

R&D on HTS tapes
Manufacturer's perspective



- Owned by:
Faraday 1867 Holdings LLC, USA
- Mission:
Serve the world market with high quality 2G HTS tape, in large volume, at an affordable price
- July 2023:
Establish world-largest 2G HTS tape production factory: full production cycle 0.4 GA-m/year
- IP:
Faraday 1867 Holdings owns all IP on manufacturing technology
- Previous company name:
SuperOx Japan LLC

HTS applications market drives HTS tape market and R&D requirements

HTS is either the enabling or superior technology for trillion-size zero-carbon markets of imminent future

**COMPACT
NUCLEAR FUSION**



\$40 trillion

Market size by 2050, Bloomberg Intelligence 2021

**OFF-SHORE
GRID**



\$1 trillion

Market size by 2040, IEA 2019

**WIND POWER
GENERATORS**



\$9 trillion

Market size by 2050, IRENA 2019

**TRANSMISSION
AND DISTRIBUTION**



\$21 trillion

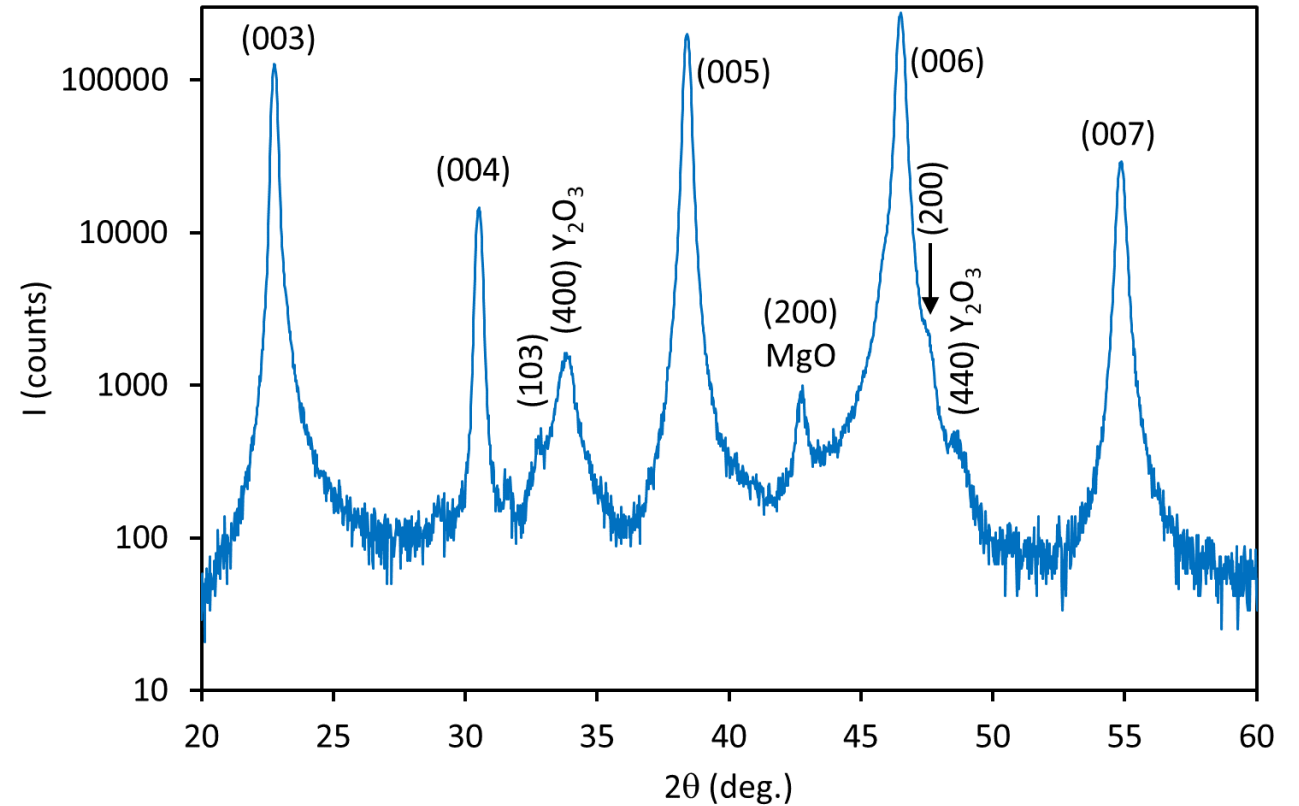
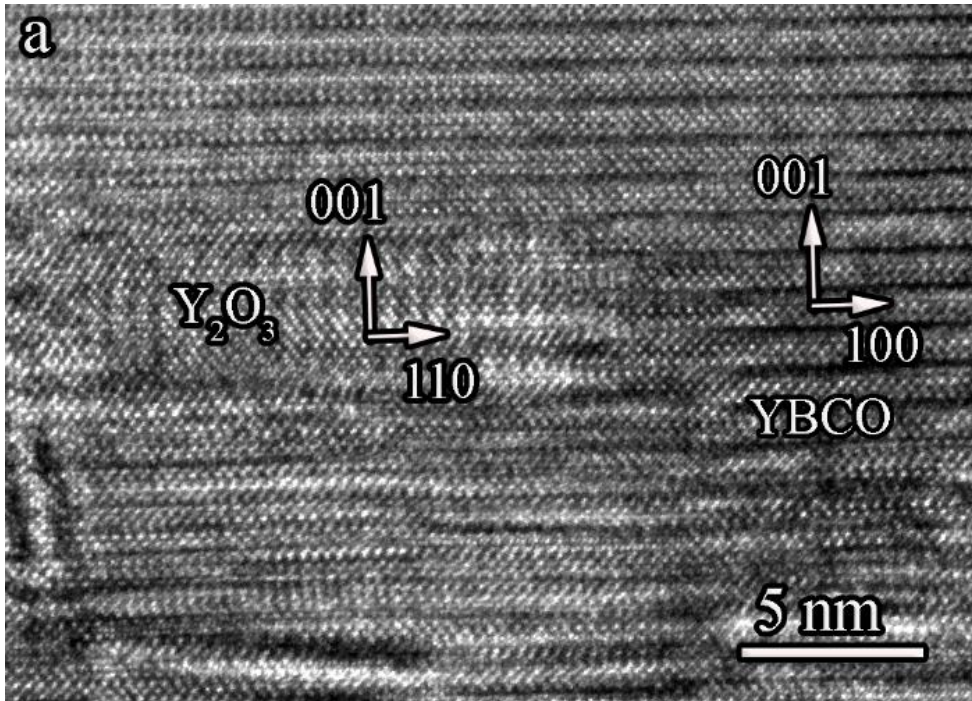
Market size by 2050, BNEF 2023

