TECHNISCHE UNIVERSITÄT WIEN
Vienna | Austria

EASITrain

Superconducting characterization of prototype LTS samples

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ATOMINSTITUT

EASITrain – European Advanced Superconductivity Innovation and Training. This Marie Sklodowska-Curie Action (MSCA) Innovative Training Networks (ITN) has received funding from the European Union's H2020 Framework Programme under Grant Agreement no. 764879

- ESR13 project

- ESR13 Nb_3Sn
  - APC
  - No APC

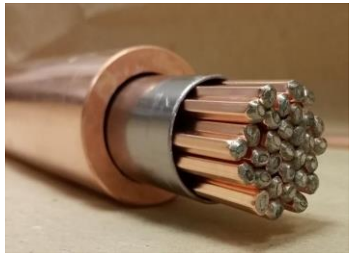
- ESR13 MgB_2

- Next steps

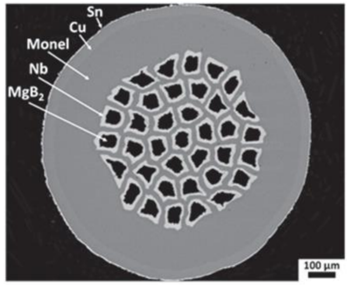
Project scope:

ESR13 focuses on the superconducting and magnetic characterization of superconducting samples suitable for FCC-hh or FCC-driven applications

Nb_3Sn



MgB_2



Hyper Tech Research, Inc.

Artificial pinning centres (APC) doped wires, Columbus (USA)

BOCHVAR INSTITUTE OF INORGANIC MATERIALS
JSC VNIINM

New “clusters” design wires, Moscow (RU)

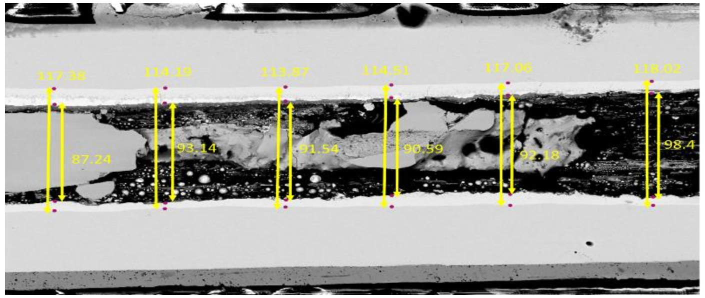
Columbus Superconductors

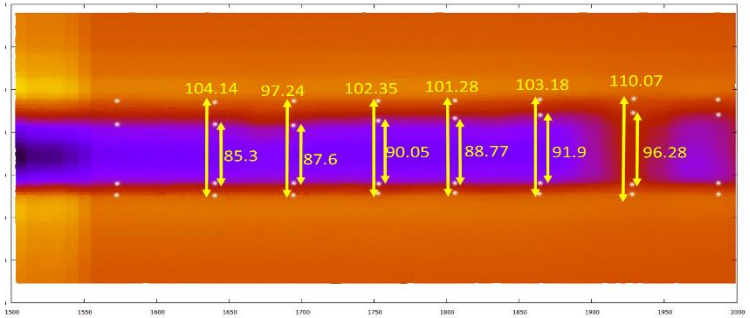
10T magnets (tapes) and FCC high current links (wires), Genova (IT)

Project structure:

- Characterize the sample received from companies:
  - T_c measurements via AC susceptibility (SQUID)
  - Bc_2 and J_c via resistive and magnetic measurements (SQUID)
  - Local properties via Scanning Hall Probe Microscopy (SHPM)

- Collaborate with ESR12 (A.Moros, TU Wien), trying to relate these quantities with microstructural properties





- Find relations with the manufacturing process and discuss with the sample suppliers about the possible improvements to be done

- ESR13 project state of the art

- ESR13 Nb_3Sn
  - APC
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- ESR13 MgB_2

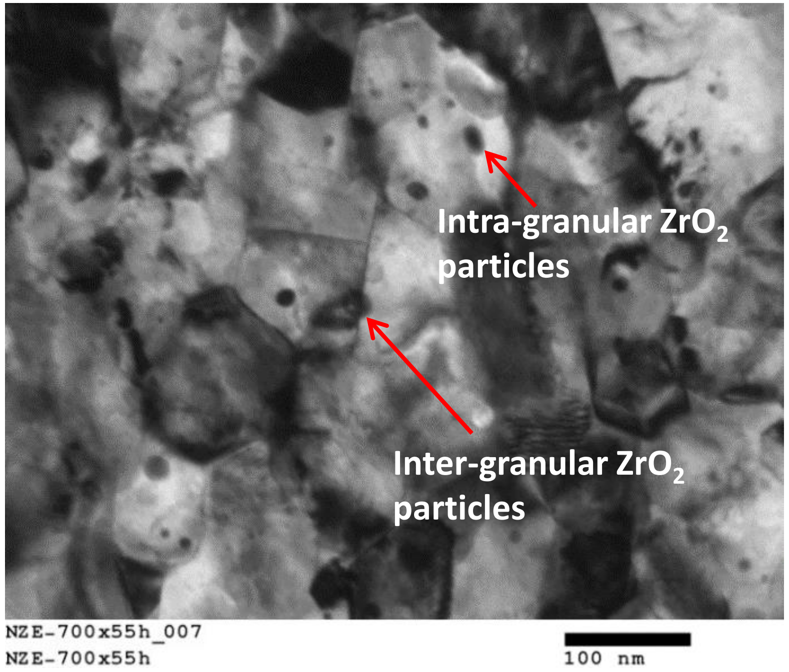
- Next steps

Prerequisites:

- Nb_3Sn wires are the best candidates envisaged for building the FCC-hh 16T dipole-magnets (cheaper than HTS)
- FCC-target performances (J_c = 1.5 kA/mm^2 at B_{appl}=16T and T=4.2 K) not yet reached with state-of-art commercial wires

Technology ("Internal oxidation method"):

- Oxygen selectively oxidizes Zr instead of Nb
- ZrO_2 nanoparticles to be used as additional pinning centres (intra and inter-granular)
- Nanoparticles should catalyse as well the A-15 grain size refinement, so that increasing Jc ($Jc = f(1/dgrain)$)



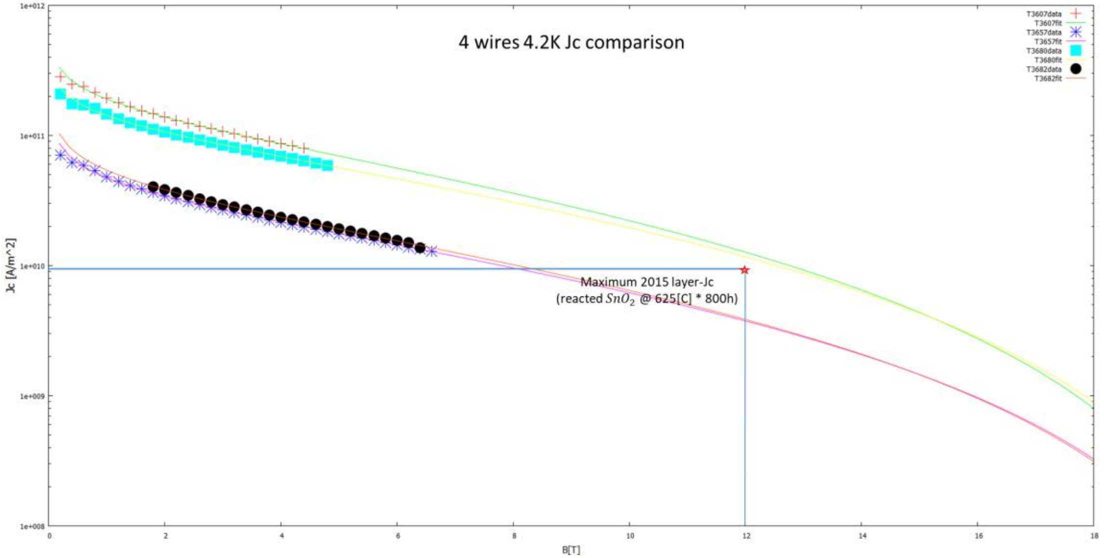
Milestones

❑ Characterization of prototype binary (ZrO_2 nanoparticles in A-15 phase) APC wires ✓

