Istituto SPIN-CNR

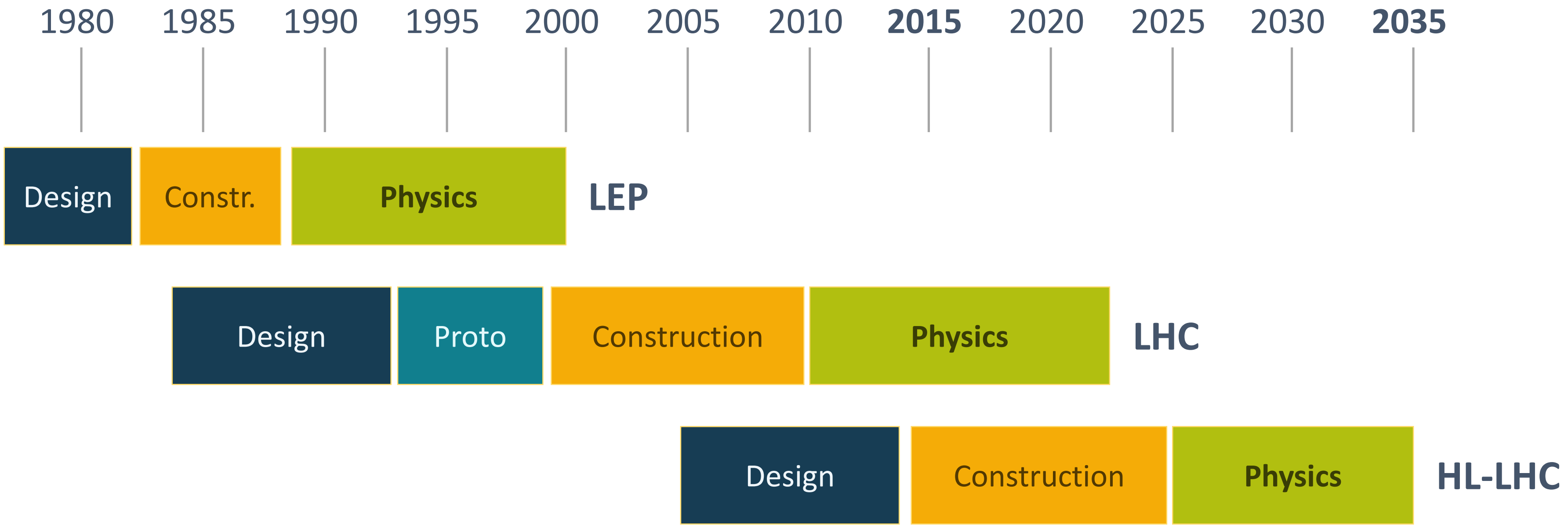
Universita’ di Napoli Federico II
Dipartimento di Fisica “Ettore Pancini”

Ruggero Vaglio

High Tc Superconducting Coatings for Beam Impedance Mitigation in the CERN Future Circular Collider (FCC)

(in collaboration with Sergio Calatroni, TE-VSC Division, CERN)

CERN Circular Colliders and FCC



1980 1985 1990 1995 2000 2005 2010 **2015** 2020 2025 2030 **2035**

Design Constr. **Physics** **LEP**

Design Proto Construction **Physics** **LHC**

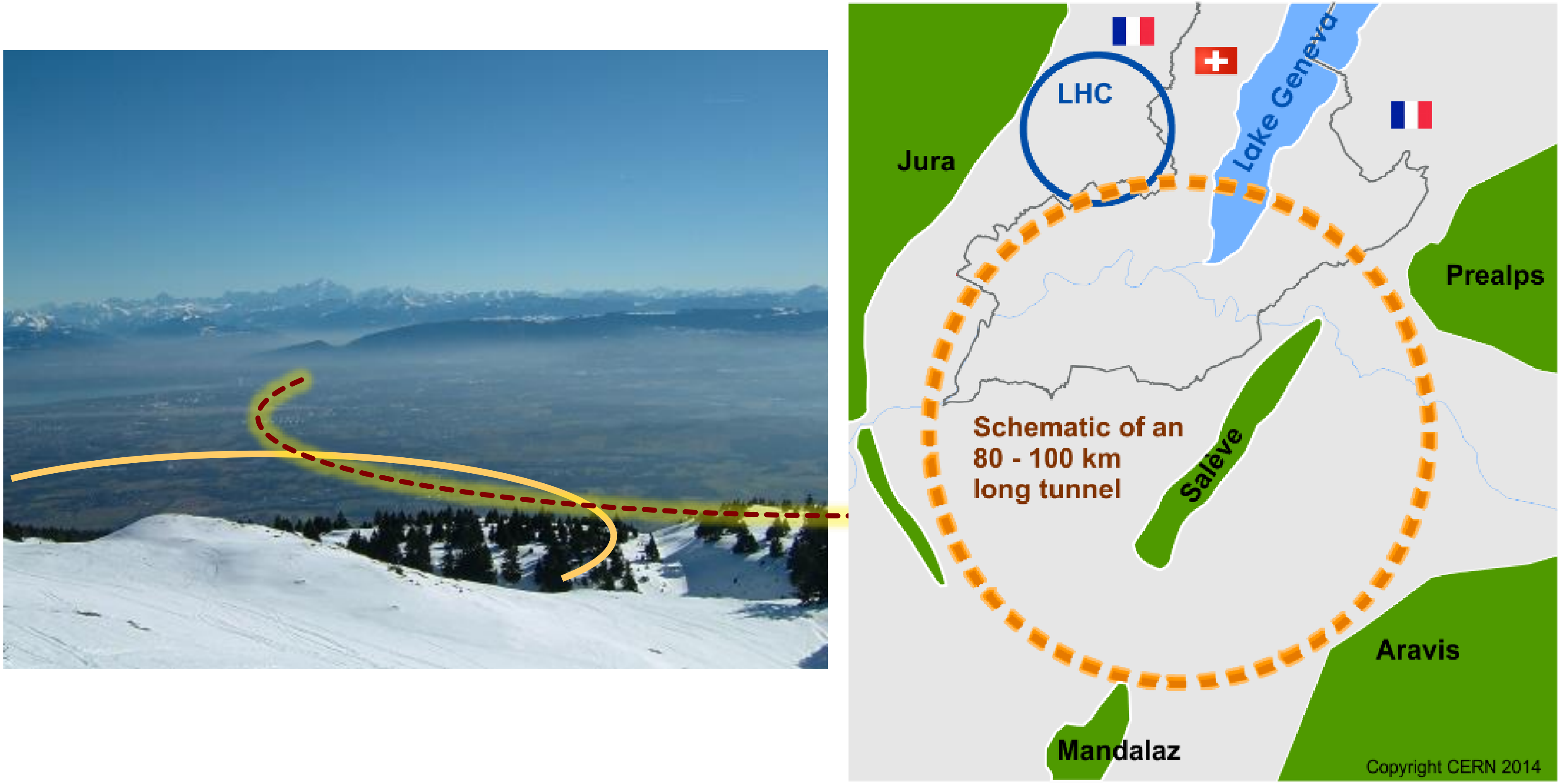
Design Construction **Physics** **HL-LHC**

Now is the time for CERN to plan for a Future Circular Collider !

Drive: pushing the energy frontier of a factor 10!

- A very large circular hadron collider seems the only approach to reach 100 TeV c.m. collision energy in coming decades
- Access to new particles (direct production) in the few TeV to 30 TeV mass range, far beyond LHC reach.
- Much-increased rates for phenomena in the sub-TeV mass range

Future Circular Collider at CERN



Schematic of an 80 - 100 km long tunnel

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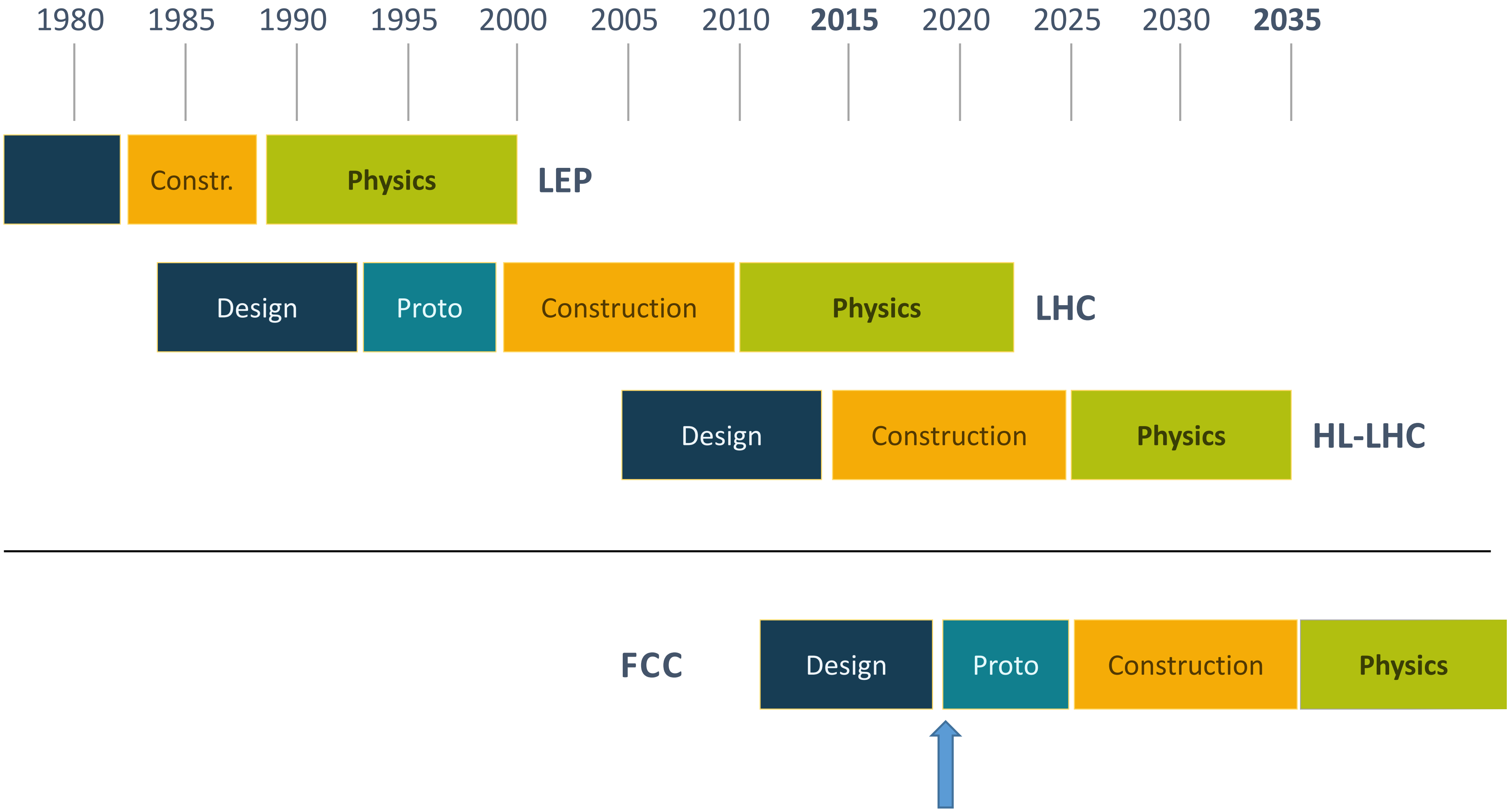
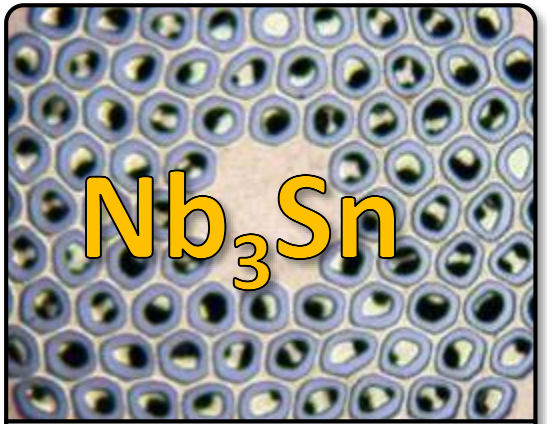
CERN Circular Colliders and FCC



