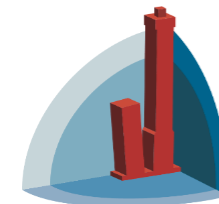




# Current Progress in HTS Bulks and Materials for Industrial Applications

Jan Plecháček, CAN SUPERCONDUCTORS



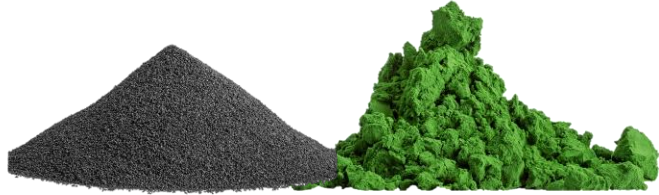
**EUCAS2023**  
Bologna, Italy  
3<sup>rd</sup>-7<sup>th</sup> September



# INTRODUCTION

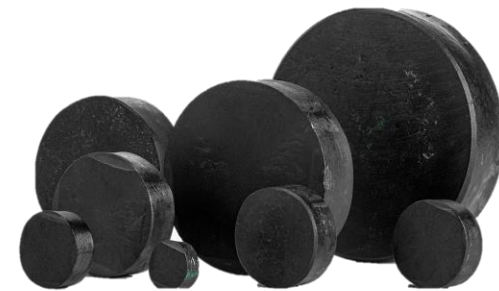
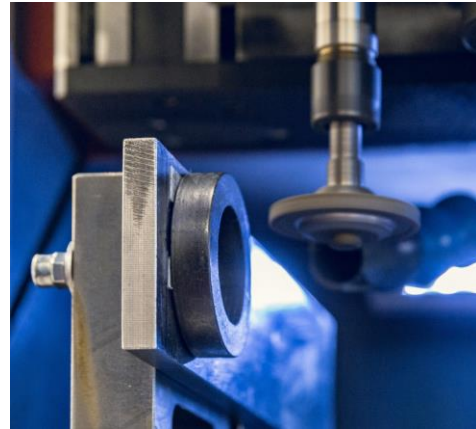


- **Czech private limited company with market presence since 1996**
- **Manufacturer of HTS materials and bulks**
- **Own extensive R&D and continuous innovation**
- **Cooperation with major academical organizations worldwide**
- **Products supplied to 45 countries**

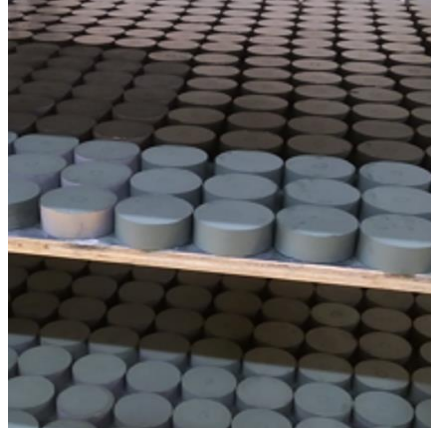


# FROM RAW MATERIALS TO BULKS

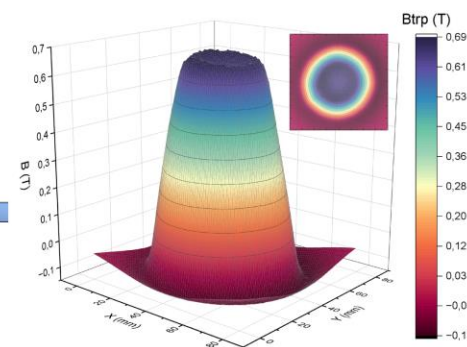
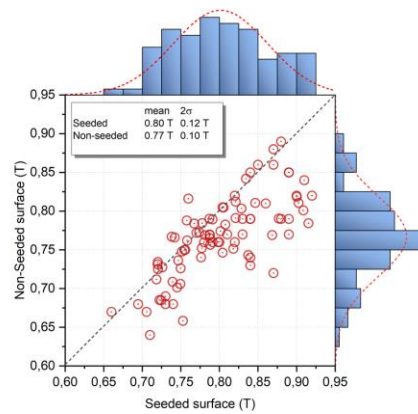
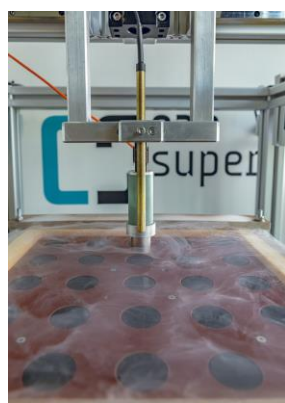
5,000+ bulks produced in 2022



**can**  
superconductors



# BATCH PRODUCTION multi-step QC, ISO Certified



**can superconductors**

**Trapped Field Mapper**  
verze 3.0 by TH

**XYZ mapping:**  
→ Počet kroků pro osy XYZ a rozlišení:  
OSA X: 12, Rozlišení os X/Y: 1, Hrubá: 2, jemná: 1, velikost pole: 30x30 mm  
OSA Y: 12  
OSA Z: 1, velikost měř. zón:

→ Měření bude provedeno na ploše:  
X: 36,000 mm, Y: 26,000 mm

**Jméno vzorku:** GC339NS  
naměřená data jsou ukládána do: data/

**Absolutní poloha:** X: 105,5 mm, Y: 71,0 mm, Z: 99,6 mm

**Průběžný graf:**  
Průběžný graf:   
Měření v čase (8 min):  
→ Měření 1x za 1 sekundu  
→ Měření X bodů v čase

**Měření magnetického pole v bodě:**  
Start: 0,021 T

**Aktuální naměřené hodnoty:**  
X: 4,00 mm, Y: 6,50 mm, Z: 0,00 mm, B: 0,02 T

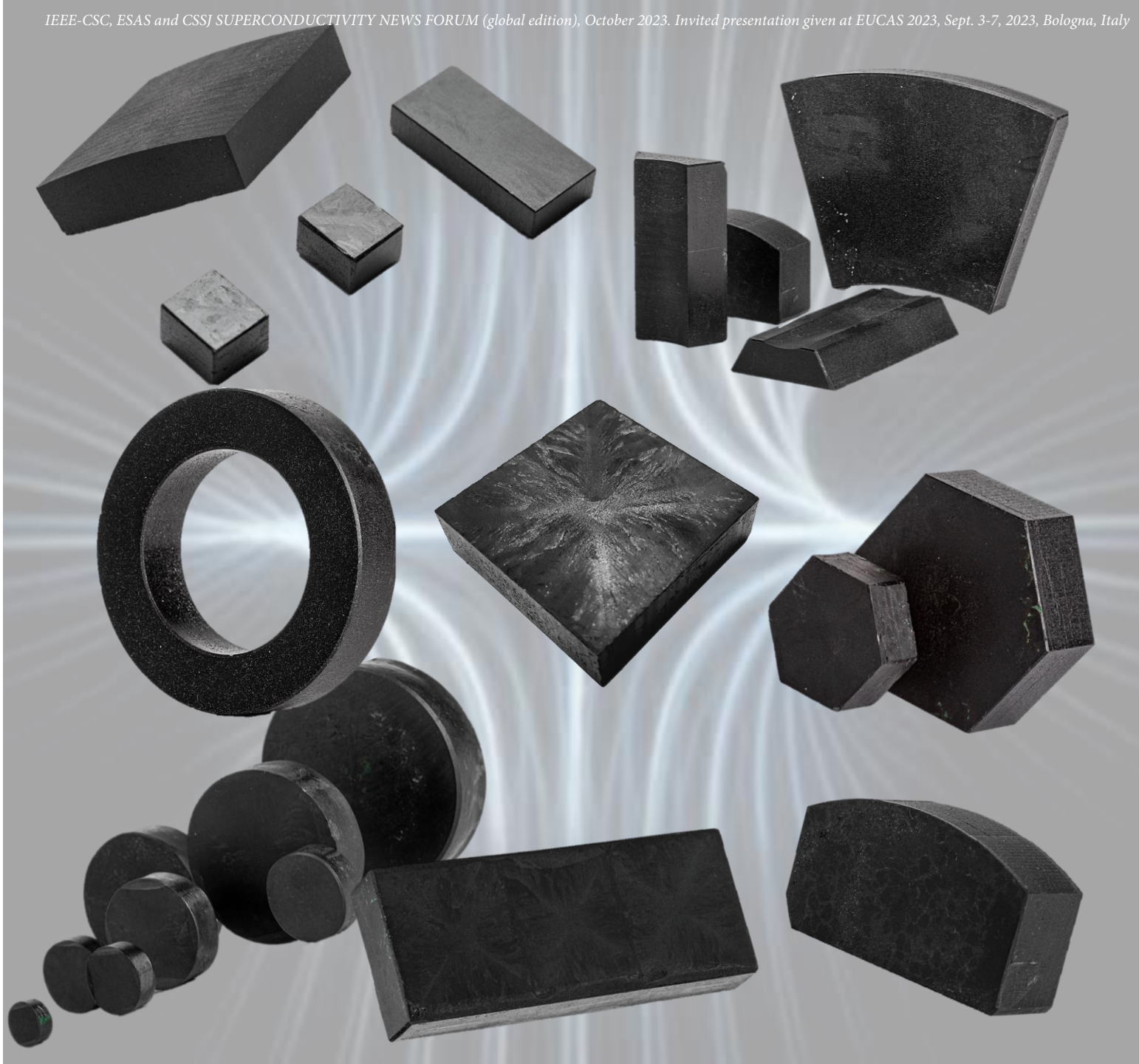
Posun sondy o 0,2 mm:  
UP, DOWN, LEFT, RIGHT, FRONT, BACK  
Desetiny (dílěk = 0,1 mm), Milimetry (dílěk = 1,0 mm)

Start

Reference  
Centr XY

# REBCO BULK

- **YBCO, GdBCO/Ag, EuBCO/Ag**
- **Simple & complex shapes**
- **Disks  $\varnothing$  up to 100 mm**
- **Std Btr up to 2.5 T @ 77 K**
- **Levitation Force up to 1,000 N**





# REBCO Bulks for Bearings





# Applications: QuinteQ Flywheel Energy Storage System



## Kinetic Battery Based on Boeing Flywheel Project

- Modular system to scale up or down to shifting local power needs
- Single flywheel power 167 kW, capacity 5 kWh, Weight 2.5 t
- Compact & mobile: 10 flywheels for 1MW bankable in 20ft container
- Very low energy losses (<0.1% per hour)
- +350.000 cycles with at least 20 years of operation
- Ideal for peak shaving frequent high-power peaks
- Shock breaker for micogrids



# QuinteQ Market Focus

## Military



## Civilian off-grid



Military and civilian microgrids,  
directed energy systems

## E-Transport



## Ports, cranes & mines



E-logistics - metro/train, construction,  
ports/cranes, fast-charging



**CS** can  
superconductors

# QuinteQ Flywheel Energy Storage System





# QuinteQ Flywheel Energy Storage System



## PROJECT

Showcasing a scalable, hybrid energy storage solution utilizing existing plant infrastructure,



**Hydroxide salt energy storage** for combined heat and power production for long-duration grid-scale energy storage by HYME

**Battery storage** consisting of used car batteries from PLS Energy Systems

**Flywheel from QuinteQ** for short duration energy storage.

Tied together by a hybrid energy management system, to balance the grid and provide stored energy when needed.

