Pushing the boundaries of UHF NMR Magnet Technology

May 17th, 2012

Dr. G. Roth, Bruker BioSpin, Karlsruhe

Bruker Corporation

Bruker Scientific Instruments (BSI)

- **Bruker MAT** –X-ray, optical emission spectroscopy, atomic force microscopy and stylus and optical metrology instrumentation
- **Bruker BioSpin** – Magnetic resonance spectroscopy and imaging (NMR, MRI, EPR)
- **Bruker Daltonics** - Mass spectrometry, gas chromatography and CBRN detection
- **Bruker Optics** – Optical Vibrational Spectroscopy (FT-IR , NIR & Raman)

Bruker Energy & Supercon Technologies (BEST)

- Superconducting magnets, high and low temperature superconductor wire development and manufacturing

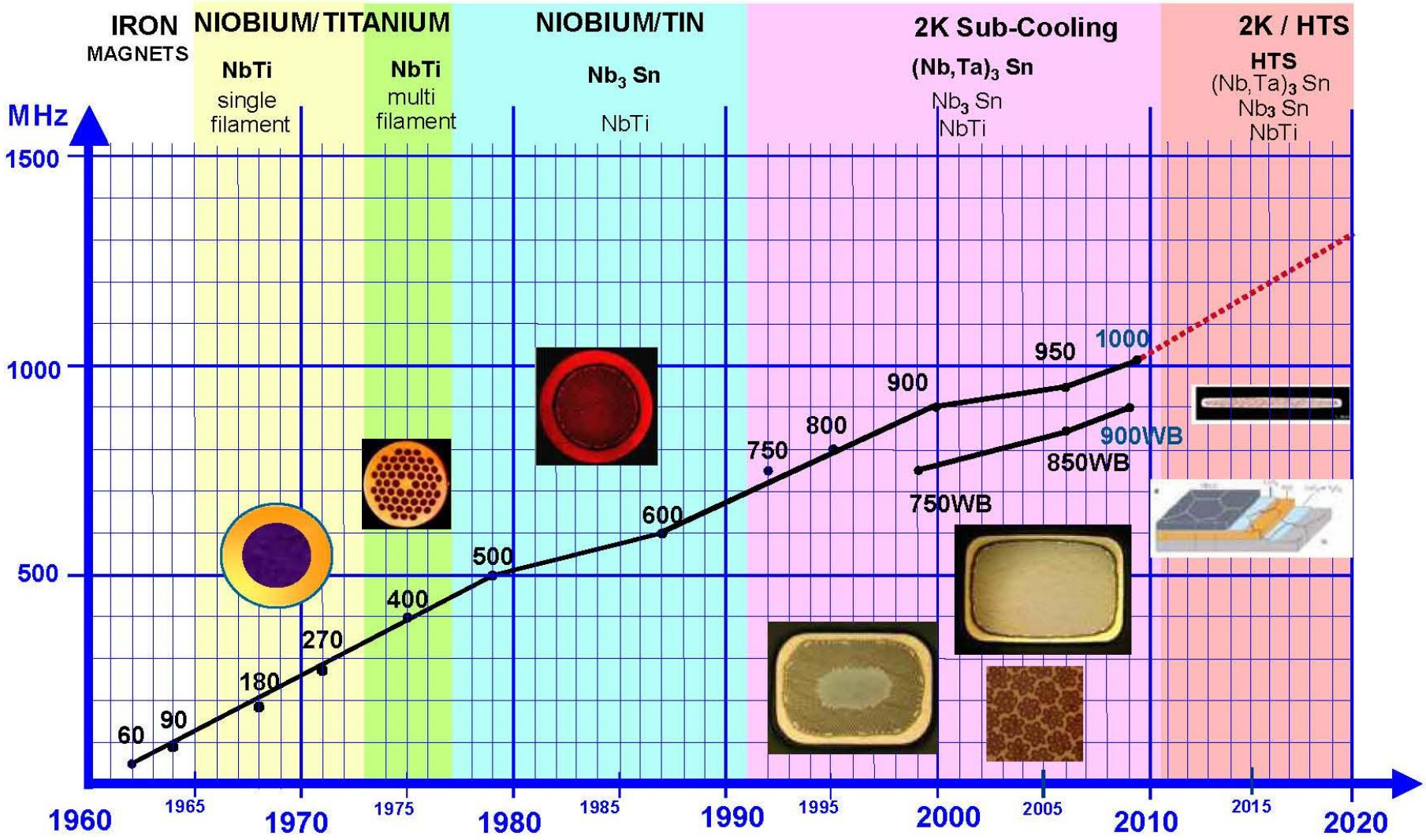
Bruker Magnet Production Sites

300 – 750 MHz NMR Magnet
production Fällanden, Switzerland

Horizontal bore MRI and FTMS
Magnet Site Wissembourg , France

750 – 1000 MHz NMR Magnet
Production Karlsruhe, Germany

High Field NMR Milestones



Magnets having full NMR specifications in persistent mode

NMR Product Line

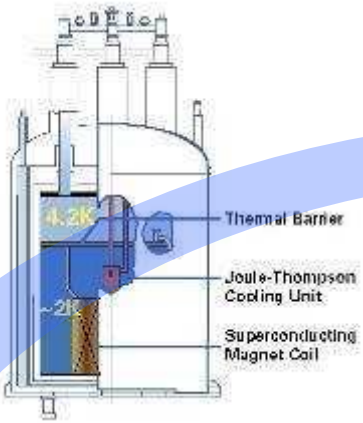
NMR enables the non-destructive and quantitative investigation of molecular structure, interaction, kinetics and the composition of mixtures of biological or synthetic solutions or composites.

