Intense Non-Thermal ECE Bursts from TFTR Plasmas Heavily Conditioned with Lithium

by

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ABSTRACT

Significant improvements in plasma performance have been obtained in TFTR as a result of lithium pellet injection and sputtering of molten lithium. When the TFTR carbon limiter was conditioned with lithium we observed intense bursts of electron cyclotron emission (ECE). The bursts have been observed for several seconds both in the Ohmic heating phase and neutral beam heating phase of D and D-T TFTR plasmas. The ECE bursts consist of intense spikes of random amplitude which last 5-30 microseconds. This phenomenon appears to be associated with the extremely low edge density in these lithium gettered plasmas and may result from the pitch angle scattering of slideaway electrons by turbulent cells in the low density edge region.

MOTIVATION

- Michelson diagnostic sees intense ECE bursts from TFTR plasma well conditioned with lithium.

- What causes this phenomenon?

Phenomenology
of
ECE Bursts

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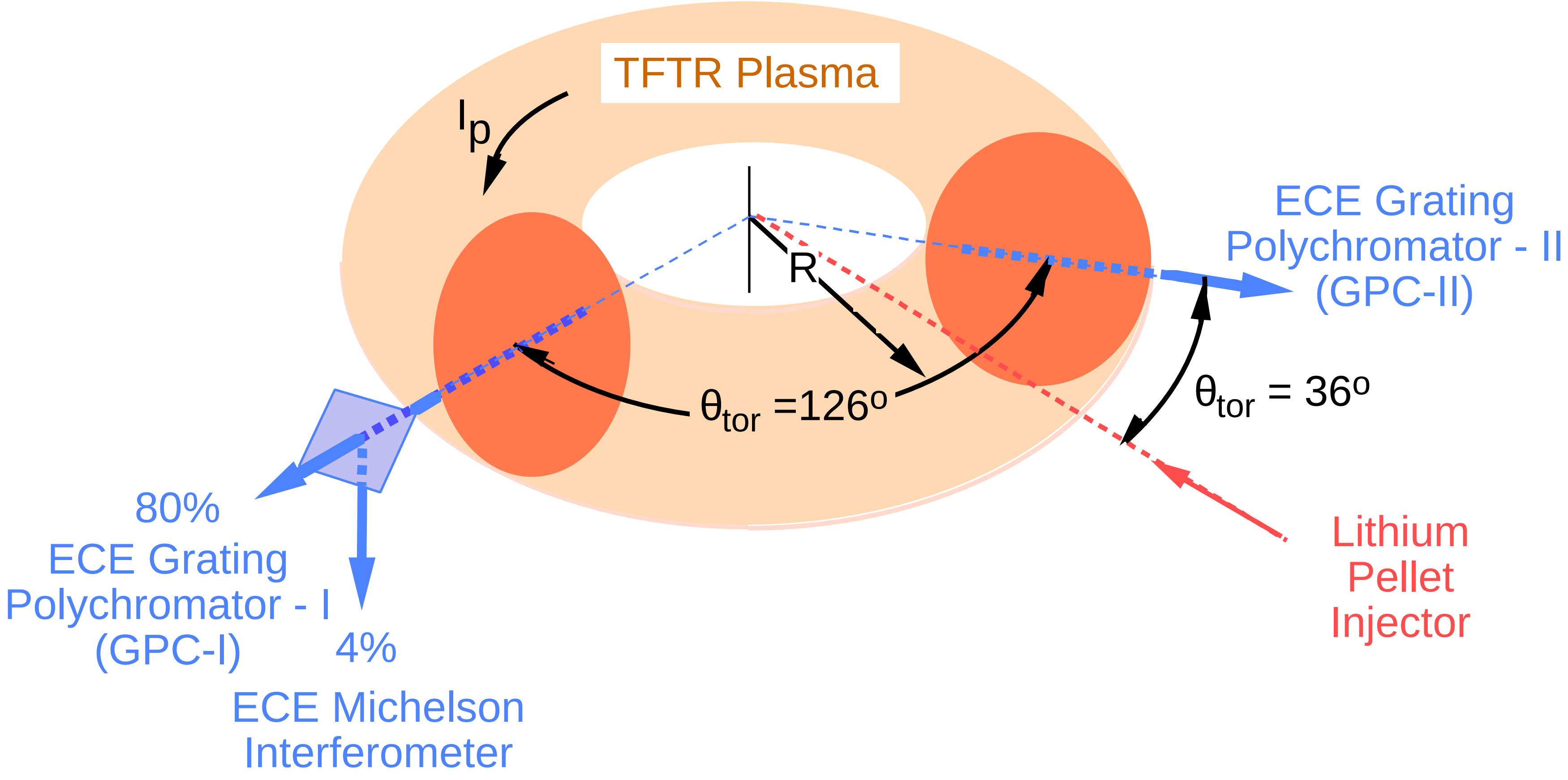
EFFECTIVE LITHIUM PELLET CONDITIONING LEADS TO IMPROVED TFTR PLASMA PERFORMANCE

- Li conditioning can significantly reduce edge recycling and density:
  - leads to improved beam penetration.
- Experiments with extensive Li pellet conditioning conducted during 1994/5:
  - Improved core confinement.
  - Large electron temperature reheat after NBI (especially in D-T).
  - Intense bursts on the Michelson ECE diagnostic ($T_{rad} \leq 170$ keV).

ECE DIAGNOSTICS AND LITHIUM PELLET INJECTOR LOCATIONS ON TFTR



- Absolutely calibrated, Michelson interferometer shares view with GPC-I.

