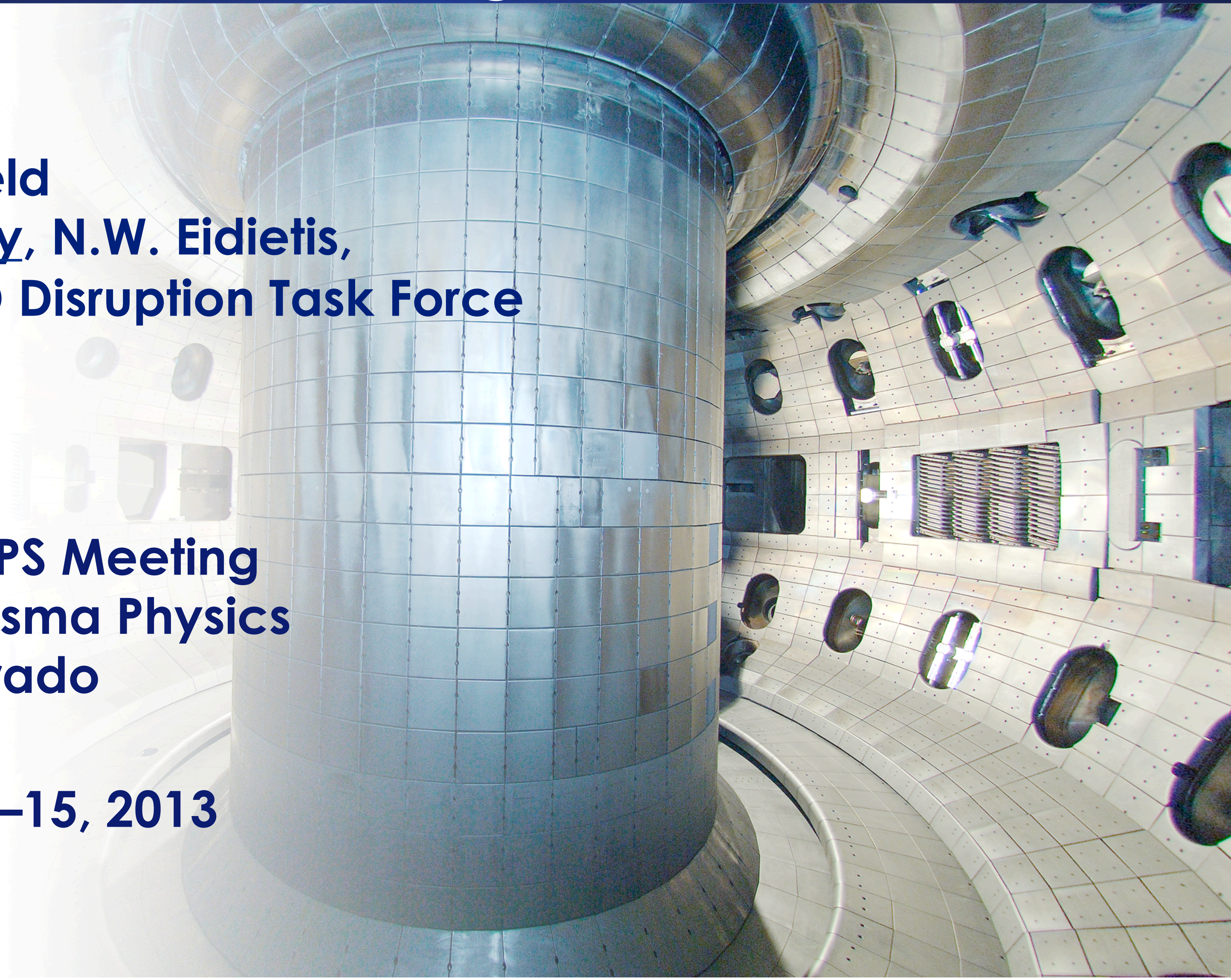
DIII-D Support for ITER Disruption Mitigation System Selection and Design



