Lithium Granule injection into ELM free H-Modes with lithium conditioned walls

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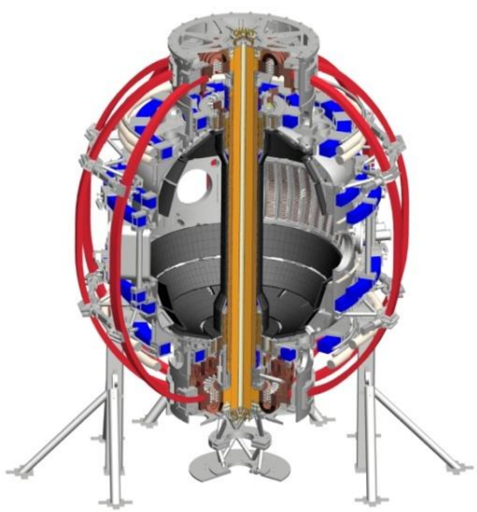

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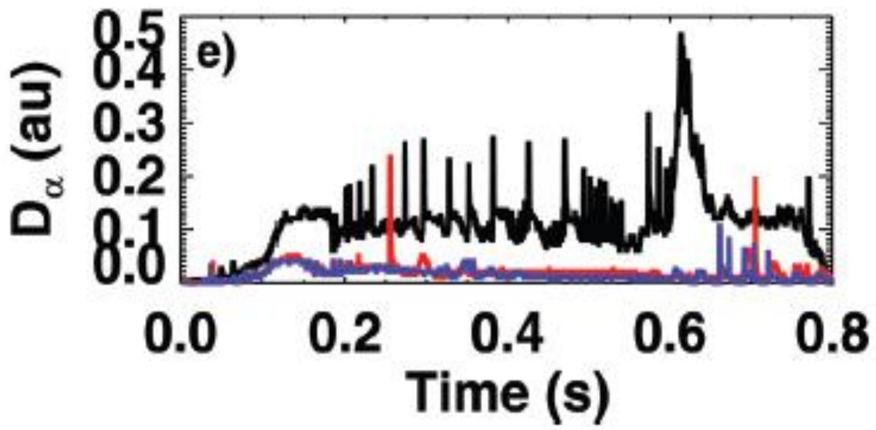
Lithium Wall Conditioning on NSTX led to ELM free H-Modes

- The introduction of lithium conditioning to the PFCs of NSTX led to ELM free H-Modes.
- This generated enhanced confinement but also led to a buildup of carbon impurities within the core of the plasma.
- The use of solid granule injection has been shown as a method for generating controlled ELMs and clamping core impurities.

