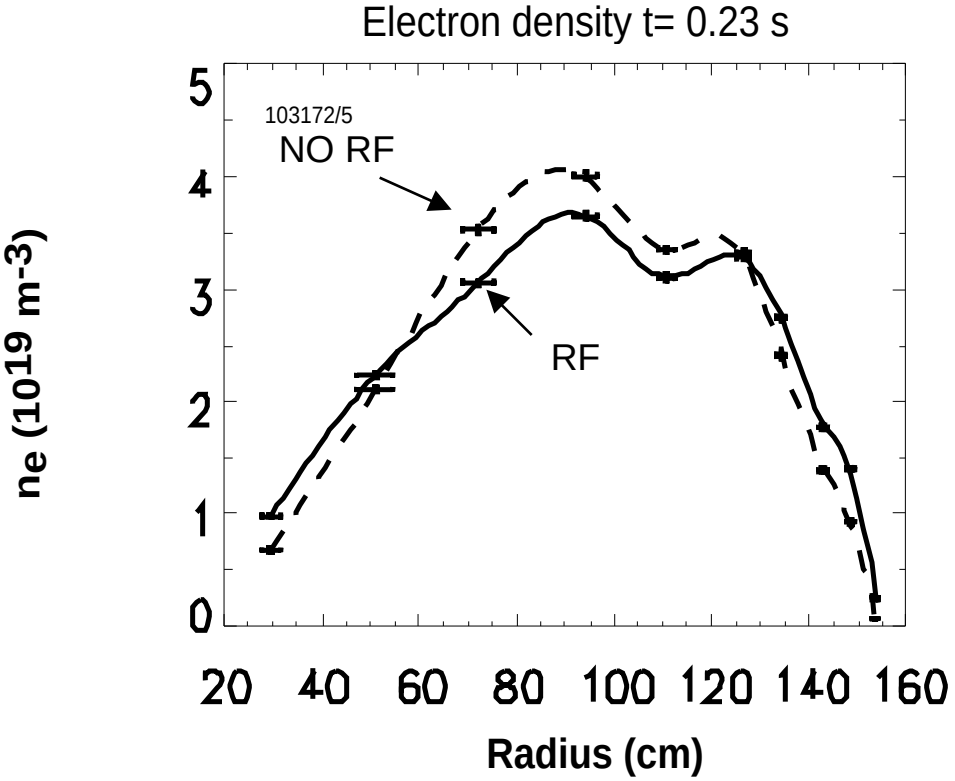
P_{RF} = 2.3 MW, Helium, $k_{||}$ = 14 m^{-1}, B_T = 0.3 T



- $T_e(0)$ increases to ~ 900 eV in helium plasma at P_{RF} = 2.3 MW
- No density increase with RF and V_{loop} decreases by ~ 30 %
- Stored energy increases to 58 kJ: β_T = 10%, β_N = 2.7