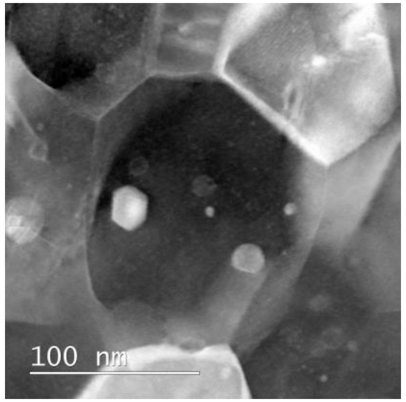
Higher Jc values than commercial wires

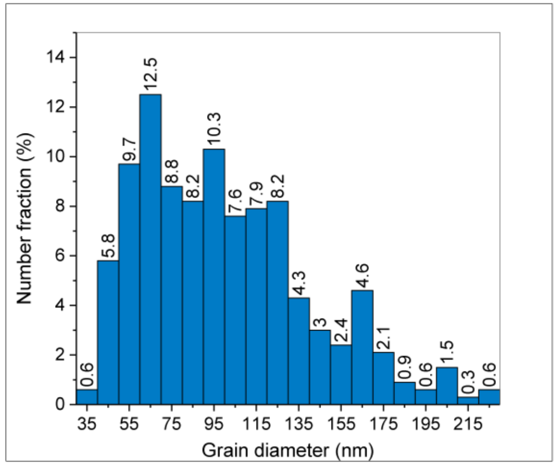
Shifted $F_p / F_{p\ max}$ peaks

Low Bc_2

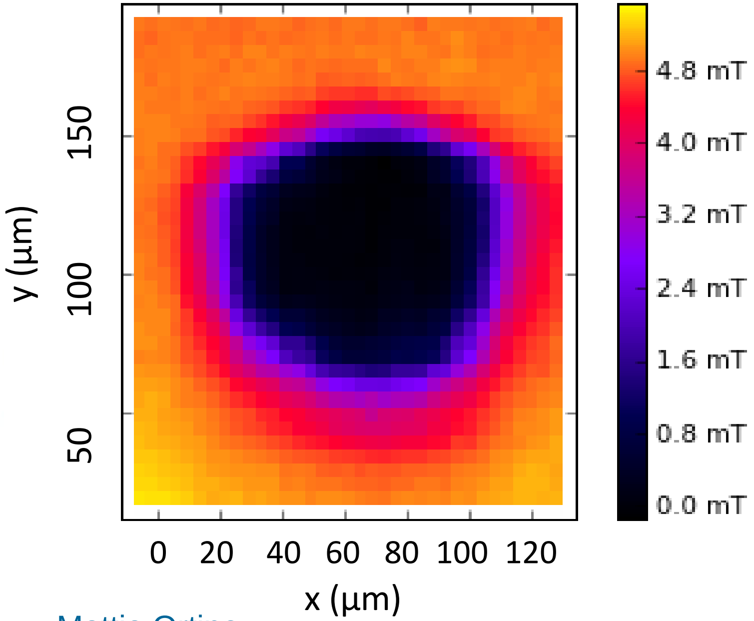


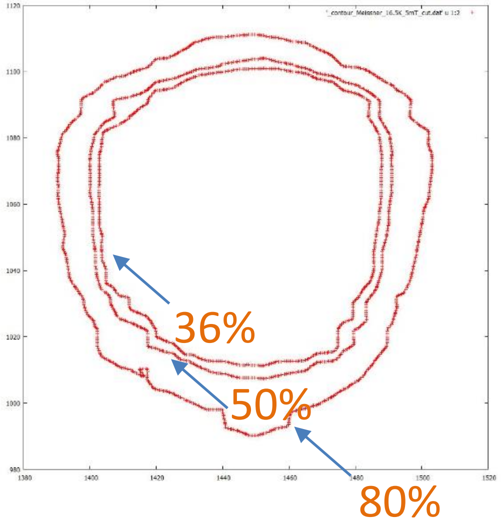
Grain size refinement





Local inhomogeneities





- Characterization of prototype ternary (ZrO_2 nanoparticles + Ta in A-15 phase) APC wires

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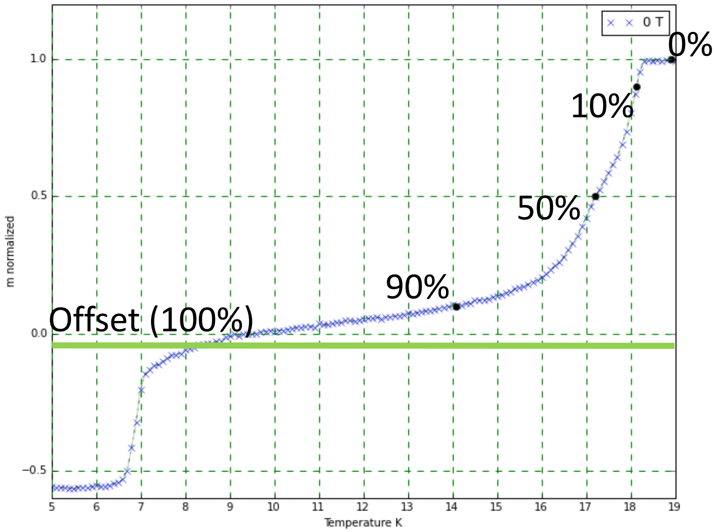
- Magnetization measurements: Tc and hysterisis loops



- Samples-slices prepared down to polishing limits (40 to 10 µm)

- SHPM

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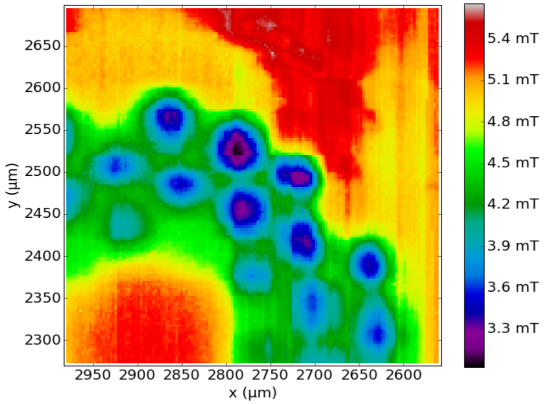

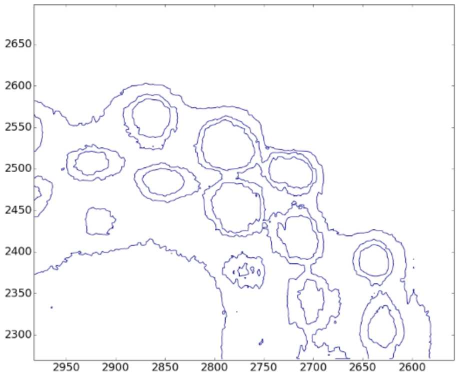

→ Possible to perform Tc-radial analysis (radial inhomogeneities investigation)

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- ESR13 Nb_3Sn
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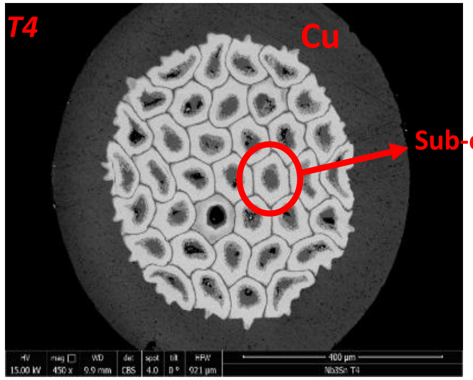
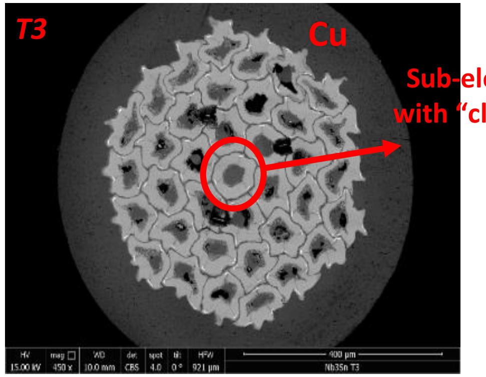
- ESR13 MgB_2

- Next steps

- 8 samples reiceved

	T1	T7 T8	T4 T5	T6	T2 T3
Wire identification	9a-4-17	16-1-17	11-3-17	11-10-17	11-2-17
Wire dia, mm	0.7	0.7	0.7	1	0.7; 0.36
Barrier	Common Ta	Common Nb+Ta	Distributed Nb	Distributed Nb	Distributed Nb+Ta
Subelement number	31	31	37	37	37
Subelement size, µm	-	-	80	120	80; 40





- Milestones:

1. ***AC magnetometry*** **-** in the range of temperature from 5 to 19 K;
Magnetic moment of wire sample as a function of temperature - M(T) curve for assessing T_c distribution.

