NSTX-U

Supported by U.S. DEPARTMENT OF ENERGY Office of Science

University of Washington Activities in CHI and DM Research on NSTX-U & CHI on QUEST

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U Washington
U Wisconsin

R. Raman

University of Washington / NSTX-U

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N. Hamada (QUEST student to be attached to NSTX-U)

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NSTX-U Q2 Review

24 April 2015

Culham Sci Ctr
U St. Andrews
York U
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ASCR, Czech Rep
U Quebec

U-Wash. Research is Responsible for Three Large Systems

- Transient Coaxial Helicity Injection (CHI) on NSTX-U
  - FY15 goal: Establish Transient CHI start-up on NSTX-U
- Disruption Mitigation (DM) Studies on NSTX-U
  - FY15 goal: Establish MGI capability on NSTX-U
- CHI Research on QUEST (Kyushu University, Japan)
  - FT15 goal: Test CHI hardware on QUEST

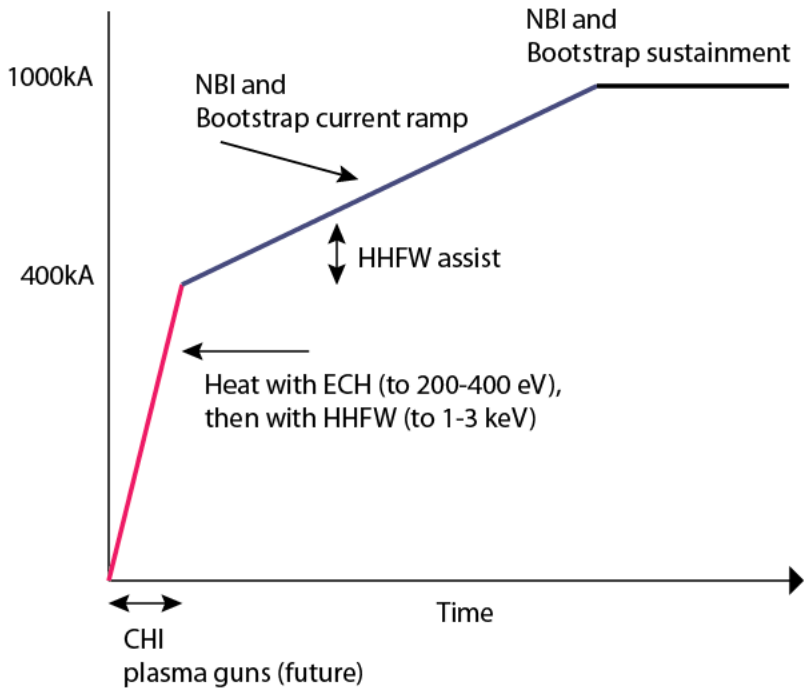
- Planned Near-Term Goal (FY16 and beyond)
  - Build and Test EPI (Electromagnetic Particle Injector) system at U-Wash., for eventual use on NSTX-U

- Desired Longer-Term Goal (FY18 and beyond) – See back-up slides
  - Restore and make operational CT injection system for eventual tests on NSTX-U

NSTX-U Aims to Develop and understand non-inductive start-up/ramp-up to project to ST-FNSF operation

- Establish physics basis for ST-FNSF, and non-inductive start-up is essential in ST
  - Simplify the tokamak concept to reduce cost
- NSTX-U is striving for fully non-inductive operations
  - Transient Coaxial Helicity Injection (CHI) start-up is the front end of that objective
  - Plasma guns and EWB will be tested after those systems are technically ready

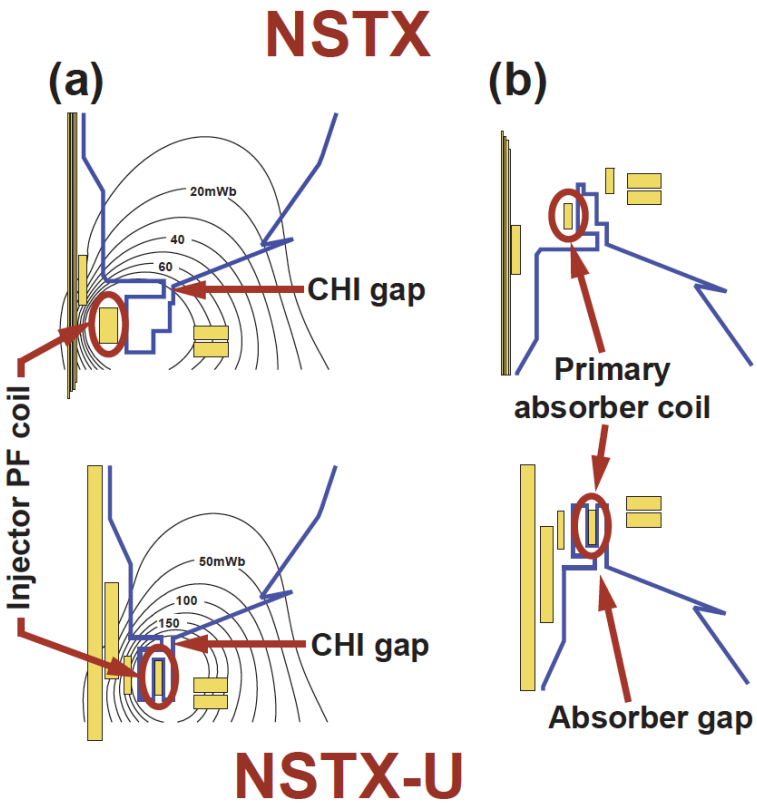
NSTX-U Start-up and Ramp-up strategy

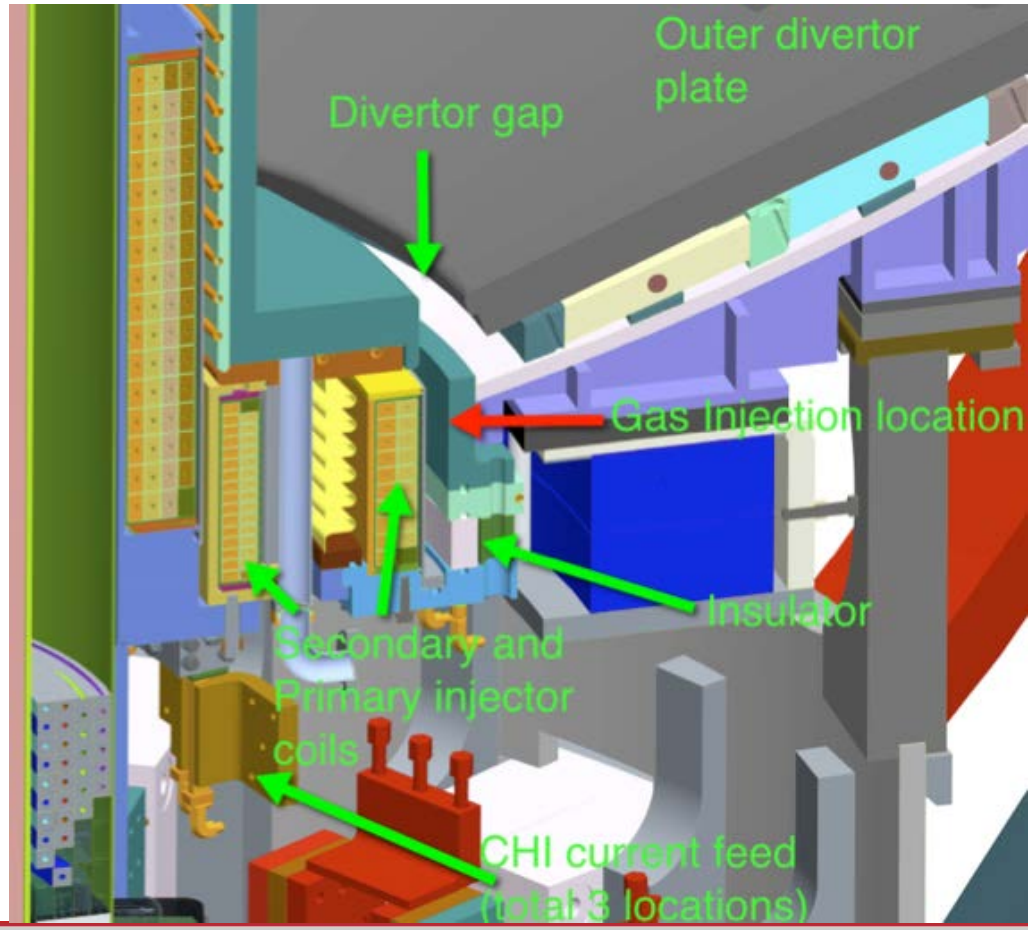


NSTX-U Upgrades that Facilitate CHI Start-up

NSTX-U Machine Enhancements for FY15 CHI

- > 2.5 x Injector Flux in NSTX (proportional to I_p)
- About 2 x higher toroidal field (reduces injector current requirements)

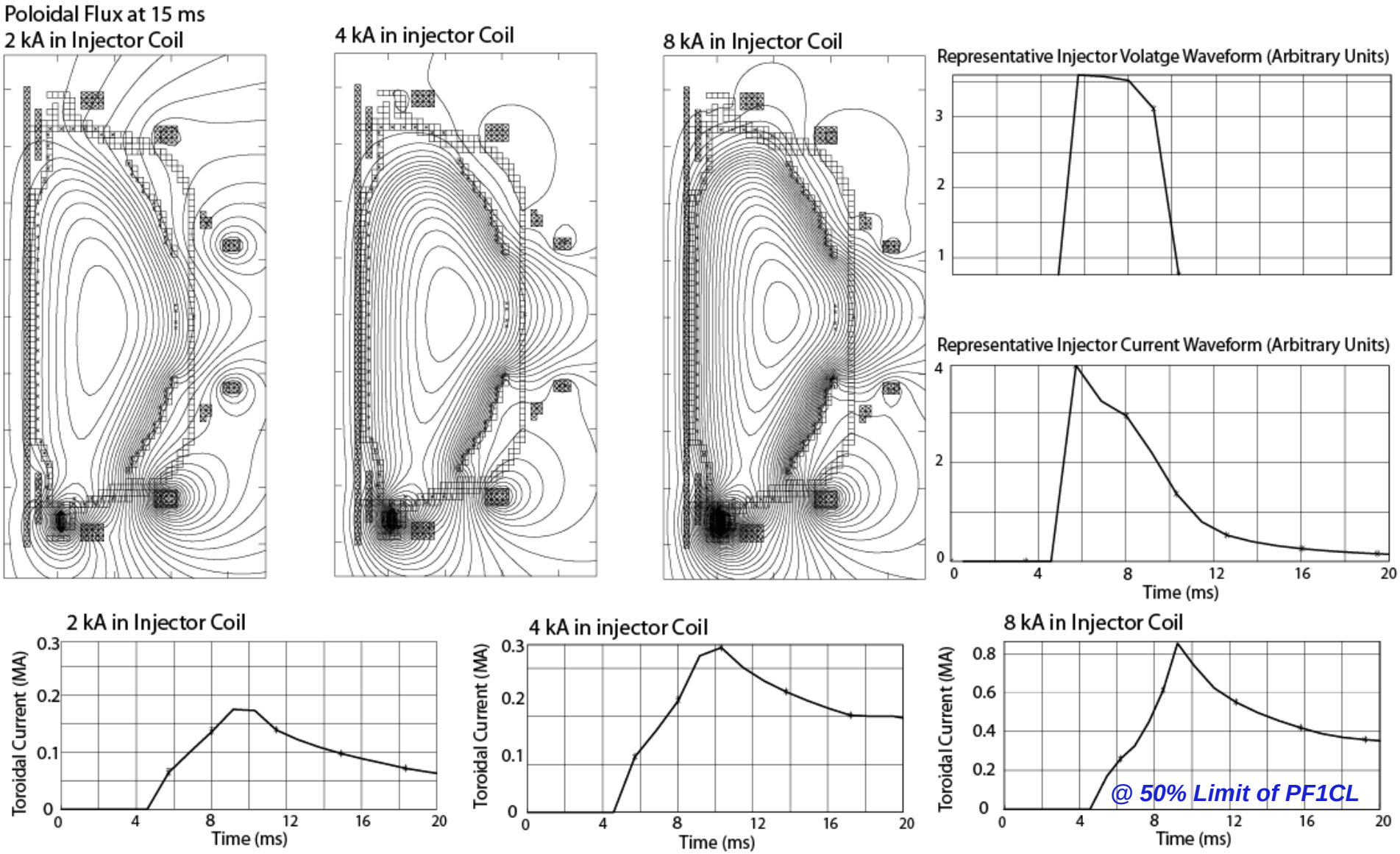




Significant changes to CHI Configuration on NSTX-U Requires Re-Establishing CHI Discharges as a First Step

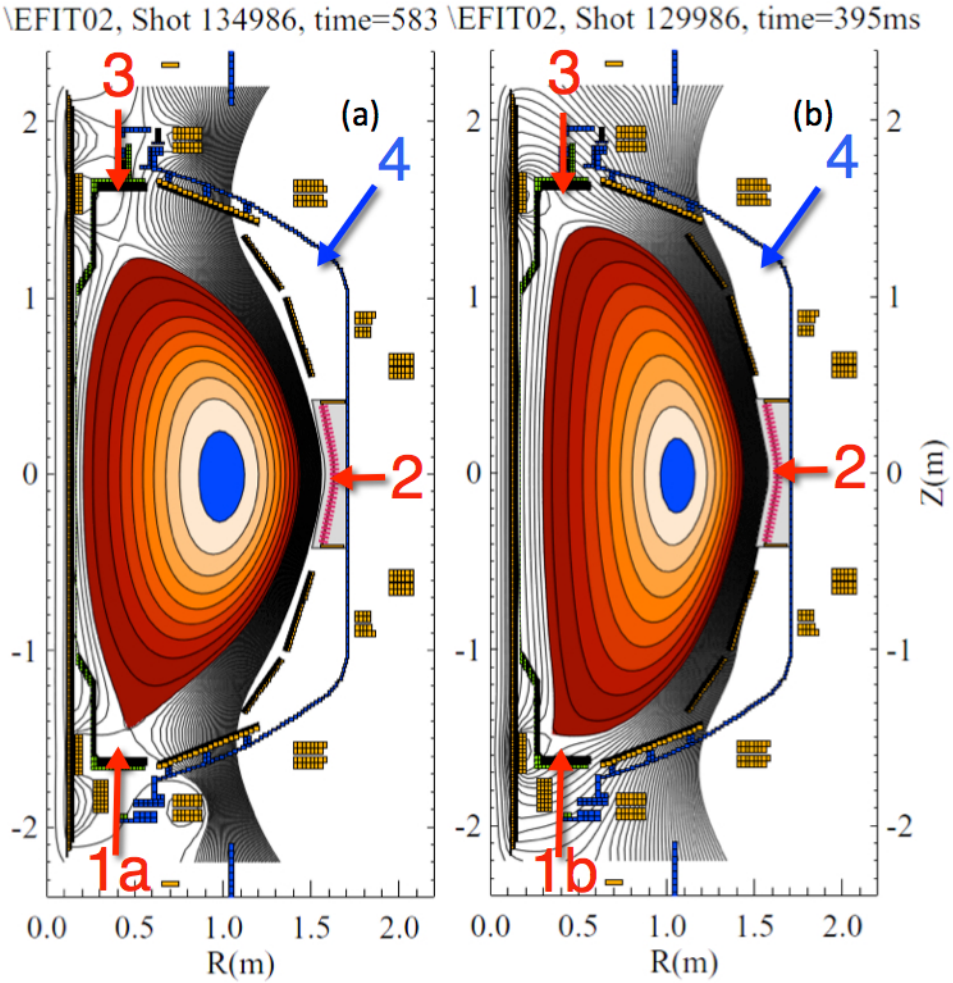
- Inner and outer electrode gap reduced on NSTX-U
  - More prone to undesirable arcing
  - Need to establish correct levels of gas injection, voltage & flux shape programming, and levels of required current in PF1CU
- Initial plan is to start with large injector flux and demonstrate reliable discharge initiation in injector region
  - This will be the CHI XMP
  - In support of this, the CHI Cap Bank has been dummy load tested at 25% voltage, which verifies that key components in Cap bank are operational
  - Full voltage test to be conducted after CD4
- XMP will be followed by main CHI XP
  - Goal is to re-establish high-current discharges demonstrated on NSTX

TSC Simulations for NSTX-U support our understanding that NSTX-U is capable of 400 kA start-up currents



Raman, et al., IEEE Transactions on Plasma Science, Vol 42, No. 8 2154 (2014)

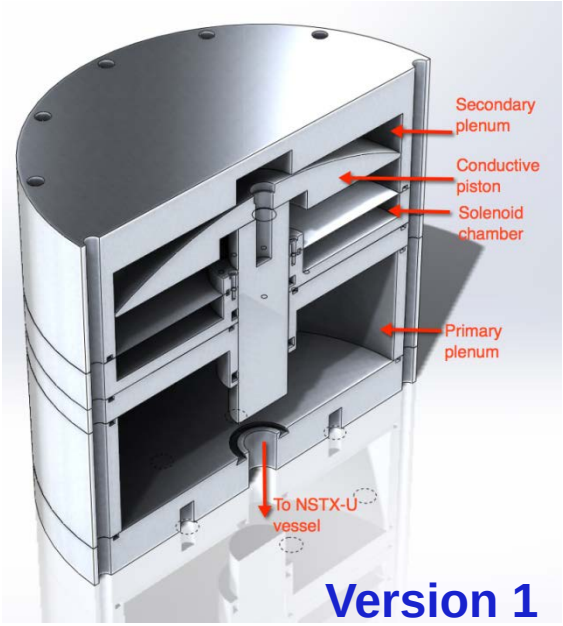
NSTX-U MGI will study poloidal injection location variation using identical MGI valves and gas transit piping

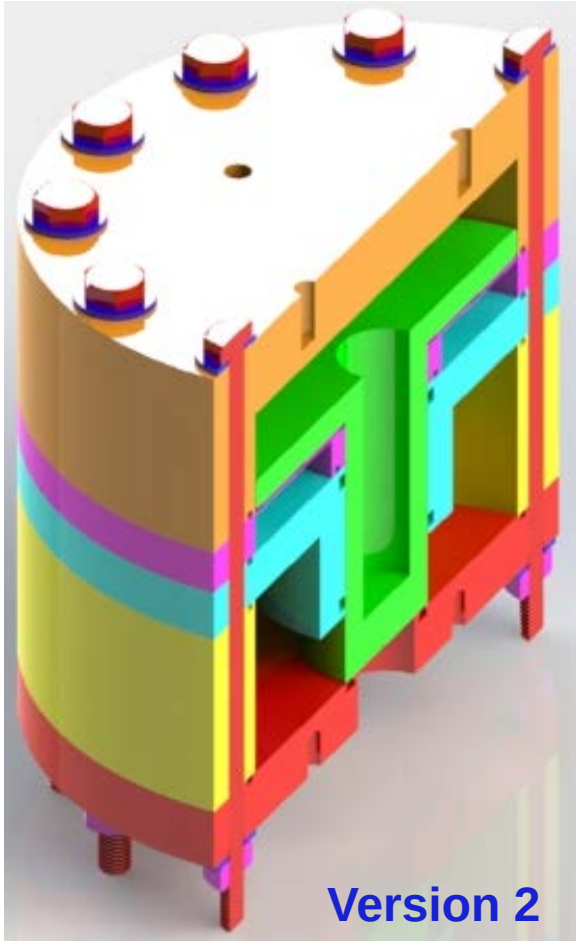


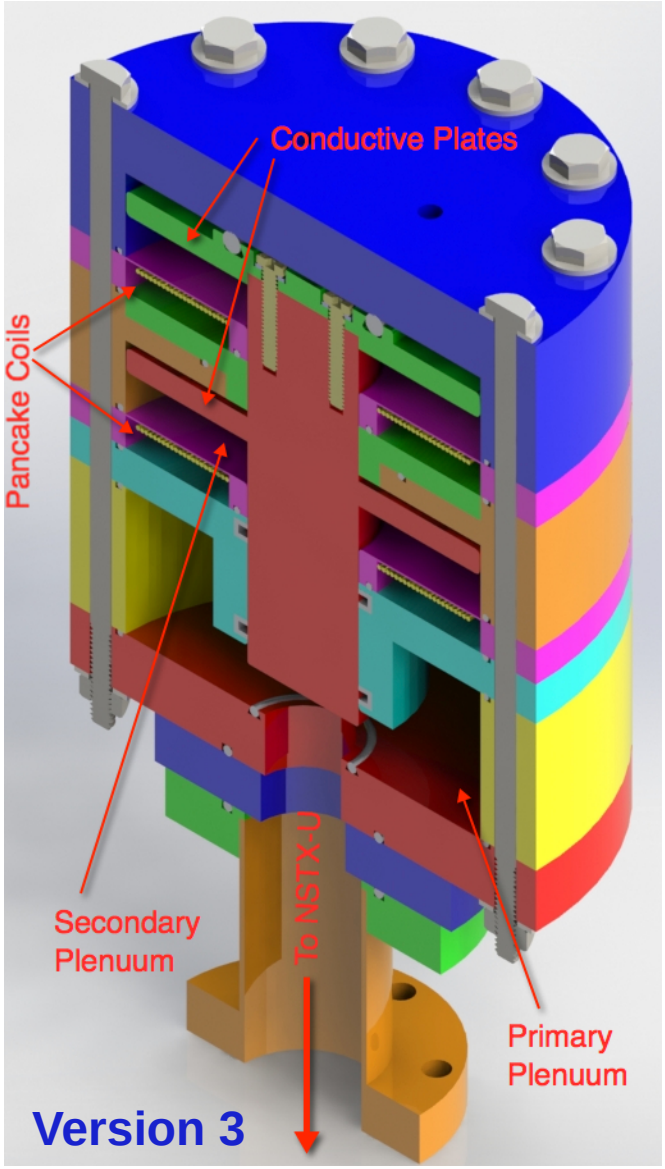
- Asses benefits of injection into the private flux region & the high-field side region vs. LFS mid-plane

1a: Private flux region
1b: Lower SOL, Lower Divertor
2: Conventional mid-plane
3: Upper divertor
4: Future installation

Off-line MGI Studies will Contribute to MGI Valve Development in support of NSTX-U and ITER





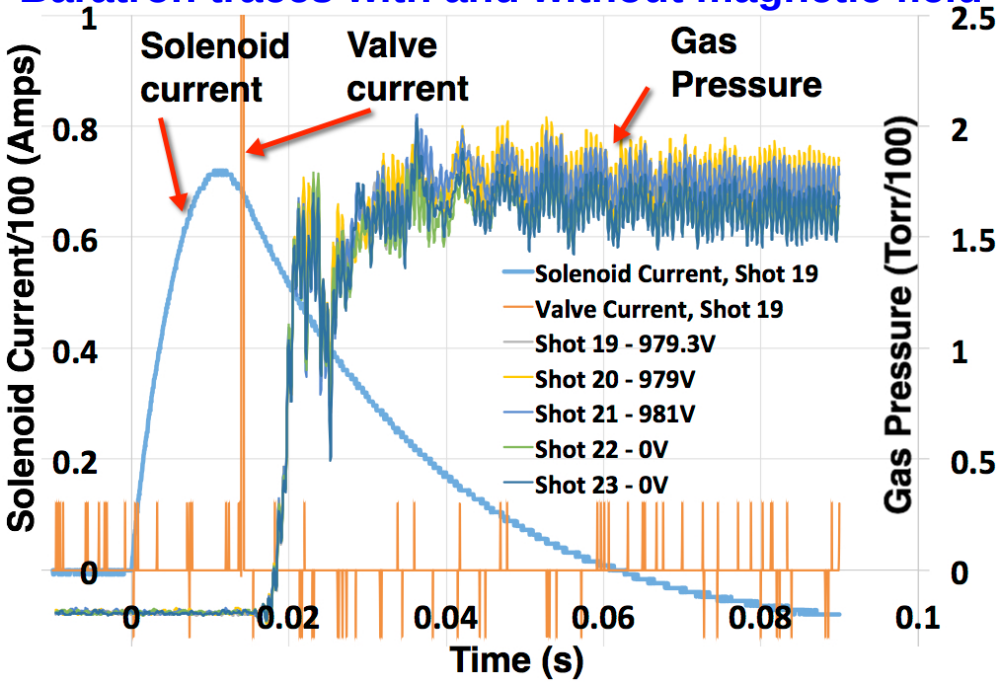


MGI valve design based on TEXTOR / JET MGI concept

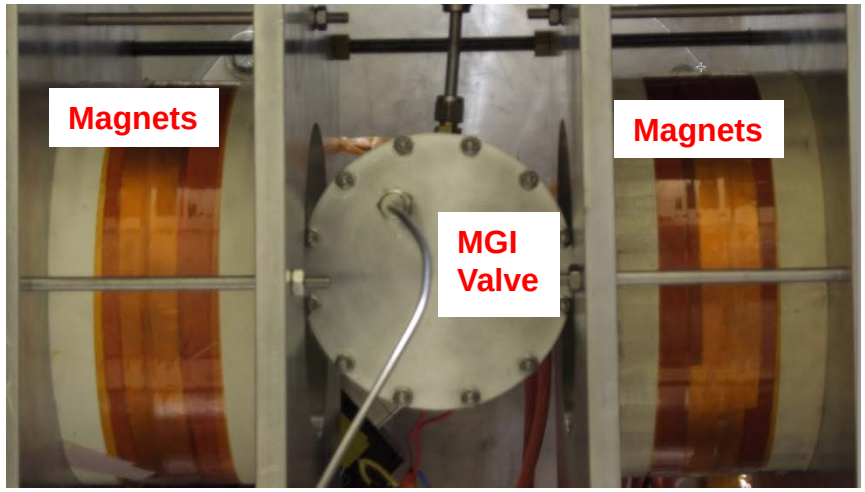
New double solenoid MGI design – V3 (zero net J x B torque) based on ORNL ITER MGI concept

