U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U

NSTX-U Program - FY2015 Q3 Report*

Jon Menard, Masa Ono

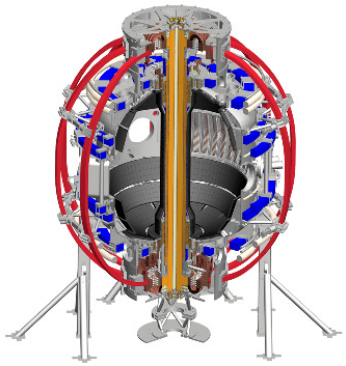
For the NSTX-U Team

PPPL and FES

July 23, 2015

*This work supported by the US DOE Contract No. DE-AC02-09CH11466

PPPL



Outline

- Research highlights for Q3
  - Emphasis on fast ion physics this time…
- Preparation for FY2016 run campaign

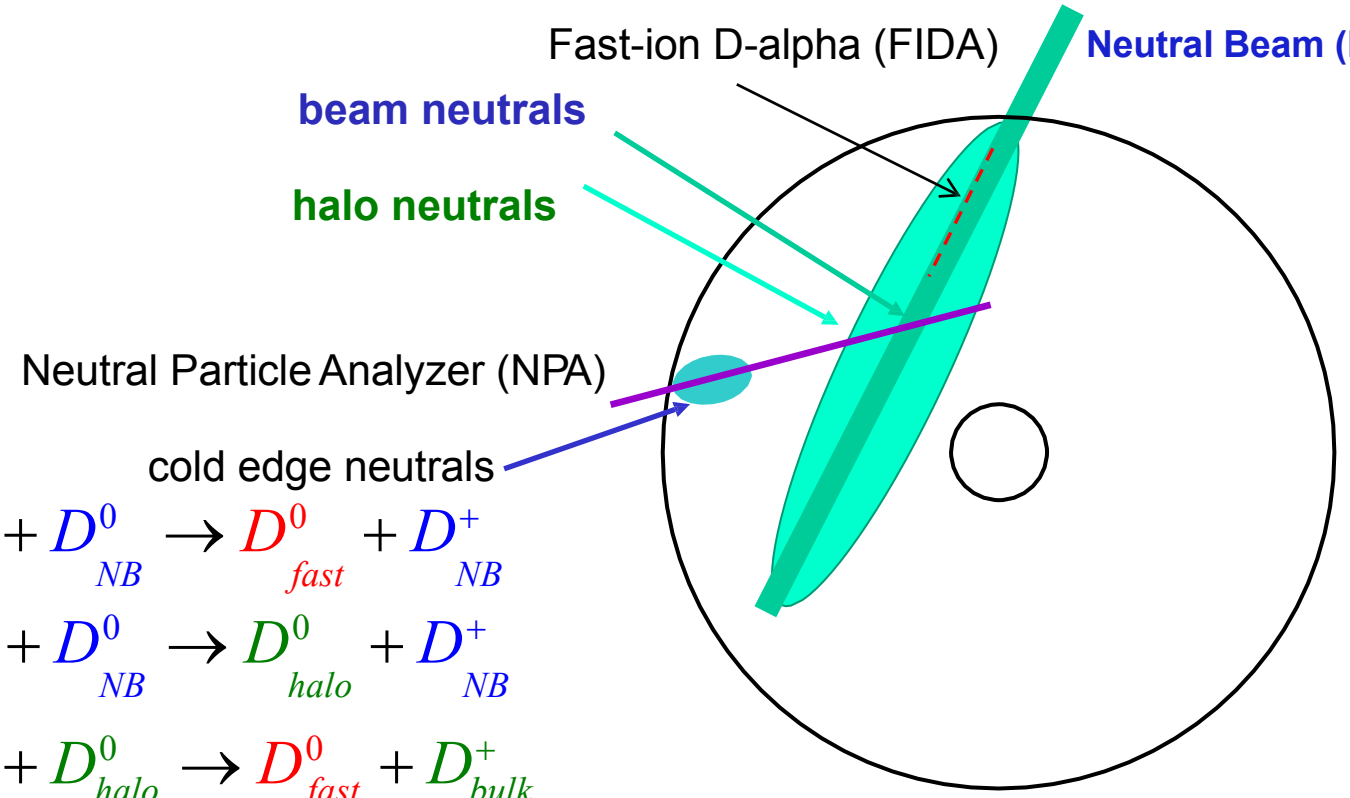
Accurate Modeling of Halo Neutrals is Important for Proper Interpretation of Fast Ion Diagnostic Signals

- Neutral Particle Analysis (NPA) and Fast-ion D_α (FIDA) are key diagnostics for interpreting the fast-ion distribution, transport
  - Both measure aspects of the energetic neutral density population
- Halo neutral density is comparable with beam neutral density
  - Increase NPA and FIDA signal, critical for synthetic diagnostics
  - Affect fast ion CX loss, thus impact basic TRANSP calculations, e.g. NB driven current, neutron yield, power balance
- Halo neutrals have a broader profile than beam neutrals
  - Could affect spatial localization of NPA and FIDA diagnostics
  - Could affect relative contribution to diagnostics from beam, halo neutrals
- A new 3D Halo model was recently developed in TRANSP / NUBEAM to replace the incorrect "volume averaged" halo neutral model.

