HHFW Power Deposition and Transport Studies in FY04*

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NSTX Research Opportunities Forum
Princeton Plasma Physics Laboratory
November 10 – 12, 2003

* This research was sponsored by the Office of Fusion Energy, U. S. Department of Energy, under contract DE-AC05-00OR22725 with Oak Ridge National Laboratory managed by UT-Battelle and under contract DE-AC02-76CH03073 with Princeton Plasma Physics Laboratory.

Understanding HHFW power deposition and transport in NSTX is critical

NSTX needs HHFW for heating and current drive

Several interesting (*i.e., not understood*) results were seen in the 2003 period:

- HHFW modulation experiments with USXR data showed *very little* (no?) heating at the center of the plasma
  - Data obtained for one plasma condition only
- Edge ion diagnostic showed dramatic heating and rotation of C and He ions near edge of the plasma when HHFW applied

We need to understand:

- Where the HHFW power is going
  - What fraction of power is being absorbed by the different species?
  - Where is the power being absorbed?
- What are the transport properties for HHFW-deposited power
  - Are they different from OH or NB heating?
  - What is the mechanism?

We propose a set of experiments to measure deposition and transport

Continue modulated HHFW power deposition studies

- Carry out modulation experiments under different plasma and HHFW conditions
  - HHFW: different phasing (co-CD, counter-CD, fast and slow symmetric,...)
  - Plasma: change I_p, B_0, density (i.e., your general fishing expedition)
  - Plasma: allow T_e profile to relax to test critical ∇T transport hypothesis
- Analyze USXR, FIReTiP and other diagnostic responses to modulation
- Model with TRANSP and other codes to compare measurements with theory

Question: How can we study power absorption by ions?

Diagnostic technique “tool kit” now available to analyze USXR (and other - FIRETiP?) data during HHFW modulation experiments

Caveats:

- These are first thoughts only – looking for input
- Collaborate with other task forces (Transport, Integrated Scenario Development) on some of this?

DETAILS OF PAST EXPERIMENT (SHOW ONLY AS NEEDED)

RF modulation experiments were done on NSTX

Plasma conditions:

- B_0 = 0.45 T
- I_p = 600 kA
- Lower-single null, diverted
- He plasma

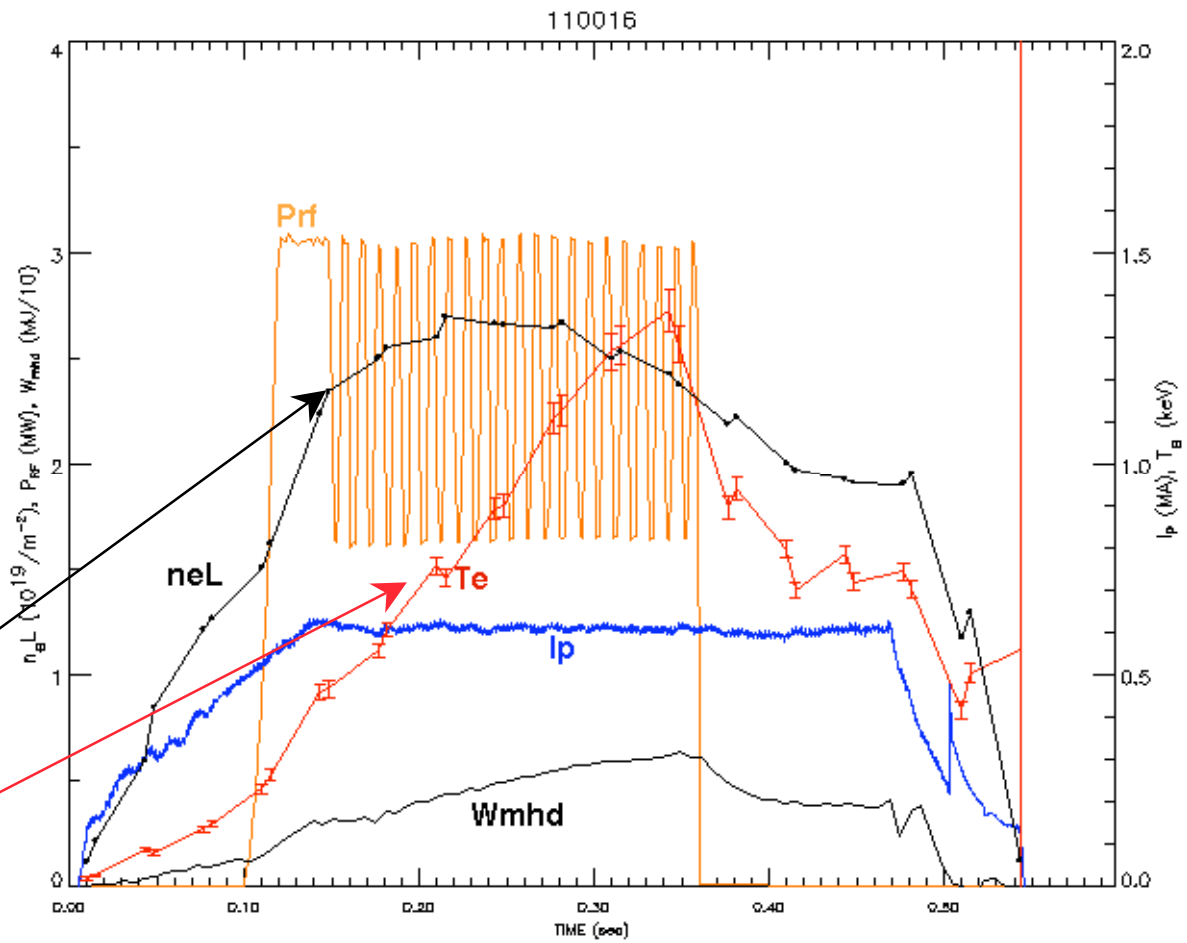
RF:

