Strategic Planning for the Disruption Mitigation Topical Area for 2024-2025

by

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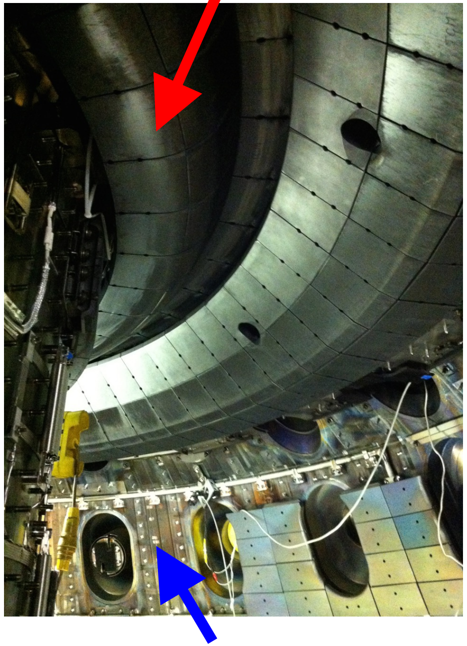
DIII-D NATIONAL FUSION FACILITY

OAK RIDGE National Laboratory

DIII-D facility is well-suited for disruption studies

- **Vacuum vessel designed to handle large disruption forces**
- **Thick all-graphite first wall can withstand high temperatures (> 2000° C)**
  - Thermal quench heat loads as well as runaway electron strikes
- **Allows disruption studies without fear of damage!**

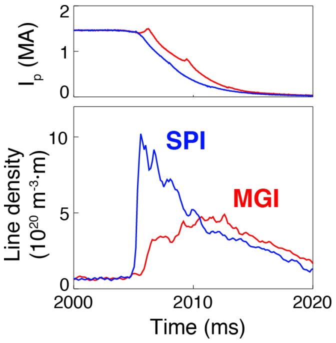
Carbon tiles
16000 kg

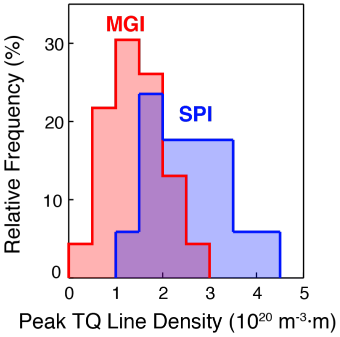


Vacuum vessel
8200 kg

DIII-D facility is well-suited for disruption studies

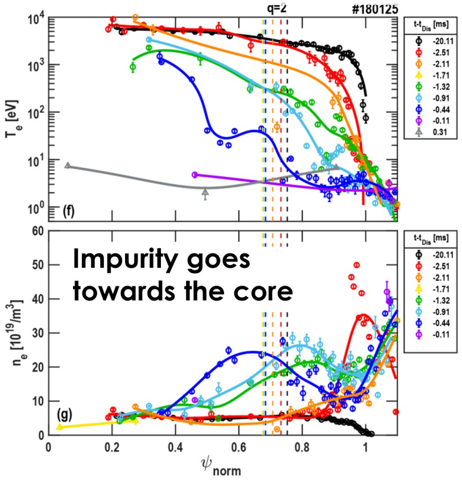
- **Variety of actuators/technologies have been tested**
  - KPs, MGI, SPI, ShPI
- **Shattered Pellet Injection developed here → selected for ITER DMS and now deployed worldwide**



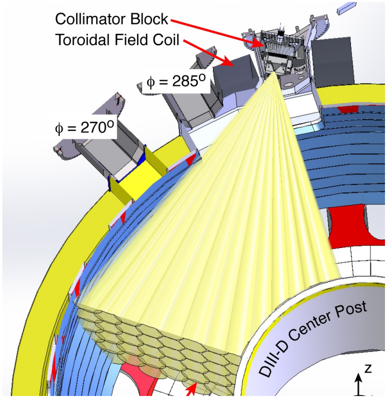


- **Diagnostics are essential to assessing mitigation efficacy, developing physics basis**

