R&D IN MgB_2 WIRES AND RELATED APPLICATIONS

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April 18, 2023

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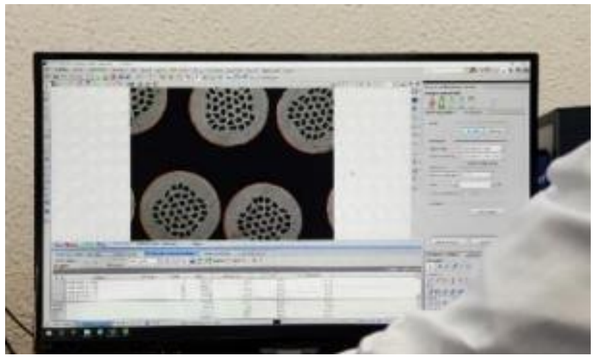
OUTLINE

- Overview of ASG Superconductors

- MgB_2 wires technology: PIT ex-situ process

- Wires portfolio: round wires and tapes
- Layout and SC performance
- R&D activities



- Applications

  - SC link at CERN for the HiLumi project
  - Cables for energy
  - R&D projects: Generator and SMES

ASG A GLOBAL LEADER IN SUPERCONDUCTIVITY

1. IBA | THERAPY — Belgium
SYNCHROCYCLOTRON

2. CERN | RESEARCH — Swiss
HI-LUMI LHC

3. CERN | RESEARCH — Swiss
MGB2 HIGH CURRENT LINKS

4. HZDR | THERAPY — Germany
MR GUIDED PROTONTHERAPY

5. IPP | FUSION — Germany
W7-X STELLARATOR

6. CERN | RESEARCH — Germany
SUPER FRS MULTIPLETS

7. MAGNET TX | THERAPY — Canada
MR GUIDED RADIOTHERAPY

8. JINR | RESEARCH — Russia
MULTI PURPOSE DETECTOR

9. FERMILAB | RESEARCH — USA
MU2E TS MAGNETS

10. KACHON | RESEARCH — South Korea
UHF MRI MAGNETS

11. ENEA | FUSION — Japan
JT-60SA TOROIDAL FIELD COILS

12. F4E | FUSION — France
ITER TOROIDAL FIELD COILS

13. F4E | FUSION — France
ITER POLOIDAL FIELD COILS

14. DIAGNOSTICS — EU | UK | USA | Kuwait
UPRIGHT MROPEN EVO

15. INAO | THERAPY — Italy
SYNCHROCYCL. & TL MAGNETS

16. ENEA | FUSION — Italy
DTT TOROIDAL FIELD COILS

ASG is a world leading company in manufacturing superconducting devices. The know how is based on many decades of manufacturing magnets & systems for specific applications, mainly related to medical or HEP sector.

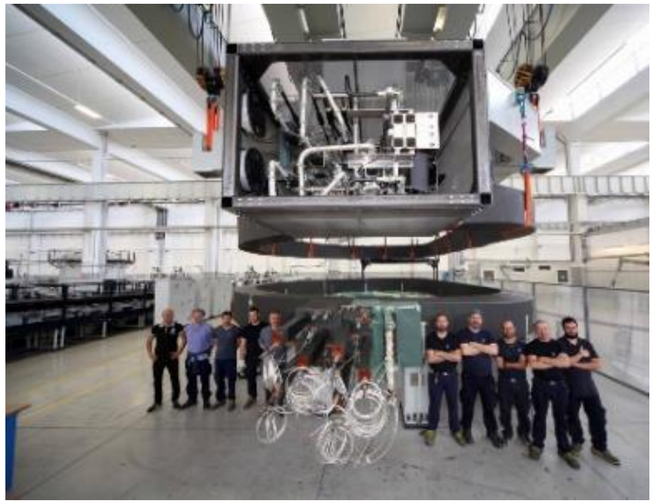
Not only systems… With the discovery of superconductivity in MgB_2, in 2001 ASG started activities related to materials development focused to produce and commercialize also superconducting wires.

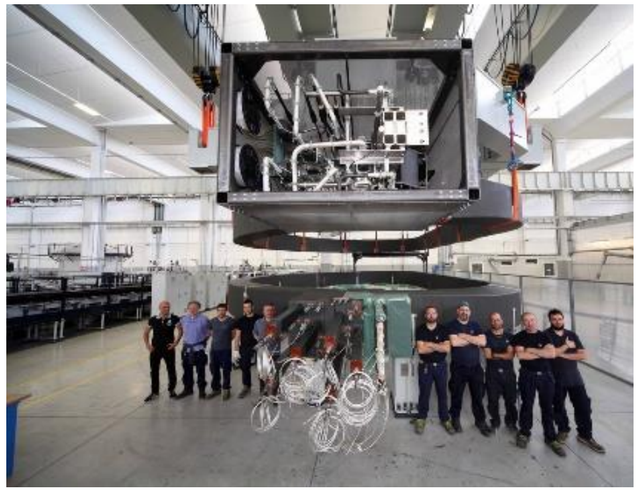
200+ DEDICATED PEOPLE

THREE PRODUCTION SITES IN ITALY dedicated to:

- Medical and research magnets & systems
- Large scale magnets & systems
- Superconducting wires