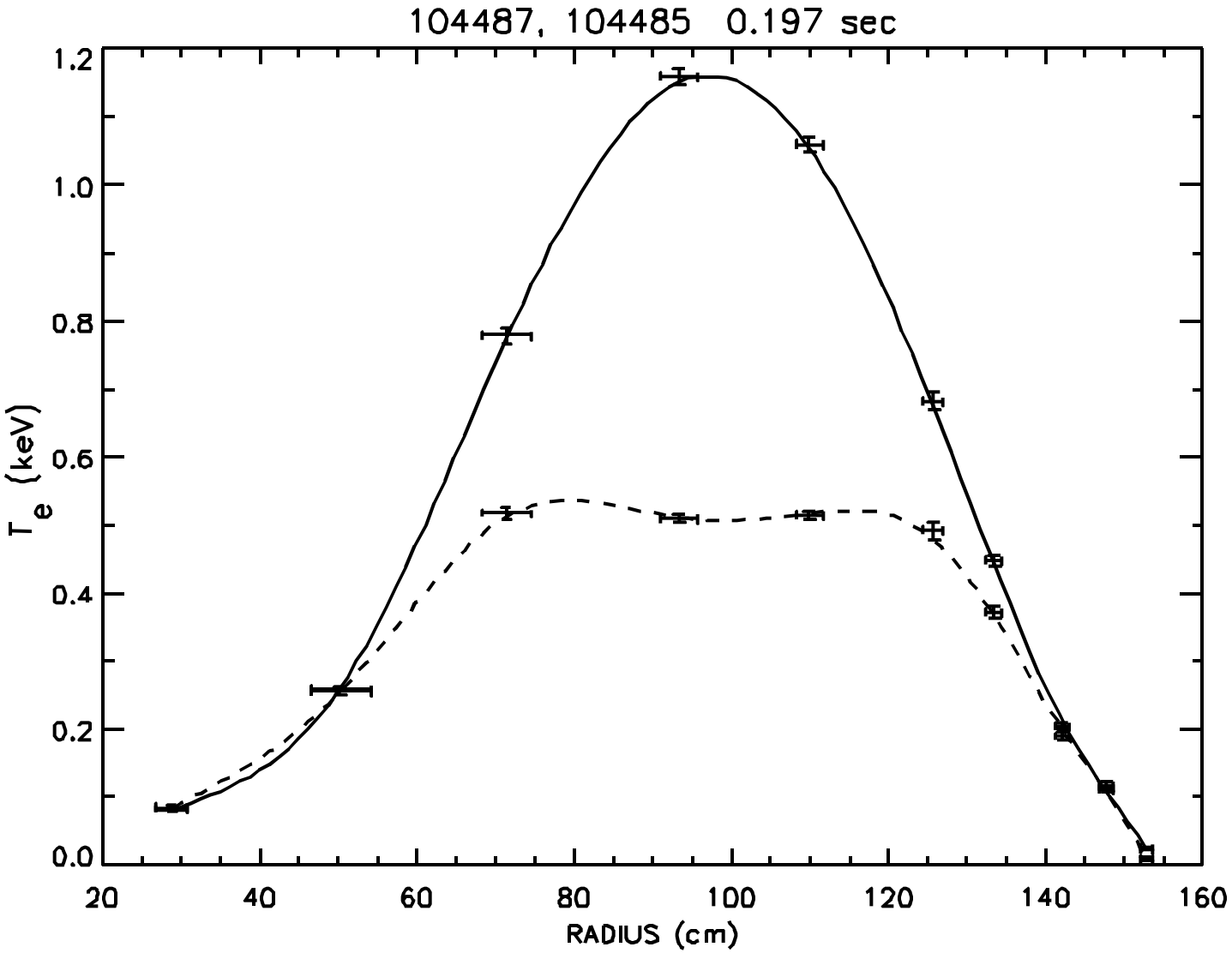
BROAD ELECTRON TEMPERATURE PROFILE OBSERVED IN PRESENCE OF M=1 MHD



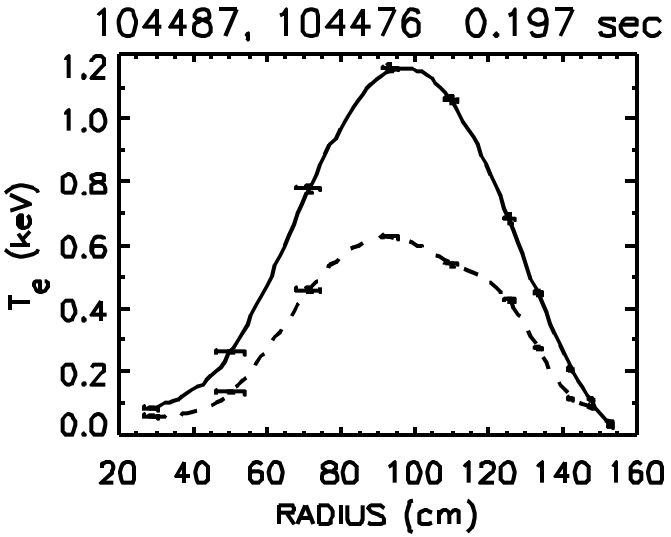


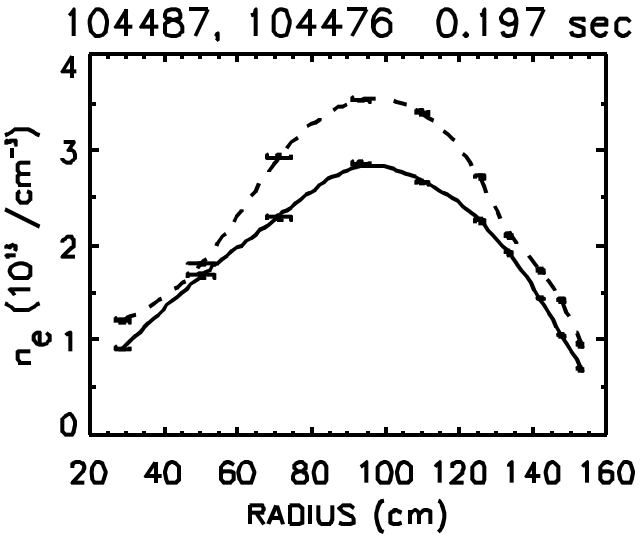
- Flattening of the T_e and n_e profiles occurs with the onset of the m = 1 MHD instability prior to the application of the RF

