Cryogenic DT targets

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Summary: DT ice layers meet the 1-μm specification and are routinely produced. Foam-DT targets also meet the specification but have additional constraints.

UR LLE

Half of the >40 DT targets produced meet the 1-μm rms roughness specification – all modes, entire surface

– roughness mostly due to crystallographic defects (<0.1μm wide)

DT layer quality is determined by the ability to:

form an initial seed crystal and control the growth rate

– 12 hr cycle; temperature ramp ~ 0.001 K / 5-min

Ice layers in foam targets have additional requirements:

– slow cooling begins at 30K – to achieve transparency, full density

– the smoothness, uniformity of the foam wall affects the layer

Cooling the target below 19.5 K *WILL* roughen the layer

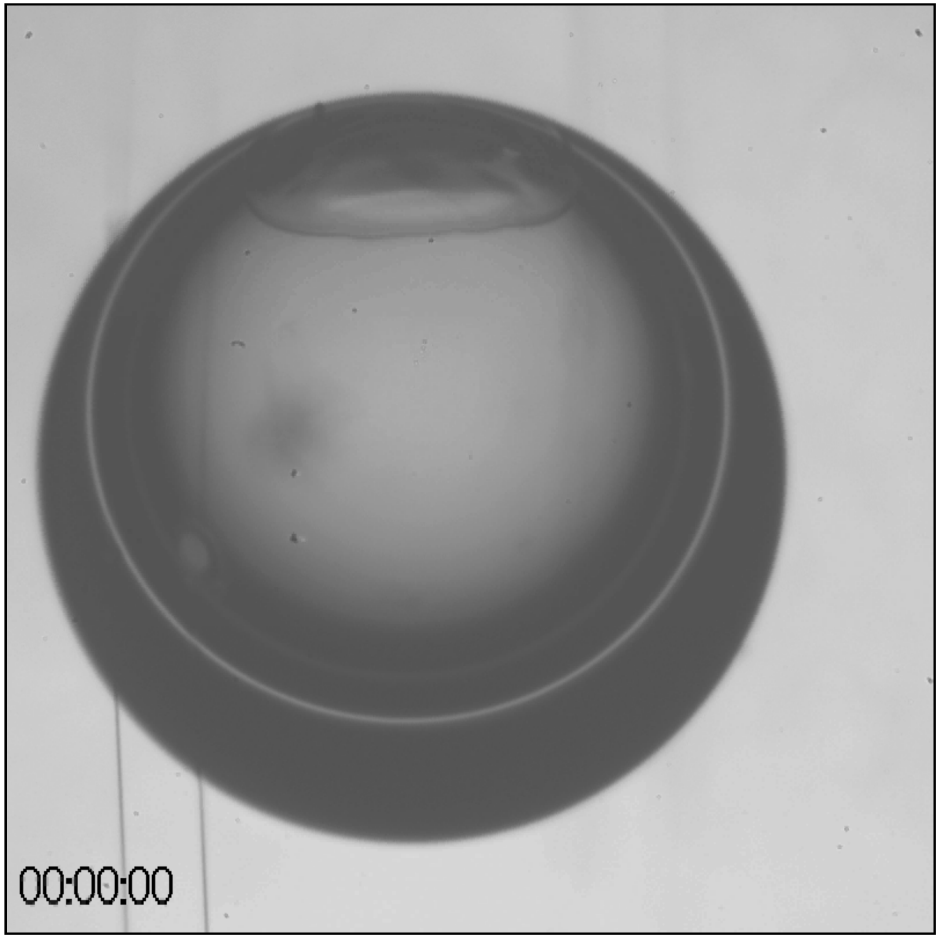
Smooth ice layers require *exquisite* control of the temperature

