Status of DiMES Program and Other Reverent DIII-D Experiments

Clement Wong, Dmitry Rudakov, Robert Bastasz,
Bill Wampler, Todd Evans, Phil West,
and the
DiMES team,
Porous plug team,
C-13 team,
ELM-suppression team
(Multi-institutional teams)

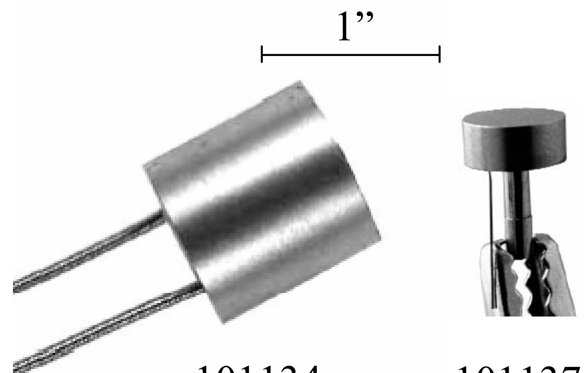
PFC Meeting, May 3-5, 2004
U. Of Illinois, Urbana, Illinois

DiMES Proposed Experiments 2003-2004			
	Title	Comments	
1	Multiple materials erosion with upper single null	With new set of plasma parameters than the 2003 exposure	Not-active
2	Hydrogen sensor	Mostly prepared, waiting for diagnostics	Piggyback
3	Porous plug with methane injection (McLean & Stangeby)	Supported by Whyte and Dmitry (Scheduled for 7/26/04)	Approved
4	Heated DiMES sample	To benchmark IR camera measurements, Coordinate with Lasnier, waiting for robust heater	Piggyback
5	DiMES-gap (Jacob & Stangeby)	To address the issue of impurities deposition Supported by Bastasz, Wampler and Whyte, (7/27) and (9/14)	Approved
6	Ar induced divertor detachment	To compare with earlier Ne discharges	Not active
7	DiMES Micro-balance	Between shot measurement of material deposition Supported by Whyte and Bastasz	Not active
8	Measure ELM erosion and deuterium deposition	In coordination with ELMing/ELM modification experiment Uses implanted DiMES.	Piggyback
9	Disruptions to simulate ITER ELMs	With more detail planning than last year and needs a few Discharges. Uses implanted DiMES.	Piggyback
10	Ti and ni distribution	Under planning	Not active
11	Li-DiMES sample W/o Li	To test heater and tile currents Waiting for diagnostics	Piggyback
12	Li-DiMES sample with Li	Waiting for results from 11	Not active
13	W-Rod	Proposed by SNL-A, piggyback opportunity later this year	Piggyback
14	W-surface	To perform after the successful exposure of the W-rod Experiment. This will also study arcing on W-surface	Not active
15	MHD effect on thin melted metal layer	Could be Al on graphite, supported by modeling from UCLA, needs Al coated and heated sample	Piggyback
16	Secondary e emission	Use tile current probes with different materials	Not active
17	Secondary e emission, from ½ W, ½ some other materials	Perform # 16 first	Not active
18	Migration of μm size C dust	Proposed by Sergei Krasheninnikov of UCSD (1st exposure 3/16)	Piggyback
19	Hall magnetic field sensor	Proposed by J. Boedo, sensor provided, to be fitted into DiMES	Piggyback

DiMES Heaters and Temperature Control

- Existing and planned DiMES heated samples:

Sample	Heater	Max W
Generic heated sample	HeatWave 101134	300
W-rod sample	HeatWave 101134	300
Li sample	HeatWave 101137	60
Tile gap sample	?	300?
Thin melted layer sample	?	500?



101134 101137

- We have purchased a temperature controller and a power supply suitable for use with the existing HeatWave heaters

Temperature controller
OMEGA CN77000

Power supply
INSTEK SPS-1820
0 - 18 V, 0 - 20 A

- HeatWave heaters have a disadvantage – low resistance, so high currents are required
- For example, 101134 has a resistance of 0.13 Ω at room temperature and 0.5 Ω at 500 C
- DiMES drive is not designed for high currents
- We are going to evaluate OMEGA CHS cartridge heaters that can work from 0-120 V AC supply

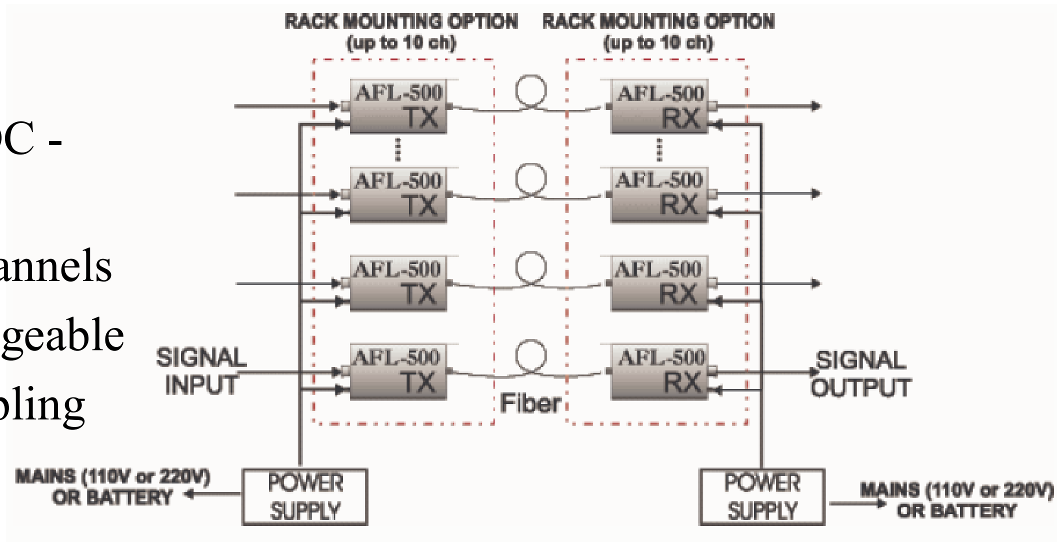
OMEGA CHS
Cartridge heaters

DiMES Instrumentation and Data Acquisition

- Some of the planned DiMES samples require data acquisition and/or remote control

