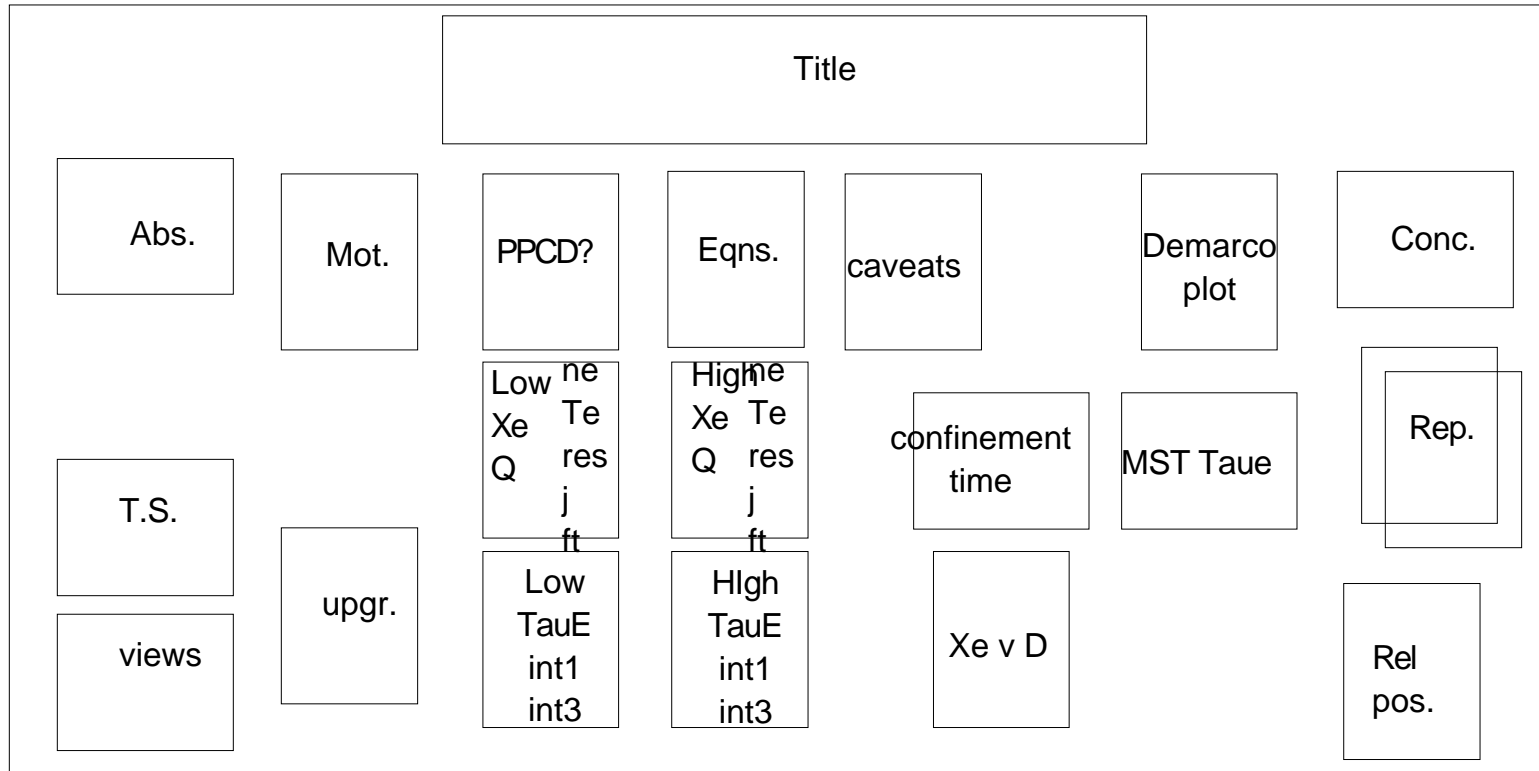


# Electron Temperature and Thermal Conductivity Profile Measurements in the MST Reversed-Field Pinch



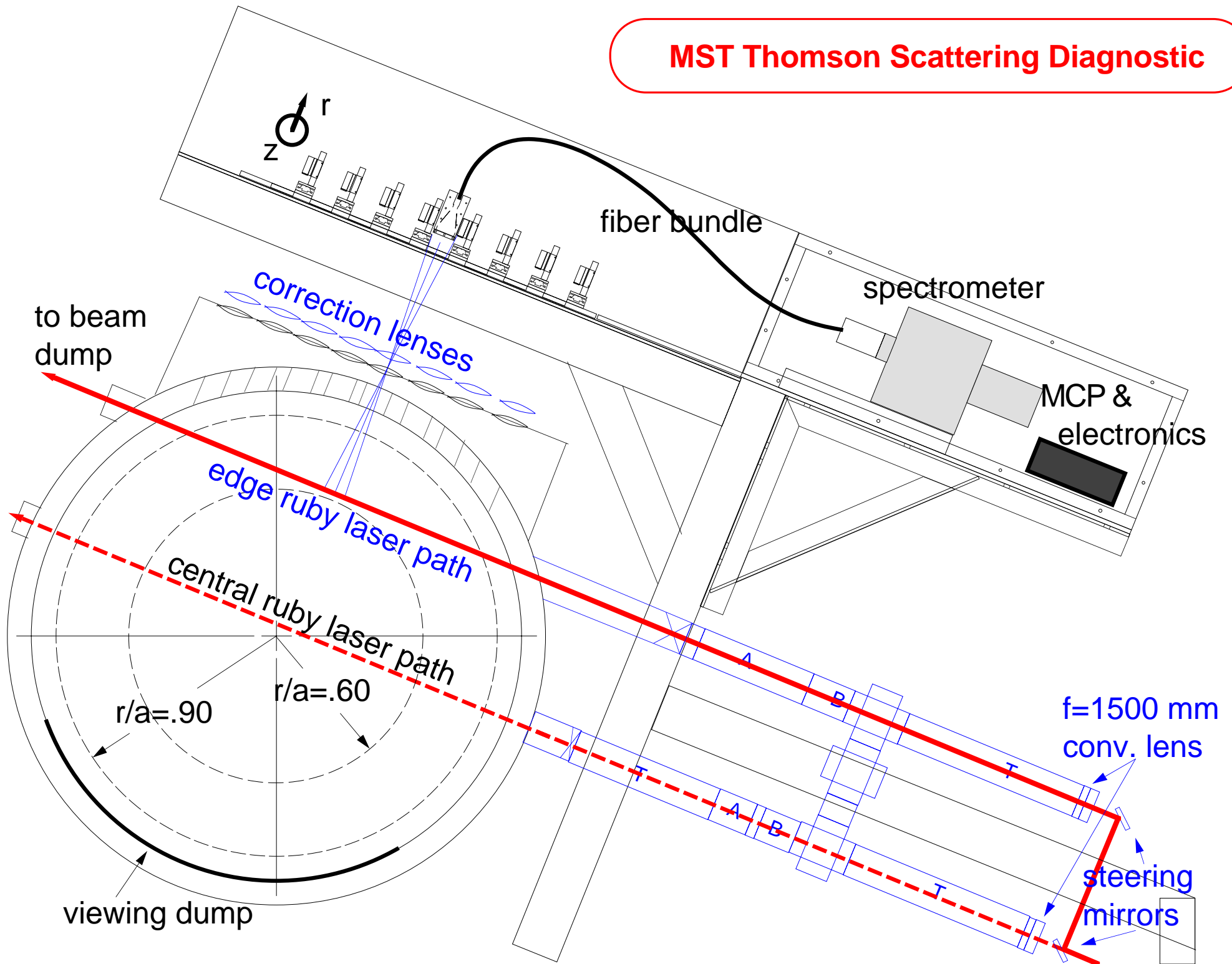
**Electron Temperature and Thermal Conductivity Profile  
Measurements in the MST Reversed-Field Pinch.**

