Overview of Recent DIII-D Experimental Results

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(LLNL)

Presented at the
62nd APS-Division of
Plasma Physics Conference
Memphis, TN
Nov 9-13, 2020

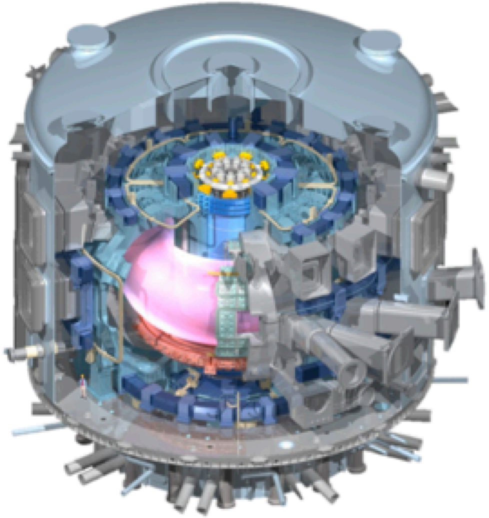
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, and under Contracts DE-FC02-04ER54698, DE-FG02-07ER54917, DE-FG02-05ER54809.
LLNL-PRES-816753

DIII-D Continues to Target U.S. Missions to Fusion Energy

- Fundamental Plasma Science

- Make ITER Better

- Develop Integrated Scenarios



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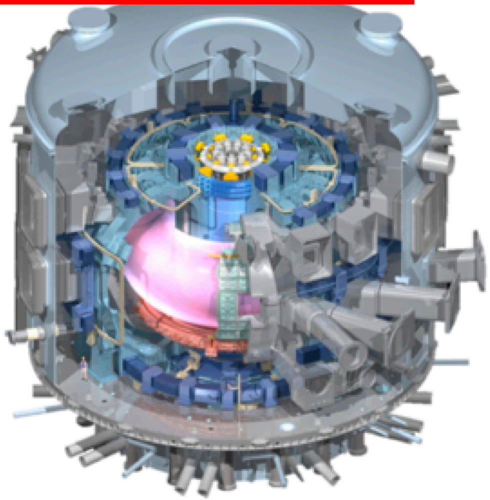
- Fundamental Plasma Science
  - Non-linear plasma response to 3D Fields
  - GAE Beam Injection Threshold
  - 2D Validated Divertor Impurity Concentration

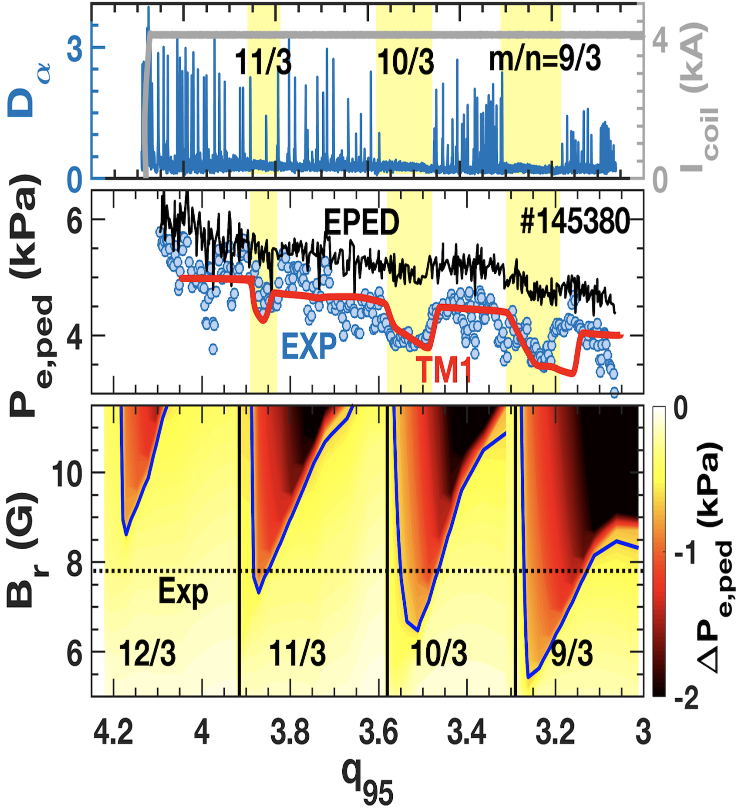
Foundational Physics Understanding

- Make ITER Better



- Develop Integrated Scenarios

TM1 Non-linear Plasma Response Model Quantitatively Predicts Narrow Isolated q_{95} Windows of RMP ELM Suppression



- ELM suppression window predicted as Δq_{95} for 15% pedestal pressure reduction

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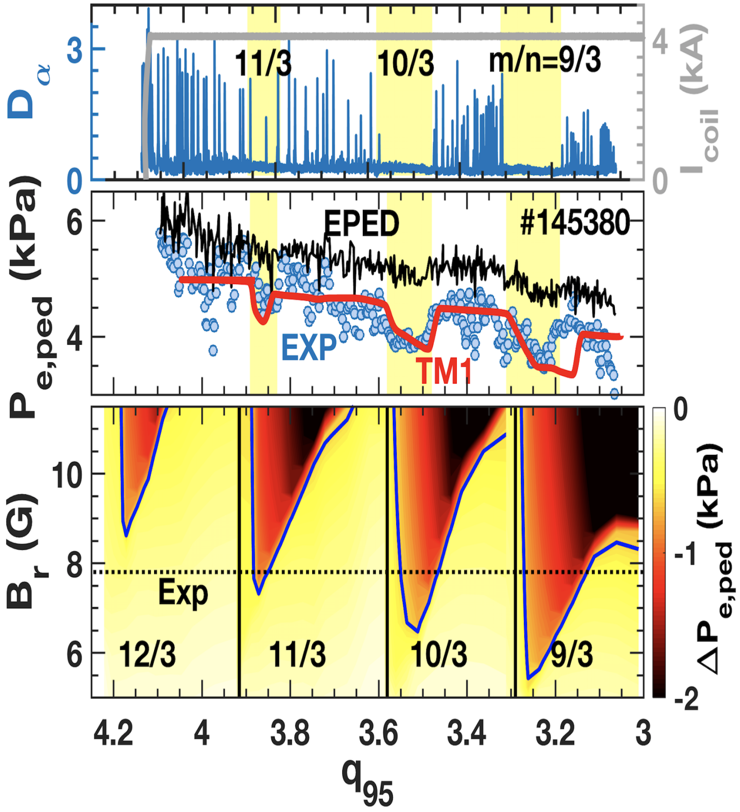
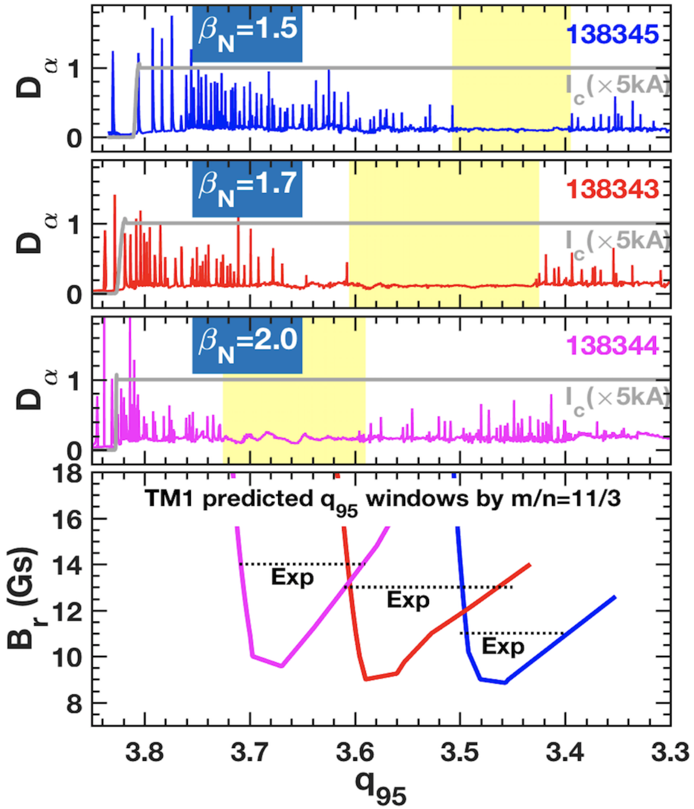
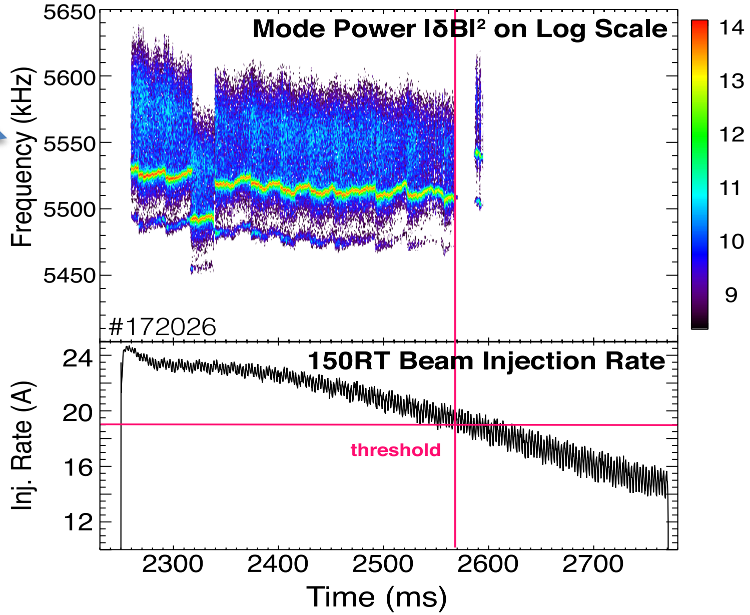




- ELM suppression window predicted as Δq_{95} for 15% pedestal pressure reduction
- Experimental β_N and shape dependence also predicted

