Some Highlights and Opportunities for DIII-D Collaboration in 2013

by
R. Nazikian

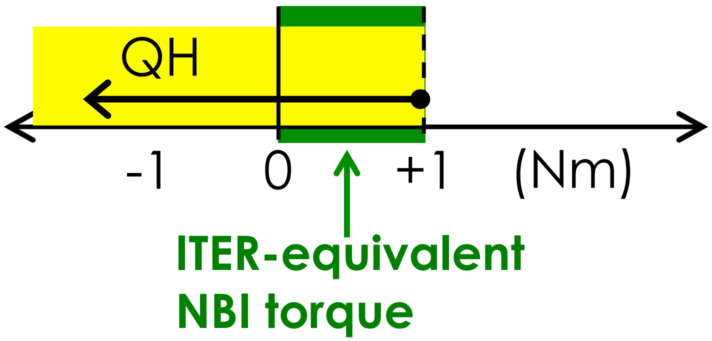
Presented at
NSTX Science Meeting
Nov. 26, 2012

DIII-D NATIONAL FUSION FACILITY

ELM Control – Subject of a JRT in FY13

- QH-mode
- RMP ELM Suppression
- ELM Pellet Pacing

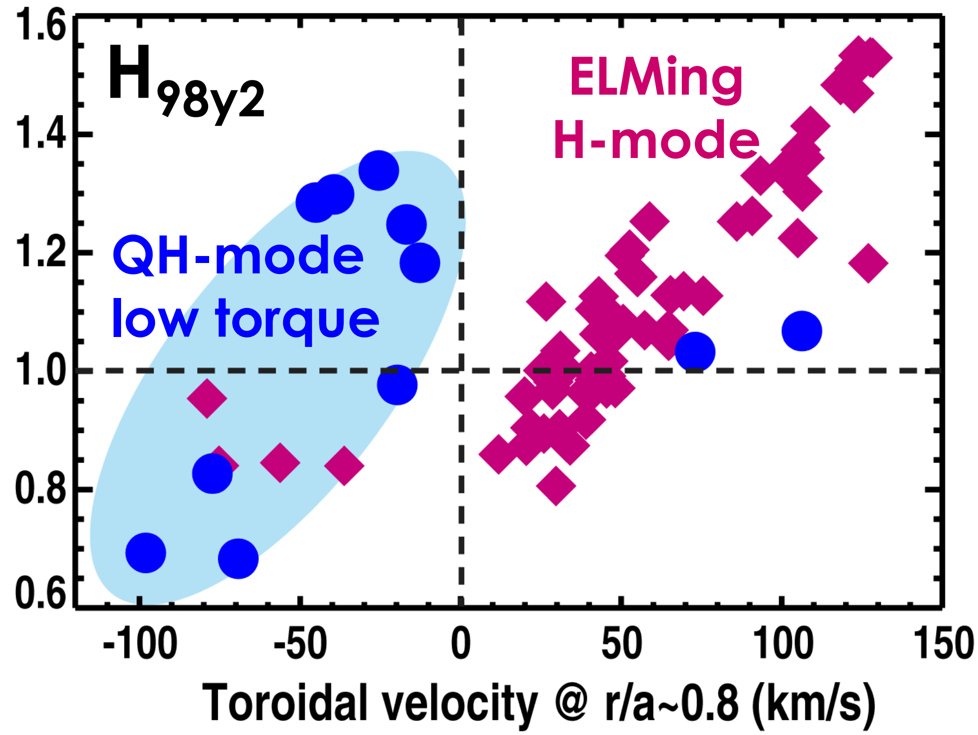
Operating Range for ELM-free QH-mode Extended to ITER Relevant Torque Using External 3D Coils