T.M. Biewer, D.J. Holly,  
J.K. Anderson, B.E. Chapman, N.E. Lanier, C.B. Forest  
*University of Wisconsin-Madison.*

Recent modifications have extended the radial range of the MST Thomson scattering system. These improvements have yielded more reliable electron temperature profiles, which when coupled with FIR interferometric measurements of plasma density and MSTFIT equilibrium reconstructions, give an estimation of the electron thermal conductivity profile in MST. Measurements with pulsed poloidal current drive (PPCD) show how edge driven current effects the stored thermal energy of the plasma and improves the energy confinement time. Preliminary results show that  $\tau_{E,e}$  increases from the MST standard time of 1 ms to roughly 4 ms during PPCD, based on neoclassical resistivity with a  $Z_{\text{eff}}$  of 1.9. Additionally,  $\beta_{p,e}$  reaches a value of 15% during PPCD plasmas. These numbers represent a lower bound on  $\tau_E$  and  $\beta_p$  because the effects of ions were not considered in these calculations.

This work was supported by the U.S. D.O.E.

# MST Thomson Scattering Diagnostic

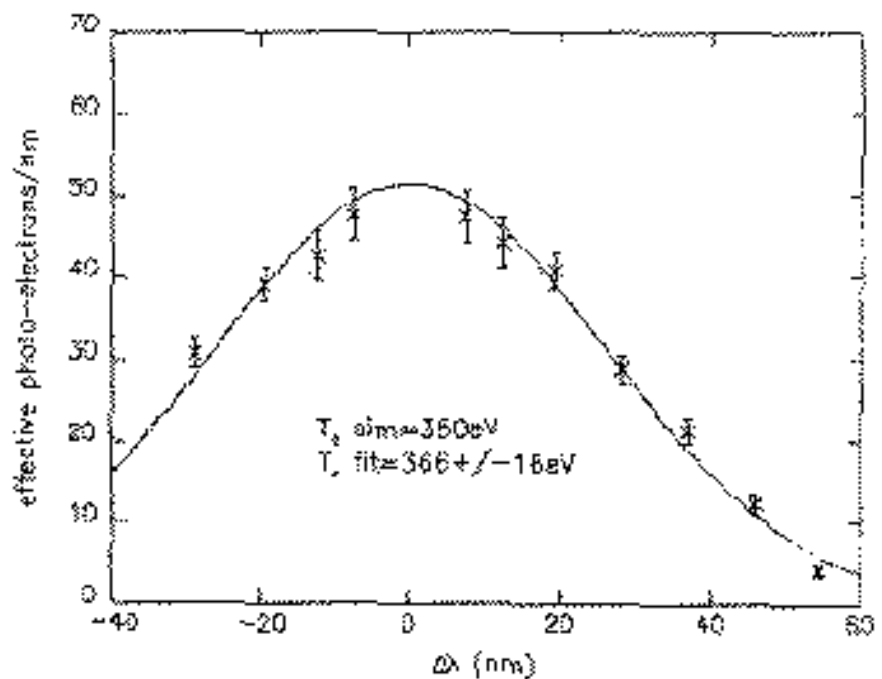
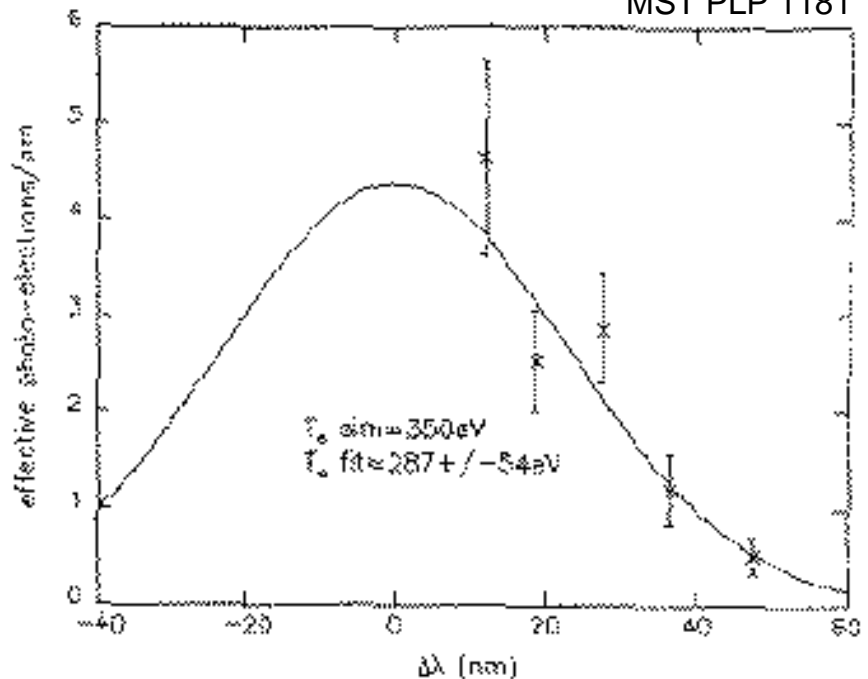