Focus on what is important

- Performance in magnetic field
Application call: compact fusion
Action: YBCO-based formulation for in-field use
- Large volume
Application call: compact fusion; other apps in the future
Action: scale up 20 times from 2019 to 2023; build modular factories in the future
- Low cost
Application call: ALL
Action: economies of scale; increase throughput; improve performance
- Long piece length
Application call: cables
Action: F-2-F stacks, splice individual tapes within continuous stack

Focus: Performance in magnetic field

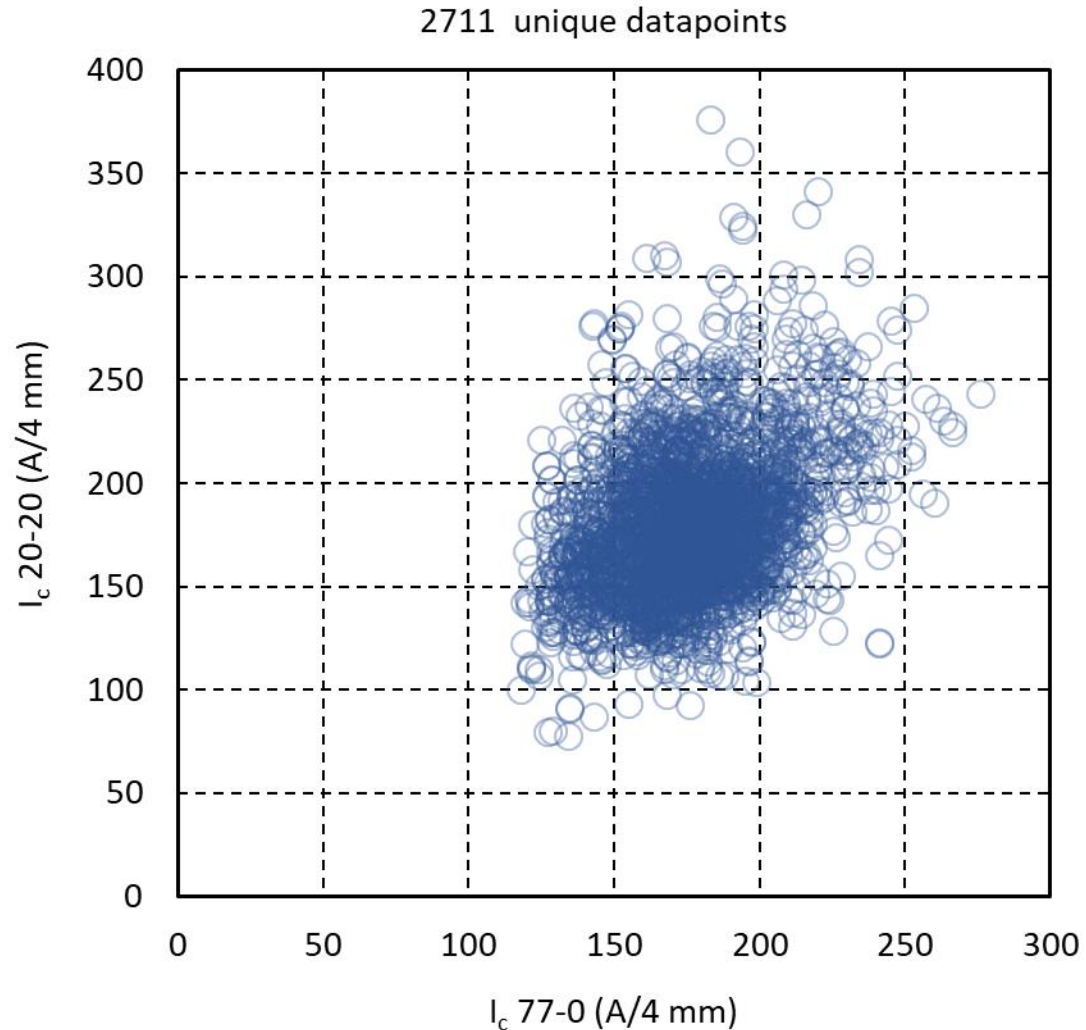
Product: YBCO 2G HTS tape, pinning by randomly distributed Y_2O_3 nanoparticles



doi.org/10.1038/s41598-021-81559-z

- ✓ Simple composition and nano-structure
- ✓ Easy to control
- ✓ Good reproducibility in manufacturing
- ✓ Amenable to high volume production

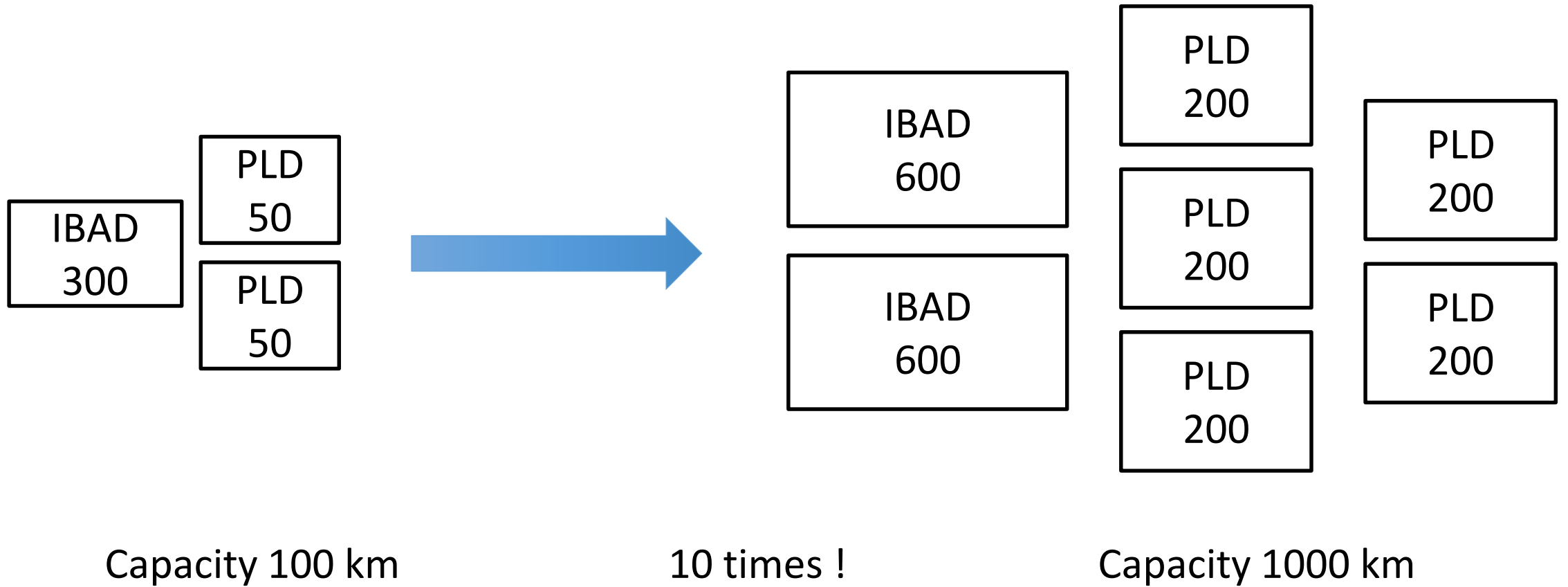
The YBCO recipe has proven very robust and amenable to industrialisation



