Status and Plans for DIII-D and General Atomics Collaborative Research Grants in Support of NSTX-U

by
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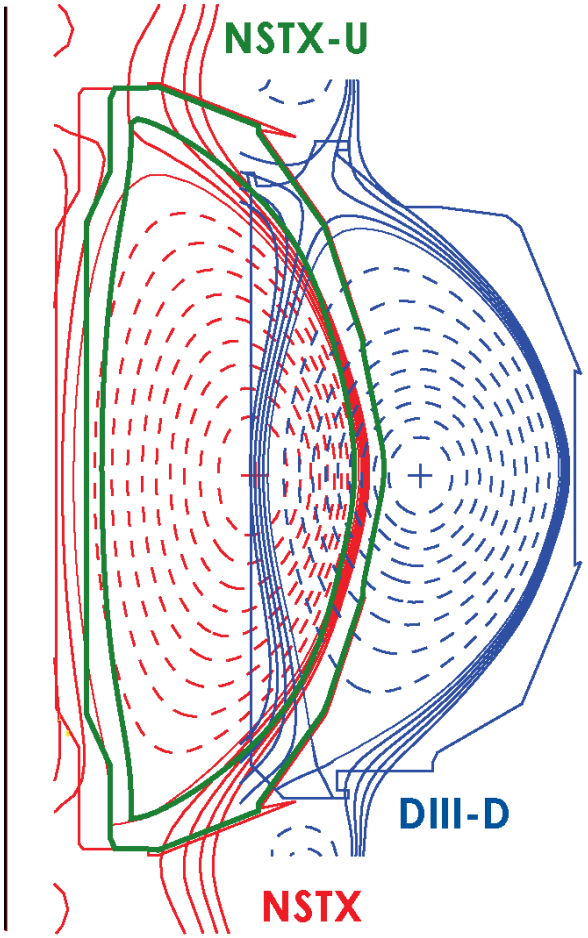
for the DIII-D team and
General Atomics grant participants