First Observation of Beam Injection Rate Threshold for Global Alfvén Eigenmode

- **Fast-ion mode disappears for beam injection rate below threshold**



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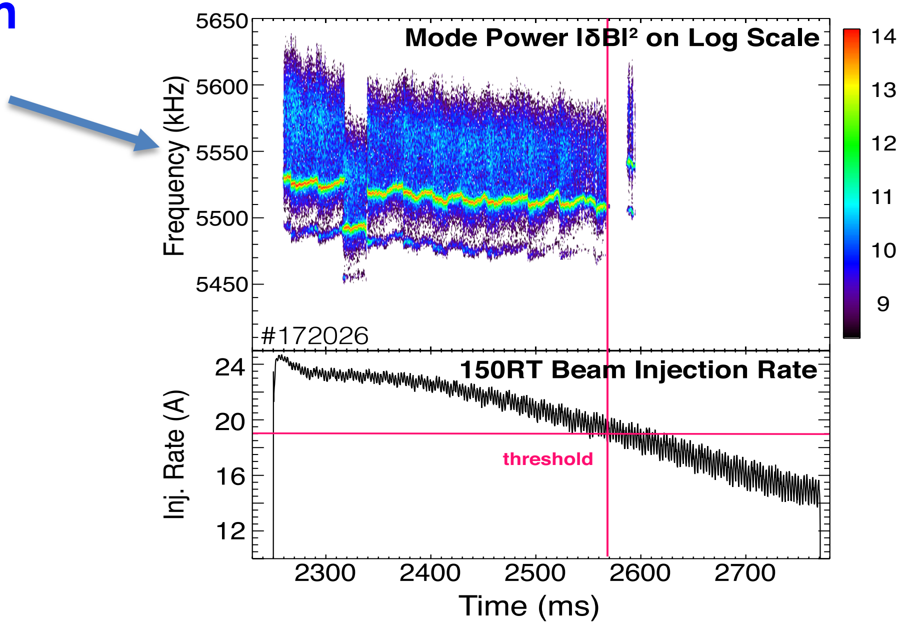
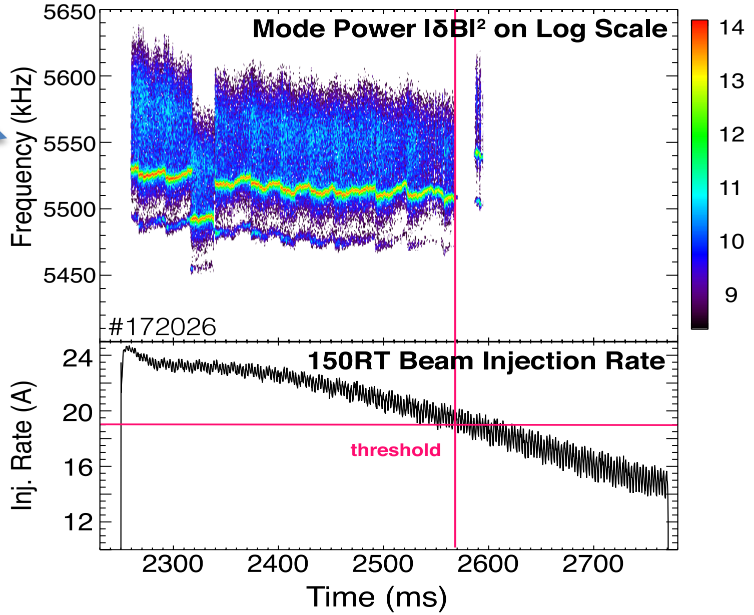


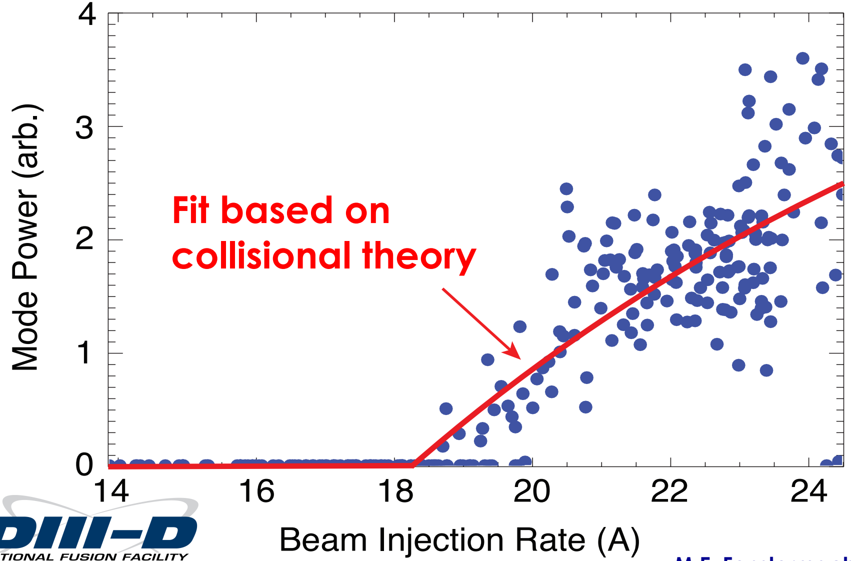
Global Alfvén Eigenmode (GAE) excited by Doppler-shifted cyclotron resonance with sub-Alfvénic fast ions

S. Tang, Fri AM

First Observation of Beam Injection Rate Threshold for Global Alfvén Eigenmode

- **Fast-ion mode disappears for beam injection rate below threshold**
- **Fit scaling with injection rate consistent with collisional saturation near marginal stability**





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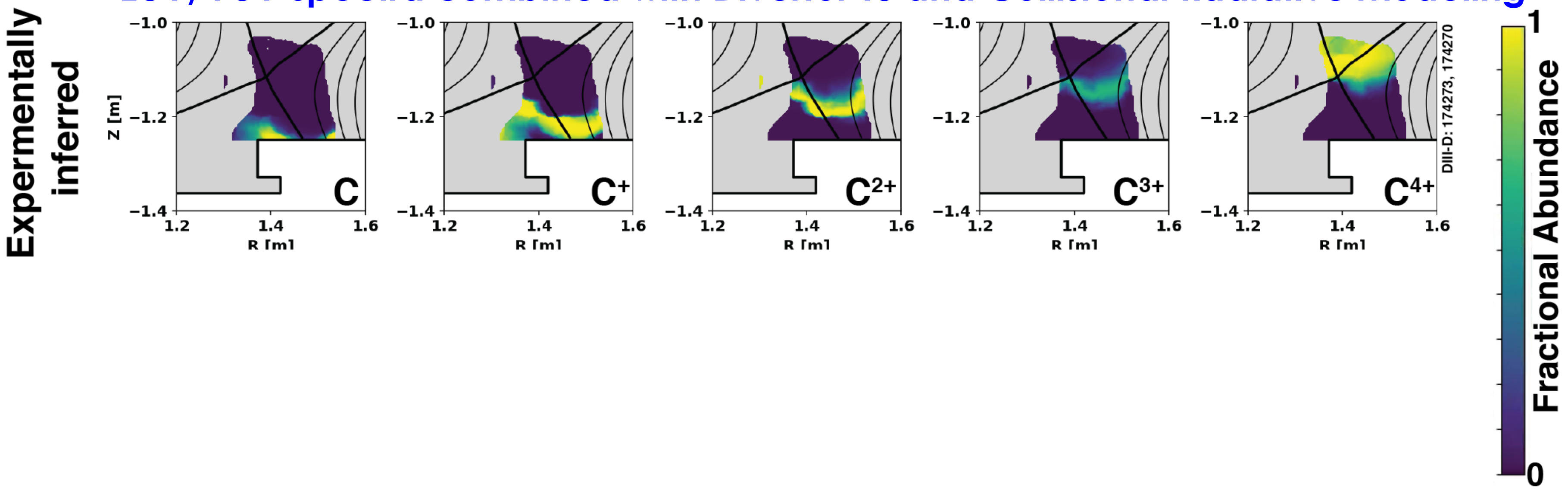
Multi-Charge-State Carbon Measurements of Large Concentration Variations in Divertor Validate Models

- **EUV/VUV spectra combined with Divertor TS and Collisional Radiative Modeling**



- **Significant departure from a fixed fraction assumption**
  - Inter-ELM intrinsic carbon impurity fraction 4.5±1.0% in attached, 0.4±0.1% in detached H-mode

McLean, This Session

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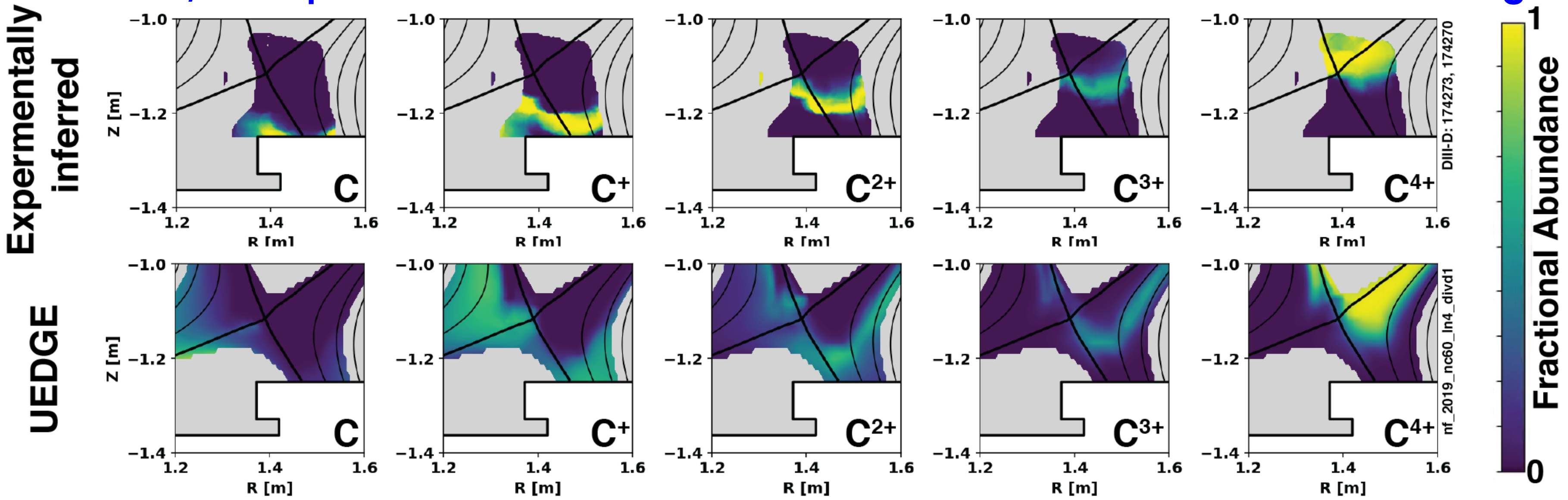

