

Bruker Energy & Supercon Technologies (BEST)



BRUKER HTS GmbH
ARIES project

BHTS August 2018



ARIES project

- **Processing 12mm wide HTS coated conductors with 50mic substrate thickness**
- **Experimental**
 - **General features when processing 50mic substrates**
 - **Increasing batch-size capabilities**
- **Results**
 - **Ic in-field performance**
 - **Addressing tape bending issue**
- **Summary and conclusion**

ARIES project

- **Processing 12mm wide HTS coated conductors with 50mic substrate thickness**
- **Experimental**
 - **General features when processing 50mic substrates**
 - **Increasing batch-size capabilities**
- **Results**
 - **Ic in-field performance**
 - **Addressing tape bending issue**
- **Summary and conclusion**

ARIES project

Key features during processing HTS coated conductors for ARIES project:

- Mechanical polishing of 12mm wide and 50mic thick stainless steel substrates
- YSZ coating of substrates on drum coater ABAD2 (w.o. diffusion barrier)
- Ceria and YBCO coating of YSZ substrates on drum coater PLD300 and PLD600
- Ag coating of HTS tapes on drum coater MET1 first, later on R2R coater Tacoma M, annealing of Ag-coated tapes on R2R oven Tacoma F

Still ToDo:

- Cu-plating of ARIES HTS coated conductors on R2R coaters PLA1 or PLA2

PROCESSING CHAIN OF HTS PILOT-LINE PRODUCTION

SUBSTRATE PREPARATION (SUB)

BUFFER LAYER COATING (ABAD)

HTS LAYER COATING (PLD)

METAL COATING (MET)

COPPER PLATING (PLA)

FINAL TAPE INSPECTION (INS)



ARIES project

- Processing 12mm wide HTS coated conductors with 50mic substrate thickness
- **Experimental**
 - **General features when processing 50mic substrates**
 - Increasing batch-size capabilities
- **Results**
 - Ic in-field performance
 - Addressing tape bending issue
- Summary and conclusion



ARIES project

Work plan

- Overview about all 12mm HTS tapes with 50mic substrate thickness processed for the ARIES project
- In addition, about 50m of 4mm wide HTS tape with 50mic substrate thickness has been processed for further analysis

Prod. Cycle	Tape ID#	SUB		ABAD		PLD		MET		CAP		INS		Bemerkungen *tape length in [m]
		IN*	OUT*	IN*	OUT*	IN*	OUT*	IN*	OUT*	IN*	OUT*	IN*	OUT*	
A12/75	17700-0-0-0	100	0											Mechanical polishing not sufficient, surface damaged
A12/75	17701-0-0-0	100	0											Tape surface damaged during mechanical polishing
A12/75	17702-1-1-0	100	90	85	85	85	81	81	81			81	79	First 50mic HTS tape with 80m length
A12/75	17703-1-1-0	100	84	84	84	84	30	30	30			30	30	First 50mic HTS tape with excellent Ic in field performance
	17703-1-2-0						54							
A12/75	17704-2-1-0	100	90	85	85	82	81	81	0					Tape handling failed, coating delamination
A12/75	17705-1-1-0	100	90	85	85	75	75	75	75			75	75	First 50mic HTS tape 2 x 75m batch processing
A12/75	17706-1-1-0	100	85	85	80	75	75	75	75			75	75	First 50mic HTS tape 2 x 75m batch processing
A12/75	17707-1-1-0	100	86	56	56									
	17707-1-1-1					26	24	24	24			24	24	
	17707-1-1-2					30	26	26	26			26	26	
	17707-2-1-0			30	30	30	25	25	25			25	25	First 50mic HTS tape with improved flatness
	Total	800	525	510	505	487	471	417	336	0	0	336	334	

ARIES project

Work plan

- Successful YBCO coating of 150m batch 12mm HTS tapes in PLD600



ARIES project

General features when processing 50mic substrates:

Compared to the standard stainless steel tapes,
the 50mic thin substrate...

- ... is very hard to polish mechanically (tape edges get easily damaged),
- ... is very sensitive during tape handling and winding, tolerances of tools and set-up must be kept very narrow,
- ... suffers from our spring on drum technology to keep tape under tension when processing,
- ... is very difficult to connect by spot welding (e.g. tape joints for R2R-transport),
- ... makes it more difficult to maintain the dimensional tape stability (e.g. strong tape curvature due to film stresses),
- ... is more sensitive to process temperature fluctuations.

Therefore, using HTS tapes with thin substrates is expected to have a significant impact on the processing yield !

ARIES project

General features when processing 50mic substrates:

Possible optimization scenarios:

- Using substrate with a higher strength (e.g. stainless steel cold rolled)
- Replacing mechanical polishing by electro-polishing.
- Avoiding spring on drum technology.

Example of a crumpled YBCO coated 12mm wide HTS tape with 50mic substrate:



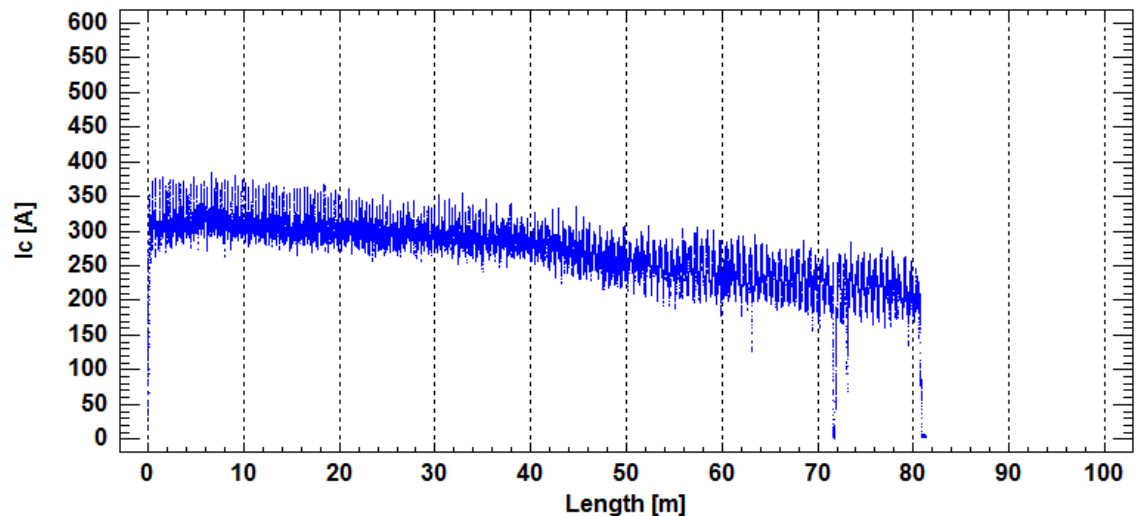
ARIES project

- Processing 12mm wide HTS coated conductors with 50mic substrate thickness
- **Experimental**
 - General features when processing 50mic substrates
 - **Increasing batch-size capabilities**
- **Results**
 - Ic in-field performance
 - Addressing tape bending issue
- Summary and conclusion

ARIES project

Increasing batch-size capabilities:

- In the past the limiting batch size for 12mm wide HTS tapes was defined by the MET1 equipment for Ag coating (tape length about 30m).
- Recent activities have been focused on the modification of the R2R coater Tacoma M to become able to process 12mm wide tape.
 - Modifications on the tape load lock were implemented and tested.
 - In July a first 80m long 12mm HTS tape was Ag coated successfully.