- Co-current drive phasing
- Max rf power ≈ 3 MW
- Modulation ≈ 50%, 100-Hz square-wave

Note:

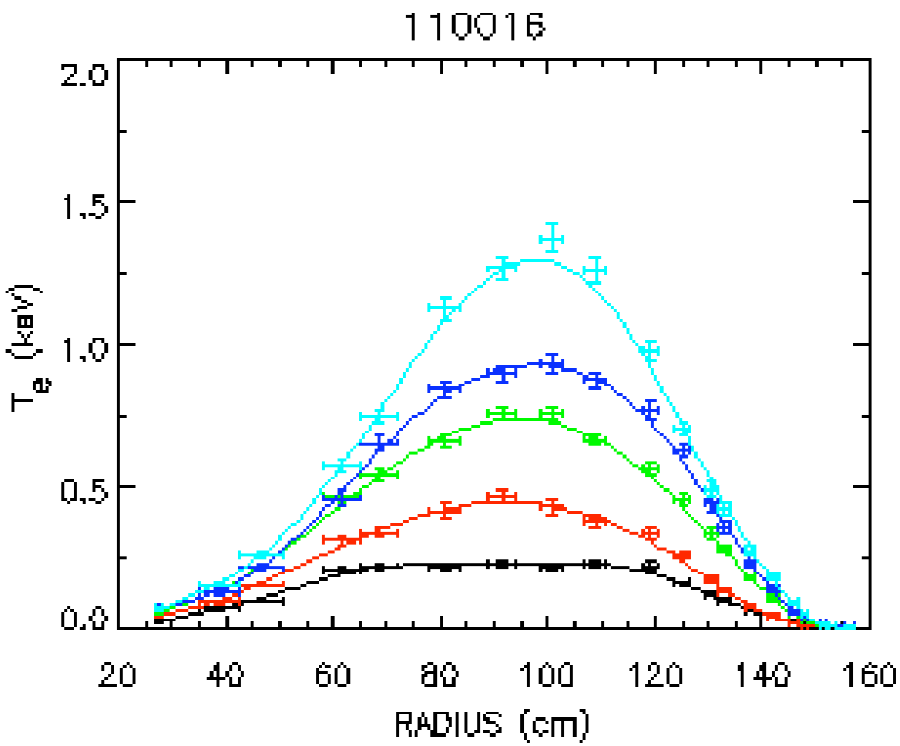
- Relatively flat density vs. t during rf modulation
- Monotonic increase in $T_e(0)$ during rf pulse.