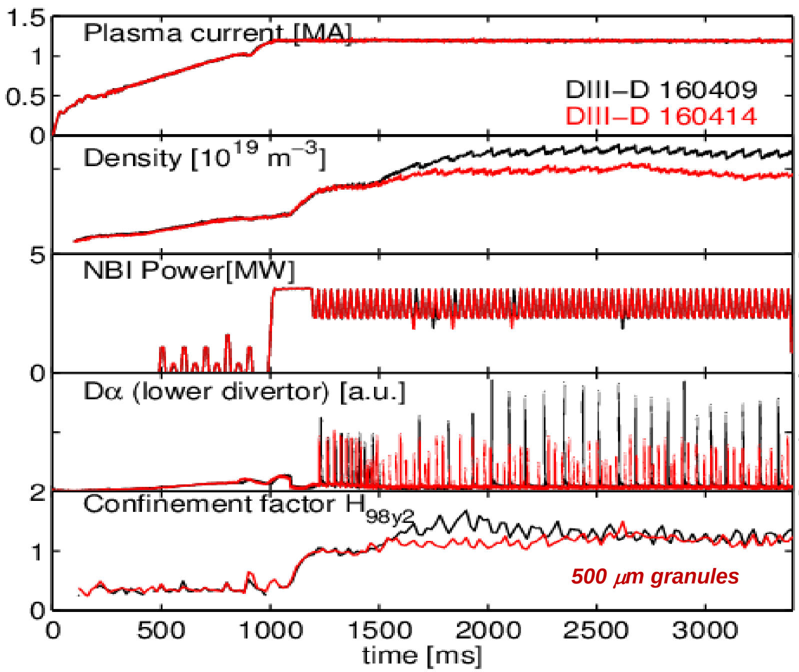


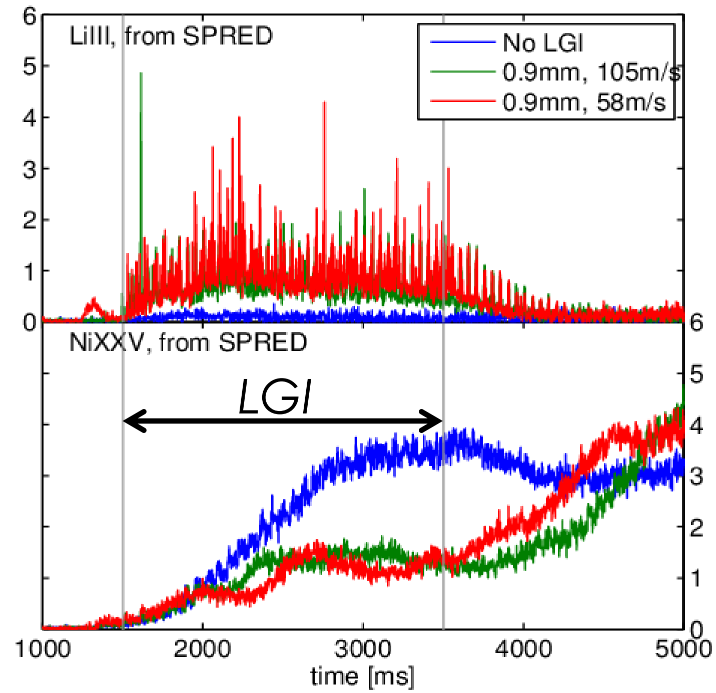
056118-8 Canik *et al.* Phys. Plasmas 18, 056118 (2011)

Comparison of pre-lithium (***black***) and post-lithium (***red*** and ***blue***) $D\alpha$ in NSTX

R15-3 High Performance Discharges : "Impurity control techniques, an example of which is ELM pacing, will be developed for the reduction of impurity accumulation in otherwise ELM-free lithium-conditioned H-modes."

Successful lithium pellet pacing experiments performed on EAST (D. Mansfield NF 53 2013) and DIII-D





By A.Bortolon for the LGI team
Presented to NSTX-U group at PPPL Jan 5th 2015

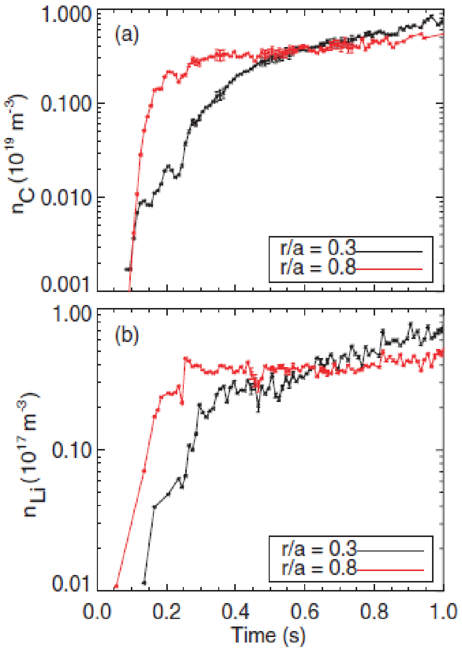
Granule injector design as will be implemented on NSTX-U has been shown to successfully generate and pace ELMs at 3 – 4x natural ELM frequency. The DIII-D experiment also showed a clamping of Ni impurity accumulation.

