LLD Front-face temperature rise and the measurement of temperature dependent particle pumping

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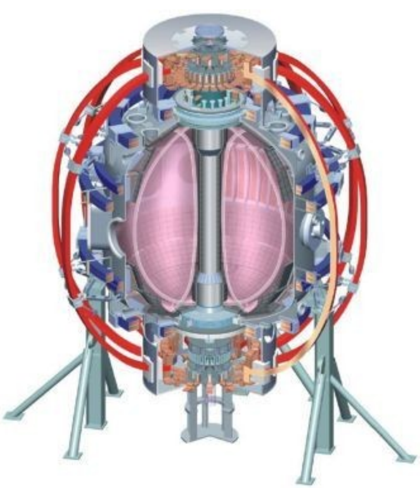

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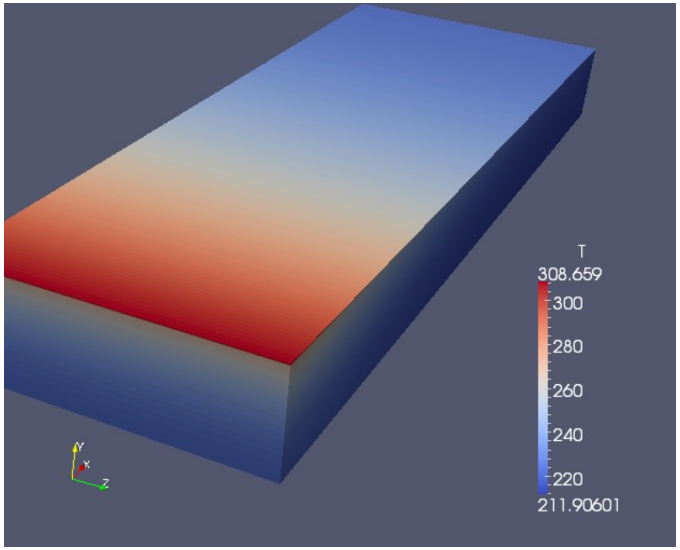
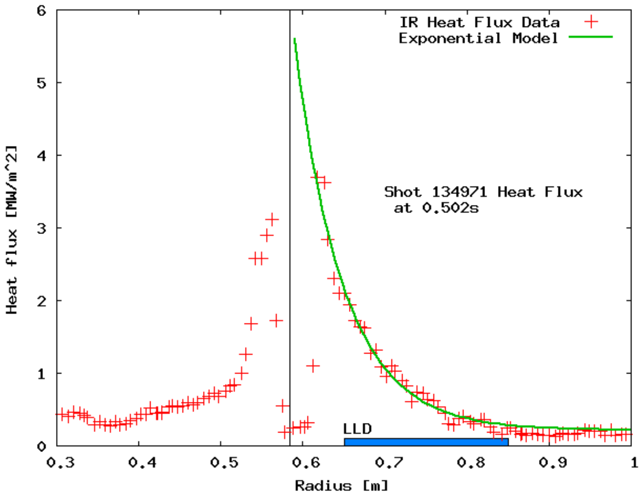
Working model for LLD temperature rise

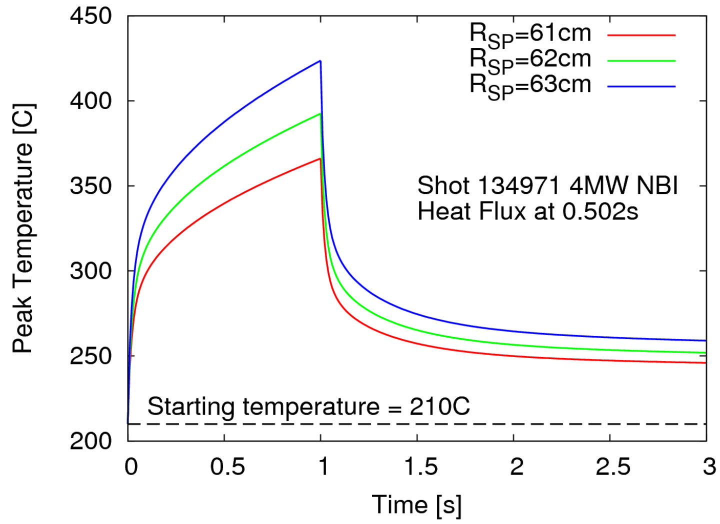
- Implemented model making estimates of temperature rise
  - Using OpenFOAM computational system to perform thermal analysis
  - Toroidal symmetry assumed (wedge modeled)
  - Using IR heat flux measurements for input (J. Kallman and R. Maingi)
  - LLD geometry and materials used (additional porous material model based on Jaworski **JNM** 2008)
- Conservative/Pessimistic boundary conditions
  - Constant heat flux for 1s pulse duration
  - No radiation or evaporative cooling (both negligible)
  - Insulated boundaries – how hot can it get?
- End result is upper-bound on temperature during heat pulse