- Significant departure from a fixed fraction assumption
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- 2D profile of fractional abundance comparable to UEDGE with drifts and multi-species carbon transport

McLean, This Session

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- Fundamental Plasma Science
  - Non-linear plasma response to 3D Fields
  - GAE Beam Injection Threshold
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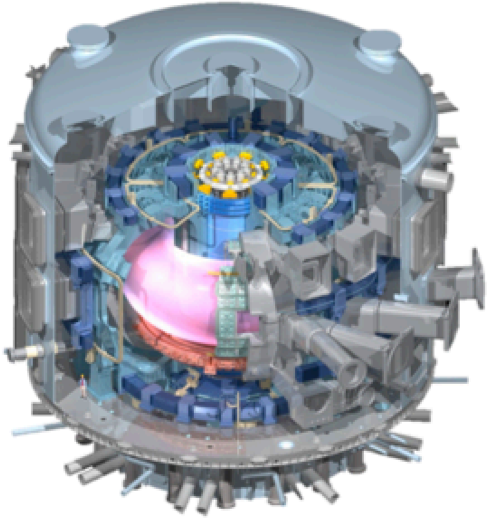
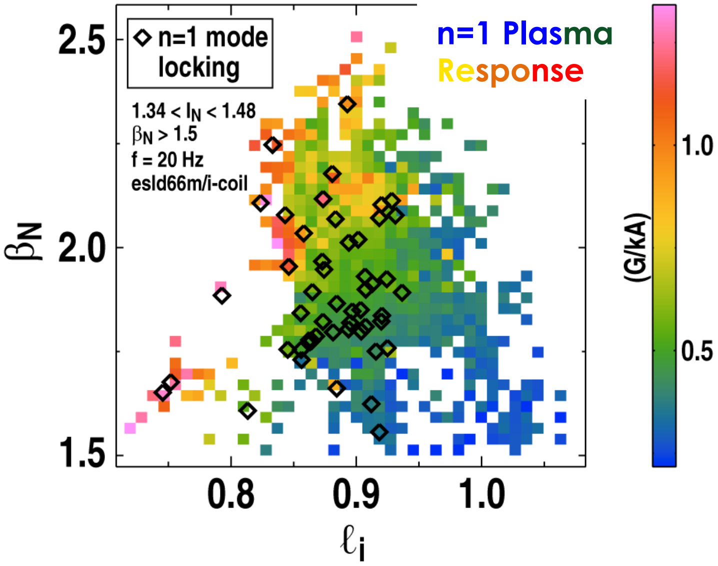
- **Make ITER Better**
  - **RWM Control**
  - **Pedestal Ion Heat Flux**
  - **Tungsten Migration**

- Develop Integrated Scenarios

Critical issues for the ITER Research Plan



Resistive MHD Including Rotation Governs Ability to Control Mode Locking and Disruption Limits in ITER Baseline Scenario



- **Plasma response amplitude increases at low l_i, high β_N**
  - **Plasma response to small applied sinusoidal n=1 from I-coils**

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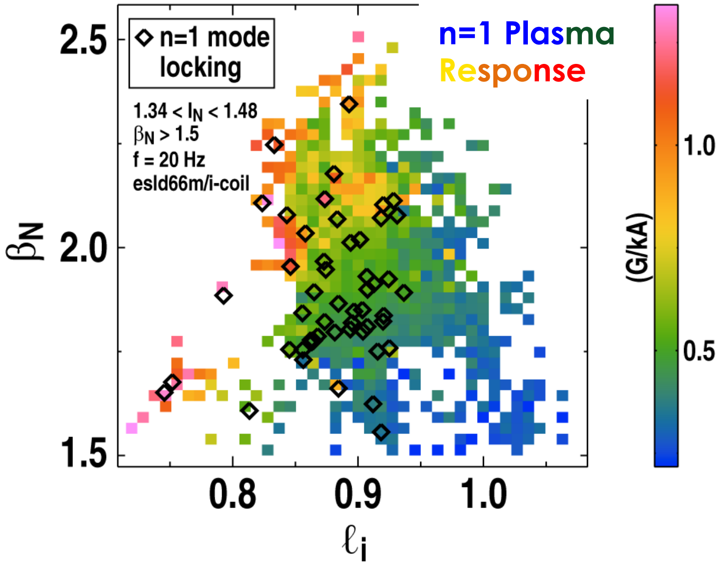

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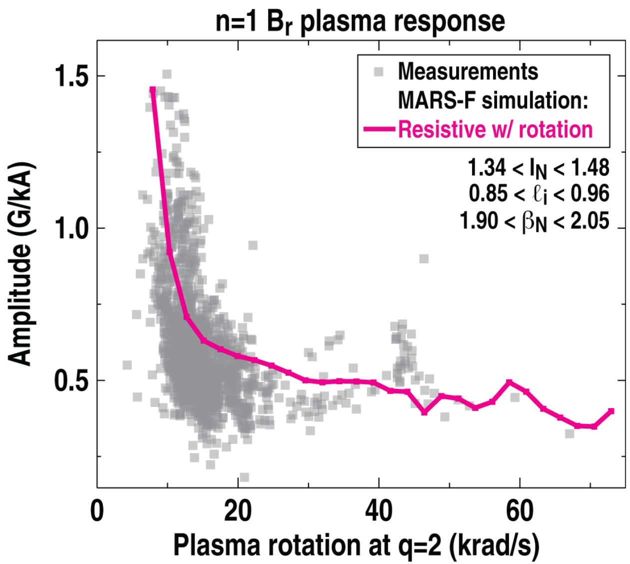

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

J. Hanson, Thurs AM

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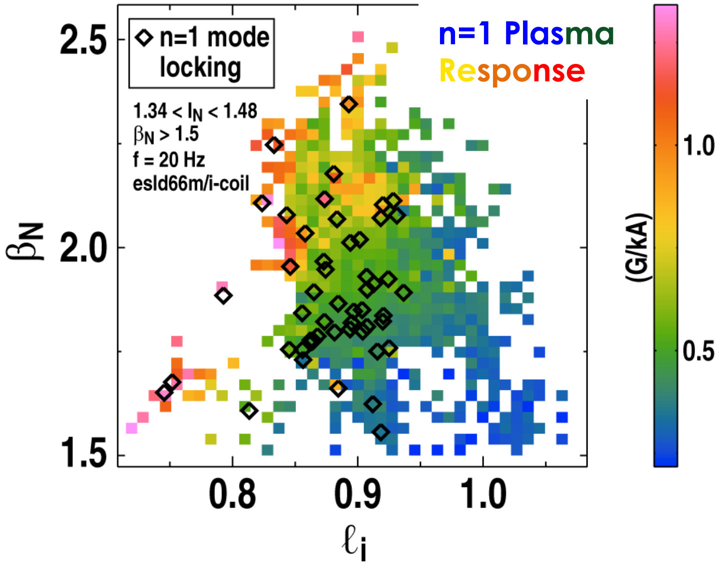

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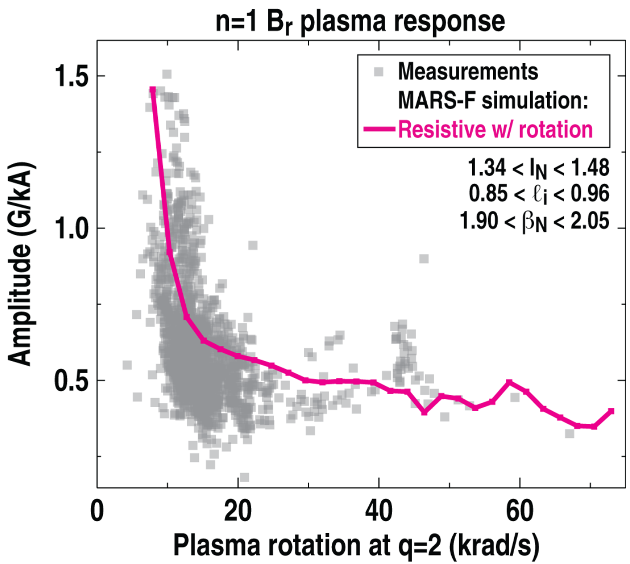

