HiLumi
HL-LHC PROJECT

Assessing MQXF Conductor Limits

Amalia Ballarino, Ch. Barth, G. Lenoir, K. Puthran

UNIGE (Nb_3Sn wires (axial strain and transverse pressure)

Twente University – Nb_3Sn cables (transverse pressure)

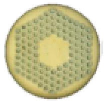
Florida State University – Nb_3Sn wires (axial strain)

CERN

12th HL-LHC Collaboration Meeting, Uppsala - Sweden

19-22 September 2022

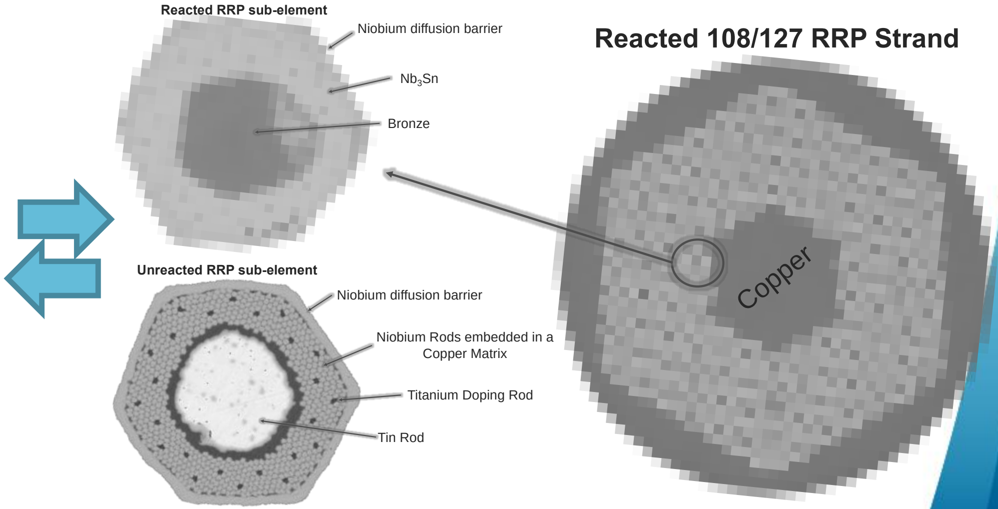
MQXF Nb_3Sn Wire

	Technology	# of subelements	Cu/non-Cu	Subelement size/shape	Diameter	I_c(16 T)
	RRP	108/127	1.2	~55 µm	0.85 mm	280 A

Heat treatment

HT N:	535	Code:	3_665_B
Furnace:	GERO_CERN163	Date:	13/09/2019

Plateau	T [°C]	Duration [h]	Ramp (up) rate [°C/h]
1	210	48	25
2	400	48	50
3	665	50	50