12 hr to form the ice layer

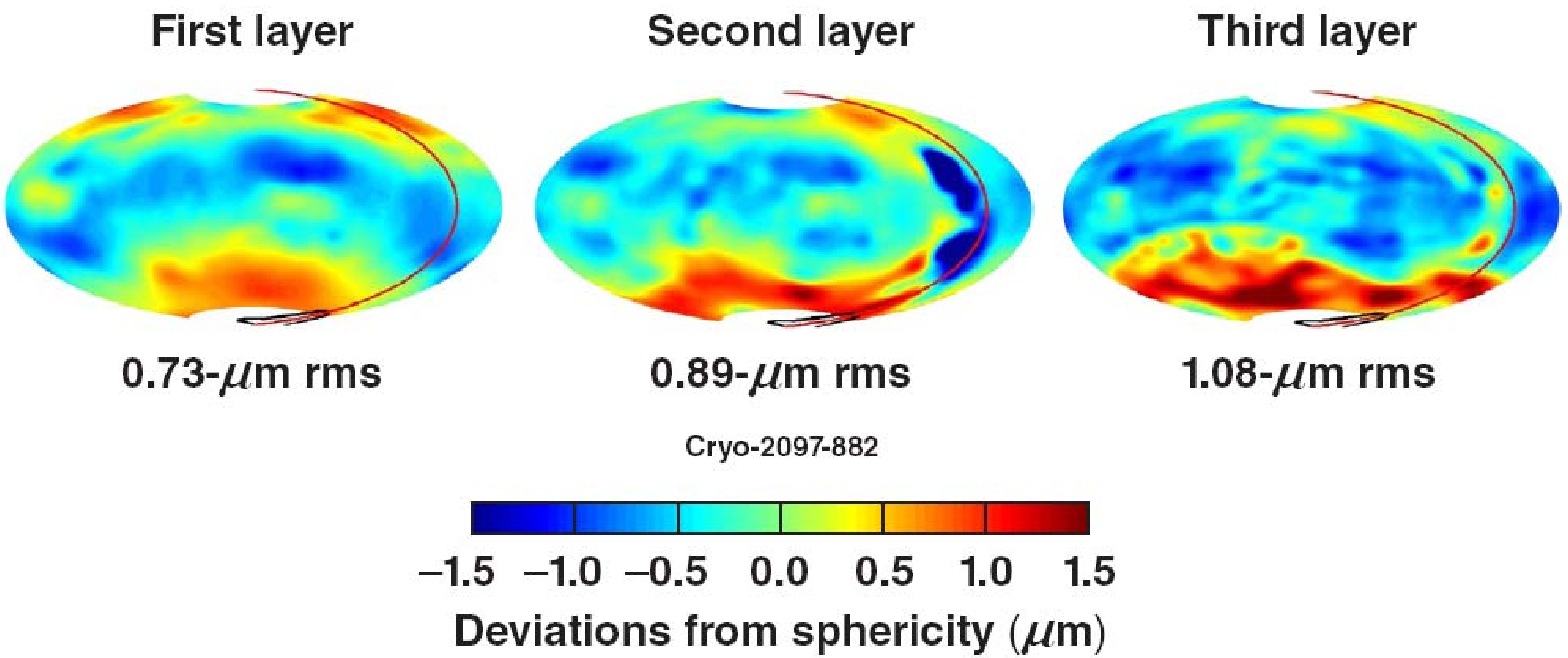
– not optimized

time-average temperature changes by < 0.001K/5min

temperature uniformity at the target wall +/- 5μK

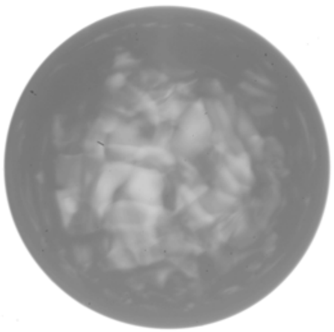


The ice crystal growth process is very repeatable. Multiple ice layers were formed in the same capsule using the same protocol.