- Scaled-up 20 times in 4 years
- 3000+ km of YBCO tape supplied
- 5 distinctly different PLD-YBCO regimes
- 3 distinctly different buffer layer regimes
- ONE dataset: same average performance, same statistical spread

Focus: Large volume / Low cost

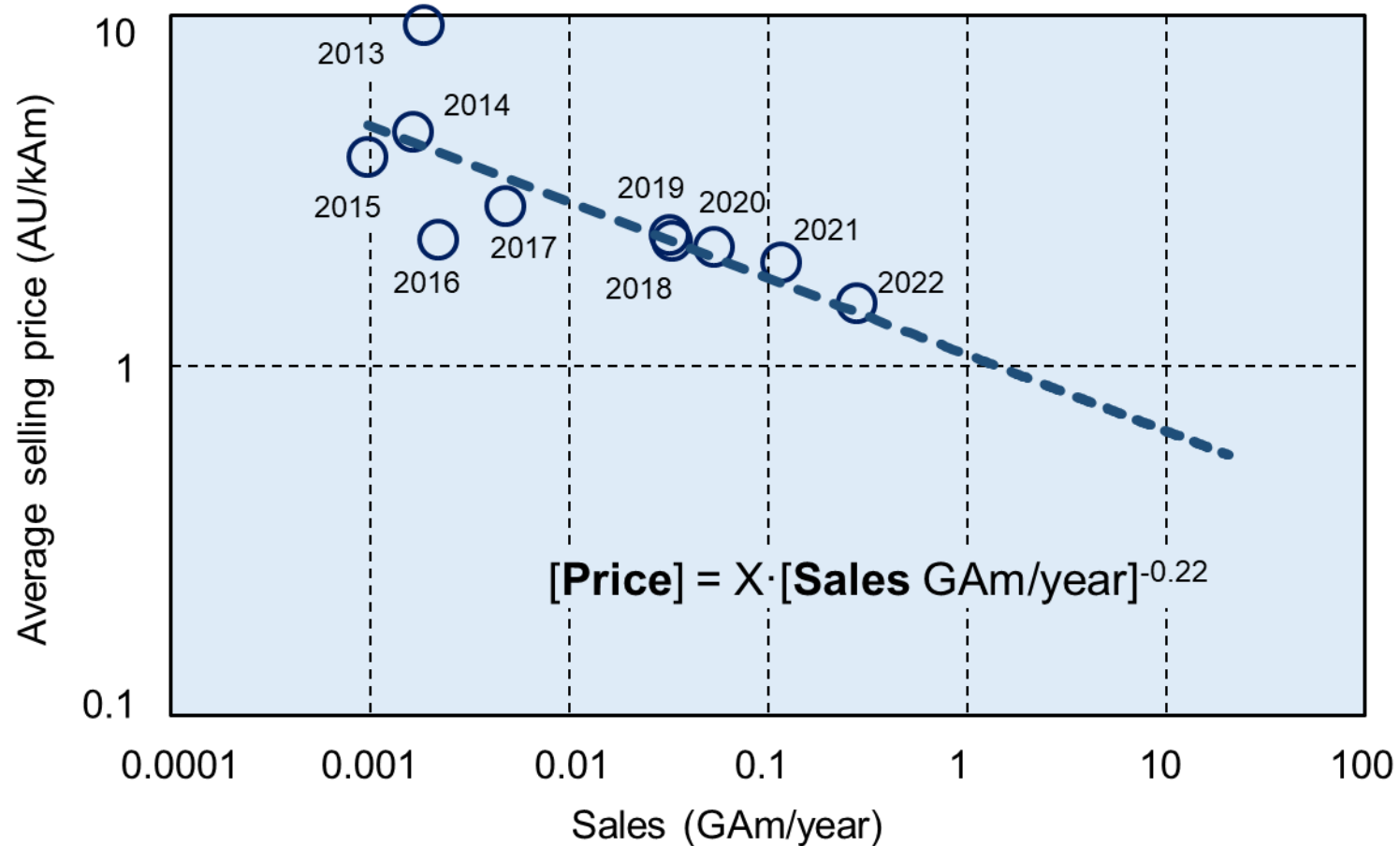
Action: (1) Increase unit throughput; (2) Multiply production units



Our recent 500 km shipment



Focus: Large volume / Low cost
Actual price learning curve



- Fusion creates demand, promotes capacity; large volume drives the cost down
- HTS price goes down 2 times with each 10-fold volume increase
- Other applications will benefit

