Comparative Studies of Magnetic Islands and Stochastic Layers in DIII-D and LHD

EX/1-3

by

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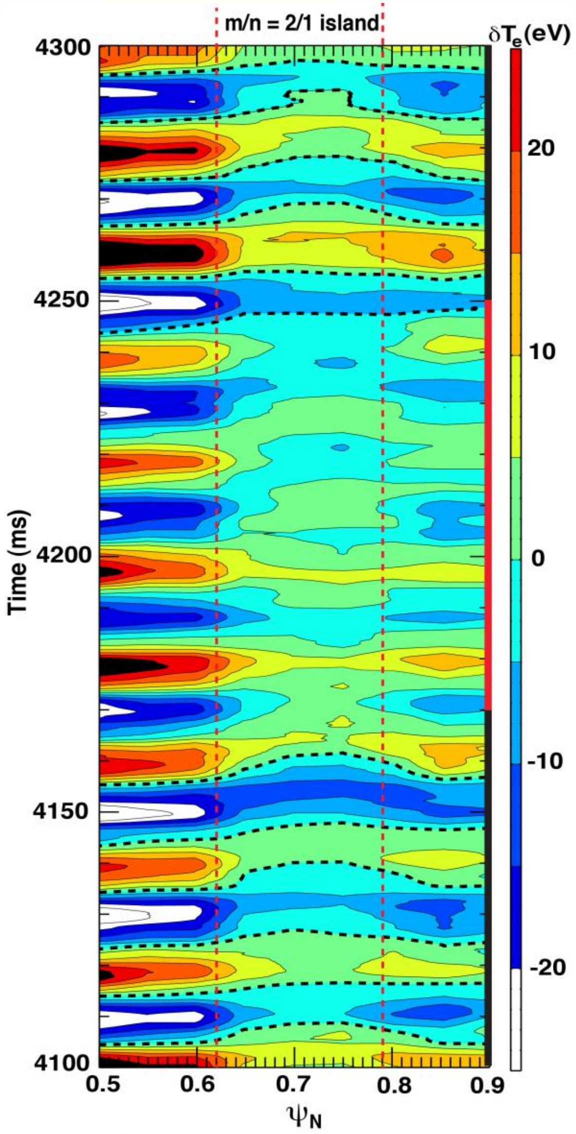

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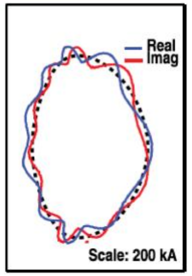
Developing RMP ELM Control for ITER Requires an Understanding of Plasma Response to 3D Fields

- **MHD plasma response models predict islands, stochasticity and stable kink modes in ELM suppressed H-modes**



Ideal kink-like mode

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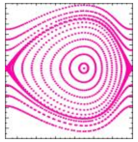
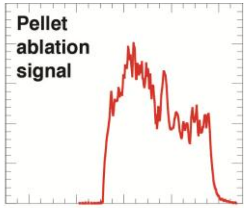
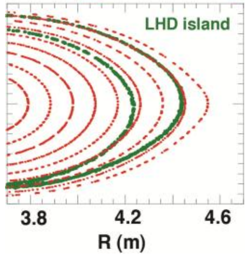


Island with nested flux surfaces

- **Stable RMP driven kinks observed in DIII-D but islands and stochasticity are not directly observed**

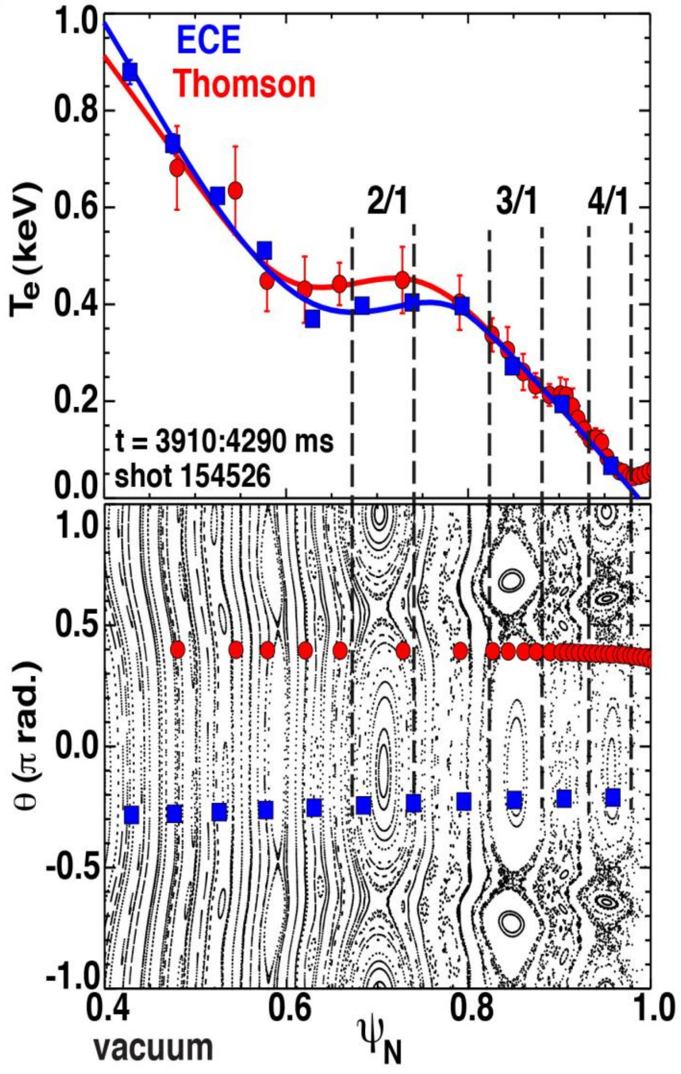
- **Joint DIII-D and LHD L-mode experiments have provided new results on the nonlinear stability of islands during:**
  - Interactions with plasma generated δB_r field triggered by stable kink mode
  - Localized pressure perturbations due to pellets injected into island O-points





