PPPL Opportunities in DIII-D Dynamics and Control Research in 2013

by

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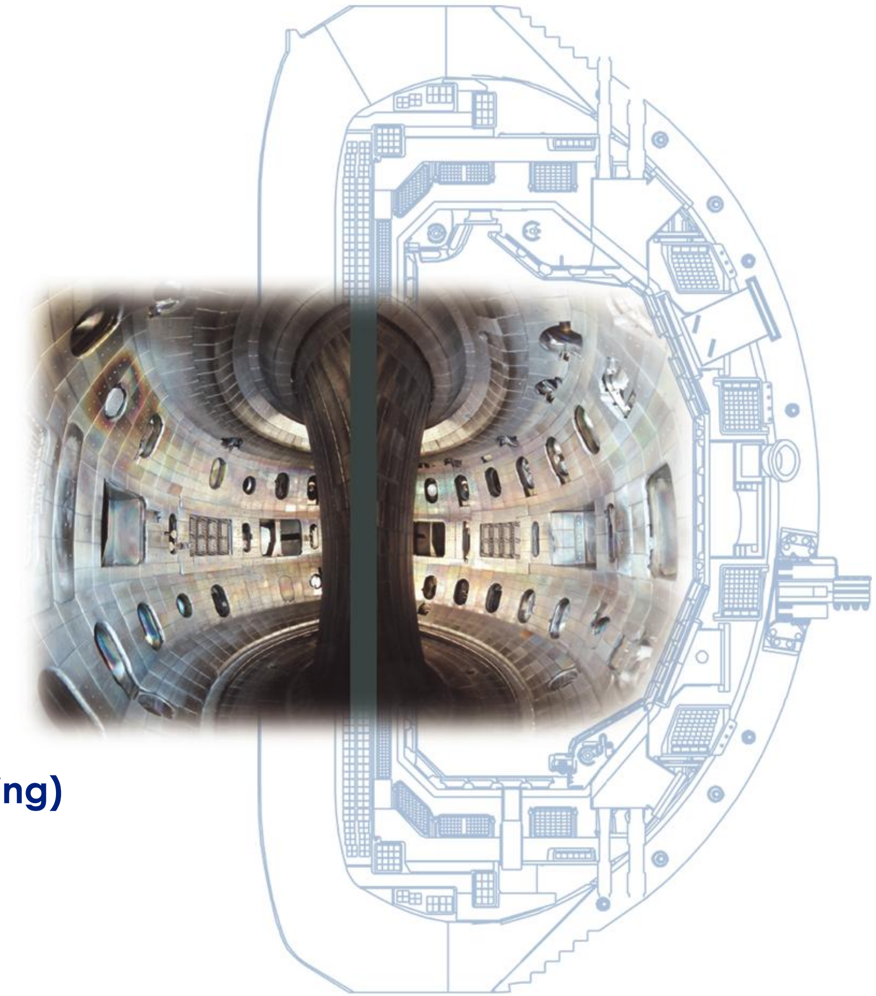

Presented at

NSTX Physics Meeting

(excerpts from DIII-D 2013 Program Goals Meeting)

Princeton, NJ

November 26, 2012

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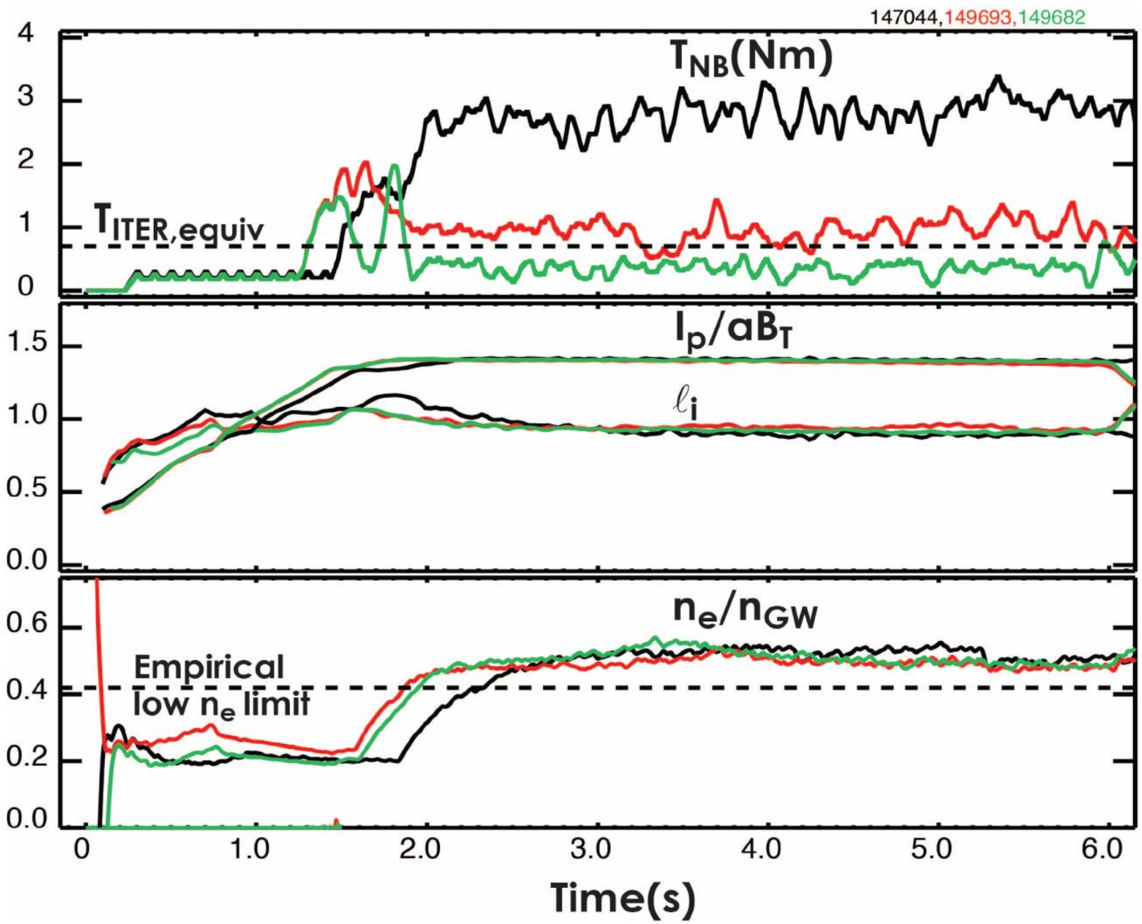
PPPL PRINCETON PLASMA PHYSICS LABORATORY

