HL-WP3 MCBRD production status at CERN

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On behalf of CERN-IHEP collaboration

HL LHC week annual meeting

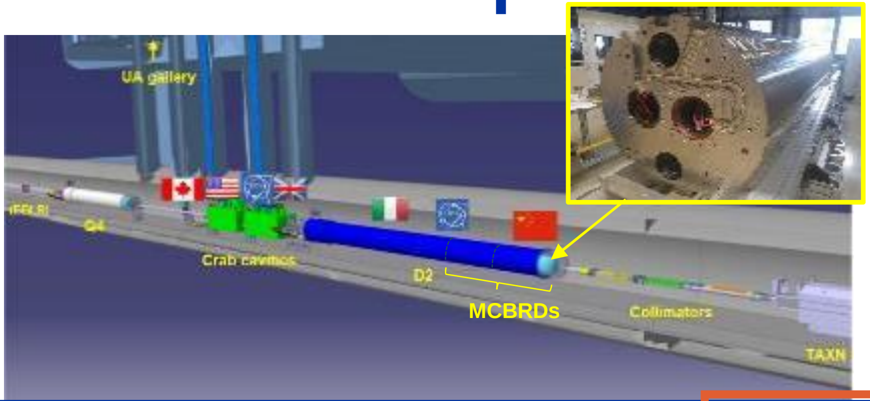
https://indico.cern.ch/event/1293138/

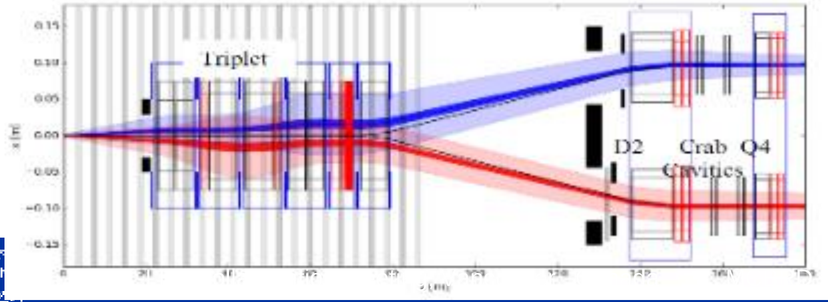
Outline

- HL-WP3 MCBRD D2 orbit correctors scope
- MCBRD11,12 features, background
- Components QC tests
- Series electrical diagram
- MCBRD11,12 Series coils production, acceptance tests, setbacks & lessons
- Electrical insulation of Coils to floating formers (MPE-MSC)
- Update schedule
- Summary

HL-WP3 MCBRD D2 orbit correctors scope

- Recombination dipole orbit correctors as part of the HL-LHC Work Package 3 based on Canted Cosine Theta (CCT)
- The MCBRD magnets constitute the **D2 orbit correctors (8 MCBRD series units + 4 spares) – IHEP responsible**
- **Completed MCBRDP4 @ CERN last 08/2022, tested successfully.**
- **Decision to start two series magnets MCBRD11,12 production at CERN 927 lab from Q1-2023 using IHEP components.**





Parameters @ nominal current (7 TeV operation)	D2 MBRD	MCBRD
Material	Nb-Ti	**Nb-Ti**
# apertures	2	**2**
Distance between apertures [mm]	188	**188**
Aperture [mm]	105	**105**
Field [T]	4.50	**2.60**
Integrated field [T.m]	35	**5**
Nominal Current [kA]	12.328	**0.394**
Stored energy [MJ]	2.26	**0.143**

Series MCBRD features

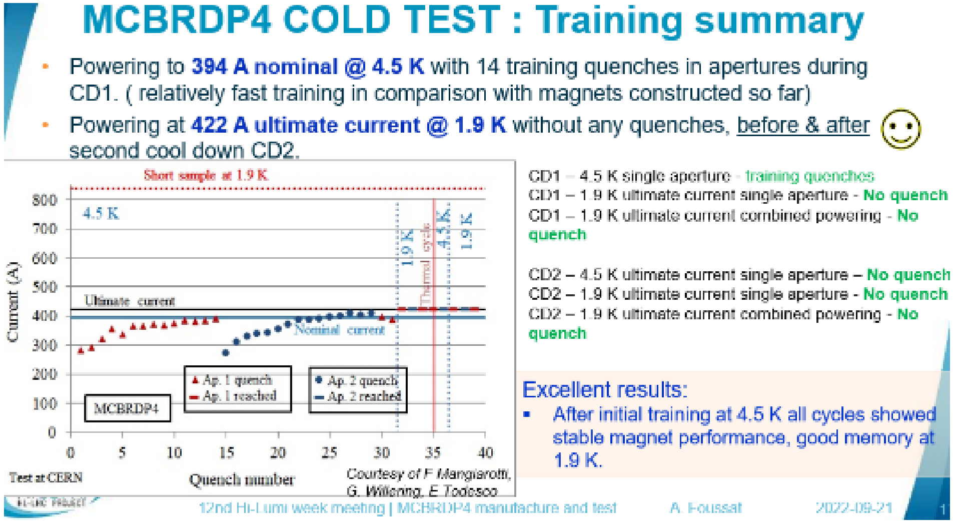
- **Last MCBRDP4 built in 2022 per the series magnet requirements. (EDMS 2051870), including recent series instrumentation consolidation.**
- **MCBRD11,12 follow the series manufacture features**

Parameters	Unit	Value
Aperture size	mm	105
Magnetic length	m	1.93
Nominal field	T	2.59
Nominal integrated field	T.m	5.0
Nominal current	A	394
Ultimate current	A	422
Short sample current at 1.9 K	A	767
Short sample current at 4.2 K	A	650
Loadline fraction at 1.9 K (WST)		53 / 47 %
Strand diameter	mm	0.825
Cu/no_Cu (WST wire)	-	1.95 (1.3)
Strand critical current at 4 T	A	700
Nominal strand current density	A/mm^2	737
Nominal superconductor current density	A/mm^2	1695
Nominal differential inductance per aperture	mH	970
Nominal stored energy per aperture	kJ	74.9
CCT skew angle	deg	30°
No. of turns per layer		365
Slot size in former (mm) (IHEP depth)		2.1 × 5.2 (4.9)
Number of CCT layers / Strands in channel		2 / 5 x 2

Background

- Since **last MCBRDP4 prototype made at CERN and successful cold test** as reported at last HL-LHC annual meeting, it was decided to **support the IHEP series production** activities and launch **MCBRD11-12 fabrication** at CERN**.**

- **All components were provided by IHEP CN sub-suppliers** (from Q1-2023).
  - *20 kms of WST insulated wires*
  - *6 tons of iron laminations*
  - *8+4 Alu formers, ext. tubes anodized*



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WST sc insulated wires delivery (MCBRD11-12)

- Last delivery of single 20 kms UL of **WST SC NbTi insulated wire** by IHEP from Q4-2022.
- Original traveller shown **several identified defects in the PI insulation** (65 microns thick), rechecked by IHEP, then at CERN.
- Standard repair procedure is applied at CERN on line.

