THE 21ST INTERNATIONAL WORKSHOP ON NEUTRINOS FROM ACCELERATORS (NUFACT2019)

@THE GRAND HOTEL DAEGU

29TH AUGUST, 2019

STATUS AND FUTURE PROSPECT OF MUON TARGET AT J-PARC MLF

J-PARC CENTER, MLF DIVISION, MUON SECTION

HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION, INSTITUTE OF MATERIAL AND STRUCTURAL SCIENCE (IMSS, KEK)

SHUNSUKE MAKIMURA, S. MATOBA, N. KAWAMURA

ON BEHALF OF MUON SCIENCE SECTION

SHUNSUKE.MAKIMURA@KEK.JP

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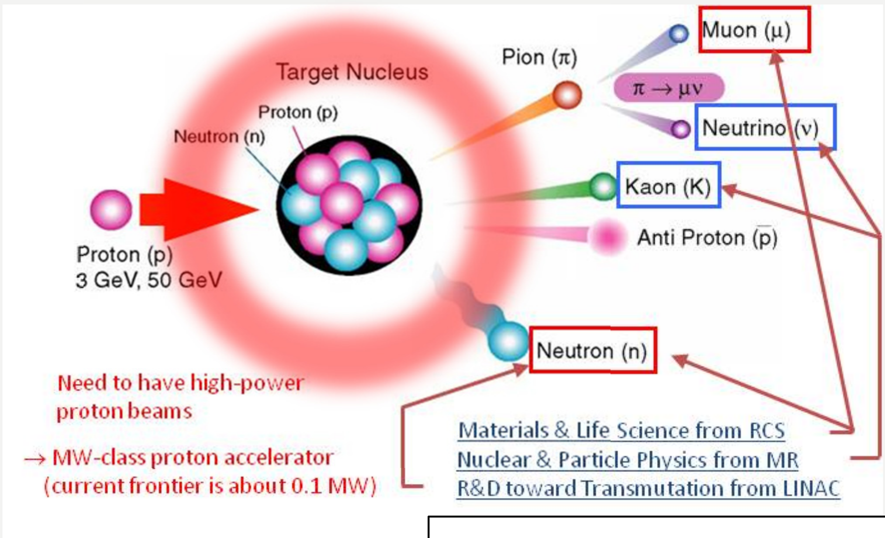
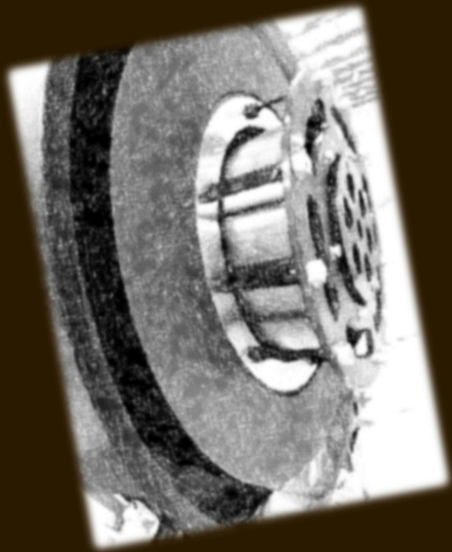


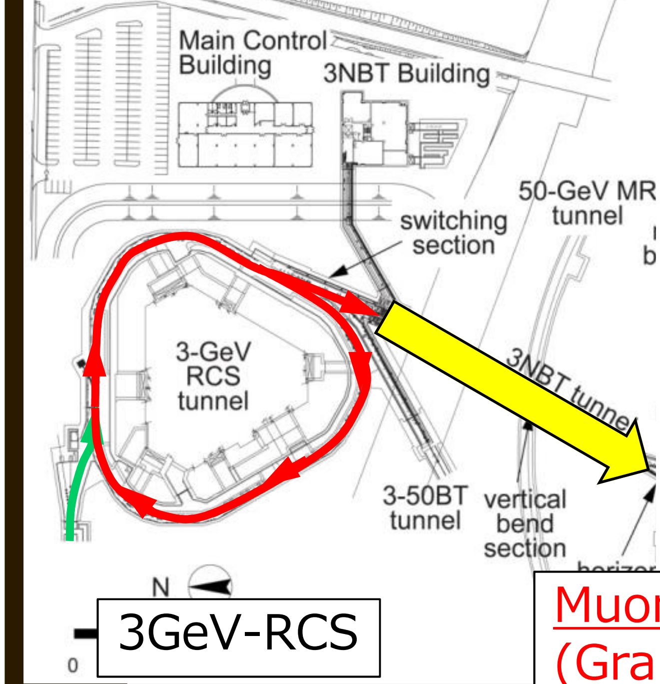
Muon Science:
Many presentations in this workshop

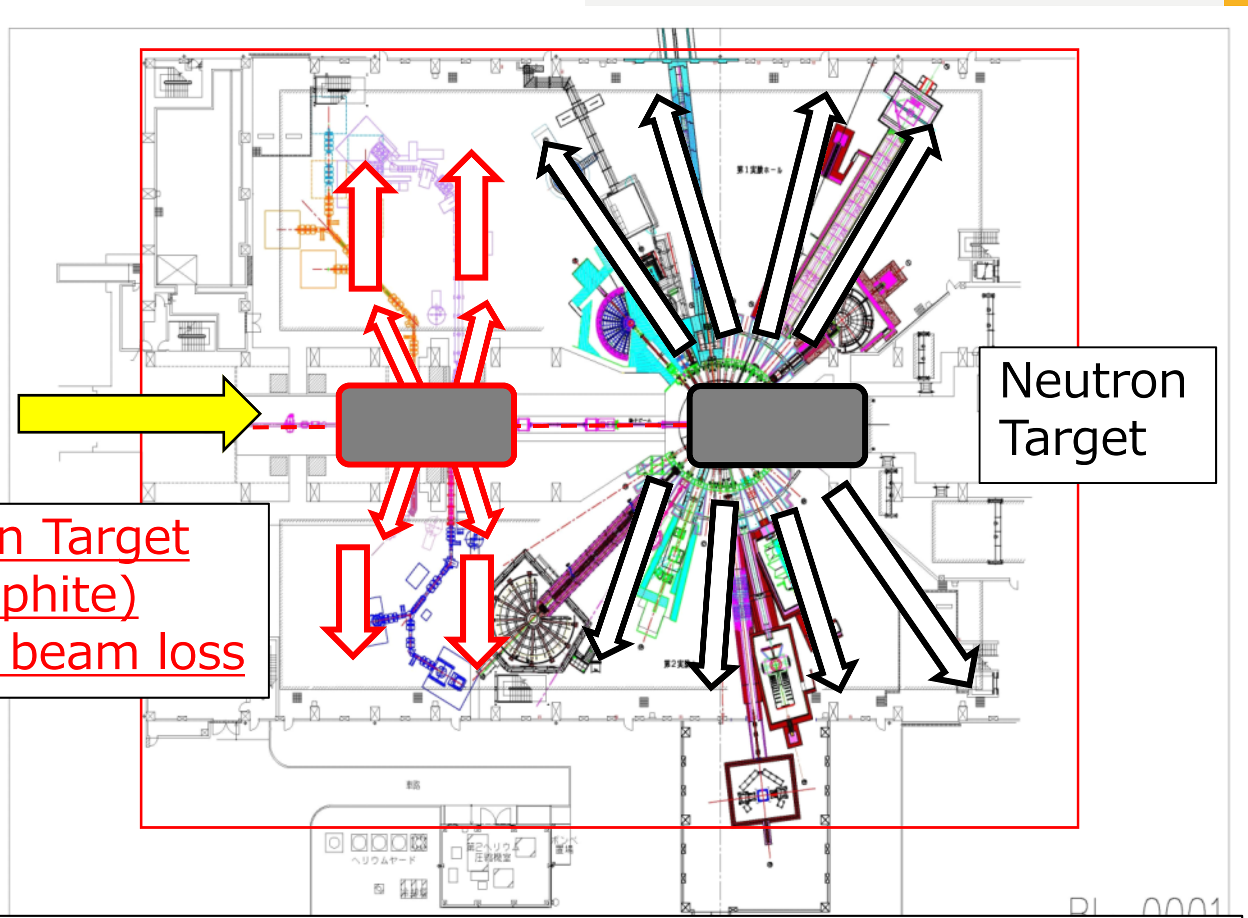


PRESENT STATUS OF MUON TARGET AT J-PARC MLF

Japan Proton Accelerator Research Complex
J-PARC
400 MeV H- Linac
Material Irradiation Facility for ADS R&D
Neutrino Experimental Facility (ν)
3GeV Rapid Cycling Synchrotron (RCS) 25Hz, 1MW
295 km to Kamioka
MLF 2nd Target Station
Materials & Life Science Facility (MLF, muon)
A round: 1,568m
Hadron Experimental Facility (HEF)
30 GeV Main Ring Synchrotron (MR)
Design beam power :
Fast Extraction to ν: 750kW → 1.3MW
Slow Extraction to HEF: > 100 kW
COMET: search for μ-e conversion