by

C.M. Greenfield

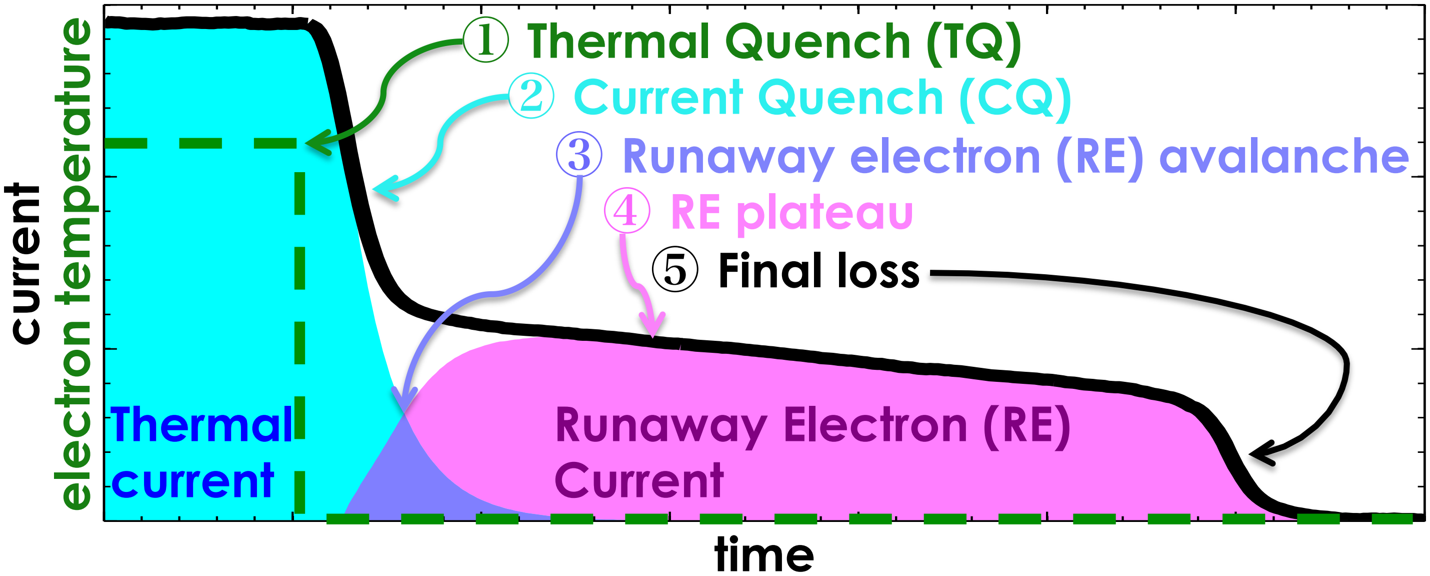
for J.C. Wesley, N.W. Eidietis, and the DIII-D Disruption Task Force

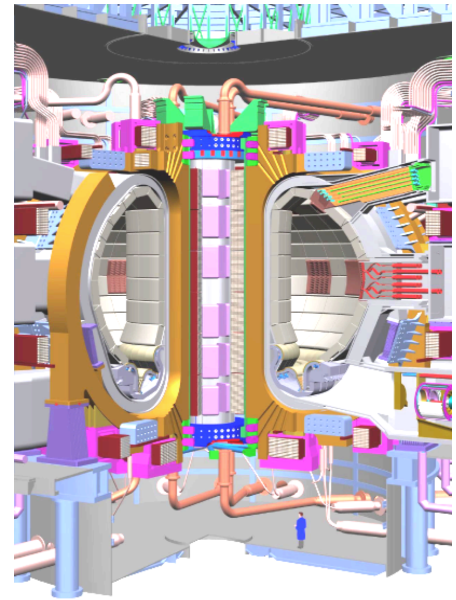
Presented at the

55th Annual APS Meeting
Division of Plasma Physics
Denver, Colorado

November 11–15, 2013

DIII-D is Addressing Critical Issues for the ITER Disruption Mitigation System





- **Preferable to avoid disruptions, but Disruption Mitigation System (DMS) needs to be available and reliable**
  - General approach: Inject particles ➔ radiate plasma's energy
- **Timescale/scope of research set by ITER DMS Final Design Review in 2017**
  - Current plan allocates space in three upper and one equatorial port
- **DIII-D research is addressing all phases of the disruption**
  - Choice/location/number of injectors
  - RE mitigation is still an unresolved issue for ITER

DIII-D is Supporting the ITER DMS Design for All Phases of the Disruption

Choice and number of injectors for ① TQ and ② CQ

- Compare ITER Preferred Injectors
- Shell Pellets
- Radiation Asymmetry
- TQ/CQ Integration

③④⑤ RE Mitigation

- ③④ Anomalous Dissipation
- ④ Dissipation & Control Scenarios
- ③④ Suppression Scenarios
- ⑤ Final Loss Physics

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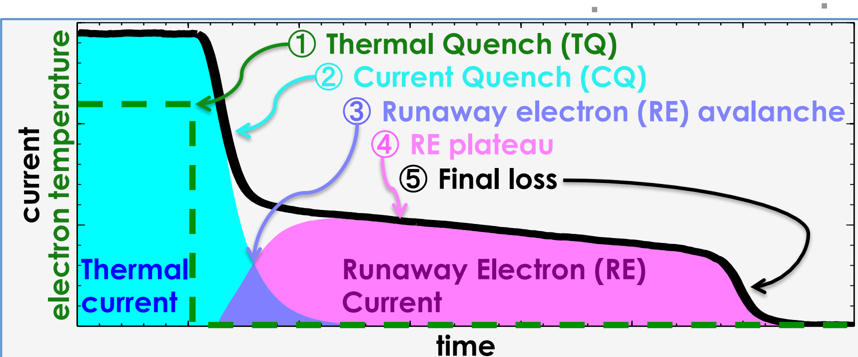