2. ***Scanning Hall Probe Microscopy (SHPM)*** - in the range of temperature from 5 to 19 K;
Magnetization maps of individual sub-elements and clusters, Tc distribution within sub-elements and clusters and its variation between central and peripheral sub-elements

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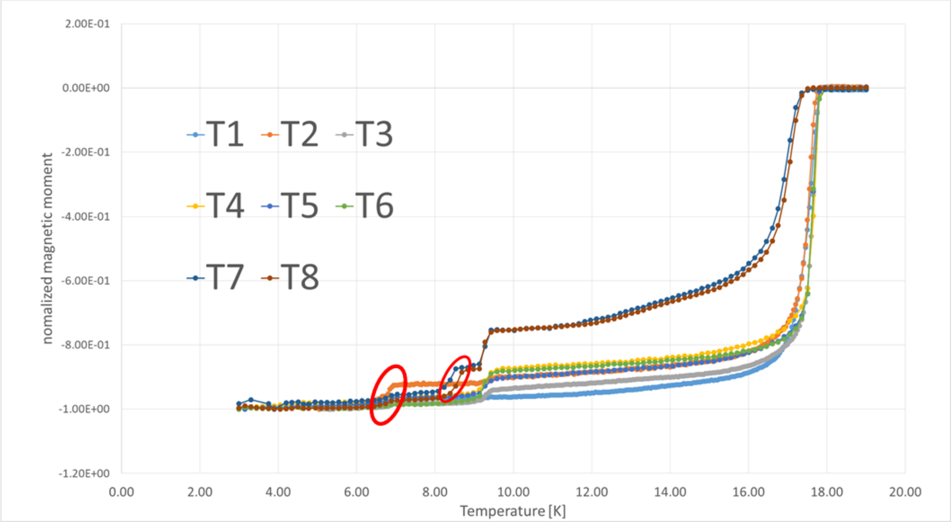
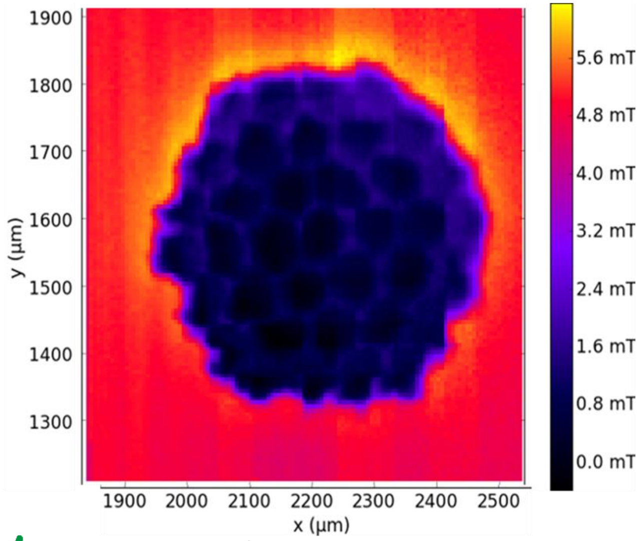
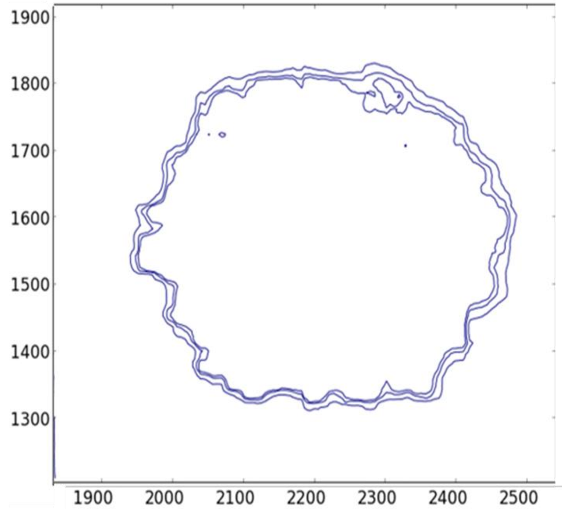
❑ AC Magnetometry ✓



