

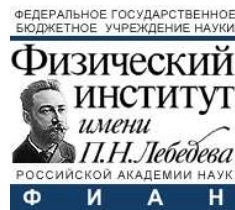
# Present directions for 2G HTS wire development at SuperOx



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C. Senatore



S. Awaji

- The SuperOx group
- Applications driving wire development
- Wire for LN2, self-field
- Wire for in-field applications

SuperOx (Moscow, Russia) 

- HTS Applications development and commercialisation
  - FCL
  - AC/DC cables
  - Coils

 S Innovations



S-Innovations (Moscow, Russia) and SuperOx Japan (Tokyo, Japan)

- 2G HTS wire production and development
  - Supply wire to SuperOx projects
  - Supply wire to outside customers

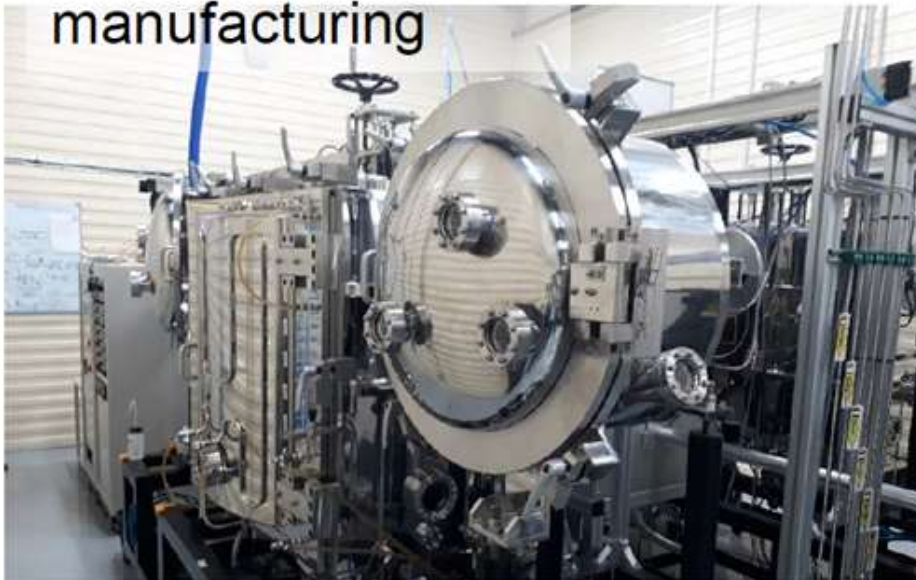
# HTS applications: 220kV / 450 MW FCL for Moscow city grid

- First FCL in Russian Power Grid
- 220 kV-class
- In operation 2019
- SuperOx manages entire project