# An upgrade is underway to improve the resolution of the MST Thomson System

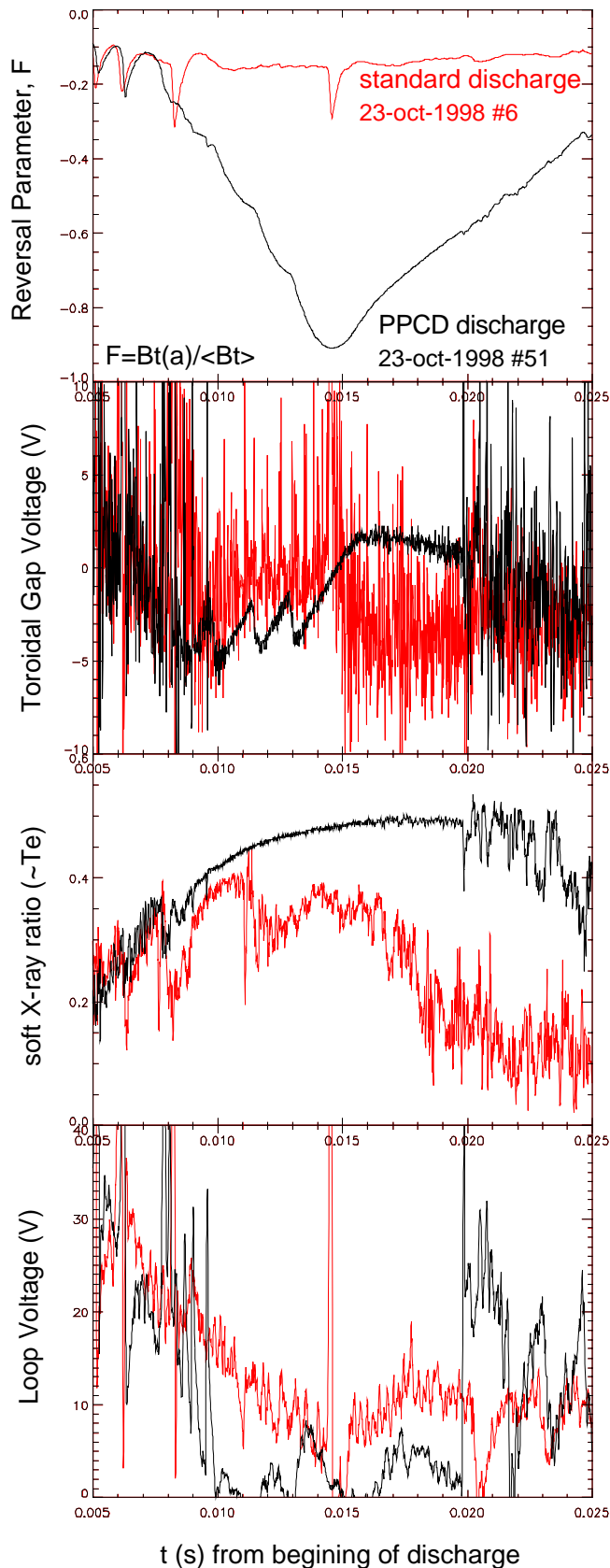
The current 5 wavelength channel MicroChannel Plate (MCP) detector will be replaced by an 11 channel Large Area Avalanche Photodiode Detector (LA APD) array. This will effectively double the wavelength range covered, and allow us to measure Thomson scattered photons on both sides of the ruby line, yielding a rudimentary estimation of the local current density.

## Simulated Improvement

M.R. Stoneking  
MST PLP 1181



# What is Pulsed Poloidal Current Drive?



During a "normal" plasma discharge a series of 5 voltage pulses are applied to the MST shell to produce a magnetic field which is in the opposite sense to the established toroidal magnetic field, forcing flux out of the MST. This opposing B is thought to be due to a poloidally driven edge current.

PPCD is observed to improve machine performance. It is believed that magnetic modes in the MST derive their free energy from the gradient in the current profile, which is steepest at the edge. By inductively driving current in the edge, PPCD could reduce the gradient and remove free energy from the magnetic modes, resulting in decreased magnetic fluctuations and hence improved particle and energy confinement.