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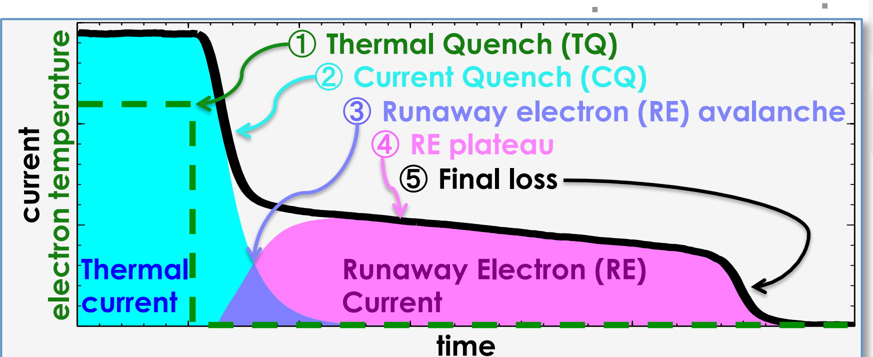

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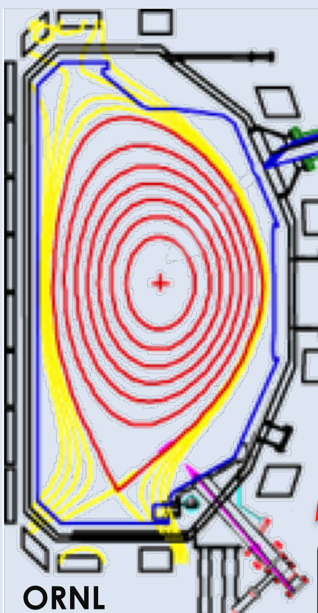
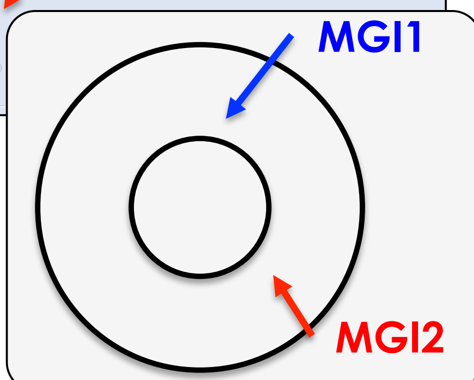
DIII-D is Evaluating Different Particle Delivery Methods for the ITER DMS

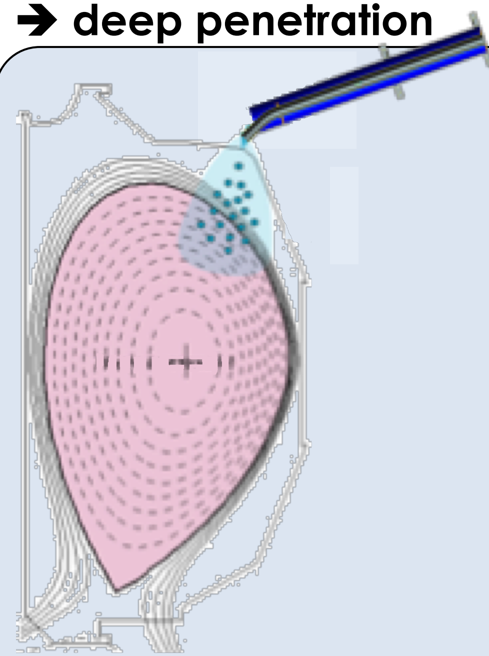
Existing

Massive Gas Injection at multiple locations





Shattered Pellet Injection ➔ deep penetration



Fall 2014

Shell Pellet Injection

UCSD

- MGI1 and MGI2 are separated both poloidally and toroidally
- SPI: Frozen D_2 pellet (~size of wine bottle cork) strikes shatter plate
- Shell: Inject boron powder in plastic shell

Goal of All Injectors is to Harmlessly Radiate Away the Energy Contained in the Plasma

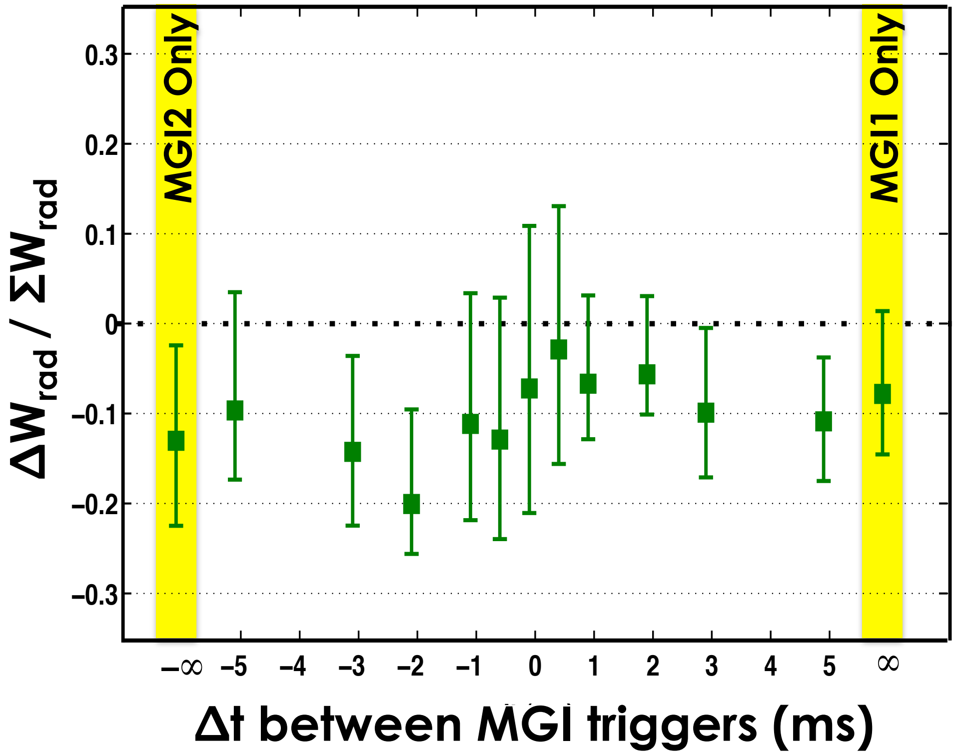
Goal #1
Radiate >90% thermal energy (protect divertor)

