NSTX-U

Supported by

U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U Research Highlights and Plans

Jonathan Menard, PPPL

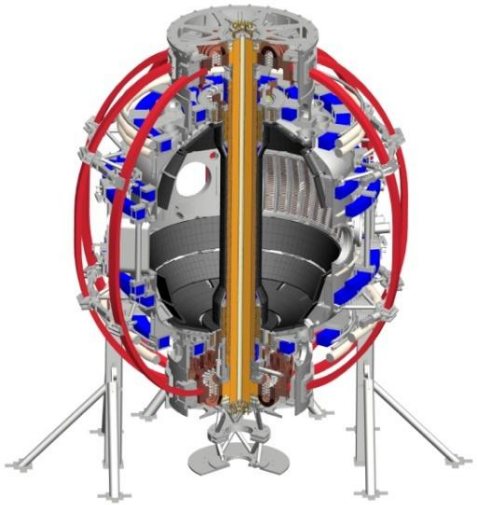
For the NSTX Research Team

IAEA FEC Meeting

October 2012

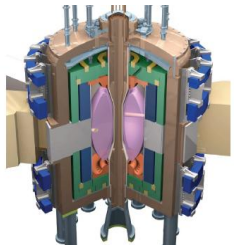
Coll of Wm & Mary
Columbia U
CompX
General Atomics
FIU
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Lehigh U
Nova Photonics
ORNL
PPPL
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Tennessee
U Tulsa
U Washington
U Wisconsin
X Science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

Culham Sci Ctr
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Inst for Nucl Res, Kiev
Ioffe Inst
TRINITI
Chonbuk Natl U
NFRI
KAIST
POSTECH
Seoul Natl U
ASIPP
CIEMAT
FOM Inst DIFFER
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep

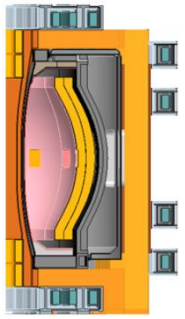


NSTX research targets predictive physics understanding needed for fusion energy development facilities

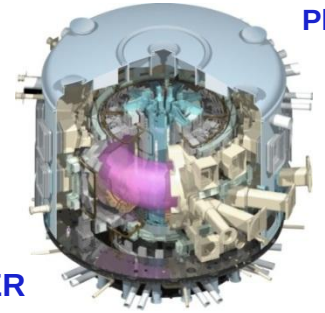
- Enable key ST applications
  - Move toward steady-state ST FNSF, pilot plant
  - Close key gaps to DEMO
- Extend understanding to tokamak / ITER
  - Leverage ST to develop predictive capability



Fusion Nuclear Science Facility (FNSF)



ST Pilot Plant

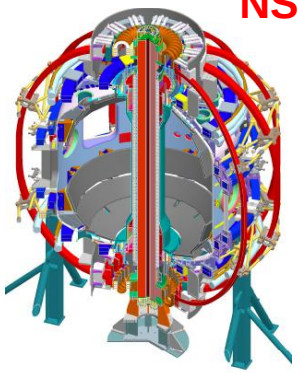


ITER

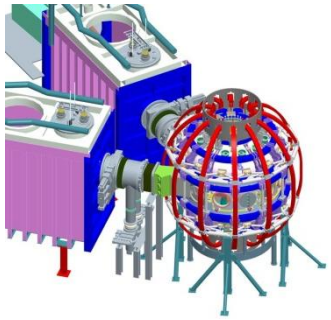
Present Research

- Develop key physics understanding to be tested in unexplored, hotter ST plasmas
  - Study high beta plasma transport and stability at reduced collisionality, extended pulse
  - Prototype methods to mitigate very high heat/particle flux
  - Move toward fully non-inductive operation