D. Liu[1], S. S. Medley[2], M. V. Gorelenkova[2], W. W. Heidbrink[1], L. Stagner[1]
[1] *University of California, Irvine,* [2] *Princeton Plasma Physics Laboratory*

Halo Neutrals are Created in the Vicinity of Neutral Beam Footprint through Charge-Exchange Reactions

Both NPA and FIDA diagnostics rely on charge-exchange (CX) reactions between fast ions and beam/halo neutrals. $Signal \propto n_{fi}\, n_{neutral} < \sigma v >$



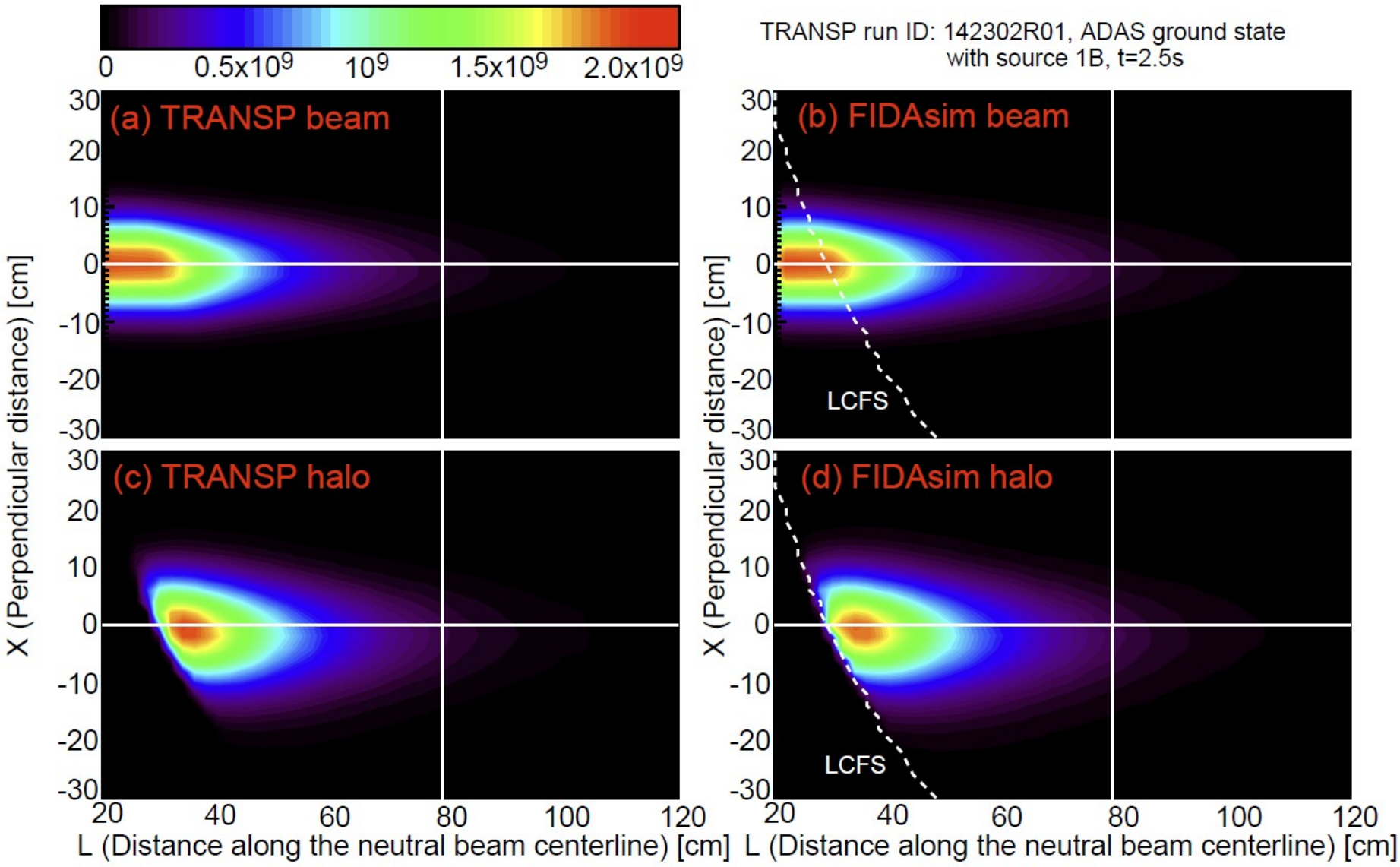
$$D^+_{fast} + D^0_{NB} \rightarrow D^0_{fast} + D^+_{NB}$$

