Fusion Reactor Technology II
(459.761, 3 Credits)

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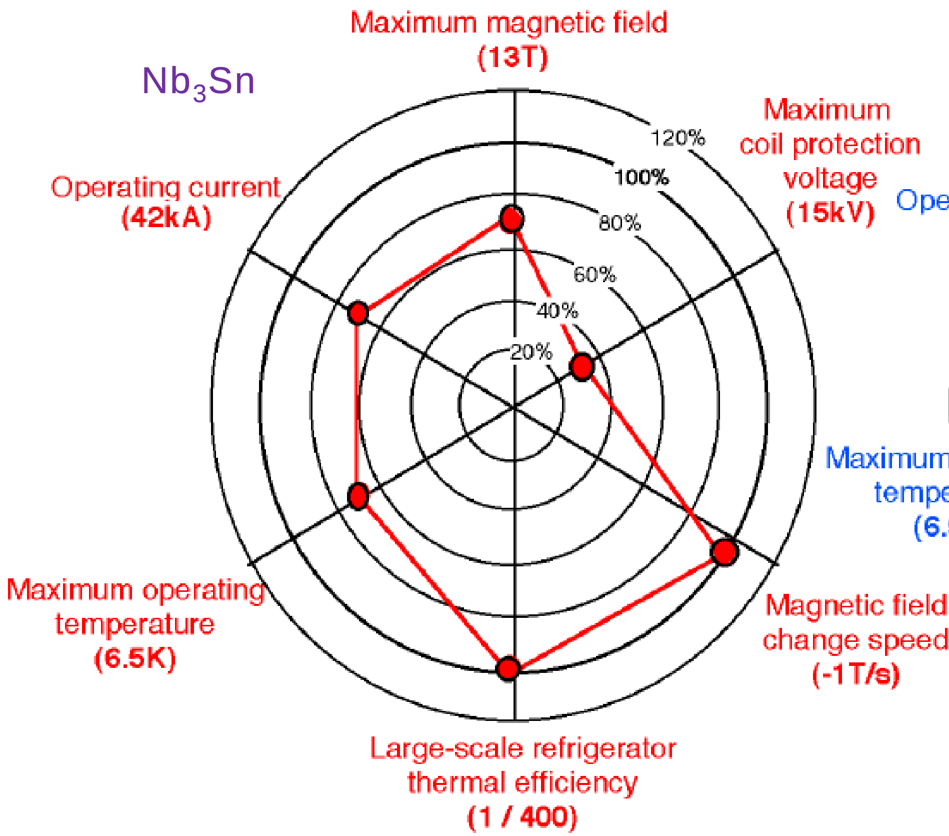
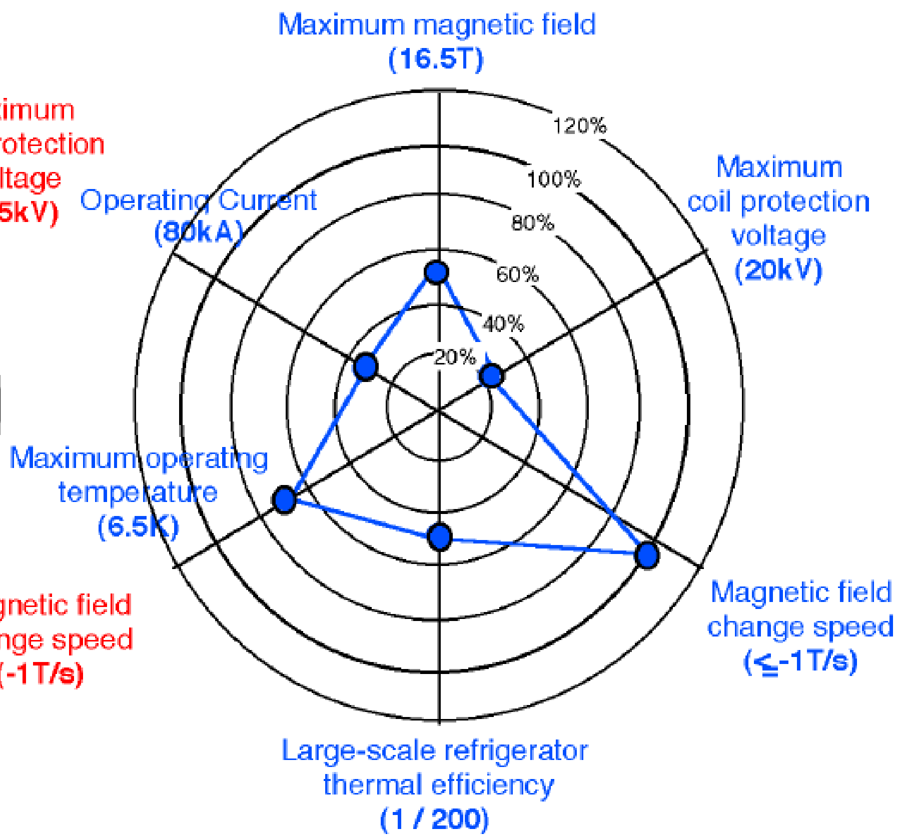
For ITER

