NSTX-U

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Fusion Energy Sciences

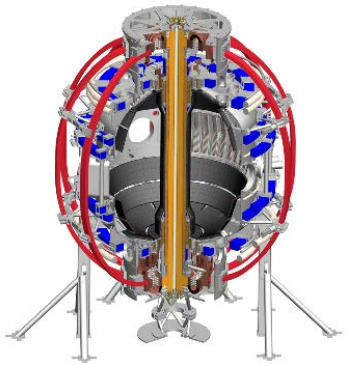
NSTX-U Team Meeting

Status & Plans for the NSTX-U Research Department

J. Menard, S. Kaye, S. Gerhardt, M. Reinke

MBG Auditorium
March 22, 2017

PPPL



Outline

- Milestone status and plans
- New NSTX-U Working Group
- Collaboration status
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Milestone overview

Research and Diagnostics

- **FY17 milestones contained in June 2016 FWP have been re-written**
  - PF1AU fault, Recovery substantially changed plans
  - Results from first run incorporated into milestones
  - Milestones aim to accelerate scenario development during commissioning phase when ops resume
  - Responsive to FY2016 PEMP, FY17 DVVRs, EoC

- **FY18 milestones build on FY17, prepare for ops**
  - 8 FY18 milestones → nearly all TSGs have milestones

Milestone status

- Developed draft ideas in December
- Finalized ideas and draft text in January
- Text completed for FWP for research and diagnostics/small actuators late February
- Planning quarterly meetings with SGs/TSGs to get status and plans for each milestone
  - Next meetings:
    - Afternoon of Friday, March 31
    - June/July

FY2017 Milestones organized by NSTX-U 3 Science Groups

1. Boundary Science
   - Divertor and Scrape-off Layer (DS)
   - Materials and Plasma Facing Components (MP)
2. Core Science
   - Macroscopic Stability (MS)
   - Energetic Particles (EP)
   - Transport and Turbulence (TT)
3. Integrated Scenarios
   - Advanced Scenarios and Control (ASC)
   - Radio-frequency wave heating and current drive (RF)
   - Solenoid-free start-up (SFSU)

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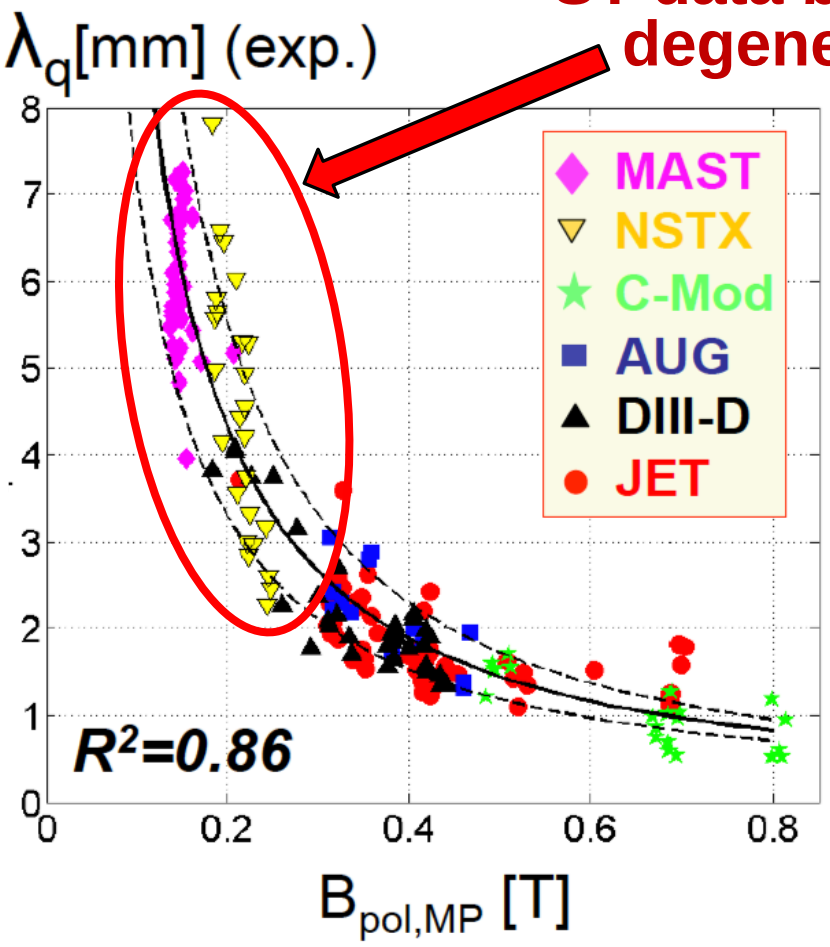
Tokamak + ST data: power exhaust width varies as 1 / $B_{poloidal}$

