IEEE/CSC & ESAS SUPERCONDUCTIVITY NEWS FORUM (global edition), April 2016.
Invited presentation 3OrCB_01 given at MT24; Seoul, Korea, October 18 to 23, 2015.

HZB Helmholtz Zentrum Berlin

High Magnetic Field Facility for Neutron Scattering

Project HFM-EXED

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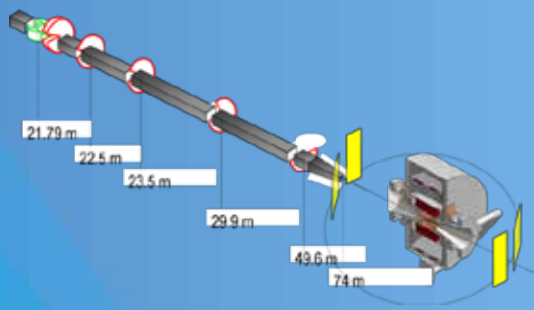
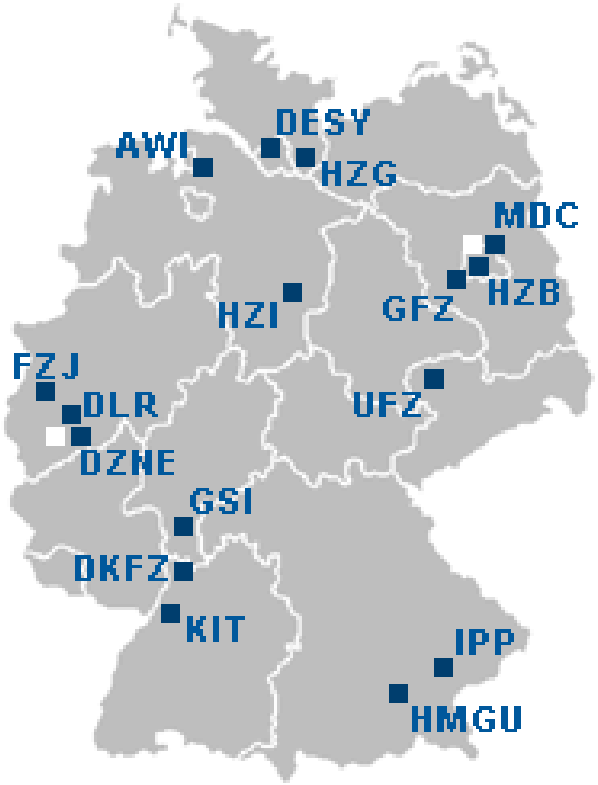


What is Helmholtz?
What is HZB?

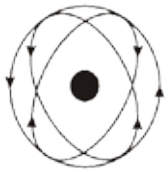


What is Helmholtz?
What is HZB?

HZB
Campus Wannsee

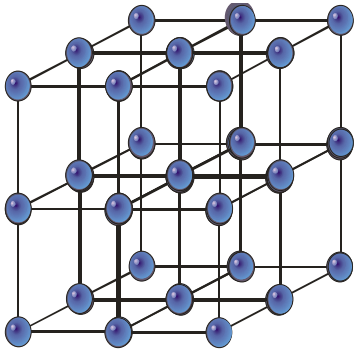
HZB
Campus Adlershof

Investigation of Structure and Dynamics of Complex Materials and Material Systems with Neutrons

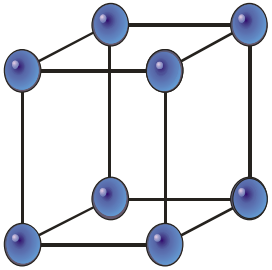


Atom

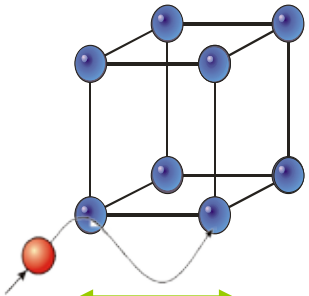
Nuclei



Atoms within crystal



Unit cell



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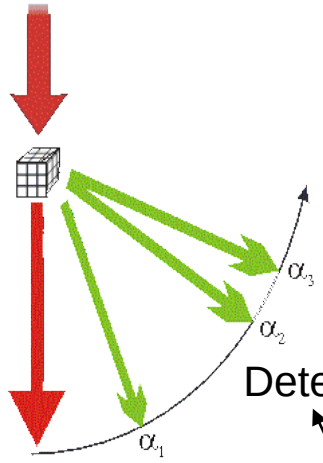
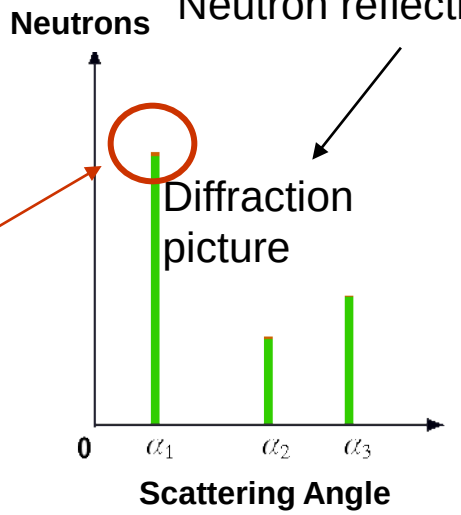
Neutron scatters at the lattice



Detector area

Neutron reflection



Diffraction picture

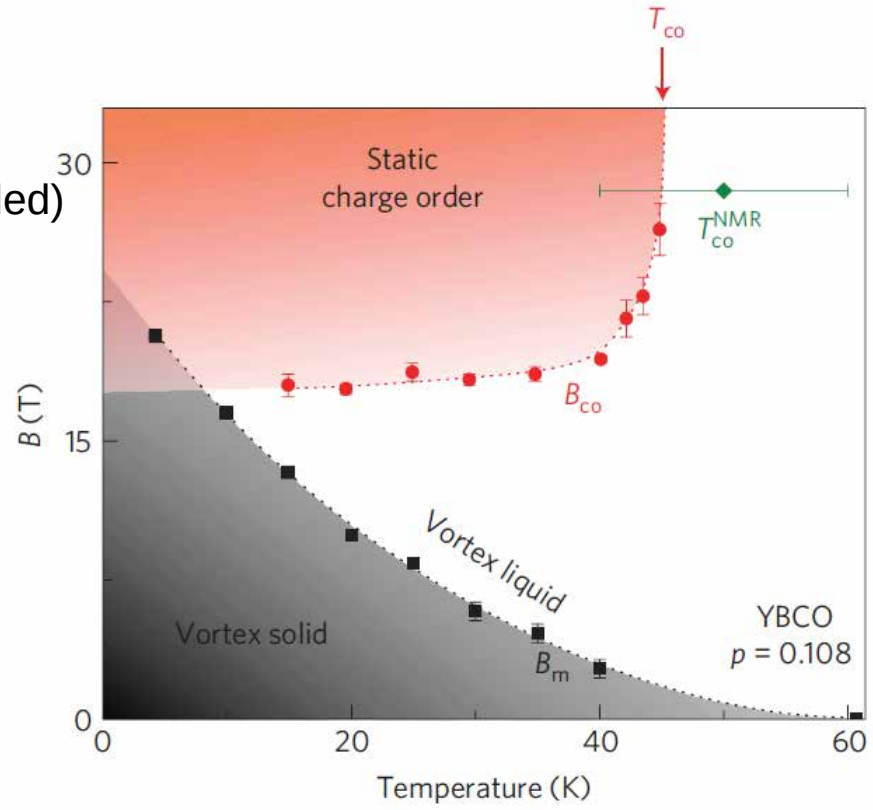
Magnetism

Unconventional Superconductors

Understanding the interplay between superconductivity and other competing orders

- **Identification of different vortex phases**
  (lattice, liquid, disentangled, entangled, decoupled)

- **Method:**
  diffraction / inelastic scattering / SANS



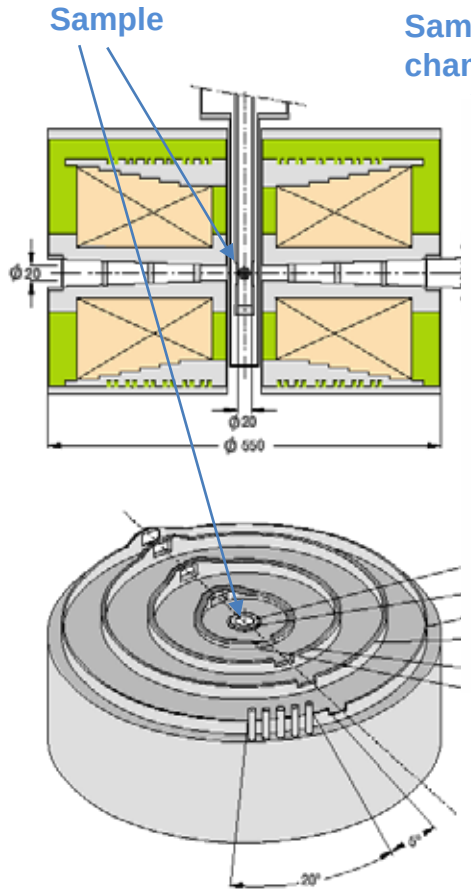
B/T phase diagram of underdoped YBCO
*Le Boeuf et. al., Nature Physics **9** (2013) 79*