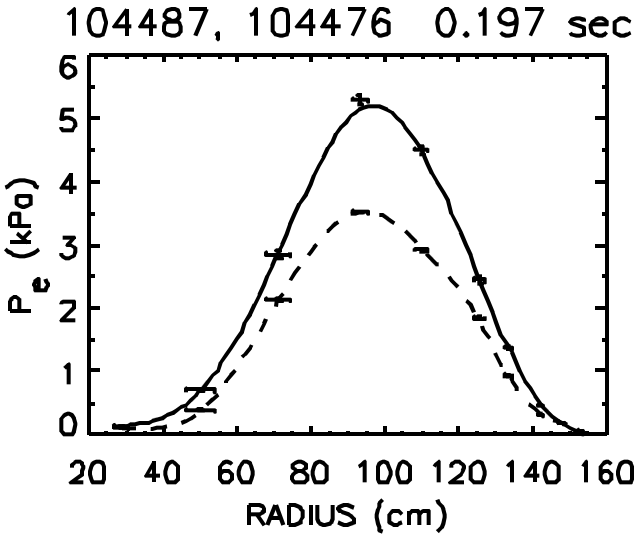
PEAKED HEATING IN THE ABSENCE OF MHD

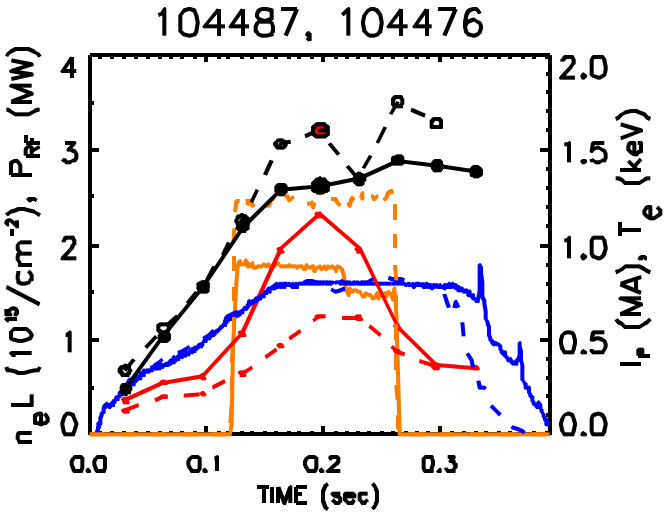


STRONGER HEATING OBSERVED IN HELIUM PLASMAS









INITIAL RESULTS FROM XP-25
HHFW HEATING DURING I_P RAMP-UP

- B_T=3kG, Deuterium, $\kappa \approx 1.8$-2