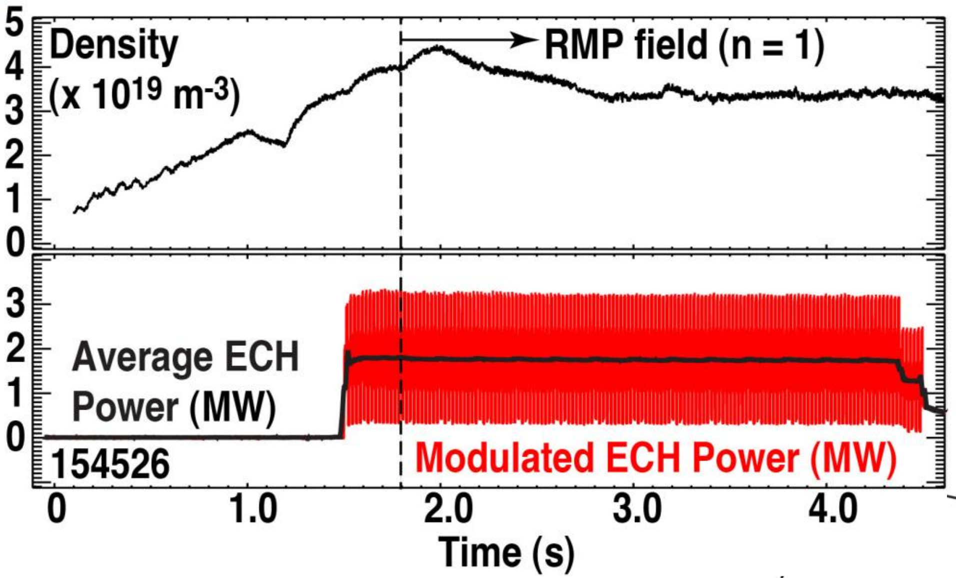
RMP = Resonant Magnetic Perturbation

T_e Profiles do not Provide Definitive Information on the Nature of the Plasma Response to RMP Fields



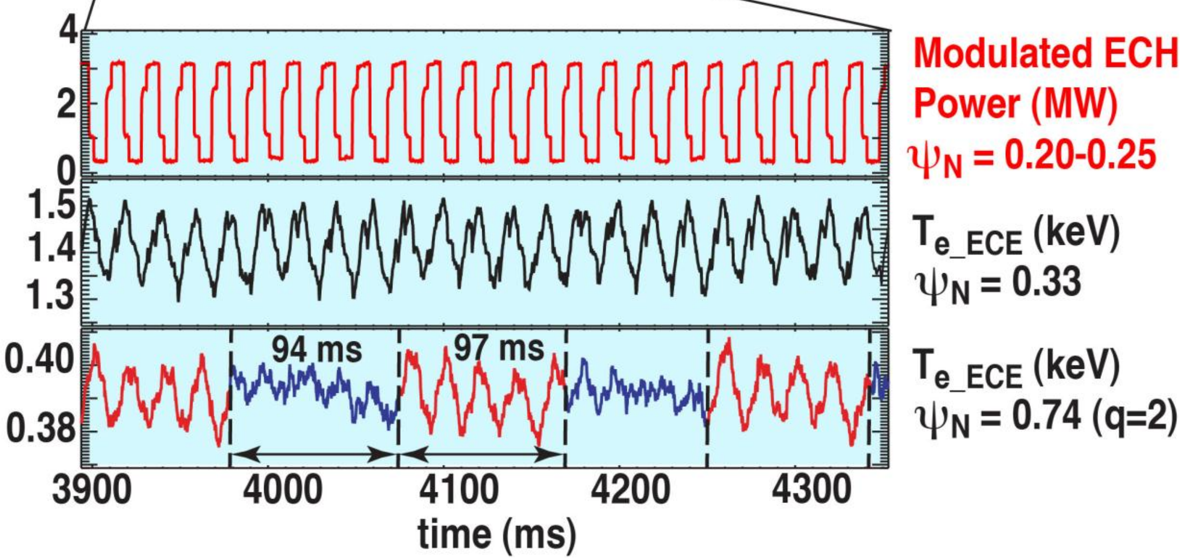
- **Flattening of DIII-D T_e profiles during RMP not consistent with vacuum island widths**
- **Wide T_e profile flattening across q = 2 surface could result from:**
  - An amplified m/n = 2/1 island
  - A partially stochastic m/n = 2/1 island
  - A fully stochastic layer
- **Additional diagnostic data needed to quantify RMP plasma response:**
  - Modulated Electron Cyclotron (MEC) heat pulse analysis used to resolve differences

Modulated EC (MEC) Heat Pulse Analysis Provides Detailed Information on Magnetic Topology



- **Plasma response to RMP field studied during stationary conditions (t = 3.9 to 4.35 s)**

- **T_{e_ECE} response at q =2 shows spontaneous bifurcations**
  - Related to changes in m/n = 2/1 island



