High Order Correctors prototypes

Marco Statera
on behalf of the LASA team
INFN Milano - LASA

8th HL-LHC Collaboration Meeting
CERN – 18 October 2018

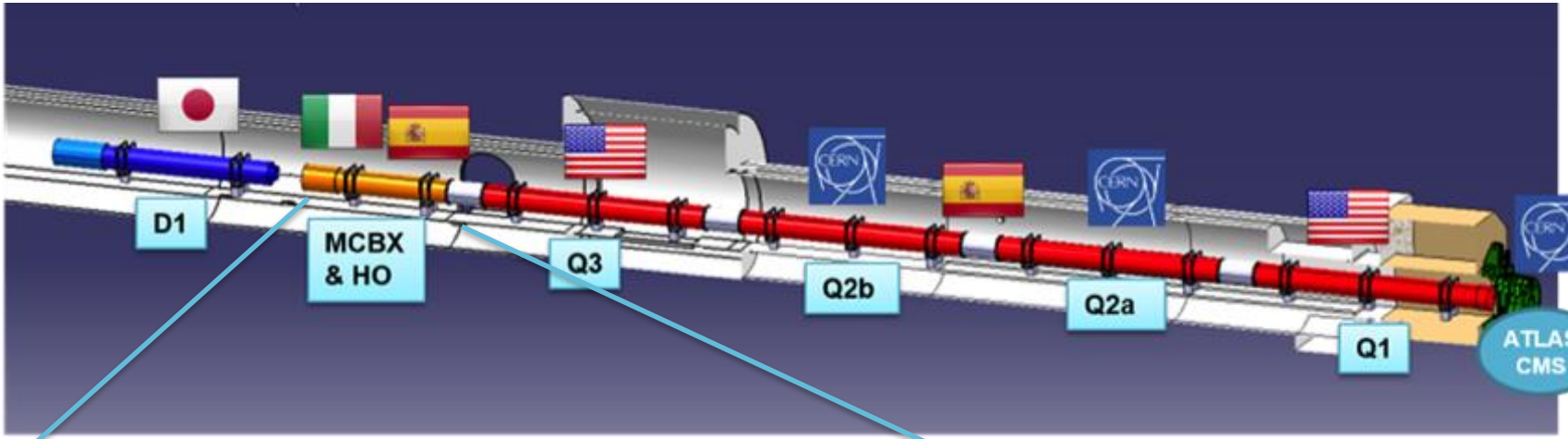
OUTLINE

- scope: the High Order correctors magnets
- coils studies
- change of scope: integrated gradient
- dodecapole **MCTXF** and quadrupole **MCQSXF**
- Round Coil Superconducting Magnet
- integration
- next steps

SCOPE - High Order Correctors

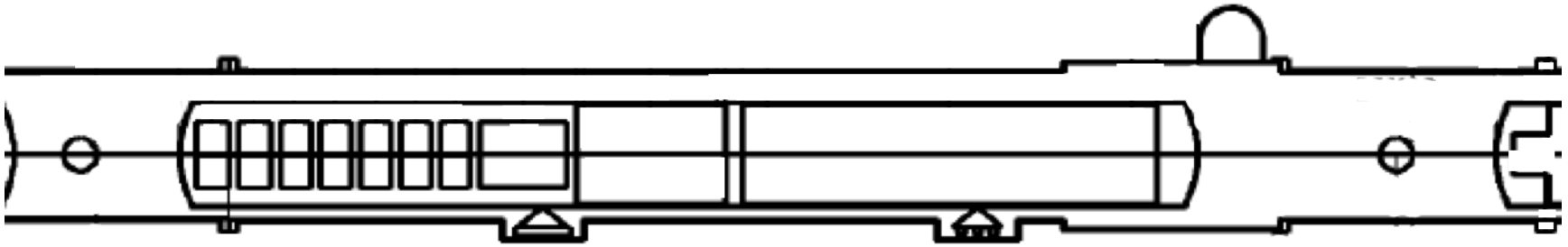
- The INFN-LASA follows the design, construction and test of the 5 prototypes of the High Order (HO) corrector magnets for the HL interaction regions of HL-LHC
- This activity is funded by INFN (Magix “activity”), and with an agreement CERN contributes for about 50%
- The INFN-LASA will follow the series production of the HO corrector magnets for the HL interaction regions of HL-LHC

THE LOW BETA SECTION and the High Order Correctors



73.6 m

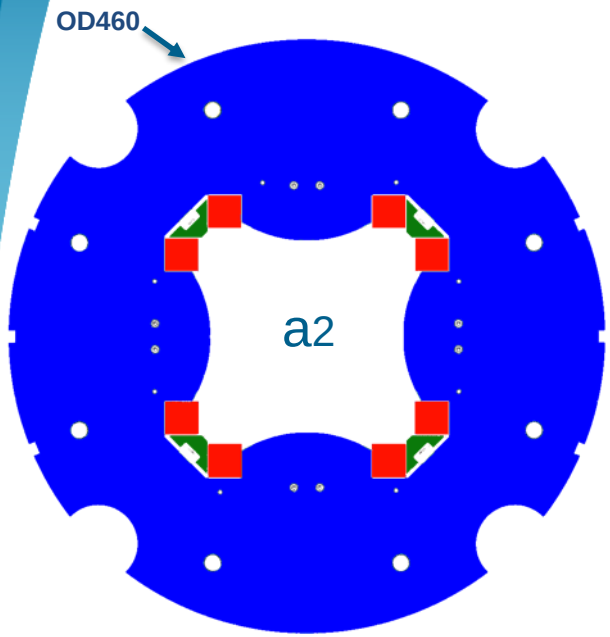
IP



b3 b4 b5 b6
a3 a4 a5 a6 a2

by P. Fessia

HO CORRECTOR MAGNETS ZOO



MCQSXFP1

MCSXFP1

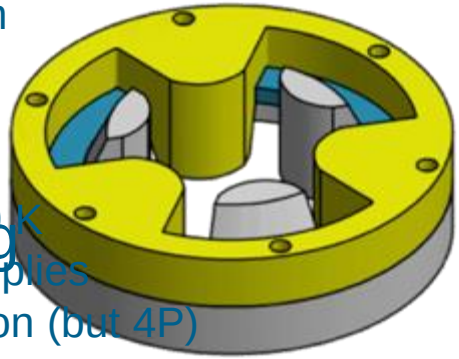
Tested 2016

MCOXFP1

Tested 2017

From 6-pole to 12-pole magnets exist in both normal and skew form

- NbTi supercon
- ducting coils
- superferric design
- 60% margin @ 1.9 K
- existing power supplies
- novel energy extraction (but 4P)