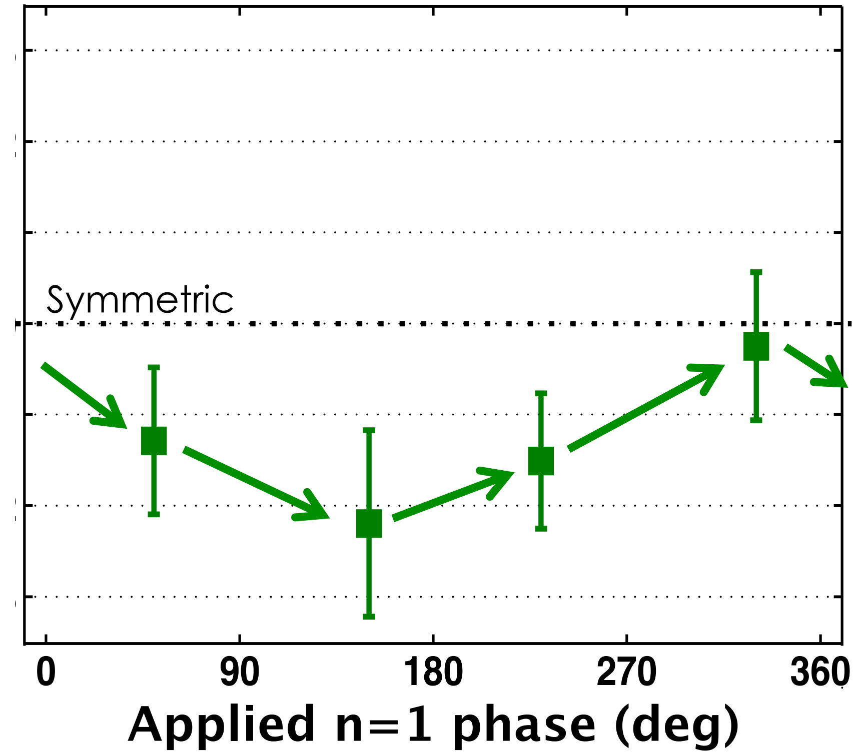
Goal #2
Minimize radiation peaking (PFC melting)

$$P_{rad}(\theta,\Phi,t) = f(\theta,\Phi,r)$$

- **Experiment and theory are working together to explore**
  - Asymmetries due to injector location
  - Asymmetries due to MHD instabilities
    [V.A. Izzo, Phys. Plasmas **20**, 056107 (2013)]

