TESTS OF TRANSPORT THEORY AND REDUCED WALL IMPURITY INFLUX WITH HIGHLY RADIATIVE PLASMAS IN TFTR*

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MAIN POINTS

- **Solution or significant amelioriation of divertor heat loading problem**

- **Challenges leading transport models**

  New insights into transport mechanisms

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MAIN RESULTS

- **Used Ar, Kr, and Xe gases to increase radiation in neutral-beam-heated discharges.**
- **Increased total radiation x 3, reduced heat load on wall.**
- **Reduced deuterium and carbon influx.**
  - Confinement improved or unchanged
  - Record fusion energy for TFTR
- **Little or no decrease in T_e Can study thermal transport.**
  - Consistent with critical-gradient model.
  - Near marginal stability.

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OUTLINE

- Use of high-Z gases to increase radiation
- Reduction of heat load and impurity influxes
- Response of confinement and T_e
- Interpretation of results by TRANSP
- T_e profile consistency in highly-radiative shots
- Comparison of results with models

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USE OF HIGH-Z GASES TO INCREASE RADIATION

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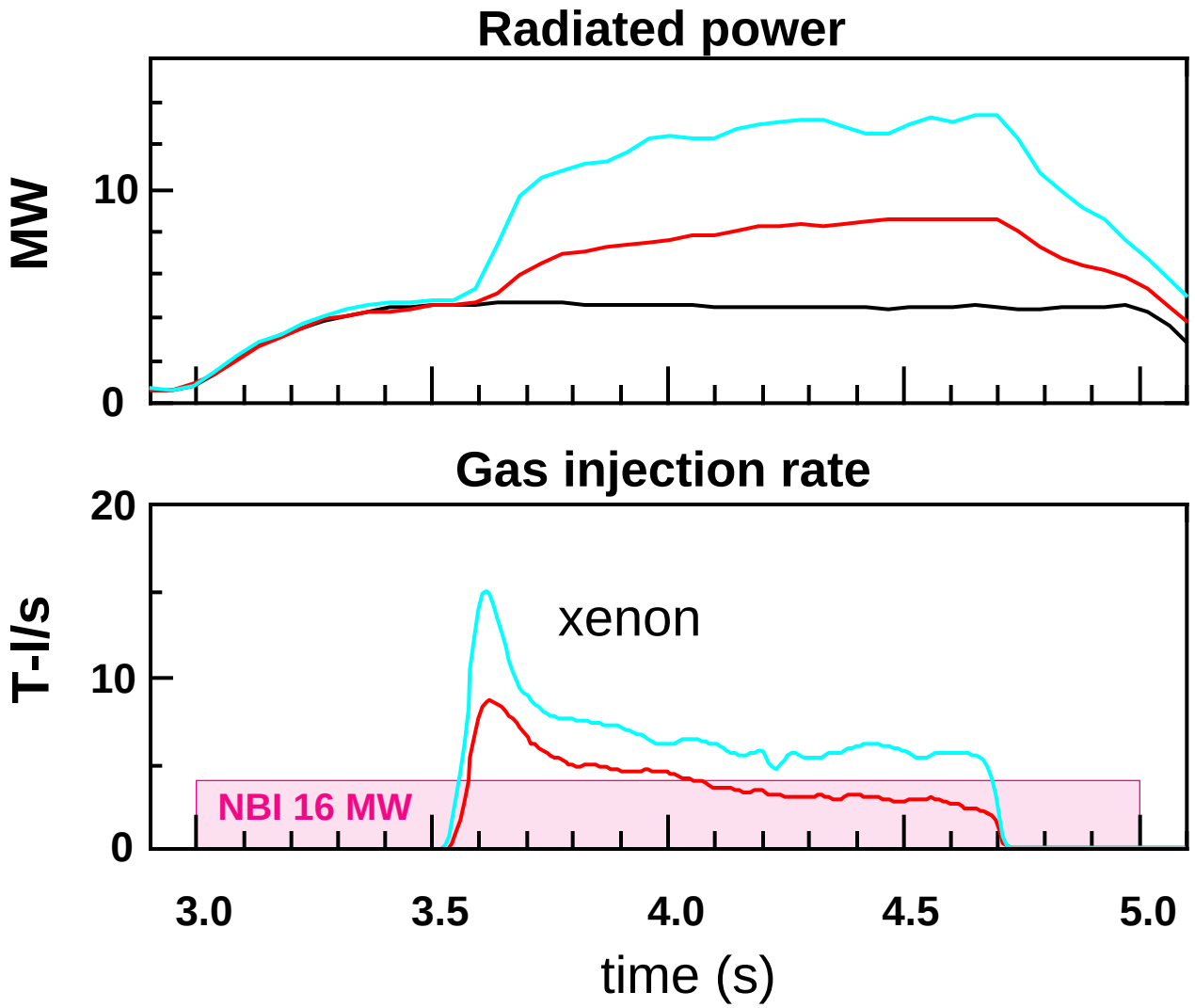
Feedback-Controlled Injection of Xenon Increases Radiated Power.



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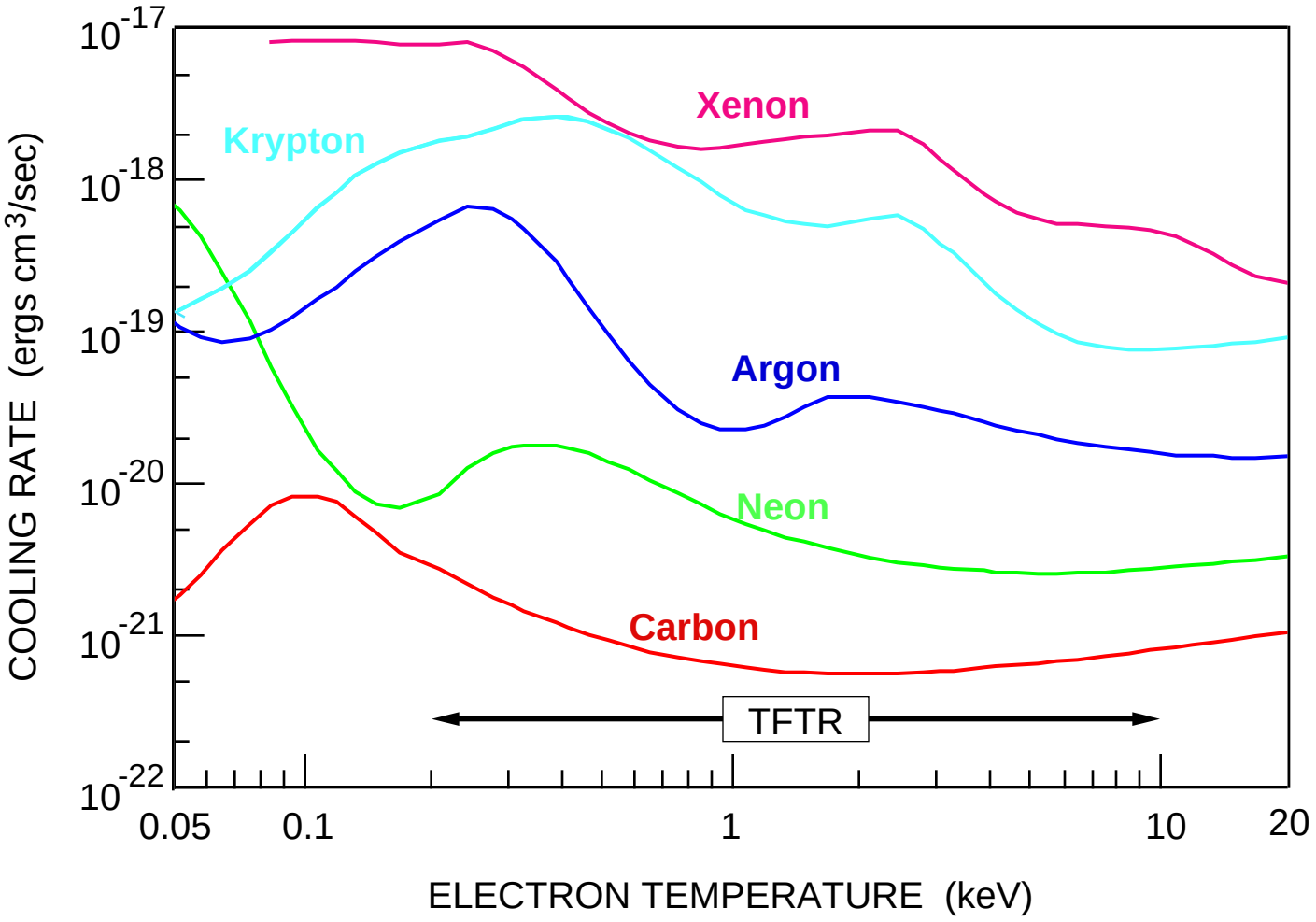
High-Z Ions Cool More Efficiently than Low-Z Ions.