DIII-D
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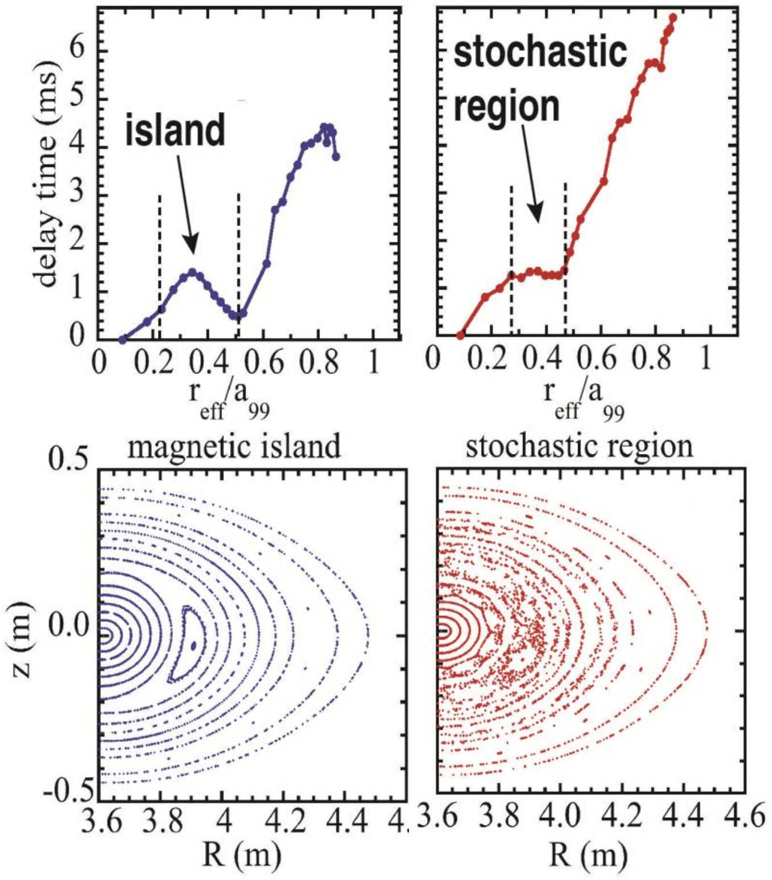
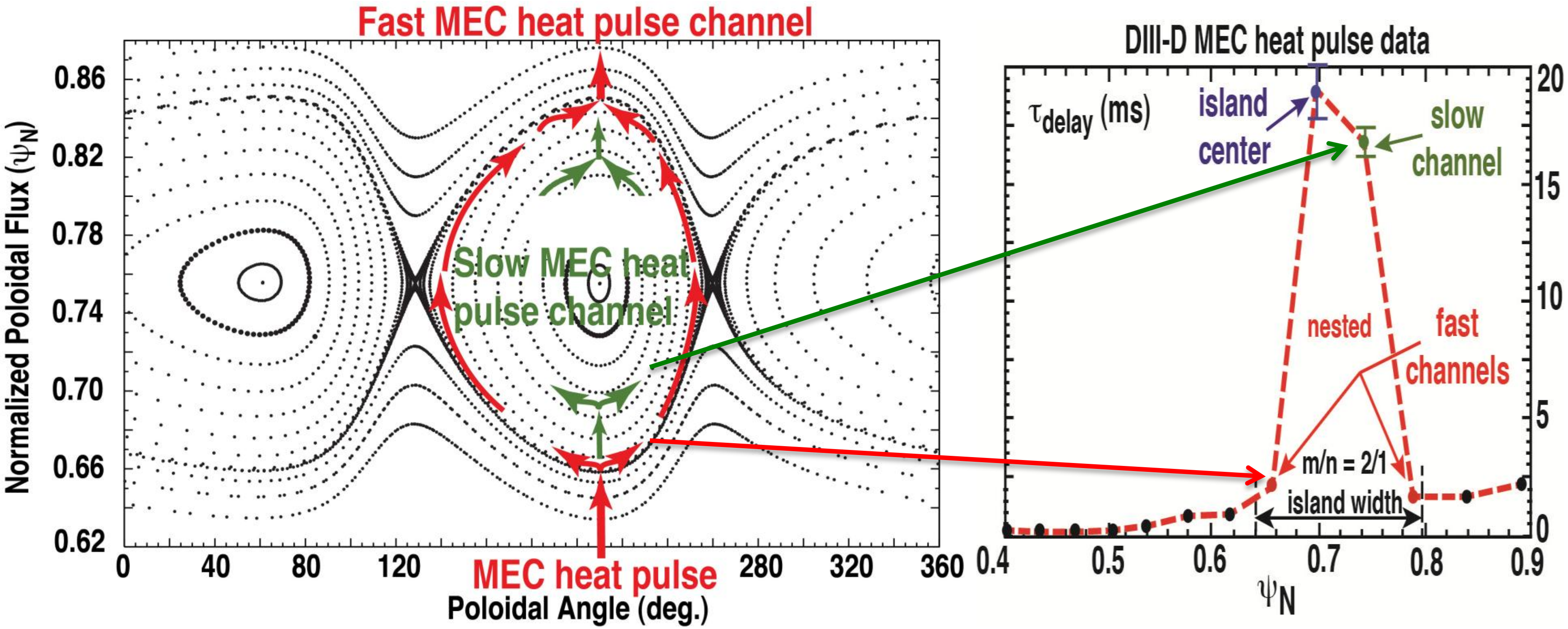
MEC Heat Pulse Analysis Developed on LHD to Identify Magnetic Islands and Stochastic Regions



- **Peak in heat pulse delay time → island**
- **Flat heat pulse delay time → stochastic**
- **Transitions from islands to stochastic layers observed in LHD with changes in magnetic shear**