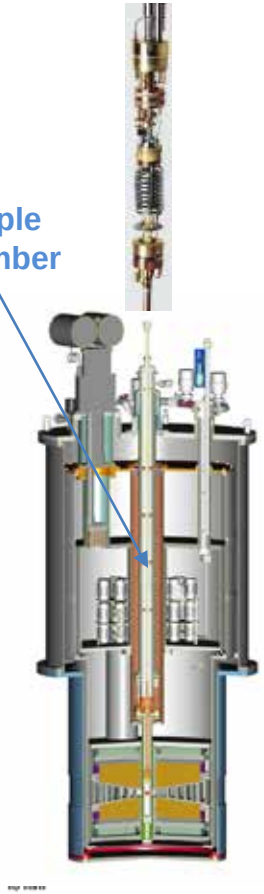
Magnet Systems for n-Scattering at HZB

Continuous Field
max. ~ 15 T – split pair configuration

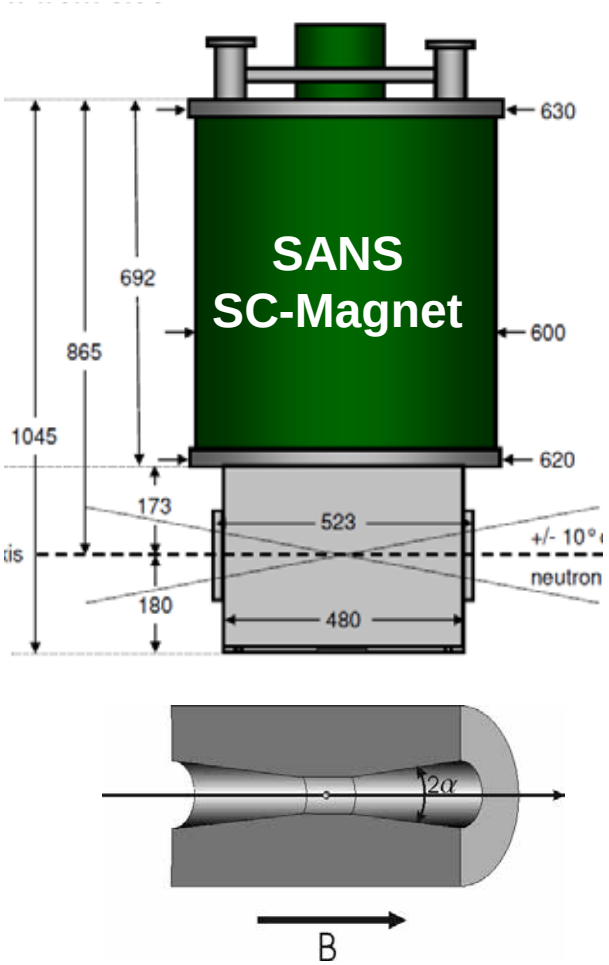
Present Cryomagnets for n-Scattering Experiments

Limitations





Vertical Field



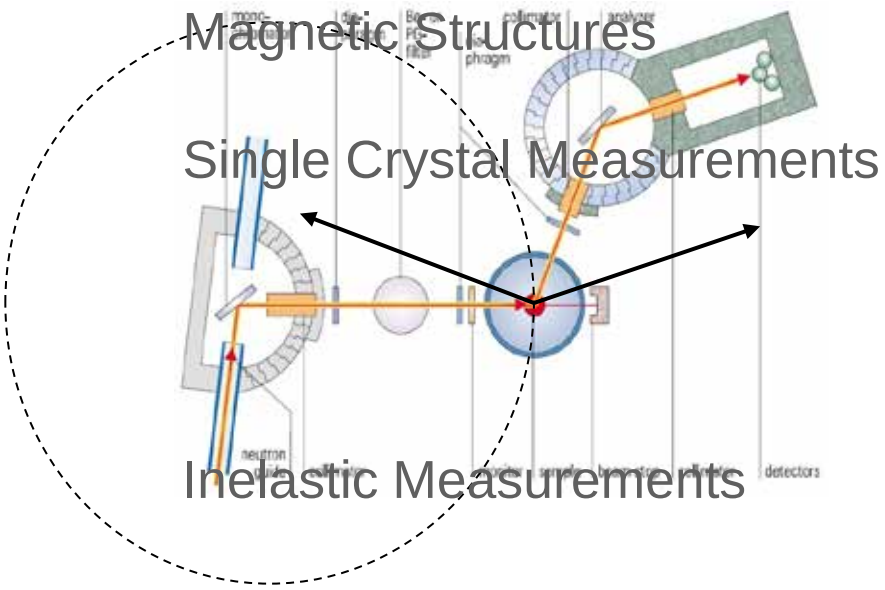
Horizontal Field

High Field Magnets for Neutron Science

Monochromatic

Triple-Axis Instrument

Split-Coil-Magnet
(vertical field)



Magnetic Structures

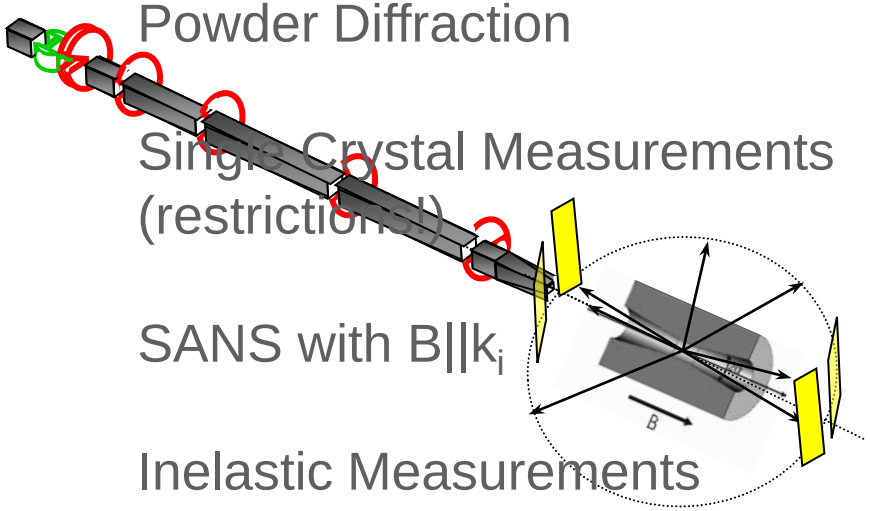
Single Crystal Measurements

Inelastic Measurements

Broad Wavelength Band of Neutrons

TOF-Instrument

Tapered Solenoid
(horizontal field)