MgB2 Round Coil Superconducting Magnet

Tested 2017

MCDXFP1

Test ongoing

MCTXFP1

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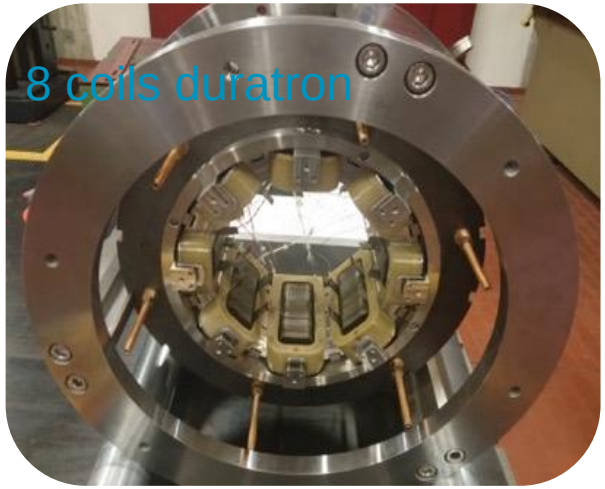
COILS STUDIES

- **ISSUE**: radiation

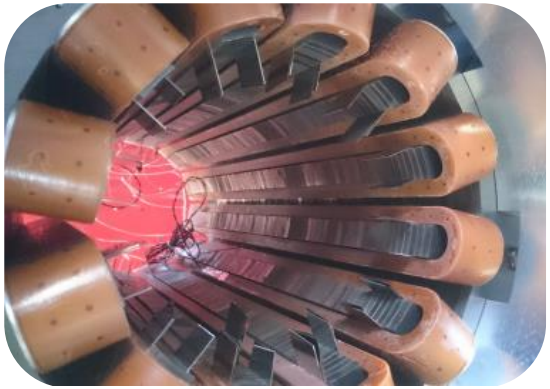
15 MGy recalculated

(35 MGy the previous estimate)

- **Validated Materials (for coils)**
  - Duratron
  - BTS2 by Arisawa
  - Hybrid BTS2/Duratron



One technology for all HO correctors coils:
11 or 12 parts BTS2



OUTLINE

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BASELINE CHANGES

- CERN requirements for magnet performances are changed.
- 6-pole, 8-pole and 10-pole are requested to have 50% of more integrated field
- increasing length or 50-60 mm (magnetic design, protection scheme, integration)
- 4-pole 30% decrease of integrated field
- length reduction 276 mm (magnetic design, protection scheme, integration)
- integration work between CERN and to manage the increased length of the cold mass (+320 mm -276 mm)
- small cost revisions may be necessary (probably ~5%), and they can be discussed after the consolidation of the final design

UPDATED LENGTHS AND QUENCH PROTECTION

	S4P	6P	8P	10P	S12P	N12P
integrated field variation	-30%	+50%	+50%	+50%	Built at LASA	
length prototype before baseline change	814	194	183	183		**575**
Updated length prototype	**538**	construction drawings change accepted by Saes Rial Vacuum (SRV)				
Updated length series	**540.4**	**263.6**	**234.6**	**246.2**	**205.6**	**582.6**
Max voltage [V]	216	72	104	57	65	268
Max temperature [K]	145	141	164	149	150	175

updated quench protection calculations by S. Mariotto

- quadrupole requires energy extraction
- ground connection in the middle of the 1.5 Ω

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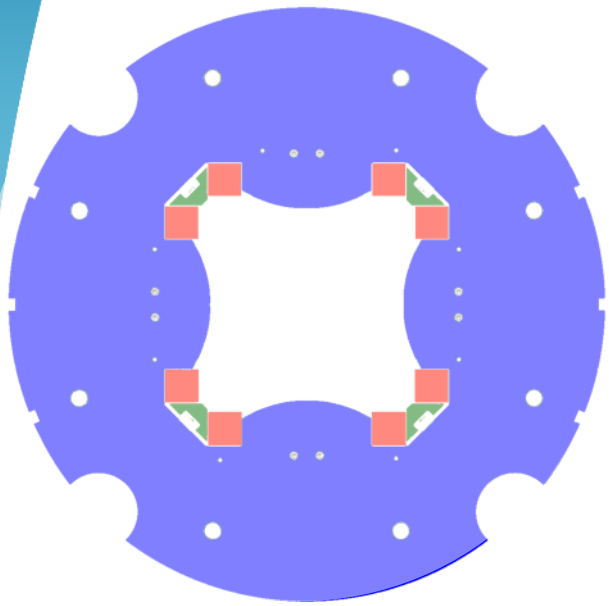
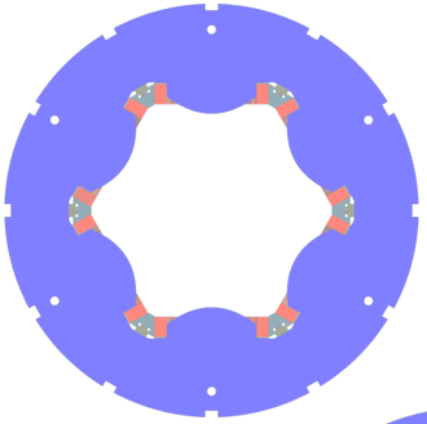
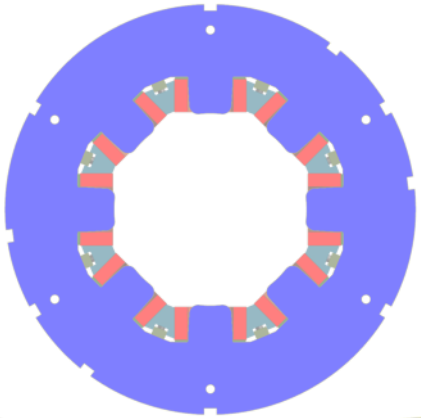


