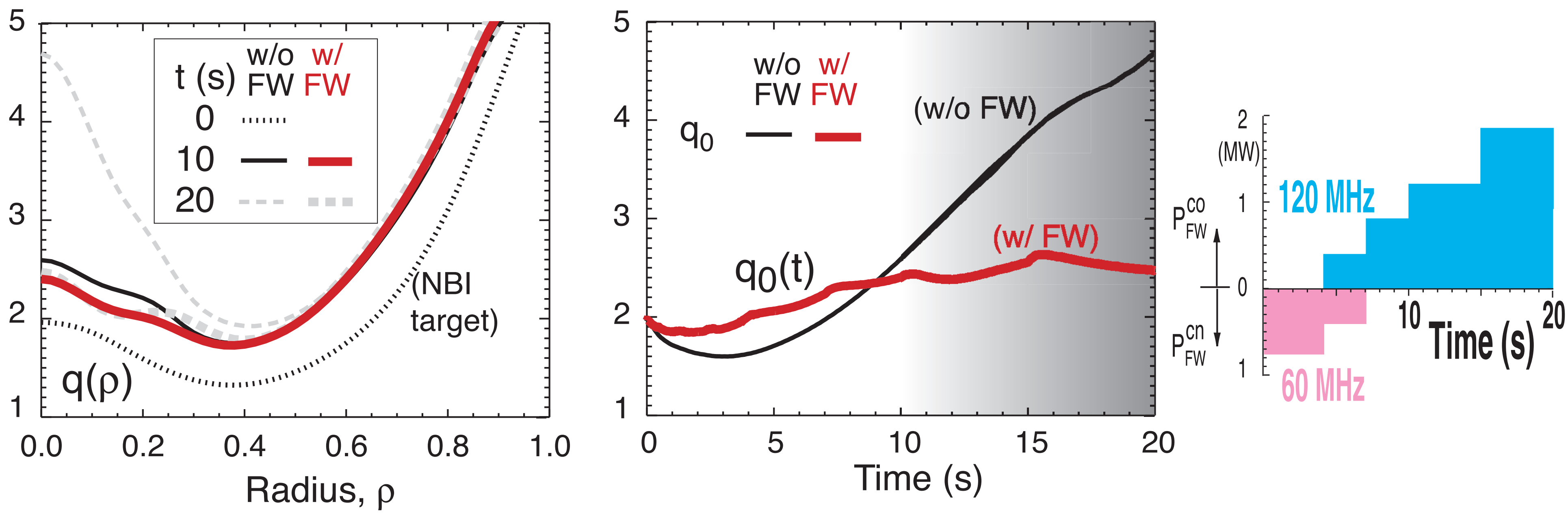
Introduction

- Important application of FW systems on DIII-D is for central electron heating and current drive in AT plasmas



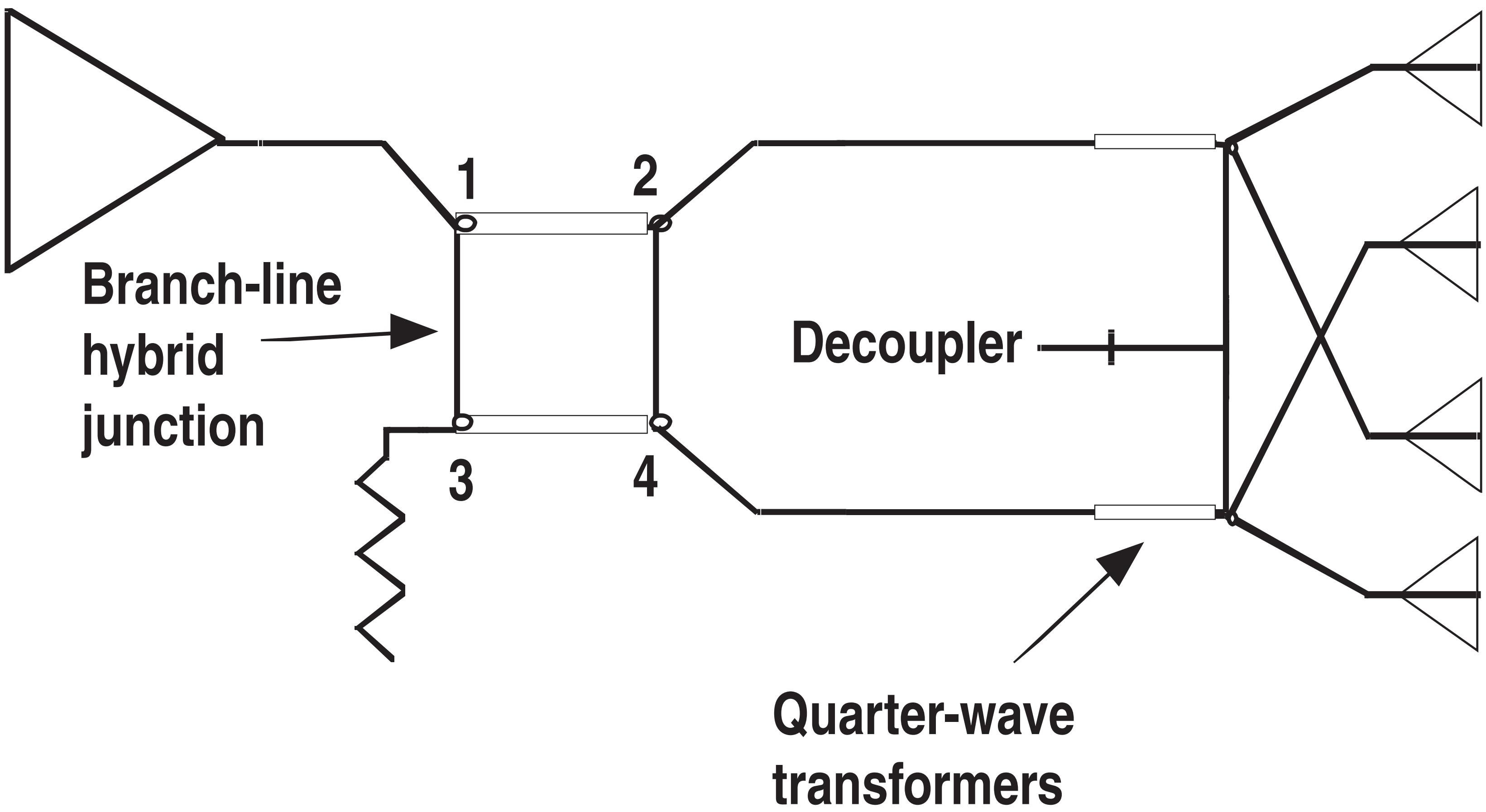
- Previous DIII-D work on FWCD physics largely in L-mode plasmas; later, exploration of FWCD in ELMing H-modes