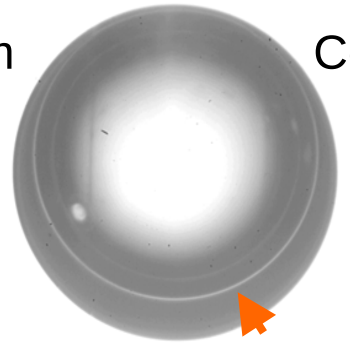
Gradual cooling of the $CH(DT)_4$ targets through the liquid phase is critical for transparency and full density.

UR LLE



Flash frozen at 17K

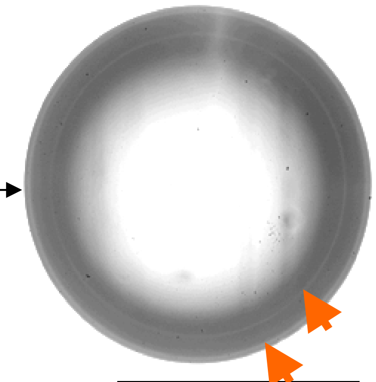
warm



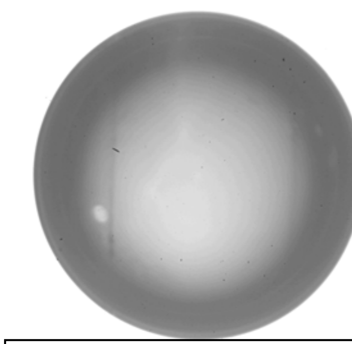
Liquid 26K

Cool, slow

Liquid 21K

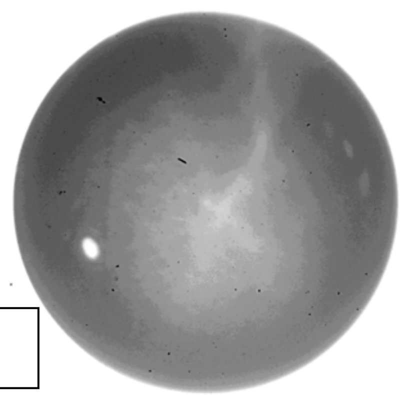


liquid 19 K



Layered ice at 18K

Multiple freeze, thaw cycles damage the foam structure and affects the transparency