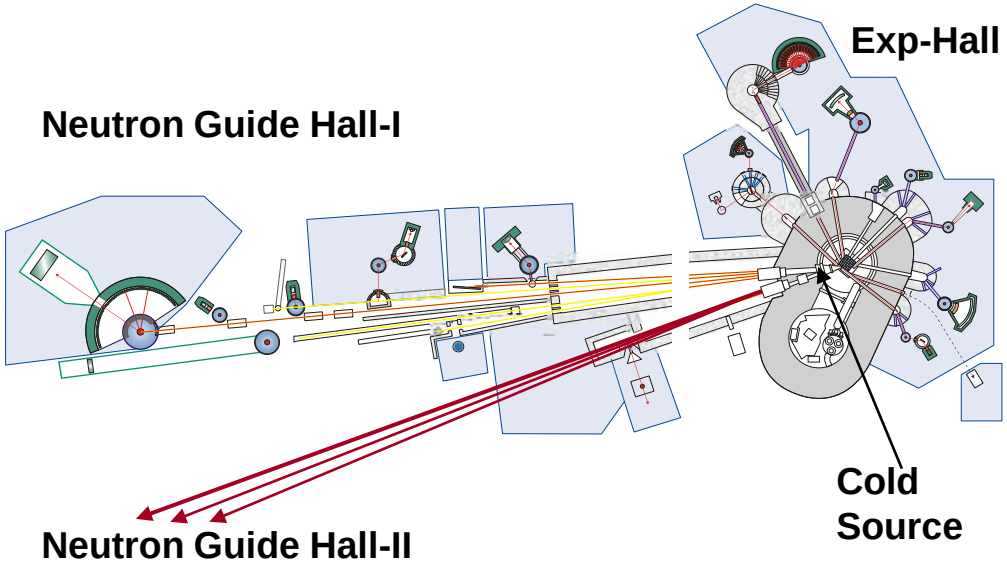
Powder Diffraction

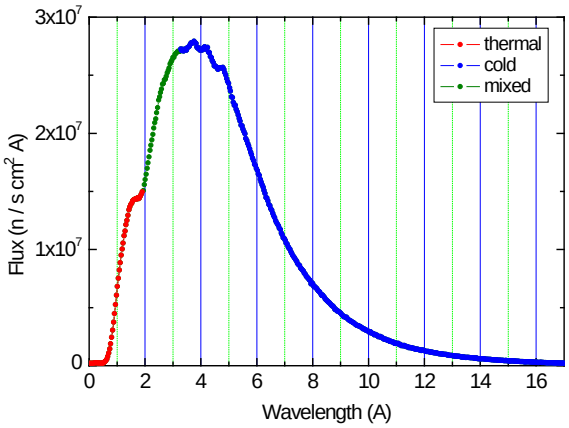
Single Crystal Measurements (restricted)

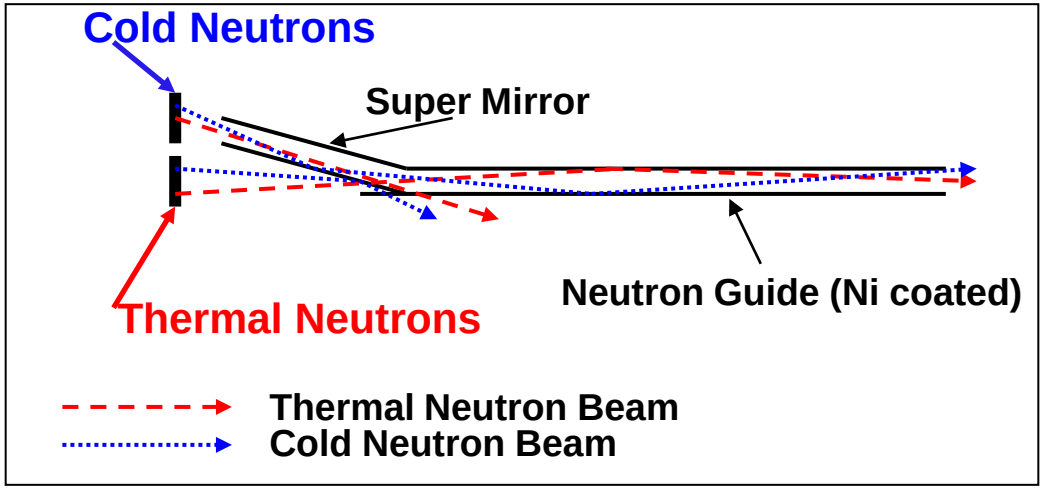
SANS with $B||k_i$

Inelastic Measurements (flux reduction!)

Neutron-Guide-Hall-2 with Multi-Spectral Guide





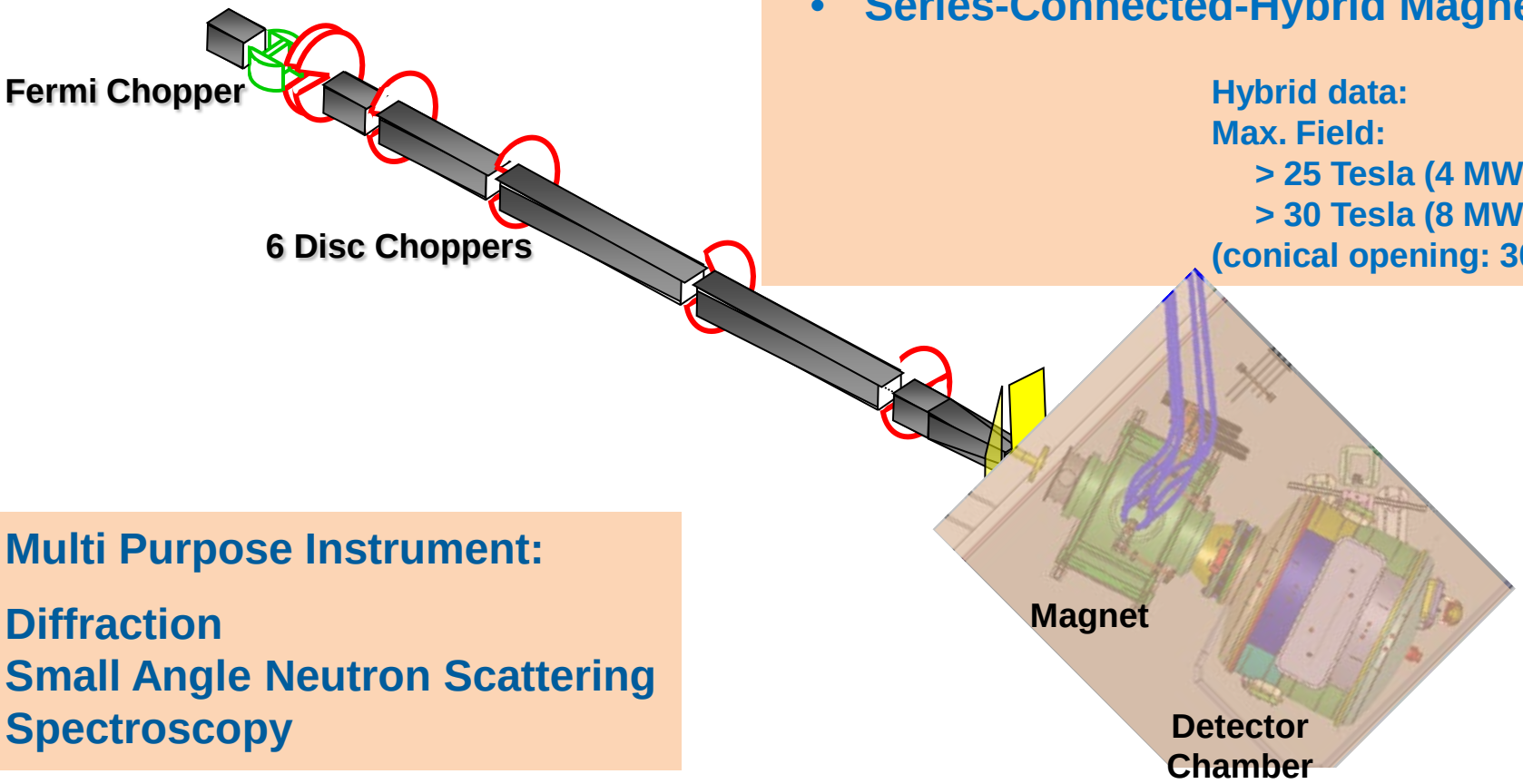


Project Preparation Phase

TOF instrumentation with multispectral neutron guide and horizontal magnet to allow optimum magnet design

- **Resistive Magnet or**
- **Superconducting Magnet or**
- **Series-Connected-Hybrid Magnet (SCH)**

Hybrid data:
Max. Field:
> 25 Tesla (4 MW)
> 30 Tesla (8 MW)
(conical opening: 30°)

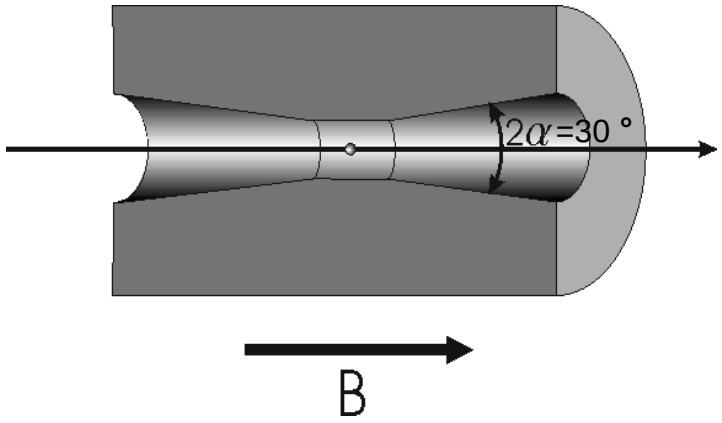


Multi Purpose Instrument:

Diffraction
Small Angle Neutron Scattering
Spectroscopy

Magnets for n-Scattering Experiments

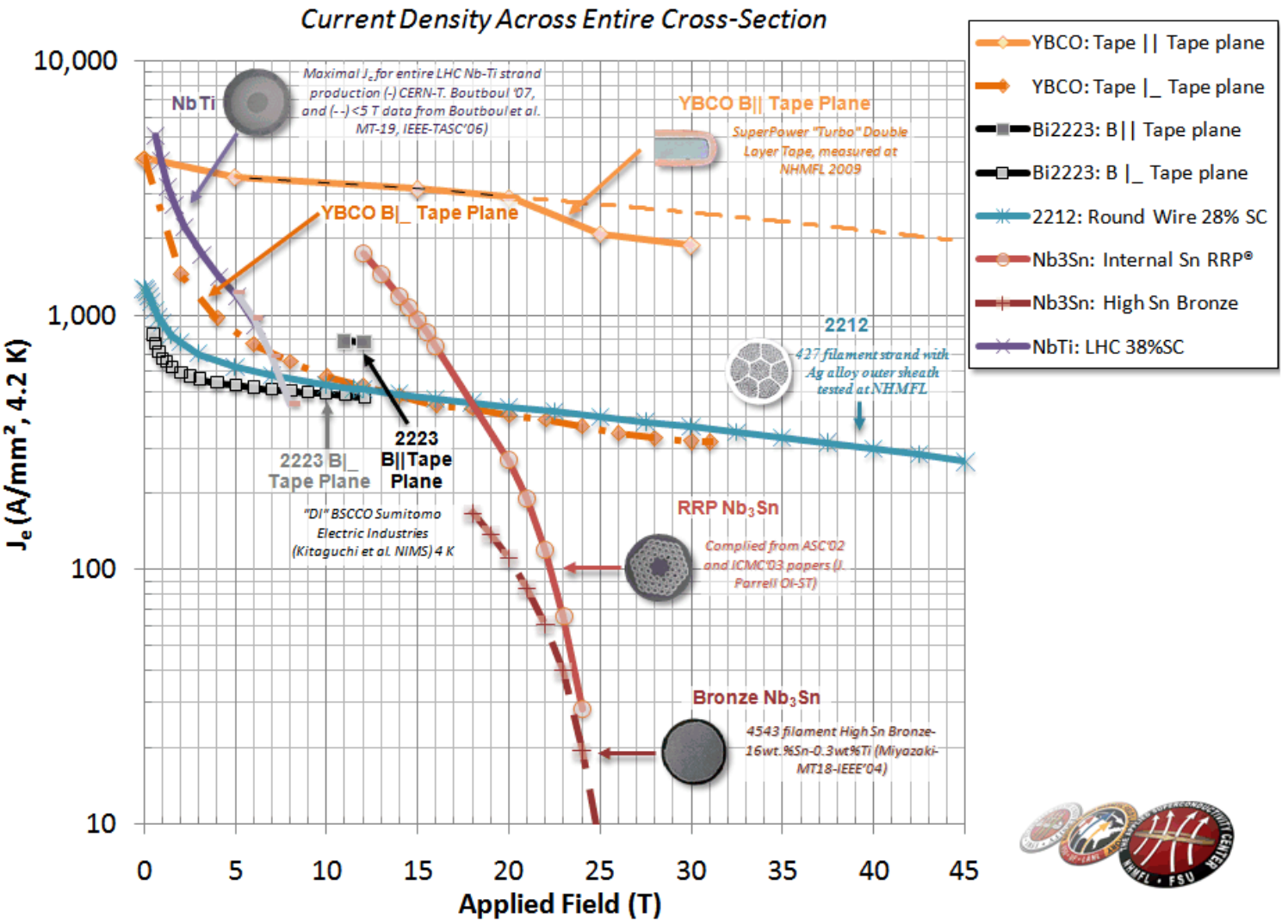
Future



25 T – 31 T Hybrid Magnet (Solenoid)

Geometry and power of resistive coil determine maximum field

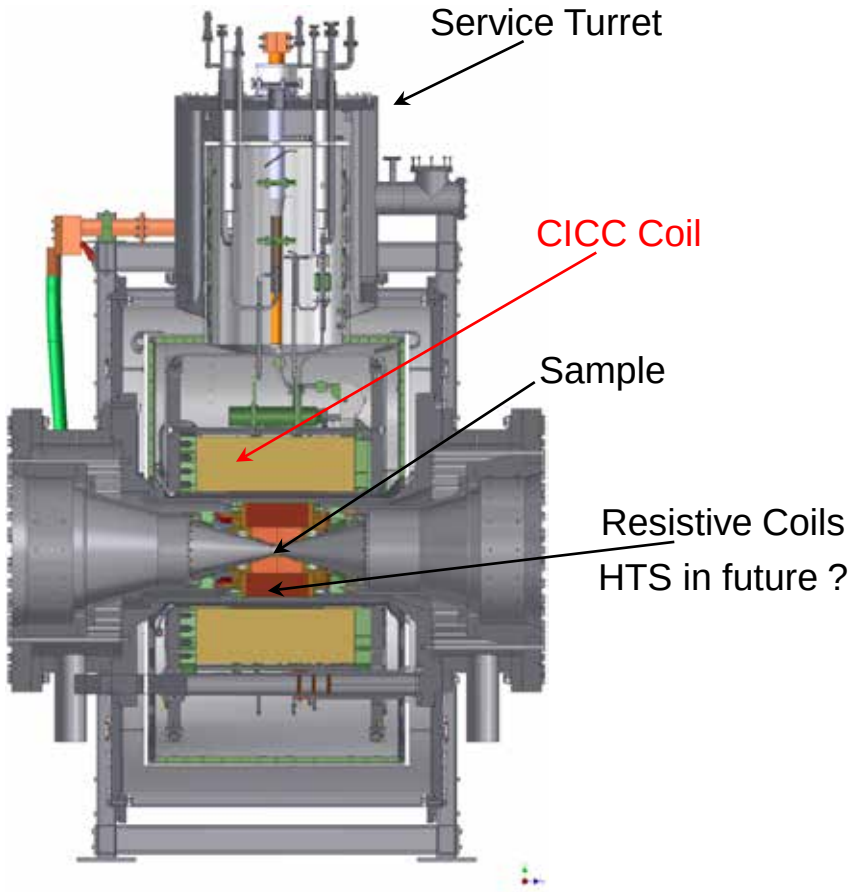
Why not a Superconducting Magnet ?