## 2. Engineering and production



## 1. Superconductor manufacturing



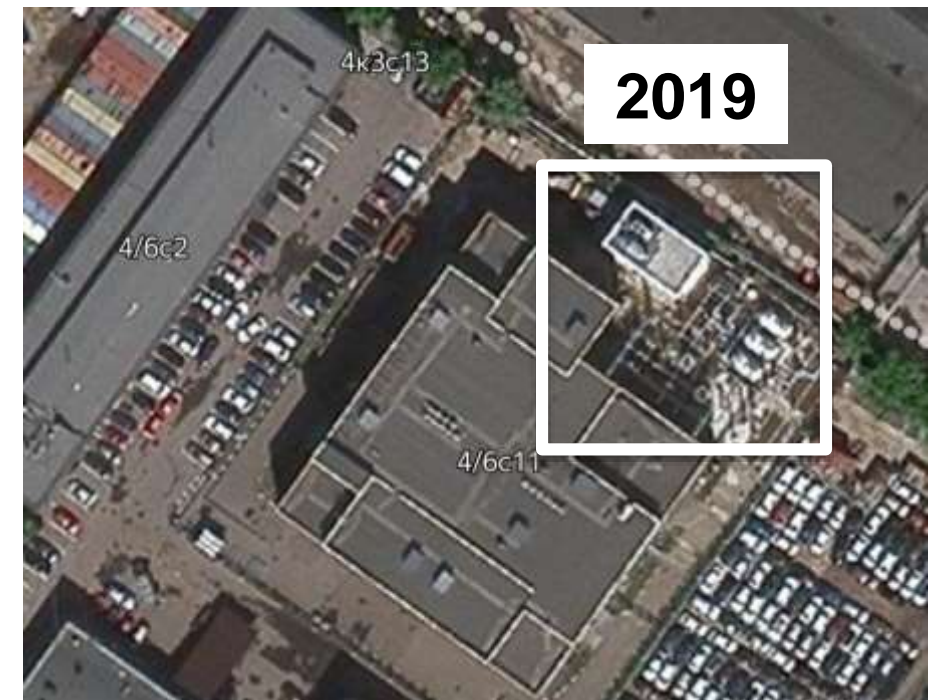
## 3. Onsite construction



# 220kV / 450 MW FCL: pilot operation in grid since June 2019



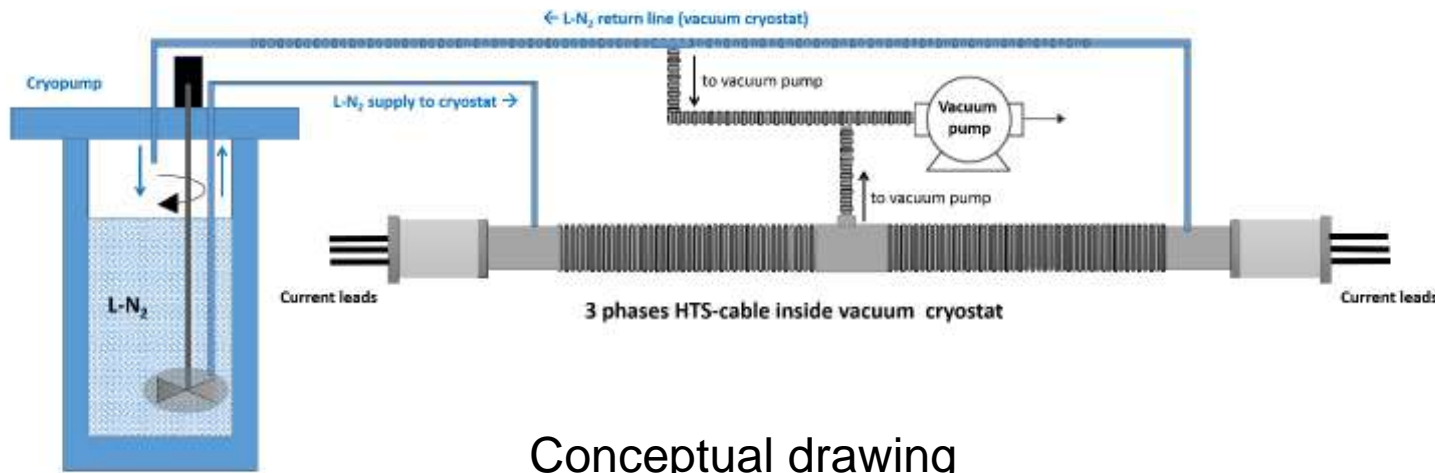
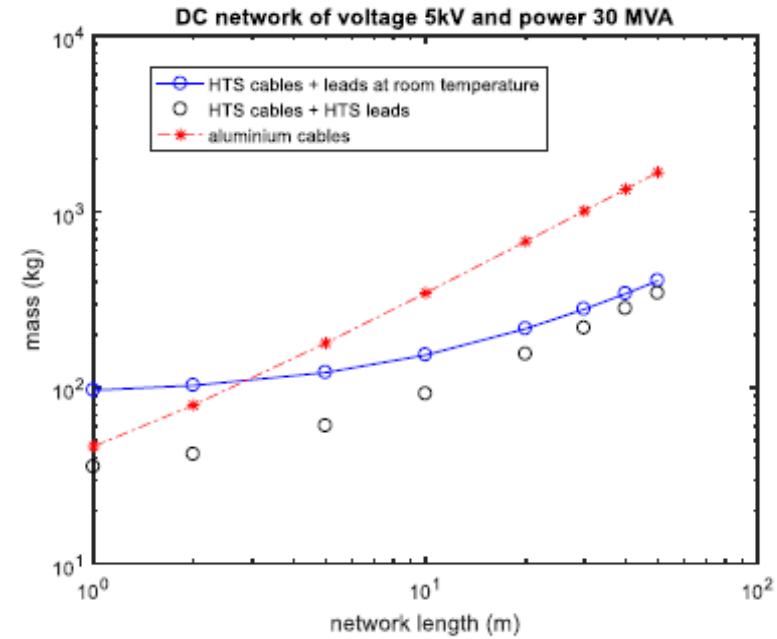
2018



2019

# HTS applications: 12 MW HTS AC cable system for Airbus

Voltage 0...6000 V  
 Current 0...2000 A (peak)  
 Frequency 0...400 Hz  
 Short circuit test 12 kA



Conceptual drawing



Assembled cable system.  
 Successful acceptance tests in May 2018.

# HTS applications: HTS motor for aircraft. Horizon 2020 consortium.

**SuperOx**



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Ministry of Science and Higher Education of Russia

## Advanced Superconducting Motor Experimental Demonstrator



Source: Airbus Group Innovations

2-LO-EA-02S  
T. Reis (Oswald)