- **Achieved using external n=3 coils to drive edge rotation shear**

QH-mode is an attractive candidate scenario for ITER

Excellent energy confinement quality at low rotation: H_{98y2}=1.3

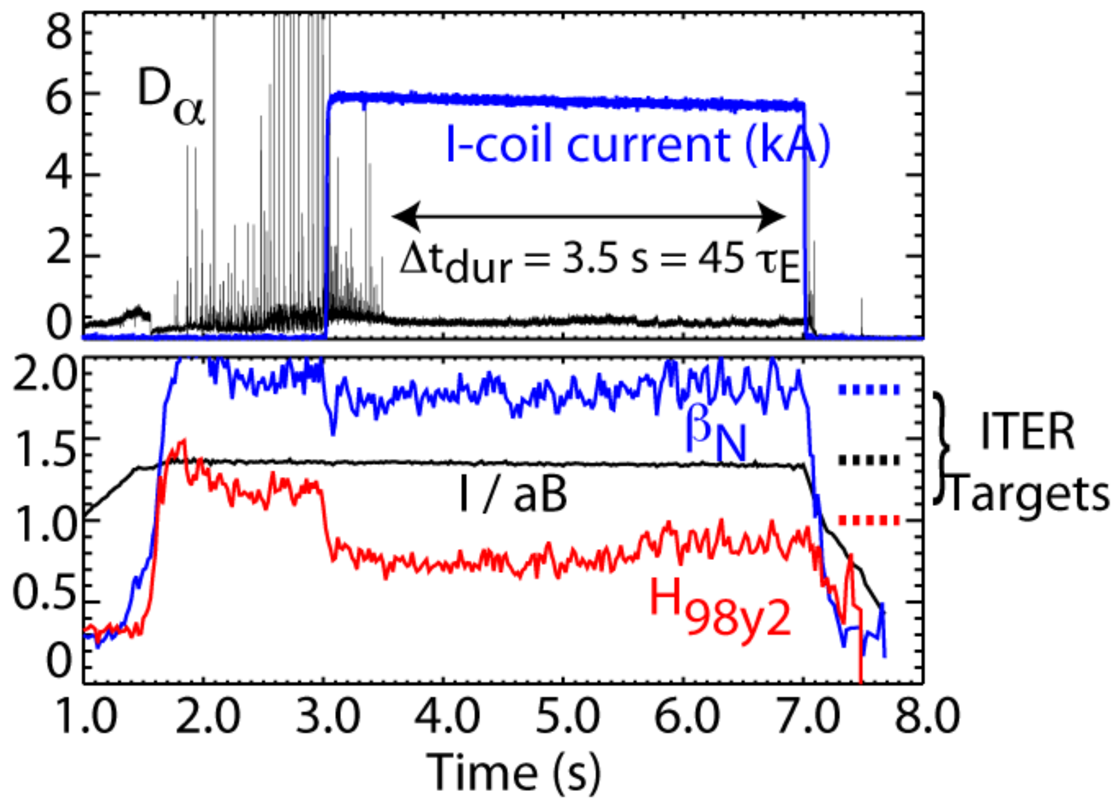


ELM Suppression is Extended for Long Duration in ITER Baseline Scenario on DIII-D

- **Sustained for 45 τ_E**
- **Only used a single row of n=3 I-coils to optimize resonance condition**
- **Close match to ITER specs**

	I/aB	β_N	H_{98}	$\nu_{*,ped}$
DIII-D	1.40	1.8	0.9	0.12
ITER	1.41	1.8	1.0	0.10

- **Confinement degradation early in RMP, improves later**
- **Confinement optimization needed in future work**



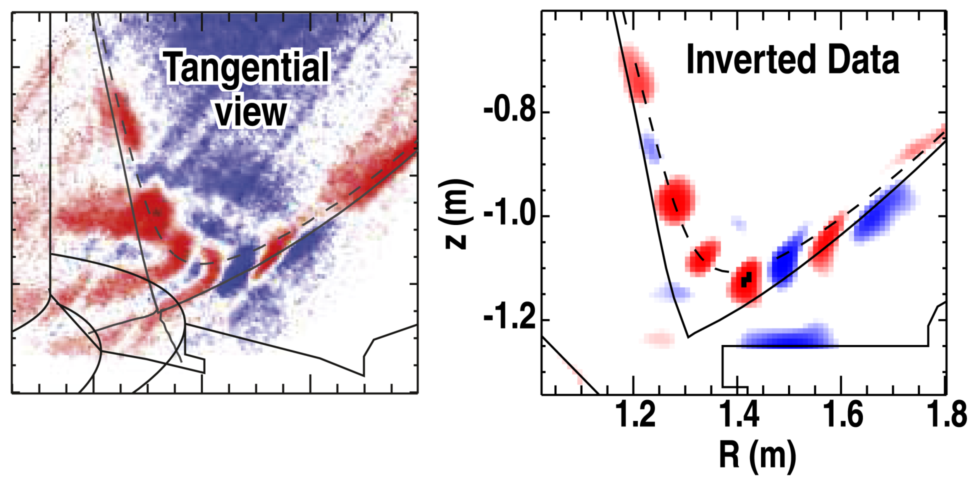
DIII-D NATIONAL FUSION FACILITY

Modulated RMP Experiments Do Not Prove Existence of Islands at Top of Pedestal. Next Step?

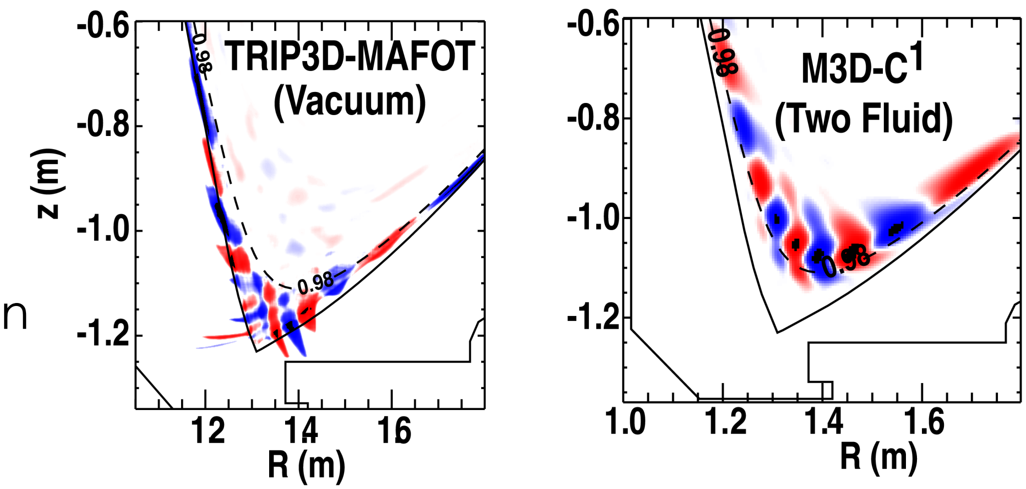
- **RMP rotation reveals MHD response**
  - Displacements seen in X-point SXR imaging
  - Compared with vacuum field and two-fluid MHD simulation