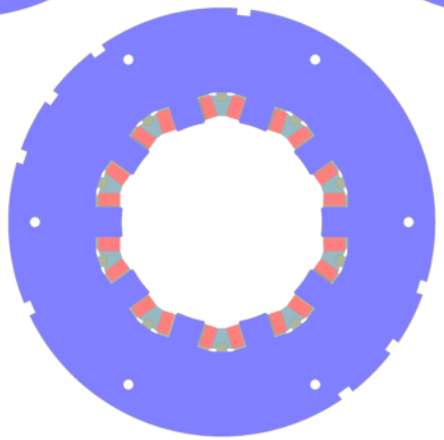
MCQSXFP1

MCSXFP1

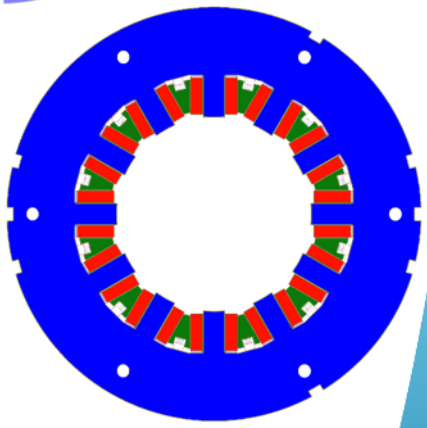


MCOXFP1





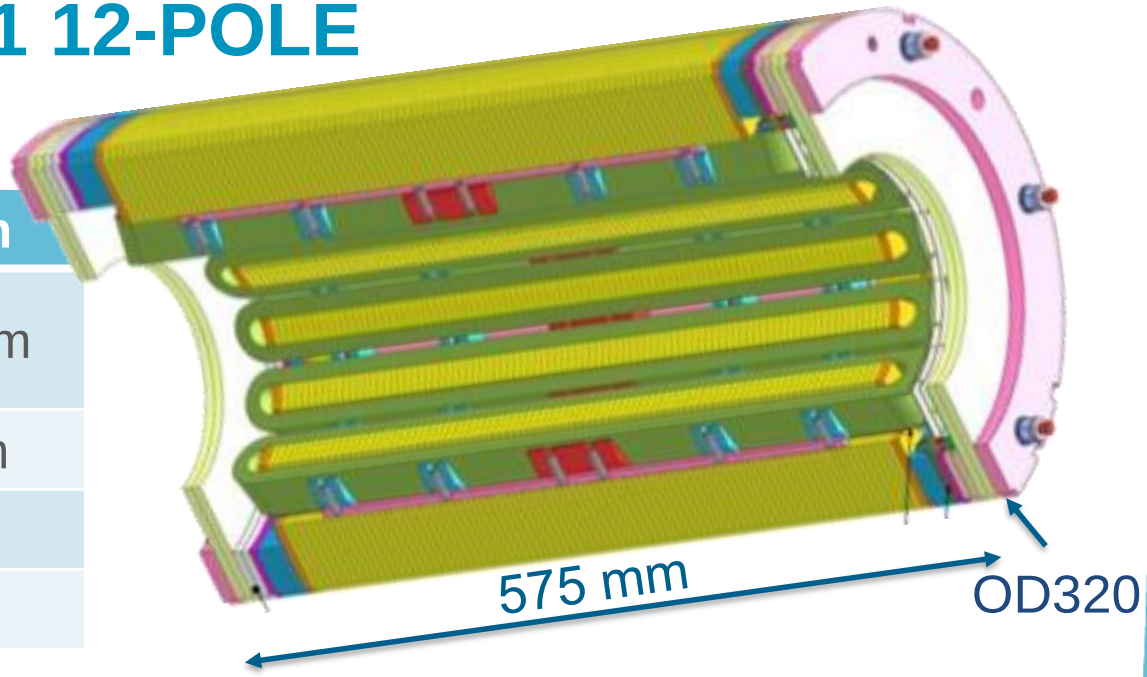
MCDXFP1



MCTXFP1

MCTXFP1 12-POLE

length	575 mm
integrated field @ Iop @ r50 mm	96.4 Tmm
magnetic length	470 mm
harmonics	<15 U
energy	5.1 kJ



NO energy extraction

- COILS
  - BTS2 Arisawa design
  - 432 windings
  - Φ 0.5 mm NbTi
  - 440 m
- Improved electrical connection design, pcb's supporting and integration with connection box

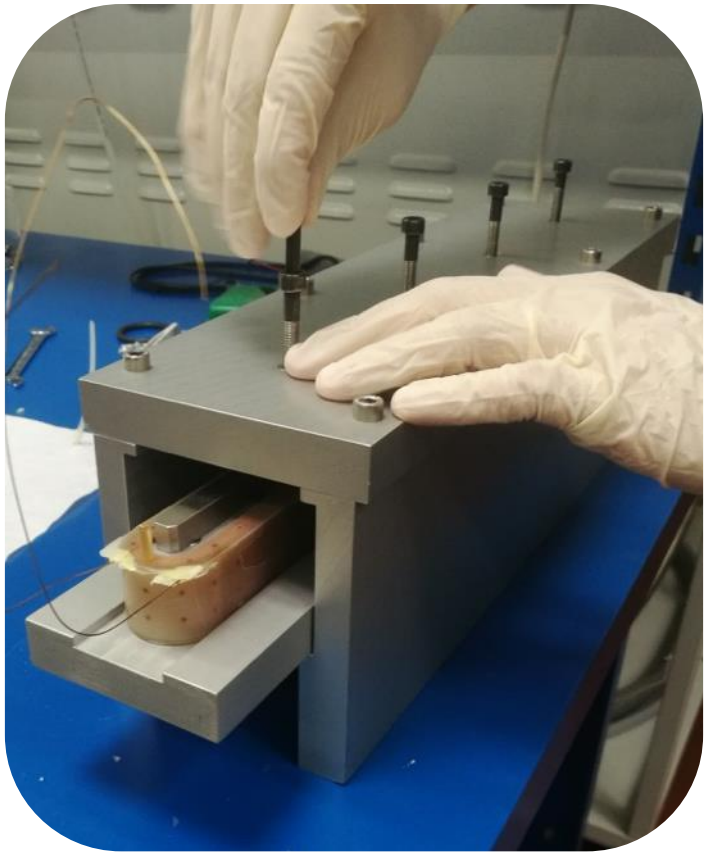
FIRST HO Corrector prototype built in INDUSTRY

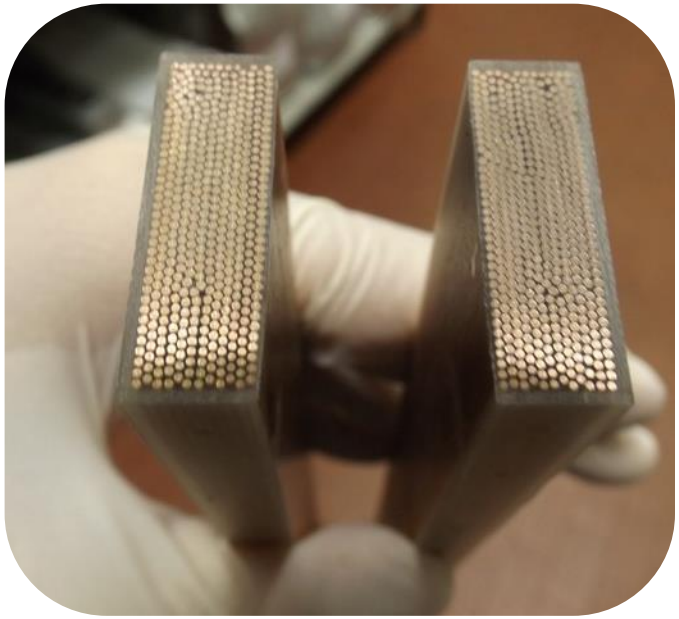
PRODUCTION IN INDUSTRY

- long prototypes produced in industry
- new winding machine
- new custom vacuum oven