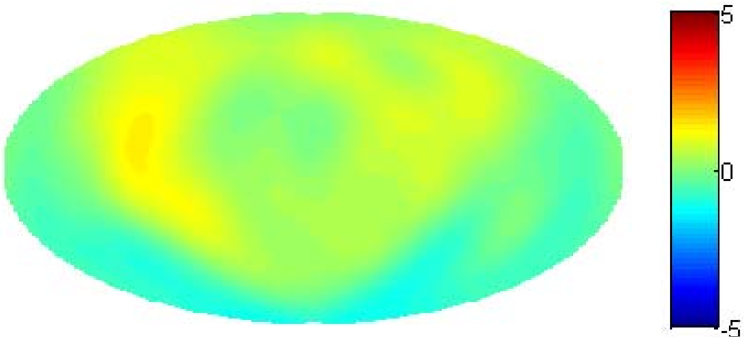


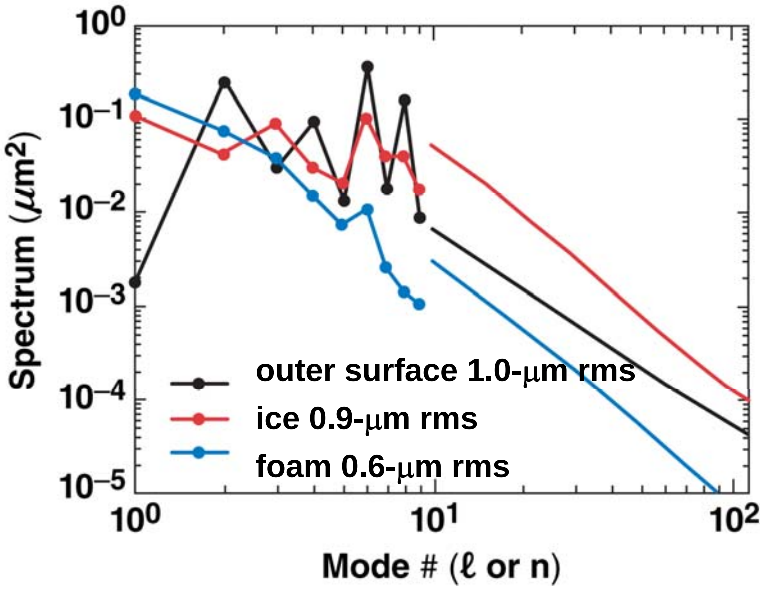
liquid 26K

68μm CH foam wall; 0.11g/cm^3

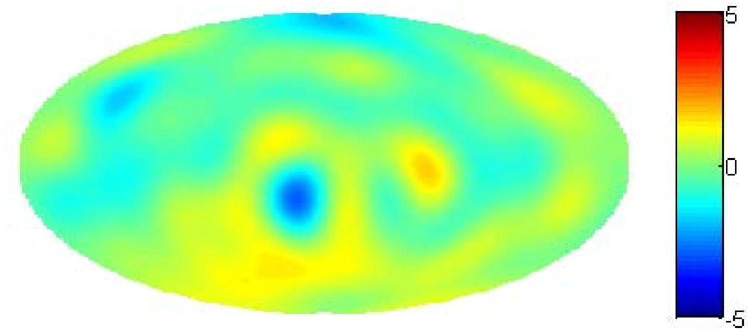
DT ice layer achieves the 1.0-μm rms specification in a foam target.

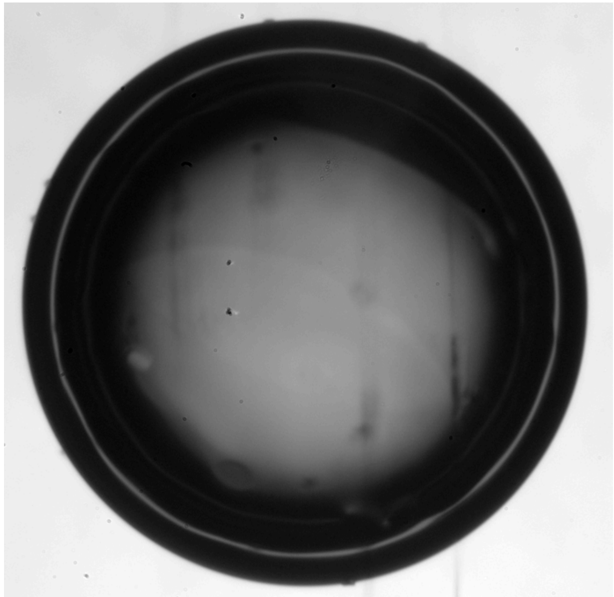
Foam wall thickness variation 0.6-μm rms





Ice layer thickness variation 0.9-μm rms

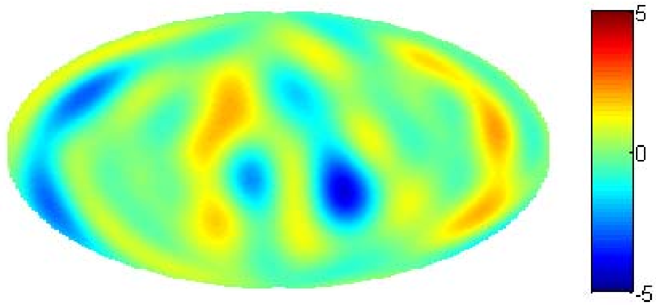




Cryo-3046-036 43 um foam; 54um ice

The *analysis* of the ice layer was affected by the roughness of the outer surface of the foam.

