CHI and MGI Operations on NSTX-U

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NSTX-U Physics Operations Training

23 July 2015
PPPL

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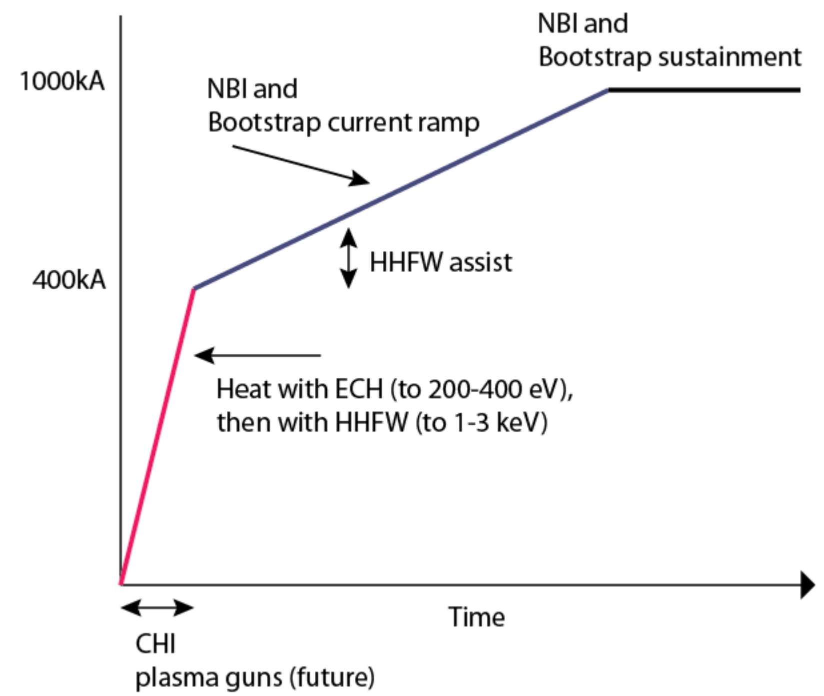
Outline

- Coaxial Helicity Injection (CHI)
  - Make ST and Tokamak reactors economical (used at start of discharge)
  - Implementation in NSTX-U
  - Experimental Operations
- Massive Gas Injection (MGI)
  - Protect our investment in a reactor (used at end of discharge)
  - Implementation in NSTX-U
  - Experimental Operations

NSTX-U Aims to Develop and Understand Non-inductive Start-up/Ramp-up to Project to ST-FNSF Operation

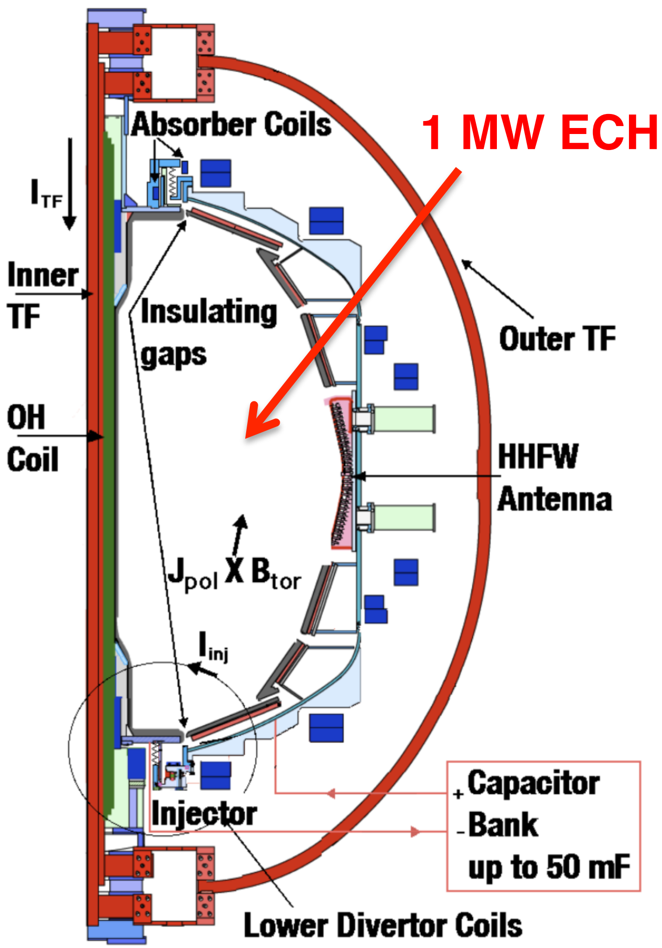
- Establish physics basis for ST-FNSF, and non-inductive start-up is essential in ST
  - Simplify the tokamak concept to reduce cost
- NSTX-U is striving for fully non-inductive operations
  - Transient Coaxial Helicity Injection (CHI) start-up is the front end of that objective
  - Plasma guns and EBW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

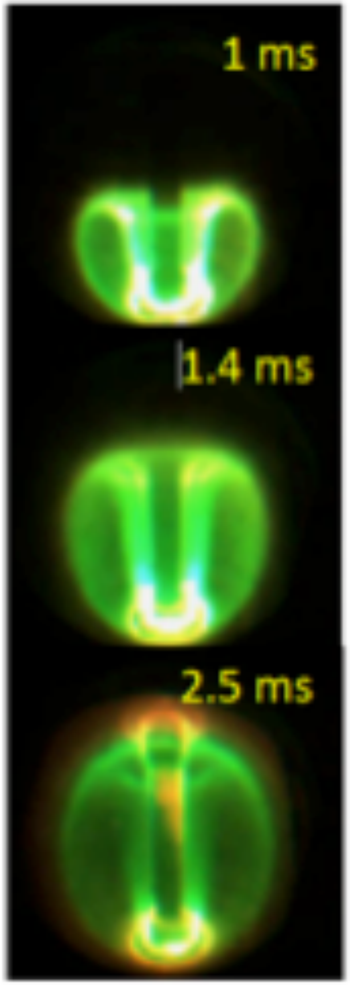
NSTX-U Start-up and Ramp-up Strategy



CHI is Planned to be Used as Initial Current Seed for Subsequent Non-inductive Current Ramp-up in NSTX-U