线材检测
Wire inspection

序号 serial number	米数（由里向外） Meters (from inside to outside)	备注（测试电压为2400V） Remarks (the test voltage is 2400V)
1	81	击穿/Electrical Breakdown
2	3762	原有标记/Original Mark
3	4642	原有标记/Original Mark
4	8492	原有标记/Original Mark
5	10752	击穿/Electrical Breakdown
6	12299	击穿/Electrical Breakdown
7	13462	原有标记/Original Mark
8	14856	原有标记/Original Mark
9	14869	击穿/Electrical Breakdown
10	14892	原有标记/Original Mark
11	16362	击穿/Electrical Breakdown
12	17118	击穿/Electrical Breakdown
13	17148	击穿/Electrical Breakdown
14	17162	原有标记/Original Mark
15	17572	原有标记/Original Mark
16	20062	击穿/Electrical Breakdown
17	20945	击穿/Electrical Breakdown

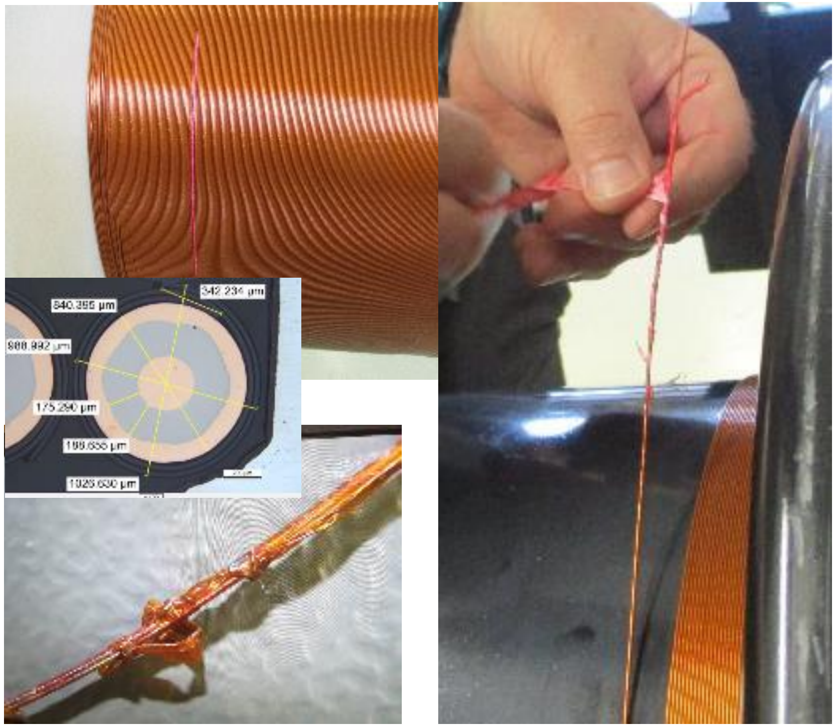


Fig. 1- Type of defects QC marked on SC supply UL

WST wires Hi-pot re-test & respooling at CERN

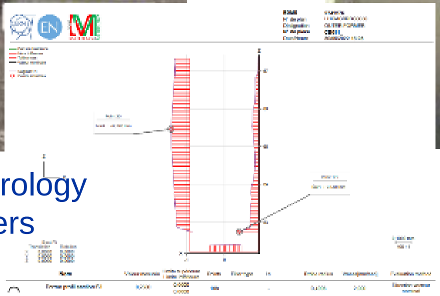
- Spool splitting work at CERN, cleaning and rewind of **44 individual ULs spools** (480 m each) involved **Hi-pot test at 2 kV**, revealing a few more defects than marked ones by IHEP supplier
- ✓ ***Further re-check of the Ic(B), metallographic tests to exclude risk of elongation during heavy spool respooling: no apparent Ic degradation.*** (NC 2790885)

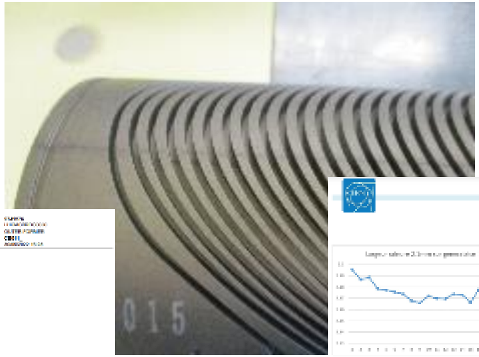
IHEP SPOOL manufacture			Fait du 27/09/22 au 30/09/22	lieu:Bat 103	Bat 927 fait le 05/10/2022			Test isolation électrique /Bat 927 Fait du 13/10/22 au 14/11/22			
technicien: F.Garnier P-A.Contat	Commentaire: La longueur des tourets ne doivent pas être inferieur à **480m**							first 0.8 meter and last 3 meters are not tested			
Projet	N°Tourets	Longueur initial	Défaut et Remarque	Total	Respooling longueur utile	Longueur restant	Défaut visuel	HVC Test Isolation at 2k	Remarque	sens polyimide sur le palan	sens polyimide Machine respool
MCBRD-AP15	2	704.00	Brulée 1199-1201,Début	1184.00	716m		Brulée: 0 à 3m Kapton:355m	2 x 10 uA fault	2 faults at the same location: 1m 10 uA	sens non bobinage	sens bobinage
MCBRD-AP15	11	485.00	Prélever 2,5m pour test le 11.11.22	5778.00	491m		Repère blanc: Brin déformé: 132m	Ok		sens non bobinage	sens bobinage
MCBRD-AP15	15	480.00		7698.00	486m		Kapton:156m Kapton:235m	Ok		sens non bobinage	sens bobinage
MCBRD-AP15	23	480.00		11695.00	486m		RAS	Ok		sens non bobinage	sens bobinage
MCBRD-AP15	25	480.00		12655.00	486m		Kapton:37m Repère blanc:248m	4 x 10 uA fault	4 faults 10uA at the same location: 233m	sens non bobinage	sens bobinage
MCBRD-AP15	29	480.00		14519.00	486m		RAS	Ok		sens non bobinage	sens bobinage
MCBRD-AP15	37	480.00		#REF!	485m		RAS	Ok		sens non bobinage	sens bobinage
MCBRD-AP15	42	480.00	Prélever 2m pour test le 11.11.22	#REF!	485m		Repère blanc: 14,8m	2x 10 4x 25 uA fault	1 fault 10uA 4 faults 25uA at the same location: 337.5m / 1 fault 10uA: 466m	sens non bobinage	sens bobinage

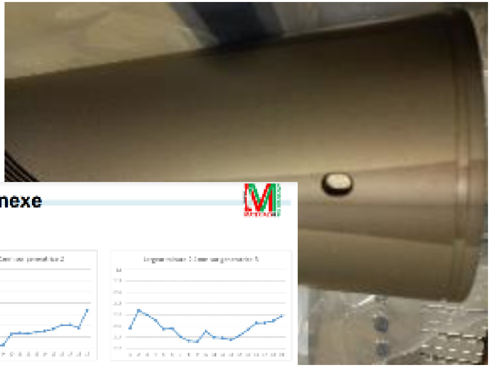
Fig.1 Initial respooling (B927), then splitting (B163).

