NSTX

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# Present Status of the Li Granule Injector and a few thoughts about it


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*and the NSTX Research Team*


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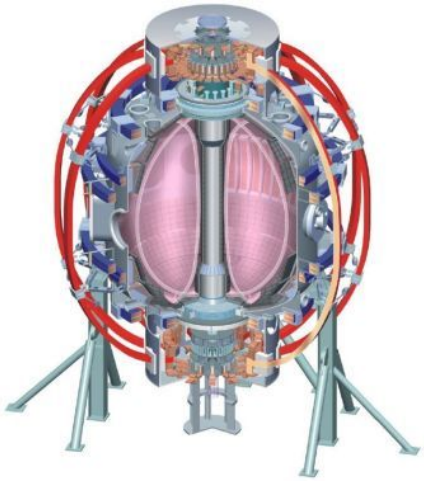
*ASIPP*
*ENEA, Frascati*
*CEA, Cadarache*
*IPP, Jülich*
*IPP, Garching*
*ASCR, Czech Rep*

# Calculated Pedestal Deposition for 1 mm Li Granules with Injection Speeds from 30 m/s to 100 m/s

**Linear Temperature and Density Profiles Assumed for Pedestal:**

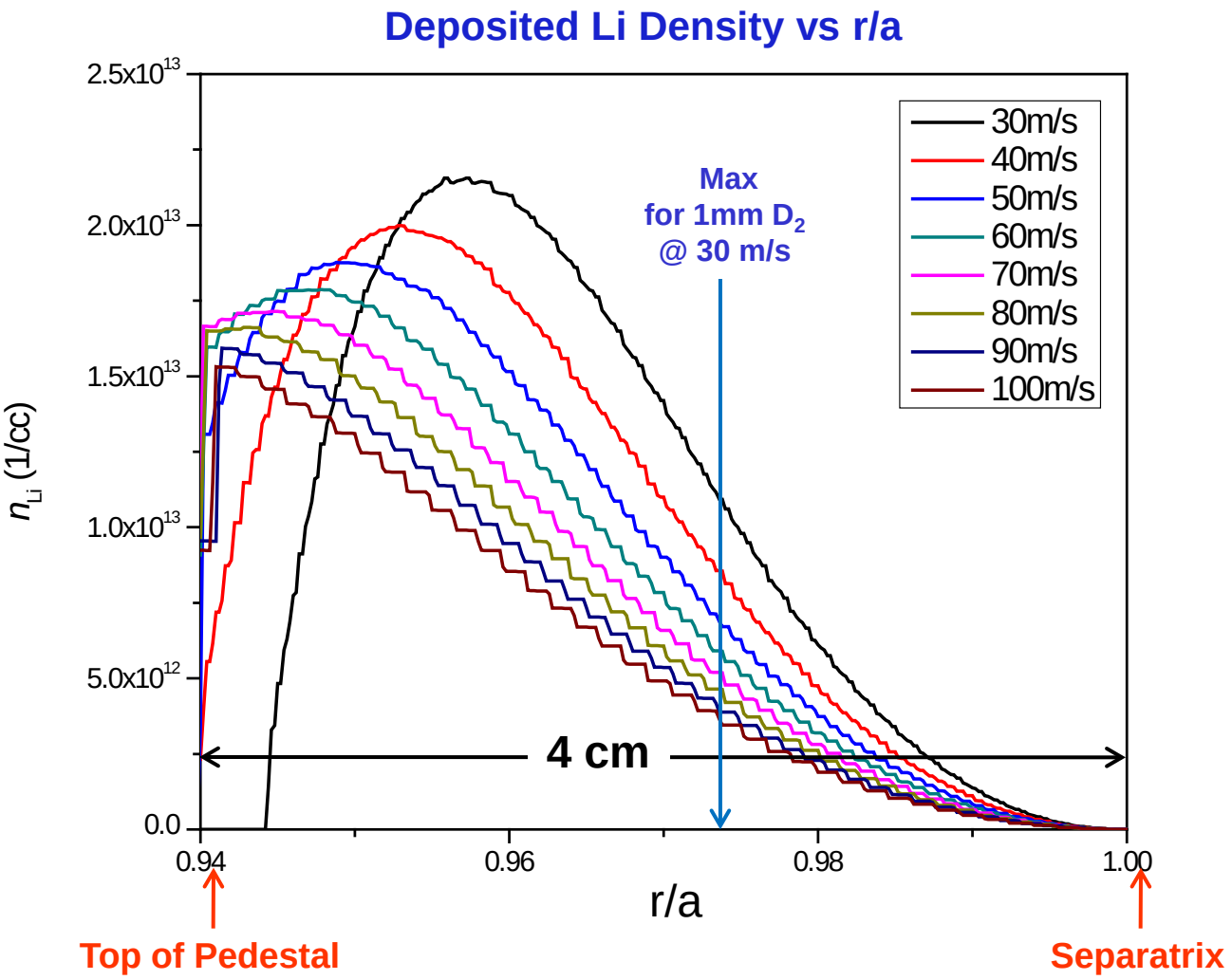
**Te (r/a = 1) = 0**
**Te(r/a = 0.94) = 1 keV**

**ne(r/a = 1 ) = 0**
**ne(r/a = 0.94) = 5 x $10^{13}$ $cm^{-3}$**

**Reasonable Approximation to DIII-D Pedestal R = 1.67 m a = 0.65 m**

**Neutral Gas Shielding Ablation Model for Li Employed**

**Results Similar to D Pellet Ablation Which Does Trigger ELMs on DIII-D**

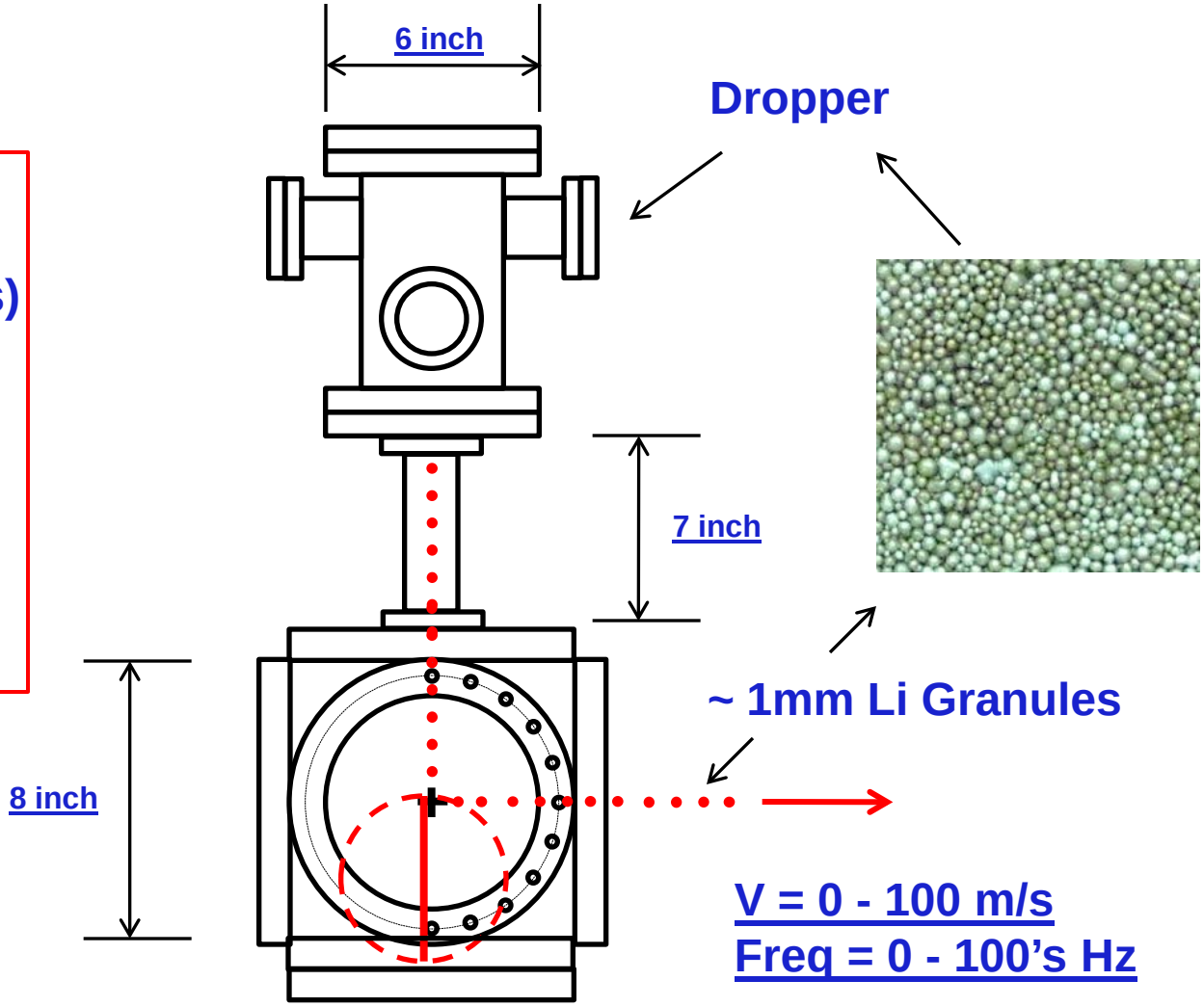



Paul Parks, Wen Wu

# The Concept Hardware

**Independent Control:**

- **Granule Size (change between shots)**
- **Injection Speed (ramp during shots)**
- **Pacing Frequency (ramp during shots)**