CHI in NSTX/NSTX-U

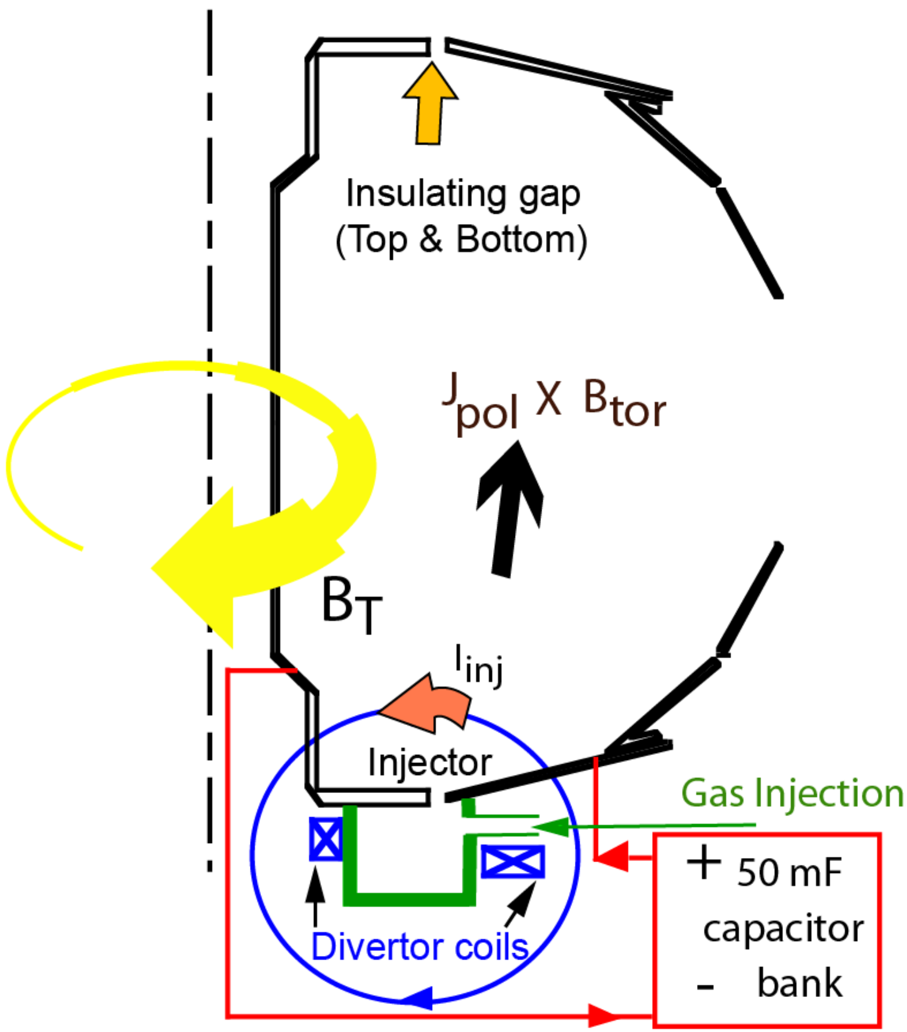


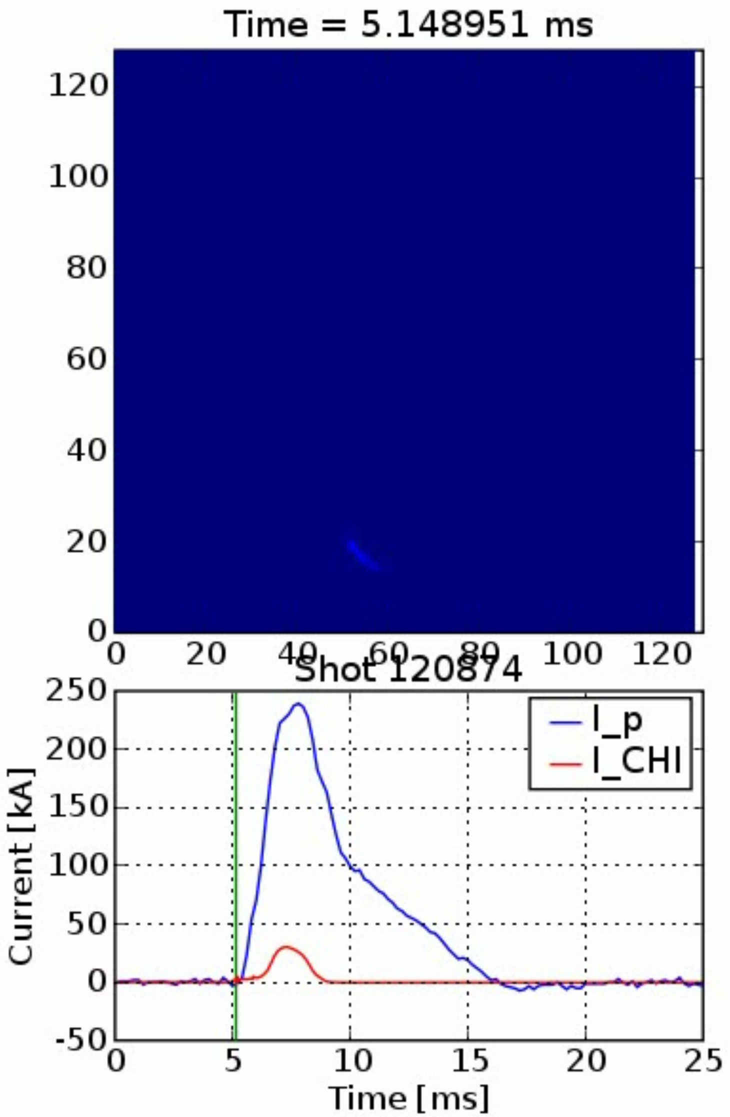


New Tools Enhance CHI Capability on NSTX-U

- > 2.5x injector flux
  - proportional to I_p
- TF = 1 T
  - increases current multiplication
- ECH
  - increases T_e
- > 2 kV CHI voltage
  - increases flux injection
- Full Li coverage
  - reduces low-Z imp.
- Metal divertor, cryo pump
  - increases T_e

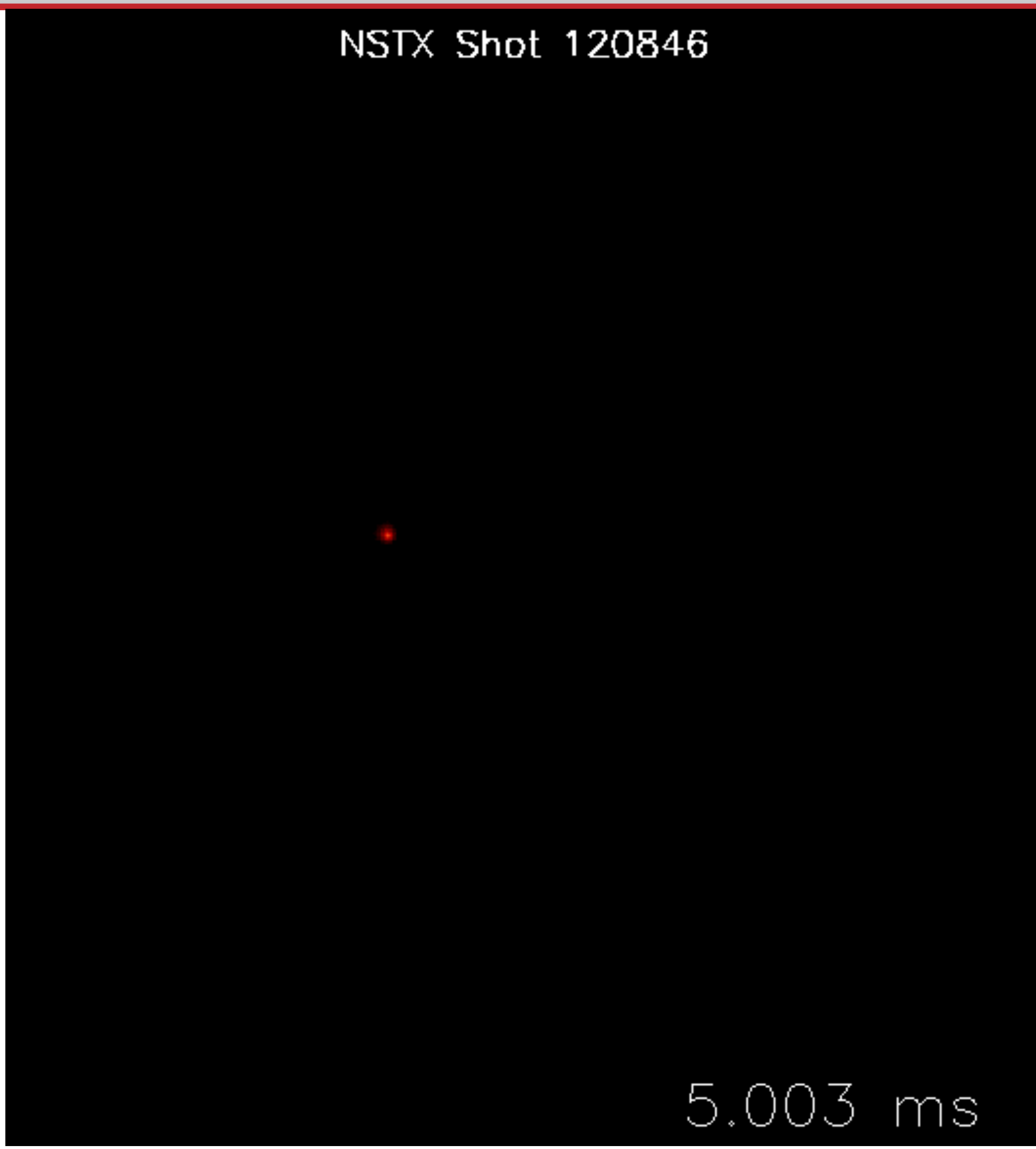
Transient CHI: Axisymmetric Reconnection Leads to Formation of Closed Flux Surfaces