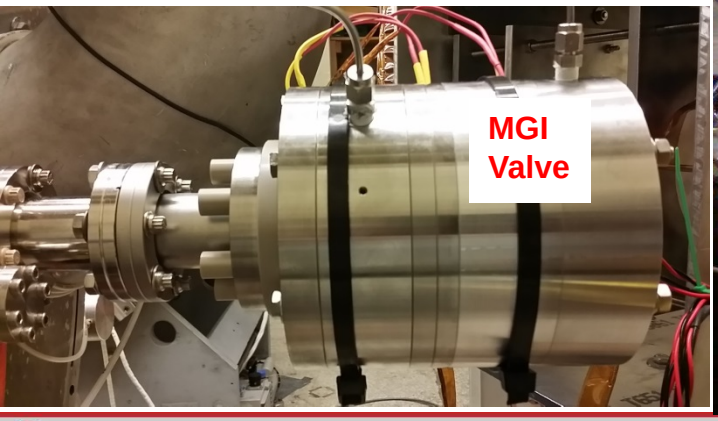
Understand Reliability and Magnetic Field Limits on Valve Operation

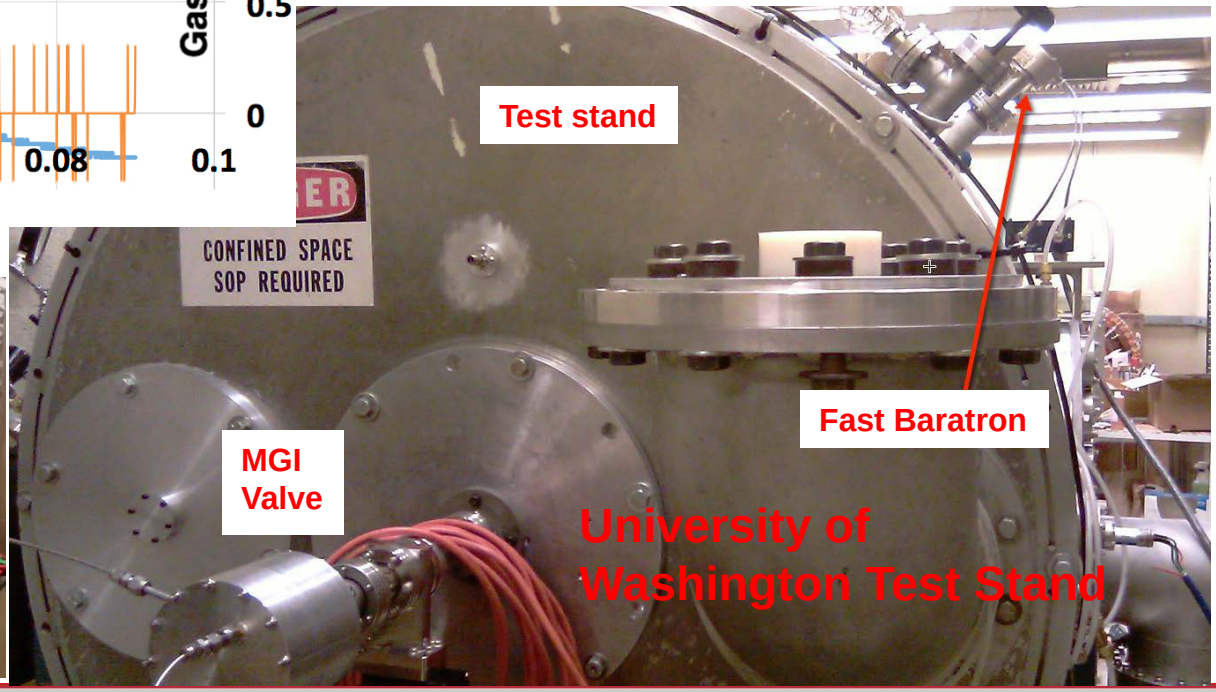
Baratron traces with and without magnetic field



R. Raman, et al., RSI, 85, 11E801 (2014)







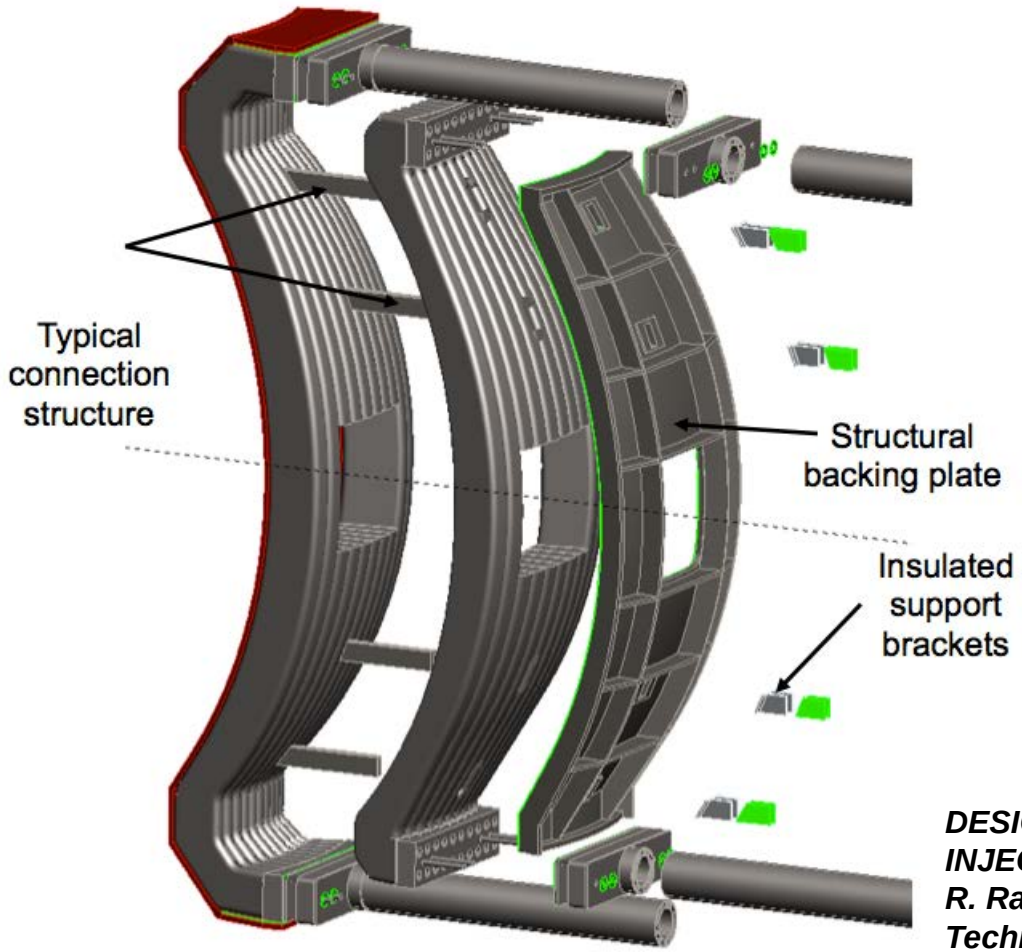
CHI Research on QUEST (Kyushu University, Japan)

- Test ECH heating of a CHI Target (in support of NSTX-U CHI)
  - QUEST is equipped with 400kW ECH
- Test CHI start-up using metal electrodes (in support of NSTX-U CHI)
  - Clean metal electrodes should reduce low-Z impurity influx
  - Reactors will use metal divertor plates
- Test CHI start-up in an alternate electrode configuration that may be more suitable for a ST-FNSF installation
  - CHI insulator is not part of a vacuum system (see ST-FNSF design studies paper)

CHI Design Studies for ST-FNSF have Identified Two Designs with > 2MA Start-up Current Generation Potential

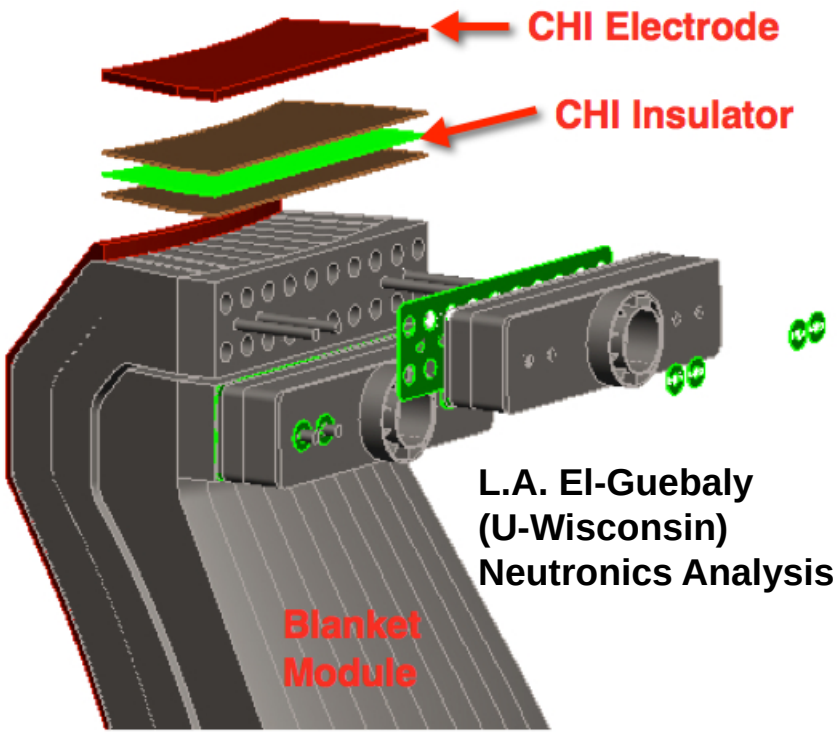
Concept – I (NSTX-like)

***Blanket modules and piping insulated from rest of vessel**



Concept – II (QUEST-like)

Toroidal electrode on top of blanket structure, analogous to CHI ring electrode previously used on DIII-D

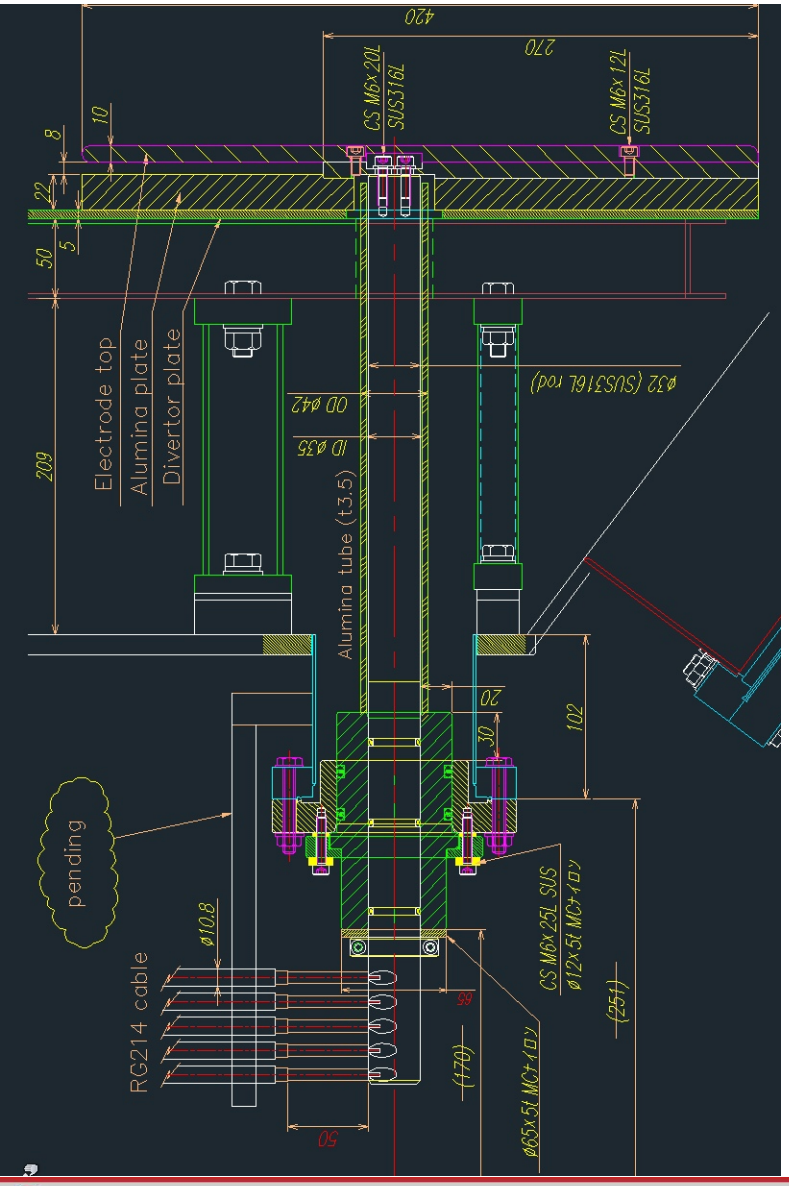


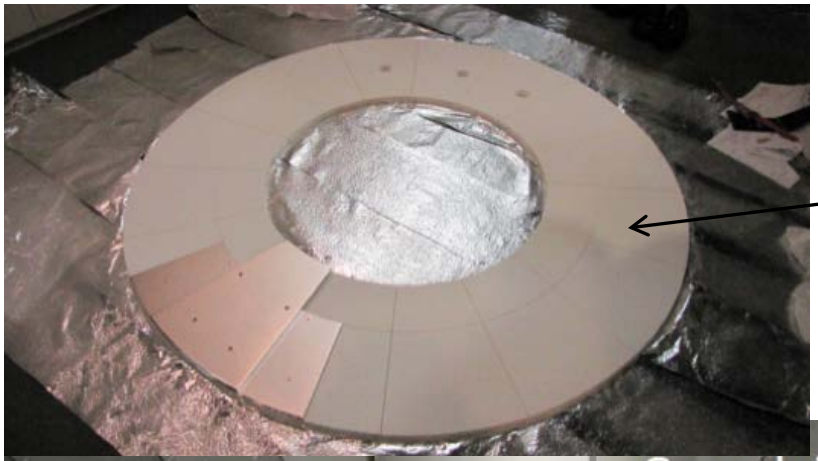
L.A. El-Guebaly (U-Wisconsin) Neutronics Analysis

DESIGN DESCRIPTION FOR A COAXIAL HELICITY INJECTION PLASMA START-UP SYSTEM FOR A ST-FNSF R. Raman, et al., accepted for publication, Fusion Science & Technology (2015)

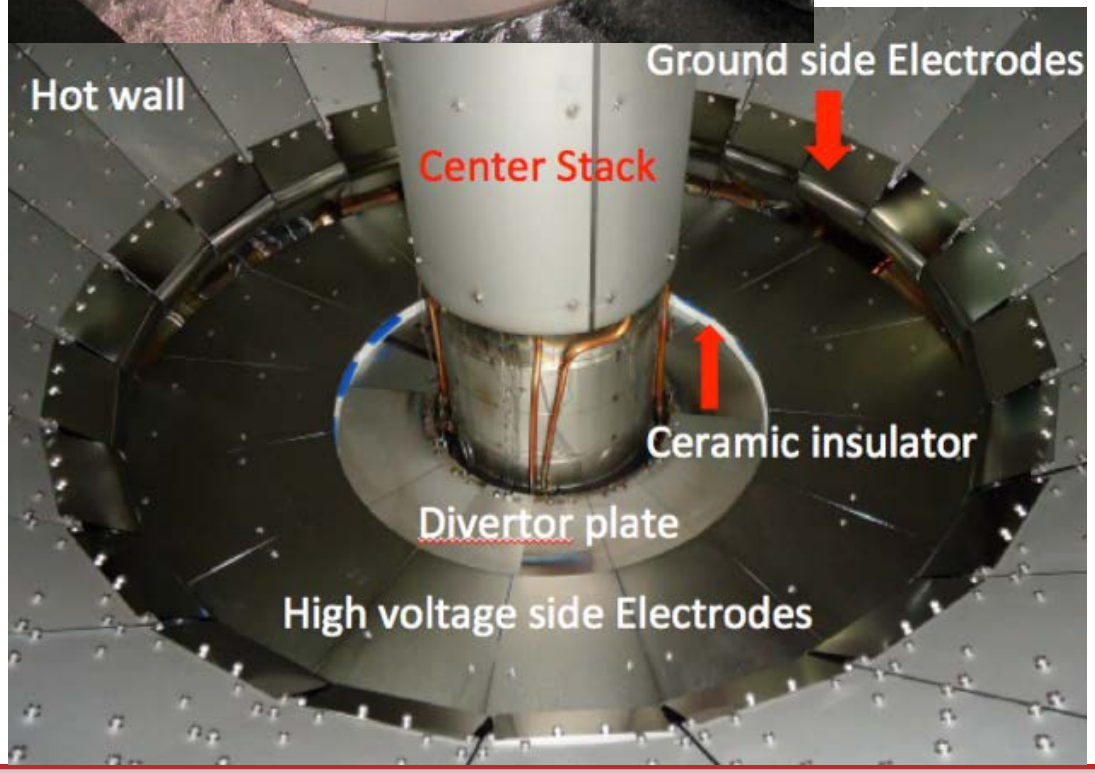
T. Brown, PPPL (Insulator Design)

Final CHI Design, and Photo of Installed Electrodes (Jan 2015)

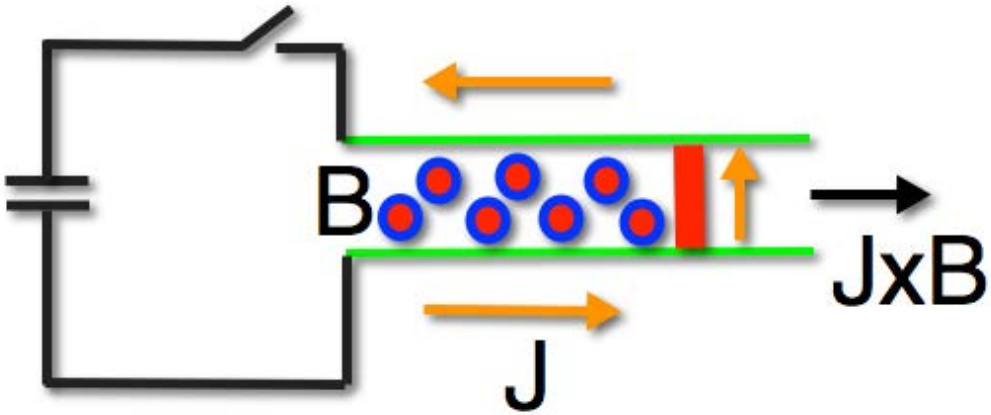




CHI Insulators (U-Washington)



Linear Rail Gun is Especially Well Suited for Operation in High-Ambient Magnetic Fields

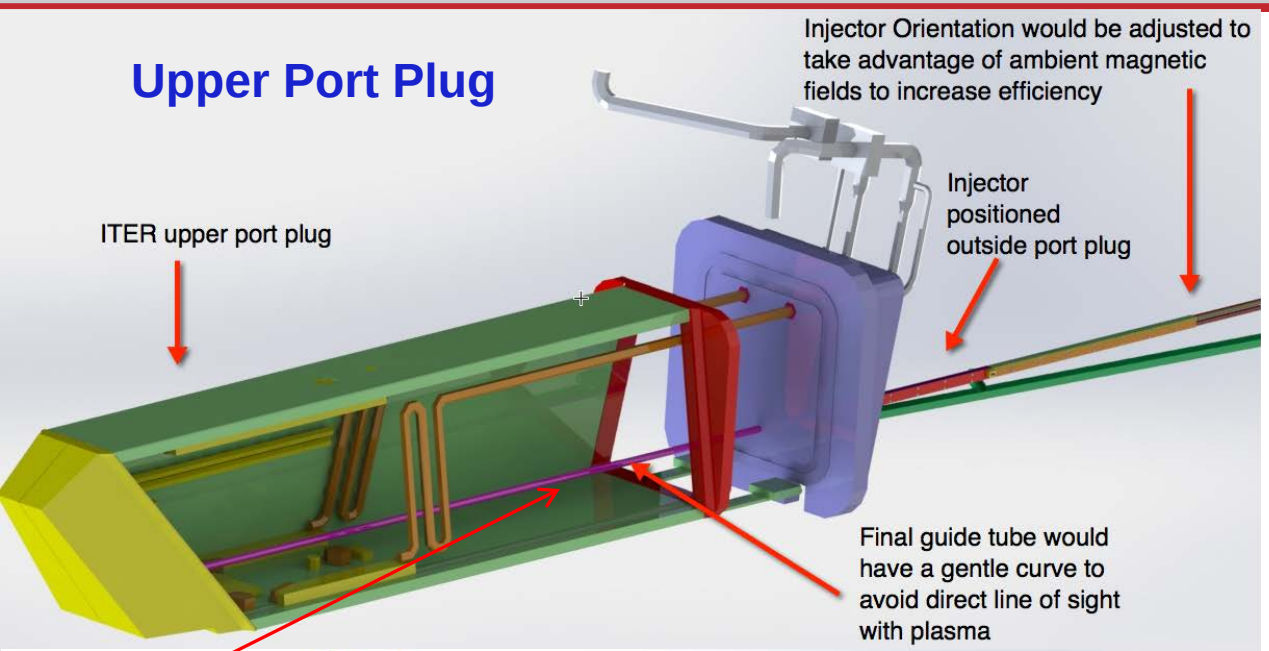


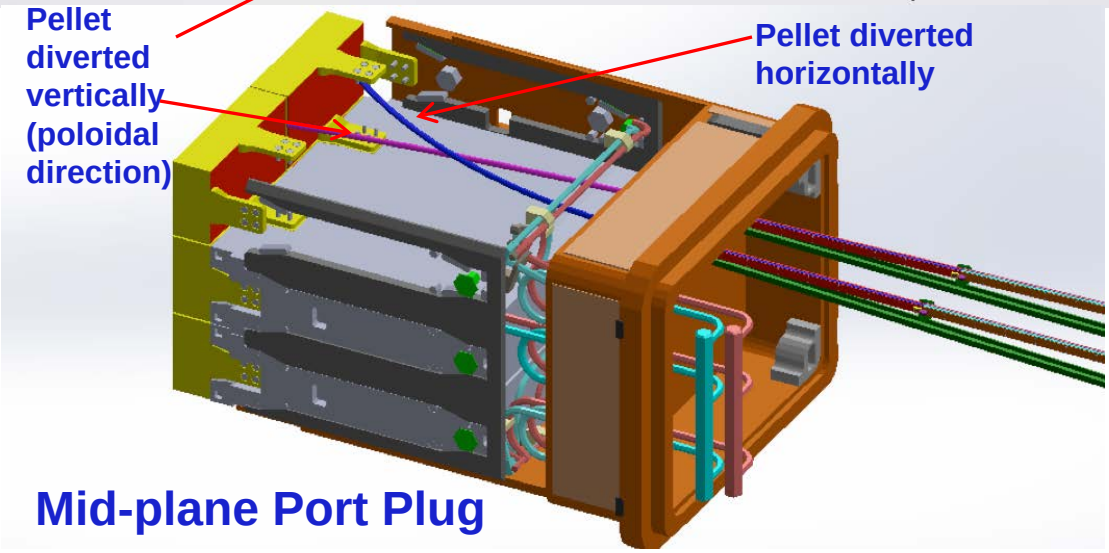
Planned Near-Term Goal* (FY16 and beyond)

1. Off-line test at U-Washington of Low-power system to confirm velocity parameters and system time response time
2. Low-power system installation on NSTX-U, other tokamaks
3. Continue off-line tests with a medium-power system for development towards a ITER high-power configuration
   - Increase EPI energy
   - Test injection through curved guide tube
   - Pellet design improvements needed for both EPI and Shell Pellet

***Need additional resources**

Scoping Studies Suggest that an EPI Installation on ITER should be feasible*





In FNSF, inclusion of EPI from early design phase should allow installation closer to the wall to benefit from high toroidal field

**** Based on three design review meetings with the US ITER group***

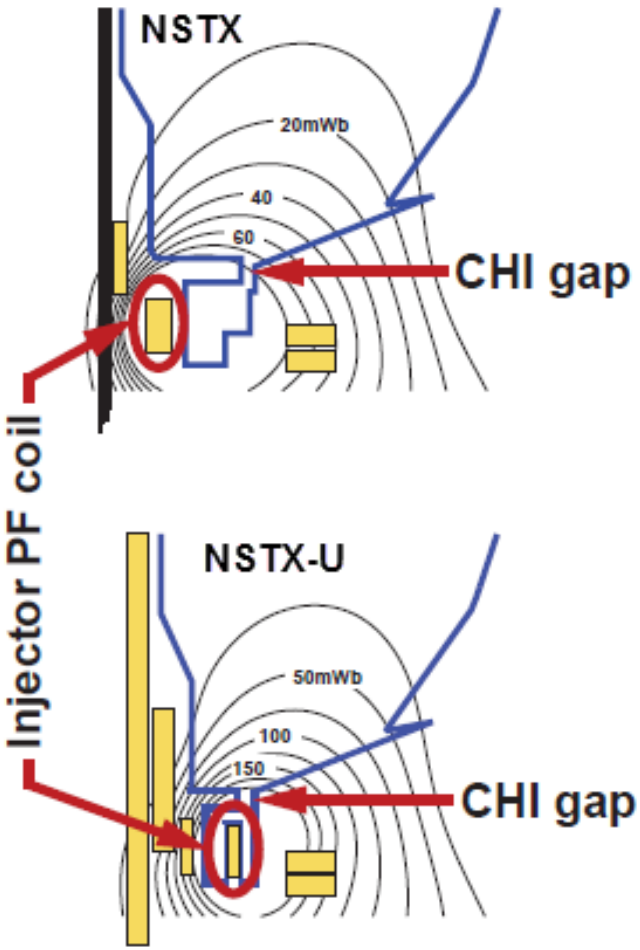
Acknowledgments:
J.E. Menard, M. Ono, S.P. Gerhard,
L. Baylor, D. Rasmussen, M. Lehnen,
R. Feder, G. Loesser, V. Barabash, R. Pitts

UW Research on NSTX-U Aims to Develop Capability for Solenoid-free plasma start-up, and MGI and EPI Technologies in Support ITER and FNSF