- Main goal of this work: predict maximum coupled FW power that will be achievable with present antennas into AT discharges

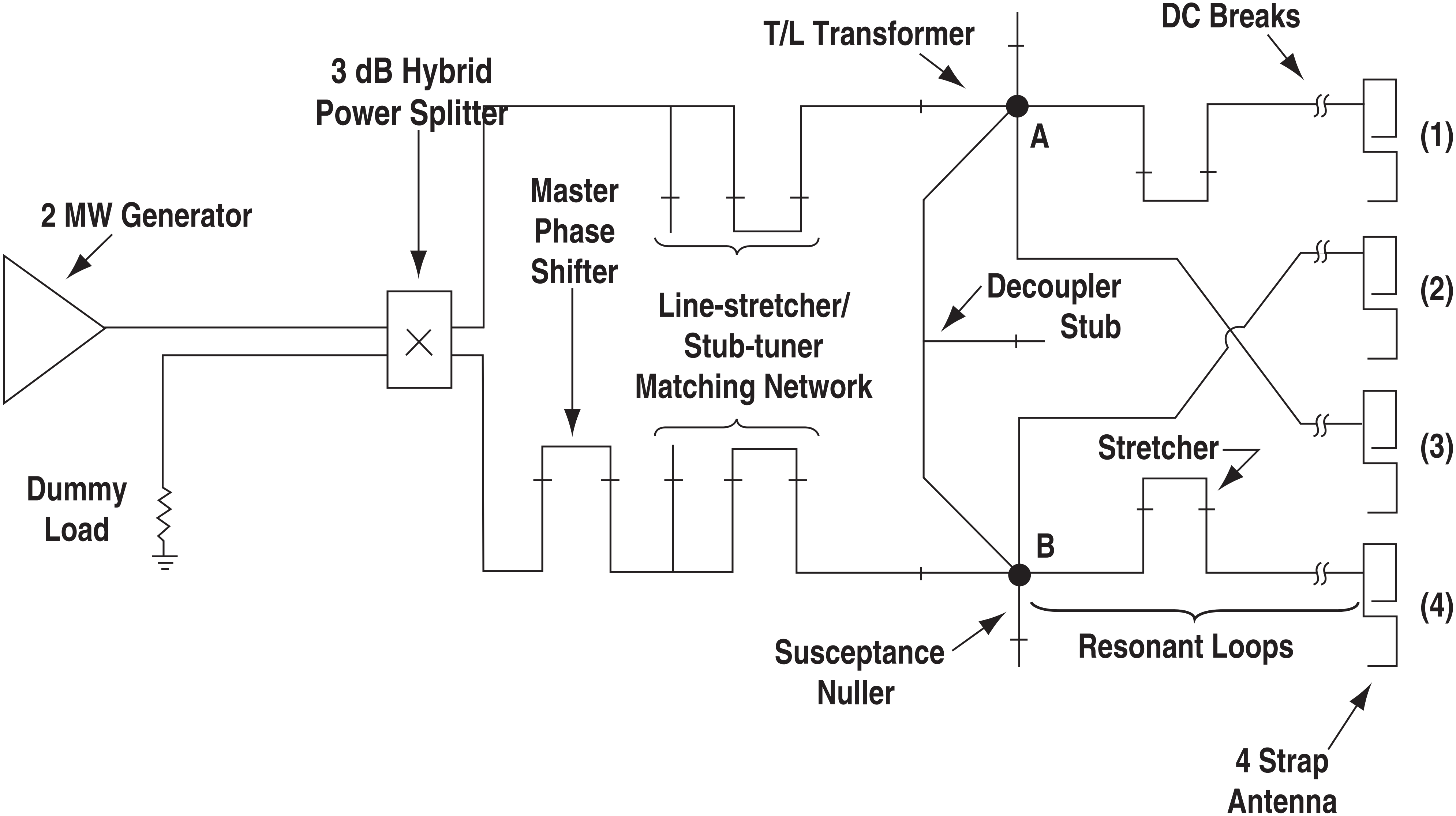
I. Technical

DIII-D FWCD systems: two designs, both of which have demonstrated that the rf source can be made to see constant load despite substantial variation of antenna load (and therefore operate at substantially higher power)

