Lithium induced disruptions in DIII-D: analysis and modeling

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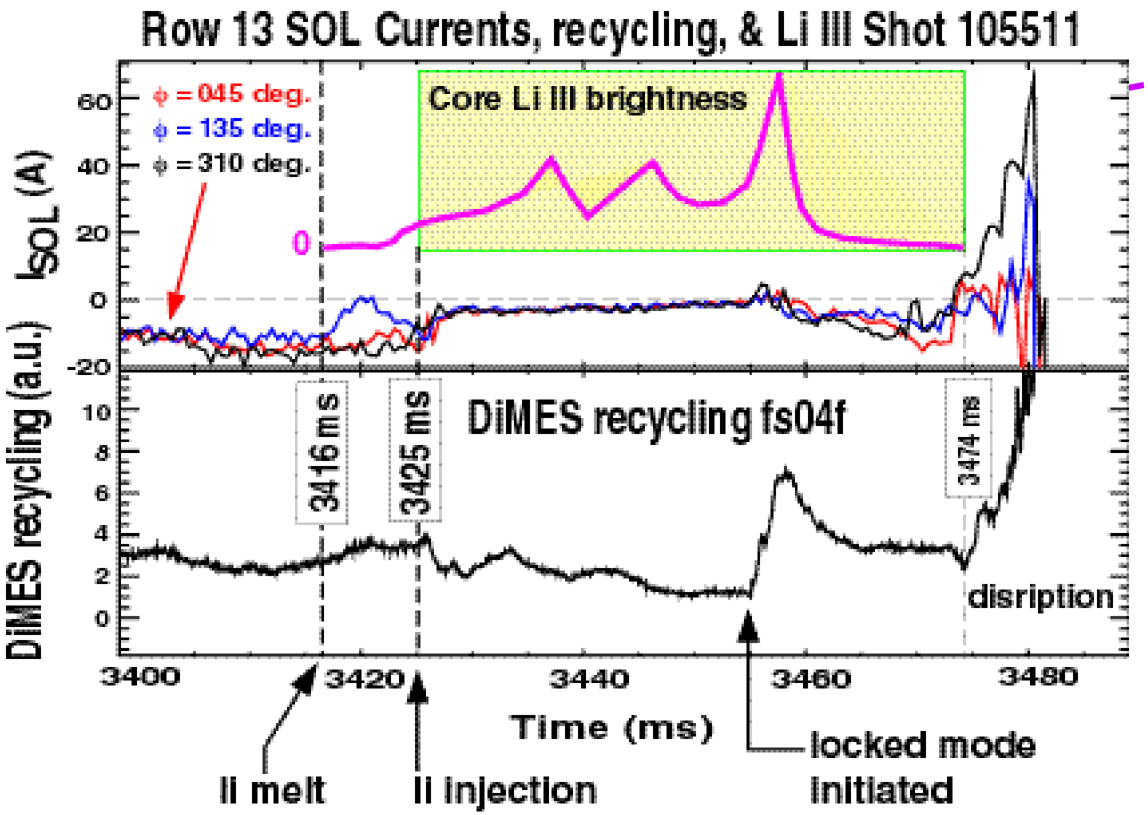
- In DIII-D any attempt to place a solid lithium sample near the outer strike point disrupts the discharge.
- Data from two experiments suggest that the lithium sample melts and is partially injected into the core by a single MHD event which then triggers the disruption.
- The detailed analysis of a low power lithium disruption shot will be discussed.
- A conceptual model of the SOL current distribution during the initial liquid lithium phase has been developed:
  - » with this initial condition it may be possible to reproduce the injection event by numerically modeling the dynamics of the sample in the liquid phase

Low power DIII-D L-mode plasmas were used in an attempt to do controlled studies of Li (solid and liquid) sputtering and transport