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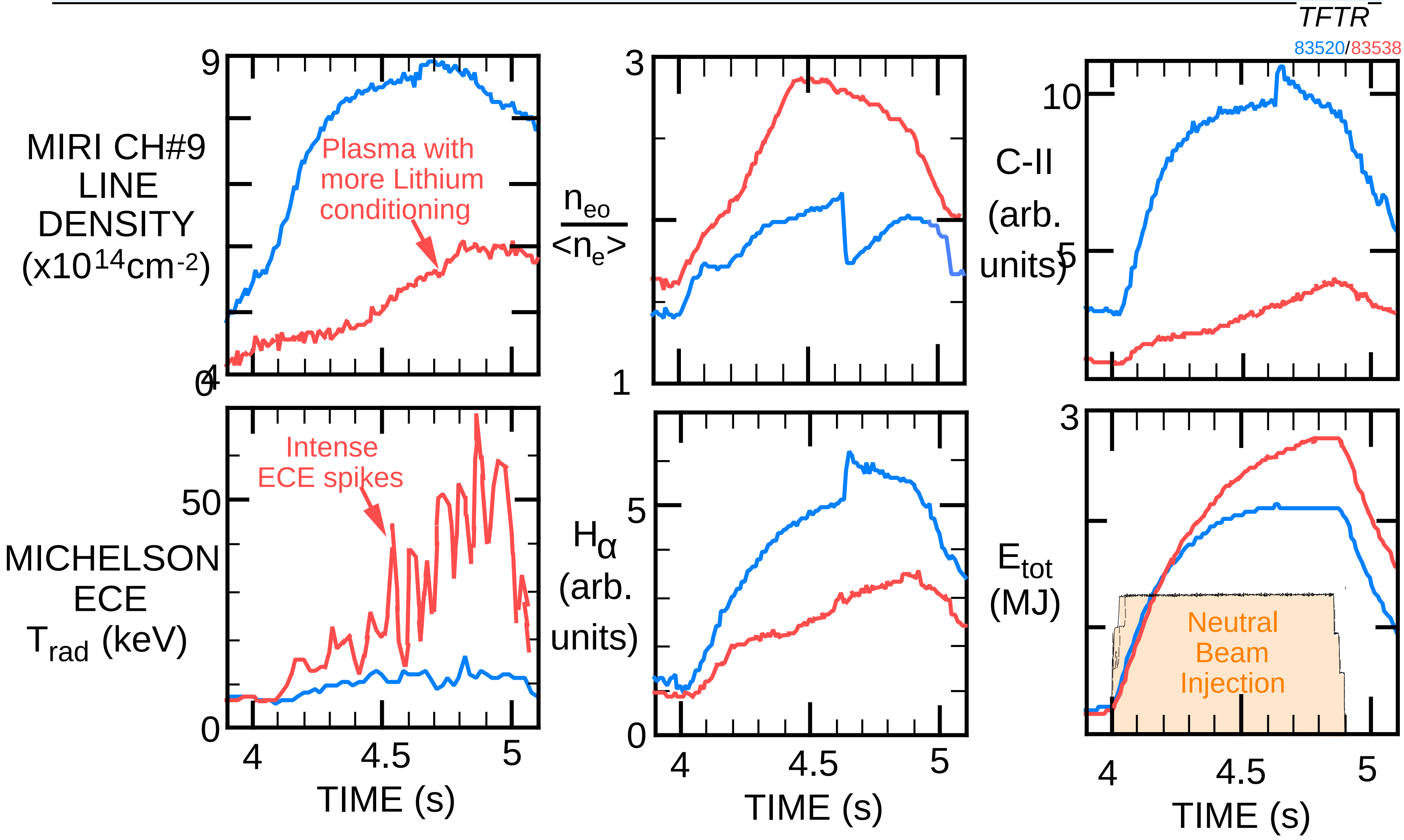
INTENSE NON-THERMAL ECE ASSOCIATED WITH REDUCED EDGE DENSITY AND RECYCLING



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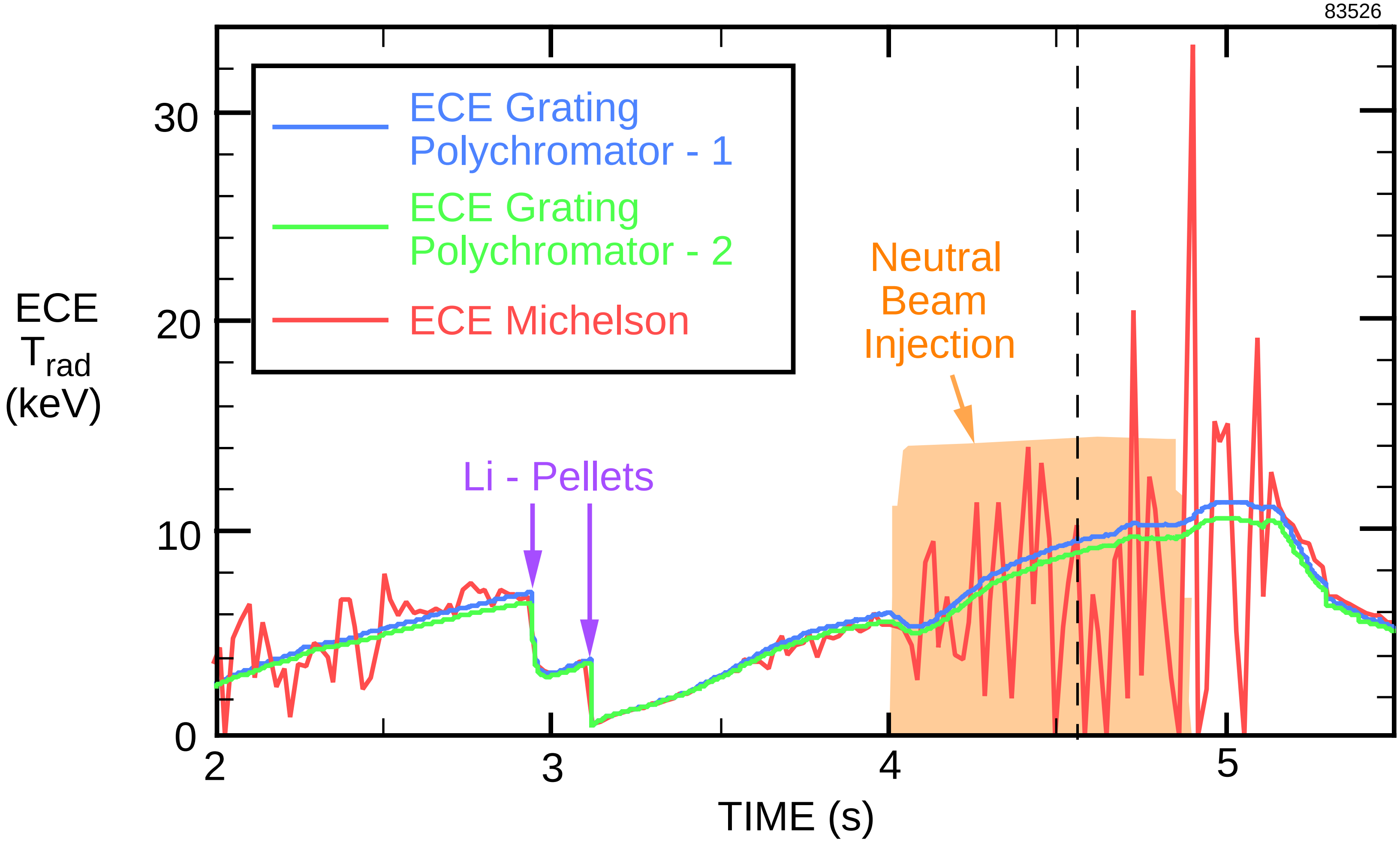
83520/83528 Comp.