Plasma current, T_e, n_eL, RF Power, and Stored energy

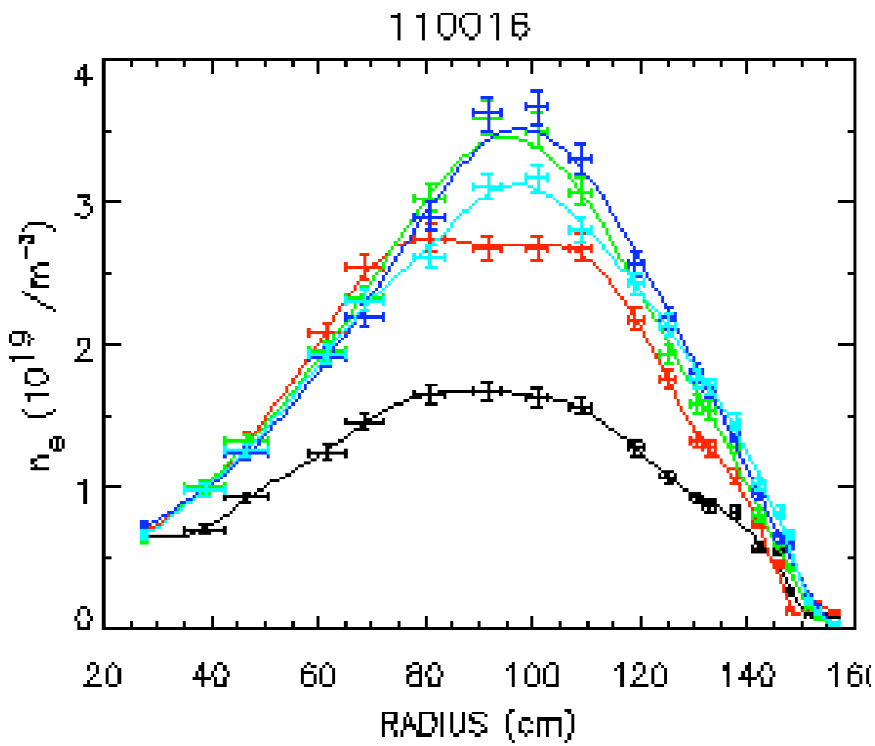


Thomson scattering profiles: T_e rises, $n_e \approx$ constant during rf

T_e and n_e profiles at 100 ms, 150 ms, 200 ms, 250 ms, 300 ms
RF modulation begins at 150 ms



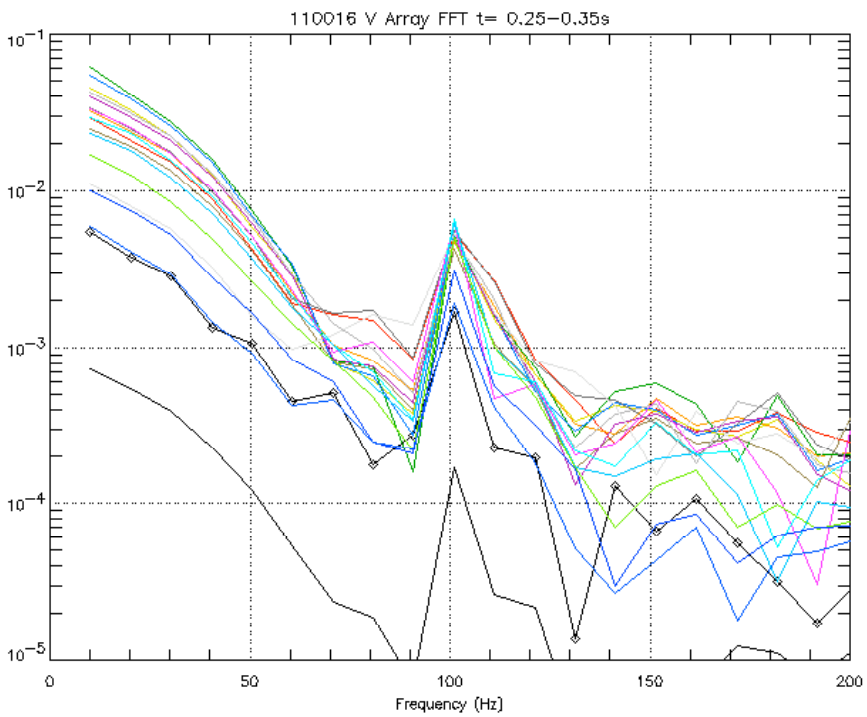
Temperature profile increases slowly with time

