



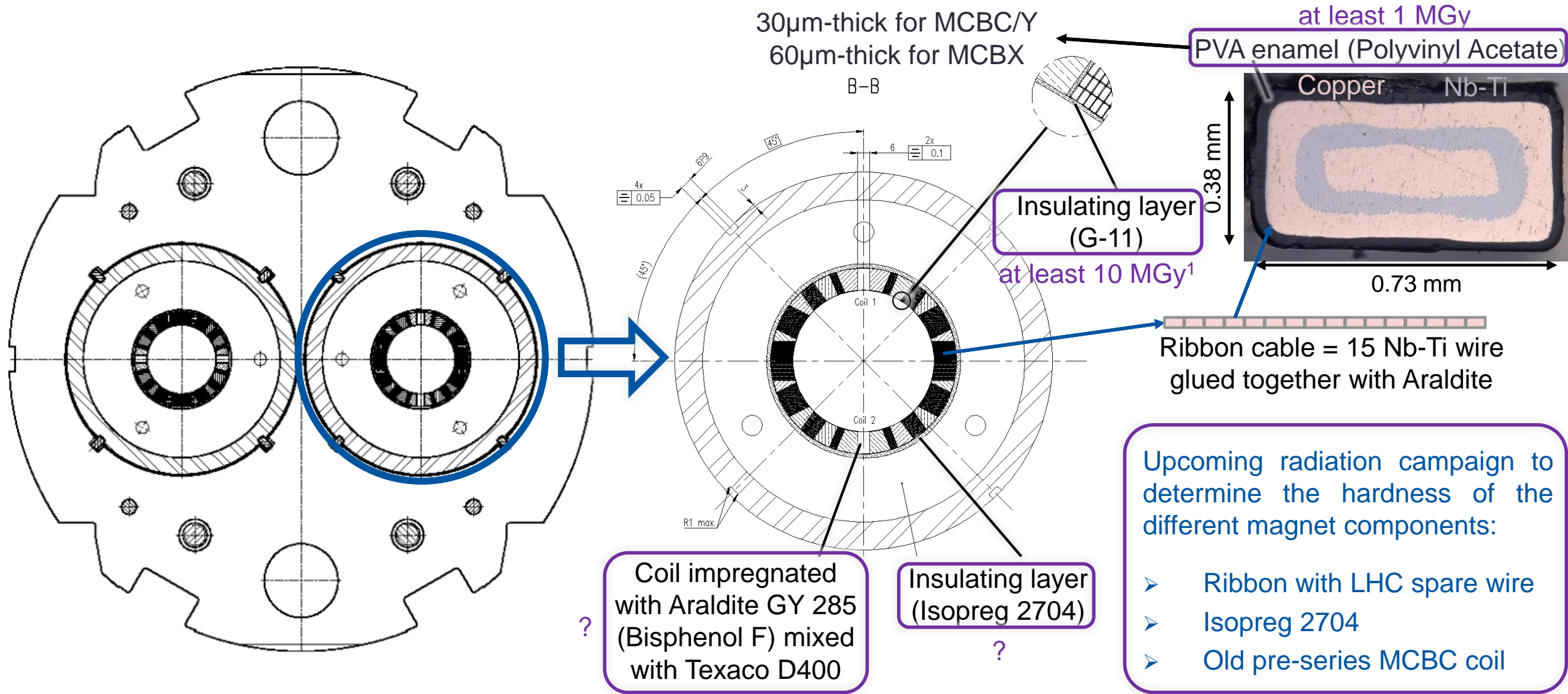
**MCBY**

**Daniel Schoerling**

# Conclusions from 88<sup>th</sup> TCC

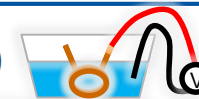
- Assuming a realistic 5 MGy MCBC/Y rad hardness, **corrective actions in LS3 and LS4 are needed**
- **20 to 22 new MCBY should be ordered before LS3** such that first magnets will be ready to be installed in LS4 (the number depends on the luminosity target)
- **Q4 in IP1,5 have to be rotated during LS3 (no additional cost** except for the cables price)
- Budget has to be made available for the procurement of the MCBY magnets before LS3
- The results of the **gamma radiation campaign are needed** to confirm the 5 MGy assumption (expected 03/2020)
- As risk mitigation, we ask for a conceptual integration study for resistive magnets as replacement for MCBYs

# MCBC/Y magnet components: radiation hardness



# Radiation hardness of present MCBC/Y magnets

→ Gamma irradiation of LHC spare and candidate wires + breakdown voltage tests in water (conservative)



