OUH Odense Universitetshospital

Risø DTU
National Laboratory for Sustainable Energy

# Production of therapeutic quantities of $^{64}Cu$ and $^{119}Sb$ for radionuclide therapy using a small PET cyclotron

**H. Thisgaard[a], M. Jensen[b], D. R. Elema[b]**

[a] Odense PET Centre, Dept. of Nuclear Medicine, Odense University Hospital, Sdr. Boulevard 29, DK-5000 Odense C, Denmark.

[b] The Hevesy Laboratory, Radiation Research Department, Risoe National Laboratory for Sustainable Energy, Technical University of Denmark, P.O. 49, DK-4000 Roskilde, Denmark.

## Introduction

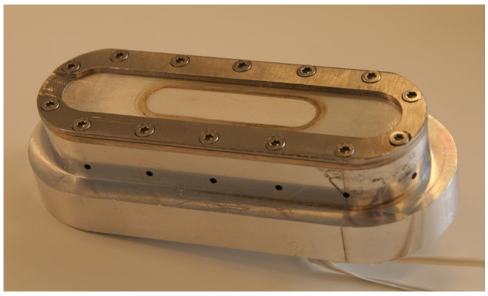
In the recent years the use of radionuclides in targeted cancer therapy has increased. In this study we have developed a high-current solid target system and demonstrated that by the use of a typical low-energy medical cyclotron, it is possible to produce tens of GBq's of many unconventional radionuclides relevant for cancer therapy such as $^{64}Cu$ and $^{119}Sb$ locally at the hospitals.

## Materials and methods

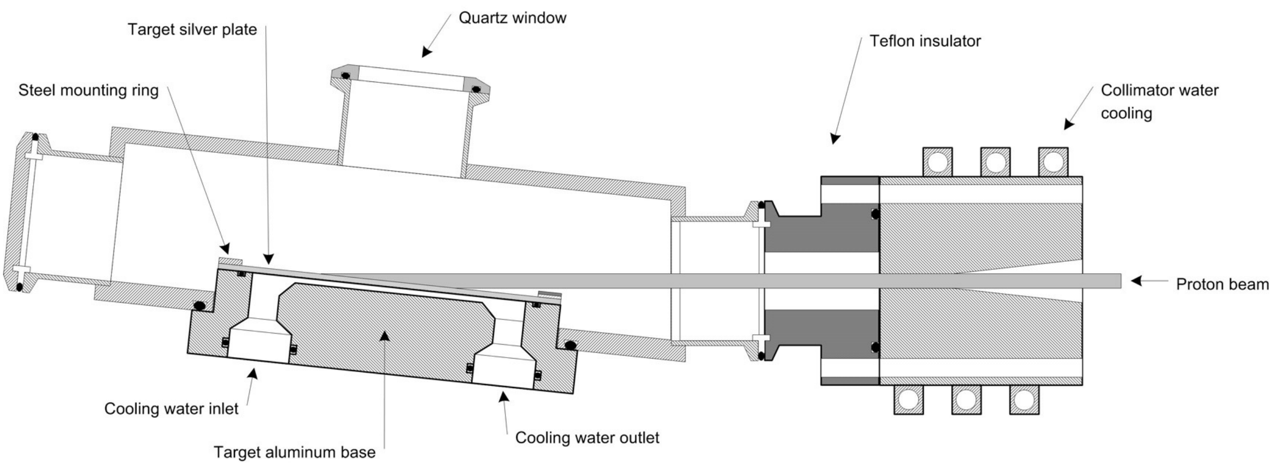
The irradiations were performed using a slightly modified GE PETtrace cyclotron equipped with a beam line. The PETtrace is originally specified to deliver > 75 µA 16.5 MeV protons or > 60 µA 8.4 MeV deuterons on target but has been shown to be capable of accelerating > 200 µA protons by careful adjustment of the central region and with much attention to vacuum conditions.

The target consists of a 2 mm thick silver plate with 8 cooling fins (height 2 mm, width 1 mm) which is mounted on top of an aluminium base with a stainless steel mounting ring (see figures). The back side of the silver plate is cooled by water flow through the rectangular channels between the cooling fins (1 mm × 2 mm) with a water flow rate of 14 l/min and a water inlet temperature of ~3°C.