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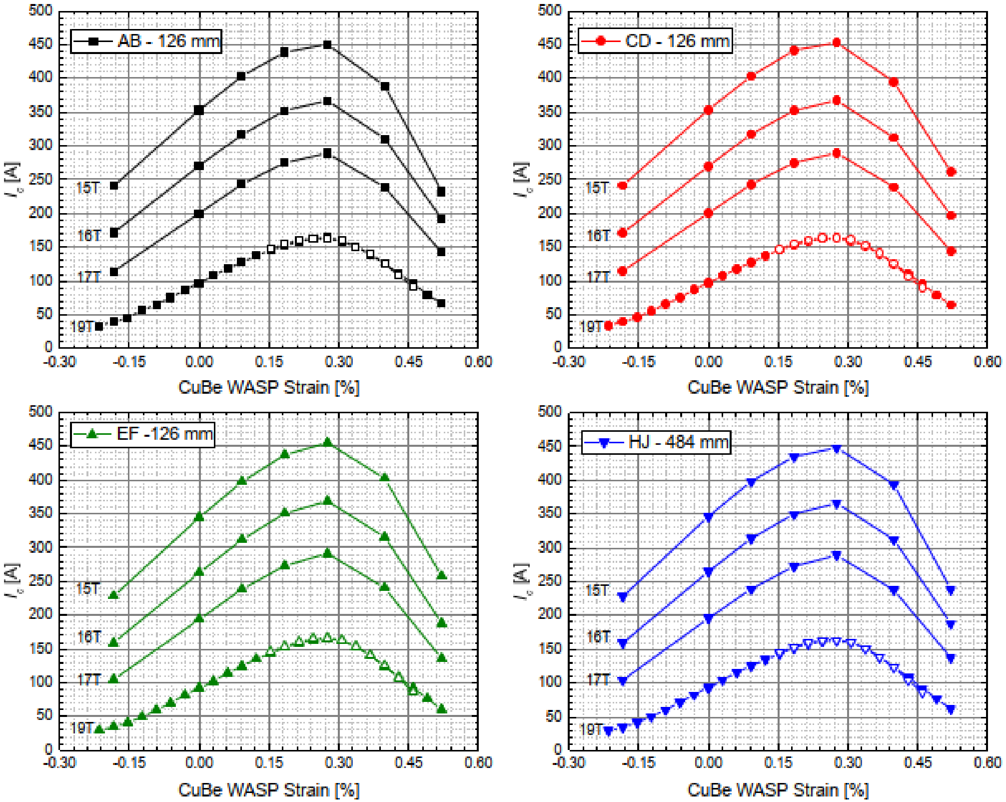
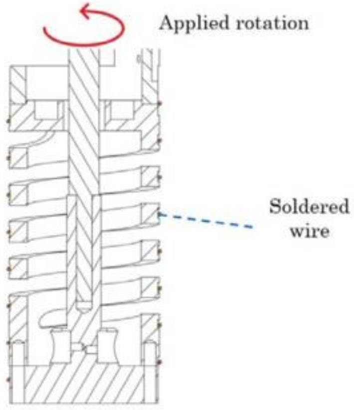
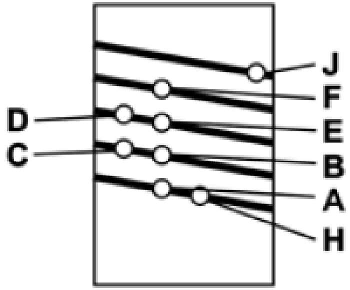
Nb_3Sn MQXF Wire – Axial Strain at 4.2 K







C-WASP, Unige

Measurements at University of Geneva

J. Ferradas Troitino et al, Supercond. Sci. Technol. **34** (2021) 035008 (10pp)

ε_{irr} = 0.48 % -0.51 %

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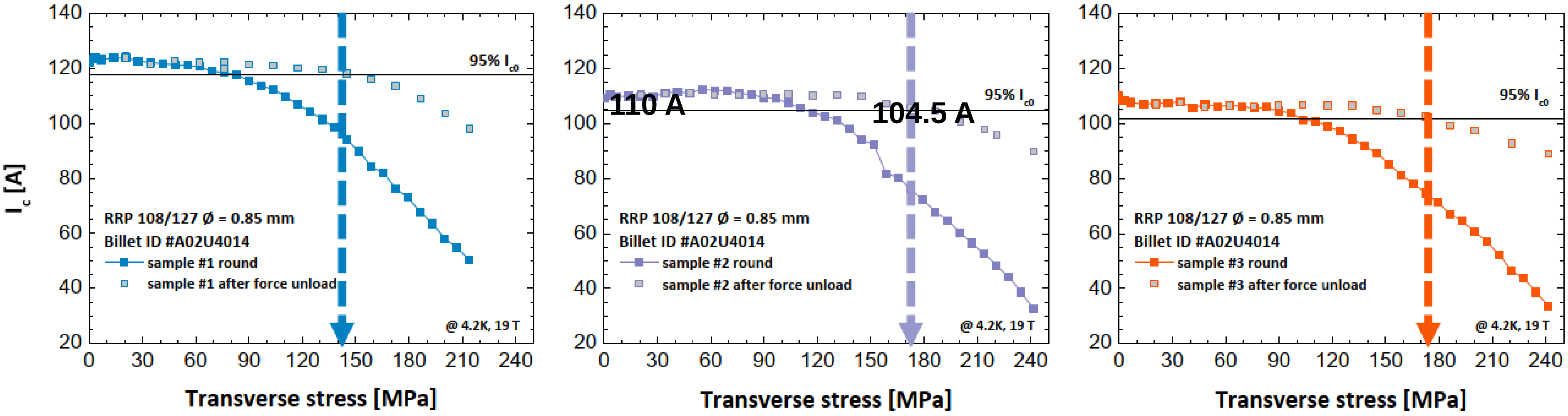
Nb_3Sn MQXF Wire - Transverse Pressure at 4.2 K