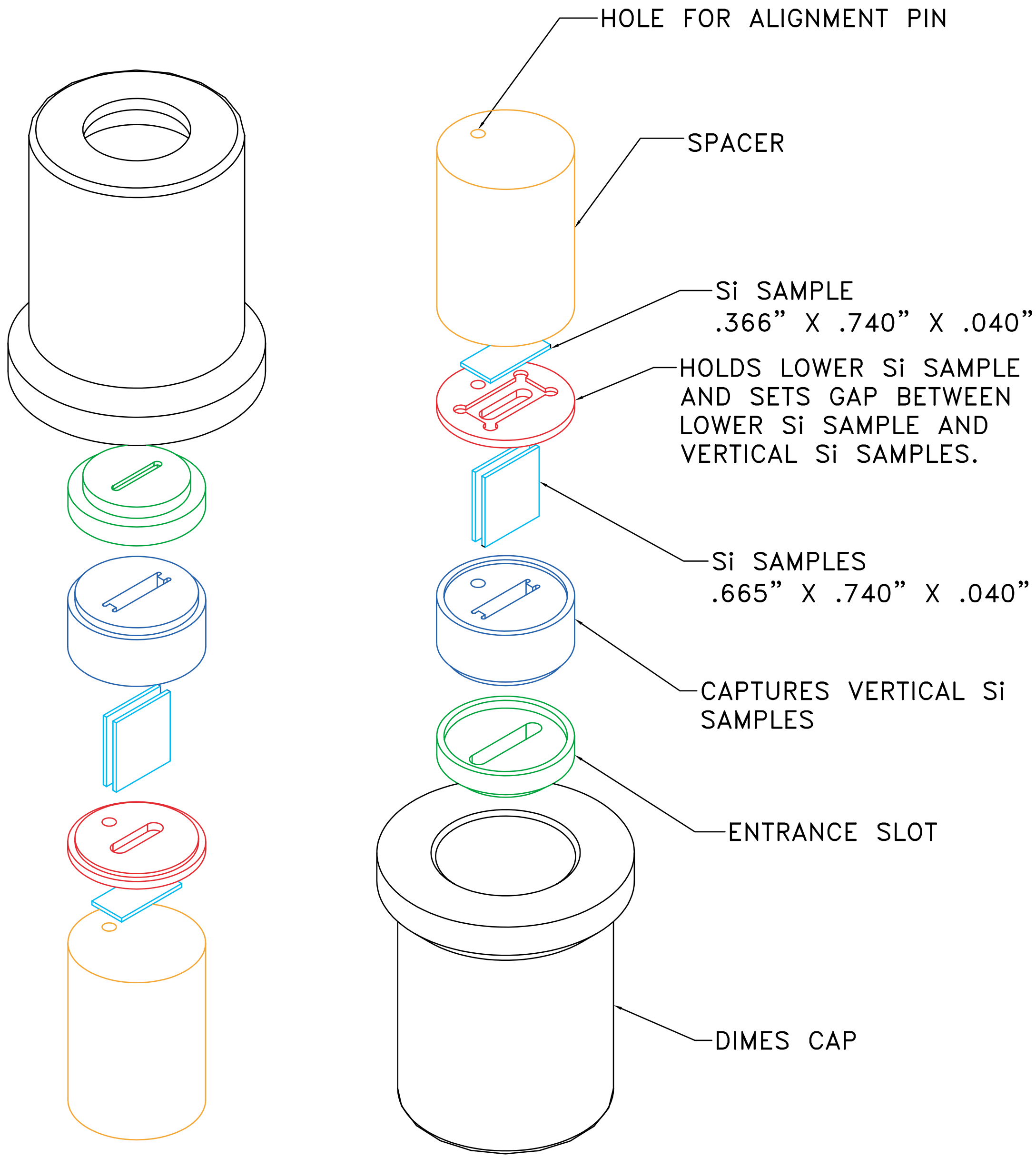
Sample	Requirement	No. of channels
Tile current array (Li sample)	Data acquisition – 5 channels	5
Porous plug sample (methane injection)	Micro-valve control Data acquisition (pressure, flow rate)	2
Hydrogen sensor	Remote heater control Data acquisition	2-5?
Hall magnetic field sensor	Data acquisition	1?

- DiMES system is referenced to the DIII-D vacuum vessel, so 5 kV isolation is required for all signals
- We purchased 5 channels of isolation amplifiers with frequency response of DC - 20 kHz
- The system will be expandable to 12 channels
- Transmitters and receivers are interchangeable
- 8 channels of data acquisition with sampling at 100 kHz for up to 5 s are requested

