Refurbishment and status of FZK test facilities

Walter H. Fietz

- Introduction to FZK facilities
- Preparation for W7-X coil testing - TOSKA refurbishment
- Current Leads for W7-X
- Current Leads for JT-60SA
- Special Current Lead Test facility - CuLTKa

TOSKA TOroidal Spulentestanlage Karlsruhe
Toroidal Test facility Karlsuhe

Cryostat

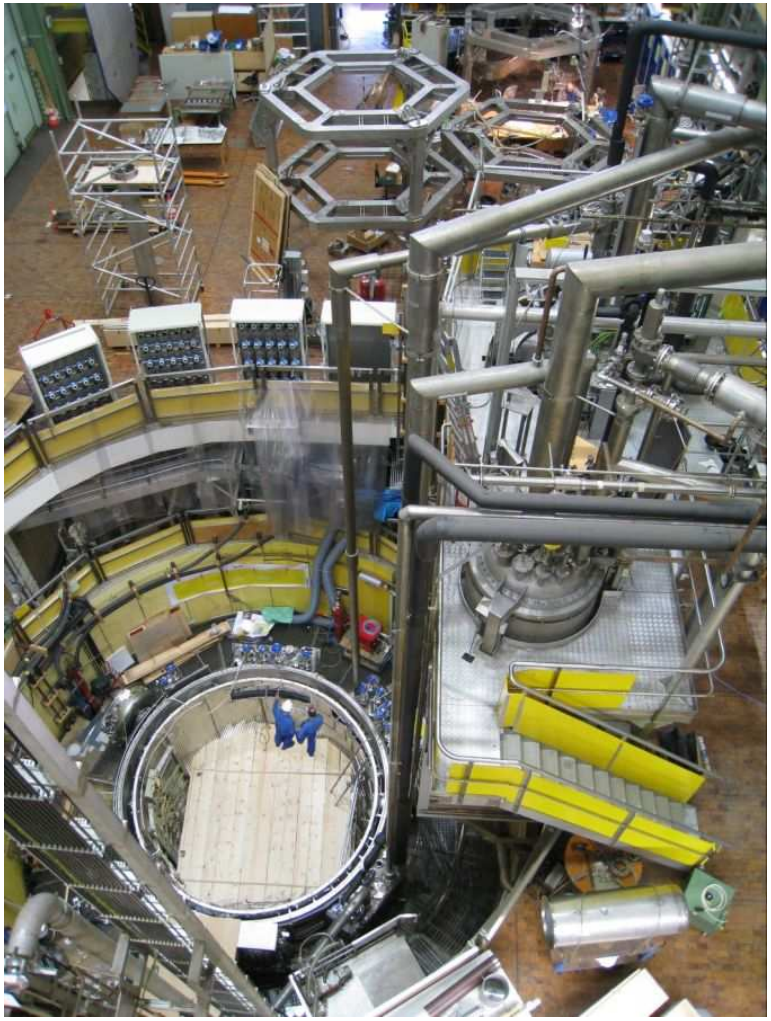
∅ 4.3 m, usable height 6.6 m

Power supplies

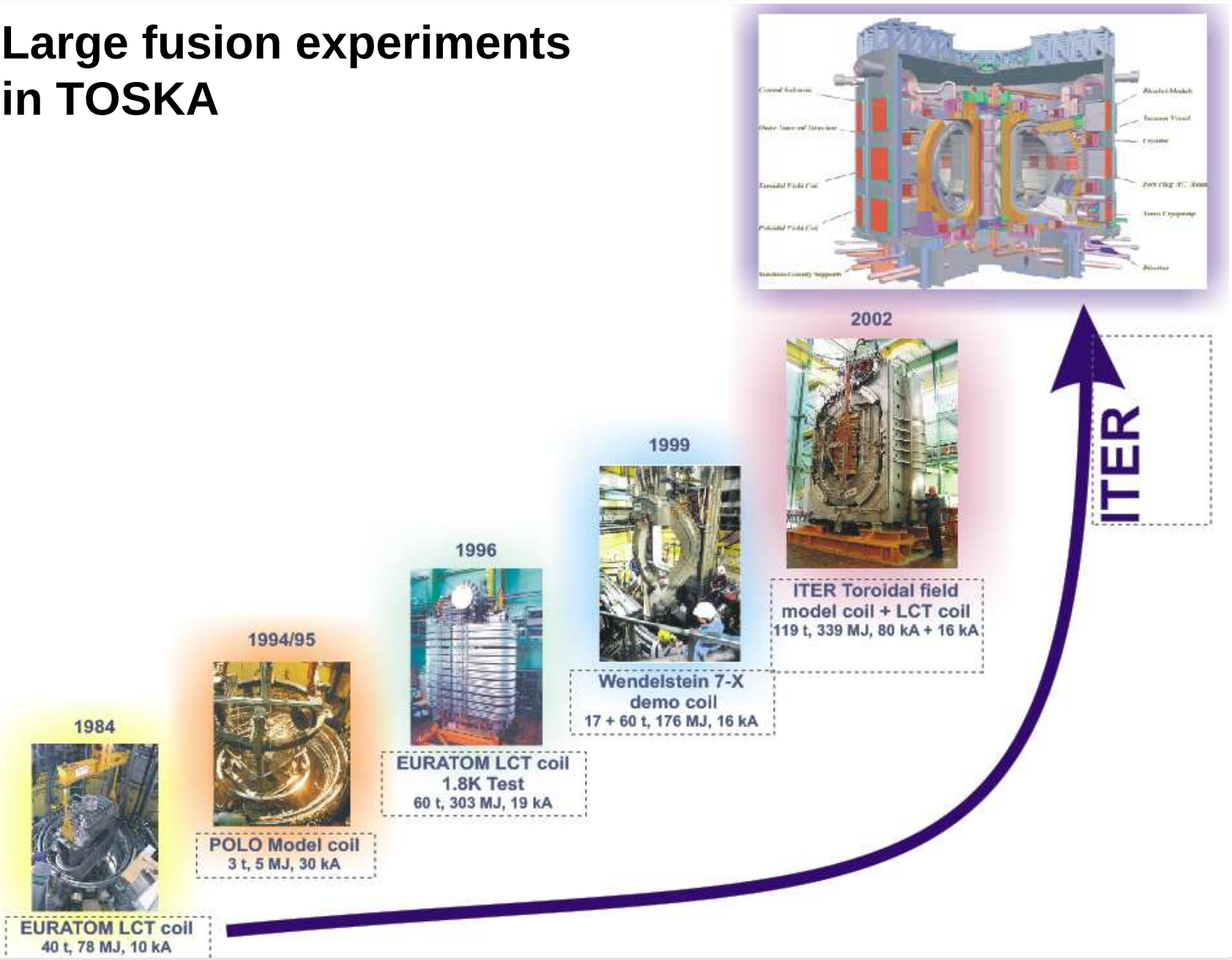
- three power supplies (20 kA, 30 kA & 50 kA)
  (connected 30 kA & 50 kA power supplies → 80 kA)
- switching circuits 30 kA & 80 kA

Cryogenics

- Refrigerator 2000 W (T = 3.5 – 4.5 K)
- Refrigerator 300 W (T = 1.8 – 4.5 K)
- Cooling circuits with supercritical He
  - 300 g/s (T = 3.5 - 4.5 K)
  - 50 g/s (T = 1.5 - 4.5 K)