MATERIALS AND LIFE SCIENCE EXPERIMENTAL FACILITY (MLF)



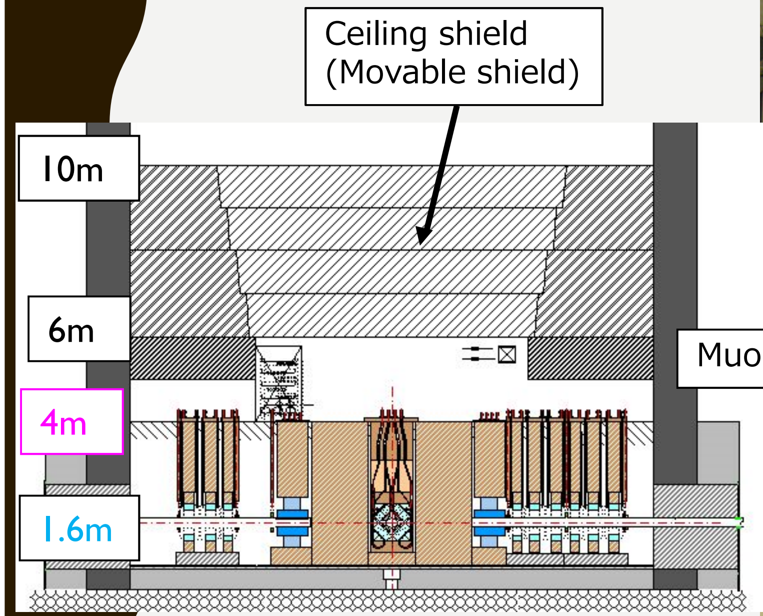


1MW in future
500kW at present

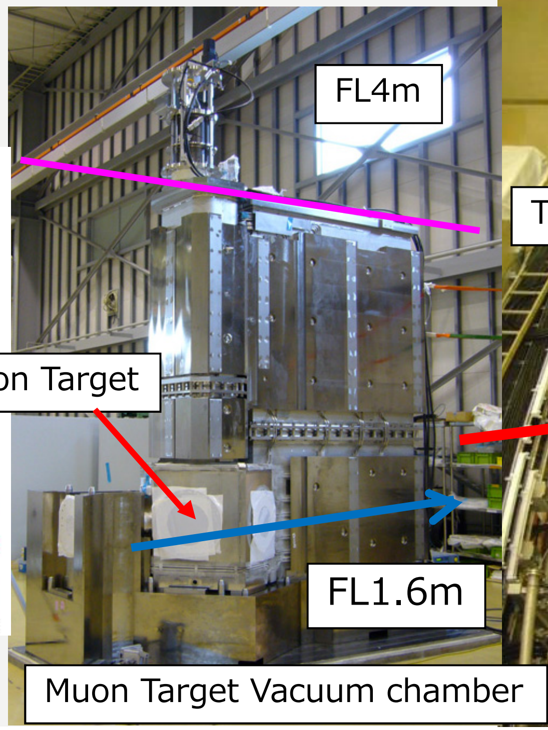
Production of the most intense pulsed muon beam all over the world

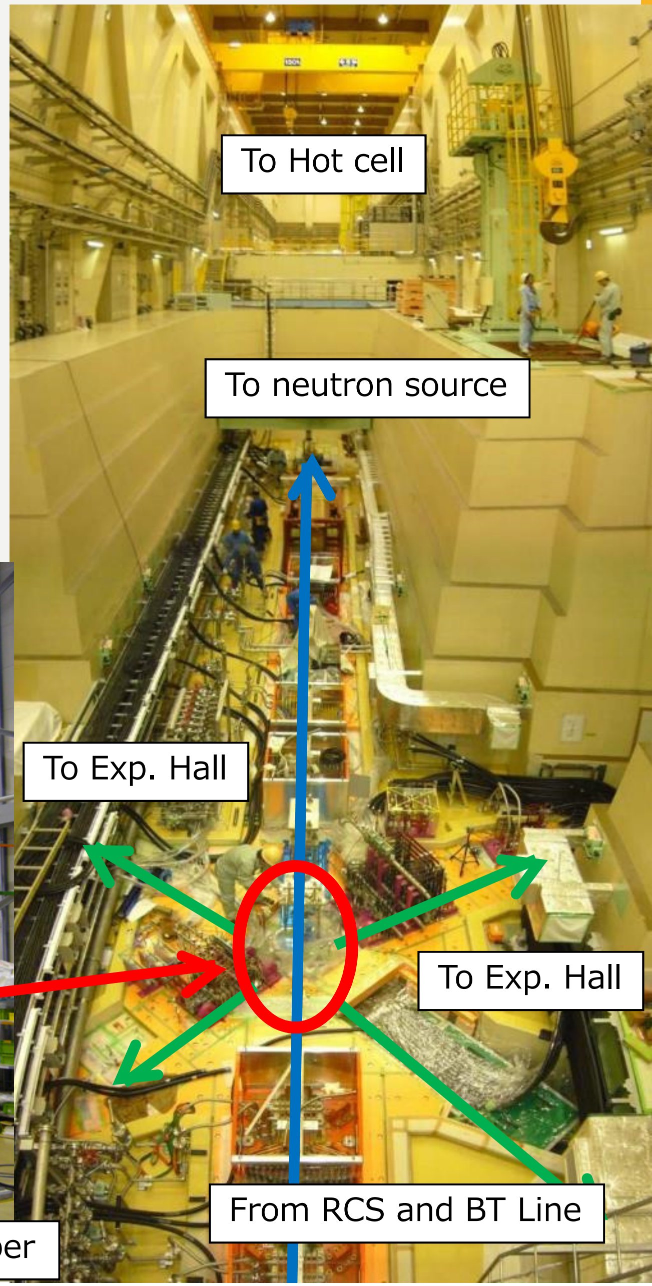
MUON TARGET AT PROTON BEAM LINE

- Muon Target at FL1.6m is highly activated.
- 2-m Iron-shield is required for maintenance
- Access of worker from maintenance area (FL 4m- 6m)
- Beam operation with Ceiling shield.
- Activated air is circulated and limited in beam line.

