Confinement in Auxiliary Heated NSTX Plasmas

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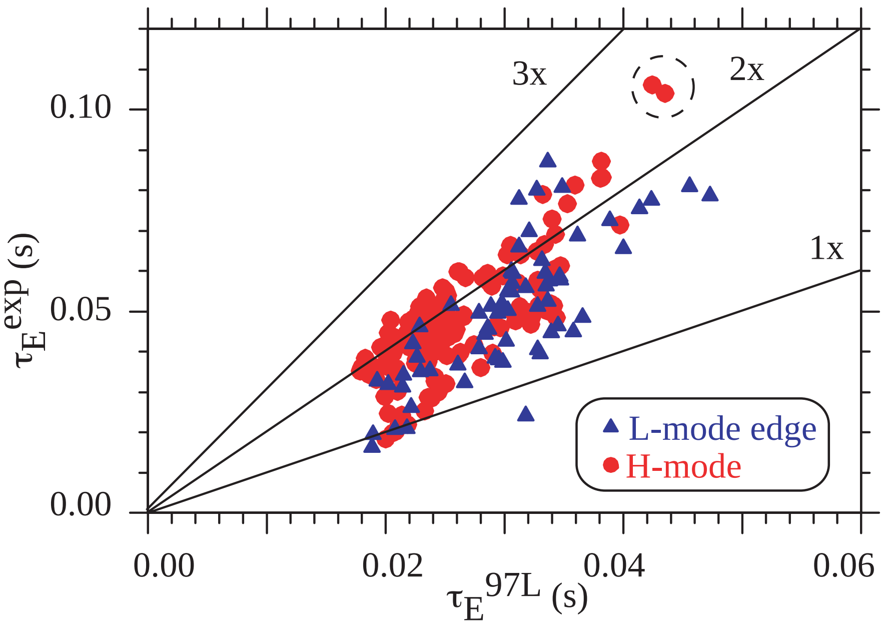
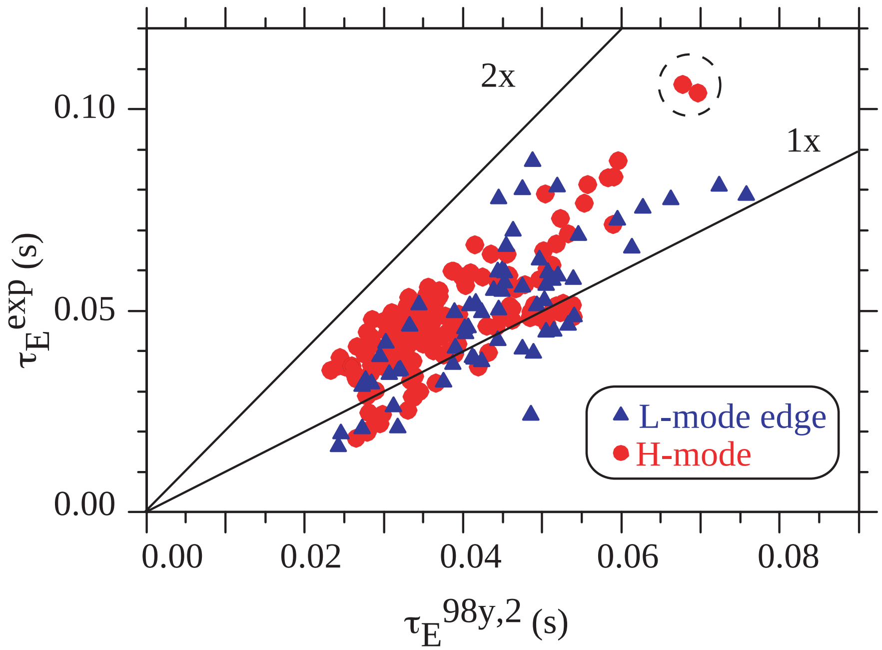
Outline

- Global confinement
- Kinetic profile measurements
- NBI heated plasmas
  - Thermal transport in H-mode plasma
- HHFW heated plasmas
  - Thermal transport in L-mode plasma
  - Electron thermal ITB
  - H-mode plasmas

Global Confinement of NBI Plasmas Exceeds Predictions from Standard Tokamak Scalings