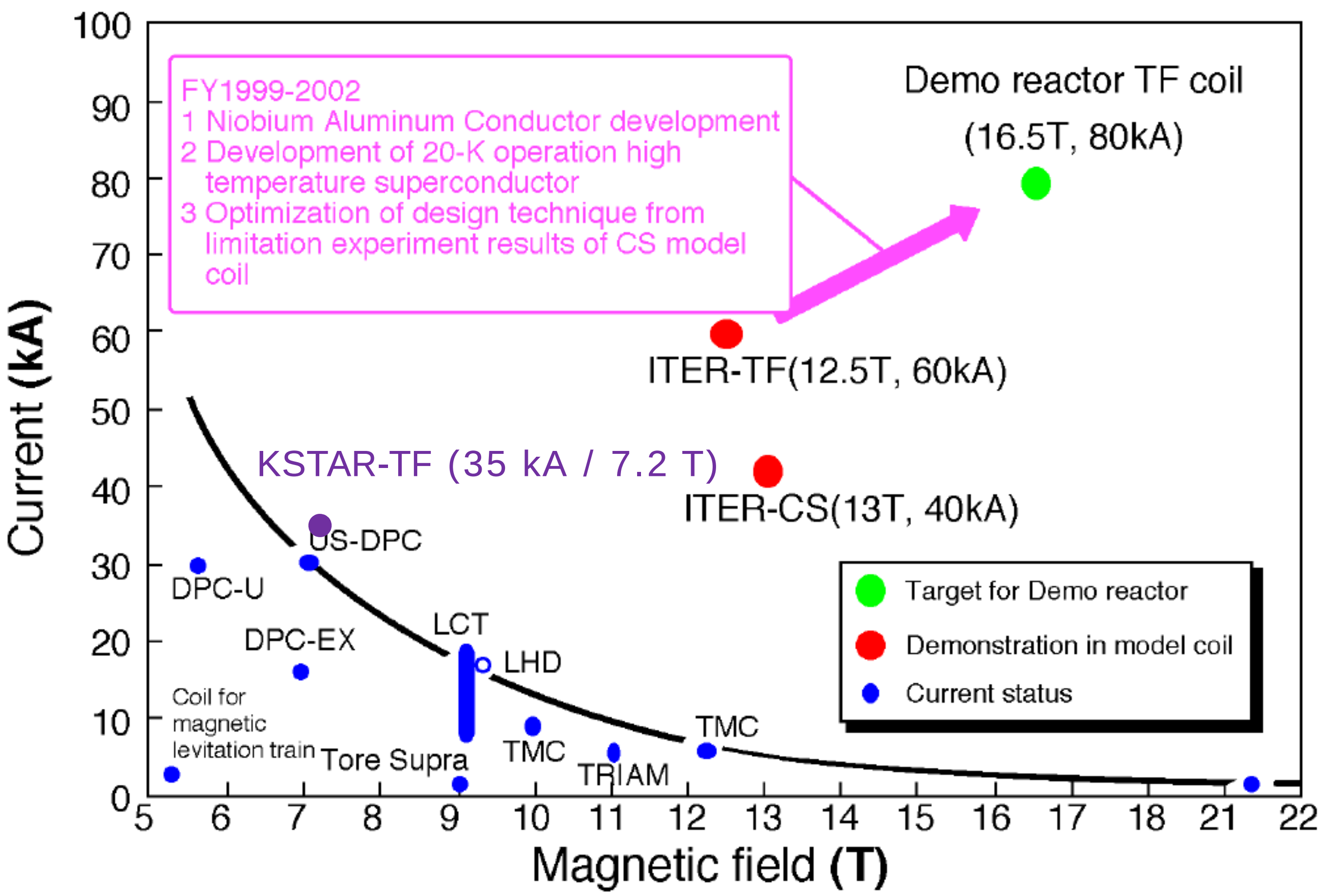
Nb_3Sn

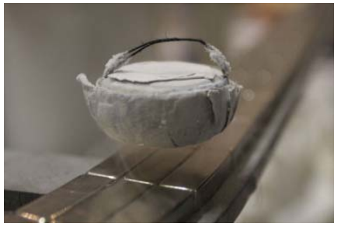


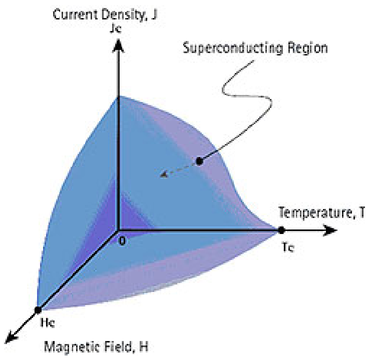
For Demo Reactor



Superconducting magnet technology

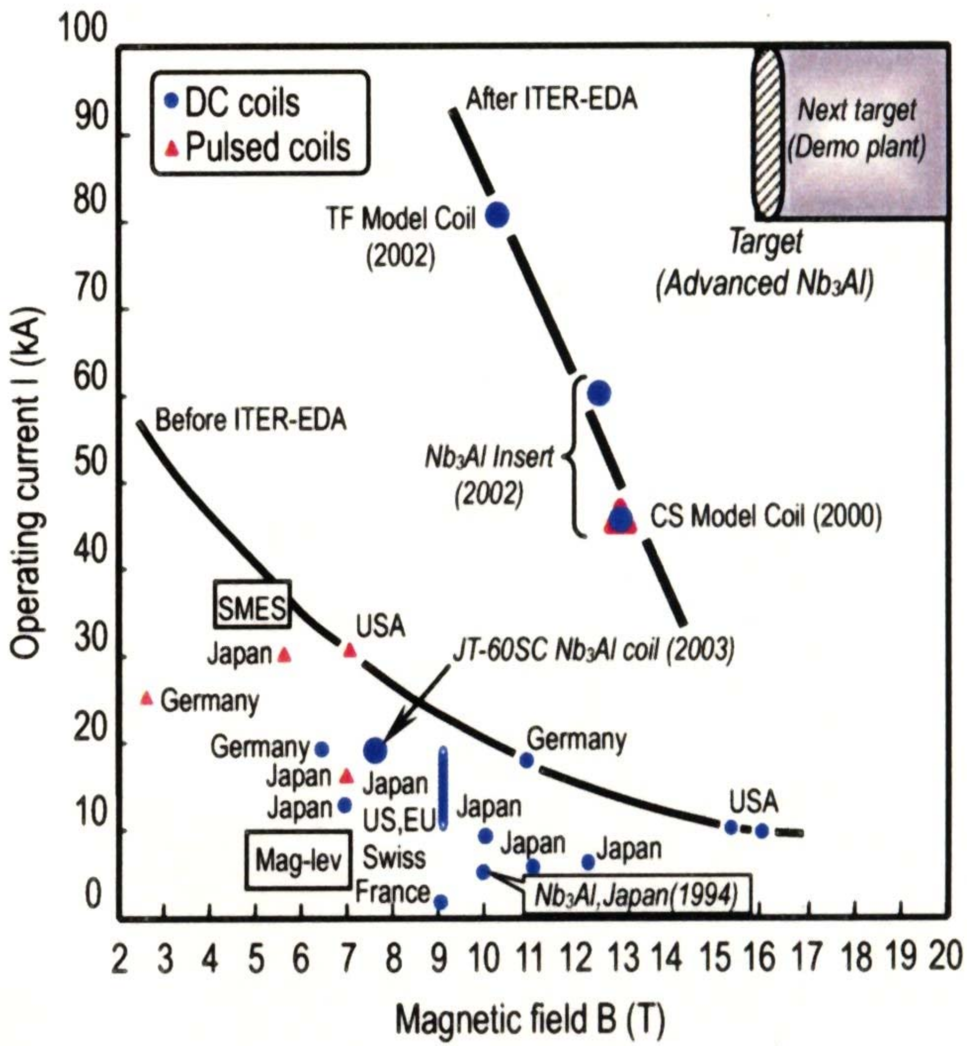






http://en.wikipedia.org/wiki/Superconductivity
http://www.amsc.com/aboutus/about_super.html

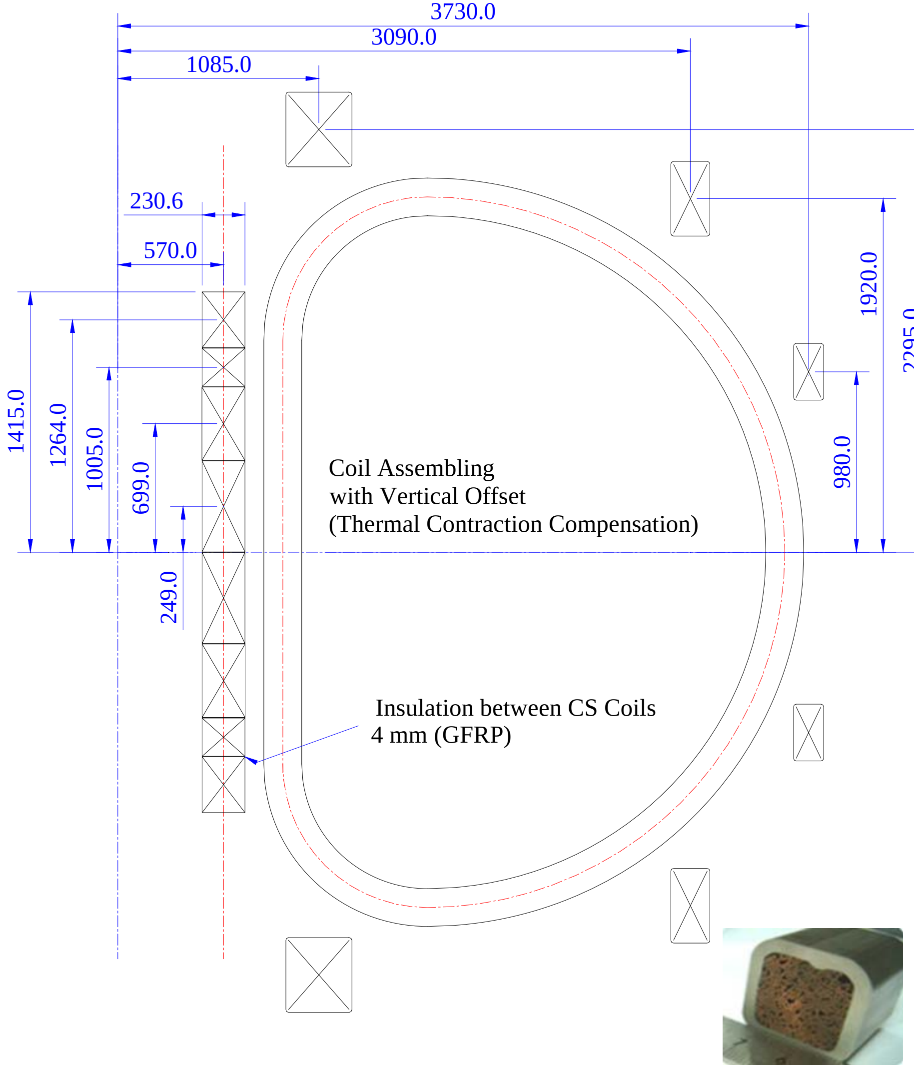
Superconducting magnet technology

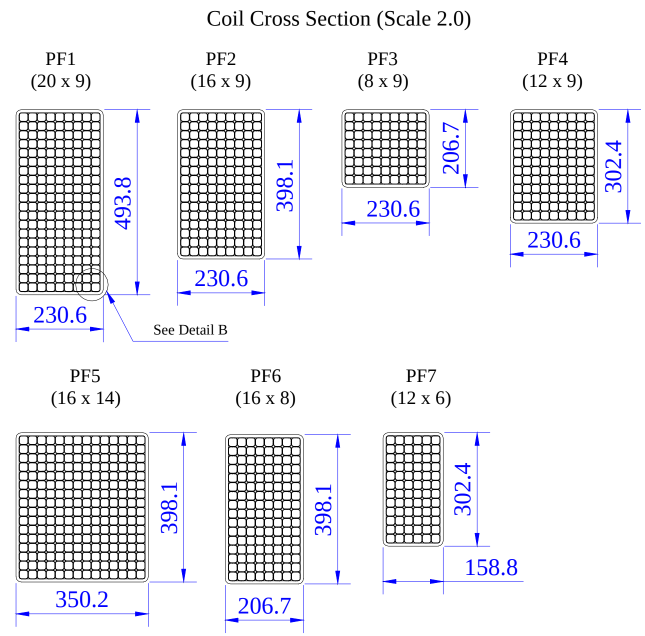


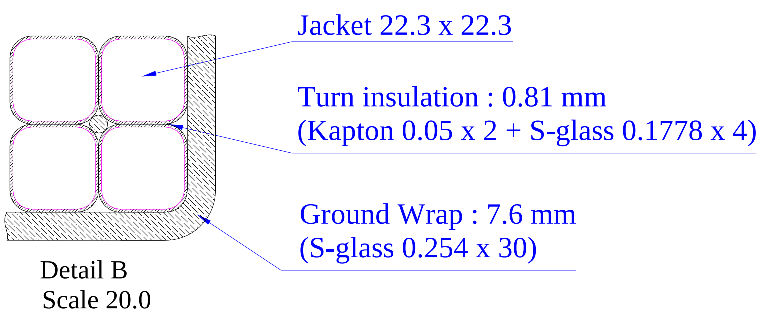
Operating points of superconducting coils constructed so far and the target for fusion demo plant[N.Koizumi, et al., 20th IAEA Fusion Energy Conf. IAEA-CN116-FT/P1-7]