σirr = 145 MPa	**σirr = 175 MPa**	**σirr = 175 MPa**
I_{co}(19 T) = 124 A	I_{co}(19 T) = 110 A	I_{co}(19 T) = 107 A

σirr → 5 % Ic reduction

Measurements at University of Geneva

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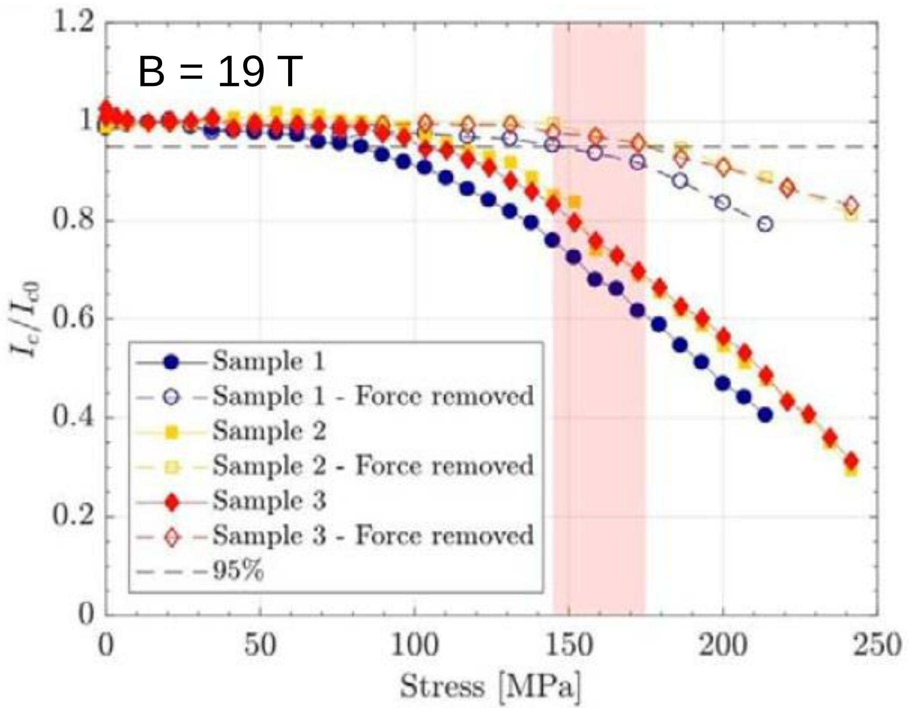
Nb_3Sn MQXF Wire - Transverse Pressure 4.2 K



σirr = 145 – 175 MPa

Ic/Ic0 @ 150 MPa = 16 % - 28 %

J F Troitino *et al* Supercond. Sci. Technol. **34** (2021) 035008

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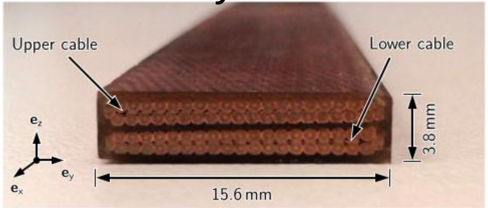
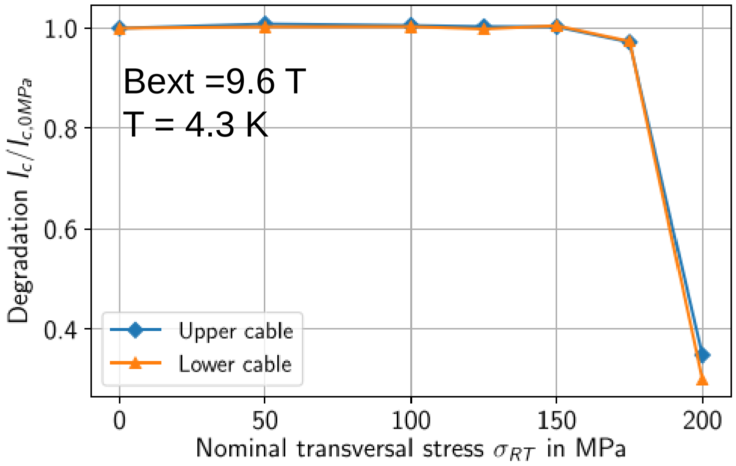
Nb_3Sn Cables under transverse pressure at RT