Conceptual Design Report (CDR) by end 2018

Examples of Key Technology R&D for FCC



Conductor R&D

- Increase critical current density
- Obtain high quantities at required quality
- Material Processing
- Reduce cost

Magnet Design

- Develop 16T short models
- Field quality and aperture
- Optimum coil geometry
- Manufacturing aspects
- Cost optimisation

V0.13 Date: 14.03.2018

FCC Week 2018 Program Overview

Day	Monday (9 APRIL)			Tuesday (10 APRIL)					Wednesday (11 APRIL)					Thursday (12 APRIL)						Friday (13 APRIL)		Day
Room Time		Plenary Room 0.4 Effectenbeurszaal		Parallel 1 Room 0.4 Effectenbeurszaal	Parallel 2 Room 0.5 Graanbeurszaal	Parallel 3 Room 1.1 Administratiezaal	Parallel 4 Room 1.9 Berlage zaal	Parallel 5 Room 1.20 Veilingzaal	Parallel 1 Room 0.4 Effectenbeurszaal	Parallel 2 Room 0.5 Graanbeurszaal	Parallel 3 Room 1.1 Administratiezaal	Parallel 4 Room 1.9 Berlage zaal	Parallel 5 Room 1.20 Veilingzaal	Parallel 1 Room 0.4 Effectenbeurszaal	Parallel 2 Room 0.5 Graanbeurszaal	Parallel 3 Room 1.1 Administratiezaal	Parallel 4 Room 1.9 Berlage zaal	Parallel 5 Room 1.20 Veilingzaal	Parallel 6 Room 1.2 Mendes Kamer	Plenary Room 0.4 Effectenbeurszaal		Room Time
08:30-09:00	Registration (0.3 Beursfoyer)	Opening, study status and physics perspectives	Welcome	FCC-hh accelerator: design I (review)	Conductor Nb3Sn: State of the art & characterization	FCC-ee Physics & Exp.: Detector Designs (review)	SRF Direction for R&D	Special Tech.: Beam Vacuum System Conceptual Design I	FCC-ee accelerator: parameters and optics (review)	EuroCirCol 16 T Other tasks	FCC-physics	Civil engineering, geodesy, alignment, transport, logistics (review)	Special Tech.: Injection & extraction I	FCC-hh Physics & Exp.: Detector Magnet, Tracker, ECAL	FCC-ee injector (review)	Special Tech.: Beam stoppers, collimators and dumps	FCC-eh: Technical developments	Safety (review)	EuroCirCol WP4 coordination (closed session)	Summaries Machines and Technologies	FCC-ee design	08:30-09:00
09:00-09:30			Physics at FCC																		FCC-hh design	09:00-09:30
09:30-10:00																					I&O/Special Technologies	09:30-10:00
10:00-10:30			Study status & further plans	Coffee Break (0.2 Grote Zaal)					Coffee Break (0.2 Grote Zaal)					Coffee Break (0.2 Grote Zaal)							Magnets/RF	10:00-10:30
10:30-11:00		Coffee Break (0.2 Grote Zaal)		FCC-hh accelerator: design II (review)	Conductor: Development for FCC	FCC-ee Physics & Exp.: Machine detector interface (review)	SRF cavity technology	Special Tech.: Beam Vacuum System Conceptual Design II	FCC-ee accelerator: MDI (review)	16 T R&D Magnets and models	FCC-physics	Cryogenics (review)	Special Tech.: Injection & extraction II	FCC-hh Physics & Exp.: Detector HCAL, Muons, Trigger	FCC-ee accelerator: energy calibration & polarization (review)	Special Tech.: Electronics & instrumentation	FCC-eh: physics	EASItrain: superconducting thin films and manufacturing	EuroCirCol WP4 coordination (closed session)	Coffee Break (0.2 Grote Zaal)		10:30-11:00
11:00-11:30		Status Machines (overview)	FCC-hh machine design																	Summaries Physics and Experiments	FCC-he	11:00-11:30
11:30-12:00			FCC- ee machine design																		FCC-hh	11:30-12:00
12:00-12:30			HE-LHC machine	Lunch (0.2 Grote Zaal)					Lunch (0.2 Grote Zaal)					Advisory Committee (closed session)	Lunch (0.2 Grote Zaal)						FCC-ee	12:00-12:30
12:30-13:00	Lunch (0.2 Grote Zaal)																			Closing remarks		12:30-13:00
13:00-13:30														1.4 Verwey kamer								13:00-13:30
13:30-14:00				FCC-hh accelerator: collimation (review)	Conductor: Other superconductors	FCC-ee Physics & Exp.: EW precision measurements (review)	SRF studies	HE LHC Options and beam-beam	FCC-ee accelerator: collective effects and top-up (review)	Other programs	FCC-hh Physics & Exp.: Higgs, top and electroweak precision physics	Cooling & ventilation, electr. distribution, energy management (review)	EASItrain CC (closed session)	Common software	HE LHC Parameters and optics (review)	Special Tech.: Development of new manufacturing technologies	FCC-hh accelerator: collective effects I (review)	EASItrain: superconduct. wires				13:30-14:00
14:00-14:30	Status Technologies and Infrastructure (overview)		Civil Engineering, I&O																			14:00-14:30
14:30-15:00			Special Technologies R&D					1.2 Mendes kamer					1.4 Verwey kamer									14:30-15:00
15:00-15:30			16 T Magnet R&D - SRF R&D	Coffee Break (0.2 Grote Zaal)					Coffee Break (0.2 Grote Zaal)					Coffee Break (0.2 Grote Zaal)								15:00-15:30
15:30-16:00	Coffee Break (0.2 Grote Zaal)			FCC-hh: Collider beam transfer and injector I (review)	EuroCirCol 16 T Designs for the FCC CDR	FCC-ee Physics & Exp.: Higgs, flavour, neutrinos, QCD (review)	SRF Innovation		CEPC and others	Other magnets for FCC	FCC-hh Physics & Exp.: Searches	Operation, reliability, radiation (review)	FCC-hh: Collider beam transfer and injector II (review)	Common technologies	HE LHC collimation and beam dynamics (review)	Special Tech.: Machine protection, circuit and powering	FCC-hh accelerator: collective effects II (review)	EASItrain: cryogenics				15:30-16:00
16:00-16:30	Status Experiments and Detectors (overview)		FCC-hh and HE LHC experiments and detector																			16:00-16:30
16:30-17:00			FCC-ee experiments and detector																			16:30-17:00
17:00-17:30			LHeC and FCC-he experiments	Poster Session 0.2 Grote Zaal					Cold refreshments (0.5 Graanbeurs, 0.3 Beursfoyer)													17:00-17:30
17:30-18:00	Cold refreshments (0.2 Grote Zaal)								Netherlands specific session	Gravitational waves: A new route to fundamental physics and cosmology				FCC & EuroCirCol Collab. Boards, EASItrain SSB (closed session)								17:30-18:00
18:00-18:30	Strategy Roadmaps Plenary Session		HEP and collider activities in the Americas	Steering Committee (closed session)						High Energy Physics detector R&D												18:00-18:30
18:30-19:00			HEP and collider activities in Asia							Research in High Magnetic Fields												18:30-19:00
19:00-19:30			HEP and collider activities in Europe & Strategy update	1.4 Verwey kamer					0.4 Effectenbeurs.	Superconductivity R&D in the Netherlands				0.4 Effectenbeurs.								19:00-19:30
19:30-20:00			Summary of the APPEC Strategy Update																			19:30-20:00

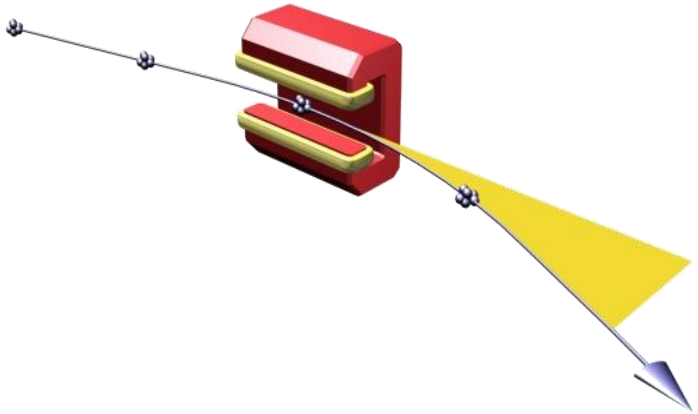
FCC Collaboration Status (2016)