NSTX-U



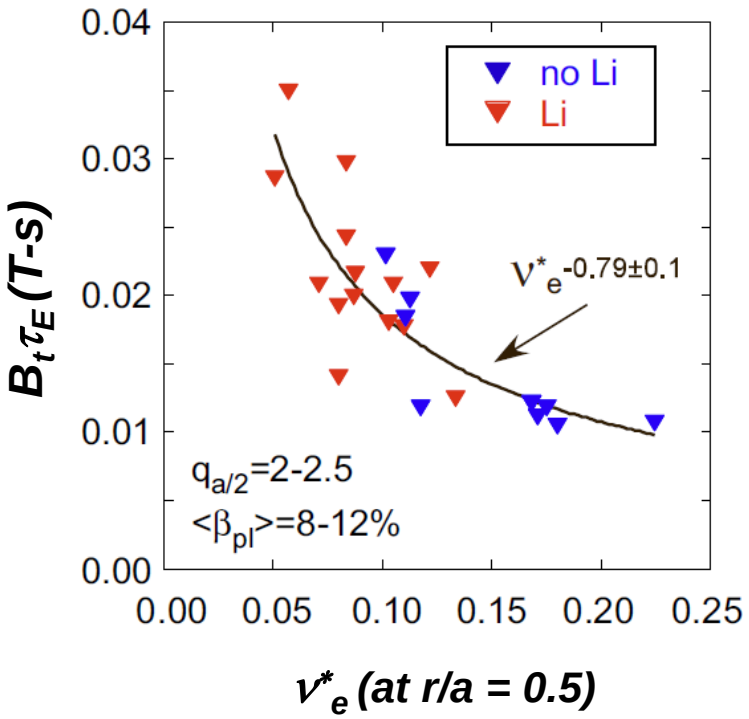
New center-stack



2nd Neutral Beam

Nonlinear microtearing simulations for NSTX consistent with measured electron heat transport dependence on collisionality