11 T forty-strand cable

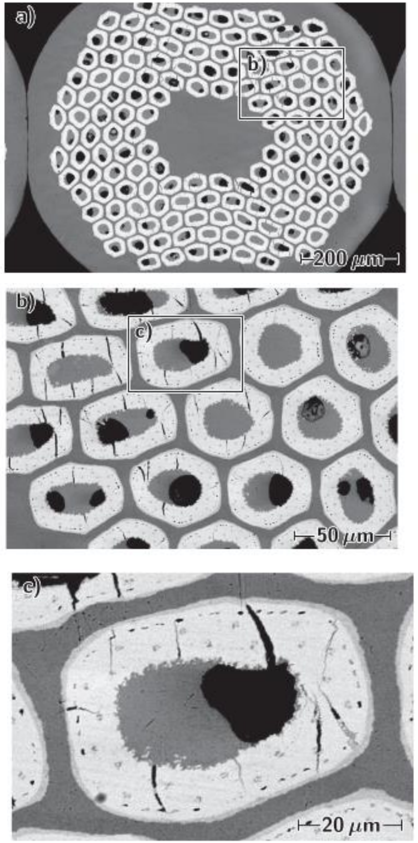


Manufacturer	CERN
Cable ID	HT15OC0190
Number of strands	40
Transposition pitch	100 mm
Keystone angle	0.79°
Mid-thickness	1.25 mm
Width	14.7 mm
Insulation	S-2 glass
Core	316 L
Packing factor	87.3%
Impregnation	CTD-101K



Crack initiation at 175 MPa

200 MPa



P Ebermann *et al* Supercond. Sci. Technol. **31** (2018) 065009

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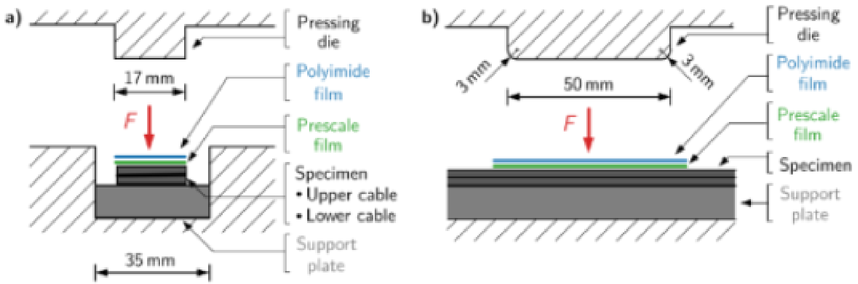
Nb_3Sn Cables under transverse pressure at RT

11 T forty-strand cable



Cable configuration	
ID	H15OC0220B
Number of strands	40
Transposition pitch	100 mm
Keystone	0.808 °
Mid-thickness	1.25 mm
Width	14.7 mm
Insulation	S-2 glass C-shaped MICA
Core material & dimensions	316L 24.3 µm x 12 mm
Impregnation	CTD-101K