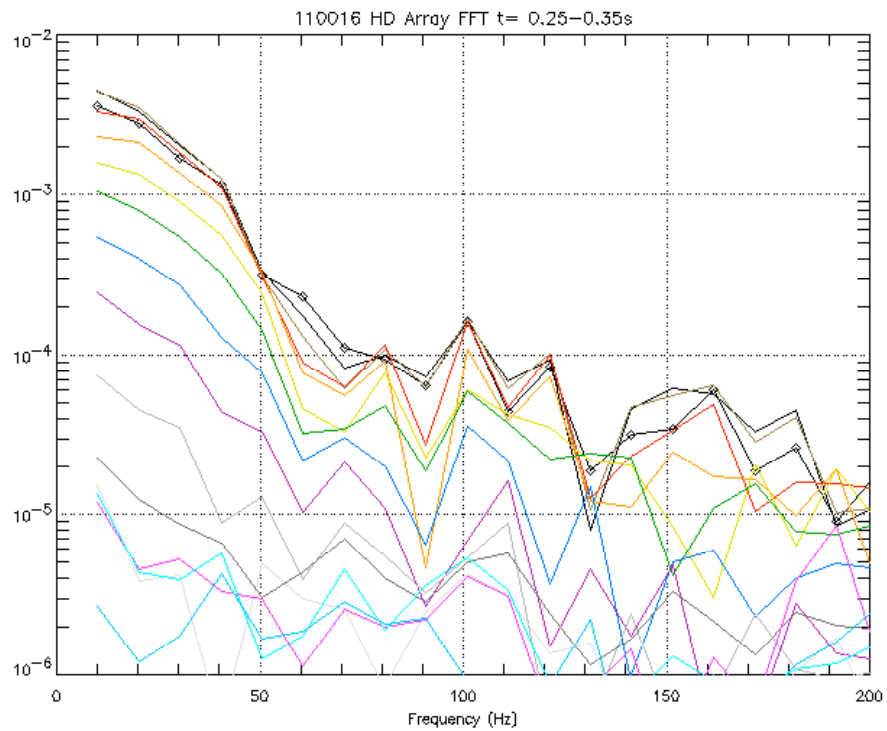


Density profile relatively constant from 200-300 ms

How do array signals respond to 100-Hz modulation?

Took Fourier transform of all signals for 0.25 s ≤ t ≤ 0.35 s, giving a data point in frequency-space every 10 Hz





Low-E array signals have significant 100-Hz component

High-E array signals have *S/N* of ≈ 1 – is signal really there?

100-Hz signal components show very different radial dependence

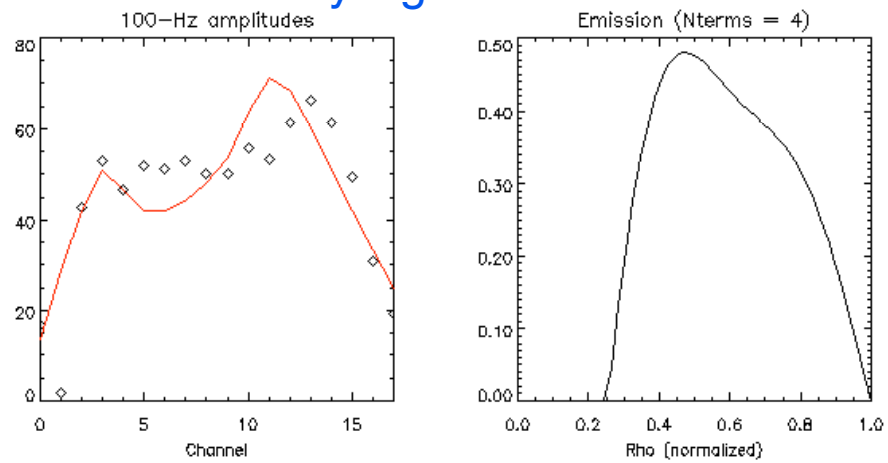
Took 100-Hz component of signal on each channel, inverted to get $S_{100Hz}(\rho)$