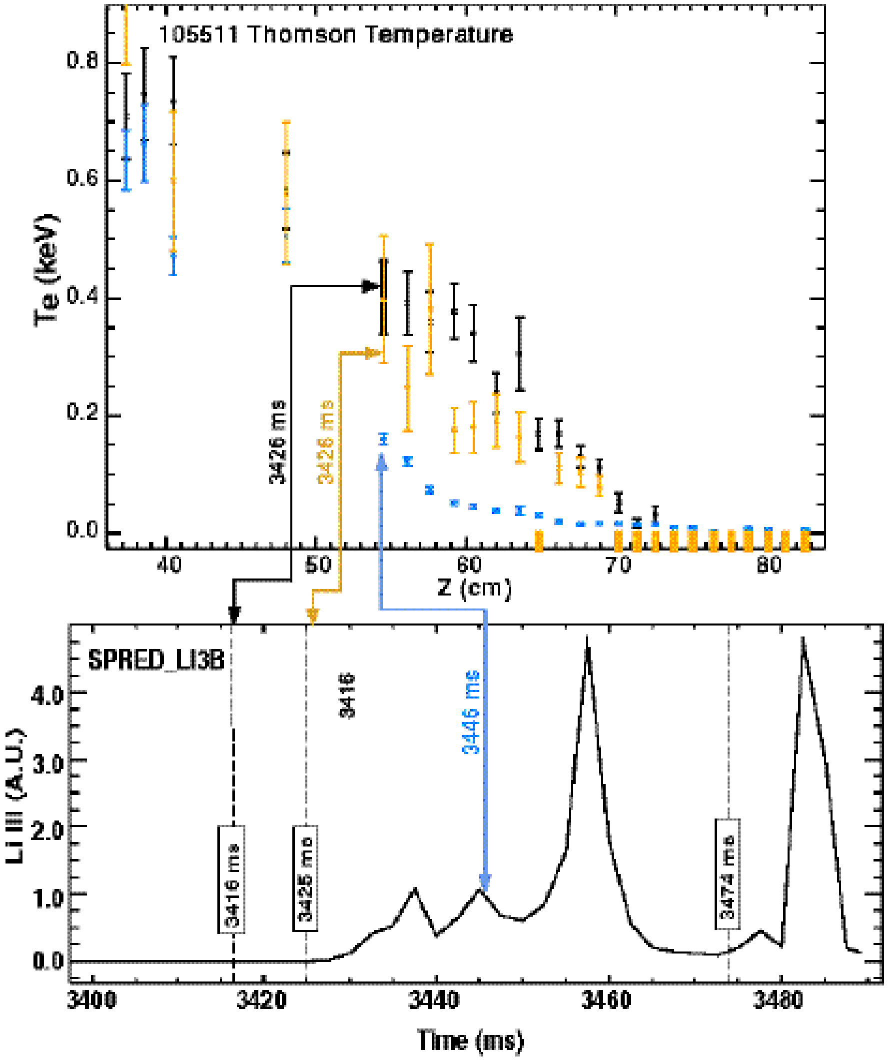
- The goal was to use very low power L-modes in order to study liquid Li without disruptions (a previous experiment disrupted during an ELM)
  - » The Li sample was exposed to 4 swept strike point shots, one with the strike point 0.05 m from the sample and one with the strike point 0.03 m from the sample (shot 105511).
  - » These plasmas had stored energies of less than 10% (about 0.14 MJ) a typical DIII-D H-mode plasma.
- During shot 105511 the sample appears to have remained solid until about 3415 ms (2315 ms into the Ip plateau)
  - » The first indication of a change in the Li sample was a drop in the j_{SOL} measured by a tile current monitor 15^o upstream along B_φ from the DiMES probe.

In a low power DIII-D L-mode plasma the core lithium emission looks like that of a single pellet



- The first peak in the core Li is when the injected droplet hits the separatrix, the second is the core ablation peak and the third is a locked mode

The collapse of the core Te profile is consistent with the injection of a single Li droplet



- An increase in the core density of 3.6 X 10^{19} m^{-3} suggests that a single 3.2-5.2 mm diameter Li droplet (10-40 mg) caused the disruption.
- A droplet with v_N = 30 m/s crosses the SOL in about 12 ms and travels about 0.27 m into the core after 9 ms.

