High temperature Superconducting materials, functionalities and devices at ICMAB

T Puig

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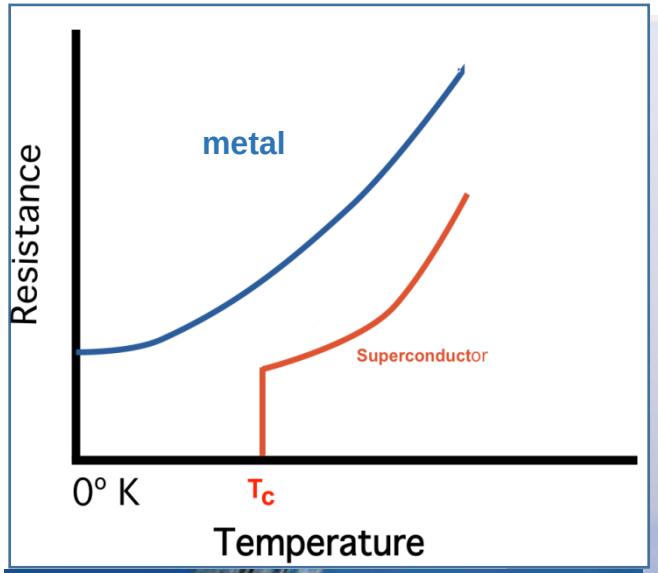
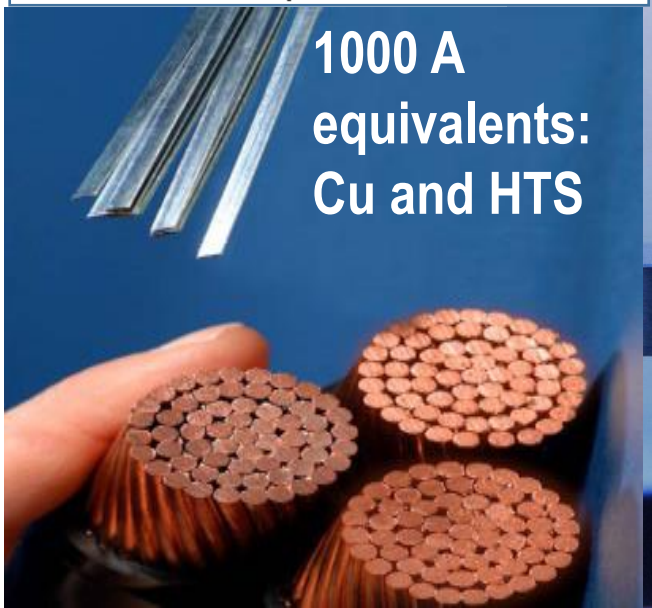
RL2: Superconducting materials for power applications



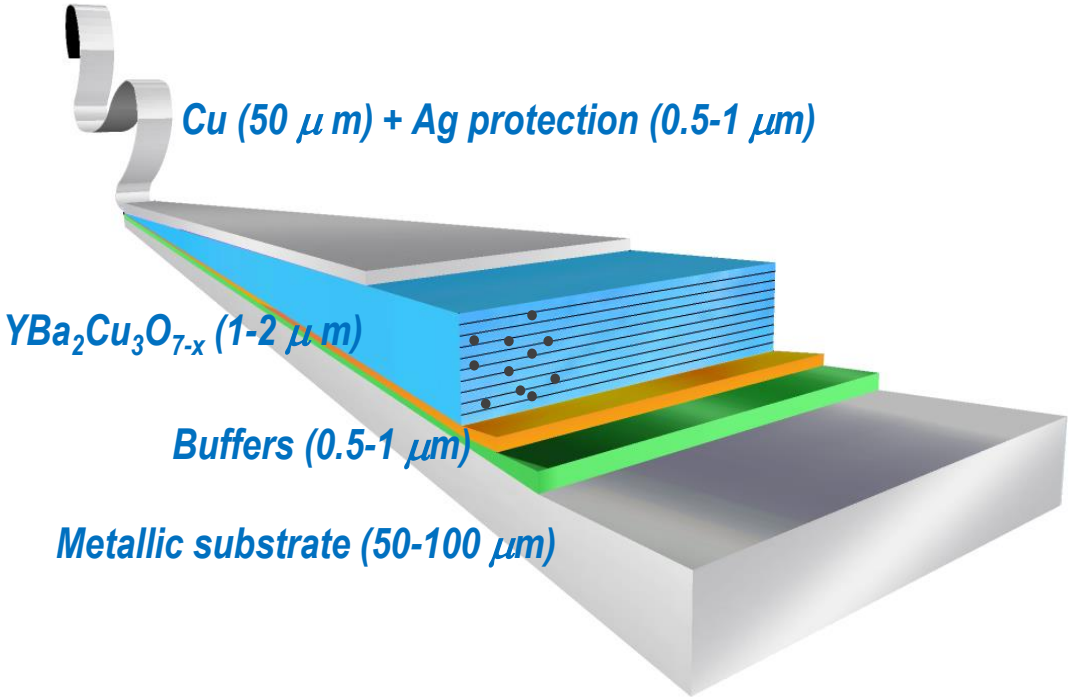


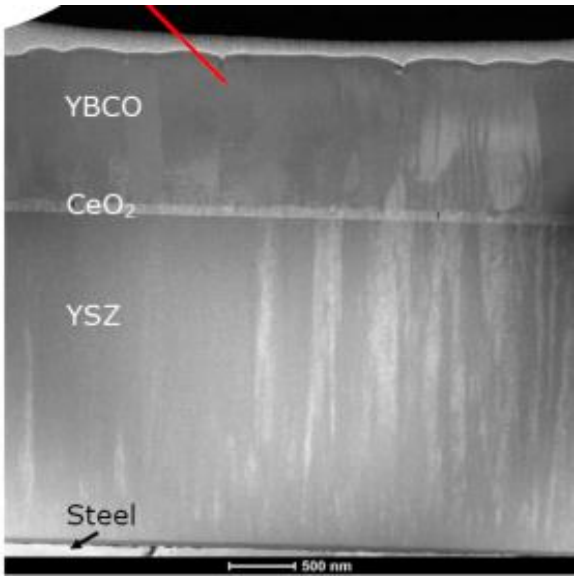
- Materials development and scalability
- New superconducting functionalities
- Materials integration in devices

High Tempearture Superconducting Coated Conductors

ICMAB
INSTITUT DE CIÈNCIA DE MATERIALS DE BARCELONA
EXCELENCIA SEVERO OCHOA
CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

A revolution in materials science





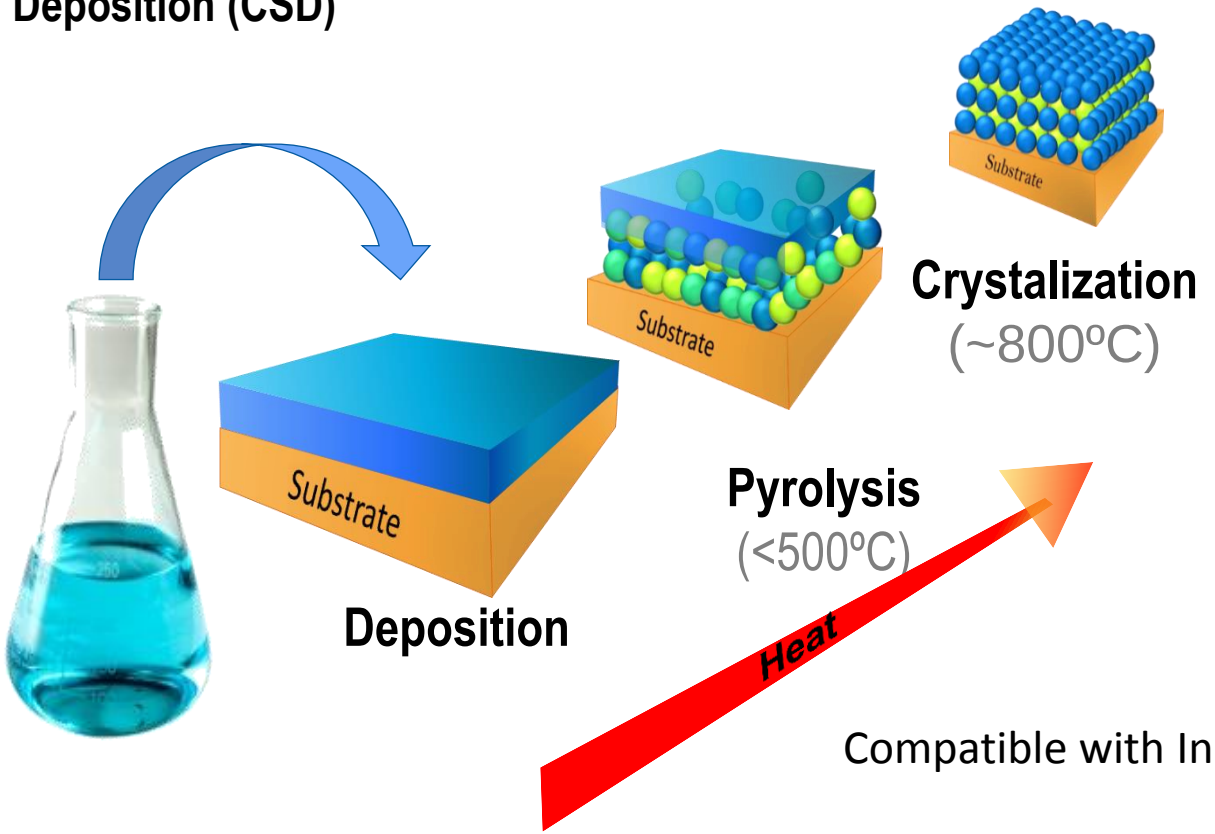
Km-length flexible epitaxial multilayer capable to carry 400 A/cm-w at 77K and 800 A/cm-w at 5 K & 30 T

