Superconducting Dipole Magnet for SAMURAI

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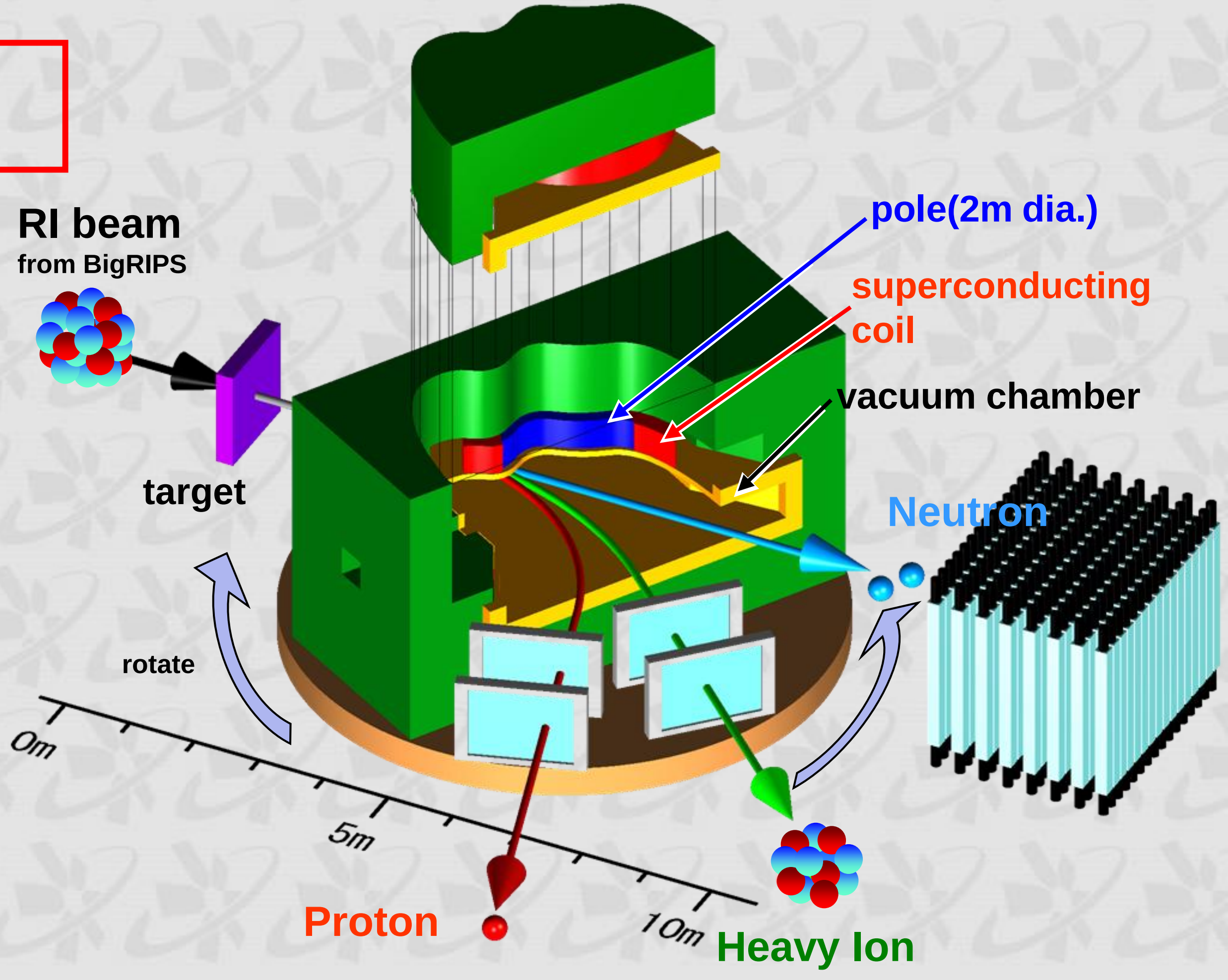
Outline of “SAMURAI”

SAMURAI spectrometer is designed for kinematically complete measurements by detecting multiple particles in coincidence.

Large angular- and momentum-acceptance

SAMURAI consists of …

- ✓Superconducting magnet
- ✓Heavy Ion detectors
- ✓Proton detectors
- ✓Neutron detectors
- ✓Large vacuum chamber
- ✓Rotatable base



Requirements

- Requirements
  - Large field integral --> for high precision momentum analysis
  - Large pole gap --> for large vertical acceptance for neutrons
  - No coil link --> for large acceptance in the horizontal direction
  - Small fringing field --> for detectors around the target region and tracking detectors
  - Flexibility --> for various experimental conditions
  - Large momentum acceptance --> for heavy fragments and protons in coincidence
  - High momentum resolution --> for deuteron-induced reactions

✓ Field Integral 7 Tm (dR/R ~ 1/700 @ 2.3 GeV/c for A/Z=3)
--> mass separation σ_A=0.2 for A=100
✓ Large Gap (0.8 m --> vertical ±5 degrees)
✓ Large opening (3.4 m --> holizontal ±10 degrees)
✓ Small Fringing Field (< 50 gauss @ 50cm from magnet)
✓ H-type magnet with cylinder poles (2m in diameter)
✓ Magnetic field … about 3T at center by ~1.9MAT
✓ Field clamp
✓ Build-in vacuum chamber
✓ Rotatable base (from -5 to 95 deg, 0.1deg/sec)