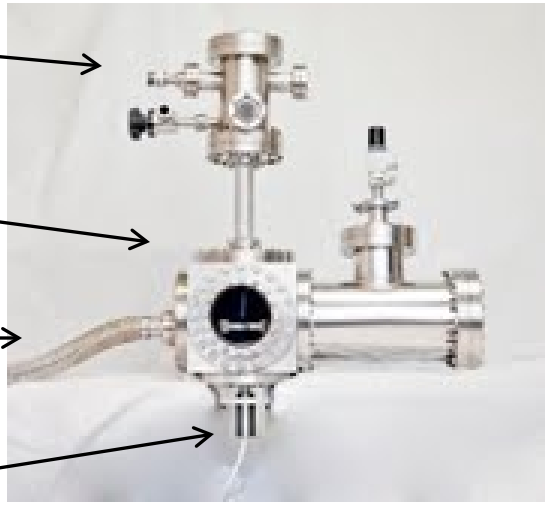
# The Present Status of the Hardware

Dropper Enclosure

Impeller Enclosure

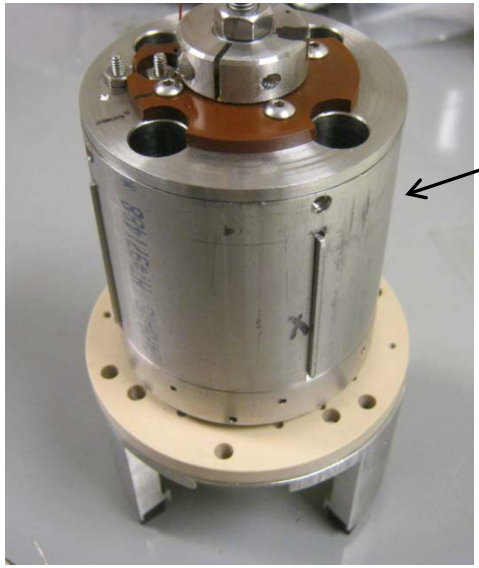
Pump-out Line

Air Motor

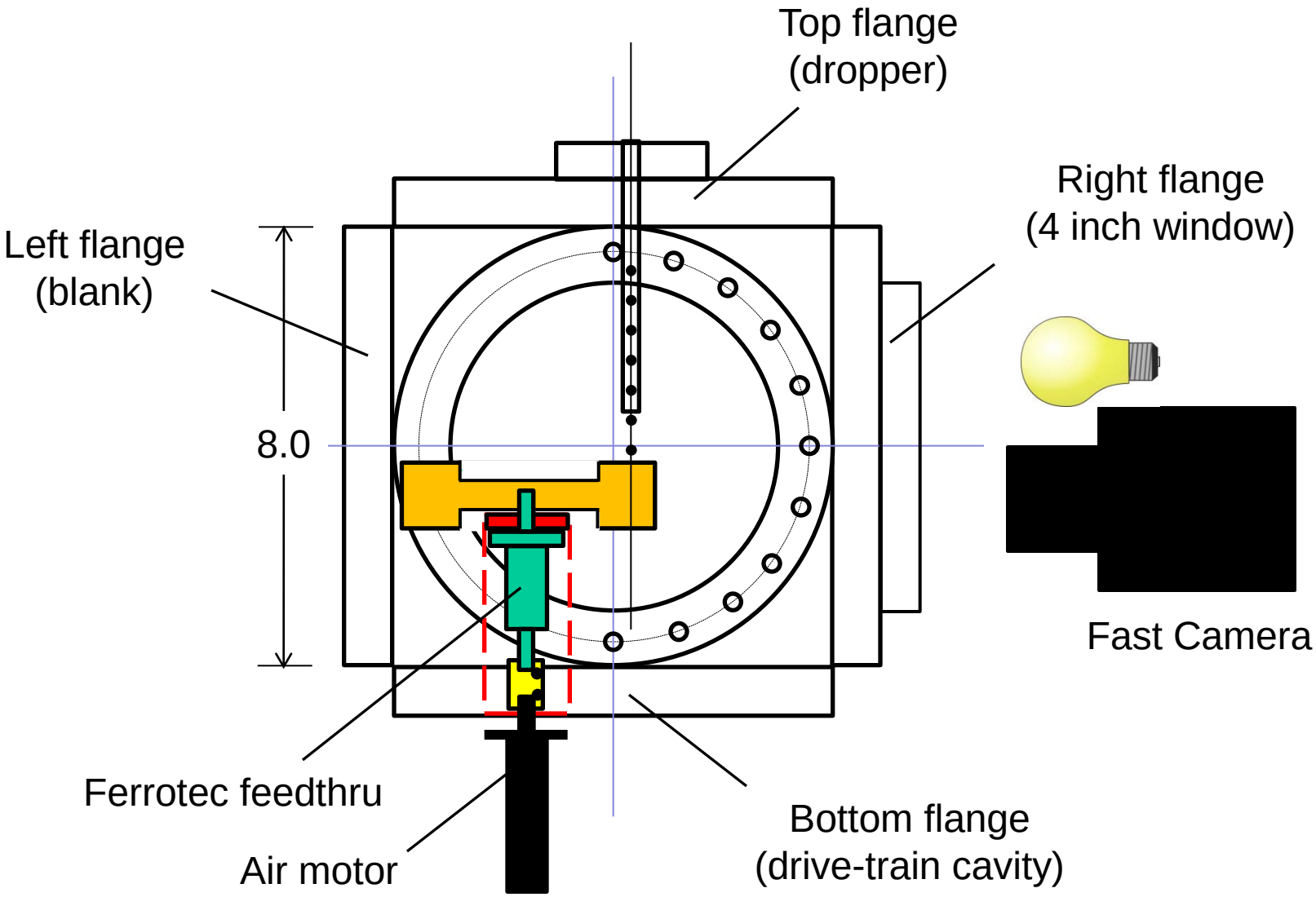


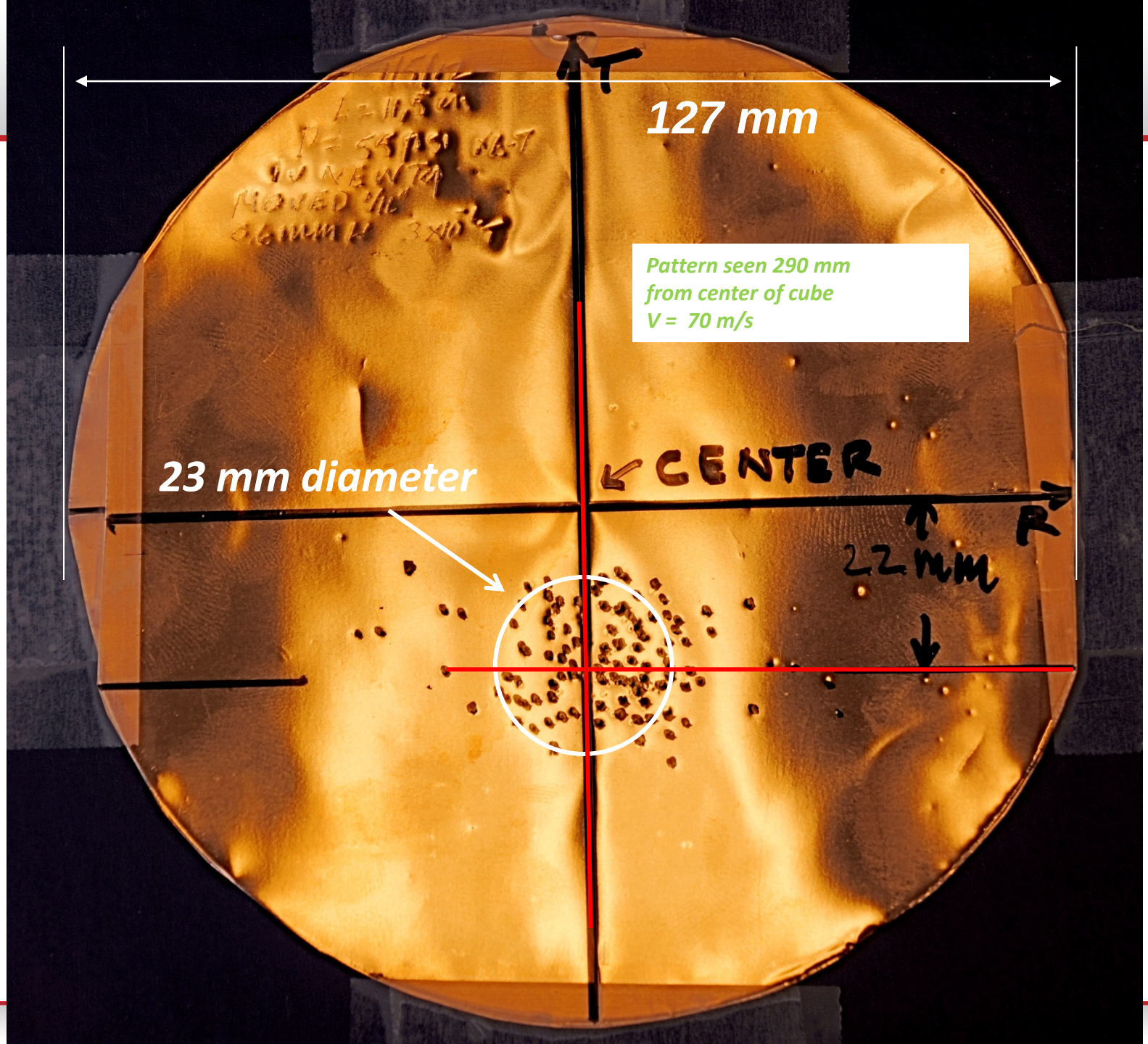
Horizontal Impeller

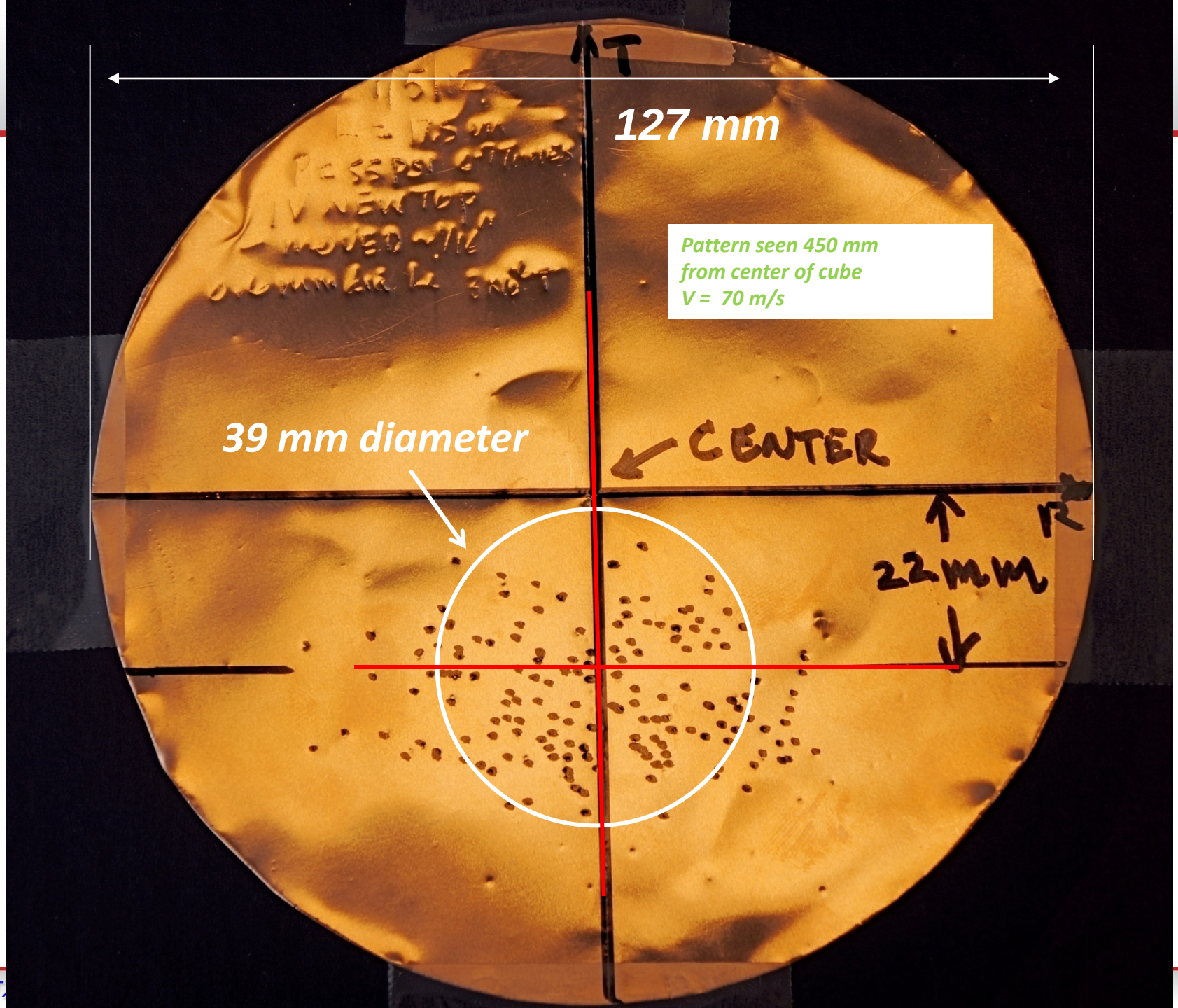
Segmented Dropper



# Looking into NSTX

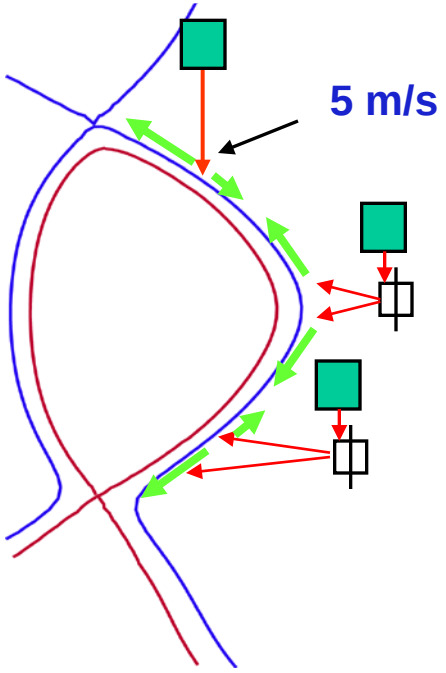



127 mm
Pattern seen 290 mm
from center of cube
V = 70 m/s
23 mm diameter
CENTER
R
22 mm


T
127 mm
Pattern seen 450 mm
from center of cube
V = 70 m/s
39 mm diameter
CENTER
R
22 mm

