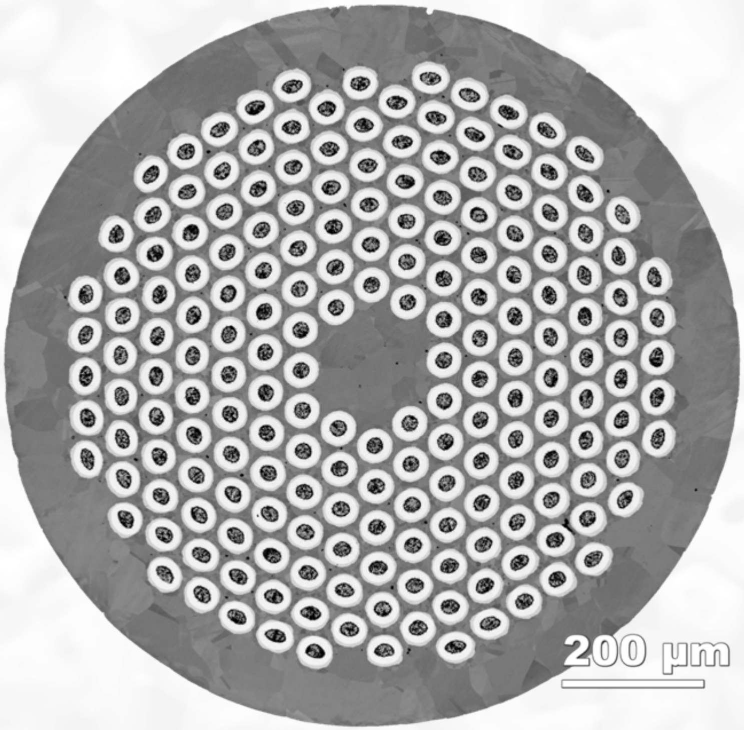
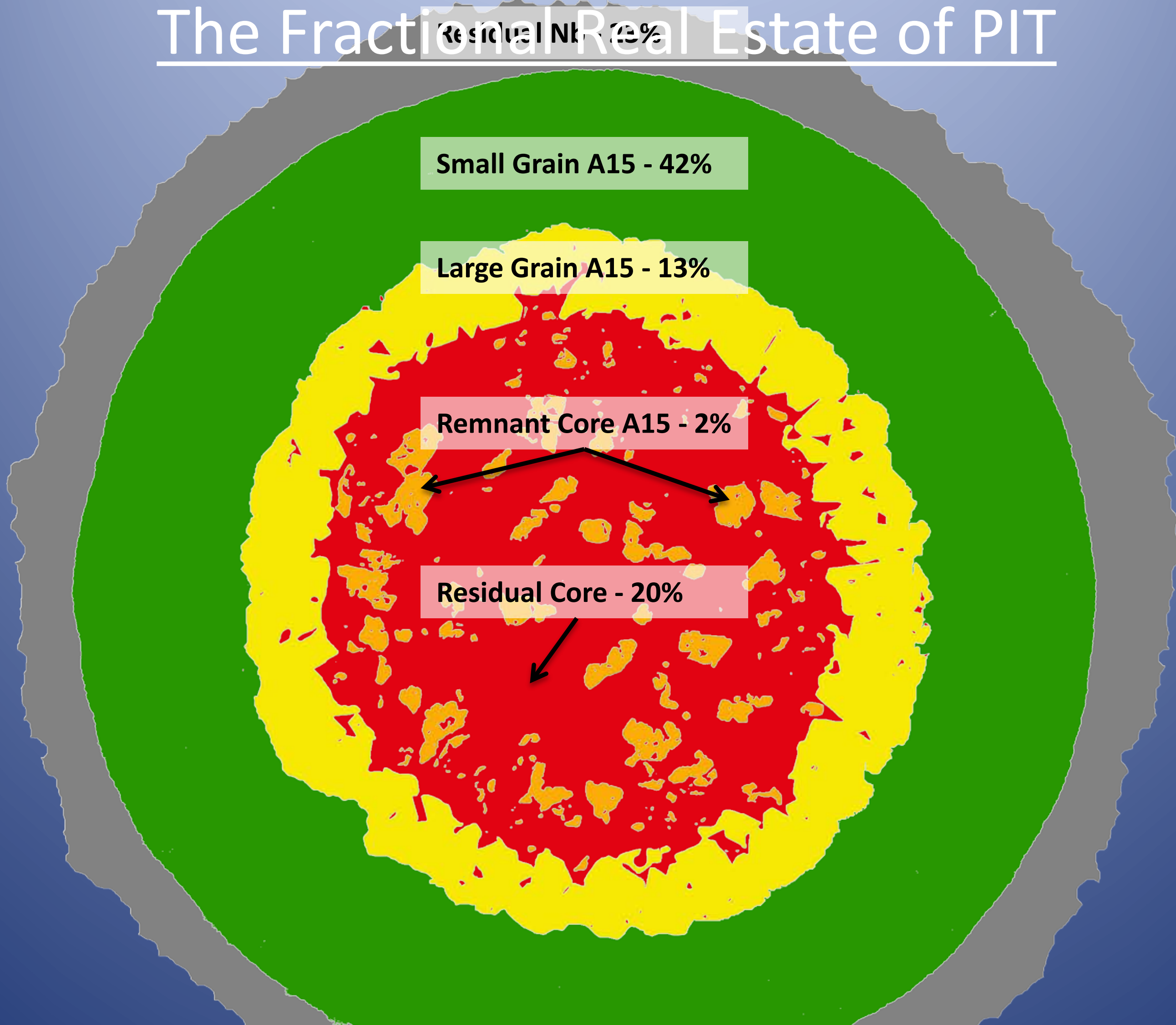
IEEE/CSC & ESAS SUPERCONDUCTIVITY NEWS FORUM (global edition), October 2014 (Preview 1).
ASC 2014 presentation and paper 4MPo2C-03; 1st Prize in Best Student Paper Contest, Materials.