FIELD offices in France, USA & UK

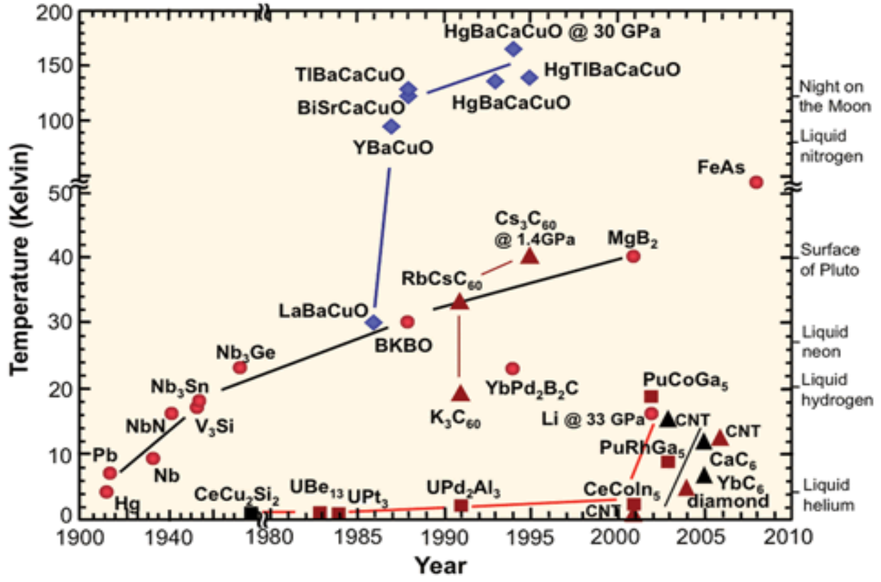


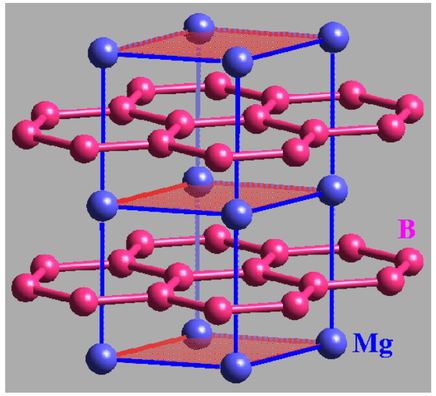


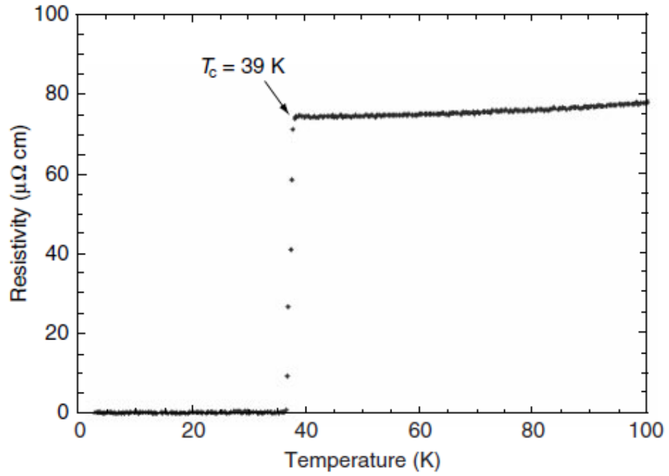
columbus mgb2 unit

LEADING MGB2 TECHNOLOGY

Nagamatsu et al. 2001
Superconductivity at 39K in magnesium diboride
Nature 410 63-4







Discovered in 2001
Now a commercial product with a high level of maturity in terms of:

- unit length
- uniformity of cross section and SC performance
- general understanding of use (handling, welding, insulation, impregnation, etc etc.)

MgB_2 WIRES FOR CABLES

MgB_2 WIRES FOR MAGNETS

MgB_2 WIRES FOR MRI

MANUFACTURING PROCESS

EX-SITU MGB2 PROCESS

- Reacted MgB2 powders
- Powders handled in controlled atmosphere
- Billet size about 48 mm
- Elongation 1:20000
- Single piece length up 6 km
- Final in-line sintering
- Supplied in reacted state

INDUSTRIALS EQUIPMENT AND RAW MATERIALS

Ex-situ MgB_2 Production Process

All the manufacturing equipment designed by ASG, produced in Italy or EU (easier procurement, quality control, maintenance, upgrade)

MgB_2 PRODUCED IN MULTIKILOMETER LONG BATCHES AND PERFECTLY FIT FOR INDUSTRIAL CABLING AND/OR WINDING PROCESSES

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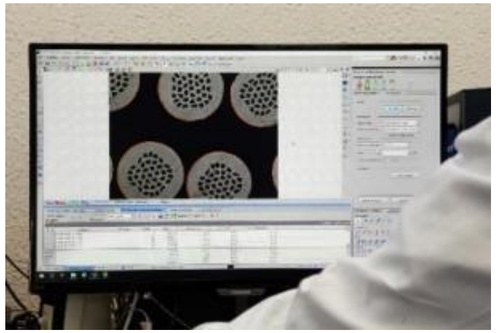
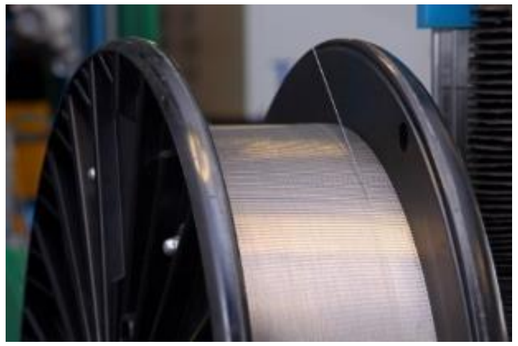


MGB2 WIRE PRODUCTION BASED ON INDUSTRIAL RAW MATERIALS

MAGNESIUM POWDERS
- Production of lightweight alloys
- Pharma products
- Pyrotechnics, rockets

BORON POWDERS
- Airbags production
- Solid combustion
- Neutron capture



NICKEL-ALLOY TUBES
- Chemical plants
- Acid resistant tubing
- Alkaline resistant tubing