Granule Injector XP2: Lithium Granule Injection into ELM free H-modes with Lithium Conditioned Walls

Goal : Locate minimum edge perturbation required to initiate ELMs in a naturally ELM-free lithiated discharge.

- Empirical study to determine the minimal size, frequency and input velocity required for reliable ELM triggering.
- Monitor core impurity transport caused by granule instigated bursting in naturally ELM free lithiated discharges.
  - Look at impurity clamping within the core as a result of stimulated ELMs
  - Is there an effective size/frequency threshold for efficient impurity flushing?
  - Examine Li transport into the core as the carbon impurities are flushed
- High speed camera measurements of granule ablation and plasmoid formation to locate mass seeding within pedestal. Compare to pellet ablation models.
- Establish NSTX-U threshold for ELM triggering with solid granules.
- Compare to limitations found elsewhere with D2 pellet triggering

Comparison of C and Li core evolution in NSTX ELM free H-Modes



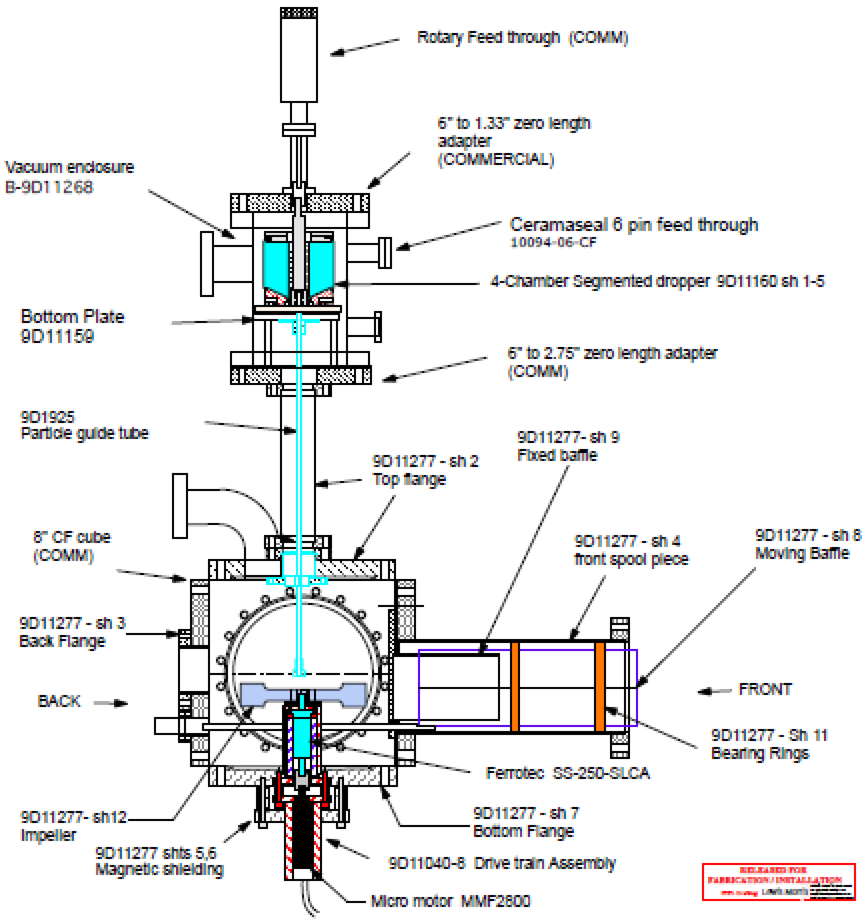
F. Scotti, Nucl. Fusion 53 (2013)

Experimental Plan

- Access ELM-free NSTX-U H-Modes through lithium wall conditioning
- Inject Lithium Granules (700 μm, 500 μm, 300 μm) to determine lower mass density limit
- Reduce injection frequency to determine cumulative edge density effects
- Reduce impeller velocity to look for lower input velocity limit
- ***1 day requested, ½ day minimum***

Backup

NSTX-U Granule Injector



Target granules are housed within the 4-chamber segmented dropper.

