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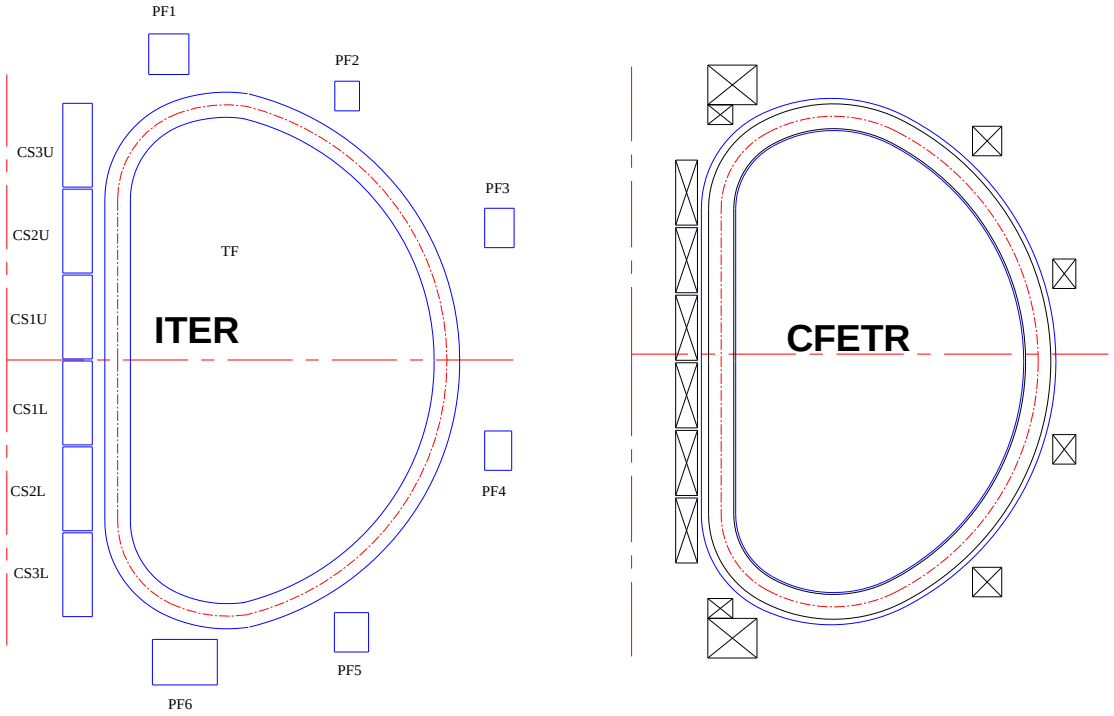
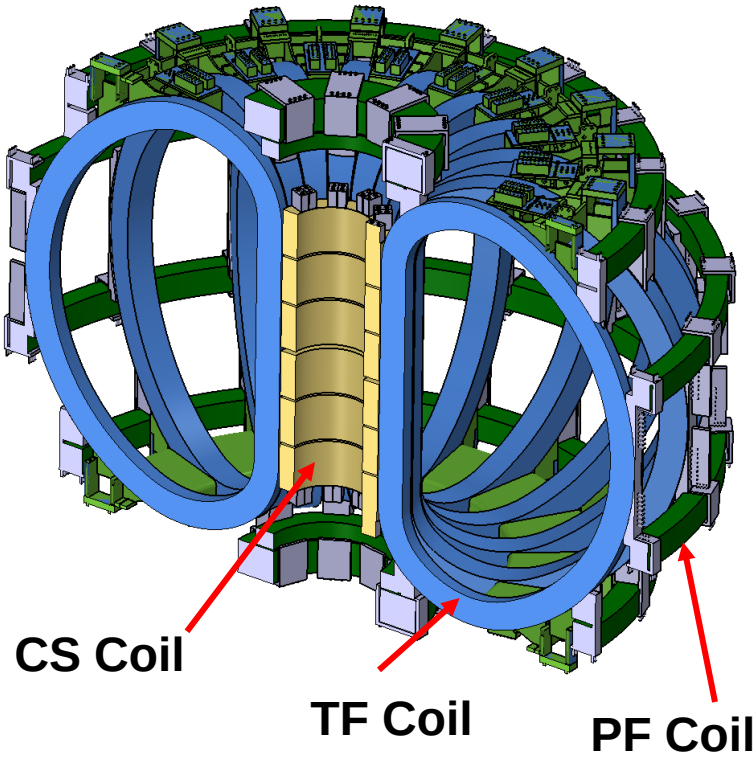
Conceptual Design of CFETR Magnets System