Specification

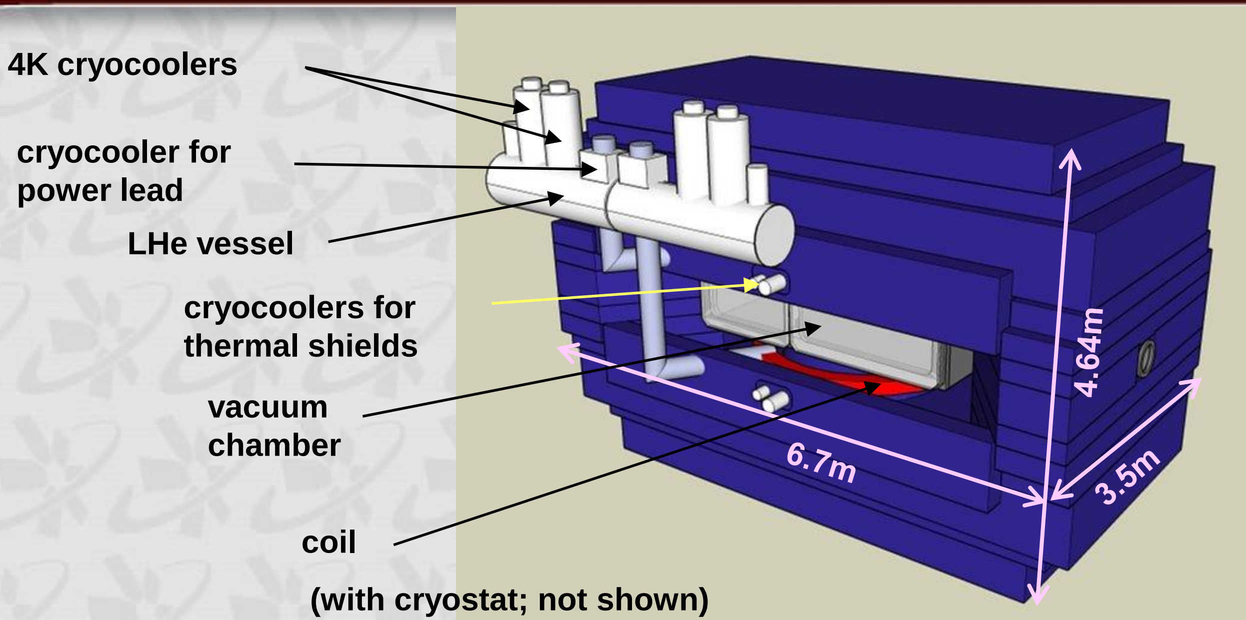
Table 1. Parameters of the superconducting dipole magnet.

	value
type	H-type, superconducting
number of turns	3411 turns/coil
current	560 A
magnetomotive force	1.9 MAT/coil
current density of coil	66.0 A/mm^2
field at the pole center (median plane)	3.1 T
BL integral at 3.1 T	7.05 Tm
maximum magnetic field in a coil	5.26 T
inductance	212 H
stored energy	33 MJ
coil inner diameter	2350 mm
outer diameter	2710 mm
cross section	180×160 mm^2
weight	1783 kg/coil
pole shape	circular
gap	880 mm
diameter	2000 mm
height	500 mm
yoke width	6700 mm
depth	3500 mm
height	4640 mm
weight	566140 kg

Table 2. Parameters of the superconducting wire.

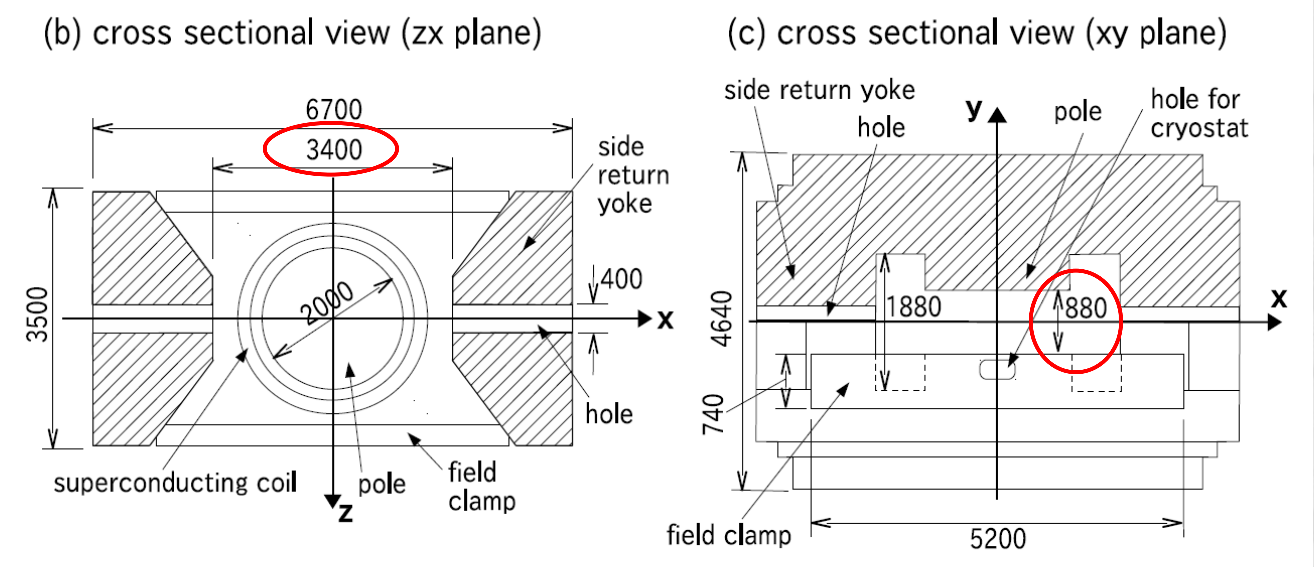
	value
material	NbTi/Cu
diameter	3 mmϕ
Cu/SC ratio	5.0 $\sim$ 6.0
insulation	PVF($\geq$ 40 μm)
filament diameter	$\sim$28 μmϕ
number of filaments	$\sim$1760
twist pitch	$\sim$88 mm
RRR	$\geq$100
critical current at 4.2 K	$>$ 4000 A at 3 T $>$ 3290 A at 4 T $>$ 2690 A at 5 T $>$ 2150 A at 6 T

