# Superconducting Magnets of the Proton Beam Line for the JHF- Kamioka Neutrino Experiment

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- Introduction
- Magnet Design
- Subjects to be done
- Summary

# Introduction

- 50 GeV primary proton beam for the neutrino experiment will be extracted inward the P/S ring and a bending field of 4 T will be essentially needed.

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## Superconducting magnets

Of course, we expect that it will bring us a significant running cost reduction.....

- Specific characteristics of this proton beam line are,
  - large energy deposition induced by 750 kW primary proton beam.
  - 10 to 20 years operation under high radiation environment.

  >> Appropriate use of Polyimide insulation, Plastic spacer, Cold diodes

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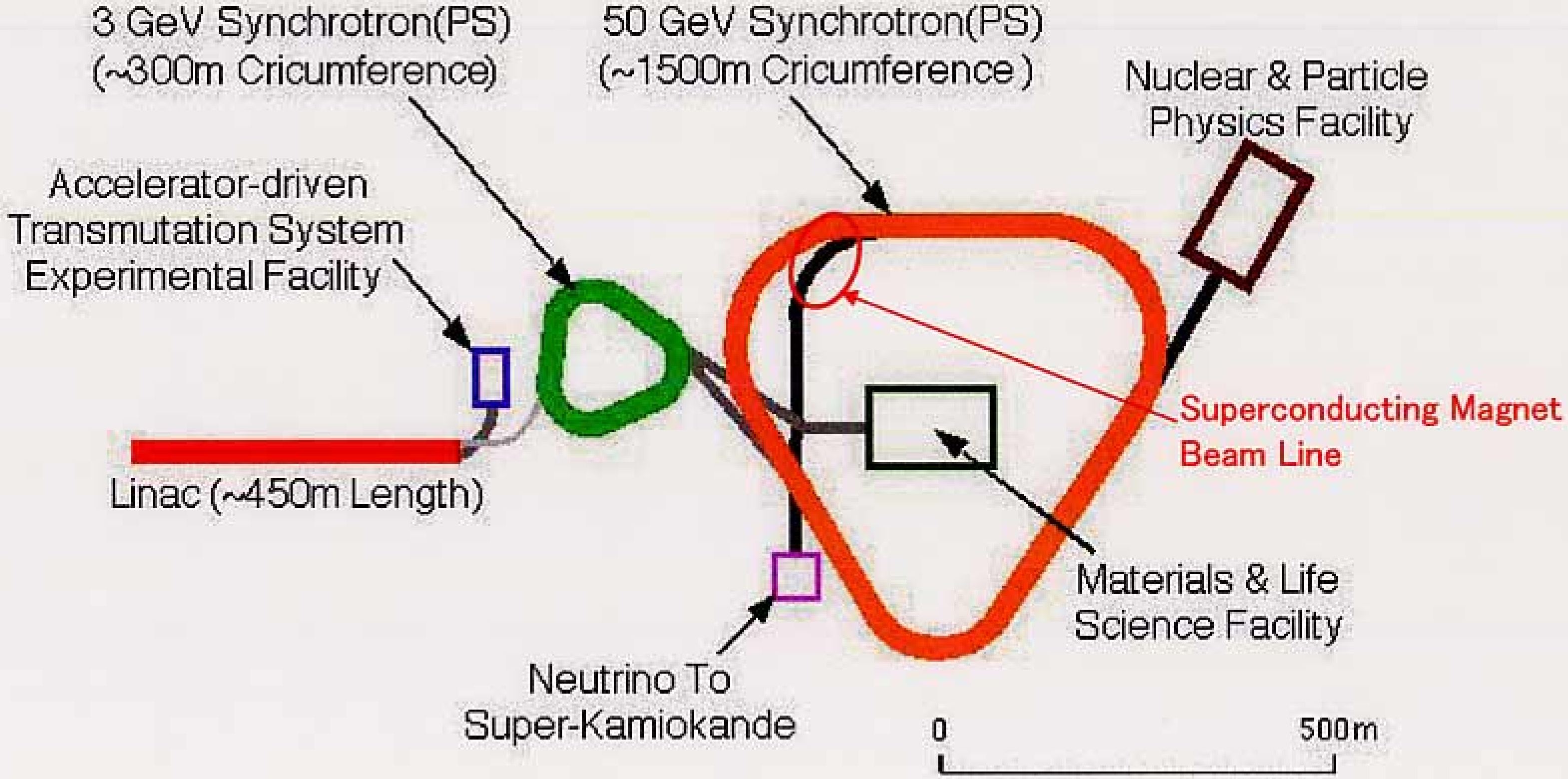
Magnet system is expected to have no trouble including magnet quenches during operation. But, "COST REDUCTION" is also one of the most important design subject.