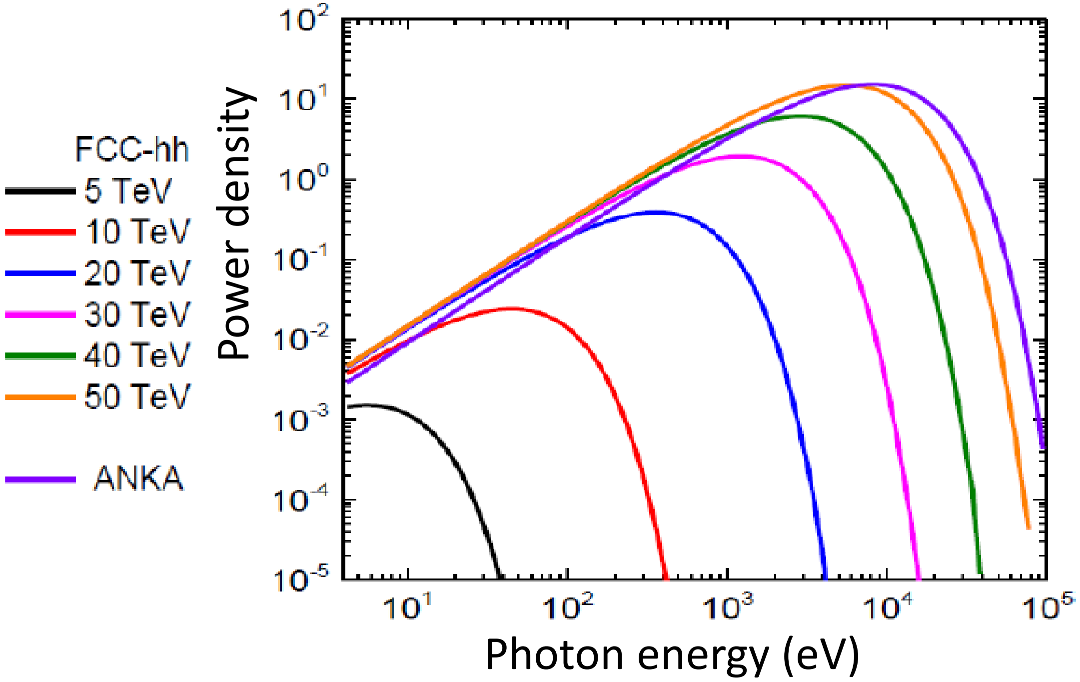
ALBA/CELLS, Spain
Ankara U., Turkey
U Belgrade, Serbia
U Bern, Switzerland
BINP, Russia
CASE (SUNY/BNL), USA
CBPF, Brazil
CEA Grenoble, France
CEA Saclay, France
CIEMAT, Spain
CNRS, France
CNR-SPIN, Italy
Cockcroft Institute, UK
U Colima, Mexico
CSIC/IFIC, Spain
TU Darmstadt, Germany
TU Delft, Netherlands
DESY, Germany
TU Dresden, Germany
Duke U, USA
EPFL, Switzerland
GWNU, Korea
U Geneva, Switzerland
Goethe U Frankfurt, Germany
GSI, Germany
Hellenic Open U, Greece
HEPHY, Austria
U Houston, USA
IIT Kanpur, India
IFJ PAN Krakow, Poland
INFN, Italy
INP Minsk, Belarus
U Iowa, USA
IPM, Iran
UC Irvine, USA
Istanbul Aydin U., Turkey
JAI/Oxford, UK
JINR Dubna, Russia
FZ Jülich, Germany
KAIST, Korea
KEK, Japan
KIAS, Korea
King's College London, UK
KIT Karlsruhe, Germany
Korea U Sejong, Korea
MEPhI, Russia
MIT, USA
NBI, Denmark
Northern Illinois U., USA
NC PHEP Minsk, Belarus
U. Liverpool, UK
U Oxford, UK
PSI, Switzerland
U. Rostock, Germany
Sapienza/Roma, Italy
UC Santa Barbara, USA
U Silesia, Poland
TU Tampere, Finland
TOBB, Turkey
U Twente, Netherlands
TU Vienna, Austria
Wroclaw UT, Poland

Synchrotron radiation/beam screen

Synchrotron radiation load for protons @50 TeV:

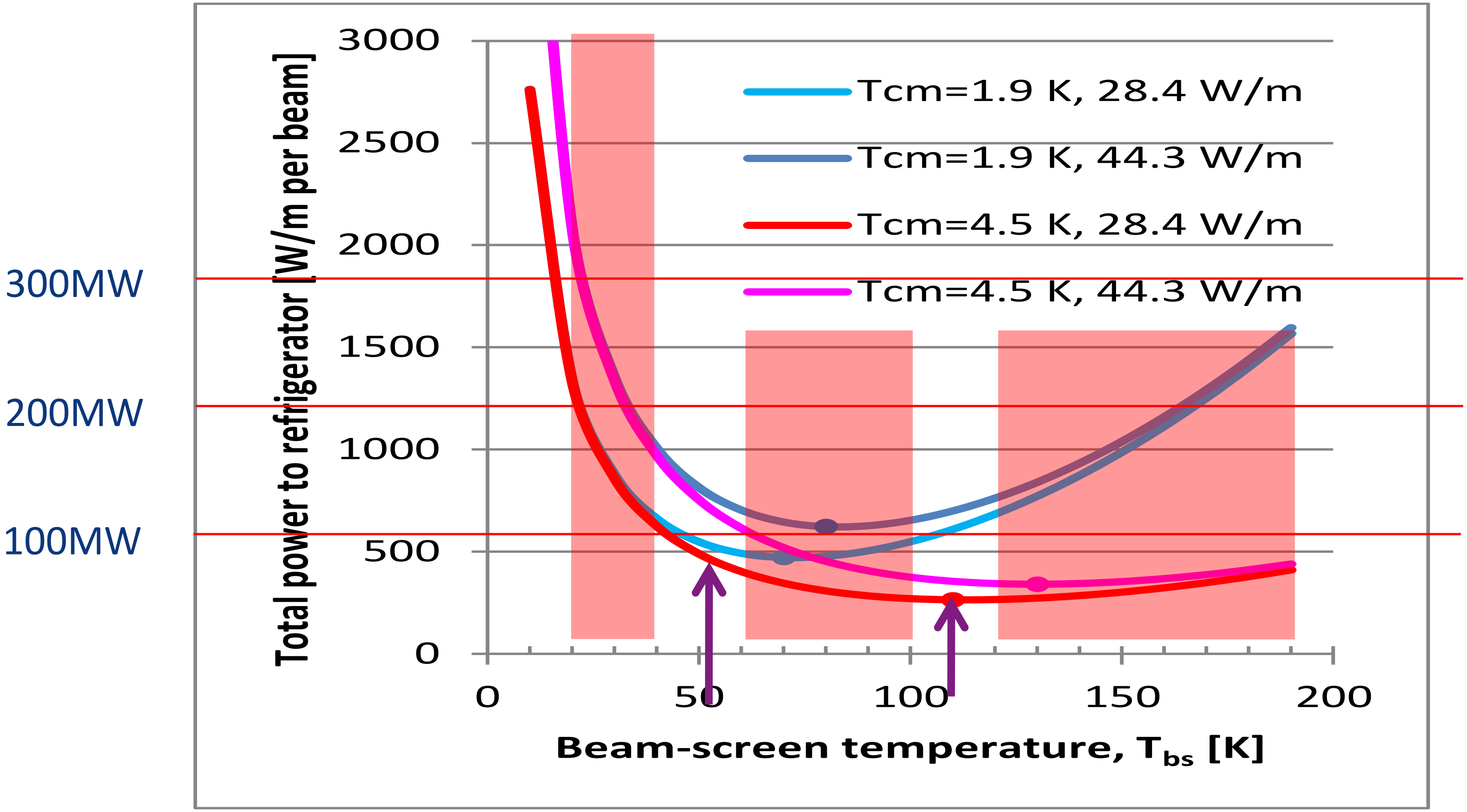
~ 25-45 W/m (@16 T)
(LHC <0.2W/m !!)
5 MW total in arcs





Cryo-power for cooling of SR heat

Overall optimization of cryo-power and vacuum
Termperature ranges: 40K-60K, 100K-120K



Impedance: image charges

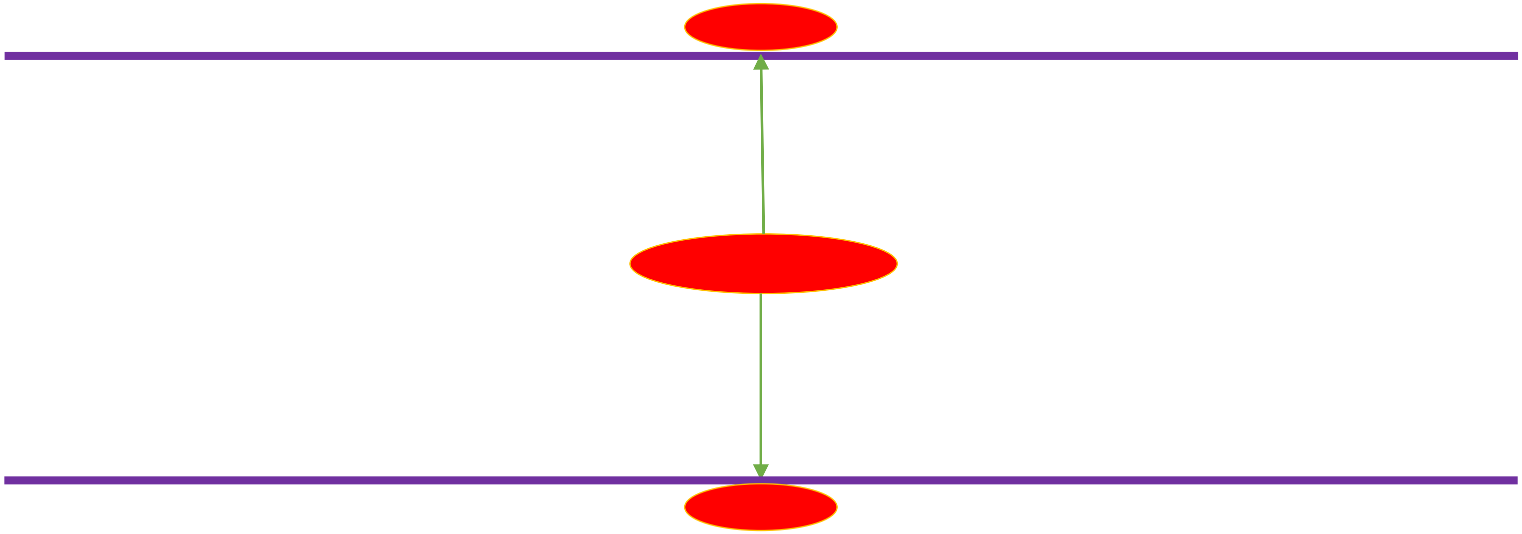


Image charges flow on the surface of the beampipe. Power dissipation from wake fields is $P_{loss} = nI_b^2 \operatorname{Re}(Z_{loss})$ where Z_{loss} is proportional to the convolution of the surface impedance Z_s over the beam power spectrum.