NSTX



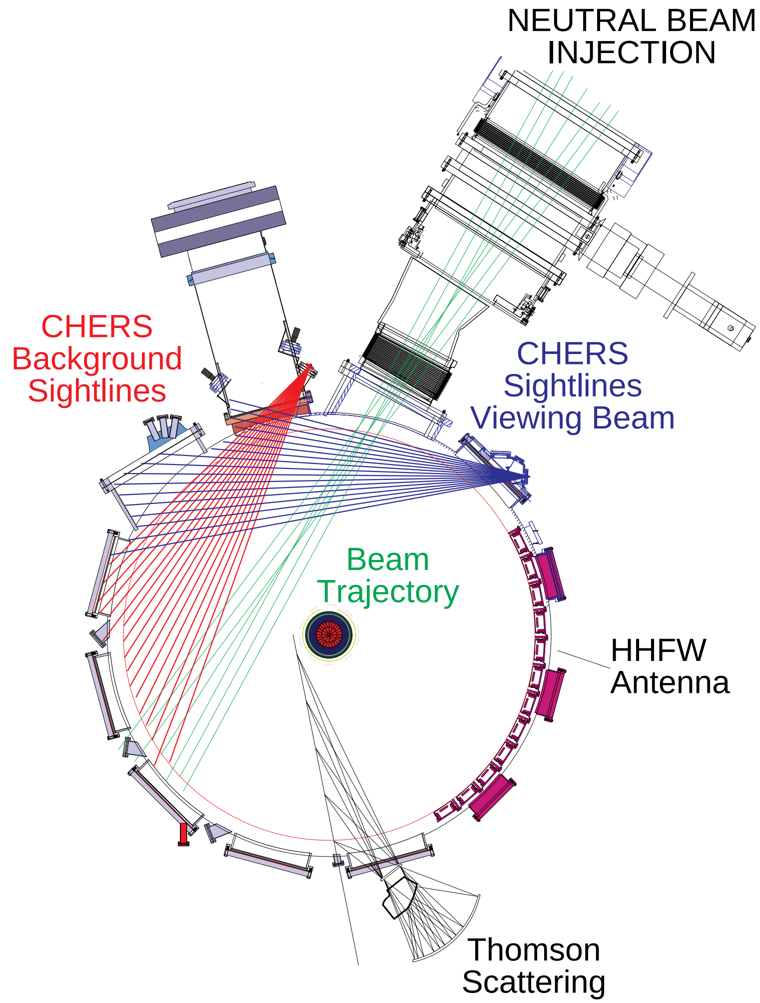


S.M. Kaye, S. Sabbagh, M. Bell

- Quasi-steady conditions except for circled points
- τ_E from EFIT magnetic reconstructions
    - Includes 15-30% energy in unthermalized NB ions

Time Dependent Kinetic Profile Measurements Allow Analysis of Local Transport

- Thomson scattering
  - $T_e(R,t)$, $n_e(R,t)$
  - *60 Hz, 20 channels*
- Impurity charge exchange recombination spectroscopy
  - $T_i(R,t)$, $v_\phi(R,t)$
  - *17 channels, Δt = 20 msec*
- Bolometer
  - $P_{rad}(R,t)$, 16 channels
- Ultra soft x-ray arrays
  - 4 fans of 16 channels each