The project in Rønne, Bornholm.



# Applications: REVTERRA FLYWHEEL



**Initial market application:  
rapid EV charging**

modular 400kW/100kWh base unit, with  
the option for expanding installations

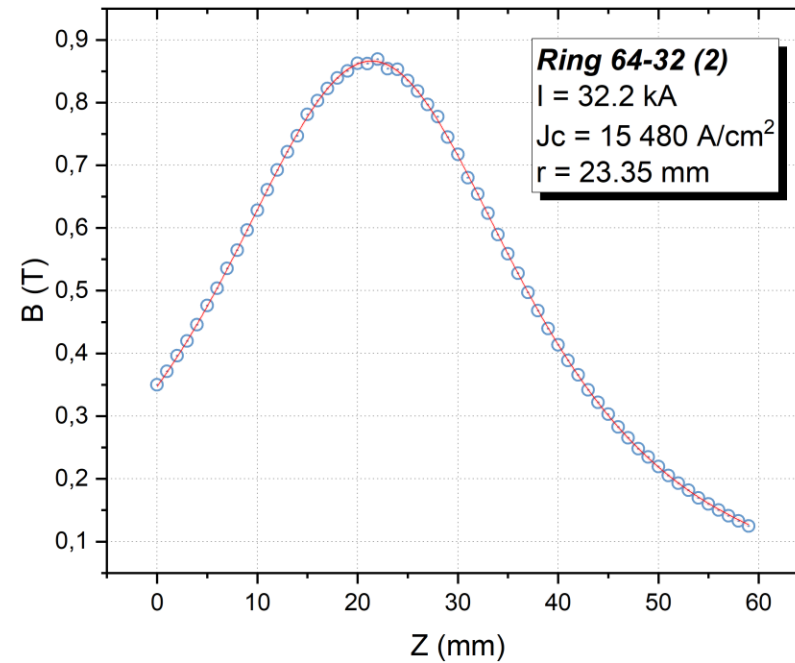




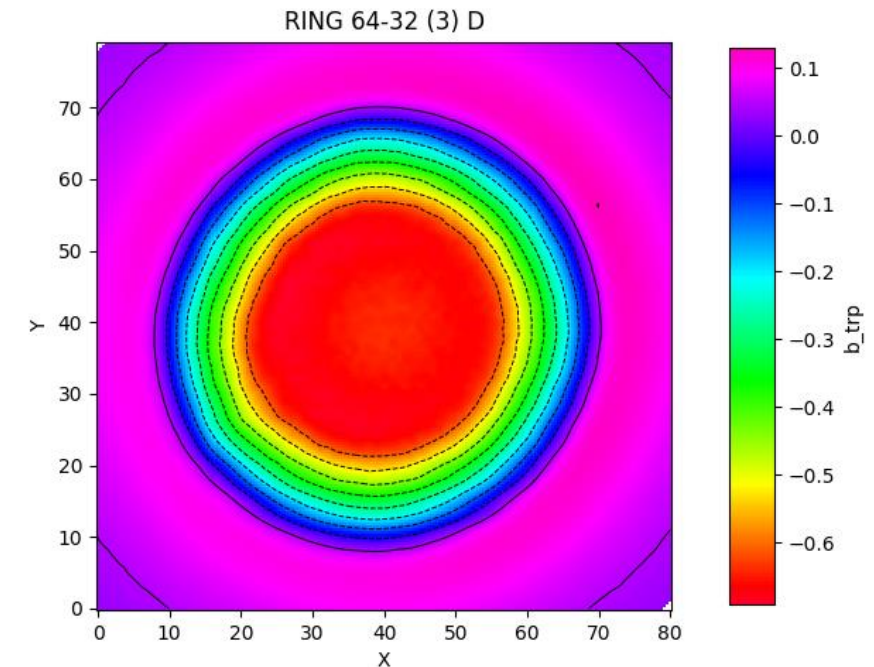
# Applications: REBCO Rings for Bulk Based MRI



EuBCO/Ag Rings  
OD 64, h 13 mm



Z-scan through the ring bore  
persistent current 32 kA at 77K



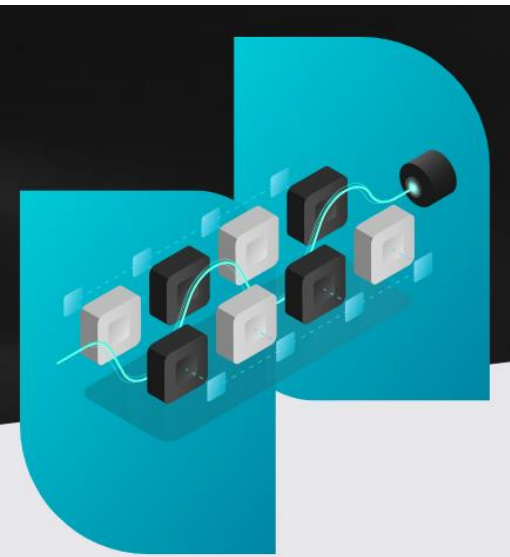
2D map trapped field  
shows high homogeneity



# Applications: GdBCO/Ag Bulks for HTS Undulators

## Undulators: accelerator based light sources

*Undulators employ successive static magnetic fields to make passing electrons oscillate, resulting in the emission of highly concentrated radiation. The emitted radiation is channeled through beamlines for experiments across different scientific domains.*