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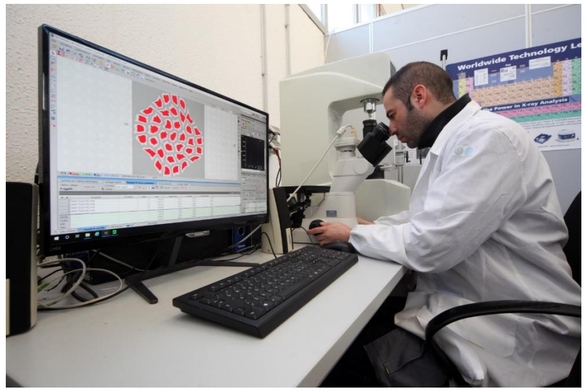
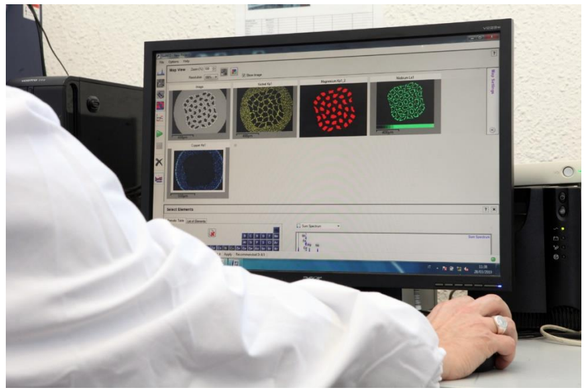
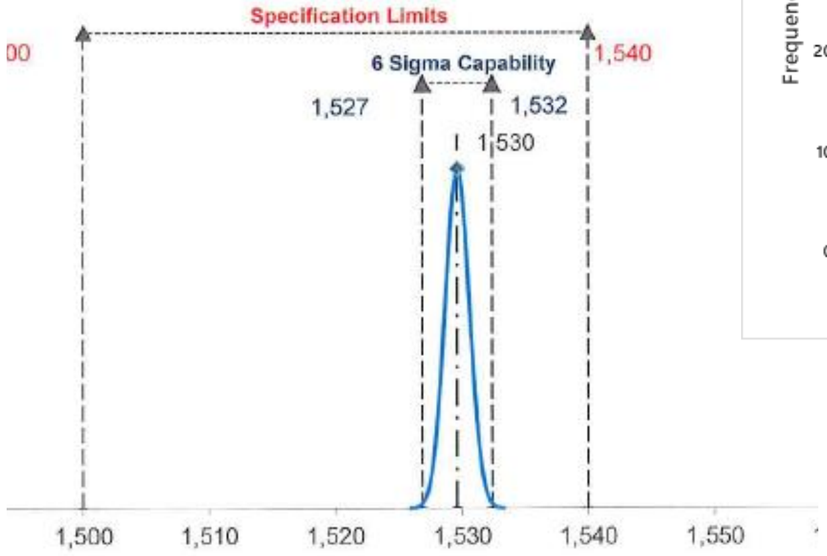
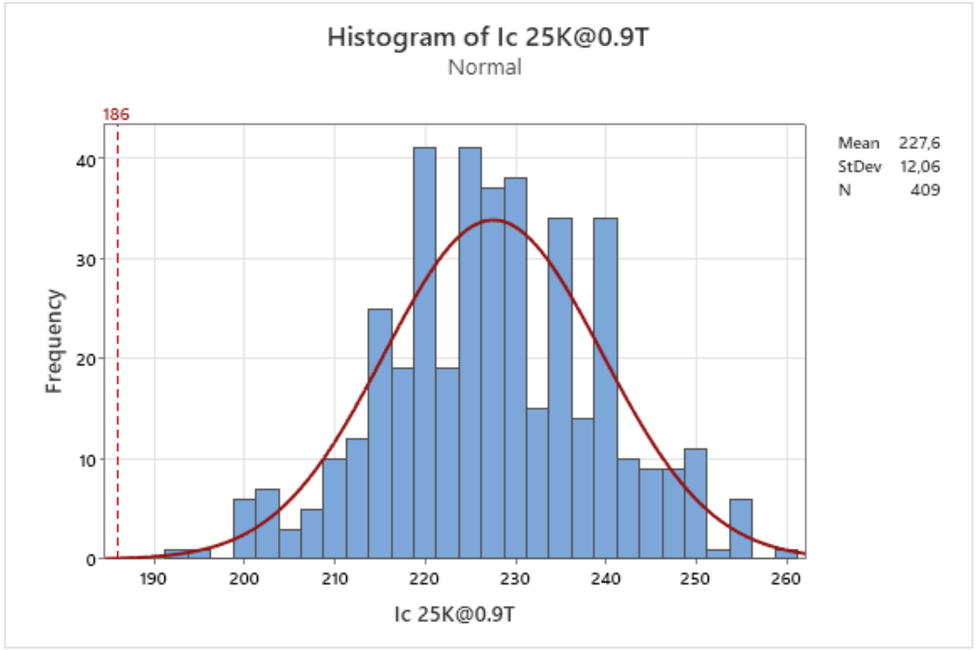
QA PROCEDURES

To guarantee stable performance, QA procedures have been define to ensure the full process control.

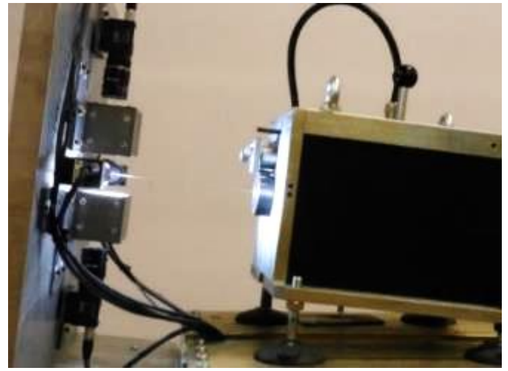








Advanced techniques for incoming materials and produced powders, in-line controls during manufacturing steps (dimensional, visual and inductive methods) and post-production analysis.

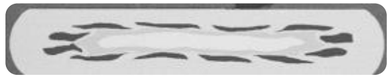


Eddy current detector to check integrity of the produced wires

WIRE PRODUCTS PORTFOLIO

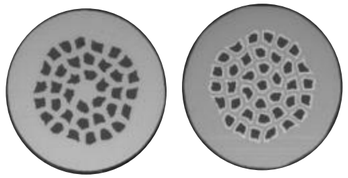
Production flexibility:
different material, shape and size