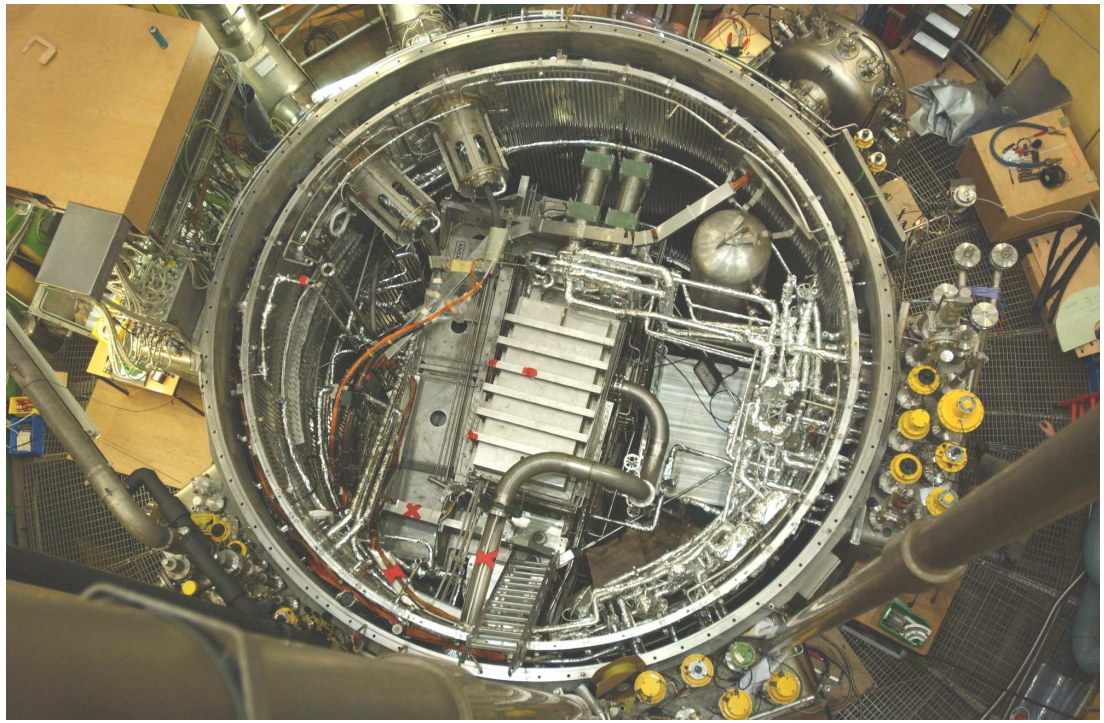


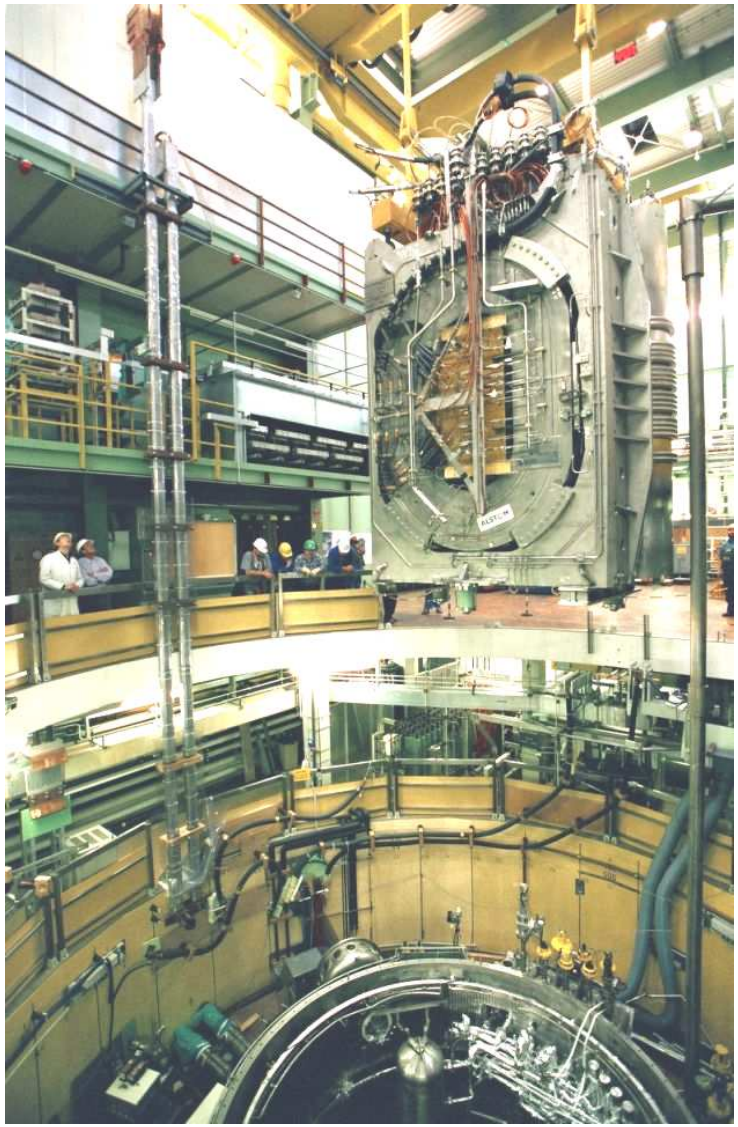
Large fusion experiments in TOSKA



ITER TFMC Test

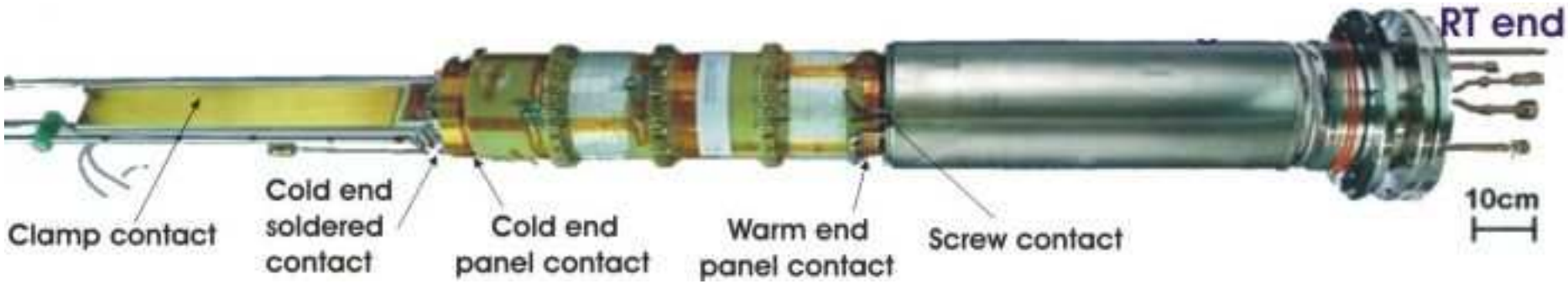
Test of ITER model coil
to validate the design concept



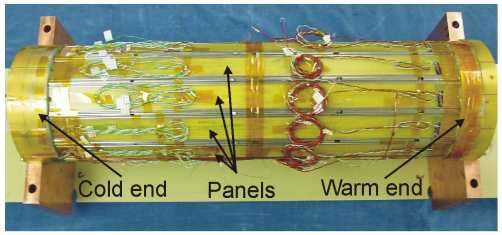


70 kA HTS Current Lead Demonstrator for ITER

The **H**igh **T**emperature **S**uperconductor (HTS) Current Lead consists of three parts:



Connection to busbar	**HTS module (Bi - 2223/AgAu)**	**Copper heat exchanger (HEX)**
4.5 K	**4.5 K - 65 K**	**65 K - 300 K**
Cooled by sc busbar He-flow@4.5 K	HTS module only conduction cooled	Cooling of HEX with 50 K He (design value)

