Muon Beam Line for COMET
- Updates for the Superconducting Magnet R&D

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NuFACT15 at Rio de Janeiro
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- Superconducting Magnet System
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Introduction

- Physics Motivation and COMET Experiment
  - Ben’s talk

- Concept Design for Superconducting solenoid
  - Reported in NuFACT13

- This talk
  - Design and testing of SC magnet elements to challenging (radiation, thermal load) operating environment.

- COMET phase-I
  - Graphite target
  - 3 kW proton beam ($2.5 \times 10^{12}$ pps)

- COMET phase-II
  - Tungsten target
  - 56 kW proton beam ($4.4 \times 10^{13}$ pps)

- Main Issue: Radiation
  - Capture Solenoid around the preduction target

- All of the following discussion are on phase-II.
Superconducting Magnet System

- **Pion Capture Solenoid**
  - Capture the pion from production target
  - 5 Tesla at peak

- **Muon Transport Solenoid**
  - Curved solenoid to select charged particle
  - Dipole magnet to select the muon momentum

- **Detector Solenoid**
  - Uniform field for muon tracking and PID
  - 1 Tesla
Status of Superconducting Magnet

- Finished the fabrication of Transport Solenoid in this year
- Vacuum test: at level of $10^{-9}$ Pa·m$^3$/sec
- Leak test: no leak
Status of Superconducting Magnet

- Finished the TS1b → e coil winding in 2014.
- R&D on Capture Solenoid is still ongoing.
- This year:
  - LHe transfer tube
  - Current box
Radiation Issue

- **Tungsten Shield**
- **Radiation damage on Magnet**
  - Electric resistivity degradation
    - Al: 0.03 nΩ·m for $10^{20}$ neutrons/m$^2$
    - Cu: 0.01 nΩ·m for $10^{20}$ neutrons/m$^2$
  - MC simulation (PHITS): $2.8 \times 10^{21}$ neutrons/m$^2$ for reaching $10^{19}$ stopped muons (230 days) at peak
- **Heat generation during the operation**
  - 35 mGy/sec at peak → 0.7 MGy for 230 days
Coil Structure for Capture Solenoid

To reduce radiation effect...

- **Al Stabilized Conductor**
  - NbTi:Cu:Al = 1:0.9:7.3
  - $RRR_{Al} \geq 500\ (RRR = \frac{\rho_{RT}(T,B)}{\rho_{CT}(T,B)})$
  - 0.1% Ni
  - Low energy deposition

- **Kapton tape → Pre-preg tape**
  - Polyimide film / Boron free glass cloth
  - To reduce the neutron effect

- **BT GFRP spacer**
  - Good radiation resistance

- **Conduction Cooling**
  - Reduce the Tritium production

- **1 mm Al strip**
  - Release the energy deposition
Coil Temperature

- **Thermal Simulation**
  - Heat generation: energy deposition $\times 1.5$
  - Thermal conductivity: using KUR measurements

- **Geometry**
  - 3 mm innermost Al strip
  - Both side cooling from 1st layer to 6th layer

- 60 day operation ($6 \times 10^{20} \text{ n/m}^2$) $\rightarrow T_{\text{max}} = 6.4 \text{ K}$

![Thermal Simulation diagram]

![Graph showing maximum temperature over operation time]
Quench Protection

- Connected all of the capture solenoid for quench protection
- Maximum temperature after quench
  - Estimated from MIITs
  - \( \text{MIITs} = \int_0^\infty I^2(t)dt = \int_{4.2K}^{T_{max}} \frac{C(T)}{R(T)}dT \)
- RRR=100 (corresponding to 60 day operation), field=5.5 T \( \rightarrow T_{max} = 270 \text{ K} \)
  - Acceptable but need to check the thermal shock on insulation tape
After 60 day operation → Quench
Thermal cycling is necessary
  - Aluminium recovers by thermal cycling perfectly
Magnet Cooling needs 15 days at least + Some preparations → 30 day
Needs 4 cycling to achieve the goal of $10^{19}$ stopped muons
Summary

- R&D of superconducting magnet for COMET experiment underway
- Capture section is facing the radiation issue due to the usage of high intense proton beam
- 60 day continuous operation for COMET magnet is possible.
- The maximum temperature will not exceed to 270 K after quench for 60 day operation
Thanks
Backup
Quench Simulation

Preliminary
Radiation test for pre-preg tape

Preliminary

![Graph showing tensile strength vs. dose for different types of tape: BTGU, BTGK-A, BTGK-B, BTGK-C. Tensile strength values are shown as markers on the graph, with error bars indicating variability. The x-axis represents dose in MGY, ranging from 0 to 10, and the y-axis represents tensile strength in MPa, ranging from 5 to 14.](image-url)
Residual Dose Rate

1 month operation + 10 month cooling (max. = 3.738 mSv/h)