- **<Z> = 10, 32, 42 for Ne, Kr, Xe at T_e = 6 keV**

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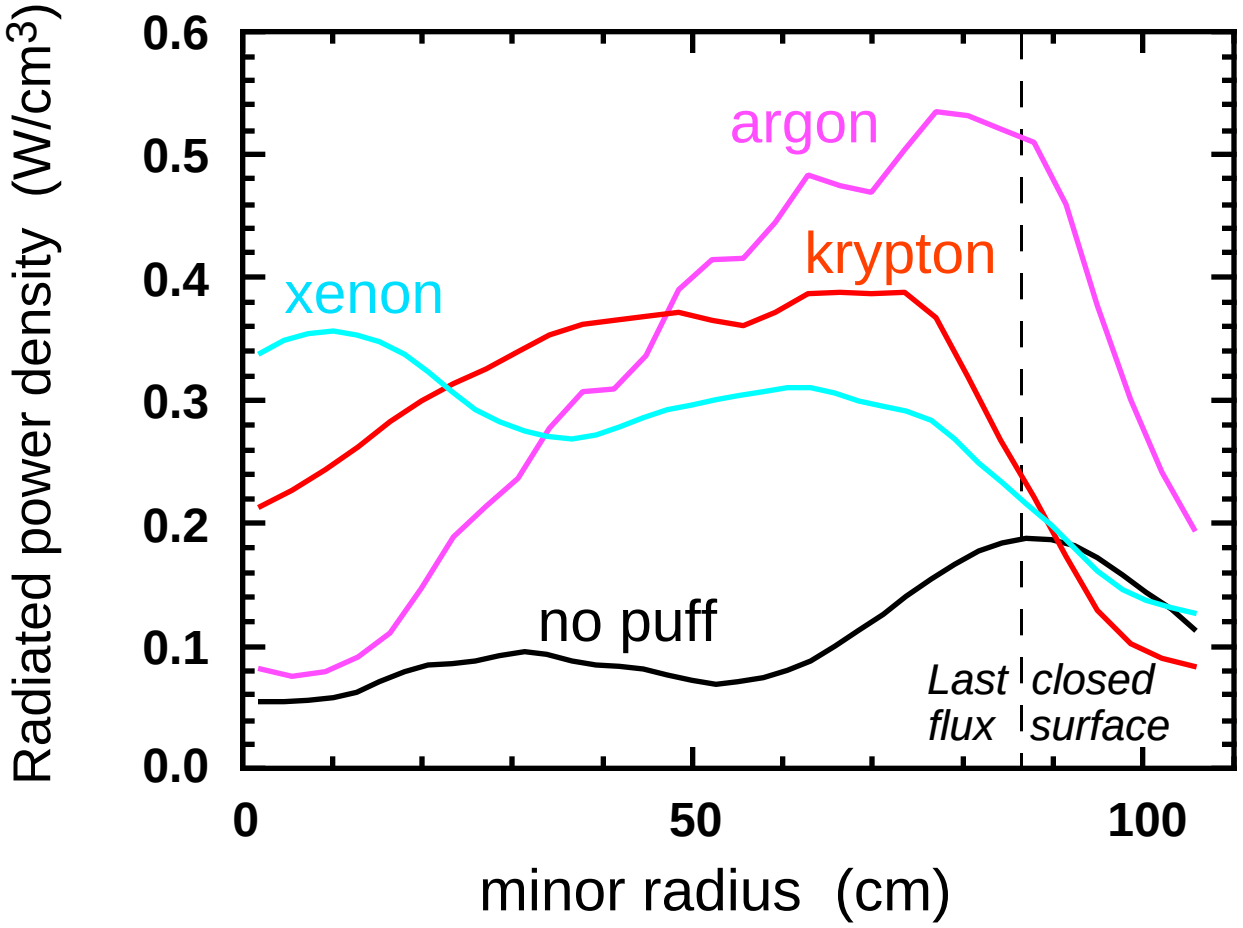
Local Radiated Power Increased Up To 6 Times