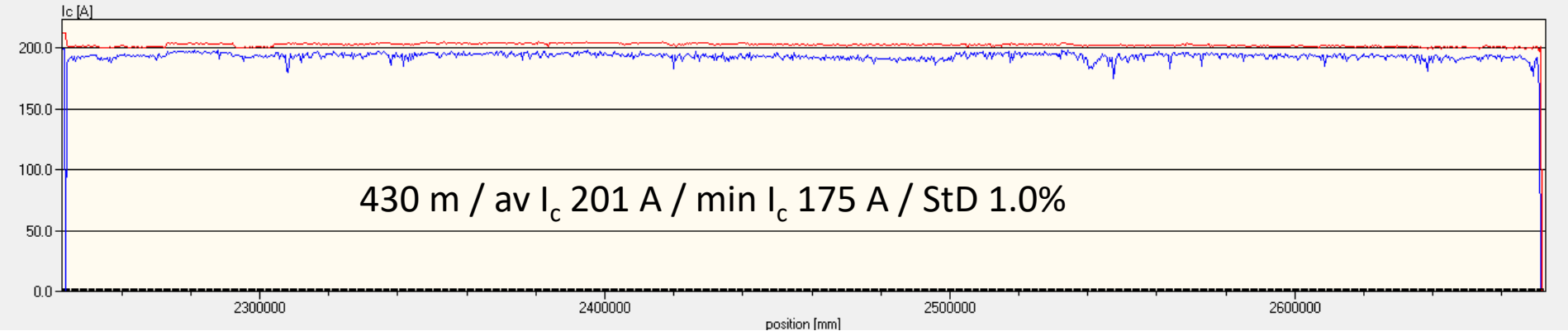
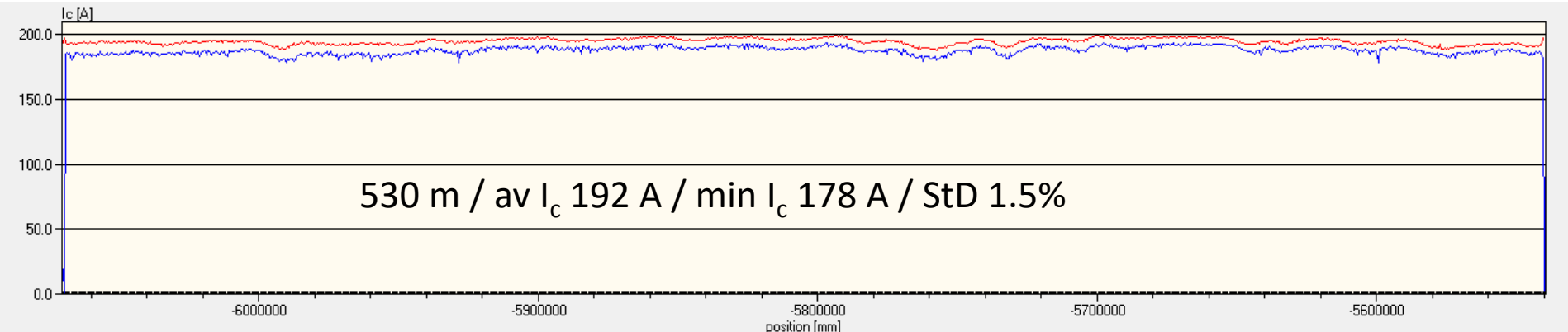
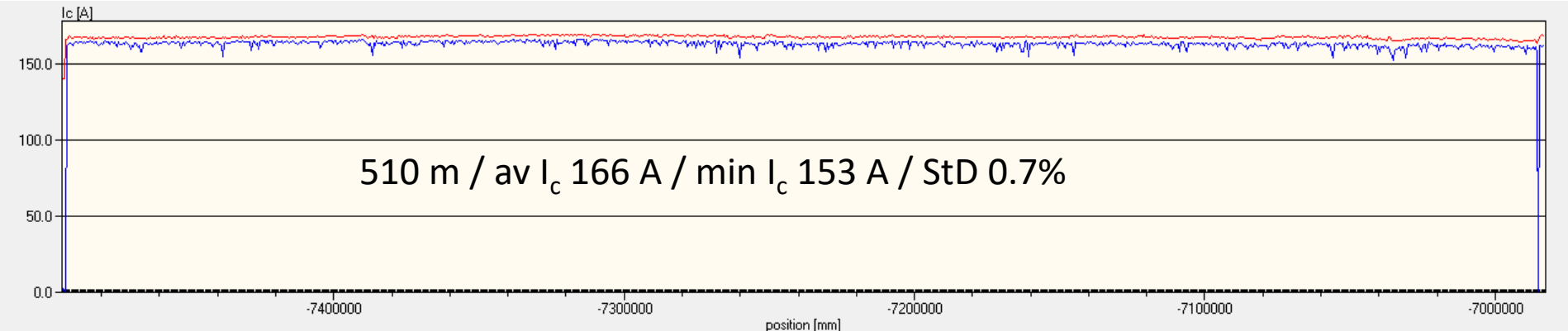
Mass production specs of today

Our entire production today works towards these specs from fusion
Tape operates at 20 K, 20 T

Substrate	Hastelloy C276
Substrate thickness	38 +/- 3 um
Piece length	> 300 m
Cu thickness	5 +/- 1 um per side
Average I_c (77-0)	> 130 A/4 mm
I_c drops	allowed with a criterion

There is synergy with almost all other applications

Available: long length, uniform properties, no I_c drops



SYNERGY TODAY :

we accept and deliver orders on

tens of km of tape,

based on our mainstream production for fusion

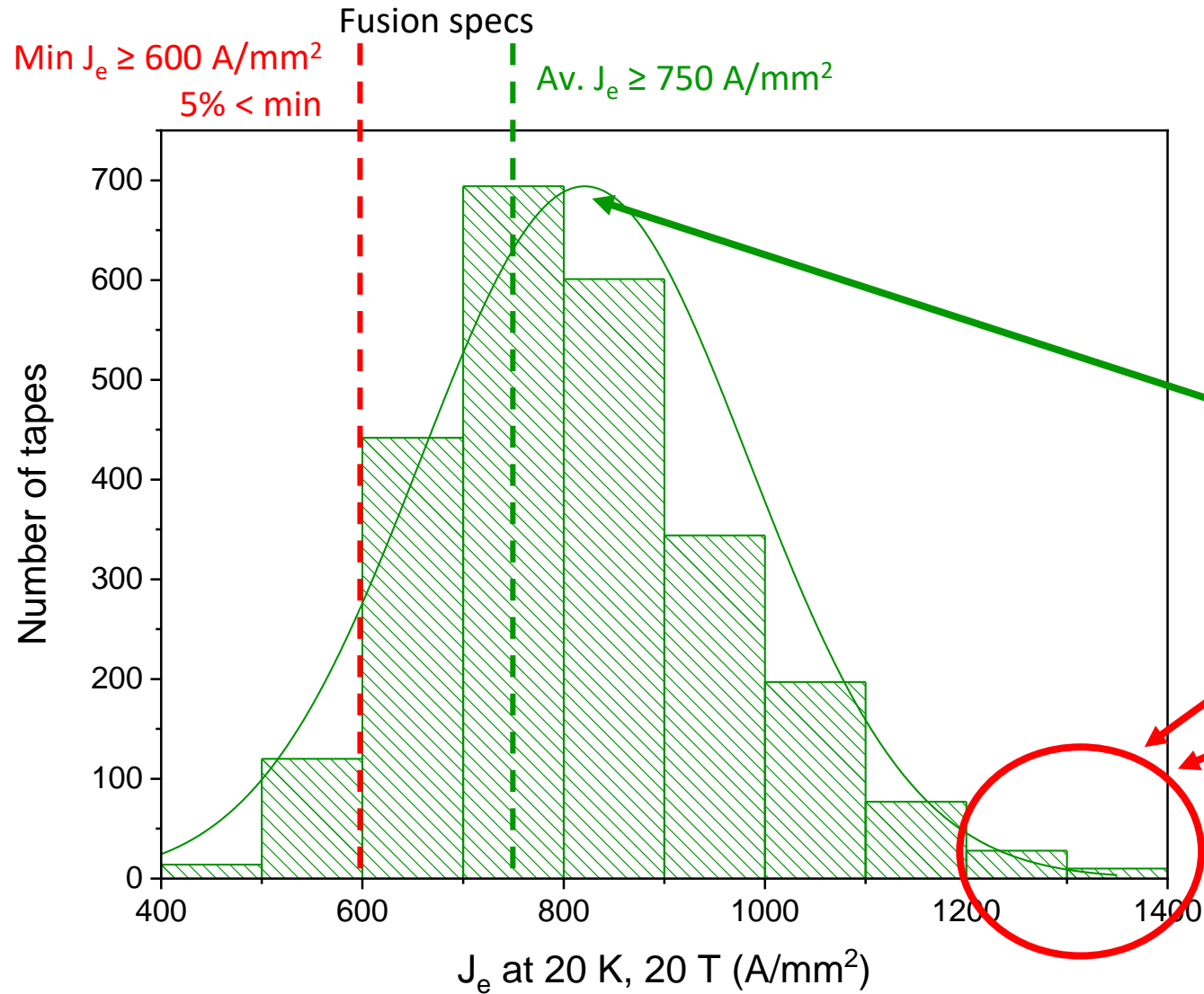
SYNERGY TOMORROW :