$T_i > T_e$ during NBI Heating

$I_p = 0.8$ MA

$B_T = 0.5$ T

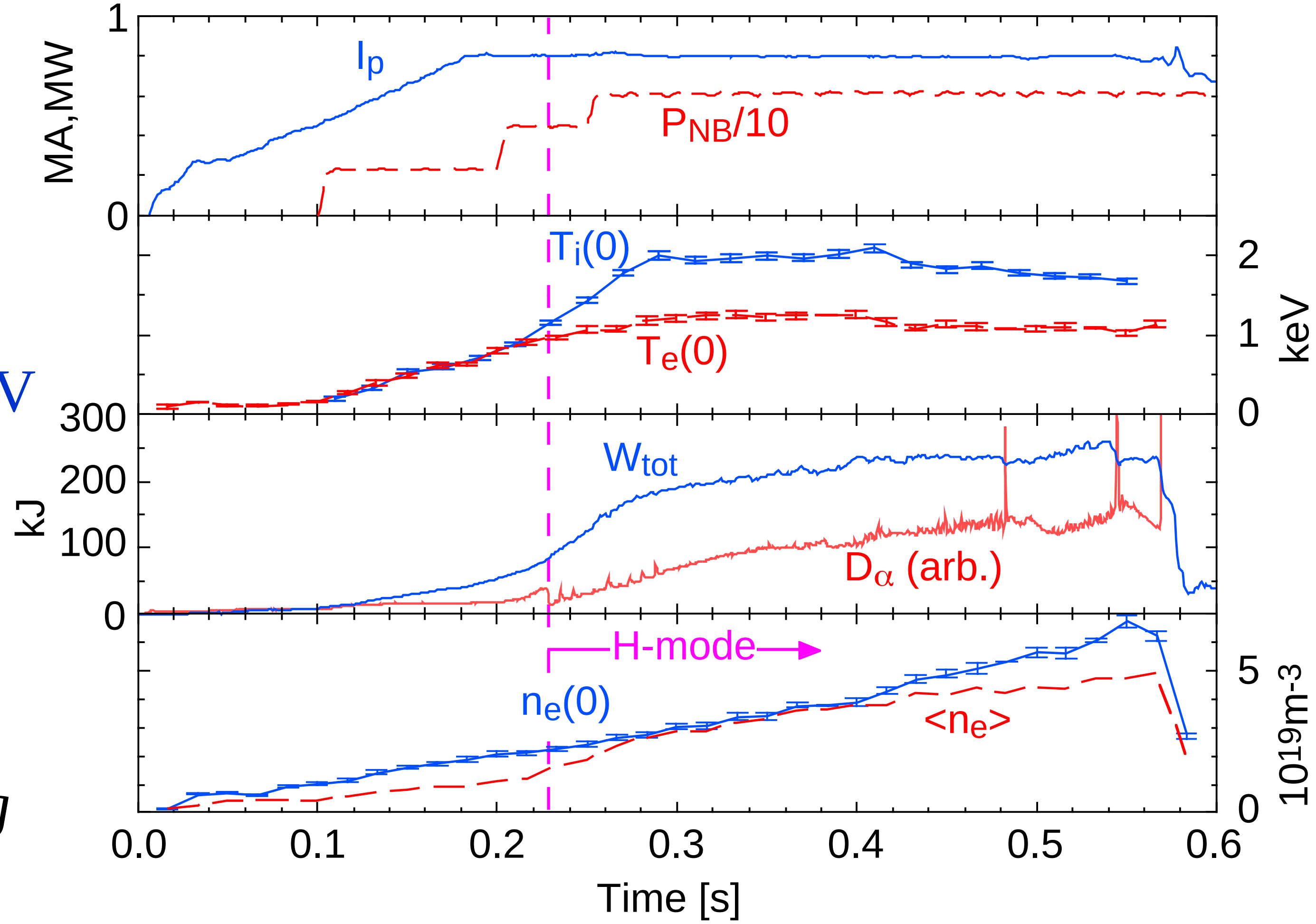
$P_{NBI} = 6$ MW

$E_{NBI} = 80$-100 keV

$\beta_T = 18\%$

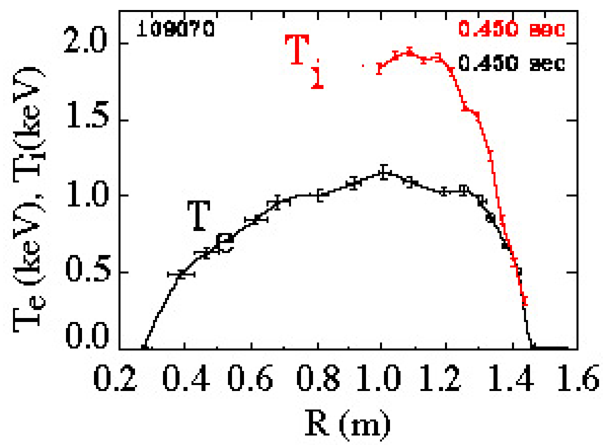
W = 0.25 MJ

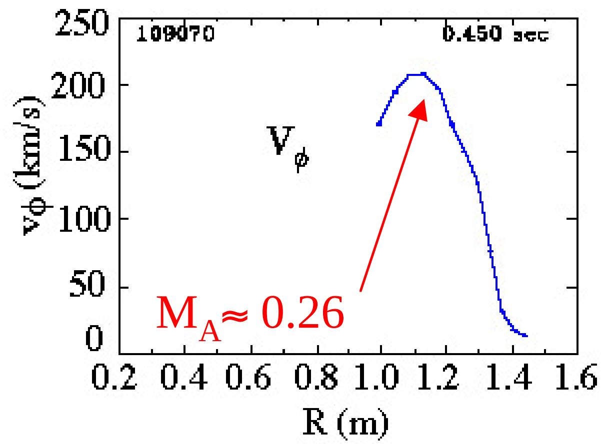
Density profile broadens during H-mode



$T_i > T_e$ during NBI Indicates Good Ion Confinement

- Classical fast particle slowing down predicts predominant electron heating
  - 62% to electrons
  - 38% to ions
- $T_i = T_e$ in edge region
- High rotation associated with good ion confinement
- $M_A = v_\phi / V_A$