INTENSE NON-THERMAL ECE ON MICHELSON NOT SEEN ON GRATING POLYCHROMATORS

TFTR



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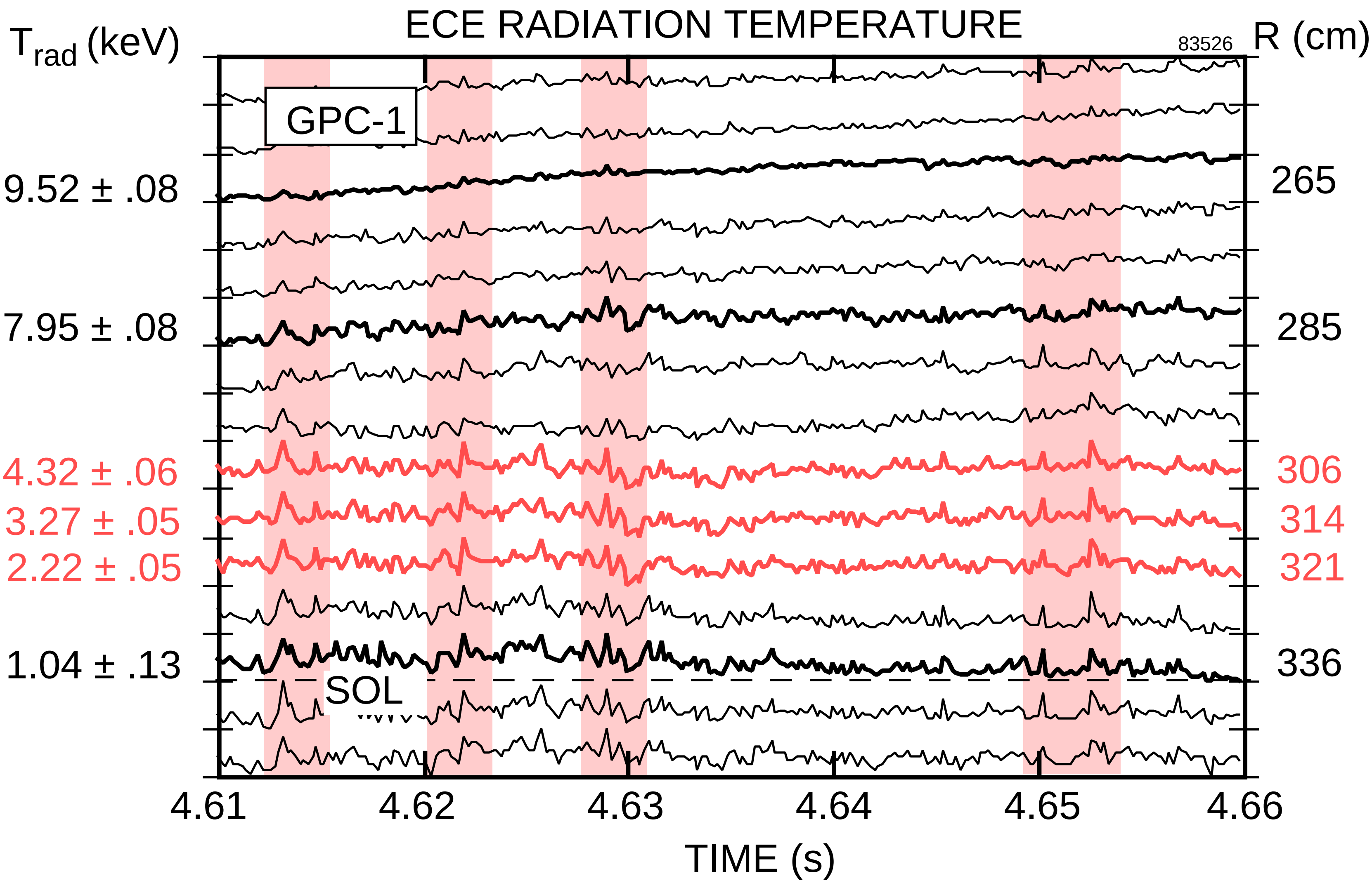
83526 ym/yg1/yg2 286 GHz

DURING INTENSE MICHELSON ECE SPIKES GPC-I MEASURES ~ 100 eV FLUCTUATIONS

TFTR



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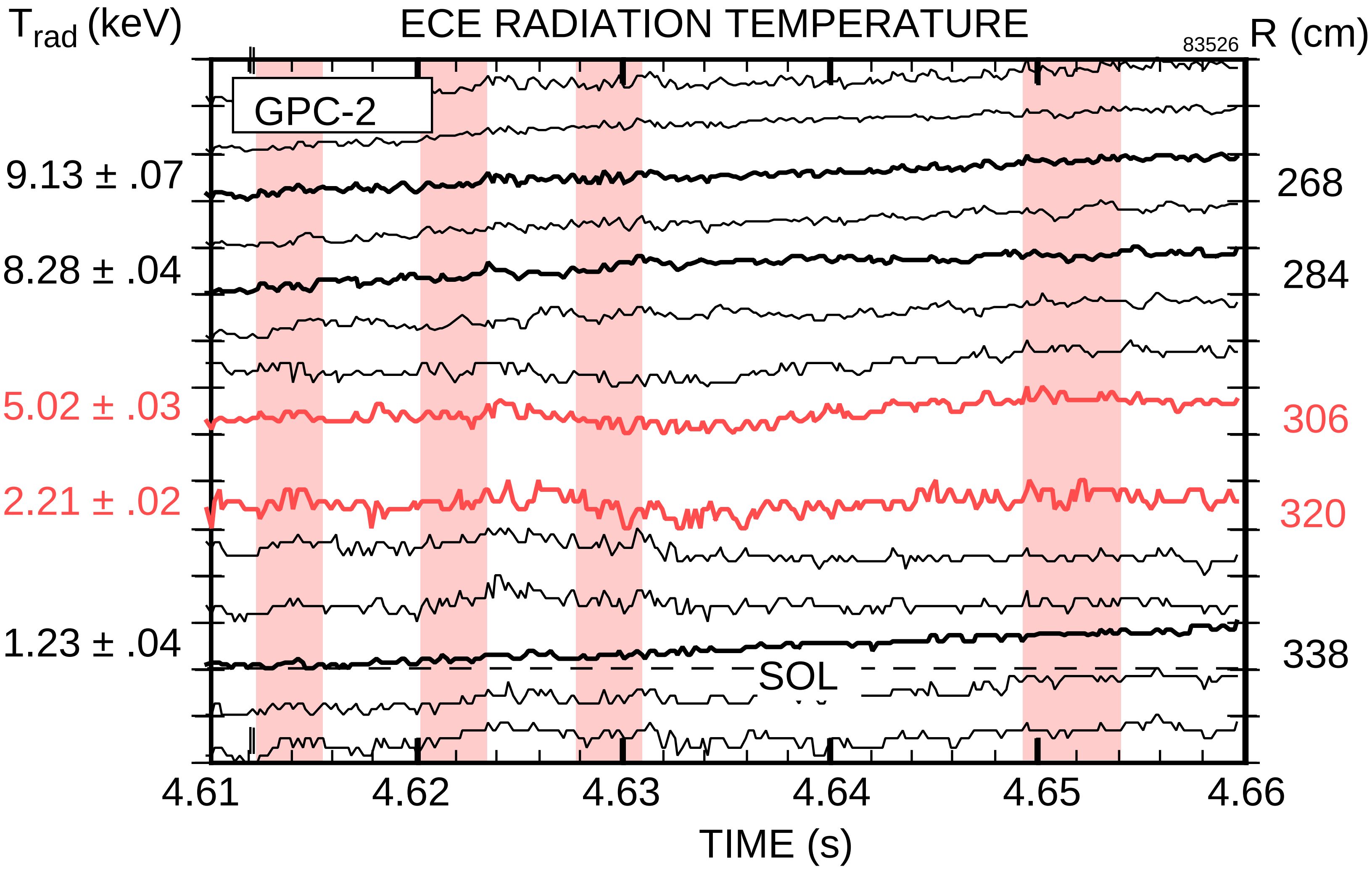
83526 YG1 4.61-4.66