# PPCD Increases Energy Confinement Time for Electrons to ~3 ms (w/est. ohmic power)

## $I_p \sim 375$ kA

Energy Confinement Time for electrons

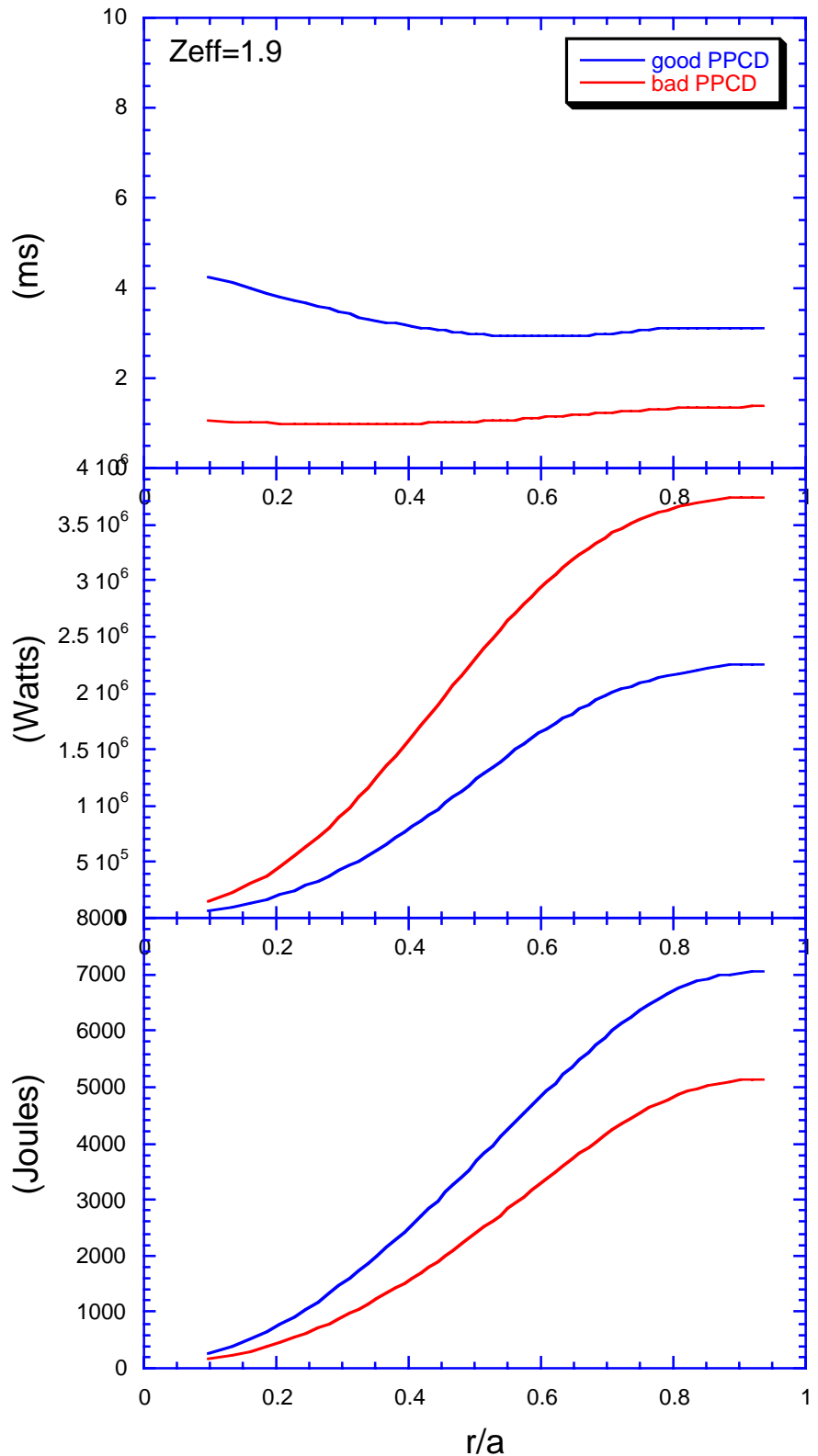
$$\tau_{E,e} \approx \frac{\int \frac{3}{2} n_e T_e \frac{\partial V}{\partial r} dr}{\int \eta j^2 \frac{\partial V}{\partial r} dr} \quad (\text{ms})$$

Ohmic Input Power

$$\int \eta j^2 \frac{\partial V}{\partial r} dr \quad (\text{Watts})$$

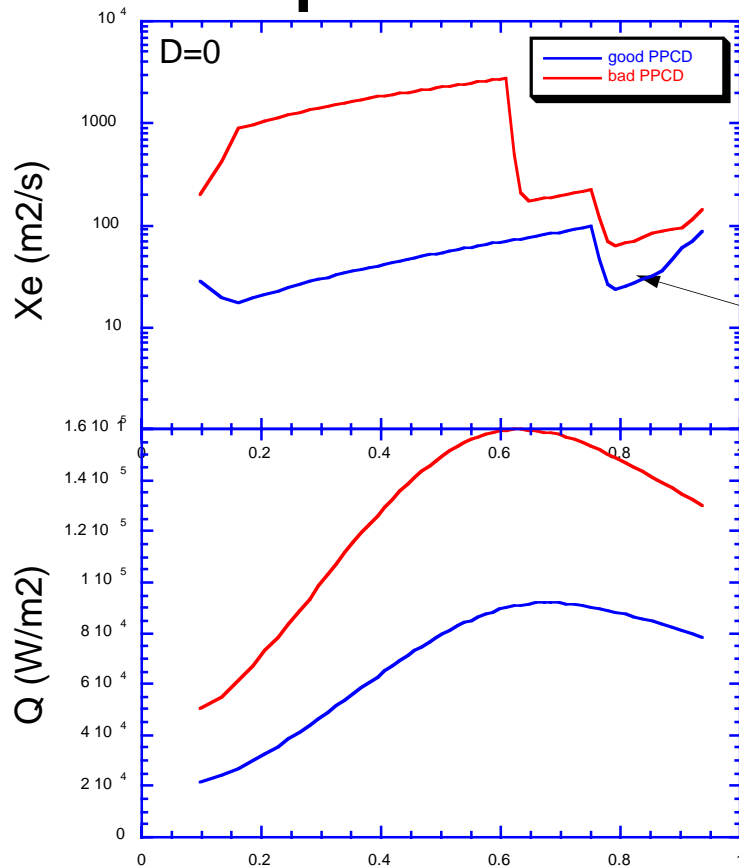
Stored Thermal Energy

$$\int \frac{3}{2} n_e T_e \frac{\partial V}{\partial r} dr \quad (\text{Joules})$$