Coated Conductors at ICMAB

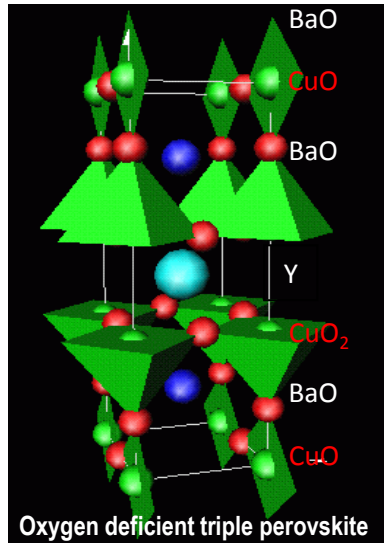
(17 years of experience)

Low cost, scalable, high –throughtput / high performance HTS-cuprate materials, film growth and materials physics understanding

Chemical Solution Deposition (CSD)



$YBa_2Cu_3O_{7-x}$

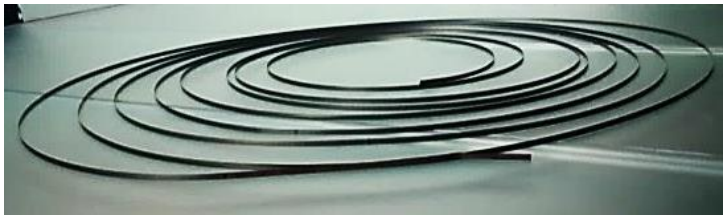


Compatible with Ink Jet Printing

Spin-off created in 2010
5 employees
500m^2 in a industrial park

Oxide layers by CSD- ink jet printing

Coated Conductors for sustainable development

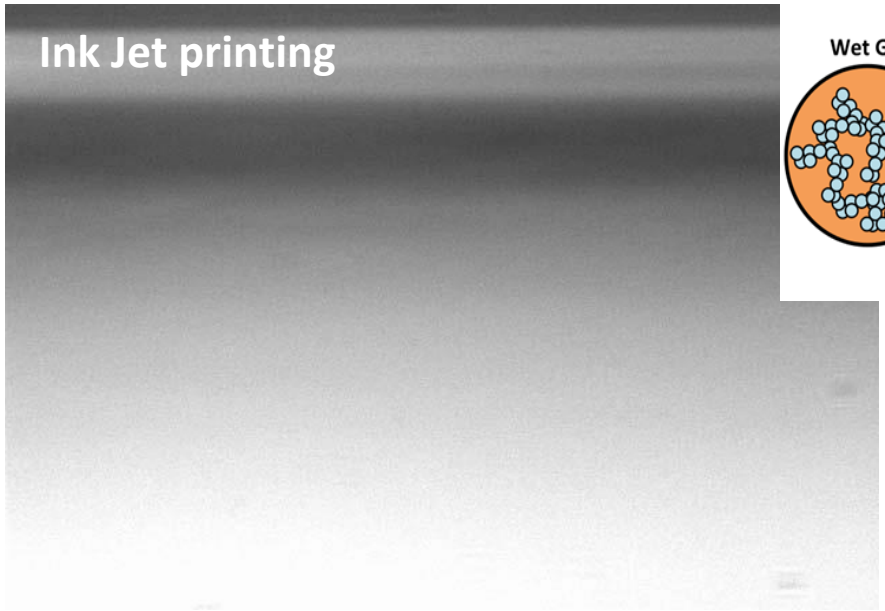


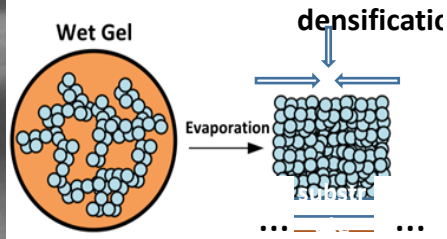
SUPERINKS: MINECO-RTC-Advanced Inks

T. Puig

Development of UV inks for coated conductors depostion

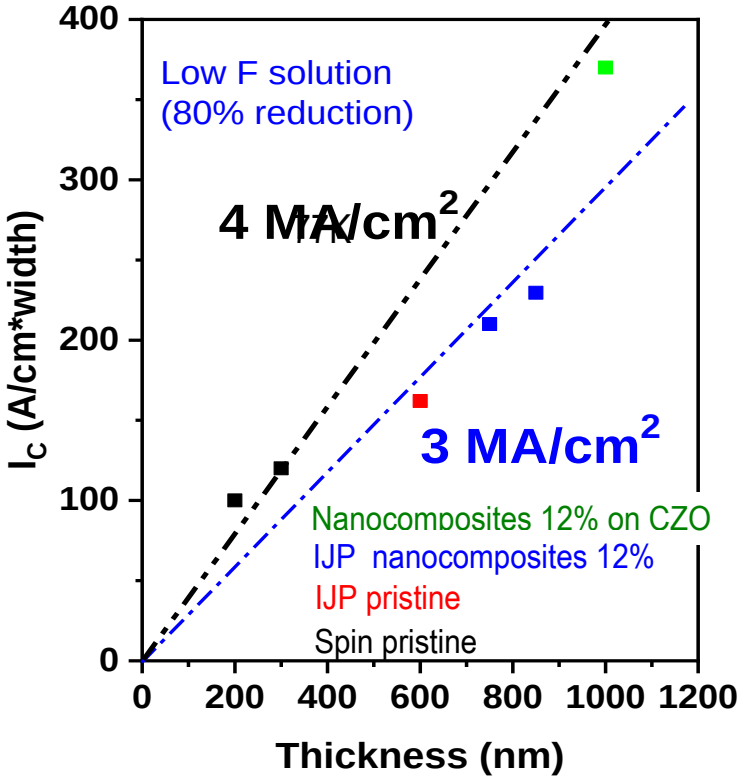
Towards growth of thick coated conductors: Scalability by innovative inks





In-situ characterization tools have been developed

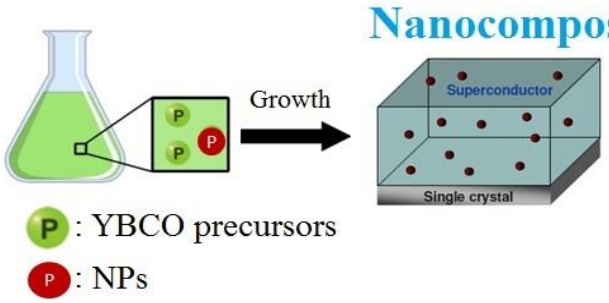
$I_c = J_c$ x thickness



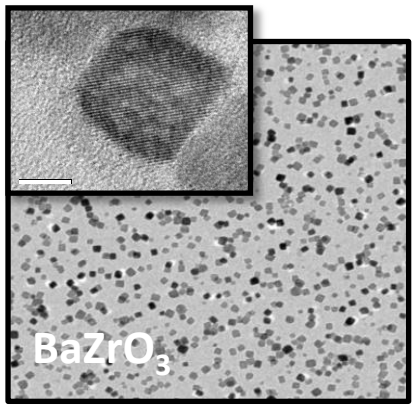
Epitaxial growth by supersaturation control

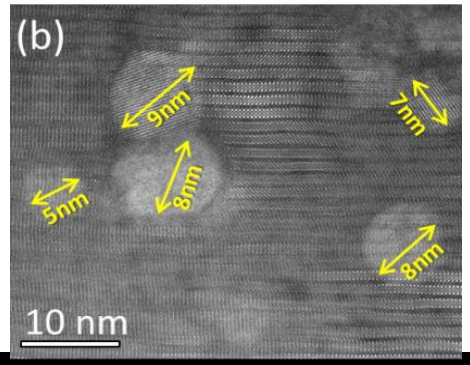
EUROTAPES: FP7 EU Integrated project

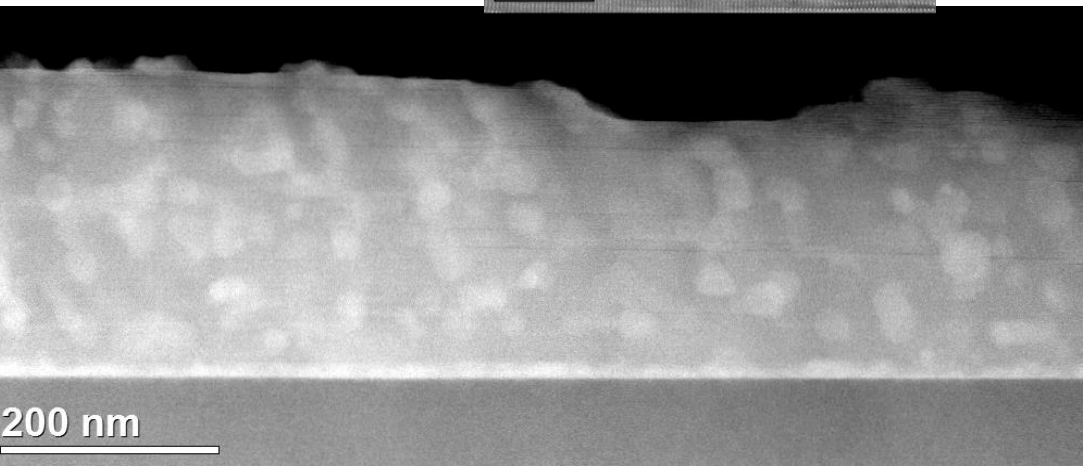
X. Obradors ICMAB coord. 21 partner (8 industrial)