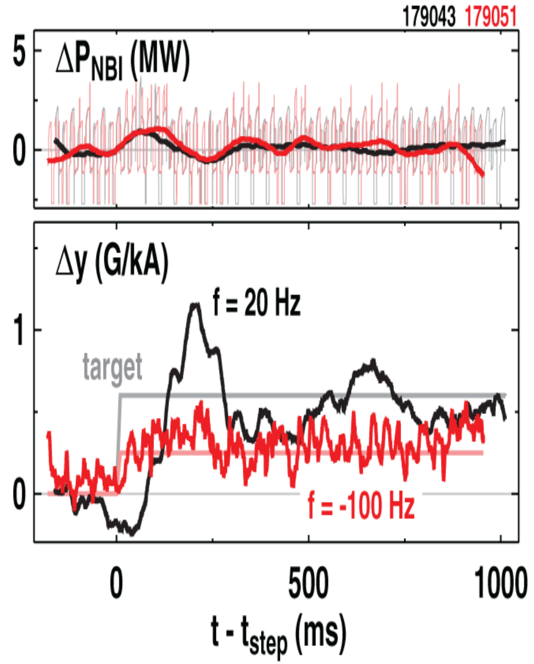

- **Plasma response Δy control demonstrated using P_{NBI}**

J. Hanson, Thurs AM

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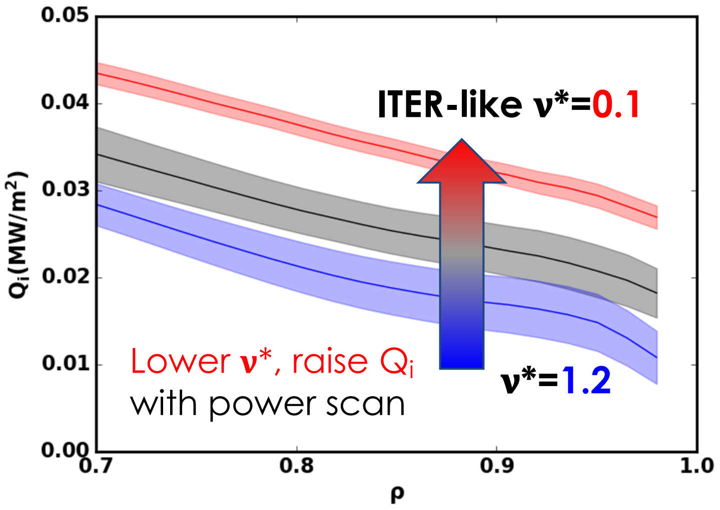
First Main Ion CER Inferred Pedestal Ion Heat Flux Shows Transition from Neoclassical at High ν*, to Neocl. + Turbulence at Low ITER ν*



- Power and density scan across order of magnitude in ν* (1.2→0.1)
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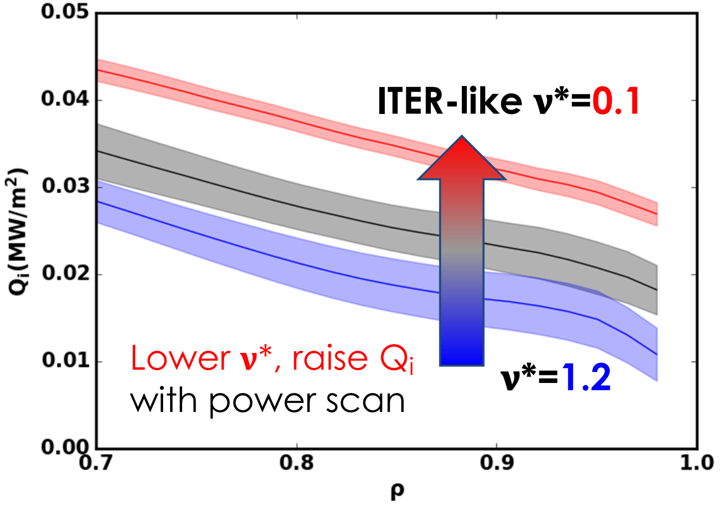
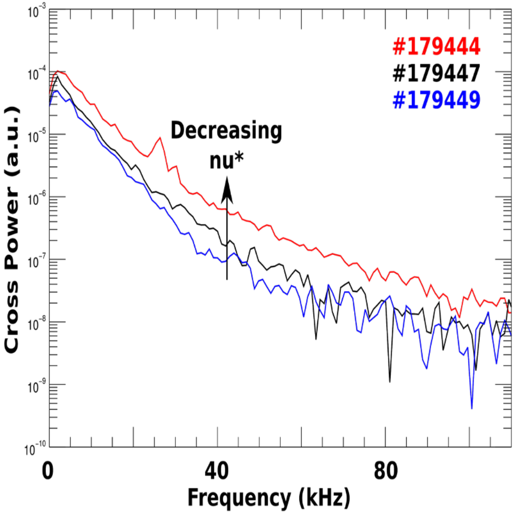


- BES fluctuations in pedestal shows higher ion-scale turbulence **at low ν***



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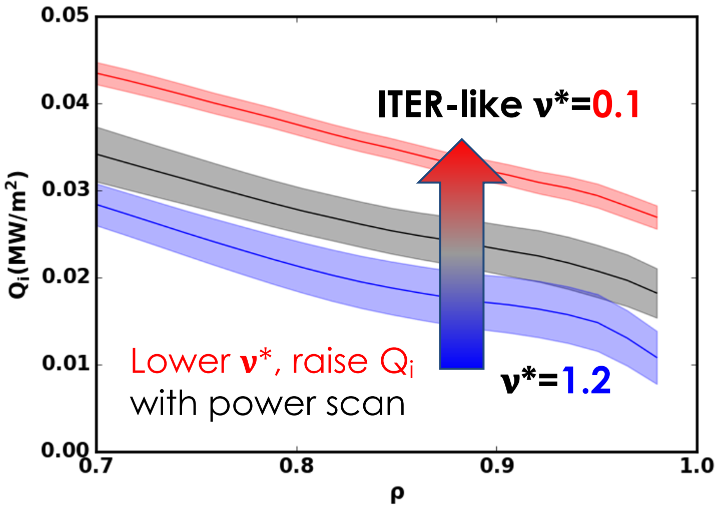

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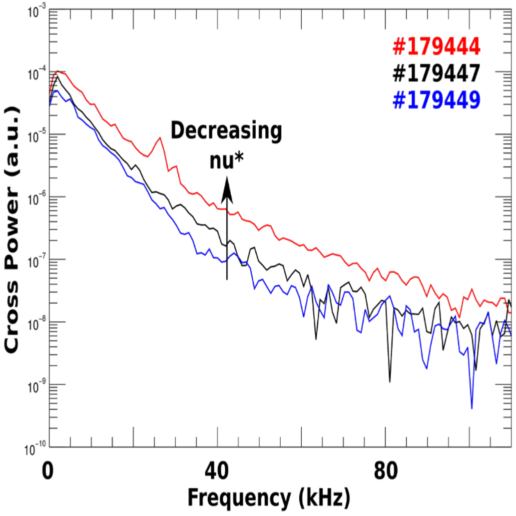
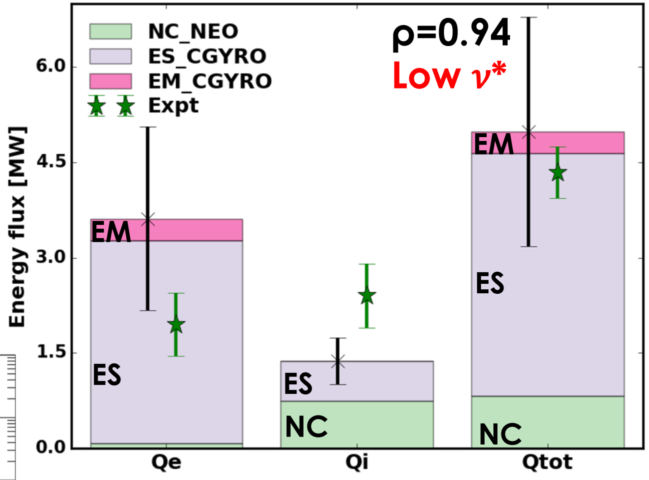
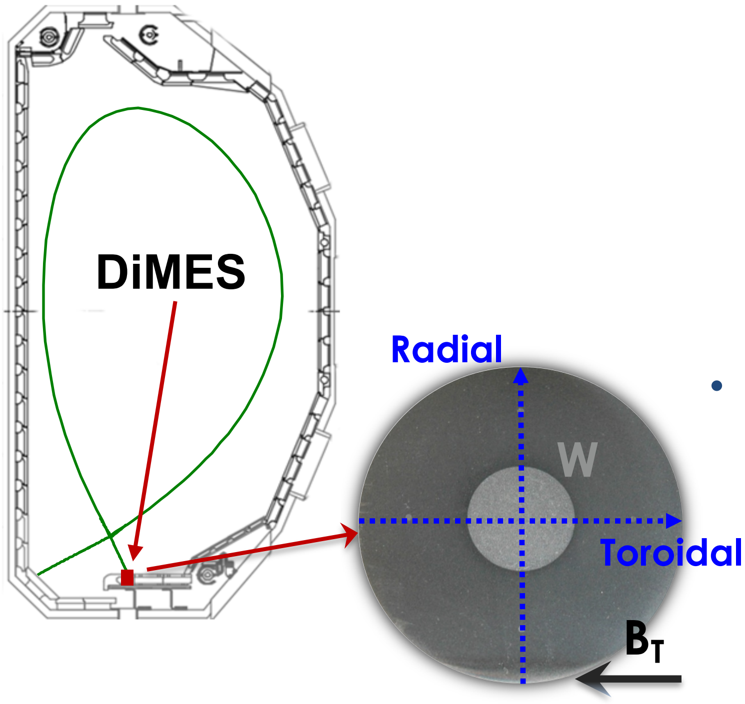




- NEO + Nonlinear CGYRO pedestal simulations in good agreement with experimental energy flux
  - Neocl. + electrostatic turbulence

Integrated Model of W Ionization and Re-deposition Quantitatively Compared Against DiMES Experiment Data



- Measured asymmetries of re-deposited W “tails” interpreted with OEDGE/WBC/ITMC-DYN codes