High Intensity Proton Accelerator Project

# Magnet Design

- Specification

| Type | Magnetic Length | Operation Field | Number |
|---|---|---|---|
| Dipole | 3 m | 3.95 T | 20 |
| Quadrupole | 1 m | 32.4 T/m | 20 |

- Design Concept

– Superconducting Cable: LHC dipole inner/outer cable (NbTi/Cu).

– Cross section: Single layer coil surrounded by plastic spacers and iron yokes.

– Plastic Spacer: No use of metallic collars → Ground insulation film are not needed.

– Some materials are commonly used in both Dipole and Quadrupole.

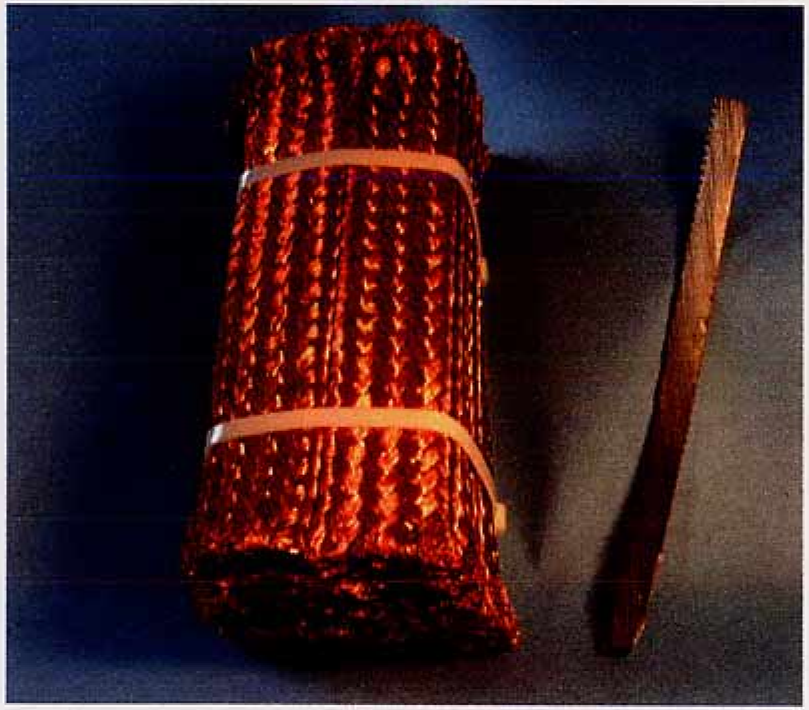
– Self-protected design for the magnet quench. (RHIC dipole at BNL)