Fast camera: **F. Scotti, L. Roquemore, R. Maqueda**

Fast Camera Fish Eye View Movie of Coaxial Helicity Injection (CHI) in NSTX

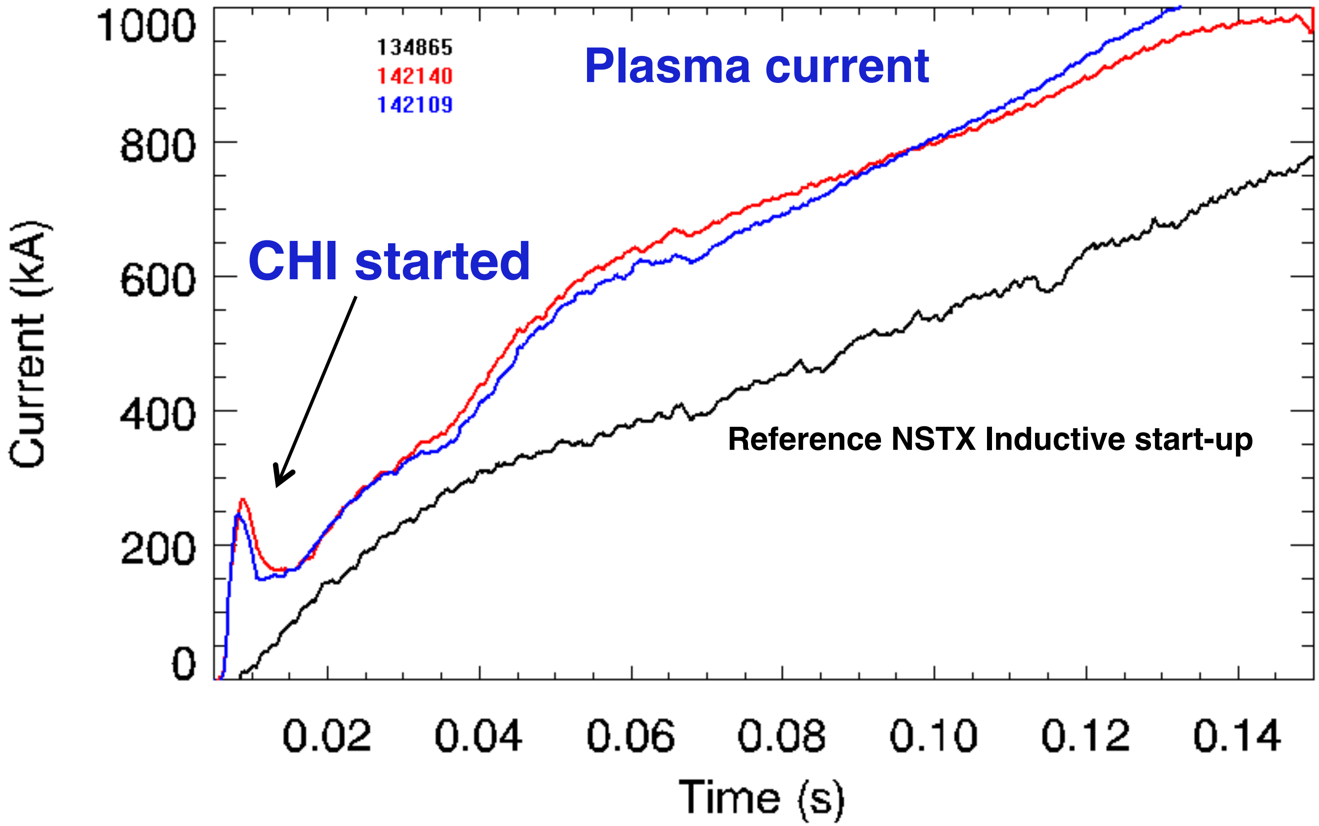


Upper divertor region of NSTX

NSTX Vacuum Vessel interior

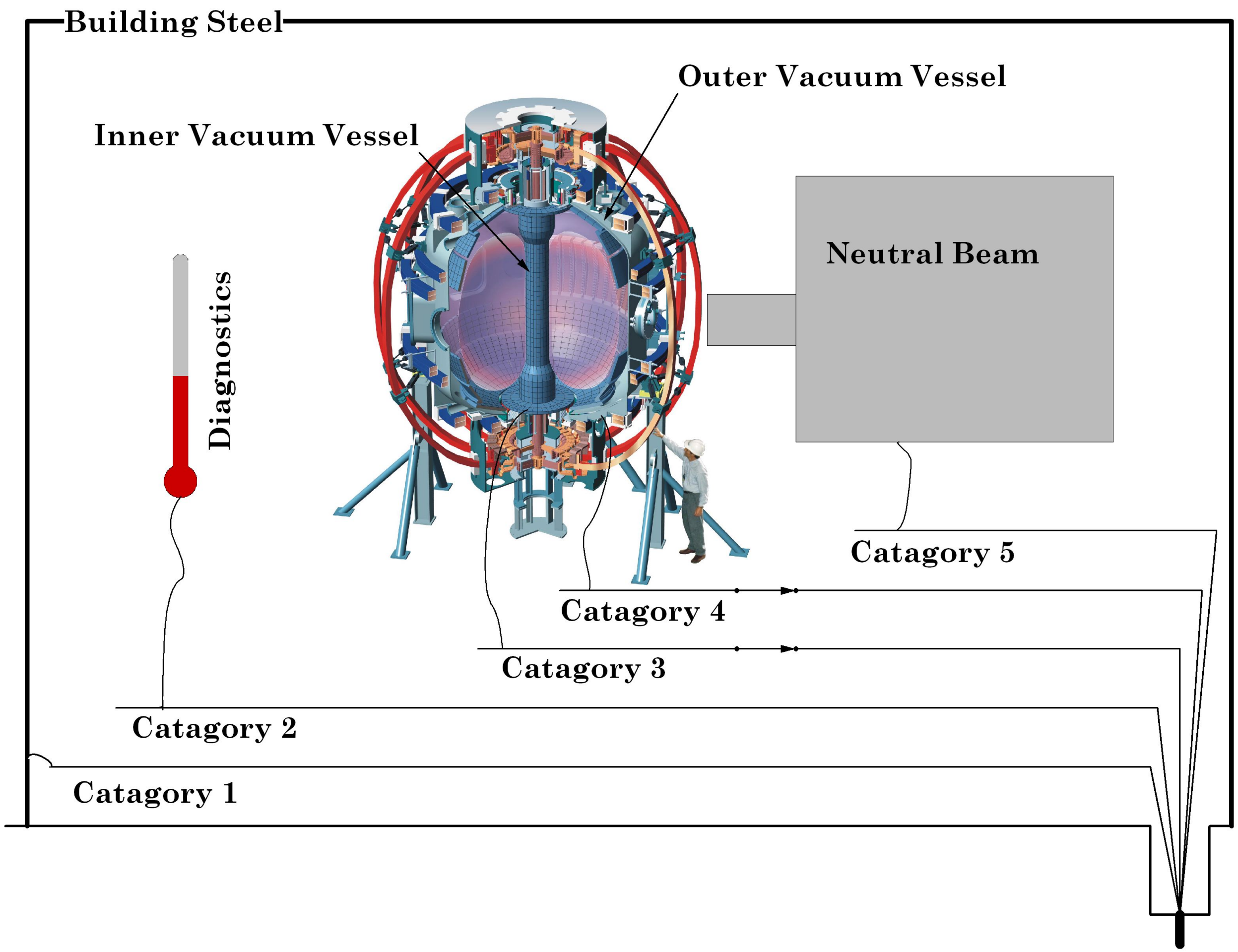
Lower divertor region of NSTX

Standard L-mode NSTX Discharge Ramps to 1MA Requiring 50% More Inductive Flux than a CHI Started Discharge