Ultra-High Field

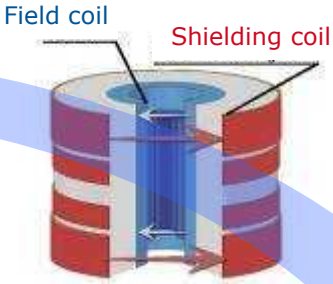
Low Field

High Field

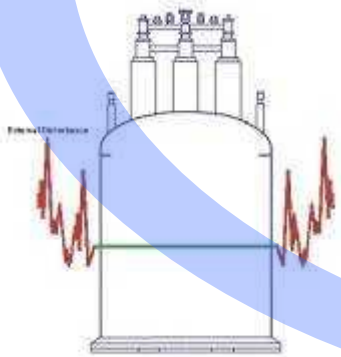
Key Technologies



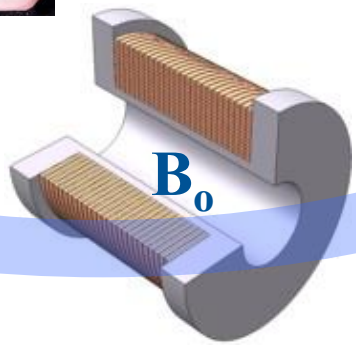
2K cooling



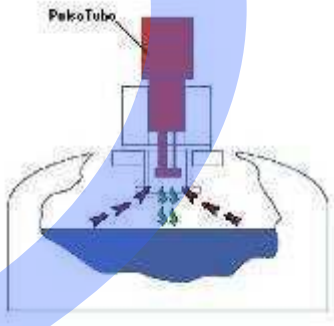
Active shielding



Artifact suppression



Coil technology



Active cooling

Todays most advanced Ultra High Field Magnets

950 MHz HR-NMR

15 T FTMS Magnet

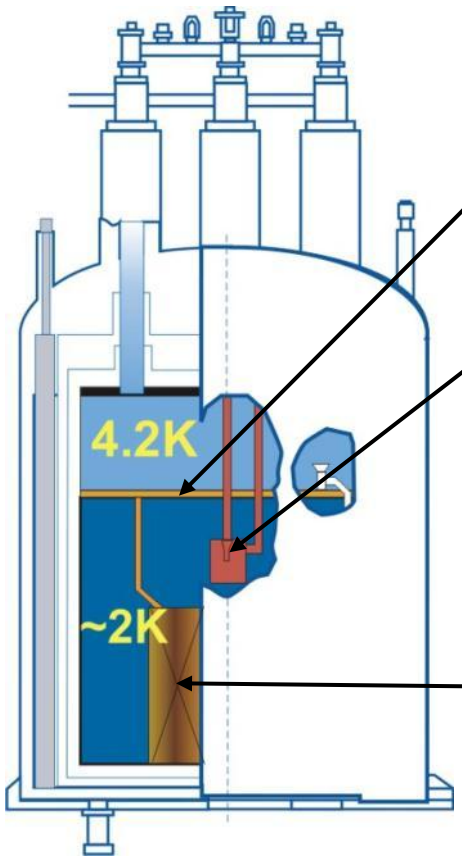
Photo courtesy of Korea Basic Science Institute (KBSI)

Most compact 850 MHz

UltraStabilized™ Sub-cooling Technology

- Long term stable magnet
- Highest field strengths
- Increased magnet stability
- Higher safety margins
- Lowest drift rates
- Easy helium refills

- Patented technology
- Pioneered by Bruker
- Proven track record
- Over 180 systems installed