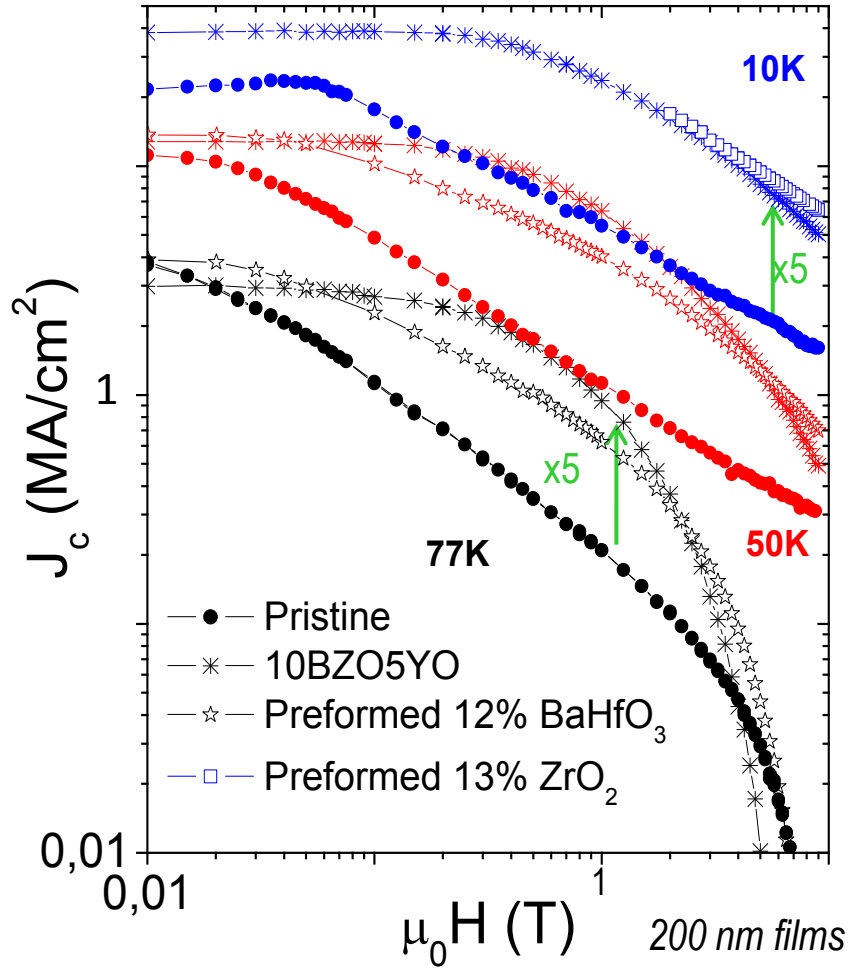


Integrating nanocomposite in coated conductors with cost effective processes



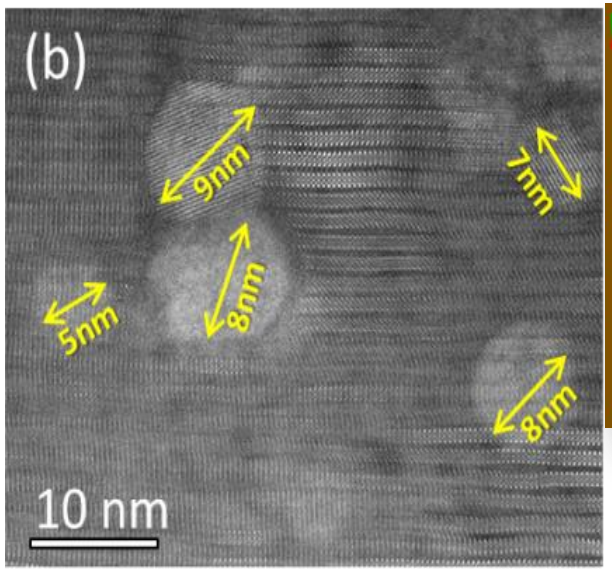


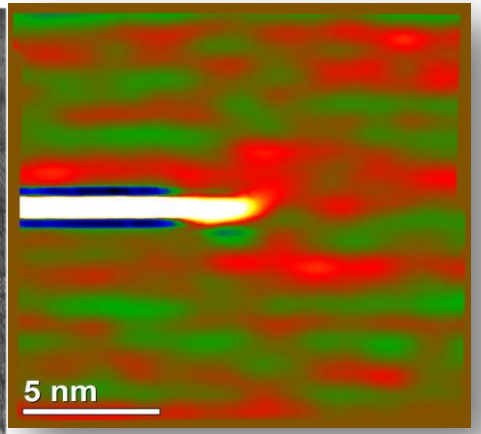




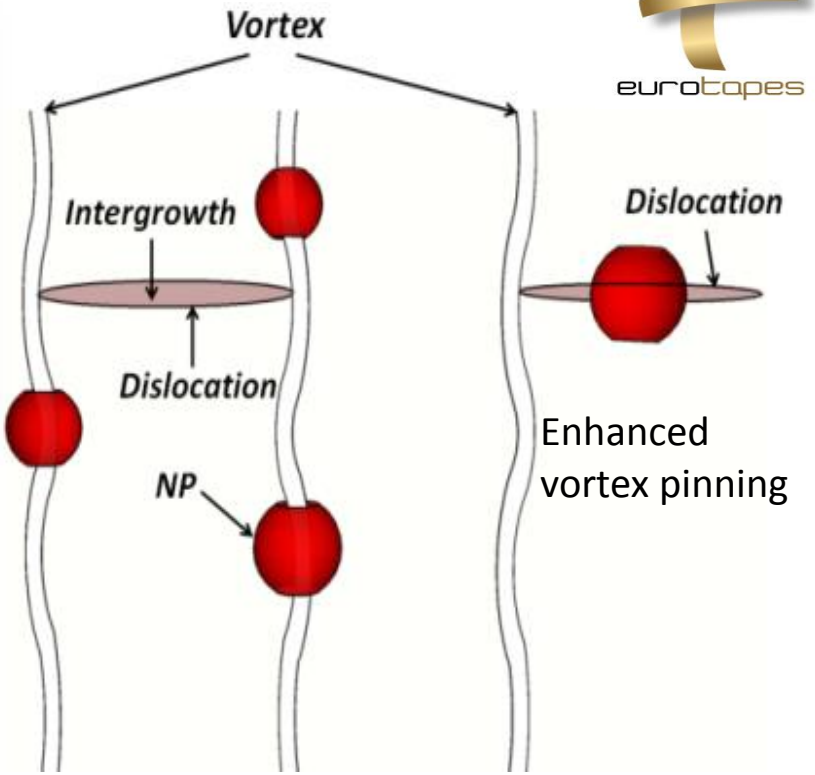
Nobel vortex pinning functionalities

Nanotechnology is key





Local strain effects generated at the partial dislocations



Enhanced vortex pinning

J. Gutierrez et al Nat Mat. (2007)
A. Llordés et al Nat Mat (2012)
Z. Li et al, to be submitted

Nanostrain and NPs (4-8 nm) Synergistic effect for enhanced vortex pinning

Control of the overdoped state should further increase performance

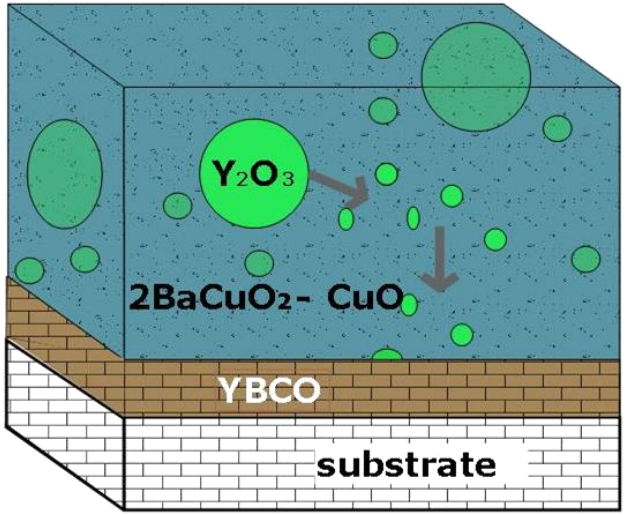
ULTRASUPERTAPE: ERC Advanced Grant H2020

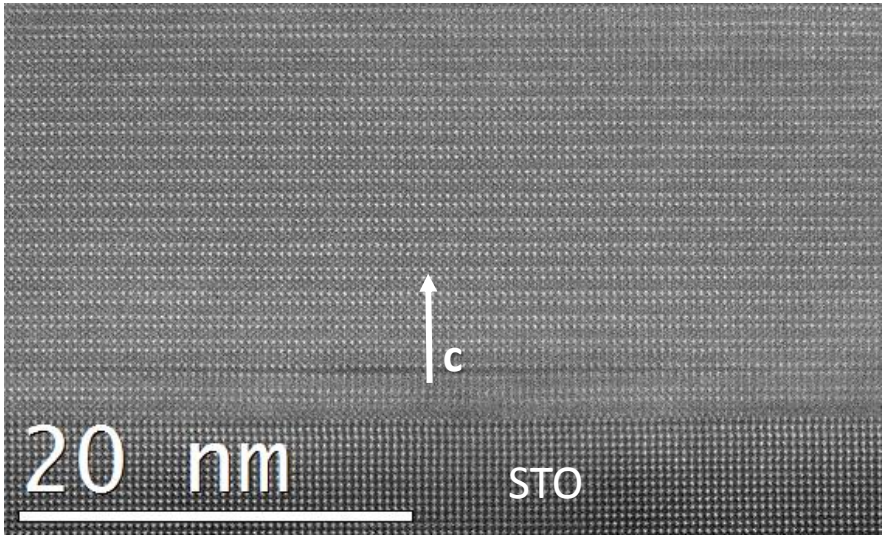
T. Puig

Ultrafast growth of ultrahigh performance superconducting tapes

- **Ultrafast CSD-Transient Liquid Assisted Growth** *(x100)*
- **Thick Strained Overdoped Nanocomposites** *(x100)*
- **Additive Manufacturing** *(scalable)*
- **New combinatorial chemistry approaches** (fast screening)