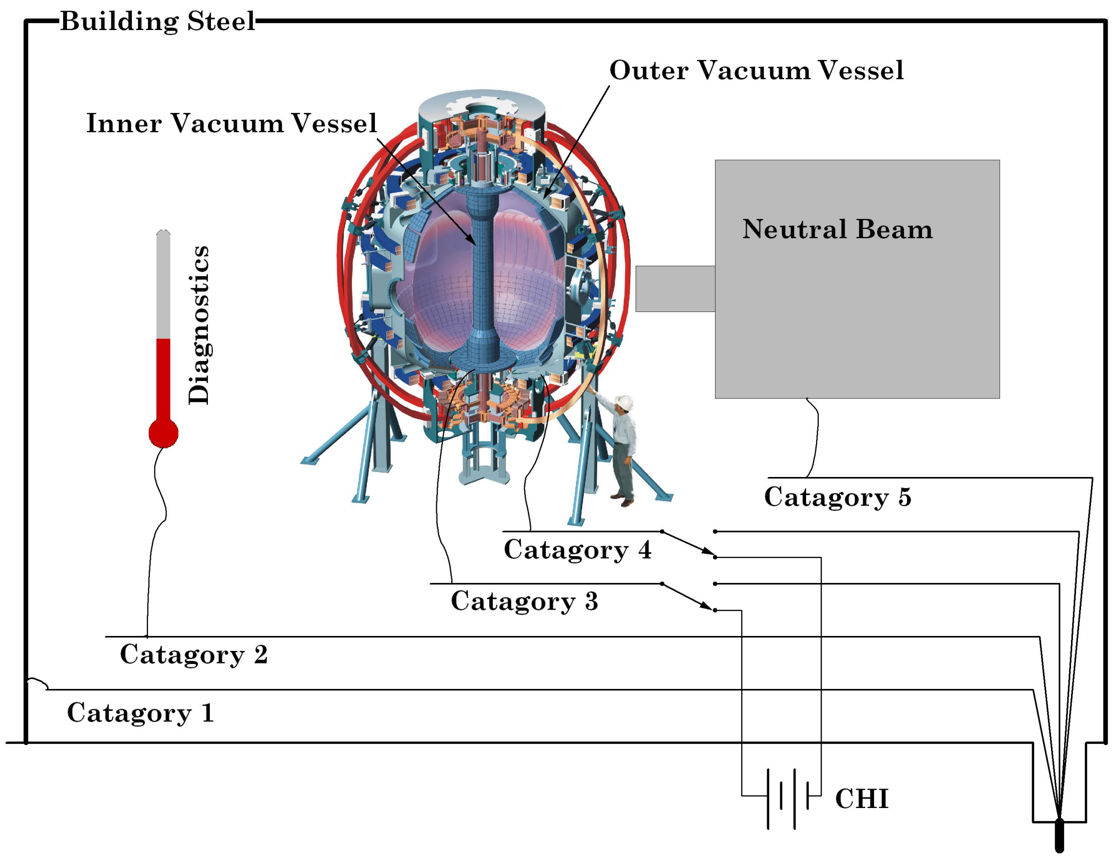
- **Reference Inductive discharge**
  - **Uses 396mWb to get to 1MA**
- **CHI started discharge**
  - **Uses 258 mWb to get to 1MA (138 mWb less flux to get to 1MA)**

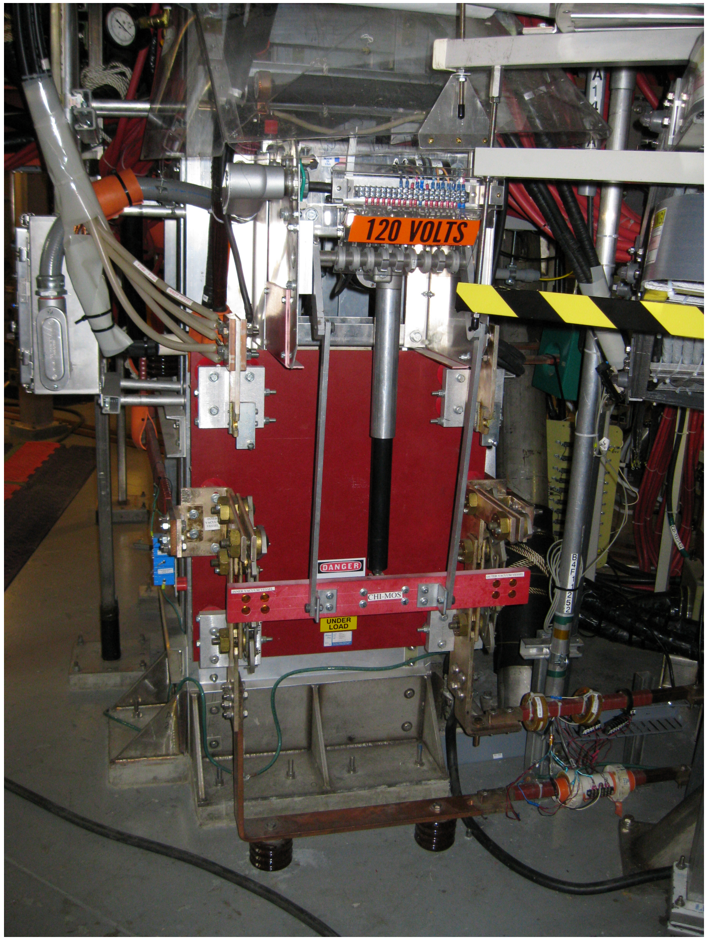
NSTX Grounds



Inner and Outer Vessel are electrically separated by two toroidal insulators, one at the top, and the second at the bottom of the machine

