NSTX

Supported by

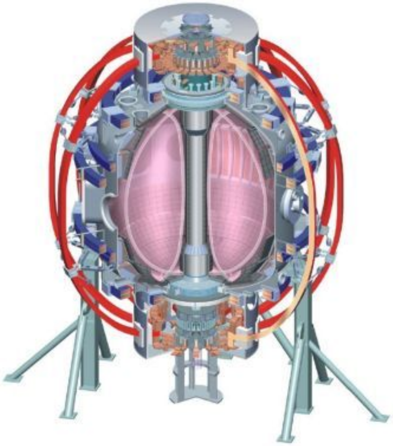
U.S. DEPARTMENT OF ENERGY | Office of Science

Characterization Of Intrinsic Rotation Drive Using Neutral Beam Torque Steps

W.M. Solomon and S.M. Kaye, PPPL

and the NSTX Research Team

XP1042 Final Review
June 10, 2010



College W&M
Colorado Sch Mines
Columbia U
Comp-X
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
PSI
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
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
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
KBSI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

Characterization Of Intrinsic Rotation Drive Using Neutral Beam Torque Steps

- Goals
  - Infer the effective torque profile associated with driving intrinsic rotation.
  - Determine if there is any interplay between intrinsic rotation drive and the torque exerted by non-resonant magnetic fields via neoclassical toroidal viscosity (NTV)

- Requirements
  - The XP requires MHD quiescent plasmas, that are also resilient to changes to the plasma rotation and the NBI torque.
    - Good success with Li evaporation and EF correction

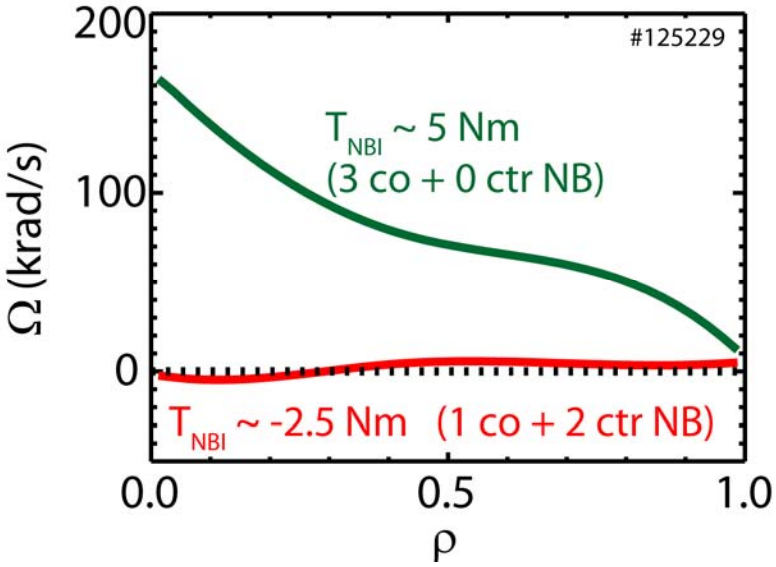
Basic Experimental Plan

- Step NBI torque down and measure angular momentum evolution to determine momentum confinement time
- Determine what, if any, missing torque to be attributed to an effective intrinsic source in steady state portions of discharge before step.
- For these torque steps, use
  - Uncompensated power steps (ie turning on or off a beam)
  - Compensated power substituting HHFW for NBI power or switching beam sources
- Perform power scan to vary H-mode pedestal
  - Appears to be a key quantity for edge intrinsic rotation drive
- Perform n=3 field strength scan
- Perform I_p scan
- Directly observe effect of the HHFW on intrinsic drive by comparing the inferred intrinsic torque with and without HHFW.