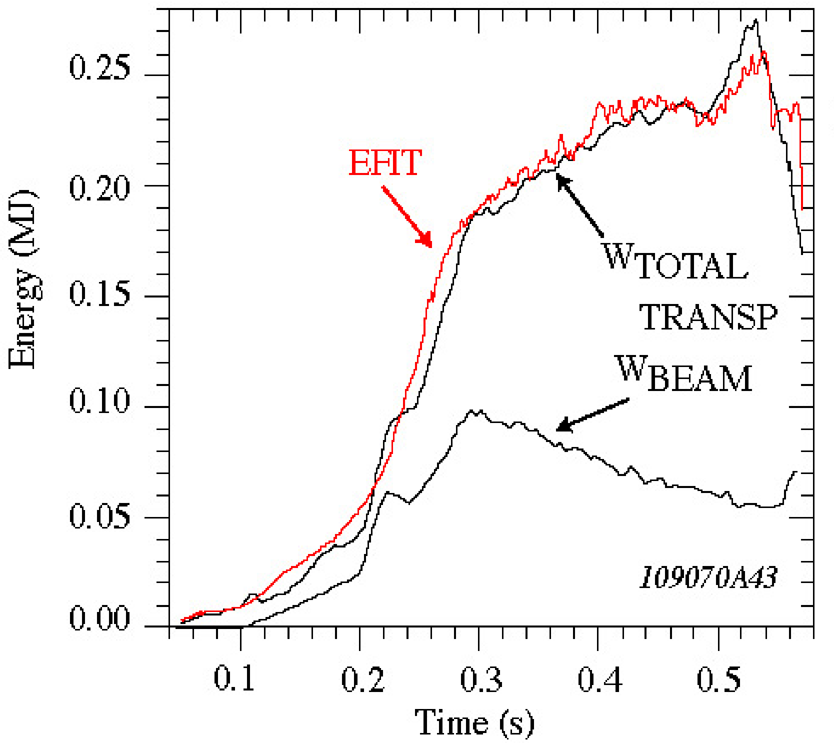


T_i and v_ϕ from CHERS, R.E. Bell

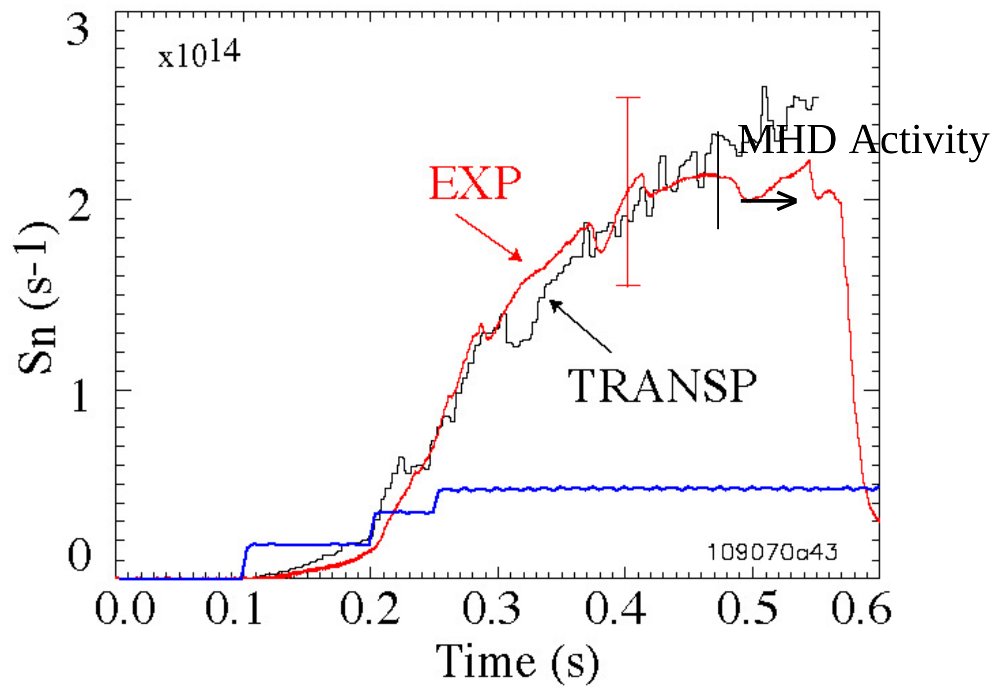
Global Parameters from Kinetic Analysis Agree With Those From Magnetic Analysis and Neutronics

NSTX

Stored Energy



Neutron Rate



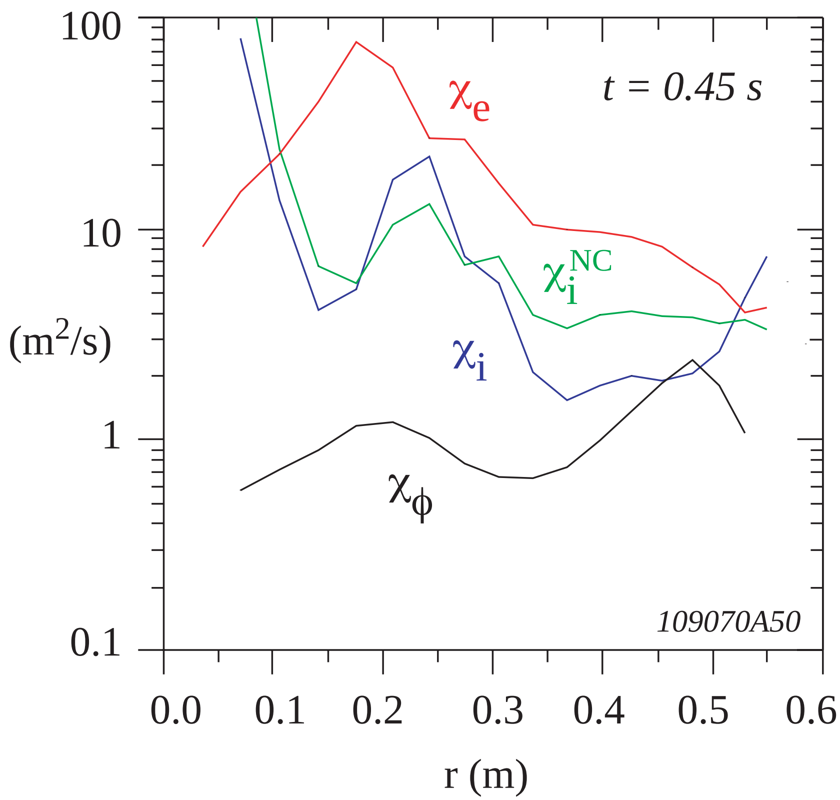
TRANSP assumes classical beam slowing down