Transient Liquid Assisted Growth: TLAG





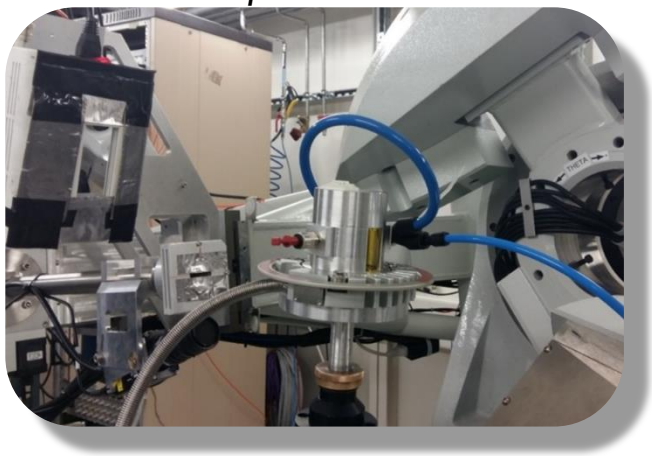
J_c (77K)= 4-5 MA/cm^2

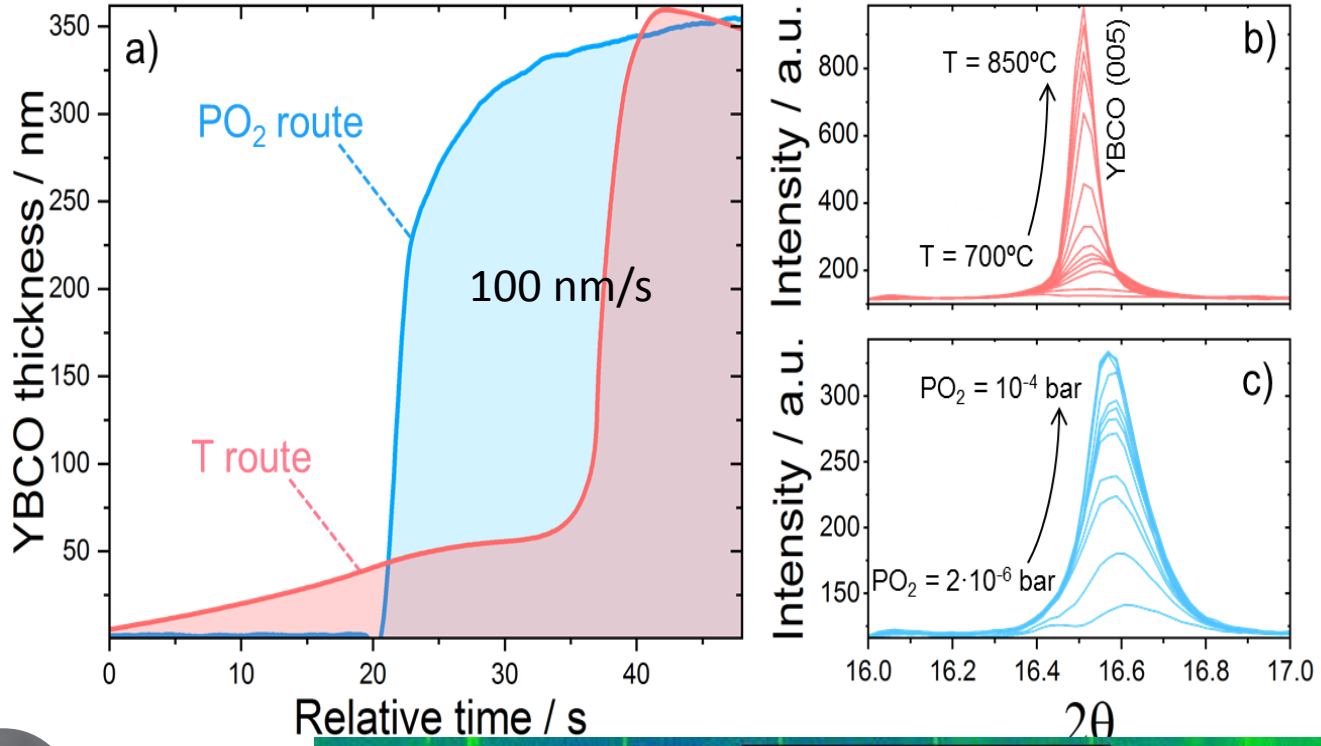
Ultrafast growth by TLAG-CSD

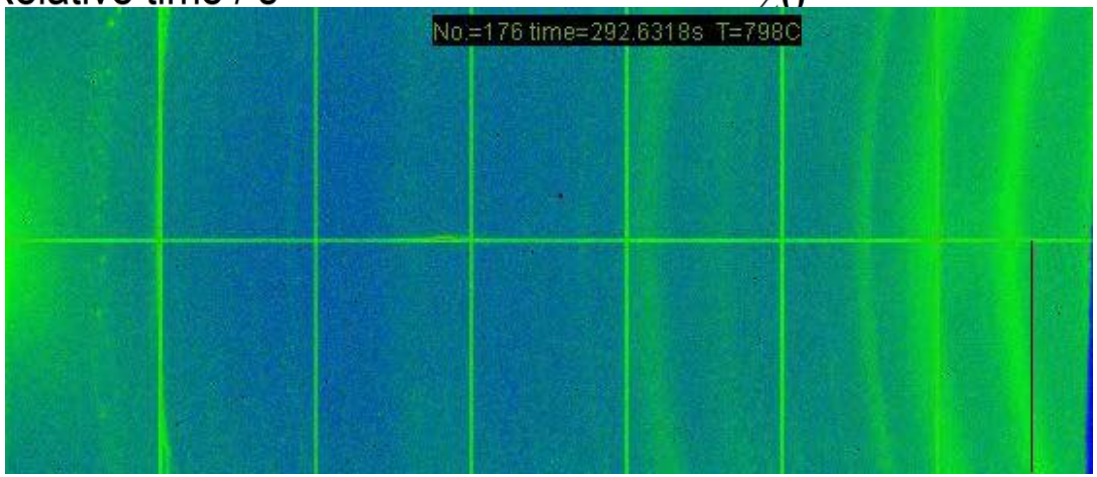
In-situ XRD synchrotron exp.