Will previous ST trend continue at 2× I_P , B_P , B_T, power?

ST data breaks aspect ratio degeneracy of data set



Issue: If peak heat flux in divertor region exceeds ~10 MW/m^2 → material damage

Wider heat-flux width may offset smaller R → maybe better than tokamak

FY17 Divertor and SOL Milestones (1)

- **R17-1:** Simulation-based projection of divertor heat flux in NSTX-U
  - **Goal:** Extend SOL heat-flux width simulations up to 2MA, 10MW NSTX-U scenarios – make prediction for NSTX-U
  - **Tools:** XGC – including physics of magnetic drift of warm ions across separatrix and cross-field E×B-drift heat-flux from edge turbulence
  - **Impact:** Understand neoclassical vs turbulent SOL transport
    - Important to NSTX-U heat flux mitigation strategies and ITER power exhaust challenge, could impact long-term PFC protection requirements

FY17 Divertor and SOL Milestones (2)

- **R17-2:** Advanced divertor operating scenario modeling for NSTX-U
  - **Goals:** (1) Assess dependence of advanced divertor vs solenoid and PF currents, perturbed 3D field effects, (2) Assess divertor radiation & heat fluxes vs current, input power, density, and seeded impurities
  - **Tools:** ISOLVER, CORSICA, SOLPS, UEDGE, GINGRED, M3D-C1, EMC3-ERENE
  - **Impact:** Define advanced divertor operational space
    - Responsive to Recovery Project issue / concern, EoC recommendation

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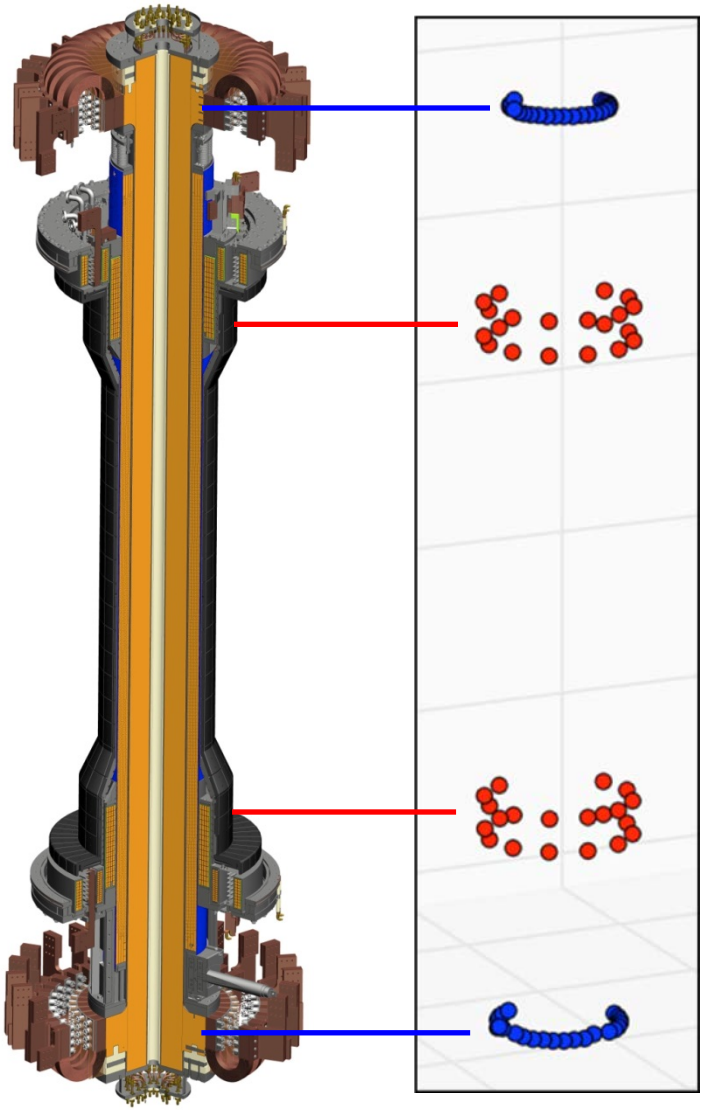
Important NSTX-U error field identified

