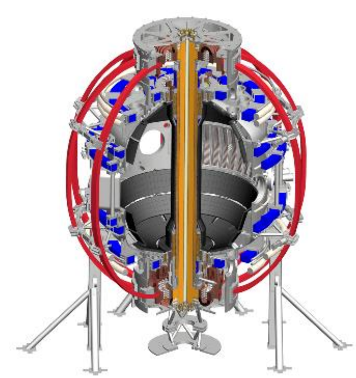
NSTX-U is sponsored by the
U.S. Department of Energy Office of Science
Fusion Energy Sciences

NSTX-U Team Meeting

J. Menard, C. Neumeyer, S. Gerhardt, S. Kaye
For the NSTX-U Team

August 30, 2017
MBG Auditorium



Safely, safely, safely

- Please work safely, and have a **safe** and enjoyable holiday weekend

- RSVP to lab picnic!
  - By September 1 (Friday)
  - Don't want to run out of hot-dogs
  - Come dunk your (least) favorite council member!

Big Bang Bash 2017

Many Voices. One Mission.

Friday, Sept. 15
11 a.m.

The Laboratory Leadership Council invites you to the PPPL Big Bang Bash 2017 for some great food, fun games and team-building activities, and the opportunity to network with friends and colleagues and meet new ones!

The Big Bang Bash includes:

- An Antique & Specialty Vehicle Show
- A Cultural Fair
- A United Way community service project
- Dunk Tank and other activities

Please click here to RSVP. If you would like to help or participate, please click the link of the appropriate document:

- Volunteer Sign-Up: https://goo.gl/forms/XDBVQNJ8pgm6gfaz1
- Cultural Fair: https://goo.gl/forms/L94sayfUmAZrTE1g1
- United Way Snack Pack: https://goo.gl/forms/7wHa2N9yFFCzr0VF3
- Vehicle Show: https://goo.gl/forms/c3b72tgW3bRTD3Z72

Agenda

- Recovery Organization
- Recovery Mission and Perspective
- Recovery Progress and Plans
- Selected Research Highlights
- Q & A

A few organizational changes…

- **Thank you Rich Hawryluk!**
- Jon/Stefan = Recovery Project Director/Deputy
- Charlie remains Recovery Engineering Director
- Responsible Engineers still responsible
- Transitioning: Finalize designs → fabricate, test
  - Draft FES FY2018 notable to build + full-power test three production PF1 coils by end of FY18 (more on this later…)
- Need strong project manager, robust system engineering + design and quality assurance
  - Also incorporate outcomes of Extent of Cause notable
- Updating R2A2s → revising organization chart

Recovery Project Mission

- Mission: Restore NSTX-U device and supporting infrastructure to a reliable operating state to achieve the performance goals originally set for the NSTX Upgrade Project in support of the Research Program
  - AND account for impacts of new (post Upgrade CD-2) physics understanding+reliability issues in engineering design
- Operate highest-performance ST in world program:
  - Explore confinement at highest ST pressure & temperature and reduced collisionality, advance predictive capability
  - Develop solutions for plasma-material-interface challenge
  - Demonstrate plasma sustainment without solenoid
  - **Develop ST as attractive path to fusion energy**

Recovery Project Perspective

- Aim to complete as much Recovery scope as available resources allow
- Impact of reducing and/or deferring scope:
  - Delays research program access to new regimes
  - Is more expensive in the long-run - cheaper to do it right (i.e. meet the requirements) the first time
  - Does not result in significant acceleration for critical path through PF1 coils (pursuing parallel fabrication)
- If resources are inadequate, scope deferral and/or Program impact may be required

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Outline

- Progress
  - Polar Region Option Down-selection
  - Draft Corrective Action Plan (CAP)
  - Conceptual Design Review

- Future Plans
  - Cost & Schedule Review
  - Draft FES Notables

FY17 Progress + Remaining Activities

			1-Oct-16	1-Nov-16	1-Dec-16	1-Jan-17	1-Feb-17	1-Mar-17	1-Apr-17	1-May-17	1-Jun-17	1-Jul-17	1-Aug-17	1-Sep-17	1-Oct-17
Start Recovery	10/1/16	10/1/16													
Establish Organization	10/1/16	11/1/16													
EoC Plan	11/1/16	11/1/16													
DVVR - CI&C	1/18/17	1/18/17													
DVVR - Project Integration	1/24/17	1/24/17													
DVVR - Heating Systems	1/30/17	1/30/17													
DVVR - Magnets	2/7/17	2/7/17													
DVVR - VV & Int Hdwe	2/14/17	2/14/17													
DVVR - Cooling Systems	2/22/17	2/22/17													
DVVR - Power Systems	2/27/17	2/27/17													
EoC Committee Review #1	3/6/17	3/6/17													
DVVR - Test Cell	3/16/17	3/16/17													
DVVR - Vacuum & Fueling	3/23/17	3/23/17													
DVVR - Bakeout	3/30/17	3/30/17													
Interim EoC Notable Report	3/31/17	3/31/17													
DVVR - Diagnostics	4/5/17	4/5/17													
DVVR - RT C & P	4/19/17	4/19/17													
Design Integration Review	4/21/17	4/21/17													
WAF Preparation	5/15/17	8/30/17													
EoC Committee Review #2	5/15/17	5/15/17													
Polar Region Option Downselection	6/4/17	6/30/17													
Inner PF Coil Prototype Procurement	6/19/17	9/11/17													
Draft EoC Notable Report	7/18/17	7/18/17													
Conceptual Design Review	8/1/17	8/3/17													
		TODAY													
Cost & Schedule Review	9/6/17	9/8/18													

Polar Region Option Downselection

National Spherical Torus eXperiment Upgrade

Evaluation of Options Related to Polar Region and Center Stack Bakeout

NSTX-U-DOC-001-01

June 30, 2017

Charles L. Neumeyer Digitally signed by Charles L. Neumeyer DN: cn=Charles L. Neumeyer, o=PPPL, ou, email=neumeyer@pppl.gov, c=US Date: 2017.07.20 14:43:58 -04'00'

Charles Neumeyer
NSTX-U Recovery Project
Engineering Director

Valeria Riccardo Digitally signed by Valeria Riccardo DN: cn=Valeria Riccardo, o, ou, email=vriccard@pppl.gov, c=US Date: 2017.07.20 23:35:02 -04'00'

Valeria Riccardo
Technical Authority

Richard J. Hawryluk Digitally signed by Richard J. Hawryluk Date: 2017.07.21 07:46:49 -04'00'

Richard Hawryluk
NSTX-U Recovery Project
Director

- Risk/Cost/Schedule assessment of design options for Polar Region
- Recommendation:
  - Single ceramic insulator, upper only
  - Double O-rings with pumped interspace on all seals
  - Retain DC current injection for center stack bakeout heating
- Reviewed and accepted by Tom Todd, Chair of EoC committee

Draft Corrective Action Plan (CAP)

PPPL Objective 2.1
Draft Notable Outcome Report

Office of Fusion Energy Science
Office of Science
U.S. Department of Energy

July 18, 2017

PPPL PRINCETON PLASMA PHYSICS LABORATORY
Princeton University

- Summary of outcome of Design Validation & Verification Reviews (DVVRs) and Extent of Condition (EoC) committee recommendations
- Presents preliminary cost & schedule estimate
- Accepted as a draft, pending the vetting of cost and schedule information via a Cost & Schedule Review (C&SR)

CAP Scope Categories

Recovery Scope	Maintenance and Run Preparation	Operations Enhancements for Improved Reliability
Scope to address DVVR issues or EoC recommendations related to design, fabrication, or installation that remedies severe design deficiencies or performance limitatations	Scope to address reliability of critical components in supporting infrastructure outside tokamak core; need not be a DVVR issue but could have been identified in the DVVR or EOC recommendations	Deferrable scope that addresses reliability of less critical components; need not be a DVVR issue
Scope to address DVVR issues related to reliability of the tokamak core (PFCs, magnets, vessel, etc.)	Routine maintenance and repair tasks; need not be a DVVR issue but could have been identified in the DVVR or EOC recommendations	Desirable but not esssential enhancements
Scope to address any known safety issue; need not be a DVVR issue	Critial scope that was planned before the start of the Recovery Project	
	Operations support functions (minimal staff opertions, allocations, energy consumption, etc.)	

CDR Addressed Six Major Scope Areas Identified in CAP

National Spherical Torus eXperiment Upgrade

INT-170724-CLN-01

TO: DISTRIBUTION
FROM: C. NEUMEYER
SUBJECT: CHARGE FOR CONCEPTUAL DESIGN REVIEW – REV. 2

1 Introduction

The NSTX-U Recovery Project recently completed the Extent of Condition (EoC) review and the final report of the EoC committee has been received. The EoC process identified a set of issues that serve as input to a Corrective Action Plan (CAP). Various corrective actions have been identified for all the NSTX-U subsystems, but a subset with the highest priority and impact are concentrated in a few key areas. A recent Design Integration Review (DIR) covered a subset of these key areas in the polar regions and generated a set of chits that need to be addressed and closed. Exploratory studies of options for re-design of NSTX-U in these key areas are nearing completion. A Conceptual Design Review (CDR) of these studies and the options considered is a necessary step toward moving forward with the NSTX-U Recovery Project.