Geometry



Weight: ~600 ton

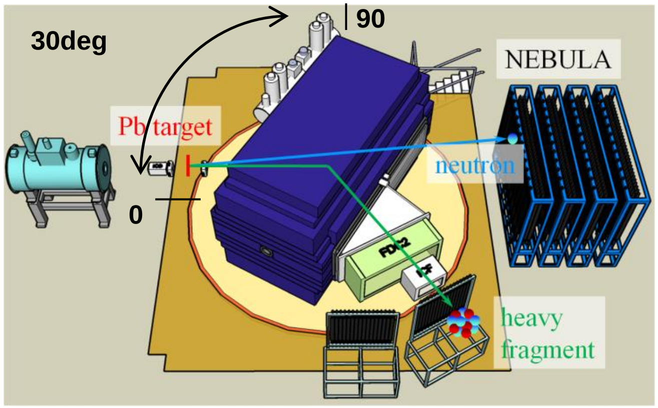
- yoke: 567 ton
- coil with cryostat: 8x2 ton
- vacuum chamber: 14 ton



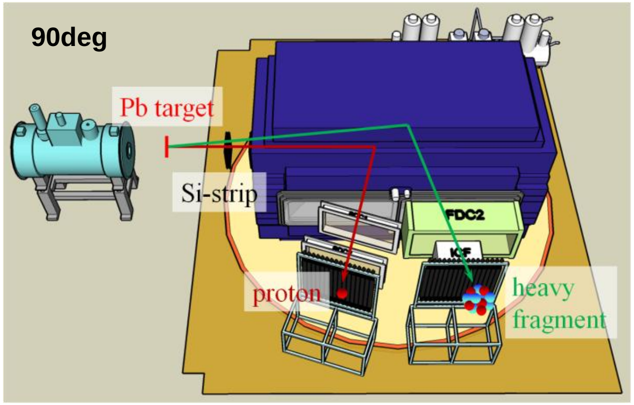
Versatile usage

Magnet can rotate around it's center.

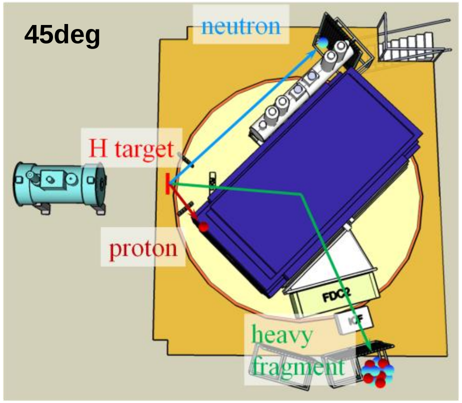
(γ, *n*) reaction: neutron-rich side



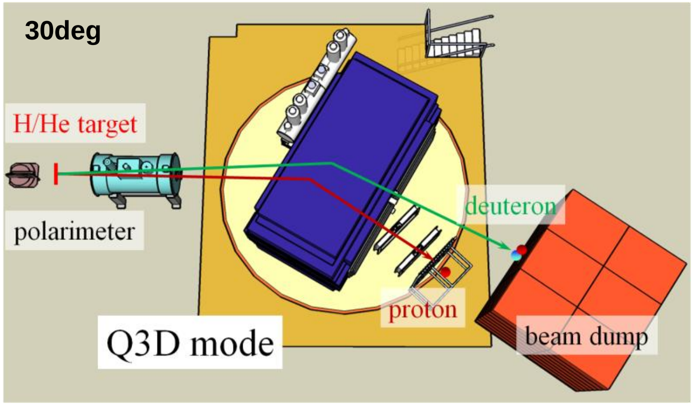
(γ, *p*) reaction: proton-rich side



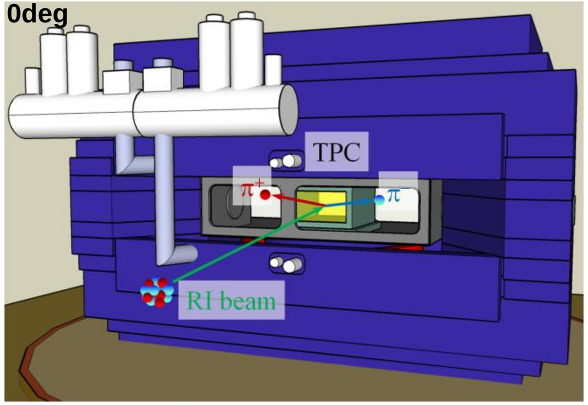
(*p*,*p'*), (*p*,2*p*), (*p*,*pn*), …



pol. *d*-induced reaction



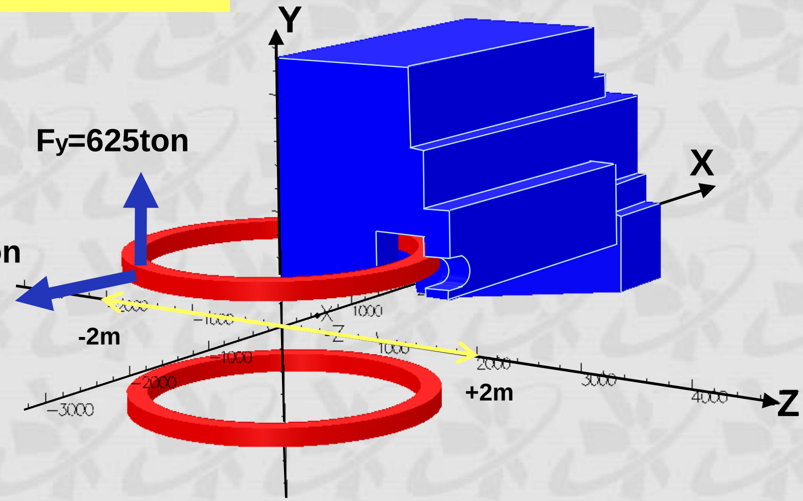
EOS measurement



Flexibility of settings is one of the good properties of SAMURAI.

Magnetic field

Magnetic field is calculated using TOSCA.