Tokamak Machine Design Team

2012.5.27 Hefei

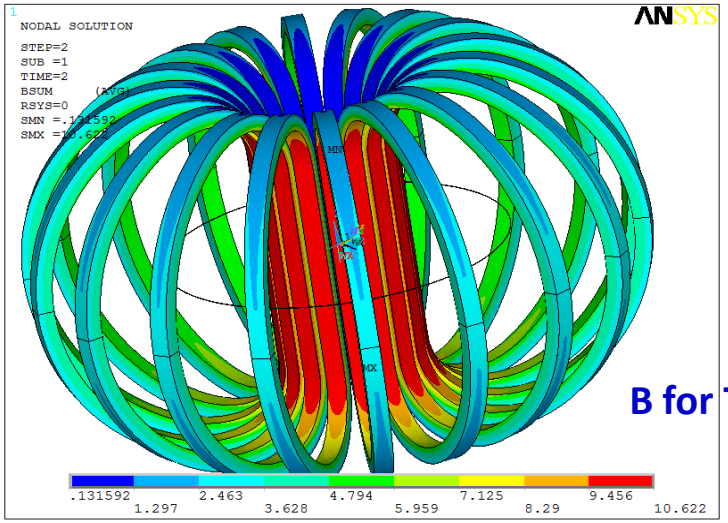
Overview of Magnets System for CFETR



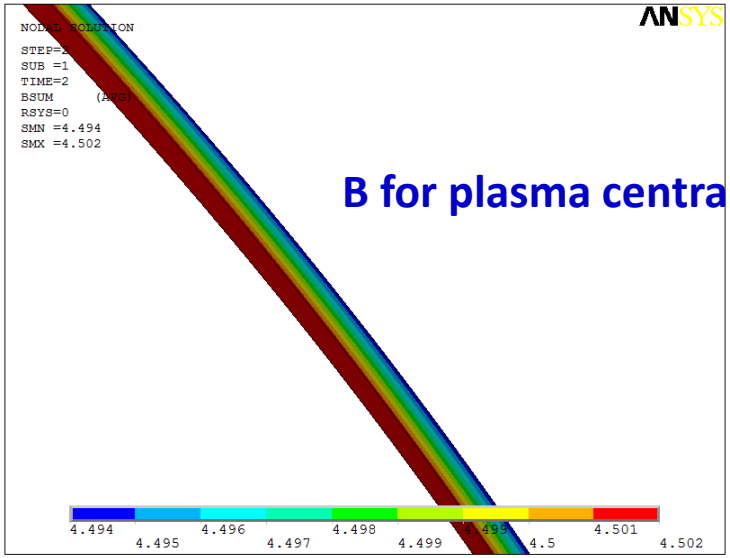


The magnet system of CFETR consists of TF, CS and PF coils.
The ITER magnet design is a good reference for CFETR