Two different target materials were used for the irradiations. Either enriched $^{64}Ni$ for the direct production of $^{64}Cu$ via the



**Target body with electroplated Sn**




**Schematic drawing of the 6° grazing incidence target design with irradiation chamber and Ø5 mm circular collimator (right). For illustration purposes the Ø5 mm collimated proton beam is shown.**

$^{64}Ni(p,n)^{64}Cu$ reaction or $^{nat}Sn$ to demonstrate the capability of producing high amounts of the Auger-electron-emitter $^{119}Sb$ via the $^{119}Sn(p,n)^{119}Sb$ reaction. The electroplating of the $^{64}Ni$ targets were done using a $^{64}Ni$ ammonium sulphate plating solution and the $^{nat}Sn$ targets were made according to our newly developed method (Thisgaard and Jensen, Appl. Rad. Isot. 67, 2009) with a hot $^{nat}Sn$ potassium hydroxide solution.

The targets were irradiated several times with the 16 MeV proton beam collimated to Ø5 mm. Both target materials were initially irradiated with a net target current of 180 μA with a collimator spill between 10–15%, i.e. with approximately 200–210 μA beam current before the Ø5 mm collimator to test the thermal performance of the targets. After the irradiations the targets were stored for a few days to let the produced activity decay and then inspected with a microscope and weighted. For production yield measurements, the targets were irradiated several times with peak target currents of 150 μA, again with a collimator spill between 10–15%, with irradiation times up to 76 minutes.

The temperature profile and the thermal induced stress (data not shown) in the silver plate were modelled using Comsol Multiphysics 3.3. The code uses a finite-element analysis (FEA) of the silver plate with 24096 mesh elements.

## Results

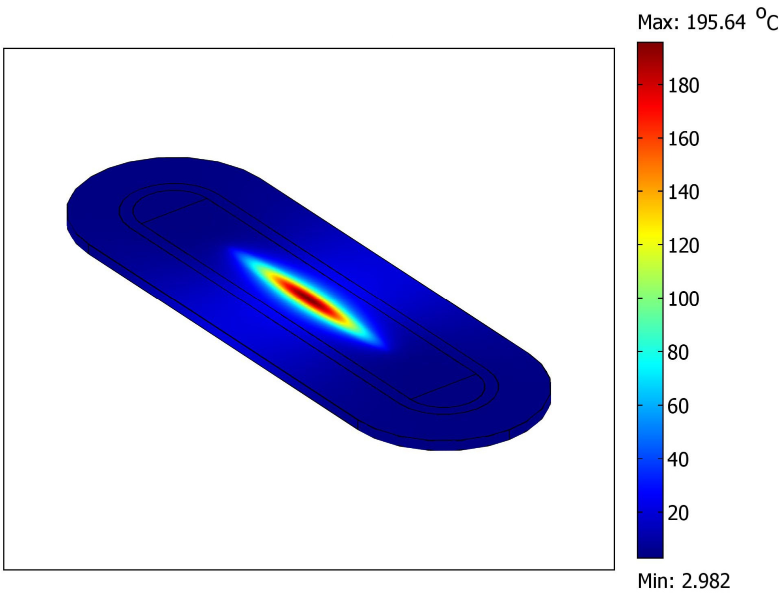
The target was capable of withstanding the 180 μA Ø5 mm proton beam with both target materials tested. No sign of melting was seen on the target surfaces and no losses of target material were found from weighing the targets after EOB. This means that the surface temperature had not been above 231.93° C during the Sn irradiations (the melting point of Sn) and probably not during the Ni irradiations either due to the higher thermal conductivity of Ni – in good agreement with the modelled results (see figure below).

From the 150 μA peak current irradiations the produced $^{64}Cu$ activity was measured to be 8.2 ± 0.7 GBq at EOB for the 76 min. irradiation (mean current of 121 μA), corresponding to 54 ± 5 MBq/μAh using 98% enriched $^{64}Ni$ with a plated target thickness of 8.5 mg/cm$^2$. This corresponds to the proton energy interval of 16.0 → 14.3 MeV, i.e. well above the maximum cross section of the excitation function for the $^{64}Ni(p,n)^{64}Cu$ reaction at approximately 11 MeV.

By increasing the plated target thickness to e.g. 30 mg/cm$^2$ of enriched $^{119}Sn$ or $^{64}Ni$ (resulting in a surface temperature increase of less than ~25° C) , it will be possible to produce ~46 GBq of $^{119}Sb$ or ~174 GBq of $^{64}Cu$, respectively, in 3 hours using 150 μA target current as above. In both examples, the total amount of enriched target material required to obtain the 30 mg/cm$^2$ thickness will be less than 60 mg due to the extremely focused proton beam (Ø5 mm), thus keeping the specific activity high and the metal impurities low.

## Conclusion

In the current study we have developed a high current solid target system and shown that by the use of a typical low-energy, medical cyclotron, it is possible to produce tens of GBq's of unconventional therapeutic radionuclides locally at the hospitals.




**The calculated temperature profile on the target face for a 203 μA beam corresponding to 180 μA on the target.**