Plot maintained by Peter Lee at: http://magnet.fsu.edu/~lee/plot/plot.htm

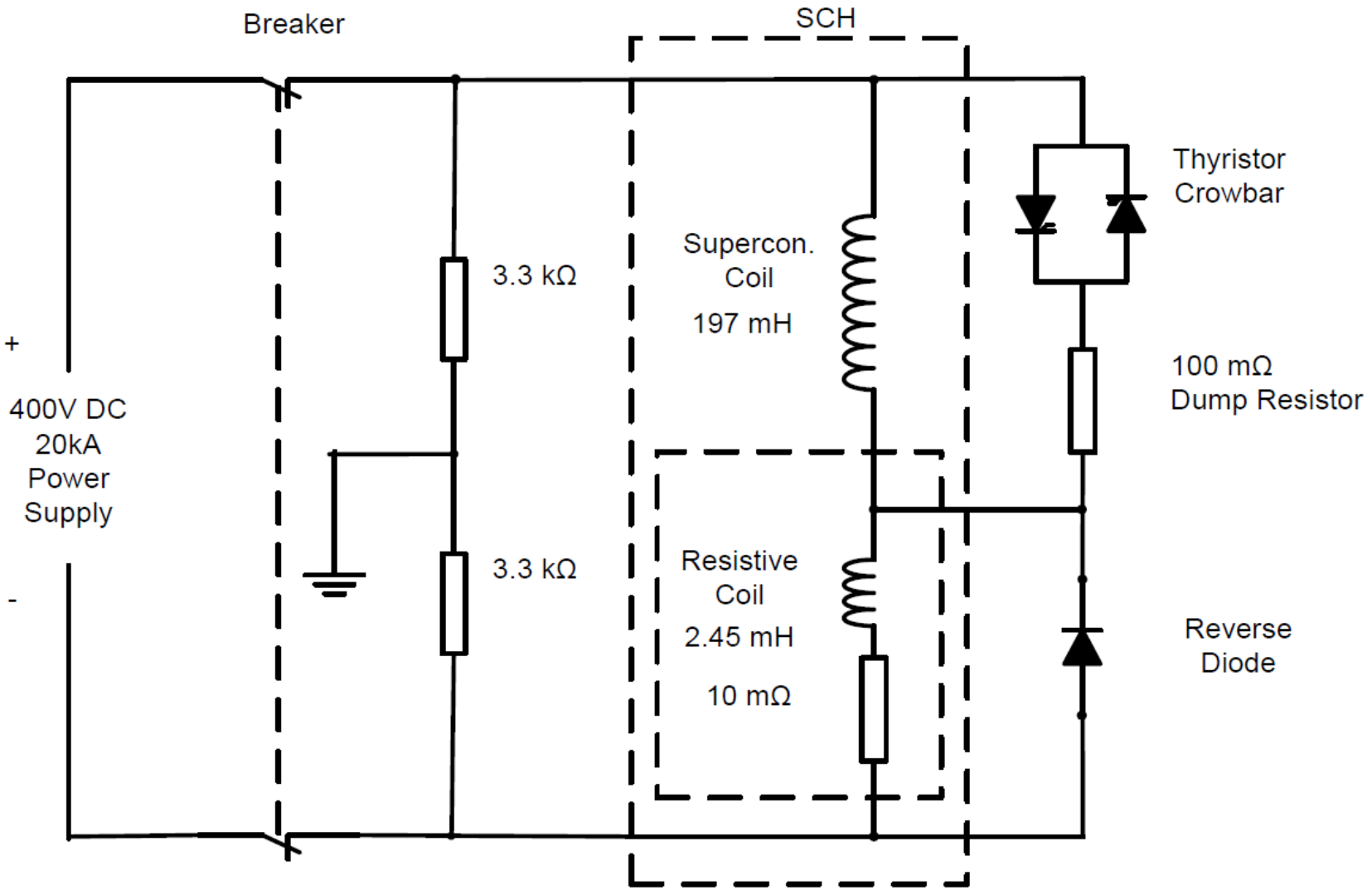
Design Parameter Hybrid Magnet

Central Field	**> 25 T (> 30) T**
Bore	**50 mm horizontal**
Opening Angle	**30°**
Power Resistive Insert	**4 MW (8 MW)**
Field Homogeneity	**< 0.5% (15 mm x 15 mm Vol.)**
Operating Current	**20 kA**
Magnetic Field of Resistive Insert	**13 T – 18 T (4 MW / 8 MW)**
Magnetic Field of Supercond. Coil	**13 T**
Height	**~ 5 m**
Total Weight	**~ 25 t**
Cold Mass	**~ 6 t**



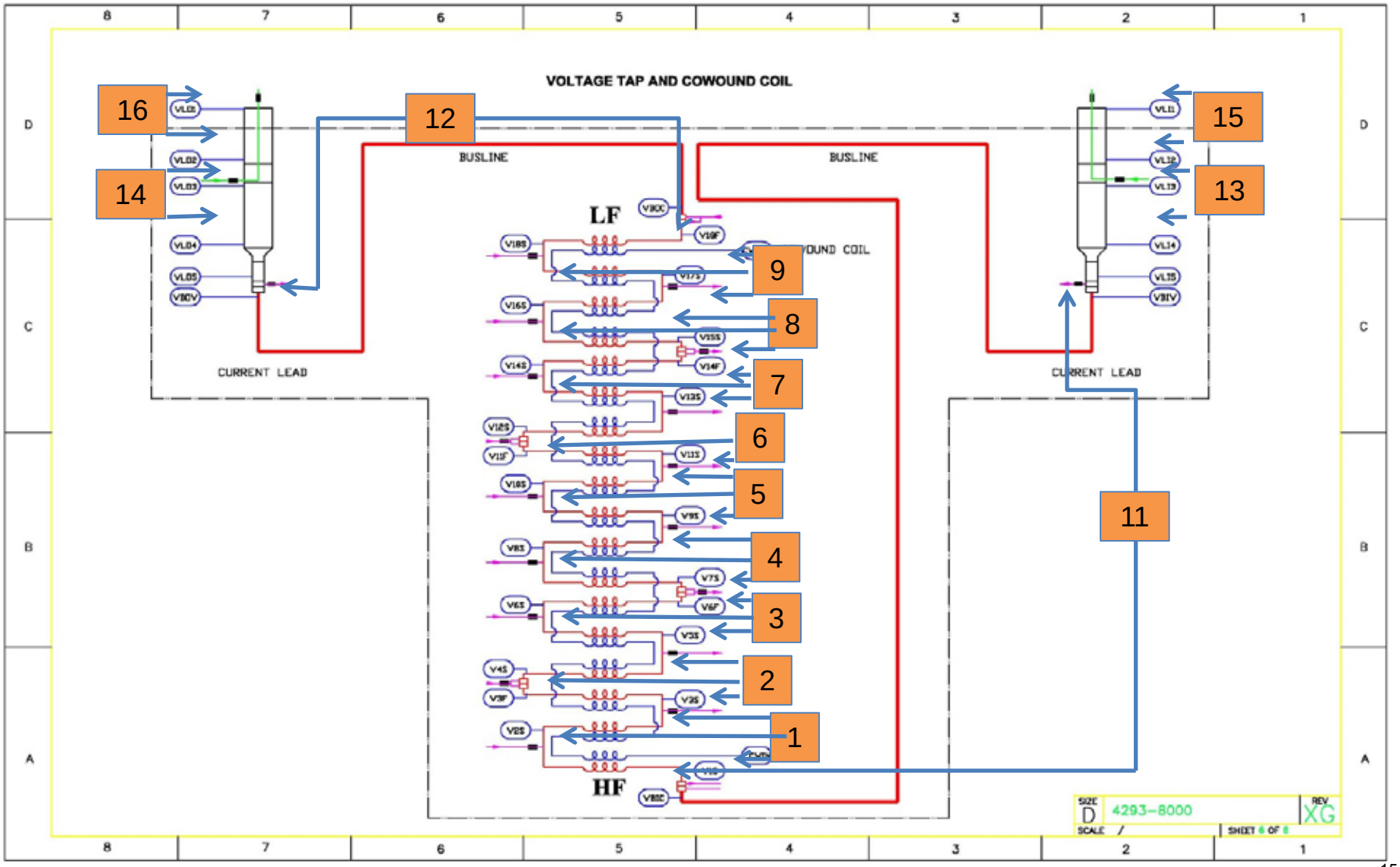
Simplified Electrical Circuit

Coil Protection



Quench Detection System

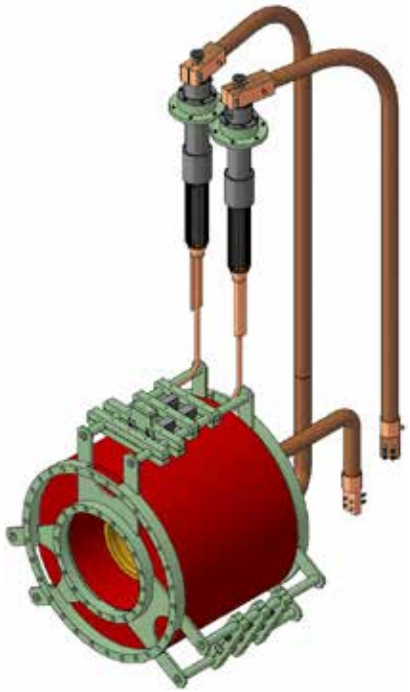
(Two independent systems)

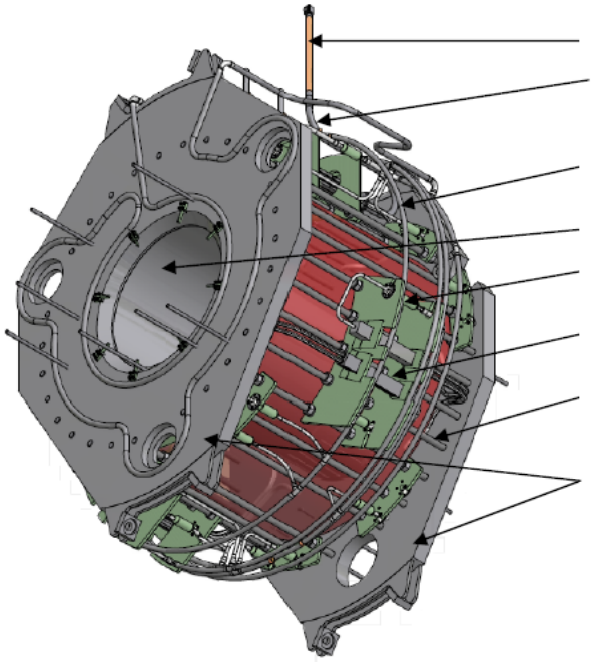


Superconducting Outsert Coil

Nb_3Sn Strand and 3 Types of Superconductor

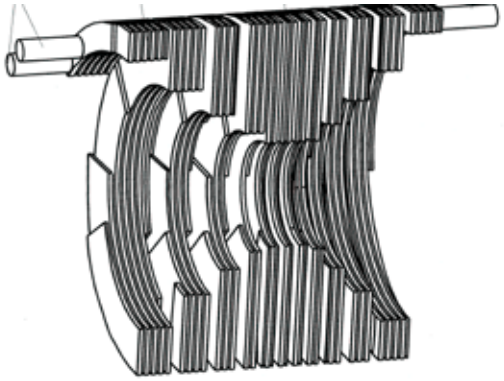
	High Field	Mid Field	Low Field
Cable Pattern	4x3x3x3**x3**=324	5x4x4**x3**=240	4x4x4**x3**=192
N sc strands/Cu strands	324/0	120/120	64/128
Strand diameter	0.81mm	0.81mm	0.81mm
Jc-nocu (12T,4.2K)	>2100A/mm2	>2100 A/mm2	>2100 A/mm2
Type of strand : Nb_3Sn	RRP	RRP	RRP
Strand coating	Chrome plating	Chrome plating	Chrome plating
Void fraction	29+/-1%	29+/-1%	29+/-1%