Wakefields have an effect on beam stability, in particular the transverse plane risetime of instabilities depends on the surface impedance of the material

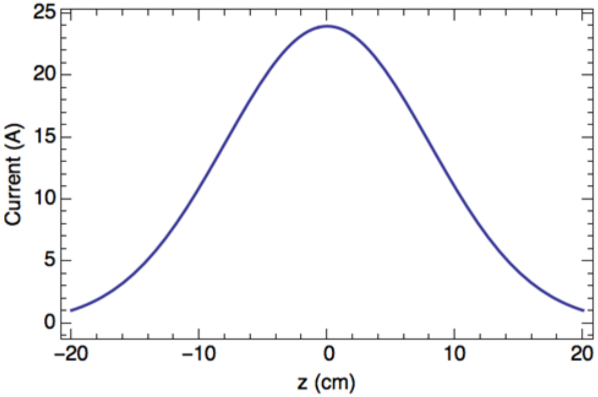
$$\frac{1}{\tau} \propto \frac{I_b M}{EL} \operatorname{Re}(Z_T^{eff}) \quad \text{with} \quad Z_T = \frac{2\pi R\, c}{\pi b^3\ \omega} Z_s$$

Copper at 50 K may not guarantee a large enough stability margin of the beam

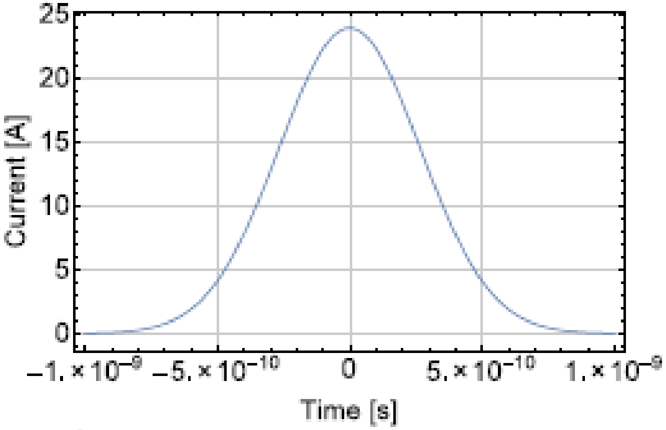
Frequency spectrum

The beam will be made of bunches of 10^{11} protons, 8 cm long

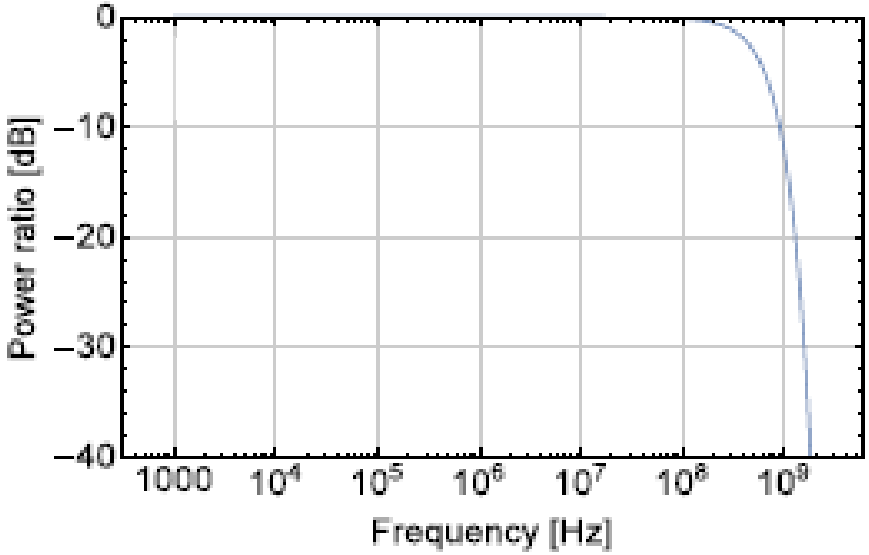
Beam instantaneous image current



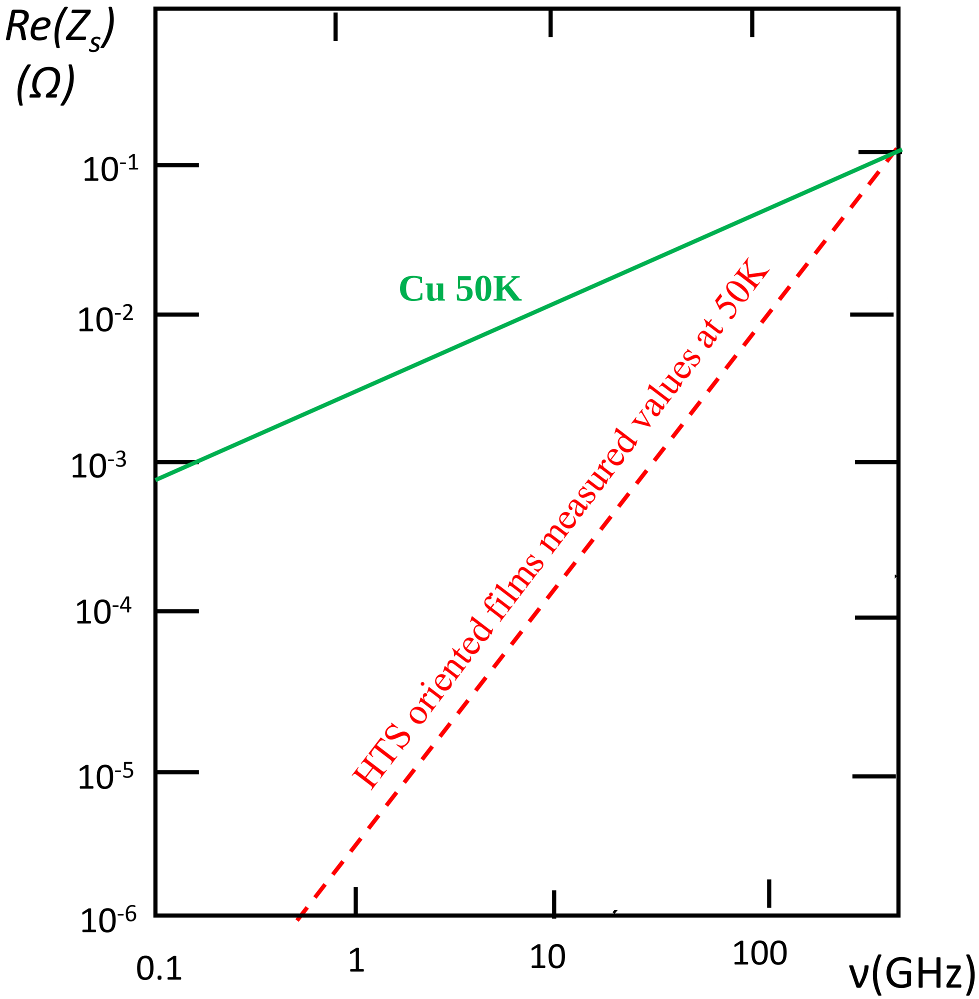
Time evolution at a fixed point



Frequency spectrum



High Temperature Superconductor at low fields present a Surface Impedance much lower than Copper at 50K!!!



$$P_{rf} \propto R_s I_{rf}^2$$

$$\frac{1}{\tau} \propto R_s$$

FCC calculations for a Cu beam screen
lead to $I_{rf} \cong 2.5 \cdot 10^8 A/m^2$ (peak value)
and to $P_{rf} \cong 1W/m^2$ (average value)

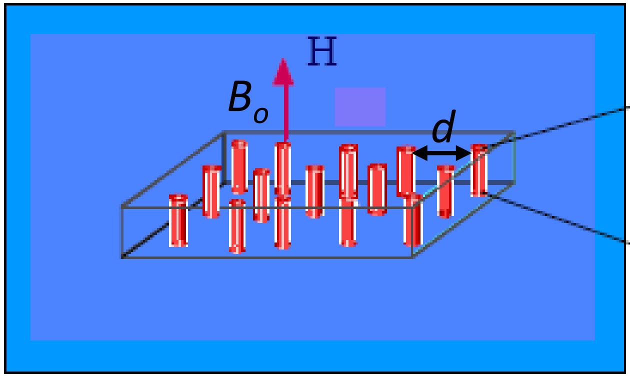
Superconductors : $\mathrm{Re}(Z_s) \propto \omega^2$
(normal metals : $\mathrm{Re}(Z_n) \propto \sqrt{\omega}$

But…the HTS film should operate in a 16T magnetic field and present $J_c >> 2.5 \cdot 10^8$ A/m^2 over a 100Km long narrow tube!

HTS Surface Impedance will still be well below copper in the assumed frequency, field, temperature and current regimes ???

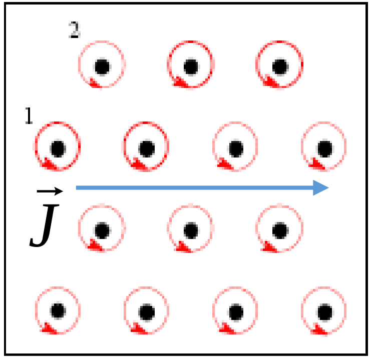
Superconductors in high fields : Abrikosov Vortices

Type II superconducting sample in a magnetic field



$$B_o = \frac{\phi_o}{d^2} = n\phi_o$$

$$B_{c2} = \frac{\phi_o}{\pi\xi^2}$$



$$\left|\vec{J}\times\vec{B}_o\right| \le \alpha_c$$

α_c = pinning force per unit volume

In d.c. operation the «critical current» $\vec{J}_c$ is reached when $\left|\vec{J}_c\times\vec{B}_o\right| = \alpha_c$

If , $\vec{J} \ge \vec{J}_c$ vortex «flux flow» regime is activated, the sample dissipates power with an equivalent resistivity :

$$\boxed{\rho_f = \rho_n \frac{B_o}{B_{c2}}}$$

R.f operation (for applied d.c. field $B_o >> B_{c1}$)

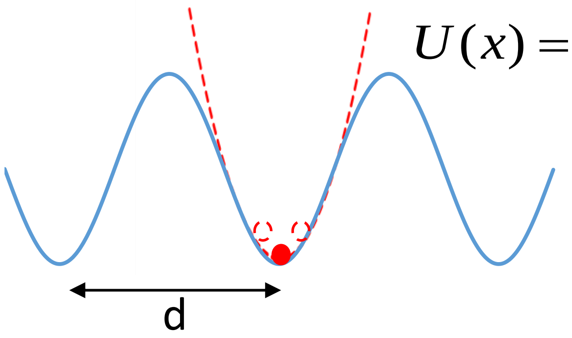
Gittleman and Rosenblum: - Phys Rev. Lett. 16, 734 (1966)
- J. Appl. Phys. 39, 2617(1968)