- Radiated power 75 - 90% of heating power

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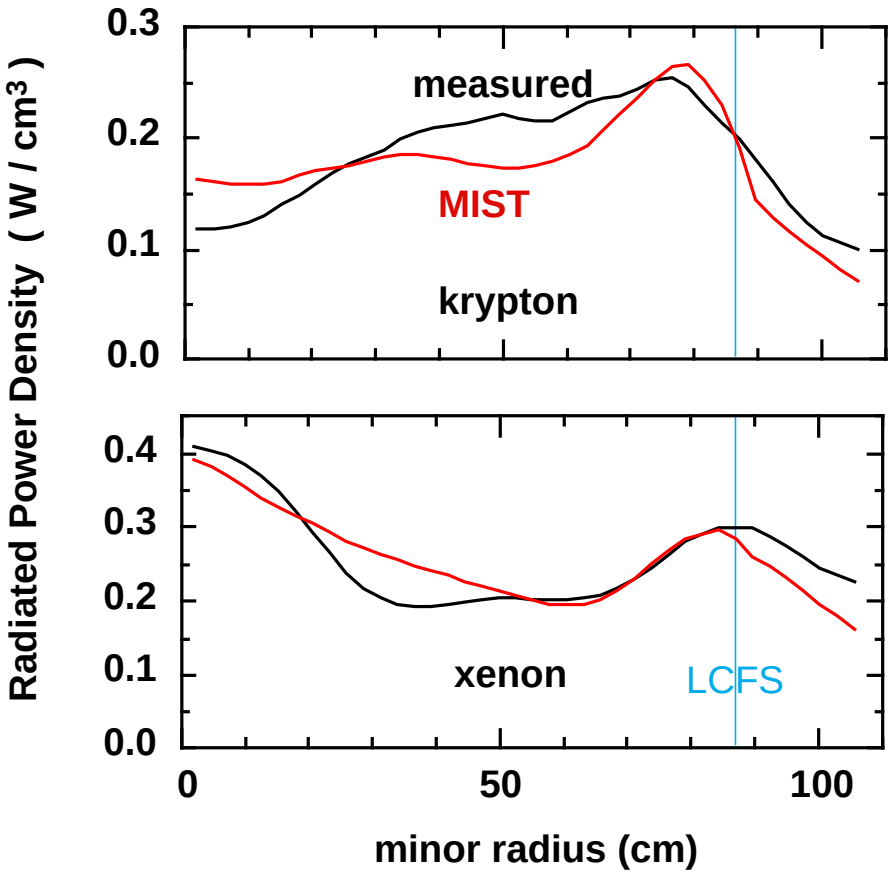
MIST Code Models Radiated Power Profile



- P_{rad} / P_{heat} = 45 - 65 %. $T_e(0)$ = 6 keV
- MIST impurity concentration adjusted to fit data
- Uniform radial profile of concentration - ~ 10^{-3}
- D = 1 m^2/s

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REDUCTION OF HEAT LOAD AND IMPURITY INFLUXES

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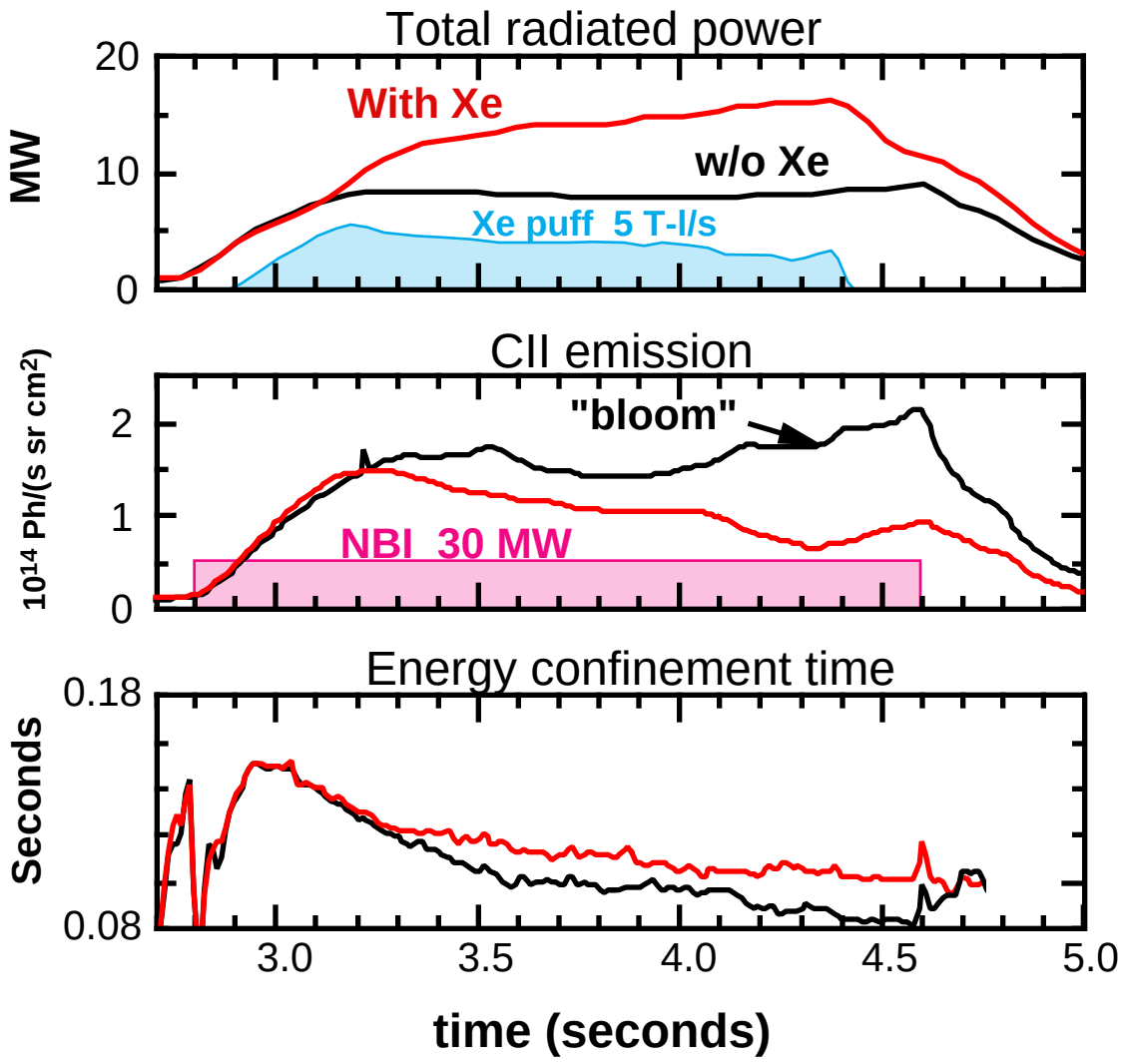
Xenon Puff Suppresses Carbon Influx ("Bloom")



- **Fusion power higher**

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Response of Confinement and Electron Temperature