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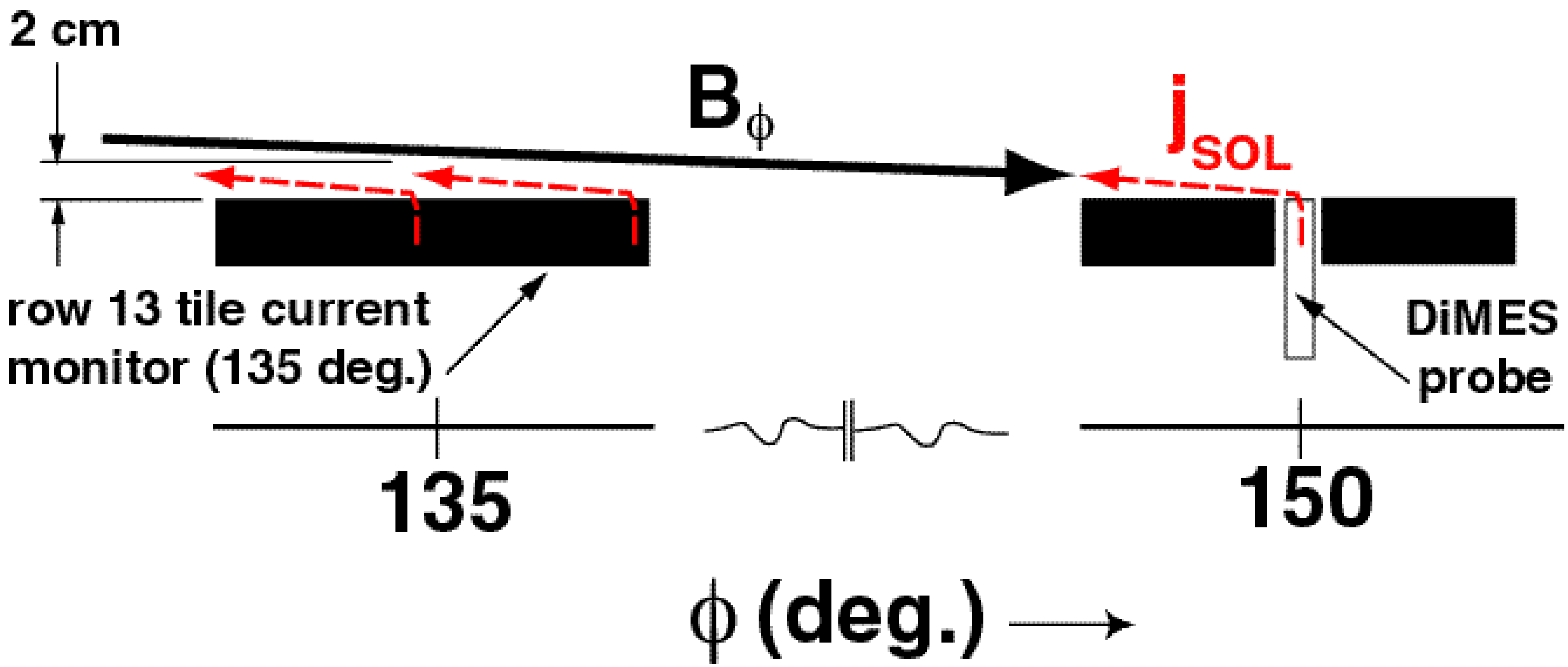
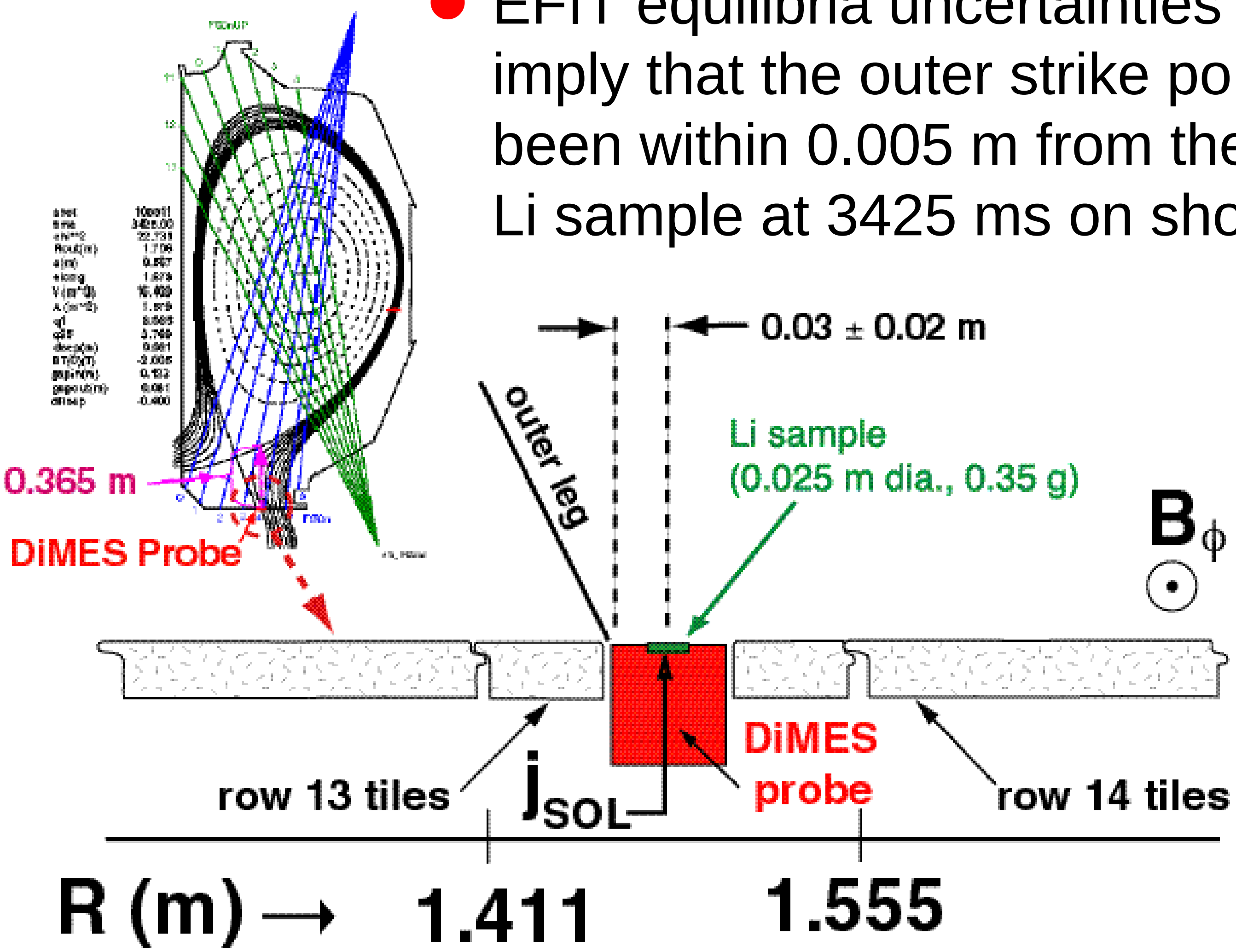
In LSN DIII-D plasmas a net SOL current I_{SOL} typically flows out of the row 13 divertor tiles