DIII-D Studying Sources of P_{rad} Asymmetry During Disruption Mitigation

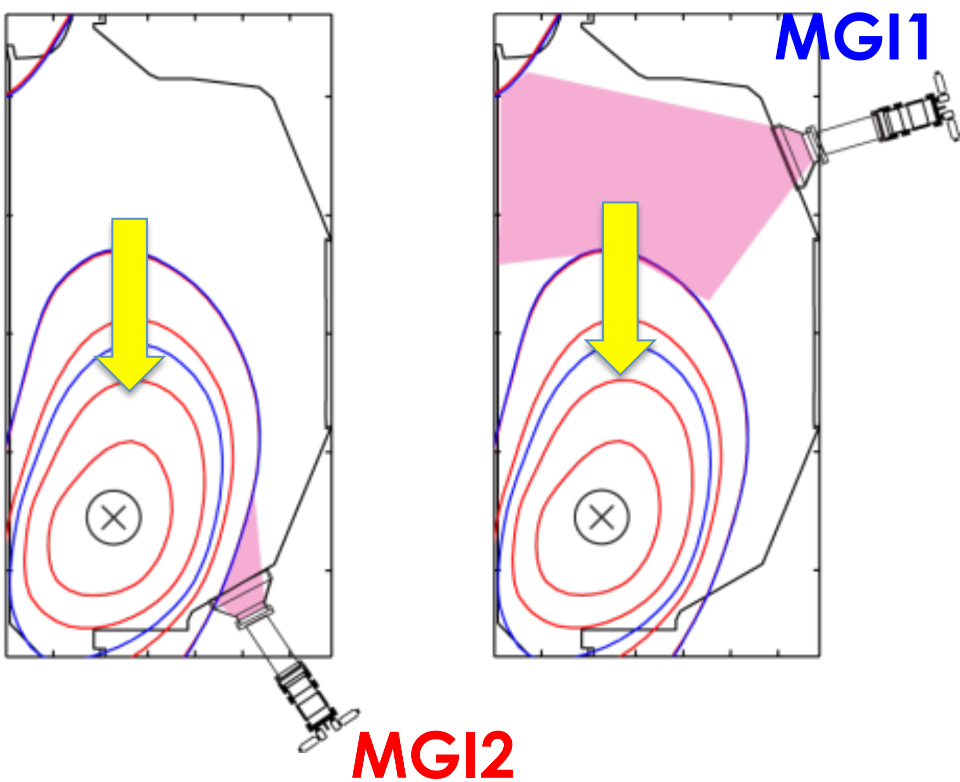




- **Injector # & distribution:** No significant effect upon TQ P_{rad} asymmetry
- **Thermal quench MHD:** Does appear to affect TQ P_{rad} asymmetry

DIII-D Studied Effect of Injector Delay & Poloidal Location on Vertical Displacement Event (VDE) Mitigation

- **ITER DMS Question:** Will lack of lower injectors impede downward VDE mitigation?
- **Timing Effect**: Clear advantage to early VDE mitigation
- **Location Effect**: Only small advantage for valve in direction of VDE



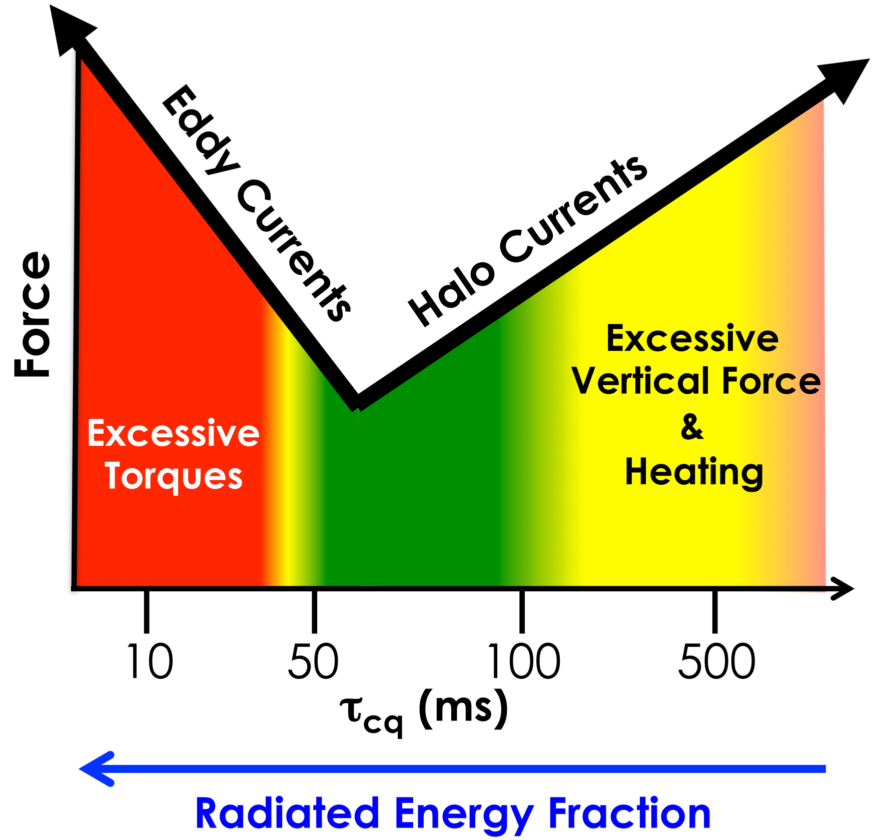
DIII-D Will Test Integrated Disruption Mitigation Scenarios that Simultaneously Meet ITER TQ & CQ Requirements

ITER DMS requirements:

Radiate 90% thermal energy
+
Maintain CQ duration
$35 \text{ ms} < \tau_{CQ} < 150 \text{ ms}$

- Conflicting requirements likely mean small operating space

- Minimal difference between DIII-D carbon wall & Be wall when using high-Z (neon) impurity injection



DIII-D is Supporting the ITER DMS Design for All Phases of the Disruption

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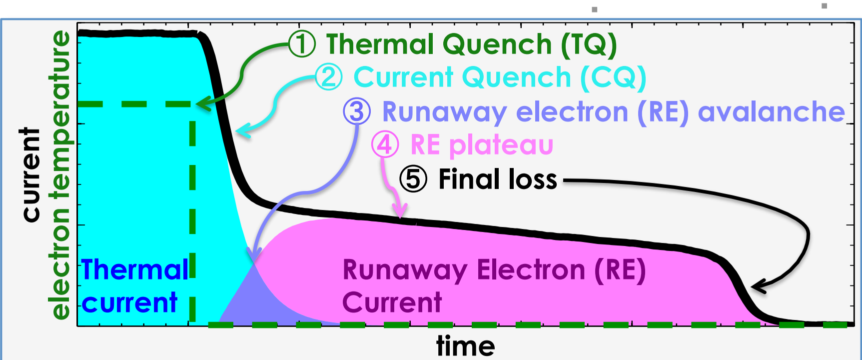