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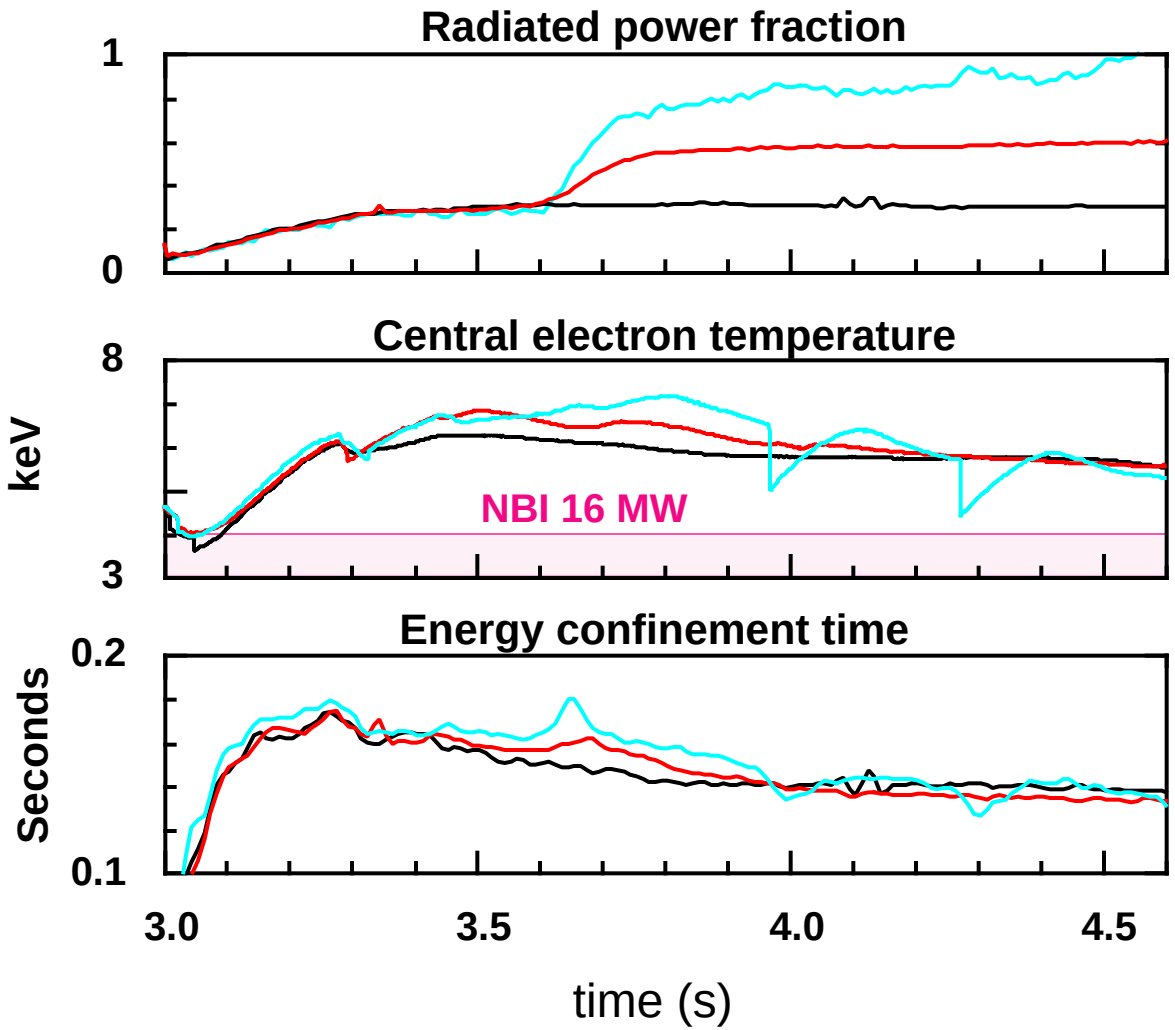
Central T_e and τ_E Little Changed at High Radiated Power Fractions

Krypton puffing



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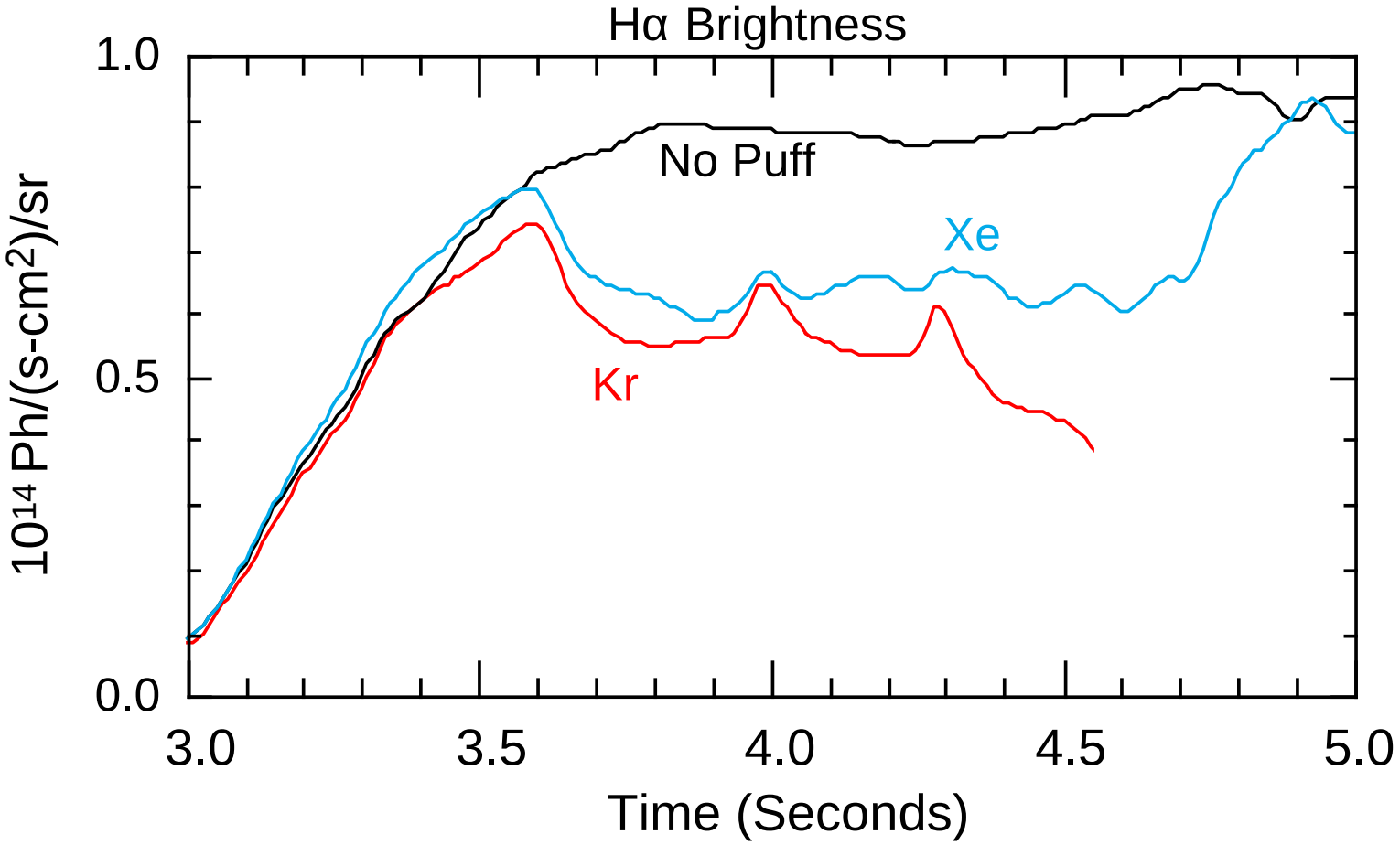
Deuterium Influx Lower with Krypton and Xenon Puffing