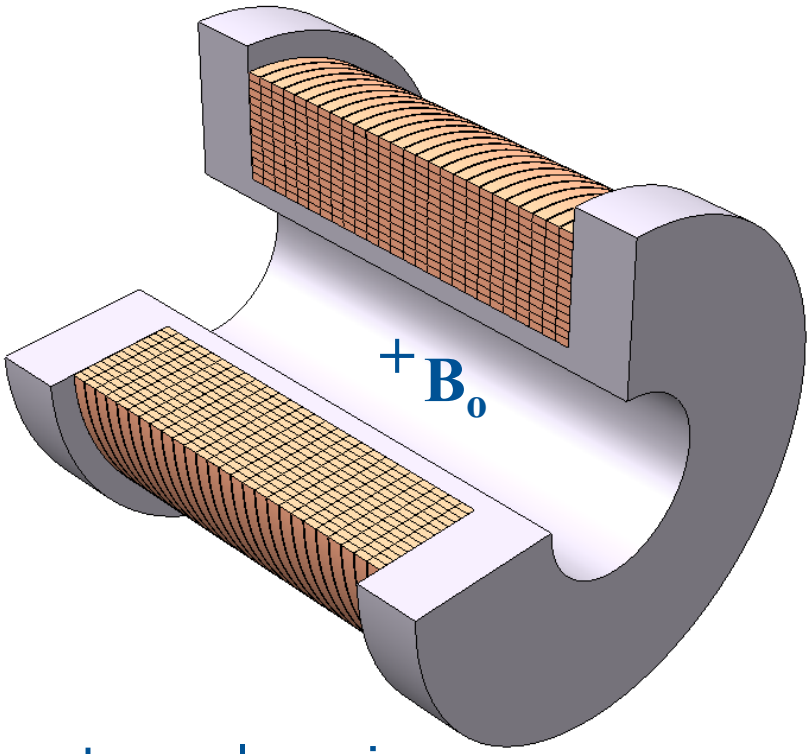


UltraStabilized™ technology delivering unique performance, stability and safety

Introduction of high current designs and rectangular wire technology

High current design

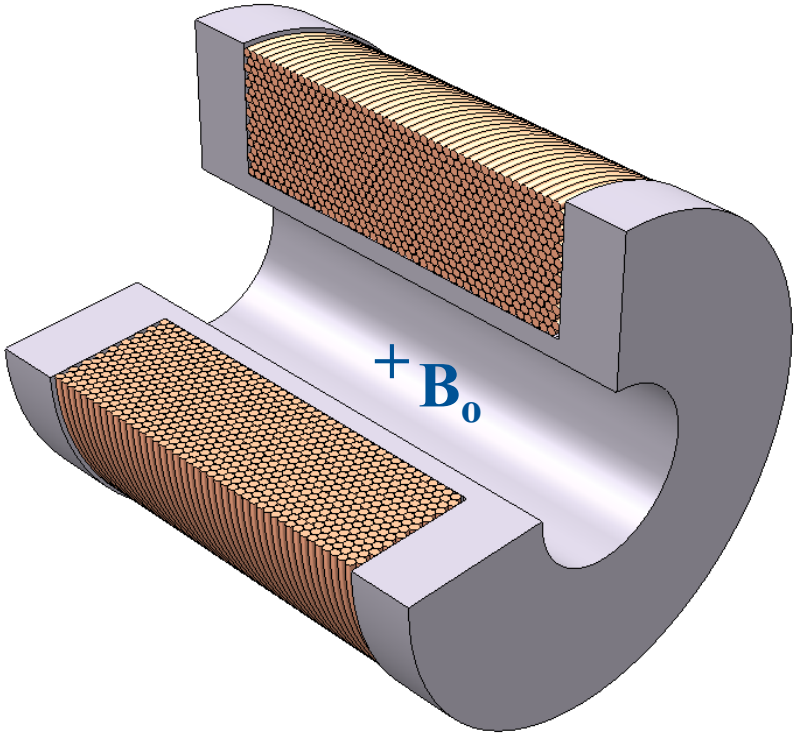
$$I_M = 2 \cdot I_o$$



- rectangular wire
- conductor area = 4 mm²

Low current design

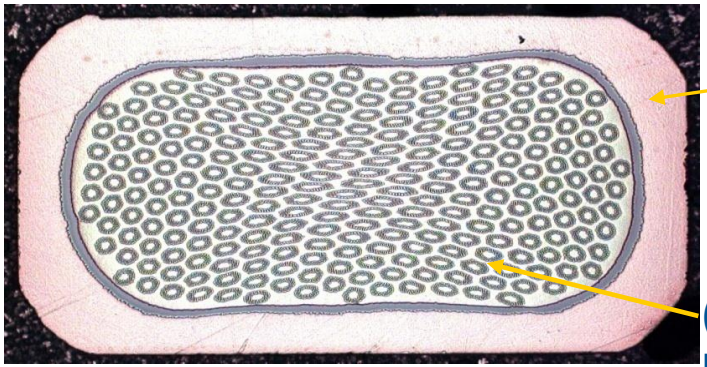
$$I_M = I_o$$



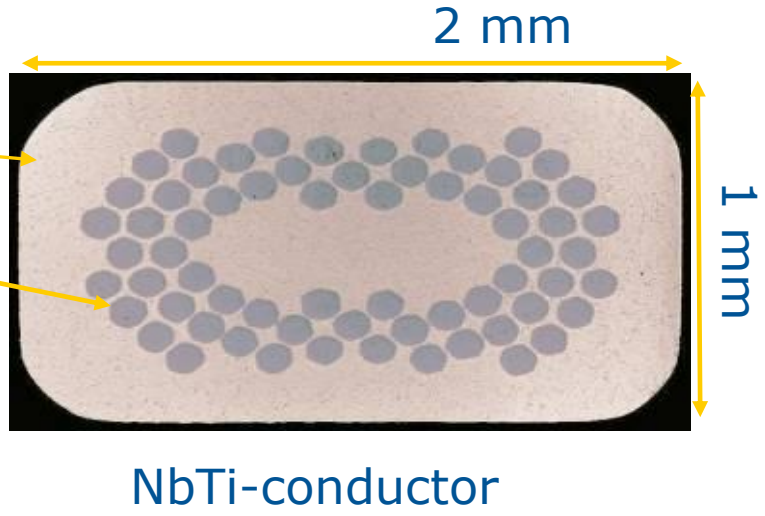
- round wire
- conductor area = 2 mm²

Advantages

- Higher current results in a larger wire cross sections
- suitable for rectangular wire
- Better winding chamber filling factor
- Less insulation material in winding chamber
- Better control of forces
- Enables highest fields