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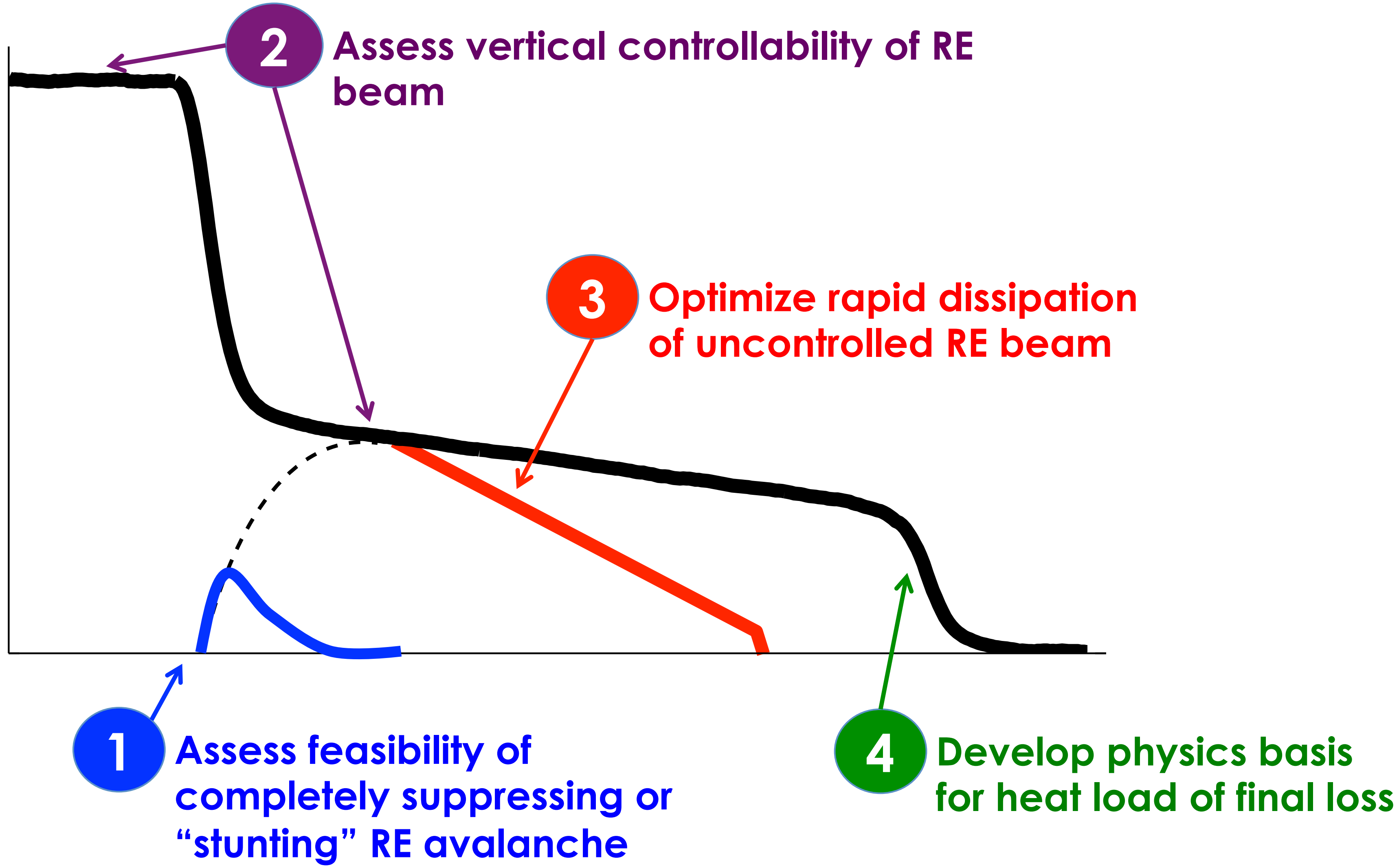
Research Program Provides Multi-Layered Approach for Minimizing RE Threat