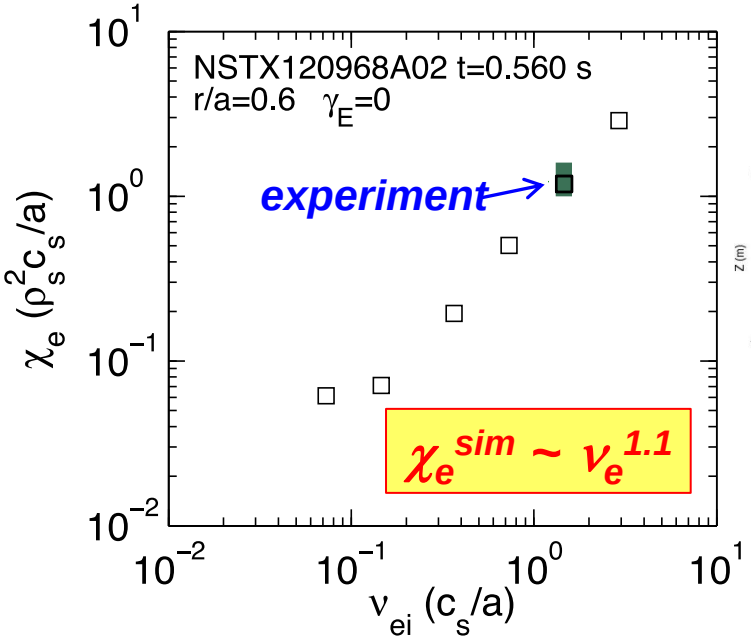
Experiment

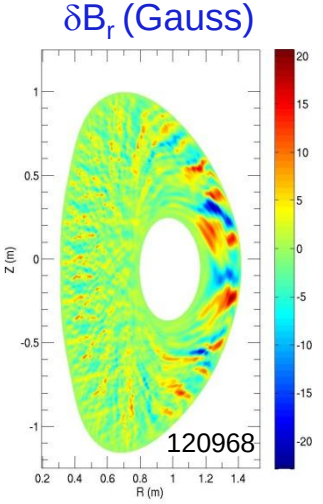


- Increase in τ_E as ν^*_e decreases
- Trend continues when lithium is used

Kaye EX/7-1

Theory





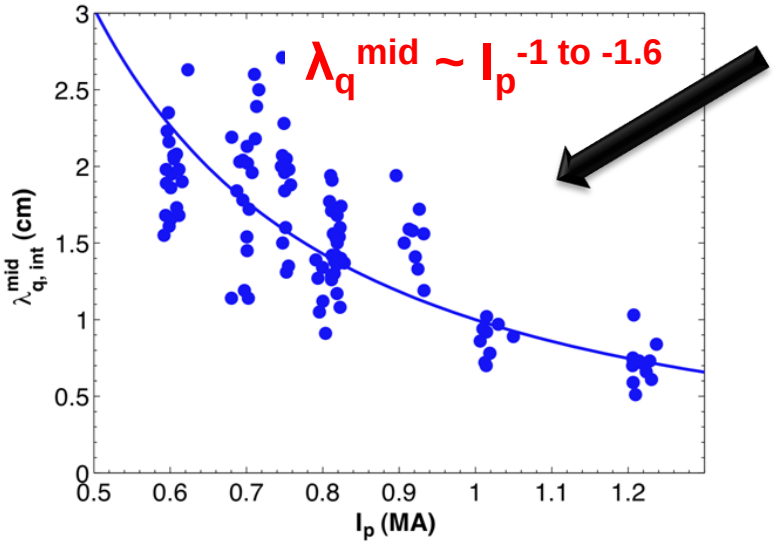
W. Guttenfelder, et al., PRL **106**, 155004 (2011)

- Predicted χ_e and scaling ~ $\nu_e^{1.1}$ consistent with experiment ($\Omega\tau_E \sim B_t\tau_E \sim \nu^{*-0.8}_e$)
- Transport dominated by magnetic "flutter"
  - $\delta B_r/B$ ~ 0.1% - possibly detectable by planned UCLA polarimetry system

Guttenfelder TH/6-1

- **NSTX-U computed to extend studies down to < 1/4 of present ν^***

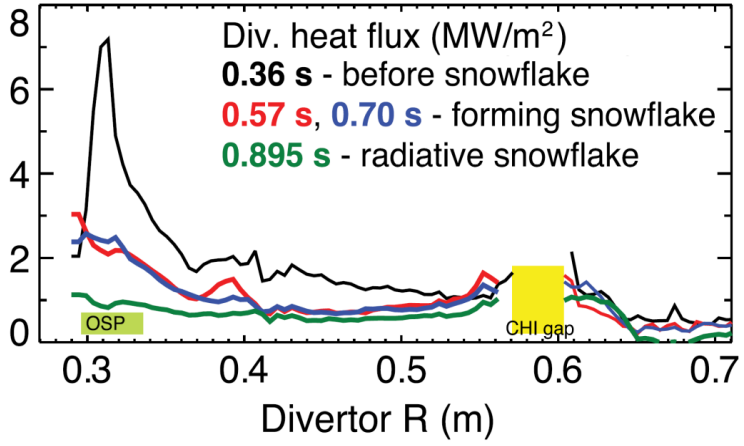
NSTX/NSTX-U investigating snowflake divertor and detachment physics for large heat-flux reduction for FNSF, ITER, and Demo