State of the art:  
Permanent magnets  
Conventional superconductors

**Challenge: HTS?**





# Applications: GdBCO/Ag Bulks for HTS Undulators

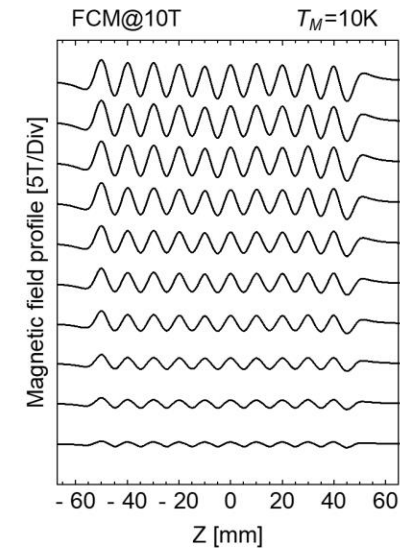
PAUL SCHERRER INSTITUT



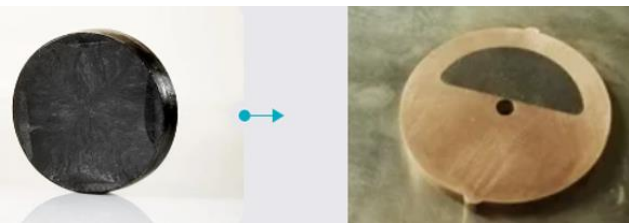
**HTS UNDULATOR AIM: to reduce the period length and increase the magnetic field beyond today capability of existing undulators (2T+??)**



Planar Hybrid: CAN-SUPERCONDUCTOR



Perfect uniformity of undulator field achieved

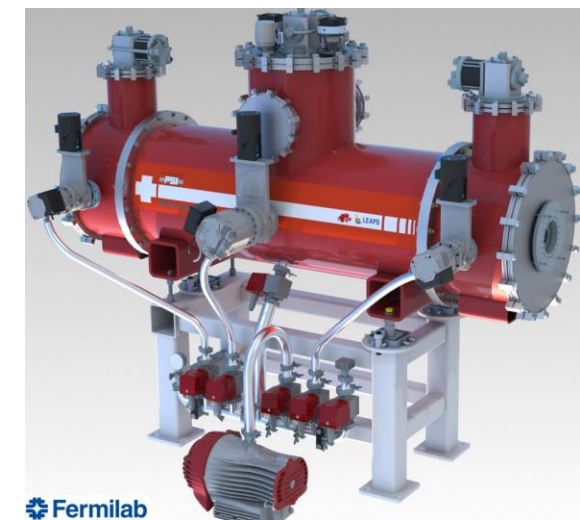
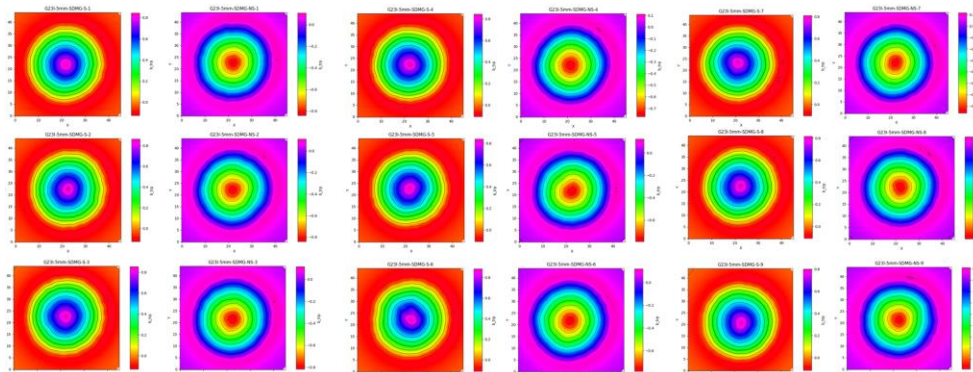
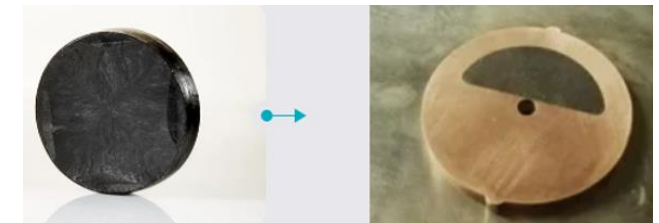


**2023 Status: High magnetic field >2T demonstrated in a short sample staggered array undulator made of GdBCO bulks exceeding existing tech.**

# Applications: GdBCO/Ag Bulks for HTS Undulators

## Challenges For Undulator Bulks:

- Maximum properties homogeneity is a must - minimum performance deviations required
- Micro-meter accuracy bulks cutting (EDM wire erosion) for shrink-fitting into a copper matrix
- Repeated QC (Btr mapping) during production, prior to cutting, after embedding
- New batch of **CAN SDMG bulks** to be tested in September
- Next step 1.0 m long prototype, will require a few hundred perfectly uniform bulks

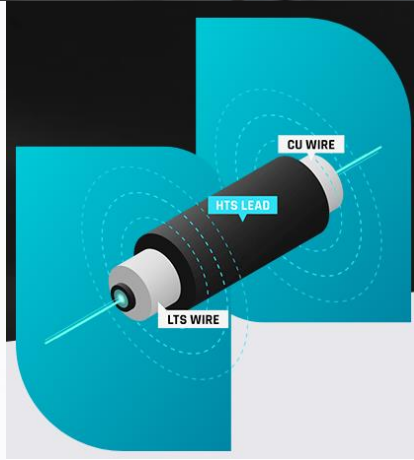


### THE METER LONG PROTOTYPE

Active length : 1.0 m  
Total length : < 2m  
period length : 10 mm  
magnetic gap : 4.0mm  
 $B_0 \sim 2.0$   
Cryocoolers  
HTS Mag-temp 10K  
LTS temp 4.0K