Dynamics and Controls Will Continue to Be Organized into Five Topical Areas

- **Inductive Scenarios**
- **Steady State Research**
- **Stability and Disruption Avoidance**
- **Plasma Control**
- **Disruptions**

Goal: Improve Fidelity to ITER Baseline – Low Torque, ELM Suppression, Dominant e- Heating

- **Significant step have been taken to push IBS toward more ITER relevant conditions**
  - Low torque
  - ELM suppression
  - Dominant electron heating (elevated q95)



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Inductive Scenarios

Goal: Improve Fidelity to ITER Baseline – Simultaneous Integration of Multiple ITER Requirements

- **Significant step have been taken to push IBS toward more ITER relevant conditions**
  - Low torque
  - ELM suppression
  - Dominant electron heating (elevated q95)

2013 Priorities

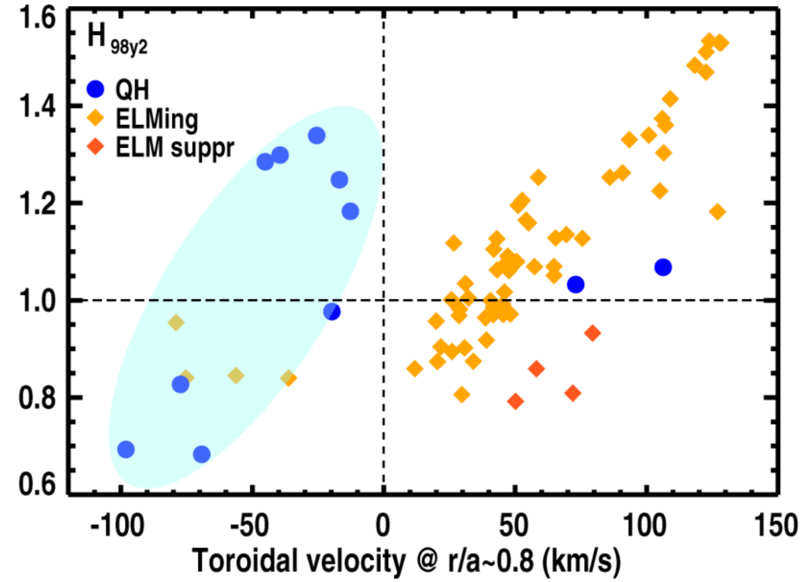
- **Extend electron heating to appropriate q_{95}**
- **Expand low torque operation with ECCD**
- **Verify stability in better ITER shape**
- **Integrate multiple elements together**

