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ELM Power Deposition on a Tungsten

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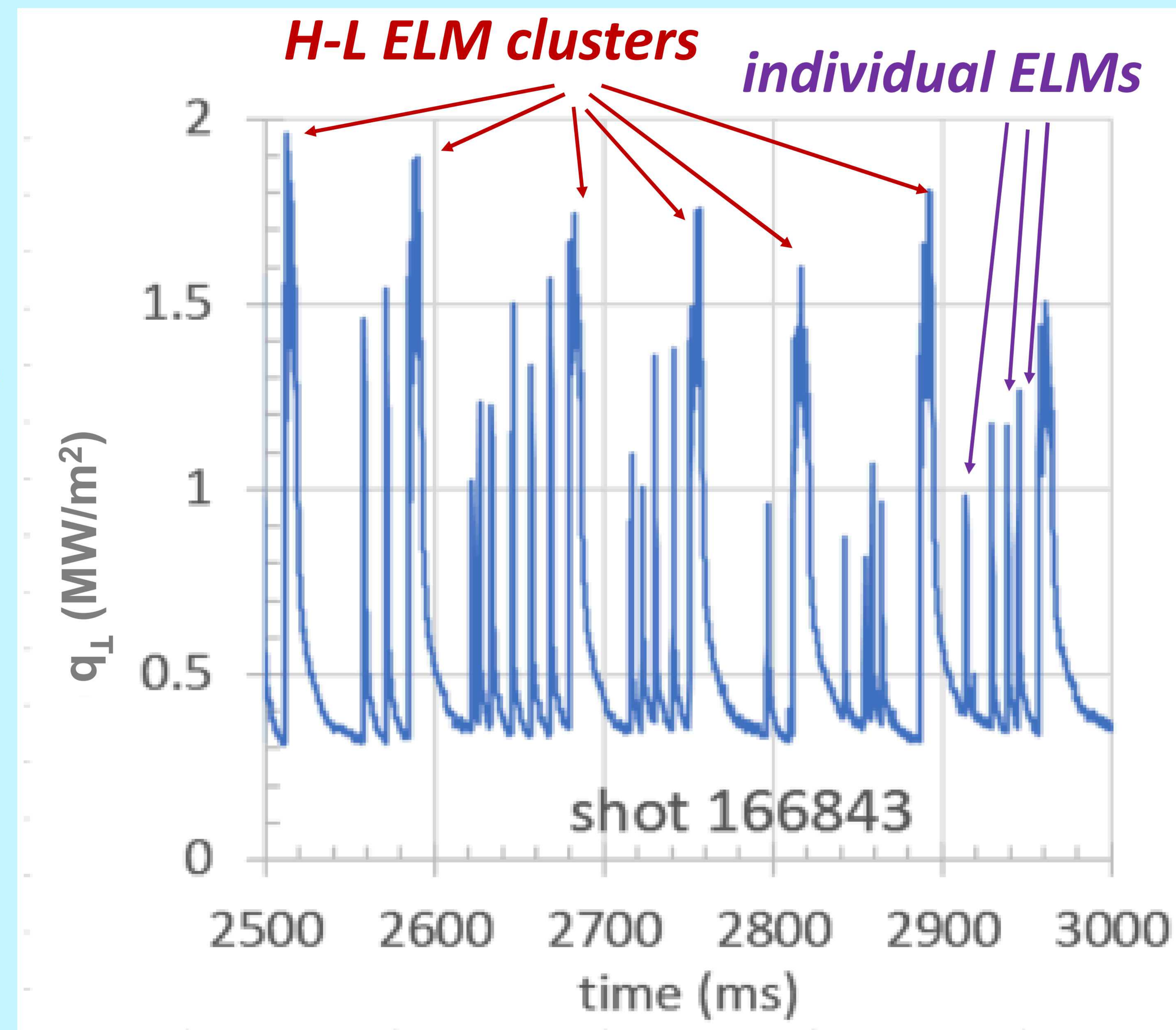
Power exhaust is among fusion's major issues. High heat loads on leading edges, ELM heat loads on PFCs and requirements for aligning and shaping PFC elements are some specific concerns.