Grwoth rate x100 standard thin film growth processes

DiffAbs beamline
100 ms acquisition time

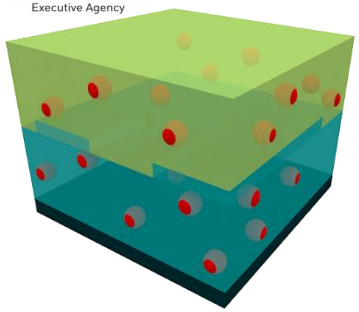


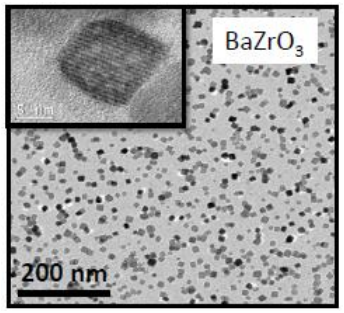


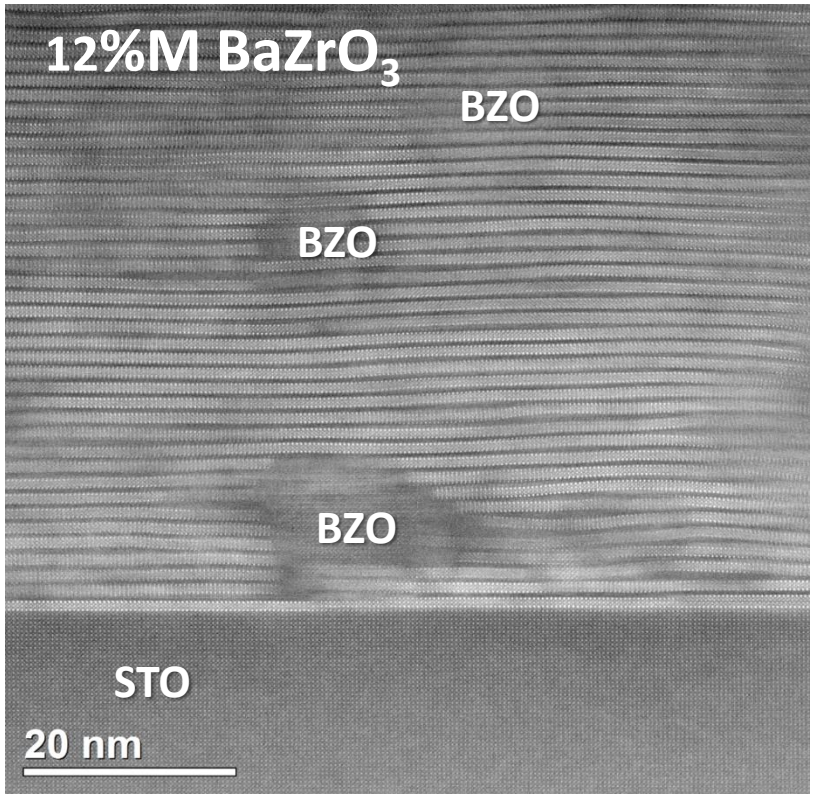


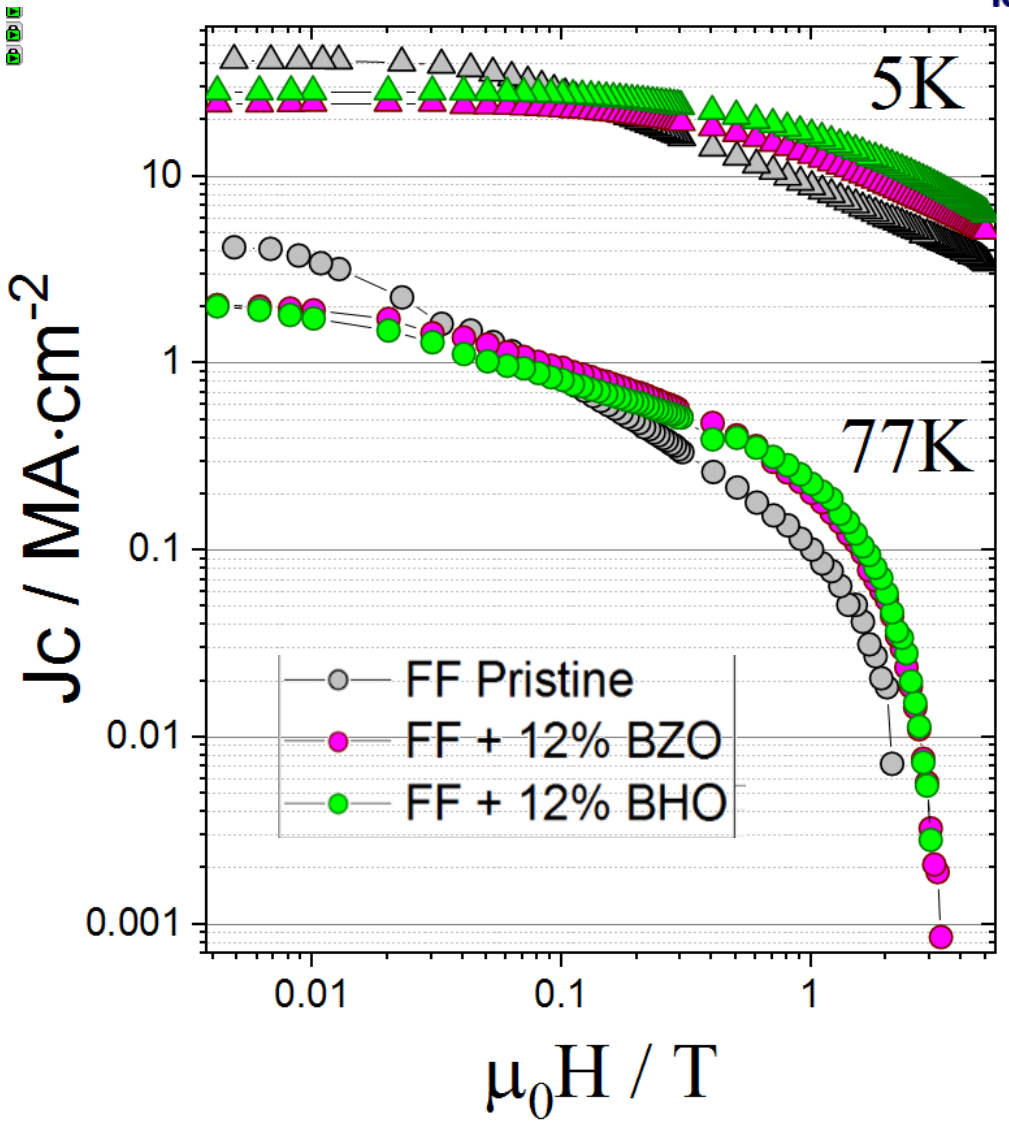
L. Soler et al, to be published

Nanocomposites by TLAG-CSD

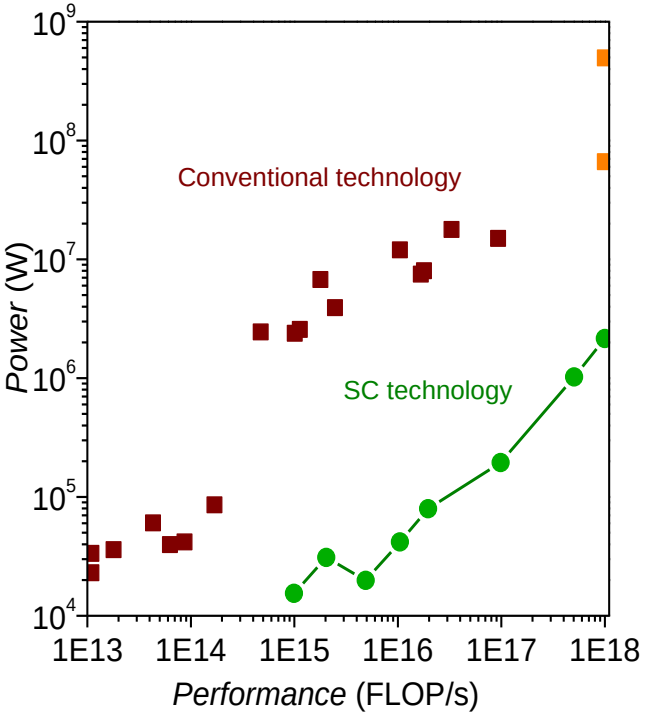








New superconducting functionalities for green energy solid state electronic devices



www.top500.org, Holmes et al. IEEE Trans. Appl. Supercond. 23, 1701610 (2013)

Superconducting technology:

by virtue of their **inherent energy-efficiency** emerges as a very promising and reliable approach to **close the growing gap between required performance and sustainability**

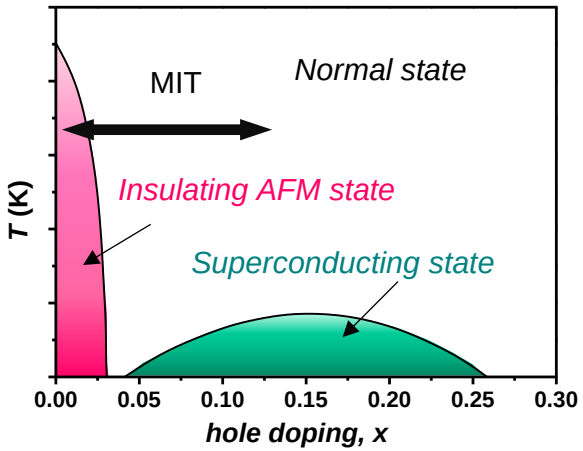
Two energy efficient approaches to encode and manipulate information.

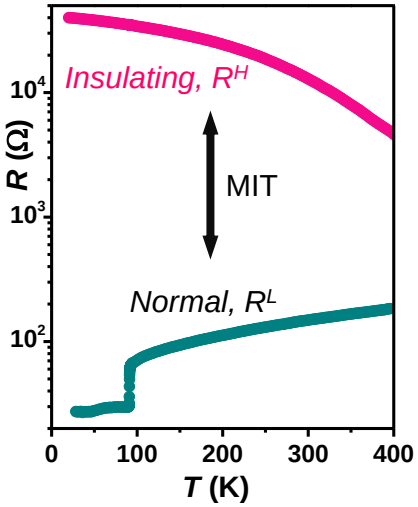
- Nanoscale electric field-induced oxygen doping modulation:
  Resistive switching phenomena
- Magnetic spin modulation with supercurrents (trapped fields):
  Hybrid SC / FM systems

Resistive Switching in YBCO Films

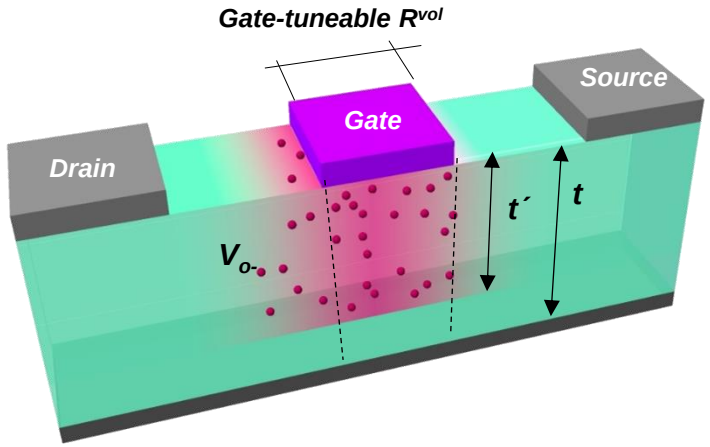
A. Palau and N. Mestres FIP proj. (SO)

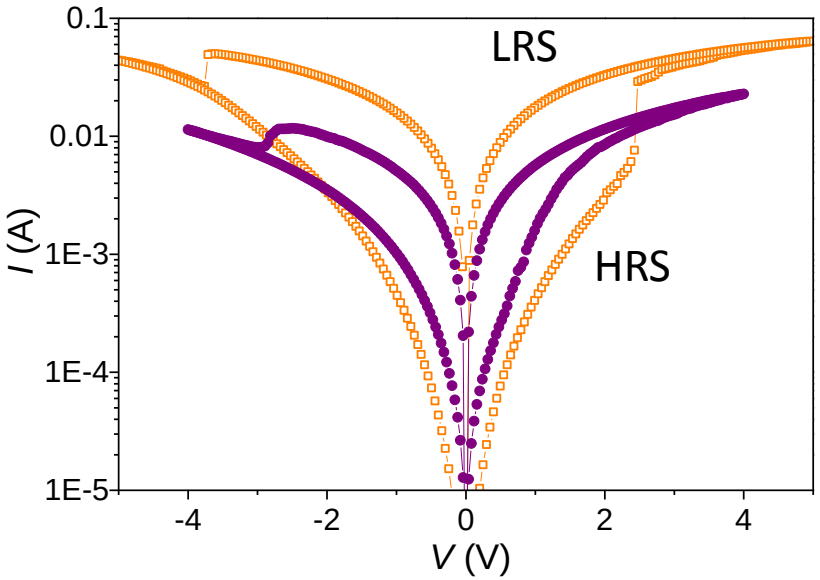
Reversible field induced Metallic / Insulating transition



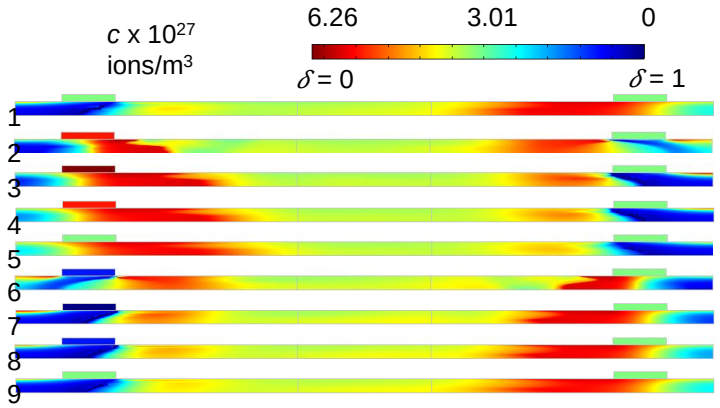


<u>Transistor like devices</u> with a free-resistance channel





Homogenously and reversibly tune a superconducting channel on and off, by means of an electric field as the external control parameter.