Two-cable stack configuration

Controlled pressure uniformly applied <u>on cables</u>

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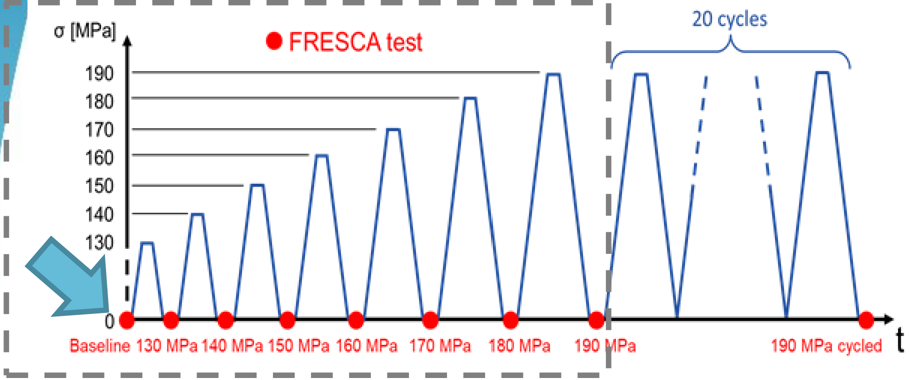
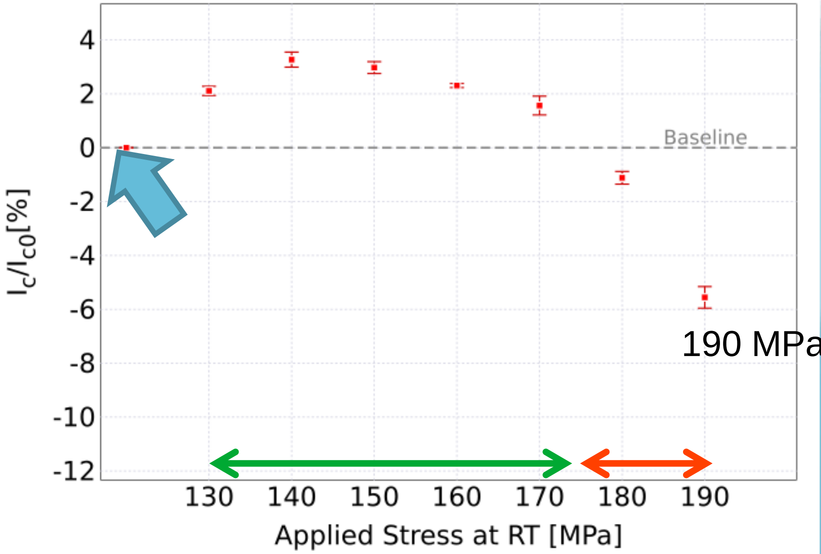
Nb_3Sn 11 T cables under transverse pressure at RT



11 T forty-strand cable



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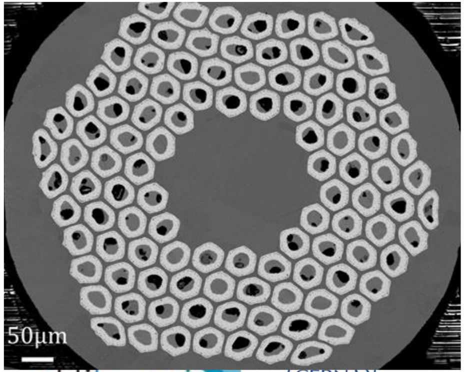