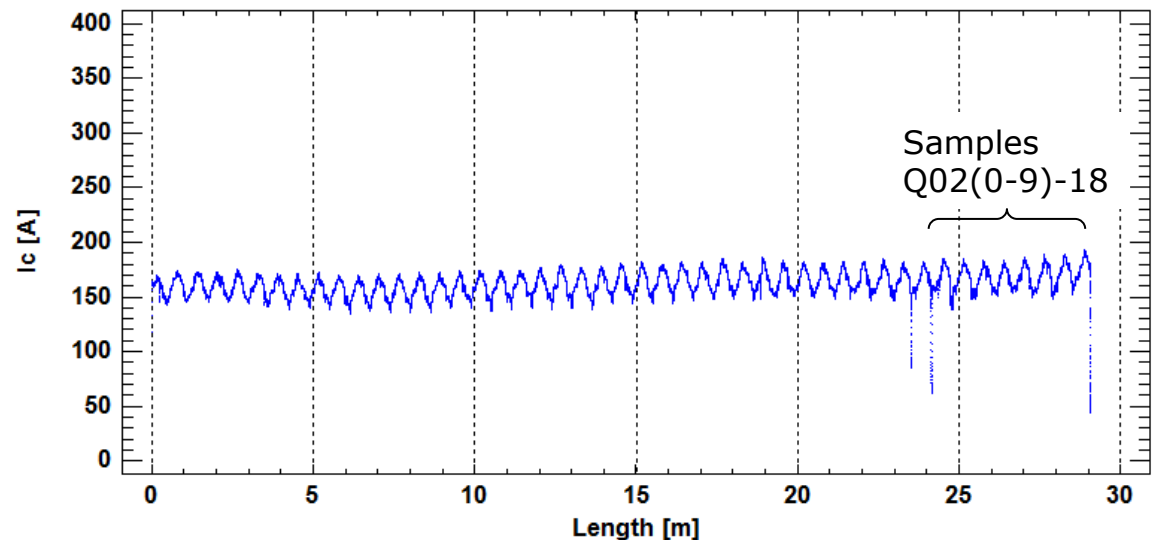
ARIES project

- **Processing 12mm wide HTS coated conductors with 50mic substrate thickness**
- **Experimental**
 - **General features when processing 50mic substrates**
 - **Increasing batch-size capabilities**
- **Results**
 - **Ic in-field performance**
 - **Addressing tape bending issue**
- **Summary and conclusion**

ARIES project

Ic in-field performance:

- PROCESSING 50 μm x 12 mm x 29 m HTS tape
 - Ic measurement from tape sample (start position) Ic-77K-SF=174A
 - Average Ic value from Hall-Probe-Measurement (TapeStar) of the 29m long HTS tape Ic-77K=161A
 - 2 x Ic drops detected in the range 23-25m



BRUKER HTS

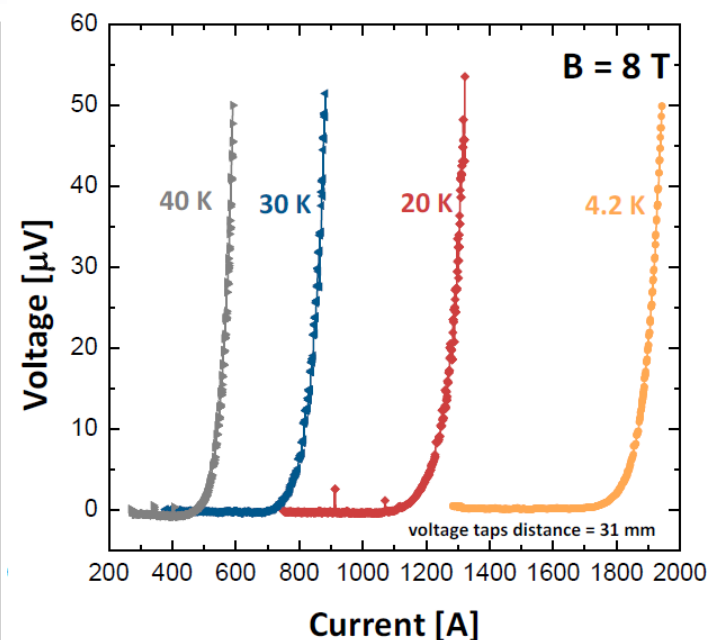
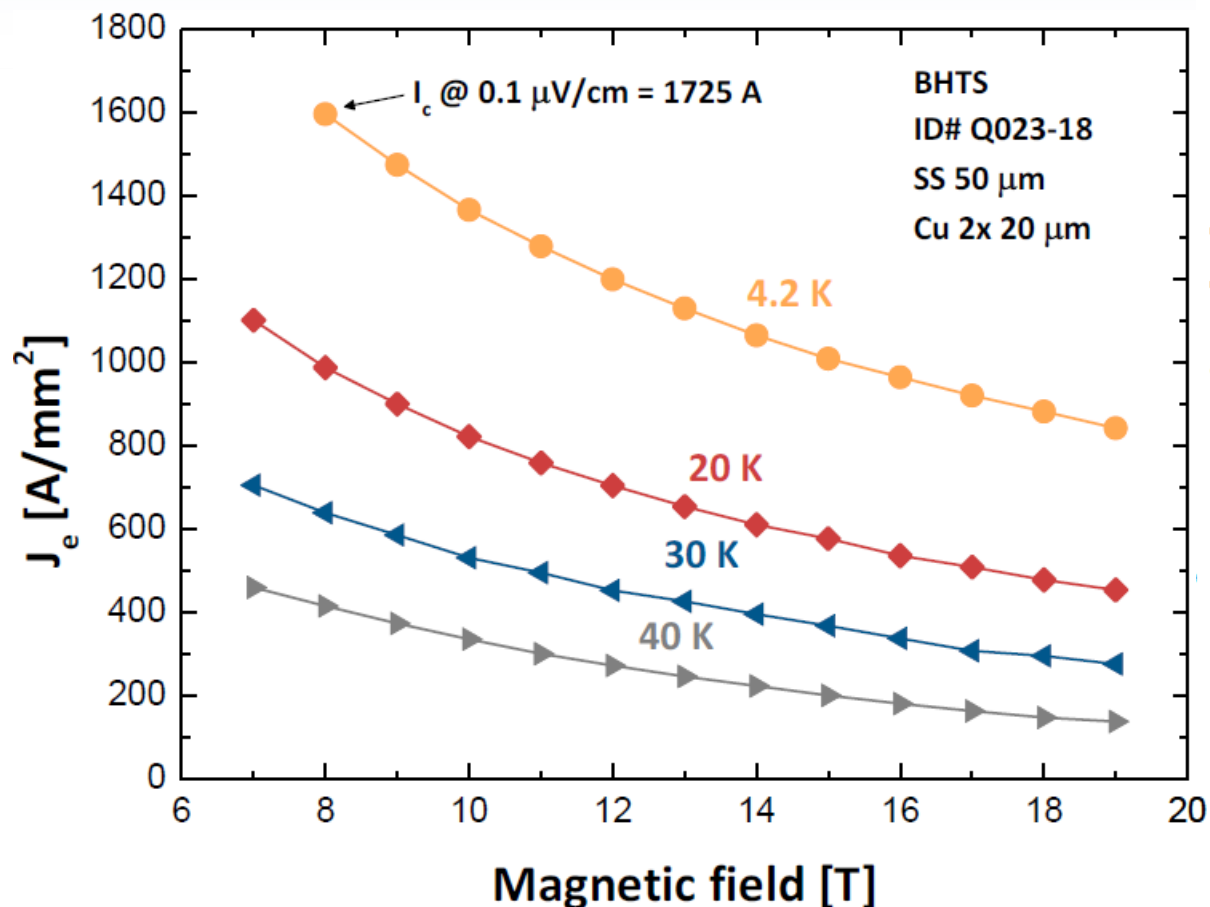
YBCO COATED CONDUCTORS FOR UH FIELDS



