Real-time VDE mitigation with gas jet injection, and mixed gas jets on Alcator C-MOD

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Gas jet disruption mitigation: Pre-programmed vs real-time

Alcator C-Mod

All previously reported experiments with gas jet disruption mitigation on C-Mod have been done on stable, non-disrupting plasmas.

- Valve trigger was fired at pre-programmed time
- Plasma was not moving prior to gas jet injection
- Time response of gas delivery system was not an issue

The gas jet triggered a disruption, and various mitigation-relevant parameters were measured and compared to 'naturally occurring' disruptions.

Goal: real-time disruption mitigation with gas jet injection.

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Carry out tests using VDEs, since we have simple and reliable methods for reproducibly making a VDE *and for early detection of a VDE*.

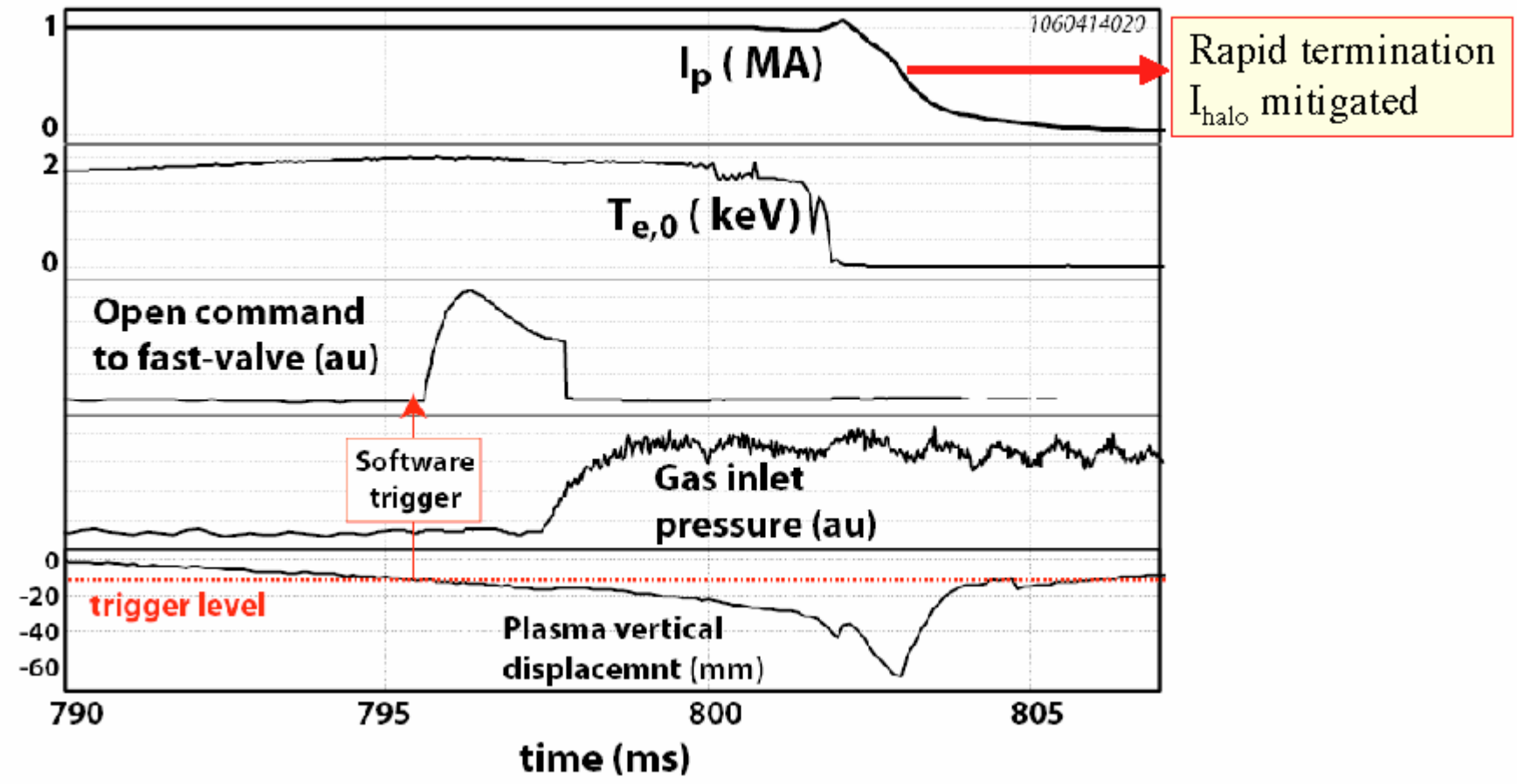
- Response time of gas delivery system now becomes an issue, since it is similar to VDE disruption timescale (a few milliseconds)
- Mitigation of VDEs may be more difficult than mitigation of non-VDE disruptions (high β, locked mode, density limit, etc.)