- TF bundle (gold) found to be tilted inside the casing (black)
- Metrology to quantify the tilt:
  - Laser tracker used to measure the tile surface (red) and the TF bundle (blue)
    - Note: tile surfaces previously located via ROMER arm
  - **The tilt is ~5 mm over ~5 m**
  - Seems small, but plasma cares
- Tilt can be reduced since center stack is removed for improvements

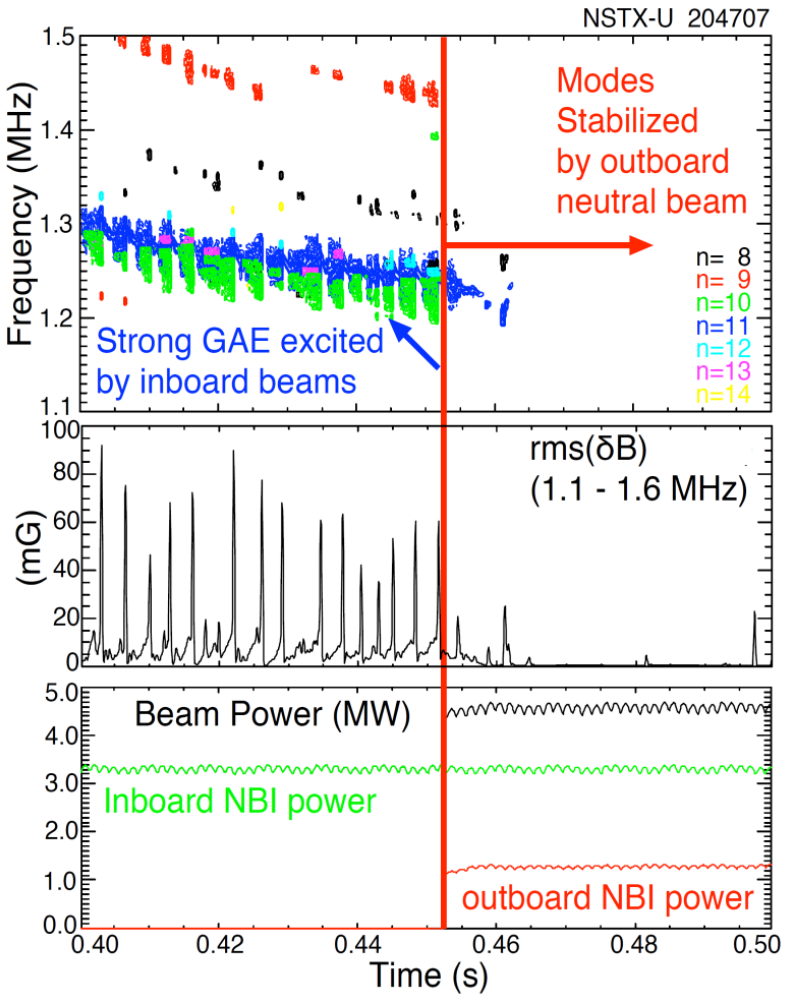


C. Myers

FY17 Macroscopic Stability Milestone

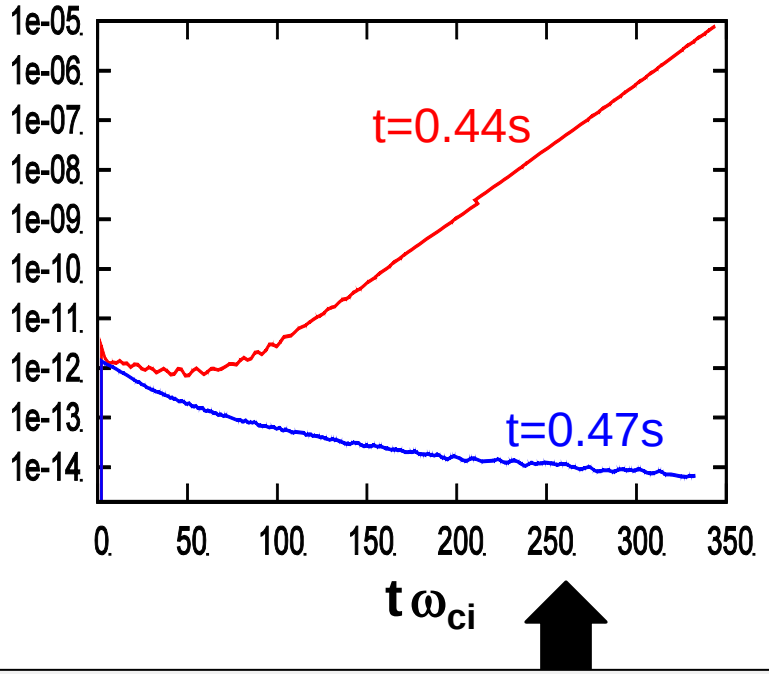
- **R17-3:** Identify, mitigate, and develop correction strategies for intrinsic error fields
  - **Goals:** Complete characterization of coil positions, shapes, model plasma response, provide guidance on TF bundle re-alignment requirements
  - **Tools:** IPEC, M3D-C1, metrology (FARO arm, laser tracking)
  - **Impact:** Minimize intrinsic error fields, access high performance more rapidly during next ops
    - Responsive to FY2016 PEMP concern, EoC Recommendations
    - Need to interface with engineering to interpret / implement requirements

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



HYM code simulation of #204707, n=10

$|\delta B_n|^2$



- 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

New 2nd NBI already powerful tool for fast-ion mode physics

FY17 Energetic Particle Milestone

- **R17-4:** Assess high-frequency Alfvén Eigenmode stability, associated transport
  - **Goals:** (1) Extend simulations of NSTX-U CAE/GAE to high heating power, plasma current, toroidal field, (2) Further validate simulations, (3) initial assessment of Ion Cyclotron Emission (ICE) observations from NSTX-U
  - **Tools:** HYM code, DIII-D National Campaign XPs
  - **Impact:** Project fast-ion, thermal electron transport from CAE/GAE, ICE for inferring ITER $f_{fast}(v)$
    - Builds on new physics discovered during FY16 NSTX-U run campaign