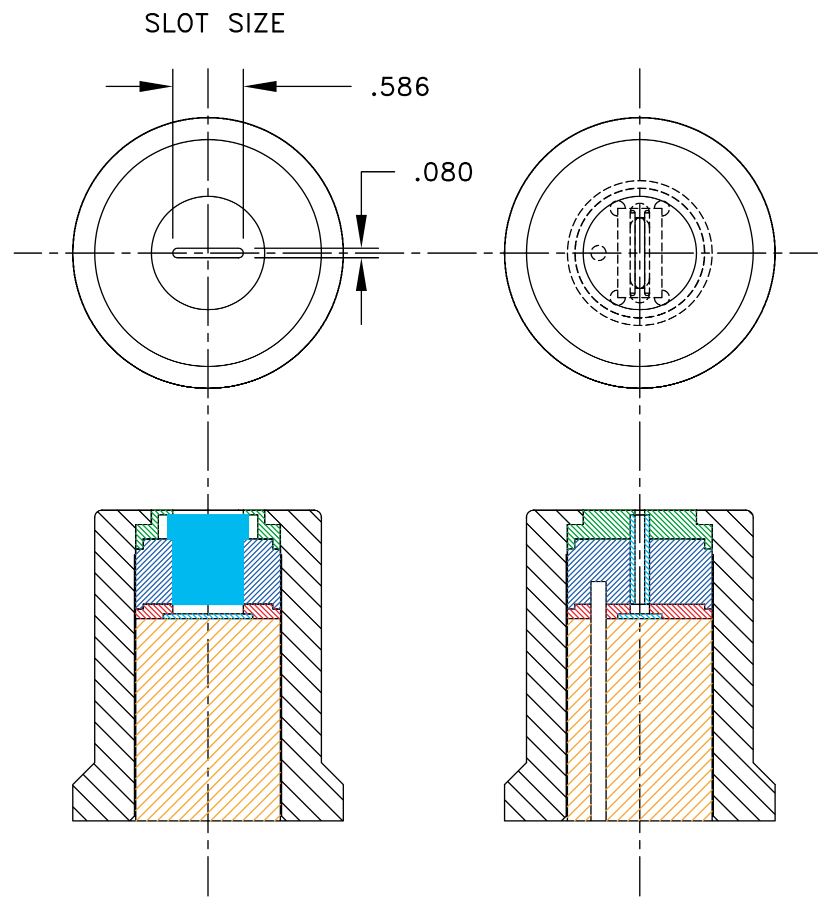


DiMES #122
Version A
2004 Feb 3

JW & RB - SNL/CA



ALL MATERIAL ATJ GRAPHITE
EXCEPT SAMPLES



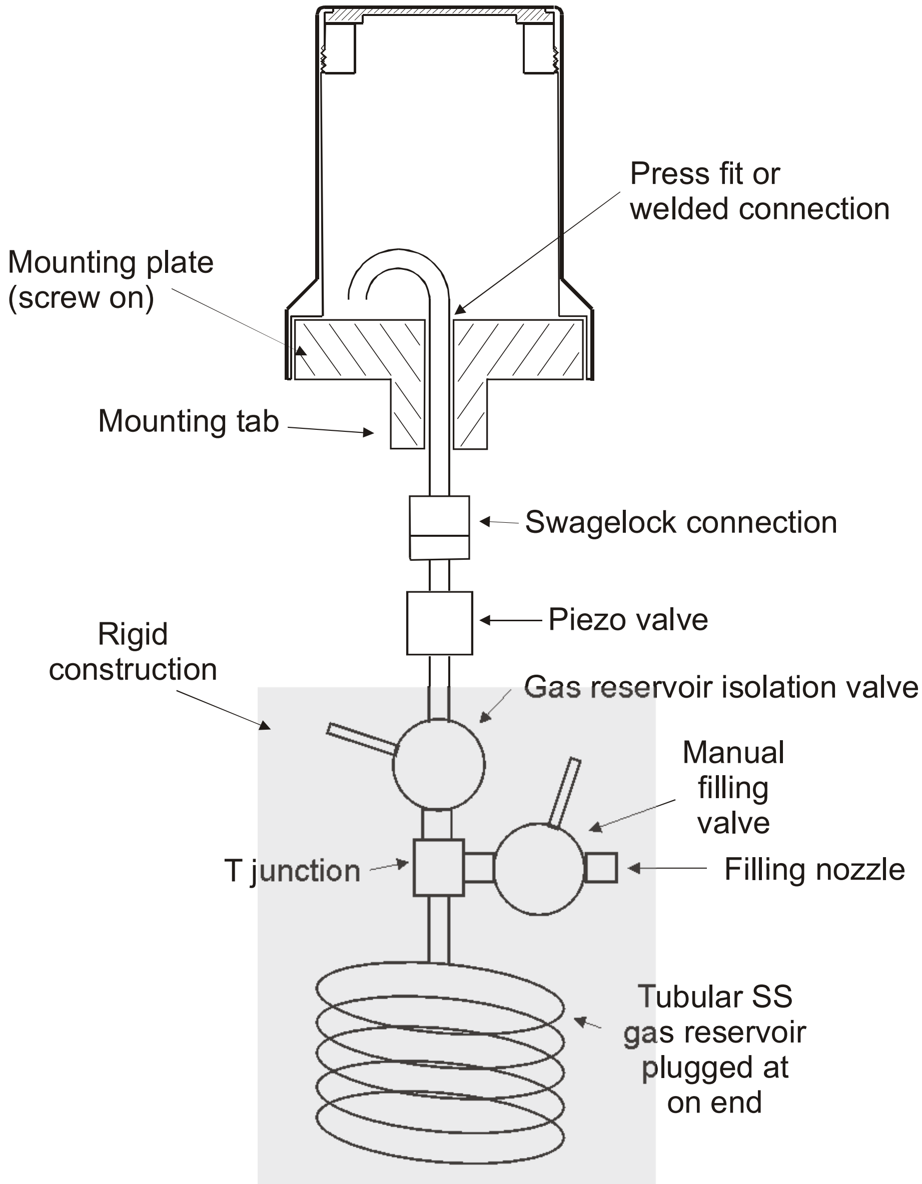
DIMENSIONS IN INCHES

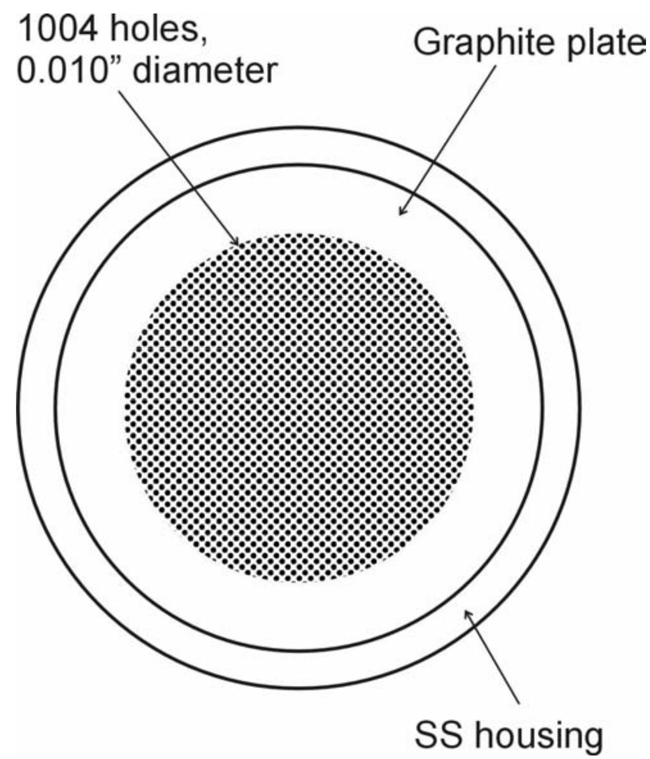
DiMES Porous Plug Injector

Jim Davis, Dmitry Rudakov, Adam McLean, Peter Stangeby, Clement Wong

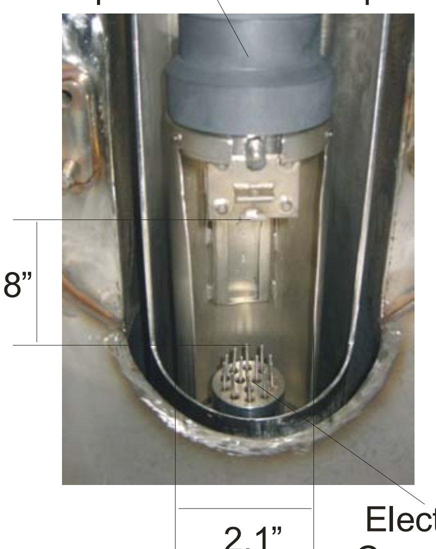
- The purpose is to admit methane (or other hydrocarbons) through a porous graphite surface, so that the molecular interaction with the plasma may closely approximate a hydrocarbon molecule released from a carbon surface by chemical erosion.
- Injecting methane at a known rate will provide direct calibration of the spectroscopic signals (Multichord Divertor Spectrometer, DiMES TV, lower tangential CID camera).
- The porous surface is designed such that size and spacing of the holes is on the order of the mean-free-path of methane molecules in a target plasma: ~1000 holes, 0.25 mm (0.010”) diameter, 0.8 mm (0.032”) spacing.
- The holes comprise <10% of the surface area so that the probe closely approximates a solid surface.

Porous Plug Injector Schematic

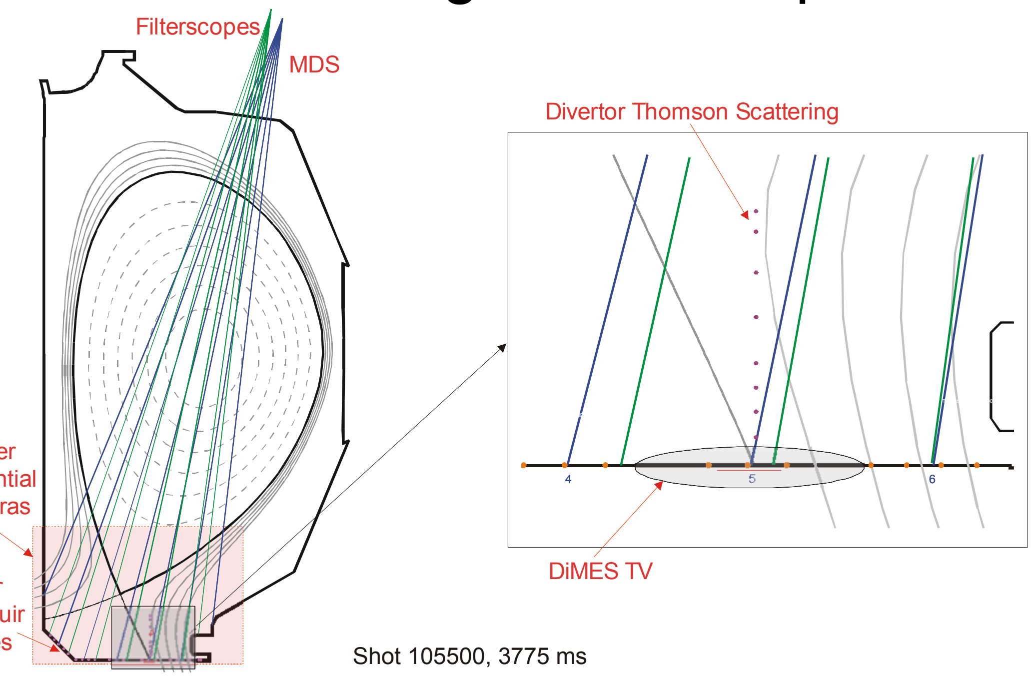




Space for Components



Diagnostic Setup



Gas Flow Characteristics:

Desired flow rate: 7E17 molecules/s

Throughput: 0.02 torr L/s

Standard flow volume: 2.1 sccm

Status:

Porous plug drilling at 0.010” is complete

All components selected, ready for design review

Scheduled for ½ run day in July in DIII-D

Planned DiMES Activities

- **Dedicated Experiments:**

  Porous plug with methane injection

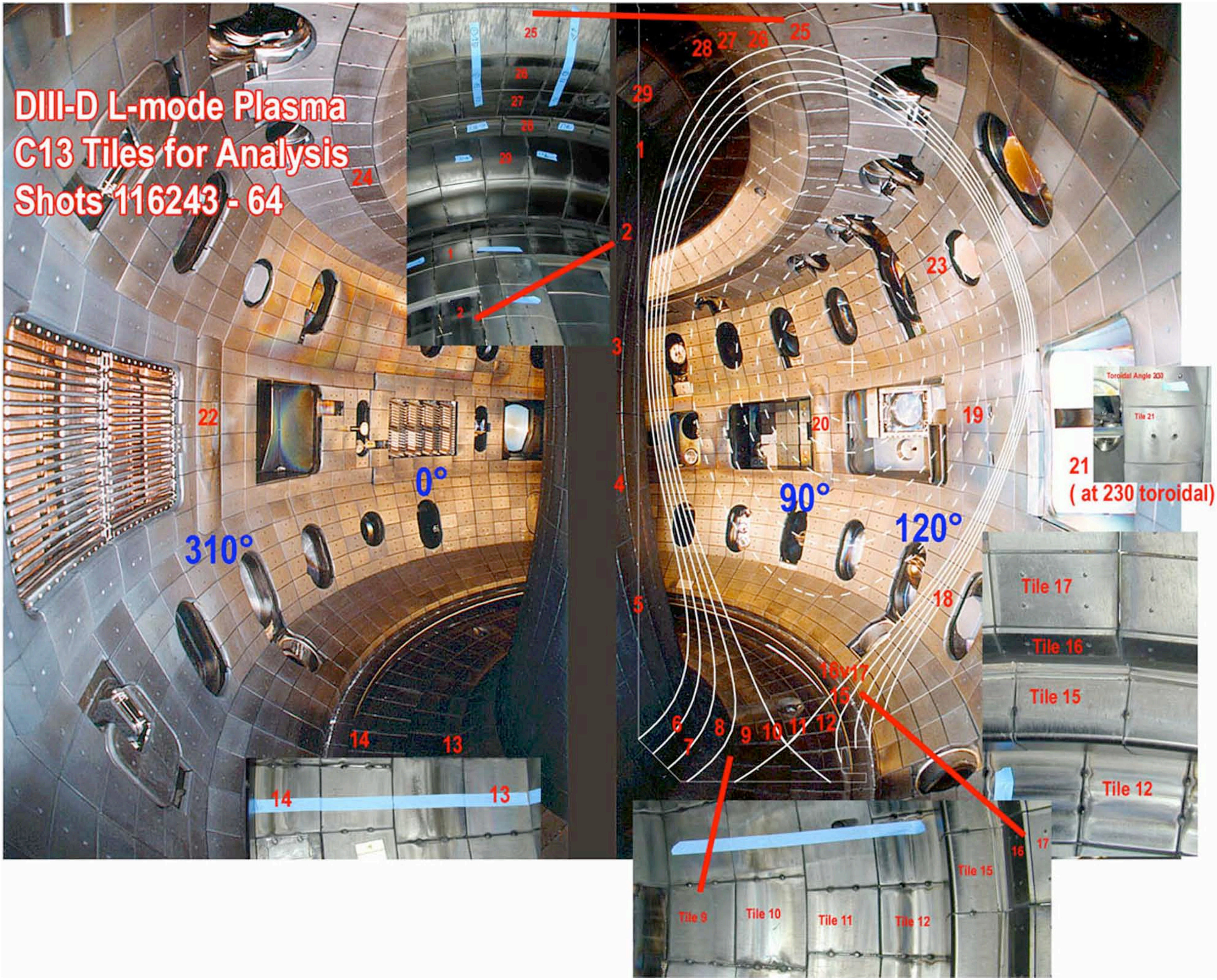
  DiMES gap experiments

- **Systems improvements:**

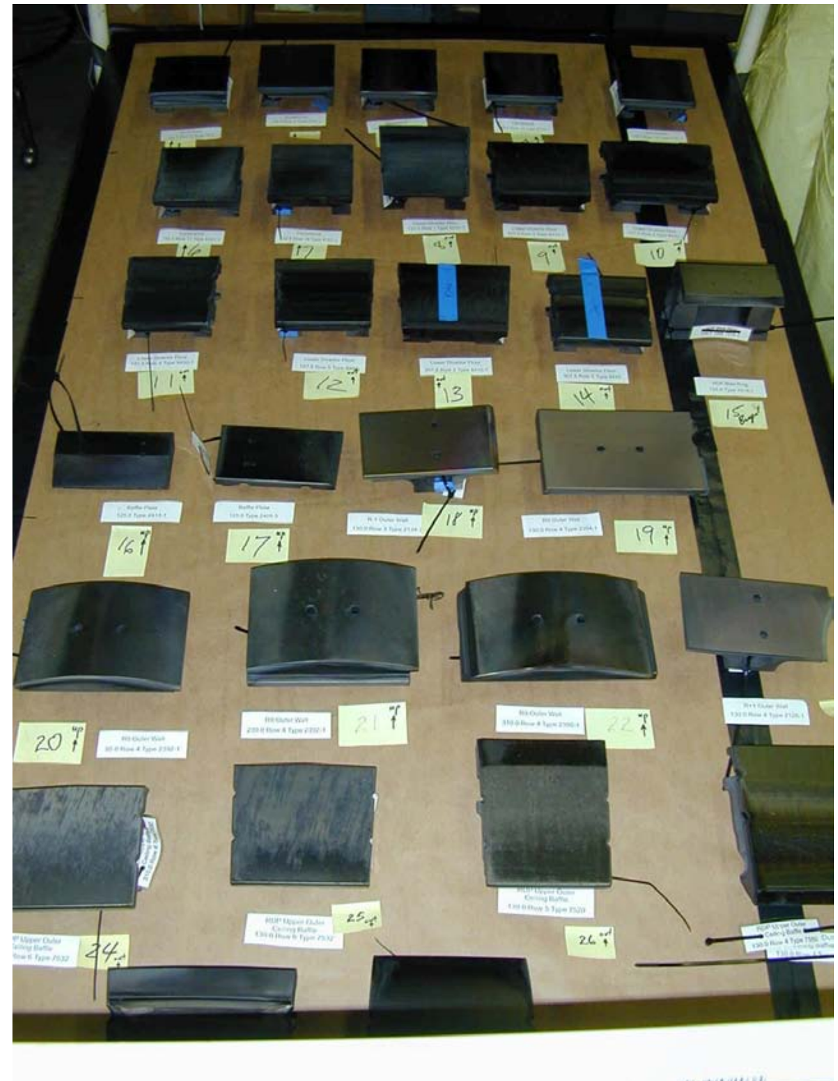
  Robust heater; and in-situ diagnostics and control

- **Piggyback experiments:**

  W-Rod, tile currents, heated surface, ELM erosion, disruption to simulate ELM, MHD effect on thin melted metal, magnetic field sensor, dust migration and hydrogen sensor.