Mitigation of VDEs on Alcator C-Mod

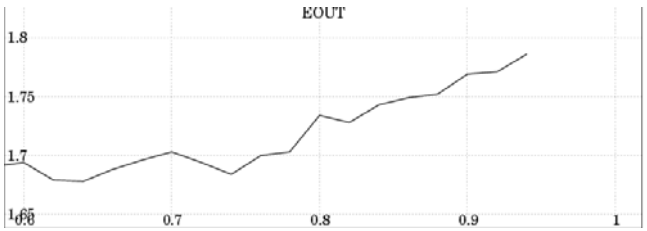
3 different experiments were done to test argon gas jet mitigation of VDEs:

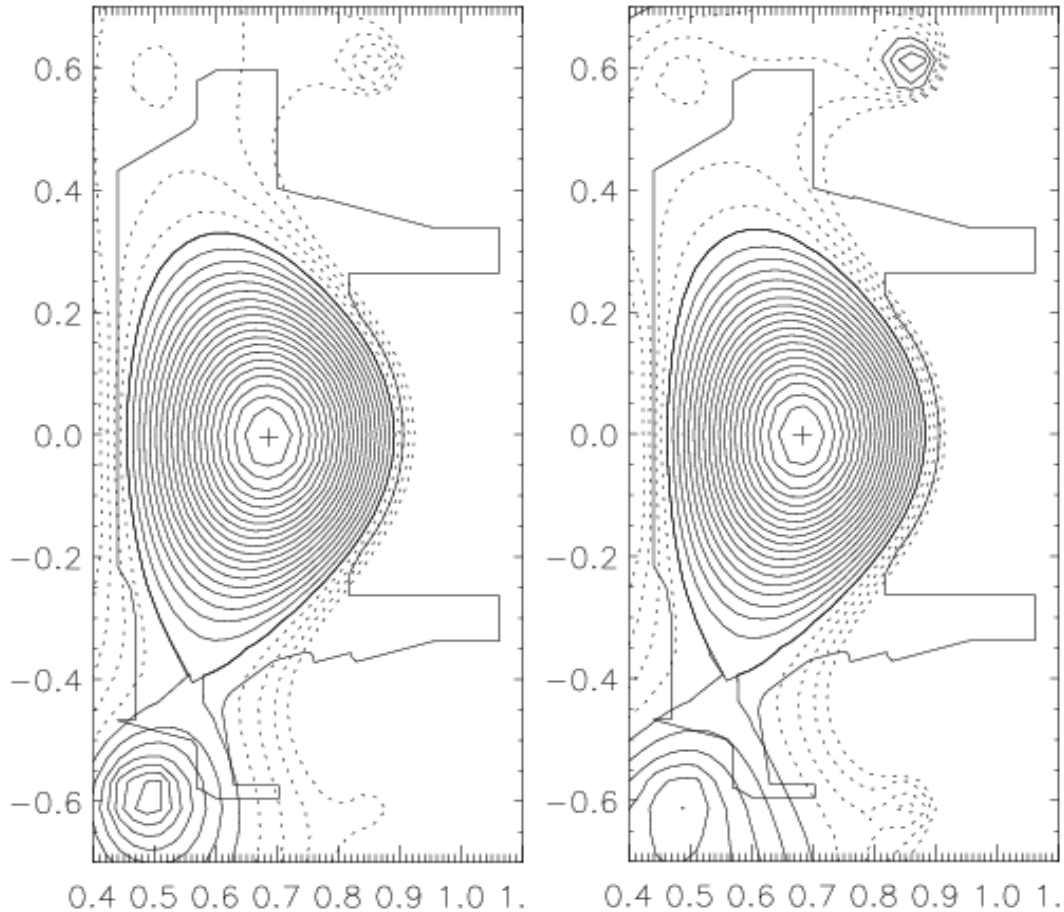
1) Pre-programmed turnoff of vertical position control, and pre-programmed firing of gas valve
   - Compare mitigation of static vs moving plasma
   - Determine trigger level (vertical displacement at which gas jet is fired)
2) Pre-programmed turnoff of vertical position control, and real-time detection of VDE by DPCS and firing of gas jet
3) Cause VDE by ramping up elongation, and real-time detection of VDE by DPCS and firing of gas jet