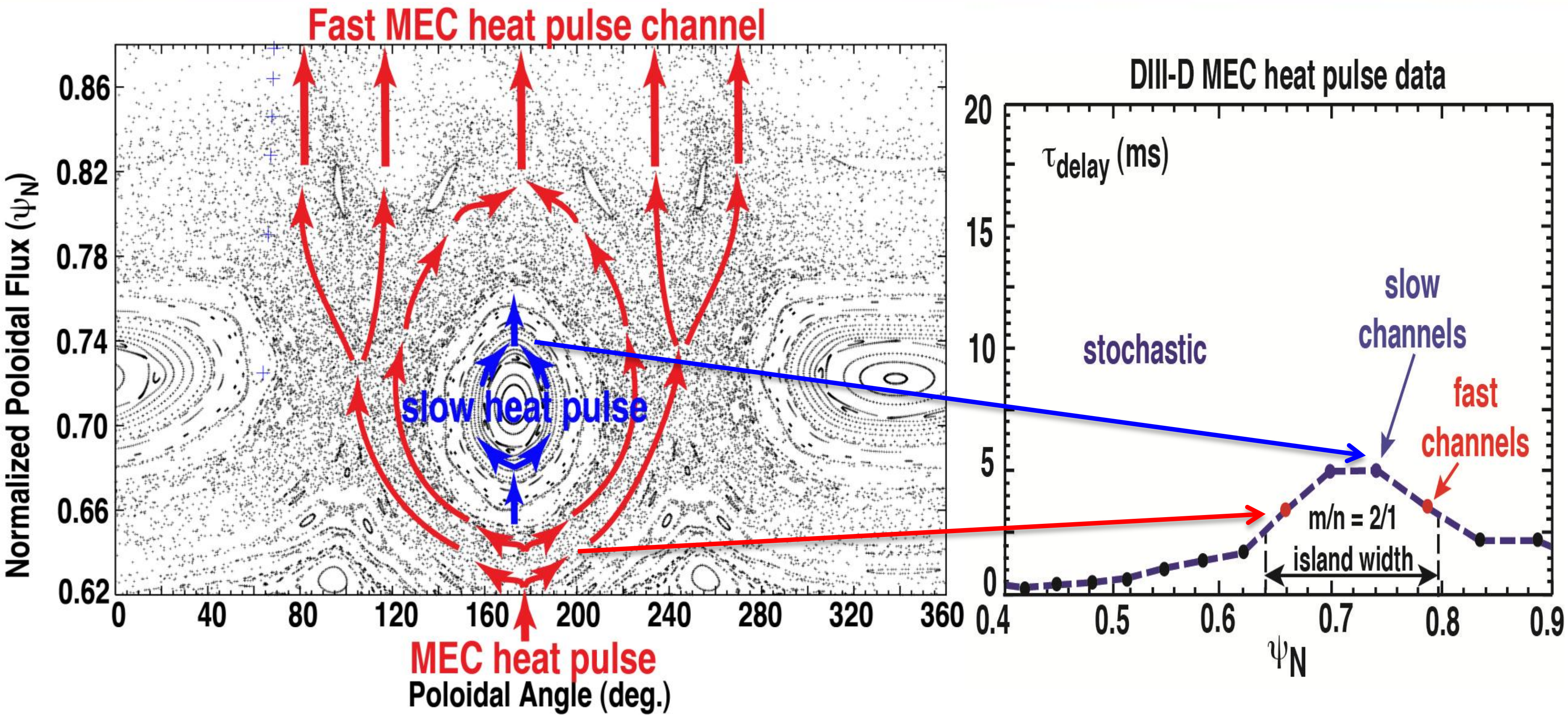
LHD Overview - OV/2-3

MEC Heat Pulse Delay Time Used to Determine Island Location and Width



- Fast heat pulse shunted around outside of island ($\chi_{||} >> \chi_{\perp}$)
- Heat pulse delay time increases at island center
- Island width determined from delay time profile

MEC Heat Pulse Time Delay Determines Degree of Stochasticity Around Islands



- **Heat pulse delay time reduced by partially stochastic island**
  - Nested flux surface in island center increases delay time