# Simple Technology Can Allow "Directed" Li Aerosol Injection into Several Geometries

**Li droplets and ions both seek the nearest x-point(s)**




**Possibilities:**

**"Directed" real time PFC conditioning**

**Triggering plasma modes / ELMs**

**Reducing Divertor Power Load**

**Killing MHD (Locked?) Modes**

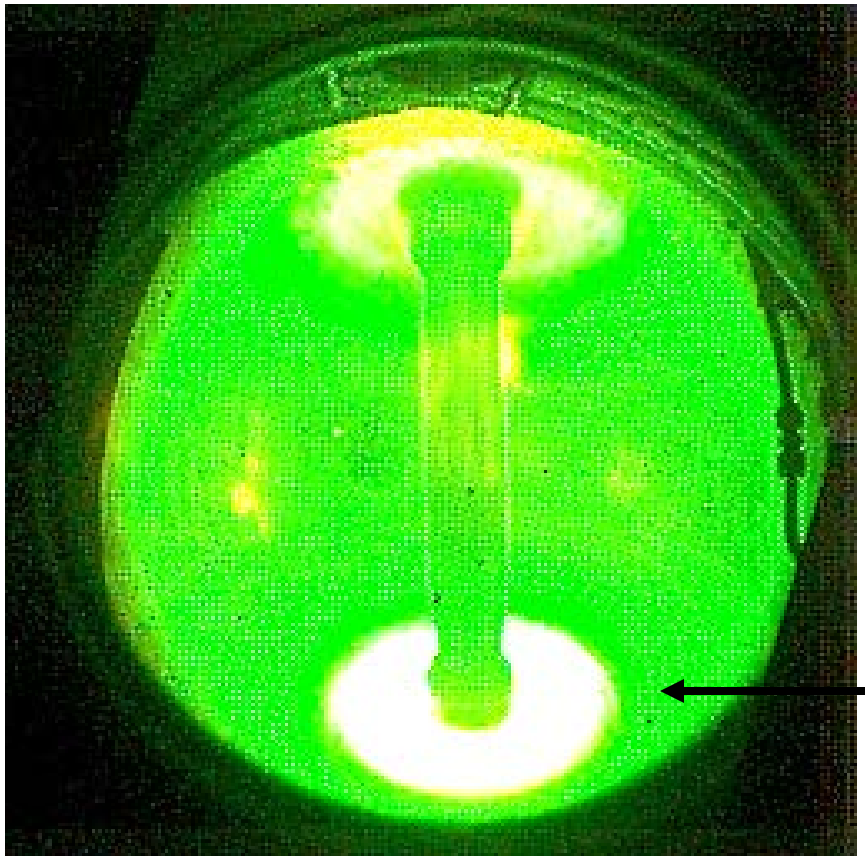
**TFTR: Aerosol prompted Te rise**

# Local Injection of Li Granules / Powder Should Reduce Divertor Power Load via Radiation

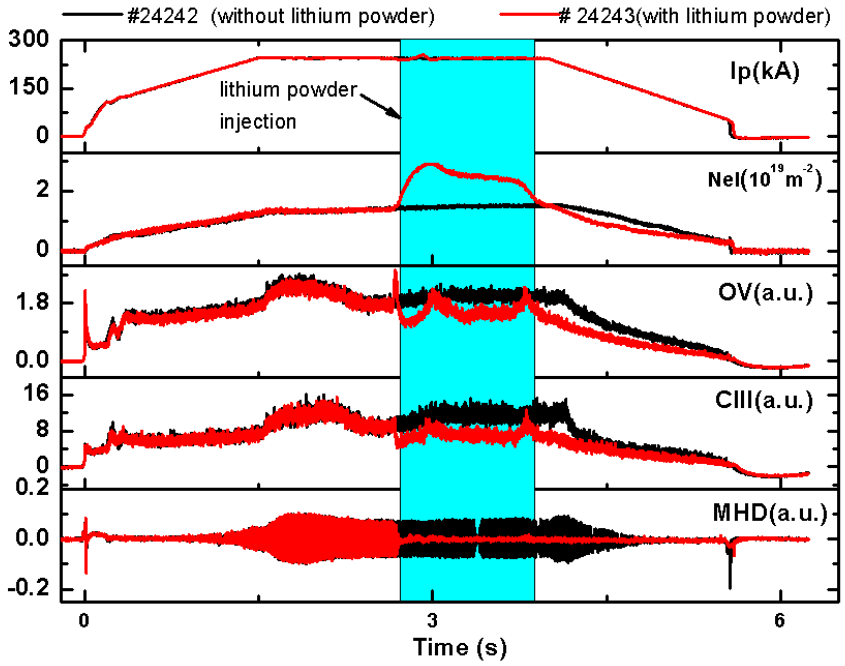
B Kuteev, Kurchatov

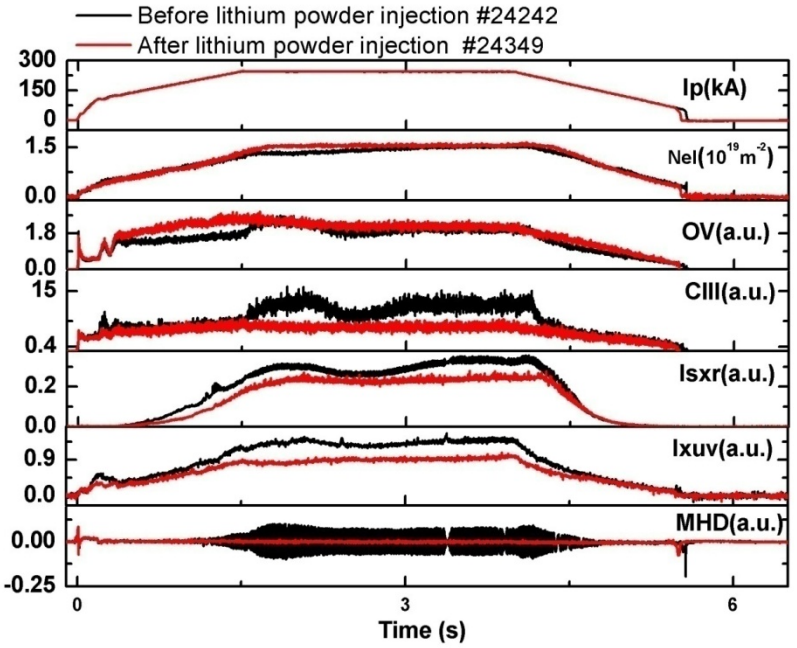
R Smirnov, UCSD

V Sergeev, SPU



# Results of Lithium Powder Injection on EAST

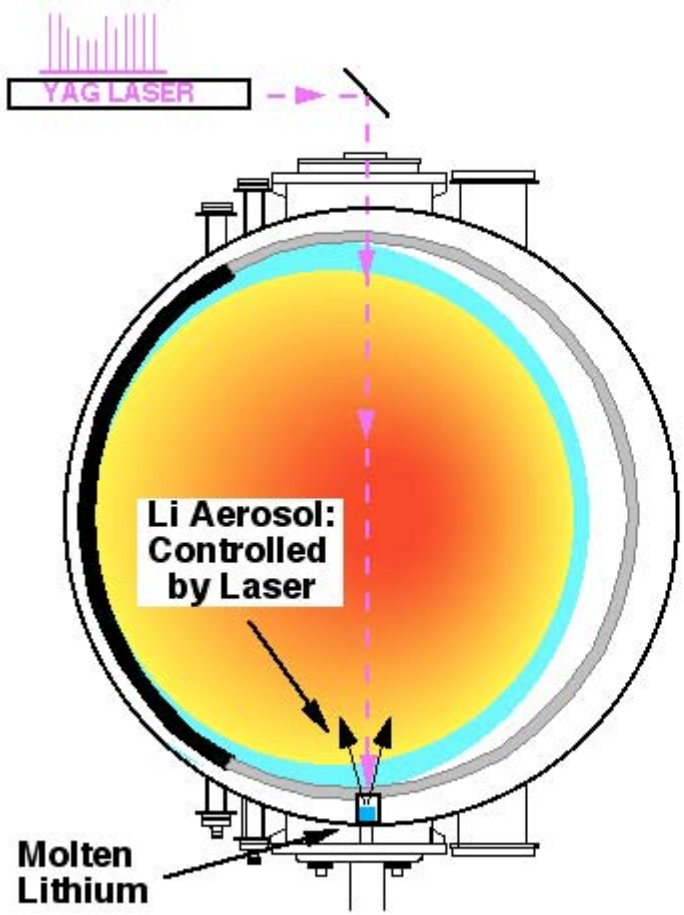


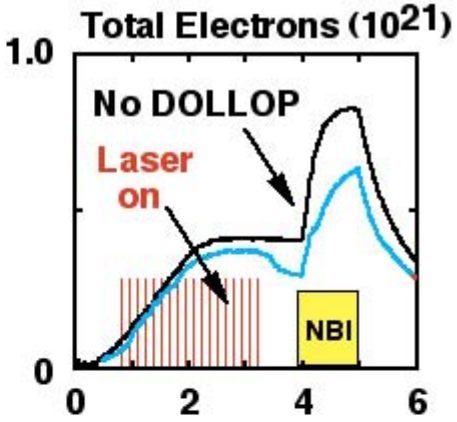



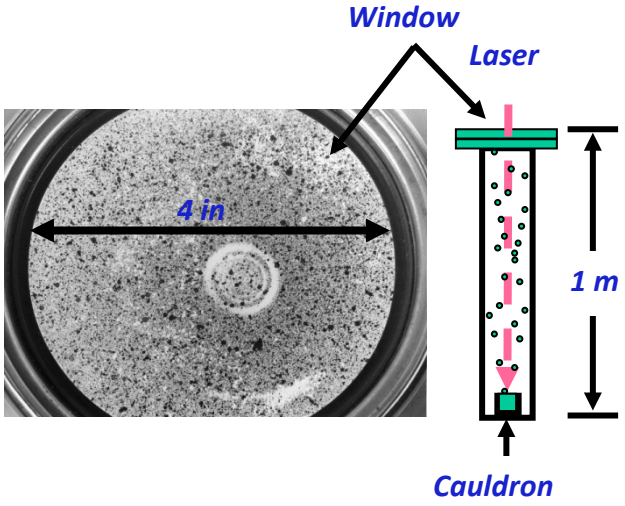

➢ *Lithium powder injection is very effective in suppressing MHD (spring campaign in 2010 on EAST ).*

# EXTRA SLIDES

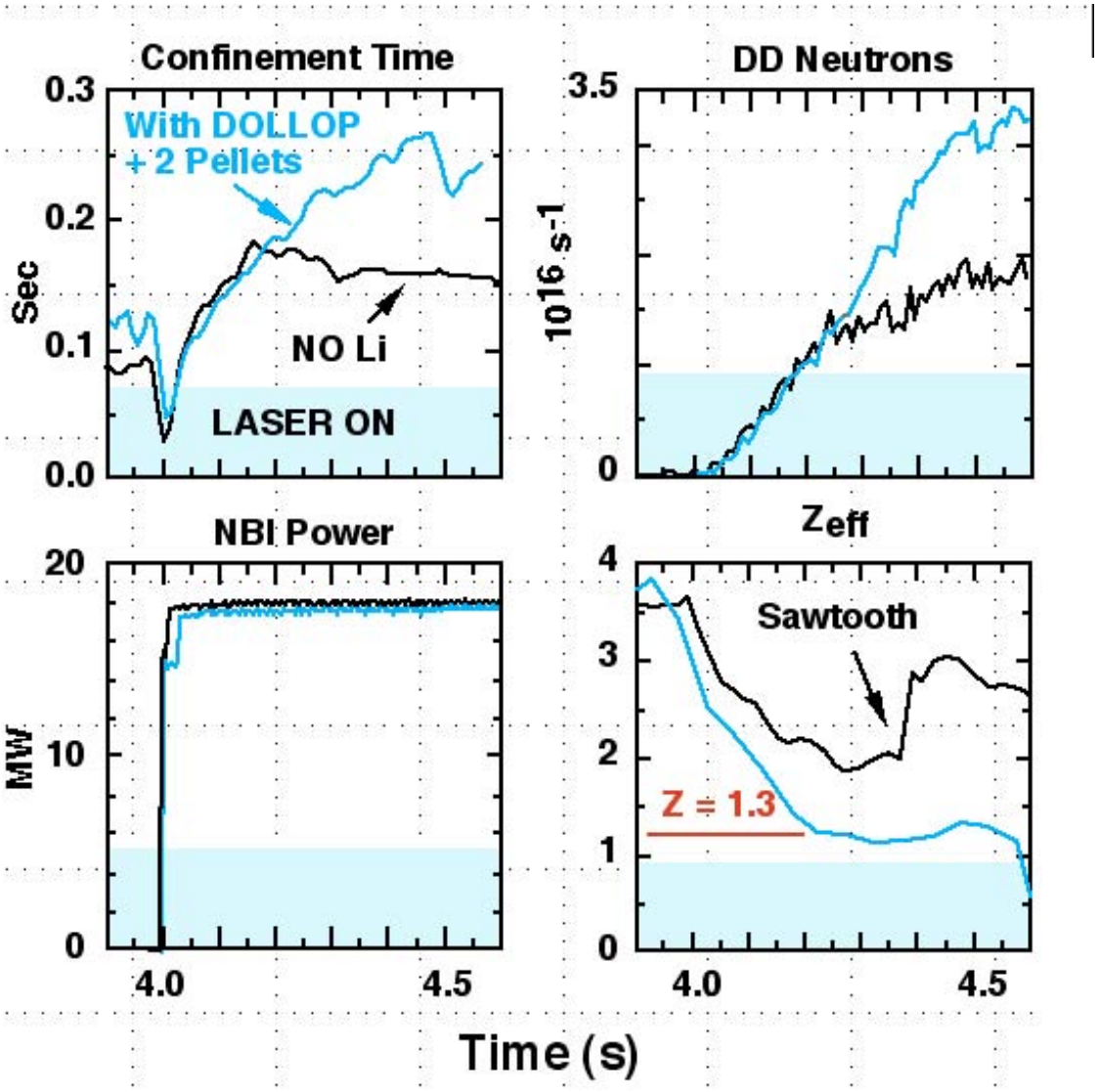
# Dollop: Deposition of Lithium by Laser Outside the Plasma