IN-FIELD TAPE PERFORMANCE: GENF, C SENATORE, APR 2018

12-mm ARIES tape: 50 μm SS + 2x 20 μm Cu

full-width test!!



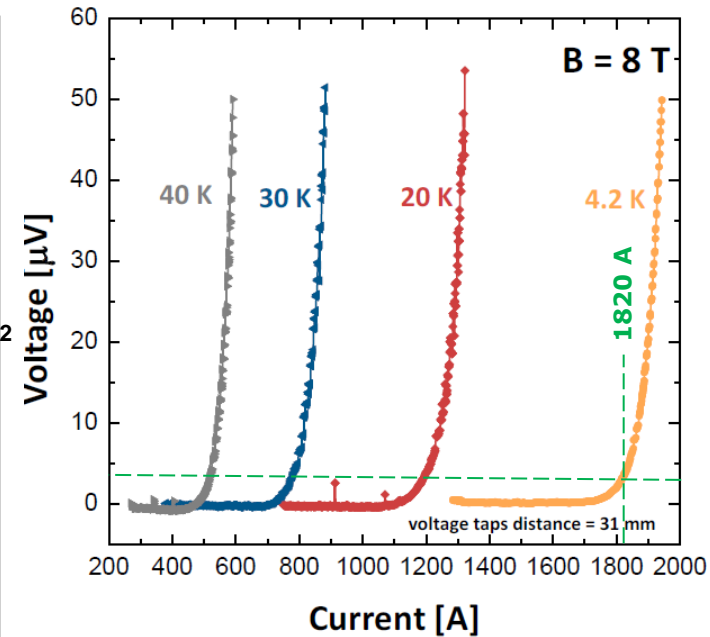
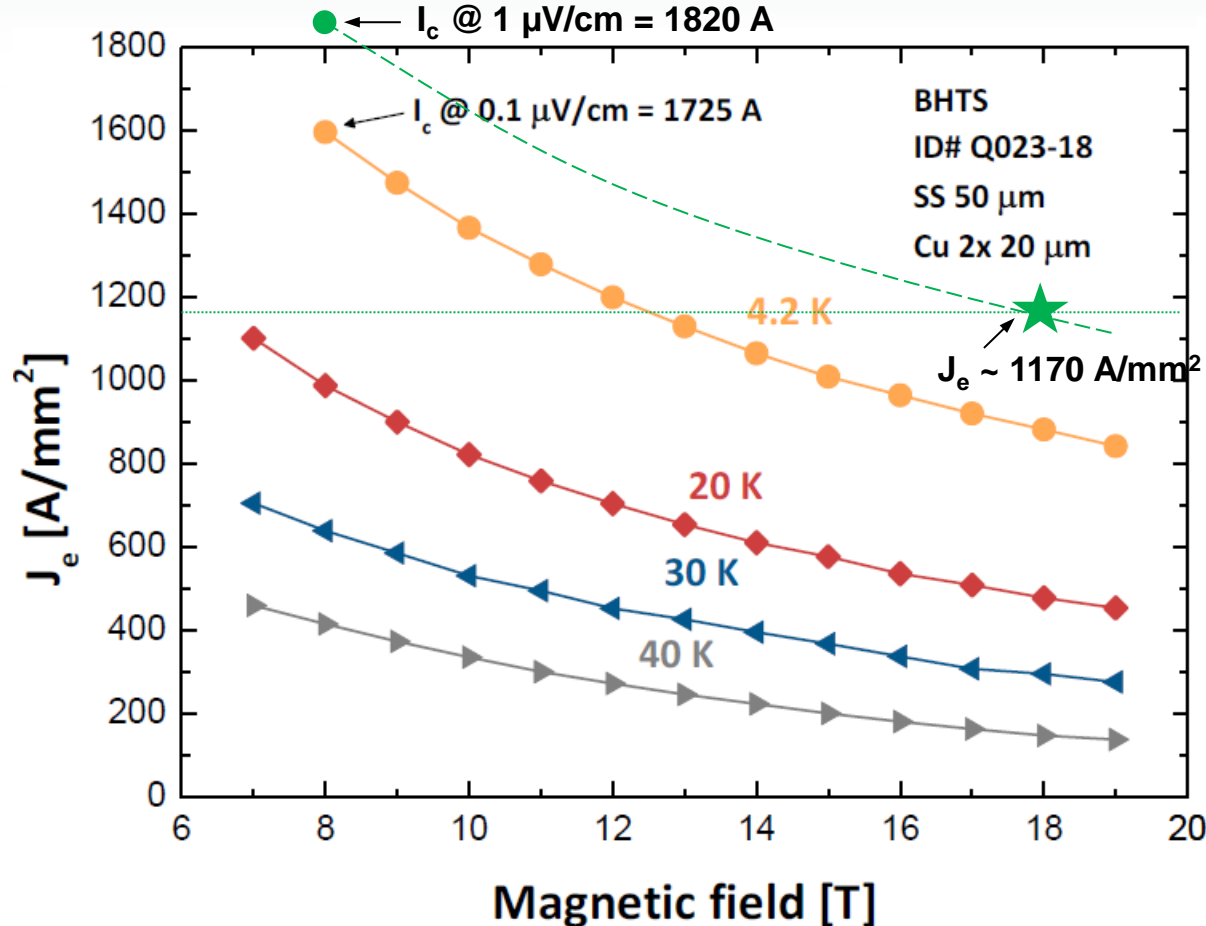
Carmine SENATORE, Christian BARTH, Damien ZURMUEHLE