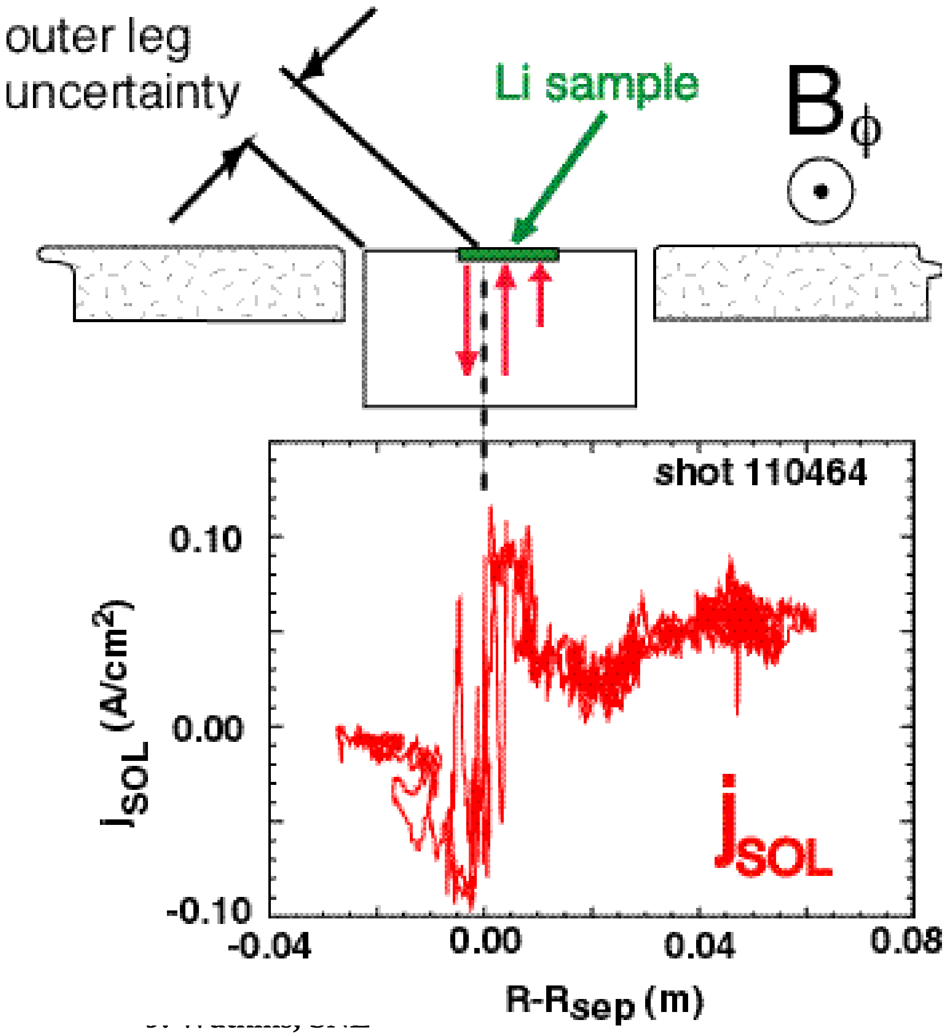
- The Li DiMES probe is located 15° (toroidally) or about 0.39 m along B_φ from the closest tile current monitor.
  - » A Li^{+1} cloud moves upstream toward the $\varphi = 135^o$ tile current monitor with a $v_{||}$ of about 70-100 m/s after the Li melt.