Digital Plasma Control System (DPCS) monitors vertical position, fires gas jet

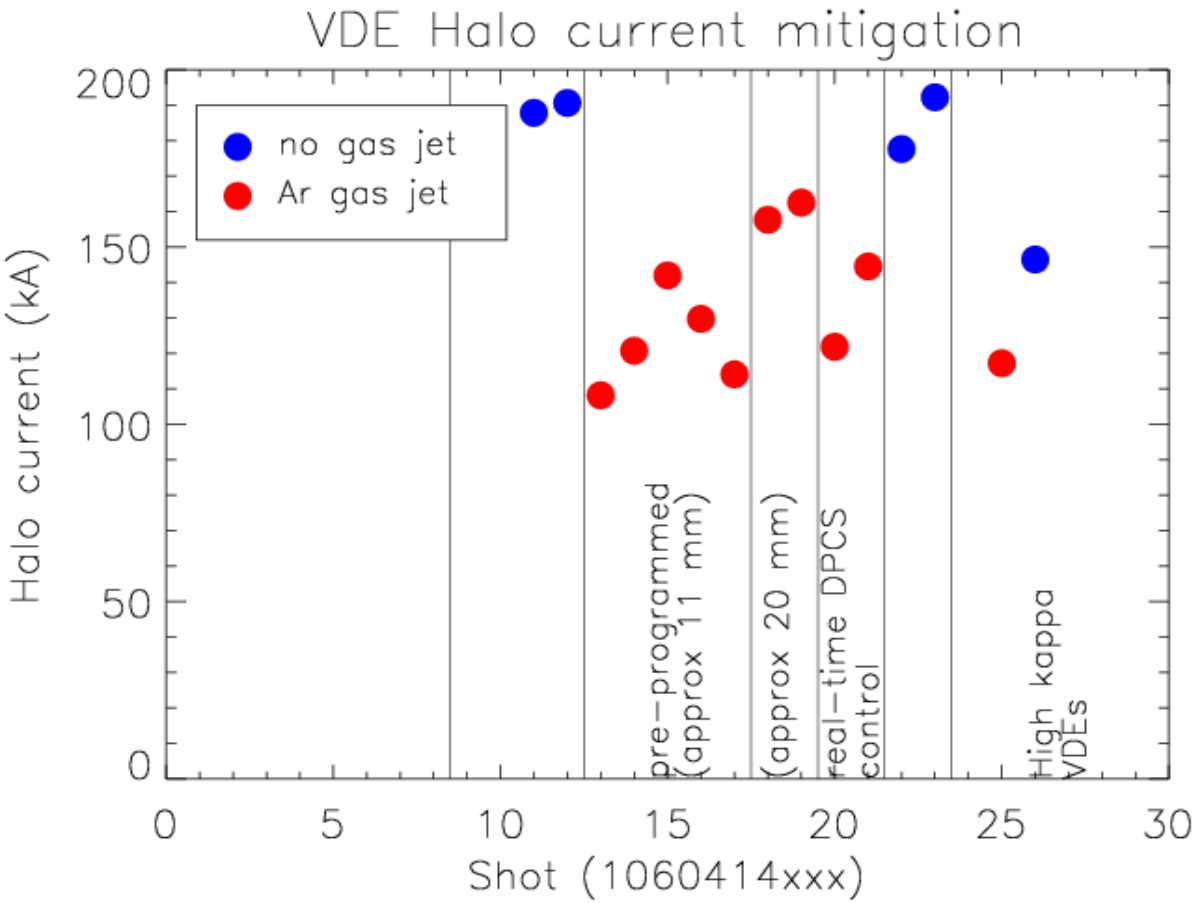


VDE initiated by ramping up elongation



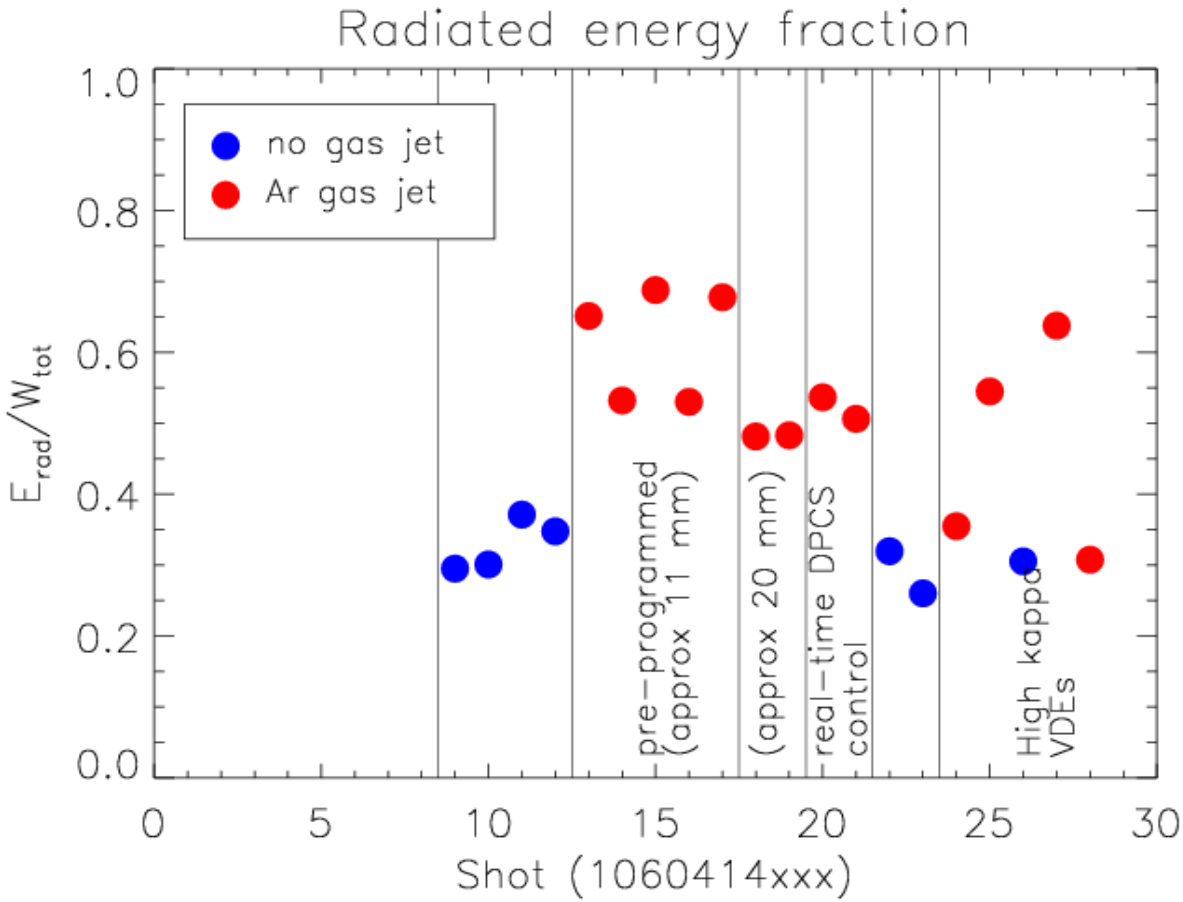


Halo current mitigated, but not quite as well as with vertically stable plasmas



For comparison, in vertically stable plasmas halo current is reduced by 50% with argon gas jet

