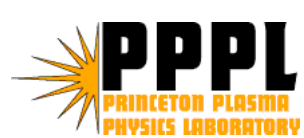
Recent Results from the Levitated Dipole Experiment

M. E. Mauel and the LDX Team

FPA Annual Meeting

September 28, 2006

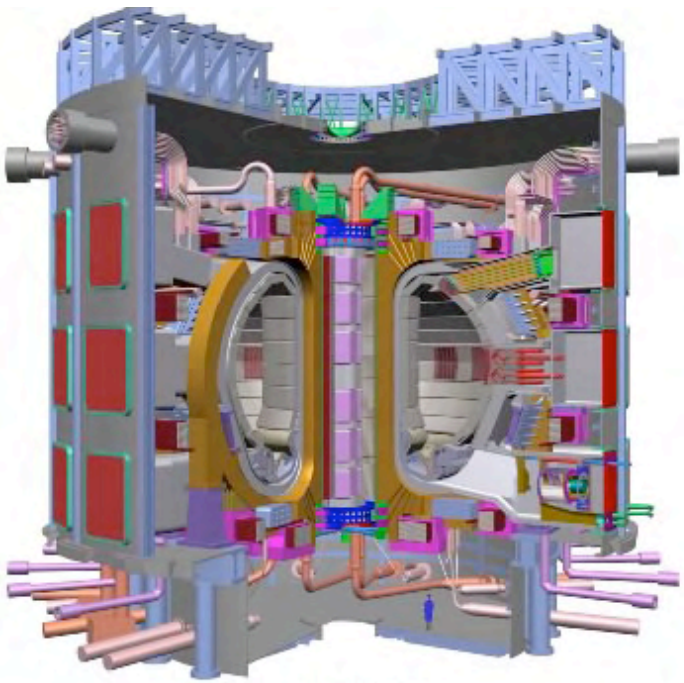


Outline

- What must be learned to establish the dipole fusion concept?
- *Our newest results:* Low-frequency fluctuations suppressed using density profile control with programmed neutral fueling.
- *Our oldest results:* Achieving and sustaining high beta equilibria by stabilizing kinetic interchange instabilities.

Dipole Fusion Concept

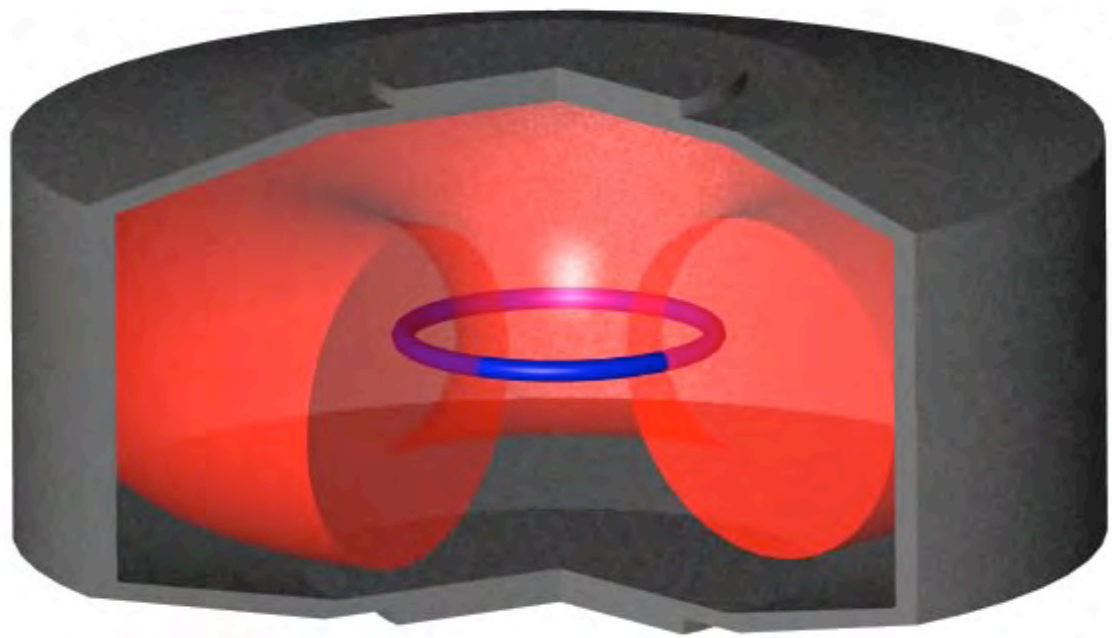
ITER



30 m

400-600 MW
DT Fusion

Levitated Dipole Reactor



60 m

500 MW
DD(He3) Fusion

Kesner, et. al. Nucl. Fus. 2002

Dipole Fusion Concept

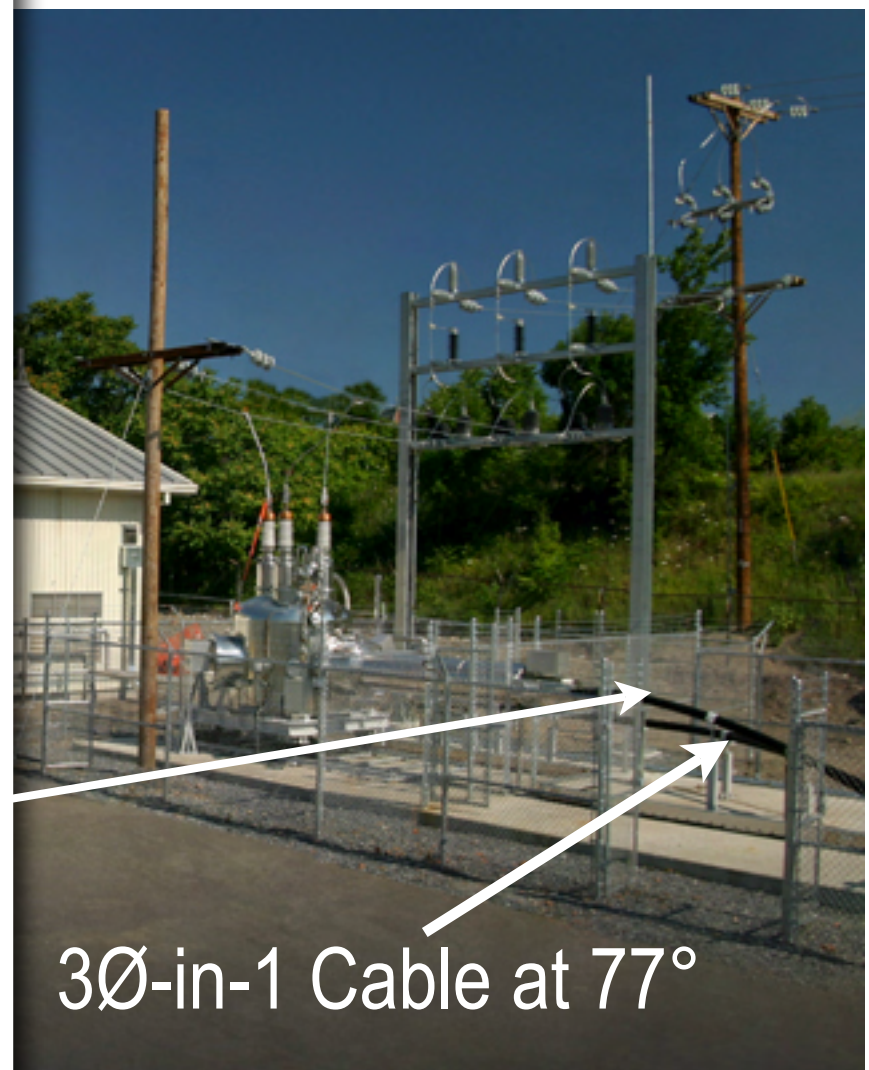
- Advanced fusion fuel…
  - D-D (^{3}He) with active triton removal
  - No tritium breeding; simplified fusion technology
- Requires…
  - High plasma beta
  - Good plasma energy confinement
  - Poor particle (*i.e.* triton) confinement
  - High-field, high-temperature superconductors