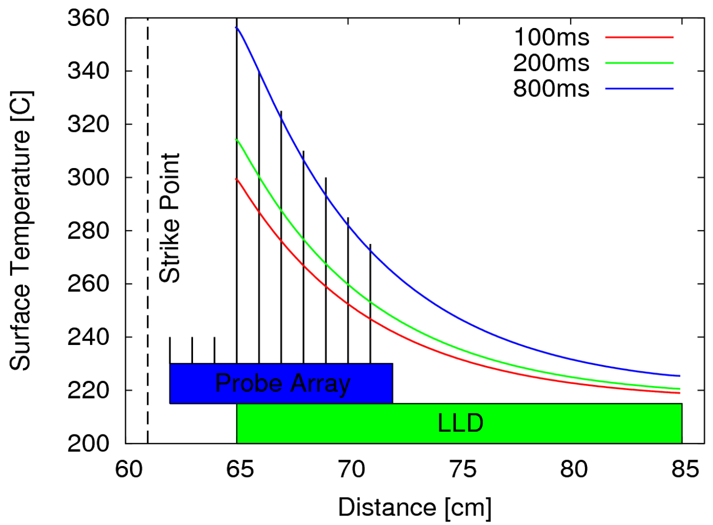




Temperature dependent particle control – Concept "Emphasis on the 'M' in PMI"

- Make use of plasma heating to obtain multiple temperatures
  - Allow the plasma heating to change temperature
  - Make use of fast gas puffs (e.g. lower plenum or SGI) to perturb SOL density
  - Measure dn/dt and n directly with Langmuir probes – deduce effective particle lifetime, $(\tau_p^*)_{SOL}$
- Spatial gradient along plate enables multiple temperatures at each puff
- **Produce a set of effective particle lifetimes (i.e. a pumping metric) vs. LLD temperature**