DIII-D L-mode Plasma
C13 Tiles for Analysis
Shots 116243 - 64
24
22
0°
310°
14
13
25
28 27 26 25
29
1
2
3
4
5
23
20
19
21
(at 230 toroidal)
Toroidal Angle 230
Tile 21
90°
120°
18
Tile 17
Tile 16
Tile 15
Tile 12
16v17
15
6
7
8
9
10
11
12
16
17
Tile 9
Tile 10
Tile 11
Tile 12
Tile 15

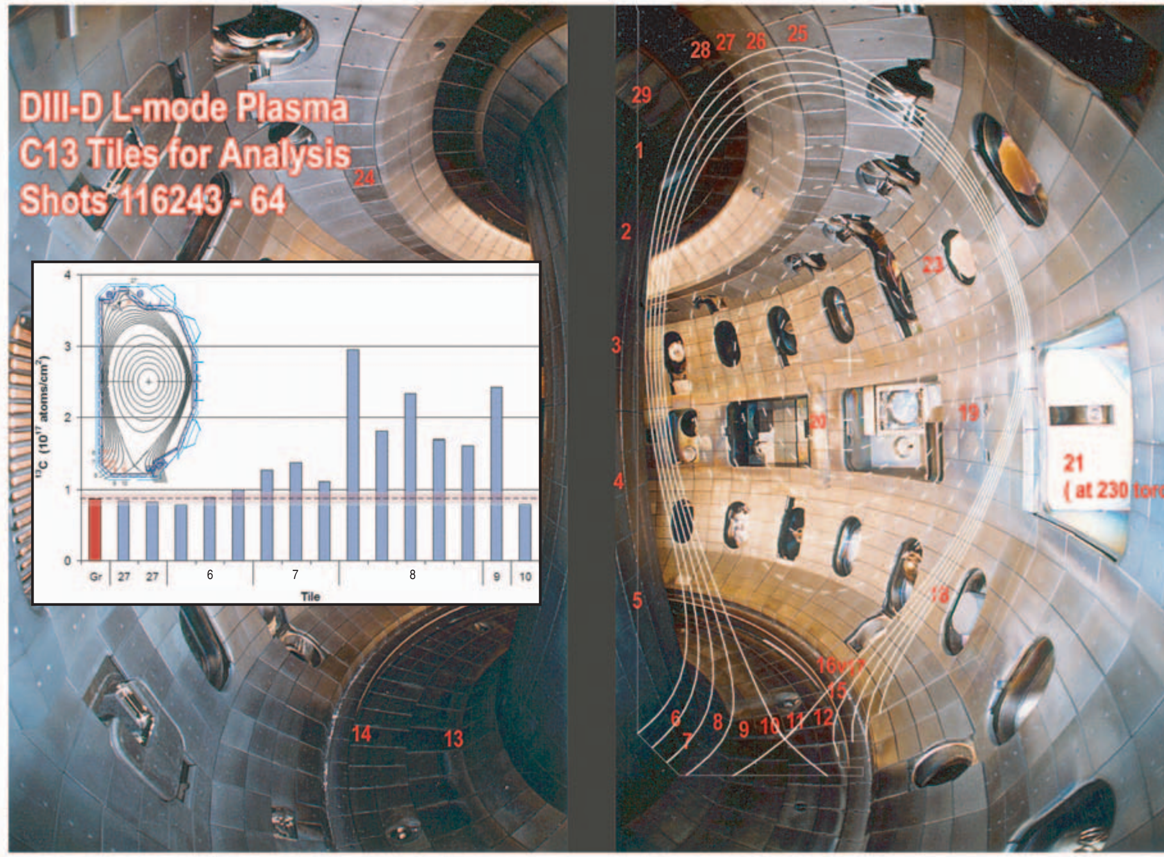
29 Tiles from DIII-D



Tiles transported to Sandia Lab, Albuquerque for Analysis (GA, Univ. Toronto, LLNL, & PPPL tile crew)

MULTI-NATIONAL COLLABORATIONS ARE FORGED TO ADDRESS TRITIUM MIGRATION AND RETENTION

- **C13 injection**
  UT, JET, UW, LLNL, PPPL, FZJ-IPP, GA
- **Surface analysis**
  SNL-NM, SNL-L
  UT, UW, GA
- **Quartz Micro Balance**
  UW, UT, JET, FZJ-IPP, GA
- **O_2 bake**
  UT, PPPL, UW, GA, SNL-NM, LLNL, FZJ, JET
- **Heated tile**
  UT, IPP Garching, UW, GA, SNL-L