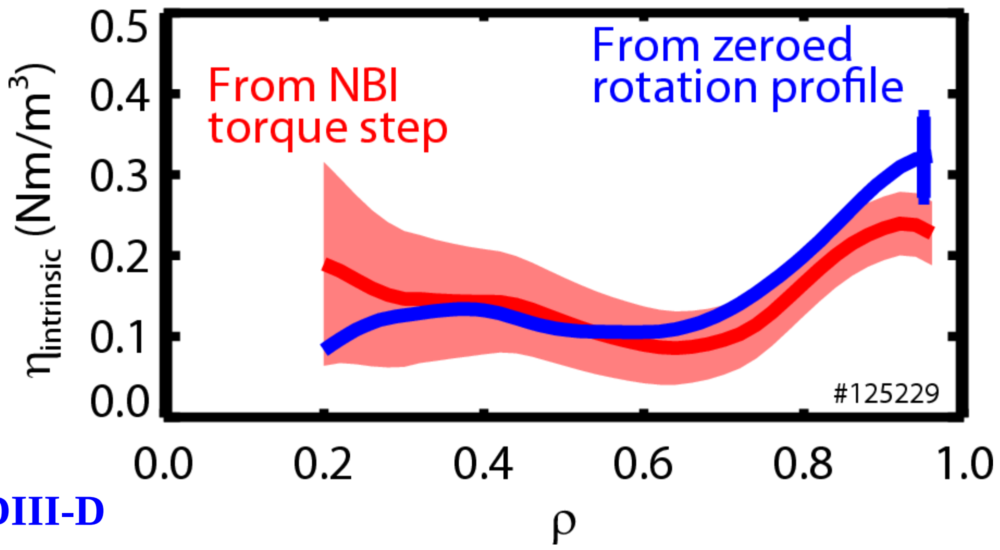
Technique For Inferring Torque Is Consistent With More Direct Measure Obtained By Zeroing Rotation

- Past measurements made by determining how much NBI torque was required to oppose intrinsic drive and produce zero rotation profile

- Torque step technique has been validated to give quantitatively consistent measurement
  - Allows intrinsic torque measurement to be made at finite rotation



DIII-D



Basic waveforms

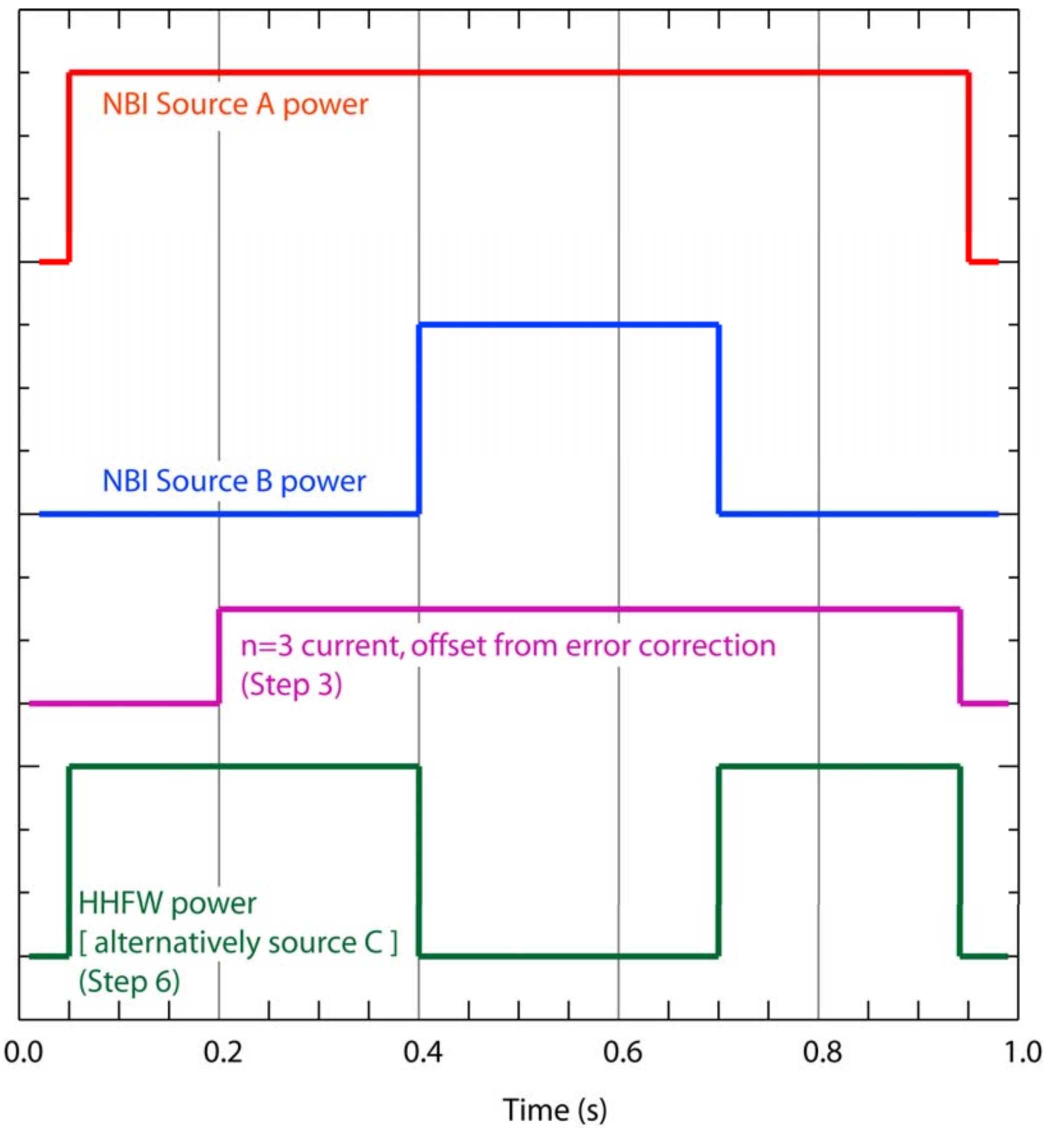
- Step 2: Power scan
  - add source C, and then invert source B waveform
- Step 3: Interaction of intrinsic drive with n=3 fields
- Step 4: Ip scan
- Step 5: Try to couple 2 MW of HHFW
- Step 6: Torque perturbation at constant power