BRUKER HTS YBCO COATED CONDUCTORS FOR UH FIELDS



IN-FIELD TAPE PERFORMANCE: GENF, C SENATORE

BHTS: WITH OTHER CRITERION – 1 μV/cm



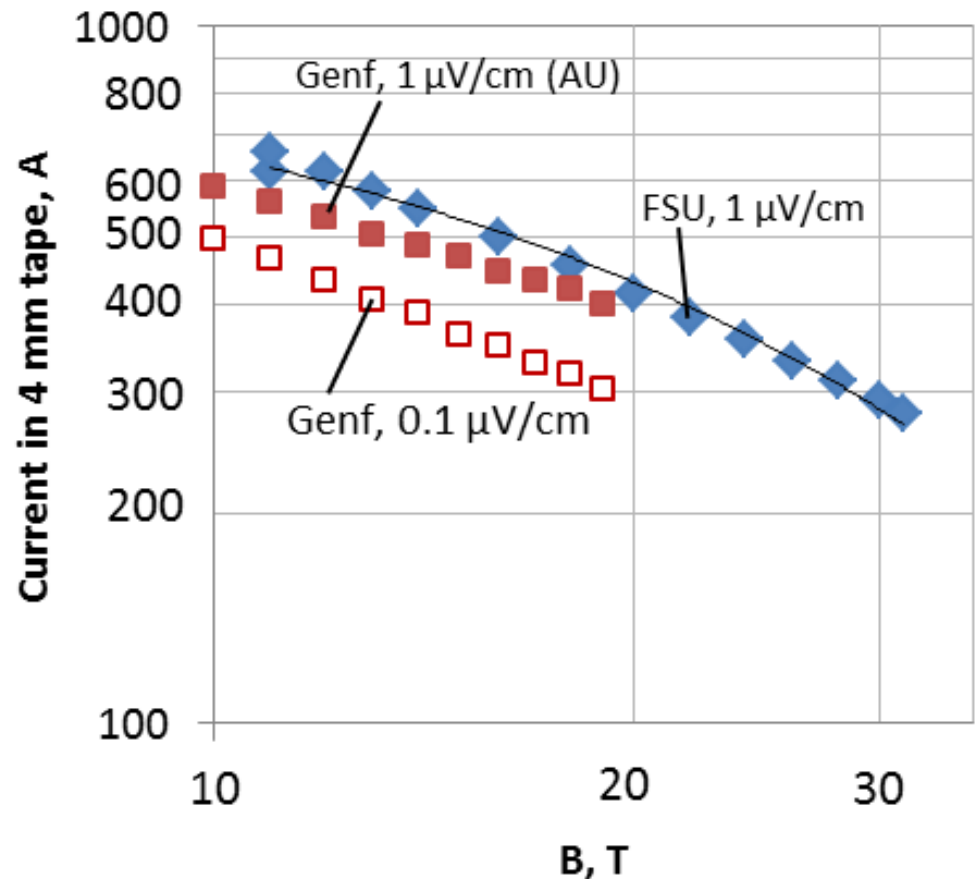
0,1 μm/cm	1725
1 μV/cm	1820
i_1/i_2	1,05507246
$(v_1/v_2)^{43}$	10,0262472
n-value	43

Carmine SENATORE, Christian BARTH, Damien ZURMUEHLE

IN-FIELD TAPE PERFORMANCE:

COMPARISON GENF AND FSU DATA FOR THE SAME TAPE

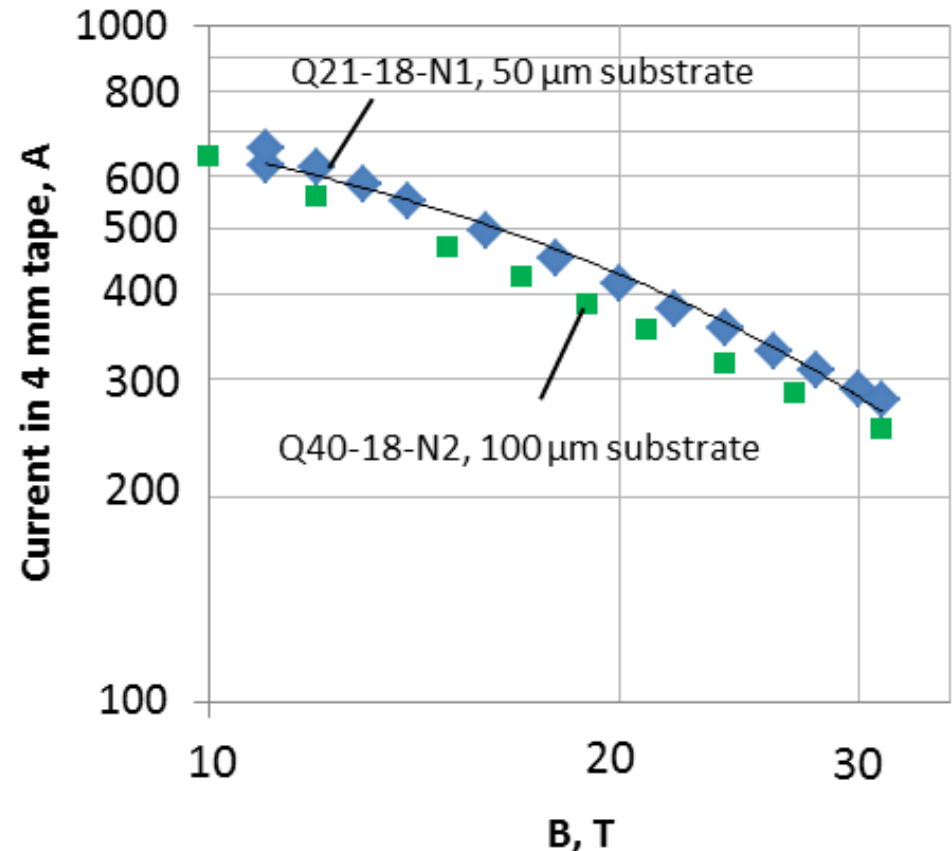
- Variation of the voltage criterion has drastic influence to the output values of critical current
- We checked that the relationship between critical currents is still in the frame of n-law validity. But anyhow, re-calculation is not a secure way.
- Recalculated critical currents are not too far from I_c -s delivered by FSU.



IN-FIELD TAPE PERFORMANCE (FSU):

Comparison of tapes based on 50 and 100 μm substrate

- Q021-18-N1 is 4mm wide sample that was cut from 12 mm wide and 90 μm thick tape based on 50 μm thick stainless steel substrate. Some other similar samples cut from this tape yielded a bit lower current.
- The Q040-18-N2 : is a sample cut from 4 mm wide tape of good, but representative quality.
- Thus, I_c level is comparable in both tapes while J_e is about 30-40% higher in thinner tape.