**OSWALD**

 UNIVERSITY OF  
CAMBRIDGE

 AIR LIQUIDE  
**SuperOx**

 **KIT**  
Karlsruhe Institute of Technology



hochschule aschaffenburg  
university of applied sciences



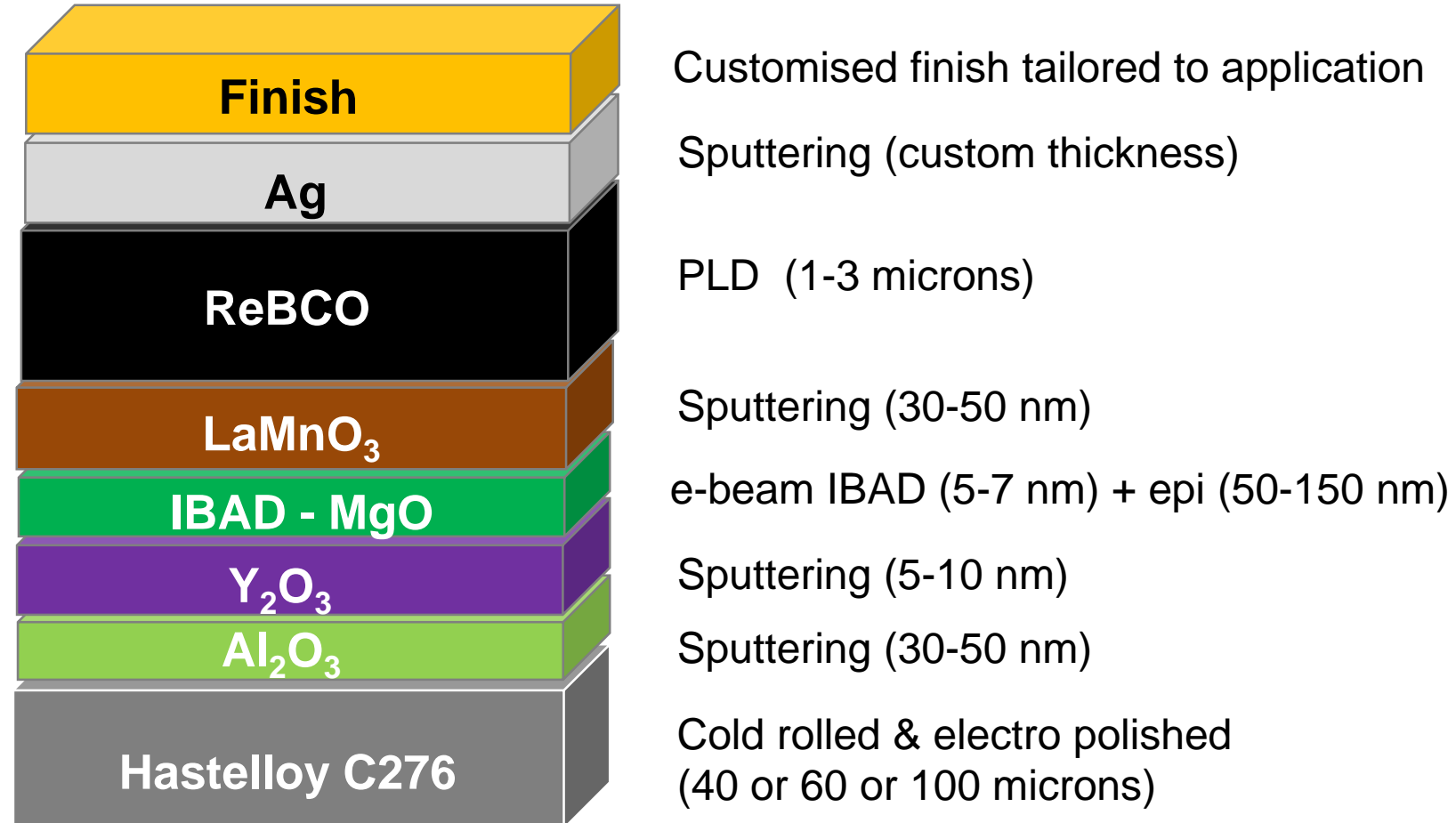
 **Rolls-Royce**

 **DEMACO**



- General
  - Cost (throughput and yield)
    - ✓ Achieved by running at capacity, adding capacity to reflect demand, and by improving and automating process control
  - Strength
    - ✓ Achieved by implementing laser slitting instead of mechanical slitting
- Application specific
  - Wire for LN2: high  $I_c$  at 77 K, s.f., good  $I_c$  uniformity
    - ✓ Achieved by continuous improvements with experience
  - Wire for in-field applications: high  $I_c$  in field, high  $J_e$ 
    - ✓ Achieved by thinner substrate, thicker HTS, and by modified HTS layer

# SuperOx 2G HTS wire architecture



## Throughput: Buffer layer deposition line

SuperOx

S Innovations



300+ km buffer tape

e-Polished Hastelloy substrate in  
Ready buffered tape with  $\text{LaMnO}_3$  on top out

Extra capacity: Textured template offered for sale

## Throughput: Moscow PLD-HTS line

SuperOx

S Innovations



Operate at **full capacity**

3-5x capacity increase scenarios in place, awaiting order commitments

# Throughput: 2019 capacity increase at SuperOx Japan

SuperOx

SUPEROX JAPAN

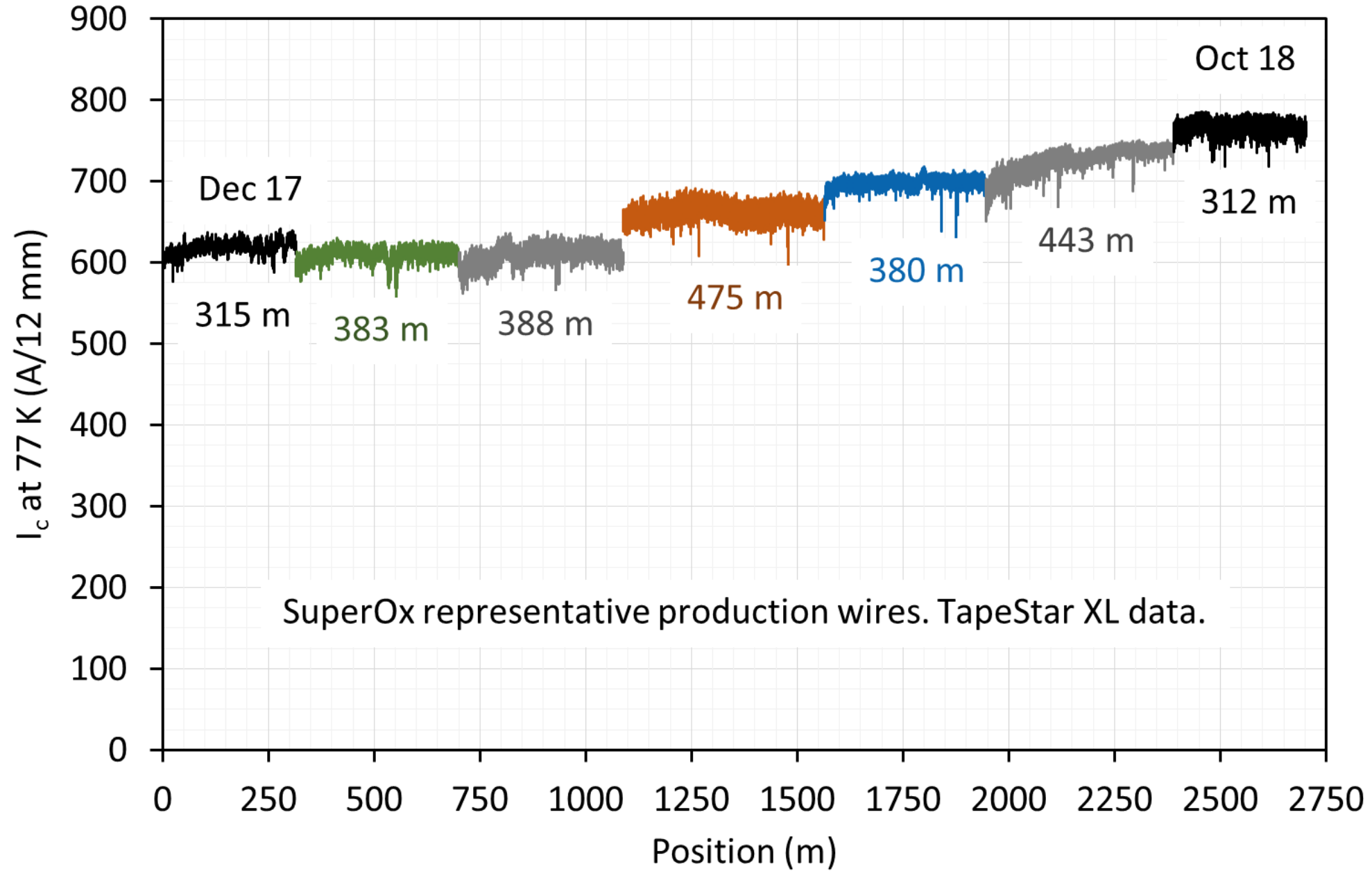


- New, more powerful laser successfully commissioned at SuperOx Japan in July
- + 100% PLD throughput