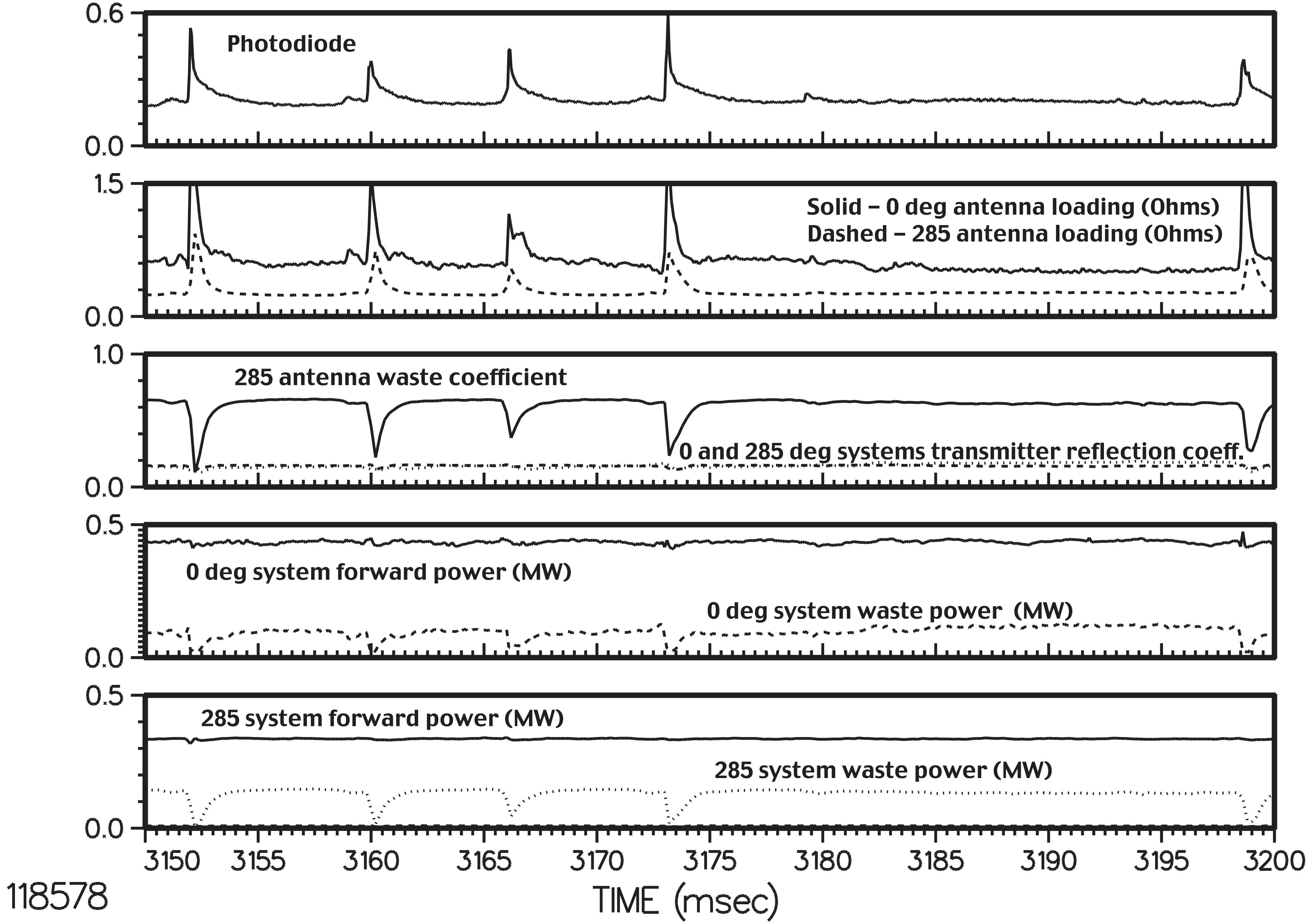
Simple tunerless transmission line configuration used on 285 antenna presents transmitter with matched impedance for all conditions



More complex (10 tuners) configuration used on 0 deg antenna can provide equally good transmitter isolation with more efficiency



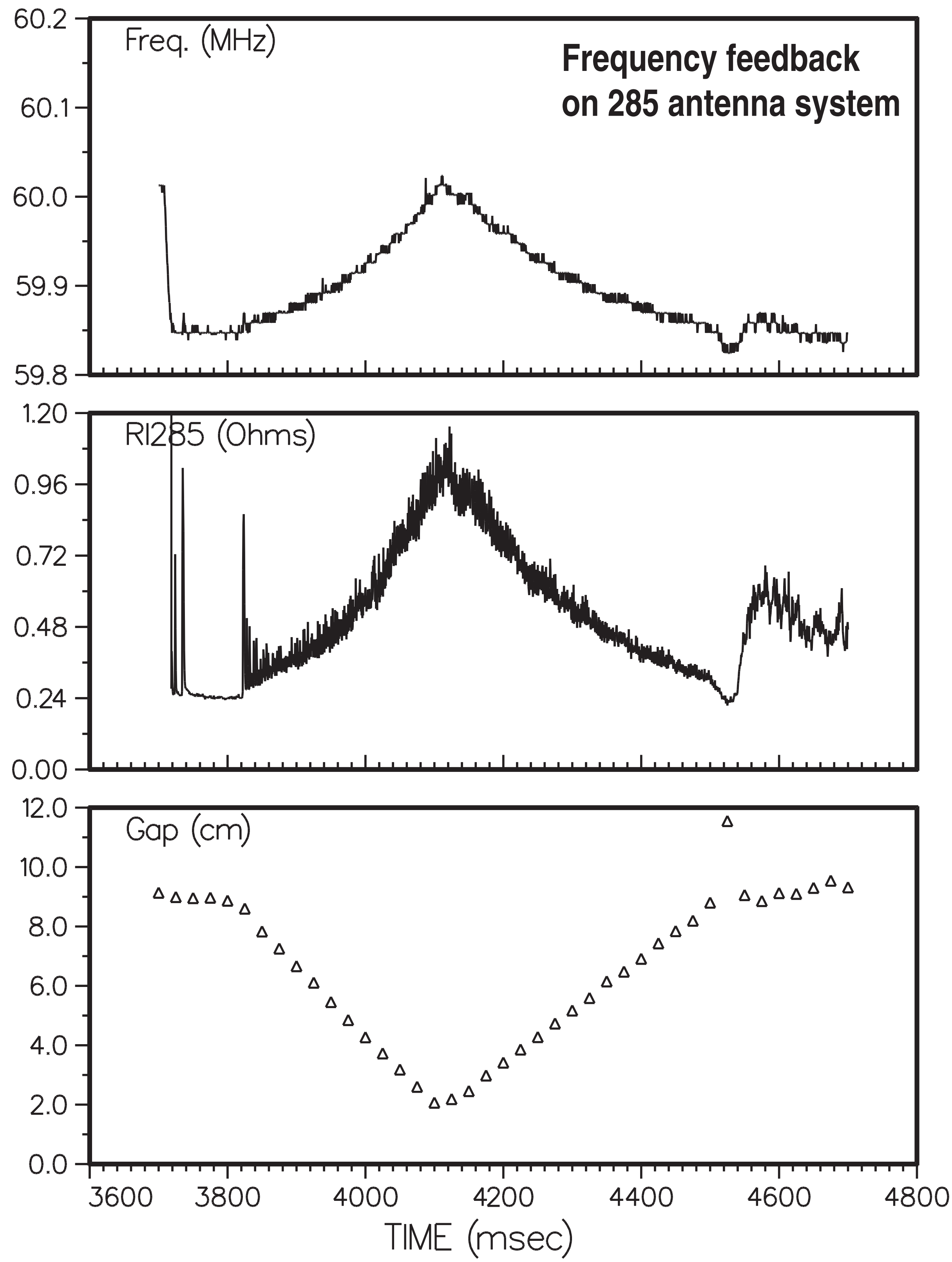
Both 0 deg and 285 deg systems provide transmitter isolation against ELMs and other time-varying loading conditions