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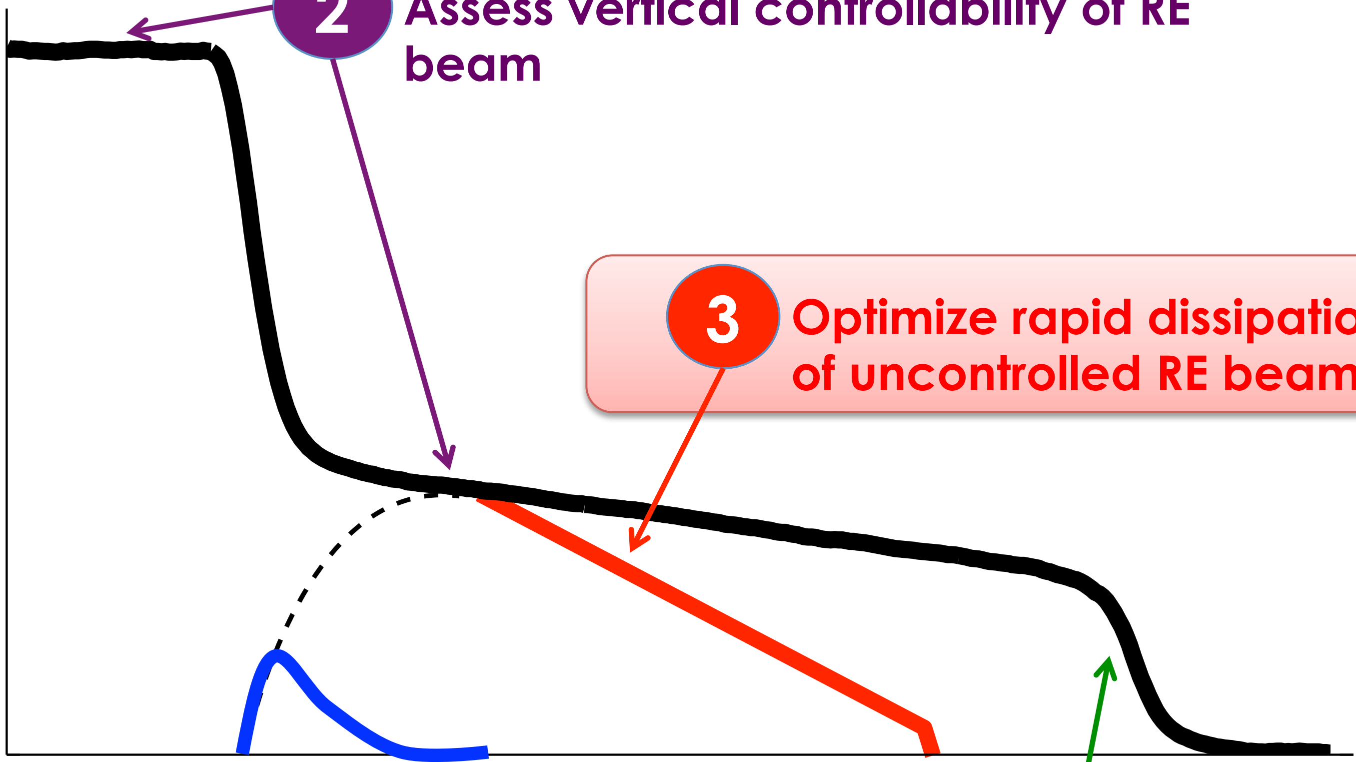


2 Assess vertical controllability of RE beam

3 Optimize rapid dissipation of uncontrolled RE beam

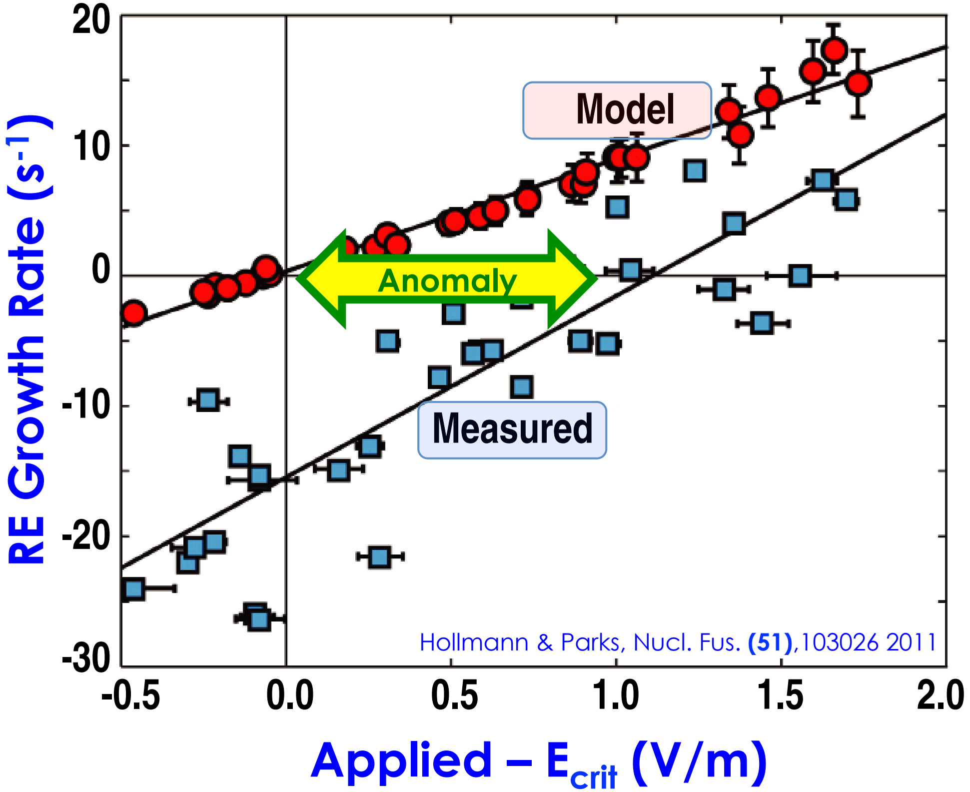
1 Assess feasibility of completely suppressing or “stunting” RE avalanche