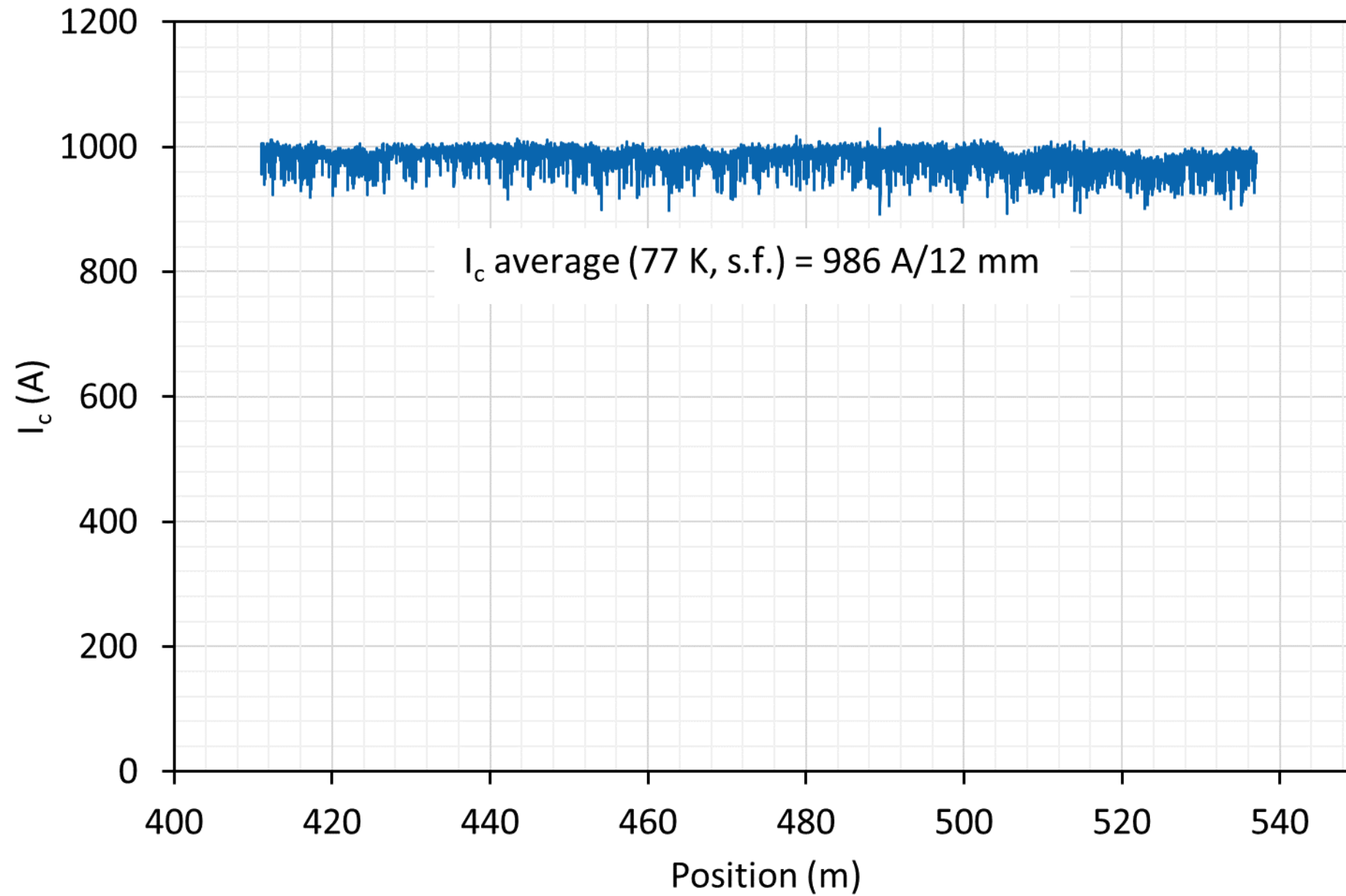
Wire made at S-Innovations in Moscow and SuperOx Japan is of identical high quality

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# Wire for LN2: steady performance increase over time



# Wire for LN2: high $I_c$ at 77 K, s.f.





Parameter	Value		
Substrate thickness	40 or 60 or 100 $\mu\text{m}$		
Tensile strength (95% $I_c$ retention)	> 500 MPa / 0.4% deformation		
Critical bend diameter	15 mm		
Wire width	4 mm	6 mm	12 mm
Average critical current @ 77 K, s.f.	100-200 A	150-300 A	300-700 A
Critical current uniformity	$I_c$ standard deviation $\leq$ 3%		

## Customisation:

- + Variable silver thickness
- + Variable copper thickness
- + Insulation: 10-20  $\mu\text{m}$  thin polyimide varnish
- + Solder plating
- + Lamination
- + Low resistance splices
- + ... just ask

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# New: SuperOx Wire for in-field use