# Bi-2223 Bulks



## Bi-2223 Magnetic Shields

Diameter up to 100 mm  
Shield > 15 mT (77K)  
Ideal for shielding SQUIDS



## Bi-2223 Current Leads

New generation of current leads  
Up to 2,000 A (77 K)  
Used in high-field systems





# Materials for production of HTS Wires

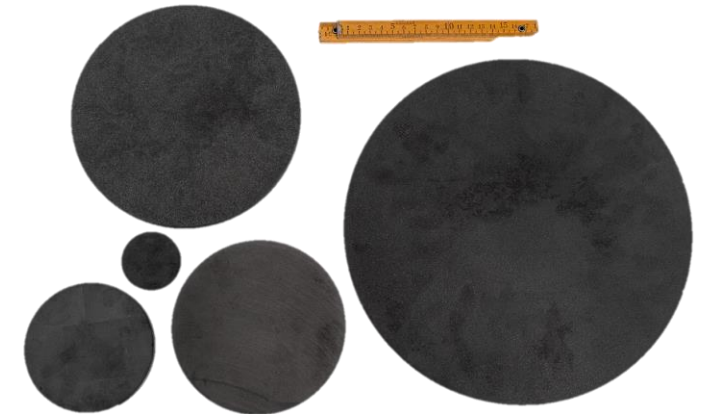
## REBCO Granulates for PVD

Over 1 ton of material/year for established CC manufacturers



## REBCO Targets for PLD

Targets up to 12" diameter,



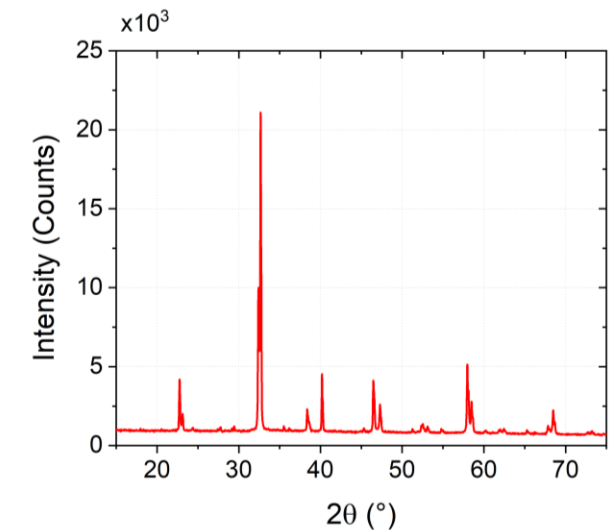
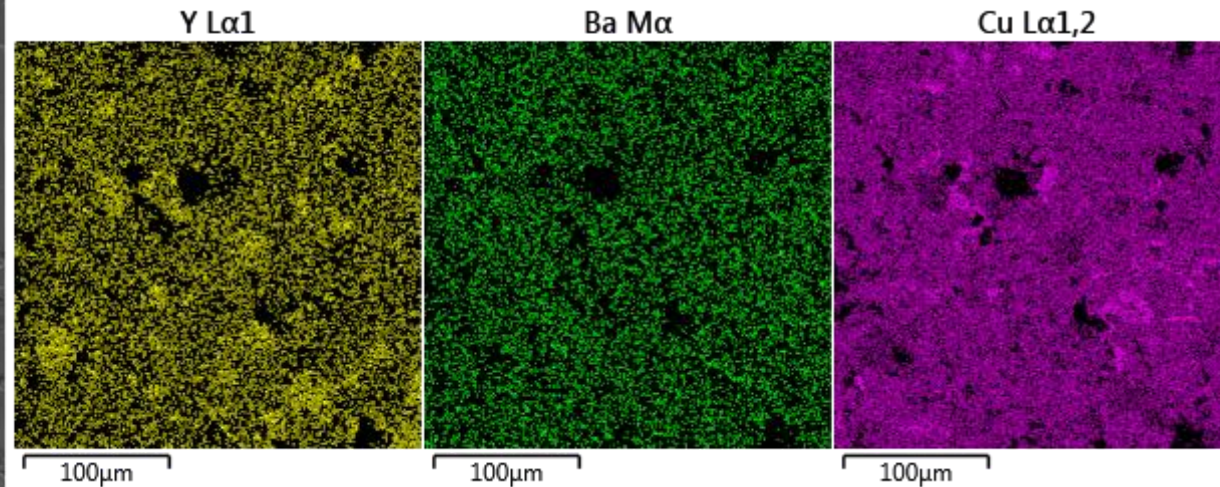
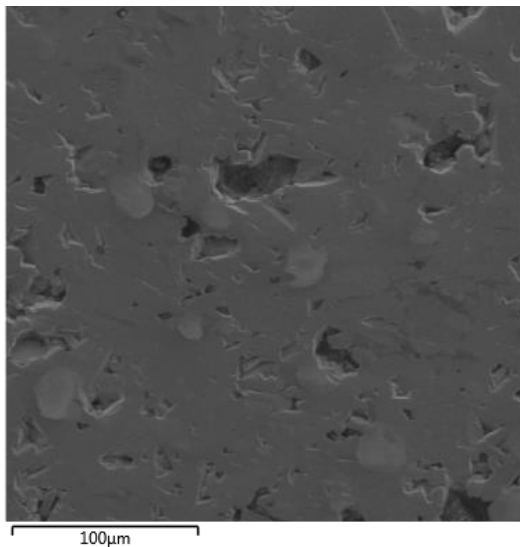