Radiated energy fraction increased, but not quite as much as with vertically stable plasmas



For comparison, in vertically stable plasmas, E_{rad}/W_{tot} is $\geq$ 80% with argon gas jet

Summary of real-time mitigation of VDEs

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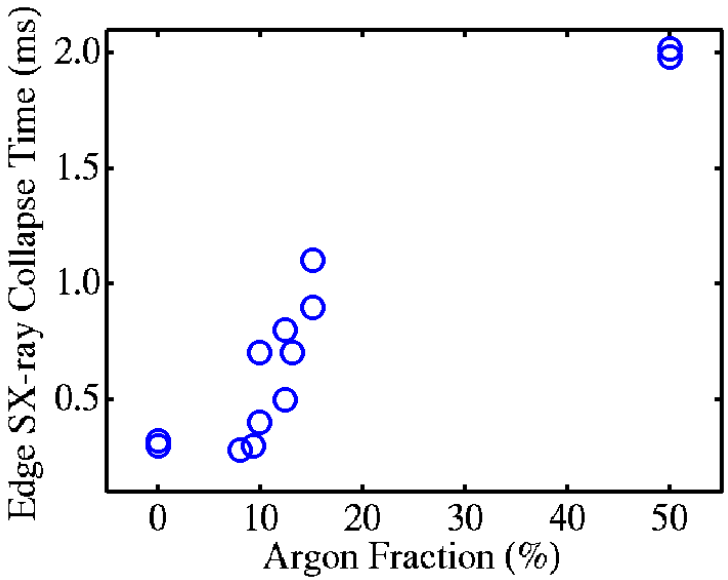
Real-time VDE prediction and gas jet firing works, and mitigation is good, although not quite as good as with pre-programmed, midplane disruptions.