for large sustainable volume for other applications,

we will develop customised products

and build dedicated factories

Focus: Low cost via high performance
Spend less, to meet the same spec

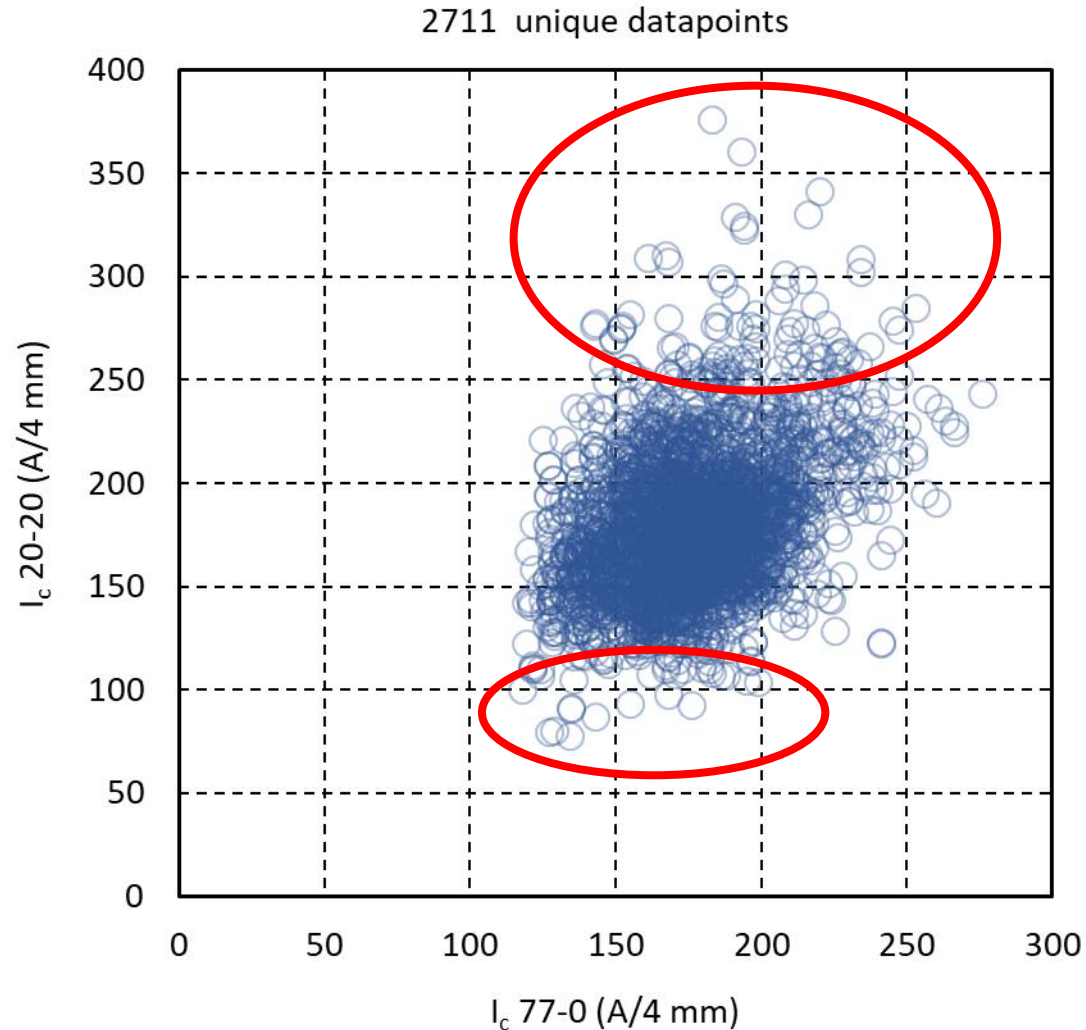


1. Learn how to make J_c that results in **this** J_e

2. Spend less: make **this** J_c to achieve **that** J_e

3. Make the spread narrower

Focus: Low cost via high performance
 Study the best- and worst-performing samples



Cost benefit through:

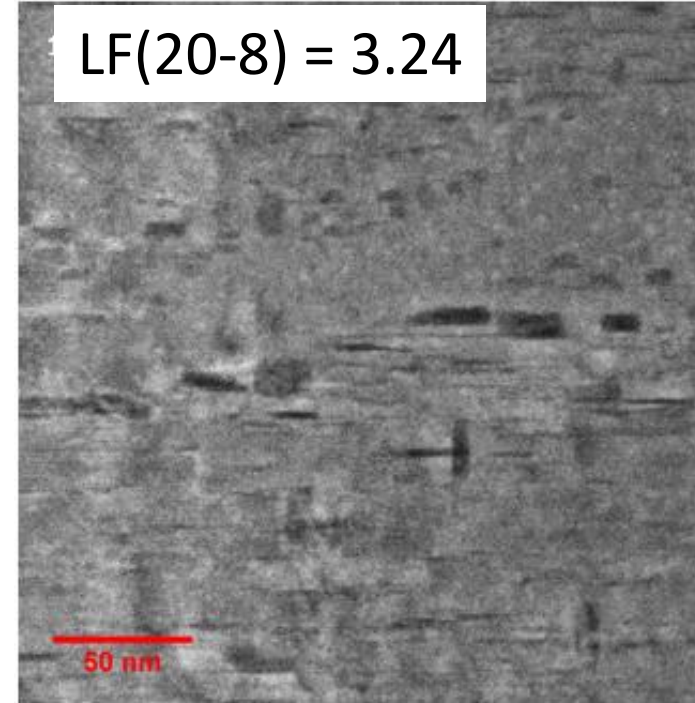
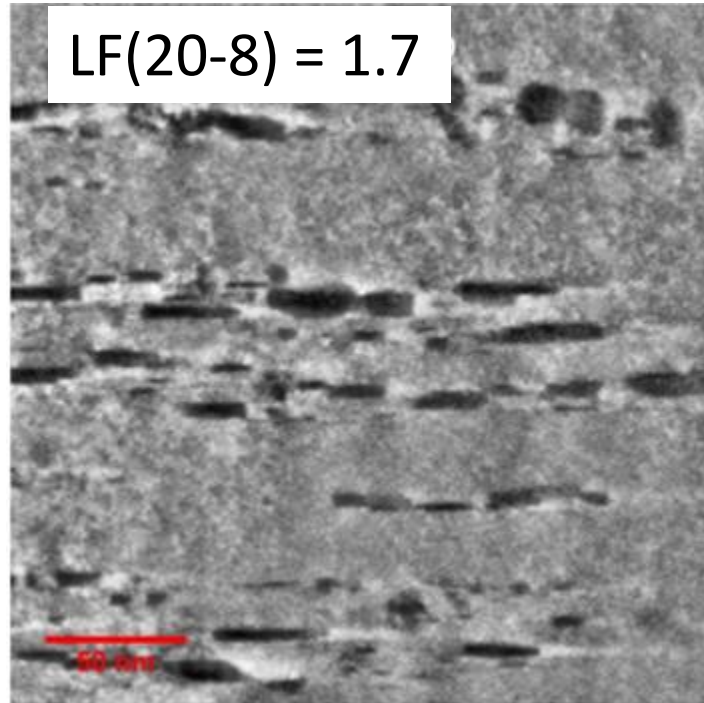
- Need less conductor to achieve the task

OR

- Spend less on making thinner HTS to achieve the same conductor performance

Focus: Low cost via high performance

Size of Y_2O_3 nanoparticles



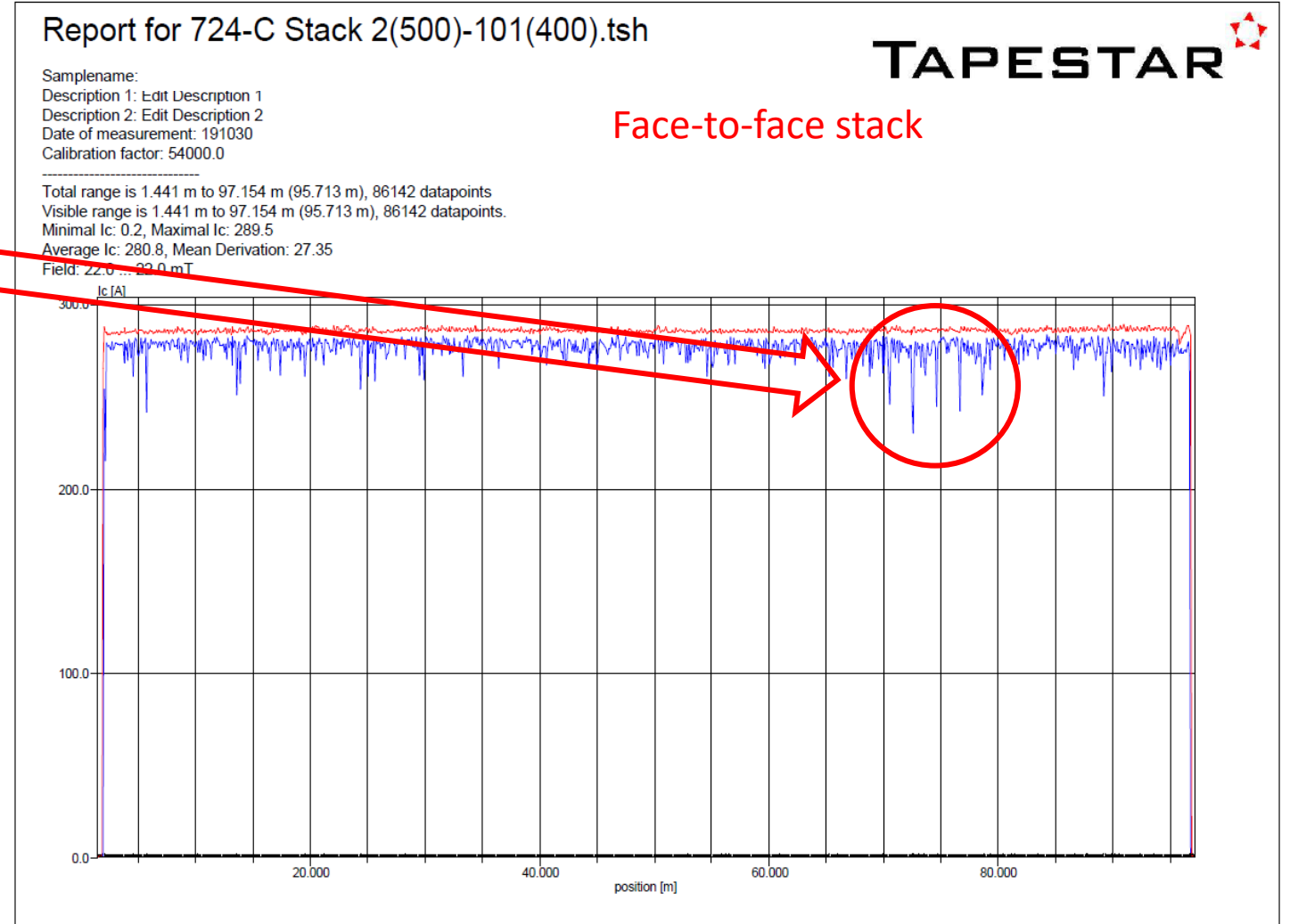
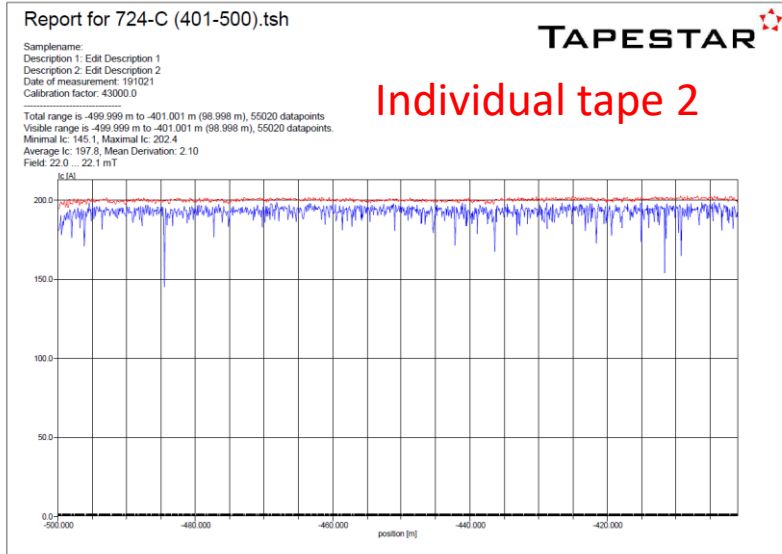
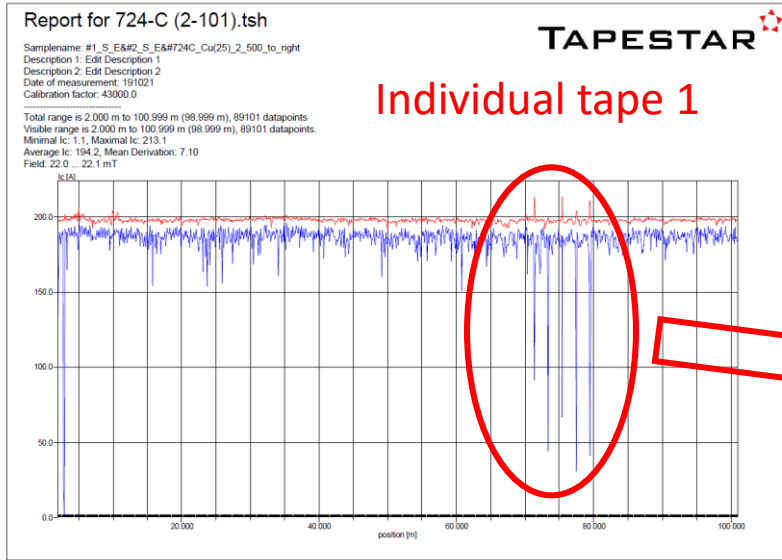
- Higher lift-factor with smaller Y_2O_3 nanoparticles
- Smaller particles \rightarrow higher density of particles \rightarrow higher density of interfacial defects as real pinning centres