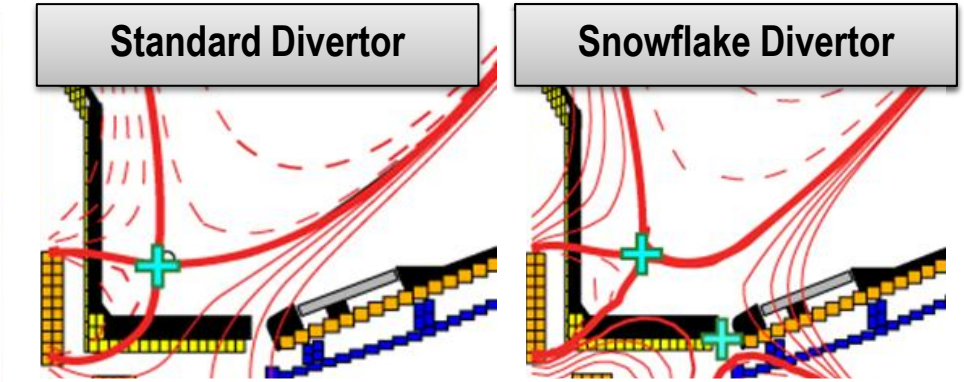


- Divertor heat flux width decreases with increased plasma current I_P

→ **30-45MW/m² in NSTX-U with conventional LSN divertor at full current and power**

NSTX data





- **Snowflake**→ high flux expansion = 40-60 lowers incident $q_\perp$, promotes detachment

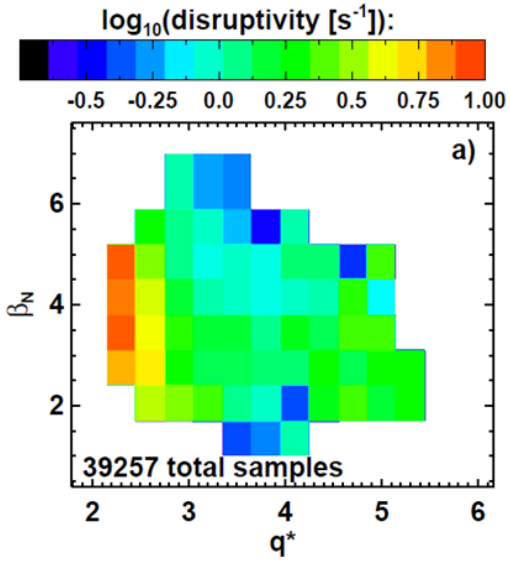
Soukhanovskii – EX/P5-21

NSTX-U: U/D balanced snowflake has < 10MW/m² at I_P = 2MA, P_{AUX}=10-15MW

Disruption detection & warning analysis of NSTX being developed for disruption avoidance in NSTX-U, potential application to ITER

Disruptivity

- All discharges since 2005 with 1/3 ms sampling time
  - Recorded equilibrium and kinetic parameters, disruption statistics

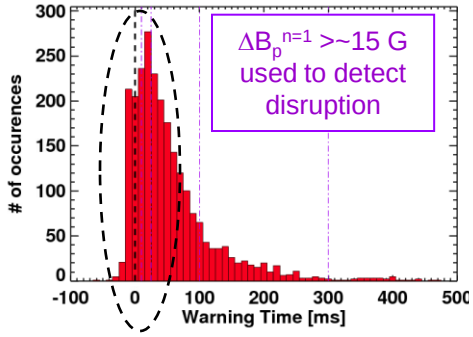


- Physics results
  - Minimal disruptivity at relatively high β_N ~ 6; $\beta_N / \beta_N^{\text{no-wall(n=1)}}$ ~ 1.3-1.5
    - Consistent with specific disruption control experiments
  - Strong disruptivity increase for q* < 2.5
  - Strong disruptivity increases for lowest rotation

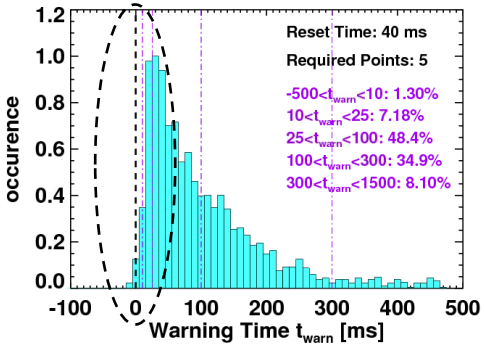
Warning Algorithms

- Disruption warning algorithm shows high probability of success
  - Based on combinations of threshold based tests; no machine learning