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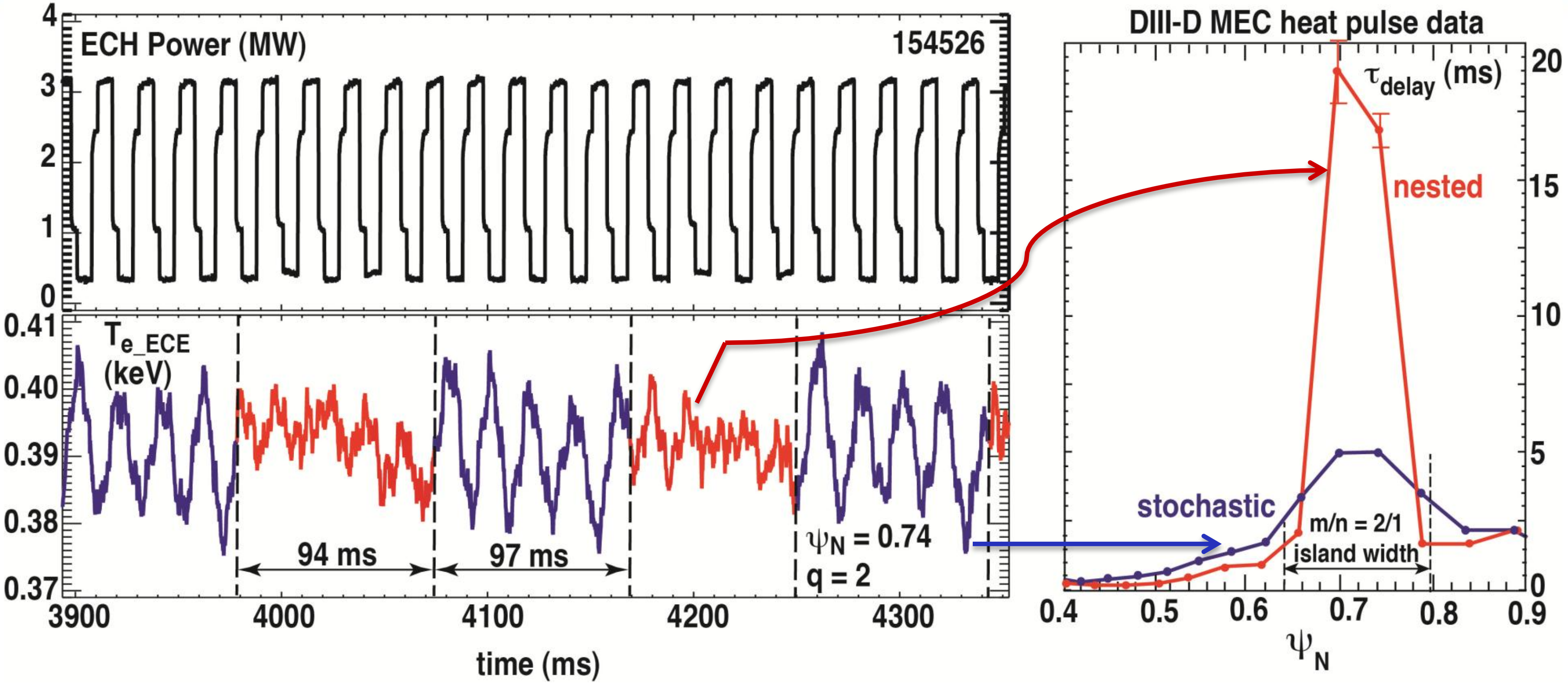
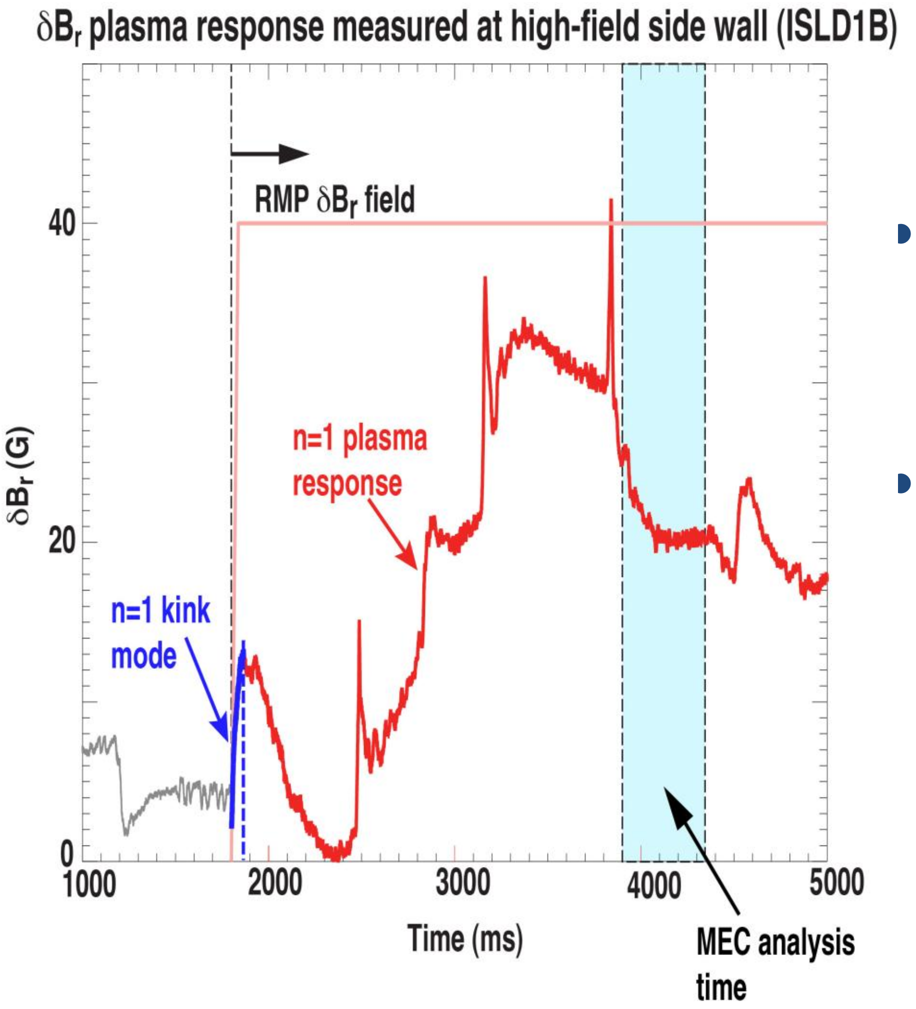
MEC Analysis Reveals Bifurcation of m/n = 2/1 Island from Nested to Partially Stochastic



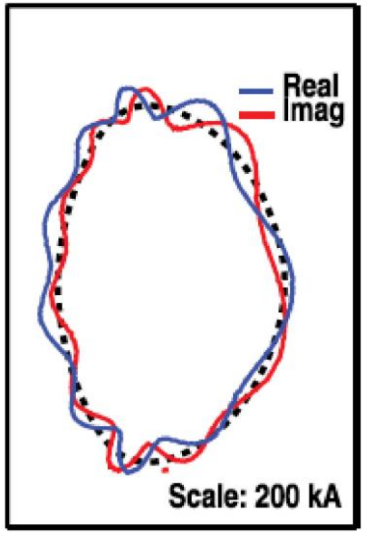
- **Periodic bifurcations of island observed during constant RMP field**
  - nested -> partially stochastic -> nested
  - *Indicates importance of plasma response on island stability*

Stable n = 1 Kink Mode Due to RMP Field Drives Large δB_r Plasma Response



- **Plasma n=1 δB_r response:**
  - Evolves on a transport timescale
- **During MEC analysis time plasma δB_r is 50% of applied RMP field**
  - Plasma n=1 δB_r affects island width

Proposed Scenario for Island Amplification and Bifurcation to Partial Stochasticity