- CHI research on NSTX-U aims to extend the plasma current start-up magnitude to levels that allow full non-inductive current ramp-up
- UW responsible CHI on QUEST, to study CHI design for FNSF & provide supporting technical data for future NSTX-U CHI upgrades
- ITER-type off-line MGI valve development aims to understand reliability and magnetic field limits on reliable valve operation
- ITER-type MGI valve will be used on NSTX-U in a configuration to do exact comparison experiments
  - Same valve & piping configuration at each poloidal location
- The EPI system has several attractive features
  - Rapid delivery of impurities deeper into plasma with fast time-response
  - Efficiency of system improves in a magnetic field environment
  - Well suited for long stand-by mode operation (single power supply and no moving parts in system)
- ST & Tokamak based reactors would significantly benefit from precise core fueling and toroidal momentum injection
  - NSTX-U is an ideal test bed for developing the CT injection capability

Back-up Slides

CHI start-up to ~0.4MA is projected for NSTX-U, and projects to ~20% start-up current in next-step STs



Parameters	NSTX	NSTX-U	ST-FNSF	ST Pilot Plant
Major radius [m]	0.86	0.93	1.2	2.2
Minor radius [m]	0.66	0.62	0.80	1.29
B_T [T]	0.55	1.0	2.2	2.4
Toroidal flux [Wb]	2.5	3.9	15.8	45.7
Sustained I_p [MA]	1	2	10	18
Injector flux (Wb)	0.047	0.1	0.66	2.18
Projected Start-up current (MA)	0.2	0.4	2.0	3.6

Injector flux in NSTX-U is ~ 2.5 times higher than in NSTX → supports increased CHI current

Transient CHI Scaling: Generated Toroidal Current is proportional to Injector Flux

NSTX-U Plans for Disruption Mitigation Studies

1. Massive Gas Injection (MGI) studies in NSTX-U will initially study effect of poloidal injection location variation

   - Will consider, and if desirable, implement additional MGI valves at different toroidal locations (for FY16 and later)

2. Off-line MGI studies at Univ. of Washington will contribute to MGI valve development (provide results to ORNL)

3. Electromagnetic Particle Injector (EPI) will develop capability for fast time-scale impurity injection into a tokamak plasma (need additional resources)
   - Off-line development work to develop NSTX-U injector
   - Then use injector on NSTX-U and/or another tokamak
   - Continue off-line work for ITER/FNSF relevant injector development

Initial Studies on NSTX-U will Enable MGI Capability

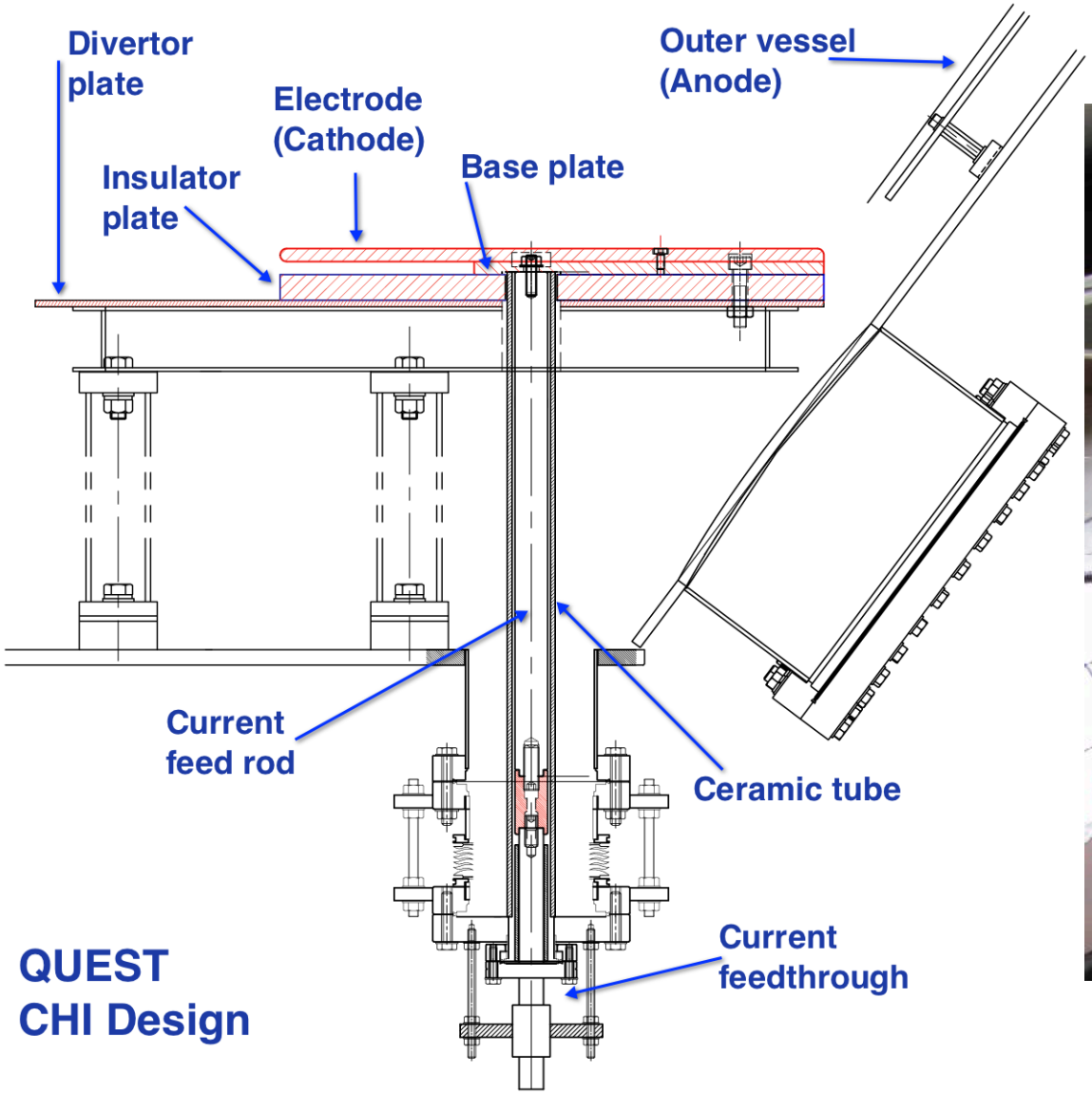
Initial Studies

- Compare mid-plane and PFR locations, and lower divertor location, for gas assimilations studies using identical gas injection set-up
  - Asses benefits of lower divertor injection (provide radiative mantle to a VDE)
  - Optimum poloidal injection location for minimizing damage from VDEs
- Measure radiated power profiles, divertor heat loads and currents in divertor tiles, and compare to unmitigated discharges

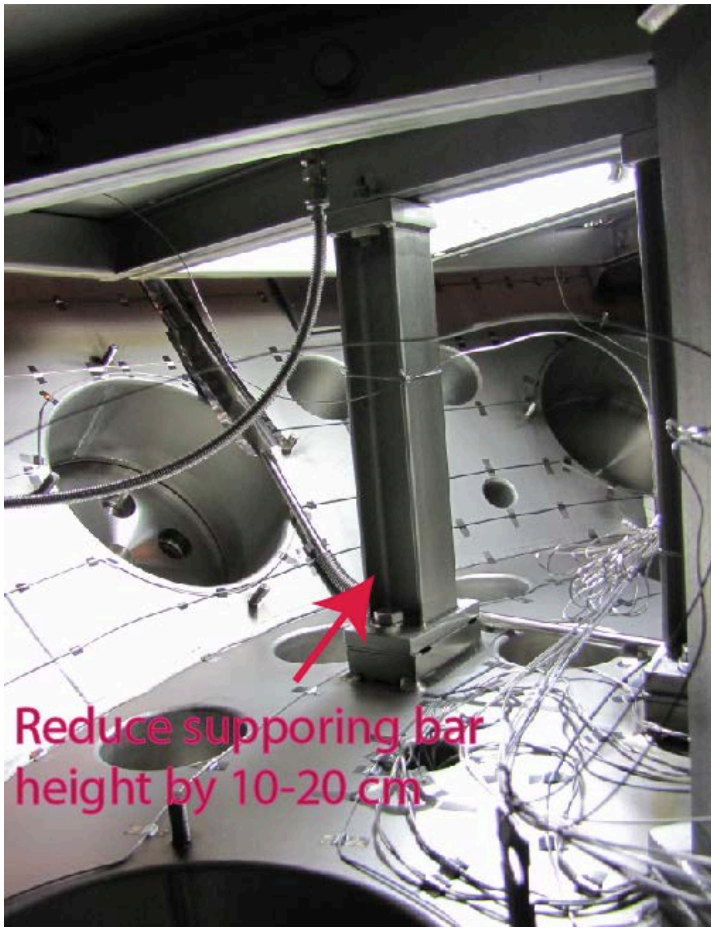
Later Studies

- Use FY15 result to asses need for other injection locations
- Proximity of q=2 surface to plasma edge
- Pre-existing MHD in discharges, and other studies
- Aspect ratio comparison studies with DIII-D

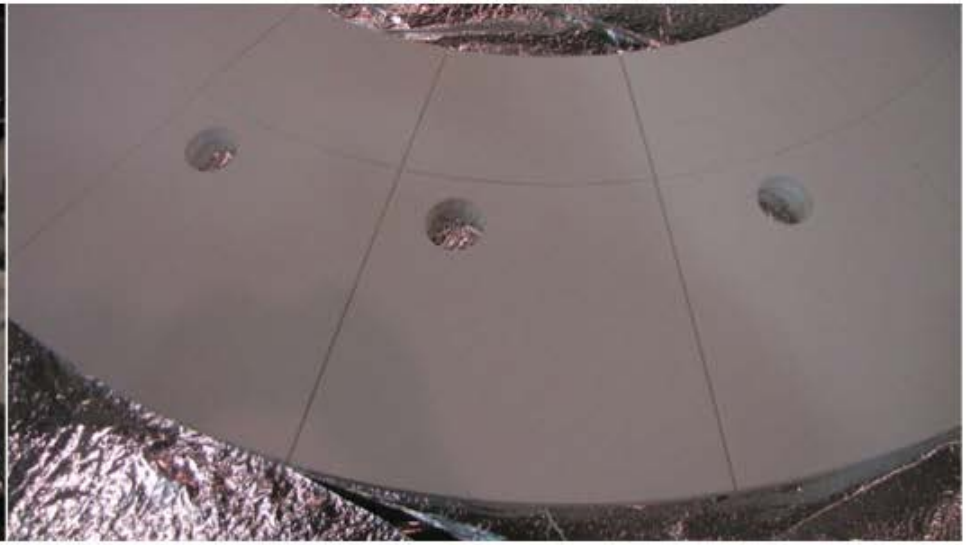
CHI Implementation on Quest Requires Electrodes that can be Intersected by Poloidal Flux

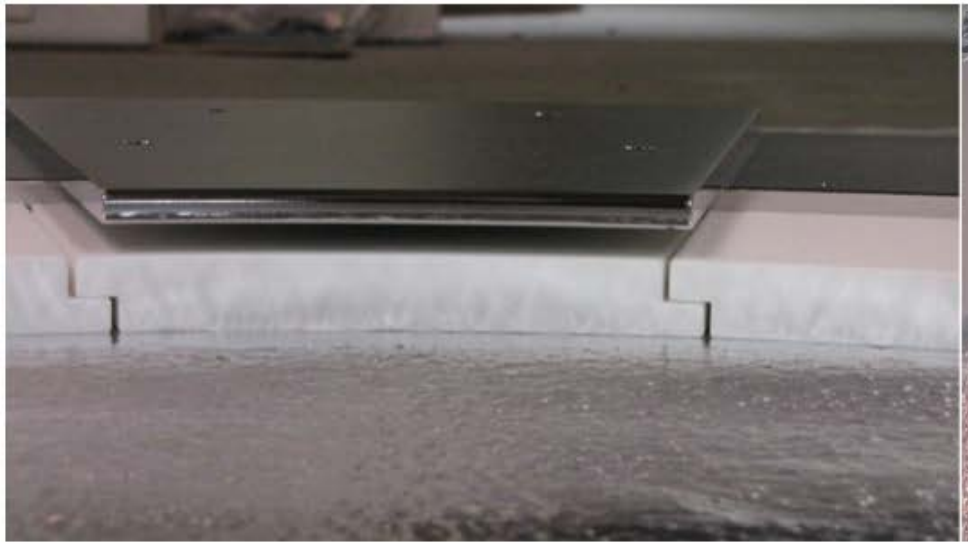


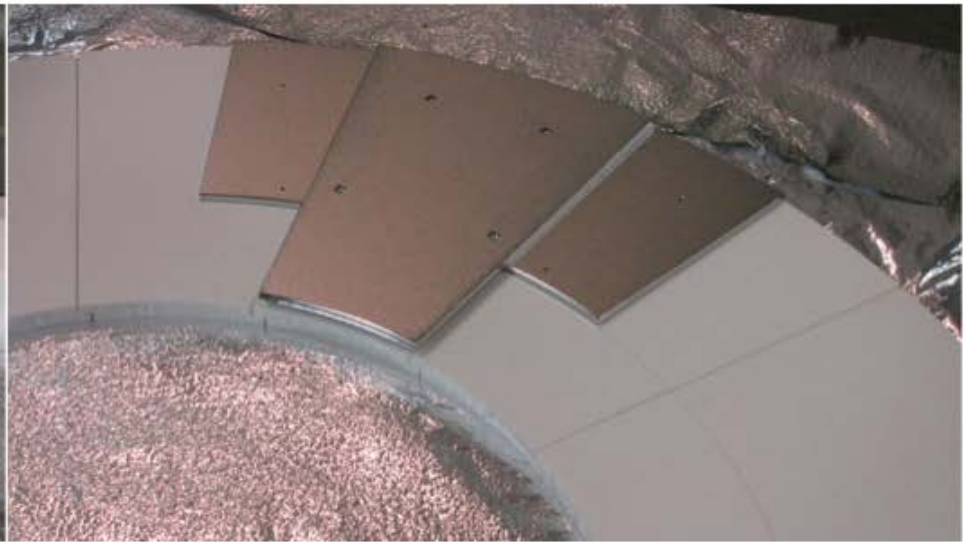
QUEST
CHI Design



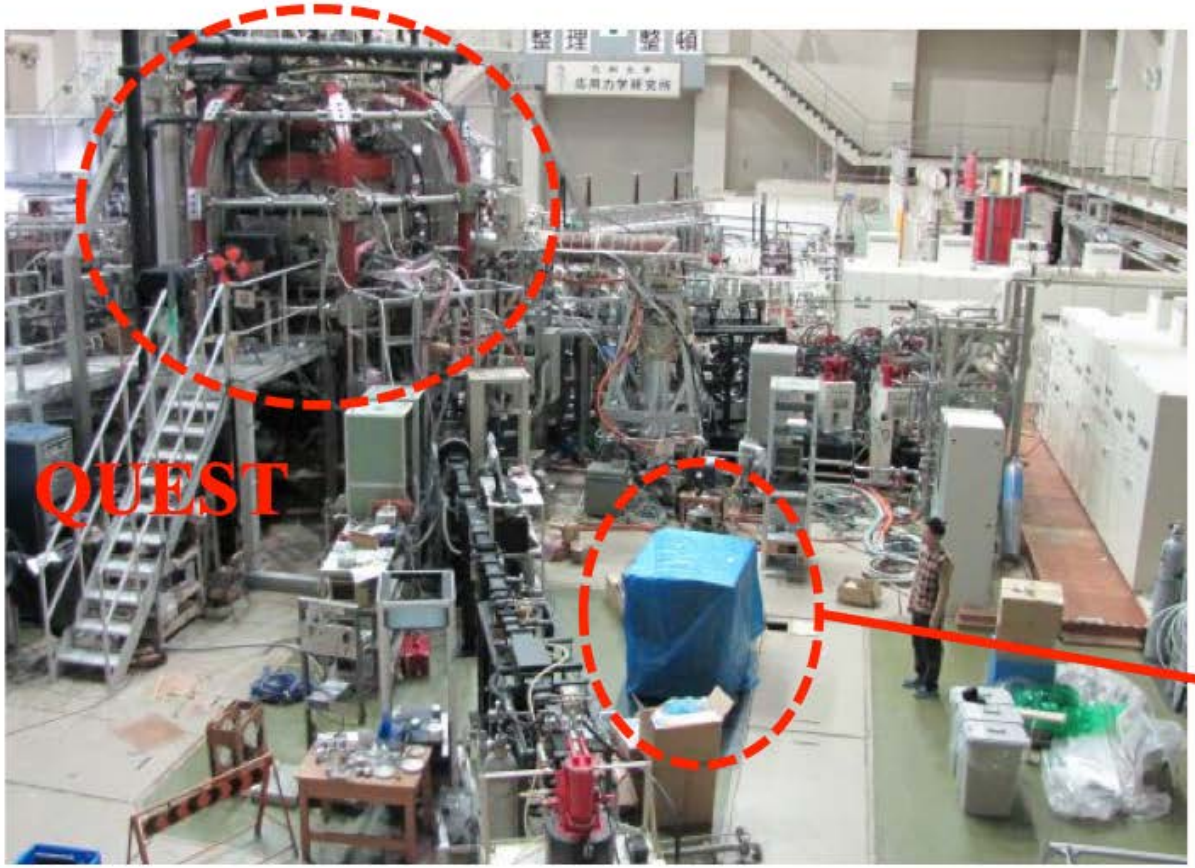
Photos of Primary CHI Insulators (US Contribution), and part of electrodes (Japanese Contribution)

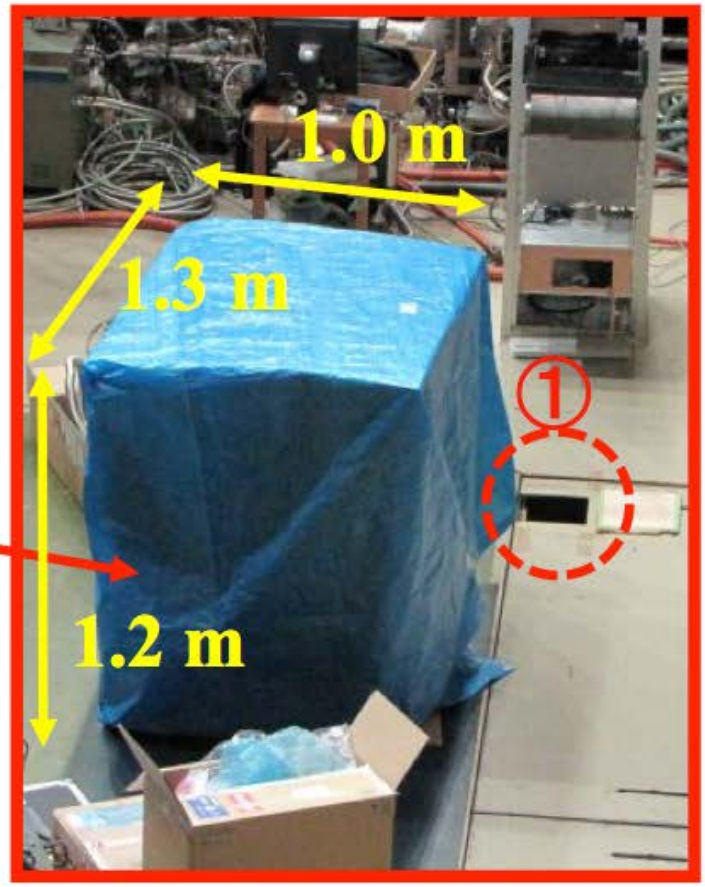






Location of Power Supply for CHI



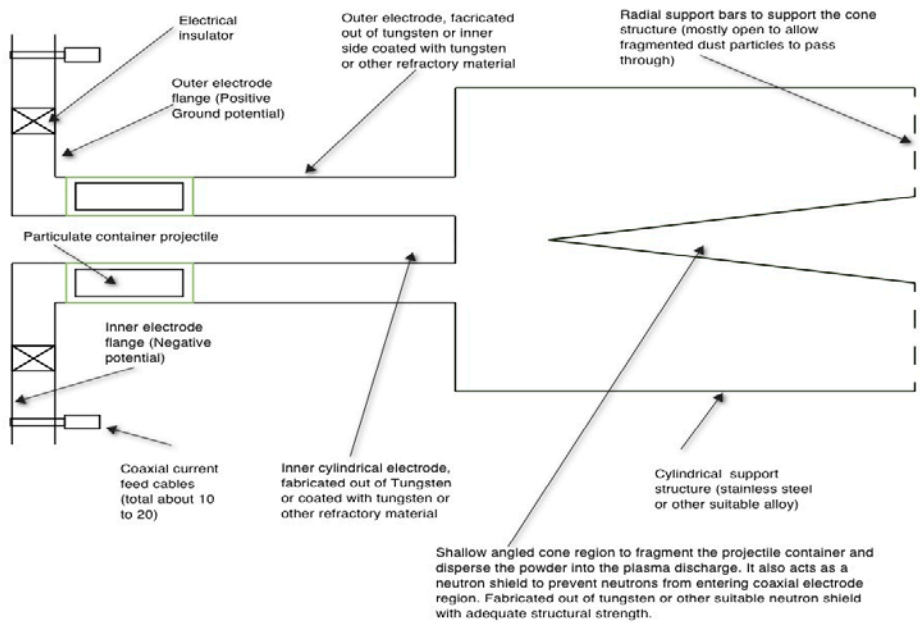


Expect CHI Capability on QUEST in 2015

- CHI insulators (provided by U-Washington) and electrodes successfully fabricated and installed on QUEST
  - The QUEST CHI electrode design is similar to one of the CHI configurations we are considering for a ST-FNSF
- Capacitor bank*, gas injection system and voltage snubber to be installed during the next few months (Univ. of Wash. contribution)
- Initial experiments will test voltage hold-off (2015)
- After that the goal is to reliably grow the CHI plasma into the vessel, and avoid absorber arcs (2016)
- Successful growth of the CHI plasma in combination with clean electrodes will allow closed flux surfaces to form, which will be studied and compared to results from NSTX, HIT-II and HIST, using ECH & metal electrode capability in QUEST

**** Capacitors provided by PPPL***

Initial Electromagnetic Particle Injector Concept Motivated by Prior Experience with CT Injector

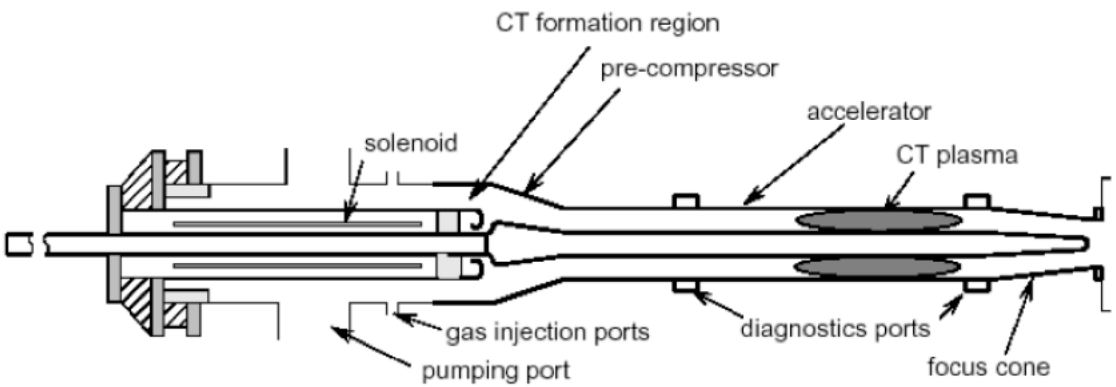


EPI injector propels solid material projectile & contains 1 electrical system

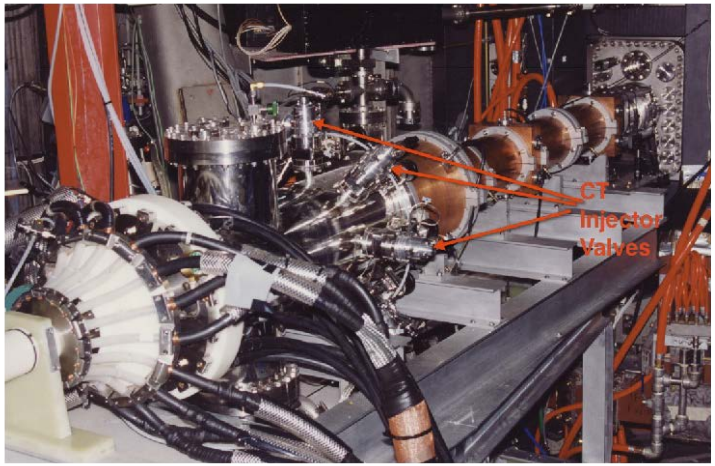
1) **Acc. cap. bank (1 ms time scale) 2-5 kV**

CT injector propels plasma armature and contains 4 electrical systems

1) **Gas Valves (10 individual valves)**
2) **Bias solenoid**
3) **Formation cap. bank (20 μs time scale)**
4) **Acc. cap. bank (10 μs time scale) ~ 40 kV**

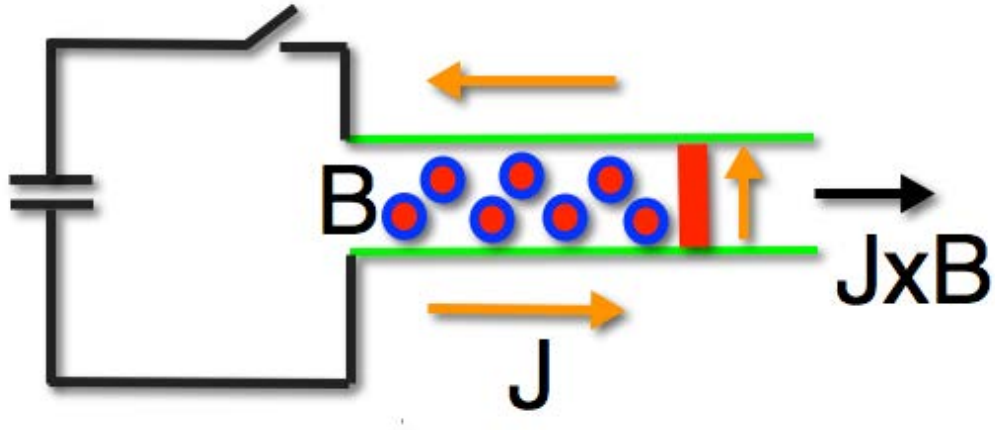


CT Injector on TdeV



Raman et al. Fusion Technol. 24, 239 (1993)