S.A. Sabbagh, S.M. Kaye   A.L. Roquemore

Low Ion Thermal and Momentum Transport, High Electron Thermal Transport

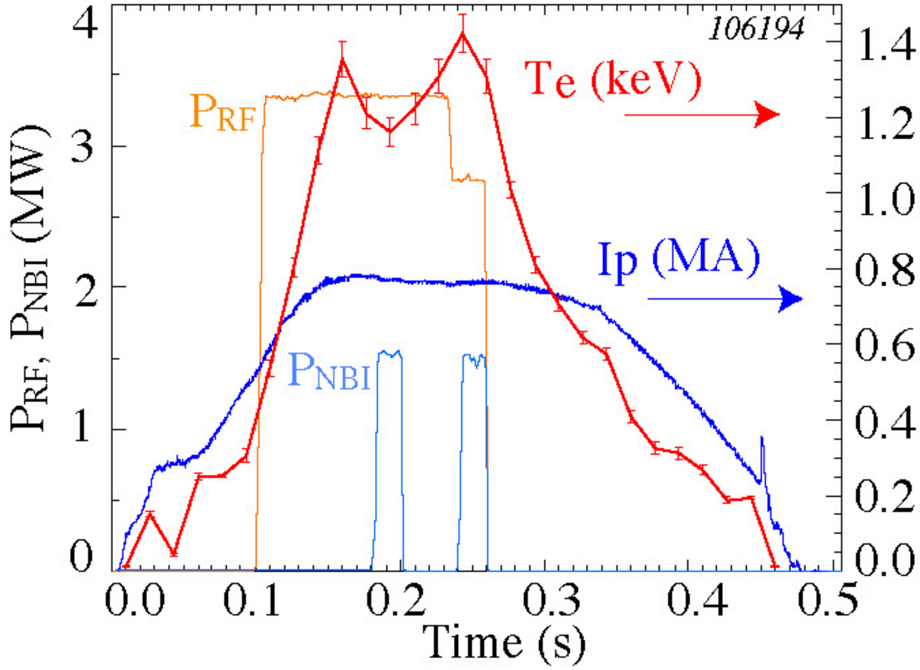
- Analysis assumes classical fast ion slowing down.
- Find χ_i within factor two of χ_i^{NC} over plasma width.
- High central χ_e, lower at edge
- $\chi_\phi < \chi_i < \chi_e$

TRANSP Analysis

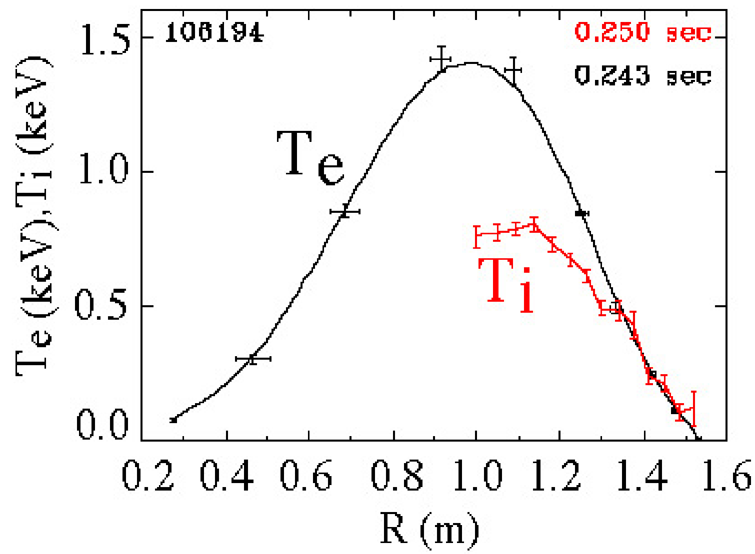


Large T_e Increase Observed during High Harmonic Fast Waves (HHFW)

He Discharge



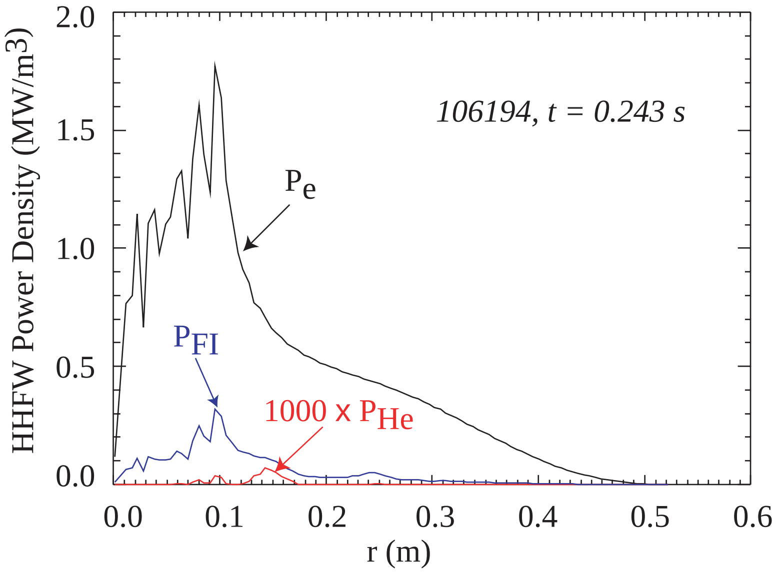
$T_e > T_i$



T_i from CHERS, R.E. Bell

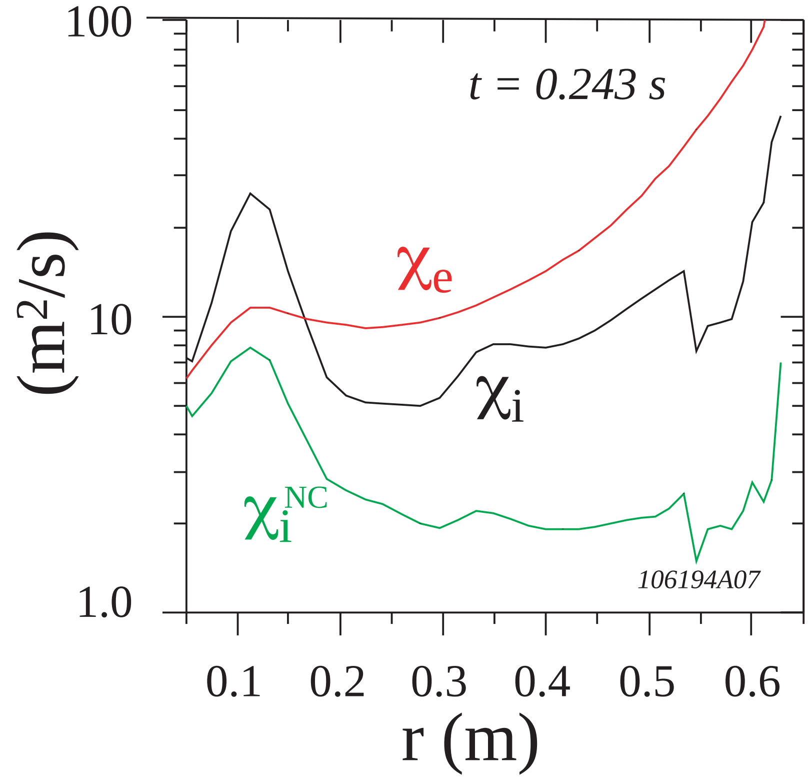
Both Ions and Electrons Exceed Neoclassical Transport in HHFW L-mode Plasmas