- **Mechanism: RMP limits width of pedestal**
  - RMP field resonant near top of pedestal
  - Island growth where ω_{*e} ~0
  - Island limits inward expansion of high-gradient pedestal

Experiment: SXR data

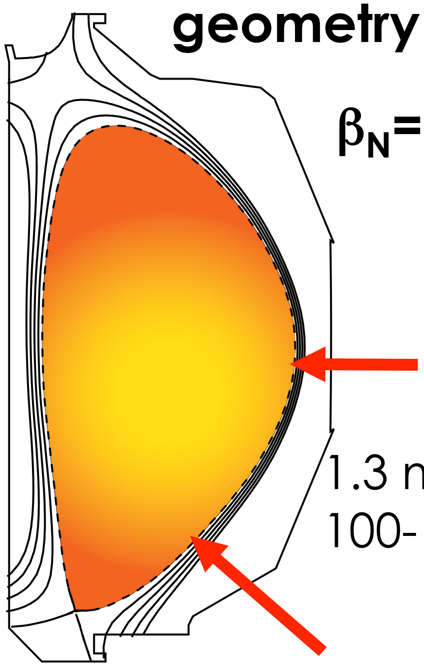


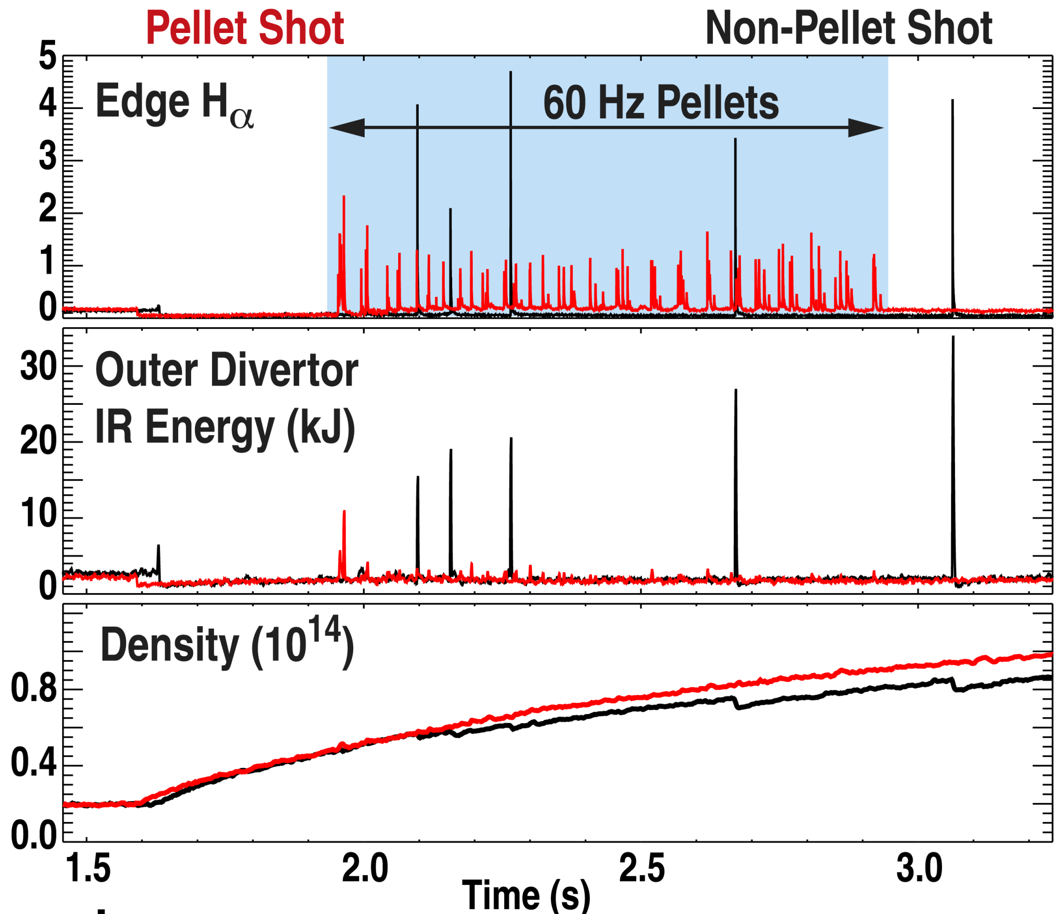
Simulation: SXR Data



N. Ferraro, TH/P4-21
G. McKee, EX/P7-06

Pellet Pacing in ITER Baseline Scenario Yields 12x Higher ELM Frequency





- Reduced ELM energy loss
- Minimal change in confinement
- No fueling increase

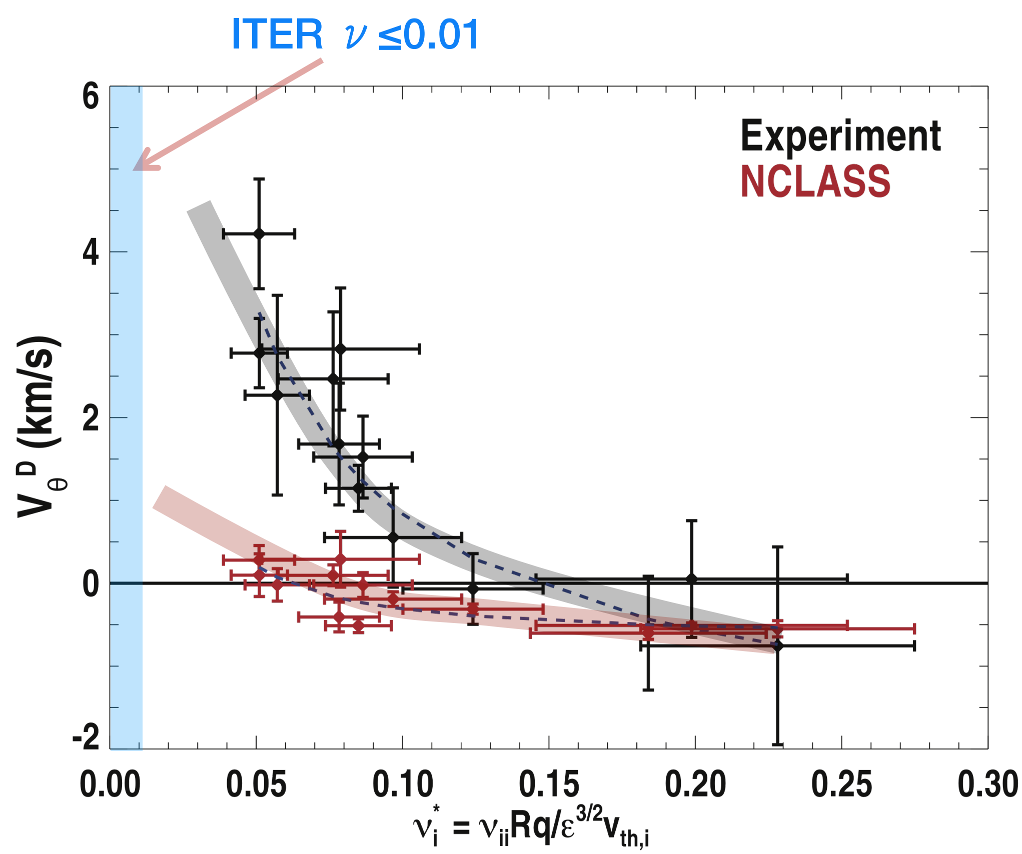
L. Baylor, EX/6-2

Transport physics