TAPES - MAGNETS

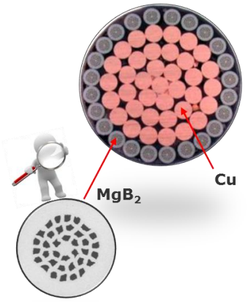


MATERIALS	UNIT PIECE LENGTH
Ni, Fe, Cu	typical 4km

ROUND WIRES - CABLES

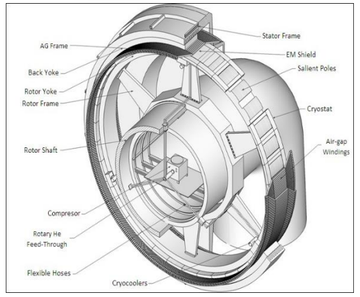


MATERIALS	UNIT PIECE LENGTH
Monel, Nb,Ni	typical 3,5km

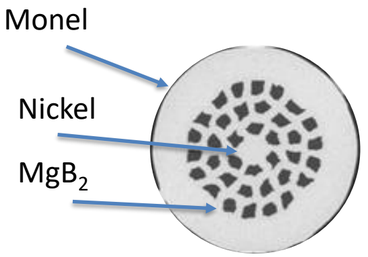


SPECIAL/CUSTOM SHAPES

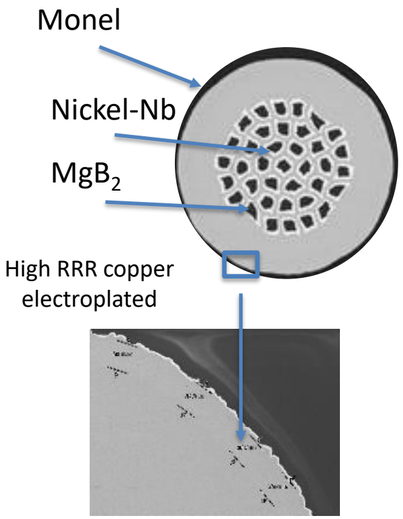
MATERIALS	UNIT PIECE LENGTH
SS, Ti, Monel,Ni	Up to 8km



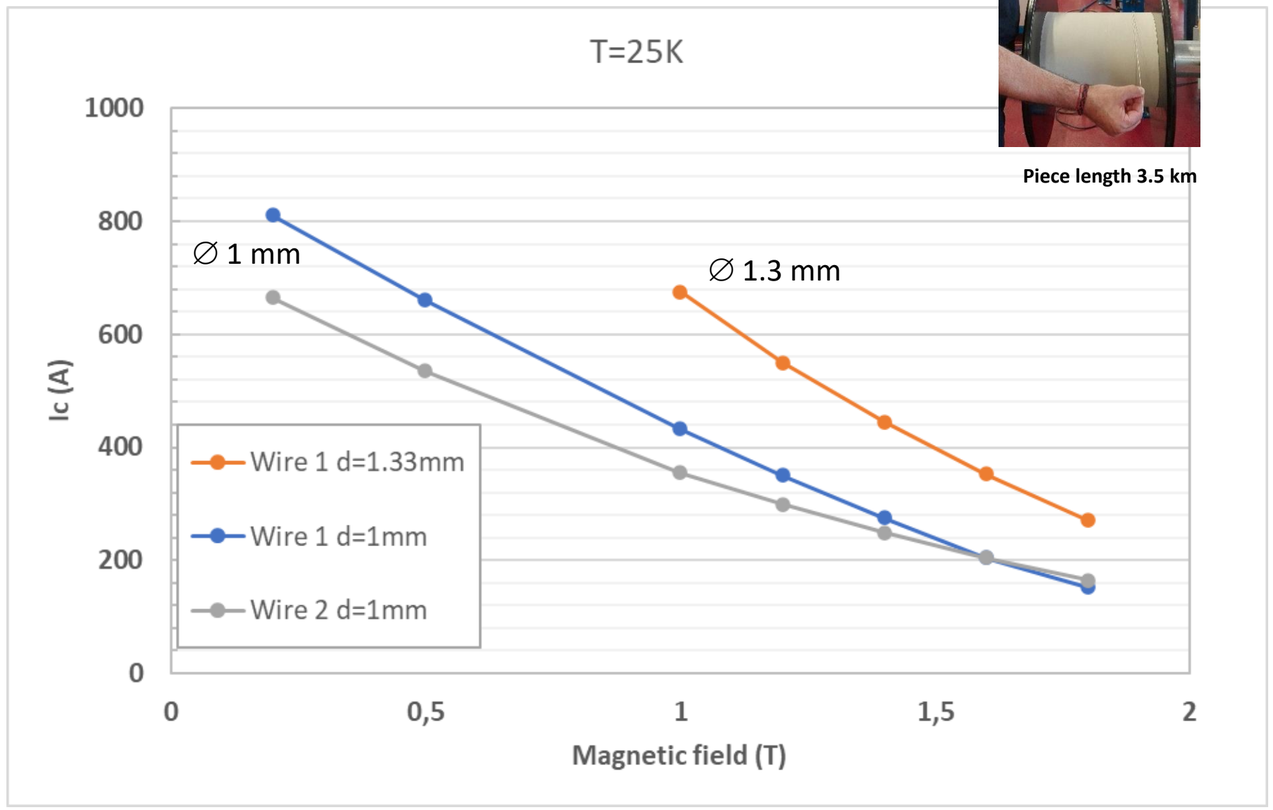
WIRES FOR CABLES



Wire 1	
Diameter (mm)	1-1.3
Filaments	36
MgB_2	17%
Monel	53%
Nickel	30%



Wire 2	
Diameter (mm)	1
Filaments	37
MgB_2	12%
Monel	46%
Nickel	15%
Nb	13%
Copper	14%



Piece length 3.5 km

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Reacted wires,
Ready and suitable for industrial cabling machine