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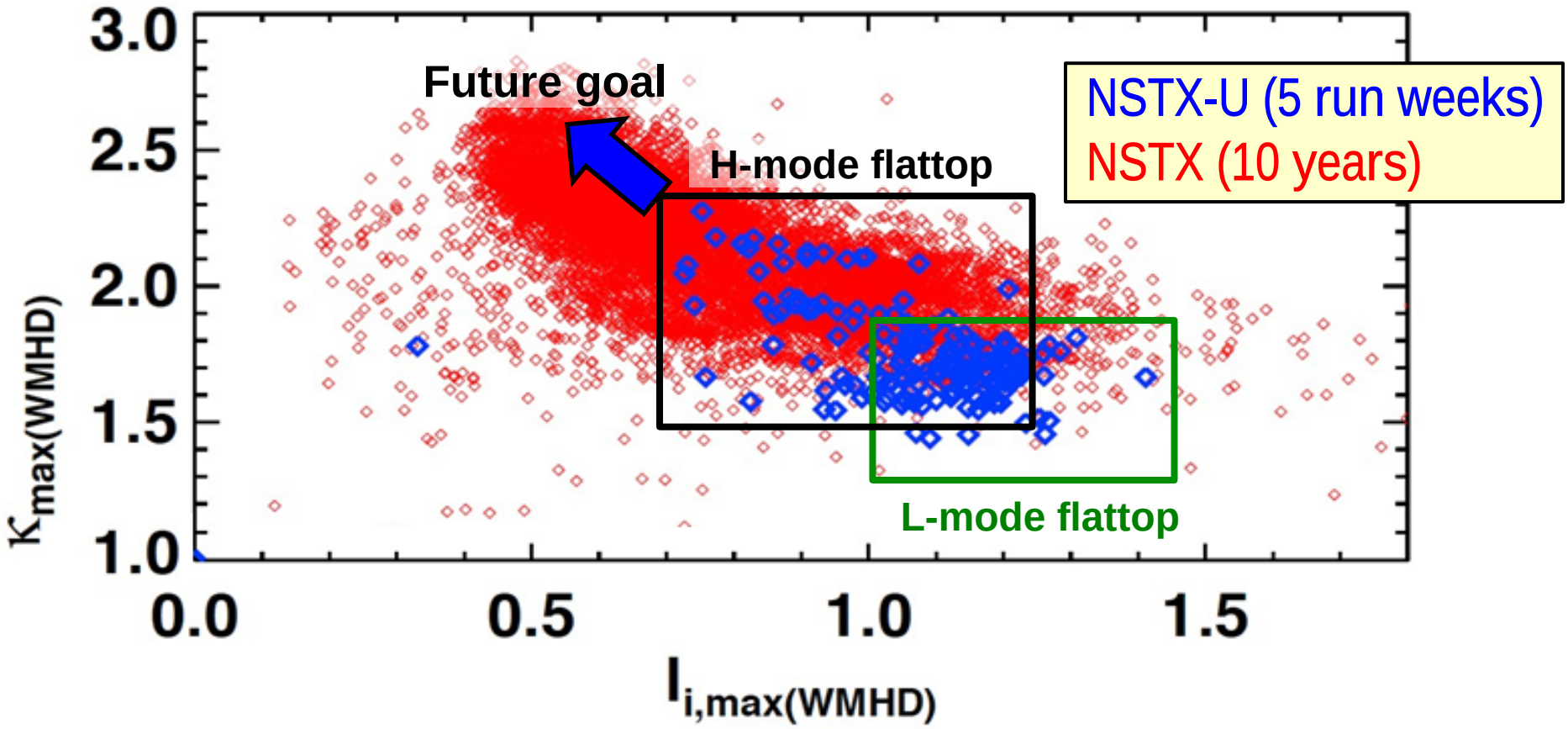
Accessed low l_i and high κ using progressively earlier H-mode and heating + optimized EFC



- **NSTX-U: Additional sensors improve estimation of Z, dZ/dt**
- **Goals for next run:**
  - **Access l_i = 0.5-0.7, κ=2.4-2.7, B_T = 0.75-1T, I_P = 1.5-2MA**

FY17 Advanced Scenarios Milestone

- **R17-5:** Analysis and modelling of current ramp-up dynamics in NSTX and NSTX-U
  - **Goal:** Understand, optimize evolution and global stability of current ramp-up phase to lower inductance, access high current scenarios to support wide-range of NSTX-U research goals
  - **Analysis:** L-H transition vs. density, shape, current, vertical growth rate (LRDFIT, TOKSYS), TRANSP, DCON/RDCON
  - **Impact:** Accelerate access to high plasma current, power scenarios when NSTX-U operation resumes
    - Responsive to FY2016 PEMP, supports entire research program

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New Working Group to specify "NSTX-U PFC performance and monitoring requirements"

- Extent of Condition review process has 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
    - Inboard vertical, CS casing, outboard tiles, limiters will also be re-analyzed
  - Possible elimination of PF1B would exacerbate heat flux
- Likely need higher core + divertor radiation (~50%?) than in GRD (12.5%) – what values can be used, controlled?
- High flux expansion is default solution, but requires low angle of incidence at strike-point (1-1.5º) – what is limit?
- Rows 2-5 of outboard divertor not qualified for high heat fluxes → need to identify safe operating values / scenarios
- What are acceptable tile surface temperature limits?
- Is real-time PFC monitoring required for 5s, 10MW?