CMM on IHEP Al6082 formers, tubes

- ***CB10,11,15,16 Alu formers received (8+4) inspected, dimensional checks at CERN:***
  - ***White spots on anodised surface, uneven change of contrast (thickness variation)***
  - ***Inner/ Outer CB10-11 with mean depth 5.2 mm (different profile from CERN)***
  - ***Inner/ Outer CB15-16 with mean depth at 4.9 mm (IHEP baseline)***
  - ***Nominal 2.1 mm width oversized by extra 40 microns***







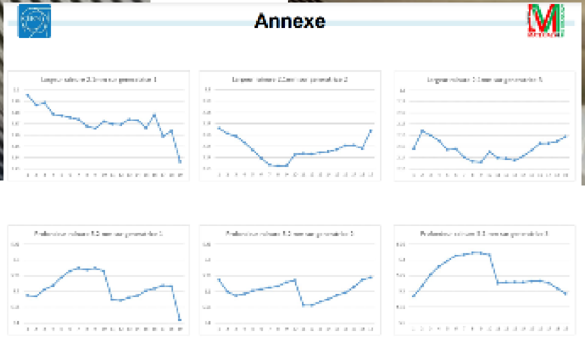
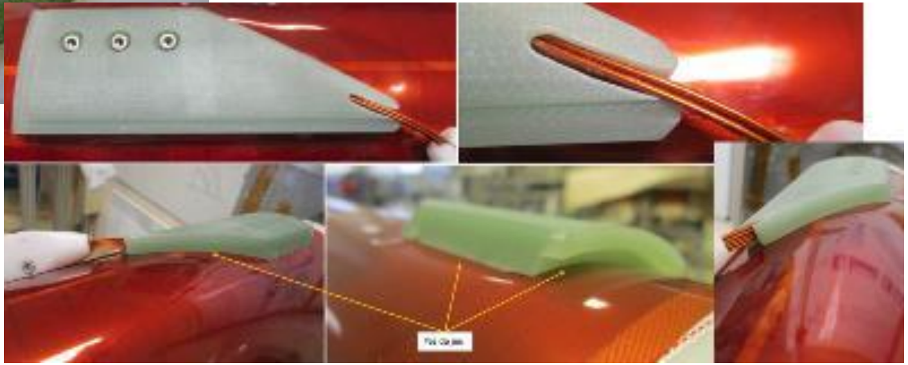


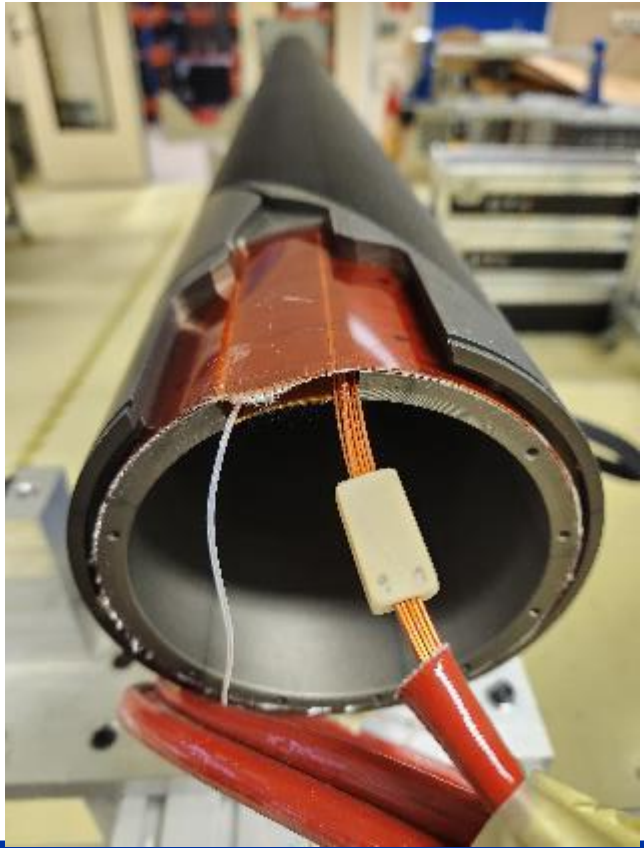
Fig. 1- CMM 3D metrology bench of IHEP formers (CERN)

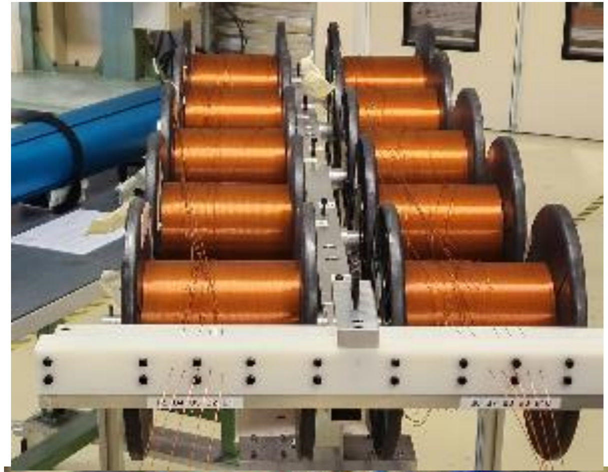
Auxiliary pieces

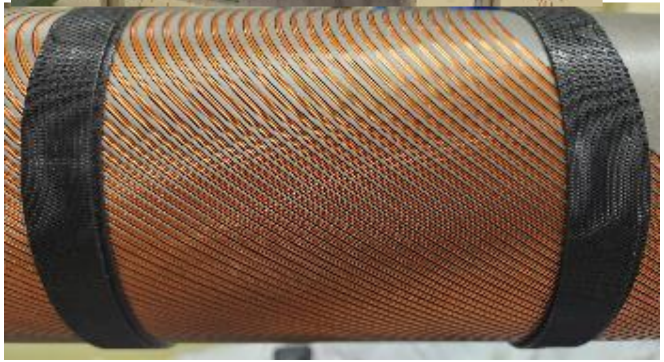
✓ *All GFRP pieces conform to IHEP drawings.* ***Layer jump and connection boxes required slight outer radius correction to match insertion gaps.***



Winding activities

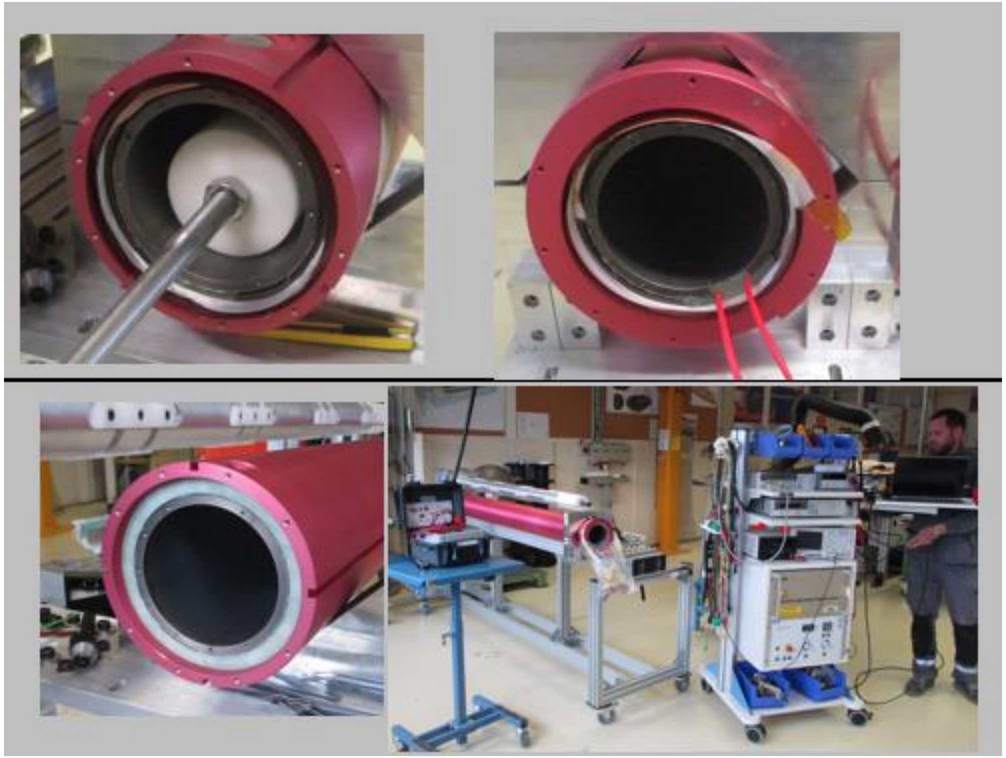


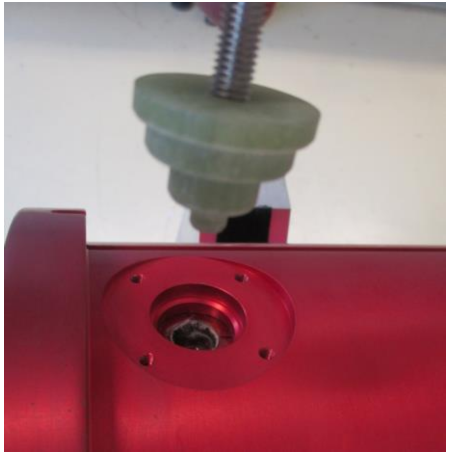




- Winding process still broadly manual **followed past qualified applied procedure on prototypes**.
- Validated on AP11, further setbacks on AP10,15, and AP16.