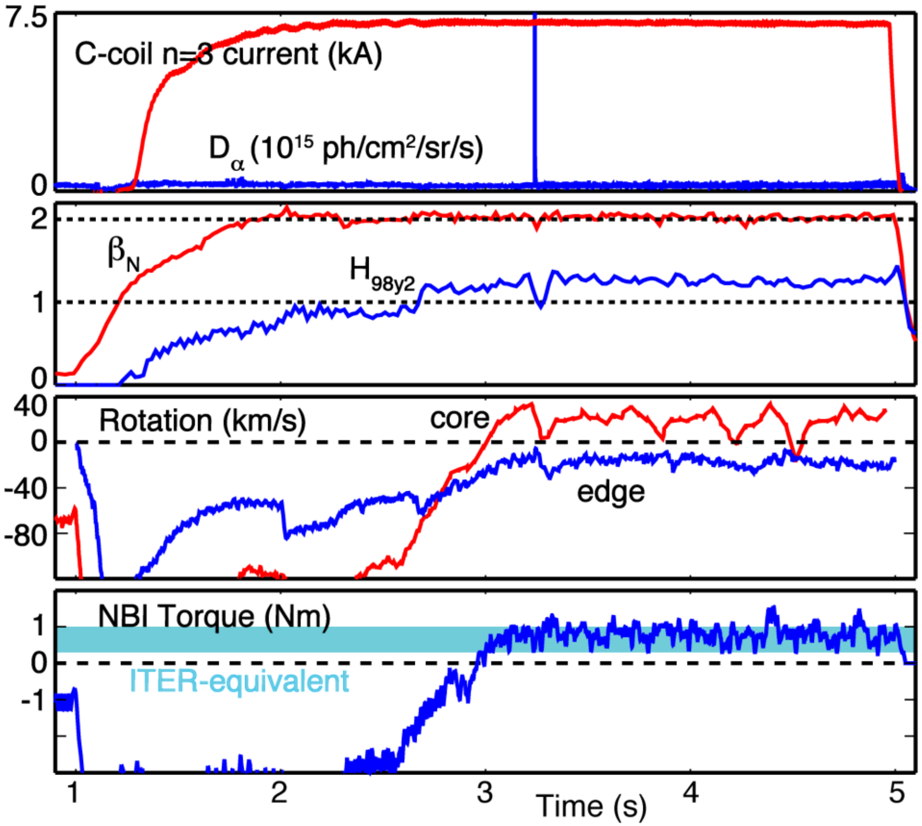
Potential Research Opportunities for PPPL: Dominant Electron Heated Regimes

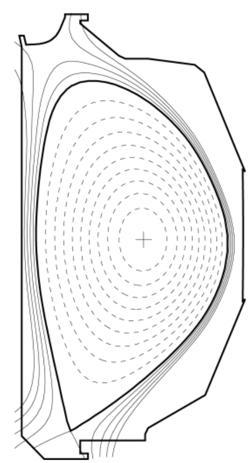
- **Understand and optimize transport in dominant electron heated regimes**
  - Investigate why electron heating in NBI heated discharges is so ineffective in raising stored energy
- **Which transport mechanisms are dominantly responsible for high electron transport, and how can they be controlled**
  - Obvious area of NSTX expertise
- **Which scenarios are most amenable to effective electron heating?**

Goal: Developing Best Inductive Solutions – High Beta, High Confinement, ELM-free Operation (QH-mode)

- **Sustained with ITER relevant NBI torque**
- **n=3 C-coil used to maintain counter-rotating edge and edge rotation shear**







- **QH-mode shows improvement in confinement at low NBI torque and rotation, unlike other H-mode plasmas in DIII-D**

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Inductive Scenarios

Goal: Developing Best Inductive Solutions – High Beta, High Confinement, ELM-free Operation (QH-mode)