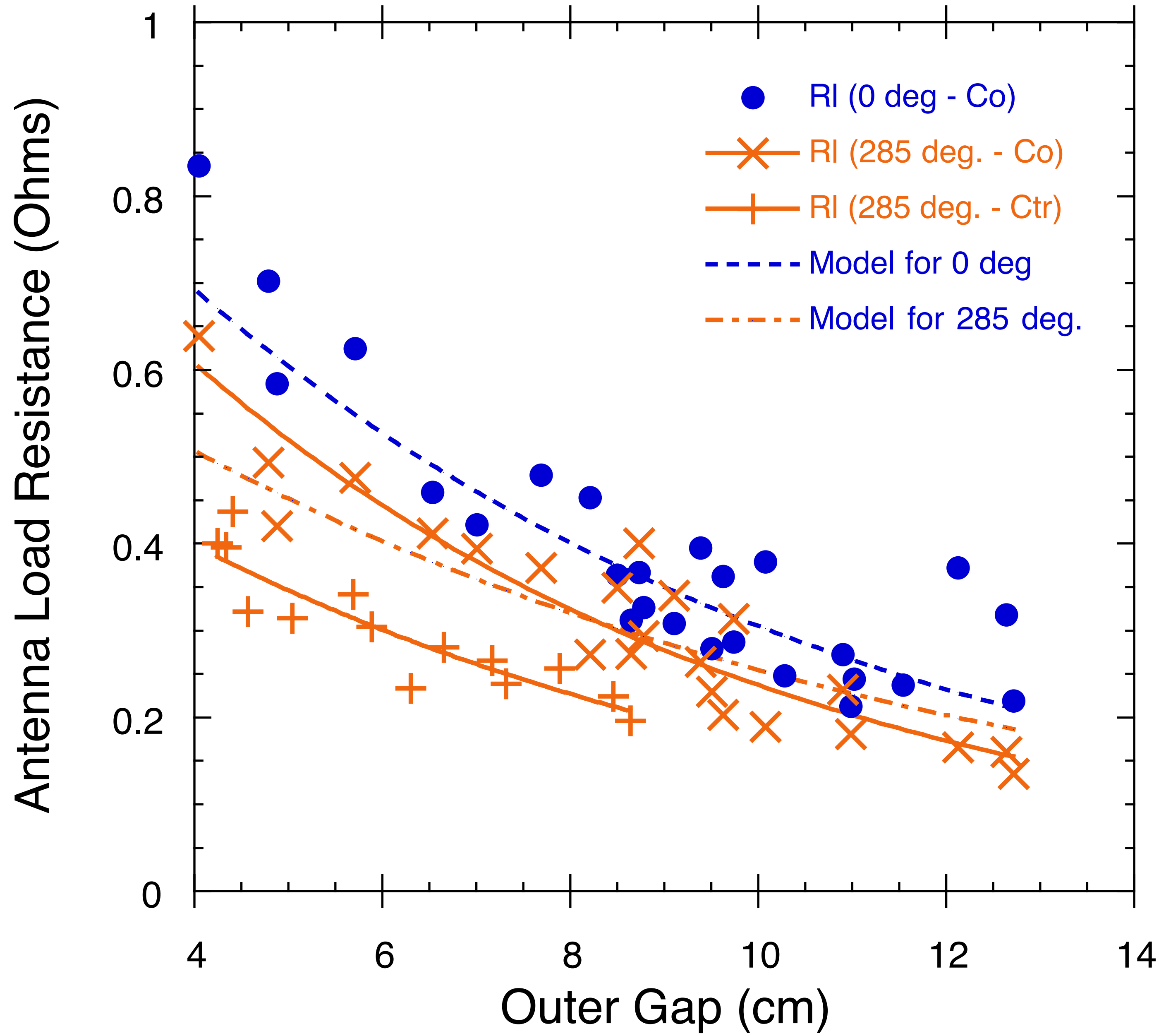
II. Loading measurements in AT plasmas

These have shown continued agreement with simple models, indicating basic understanding of FW antenna loading has been achieved