The outer strike point is positioned 3 cm inside the center of the Li DiMES sample on shot 105511

- EFIT equilibria uncertainties of ± 0.02 m imply that the outer strike point could have been within 0.005 m from the edge of the Li sample at 3425 ms on shot 105511.



The current distribution across the surface to the Li sample is non-uniform and time dependent resulting in radial components with complex j X B forces



- The surface distribution of j_{SOL} across a solid or liquid Li sample has not yet been measured.
- A large influx of Li neutrals following a solid-liquid phase change may have a significant impact on the j_{SOL} surface distribution.

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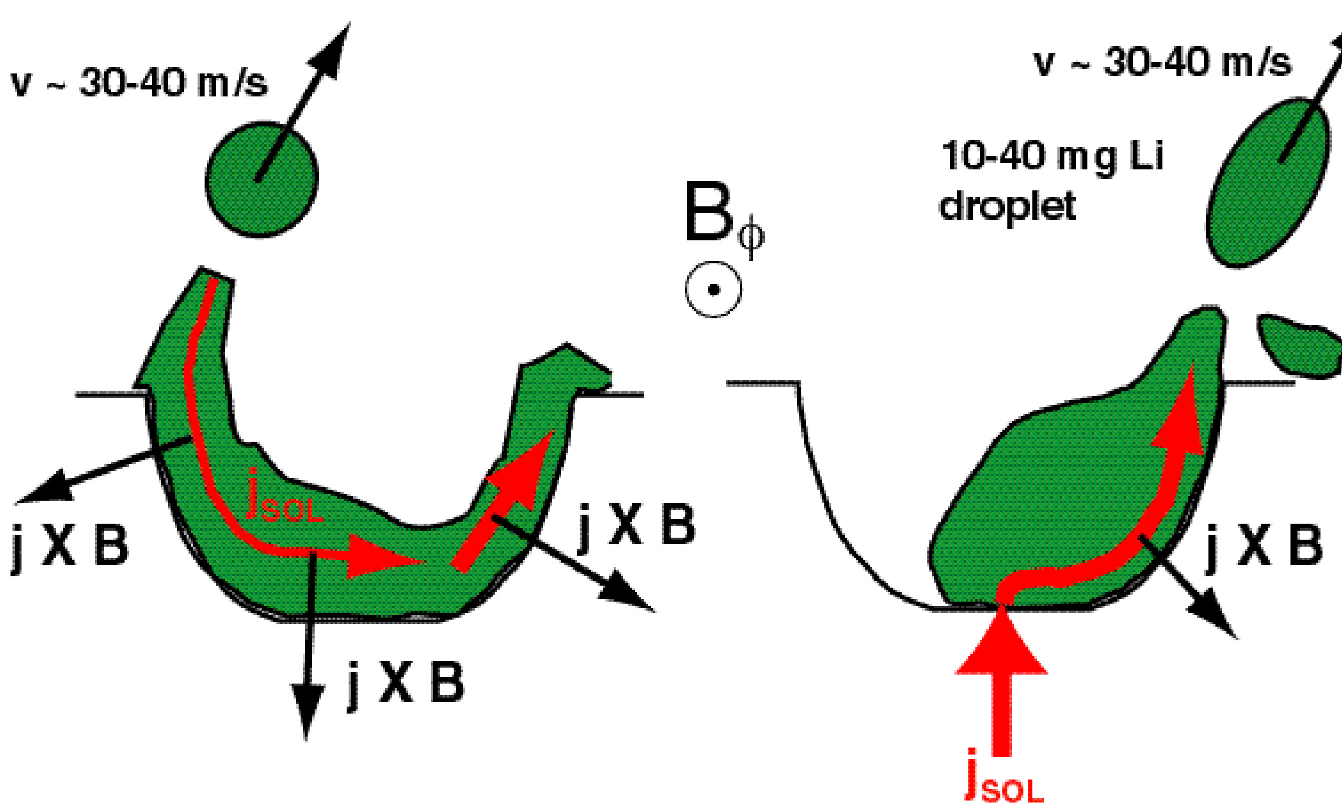
A better understanding of the internal Li current distribution is needed to model the droplet ejection



- Additional experimental measurements and 3D dynamic modeling of the liquid response are needed.
- Biasing experiments may be useful.