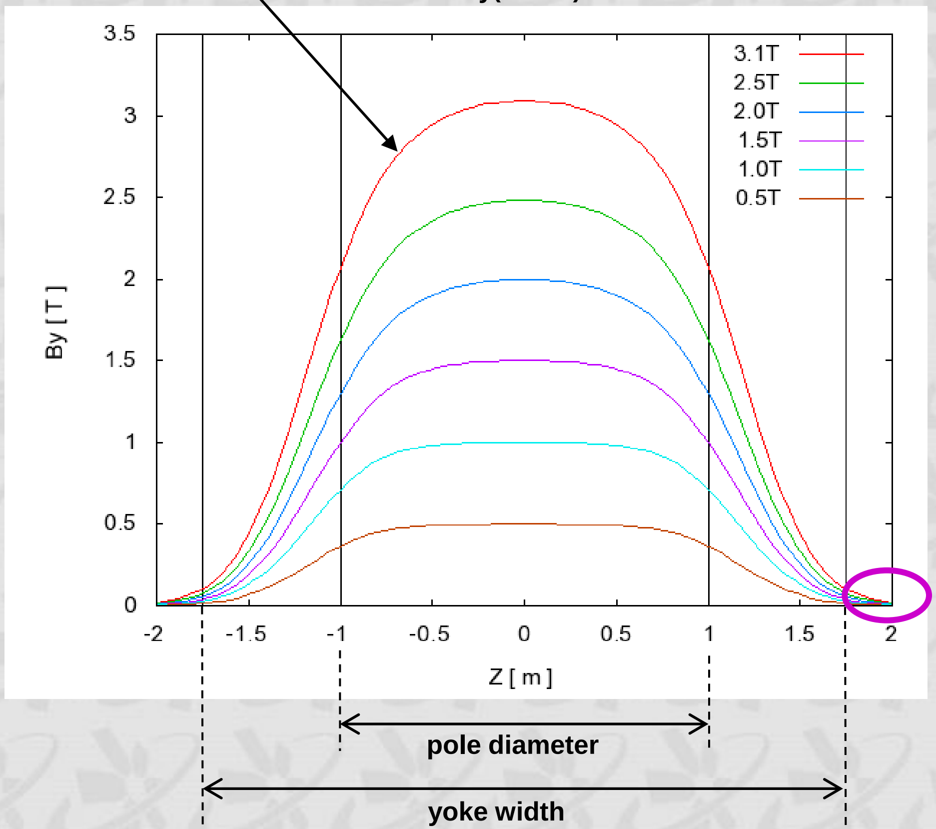


1.9 MAT/coil

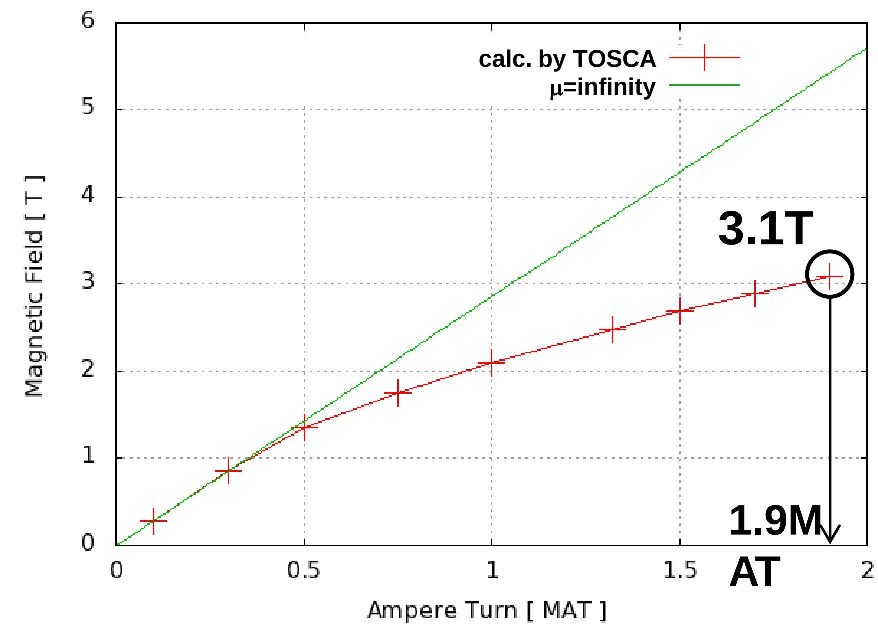
I=560 A (66 A/mm^2)