Presented at the
NSTX-U Research Forum

February 24-27, 2015



Aspect Ratio R/a = 1.4, 1.7, 2.7

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

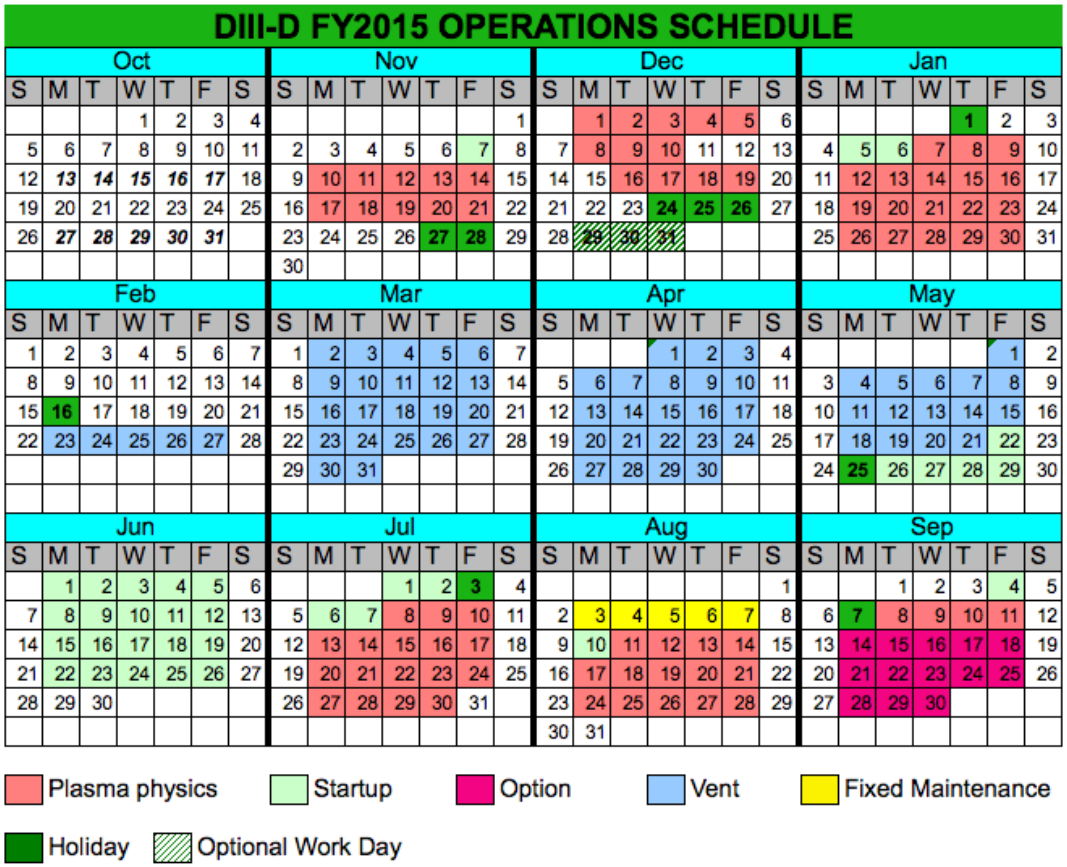
NSTX-U

GENERAL ATOMICS

DIII-D Status & Schedule, Plans for the Year

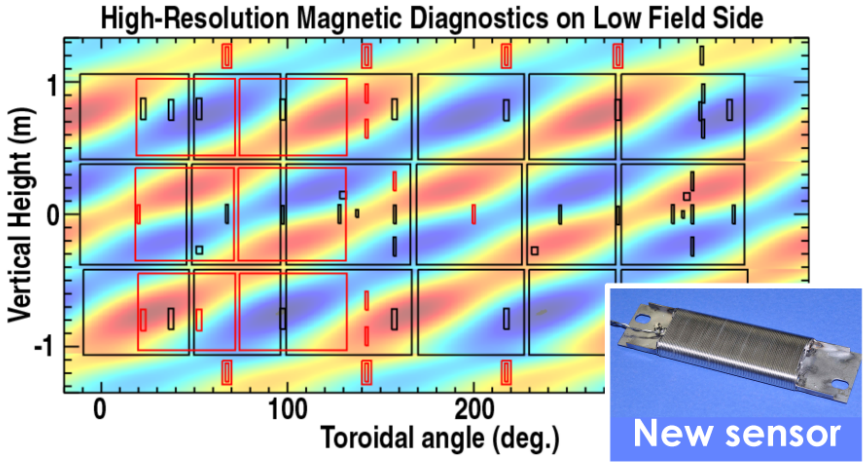
- **Last day of physics experiments for first part of FY15 campaign (Jan 30, 2015)**
  - vent Feb. 23 – May 21
- **Research Opportunities Forum (March 2-4) for second part of FY15 campaign (Jul. 8-Sep. 11) and FY16 together**
  - https://fusion.gat.com/global/Rof2015
    - DIII–D internal web area
- **Plans for this year**
  - install physics prototype helicon antenna (100 W) (slide follows)
  - diagnostics upgrades
  - disruption mitigation system
    - shell pellet injection relocate

FY15 15 weeks



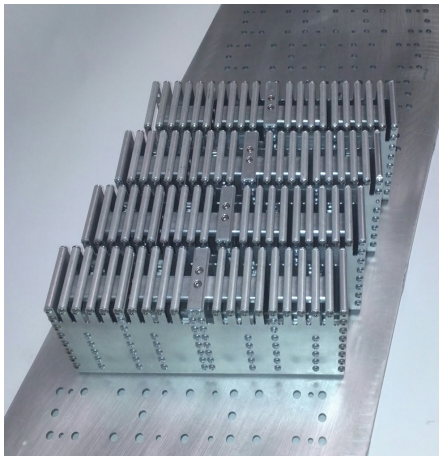
Improvements to the DIII-D Facility Are Enabling Key 5 Year Priorities to be Advanced in FY14-16