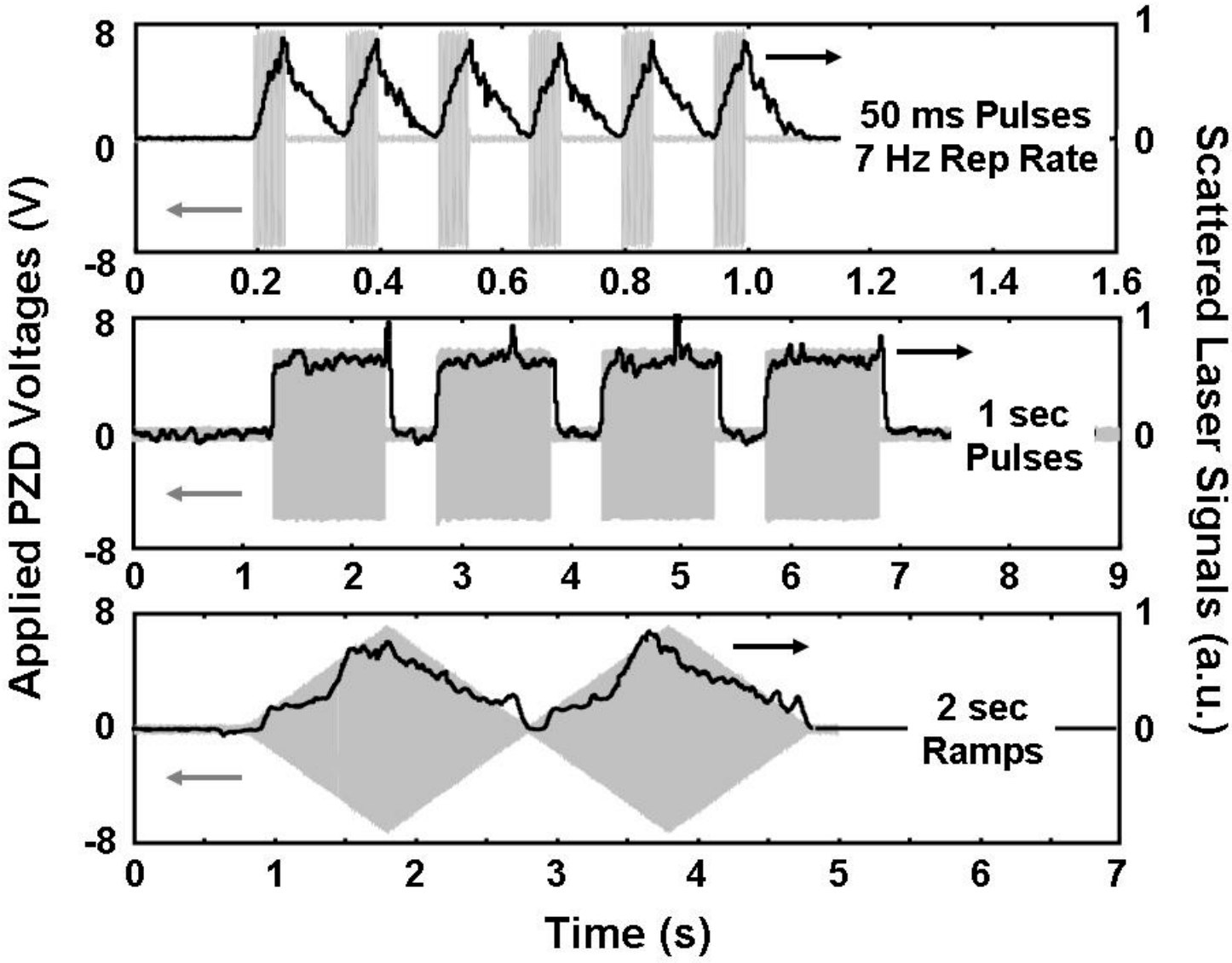



# Results from the Initial use of Li Aerosol on TFTR

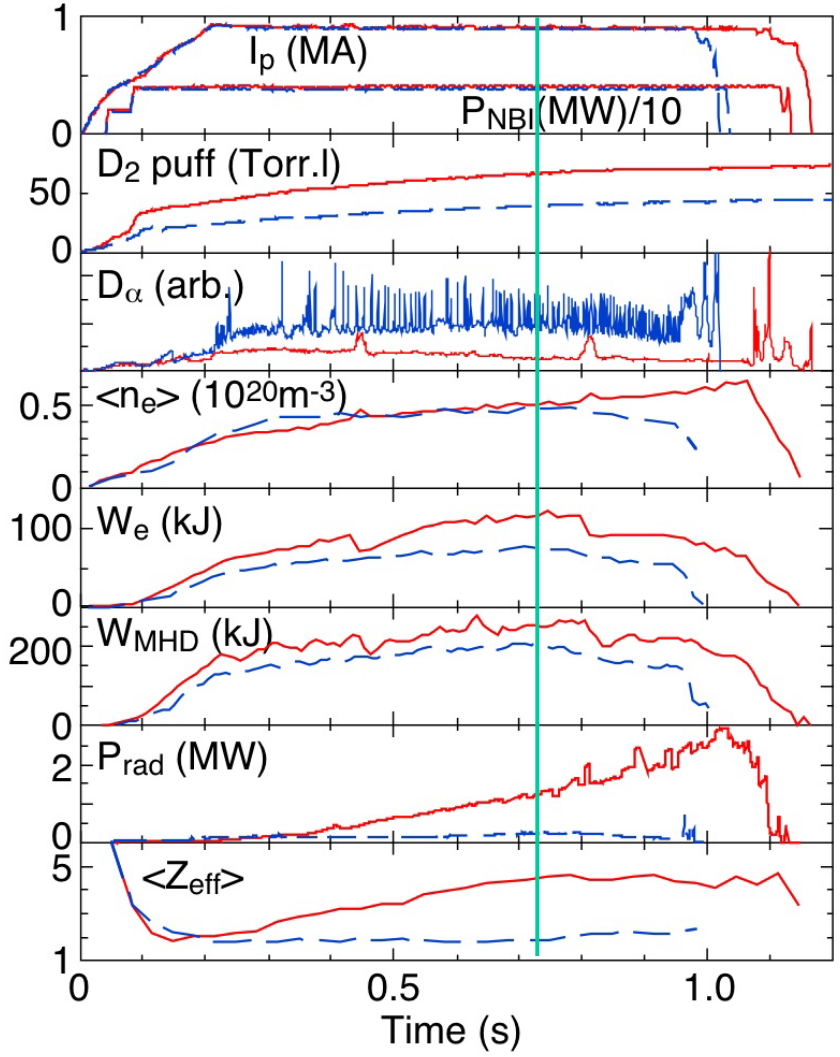


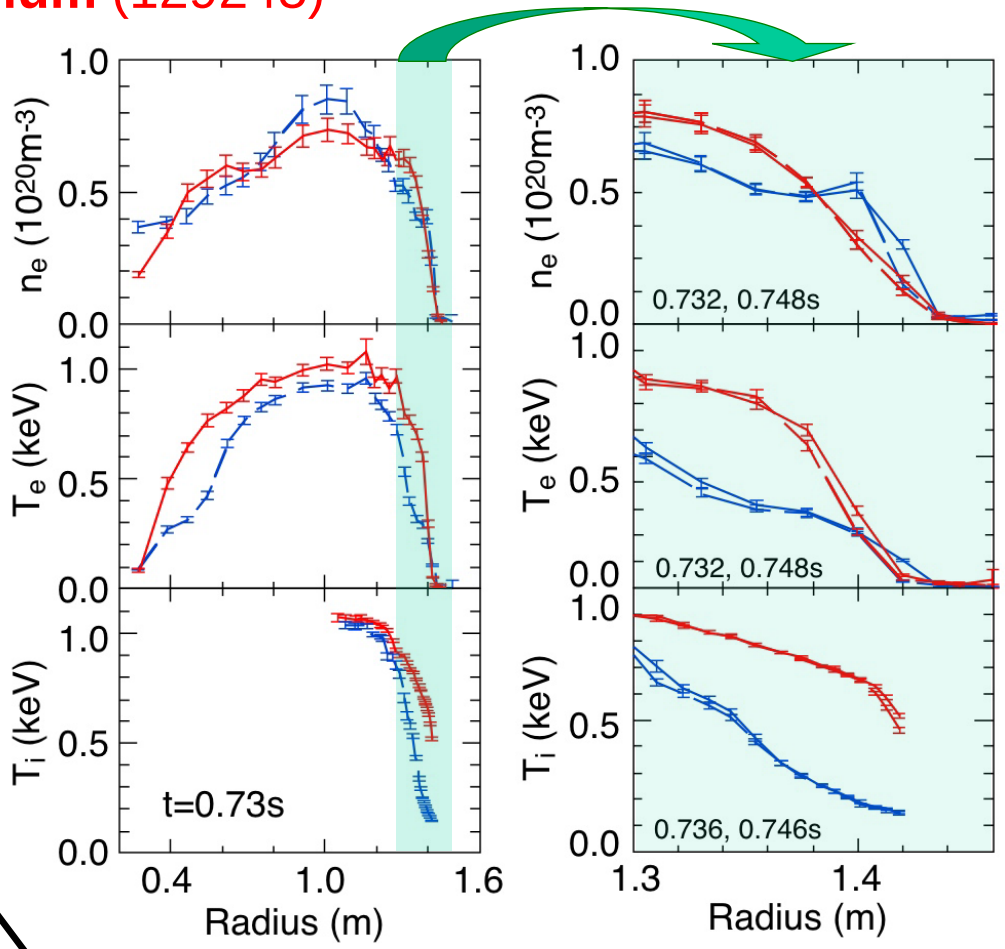
# A Few Arbitrary Waveforms and Associated Laser Signals at Resonance (2.25 kHz)



# Lithium Coating Reduces Deuterium Recycling, Suppresses ELMs & Improves Confinement in NSTX

**No lithium** (129239); **260mg lithium** (129245)

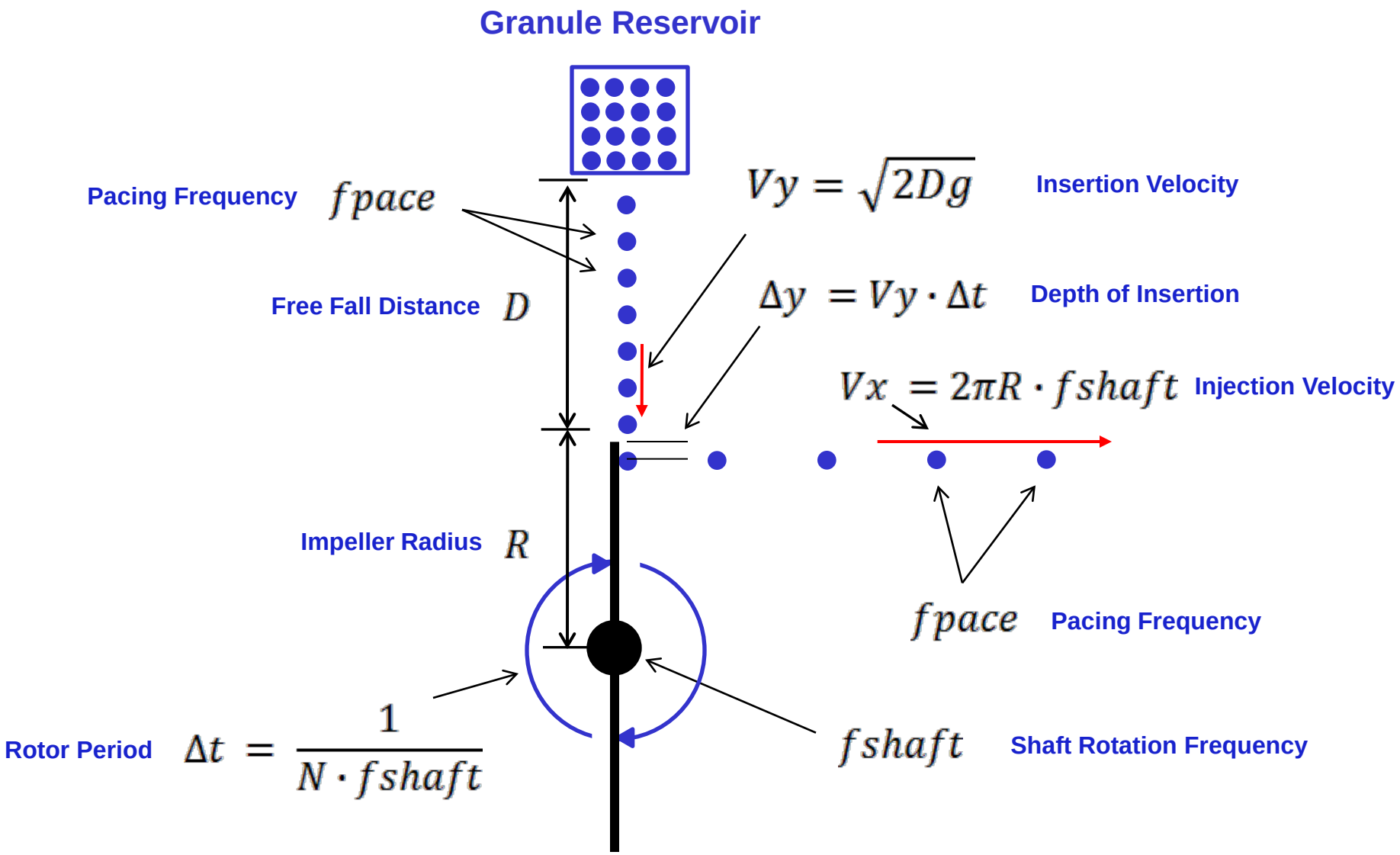


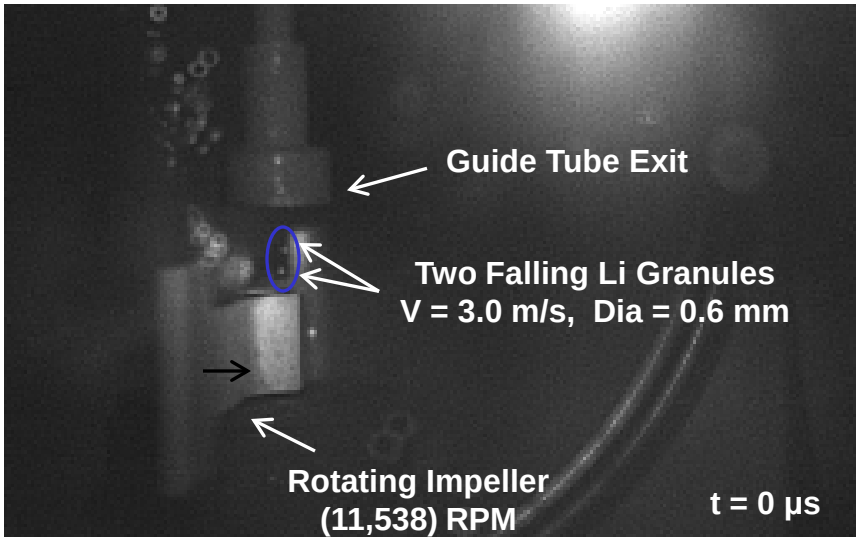

Without ELMs, impurity accumulation increases radiated power and $Z_{eff}$

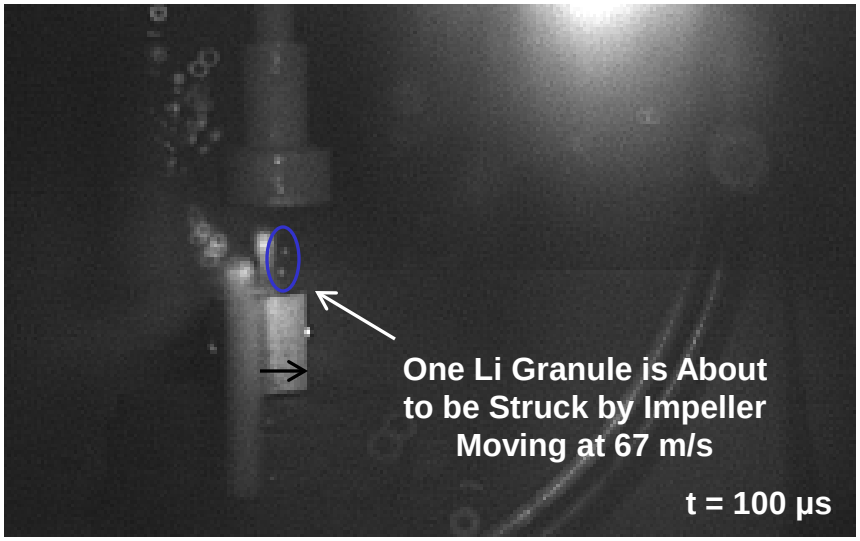
*H. Kugel, B. LeBlanc, R.E. Bell, M. Bell*