This CDR will take place before completion of the PPPL Extent of Cause review and before actions items from that review are closed. To ensure that the CDR is rigorous and compatible with the greater level of design assurance that will be required once the Extent of Cause actions are in place, ENG-033 requirements are imposed as a baseline, with supplemental requirements as follows:

- Review charge, objectives, and input documents are clearly delineated via this memo
- Engineering Department Head, as acting Technical Authority of PPPL, will chair the review, acting with independence from the NSTX-U Recovery Project
- Committee shall include subject matter experts in each topical area, with a minimum of one such expert per topical area from an institution external to PPPL
- Committee shall include the NSTX-U Responsible Engineers and representatives from the PPPL Quality Assurance and Environmental Safety & Health groups

In addition it is noted that:

- Requirements that have evolved since the baseline NSTX-U requirements documents (including Design Point Spreadsheet) are highlighted as tentative for

---

- Inner PF Coils
  - Redesign + replace PF1A/B/C with mandrel-less coils
- Plasma Facing Components (PFCs)
  - Redesign + replace to recover heat flux and halo current capacity
- Polar Region Components
  - Redesign and replace
    - Seals + O-rings
    - Coil supports
    - Heating/cooling lines
- Bakeout Systems
  - Redesign and modify to address safety and performance issues
- Test Cell Shielding
  - Improve shielding of penetrations
- Machine Instrumentation
  - Provide system to benchmark analysis and provide trending

CDR Results (1)

- Achieved purpose stated in charge letter
  - *The purpose of the CDR is to review the exploratory studies for redesign of key areas of NSTX-U, to identify the applicable requirements, to define interfaces, to respond to the DVVR chits, and to confirm the selection of options to further pursue.*

- Positive comments from EoC chair Tom Todd

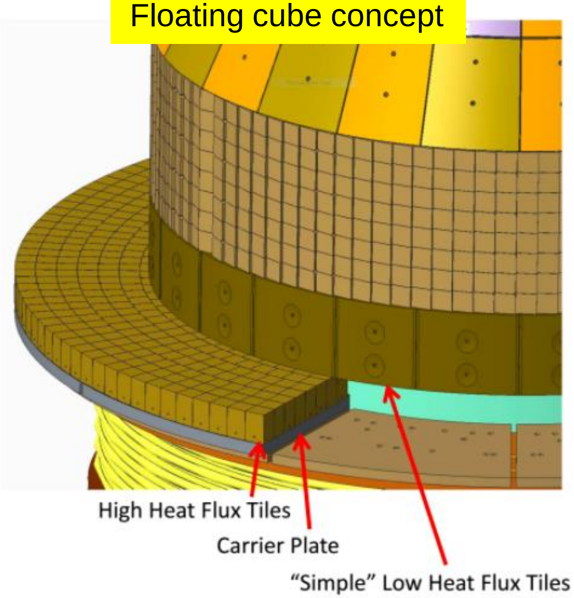
- 41 presentations, 103 chits

- Chits have been dispositioned by the committee

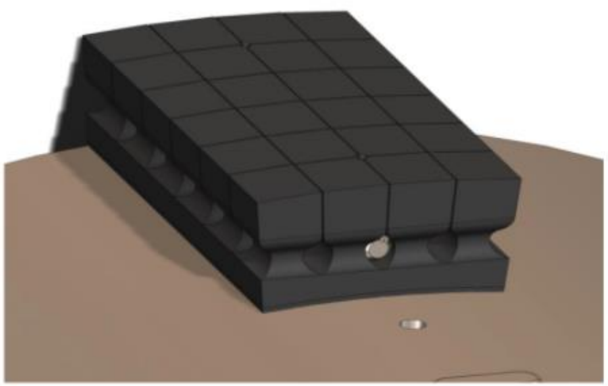
- CDR Summary Report was issued on August 13

CDR Results (2)

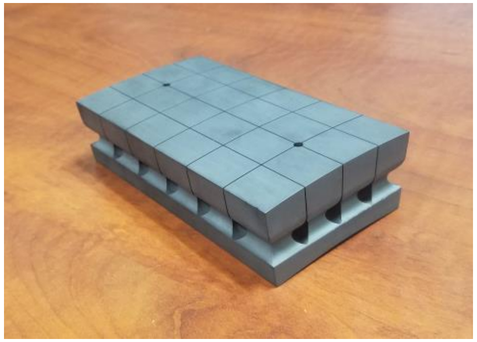
Floating cube concept



Castellated concept



- Inboard Divertor Horizontal (IBDH) and Vertical (IBDV) are the most challenging PFC surfaces
  - High heat flux and strong halo loads
- Two concepts have been identified and path to downselection is nearly complete
  - ✓ Bring alternative concept to same level of analysis maturity
  - ✓ Compare technical features (alignment, diagnostics, scenario compatibility,…)
  - ✓ If the above steps lead to a similar level of confidence, use cost and schedule to down-select
  - ✓ Carry out high heat flux tests on selected concept, reserve alternate as fall-back for risk mitigation



Sample castellated tile EDM cut from Sigrafine material

CDR – PFC Follow-Up

STATEMENT OF WORK
FOR
PLASMA-FACING MATERIALS AND COMPONENTS
TESTING AND EVALUATION

HIGH-HEAT FLUX TESTING OF CANDIDATE MATERIALS AND COMPONENTS
FOR THE NSTX-U RECOVERY PROJECT

NSTX-U-SOW-VV+IH-001-00

DATED AUGUST 9, 2017

Michael A Jaworski

PREPARED BY: M. JAWORSKI
COGNIZANT INDIVIDUAL / ATI/PTR

REVIEWED BY: Frank Malinowski Reason: I have reviewed this document Date: 2017.08.10 10:39:58 -04'00'
QUALITY ASSURANCE

REVIEWED BY: G. D. LOESSER
RESPONSIBLE ENGINEER

Charles L. Neumeyer Digitally signed by Charles L. Neumeyer DN: cn=Charles L. Neumeyer, o=PPPL, ou, email=neumeyer@pppl.gov, c=US Date: 2017.08.10 11:45:11 -04'00'

APPROVED BY: C. NEUMEYER
RLM

PRINCETON UNIVERSITY
PLASMA PHYSICS LABORATORY
P.O. BOX 451
PRINCETON, N.J. 08543
609-243-2000

- Down-selection meetings held during last 2 weeks
- Four external participants invited
  - T. Todd
  - D. Youchison
  - B. La Bombard
  - A. Kellman
- Final analysis of castellated concept expected this week
- Outcome will be vetted by PPPL management
- Statement of Work in process for high heat flux testing at Penn State Applied Research Lab

Cost and Schedule Review
September 6-8, 2017

- Need to refine/vet the cost and schedule that was developed as part of the Corrective Action Plan to bring closure to the Extent of Condition activity by end of FY17

- Need to inform DOE of our budgetary needs

Charge Questions

1. Technical: Is the technical scope in the notable outcome report appropriately captured in the basis of cost and schedule estimates?

2. Cost and Schedule: Is the estimate of cost and schedule appropriate for the current level of design maturity? The primary documentation will be the Work Approval Forms (WAFs) and the Primavera schedule.

3. Risk Assessment: Are the cost uncertainties in the WAFs and the event driven risks sufficiently identified to form an adequate basis for a contingency estimate for the current level of design maturity?

4. Accelerator Safety: Does the overall approach to the NSTX-U Recovery Project appropriately incorporate the requirements of DOE Order 420.2C regarding accelerator safety and does the schedule basis include adequate duration to execute these requirements?

Cost & Schedule Review Committee

Name	Affiliation	Project Management	PFCs	Magnets	VV + Int Hdwe	Test Cell	Diagnostics	Power Systems	Heating Systems	Bakeout + Cooling	Real Time C + P	Vacuum + Fueling	Central I + C	Integration + Analysis
Bob Iotti (CHAIR)	Consultant	x												
Ruben Fair	J-Lab			x										
Vincent Genetti	PNNL	x												
Steve Hartman	ORNL										x		x	
Jim Irby	MIT					x		x		x				
Dale Knutson	Consultant	x												
Brad Nelson	US ITER - ORNL				x									
Dave Rasmussen	US ITER - ORNL								x			x		
Wayne Reiersen	US ITER			x										x
Sam Rozycki	PU	x				x								
Thomas Todd	CCFE, ret.													x
Mark Wilson	PU	x				x								
Dennis Youchison	ORNL		x											

Draft FES Notable Outcomes for FY 2018

- **Goal 2.0 - Design, Fabrication, Construction and Operation of Research Facilities**
  - **FES:** Complete final design reviews for six inner poloidal magnetic field coils (PF1AU/L, PF1BU/L, PF1CU/L) by no later than 3/31/18 (Objective 2.1)
  - **FES:** Build at least 1 prototype PF1A inner poloidal magnetic field coil. Verify the quality of the coil's insulation system through electrical testing followed by destructive sectioning and inspection. Qualify the coil by operating it at both the maximum required current and at maximum joule heating. Submit a final report documenting results by no later than 7/15/18. (Objective 2.2)
  - **FES:** Build and test at least one of each type of production inner poloidal magnetic field coil (viz. PF1A, PF1B, and PF1C). Qualify each coil by operating at both the maximum required current and at maximum joule heating by no later than 9/30/18 (Objective 2.2)
- **PPPL next step**: Place contracts for prototypes

Agenda

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NSTX-U researchers actively engaged in Recovery efforts

- Aided Extent of Condition reviews:
  - Aided in System Design Description (SDD) formulation, edits
  - Design Validation and Verification Reviews (DVVRs)
    - Aided in preparation of presentations, chit submission, chit response
- PFC requirements working group (next slide)
  - Extent of Condition review process identified PFC power handling issues that must be addressed
    - Narrower SOL width not incorporated in GRD (2009-2012)
    - Increased halo peaking on IBDH → T-bar design insufficient
  - Extensive equilibrium & heat-flux scans performed, more to come
- Topical Science Group contributions:
  - Re-assessed scenario needs: first 2yrs of ops + 5/7 year plan
    - Magnetic balance and δ variations influence PFC design considerations
  - Assessed impact of polar region mods on research plans

Working Group for NSTX-U PFC performance and monitoring requirements will continue into FY18

- Leader / deputy:
  - Matt Reinke (ORNL) / Mike Mardenfeld (PPPL engineering)
- Working Group charges: (click here for more info)
  - Define which (additional) parameters need to be specified in an updated requirements document for the NSTX-U PFCs
  - Facilitate generation of updated requirements utilizing:
    - Available reduced models, empirical scalings, boundary simulations
    - Ultimately, a validated model for specifying heat loads to all plasma facing components for arbitrary NSTX-U scenarios
  - In preparation for operations, develop:
    - Instrumentation plan for intra and inter-shot PFC monitoring
    - A reduced model for heat loading for pre-shot planning
    - Guidance on how to best integrate monitoring with operations
    - Control, diagnostic requirements for real-time heat-flux control
  - Work w/engineers/analysts to develop/implement requirements

Use Conservative Approach: Assume Narrow λ_q

Three scalings of heat flux width, λ_q, with eng. parameters

- **Heuristic Drift Scaling [Eich, PRL 2011]:** **(7), (9-10) results in** $\boldsymbol{\lambda_q \sim B_T^{-7/8} q_{cyl}^{9/8}}$ — **1.95 [mm]**
- MAST scaling [Thornton, PPCF 2014]: $\lambda_q[mm] = 1.84(\pm 0.48) B_{pol,omp}^{-0.68(\pm 0.14)} P_{SOL}^{0.18(\pm 0.07)}$ — 4.09 [mm]
- Eich Scaling [Eich, NF 2013]: $\lambda_q[mm] = 1.35 \varepsilon^{0.42} R_{geo}^{0.04} B_{pol,omp}^{-0.92} P_{SOL}^{-0.02}$ — 2.96 [mm]