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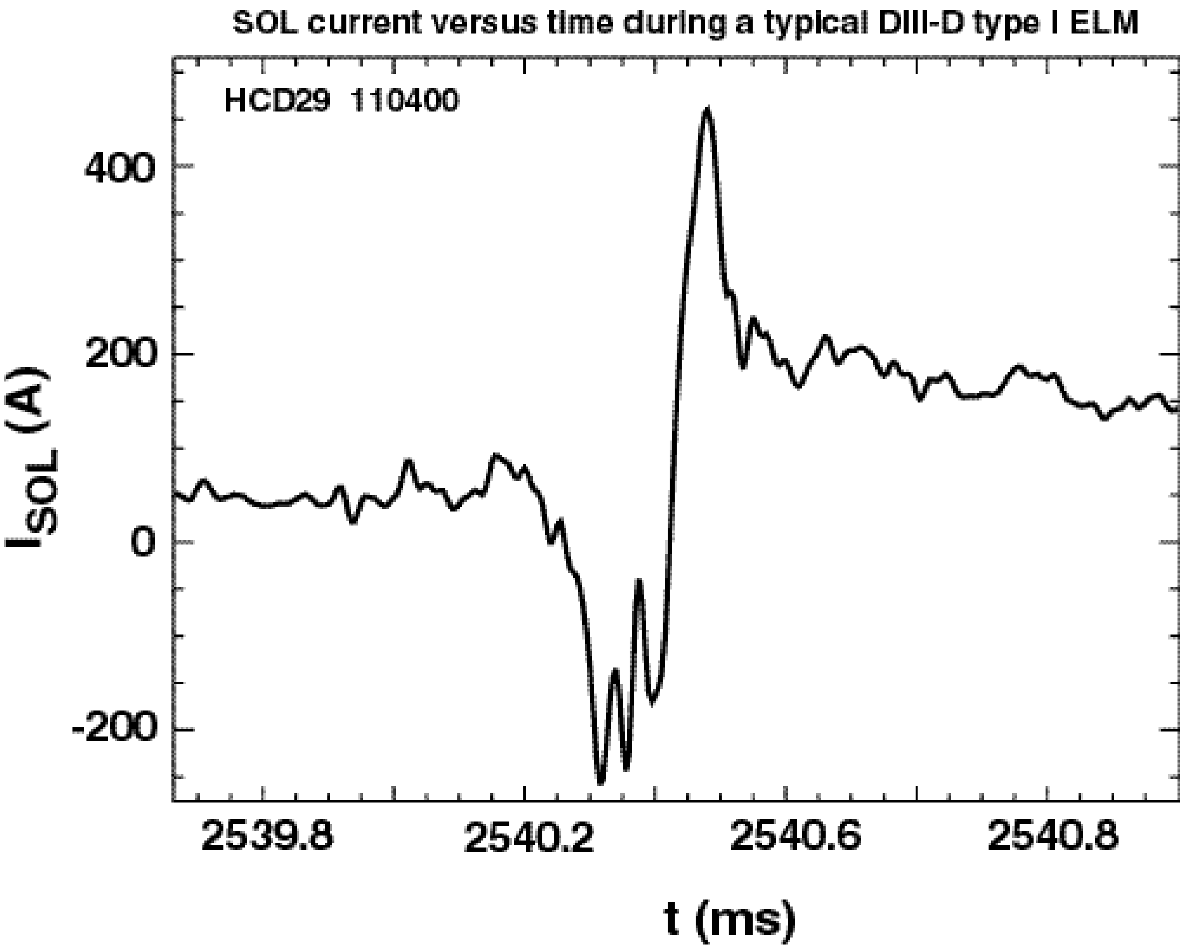
The dynamics of the total SOL current through a single row 13 tile during an ELM are quite complex



- SOL currents during type I ELMs are 10-20 times larger than L-mode SOL currents with both positive and negative spikes.
- ELMs pose a significant challenge for Li divertors.

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Summary and conclusions

- In low power DIII-D plasmas Li disruptions appear to be triggered by the injection of a single liquid Li droplet.
- The data suggest that J X B forces in the liquid cause the injection but:
  - » A better understanding of the current distribution in the Li sample, as well as self-consistent modeling of the liquid dynamics, is needed.
- New diagnostics are required to determine:
  - » When the Li sample becomes a liquid
  - » How the liquid surface evoleves
  - » How the current distribution in the sample changes with plasma conditions and surface shape.
- Sample biasing may help control the injection process in L-mode plasmas but will not provide a solution during ELMs

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