Integral BL=7.05 Tm

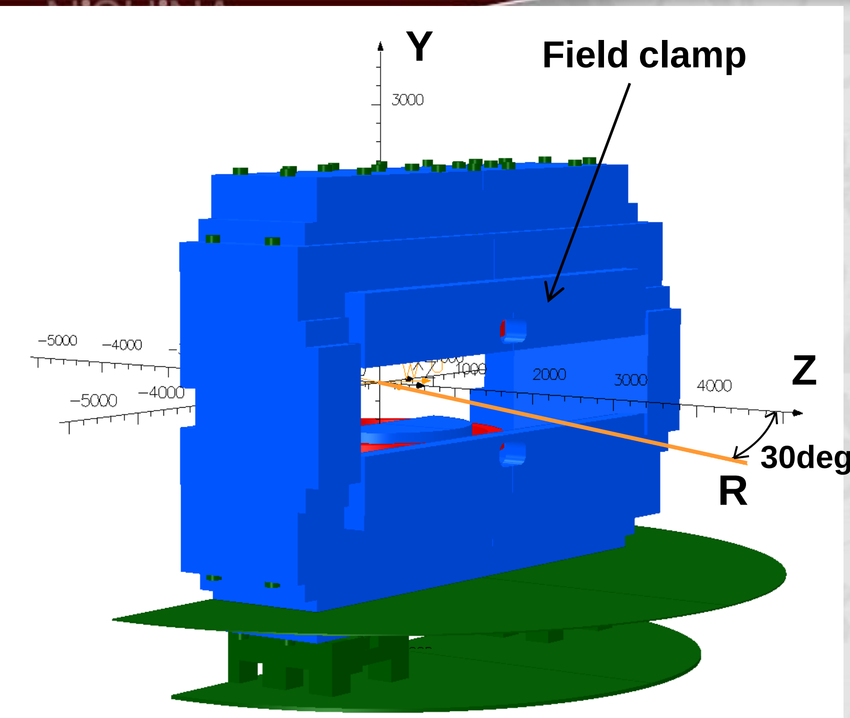
$B_{y(center)}$=3.1T

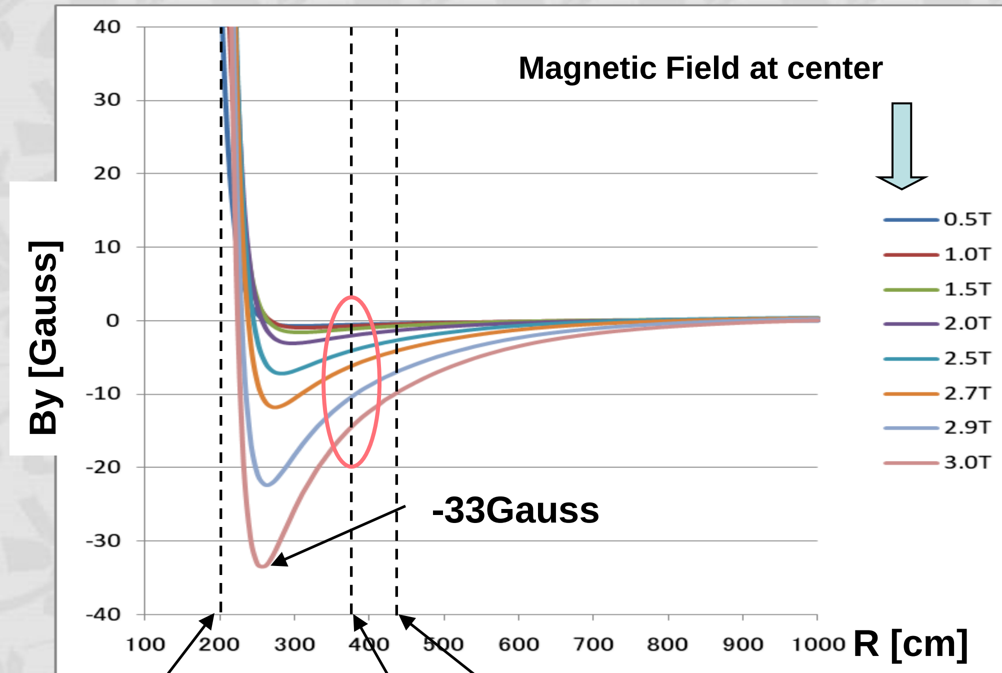


excitation curve @ center



Fringing field at detector position



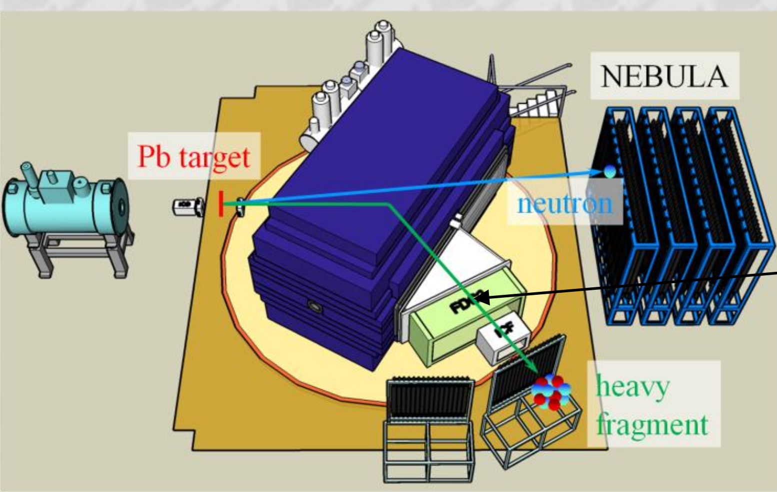


edge of field clamp

(R=202)

edge of stage

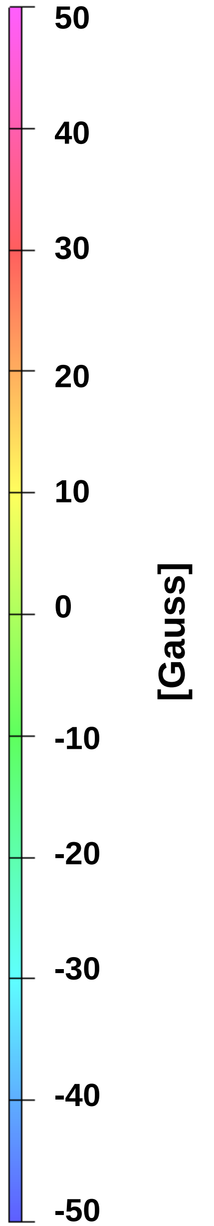
(R=440)



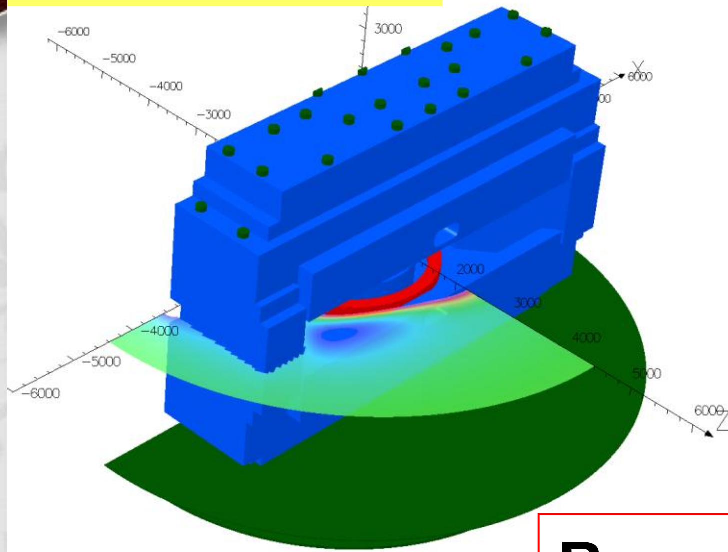
Center of FDC2

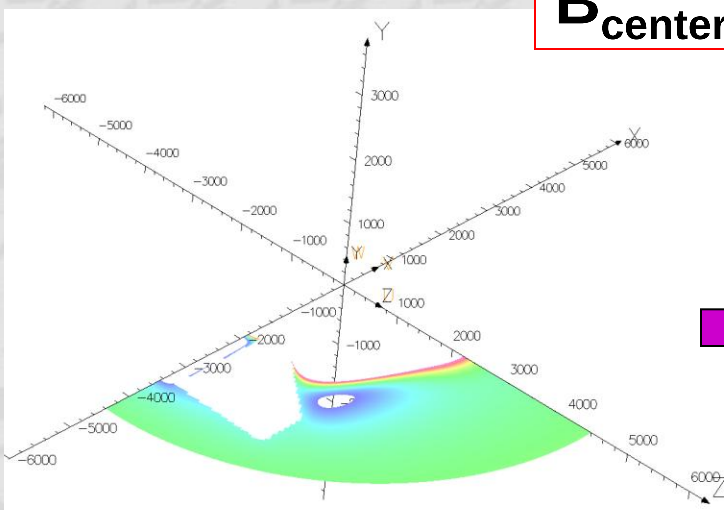
Requirement is fulfilled.

