PRESENT STATUS OF MUON PRODUCTION TARGET AT J-PARC MLF MUSE

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This talk is my final presentation and my final job for muon production target.
My next interest is to develop the target out of SiC and tungsten. In four days, I will transfer to Hadron Section in J-PARC to construct COMET target.
OVERVIEW OF MUON PRODUCTION TARGET AT J-PARC MLF MUSE
MATERIALS AND LIFE SCIENCE EXPERIMENTAL FACILITY (MLF)

- Neutron Target
- 3GeV-RCS
-Muon Target (Graphite)
-5 % beam loss

1MW in future
500kW at present

Production of the most intense pulsed muon beam all over the world
**MUON TARGET AT PROTON BEAM LINE**

- Muon Target at FL 1.6m is highly activated.
- 2-m Iron-shield is required for maintenance
- Access of worker from maintenance area (FL 4m- 6m)
- Replacement by remote handling

- Residual radiation dose: 5 Sv/h @ surface
- Tritium production on target: 0.5 TBq/year @ 1 MW

**Cutting section of proton beam line**
MUON PRODUCTION TARGET

- Target material is polycrystalline graphite, IG-430U.
- To extend lifetime, the fixed target was replaced with rotating target that disperse the radiation damage of graphite.

Fixed target, from 2008 to 2014
Lifetime: Irradiation damage of graphite
1 year at 1 MW operation

Rotating target, from 2014
Lifetime: Bearings
Aiming Lifetime: 10 years at 1 MW operation

H. Matsuo, graphite1991
[No.150] 290-302
CONCEPTUAL DESIGN AT MLF MUSE, BASED ON INSTRUCTION FROM PSI

- Since Muon Technical Advisory Committee, 2004
- Rotating Target, Vacuum chamber, Pillowseal, Cask,

**Recent collaboration**
- Investigation of bearing with long lifetime
- Application to external funding for further collaboration
- Remote handling, Vacuum application, Industrial technologies,
In front of Hot cell
September 2014

MUON TARGET SYSTEM
# HISTORY OF MUON TARGET SYSTEM

<table>
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<tr>
<th>Year</th>
<th>M1/M2</th>
<th>F-Target</th>
<th>R-Target</th>
<th>T system</th>
<th>R. H.</th>
<th>Diagnostic</th>
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## Timeline

- **2010**: Operation
- **2011**: Shutdown by Earthquake
- **2012**: Operation
- **2013**: Shutdown by Hadron Accident
- **2014**: FT → RT#1
- **2015**: Interruption 2 weeks by trouble on rotation system
- **2016**: Operation
- **2017**: SC-1#1 → SC-1#2
- **2018**: Replacement
- **2019**: Replacement

**Legend**
- Red: Operation
- Orange: Interruption
- Blue: Design
- Green: Replacement
- Black: Developments & Fabrication
- Yellow: Installation
M1/M2 TUNNEL

Air-circulation system
Closed with operation
Open w/o operation

Movable ceiling shields

Profile monitor & Current transformer

Maintenance area

Turbo molecular pump

Muon target

Scraper #1,2

Magnets

To Neutron source

From 3NBT, RCS

M1 tunnel

M2 tunnel

FL10m

FL4m

FL1.6m
MUON TARGET SYSTEM

- Typical vacuum pressure: $3 \times 10^{-5}$ Pa
- Black coating inside the chamber for increment of emissivity

- Pillowseal: I.D. 250mm
- $10^{-8}$ Pam$^3$/sec.

- Thermal spraying of Al
For beam collimation, two scrapers are located downstream of muon target.

- 20 kW beam loss on scraper #1
- Thermocouples were affected by thermal radiation from rotating target.
- Scraper #1 was replaced with modified one in September 2015.
- Measurements of temperature are appropriate at present.

Temperature rise: 17 K @ 500kW operation

Beam path along beam emittance
TRANSFER CASK

- Transportation of radioactive components by Transfer cask
- Beam line, Tentative storage pod, Hot cell, Underground storage room, Water-piping drying room
- Remote-controlled gripper

30-m travel to underground storage room
REMOTE-CONTROLLED REPLACEMENT OF TARGET

- Used target rod is replaced with new one in Hot cell. Plug shield is re-used.
- Volume reduction by cutting device.
- Stored in storage vessel.

