EuCARD-2 is co-funded by the partners and the European Commission under Capacities 7th Framework Programme, Grant Agreement 312453

Investigation of the Roebel cable geometry and current homogeneity over lengths relevant to accelerator-type demonstrator magnet.

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CERN, Geneva, Switzerland

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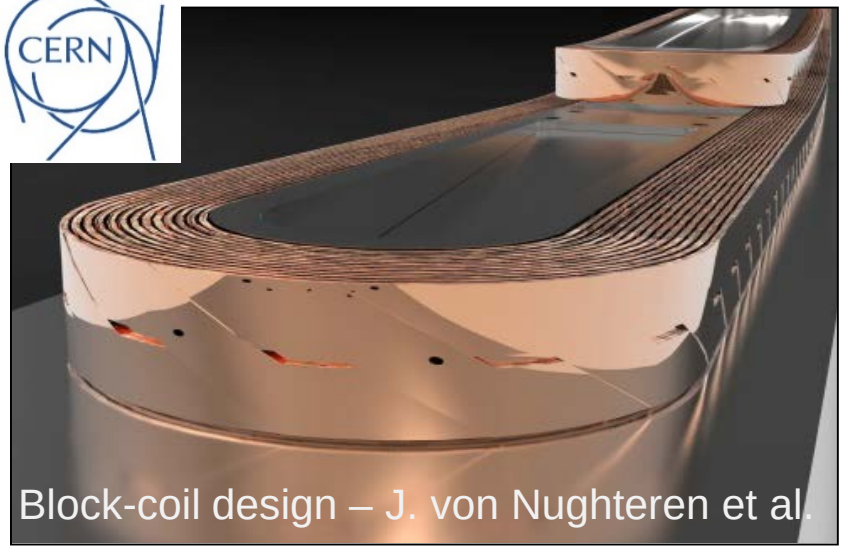
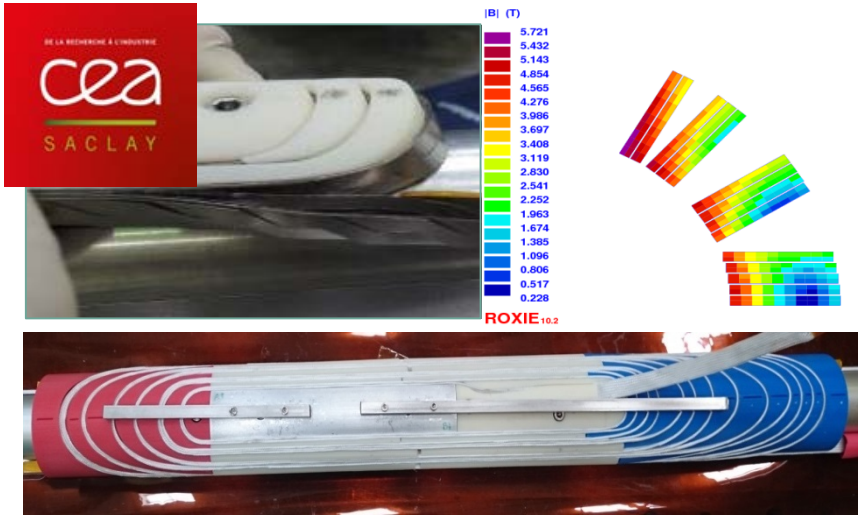
Roebel cable for accelerator-type demonstrator magnets:



Block-coil design – J. von Nughteren et al.



Cos-theta coil design – C. Lorin et al.

Cable geometry:

- Tape edge quality (burr)
- Punch-and-coat technique
- Transposition length accuracy

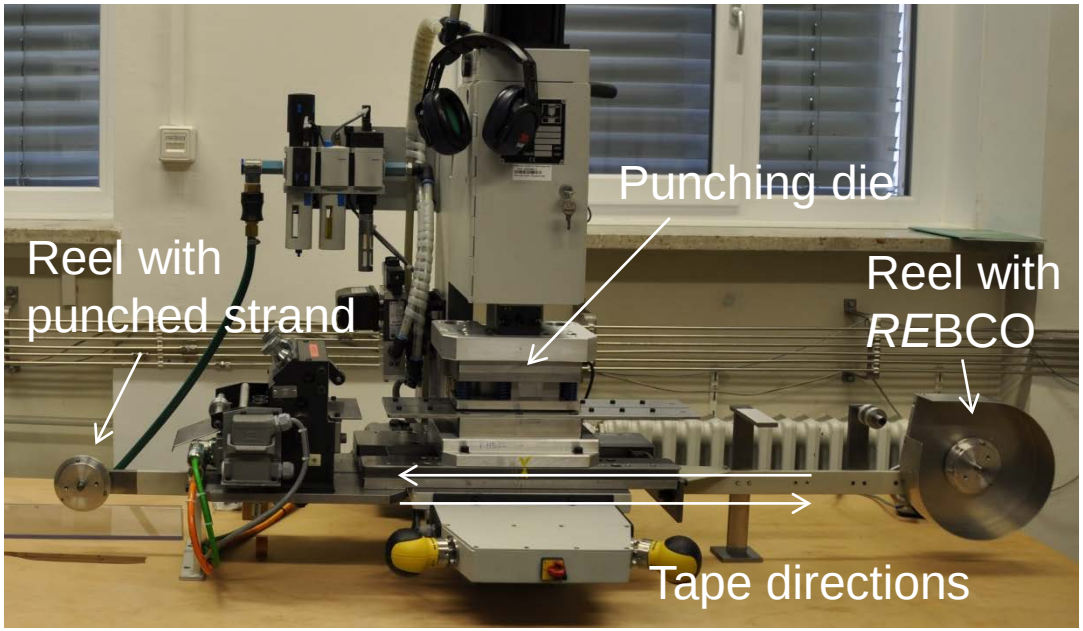
Current homogeneity:

- Roebel strand critical current
- Transport current RTR system
- Resistance between Roebel strands

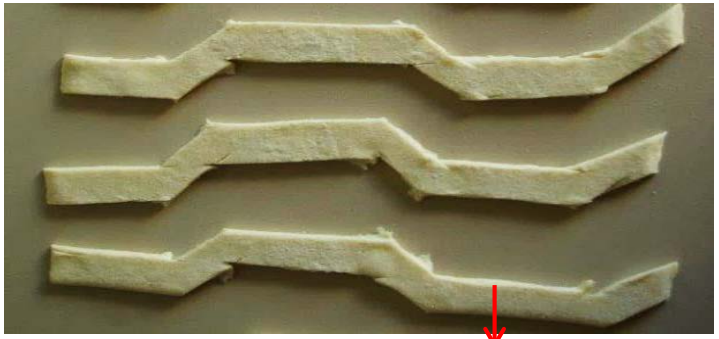
Thu-Mo-Or31-02
HTS Accelerator Magnet Dipole Assembly and Cold Test by CERN for EuCARD^2
Glyn Kirby, Jeroen van Nugteren et al. CERN