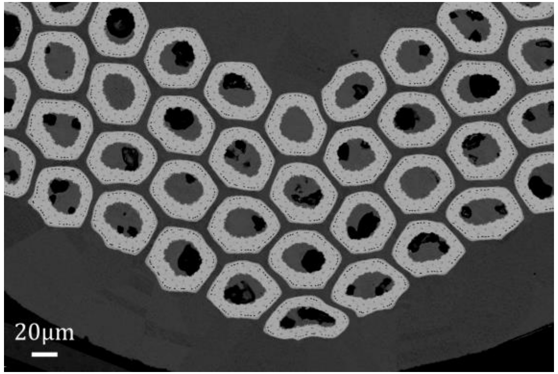

Cross section of baseline cable

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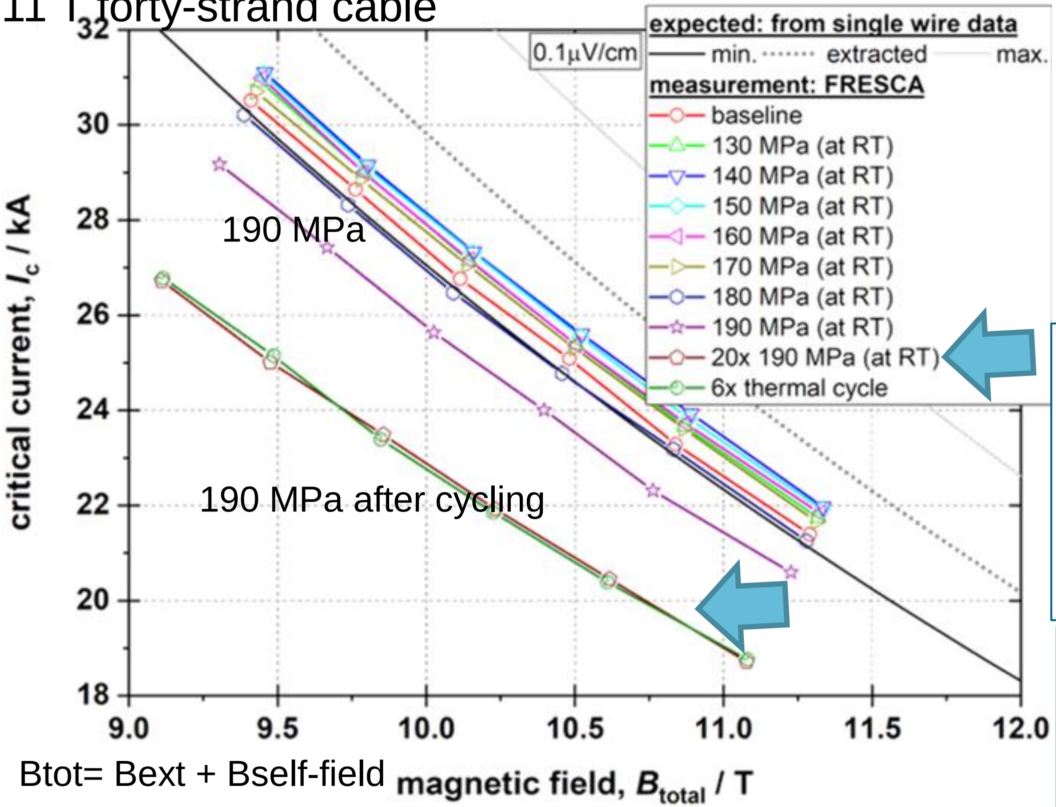
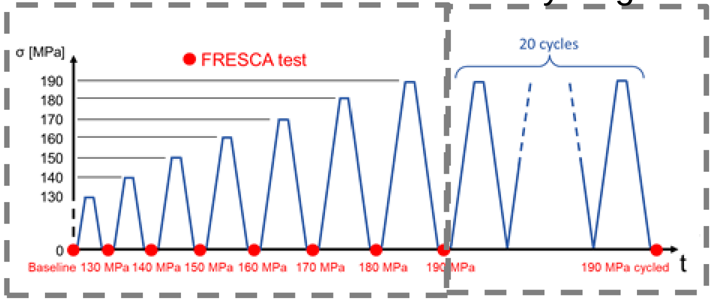
Nb_3Sn Cables under transverse pressure at RT

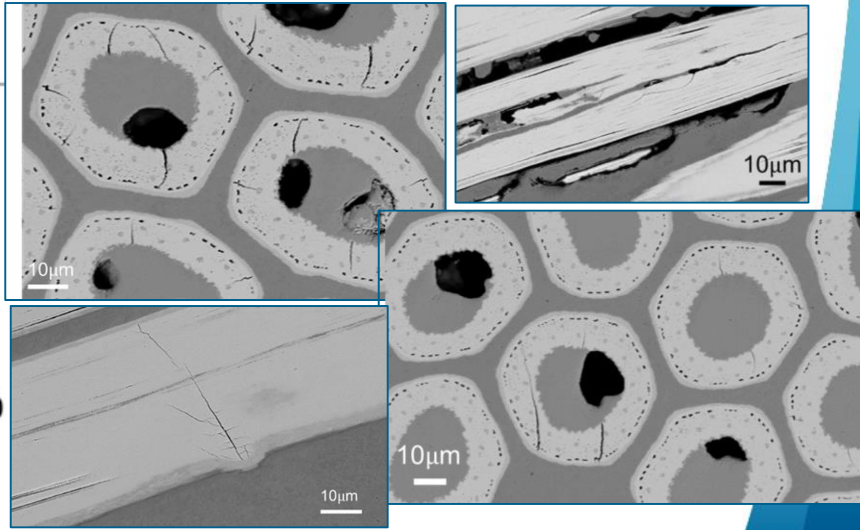
11 T forty-strand cable



Btot= Bext + Bself-field

Cycling





0-190 MPa + 20 cycles to 190 MPa + 5 thermal cycles (RT to 77 K) + cool down to 4.2 K

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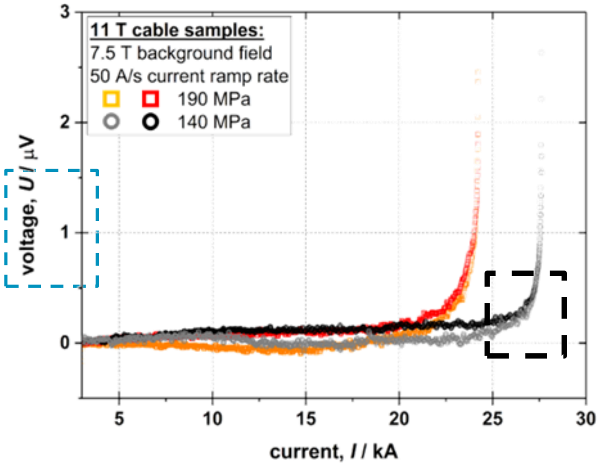
Effect of micro-cracks