The 2016 DIII-D DiMES tungsten (W) leading edge experiment in support of ITER studied heat loads from ELMs in helium (He) plasmas. The regime, with He plasmas close to the threshold for L mode to H mode transitions and high particle and heat exhaust, may have relevance for He plasmas in ITER's start-up phase.

Compound ELMs (C-ELMS) associated with L-H back-transitions dominated the transient particle exhaust in shots with ECRH, These reduced the plasma density significantly, and some triggered automated gas puffing.



Thermal Model

We cannot measure T_{LE*} directly and accurately. Nor do we need to do this.

*LE is leading edge. T is temperature.

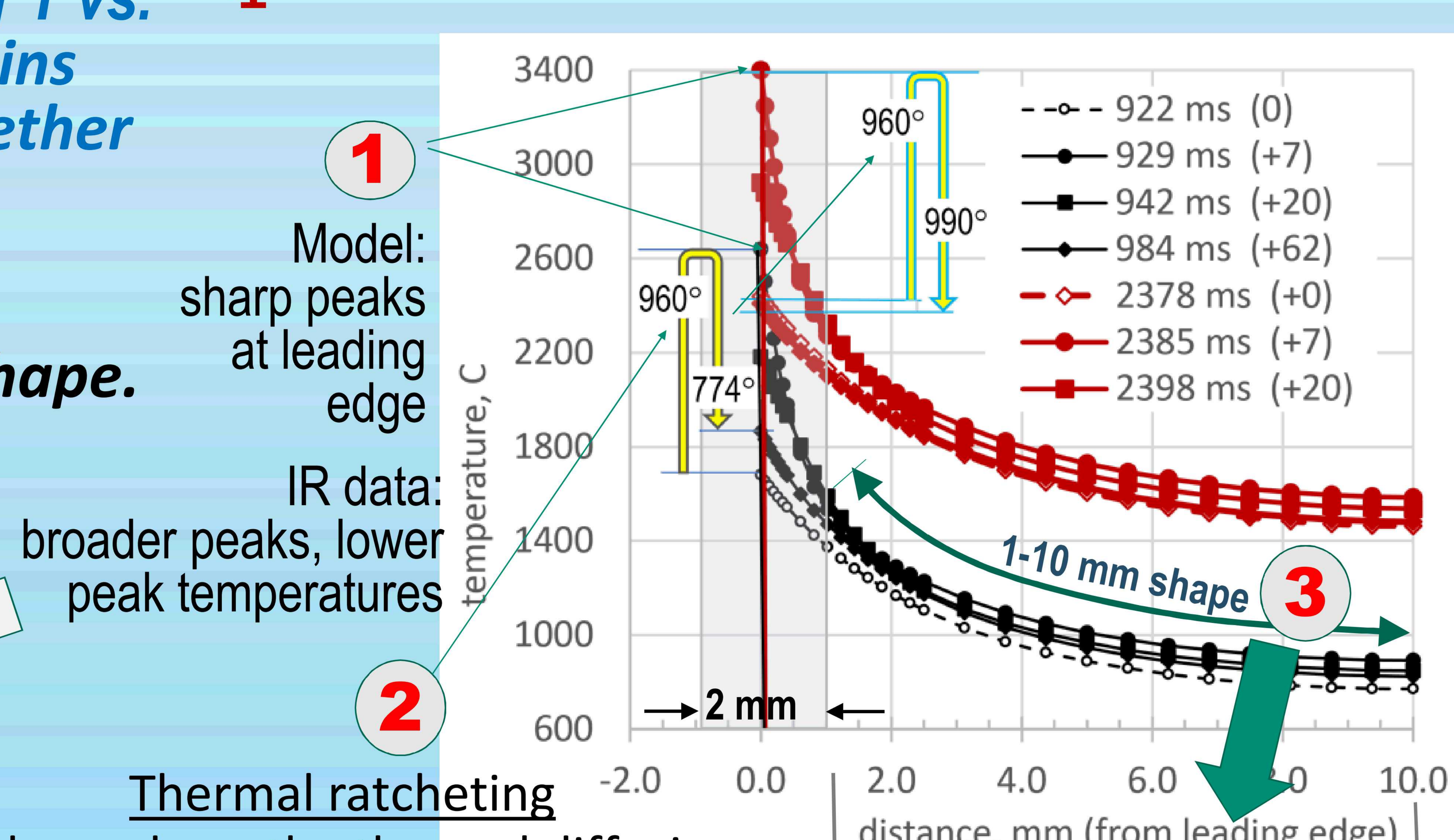
T_{LE} surges during ELMs, then relaxes as the heat diffuses between ELMs.