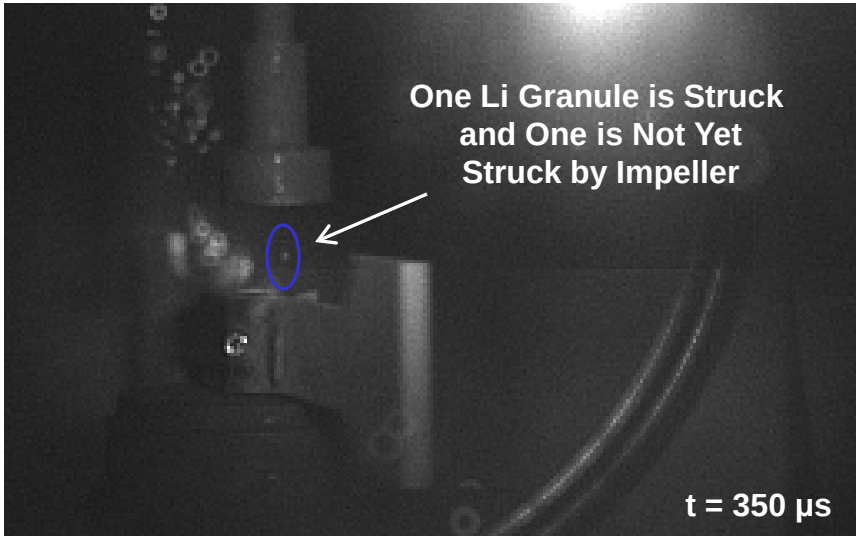
# The Scheme: Redirecting an Unsynchronized Stream of Falling Li Granules with a Rotating Impeller