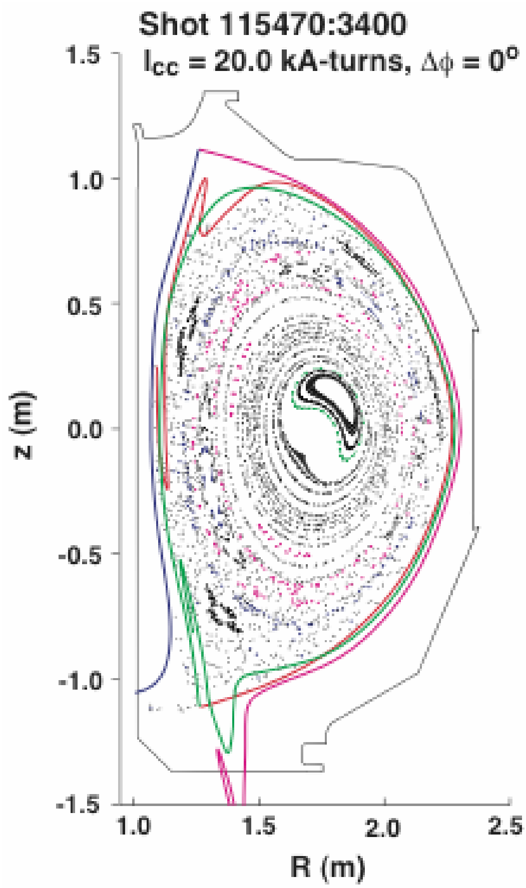


Preliminary Result: C13 found in tiles near inner strike point

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

065-04/TST/rs

ELM suppression with a stochastic boundary in DIII-D



T. E. Evans, R. J. Groebner, R. J. La Haye, T. H. Osborne, M. J. Schaffer - *General Atomics, San Diego, CA, USA*

R. A. Moyer - *UCSD, La Jolla, CA, USA*

J. G. Watkins - *Sandia National Laboratory, USA*

T. L. Rhodes, G. Wang, L. Zeng - *UCLA, Los Angeles, CA, USA*

P. R. Thomas - *CEA Caderache, France*

M. E. Fenstermacher, M. Groth, C. J. Lasnier - *LLNL, CA, USA*

K. H. Finken - *FZ-Jülich, Germany*

N. Ohyabu, S. Masuzaki - *NIFS, Japan*

J. Harris, D. Pretty - *Australian National University, Australia*

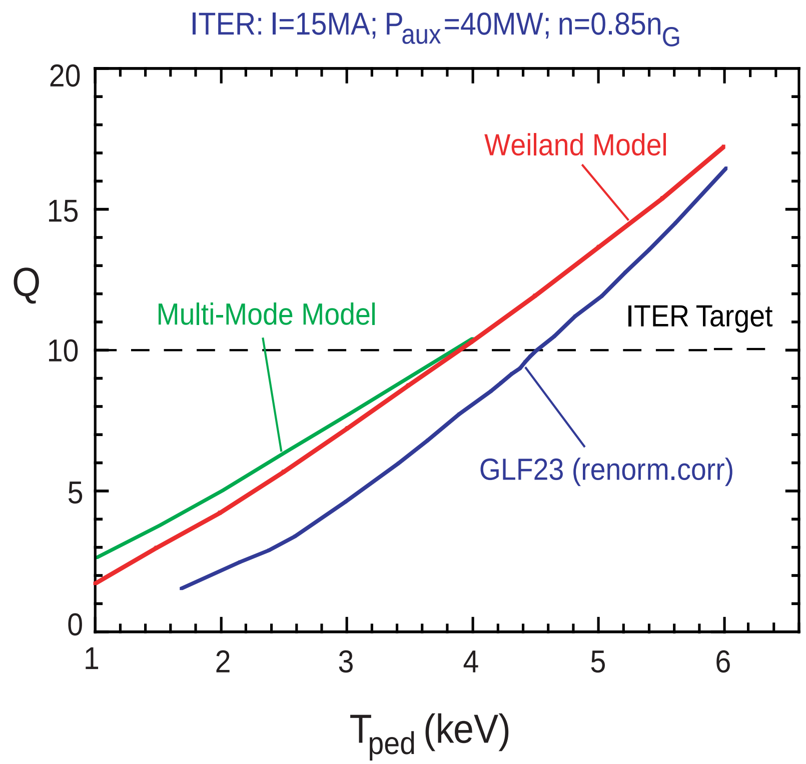
H. Reimerdes - *Colombia University, NY, USA*

PFC Meeting, Urbana IL.

May 3-5, 2004

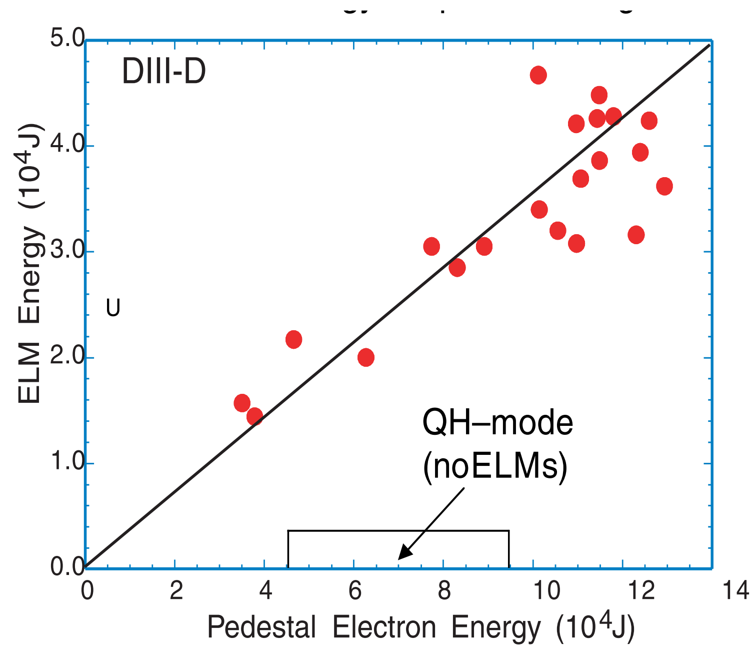
Pedestal control is a critical issue for next-step fusion devices

- **Core performance is tightly coupled to pedestal height by stiff radial transport**



  – Pedestal T_e uncertainty affects ITER Q_{fus} more than transport model

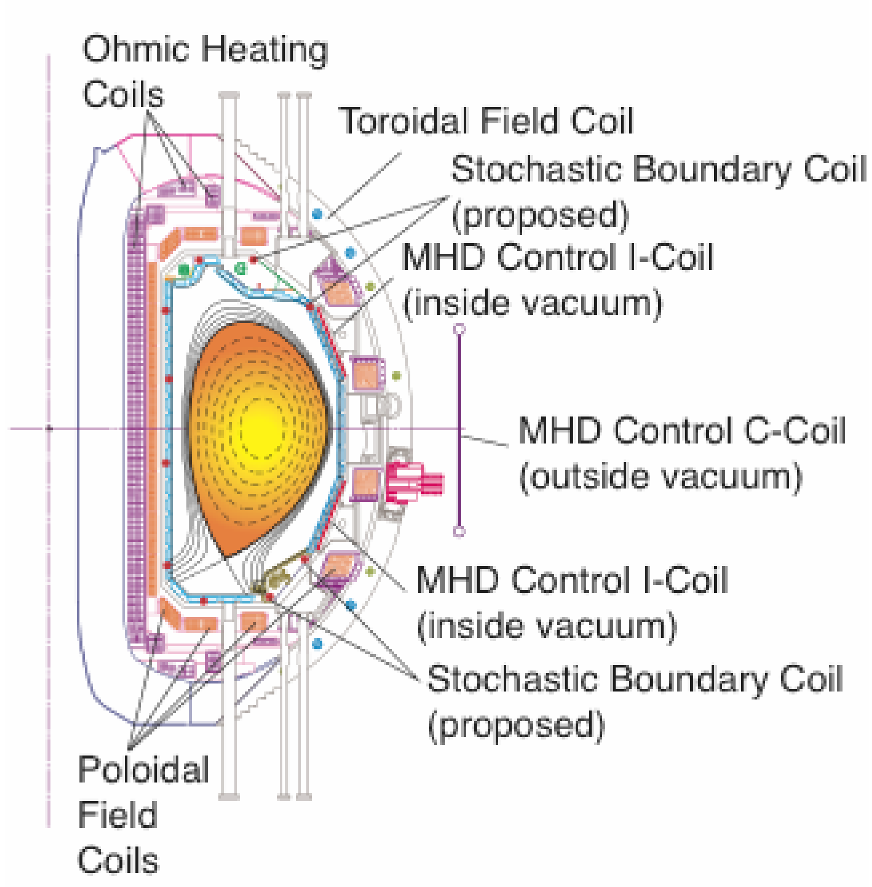
- **ELMs affect core plasma performance...**
  – **Directly by reducing pedestal height**
  – **Indirectly by affecting pedestal stability**