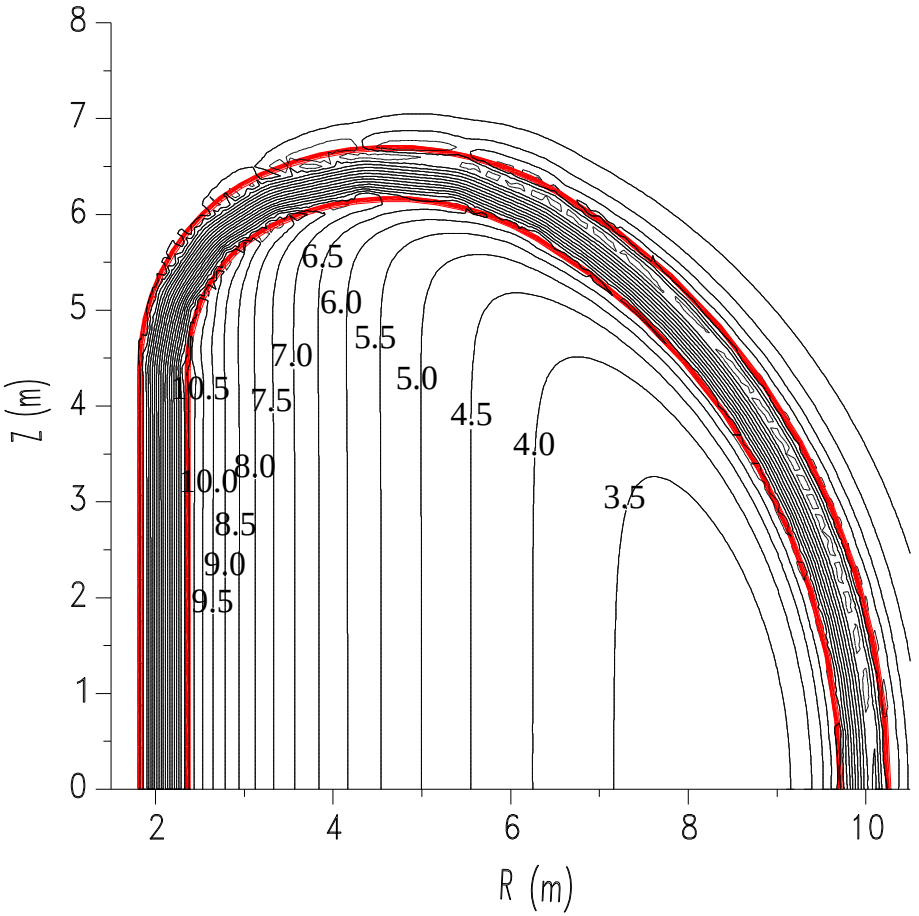
Magnetic field analysis for TF coil



B for TF coils



B for plasma central



Contour distribution for B

Maximum magnetic field for TF 10.6T
magnetic field in plasma central 4.5T.

TF coils for CFETR

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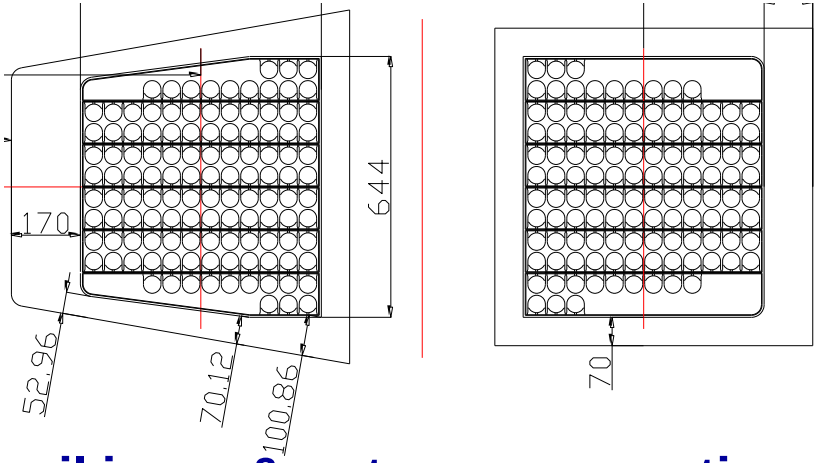
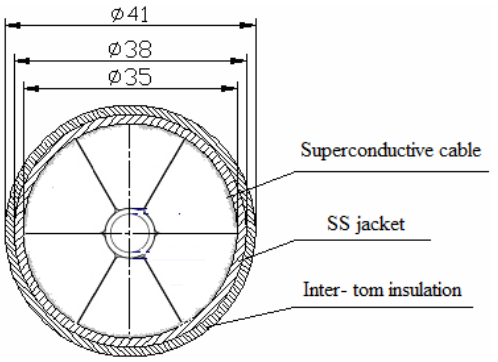
Parameters of TF coils