PRODUCTION IN INDUSTRY 2

- 2 test coils produced
- first coil produced in industry





Long prototypes' test

- MCTXFP1 ongoing
- MCQSXFP1 in December

PRODUCTION IN INDUSTRY 3

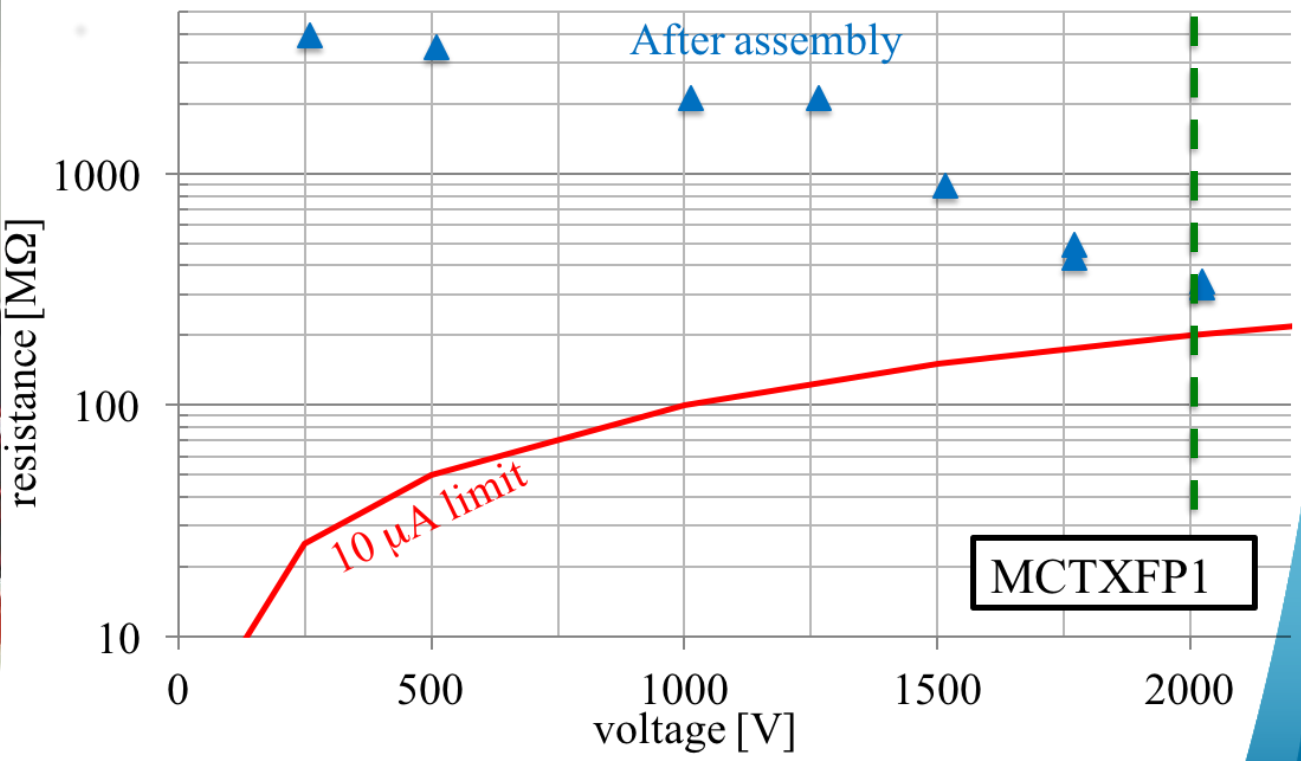
- 15 coils produced
  - 12 installed
  - 3 NC

All coils measured

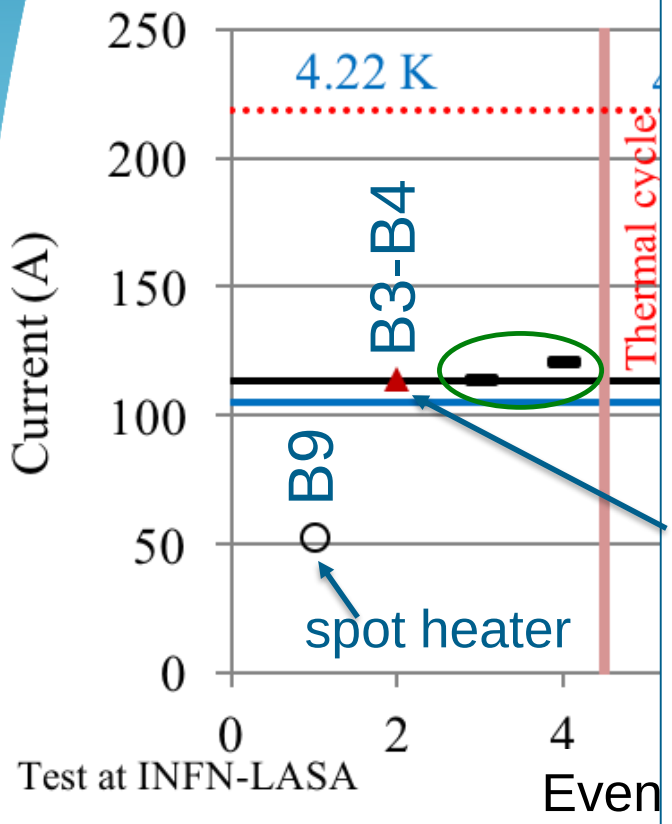
- HV up to 2.5 kV
- geometry
- resistance not sensistive to one turn due to wire properties variation over length