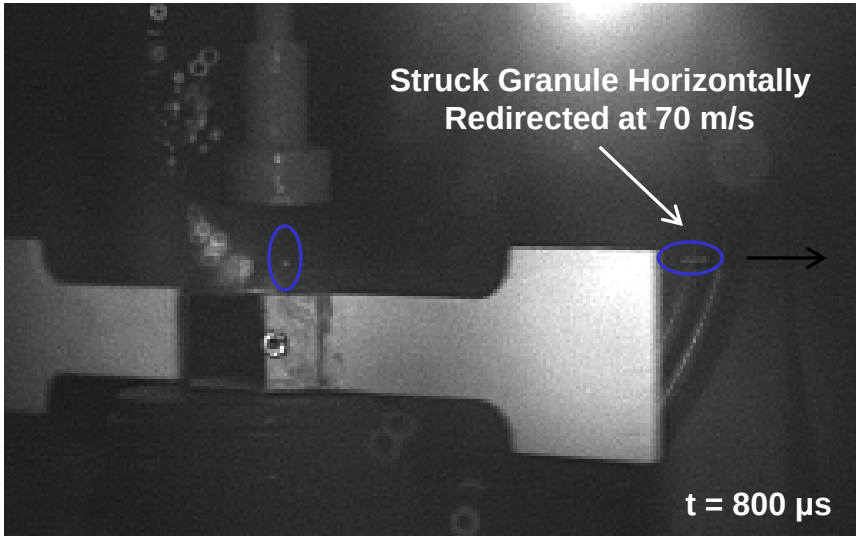


# Video of Li Granules "Injected" Horizontally at ~ 70 m/s



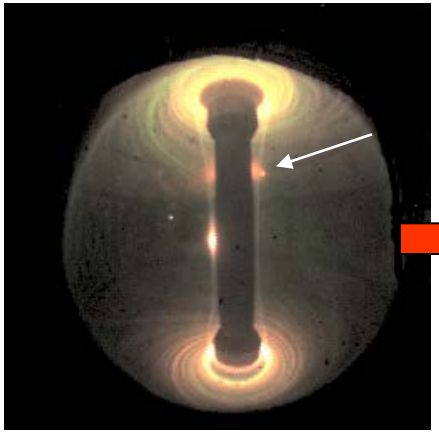



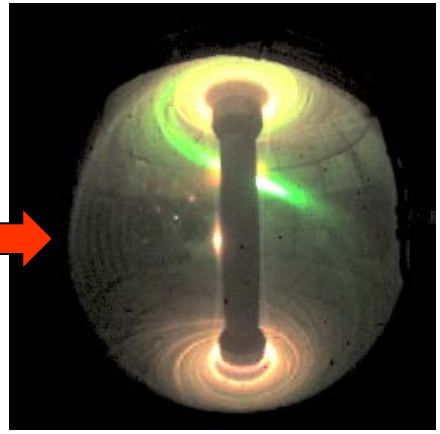



# Examples of Edge Perturbations from Low-Velocity (~ 5m/s) Lithium Granules (~ 2mm) in Four Discharges (2008)

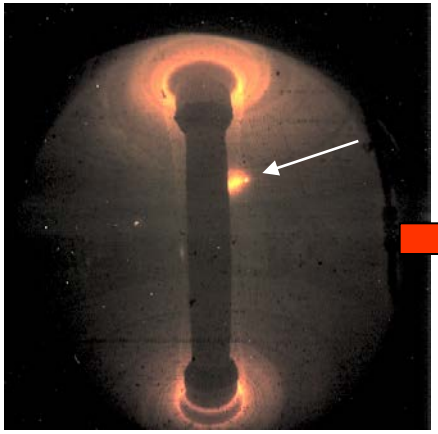
135064@ *272 ms*



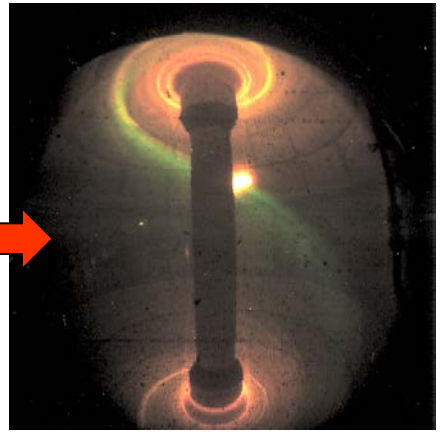
135064@ *280 ms*



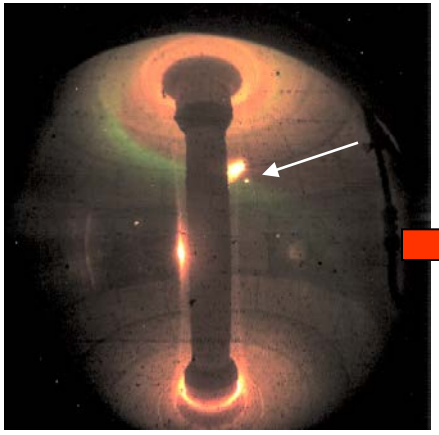
130389@ *353 ms*



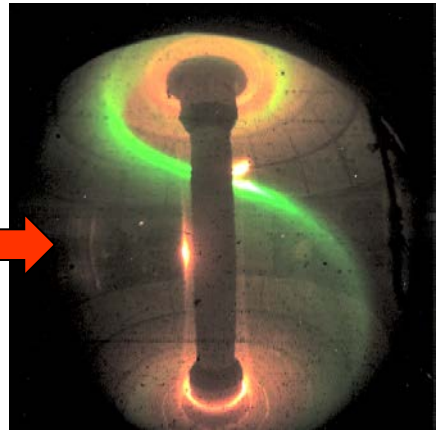
*130389@ 356 ms*



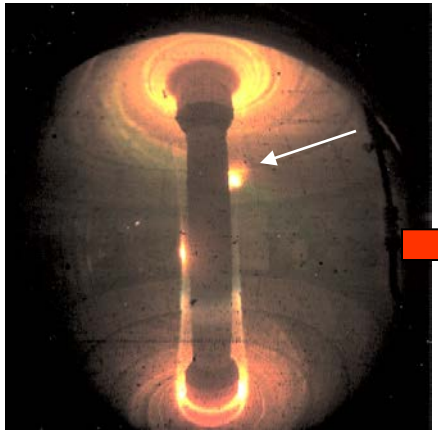
*130387@ 191 ms*



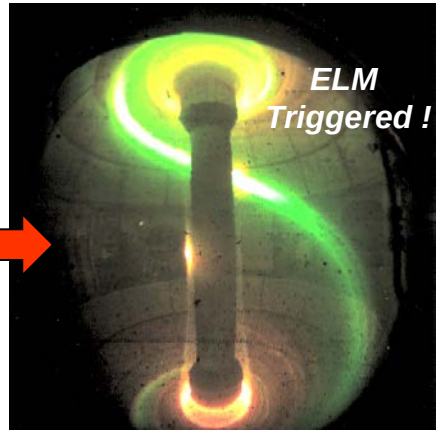
130387@ *197 ms*



*130385@ 393 ms*



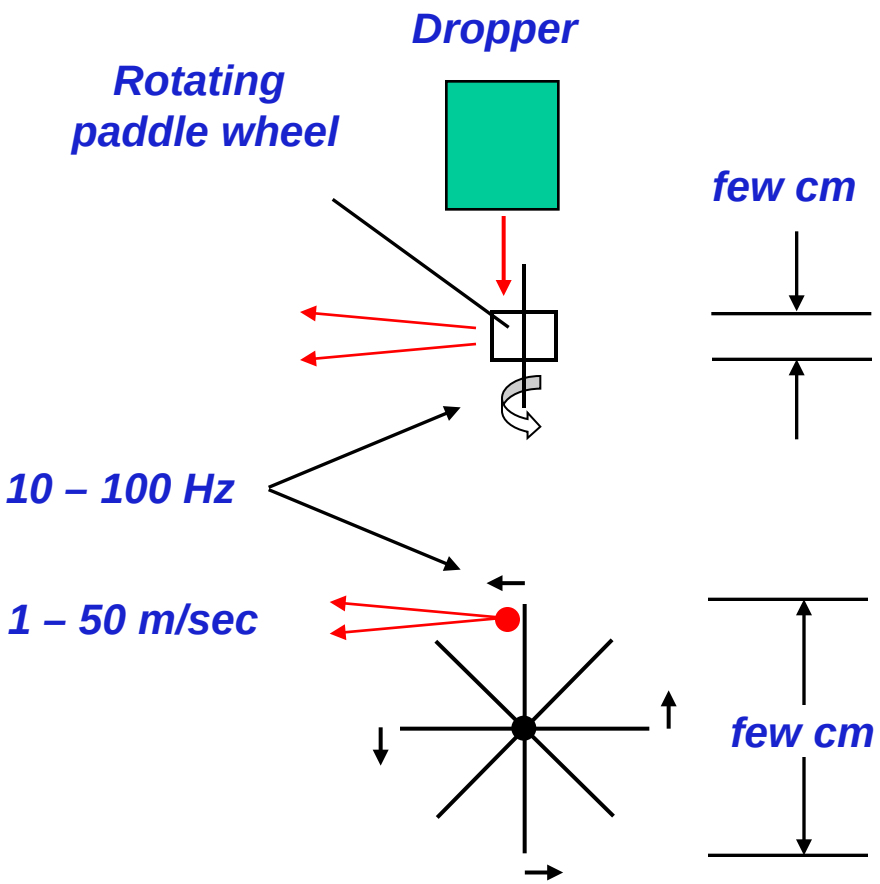
*130385@ 400 ms*



# Present Status of the Effort to Trigger High Frequency ELMs using Injected Lithium granules

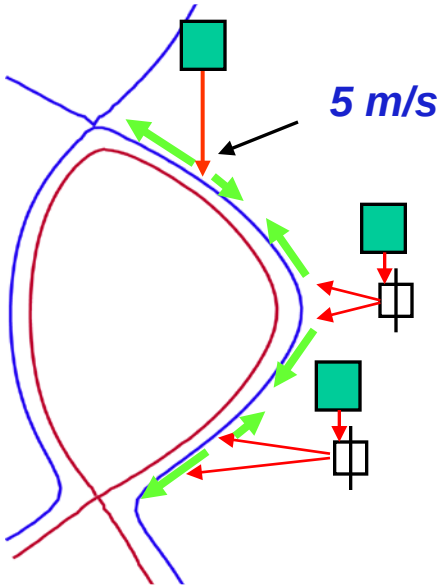
- The injector hardware is built and being tested.
- Spherical Lithium granules (0.6 mm) have been horizontally redirected at speeds approaching 100 m/s.
- Dropping rates (pacing frequencies) of 500 Hz have been readily achieved.
- A dropper apparatus which allows the granule size to be changed between discharges has been built and is being tested.
- Tests on a fusion device should proceed during 2012-13.

# Simple Additional Technology Can Allow "Directed" Li Aerosol Injection into Other Geometries




*Paddle wheel viewed from above*

*Li droplets and ions both seek the nearest x-point(s)*




***Possibilities:***

*"Directed" PFC conditioning*