Statistics for a single threshold test



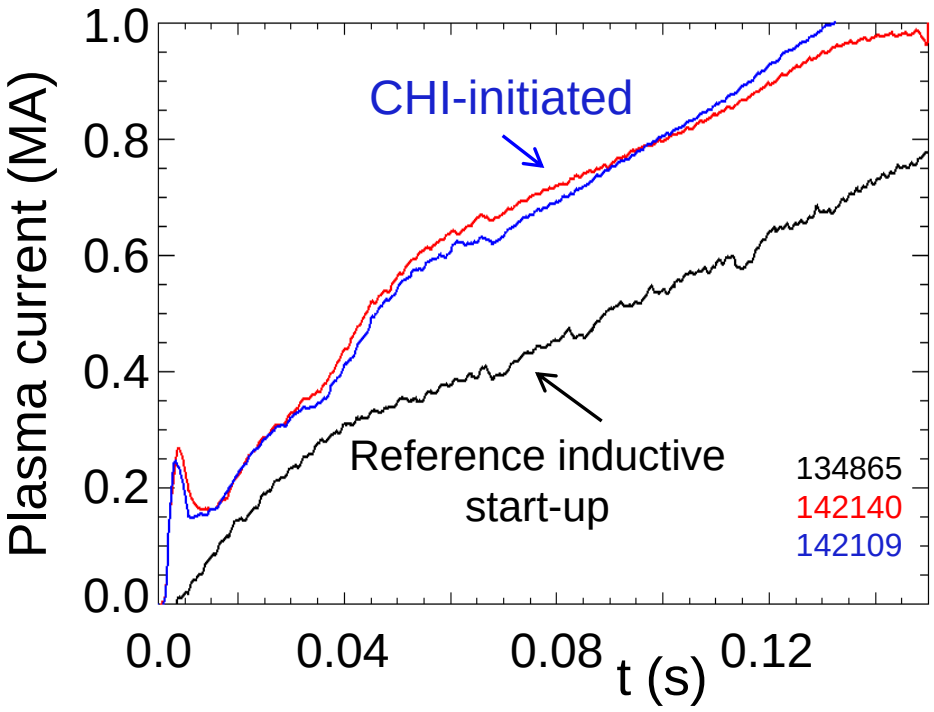
Statistics of full warning algorithm



- Results & Physics implications
  - ~98% disruptions flagged with at least 10ms warning, ~6% false positives
  - Most false positives are due to "near disruptive" events
    - Early MHD slows ω_ϕ
    - recoverable Z motion