Charges to Working Group

- Define which (additional) parameters need to be specified in an updated requirements document for the PFCs
- Facilitate generation of updated requirements utilizing:
  - Available reduced models, empirical scalings, boundary simulations
    - *Supports R(18-1): Modeling of high divertor heat flux mitigation in NSTX-U*
  - 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 closely w/ engineers/analysts to develop, implement
- Thanks to Matt Reinke (ORNL) for leading this WG
  - Please support this effort - contact Matt for additional information

Charges to Working Group

- Define which (additional) parameters need to be specified in an updated requirements document for the PFCs
- Facilitate generation of updated requirements utilizing:
  - Available reduced models, empirical scalings, boundary simulations

Request updated list of parameters to specify, and updated parameter and/or scenario *ranges* by **April 7, 2017** to support prep for tile CDR

Most interested in identifying any analysis errors in present models, or major deviations from present physics assumptions

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Enhanced collaborations during NSTX-U outage Targets NSTX-U research goals

- **EAST**: edge physics, plasma materials interactions (high-Z, Li)
  - R. Maingi + collaborators leading expts
- **JET**: EP studies, plasma ramp-down scenarios and modeling
  - M. Podesta, D. Darrow, F. Poli
- **KSTAR**: Core MHD, rotation physics, plasma control
  - Columbia Univ (Sabbagh, Berkery, Park et al.), J-K Park, J-W Ahn (ORNL)
- **MAST-U**: Control, scenario modeling supporting first plasma
  - D. Battaglia (on-site for several months), D. Boyer
- **W7-X**: wall conditioning using boron powder dropper
  - R. Lunsford
- **WEST**: ~~Start-up,~~ RF physics, high-Z PMI, real-time wall protection
  - Mueller (?), M. Reinke (ORNL), RF physicists
- **QUEST:** Coaxial Helicity Injection (CHI) + ECH/EBW heating
  - R. Raman (UW), M. Ono
- **LAPD**: RF coupling and heating physics, cavity modes
  - R. Perkins
- **HL-2A (China)**: Dedicated campaign – Y. Ren coordinating proposals
- **DIII-D**: Dedicated campaigns (see following vgs)

Priority 1 - Boundary

- 3 days allocated
- Lunsford - EC
  - Understand differences between NSTX-U and DIII-D impurity transport in response to Li aerosol injection (1 day)
- Soukhanovskii (LLNL)
  - Divertor detachment studies in NSTX-U similarity for JRT2017 (1 day)
- Bortolon/Gray (ORNL) - EC
  - Enhancement of divertor radiation in Small-Angle Slot divertor; also obtain SOL turbulence data (1 day)

Priority 1 - Core

- 4.5 days allocated
- Tang (UCLA) - EC
  - CAE frequency and wavenumber dependence on beam pitch angle and energy (1 day)
- Ren – EC
  - Study of collisionality dependence of ion- and electron-scale turbulence in advanced inductive scenario with ST-relevant q_{95} (1 day)
- Myers/Ferraro – EC
  - Impact of resonant vs non-resonant applied 3D fields on n=2 locking in OH- and L-mode plasmas (1 day)
- Guttenfelder – EC
  - Validate electromagnetic effects on transport in high-performance plasmas (1 day)
- Raman
  - Scaling of SPI penetration in high-temperature plasmas (0.5 day)

Priority 1 – Integrated Scenarios

- 0.5 days allocated
- Boyer - EC
  - Feedback control of stored energy and rotation, combined with stable ramp-down control (0.5 days + control session)

- ***Priority 1 proposal authors working with DIII-D contacts to develop detailed shot lists by early Feb.***

