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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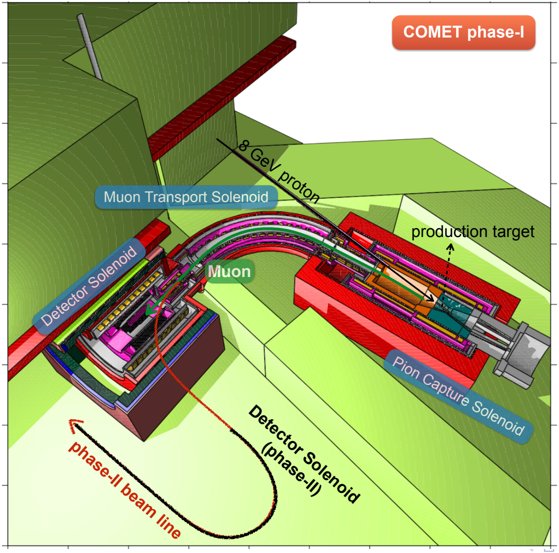
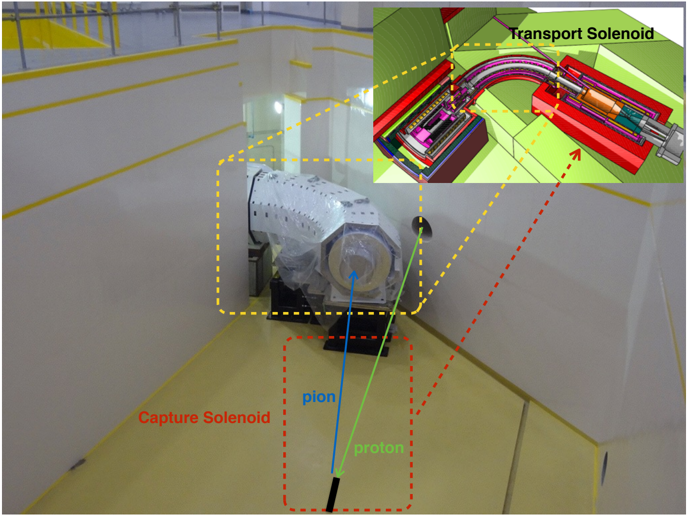
- Physics Motivation and COMET Experiment
  - Ben's talk
- Concept Design for Superconducting solenoid
  - Reported in NuFACT13
- This talk
  - Design and testing of SC magnet elements to challenging (radiation, thermal load) operating environment.
- COMET phase-I
  - Graphite target
  - 3 kW proton beam (2.5×10^{12} pps)
- COMET phase-II
  - Tungsten target
  - 56 kW proton beam (4.4×10^{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

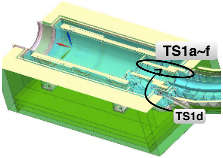
Status of Superconducting Magnet



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

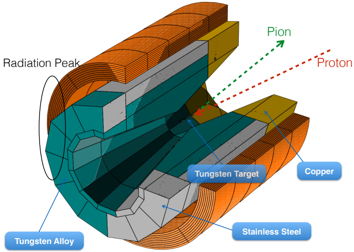
Status of Superconducting Magnet

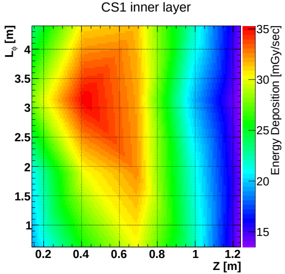
- Finished the TS1b → e coil winding in 2014.
- R&D on Capture Solenoid is still ongoing.
- This year:
  - LHe transfer tube
  - Current box

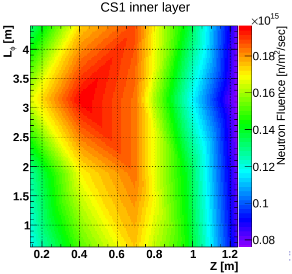


Radiation Issue

- Tungsten Shield
- Radiation damage on Magnet
  - Electric resistivity degradation
    - Al: 0.03 n$\Omega\cdot$ m for 10^{20} neutrons/m^2
    - Cu: 0.01 n$\Omega\cdot$ m for 10^{20} neutrons/m^2
  - MC simulation (PHITS): 2.8×10^{21} neutrons/m^2 for reaching 10^{19} stopped muons (230 days) at peak
- Heat generation during the operation
  - 35 mGy/sec at peak $\rightarrow$ 0.7 MGy for 230 days



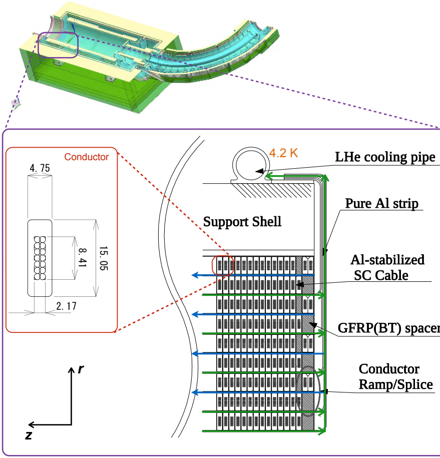




Coil Structure for Capture Solenoid

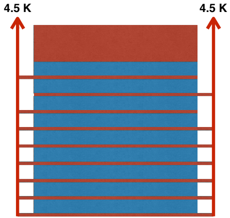
To reduce radiation effect...