Can Higher Critical Current of Powder In Tube (PIT) Nb_3Sn be further developed without loss of RRR



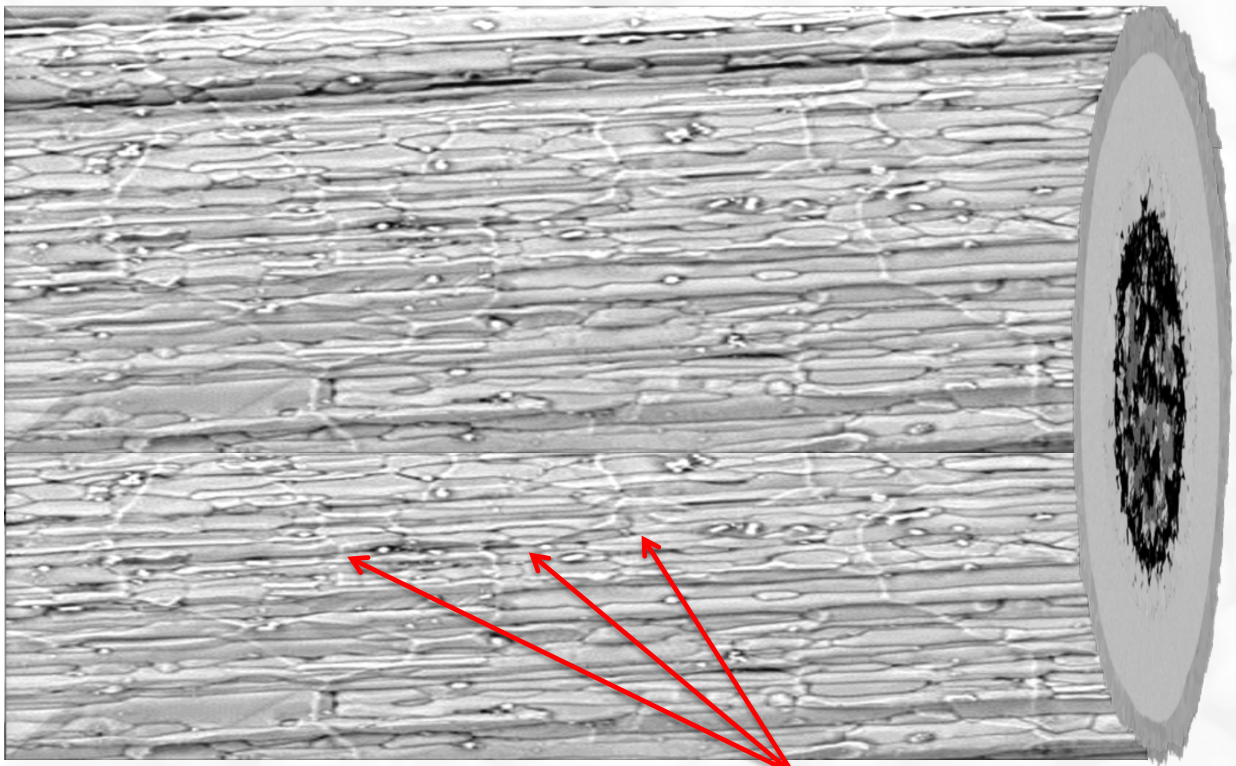
Chris Segal
August 11, 2014

The Fractional Real Estate of PIT



- The diffusion barrier is fragile and the reaction must be carefully managed
- Only small grain A15 carries current

Are the large grains really contributing to current carrying capability?