Particle drop rates are controlled by voltage applied to a piezoelectric disk.

The granules travel down a guide tube where they are impacted by a pneumatic rotary impeller and driven into the plasma.

Available sizes (approximate)
900μm, 700μm, 500μm, 300μm

Proposed Granule Composition
Lithium, Boron Carbide, Vitreous Carbon

Injection Velocity
50 – 150 m/sec

Granule to Granule Injection Frequency
50 – 500 Hz

Granule Injector XMP : Pre-Experiment Requirements

Granule Injector Subsystem	Required Actions
Air Operated Impeller	Check air pressure, calibrate impeller speeds, and confirm photodiode operation.
Timing and Triggers	Confirm pulsed dropper operation and time of flight calculations
Injector Alignment	Confirm species specific particle alignment.*
Particle Selectability	Test ability to inject various size particles
Full Systems Check	Confirm Operational Readiness

* Will need to be reconfirmed when switching particle species

While the final four items require an active plasma, there are minimal restrictions on discharge characteristics.

Thus piggybacking with other XMPs is possible if they are not adversely impacted by the granule injection.

XMP Request : 0.5 Day

LGI on EAST

Nucl. Fusion 53 (2013) 113023 D.K. Mansfield *et al*

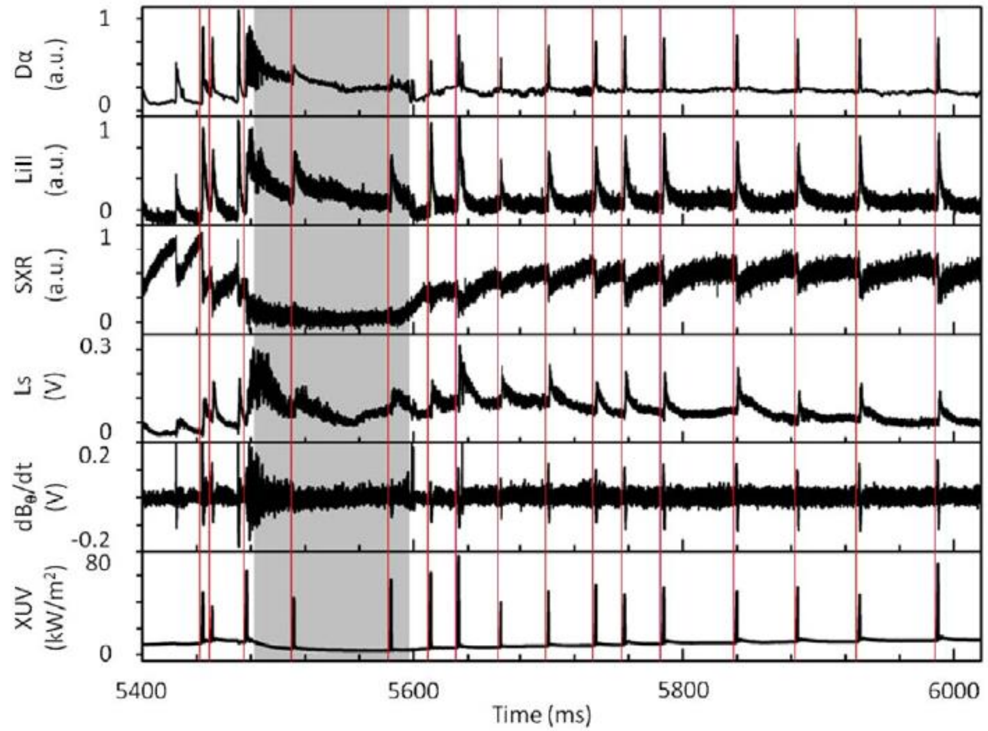
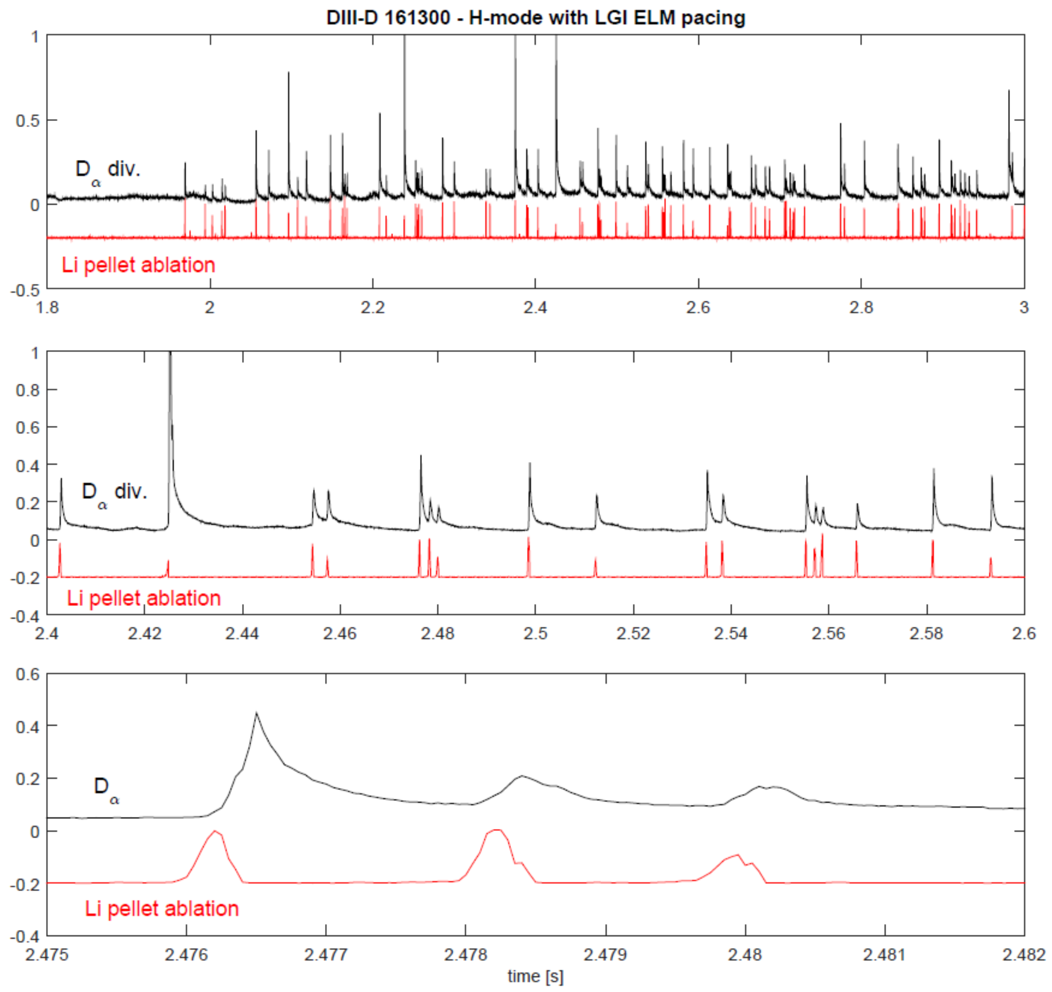


Figure 4. An expanded view of the granule injection phase during shot 42477. Included are traces of multiple diagnostics typically used to establish the presence or absence of ELM activity. They are in descending order: D-alpha emission, Li II emission, edge soft x-ray emission, divertor Langmuir probe signal, Mirnov coil signal and edge XUV emission. Red vertical lines have been drawn from the leading edge of each edge XUV emission event (bottom trace) and superimposed over all other data. The use of this signal for such timing purposes is based on the fact that sharp XUV emission was observed to correspond with the entry of a granule into the plasma edge whether or not the discharge was in the H- or L-mode. Granules 17 and 18 are not shown in this diagram. The grey area encompasses the H–L–H transition brought on by the third injected granule.

LGI into DIII-D Super H-Mode



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