- Response time of gas delivery system may be an issue
- Response time is dominated by flow speed of argon in the gas tube

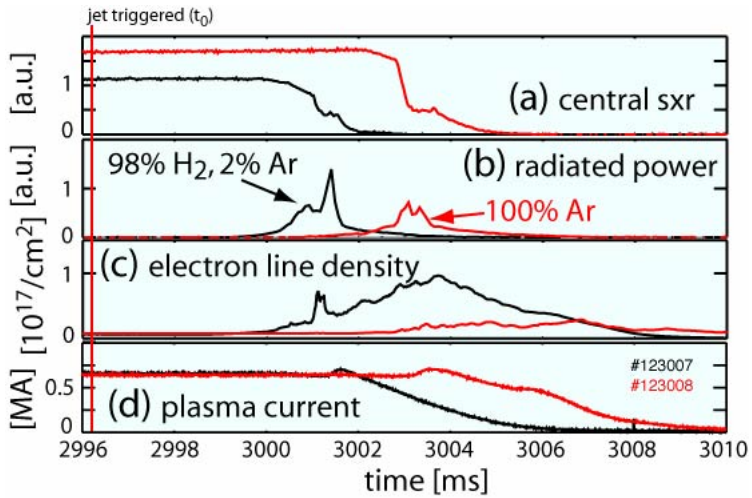
Experiments with mixed gas jets

Mixed gases: He or H_2 carrier with Ar seed speeds up delivery of argon

C-Mod
Helium + Argon



DIII-D
Hydrogen + 2% Argon



Thermal quench in both machines starts several ms earlier with He or H_2 + few percent Ar compared to pure argon