- **Diagnostics:**
  - ✓ New magnetics commissioned
  - ✓ Main ion CER upgrade increases resolution in the edge region
  - ✓ 2D Divertor TS
  - – Cross polarization scattering for internal magnetic fluctuations
  - – Polarimeter (3 chords)
  - – 2D mm–wave imaging reflectometer
  - – Hard X ray camera/gamma ray imager
  - – Divertor bolometer upgrade
  - – Coherence edge flow imaging
  - – fast-ion D_α (FIDA) upgrade
  - – CECE upgrade

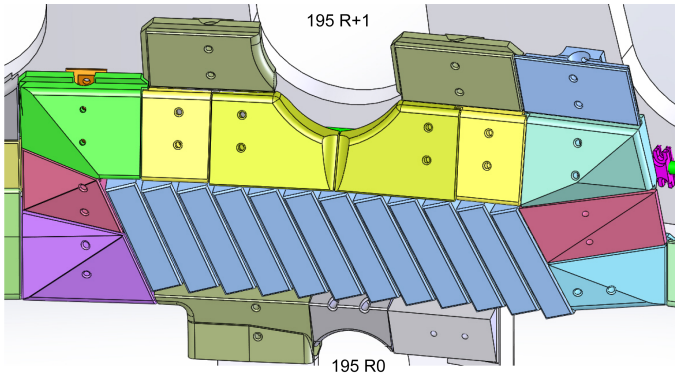


- **Hardware:**
  - – Electron cyclotron system to increase to 8 gyrotrons (5.3 MW) from 6 (3.5 MW)
  - – New prototype super-supply SPA for increased 3D harmonic (I-coil) & shaping (F-coil) flexibility
  - – Disruption mitigators enhancements for ITER physics tests & reliability

Helicon Program is Aimed at a Proof-of-principle Test of Current Drive at Mid-radius in High-β_N Plasmas in FY16



'Comb-line' model for lab cold tests



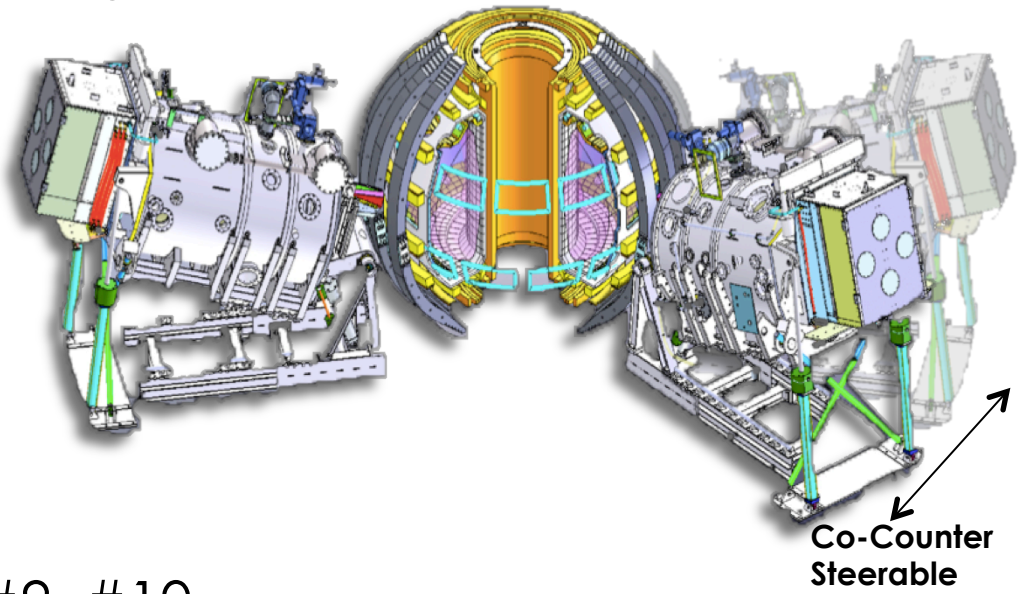
12-element low-power (~100W) antenna to be installed in DIII-D