- Low-E array signal is highest in outer half of plasma

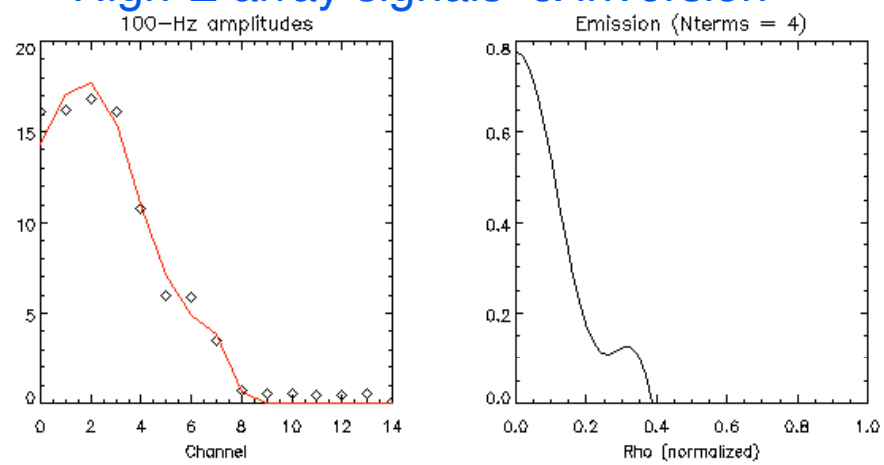
- High-E array signal is peaked near the center

4-parameter inversion gives *reasonably* good fit to signal data.

Low-E array signals & inversion



High-E array signals & inversion



From high-E data, ΔT_e very small near center

Observations:

- 100-Hz component has radial profile identical (to within error bars) to unmodulated signal
- Peak-to-peak amplitude of largest channel signal appears to be only about 2% of the total signal amplitude
- Cross-correlation coefficient (r) of this signal with rf modulation is low, ≈ 0.2

Signal amplitude should be very sensitive to changes in T_e

- Near center, $S \sim n^2 Z^2 T_e^{2.3}$

Conclusion:

- Upper bound on $\Delta T_e/T_e$ caused by the modulation is $\leq 1\%$ in central part of the plasma ($\rho \leq 0.3$)

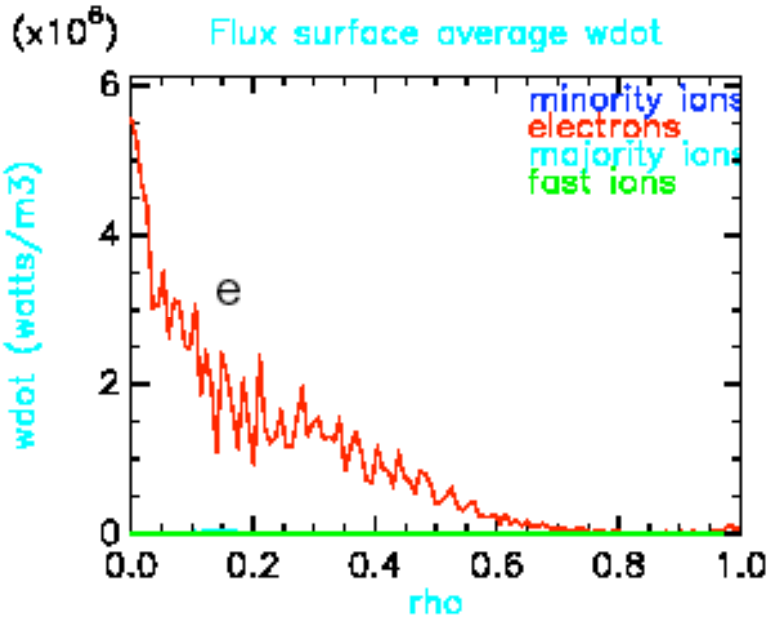
What should we expect to see?

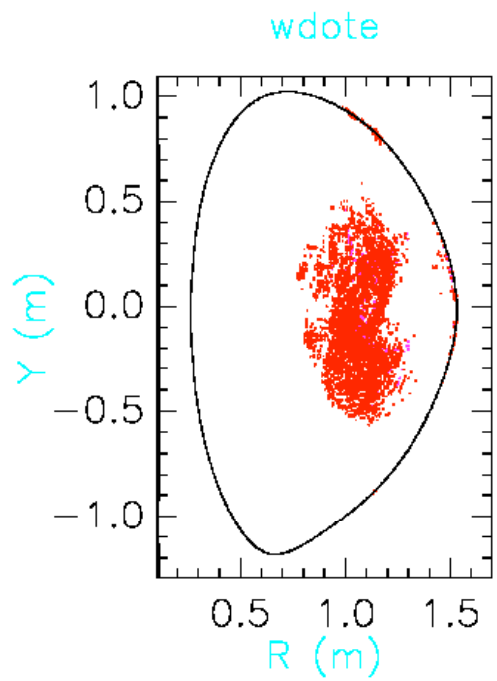
For experimental plasma conditions, calculated power deposition using the AORSA 2D code