RF power deposition from HPRT ray tracing code



HPRT, A. Rosenberg, J. Menard

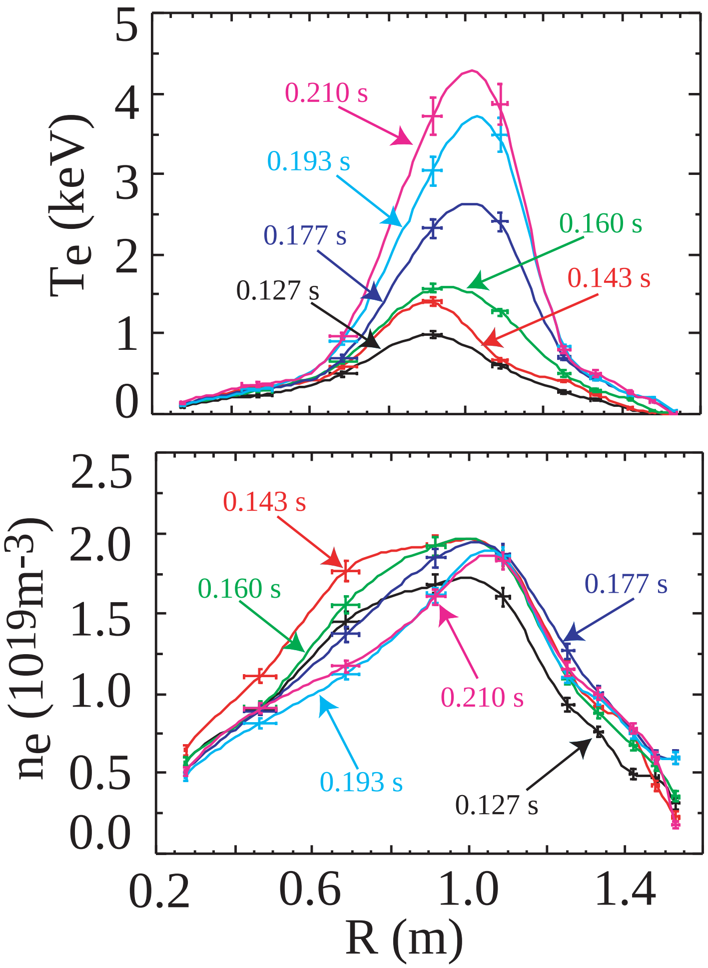
$\chi_i^{NC} < \chi_i < \chi_e$

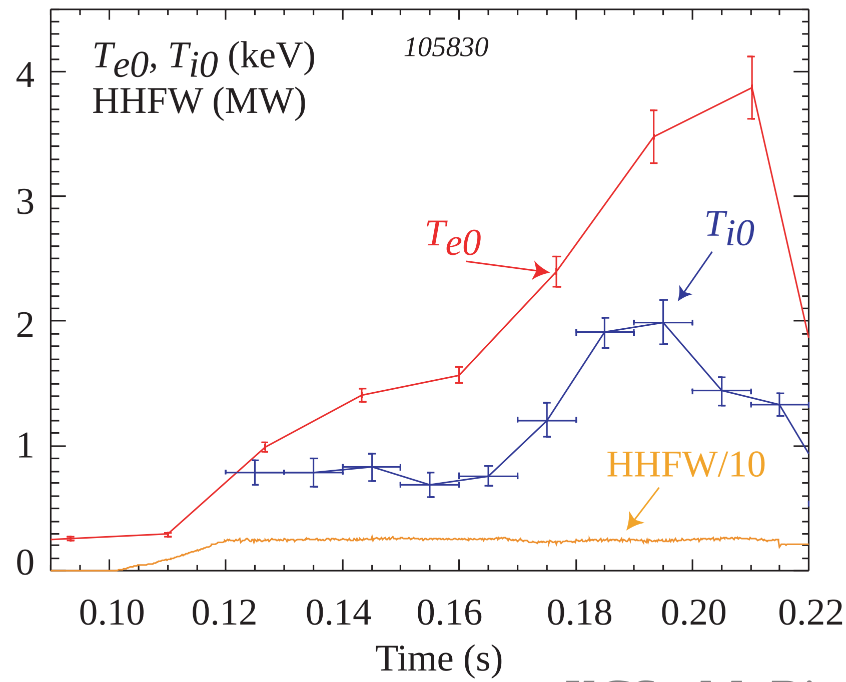


<u>Increasing</u> χ_e with radius