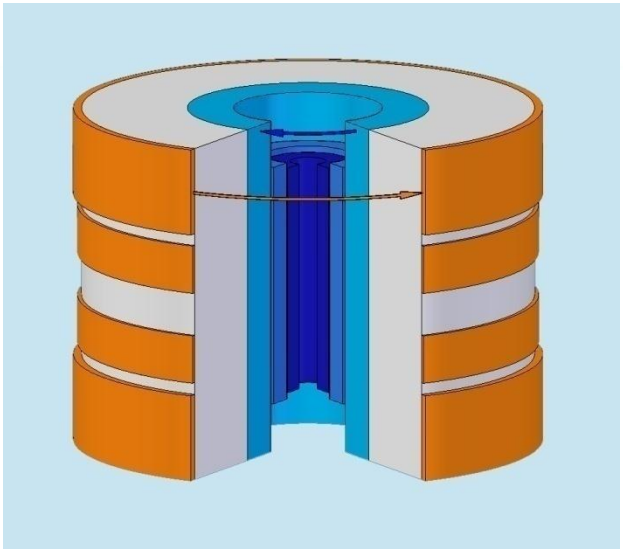


$(NbTaTi)_3Sn$-conductor



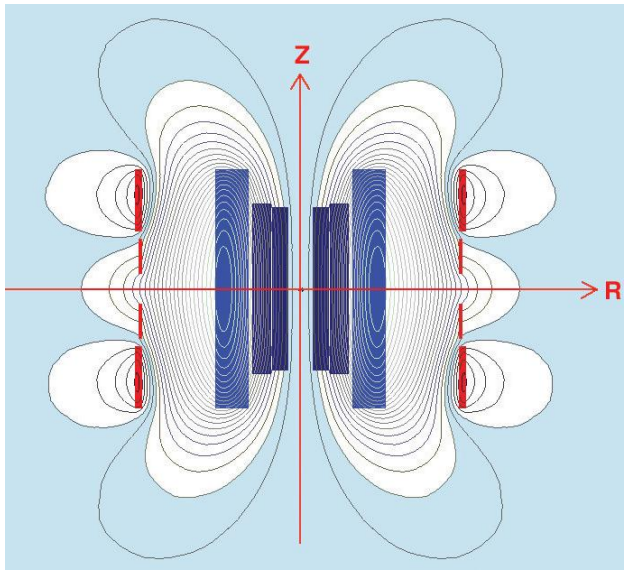
NbTi-conductor

UltraShield Technology



Inner sections (Blue): main field coils

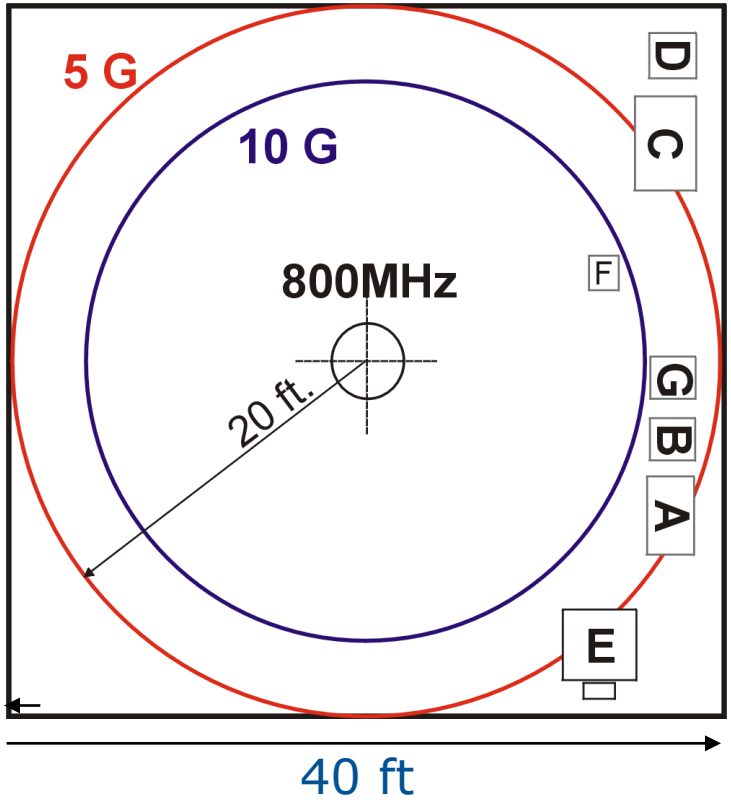
Outer sections (Red): shielding coils



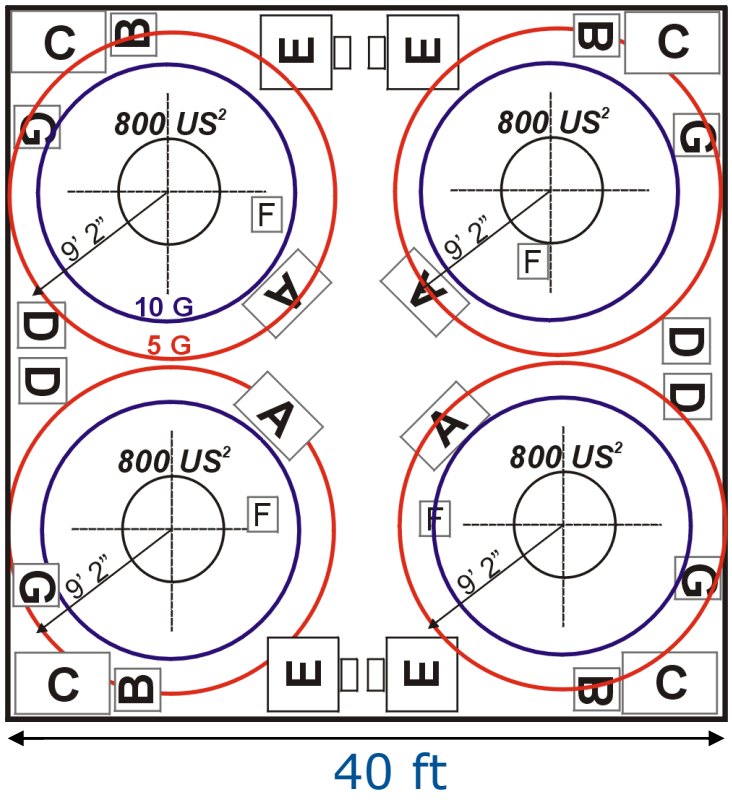
- Significantly smaller stray fields
- improved screening against external field perturbations