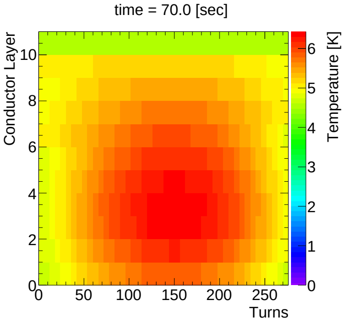
- Al Stabilized Conductor
  - NbTi:Cu:Al = 1:0.9:7.3
  - $\mathrm{RRR}_{Al} \geq 500$ $(RRR = \frac{\rho_{RT}(T,B)}{\rho_{CT}(T,B)})$
  - 0.1% Ni
  - Low energy deposition
- Kapton tape → Pre-preg tape
  - Polyimide film / Boron free glass cloth
  - To reduce the neutron effect
- BT GFRP spacer
  - Good radiation resistance
- Conduction Cooling
  - Reduce the Tritium production
- 1 mm Al strip
  - Release the energy deposition

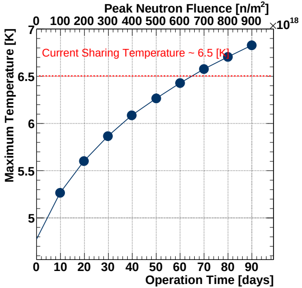


Coil Temperature

- Thermal Simulation
  - Heat generation: energy deposition × 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 (6×10^{20} n/m^2) → T_{max} = 6.4 K

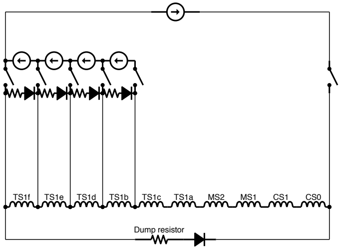


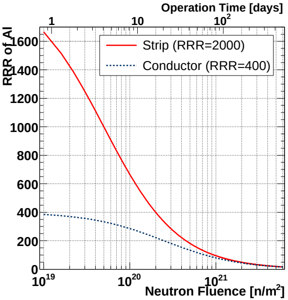


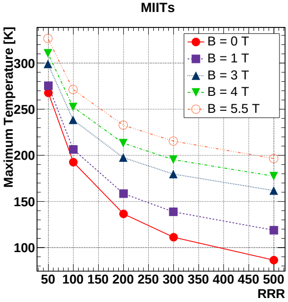


Quench Protection

- Connected all of the capture solenoid for quench protection
- Maximum temperature after quench
  - Estimated from MIITs
  - $MIITs = \int_0^\infty I^2(t)dt = \int_{4.2K}^{T_{max}} \frac{C(T)}{R(T)} dT$
- RRR=100 (corresponding to 60 day operation), field=5.5 T → T_{max} = 270 K
  - Acceptable but need to check the thermal shock on insulation tape

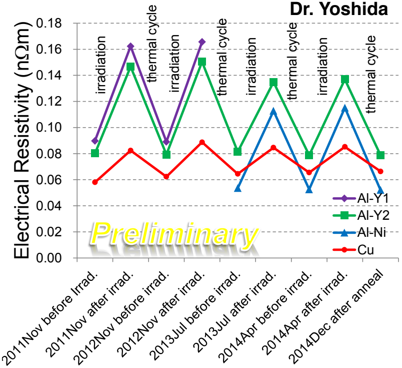


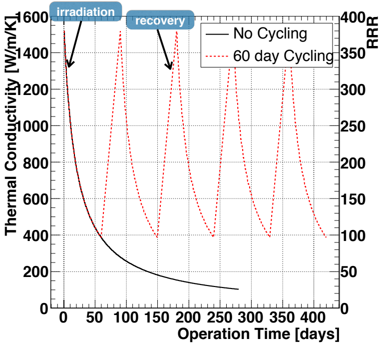




Operation

- 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

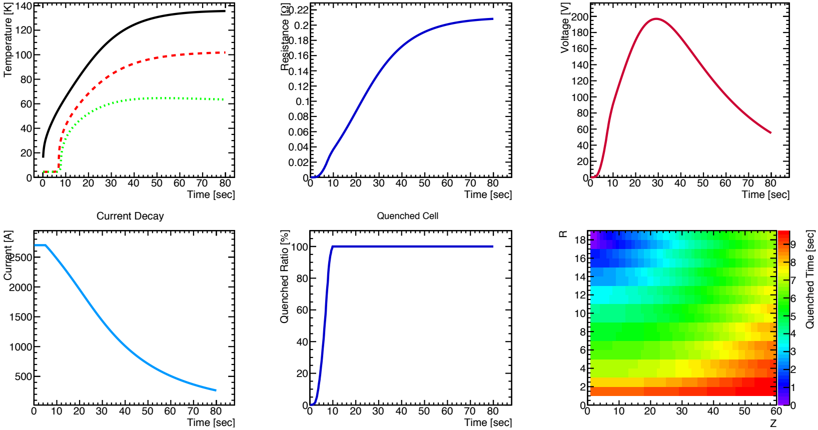
Thanks

Thanks!

- Backup

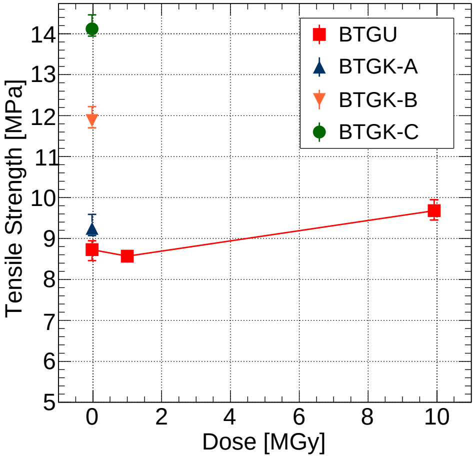
Quench Simulation

Preliminary



Radiation test for pre-preg tape

Preliminary



Residual Dose Rate