$$D^+_{bulk} + D^0_{NB} \rightarrow D^0_{halo} + D^+_{NB}$$

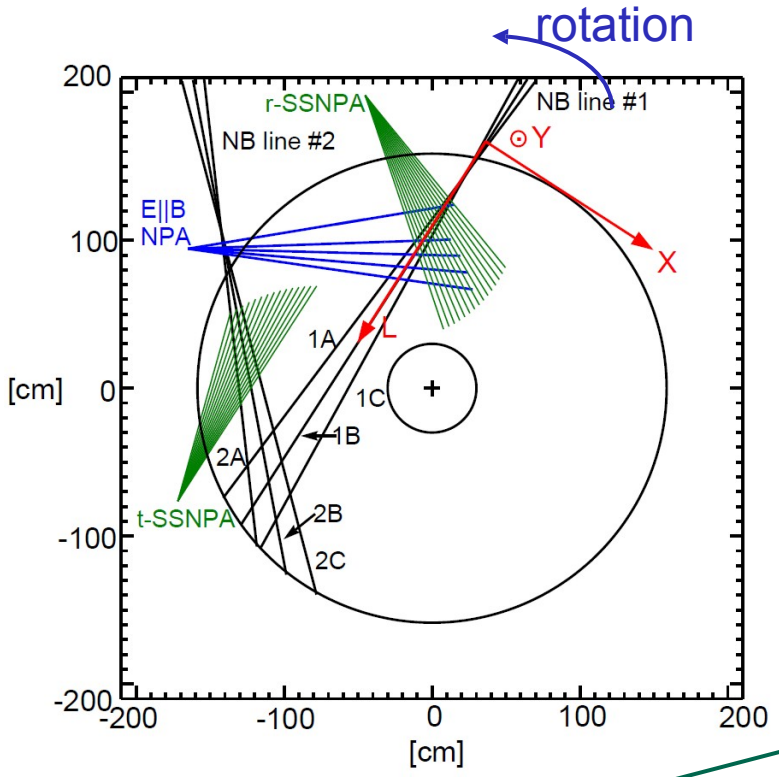
$$D^+_{fast} + D^0_{halo} \rightarrow D^0_{fast} + D^+_{bulk}$$

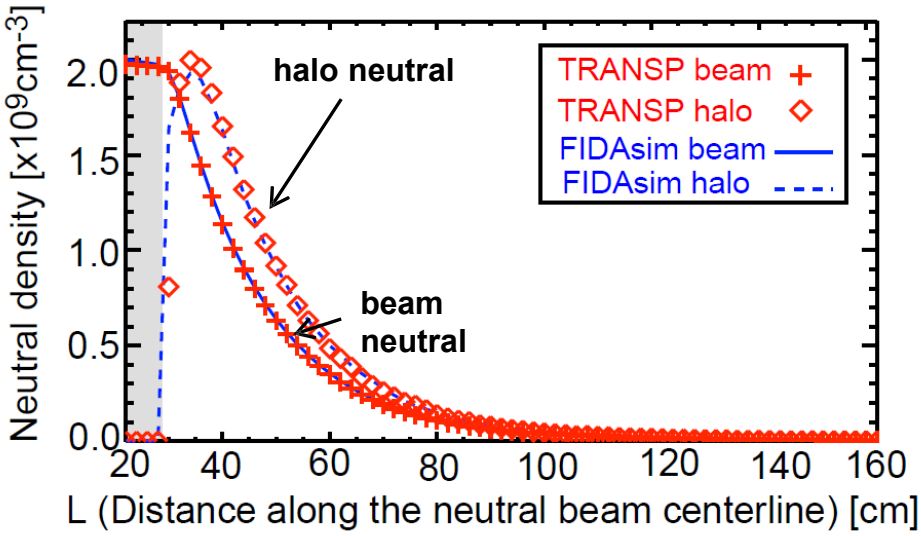
$$D^+_{bulk} + D^0_{halo} \rightarrow D^0_{halo\_high\_generation} + D^+$$

Excellent Agreement between TRANSP and FIDAsim when Using the Same ADAS Ground State Cross Section Tables (1)

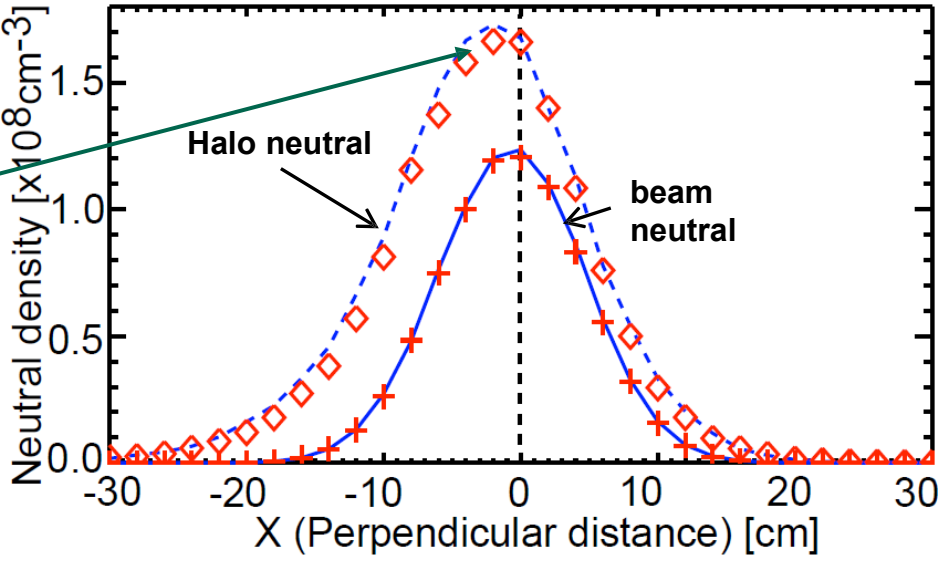


Excellent Agreement between TRANSP and FIDAsim when Using the Same ADAS Ground State Cross Section Tables (2)