Aperture final preparation steps





- Components dimensions compatible with common series CCT assembly procedure

Series electrical diagram

- **The applied electrical diagram was updated for series (EDMS [2817784/1.0](#),** used on MCBRD11, 12
  - No central VTs, no CLIQ lead, no T-sensors.
- **All past MCBRD P03b, P04 prototypes & S02 were modified** to comply with the series diagram.
- **IHEP confirmed diagram compliance of series from MBRD04 (V2)**

Aperture V1: AP10

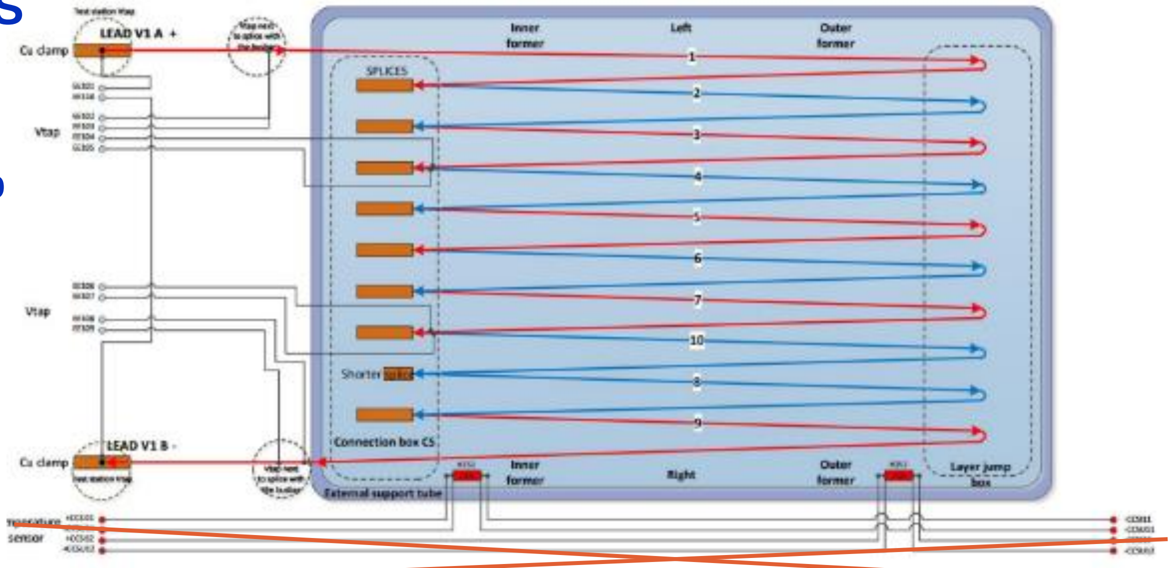


Figure 6. Wiring scheme for aperture V1 (MCBRD-AP10) EDMS 2817784

EDMS 2817784/2.1

Coils winding production update schedule

Coil #ID number	Period
AP11	Jan – Feb. 2023
AP10	Mar. 2023 / Nov 23 - Jan 2024
AP16	Apr. 2023 / Oct. - Nov. 2023
AP15	July 2023 / on going - Oct. 2023

MCBRD12 AP11: Hi-pot & magnetic tests acceptance

- ✓ *Hi-pot test passed <u>after</u> impregnation (PAI), ready on shelves (QC Hi pot test to formers at dry is mainly for check). AP11 insulation similar to majority of coils*
- ✓ *Magnetic test is conform*

		Test name		**PAiWi**	**(Fiber glass+ Kapton + layer jump box)**	**PAWi**	**PBI**	**PAI**	**Final**	
		Date		27/01/23	06/02/23	15/02/23	15/03/23	13/04/23		
		Operator name		PA Contat	PA Contat	PA Contat	PA Contat	PA Contat		
		T_{amb} [°C]		19.6	21	20.9	20.6	21.9		
		Humidity [%]		23.5	26.6	28	29	30.2		
	Insulation resistance	U[test]	time	measured	measured	measured	measured	measured	measured	nominal
		[V]	[s]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]
MCBRD-AP11	coil ---> former inner	500	30	59.9	25.7	22.10	X	X	X	>1
	coil ---> former outer	500	30	X	X	15.51	X	X	X	>1
	inner former ---> outer former	500	30	X	X	X	X	X	X	>1
	inner former ---> ext. tube	1000	30	X	X	X	21.00	168.2	X	>1
	coil ---> inner former	500	30	X	X	X	X	X	X	>1
	coil ---> inner former	1000	30	X	X	X	220MΩ	17.89	X	>1
	coil ---> ext. tube / ground	500	30	X	X	X	20.90	X	X	>1
	coil ---> ext. tube / ground	1000	30	X	X	X	14.26	177.2		>1
	coil ---> ext. tube / ground	3250	30	X	X	X	X	156.5		>1
	CCS 308 ---> all tubes	500	30	X	X	X	1.563MΩ	X	X	>1
	CCS 308 ---> all tubes	1000	30	X	X	X	X	2540		>1
	CCS 355 ---> all tubes	500	30	X	X	X	521	X	X	>1
	CCS 355 ---> all tubes	1000	30	X	X	X	X	>3T		>1
	coil ---> CCS 308	500	30	X	X	X	1.45	X	X	>1
	coil ---> CCS 308	1000	30	X	X	X	X	2140		>1
	coil ---> CCS 355	500	30	X	X	X	466	X	X	>1
	coil ---> CCS 355	1000	30	X	X	X	X	>3T		>1

MCBRD12 AP 10: Hi-pot tests acceptance

- *AP-10 Hi-pot test shown unusual low insulation resistance level (10 kOhms) between coil and floating inner/outer former <u>After</u> impregnation (PAI) (EDMS NC 2907797).*