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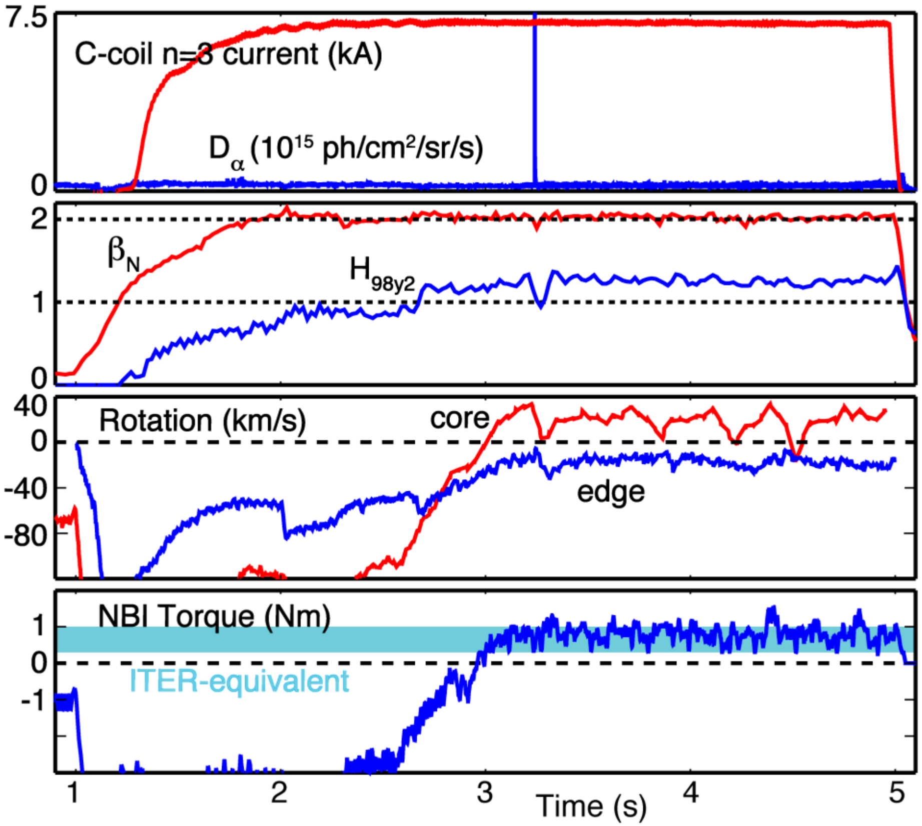
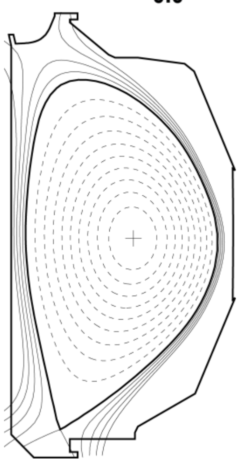
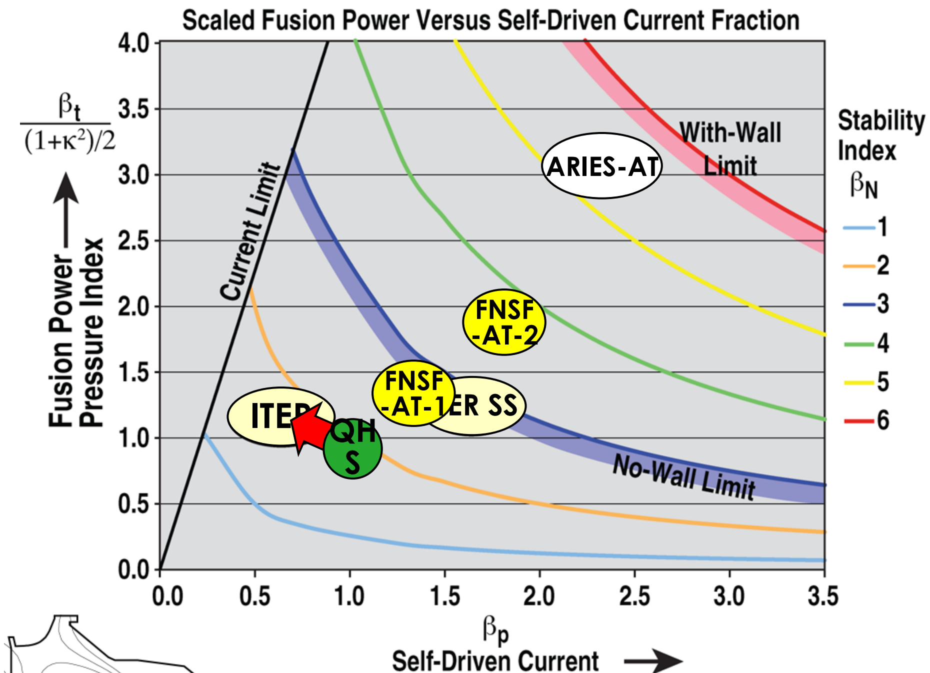






2013 Priorities

- Need to reduce q_{95} at constant β_N to match ITER baseline

Potential Research Opportunities for PPPL: QH-mode Sensitivity to Wall, Transport, NTV, …

- **QH-mode has proven to be particularly sensitive to wall conditions**
  - Days of experimental time are sometimes needed to get into robust QH-mode conditions, but not a very sound understanding of why