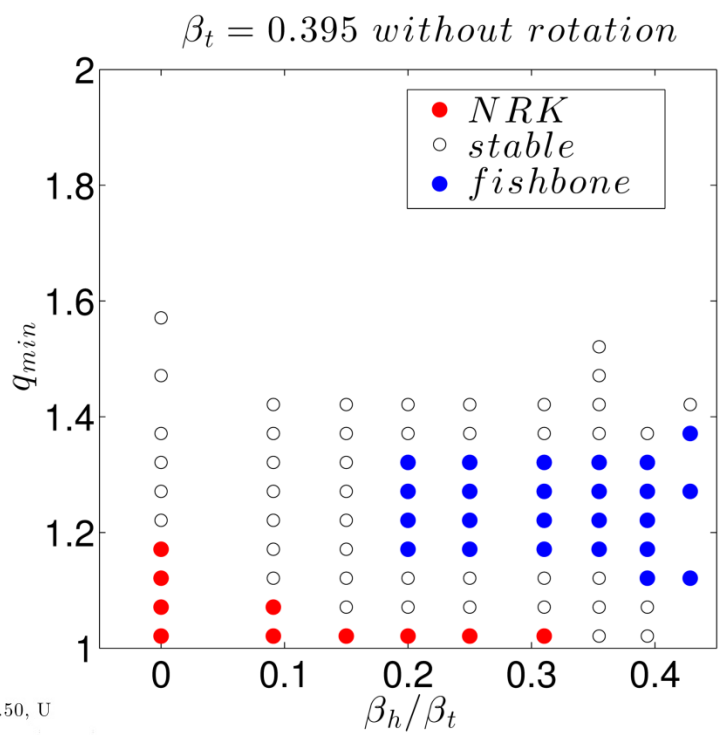
The peak of halo neutrals shifts in the same direction as toroidal rotation, as expected

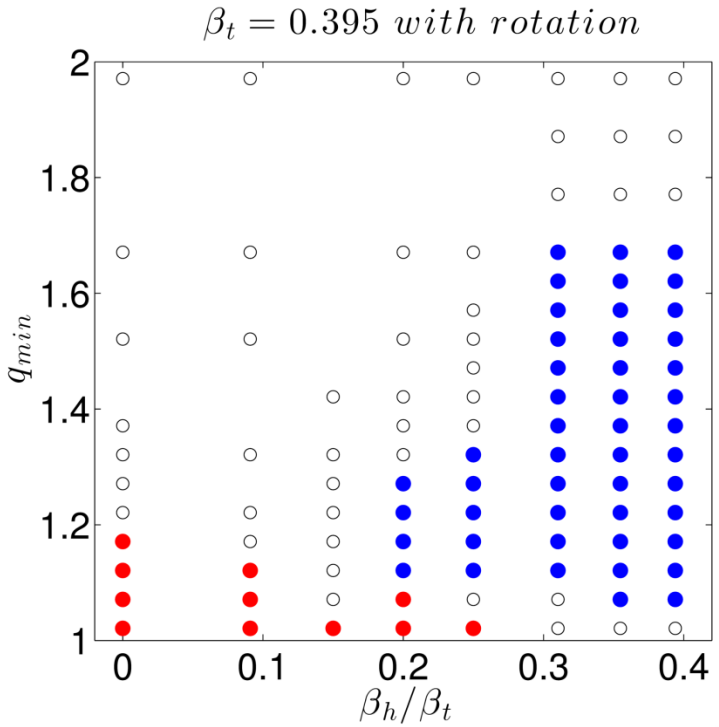


Key result: UCI + PPPL have verified halo models in TRANSP and FIDAsim

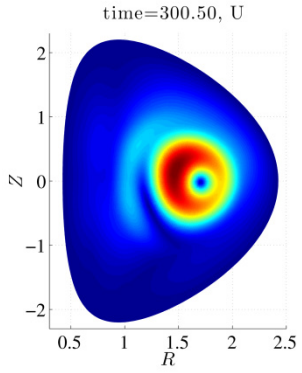
- When using same cross section databases, TRANSP & FIDAsim predictions of beam & halo neutral densities get excellent agreement in both magnitude & spatial profile.
- Halo neutral density is comparable with beam neutral density and halo neutrals spread broader than beam neutrals due to multi-generations and halo diffusion.
- Halo neutrals significantly increase the NPA flux and FIDA emission, but they have minor effects on NPA energy spectrum or FIDA spectrum/spatial profile.
- The calculation of halo neutral density (and also fast ion density, NBCD, neutron rate) is relatively sensitive to the choice of atomic cross section databases.

Linear stability analysis of fishbones with M3D-K finds rotation / rotation shear destabilizing at elevated q