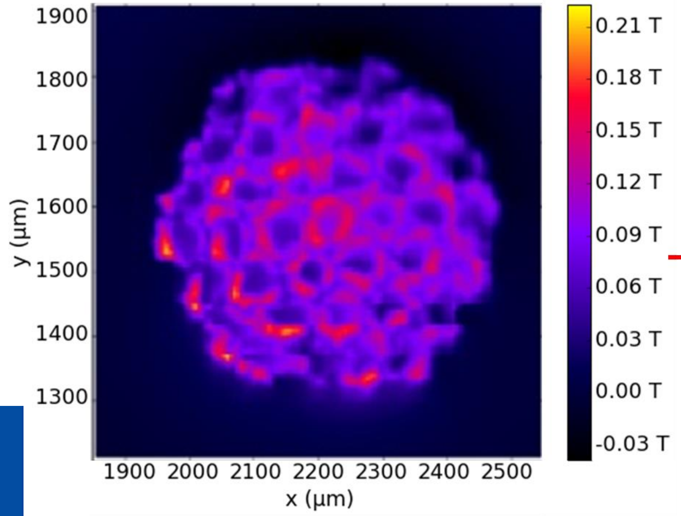
❑ SHPM : Meissner-state measurements ✓

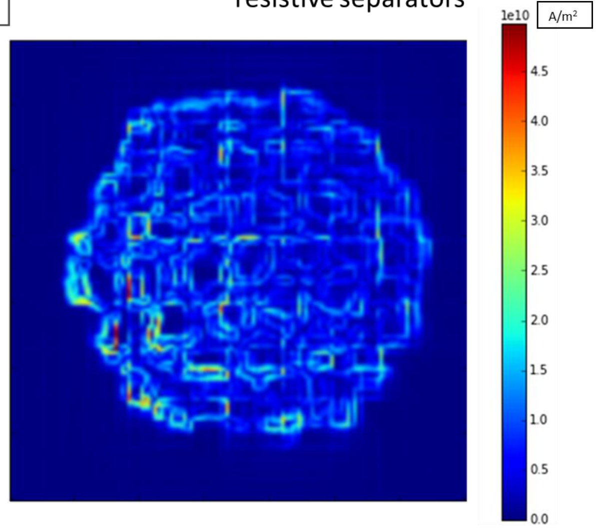




No field penetration into the resistive separators → No evidence of A-15 cross-sections variations ($f(T)$) → No radial T_c distribution achievable

❑ SHPM : Remnant field-state measurements ✓



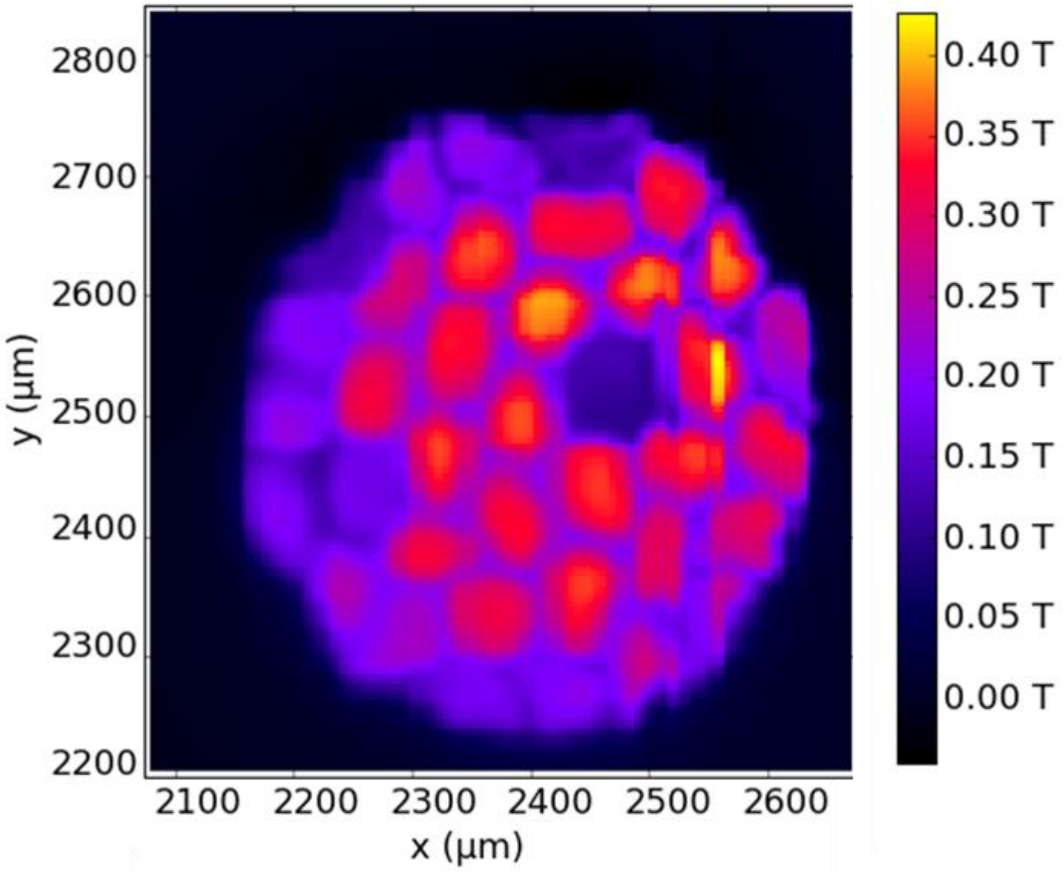


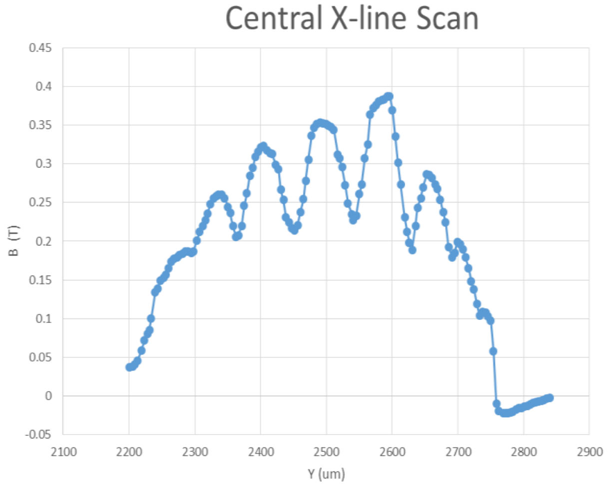
Remnant field scans used for local current evaluation