- **Cracks** generate a **reduction of current carrying cross section**

- Do cracks always generate a reduction of critical current (Ic) ? **Narrow/micro cracks** even with high density but with a size that does not impact on current distribution and electrical connectivity in the superconducting filaments **may not be detectable** via Ic measurements, i.e. via V-I measurements



$$V(I) = Ec\,L\,(\frac{I}{Ic})^n + \sum_i V_i$$

$$V_i = R_m I_{m,i}$$

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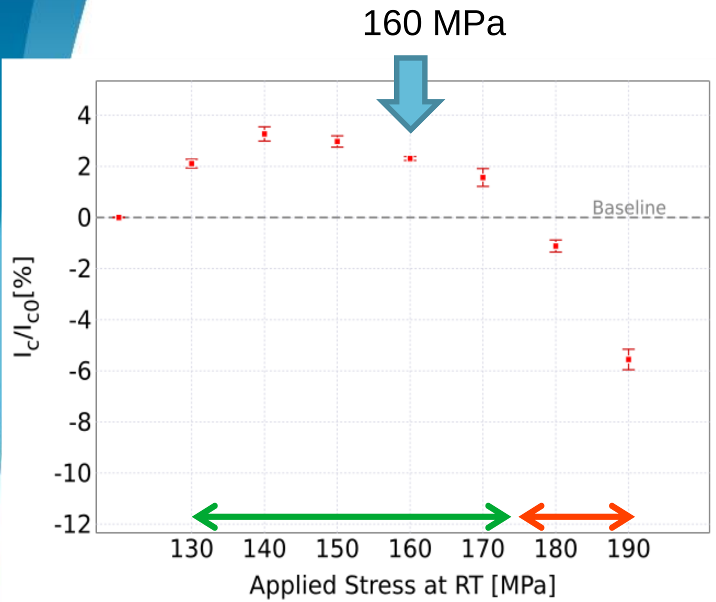
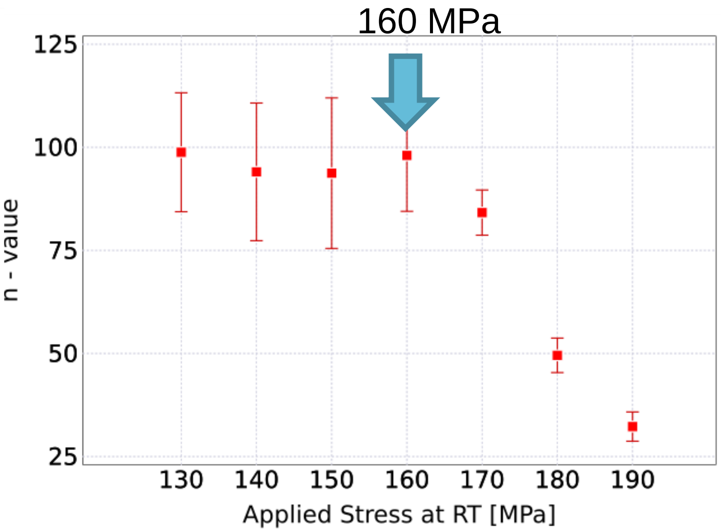
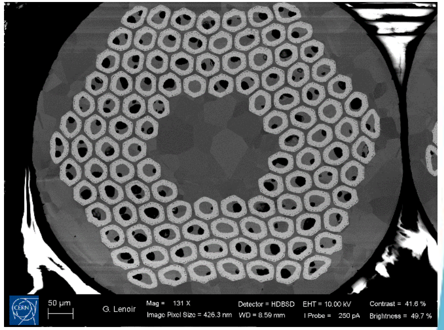
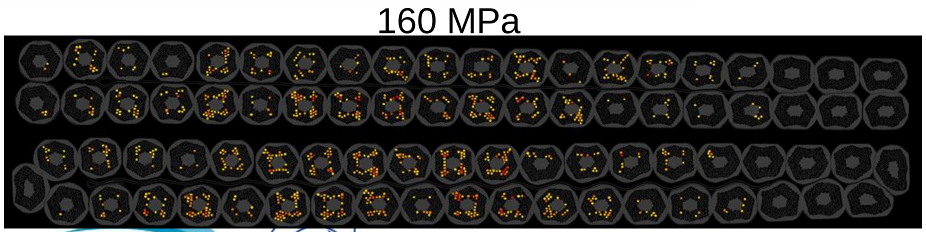
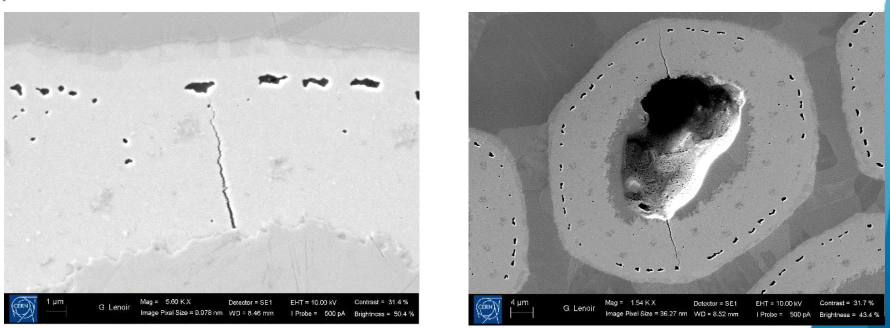
Effect of micro-cracks