Ideal kink mode

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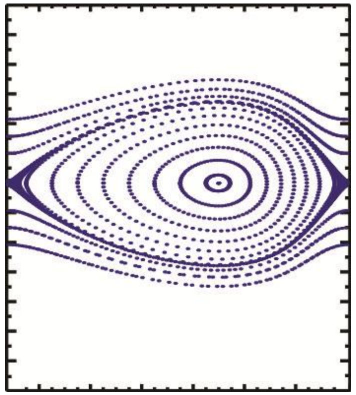
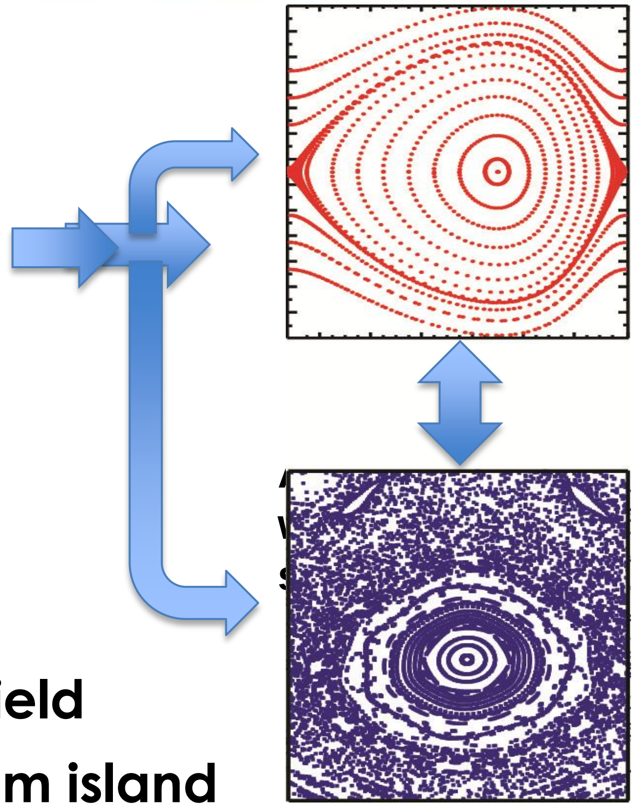

Vacuum island with nested flux surfaces

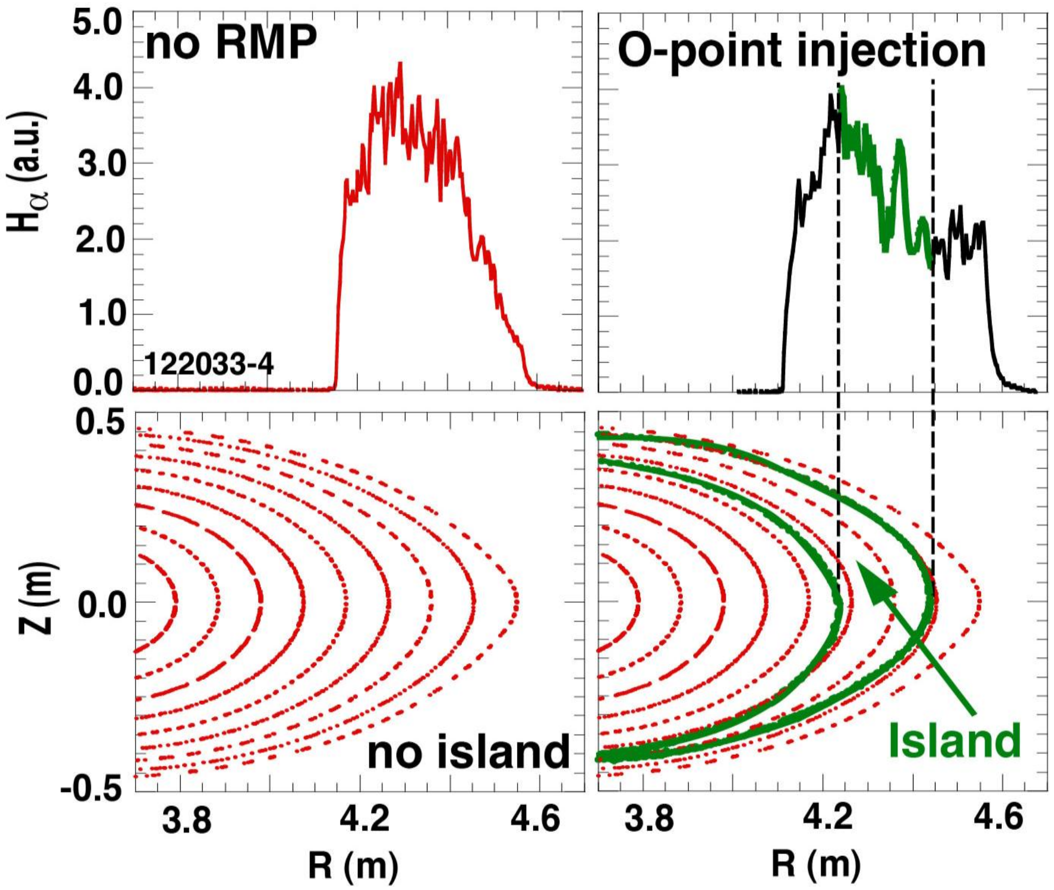


- RMP field drives stable n=1 kink mode
- Kink mode produces n = 1 δB_r plasma field
- δB_r n = 1 plasma field couples to vacuum island
- Results in larger m/n = 2/1 island width
- m/n = 2/1 island spontaneously bifurcates between nested and partially stochastic island

3D Physics – EX/1-1

Pressure Driven Instabilities May Cause Bifurcations of Islands between Nested and Stochastic Structures