# Magnet Design

- Superconducting Cables

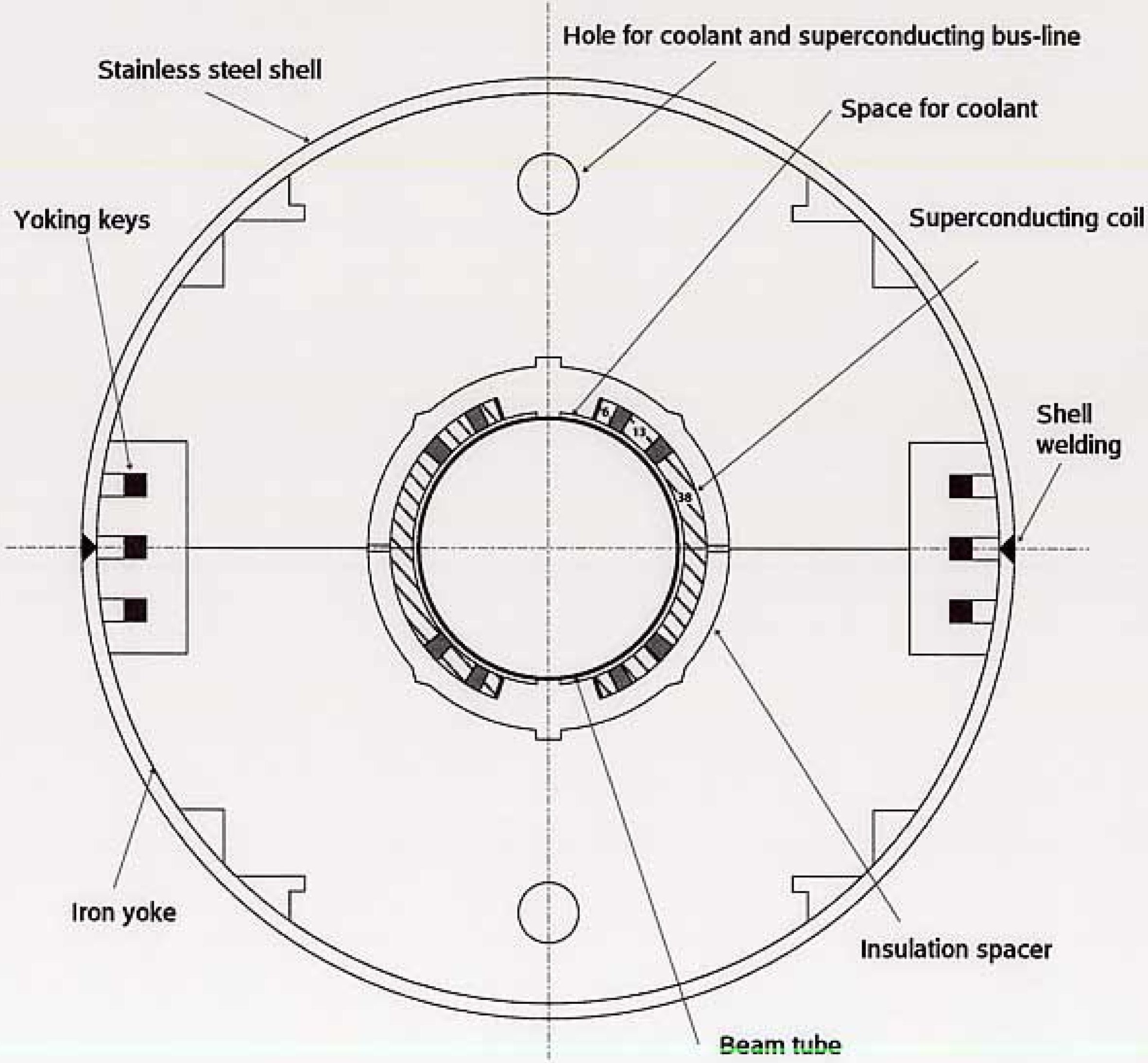
: Insulated by Polyimide Film

| | | D= 220mm<br>LHC-Dipole-Inner Cable | D= 180 mm<br>LHC-Dipole-Outer Cable |
|---|---|---|---|
| Strand | Diameter [mm] | 1.065±0.0025 | 0.825±0.0025 |
| | Copper to super ratio | 1.6~1.7±0.03 | 1.9~2.0±0.03 |
| | Filment size [μm] | 7±0.1 | 6±0.1 |
| | Filment spacing [μm] | >1 | >1 |
| | Number of filaments | 8700~8900±20 | 6300~6550±20 |
| | RRR | >70 | >70 |
| | Twist pitch [mm] | 18±1.5 | 15±1.5 |
| | Critical current 1.9K [A] | >515 @ 10T | >380 @ 9T |
| | n value at 7 T, 4.2 K | >30 | >30 |
| | Thickness of coating [μm] | 1 | 1 |
| Cable | Number of strands | 28 | 36 |
| | Thickness [mm] | | |
| | Thin | 1.900±0.006 | 1.480±0.006 |
| | Center | 1.736±0.006 | 1.362±0.006 |
| | Thick | 2.064±0.006 | 1.598±0.006 |
| | Width [mm] | 15.1±0.02 | 15.1±0.02 |
| | Cable twist pitch [mm] | 115±5 | 100±5 |
| | Keystone angle [deg.] | 1.25±0.05 | 0.90±0.05 |
| | Critical current 1.9K [A] | >13750 @ 10T | >12960 @ 10T |
| | Cross-contact resistance [μΩ] | ~15 | ~40 |