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MUON PRODUCTION TARGET

Muon Fixed Target in beam line
November 2013
Muon Fixed Target from 2008 till 2014

Isotropic Graphite IG-430U (Toyo Tanso)
Diameter; 70mm
Thickness; 20mm

P-Beam diameter; 14 mm (2sigma)
Design: 4kW heat @ 1MW proton beam
In actual: 1.3 kW @ 333 kW p-beam

Titanium layer as stress absorber
Silver brazing method

Stainless steel pipe (Water)
Copper frame
Hot Iso-static Press method

6-years stable operation W/O replacement
Lifetime: Irradiation damage of graphite 1 year at 1 MW operation

R&D FOR FABRICATION OF MUON FIXED TARGET

- HIP method for fabrication of Cu frame
- Cu-SS316L bonding, and Cu-Cu bonding
- Silver brazing method for graphite
- Metallization by 72Ag/26Cu/2Ti in advance
MUON ROTATING TARGET SINCE 2014

- Rotating target method is applied to distribute the irradiation damage of graphite to a wider area.
- Cooling by thermal radiation
- Lifetime of graphite: 30 years
- Lifetime is determined by solid lubricant of bearings

**Solid lubricant:**
- Silver coating with MoS2, Lifetime: < 1 year
- Tungsten Disulfide at J-PARC MLF
  Aiming lifetime; 10 years

P-Beam diameter; 14 mm (2s)
4kW heat @ 1MW proton beam
Thickness of graphite 20 mm
DEVELOPMENTS OF MUON ROTATING TARGET

- Validation for FEM simulation
- Duration tests for WS$_2$ lubricants in vacuum & at high temperature.
- Actual operation: 15 r.p.m.
- Accelerated test: 300 r.p.m.
- Stable operation with $5 \times 10^6$ revolutions
- Finally, rotating target was installed in 2014.

Motor Torque (x 10%)

WS$_2$ lubricants

9 days with 300 r.p.m.
HISTORY OF BEAM OPERATION

By Fixed target

Rotating Target without replacement
- Operational time: 17000 hours (Nov. 2014 ~ July. 2019)
  6000 MWh
- Rotation: ~16 M revolutions
  (4.5 M revolutions /year @ 15r.p.m.)
- Stable 500-kW operation in 1 year

By Rotating target

Oct. 2014

1 MW proton beam operation

Trouble on rotation system Muon experiment was interrupted for 2 weeks.
RECENT PROGRESS OF MUON TARGET

Scraper replacement
September 2015
ALMOST 1-MW OPERATION TEST

The 1-MW operation for 11 hours was successfully completed on 3rd July, 2019.

The results showed in good agreement with predictions through the simulations.
Trouble on Rotation System in 2018

- When rotation feedthrough from air to vacuum was replaced in regular maintenance of 2018, the flexible coupling was broken.
- We found the mistake of the machining process.
- We could replace the broken one.
- But the problem is that two couplings are used in the rotating target. The lower one could not be replaced easily.
- Continuation of operation by current target with upgrade of exhaust of vacuum pump system and diagnostic.

1MW test

4(He, HT)

3(He, T, HD, H₃)

Quadrupole mass spectroscopy

Buffer tank for tentative storage of exhaust

Rotating target

Flexible couplings

Broken flexible coupling

Rotation motor
Trial for Replacement of Coupling

Replacement of Rotating Target

☐ Trial for replacement of coupling (Plan A)
   Residual radiation dose at coupling position:
   2 mSv/h @ surface 100 times higher than prediction due to effect of Th. Neutron
   Resign

☐ Replacement of target (Plan B)
   Residual radiation dose at target position:
   500 mSv/h @ 10 cm
   Completed

Commissioning of Plan A in storage pod by cold target

Green house for contamination barrier

Air-blower to keep negative pressure inside cask

Used rotating target in storage pod

by Matoba
Upgrade of Diagnostic system

- To measure temperature of rotating target quickly, radiation-hard infrared camera was installed 12-m upstream of target this summer.
- The measurements will start in November 2019.
Position of target chamber in September, 2005

ACKNOWLEDGEMENT
Thank you so much for your support & collaboration. Keep support & collaboration with Muon group. I will move forward, and you should.

It was a great fun!!

SUMMARY