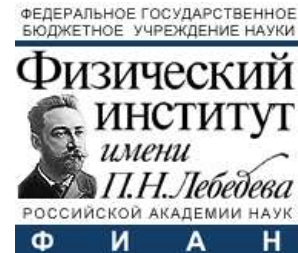
SuperOx



UNIVERSITÉ DE GENÈVE  
FACULTÉ DES SCIENCES



TOHOKU UNIVERSITY



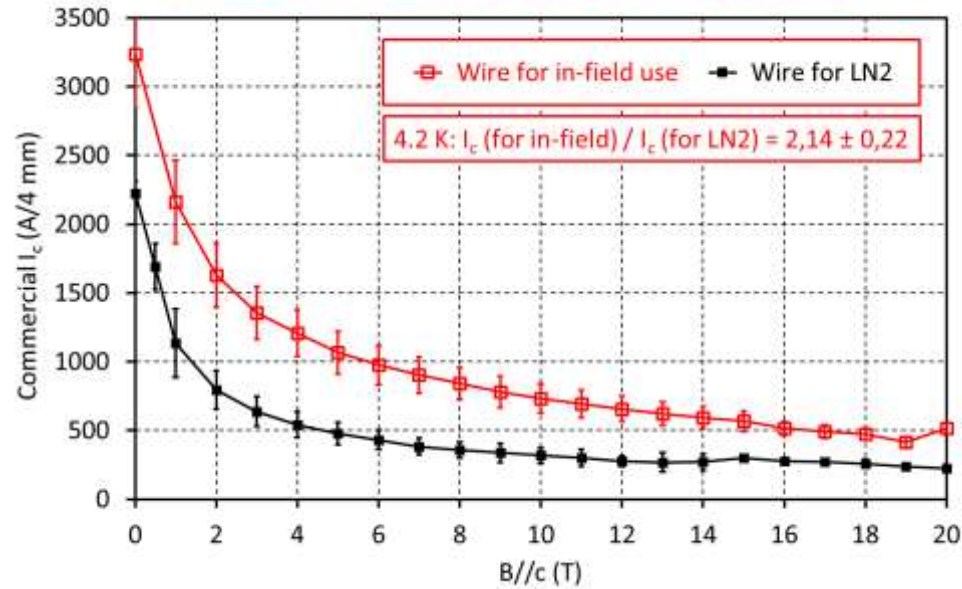
2-MO-CP-06S

A. Markelov

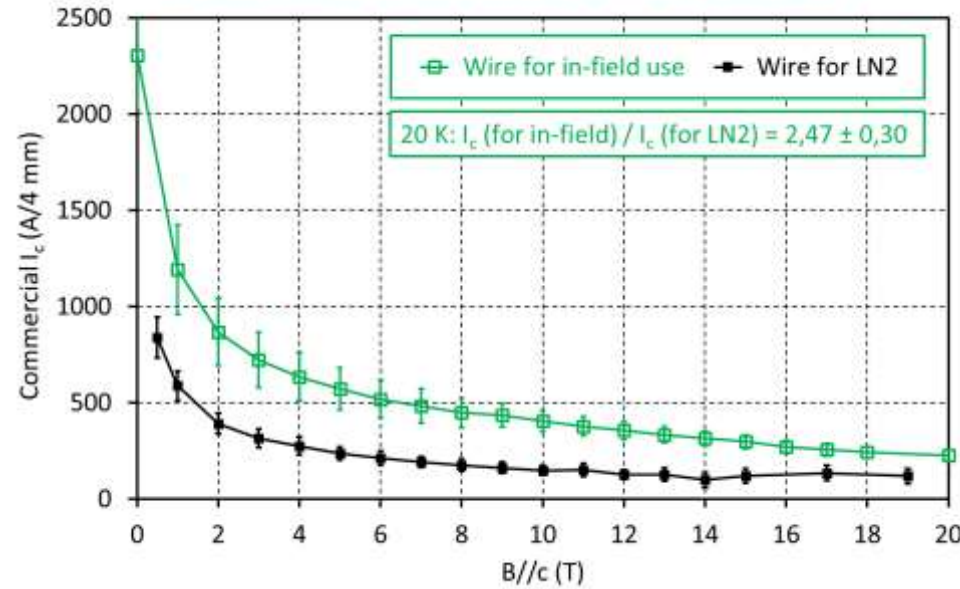
1-MP-FP2-S15

V. Petrykin

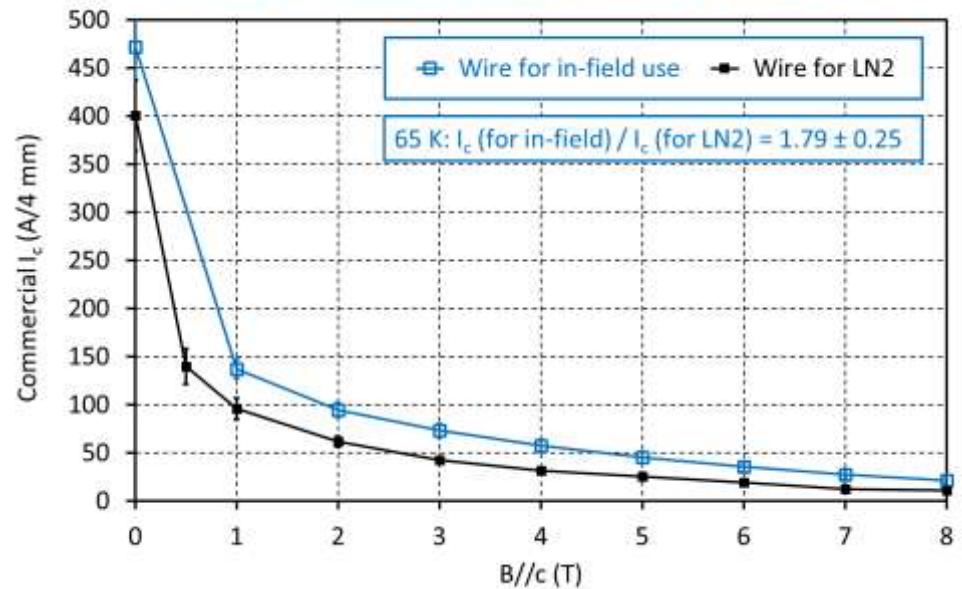
SuperOx wire performance at 4.2 K: for in-field use vs. for LN2