	CFETR	ITER
Coil number	18	18
Turn	120	134
Major radius (m)	5.5	6.2
Width (m)	8.06	8.638
Height	12.35	13.276
Cross-section (m^2)	0.594×0.644	0.622×0.829
Current (kA)	57	68
Center field (T)	4.5	5.3
Peak field (T)	10.6	11.8
Inductance (H)	13.44	17.7
Energy (GJ)	21.8	41



coil inner & outer cross-section



TF Conductor: Nb_3Sn , 57 kA

Calculation for Volt seconds of PF and CS coils

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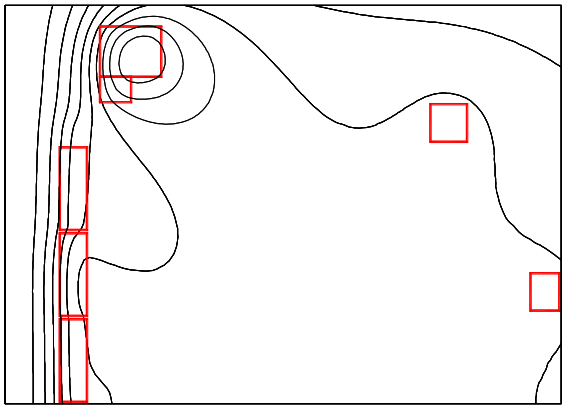
Volt seconds is about 100Vs.

The stray magnetic field not beyond 15GS at the plasma region

PF and CS coils location and current

coil	R(m)	Z(m)	△R(m)	△Z(m)	turns
CS3U	1.294	4.0475	0.512	1.559	374
CS2U	1.294	2.4285	0.512	1.559	374
CS1U	1.294	0.8095	0.512	1.559	374
CS1L	1.294	-0.8095	0.512	1.559	374
CS2L	1.294	-2.4285	0.512	1.559	374
CS3L	1.294	-4.0475	0.512	1.559	374
PF1U	2.0897	5.9151	0.587	0.476	80
PF2U	2.3747	6.6281	1.157	0.95	320
PF3U	8.3745	5.2835	0.689	0.707	196
PF4U	10.1925	2.1035	0.545	0.707	154
PF4L	10.1925	-2.1035	0.545	0.707	154
PF3L	8.3745	-5.2835	0.689	0.707	196
PF2L	2.3747	-6.6281	1.157	0.95	320
PF1L	2.0897	-5.9151	0.587	0.476	80

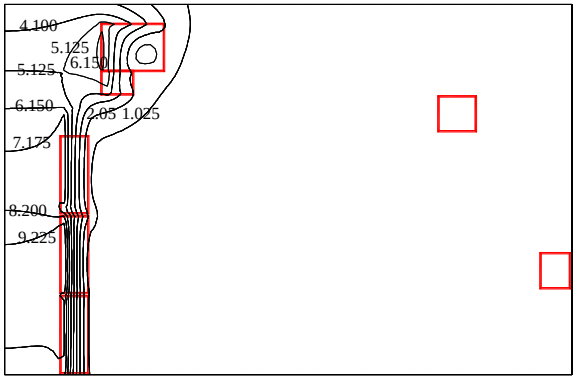


Distribution for magnetic flux

The maximum total magnetic field: 6.5T on PF2U.

The maximum total magnetic field: 10.25T on the CS coils.

Location	Magnetic field (GS)	Magnetic flux (Wb)
(3.9,0)	9.73	50.01
(5.5,0)	3.45	50.00
(7.1,0)	8.44	49.97
(4.5,1.3)	6.51	50.02
(5.5,1.6)	3.23	50.02
(6.0,1.5)	4.37	50.01