DURING INTENSE MICHELSON ECE SPIKES GPC-2 SHOWS NO CLEAR EVIDENCE OF SPIKES

TFTR



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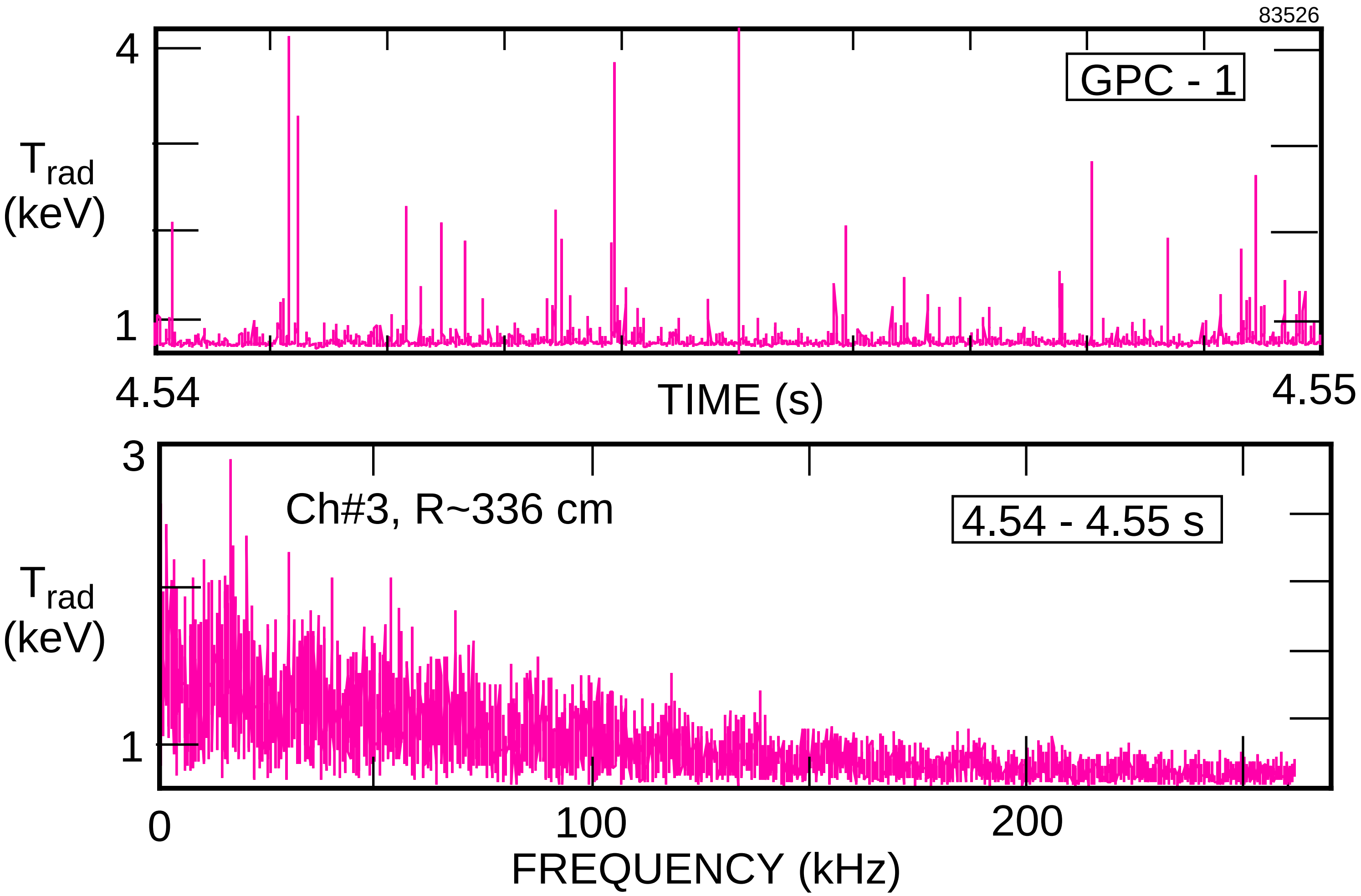
83526 YG2 4.61-4.66 s

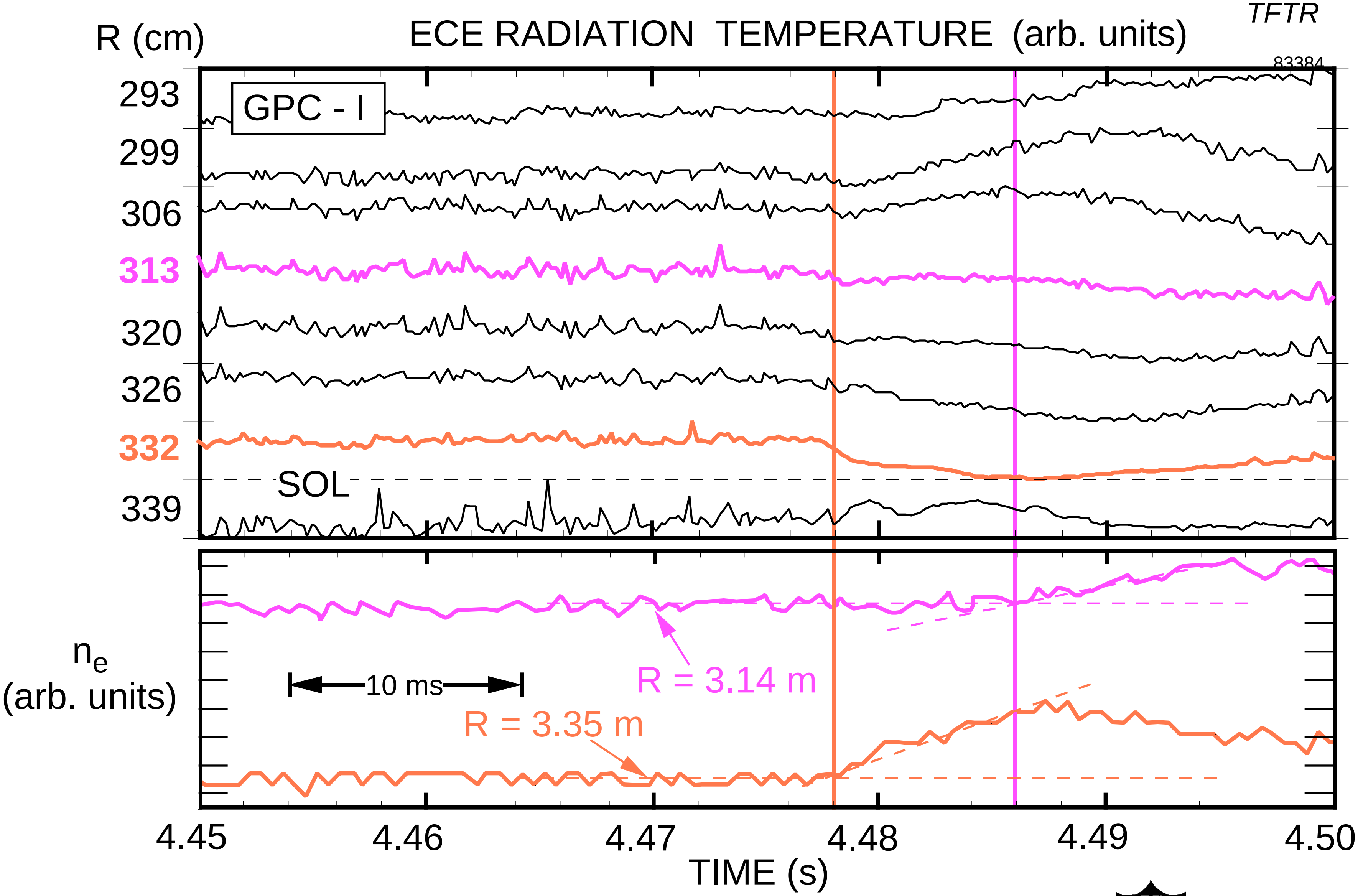
BURST FLUCTUATION BANDWIDTH ~ 100 kHz



- Fast (500 kHz digitized) GPC-1 data show individual ECE spikes last 5-10 μs with peak radiation temperatures ~ 4 keV.