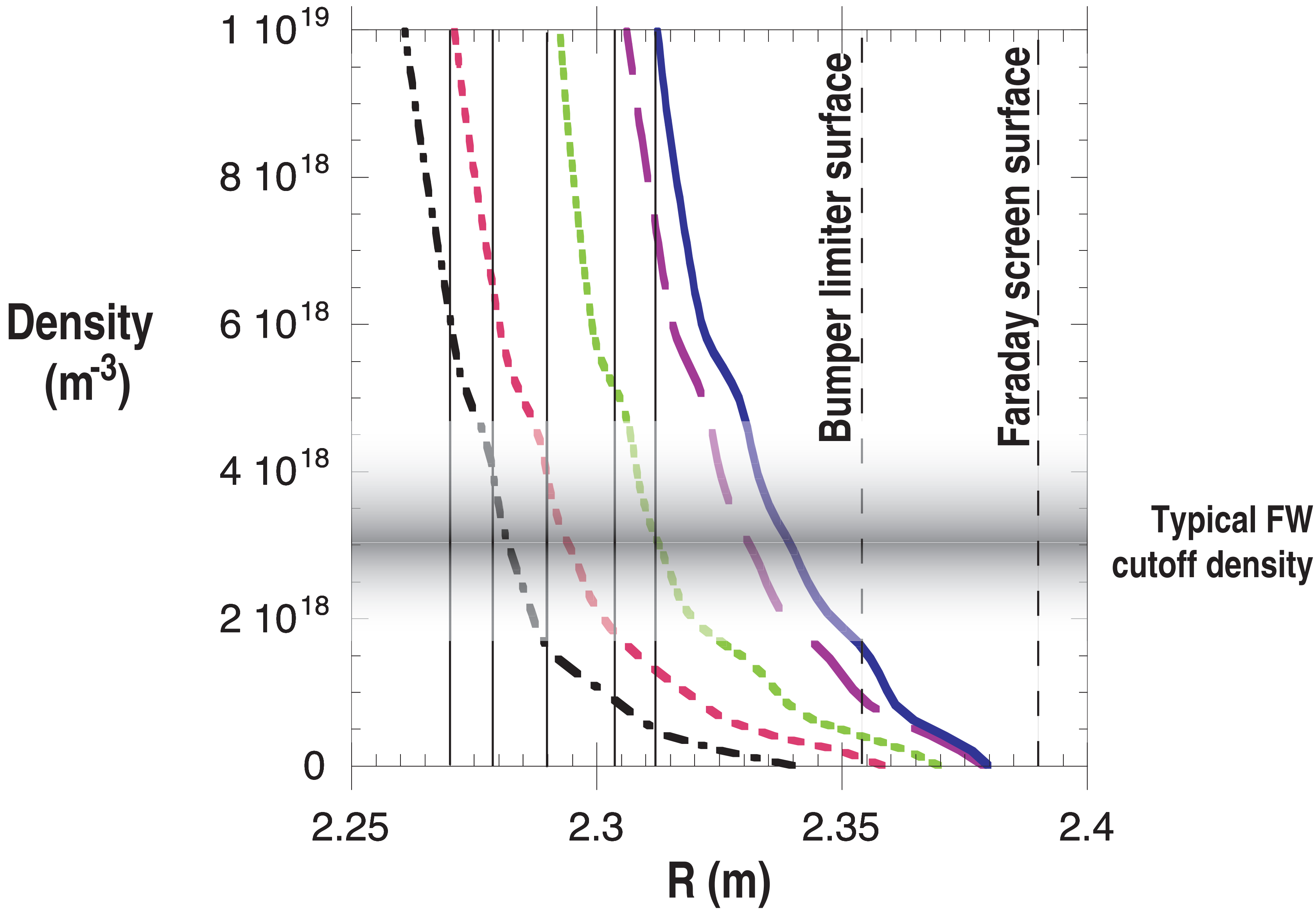
Both resistive and reactive antenna loading vary with the outer gap (L-mode example)



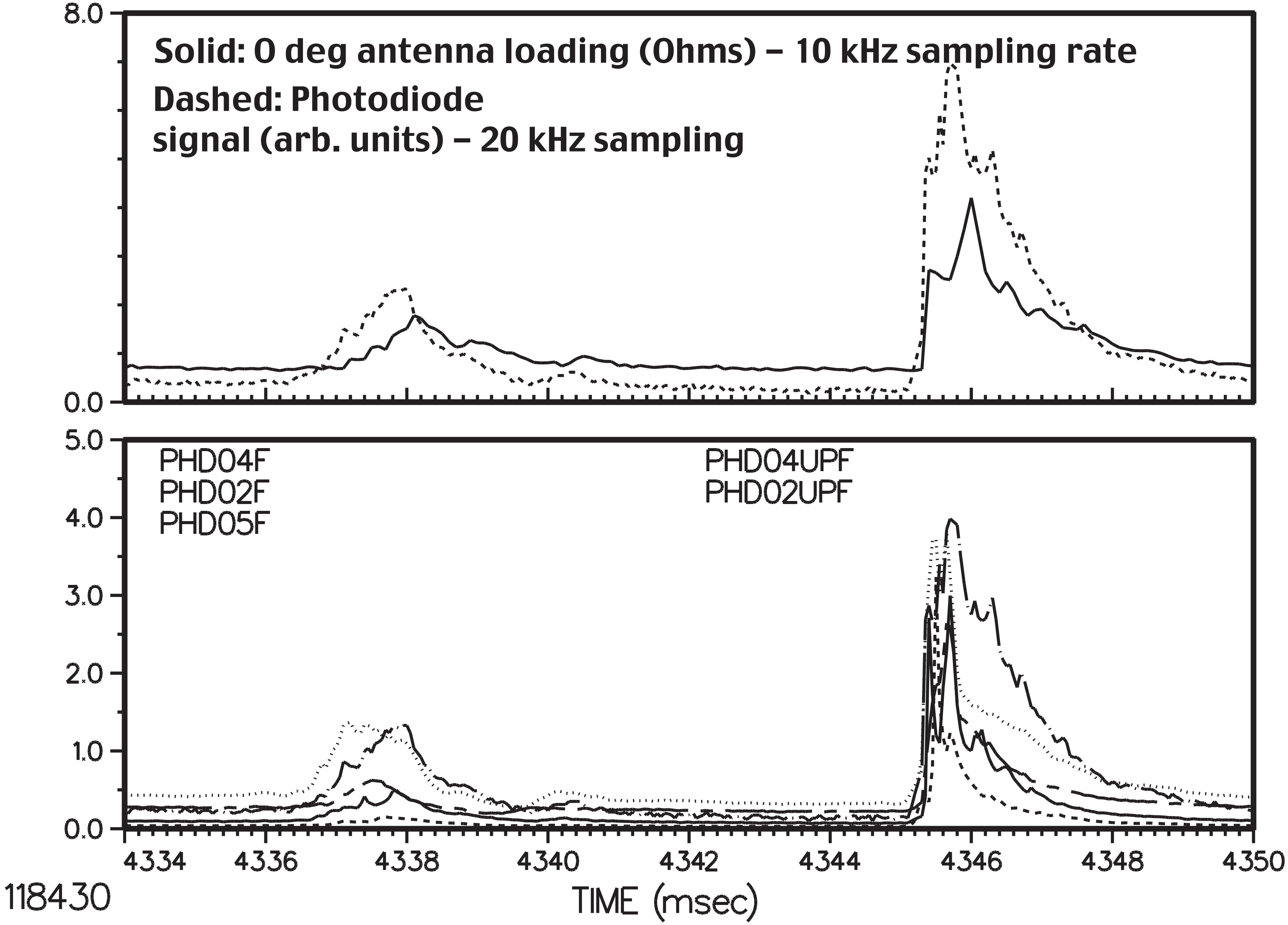
Antenna loading measured in dynamic gap ramps (between ELMs) is in reasonable agreement with predictions of a very simple model