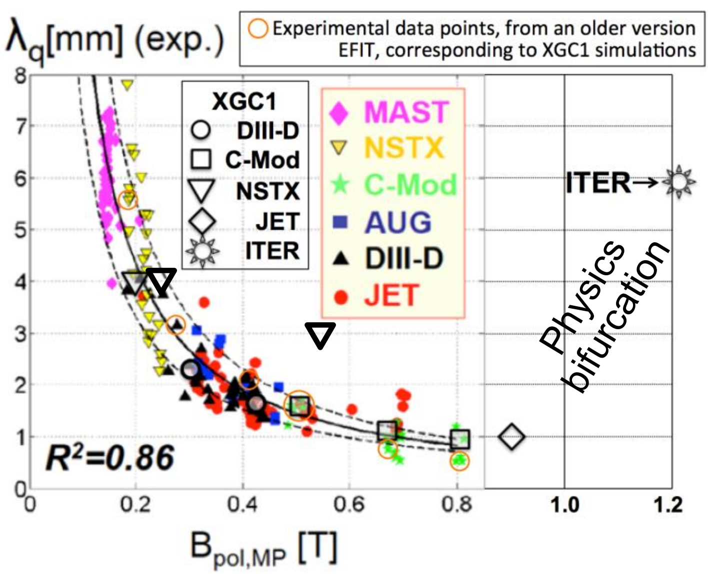
2 MA, 1 T, 10 MW Scenario

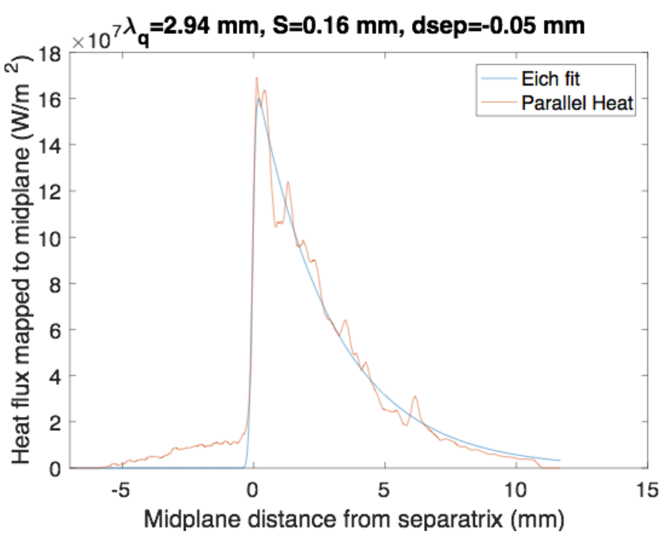
- **PFC Requirements developed assuming Heuristic Drift Scaling**
- **PFC requirements assume 30% radiated power fraction based on best-fits to scalings (small data set)**

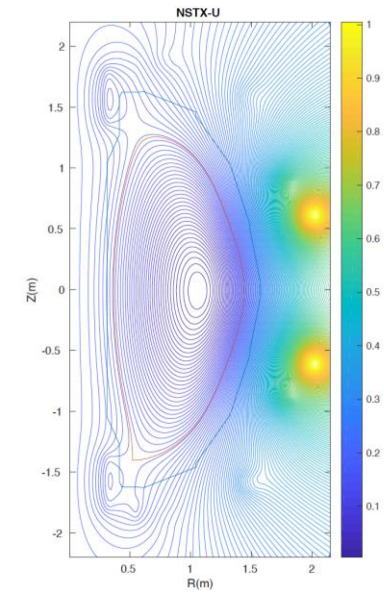
Milestone R17-1

XGC1 heat-load width prediction for 2MA NSTX-U

- An up-scaled NSTX-U plasma equilibrium from NSTX #139047 is used.
  - Similar magnetic equilibrium shape, B_p=0.58 T, heat input = 7.8MW
- **XGC1 finds that λ_q^{Eich} for lower inboard divertor in NSTX-U is ≈ 3 mm, which is ~1.5-2x larger than the Eich-Goldston scaling prediction.**
  - The physics cause appears to be from more pronounced lack of Grad-B drift into the private flux region at higher B → S-number smaller, λ_q^{Eich} greater
- XGC1 finds that $P_{outer\ leg}/P_{inner\ leg}$ ≈ 2.2, similar to the NSTX #139047 value.

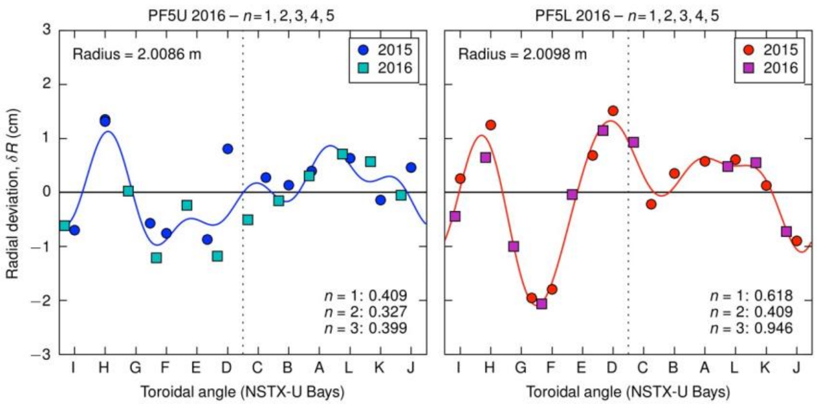


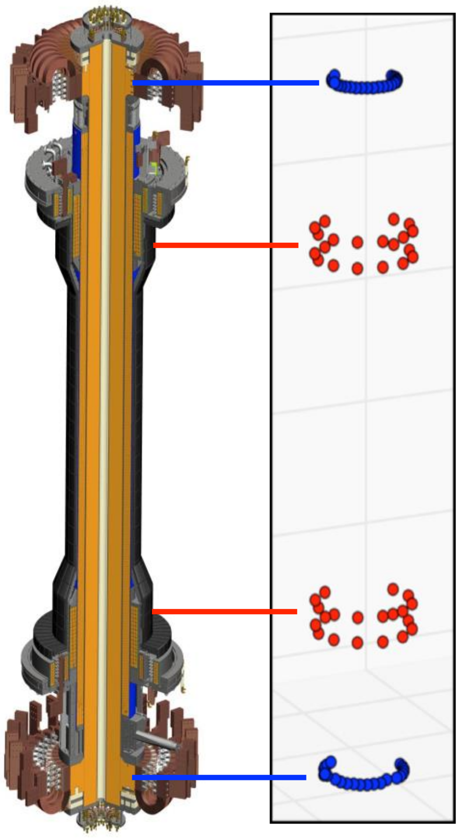


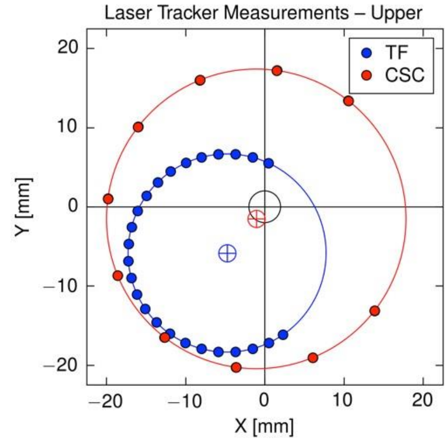


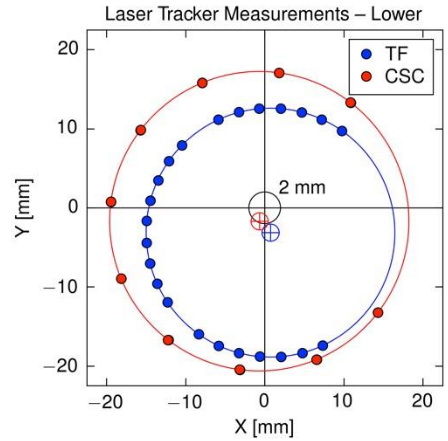
Coil metrology conducted on TF rod, center-stack casing (CSC), and PF5 coil

- Combine metrology techniques: ruler, ROMER arm, laser tracker
- PF5 $n = 1$ amplitude and phase:
  - $\delta R \sim 6$ mm at $\phi = 16°$
- TF rod shift and tilt:
  - Shift = 4.9 mm at $\phi = 246°$
  - Tilt = 1.2 mrad at $\phi = 206°$ (6 mm)