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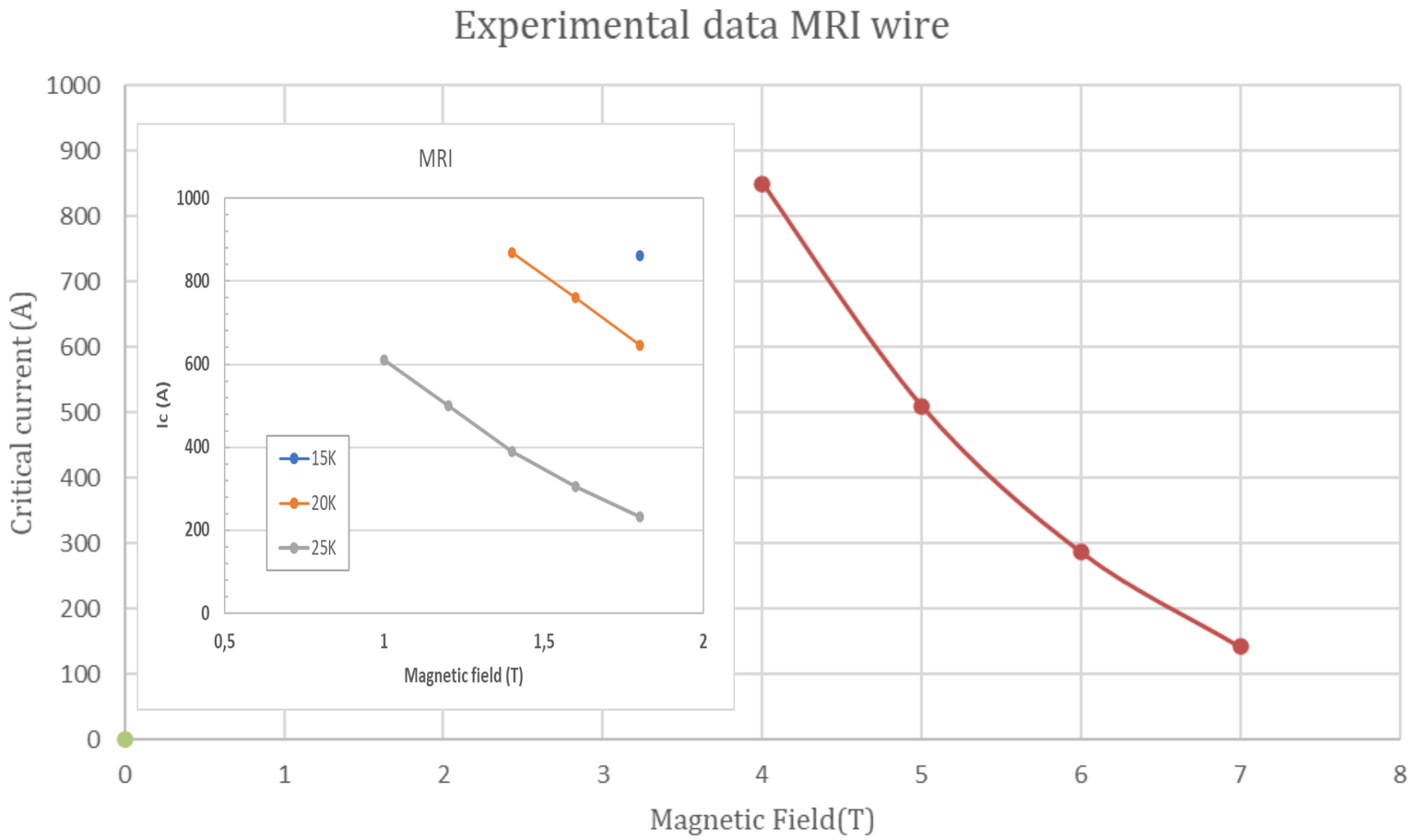
ROUND WIRES FOR MAGNETS

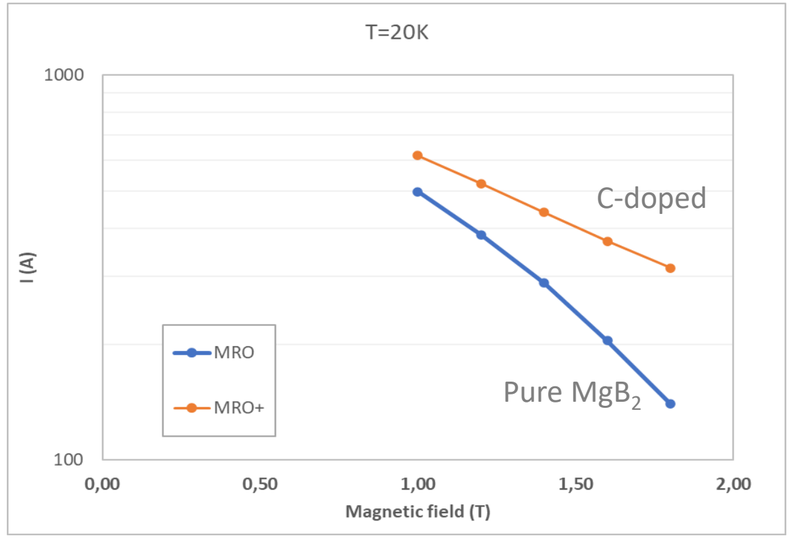
Wire MRI	
Overall bare conductor dimensions [mm]	Diameter 1.52 mm
Overall Area [mm^2]	1.8 mm^2
Doped MgB_2 area [mm^2 and %]	0,26 mm^2 - 12%
Ni area [mm^2 and %]	1,39 mm^2 – 63%
Fill Factor [%]	26%
Minimum bending radius	125 mm