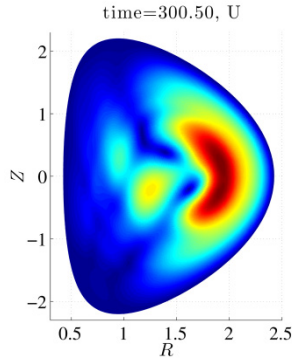




Guoyong Fu, Feng Wang
NSTX-U / theory partnership



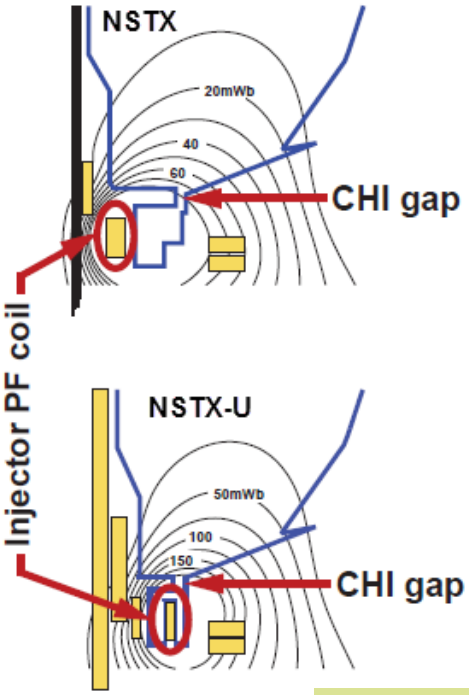
- Eigenfunction broadens with rotation
  - Enhanced fast-ion transport or triggering / seeding of tearing modes?
  - Next step: investigate with non-linear runs.



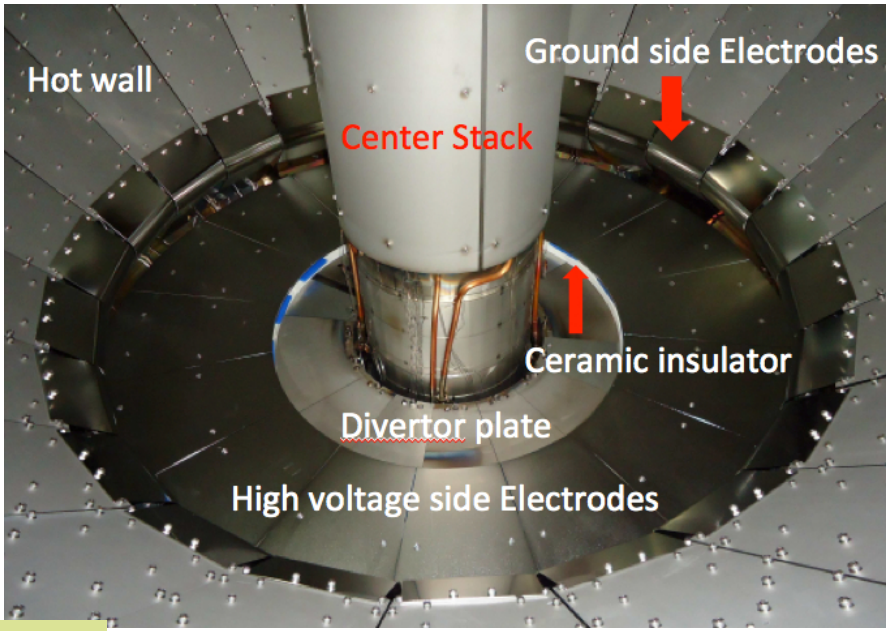
Collaborating with QUEST to explore CHI + ECH solenoid-free start-up in support of ST-FNSF

CHI Start-Up

- **Inj. Flux in NSTX-U is about 2.5 times higher than in NSTX**
- **NSTX-U coil insulation greatly enhanced for higher voltage ~ 3 kV operation**



CHI Implementation on QUEST showing installed electrodes



U. Washington

- Refurbishment of CHI Cap Bank completed.
- Fabrication of the CHI gas injection system and operation procedure for the QUEST ST experiment in Japan completed.
- Fabrication of the CHI capacitor bank for QUEST is nearing completion.

Ramping up efforts to study high-Z impurity sources, transport, mitigation techniques

NEWS

PPPL physicist wins Early Career Research Program grant to develop tools to eliminate impurities in fusion plasmas

By Jeanne Jackson DeVoe
May 11, 2015

Tweet 3 | g+1 4 | Share 44 | print

(Photo by Photo by Claudia Cisneros)

Luis Delgado-Aparicio

- Matt Reinke recently hired by ORNL to work at NSTX-U
  - Leading revival / upgrade of NSTX-U bolometry systems
  - Leadership for ORNL NSTX-U experimental boundary physics

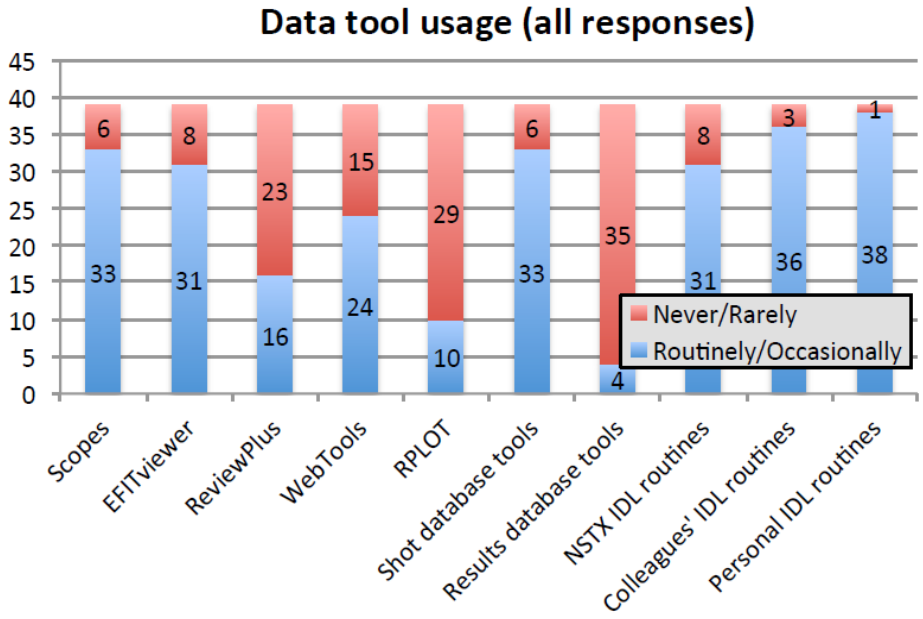
NSTX-U collaborators helped lead Data Resources Survey to improve computational environment