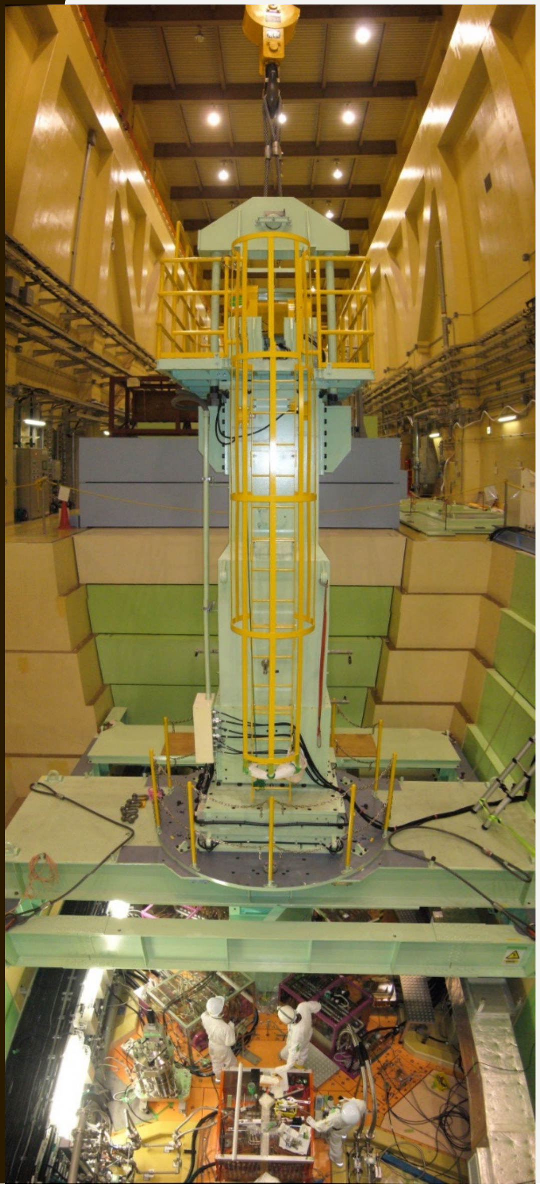


Cutting section of proton beam line





REPLACEMENT OF MUON TARGET



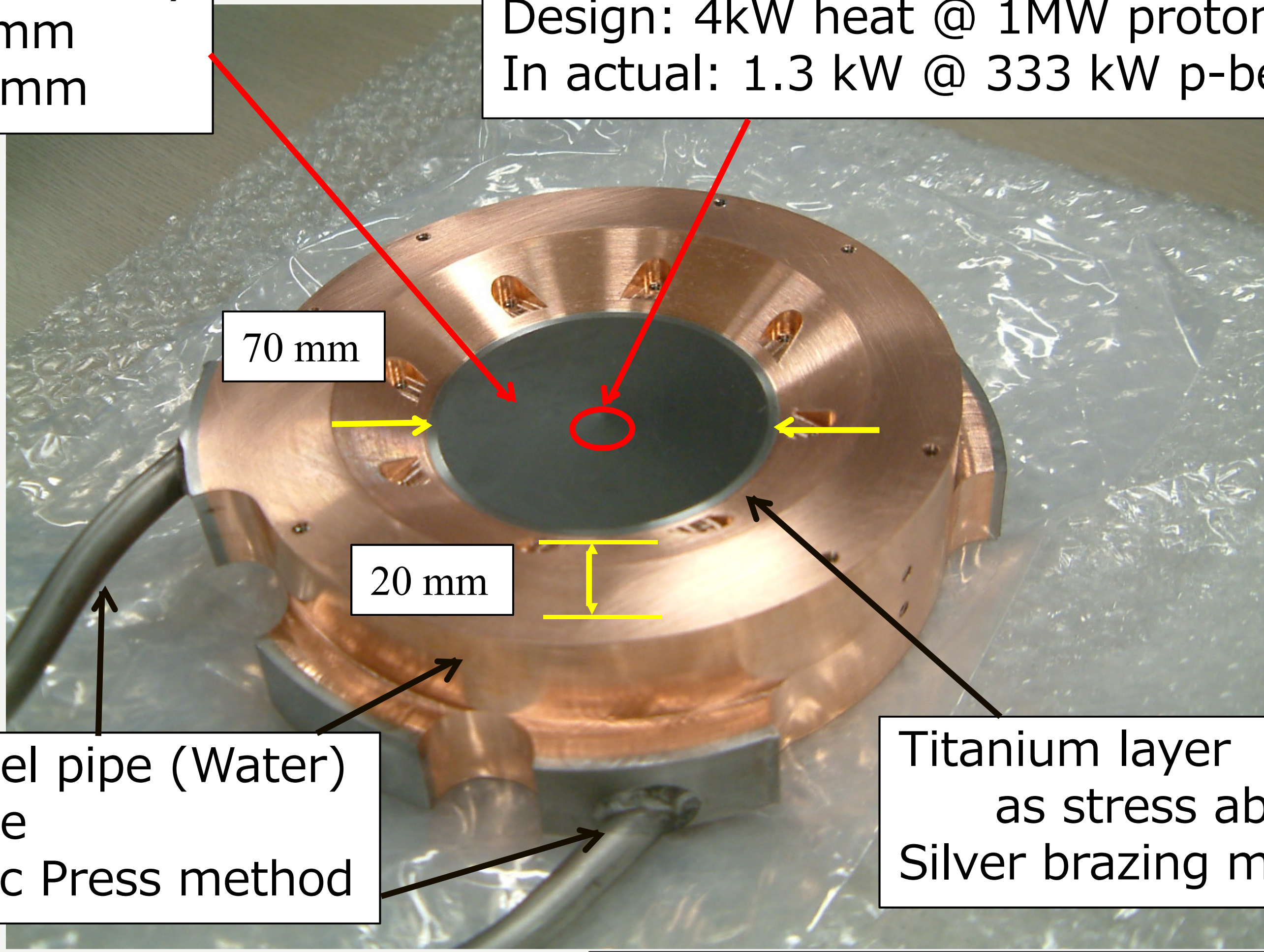
- Transportation of target by Transfer cask
- Replacement of target at Hot cell
- Measures against contamination, Clean booth with negative pressure, Air-line mask and Anorak suit

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

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



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

Titanium layer
as stress absorber
Silver brazing method

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

- Journal of Nuclear Materials 377 (2008) 28-33.
- JPS Conf. Proc. , 051002 (2015), DOI /10.7566/JPSCP.8.051002

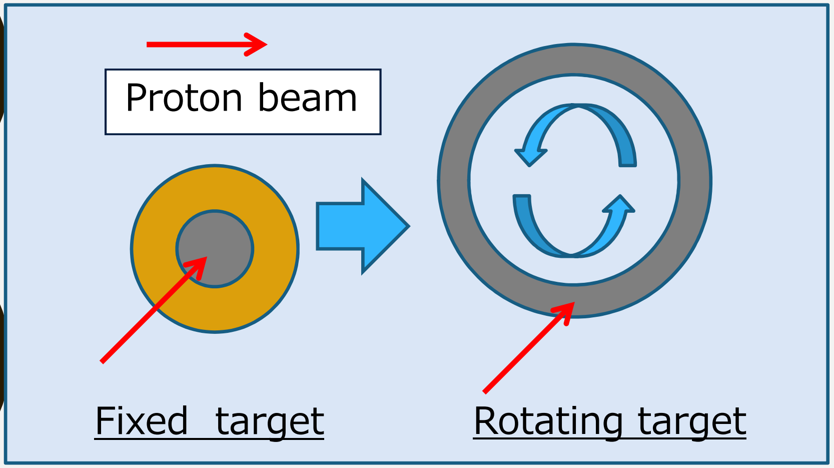
MUON ROTATING TARGET SINCE 2014

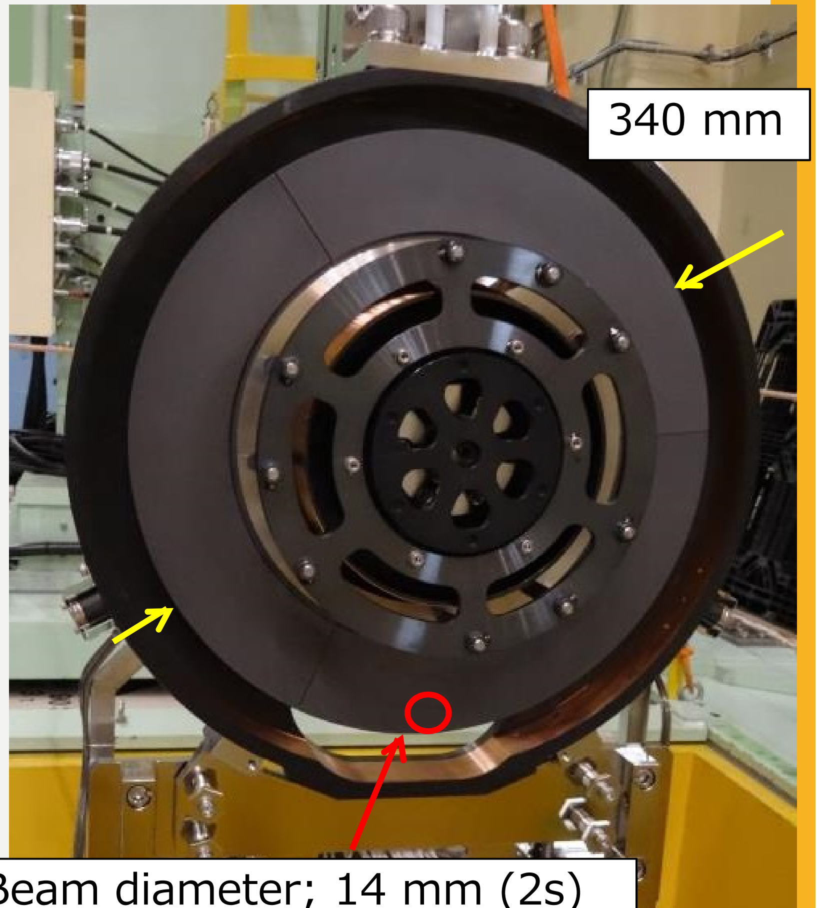
- Rotating target method is applied to distribute the irradiation damage of graphite to a wider area.
- Cooling by thermal radiation
- Lifetime of graphite: 30 years
- Lifetime is determined by solid lubricant of bearings

