Automation of Nb cavity production for rapid and wider application of SRF technology

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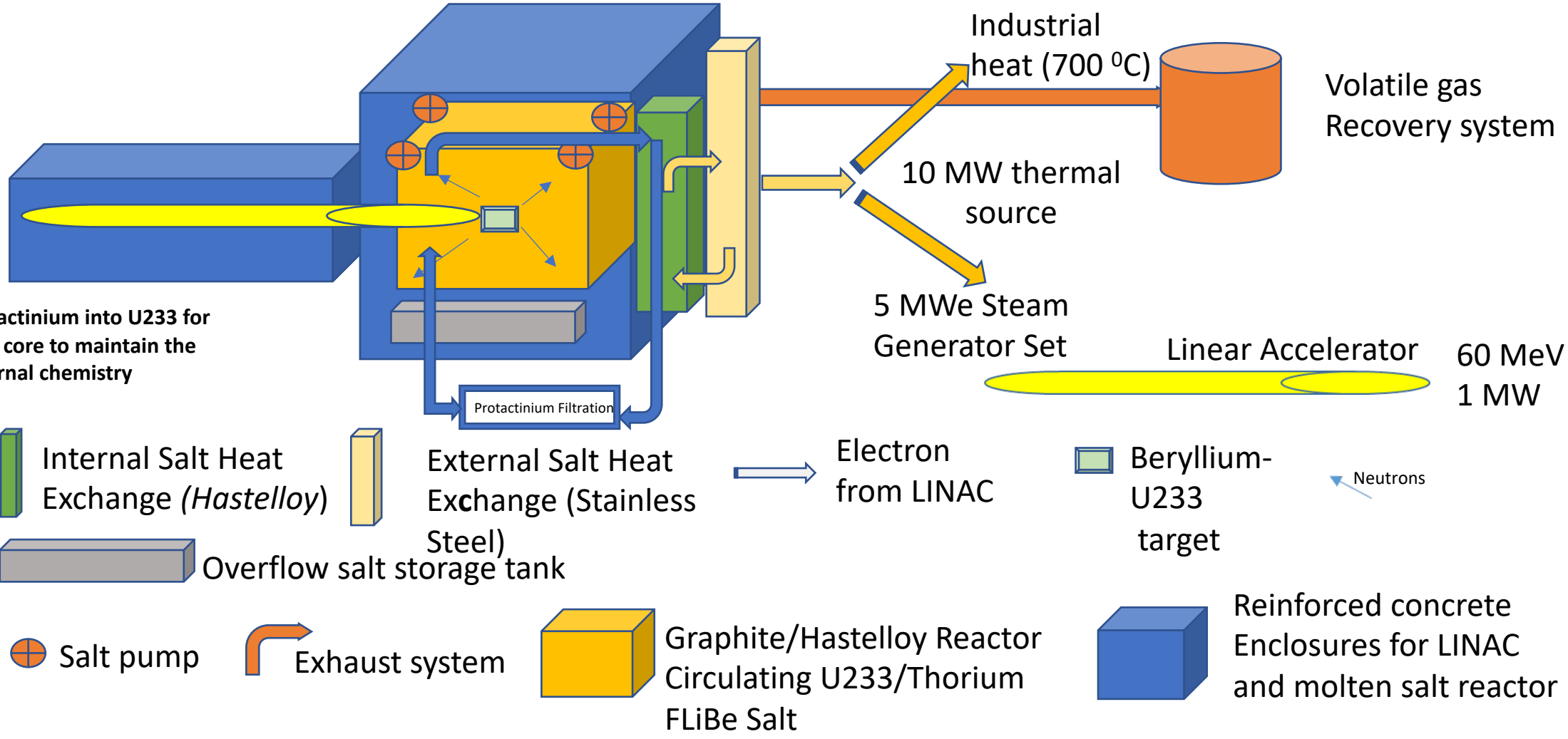
Overview

- CW Electron Accelerator based green energy ASMR with Thorium
- SRF Niobium-Hydrogen Issue Path Forward

Advanced Subcritical Micro Reactor (ASMR) – 10 MWt/5 MWe
Low Cost, Incremental Power Route to a Zero Carbon Future