## Type A (LHC MCBC/Y spare wire)

Nb-Ti/Cu  
+PVA enamel



Sample name	Breakdown voltage (kV)	Gamma irradiation dose (MGy [air])	Average breakdown voltage (kV)
A1	1,8	0	1,5
A2	1,5		
A3	1,1		
A4	2,8		
A5	1,6		
A6	2,8		
A7	0,0	2,5	0,0
A8	0,0		
A9	0,0		
A10	0,0	5	0,0
A11	0,0		
A12	0,0		

radiation hardness in the 1-2.5 MGy [air]  $\approx$  0.9-2.3 MGy [coil]<sup>1</sup> range

## Type C (candidate wire from Supercon Inc)

Nb-Ti/Cu  
+Pyre-ML enamel



Sample name	Breakdown voltage (kV)	Gamma irradiation dose (MGy [air])	Average breakdown voltage (kV)
C1	3,1	0	3,2
C2	3,1		
C3	3,4		
C4	3,3		
C5	3,1		
C6	2,0		
C7	3,7		
C8	4,3		
C9	3,5		
C10	Not performed	2,5	2,8
C11	Not performed		
C12	Not performed		
C13	Not performed	5	3,8
C14	Not performed		
C15	Not performed		
		10	Not performed
		20	Not performed

radiation hardness over 5 MGy [air]  $\approx$  4.5 MGy [coil]<sup>1</sup> range

## Type B (candidate insulation)

Cu  
+Super-Pi enamel



Sample name	Breakdown voltage (kV)	Gamma irradiation dose (MGy [air])	Average breakdown voltage (kV)
B1	3,0	0	2,8
B2	2,5		
B3	2,8		
B4	2,1		
B5	1,9		
B6	1,8		
B7	3,3	1	1,9
B8	1,5		
B9	1,9		
B10	0,0	2,5	2,2
B11	0,0		
B12	0,3		

radiation hardness in the 2.5-5 MGy [air]  $\approx$  2.3-4.6 MGy [coil]<sup>1</sup> range

## Type D (Type C + ribbon glue)

Nb-Ti/Cu  
+Pyre-ML enamel  
+Araldite 2011



Sample name	Breakdown voltage (kV)	Gamma irradiation dose (MGy [air])	Average breakdown voltage (kV)
D1	4,7	0	4,1
D2	3,3		
D3	4,3		
D4	4,1		
D5	3,6		
D6	4,8		
D7	2,6		
D8	4,1		
D9	1,9		
D10	Not performed	2,5	4,2
D11	Not performed		
D12	Not performed		
D13	Not performed	5	2,9
D14	Not performed		
D15	Not performed		
		10	Not performed
		20	Not performed

radiation hardness over 5 MGy [air]  $\approx$  4.5 MGy [coil]<sup>1</sup> range

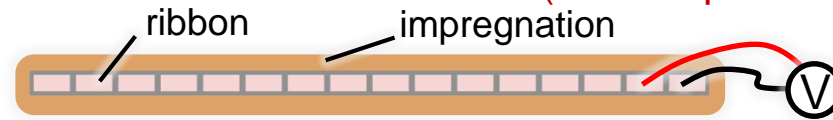
→ Results show conservative limit of 1 MGy for present MCBC/Y magnets (more realistic tests are planned)

→ Candidate wire from Supercon Inc ok

# Plan for upcoming gamma radiation campaign

- Ribbon cable with LHC spare strands (glued with Araldite 2011\*) impregnated with Araldite GY 285 + Jeffamine D400\* (coil epoxy impregnation) and irradiated in He and in air (for comparison of atmosphere effect) → **more realistic tests**

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J. Mazet



- breakdown voltage tests between wires in air
- mechanical three point bending tests to evaluate shear strength

- Samples of Isopreg 2704 (outer insulating layer)

D. Sousa

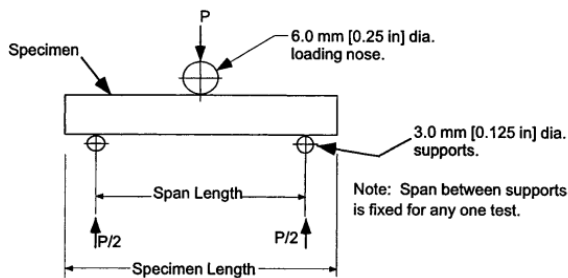
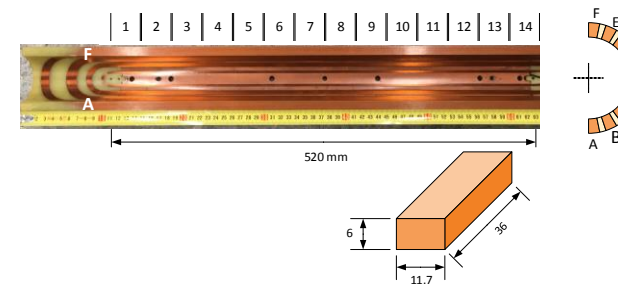
- mechanical three point bending tests to evaluate shear strength @ RT/77K