Layout of the KSTAR magnet

Insulation Thickness :
Turn insulation : 0.81 mm
Ground wrap : 7.6 mm







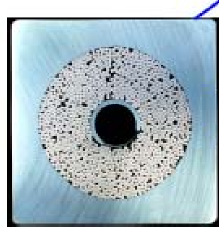
Superconducting magnet technology

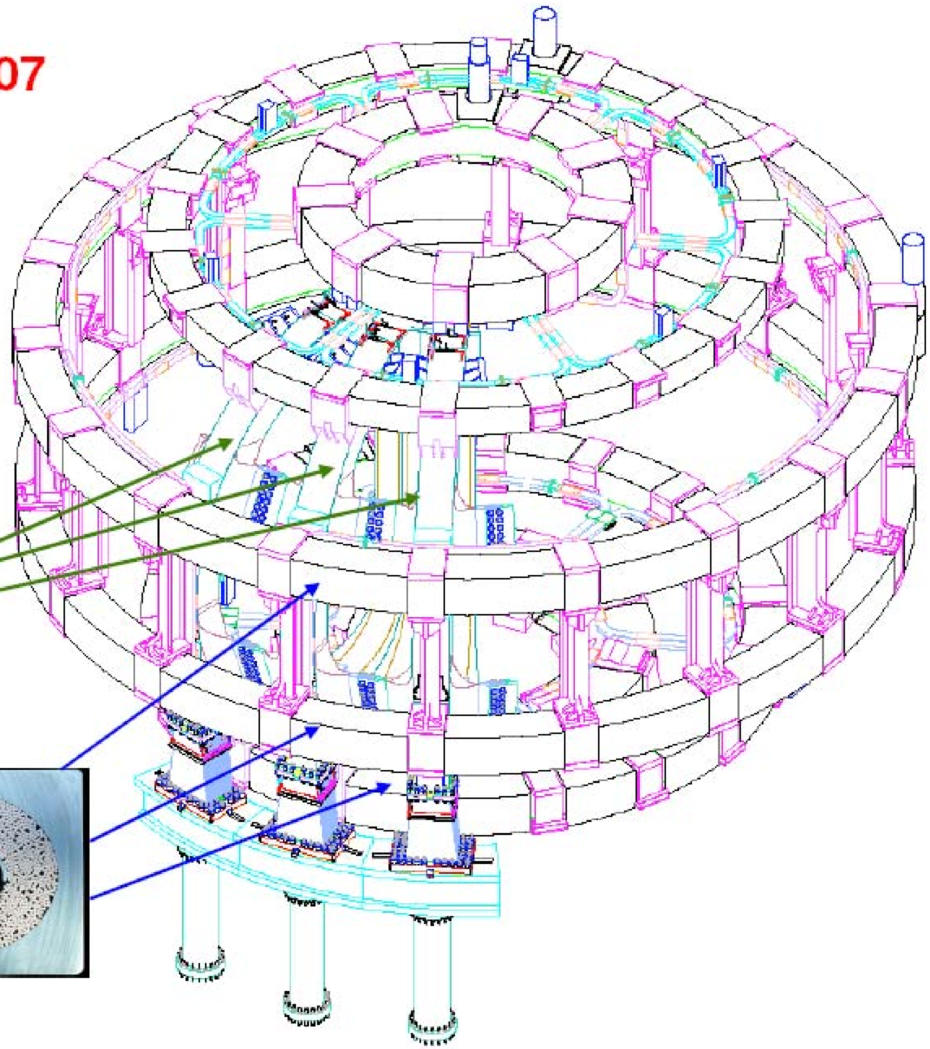
ITER conductors in 2007

CS Conductor,
Nb_3Sn

TF Conductor,
Nb_3Sn

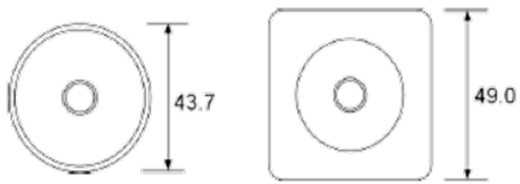
PF Conductor,
NbTi





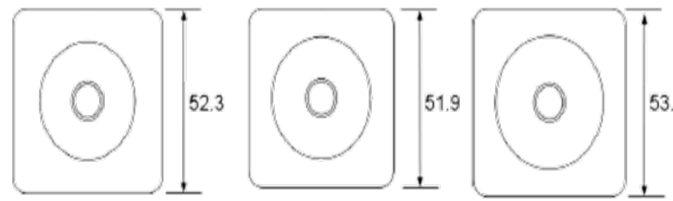
ITER conductor

Nb_3Sn conductor



	TF	CS
Iop (kA)	68	40 (IM) 45 (EOB)
Bmin – Bmax (T)	10.5 – 11.8	12.4 - 13.0 (IM) 12.0 - 12.6 (EOB)
Top (K)	5.0	4.7
ε (%)	-0.77	-0.69
τ discharge (s)	11 + 2s delay	7.5 + 2s delay
sc strand diam. (mm)	0.82	0.83
sc strand Cu:nonCu	1	1
cabling layout	((2sc+1Cu) x 3 x 5 x 5 +core) x 6	(2sc+1Cu) x 3 x 4 x 4 x 6
core in 4^{th} stage	3 x 4 Cu wires 0.82 mm	na
Cu strand in 1st triplet	1	1
sc strand Nr	900	576
local Vf (%)	33.2	33.2
cable diam. (mm)	40.5	32.6
central spiral od x id (mm)	9 x 7	9 x 7
flow area in annulus (mm^2)	406.5	252.3
total flow area (mm^2)	445.0	290.8

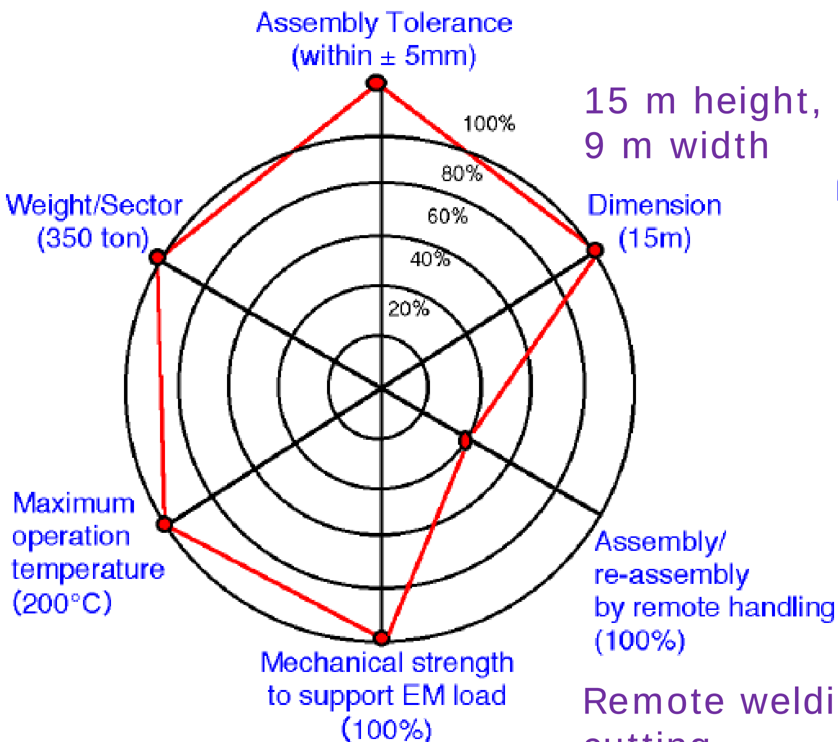
PF conductor



	PF2/3/4	PF5	PF1/6
Iop (kA)	45	45	45
Bpeak (T)	4	5	6
Top (K)	5.0	5.0	5.0
τ discharge (s)	14 +2s delay	14 +2s delay	14 +2s delay
sc strand diam. (mm)	0.73	0.72	0.73
sc strand Cu:nonCu	6.9	4.4	1.6
cabling layout	((3 x 3 x 4+1) x 4+1) x 6	((3 x 3 x 4+1) x 5+1) x 6	3 x 4 x 4 x 5 x 6
Cu core diam 2/3/4 stage (mm)	0.0/1.8/3.5	0/1.2/2.7	0.0/0.0/0.0
sc strand Nr	864	1080	1440
local Vf (%)	34.2	34.3	34.5
cable diam. (mm)	34.5	35.4	38.2
central spiral od x id (mm)	10 x 12	10 x 12	10 x 12

Vacuum vessel technology

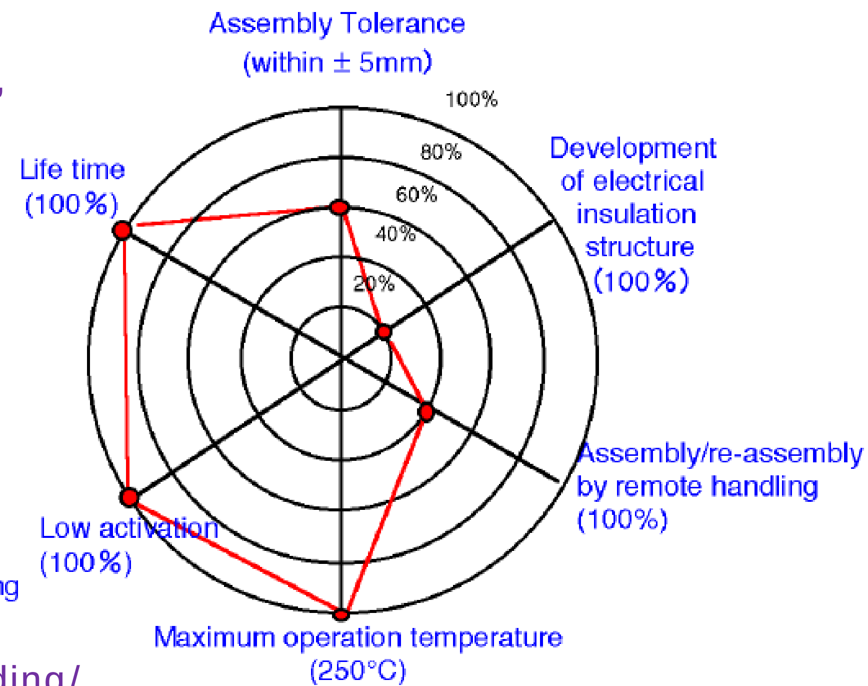
For ITER



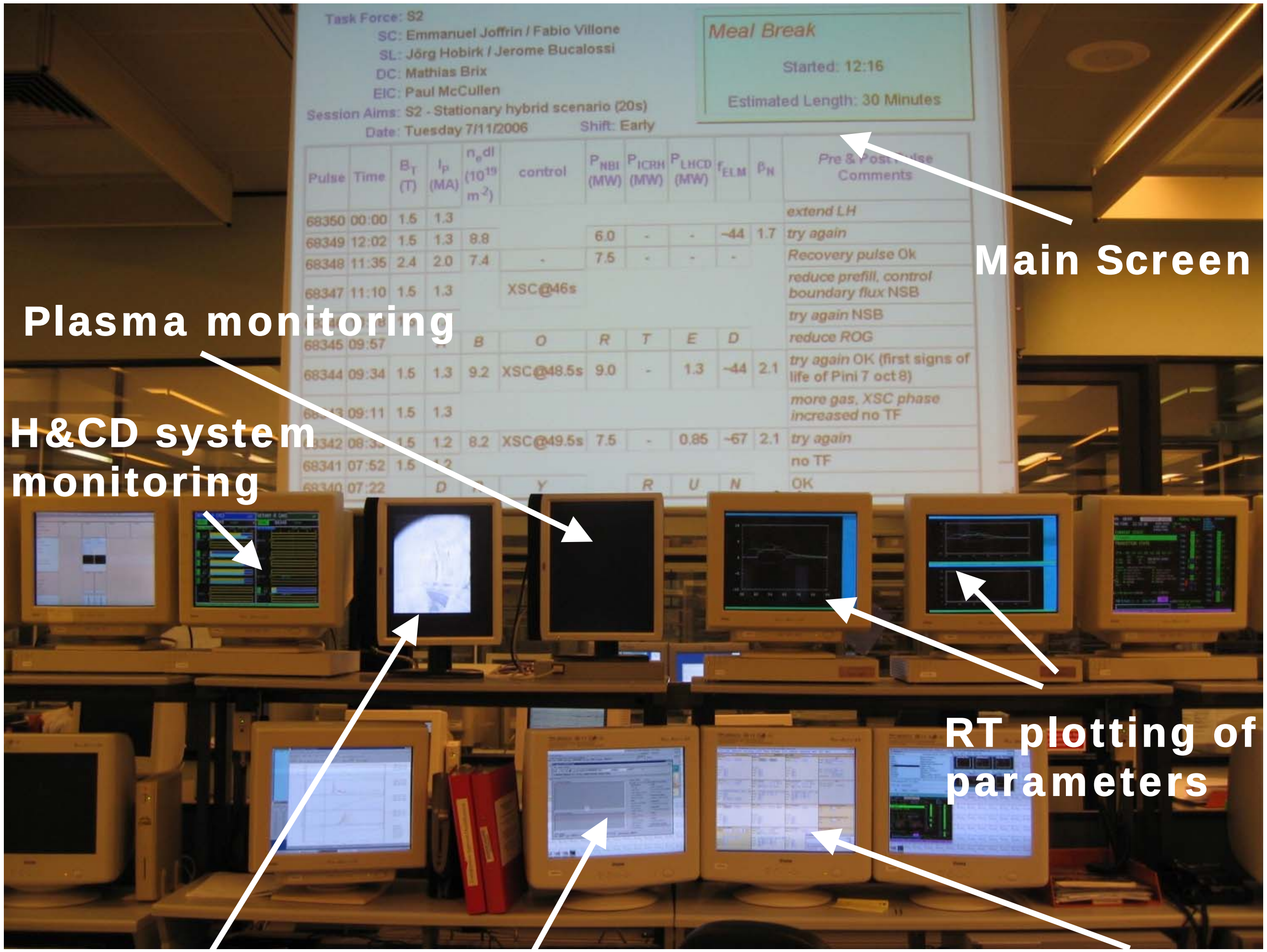
15 m height,
9 m width

Remote welding/
cutting

For Demo Reactor



JET control room



IR Camera
(PFC monitoring)