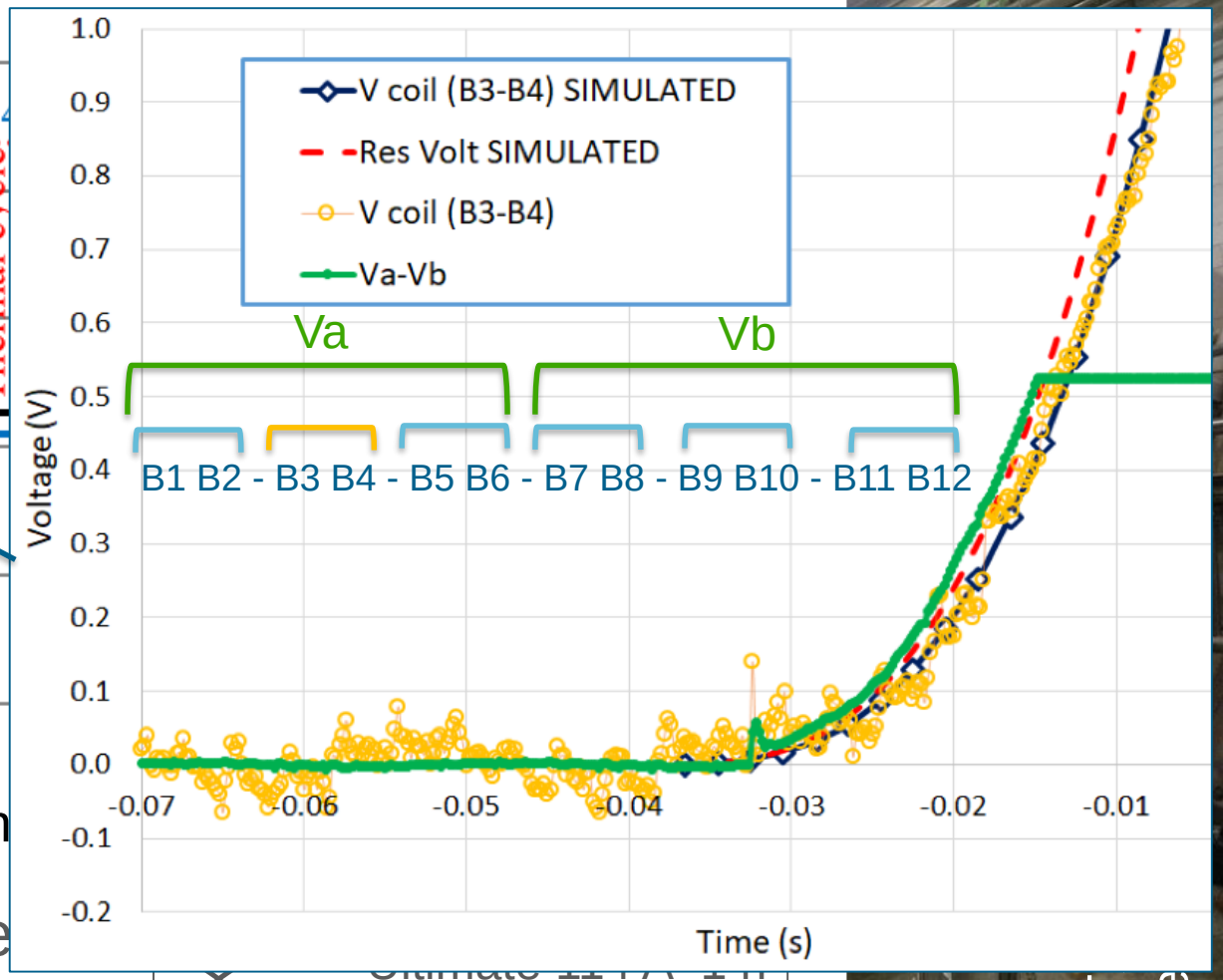
Factory Acceptance Test

- Geometry ✓
- HV ground insulation ✓



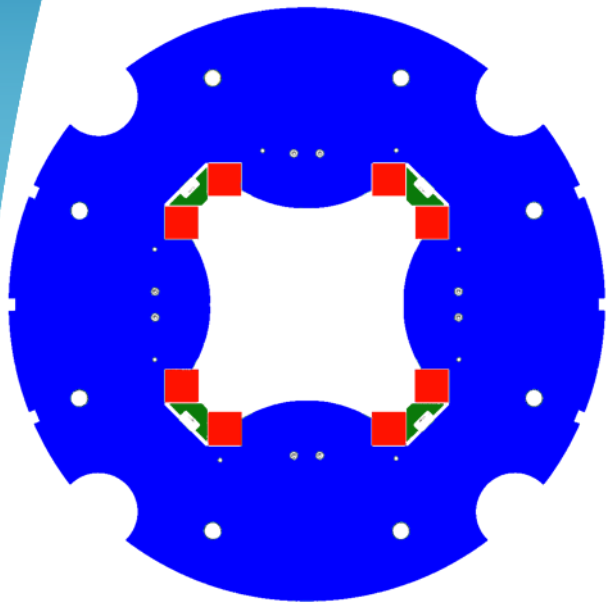
12-POLE COLD TEST PRELIMINARY RESULTS





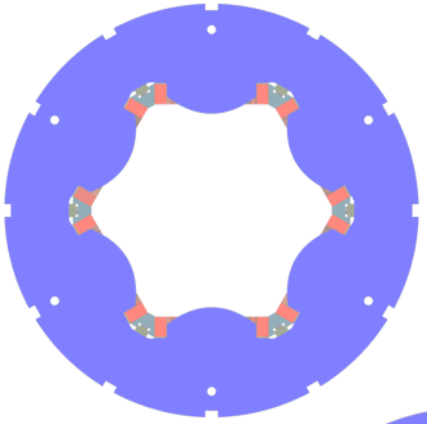
- Ultimate 114 A -1 h te
- Tested @115% I_{op}