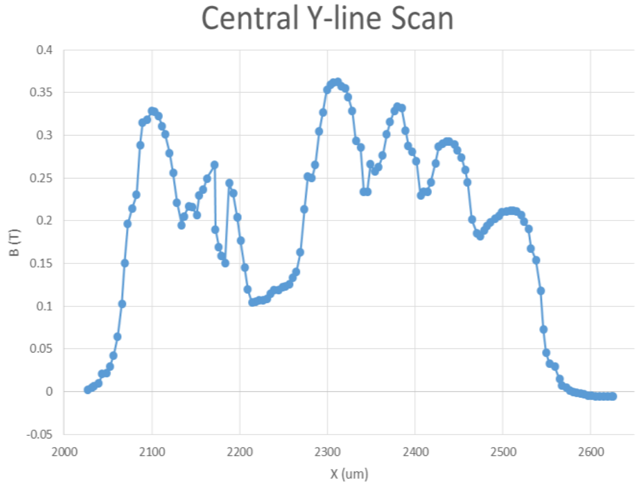
↓

In line with the state-of-art RRP wires (@ 10K, 0 T)

Sample without *clusters* (**T4**-distributed Nb)







Line scans reveal an inter-subelements coupling

- ❑ SHPM : Meissner and remnant-field scans on other samples

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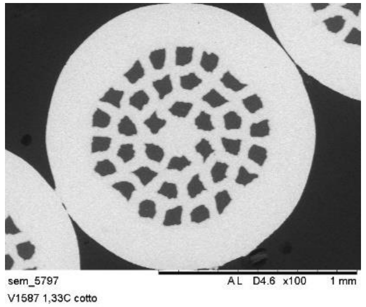
- ESR13 Nb_3Sn
  - APC
  - No APC

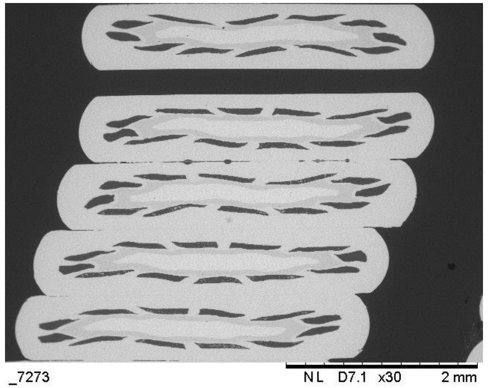
- ESR13 MgB_2

- Next steps

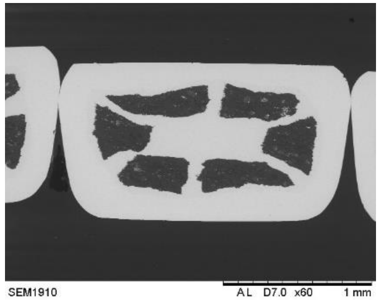
- 4 samples reiceved



1 wire



3 tapes



+ MgB_2 powder

- Titanium matrix

- Milestones:

1. Magnetometry (SQUID)-

- In the range of temperature from 5 to 39 K; Magnetic moment of wire sample as a function of temperature - M(T) curve for assessing Tc distribution.
- Hysteresis loops (Jc) and Bc2 (SQUID)

2. Scanning Hall Probe Microscopy (SHPM) –

- In the range of temperature from 5 to 39 K; Magnetization maps of individual sub-elements,
- Tc distribution within sub-elements (if possible)
- Jc from Biot-Savart law inversion

Together with ESR7 (M.Donato, ASG Superconductors)

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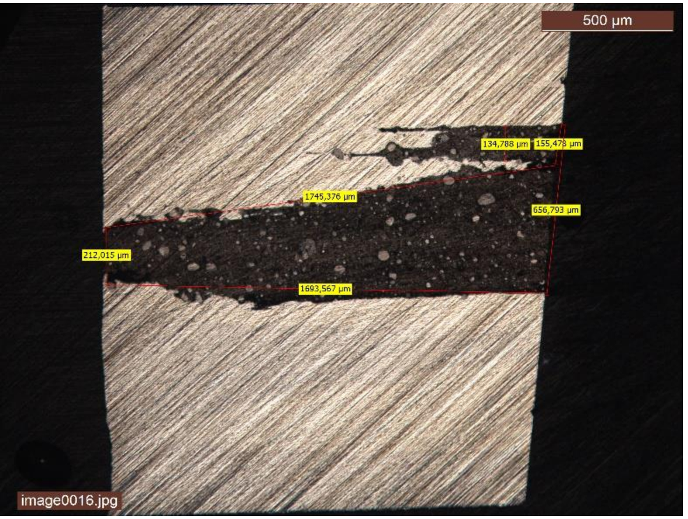
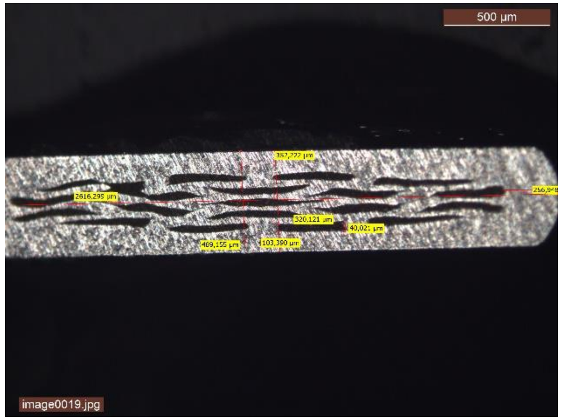
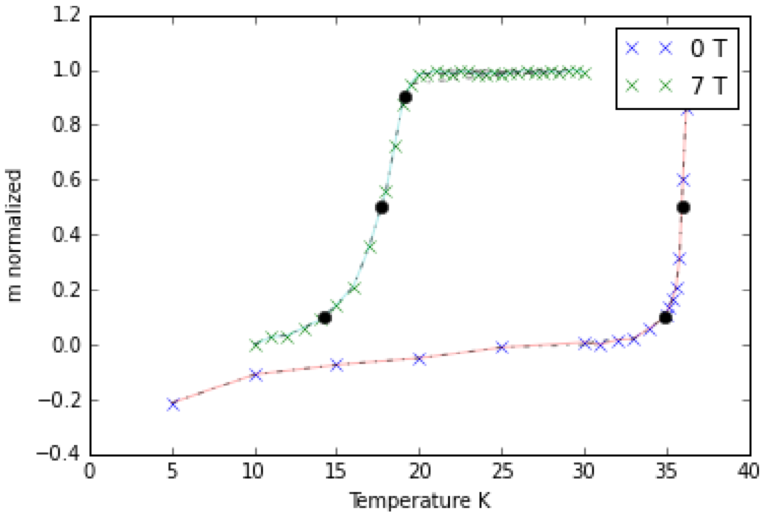