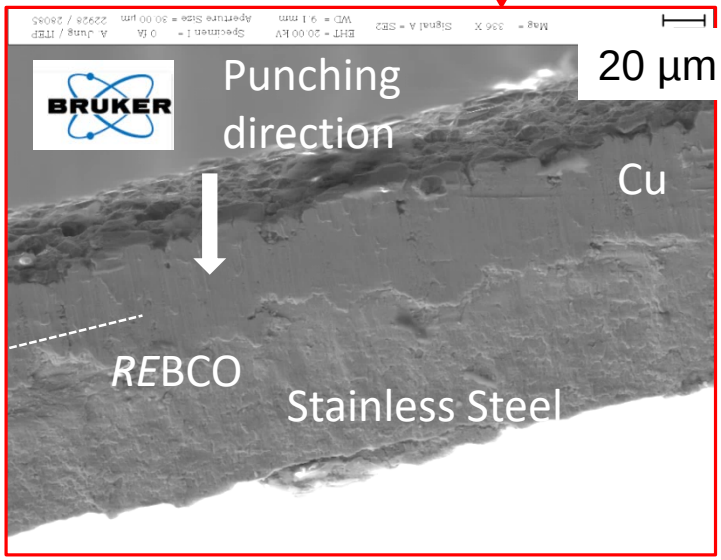
Thu-Mo-Or28-01
The EuCARD^2 Future Magnets Program for particle accelerator high field dipoles: review of results and next steps, Lucio Rossi et al. CERN

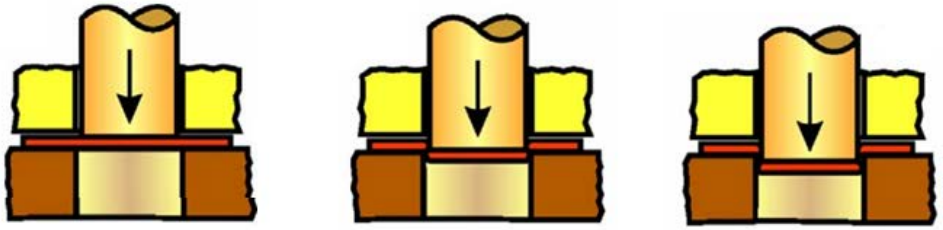
Preparation of the Roebel cable – punching:



- Reel-to-reel process
- Different transposition lengths possible



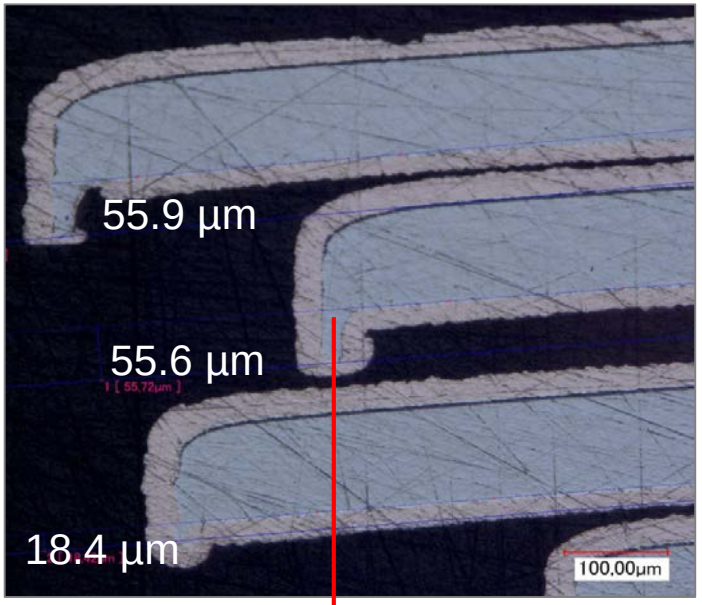




1. Charging of the punch
2. Shearing and cracking
3. Break through

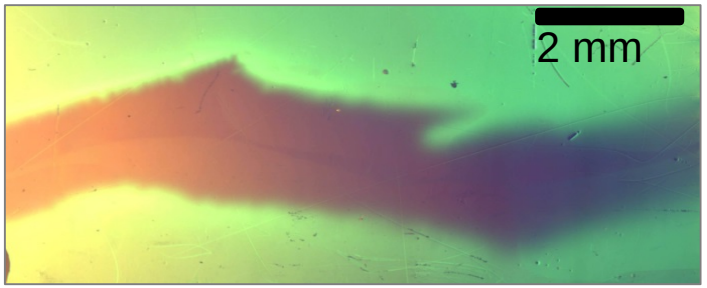
Ideal edge quality:

- Burr coming from different cutting techniques
- Might cause mechanical damage to other strands under transverse stress
- New punching tool set with tape properties within CERN collaboration agreement