Minimizing required Lab Space

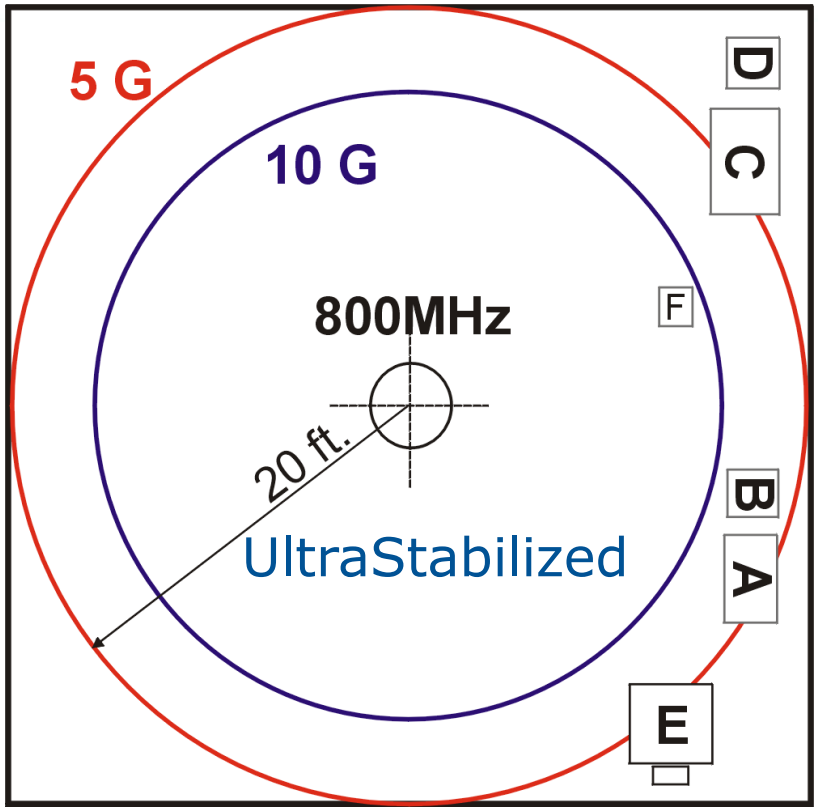
800 MHz UltraStabilized

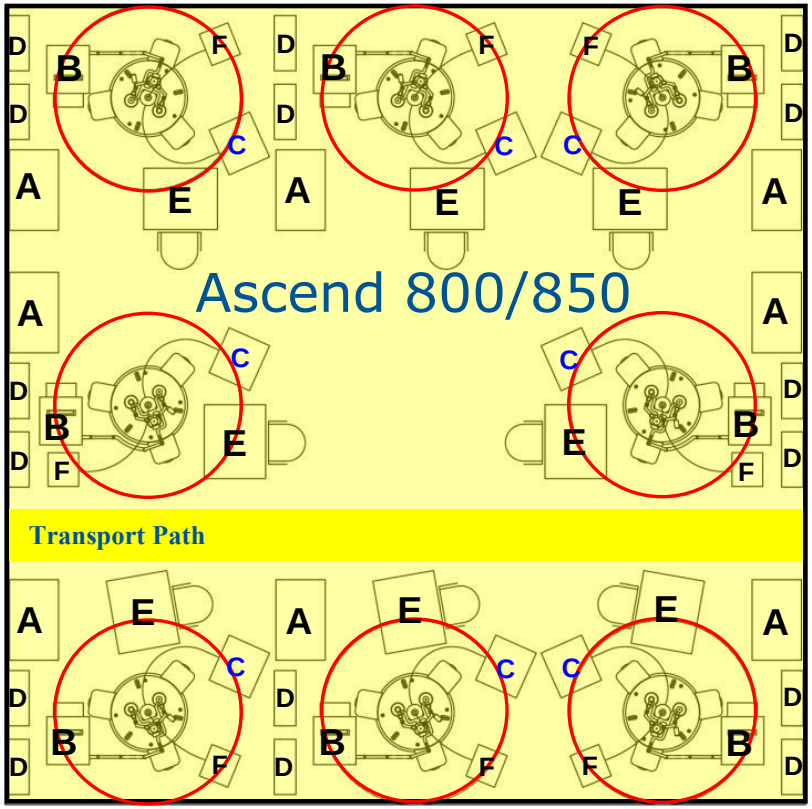


800 US²™



Ascend 800/850 - Minimum Space Requirements

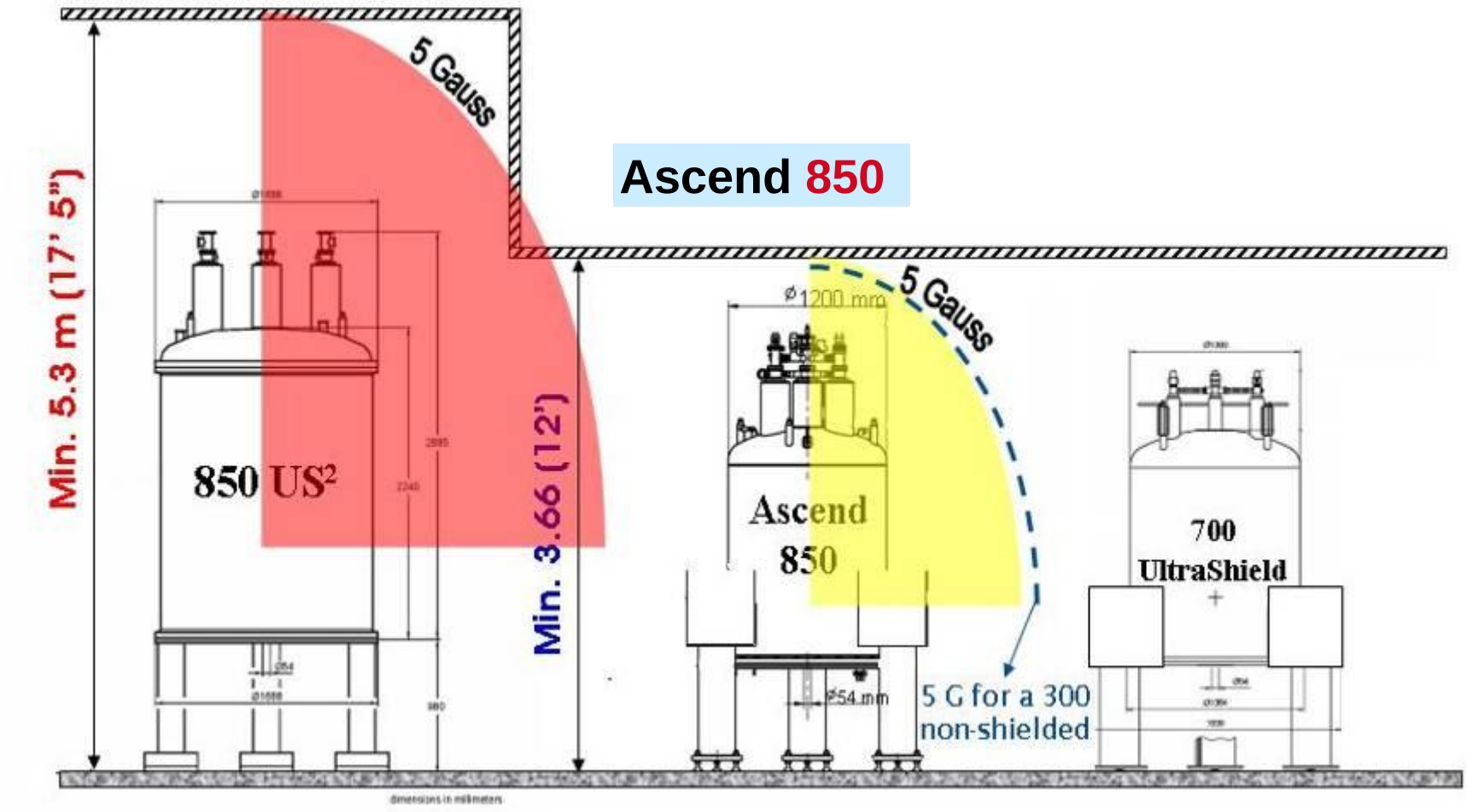




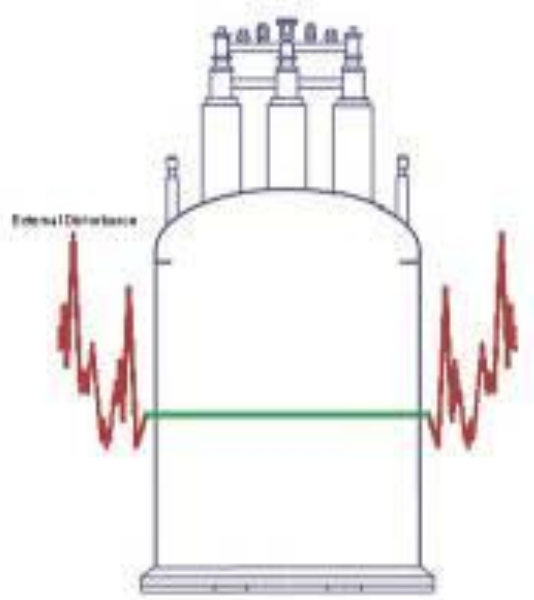
A - Spectrometer	D - UPS
B - BMPC	E - Working Table
C - Pumping Unit	F - BCU 05 Unit

A - Spectrometer	D - UPS
B – BMPC II	E - Working Table
C – Cryoplatform	F - BCU 05 Unit

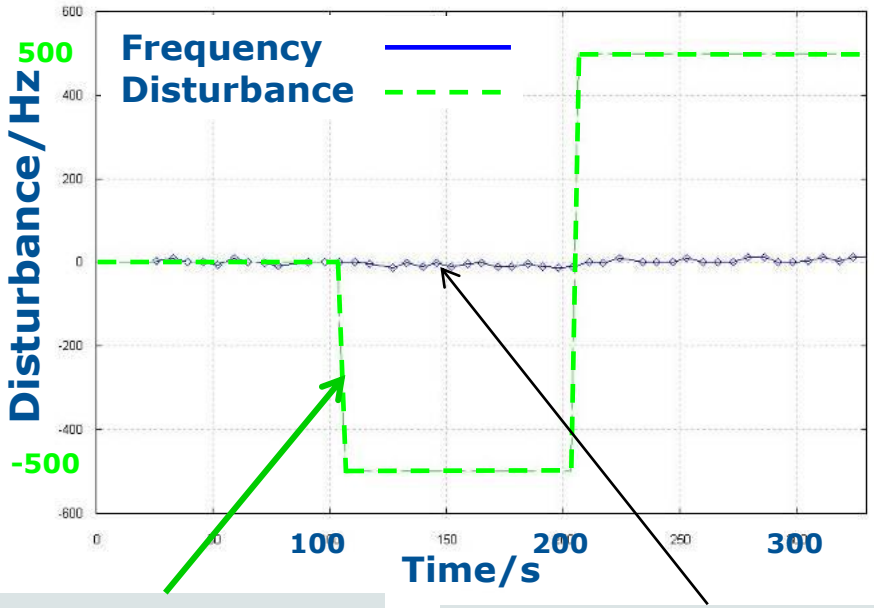
The Ascend 850 MHz– Fits in Single Story Lab



EDS™ : External Disturbance Supression
Example: Ascend 850



External Disturbance Suppression



Ext. Disturbance

Frequency response

Bruker Ultra High Field Magnets

Total: over
180 installations

WB (89 mm)

SB (54 mm)

800	850	900	950	1000	MHz
18.8	*20.0*	*21.1*	*22.3*	*23.5*	*T*

Installed High Field Spectrometers

The US² Series
850 WB, 900, 900 WB and 950

- Advanced active-shielding delivering **small stray fields**
  - 5 Gauss horizontal: 3.3 m
  - 5 Gauss vertical: 4.6 m
- Reduced overall system footprint for **increased siting flexibility**