A key is the temperature pattern on the top of the W block, specifically the shape of T vs. distance from the LE. This T-shape remains quite constant. It is not sensitive to whether an IR is during or after an ELM

Our approach

- ***Calibrate a thermal model; match T-shape.***
- ***Compute T_{LE} with the thermal model.***

We get $q_\perp$ from IRTV data (IR60) on an ATJ graphite tile away from DiMES processed using THEODOR. From $q_\perp$ and **B** we calculate $q_\parallel$ and the angle of incidence. We compare $q_\perp$ with values from the new model's best fit.



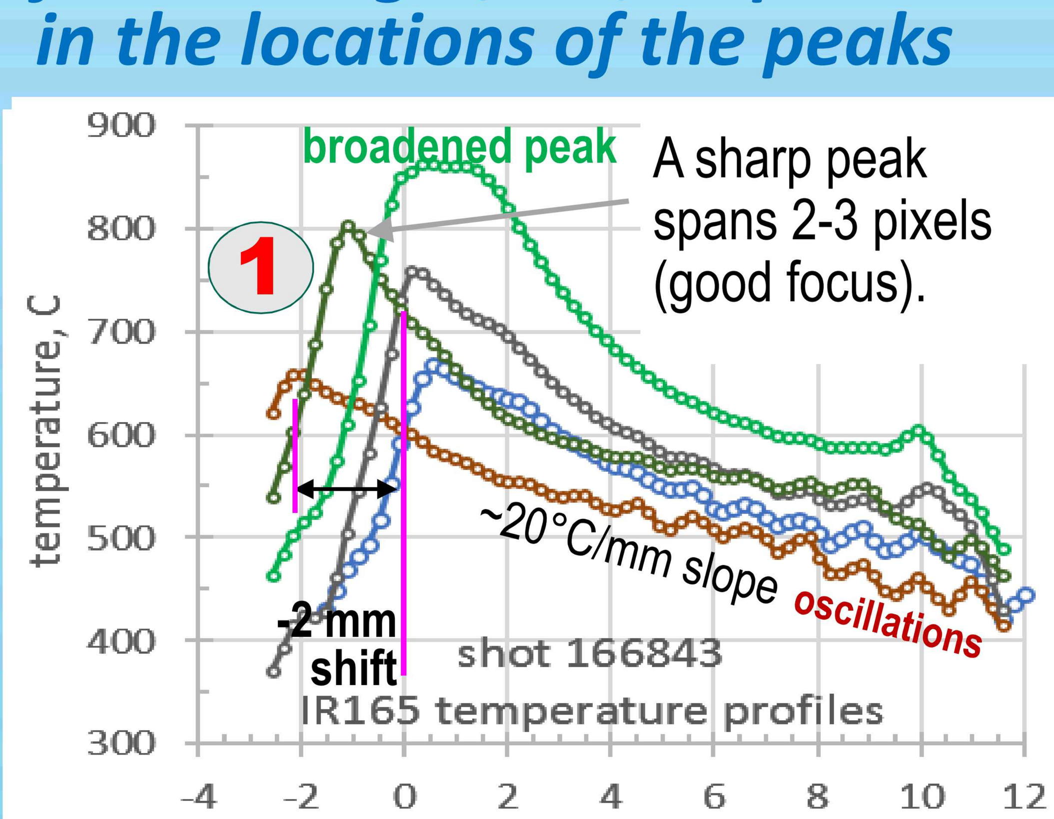
The resolution (~0.4 mm) smears the IR image at sharp features, e.g., the LE. So the peak in IR temperature at LE is broader and lower than the true temperature.

Vibration of the optic system causes phasing of the frame-to-frame images, i.e., displacement in the locations of the peaks

Thermal ratcheting

This depends on the thermal diffusion during relaxation between ELMs. Leading edge ratcheting is less at higher temperature due to greater conduction (larger dT/dz) and radiation losses.