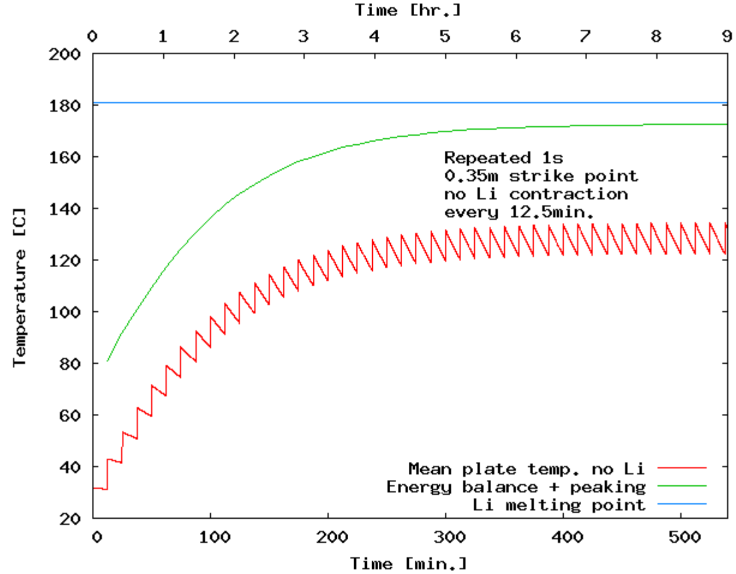


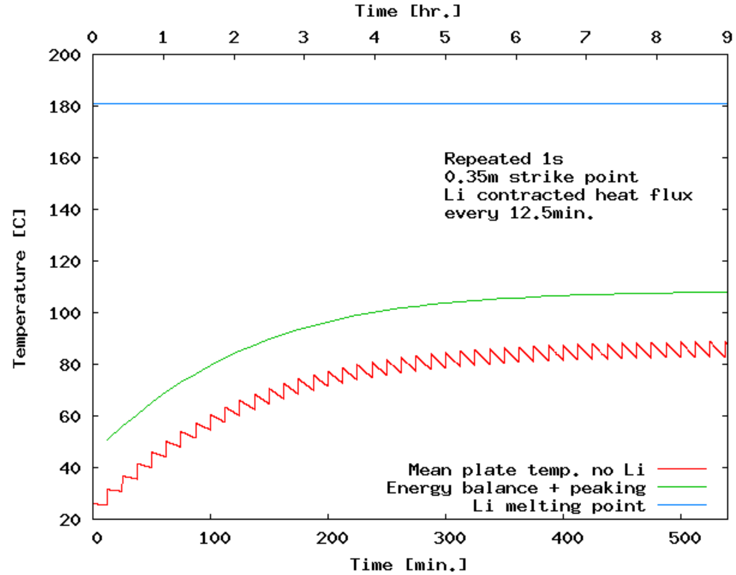
Methodology

- All shots use intermediate triangularity with same fueling scenario developed in XP1000
- Start with cold LLD and fresh Li
  - Pulse with 3 gas puffs (1 shot + 2 development)
  - Obtains data for all 4 plates at the same temperature
- Pulse after thermal ratcheting with fresh Li
  - Set active plates to expected steady state ratcheting
  - Pulse with 3 gas puffs (1 shot)
  - Obtains pumping metric for expected operating temperature range of malfunctioning LLD plate
- Cold LLD without LITER
  - Pulse with gas puffs and look for Li saturation on cold LLD (~5 shots ?)
- Warm LLD operation with fresh Li
  - Operate other three plates at “warm” setpoint
  - Pulse with 3 gas puffs (1 shot)
  - Obtains pumping metric for higher temperatures and possibly account for 4^{th} plate
- Warm LLD without LITER
  - Repeat shots with gas puffs (~5 shots?)
  - Look for saturation of ATJ surfaces and measure change in pumping metric
  - Compare with Cold LLD shots on previous day
- 15 total shots (uncertainty here)
- Post-calculate temperature for all cases
  - Treat LLD as calorimeter
  - Cross-check heat fluxes

Possible use for *starting* temperature scan

- Temperature of unheated plate will ratchet
  - Thermal calculations very preliminary here
  - Unknown emissivity and effective radiating surface area (geometric and B.B. used here)
- Fiducial temperature profile used here
  - 1 MW/m2 inboard, 0.6 MW/m2 outboard without Li
  - Contraction to half this due to Li effect (both via. R. Maingi)
  - 12.5 minute shot cycle
  - Potential to transition unheated plate to liquid state within a shot
- More operational data needed and small experiments in C128 to make a better estimate





Recycling coefficient and hot-spot stability

- Can combine particle flux to wall with filterscope data for local recycling coefficient
  - Vlad's APS poster showed this
  - Triple Langmuir probe can provide (plasma) temperature correction for local density as well as time-resolved plasma parameters
  - Temperature rise gas-puff method with previous techniques can measure local recycling as a function of temperature
- $(\tau_p{}^*)_{SOL}$ Important equilibration time in hot-spot formation (Krasheninnikov, PoP 2006)
  - Fully absorbing wall (i.e. small τ) likely to be stable to density perturbations which lead to hot-spots
  - NSTX SOL characterization can begin addressing hot-spot formation theory and if strongly variable with Li temperature, create unique opportunity to study the phenomena
- Also: benchmark thermal code and compare IR cameras with local plasma parameters and LLD calorimetry data