Fringing field on/off median plane

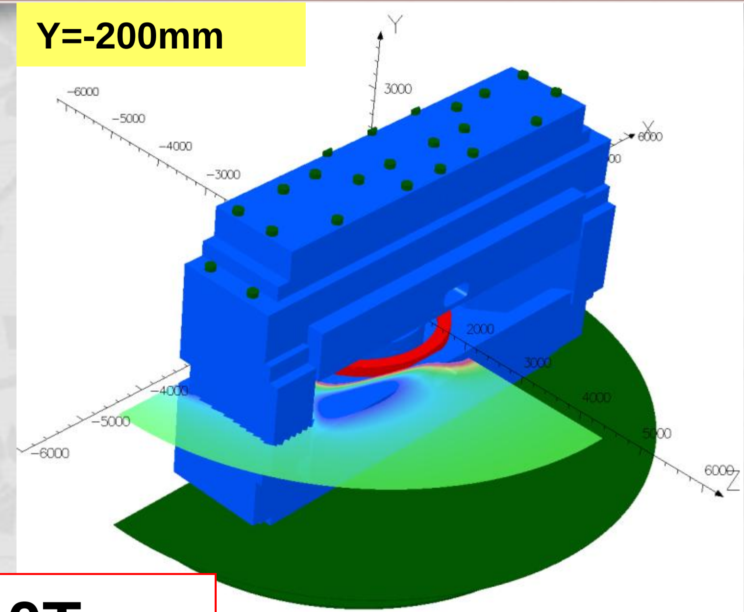


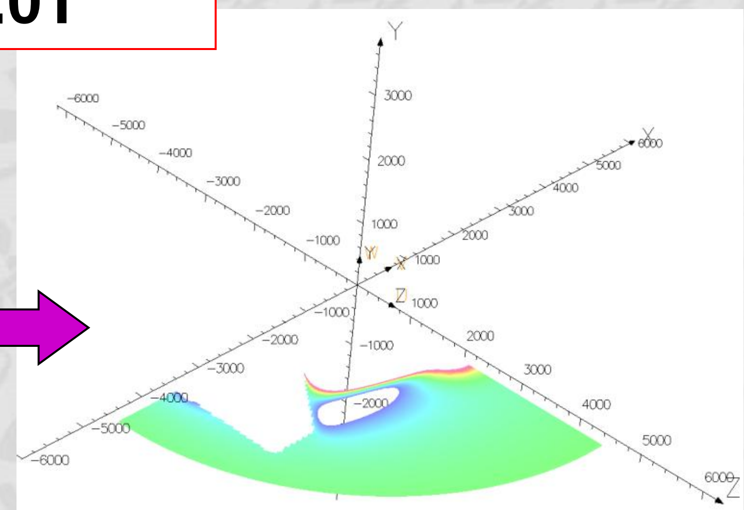
On median plane





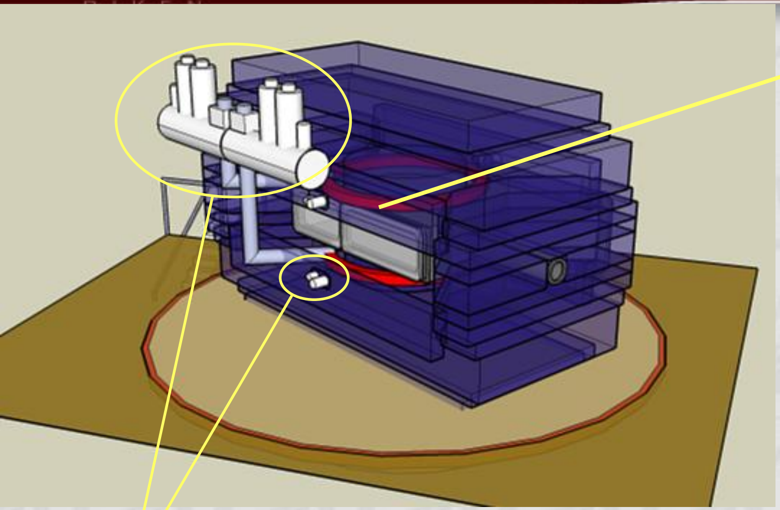
Y=-200mm





B_{center}=3.0T

Superconducting coils



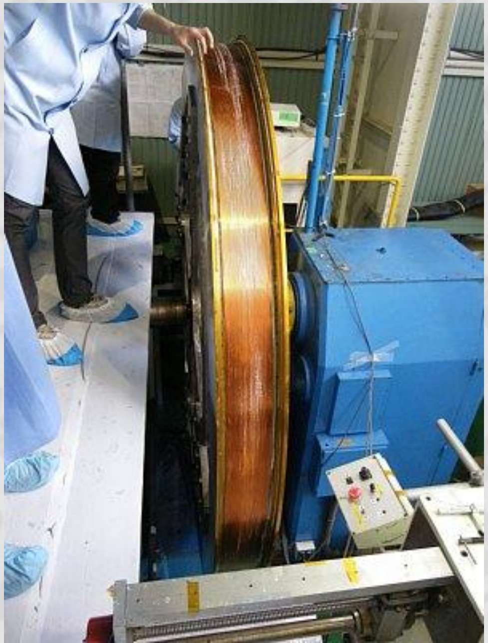
Superconducting coil

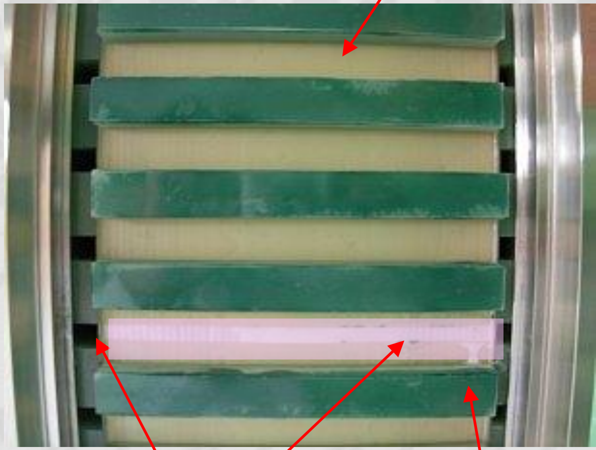
- ✓Nb/Ti wire (3mmϕ)
- ✓3411 turns/coil
- ✓Cooled by liquid-He
- ✓No coil link
- ✓Cross section: $18\text{x}16\text{cm}^2$
- ✓Outer diameter: 2.71m
- ✓Inner diameter: 2.35m

Cryocoolers

- ✓UP and DOWN independent
- ✓For 4.2K: GM-JT x4, 3.5W@4.3K
- ✓For 20K: GM x4, 5W@20K
- ✓For 80K: GM x4, 45W@40K
- ✓For current lead: GM x2, 60W@40K

14 cryocoolers are used in total.