LG A15 appears very disconnected

And here we can see Cu-rich phases penetrating between LG's

630C200h B29992 Longitudinal Cross Section

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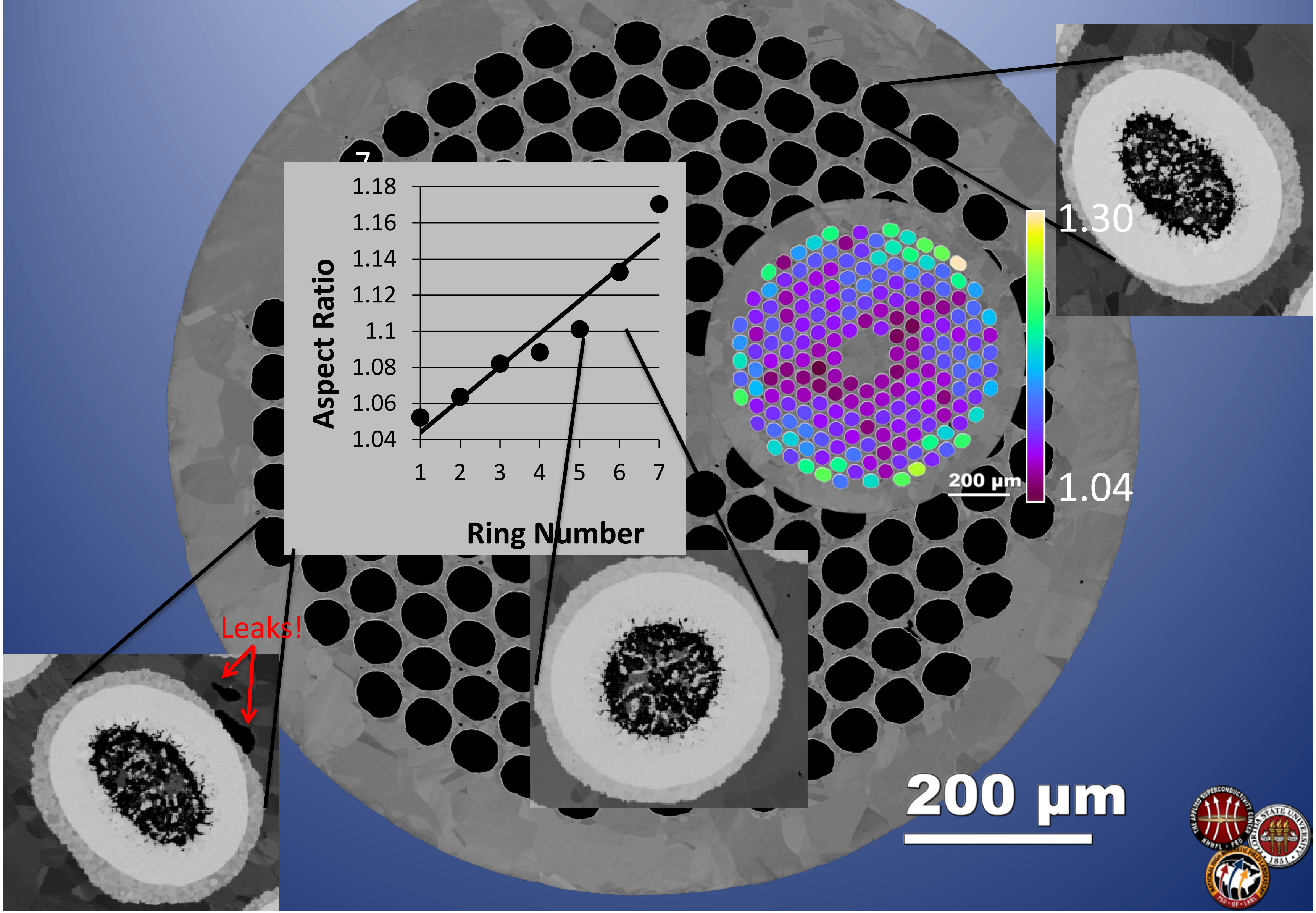
How do we make **more current carrying** superconducting A15 phase?

We must do this while maintaining…

- High Residual Resistance Ratio (RRR)
  - Keep diffusion barriers intact
- High grain boundary (GB) density
  - Produce small grains

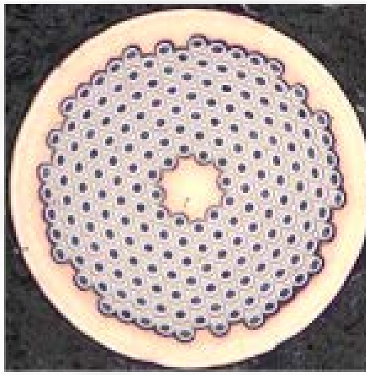
Shape Analysis shows non-uniform deformation



How RRR varies within filament pack

-Serial etching experiment

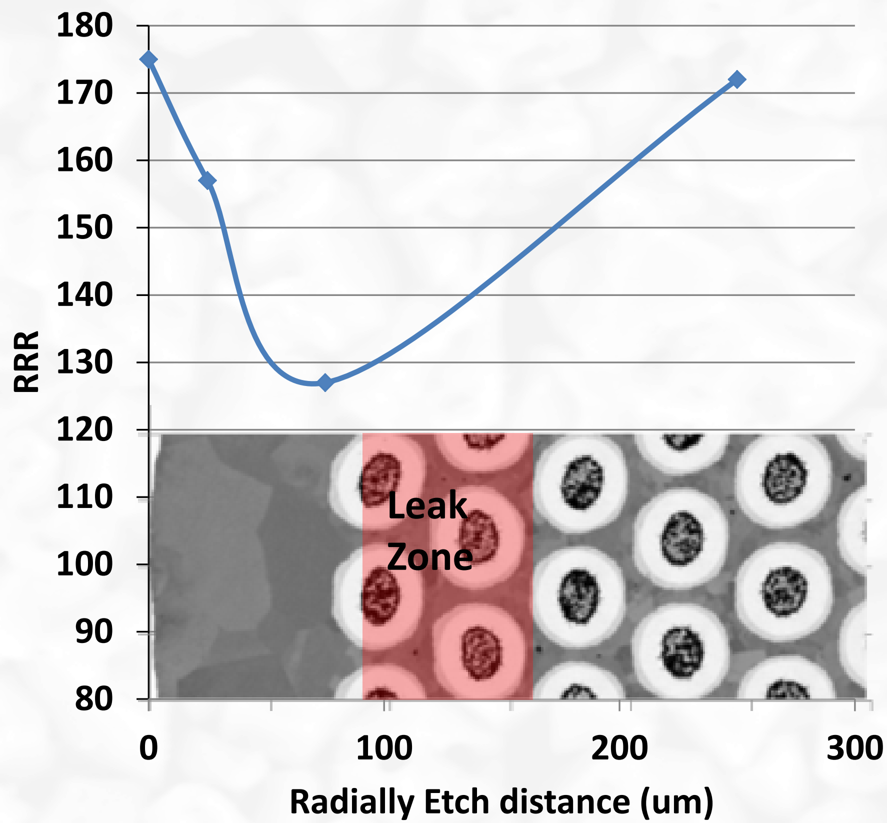
Initial sample **Etch 1** **Etch 2** **Etch 3**