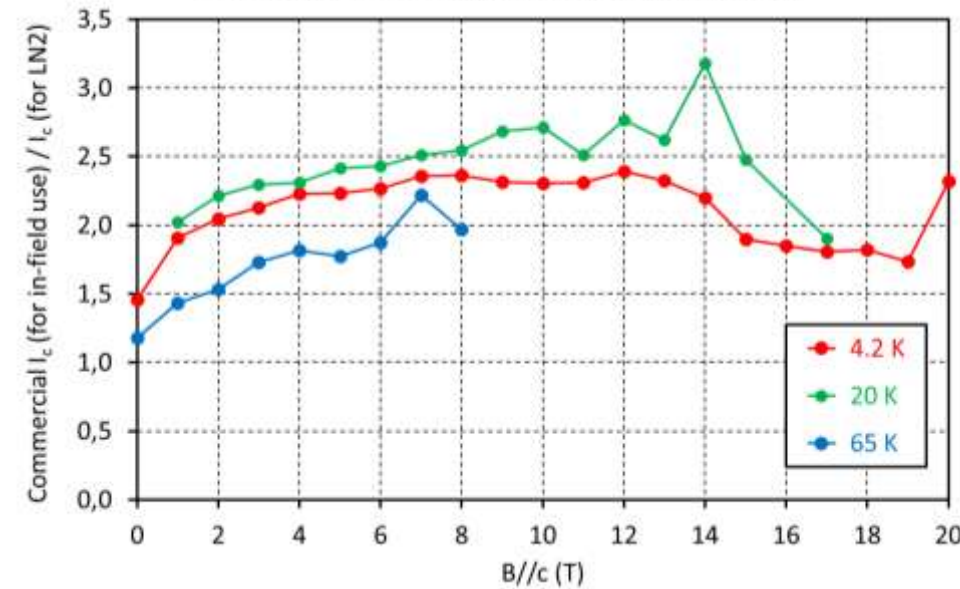
SuperOx wire performance at 20 K: for in-field use vs. for LN2



SuperOx wire performance at 65 K: for in-field use vs. for LN2



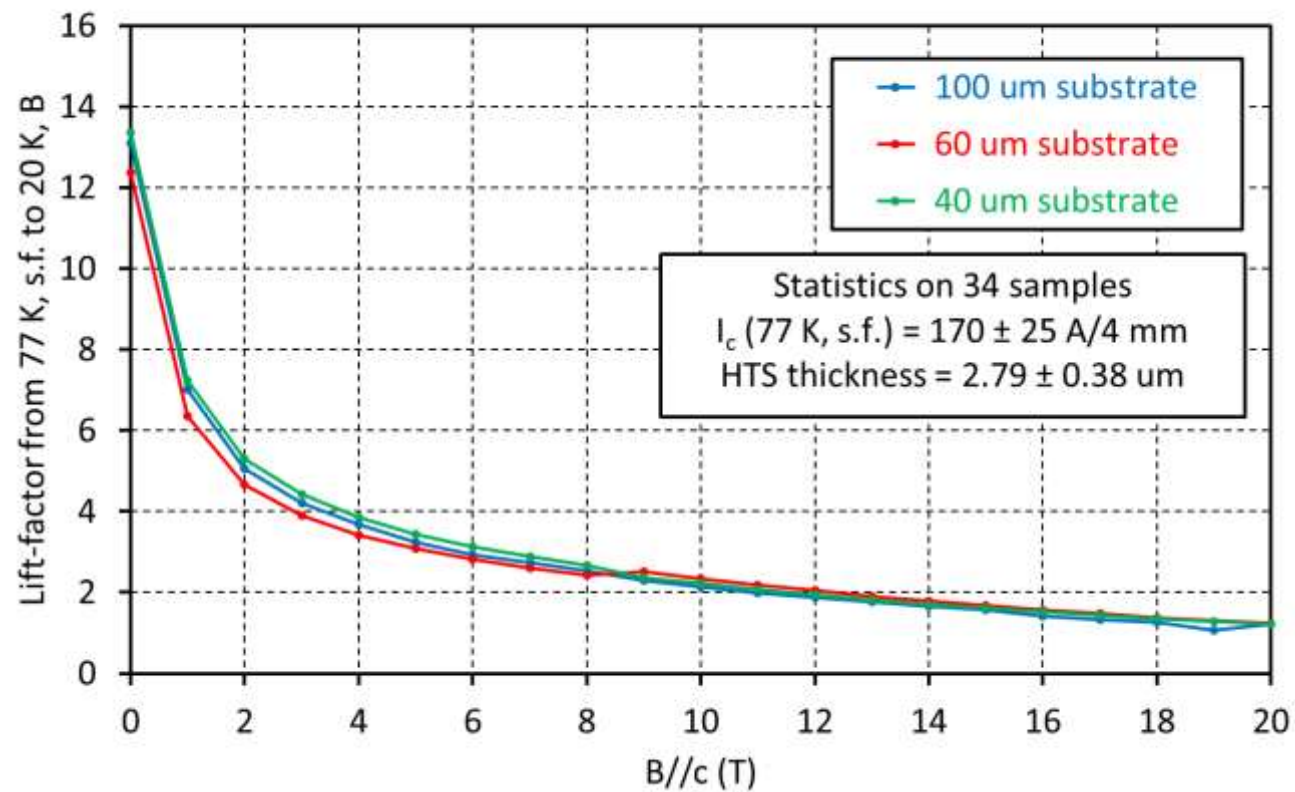
SuperOx wire performance: for in-field use vs. for LN2