# Materials for production of HTS Wires

## R&D of primary materials for CC manufacturers and startups

Custom matrix compositions  
Thorough analyses

Various dopants  
Individual approach

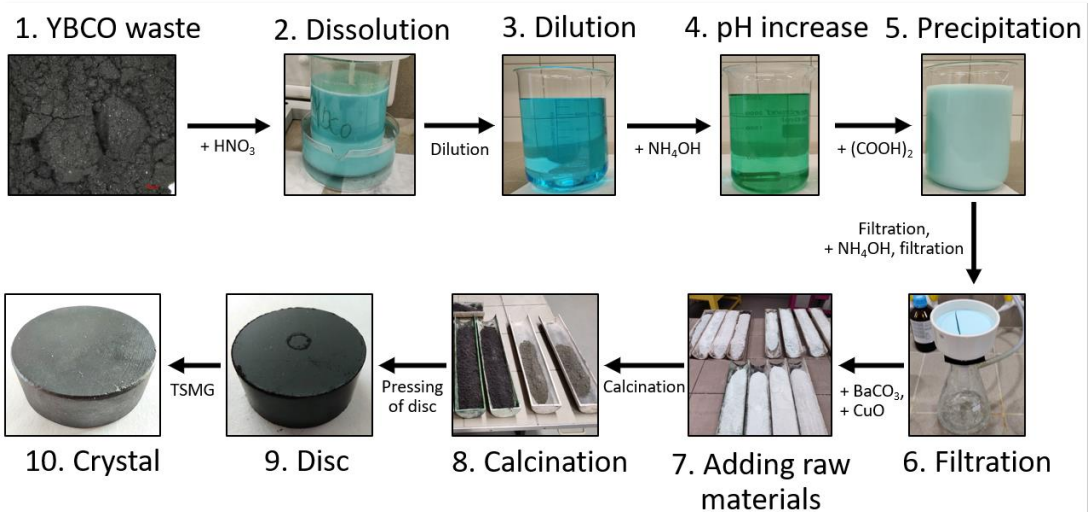


# CHALLENGES: REBCO Recycling



**TSMG overall growth failure rate: a few % to tens of % depending on size**

- may become important with increasing production volumes
- established method for chemical recycling of REBCO and Ag
- can easily be scaled up



## SILVER RECYCLING

REBCO/Ag dissolution in nitric acid and subsequent selective precipitation resulting in pure metallic silver





# CHALLENGES: REBCO Recycling



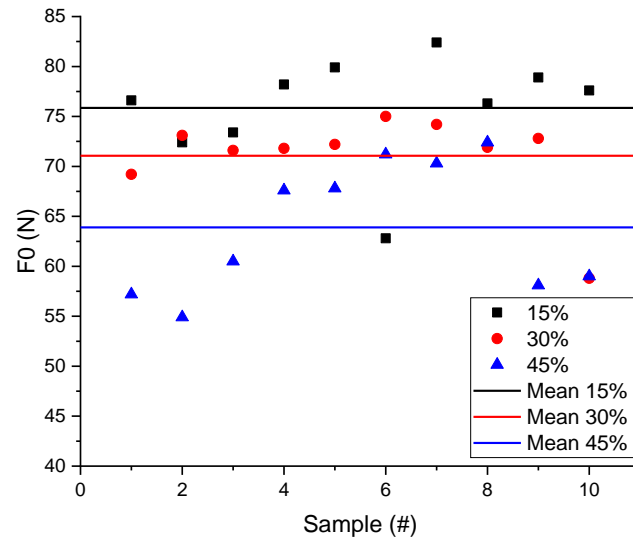
Adding 15 - 30% of recycled material...

...does not significantly impact levitation force of YBCO crystals.

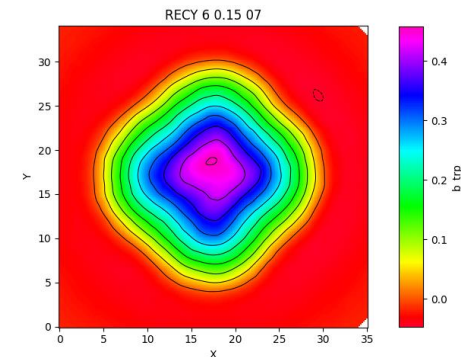
...does not prevent single domain character of YBCO bulks.



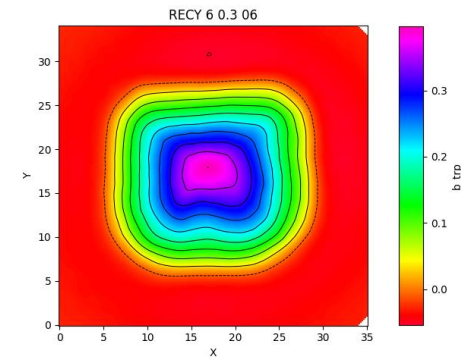
(28 mm YBCO disks LF > 70 N)