[redacted]

RRR 175

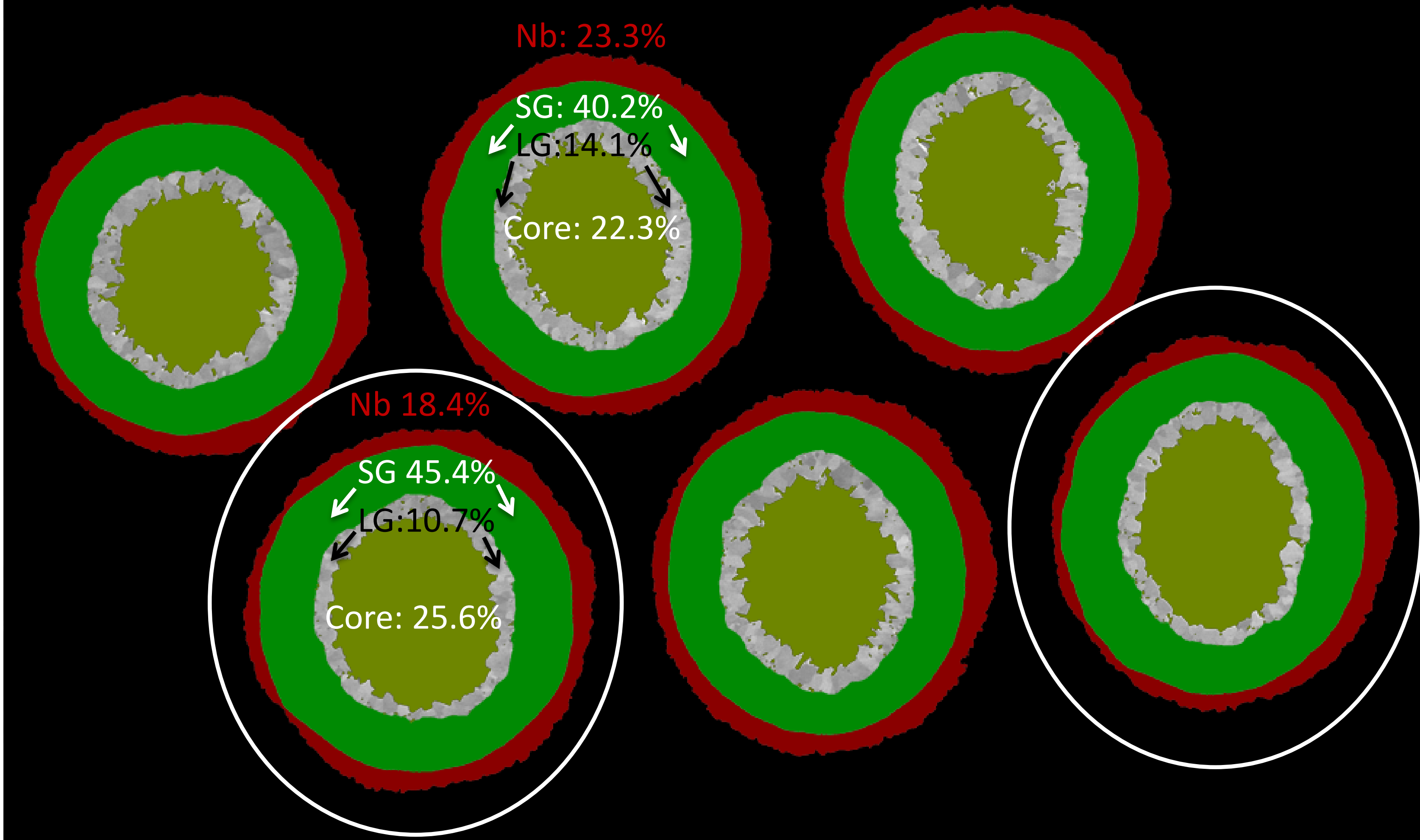
RRR varies depending on local Cu quality