Albany Cable Project: 48MVA using 350 m BSCCO

DOE Funding = $4.5M/year

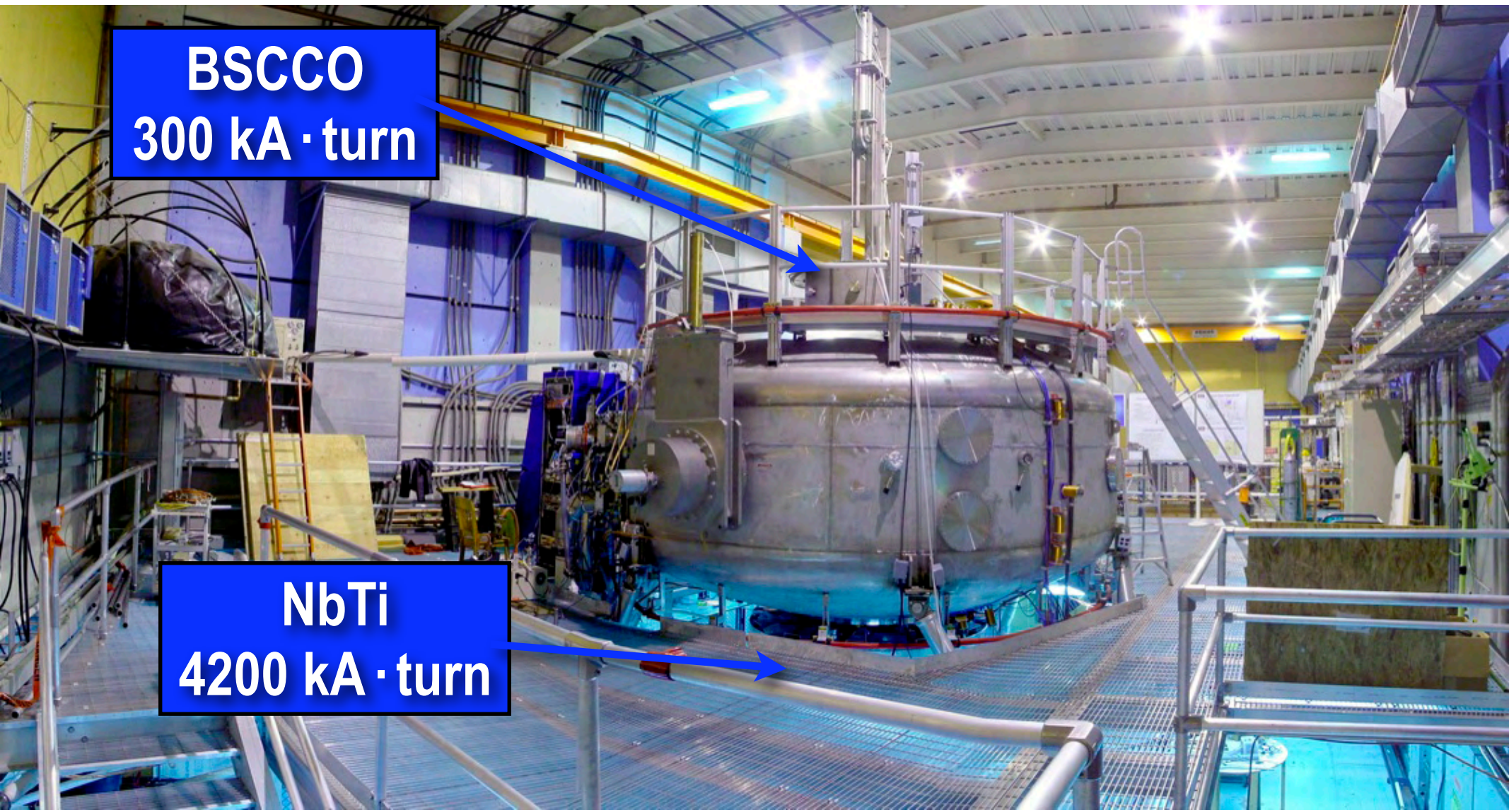
SuperPower Inc. SUMITOMO ELECTRIC BOC nationalgrid NYSERDA

sing 350 m BSCCO & 30 m YBCO!!!

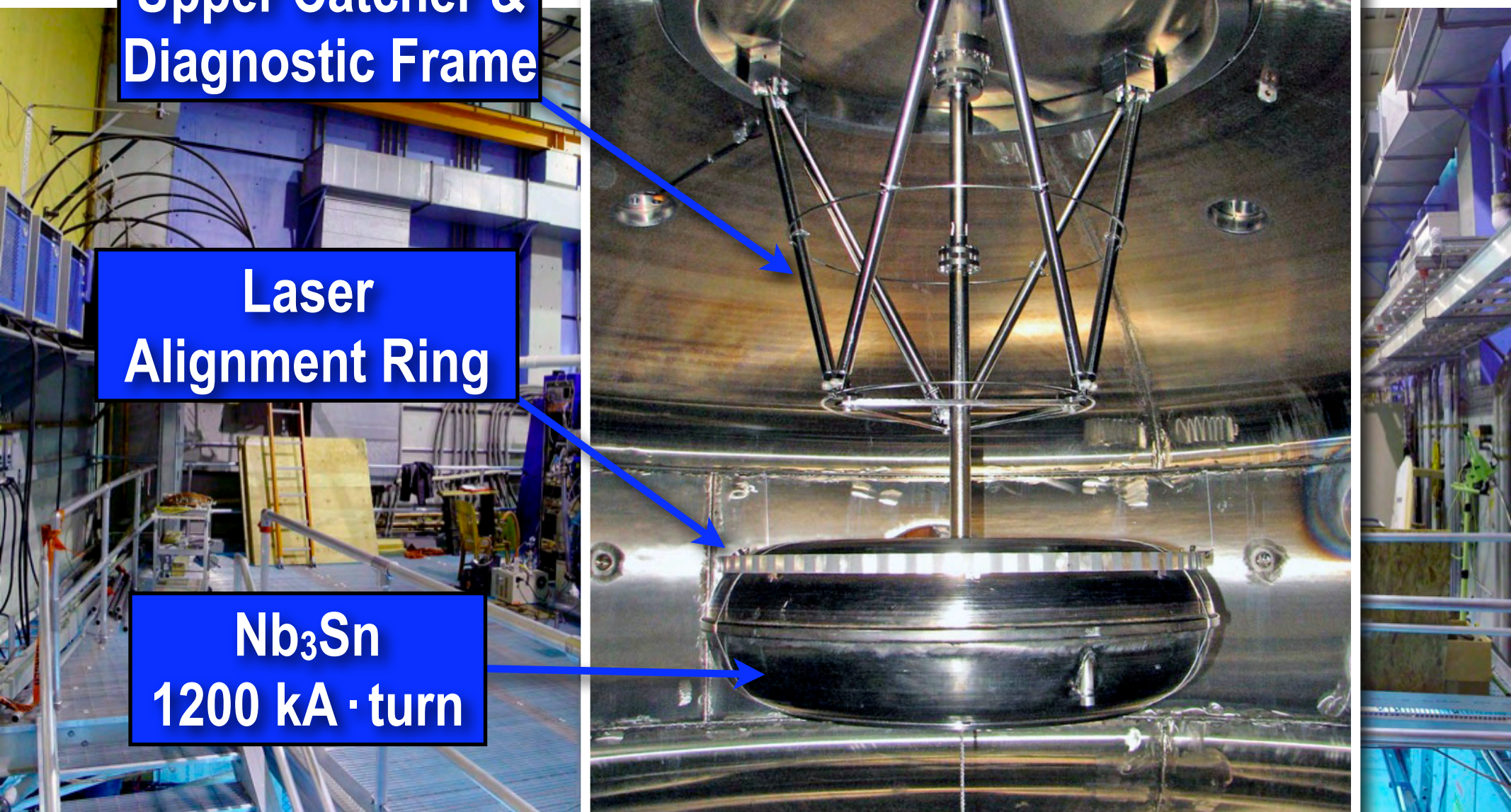


Same conductor as used in Kesner, et al. (2002)

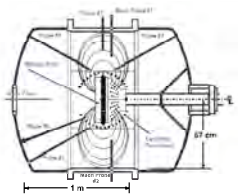
Levitated Dipole Experiment



Levitated I t



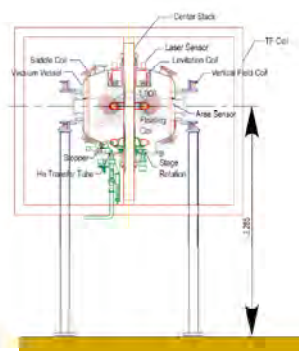
Today's Dipole Experiments



Investigate Instability- or Electrostatically-Driven Interchange Mixing

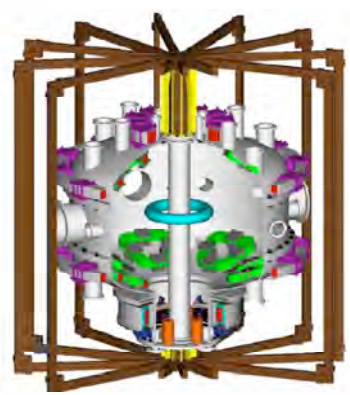
CTX (Columbia)