- **Pellets used on LHD to study pressure driven Island stability**

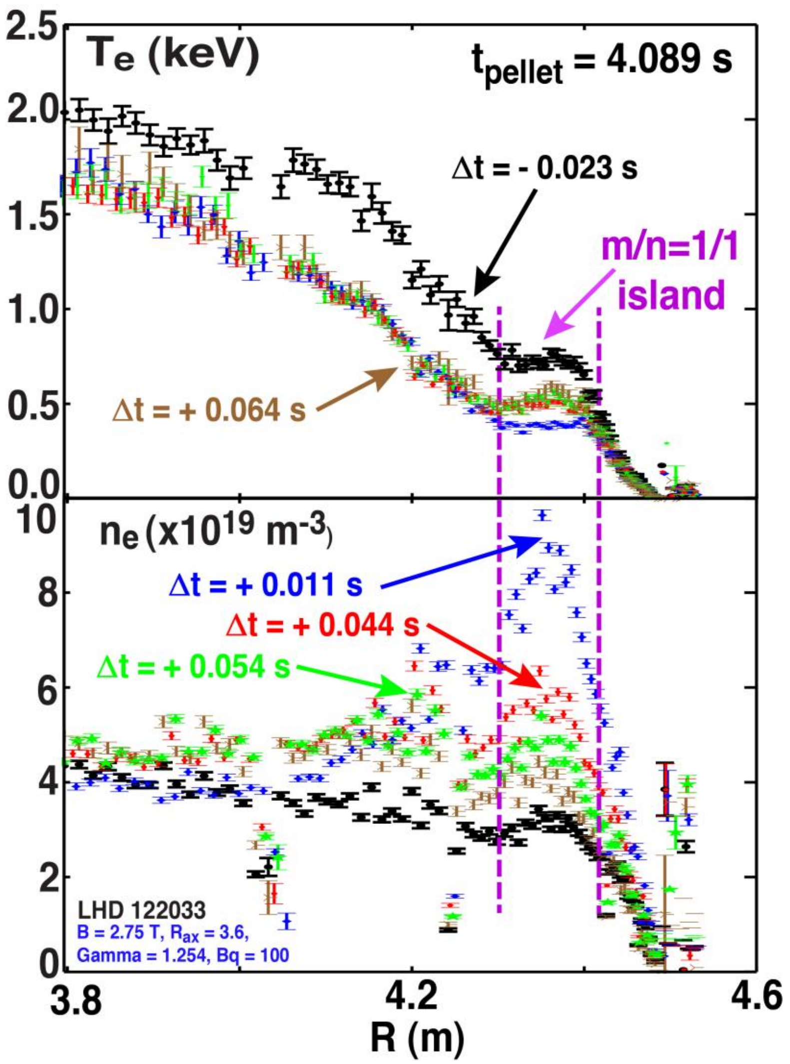


Pellet ablation profiles

LHD flux surfaces

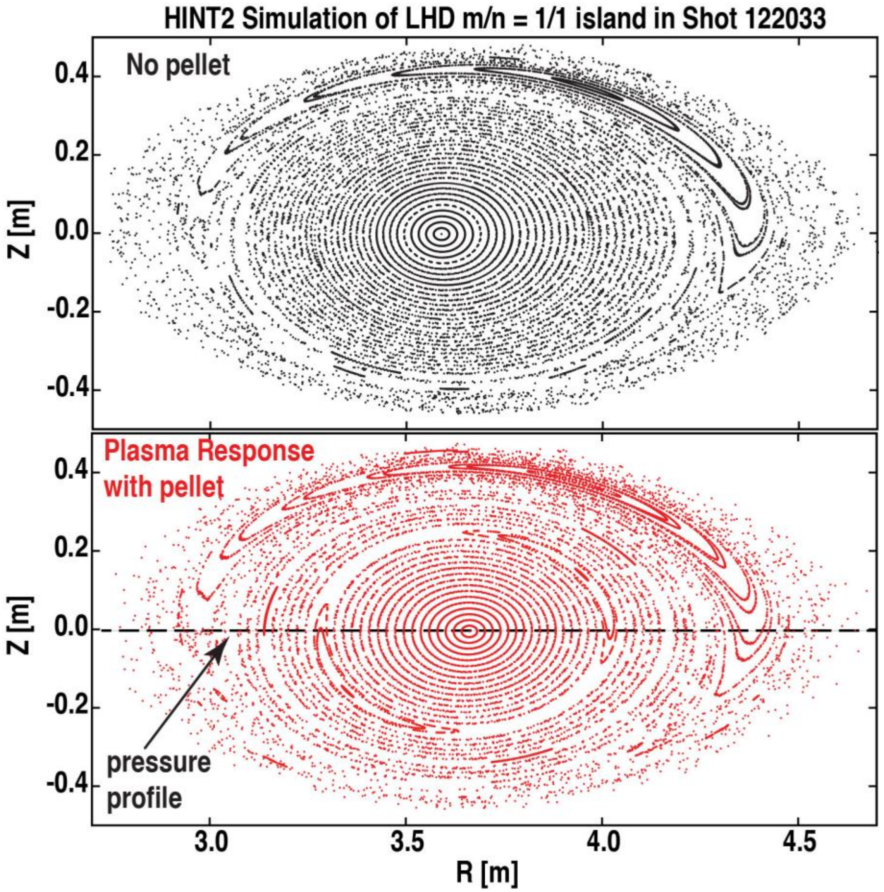
- **Thomson scattering profiles used to quantify island stability and transport**