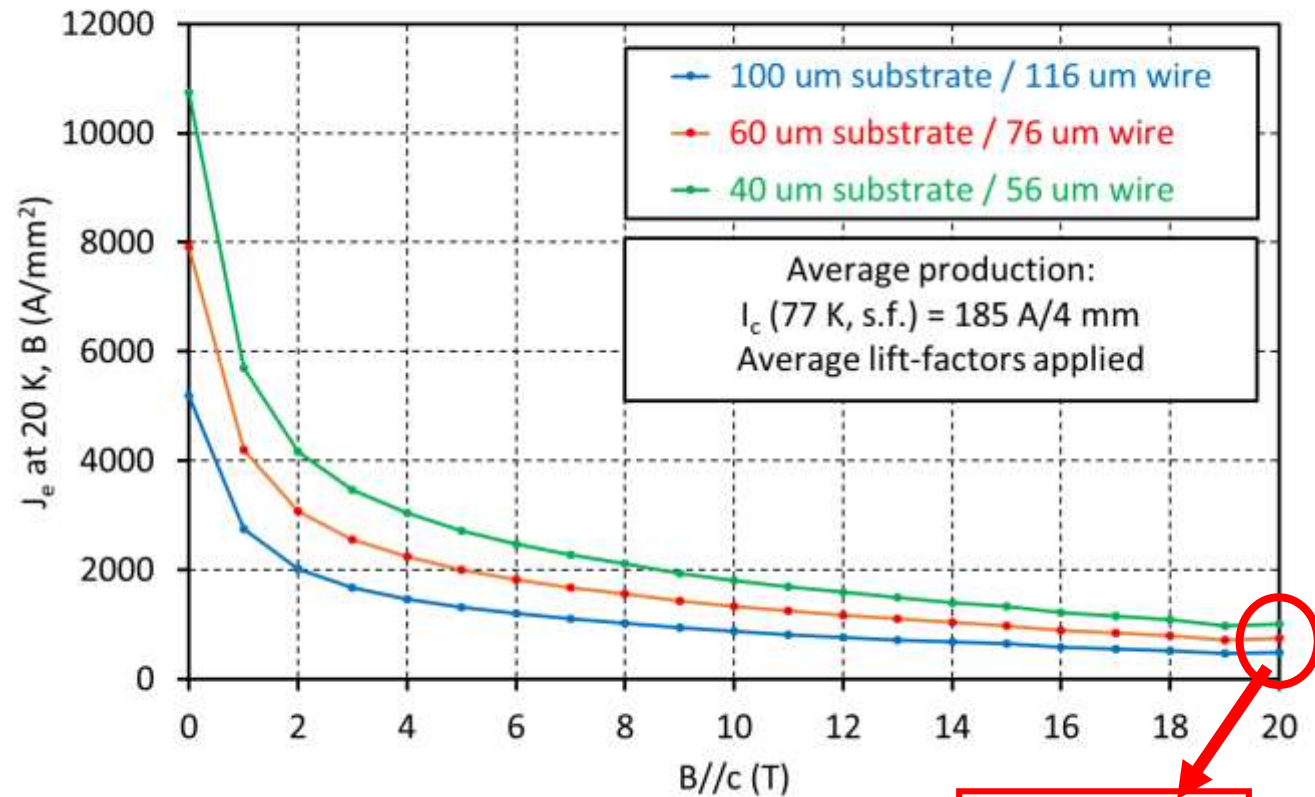
80-150% improvement at 4.2-65 K. Manuscript in preparation.