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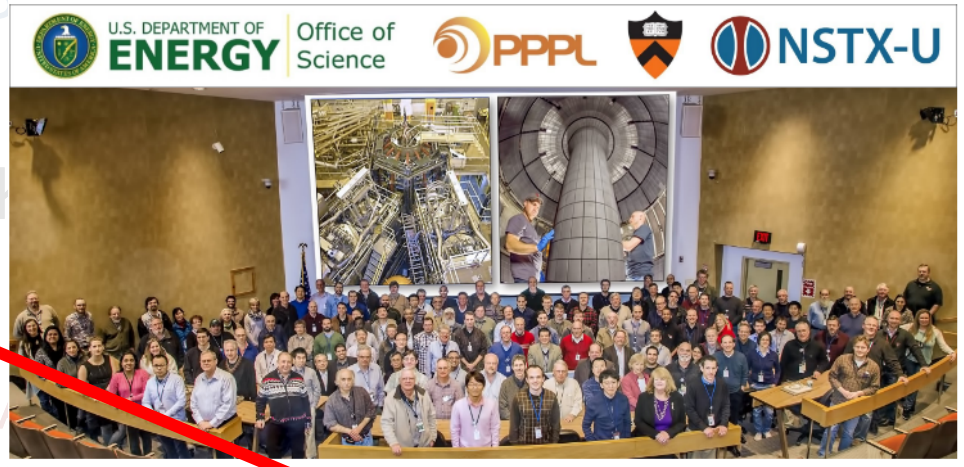
Top banner has changed at the request of FES

Please use updated PPT template



Upcoming and Recent NSTX-U Meetings:

- NSTX-U FY17 Q1 Quarterly Review - February 6, 2017
- PPPL colloquium: "Motivations for Spherical Torus research and initial results from NSTX Upgrade" - January 11, 2017
- Results Review - Sept. 21-22, 2016 Agenda Presentations Zoom
- NSTX-U FY2016 Year-End Report
- Theory and Simulation of Disruptions Workshop - July 20-22, 2016
- NSTX-U dedication - May 20, 2016

Quick Links for Additional Information:

- Monday Physics Meetings
- Presentation templates:
  - 4x3: PPT PPTX LaTeX
  - 16x9: PPT PPTX
  - Templates and Graphics Folder
  - Hi-res NSTX-U cross-section image (for illustration purposes only)
- Information for Collaborators
- NSTX-U Status and Run Schedule
- Experimental Proposals
- Annual Research Forum
- Physics Operator Training Course

Will be transitioning to new PPT template

- Goal: Have common PPPL, NSTX-U template
- Will inform team when final and available

Thank you!

Any questions?

DIII-D Campaign

- Guidance from DOE: 2 run weeks (8 days)
- Solicited and received proposals from NSTX-U Team (and others)
- Run-time oversubscribed by factor of 4
  - Boundary: 17 proposals, 17 run days requested
  - Core: 12 proposals, 12 run days requested
  - Integrated Scenarios: 8 proposals, 7.5 run days (+ control sessions) requested
- Prioritization process
  - NSTX-U recommendations based on: near-term NSTX-U goals (including JRT), well-defined ideas that require minimal development time, Early Career considerations
- Selections finalized after discussions with GA, FFCC in December
- Chose proposals: 8 days Priority 1, 4 days Priority 2

Priority 2 Experiments (4 days)

- Morton (GA)/Canal (GA)/Smith (UWisc) - EC
  - Ideal and resistive MHD as a function of aspect ratio, combined with aspect ratio scaling of tearing stability and core turbulence (1 day)
- Vail (PU)/Soukhanovskii (LLNL) – EC (Vail)
  - Snowflake divertor control development leading to density control in SFD (1.5 days + 2 control sessions)
- Jaworski – EC
  - High-Z and textured surface arcing susceptibility (0.5 day)
- Sabbagh (CU)
  - NTM entrainment (1 day)

HL-2A Collaborative Campaign
SWIP, Chengdu, China

- Offered substantial amount of run time
  - No preset run time allocation – depends on proposals
  - Run from March – June 2017

- HL-2A
  - R/a=1.65/0.4 m, I_p=0.15 – 0.3 MA, B_T=1.3 – 2 T
  - 2 – 3 MW ECRH, 1 – 2 MW NBI, 1 MW LH, Pellet, SMBI
  - Over 30 diagnostics

- See:http://nstx.pppl.gov/DragNDrop/NSTX_Meetings/Monday_Physics_Meetings/2016/2016_12_12/HL-2A_opportunities_diagnostics.pdf