150 kA turns
(Not Levitated)
0.15 m



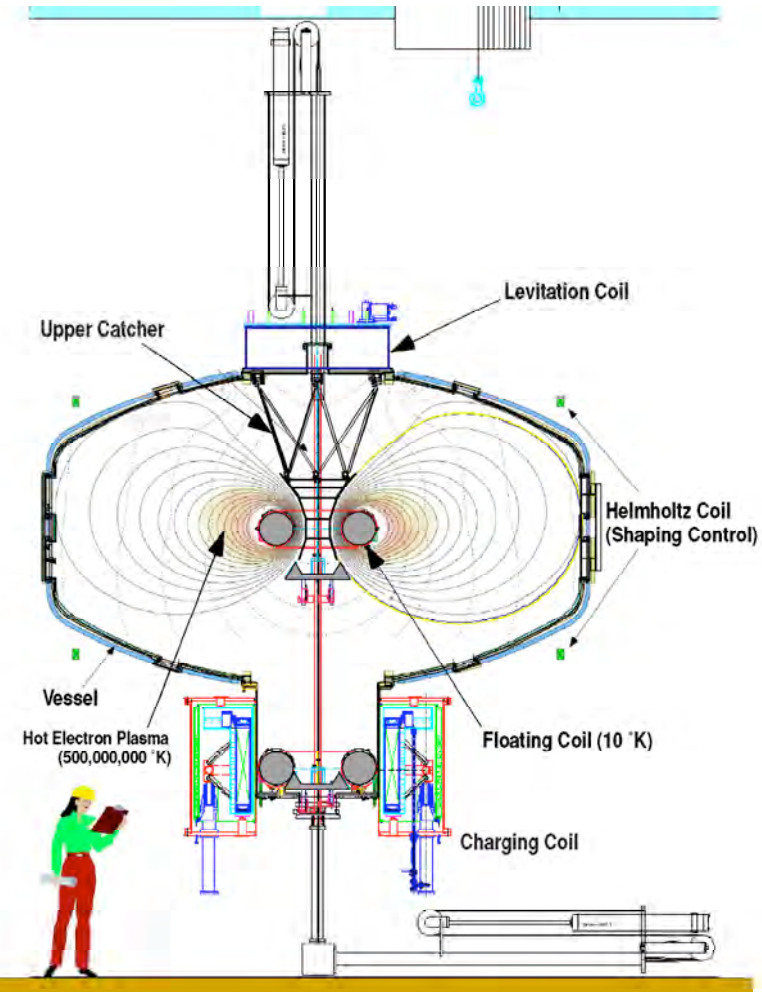
Mini-RT (Univ. Tokyo)

50 kA turns
17 kg
0.15 m



RT-1 (Univ. Tokyo)

250 kA turns
110 kg
0.25 m



LDX (Columbia-MIT)

1200 kA turns
565 kg
0.34 m

Test Beltrami Physics

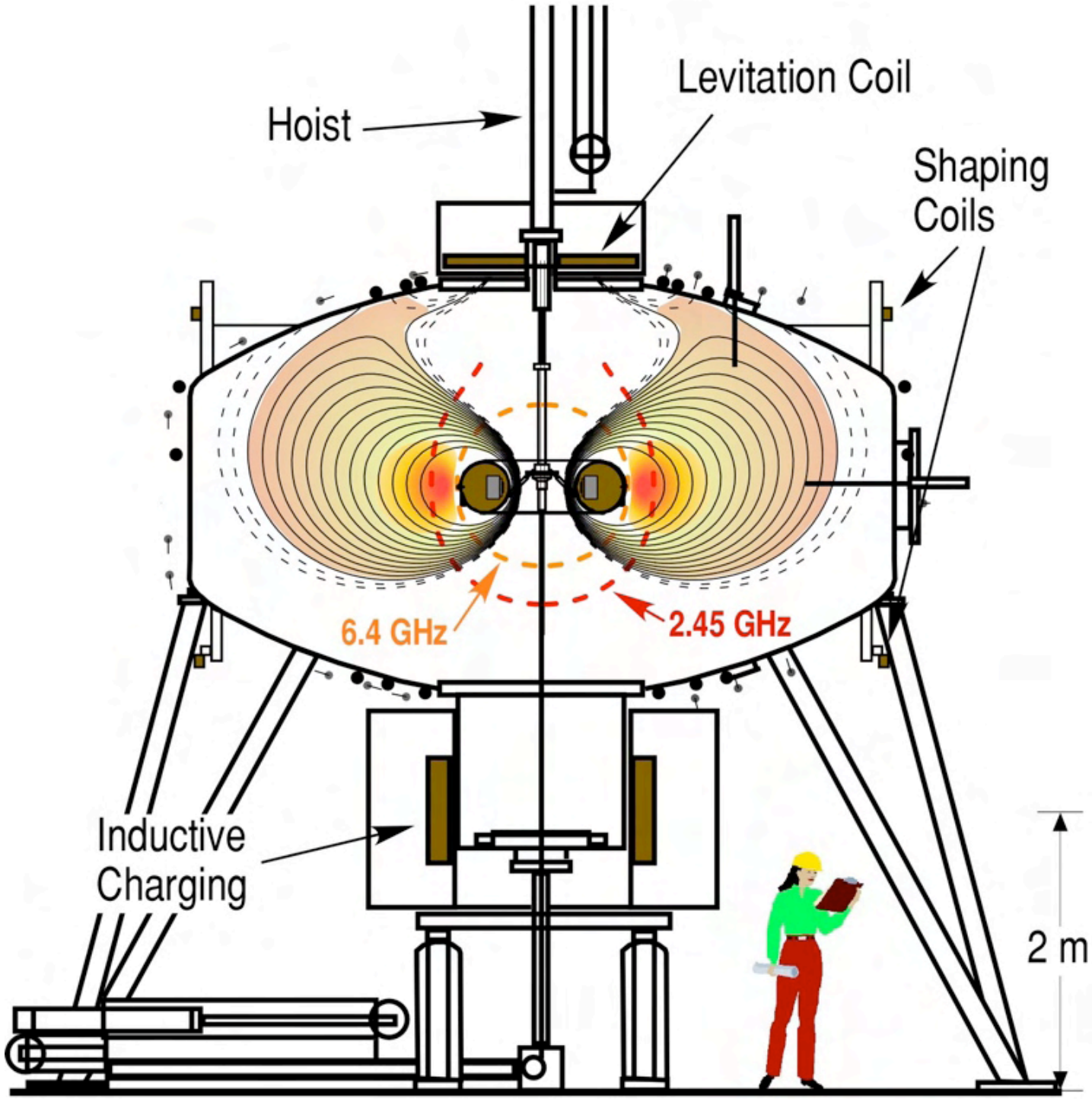
Test Fusion-Dipole Physics

Our Newest Results

1. Create long-pulse (10 s) high-beta (20% local) plasma in "**levitated**" magnetic geometry.

2. Using transient fueling to alter density profile.

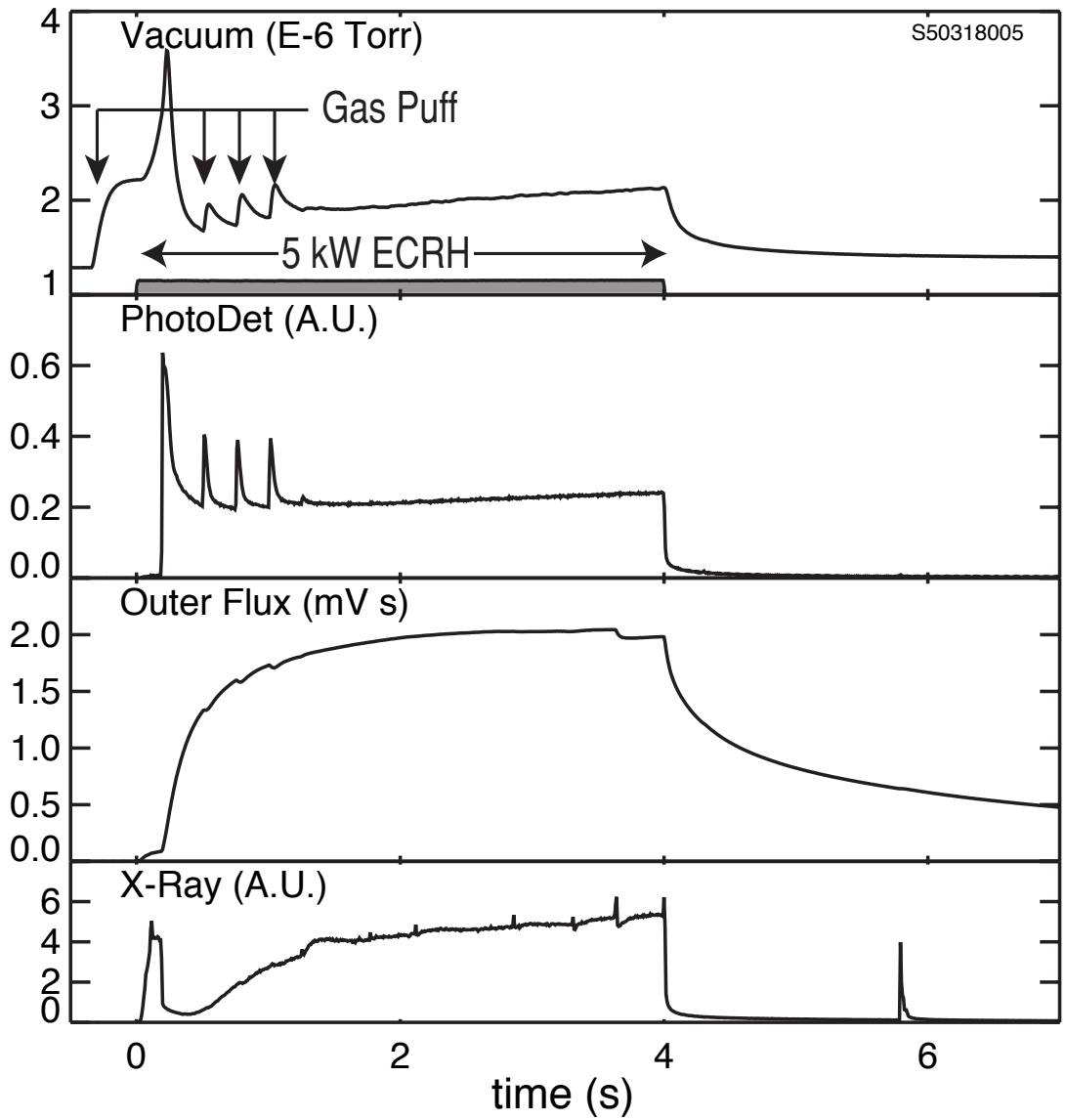
3. Observe coherent low-frequency fluctuations that can be altered or suppressed with changing profiles.