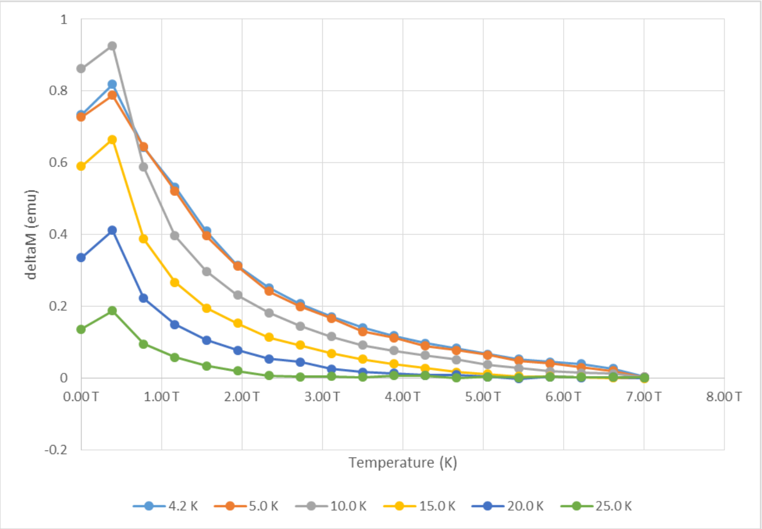


- ❑ Sample preparation ✓

- ❑ AC Magnetometry ✓



- ❑ Jc from Hysteresis Loops ✓



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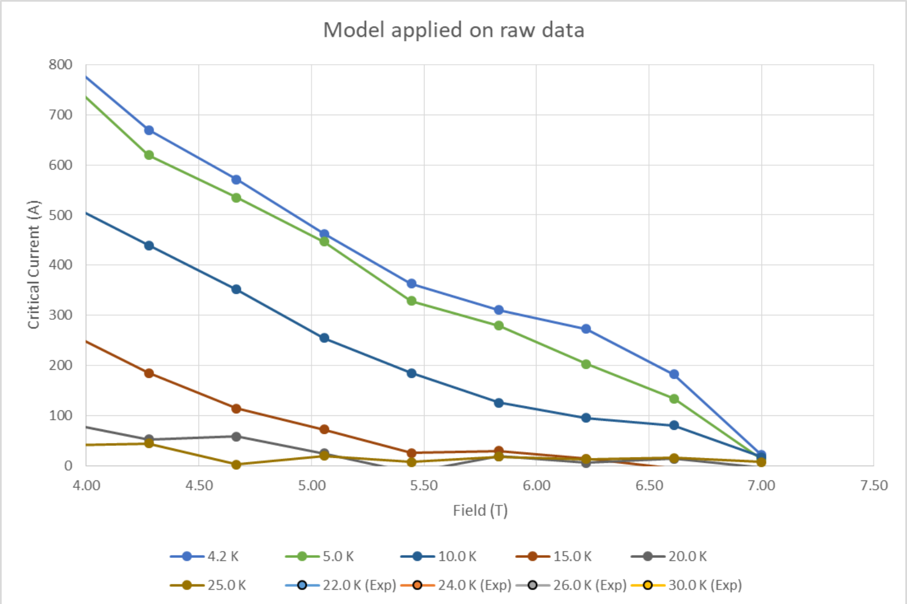
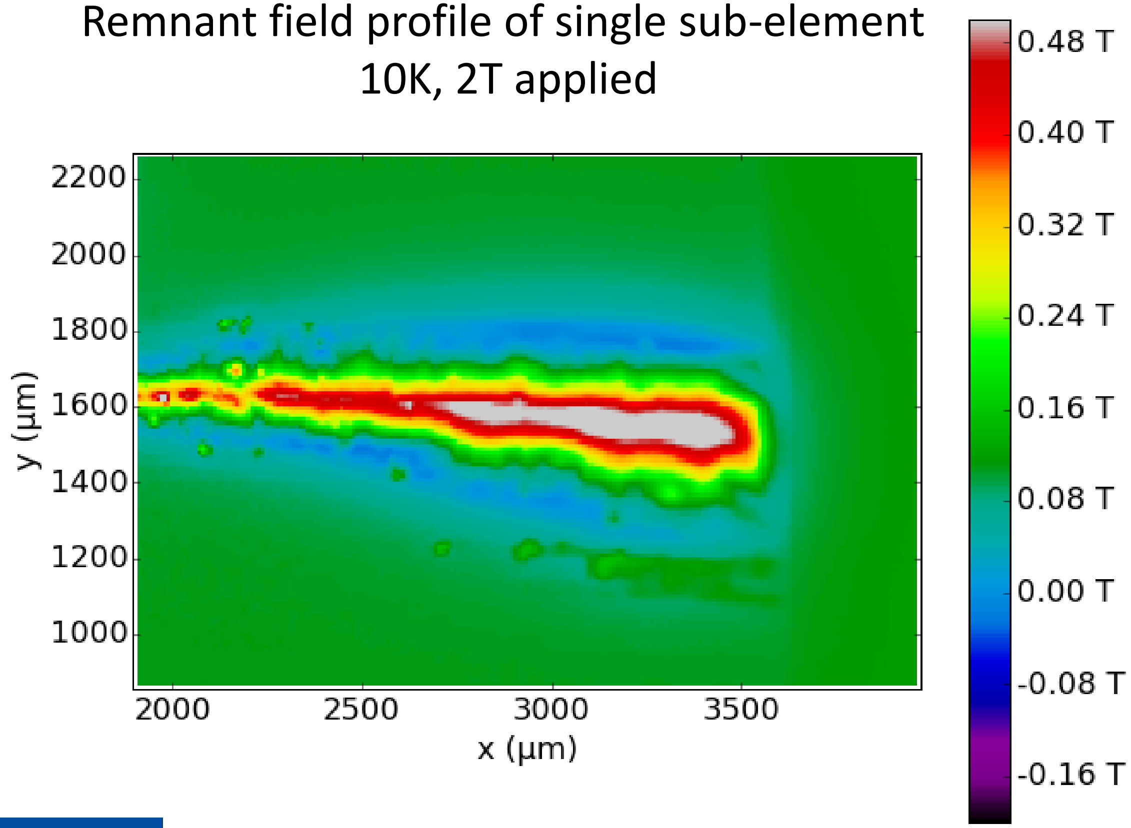
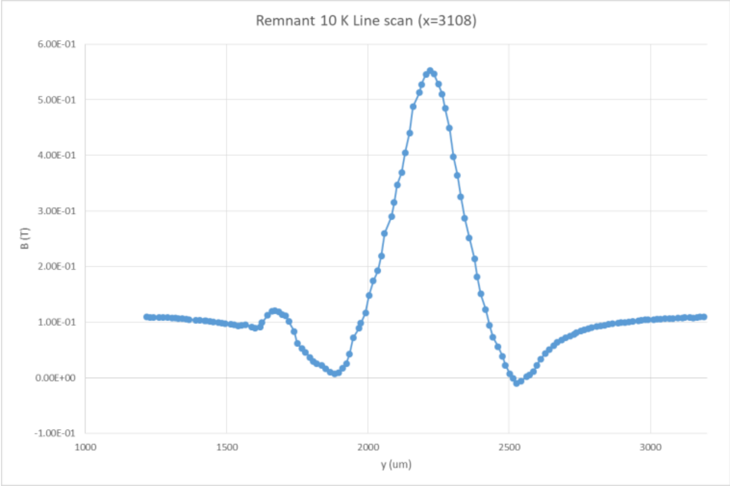