Outer surface variation 1.0-μm rms



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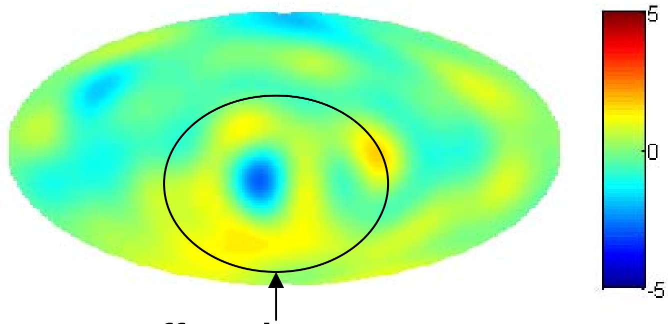
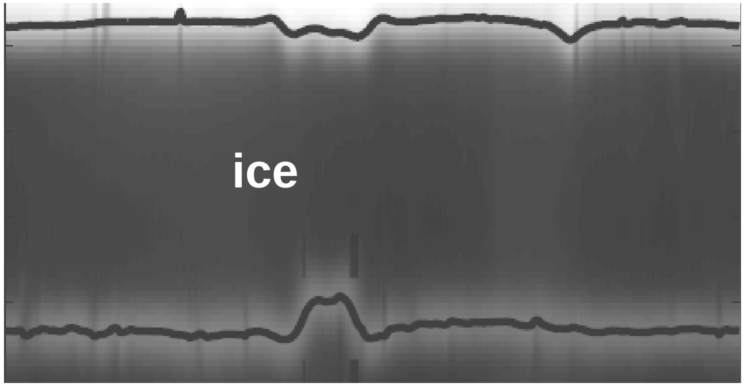