900 WB US², Courtesy of KAUST

900 US², Courtesy of National Institute or Standard and Technologies (NIST)

950 US², Courtesy of University of Maryland at Baltimore

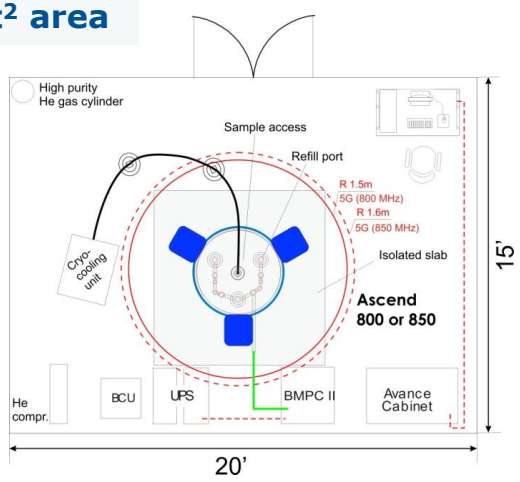
Ascend™ 800 and 850

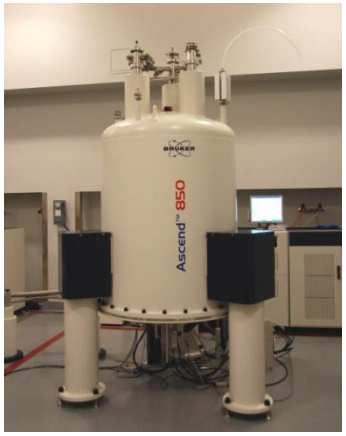
Most Compact Ultra-High Field Magnets

- **Fit in a single-story lab**, minimum ceiling height of only 3.6 m (12’)
- Total weight: 3,500 kg, **suitable for upper floors**
- Most advanced active-shielding delivering:
  - **minimum stray fields**, 5 Gauss at 1.6 m radially and 2.7 m axially from the MC (850 MHz)
  - **99% suppression of external field disturbances**
- **Over 40 x Ascend 800/850 installed** at customer sites worldwide

Ascend 850, Courtesy of University of Delaware

300 ft² area





Ascend 850, Courtesy of MUSC, Charleston, SC

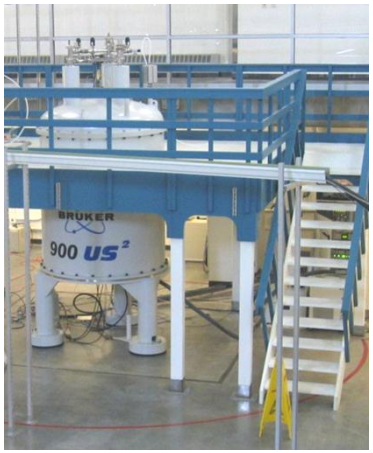
Ascend 850, Courtesy of University of Minnesota

Ultra-High Field (750 – 1000 MHz)

More than 180 installations worldwide

11 x
750 MHz
installations

130 x
800 – 850 MHz installations
(including 40 compact)



35 x
900 – 950 MHz
installations

MRI Product Line

Icon™

1T

ClinScan®

4.7T

7T

9.4T

11.7T

17.2T

PharmaScan®

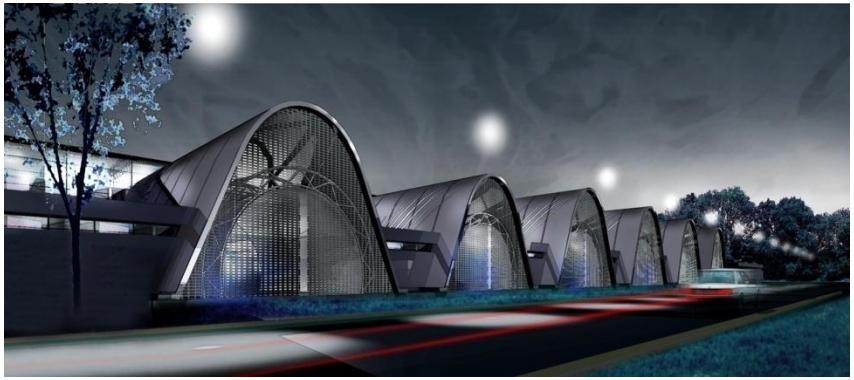
BioSpec®

Research UHF Systems

World's Highest Field Preclinical MRI system

BioSpec® 172/26

- *In vivo* imaging at 17.2 T
- Sub-cooling technology delivers ultra-high magnetic fields
- Compact magnet design



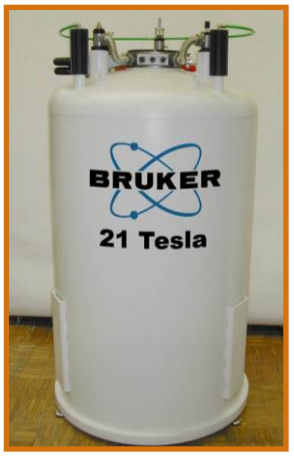
Courtesy: D. Le Bihan, NeuroSpin, Paris, France

21.0 T / 11 cm FT-ICR Magnet

- Project awarded by NHMFL at Florida State University
- Highest resolution mass spectrometer
- Special stray field features designed for ICR application
- Sub-cooled and refrigerated magnet with low He consumption

Examples of Special HF Magnets

Actively shielded laboratory magnet
21 T/64 mm or 20 T/80 mm



9.7 T gyrotron magnet for DNP

Examples of Special HF Magnets

16 T split-coil actively shielded magnet

- Highest field for Neutron scattering

12 T EPR magnet – cryogen free

AVANCE 1000
World's First 1 Gigahertz NMR Spectrometer

- World's first, standard-bore, high homogeneity 1 GHz NMR magnet
- Persistent superconducting magnet
- UltraStabilized™ sub-cooling technology
- Magnetic field strength of 23.5 T
- Standard bore size of 54 mm
- The high field strength and high field stability in combination with the first 1 GHz 5mm triple-resonance CryoProbe™ enables unique 1 GHz NMR applications
- Installed in Lyon

How can 1 GHz be exceeded?