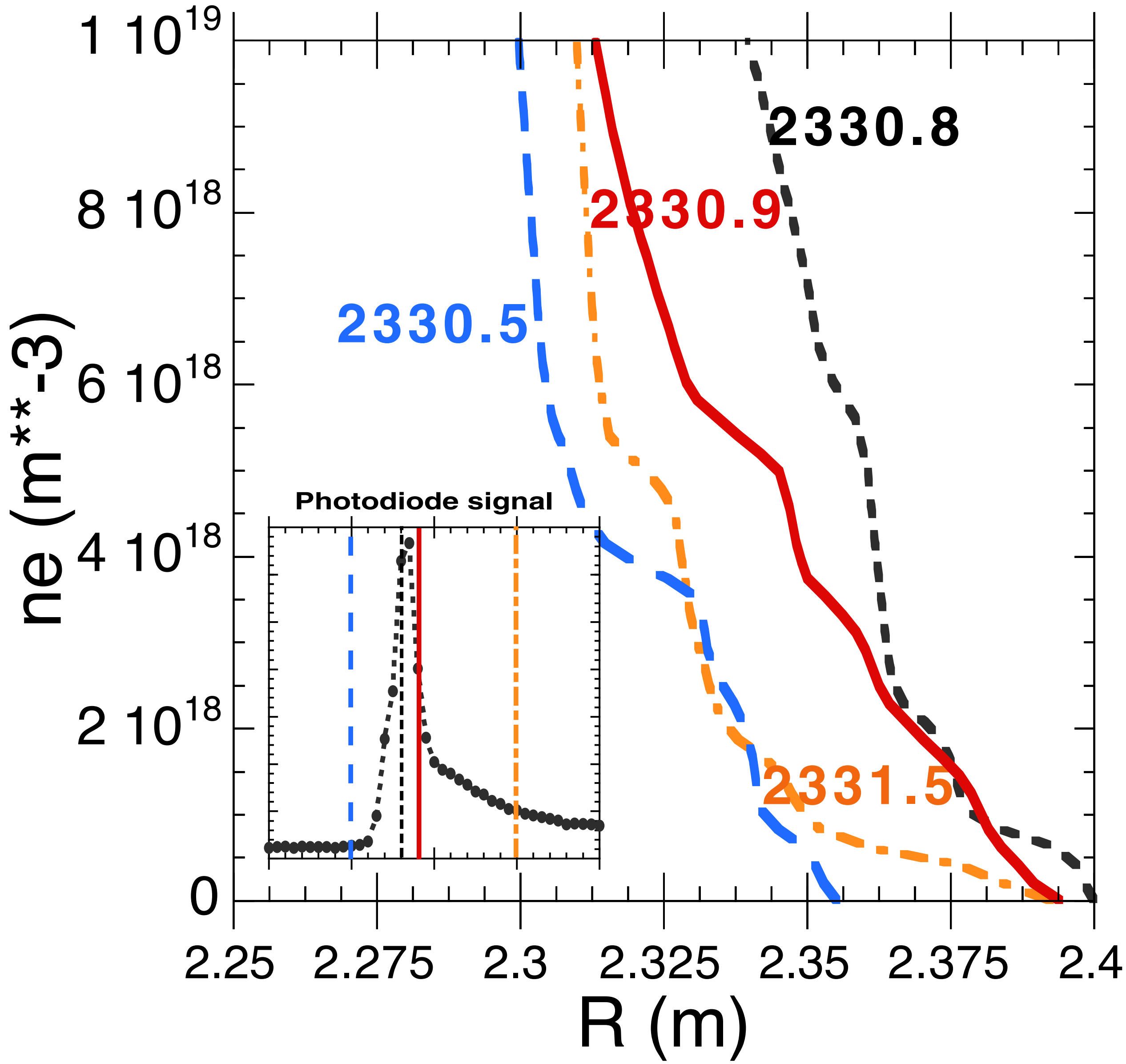
Edge density profiles (between ELMs) are essentially translated without much change in slope or shape by outer gap ramp