- τ_E $H\alpha^{-0.24}$

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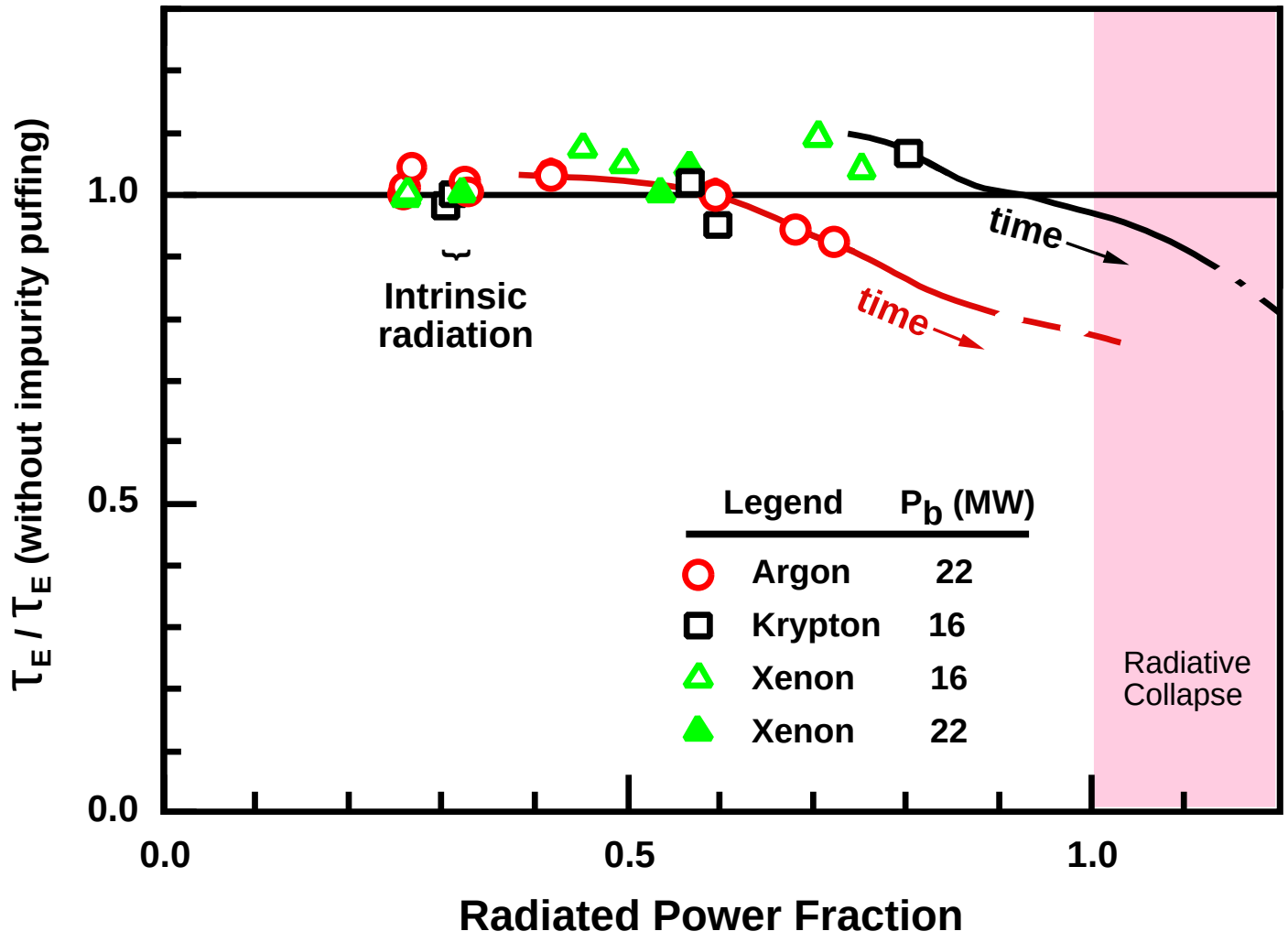
Less Confinement Degradation With Kr and Xe at High Radiated Power



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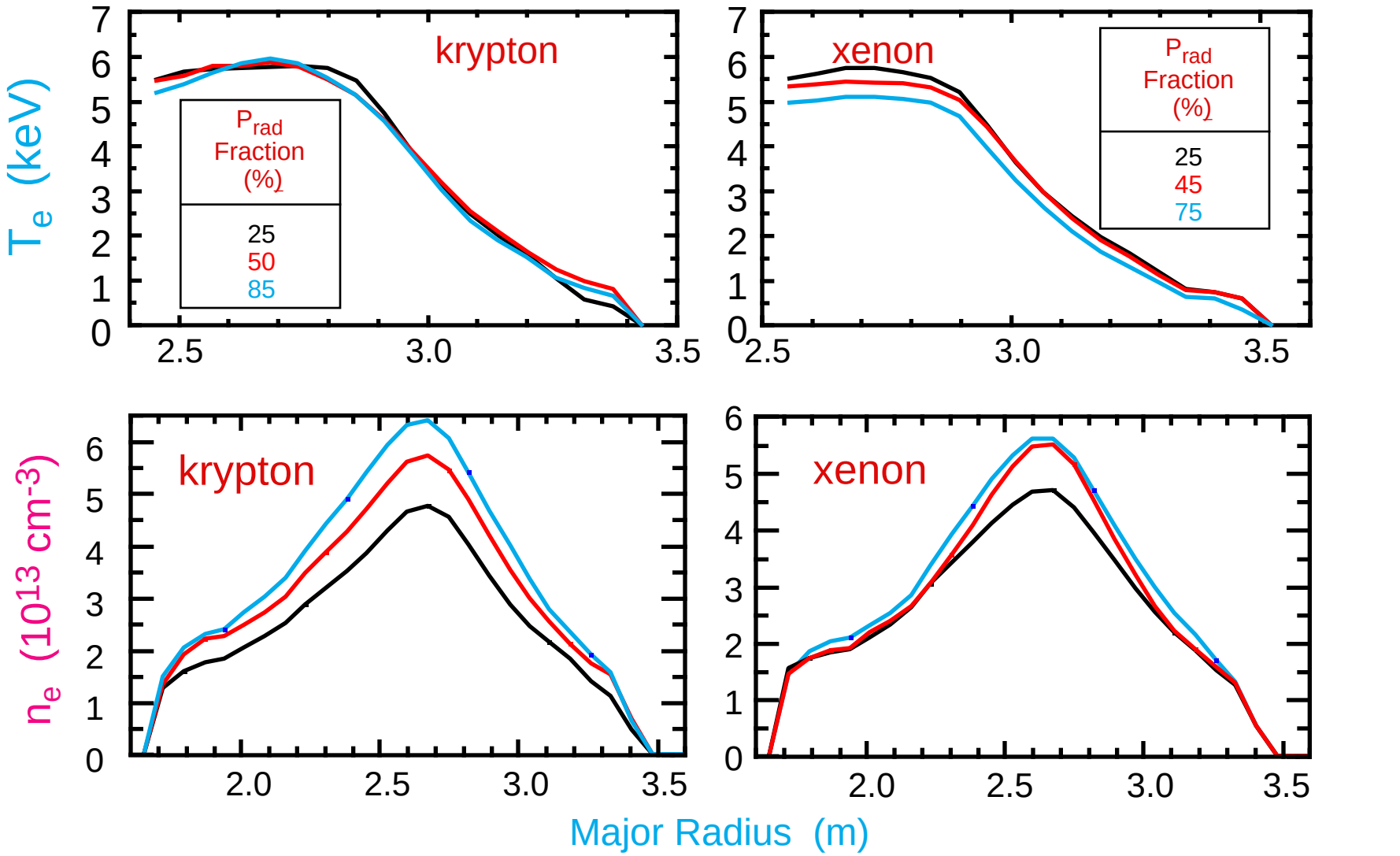
T_e Profile Unchanged, Particle Confinement Better with Kr or Xe Puffing