At $B_o >> B_{c1}$ repulsion forces between fluxon lines are higher in respect to the pinning forces. The fluxon array moves rigidly and feels a periodic force of the form :

$$f_p = -J_c \phi_o \sin\left(\frac{2\pi x}{d}\right)$$ (pinning force per unit lenght)

$$U(x) = \frac{1}{2} k x^2$$

$$(J_{rf} << J_c)$$



$$\boxed{f_p = -kx}$$ $$(k = \frac{2\pi}{d} J_c \phi_o)$$

Equation of motion for the fluxon lattice

$$\boxed{m\ddot{x} + \eta\dot{x} + kx = J_{rf}\phi_o}$$

m : fluxon mass per unit lenght

$\eta = \dfrac{\phi_o B_{c2}}{\rho_n}$:fluxon viscosity per unit lenght

$$(m \cong 0) \qquad J_{rf} = J_{rfo}e^{i\omega t},\ \dot{x} = v = v_o e^{i\omega t}$$

$$\eta v_o\left(1 - i\frac{\omega_o}{\omega}\right) = J_{rfo}\phi_o \quad \left(\omega_o = \frac{k}{\eta}\right)$$

$$\boxed{v_o = \frac{J_{rfo}\phi_o}{\eta}\left(\frac{\omega^2}{\omega^2 + \omega_o^2} + i\frac{\omega\omega_o}{\omega^2 + \omega_o^2}\right)}$$

S. Calatroni, R.Vaglio : IEEE Trans. Superconductivity

$$\vec{J}_{rf} = (\sigma_1 - i\sigma_2)(\vec{E}_{rf} - \vec{v}\times\vec{B}_o)$$

($\vec{v}\times\vec{B}_o$ is the «Lorentz field»)

$$\rho_{eff} = \frac{\vec{E}_{rf}}{\vec{J}_{rf}} = \frac{1}{\sigma_1 - i\sigma_2} + \frac{\vec{v}\times\vec{B}_o}{\vec{J}_{rf}} = \rho_s + \rho_f$$

ρ_{eff} : resistivity of a superconductor in the presence of an oscillating fluxon array

$$\boxed{\rho_f = \rho_n \frac{B_o}{B_{c2}}[\alpha(\omega) + i\beta(\omega)]}$$

$$\boxed{\alpha(\omega) = \frac{\omega^2}{\omega^2 + \omega_o^2}\ ;\ \beta(\omega) = \frac{\omega\omega_o}{\omega^2 + \omega_o^2}}$$

$$\omega >> \omega_o\ , \alpha = 1\ ,\ \beta = 0 \Rightarrow \boxed{\rho_f = \rho_n \frac{B_o}{B_{c2}}} \qquad \omega_o = \frac{k}{\eta}$$

«depinning frequency»

⇧

(ρ_f is the same as that of a superconductor in flux-flow regime)

$$Z_{sf} = (1+i)\sqrt{\frac{\mu_0\omega}{2}\rho_{eff}} \quad , \quad \rho_f = \rho_n \frac{B_o}{B_{c2}}\left[\alpha(\omega) + i\beta(\omega)\right] \quad , \quad \alpha(\omega) = \frac{\omega^2}{\omega^2 + \omega_o^2} \; ; \; \beta(\omega) = \frac{\omega\omega_o}{\omega^2 + \omega_o^2}$$

$$(R_{sf} = \mathrm{Re}\left[Z_{sf}\right], R_n = \sqrt{\frac{\mu_o\omega}{2}\rho_n})$$

$$\boxed{R_{sf} = R_n\sqrt{\sqrt{A^2 + B^2} - B}}$$

$$\boxed{\begin{aligned} A &= \frac{\sigma_1/\sigma_n}{\left(\sigma_2/\sigma_n\right)^2} + \frac{B_o}{B_{c2}}\alpha(\omega) \\ B &= \frac{1}{\sigma_2/\sigma_n} + \frac{B_o}{B_{c2}}\beta(\omega) \end{aligned}}$$

General expression for the surface resistance of a superconductor in presence of a rigid vortex array, with the rf current perpendicular to the magnetic field

Surface Impedance in the Large Field, Low Frequency limit

$$\boxed{\omega_o = \frac{k}{\eta} = \frac{2\pi J_c \rho_n}{dB_{c2}} = 2\pi \frac{\sqrt{B_o}\, J_c \rho_n}{\sqrt{\phi_o}\, B_{c2}}}$$

FROM THE LITERATURE, FOR HIGH QUALITY HTS:

$$\boxed{f_o = \frac{\omega_o}{2\pi} \cong 5 - 20GHz}$$

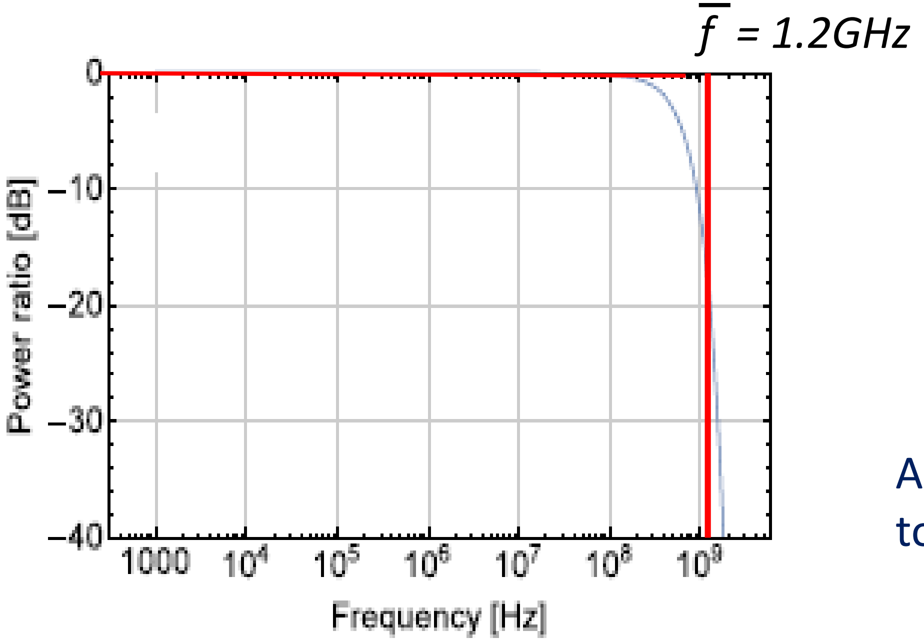
(much lower values are generally found for LTS)

$$\omega \leq \omega_o \Rightarrow \qquad A \cong \frac{B_o}{B_{c2}} \frac{\omega^2}{\omega_o^2} \quad ; \quad B \cong \frac{B_o}{B_{c2}} \frac{\omega}{\omega_o}$$

$$\boxed{R_{sf}(\omega, T) = \frac{R_n}{\sqrt{2}} \sqrt{\frac{B_o}{B_{c2}}} \left(\frac{\omega}{\omega_0} \right)^{3/2}}$$

Average value of R_{sf} *over the FCC frequency spectrum*

$$\bar{R}_{sf}(T) = \int_0^\infty S(f) R_{sf}(\omega,T) d\omega$$



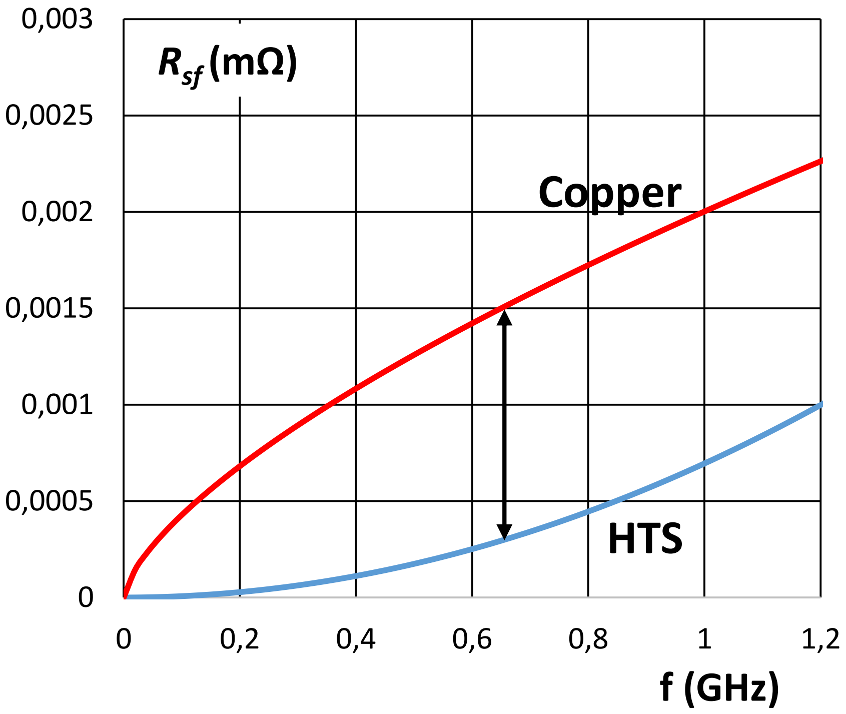
Approximating the real spectrum to a step function, we get :

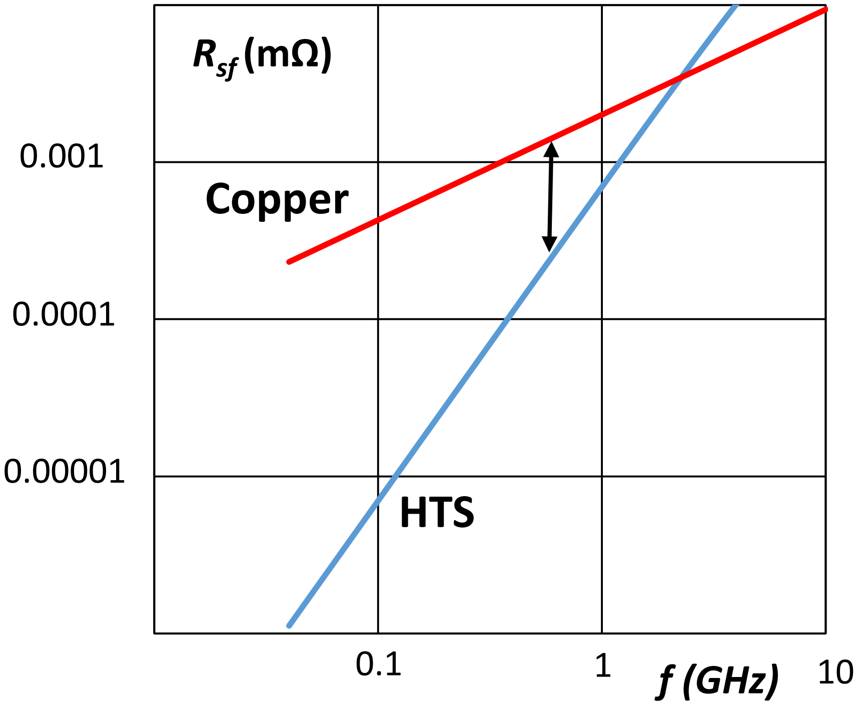
$$\bar{R}_{sf}(T) = R_{sf}(\omega^*,T) \;\; ; \;\; \frac{\omega^*}{2\pi} = 0.65 GHz$$