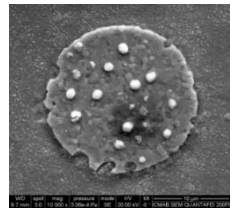


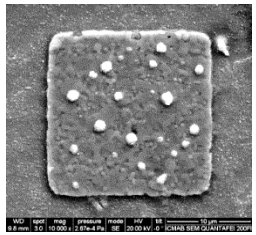
A. Palau et al. Applied Materials & Interfaces, 10 (2018)
J.C. Gonzalez-Rosillo et al, J Electroceram, 39 (2017)

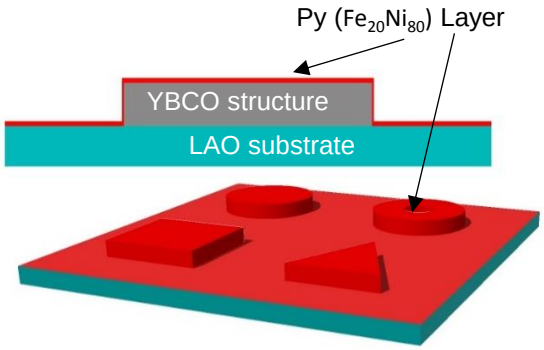
Encoded spin textures in FM / SC Hybrid Systems

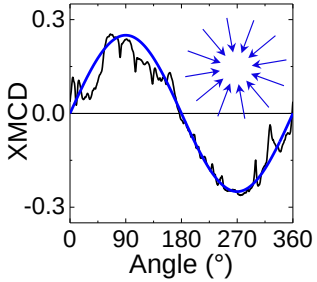
A. Palau

YBCO-CSD film patterned with SC dots (20 µm x 20 µm) of different shapes, covered by a Soft FM

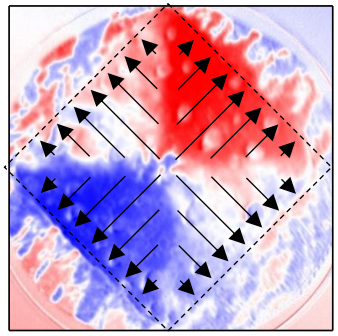


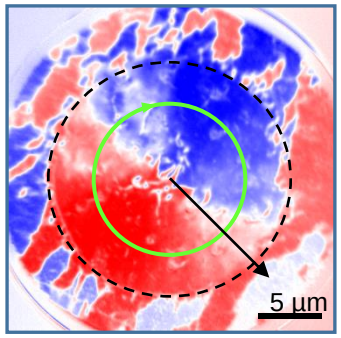


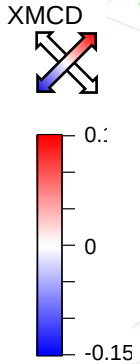


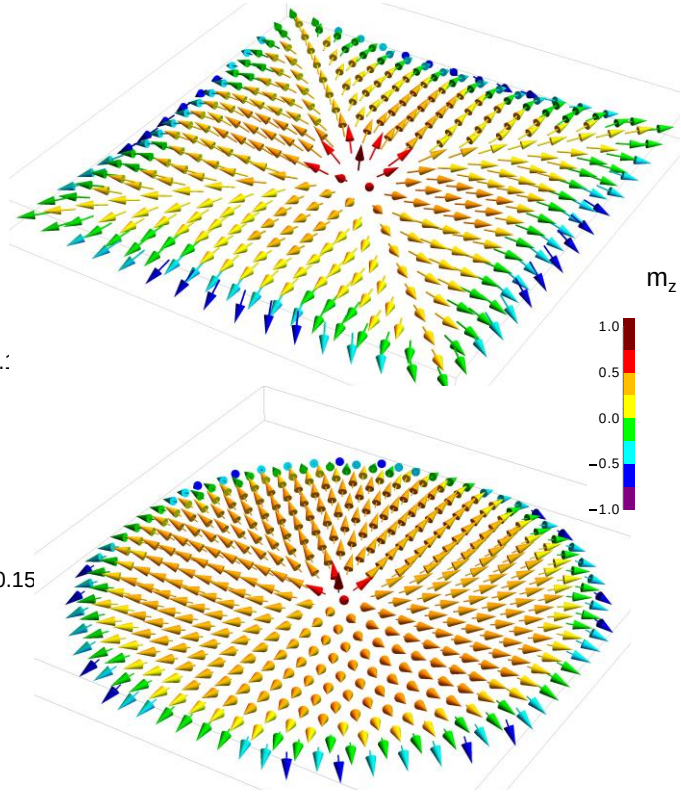


T =45K B_{max} = +30 *mT*





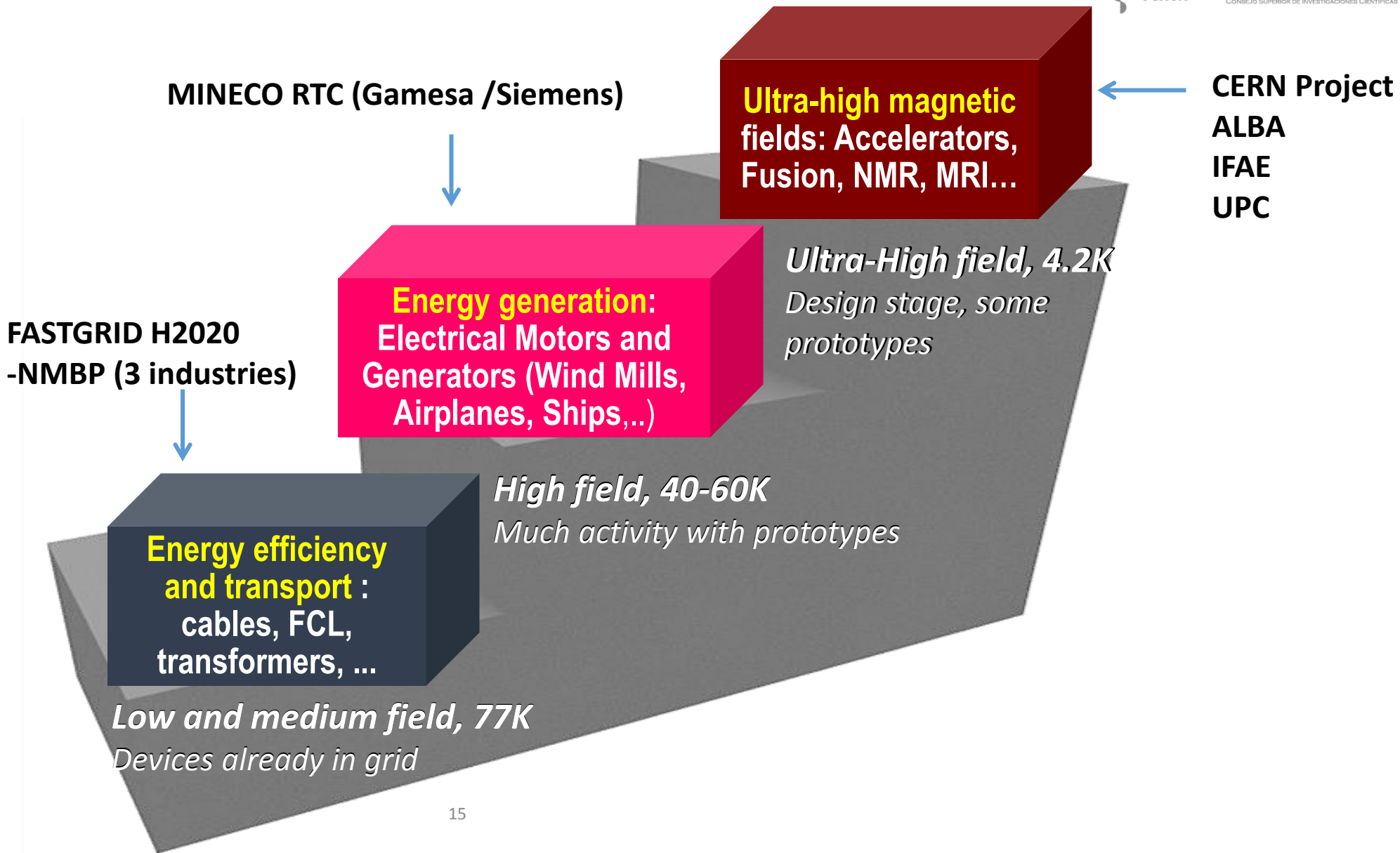




Versatile option to generate, modify and annihilate a large number of singular spin configurations for potential applications in logic or memory devices