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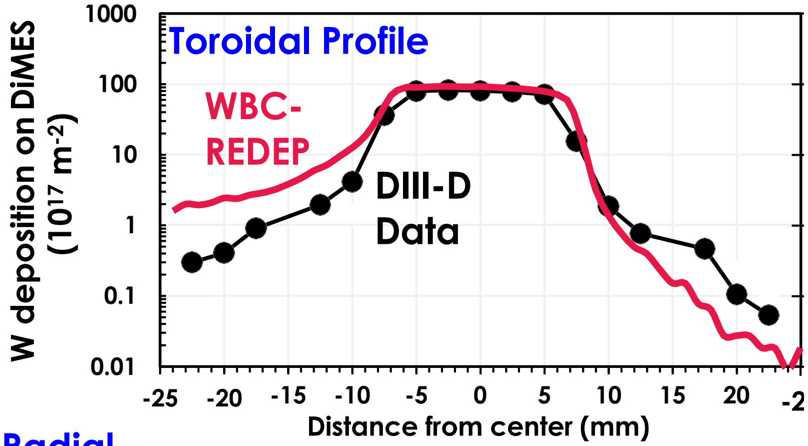

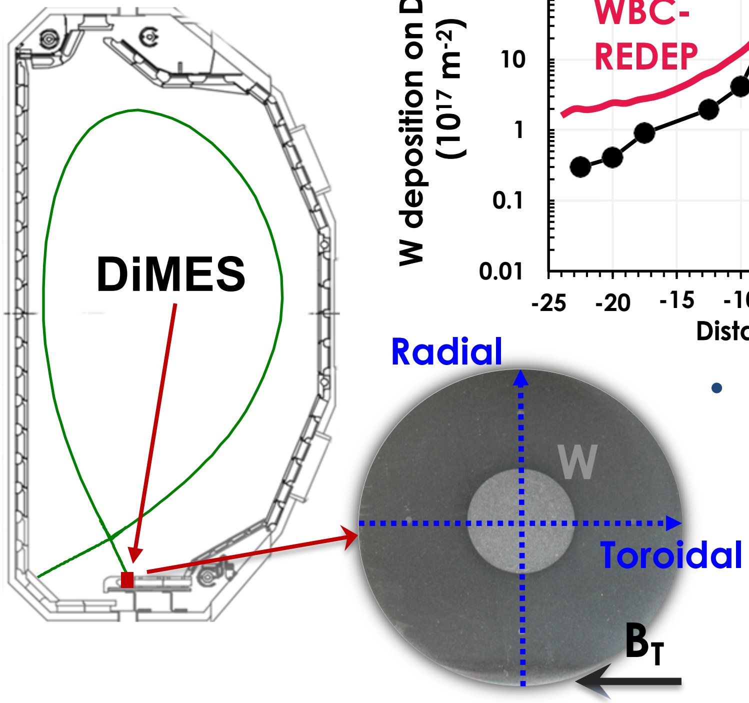

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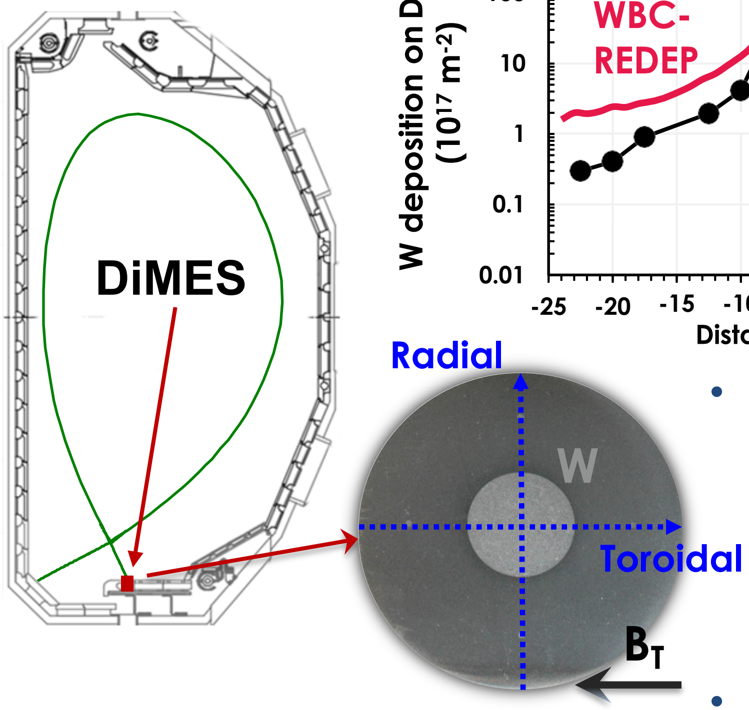

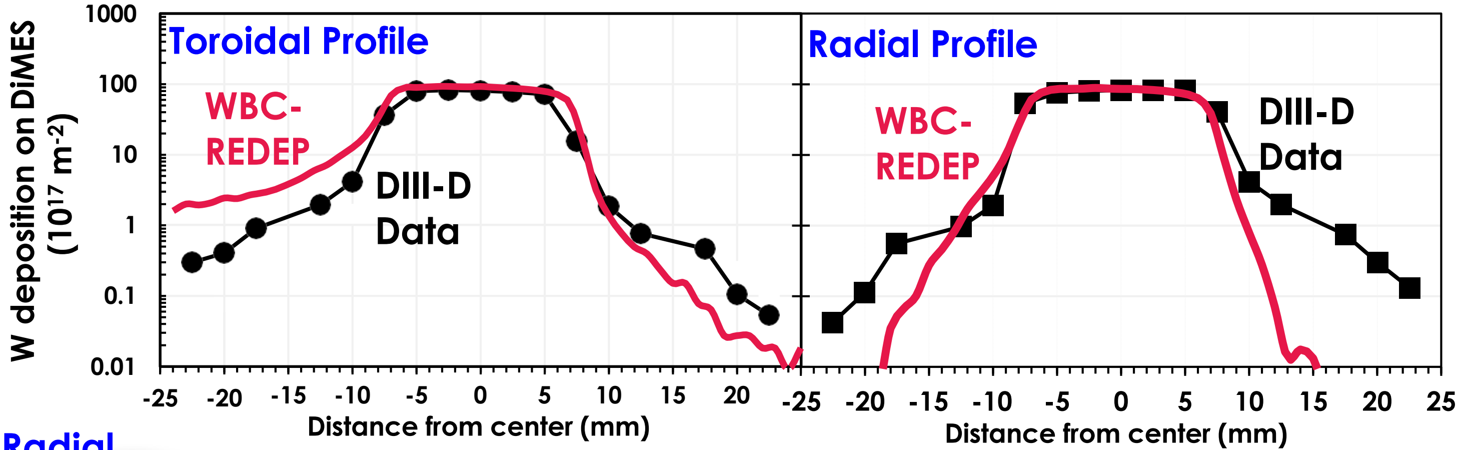

- **Measured asymmetries of re-deposited W "tails" interpreted with OEDGE/WBC/ITMC-DYN codes**
  - Toroidal asymmetry: Plasma flow and impurity/plasma collisions along B_T field line
  - Radial asymmetry: Difference in W ionization lengths from radial density gradients
- **Validation effort will lead to better predictive capability for ITER W migration**

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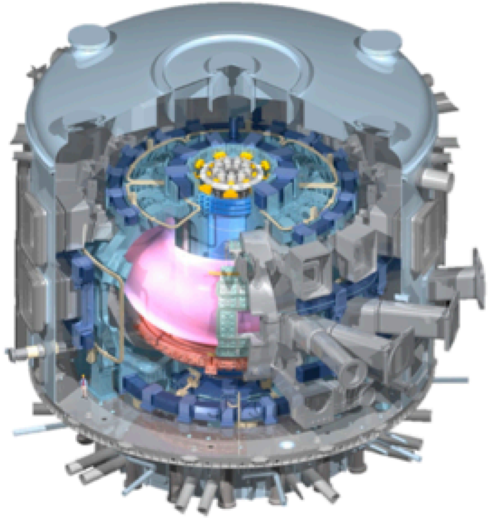
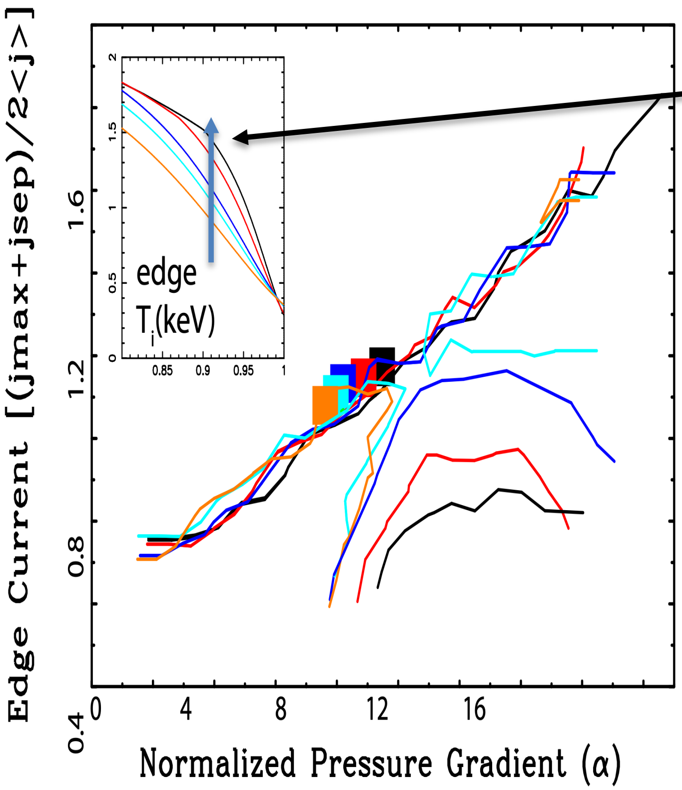
- **Develop Integrated Scenarios**
  - SS Hybrid Projection to ITER
  - High q_min Fast Ion Confinement
  - High Beta_p with Impurities
  - Potential of Negative Triangularity

Solutions for AT Scenarios



Steady State Hybrid Scenario Can Be Optimized With High Density and Pedestal Pressure



