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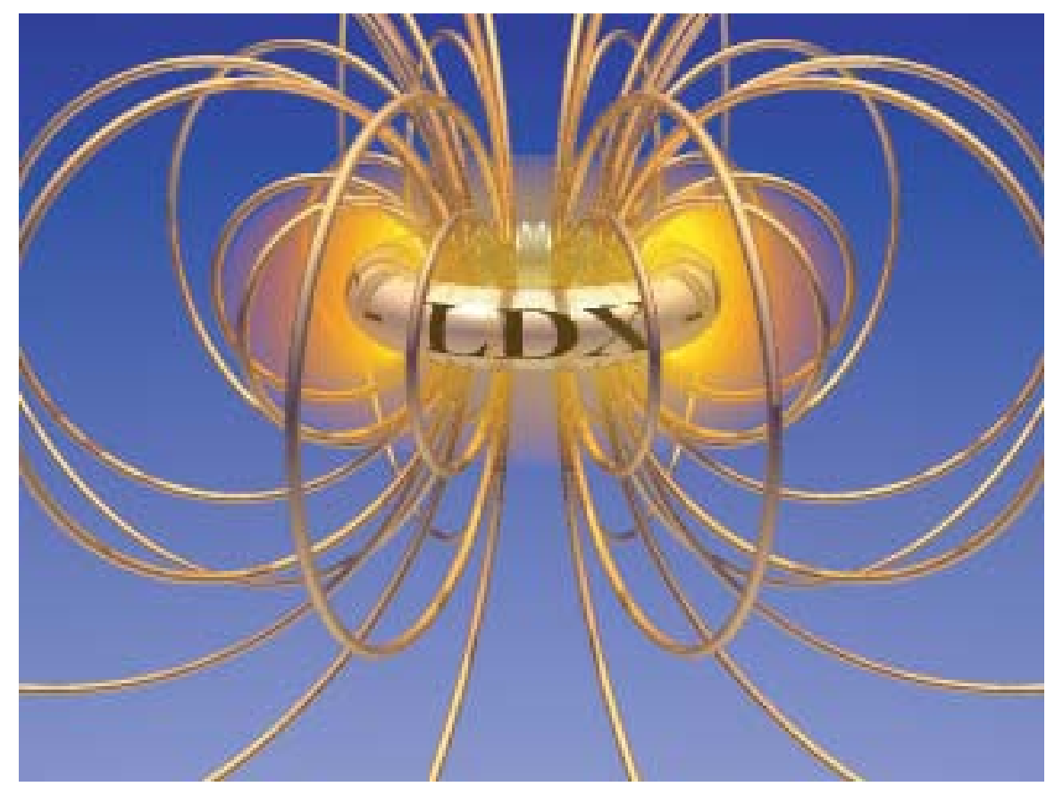

Plan for first plasmas in LDX

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Abstract

Initial experiments on the Levitated Dipole Experiment (LDX) will establish reliable operation of the superconducting coils during plasma experiments and to provide a physics baseline for succeeding experimental phases. Initially the dipole coil will be mechanically supported rather than levitated. A glow discharge cleaning system will be installed to remove impurities before first plasma and between experimental operations. Hot electron plasmas will be produced with ECRH: 3 kW at 6 GHz with additional sources to be added soon afterwards. Shaping coils will be employed to modify the equilibrium. The base diagnostic set includes: external magnetics for equilbrium reconstruction, internal Mirnov coils for fluctuation measurements, electrostatic probe arrays for fluctuation measurements, emissive probes for potential and biasing studies, X-ray pulse-height analyzers for energy spectra, an X-ray imaging camera (provided through a PPPL collaboration) to investigate X-ray asymmetries, and a microwave interferometer for density measurements, including drift wave stability studies.

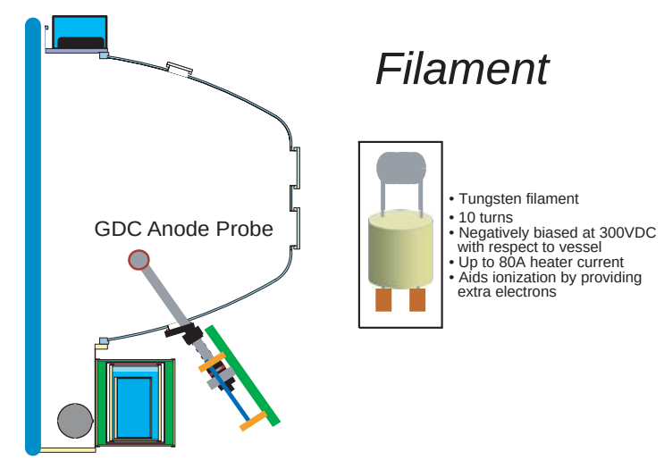
This work is supported by U.S. DOE Grants DE-FG02-98ER54458 and DE-FG02-98ER54459

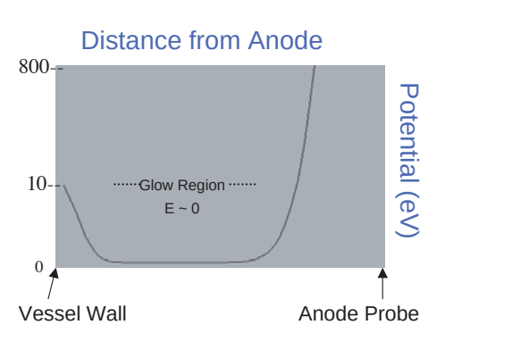
Glow Discharge Cleaning will be Used to Maintain Clean Conditions

GDC Anode Probe

GDC Anode Probe on Vacuum Vessel (Temporary Orientation)

Probe inserted Into Vacuum Vessel (Final Orientation)





~10eV potential at vessel wall ionizes impurities on the wall

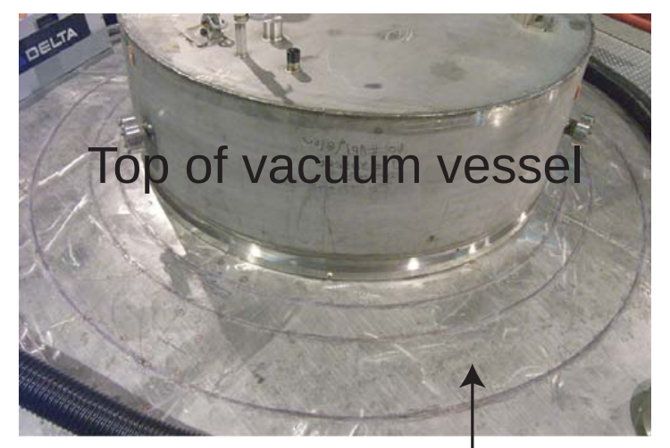
- The glow discharge system will be used:
  - Before first magnetized plasma operation.
  - Between discharges during normal operation, as needed.
  - Overnight between run days.