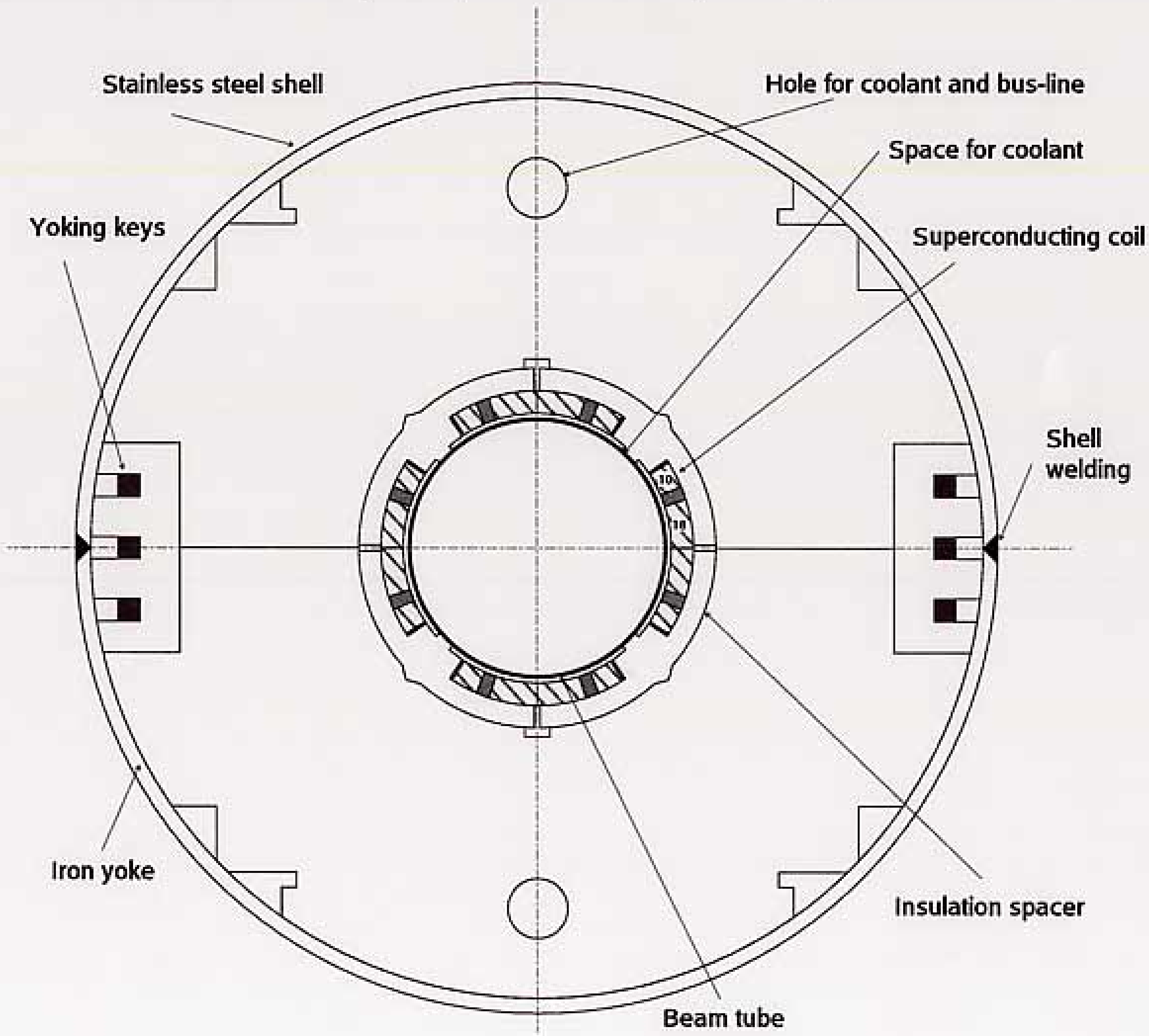
# Magnet Design

- Cross sectional view of Dipole (ID=180 mm)



# Magnet Design

- Cross sectional view of Quadrupole (ID=180 mm)