Hoist
Levitation Coil
Shaping
Coils
6.4 GHz
2.45 GHz
Inductive
Charging
2 m

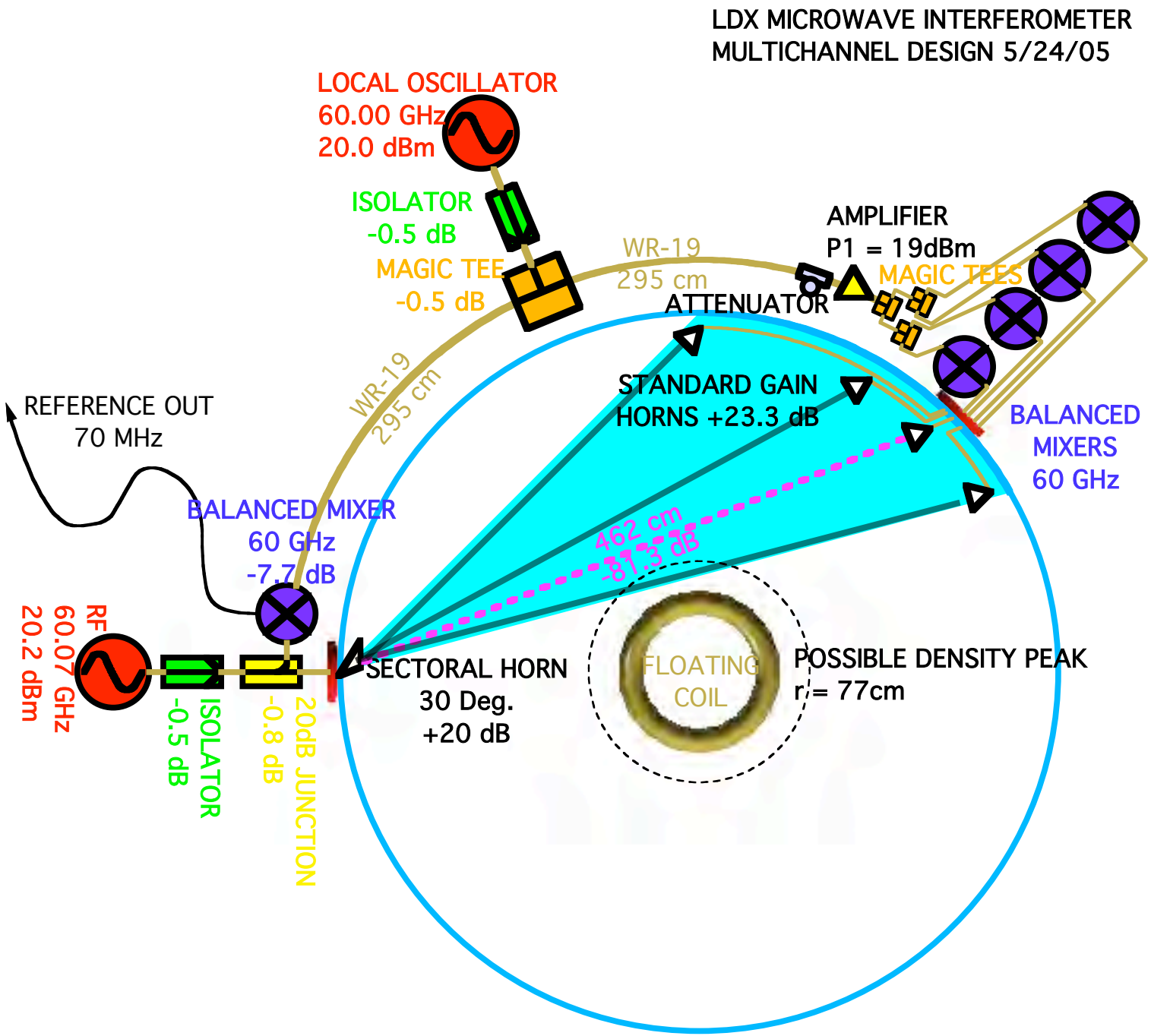
Controlling the LDX Discharge: Gas & Multifrequency ECRH

- ECRH: 2.45 & 6.4 GHz; Up to 5 kW total power
- Pulsed or continuous D_2 fueling
- 2 mV · s represents 3 kA of plasma current; W_p ~ 300 J; β_{peak} ~ 20%

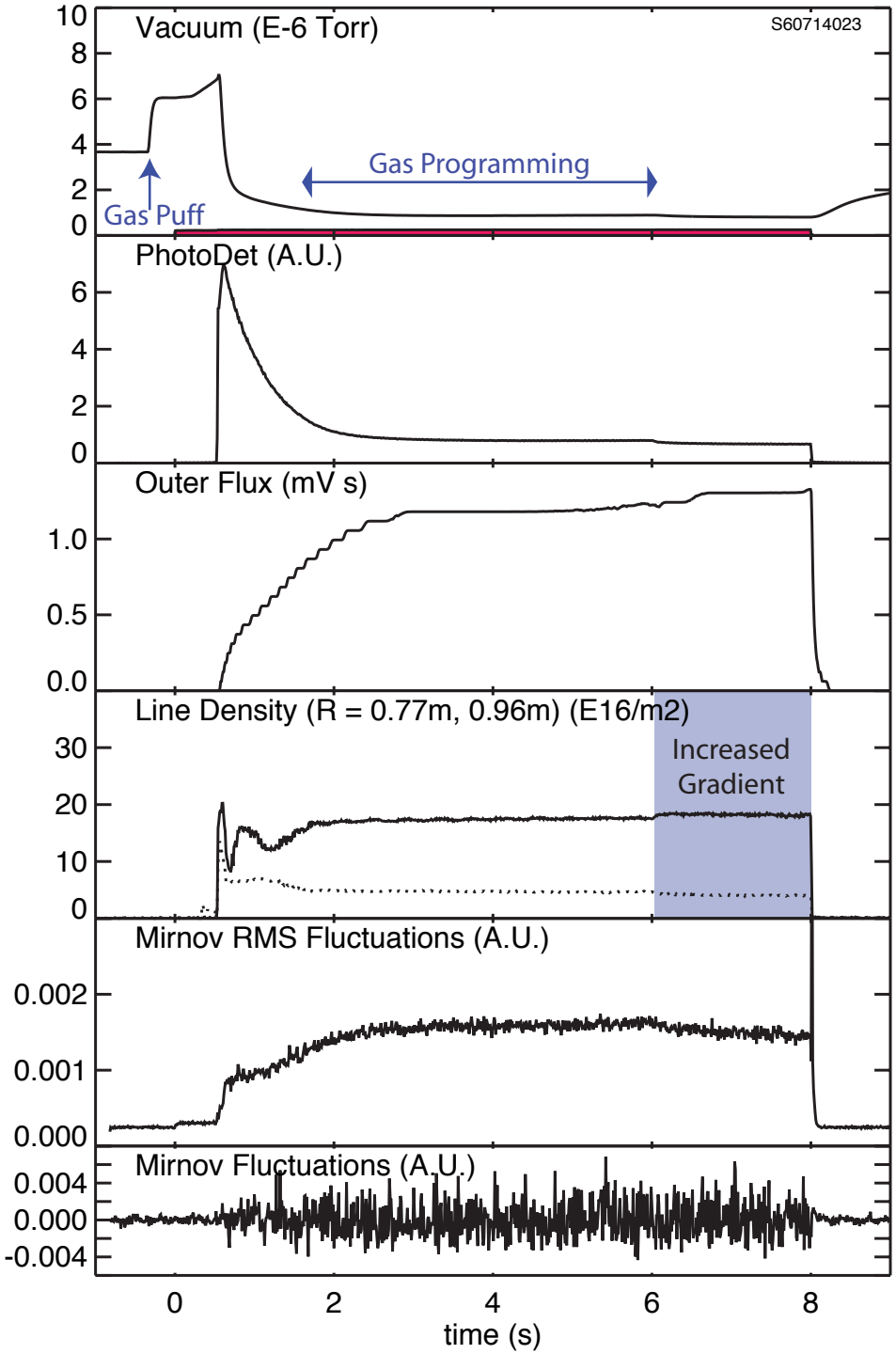
(More later…)