			Test name		PAiWi (Fiber glass)	After inner winding (Fiber glass+ Kapton + layer jump box)	(Fiber glass+ Kapton + layer jump box) outer former insertion	(Fiber glass+ Kapton + layer jump box) outer former insertion	PAWi	PAWi extra test for validation	PBI	PAI
			Date		02/12/22	06/12/202	08/12/22	12/12/22	19/12/22	31/03/23	12/04/23	01/06/23
			Operator name		PA Contat	PA Contat	PA Contat	PA Contat	PA Contat	PA Contat	PA Contat	PA Contat
			T_{amb} [°C]		20.8	19.9	18.6	19.9	34.6	22.4	21.3	23.7
			Humidity [%]		29.5	31.5	28.6	24.8	20.5	41.9	38.7	48.5
MCBRD-AP10	Insulation resistance		U[test]	time	measured	measured	measured	measured	measured	measured	measured	measured
			[V]	[s]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]
	coil ---> former inner		500	30	13.61	20.4	X	X	14.15	X	X	X
	coil ---> former outer		500	30	X	X	20.0	18.32	18.07	14.57MΩ	X	X
	inner former ---> outer former		500	30	X	X	14.32	17.67	X	X	X	X
	inner former ---> ext. tube		1000	30	X	X	X	X	X	X	13.61	139.4
	coil ---> former inner		500	30	X	X	X	X	X	X	X	X
	coil ---> former inner		1000	30	X	X	X	X	X	X	Brd 1025V /918MΩ	<10kΩ 61V
	coil ---> ext. tube / ground		500	30	X	X	X	X	X	X	35.90	X
	coil ---> ext. tube / ground		1000	30	X	X	X	X	X	X	13.56	132.2
	coil ---> ext. tube / ground		3250	30	X	X	X	X	X	X	X	138.5
	CCS 351 ---> all tubes		500	30	X	X	X	X	X	X	152	X
	CCS 351 ---> all tubes		1000	30	X	X	X	X	X	X	X	2380
	CCS 352 ---> all tubes		500	30	X	X	X	X	X	X	453	X
	CCS 352 ---> all tubes		1000	30	X	X	X	X	X	X	X	1928
	coil ---> CCS 351		500	30	X	X	X	X	X	X	139	X
	coil ---> CCS 351		1000	30	X	X	X	X	X	X	X	1895
	coil ---> CCS 352		500	30	X	X	X	X	X	X	684	X
	coil ---> CCS 352		1000	30	X	X	X	X	X	X	X	2230

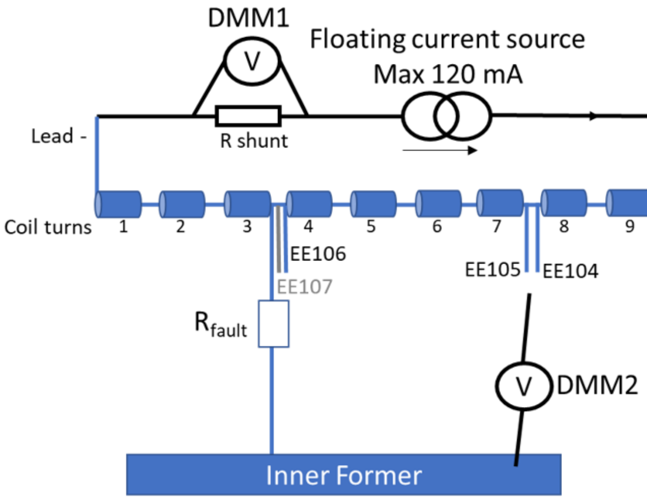
See next localisation and frequency Z method confirmed fault value to floating former.
Note excellent ground insulation at 140 Gohms.

Root cause analysis, AP10 - Actions

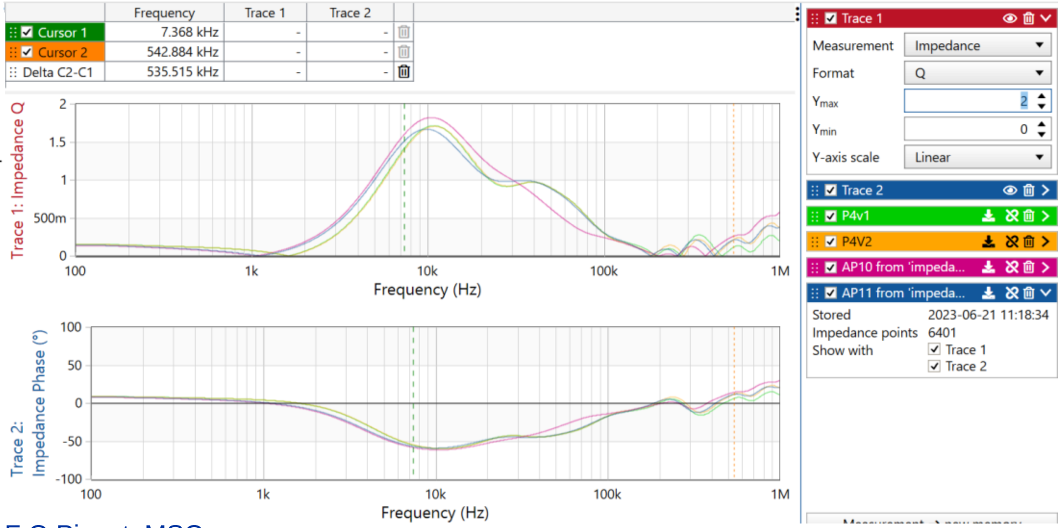
- *A1- Splicing* : AP10 suffered a first **unusual issue of broken strand during splicing** which required repair (NC 2818415)
- *A2- Post impregnation* : The insulation **resistance coil to formers of few MOhms did not increase after impregnation (PAI)** like most of past coils to Gohms.
  - Localization test on **direct fault** (~10kOhms, post impregnation), **close to interconnection box**, i.e not related to winding.
  - Plausible root cause is **loss of EE107 VTs worsening** during tube insertion.
  - As no feedback on possible fault time evolution, **decision not to be installed**.
- Recovery actions :
  - Production of **new Alu formers, tube** at CERN as replacement of AP10
  - Use left CERN stock of sc insulated wires. Parallel order of a **10 kms reserve SC insulated wire** (enhanced bonding).

AP10 diagnostics

- DC voltage fault localisation method allowed to locate **direct short of 13 kΩ at about 6 cm from splicing box** entrance, close to EE106 voltage tap. (EDMS 2918370, MPE report)
- **Z frequency measurement : insight from quality factor Q measurement vs. frequency** showing clear deviations from the sane coils



Mateusz Bednarek, MPE



F.O Pincot, MSC

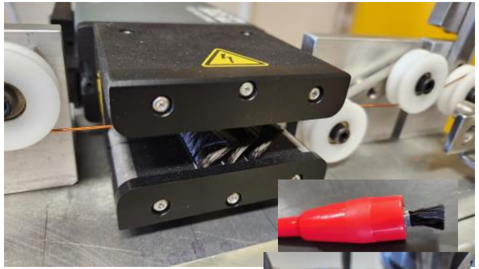
AP16 – Hi-pot test outcome- (winding stage)

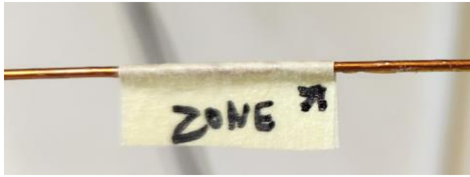
- ✓ ***AP-16 Hi-pot test passed <u>during winding</u> (PAWI) but <u>not before Impregnation (PBI)</u>.***
- ✓ *Following experience from AP10, decision **not to further impregnate, investigate (on going) and rewind once root cause identified.***

		Test name		PAiWi	PAWi	PBI	PBI_bis	PBI_bter
		Date		29/03/23	30/04/23	26/06/23	27/06/23	28/06/23
		Operator name		PA Contat	PA Contat	PA Contat	PA Contat	PA Contat
		T_{amb} [°C]		21.7	22.1	28.1	24.6	23.5
		Humidity [%]		28.2	52.45	45.3	51.5	42.3
MCBRD-AP16	**Insulation resistance**	U[test]	time	measured	measured	measured	measured	measured
		[V]	[s]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]
	coil ---> former inner	500	30	33.0	2.43	X	X	X
	coil ---> former outer	500	30	X	7.91	X	X	X
	inner former ---> outer former	500	30	X	X	X	X	X
	inner former ---> ext. tube	1000	30	X	X	2.40	10.75	18.34
	coil ---> inner former	500	30	X	X	X	2.43	2.38
	coil ---> inner former	1000	30	X	X	Brd 589V	Brd	Brd
	coil ---> inner former	1000	Ramp 2kV/min	X	X	X	X	Brd 602V / 82.1MΩ
	coil ---> outer former	500	30	X	X	X	X	2.94
	coil ---> outer former	1000	30	X	X	X	X	Brd
	coil ---> outer former	1000	Ramp 2kV/min	X	X	X	X	Brd 962V / 106.9MΩ
	coil ---> ext. tube / ground	500	30	X	X	3.05	24.20	17.97
	coil ---> ext. tube / ground	1000	30	X	X	4.05	21.80	29.70
	coil ---> ext. tube / ground	3250	30	X	X	X	X	X