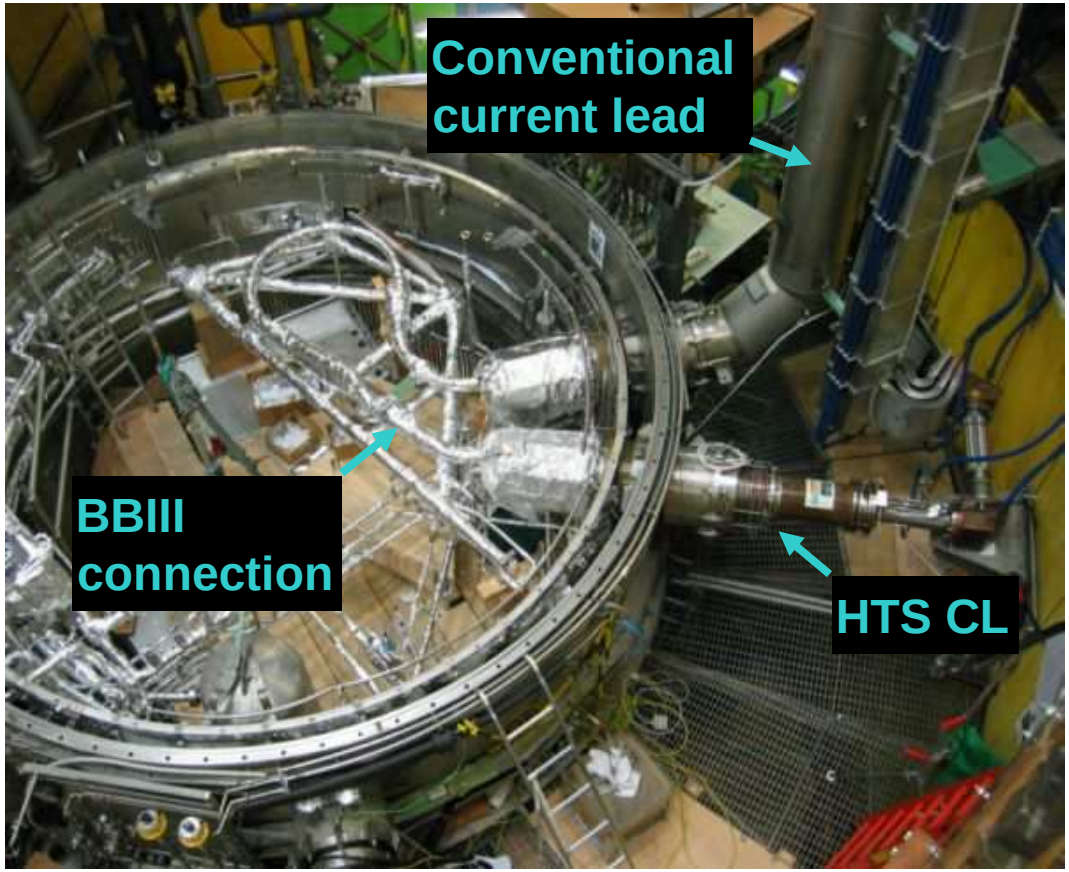


Assembly and installation of 70 kA HTS current lead

Assembled and ready for installation

Install Detail

HTS CL installed in B300 of TOSKA facility



High Voltage Area of Expertise

Expertise in cryogenic high voltage testing

- of superconductors in power applications e.g. low temperature high voltage testing up to 200 kV
- for fusion

To support ITER

- high voltage tests on TFMC
- transient voltage calculations for TF coil
- transient voltage calculations for PF coil
- definition of coil test procedures

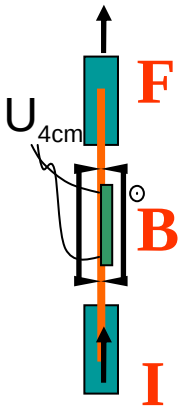
Details ⇒ presentation of Stefan Fink

Mechanical characterization of fusion relevant materials in cryogenic environment

Numerous samples were measured in FZK in the **CRYO**genic **MA**terial test facility **K**arlsruhe **CRYOMAK** with respect to tensile, fracture toughness, fatigue crack growth rate, fatigue life
including ready component tests with Mock-ups

TF-Mock-up built by CEA tested in CRYOMAK

In addition FBI facility to characterize superconductor strands od cables



F ≤ 100 kN
B ≤ 14 T
I ≤ 10 kA

Details ⇒ presentation of Klaus Weiss

W7-X coil testing in TOSKA

- Stellerator principle
- W7-X coil testing in Saclay
- TOSKA refurbishment
- HTS current leads for W7-X

In 2006 politicians in German were concerned that the construction of the stellerator W7-X may be delayed in case of a problem in the W7-X coil testing enviroment in Saclay.

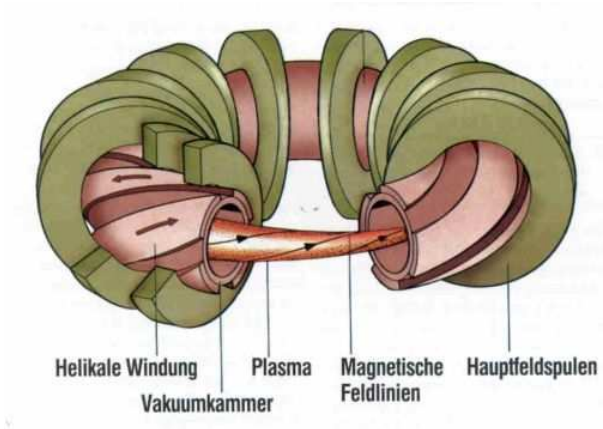
As a consequence it was strongly suggested that TOSKA should be refurbished for W7-X coil testing as a back up of Saclay.

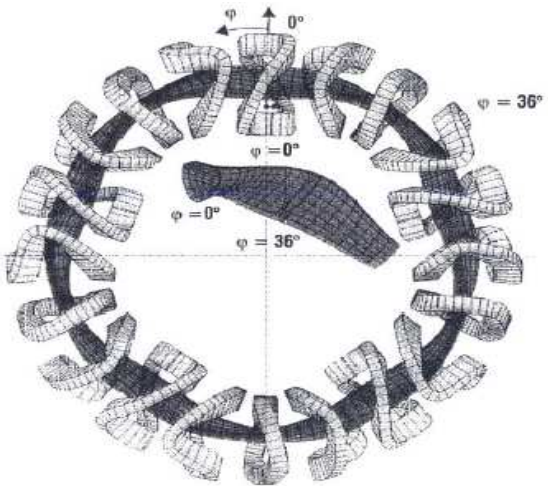
In August 2007 a contract was signed

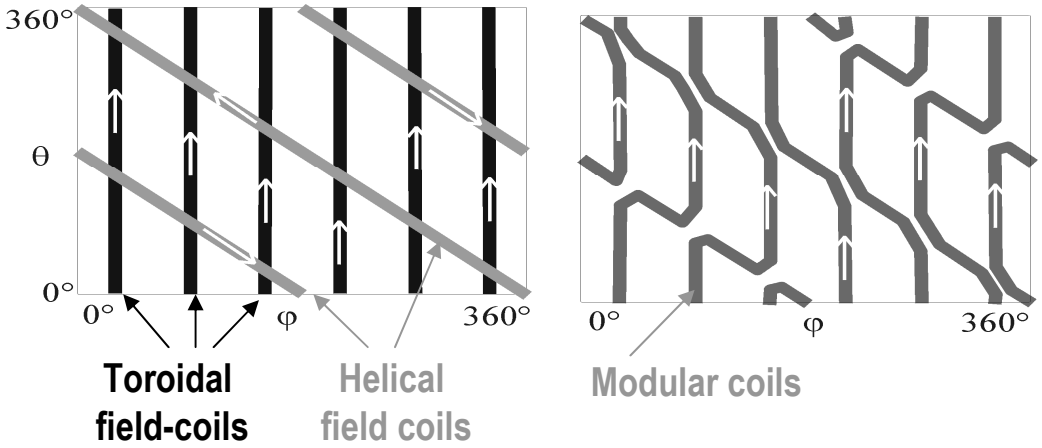
for refurbishing TOSKA for W7-X coil testing.

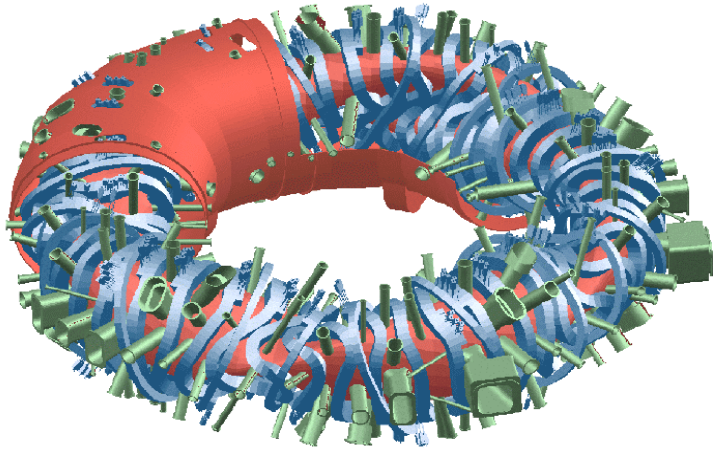
From Stellerator to a "modular concept" → W 7-X