Contour for the magnetic flux density

Plasma equilibrium calculation and magnetic analysis for PF and CS coils

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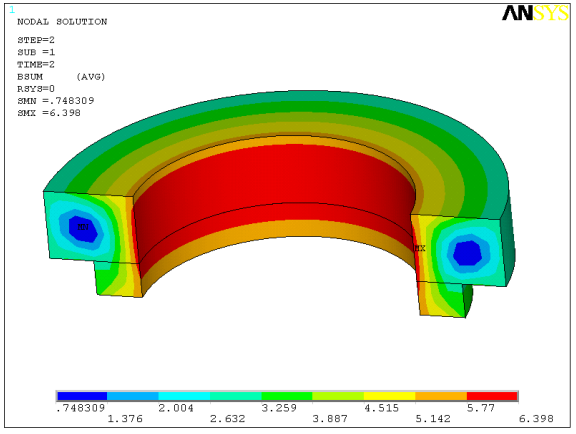
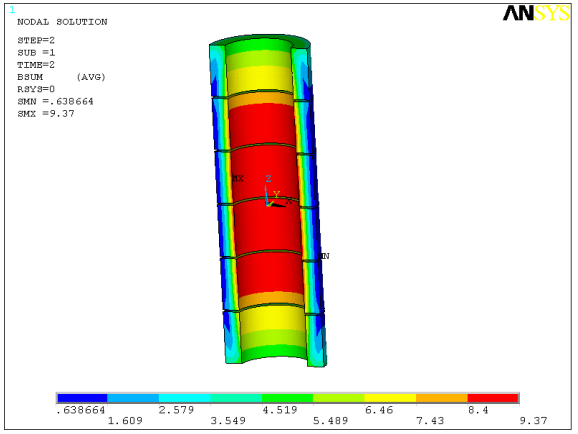
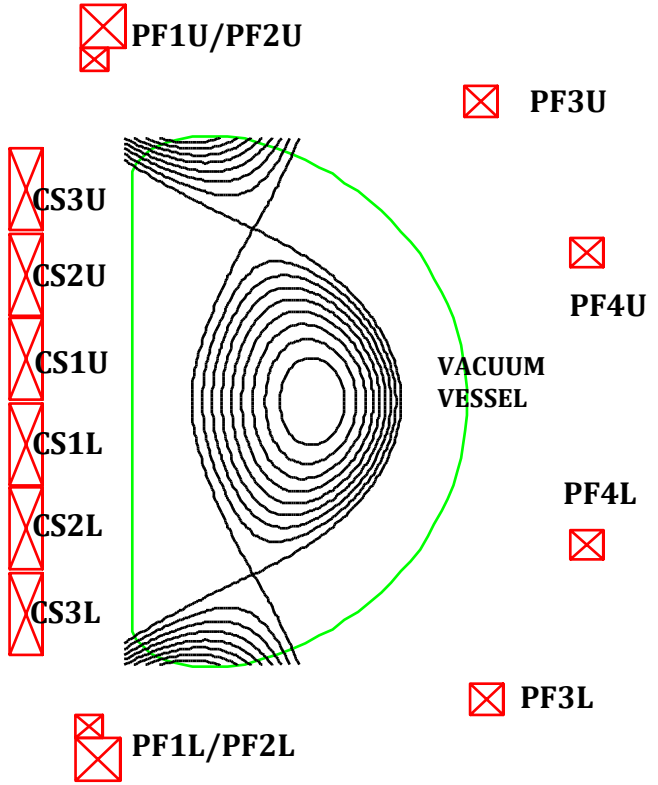
Current of PF coils for equilibrium (MAT)

CS3U/CS3L	CS2U/CS2L	CS1U/CS1L	PF1U/PF2U PF1L/PF2L	PF3U/PF3L	PF4U/PF4L
-12.21	-11.96	-11.04	15.86	-3.52	-3.95



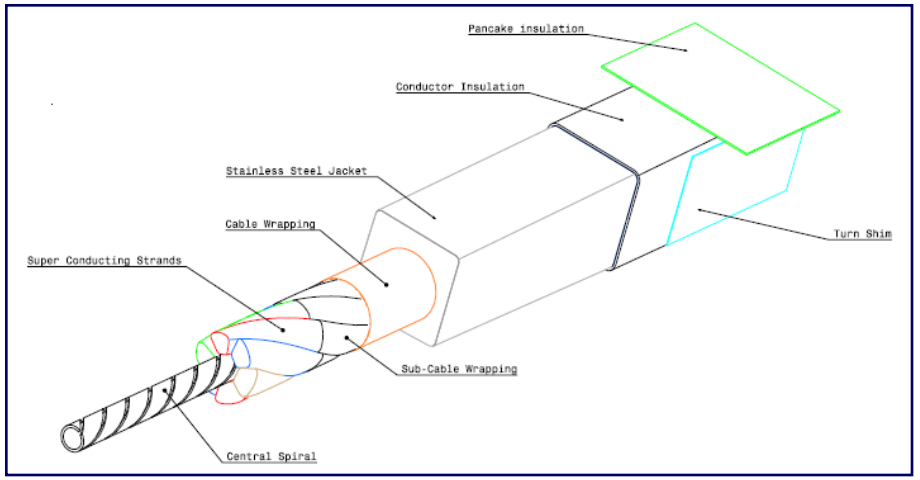


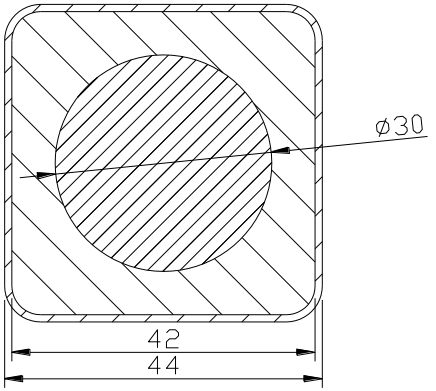


Maximum total magnetic field: 6.4T for PF1/2U
Maximum total magnetic field: 9.4T for CS