- Single toroidal mode [n_ϕ = -12, co-current drive direction]

Results:

- Almost all the power should be absorbed by electrons
- Power deposition is centrally peaked
- These results are *not* very sensitive to assumptions on plasma conditions



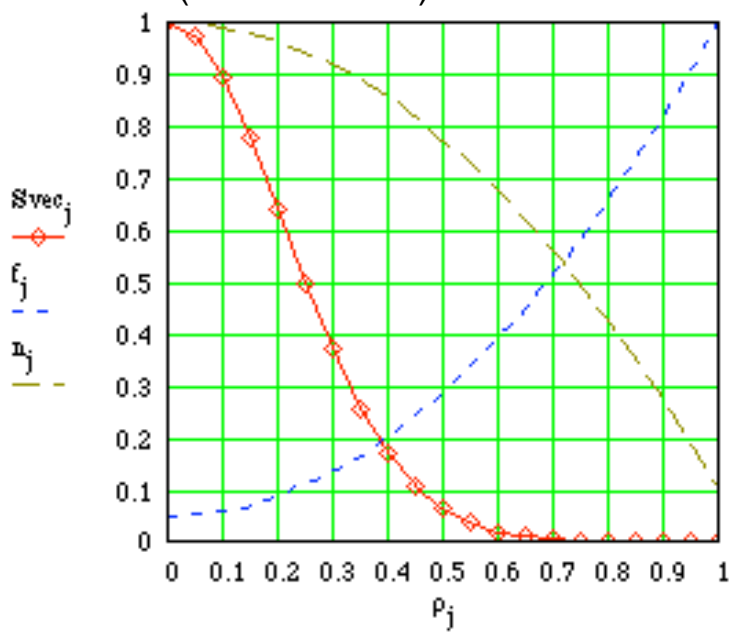
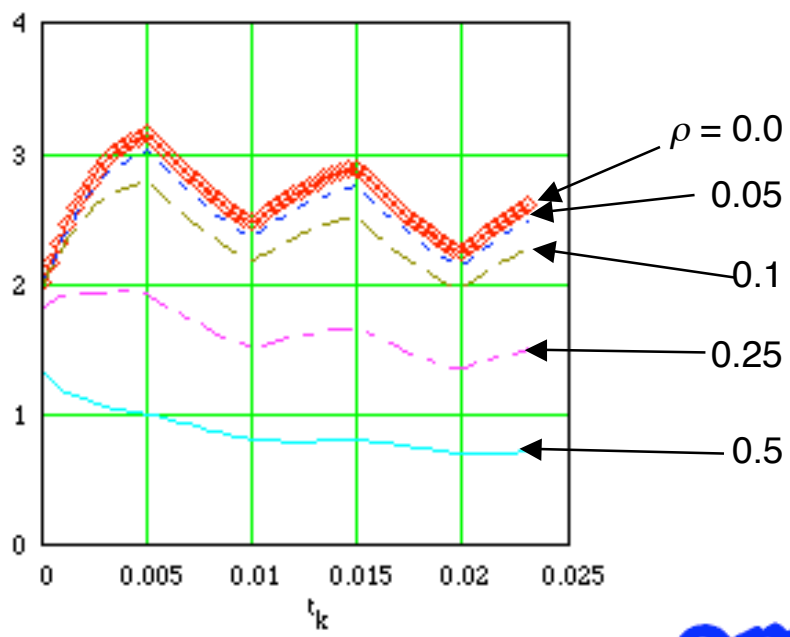


Centrally-peaked power deposition should give 10-20% $\Delta T_e/T_e$

1D model

- Specified constant density profile
- χ_e profile *shape* specified [$\chi(\rho) = \chi(0) + (\chi(1) - \chi(0))\rho^{\alpha}$] magnitude adjusted to give experimental $\tau_e \approx 12$ ms
- Gaussian power deposition profile to electrons, approx. same as from AORSA

Power deposition profile
Density profile
χ_e profile [$\chi(0)/\chi(1) = 0.05$, $\alpha = 2$]
(all normalized)



$T_e(t)$ for different ρ values
with 50% modulation
(arb. units)