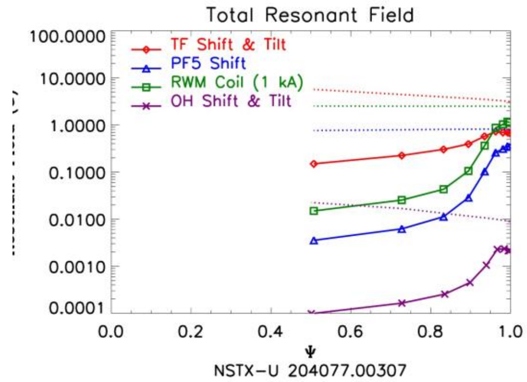


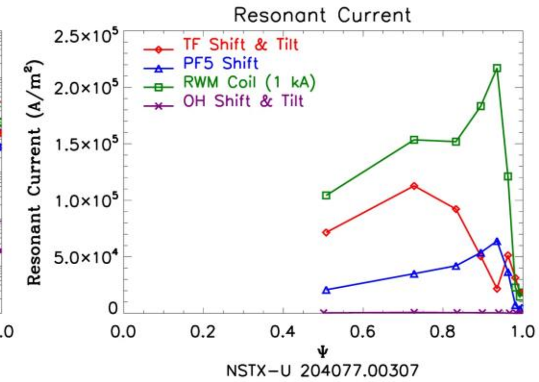


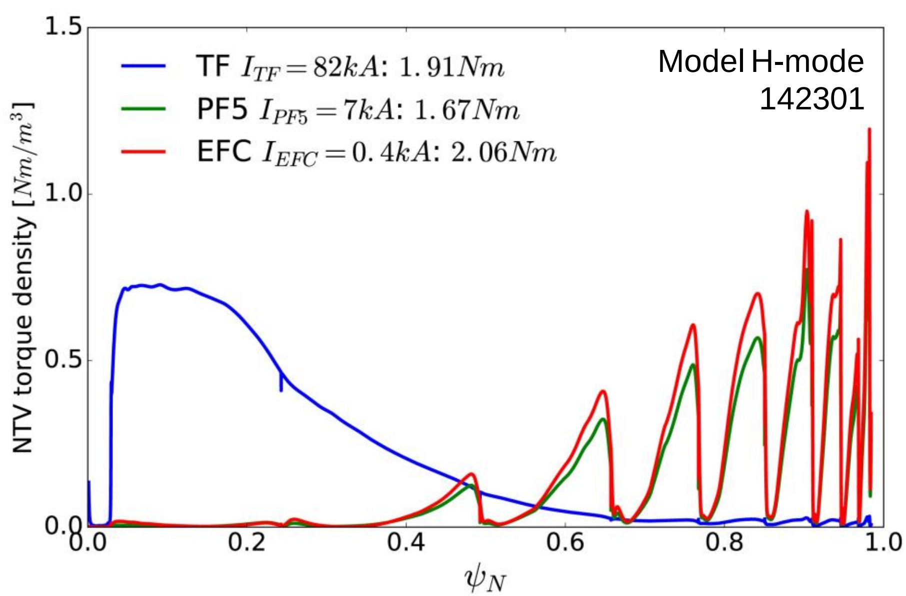


Modeling results → need to impose 2 mm tolerance for TF alignment to mitigate TF error field effects

- Metrology → coil shape models
  - Feed to IPEC & M3D-C1
- Resonant fields and currents:
  - TF error field is dominant
  - TF EF phase not constant
  - Difficult to correct
- Neoclassical toroidal viscosity:
  - RWM coils are poorly matched to TF NTV spectrum
- Tolerance of 2 mm:
  - Resonant fields below locking threshold without EFC
  - Reduces TF NTV by 10×

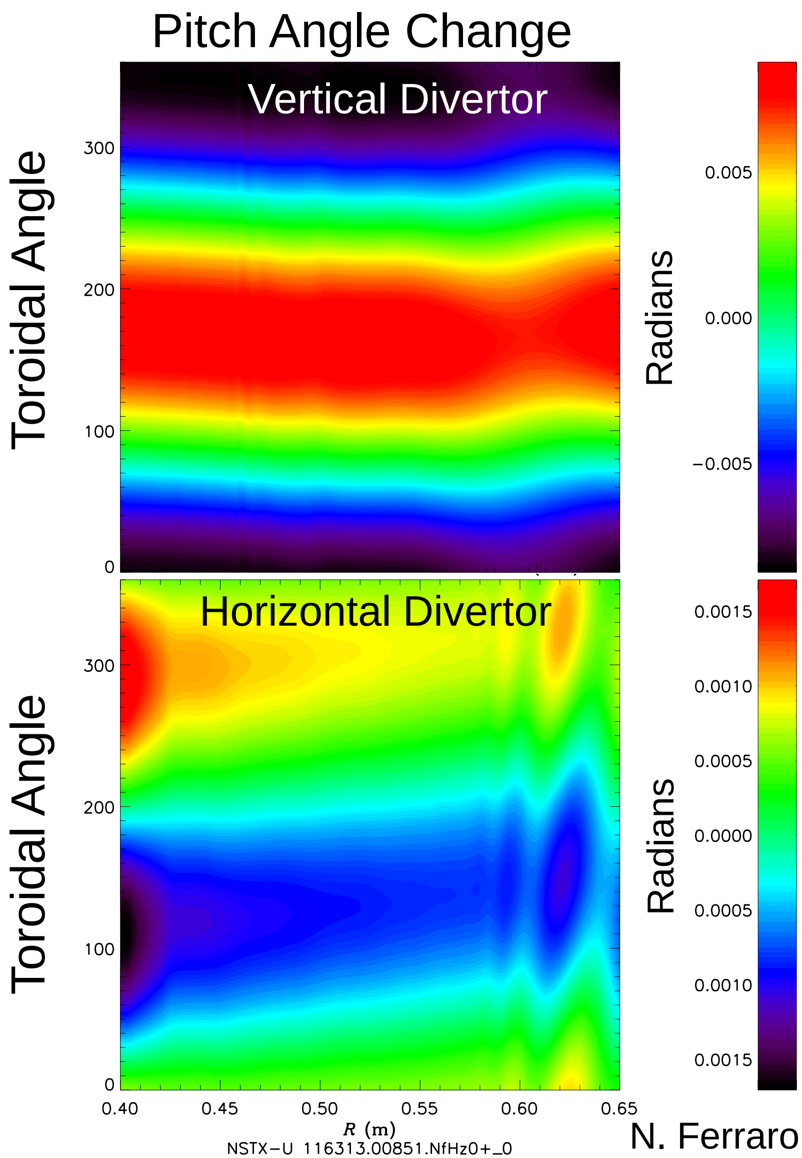






Error Field modeling informing PFC design

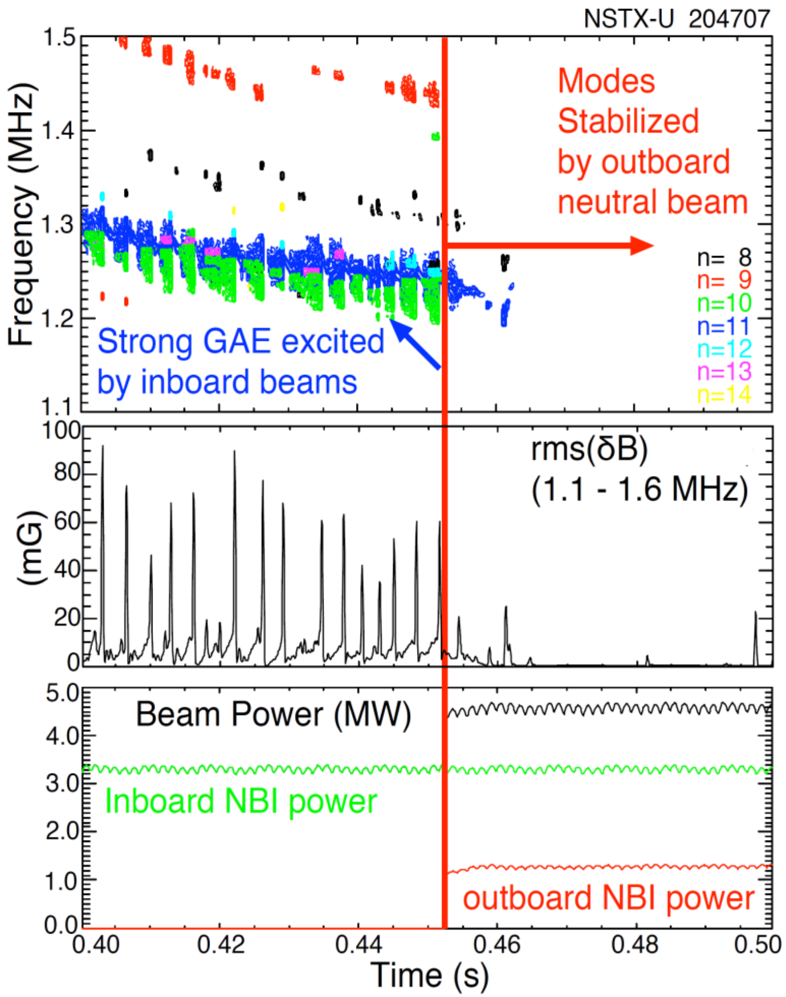
- Error fields may significantly affect heat flux to divertor PFCs
  - Change incidence angle of B-field
  - Cause radial and toroidal variations in the heat flux due to magnetic lobes
- Effect of error fields on magnetic pitch angle calculated with M3D-C1 for high-performance model NSTX-U equilibria
- Largest known error field in NSTX-U (TF error) would cause pitch angle changes of up to 0.5°
  - This is significant, but likely not large enough to cause concern after improved TF realignment

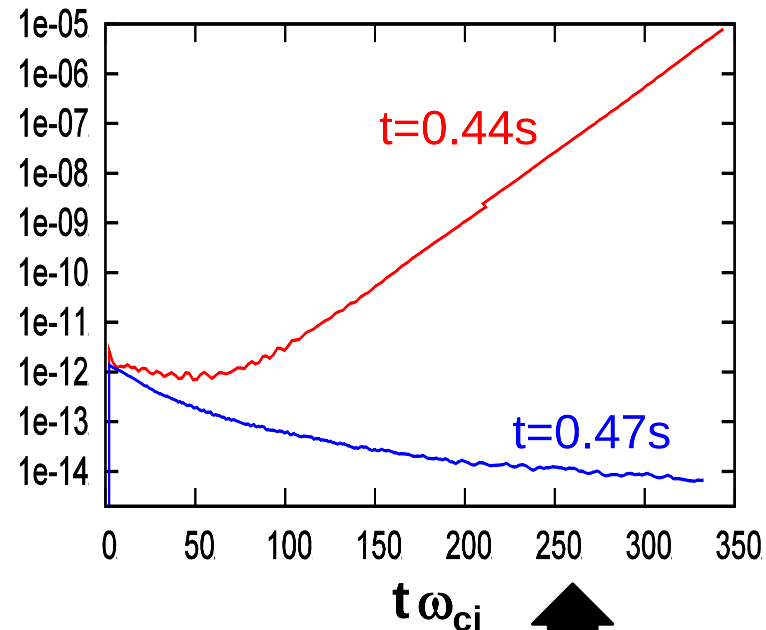


N. Ferraro

NSTX-U: Tangential 2nd neutral beam suppresses Global Alfven Eigenmode (GAE) – consistent with simulation

Published in Phys. Rev. Lett. 6/2017 - E. Fredrickson et al.