- Rotation
- Electron Transport
- L-mode edge
- Beam Ion Transport

Main-ion CER Indicates Poloidal Rotation Increases More Strongly with $1/\nu^*$ than Neoclassical Theory

- **At high collisionality the poloidal flow appears neoclassical**
- **At low collisionality poloidal flow is anomalously large in ion diamagnetic direction**
- **Implications for ITER are higher fusion reactivity according to TGLF**



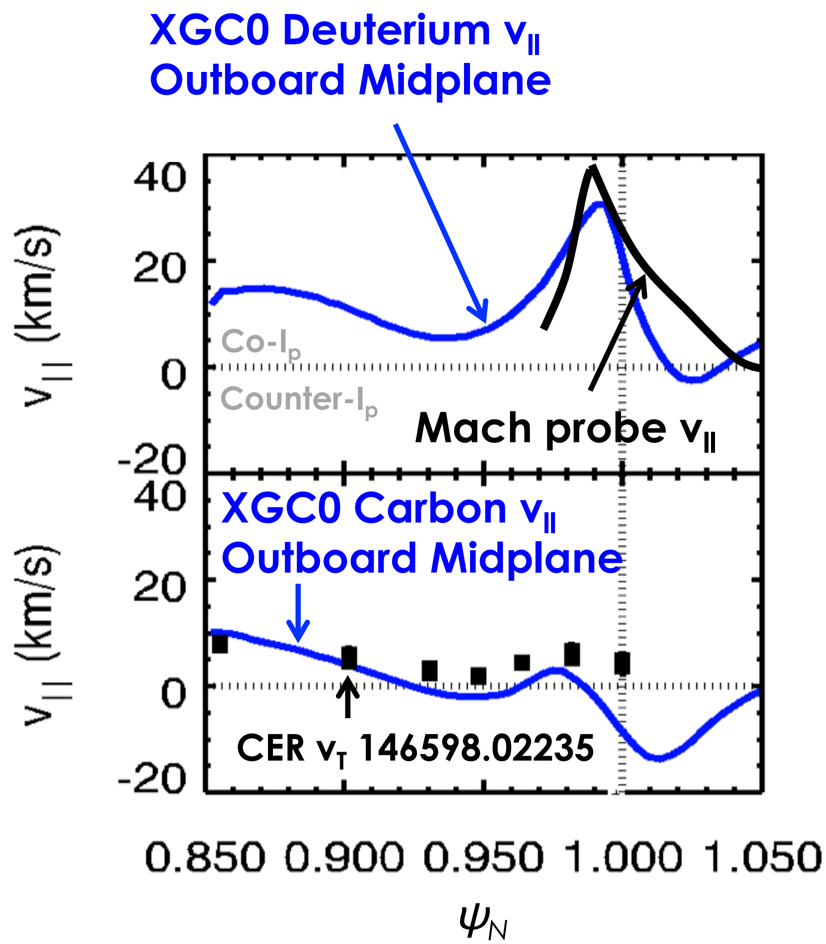
B. Grierson

DIII-D NATIONAL FUSION FACILITY

XGC0 Reproduces Strong "Intrinsic" Edge Co-I_p Deuterium Flow Measured by Mach Probe