<u>Solid lubricant;</u>

- Silver coating with MoS2 at PSI, < 1 year
- Tungsten Disulfide at J-PARC MLF

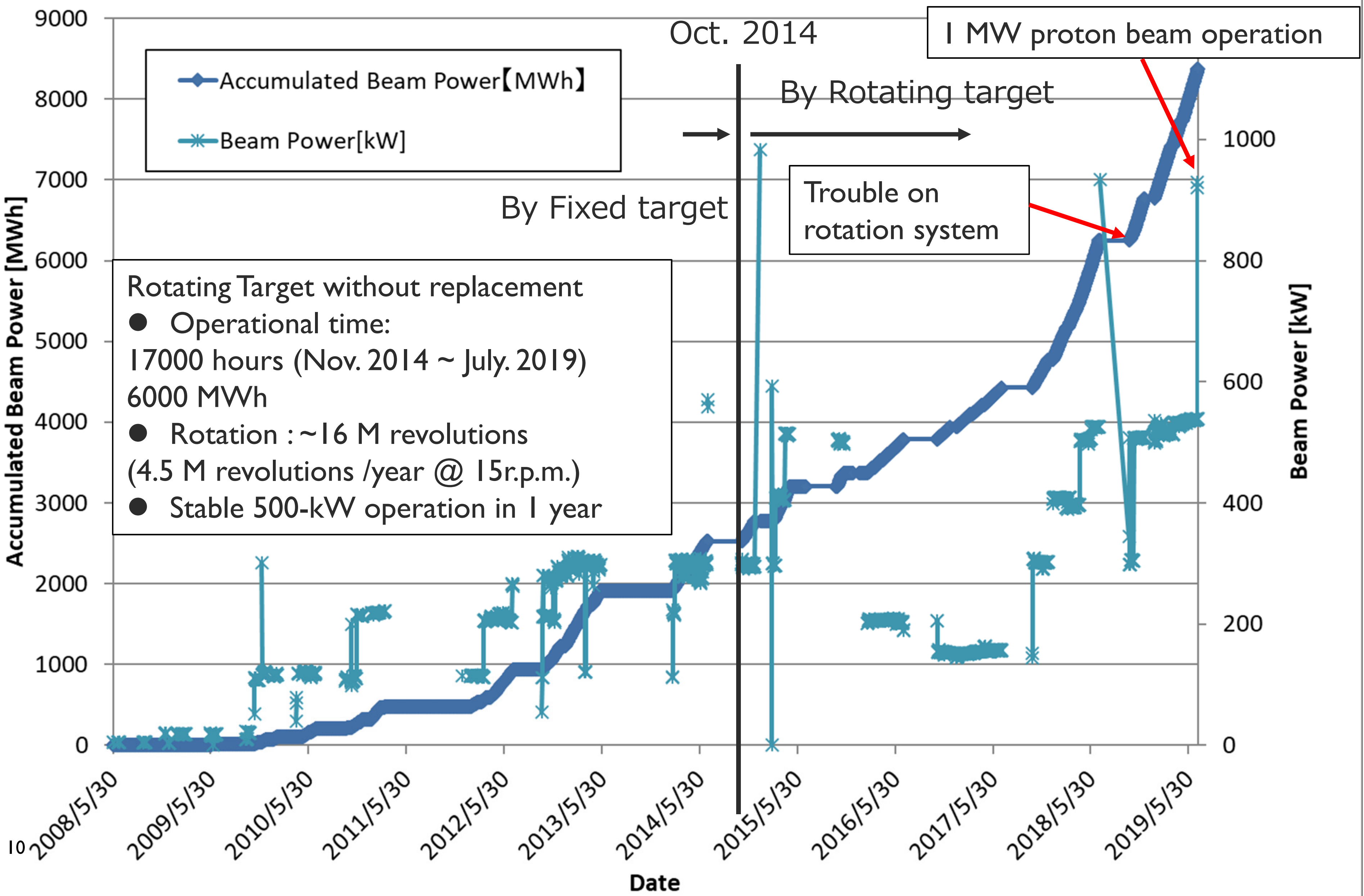
Aiming lifetime; 10 years





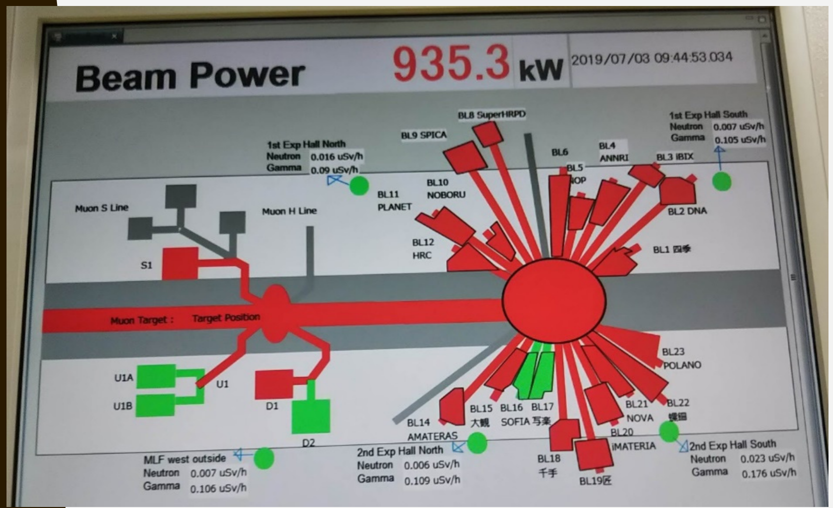
P-Beam diameter; 14 mm (2s)
4kW heat @ 1MW proton beam
Thickness of graphite 20 mm