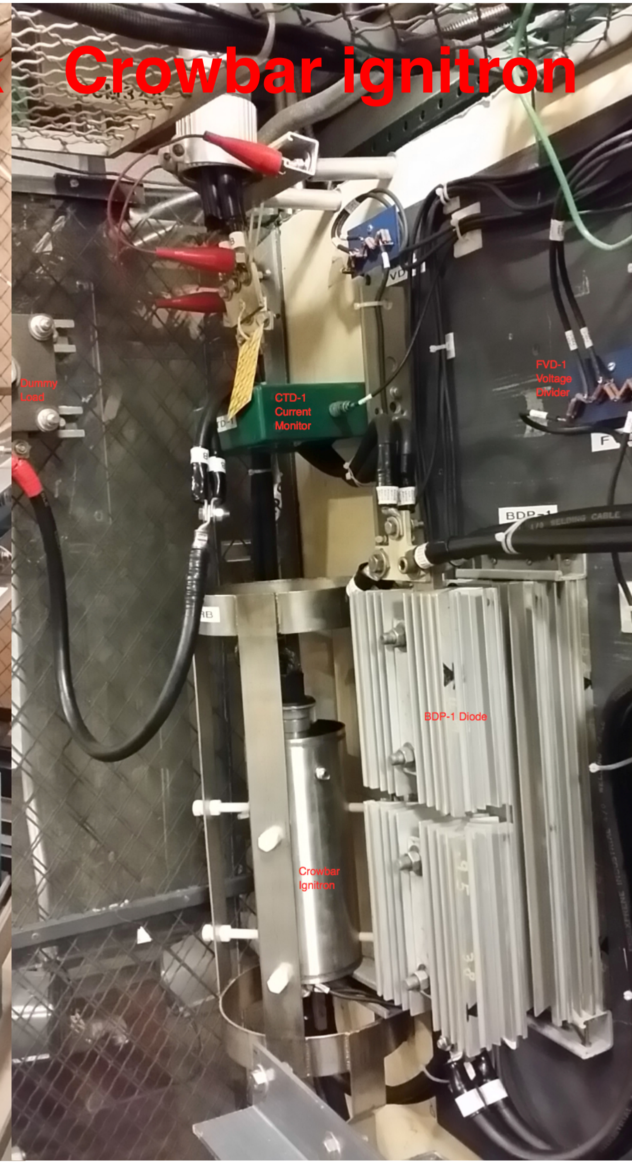
In CHI Configuration McBride Switch Connects Inner and Outer Vessel to CHI Cap Bank