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INTERPRETATION OF RESULTS BY TRANSP

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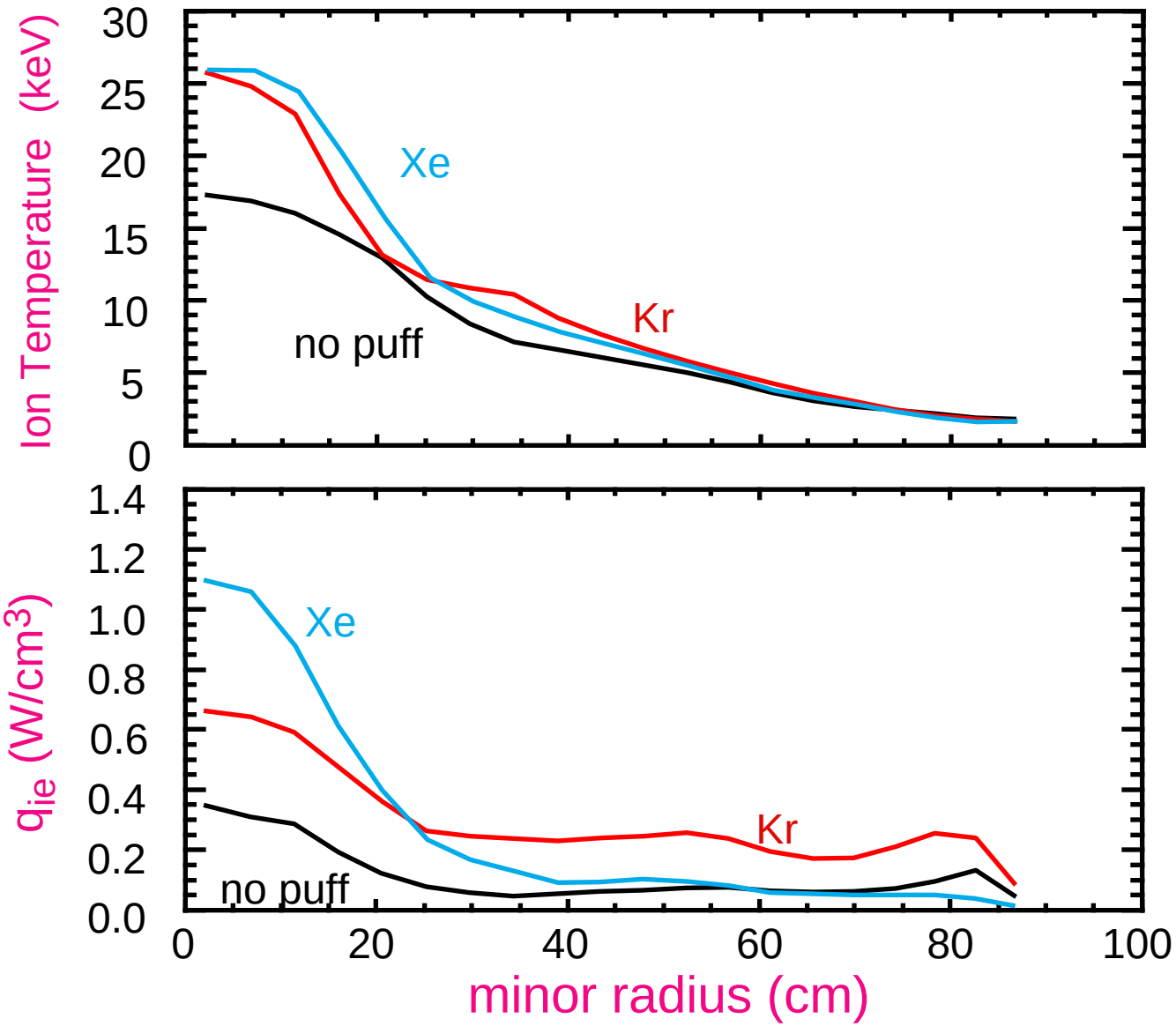
T_i and Ion-Electron Equilibration Power Higher with Kr or Xe Puffing



- $q_{ie} \sim n_e^2 (T_i - T_e) / T_e^{3/2}$

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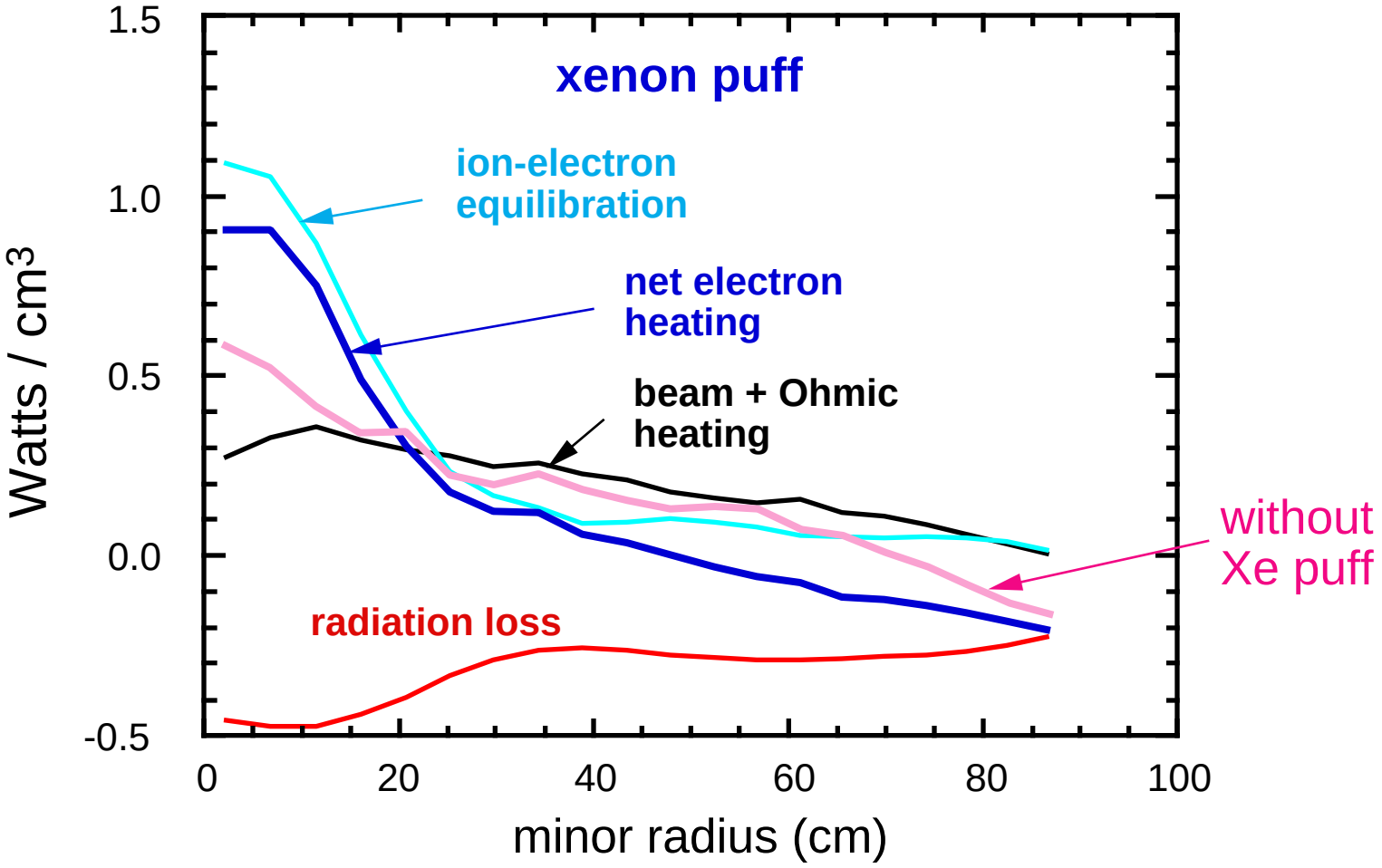
Ion-Electron Power Compensates for Increased Radiation Loss