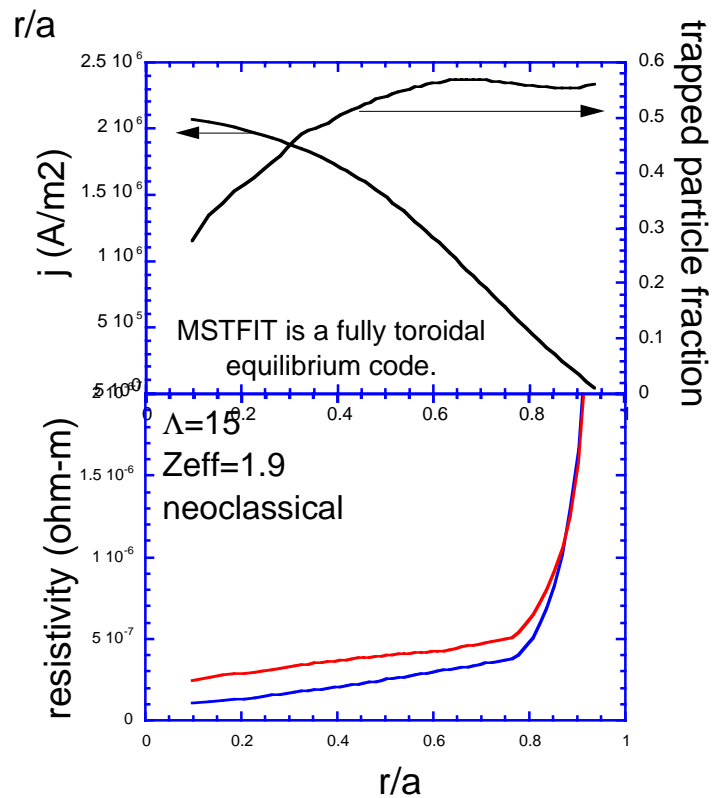
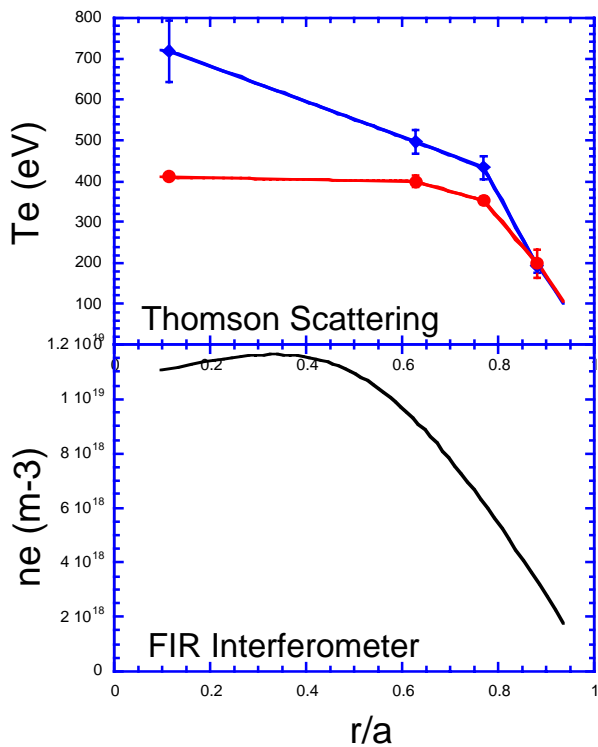
# PPCD Leads to Lower Electron Thermal Conductivity

## $I_p \sim 375$ kA



Xe is reduced by a factor of 50 in the core and by a factor of 5 at the edge.

Better Xe at the edge leads to an energy transport barrier for electrons.



# PPCD Increases Energy Confinement Time for Electrons to ~4 ms (w/est. ohmic power)

**$I_p \sim 200$  kA**

Energy Confinement Time for electrons

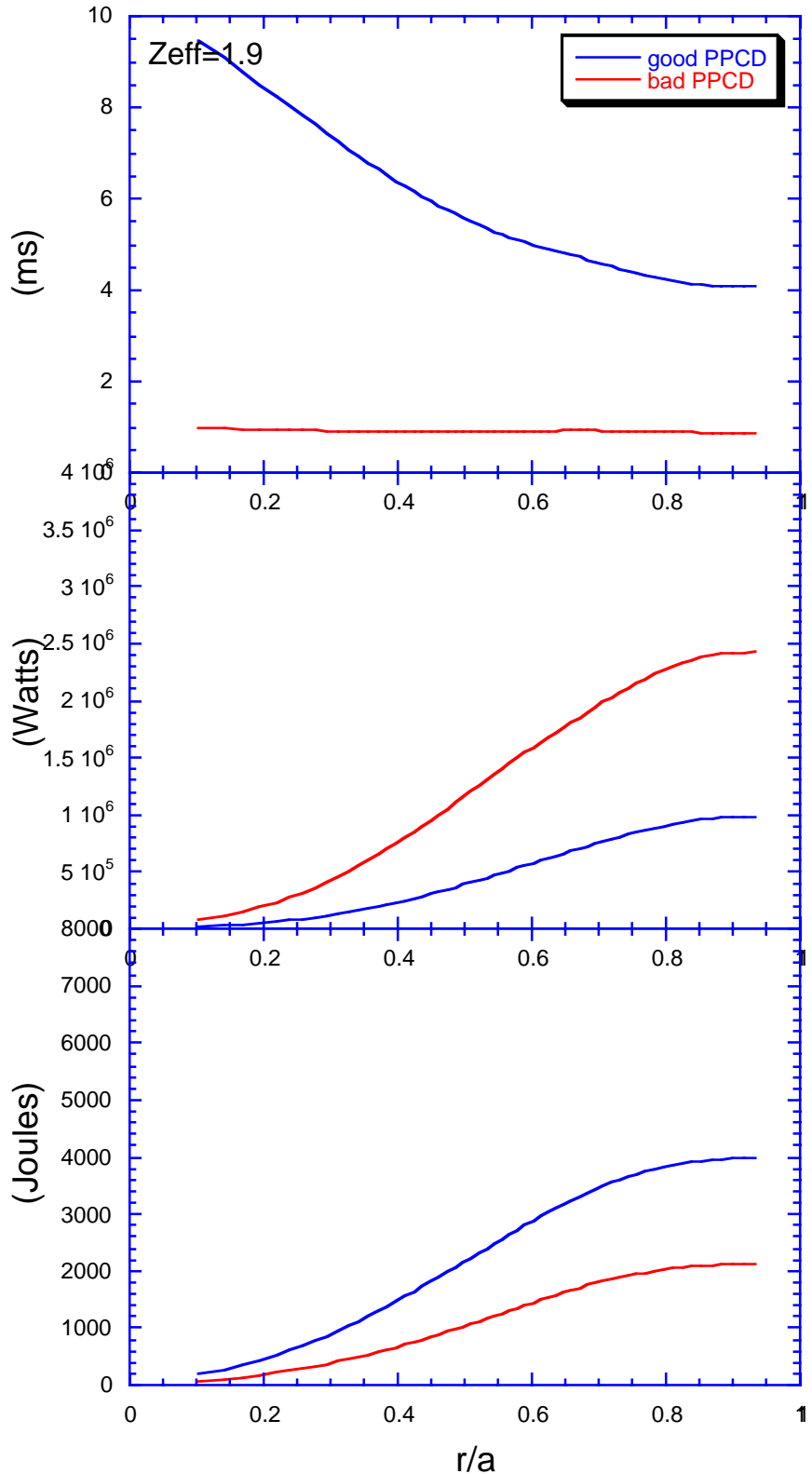
$$\tau_{E,e} \approx \frac{\int \frac{3}{2} n_e T_e \frac{\partial V}{\partial r} dr}{\int \eta j^2 \frac{\partial V}{\partial r} dr} \quad (\text{ms})$$