Toroidal fiel coils and helical coils are integrated to non planar modular coils





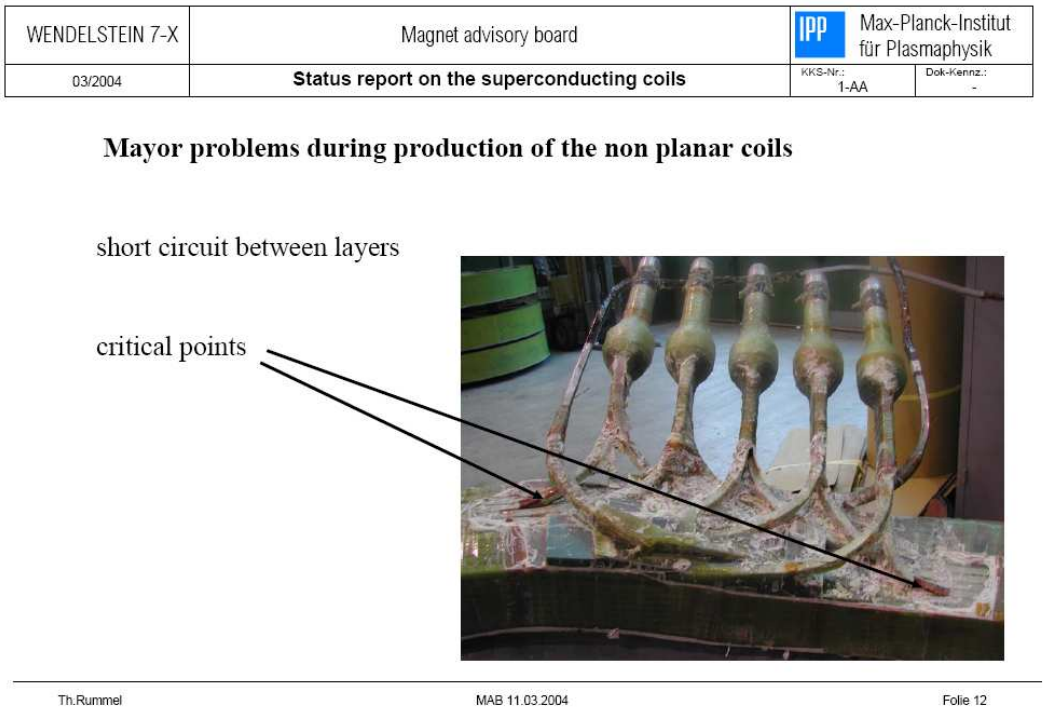




H.S. Bosch, 9.5.2006, HGF – Siemens Fusions-Workshop, Karlsruhe

W7-X coil testing in Saclay

W7-X coils are tested in a dedicated test facility in CEA - Saclay.



WENDELSTEIN 7-X	Magnet advisory board	IPP Max-Planck-Institut für Plasmaphysik	
03/2004	**Status report on the superconducting coils**	KKS-Nr.: 1-AA	Dok-Kennz.: -

Mayor problems during production of the non planar coils

short circuit between layers

critical points

Th.Rummel MAB 11.03.2004 Folie 12

In several cases problems were found.
Main problems are:

- high voltage faults (Paschen tightness)
- vacuum leaks

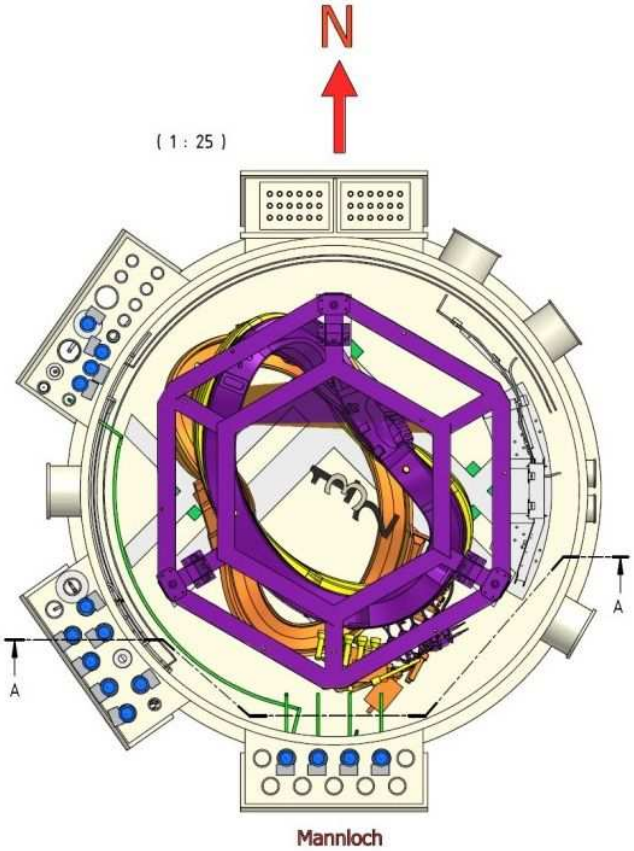
Therefore several coils have to be retested

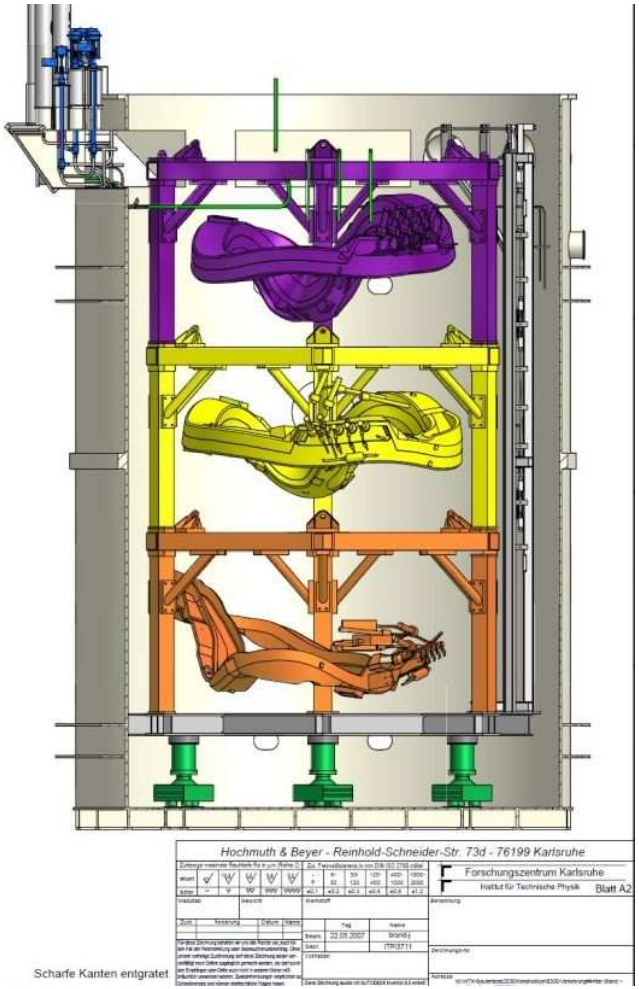
Details ⇒ presentations of Markus Borlein

Coil frames and installation in TOSKA

CEA version

Version planned for TOSKA: 3 coils installed in parallel to optimze cool down + warm up time





TOSKA refurbishment

An enormous amount of work ended in Nov 2008 with an "TOSKA ready for testing".
However, Saclay had an optimal testing period and politics decided to stop this activity in TOSKA

Current Leads for W7-X

W7-X needs 14 current leads
with a maximum current of 18.2 kA
installed in upside down position.