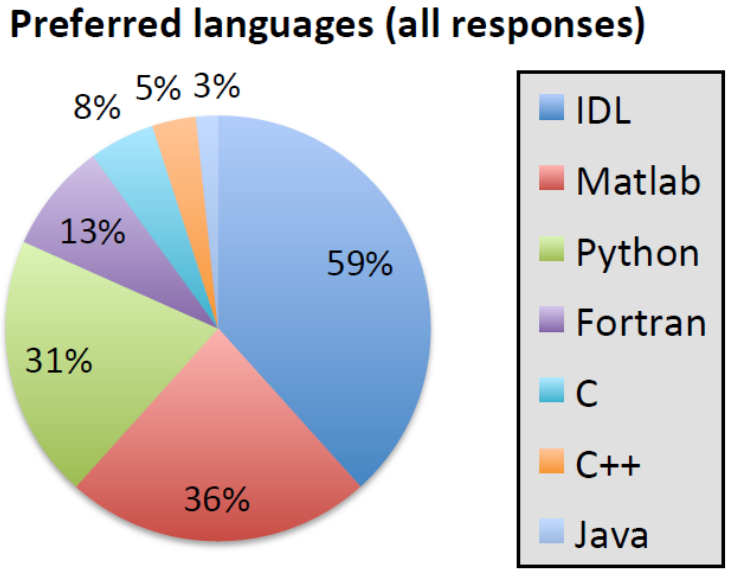
D. Smith (UW), H. Yuh (Nova Photonics), K. Tritz (JHU)

- Goals
  - Increase scientific productivity of NSTX/NSTX-U data
  - Reduce barriers to entry for new team members
  - Reduce burden for data publication requirements

- Objectives
  - Identify inefficiencies in data ecosystem
  - Develop strategies for improvement
    - Software framework for data access and management

A few sample survey results





- Most popular: scopes, EFITviewer, IDL, shot db
- Next: WebTools and ReviewPlus
- Least: RPLOT, results db tools
- Earlier career responses
  - more ReviewPlus, less WebTools

- Overall usage
  - 59% IDL, 36% Matlab, 31% Python
- Earlier career responses
  - Higher usage of Matlab & Python (47%/ 47%)

Key findings / action items

- Language usage: 60% IDL, 35% Matlab, 30% Python
  - Among earlier career responses: 60% / 50% / 50%
- There is overall agreement that the computing staff provides sufficient software support
- Broad agreement that significant and inefficient **code duplication** exists within the NSTX team
- Contend that better software framework could improve efficiency, extensibility, scalability, collaboration
- Likely actions:
  - Improve/better document code repository for key IDL routines
    - Need to identify and focus on most important and widely-used routines: flux mapping, profile fitting, boundary identification… (TBD)
  - Pilot / test python as improved software framework

NSTX-U university collaborators spearheaded new outreach seminar effort – to begin this fall

J. Berkery (CU)
D. Smith (UW)

National Spherical Torus Experiment Upgrade

Search this site

Home | Meetings | Drag & Drop | Calendars | Phone Book | Sitemap

NSTX-U Web Pages:

- Home
- Overview
- Mission
- Accomplishments
- Collaboration Info
- Data Management Plan
- Diagnostics
- Five Year Plans
- Group Links / Files / Email
- Joint Research Targets
- Milestones
- Operations
- Organization
- **Outreach Seminars**
- Program
- Project
- Publications & Presentations
- Remote Connection Info
- Reports
- Research Forum - 2015
- Run Coordination
- Run Schedule Calendar
- Science Groups
- Scientific Conferences
- Software
- Surface Science
- Task Forces
- User Information Form
- Working Groups
- NSTX Upgrade Overview
- NSTX Upgrade Project

Program >

Outreach Seminars

The following NSTX-U team members are available to give seminars at your institution on the topics / titles listed below, and may also be willing to speak on other related topics as well. If you are interested, please contact the speaker directly and CC Stan Kaye (kaye@pppl.gov), or click on an e-mail link below.