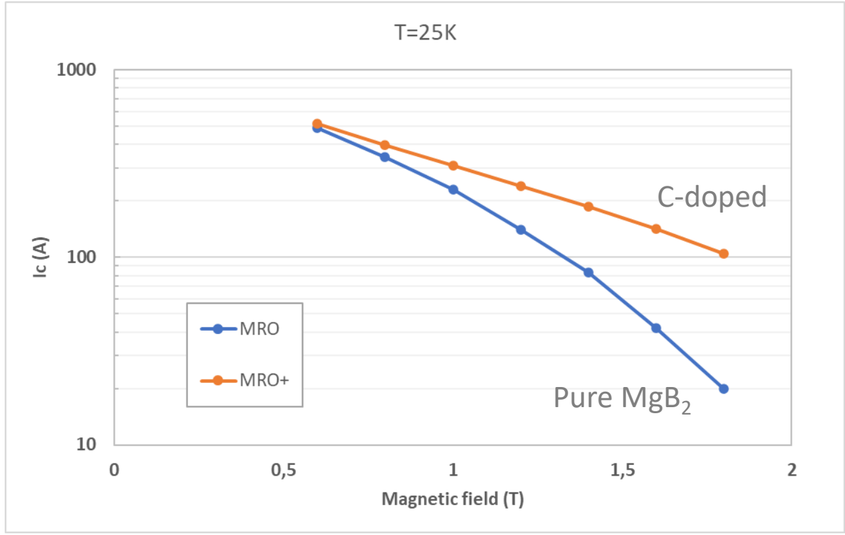
C-doped MgB_2
High FF

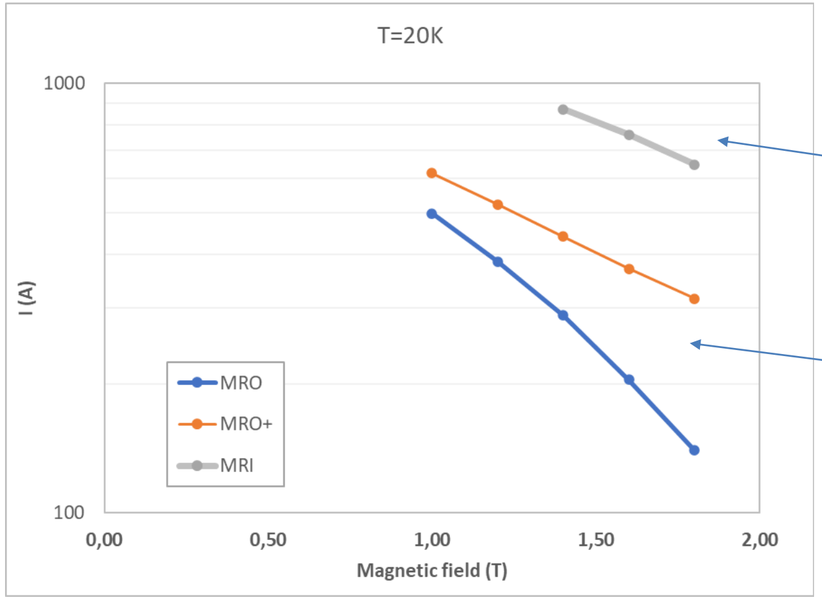


TAPES FOR MAGNETS

Wire MRO - MROPlus	
Overall bare conductor dimensions [mm]	3.67 X 0.65 mm
Overall Area [mm^2]	2,2 mm^2
Doped MgB_2 area [mm^2 and %]	0,26 mm^2 - 12%
Ni area [mm^2 and %]	1,39 mm^2 – 63%
Iron area [mm^2 and %]	0,22 mm^2 – 10%
Copper area [mm^2 and %]	0,33 mm^2 – 15%
Fill Factor [%]	12%
Minimum bending radius	60 mm







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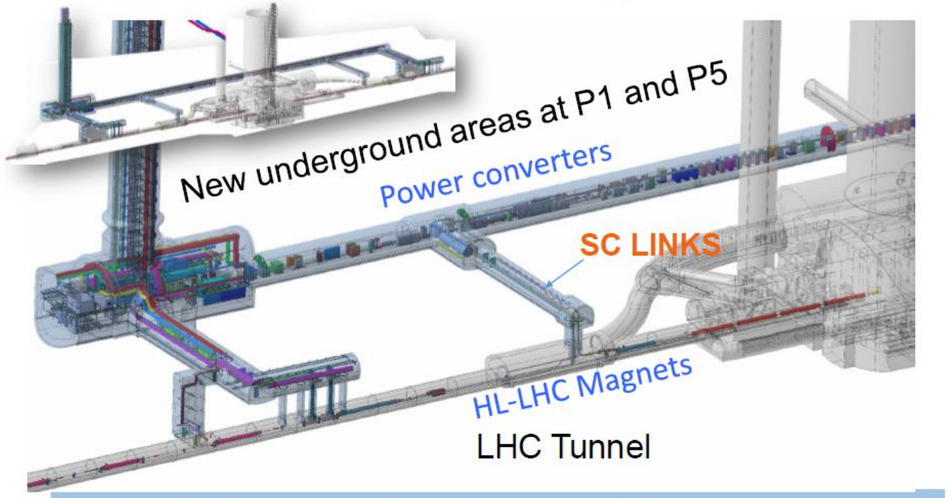
APPLICATIONS: SC LINKS AT CERN

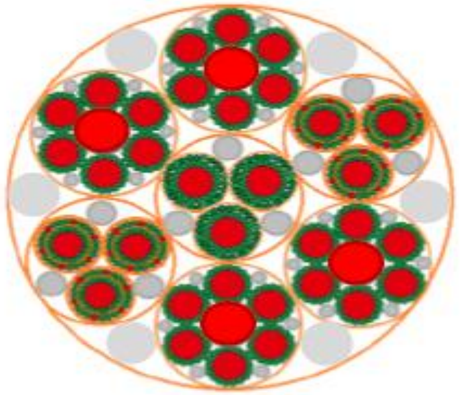
HTS for LHC – SC Link System



Ten Systems for HL-LHC : 5 for the Triplets and 5 for the Matching Sections

A. Ba

HiTAT Workshop
High Temperature superconductors for Accelerator Technology
CERN, 9–10 March 2023