In addition to cleaning, glow discharge plasmas will allow testing of some diagnostics.

- Electrostatic probes
- Visible camera

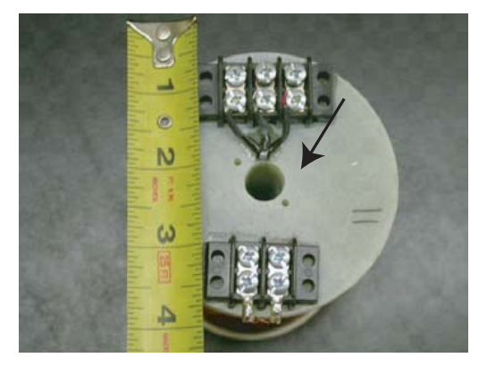
We will have Magnetic Measurements for Both Equilibrium and Fluctuations

Side View of Pickup Coil



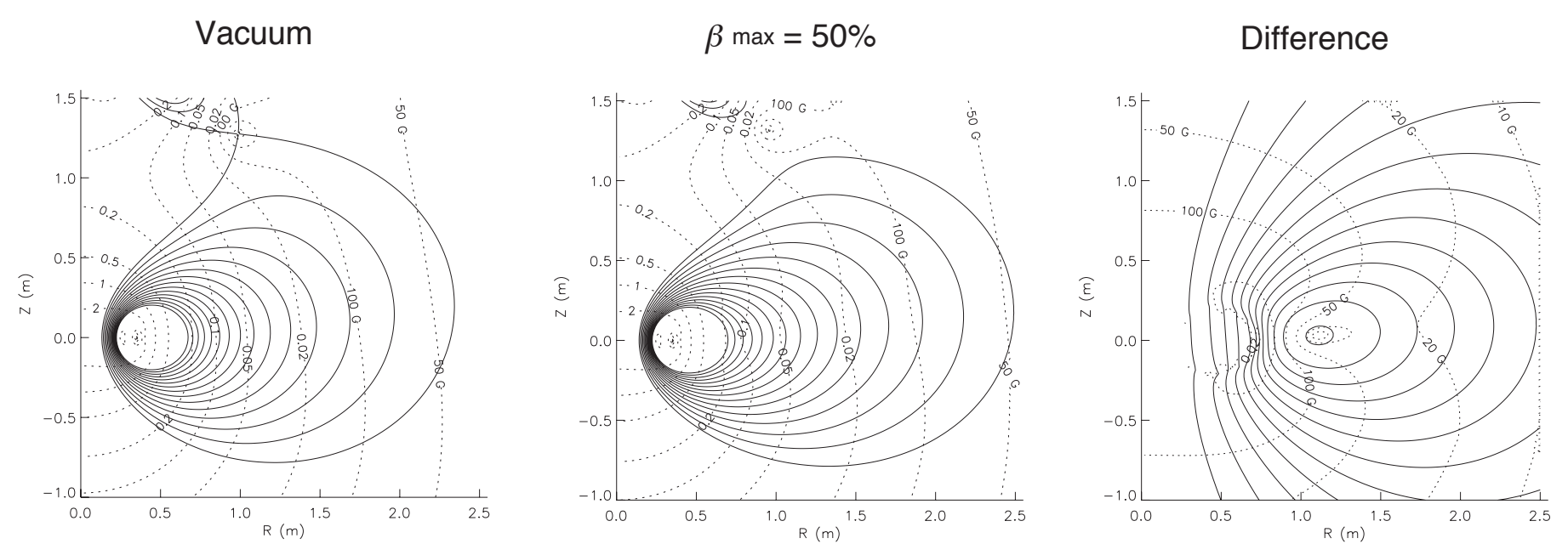
Flux Loops

Top View of Pickup Coil with Hall Probe



- Equilibrium Magnetics
  - Flux loops (9)
  - Pickup coils
    - 9 tangential
    - 9 normal
    - Forms also have Hall probes attached.
  - Mounted outside the vacuum vessel.
- Fluctuation Magnetics
  - Pickup (aka Mirnov) coils [8].
    - Bandwith?
  - Installed inside the vacuum vessel.