15 % recycled



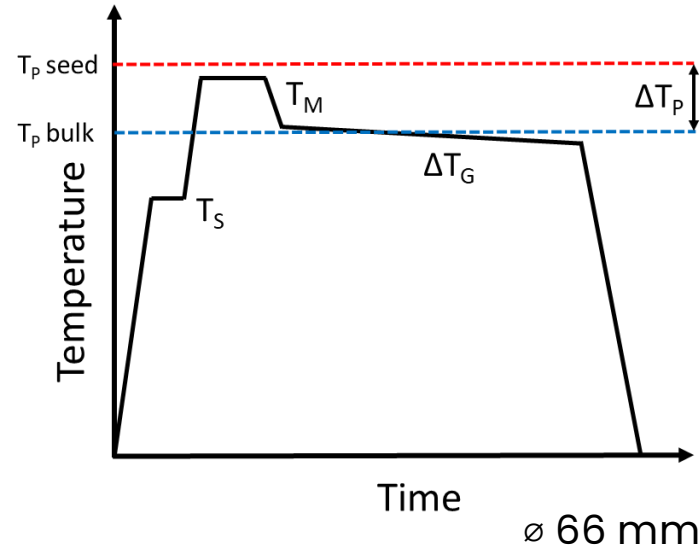
30 % recycled





# SDMG – Single Direction Melt-Growth

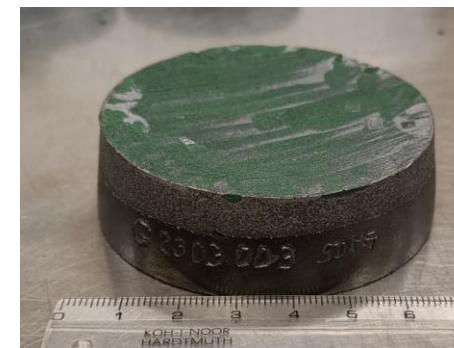
- Developed by Dr. Motoki  
*Supercond. Sci. Technol.* **35** 09400 (2022)
- Novel method of crystal growth
- REBCO bulk is used as a seed
- Utilizes different  $T_p$  of REBCO systems
- Entire bulk is grown in a single-direction



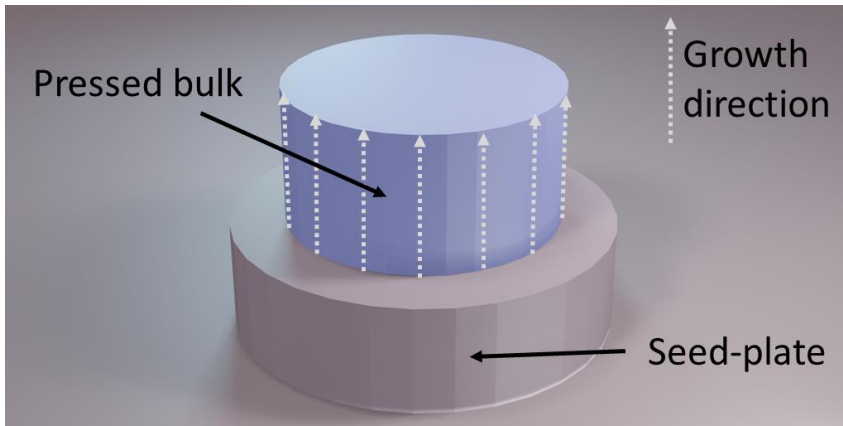
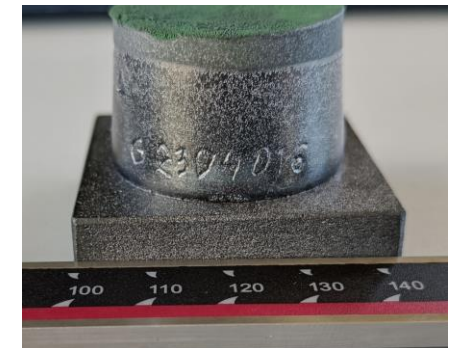
∅ 32 mm ring



∅ 66 mm



∅ 35 mm

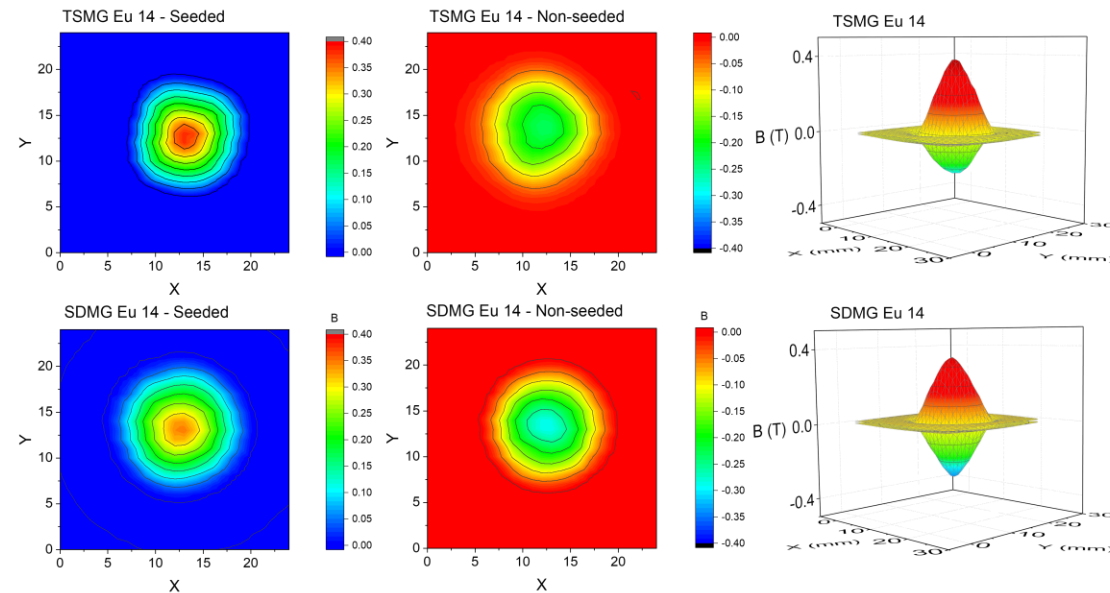
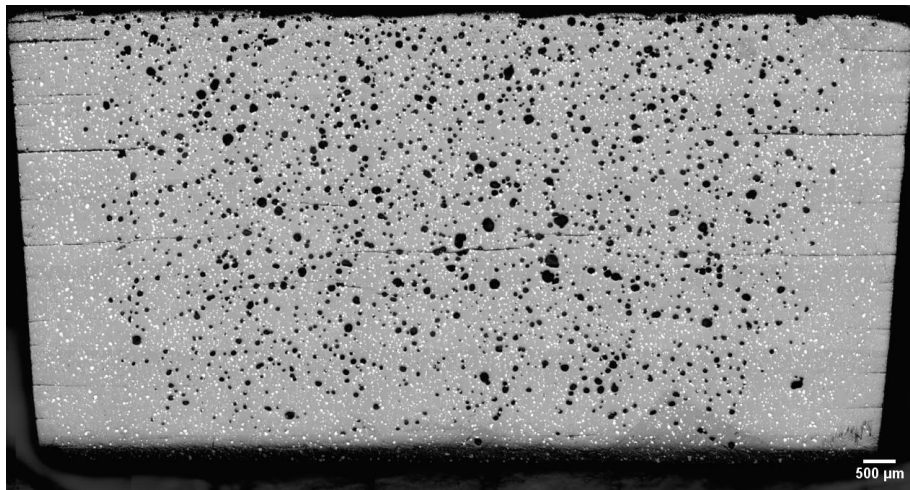


