

SC Detector Magnets for Future Colliders
& Physics Experiments

Superconducting Technology in Toshiba

TOSHIBA

Toshiba Energy Systems & Solutions Corporation

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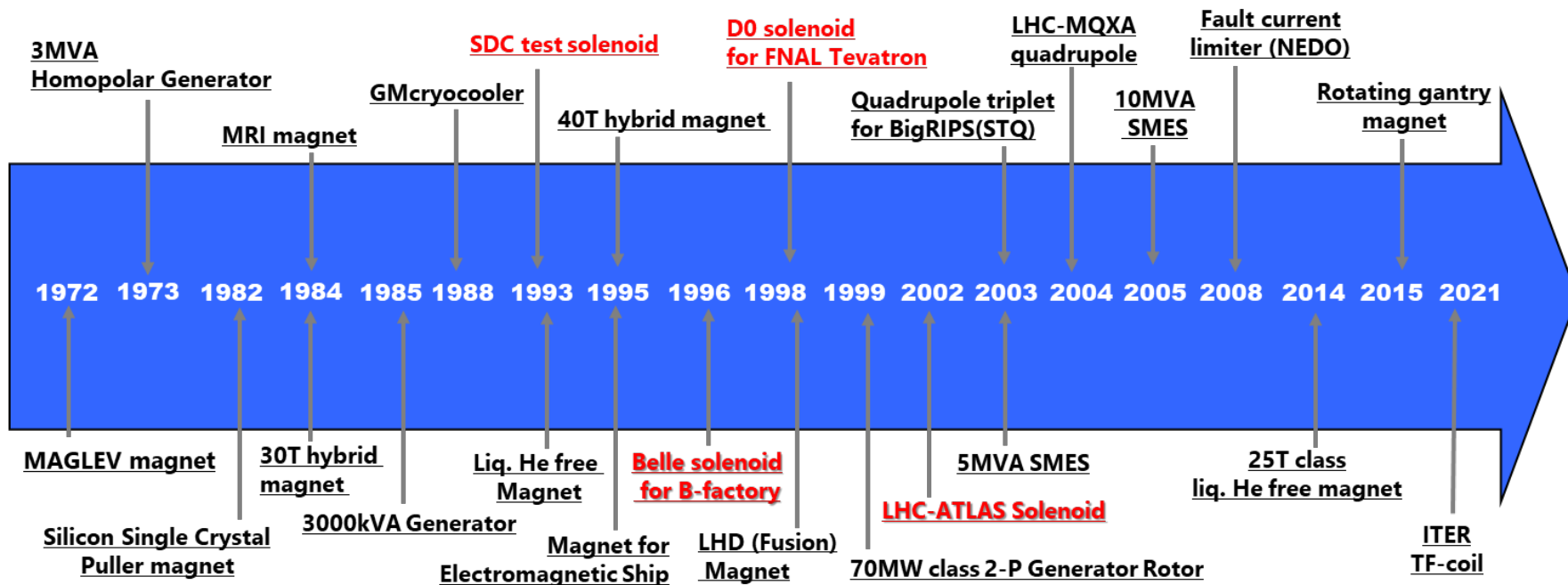
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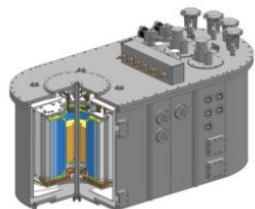
01

The History of Superconducting Applications

01-1. The History of Superconducting Applications



➤ Basic Science



High Magnetic Field

➤ Power/Energy

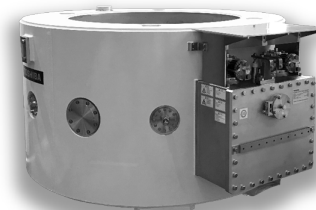


Generator



ITER

➤ Industry/Medical



Si Crystal Puller



Ion Therapy

02

Detector Magnets

02-1. Detector Solenoid Magnet for Accelerator

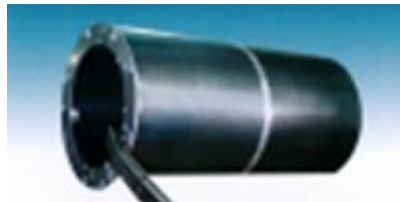
Detector	Accelerator	Year	Coil ID (m)	Coil L (m)	B0 (T)	Stored E (MJ)	Current (kA)	Notes
SDC	SSC	1993	3.7	1.9	1.5	12	8.0	Test only
BELLE	B-factory	1996	3.6	3.9	1.5	35	4.0	
D0	Tevatron	1998	1.1	2.6	2.0	5	4.7	
ATLAS	LHC	2002	2.5	5.3	2.0	39	7.6	