4 Develop physics basis for heat load of final loss

DIII-D is Investigating "Anomalous" RE Transport Physics and Feasibility of Suppressing RE Avalanche

- **Theory: Increasing critical electric field (E_{crit}) enough to suppress avalanche requires ~100X $n_{e,0}$ during CQ**
  - Not compatible with other ITER operating limits

- **Experiment: Enhanced dissipation (higher threshold E) observed**
  - Lower n_e for RE suppression may be possible



- **Anomalous RE dissipation measured in both post-disruption RE & ohmic flattop quiescent RE (QRE) beams**

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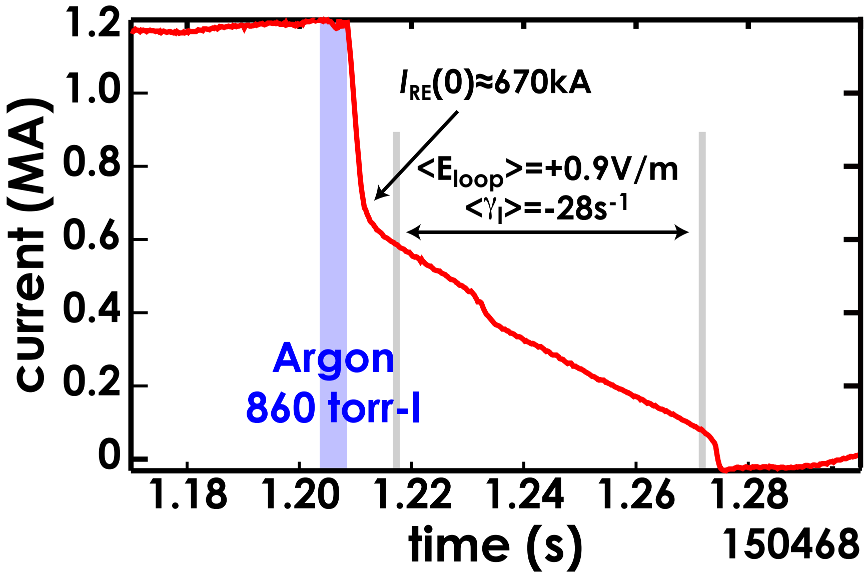
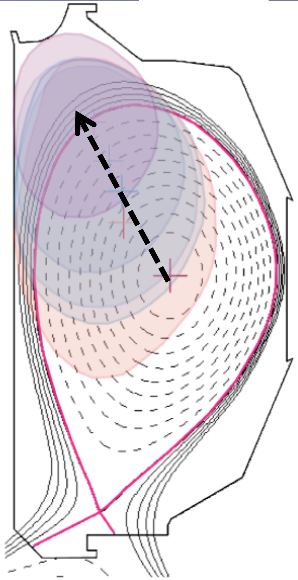
DIII-D is Exploring Scenarios for Dissipation of an Existing RE Beam

3



- **Pre-emptive high-Z Massive Gas Injection provides fast RE shutdown**
- **DIII-D has demonstrated 4× dissipation increase with small quantities of high-Z gas**
- **DIII-D results *suggest* that gas or pellet injection systems sized for ITER disruption mitigation will also be effective for 'post-emptive' RE dissipation**
- **Future DIII-D studies with Ar, He and Xe needed**

Future Work Will Asses Controllability and Termination Physics of RE Beams

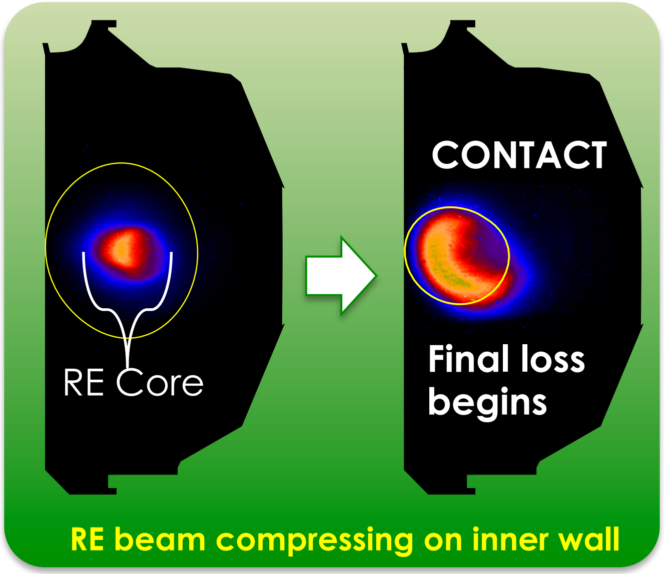


2 Assess vertical controllability of RE beam

- What are true limits?
- Improved controllability by pre-placing plasma at neutral point before disruption?

4 Pursue physics basis for onset of RE final loss and assess impact to vessel

- Thermal Footprint
- Magnetic → Kinetic energy transfer



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