Electron Channel



- $q_{ie} \sim n_e^2 (T_i - T_e) / T_e^{3/2}$

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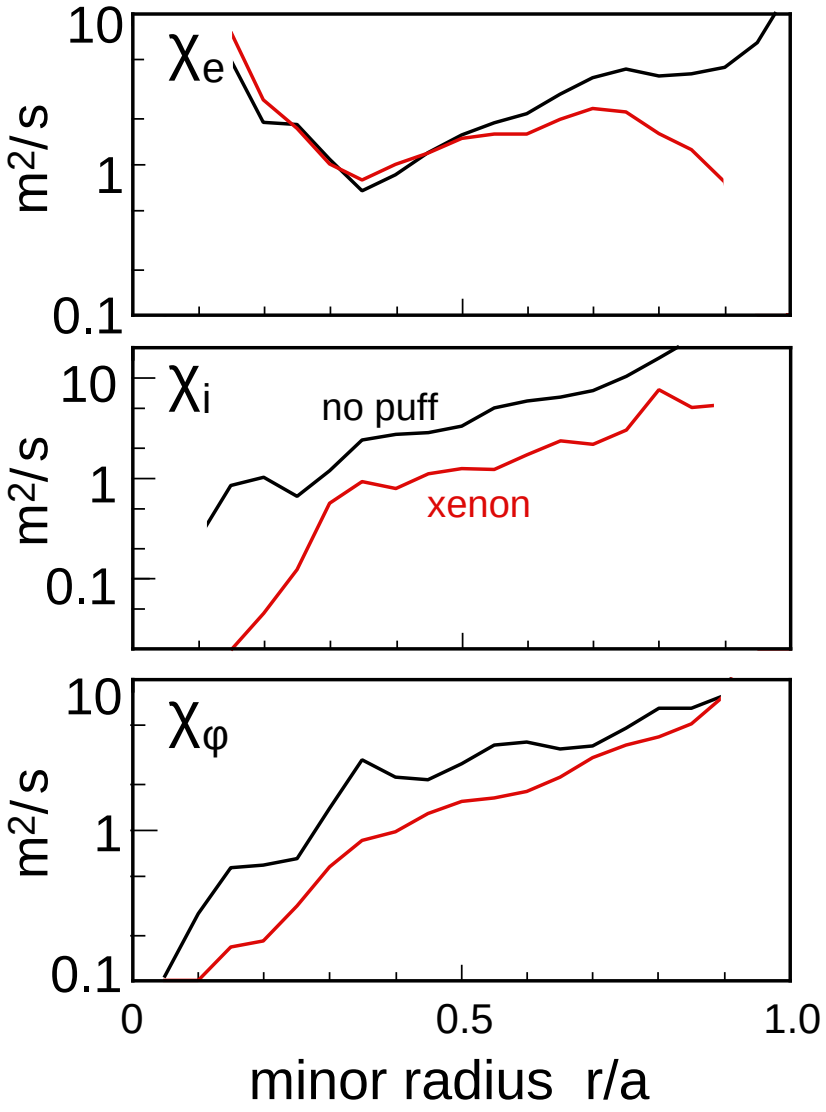
Ion Thermal and Momentum Diffusivities Lower With Xenon



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RADIATIVE PLASMA HAS HIGH P_{RAD} BUT LITTLE TEMPERATURE CHANGE

- Krypton or xenon puffing increases the radiated power.
- Core density rises, and
- Higher q_{ie} offsets increased P_{rad} in the electron channel.
- Lower net heating in ion channel, but T_i doesn't drop.
- Need a stiff transport model near marginal stability?