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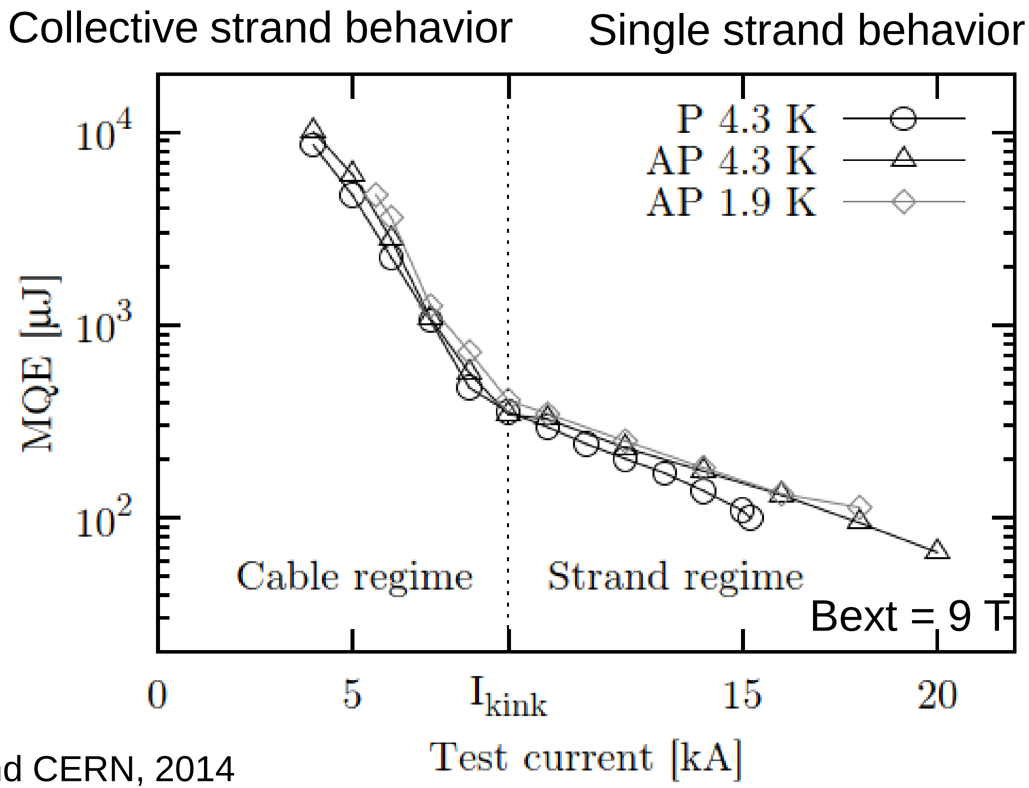
Nb_3Sn Cables: Thermal Stability



W. D. Rapper
PhD Twente University and CERN, 2014

RRP Wire, 0.7 mm diameter, 27 strands

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Thanks for your attention !