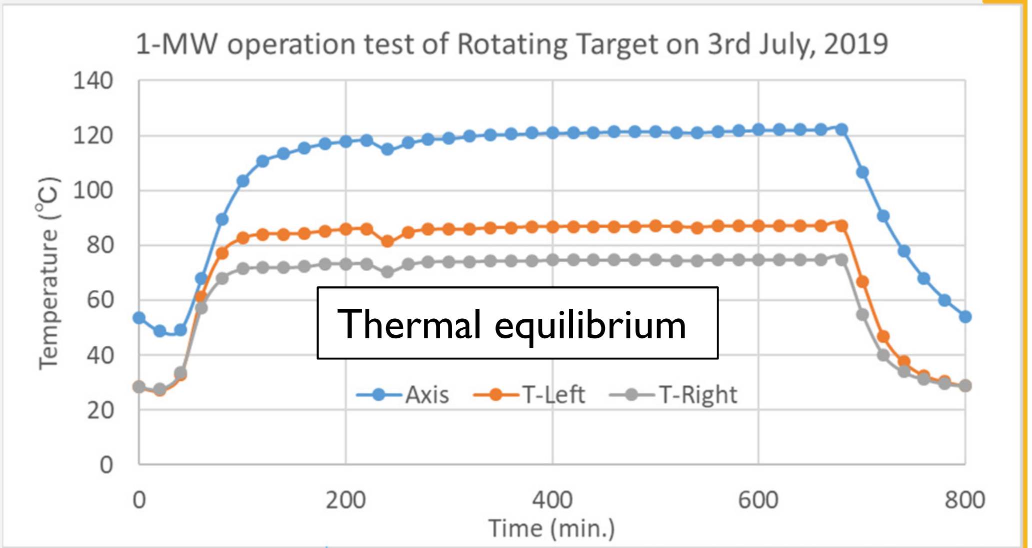
HISTORY OF BEAM OPERATION

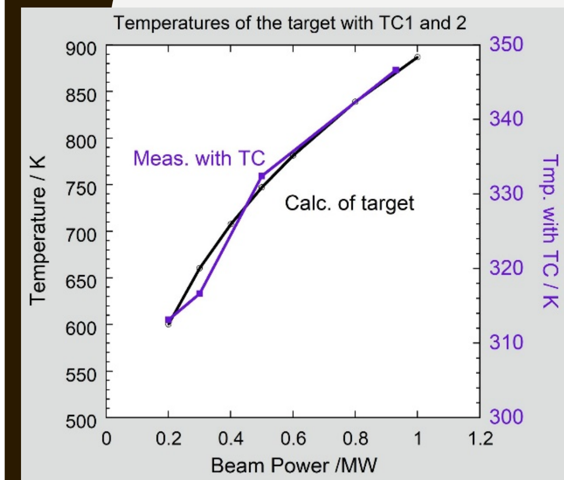


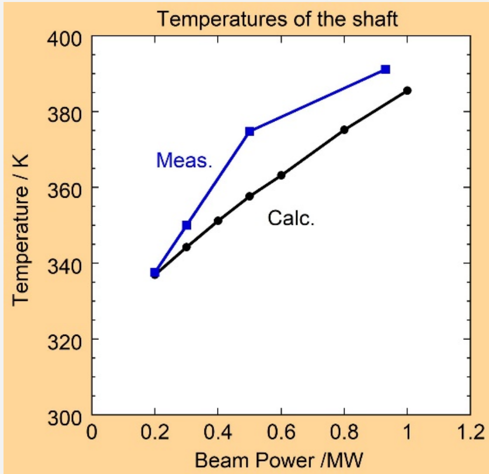
ALMOST 1-MW OPERATION TEST

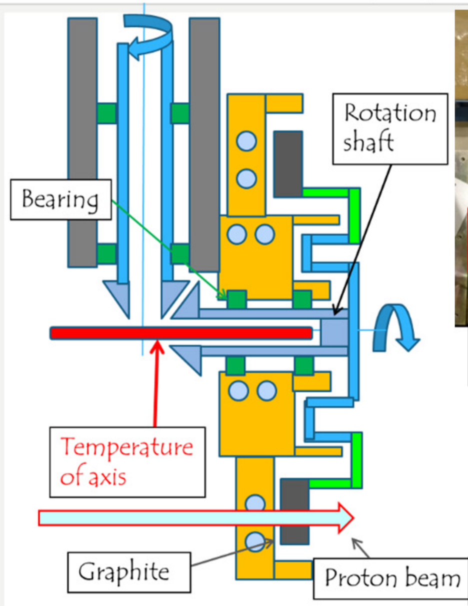
The 1-MW operation for 11 hours was successfully completed on 3rd July, 2019

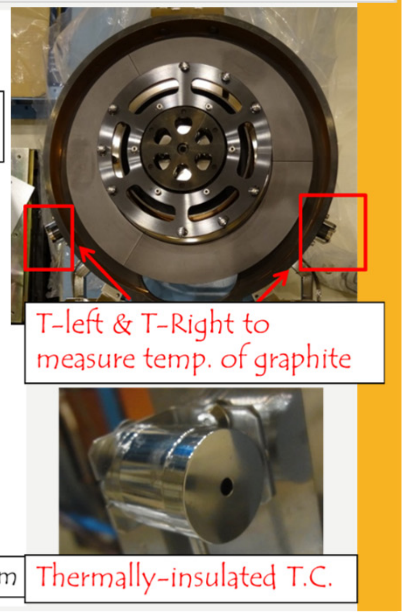












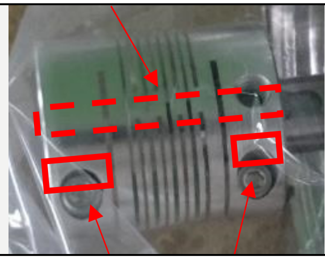
The results showed in good agreement with predictions through the simulations.

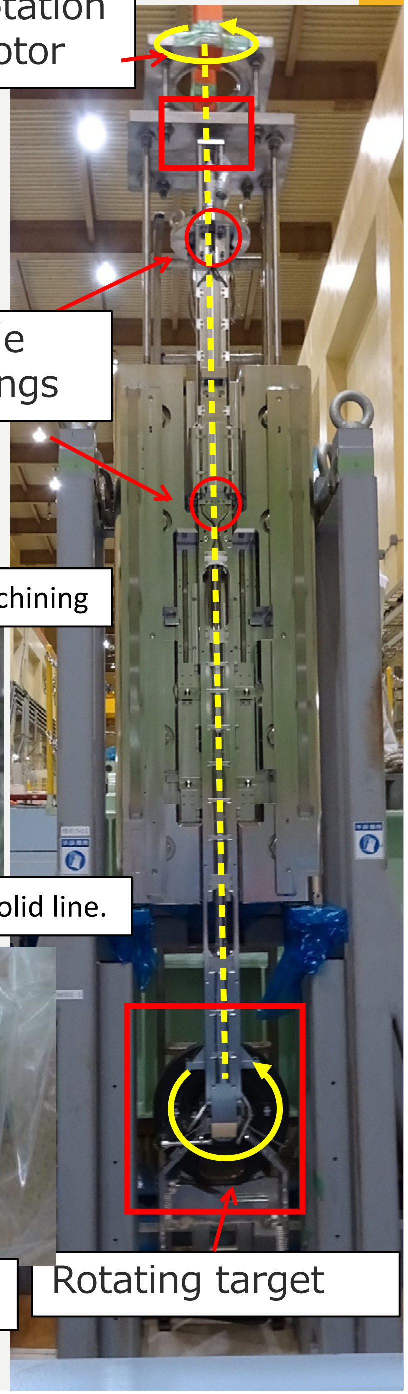
Trouble on Rotation System in 2018

- Rotating target has been successfully operated for 5 years.
- When rotation feedthrough from air to vacuum was replaced in regular maintenance of 2018, the flexible coupling was broken.
- During operation, it was intact.
- 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.

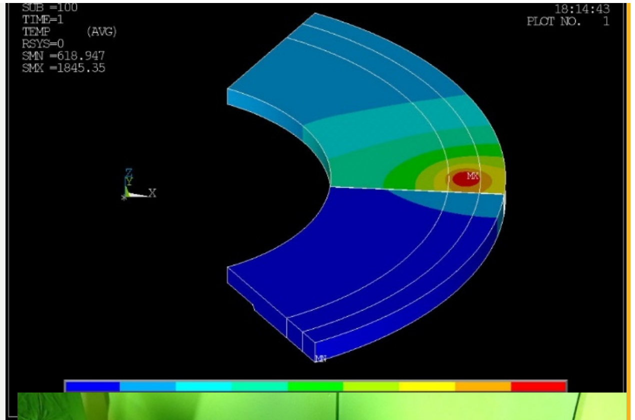
<u>Decision</u>

- ➢ Replacement of target with extension of shutdown for entire MLF
- ➢ Continuation of operation by current target