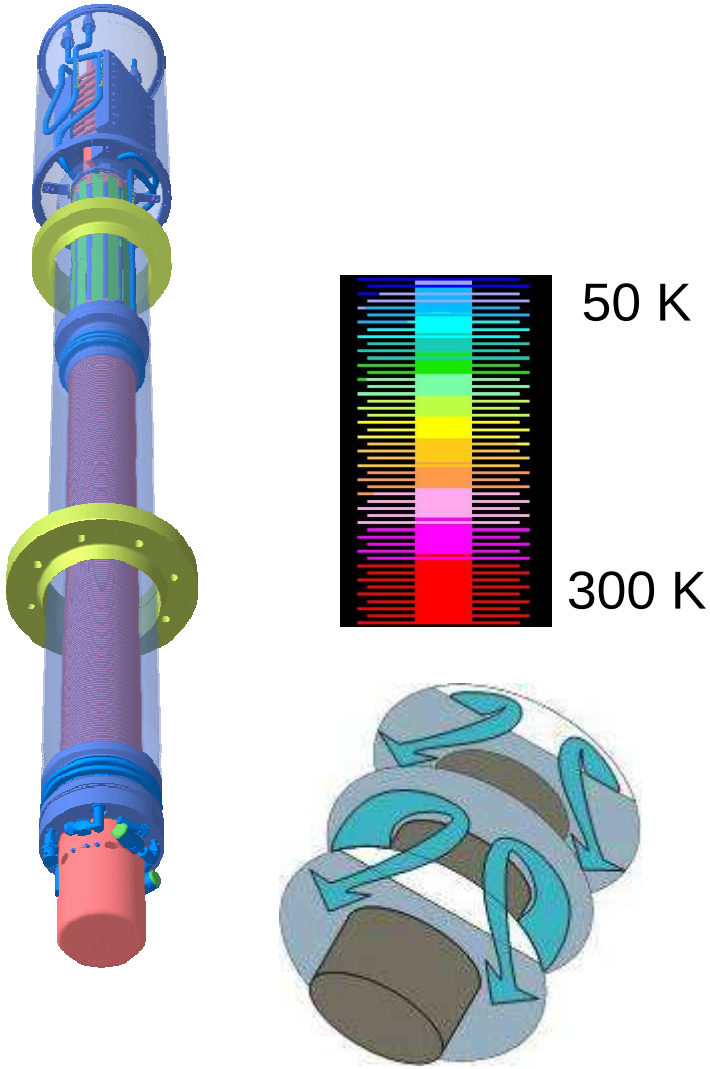
FZK will design, construct and build
these current leads in an HTS version.

The use of HTS material mitigates the
"upside down problem"

- Density difference He 4.4K/300K: factor 126
- Density difference He 50 K/300K: factor 8

HTS CL solve upside down problem
HTS CL lower the load on the cryo system

A contract between IPP and FZK was signed.
The current lead design is progressing.



Details of HTS current leads ⇒ Rainer Wesche

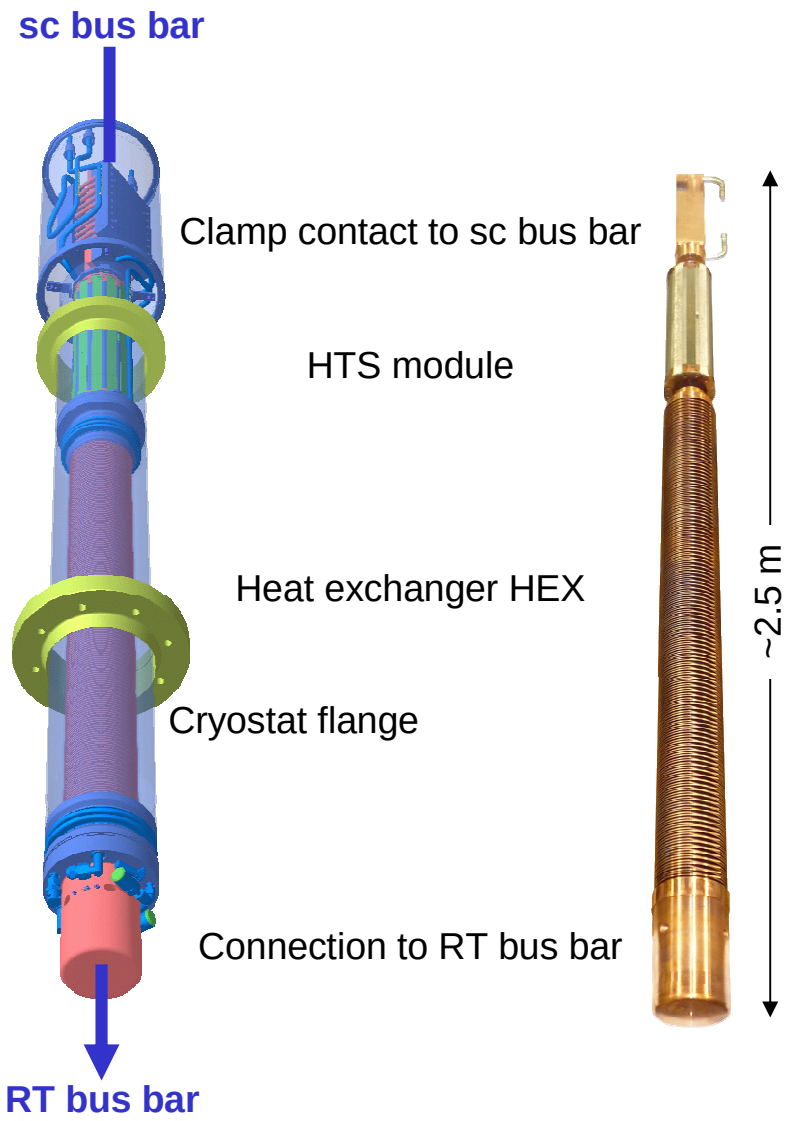
HTS Current Leads for W7-X - General Parameters

Design features

- Upside-down orientation
- Clamp contact with Nb_3Sn inserts to sc bus bar
- HTS module (Bi-2223 stacks), conduction cooled
- Meander fin type heat exchanger (50 K He)
- Paschen tight HV insulation

Main parameters

Parameter	Value
Number of current circuits of non planar/planar coils	5/2 (10 coils in series each)
Number of current leads	14
Maximum design current	18.2 kA
Nominal current	14 kA
Max. voltage to ground (test voltage)	±13 kV
Orientation	cold end at top
Overall length	2500 mm
Max. diameter	200 mm
Basic operation schedule	steady state for 4-5 days



HTS Current Leads for W7-X - HTS module

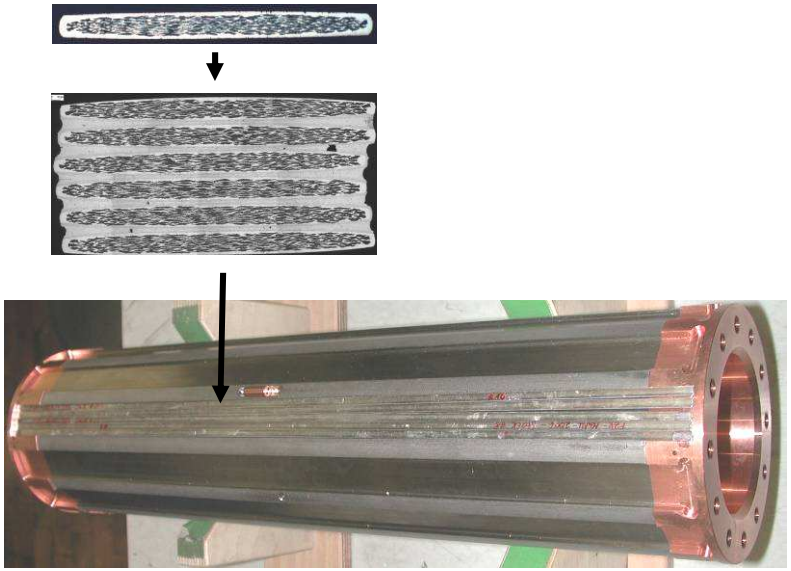
Design features

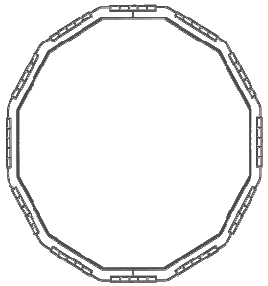
- Bi-2223
- AgAu matrix (low thermal conductivity)
- AgAuMg outer sheath (high mechanical strength)
- Bi-2223 HTS tapes soldered to stacks
- Stacks soldered to a stainless steel structure with Cu ends
- SS structure reduces thermal runaway in case of loss of coolant or quench

Tape

Stack

SS structure with Cu ends





Main parameters of HTS tape

Parameter	Value
Matrix / sheath material	AgAu/AgAuMg
Ic (77 K, s.f.)	>110 A
Width	3.9 mm
Thickness	0.23 mm
Filament number	121
Sc filling factor	39.8% (av.)
Tensile strength at RT (<5% Ic-degradation)	>95 MPa
Tensile strength at 77 K (<5% Ic-degradation)	>120 MPa