GdBCO + 10 %  $Ag_2O$

# SDMG – Single Direction Melt-Growth

## ADVANTAGES

- Improved properties homogeneity
- Decoupling of diameter and growth time
- Robust growth with high yields
- Allows growth of complex shapes



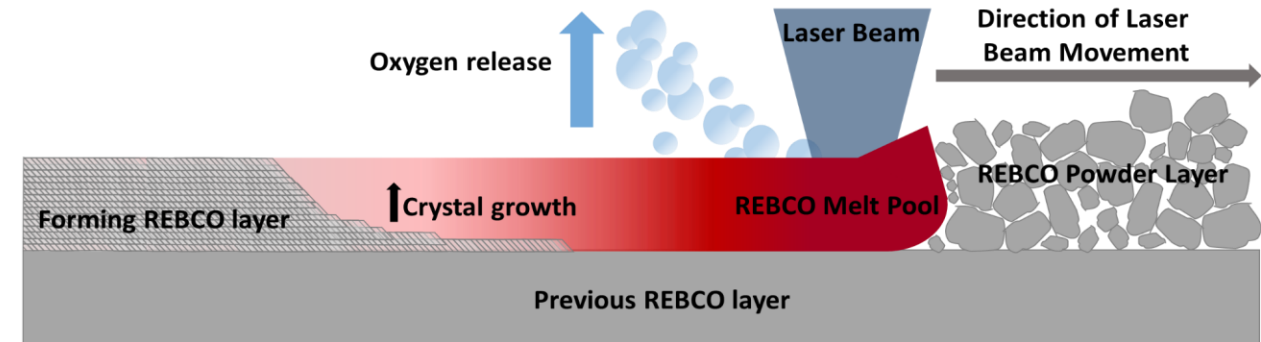
## CHALLENGES

- Requires bulks as seeds (difficult for REBCO systems with high  $T_p$ )
- Still needs further tuning

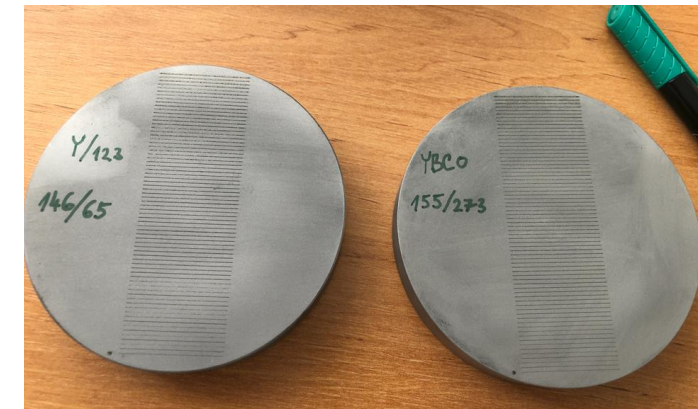


# Challenge: Additive REBCO Manufacturing

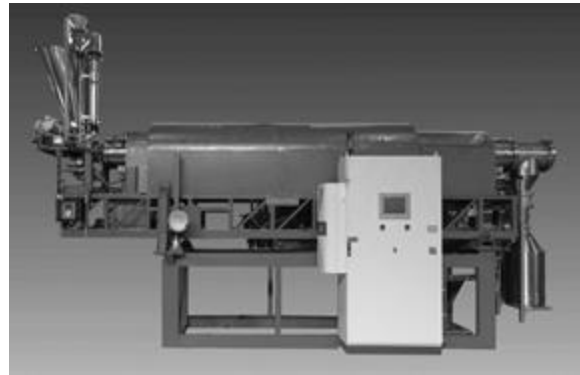
- SLM – selective laser melting – 3D printing technique used in metallurgy
- Can likely be used for REBCO due to its unique properties
- Preparation of dense body by SLM and growth via SDMG



- Developed spreadable REBCO powder
- Singletracks currently underway



# CHALLENGES: Scaling up



## Driving progress: Where Chemistry Meets Capacity

**Precursors:** plan to transfer to high-capacity equipment available in market for advanced chemicals, tests underway

**Bulks:** ongoing batch production in foreseeable future, larger batches – larger furnaces –, yield increase (SDMG), continuous production not expected

**REBCO Granulates:** successful industrial trials completed, transition from lab-scale to advanced technology platform





# From Laboratory Benchmarks To Industrial Innovations