Thorium based breeder-burner in equilibrium

Myneni Ganapati, TTC2023 FNAL

ASMR's Unique Aspects

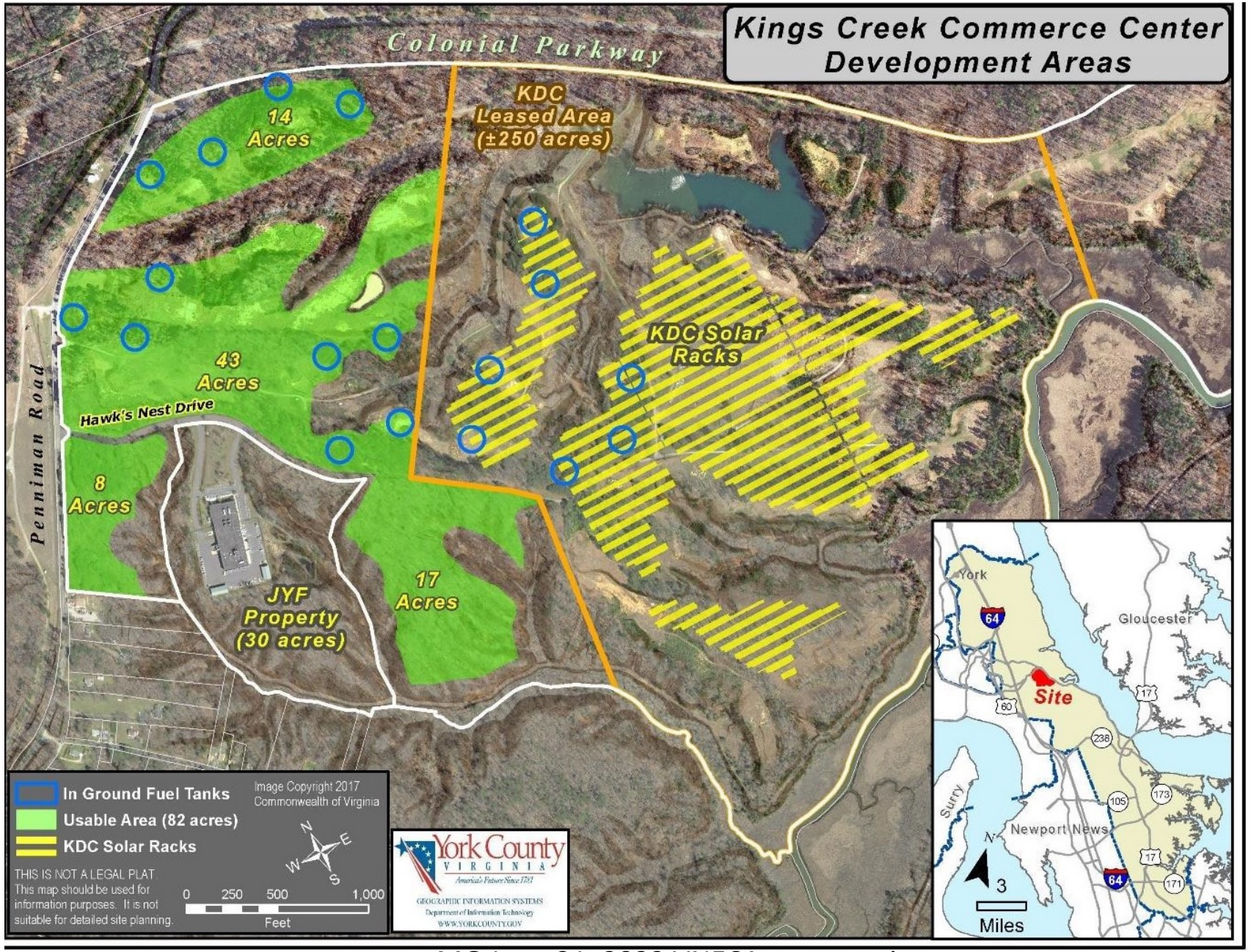
- Divorce from minor actinides by disassociating with ^{235}U & ^{238}U
- Reduce/remove concerns regarding nuclear proliferation & low waste
- Serve as backup generators to renewables
- Usher in much needed Hydrogen Economy
- Serve as high temperature heat sources for industrial processes
- Highly economical, ultra clean, super safe and distributed source