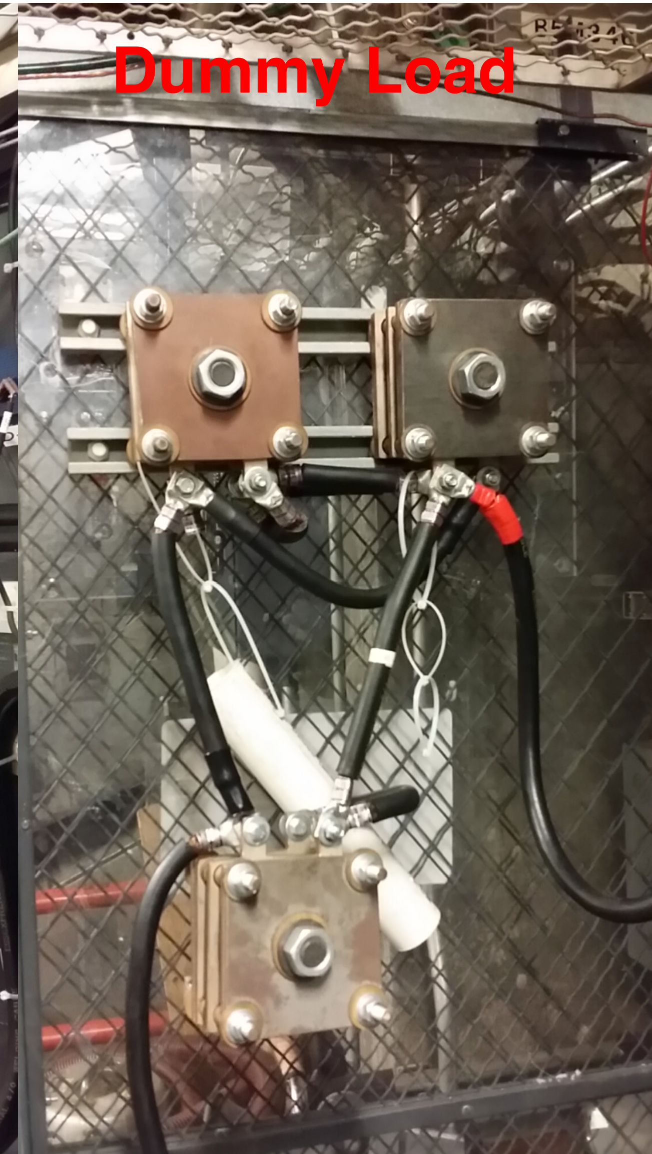




McBride Switch

CHI Capacitor Bank is located in the basement, below the NSTX-U device





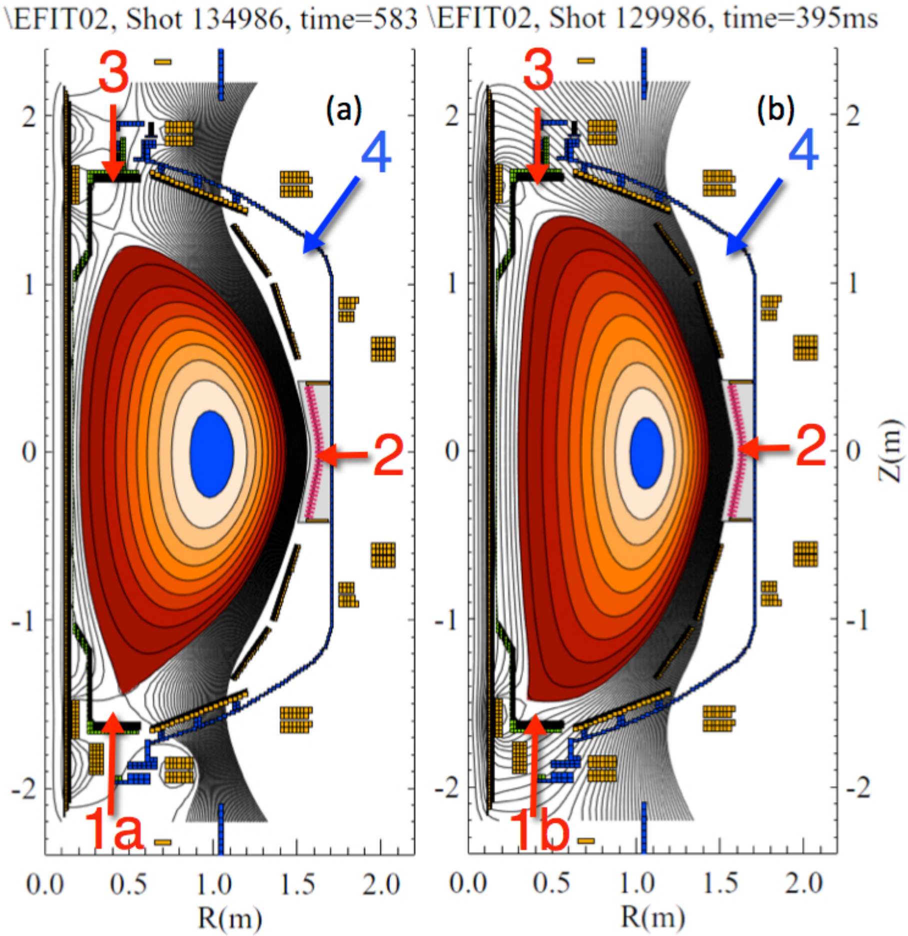
CHI Operations Sequence

- XP leader specifies gas pressure to be used in the experiment
  - Physics Operator informs Gas Systems Operator to fill the CHI gas plenums to the required pressure
- XP leader specifies voltage and the crowbar delay for the CHI cap bank
  - Physics Operator informs COE, who enters this information in the cap bank control panel & monitors the system during charging
- XP leader specifies the time at which the CHI valves & the CHI cap bank are to be triggered
  - Physics Operator enters this timing information in the PCS
- The discharge shape is manually programmed in PCS with the required coil current shapes, and the shot executed
- Li is used between shots & fast camera is actively used
- In some cases CHI is coupled to induction, initially using pre-programmed coil current, transitioning to feed back control
- On NSTX-U, starting in FY17 or 18, we will try to ramp these discharges using NBI with ECH and HHFW assist

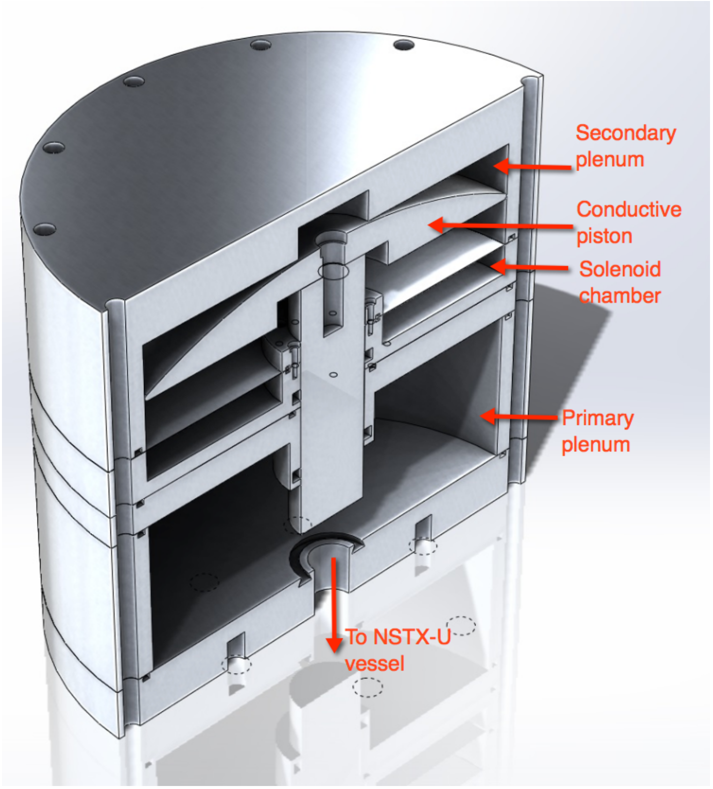
Massive Gas Injection for Disruption Mitigation Studies in NSTX-U

- In tokamaks and STs some disruptions may be unavoidable
- For these discharges a safe plasma termination method is needed
- Requirements for the mitigation of disruption effects fall into three categories:
  - (1) Reducing thermal loads on the first wall;
  - (2) reducing electromagnetic forces associated with "halo" currents, i.e. currents flowing on open field lines in the plasma scrape-off layer; and
  - (3) suppressing runaway electron (RE) conversion in the current quench phase of the disruption.