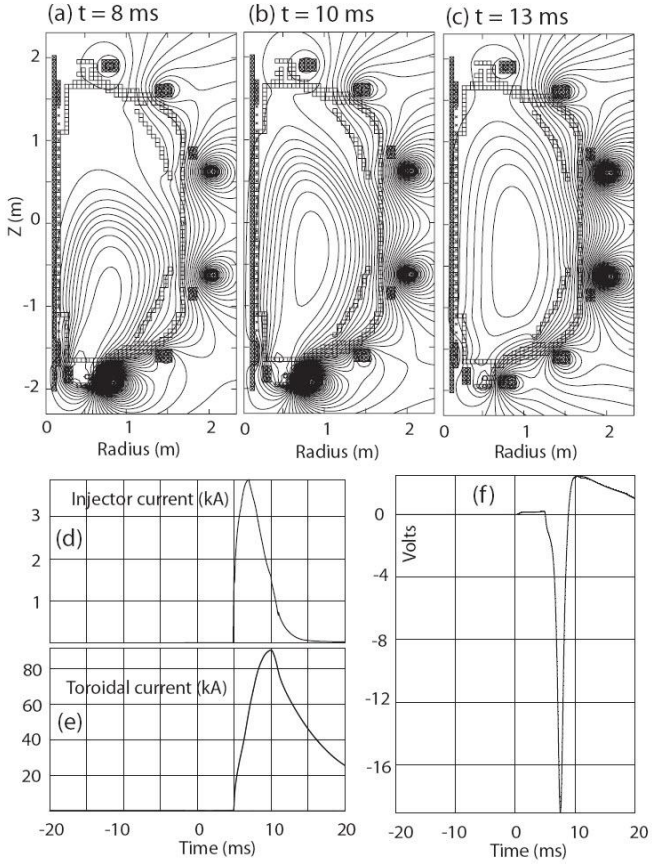
Gerhardt EX/9-3

L-mode discharge ramping to 1MA requires 35% less inductive flux when coaxial helicity injection (CHI) is used



- Reference inductive discharge
  - Uses 396 mWb to get to 1MA
- CHI initiated discharge
  - Uses 258 mWb to get to 1MA (35% less inductive flux)
- Doubling of CHI closed flux current projected for NSTX-U: 200→400kA