SDC (SSC: R&D)
for KEK



Belle for KEK B Factory

D0 for FNAL
Tevatron



ATLAS for LHC

1990

1995

2000

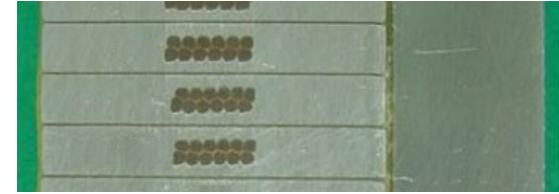
2005

02-2. Detector Magnet "BELLE"

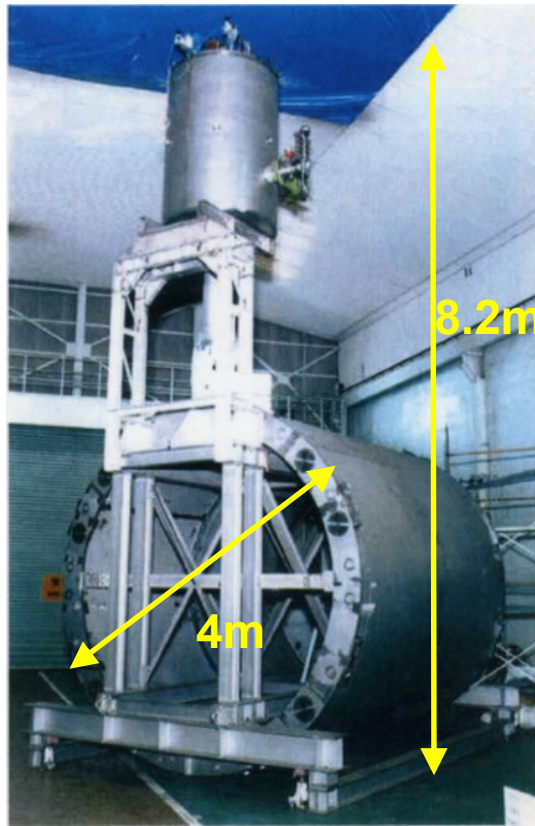
Toshiba manufactured **BELLE** Solenoid Magnet, including Chimney and Cryostat.

BELLE has 3.6 meters inner diameter coil with Aluminum stabilized conductor.

And also indirect cooling system was adopted. Instead of liq. He bath cooling.



Aluminum stabilized NbTi conductor



BELLE Solenoid Magnet

Main Parameters of BELLE Solenoid Magnet

Central Field	T	1.5
Stored Energy	MJ	37
Coil ID	m	3.6
Coil Length	m	3.9
Current	kA	4.2
Conductor	mm	3×33 NbTi / Cu / Al
Cryostat OD	m	4.0
Cryostat Length	m	4.4
Cryostat material	-	SUS304
Magnet Weight	ton	20