There is clearly a zone more susceptible to leaks which is found in rings 6 & 7

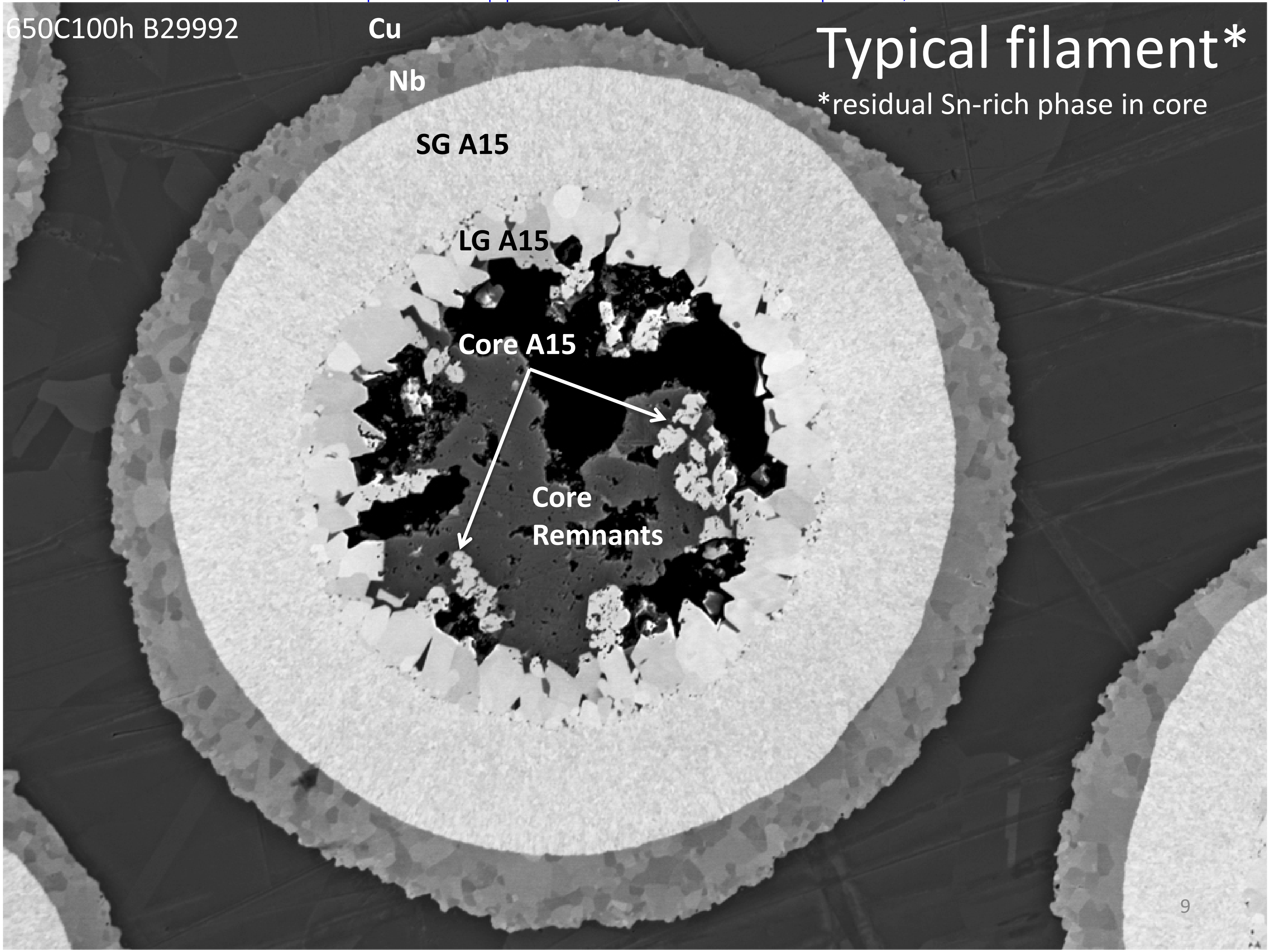
- Longer reaction time will not help! **Where else can we make gains in J_c?**