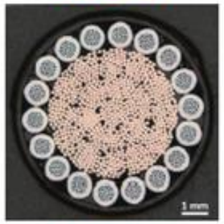


120 kA @ 25 K and 1 T
Φ~90 mm

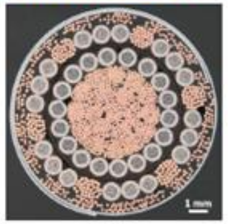
Cabling made from reacted wire

Series cabling at TRATOS/ICAS

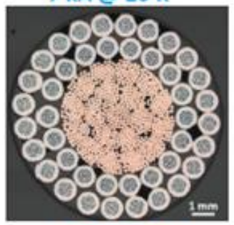
3 kA @ 25 K



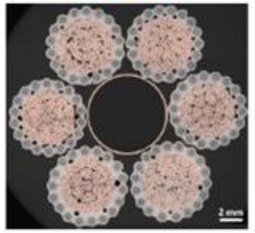
3 kA coaxial @ 25 K



7 kA @ 25 K



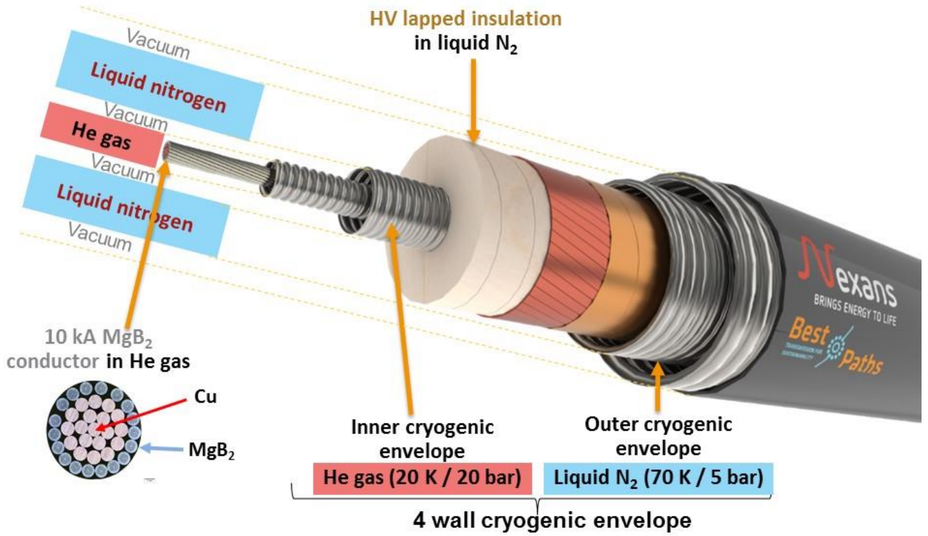
18 kA @ 25 K



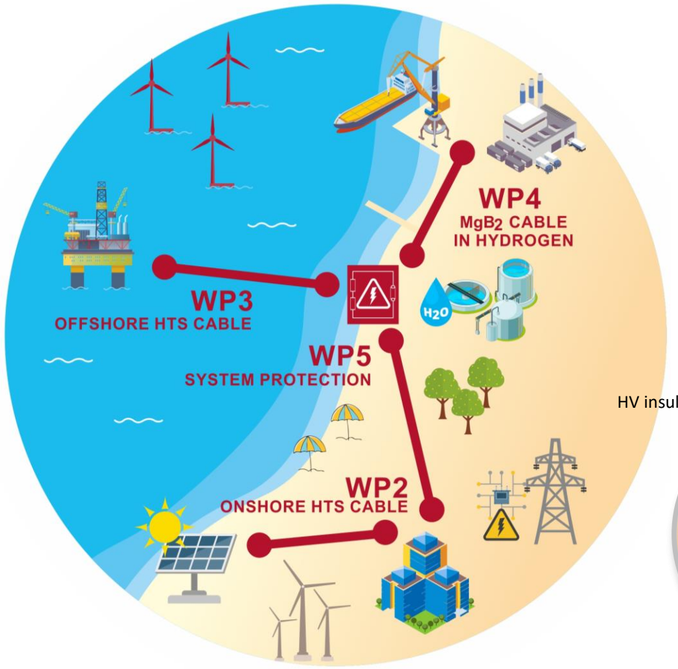
More than 1400km of wires delivered and fully qualified
Unit length up to 4km

APPLICATIONS: CABLE FOR ENERGY

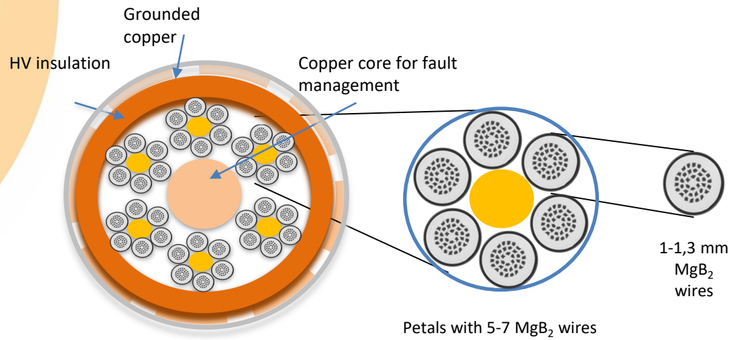
3 GW CLASS HVDC SUPERCONDUCTING CABLE SYSTEM OPERATING AT 320 KV AND 10 KA DEMONSTRATED



Design and industrially manufacture high-power superconducting cables (20kA-25kV) focused on **liquid hydrogen-**cooling



MULTI-STAGE DESIGN



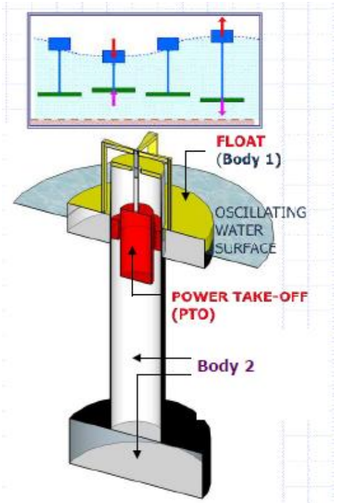
20 kA cable with 6 petals
with 30-42 wires
OD: 23 mm

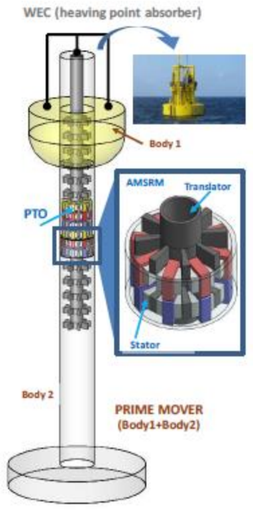
APPLICATIONS: GENERATORS-SMES

ASG SUPERCONDUCTORS

SeaTitan

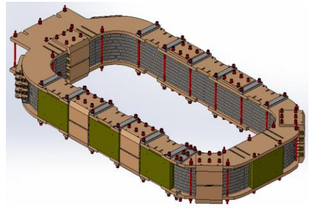
IMPROVEMENT OF THE EFFICIENCY IN A PTO (POWER TAKE-OFF) FOR WAVE ENERGY CONVERTER