The temperature profiles have a similar shape from 1 to 10 mm (90% of the top). The overall temperature rises incrementally.



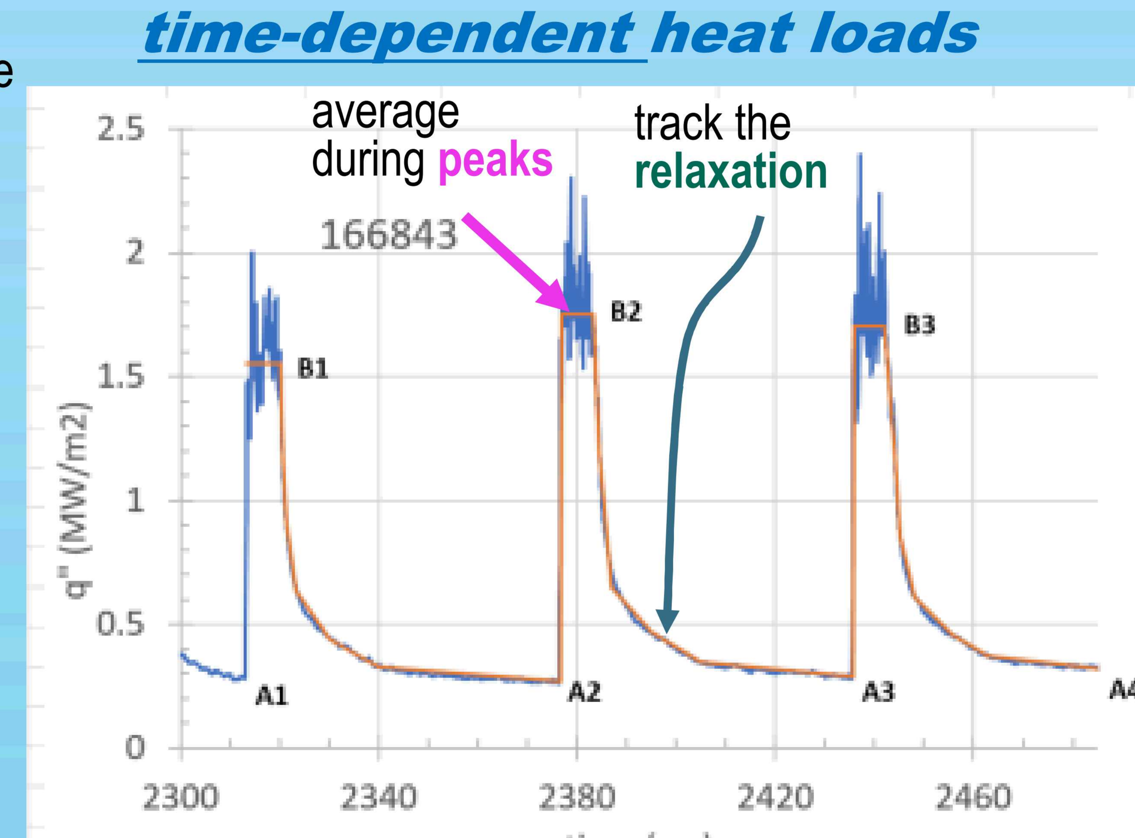
Frame-to-frame phasing (peak shift) indicates vibration with a base frequency of ~ 60 Hz.

An early analysis with spatial averaging (poor focus) produced broadening like curve *2553.917 ms*. It's broadening (~4mm) is similar to the estimate below for ripples.

The ripples correspond to motion of ~4 mm in the field of view based on their amplitude and the slope of the curve. This implies a much higher sweep frequency (~60 kHz). Sweeping of the filaments that occur during ELMs may7 be a more likely cause the a mechanical vibration at the high frequency.