Ohmic Input Power

$$\int \eta j^2 \frac{\partial V}{\partial r} dr$$

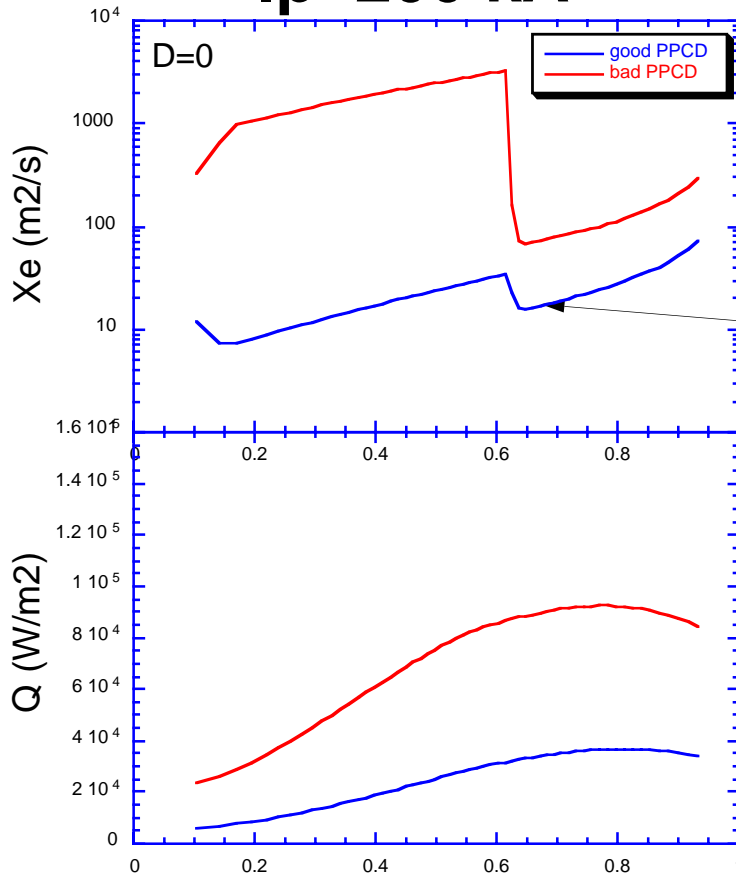
Stored Thermal Energy

$$\int \frac{3}{2} n_e T_e \frac{\partial V}{\partial r} dr$$



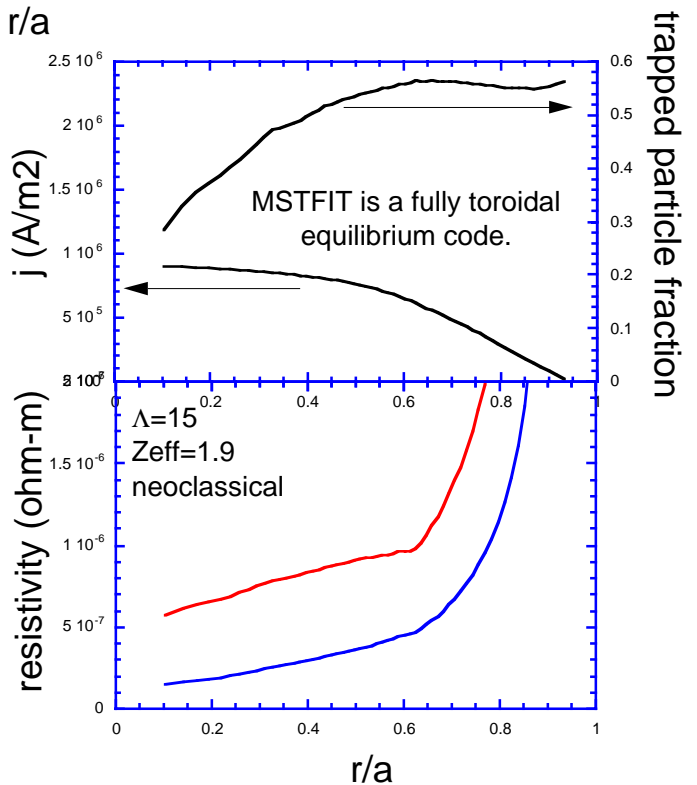
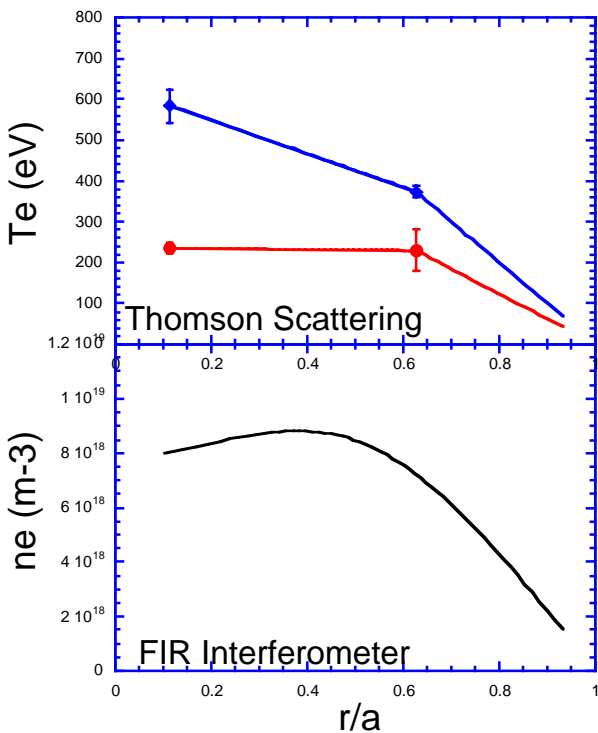
# PPCD Leads to Lower Electron Thermal Conductivity