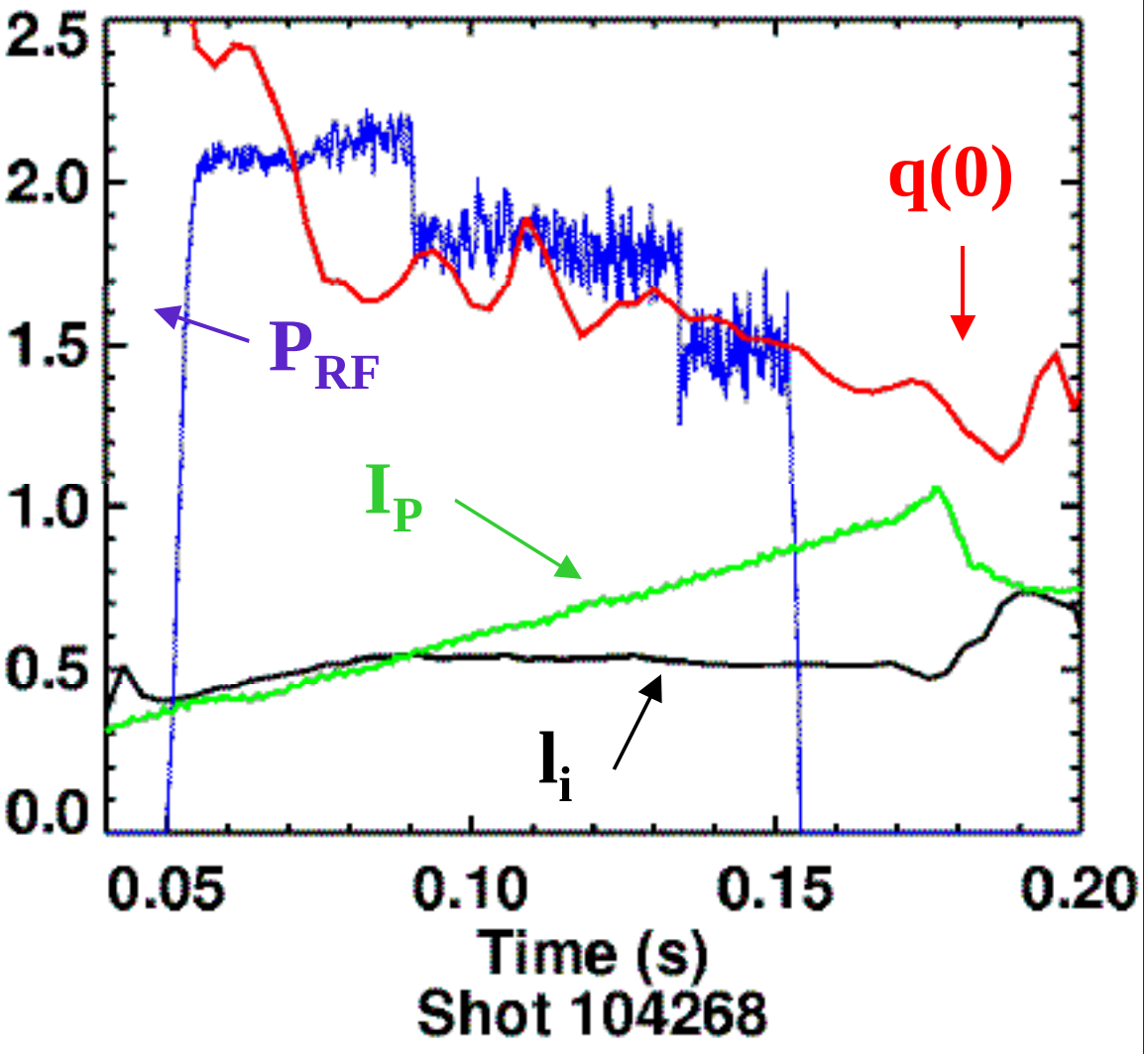
- Important operational results:
  - l_i kept ≤ 0.5 up to 1MA and into flat-top
  - q(0) elevated during ramp-up and after
  - Flux consumption reduced
  - 1MA plasma current more reliably achieved