The optical system has two mirrors each articulated with a clamped rod and post. Torsional vibration of the 2nd mirror would cause an apparent toroidal sweep in the field of view.

time-dependent heat loads



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Leading Edge in a DIII-D He Plasma

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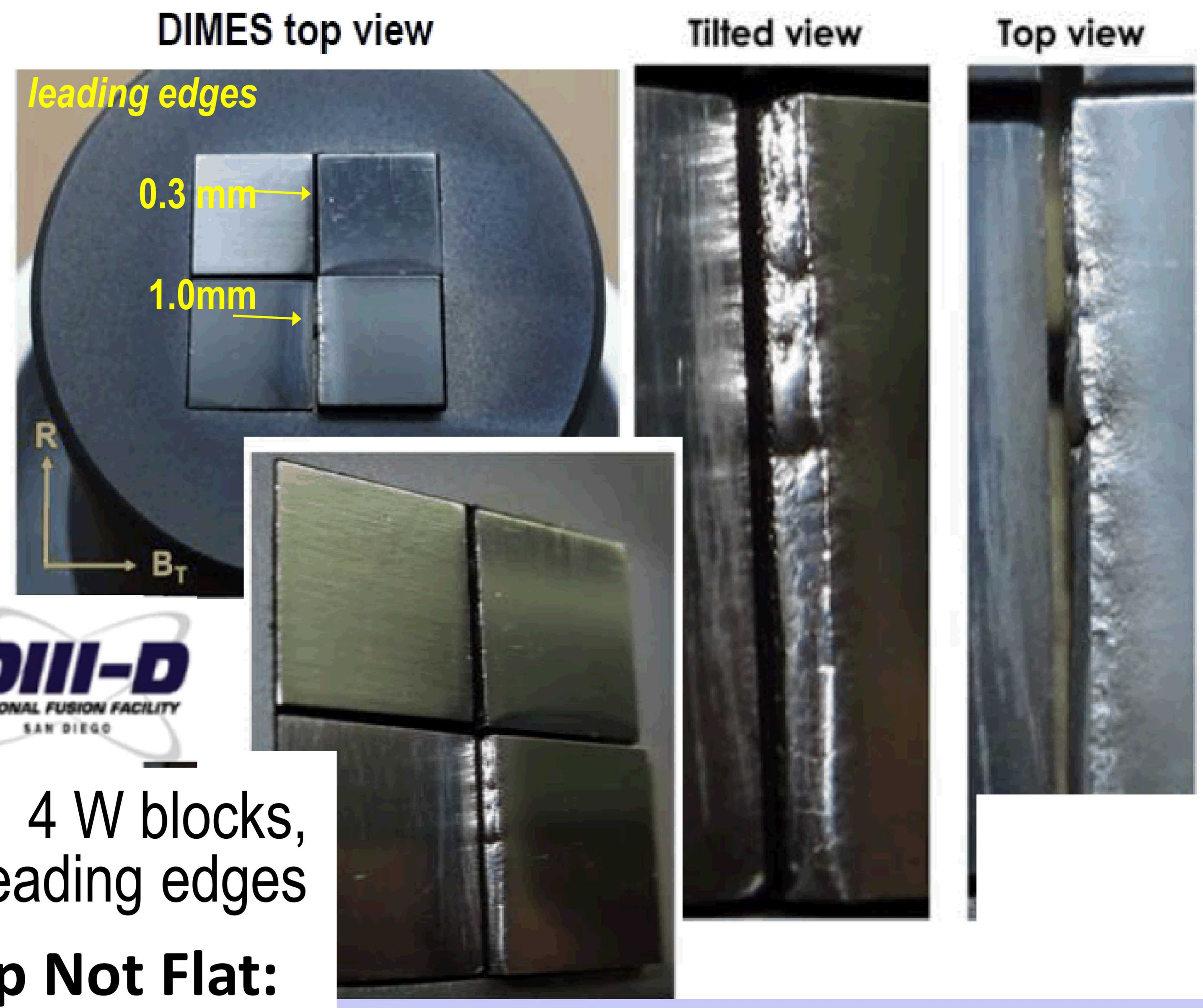
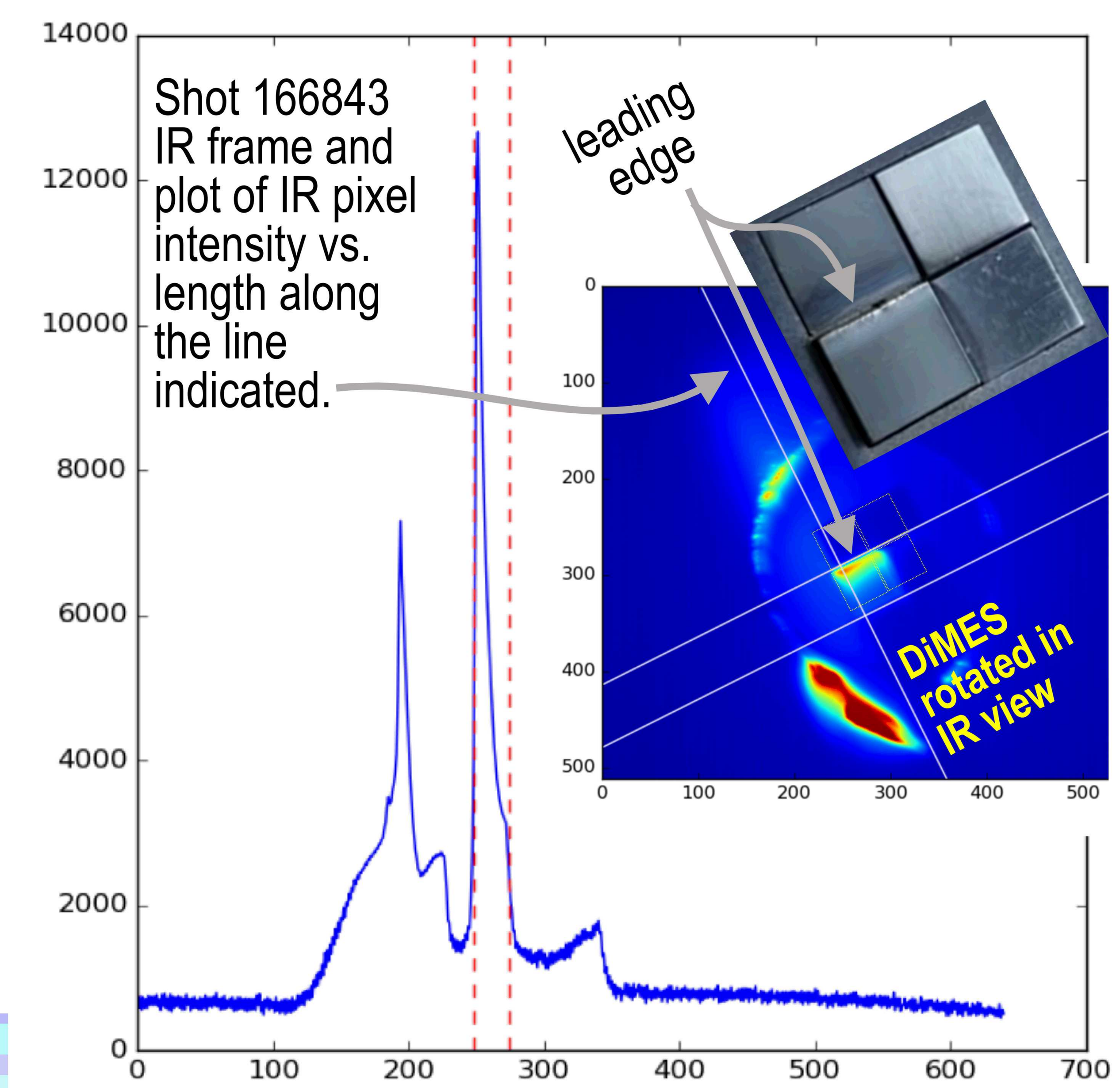