Effect due to outer surface



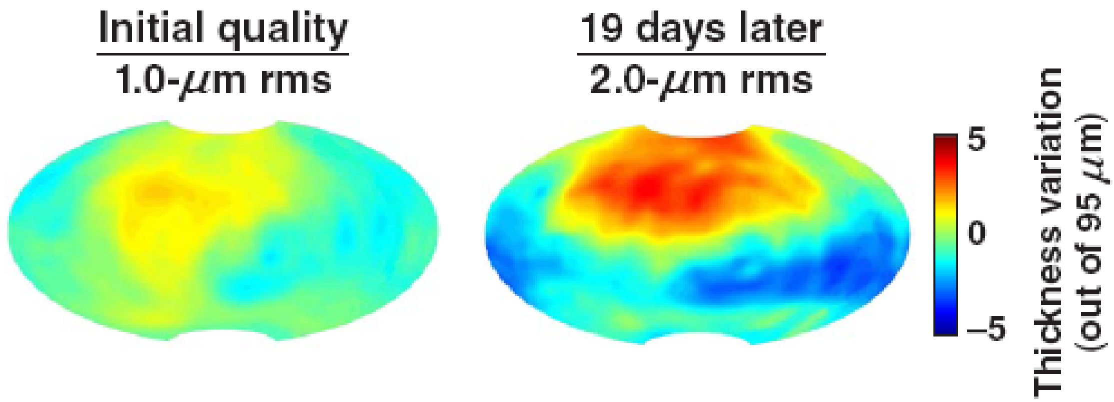
outer surface

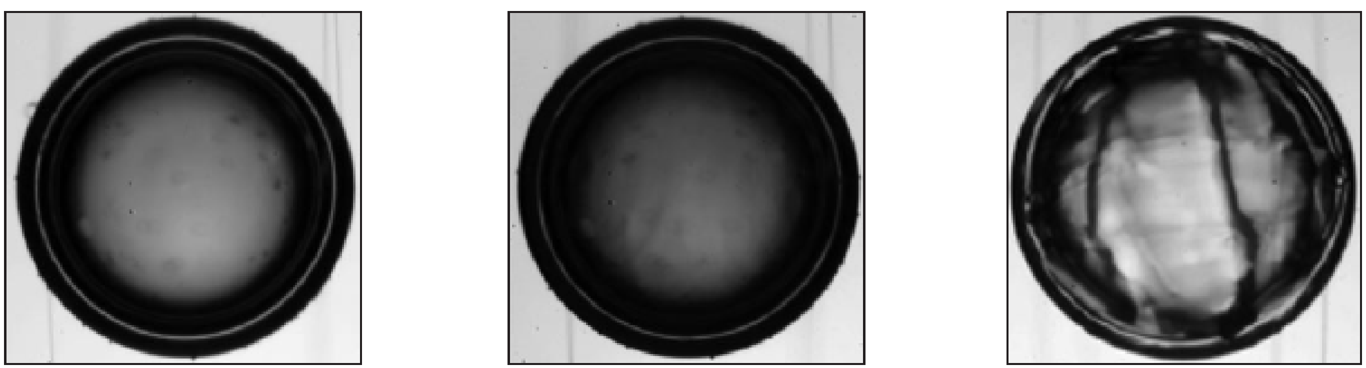
inner surface

Unwrapped image of a 2-D slice through a target showing the ice layer

The DT ice layer roughens with time, though not on a time scale of concern to IFE.

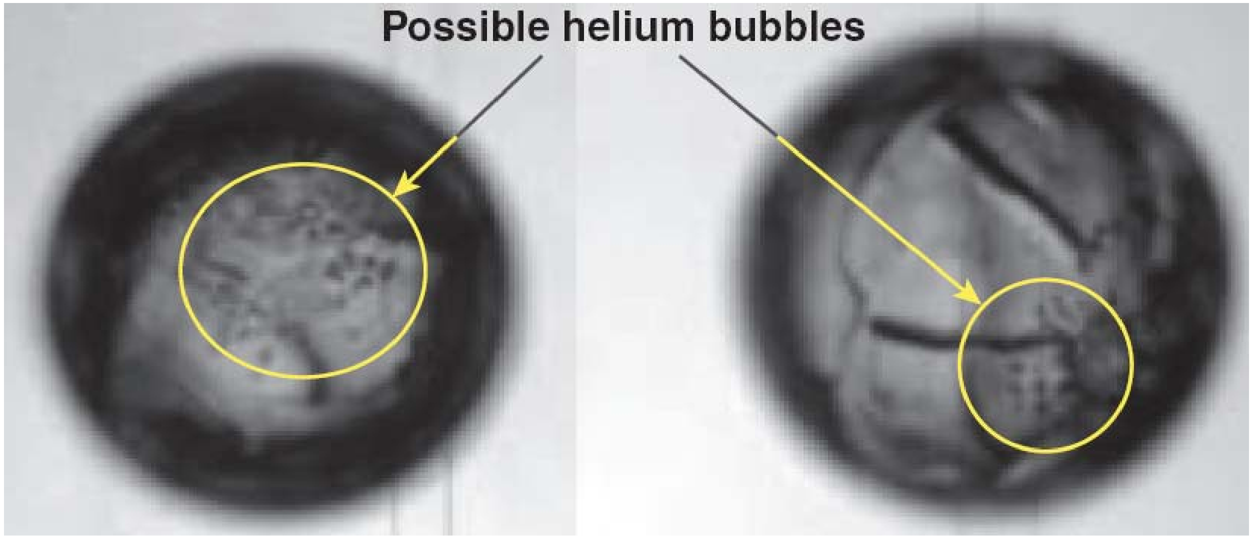
- Effect is attributed to the decay of tritium and accumulation of ^{3}He; there is no evidence of He bubbles in the ice layer.





Initial | 19 days at 19.5 K | 40 h at 17.7 K—no bubbles

^{3}He bubbles were observed after 7-days, and then only when the ice layer was 2K below the triple point