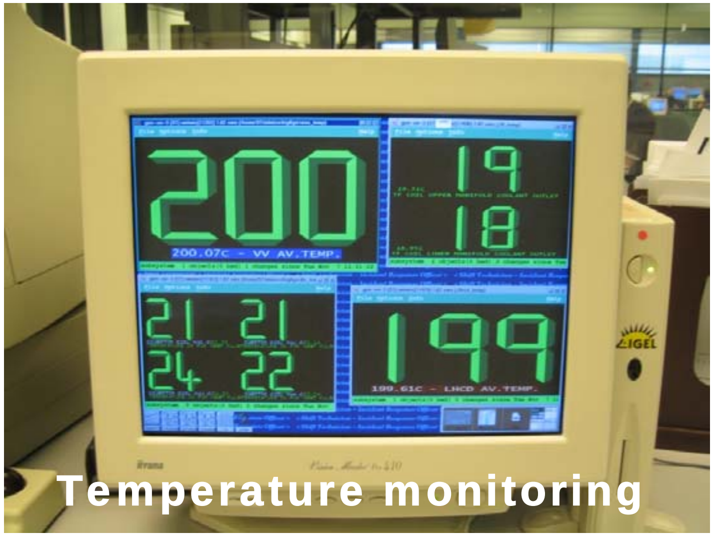
Shot comments

Shot editing

Session Leader

JET control room

Vacuum system monitoring



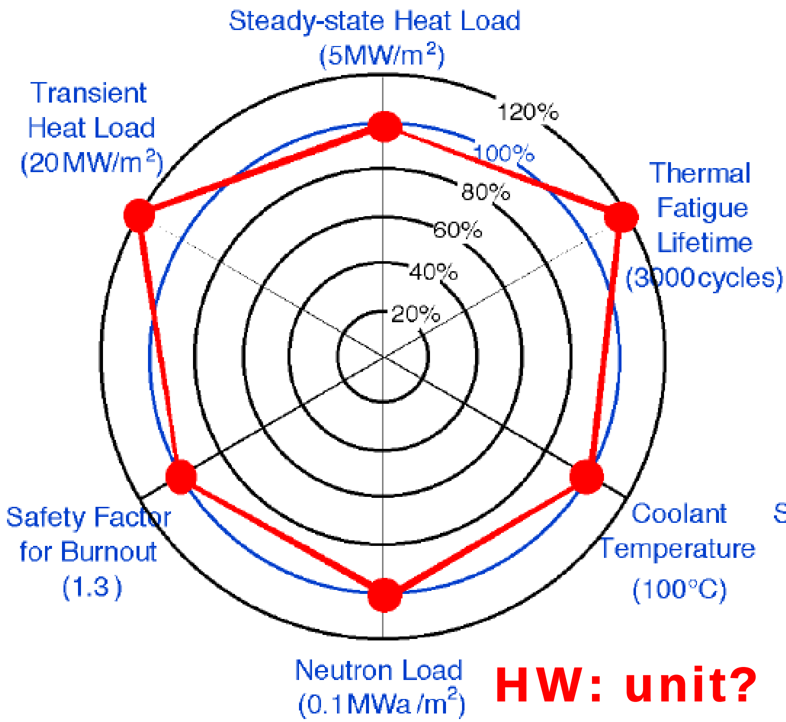
Temperature monitoring

Central interlock safety system

Divertor and high heat-flux component technology

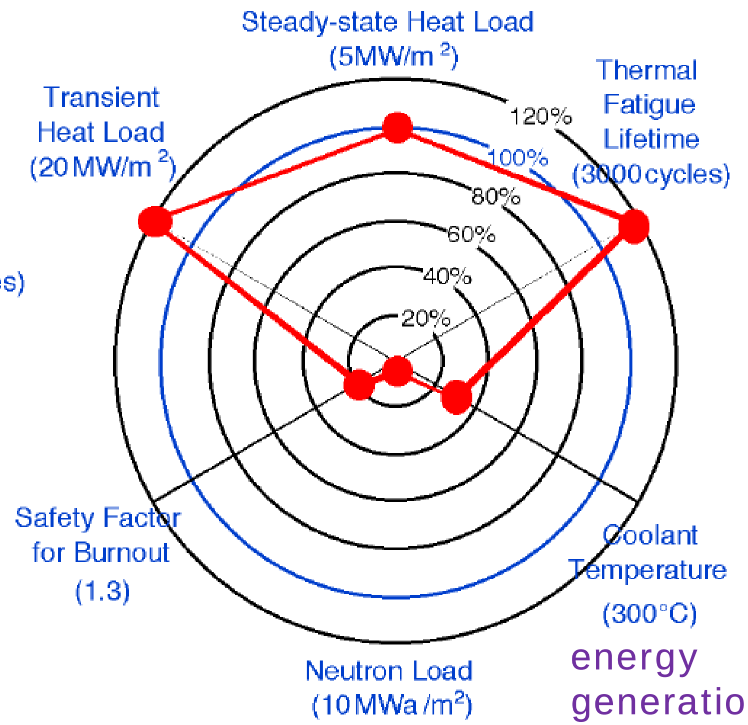
- ITER divertor requirements
- heat load: 5-20 MW/m^2
- Coolant temperature: 100-150 °C
- Neutron influence: 0.1 MWa/m^2

For ITER



HW: unit?

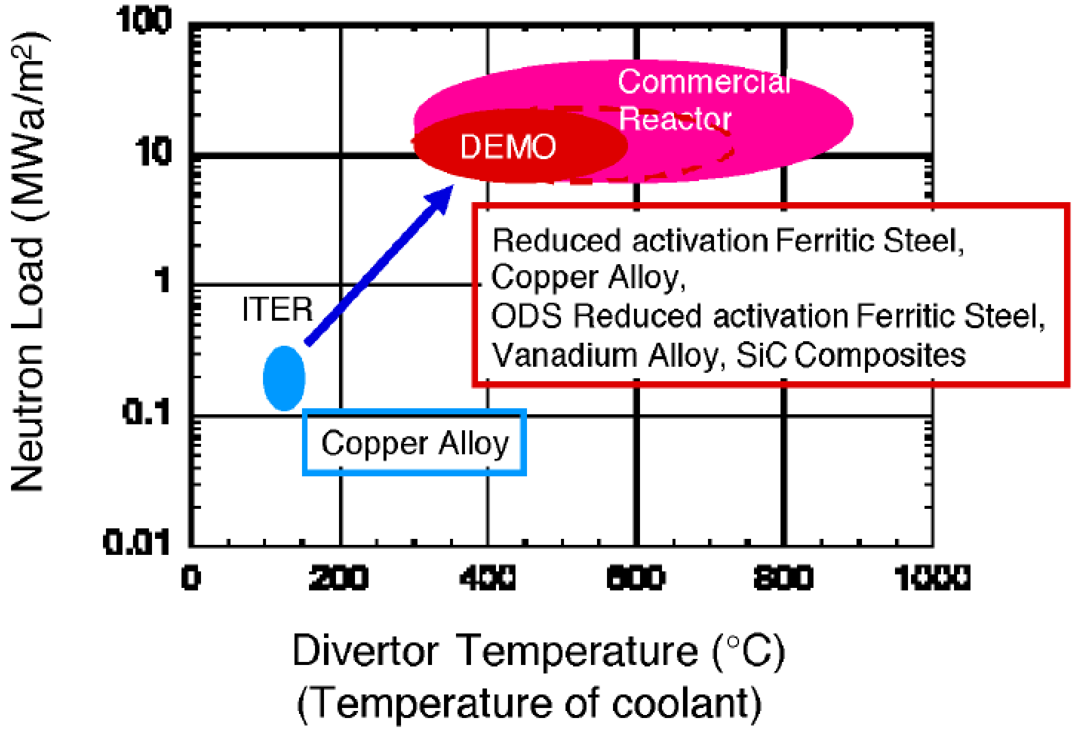
For Demo Reactor



energy generation

Divertor and high heat-flux component technology

Heat load : more than 5 MW/m^2



Blanket technology

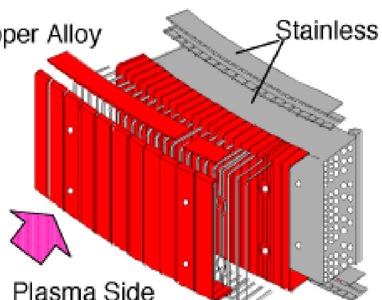
1. Shield Blanket for ITER

■ Requirements and Structure

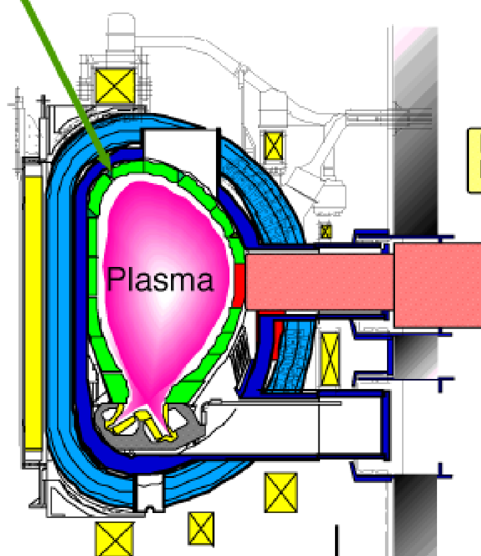
1) Withstand High Thermal Stress
2) Withstand High Electromagnetic Force
3) Provide High Shielding Capability

⇩

Copper Alloy for Heating Surface
Stainless Steel for Structure and
Cooling Tubes



ITER Crosssection



■ Technology Challenge

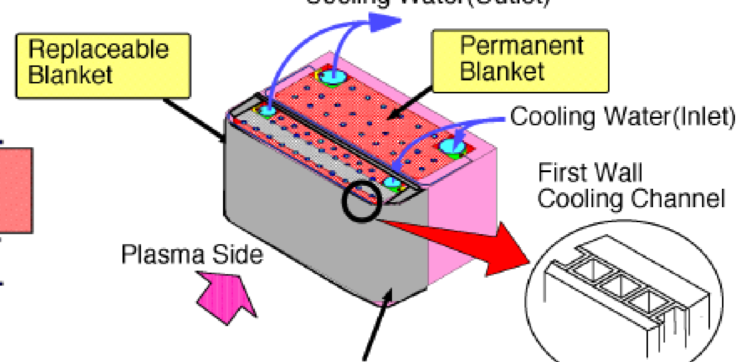
Simultaneous Hot Isostatic Pressing (HIP) bonding of SS/SS, Cu/Cu, and SS/Cu has been successfully developed at 1050°C,150MPa, and 2 hours holding time, and a prototype blanket module has been completed.