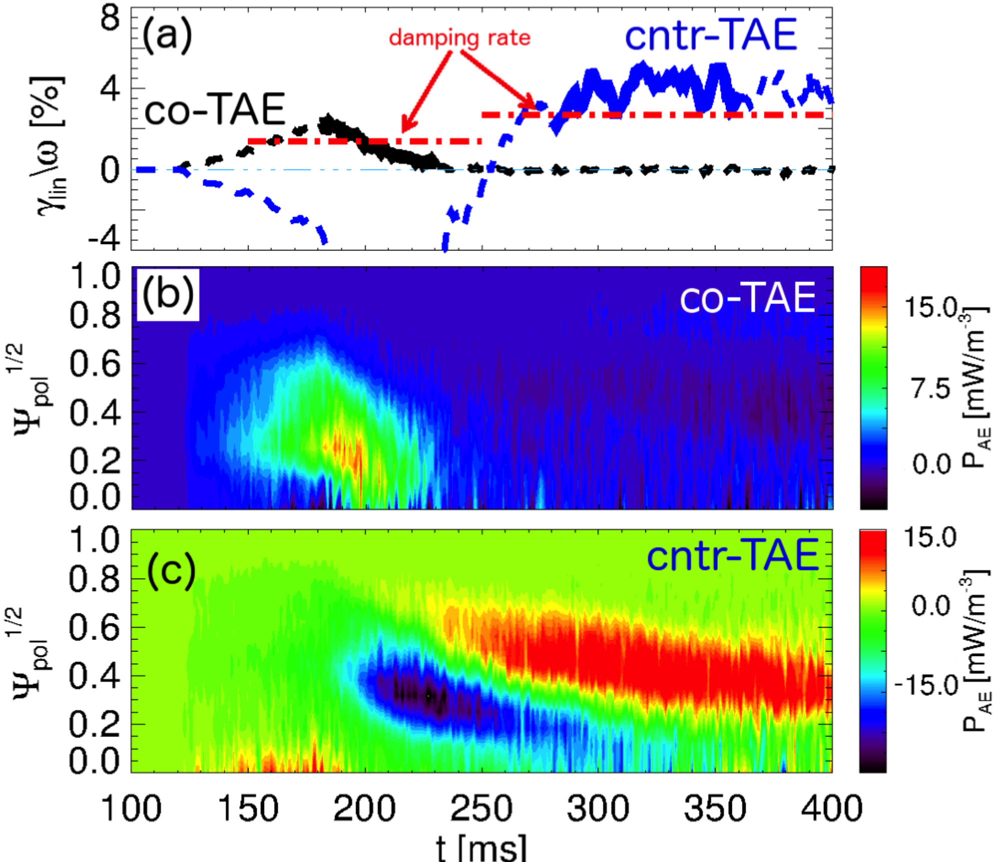


- HYM code: growth of n=10 counter-GAE from 1st NBI
- HYM: suppression of n=10 counter-GAE by 2nd NBI
- Most unstable *n*-number, mode ω consistent with HYM

Linear TAE stability vs time from TRANSP + *kick model* is consistent with NSTX-U experiments

- Compute power from fast ions to mode
  - Infer growth rate [Podestà, PPCF 2017]
  - Using damping rate from NOVA-K
- Timing of most unstable |n|=1 TAE modes compares well with experiments
- Stability related to gradients in both radius & energy
  - Not the usual "universal drive"

[Podestà, PRL 2017 (submitted)]



- *Flexibility of TRANSP + kick model approach enables scenario development for realistic geometry*
  - Example: ~0.5MW "blips" with 1st NBI predicted to stabilize cntr-TAEs

Publish your NSTX-U results!!!

Before you forget and/or engage deeply in collaborations

IOP Publishing | International Atomic Energy Agency

Nuclear Fusion

Nucl. Fusion 57 (2017) 102006 (17pp)

https://doi.org/10.1088/1741-4326/aa600a

Overview of NSTX Upgrade initial results and modelling highlights

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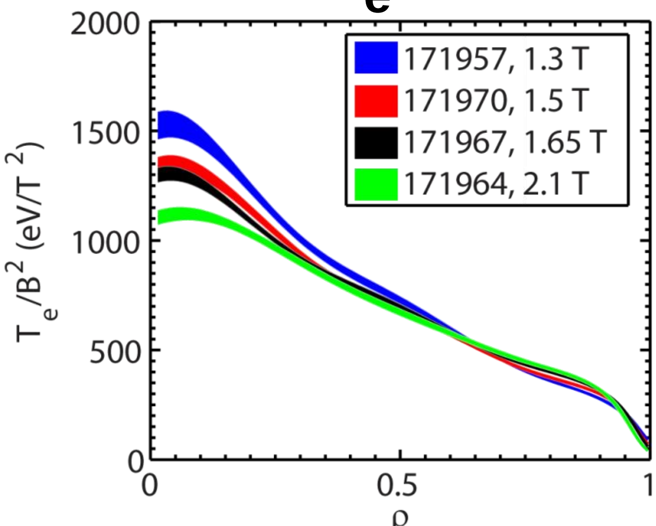
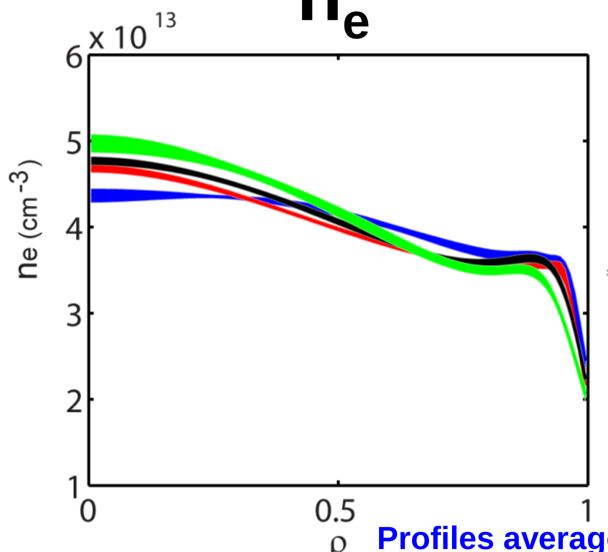
Collisionality Dependence of H-mode Energy Confinement Scaling was Studied in the DIII-D/NSTX-U National Campaign

- ν* dependence of H-mode confinement scaling not understood
  - Strong inverse dependence on collisionality ($\propto \nu_e^{*-1}$) in STs
  - A weaker dependence observed on DIII-D ($\propto \nu_e^{*-0.5}$)
- An experiment was successfully carried out on DIII-D
  - Using advanced inductive hybrid scenario with ST-relevant q_{95}~6.6
  - Achieved reasonable profile matching for a dimensionless collisionality scan
    - E.g. T_e/B^2 and n_e matched to keep β_e and ρ* nearly constant
  - Achieved a factor of about 7 change in the electron collisionality

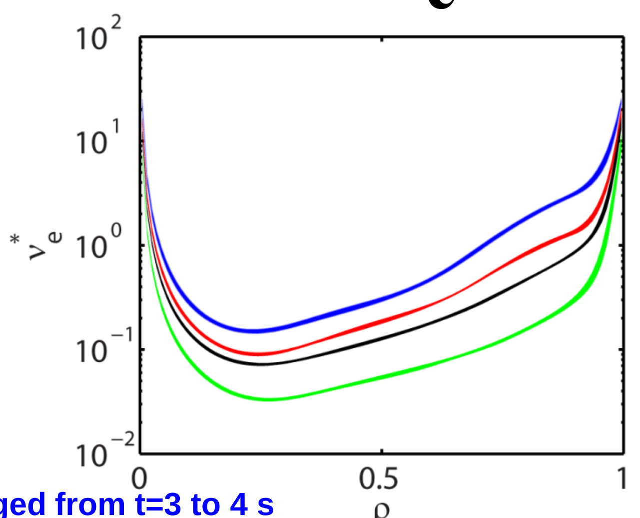
T_e/B^2



n_e



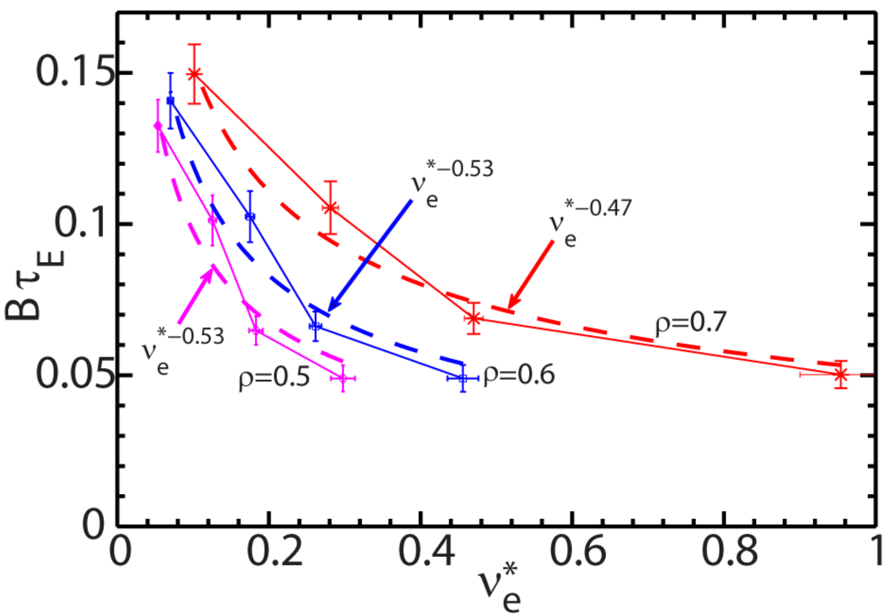
ν^*_e

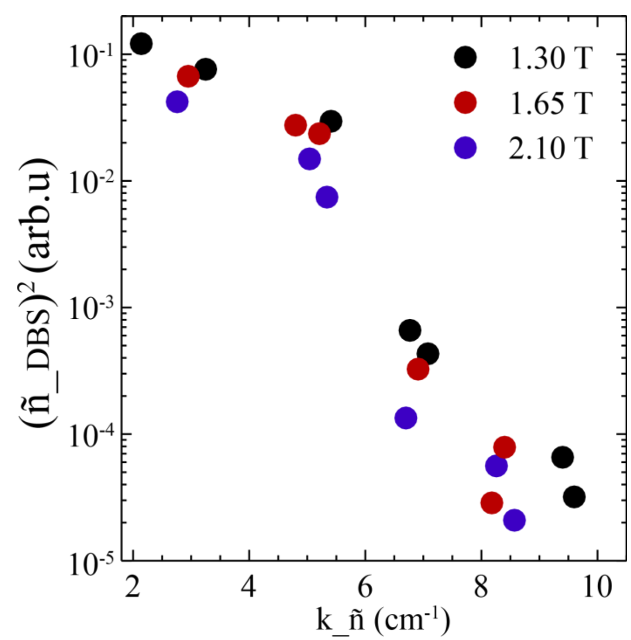


Profiles averaged from t=3 to 4 s

Collisionality Dependence of H-mode Energy Confinement Scaling was Studied in the DIII-D/NSTX-U National Campaign