A. Palau et al, Adv. Science (2017)

Coated Conductors costumization for Integration in large scale devices

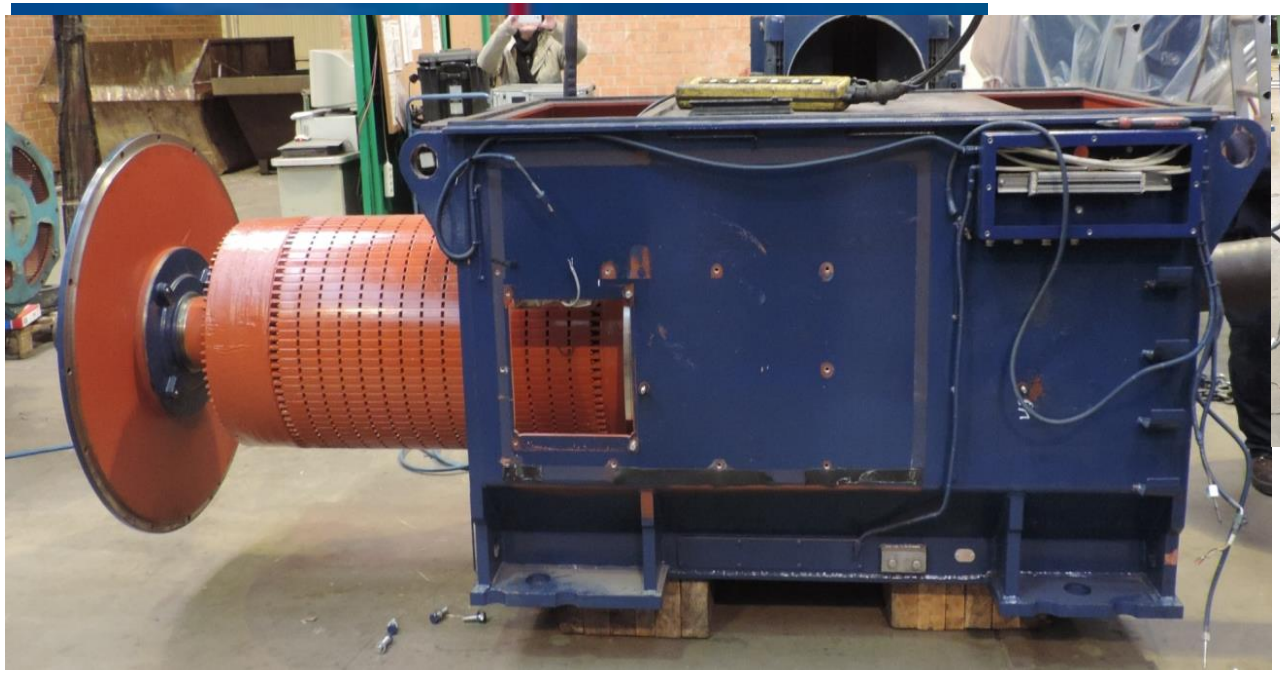


GAMESA project: MINECO-RTC-Wind Generator

X. Granados

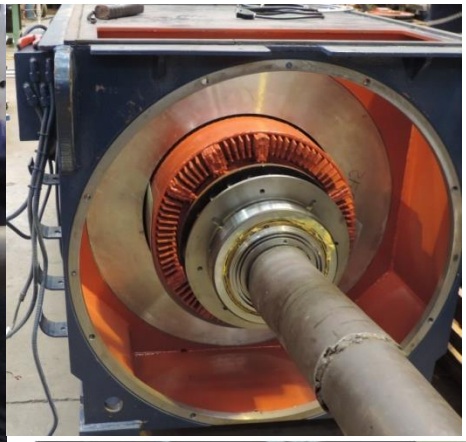
"Design of a new generation of wind generator and auxiliary equipment for solar energy based on superconductors"

Towards wind turbines generators based on HTS for next generation 10 MW

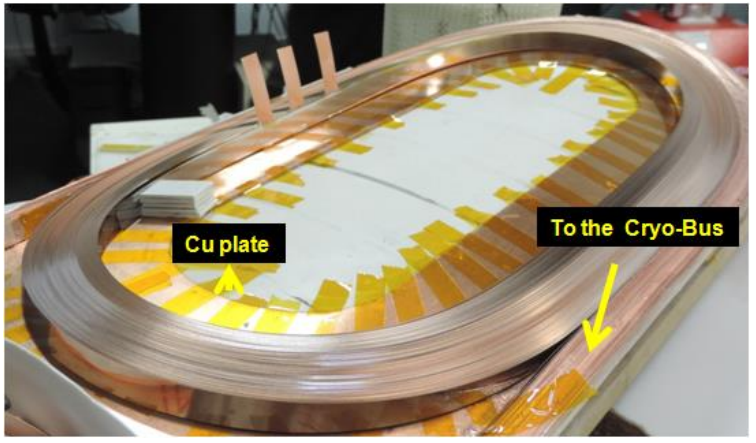


HTS stator for wind generator of 2 MW

Financing support phase 2 pending: HTS rotor (5 MW) (from 6.5 tm down to 2 tm)



More efficiency
Less weight
Less volume



HTS coil

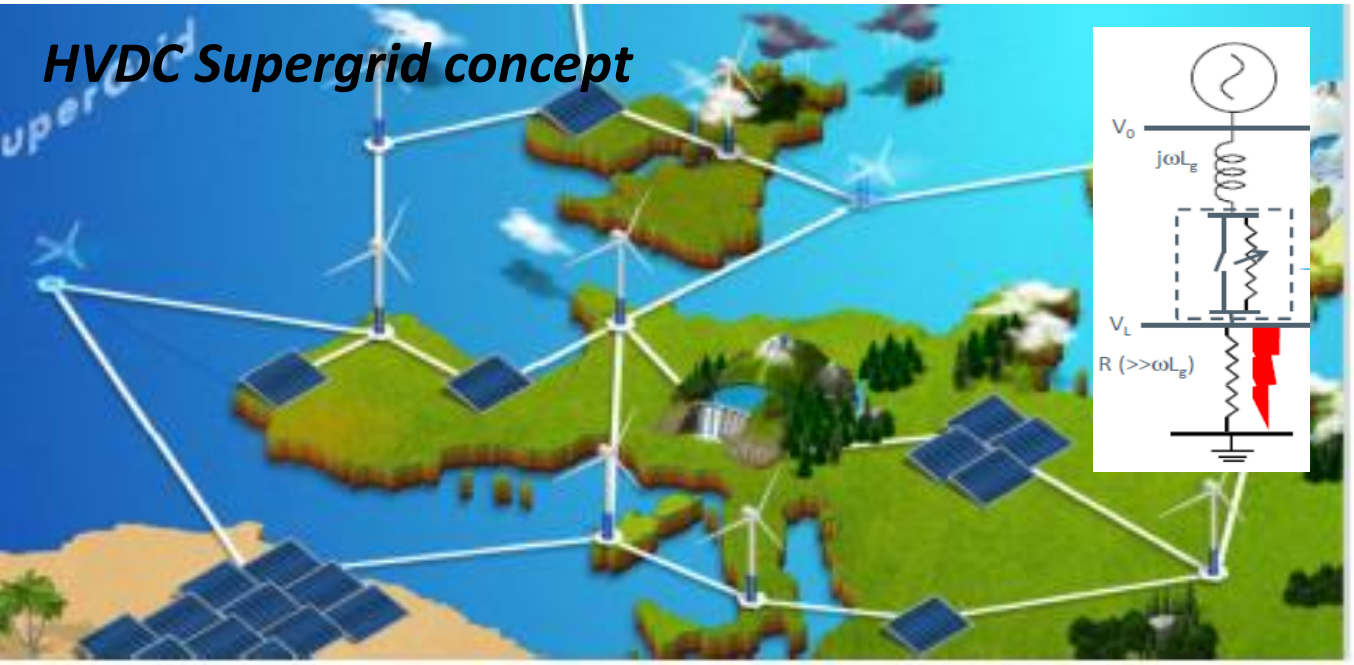
FASTGRID H2020-NMBP

X. Obradors *12 partners (coord. CNRS, France)*

"Cost effective FCL using advanced superconducting tapes for future HVDC grids"

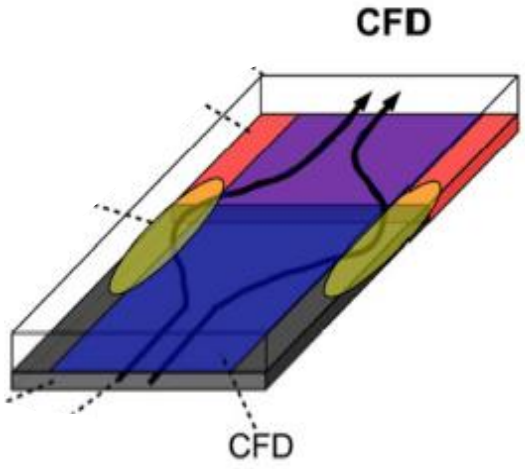
Smart DC SCFCL module (1 kA – 50 kV) for HVDC cables

Novel architectures to modulate the superconducting transition



New materials concepts:

- New nanolayer at the surface to increase quench velocity (x10)
- New architecture based on sapphire to increase electric field (x20)