- **Increased edge ∇T_i from higher P_{heat}**

F. Turco, Thurs PM

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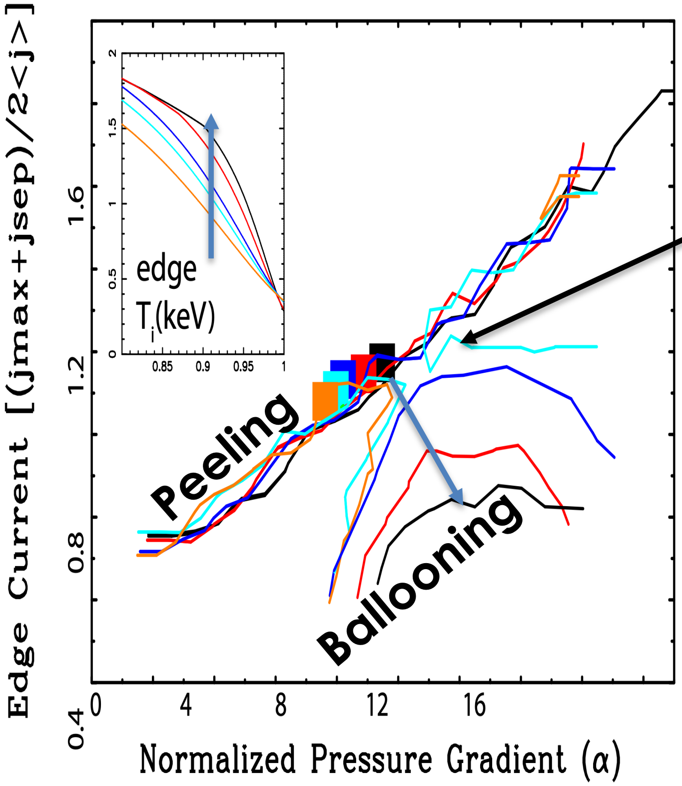

- **Increased edge ∇T_i from higher P_{heat} decouples peeling from ballooning limit**
  - **Higher p_{ped} & τ_E at higher density**

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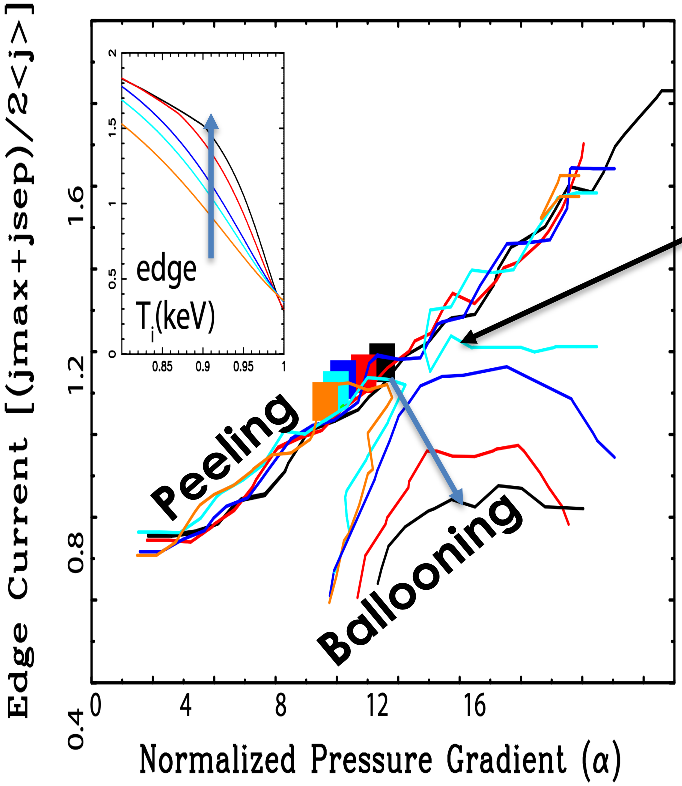
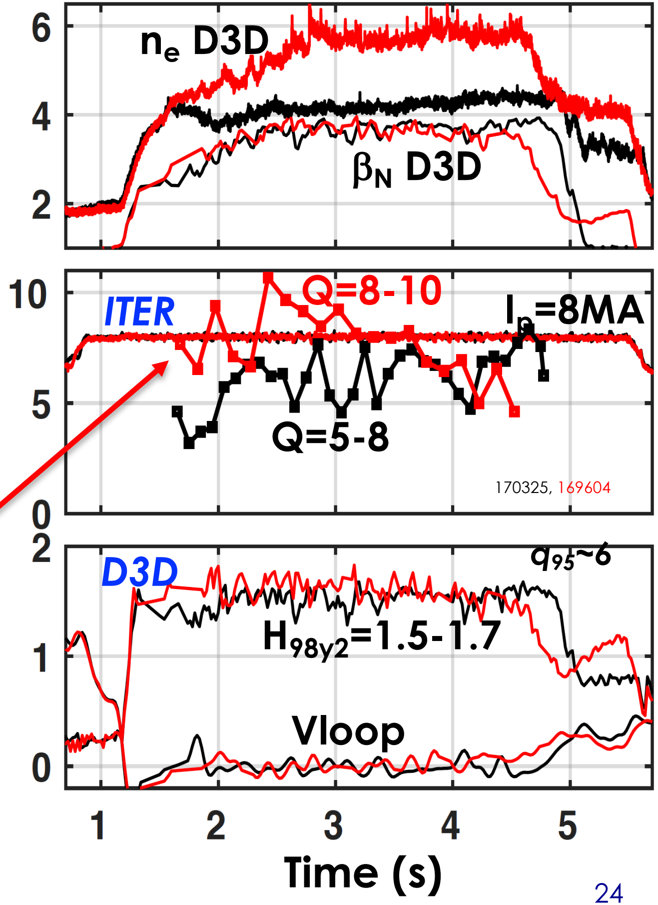
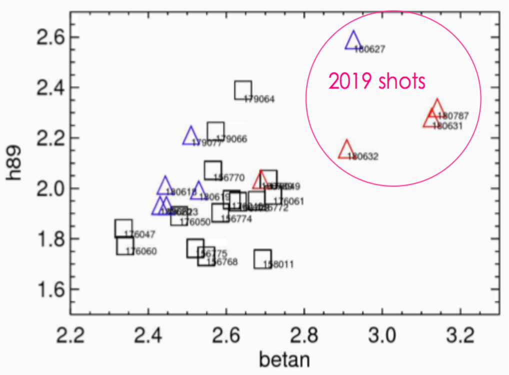


- **Increased edge ∇T_i from higher P_{heat} decouples peeling from ballooning limit**
  - **Higher p_{ped} & τ_E at higher density**
- **Rho*-scaling projections to ITER predict Q~5 near Ip=8 MA**
  - **Optimization at 9 MA allows for $f_{GW}^{ped}<1$**



F. Turco, Thurs PM

Increased Off-Axis NB Power Reduces AE Drive Giving Improved Fast Ion Confinement in High-q_{min} Plasmas



- **More off-axis beams gave 15% higher β_N**
  - **Reduced beam maximum pressure gradient at rho_qmin**

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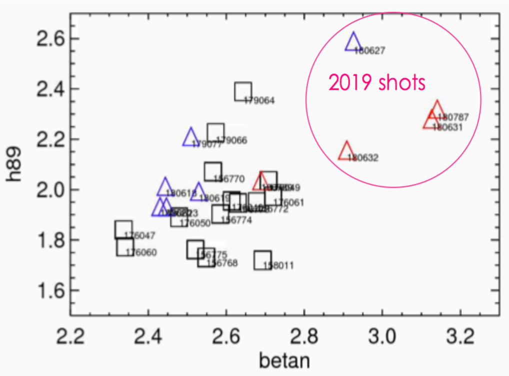

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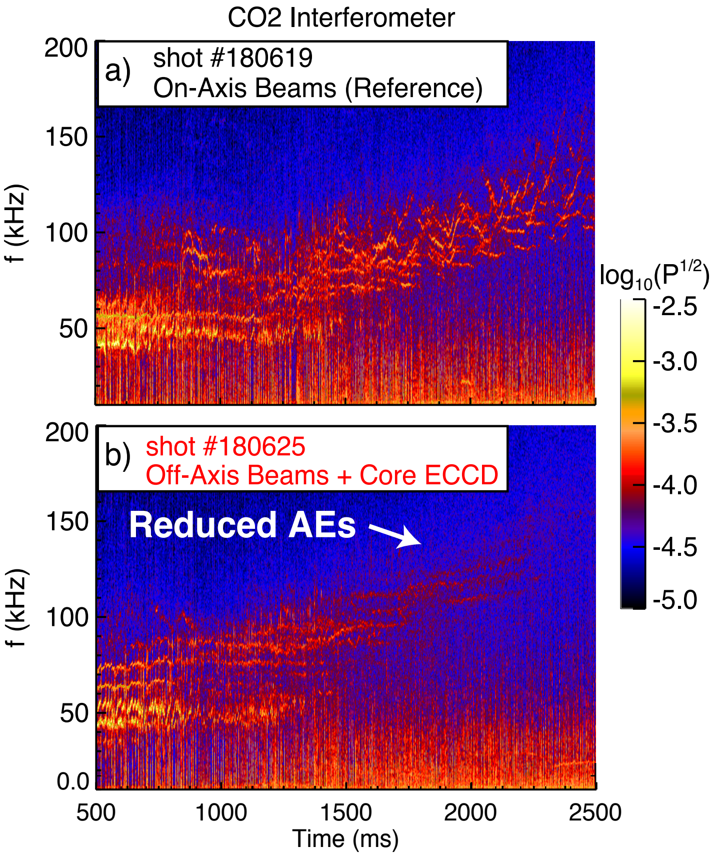