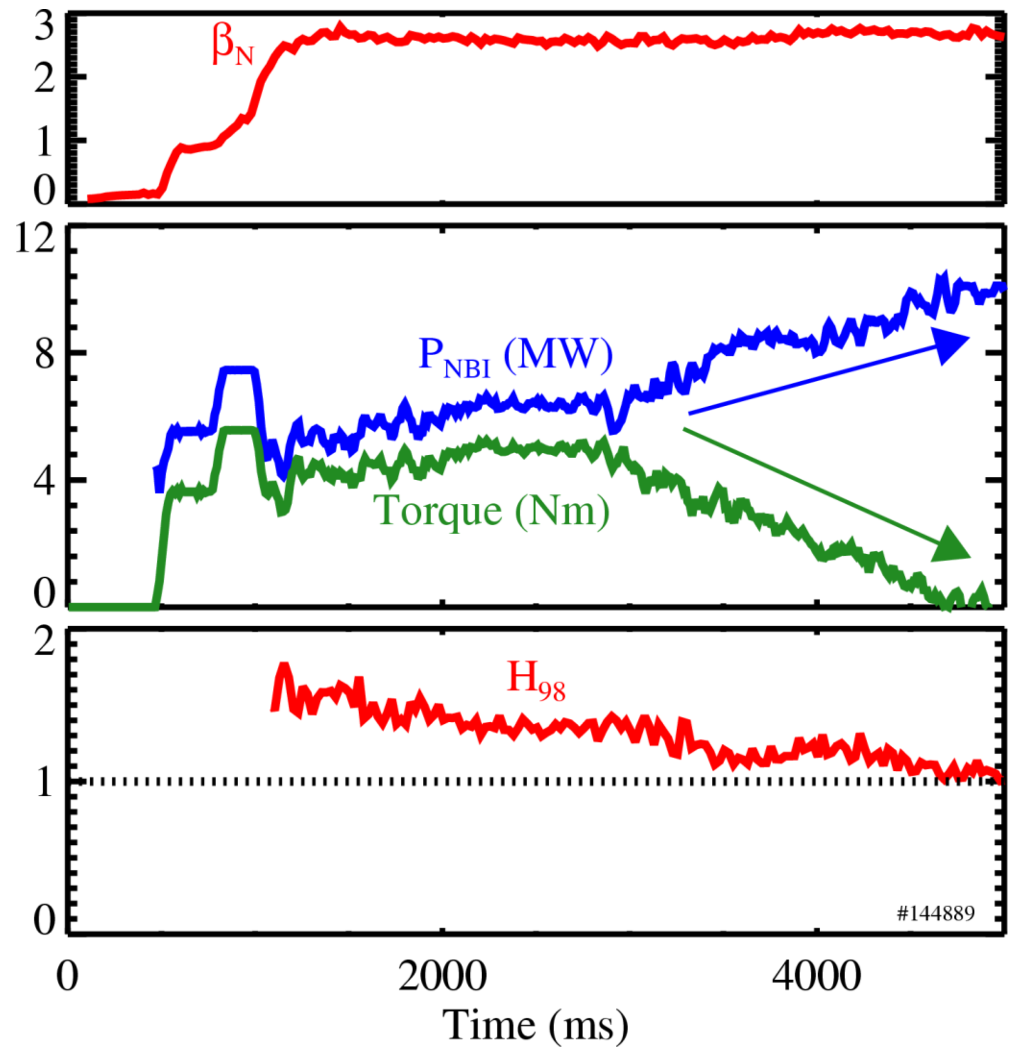
- **Lithium dropper on loan from NSTX**
  - NSTX collaboration already in place, but clearly can be expanded with wide range of NSTX expertise and experience
  - Other uses, eg rapid ELM pacing?

- **Further benchmarking of NTV theory**
  - IPEC

- **Develop non-linear model of EHO to quantitatively understand and predict heat and particle transport provided by EHO**
  - M3D-C1 + transport models

Significant Reduction in Confinement Observed in Advanced Inductive Plasmas as Torque Is Reduced

- For fixed β_N, power demand increase ~60% at low torque
- H_{98} reduced from >1.5 to approx 1.0