Calculations performed using high quality HTS (YBCO) parameters show a large R_{sf} reduction in respect to Copper

T_c =92K	T=50K	B_o=16T	J_c (50,16)=7.5 $10^9/m^2$	B_{c2} (50)=40T	ρ_n =60μΩ cm

f_o =10Ghz

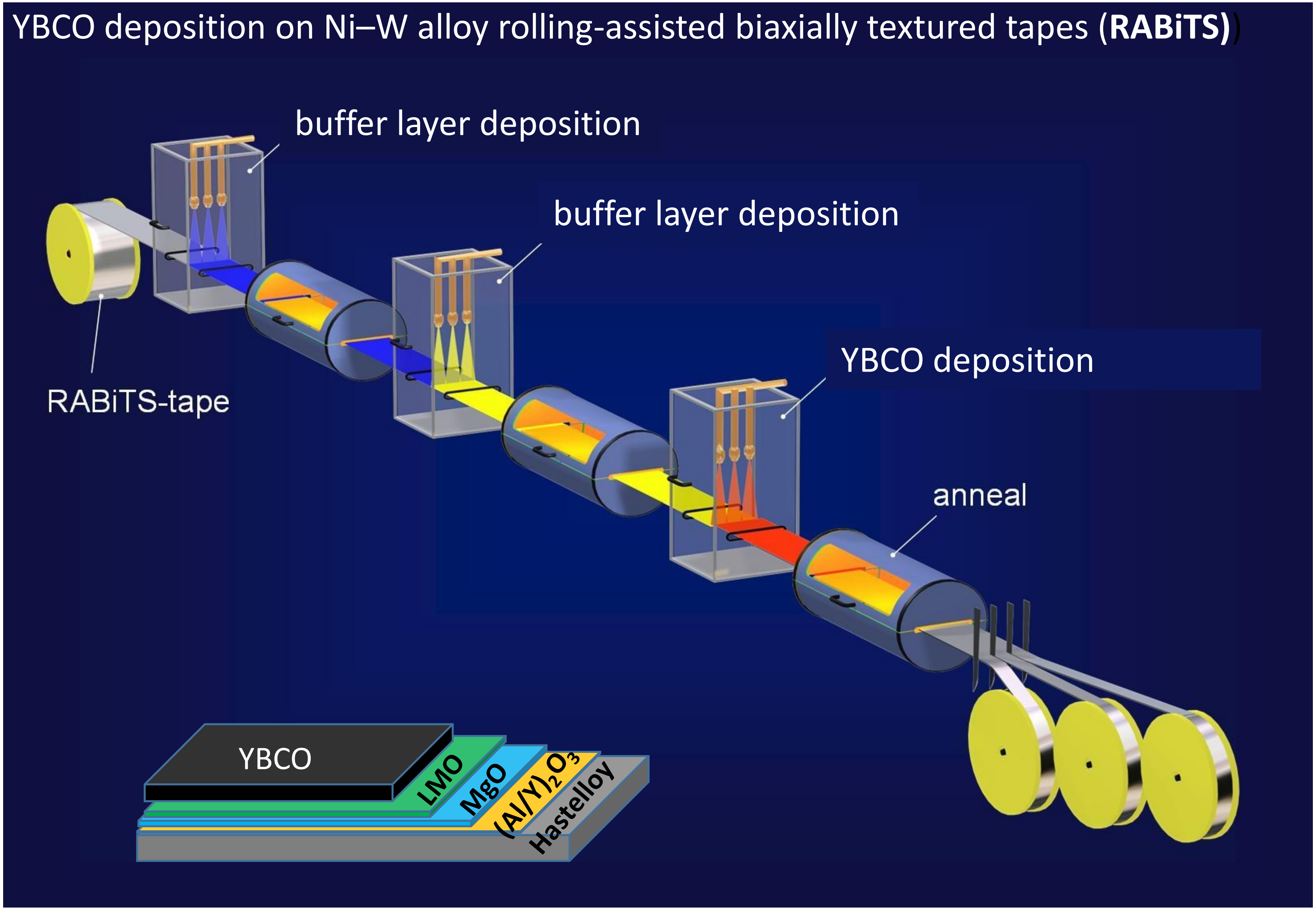




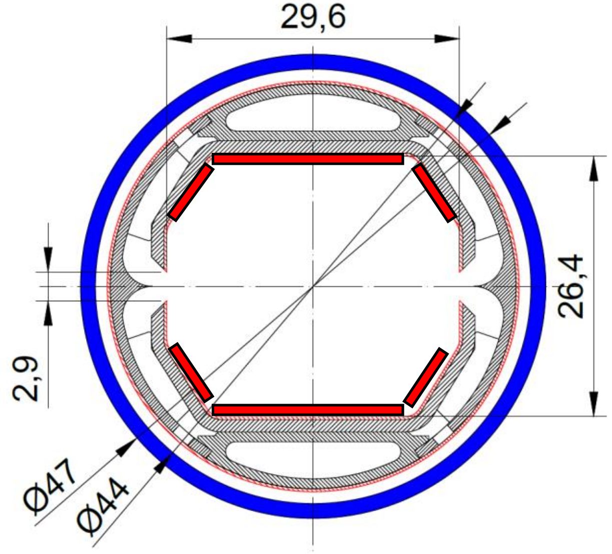
Possible HTS materials:

HTS	T_c	B_{c2}(50K)	Anisotropy	Substrate requirements
Y-123	90 K	40T	~ 7	High quality, biaxial texture
~~Bi-2212~~	~~85 K~~	~~70T~~ ~~(very low B_{irr})~~	~~>20~~	~~No special texture requirements~~
Tl-1223	125 K	80T	~ 8	No special texture requirements

Solution 1: YBCO tapes glued on the beam screen

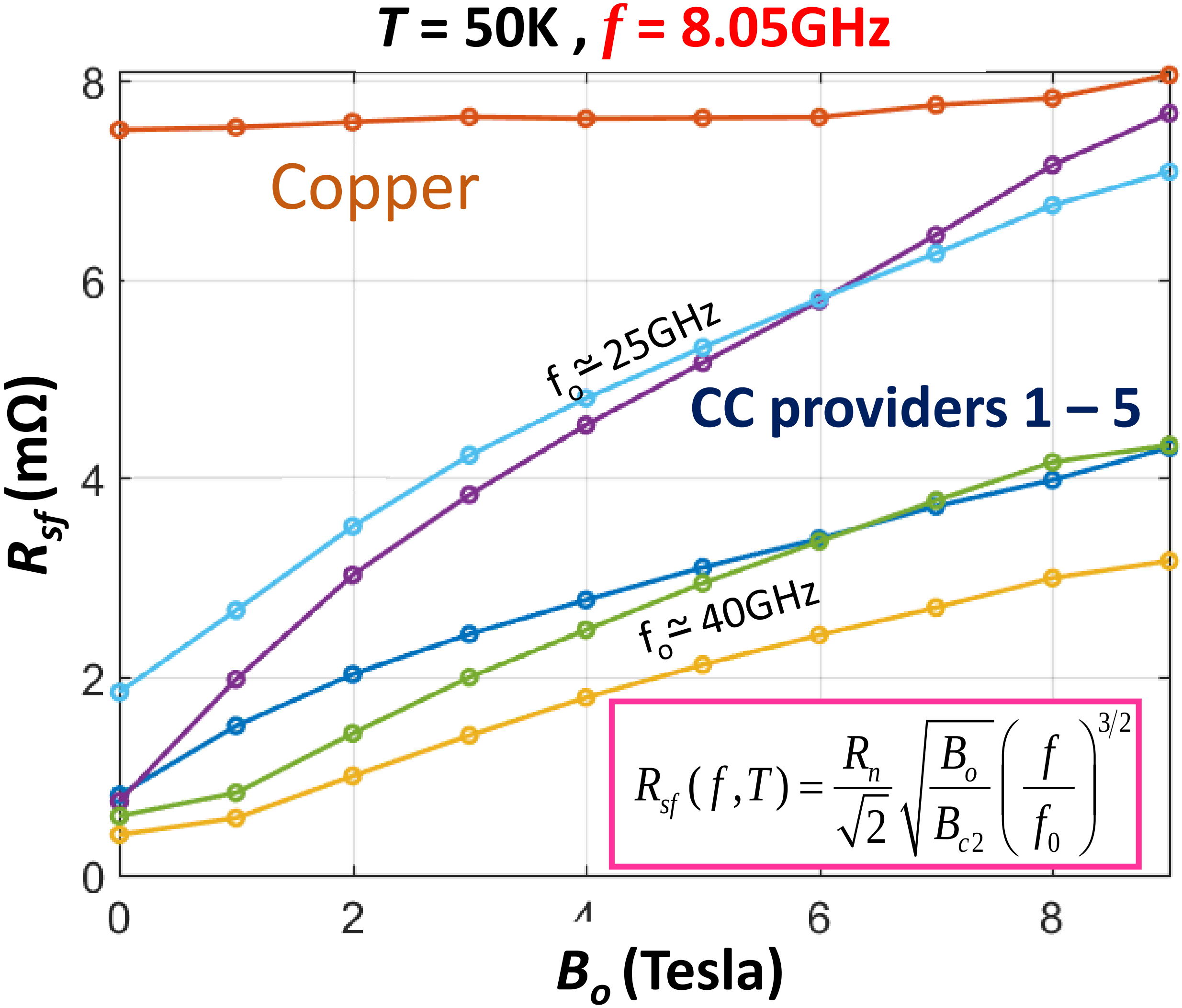


Presently produced by American Superconductor, BRUKER, Fujikura, SuNAM, SuperOx, SuperPower Inc. A Furukawa Company, STI, THEVA, Shanghai, 上海超导, OXOLUTIA, deutsche nanoschicht, MetOx



Segmentation should also reduce potential problems due to persistent currents generated during field ramping

Preliminary measurements performed on small samples from 5 different providers, show reasonable agreement with the theory and extremely encouraging results!