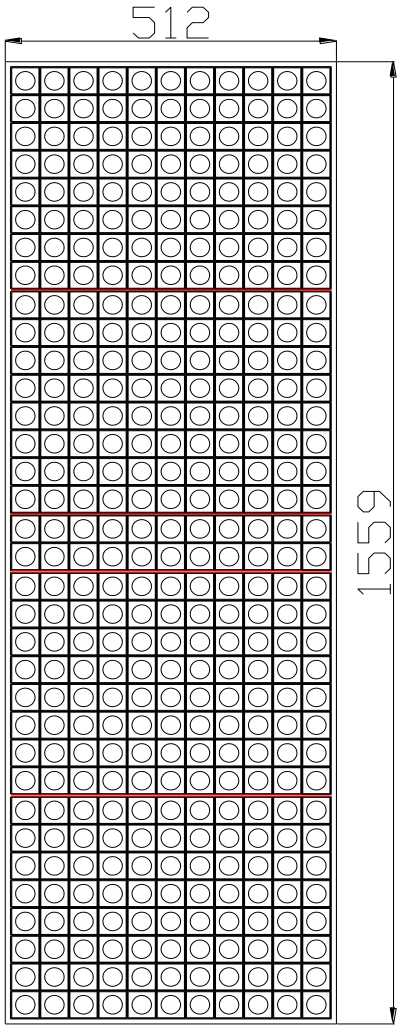
Preliminary consideration for CS coils

- 6 module consisting of Octa & dual-pancakes
- 374 turns each module
- Conductor design is similar as ITER:
  ~ 45 kA multi-stage Nb_3Sn cable with central cooling channel, circular in square conduit





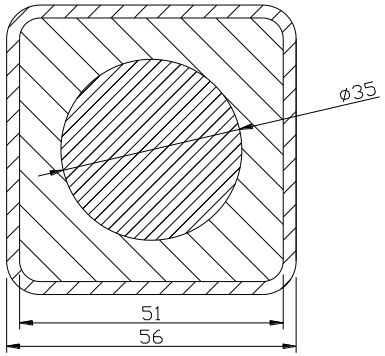
CS Conductor



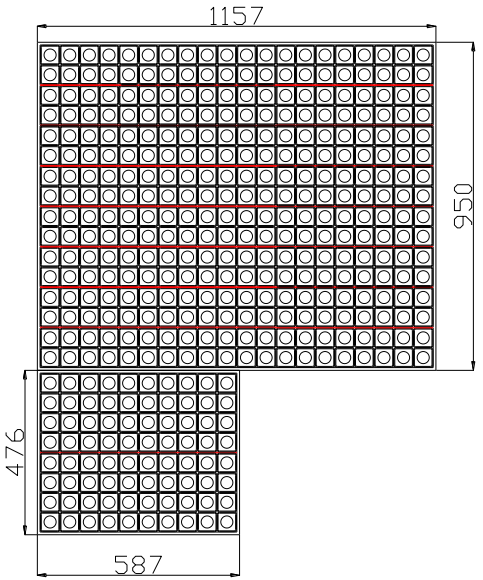
Cross section of one CS module

Preliminary consideration for PF coils

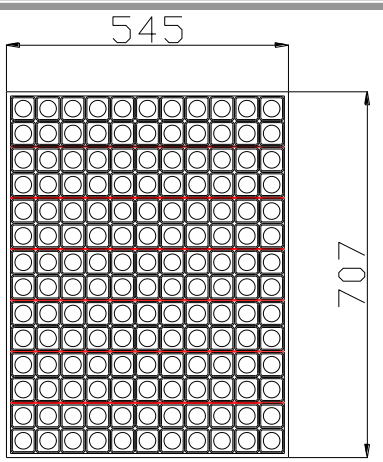
- 400 turns in PF1U/PF2U/PF1L/PF/2L coil
- 196 turns in PF3U/ PF3L coil
- 154 turns in PF4U/ PF4L coil
- Conductor: 40-50 kA NbTi multi-stage cable with central cooling channel.