4 W blocks, 2 leading edges



Top Not Flat:

- For $q_\perp$ of 0.54 MW/m², B incident at 1.1º **$q_{||}$ is 28 MW/m²**.
- The 1-mm leading edge block's forward slope is **0.12**.
- The top intercepts 7X $q_\perp$. **q_{Top}** is **3.9 MW/m²**.
- During the LHBTEs, the IR data shows rapidly rising OSP peak that bifurcates. The true $q_\perp$ is difficult to determine. **$q_{||}$** & **q_{Top}** of **~50 & ~12 MW/m²** best fit the DiMES IR data.

Heat from the W block goes into the mounting structure.

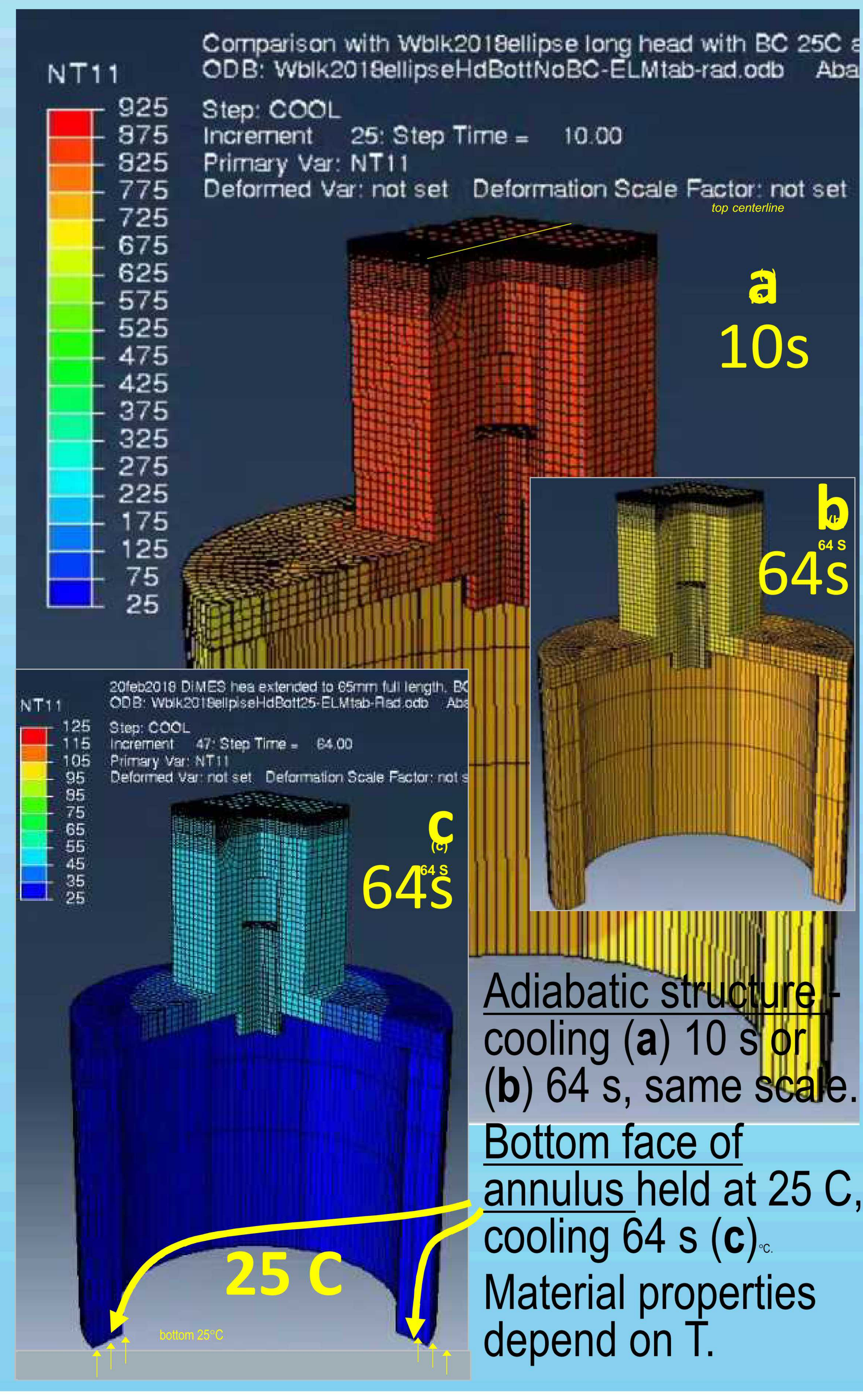
Our experience favors the adiabatic model (below).

When we withdraw DiMES to change samples rapidly between shots, the head is too hot to handle.