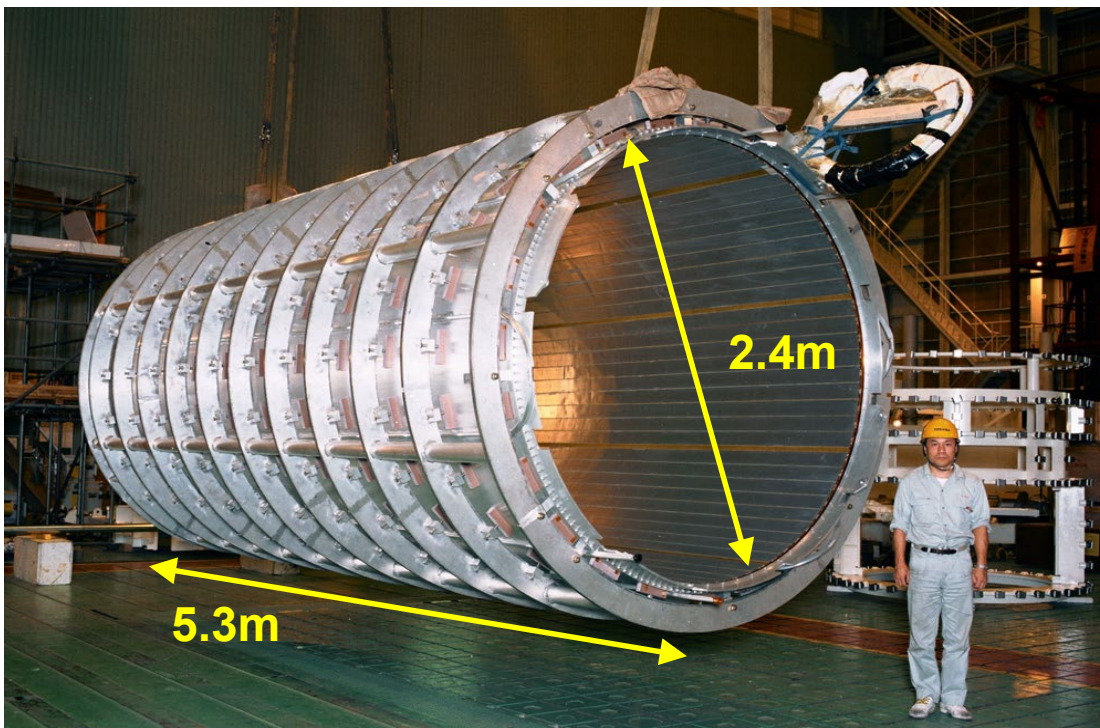
02-3. Detector Magnet "ATLAS"

ATLAS solenoid coil is 5.3m length with 2.4m inner diameter, and central field is 2.0T.

Aluminum stabilized conductor and indirect cooling system are also adopted. The solenoid coil consists of 4 winding-blocks and 3 conductor welding joints.

Main Parameters of the ATLAS Solenoid

Central Field	T	2.0
Stored Energy	MJ	39
Coil ID	m	2.4
Coil Length	m	5.3
Current	kA	7.6
Conductor	m m	4.3×30 NbTi / Cu / Al
Vacuum Shell Length	m	6.8
Cold mass Weight	ton	6.0



ATLAS Solenoid Coil

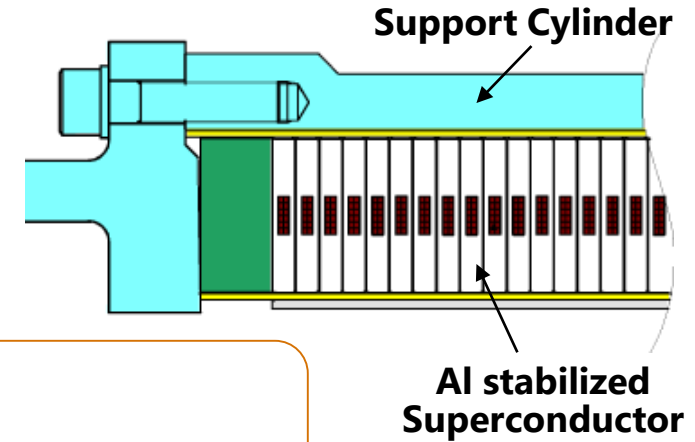
03

Key Technologies for Detector Magnet

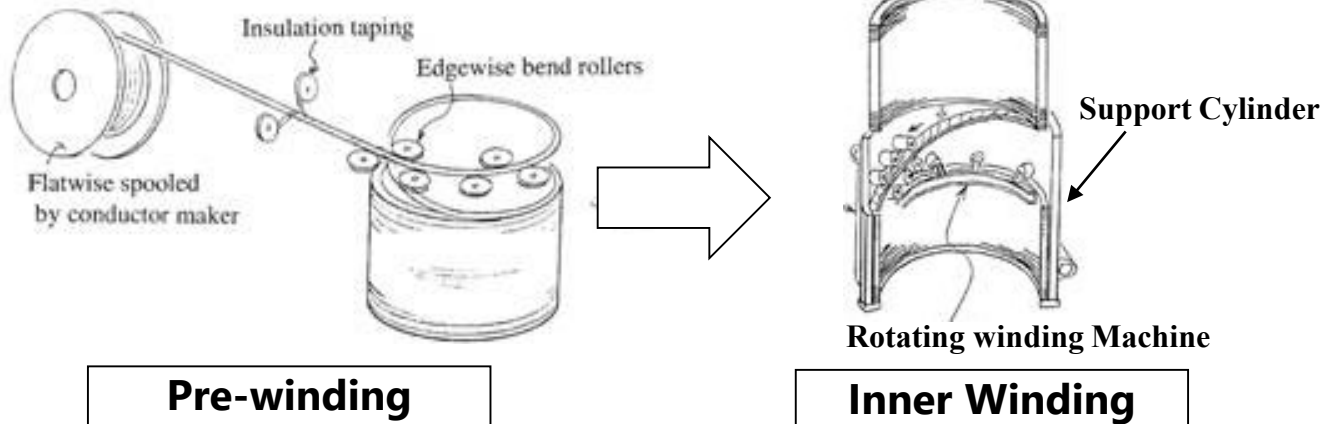
03-1. Key technologies for the Coil Fabrication