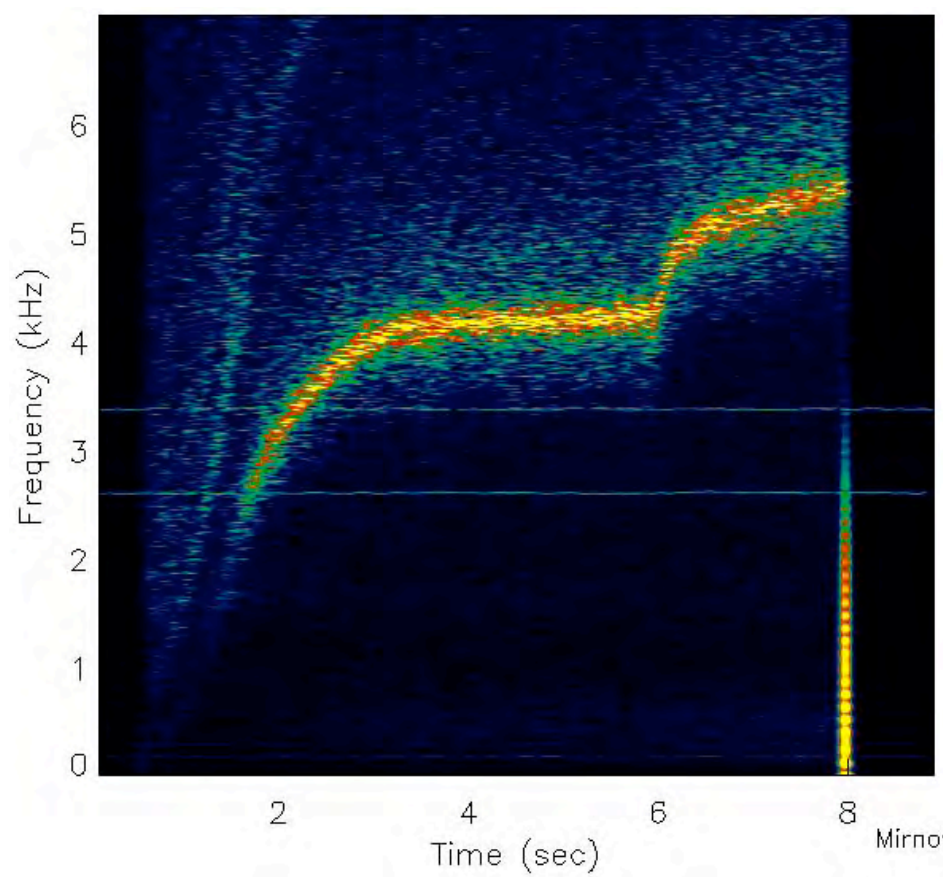


New 4-Channel Interferometer

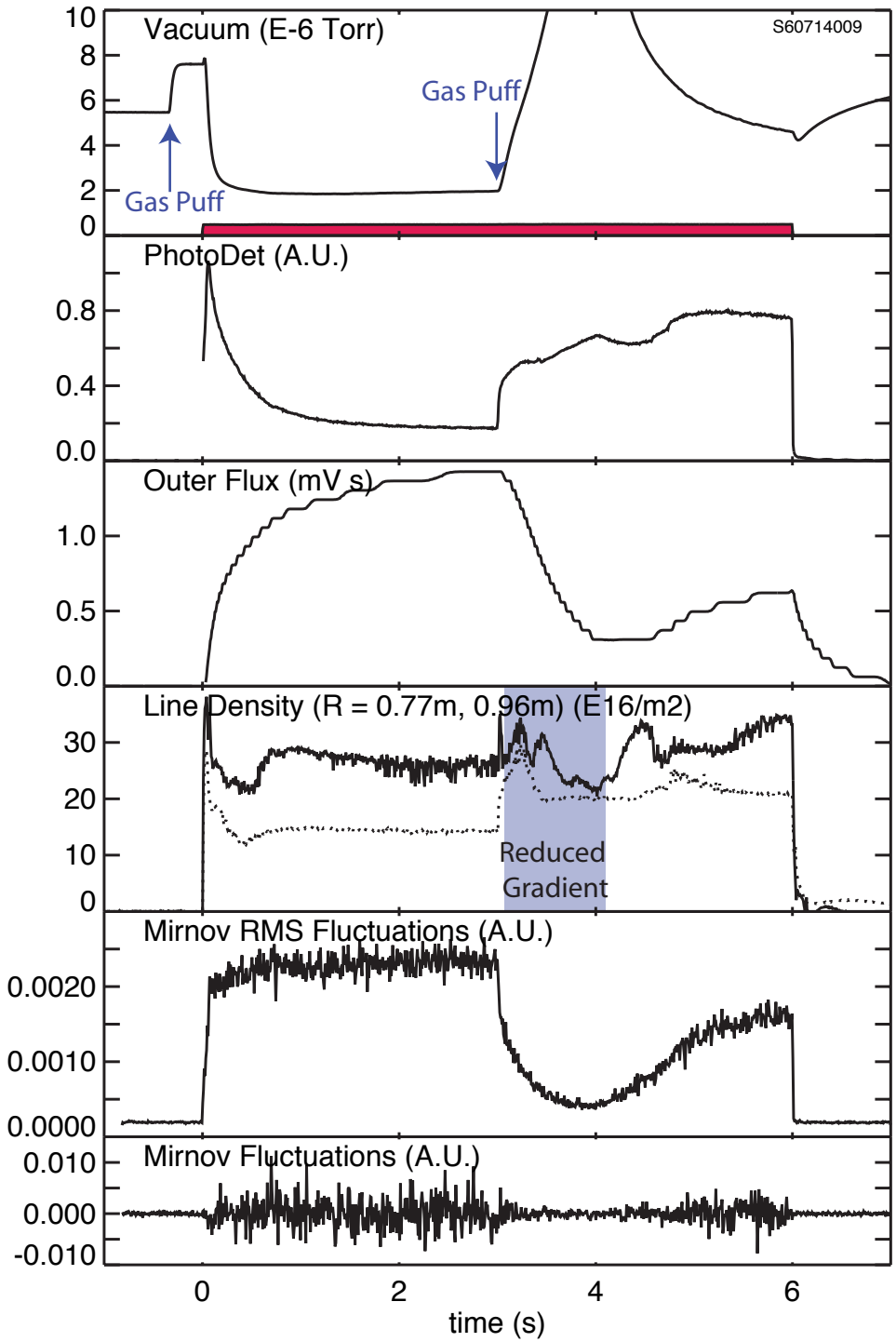


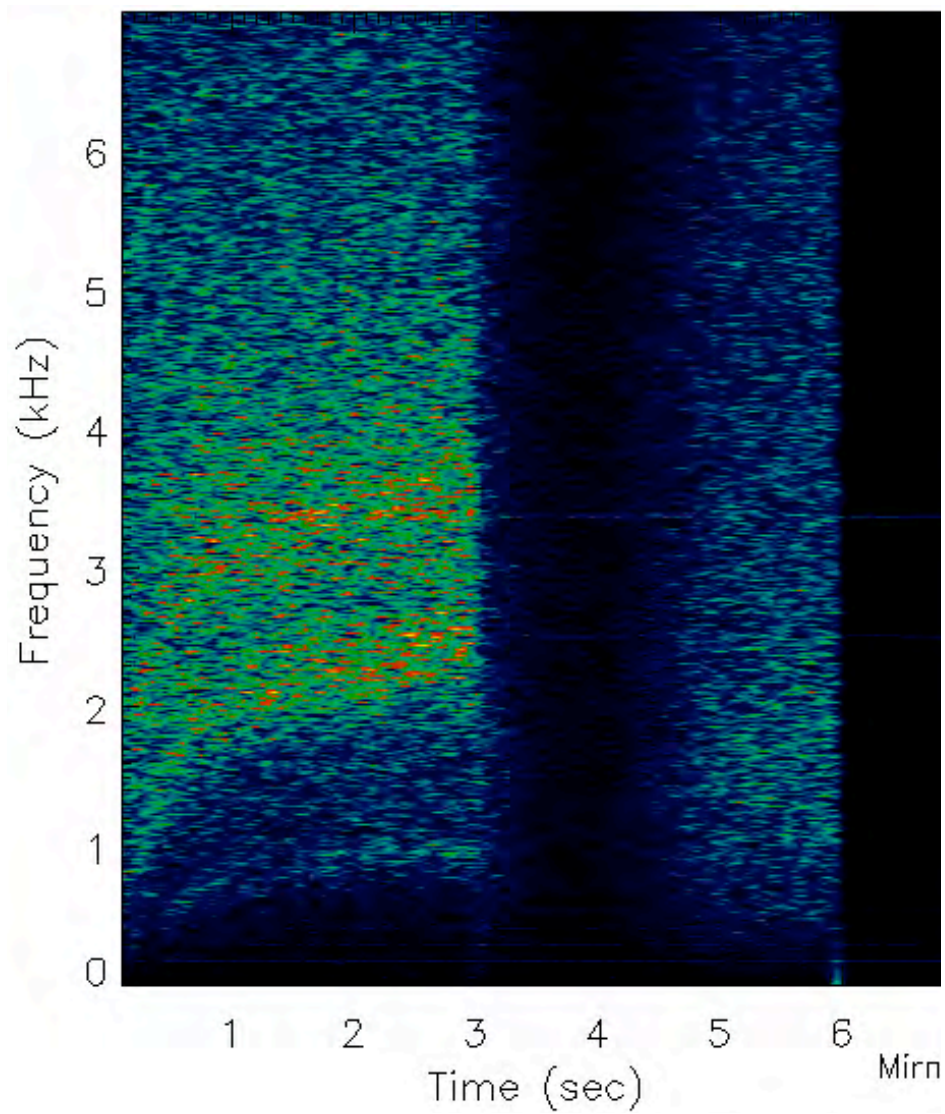
Low Frequency Fluctuations Modified by Density Gradient