NON-THERMAL ECE SUPPRESSED AT ALL FREQUENCIES AT TIME OF COLD EDGE INFLUX

TFTR



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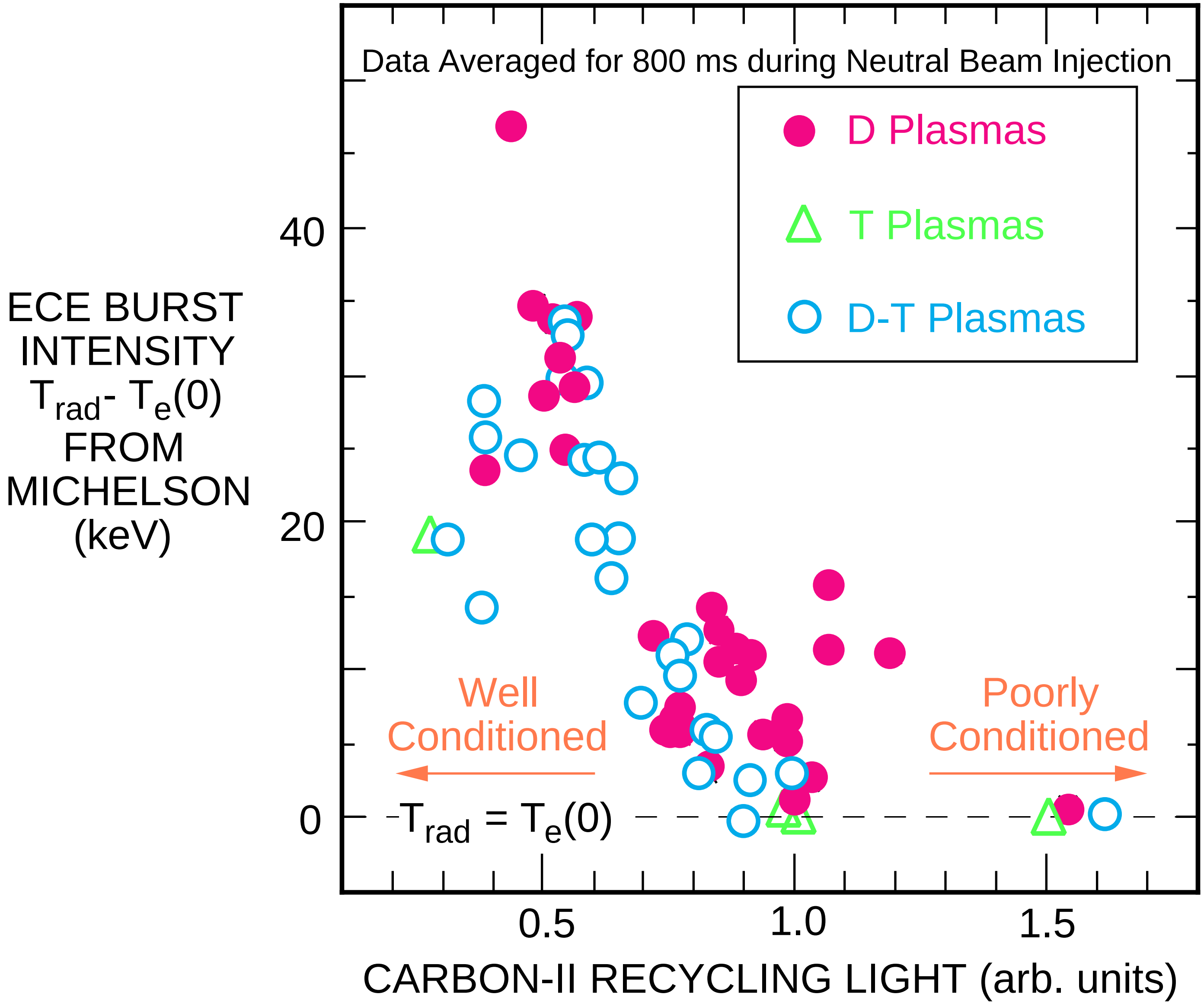
83384 YG1/FM Cold Wave

ECE BURST INTENSITY INCREASES WITH DECREASING RECYCLING FROM CARBON LIMITER

TFTR



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Trad vs c2 10/28/97

ECE BURSTS INTENSITY INCREASES WITH DECREASING EDGE DENSITY

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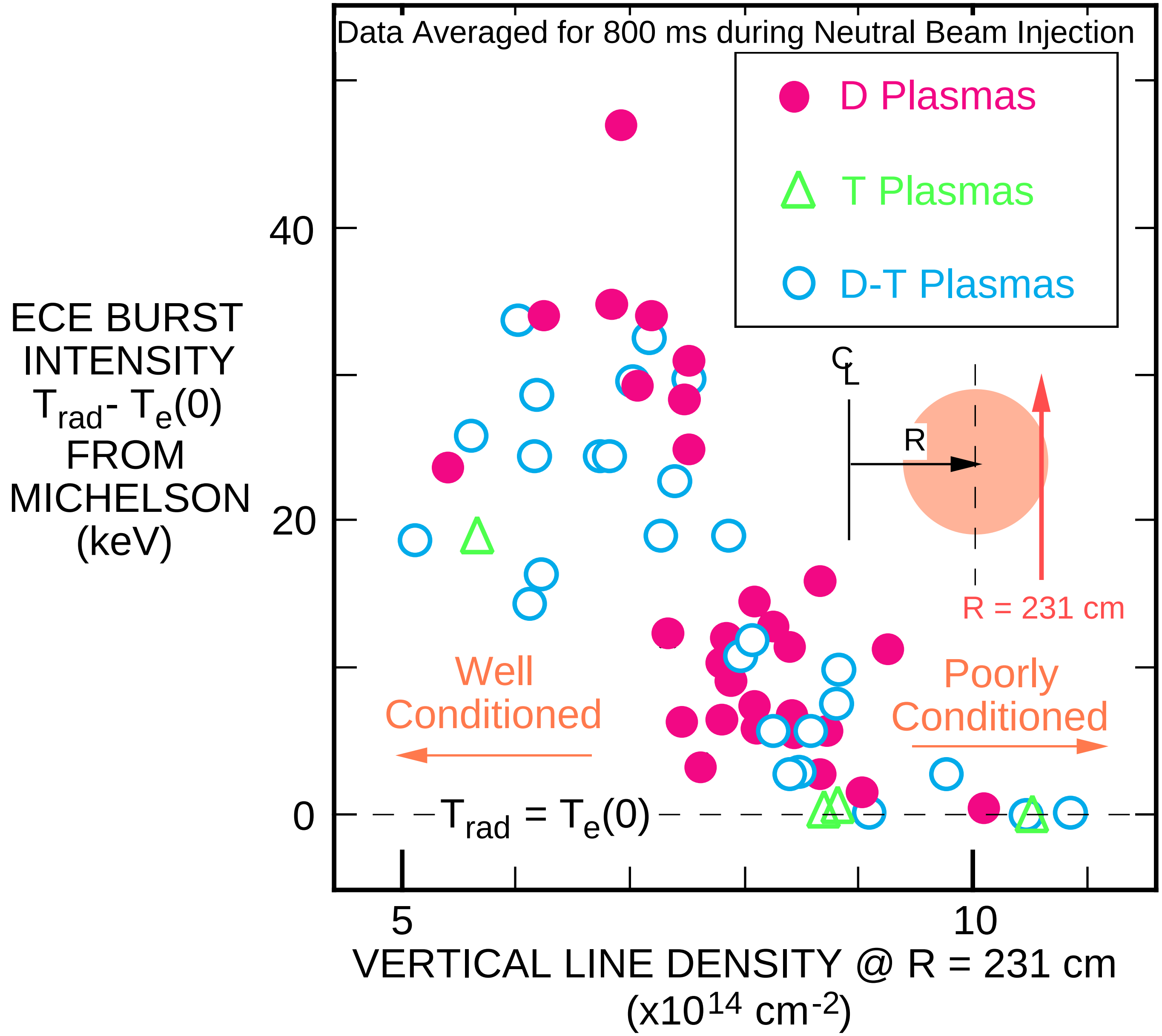