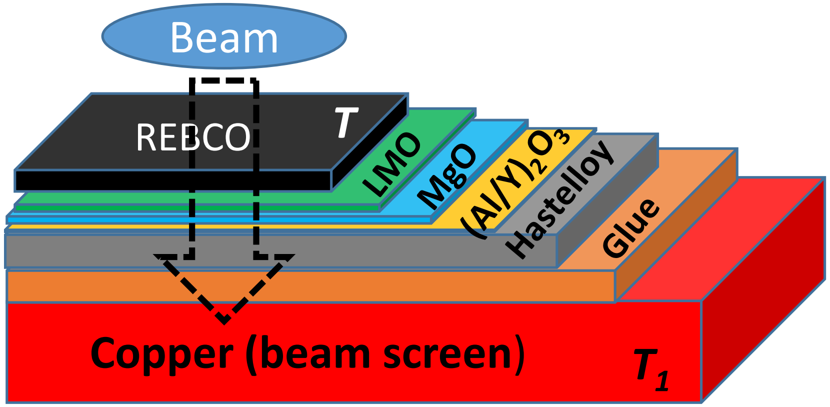


$$R_{sf}(f,T) = \frac{R_n}{\sqrt{2}}\sqrt{\frac{B_o}{B_{c2}}\left(\frac{f}{f_0}\right)^{3/2}}$$

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

ALBA

A possible problem for YBCO tapes : thermal runaway



One dimensional thermal model : $R_T = \frac{d_1}{k_1} + \frac{d_2}{k_2} + \frac{d_3}{k_3} + \frac{d_4}{k_4} + \frac{d_5}{k_5}$ + Kapitza interface terms

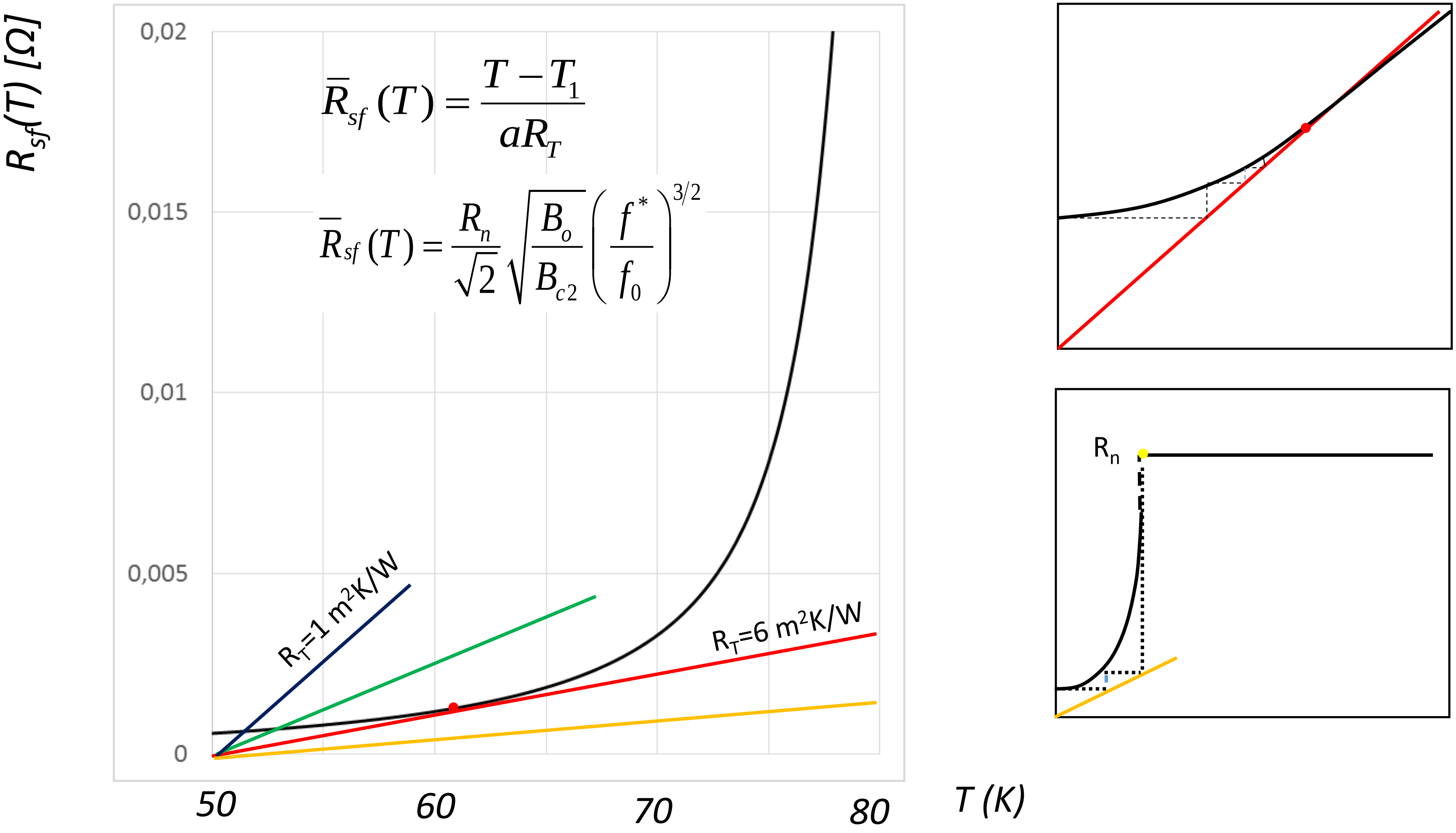
$$\begin{cases} T = T_1 + \Delta T \\ \Delta T = R_T P_{rf}(T) \\ P_{rf}(T) = a\bar{R}_{sf}(T) \end{cases}$$

P_{rf} (T) is the average power per unit surface disspated by the beam.
CERN-FCC calculations estimate $P_{rf} \sim 1 W/m^2$ for copper, since $R_{nCu} = 1 m\Omega$ (at ~~0~~.65GHz), $a = 10^{-3}\ W/\Omega m^2$

$$\boxed{T = T_1 + aR_T\bar{R}_{sf}(T)}$$

An increase in *T* due to the *rf* power increases the superconductor surface resistance $R_{sf}(T)$ that produces a further increase in *T.* The process leads to a surface equilibrium temperature $T > T_1$, or can lead to a thermal runaway !

Thermal runaway : graphical solution



$$\bar{R}_{sf}(T)=\frac{T-T_1}{aR_T}$$

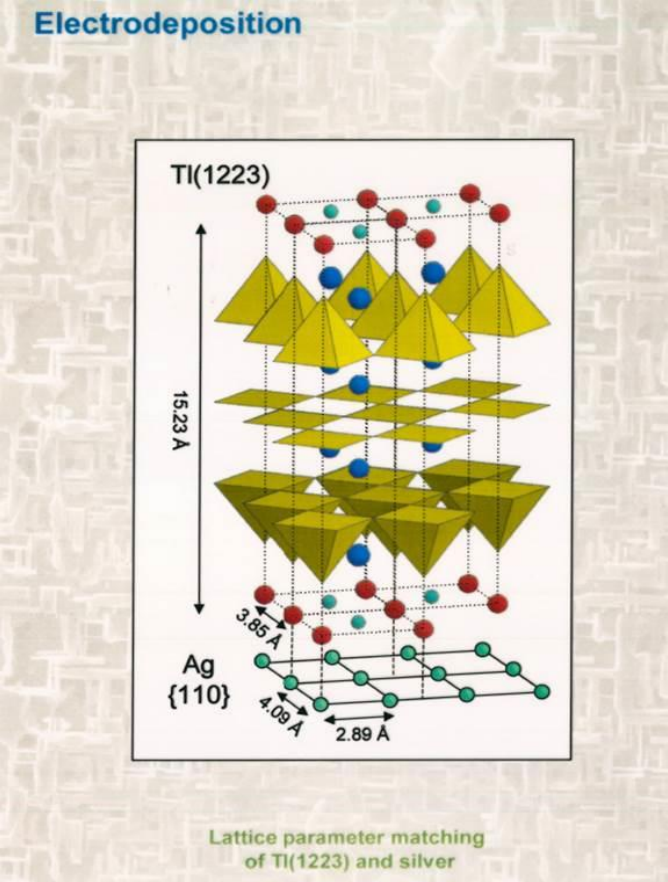
$$\bar{R}_{sf}(T)=\frac{R_n}{\sqrt{2}}\sqrt{\frac{B_o}{B_{c2}}}\left(\frac{f^*}{f_0}\right)^{3/2}$$

Solution 2: Tl 1223 directly grown on the Copper beam screen (with a Silver buffer layer)

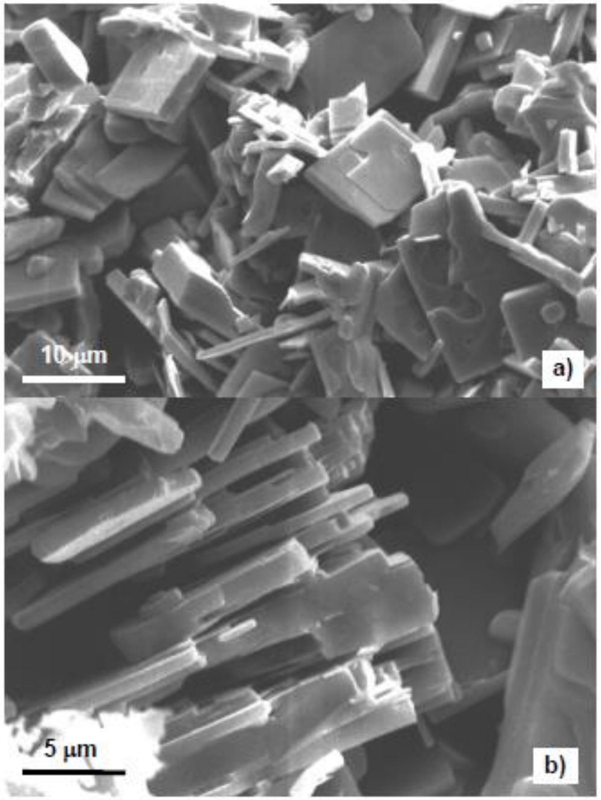
IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 9, NO. 2, JUNE 1999 1783

Preparation of Highly Textured Tl(1223)/Ag Superconducting Tapes

Emilio Bellingeri, Roman E. Gladyshevskii, Frank Marti and René Flükiger
Département de Physique de la Matière Condensée, Université de Genève, 24 Quai Ernest Ansermet, CH-1211 Genève 4, Switzerland