Electron ITB Formation with HHFW in Lower Density Deuterium Plasma

NSTX



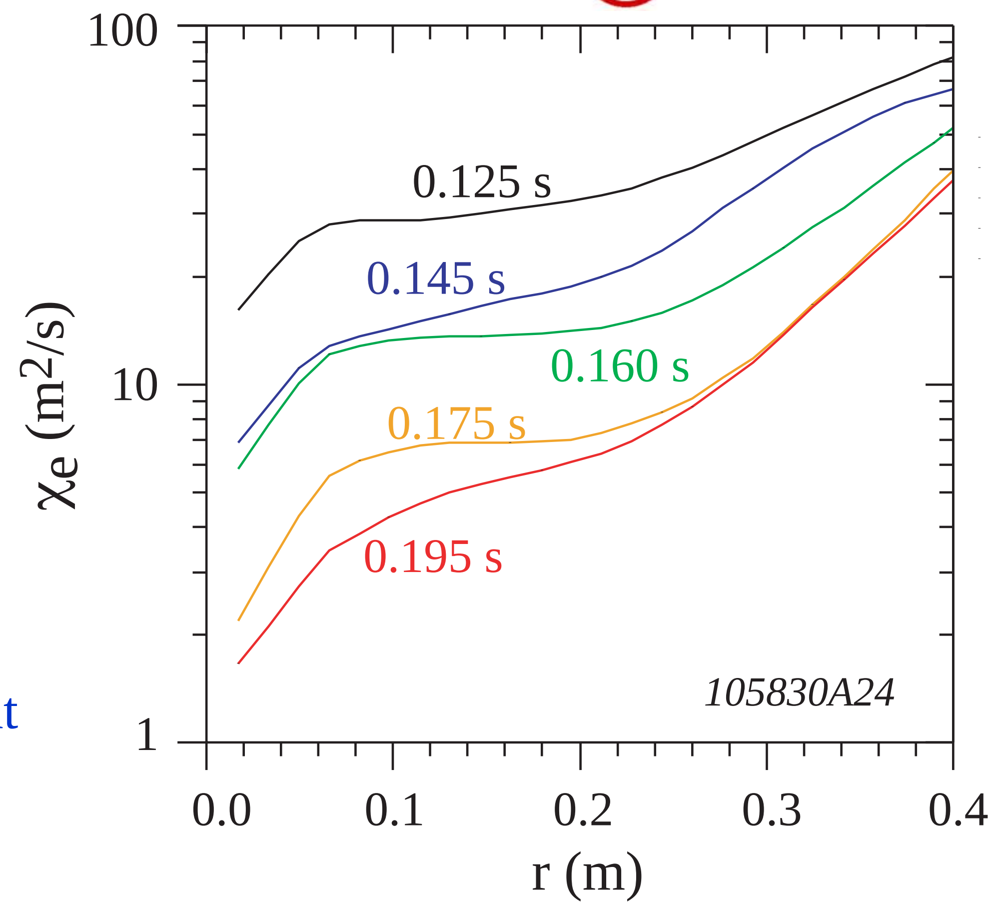


XCS, M. Bitter

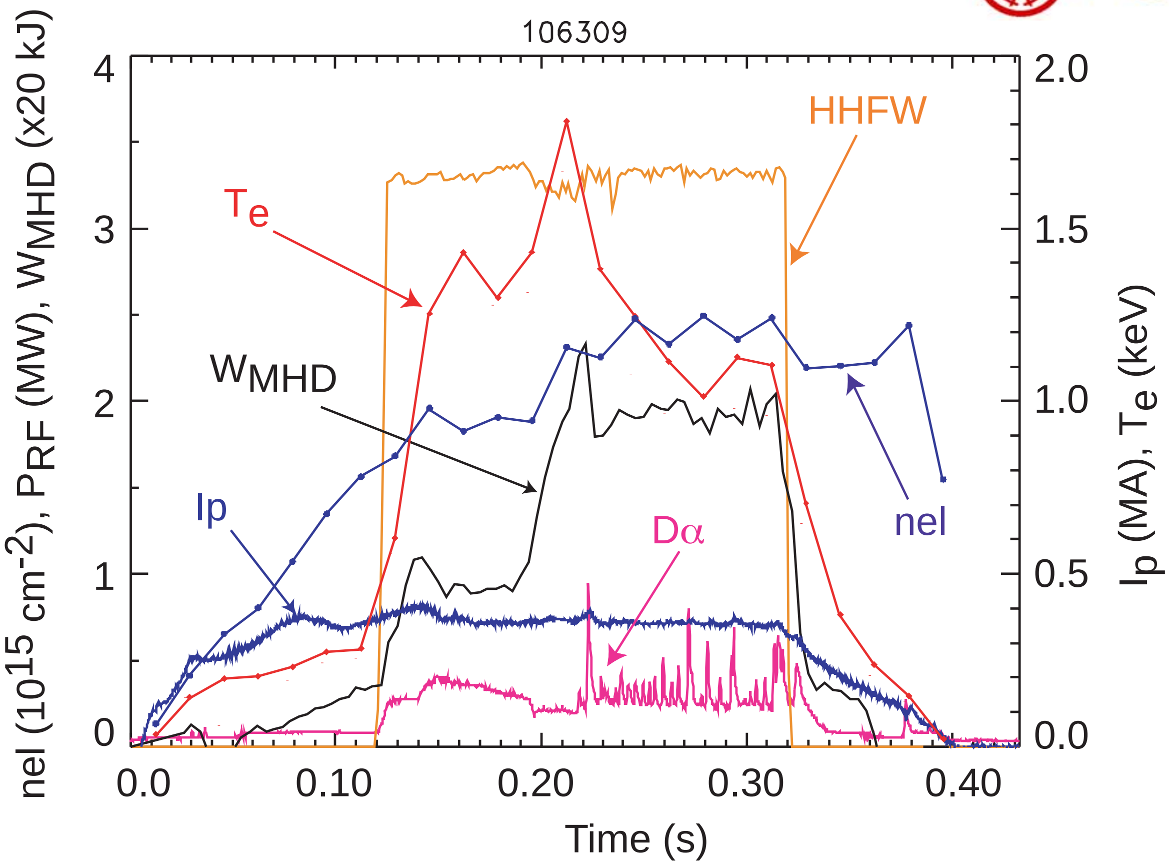
- Deuterium, low density, 0.8 MA
- VB: line avg. Zeff = 3 - 4.5
- USXR: Peaked Zeff profile
- Bolomoters: Radiative core