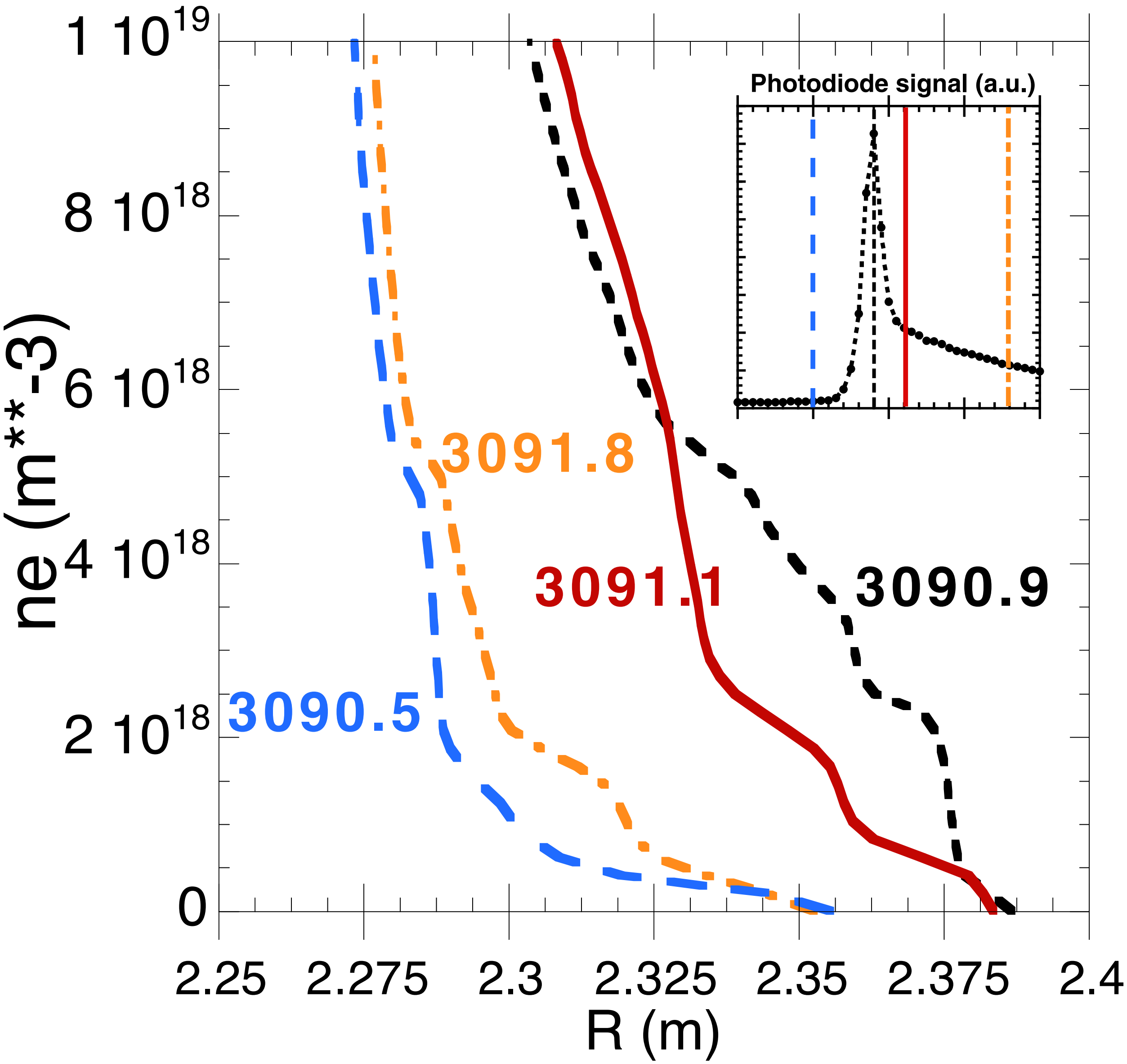
Antenna loading resistance is almost always nearly identical in time dependence to photodiode signals (D-alpha recycling light)



Edge density profiles measured with the FM reflectometry system during an ELM; outer gap of 4.6 cm



Edge density profiles measured with the FM reflectometry system during an ELM; outer gap of 8.3 cm



III. Power and voltage limits in AT plasmas

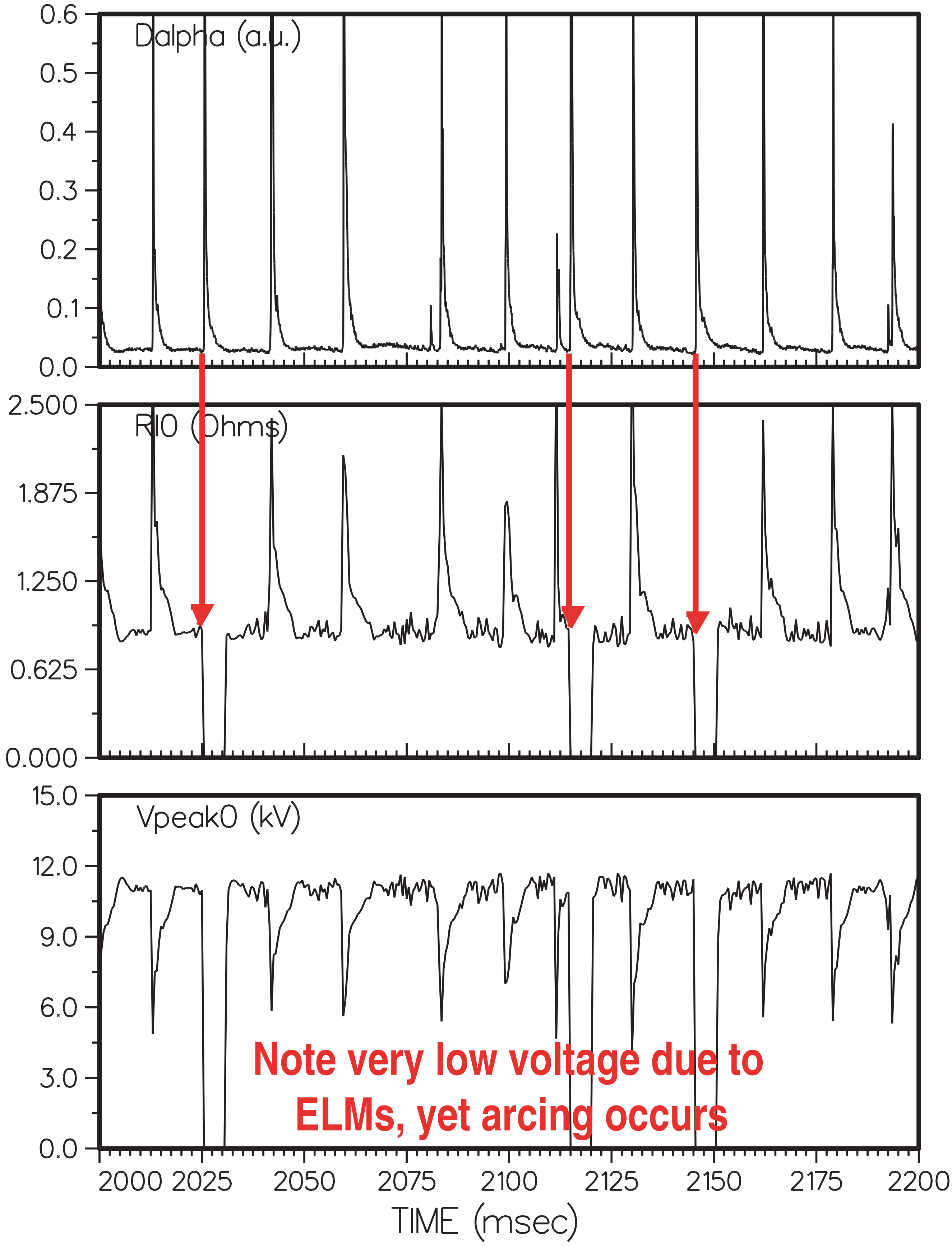
- **‘Traditional’ prediction of coupled power level**
  - Assume electric field limit is independent of plasma conditions
  - Therefore measurement of antenna loading directly leads to a simple estimate of power limit