Two distinct filament types

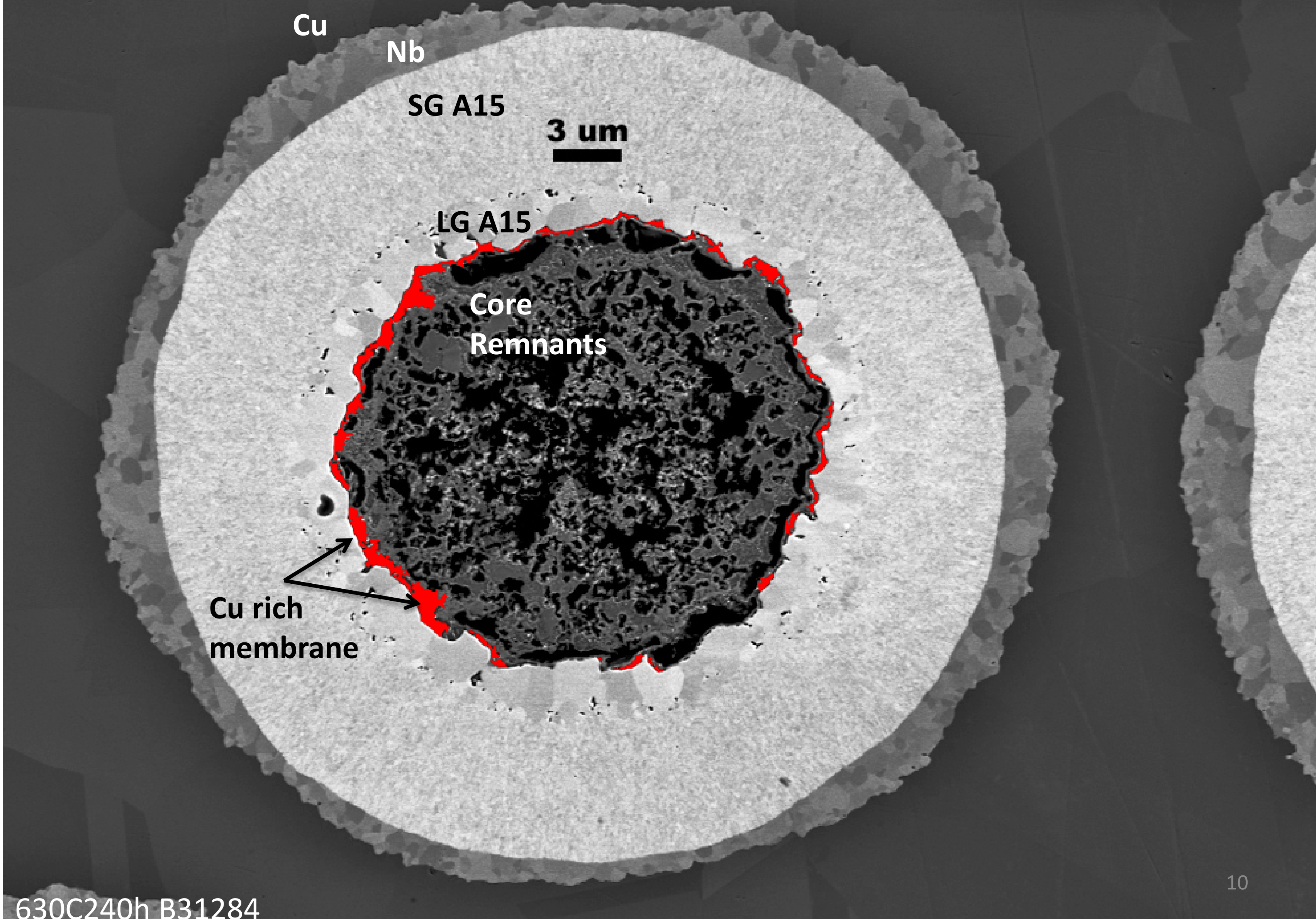


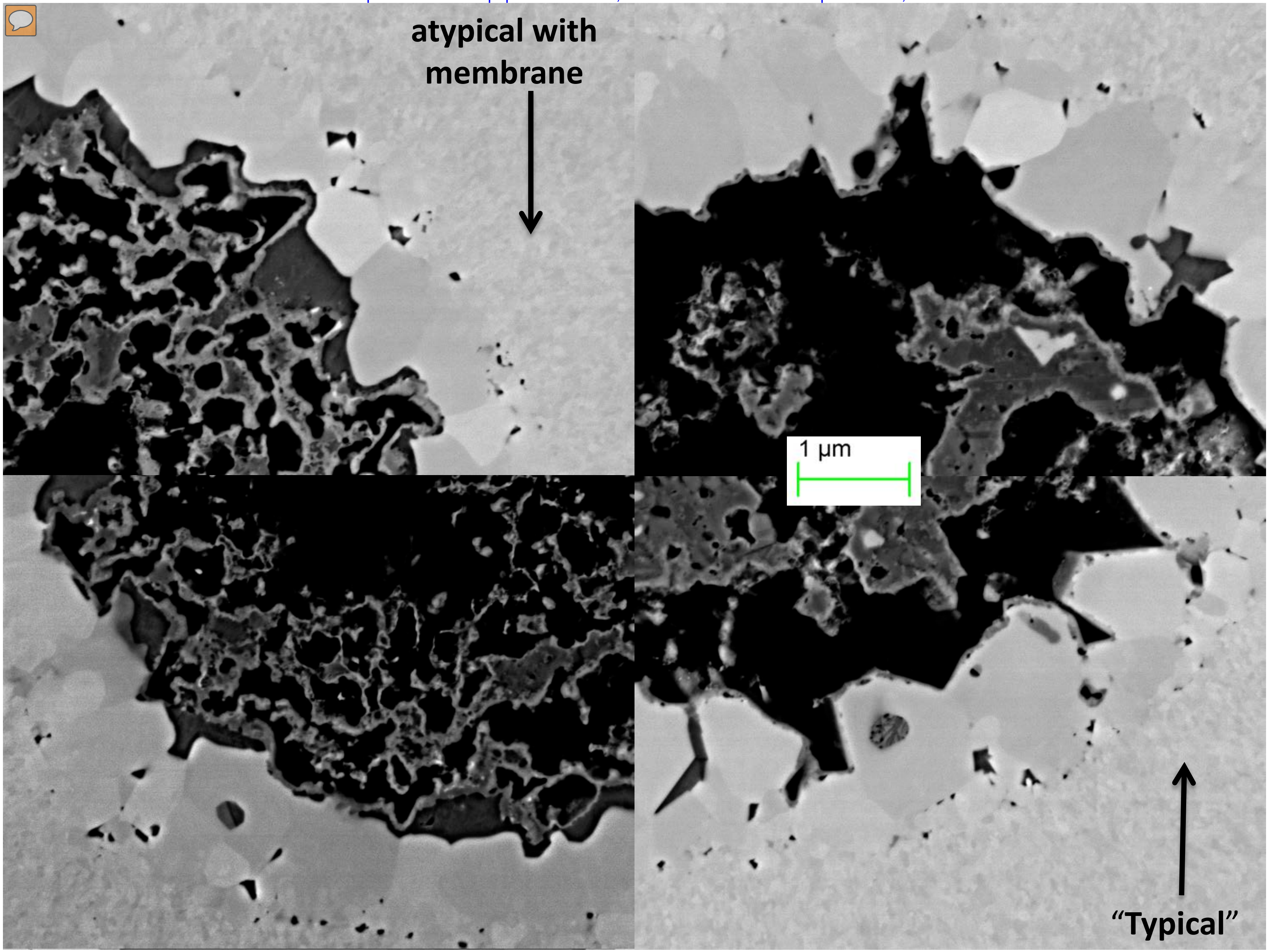
Typical filament*

*residual Sn-rich phase in core

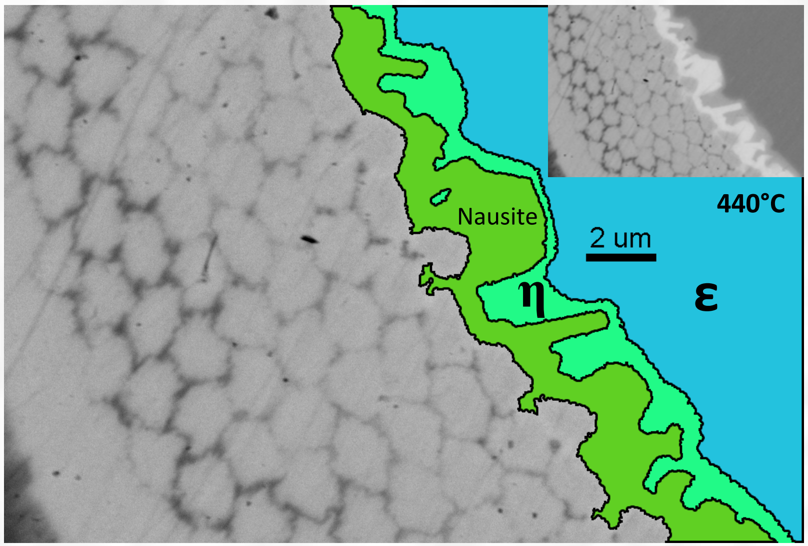