Linear Rail Gun is Especially Well Suited for Operation in High-Ambient Magnetic Fields

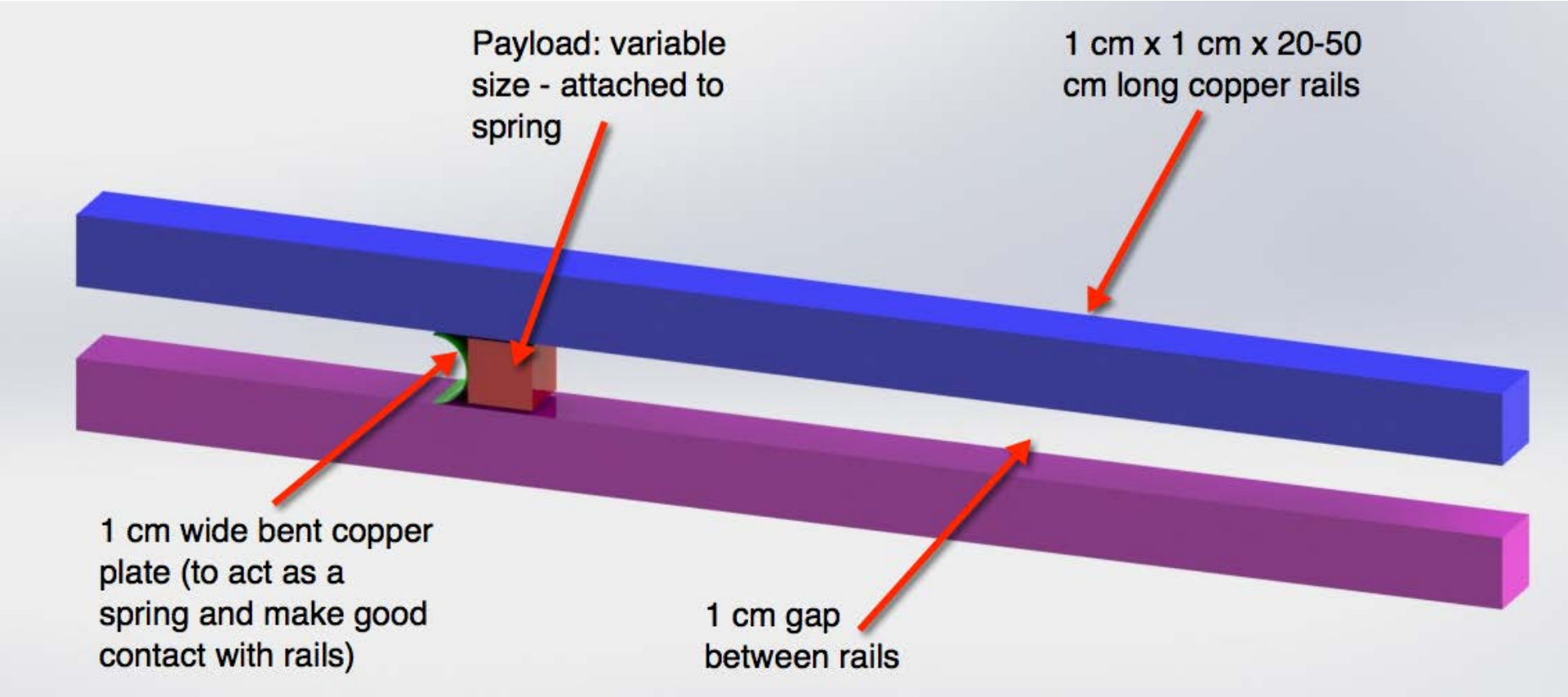


Planned Near-Term Goal* (FY16 and beyond)

- In a simple rail gun, the magnetic field is produced by the current flowing along the rails
- To increase the JxB force accelerating the projectile, the current along the rails needs to be increased
- An important advantage of a linear rail gun is that the ambient magnetic field in ITER can be used to increase the gun efficiency
- Injector can to be positioned very close to the vessel, which further improves the system response time and efficiency

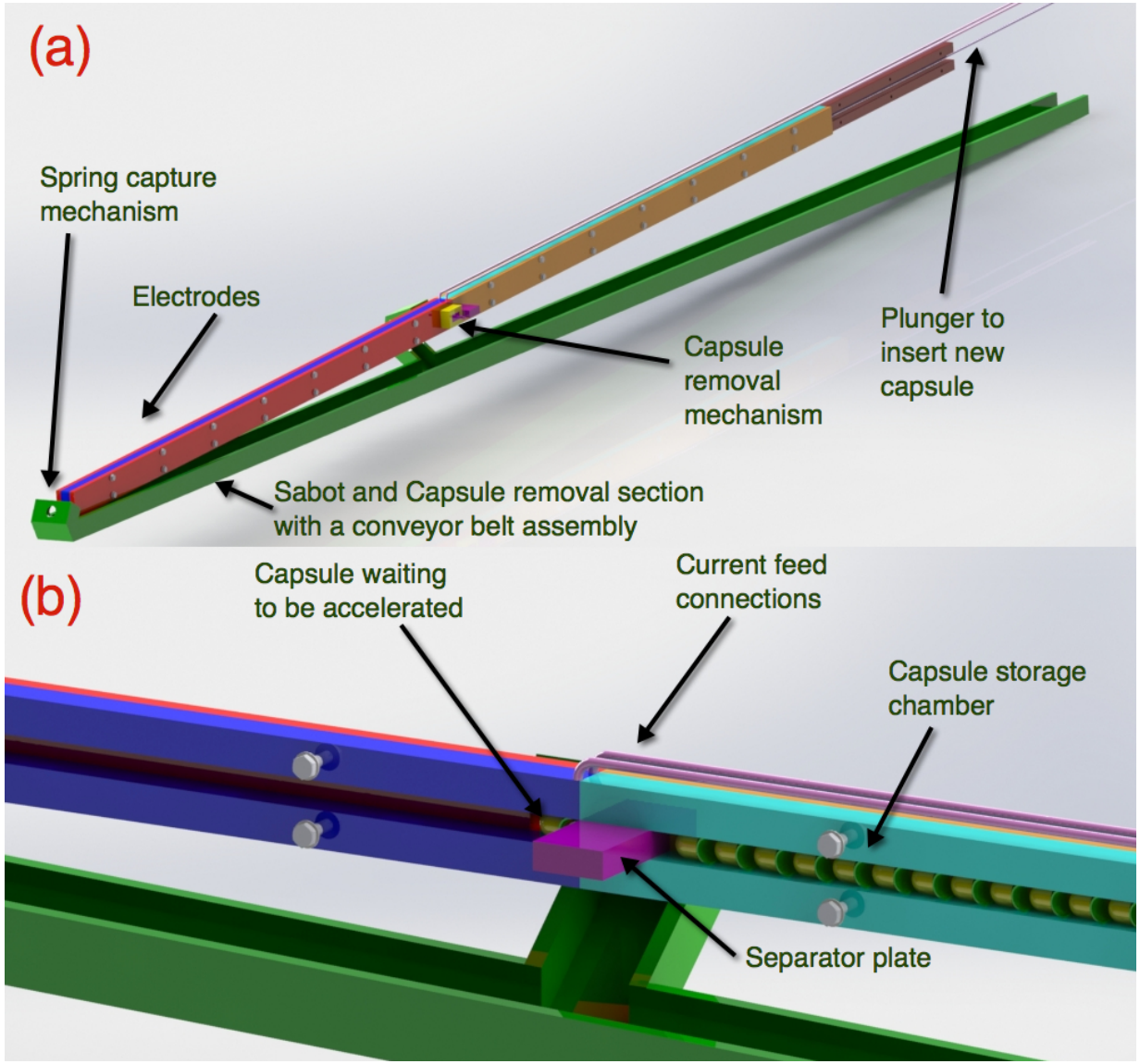
Need additional resources

Initial Test Configuration will Accelerate 1 to 2g payloads

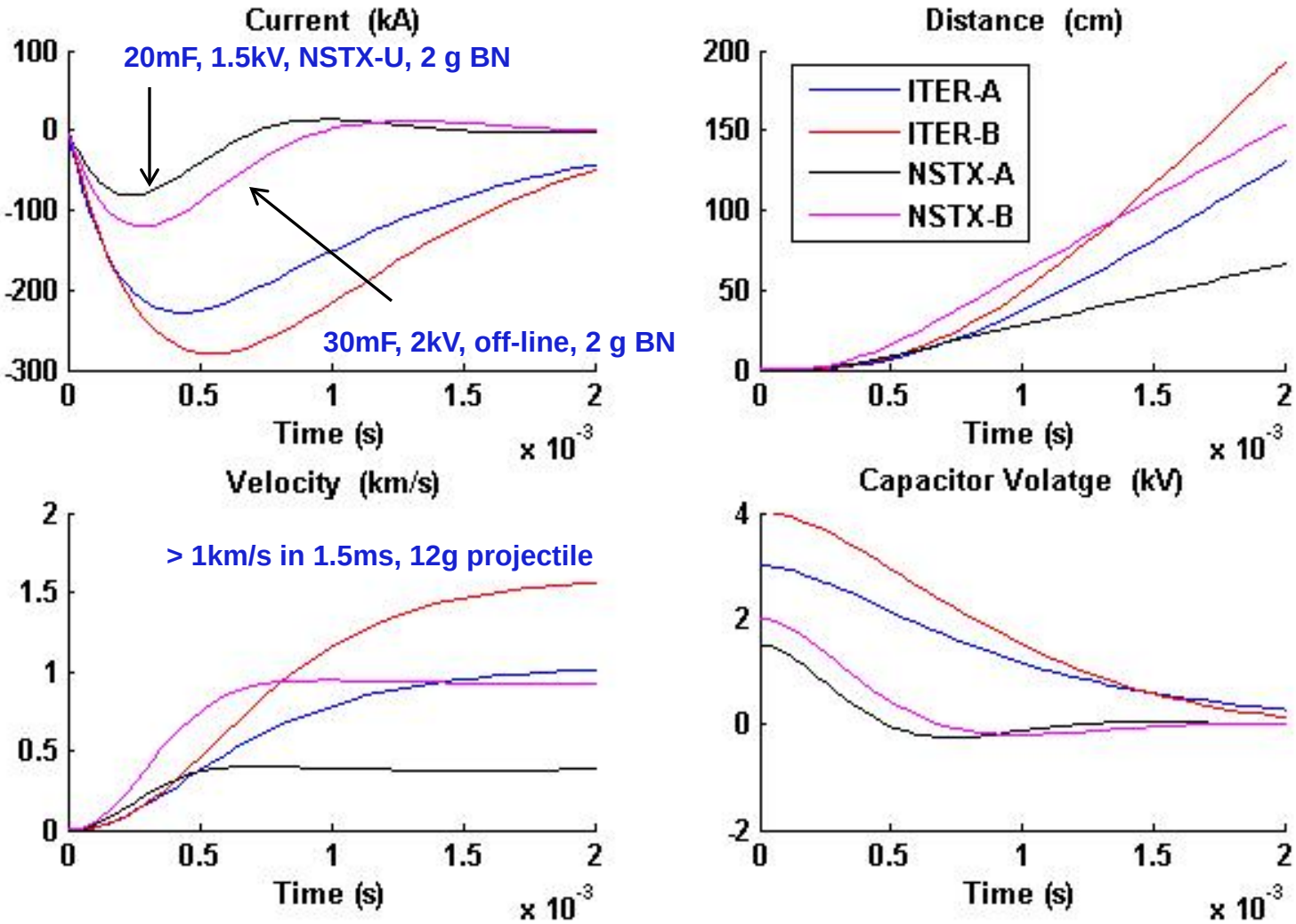


Rails will be sandwiched between insulating plates with small hole optical access to track projectile motion with fast photo diodes

Primary Components of an EPI System for ITER



Small, 20mF, 1.5kV capacitor bank allows test of a NSTX-U/DIII-D relevant injector



NSTX-U DM Research Aims to Develop MGI and EPI Technologies in Support ITER and FNSF

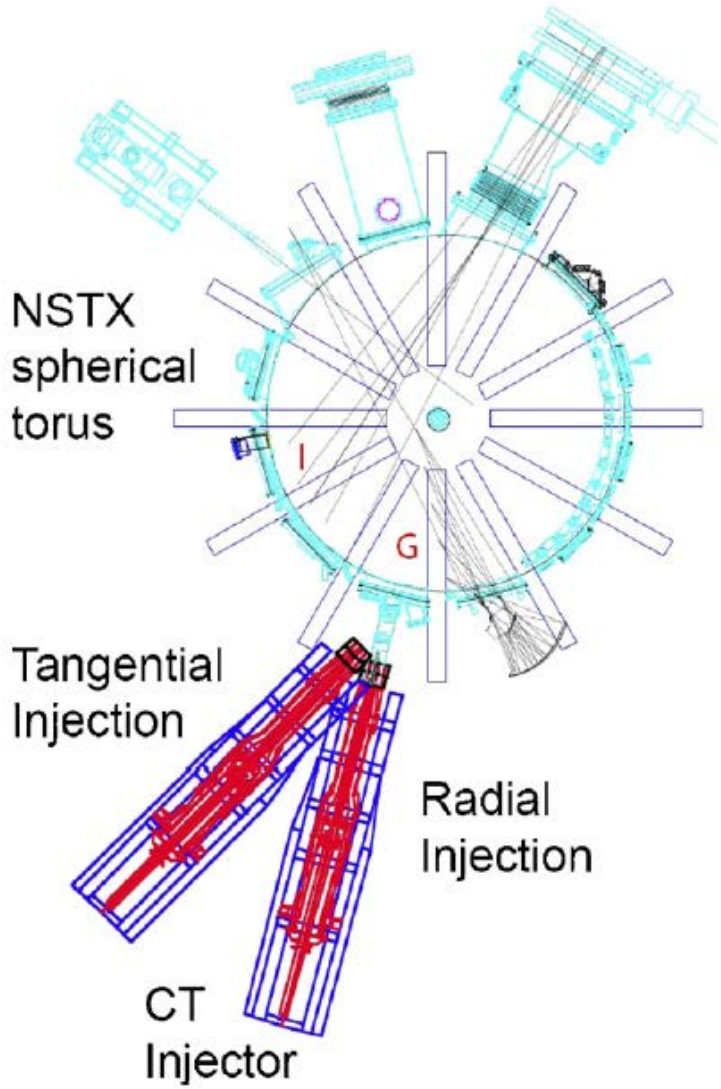
- ITER-type off-line MGI valve development aims to understand reliability and magnetic field limits on reliable valve operation
- ITER-type MGI valve will be used on NSTX-U in a configuration to do exact comparison experiments
  - Same valve & piping configuration at each poloidal location
- Similar plasma poloidal size and shape on DIII-D and NSTX-U allows multi-machine comparison studies
  - FY15 will focus on enabling MGI capability
  - FY16 and beyond will focus on more detailed studies
- The EPI system has several attractive features
  - Rapid delivery of impurities deeper into plasma with fast time-response
    - < 5ms from trigger to delivery at 7m from plasma
    - ~ 2ms delivery time, if installed closer to vessel (FNSF)
    - >10ms for Shell Pellet (>20ms for high-Z MGI)
  - Efficiency of system improves in a magnetic field environment
  - Well suited for long stand-by mode operation (single power supply and no moving parts in system)

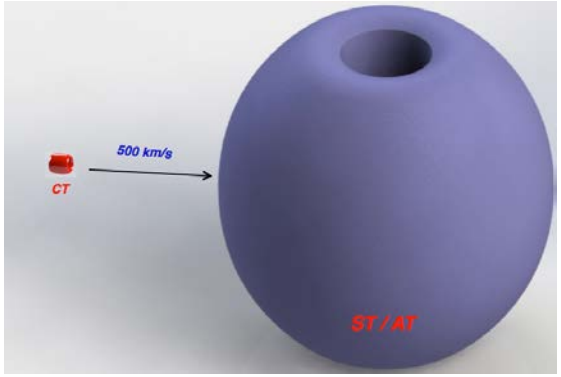
Desired Longer-Term Goal (FY18 and beyond)

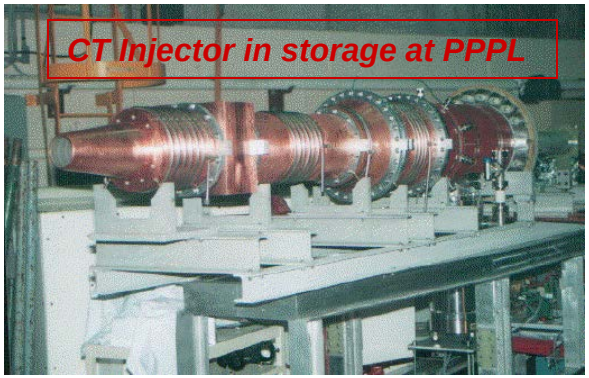
Restore and make operational CT injection system for eventual tests on NSTX-U

Need significant additional resources for this activity

In Tokamak/ST based Reactors, Flexible Fueling System may be the Only Choice for Density Profile, and providing Rotation and Rotation Shear







- A flexible fueling system is all that a DEMO device may be able to rely on to alter core plasma conditions (in addition to a small fraction of external current drive)
- In a device with high bootstrap current fraction, optimized density and pressure profiles must be maintained
- Toroidal rotation and rotation shear is necessary for maintaining MHD stability and reducing anomalous transport, but ITER and AT/ST DEMO may have low toroidal rotation

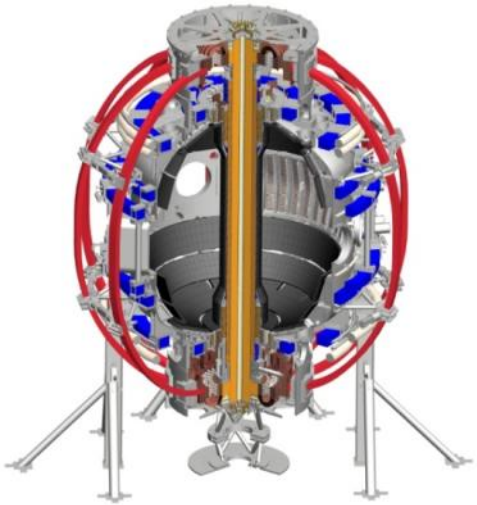
NSTX-U Project / Facility Status

Masa Ono and Jon Menard

for the NSTX-U Team

NSTX-U FY 2015 Q2 Review Meeting
April 24, 2015

Columbia U
CompX
General Atomics
FIU
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
ORNL
PPPL
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Washington
U Wisconsin

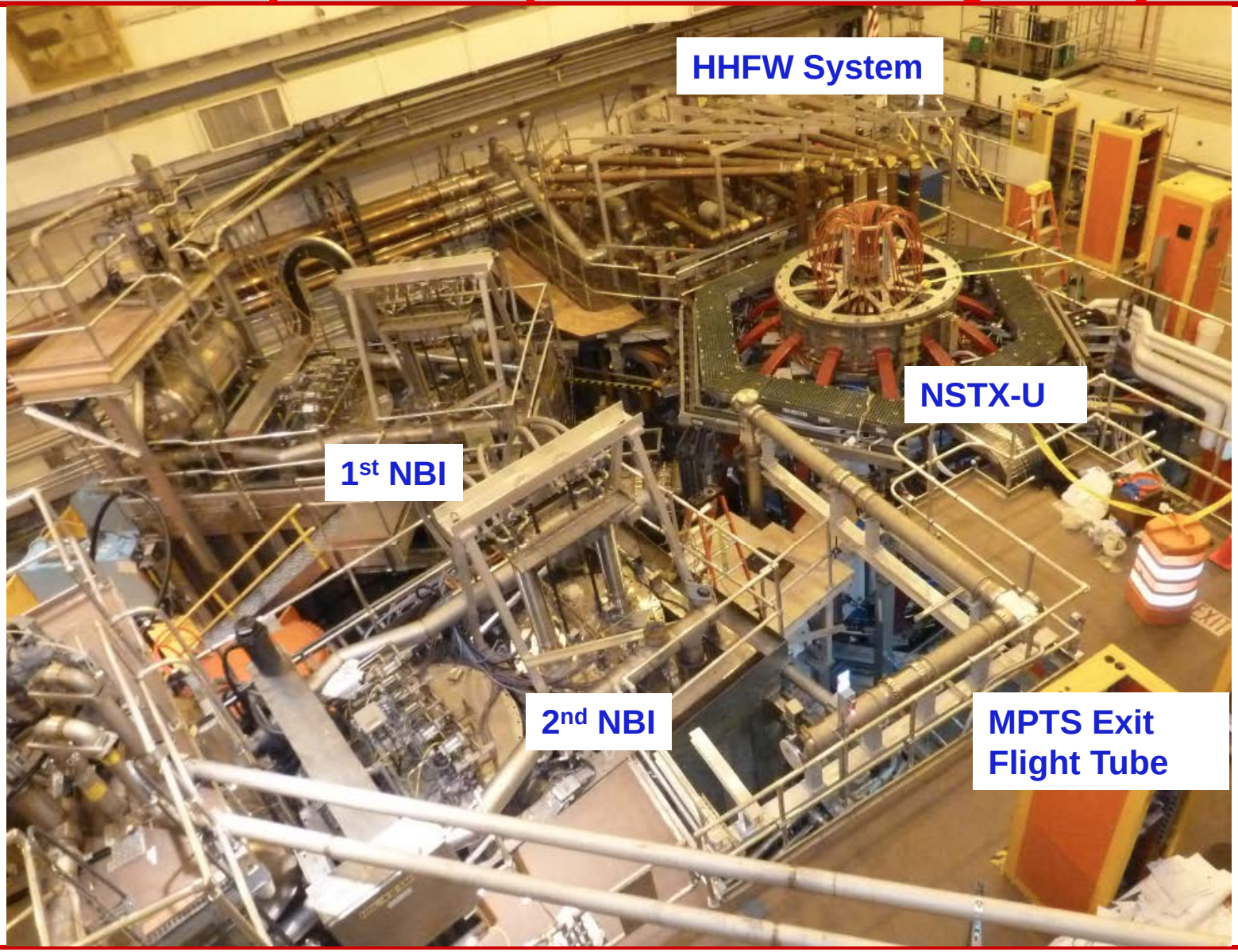


Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Tsukuba U
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
NFRI
KAIST
POSTECH
SNU
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep

Outline

- **Preparation toward Operation**
- **Research Operations Plan**
- **Research facility / diagnostic enhancement activities**
- **Incremental budget**
- **Summary**

NSTX-U Construction and ISTP completed
CD-4 plasma operation starting today

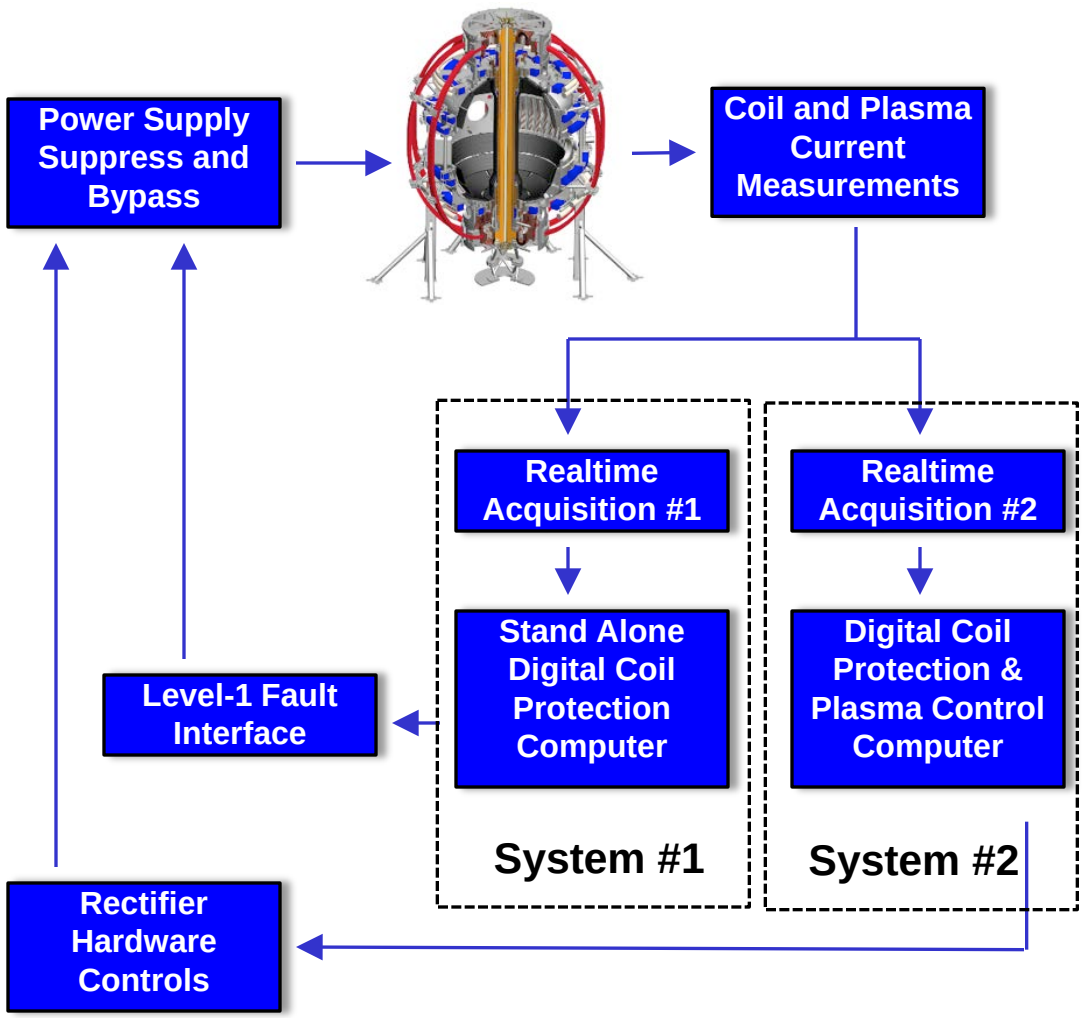


NSTX-U ISTP was completed successfully
CD-4 Plasmas should be achieved soon

- The NSTX-U Activity Certification Committee (ACC) has completed its review of operational readiness on April 10, 2015.
- The NSTX-U operations safety certificate was issued on April 10.
- The center-stack bake was performed over weekend, April 10 -12.
- The NSTX ISTP has started on April 16.
- Magnetic calibration performed utilizing ISTP single coil pulses.
- Magnetic reconstruction codes LRDFIT and EFIT are both exercised
- DCPS has been exercised and working very reliably.
- With the CD-4 achievement now imminent, we are updating the detailed plan toward research operations.