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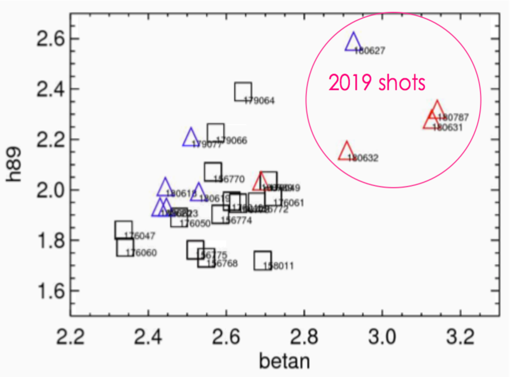

- **More off-axis beams gave 15% higher β_N**
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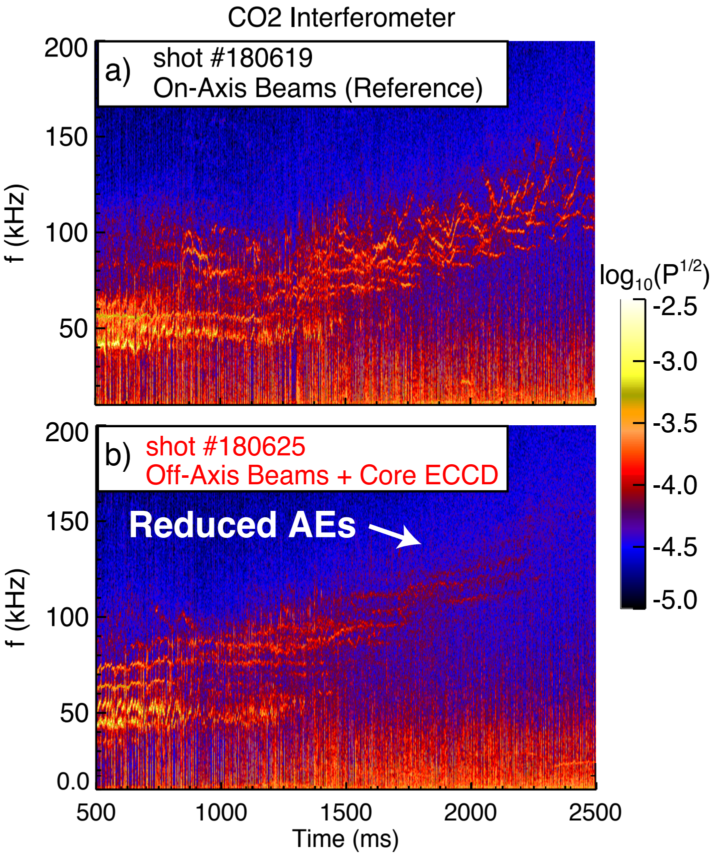
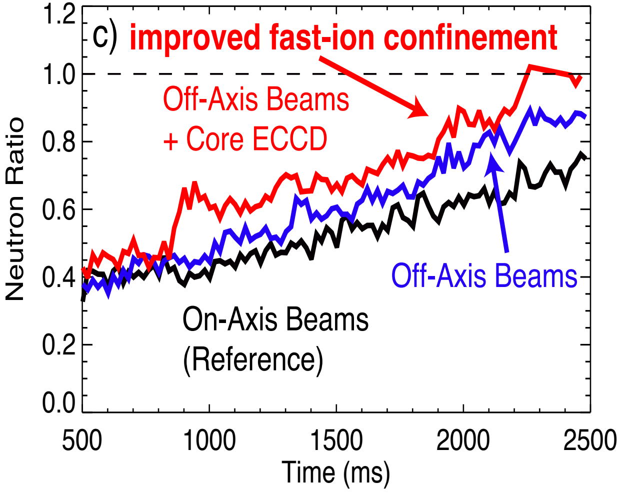
  - **Neutrons/TRANSP (classical) increased**

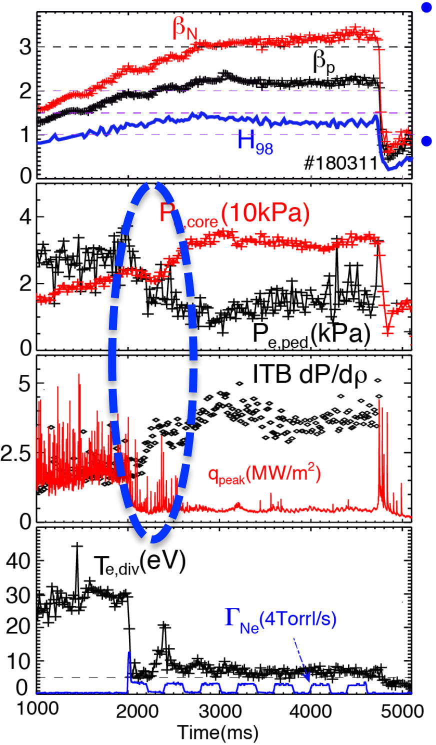




- **RSAEs can be controlled with q-profile manipulation**
  - **Up to 36% higher neutron ratio with on-axis ECCD**

C. Collins, This Session

Formation of Large Radius ITB Compensates Pedestal Degradation due to Detachment, Achieving Excellent Core-Edge Integration Compatibility



- **Sustained high performance core**
  β_N>3, β_p~2.3, H_{98}~1.4, f_{GW}>1
- **Neon seeded ELM suppression and divertor detachment, $T_{e,LP}$<10eV $q_{peak,IR}$~0.4MW/**

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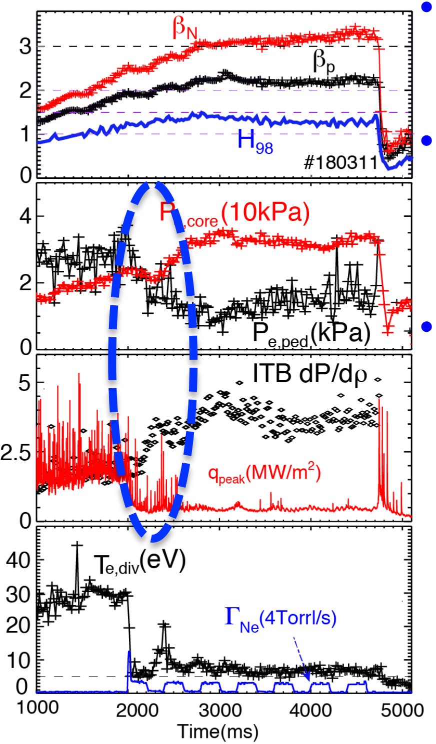

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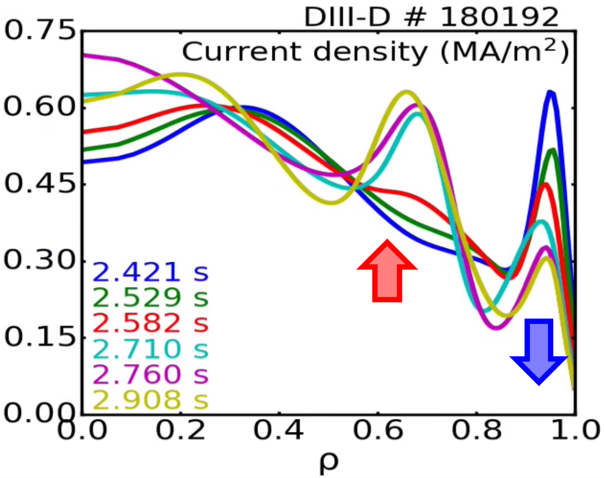

Pedestal height decreases -> Magnetic shear decreases at large radius

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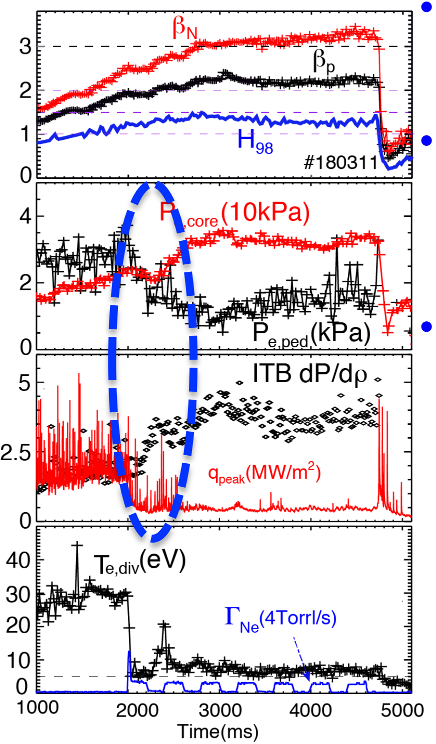

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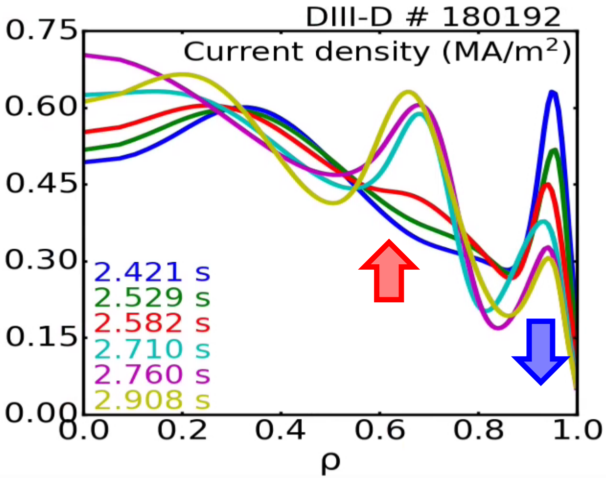
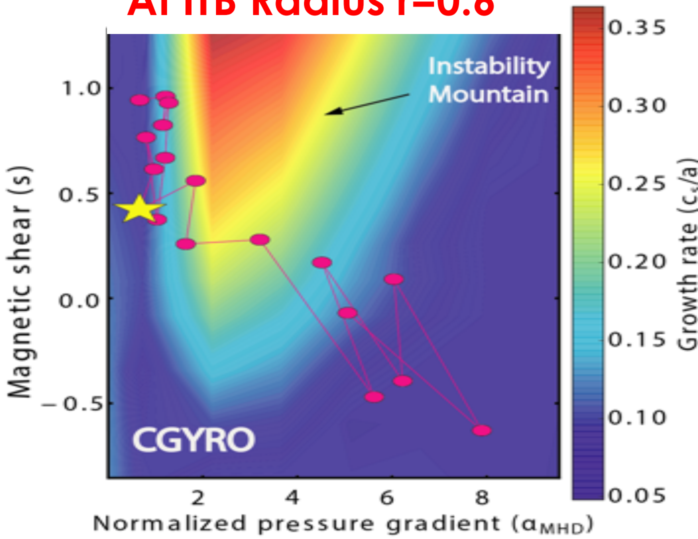