- '10-stack' samples cut out of the existing old pre-series MCBC coil

F. Wolf

- mechanical three point bending tests to evaluate shear strength @ RT/77K



mechanical three point bending test

Gamma irradiation of all samples at 0, 2.5, 5 and 10 MGy [air]

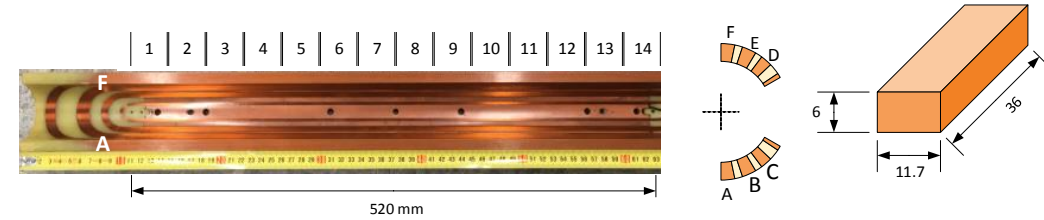
Campaign will cost 17250€ and will last about a month

\*Similar to product used in previous MCBC/Y but not identical

# Plan for next gamma irradiation tests for MCBC/Y/X

## Objective:

Determine the impact of irradiation on the inter-laminar shear strength of '10-stack' samples cut out of the existing old pre-series MCBC coil by Short Beam Bending test (SBB-test).



F. Wolf

## Task list:

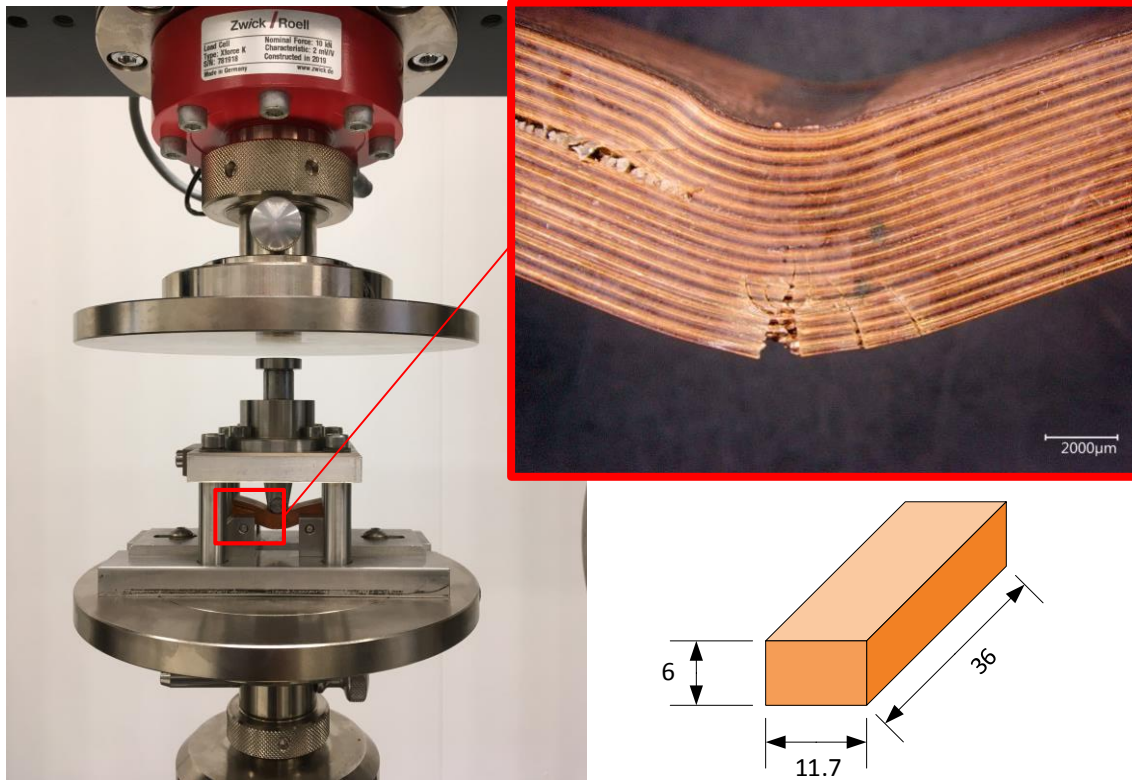
- Prepare the samples by diamond saw wire cutting - done 54 samples cut
- Perform pre-test at RT to determine the deviation of the SBS-test results - done EDMS:2317154
- Installation of samples to sample holders for irradiation – done, three sample holder for (2.5, 5, 10 MGy) equipped each with 12 samples

## To be done:

- gamma irradiation at different levels (2.5, 5, 10 MGy [air])
- post-irradiation Short Beam tests to evaluate shear strength @ RT/77K



# SBB-test of non-radiated cable stacks at RT



- SBS-test on EDMS: 2317154
- 6 samples tested at RT
- Mean short beam strength of  $81.3 \text{ MPa} \pm 4.5 \text{ MPa}$

The failure mode is mixed with:

- delamination by rupture of the insulation,
- rupture of SC cables by tension.