- Central T_e increase generally modest
  - Higher $T_e(0)$ with smaller outboard gap

- Rapid density increase w/ broad n_e profile
  - Smaller density rise when $\Delta T_e(0)$ is larger

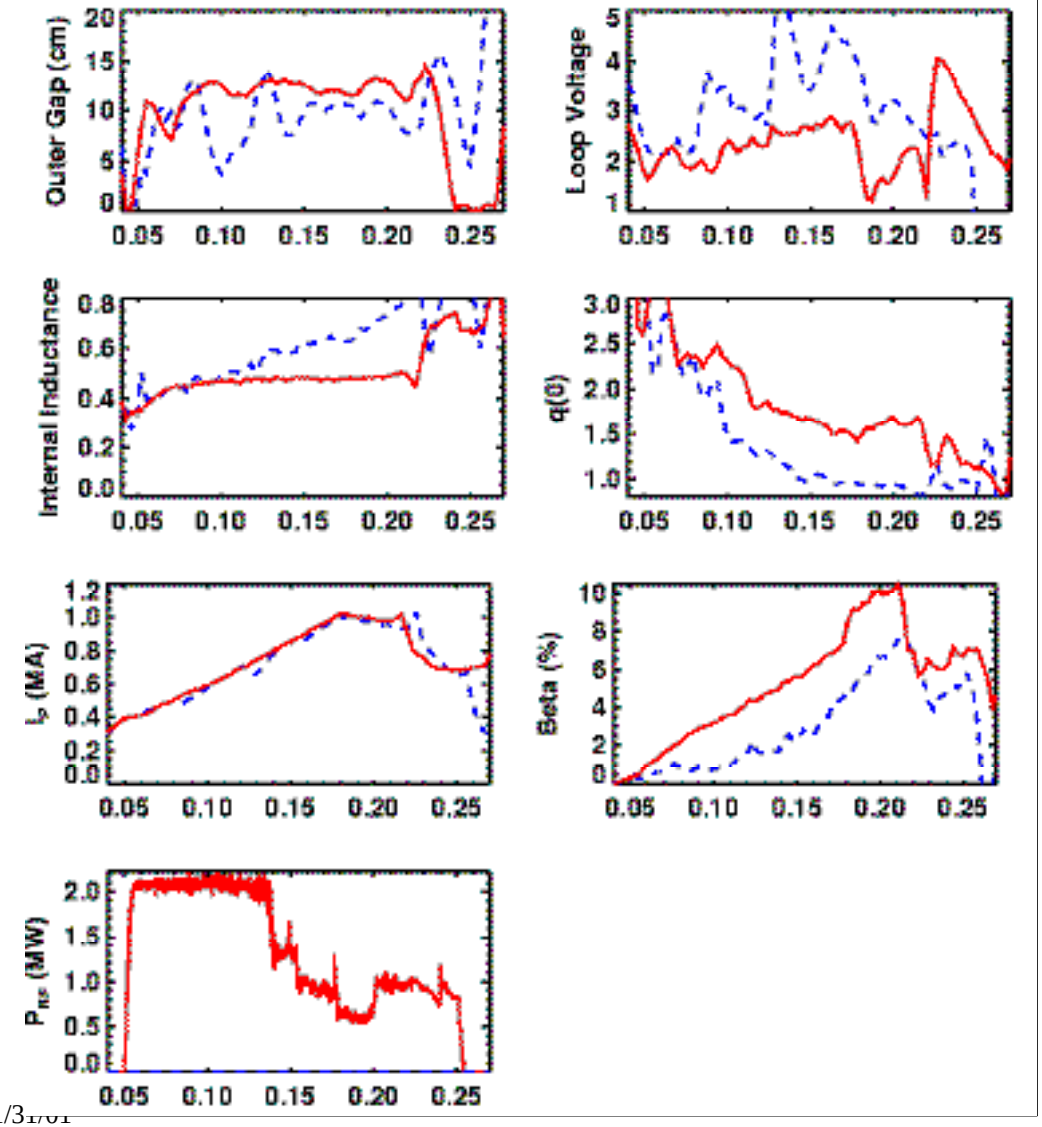
- Results depend on gap and having all 6 XMTRs
  - Transmitter drop-outs modify spectrum and Power