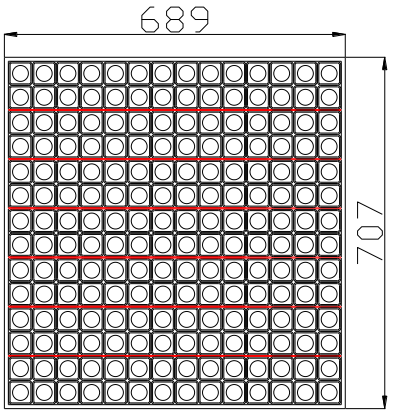
PF1U/PF2U
PF1L/PF2L Conductor



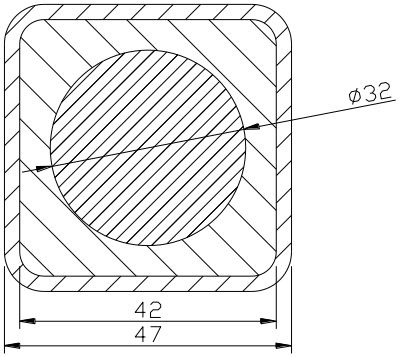
Cross section of
PF1U/PF2U
PF1L/PF2L Coil



Cross section
PF4U/PF4L Coil



Cross section
PF3U/PF3L Coil



PF3U/ PF4U
PF3L/PF4L Conductor

Magnets Feeder & Cryogenic system

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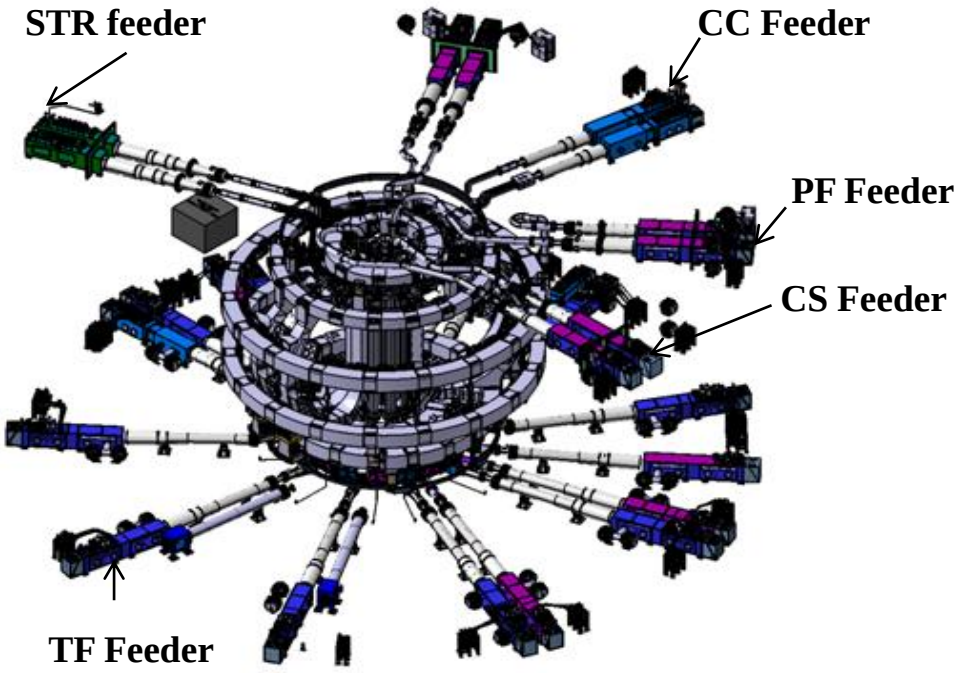
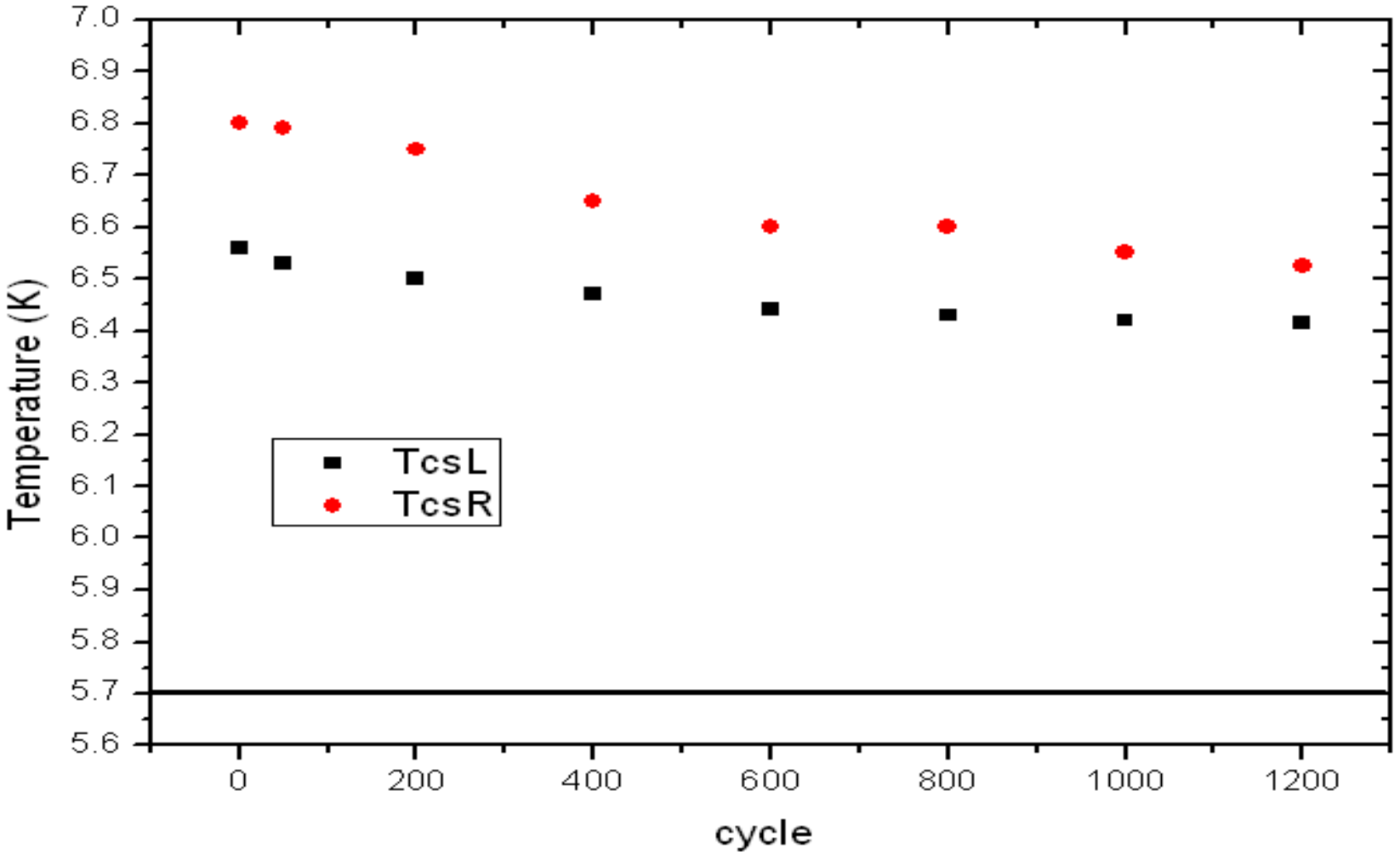
SHe Pumping Loops	He volume in coil systems (m^3)	He volume in Feeder system (m^3)	Total He volume (m^3)
TF System	~32	~6.5	~38.5
CS System	~5.2	~3.26	~8.5
PF+CC System	~25.7	~3.57	29.3
TF+CS str system	~2.2	~2.05	~4.3
Total for magnet system	~65.1	~15.4	~80.5



Layout of ITER magnets feeders

- Feeder design is similar with ITER
- HTS-CLs will be adopted for Feeders
- the total LHe value in cooling loops of magnet system around ~80 (m^3)
- Estimated heat load of magnet system is ~20kW @ 4.5 K
- The Cryogenic system consist of Cryoplant & Cryodistribution system. The capacity of LHe Plan will be fixed late

Thanks for your attention!



Degradation of Sultan test sample TF CN2
Left leg 0.2 K, Right leg 0.1