- SHPM : Remnant field-state measurements LOADING... → Only one tape analysed so far

Remnant field profile of single sub-element
10K, 2T applied





High magnetic background (Nichel)

On thin slices (<80 µm) reliable Jc extrapolation from Biot-Savart inversion (results comparable with those from resistive measurements)

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- ESR13 Nb_3Sn
  - APC
  - No APC

- ESR13 MgB_2

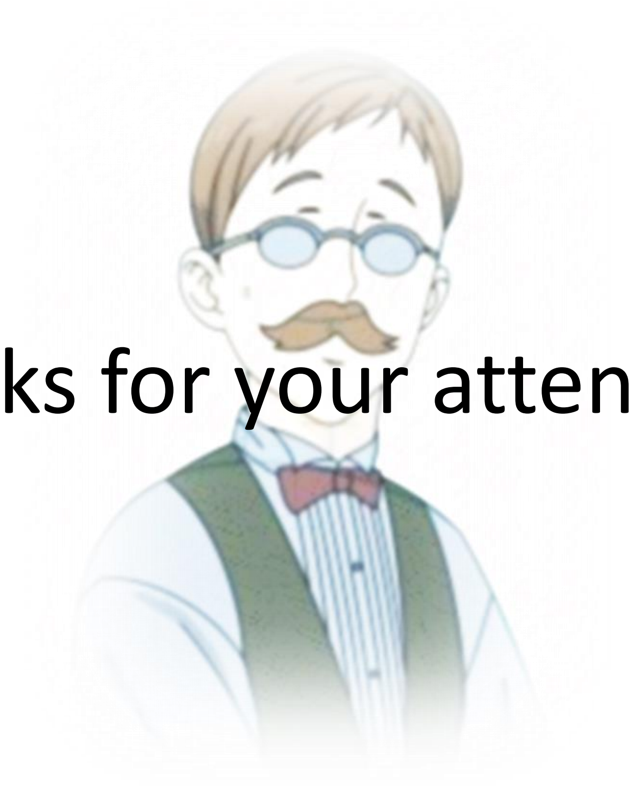
- Next steps

Next steps

- Nb_3Sn APC →
  - Sample preparation getting more important: new thin slices required for SHPM
  - Analyse local properties data (radial inhomogeneities, local currents) and relate them with microstructural ones
  - Analyse magnetometry data for Jc and Bc2 evaluation

- Nb_3Sn no APC →
  - Focus on samples with innovative layouts (T7 & T8) for local properties investigation
  - Isolate sub-elements (Cu-etching) for individual magnetic measurements
  - Relate results with microstructural ones (barriers width, elemental composition)

- MgB_2 →
  - New samples (new powder composition, new doping) coming: compare and understand performance differences from Jc and granulometry data
  - Etching of Nichel/Monel from bulk samples in order to measure with less magnetic background
  - Secondment in ASG Superconductors in October



Thanks for your attention!