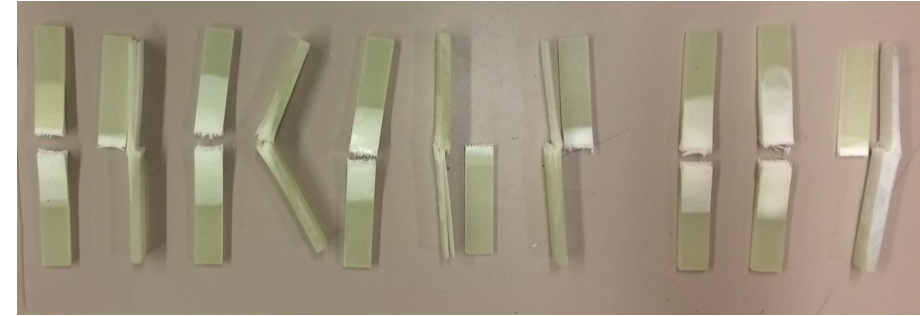
The results can be used as reference for comparison to tests on irradiated specimens.

**Test machine and detailed view on the broken sample.**

# Plan for next gamma irradiation tests for MCBC/Y/X

## Objective:

Determine the impact of irradiation on the flexural strength, inter-laminar shear strength and Charpy impact strength of **ISOPREG EP 2704**.



*Charpy Impact test done at 77 K*

## Task list:

- Prepare the samples - **done 160 samples cut**
- Perform pre-test at RT and 77 K to determine the deviation of the flexural and SBS test results – **in progress**
- Perform pre-test at RT and 77 K to determine the deviation of the Charpy test results – **done**
- Installation of samples to sample holders for irradiation – **done, three sample holders for 2.5, 5, 10 MGy equipped each with around 40 samples.**

## To be done:

- Gamma irradiation at different levels (2.5, 5, 10 MGy [air])
- Post-irradiation flexural and Charpy impact tests to evaluate shear strength @ RT/77K



# Plan for next gamma irradiation tests for MCBC/Y/X

Results of the Charpy impact test (0 MGy):

Temperature	Charpy impact strength (kJ/m <sup>2</sup> )	
	Average	St. deviation
RT	96,25	6,72
77 K	166,88	12,86

# Plan for next gamma irradiation tests for MCBC/Y/X

## Objective:

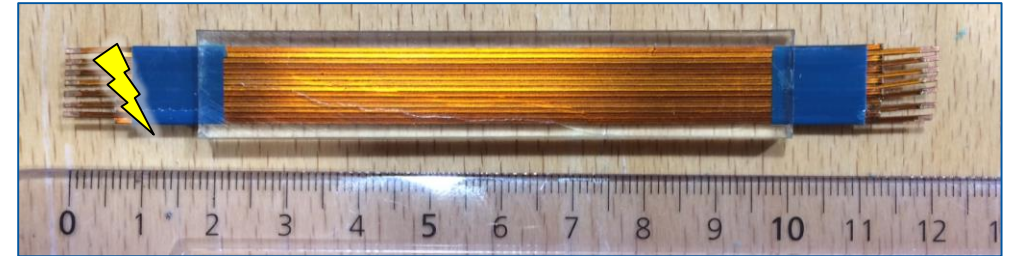
Determine the impact of irradiation on the breakdown voltage of an impregnated ribbon cable (NbTi). The impregnation is done with Araldite GY 285 + Jeffamine D400 (similar product to the one used previously in MCBC/Y).

## Task list:

- Prepare the samples – 30 were prepared, NOT VALID.
- Validation of the new geometry – in progress, third trial.

## To be done:

- Manufacture of the new samples
- Perform pre-test at RT to determine the deviation of the breakdown voltage test results
- Gamma irradiation at different levels (2.5, 5, 10 MGy [air])
- Post-irradiation breakdown voltage tests



*First non-valid sample. Short circuit at the ends.*



*Second non-valid sample. The bending damages the insulation.*

# Plan for next gamma irradiation tests for MCBC/Y/X

## Gamma irradiation:

The irradiation of all the samples could take up to two months, depending on the availability of the facility and radiation dose rate used. It will be done at BGS (Germany).

## Task list:

→ Prepare the documentation for BGS (Germany) – done

## Options:

→ Wait for the impregnated ribbon cable samples to be ready OR

→ Send now the 10 stack and the ISOPREG EP 2704 samples to the facility.