Declining Coal - Enthroning Nuclear - Fizzling out Gas -
Enabling Renewables – Pathway to Zero Carbon

We propose to build an Advanced Subcritical MSR ^{233}U & ^{232}Th breeder-burner in equilibrium Micro-Reactor (ASMR) R&D Center under a PPP in Yorktown,

These micro-reactor's linacs have dual use for the production of $^{225}Actinium$ for medical applications

VA ASMR site identified



Historical remarks on SRF Technology*

- Stanford and UCCI
  - X-band cavities reached very high gradients and quality factors (clean vacuum procedures due to small structures)
  - L-band ingot niobium cavities poorly performed due to contamination & vacuum leaks

- CEBAF at JLab
  - Even for low gradient (5 MV/m) and quality factor (2e9) specs - Vacuum leaks set back at the beginning
  - 6 GeV energy reach, 50% higher than design via helium processing (mostly Hydrogen removal)
  - 12 GeV upgrade vows (filed emission etc. due to Ion Pumps (I strongly recommended not to install them)

    Would have reached 12 GeV at the beginning itself (1995) if 1990 proposed clean processes were implemented

- XFEL success may be attributed to good QA procedures

* *SRF TECHNOLOGY—PAST, PRESENT AND FUTURE OPTIONS**

G. Myneni#, A. Hutton, Jefferson Lab, Newport News, VA 23606, U.S.A Proceedings of EPAC08, Genoa, Italy MOPP130
CERN Courier View Point, "SRF technology comes full circle" 20 October 2008. Ganapati Myneni

Extrinsic and intrinsic contamination of Nb determines the performance of the cavities

Extrinsic

- Surface contamination
  - Molecular and particulates from vacuum systems

Mostly understood
But requires vigilance

Intrinsic

- Niobium is a prolific hydrogen absorber in the absence of the natural surface oxide
  - Hydride formation
  - Dislocations

H_2 Absorbed in the EBW heat affected region where grain structure changes leading to MP &/ Magento-Thermal premature quenches

• SRF Niobium-Hydrogen Issue Path Forward

- Automated clean cavity production processes that preclude H_2 absorption/adsorption
  - Nanoscale machining (NM) of MG Nb discs, final NM of the half cells and laser welding

- Specific heat measurements on samples @ 2 K as a function of magnetic field will help optimize cavity process procedures

BSCE is planning to implement these with MG Nb Technology, during the next five years, for developing the required CW SRF linacs for the mass production of badly needed ASMRs in collaboration with world's Institutions and Industry

Looking forward to your collaboration

Thank you

Nb Technologies for SRF

Fine Grain (FG) Rolled Nb sheets	Medium Grain (MG) Forged Ingot Nb discs	Large Grain (LG) Ingot Nb discs
Up to fourteen manufacturing steps Labor intensive	E-beam melted ingot of larger dia. forged to required dia and then sliced	E-beam melted ingot of required dia. is sliced
Grain Size ASTM 5 ~ 50 µm	ASTM 0 – 3, < 1 mm	Large non uniform grains >>1 cm
Widely used complex technology prone to contamination	New kid on the block and very clean surfaces	Proven clean surface technology
Uniform & adequate mechanical properties	Better uniform mechanical properties	Non uniform mechanical properties
Requires stringent QA & expensive	Better Cost advantage	Cost advantage