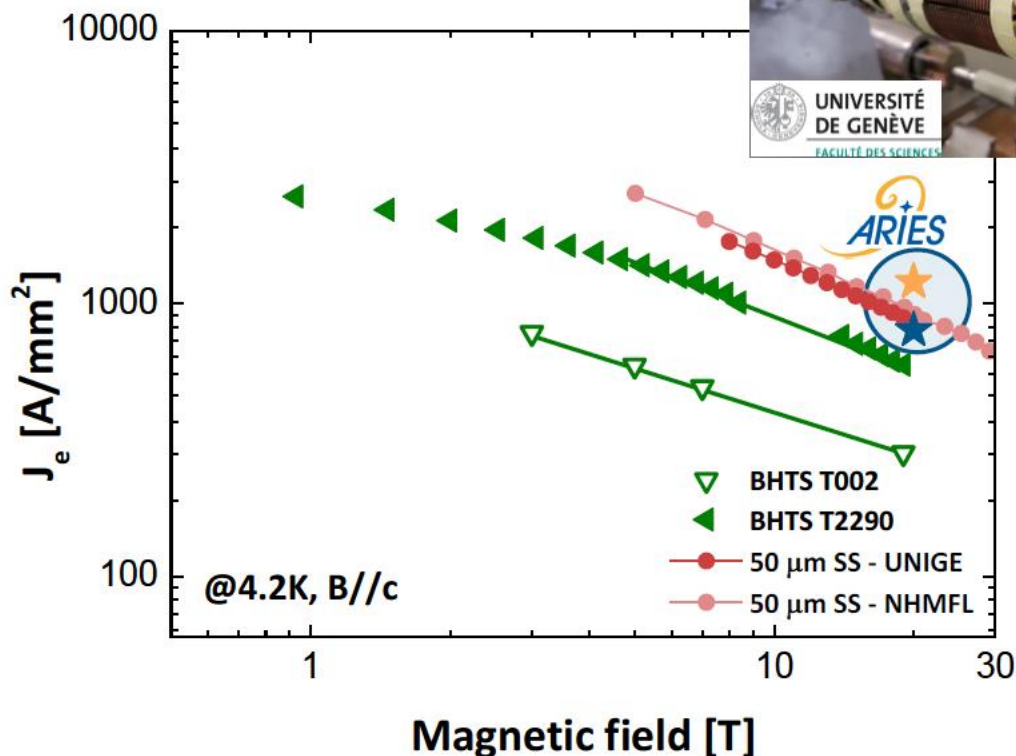
BRUKER HTS YBCO COATED CONDUCTORS FOR UH FIELDS



IN-FIELD TAPE PERFORMANCE: GENF, C SENATORE, MAY 2018

First I_c measurements: where do

- Comparison between FSU and GENF data was shown at ARIES meeting (Riga, May 2018) with too low J_e -s.
- FSU team does not understand origin of these low values as well



MS45 is successfully achieved !!

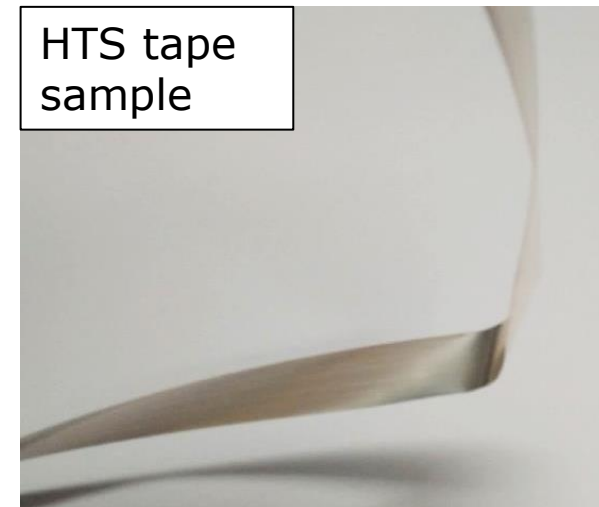
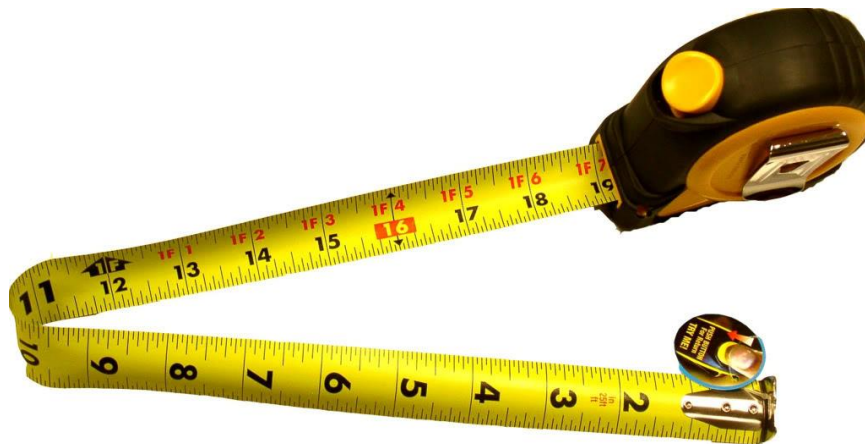
ARIES project

- **Processing 12mm wide HTS coated conductors with 50mic substrate thickness**
- **Experimental**
 - **General features when processing 50mic substrates**
 - **Increasing batch-size capabilities**
- **Results**
 - **Ic in-field performance**
 - **Addressing tape bending issue**
- **Summary and conclusion**

1st year project report / Apr 26th 2018

GENERAL APPEARANCE OF HTS TAPES WITH 50 μm SUBSTRATES

- HTS tapes reveal a strong tape curvature (tape bow) due to intrinsic film stresses of the coatings
- By bending, 50 μm thick tape exhibits a transient area between transversal to longitudinal curvatures. This leads to a characteristic „knee“ when the free tape is bent e.g. by own weight. Within this knee, curvature does not exceed the critical one: no deterioration of I_c is observed after flattening - **bi-stabile mechanics of pre-stressed tape***



*International Journal
of Solids and Structures
41 (2004) 2801-2820

1st year project report / Apr 26th 2018

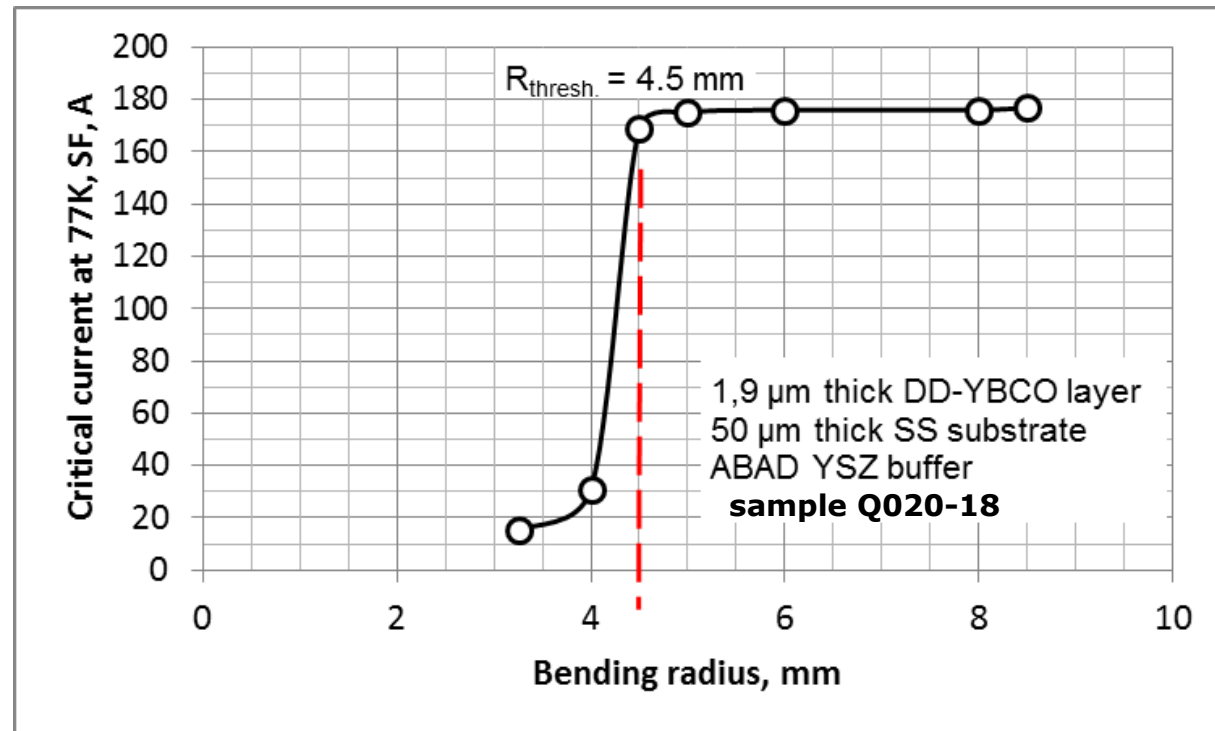
MECHANICAL TESTING

- Measurement of I_c -77K-SF versus a bending radius

Simple device:



Result:

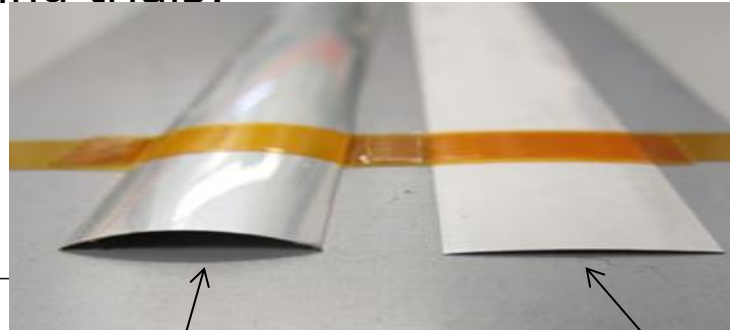


1st year project report / Apr 26th 2018

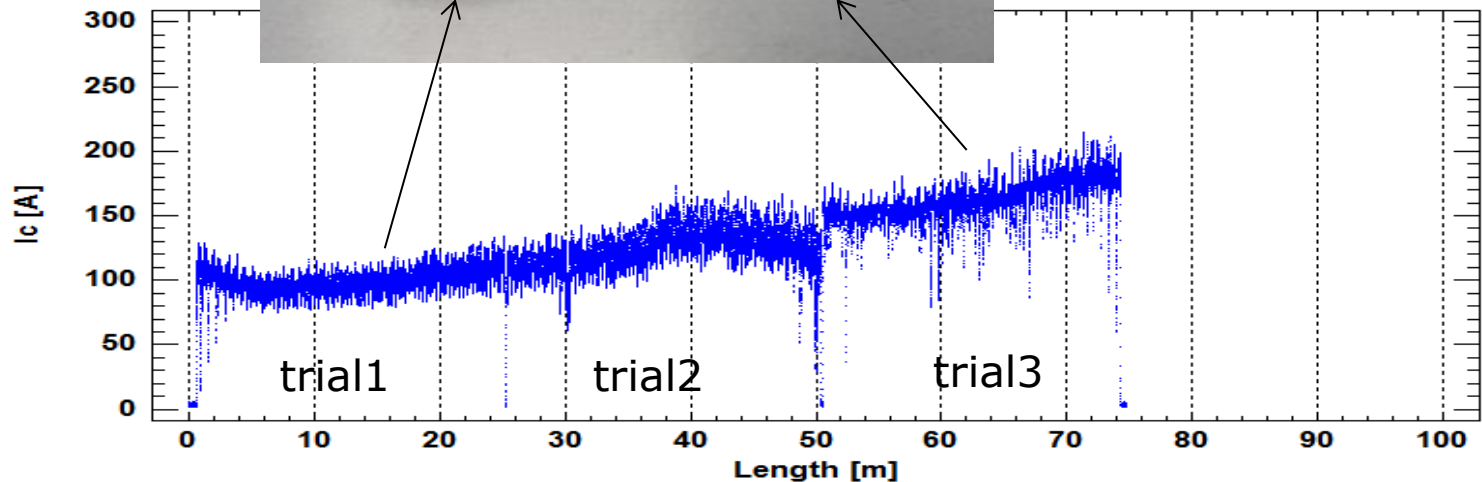
Process development activities with the aim to DECREASE THE TAPE BOW of 12mm wide HTS tapes with 50mic substrates, significantly.

- First results from coating trials:

TapeStar analysis of 3 x 25m HTS tapes



12 mm wide HTS tapes with different tape curvature in transverse cross-section

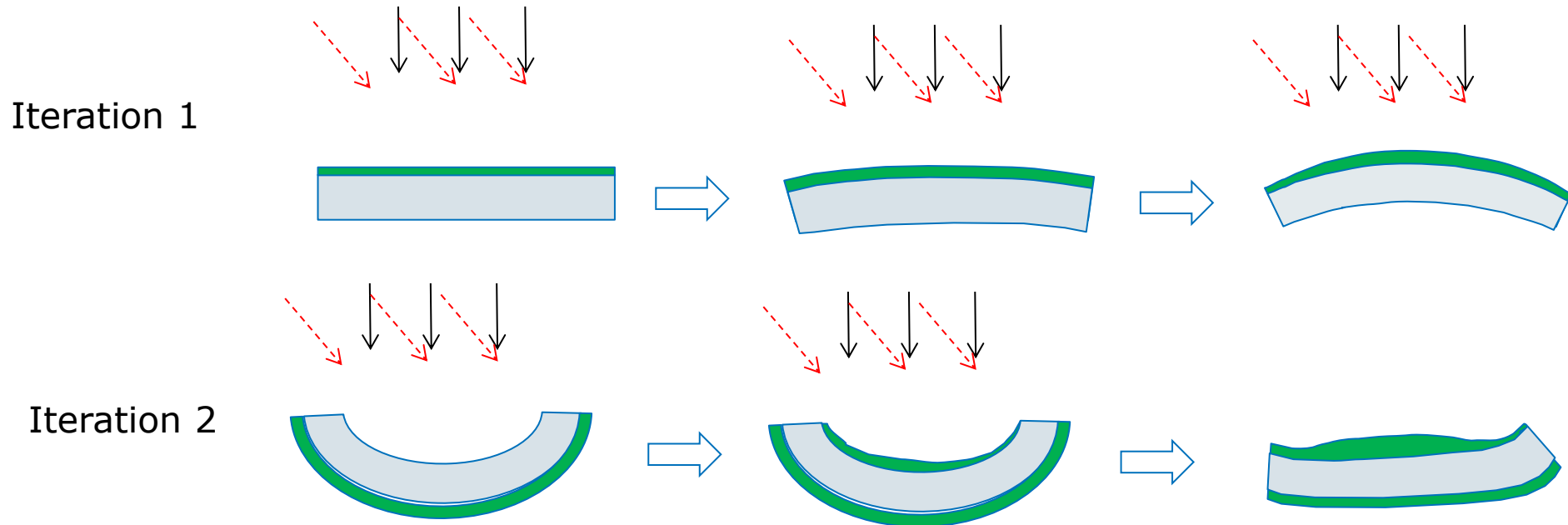


ARIES project

Addressing tape bending issue

Alternative solution: Shape correction procedure (schematic)