New Digital System Provides Comprehensive Coil Protection

Protects NSTX-U machine against electromagnetic loads



Computes forces and stresses in real-time based on reduced models of the full mechanical structure

Redundant systems: both systems are ready for CD-4!

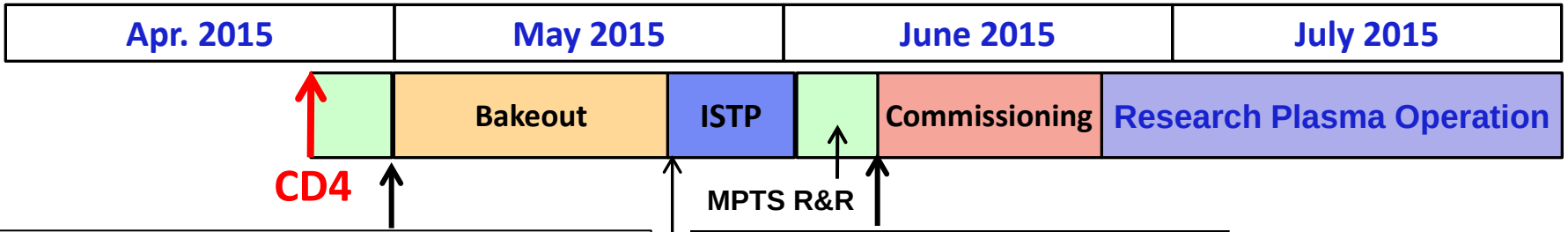
System #1 is used during rectifier dummy-load testing and ISTP, ready fo CD-4 plasma ops.

System #2 is also exercised and ready to support CD-4 and beyond.

Full commissioning system will be a key part of early operations and it is working very well!

Post CD-4 / Pre-research operation activities

Critical period to prepare for research operations



Activities before bakeout:

MPTS Input / exit flight tubes

MPTS Initial Stray light Assess.

Bakeout system for MPTS flight tubes

Complete shutter actuation

IR Cameras

Bakeout connections to inbd. div.

Coil related activities for ISTP

Ip Calculator + Permissive Generator Testing

PF-1a, PF-1c, PF-2 DL testing

FCC DCPS Watchdog Timer

Interface to L1 Fault System

HF+SPA testing

Needed for commissioning

"Injector 4" puff valve

Boronization

GDCs

MAPP

Zeus, LoWeuS, MonaLisa

Fast Mirnov DTACq

Midplane Bolometer

EIES & Filter scopes

2nd plasma TV

VIPS, DIMS,…

MPTS R&R:

N2 Raman and Rayleigh

Repeat with Argon

Window chromatic calibration with in-situ probe.

Other priority items

LITER brackets

SGI

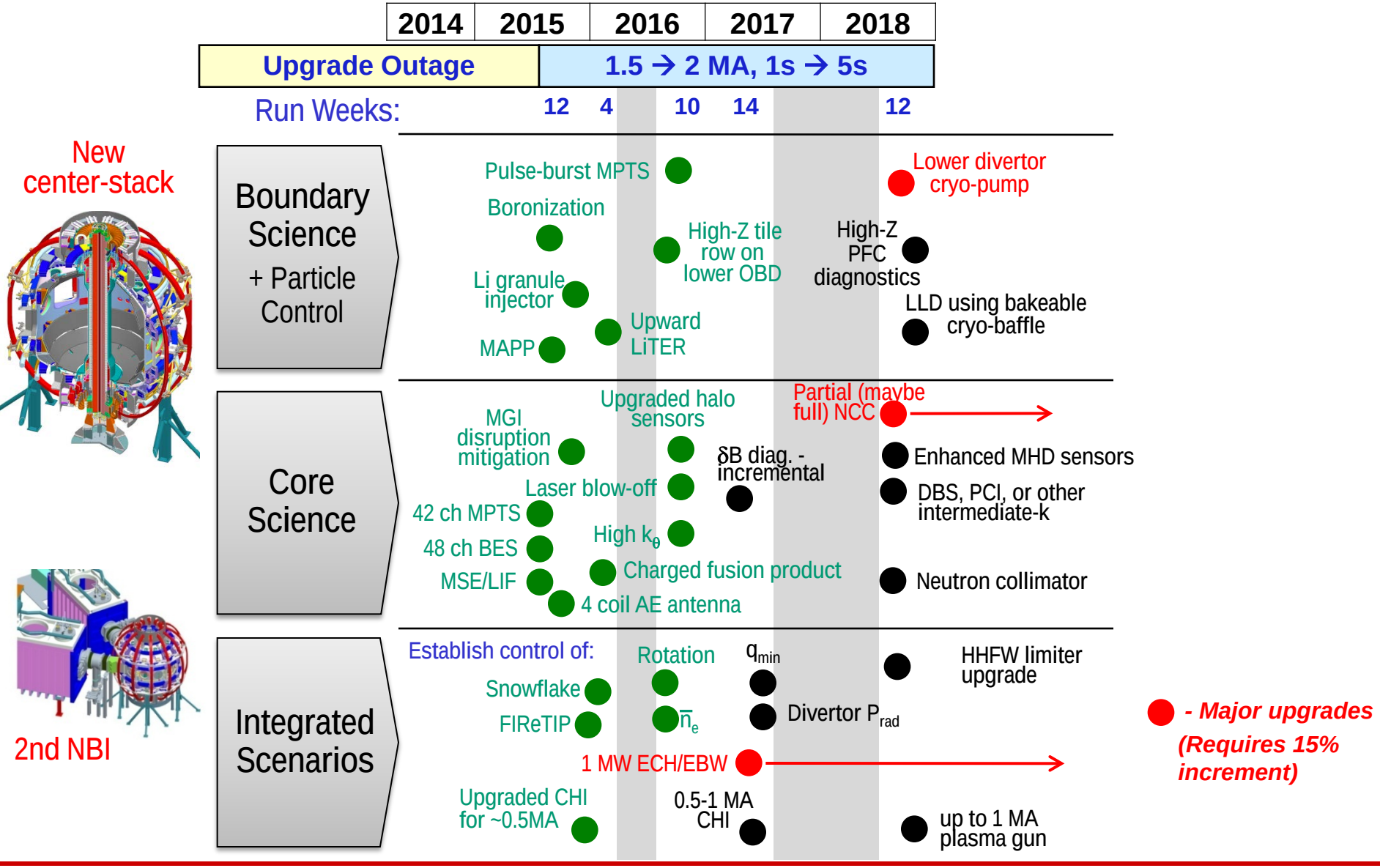
Divertor Injectors

CHI injectors

MGI

Five Year Facility Enhancement Plan (green – ongoing)

Engineering design for ECH, Cryo-Pump and NCC performed in 2015



NSTX-U diagnostics to be installed during first year

All center stack sensors mounted & ex-vessel terminations in progress

MHD/Magnetics/Reconstruction

Magnetics for equilibrium reconstruction
Halo current detectors
High-n and high-frequency Mirnov arrays
Locked-mode detectors
RWM sensors

Profile Diagnostics

MPTS (42 ch, 60 Hz)
T-CHERS: $T_i(R)$, $V_\phi(r)$, $n_C(R)$, $n_{Li}(R)$, (51 ch)
P-CHERS: $V_\theta(r)$ (71 ch)
MSE-CIF (18 ch)
MSE-LIF (20 ch)
ME-SXR (40 ch)
Midplane tangential bolometer array (16 ch)

Turbulence/Modes Diagnostics

Poloidal FIR high-k scattering (installed in 2016)
Beam Emission Spectroscopy (48 ch)
Microwave Reflectometer,
Microwave Interferometer
Ultra-soft x-ray arrays – multi-color

Energetic Particle Diagnostics

Fast Ion D_α profile measurement (perp + tang)
Solid-State neutral particle analyzer
Fast lost-ion probe (energy/pitch angle resolving)
Neutron measurements
Charged Fusion Product

New capability,
Enhanced capability

Edge Divertor Physics

Gas-puff Imaging (500kHz)
Langmuir probe array
Edge Rotation Diagnostics (T_i, V_ϕ, V_{pol})
1-D CCD H_α cameras (divertor, midplane)
2-D divertor fast visible camera
Metal foil divertor bolometer
AXUV-based Divertor Bolometer
IR cameras (30Hz) (3)
Fast IR camera (two color)
Tile temperature thermocouple array
Divertor fast eroding thermocouple
Dust detector
Edge Deposition Monitors
Scrape-off layer reflectometer
Edge neutral pressure gauges
Material Analysis and Particle Probe
Divertor VUV Spectrometer

Plasma Monitoring

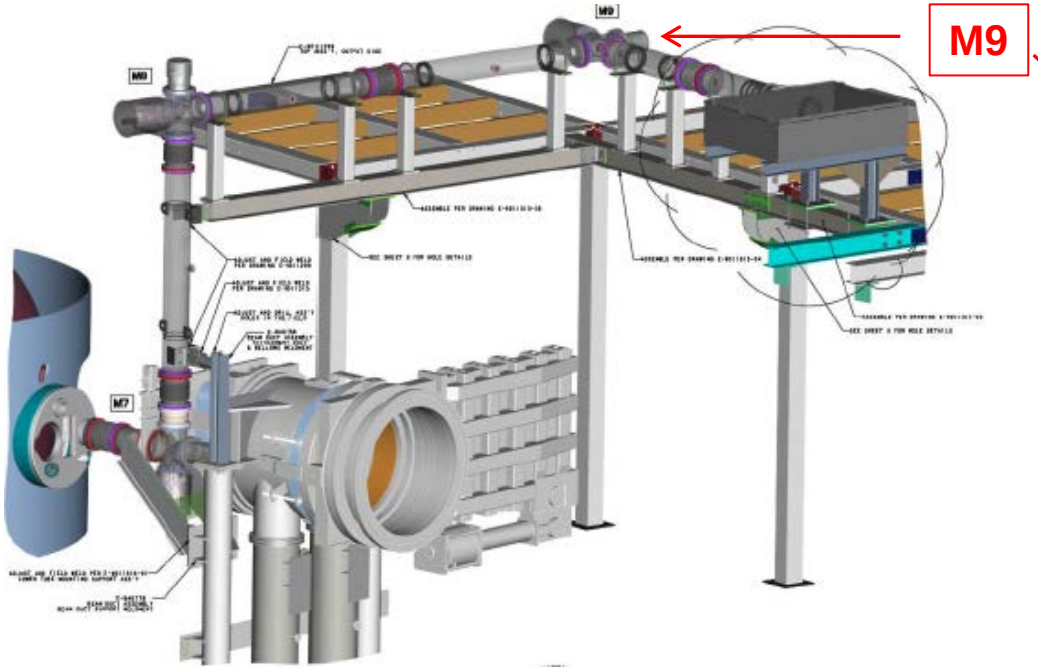
FIReTIP interferometer
Fast visible cameras
Visible bremsstrahlung radiometer
Visible and UV survey spectrometers
VUV transmission grating spectrometer
Visible filterscopes (hydrogen & impurity lines)
Wall coupon analysis

Multi-Pulse Thomson Scattering System

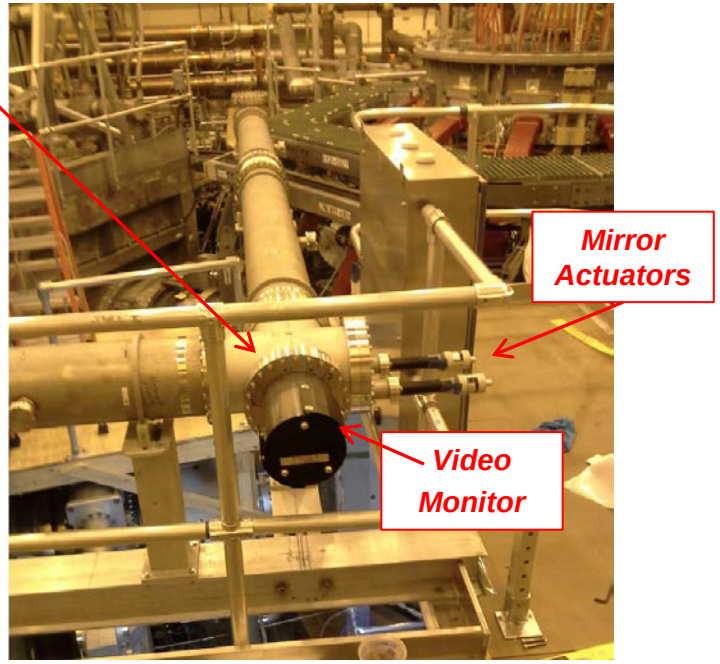
New pulse burst MPTS system being prepared

- **Realignment of MPTS nearing completion**
- **42 spatial channels – improved spatial resolution in pedestal**
- **Plan to have MPTS ready for calibration in May, 2015**
- **Pulse burst MPTS (Early Career Research Proposal Award) to be available for FY 2016 The 2nd year progress report submitted.**

MPTS laser exit flight tube



Exit flight tube installed

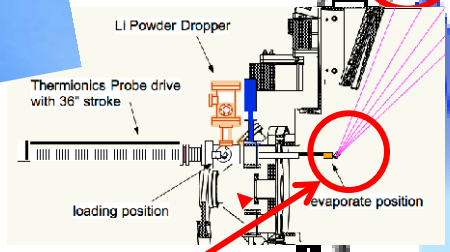


Comprehensive Boundary Physics Tools

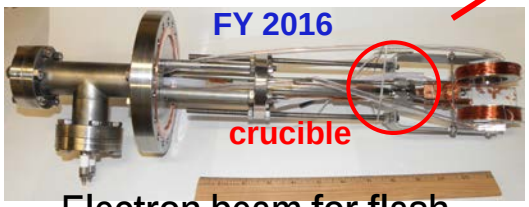
Boronization, Lithium Evaporators, Granule Injector, High Z tiles

Lithium Evaporator (LITERs)

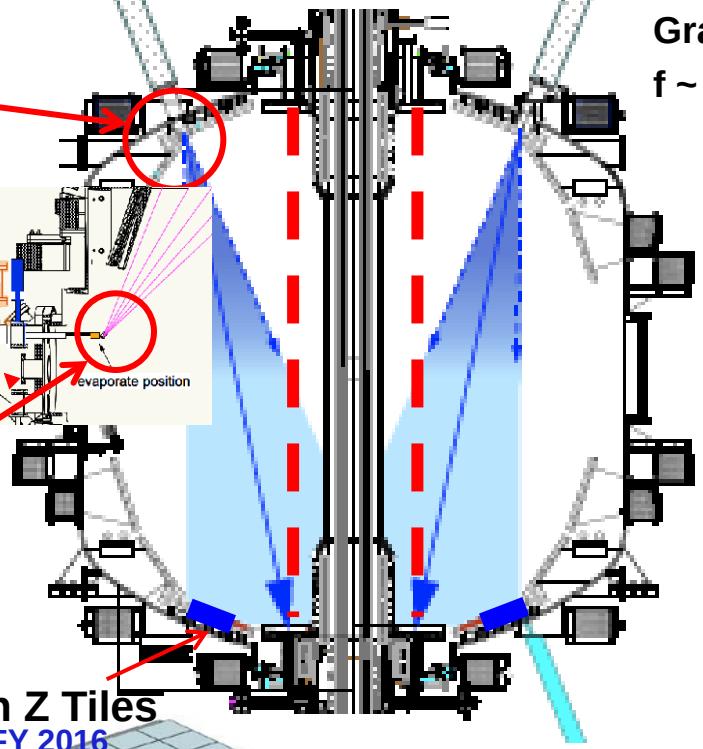
LITERs



Upward Li evaporator

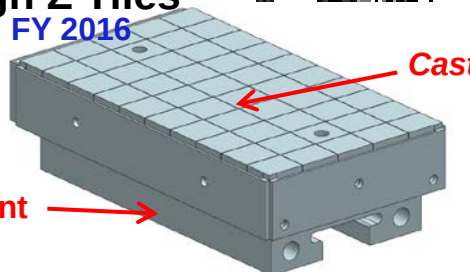


Electron beam for flash evaporation



High Z Tiles

FY 2016

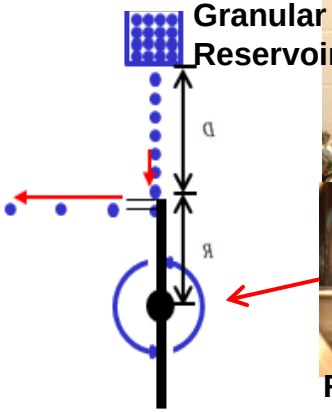


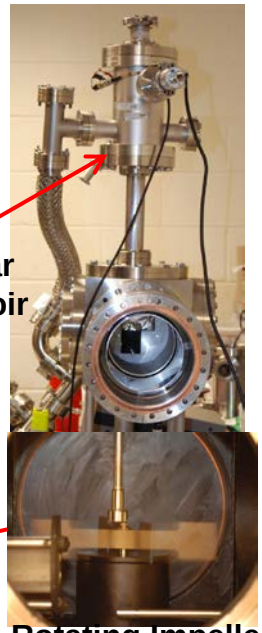
Granule injector (GI) for ELM pacing

Successfully tested on EAST and DIII-D

Granules: Li, B_4C, C

f ~ up to 500 Hz



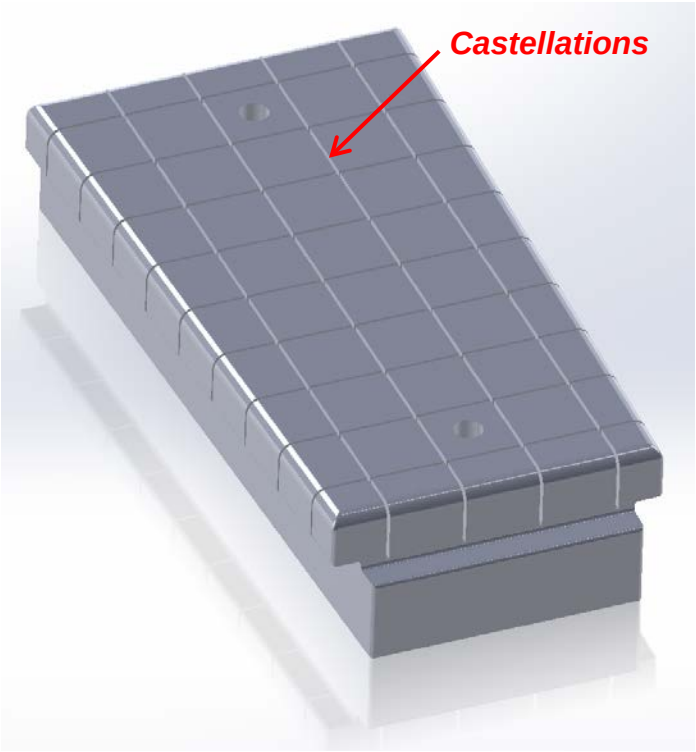


Boronization System

dTMB Gas Cabinet.

High-Z Tile Design Progressing
(plan to be ready by Jan. 2016)

- **WAF (work authorization form) is complete, waiting for review & signature**
- **WP (work package) Form is complete**
- **System Design Document (SDD) 1st draft is complete, a review meeting planned in May.**
- **Initial tile analysis is 75% complete**
  - **Thermal, EM & Structural, Combined Load Case**
  - **Will produce a calculation sheet.**
- **After analysis complete, a CDR/Manufacturing Readiness Review (MRR) will be held in May**
  - **Will present design & analysis results to determine material selection & lead the way for raw material selection & purchase (long lead item).**
  - **This will also serve to fully define the project's scope.**

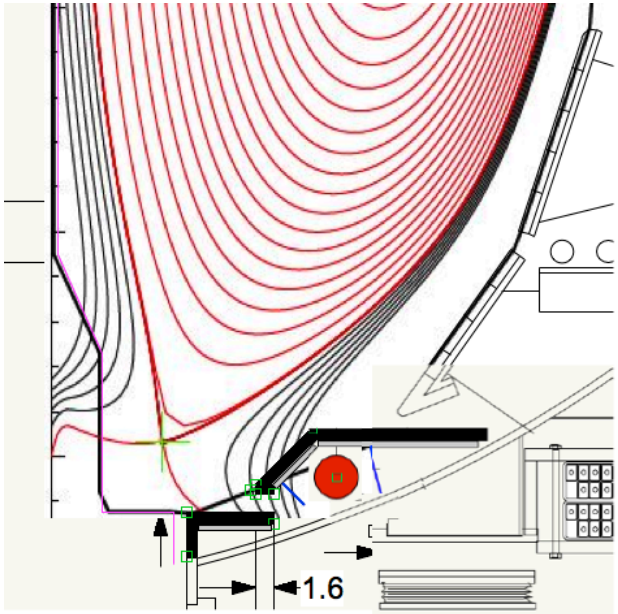


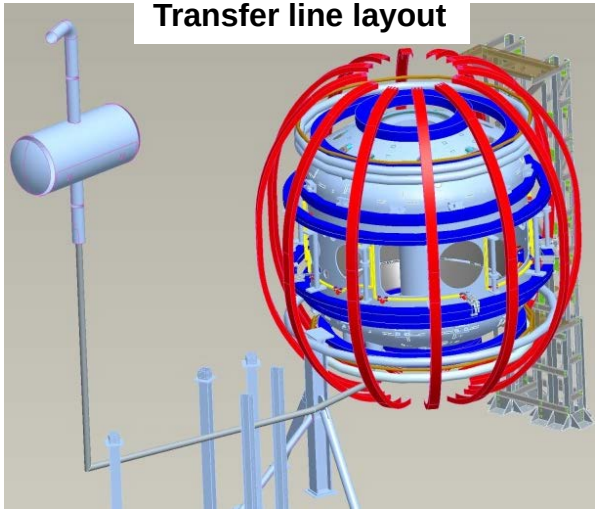
K. Tresemer

Divertor Cryo-pump Physics Design Activities Started

Develop engineering design and cost/schedule this year

- **Several options for the cryo feed line considered and made some key decisions:**
  - **The size of the liquefier determined.**
  - **Bay“D” bottom port identified as the candidate access port for the LN/LH feedthrough, which allows us to finalize the route for the transfer lines.**
- **We will be starting the divertor conceptual design.**
- **Design review schedule to follow this outline:**
  - **System level CDR soon (mid summer).**
  - **Break out PDRs and FDRs for the other elements as needed to support procurements and installations (cost and schedule).**
  - **Hold integrated system FDR prior to commissioning.**
  - **Liquid He system is identified as a long lead item ~ 18 months.**

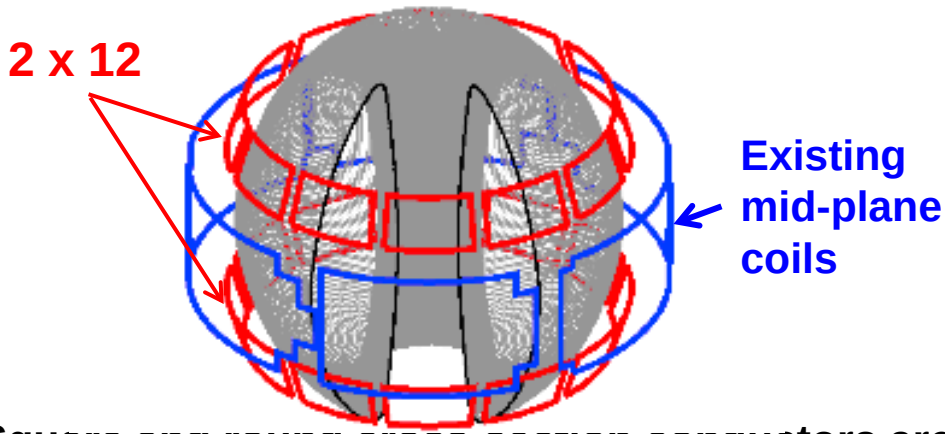




NCC Coils Design Activity Started

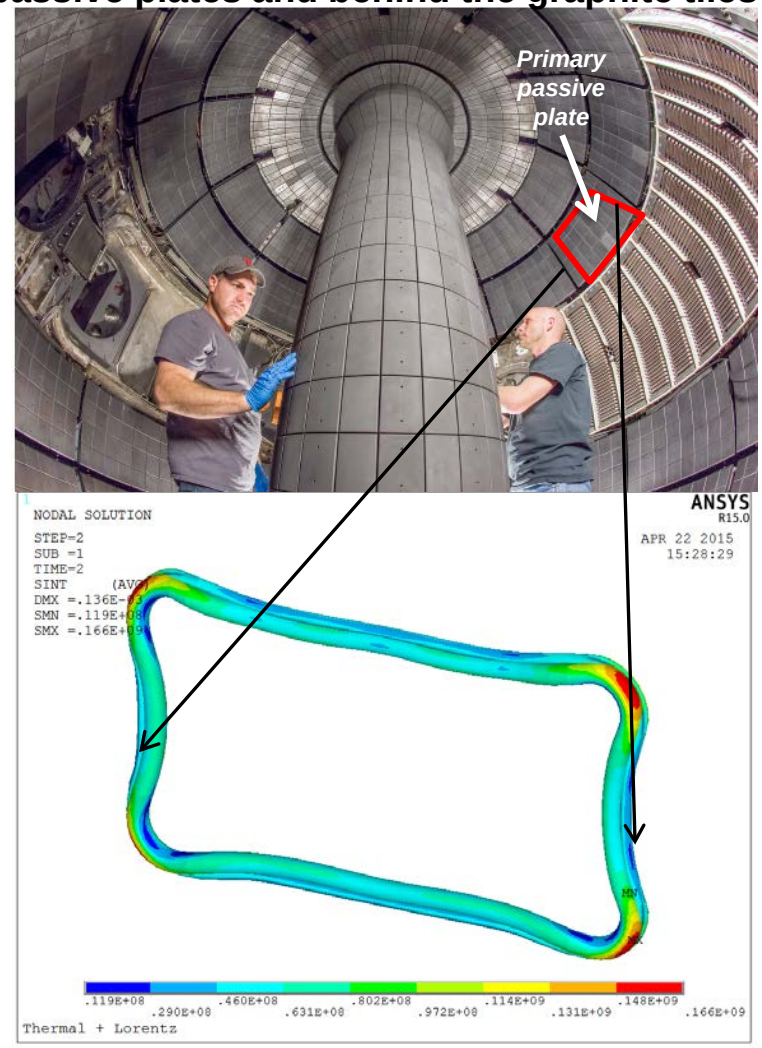
Develop engineering design and cost/schedule this year

