Diffusion of tritium produced in a graphite and SiC target

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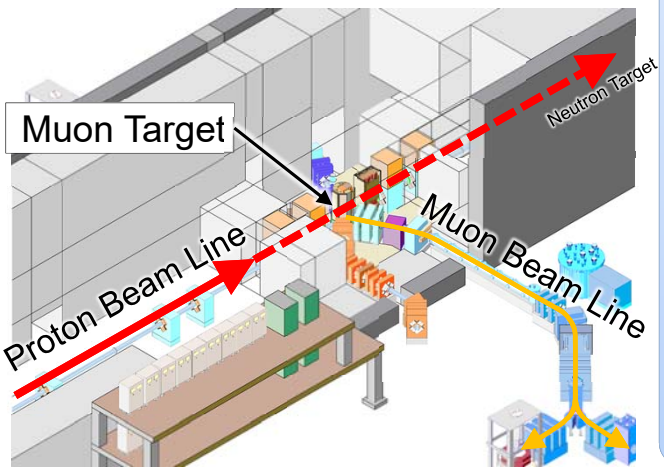
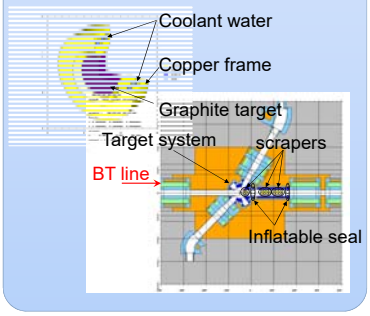
Proton beam
- ✓ 3 GeV, 1 MW, 25 Hz
- ✓ Beam radius: 3.5 mm (1 σ)

Muon Target
- ✓ Location: 30-m upstream of neutron target
- ✓ Material: 20-mm thick Graphite (IG-430U)
- ✓ Heat deposit: 3.5 kW under 1 MW beam
- ✓ Beam loss: 5% of proton beam due to scattering and secondary particle generation



Conceptual design by Monte-Carlo simulation
- ✓ Heat generation
  - ➢ Thermal stress calc. by FEM code. ⇒ Titanium absorber
- ✓ Radiation damage
  - ➢ Life time of target 1 DPA/year in fixed target ⇒ Rotating target
- ✓ Activation
  - ➢ Air, water
  - ➢ Tritium generation in Graphite
- ✓ Residual activity
  - ➢ Maintenance scenario ⇒ Cask design



Fixed Target 2008 - 2014

Rotating Target 2014 -

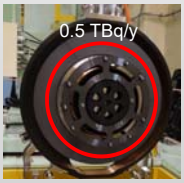
Fixed target
- ✓ Coolant water pipe embedded in copper frame
- ✓ Titanium layer between graphite and copper absorbing the difference of thermal expansion

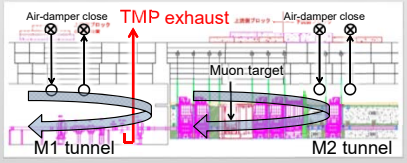
Rotating target
- ✓ Distributing the radiation damage along the circumference
- ✓ Solid lubricant: Tungsten Disulfide High temp., high vac., and high rad.

Administrator

Where is the tritium produced in the target material? Still in the target? Go out to the beamline vacuum?

Gaseous activities control

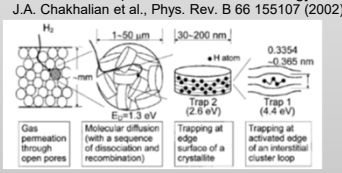


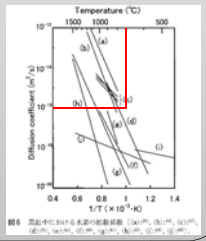


- Tritium production in graphite is evaluated to be 20 GBq/cycle under 1 MW operation.
- The beamline vacuum is continuously exhausted by a TMP during beam operation. Getter pump is not be adopted, because vacuum level is low.
- Tritium diffusion in graphite is an important information to control the gaseous activities exhaust.

Tritium diffusion in graphite

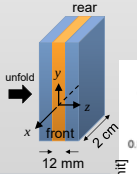
- Tritium diffusion in graphite is not so fast according to any exp. data.
  - At most, $D = 10^{-16}$ m²/s at 700 deg C, *i.e.* $\sqrt{D \times 1\mathrm{s}} = 10$ nm
    A wide deviation in the experimental data; 10^{-20} ~ 10^{-16} for hydrogen sample dependency; poly or single, grain size, vacancy concentration, *etc.*
  - Target temperature will not exceed 700 deg C even in 1 MW operation.
  - Consistent with μSR data: Activation energy is around 500 deg C
    J.A. Chakhalian et al., Phys. Rev. B 66 155107 (2002)



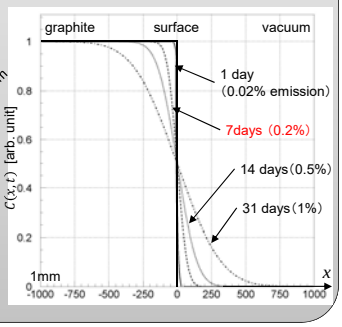


- Contamination of 27 kBq/cm² is observed around the TMP
- Mechanism of tritium is not well understood.

Tritium diffusion simulation



Numerical analysis for $C(x,t)$ under 700 deg C. $D = 10^{-16}$ m²/s



2GBq is the lower limit of tritium detection by silica-gel leachate method.
Operation period is 7 days/cycle in J-PARC.
In 2 years, accumulated tritium exceeds 1 TBq (= 2 GBq/0.2%), and tritium may be detectable.

Around the graphite surface, diffusion equation $\frac{\partial C}{\partial t} = -D\Delta C$ is approximately solved for x direction:

$C(x,t) = \frac{1}{2\sqrt{\pi D' t}} \int_{-\infty}^{x} e^{-\frac{x'^2}{4D't}} dx'$,
where $D' = D/3$.

Summary

- In any high power target materials, graphite, SiC and so forth, tritium is inevitable radio-activity.
- In graphite, tritium diffusion is not so fast, but not negligible, especially in a hot target.
- Although amount of the tritium is expected to be not so high, exhaust gas must be controlled in compliance with the law.
  ⇒ We will install buffer tanks after the TMP
- Scientifically, yet no comprehensive understanding of tritium diffusion; dependence on the production method (grain size *etc.*) and use history (vacancy due to irradiation).
  ⇒ Systematic studies by TDS, muon spin relaxation study, positron annihilation spectroscopy are considered.