AP15 winding, root cause analysis, actions

- First decision to add bottom extra 0.17 mm tck fiber glass at bottom like IHEP (extra height and electrical barrier)
- **Additional QC intermediate Hi-pot tests on the manual winding process (~ each 1/5th layer)**
- **2/3 inner layer passed Hi-pot test, last section did not**.
  - Root cause analysis report EDMS 2936245 pinpoints occurrence of damage at each tip (50 cm) under 1kV test
  - **Only two bottom wires affected due to winding process, enhanced by *low bonding of WST wire insulation*** *(270 deg C cured, vs.400 degC on P4)* ***and relative sharp former edge***.
- *Actions:*
  - *CERN 927 team developed an **improved tooling with extra protection** (next slide).*
  - ***Rewind started** using SC CERN wires from **stock with best curing temperature** feature (310 degC).*





QC analysis and improvement of winding

- **New PI sheet travelling funnel** as protection of bottom wires insulation (Fig.1)
- **Progressive Hi-pot testing** during winding to check any porous insulation (Fig.2)
- Occurrence of **breakdowns at ramps to 1 kV at respective 600 V or 900 V** due to **Paschen conditions** in either possible 65 microns or 110 microns wide **air gap**. (Fig.3)

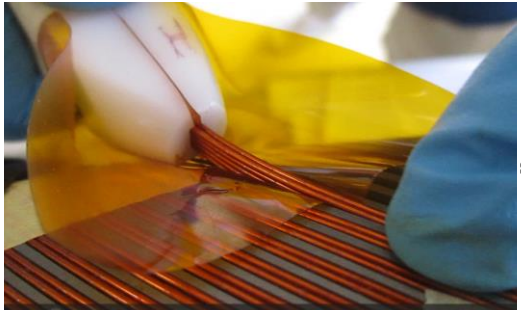


Fig. 1- New travelling PI protective sheet, 50 mic. thick guiding funnel

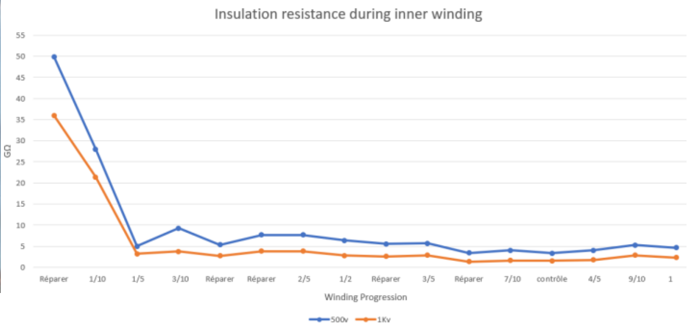


Fig. 2 - on going progressive Hi-Pot test coil to inner former on AP15 winding (09/2023)

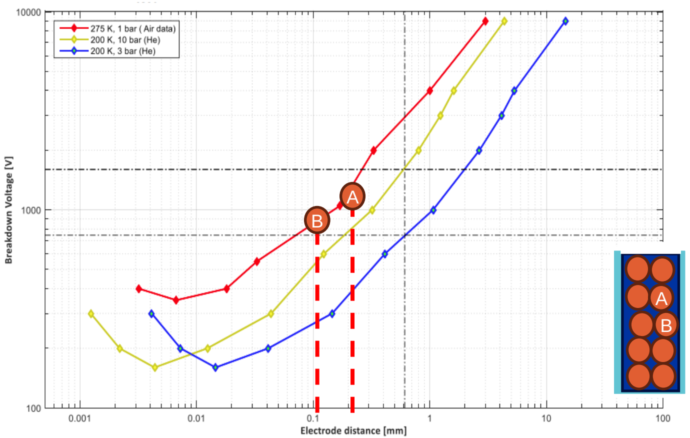
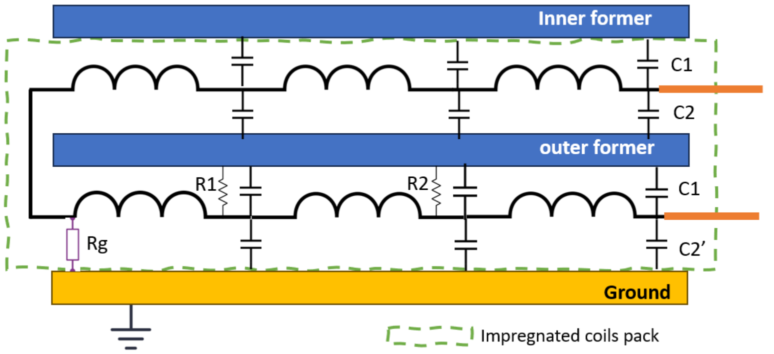


Fig. 3 - Paschen curve in air, 1 bar, @273 K (red line)

Electrical insulation of floating formers to Coils (MPE-MSC)



CCT electrical schematic, SMT A Foussat

- **A- "Occurrence of one short coil to the formers on its own does not pose any problems for the operation unlike multiple shorts"**
  - What are acceptable double short values level of R1,R2 ?
  - From quality assessment point of view, too weak insulation is a strong indication and can be a cause of rejection. (note no information on fatigue)
- **B- Insulation faults to floating inner formers cannot be detected after magnet assembly. QC tests during manufacture** like hi-pot test and Impedance measurements can **intercept shorts at production**.

- ***C- Indications of Capacitive effect from floating formers (~200 nF)*** during Hi-pot testing campaign of AP10: Charging from dV/dt hi-pot test history of several 10's volts. To be further discussed with MPE to analyse pro & con's, see if any measures to be taken. (inner formers not accessible in MCBRDs)

Assembly schedule (next 6 months)

Milestones	Date
MCBRD 11, 12 components delivered at CERN	mid Feb. 2023
1st series magnet assembly at CERN (MCBRD12)	Nov. 2023
2nd series magnet assembly at CERN (MCBRD11) *	Feb 2024
Cold test at CERN (MCBRD12)	Dec. 2023 – Jan 24
Cold test at CERN (MCBRD11)	By April. 2024

* Need IHEP delivery of **MCBRD11 structure by End September 2023**.

Summary

- The **manufacture of MCBRD11, 12** has started with apertures production using **IHEP delivered components** following last proven MCBRDP4 procedures.
  - ***Aperture AP11 is ready***, *approved* ***for magnet assembly***,
  - *Impregnated* ***AP10 shown low electrical insulation to formers***, *rejection of coil. Production of new formers by December 23.*
  - ***Further setbacks providing several insights from AP15, AP16 winding*** *in presence of weak wire insulation type, partial anodisation cases.* ***Production back to track with adaptation of 927 winding tool***. *Target of* ***first 2 coils readiness for assembly by November 23.***

- Last update **series electrical diagram approved by** IHEP as compliance set from MCBRD04

- **Large work of standardisation consolidation and repair in front ends** carried out at CERN (180, 927 teams) on CERN prototypes (3,4) and first IHEP series 01, 02 then 03.