I. Inner Winding Method

Al stabilized superconductors are cooled by Helium pipe welded on the support cylinder. Therefore the outer surface of coil should be well contacted to the support cylinder.



Process of Inner Winding Method



II. Welding Conductor Joint

The conductor joints were made by welding for corresponding to 1 turn. (7.6m for ATLAS)
Its typical resistance achieved $<0.5\text{m}\Omega/\text{joint}$ without I_c degradation.



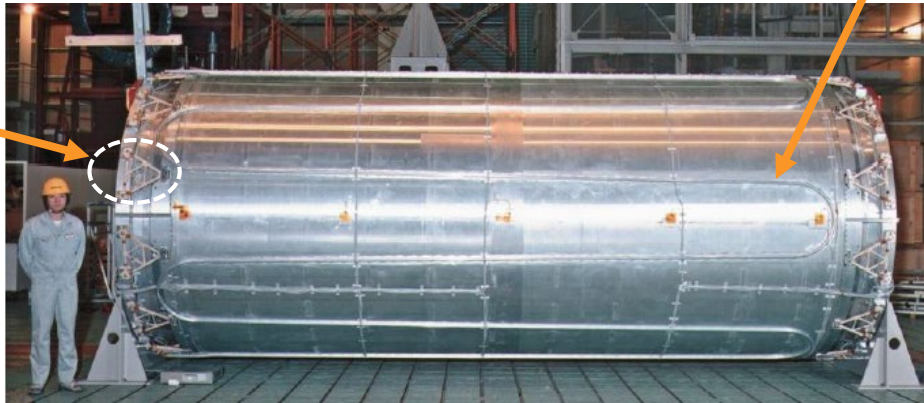
Conductor joint sample

03-2. Key technologies for Magnet Assemble

I. Indirect cooling system

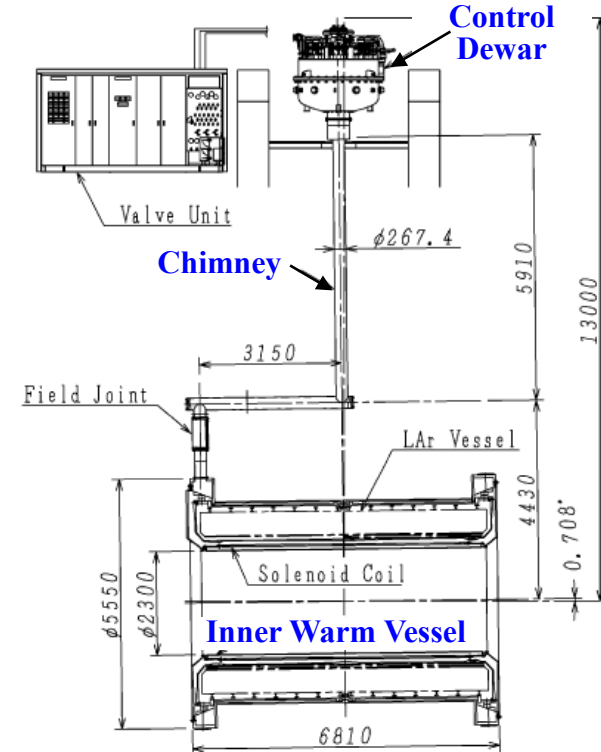
Welding the liquid helium pipe to the support cylinder. Gas helium are re-condensed at the Control Dewar, and circulating by thermo-siphon effect.