Mixed gases: An optimum argon fraction exists for mitigation effects

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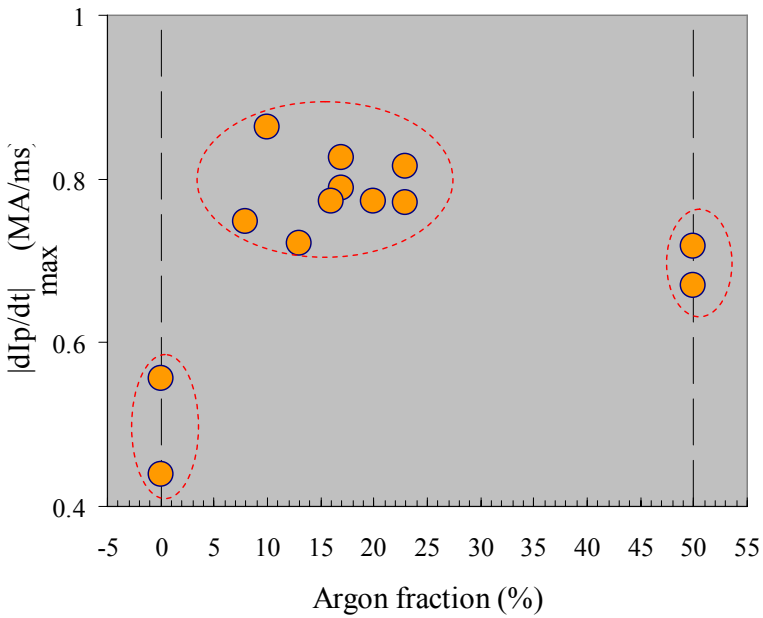
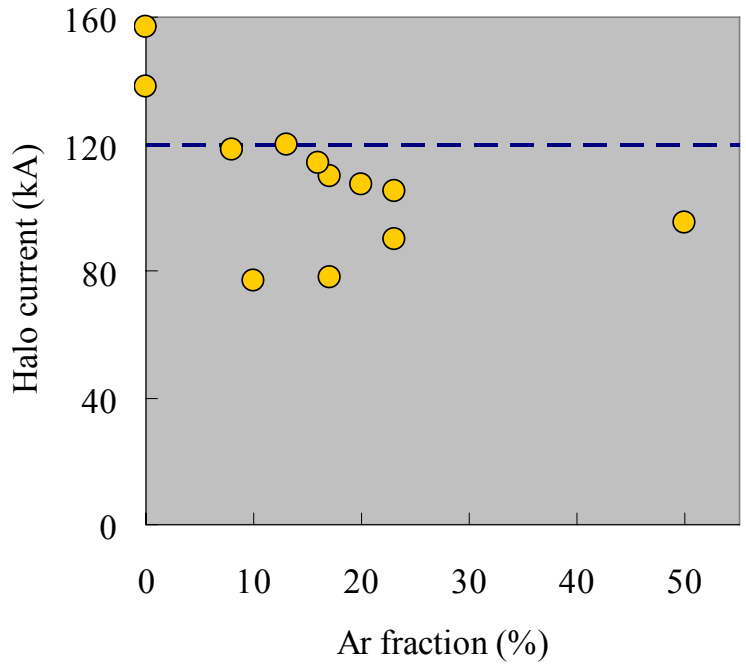
Current quench rate



Halo current



He-Ar mixture reduces halo current better than pure helium and is quicker than pure argon