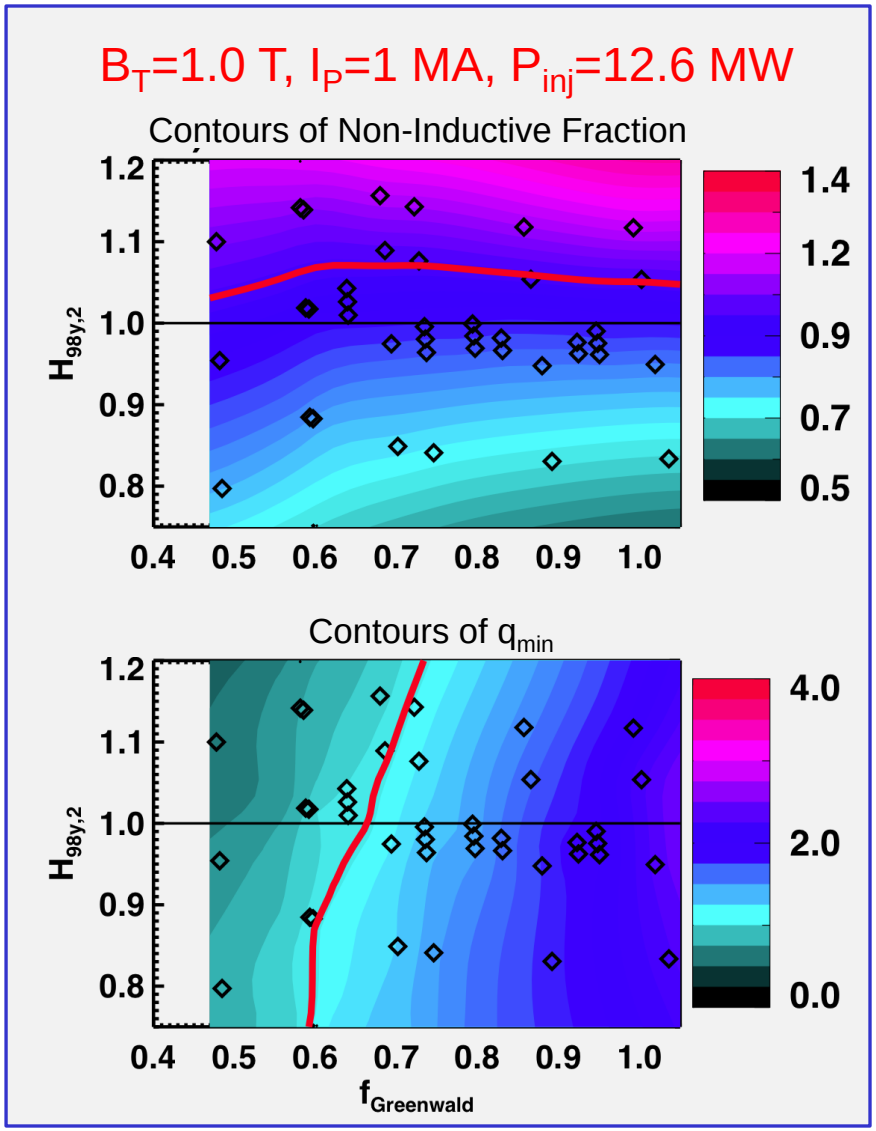
TSC simulation of NSTX CHI startup



- Decaying poloidal flux induces positive loop voltage, causes flux closure

Raman EX/P2-10

100% non-inductive NSTX-U operating points projected for range of toroidal fields, densities, and confinement levels



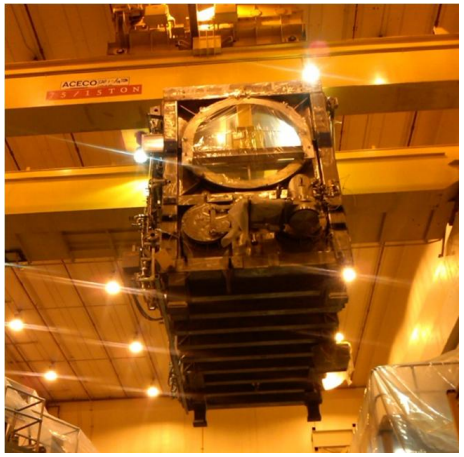
Projected Non-Inductive Current Levels for κ~2.85, A~1.75, f_{GW}=0.7

B_T [T]	P_{inj} [MW]	I_P [MA]
0.75	6.8	0.6-0.8
0.75	8.4	0.7-0.85
1.0	10.2	0.8-1.2
1.0	12.6	0.9-1.3
1.0	15.6	1.0-1.5

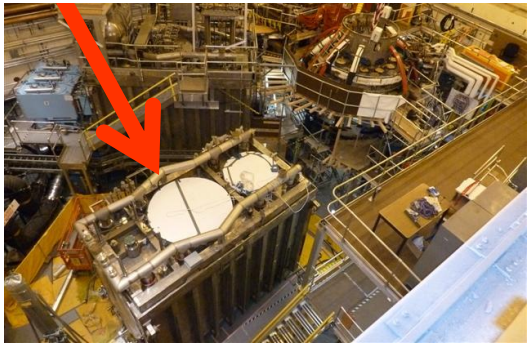
- From GTS (ITG) and GTC-Neo (neoclassical):
  - $\chi_{i,ITG}/\chi_{i,Neo} \sim 10^{-2}$
  - Assumption of neoclassical ion thermal transport should be valid

Rapid progress being made on NSTX Upgrade Project
First plasma anticipated mid-2014