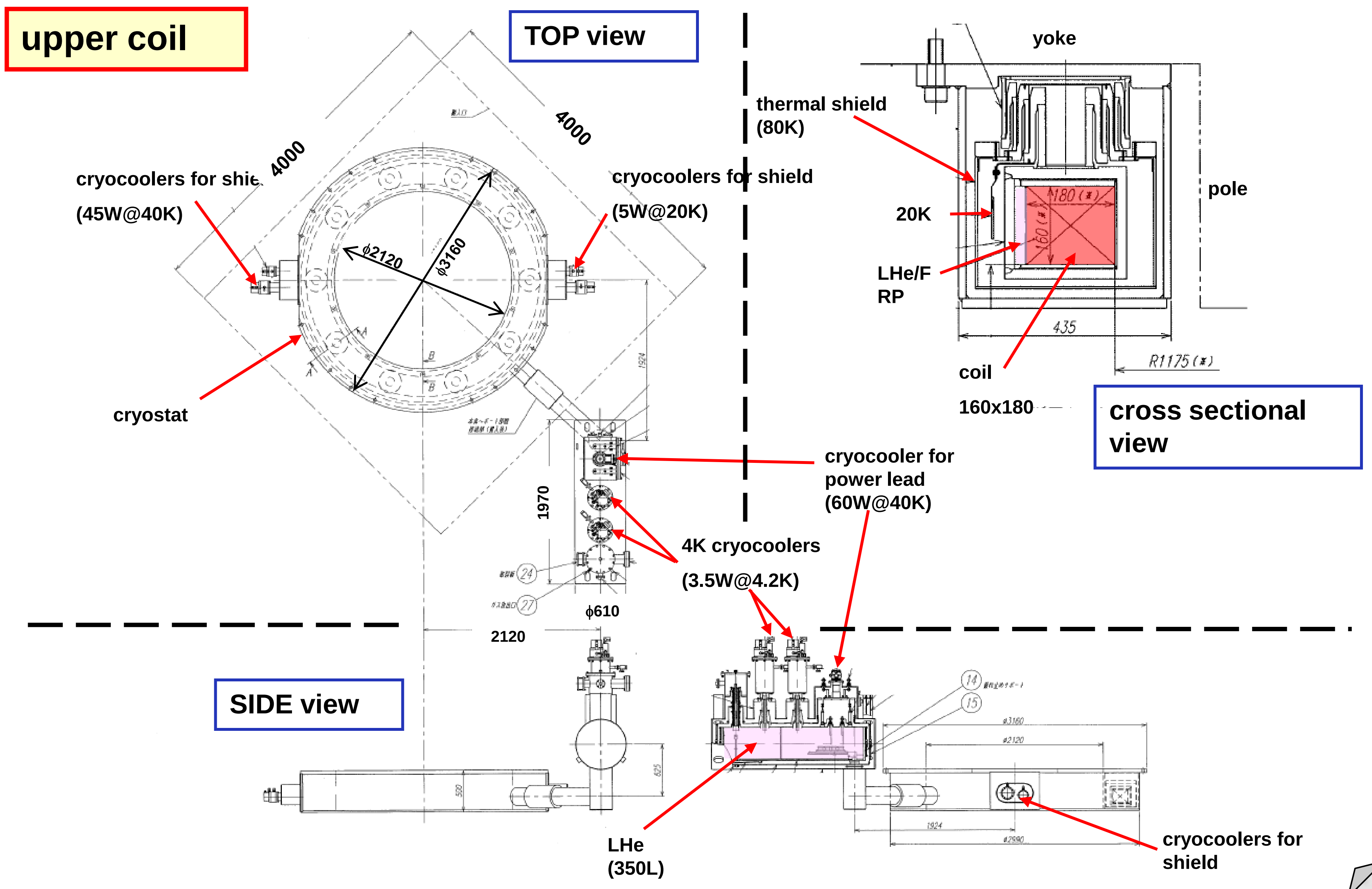


coil covered with resin

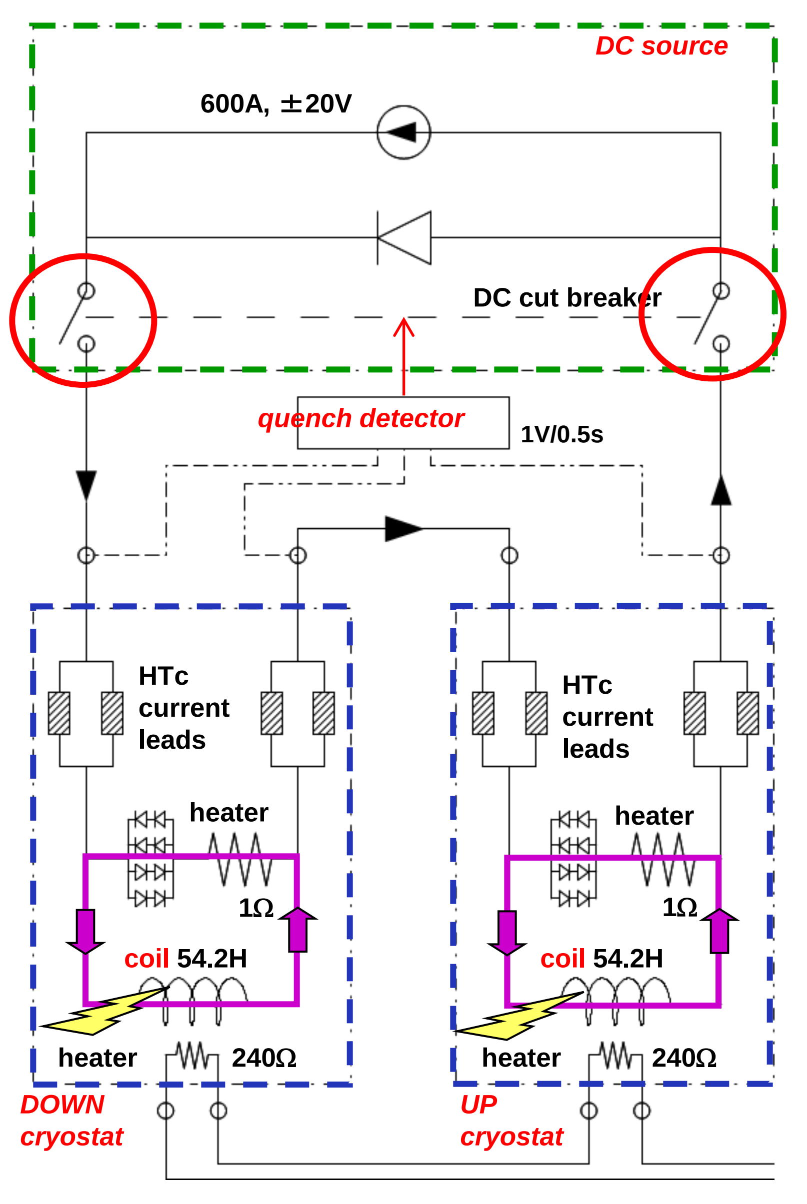
space for LHe

FRP

Cryostat for superconducting coils

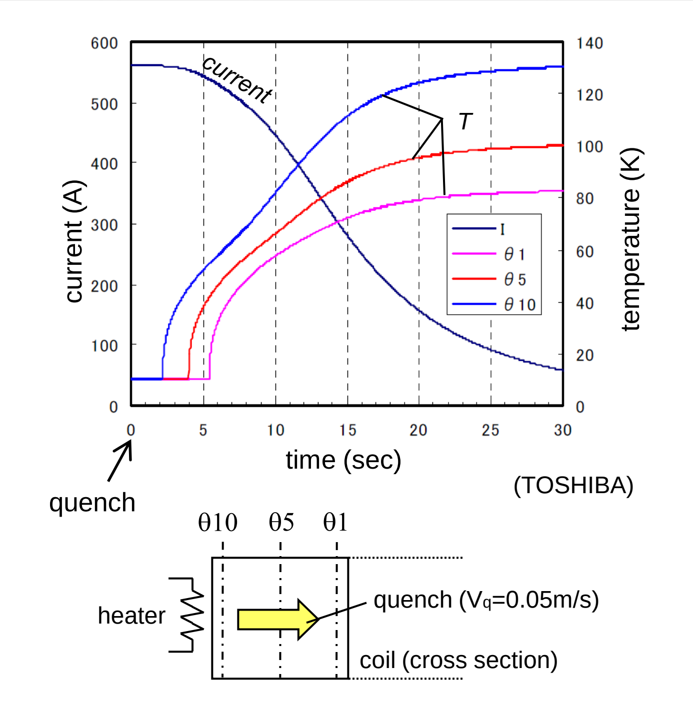


Coil circuit (quench protection)



If quench occurs …

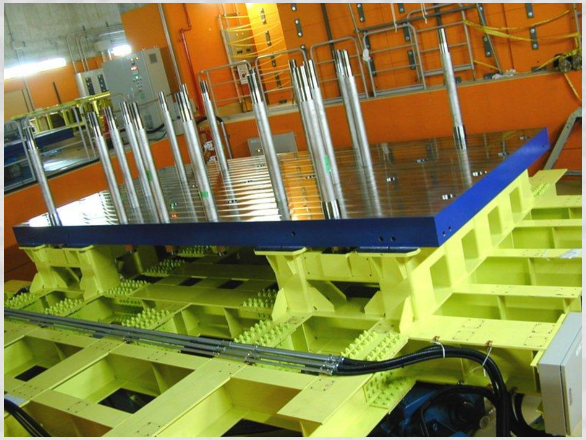
1. Quench detector catch the voltage over 1V, 0.5s
2. DC cut breaker : ON
3. Current flows between the coil and heater
4. Additional heater : ON
5. Normal region expands
6. Stored energy is dumped by the coil
7. T_{av}~100K in 30 seconds



Photos ~magnet construction~

Magnet construction have started in RIBF site.

Rails for rotatable base



Rotatable base with the first layer

Magnet yoke with poles

Coils with cryostats, LHe vessels

Vacuum chamber

NOW

Summary

- ✓Superconducting dipole magnet for SAMURAI
- ✓Center field =3T, BL=7Tm
- ✓Large acceptance
- ✓Rotatable from -5 to 95 degree

- ✓The magnet is now constructing.
- ✓Assembling of the main parts have already done.
- ✓Excitation test will start from April.
- ✓The construction of the magnet will finish by the end of May.
- ✓After that, other parts (beam ducts, detectors, etc…) will be set.