Example of Equlibrium Reconstruction



Mirnov Coil

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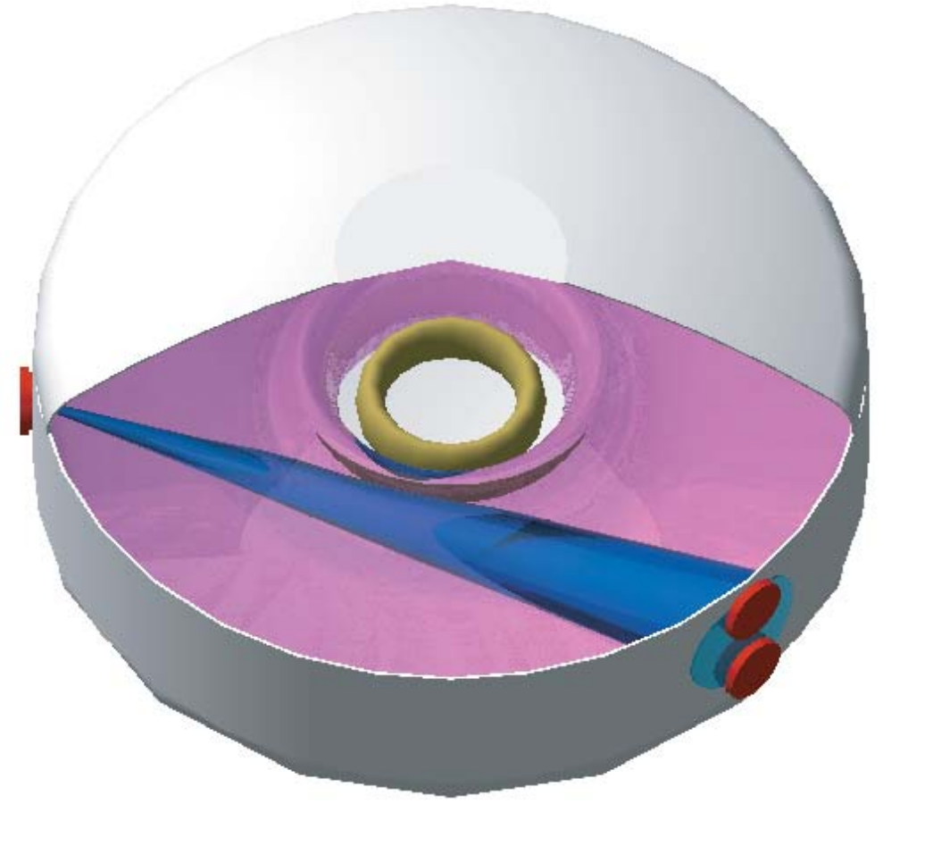
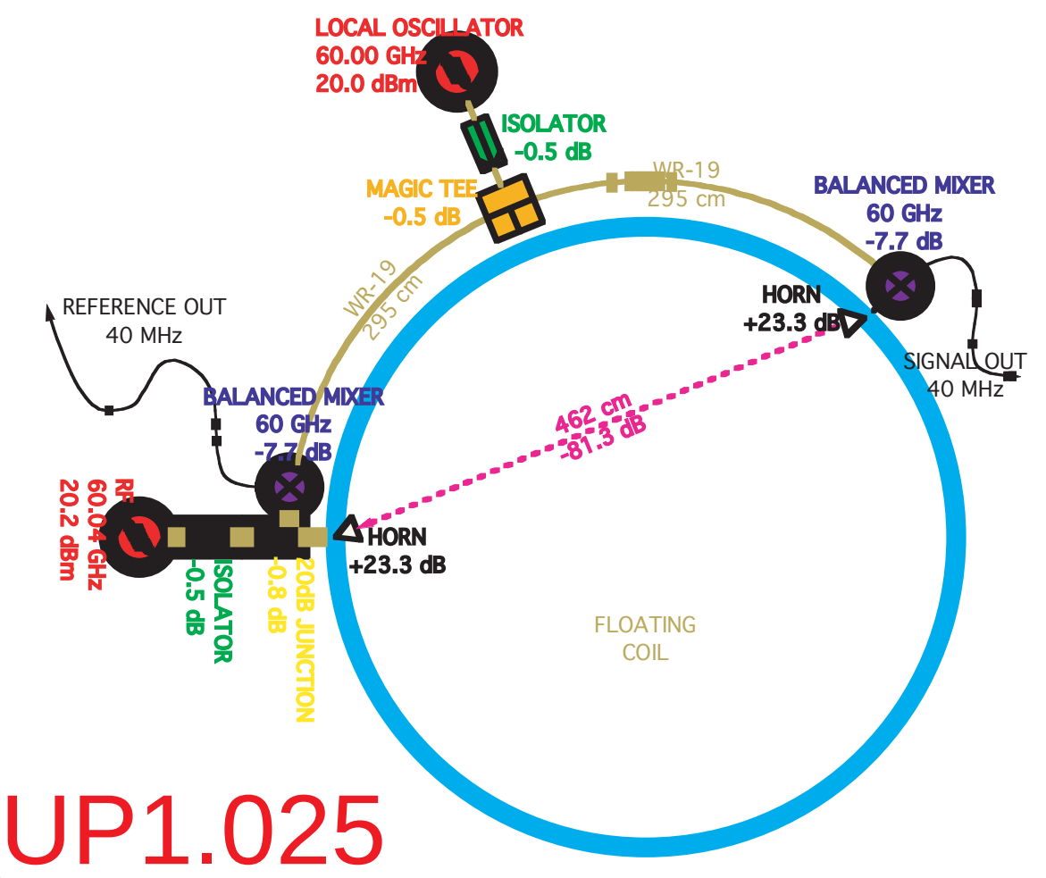
A Microwave Interferometer will Measure the Electron Density

Cutaway View of LDX, Showing Lines of Sight for the Microwave Interferometer



- A density profile measurement is important for LDX.
  - The density can vary by orders of magnitude between its peak value and the plasma edge.
  - Knowledge of the density profile is necessary to understand the stability of low frequency drift modes.
    - This also requires knowing the temperature or pressure profile.
- We are constructing a multichannel microwave interferometer.
  - center frequency of 60GHz
  - Initially we will use a one-channel superheterodyne interferometer, with two free-running Gunn oscillators.
    - Once it works, we will add channels

Block Diagram of Interferometer Setup



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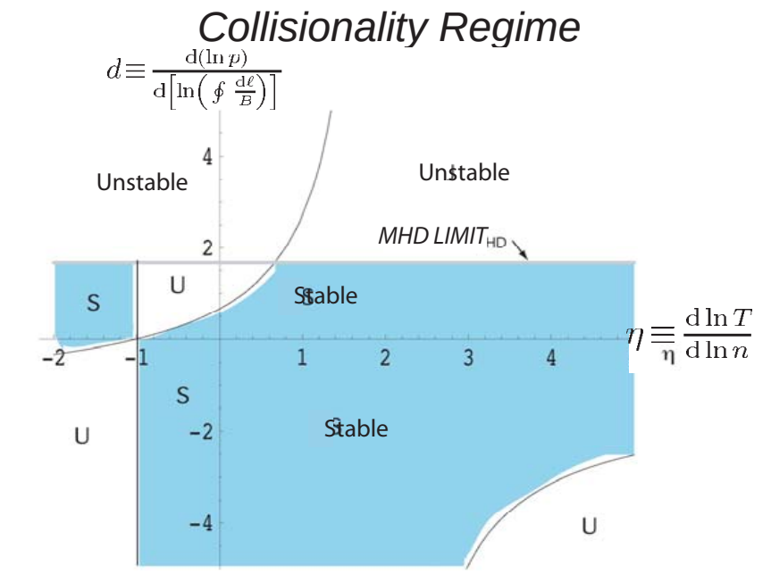
Stability of Drift Modes in LDX-Relevant Collisionality Regime



From Kesner, J. and Hastie R. J., *Phys. Plasmas* **9**, 395, (2002).