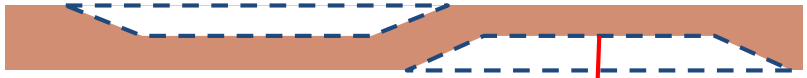
Magneto-optical imaging

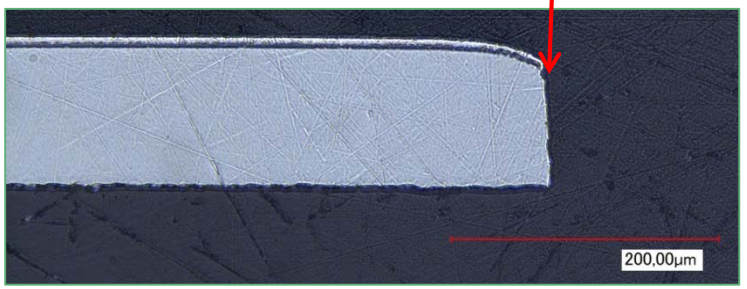
60 K, 20 mT

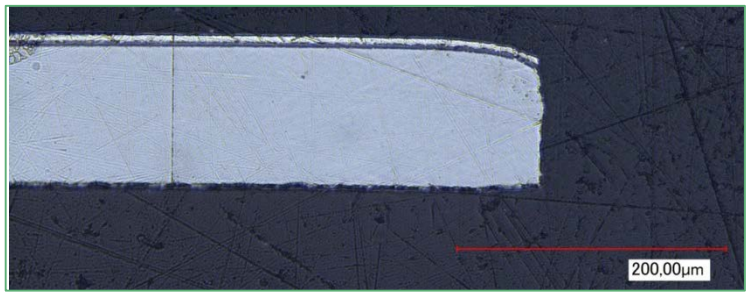


61 K, 30 mT

One-step punching TL = 300 mm

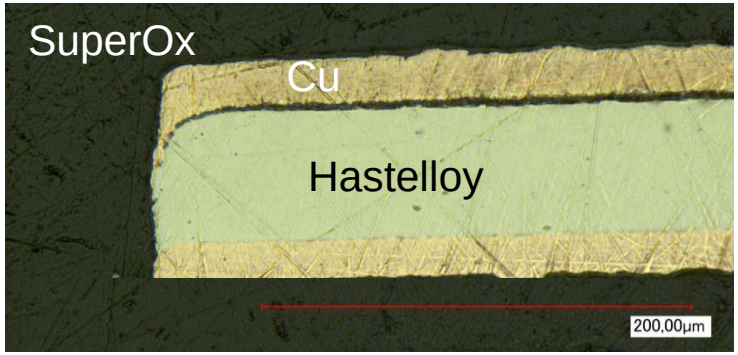


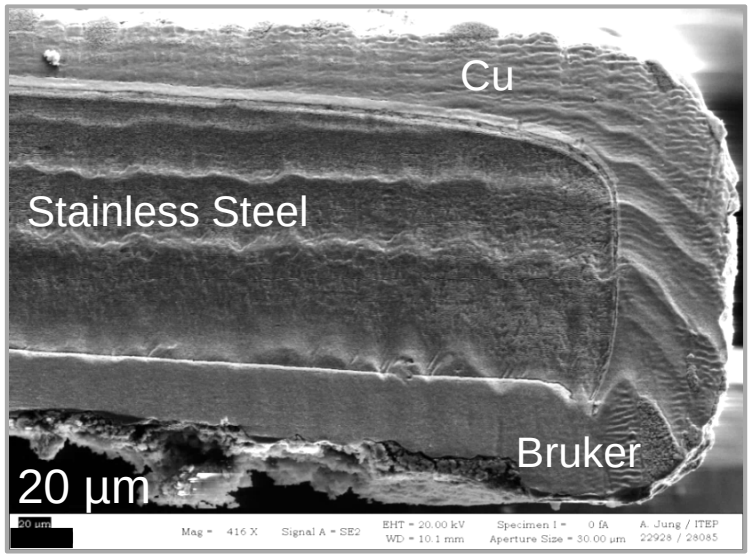


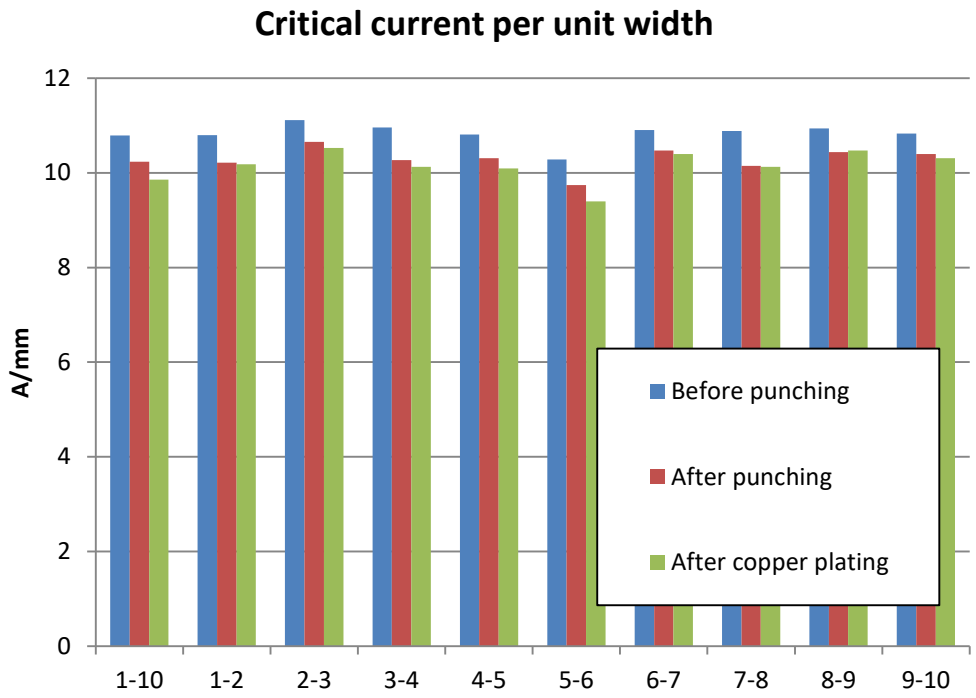


Bruker punched tape – cross section

Punch and coat process – Bruker tapes:

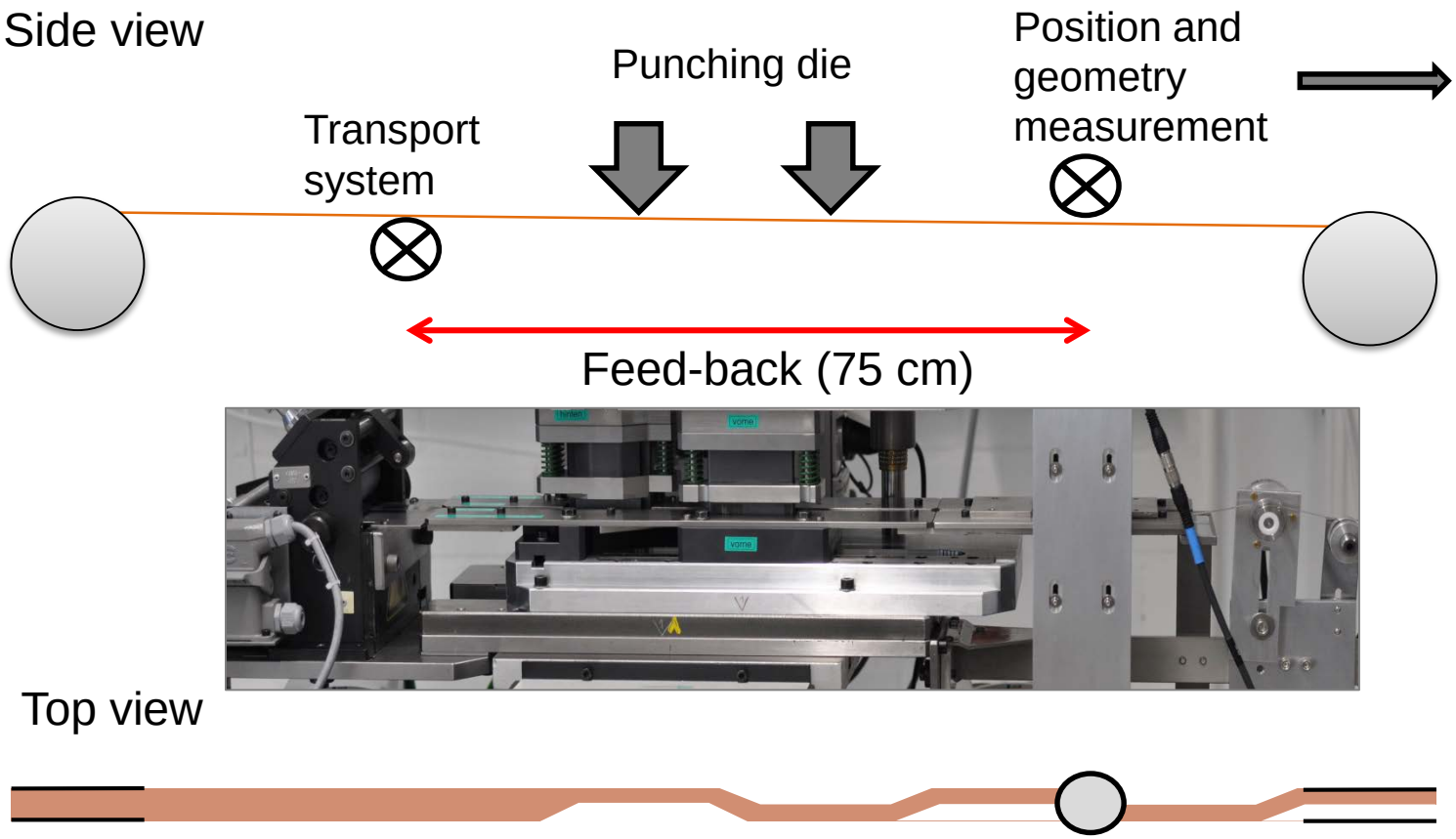


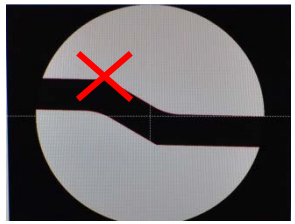


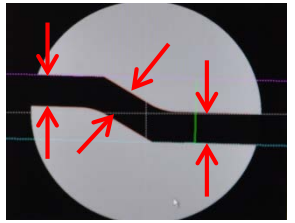


- The average critical current per unit width degraded by 6% after punching and copper plating.
- No local defects were found.

Geometry control in punching system for preciseness over long length:

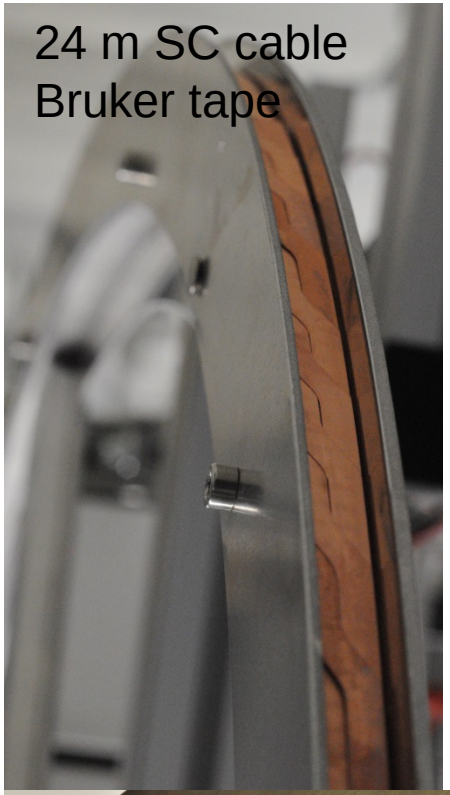




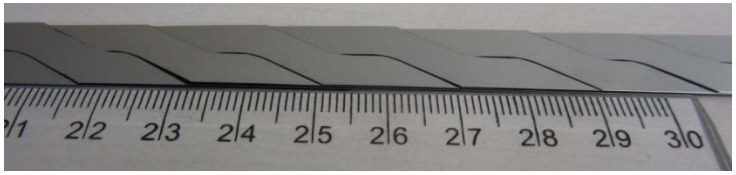


- Automatic correction system for errors in the transposition length
- Feed back signal with reel-to-reel adjusting system
- Used for measurement of the tape geometry after punching

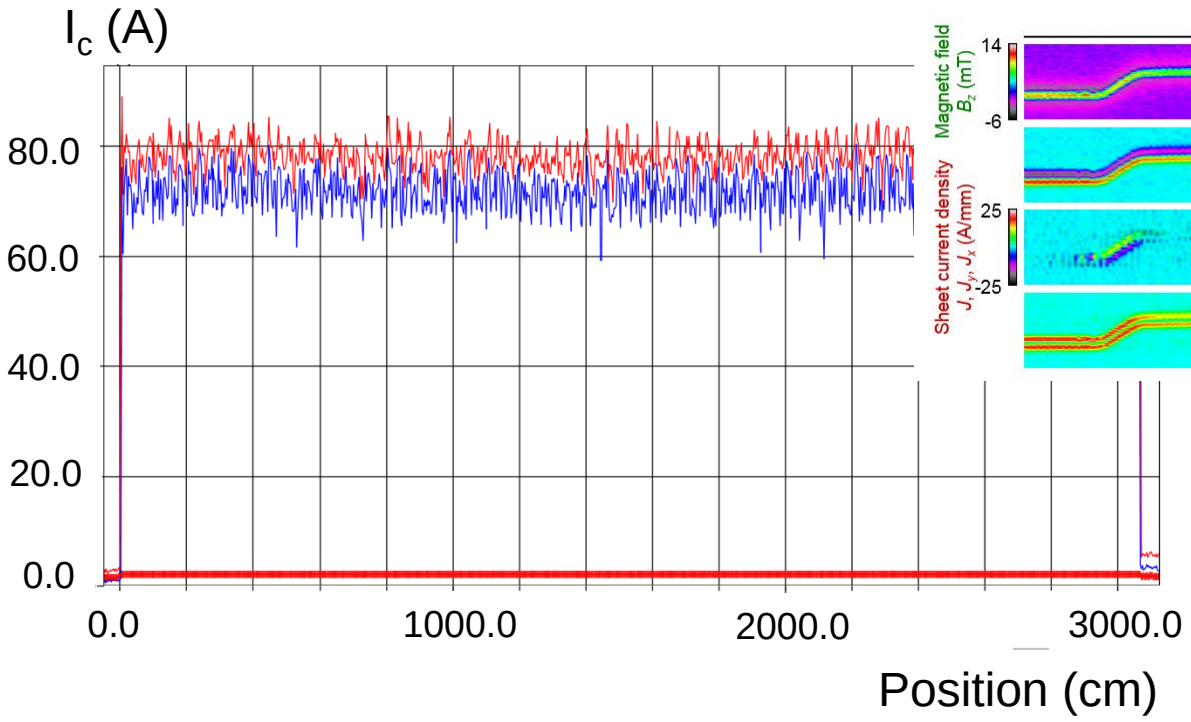
Demonstration of 100 m dummy Roebel cable:

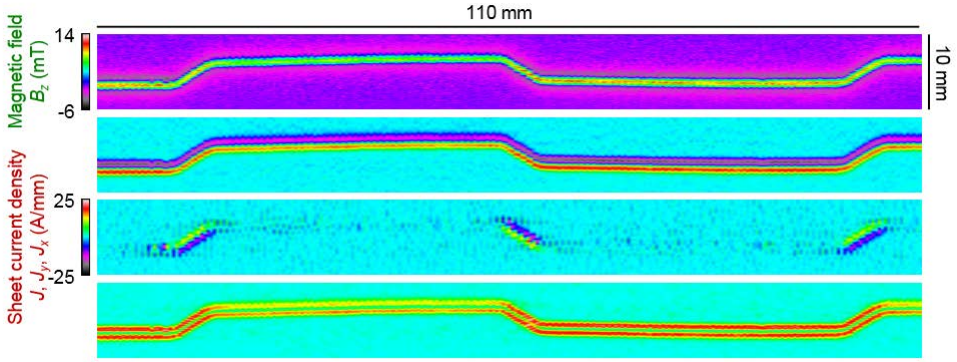


- Superconducting cables of 5 - 6 m using tapes from: Bruker, SuperPower, SuNAM and SuperOx
- Stainless steel dummy cables for coil winding test
- Superconducting cables of 24 m length from Bruker tapes (2 lengths, Feather-2 winding)
- 100 m dummy cable with EuCARD^2 geometry: 5.85 strand width, 300 mm transposition length, 13 strands



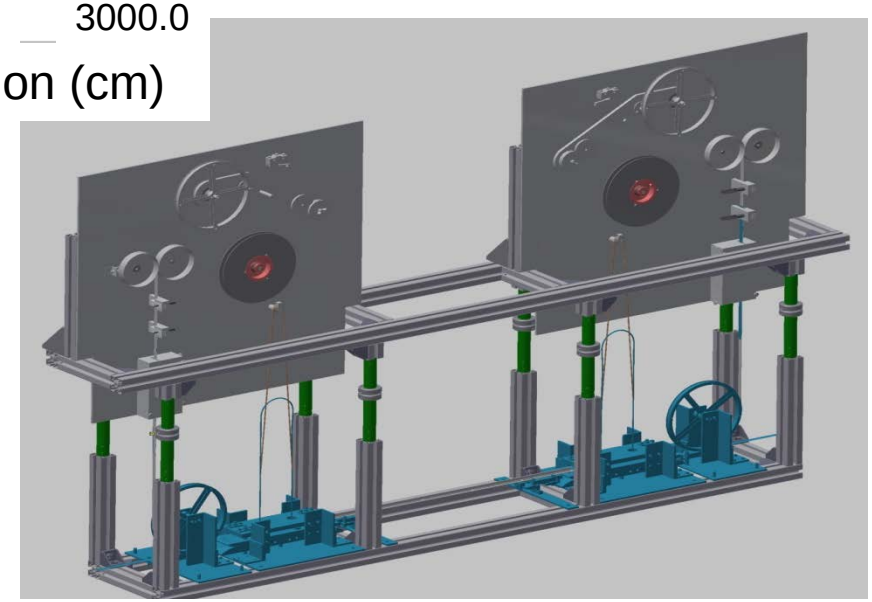
Reel-to-reel transport measurement system at LN_2:



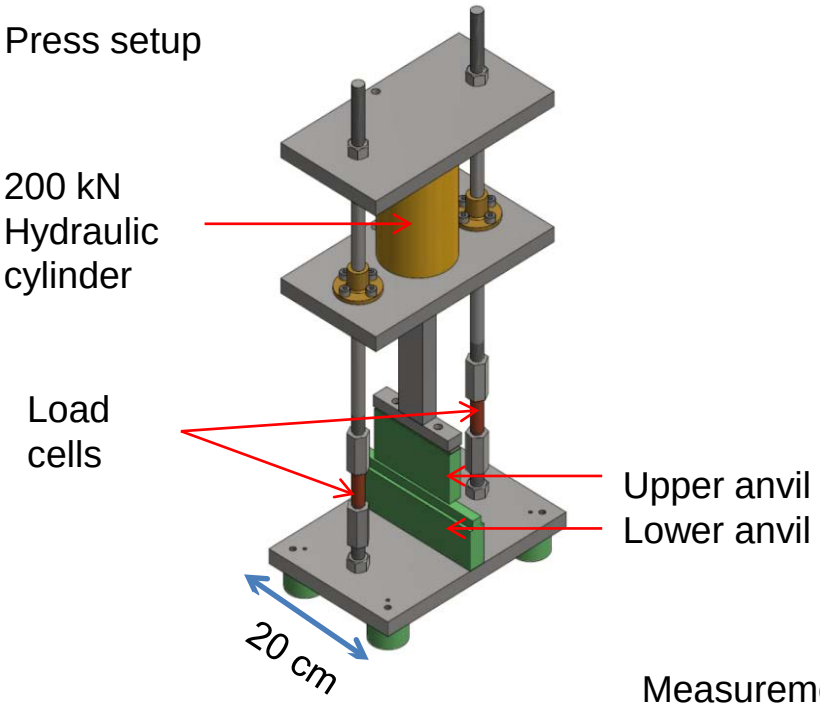


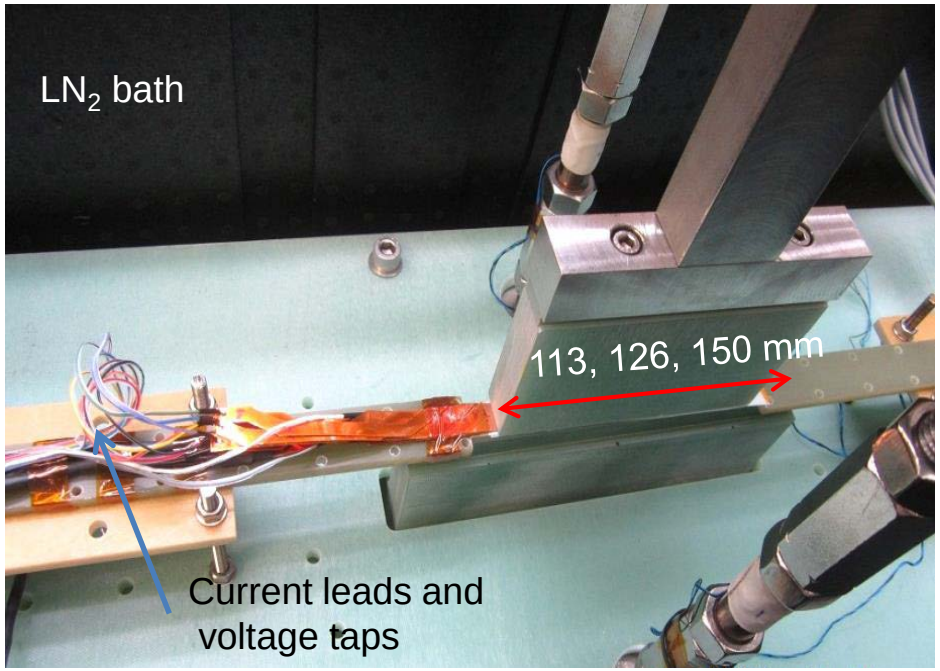
K. Higashikawa et al., Characterization of Critical Current Distribution in Roebel Cable Strands Based on Reel-to-Reel Scanning Hall-Probe Microscopy, IEEE Transactions on Applied Superconductivity, Vol. 27, 4, June 2017.

- Tapestar measurement – punch and coat Roebel strand- remarkable
- Transport system for LN_2 designed and built
- Each tape will be characterised before and after punching



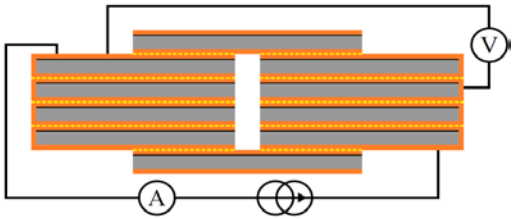
Inter-strand resistance in the Roebel cables:

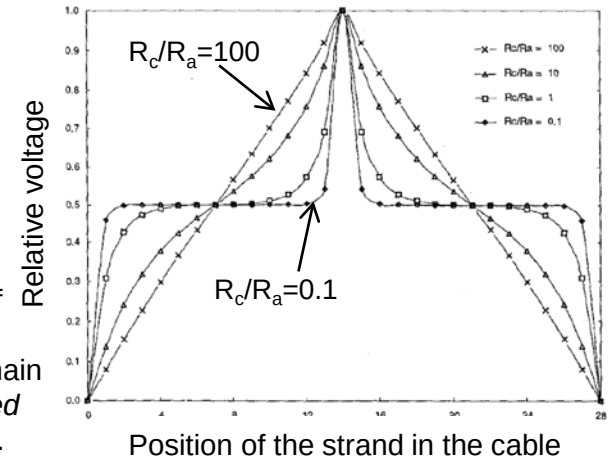




- Strands are electrically insulated outside of pressed area
- Pressure applied over one transposition length