Triangle Support



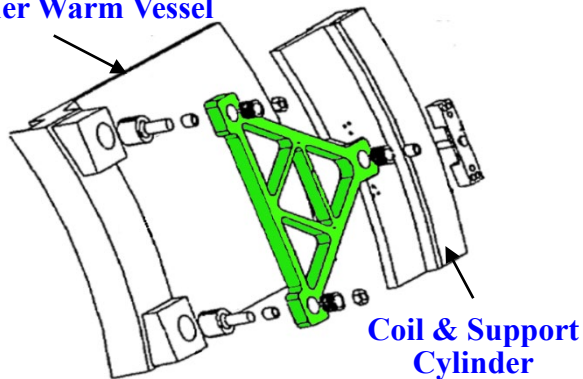
Cold mass structure of ATLAS Solenoid

LHe Piping



Indirect Cooling System of ATLAS

Inner Warm Vessel



Coil & Support Cylinder

II. Triangle Alignment Support

Mechanical supports which have a sliding and rotate mechanism provide to allow free thermal contraction. The solenoid was aligned within a tolerance of 1mm by using this eccentric function.

Triangle Support Fabrication

04

Reference Technologies for Future Detector Magnets

04-1. Small Cryocooler Cooling System

Superconducting Dipole Magnet for SAMURAI Spectrometer for RIKEN RI Beam Factory

- Small cryocoolers are installed for re-condensing the Helium, instead of large cooling systems.

	Helium Vessel	20K Shield	80K Shield	Power Lead
Type of Cryocooler	GM-JT	GM	GM	GM
No. of pcs.	2	4	4	2
Cooling capacity	2.5W @4.3K	4.2W @12K	100W @80K	54W @40K



H-Type Dipole Magnet for SAMURAI

Main Parameters of the SAMURAI Dipole Magnet

Type	-	H-Type Dipole
Central Filed	T	3.1
Stored E	MJ	27.4
Coil ID	m	2.4
Coil Length	m	0.2
Current	A	563
Conductor	mm	Φ3.0 / NbTi-Cu
Core Weight	ton	570

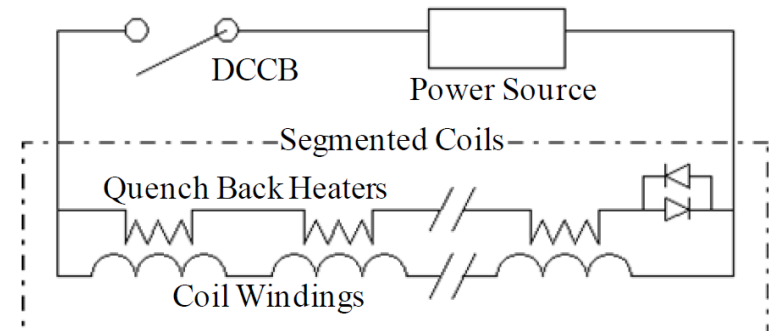
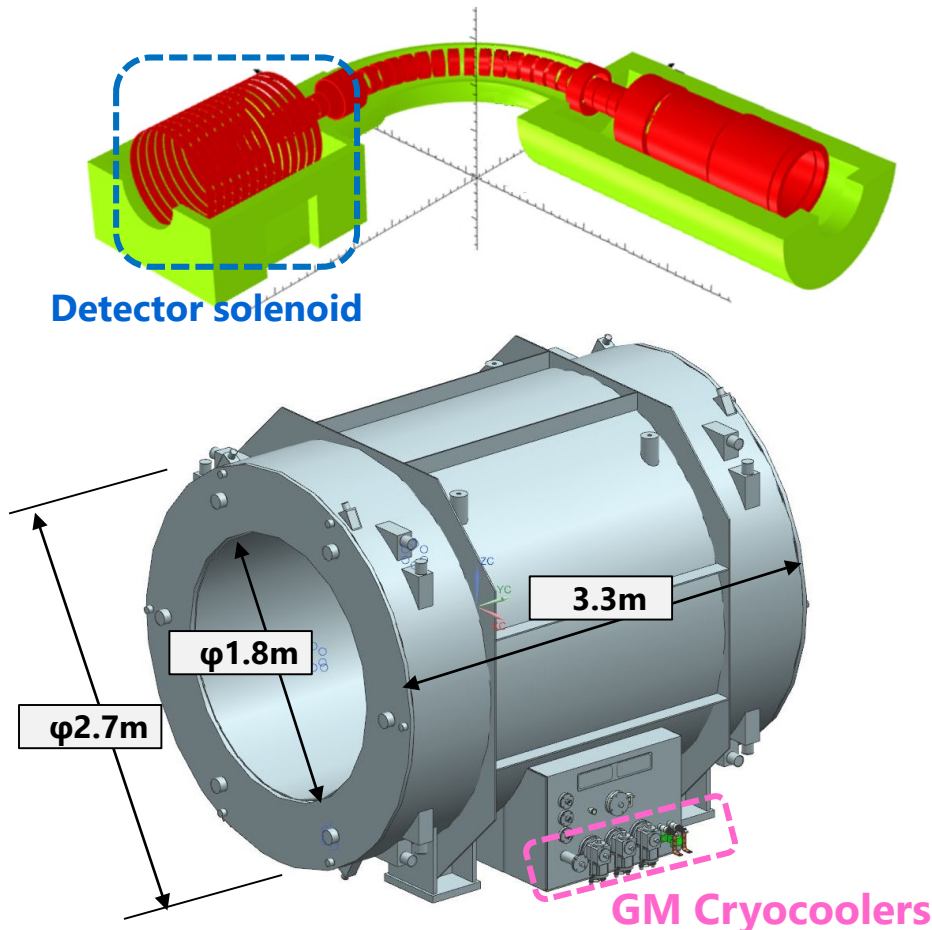
04-2. Liquid Helium Free Magnet