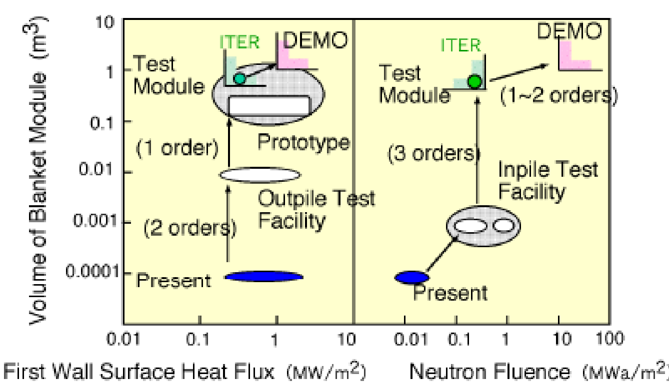
2. Blanket for Power Reactor

(Tritium Breeding and Power Generation)

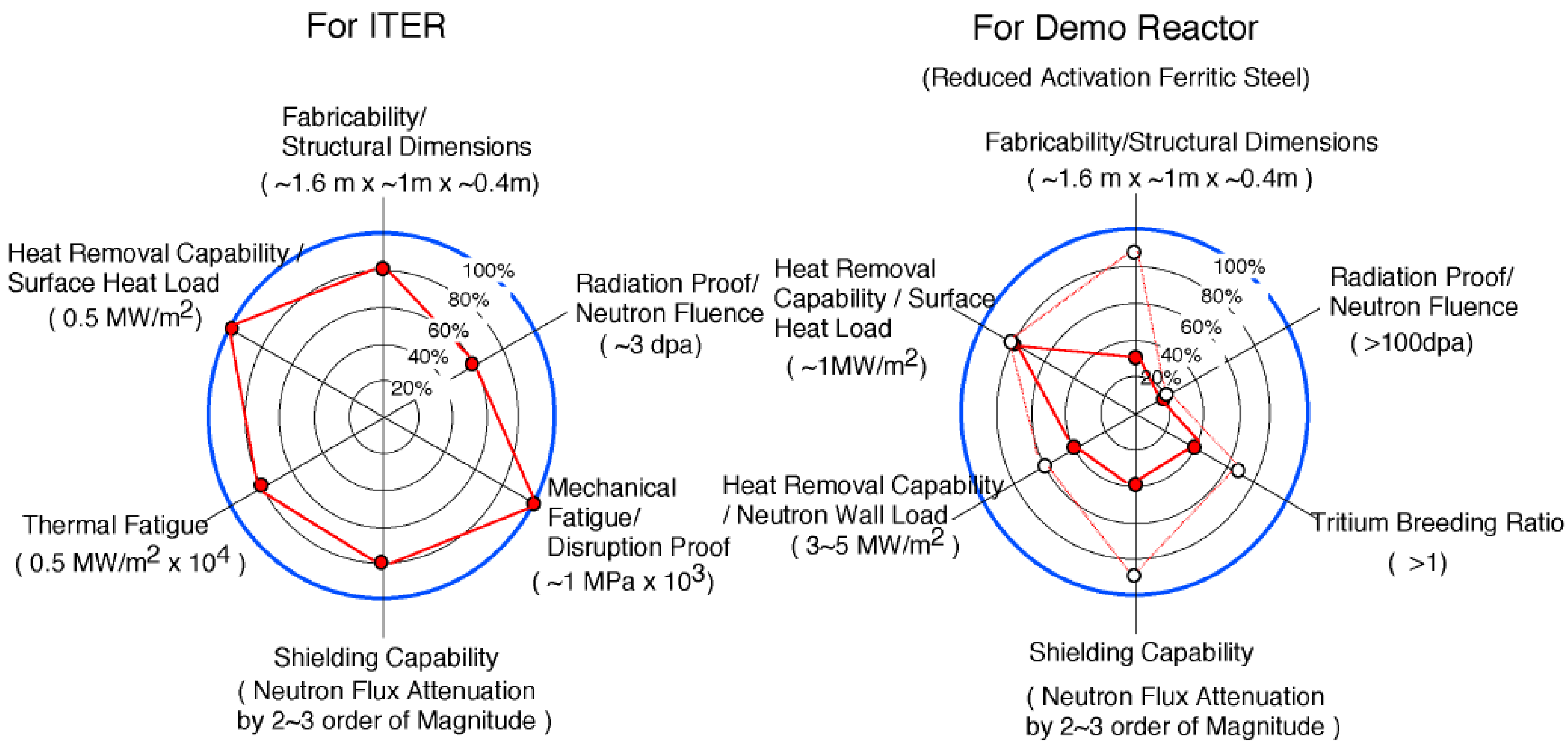
Double Layered Structure with Replaceable and Permanent Blankets

R&D Items: Development of a blanket structure capable of tritium breeding and high heat generation for power generation, under high heat load and neutron wall load





Blanket technology



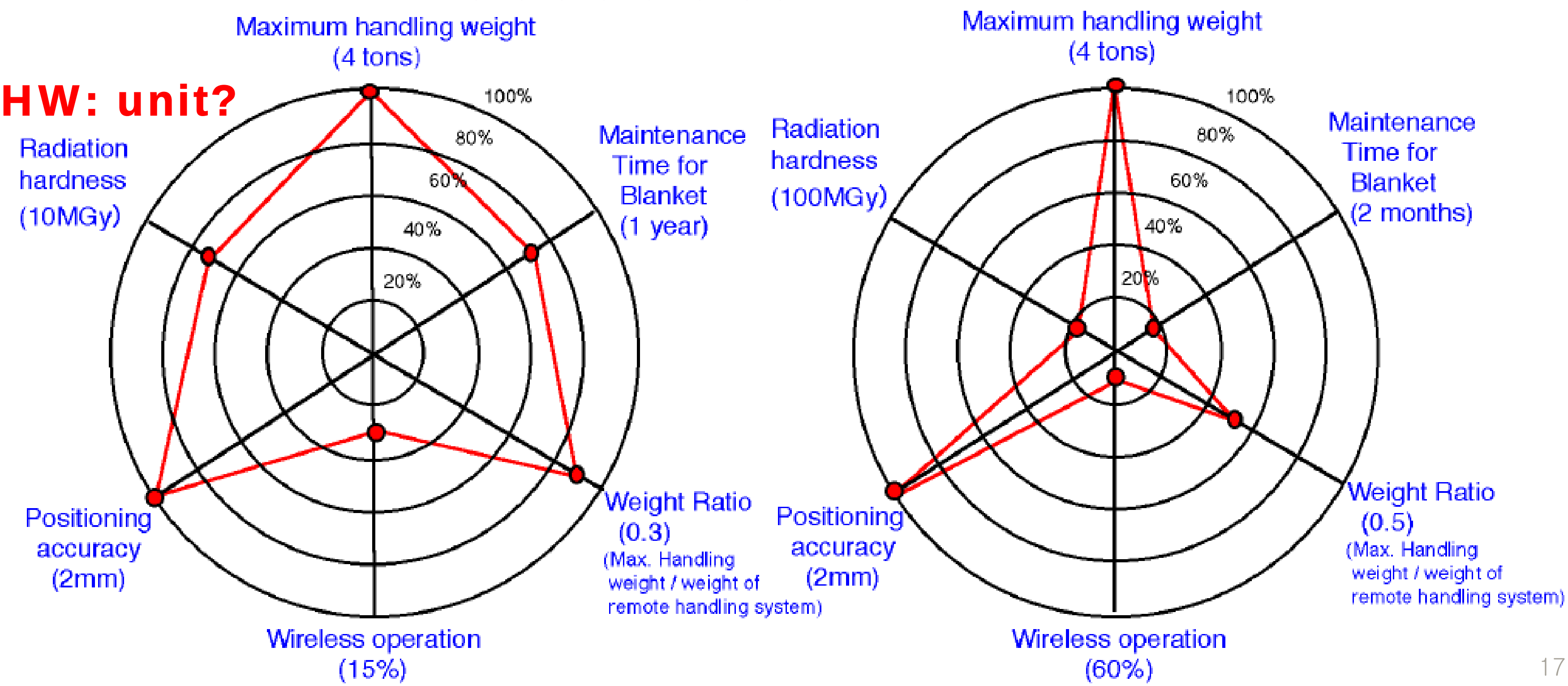
Remote handling technology

- Minimisation of the maintenance time
- Development of radiation-resistant components
  (radiation-resistant battery, signal transmitter for wireless control)