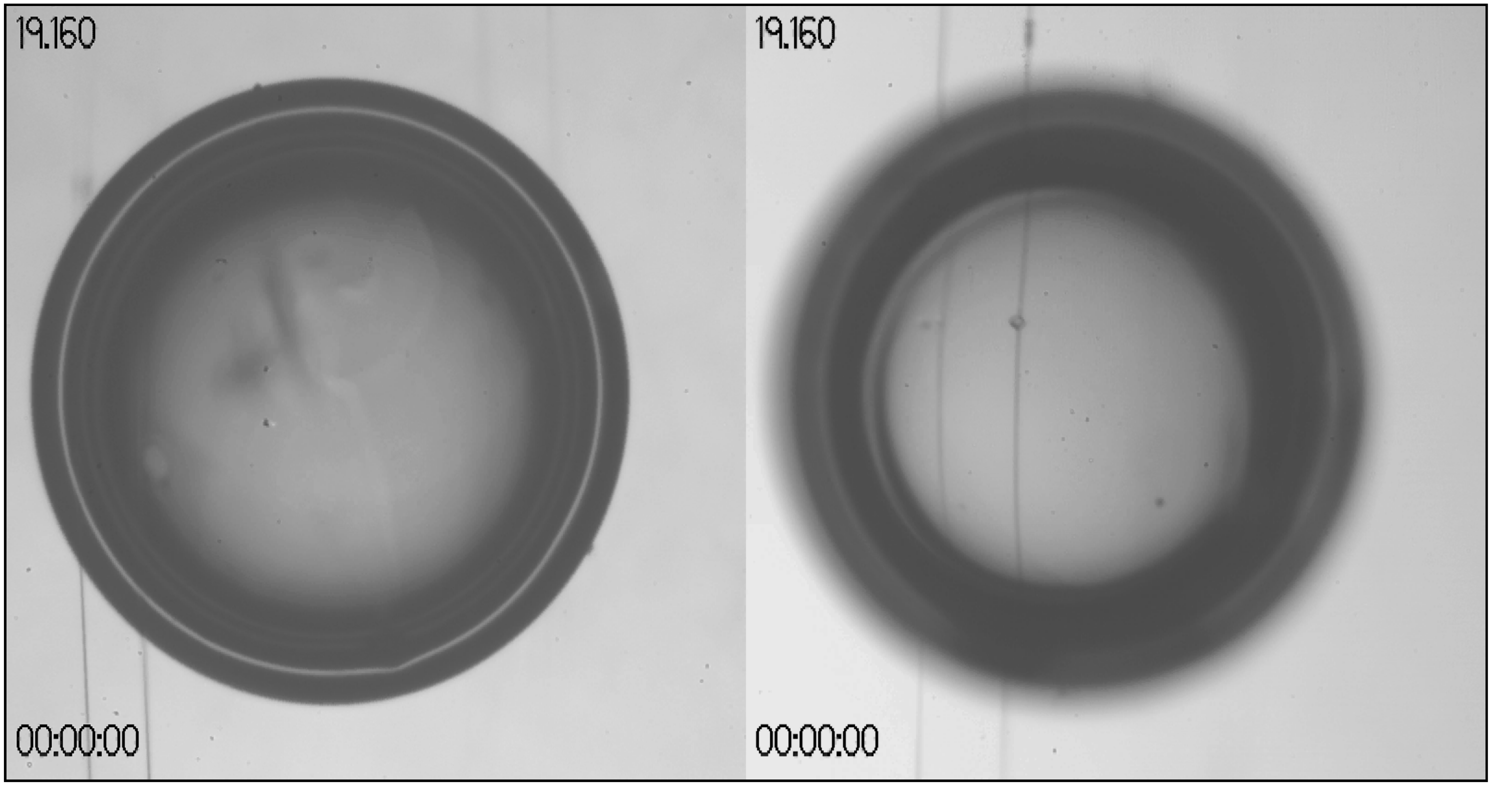


Postulate: grain boundaries are needed for ^{3}He to coalesce and time is needed for sufficient ^{3}He to accumulate to be seen

– implication: ^{3}He formed in the ice layer is "trapped"