NEX
- quench test
- Max 160% I_{op}

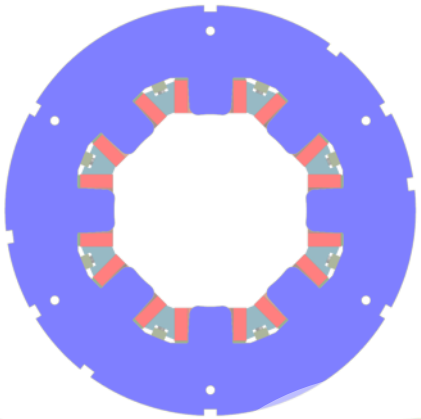


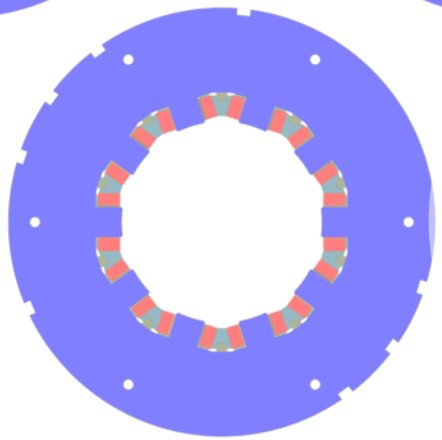
MCQSXFP1

MCSXFP1

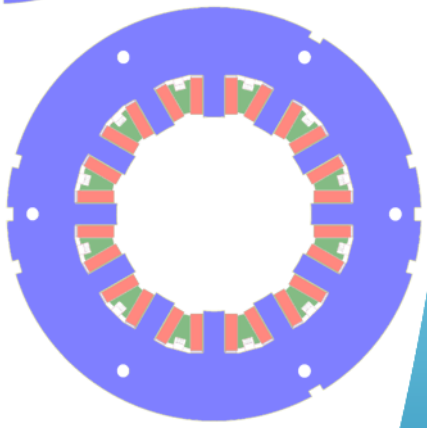


MCOXFP1





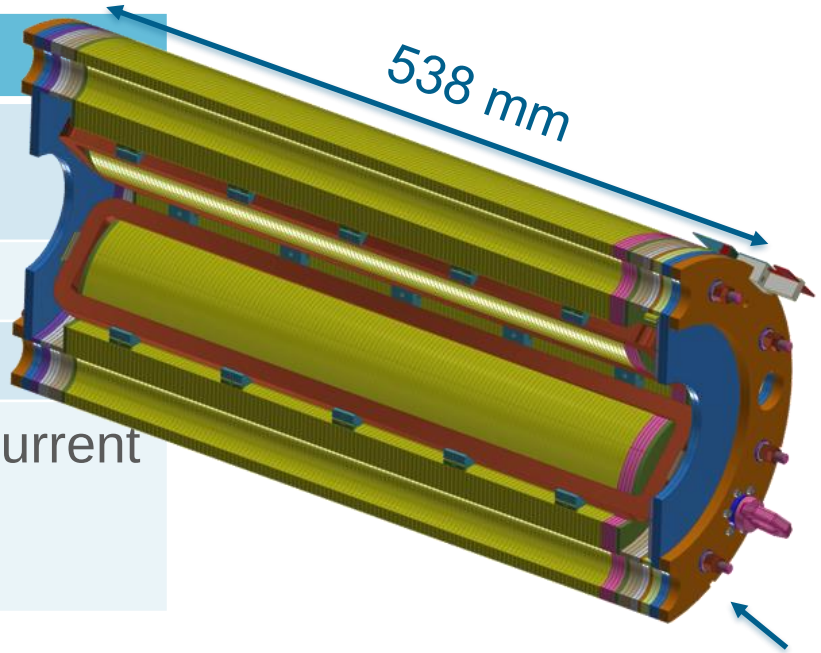
MCDXFP1



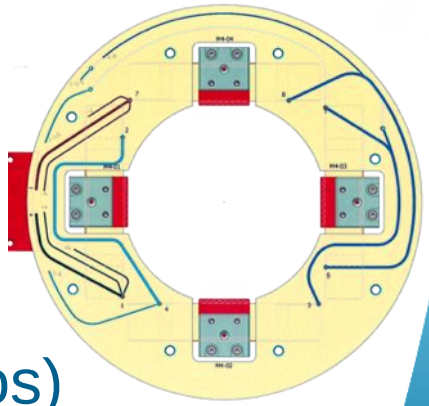
MCTXFP1

SKEW QUADRUPOLE MCQSXFP1

length	538 mm
integrated field @ Iop @ r50 mm	0.718 Tm
magnetic length	401.3 mm
energy @Iop	37.6 kJ
harmonics	B6= -30 U at low current B6= 30 U at I_{op} B10= -8 U ÷ -12 U



- I_{op}= 182 A
- Energy extraxtion
  1.5 Ω dump – ground in the middle
- COILS
  - BTS2 Arisawa design
  - 754 windings
  - Φ 0.7 mm NbTi
  - 815 m

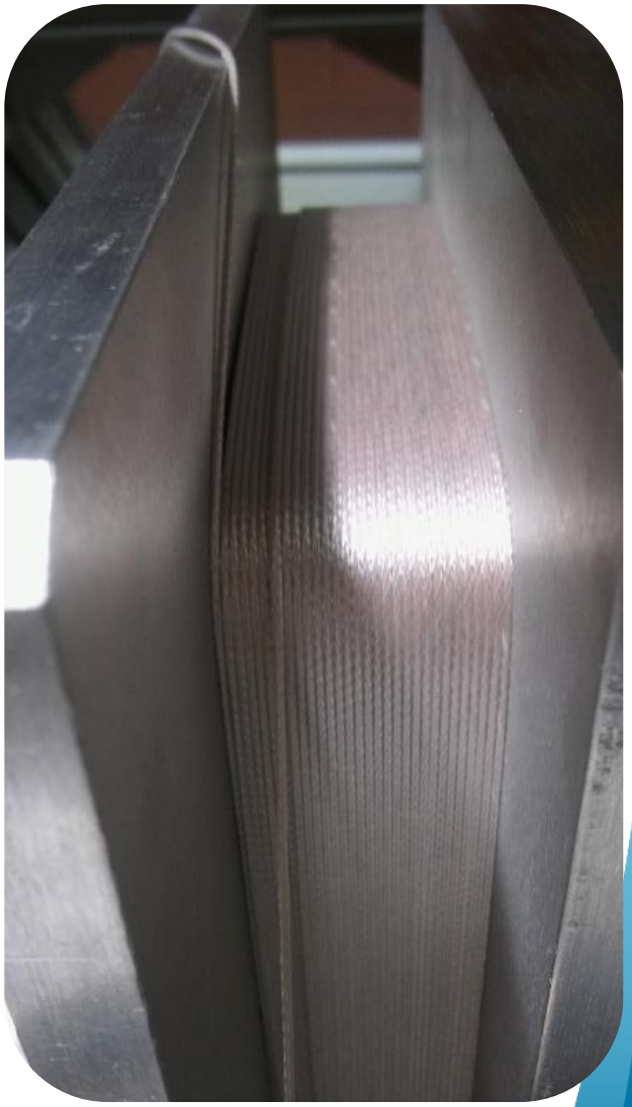


First PCB having double connections (F. Rodrigues Mateos)

SKEW QUADRUPOLE MCQSXFP1 STATUS

- Mechanics machined
- Winding test in industry performed
- Coils' fabrication ongoing
  - G10 insulated Test coil
  - BTS2 insulated coils (6)

Magnet delivery
first week of December (week 49)