TYPICAL SHOT WITH HHFW-ELEVATED q(0)



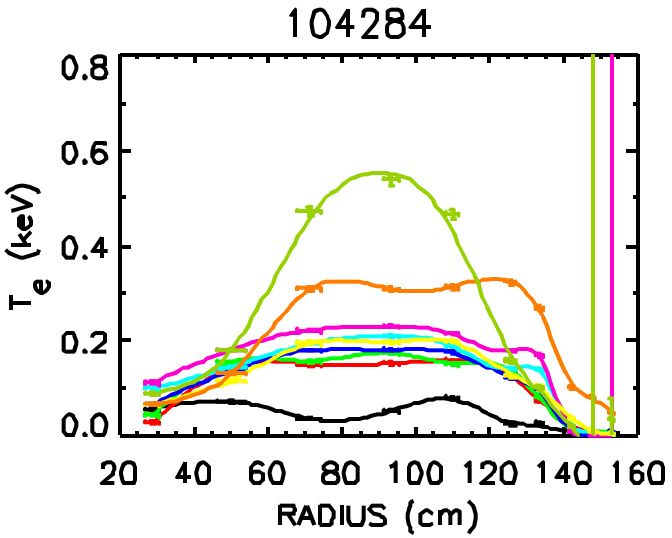
- 7 shots with significant change in q(0), l_i
- These shots have P_{RF} (t=50ms) = 2MW
- Lower powers did not have gap scan
- Higher power (3MW) not tried at all

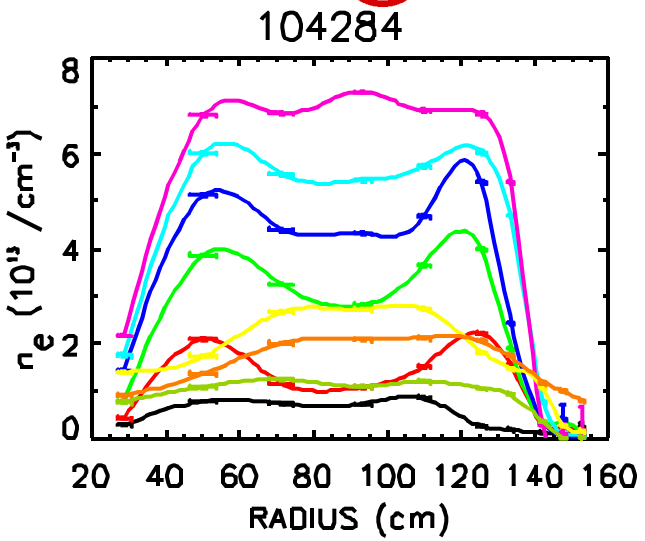
EARLY HHFW LOWERS V_{LOOP} & RAISES q(0)