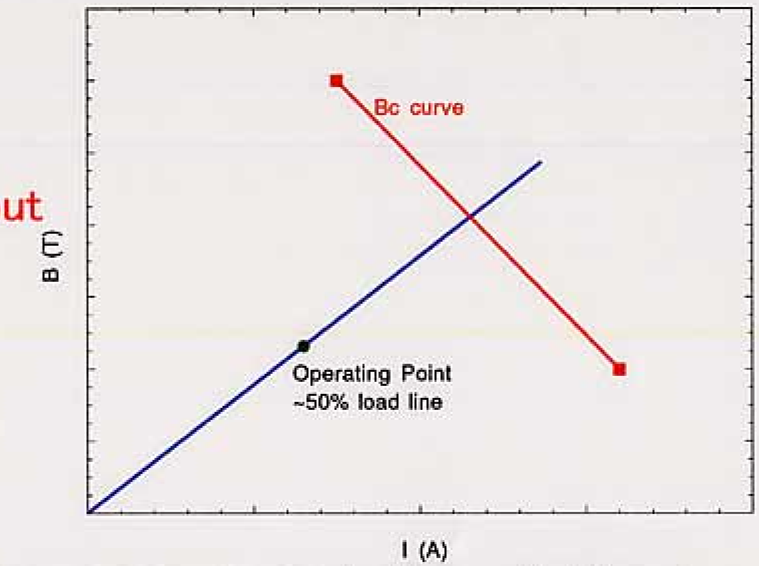


# Magnet Design

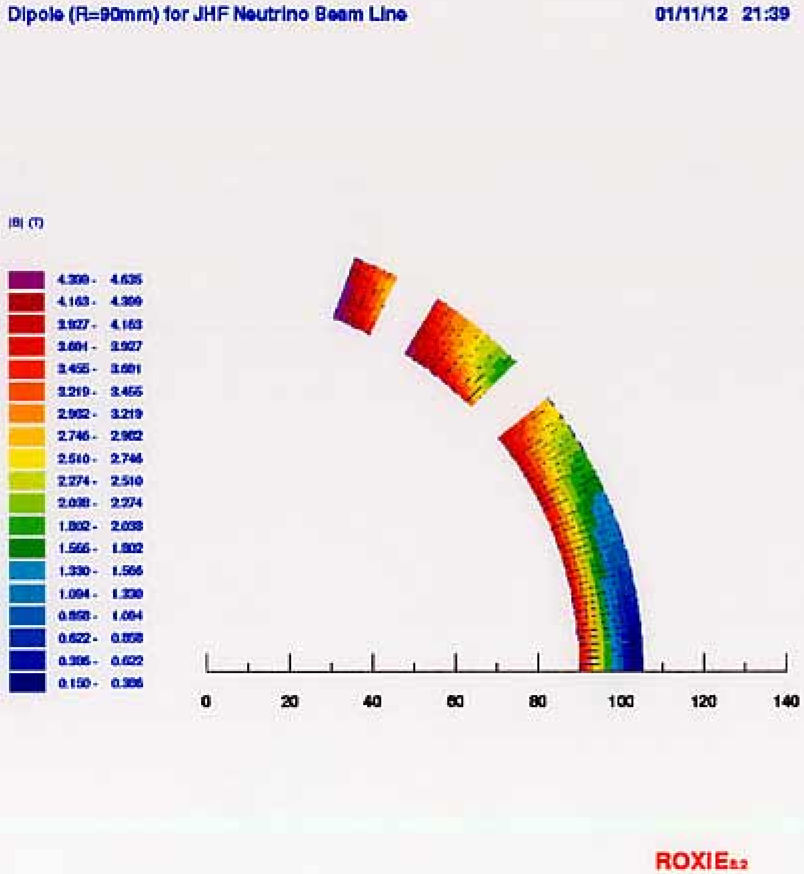
- Magnetic Design of Dipole (ID=180 mm)