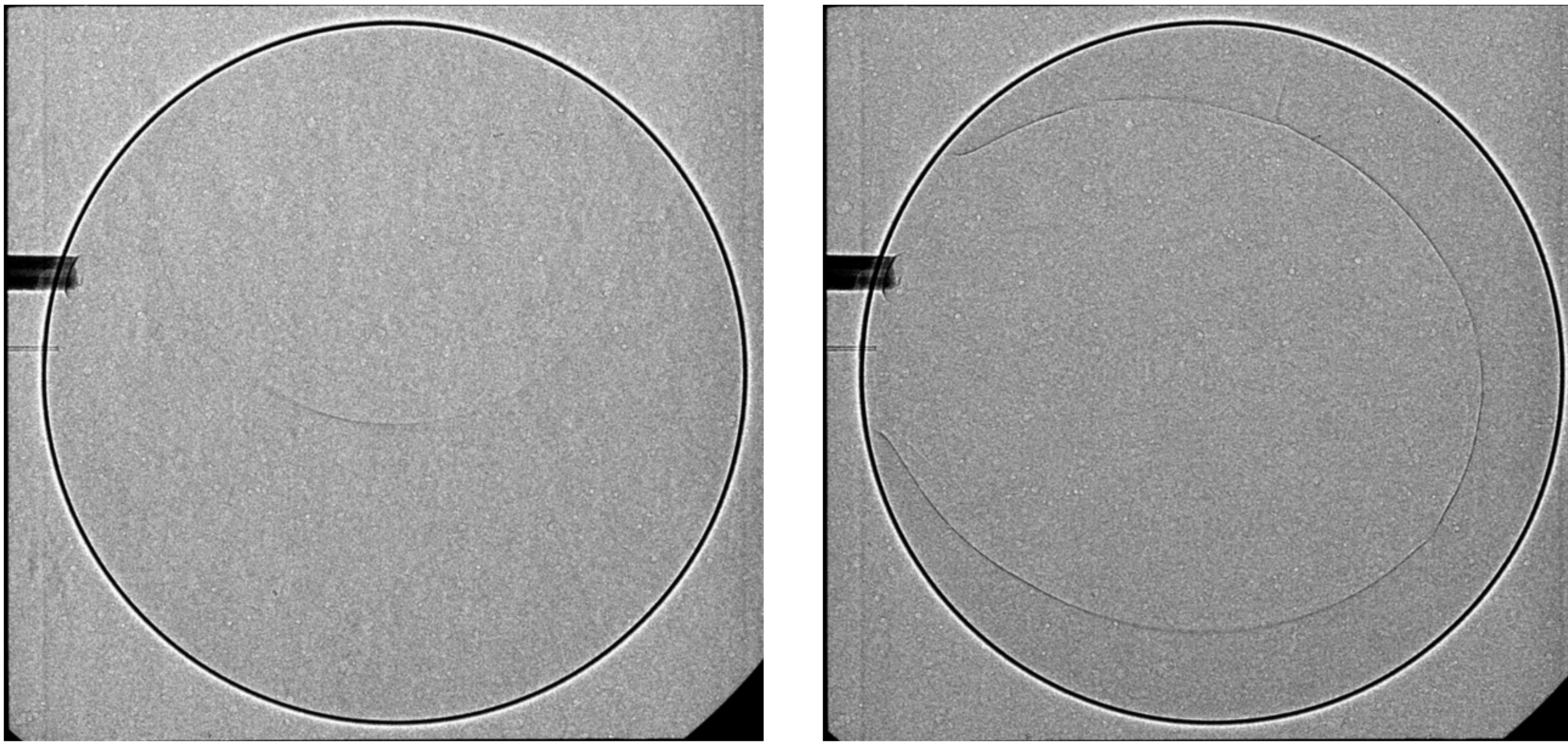
only ^{3}He due to "dirty, aged" DT is in the void

Cooling the target 0.7K below the triple point results in cracks: initially along crystallographic planes, they ripen and expand



Best option for preserving the ice layer quality at a low gas density is to cool the target as rapidly as possible and immediately before the implosion

We have added a new cryogenic capability to study targets with fill-tubes using X-ray phase contrast imaging.



We can more easily image foam targets to optimize the layering protocol and determine whether the foam/ice is fully dense

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