New Superconductors for Ultra High Field Magnets

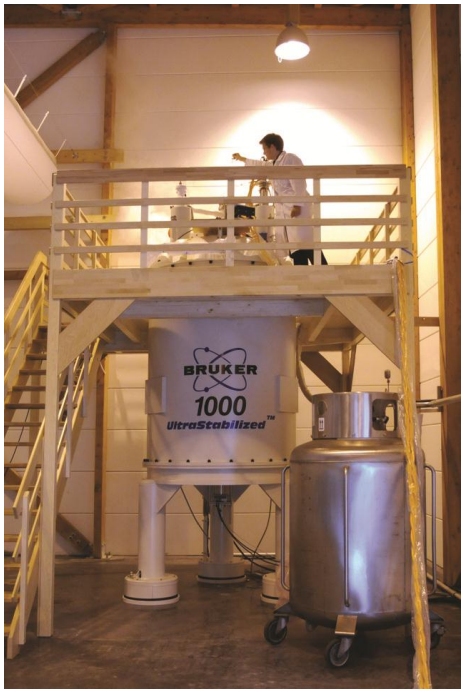
Need to have:

- High critical current at B > 23.5 T
- High mechanical strength

Potential new conductors

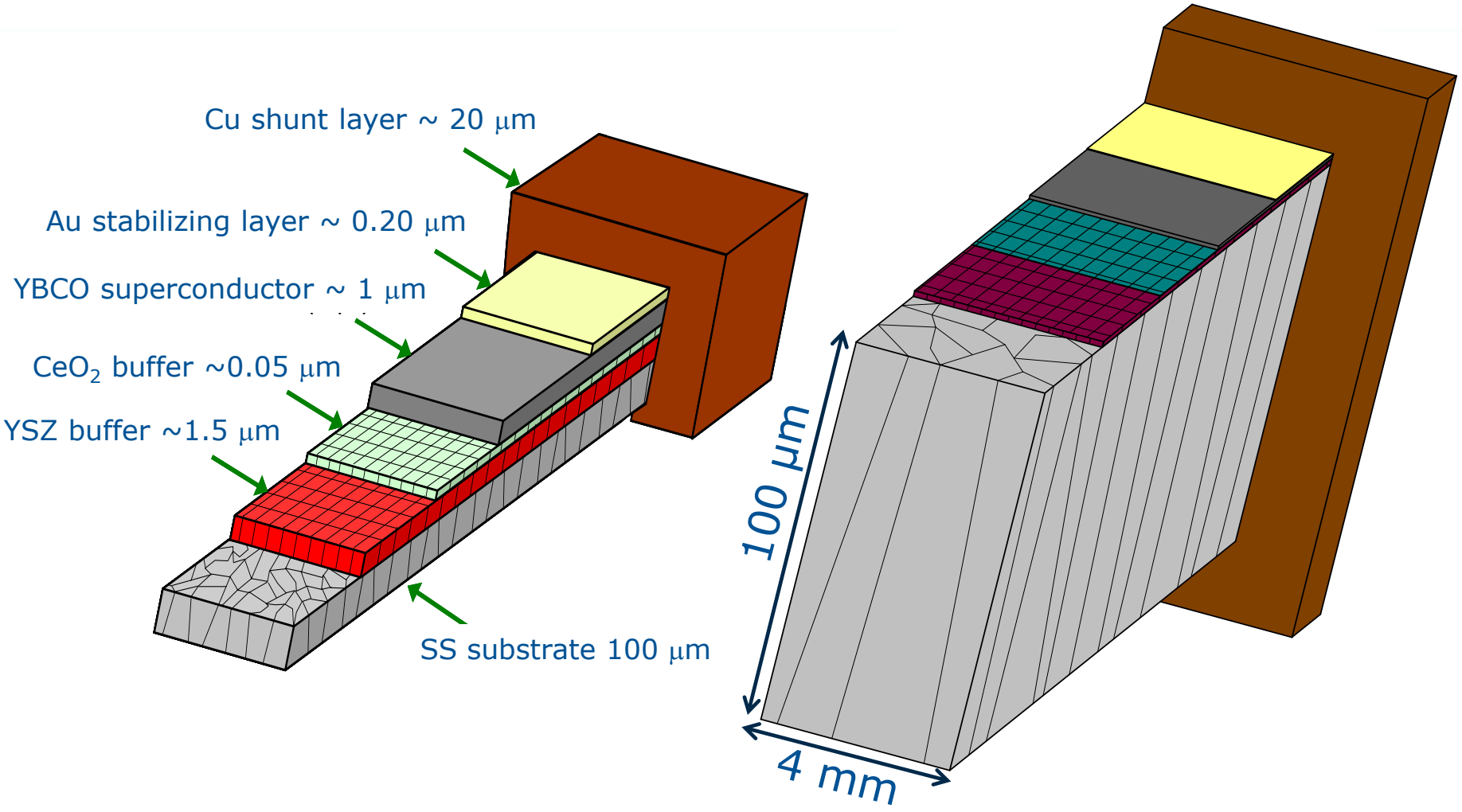
- BSCCO: Bi 2223 or Bi 2212 (1. generation)

- YBCO Coated Conductors (2. generation) show good promise for even higher fields



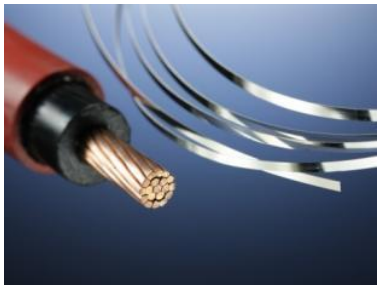
Courtesy of Centre de RMN à Très Hauts Champs' Lyon, France

Yttrium Barium Copper Oxide (YBCO) Coated Conductor



Bruker Energy & Supercon Technologies ('BEST')

BEST HTS Material Development and Production

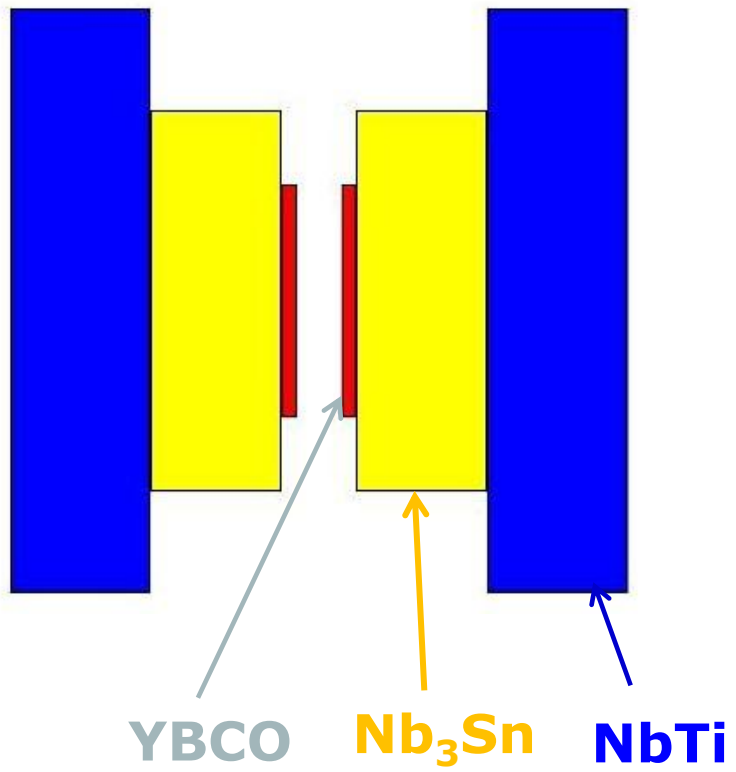


- **Production of long length, 1G HTS**, Bi2223 for generators and future energy related applications

- **Installation of machinery for long length** (~ 2km) and **high volume** coated **YBCO** conductors in progress