Increase in T_e Corresponds to Decrease in χ_e

- Power deposition from ray tracing
- T_{io}(R,t) derived from XCS and TS
- χ_e decrease in core
- Stabilizing factors
  - HHFW driven $T_e > T_i$
  - Impurity content
  - Reversed *q* profile might be caused by resistive core (TRANSP)

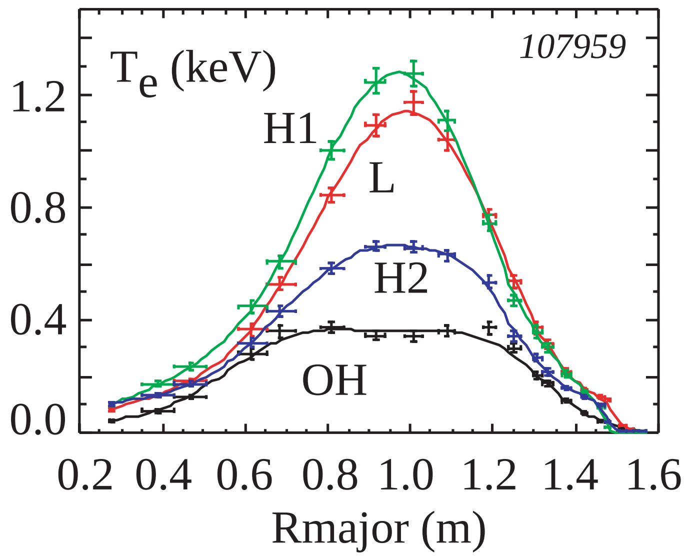


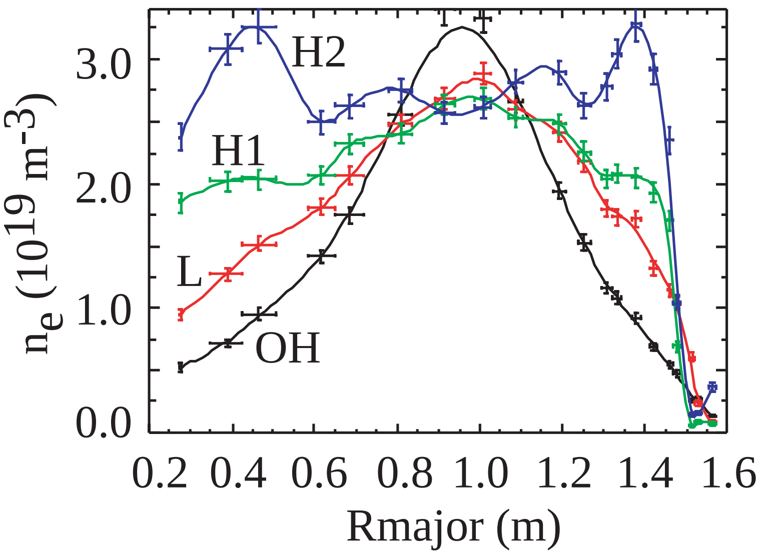
H-mode Plasmas Obtained with HHFW Heating



- Doubling of stored energy.
- 40% bootstrap current

HHFW H-mode Profiles





- T_e pedestal observed
- Large edge n_e gradients with “shoulders.

Conclusions (1)

- Global confinement exceeds standard scalings
  - $\tau_E \approx$ 2-3 x τ_E^{97L}
  - $\tau_E \approx$ 1.5 x τ_E^{98Pby2}
- Many diagnostics implemented for transport analysis
  - Estimates of global parameters from kinetics agree with those from magnetic and neutron measurements
- NBI heated plasma
  - Low ion thermal transport over wide region, $\chi_i \approx \chi_i^{NC}$ in high power H-mode plasma. Low edge thermal transport.
    - May be hiding instrumental issues, although have good match to global parameters.
    - May be hint of additional effects besides classical slowing down contributing to the partition of NBI power between ions and electrons.

Conclusions (2)

- NBI heated plasma (continued)
  - Thermal losses dominated by electron transport
- HHFW provides effective electron heating
  - Electron loss still dominates, but core χ_e lower than in NBI, and $\chi_i > \chi_i^{NC}$.
  - Electron ITB observed on T_e profile
    - Increasing T_e with decreasing χ_e
- H-mode plasmas obtained with HHFW heating

END OF TALK