PROFILE CONSISTENCY IN HIGHLY-RADIATIVE PLASMAS

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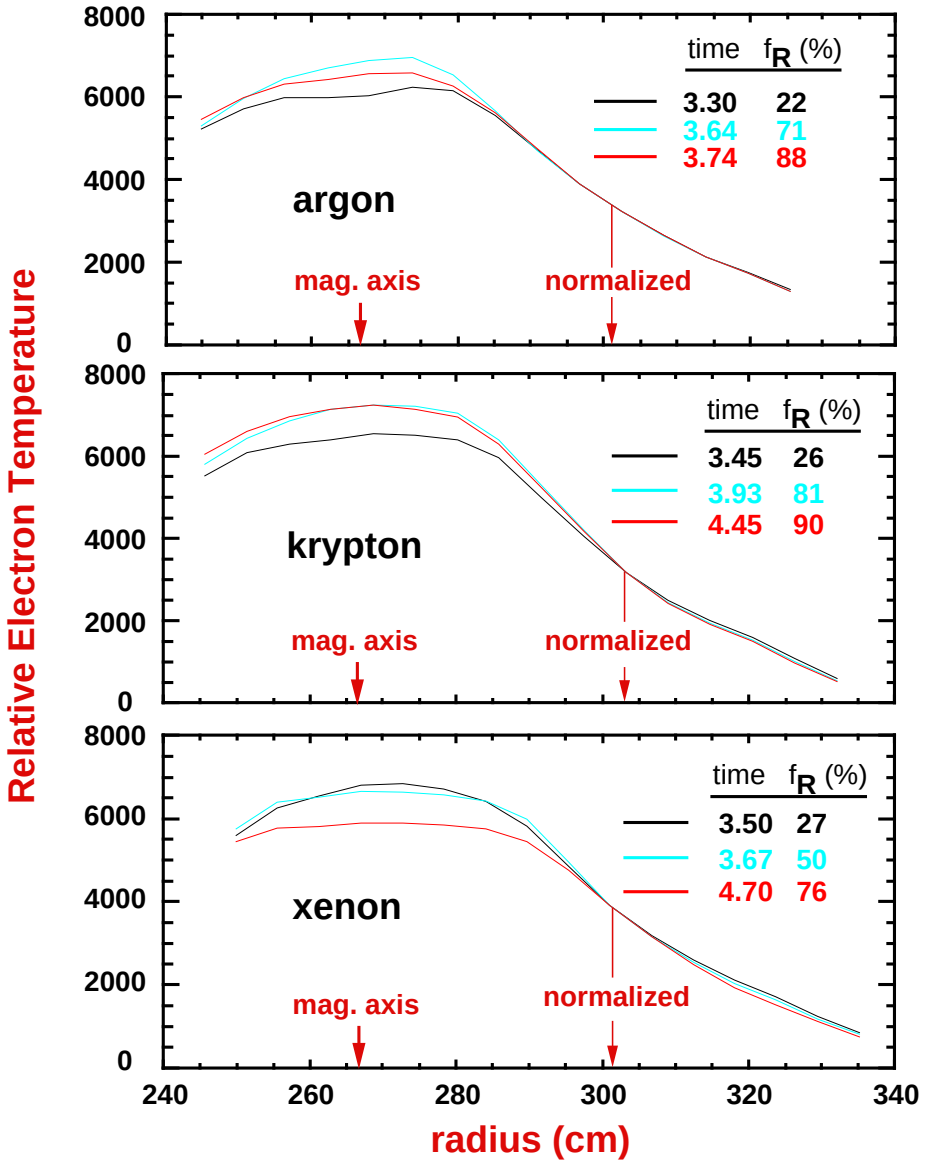
T_e Profile Consistency Maintained at High Radiated Power Fractions f_R



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COMPARISON OF RESULTS WITH MODEL PREDICTIONS

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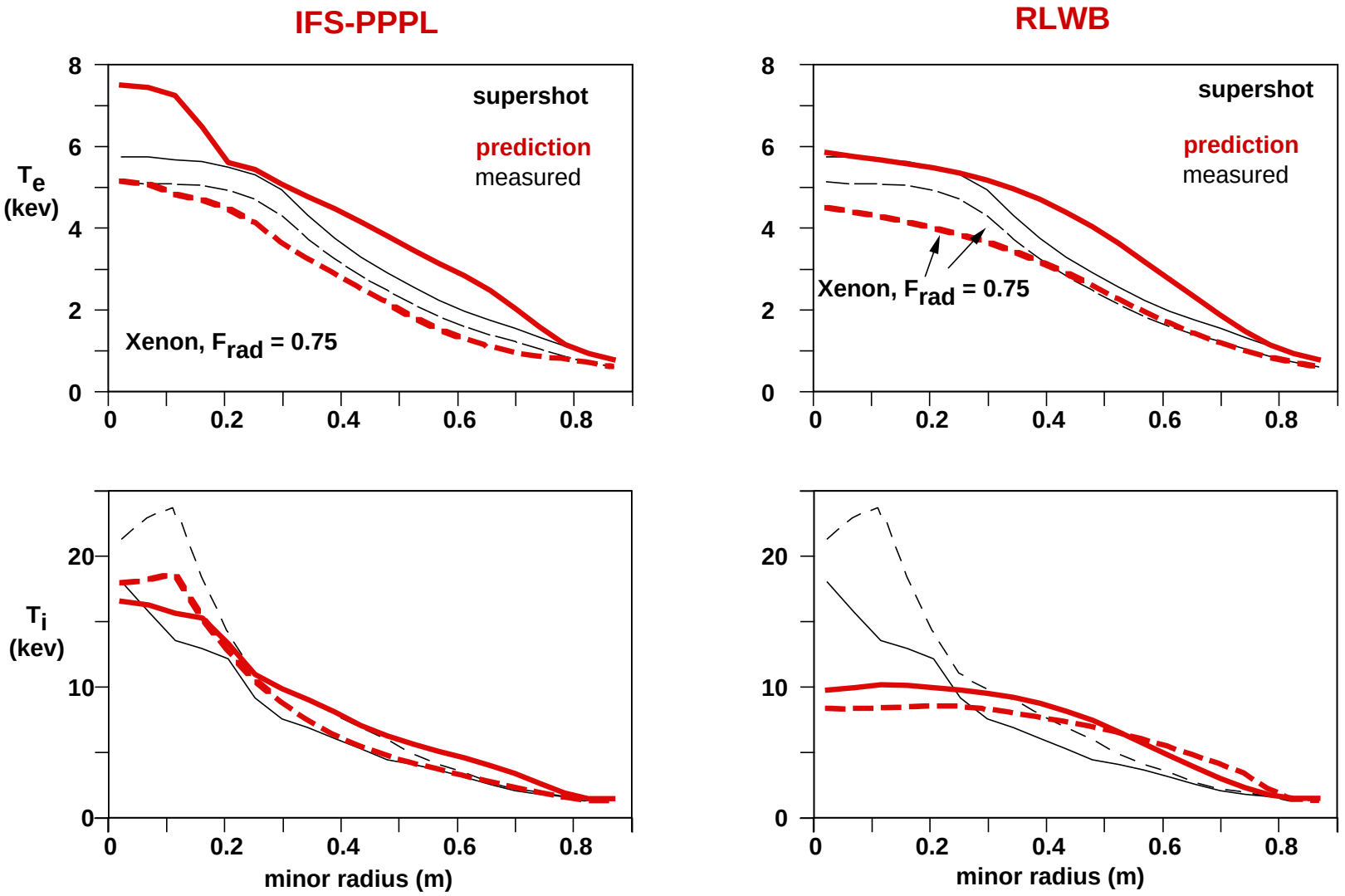
Model T_E Drop Too Large; T_I Change Has Wrong Sign



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KRYPTON AND XENON WORKED WELL FOR TFTR

- **Multi-megawatt levels of radiation in high power supershots (>30 MW)**
  - Lower heat load to limiter
  - Confinement unchanged or improved
  - Reduced deuterium and carbon influxes
  - Negligible dilution of core fuel ions
  - Higher fusion power
  - Record fusion energy for TFTR
- **Argon tested at lower power (P_{NBI} < 22 MW)**
  - Confinement effect not as favorable
  - Carbon influx higher at modest puff rates
  - Higher dilution

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SUMMARY OF EXPERIENCE WITH HIGH-Z RADIATORS

- **Greatly ameliorates divertor heat-load problem for large machines.**
  - Power flow to edge reduced by two-thirds
  - Performance improved
- **Edge recycling reduced.**
- **Particle confinement improved.**
- **Profile consistency maintained.**
  - Suggests need for "stiff" electron thermal transport models.