Focus: long piece length

Cable conductor concept: Copper-laminated face-to-face stack

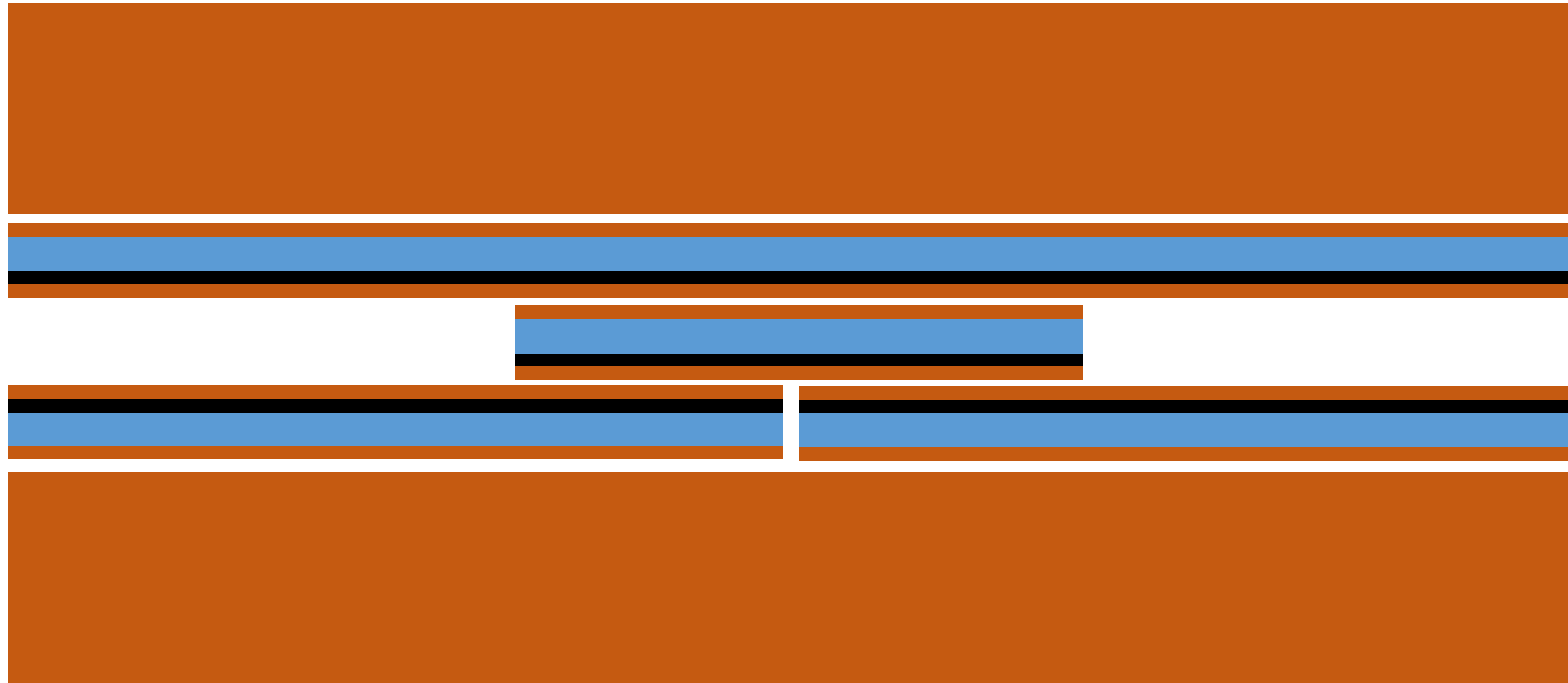


Cable conductor concept: Copper-laminated face-to-face stack: defect forgiveness



Focus: Long piece length

Cable conductor concept: Virtually unlimited length with splices

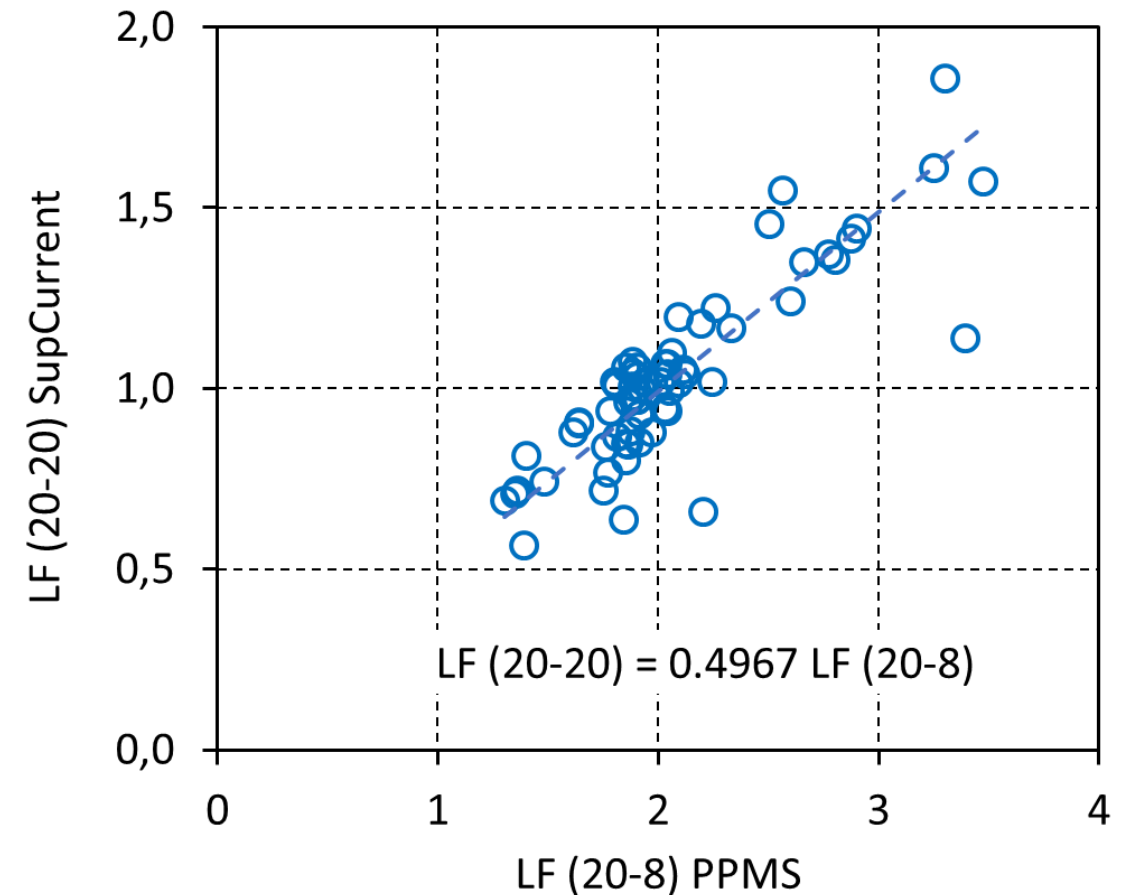
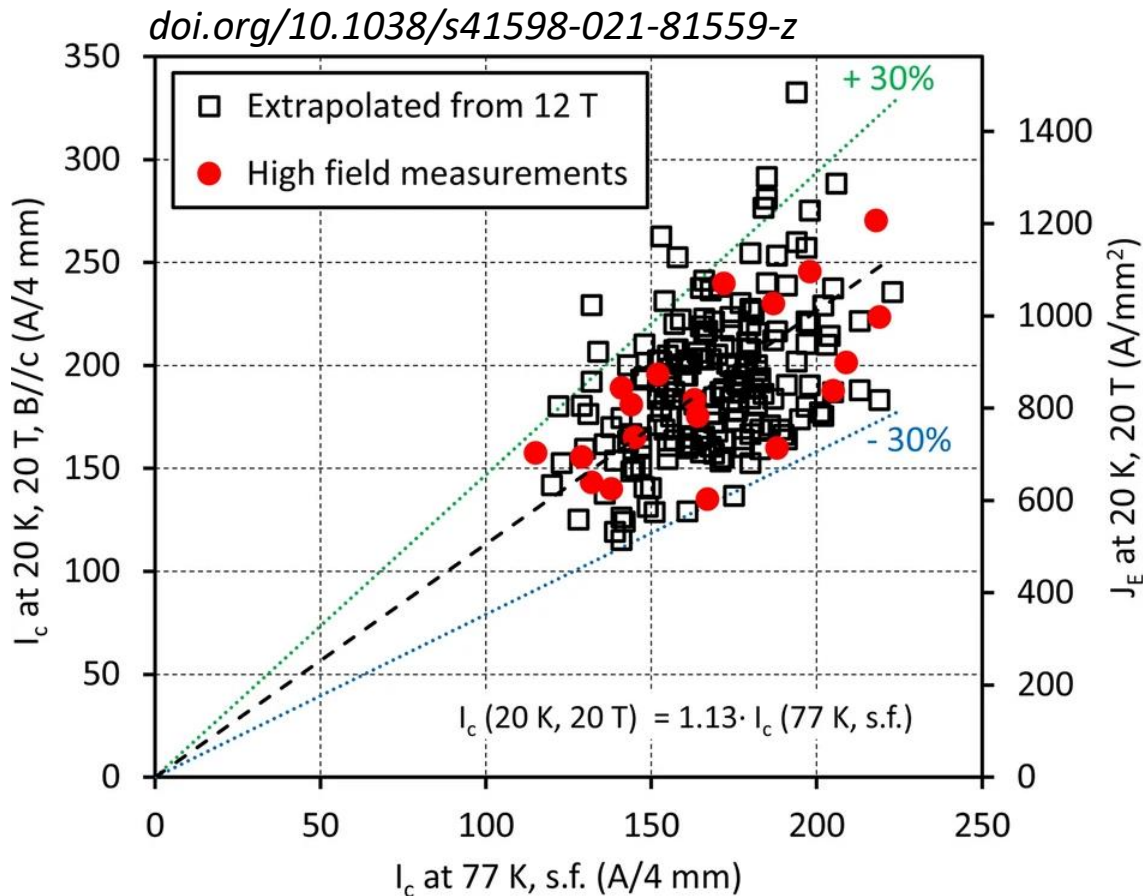


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ADDITIONAL SLIDES

QA and R&D tools for I_c in magnetic field:

- Independent: Direct high-field measurements at Tohoku U, U Geneva, NHMFL Tallahassee
- Customer: SuperCurrent direct measurements: extrapolate field dependence measured up to 12 T
- Manufacturer: PPMS magnetisation measurements: lift-factor up to 8 T, correlate well with SuperCurrent
Have ordered own SuperCurrent machine



Cable conductor concept:

Copper-laminated face-to-face stack: Preliminary example specs

- Two individual 4 mm wide tapes, each ~ 55 mm thick
- Stack width 4.8 mm
- Laminated with two 100 mm thick copper tapes
- Stack thickness: ~ 320 mm
- Bend radius, no splice: < 10 mm
- Bend radius with splice: 25 mm
- Twist with splice: 10 mm diameter at 30°
- I_c : ~ 85% of the sum