There is an optimum Ar fraction

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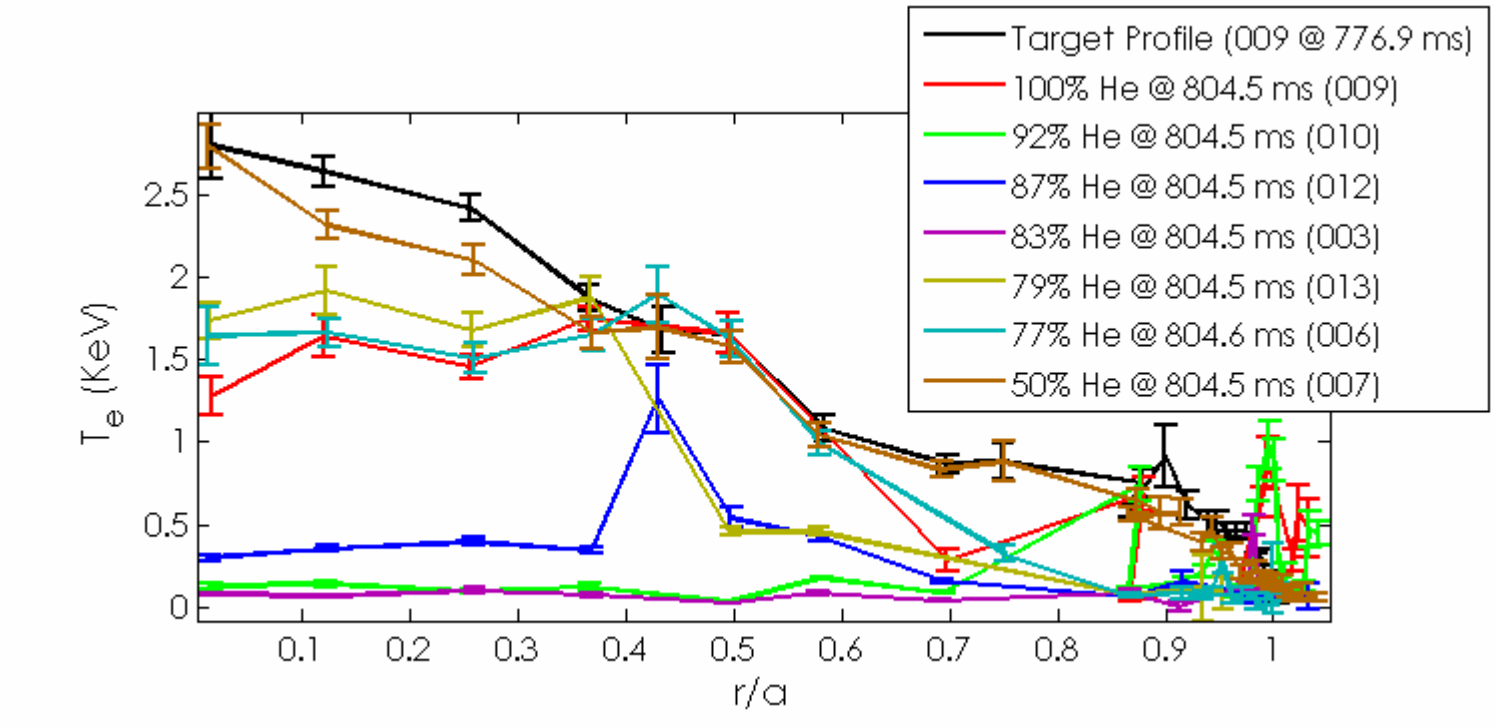

These T_e profiles show an optimum effect in the range of 8–17% argon fraction

Summary

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- Real-time gas jet mitigation of VDEs was successful
  - Mitigation was not quite as good as for stable, midplane plasmas
  - Time response of gas jet delivery may be an issue
- Mixing argon into helium carrier speeds up response time by ~ 2 ms while still resulting in good mitigation