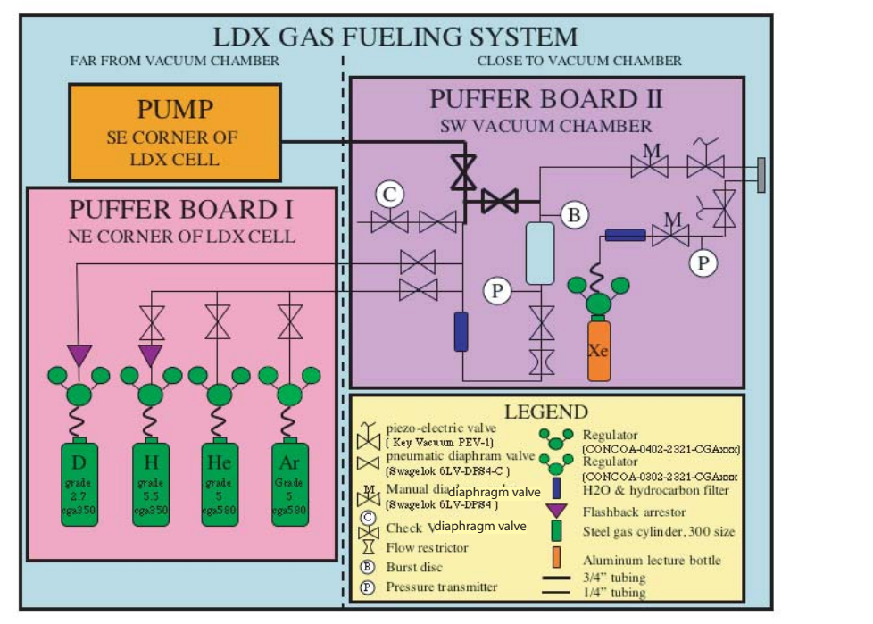
What's New:

Installation of all major physics-relevant components is proceeding.

Outline

- Operations
  - Fueling
  - Glow Discharge
  - Multi-frequency ECRH
  - Shaping Coils
- Diagnostics
  - Magnetics
  - Electrostatics
  - Interferometer
  - X-ray

The Fueling System Allows the Gases to be Mixed



We will use two separate manifolds:

- Manifold 1
  - H
  - D
  - He
  - Ar
  - All bottles feed into a holding chamber, from which the mixture is puffed.
- Manifold 2
  - Xe
  - This is separate for a couple of reasons.
    - Cost of gas
    - Allows for high-Z doping of low-Z discharges.

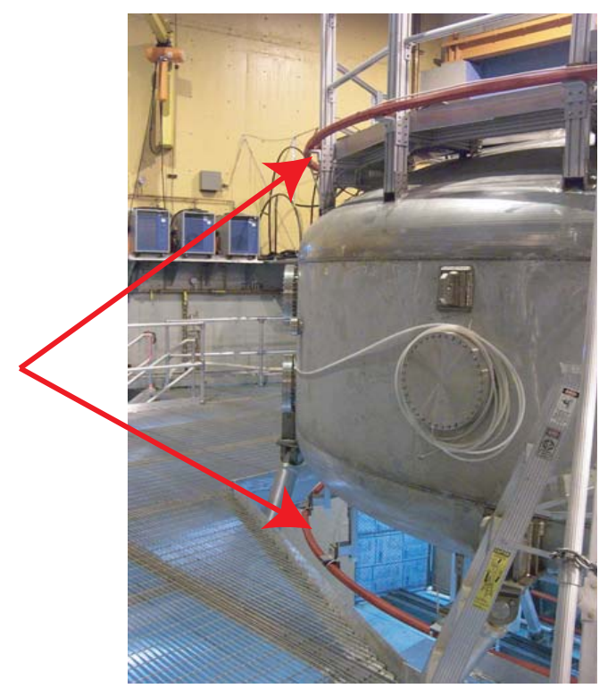
Gas Bottles and Valves ("Board 1")

Inlet Valves, Inlet Filter, and Holding Chamber ("board 2"), Attached to LDX Vacuum Vessel

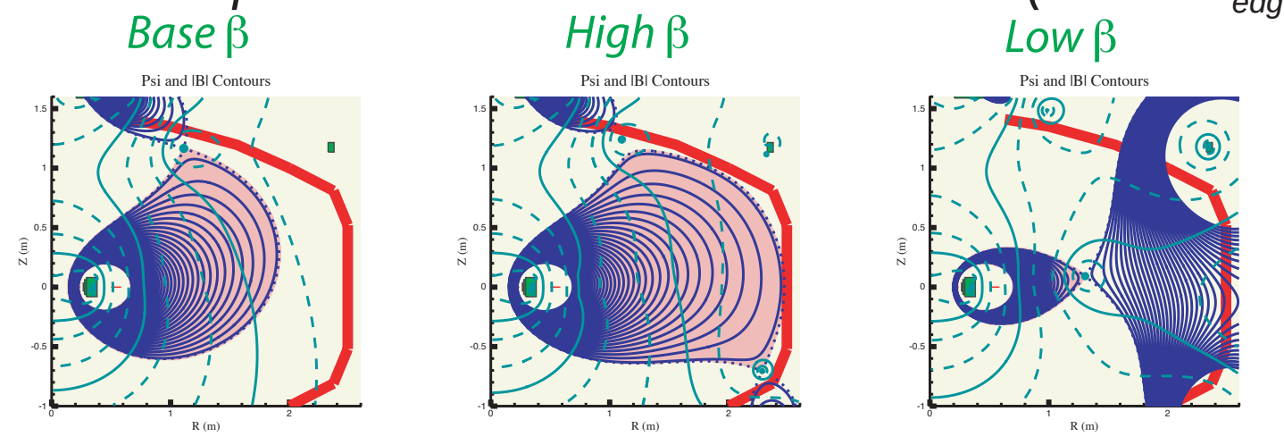
Shaping the Plasma can Change the Peak Pressure

- The dipole equilbrium at marginal MHD stability satisfies: $\frac{P_{\mathrm{core}}}{P_{\mathrm{edge}}} \leq \left(\frac{V_{\mathrm{edge}}}{V_{\mathrm{core}}}\right)^{\gamma}$, where $V \equiv \oint \frac{d\ell}{B}$ and $\gamma = \frac{5}{3}$.
- By changing the plasma volume ($\sim V_{\mathrm{edge}}/V_{\mathrm{core}}$)we can dramatically affect the pressure gradient ($\sim P_{\mathrm{core}}/P_{\mathrm{edge}}$).
- We will accomplish this via a set of Helmholtz coils mounted outside the vacuum chamber. These will be operated with:
  - The same current in both coils, i.e. a true Helmholtz configuration.
  - Different currents in each coil.