- CERN **Magnet assembly of MCBRD12,11** planned respectively **by Dec 23, Feb 24** followed by cold test in SM18. (last IHEP structure shipment by end Oct.)

Acknowledgment to active contributors from 927 SMT team

Carlos Fernandez, Frederic Garnier, Veronica Ilardi, Pierre Antoine Contat, Francois Olivier Pincot, Ruth Diaz Vez, Sabine Menu, Pietro A. Rizzo, Dominique Cote, Ahmed Benfkih, Cedric Urscheler, Sebastien Clement, Roland Piccin, Diego Perini, Ezio Todesco.

and our colleagues from IHEP supplying components:

Qingjin Xu, Yingzhe Wang

Thank you for your attention

BACK UP SLIDES

splicing resistance

MCBRD exhibit joint average resistances at 6 but some deviates on series up to 10 nOhms at nominal current. Some update design is being considered in future CCT to target 1-2 nOhms range. (key for large joints number in CCTs)

Long series MCBRD : 9 splices per aperture

- 45 mm long
- Crimping with “non insulated end-

sleeve “ (= tube)

- Sn96Ag4 welding alloy
- Flux MOB39
- Polyimid sleeve for protection
- G10 connexion box

MCBRD1

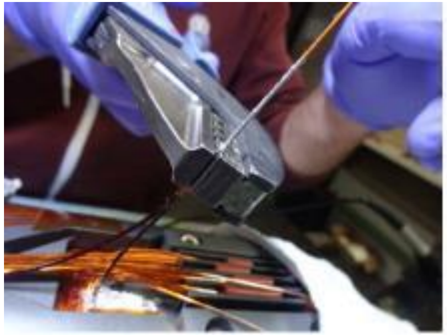
Ap.	V taps	Resistance [nΩ]
1	EE24-EE25	6.55 ± 0.02
	EE26-EE27	6.62 ± 0.04
2	EE14-EE15	5.38 ± 0.06
	EE16-EE17	5.03 ± 0.07

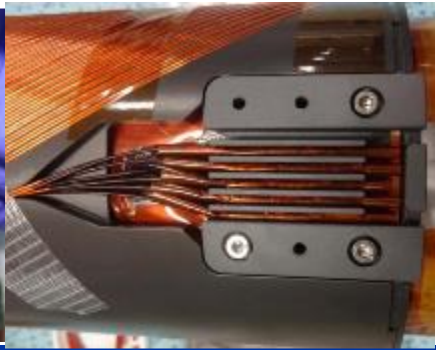
MCBRD1b

Aperture	V taps	Resistance [nΩ]
V1	EE14-EE15	5.36 ± 0.6
	EE16-EE17	5.32 ± 0.5
V2	EE24-EE25	3.20 ± 0.4
	EE26-EE27	

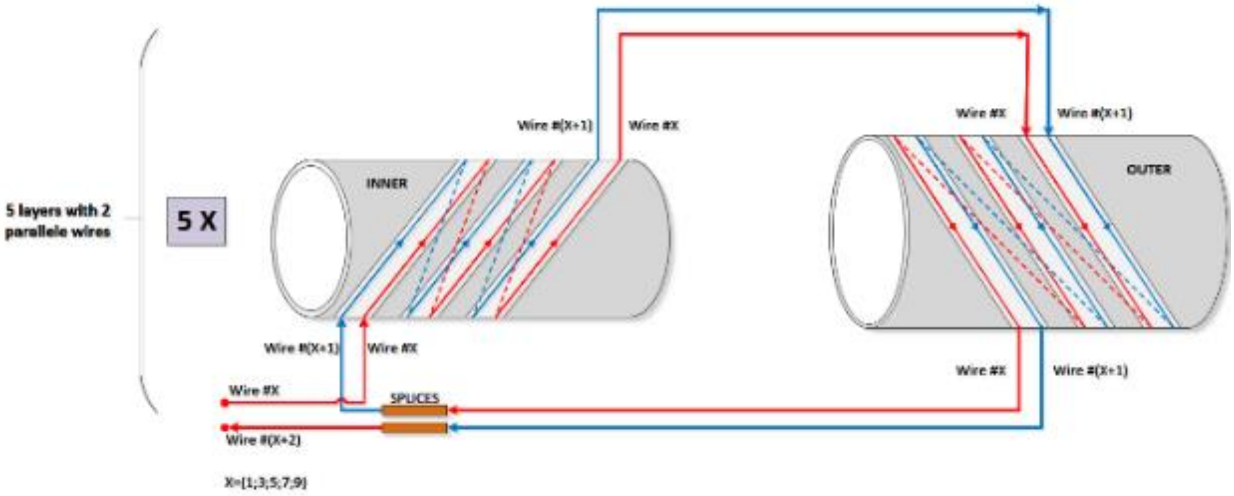
MCBRD3

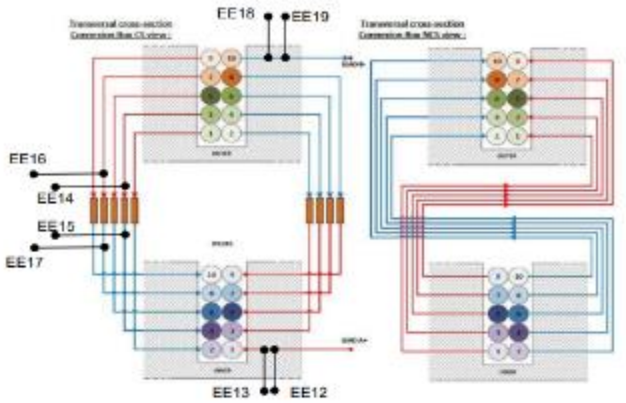
Ap.	V taps	Resistance [nΩ]
1	EE108-EE109	9.16 ± 0.12
2	EE24-EE25	6.77 ± 0.03
	EE26-EE27	6.51 ± 0.05





Inter layers series splicing





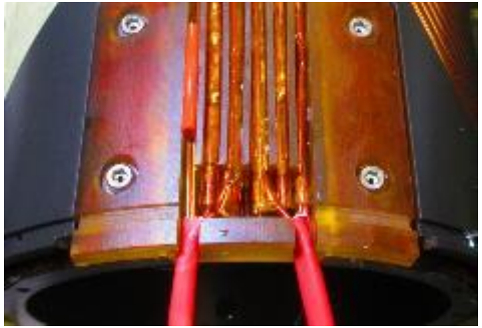
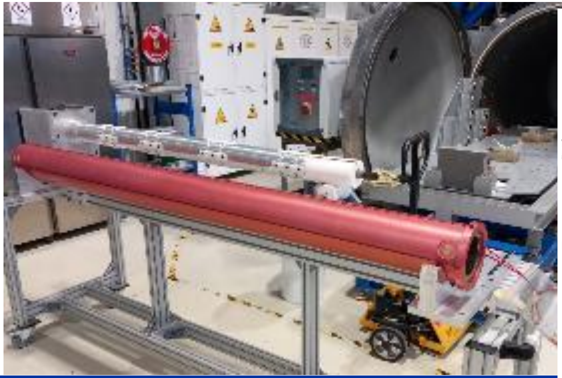


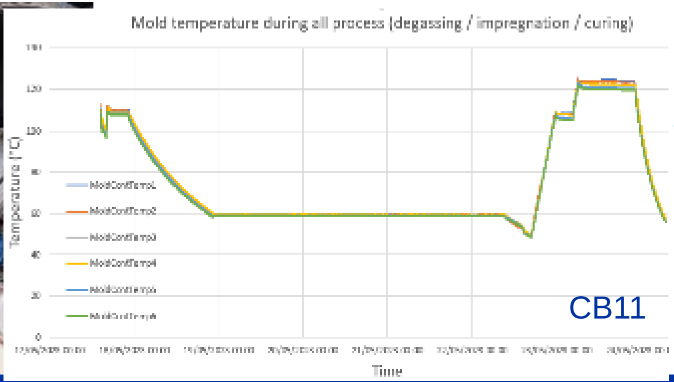
Fig.1 Series splicing terminal connection box