Name	e-mail	Research interest / specialty	Prospective Talk Title
Jack Berkery	jberkery@pppl.gov	Fusion plasma stability	"Resistive wall mode stability in NSTX"
Walter Guttenfelder	wgutten@pppl.gov	Turbulence in magnetized fusion plasmas	"Understanding turbulence at 100 million degrees"
Ahmed Diallo	adiallo@pppl.gov	H-mode pedestal, diagnostics	"Taming the plasma edge for optimum fusion performance"
Devon Battaglia	dbattagl@pppl.gov	Tokamak startup, H-mode physics, high-performance computing	"Physics operations and scenario development on NSTX-U"
Jon Menard	jmenard@pppl.gov	Research program, next-step devices, MHD physics	"NSTX-U program overview" ***or*** "Prospects for next-step STs"
David Smith	drsmith@pppl.gov	Plasma turbulence and instabilities, turbulence diagnostics	"Characterizing edge instabilities with machine learning techniques"
Clayton Myers	cmyers@pppl.gov	Tokamak disruptions and error fields, laboratory astrophysics	"Two Challenges for Steady State Tokamak Operation: Error Fields and Disruptions" ***or*** "Bringing the Cosmos Down to Earth: Studying Astrophysical Processes in Laboratory Experiments"
Rory Perkins	rperkins@pppl.gov	Radio frequency heating	"Fast wave power flow along scrape-off-layer field lines in NSTX"
Steven Sabbagh	sabbagh@pppl.gov	Tokamak plasma stability and control for disruption prediction and avoidance	"Global Mode Stabilization for Disruption Avoidance in Tokamaks"

FES solicitation for U.S. University and Industry DIAGNOSTIC Collaboration on NSTX-U now available

- FES solicitation cycle divided into 3 groups:
  - **University & Industry → Diagnostics → National Laboratories**
- Issue Date for FOA: 07/01/2015
- Pre-Application Due Date: 07/29/2015 at 5 PM Eastern Time
  - Pre-Application is required, 2-3 pages (Title, abstract, collaborators, …)
- Application Due Date: 09/18/2015 at 11:59 PM Eastern Time

- NSTX-U gathered 30+ diagnostic ideas from team
  - Shared with SG/TSG leaders for final comment/consideration/inclusion
- PAC-36 reviewed draft Program Letter June 23
- **PAC report very helpful for improving letter**
- PAC would like to be more frequently informed of project status
  - PAC now has option to be included in weekly highlights e-mail distribution

Outline

- Research highlights for Q3

- Preparation for FY2016 run campaign

Chosen first 30 experiments to review: Order based on Priority 1 + expected period to be run during campaign

At least 30 XPs will be fully reviewed prior to start of research campaign

- **17 XPs already reviewed**

XP number	XP title	Responsible Group	XP author first name	XP author last name	XP author e-mail	Priority	Run Weeks 1-4	Run Weeks 5-8	Run Weeks 9-12	Run Weeks 13-16
1501	Optimization of vertical control algorithm	ASC-TSG	Dan	Boyer	mboyer@pppl.gov	P1a	1			
1502	Tuning of the Automated Rampdown Software	ASC-TSG	Stefan	Gerhardt	sgerhard@pppl.gov	P1c	1			
1503	X-point control integration with shape control	ASC-TSG	Egemen	Kolemen	ekolemen@princeton.edu	P1a	1			
1504	Beam power and beta-N control	ASC-TSG	Dan	Boyer	mboyer@pppl.gov	P1b	0.5	0.5		
1505	Optimizing Boronization XMP	MP-TSG	Charles	Skinner	cskinner@pppl.gov	P1a	0.5	0.5		
1506	Low-beta, low-density locked mode studies	MS-TSG	Clayton	Myers	cmyers@pppl.gov	P1a	0.25	0.75		
1507	Maximizing the non-inductive current fraction in NSTX-U H-modes	ASC-TSG	Stefan	Gerhardt	sgerhard@pppl.gov	P1a		0.5	0.25	0.25
1508	Controlled Snowflake Studies	ASC-TSG	Egemen	Kolemen	ekolemen@pppl.gov	P1b		0.25	0.5	0.25
1509	Combined betaN and li feedback control	ASC-TSG	Dan	Boyer	mboyer@pppl.gov	P1b		0.25	0.25	0.5
1510	Characterizing the SOL Losses of HHFW Power in H-Mode Plasmas	RF-TSG	Rory	Perkins	rperkins@pppl.gov	P1a		0.5	0.25	0.25
1511	Multi-machine studies of the L-H power threshold dependence on aspect ratio	PS-TSG	Michael	Bongard	mbongard@wisc.edu	P1b		1		
1512	Characterization of the Pedestal Structure as function Ip, BT, and Pnbi	PS-TSG	Ahmed	Diallo	adiallo@pppl.gov	P1a		0.5	0.5	
1513	Effects of B-> Li transition on the pedestal structure	PS-TSG	Rajesh	Maingi	rmaingi@pppl.gov	P1a		0.5	0.5	
1514	Heat flux and SOL width Scaling in NSTX-U	DS-TSG	Travis	Gray	tkgray@pppl.gov	P1a		0.25	0.5	0.25
1515	High-beta n=1,2,3 feed-forward error field correction	MS-TSG	Clayton	Myers	cmyers@pppl.gov	P1a		0.5	0.5	
1516	Optimization of PID dynamic error field correction	MS-TSG	Clayton	Myers	cmyers@pppl.gov	P1a		0.5	0.5	
1517	Neoclassical toroidal viscosity at reduced collisionality (independent coil control)	MS-TSG	S.A.	Sabbagh	sabbagh@pppl.gov	P1a		0.25	0.5	0.25
1518	RWM PID control optimization based on theory and experiment	MS-TSG	S.A.	Sabbagh	sabbagh@pppl.gov	P1a		0.25	0.5	0.25
1519	Massive Gas Injection Studies on NSTX-U	MS-TSG	Roger	Raman	raman@aa.washington.edu	P1a			0.5	0.5
1520	Ip/Bt scaling	TT-TSG	Stan	Kaye	kaye@pppl.gov	P1a		0.5	0.25	0.25
1521	Validation of gyrokinetic codes in NSTX-U NBI-heated L-mode plasmas	TT-TSG	Yang	Ren	yren@pppl.gov	P1a		0.5	0.25	0.25
1522	Beam ion confinement of 2nd NBI	EP-TSG	Deyong	Liu	deyongl@uci.edu	P1a		0.75	0.25	
1523	Characterization of 2nd NBI line	EP-TSG	Mario	Podesta	mpodesta@pppl.gov	P1a		0.25	0.5	0.25
1524	AE Critical Gradient	EP-TSG	Bill	Heidbrink	wwheidbr@uci.edu	P1a		0	0.25	0.75
1525	Rotation effects on CAEs and GAEs	EP-TSG	Neal	Crocker	ncrocker@physics.ucla.edu	P1a				1
1526	Establish heat transmission pathways in high-Z reference shape	MP-TSG	Michael	Jaworski	mjaworsk@pppl.gov	P1a		0.25	0.25	0.5
1527	ELM pacing via multi-species granule injection and 3D field application for main ion c	PC-TF	Robert	Lunsford	rlunsfor@pppl.gov	P1a		0.75	0.25	
1528	Characterize plasma near planned plenum entrance position	PC-TF	John	Canik	canikjm@ornl.gov	P1a		0.75	0.25	
1529	Controlled introduction of Lithium into NSTX-U	PC-TF	Rajesh	Maingi	rmaingi@pppl.gov	P1a		0.5	0.5	
1530	Triggering ELMs with LGI and 3-D fields in lithiated discharges	PC-TF	Robert	Lunsford	rlunsfor@pppl.gov	P1a			0.75	0.25