Beam box craned over NSTX



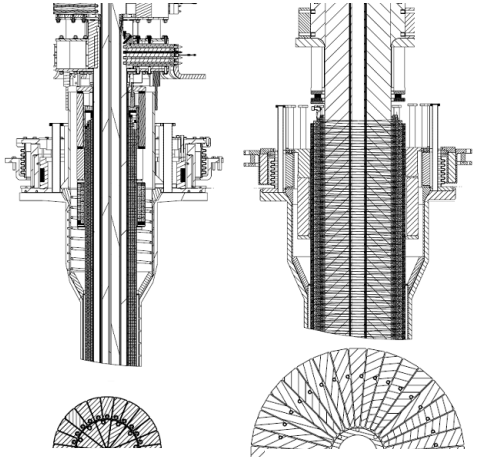
Box + cryo-panels next to NSTX



- 2nd NBI box moved into place
  - 1 month ahead of schedule

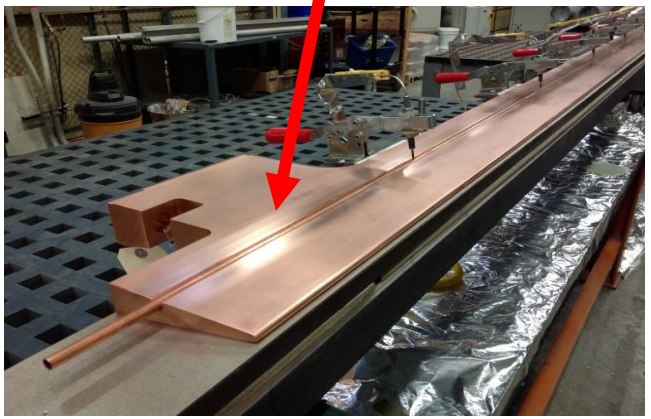
Old center stack

NEW Center Stack



TF OD = 20cm

TF OD = 40cm



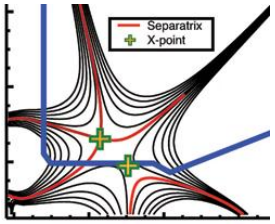
- Center-stack upgrade TF conductors being fabricated

Formulating FY2014-18 5 year plan to access new ST regimes with Upgrade + additional staged & prioritized upgrades

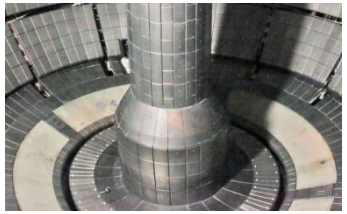
2009	2010	2011	2012	2013	2014	2015	2016	2017	2018

1 MA Plasma

- CHI Control Coils
- LLD
- Moly-tile
- HHFW Upgrade



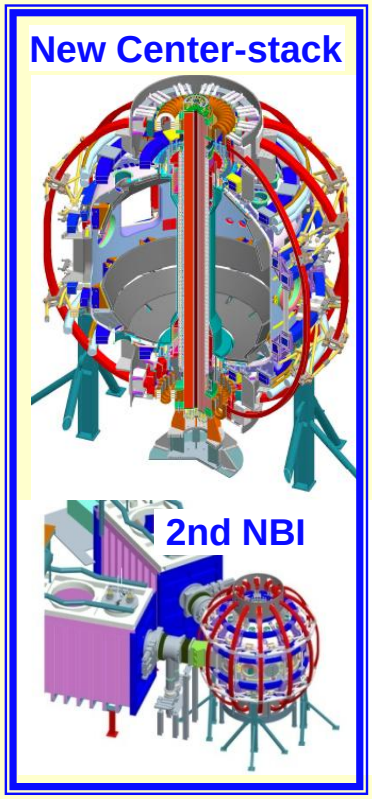
"Snowflake"



Lithium

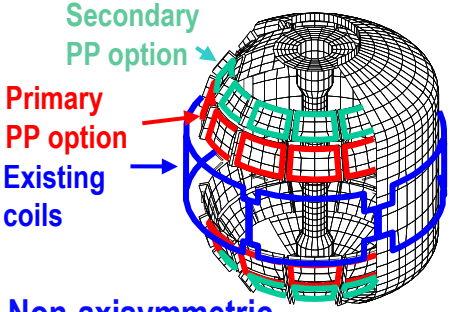
Upgrade Outage

- New Center-Stack
- 2nd NBI



1.5 → 2 MA Plasma

- 0.5 MA CHI
- 1 MA CHI / Plasma Gun
- ECH/EBW
- 1MW → 2 MW
- 0.5 MA Plasma Gun
- Long–pulse Divertor
- NCC Upgrade



Non-axisymmetric Control Coils (NCC)

NSTX Upgrade research goals in support of FNSF and ITER

- Low collisionality plasma regimes
- 100% non-inductive operation
- Long-pulse, high power divertor
- Advanced high-β scenarios

NOTE: Upgrade operation would be delayed ~1 year to mid-2015 w/o incremental, other follow-on upgrades are further delayed