- Observed confinement scaling ($\propto \nu_e^{*-0.5}$) consistent with the previous DIII-D result (Luce et al., PPCF, 2008)
- DBS measurement showing turbulence spectral power reduction with the increase in B_T (decrease in collisionality), consistent with energy confinement improvement
- Further analysis is ongoing

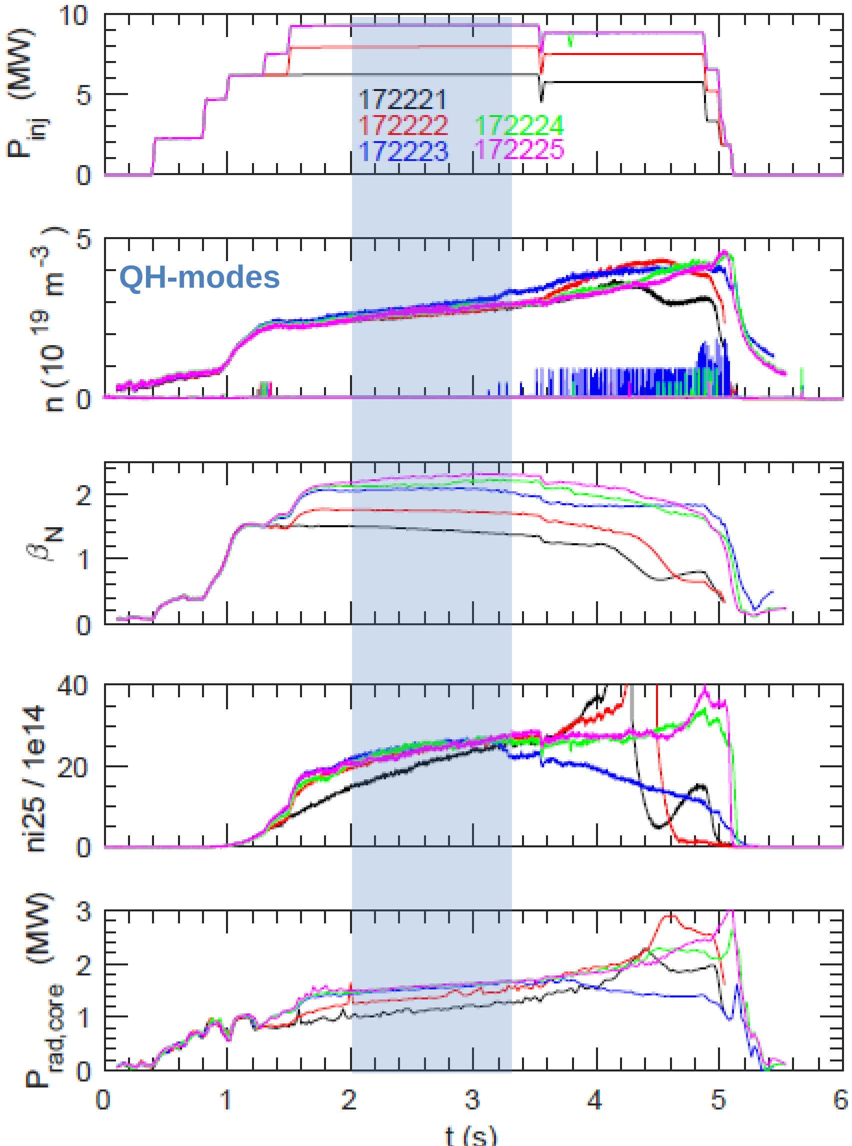




DBS measurement at ρ~ 0.55-0.65, averaged for t=3.75-4 s

DIII-D "NSTX-U campaign" MP to measure core CPS ($\sim\delta B$) to validate electromagnetic microturbulence effects

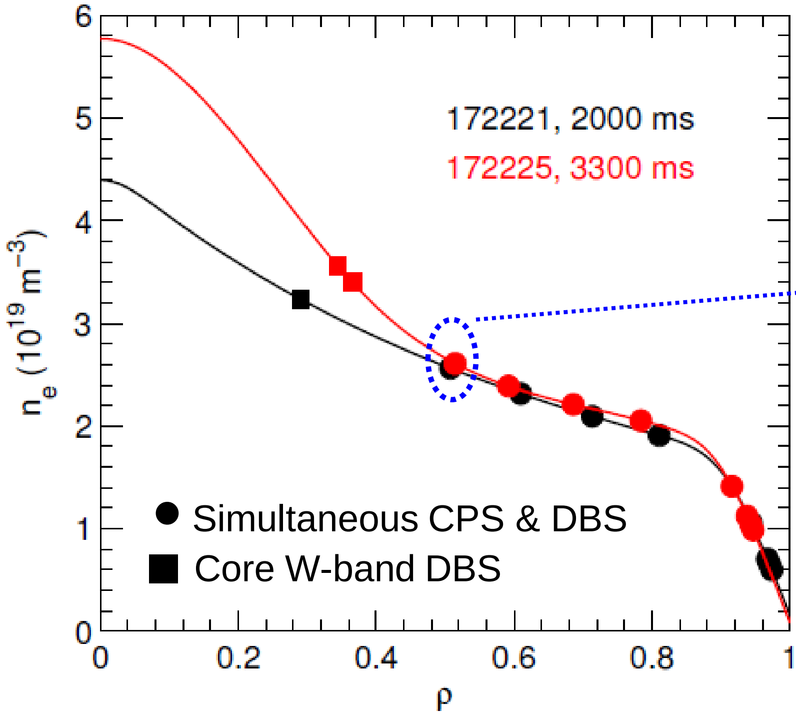
- EM effects important in spherical tokamak (ST) H-modes *and* deep core (ρ<0.5) tokamak H-mode
  - Increasing β stabilizes ITG, TEM
  - Can lead to EM instabilities: MTM, KBM
- Obtained β_N scan (1.5-2.3)
  - Large impurities, performance evolving throughout day
- Goal: measure δB using UCLA cross-polarization scattering (CPS) to validate GK predictions (*plans to install CPS on NSTX-U*)



DIII-D NATIONAL FUSION FACILITY UCLA

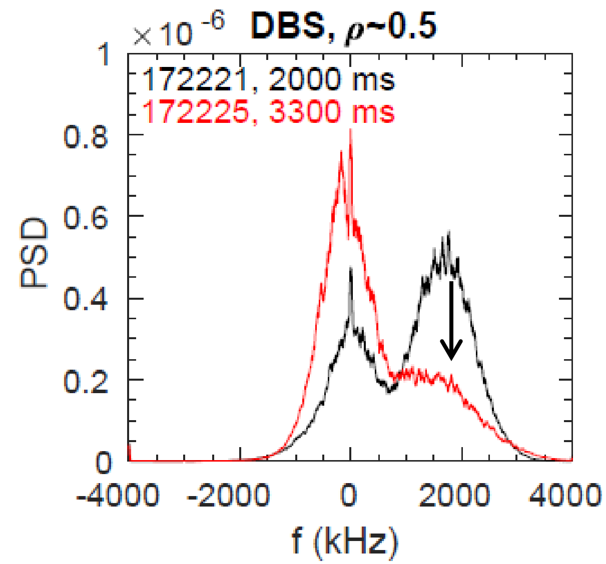
Initial results: core (ρ~0.5) CPS measurement distinct from DBS, both change with increasing power

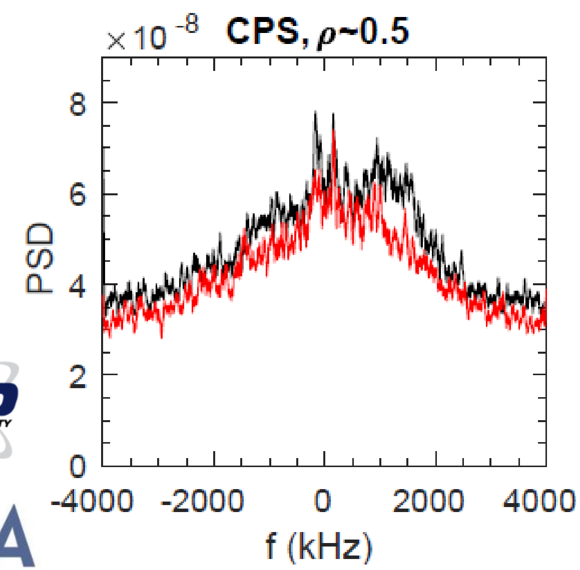
- Broad range of locations and wavenumbers:
  - CPS ($k_r\rho_s$=1.2–6), DBS ($k_\theta\rho_s$= 0.3–3)
- Will require extensive ray tracing + synthetic diagnostics for comparison & gyrokinetic validation



β_N=1.5

β_N=2.3 (higher T_i/T_e, n_{beam}/n_e, …)





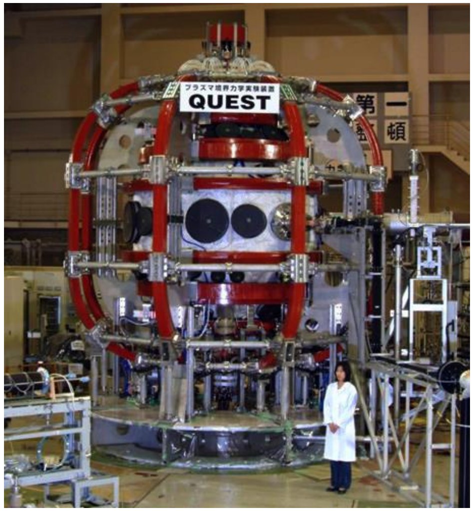
Two of three DBS systems (W- & V-band) on loan from UCLA/NSTX-U

DIII-D NATIONAL FUSION FACILITY

UCLA

Major goal of the QUEST program is to generate steady-state fully non-inductive plasmas

- QUEST will ultimately use a combination of 2.45, 8.2, 8.56 and 28 GHz heating to generate steady-state, fully non-inductive plasmas with 3 MW of RF power:
  - *Present capability:*
    ~ 50 kW of 2.45 GHz
    ~ 400 kW of 8.2 GHz
    ~ 250 kW of 28 GHz
- The QUEST CHI system has been commissioned by University of Washington team and will be used with 28 GHz heating later this year