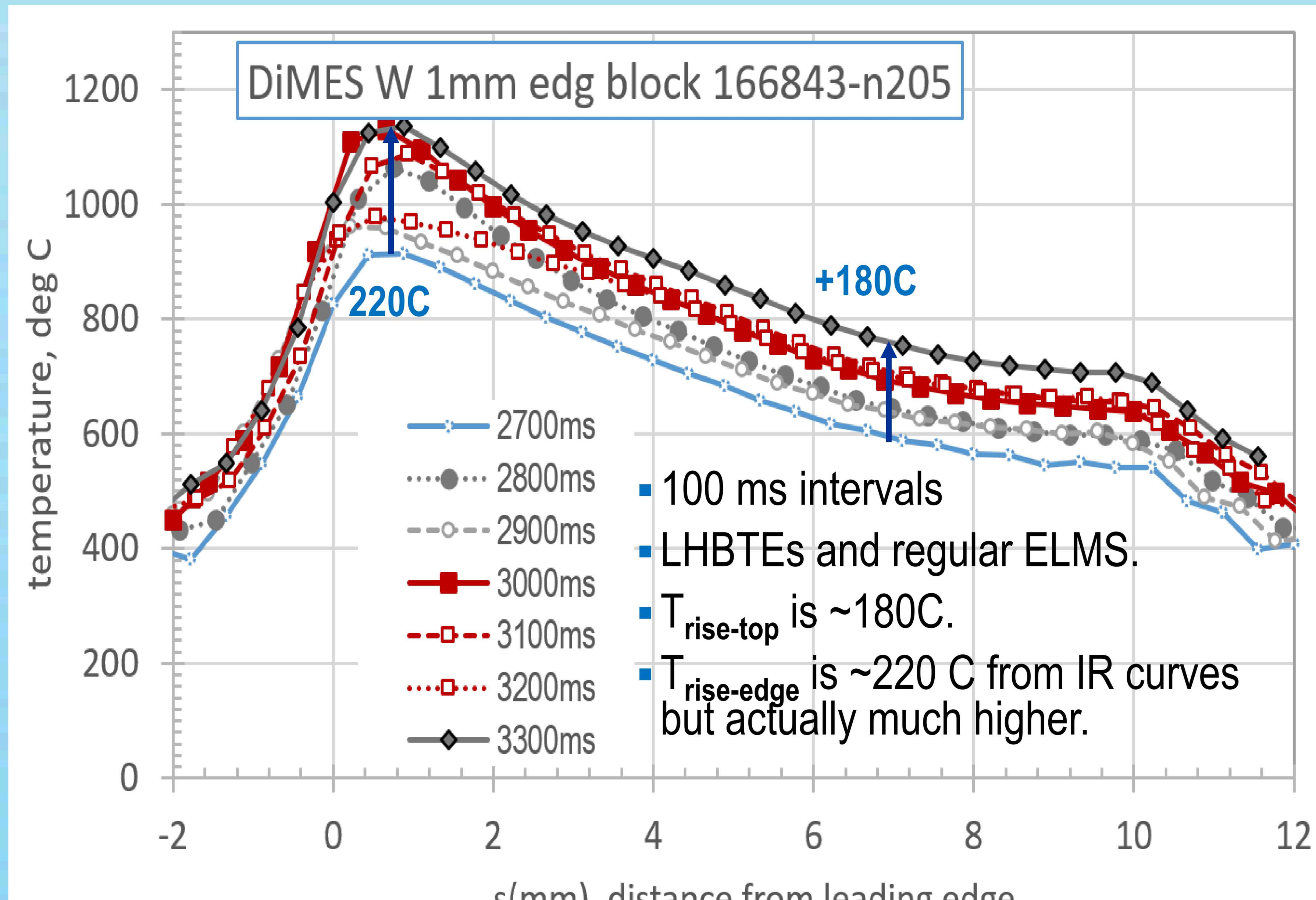
Interval analysis of Compound ELM heat loads

We can estimate the power absorbed by the W block from the change in the IR images, and get independent estimate of q_{Edge} and q_{Top}.

The heat flow is complex. ELM heating is ~15% of the total.



Adiabatic structure cooling (**a**) 10 s or (**b**) 64 s, same scale.
Bottom face of annulus held at 25 C, cooling 64 s (**c**).
Material properties depend on T.



We use the same approach for ELMs in NB shot 166858, but the power is less and the resolution poorer. A series of similar ELMs still gives a measurable temperature rise that we can track in the IR data.

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