Coherent Fluctuations Suppressed with Flatter Gradient





Our Oldest Results

(2 years old)

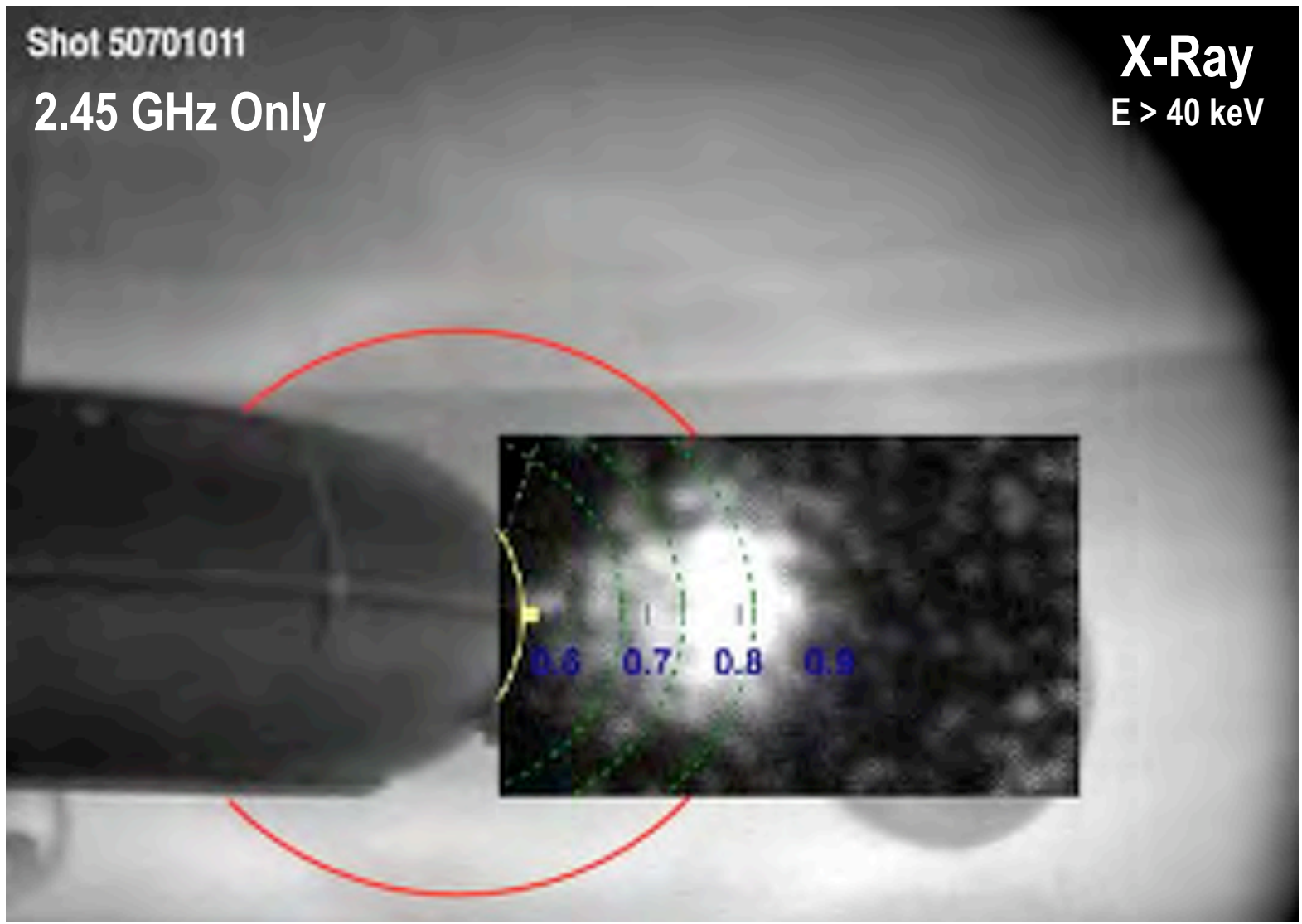
1. Inject 5 kW of multiple-frequency ECRH power to create and sustain long-pulse discharges.

2. Program neutral fueling rate to stabilize kinetic interchange instability.

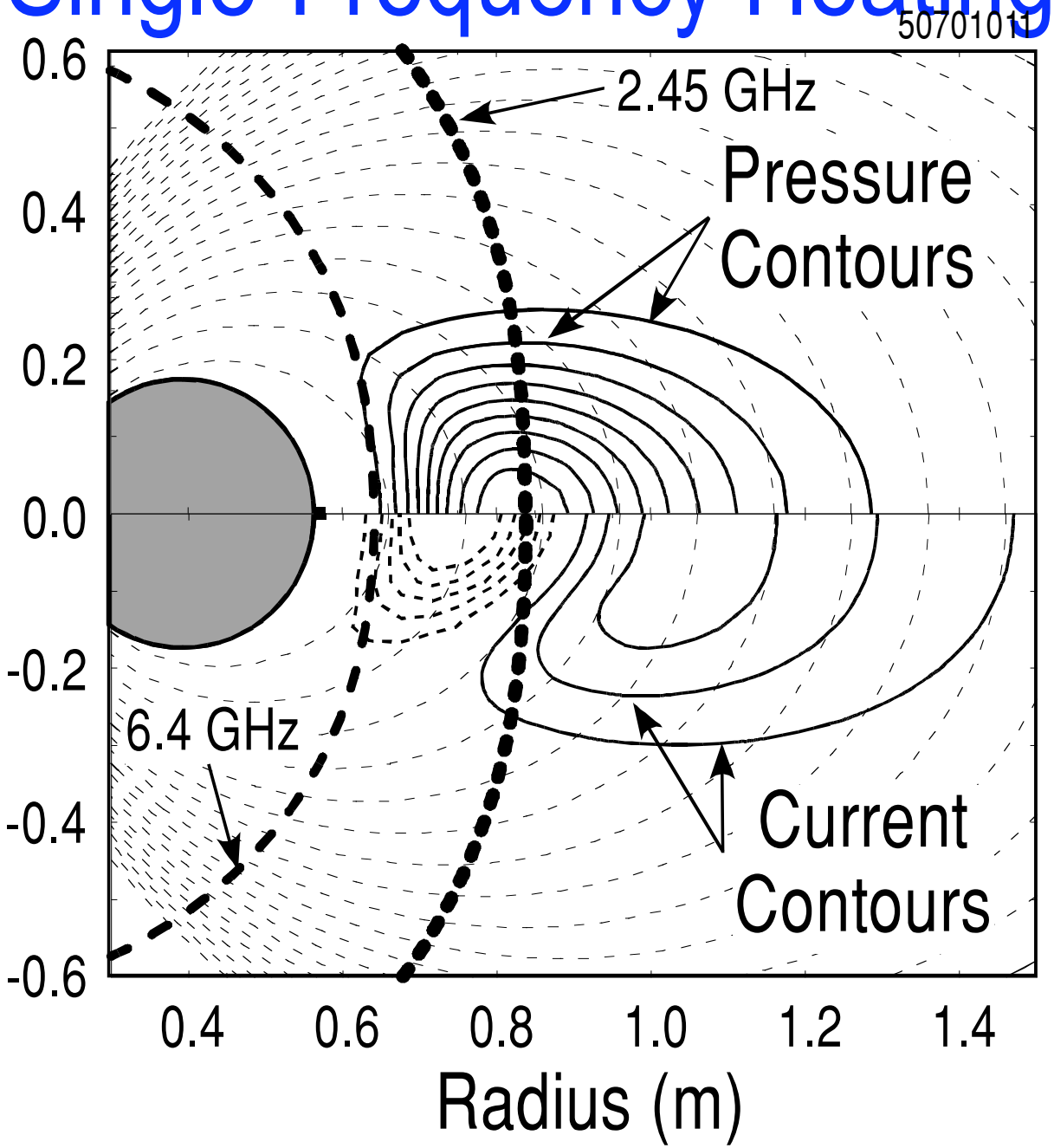
3. Observe and study properties of high-beta equilibria generated by anisotropic ~ 150 keV trapped electrons.

Long pulse high beta plasma achieved on our first shot!!!