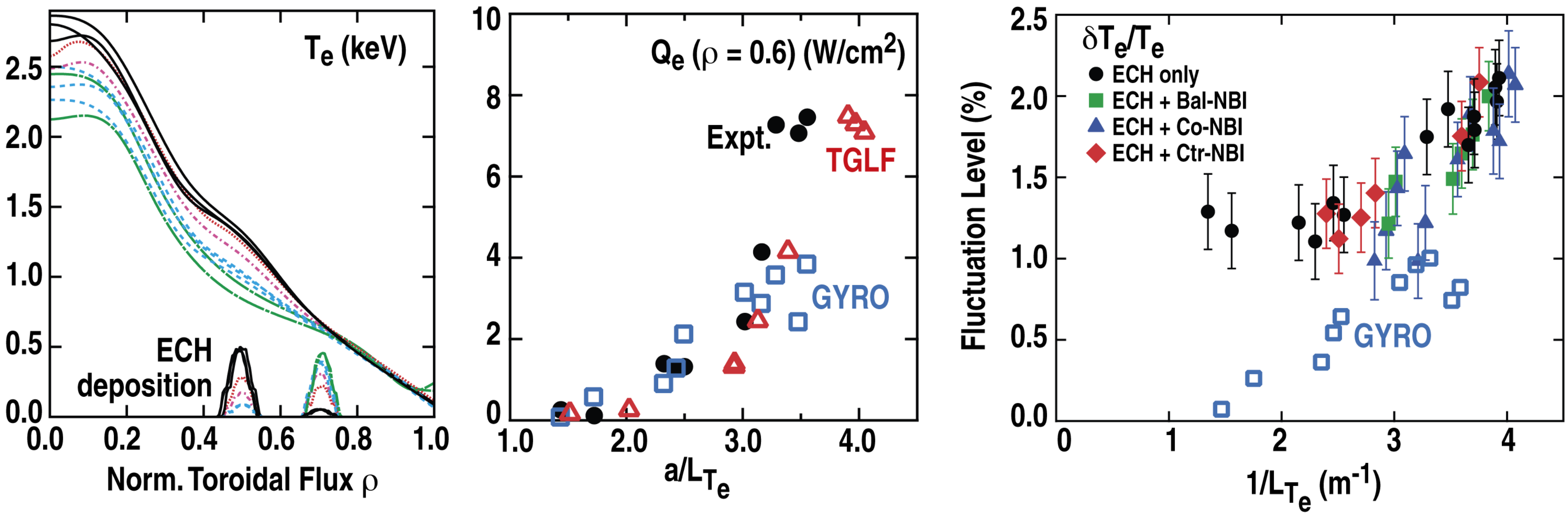
- **Close match between XGC0 and Mach probe data**
  - Deuterium has strong in-out asymmetry, peaked at outboard midplane
  - Flow driven by loss hole in thermal ion velocity distribution

- **Close match between XGC0 and CER Carbon flow data**
  - Co-I_p carbon flow is more polloidally symmetric and peaks at inboard midplane



DIII-D NATIONAL FUSION FACILITY

Critical-Gradient Transport Experiments Test Profile Stiffness Predictions

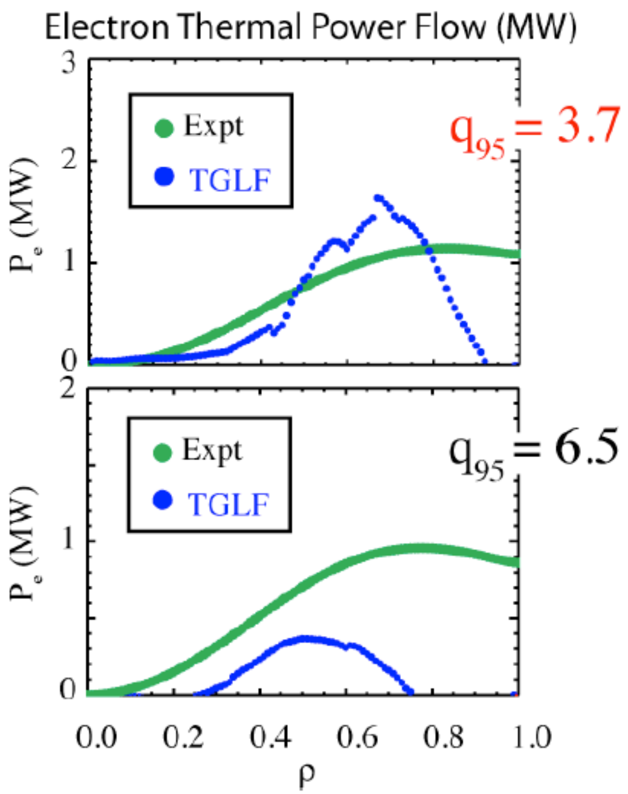


- Vary ECH location to change L-mode ∇T_e with T_e ~ constant
- Transport exhibits critical gradient threshold; agrees with simulation
- Sharp rise in measured T_e fluctuations is consistent with TEM dominant turbulence; effort underway to understand mismatch with gyrokinetic simulations