For Beam operation, and Replacement of Target

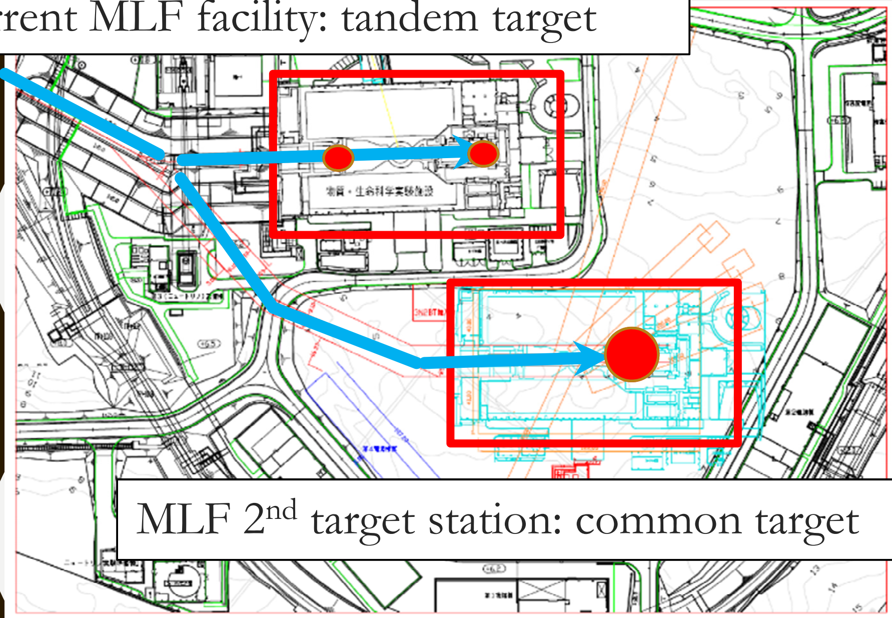


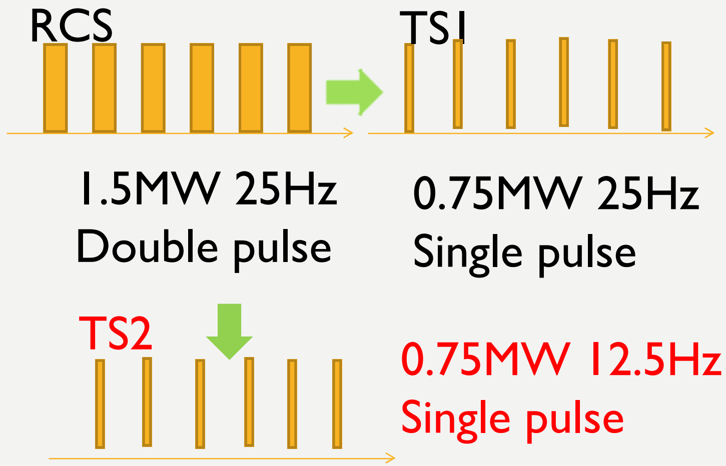
- ☐ It has been confirmed that the rotating target is not broken with current 500-kW proton beam even without rotation through FEM simulation . Furthermore Monitoring system was upgraded.
- ☐ The main issue is emission of tritium from hot graphite.
- ☐ The exhaust of vacuum pump is temporarily stored in a buffer tank system and is vented after measurement of concentration of RI.

- ■ <u>Proton beam operation started again with upgrade of the monitoring and the buffer tank system.</u>
- ■ <u>It was not broken.</u>
- ■ <u>The target will be replaced with a new and appropriate one next week.</u>

FUTURE PROSPECT OF MUON TARGET AT J-PARC MLF

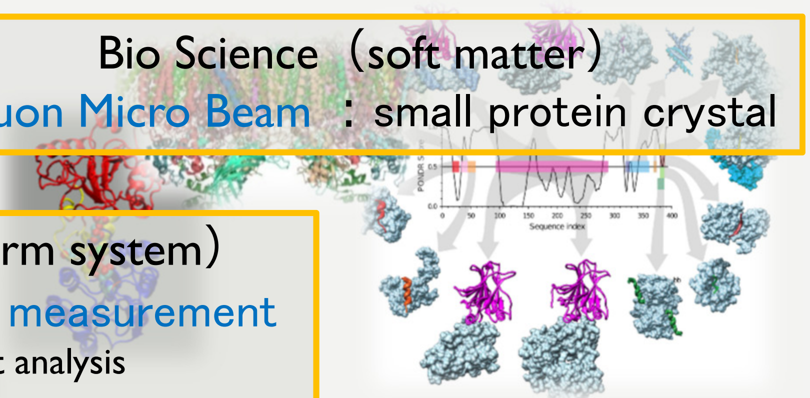
MLF 2ND TARGET STATION (TS2)
PROPOSAL OF FUTURE PROJECT WAS SUBMITTED





Time structure of a possible plan
--Science by higher peak intensity

Extreme Condition
(High pressure, High external field)
Muon Micro Beam ：small sample



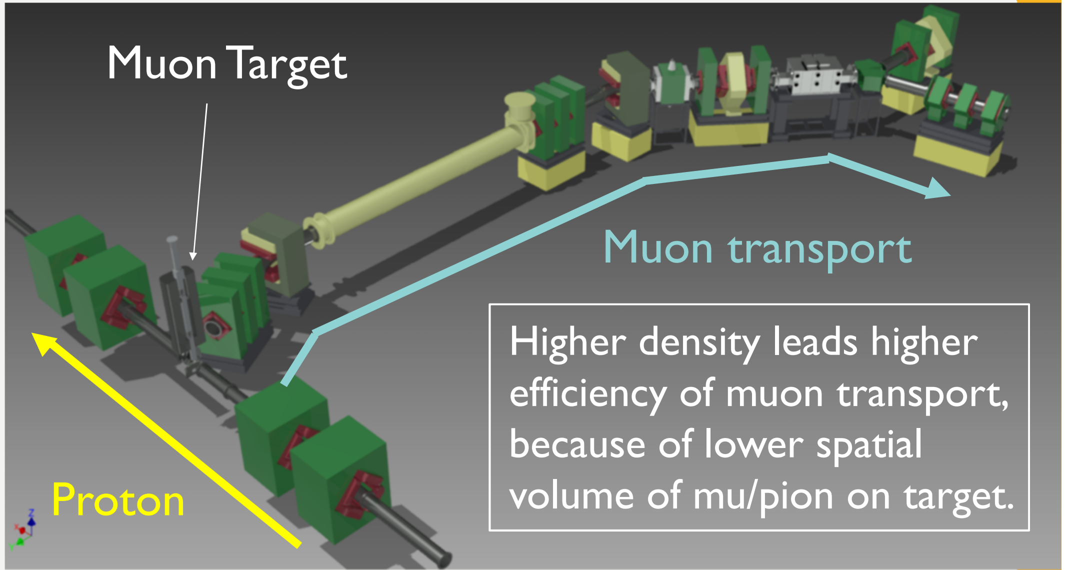
Bio Science (soft matter)
Muon Micro Beam ：small protein crystal

Real Space, Real time (nonuniform system)
Muon Micro Beam, Stroboscopic measurement
Imaging, In situ, Operand, Element analysis
Industrial applications,

DEMANDS FOR NEW TARGET MATERIALS

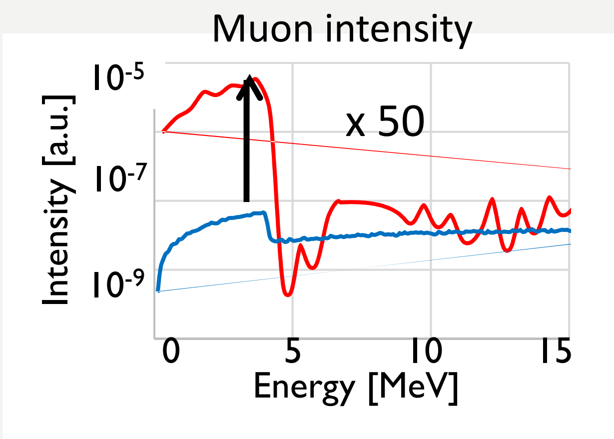
For MLF TS1:

- ☐ Graphite is the most popular and excellent target material.
- ☐ Demands for Graphite-substitute material
  - Higher oxidation resistance: SiC-coated graphite
  - Higher density: NITE SiC/SiC



For MLF TS2:

- ☐ Common target with Neutron target
- ☐ Tungsten is desired for higher efficiency of Muon production.
- ☐ TFGR W-TiC tungsten: solution to recrystallize and irradiation embrittlement
- ☐ Tungsten by Additive manufacturing