TQ profile measurements



Gamma ray imager



Current research goals are listed in DIII-D Field Work Proposal

- **FY23 Research Goals**
  - Characterize assimilation dynamics for ITER-relevant SPI shutdown scenarios utilizing parallel and sequential multi-injector schemes
  - Measure RE seed transport and resulting prompt loss of REs during TQ
  - Assess MHD effects in post-disruption RE plateaus through internal magnetic measurements and final loss events
- **FY24 Research Goals**
  - Determine effect of RE final loss dynamics and spatial structure on resulting wall heating
  - Deliver mitigating impurity load to plasma core utilizing intact delivery of shell pellet with sabot-based acceleration
  - Characterize RE seed generation based on optimally constructed shell pellets in high-temperature plasma scenarios
- **FY25 Research Goals**
  - Assess ability to achieve “inside-out” shutdowns based on cryogenically formed layered pellets
  - Assess interaction of REs with rf and current-drive actuators as a potential path to controlling RE distribution function
  - Characterize effect of penetration depth on SPI mitigation with a two-stage light gas gun

DIII-D program milestone on shell pellets proposed for 2025

- **Milestone 2025-2 (Proposed for FY25):**

  Evaluate the efficacy of inside-out disruption mitigation using Li-coated pellets

  Dispersive shell pellet (DSP) injection has been proposed as an alternative to SPI due to its potential to address the three major mitigation requirements: thermal quench (TQ), current quench, and runaway electron mitigation. Previous DSP experiments in DIII-D utilized high-density carbon (HDC) shells which resulted in high levels of $Prad$ and large perturbations to Wth prior to the deposition of the boron powder payload. To reduce the impact of shell ablation before payload deposition, lithium coatings have been proposed as the outer pellet surface material. Lithium is the lowest-Z, lowest radiating solid available, and thus presents the best opportunity for true core impurity deposition. Injection with the fragile Li coating will be enabled by upgrading the existing pellet injector to use a sabot that protects the shell during launch. Both solid cores and HDC shells will be tested with the Li coating, with solid cores allowing for higher injection velocities. The deposition of the pellets with varying coating thicknesses and injected velocities will be measured to better design future pellets and launchers. Te profiles before, during, and after injection will be measured to determine if an inside-out TQ is indeed triggered. The results should enable the first true comparisons of modelling and experiments for inside-out TQ mitigation.

Longer term research goals are identified in DIII-D 5-Year Plan

- **Challenge 1: Optimized particle delivery schemes by SPI**
  - Goal 1: Multi-SPI optimization for ITER application
- **Challenge 2: Develop methods to suppress and mitigate runaway electrons**
  - Goal 1: Robust diagnosis of RE seeds
  - Goal 2: Extrapolate RE avoidance and mitigation via MHD and kinetic instabilities
- **Challenge 3: Passively resilient device DMS edesign**
  - Goal 1: Passive 3D coil for RE seed deconfinement
  - Goal 2: Self-healing first wall materials test: Divertor plates, flowing first-wall materials, etc.
- **Challenge 4: Alternative active DMS: Central deposition and reduced response time**
  - Goal 1: High-speed injection technology
  - Goal 2: Dispersive shell pellet

Group discussion led to proposal for a single Disruption Mitigation thrust

- **Topical area met on August 22nd and September 5th**
- **Various thrust proposals were discussed**

- **Consensus was behind proposing a single Disruption Mitigation thrust, rather than specific sub-topics**
  - This is a better fit for the size of the group
  - Must have clear goals and plans

Disruption Mitigation Thrust for 2024-2025 focuses on key elements identified in 5 Year Plan

- **SPI optimization for ITER:** (Top level ITER R&D Issue)
  - What sequence/distribution/quantities of species provide TQ/CQ/RE optimum?

- **RE Solutions (suppression and/or mitigation):**
  - How do RE seed transport and loss affect beam formation? (*Is suppression viable? If not, knowing magnitude of final beam sets mitigation requirements*)
  - How does RE damage depend on final loss dynamics? How can actuators affect this process (e.g. through ionization levels, MHD, etc.)?

- **Development of advanced techniques**
  - How robustly do core-particle-deposition approaches lead to “inside-out” TQ?
  - Can dust injection increase drag on RE seeds relative to thermal electrons?