Measurement scheme

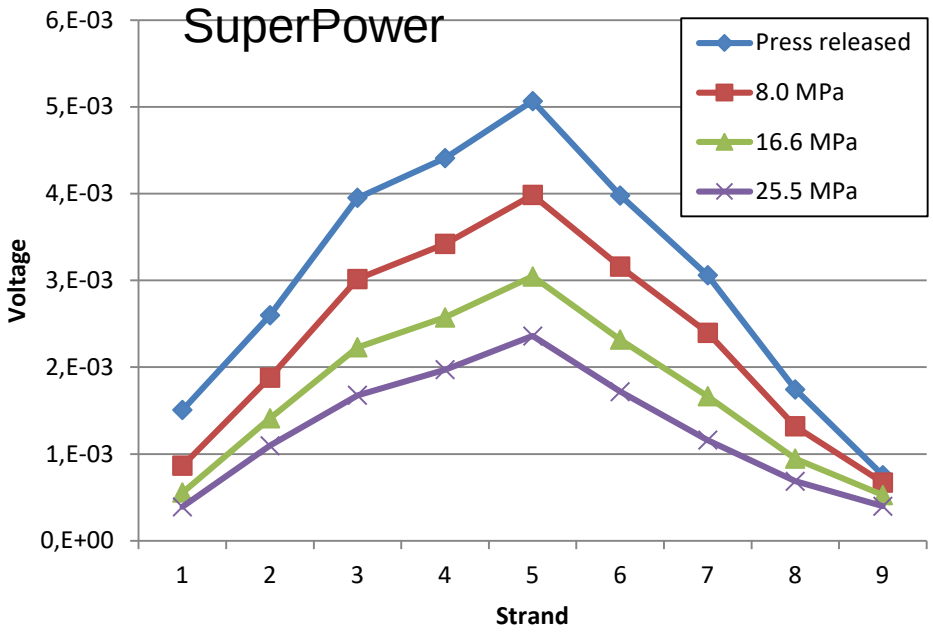


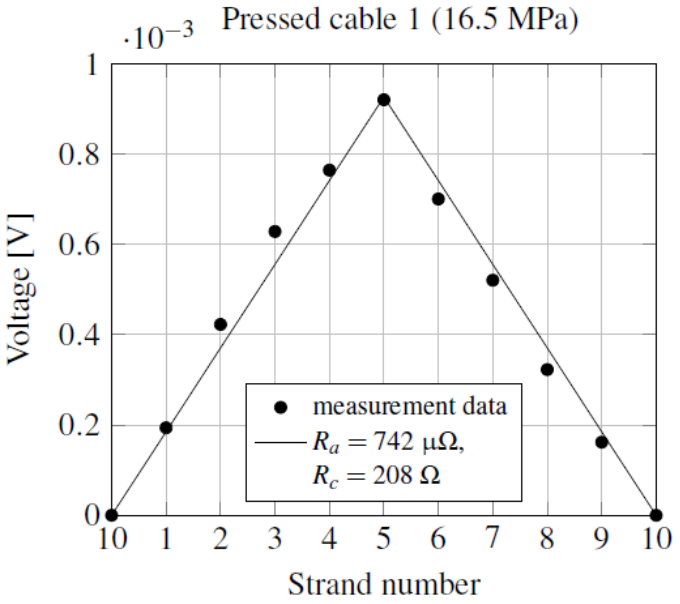


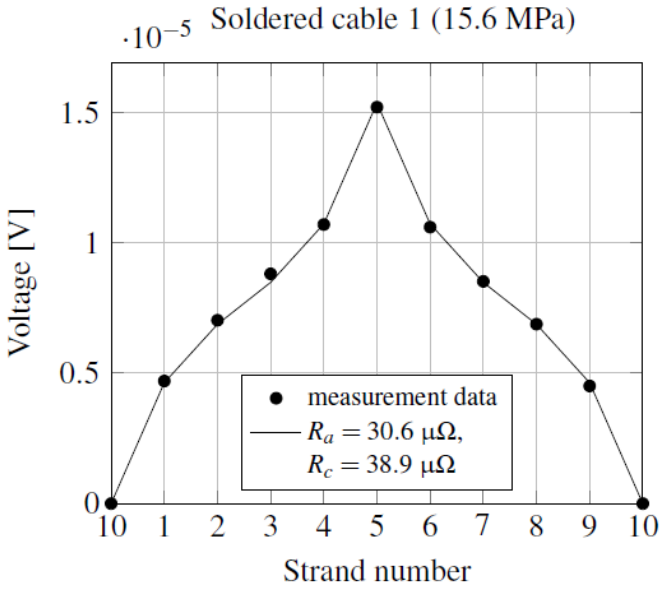
Richter, D., et al. "DC measurement of electrical contacts between strands in superconducting cables for the LHC main magnets." *IEEE transactions on applied superconductivity* 7.2 (1997): 786-792.

Inter-strand resistance in pressed and soldered Roebel cable:

- 10-strand cables with 126 mm transposition length
- Punched Cu coated conductor, I = 10 A applied at 77 K