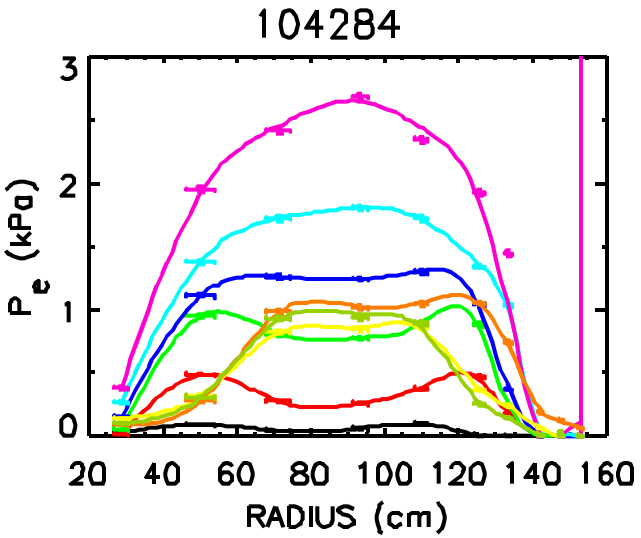


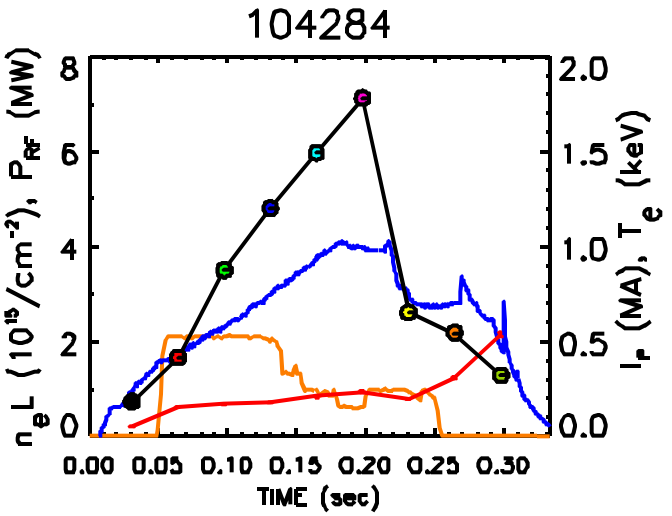
Result requires outer gap of 10 cm - smaller gap leads to larger temperature and smaller density increase with less effect on q(0)