*Injection of trace Li into SOL*
*Triggering plasma modes / ELMs*
*TFTR: Aerosol prompted Te rise*

# "Early and Surgical" Injection of Li Powder to Kill the Low-Density Locked Mode Before it Kills the Discharge

- *Breakdown in lean mixture of $D_2$ gas and Li powder localized on the center stack*

  *Not much gas, not much Li*
  *Li pumps out onto center stack*
  *Li powder has big effect early in the discharge, but will not delay H-Mode*

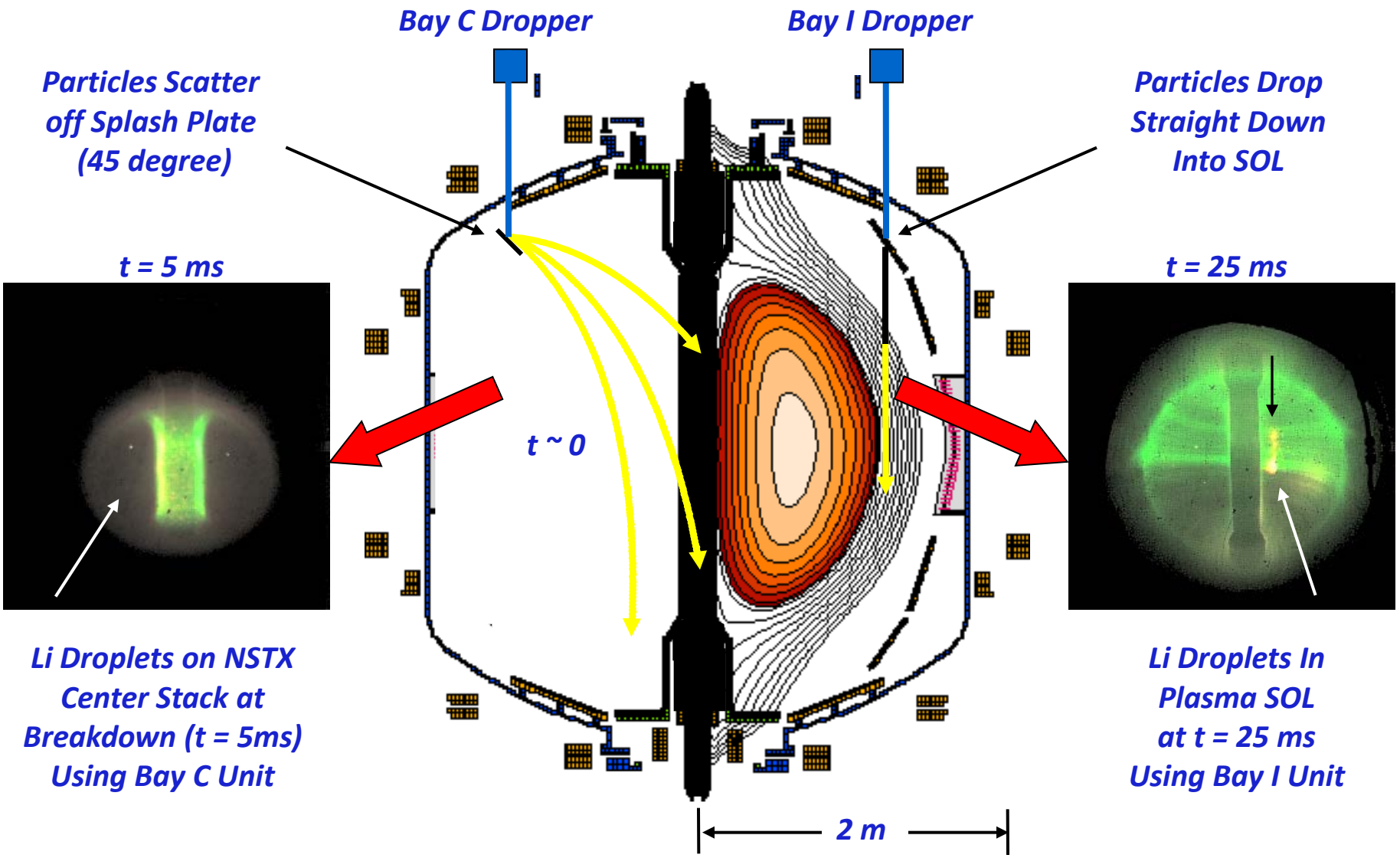
- *Plasma expands while Li influx decreases*

  *H-Mode shows up as planned just after Ip flat top*

- *Look for signs of improved low density behavior*

  *Do locked modes survive this radically different breakdown?*

# The Center Stack Can be Encircled with Dispersed Li Powder at Breakdown Using the Bay C Dropper Early



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- *Plasma expands while Li influx decreases*

  *H-Mode shows up as planned just after Ip flat top*

- *Look for signs of improved low density behavior*

  *Do locked modes survive this radically different breakdown?*

# Points to be Made

- Injecting small, slow Li granules should trigger ELMs
- A simple prototype injector allows scans of size, speed and frequency so ELM physics can be explored efficiently
- Long-pulse injection possible for Dia = 0.2 - 1.5 mm, Vel = 0 - 100 m/s, Pacing Frequency = 0 - 500 Hz
- This concept allows other non-cryogenic "pellets" to be injected ( Li, LiD, Be, B …)
- "Synchronized engineering masterpiece" will follow…