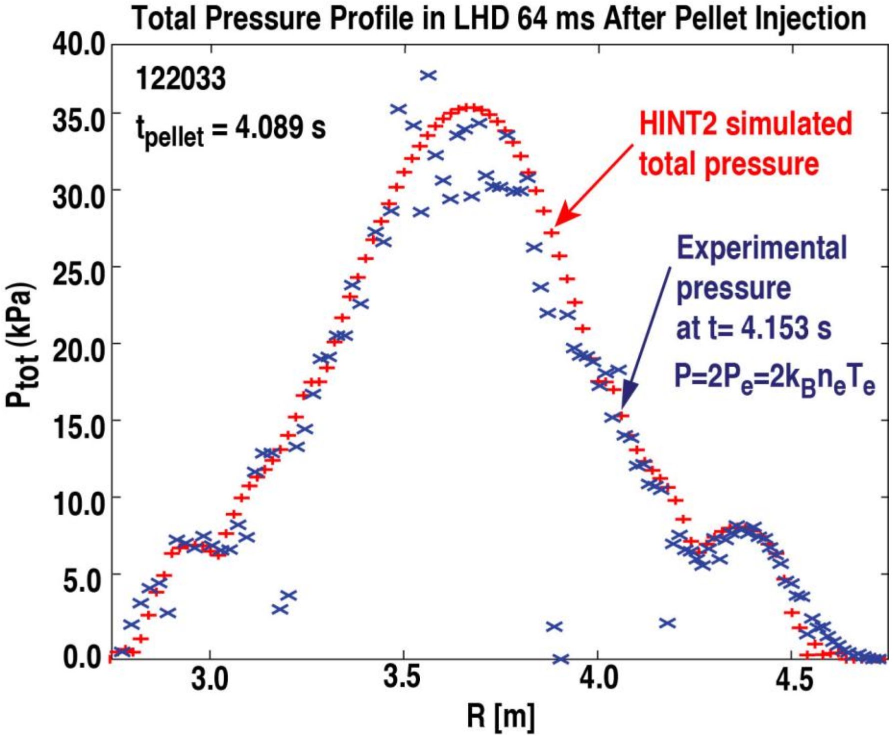
Edge m/n=1/1 Island Stable to 60 % Increase in Pressure During Pellet Injection in LHD



- **No significant change in island O-point T_e profile during pellet injection**
- **Island width remains relatively constant with factor of 3 increase in n_e**
  - β inside island increases by ~ 60%
- **MHD modeling needed to determine internal island structure**

HINT2 Simulations Demonstrate Edge m/n=1/1 Island Structure is Unaltered during Pellet Injection





- β_{island} less than 2% pressure driven island stability limit

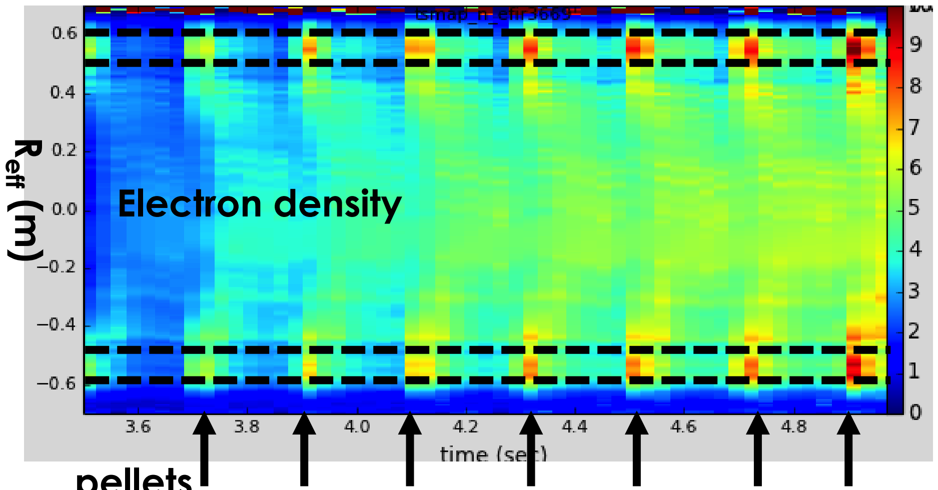
Edge m/n = 1/1 Magnetic Island Inhibits Inward Transport of Pellet Particles in LHD

- **Pellet particles localized to edge region with RMP field**
  - Relatively small inward pellet mass redistribution
- **Without islands pellet mass spreads over larger edge region**
  - Inward particle transport between pellets is much larger

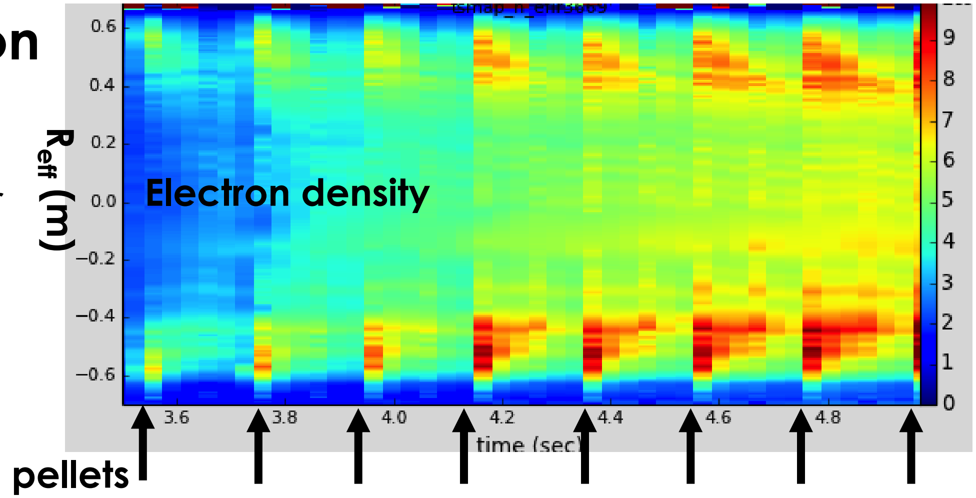
LHD Overview - OV/2-3

Density evolution during pellets in LHD

Magnetic island (with RMP) at $\rho = 0.5 - 0.6$



No magnetic island (without RMP)



Results and Conclusions

- ***Joint DIII-D and LHD experiments have demonstrated that the plasma response to the RMP field must be included to understanding the physics of ELM suppression***
  - In DIII-D plasma response to n=1 RMP field increases island width and causes spontaneous bifurcations of the internal island topology
  - In LHD the topology of an edge island is unaffected by a 60% increase in β and inward particle transport is inhibited