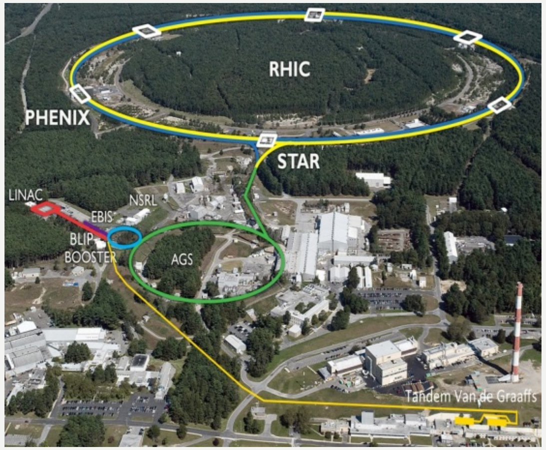


TS1 vs TS2

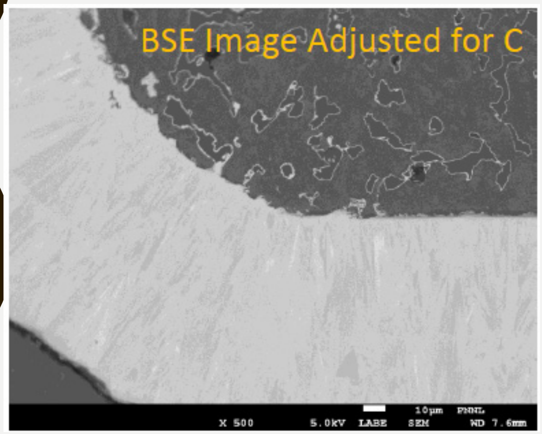
	Density
	g/cc
W	19.3
Hg	13.5
Pb	11.4
PbBi	10.6
Fe	7.87

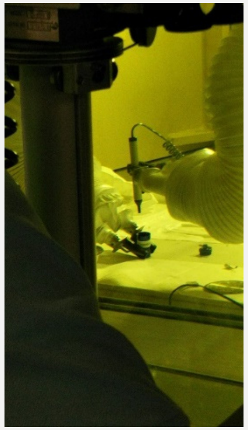
RESEARCH FOR SIC-COATED GRAPHITE UNDER RADIATE COLLAB.

Supported by US-JP collaboration



- Higher oxidation resistance
- Proton Irradiation at BLIP, Brookhaven National Laboratory
- Post Irradiation Effect at Pacific Northwest National Laboratory
- Thermal shock experiment, HRT43 at CERN





SiC coated IG-110 were finally broken to pieces. Other graphite survived

PIE testing at Pacific Northwest National Laboratory

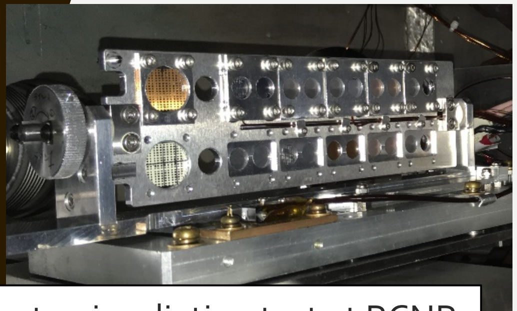
SEM microscope analysis of cold specimens
SiC coating deposited by CVD is intact.

Visual check of irradiated specimens
Crack was observed only on IG-110U substrate specimens, that was not designed for SiC coating

RESEARCH FOR NITE SIC/SIC

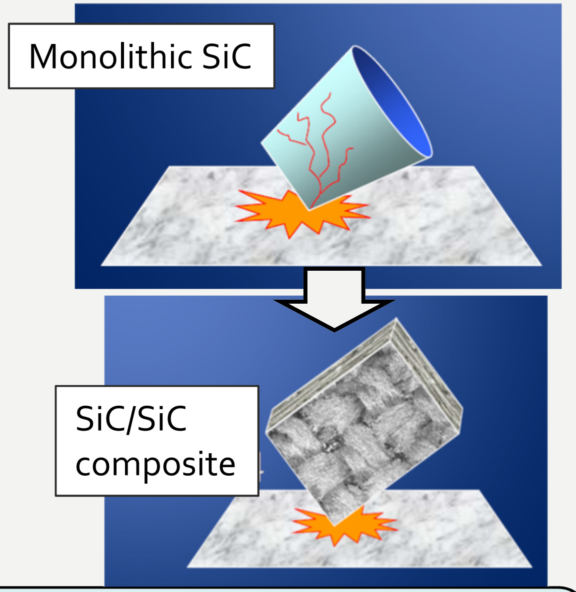
JSPS KAKENHI, JP16H03994

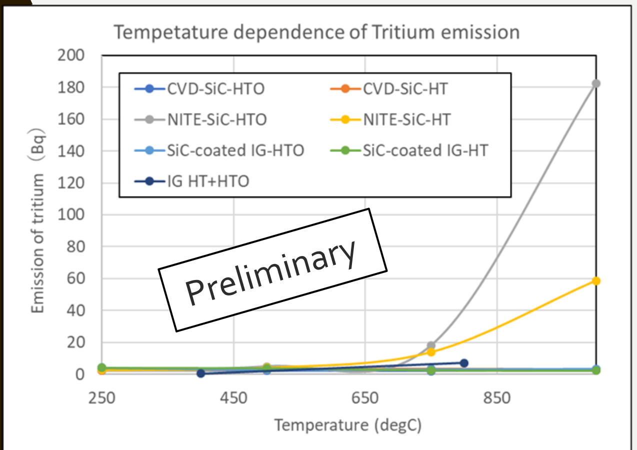
- Higher efficiency of muon transport due to higher density
- Solution of brittleness by pseudo ductility of SiC composite material
- Proton-irradiation tests at RCNP, Osaka
- Measurement of Tritium emission
- Thermal shock experiment, HRT35 at CERN



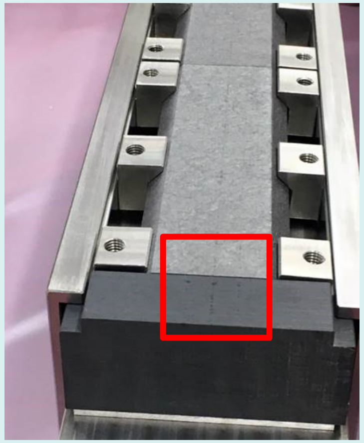
Proton irradiation test at RCNP

Two tube furnace and 3H traps, HT & HTO

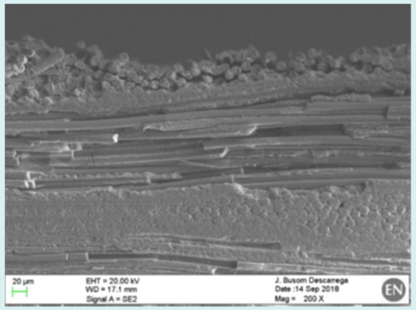




Completely different emission from CVD-SiC



Temperature rise by thermal shock: 2100 K



Stripe-like damage was observed.
Results of SEM analysis by J. Maestre et al.

<u>Disturbance of crack propagation was observed.</u>

CERN HiRadMat HRT35
440 GeV, 1.2E11 protons/pulse, Gaussian, σ=0.3 mm.

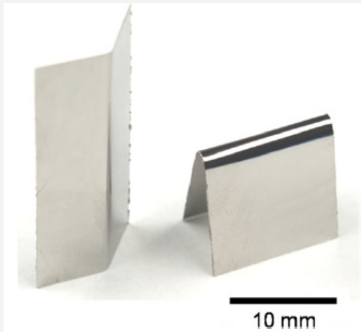
TUNGSTEN AS TARGET MATERIAL

MTC-KEK collaboration,
JSPS KAKENHI 19H01913.

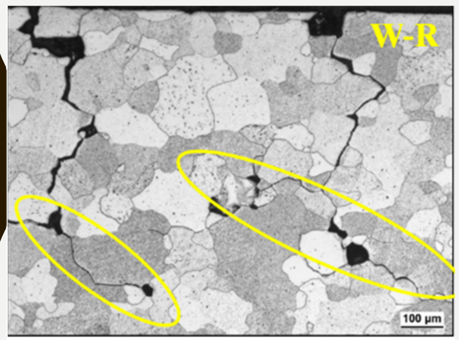
- Tungsten is expected as the target material.
- For use of tungsten as muon production target, the boundary between cooling material and vacuum in beamline disturb transportation of muon. Thermal radiation cooling is desired. It should be used at high temperature. (MLF TS2, COMET, mu2e,,,)

✓ Tungsten is brittle because grain boundary is weak.

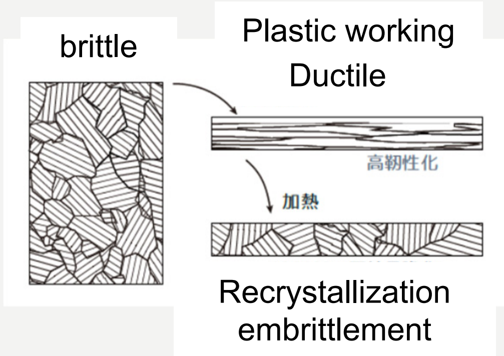
✓ Brittleness is improved by heavy plastic working.