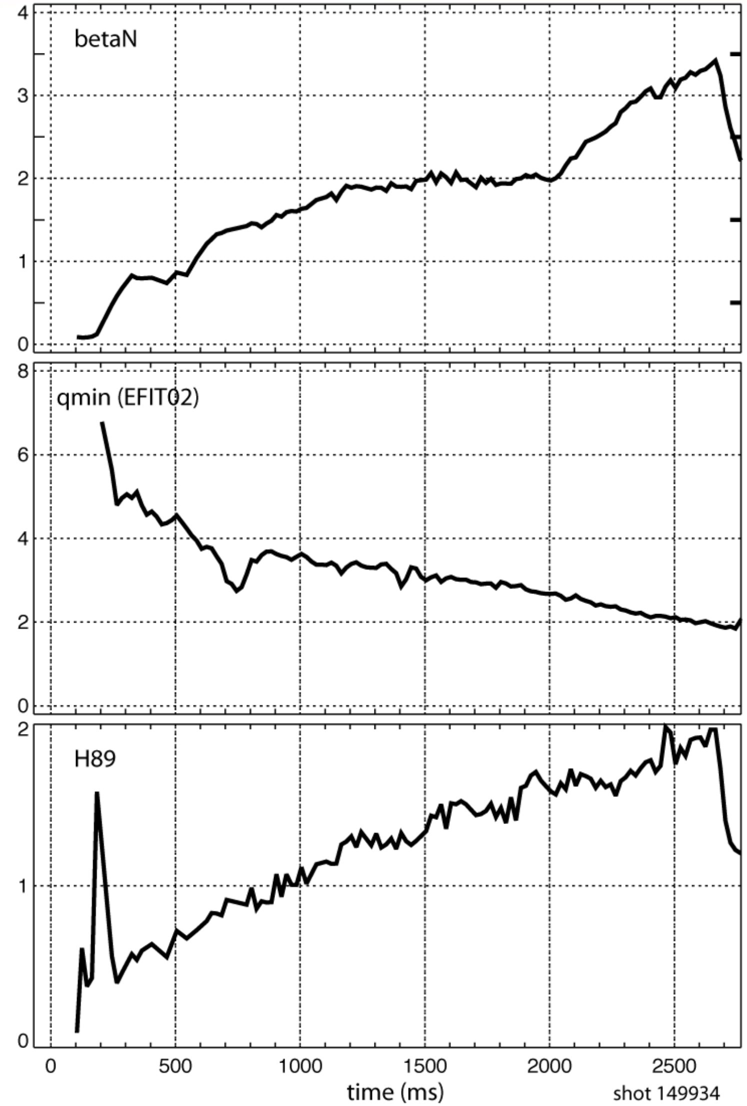


Potential Research Opportunities for PPPL: Transport at Low Torque

- **TGLF modeling suggests that the reduced performance at low rotation is simply a consequence of reduced ExB shear**
- **If so, can enhanced confinement be recovered by careful crafting of ExB shear profile?**
  - Modeling effort could guide experiment
- **Alternatively, is a modified q-profile more suitable for low rotation conditions?**

Goal: Develop SS Plasmas with β_N =4-5 – Achieved q_{min}>2, β_N≤3.5, Limited by Confinement

- **2011 result: q_{min}>2 plasmas had H_{89}<2**
- **2012 Goal: Run at reduced B_T (1.4 T) to get β_N>4 with same power**
- **Result: Unsuccessful**
  - Available co-NBI power was 10-11 MW in 2012
  - Negated expected benefit of lower field



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Steady State

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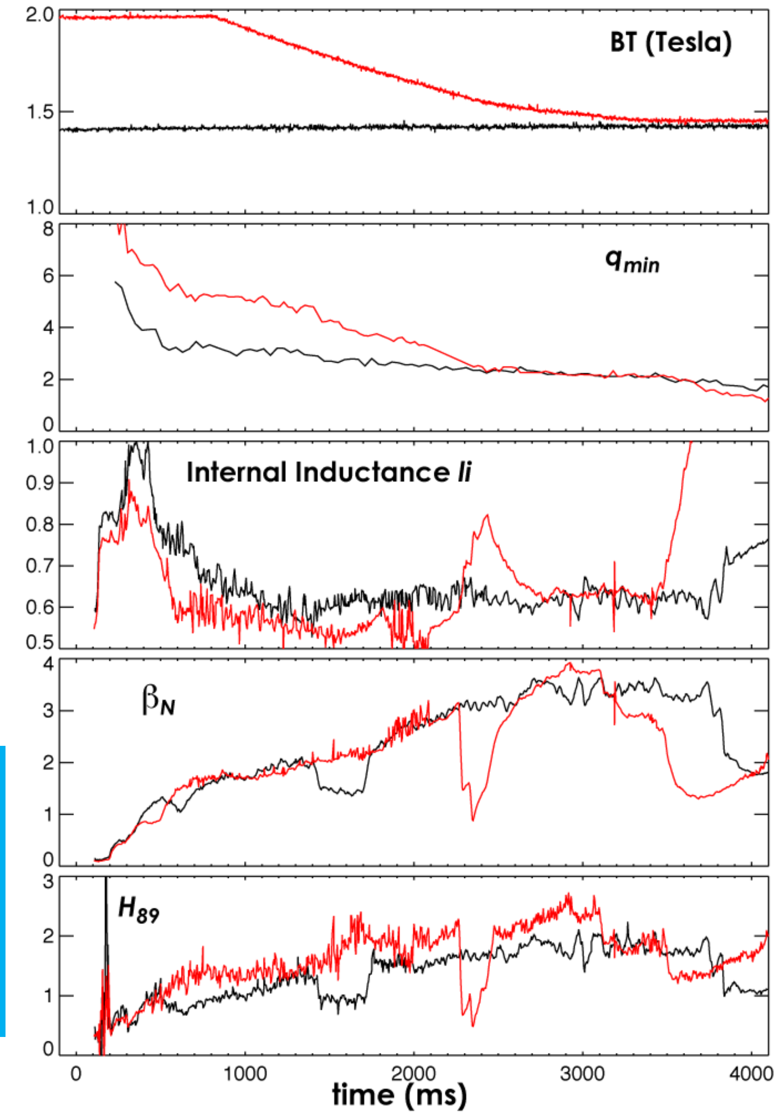
Goal: Develop SS Plasmas with β_N =4-5 – B_T Ramps Suggest Confinement Improvement Possible

- **Mixed results:**
  - ✓ Transient β_N~4, q_{min}~2
  - ✓ H_{89}≥2 with q_{min}≥2 in many shots
  - ✗ RWM's and locked modes triggered when q_{min} crossed 4 & 3 while ℓ_i<0.6

- **Analysis needed to find why H_{89} is higher than shots without ramps**



2013 Priorities

- **Focus on understanding/optimizing confinement with q_{min}>2; find key requirements for achieving H_{89}>2**