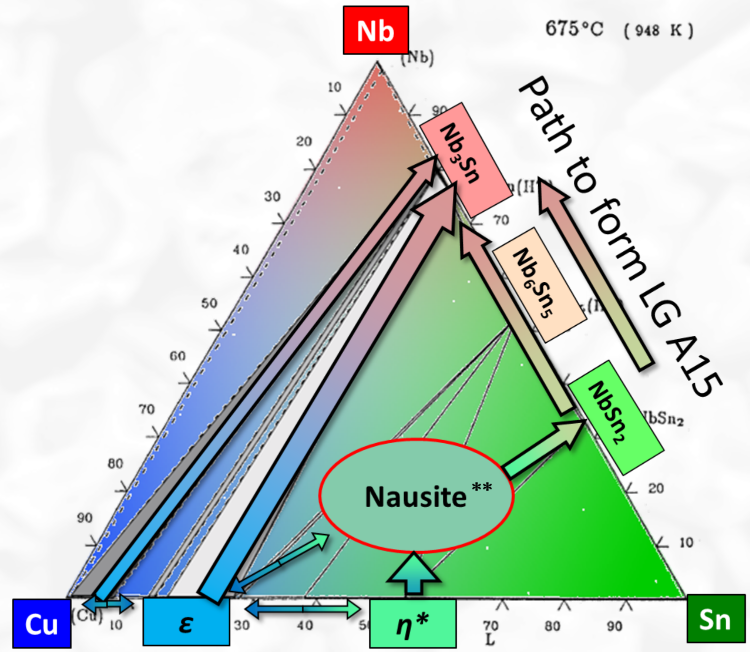
Filament with evidence of a Cu rich regulating membrane




atypical with membrane
1 µm
"Typical"

An intermediate Cu-Nb-Sn phase (Nausite) forms in internal tin strands[1]