  <u>*either*</u>

  HHFW compensated

  <u>*or*</u>

  Switch between B&C sources
- Step 7: Use n=3 fields to apply torque step
  - adjust dc bias to get rotation scan



Shot plan

1. Reproduce #134750, Bt=0.45 T, Ip=0.9 MA
    a. Apply error field correction as early as possible in the discharge 1 shot

 # shots: 1 + 2 contingency

Decision: If unsuccessful at producing suitable MHD quiescent discharge, reevaluate and consider deferring.

2. Perform power scan, with torque perturbation from NBI (uncompensated power). In all cases, the torque perturbation will come from source B. Derate source B as far as practical while still providing measurable change to rotation. Ideally, the torque step will occur from 400-700 ms, but there needs to be at least 100 ms of steady conditions before the step for the measurement to be successful. If necessary, delay the torque step appropriately.
    a. 1 source level (source A). Try nominal voltage for B first, and adjust as appropriate. 2 shots
    b. 2 source level (sources A+C) 1 shot
    c. 3 source level (produce torque steps by turning ***off*** B) 1 shot

 # shots: 4 + 2 contingency

Decision: If highest power level results in significant MHD that compromises the measurement, then we should proceed without this point.

Shot plan

3. Investigate interaction of intrinsic drive with NTV from n=3 fields. Repeat best condition with varying n=3 field strength. Apply n=3 field at least 100 ms (preferably 200 ms) before the NBI torque pulse.
   a. 400 A — 1 shot
   b. 800 A — 1 shot
   c. 600 A — 1 shot

   # shots: 3 + 2 contingency

Decision: If low levels of n=3 field causes MHD and/or mode locking, then obviously there is no value in going to higher fields. In that case, we would attempt to complete a three-point scan by moving down in current as appropriate.

4. Repeat Step 2, and perform I_p scan
   a. 1.0 MA — 3 shots
   b. 0.8 MA — 3 shots

   # shots: 6 + 2 contingency

5. Repeat Step 2, with addition of 2 MW of HHFW heating (configuration similar to eg #128663).

   # shots: 3 + 3 contingency

Decision: If we are struggling to couple the HHFW power to the plasma, then we should abandon this step and Step 6 involving the HHFW and move to the alternate step 6 option.

Shot Plan

6. Repeat Step 2, but attempt to run with constant power using HHFW during torque perturbation. Specifically, apply HHFW power throughout (power to match source B), starting around 200 ms, and step off when source B is turned on (invert the HHFW waveform for part c).

   # shots: 3 + 2 contingency

6. (alternative) Attempt a moderate power scan with torque step at constant power by switching between sources B and C (ie begin with lower torque source, and switch to higher torque source B)
   a. Source B and C at 80 kV — 1 shot
   b. Source B and C at 50 kV [or low as practical within beam conditioning specs] — 1 shot
   c. Source B and C at 65 kV [midway between voltages of (a) and (b)] — 1 shot

   # shots: 3 + 2 contingency

7. Repeat Step 2a, but use an n=3 perturbation (approximately 400 A) in place of source B. Obtain a rotation scan by applying this 400 A step on top of a DC perturbation.
   a. 0 → 400 A — 1 shot
   b. 200 → 600 A — 1 shot
   c. 400 → 800 A — 1 shot

   # shots: 3 + 0 contingency

TOTAL: 23 good shots + 13 contingency