# Wire for in-field use: increase $J_e$ by thin substrate, thick HTS

Wire for in-field use: the same properties on different substrates

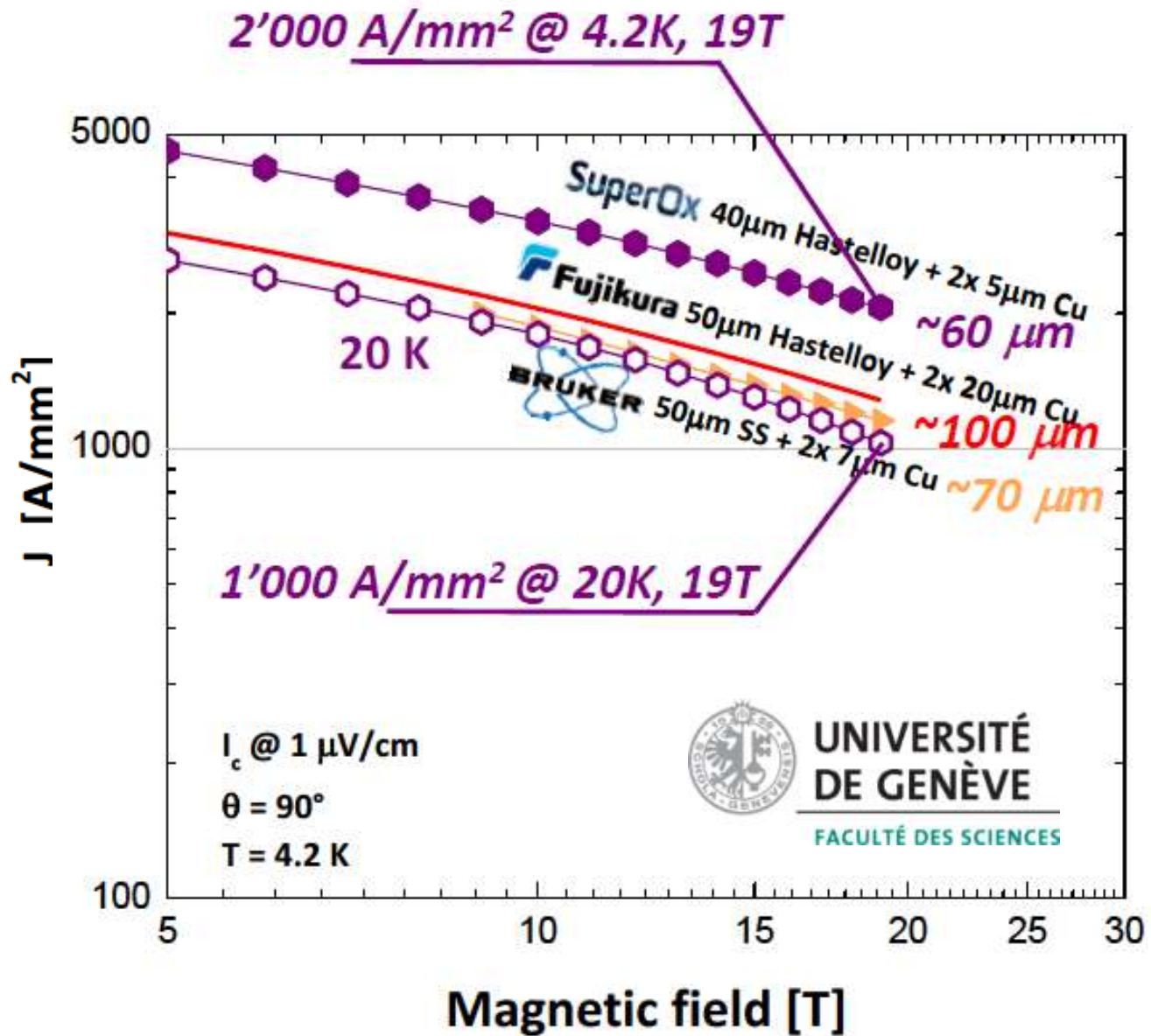


Wire engineering current density, 5  $\mu\text{m}$  Cu per side

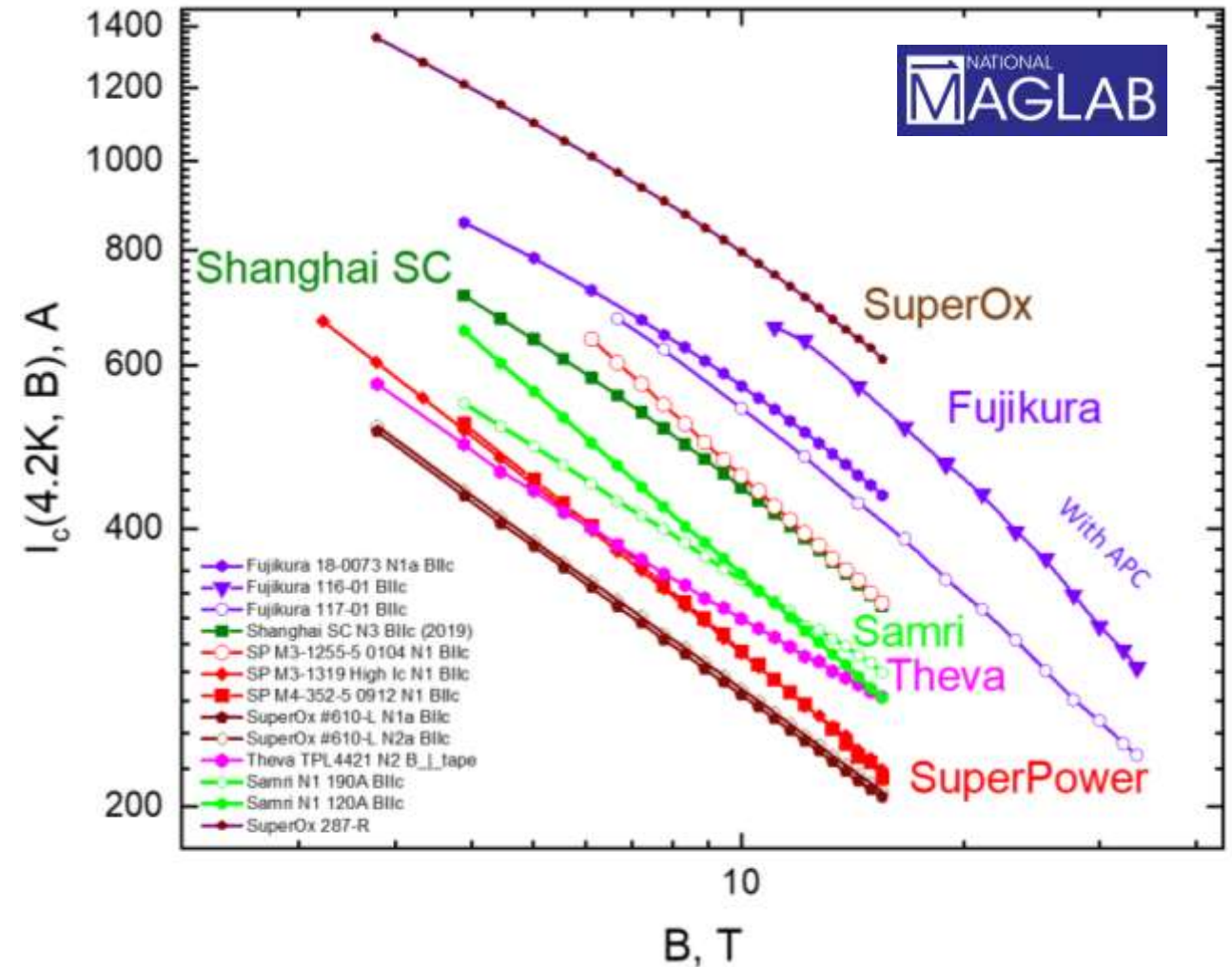


1000 A/mm<sup>2</sup>  
700 A/mm<sup>2</sup>  
500 A/mm<sup>2</sup>

# Wire for in-field use: record commercial $J_e$ at 20 and 4.2 K



C. Senatore, June 2019, FCC Week



D. Abraimov, July 2019, ICMC

- The SuperOx group:
  - Commercialise HTS applications
  - Produce HTS wire for own use
  - Sell HTS wire to others
- Applications driving wire development:
  - FCL, Cables, Coils
- Wire for LN2, self-field: **Available from stock**
  - Steady improvement beyond 800 A/12 mm at 77 K
- Wire for in-field applications: **Available from production**
  - 80-150%  $I_c$  improvement in the 4.2-65 K range
  - Record commercial  $J_e$ : 1000+ A/mm<sup>2</sup> at 20 K, 20 T; 2000+ A/mm<sup>2</sup> at 4.2 K, 20 T

Thank you for your attention