Coils on the Vacuum Vessel



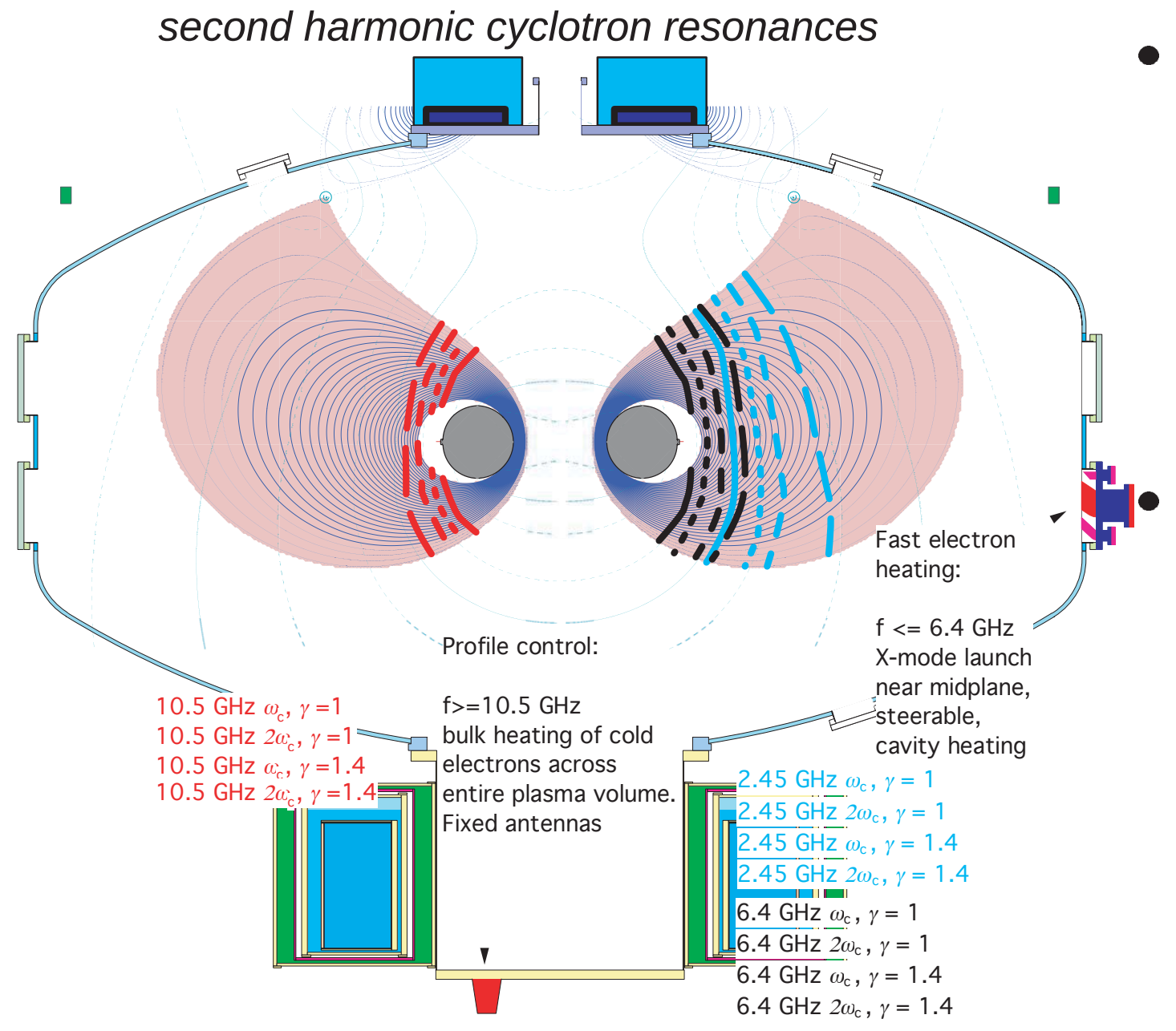
Reference Equilibria for Different Coil Currents (Same P_{edge})



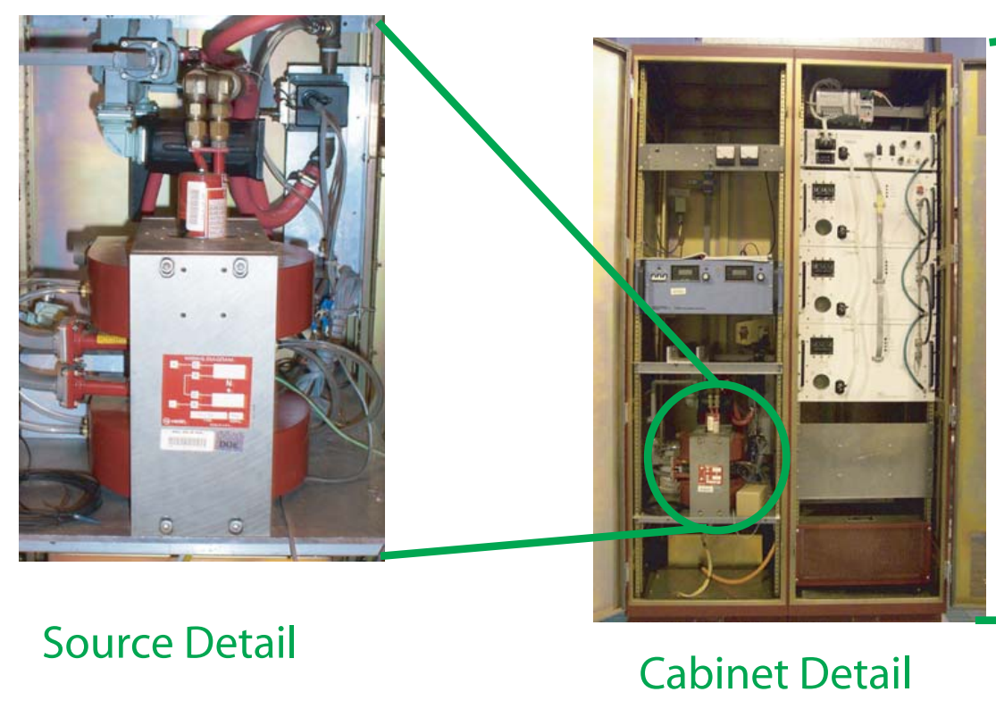
	Base β	High β	Low β
Shaping Coil Currents:	0 kA 0 kA	1 kA 12 kA	50 kA 50 kA
V_{edge}/V_{core}:	43.8	187	22.6
P_{core}/P_{edge}:	544	6120	180