OUTLINE

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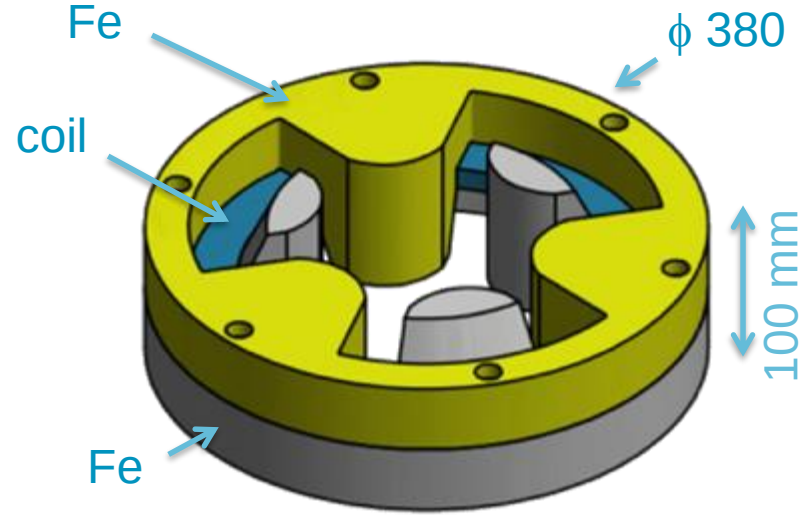
ROUND COIL SUPERCONDUCTING MAGNET

demonstrator



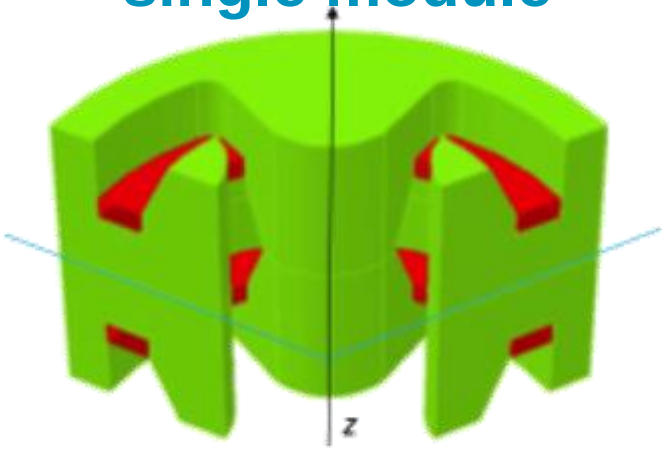
G. Volpini et al. Eletromagnetic Study of a Round Coil Superferric Magnet,IEEE Tr. App. Sup, 26, 4 (2016)

- multipolar MgB_2 magnet
- inner bore ϕ 150 mm
- single MgB_2 coil
  - bare diameter 1 mm
- electromagnetic design
  - working point 133 A @4.2 K
  - margin 48 % on the load line
  - adiabatic hot spot temperature < 90 K

SCHEDULE

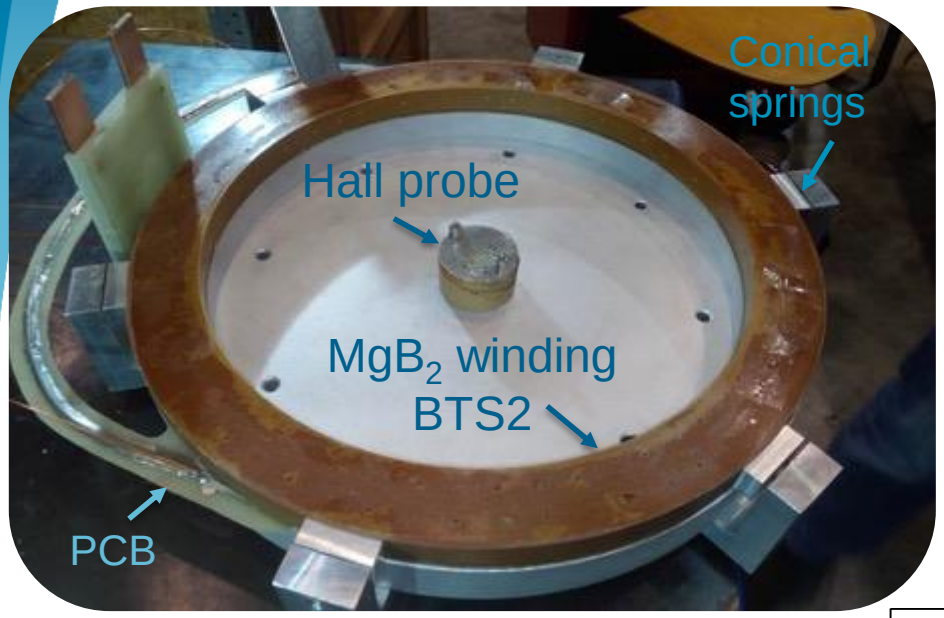
- winding MgB_2 wire **2017**
- impregnation **2017**
- cold test of the coil **2018**
- magnet assembly **2019**