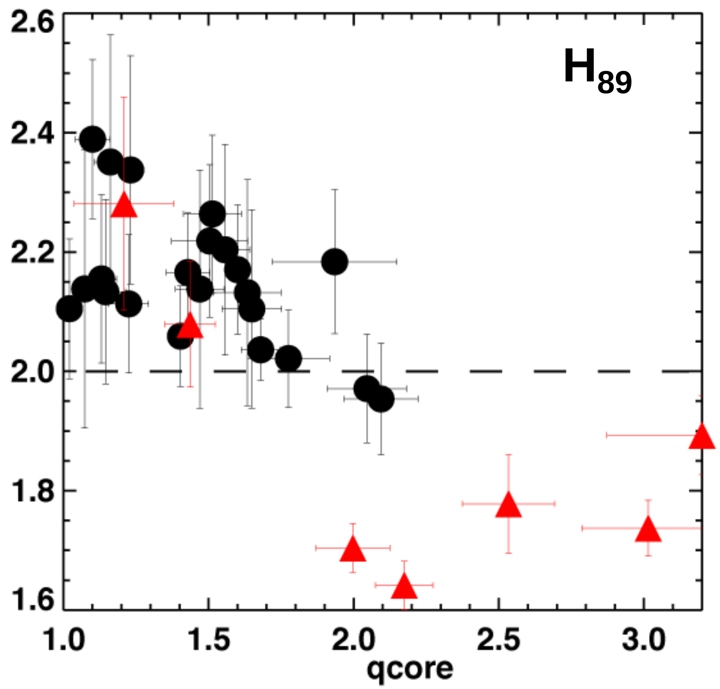
Steady State

Enhanced Fast Ion Transport May Contribute to Lower H_{89} at the Highest q_{min}

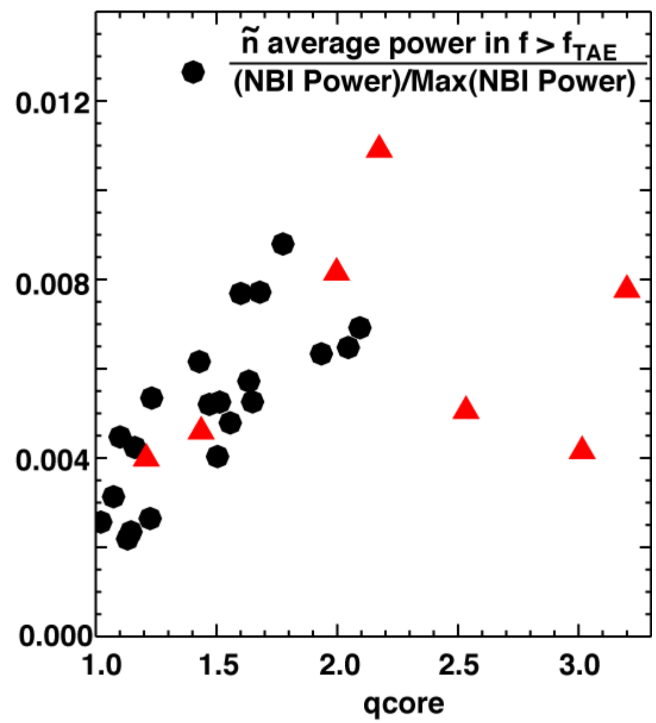
● No off-axis beams used

▲ Off-axis beams used

"*qcore*" is average of *q* from ρ=0-0.3



Fluctuation power in Alfvén Eigenmode frequency range generally increases with *qcore*



- **At high *qcore*, total stored energy computed by ONETWO transport code exceeds that measured by EFIT unless anomalous fast ion transport is included**

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Holcomb IAEA 2012

Potential Research Opportunities for PPPL: Understanding Transport in High qmin Scenario

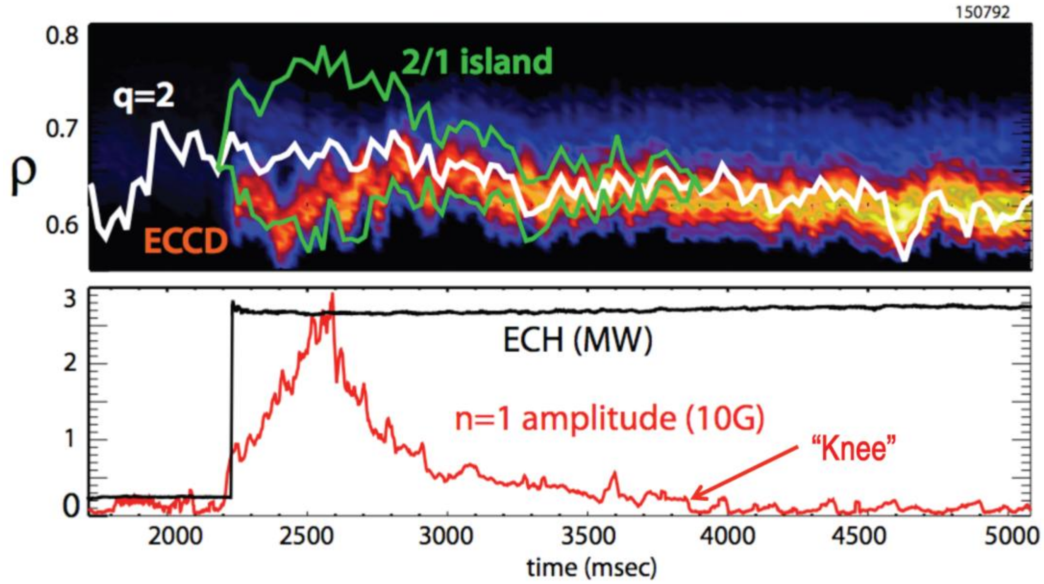
- **What is the cause of the poor global confinement of high qmin plasmas?**
  - Can it really be poor fast ion transport? Implications for off-axis current drive
  - Which Alfvenic instabilities are expected to be unstable and can we see direct evidence for them?