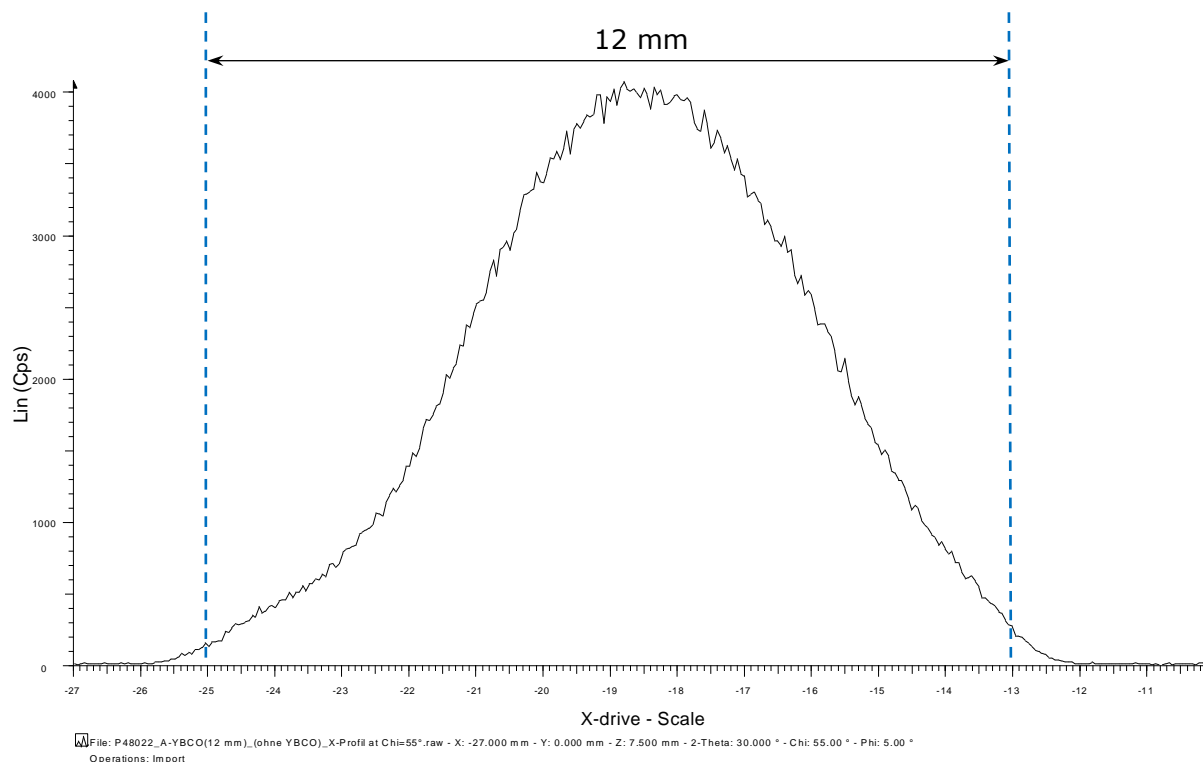
- Correction of tape profile follows at either before or after ABAD-YSZ buffer deposition:



ARIES project

Addressing tape bending issue

Result of shape correction via Iteration 2; X-profile of (111)YSZ peak:

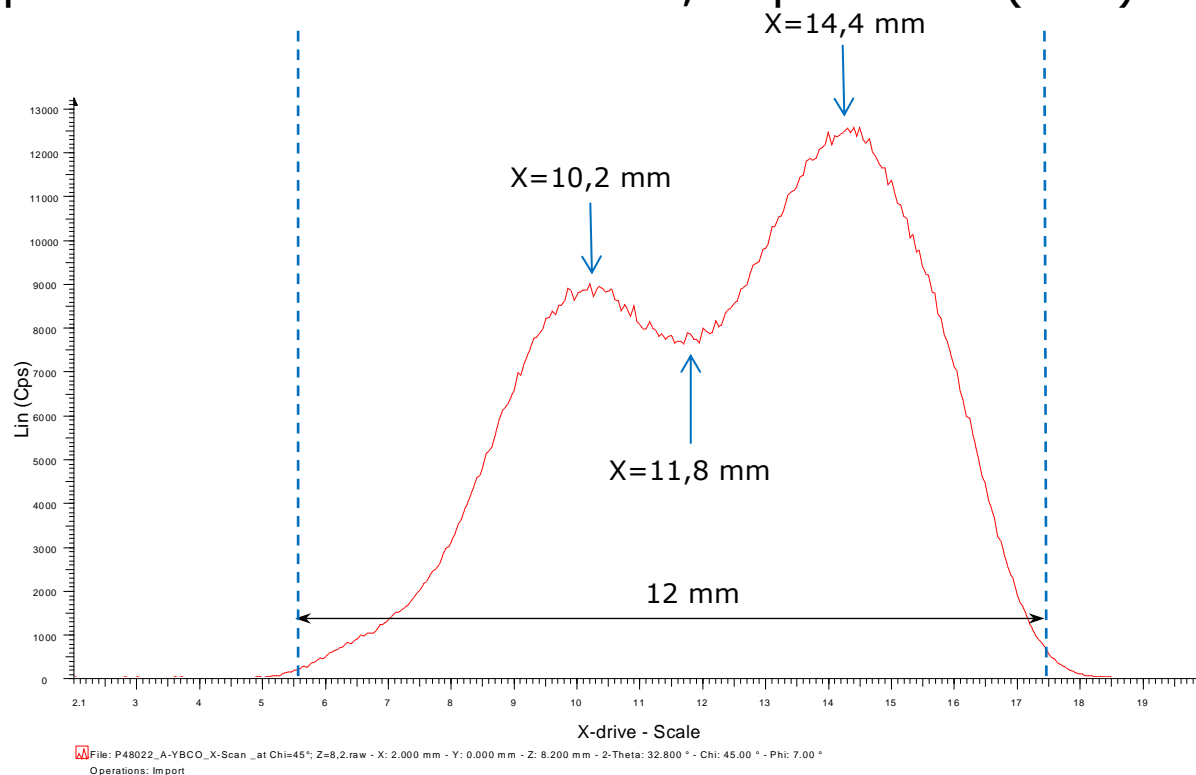


Aufgenommen bei $\Phi=0^\circ$ (1-er Peak des Phi-scans)

ARIES project

Addressing tape bending issue

Result of shape correction via Iteration 2; X-profile of (103) YBCO peak:



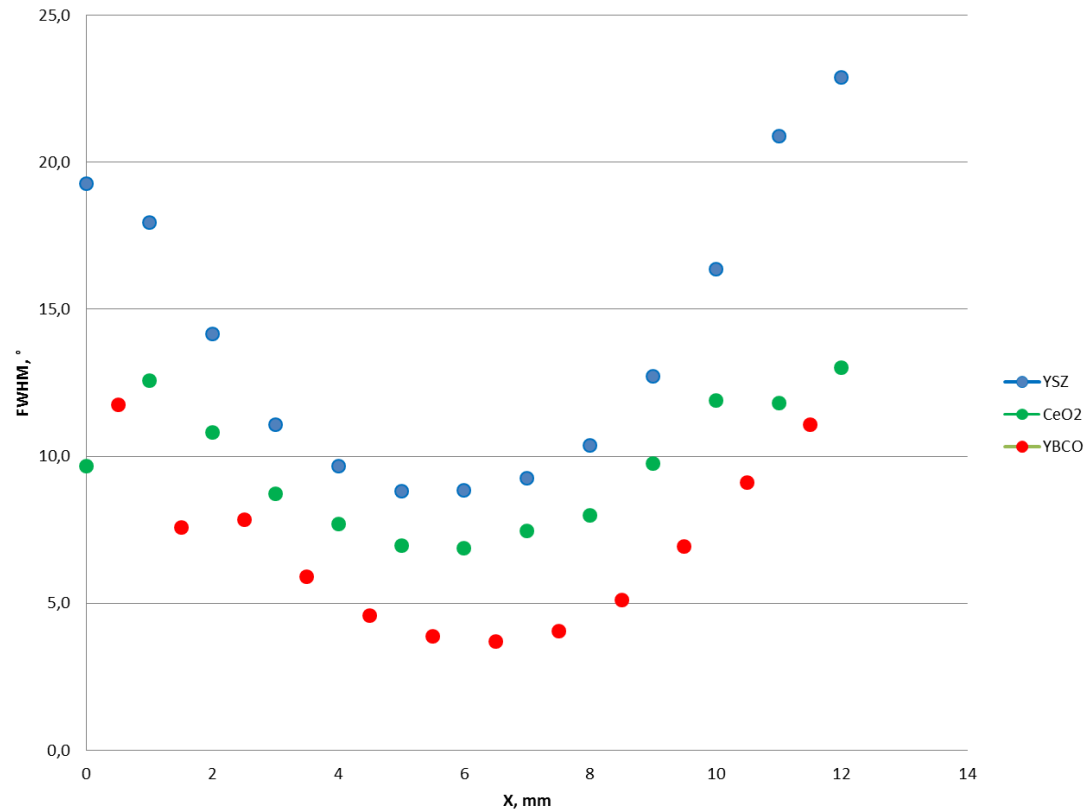
Recorded at $\Phi=0^\circ$ (1-st peak of Φ -scans)

ARIES project

General features when processing 50mic substrates:

Result of shape correction via Iteration 2

- in-plane texture of YSZ, CeO₂ and YBCO layers

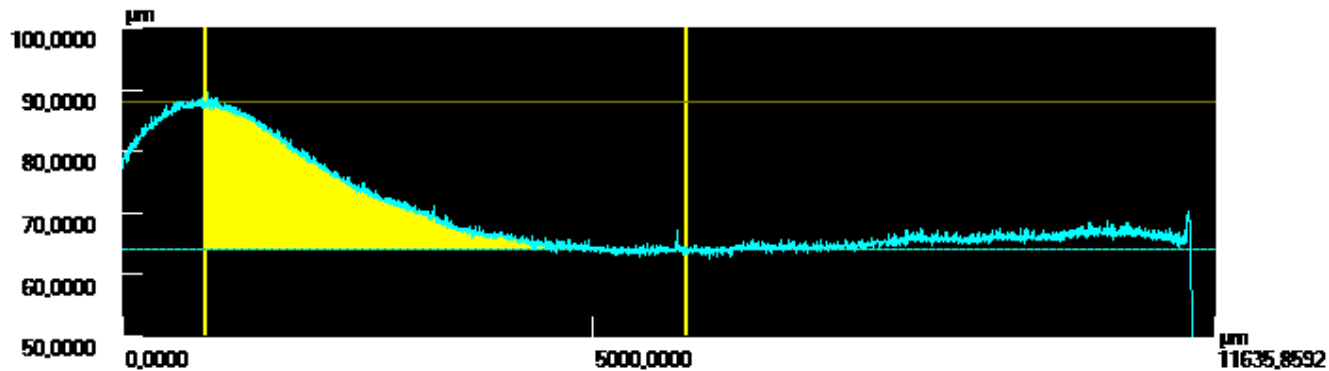


ARIES project

Addressing tape bending issue

Result of shape correction via Iteration 2

- Tape shape in transversal cross-section



Profil1	Horiz.Abst.	Höh.Unters.
Alle	11635,8592...	47,6515µm
Seq.1	5123,9876µ...	23,7120µm
Seq.2		

ARIES project

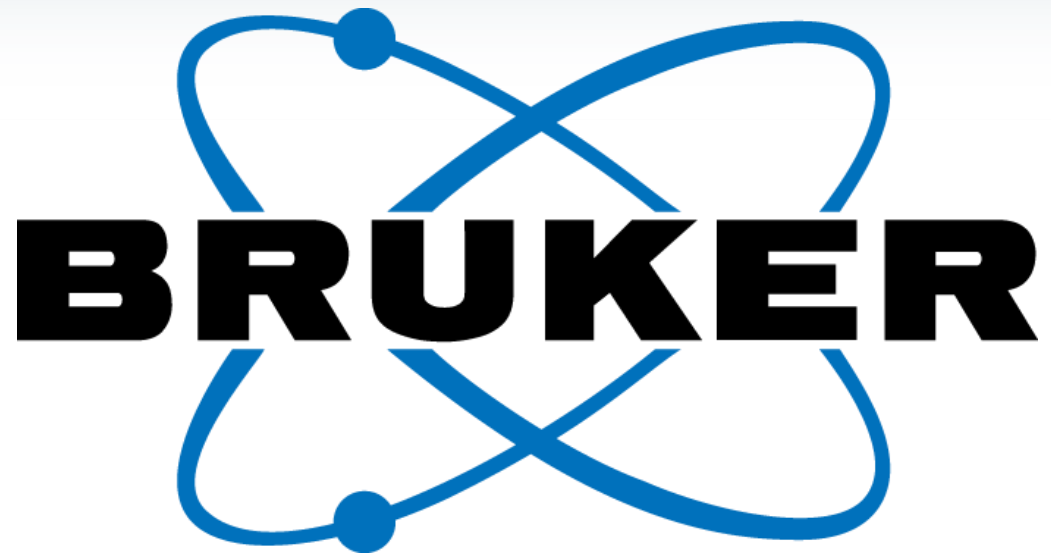
- **Processing 12mm wide HTS coated conductors with 50mic substrate thickness**
- **Experimental**
 - **General features when processing 50mic substrates**
 - **Increasing batch-size capabilities**
- **Results**
 - **Ic in-field performance**
 - **Addressing tape bending issue**
- **Summary and conclusion**



ARIES project

Summary and conclusion

- HTS tapes based on 12 mm wide and 50 μm thick stainless steel substrates have been processed successfully at BHTS. However, due to a higher sensitivity of the thin substrates a detrimental effect on the processing yield must be expected.
- The in-field performance of such tapes has been measured at different labs, critical engineering currents exceeded 1000A/mm² at 4.2K, 18T B//c.
- A successful increase of the processing capability for 12mm wide HTS tapes has been achieved:
 - The PLD600 is capable to process 150m long 12mm wide HTS tapes batches in one coating run.
 - By utilizing the Tacoma M equipment, the batch-size for 12mm wide HTS tapes has been increased successfully from about 30m to above 80m.
 - Therefore, the bottle neck of the BHTS pilot-line in regards to the batch size is the mechanical polishing step with a maximum tape length of about 90m for the 12mm wide substrates.
- New development steps have been performed to reduce the tape bowing.



Innovation with Integrity