Load line ratio ∽50% >> Margin for heat input

Load line of Magnet




Quadrant coil



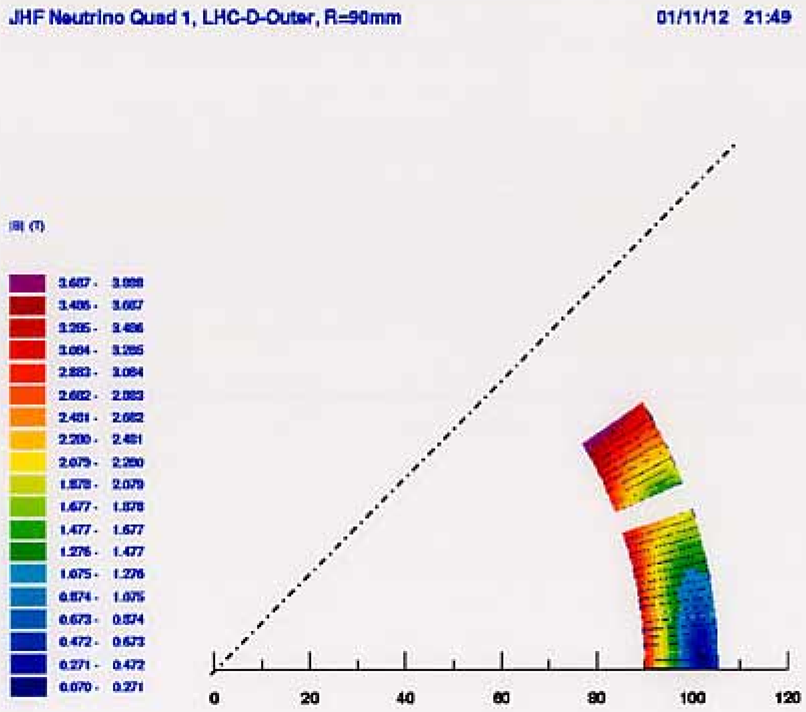

| | ID = 180 mm | ID = 220 mm |
|---|---|---|
| Current [A] | 6500 | 7800 |
| Yoke ID [mm] | 240 | 280 |
| Yoke OD [mm] | 600 | 720 |
| Magnet OD [mm] | 620 | 740 |
| Number of cable | | |
| 1st coil block (median plane) | 38 | 28 |
| 2nd coil block | 13 | 12 |
| 3rd coil block (pole) | 6 | 6 |
| Field [T] | 4.039 | 3.993 |
| Multipole coefficients [units] | | |
| b3 | 0.00394 | 0.06850 |
| b5 | 0.00663 | 0.00058 |
| b7 | 4.20610 | 1.85561 |
| b9 | -4.51876 | -1.20348 |
| b11 | 0.18207 | 0.05185 |
| Coil peak field [T] | 4.635 | 4.715 |
| Inductance [mH/m] | 10.75 | 10.39 |
| Stored energy [kJ/m] | 227.0 | 316.0 |
| MIITs [$MA^2$sec] | 30 | 50 |
| MIITs/I [sec] | 0.7 | 0.8 |
| Superconducting cable | LHC-Dipole-Outer | LHC-Dipole-Inner |

Rref=50mm, iron permeability=400, b2=10000 units

# Magnet Design

- Magnetic Design of Quadrupole (ID=180 mm)