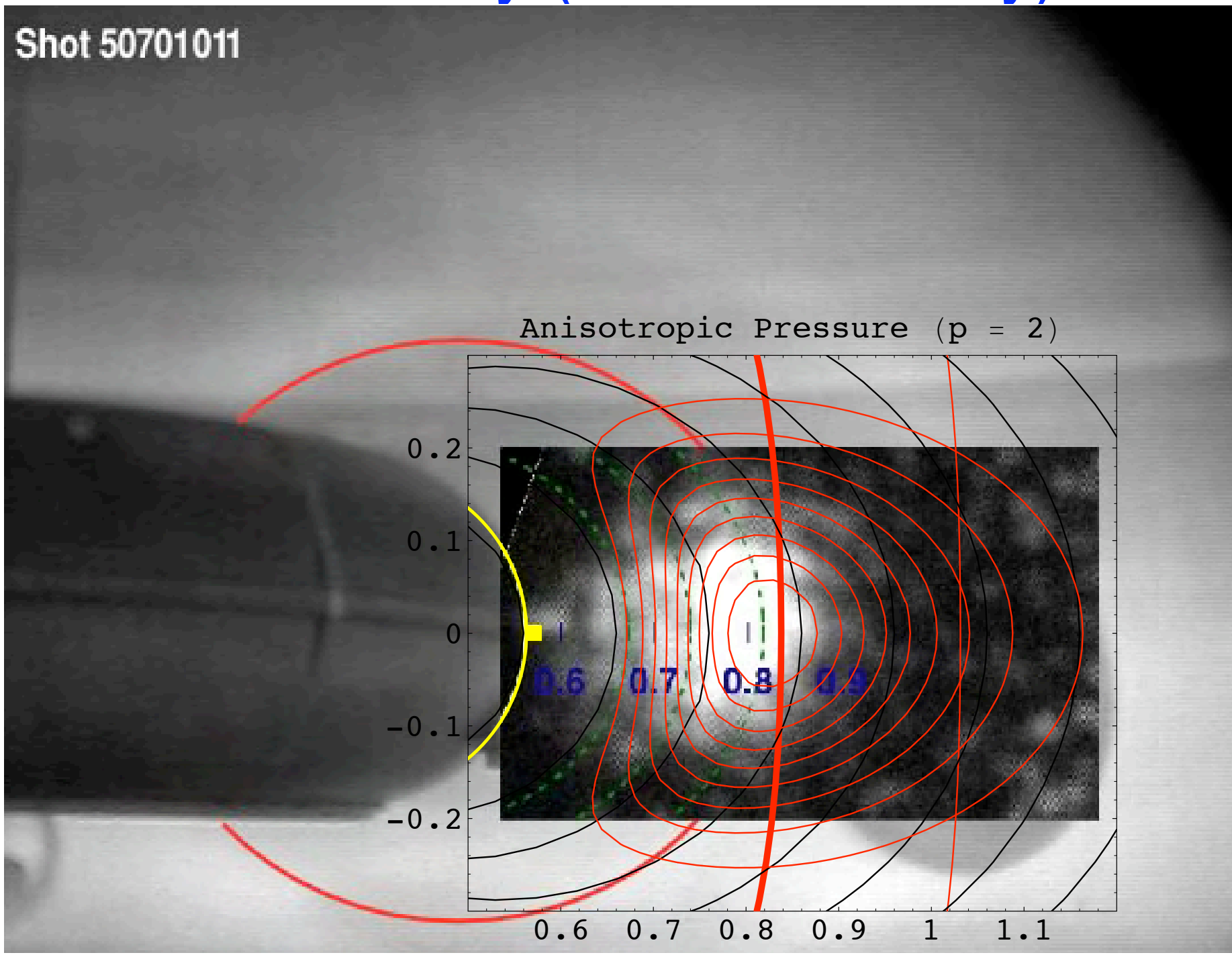
X-Ray Measurement of Fast Electrons Constrain Equilibrium



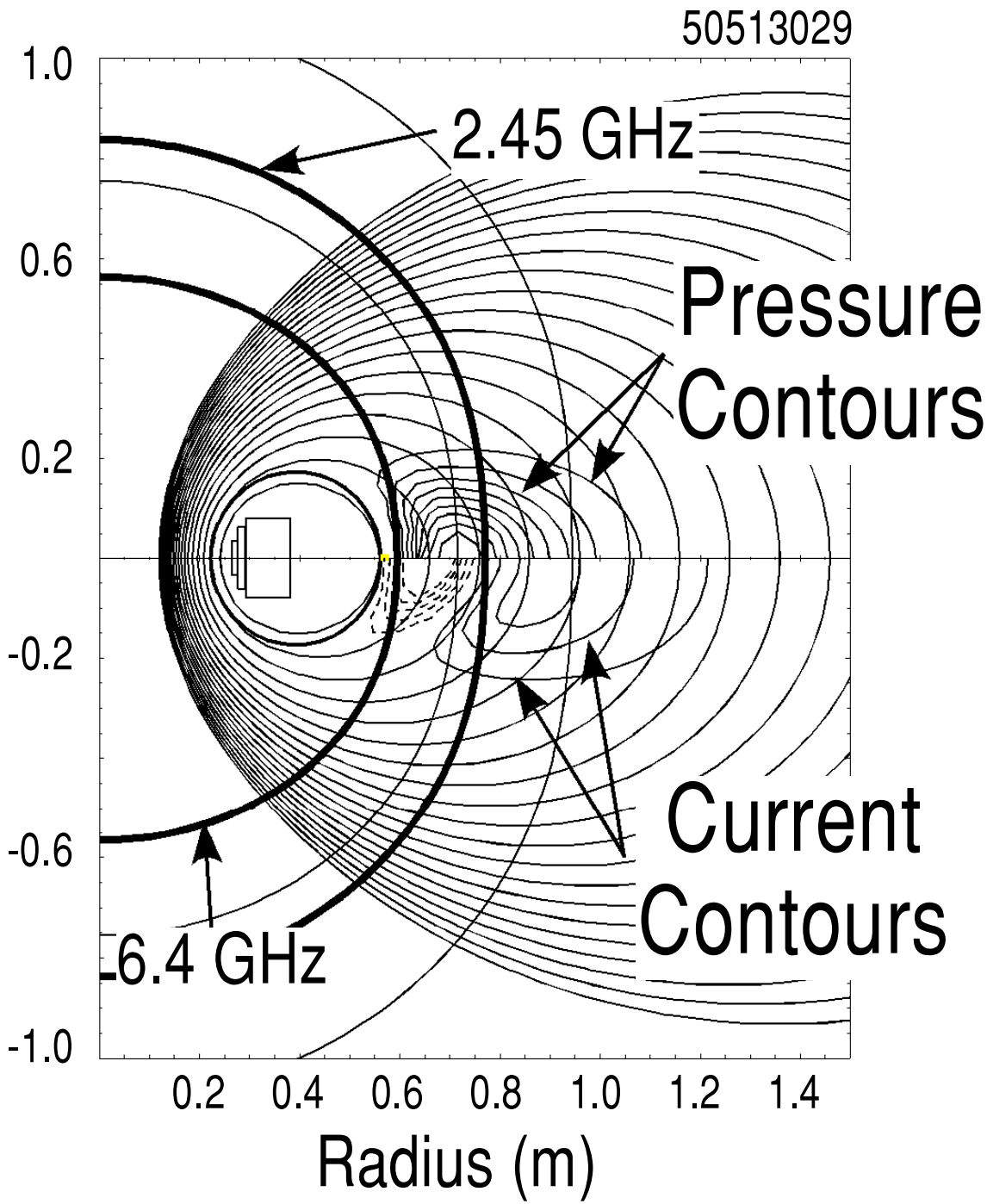
Best Fit Equilibrium for (2.45 GHz) Single-Frequency Heating



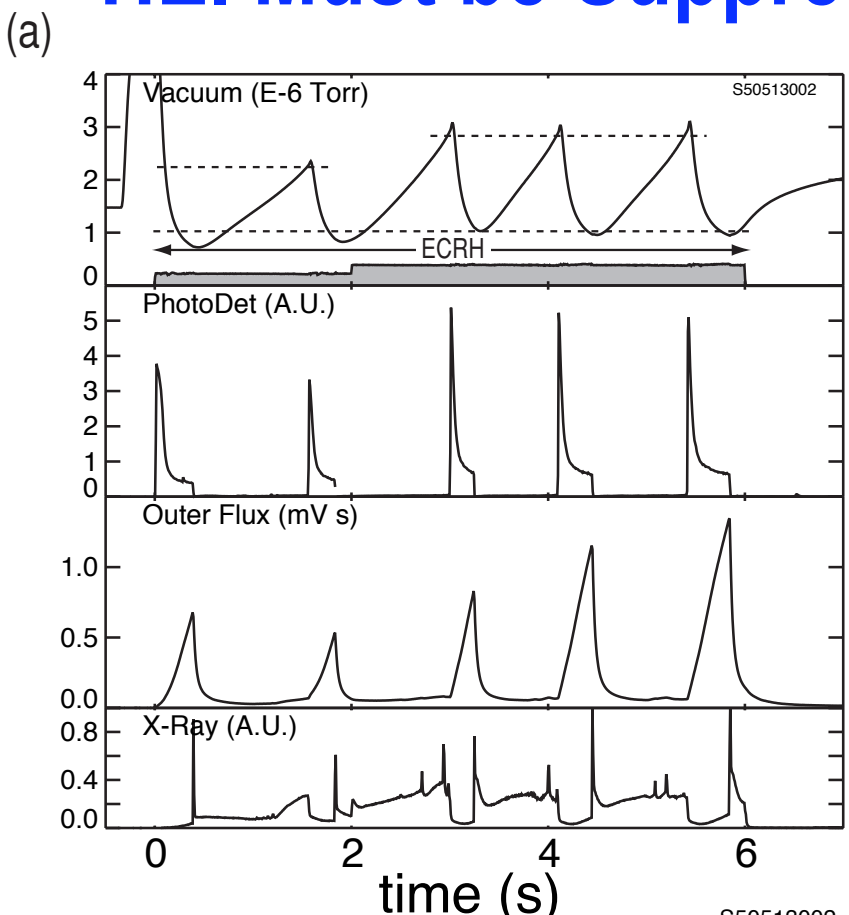
Fit Summary (2.45 GHz Only)