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Trad vs nedge 10/28/97

Interpretation
of
ECE Data

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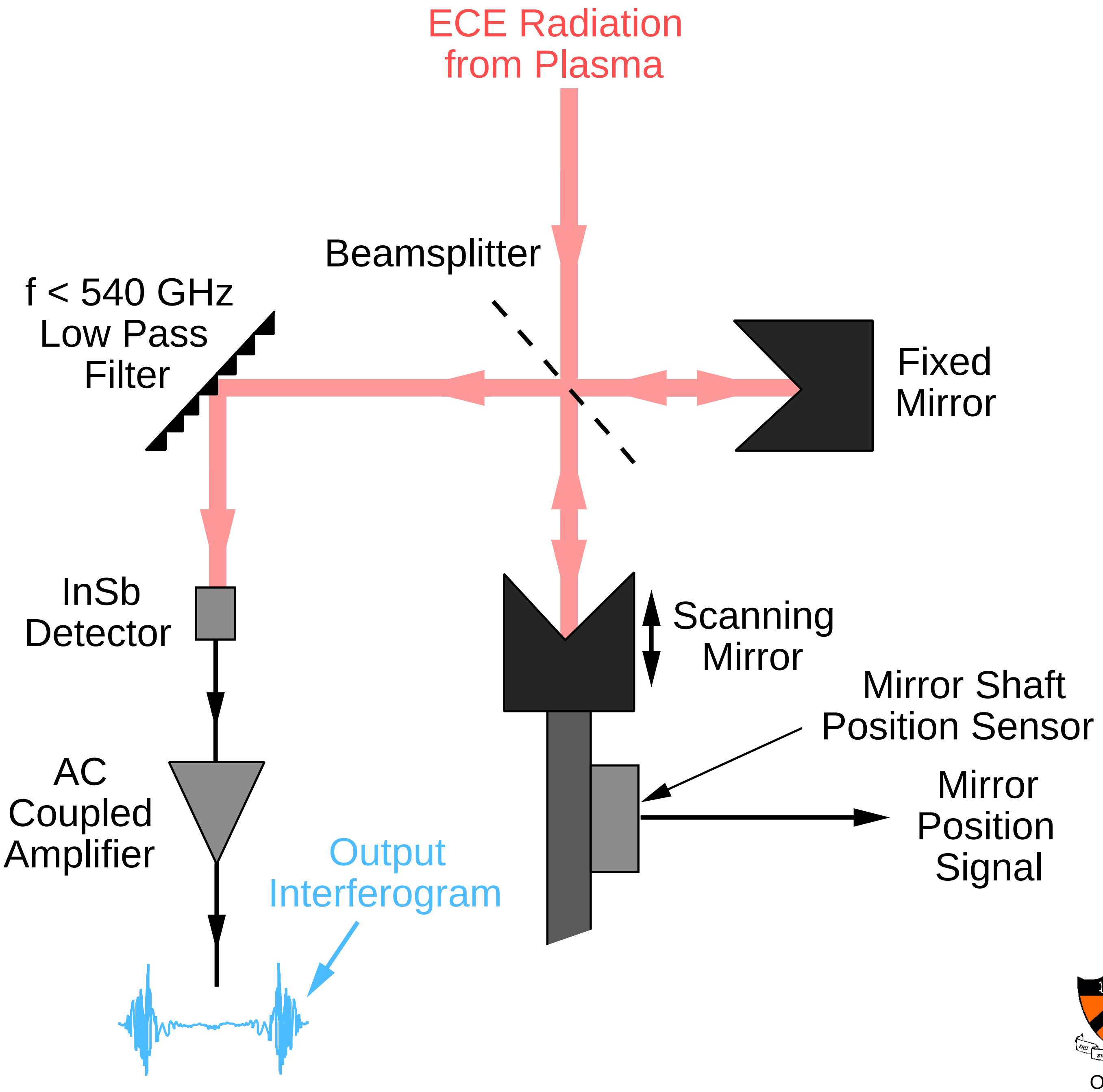
ECE DIAGNOSTIC PERFORMANCE CONSTRAINS DATA INTERPRETATION

- TFTR ECE diagnostics have only limited capabilities:
  - Michelson not suitable for fast phenomena (< 20 ms), measures Fourier transform of ECE.
  - Grating polychromators not suitable for broadband phenomena (> 50 GHz) .
  - Midplane views limit ability to determine location of a non-thermal ECE source.

TFTR ECE DIAGNOSTICS: Michelson

- Measures from below fundamental up to fourth harmonic ECE:
  - has lowpass filter at ~ 540 GHz.
- Scans ECE spectrum in ~ 5 ms.
- Relies on Fourier transform of the Michelson interferometer output:
  - analysis assumes a quasi-stationary ECE spectrum during a scan.
  - large fluctuations in ECE spectrum can result in analysis artifacts.