For ITER

For Demo Reactor

4 tons for blanket,
15 tons for divertors

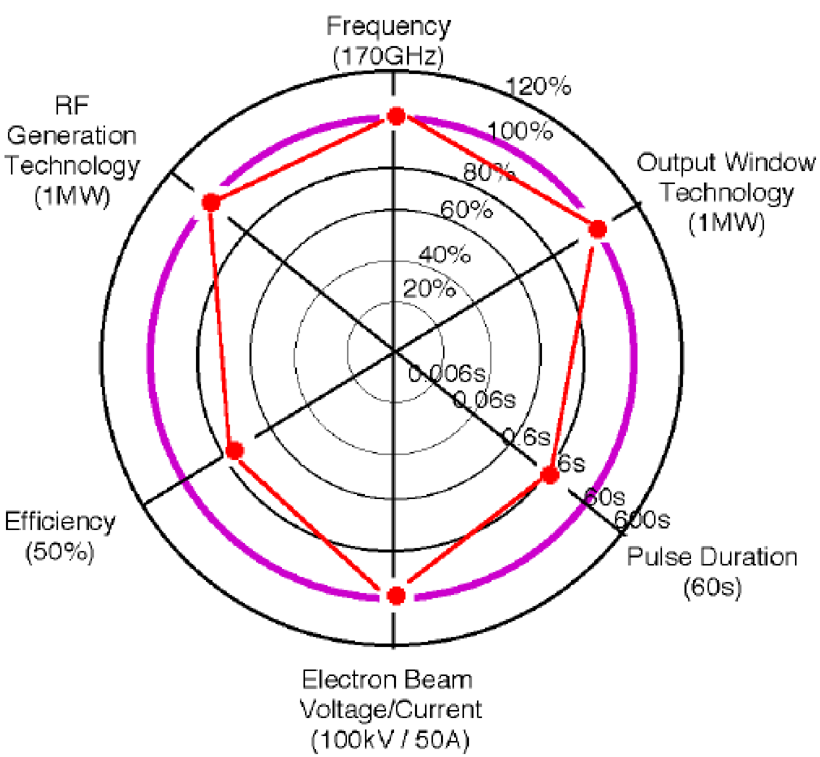


Heating and CD system technology

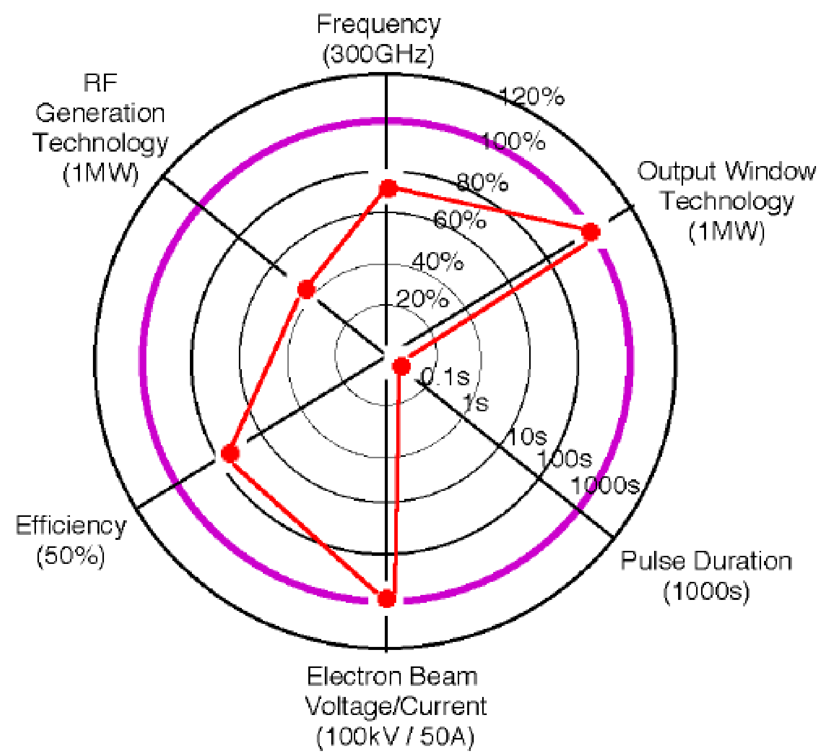
- RF heating and CD technology in DEMO

- Frequency of 300 GHzheat load: 5-20 MW/m²
- Resonator enabling higher frequency oscillation, diamond window, frequency variable oscillator, etc.

For ITER

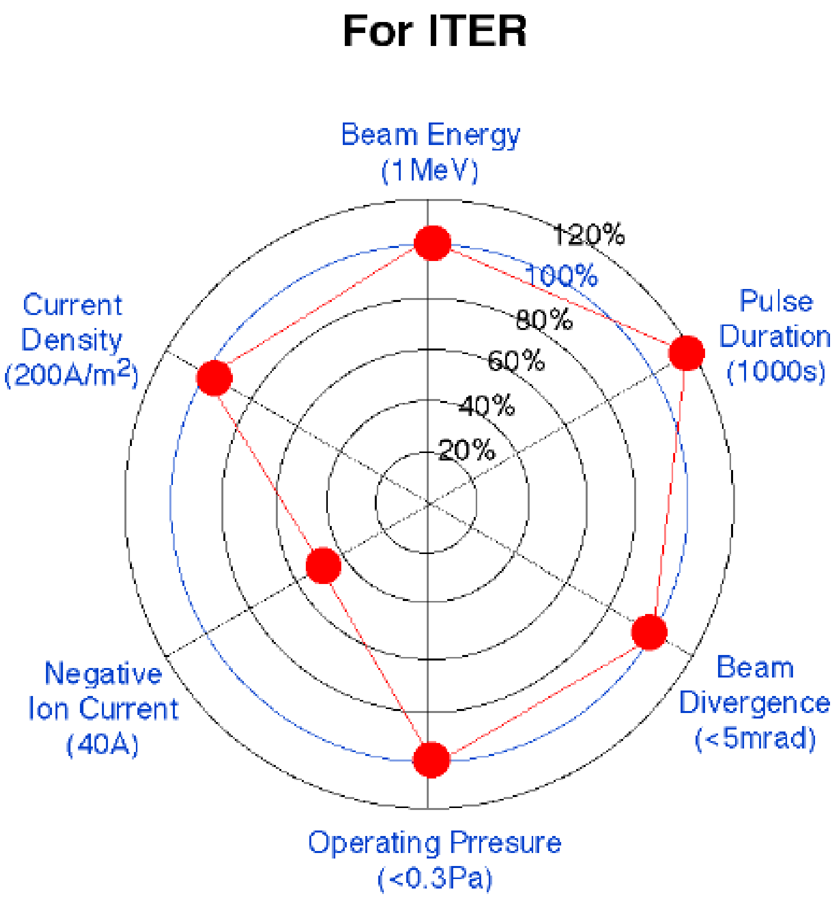


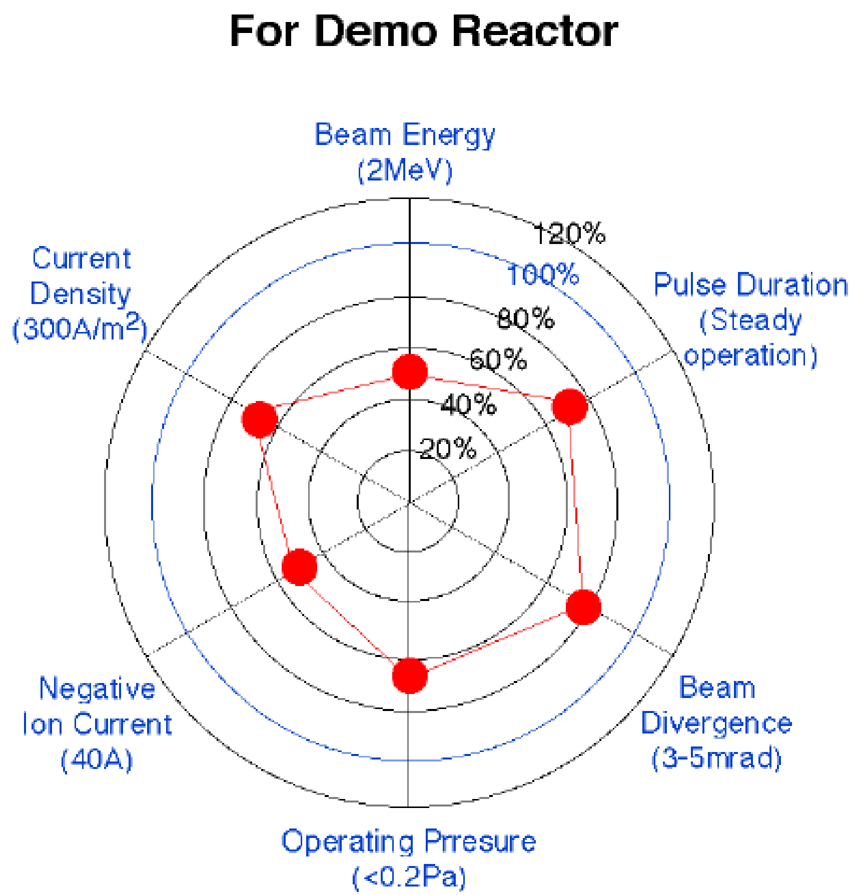
For Demo Reactor



Heating and CD system technology

- NBI technology in DEMO
- Beam energy of 2 MeV
- Maintenance-free negative ion source, plasma neutraliser with higher efficiency