NCC = Non-axisymmetric Control Coil



- **Square and round cross-section conductors are considered. The selection criteria include thermal capability, manufacturability, impact on interfacing objects, fabrication lead time and cost.**
- **Helium and water cooling systems are being quantified. Water can cool faster but maybe riskier for use inside the vacuum vessel.**
- **A WAF estimate (cost and schedule) will be prepared as part of the CDR which is targeted for September 2015.**

NCC to be installed in front of the primary passive plates and behind the graphite tiles



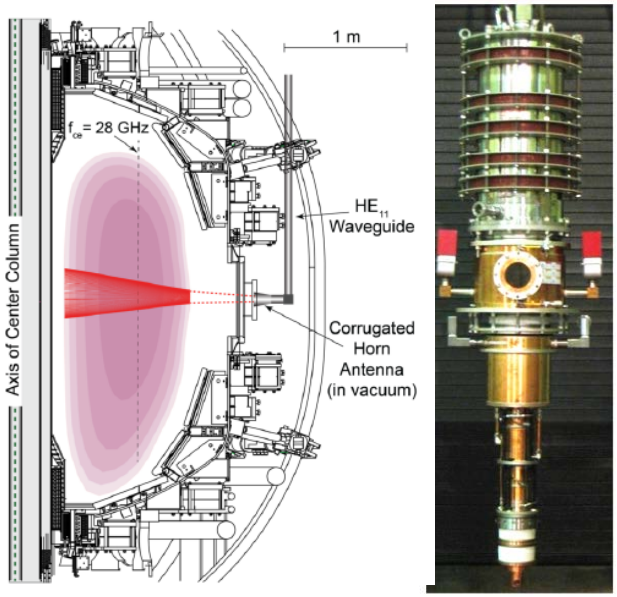
Good progress made in design and analysis

28 GHz ECH System Design Activity Started

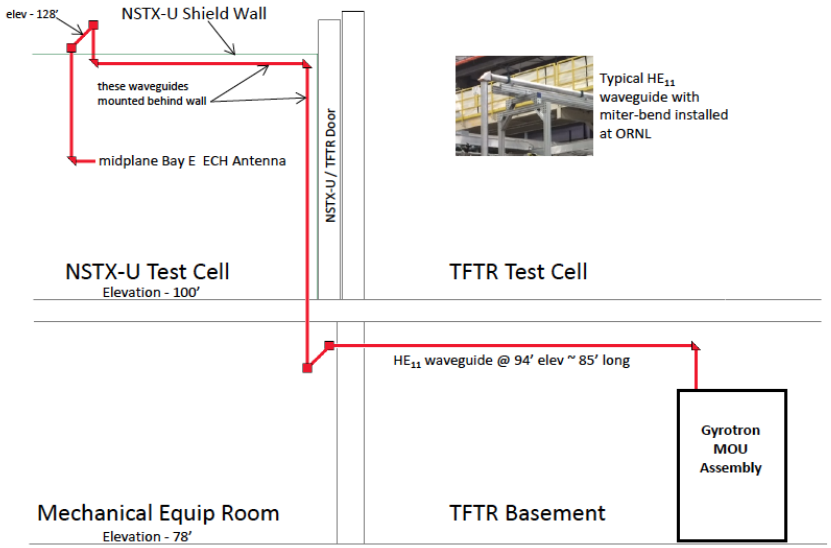
Develop engineering design and cost/schedule this year

- **CHI can form a 200-400 kA seed plasma, but it is too cold for HHFW absorption.**
- **Use of ECH can "bridge the T_e gap" to where HHFW and then NB current drive can support the ramp and sustain the current – crucial for OH solenoid-free compact STs.**
  - **Good first pass absorption predicted.**
- **Goal of first ECH power in 2017 run with 15% incremental funding.**

28 GHz 1 MW Tube by Tsukuba



Schematic of waveguide run from NSTX-U Test Cell to Gyrotron in TFTR Test Cell Basement



- **Gyrotron will be located in the TFTR basement.**
- **The revised waveguide path passes through the NSTX area floor near the corner of NSTX-TFTR door and South side of the Shield Wall.**
- **A commercial waveguide manufacturer was contacted and expect be able to complete the list of the components we need for our NSTX-U 1+ MW ECH waveguide system.**

NSTX FY 2017 FWP Budget Summary ($M)

Incremental budget enables full 5 year plan implementation

	FY2014	FY2015	FY2016		FY2017				
Budget Cases	BA	BA	Base	Base+15%	Warm Shutdown	Base-5%	Base	Base+10 %	Full/15%
Run Weeks	0	12	14	16	0	12	14	16	16
Facility Ops	$17.02	$31.46	$32.73	$33.28	$24.12	$31.44	$32.36	$32.91	$32.91
Facility Enhancements	$0.86	$6.96	$4.13	$11.53	$0.00	$3.54	$4.11	$8.13	$11.41
CS & 2nd NBI	$23.70	$1.77	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Facility Total	**$41.58**	**$40.19**	**$36.86**	**$44.81**	**$24.12**	**$34.98**	**$36.47**	**$41.04**	**$44.32**
PPPL Research	$10.41	$14.22	$14.42	$14.88	$12.66	$13.66	$14.78	$15.44	$15.44
Collab Diag Interf	$0.40	$2.48	$1.00	$1.10	$0.00	$1.03	$1.03	$1.03	$1.03
Collaborations	$9.95	$9.25	$9.25	$10.18	$7.40	$8.79	$9.25	$10.18	$10.18
Science Total	**$20.76**	**$25.95**	**$24.67**	**$26.16**	**$20.06**	**$23.48**	**$25.06**	**$26.65**	**$26.65**
NSTX-U Total $M	**$62.34**	**$66.14**	**$61.53**	**$70.97**	**$44.18**	**$58.45**	**$61.53**	**$67.68**	**$70.97**
NSTX-U/PPPL Total FTEs	**150**	**158.6**	**141.3**	**152.3**	**107**	**134.1**	**139.4**	**150**	**157.6**

- **FY2015 EXCLUDES ~ $2.2M set aside for GPP**
- **FY2015 Facility Enhancements budget enables implementation of 5 year plan and also includes BASE Program Activities (dTMB & OH Clg Water preheater)**
- **President's base budget in FY 2016 – 2017 enables NSTX-U base operation schedule and perform one five year plan major facility enhancement.**
- **15% incremental budget enables optimal NSTX-U operation and implementation of all three five year plan major facility enhancements.**

Incremental FWP Budget Summary ($M)

Incremental budget enables full 5 year plan implementation

All Values shown in Millions								
		FY15 BASE	FY16 BASE	FY16 +15%	FY17 BASE	FY17I +10%	FY17I +15%	
Increased Run-Week (2)				$0.55		$0.56	$0.56	
Facility Enhancements								Pre-Conceptual Design Estimates
	High Z Tiles	$0.88	$0.32					$1.2
	LDC	$0.82	$3.75		$3.54			$8.1
	ECH	$1.65		$5.70		$2.73	$2.73	$10.1
	NCC	$0.78		$1.70		$1.28	$4.57	$7.0
PPPL Research				$0.46		$0.66	$0.66	
Collab Diag Interf				$0.10				
Collaborations				$0.93		$0.93	$0.93	
TOTAL		$4.13	$4.07	$9.44	$3.54	$6.15	$9.44	

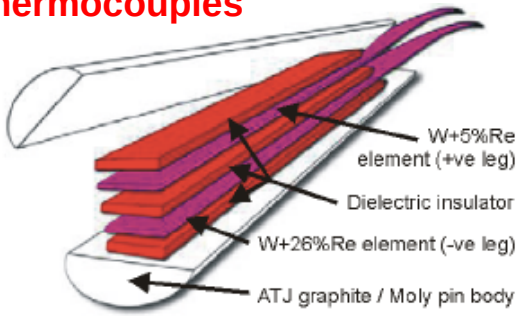
- **The additional run week estimate is ~ $275K/week based on latest estimate of power usage, consumables and overtime once.**
- **The facility enhancements incremental request is based on pre-conceptual estimates for each system. More accurate cost and schedule should be available in September, 2015 after the engineering design work.**
- **For NSTX-U/PPPL research, incremental funds in FY16 and FY 17 will support a post-doc on liquid metal/surface science, to continue the ongoing effort of theory support. In F17, the increased can fund one more post-doc or to support promoting one of our current post-docs to research staff.**
- **In collaborator interface in FY16 was increased 10% to cover additional engineering support for collaborators.**
- **Our collaborators budget was increased by 10% (+$0.93M) in each year.**

Summary of Facility and Diagnostics
Preparation toward NSTX-U Operation

- **NSTX Upgrade Project has entered the final phase. Integrated Systems Test Procedures completed and the plasma operation toward CD-4 is beginning today.**
- **Research operation schedule / commissioning – Presently planning to start research plasma operation in late June, 2015. Working toward minimizing the research prep time (~ 2 months) after CD-4.**
- **Diagnostic Enhancements / Commissioning are progressing well. All of the planned diagnostics should be available during the first year of plasma operations.**
- **Boundary Physics Enhancement / Preparation is going well (lithium and boronization).**
- **Engineering design work has started for the major facility enhancements: high-Z tiles, divertor cryo-pump, ECH, and NCC.**
- **Incremental budget enables full research operation and 5 year plan facility/diagnostic enhancements.**

Enhanced Capability for PMI Research
Multi-Institutional Contributions

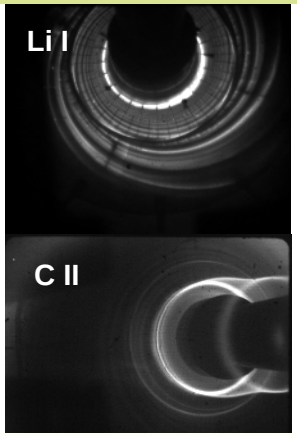
Divertor fast eroding thermocouples



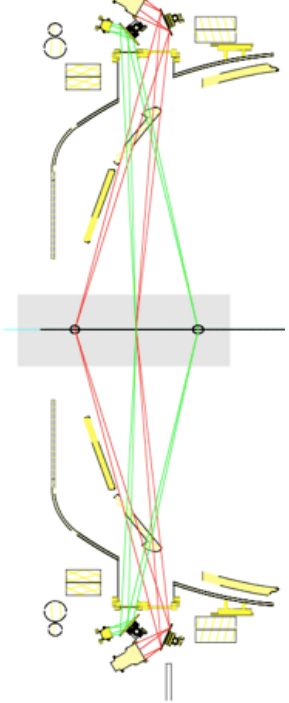
Divertor Imaging Spectrometer

Two fast 2D visible and IR cameras with full divertor coverage

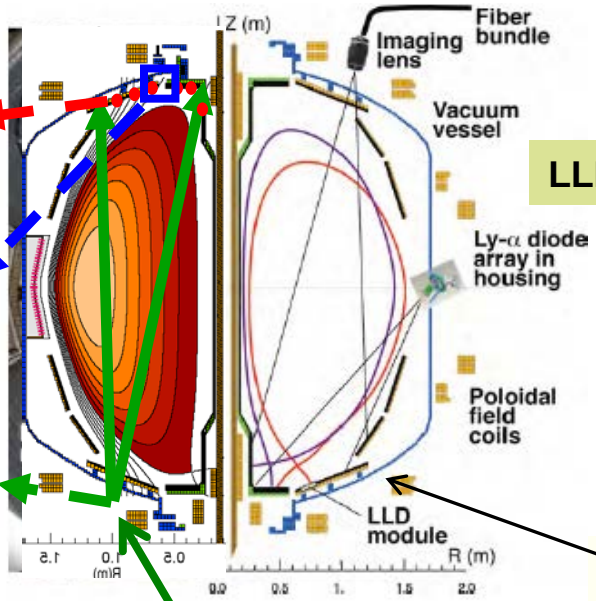
LLNL, ORNL, UT-K



Lithium CHERS

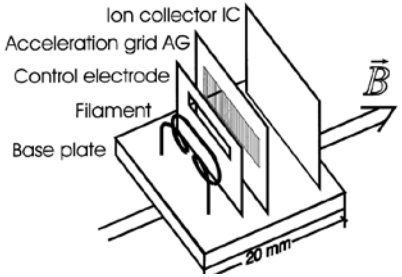


ORNL

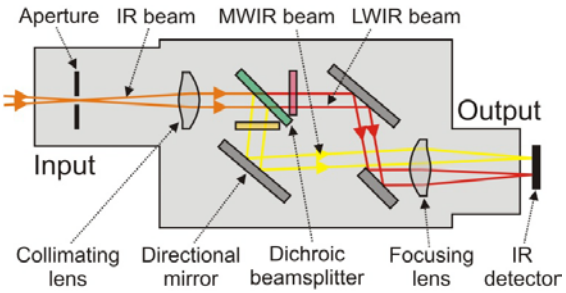


LLNL

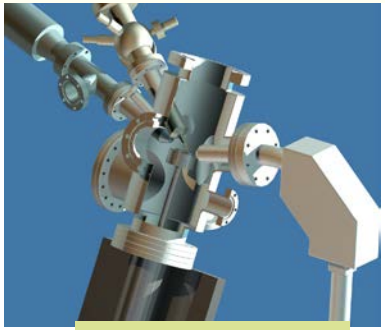
Divertor fast pressure gauges



Dual-band fast IR Camera



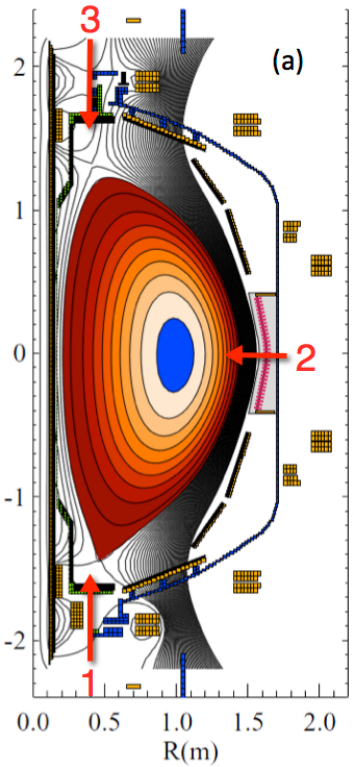
MAPP probe for between-shots surface analysis – Tested in LTX



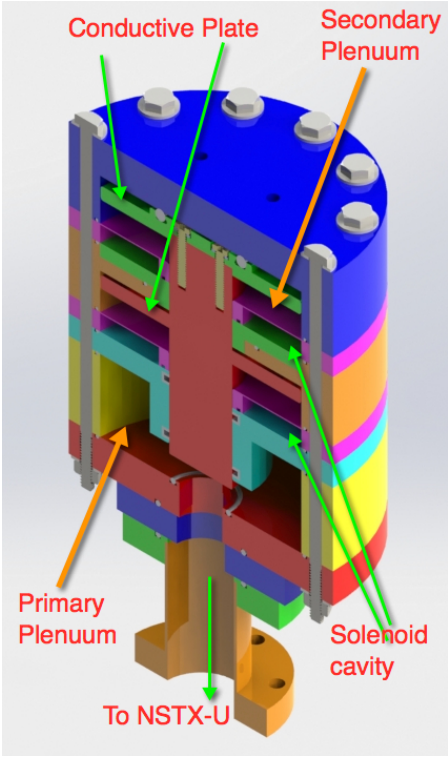
U. of Illinois

Disruption and Plasma Control Tools for NSTX-U

Massive gas injection system for disruption mitigation study

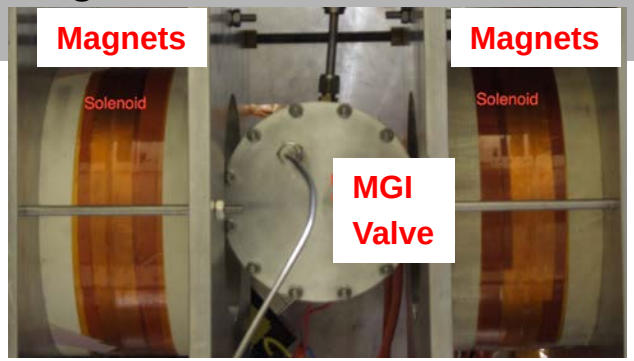


NSTX-U MGI Valve



- **Massive gas injector system installed at multi-poloidal location with identical injection set-up.**
- **A new double solenoid MGI design (zero net J x B torque) based on the ORNL ITER MGI design.**

MGI also being tested on the U. Washington test stand with magnetic field.



FY 2015-16:

- **Multi-poloidal location massive gas injector system for disruption mitigation will be implemented to test the efficiency vs location.** U. Washington
- **A Real-Time Velocity (RTV) diagnostic will be incorporated into the plasma control system for feedback control of the plasma rotation profile.**

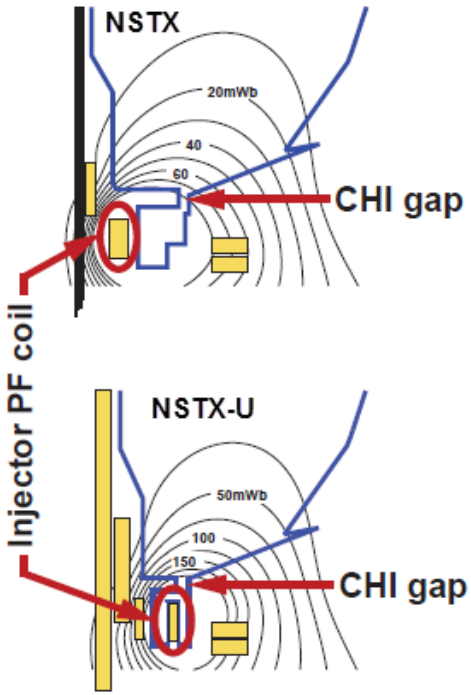
Solenoid-free start-up in support of ST-FNSF

NSTX-U CHI configuration permits ~ 400 kA level start-up

CHI Start-Up

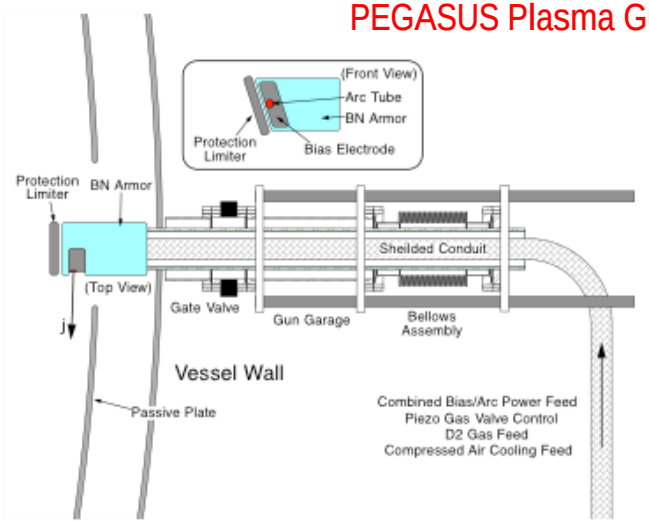
- Inj. Flux in NSTX-U is about 2.5 times higher than in NSTX
- NSTX-U coil insulation greatly enhanced for higher voltage ~ 3 kV operation

U. Washington



Point Source Being Developed

PEGASUS Plasma Gun



U. Wisconsin

FY 2015 - 2016 Non-Inductive Start-up Systems Design for Post-Upgrade Operations

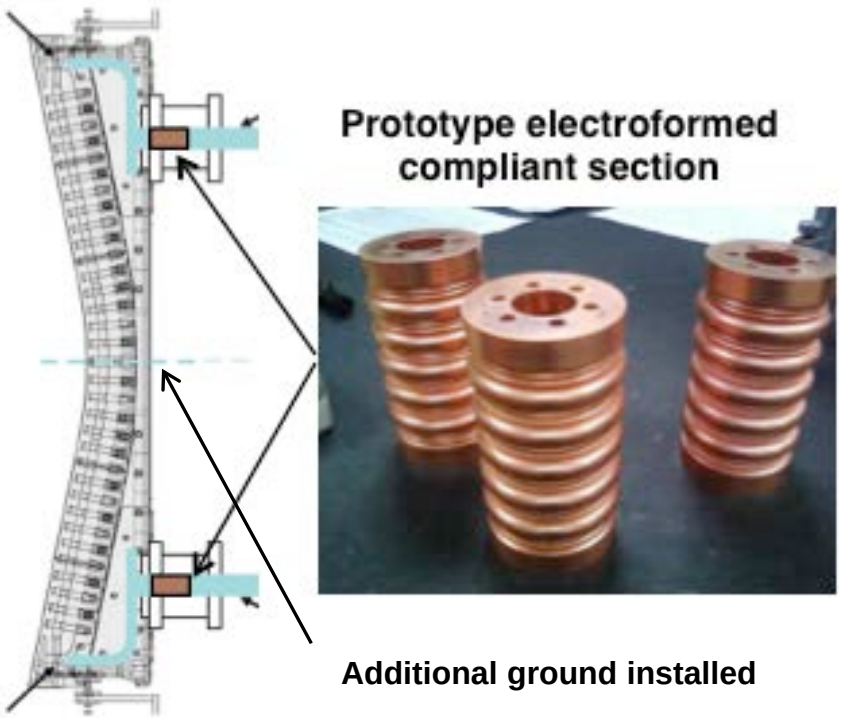
- **CHI will start with the present 2 kV capability then enhanced to ~ 3 kV higher voltage as needed.**
- **PEGASUS gun start-up producing exciting results Ip ~ 160 kA. The PEGASUS gun concept is technically flexible to implement on NSTX once fully developed. High voltage gun for the NSTX-U will be developed utilizing the PEGASUS facility in collaboration with University of Wisconsin.**

HHFW to Support Current Ramp-up Research

Efficient electron heating and CD even at low Ip

New Compliant Antenna Feeds

Allow HHFW antenna feedthroughs to tolerate 2 MA disruptions



- Prototype compliant feeds tested to 46 kV in the RF test-stand. Benefit of back-plate grounding for arc prevention found.
- RF diagnostics also installed.

Antennas were re-installed with the new feeds and back-plate grounding

Transmission lines being installed & tuned.

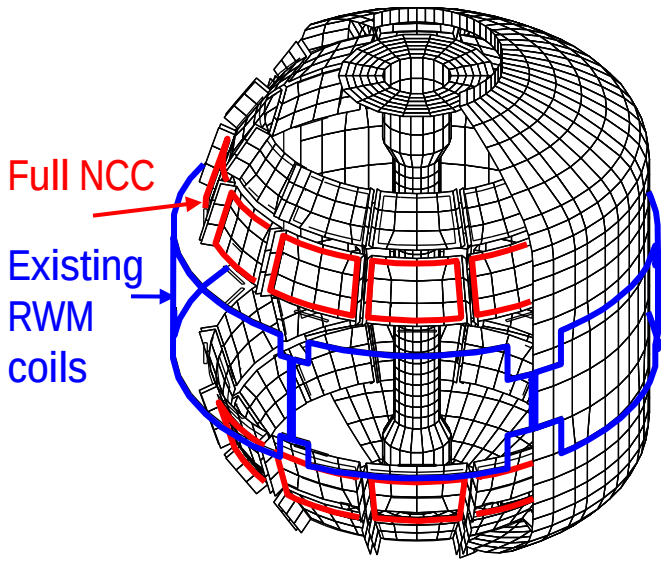
Remaining tasks: Energize RF power supplies in May to be ready by June.