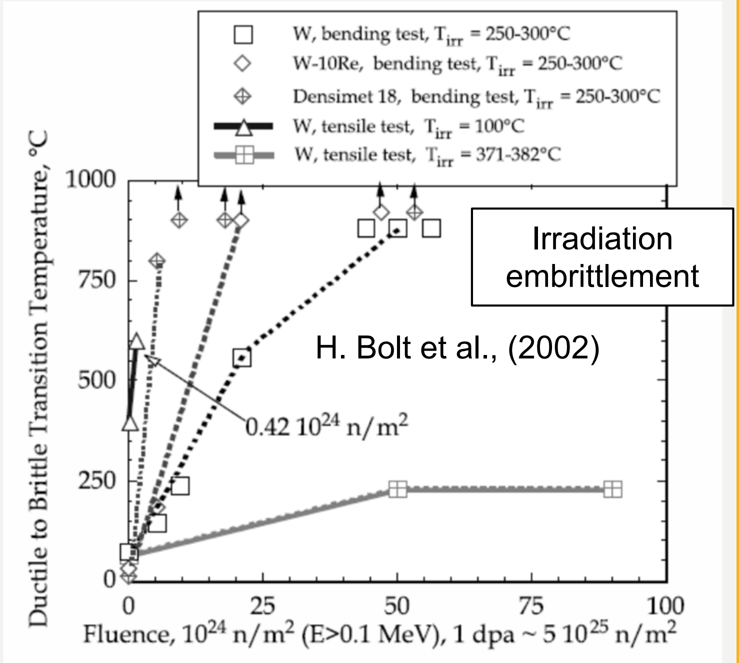


J.Reiser et al. JNM, 423 (2012) 1.



G. Pintsuk et al.





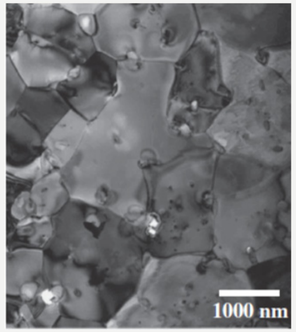
Ductile to Brittle Transition Temperature should be less than room temperature.

- The use of W as target material is limited by "recrystallization embrittlement" and "irradiation embrittlement".

RESEARCH FOR TFGR W-TIC TUNGSTEN

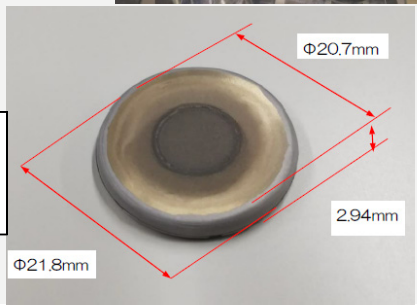
Toughened Fine-Grained Recrystallized W-TiC, (TFGR W-TiC) is developed by Prof. Kurishita at Tohoku University. Now the activities are transferred to KEK and Metal Technology Co. LTD collaboration.

- Equiaxed, fine grains with TiC precipitates
- GB reinforced by TiC enrichment
- No recrystallization embrittlement
- High sink density: Resistance to irradiation is anticipated.
- DBTT (nil-ductility tem.) < RT
- Thermal shock experiment, HRT48 at CERN

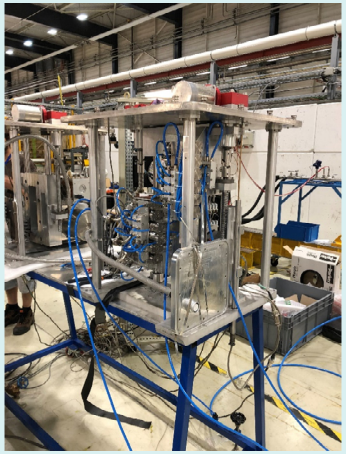
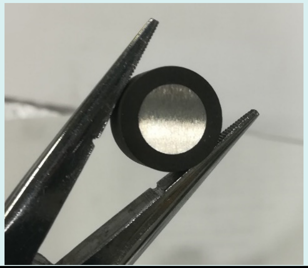


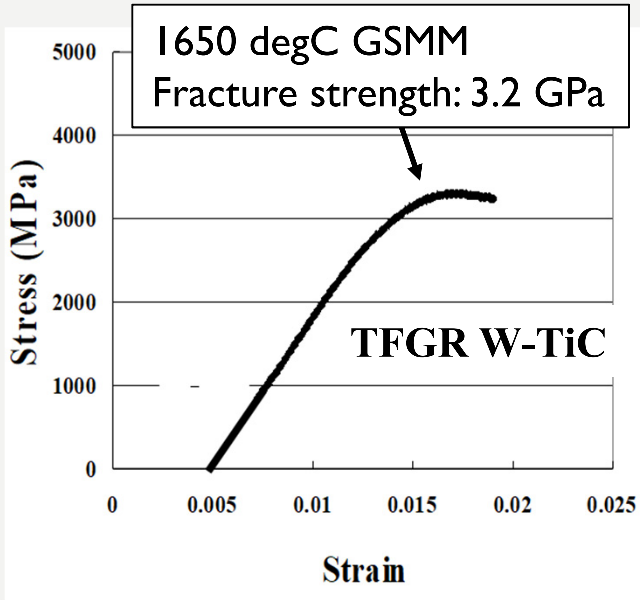
Mater. Trans. 54 (2013) 456-465.


Mechanical alloying



TFGR after GSMM

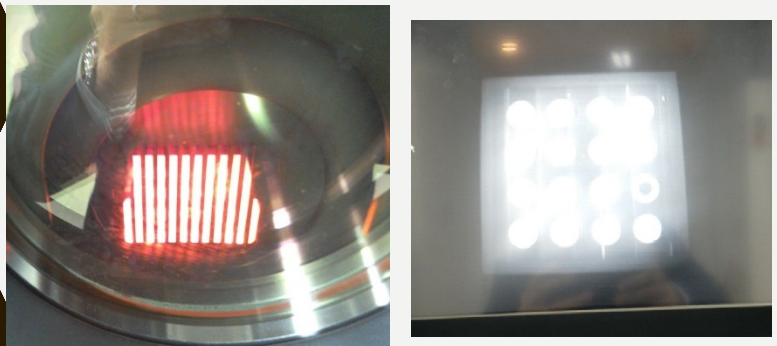


JSPS KAKENHI 17K18787

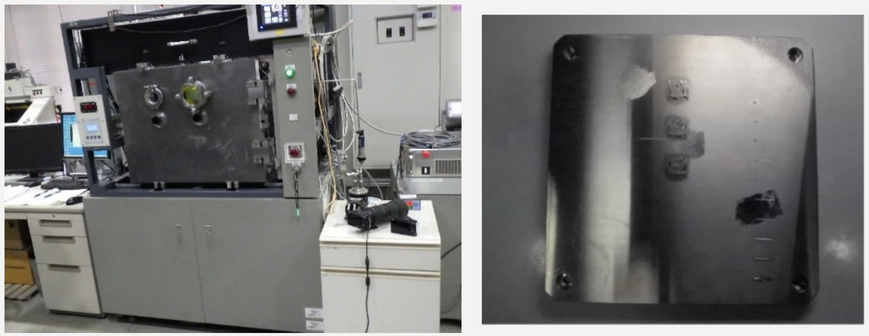
RESEARCH FOR TUNGSTEN BY ADDITIVE MANUFACTURING

- Removal of impurity by pre-heating in vacuum
- Improvement of mechanical property by columnar structure
- New target concept by near-net-shape

Results will come soon!!



Additive Manufacturing by EB



Additive Manufacturing by laser in vacuum

SUMMARY

SUMMARY

Present status

- Muon production by Fixed target from 2008 till 2014
- High residual radiation dose and contamination
- Installation of Rotating target in 2014 to extend lifetime
- The successful 1-MW operation for 11 hours on 3rd July, 2019
- Trouble on rotation system
- Replacement of Rotating target next week

Future prospect

- Future facility: MLF 2nd target station
- Developments of SiC coated graphite, NITE SiC/SiC, TFGR tungsten, Additive manufacturing of tungsten
- Proton irradiation tests & PIE tests

Thanks for your attention