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

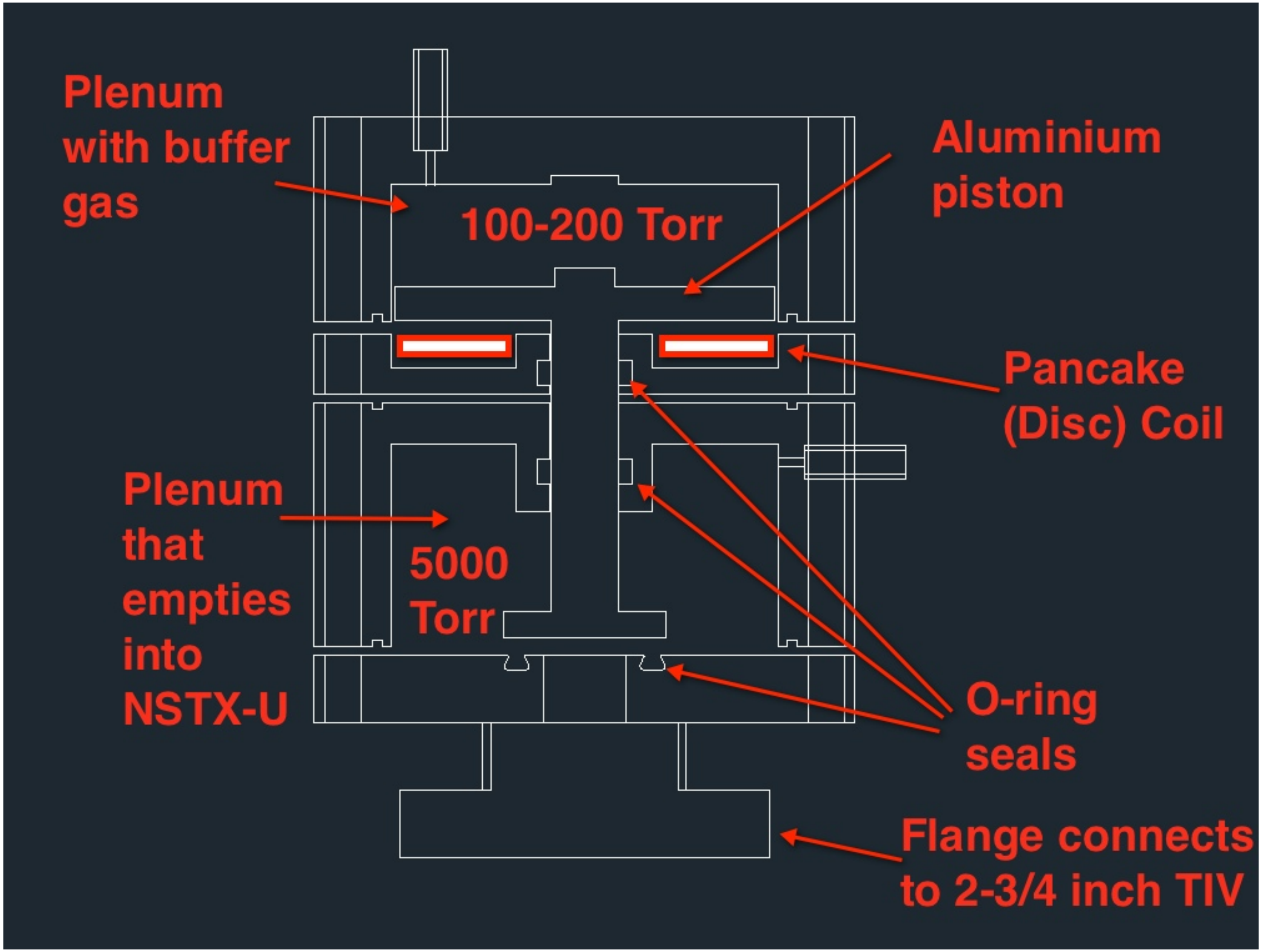


Low triangularity **High triangularity**

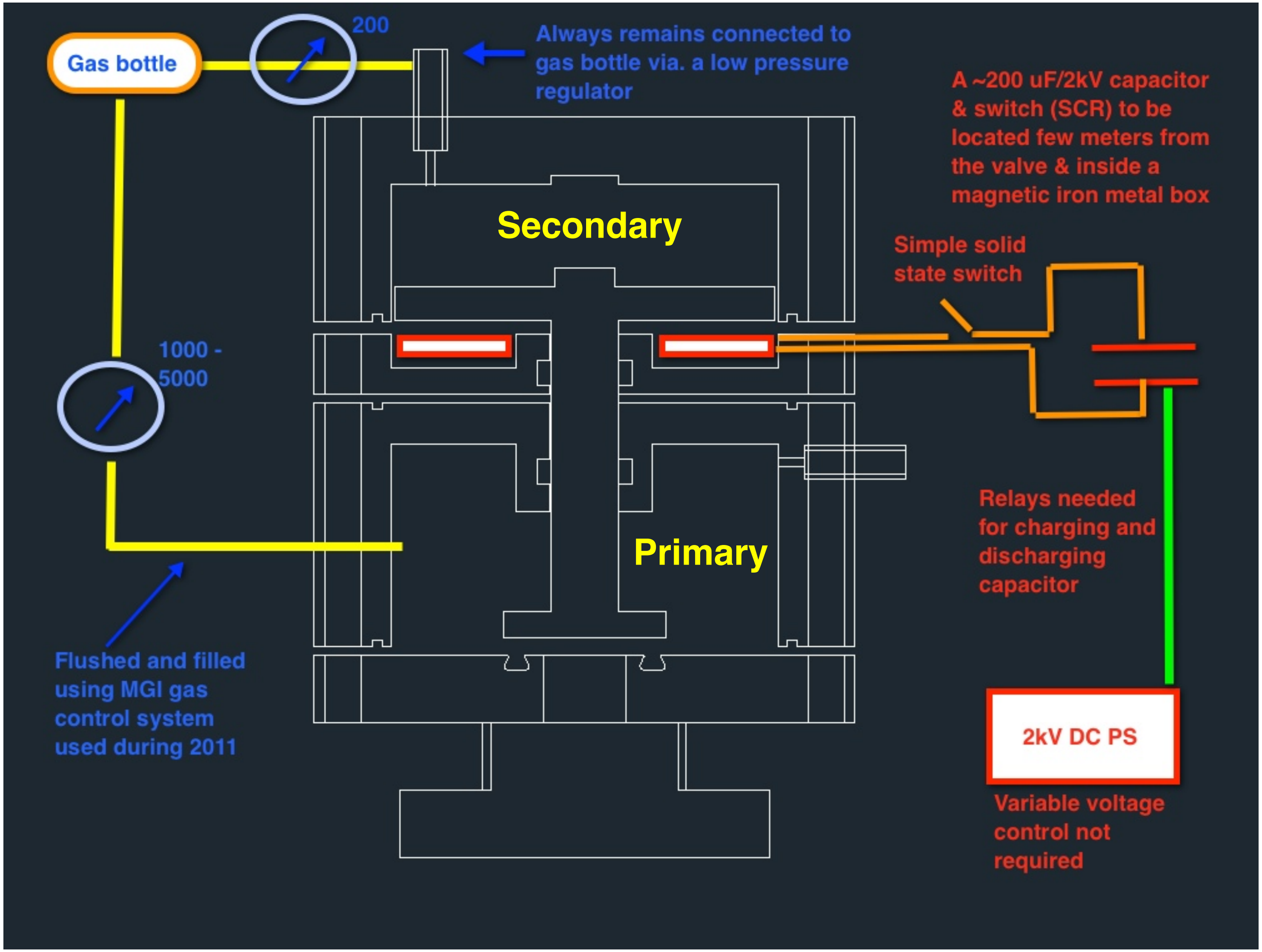


1a: Private flux region
1b: Lower SOL, Lower Divertor
2: Conventional mid-plane
3: Upper divertor
4: Future installation