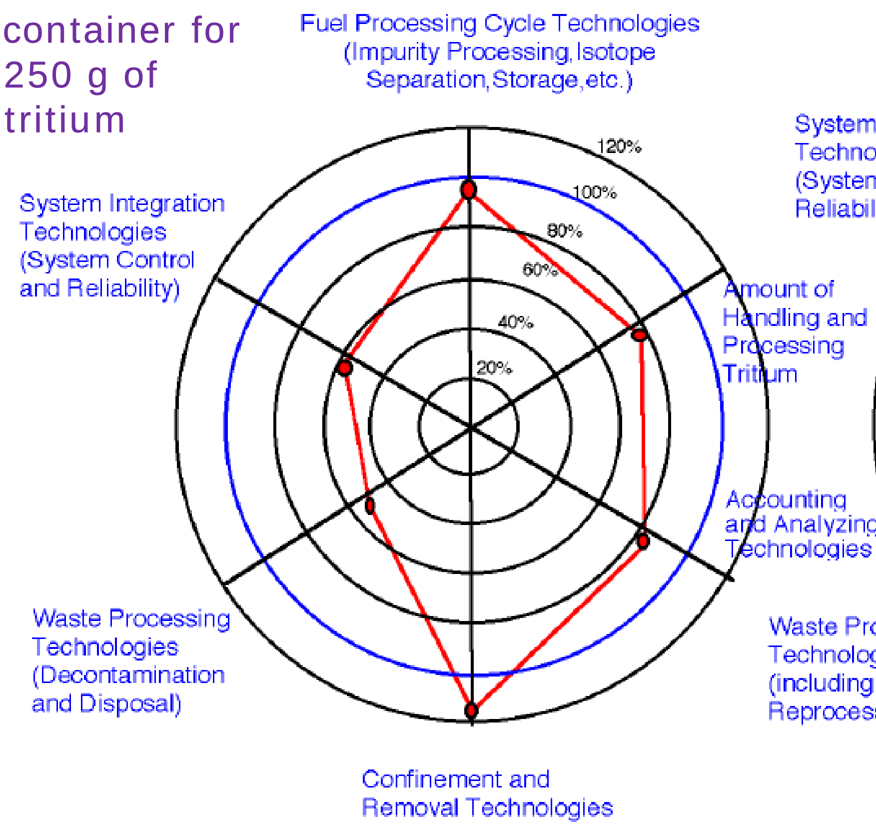


Tritium processing and safety technology

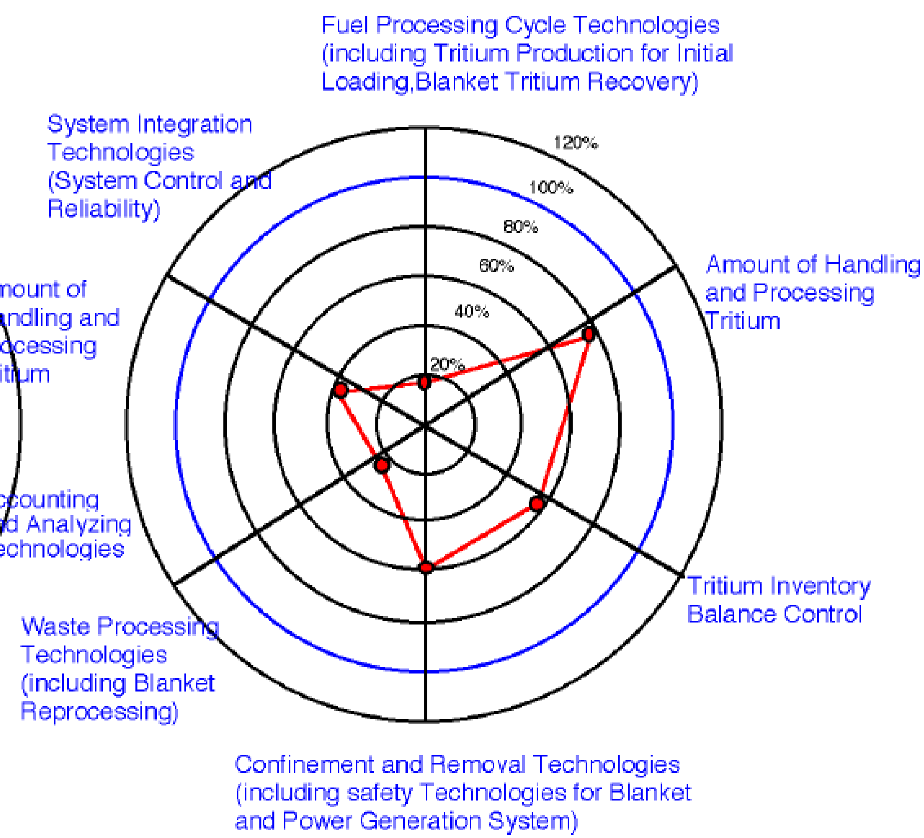
- Reliable tritium processing for steady and continuous long-term operation
- Safety for the power generation plant
- Production and security of necessary amounts of tritium
- Efficient tritium removal/recovery from contaminated wastes

container for 250 g of tritium

For ITER



For Demo Reactor



Tritium processing and safety technology

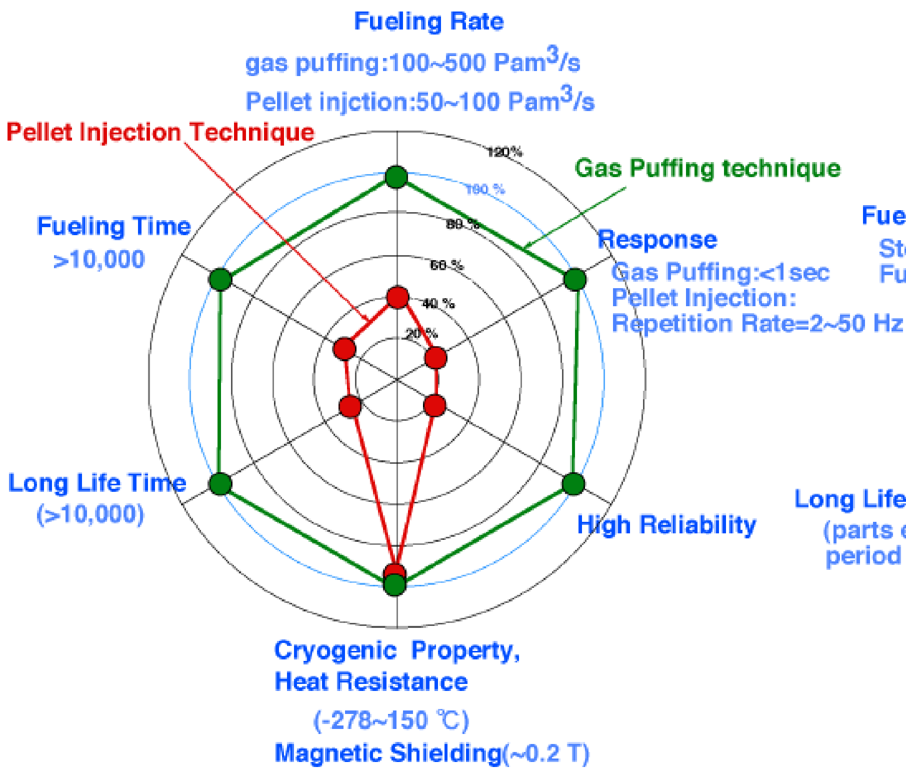
- Tritium Export
  - **Total tritium to be received:**
    ~ 29 kg due to tritium decay
  - – Decay rate: 5.47 %/y (Half life; 12.3 y)
  - ITER Tritium Plant will be ready by 2016
  - Tritium available worldwide: ~ 20 kg (2006, Canada OPG) (+ Korea WTRF)
  - – ITER Tritium credit: $30M/kg
  - – Market value: $100M-$200M/kg
  - Only one supplier for ITER written on the ITER documents now: Canada
  - Canada OPG sells ~ 0.1 kg/yr for other purposes.
  - **There is no other kg's order civilian tritium source at all.**
  - WTRF can produce more than 0.7 kg/yr from this year (2006).
  - We have Tritium and good reason to supply.
  - – Korea is a partner for ITER, Canada is not.
  - – Korea is to procure the Tritium Storage and Delivery System for ITER.

C. S. Kim, "Tritium Export Preparation for ITER Operation and Fusion Applications", May 25, 2006, NFRI

Fuelling and vacuum pumping technology

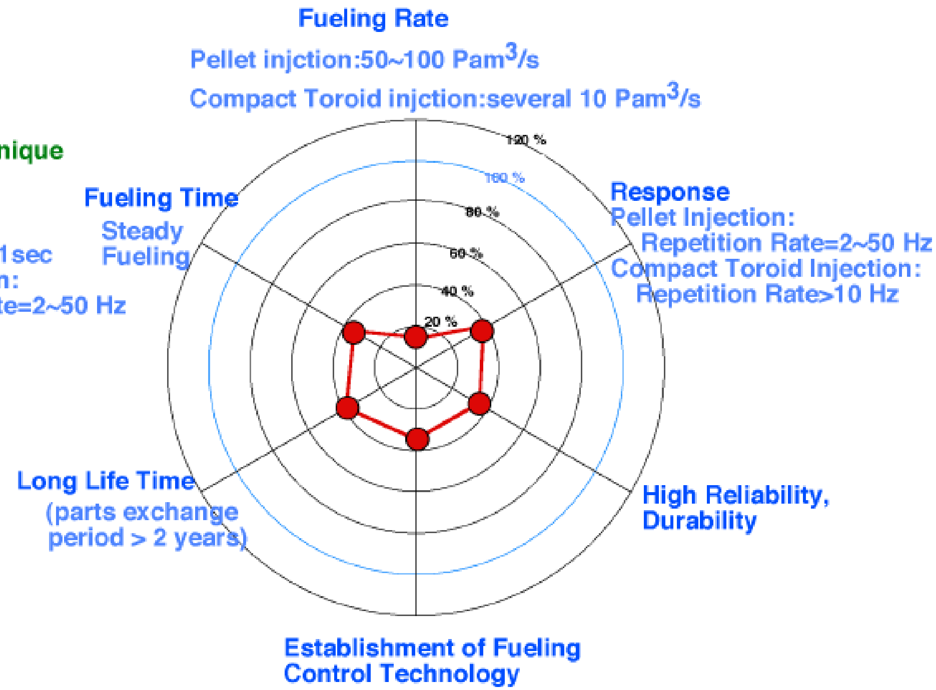
For ITER

* development of gas puffing technique
* development of pellet injection technique



For Demo Reactor

* development of centor fueling technique



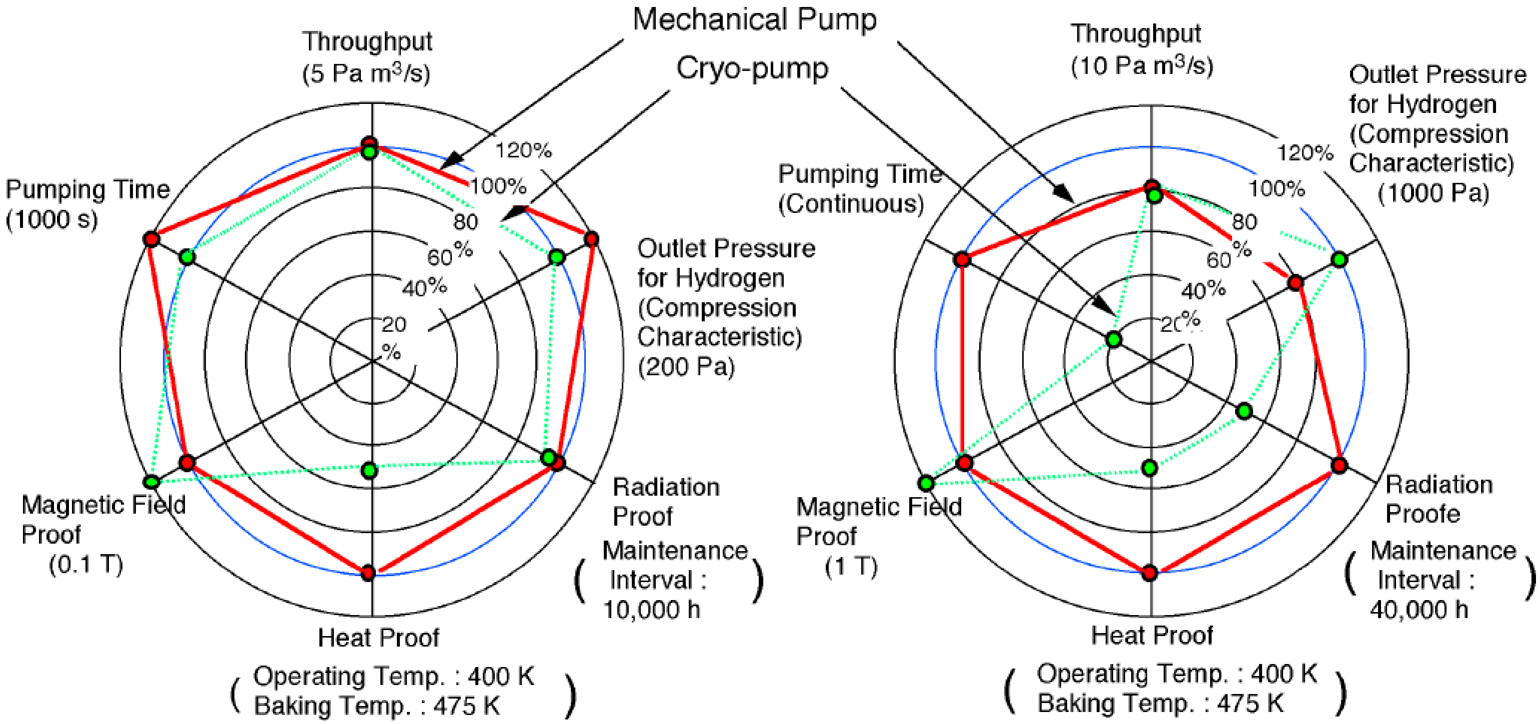
HW: compact toroid injection?