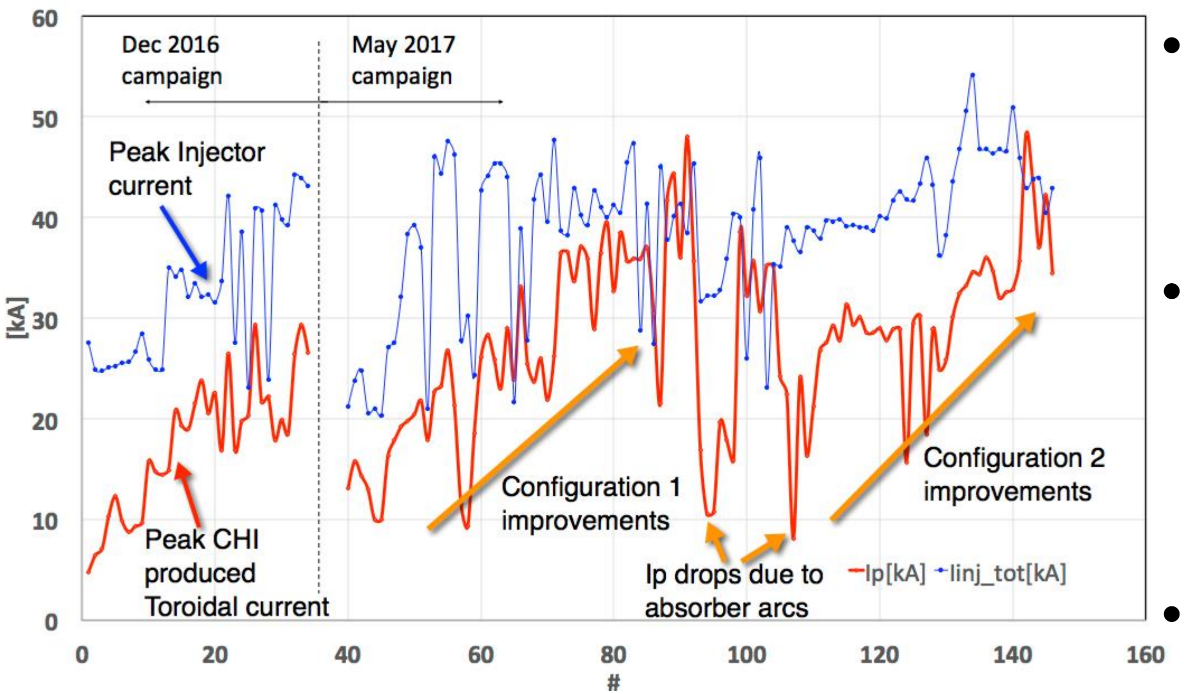


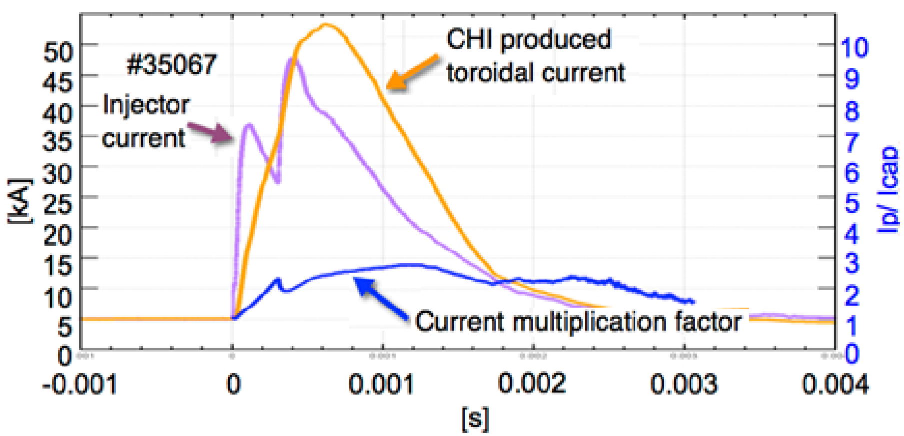
QUEST Spherical Tokamak

Major Radius	0.68 m
Minor Radius	0.40 m
Aspect Ratio	1.70
Vacuum Chamber Radius	1.4 m
Vacuum Chamber Height	2.8 m
Toroidal Magnetic Field	0.25 T (steady state), 0.5 T (pulse)
Plasma Current	100 kA (current) → 300 kA (target)
Heating Power	8.2 GHz + 8.56 GHz + 28 GHz: 3 MW (target)

QUEST Parameters

QUEST: Steady progress increasing plasma current using Coaxial Helicity Injection (CHI)



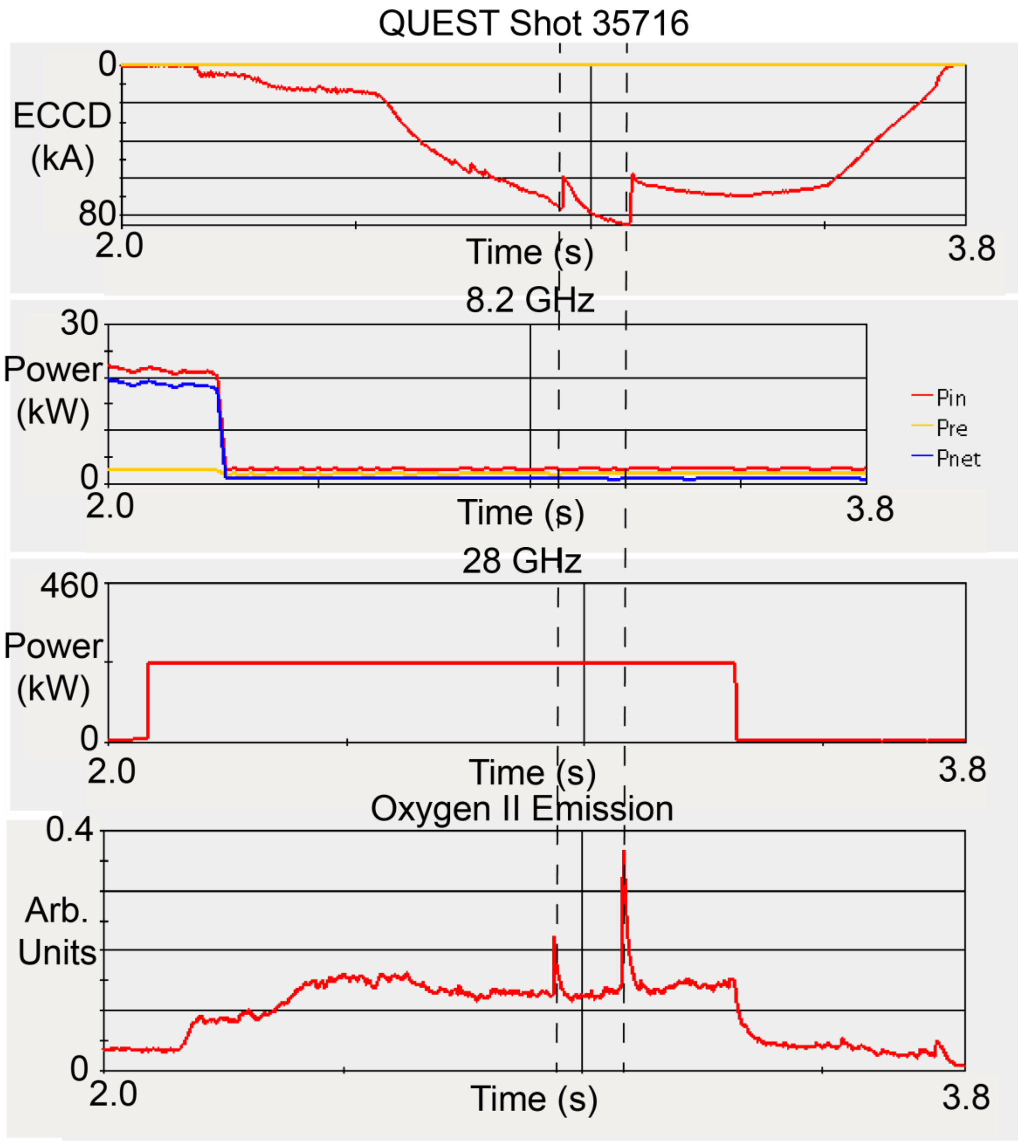


- Increased peak toroidal current from 29 kA (Dec 2016) to 48 kA
- CHI produced toroidal current exceeded injector current during this campaign
- Config. 2 used VF & narrower flux footprint
- Considerable amount of magnetics data to be analyzed to further improve discharges during Campaign 3

Generated up to 85 kA with 230 kW

- Limited by large drops in generated current, coincident with bursts in the Oxygen-II emission
- Analysis ongoing to investigate cause
- Also collaborating on kinetic modelling of energetic electron population and current drive (Bertelli - PPPL)

G. Taylor (PPPL)



NSTX-U researchers also actively engaged in generating input for National Academy panel

Workshop Info

Agenda
Meeting Venue
Remote Connection (Zoom)
Upload Presentation / File
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Submit Chit (Comment / Recommendation)
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Discussion Session Groups
Discussion Session Guidance
Discussion Session Questions
Registration
View / Download Whitepaper
Whitepaper Guidance & Template
Announcement PDF
Overview
Hotel Information
Workshop Governance & Process
Program Committee
MFR Report Archive
Sitemap

NAS Study Info

NAS Charge and Schedule
NAS Committee

Agenda

US Magnetic Fusion Research Strategic Directions Workshop

University of Wisconsin – Madison

July 24 – 28, 2017
Last updated July 20, 2017

Zoom URL (only available during plenary presentations):
https://zoom.us/j/5669851878 or here
PLEASE MUTE YOUR MICROPHONE!

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Monday, July 24

Plenary Session: Workshop Goals / Strategic Planning Perspectives / Program Health

(Chair: M. Wade)

8:30 O. Schmitz: Welcome and Workshop Logistical Details (10)

8:40 J. Menard: Overview of Goals and Organization of Workshop (15+5)

9:00 M. Mauel: A Strategic Plan for US Burning Plasma Research (15+5)

9:20 M. Greenwald: Community Planning For Fusion Energy and Plasma Science (25+5)

9:50 M. Shochet: Overview of P5 Planning Process: Lessons Learned (20+10) (Remote via Zoom)

10:20 T. Carter: The Current Status and Health of US Magnetic Fusion Energy research (15+5)

10:40 Coffee break

Plenary Session: Strategic Directions / Vision for the Future

Next workshop in Austin week of December 11, 2017 – stay tuned

Thank you!