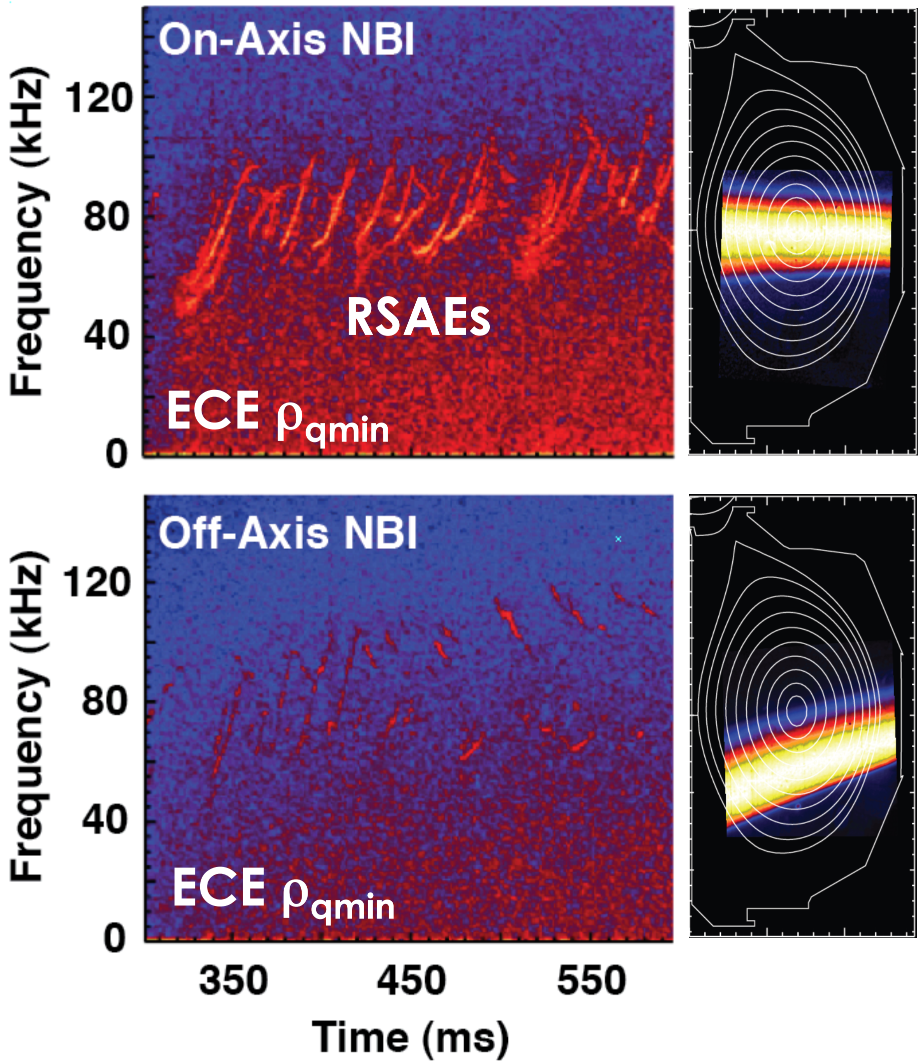
DIII-D NATIONAL FUSION FACILITY SAN DIEGO

L-mode Edge and The Disconnect with theory

- **Edge transport shortfall**
  - Push edge L-mode shortfall to greater extremes and connect to H-mode "gap" between ρ=0.84 and top of pedestal
    - Study ion and electron channels
    - Scan ν*, ρ*, β; use off-axis beams
  - Connect edge shortfall to transport stiffness and critical gradients
    - Study larger radii where flux shortfall is greater
    - Study "heat pinch" regime at higher ν* and q_{95}



Off-Axis Beam Allows Variation of Alfvén Eigenmode Drive and Test of Fluctuation Driven Transport



- **Vary fast ion pressure gradient to change Alfvén Eigenmode (AE) drive/ stability**
- **Reversed-Shear AEs mostly stable with off-axis injection**
- **Confinement consistent with classical transport in off-axis case**
  - Change of story due to evolving understanding of FIDA measurement