- **What is different about Bt ramp plasmas that leads to better confinement, and how can this be translated to a stationary solution?**

Goal: Reliable Disruption Avoidance and NTM Control – Through Routine Use of Real-Time ECCD Mirror Steering

2013 Priorities

- Improve early 2/1 catch (by n=1 Mirnov filtering)
- Demonstrate average EC power minimized with catch and subdue
- Implement real-time ray tracing
- Sawteeth and/or multiple mode control
- Investigate ECE for detection/alignment etc



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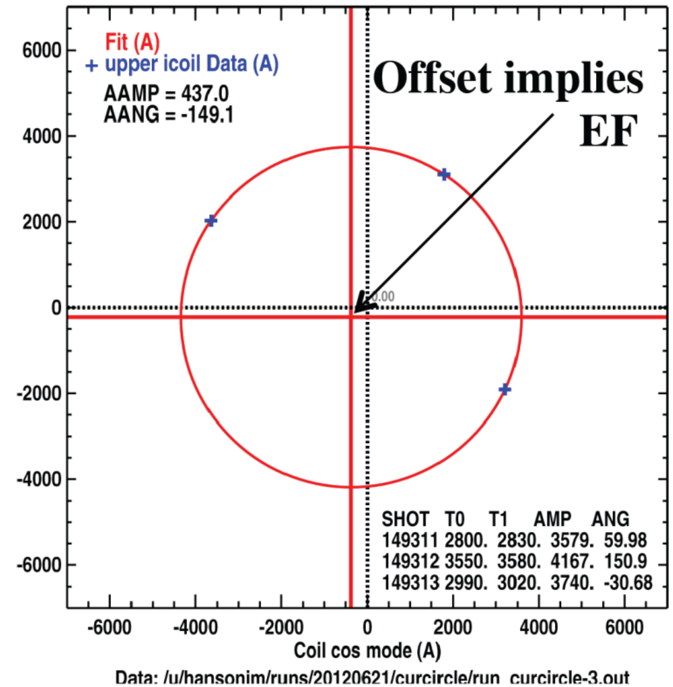
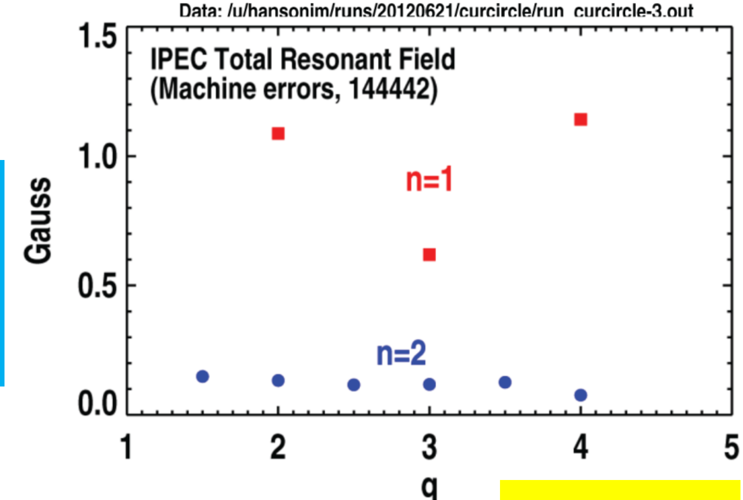
Stability

Goal: Optimization of Non-Axisymmetric Fields - Develop Improved Error Field Correction Strategies

- **Phase scan of n=2 I-coil field confirm existence of n=2 intrinsic error field**
- **IPEC finds n=2 pitch-resonant fields ~5-10x smaller than n=1**
  - Suggests n=2 EF acts via magnetic braking
  - Points to importance of n=2 error field correction at high beta not low density





2013 Priorities

- **Obtain coefficients for n=2 EFC (algorithm implemented in PCS)**

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Stability

Potential Research Opportunities for PPPL: Stability and Non-Axisymmetric Fields

- **Improved implementation of 2/1 NTM search and suppress algorithm**
  - Egemen already heavily involved in this
- **IPEC modeling of EFC experiments**
- **ELM control**
- **NTV (IPEC)**