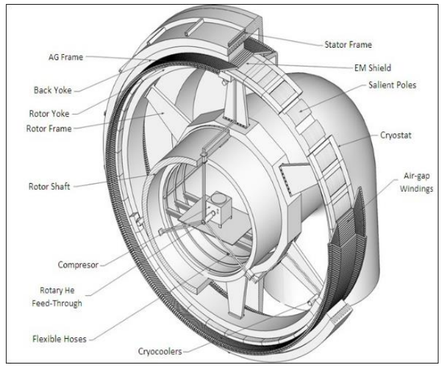




suprapower

Superconducting light generator for large offshore wind turbines

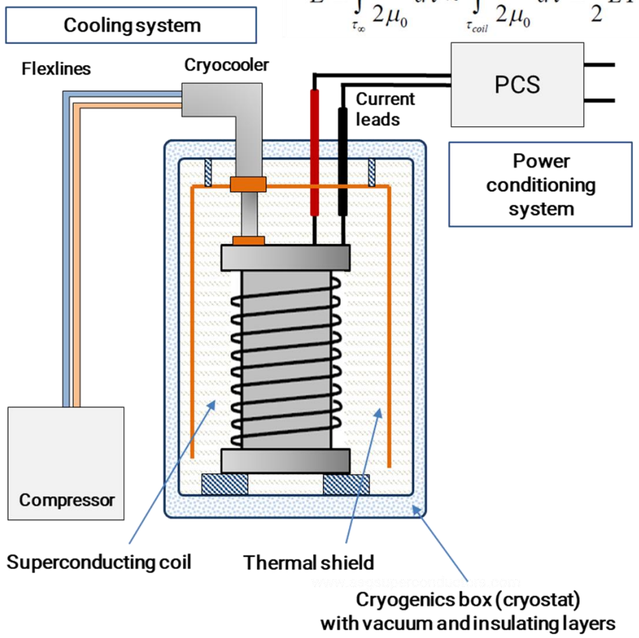


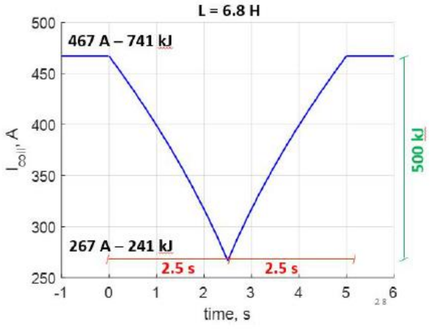


DRYSMES4GRID

Superconducting Energy Storage for Smart Electrical Grid

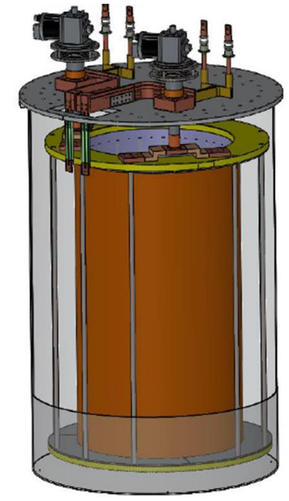
$$E = \int_{\tau_\infty} \frac{B^2}{2\mu_0} d\tau \approx \int_{\tau_{coil}} \frac{B^2}{2\mu_0} d\tau = \frac{1}{2} L I^2$$





500kJ-200kW design

Inner radius, mm	300
Height, mm	1200.6
Number of layers	10
Number of turns per layer	522
Length of cable, km	10.1
Voltage of the dc bus, V	750
Min Current, A	266.6
Max current, A	467
Field on conductor (at Imax), T	1.63
I/Ic ratio (at Imax)	0.6
Inductance, H	6.80
Total eneregy (at Imax), kJ	741
Deliverable energy, kJ	500.4
Dump resistance, Ω	2,14
Max adiabatic hot spot temp., K	95.6



APPLICATIONS: SMES ON ELECTRIC VESSELS

V-ACCESS

Vessel Advanced Clustered and Coordinated Energy Storage Systems

Vessel's requirements and specifications




State-of-the-art

Battery technology

- Bespoke design
- Battery required to supply all energy and power peaks
- Impossible to optimise power flows

No flexibility in the design:
- Large capacity to preserve battery life
- High weight and volume
- High cost

V-ACCESS

Combined storage system
Battery technology
+
Supercapacitors, SMES



Principal innovations:
- multi-bus DC microgrids to regulate power flows
- Novel control to preserve batteries from power peaks
- Optimal energy and power performance

Flexible design:
- 20-25% reduction of weight
- 30% lower TCO
- 35% lower emissions
- 20-25% longer battery lifetime

co-funded by the European Union

Grant agreement ID 101096831

CONCLUSIONS

In our MgB_2 plant we are using the PIT ex-situ technique to produce MgB_2 wires and the technology is now mature:

- We have 6 layout of wires with different materials, shapes and dimensions
- C-doping has been implemented to enhance in-field performance
- Lengths up to 6 km are already available in the round configuration
- Homogeneity and integrity of the delivered wires are internally checked with well defined QA procedures
- Results have been confirmed by the coustoumers and by CERN, for more than 1400km delivered

There are some specific application where MgB_2 can already play a crucial role:

- Magnets for MRI in the low-intermediate magnetic fields (0.5T to 1T)
- Cable for powering magnet (up to 120kA in the HiLUMI SC links)

We are working with partners in founded European projects to increase the TRL of SC solutions and take MgB_2 related application closer to the market (cable for energy transmission, generator and SMES)

We believe that MgB_2 can also play a role in accelerators and beam lines magnets, expecially when power dissipation and large energy consumption need to be rediced
(revamping of existing beam lines magnets, develop superferric or new magnets)

Electromagnetic Study of a
Round Coil Superferric Magnet

Giovanni Volpini, Juho Rysti, Marco Statera

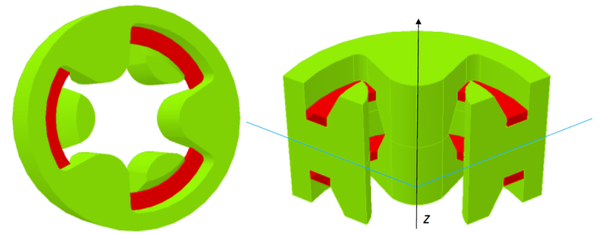


Fig. 2. Two possible implementations, with one and two coils, of the RCSM to sextupole design. The features of the magnetic field are described in the text and in Table I.

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Speaker: Stefano Sorti