**$I_p \sim 200$  kA**



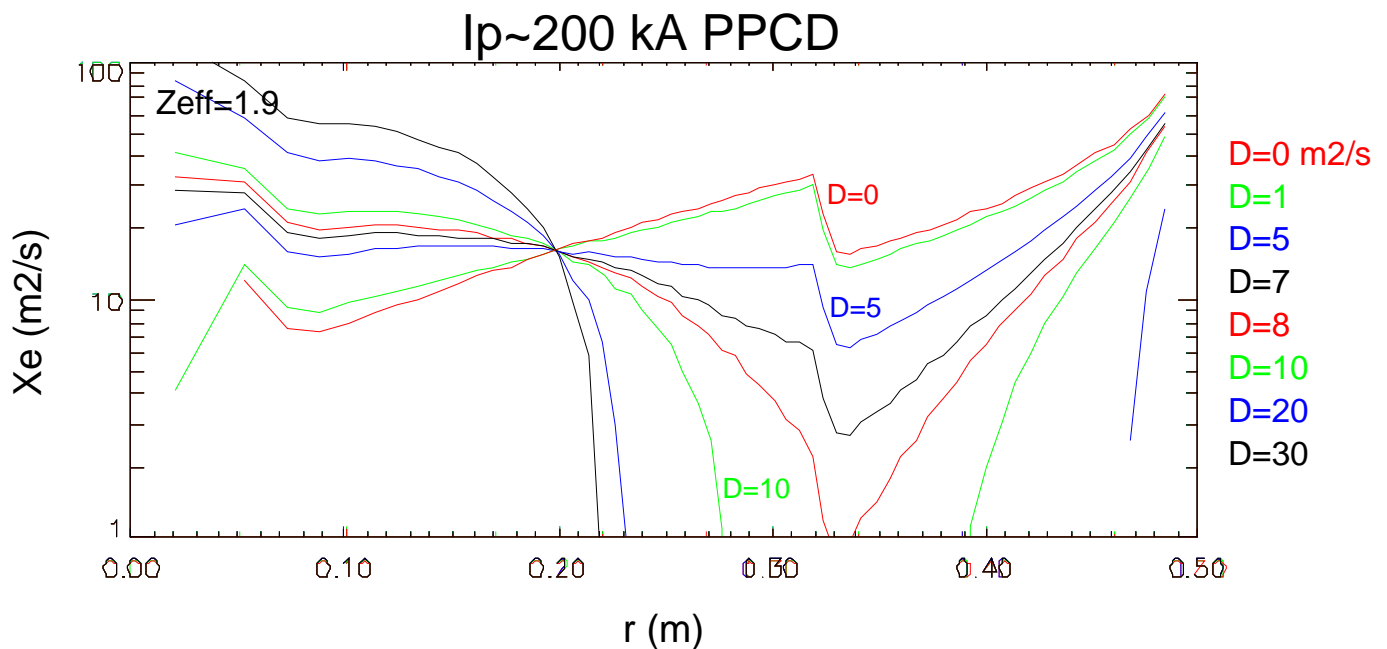
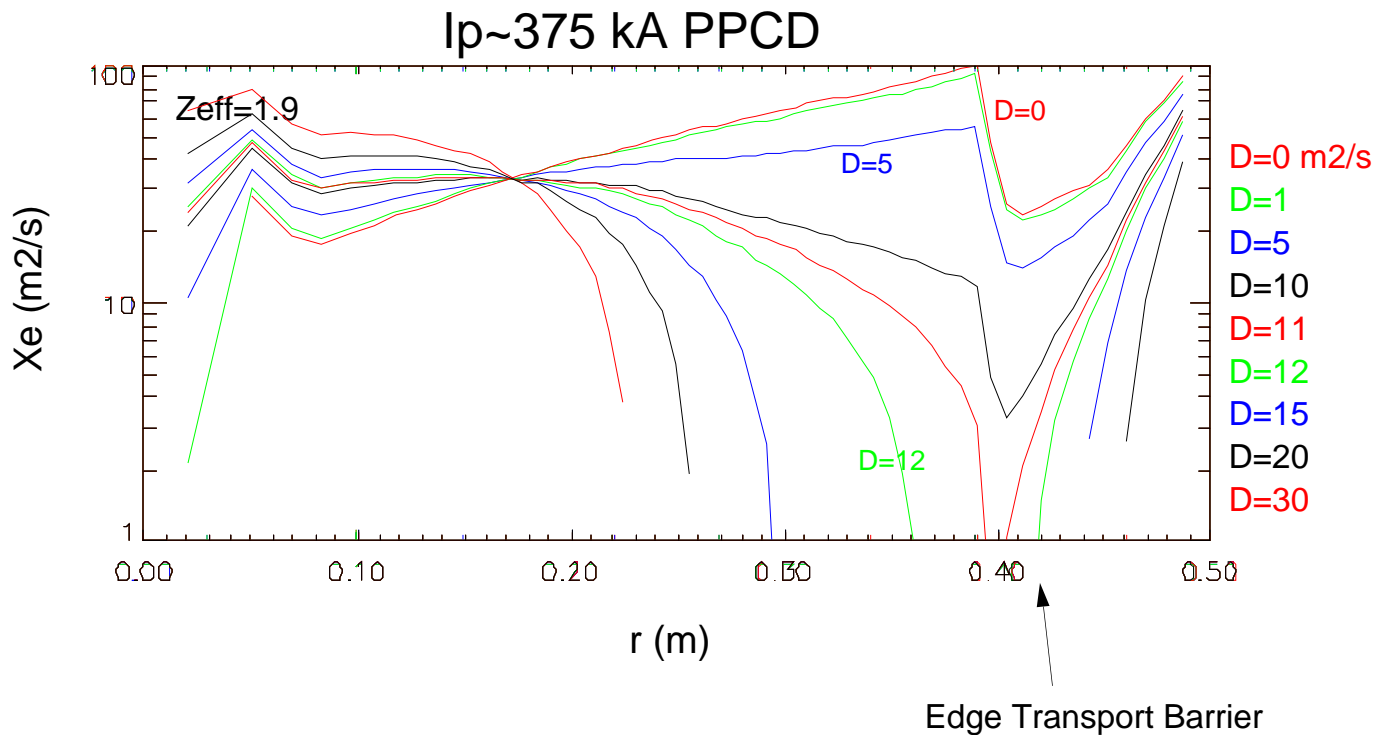
$X_e$  is reduced by a factor of 100 in the core and by a factor of 5 at the edge.