Current Leads for JT-60SA

Broader Approach

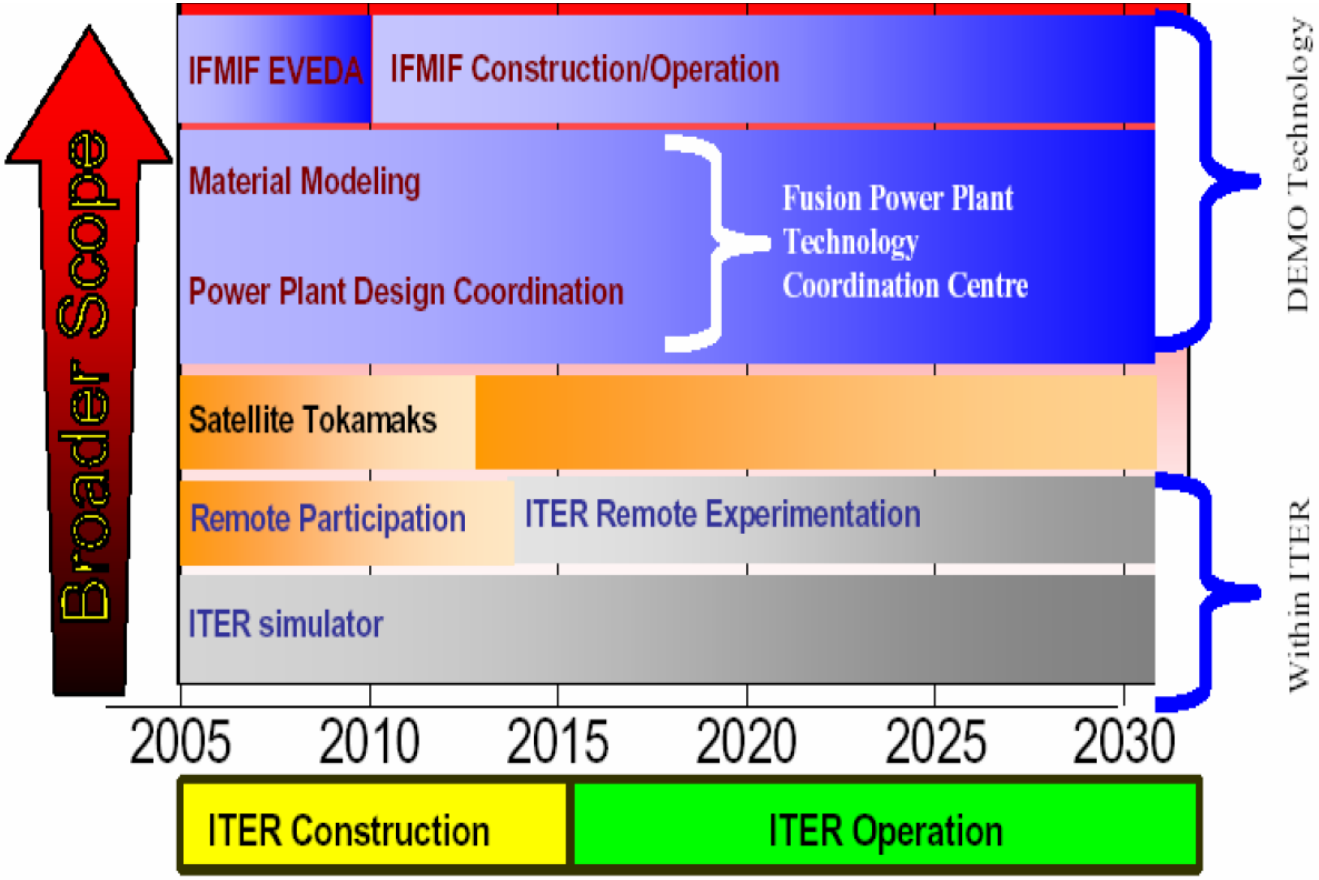
JT-60 -> JT-60SA

TF coils built by EU (major contributions from France and Italy)

Superconducting current leads for JT-60 SA

Broader Approach

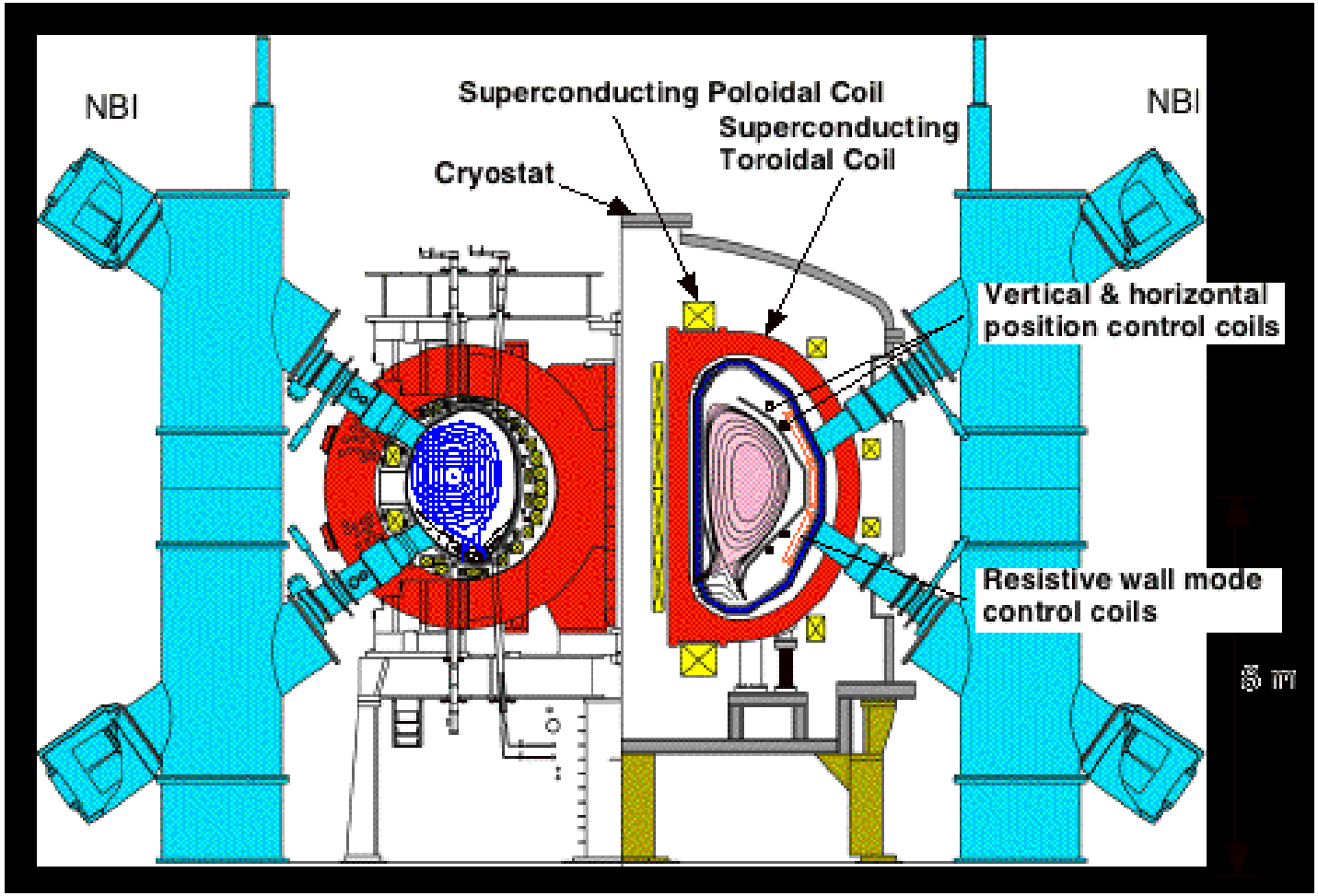
During ITER location negotiation Japan & EU agreed to have a broader approach