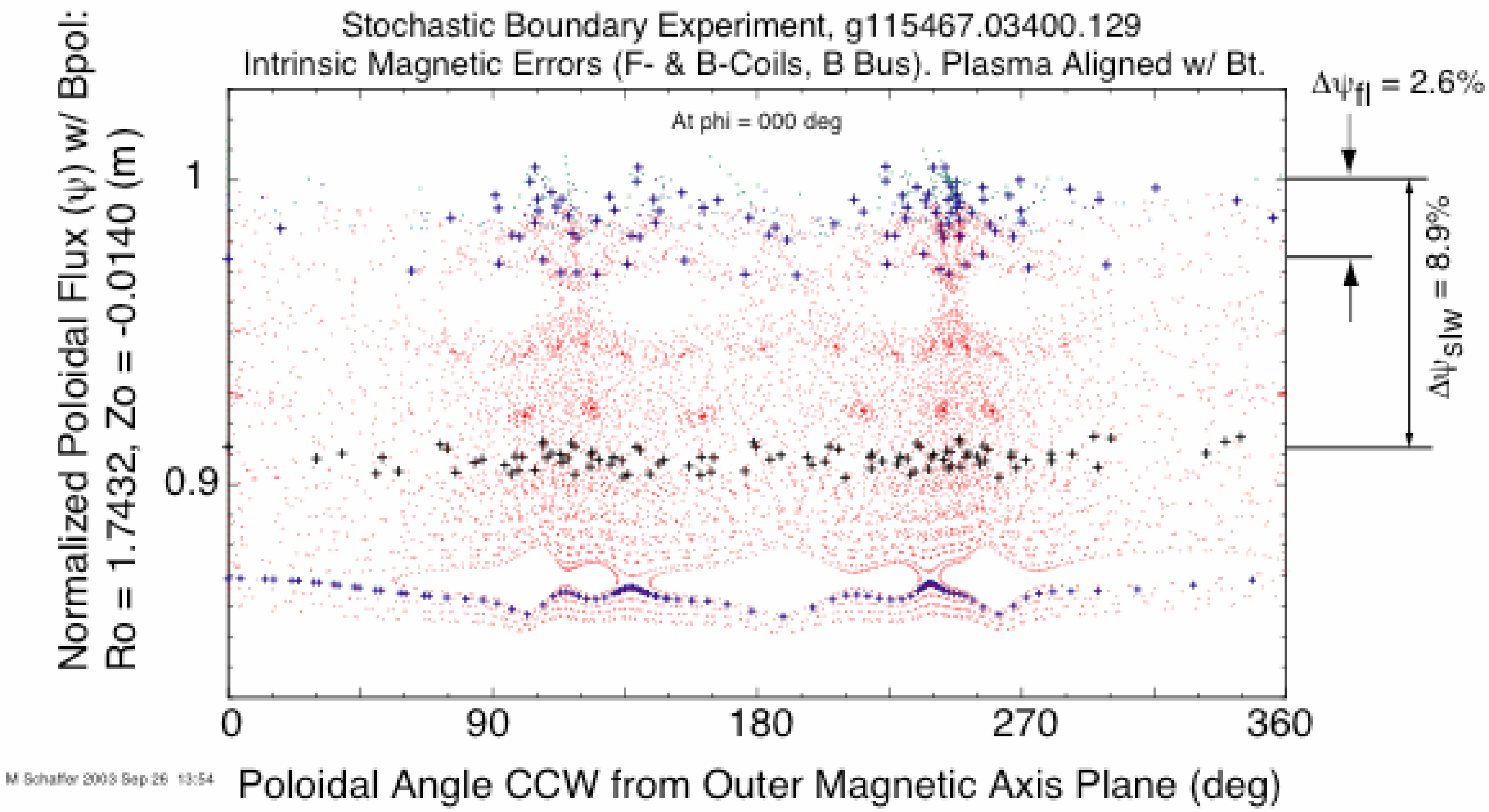
- ELMs limit divertor plate lifetime
  – Impulsive heat flux erodes material

An edge stochastic layer may be a good solution for pedestal control

- **Dedicated pedestal control experiments, using the error field correction coil (C-coil) and internal MHD control coil (I-coil) were initiated in 2003 on DIII-D**
- **First results from these experiments look very promising**
- **Additional experiments are planned for 2004**
- **If these experiments with the existing coils continue to look favorable a new set of coils will be installed in DIII-D that are specifically designed to optimize the edge stochastic layer**



The stochastic layer structure is characterized by its width $\Delta\psi_{slw}$ and poloidal magnetic flux loss $\Delta\psi_{fl}$



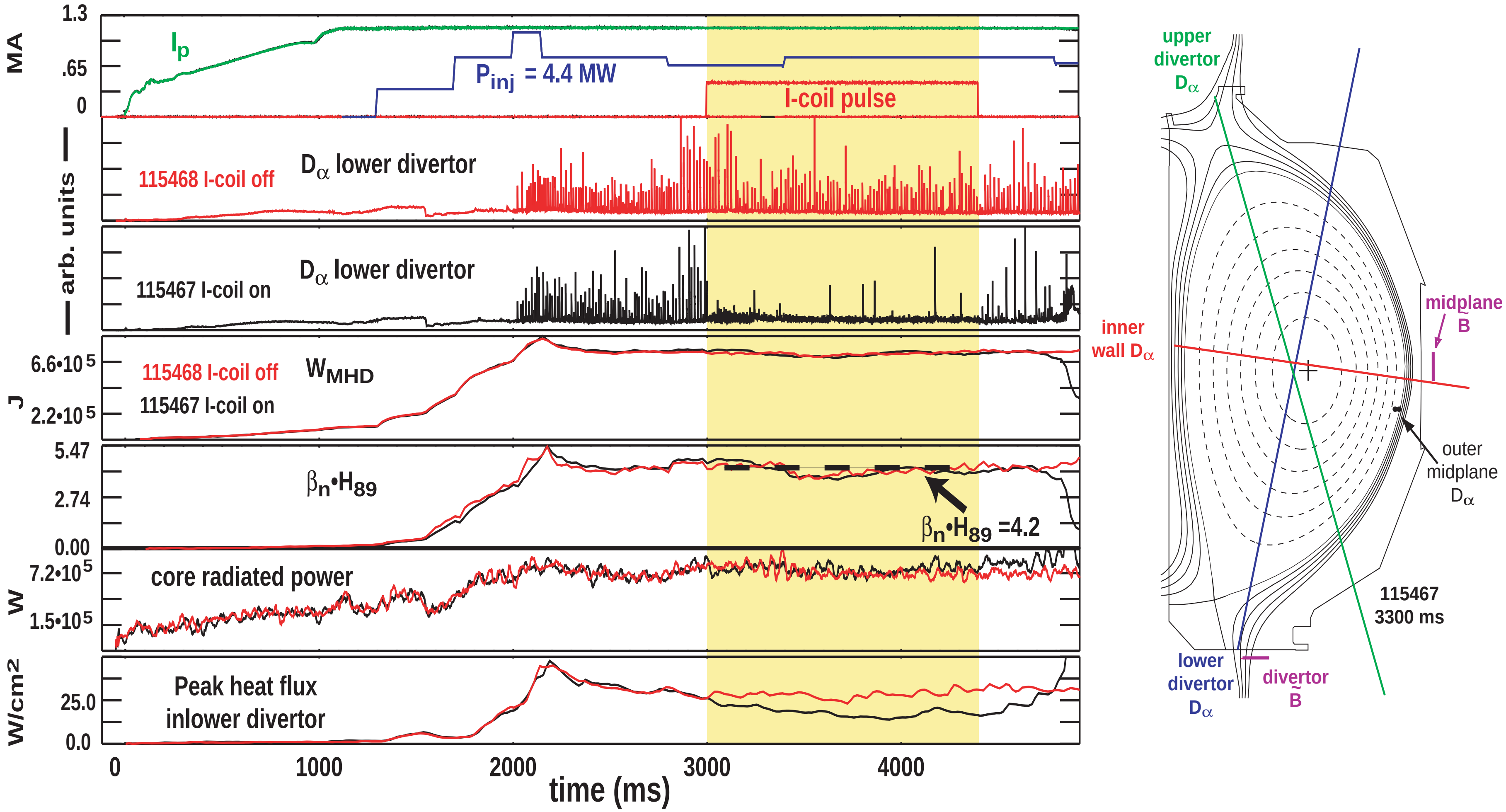
- Rectangular Poincaré plot showing a TRIP3D calculation of the magnetic structure in DIII-D pedestal with measured error fields only (no C- or I-coil).