The Plasma will be Heated with Multi-Frequency ECRH

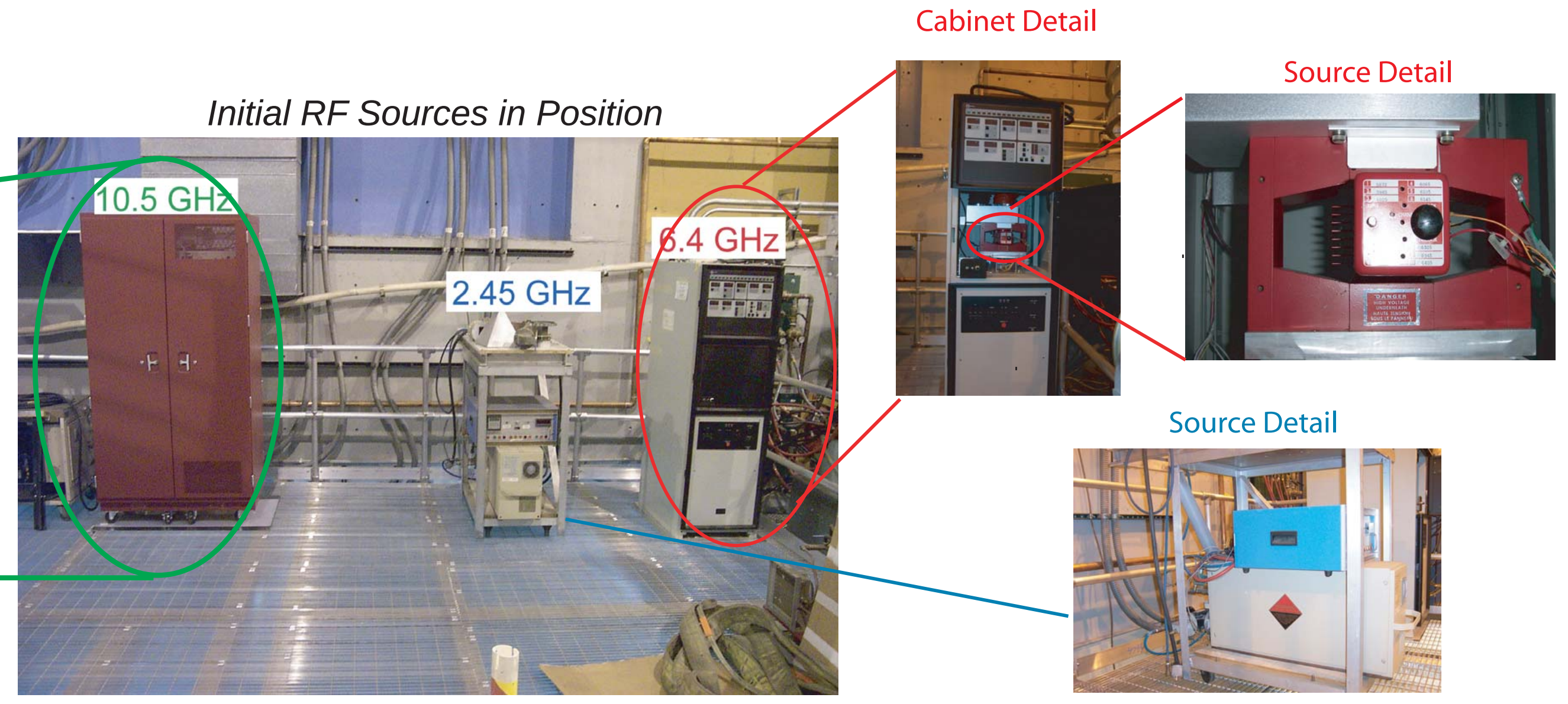
LDX plasma, showing field lines, |B| surfaces, and cold-plasma + 200 keV fundamental and second harmonic cyclotron resonances



- ECRH is an effective way to create a high β hot electron population.
- Initial plans:
  - We will have 2.45 and 6 GHz for the first plasmas, with 10.5 GHz to come on line soon after.
    - 2.45 and 6.4 GHz will be used to establist the base, localized hot-electron plasma.
    - 10.5 GHz and higher frequencies will be used to heat the bulk electrons across the whole plasma.
  - We will assess the the response of the plasma to single frequencies, primarily via X-ray diagnostics:
    - X-ray pulse-height analyzers.
    - X-ray camera (collaboration with S. Zweben, PPPL).
- Ultimate goals:
  - Tailor multi-frequency heating power to produce ideal (stable) pressure profile with maximum peak β.
  - Attempt to drive instabilities by driving the pressure gradient above marginality.
    - Find saturation amplitude.
    - Assess the transport.