SCHEMATIC OF ECE MICHELSON INTERFEROMETER



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INTENSE ECE BURSTS ON MICHELSON SIGNAL SUPPRESSED DURING EDGE INFLUX

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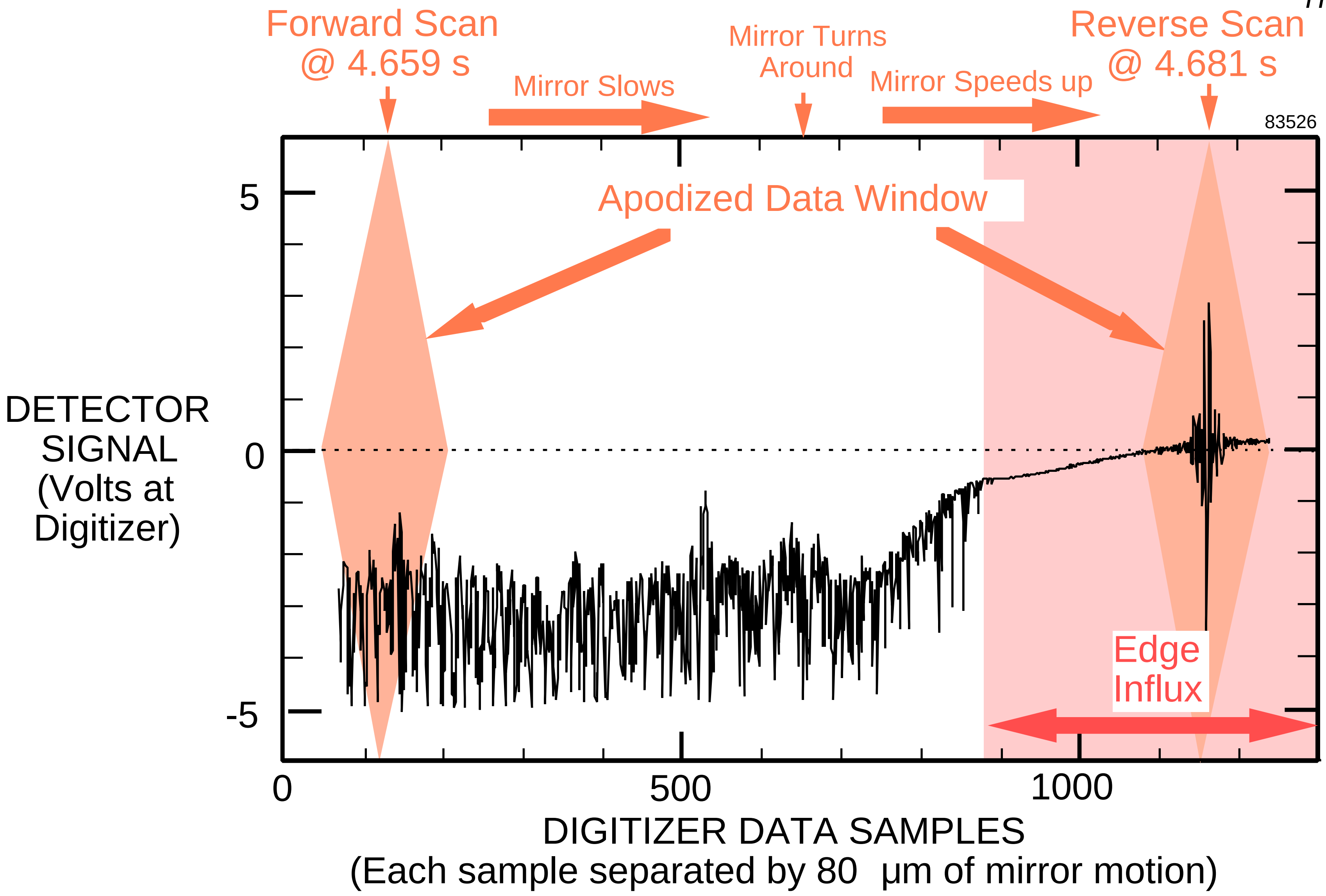

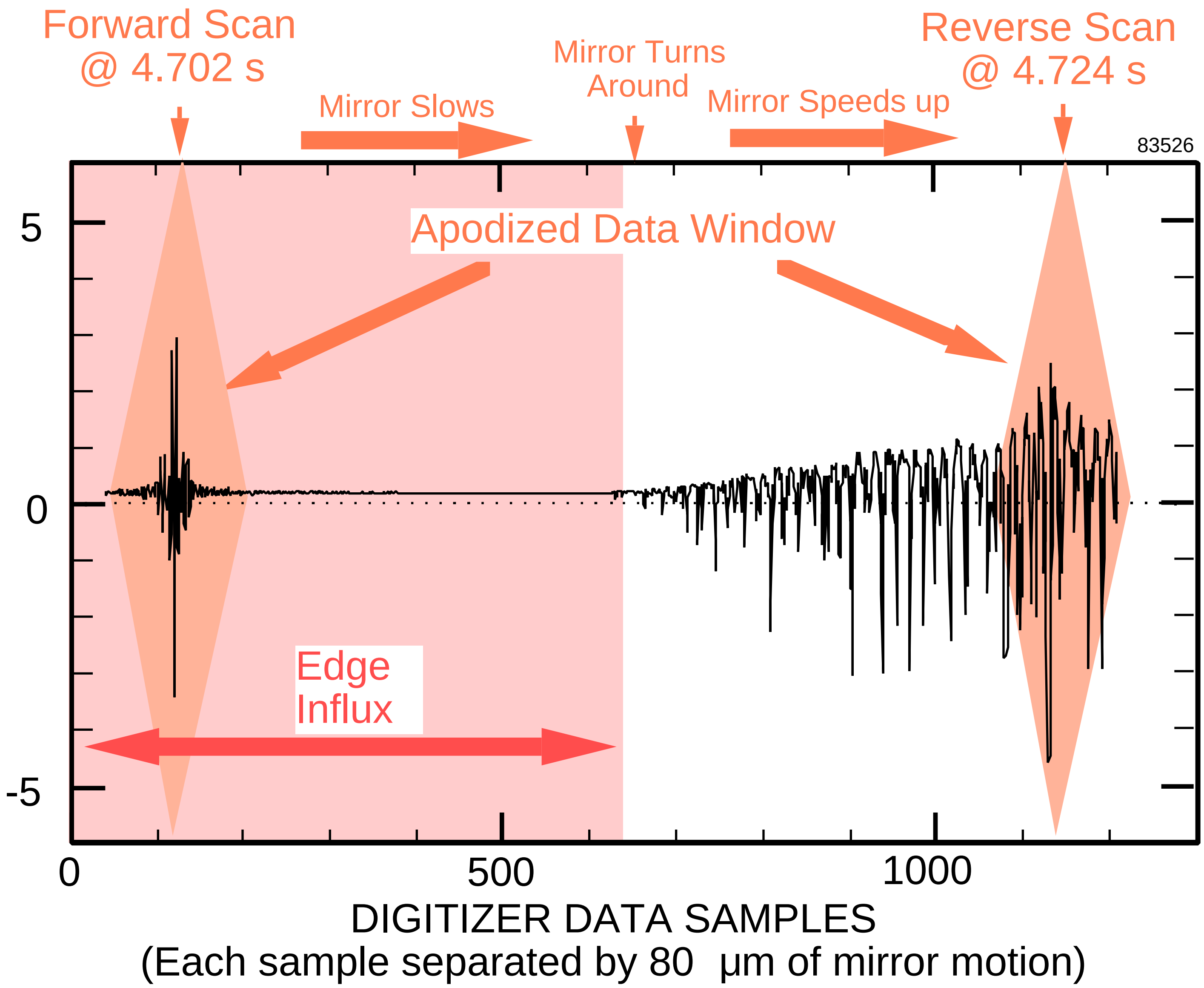

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83526 YM Raw@4.7s

TFTR ECE DIAGNOSTICS: Grating Polychromators (GPCs)

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- Two GPCs, separated toroidally by 126°, measure second harmonic ECE:
  - lowpass filters in waveguide run reject second order (fourth harmonic ECE).
- Second order rejection is not perfect due to finite filter rolloff.
- GPC-2 has better second order rejection:
  - GPC-1 has 3 lowpass filters.
  - GPC-2 has 6 lowpass filters.