Latest run plan for 2016

Goal is to operate 14-16 run weeks as per research forum

➔ **Want as much data as possible for IAEA synopses (due Jan/Feb)**

- October: 3-4 run weeks
- November: 0-2 run weeks
  - May want to pause for ST workshop, APS, Thanksgiving
- December: 3 run weeks
- January: 2 run weeks
  - Mid-run assessment (if applicable), PAC-37
- Feb-Mar: 3-8 run weeks, complete FY16 run
- Mar/Apr: Start outage: install high-k, high-Z tiles, …
- Resume operations fall 2016 for FY17

Overview of FY2015-17 NSTX-U research milestones

- **FY2016**
  - Obtain first data at 60% higher field/current, 2-3× longer pulse:
    - Re-establish sustained low l_i / high-κ operation above no-wall limit
    - Study thermal confinement, pedestal structure, SOL widths
    - Assess current-drive, fast-ion instabilities from new 2nd NBI
- **FY2017**
  - Extend NSTX-U performance to full field, current (1T, 2MA)
    - Assess divertor heat flux mitigation, confinement at full parameters
  - Access full non-inductive, test small current over-drive
  - First data with 2D high-k scattering, prototype high-Z tiles
- **FY2018**
  - Study low-Z and high-Z impurity transport
  - Assess causes of core electron thermal transport
  - Test advanced q profile and rotation profile control
  - Assess CHI plasma current start-up performance

See backup for detailed Research Milestone timeline

NSTX-U Milestone Schedule for FY2016-18

	FY2016	FY2017	FY2018
Run Weeks:	Incremental: **14** / 16	**16** / 18	**12** / 16
Boundary Science + Particle Control	R16-1: Assess H-mode confinement, pedestal, SOL characteristics at higher B_T, I_P, P_{NBI}	R17-1: Assess scaling, mitigation of steady-state, transient heat-fluxes w/ advanced divertor operation at high power density R17-2: Assess high-Z divertor PFC performance and impact on operating scenarios	R18-1: Assess impurity sources and edge and core impurity transport IR18-1: Investigation of power and momentum balance for high density and impurity fraction divertor operation
Core Science	R16-2: Assess effects of NBI injection on fast-ion f(v) and NBI-CD profile	R17-3: Assess τ_E and local transport and turbulence at low ν^* with full confinement and diagnostic capabilities	IR18-2: Assess role of fast-ion driven instabilities versus micro-turbulence in plasma thermal energy transport Begin ~1 year outage for major facility enhancement(s) sometime during FY2018
Integrated Scenarios	R16-3: Develop physics + operational tools for high-performance: κ, δ, β, EF/RWM	IR17-1: Assess fast-wave SOL losses, core thermal and fast ion interactions at increased field and current R17-4: Develop high-non-inductive fraction NBI H-modes for sustainment and ramp-up	R18-2: Control of current and rotation profiles to improve global stability limits and extend high performance operation R18-3: Assess transient CHI current start-up potential in NSTX-U
FES 3 Facility Joint Research Target (JRT)	C-Mod leads JRT: Assess disruption mitigation, initial tests of real-time warning, prediction	DIII-D leads JRT: TBD… possibly something on energetic particles	NSTX-U leads JRT: TBD

Summary

- Continued scientific productivity during long outage
  - But very excited to get some new data!
- Research milestones shifted by ~1 fiscal year due to OH arc fault
- Taking advantage of the extra time, XP reviews on track to have ≥ 1/2 of run-time fully defined before run