STRONG DENSITY INCREASE OBSERVED WITH EARLY HEATING

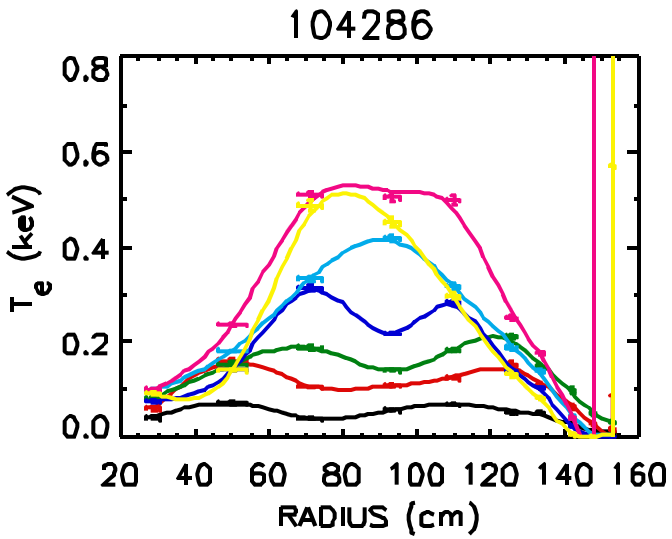


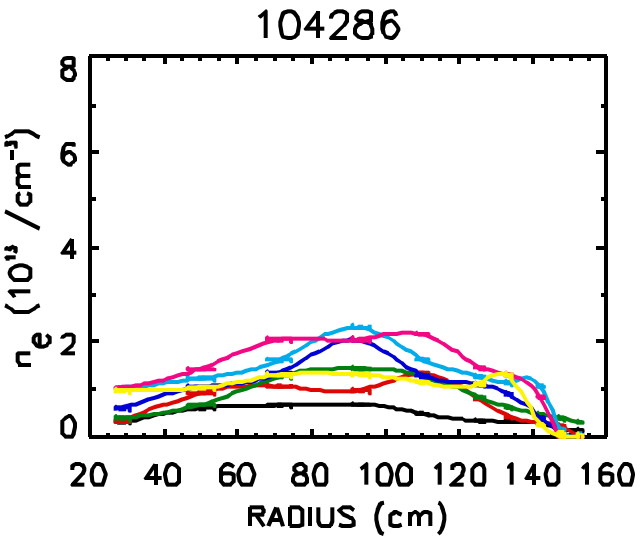


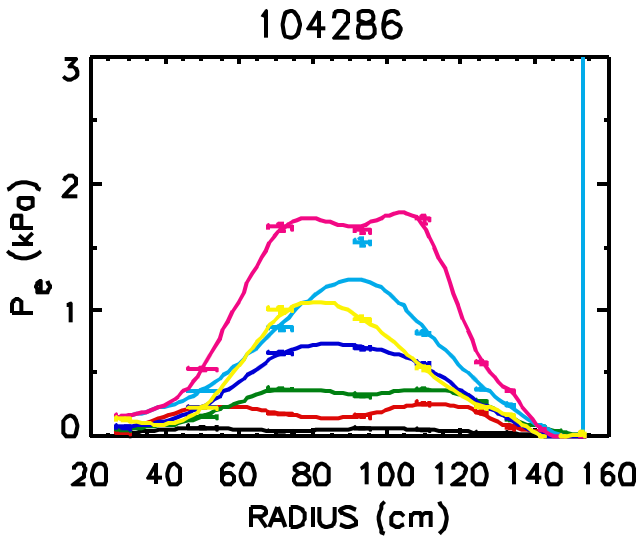


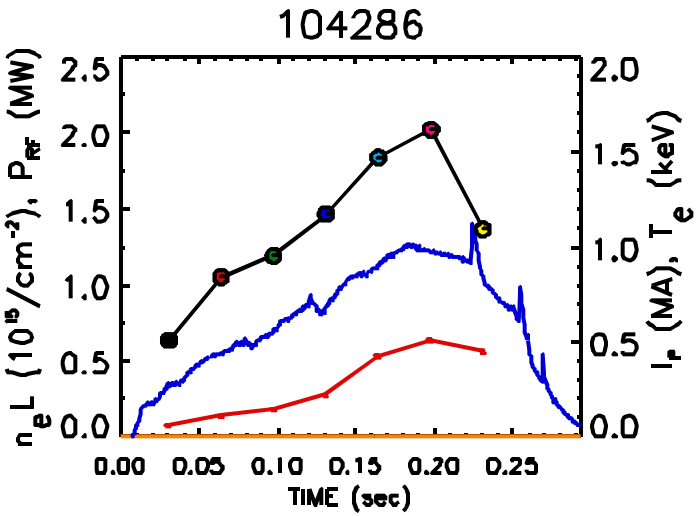


OHMIC COMPARISON









HHFW PLANS (2001)

- Quantitative comparison of electron heating and modeling
  - Requires second TS laser
  - Explore scattering theory
- Continue to exploit HHFW as tool
  - Understand early result
  - Attempt to broaden pressure profile for higher β
  - Begin current drive studies
- Begin ion interaction experiments
  - Need CHERS, NPA, lost ion probes
  - PhD Dissertation
  - HHFW interaction with NBI

TECHNICAL GOALS AND PLANS (2001)

- Operate to full power (6MW)
  - Reinstall λ/4 transformers (smaller impedance ratio)
    - Reduces voltage in feed lines
  - Full bakeout
  - Dedicated rf camera
- Complete full closed loop phase feedback
  - Fiber bundle has been pulled (1/01)
  - Should allow quicker phasing changes
    - Makes phase independent of matching
  - Allows phase changes during pulse

HHFW PLANS (2002)

- Begin serious current drive studies
  - Requires MSE
- Continue use of HHFW as tool
  - Integrate with plasma control system
  - Begin study of CHI to HHFW handoff
- Complete ion interaction study

SUMMARY

- HHFW research is making good progress
  - Full system in operation
  - Electron heating produced
  - Use of HHFW as discharge control tool begun

- Plans in place to continue both HHFW particular physics and exploitation as tool
  - Detailed comparisons with theory/modeling
  - Current drive
  - Ion interactions
  - Early heating/CD and pressure profile modification