Initial RF Sources in Position



OPERATIONS

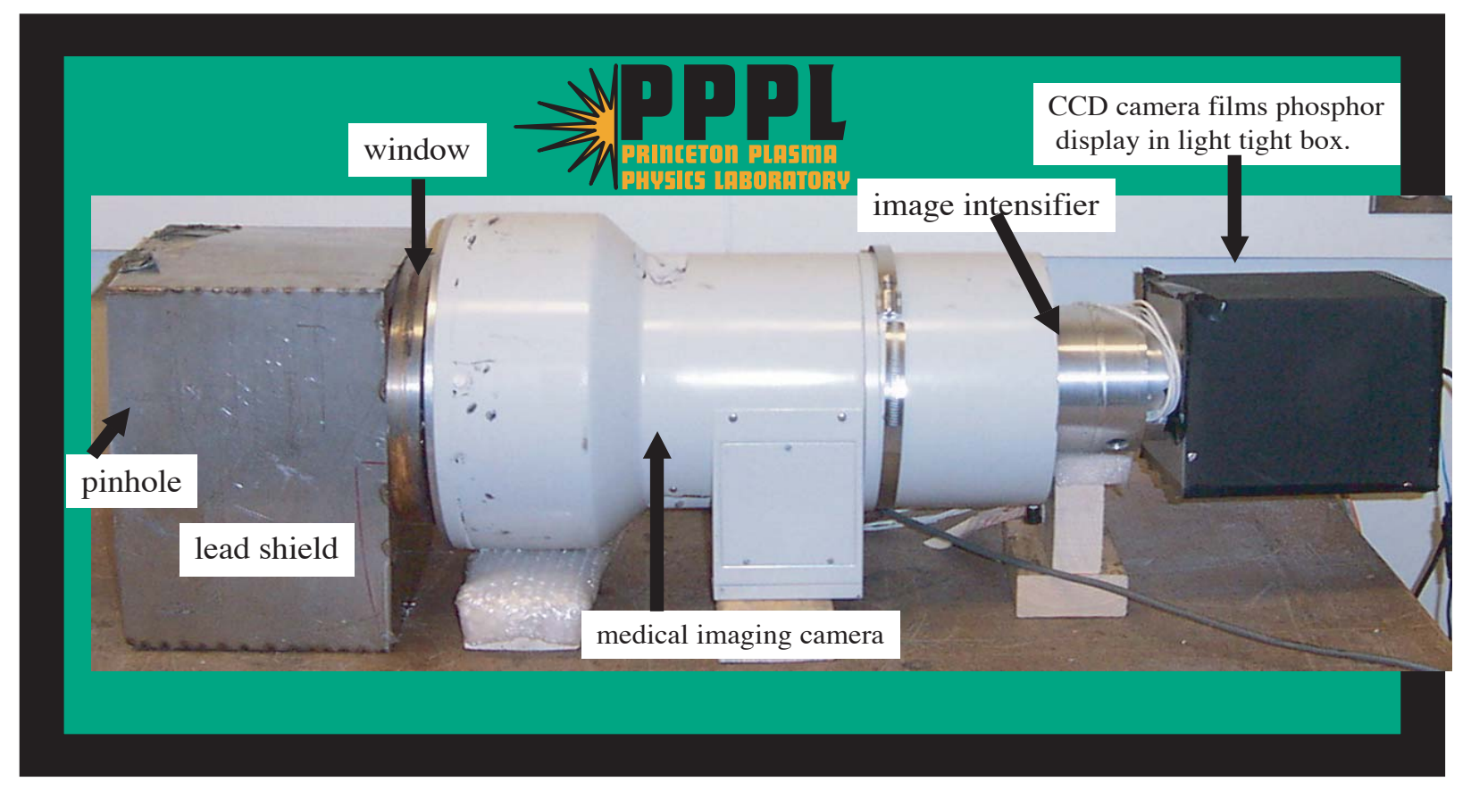
X-ray Diagnostics will Assess the Energy of the Hot Electrons

Pulse Height Analyzers

CZT

NaI

X-Ray Camera
(via a collaboration with PPPL)



- The pulse height analyzers will look at the Bremsstrahlung X-ray energy spectrum in four radially separate views.
  - Useful for assessing the ECRH power deposition
- The camera will be used to indicate toroidal asymmetries in the plasma
  - Expected to be in the ions because the hot electron population is symmetrized by its rapid toroidal drift
  - Possible signature of convective cells

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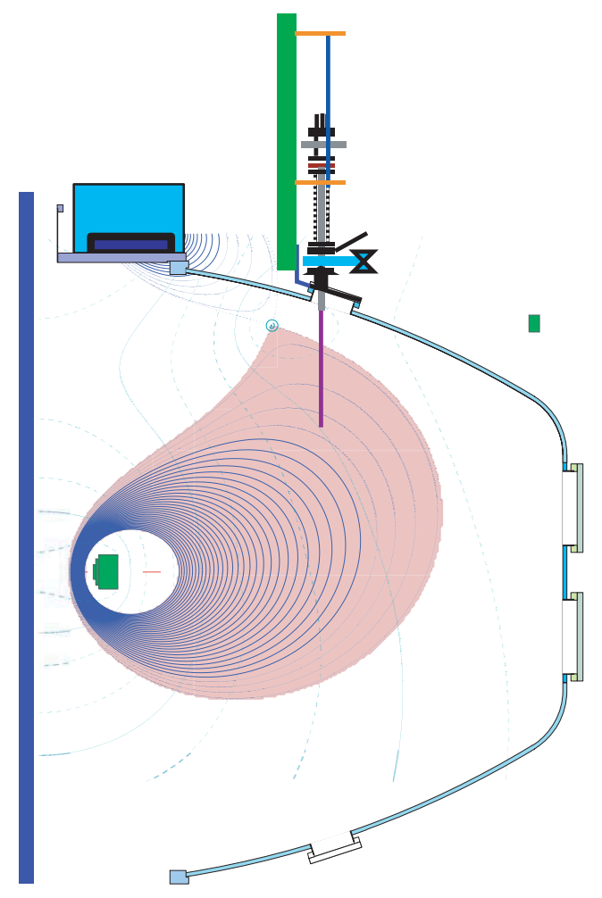
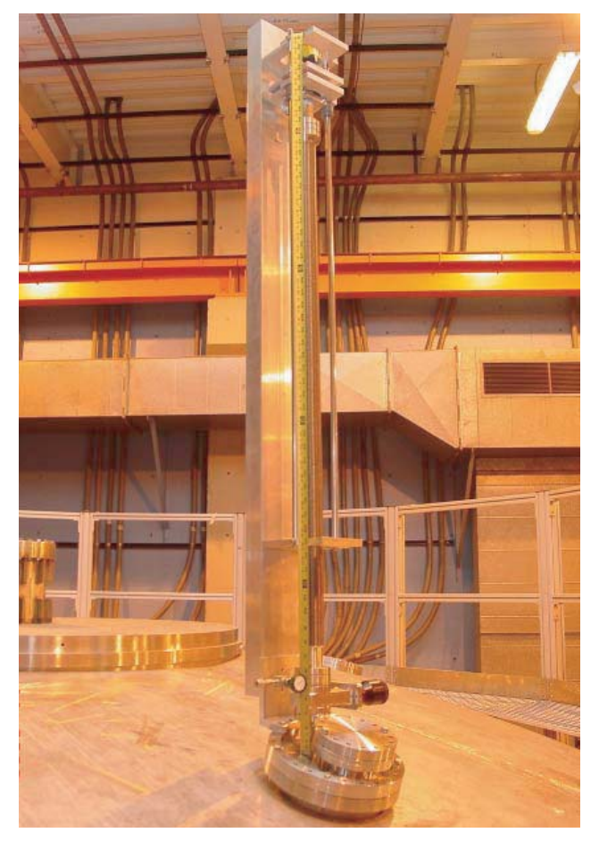
Electrostatic Diagnostics will Probe Instabilities.