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BURSTS ARE AT FREQUENCIES ABOVE THIRD HARMONIC ECE OR MAY BE AT OR BELOW ECE FUNDAMENTAL

- Not second harmonic ECE:

  - since bursts not seen on GPC-2.

- Not third harmonic ECE:

  - since for T_{rad} ~ 100 keV expect ~ 50 GHz downshift of third harmonic ECE to second harmonic.

- GPC-1 bursts may be second order leakage of fourth harmonic ECE.

- Bursts may also be at or below fundamental ECE frequencies:

  - since bursts are seen on Michelson but not GPC-2.

SUMMARY OF BURST CHARACTERISTICS

- Burst emission frequency either greater than ECE third harmonic or may be at or below ECE fundamental.
- Source at r/a > 0.7 (from transient edge influx events).
- $T_{rad} \leq 170$ keV.
- Most intense during NBI (but sometimes seen in OH phase).
- Burst intensity increases with decreasing carbon limiter recycling and edge density.
- Intensity grows and decays on time scale of stored energy, so could be pressure driven.

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Possible Generation Mechanisms?

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POSSIBLE BURST MECHANISMS REQUIRE RUNAWAY ELECTRONS - BUT HOW ARE THEY GENERATED?

- T_{rad} > 100 keV implies presence of runaway electrons.
- But electron thermal velocity ~ 0.1 x critical velocity for runaway electron generation using measured loop voltage (< 0.2 V/m).
- Could runaway electrons be accelerated by a large internal inductive electric fields?

  [Chu, Phys. Plasmas **4** 3306 (1997)]
- Could runaway electrons be accelerated/scattered by strong local electric fields generated at an internal transport barrier?

  [Bell, Invited Paper kWeaI1.02, this conference]

BURST GENERATION MECHANISMS - Cherenkov Emission

- If bursts are at frequencies below the ECE fundamental frequency, could be Cherenkov resonance with runaways.

  [Freund, Lee & Wu, Phys. Rev. Lett. **40** 1563 (1978)]

- GPC-1 should not see below ECE fundamental, so why does it measure small bursts?

BURST GENERATION MECHANISMS - Edge Turbulence

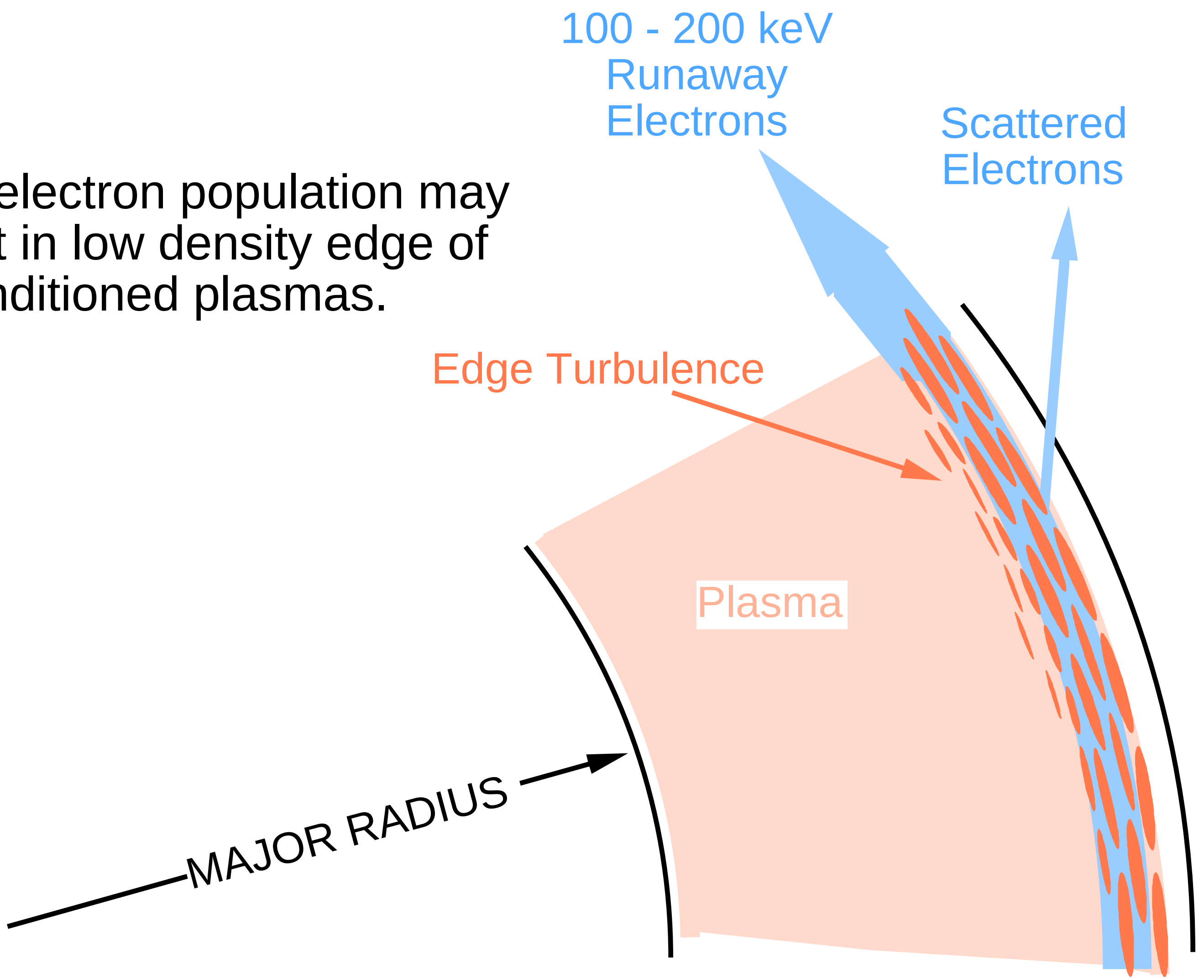
- If bursts are at frequencies above the ECE third harmonic, could be pitch angle scattering of runaways by fluctuations in the edge density.

- 20% edge density fluctuations have been measured by Beam Emission Spectrocopy (BES) in similar TFTR plasmas.

  [Fonck *et al.*, Phys. Rev. Lett. **70** 3736 (1993)]

INTENSE ECE BURSTS MAYBE DUE TO RUNAWAY ELECTRONS SCATTERED BY EDGE TURBULENCE

- Runaway electron population may be present in low density edge of lithium conditioned plasmas.



SUMMARY

- Intense bursts in plasmas with very low edge densities.
- Emission frequency either above the third ECE harmonic, where the plasma is optically thin, or below ECE fundamental.
- Evidence for the source being near the plasma edge.
- T_{rad} > 100 keV implies runaway electrons, but runaway generation process is unclear.
- Bursts most intense during NBI, possibly pressure driven.
- Bursts mechanism is not understood.