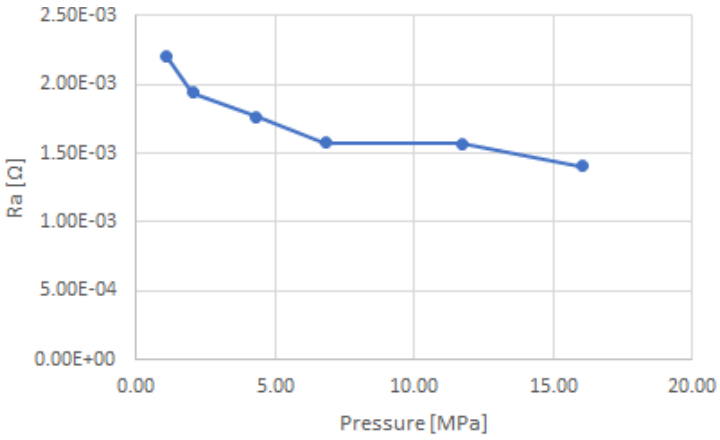


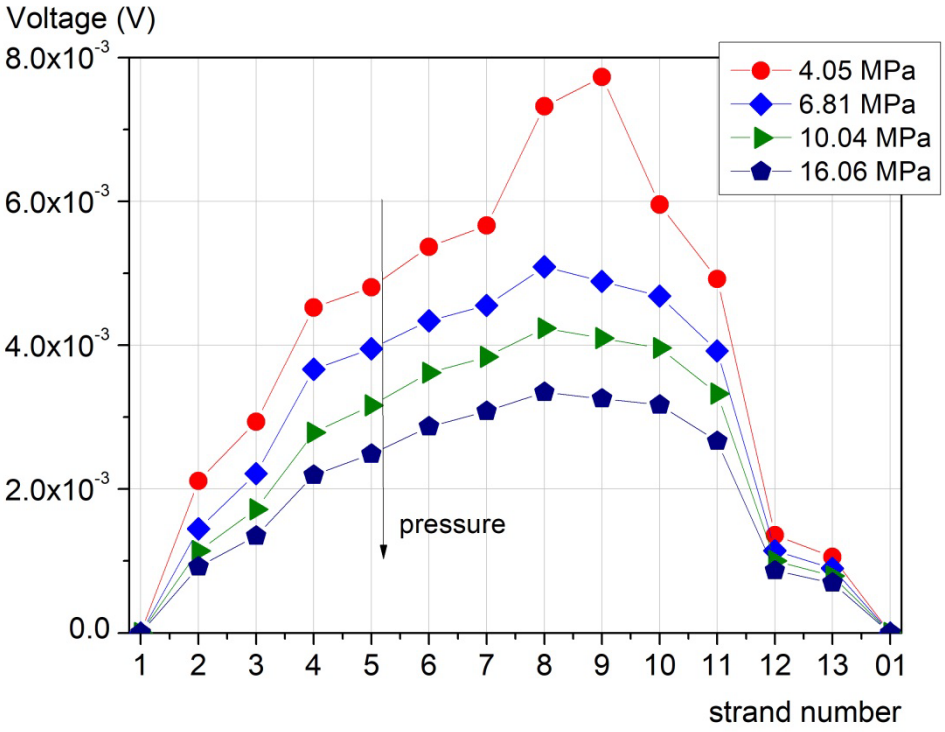


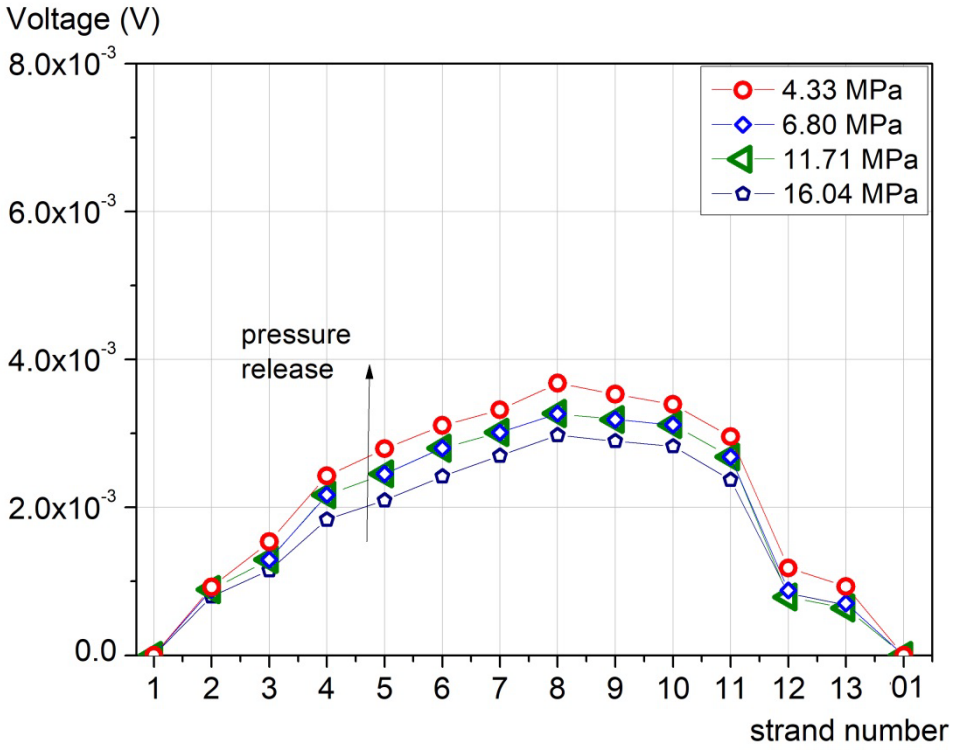
- Pressed cable: R_a = 742 µΩ, R_c =208 Ω at 16.5 MPa, transverse stress dependent
- Soldered cable: R_a = 30.6 µΩ, R_c = 38.9 µΩ at 15.6 MPa no dependency from transverse stress

Inter-strand resistance in EuCARD^2 type Roebel cable:

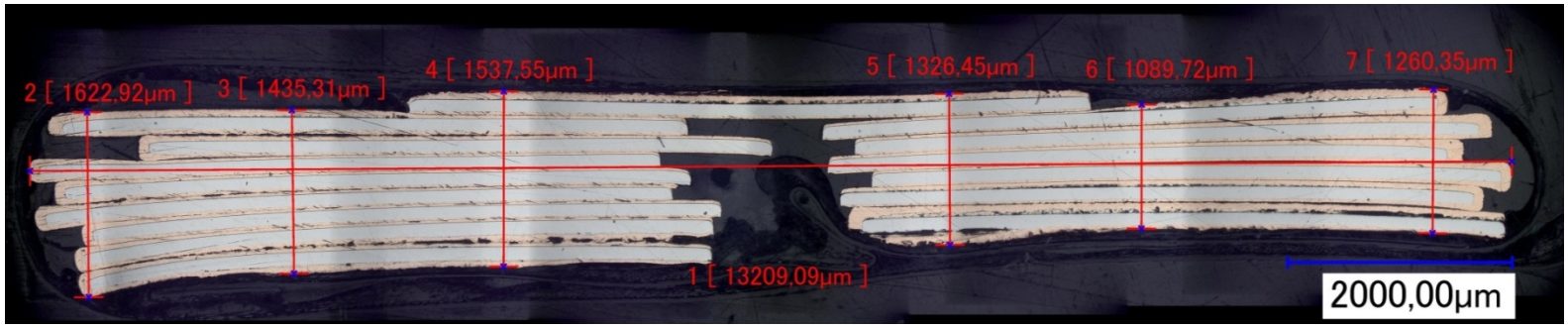
- 13-strand cables with 300 mm transposition length using Bruker tape
- Punch-and-coat strands, I = 10 A applied at 77 K over 150 mm
- Pressed cable: R_a = 141 µΩ at 16.1 MPa







Evolution of geometry homogeneity and critical current in Roebel strands:



Thickness:
- 1.6 mm

Width:
- 13.3 mm

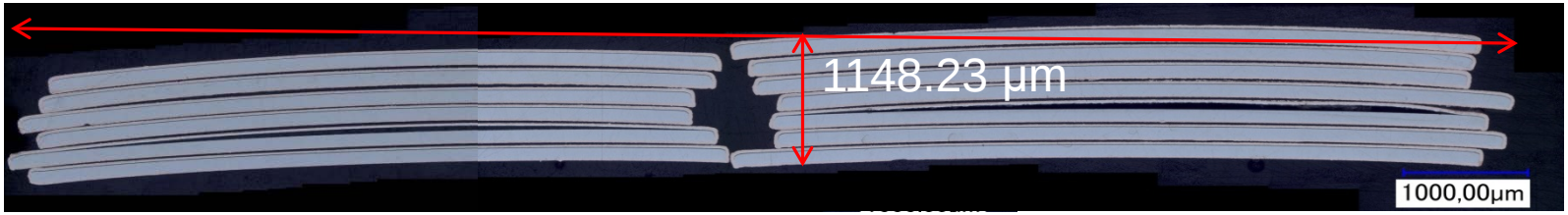
S=21.8 mm^2

Number of strands	I_c strand (average, 77K)
2	51.5
3	52.6
2	61.1
4	56.9
4	62.8

In Feather-1 magnet

Number of strands	I_c strand (average, 77K)
3	98
2	81
3	140
1	132
1	146
2	210

Will be wound - Feather-2 magnet



Thickness:
- 1.1 mm

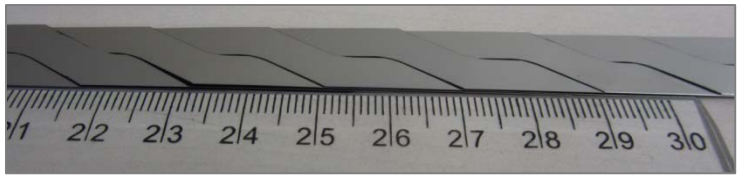
Width:
- 12.3 mm

S=13.5 mm^2

Summary:

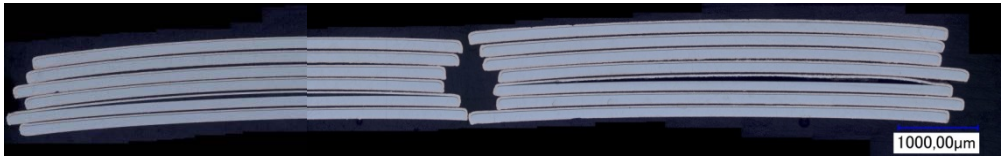
Karlsruhe Institute of Technology

Cable geometry:



- Punching tool optimised for tape geometry
- Punch-and-coat technique on the long length of the conductor
- Transposition length controlled by measurement system installed in the tool

Current homogeneity:



- Tapestar measurement not fully suitable for Roebel strand qualification
- Transport current RTR system build - LN_2 measurements
- Resistance between Roebel strands for even and uneven number of strands
- Current homogeneity vs. resistance and current redistribution – open question