Summary

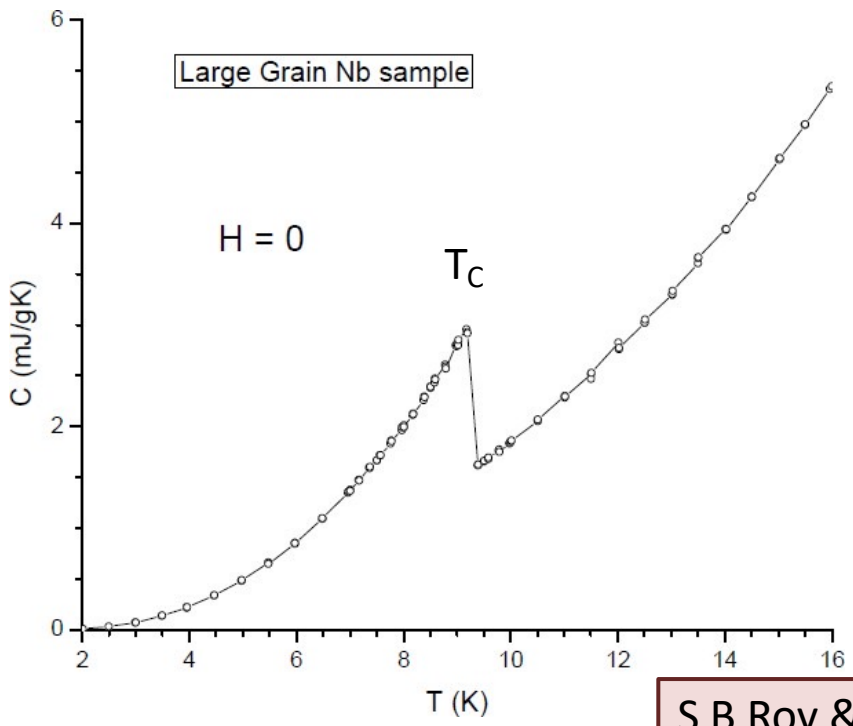
- BSCE is requesting world community's support for developing economic and efficient SRF linacs for use in the industrial applications

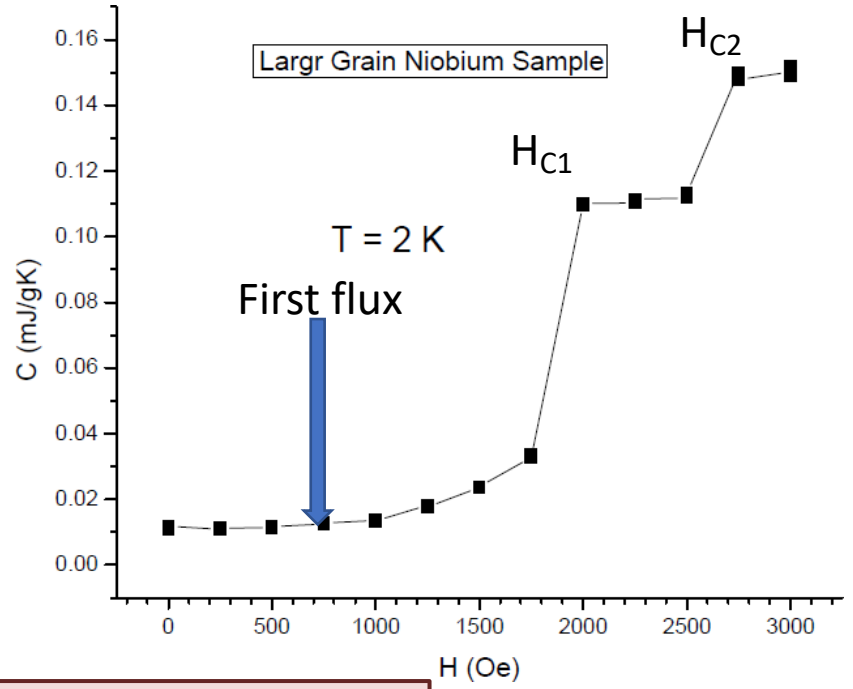
- We will be presenting an invited talk on ASMR's at the INSIC-2023, Mumbai, December 12-15, 2023

- ISOHIM, in collaboration with Indian Nuclear Society, is organizing the First International Green Hydrogen And SMR Technologies-2024 in India March 7-9, 2024 where we will have a session on SRF Technologies

https://www.jlab.org/video/accelerator-seminar-dr-ganapati-myneni-st-lessons-learned-good-bad-and-ugly

Temperature and magnetic field dependence of heat capacity of superconducting large grain Niobium