Superconducting detector solenoid for COMET project(KEK).

- A liq. He-free type magnet using conduction cooling system by small GM cryocoolers.
- Quench protection system using the quench back heaters is adopted.

Main Parameters of the COMET Detector Magnet

Central Filed	T	1.0
Stored E	MJ	4.2
Coil ID	m	2.1
Coil Length	m	2.9
Current	A	189
Conductor	mm	Φ1.2/NbTi-Cu
Cryocooler	W	1.5W @4.2K ×3 35W @50K ×3



COMET Detector Magnet

Quench protection circuit

05

Recent Applications

05-1. High Field Magnets

Toshiba supplied world top class high field magnets for scientific researches.

It has been contributing to many of material science achievements.



25T class Liq. He free Hybrid Magnet for Tohoku univ. (2014)

- LTS+HTS conductor coil w/o Liq.He cooling.

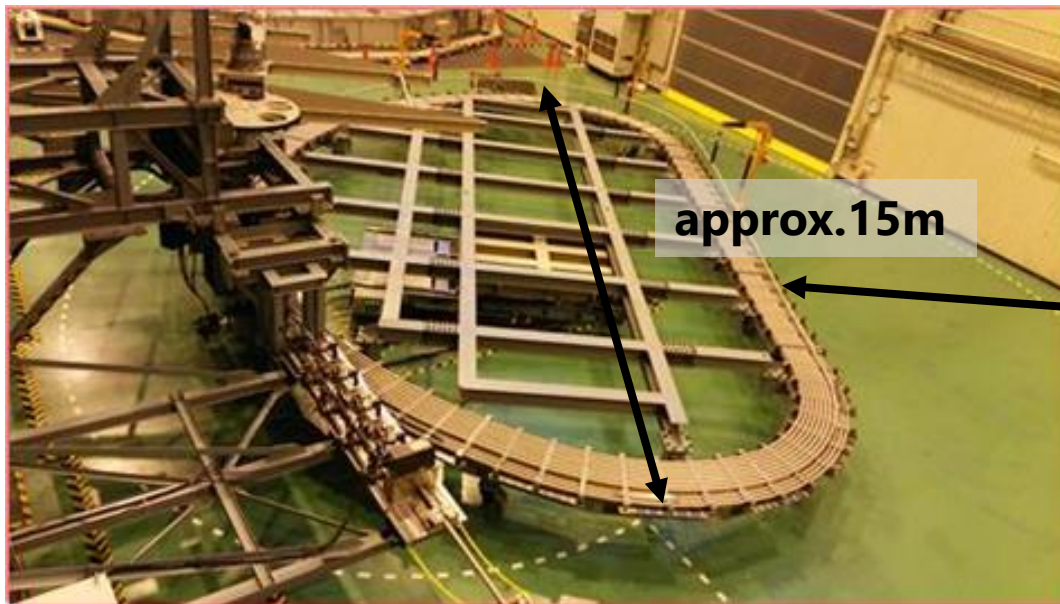


40T Hybrid Magnet (1995)