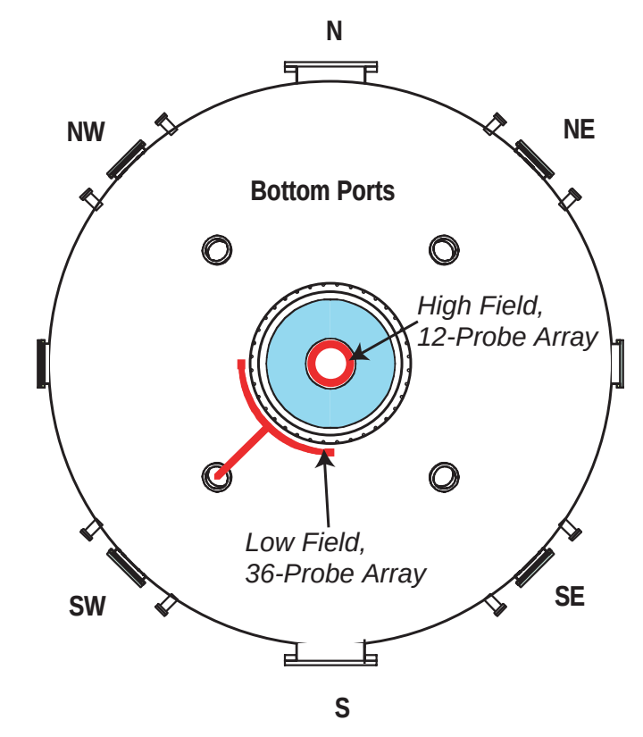
Emissive Probe on LDX



Probe Stand

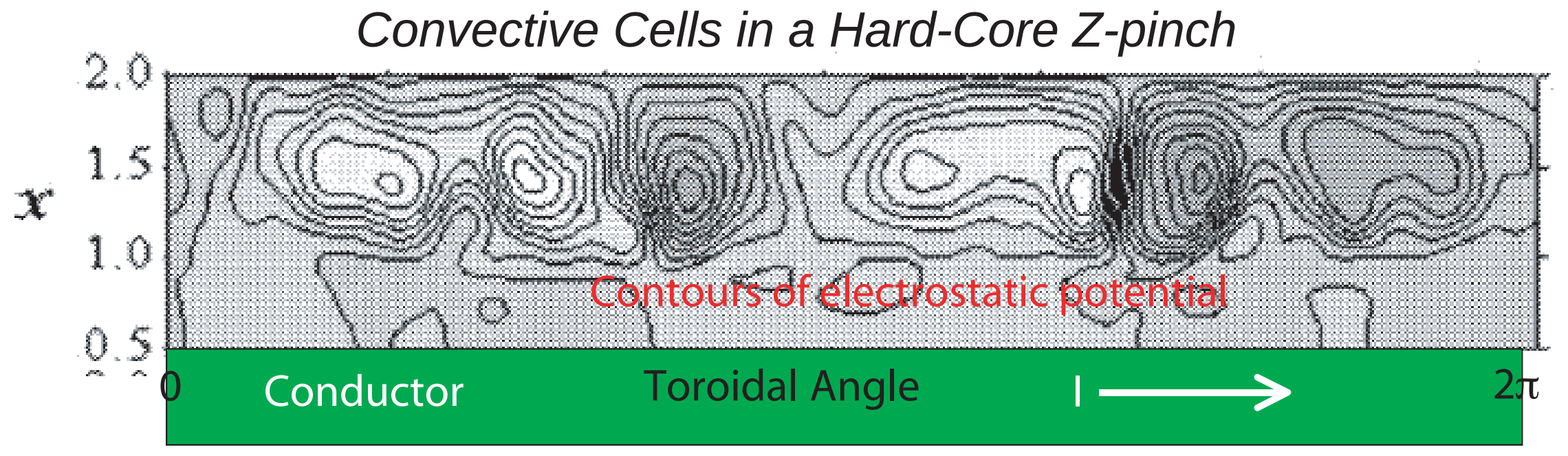


Fixed Array Probes



- Emissive probe:
  - Radially movable.
  - Measure plasma potential.
  - Biasing
    - Toroidally localized
      - Due to absence of rotational transform.
    - Drive instabilities, e.g. convective cells.
- Fixed probe arrays:
  - 32 on low field side.
    - 90° coverage in toroidal angle
  - 12 on high field side.
    - 360° coverage
  - Resolve spatial structure of instabilities.

Convective Cells in a Hard-Core Z-pinch



From V.P Pastukov and N.V. Chudin, *Plasma Physics Reports* **27**, 907 (2001).

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DIAGNOSTICS

Summary

- Operations systems and diagnostics are being installed.
- Preparations for first plasma are proceeding at a feverish pace!

For reprints of this or other LDX posters, visit our website: http://www.psfc.mit.edu/LDX