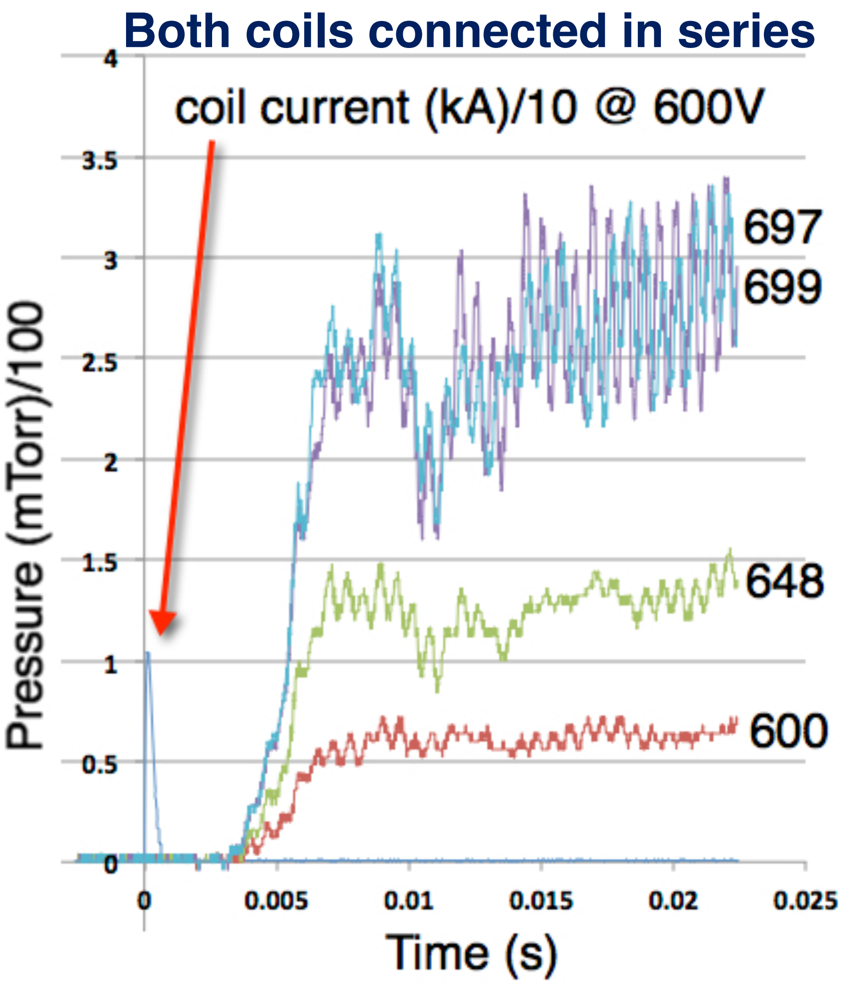
Primary Components of NSTX-U MGI Valve

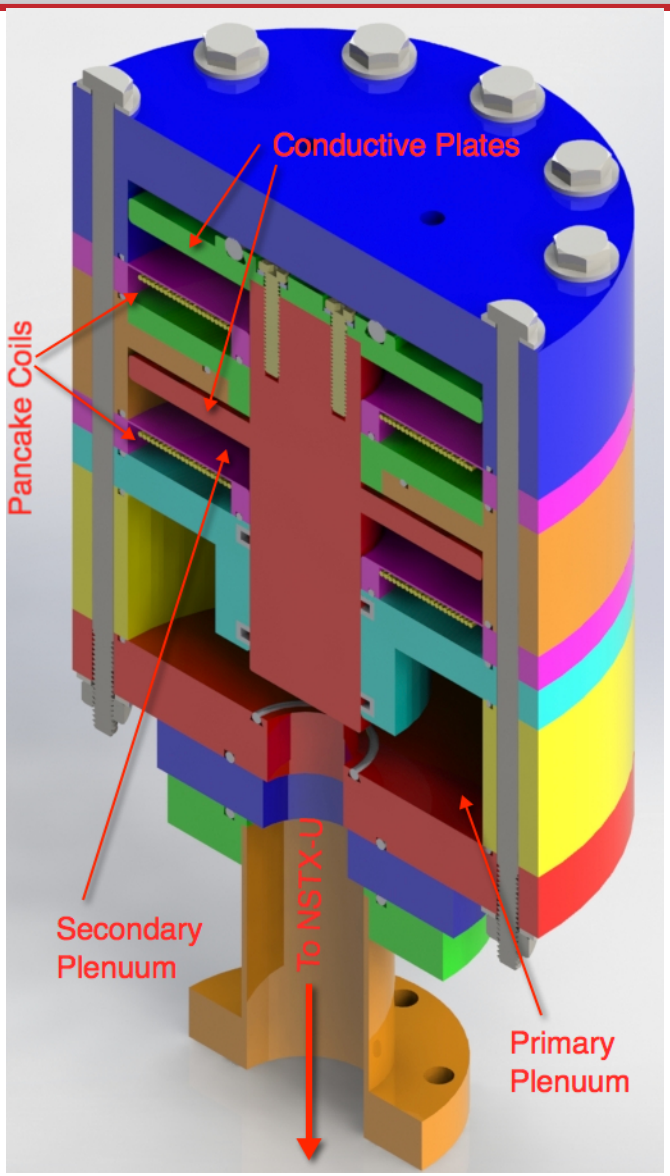


Valve Operating Sequence: 1) Secondary Plenum and 2) Primary Plenum filled, 3) Energized capacitor discharged



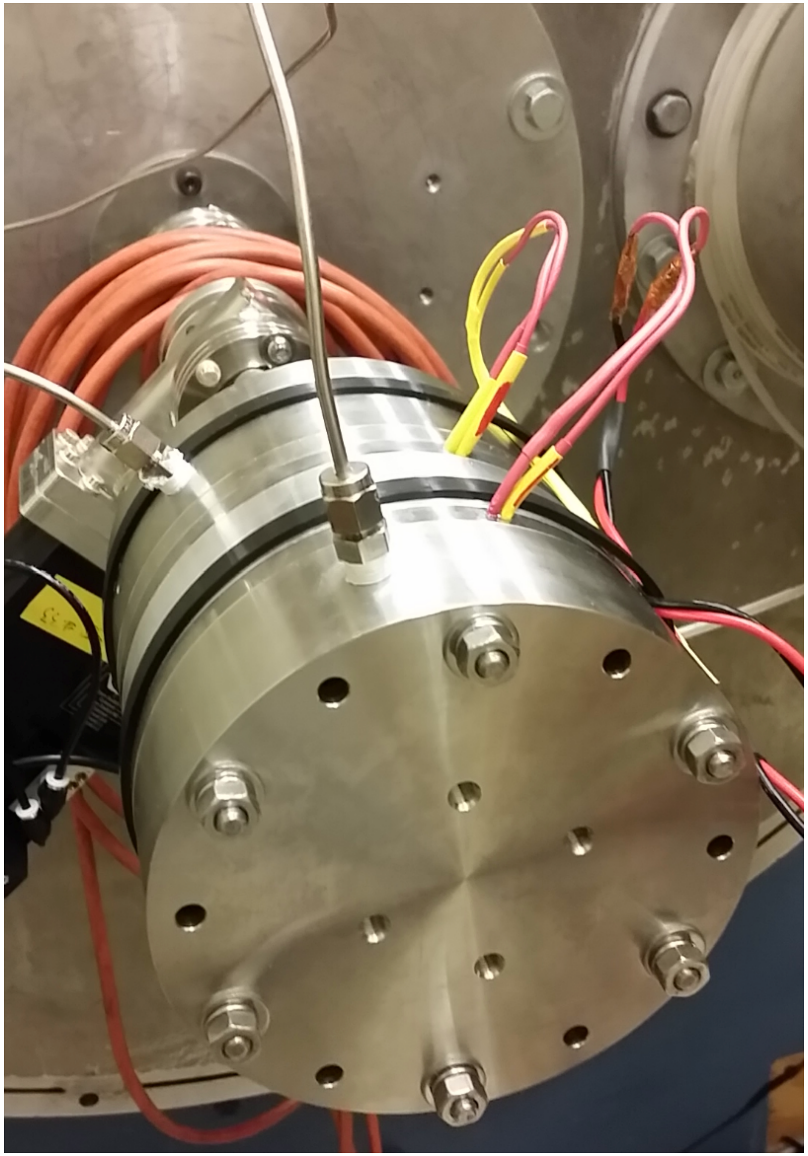
V3 Valve Uses Double Solenoids to Create Cancelling Torque in a Magnetic Field (NSTX-U Valve)





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

NSTX-U Upper MGI Valve



MGI Operations Sequence

- XP leader specifies gas pressure to be used in the experiment
  - Physics Operator informs Gas Systems Operator to fill the Primary and Secondary plenums to the required pressure (Gas species is determined the day before the experiment)
- XP leader specifies the time at which the MGI valves are to be triggered
  - Physics Operator enters this timing information in the PCS
- The discharge to be used is loaded and the shot executed
- Will most likely conduct 15 to 20 min HeGDC between shots to recover vessel conditions
- Because of the large quantities of impurity gases to be injected (~50 to 300 Torr.L Neon and as much as 1000 Torr.L in future), the gains on all the required diagnostics should be adjusted the day before, and diagnostics not needed should be powered down and the TIV and shutters to those diagnostics closed

Summary

- Coaxial Helicity Injection (CHI) will develop capability for eventually supporting full non-inductive operations on NSTX-U in support of a ST-FNSF

- Massive Gas Injection (MGI) will study the benefits of varying the poloidal gas injection location and better understand the MGI gas assimilation efficiency in support of ITER research