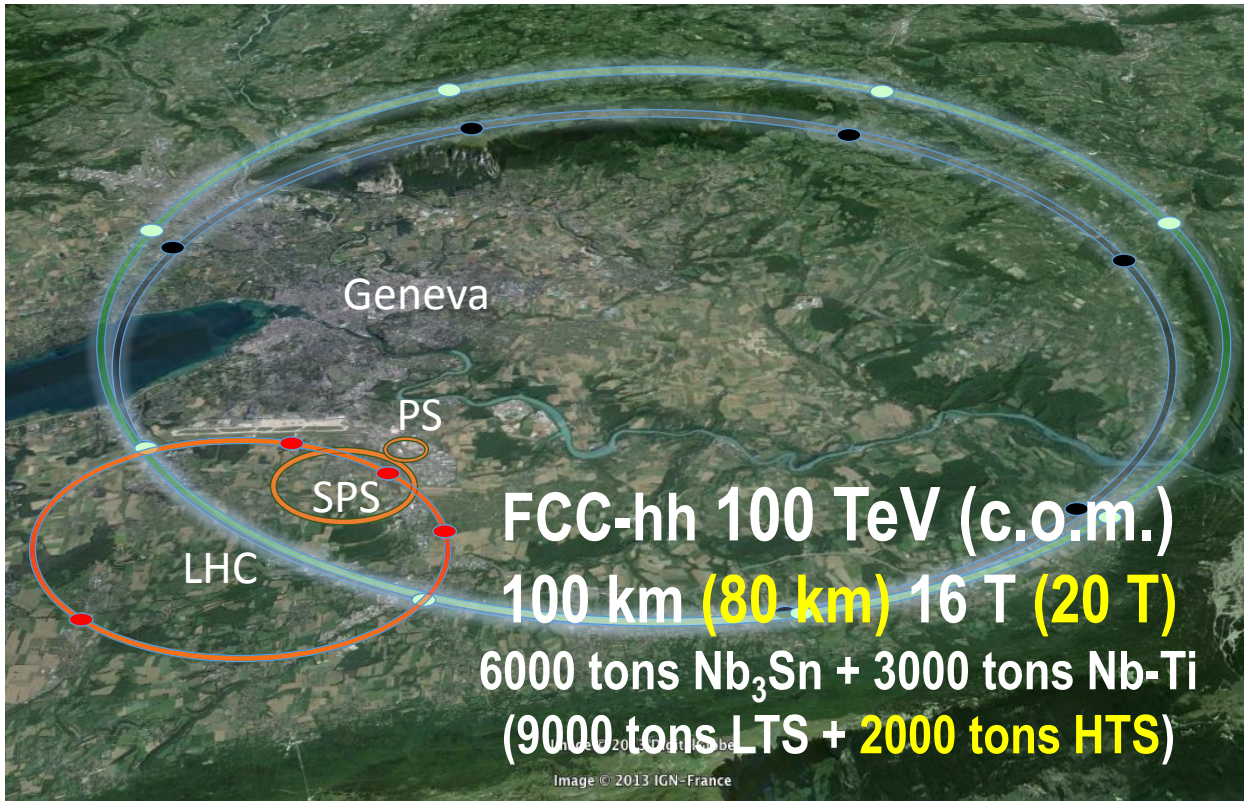


CERN collaborative project + FIP Proj. (SO)

J. Gutierrez, X. Granados, T. Puig

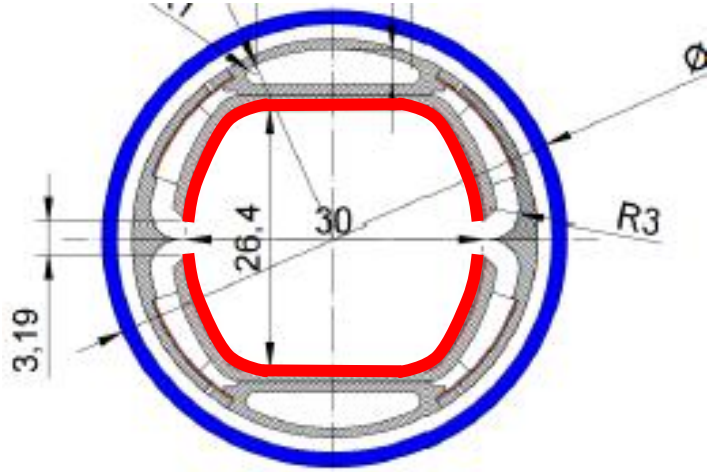
"HTS coated conductors for FCC beam screen"

Future Circular Collider (FCC)



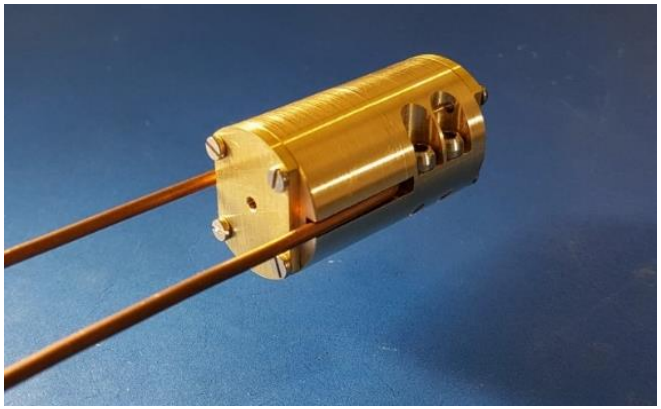
New HTS coated FCC chamber

Need of low surface impedance material for beam screen



CCs welded to stainless steel walls

REBCO CCs show the potential to outperform Cu under the FCC working conditions

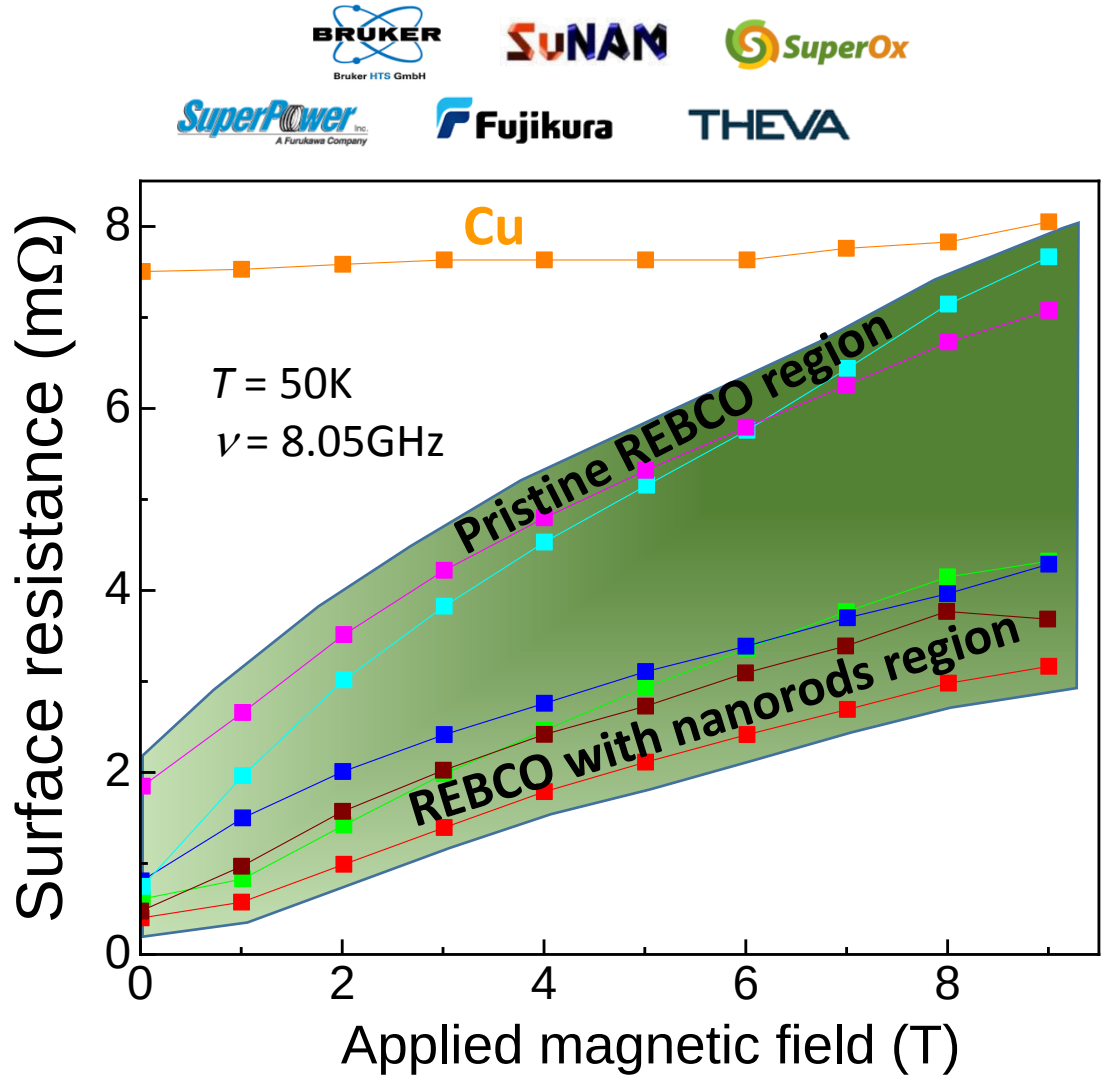


In house developed 8.05 GHz cavity resonator compatible with 25mm bore 9 T magnet at ICMAB

We have a 1 GHz resonator compatible with a 25 mm bore magnet in its final stage of design

REBCO CCs outperform Cu at 50K and up to 9T

R_{Sf} is microstructure dependent



CONCLUSIONS

The Superconductivity RL is strongly involved in:

- Materials development and scalability
- New superconducting functionalities
- Materials integration in devices

We want Superconducting materials and devices to penetrate the market

A group of physicist, chemists, materials science and engineers working together to make it possible

Cost/performance is the main challenge

We need Superconductivity dissemination to all levels

Welcome to the Superconducting Materials group