- Goal: show that 'helicon' (very high harmonic fast wave) can drive current at mid-radius
- Plan: utilize 'comb-line' antenna (GA design) with 1 MW 476 MHz klystron (from SLAC) to drive current at ρ~0.55 in high-performance DIII-D discharge
- Implementation:
  - A) Install **low-power prototype** antenna **in Spring 2015** to determine the needed width of high-power antenna, establish coupling to helicon
  - B) Install **high-power antenna**, waveguide, etc., **in 2016**; get initial physics results before Long Torus Opening in CY17

FY15 Funding Provides Start on Several Projects that Keeps Major Vent in FY17 on Schedule

- **Improved NB systems**
  - Conceptual design to convert 210° BL to co/counter steerable, fixed off-axis
  - ➢ ***Preparing for installation in full-year vent in FY17***

2nd Off-Axis NBI

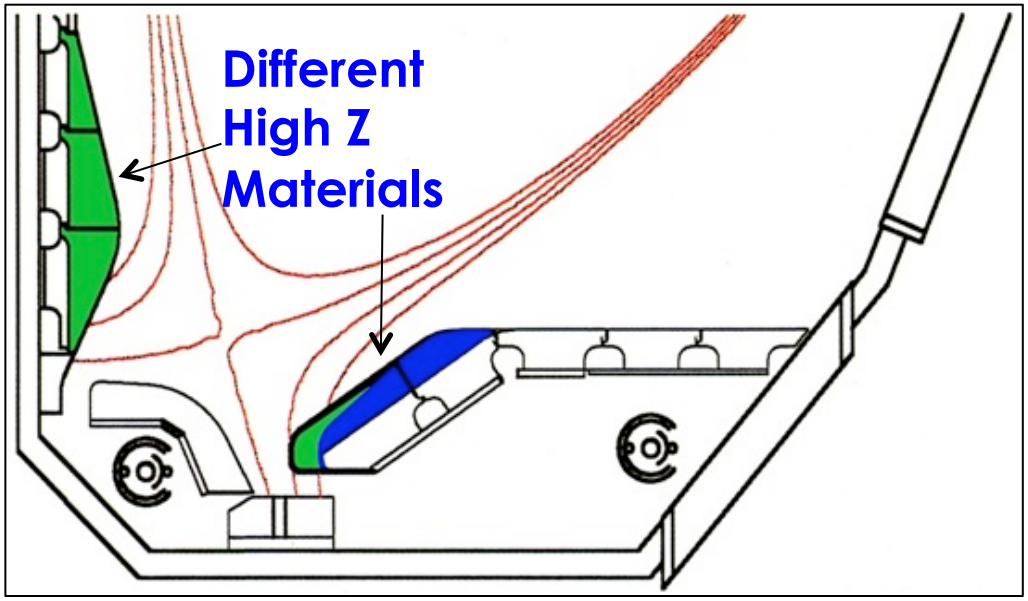


- **Enhanced ECH capabilities**
  - Start building design for gyro #9, #10

Discussing with DOE possibility of Installing High Z Tiles of Different Materials in early FY17

- Concept: Utilize toroidal rows of coated high-Z tiles to assess where major source of core contamination originates

- Materials being considered
  - Tungsten
  - Molybdenum
  - Zirconium
  - Tantalum
  - ???



- Limited duration campaign (~ 3 weeks) to make migration measurements more tractable

General Atomics DOE Grants on Collaborative Research to Support NSTX (and now NSTX-U)

- 1999-2005 Principal Investigator John Ferron on two 3-year grants
- 2005-2014 Principal Investigator Rob La Haye on three 3-year grants
- 2014-2018 Principal Investigators Todd Evans and Rob La Haye on two *separate* 4-year grants

Plasma Boundary Interfaces (PI Todd Evans)

H-mode Edge Pedestal Characterization (Key researchers are Tom Osborne, Phil Snyder and Gustavo Canal)