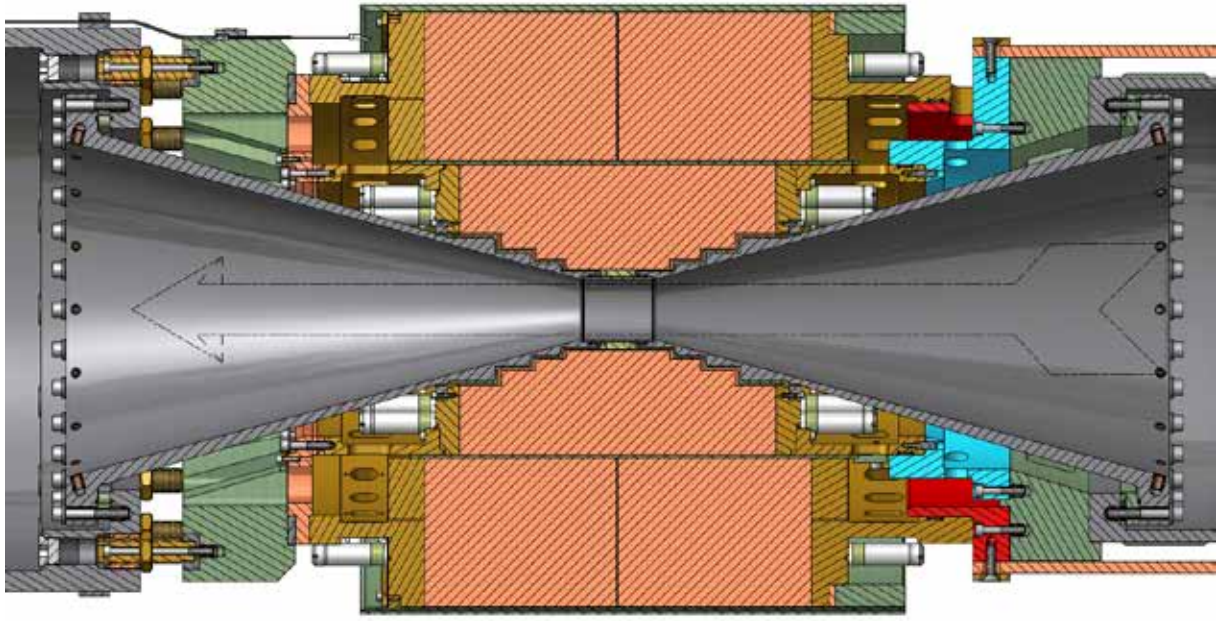




Resistive Insert Coil

Horizontal



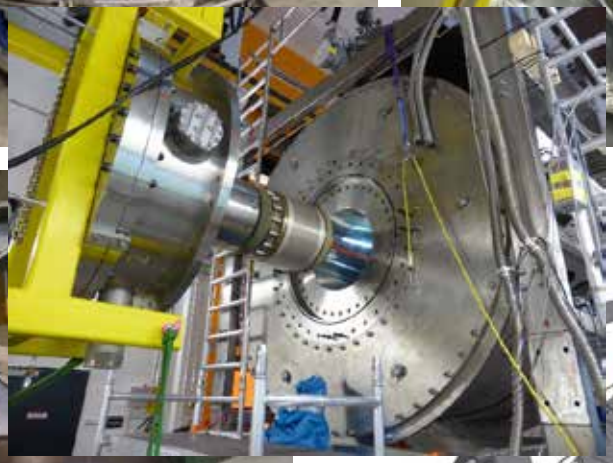


Superconducting Outsert Coil

Final Assembly



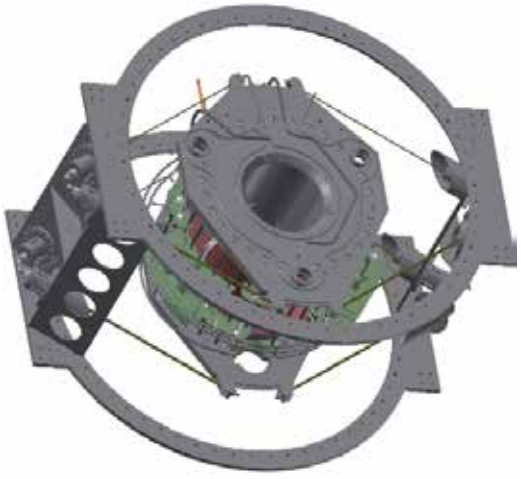






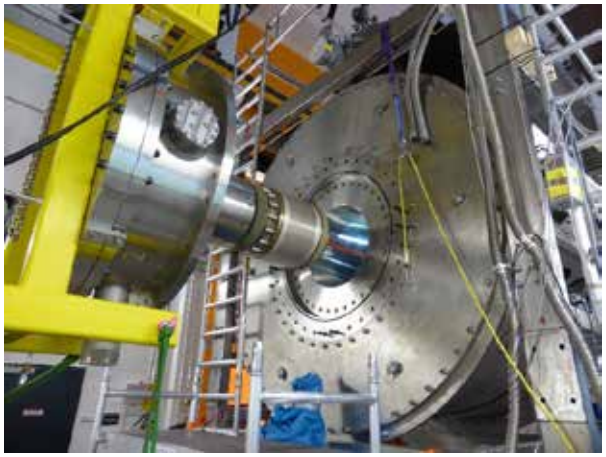
Superconducting Outsert Coil

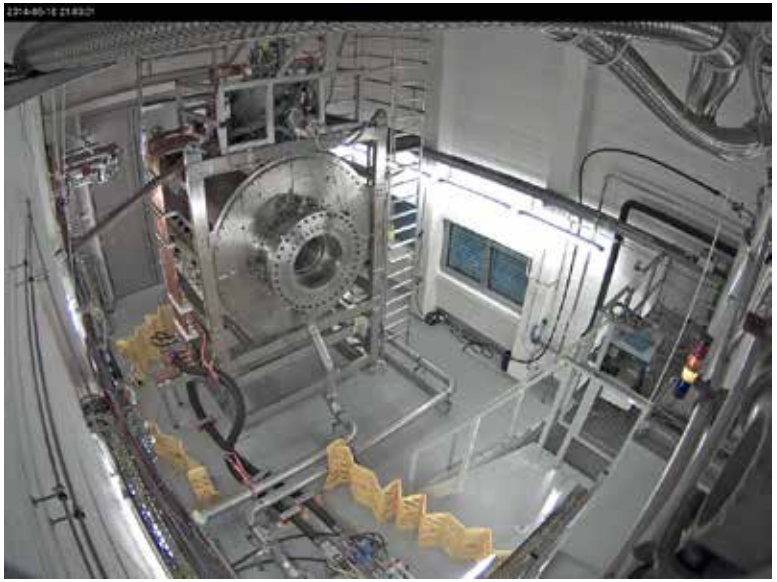