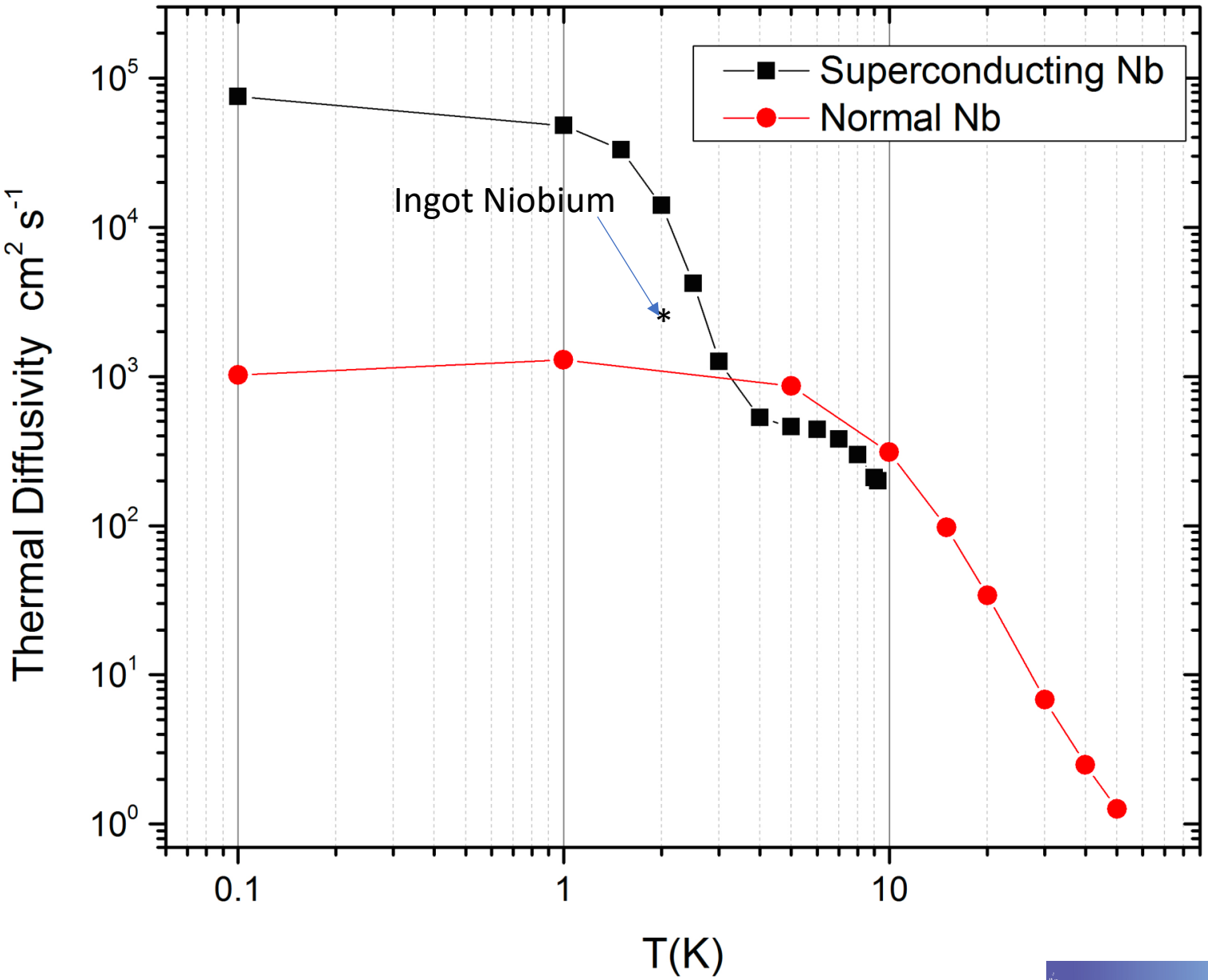




S B Roy & G. Myneni (unpublished)

During cavity operation heat is deposited in the sc layer of ~60 nm τ (1.5 GHz) ~ 6.6×10^{-10} s

Thermal diffusivity$_{2K}$ α_{2K} ~ k/ρC = 2333 cm^2 s^{-1}


Superconducting Nb
Normal Nb
Ingot Niobium
Thermal Diffusivity cm^2 s^{-1}
10^5
10^4
10^3
10^2
10^1
10^0
0.1
1
10
T(K)