- Validate and extend models for H-mode pedestal structure and stability to low aspect ratio
- Apply pedestal models to understand NSTX-U results with Li conditioning, the snowflake divertor, RMP coils or in novel ELM regimes
- Support pedestal analysis by PPPL staff

Calculations of High-Resolution 3D Divertor Footprints (Key researchers are Todd Evans, Nate Ferraro, Wen Wu, Phil Snyder and Gustavo Canal)

- Develop predictive models of heat and particle flux distributions on the NSTX-U divertor target plates and compare with experimental data

Non-axisymmetric Control Coil (NCC) Modeling (Key researchers are Todd Evans, Nate Ferraro and Wen Wu)

- Identify NCC configurations and NSTX-U operating space needed for ELM suppression with 3D fields

Collaborative Research on Configuration Optimization of Advanced Operating Scenarios and Control Including Macroscopic Stability (PI Rob La Haye)

Advanced Operating Scenarios and Control (Key researcher is Dave Humphreys supported by Nick Eidietis, Mike Walker and Anders Welander, with Bob Johnson providing programming support)

- Support ongoing upgrades/development of NSTX-U plasma control system (PCS)
- Features to include n=0 control at kappa~3, real-time MSE EFIT, precise strike point control

Macroscopic Plasma Stability (Key researcher is Rob La Haye supported by Josh King, Carlos Paz-Soldan, Ted Strait, Richard Buttery and John Ferron)

- Help explore the optimization of the current/safety-factor/rotation profiles on stability limits, especially to the beta limit by n=1 tearing modes
- Document any stability advantages (i.e. curvature) at low aspect ratio, compare NSTX-U to NSTX and DIII-D (off-axis NBI common with NSTX-U allows coordinated experiments)

Extending 3D Magnetic Diagnostics (Key researchers are Ted Strait and Josh King)

- Conceptual design for an extension of the NSTX-U magnetic diagnostic system aimed at more complete measurements of the non-axisymmetric 3D magnetic field
- Recent upgrade of DIII-D magnetic diagnostics has pointed to new physics of multiple modes as beta is increased that may be of even more consequence at low aspect ratio

Attending this Week from DIII-D and/or General Atomics

- **Tom Osborne and Gustavo Canal**
  - interests boundary TSGs (Pedestal Structure Control)
- **Rob La Haye and Josh King**
  - interests core TSGs (Macroscopic Stability and Advanced Scenarios and Control)

Overview of XPs by DIII-D Researchers

- **MSG**
  - XP10: make contact with NSTX for n=1 tearing stability (La Haye)
  - XP32: 3D plasma response data for MHD and transport code validation (Evans)
  - XP47: assess β_N and q_{min} n=1 tearing stability limits at the increased aspect ratio of NSTX-U (La Haye)
  - XP78: real-time EFC using extremum seeking (Lanctot)
  - XP93: compare benefits of off-axis NBI… (Ferron, also XP89 to ASCG)
  - XP103: comparative study of EM torque … for locking avoidance (Okabayashi)
  - XP169: massive effect of extrinsic asymmetry… (Izzo)
  - XP172: study 3D and OD aspects of LM mitigation (Izzo)
  - XP174: PFR MGI as "super radictive divertor" for disruption mitigration (Eidietis)
  - XP175: measuring disruption heat flux expansion… (Izzo)
  - XP?: tearing onset through driven reconnection… (Paz-Soldan)

Overview of XPs by DIII-D Researchers

- **DSG**
  - XP71: assessment of 3D field effects on the properties of the snowflake divertor (Canal)
- **EPG**
  - XP74,75,76: fast–ion and AE ideas (Heidbrink)
- **PSG**
  - XP139: effects of different impurities on pedestal (Osborne)
  - XP140: pedestal stability (Osborne)
  - XP;177 generating and characterizing EHO (McKee)
- **TTG**
  - XP176: impact of 3D… peturbations… (McKee)

BON VOYAGE FROM ALL ON DIII-D ON STARTUP OF NSTX-U