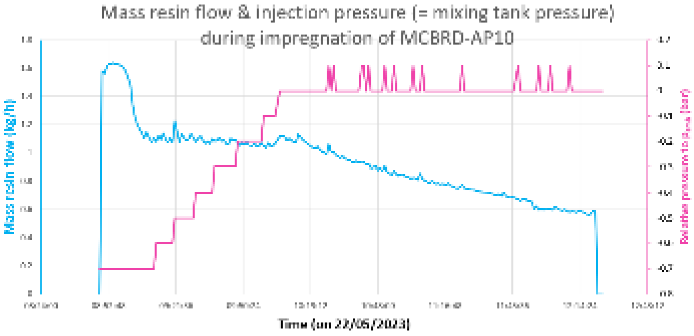
- 10 wires winding layers spliced in series in the connection box
  - 10 voltage taps wires and 9 SC wires splicing
  - Crimping, Sn96Ag4 soldering and polyimide insulating
  - Current design reaches joint resistances values of 7-8 nOhms at cold when procedure is applied.

VPI impregnation

- *CB 10,11 followed the VPI update CERN procedure [EDMS 2002875]*
  - *Use of milking cycle turn out useful, N2 gas overhead pressure on tank*
- *All apertures VPI impregnation followed same procedure and exhibit similar filling, hydraulic behavior as previous MCBRDP4 (circ. 1h filling time, overhead pressure up 0.7 b in tank)*
- *Capacitance monitoring had issues of grounding, partially good on AP10 (under progress)*

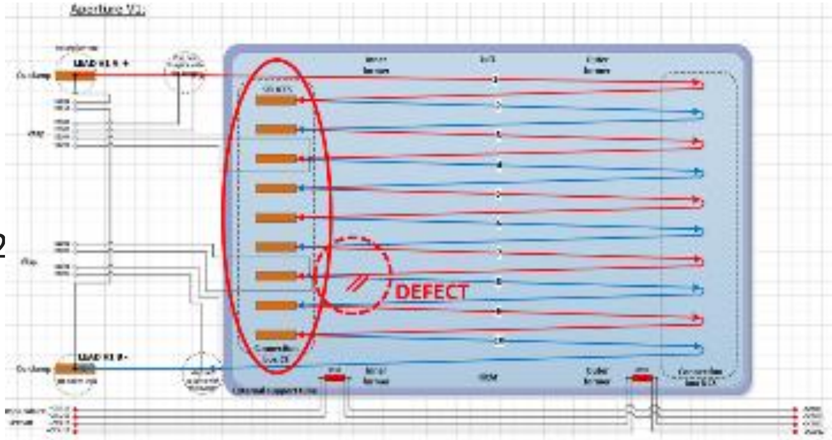






Splicing

- ❑ Splicing executed according CERN procedure EDMS 2002873/1.1 .
- ❑ ***NC 2818415 on AP10 :*** Broken wire MCBRD12-V1 - HCMCBRD_C015-CR000001
  - An issue occurred due to **misalignment of crimping tool**;
  - Solution: wires connection order could be adapted:
    - ✓ outer wire 7 spliced with the inner wire 10 with 2 Vtaps.
    - ✓ outer 10 is spliced with the short inner 8 without instrumentation.



Consolidation of CS front end

- **Following Hi-pot voltage limitation found below 1650V test value at cold on both MBRD01, MBRD02 during Q4-2022, baseline design was updated to minimize assembly risk.**
- Issuance of ECR 2797173,
- MCBRD01: NC2755485, MCBRD02: NC2795912
- Finding of damaged VT wires, braids during front end assembly, not all PI insulated wires.
- **A new routing was proposed to minimize wires crossings (see next slide). All protective fibre glass sleeves have to be replaced, soldered joint consolidated with PI sleeves and thermo shrinkable sleeves.**

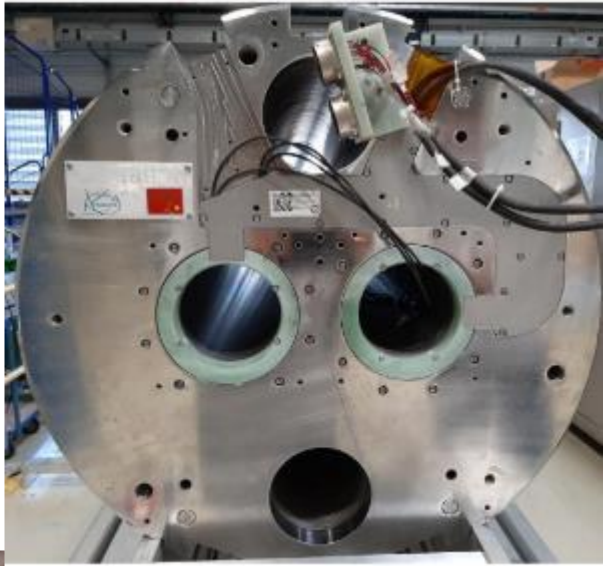
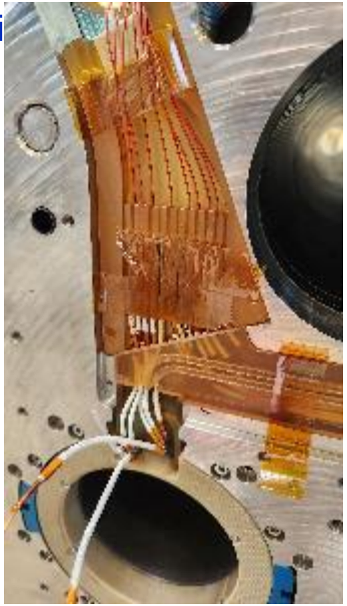


Figure 10 – Vtap exposed conductor

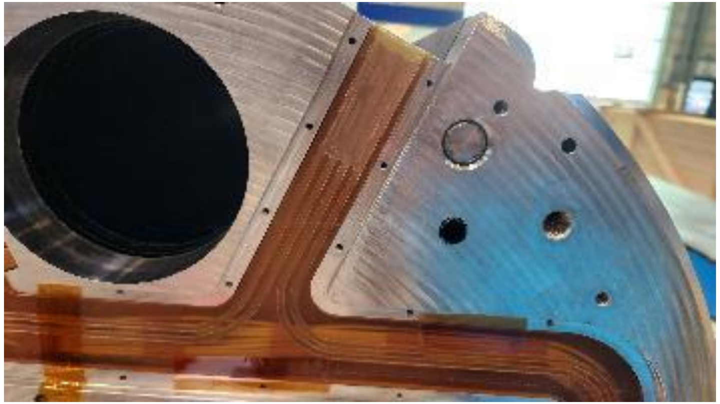
Figure 11 – Pinched CCS T-sensor wire

Front end wires routing

- **Routing update decided of VTs and leads wires from MCBRD01, 02, 11, 12, P3, P4. localized in front end routing CERN agreed to update design to limit risk during assembly**
  - In-situ local machining of end plates
  - Separation of VTs and Leads channels on double level to avoid successive crossi
  - Use of newly produced transparent Ultem® covers.



- **CERN decided to apply this update to all 6 magnets incl. P3b & P4**



End plate machining

- Local machining example on MCBRDP3b of the central channel in SS end plate for installation of new routing covers