TRIP3D modeling (no plasma response included)

T. Evans, et al., PRL in press

Large ELMs are suppressed without degrading the core confinement during the n=3 I-coil pulse

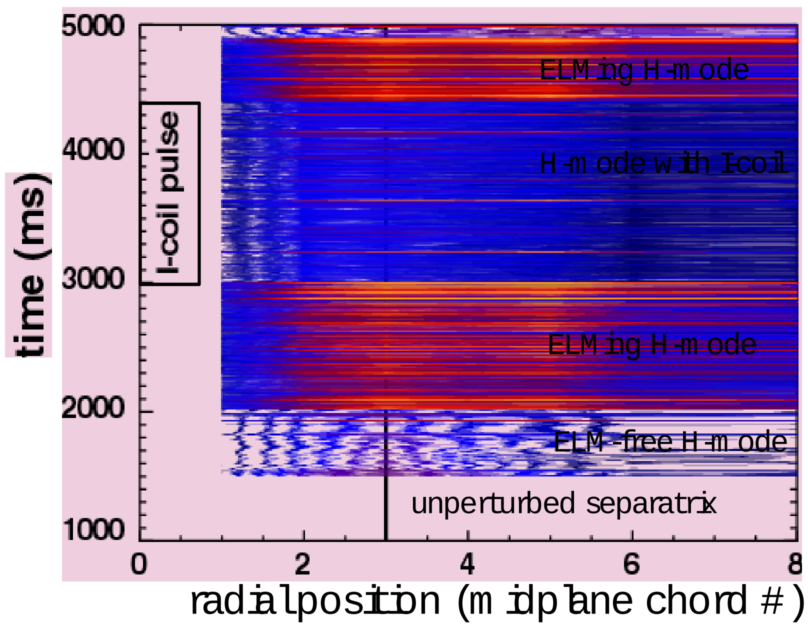
- Type I ELMs suppressed in high performance ELMing H-modes ($\beta_n \cdot H$ = 4.2) with and edge resonant perturbation.

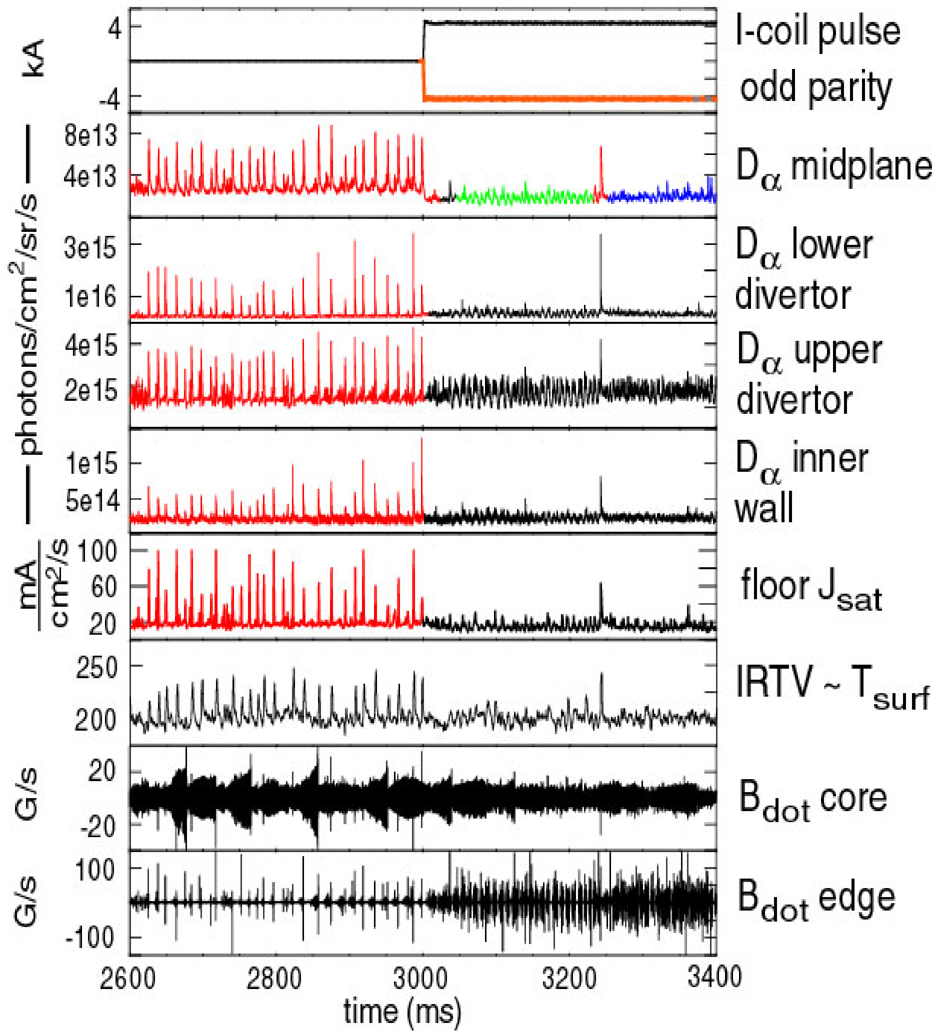


T. Evans, et al., PRL in press

Large 70 Hz type-I ELMs are converted into small 130 Hz oscillations punctuated by isolated events

- **Suppression is global and readily apparent on:**
  - **All D_α arrays (outer midplane, upper and lower divertor, inner wall**
  - **Particle flux and heat flux to the primary (lower) divertor**





T. Evans, et al., PRL in press

Summary and Conclusions

- **An edge resonant magnetic perturbation from the I-coils has been used to suppress Type I ELMs in high confinement DIII-D H-modes**
  - Suppression is not (yet?) complete - Type I ELM rate drops from 70 Hz to about 7 Hz, assuming that the surviving large events are Type I ELMs
  - Scaling to next-step devices is unknown! (we don't have an ITER solution yet, just a promising start!); An obvious next step is to use an ITER shape (e.g. low triangularity single null divertor)
  - The nature of the surviving irregular oscillations not yet determined (e.g. are they Type II ELMs?)
  - Edge pedestal remains second stable (doesn't fit Type II ELM model)
  - Pedestal height is not reduced
  - **Core confinement remains high despite a large loss of toroidal rotation**.