1.2 GHz Project

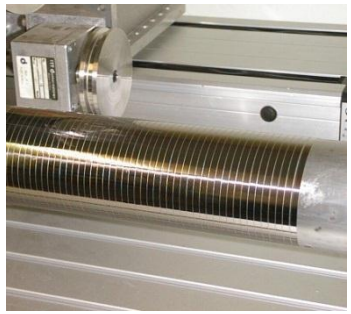
- Bruker has started development of 1.2 GHz before completion of the 1 GHz project
- 1.2 GHz development is part of the continuing co-operation with KIT* (Karlsruhe Institute of Technology)
- KIT has been our Ultra High Field development partner for over 25 years



*former name: Forschungszentrum Karlsruhe

1.2 GHz Challenges

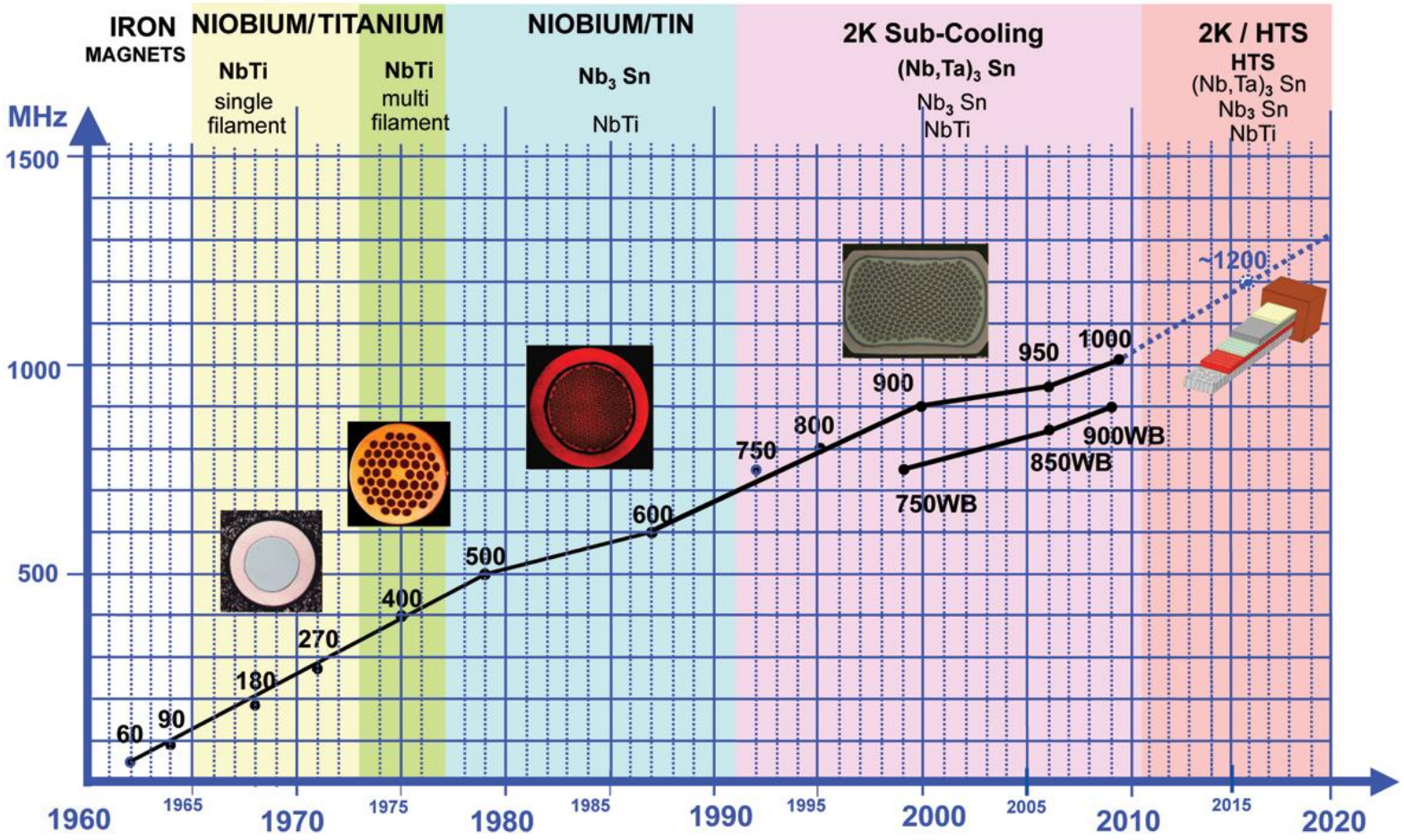
HTS conductors need to:



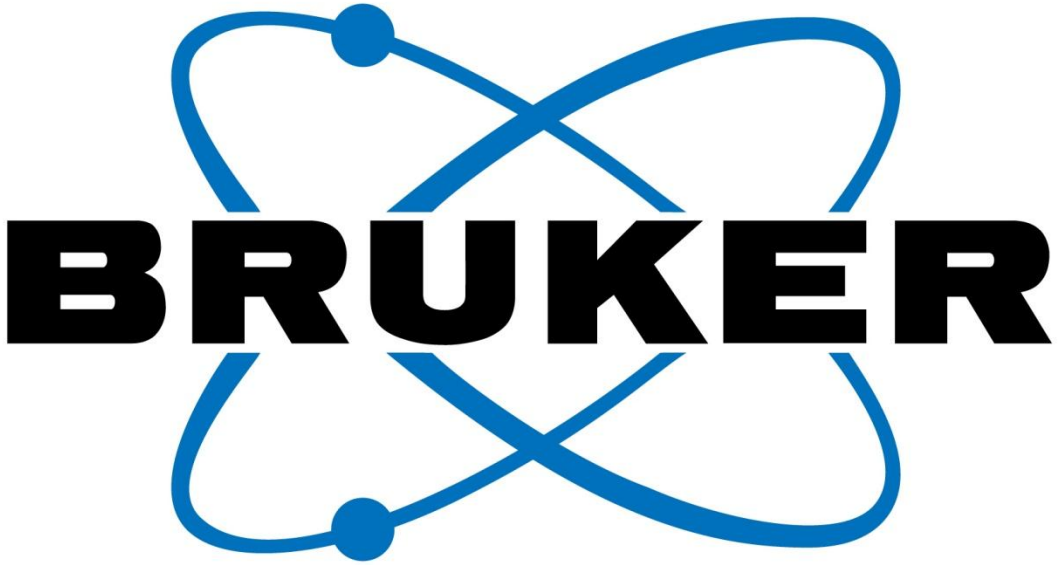
- Overcome intrinsic resistivity
- New solenoid winding technology
- Quench protection
- Long term stability at RT and 2 K
- Two dimensional properties
- Long lengths (min. 1000 m)
- Continuous reproducible conductor quality
- Joint technology

All issues must be solved to design a long term stable and reliable NMR magnet!

When will 1.2 GHz become reality?



Magnets having full NMR specifications in persistent mode



www.bruker-biospin.com