- **Example:**

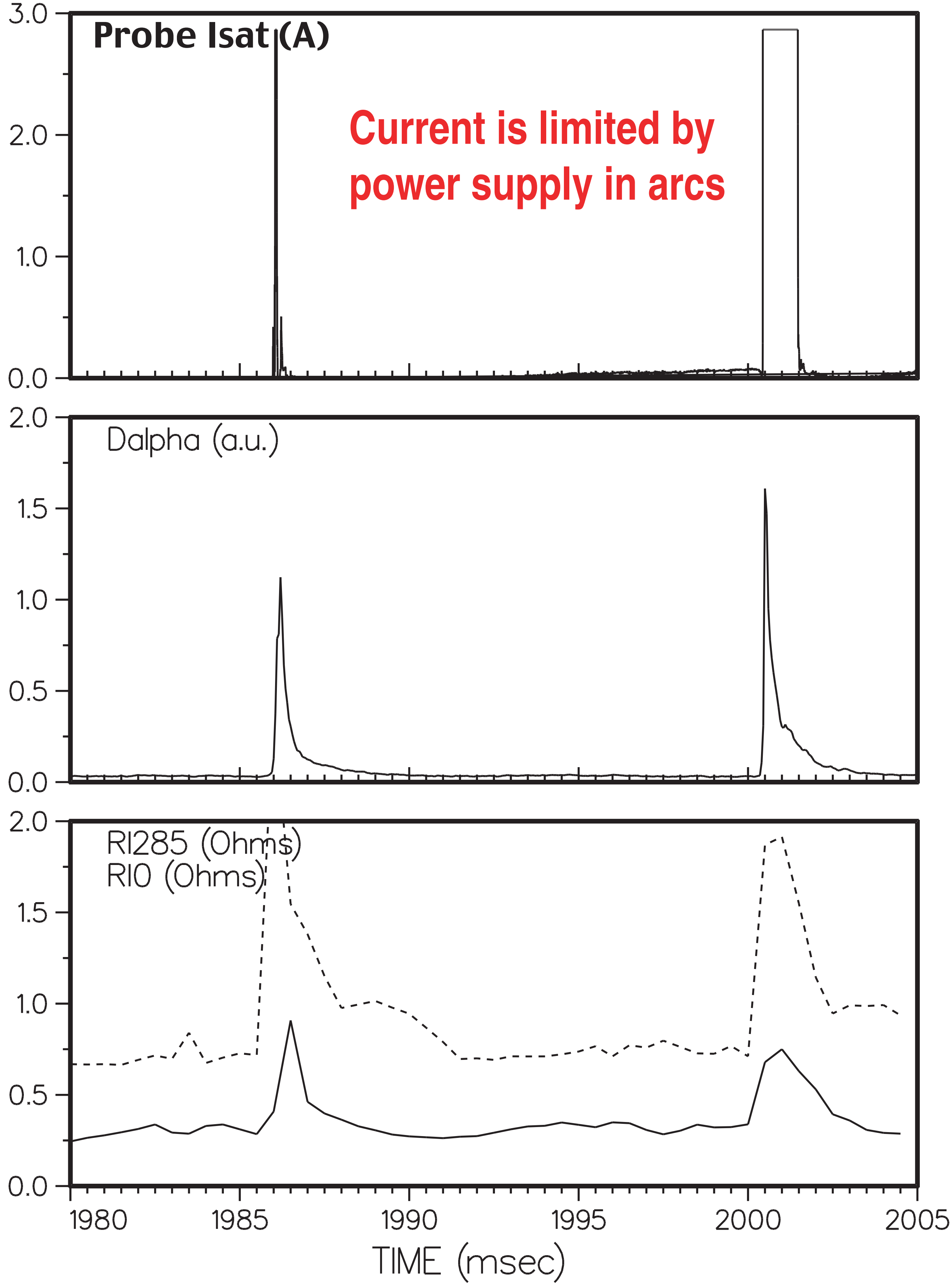
Antenna	Loading at 6 cm outer gap	Coupled power fraction	Coupled power at 20 kV	Coupled power at 25 kV	Coupled power at 30 kV
285	0.4 Ohms	73%	0.41 MW	0.64 MW	0.92 MW
0 **(117.6 MHz)**	0.8 Ohms	71%	0.73 MW	1.14 MW	1.64 MW

- **But in fact the assumption that the electric field limit is independent of plasma conditions is demonstrably incorrect, at least in DIII-D**
- **Experience indicates that non-zero plasma density in the antenna boxes lowers the tolerable peak electric field, sometimes drastically**
- **ELMs, for example, can cause such degradation of the standoff voltage**

An ELM has a rather high probability of triggering an antenna arc - here, 3 of 14 ELMs trigger arcs



Unipolar (DC) arcs are often seen on the reciprocating Langmuir probe (UCSD), triggered by ELMs also



Avenues to improvement in antenna performance

- Optically opaque Faraday screen, or even sealed antenna
- Very much lower impedance (= lower electric field) launchers
  - Either take up voltage in capacitor with private (high) vacuum
  - Or segmented strap (Probert, Bosia, et al.)

- ITER necessitates radically improved FW coupling structures
  - Marginal improvements of present antennas will NOT suffice

The time to demonstrate a substantial (i.e. factor of 4-5) improvement is now!

Summary

- Impedance matching and phase control networks successful in isolating transmitter from load variations

- Antenna loading is well understood; no important deviations from classical behavior observed to date

- Maximum tolerable rf electric field depends strongly on edge plasma conditions, reducing the achievable coupled power substantially relative to the 'traditional' prediction