Octant coil




| | D = 180 mm | D = 220 mm |
|---|---|---|
| Current [A] | 6500 | 7800 |
| Yoke ID [mm] | 240 | 280 |
| Yoke OD [mm] | 600 | 720 |
| Magnet OD [mm] | 620 | 740 |
| Number of cable | | |
| 1st coil block (median plane) | 18 | 20 |
| 2nd coil block (pole) | 10 | 9 |
| Field Gradient [T/m] | 35.9123 | 32.2911 |
| Multipole coefficients [units] | | |
| b6 | 0.00070 | -4.08777 |
| b10 | -2.23934 | -1.53835 |
| b14 | 0.42312 | 0.03860 |
| Coil peak field [T] | 3.888 | 4.291 |
| Inductance [mH/m] | 4.48900 | 5.18744 |
| Stored energy [kJ/m] | 94.83016 | 157.80190 |
| Superconducting cable | LHC-Dipole-Outer | LHC-Dipole-Inner |

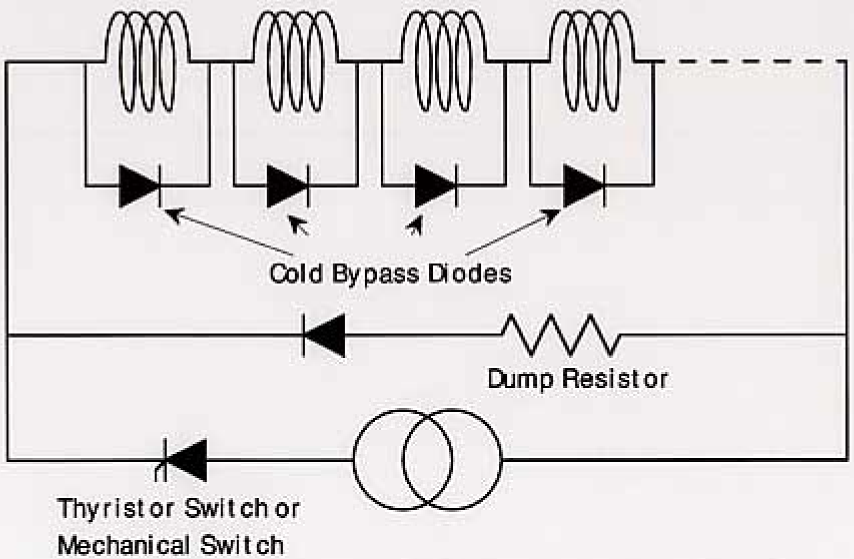
Rref=50mm, iron permeability=400, b2=10000 units

ROXIE

# Magnet Design

- Quench Protection

| | RHIC Dipole | JHF-Neutrino Dipole |
|---|---|---|
| Current[A] | 5093 | 6500 |
| Field [T] | 3.458 | 4.039 |
| Inductance [mH] | 28 | 32.3 |
| Stored energy [kJ] | 351 | 681 |
| MIITs [$MA^2$sec] | 8.6 | 30 |
| MIITs/$I^2$ [sec] | 0.34 | 0.7 |
| Quench velocity [m/sec] | 15 | --- |




Excitation scheme of Dipole and Quadrupole
: 2 circuits for 40 magnets

## Subjects to be done

- Precise Monte-Carlo simulation for:
  - Heat input of coils induced by primary proton beam
  - Radiation damage of insulation materials and electrical parts
- Development of:
  - Beam tube
  - Current lead
  - Cryostat
  - RELIABLE Quench detection system
- How to cool the magnet ??
  - Supercritical helium
  - Forced 2-phase flow
  - Single phase helium flow

## Summary

- Conceptual design of the superconducting magnet beam line for the JHF–Kamioka neutrino experiment has been carried out.
- We still have some subjects to be solved in prior to the construction of the magnets.
- Schedule

| | |
|---|---|
| 2002 | Magnetic and mechanical design |
| | Procurement of the prototypes |
| 2003 | Fabrication of the prototypes |
| | Procurement of the production magnets |
| 2004 | Excitation tests of the prototypes (LHC insertion quadrupole test stand in KEK) |
| | Fabrication of the production magnets |
| 2005 | Installation of the cryostat |
| 2006 | Ready for the operation |