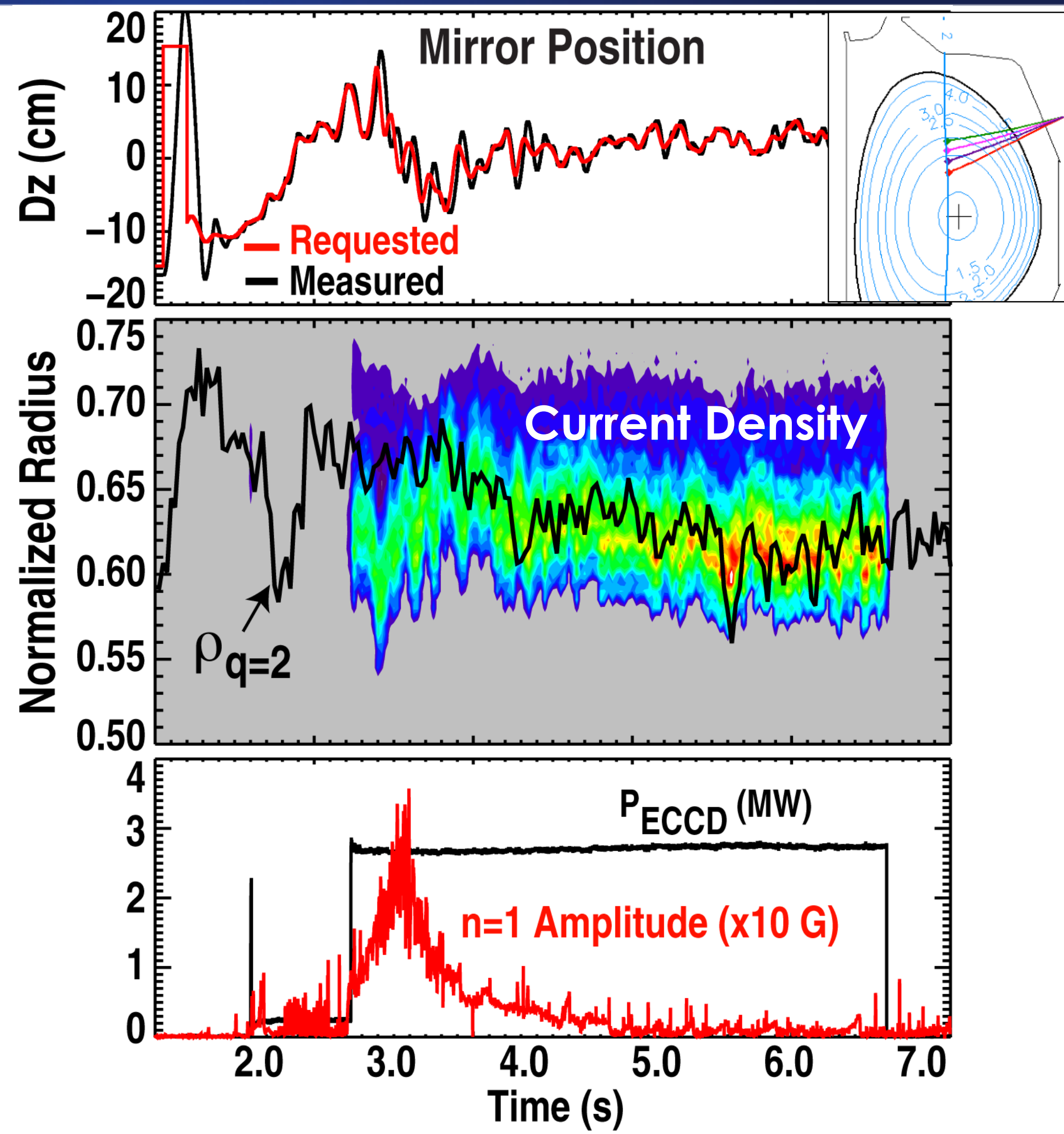
DIII-D NATIONAL FUSION FACILITY

Plasma Control

- NTM Suppression
- Snowflake Divertor
- Disruption Mitigation

Successful Integration of Key Elements of Tearing Mode Control for ITER: 2/1 suppression

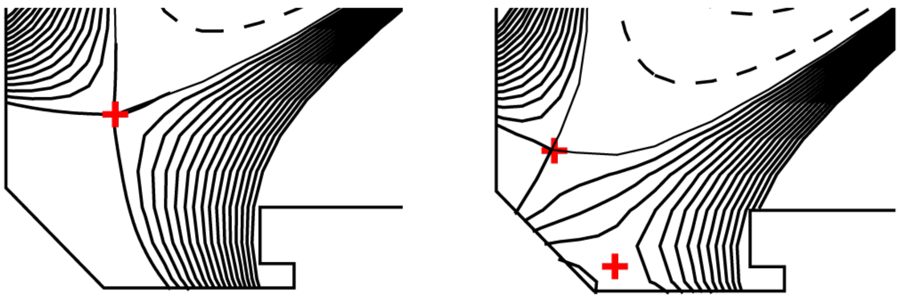
- ***Real-time*** **control of EC power and mirror steering to q=2 surface**
- **PCS detects growing 2/1 tearing mode and turns on ECCD**
- ***Real-time*** **control provides complete stabilization of m/n=2/1 tearing mode**