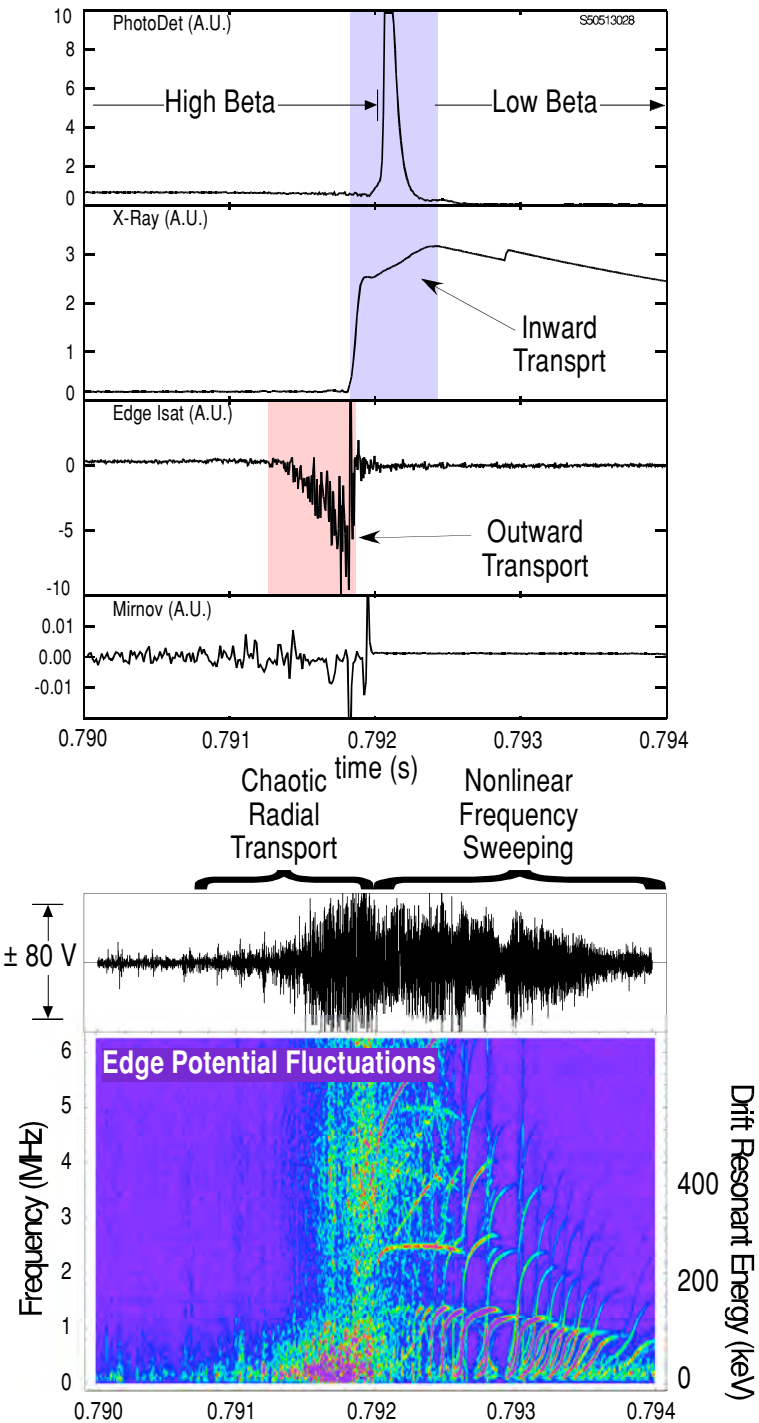


Best Fit Equilibrium for β_{peak} > 20% using Multi-Frequency Heating



HEI Must be Suppressed to Reach High Beta

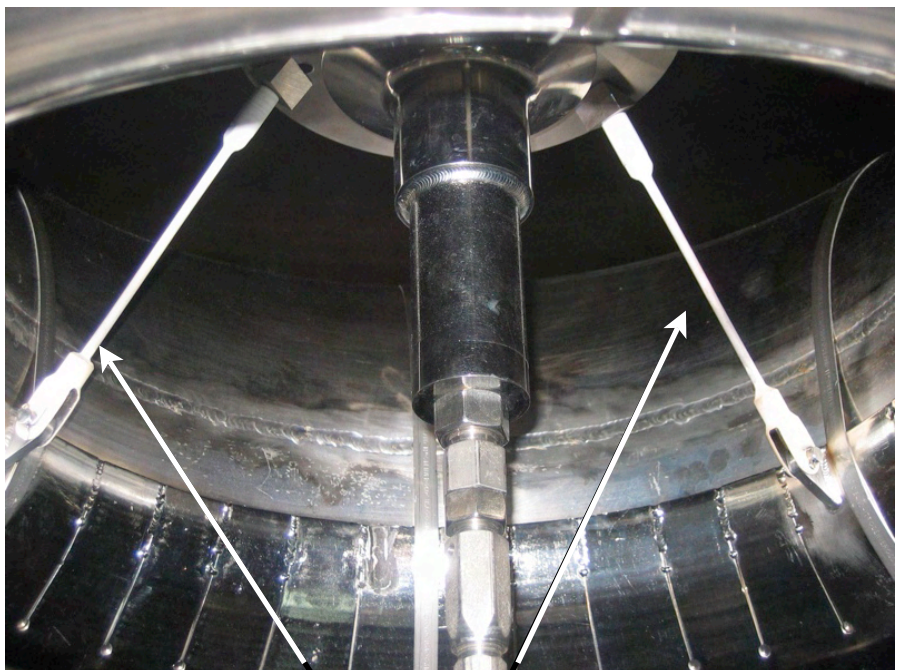




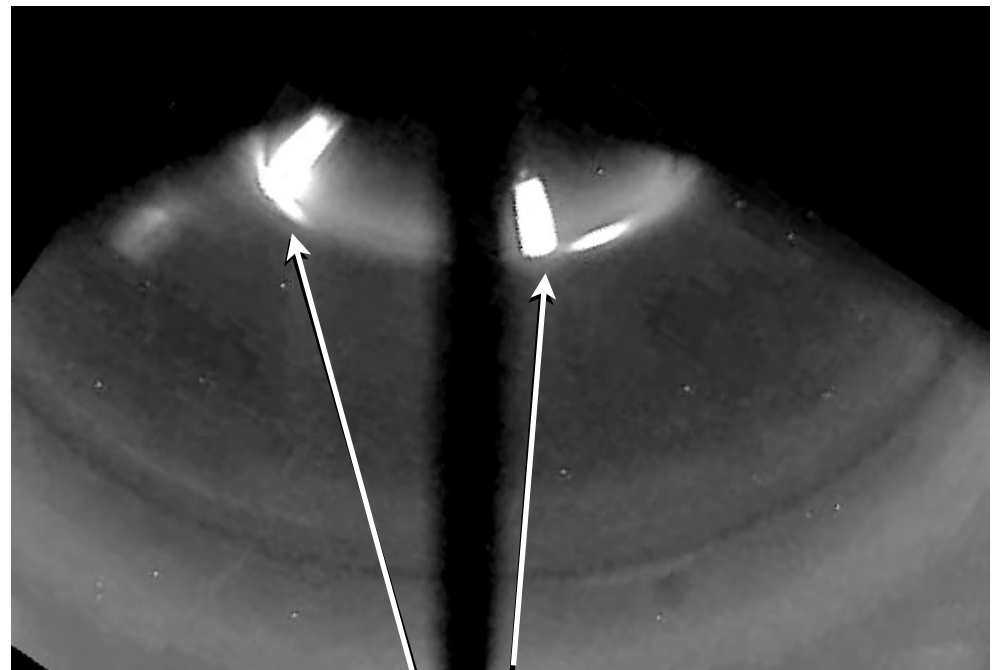
Summary

- Dipole concept offers fusion an alternate technology path: HT_c superconductors; no tritium breeding; simplified fusion materials.
- Requires high beta, good energy confinement, poor triton particle confinement.
- LDX is the world's only device exploring the basic physics for dipole fusion. First results:
  - Steady high beta equilibria with HEI stabilization
  - Fluctuations suppressed with density profile modifications

Thin Supports were a Major Power Loss…



Three high-strength, alumina-coated spokes support dipole during Phase I experiments



Supports become “warm” during high-beta plasma operation

Elimination of supports, next step, will further enhance confinement, density, …

Levitation…

- ✓ All equipment on hand
- ✓ Integrated magnet test complete
- ✓ Laser detection of floating dipole tested during plasma ops
- ✓ RT active control system tested
- ➡ "Drop test" of safety catcher underway