Fuelling and vacuum pumping technology

- Mechanical pump: metallic rotors requring magnetic shield, low tritium inventory
- Cryopump: not disturbed by a magnetic field, operation has to be stopped periodically for regeneration of the cryopanel.

For ITER

For Demo Reactor



vacuum leak detection method

Assuming a ceramic pump driven by a compressed gas in a Demo reactor.

Diagnostics technology

For ITER

* Development of Diagnostic Elements

Ceramics Insulatotion,
Optical Elements (Mirror/Reflector,Windw Materials, Optical Fiber),
Sensors (Magnetic Probe, Bolometor, Pressure Gauge, etc.),
Electric Cable

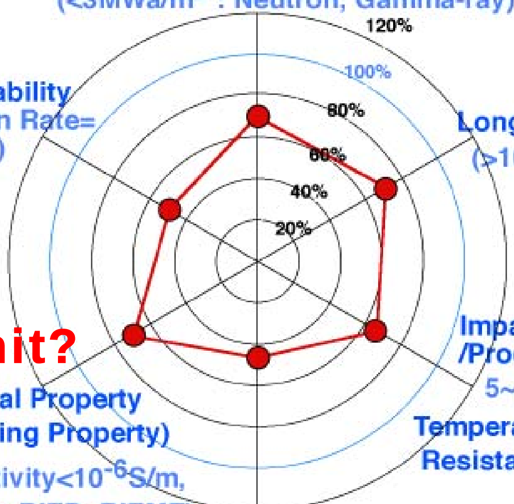
* Development of Prototype

Sensors, Vacuum Seals for Diagnostic Window,
Optical fiber/ Electric Cable Feedthroughs, etc.

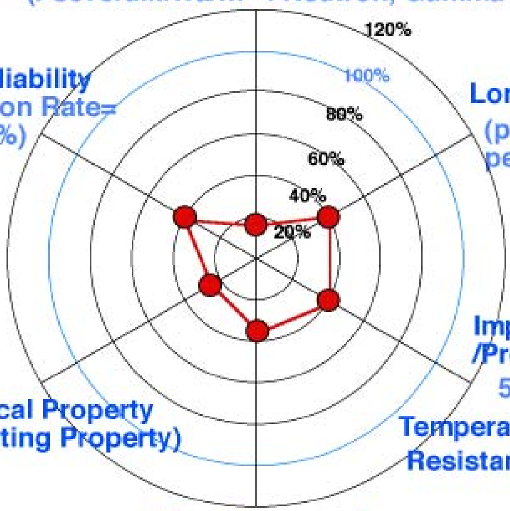
For Demo Reactor

* Development of Diagnostic Elements/Prototype

Development of Advanced Materials,
Heavy Irradiation Tests with <20 dpa



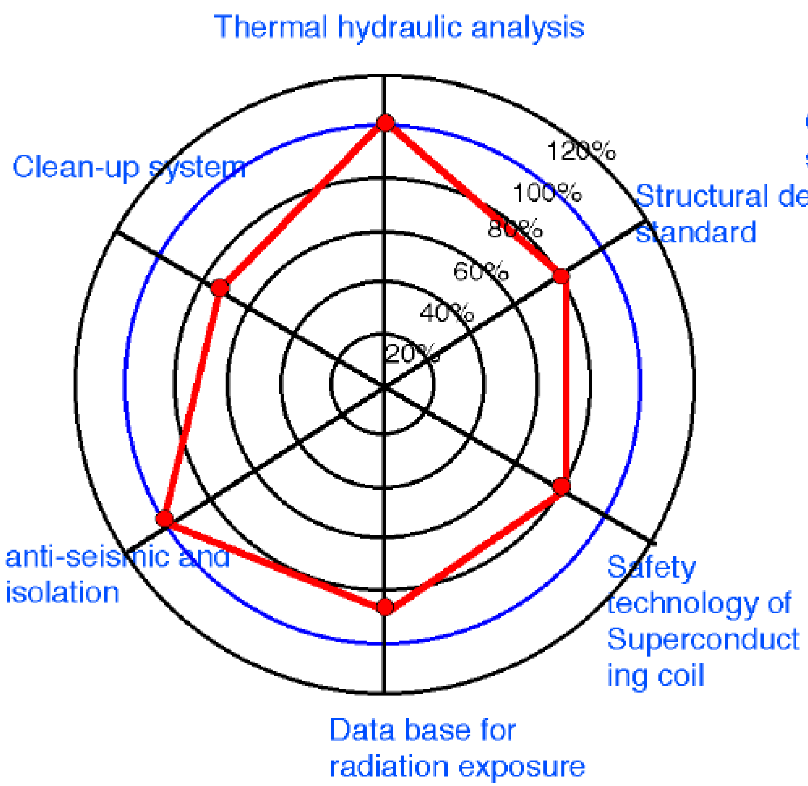
HW: unit?



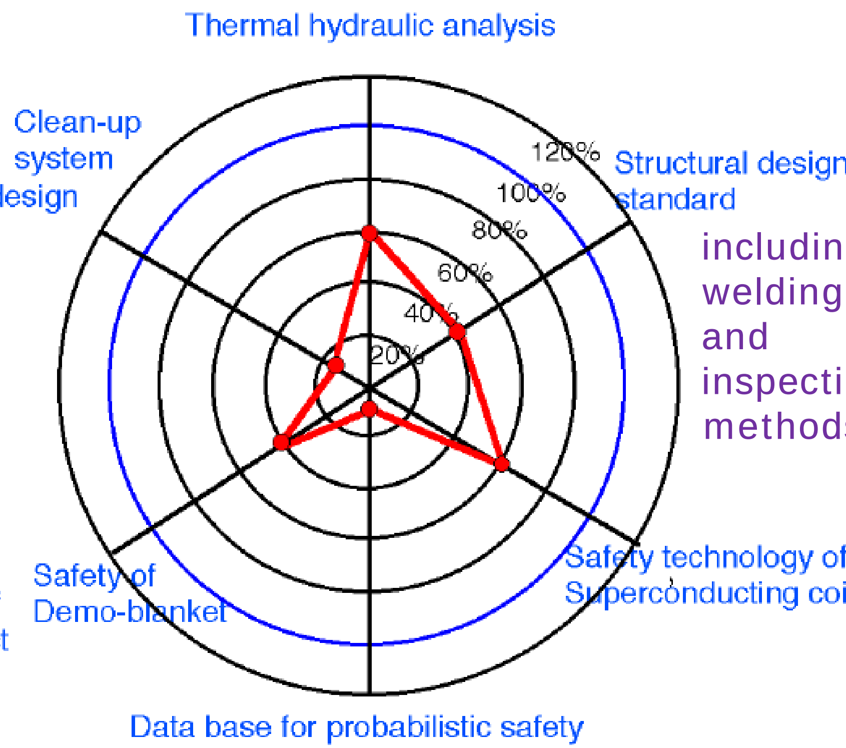
Safety technology

- Improvement of the safety system reliability for abnormal events of the cooling system due to high coolant temperature, high heat flux, and high neutron flux for power generation, and the improvement of social receptivity of the programme by reaionalisation and passiveness.

For ITER



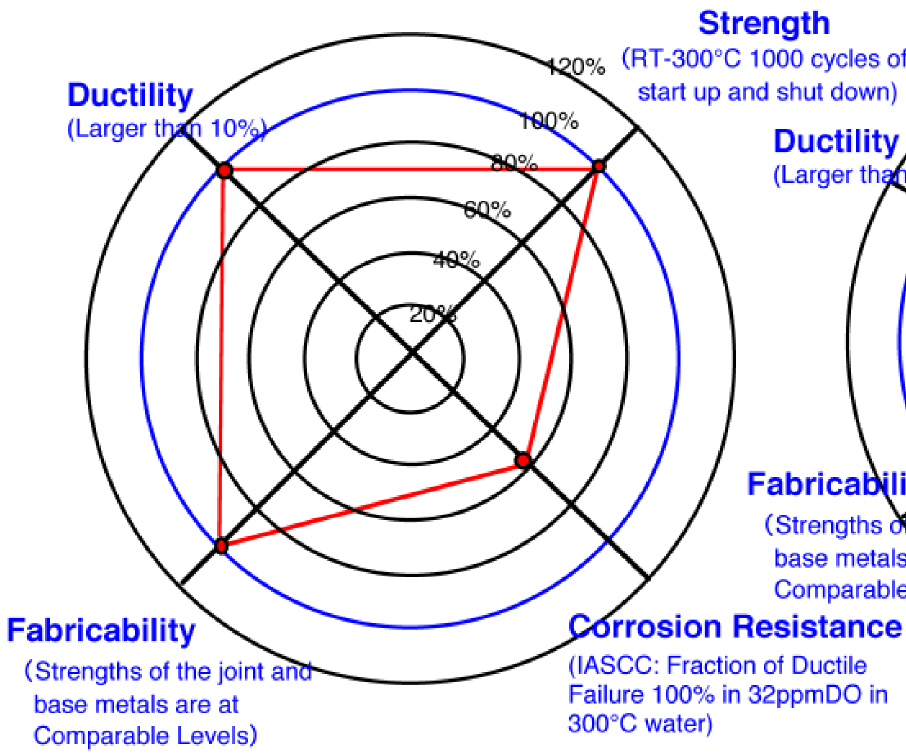
For Demo Reactor



including welding and inspection methods

Materials development

For ITER
(Austenitic Steel)



For Demo Reactor
(Reduced Activation Ferritic
/ Martensitic Steels)