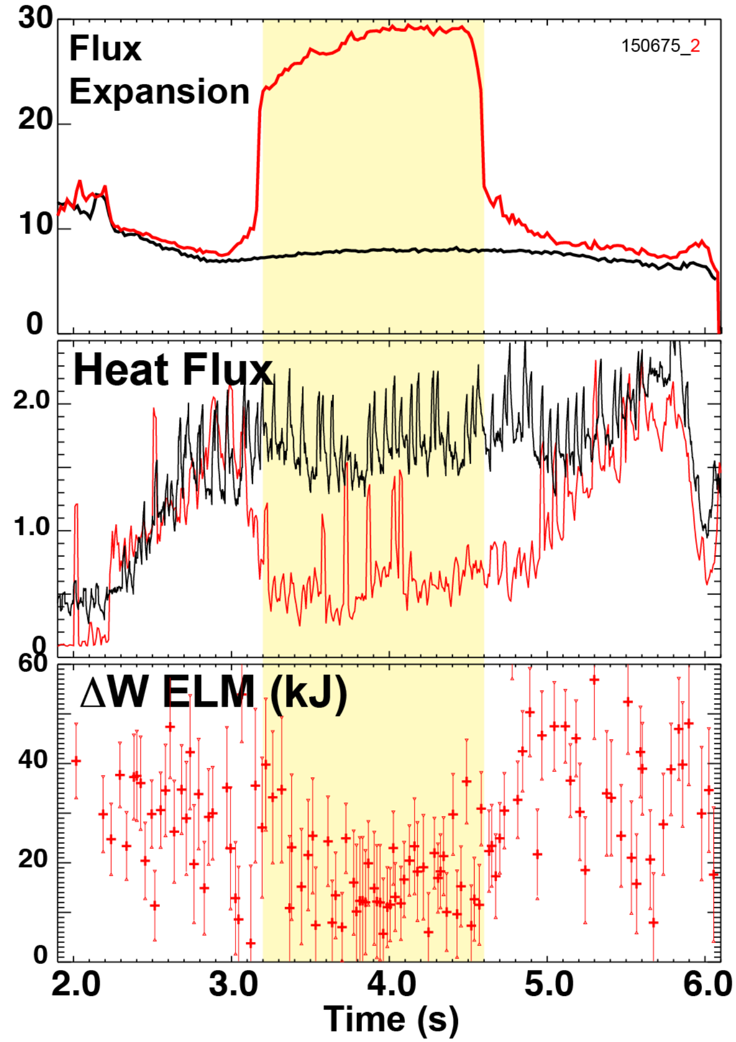
Kolemen

DIII-D NATIONAL FUSION FACILITY

Snowflake Divertor Configuration Reduces ELM and Steady-State Heat Flux



- SF configuration reduces heat flux 2-3X by flux expansion
- ΔW(ELM) reduced
- Core confinement ($H_{98y2} > 1$) and pedestal constant

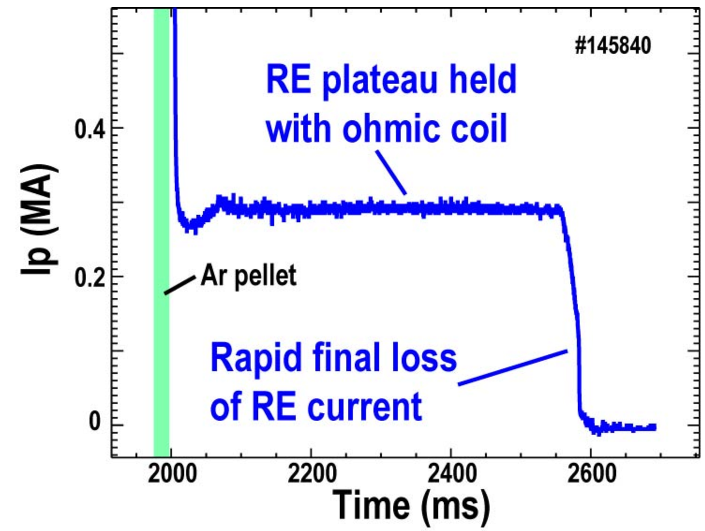


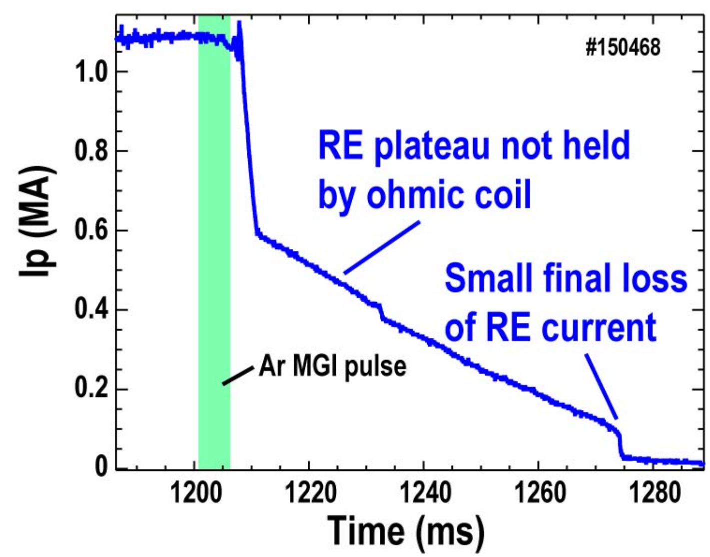
Soukhanovskii, Kolemen

DIII-D NATIONAL FUSION FACILITY

Disruption Runaway Electrons Current can be Dissipated with Sufficient High-Z Impurities

- Large runaway electron beams can be formed with sudden Ar injection
- Low Ar content gives weakly dissipating beam which can be held with ohmic coil
- High Ar content gives rapidly dissipating beam which cannot be held by ohmic coil
- Possible path for ITER to dissipate disruption RE current - with massive Ar injection into RE plateau?





DIII-D NATIONAL FUSION FACILITY

Discussion

- Research Opportunities Forum Dec. 3-4
  - PPPL slot available on first day

- Only one task force: Disruption mitigation

- Three Physics Groups:
  Dynamics and Control – Solomon
  Boundary physics – Leonard
  Burning plasma - Petty