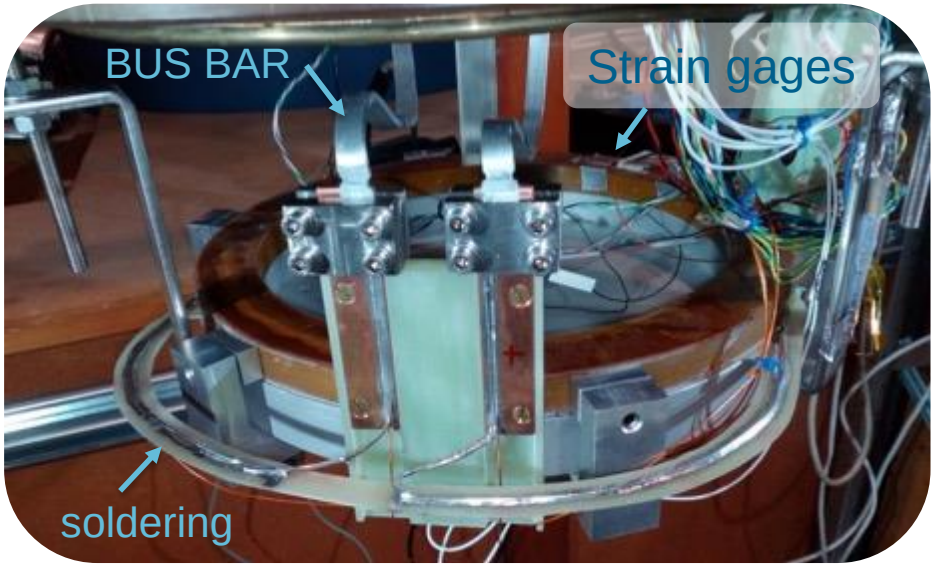
single module



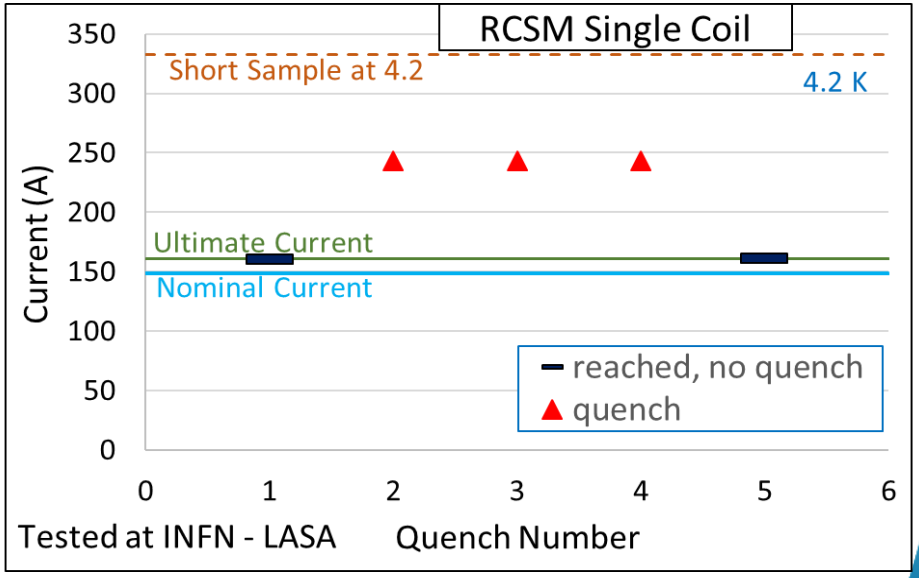
G. Volpini et al. Eletromagnetic Study of a Round Coil Superferric Magnet,IEEE Tr. App. Sup, 26, 4 (2016)

RCSM Single Coil Test





- no quench training
- the Coil is stable at the Ultimate Current (108% I_{op})
- maximum value of the current reached: 73% of the Short Sample Limit



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- scope: the High Order correctors magnets
- coils studies
- the decapole **MCDXF** : cold test results
- increased gradient
- dodecapole MCTXF and quadrupole MQSXF
- Round Coil Superconducting Magnet
- integration
- next steps

INTEGRATION

- integration in the **cold mass** ongoing H. Prin
  - position
  - lengths
  - disetances - magnetic coupling
  - alignment
  - cabling
  - fix threads by resin (CTD 101K) and anti vibration washers
  - position and diameter for the Heat Exchanger (MCQSXF)
  - connection box and cabling
- integration in the **power grid** and **electrical tests** F. Rodrigues Mateos
  - all magnets but quadrupole no energy extraction (simulation and test)
  - defining quench protection parameters (thresholds, Δt, resistance and protection circuit)
  - defining voltage tests (focus on series production)
  - power connections
- Documentation

See A. Musso talk

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CONCLUSIONS AND NEXT STEPS

- coils' design finalized and optimized
- baseline change: new integrated fields, length and integration
- first prototype produced in industry (SRV)
- dodecapole MCTXFP1 preliminary test
- skew quadrupole in production
- MgB_2 coil for the Round Coil Superconducting Magnet tested

NEXT STEPS

- Oct 2018 MCTXFP1 test ongoing, preliminary results
- Dec 2018 MCQSXFP1 delivered to LASA
- Dec 2018-Jan 2019 MCQSXFP1 test at LASA
- 2019 ...the series is coming

next talk by Massimo Sorbi

THANK YOU

INFN LASA
Istituto Nazionale di Fisica Nucleare
Laboratorio Acceleratori e Superconduttività Applicata

LASA team
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CERN A. Musso, E. Todesco

spares

Fase	Responsabile	Completamento %	Attività	mese	ago-18					set-18					ott-18					nov-18				dic-18			
				settimana	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
DODECAPOLO M12	Rodofil	0	Produzione stampi di impregnazione definitivi																							
	SAES	80%	Produzione bobine																							
	SAES	46%	Test elettrici e dimensionali bobine																							
	INFN LASA		Validazione bobine per assemblaggio																							
	Rodofil	0	Produzione lamierini e componenti meccanici																							
	Rodofil	0	Controllo dimensionale																							
	SRV		Cleaning																							
	SRV		Assemblaggio lamierini polo																							
	SRV		Assemblaggio bobine e connessioni elettriche, completamento assemblaggio																							
	SRV		Controllo dimensionale e test elettrici (FAT)																							
	INFN LASA		Valutazione dei risultati dei test dodecapolo																							
	INFN LASA		Approvazione dei risultati dei test dodecapolo																							
	SRV		Imballaggio e trasporto a INFN LASA																							
	SRV		Consegna dodecapolo presso INFN LASA																							
	SRV		Imballaggio presso LASA e spedizione al CERN (TBD)																							
QUADRUPOLO M04	Rodofil	20%	Produzione rocchetto pilota																							
	SAES		Attività di prototipazione avvolgimenti quadrupolo																							
	SAES		Emissione disegni definitivi stampo quadrupolo																							
	Rodofil		Produzione stampi impregnazione definitivi																							
	Rodofil		Produzione kit BTS2																							
	SAES		Attività di collaudo e prototipazione impregnazione quadrupolo																							
	SAES		Produzione bobine																							
	SAES		Test elettrici e dimensionali bobine																							
	INFN LASA		Validazione bobine per assemblaggio																							
	Rodofil	70%	Produzione lamierini e componenti meccanici																							
	Rodofil		Controllo dimensionale																							
	SRV		Cleaning																							
	SRV		Assemblaggio lamierini polo																							
	SRV		Assemblaggio bobine e connessioni elettriche, completamento assemblaggio																							
	SRV		Controllo dimensionale e test elettrici (FAT)																							
	INFN LASA		Valutazione dei risultati dei test quadrupolo																							
	INFN LASA		Approvazione dei risultati dei test quadrupolo																							
	SRV		Imballaggio e trasporto a INFN LASA																							
	SRV		Consegna quadrupolo presso INFN LASA																							
	SRV		Imballaggio presso LASA e spedizione al CERN (TBD)																							
CHIUSURA CONTRATTO	SAES		Manuali d'uso e marchiatura CE "Special Tools"																							
	SRV - SAES	90%	Completamento documentazione tecnica di progetto																							
	SRV - SAES		Consegna degli "Special Tools" presso INFN LASA (TBD)																							
	INFN LASA		Approvazione documentazione e accettazione macchine																							

CHIUSURA ESTIVA