A Schematic view of the elements of the broader scope

JT-60 ⇒ JT-60SA

Japanese Tokamak JT-60 shall be equipped with superconducting coils



TF coils will be built by EU

Conceptual Design Report on the Satellite Tokamak JT-60SA

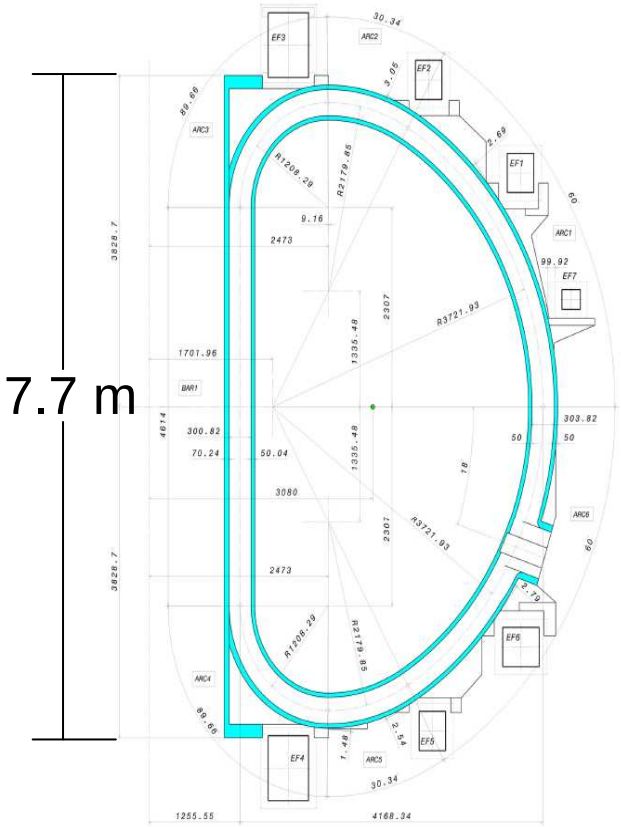
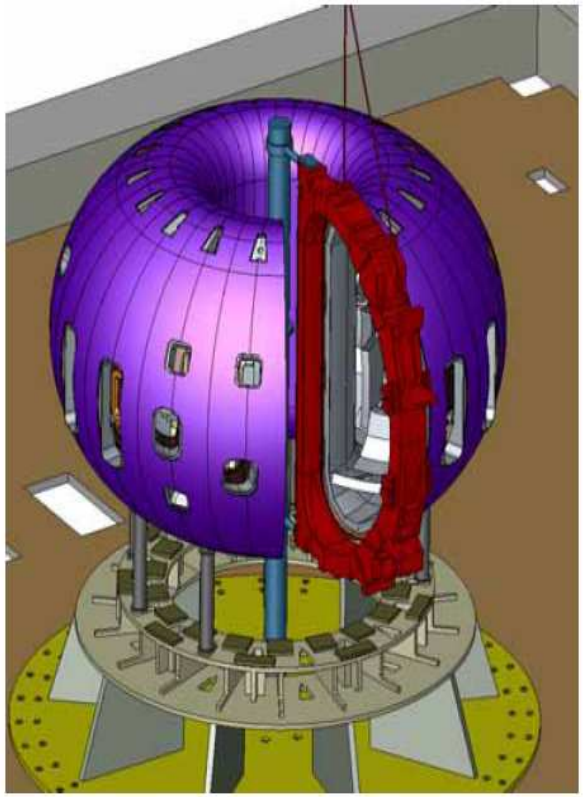
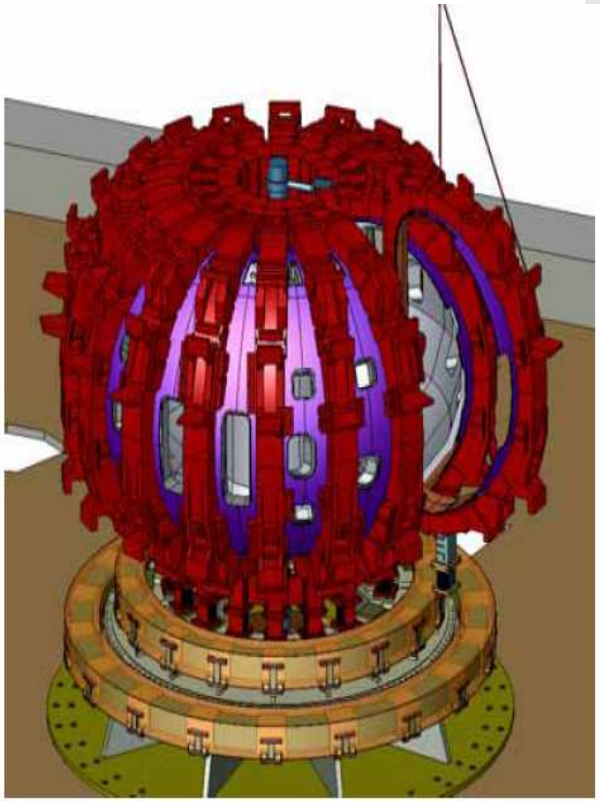


Fig. 3.1.2.2-4 Elevation view of a TF coil cross section

3. Plant Description Sec.3.1.2 Page 11



[Step 13] TFC lifting up



[Step 14] Adjusting 18-TFC

More details ⇒ Christophe Portafaix

JT-60SA: ITP/FZK contribution: Current Leads

ITP shall design, construct and built the current leads for JT-60SA.

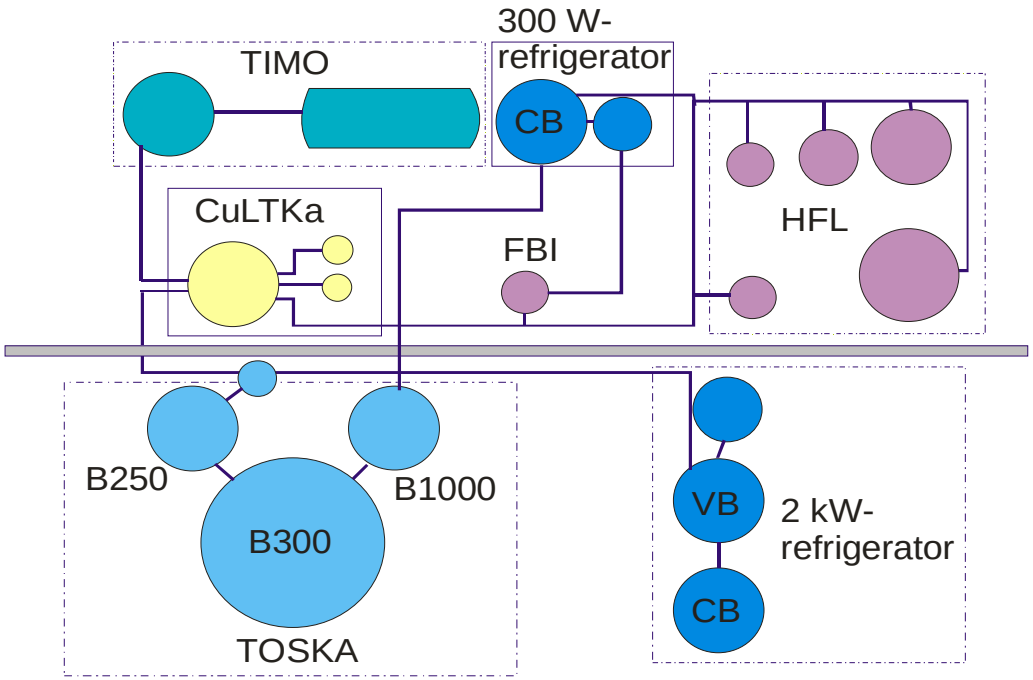
The design of the W7-X current leads will be adapted to the needs of JT-60SA.

First parameter for current leads:

Coil	Number	Current
TF	6	25.7 kA
CS	6	20 kA
EF	14	20 kA

Current Lead Test facility CuLTKA

To test the current leads for W7-X & JT-60SA the
Current **L**ead **T**est facility **Ka**rlsruhe
will be installed in the hall next to TOSKA.



H. Neumann | CuLTKa Cryo-Kick-Off Meeting | 03.04.2007

CuLTKA integration has to preserve cryo linking for other experiments (e.g. TIMO).
CuLTKa is under construction (valve boxes, control cryostat & transfer lines, ...)