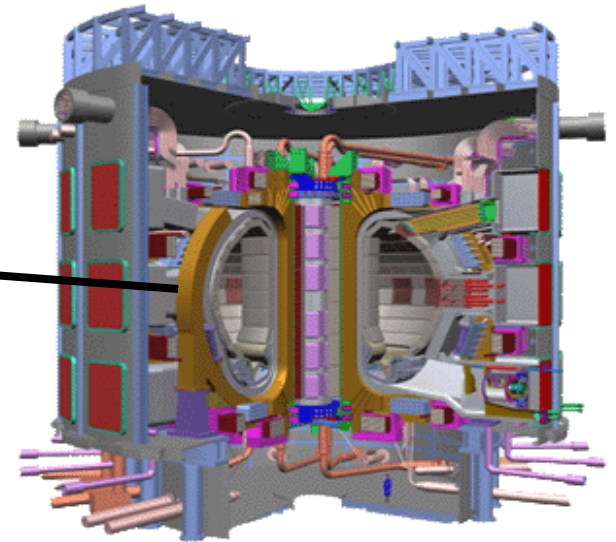
- LTS+Copper conductor coil with Liq.He cooling.

05-2. Large Scale Coil for Fusion Reactor

Toshiba manufactured TF (Toroidal Field) Coils for ITER (International Thermonuclear Experimental Reactor).



D-shaped double pancake coil of ITER-TFC and its winding tools

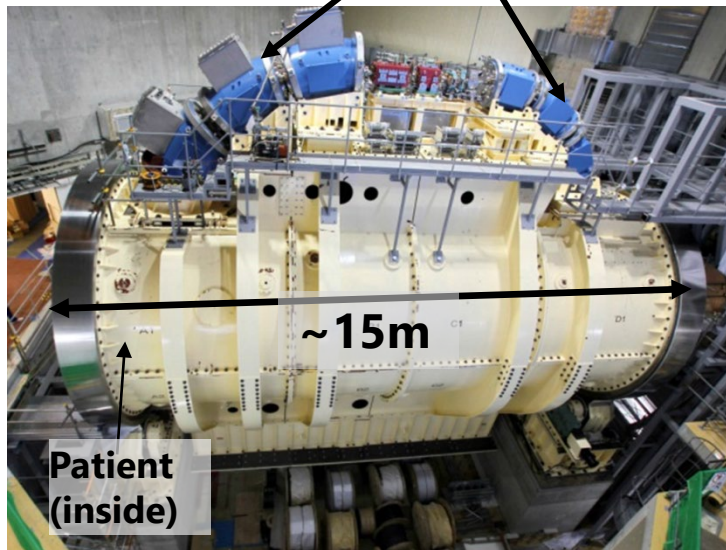


International Thermonuclear Experimental Reactor (ITER)

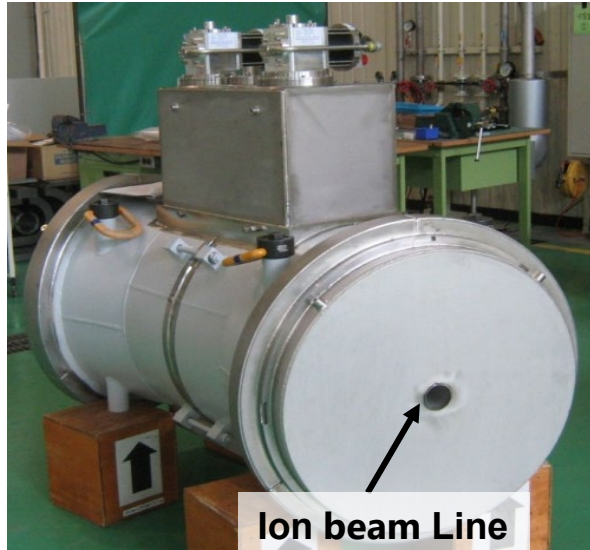
05-3. Liq.He free Magnet for Heavy Ion therapy

Toshiba developed compact superconducting magnets mounted on rotating gantry for heavy ion radiotherapy, which rotates the irradiation port in a 360-degree circle and reduces both patient stress and treatment time.

Magnets (Blue ones)



Rotating gantry



Liq. He free magnet for rotating gantry



Saddle-shaped and curved coil manufactured by 3D winding technology

Acknowledgement

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□ KEK

□ FNAL

□ Furukawa Electric Co., LTd.

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development of Detector Solenoid Technologies with
Toshiba.**

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