Any questions?

MAST-U areas of collaborative opportunities (1)
(coordinated by S. Kaye)

- Startup development – LRDFIT for null, wall modeling, vertical shape control, real-time EFIT and PCS upgrade:
  - D. Battaglia spending 2 ½ months at MAST-U – through August
    - Also engaging D. Boyer, K. Erickson both from PPPL
- Core physics
  - Transport and confinement: TRANSP, expts (S. Kaye)
  - Core turbulence using BES, DBS (Y. Ren)
  - MHD stability
    - Error fields and tearing modes (N. Ferraro, C. Myers)
    - Equilibrium reconstruction and MHD stability (S. Sabbagh, J. Berkery)
- Energetic particles
  - TAE modes, NB characterization (M. Podesta, E. Fredrickson, E. Belova, N. Gorelenkov)
  - High-frequency AE (N. Crocker)

MAST-U areas of collaborative opportunities (2)
(coordinated by S. Kaye)

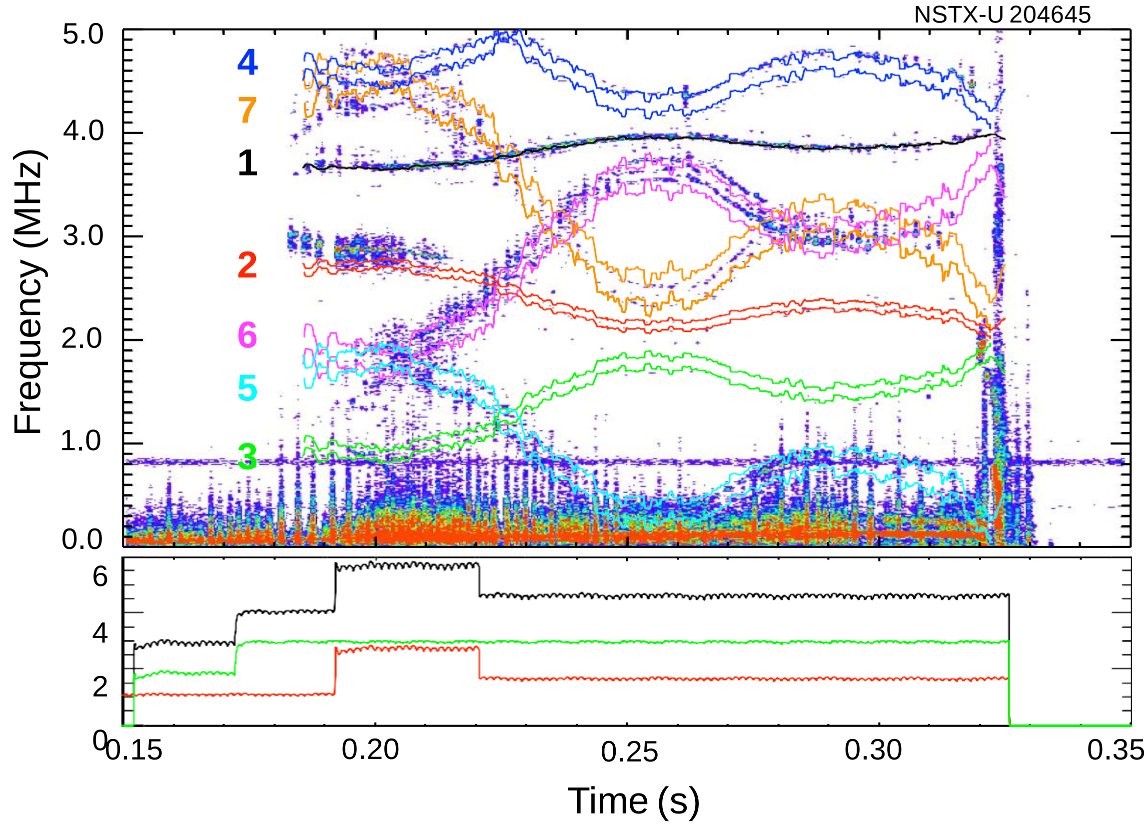
- Pedestal physics
  - Turbulence, pedestal structure (A. Diallo – continuing active collaboration, T. Rhodes)
  - Gas puff imaging (S. Zweben)
  - Pedestal & ELM stability modeling: (possibly G. Canal)

- Exhaust physics
  - Bolometry, radiative divertor physics (M. Reinke – already funded)
  - Divertor IR: TBD (J.-W. Ahn, T. Gray)
  - Divertor spectroscopy, turbulence, snowflake divertor ops (V. Soukhanovskii)

Investigating newly observed Ion Cyclotron Emission (ICE) from NSTX-U discharges

- Spatially coherent → argues for mode
- Bursty rather than CW → unstable mode - what defines mode *f* ?
- Doesn’t follow Alfvénic scaling - not Alfvén eigenmode?
- Like conventional ICE, higher harmonics largest amplitudes

- Strongest ICE correlated with source 1C – the most perpendicular source
- Amplitude decreases with increasing density
- TRANSP runs started to study β_{fast} dependence
- **Can ICE be correlated with confined fast-ion distribution parameters?**
- **Needs theory support**

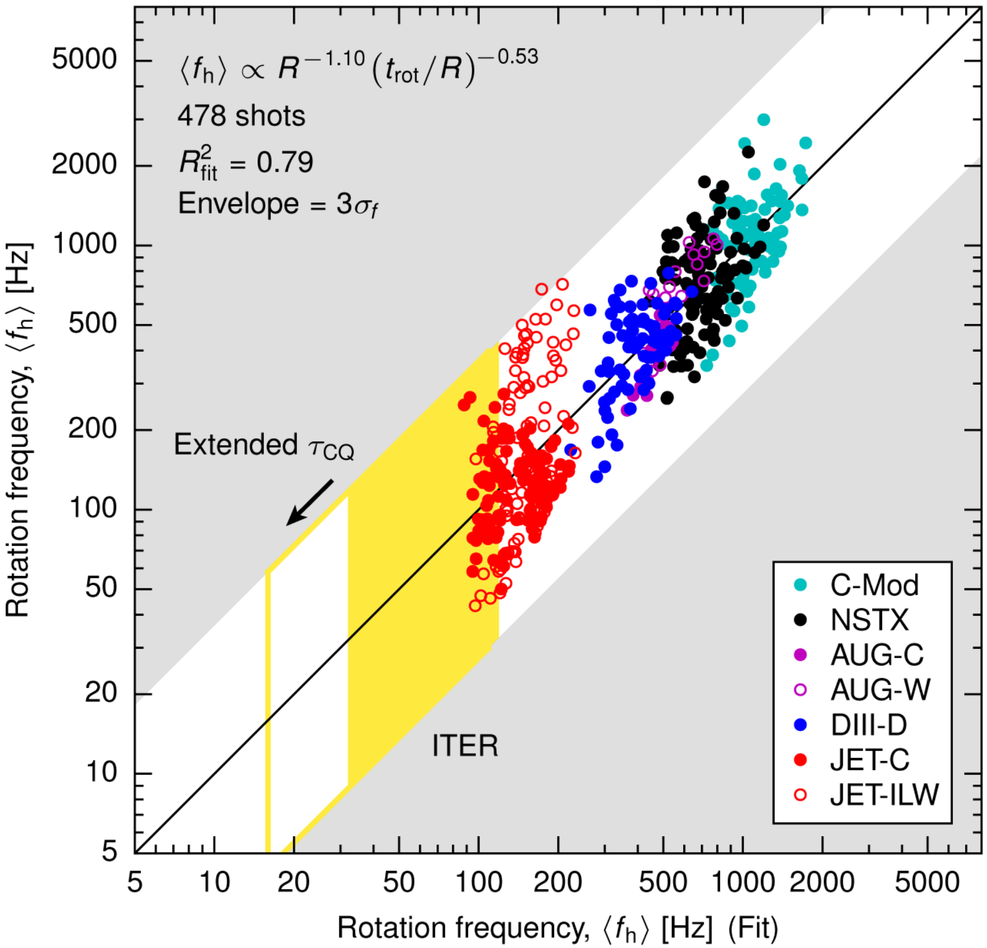


Leading halo current propagation studies

C. Myers (PPPL)

- The concern for ITER:
  - Concern is for asymmetric halo currents during unmitigated disruptions
  - Forces are dynamically amplified if $N_{rot} > 2\text{-}3$
  - Critical mechanical resonances in the 3-8 Hz range [Schioler FED 2011]
  - Overall response is broader (10-20 Hz) [Bachmann FED 2011 & Lehnen]
- **Could halo current forces be dynamically amplified in ITER?**
  - **Could the halo currents rotate at frequencies below 20 Hz?**
  - **Could the rotation last long enough to complete 2-3 rotations?**
- Substantial halo current rotation observed in a number of devices:
  - JET Noll 1996, Riccardo 2004 & 2009, Gerasimov 2014 & 2015
  - C-Mod Granetz et al. *Nucl. Fusion* **36**, 545 (1996)
  - DIII-D Evans et al. *J. Nucl. Mater.* **241-243**, 606 (1997)
  - AUG Pautasso et al. *Nucl. Fusion* **51**, 043010 (2011)
  - NSTX Gerhardt *Nucl. Fusion* **53**, 023005 (2013)

Simple rotation frequency scaling: $\langle f_h \rangle \sim 1/R$
Cannot rule out dynamic force amplification in ITER



- Key quantities:
  - N_{rot} = number of rotations
  - t_{rot} = rotation duration
  - $\langle f_h \rangle = N_{rot} / t_{rot}$ = rotation frequency
- Carry out regression using two parameters → R, t_{rot}
- Additional parameters do not improve regression (e.g., I_p, B_T)
- $\langle f_h \rangle \sim 1/R \sim$ constant $\langle v_h \rangle$
- ITER projection:
  - Rotation at $\langle f_h \rangle < 20$ Hz probable
  - Rotation duration analysis → Cannot rule out dynamic force amplification in ITER

C. E. Myers, et al. (Manuscript submitted to *Nuclear Fusion*)