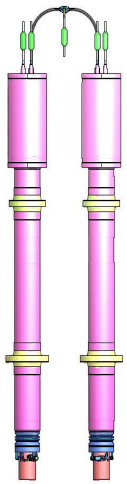
Current Lead test facility CuLTKa

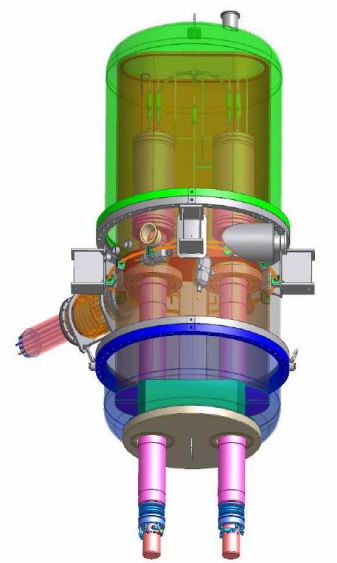
A location for current lead testing was identified next to the TOSKA hall, but has to be cleared first.

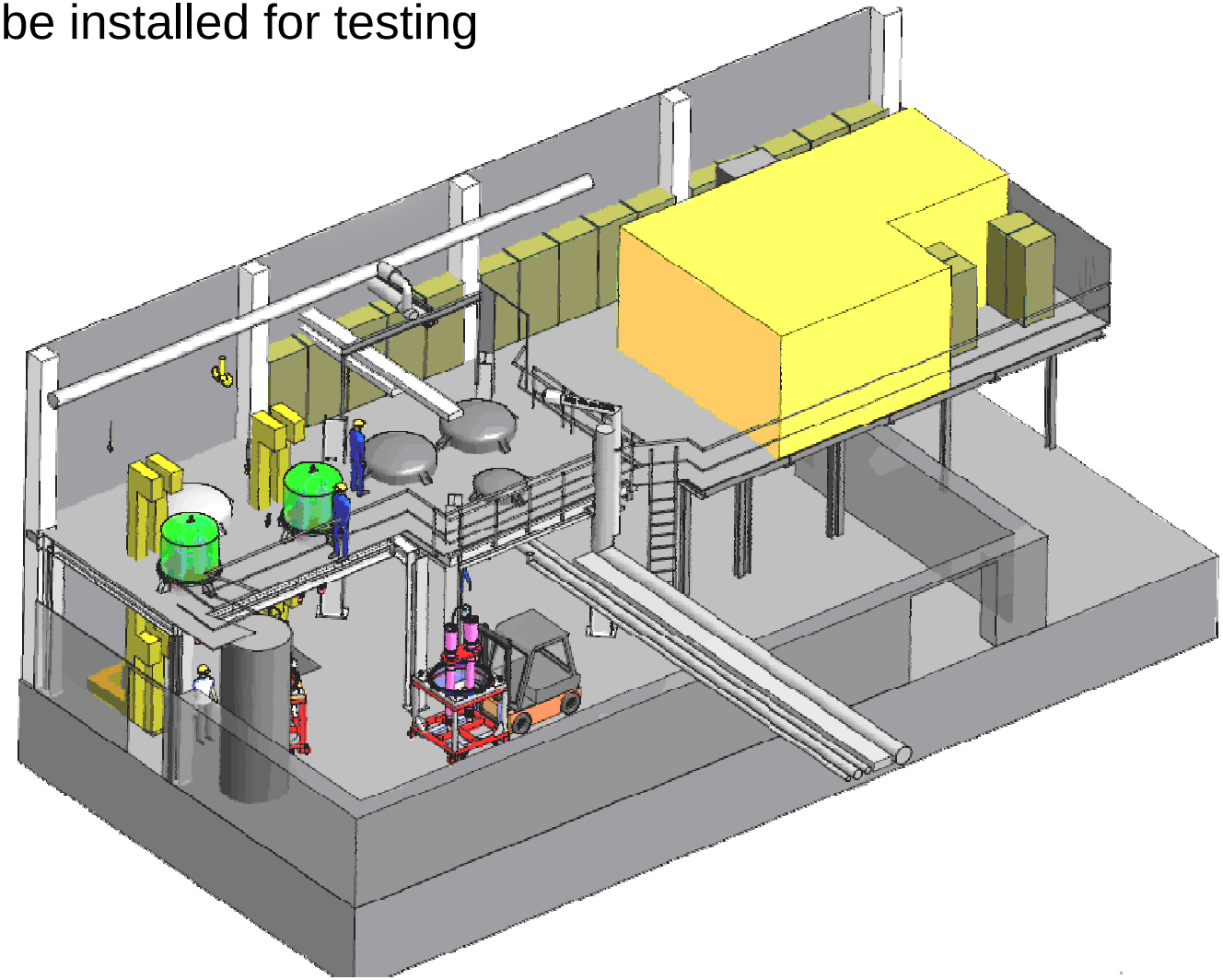
Here the **Cu**rrent **L**ead **T**est facility **Ka**rlsruhe (**CuLTKa**) will be located

Current Lead test facility CuLTKa

CAD view of facility with two test cryostats
Pairs of current leads will be installed for testing



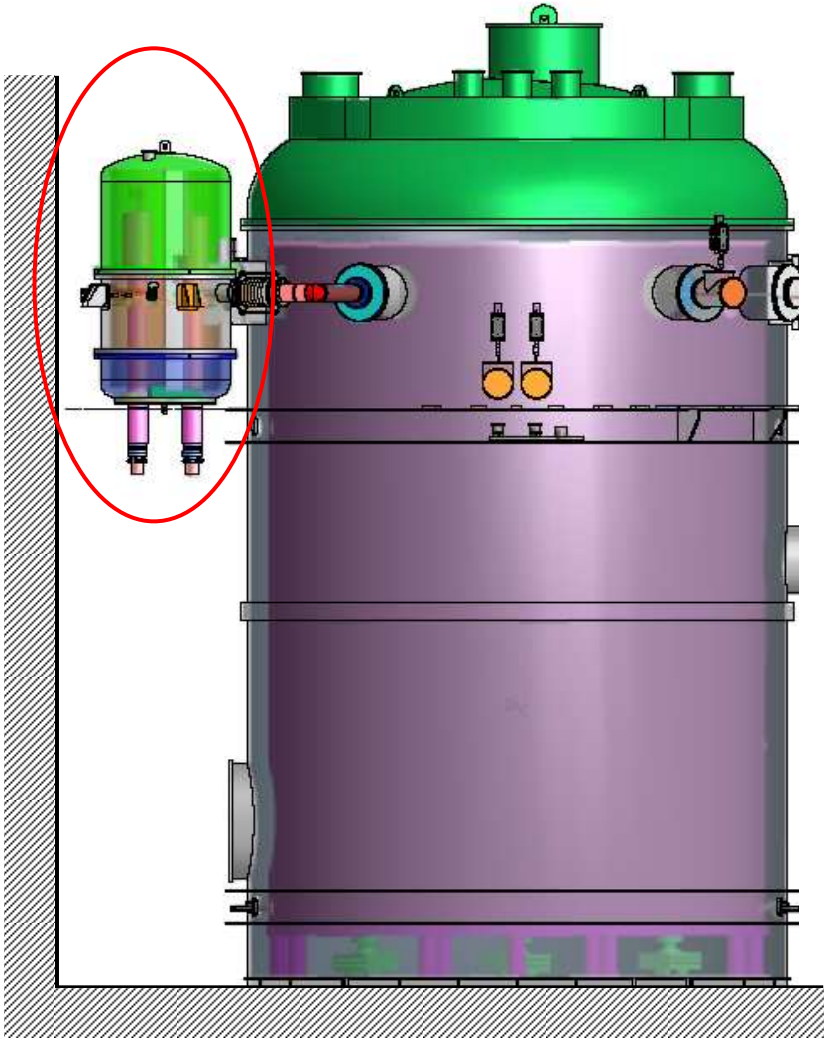




Current Lead Prototype Test using TOSKA

To allow a prototype testing before CuLTKa is completed, the prototype tests will be performed using TOSKA.

The test cryostat of CuLTKa will be flanged on the side of the TOSKA cryostat.



Summary

After upgrading the TOSKA facility the team currently concentrates on

- Construction of 2 prototype HTS current leads
- Construction of 14 HTS current leads for W7-X (18.2 kA)
- Construction of 26 HTS current leads for JT-60SA (20kA / 25.7kA)
- Construction of a dedicated current lead test facility CuLTKa
- Testing of these HTS current leads

In addition

- support of ITER by cryogenic material testing in CRYOMAK
- support of ITER in high voltage field
- basic development for high current HTS fusion conductor is started