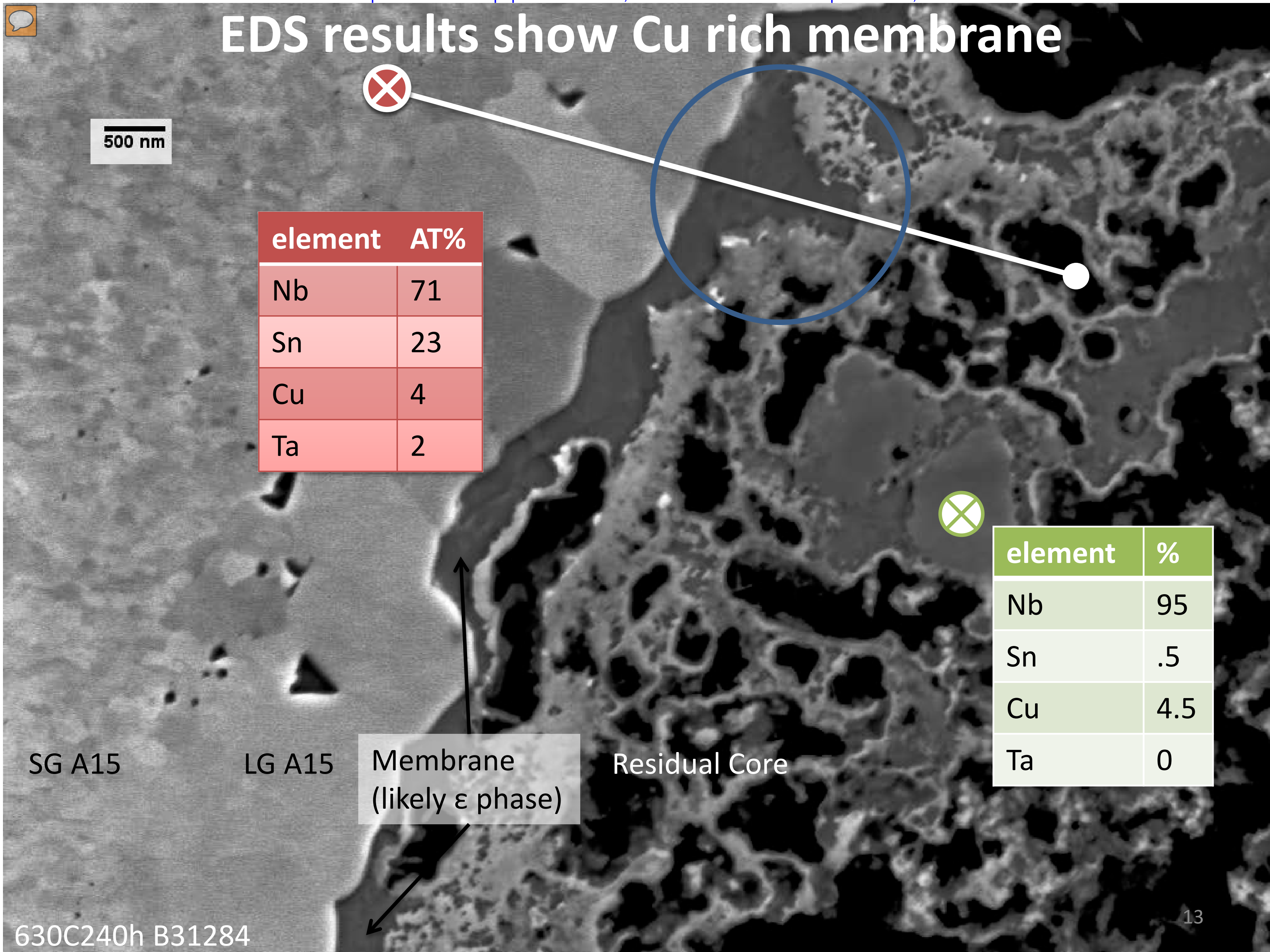




Phase illustration by C. Sanabria

[1] **I. Pong**, L.-R. Oberli, and L. Bottura, “Cu diffusion in Nb_3Sn internal tin superconductors during heat treatment,” Supercond. Sci. Technol., vol. 26, no. 10, p. 105002, Oct. 2013.

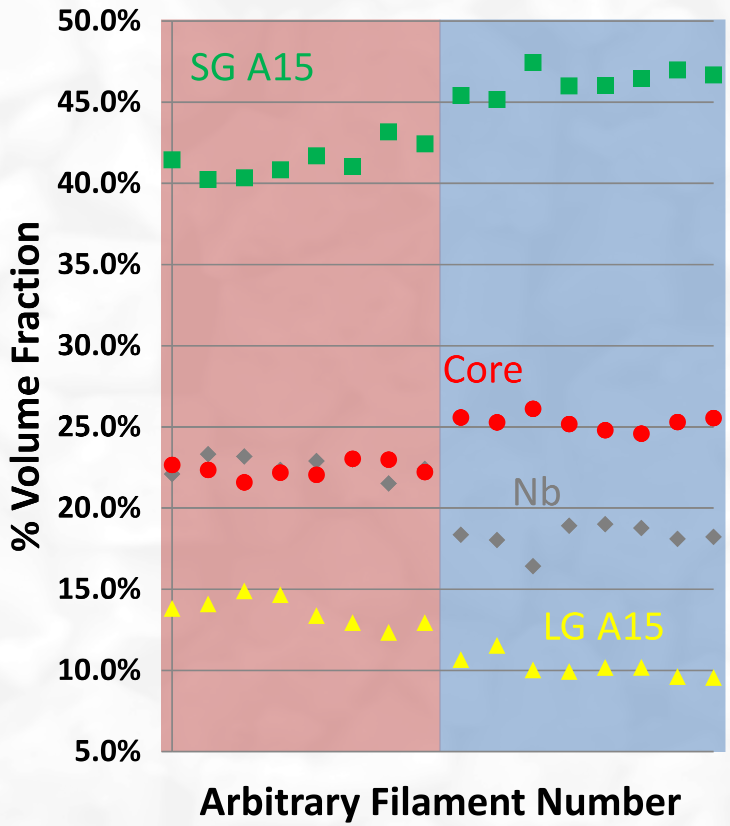
EDS results show Cu rich membrane



element	AT%
Nb	71
Sn	23
Cu	4
Ta	2

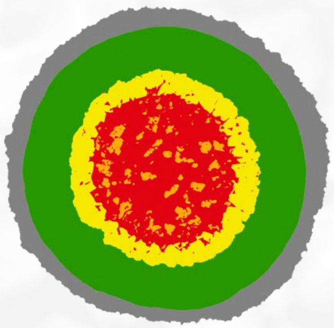
element	%
Nb	95
Sn	.5
Cu	4.5
Ta	0

Comparison of typical and atypical filaments



element	AT%
Nb	22.6
SG A15	41.4
LG A15	13.6
Core	22.4

element	AT%
Nb	18.2
SG A15	46.3
LG A15	10.2
Core	25.3



element	% change
Nb	-20
SG A15	+12
LG A15	-25
Core	+13

12% increase in the good stuff!

Comparison of end phase fractions of PIT and RRP

Condition and Component %	54/61 RRP® (Tarantini SuST 2014)	PIT 192 (CS evaln 2013)	PIT 192 (CS evaln 2014 –atypical filaments
HT	620C, 192h	650°C, 100 h	630°C, 240 h
RRR	**377**	**177**	**177**
A15 total %	58.8	56	56.7
A15 SG %	**58.8**	**40**	**46**
A15 LG %		16	**10.7**
Residual DB %	8.1	24.5	**17.6**
Residual core %	**33.1**	**19.5**	**25.7**
	* = 169 and 217 RRP® stacks need ~10% residual DB		

Increase in SG A15 without loss of RRR!

Findings for discussion

- A Cu rich membrane to mediate the reaction appears VERY useful
  - Why does this membrane form and why does it positively affect A15 growth?
- The issue – better control the reaction path:
  - **Can we avoid large grain A15?**
  - Consume all present Sn in package to produce current carrying SG A15
- The payoff?
  - Typical filaments have a 3:1 SG:LG ratio
  - Untypical filaments have a 4:1 SG:LG ratio!
  - Even more valuable, the total amount of SG A15 is enhanced from an average of 41% to 46%, a 12% increase – surely beneficial for J_c

Acknowledgements

Applied Superconductivty Center (ASC), NHMFL, FSU

David Larbalestier

Peter Lee

Chiara Tarantini

European Organization for Nuclear Research (CERN)

Amalia Ballarino

Luca Bottura

Christian Scheuerlein

Luc-Rene Oberli

Bernardo Bordini

David Richter

Bruker EAS GmbH

Bernd Sailer

Vital Abaecherli

Manfred Thoener

Klaus Schlenga