Higher B_T should improve heating efficiency

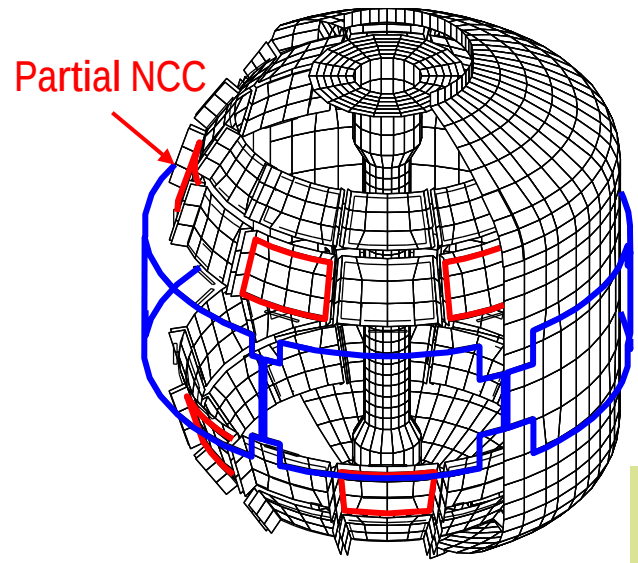
Flexible Mid-Plane Feedback Coils for MHD Studoes

NCC will greatly enhance MHD physics studies and control

Full toroidal NCC array (2 x 12)



Partial toroidal NCC array (2 x 6)



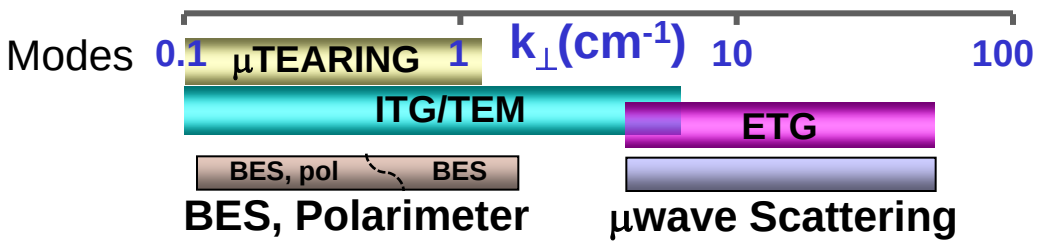
Columbia U
General Atomics

- **6-channel Switching Power Amplifier (SPA) powers independent currents in existing EFC/RWM and NCC coils.**
- **NCC (a facility enhancement) can provide various NTV, RMP, and EF selectivity with flexibility of field spectrum (n ≤ 6 for full and n≤ 3 for partial)**

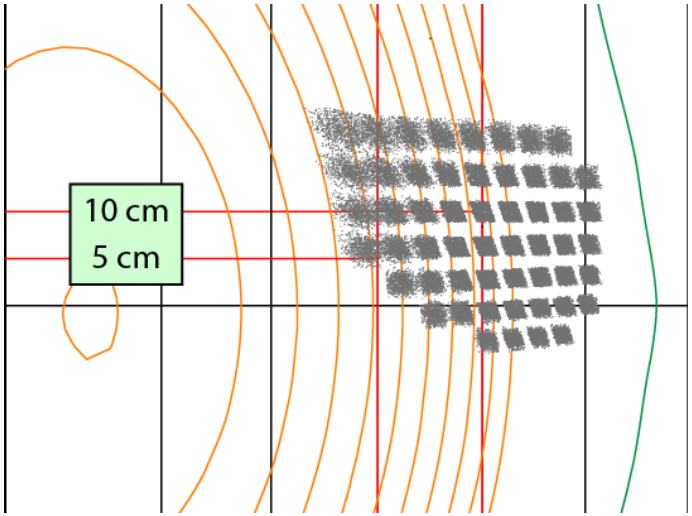
Base – Engineering design work on NCC to be performed in 2015. 10% incremental funding enables start of procurement in FY 2016 and installation in FY 2017 to be available in FY 2018.

Enhanced turbulence diagnostics will give comprehensive view

MSE-CIF and MSE-LIF will provide Er information



48 ch BES available for NSTX-U (24 ch BES available in 2011)

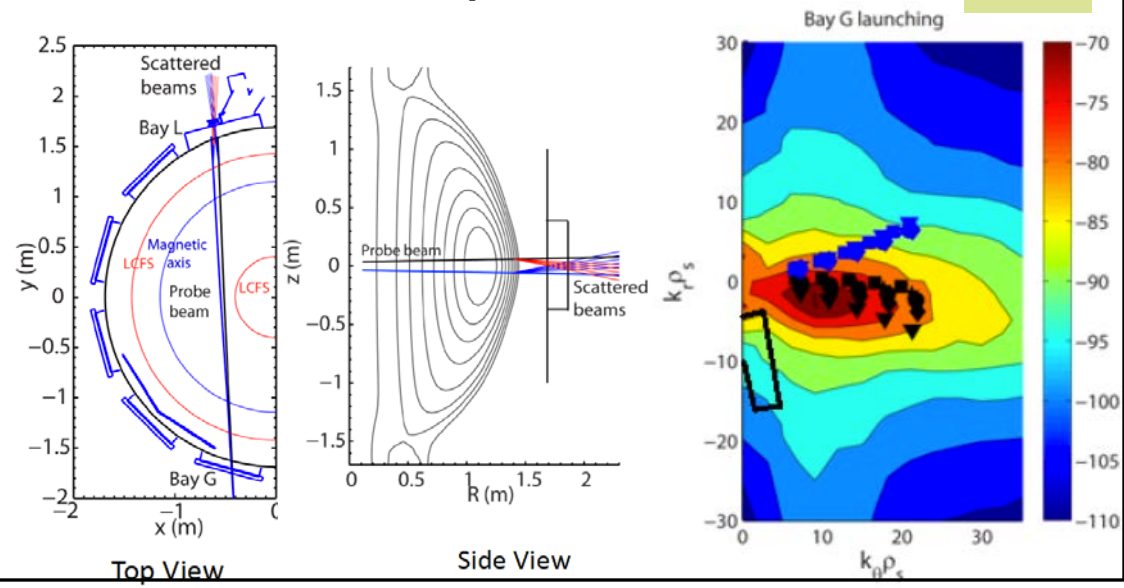


- **New 2-D fiber holder will provide better radial and poloidal coverage of r/a~0.4-SOL region**

U. Wisconsin

New high-k scattering system for allowing 2-D k spectrum in FY 2016

UCD



Preliminary magnetic fluctuation measurement concept under development at DIII-D; also initial tests performed on MAST. Proto-type on NSTX-U.

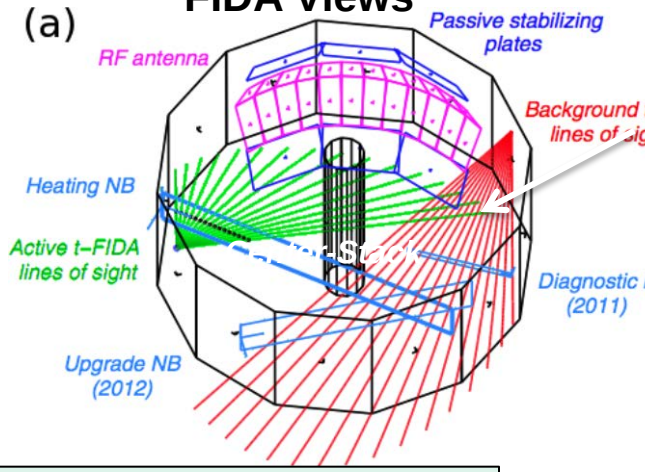
UCLA

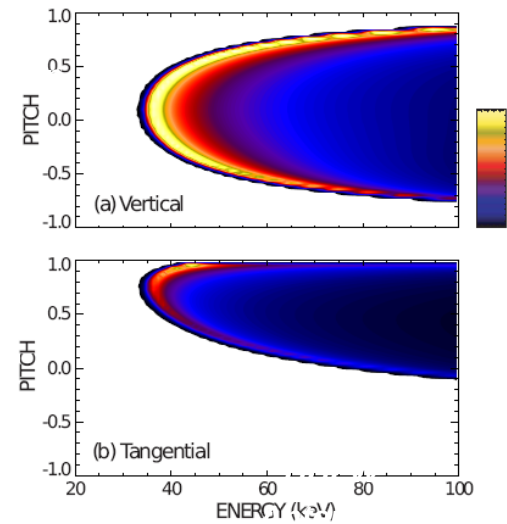
Enhanced FIDA will measure NBI distribution function
For NBI fast ion transport and current drive physics

Fast Ion D-Alpha Diagnostics

- Both vertical (perpendicular) and new tangential (parallel) FIDA systems are ready.
- Both FIDA systems have 10 ms, 5 cm, ≈ 10 keV resolutions.

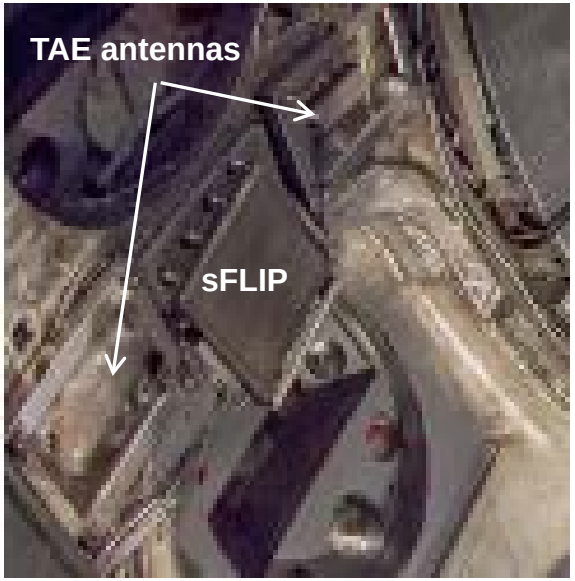
FIDA Views





FY 2015 - 2016 Energetic Particle Conceptual Design and Diagnostic Upgrade

- SS-NPA enhanced due to removal of scanning NPA (neutral particle analyzer). UCI
- sFLIP is installed for lost ion measurements
- Active 2 X 2 TAE antennas installed. Initially passive spectroscopy then active excitation at few kW level.
- Proto-type charged fusion product (CFP) profile diagnostic to be installed this year. FIU



NSTX-U

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NSTX-U Program - FY2015 Q2 Report

Coll of Wm & Mary
Columbia U
CompX
General Atomics
FIU
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Lehigh U
Nova Photonics
Old Dominion
ORNL
PPPL
Princeton U
Purdue U
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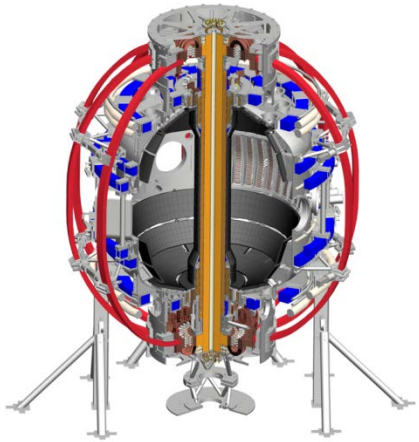
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Tennessee
U Tulsa
U Washington
U Wisconsin
X Science LLC

Jon Menard, Masa Ono
For the NSTX-U Team

PPPL and FES
April 23, 2015



Culham Sci Ctr
York U
Chubu U
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Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
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TRINITI
Chonbuk Natl U
NFRI
KAIST
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Seoul Natl U
ASIPP
CIEMAT
FOM Inst DIFFER
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep

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

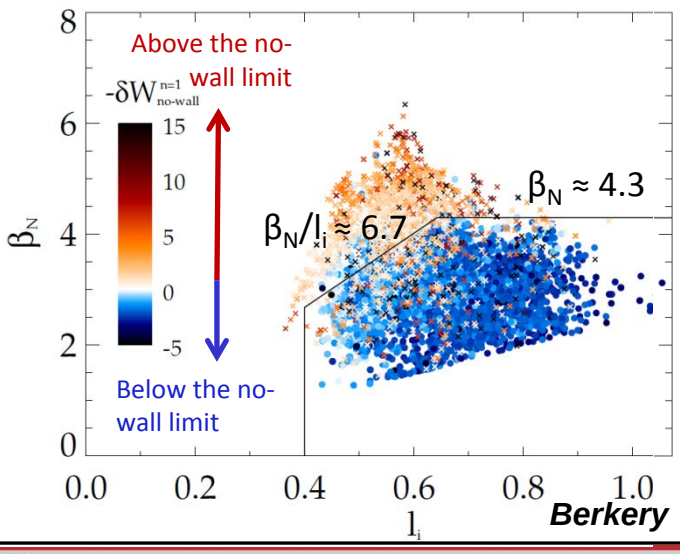
Outline

- Research highlights for Q2
- Preparation for 2015 run campaign

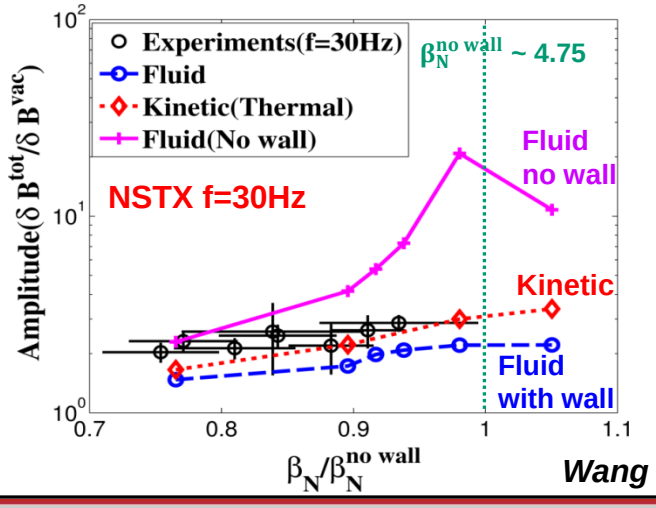
Highlights of the Macroscopic Stability TSG for FY15-Q2

- Seven leadership positions in the 2015 FES Workshops, five presentations at the Transients Workshop, many whitepapers
- 37 experimental proposals received for FY15 NSTX-U run, 20 of those awarded 10 run days in priorities 1, 2 and cross-cutting time
- Disruption Prediction, Avoidance, and Mitigation Working Group established to understand and reduce disruptions in NSTX-U
- Two posters presented at the Sherwood Fusion Theory Conference
- One paper submitted to PPCF and one accepted by PRL

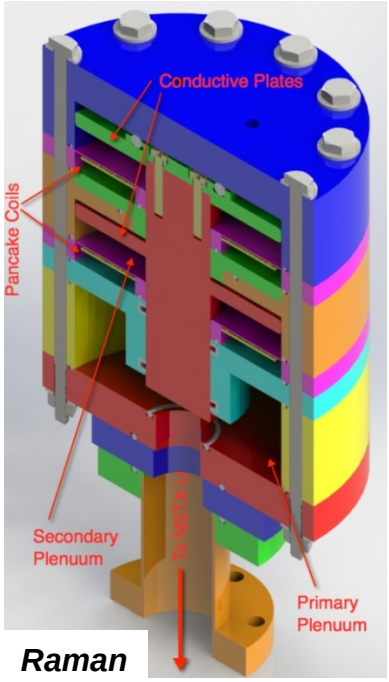
Expansive DCON calculations confirm previous assessment of the NSTX ideal n=1 no-wall limit



Kinetic plasma response resolves issue of disagreement between fluid response and NSTX experiments near/above no-wall limit



ITER "Proto-Type-like" MGI Valve Developed, Tested, and Delivered to NSTX-U to Support FY15 MGI Studies



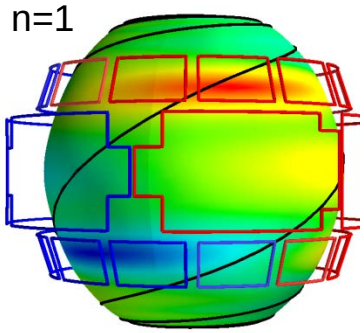
NSTX-U Macroscopic Stability group has very strong participation in FES Community Planning Workshops

- **Leadership:**
  - D.P. Brennan: co-lead of Transients panel "Preventing device damage from disruptions" and of Integrated Simulations panel "Disruption prevention, avoidance, and mitigation"
  - S.A. Sabbagh: lead of Transients sub-panel "Disruption Prediction"
  - D. Gates: co-lead of Transients sub-panel "Disruption Avoidance" (also S.A. Sabbagh, S.P. Gerhardt, and E. Koleman member of that sub-panel)
  - S.P. Gerhardt: member of Integrated Simulations panel "Disruption prevention, avoidance, and mitigation"
  - R. Raman: member of Transients sub-panel "Disruption Mitigation"
  - J.-K. Park: member of Transients sub-panel "ELM Suppression or Mitigation with Resonant Magnetic Perturbations"
- **Transients Workshop, March 30 – April 1, 2015**
  - S.A. Sabbagh: "Disruption Prediction sub-panel status"
  - Z.R. Wang: "The drift kinetic and rotational effects on determining and predicting the macroscopic MHD instability"
  - D.P. Brennan: "Outstanding theory and modeling needs for validated predictive modeling of disruptions"
  - R. Raman: "Outstanding Issues for ITER and FNSF, NSTX-U MGI and EPI, Plans and Key Contributions to Mitigation"
  - J.-K. Park: "Filling the gaps in physics understanding of resonant magnetic perturbations with spherical tokamaks"
- **White Papers** (see above + below)
  - S.A. Sabbagh et al., "A National Initiative for Disruption Elimination in Tokamaks (Brief summary)"
  - J.W. Berkery and S.A. Sabbagh: "Disruptivity Reduction Plan for NSTX-U, Including Characterization of Causes and Implementation of Kinetic Stability Theory Models"
  - S.P. Gerhardt and J.W. Berkery "Improving Understanding of 3D Disruption Halo Currents"
  - Many more…

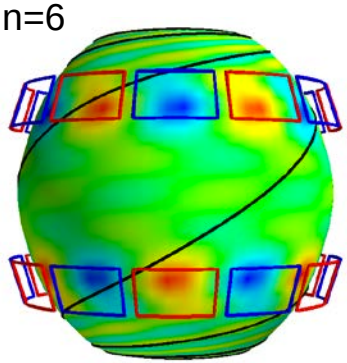
NCC Physics Design nearing completion: Optimization for NTV braking has been performed with IPEC coupling matrix

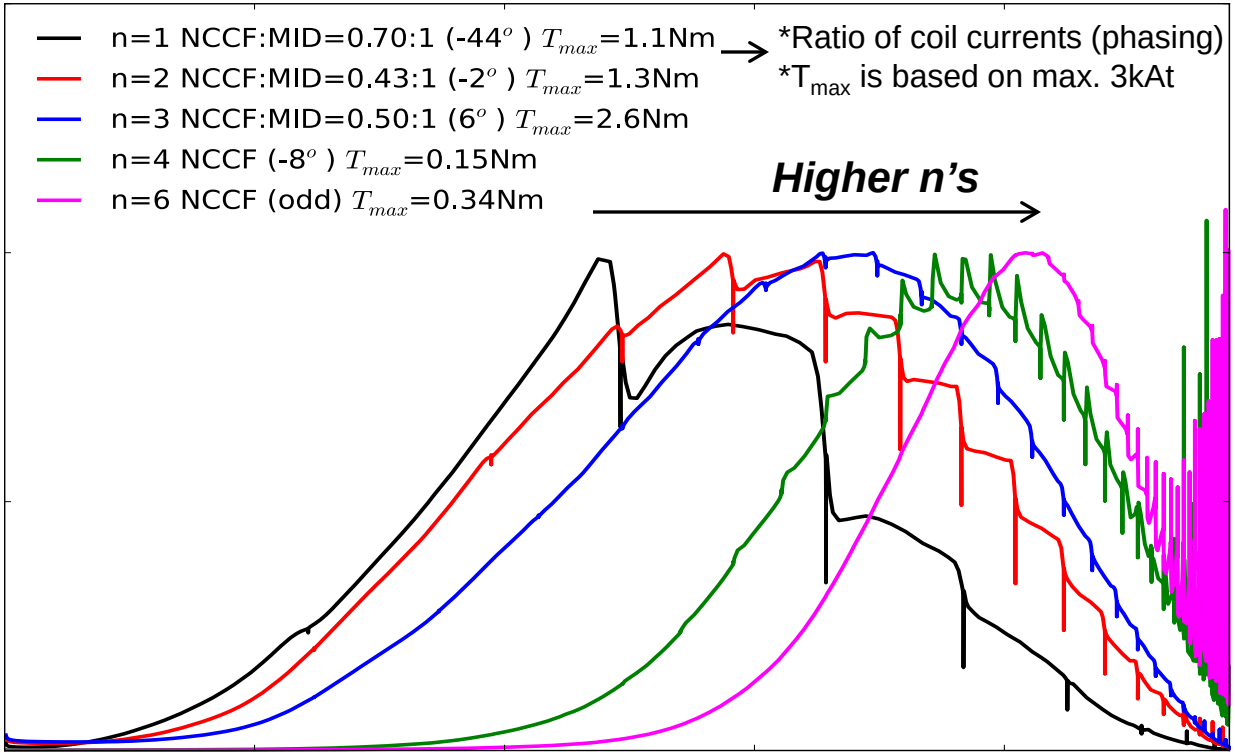
- NCC and midplane coils can be combined to remove the dominant resonant modes up to the second, giving the optimized NTV for core
  - NCC 2x12 provides n=1,2,3,4,6 optimized NTV, and 2x6 provides n=1,2,6
  - Optimized NTV can be used to control local torque with minimized resonance

n=1



n=6

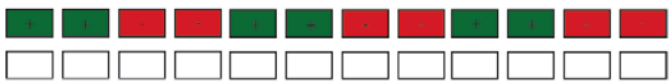
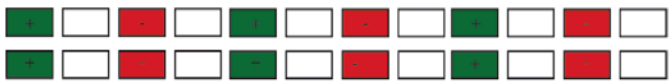
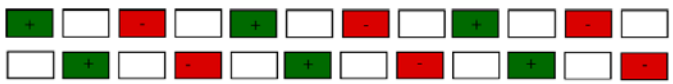


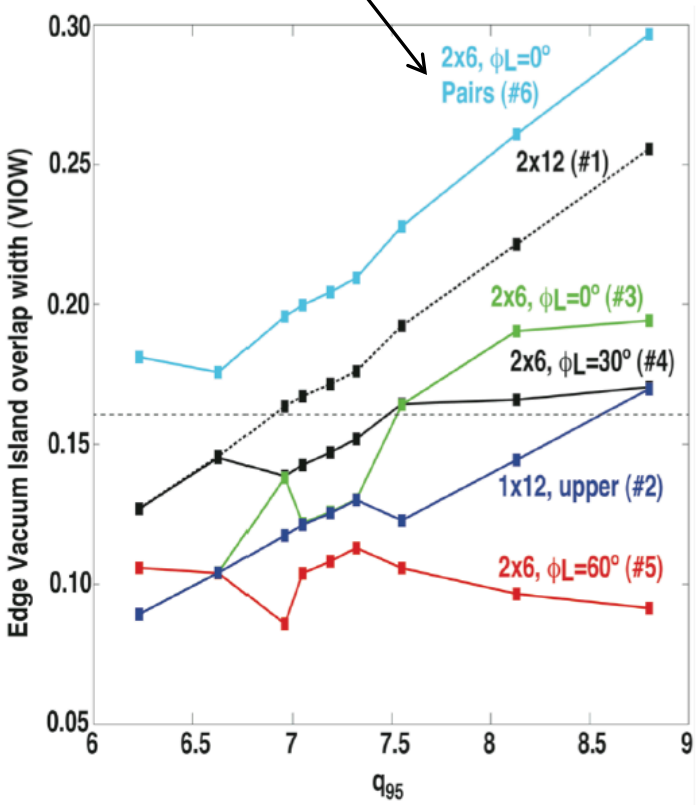


Study of RMP characteristics with NCC extended with TRIP3D (T. Evans, GA) – 2x12 NCC (and 2x7) favorable for RMP

- Vacuum Island Overlap Width (VIOW) analysis shows full NCC 1kAt can produce sufficient VIOW in a wide range of q_{95}, but partial NCC needs more currents with low q_{95} targets
  - Also shows 2x7, with "one" more additional array upon partial NCC can provide the greater VIOW by toroidal coupling (n=2,4,9)

NCC Configurations Used for the plots Shown in Figures 1 and 2

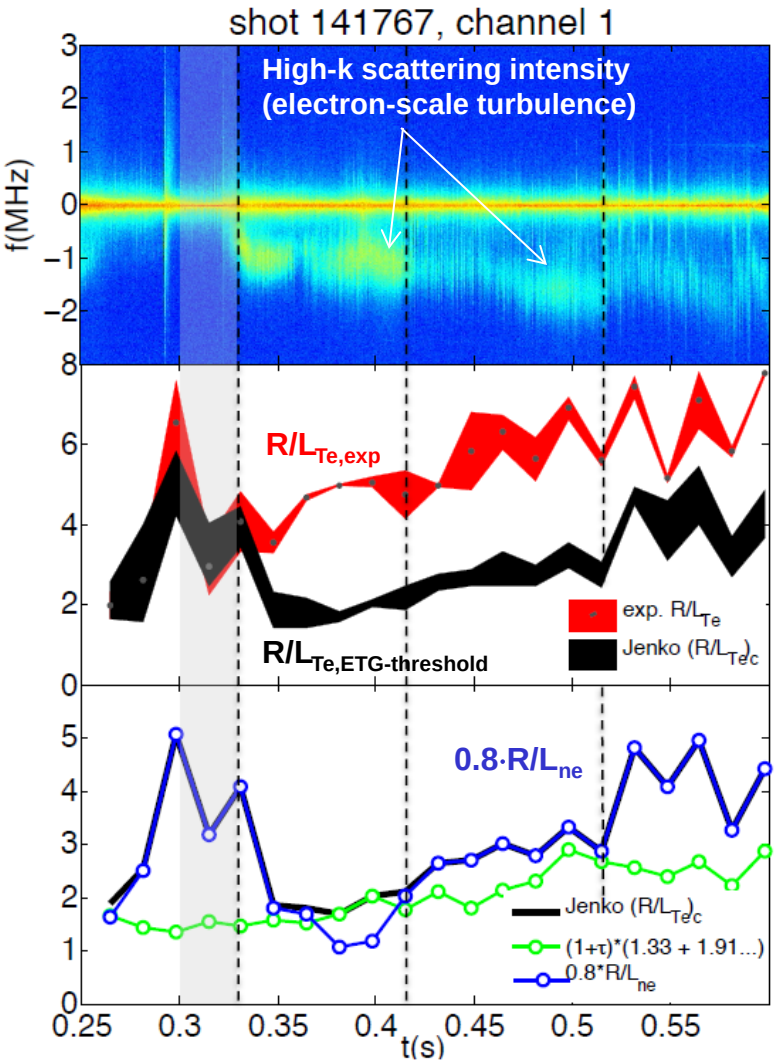
#	Description, Color	NCC Configuration Layout
1	2x12 **dashed black line**	
2	1x12, upper **solid blue line**	
3	2x6, ϕ_L=0° **solid green line**	
4	2x6, ϕ_L=30° **solid black line**	
5	2x6, ϕ_L=60° **dashed red line**	
6	2x7, ϕ_L=0° Pairs **solid light blue line**	



Transport and Turbulence group investigating ST and AT transport through wide range of collaborations