Final Assembly



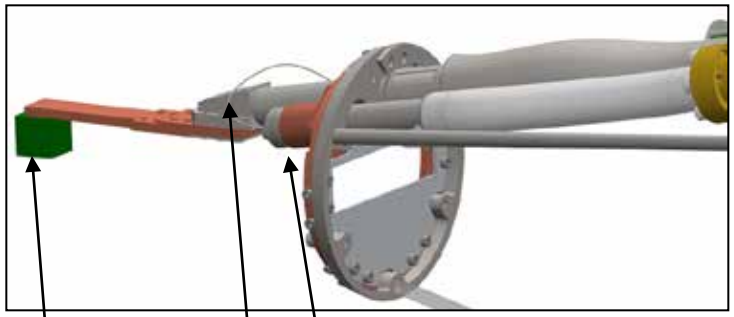
Superconducting Outsert Coil

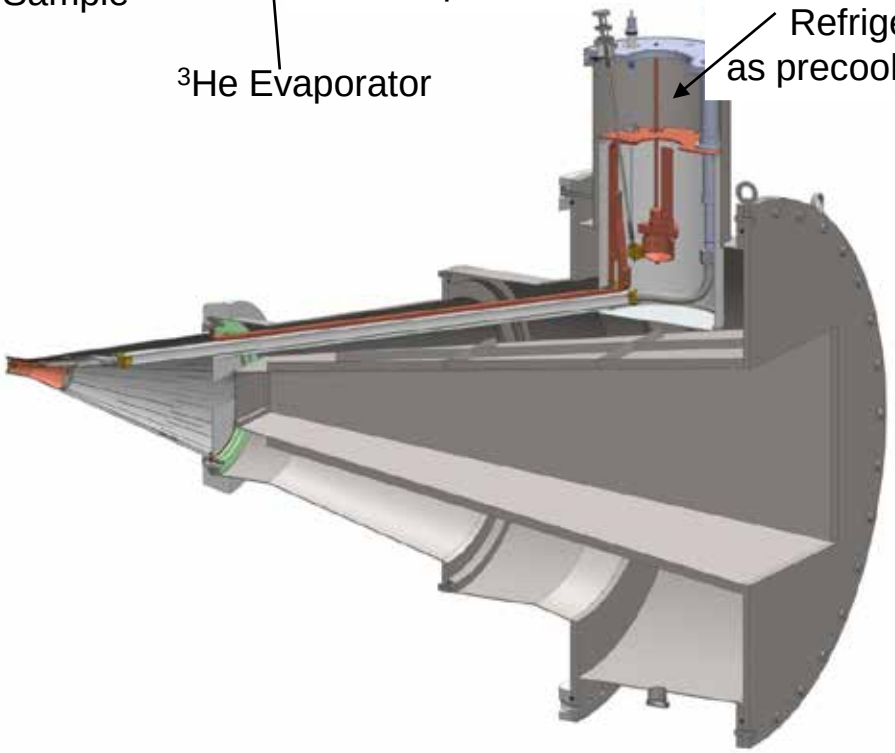
Final Assembly

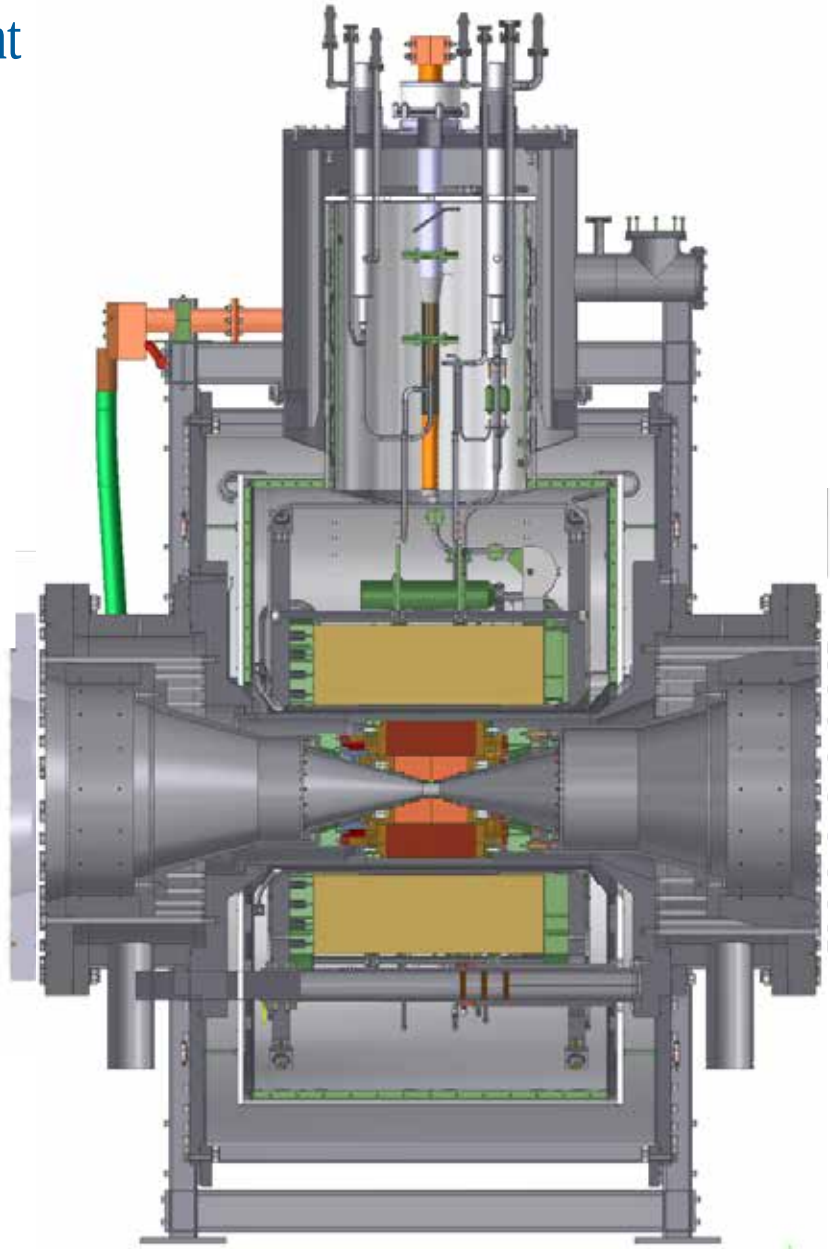




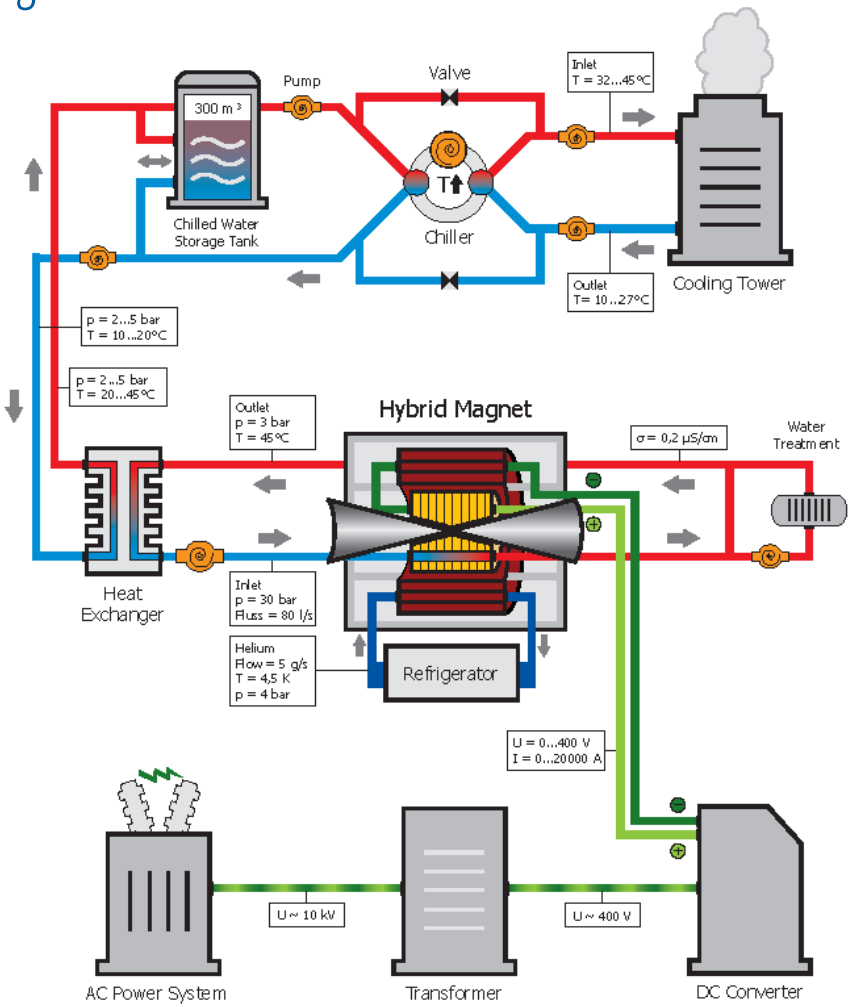
Sample Environment







Hybrid Magnet + Technical Infrastructure



Operation:

§ 400 V / 20 kA DC power supply

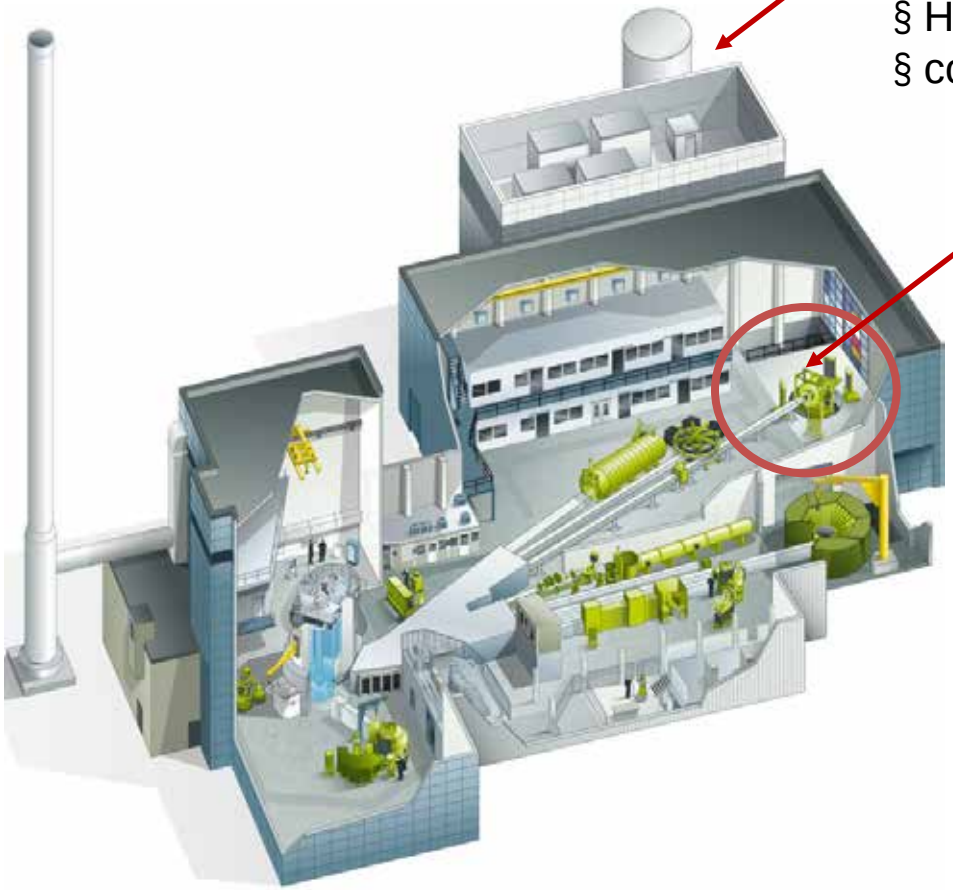
§ Helium refrigerator for
CICC coil, radiation shields and current leads

§ high pressure, high purity cooling water
4 / 8 MW cooling power for resistive coil

HZB Neutron Scattering Facilities

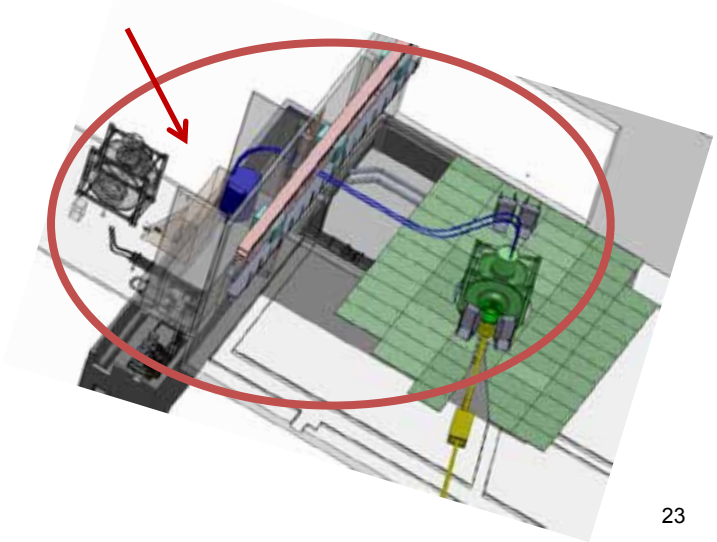
Technics Building:

§ DC power supply
§ Helium refrigerator
§ cooling water facility



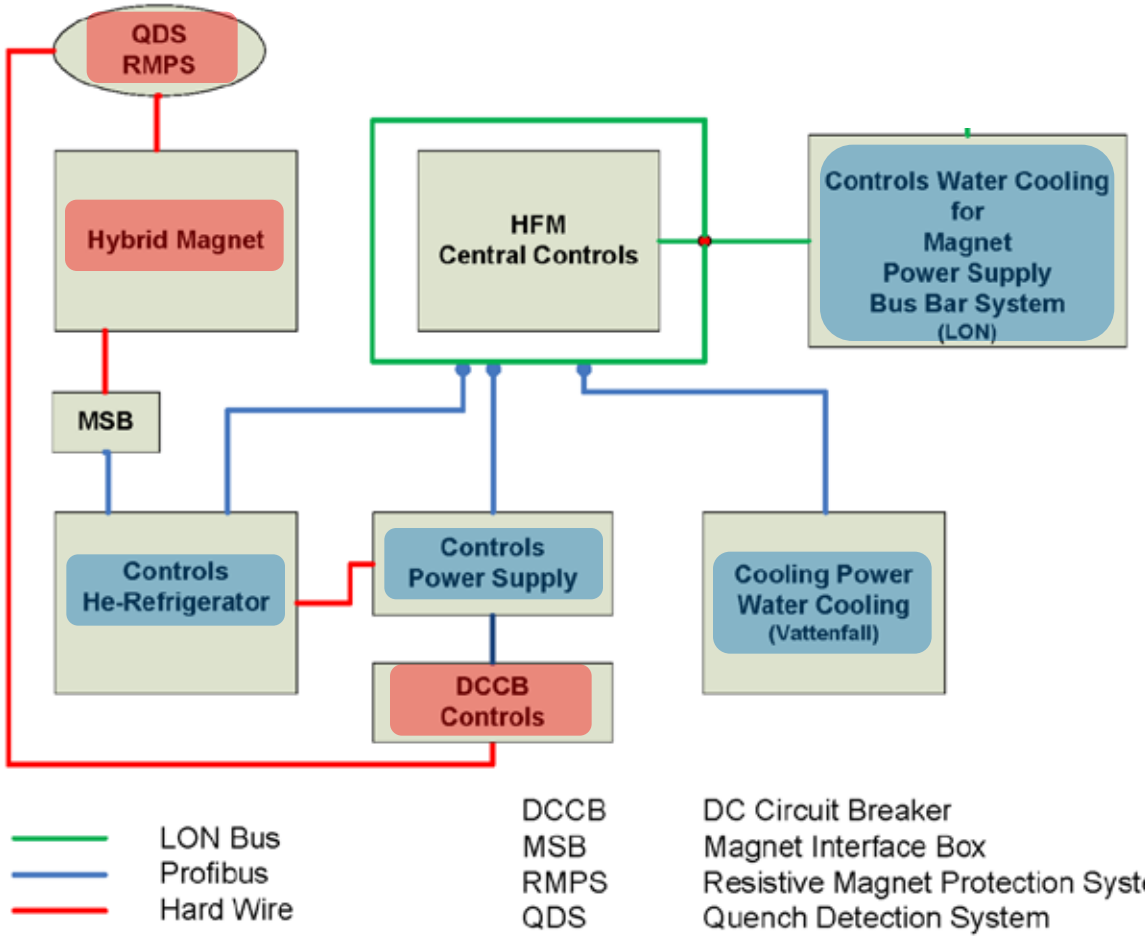
Neutron Instrument & HFM

HFM Assembly and Test Site in Technics Building



Infrastructure Building

Control System – Hybrid Magnet



Combine Controls for:

Magnet +

Power Supply +
Water Cooling +
Helium Refrigerator +

Data monitoring and safety procedures

User Terminal

Commissioning Hybrid Magnet

Aug 2015	Start of cooldown of superconducting coil
16 Oct 2014	First successful magnet test at 20 kA (26 T)
12 Dec 2014	Relocation of magnet system from HFM technics building to Neutron Guide Hall
Jan. 2015 to Feb. 2015	Installation of magnet on neutron instrument EXED Start HFM/EXED commissioning
07 Apr 2015	Successful test on instrument 20 kA (26 T) for 3 hours