Better  $X_e$  at the edge leads to an energy transport barrier for electrons.



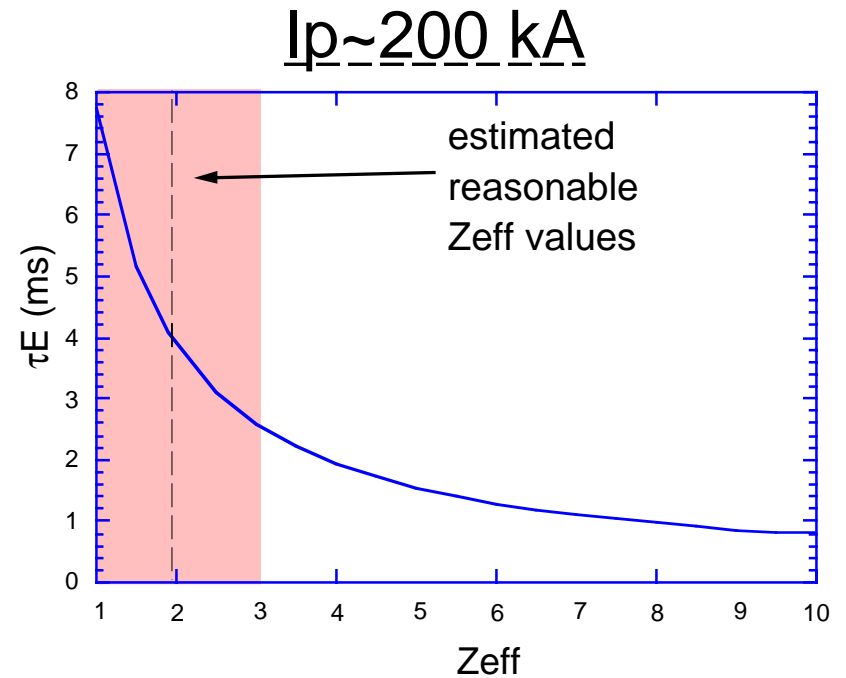
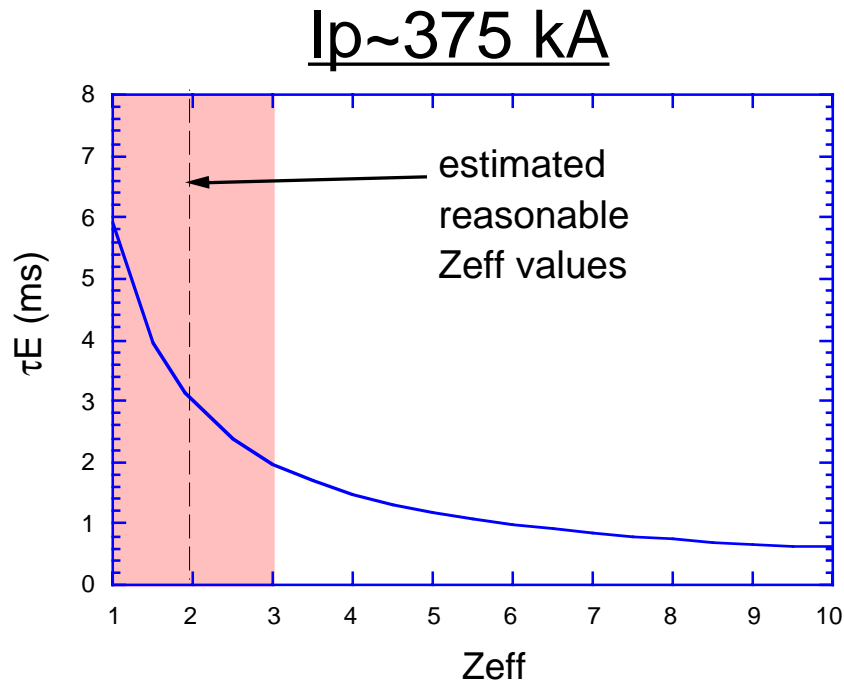
# Local Power Balance Constrains $D < \sim 10 \text{ m}^2/\text{s}$ for $r/a > 0.8$ (for a $Z_{\text{eff}}$ of 1.9)

Increasing the particle diffusion coefficient,  $D$ , results in unphysical Xe values.



Increasing  $Z_{\text{eff}}$  raises the Xe curves and allows a higher bound on  $D$ .

# $\tau_{E,e}$ in the MST during PPCD probably reaches ~4 ms



Tentatively,  
For  $Z_{eff}=1.9$   
 $\tau_E=3.1$  ms  
and  
 $\beta_{p,e}=6.7\%$

$$\beta_{p,e} = \frac{P_{plasma}}{P_{magnetic}} = \frac{\frac{1}{V} \int n_e T_e dV}{\frac{1}{2\mu_0} B_p^2}$$

Tentatively,  
For  $Z_{eff}=1.9$   
 $\tau_E=4.1$  ms  
and  
 $\beta_{p,e}=15\%$

These values represent a lower bound, including neoclassical trapped particle effects.

# Energy Confinement Times in MST: a historical perspective

$\tau_E$	<u>conditions</u>	<u>Pohmic</u>	<u><math>Z_{eff}^* = Z_{eff} / (1-f_t)</math></u>
~1 ms	MST "standard" 1996	measured $P_{ohmic} = P_{input} - P_{mag.}$	2.5
~5 ms	single pulse PPCD 1996	measured $P_{ohmic} = P_{input} - P_{mag.}$	1.7
~4 ms	multi-pulse PPCD 1998	MSTFIT est.	1.9/(1- $f_t$ )

$Z_{eff}$  was estimated by comparing  $\alpha$ -model calculations of  $\eta_j^2$  to measured  $P_{ohmic}$ . In this way  $Z^*$  includes trapped particle corrections.

$P_{ohmic}$  could not be measured directly. Instead,  $Z_{eff}$  was guessed to be 1.9 based on NIRB measurements. MSTFIT modeling was used to calculate  $j$  and the trapped particle fraction (~0.55).