- Collaboration on NSTX high-k analysis and ETG simulations (Ruiz, White - MIT; Ren, Guttenfelder – PPPL)
  - Observed linear and nonlinear stabilization effects of density gradient on electron-scale turbulence in a set of NSTX H-modes; MIT student masters thesis and paper in preparation
- Investigating role of Kelvin-Helmholtz and collisional TEM turbulence in NSTX confinement (Wang, PPPL theory)
  - Invited talk at IAEA-TM on Theory of Plasma Instabilities
- Collaboration on DIII-D transport analysis (Guttenfelder, Grierson – PPPL; Ernst – MIT; Burrell, Rhodes, Garofalo, Staebler – GA)
  - Investigating role of rotation and finite beta in deep core of QH-modes and high-β_p H-modes; to be presented at US-EU TTF 2015 (Salem, MA)
- New UCLA graduate student (S. Tang, w/ N. Crocker, from Dec. 2014), investigating GAE & CAE activity and their role in core energy transport in NST
- Additional papers published, in review
  - IAEA NSTX Overview paper [Kaye, Nucl. Fusion **55**, 104002 (2015)]
  - Observation of nonlocal turbulence and transport in NSTX (Ren, Phys. Plasmas, in review)
  - Influence of centrifugal effects on impurity and momentum transport in NSTX (Buchholz, U-Bayreuth collaboration, in team review)
- Contributing to FES Community Planning Workshops 2015 through panel members (Kaye, Tritz) & whitepaper contributions (Guttenfelder)

Inverse correlation between electron-scale turbulence and density gradient related to ETG stabilization



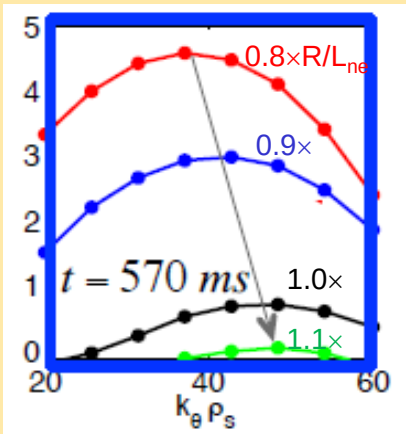
J. Ruiz Ruiz (MIT)

- Early in discharge (t<320 ms), no electron-scale turbulence measured
  - Large density gradient (R/L_{ne}) *linearly* stabilizes ETG ($R/L_{Te,exp} \sim R/L_{Te,ETG\text{-}threshold}$)
- Electron scale turbulence develops & evolves for t>320 ms ($R/L_{Te,exp} > R/L_{Te,ETG\text{-}threshold}$)
  - Turbulence intensity reduced during evolution of discharge, correlated with increasing density gradient → *nonlinear stabilization*

ETG instability weakened & shifted to higher k_θ with increased R/L_{ne}

- Both expected to reduced transport (nonlinear simulations underway)

ETG growth rates (GS2)



Energetic Particle group research has focused on code development & validation, simulations of NSTX data

- Focus on NSTX scenarios with multiple unstable TAEs
  - "Critical gradient" model shows reasonable agreement with experiment *[Gorelenkov, White, IAEA 14]*
    - Comparison with ORBIT simulations under way
  - "Kick" model in TRANSP being tested *[Podestà, NF 2015]*
    - Shows importance of selective phase space EP transport to compute NB-CD
  - Linear & nonlinear M3D-K simulations performed for TAEs, fishbones
    - (Linearly) unstable TAEs from M3D-K compare well with experiment *[Liu, PoP 2015]*
    - Nonlinearly, strong mode-mode interaction results in enhanced EP transport *[Fu, 2015]*
- Theory of chirping AEs is the focus of a collaboration with Univ. Texas at Austin *[Duarte, Berk, Gorelenkov, Sherwood 2015]*
- HYM code revealed new mechanism for energy channeling from NB ions to thermal electrons *[Belova, PRL 2015 (under review)]*
  - May help to explain central electron heating deficit in NSTX NBI shots
- NSTX-U/PPPL is leading two new ITPA-EP activities *[Podestà, ITPA-EP 2015]*
  - Joint Exp't on NB-CD physics
  - Joint Modeling Activity on EP transport studies via reduced models

New "kick" model for fast-ion transport predicts different J_{NB}, ion/electron power split, inferred thermal transport

Nucl. Fusion **55** (2015) 053018 M. Podestà *et al*

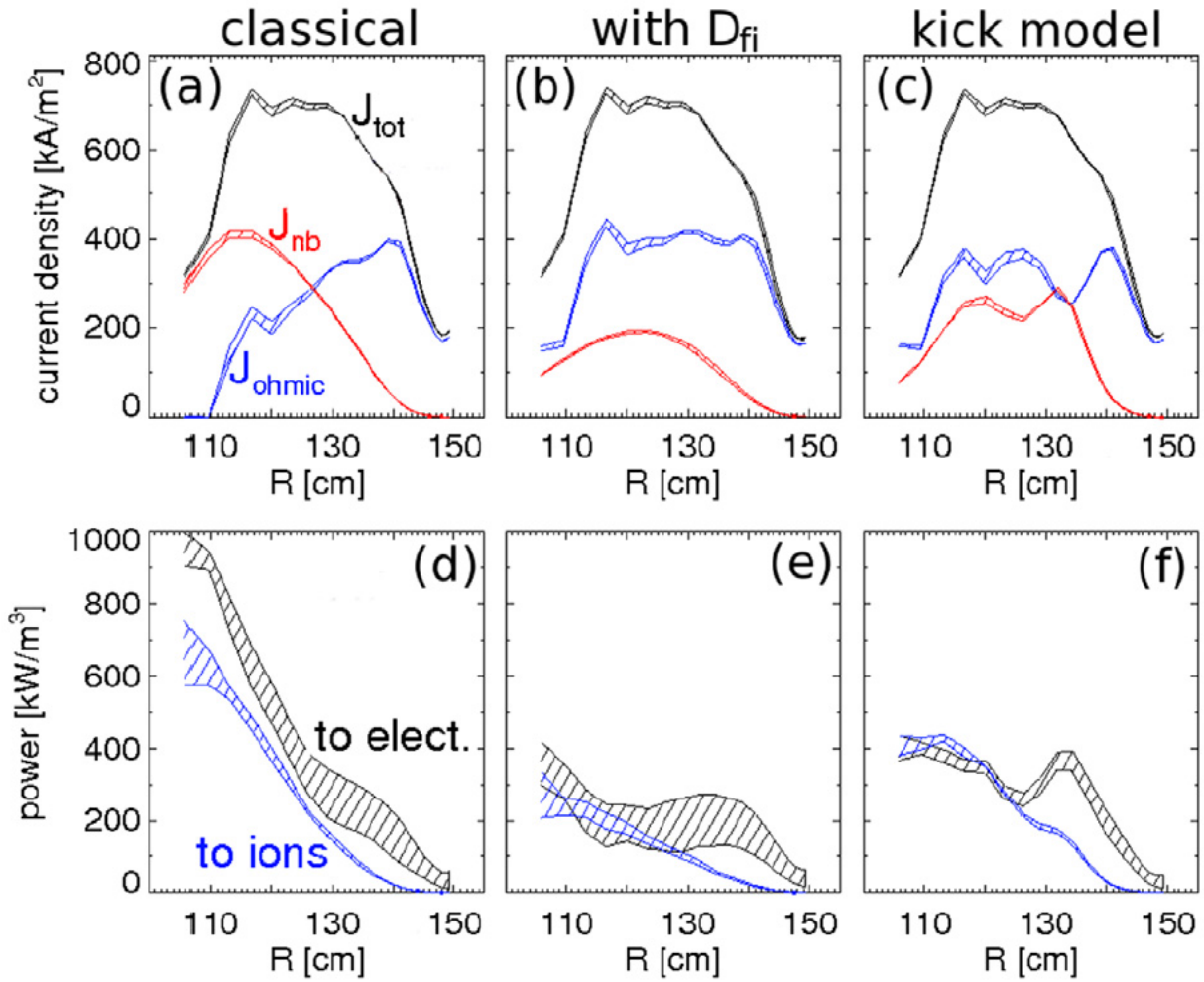


Figure 11. (*a*)–(*c*) Current density profiles calculated by TRANSP with different assumptions for fast ion transport (NSTX #139048). TRANSP results are averaged over $t = 300$–305 ms. (*d*)–(*f*) Total heating power transferred to electrons and ions for the three cases.

NSTX-U Boundary Science Group Activities for Q2 FY15

- Three NSTX-U related talks presented at the Transients Control e-meeting (Mar 30-Apr 2), with several white papers in preparation
- Ten talks to be presented at the PMI workshop (May 4-6), with white papers in preparation
- Two collaborative Lithium related papers
  - New Steady-State Quiescent High-Confinement Plasma in an Experimental Advanced Superconducting Tokamak (J.S. Hu, et. al., Phys. Rev. Letts. 114 (2015) 055001)
  - Enhanced H-mode pedestals with lithium injection in DIII-D (T.H. Osborne, et. al., Nucl. Fusion 2015 at press)
- A guest lecture on principles of magnetic confinement fusion and plasma-wall interactions, including effects of lithium walls in NSTX, presented at Cornell Univ.

Integrated Scenarios Group Activities for Q2 FY15

- Advanced Scenarios: S. Gerhardt + D. Battaglia
  - **Priority #1 → Get NSTX-U operational**
- RF group:
  - Publications:
    - R. J. Perkins et al., "The contribution of RF rectification to field-aligned losses of high-harmonic fast wave power to the divertor in the National Spherical Torus eXperiment," Phys. Plasmas 22, 042506 (2015).
  - Engagement in upcoming FES workshops
    - Two white papers (1 first author + 1 co-author) to boundary workshop
    - Three first-author white papers to integrated modeling workshop in collaboration with RF SciDAC team
- Solenoid-Free Start-up
  - Publications:
    - Paper accepted for publication in FS&T: "Design Description for a Coaxial Helicity Injection Plasma Start-up System for a ST-FNSF (2015)"
      - R. Raman, T. Brown, L.A. El-Guebaly, T.R. Jarboe, B.A. Nelson, J.E. Menard
    - "Plasmoids formation during simulations of CHI in NSTX", submitted to PRL
      - F. Ebrahimi and R. Raman

Outline

- Research highlights for Q2
- Preparation for 2015 run campaign

NSTX-U Science Program Organizational Structure for 2015

NSTX Upgrade Science Program

Project Director
Masayuki Ono

Program Director
Jon Menard
Deputy: Stan Kaye

Collaborators in Science Program Leadership:

1 ORNL
2 University of Wisconsin
3 LLNL
4 UT Knoxville
5 University of Illinois
6 Columbia University
7 Princeton University
8 Johns Hopkins University
9 UC Irvine
10 UC Los Angeles
11 University of Washington
12 MIT

Task Force (TF)

Science Group (SG)

Topical Science Group (TSG)

Physics Analysis
Stan Kaye

Run Coordination
Jon Menard
Stefan Gerhardt (deputy)

Cross-Cutting XMP/XPs

Boundary Science Group
R. Maingi, C.-S. Chang (deputy)

Pedestal Structure and Control
A. Diallo, R. Maingi
Theory/Modelling: J. Canik[1]
University Rep: D. Smith[2]

Divertor and Scrape-Off-Layer
V. Soukhanovskii[3], J.-W. Ahn[1]
Theory/Modelling: D. Stotler
University Rep: O. Schmitz[2]

Materials and PFCs
M. Jaworski, C. Skinner
Theory/Modelling: B. Wirth[4]
University Rep: J.-P. Allain[5]

Core Science Group
S. Kaye, S. Sabbagh[6] (deputy)

Macroscopic Stability
J. Berkery[6], J.-K. Park
Theory/Modelling: S. Jardin
University Rep: D. Brennan[7]

Transport and Turbulence
W. Guttenfelder, Y. Ren
Theory/Modelling: W. Wang
University Rep: K. Tritz[8]

Energetic Particles
M. Podestá, D. Liu[9]
Theory/Modelling: N. Gorelenkov
University Rep: N. Crocker[10]

Integrated Scenarios Group
S. Gerhardt, R. Raman[11] (deputy)

Advanced Scenarios and Control
D. Battaglia, S. Gerhardt
Theory/Modelling: F. Poli
University Rep: E. Kolemen[7]

Solenoid-free Start-up & Ramp-up
D. Mueller, R. Raman[11]
Theory/Modelling: F. Ebrahimi[7]

Wave Heating and Current Drive
R. Perkins, J. Hosea
Theory/Modelling: N. Bertelli
University Rep: P. Bonoli[12]

Particle Control Task Force (FY2015-16)
Leader: R. Maingi, Deputy: J. Canik[1]
Goal: Develop pumping and fueling tools, operating scenarios, and control systems to achieve main-ion and impurity density control for long-pulse

Each TSG will have a leader, deputy, theory rep, and at least 1 university rep to enhance university participation

Successful Research Forum held Feb 24-27, 2015

Pre-Forum Run-time Guidance for XP Prioritization:

Baseline (12+4 weeks) # run weeks:	16	
Estimated total # run days:	80	
Estimated XMP run-days	25	Cross-cutting commissioning, shot development, calibrations (may not include TSG-specific XMPs)
Reserve for multi-TSG XPs	10	
Contingency / director's reserve	5	
Nominal total days for TSG/TFs to prioritize	50	
Minimum # run days per TSG / TF	2.5	
Milestone weighting for FY15-early FY16 run	0.75	0.25

Priority #1 fraction
0.75

	TSG / Task Force	FY 15 Milestones	FY16 Milestones	FY15 count	FY16 count	Milestone additional runtime	Forum Idea Count Increment	Nominal TSG / TF run days for single TSG XPs	Nominal TSG / TF run days for multi-TSG XPs	Nominal TSG / TF run days for all XPs	Nominal Priority 1 XP run time	Nominal Priority 2 XP run time
Boundary	Pedestal	R15-1		1	0	0.75	0.5	3.5	1	4.5	3.5	1
	Divertor and SOL	R15-1	R16-1	1	1	1	1	4.5	1	5.5	4	1.5
	Materials and PFCs		R16-2		1	0.25	0	2.5	1	3.5	2.5	1
Core	Macroscopic Stability	JRT-15, R15-3	JRT-16	2	1	1.75	1	5	1	6	4.5	1.5
	Transport & Turbulence	JRT-15, R15-1		2	0	1.5	0.5	4.5	1	5.5	4	1.5
	Energetic Particles	JRT-15, R15-2	R16-3	2	1	1.75	0.5	4.5	1	5.5	4	1.5
Scenarios	Advanced Scenarios and Control	Notable, JRT-15, R15-2, R15-3	JRT-16, R16-4	4	2	3.5	1	7	1	8	6	2
	Solenoid-Free Start-up		R16-4	0	1	0.25	0	2.5	1	3.5	2.5	1
	Wave Heating and Current Drive		R16-3	0	1	0.25	0	2.5	1	3.5	2.5	1
Task Forces	Particle Control	R15-3		1	0	0.75	0.5	3.5	1	4.5	3.5	1
						Total:		40	10	50	37	13

Some statistics on XMP/XP idea submissions:

Topical Science Group or Task Force	Run Days Requested	Fraction
Macroscopic Stability (MS)	40.75	14.9%
Cross-cutting and Enabling (CC)	34.85	12.8%
Divertor and Scrape-off-layer (DS)	33.5	12.3%
Advanced Scenarios and Control (ASC)	33	12.1%
Pedestal Structure and Control (PS)	25	9.2%
Particle Control Task Force (PC)	23	8.4%
Energetic Particles (EP)	22.5	8.3%
Turbulence and Transport (TT)	21	7.7%
Materials and PFCs (MP)	15.5	5.7%
Solenoid-free Start-up and Ramp-up (SR)	14.5	5.3%
Wave Heating and Current Drive (RF)	9	3.3%
	272.6	100%

#	Institution	Run Days Requested	Fraction
1	Princeton Plasma Physics Laboratory	112.1	41.1%
2	Oak Ridge National Laboratory	28.5	10.5%
3	Princeton University	20.5	7.5%
4	Lawrence Livermore National Laboratory	18	6.6%
5	General Atomics	17	6.2%
6	ITER (France)	12	4.4%
7	University of Washington	11.5	4.2%
8	Columbia University	10.5	3.9%
9	University of Wisconsin	9	3.3%
10	University of California - Irvine	7.5	2.8%
11	Nova Photonics	6	2.2%
12	University of Illinois	4	1.5%
13	Massachusetts Institute of Technology	4	1.5%
14	University of California - San Diego	3	1.1%
15	Johns Hopkins University	3	1.1%
16	University of Tennessee	2	0.7%
17	Lehigh University	1	0.4%
18	Florida International University	1	0.4%
19	University of California - Los Angeles	1	0.4%
20	University of York (United Kingdom)	1	0.4%
		272.6	100%

Requested / Available Run Time:

Total: 273 / 80 = 3.4×

Research: 248 / 55 = 4.5×

84 unique lead author names

Prioritization, run-time, expected run-month – all documented online for every experimental proposal, shared with team

NSTX-U master XP list 2015

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Next unique XMP/XP number:

	A	C	D	E	F	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV
1	Next unique XMP/XP number:	108	1526										Estimated fractional distribution of run time assigned to a 4 run week (RW) period							Priority 1 XMP/XP run-time					Cross-cutting and Enabling run-time			
2	TSG / TF	XMP Number	XP Number	Title of proposal	Author last name	Priority Label	Priority 1 run time assigned at forum	Priority 2 run time requested at forum	Non-XMP CCE run time assigned after forum	Multi-TSG XP run time assigned after forum	Comments / notes		Run Weeks 1-4	Run Weeks 5-8	B--> Li (actual timing TBD)	Run Weeks 9-12	Run Weeks 13-16	Sum Chk		Run Weeks 1-4	Run Weeks 5-8	Run Weeks 9-12	Run Weeks 13-16		Run Weeks 1-4	Run Weeks 5-8	Run Weeks 9-12	Run Weeks 13-16
3	Diagnostic Operations XMPs	106		Magnetics Calibration	Myers	P1a	1.5	0					1					1		1.5	0	0	0		0	0	0	0
4				MSE-CIF Calibration	Levinton	P1a	1	0					1					1		1	0	0	0		0	0	0	0
5				MSE-LIF Calibration	Levinton	P1b	1	0					1					1		1	0	0	0		0	0	0	0
6				MSE Measurement of NB Interference	Levinton	P1b	1	0					1					1		1	0	0	0		0	0	0	0
7				FIDA'ss NPA's FLIP checkout	Liu	P1c	1	0					1					1		1	0	0	0		0	0	0	0
8		103		Materials Analysis Particle Probe Com	Allain	P1c	0.5	0.5					1					1		0.5	0	0	0		0	0	0	0
9				Neutron diagnostic calibration plasma	Darrow	P1a	0.5	0			SPG: Defines safety envelope. MUST do		1					1		0.5	0	0	0		0	0	0	0
10		107		Commissioning the Thomson Scatteri	LeBlanc	P1a	0.5	0					1					1		0.5	0	0	0		0	0	0	0
11		104		MHD Spectroscopy Checkout	Berkery	P1c	0.25	0					1					1		0.25	0	0	0		0	0	0	0
12				IR thermography calibration and comm	Ahn	P1b	0	0					1					1		0	0	0	0		0	0	0	0
13				CHERS XMP	Podesta	P1a	1	1					0.5	0.5				1		0.5	0.5	0	0		0	0	0	0
14	Physics Operations XMPs	100		CD-4 XMP	Mueller	P1a	0.5	0																				
15				Commission rtEFIT, ISOFLUX	Boyer	P1a	3	0			JEM: reduced from 4 to 3		1					1		3	0	0	0		0	0	0	0
16				Initial H-mode access on NSTX-U	Battaglia	P1a	1	0					1					1		1	0	0	0		0	0	0	0
17		101		NSTX-U breakdown scenario developr	Battaglia	P1a	0.5	0.5					1					1		0.5	0	0	0		0	0	0	0
18				NSTX-U Automatic Shutdown	Gerhardt	P1b	0.5	0.5					1					1		0.5	0	0	0		0	0	0	0
19				6 SPA and Proportional RWM control C	Gerhardt	P1b	0.5	0.25					1					1		0.5	0	0	0		0	0	0	0
20		105		Software Test for n=0 Control	Boyer	P1b	0.5	0					1					1		0.5	0	0	0		0	0	0	0
21				Soft-Limiting of Coil Forces and Stress	Gerhardt	P2b	0.5	0			SPG: eliminate until the algorithm is defi		1					1		0.5	0	0	0		0	0	0	0
22				Optimization of the between-shot heliu	Battaglia	P1c	0	0.25					1					1		0	0	0	0		0	0	0	0
23		102		Flow rate calibration of gas valves	Battaglia	P1a	0	0					1					1		0	0	0	0		0	0	0	0
24				Full shape control development	Kolemen	P1b	2	1			SPG: This must include S.P. control		0.75	0.25				1		1.5	0.5	0	0		0	0	0	0
25				Discharge Development of Double Nu	Gray	P3	0	0			SPG: Mueller/Boyer/Battaglia should co		0.5	0.5				1		0	0	0	0		0	0	0	0
26				Granule Injector operational readiness s	Lunsford	P1c	0.5	0					0.5	0.5				1		0.25	0.25	0	0		0	0	0	0
27				drsep Control Check-out	Gray	P3	0	0			SPG: Mueller/Boyer/Battaglia should co			1				1		0	0	0	0		0	0	0	0
28				HHFW antenna conditioning and perfo	Perkins	P1a	2	1			SPG: Either must be done, or skip entire			0.75		0.25		1		0	1.5	0.5	0		0	0	0	0
29				Increase Bt above 0.5T, Ip above 1MA	Battaglia	P1a	1	0						0.75		0.25		1		0	0.75	0.25	0		0	0	0	0
30				Real-time EFC algorithm development	Kolemen	P3	0	0			JEM: May need XMP time for EFC algori			0.5		0.5		1		0	0	0	0		0	0	0	0
31				Initial snowflake divertor with Pre-progr	Soukhanovskii	P1b	0.5	0						0.5		0.5		1		0	0.25	0.25	0		0	0	0	0
32				High-Z reference discharge developm	Jaworski	P1c	0.5	0.5			JEM: Run days reduced			0.5		0.5		1		0	0.25	0.25	0		0	0	0	0
33				Commissioning the CHI System	Raman	P1a	1	0						0.25		0.75		1		0	0.25	0.75	0		0	0	0	0
34				Commissioning the MGI Valves	Raman	P1a	1	0								1		1		0	0	1	0		0	0	0	0
35				RWM state-space control with 6 coils -	Sabbagh	P1c	0.25	0								0.75	0.25	1		0	0	0.1875	0.0625		0	0	0	0
36				Snowflake Control	Kolemen	P1b	1	0.5								0.5	0.5	1		0	0	0.5	0.5		0	0	0	0
37				Checkout real-time diagnostic connect	Kolemen	P2b	0	0			SPG: Piggyback, no run time					0.25	0.75	1		0	0	0	0		0	0	0	0
38				LGI Control	Kolemen	P3	0	0			JEM: We have not yet committed to doin					0.25	0.75	1		0	0	0	0		0	0	0	0
39				Rotation Control using 3D coils	Kolemen	P3	0	0.5			JEM: Need to develop plan. Rotation co						1	1		0	0	0	0		0	0	0	0
40						Total:	25	6.5	0	0													Total:	24.50				Total:
41						Guidance:	25	0															Check	25.00				
42																												
43	Advanced Scenarios and Control (ASC)		1501	Optimization of vertical control algorith	Boyer	P1a	0	0	1				1					1		0	0	0	0		1	0	0	0
44			1502	Tuning of the Automated Rampdown S	Gerhardt	P1c	0	0	0.5				1					1		0	0	0	0		0.5	0	0	0
45			1503	X-point control integration with shape c	Kolemen	P1a	0	0	1		SPG: This moved to CC&E		1					1		0	0	0	0		1	0	0	0
46			1504	Beam power and beta-N control	Boyer	P1b	0	0	0.5				0.5	0.5				1		0	0	0	0		0.25	0.25	0	0
47			1507	Maximizing the non-inductive current fra	Gerhardt	P1a	2	0						0.5		0.25	0.25	1		0	1	0.5	0.5		0	0	0	0
48			1508	Controlled Snowflake Studies	Kolemen	P1b	1	0.5	0.5					0.25		0.5	0.25	1		0	0.25	0.5	0.25		0	0.125	0.25	0.125
49			1509	Combined betaN and li feedback contr	Boyer	P1b	0.75	0.5						0.25		0.25	0.5	1		0	0.1875	0.1875	0.375		0	0	0	0
50				Develop VERY long pulse H-mode for	Battaglia	P1c	1	0	0.5							0.25	0.75	1		0	0	0.25	0.75		0	0	0.125	0.375
51				Current profile controllability scoping s	Boyer	P1b	0.75	0			Myers/LaHaye inclusion...					0.25	0.75	1		0	0	0.1875	0.5625		0	0	0	0
52				Closed Loop Density Feedback	Battaglia	P2a	0	0	0.5							0	1	1		0	0	0	0		0	0	0	0.5
53				NBI sustainment	Poli	P1c	0.5	0			Matched with 1/2 day from SFSU, so 1 t						1	1		0	0	0	0.5		0	0	0	0
54				Rotation Control	TBD	P2a	0	0.5			Need to identify a leader for this						1	1		0	0	0	0		0	0	0	0
55				Reversed Shear Plasma with Relaxed	Gerhardt	P2a	0	0.5			Will be led by H. Yuh						1	1		0	0	0	0		0	0	0	0
56				EPH access and long-pulse developm	Canik	P2b	0	0			Push to later years						1	1		0	0	0	0		0	0	0	0
57				Compare the benefits of off-axis NBI fo	Ferron		0	0			Most of the scope can be accomplished						1	1		0	0	0	0		0	0	0	0
58				Combining High Non-Inductive Fractio	Gerhardt	P2b	0	0			Reconsider at mid run assessment						1	1		0	0	0	0		0	0	0	0
59				Radiation Control	Kolemen	P2b	0	0			Need the PCS capabilities. Consider aga						1	1		0	0	0	0		0	0	0	0

2 XP reviews completed today, 15-20 more (per month) expected for May, June

Summary

- Continued scientific productivity on NSTX-U, collaborations
- Strong leadership and participation in community workshops
- Successful Forum, XP prioritization complete, reviews started
- **Research Team rapidly getting ready for the 2015 Run!**