Lattice parameter matching of Tl(1223) and silver

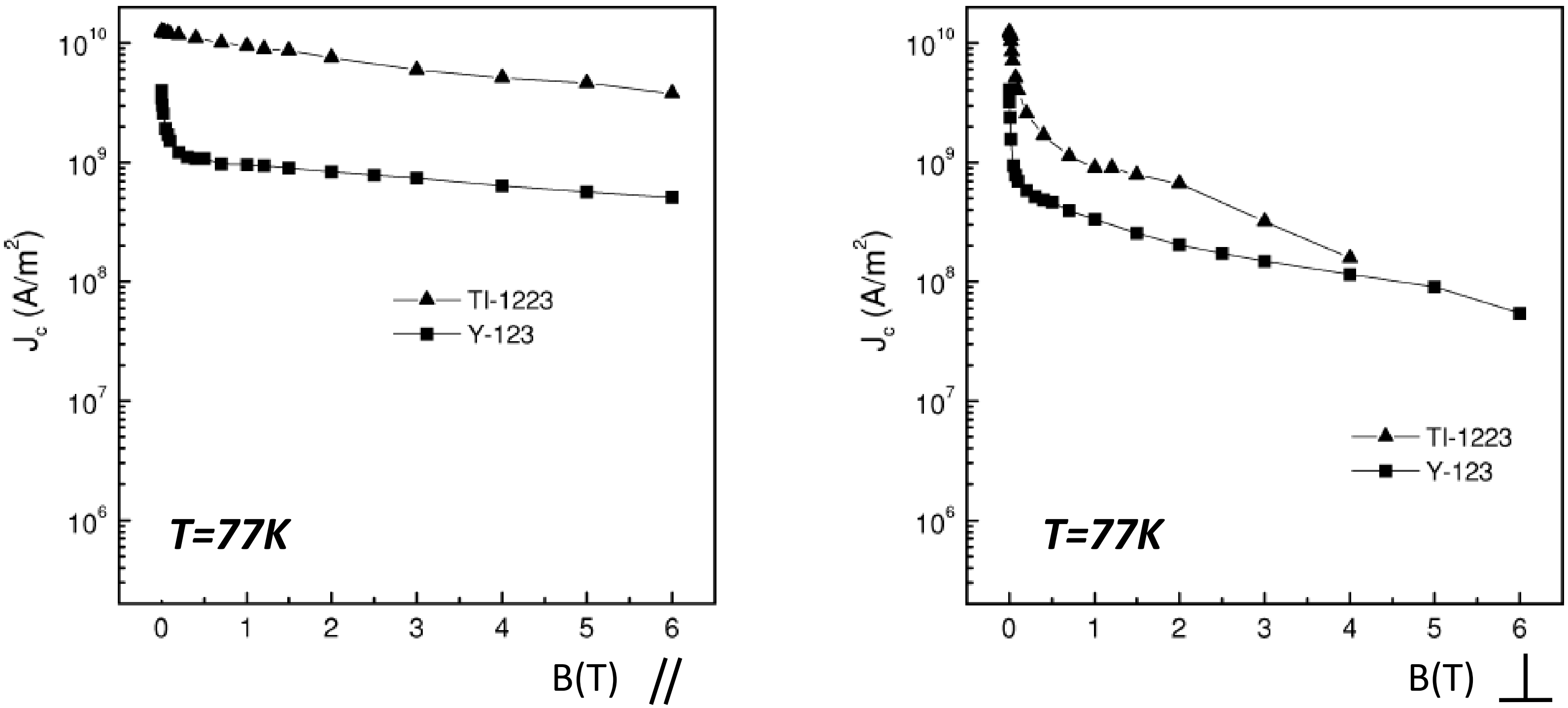


SEM images of a Tl,Pb,Bi(1223) powder melted at 1020°C (a), 1080°C (b) (0.5 h) after a second reaction at 930°C (3 h).

Comparison: Y-123 and Tl-1223 Critical Currents

■ **Y-123 : coated conductor, PLD on IBAD-YSZ buffer layer**

▲ **Tl-1223 : film by screen print on a monocrystalline substrate**

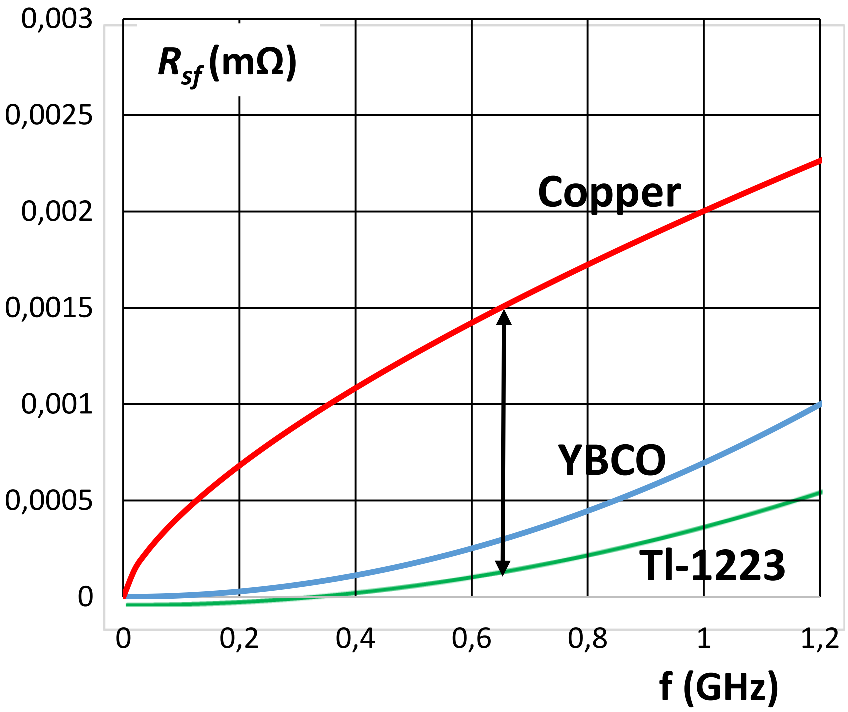


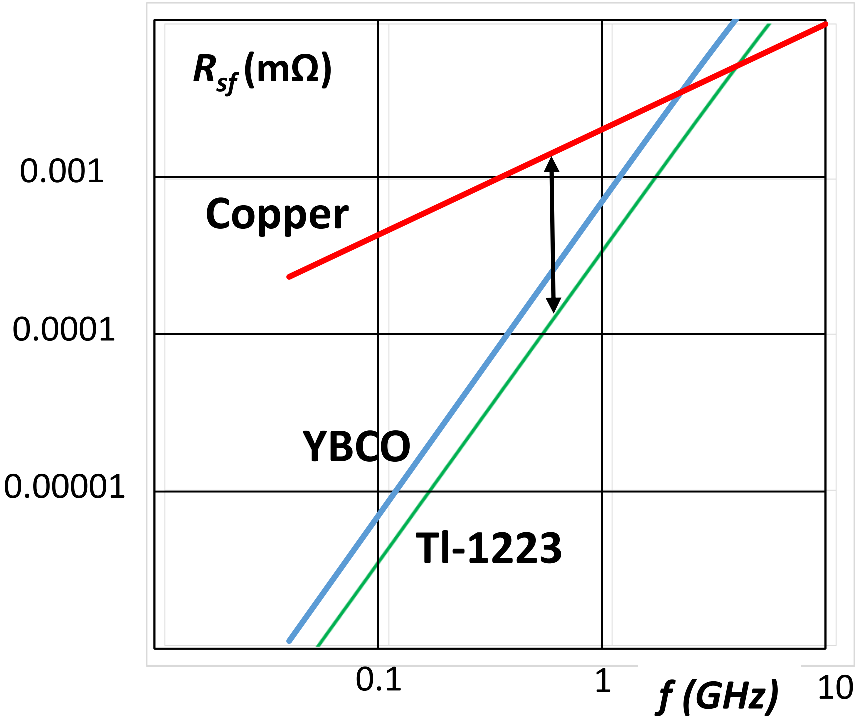
Susanne Tönies, Harald W. Weber, Gerhard Gritzner, Oliver Heiml, and Mario H. Eder,
IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 13, NO. 2, JUNE 2003
(TU-WIEN)

Calculations performed using high quality Tl-i223 parameters

T_c =125K | T=50K | B_o=16T | J_c (50,16)=10^{10} A/m^2 | B_{c2} (50)=80T | ρ_n =80µΩ cm

f_o =14Ghz





	YBCO	**Tl1223**
PROs	• Industrial developement of high quality tapes	• Very high Tc • High Jc • Very high B_{c2} • Very tolerant for out stoichiometry
CONs	• Very expensive and complex preparation on large scale • Possible thermal problems	 • Weak links effect on Jc may not be overcome at the desired level

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CERN/FC/0022/RA
Original: English
4 December 2015

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Action to be taken		*Voting Procedure*
FOR APPR L	**FINANCE COMMITTEE** 354th Meeting **16 December 2015**	Simple Majority of the Member States represented and voting

Proposal to negotiate two collaboration agreements concerning the development of High-Temperature Superconducting coatings for the Future Circular Collider (FCC) study

This document concerns the negotiation of two collaboration agreements concerning the development of High-Temperature Superconducting (HTS) thallium-based impedance mitigation coatings for the FCC.

The Finance Committee is invited to agree to the negotiation of two three-year collaboration agreements with:

- CONSIGLIO NAZIONALE DELLE RICERCHE – INSTITUTE FOR SUPERCONDUCTORS, OXIDES AND OTHER INNOVATIVE MATERIALS AND DEVICES (CNR – SPIN) for development activities concerning thallium-based HTS material production for a total amount not exceeding XXXXXX euro (XXXXXX Swiss francs), not subject to revision.
- TECHNISCHE UNIVERSITÄT WIEN (TU WIEN) for development activities concerning the characterisation of the current transport, microstructural and magnetic properties of thallium-based HTS materials for a total amount not exceeding XXXXXX euro (XXXXXX Swiss francs), not subject to revision.

New Labs for safe Tl manipulation have been set up at SPIN-Ge

Summarizing :

- There is a very strong motivation for HTS coatings for FCC beam screens, with potential for drastically reducing beam impedance.

- Theoretical calculations based on standard models show a potential significant advantage in using HTS in place of copper

- No experimental data are available in the FCC regime, however the theoretical model well describes experiments performed in close regimes.

- The HTS film has to be set/grown on a 100Km long, 3cm diameter tube.
  Two solutions have been considered:
  - YBCO tapes (industrial)
  - Tl-1223 electro-deposited on Ag (development at CNR-SPIN under way)

Work is in progress to test samples in the FCC regime and to identify the best technical solution