At ITB Radius r=0.6

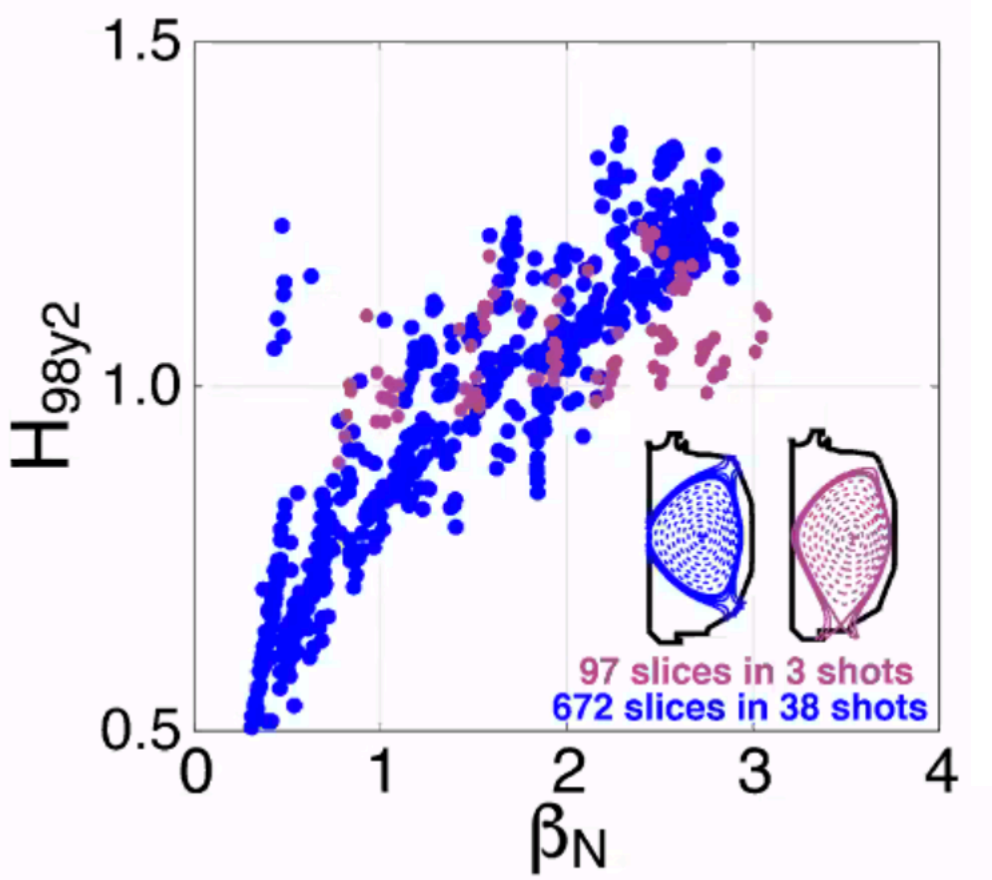


Pedestal height decreases -> Magnetic shear decreases at large radius

Plasma makes a detour around the instability mountain to access low transport

H. Wang, Thurs PM

High Power, Diverted Negative Triangularity Discharges Show High Confinement, Significant β_N and ELM-free L-mode Edge



- **No ELMs L-mode edge with up to 5x P_{L-H}, high-confinement and up to β_N=3.0**
  - Combination of shape-induced effects that weaken turbulent transport
  - Only got H-mode at less negative triangularity

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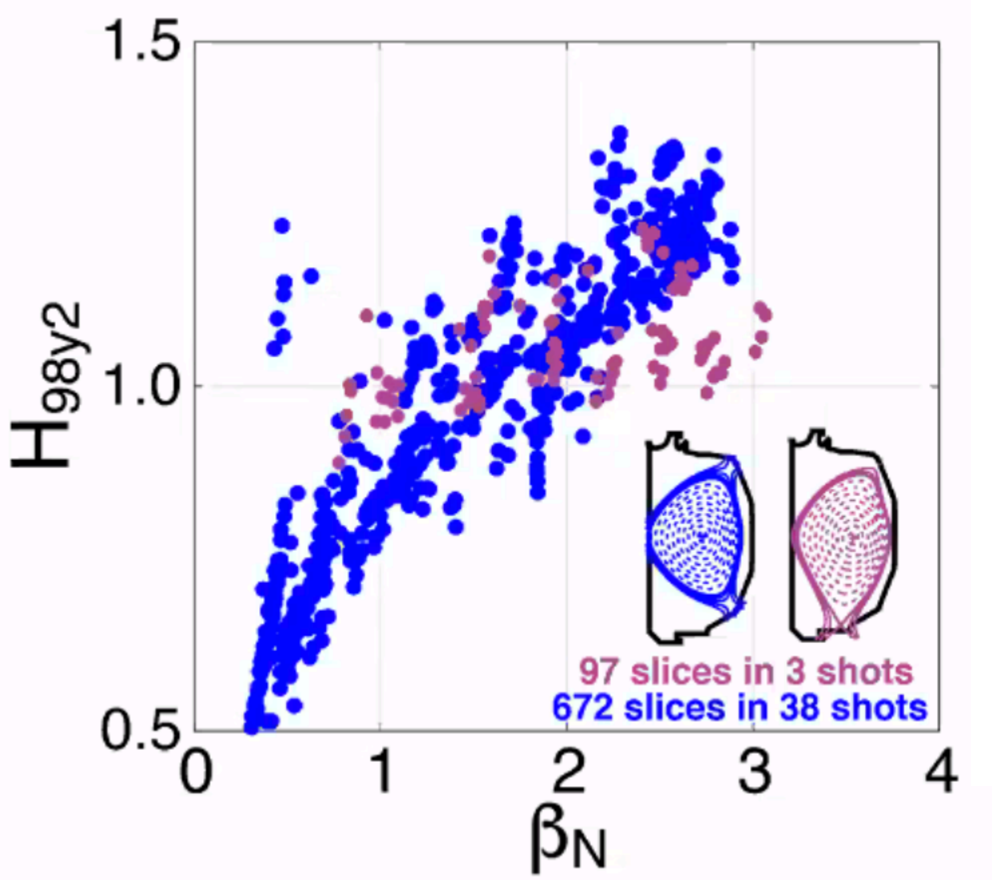

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  - **Combination of shape-induced effects that weaken turbulent transport**
  - **Only got H-mode at less negative triangularity**
- **NT is also promising candidate for core-edge integration**
  - **Robustly ELM-free with divertor at large R**
  - **Broad λ_q and low P_{Sep}**

DIII-D Program Much Broader Than Can Be Described Here – See Invited and ITER Talks Plus Two Poster Sessions

Invited Talks			
Tues	10:00	S. Haskey	Main-ion Thermal Transport in High Performance DIII-D Edge Transport Barriers
Tues	10:30	S. Ding	The Role of Toroidal Rotation in the Very High Energy Confinement Observed in Super H-mode Experiments on DIII-D
Tues	12:00	L. Schmitz	Reducing the L-H Power Threshold in ITER - What Can We Learn from Microscopic Transition Physics?
Wed	10:30	R. Wilcox	Pellet ELM triggering with low collisionality, peeling-limited pedestals in DIII-D
Wed	11:00	Qiming Hu	Predicting operational windows of ELMs suppression by Resonant Magnetic Perturbations in DIII-D and KSTAR
Wed	11:30	M. Austin	Reactor-friendly core and boundary of DIII-D diverted negative triangularity plasmas with persistent L-mode edge
Wed	12:00	D. Ernst	Favorable Core and Pedestal Transport Properties of the Wide Pedestal QH-Mode Regime
Thur	9:30	M. Beidler	Spatially-dependent simulation of runaway electron mitigation experiments on DIII-D
Thur	10:30	V. Izzo	MHD modeling of dispersive shell-pellet injection as an alternative disruption-mitigation technique
Thur	12:00	J. Hanson	Non-ideal stability and control of ITER baseline demonstration discharges
Thur	4:30	H. Wang	First Observation of A Fully Detached Divertor Natural Compatibility with A High Confinement Plasma State for Steady-State
Thur	4:30	F. Turco	The physics basis to integrate an MHD stable, high-power core to a cool divertor for steady-state reactor operation
Fri	9:30	S. Tang	Stabilization of Alfven Eigenmodes in DIII-D via Controlled Energetic Ion Density Ramp: Validation of Theory & Simulation
ITER Oral Session			
Mon	2:00	L. Baylor	Research on Disruption Mitigation Enabled by Shattered Pellet Injection Systems on DIII-D, JET, KSTAR in Support of ITER
Mon	2:48	C. Johnson	Diagnosing metastable populations in fusion edge plasmas using collisional-radiative modeling constrained by experiment
Mon	3:48	K. Thome	Changes in Impurity Transport with Applied Torque in DIII-D ELMy H-mode Plasmas
Mon	4:24	A. Garofalo	The high poloidal beta path towards steady state tokamak fusion.
DIII-D Posters Tuesday and Thursday Mornings			